Input to the European Particle Physics Strategy Update 2018-2020

European Strategy Update

Report of Contributions

Contribution ID: **1** Type: **not specified**

Searches for Sterile Neutrinos at CERN: Contribution to European Strategy for Particle Physics

These are some suggestions concerning ongoing and future tests that can be performed at CERN to search for possible sterile neutrinos and set constraints on their masses and mixings. In addition to European participation in neutrino oscillation experiments, in searches for neutrinoless double beta decay, and in KATRIN, it is emphasized here that sensitive searches for sterile neutrinos can be carried out onsite at CERN, including further searches for heavy neutrinos by NA62 and the proposed SHIP experiment, and related general searches for long-lived neutral weakly interacting particles.

Primary author: SHROCK, Robert (Stony Brook University)

Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **2** Type: **not specified**

Newtonian Test of the Standard Model

Isaac Newton's book 'Opticks' from the 18th century includes a number of hypotheses on the structure of matter. Most of the hypotheses were confirmed during the 19th and 20th centuries at the scales of nucleons, nuclei, atoms, molecules and macromolecules. Conflicts appear however at the scale of quarks and gluons according to the Standard Model of particle physics. The confirmations at the larger scales, and the conflicts at the smallest scale, are described and discussed here. Various precursors to the Standard Model for which the conflicts are less severe are also described. These date back to Yukawa's meson model of 1935, and they require substructure in the proton at a fine scale. Observations with electron-proton colliders could clarify the situation.

Primary author: Prof. YOCK, Philip (University of Auckland)

Track Classification: Other (communication, outreach, strategy process, technology transfer, individual contributions,...)

Contribution ID: **4** Type: **not specified**

TIARA contribution to the European Strategy of Particle Physics

This letter highlights the importance of Accelerator Science and Technology for the future of particle physics and suggests some recommendations in this area for the elaboration of the update of the European Strategy for particle physics.

Primary authors: TIARA CONSORTIUM; Dr ALEKSAN, Roy (on behalf of TIARA)

Track Classification: Accelerator Science and Technology

Contribution ID: **5** Type: **not specified**

A European Data Science Institute for Fundamental Physics

In order to facilitate the deployment of modern data science technologies (e.g., Deep Learning) into theoretical and experimental research in high energy physics, we suggest that the creation of a **European Data Science Institute for Fundamental Physics** is included among the recommendations of the European Strategy group. Such an institute would facilitate the development of cross-collaboration and across-border work on general-interest techniques, as well as yield knowledge transfer from and to other scientific communities (astrophysics, cosmology, computer science, etc.) and tech companies worldwide.

Primary author: PIERINI, Maurizio (CERN)

Track Classification: Instrumentation and computing

Contribution ID: **6** Type: **not specified**

Gamma Factory for CERN

This contribution discusses the possibility of creating novel research tools at CERN by producing and storing highly relativistic atomic beams in its high-energy storage rings, and by exciting their atomic degrees of freedom by lasers to produce high-energy photon beams. Their intensity would be, by several orders of magnitude, higher than those of the presently operating light sources, in the particularly interesting gamma-ray energy domain reaching up to 400 MeV. In this energy domain, the high-intensity photon beams can be used to produce secondary beams of polarised electrons, polarised positrons, polarised muons, neutrinos, neutrons and radioactive ions. The atomic beams, the photon beams and the above secondary beams are the principal research tools of the proposed Gamma Factory. New research opportunities in a wide domain of fundamental and applied physics can be opened by the Gamma Factory scientific programme.

Primary author: KRASNY, Mieczyslaw Witold (Centre National de la Recherche Scientifique (FR))

Track Classification: Accelerator Science and Technology

Contribution ID: **7** Type: **not specified**

Advanced LinEar collider study GROup (ALEGRO) Input

Advanced and Novel Accelerators (ANAs) can provide acceleration gradients orders of magnitude greater than conventional accelerator technologies, and hence they have the potential to provide a new generation of more compact, high-energy machines. Four technologies are of particular interest, all of which rely on the generation of a wakefield which contains intense electric fields suitable for particle acceleration. In the laser wakefield accelerator (LWFA) and plasma wakefield accelerator (PWFA) the wakefields are driven in a plasma by intense laser or particle beams, respectively; in the structure wakefield accelerator (SWFA), the wake is excited by a particle bunch propagating through a structured tube; and in the dielectric laser accelerator (DLA), a laser pulse directly drives an accelerating mode in a dielectric structure.

In view of the great promise of ANAs, and the substantial effort worldwide to develop them, the Advanced LinEar collider study GROup, ALEGRO, was formed at the initiative of the ICFA ANA panel. ALEGRO aims to foster studies on accelerators based on ANAs for applications to high-energy physics, with the ambition of proposing a machine that would address the future goals of particle physics. This document summarizes the current view of the international community on this topic. It proposes a list of priorities that the community would like to invest effort in over the next five to ten years.

We propose as a long-term goal the design of an e+/e⊠/gamma collider with up to 30 TeV in the center of mass - the Advanced Linear International Collider (ALIC). On the path to this collider, a number of stepping stones have to be established. These will lead to spin-offs at lower energy that will benefit ultrafast X-ray science, medicine, and industrial applications. The major goal for our community over the next five to ten years is the construction of dedicated ANA facilities that can reliably deliver high-quality, multi-GeV electron beams from a small number of stages. The successful demonstration of robust stages of this type would provide a platform for ANAs with large number of
stages generating high-quality beams in the TeV range.
The document also discusses other challenges that must be met for the complete ALIC concept. These include the design of appropriate particle sources, the development of high-power lasers needed for LWFAs and DLAs, the achievement of required tolerances, and the need for additional tools such as the development of novel diagnostics for the ultra-fast bunches generated by ANAs, and fast simulation methods.

Primary authors: Dr CROS, Brigitte (CNRS LPGP); Dr MUGGLI, Patric (Max Planck Institute for Physics)

Track Classification: Accelerator Science and Technology

Contribution ID: **8** Type: **not specified**

DM follies and the 'Krisis' of particle physics

This document has been prepared as an input for the discussions on an
European Strategy for Particles Physics.

Primary author: Dr RICHARD, Francois (LAL-Orsay)

Track Classification: Other (communication, outreach, strategy process, technology transfer, individual contributions,…)

Contribution ID: **9** Type: **not specified**

Prospects for exploring the Dark Sector physics and rare processes with NA64 at the CERN SPS

The CERN SPS offers a unique opportunity for exploring new physics due to the availability of high-quality and high-intensity secondary beams. In the 2016-18 runs, the NA64 experiment has successfully performed sensitive searches for Dark Sector and other rare processes in missing energy events using high energy electron interactions in an active dump. The NA64 Collaboration plans to continue such searches to fully exploit the potential of the experiment and increase its discovery reach with high-energy muon and hadron beams.
Our research program with e^- - beam aims at a high sensitivity search for visible and invisible decays of dark photons, A', and the exploration of the parameter space for the sub-GeV Dark matter production in invisible decays of A' mediator motivated by thermal Dark Matter models. It also includes clarification of the origin of the ^{8}Be anomaly, observed by the Atomki experiment, and searches for Axion Like Particles (ALP) particles. With the M2 muon beam, we propose to focus on the unique possibility to search for new states weakly coupled predominantly to muons, in particular a new gauge Z_μ boson of $L_\mu - L_\tau$ symmetry, which can resolve the long standing muon (g-2)$_\mu$ discrepancy. Further, more sensitive searches for the Z_μ as a vector mediator of Dark Matter production, LFV $\mu - \tau$ conversion and millicharged particles are also planned. Finally, the program includes probing Dark Sector with π, K beams, by looking for invisible decays $\pi^0, \eta, \eta', K^0_S, K^0_L \to invisible$ of neutral mesons, which is complementary to the current CERN program in the kaon sector.

Primary author: THE NA64 COLLABORATION

Track Classification: Dark matter and dark sector (accelerator and non-accelerator dark matter, dark photons, hidden sector, axions)

Contribution ID: **11** Type: **not specified**

The Belle II experiment at SuperKEKB: input to the European Particle Physics Strategy (update 2018-2020)

In the present document we outline some reflections related to the next mid-term particle physics strategy: the need for complementary approach among various frontiers in searches and interpretations of NP; an experimental initiative in the aforementioned efforts, especially after the Higgs boson discovery at the LHC; the specific advantages of e^+e^- over hadron colliders; and the complementarity within the existing experiments at the intensity frontier. We present arguments on the scientific importance of activity of a significant part of the European high-energy physics community at the Belle II experiment at KEK, Tsukuba, Japan.

Primary authors: Prof. GOLOB, Bostjan (Univ. of Ljubljana & JSI); BELLE II COLLABORATION

Track Classification: Flavour Physics and CP violation (quarks, charged leptons and rare processes)

Contribution ID: **12** Type: **not specified**

The SHiP experiment at the SPS Beam Dump Facility

The SHiP Collaboration has proposed a general purpose experimental facility
at the CERN SPS accelerator to search for feebly interacting GeV-scale particles.
SHiP complements the world-wide program of New Physics searches by covering a large
region of parameter space which cannot be addressed by other experiments.
The SHiP detector is sensitive both to decay and scattering signatures of models
with heavy neutral leptons, dark photons, dark scalars, light dark matter and
other super-weakly interacting particles. In addition, SHiP can perform
unprecedented measurements with tau neutrinos and neutrino-induced charm production.
Following the continued development since the Technical Proposal submitted in 2015,
this paper is a comprehensive overview of the re-optimized SHiP spectrometers and
the improved physics performance.

Primary author: SHIP COLLABORATION

Track Classification: Dark matter and dark sector (accelerator and non-accelerator dark matter, dark photons, hidden sector, axions)

Contribution ID: **13** Type: **not specified**

Proposal from the NA61/SHINE Collaboration for the update of the European Strategy for Particle Physics

Based on the success of the currently running program and motivated by new physics needs the NA61/SHINE Collaboration proposes to continue the measurements of hadron and nuclear fragment production properties in reactions induced by
hadron and ion beams after the CERN Long Shutdown 2 (LS2).
These measurements are requested by heavy ion, cosmic ray and neutrino communities and they include:
(i) measurements of charm hadron production in Pb+Pb collisions for heavy ion physics to find out how the onset of deconfinement impacts open charm and J/ψ production.
(ii) measurements of nuclear fragmentation cross section for cosmic ray physics
to study the origin of Galactic cosmic rays and evaluate the cosmic-ray background for signatures of astrophysical dark matter
(iii) measurements of hadron production induced by proton, pion and kaon beams for neutrino physics to improve further the precision of hadron production measurements necessary for initial neutrino flux predictions for the T2K, T2K-II, Hyper-Kamiokande, and DUNE long-baseline neutrino oscillation experiments.

The requested measurements require a substantial detector upgrade which is planned to be executed during the LS2 and the measurements are scheduled in the period 2021-2024.

Primary author: GAZDZICKI, Marek, for NA61/SHINE (Johann-Wolfgang-Goethe Univ. (DE))

Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **14** Type: **not specified**

Complex NEVOD for multi-component investigations of cosmic rays in the record-wide energy range 10^10 – 10^19 eV

The wide energy range covered by the complex NEVOD is determined by a unique combination of detectors and installations that have no analogues in the world. The energy region from few GeV to ~ 100 GeV is covered by muon hodoscope URAGAN with an area of 46 m^2. The region from several tens of GeV to several tens of TeV is covered by the Cherenkov water calorimeter with a volume of 2000 m^3 with a dense lattice of quasi-spherical measuring modules. The region from ~ 10^14 to 10^17 eV is covered by four installations for registration of various components of EAS. The scintillation calibration telescope system with an area of 80 m^2 is used for registration of the EAS in the threshold energy region (~ 10^14 eV). The NEVOD-EAS installation allows investigation of the EAS in the energy region of 10^15 – 10^17 eV. The prototype installation PRISMA-32 of 400 m^2 and the first phase of the URAN detector with area of 2000 m^2 are intended for registration of the neutron component over the entire area of EAS in the energy region of 10^15 – 10^16 eV. The region of very- and ultra-high energies (10^15-10^19 eV) is covered by a coordinate-tracking detector DECOR with a total area of 70 m^2; it is designed for the registration of muon bundles generated in inclined EAS.

In recent years, two important results have been obtained at the complex NEVOD: a growing excess of muons with the rise of energy in the EAS, which is not explained by existing models (so-called "muon puzzle") has been revealed, and a method of muonography of near-Earth space has been developed with the purpose of the early detection of potentially dangerous phenomena in the heliosphere, magnetosphere and the Earth's atmosphere.

The upcoming task of the complex is solution of the "muon puzzle" by means of independent measurements of the number of muons in the bundles in the coordinate-tracking detector and their energy release in the Cherenkov water calorimeter. With the inclusion of new muon generation processes, the specific energy release (per muon) will start increasing.

The scheduled upgrade of the complex NEVOD, in particular, the creation of a new co-ordinate-tracking detector TREK with an area of 250 m^2 and the expansion of the detection system of the Cherenkov water detector to its full volume will significantly improve the conditions and will reduce the necessary duration of this experiment. In the field of muonography, it is planned to develop the muon hodoscope of the new generation to create a distributed network in Russia and Europe for the continuous monitoring of the space weather.

Primary authors: Prof. PETRUKHIN, Anatoly (MEPhI); Prof. KOKOULIN, Rostislav (MEPhI); Prof. YASHIN, Igor (MEPhI)

Track Classification: Large experiments and projects

Contribution ID: **15** Type: **not specified**

Contribution of the french physics society

The French physics society and its division Champs et Particules, after a large consultation of its members, has reached a consensus, and proposes a list of hierarchized items for the European strategy for particle physics. It is motivated by the search of new physics and our belief that Europe must continue playing the leading role in this domain.

Primary author: KARYOTAKIS, jean (LAPP)

Track Classification: National road maps

Contribution ID: **16** Type: **not specified**

Strategic R&D Programme on Technologies for Future Experiments

Instrumentation is a key ingredient for progress in experimental high energy physics. The Experimental Physics Department of CERN has defined a strategic R&D (Research and Development) programme on technologies for future experiments. Provided the required resources can be made available, it will start in 2020 and initially extend over five years. The selection of topics and the established work plans are the result of a transparent and open process, which lasted 14 months and involved several hundred of physicists and engineers at CERN and in the broader HEP community.
This R&D programme is in the tradition of previous similar initiatives, the DRDC projects in the 1990's and the White Paper R&D programme (2008-2011) that have been instrumental in providing the technologies which are presently in use at the LHC experiments or which will be deployed in the coming LHC upgrades (Phase-I and Phase-II). Examples of the achievements of the White Paper R&D programme are the validation of the CMOS 130 nm technology, the GEM single mask technique, radiation hard optical links, DC-DC converters and the CernVM file system.
The results of this new R&D programme will be building blocks, demonstrators and prototypes, which will form the technological basis for possible new experiments and experiment upgrades beyond the LHC Phase-II upgrades scheduled for the long shutdown LS3. These include in particular detectors at CLIC, FCC-hh and FCC-ee but also further upgrades of the LHC experiments. The main challenges come on the hadron collider side from the very high luminosity operation, leading to extreme pile-up, track density, radiation loads and data throughput, but also from the need for unprecedented precision in vertexing and tracking, combined with very low material budgets and highly granular calorimetry on the lepton collider side.
The new programme targets the primary challenges of the detectors complemented by equally demanding challenges in the domains of electronics, mechanics, cooling, magnets and software. A large part of the required R&D work will be carried out jointly with external groups from universities and research labs exploiting organically grown networks and relations, but also dynamic and efficient structures like the RD50 and RD51 collaborations. For many developments, close cooperation with industrial partners will be crucial.

Primary authors: ONNELA, Antti (CERN); CURE, Benoit (CERN); SCHMIDT, Burkhard (CERN); D'AMBROSIO, Carmelo (CERN); JORAM, Christian (CERN); REMBSER, Christoph (CERN); GARGIULO, Corrado (CERN); DANNHEIM, Dominik (CERN); OLIVERI, Eraldo (CERN); FACCIO, Federico (CERN); VASEY, Francois (CERN); STEWART, Graeme (CERN); PERNEGGER, Heinz (CERN); TEN KATE, Herman (CERN); BLOMER, Jakob (CERN); MUSA, Luciano (CERN); LINSSEN, Lucie (CERN); KRAMMER, Manfred (CERN); ALEKSA, Martin (CERN); CAMPBELL, Michael (CERN); DOSER, Michael (CERN); JANOT, Patrick (CERN); RODRIGUES SIMOES MOREIRA, Paulo (CERN); MATO VILA, Pere (CERN); RIEDLER, Petra (CERN); FARTHOUAT, Philippe (CERN); FORTY, Roger (CERN); RIEGLER, Werner (CERN)

Track Classification: Instrumentation and computing

Contribution ID: **17** Type: **not specified**

Status and perspectives of the neutron time-of-flight facility n_TOF at CERN

Since the start of its operation in 2001, based on an idea of Prof. Carlo Rubbia[1], the neutron time-of-flight facility of CERN, n_TOF, has become one of the most forefront neutron facilities in the world for wide-energy spectrum neutron cross section measurements. Thanks to the combination of excellent neutron energy resolution and high instantaneous neutron flux available in the two experimental areas, the second of which has been constructed in 2014, n_TOF is providing a wealth of new data on neutron-induced reactions of interest for nuclear astrophysics, advanced nuclear technologies and medical applications.
The unique features of the facility will continue to be exploited in the future, to perform challenging new measurements addressing the still open issues and long-standing quests in the field of neutron physics. In this document the main characteristics of the n_TOF facility and their relevance for neutron studies in the different areas of research will be outlined, addressing the possible future contribution of n_TOF in the fields of nuclear astrophysics, nuclear technologies and medical applications. In addition, the future perspectives of the facility will be described including the upgrade of the spallation target.

Primary author: Dr CHIAVERI, Enrico (University of Manchester)

Track Classification: Accelerator Science and Technology

Contribution ID: **18** Type: **not specified**

Feasibility Study for an EDM Storage Ring

This project exploits charged particles confined as a storage ring beam (proton, deuteron, possibly ^{3}He) to search for an intrinsic electric dipole moment (EDM, $\vec{d}$) aligned along the particle spin axis. Statistical sensitivities can approach 10^{-29}e·cm. The challenge will be to reduce systematic errors to similar levels. The ring will be adjusted to preserve the spin polarization, initially parallel to the particle velocity, for times in excess of 15 minutes. Large radial electric fields, acting through the EDM, will rotate the polarization ($\vec{d} \times \vec{E}$). The slow rise in the vertical polarization component, detected through scattering from a target, signals the EDM. The project strategy is outlined. It foresees a step-wise plan, starting with ongoing COSY activities that demonstrate technical feasibility. Achievements to date include reduced polarization measurement errors, long horizontal-plane polarization lifetimes, and control of the polarization direction through feedback from the scattering measurements. The project continues with a proof-of-capability measurement (precursor experiment; first direct deuteron EDM measurement), an intermediate prototype ring (proof-of-principle; demonstrator for key technologies), and finally the high precision electric-field storage ring.

Primary author: Prof. STROEHER, Hans (Forschungszentrum Juelich, Germany)

Track Classification: Accelerator Science and Technology

Contribution ID: **19** Type: **not specified**

The JUNO Experiment

Input to the European Particle Physics Strategy by JUNO experiment, main document and addendum.

Primary author: Dr DRACOS, Marcos (Centre National de la Recherche Scientifique (FR))

Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **20** Type: **not specified**

PBC Conventional Beams Executive Summary

This document summarises the main conclusions of the Conventional Beams Working group, which has analysed the beam related and technical requirements and requests in the proposals to the Physics Beyond Colliders study for the North Area at the CERN SPS. We present results from studies on feasibility, requirements, compatibility between proposals and, where possible, the order of magnitude of the costs. The physics interest, sensitivity reach and competitiveness world wide of the proposals is discussed in the BSM and QCD physics working groups, which work in synergy with the Conventional Beams group.

Primary authors: GATIGNON, Lau (CERN); BANERJEE, Dipanwita (Univ. Illinois at Urbana Champaign (US)); BERNHARD, Johannes (CERN); BRUGGER, Markus (CERN); CHARITONIDIS, Nikolaos (CERN); D'ALESSANDRO, Gian Luigi (University of London (GB)); DOBLE, Niels (INFN Sezione di Pisa, Universita' e Scuola Normale Superiore, P); VAN DIJK, Maarten (CERN); GERBERSHAGEN, Alexander (CERN); MONTBARBON, Eva (CERN); ROSENTHAL, Marcel (CERN)

Track Classification: Accelerator Science and Technology

Contribution ID: **21** Type: **not specified**

Initial contribution of the INFN Hadron Physics Community

INFN has a strong tradition in high-energy hadron physics, both in the heavy-ion sector and in the deep-inelastic-scattering sector, with important participation in international programmes, that also include relevant and specific contributions in terms of dedicated detectors. In this context, it is recognized that high centre-of-mass energy is a fundamental handle for the future investigation: at higher energy, wider and novel kinematical phase-space regions become reachable offering an enlarged panorama of complementary phenomenological views.
The high-energy opportunities in hadron physics of interest for the dedicated INFN community are considered. They include perspectives for further investigations with ALICE at the upgraded LHC complemented by measurements at SPS and novel opportunities with electron-ion colliders.

Primary author: TAIUTI, Mauro (University of Genova, INFN)

Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **22** Type: **not specified**

Communicating particle physics matters

Public and political support for particle physics is essential for sustaining the long-term future of the field - whether this is for attracting young people into STEM careers, gaining support from local communities for building new experiments, or for securing government funding for new and existing experiments. The importance of communicating particle physics has long been recognised by the discipline, with significant effort invested over many years by institutions and individuals to inspire and involve young people and adults. The current European Strategy for Particle Physics emphasises that sharing the excitement of scientific discoveries with the public is part of the duty of researchers, and recommends that communication and outreach in particle physics should receive adequate funding and be recognised as a central component of the scientific activity. This submission stresses the need for the next version of the Strategy to expand on the recommendation [1] from the previous version as follows:

> **1) "Outreach and communication in particle physics should receive adequate funding and be recognised as a central component of the scientific activity"**
> **across all European countries. Professional communication teams should be in place, to ensure that increasing visibility and enhancing reputation are always included in any communication activity.**

In addition, we make the following recommendations to:

> **2) Maintain and support effective networks of professional communications staff to plan and deliver communications activities strategically, effectively and in a coordinated manner, making use of new tools and techniques, and sharing best practice;**
> **3) Demonstrate to the widest possible audiences the societal and economic benefits arising from current and historic investment in particle physics using appropriate metrics;**
> **4) Play a positive role in promoting equality, diversity and inclusion in particle physics through the coordinated planning and delivery of specific communications campaigns, materials and activities that also target new and underserved audiences across Europe and beyond.**

This document also discusses the current and future challenges that particle physics communicators face; notably the pace of change in social media tools and channels, the speed of dissemination of good news, bad news and rumours, the need to maintain trust and transparency, and the complexities of maintaining media interest until the next big discovery. A significant challenge is the decline in dedicated science journalism within the mainstream media. All of these issues require a network of professional science communicators to work together, sharing best practice to achieve our common goals. The overall goals of our communication strategy are to ensure the long-term future for particle physics and fundamental research, and to share new discoveries and the process of extending human knowledge with the wider society.

[1] See https://cds.cern.ch/record/1567258/files/esc-e-106.pdf, page 3 n)

Primary authors: ROYOLE-DEGIEUX, Perrine (CNRS); MARSOLLIER, Arnaud (CERN); THE EUROPEAN PARTICLE PHYSICS COMMUNICATION NETWORK (EPPCN), WITH SUPPORT OF THE INTERACTIONS COLLABORATION

Track Classification: Other (communication, outreach, strategy process, technology transfer, individual contributions,…)

Contribution ID: **24** Type: **not specified**

THE BIENNIAL AFRICAN SCHOOL ON FUNDAMENTAL PHYSICS AND APPLICATIONS

We have established a biennial school in Africa, on fundamental physics and its applications (ASP). We find that fundamental physics provides excellent motivation for students of science. The aim of the school is to build capacity to harvest, interpret, and exploit the results of current and future physics experiments and to increase proficiency in related applications. The school is based on a close interplay between theoretical, experimental, and applied physics. The participating students are selected from all over Africa. The school also offers a workshop to train high school teachers, an outreach to motivate high school pupils and a physics conference to support a broader participation of African research faculties. The duration of the school allows for networking–interactions among the participants. Support for the school comes from institutes in Africa, Europe, USA and Asia. The first school took place in Stellenbosch, South Africa on August 1–21 2010, the second edition in Kumasi, Ghana on July 15-August 8 2012, the third edition in Dakar Senegal on August 3–23 2014, the fourth biennial school at the University of Rwanda on August 1–19 2016, and the fifth edition in Namibia on June 24–July 14 2018. The next edition of the school is planned in 2020 in Morocco. In this proposal, we discuss strategies to make the school sustainable and call for support from the international community. We consider access and participation in fundamental science to be an important right. Through this work, it is hoped that the community of scientists who are at the forefront of science is enhanced and diversified thus fulfilling the mission of international research and education institutes.

Primary authors: Dr ASSAMAGAN, Ketevi Adikle (Brookhaven National Laboratory (US)); DIWAN, Milind Vaman (Brookhaven National Laboratory (US))

Track Classification: Other (communication, outreach, strategy process, technology transfer, individual contributions,…)

Contribution ID: **25** Type: **not specified**

Charged Lepton Flavour Violation using Intense Muon Beams at Future Facilities

Charged-lepton flavour-violating (cLFV) processes offer deep probes for new physics with discovery sensitivity to a broad array of new physics models — SUSY, Higgs Doublets, Extra Dimensions, and, particularly, models explaining the neutrino mass hierarchy and the matter-antimatter asymmetry of the universe via leptogenesis. The most sensitive probes of cLFV utilize high-intensity muon beams to search for μ → e transitions.
We summarize the status of muon-cLFV experiments currently under construction at PSI, Fermilab, and J-PARC. These experiments offer sensitivity to effective new physics mass scales approaching $calO(10^4)$ TeV/c^2. Further improvements are possible and next-generation experiments, using upgraded accelerator facilities at PSI, Fermilab, and J-PARC, could begin data taking within the next decade. In the case of discoveries at the LHC, they could distinguish among alternative models; even in the absence of direct discoveries, they could establish new physics. These experiments both complement and extend the searches at the LHC.

Primary authors: BALDINI, Alessandro Massimo (Universita & INFN Pisa (IT)); GLENZINSKI, Douglas; KAPUSTA, Frederic (LPNHE-Paris); KUNO, Yoshitaka (Osaka University); LANCASTER, Mark (UCL); Prof. MILLER, James (Boston University); MISCETTI, Stefano (Istituto Nazionale Fisica Nucleare Frascati (IT)); MORI, Toshinori (University of Tokyo (JP)); PAPA, Angela; SCHOENING, Andre (Ruprecht Karls Universitaet Heidelberg (DE)); UCHIDA, Yoshi (Imperial College London)

Track Classification: Flavour Physics and CP violation (quarks, charged leptons and rare processes)

Contribution ID: **26** Type: **not specified**

Initial INFN input on the update of the European Strategy for Particle Physics

This document contains some initial input from INFN to the update of the European Strategy for Particle Physics. It does not aim at providing a comprehensive overview of the INFN position on all the relevant aspects of the Strategy: this will be defined with the other actors all along the update process, from the Open Symposium of May 2019 to the Strategy Drafting Session of January 2020. It aims instead at emphasizing the INFN position on three key issues that according to INFN deserve special attention:
• An ambitious post-LHC accelerator project at CERN
• The relation between CERN and AstroParticle Physics
• The CERN laboratory and the laboratories in the Member States

The content of this document takes into account the information presented and the extensive discussions held at a National INFN "Town Meeting", which took place in Rome on 6-7 September 2018: https://agenda.infn.it/conferenceOtherViews.py?view=standard&confId=15968
Independent and more detailed input is being submitted by some of the National INFN Scientific Committees and Laboratories, in particular CSN1 (Particle Physics), CSN2 (AstroParticle Physics), CSN3 (Hadronic Physics), C3S (Physics and Computing) and LNF (Frascati).

Primary authors: ZOCCOLI, Antonio (INFN Executive Board); ZWIRNER, Fabio (INFN Executive Board)

Track Classification: National road maps

Contribution ID: **27** Type: **not specified**

The International Axion Observatory (IAXO): case, status and plans. Input to the European Strategy for Particle Physics

The International Axion Observatory (IAXO) is a next-generation axion helioscope that will search for solar axions with unprecedented sensitivity. IAXO has a unique position in the international landscape of axion experiments, with sensitivity to a region of the axion parameter space that no other experiment can access. In particular, it will explore QCD axion models in the meV to eV mass range, encompassing models hinted by astrophysics, and potentially also axion dark matter models. IAXO relies on proven solutions and technologies, as well as on the 15-year-long experience with CAST. An intermediate demonstration prototype, BabyIAXO, will further mitigate risk and produce first physics. BabyIAXO is under review now at DESY and will be built and operated in the coming few years, while preparing the ground for IAXO. The scale of IAXO surpasses the traditionally small size of axion experiments and thus requires consideration in the context of the European Strategy.

Primary author: IRASTORZA, Igor (Universidad de Zaragoza)

Track Classification: Dark matter and dark sector (accelerator and non-accelerator dark matter, dark photons, hidden sector, axions)

Contribution ID: **28** Type: **not specified**

REDTOP: Rare Eta Decays with a TPC for Optical Photons

The REDTOP experiment is primarily intended to look for new violations of
the basic symmetries. It aims to improve the sensitivity level of key physics conservation laws by several orders of magnitude beyond those of previous experiments. In doing so, it will open doorways for possible Physics Beyond the Standard Model including dark matter and energy, and/or new forces. The REDTOP measurements will focus on rare decays of the η and η' mesons produced by proton beams of a few GeV energy and high intensity. Physics BSM is searched mainly in the decay products of the η and η' mesons.

Primary author: Dr GATTO, Corrado (Isituto Nazionale di Fisica Nucleare and Northern Illinois University)

Co-author: REDTOP, Collaboration

Track Classification: Flavour Physics and CP violation (quarks, charged leptons and rare processes)

Contribution ID: **29** Type: **not specified**

CEPC Input to the ESPP 2018 - Physics and Detector

The Higgs boson, discovered in 2012 by the ATLAS and CMS Collaborations at the Large Hadron Collider (LHC), plays a central role in the Standard Model. Measuring its properties precisely will advance our understandings of some of the most important questions in particle physics, such as the naturalness of the electroweak scale and the nature of the electroweak phase transition. The Higgs boson could also be a window for exploring new physics, such as dark matter and its associated dark sector, heavy sterile neutrino, et al. The Circular Electron Positron Collider (CEPC), proposed by the Chinese High Energy community in 2012, is designed to run at a center-of-mass energy of 240 GeV as a Higgs factory. With about one million Higgs bosons produced, many of the major Higgs boson couplings can be measured with precisions about one order of magnitude better than those achievable at the High Luminosity-LHC. The CEPC is also designed to run at the Z-pole and the W pair production threshold, creating close to one trillion Z bosons and 100 million W bosons. It is projected to improve the precisions of many of the electroweak observables by about one order of magnitude or more. These measurements are complementary to the Higgs boson coupling measurements. The CEPC also offers excellent opportunities for searching for rare decays of the Higgs, W, and Z bosons. The large quantities of bottom-quarks, charm-quarks, and tau leptons produced from the decays of the Z bosons are interesting for flavor physics. The clean collision environment also makes the CEPC an ideal facility to perform precision QCD measurements. Several detector concepts have been proposed for the CEPC. Dedicated simulation and R&D program confirm these concepts can fulfill the CEPC physics requirements.
In this document, we provide a brief summary of the physics potential and the detector design concepts, both of which are laid out in detail in the Conceptual Design Report (CDR) released in November 2018. We also outline future directions and challenges. In the Addendum, we briefly describe the planning and the international organization of the CEPC. The next step for the CEPC team is to perform detailed technical design studies. Effective international collaboration would be crucial at this stage. This submission for consideration by the ESPP is part of our dedicated effort in seeking international collaboration and support. Given the importance of the precision Higgs boson measurements, the ongoing CEPC activities do not diminish our interests in participating in the international collaborations of other future electron-positron collider based Higgs factories.

Primary author: Prof. RUAN, Manqi (Institute of High Energy Physics, CAS)

Track Classification: Large experiments and projects

Contribution ID: **30** Type: **not specified**

Large-scale neutrino detectors: input for the 2020 update of the European Strategy for Particle Physics from the Institute for Nuclear Research of the Russian Academy of Sciences

We propose a multi-purpose neutrino observatory comprising two very large detectors solving different problems at the intersection of particle physics, astrophysics and Earth science. Baikal-GVD will work jointly with KM3NET and IceCube in the Global Neutrino Network, aiming at the detection and study of high-energy astrophysical neutrinos. The new Baksan neutrino telescope (NBNT) will inherit from its smaller precursor, Borexino, but will become the only large-scale neutrino detector geographically located in Europe. Thanks to the unique low-background conditions at Baksan, determined by a combination of depth and of location far from artificial nuclear reactors, it will be the best instrument in the world to measure the CNO solar neutrino flux, at the same time addressing a wide range of other problems.

Primary author: Prof. KRAVCHUK, Leonid (INR RAS Director)

Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **31** Type: **not specified**

Input from the Spanish Particle Physics Community

Input to the update of the European Strategy for Particle Physics provided by the Spanish Scientific Particle Physics community. It contains two files, the main document plus an addendum

Primary author: RODRIGO, Teresa (IFCA)

Track Classification: National road maps

Contribution ID: **33** Type: **not specified**

Statement by the German Particle Physics Community as Input to the Update of the European Strategy for Particle Physics

The German Committee for Particle Physics (KET), arranged, jointly with the German Committees for astroparticle physics (KAT) and for hadronic and nuclear physics (KHuK), a series of workshops to discuss status and future plans of particle physics and neighbouring fields. KET has extracted central statements and strategic proposals from the joint declaration and hereby submits them to the 2020 update of the European Strategy for Particle Physics.

Primary authors: GERMAN COMMITTEE FOR PARTICLE PHYSICS (KET); UWER, Ulrich (Ruprecht Karls Universitaet Heidelberg (DE))

Track Classification: National road maps

Contribution ID: **34** Type: **not specified**

Israeli Input to the European Strategy for Particle Physics

European Strategy for Particle Physics, Israeli Input

Steering committee
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The enclosed document is based on a compilation of theoretical concepts and experimental methods solicited from the Israeli community by a steering committee with representatives from all the high-energy-physics (HEP) groups in Israel. An important component of this process was a national town-hall meeting, with presentations and status reports on the diverse experimental activity and future proposals that are pursued by various Israeli groups followed by an open discussion. A preliminary version of this report was discussed at the meeting and comments from the Israeli HEP community at large were received and impacted the document in an essential manner. The document is rather concise, less than 4 pages, and should be read as a whole.

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Track Classification: National road maps

Contribution ID: **35** Type: **not specified**

AWAKE: On the path to Particle Physics Applications

Proton-driven plasma wakefield acceleration allows the transfer of energy from a proton bunch to a trailing bunch of particles, the 'witness' particles, via plasma electrons. The AWAKE experiment at CERN is pursuing a demonstration of this scheme using bunches of protons from the CERN SPS. Assuming continued success of the AWAKE program, high energy electron or muon beams will become available, opening up an extensive array of future particle physics projects from beam dump searches for new weakly interacting particles such as Dark Photons, to fixed target physics programs, to energy frontier electron-proton, electron-ion, electron-positron and muon colliders. The time is right for the particle physics community to offer strong support to the pursuit of this new technology as it will open up new avenues for high energy particle physics.

Primary author: CALDWELL, Allen (Max-Planck-Institut fur Physik (DE))

Track Classification: Dark matter and dark sector (accelerator and non-accelerator dark matter, dark photons, hidden sector, axions)

Contribution ID: **36** Type: **not specified**

Dark Sector Physics with a Primary Electron Beam Facility at CERN

This input is a summary of an Expression of Interest (SPSC-EOI-018) submitted to the CERN Scientific Committee for the SPS accelerator, SPSC.

A primary electron beam facility is proposed with the main motivations being (i) dark sector experiments, and (ii) to enable a suite of development projects in acceleration technology. The facility would deliver a beam to a Light Dark Matter eXperiment, LDMX, which could probe thermal dark matter over a majority of the viable sub-GeV mass range. LDMX can achieve orders of magnitude better sensitivity than any previous or currently envisioned experiment. LDMX uses missing momentum to search for dark matter produced via dark bremsstrahlung from in the interaction of electrons in a thin target. This requires a low-current, high repetition-rate electron beam, with optimal energy of ~ 16 GeV. We propose to create this electron beam at CERN by restoring the SPS's electron acceleration capability.

The proposed facility would also strengthen the CERN accelerator R&D programme. This is desirable on general grounds, but even more-so now when there is some uncertainty about the optimal next step for CERN's future main accelerator.

Primary authors: AKESSON, Torsten (Lund University (SE)); STAPNES, Steinar (CERN)

Track Classification: Accelerator Science and Technology

Contribution ID: **37** Type: **not specified**

Future of Heavy Ion Physics at Colliders

the Germany ALICE community points out a future direction with a new nearly massless detector

Primary author: Prof. STACHEL, Johanna (Heidelberg University)

Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **38** Type: **not specified**

COMET

The search for charged lepton flavour violation (CLFV) has an enormous discovery potential in probing new physics Beyond the Standard Model (BSM). The observation of a CLFV transition would be an undeniable sign of the presence of BSM physics which goes beyond non-zero masses for neutrinos. Furthermore, CLFV measurements can provide a way to distinguish between different BSM models, which may not be possible through other means. So far muonic CLFV processes have the best experimental sensitivity because of the huge number of muons which can be produced at several facilities world-wide. In coming years new muon beam-lines will be built, leading to several orders of magnitude increase in beam intensity. Among muonic CLFV processes, $\mu \to e$ conversion is one of the most important processes, having several advantages compared to other such processes.

We describe the COMET experiment, which is searching for $\mu \to e$ conversion in a muonic atom at the J-PARC proton accelerator laboratory in Japan. The COMET experiment has taken a staged approach; the first stage, COMET Phase-I, is currently under construction at J-PARC, and is aiming at a factor 100 improvement over the current limit. The second stage, COMET Phase-II is seeking another 100 improvement (a total of 10,000), allowing a single event sensitivity (SES) of 2.6×10^{-17} with 2×10^7 seconds of data-taking. Further improvements by one order of magnitude, from refinements to the experimental design and operation are being considered within the beam power and the beam time as originally assumed. Such a sensitivity could be translated into probing many new physics constructions up to $\mathcal{O}(10^4)$ TeV energy scales, which would go far beyond the level that can be reached directly by collider experiments. The search for CLFV $\mu \to e$ conversion is thus highly complementary to BSM searches at the LHC.

Primary authors: DRUTSKOY, Alexey (LPI); TEIXEIRA, Ana M. (LPC Clermont); CARLOGANU, Cristina (Univ. Blaise Pascal Clermont-Fe. II (FR)); LOMIDZE, David (Georgian Technical University (GE)); Prof. GRIGORIEV, Dmitri (BINP); SHOUKAVY, Dzmitry (Joint Institute for Nuclear Research (RU)); KAPUSTA, Frederic (Laboratoire de Physique Theorique et Hautes Energies (LPTHE)); Prof. TEVZADZE, Iuri (Tbilisi State University); Prof. ANGELIQUE, Jean-claude (LPC Caen); ZUBER, Kai (Technische Universitaet Dresden); FINGER, Miroslav (Charles University (CZ)); LEBRUN, Patrice (Institut de Physique Nucleaire de Lyon (IPNL)); Dr LITCHFIELD, Phillip (Imperial College, London); Dr KACHELHOFFER, Thomas (CC-IN2P3); VRBA, Vaclav (Czech Technical University (CZ)); DA SILVA, Wilfrid (Laboratoire de Physique Theorique et Hautes Energies (LPTHE)); UCHIDA, Yoshi (Imperial College London); KUNO, Yoshitaka (Osaka University); TSAMALAIDZE, Zviadi (Tbilisi State University (GE))

Track Classification: Flavour Physics and CP violation (quarks, charged leptons and rare processes)

Contribution ID: **39** Type: **not specified**

EPIC: Exploiting the Potential of ISOLDE at CERN

The user's community of ISOLDE, CERN's radioactive ion beam (RIB) facility, has been steadily growing in the last 10-15 years, thanks to the increasing range of research fields that opened up when post-accelerated radioactive beams and more isotopes became available. The demand for beam time therefore outnumbers the current production capabilities. The EPIC project takes full advantage of the recent upgrades at CERN, driven by the LHC Injectors Upgrade (LIU). In particular, the new Linac4 with its higher proton currents and the PS booster with its higher proton beam energies allow expanding the scope of ISOLDE. With a higher proton beam intensity and energy impinging on the ISOLDE target stations, significantly higher radioactive beam intensities are achieved. Additionally, this higher proton current can be divided among two target stations, constructed in such a way that parallel radioactive beams can be delivered to the many low energy (40-60 keV) and high-energy (1-10 MeV/nucleon from HIE-ISOLDE) radioactive beam experiments. This will allow doubling the amount of beam time, which is highly demanded by the continuously growing ISOLDE user's community. Furthermore, ISOLDE aims at attracting new users to take even more advantage of the increased beam time, by constructing a storage ring behind the HIE-ISOLDE post-accelerator. Thus, stored cooled exotic beams from light up to heavy short-lived isotopes will be available and open up new possibilities in the fields of astrophysics, fundamental symmetry studies, atomic physics and nuclear physics. All of these upgrades guarantee that ISOLDE remains a unique facility in Europe and even in the world, as nowhere else a proton driver with these properties is available for producing a very wide range of radioactive isotopes, nor is there a facility that has (or plans) a low-energy storage ring for short-lived isotopes, allowing unique experiments in diverse fields.

Primary authors: NEYENS, Gerda (CERN); RIISAGER, Karsten (Aarhus University (DK)); BLANK, Bertram (CEN Bordeaux-Gradignan); CATHERALL, Richard (CERN)

Track Classification: Large experiments and projects

Contribution ID: **40** Type: **not specified**

Input of Nuclear Physics Section, Division of Physical Sciences of the Russian Academy of Sciences to European Strategy for Particle Physics Update

See attached file

Primary author: Prof. RUBAKOV, Valery (Nuclear Physics Section, Russian Academy of Sciences)

Track Classification: National road maps

Contribution ID: **41** Type: **not specified**

Further searches of the Higgs scalar sector

Recent decades have witnessed remarkable confirmations of the Standard Model (SM) describing the Electro-Weak and Strong Interactions. The experimental discovery of the Higgs boson Ho at the CERN/LHC has crowned a success of the SM and calls for further studies on this newly observed sector. New and more precise activities are needed in order to extend more precisely this new discovery within Particle Physics. Like for the previous Zo studies, additional projects using leptons rather than hadrons should be investigated.
The presently described (μ+ μ-) initiated cross section is greatly enhanced with respect to the one with (e+ e-), since Ho particle is a scalar and therefore the leptons pair coupling is proportional to the square of the lepton mass. The μ+μ- Collider is preferable to the other proposed huge e+e- future options because of its much smaller dimensions and cost and since it may easily fit within one of the already existing European sites. However it requires the success of a substantial R&D in order to convincingly produce the adequate accumulation and cooling in 6D phase space of the muon beams.
High intensity bunches from a negative H- source are converted into protons, producing secondary particles (mostly π±). The π's decay to μ's and the μ's are captured, bunched, cooled and accelerated in a storage ring to produce an appropriate rate of high energy muon collisions.
The (μ+μ-) Collider is primarily concentrated on the optimal scenario offered by further developments of the European Spallation Source (ESS) already under construction in the Lund site as the most intense future source of spallation neutrons.
Two configurations are described: the Higgs mass s-channel resonance at √ s = 125.5 GeV to study with very small backgrounds the many Ho decay modes with L ≈ 1032 cm-2 s-1 and the higher energy Collider with L ≈ 1034 cm-2 s-1at √ s = 500 GeV to study the other main Ho related processes of the scalar sector.
As a preliminary part of the program, cooling should be experimentally studied in the μ+μ- ring configuration with the much cheaper and simpler Initial Cooling Experiment. Several European laboratories, like for instance in the UK, Switzerland, France, CERN or Sweden (Lund) could be considered as possible locations of this initial program.
Provided muon cooling has been experimentally verified in its many aspects, the subsequent realization of the full scale μ+μ- Collider program may be carried out for instance at the laboratory of the European Spallation Source (ESS) with the help of several conventional accelerator technologies of reasonable dimensions.

Primary author: Prof. RUBBIA, Carlo (GSSI)

Track Classification: Electroweak physics (physics of the W, Z, H bosons, of the top quark, and QED)

Contribution ID: **42** Type: **not specified**

The Physics Beyond Colliders Study at CERN

The Physics Beyond Colliders (PBC) study was mandated by the CERN Management in 2016 in order to prepare the next update of the European Strategy for Particle Physics. The present document reproduces the PBC mandate, presents the organization of the PBC activities and quotes the executive summary of the PBC summary report. The full summary report is appended as addendum.

Primary authors: LAMONT, Mike (CERN); JAECKEL, Joerg (ITP Heidelberg); VALLEE, Claude (Centre de Physique des Particules de Marseille)

Track Classification: Large experiments and projects

Contribution ID: **43** Type: **not specified**

Research Plans of the Norwegian Particle, Astroparticle and Nuclear Physics Communities till 2025

Norwegian particle physics, heavy-ion physics, nuclear physics, astroparticle physics, particle, astroparticle and cosmology theory present their research program for the next period of the European Strategy Update.

Primary authors: EIGEN, Gerald (University of Bergen (NO)); OSNES, Eivind

Track Classification: National road maps

Contribution ID: **44** Type: **not specified**

HFLAV input to the update of the European Strategy for Particle Physics

The Heavy Flavor Averaging Group provides with this document input to the European Strategy for Particle Physics. Research in heavy-flavor physics is an essential component of the particle-physics program, both within and beyond the Standard Model. To fully realize the potential of the field, we believe the strategy should include strong support for the ongoing experimental and theoretical heavy-flavor research, future upgrades of existing facilities, and significant heavy-flavor capabilities at future colliders, including dedicated experiments.

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Track Classification: Flavour Physics and CP violation (quarks, charged leptons and rare processes)

Contribution ID: **45** Type: **not specified**

Future Opportunities in Accelerator-based Neutrino Physics

This document summarizes the conclusions of the Neutrino Town Meeting held at CERN in October 2018 to review the neutrino field at large with the aim of defining a strategy for accelerator-based neutrino physics in Europe. The importance of the field across its many complementary components is stressed. Recommendations are presented regarding the accelerator based neutrino physics, pertinent to the European Strategy for Particle Physics. We address in particular i) the role of CERN and its neutrino platform, ii) the importance of ancillary neutrino cross-section experiments, and iii) the capability of fixed target experiments as well as present and future high energy colliders to search for the possible manifestations of neutrino mass generation mechanisms.

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Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **46** Type: **not specified**

Heavy-flavour production in relativistic heavy-ion collisions and development of novel generation of extra-low-material-budget Vertex Detectors for future experiments at CERN and JINR

One of the key requirements to be met by the future experimental installations like ALICE is to increase the accuracy of secondary vertices reconstruction in order to meet the challenging task of high precision studies in relativistic heavy-ion collisions of such rare processes like heavy-flavour production. This task requires the further reduction of the existing values of material budget of the Inner Tracking System and it is one of the main goals of the ALICE upgrade during the Long Shutdown 3 (LS3) in the period 2023-2024. The Inner Tracking System (ITS2) – the main vertex detector of ALICE – already has the record level of 0.3% radiation length (X/Xo) per layer. The new task is the development of a new high granularity fast detector which will be capable to ensure X/Xo below of 0.05% per layer. This challenge of development of high precision Vertex Detector is relevant not only to ALICE but to all experimental HEP installations both in Europe and Russia.
The proposal of the ALICE/ITS Collaboration, aimed at the R&D of the Ultra Lightweight Vertex Detector for the future ITS3 to be installed after the LS3, was developed recently and the Saint-Petersburg State University team is one of the participants. This Ultra Lightweight Vertex Detector will consist of ultra-thin (˜20μm) silicon sensors with MAPS technology, arranged in perfectly cylindrical layers, featuring an unprecedented low material budget of 0.05% X0 per layer. The given task is also paving the way for the construction of a new all-silicon tracker with unprecedented low mass, that would allow reaching down to an ultra-soft region of the phase space and to measure the production of very-low transverse momentum lepton pairs, photons and hadrons at the LHC after Long Shutdown 4 (LS4). Among the real strong challenges to be met are the design and development of the extra-lightweight, state-of-the-art support structures capable to ensure the high level of thermo- and mechanical- stability of the large arrays (of many square meters) of these ultra-thin silicon sensors. Another challenge is the efficient, very low speed, gas cooling system that will provide the functionality of these MAPS sensors.
The implementation of these advanced detector and carbon fiber composite technologies to the vertex trackers will also expand considerably the heavy-flavour research physics programs at the fixed-target NA61/SHINE at the SPS, during the LS2 in 2019-2021, and to the future BM@N, MPD and SPD experiments at NICA collider at JINR.

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Track Classification: Instrumentation and computing

Contribution ID: **47** Type: **not specified**

Physics opportunities for a fixed-target programme in the ALICE experiment

A fixed-target programme in the ALICE experiment using the LHC proton and lead beams offers many physics opportunities related to the parton content of the nucleon and nucleus at high-x, the nucleon spin and the Quark-Gluon Plasma. We investigate two solutions that would allow ALICE to run in a fixed-target mode: the internal solid target coupled to a bent crystal and the internal gas target. The feasibility of these solutions are being studied for a possible installation at the LHC interaction point IP2 during the Long Shutdown 3.

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Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **48** Type: **not specified**

Conclusions of the Town Meeting: Relativistic Heavy Ion Collisions

This text summaries the consensus view of the scientific community on priorities in the field of relativistic heavy ion collisions, as expressed by the 421 registered participants of the Town Meeting held on 24 October 2018 at CERN.

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Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **49** Type: **not specified**

Precision experiments at electron-positron collider Super Charm-Tau Factory

This document describes research program of Budker INP (Novosibirsk) on high energy physics for the next two decades based on the flagship project of the electron-positron collider Super Charm-Tau (SCT) factory. The SCT factory is designed to operate in the center-of-mass energy range from 2 to 6 GeV with peak luminosity of 10**35 cm-2s−1 above 4 GeV. Longitudinal polarization of the electron beam at the interaction region enhances the collider discovery potential. The facility, equipped with a state-of-the-art universal particle detector, allows precision measurements of decays of tau lepton and hadrons formed by quarks of the two first generations.

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Track Classification: Flavour Physics and CP violation (quarks, charged leptons and rare processes)

Contribution ID: **50** Type: **not specified**

Particle physics applications of the AWAKE acceleration scheme

The AWAKE experiment had a very successful Run 1 (2016-8), demonstrating proton-driven plasma wakefield acceleration for the first time, through the observation of the modulation of a long proton bunch into micro-bunches and the acceleration of electrons up to 2 GeV in 10 m of plasma. The aims of AWAKE Run 2 (2021-4) are to have high-charge bunches of electrons accelerated to high energy, about 10 GeV, maintaining beam quality through the plasma and showing that the process is scalable. The AWAKE scheme is therefore a promising method to accelerate electrons to high energy over short distances and so develop a useable technology for particle physics experiments. Using proton bunches from the SPS, the acceleration of electron bunches up to about 50 GeV should be possible. Using the LHC proton bunches to drive wakefields could lead to multi-TeV electron bunches, e.g. with 3 TeV acceleration achieved in 4 km of plasma. This document outlines some of the applications of the AWAKE scheme to particle physics and shows that the AWAKE technology could lead to unique facilities and experiments that would otherwise not be possible. In particular, experiments are proposed to search for dark photons, measure strong field QED and investigate new physics in electron-proton collisions. The community is also invited to consider applications for electron beams up to the TeV scale.

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Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **51** Type: **not specified**

CEPC Input to the ESPP 2018 -Accelerator

Executive summary
The discovery of the Higgs boson at CERN's Large Hadron Collider (LHC) in July 2012 raised new opportunities for a large-scale accelerator. Due to the low mass of the Higgs, it is possible to produce it in the relatively clean environment of a circular electron–positron collider with reasonable luminosity, technology, cost and power consumption. The Higgs boson is a crucial cornerstone of the Standard Model (SM). It is at the center of some of its biggest mysteries, such as the large hierarchy between the weak scale and the Planck scale, the nature of the electroweak phase transition, and many other related questions. Precise measurements of the properties of the Higgs boson serve as excellent tests of the underlying fundamental physics principles of the SM, and they are instrumental in explorations beyond the SM. In September 2012, Chinese scientists proposed a 240 GeV Circular Electron Positron Collider (CEPC), serving two large detectors for Higgs studies. The tunnel for such a machine could also host a Super Proton Proton Collider (SPPC) to reach energies beyond the LHC.
The CEPC is a large international scientific project initiated and hosted by China. It was presented for the first time to the international community at the ICFA Workshop "Accelerators for a Higgs Factory: Linear vs. Circular" (HF2012) in November 2012 at Fermilab. A Preliminary Conceptual Design Report (Pre-CDR, the White Report)[1]was published in March 2015, followed by a Progress Report (the Yellow Report)[2] in April 2017, where CEPC accelerator baseline choice was made. The Conceptual Design Report (CEPC Accelerator CDR, the Blue Report) [3]has been completed in July 2018 by hundreds of scientists and engineers after international review from June 28-30, 2018 and formally released on Sept 2, 2018.
The CEPC is a circular e+e- collider located in a 100-km circumference tunnel beneath the ground. The accelerator complex consists of a linear accelerator (Linac), a damping ring (DR), the Booster, the Collider and several transfer lines. In the tunnel, space is reserved for a future pp collider, SPPC. The center-of-mass energy of the CEPC is set at 240 GeV, and at that collision energy CEPC will serve as a Higgs factory, generating more than one million Higgs particles. The design also allows for operation at 91 GeV as a Z factory and at 160 GeV as a W factory. The number of Z particles produced will be close to one trillion, and W+W-pairs close to 20 million. The heart of the CEPC is a double-ring collider (except at SCRF region, where electron and positron use common beam pipe). Electron and positron beams circulate in opposite directions in separate beam pipes but with the common SCRF system. They collide at two interaction points (IPs), where large detectors as described in detail in the CDR (Volume II) are located. The CEPC Booster is located in the same tunnel above the Collider. It is a synchrotron with a 10 GeV injection energy and extraction energy equal to the beam collision energy. The repetition cycle is 10 seconds. Top-up injection will be used to maintain constant luminosity. The 10 GeV Linac, injector to the Booster, built at ground level, accelerates both electrons and positrons. A 1.1 GeV damping ring reduces the positron emittance. Transport lines made of permanent magnets connect the Linac to the Booster. The tunnel size is large enough to accommodate the future SPPC without removing the CEPC collider ring. This opens up the exciting possibilities of ep and e-ion physics in addition to ee physics (CEPC) and pp and ion-ion physics (SPPC). In addition to particle physics, the Collider can operate simultaneously as a powerful synchrotron radiation (SR) light source. It will extend the usable SR spectrum into an unprecedented energy and brightness range. Two gamma-ray beamlines are included in the design. The circulating CEPC beams radiate large amount of SR power, 30 MW per beam. Reducing power consumption is an important criterion in the design. By using superconducting radio frequency (SCRF) cavities, high efficiency klystrons, 2-in-1 magnets, combined function magnets, large coil cross-section in the quadrupoles, the total facility power consumption is kept below 300 MW. The power conversion efficiency from the grid to the beam will be more than 20%, higher than other accelerator facilities. Prior to the construction will be a five-year R&D period (2018-2022). During this period, prototypes of key technical components will be built and infrastructure established for industrialization for manufacturing the large number of

required components. There are numerous considerations in choosing the site. At this moment six sites have been considered and they all satisfy the technical requirements. A detailed cost estimate based on a Work Breakdown Structure (WBS) has been carried out. CEPC Construction is expected to start in 2022 and be completed in 2030. After commissioning, a tentative operation plan will be running 7 years for Higgs physics, followed by 2 years for operation in Z mode and 1 year for operation in W mode. The large number of particles produced makes the CEPC a powerful instrument not only for precision measurements on these important particles, but also in the search for new physics. The CEPC is an important part of the world plan for high-energy physics research. It will support a comprehensive research program by scientists from throughout the world. Physicists from many countries will work together to explore the science and technology frontier, and to bring a new level of our understanding of the fundamental nature of matter, energy and the Universe.

Parameters and the optimization design
According to the CEPC physics goals at the Higgs and Z-pole energies, the CEPC should provide e+e- collisions at the center-of-mass energy of 240 GeV and deliver a peak luminosity of 21034 cm-2s-1 at each interaction point. The CEPC has two IPs for e+e- collisions. At the Z-pole the luminosity is required to be larger than 11034 cm-2s-1 per IP. Its circumference is around 100 km in accordance with the SppC, which is designed to provide proton-proton collisions at 100 TeV center-of-mass energy using 16 Tesla superconducting dipole magnets.
The CEPC baseline design is a 100 km fully partial double ring scheme based on crab waist collision and 30 MW radiation power per beam at Higgs energy, with the shared RF system for both electron and positron beams. As an alternative option, Advanced Partial Double Ring (APDR) has been also studied systematically with the aim of comparing the luminosity potentials and saving cost.
The luminosities for Higgs and W operation are mainly limited by the SR power (30 MW). The luminosity at Higgs is 3 1034 cm-2s-1 with 242 bunches; the luminosity at the W is 1 1035 cm-2s-1 with 1524 bunches. At the Z pole, the luminosity for 3T detector solenoid is 1.7 1035 cm-2s-1 and is 3.2 1035 cm-2s-1 for 2T detector solenoid, both with 12,000 bunches. The limit of bunch number comes from the electron cloud instability of the positron beam. The minimum bunch separation for Z due to electron cloud effect is 25 ns and a 10% beam gap is left for cleaning. There is still some space for parameter optimization at z pole to get even higher luminosity. Beam-beam interaction in is one of the most important limitations to the CEPC performance, which is calculated both by analytical method and computer simulations to make optimized parameter design and choose optimum operating conditions. The crab-waist scheme increases the luminosity by suppressing vertical blow up, which is a must to reach high luminosity. Beamstrahlung is synchrotron radiation excited by the beam-beam force, which is a new phenomenon in a storage ring based collider. It will increase the energy spread, lengthen the bunch and may reduce the beam lifetime due to the long tail of the photon spectrum. The beam-beam limit at the W/Z is mainly determined by the coherent x-z instability instead of the beamstrahlung lifetime as in the Higgs mode. Longer bunch length will help to suppress the coherent instability.
The CEPC CDR design goals have been evaluated and checked from the point view of beam-beam interaction, which is feasible and achievable.

Lattice optics
The CEPC lattice optics is designed with requirements and constraints mainly from top-level parameters, geometry, minimizing cost, compatibility of Higgs, W and Z modes, and compatibility with SPPC. The interaction region is designed to provide strong focusing and crab-waist collision. A local correction scheme is adopted to get a large momentum acceptance. An asymmetric lattice is adopted to allow softer synchrotron-radiation photons from the upstream part of the IP. Twin-aperture dipoles and quadrupoles are used in the arc region to reduce power. The two beams are separated by 35 cm. For the arc region, a FODO cell structure is chosen to provide a large filling factor of dipoles. The 90/90-degrees phase advances and non-interleaved-sextupole scheme are selected due to aberration cancellation. In the RF region, the RF cavities are shared by the two rings. Each RF station is divided into two sections for bypassing half of the cavities when running in W or Z modes. An electrostatic separator combined with a dipole magnet avoids bending the incoming beam. The sawtooth effect is expected to be curable by tapering the magnet strength to take into account the beam energy at each magnet. The vertical emittance due to the solenoid field

coupling is limited and acceptable.
The requirements of dynamic aperture (DA) are got from injection and beam-beam effects to get efficient injection and adequate beam life time. A differential evolution algorithm based optimization code has been developed for CEPC, which is a multi-objective code called MODE. The SAD code is used to do the optics calculation and dynamic aperture tracking. Strong synchrotron radiation causes strong radiation damping which helps enlarge the dynamic aperture to some extent. Quantum fluctuations in the synchrotron radiation are considered in SAD, where the random diffusion due to synchrotron radiation in the particle tracking is implemented in each magnet. Thirty-two arc sextupole families, 10 IR sextupole families and 8 phase advance tuning knobs between different sections are used to optimize the DA. All the sextupoles (˜250) could be free. There exists no clear difference with more sextupole families. The optimized DA could meet the requirement of injection and colliding beam lifetime. The work of DA with errors and correction are undergoing.

Machine-detector interface (MDI)
The machine-detector interface (MDI) is about 7 m in length in the Interaction Region (IR), where many elements need to be installed, including the detector solenoid, anti-solenoide, luminosity calorimeter, interaction region beam pipe, beryllium pipe, cryostat, beam position monitors (BPMs) and bellows. The cryostat includes the final doublet superconducting magnets and anti-solenoid. The CEPC detector consists of a cylindrical drift chamber surrounded by an electromagnetic calorimeter, which is immersed in a 3T superconducting solenoid of length 7.6 m. The accelerator components inside the detector should not interfere with the devices of the detector. The smaller the conical space occupied by accelerator components, the better will be the geometrical acceptance of the detector. From the requirement of detector, the conical space with an opening angle should not larger than 8.11 degrees. After optimization, the accelerator components inside the detector without shielding are within a conical space with an opening angle of 6.78 degrees. The crossing angle between electron and positron beams is 33 mrad in horizontal plane. The final focusing quadrupole is 2.2 m (L*) from the Interaction Point (IP). The luminosity calorimeter will be installed in a longitudinal location 0.95˜1.11 m, with an inner radius of 28.5 mm and outer radius 100 mm. Primary results are got from the assembly, interfaces with the detector hardware, cooling channels, vibration control of the cryostats, supports and so on.
A water cooling structure is required to control the heating problem of HOM in IR vacuum chamber. For the beam pipe within the final doublet quadrupoles, since there is a 4mm gap between the outer space of beam pipe and the inner space of Helium vessel, a room temperature beam pipe has been chosen.
SR photons in the IR are mainly generated from the final upstream bending magnet and the IR quadrupole magnets due to eccentric particles. With 3 mask tips along the inside of the beam pipe to shadow the inner surface of the pipe the number of scattered photons that can hit the central beam pipe is greatly reduced to only those photons which forward scatter through the mask tips. With collimators in the ARC far from IP the SR photons from IR quadrupoles will not damage the detector components and cause background to experiments.
Beam loss background are mainly from Bhabha scattering, beamstrahlung, beam-thermal photon scattering and beam-gas inelastic scattering. With collimators in the ARC far from IP, beam loss background can be reduced significantly and can be accepted by the detector.

CEPC SCRF system
CEPC will use a 650 MHz RF system with 240 2-cell superconducting cavities for the Collider and a 1.3 GHz RF system with 96 9-cell superconducting cavities for the Booster. The Collider is a fully partial double-ring with common cavities for electron and positron beams in Higgs operation mode and a double ring for separate cavities for electron and positron beams in W and Z operation modes. Full installation of the same types of cavities and cryomodules for Higgs, W, and Z-pole modes without changing any hardware is the baseline configuration. The Collider SCRF system is optimized for the Higgs mode of 30 MW SR power per beam, with enough tunnel space and operating margin to allow higher RF voltage and/or SR power (50 MW SR power per beam) by adding cavities. Each Collider cavity has two detachable coaxial HOM couplers mounted on the cavity beam pipe with HOM power handling capacity of 1 kW. Each 11 m-long cryomodule consists of six cavities. Each cryomodule has two beamline HOM absorbers at room temperature outside the vacuum vessel with HOM power handling capacity of 5 kW each.

HOM power limit per cavity and the fast-growing longitudinal coupled-bunch instabilities (CBI) driven by both the fundamental and higher order modes impedance of the RF cavities determine to a large extent the highest beam current and luminosity obtainable in the Z mode. Transient beam loading is also a concern. For a higher luminosity Z upgrade, because of the high HOM power and the need to have the smallest number of cavities, KEKB / BEPCII type single cavity cryomodules with very high input coupler power will be needed.
The CEPC SCRF technical challenges that require R&D include: achieving the cavity gradient and high quality factor in the real cryomodule environment (Q0 > 4×1010 at 22 MV/m for the vertical acceptance test with nitrogen-doping technology, and normal operation gradient below 20 MV/m with the lower limit of Q0 of 1.5×1010 for long term operation), robust and variable high power (> 300 kW CW) input couplers that are design compatible with cavity clean assembly and low heat load, efficient and economical damping of the HOM power with minimum dynamic cryogenic heat load, and fast RF ramp and control of the Booster.
In parallel with design and key R&D, extensive development of SCRF personnel, infrastructure and industrialization is essential for the successful realization of CEPC. This will have synergy with ongoing SCRF-based accelerator projects in China, such as SHINE (Shanghai HIgh repetition rate XFEL aNd Extreme light facility) in Shanghai and ADANES (Accelerator Driven Advanced Nuclear Energy System) in Huizhou, etc.

Collective effects
Interaction of an intense charged particle beam with the vacuum chamber can lead to collective instabilities. These instabilities will induce beam quality degradation or beam losses, and finally restrict the performance of the machine.
The impedance and wake are calculated both with formulas as well as simulations with ABCI and CST. Both longitudinal and transverse impedances are dominated by the resistive wall and elements of which there is a large quantity. The longitudinal loss factor is mainly contributed by the resistive wall and the SCRF cavities.
The impedance driven instabilities include single bunch and multi-bunch effects. The limitation on the longitudinal broadband impedance mainly comes from microwave instability and bunch lengthening. The microwave instability will rarely induce beam losses, but may reduce the luminosity due to the distorted beam distribution and increasing of the beam energy spread. The limitation on the transverse broadband impedance mainly comes from the transverse mode coupling instability. Considering the bunch lengthening due to the longitudinal impedance, the transverse effective impedance will decrease with bunch intensity. The narrowband impedances are mainly contributed by cavity like structures. These impedances may induce coupled bunch instabilities in both longitudinal and transverse planes. The dominant contributions to the coupled bunch instability include resistive wall impedance and the HOM of the SCRF cavities. In order to damp the instabilities, bunch by bunch feedback systems are required. For different operation scenarios, the Z-pole mode has the most critical restrictions for both broadband and narrowband impedances.
Except the impedance driven effects, there are also two stream instabilities that may restrict the beam performance in the collider. In the electron ring, instabilities can be excited by residual gas ions accumulated in the potential well of the electron beam. Fast beam ion instability is a transient beam instability excited by the beam-generated ions accumulated in a single passage of the bunch train. The instability can be faster than the radiation damping. For the most critical case of Z-pole energy, multi-bunch train filling patterns and transverse feedback system are required.
Electron Cloud Effect is one of the considerations in positron ring of CEPC collider. The photon electrons and secondary electron emission will be the main contribution to the electron cloud. The most effective mitigation on electron cloud is coating TiN or NEG to depress secondary electron emission yield (SEY) to approximation one. The simulation for electron cloud density in different SEY and its threshold have been carried out during the conceptual design of CEPC. The shortest bunch spacing during Z-pole operation is 25 ns with bunch population 8.0x1010. A transverse feedback system for damping ECI is also taken as a backup.

CEPC booster
The booster provides electron and positron beams to the collider at different energies. Both the initial injection from zero current and the top-up injection should be fulfilled. The booster is in the same tunnel as the collider, placed above the collider ring except in the interaction region where

there are bypasses to avoid the detectors at IP1 and IP3.
The injection system consists of a 10 GeV Linac, followed by a full-energy Booster ring. Electron and positron beams are generated and accelerated to 10 GeV in the Linac, are injected into the Booster. The beams are then accelerated to full-energy, and injected into the Collider. For different beam energies of Higgs, W, and Z experiments, there will be different particle bunch structures in the Collider. To maximize the integrated luminosity, the injection system will operate mostly in top-up mode, but also has the ability to fill the Collider from empty to full charge in a reasonable length of time. A traditional off-axis injection scheme is chosen as a baseline design of the beam injection to the main collider, and a swap-out injection is given as another choice for Higgs injection.
The design goal for the booster optics is to make sure the geometry is the same as the collider and satisfy the requirements of beam dynamics. The total number of magnets and sextupole families is minimized taking into account capital and operating costs. The maximum cell length and hence the maximum emittance in the booster is limited by the collider injection requirements. The length of two FODO cells in the booster corresponds to three FODO cells in the collider. The horizontal position of the booster has been designed in the center of collider two beams. The height difference between booster and collider is 2.4m and the horizontal position error of booster is controlled under 0.17m. CEPC booster has the same circumference as the collider (100016.4m). 90/90 FODO cell and non-interleave sextupole scheme is adopted to achieve the biggest Dynamic aperture (DA).
DA reduction due to sawtooth effect at 120GeV is negligible so magnets energy tapering is unnecessary in booster. The error analysis has been done and so far the errors in the booster are tolerable.
During ramping, parasitic sextupole field is induced on beam pipe inside dipoles due to eddy current. So the ramping rate (0.1Hz) is limited by eddy current effect. Dedicated ramping curve is found to control the maximum K2. Even if the dynamic chromaticity distortion is corrected by the independent sextupoles during ramping, the DA reduction around 20GeV is serious. A beam simulation of the entire period in the booster from injection to extraction is needed to verify the design, using a realistic beam from the linac.
Low field dipole magnet is aslo a big challenge for CEPC because the booster dipoles have to start from 29 Gauss. The requirement for field error field reproducibility at low energy is difficult to reach. Both technical solutions and physical solutions will be explored.

CEPC linac injector
The CEPC linac injector to booster is a normal conducting S-band linac with frequency 2860 MHz providing electron and positron beams at an energy of up to 10 GeV at a repetition rate of 100 Hz. One-bunch-per-pulse is adopted and bunch charge should be larger than 1.5nC.
In the design of CEPC linac, the reliability and availability of the linac injector was emphasized because it is one of the indispensable facilities. The S-band linac has a robust design based on well proven technologies, and a 15% overhead of accelerating structure and klystron is foreseen to provide margins. The linear type layout of CEPC linac is adopted and one electron transport line at an energy of 4 GeV is desiged to bypass the positron source and part accelerating section. All the lattice design and multi-particle simulations are conducted and the linac can meet all the requirements with errors.
A thermionic gun is adopted and can provide 11 nC electron beam for positron production. To keep the potential to meet higher requirements and possibility of updates in the future, the linac can provide bunch charge larger than 3 nC electron beam and posirton beam. The positron source is a conventional design with a tungsten target of 15 mm in length and adiabatic matching device of 6 T in peak magnetic field. The energy of electron beam for positron production is 4 GeV and rms beam size is 0.5 mm.
A 1.1 GeV damping ring with 58.8m circumference is adopted to reduce the transverse emittance of positron beam to suitably small value. Longitudinal bunch length control has provided to minimize wake field effects in the linac by a bunch compressor system after the damping ring. Both parameters for damping ring and bunch compressor have designed, also the lattice design is finished and the DA can fulfill the requirement.

CEPC collider magnets
There are 2466 dipoles, 3052 quadrupoles, 948 sextupoles and 2904 correctors in the CEPC collider

ring. Theses conventional magnets occupy over 80% of the 100 km circumference, therefore, the cost and power consumption are two of the most important issues for magnet design. The 2384 dipoles and 2392 quadrupoles are designed to be dual aperture magnets to provide magnetic field for both beams separated by 350 mm. Several special technologies are used to reduce the cost of the magnets, including core steel dilution for dipoles and aluminum coils instead of copper. In addition, the magnets are designed for low-current high-voltage operating mode as much as possible to reduce the power consumption in the power cables. Radiation shielding is also considered. In the Technical Design Report (TDR) R&D phase, the dual aperture dipole and quadrupole short prototype magnets will be developed.

Booster magnets
The circumferences of the booster is about 100 km, which has 16320 dipoles, 2036 quadrupoles, 448 sextupoles and 350 correctors. The gap of the dipole magnets is 63 mm, the most of them are 4.7 m long, the others are 2.4 m and 1.7 m long. The field will change from 29 Gauss to 392 Gauss during acceleration. The field errors in good field region are required to be less than 1E-3. Due to very low field level, the cores are composed of stacks of 1 mm thick low carbon steel laminations spaced by 1 mm thick aluminium laminations. Since magnetic force on the poles is very small, the return yoke of the core can be made as thin as possible. In the pole areas of the laminations, some holes will be stamped to further reduce the weight of the cores as well as to increase the field in the laminations. All above considerations can improve the performance of the iron core and considerably reduces the weight and the cost. Also for economic reasons, the excitation bars are made from pure aluminum of cross section 3040 mm2 without water cooling.
The bore diameter of the quadrupole magnets is 64 mm, the magnetic length are 1 m, 1.5 m and 2.2 m respectively, the max. quadrupole field is 16.6 T/m. The min. quadrupole field is 1/12 of the max. field. For cost reduction, hollow aluminum instead of copper conductors are selected to wind the coils. The iron cores are made of 0.5 mm thick laminated low carbon silicon steel sheets. The magnet will be assembled from four identical quadrants, and can also be split into two halves for installation of the vacuum chamber.
The bore diameter of the sextupole magnets is also 64 mm, all the magnets are 400 mm long, the max. sextupole field is 440 T/m2. The min. sextupole field is 1/12 of the max. field. The cores of the magnets have a two-in-one structure, made of low-carbon silicon steel sheets and end plates. By using end chamfering, the field errors can be reduced to meet the strict field requirements. The coils of the magnets have a simple racetrack-shaped structure, which are wound from solid copper conductors without water cooling.
The gap of the correctors is 63 mm, the max. field is 200 Gs, the field errors in good field region is required to be less than 1E-3. To meet the field quality requirements, the correctors have H-type structure cores so the pole surfaces can be shimmed to optimize the field. The cores are stacked from 0.5 mm thick laminations. The racetrack shaped coils are wound from solid copper conductor. Each coil has 24 turns, which are formed from 4 layers; no water cooling is required.

CEPC interaction region superconducting magnets
Compact high gradient final focus superconducting quadrupole doublet magnet (QD0 and QF1) are required on both sides of the collision points of CEPC collider ring. QD0 and QF1 are double aperture quadrupoles and are operated fully inside the field of the Detector solenoid with a central field of 3.0 T. To minimize the effect of the longitudinal detector solenoid field on the accelerator beam, anti-solenoids before QD0, outside QD0 and QF1 are needed. The total integral longitudinal field generated by the detector solenoid and anti-solenoid coils is zero. It is also required that the total solenoid field inside the QD0 and QF1 magnet should be close to zero. The superconducting QD0, QF1, and anti-solenoid coils are in the same cryostat, which makes up a combined function magnet. In the TDR R&D phase, superconducting prototype magnets for the CEPC interaction region will be developed in three consecutive steps: 1) Double aperture superconducting quadrupole prototype magnet QD0 (136T/m, 2m long). 2) Short combined function superconducting prototype magnet including QD0 and the anti-solenoid. 3) Long combined function superconducting prototype magnet including QD0, QF1 (110T/m, 1.48 long) and anti-solenoid.

CEPC vacuum system
R & D of the CEPC vacuum system include the vacuum chambers, RF shielding Bellows and NEG coating inside the inner surface of the vacuum system in the positron ring.

The Collider will have an aluminum chamber for the electron beam and a copper chamber for the positron beam. The aluminum chamber is similar to the LEP chamber. It has a beam channel, a cooling water channel, a pumping port used to install ion pump, and thick lead shielding blocks covering the outside. The copper chamber has a beam channel and a cooling water channel, and NEG coating will be used. In the R&D program both types of chambers will be fabricated and tested. The prototypes of both copper and aluminum vacuum chambers will be fabricated and tested. The ultimate pressure of the vacuum chambers is less than 210-10Torr⊠The thermal outgassing rate is less than 5×10-12Torr•L/s/cm2.
The NEG coating is a titanium, zirconium, vanadium alloy, deposited on the inner surface of the chamber through sputtering. R&D is required so the sputtering process for NEG film deposition is optimized to avoid instability and lack of reproducibility. These problems can significantly change the gas sorption and surface properties (e.g. secondary electron yield, ion-induced gas desorption). During tests of the coating, all related parameters (plasma gas pressure, substrate temperature, plasma current, and magnetic field value) will be recorded and suitably adjusted to ensure stability of the deposition process. After coating, the chambers will be cooled down to room temperature, exposed to air and left to age for a couple of days before being visually inspected again. Aging is a recommended procedure, since it helps identify areas where the film adhesion is poor. The design specification with pumping speed of 0.5 L/s/cm2 (H2) for the coating vacuum chamber will be achieved.
The primary function of the RF shielding bellows is to allow for thermal expansion of the chambers and for lateral, longitudinal and angular offsets due to tolerances and alignment, while providing a uniform chamber cross section to reduce the impedance seen by the beam. The usual RF-shield has many narrow Be-Cu fingers that slide along the inside of the beam passage as the bellows is compressed. The design specification of the contact pressure for RF contact fingers is 12525g/finger.

CEPC 650MHz high efficiency klystron
The CEPC two beam synchrotron radiation power is more than 60 MW, it needs high efficiency RF source to minimize CEPC AC power consumption. Considering the klystron operation lifetime and power redundancy, a single 650MHz 800 kW klystron amplifier will drive two of the collider ring SC cavities through a magic tee and two rated circulators and loads. The CEPC high efficiency 650MHz klystron design goals are to set the efficiency to be above 80% and successful industrialization.

Civil and conventional facilities
Underground structures of CEPC consist of collider ring tunnel (L=99.67km), experiment halls (2 experiment halls for CEPC, and 2 future experiment halls for SPPC), CEPC linac injector is located on the surface. Surface structures within the collider ring area, such as auxiliary equipment structures, cooling towers, substations and ventilation systems, are located close to the shafts. The total area of surface structures is 140450m2. The total CEPC tunnel civil construction period is 54 months, including 8 months for construction preparation, 43 months for construction of main structures and 3 months for completion. The total electrical load for physical experiments and general facilities is 270MW. It is proposed to use 220kV for the project, and to have two 220kV central substations (220kV/110kV/10kV) in the project area. The total heat load absorbed by the cooling water system is 213MW during CEPC operation for Higgs physics experiments. There are 16 pump stations at each point of the ring and an additional one for Linac. The air conditioning cold load of the collider ring tunnel is about 6MW. The tunnel is divided into 32 sections. Each section is considered to be independent for the ventilation and primary return air conditioning system. Fire prevention and exhaust systems, hydrant and fire extinguisher systems, and fire detection and fire alarm systems are combined with building fire prevention and evacuation, to minimize fire hazards.

CEPC cost, site selection, management and construction
The cost of CEPC contains mainly three parts, civil engineering, accelerator with two detectors. As cost repartition (without detectors, for example), civil engineering 40%; collider magnets 12%; booster magnets 6%, vacuum system 9%; RF power system 6%; SRF system 4%; mechanical system 5%; instrumentation 4%; cryogenic system 4%; linac injector 2.5%; and others. As for CEPC site selection, the technical criteria are roughly quantified as follows: earthquake intensity less than seven on the Richter scale; earthquake acceleration less than 0.1 g; ground surface-vibration amplitude less than 20 nm at 1–100 Hz; granite bedrock around 50–100 m deep, and others. The site-

selection process started in February 2015，preliminary studies of geological conditions for CEPC's potential site locations have been carried out in Qinhuangdao and Xiongan in Hebei province; Shenshan special district in Guangdong province; Huangling county in Shanxi province; Huzhou in Zhejiang province; and Chuangchun in Jilin province, and all these sites satisfies the CEPC construction requirements.
The scheduled timeline for CEPC construction is that after the TDR finished in 2022, CEPC will start the civil construction. According to Chinese civil construction companies involved in the siting process, a 100 km tunnel will take less than five years to dig using drill-and-blast methods, which is followed by accelerator and detectors' installation. Around 2030, CEPC construction will be finished followed by machine operation.
The CEPC by nature is Chinese initiated international large science project, and the project will be participated, contributed and managed in an international way in all its level and in all of its process from CDR, TDR, construction and operation for physics experiments.

SppC
SppC (Super proton-proton Collider) as an integral part of the CEPC-SppC project, aims for energy-frontier discoveries, which will be a long-term development or more than twenty years from now after CEPC as an electron-positron collider will accomplish its main physics goals. However, it is important to include the SppC in the general CEPC study, as we do not wish that the CEPC design would not hinder the future development to add the SppC collider in the same tunnel. Other physics possibilities such as e-p collision that involves both CEPC and SppC beams should not be forgot during the general project planning.
As SppC is a long-term project with many technical challenges, it is necessary to pursue studies to work on critical physics and technological key issues. One of the key issues is high-field superconducting magnets of at least 12 T. The SppC baseline design of is to use 12 T high-temperature iron-based superconductors for high field dipole magnets to allow proton–proton collisions at a centre of mass energy of 75 TeV and a luminosity of 1035 cm−2 s−1.
About the accelerator physics study on SppC, the studies include: machine layout and lattice design with compatibility to CEPC; collimation method and machine protection scheme to handle the extremely high stored energy in beams; potential in collision luminosity and critical interaction regions, etc. As SppC collider needs an injector chain that consists of a series of powerful accelerators, current design of injector chain consists of four accelerators in cascade.
As for the timeline of SppC, till 2035 is CDR and R&D period; till 2040 is the Technical Design Report period, from 2040-2045 is SppC construction period, and SppC will be put to operation started from 2045.

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Future colliders - Linear and circular

The completion of the Standard Model of particle physics by the discovery of a light Higgs boson at the LHC in 2012 triggered the debate about the best way forward to discover physics beyond the Standard Model. At the eve of the update of the European Strategy of particle physics, this article summarises the motivation and status of the different collider projects in particle physics at the energy frontier. This article reflects the status as of December 2018 and the reader is invited to follow closely updated information of the presented projects.

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Track Classification: Large experiments and projects

Contribution ID: **53** Type: **not specified**

HEP Computing Evolution

High Energy Physics (HEP) has demonstrated a unique capability with the global computing infrastructure for LHC, achieving the management of data at the many-hundred-Petabyte scale, and providing access to the entire community in a manner that is largely transparent to the end user. Other HEP experiments have expressed a desire to benefit from this infrastructure and organization, and recent interactions with other related science communities that have similar needs on the HL-LHC timescale show interest in collaboration. In this paper we outline a proposed strategy by which the computing infrastructure developed for LHC could be broadened in collaboration with other interested HEP experiments, while retaining the LHC-specific needs within the WLCG collaboration. This proposal is in line with the WLCG strategy for addressing computing for HL-LHC, and is aligned with European and other international strategies in computing for large scale science.

Primary authors: BIRD, Ian (CERN); CAMPANA, Simone (CERN)

Track Classification: Instrumentation and computing

Contribution ID: **54** Type: **not specified**

CERN's view on Knowledge Transfer as input for the European Strategy on Particle Physics update

Please refer to the document attached.

Primary author: ANELLI, Giovanni (CERN)

Track Classification: Other (communication, outreach, strategy process, technology transfer, individual contributions,…)

Contribution ID: **55** Type: **not specified**

Particle Physics in Finland

Abstract: In the report current plans and some ideas for future are reported for particle physics and related fields in Finland.

Primary authors: Prof. HUITU, Katri (Helsinki Institute of Physics); Prof. LAPPI, Tuomas (Dept. oh Physics, Univ. of Jyväskylä)

Track Classification: National road maps

Contribution ID: **56** Type: **not specified**

Ultra-relativistic Heavy-Ion Collisions: Inputs of the Italian community for the ESPPU 2018–2020

This document was prepared by the community that is active in Italy, within INFN (Istituto Nazionale di Fisica Nucleare), in the field of ultra-relativistic heavy-ion collisions. The experimental study of the phase diagram of strongly-interacting matter and of the Quark–Gluon Plasma (QGP) deconfined
state will proceed, in the next 10–15 years, along two directions: the high-energy regime at RHIC and at the LHC, and the low-energy regime at FAIR, NICA, SPS and RHIC.The Italian community is strongly involved in the present and future programme of the ALICE experiment, the upgrade of which will open, in the 2020s, a new phase of high-precision characterisation of the QGP properties at the LHC. The community also contributes to the heavy-ion programme of the LHCb experiment. The physics case of a very-high-luminosity programme in the 2030s at the LHC using intermediate-mass nuclei is considered with interest. In addition, there is a growing interest in a possible future experiment at the SPS, which would primarily target the search for the onset of deconfinement using dimuon measurements. The strong expertise of the community in detector development and construction, in particular in the sector of low-material silicon trackers, can serve as a common basis for these new projects at the LHC and SPS.On a longer timescale, the community participates in the ongoing studies for a heavy-ion programme at the Future Circular Collider or the High Energy LHC.

Primary authors: DAINESE, Andrea (INFN - Padova (IT)); BRUNO, Giuseppe (Universita e INFN, Bari (IT)); SCOMPARIN, Enrico (Universita e INFN Torino (IT)); USAI, Gianluca (Universita e INFN, Cagliari (IT))

Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **57** Type: **not specified**

A high precision neutrino beam for a new generation of short baseline experiments

The current generation of short baseline neutrino experiments is approaching intrinsic source limitations in the knowledge of flux, initial neutrino energy and flavor. A dedicated facility based on conventional accelerator techniques and existing infrastructures designed to overcome these impediments would have a remarkable impact on the entire field of neutrino oscillation physics. It would improve by about one order of magnitude the precision on ν_μ and ν_e cross sections, enable the study of electroweak nuclear physics at the GeV scale with unprecedented resolution and advance searches for physics beyond the three-neutrino paradigm. In turn, these results would enhance the physics reach of the next generation long baseline experiments (DUNE and Hyper-Kamiokande) on CP violation and their sensitivity to new physics. In this document, we present the physics case and technology challenge of high precision neutrino beams based on the results achieved by the ENUBET Collaboration in 2016-2018. We also set the R\&D milestones to enable the construction and running of this new generation of experiments well before the start of the DUNE and Hyper-Kamiokande data taking. We discuss the implementation of this new facility at three different level of complexity: ν_μ narrow band beams, ν_e monitored beams and tagged neutrino beams. We also consider a site specific implementation based on the CERN-SPS proton driver providing a fully controlled neutrino source to the ProtoDUNE detectors at CERN.

Primary author: Prof. LONGHIN, Andrea (Padova University and INFN)

Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **58** Type: **not specified**

AWAKE++: the AWAKE Acceleration Scheme for New Particle Physics Experiments at CERN

The AWAKE experiment reached all planned milestones during Run 1 (2016-18), notably the demonstration of strong plasma wakes generated by proton beams and the acceleration of externally injected electrons to multi-GeV energy levels in the proton driven plasma wakefields. During Run 2 (2021 - 2024) AWAKE aims to demonstrate the scalability and the acceleration of electrons to high energies while maintaining the beam quality.
Within the Physics Beyond Colliders (PBC) study AWAKE++ has explored the feasibility of the AWAKE acceleration scheme for new particle physics experiments at CERN. Assuming continued success of the AWAKE program, AWAKE will be in the position to use the AWAKE scheme for particle physics applications such as fixed target experiments for dark photon searches and also for future electron-proton or electron-ion colliders. With strong support from the accelerator and high energy physics community, these experiments could be installed during CERN LS3:
Integration and beam line design studies show the feasibility of a fixed target experiment in the AWAKE facility, downstream of the AWAKE experiment in the former CNGS area. The expected electrons on target for fixed target experiments exceeds the electrons on target by three to four orders of magnitude with respect to the current NA64 experiment, making it a very promising experiment in the search for new physics.
Studies show that electrons can be accelerated to 70 GeV in a 130 m long plasma cell installed in an extended TI2 extraction tunnel from SPS to the LHC and transported to collision with protons/ions from the LHC. The experiment would focus on studies of the structure of matter and QCD in a new kinematic domain.
The AWAKE scheme offers great potential for future high energy physics applications and it is the right moment now to support further development of this technology leading to unique facilities.

Primary authors: GSCHWENDTNER, Edda (CERN); BARTMANN, Wolfgang (CERN); CALDWELL, Allen (Max-Planck-Institut fur Physik (DE)); CALVIANI, Marco (CERN); CHAPPELL, James Anthony (University of London (GB)); CRIVELLI, Paolo (ETH Zurich (CH)); DAMERAU, Heiko (CERN); DEPERO, Emilio (ETH Zurich (CH)); DOEBERT, Steffen (CERN); GALL, Jonathan (CERN); GNINENKO, Sergei (Russian Academy of Sciences (RU)); GODDARD, Brennan (CERN); GRENIER, Damien (CERN); HARTIN, Anthony (DESY); HESSLER, Christoph (CERN); KEEBLE, Fearghus (University College London); OSBORNE, John Andrew (CERN); PARDONS, Ans (CERN); PETRENKO, Alexey (Budker Institute of Nuclear Physics (RU)); SCAACHI, Adam; WING, Matthew (University College London)

Track Classification: Accelerator Science and Technology

Contribution ID: **59** Type: **not specified**

Initial INFN input on the update of the European Strategy for Particle Physics: software and computing

The INFN sees two major areas of application for high energy physics computing in the time scale relevant for the Strategy Update: the exploitation of high performance computing (HPC) and the use of Quantum Computing. The first one can be realized within few years, with high energy physics experiments becoming major users of HPC. Quantum computing is still at the level of research and development, but it can be the new disruptive technology changing the computing horizon. The exploitation of the former and the research and development of the latter are described in the document.

Primary author: LUCCHESI, Donatella (Universita e INFN, Padova (IT))

Track Classification: Instrumentation and computing

Contribution ID: **60** Type: **not specified**

PBC technonlogy subgroup report

This document contains results of the work of the PBC technology subgroup set up by the Physics Beyond Collider Working Group.

Goal of the technology subgroup set by PBC:
Exploration and evaluation of possible technological
contributions of CERN to non-accelerator projects possibly
hosted elsewhere: survey of suitable experimental initiatives
and their connection to and potential benefit to and from CERN;
description of identified initiatives and how their relation to the
unique CERN expertise is facilitated.

Primary authors: DOBRICH, Babette (CERN); SIEMKO, Andrzej (CERN); CANTATORE, Giovanni (Univ. + INFN); DELIKARIS, Dimitri (CERN); MAPELLI, Livio (Princeton University (US)); CAVOTO, Gianluca (Sapienza Universita e INFN, Roma I (IT)); PUGNAT, Pierre (Lab. des Champs Magnet. Intenses (FR)); SCHAFFRAN, Joern (Deutsches Elektronen-Synchrotron (DE)); SPAGNOLO, Paolo (INFN Sezione di Pisa, Universita' e Scuola Normale Superiore, P); TEN KATE, Herman (CERN); Prof. ZAVATTINI, Guido (Universita e INFN, Ferrara (IT))

Track Classification: Accelerator Science and Technology

Contribution ID: **61** Type: **not specified**

Input to the ESPP process from the community of Danish high-energy and nuclear experimentalists and theorists.

This documents presents the interests and priorities of the Danish high energy and nuclear physics community based on the town meeting held by the National Center for CERN research (NICE) in June 2018 in Middelfart, DK.

Primary author: Prof. GAARDHØJE, Jens Jørgen (Niels Bohr Institute)

Track Classification: National road maps

Contribution ID: **62** Type: **not specified**

Future Dark Matter Searches with Low-Radioactivity Argon

We present the case for the DarkSide-Argo program for direct dark matter searches with low-radioactivity argon.

The immediate objective is the DarkSide-20k two-phase liquid argon detector, currently under construction at the Gran Sasso laboratory (LNGS). DarkSide-20k will have ultra-low backgrounds, with the ability to measure its backgrounds in situ, and sensitivity to WIMP-nucleon cross sections of 1.2 × 10−47 cm2 (1.1 × 10−46 cm2) for WIMPs of 1TeV/c2 (10TeV/c2) mass, to be achieved with a 5 yr run and an exposure of 100 t × yr. This projected sensitivity is a factor of >50 better than currently-published results above 1TeV/c2, and covers a large fraction of the parameter space currently preferred by supersymmetric models. With 100 t × yr exposure 1.6 NR events are expected from the coherent scattering of atmospheric neutrinos, making DarkSide-20k the first ever direct dark matter detection experiment to reach this crucial milestone. The sensitivity would further improve to 7.4 × 10−48 cm2 (6.9 × 10−47 cm2) for WIMPs of 1 TeV/c2 (10 TeV/c2) mass for a decade run with exposure of 200 t × yr. DarkSide-20k is foreseen to start operations in 2022 and will either detect WIMP dark matter or exclude a large fraction of the favored parameter space.

In parallel to DarkSide-20k, a second and important element for this program will be a detector of the order of 1 t in mass: DarkSide-LowMass (DS-LM), which we will propose to be installed at LNGS and specifically optimized for the observation of the electroluminescence signal below 10 GeV/c2 with strong restriction of electron recoils background through careful detector design. Based on demonstrated ultra-low threshold and world-leading sensitivity achieved with DarkSide-50, and coupled to additional 39Ar reduction by distillation in Aria and the use of a massive liquid argon veto, this dedicated search would display an excellent discovery capability, reaching through the so-called "neutrino floor" in the low-mass search region.

The crowning objective, towards the end of the next decade, will be the construction of the ultimate Argo detector with a 300 t fiducial mass to push the sensitivity to the region where neutrino background will be a limitation in detectors without directional capability. The WIMP detection sensitivity will only be limited by systematic uncertainties in nuclear recoil background from Coherent Neutrino Scattering of Atmospheric neutrinos. The strong electron recoil rejection will eliminate background from solar neutrinos and some residual internal backgrounds such as radon. This unique property of argon extends the sensitivity with respect to technologies with more limited electron recoils discrimination. The throughput of the Urania argon extraction system would enable 400 t of underground argon to be extracted and purified in the Aria facility over a period of about 6 yr. SNOLAB would be strong potential site for this detector motivated by the dark matter search, but also possibly enabling the observation of ultra-rare solar neutrino sources (CNO, hep).

Primary author: THE GLOBAL ARGON DARK MATTER COLLABORATION

Track Classification: Dark matter and dark sector (accelerator and non-accelerator dark matter, dark photons, hidden sector, axions)

Contribution ID: **63** Type: **not specified**

Japan's Updated Strategy for Future Projects in Elementary Particle Physics

In September 2017, the Japanese high energy physics community, JAHEP (Japan Association of High Energy Physicists), updated the strategy for future particle physics by endorsing the Final Report of the Committee on Future Projects in High Energy Physics.

The Final Report summarizes Japan's future strategy as follows:

In 2012, not only was a Higgs boson with a mass of 125 GeV discovered at the LHC, but three-generation neutrino mixing was also established. Taking full advantage of the opportunities provided by these discoveries the committee makes the following recommendations concerning large-scale projects, which comprise the core of future high energy physics research in Japan.

- With the discovery of the 125 GeV Higgs boson at the LHC, **construction of the International Linear Collider (ILC) with a collision energy of 250 GeV should start in Japan immediately** without delay so as to guide the pursuit of particle physics beyond the Standard Model through detailed research of the Higgs particle. In parallel, continuing studies of new physics should be pursued using the LHC and its upgrades.
- Three-generation neutrino mixing has been established and has provided a path to study CP symmetry in the lepton sector. Therefore, **Japan should promote the early realization of Hyper-Kamiokande as an international project** due to its superior proton decay sensitivity, and should continue to search for CP violation with the T2K experiment and upgrades of the J-PARC neutrino beam. The High Energy Physics Committee should pursue all available options to achieve the early realization of these key, large-scale projects.

It is important to complete construction of SuperKEKB and start physics studies as scheduled. Some of the medium- and small-scale projects currently under consideration have implicit potential to develop into important research fields in the future, as hap- pened with neutrino physics. They should be promoted in parallel in order to pursue new physics from various directions. Flavor physics experiments, such as muon experiments at J-PARC, searches for dark matter and neutrinoless double beta decay, observations of CMB B-mode polarization and dark energy, are considered to be projects that have such potential.

Furthermore, accelerator R&D should be continued to dramatically increase particle collision energies in preparation for future experimental efforts that may indicate the existence of new particles and new phenomena at higher energy scale.

Primary author: Prof. MORI, Toshinori (The University of Tokyo)

Track Classification: National road maps

Contribution ID: **64** Type: **not specified**

GRAVITATIONAL WAVES IN THE EUROPEAN STRATEGY FOR PARTICLE PHYSICS

This document briefly describes some of the scientific and technological synergies that are possible between the nascent field of Gravitational Waves (GWs) and High Energy Particle Physics (HEPP). It is submitted by the ET steering committee under the supervision of GWIC-3G (a team of the Gravitational Wave International Committee (GWIC)) as contribution to the European Strategy for Particle Physics and in view of the submission of the Einstein telescope (ET) observatory project to the ESFRI Roadmap.

Primary author: Dr PUNTURO, Michele (INFN)

Track Classification: Large experiments and projects

Contribution ID: **65** Type: **not specified**

The JUAS and ESIPAP graduate schools, essential vectors of European training in particle accelerators and detectors

With the attached text, the authors wish to draw the attention of the high-energy community on the need to include in its strategic plan an exceptional effort towards attracting and training new young talents to particle accelerator and detector physics.

Primary authors: METRAL, Elias (CERN); HOFFMANN, Hans Falk (European Scientific Institute (FR)); COLLOT, Johann (university Grenoble Alpes (FR)); LEBRUN, Philippe (European Scientific Institute (FR)); HOLLAND, Robert Lionel (European Scientific Institute (FR))

Track Classification: Other (communication, outreach, strategy process, technology transfer, individual contributions,…)

Contribution ID: **66** Type: **not specified**

The International Linear Collider. A European Perspective

The International Linear Collider (ILC) being proposed in Japan is an electron-positron linear collider with an initial energy of 250 GeV. The ILC accelerator is based on the technology of superconducting radio-frequency cavities. This technology has reached a mature stage in the European XFEL project and is now widely used.
The ILC will start by measuring the Higgs properties, providing high-precision and model-independent determinations of its parameters. The ILC at 250 GeV will also search for direct new physics in exotic Higgs decays and in pair-production of weakly interacting particles. The use of polarised electron and positron beams opens new capabilities and scenarios that add to the physics reach. The ILC can be upgraded to higher energy, enabling precision studies of the top quark and measurement of the top Yukawa coupling and the Higgs self-coupling.
The international - including European - interest for the project is very strong. Europe has participated in the ILC project since its early conception and plays a major role in its present development covering most of its scientic and technological aspects: physics studies, accelerator and detectors. The potential for a wide participation of European groups and laboratories is thus high, including important opportunities for European industry.
Following decades of technical development, R&D, and design optimisation, the project is ready for construction and the European particle physics community, technological centers and industry are prepared to participate in this challenging endeavour.

Primary authors: Prof. BRAU, James (University of Oregon); FUSTER VERDÚ, Juan (IFIC-Valencia (ES)); STAPNES, Steinar (CERN)

Track Classification: Large experiments and projects

Contribution ID: **67** Type: **not specified**

Community Support for A Fixed-Target Programme for the LHC

This contribution aims at promoting the ground-breaking physics programme accessible with the multi-TeV LHC proton and ion beams used in the fixed-target mode. It can be realised in a parasitic mode for the LHC complex using existing detectors like those of the LHCb and ALICE collaborations or new dedicated systems during the LHC lifetime. It contains a brief description of the different technical implementations which are currently under investigation as well as the basic performances offered by the use of the ALICE and LHCb detectors in the fixed-target mode. In short, the multi-TeV LHC beams allow for the most energetic fixed-target experiment ever performed opening the way for unique studies of the nucleon and nuclear structure at high x, of the spin content of the nucleon and of the phases of the nuclear matter from a new rapidity viewpoint at seldom explored energies.

Primary authors: BJORKEN, J.D.; BRAMBILLA, N.; BRODSKY, S. J.; CLEYMANS, J.; DONATO, F.; ECHEVARRIA, M.; HALZEN, F.; HOYER, P.; KUSINA, A.; LANSBERG, J.P.; MULDERS, P.J.; PAJARES, C.; SATZ, H.; SEIXAS, J.; SIGNORI, A.; SIVERS, D.; STRIKMAN, M.; SZYMANOWSKI, L.

Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **68** Type: **not specified**

ECFA Detector Panel Report

The ECFA Detector Panel is a European Committee composed of detector physicists from a variety of experimental communities in particle and astro-particle physics. Its primary role is to review early stage detector R&D for programmes in these areas that are not yet linked to a host or leading laboratory with its own established review mechanisms. The role and composition of the panel make it well placed to provide an input on behalf of the European detector community for the ongoing update of the European Strategy for Particle Physics. To this end, a survey of this community was launched over the summer of 2018, with over 700 respondents representing 2900 FTEs at a variety of career stages in 37 countries. Perceptions of opportunities and challenges were investigated, along with attitudes to detector R&D activities within the wider community and associated issues with career opportunities. The survey was also able to identify the main areas of current detector R&D for particle and astro-particle physics in Europe as well as the community's views on the most promising future directions. This report outlines the main findings and the recommendations of the panel based on both the numerical data and the large number of highly informative comments provided by many of the respondents.

Primary author: ECKSTEIN, Doris (DESY)

Co-authors: CATTAI, Ariella (CERN); STRAESSNER, Arno (Technische Universitaet Dresden (DE)); KOFFEMAN, Els (Nikhef National institute for subatomic physics (NL)); SERIN, Laurent (LAL-CNRS/IN2P3 Orsay(Fr)); LINSSEN, Lucie (CERN); ALLPORT, Philip Patrick (University of Birmingham (UK)); DALLA TORRE, Silvia (Universita e INFN Trieste (IT))

Track Classification: Instrumentation and computing

Contribution ID: **69** Type: **not specified**

Statement by the German Astroparticle Physics Community as input to the European Strategy for Particle Physics

The German Committee for Astroparticle Physics, KAT, is the elected representation of all astroparticle physicists working at German research institutions of the Helmholtz Association, Max
Planck Society and at German universities. This paper comprises the statements of the German astroparticle physics community to the 2020 update of the European Strategy for Particle Physics. The three German committees for particle physics, KET, for astroparticle physics, KAT, and for hadronic and nuclear physics, KHuK, in the last 1.5 years jointly arranged a series of workshops where the current status and future plans for the wider scientific field were evaluated and discussed within these three communities. KAT extracted the statements and strategic proposals relevant for
astroparticle physics from the joint declaration of these workshops and finalized this paper at its strategy meeting with all group leaders/professors in astroparticle physics in Germany end of November 2018.
The main research topics of astroparticle physics in Germany are the nature of neutrinos and of dark
matter, the origin of cosmic rays, and the understanding of the non-thermal Universe. The nature of
neutrinos and of dark matter are fundamental questions of particle physics that have a large overlap with accelerator-based particle physics. Therefore, this document focuses on our vision for these subjects as input to the European Strategy for Particle Physics.

Primary author: WEINHEIMER, Christian Philipp (Westfaelische Wilhelms-Universitaet Muenster (DE))

Track Classification: National road maps

Contribution ID: **70** Type: **not specified**

A memorandum by the Global Neutrino Network as input to the update of the European Strategy for Particle Physics

The Global Neutrino Network is an association of the neutrino telescope projects targeting the investigation of cosmic and atmospheric neutrinos in the energy range from GeV to beyond PeV. The main scientific objectives are the exploration of high-energy cosmic neutrinos from non-thermal astrophysical sources (neutrino astronomy), the investigation of fundamental questions of particle physics with atmospheric, but also cosmic neutrinos (neutrino physics), and further particle physics topics such as the search for dark matter. In this document we focus on the particle physics aspects and provide information that we consider useful in linking neutrino telescopes to the European Strategy for Particle Physics.

Primary authors: KATZ, Uli (University of Erlangen); ON BEHALF OF THE GLOBAL NEUTRINO NETWORK

Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **73** Type: **not specified**

Romanian input to the European Particle Physics Strategy Update 2018-2020

The document represents a synthesis of the input provided by research groups from Romanian National Institutes and Universities which are currently participating in the CERN Scientific Programme. The Romanian groups are focused on key areas of particle physics with large discovery potential, precision measurements and searches for new physics. Development of new detectors or performance upgrade of the existing ones together with high-performance computing and software are essential to pursuit such physics objectives. The Romanian groups are providing a visible and competitive contribution on R&D for new generation of detectors, testing of new radiation hard technologies to cope with high luminosities, construction, installation and commissioning of full sub-detectors or significant components for Phase I and II Upgrade of LHC detectors, as well as in non-LHC based experiments.

Primary authors: BRAGADIREANU, Alexandru Mario (IFIN-HH (RO)); Dr ACATRINEI, Ciprian (IFIN-HH (RO)); ALEXA, Calin (IFIN-HH (RO)); DOBRIN, Alexandru Florin (CERN); DULEA, Mihnea-Alexandru (IFIN-HH (RO)); JIPA, Alexandru (University of Bucharest, Faculty of Physics); LAZANU, Ionel (University of Bucharest); MACIUC, Florin (IFIN-HH (RO)); MARGINEAN, Nicolae (IFIN-HH (RO)); NEGRET, Alexandru Liviu (IFIN-HH (RO)); PETROVICI, Mihai (IFIN-HH (RO)); PINTILIE, Ioana (NIMP Bucharest-Magurele, Romania); POPA, Vlad (Institute of Space Science (RO)); RISTEA, Catalin (Institute of Space Science (RO))

Track Classification: National road maps

Contribution ID: **74** Type: **not specified**

Electron Ion Collider Accelerator Science and Technology - Designs, R&D and Synergies with European research in Accelerators

A U.S.-based Electron-Ion Collider (EIC) has recently been endorsed by the U.S. National Academies of Sciences, Engineering, and Medicine (NAS). This brings the realization of such a collider another step closer, after its earlier recommendation in the 2015 Long-Range Plan for U.S. nuclear science of the Nuclear Science Advisory Committee "as the highest priority for new facility construction following the completion of FRIB". The connections between the scientific questions addressed at CERN and at the EIC as well as the shared interest regarding detector R&D are addressed in a separate submitted document "Synergies between a U.S.-based Electron-Ion Collider and the European research in Particle Physics". There are, also, a large number of accelerator R&D topics that are associated with the US EIC that could be undertaken in collaboration that would be of enormous mutual benefit for European research centers and the US EIC.

An EIC will be an unprecedented collider that will need to maintain high luminosity (10^{33-34} cm^{-2} s^{-1}) over a very wide range of Center-of- Mass energies (20 GeV to ~100 GeV, upgradable to ~140 GeV), while accommodating highly polarized beams and many different ion species. Addressing the challenges of this machine requires R&D in areas such as crab cavities, energy-recovery linacs (for ion beam cooling), and high field magnets for the interaction points - areas in which U.S. and European centers are already investing in R&D, in many cases jointly.

A multi-laboratory collaboration is presently working on two site-specific EIC designs - eRHIC led by Brookhaven National Laboratory and JLEIC led by Jefferson Lab. While the designs are different, there are many common R&D issues on which eRHIC and JLEIC efforts are cooperating closely. The purpose of the present paper is to outline the status of the EIC accelerator designs and to discuss the most significant R&D subjects that have strong connection with developments in Europe, with the purpose of enlarging EIC collaboration both in physics and accelerator, to strengthen synergies with European accelerator projects, and - more generally - to maximize positive impact of fundamental science on society worldwide.

*) Submitted on behalf of Electron Ion Collider accelerator design team

**) U.S. R&D efforts on EIC are supported by the Department Of Energy Office of Nuclear Physics.

Primary authors: WILLEKE, Ferdinand (Brookhaven National Laboratory); SERYI, Andrei (Jefferson Lab)

Track Classification: Accelerator Science and Technology

Contribution ID: **75** Type: **not specified**

MATHUSLA

The observation of long-lived particles at the LHC would reveal physics beyond the Standard Model could
account for the many open issues in our understanding of our universe and conceivably point to a more
complete theory of the fundamental interactions. Such long-lived particle signatures are fundamentally
motivated and can appear in virtually every theoretical construct that addresses the Hierarchy Problem, Dark
Matter, Neutrino Masses and the Baryon Asymmetry of the Universe. We describe in this document a large detector, MATHUSLA, located on the surface above an LHC pp interaction point that could observe longlived
particles with lifetimes up to the Big Bang Nucleosynthesis limit of 0.1 s at the HL-LHC. We also note that its large detector area allows MATHUSLA to make important contributions to cosmic ray physics.
Because of the potential for making a major breakthrough in our conceptual understanding of the universe,
long-lived particle searches should have the highest level of priority.

Primary author: Prof. LUBATTI, Henry (Corresponding author, University of Washington, Seattle)

Track Classification: Beyond the Standard Model at colliders (present and future)

Contribution ID: **76** Type: **not specified**

Input from J-PARC to the update of the European Strategy for Particle Physics

Current research activities of Japan Proton Accelerator Research Complex (J-PARC) and the future prospects are summarized with emphasis on the particle physics experiments.

Primary author: Prof. KOMATSUBARA, Takeshi (KEK-IPNS / J-PARC Center)

Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **77** Type: **not specified**

The International Linear Collider. A Global Project

A large, world-wide community of physicists is working to realise an exceptional physics program of energy-frontier, electron-positron collisions with the International Linear Collider (ILC). This program will begin with a central focus on high-precision and model-independent measurements of
the Higgs boson couplings. This method of searching for new physics beyond the Standard Model is orthogonal to and complements the LHC physics program. The ILC at 250 GeV will also search for direct new physics in exotic Higgs decays and in pair-production of weakly interacting particles.
Polarised electron and positron beams add unique opportunities to the physics reach. The ILC can be upgraded to higher energy, enabling precision studies of the top quark and measurement of the top Yukawa coupling and the Higgs self-coupling.
The key accelerator technology, superconducting radio-frequency cavities, has matured. Optimised
collider and detector designs, and associated physics analyses, were presented in the ILC Technical Design Report, signed by 2400 scientists.
There is a strong interest in Japan to host this international eort. A detailed review of the many aspects of the project is nearing a conclusion in Japan. Now the Japanese government is preparing for a decision on the next phase of international negotiations, that could lead to a project start within a few years. The potential timeline of the ILC project includes an initial phase of about 4 years to obtain international agreements, complete engineering design and prepare construction, and form the requisite international collaboration, followed by a construction phase of 9 years.

Primary authors: Prof. BRAU, James (University of Oregon); FUSTER VERDÚ, Juan (IFIC-Valencia (ES)); STAPNES, Steinar (CERN)

Track Classification: Large experiments and projects

Contribution ID: **78** Type: **not specified**

Slovenian input to the European Strategy for Particle Physics Update 2018–2020

This document reflects the view of the Slovenian HEP community on its engagement in current and future particle physics projects. It represents the input of a relatively small particle physics community to the European Strategy for Particle Physics.

Primary author: Prof. GOLOB, Bostjan (Univ. of Ljubljana and Jozef Stefan Inst.)

Track Classification: National road maps

Contribution ID: **79** Type: **not specified**

The Importance of Software and Computing to Particle Physics

In 2017 the experimental High-Energy Physics community wrote a Roadmap for HEP Software and Computing R&D for the 2020s. This effort was organised by the HEP Software Foundation (HSF) and was supported by more than 300 physicists from more than 100 institutes worldwide. It delivered a strategy outlining the most important areas in which investment is needed to ensure the success of our experimental programme. This contribution to the ESPP is an executive summary of the most critical and relevant points raised in that white paper.

Primary authors: STEWART, Graeme (CERN); HEP SOFTWARE FOUNDATION

Track Classification: Instrumentation and computing

Contribution ID: **80** Type: **not specified**

Input of Joint Institute for Nuclear Research

Abstract

This document summarizes the discussions of representatives of laboratories of the Joint Institute for Nuclear Research (intergovernmental, international organization in Dubna) concerning the European Strategy for Particle Physics Update. The document reflects the forward view of JINR scientists to the development of PP in Europe based on long and successful history of CERN - JINR collaboration. Emphasis is put on study of hot and dense nuclear matter in heavy ion collisions, spin physics research with polarized proton and deuteron beams at new accelerator facility NICA as well as on neutrino and astroparticle physics.

Primary author: Prof. SHARKOV, Boris (JINR)

Track Classification: Other (communication, outreach, strategy process, technology transfer, individual contributions,...)

Contribution ID: **81** Type: **not specified**

A View on the European Strategy for Particle Physics

Worldwide, the particle physics and accelerator community is very actively working towards the next major facility. We emphasize the need to evaluate and compare progress on linear and circular e+e- collider designs in the 100 to 360 GeV centre-of-mass energy and their respective performance potential for making the optimal choice.

Primary author: AMALDI ET AL, Ugo

Track Classification: Other (communication, outreach, strategy process, technology transfer, individual contributions,…)

Contribution ID: **82** Type: **not specified**

Submission to the European Strategy from University of Liverpool Experimental Particle Physics Group

The Particle Physics Group at the University of Liverpool has prepared this submission to the European Strategy Update. This was performed as a consultation process across the whole group including academics, research scientists, engineers, and research associates.

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Track Classification: National road maps

Contribution ID: **83** Type: **not specified**

Ensuring the future of particle physics in a more sustainable world

As the European particle physics community engages in an updated strategy for the coming years, we present three recommendations that will ensure a more sustainable future for the field of particle physics in view of climate change. The text and recommendations are signed by 314 particle physicists, representing a diverse set of the community.

Primary authors: BOISVERT, Veronique (Royal Holloway, University of London); SPANO, Francesco (Royal Holloway, University of London (GB)); GHAG, Chamkaur (University College London); Prof. WATERS, David (UCL)

Track Classification: Other (communication, outreach, strategy process, technology transfer, individual contributions,…)

Contribution ID: **84** Type: **not specified**

APPEC Contribution to the European Particle Physics Strategy

APPEC strongly supports and encourages the prospects of an even stronger synergy between Astroparticle Physics and Cosmology with Particle Physics. Areas of synergy between the above domains are identified: dark matter and dark energy; multi-messenger astrophysics, with the recently achieved discoveries of gravitational waves and the extraordinary opportunities also offered by gamma-ray and neutrino observatories for the exploration of powerful accelerators of the universe; the current neutrino precision program in relationship with cosmology, that promise either an unprecedented confirmation of the two standard models of Particle Physics and Cosmology, or a gate to new physics beyond both. These synergies include R&D on photosensors, cryogenic and vacuum techniques, optimisation of large scale infrastructures (civil infrastructure, vacuum, cryogenics) and of their governance and long-term operation, computing strategies for analysis and handling of large volumes of data, and policies leading to open science. Their development also requires grounding fundamental science within society, including, outreach and education. In view of the above synergies the present document introduces and briefly discusses four recommendations related to the role of PP in i) the dark matter searches; ii) the multi-messenger astronomy, in particular the 3G GW experiments (ET); iii) the neutrino physics; iv) the creation of a European Center for AstroParticle Theory (EuCAPT).

Primary author: Prof. MONTARULI, Teresa (APPEC)

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Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **85** Type: **not specified**

LPNHE scientific perspectives for the European Strategy for Particle Physics

This note summarizes the activities and the scientific and technical perspectives of the Laboratoire de Physique Nucleaire et de Hautes Energies (LPNHE) at Sorbonne University, Paris. Although the ESPP is specifically aimed at particle physics, we discuss in this note in parallel the three scientific lines developed at LPNHE (Particle Physics, Astroparticles, Cosmology), first with the current scientific activities, then for the future activities. However, our conclusions and recommendations are focused on the particle physics strategy.

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Track Classification: National road maps

Contribution ID: **86** Type: **not specified**

PARTICLE PHYSICS AT PIK REACTOR COMPLEX

Abstract

The Standard Model provides estimations on neutron EDM (nEDM) value on the level inaccessible for the modern experiment: 10^{-30}–10^{-33} e·cm. CP-violation (and nEDM) arises only in the second order of smallness on the weak interaction constant. SM fails to account for baryon asymmetry of Universe. Search for nEDM is expected to be search for some phenomena beyond the framework of SM. To improve limitation on nEDM accuracy more intense UCN source is needed. UCN source with superfluid He which is preparing at PNPI will make it possible to reach the highest UCN density 10^3–10^4 cm^{-3}.

Reactor Antineutrino Anomaly gives new average ratio of the observed antineutrino flux to the expected 0.934 ± 0.024 (2σ accuracy). The possible reason for deficiency is oscillations of neutrino into the fourth, sterile state which has considerably less cross-section of interaction with known particles. This assumption requires extension of ideas of the elementary particles interaction, and in case of its detection, a new state of neutrino would be the way to a new physics.

Predicted and discovered electric fields in noncentrosymmetric crystals which may act on a neutron, provide new possibilities for measuring the neutron electric dipole moment (nEDM) by the crystal-diffraction method with the sensitivity about UCN method.

Recent detection of gravitational waves raised the question of the place of this phenomenon in the process of matter generation in the Universe. The project PITRAP proposes to combine a powerful source of exotic nuclides with ultra-sensitive detection of studying this phenomenon for the experimental determination of the mass landscape of exotic nuclides involved in the process of fast neutron capture.

Search for neutron–antineutron oscillations is another possibility of employing UCN in fundamental experiments at new UCN source. A transition of a neutron to an antineutron is possible only under conditions of baryon-number violation, which is one of Sakharov's conditions for the formation of the Universe.

Primary authors: VORONIN, Vladimir (PNPI); FEDIN, Oleg (Petersburg Nuclear Physics Institut (RU)); Prof. SEREBROV, Anatolii (PNPI)

Track Classification: Other (communication, outreach, strategy process, technology transfer, individual contributions,...)

Contribution ID: **87** Type: **not specified**

Development of the Micro-Pattern Gaseous Detector Technologies: an overview of the CERN-RD51 Collaboration

RD51 is a well-established collaboration with the aim to develop Micro-Pattern Gaseous Detector (MPGD) technologies, to support experiments using this technology, and to disseminate the technology within particle physics and in other fields. Originally created for a five-year term in 2008, RD51 was extended for a third five years term beyond 2018. The rich portfolio of MPGD projects, under constant expansion, is accompanied by novel ideas on further developments and applications. The cultural, infrastructure and networking support offered by RD51 has been essential in this process: this effort will continue thanks to the RD51 extension. Also in the next years, a collaborative R&D phase and the right environment will have a strong impact on project-oriented activities - similarly to the current scenario where three of the major upgrades for the LHC experiments benefited from the RD51 framework. The vast R&D program requires acquiring additional, up-to-date expertise in advanced technologies; it is also expected to enrich our basic knowledge in detector physics, to form a generation of young detector experts - paving the way to new detector concepts and applications.
RD51 and MPGD success is related to the RD51 model in performing R&D: combination of generic and focused R&D with bottom-top decision processes, full sharing of "know-how", information, common infrastructures. This model has to be continued and can be exported to other detector domains.

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Track Classification: Instrumentation and computing

Contribution ID: **88** Type: **not specified**

Inputs to European Strategy Update 2018-2020 by the Czech particle physics community

Although the Standard Model has been very successful in predicting and interpreting current measurements in particle physics, it has become clear that it cannot answer all the outstanding questions. To resolve the remaining issues new theories have been developed and further measurements are needed. The experience shows that diverse and complementary scientific program is the right approach to tackle the questions. To maintain this, the Czech high-energy physics community agreed upon a strong support of the activities listed below.

Primary author: DAVIDEK, Tomas (Charles University (CZ))

Track Classification: National road maps

Contribution ID: **89** Type: **not specified**

Future strategies for the discovery and the precise measurement of the Higgs self coupling

The European Strategy for Particle Physics (ESSP) submitted in 2013 a deliberation document to the CERN council explaining that a lepton collider with "energies of 500 GeV or higher could explore the Higgs properties further, for example the [Yukawa] coupling to the top quark, the [trilinear] self-coupling and the total width.".

In view of the forthcoming ESPP update in 2020, variations on this qualitative theme have been applied, inaccurately, to the case of the ILC, to argue that an upgrade to 500 GeV would allow the measurement of the Higgs potential and would increase the potential for new particle searches. As a consequence, the strategic question was raised again whether the FCC-ee design study ought to consider a 500 GeV energy upgrade. In this note, we revisit the ESSP 2013 statement quantitatively and find

- that the FCC-ee can measure the total width of the Higgs boson with a precision of 1.3% – the best precision on the market – with runs at $\sqrt{s} = 240$, 350, and 365 GeV, and without the need of an energy upgrade to 500 GeV;
- that the top Yukawa coupling will have been determined at HL-LHC at the $\pm 2.5\%$ level, albeit with some model dependence, without the need of 500 GeV e^+e^- collisions; and that the combination of this HL-LHC result with the FCC-ee absolute Higgs coupling and width measurements breaks the model dependence, without the need of an energy upgrade to 500 GeV;
- that, with the run plan presented for the ILC, the trilinear Higgs self-coupling can be inferred with a 3σ significance from the double-Higgs production cross-section measurement at the ILC500 after three decades of operation; but that the FCC-ee provides a similar sensitivity in 15 years, from the precise measurement of the single-Higgs production cross section as a function of $\sqrt{s}$, without the need of an energy upgrade to 500 GeV;
- that the same FCC-ee, with four experiments instead of two, might well achieve the first model-independent 5σ demonstration of the existence of the trilinear Higgs self-coupling, while a centre-of-mass energy of about 1 TeV or more is required for a linear collider to reach a similar sensitivity in a reasonable amount of time; and that a precise measurement of the trilinear Higgs self-coupling at the few per-cent precision level can realistically only be provided by the combination of FCC-ee and FCC-hh, being beyond reach of lepton colliders with a centre-of-mass energy up to at least 3 TeV.

On the new particle search front, the run plan of the FCC-ee includes an electroweak precision measurement program that is sensitive to new physics scales up to 70 TeV. The Z factory run of the FCC-ee with 5×10^{12} Z decays can discover particles (e.g., dark matter or heavy neutrinos) that couple with a strength down to as little as 10^{-11} of the weak coupling. Finally, the FCC-hh potential for new particle searches at high mass exceeds that of any proposed linear collider project.

We conclude that 500 GeV is not a particularly useful energy for the lepton colliders under consideration, especially for the FCC-ee. A 5σ demonstration of the existence of the Higgs self-coupling is within reach at the energies foreseen for the FCC-ee, with a moderate change of configuration, which certainly deserves consideration.

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Track Classification: Electroweak physics (physics of the W, Z, H bosons, of the top quark, and QED)

Contribution ID: **90** Type: **not specified**

Study of hard and electromagnetic processes at CERN-SPS energies: an investigation of the high-μ_B region of the QCD phase diagram

The exploration of the phase diagram of Quantum ChromoDynamics (QCD) is carried out by studying ultrarelativistic heavy-ion collisions. The energy range covered by the CERN SPS ($\sqrt{s_{\rm NN}} \sim$ 6–17˜GeV) is ideal for the investigation of the region of the phase diagram corresponding to finite baryochemical potential ($\mu_{\rm B}$), and has been little explored up to now. We propose in this document a new experiment, NA60+, that would address several observables which are fundamental for the understanding of the phase transition from hadronic matter towards a Quark–Gluon Plasma (QGP) at SPS energies. In particular, we propose to study, as a function of the collision energy, the production of thermal dimuons from the created system, from which one would obtain a caloric curve of the QCD phase diagram that is sensitive to the order of the phase transition. In addition, the measurement of a ρ–$\rm a_1$ mixing contribution would provide conclusive insights into the restoration of the chiral symmetry of QCD.
In parallel, studies of heavy quark and quarkonium production would also be carried out, addressing the measurement of transport properties of the QGP and the investigation of the onset of the deconfinement transition. The document also defines an experimental set-up which couples a vertex telescope based on monolithic active pixel sensors (MAPS) to a muon spectrometer with tracking (GEM) and triggering (RPC) detectors within a large acceptance toroidal magnet.
Results of physics performance studies for most observables accessible to NA60+ are discussed, showing that the results of the experiment would lead to a significant advance of our understanding of strong interaction physics.

Primary authors: DAHMS, Torsten (Technische Universitaet Muenchen (DE)); SCOMPARIN, Enrico (Universita e INFN Torino (IT)); USAI, Gianluca (Universita e INFN, Cagliari (IT))

Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **91** Type: **not specified**

Synthesis on the ELN Project by A.Zichichi

Accelerator Science and Technology

Primary author: Prof. ZICHICHI, Antonino (University of Bologna, INFN Italy,Fermi Centre, CERN)

Track Classification: Accelerator Science and Technology

Contribution ID: **92** Type: **not specified**

PROSPECT OF THE IN2P3 COMMUNITY INVOLVED IN THE ILC PROJECT

A large community of the French national funding agency IN2P3/CNRS has been involved since two decades in the developments addressing a linear electron-positron collider at the energy frontier, within an international collaboration involving nearly 100 laboratories around the world. This long term involvement has progressively generated a concrete project named International Linear Collider (ILC), anticipated to be hosted by Japan. The achieved maturity of the project allows considering its realisation in the coming decade. This document suggests to examine closely the opportunity for Europe to join the international consortium necessary to realise the ILC project, within a framework where only about 20 % of the total investment would be expected from Europe, moreover expressed through an in-kind contributions exploiting the industrial
know-how deployed for the European XFEL light source and its spin-os.
The purpose of this document is to summarise the main achievements and associated expertise, on-going activities and forthcoming plans of the nine research teams of IN2P3/CNRS involved in accelerator and detector R&D as well as in physics studies for the ILC project in Japan. The latter has undergone steady progress since the previous European Strategy update, ending up with a situation where an opportunity to realise the collider in a few years from now may arise. Some of the most recent steps of the project supporting this expectation are recalled in this document, thereby setting the landscape backing up the strong wish of the IN2P3 research teams to see the ILC in Japan emerging as one of the short term top priorities in the upcoming European Strategy for particle physics.
The authors of the document act as liaison of the IN2P3 laboratories presently involved in the ILC project. The latter is addressed at the national level through the (Linear Collider Committee (CCL) [1]), where the project evolution and important ILC related issues are discussed.

Primary author: Mr WINTER, Marc (IPHC-CNRS)

Track Classification: Accelerator Science and Technology

Contribution ID: **93** Type: **not specified**

Nuclotron-based Ion Collider Facility at JINR (NICA Complex)

NICA Application;
NICA Addendum

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Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **94** Type: **not specified**

FASER: ForwArd Search ExpeRiment at the LHC

FASER, the ForwArd Search ExpeRiment, is a proposed experiment dedicated to searching for light, extremely weakly-interacting particles at the LHC. Such particles may be produced in the LHC's high-energy collisions in large numbers in the far-forward region and then travel long distances through concrete and rock without interacting. They may then decay to visible particles in FASER, which is placed 480 m downstream of the ATLAS interaction point. In this work, we describe the FASER program. In its first stage, FASER is an extremely compact and inexpensive detector, sensitive to decays in a cylindrical region of radius R = 10 cm and length L = 1.5 m. FASER is planned to be constructed and installed in Long Shutdown 2 and will collect data during Run 3 of the 14 TeV LHC from 2021-23. If FASER is successful, FASER 2, a much larger successor with roughly R ˜ 1 m and L ˜ 5 m, could be constructed in Long Shutdown 3 and collect data during the HL-LHC era from 2026-35. FASER and FASER 2 have the potential to discover dark photons, dark Higgs bosons, heavy neutral leptons, axion-like particles, and many other long-lived particles, as well as provide new information about neutrinos, with potentially far-ranging implications for particle physics and cosmology. We describe the current status, anticipated challenges, and discovery prospects of the FASER program.

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Track Classification: Beyond the Standard Model at colliders (present and future)

Contribution ID: **95** Type: **not specified**

On the Prospect and Vision of Ultra-High Gradient Plasma Accelerators for High Energy Physics

Plasma accelerators generate accelerating fields that are up to 1,000 times higher than fundamentally possible in RF accelerators. They therefore offer a promising alternative path to the high-energy frontier. In 2012 the European Strategy Preparatory Group received for the first time detailed input about the prospects and promise of plasma accelerators, a 15 page report provided by the EU-funded European Network for Novel Accelerators (EuroNNAc). The network published a 31 page report on a European strategy for plasma accelerators in 2017. Here we provide a short update on the prospect of plasma accelerators for high energy physics. We propose that the next European strategy for particle physics should explicitly list ultra-high gradient plasma acceleration and, if possible, its supporting international projects as essential R&D towards a compact alternative for future colliders.

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Track Classification: Accelerator Science and Technology

Contribution ID: **96** Type: **not specified**

STFC input to the "European Strategy for Particle Physics" related to Innovation/Technology Transfer, Knowledge Exchange

The infrastructure and research related to Particle Physics plays an important role in creating a more sustainable society by actively pushing the frontiers of human understanding. Whilst positively contributing to the EU's social and economic growth through innovation and Knowledge Transfer. In this short paper, STFC outlines its innovation strategy, in the context of Particle Physics, and its role in maximising the economic and social impact.

Primary author: Ms BAIN, Elizabeth (Science and Technology Facilities Council, UK Research and Innovation,)

Track Classification: Other (communication, outreach, strategy process, technology transfer, individual contributions,...)

Contribution ID: **97** Type: **not specified**

Input from the DARWIN collaboration to the European Strategy for Particle Physics

The DARWIN collaboration (www.darwin-observatory.org) is planning to build the "ultimate" underground-based direct detection dark matter detector, with a dark matter sensitivity limited only by irreducible neutrino backgrounds. The core of the detector will have a 40 ton liquid xenon target instrumented as a dual-phase time projection chamber. The large xenon target, the exquisitely low radioactive backgrounds and the low energy threshold will allow a diversification of the physics program beyond purely the search for dark matter particles: DARWIN will be a true low-background, low-threshold astroparticle physics observatory.

Primary authors: Prof. BAUDIS, Laura (University of Zurich); Prof. SCHUMANN, Marc (Universitaet Freiburg)

Track Classification: Dark matter and dark sector (accelerator and non-accelerator dark matter, dark photons, hidden sector, axions)

Contribution ID: **98** Type: **not specified**

The European Spallation Source neutrino Super Beam ESSνSB

The European Spallation Source linear proton accelerator will have a uniquely high beam power of 5 MW to be used for spallation neutron production. The beam power can be raised to 10 MW by increasing the accelerator duty cycle from 4% to 8% and the additional 5 MW used to generate a uniquely intense neutrino Super Beam ESSνSB for measurement of leptonic CP violation. ESSνSB is complementary to other proposed Super Beam experiments by the fact that the resulting high neutrino-beam intensity makes it possible to locate the large water Cherenkov neutrino detector that will be used, at the second neutrino oscillation maximum, making the performance of ESSνSB for leptonic CP violation precision measurements highly competitive.

Primary authors: EKELOF, Tord Johan Carl (Uppsala University (SE)); DRACOS, Marcos

Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **99** Type: **not specified**

Synergies between a U.S.-based Electron-Ion Collider and the European research in Particle Physics

This document is submitted as input to the European Strategy for Particle Physics Update (ESPPU). The U.S.-based Electron-Ion Collider (EIC) project recently received strong endorsement by the U.S. National Academies of Sciences, Engineering, and Medicine, bringing its realization another step closer. A large group of European scientists is already involved in the EIC project. Currently, more than a quarter of the EIC User Group (consisting of over 800 scientists) is based in Europe. This European involvement is not only an important driver of the EIC, but can also be beneficial for a number of related ongoing and planned particle physics experiments at CERN. In this document, the connections between the scientific questions addressed at CERN and at the EIC are outlined, as well as the shared interest regarding detector R&D. The aim is to highlight how the synergies between the European Particle Physics research and the EIC project offer ample opportunities to foster progress at the forefront of collider physics.

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Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **100** Type: **not specified**

Precision calculations for high-energy collider processes

For the field of particle physics to benefit from the immense body of data from present and possible future colliders, it is essential to be able to accurately relate the experimental observations to the underlying Lagrangian. This is the case whether searching for physics beyond the Standard Model, exploring the many facets of the Higgs sector, or pinning down fundamental parameters such as coupling constants and particles masses, which have implications for foundational questions such as the stability of the universe. This document discusses the current status and future objectives of precision theory for collider processes, and outlines the needs required to accomplish them.

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Track Classification: Electroweak physics (physics of the W, Z, H bosons, of the top quark, and QED)

Contribution ID: **101** Type: **not specified**

Theory Requirements and Possibilities for the FCC-ee and other Future High Energy and Precision Frontier Lepton Colliders

The future lepton colliders proposed for the High Energy and Precision Frontier set stringent demands on theory. The most ambitious, broad-reaching and demanding project is the FCC-ee. We consider here the present status and requirements on precision calculations, possible ways forward and novel methods, to match the experimental accuracies expected at the FCC-ee. We conclude that the challenge can be tackled by a distributed collaborative effort in academic institutions around the world, provided sufficient support, which is estimated to about 500 man-years over the next 20 years.

Primary authors: GLUZA, Janusz (University of Silesia); BLONDEL, Alain (Universite de Geneve (CH)); JANOT, Patrick (CERN); JADACH, Staszek (Polish Academy of Sciences (PL)); RIEMANN, Tord; HEINEMEYER, Sven (CSIC (Madrid, ES)); FREITAS, Ayres (University of Pittsburgh)

Track Classification: Electroweak physics (physics of the W, Z, H bosons, of the top quark, and QED)

Contribution ID: **102** Type: **not specified**

TauFV: a fixed-target experiment to search for flavour violation in tau decays

TauFV is a fixed-target experiment designed to search for Lepton Flavour Violation in tau decays, utilising a high energy, high intensity proton beam impinging on a distributed system of targets. In the baseline proposal, TauFV will be situated on the high-intensity beam line the Beam-Dump Facility of the SPS, upstream of the SHiP experiment. Its performance will rely on advanced detector technologies, currently under development for applications at future hadron-collider experiments, with excellent radiation hardness and the capabilities to provide timing information with a precision of a few tens of picoseconds. Preliminary studies indicate a sensitivity to the mode $\tau^- \to \mu^-\mu^+\mu^-$ down to branching ratios of 10^{-10}. The experiment will be able to perform searches and measurements in many other tau decays, and across a wide range of topics in kaon and charm physics.

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Track Classification: Flavour Physics and CP violation (quarks, charged leptons and rare processes)

Contribution ID: **103** Type: **not specified**

The ”DIS and Related Subjects” Strategy Document: Fundamental Science from Lepton-Hadron Scattering

The diverse community of scientists involved in Deep Inelastic Scattering includes about 2000 experi- mental and theoretical physicists worldwide and envisages projects such as the EIC, LHeC, FCC-eh and VHEeP as future lepton-hadron scattering facilities. The proposed facilities will address fundamental ques- tions in strong interaction / QCD physics, including a first-ever tomographic mapping of the hadrons' internal structure, a solution to the proton mass and spin problems, understanding of the high-energy structure of hadronic matter and insight into connections between gravity and the strong interactions. They also extend and enhance the CERN programme of searches for new physics at the energy frontier, through a standalone precision Higgs and top programme, considerable sensitivity to the direct production of new particles and the most precise determinations of proton and nuclear structure in the kinematic range that is relevant to the LHC. In particular, we highlight the complementary aspects of the different lepton-hadron projects, and underscore how all are required to provide a complete characterization of the physics across the full kinematic reach. This review of the proposed facilities and their vast potential for particle physics was inspired by the discussions in the 2018 "DIS and Related Subjects" Workshop.

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Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **104** Type: **not specified**

Future Challenges in Particle Physics Education and Outreach

This document is meant to serve as input from the IPPOG Collaboration for the open call for the European Particle Physics Strategy Update 2020. It emphasises the strategic relevance of concerted, global outreach activities in particle physics today and beyond when envisaging new large-scale projects.

Primary authors: BECK, Hans Peter (Universitaet Bern (CH)); GOLDFARB, Steven (University of Melbourne (AU)); IPPOG COLLABORATION

Track Classification: Other (communication, outreach, strategy process, technology transfer, individual contributions,…)

Contribution ID: **105** Type: **not specified**

An Open Lab for the Development of Technical Superconductors

Abstract

Superconductivity is a core technology that has fueled the progress in high-energy physics (HEP) accelerators, from the Tevatron of the early 1980's to the Large Hadron Collider of the late 2010's [1,2,3,4]. The engineering knowledge of superconducting materials in the form of composite wires, tapes, or thin layers finds application in high-field accelerator magnets [5], very large detectors magnets [6] and high-gradient/low-loss RF cavities [7]. The progress witnessed in the past years has been remarkable. Comparable progress will be required to meet a number of HEP challenges in the close future, and mainly:

• Realize ultimate performance in Nb3Sn, as it has been specified for the realization of the main magnets of a Future Circular Collider in a new (FCC) or existing (HE-LHC) tunnel [8];
• Demonstrate the potential of HTS materials to surpass LTS accelerator magnet technology, providing efficient very-high-field or high operating margin options for specific locations in existing and future colliders, and eventually to extend the energy reach of circular synchrotrons [9].

This success was possible so far thanks to a virtuous circle of applied superconductivity, encompassing fundamental science, applied research and industrial production. Due to several factors, we observe that this virtuous circle is losing its effectiveness. This is perceived as a serious threat to the future of a robust applied superconductivity program for HEP and is the main justification for this proposal. In short, we propose to secure this technology by founding an Open Laboratory for Applied Superconductivity that will work as a bridge between academia and industry. This proposal is driven by an identified need, and at this stage the implementation is not localized in a specific institute.

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Primary authors: BOTTURA, Luca (CERN); BORDRY, Frederick (CERN)

Track Classification: Accelerator Science and Technology

Contribution ID: **106** Type: **not specified**

Research and Development for Near Detector Systems Towards Long Term Evolution of Ultra-precise Long-baseline Neutrino Experiments.

With the discovery of non-zero value of θ_{13} mixing angle, the next generation of long-baseline neutrino (LBN) experiments offers the possibility of obtaining statistically significant samples of muon and electron neutrinos and anti-neutrinos with large oscillation effects.
In this document we intend to highlight the importance of Near Detector facilities in LBN experiments to both constrain the systematic uncertainties affecting oscillation analyses but also to perform, thanks to their close location, measurements of broad benefit for LBN physics goals. A strong European contribution to these efforts is possible.

Primary authors: BORDONI, Stefania (CERN); SALA, Paola (CERN and INFN Milano)

Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **107** Type: **not specified**

The ILD Detector at the ILC

The international large detector, ILD, is a detector concept which has been developed for the electron-positron collider ILC. The detector has been optimised for precision physics in a range of energies between 90~GeV and 1~TeV. ILD features a high precision, large volume combined silicon and gaseous tracking system, together with a high granularity calorimeter all inside a solenoidal magnetic field. The paradigm of particle flow has been the guiding principle of the design of ILD. In this document the required performance of the detector, the proposed implementation and the readiness of the different technologies needed for the implementation are discussed. This is done in the framework of the ILC collider proposal, now under consideration in Japan, and includes site specific aspects needed to build and operate the detector at the proposed ILC site in Japan.

Primary author: BEHNKE, Ties (Deutsches Elektronen Synchrotron (DESY))

Track Classification: Large experiments and projects

Contribution ID: **108** Type: **not specified**

Research Strategy of the Austrian Particle Physics Community

In the following, Austria's particle physicists outline their current research program on particle physics and define their visions and plans. The overarching goal is to contribute to the understanding of known particle physics as well as the discovery of physics beyond the standard model and its theoretical understanding. This is achieved through Austria's involvement in major international experimental endeavours, both present and future, as well as in theoretical research in these areas.

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Track Classification: National road maps

Contribution ID: **109** Type: **not specified**

The EuPRAXIA Research Infrastructure: A Required Intermediate Step Towards Plasma Accelerators for the Energy Frontier

The EU Horizon2020 program funded the EuPRAXIA design study in 2015. The project is coordinated by DESY and by now has 41 participating institutes from Europe, Asia and the US. It will deliver a conceptual design report in October 2019. EuPRAXIA aims at the construction of an innovative linear electron accelerator based on plasma acceleration technology. This machine will have an accelerating field of 50 GV/m, a final electron beam energy of 1 to 5 GeV, significantly improved beam quality, various user applications and demonstrated benefits in size and cost when compared to RF technology. The improved beam quality and the ultra-high accelerating fields will be achieved by combining cutting-edge plasma accelerator technology, high power lasers from European industry, modern RF technology (including X-band from CERN) and latest diagnostics and instrumentation. EuPRAXIA is designed to fully develop a 5 GeV plasma accelerator module to user readiness. It is the required intermediate step to a plasma based linear collider that would then combine many such modules. We propose that the next European Strategy for Particle Physics should explicitly list ultra-high gradient plasma acceleration and, if possible, the EuPRAXIA project as essential R&D towards a compact alternative for future colliders.

Primary authors: THE EUPRAXIA CONSORTIUM; ASSMANN, Ralph Wolfgang (DESY); ET AL

Track Classification: Accelerator Science and Technology

Contribution ID: **110** Type: **not specified**

A next-generation LHC heavy-ion experiment

The present document discusses plans for a compact, next-generation multi-purpose detector at the LHC as a follow-up to the present ALICE experiment. The aim is to build a nearly massless barrel detector consisting of truly cylindrical layers based on curved wafer-scale ultra-thin silicon sensors with MAPS technology, featuring an unprecedented low material budget of 0.05$\%$ X_0 per layer, with the innermost layers possibly positioned inside the beam pipe. In addition to superior tracking and vertexing capabilities over a wide momentum range down to a few tens of MeV/c, the detector will provide particle identification via time-of-flight determination with about 20 ps resolution. In addition, electron and photon identification will be performed in a separate shower detector. The proposed detector is conceived for studies of pp, pA and AA collisions at luminosities a factor of 20 to 50 times higher than possible with the upgraded ALICE detector, enabling a rich physics program ranging from measurements with electromagnetic probes at ultra-low transverse momenta to precision physics in the charm and beauty sector.

Primary author: ANTINORI, Federico (Universita e INFN, Padova (IT))

Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **111** Type: **not specified**

The LHCSpin Project

LHCSpin aims at installing a polarized gas target in front of the LHCb spectrometer, bringing, for the first time, polarized physics to the LHC. The project will benefit from the experience achieved with the installation of an unpolarized gas target at LHCb during the LHC Long Shutdown 2. LHCb will then become the first experiment simultaneously running in collider and fixed-target mode with polarized targets, opening a whole new range of explorations to its exceptional spectrometer. LHCSpin will offer a unique opportunity to probe polarized quark and gluon parton distributions in nucleons and nuclei, especially at high x and intermediate Q^2, where experimental data are still largely missing. Beside standard collinear parton distribution functions (PDFs), LHCSpin will make it possible to study multidimensional polarized parton distributions that depend also on parton transverse momentum (transverse-momentum-dependent PDFs, or TMDs). LHCSpin stands out at the moment as the most promising project, going beyond the kinematic coverage and the accuracy of the existent experiments, especially on the heavy-quark sector.

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Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **112** Type: **not specified**

A European Strategy Towards Finding Axions and Other WISPs

Since the last update of the European strategy on particle physics (ESPP) the interest in hypothetical very weakly interacting slim particles, dubbed WISPs, has gained significant momentum. Searches for WISPs with masses below about 1 eV require new approaches beyond accelerator experiments. This document summarizes the physics case, the experimental status and its prospects for the coming 10-20 years. Its focus is on larger scale experiments with European leadership requiring a more strategic approach for their potential realization. This document will be submitted in December 2018 as an input to the update process of the European Strategy on Particle Physics (ESPP).

Primary authors: DESCH, Klaus (University of Bonn (DE)); DOBRICH, Babette (CERN); GARCIA IRASTORZA, Igor (Universidad de Zaragoza (ES)); JAECKEL, Joerg (ITP Heidelberg); LINDNER, Axel (DESY); MAJOROVITS, Bela (MPI for Physics); RINGWALD, Andreas (Deutsches Elektronen-Synchrotron DESY)

Track Classification: Dark matter and dark sector (accelerator and non-accelerator dark matter, dark photons, hidden sector, axions)

Contribution ID: **113** Type: **not specified**

Vacuum Magnetic Birefringence & Axion search using pulsed magnetic fields

We propose to combine state of the art optical instrumentation with very high pulsed magnetic fields to study magneto-optical phenomena in the quantum vacuum, i.e. the experimental proof of the magneto-optical properties of quantum vacuum.

Our goal is to realize the first ever measurement of the linear magnetic birefringence of vacuum which corresponds to a variation in the velocity of light depending on its polarisation in the presence of transverse magnetic field.

The study of photon propagation inside a transverse magnetic field can also test physics beyond the standard model. In particular, photons in a magnetic field are predicted to oscillate into weakly interacting massive particles (WIMPs), such as the axion. The VMB setup that is proposed in this submission will also make an important contribution to the search for axions.

Primary authors: Prof. BATTESTI, Rémy (LNCMI); Dr HARTMAN, Michael (LNCMI); Prof. RIZZO, Carlo (LNCMI)

Track Classification: Dark matter and dark sector (accelerator and non-accelerator dark matter, dark photons, hidden sector, axions)

Contribution ID: **114** Type: **not specified**

Monte Carlo event generators for high energy particle physics event simulation

Monte Carlo event generators (MCEGs) are the indispensable workhorses of particle physics, bridging the gap between theoretical ideas and first-principles calculations on the one hand, and the complex detector signatures and data of the experimental community on the other hand. All collider physics experiments are dependent on simulated events by MCEG codes such as Herwig, Pythia, Sherpa, POWHEG and MG5_aMC@NLO, to design and tune their detectors and analysis strategies. The development of MCEGs is overwhelmingly driven by a vibrant community of academics at European Universities, who also train the next generations of particle phenomenologists. The new challenges posed by possible future collider-based experiments and the fact that the first analyses at Run II of the LHC are now frequently limited by theory uncertainties urge the community to invest into further theoretical and technical improvements of these essential tools. In this short contribution to the European Strategy Update, we briefly review the state of the art, and the further developments that will be needed to meet the challenges of the next generation.

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Track Classification: Electroweak physics (physics of the W, Z, H bosons, of the top quark, and QED)

Contribution ID: **115** Type: **not specified**

Hadron Physics Opportunities in Europe

On November 20 and November 21 this working group has met in order to discuss and summarize future Hadron Physics Opportunities in Europe. The work of this working group is based on the Long Range Plan of the Nuclear Physics European Collaboration Committee from November 27, 2017 (NuPECC is an Expert Committee of the European Science Foundation). Furthermore it is based on a series of four strategy workshops organized in common by the German committee for Hadron and Nuclear Physics (KHuK), the German committee for elementary particle physics (KET) and the German committee for astroparticle physics (KAT) between January 2017 and May 2018. The document discusses experimental and theory activities for the understanding of the structure and excitation spectrum of hadrons in the non-perturbative regime of QCD.
The meeting featured short presentations on existing and planned future experiments at CERN, at GSI/FAIR, and other facilities. The meeting concluded with an open 4-hour discussion of the priorities in the field. The following text is not endorsed officially by any of the experimental collaborations and facilities mentioned, but summarizes the consensus view of the scientific community on the priorities of the field, as expressed by the participants of the meeting.

Primary author: Prof. MAAS, Frank (Helmholtz Institute Mainz)

Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **116** Type: **not specified**

IN2P3 contribution for the update of European Strategy for Particle Physics

The “Institut de Physique Nucléaire et de Physique des Particules” (IN2P3) comprises 25 laboratories located in major universities. IN2P3 is in charge of coordinating nuclear, particle and astroparticles physics in France. The number of people working at IN2P3 is 3200, about half of them PhDs. This represents 600 CNRS physicists, 400 professors from universities and 1500 engineers, technicians and administrative staff. This document contains two parts: an executive summary and the main contributions from IN2P3 physicists.

Primary author: VERDIER, Patrice (IN2P3)

Track Classification: National road maps

Contribution ID: **117** Type: **not specified**

Statement of the Pierre Auger Collaboration as input for the European Particle Physics Strategy Update 2018 - 2020

There is large overlap in the research interests of the European particle physics community and the Pierre Auger Collaboration and there is a remarkable complementarity of the measurement principles and information accessible at accelerators and the Auger Observatory. With this statement, we provide input to the European Particle Physics Strategy Update 2018 - 2020. We strongly encourage very close interaction and collaboration of the particle physics and astroparticle physics communities with respect to experimental, theoretical, instrumental, computational, and organizational activities and indicate the expected benefits for both communities. Examples for joint projects are outlines.

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Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **118** Type: **not specified**

The MUonE experiment

We propose a new approach to measure very precisely
the hadronic leading order corrections to the muon $g-2$,
%the $\mu - e$ differential cross section in order to determine
a_μ^{HLO}, with space-like data,
measuring the hadronic contribution to the effective electromagnetic coupling
α, by means of the elastic scattering $\mu - e$ of 150 GeV muons
(currently available at CERN North area) off atomic electrons.
Such a direct measurement of a_μ^{HLO} will provide a new independent
determination and will consolidate the theoretical prediction
of the muon $g-2$ in the Standard Model, which currently shows a
3.5˜σ discrepancy between theory and experiments.
This project is part of the Physics Beyond Colliders Working Group.

Primary authors: MATTEUZZI, Clara (INFN and Universita Milano-Bicocca); VENANZONI, Graziano (INFN Pisa)

Track Classification: Flavour Physics and CP violation (quarks, charged leptons and rare processes)

Contribution ID: **119** Type: **not specified**

GRAND: Giant Radio Array for Neutrino Detection input for the European Particle Physics Strategy Update 2020

The Giant Radio Array for Neutrino Detection (GRAND) is a planned large-scale observatory of ultra-high-energy (UHE) cosmic particles — cosmic rays, gamma rays, and neutrinos with energies exceeding 10^8 GeV. Its ultimate goal is to solve the long-standing mystery of the origin of UHE cosmic rays. It will do so by detecting an unprecedented number of UHECRs and by looking with unmatched sensitivity for the undiscovered UHE neutrinos and gamma rays associated to them. Three key features of GRAND will make this possible: its large exposure at ultra-high energies, sub-degree angular resolution, and sensitivity to the unique signals made by UHE neutrinos. The Science Case and the Design of GRAND have recently been documented in a White Paper (J. Àlvarez-Muñiz *et al.*, *Giant Radio Array for Neutrino Detection: Science and Design*, arXiv:1810.09994) that is publicly available and attached to this submission.
The strategy of GRAND is to detect the radio emission coming from large particle showers that develop in the terrestrial atmosphere — extensive air showers — as a result of the interaction of UHE cosmic rays, gamma, rays, and neutrinos. To achieve this, GRAND will be the largest array of radio antennas ever built. The relative affordability of radio antennas makes the scale of construction possible. GRAND will build on years of progress in the field of radio-detection and apply the large body of technological, theoretical, and numerical advances, for the first time, to the radio-detection of air showers initiated by UHE neutrinos.
The design of GRAND will be modular, consisting of several independent sub-arrays, each of 10,000 radio antennas deployed over 10,000 km^2 in radio-quiet locations. A staged construction plan ensures that key techniques are progressively validated, while simultaneously achieving important science goals in UHECR physics, radio astronomy, and cosmology early during construction.
Already by 2025, using the first sub-array of 10,000 antennas, GRAND could discover the long-sought cosmogenic neutrinos — produced by interactions of ultra-high-energy cosmic-rays with cosmic photon fields — if their flux is as high as presently allowed, by reaching a sensitivity comparable to planned upgraded versions of existing experiments. By the 2030s, in its final configuration of 20 sub-arrays, GRAND will reach an unparalleled sensitivity to cosmogenic neutrino fluxes of 4×10^{-10} GeV cm^{-2} s^{-1} sr^{-1} within 3 years of operation, which will guarantee their detection even if their flux is tiny. Because of its sub-degree angular resolution, GRAND will also search for point sources of UHE neutrinos, steady and transient, potentially starting UHE neutrino astronomy. Because of its access to ultra-high energies, GRAND will chart fundamental neutrino physics at these energies for the first time.
GRAND will also be the largest detector of UHE cosmic rays and gamma rays. It will improve UHECR statistics at the highest energies ten-fold within a few years. Many thousands of hadronic interactions with a center-of-mass energy ranging between 15 and 60 times the LHC center-of-mass energy will be collected. GRAND will either discover UHE gamma rays or improve their limits ten-fold. In the case of discovery photon-nucleon interactions at much higher energy than that of the LHC will be measured.
Further, GRAND will be a valuable tool in radio astronomy and cosmology, allowing for the discovery and follow-up of large numbers of radio transients — fast radio bursts, giant radio pulses — and for precise studies of the epoch of reionization.
Following the discovery of high-energy astrophysical neutrinos, gravitational waves, and the multi-wavelength, multi-messenger detection of neutron-star mergers, we stand today at the threshold of a new era in astroparticle physics. Several exciting high-energy astroparticle experiments are planned, both extensions of existing cosmic-ray and neutrino experiments — AugerPrime, TA×4, IceCube-Gen2 — and new experiments — LSST, CTA, LISA. At the ultra-high-energy front, GRAND completes the picture.

The realisation of GRAND will be greatly facilitated by help from the European Particle Physics

Community in the following domains:
1. Recognition by the community that ultra-high-energy cosmic ray physics is one of the essential building blocks to understand our universe in terms of particle physics would strongly support our own arguments.
2. GRAND will be a large collaboration and advice of the Particle Physics Community in setting up its governance will be highly appreciated.
3. GRAND will be faced with numerous technical issues that overlap with competences in the Particle Physics community, such as cheap (low power) electronics, cheap strong low mass mechanical constructions, reconstruction and analysis software and computing resources. Help with and advice on resolving these issues will be highly appreciated.
4. If GRAND would become a **recognised experiment at CERN** it would have access to central repositories for documents and design documentation. It would also get access to a meeting venue that is central in Europe. And it would also facilitate access to the help and advice mentioned in the two previous points.
5. The interpretation of hadronic interactions in the early stages, at the TeV scale, of particle showers from ultra-high-energy tau hadronic decay products and cosmic rays would be greatly helped by the study of intermediate mass (e.g. nitrogen or oxygen) nucleus scattering off each other (N-N) or off protons (p-N) at LHC energy and we encourage realising these experiments at the LHC in its next run after the LS2 shutdown.

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Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **120** Type: **not specified**

Muon Colliders

Muon colliders have a great potential for high-energy physics. They can offer collisions of point-like par- ticles at very high energies, since muons can be accelerated in a ring without limitation from synchrotron radiation. However, the need for high luminosity faces technical challenges which arise from the short muon lifetime at rest and the difficulty of producing large numbers of muons in bunches with small emittance. Addressing these challenges requires the development of innovative concepts and demanding technologies.
The document summarizes the work done, the progress achieved and new recent ideas on muon colliders. A set of further studies and actions is also identified to advance in the field. Finally, a set of recommen- dations is listed in order to make the muon technology mature enough to be favourably considered as a candidate for high-energy facilities in the future.

Primary author: PASTRONE, Nadia (INFN Torino (IT))

Track Classification: Large experiments and projects

Contribution ID: **121** Type: **not specified**

Particle Physics and Related Topics at the Paul Scherrer Institute

We highlight the specific and unique opportunities that PSI offers for particle physics. The input outlines mid- and longterm projects and asks for support and cooperation of the international community. It exemplifies the benefits of the particle physics activities for other fields and also the return from developments elsewhere into the particle physics program. Sharing of facilities, e.g., with material science applications broadens the scope. Spin-offs from developments, e.g., in detector technology and electronics are beneficial to many applications. Radio chemistry enables unique experiments, irradiations using shared accelerator infrastructure and new developments in accelerator and magnet technology present opportunities for a broad variety of applications.

Primary authors: KIRCH, Klaus (PSI - ETHZ); RIVKIN, Lenny (PSI - EPFL); RUEEGG, Christian (PSI - University of Geneva); SEIDEL, Mike (PSI)

Track Classification: Accelerator Science and Technology

Contribution ID: **122** Type: **not specified**

Belgian national input to the EPP Strategy update

This document summarizes the input of the Belgian scientists to the European Strategy Group (ESG) in the context of the upcoming European strategy update for particle physics research. The Belgian HEP community (permanent researchers from particle and astroparticle physics) met in Brussels on September 12th, 2018. During this meeting we took stock of our current activities, evaluated our current person power and growth potential and discussed our individual and common interest in future collider and non-collider based high energy physics experiments. Our feedback to the ESG consists of a short overview of the Belgian tradition and current involvements in experimental HEP, followed by our opinions and priorities on future large-scale HEP projects. A separate statement from the nuclear physics community in Belgium is added in an addendum.

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Track Classification: National road maps

Contribution ID: **123** Type: **not specified**

Electric dipole moment community input to the update of the ESPP

We describe the status and prospect of the European community of electric dipole moment searches for the input to the update of the European strategy for particle physics.

Primary authors: Dr SCHMIDT-WELLENBURG, Philipp; KIRCH, Klaus (PSI); RIES, Dieter (Johannes Gutenberg University Mainz); PIGNOL, Guillaume (LPSC)

Track Classification: Flavour Physics and CP violation (quarks, charged leptons and rare processes)

Contribution ID: **124** Type: **not specified**

Neutrino Beam from Protvino to KM3NeT/ORCA

The Protvino accelerator facility located in the Moscow region, Russia, is in a good position to enable a rich experimental research program in the field of neutrino physics. Of particular interest is the possibility to direct a neutrino beam from Protvino towards the KM3NeT/ORCA detector which is currently under construction in the Mediterranean sea 40 km offshore Toulon, France. Such an experiment, nicknamed P2O (Protvino-to-ORCA), would yield an unparalleled sensitivity to matter effects in the Earth, allowing to determine the neutrino mass ordering with a high level of certainty due to its baseline of 2595˜km after only few years of running time at a modest beam intensity up to 100˜kW. A second phase of the experiment, comprizing a further intensity upgrade of the accelerator complex and a significant densification of the ORCA detector would allow for a competitive and complementary measurement of the leptonic CP-violating Dirac phase with a Mton detector but avoiding underground excavation costs. The initial composition and energy spectrum of the neutrino beam would need to be monitored by a near detector, to be constructed several hundred meters downstream from the proton beam target. The same neutrino beam and near detector set-up would also allow for neutrino-nuclei cross section measurements to be conducted.

Primary author: BRUNNER, Juergen (CPPM)

Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **125** Type: **not specified**

Polish input to the Update of European Strategy for Particle Physics 2020-2025

This is a position paper which aims at describing the current status and plans of Polish PP research community for the coming Update of ESPP 2020. The document does not discuss some subject closely related to PP in Poland like the Polish research in Astroparticle Physic and Nuclear Physics, and education, outreach and technology transfer issues.
The worldwide activities of PP in the coming five to ten years are already, to large extend, defined by the present world wide programme of LHC and HL-LHC, KEK, and LBNO (DUNE) preparations. The main unknown is the shape of PP in the longer perspective. In particular, both the time-scale and venues of the future colliders, many of which are in the various stages of discussions and planning, are presently unknown.
It is clear to us that the present update of the ESPP has to include, as one of the high priority items, strategic decisions on the future development of the high-energy frontier, as well as the accelerator and detector research needed for future colliders.
The Addendum to this document describes in more detail the current activities of the Polish PP community with some informations on funding, resources (including HR) and future plans.

Primary author: Prof. KROLIKOWSKI, Jan (University of Warsaw)

Track Classification: National road maps

Contribution ID: **126** Type: **not specified**

Deep Underground Neutrino Experiment (DUNE)

The 2013 European Strategy for Particle Physics (ESPP) identified the long-baseline neutrino programme as one of the four scientific objectives that require international collaboration. This strong recommendation led to the formation of DUNE as an international collaboration in 2015. The DUNE Collaboration now includes CERN and 14 of its member states, with approximately 400 European collaborators, and has a fully international governance model.

The DUNE experiment has three primary physics objectives: (i) the discovery of leptonic CP violation; (ii) Search for baryon number violation and (iii) detection of neutrinos emitted by a core-collapse supernova. This physics programme is enabled by the combination of a high-intensity neutrino beam, a powerful multi-purpose near detector and the precision imaging liquid-argon technology of the far detector.

Primary authors: SOLDNER-REMBOLD, Stefan (University of Manchester (GB)); BLUCHER, Edward (University of Chicago (US))

Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **127** Type: **not specified**

Submission from the Swedish Particle Physics Community to the European Strategy for Particle Physics Update 2018-2020

A national submission from the particle physics community (experiment and theory) in Sweden is given. The status and plans of the community are described and are used to inform a set of recommendations to the Strategy Update. In addition to recommendations of direct relevance to ongoing and planned Swedish research, the community's views on proposed major facilities and the general direction of the field are also provided.

Primary author: MILSTEAD, David Anthony (Stockholm University (SE))

Track Classification: National road maps

Contribution ID: **128** Type: **not specified**

Quantum Computing for High Energy Physics

High Energy Physics (HEP) is once again facing a “requirement wall” in all dimensions of Information and Communication Technology (ICT). Considering the current estimations of computing needs, the constrained budget that will be devoted to HEP computing, and the projected evolution of the actual capacity delivered by technology to HEP computing, a shortage of an order of magnitude in the next ten years and beyond seems to be a fair prediction. To maintain the discovery potential of HEP research infrastructures and to benefit fully from the data that will be collected — at great cost — by future experiments, it is important to find ways to reduce this expected shortfall. HEP has already faced such situations in the past, and the solution has often been to turn promising technologies from prototype to reality by working closely with hardware and software providers and ICT experts from academia and other research fields. HEP computing is often several years ahead of other, more general computing fields.
While pursuing its mission of exploring the fundamental nature of matter at the smallest possible scale, CERN has established a solid reputation of innovation in ICT. CERN was an early adopter of many computing technologies. In addition to the World Wide Web, CERN has provided pioneering contributions to computer networking, grid, and cloud technologies.
In order to ensure the availability of sufficient computing resources, CERN and the HEP community should continue investigating innovative ICT technologies in close collaboration with the main actors.

Primary author: CARMINATI, Federico (CERN)

Track Classification: Instrumentation and computing

Contribution ID: **129** Type: **not specified**

SPS Beam Dump Facility

The proposed Beam Dump Facility (BDF) is foreseen to be located at the North Area of the SPS. It is designed to be able to serve both beam dump like and fixed target experiments. The SPS and the new facility would offer unique possibilities to enter a new era of exploration at the intensity frontier. Possible options include searches for very weakly interacting particles predicted by Hidden Sector models, and flavour physics measurements. The SPS BDF team has performed in-depth studies and prototyping for all critical aspects of the facility design. The feasibility study has demonstrated that, with suitable modifications, the SPS can deliver the beam required for the proposed Search for Hidden Particles (SHiP) experiment at the BDF with the required characteristics and with acceptable losses. The study has proven the feasibility of the robust high-power target housed in a dedicated target complex, and completed the initial design of the primary beam transfer line. Civil engineering, integration, safety and radiation protection studies have also been completed.

Primary authors: PERILLO MARCONE, Antonio (CERN); GODDARD, Brennan (CERN); HESSLER, Christoph (CERN); AHDIDA, Claudia Christina; GRENIER, Damien (CERN); LOPEZ SOLA, Edmundo (CERN); KOUKOVINI PLATIA, Eirini (CERN); BARDOU, Florian; VELOTTI, Francesco Maria (CERN); SANCHEZ GALAN, Francisco (CERN); ARDUINI, Gianluigi (CERN); VINCKE, Heinz (CERN); VINCKE, Helmut (CERN); GRENARD, Jean-Louis (CERN); BAUCHE, Jeremie (CERN); OSBORNE, John Andrew (CERN); GALL, Jonathan (CERN); BUSOM DESCARREGA, Josep (CERN); KERSHAW, Keith (CERN); GATIGNON, Lau (CERN); DOUGHERTY, Liam Andrew (CERN); STOEL, Linda Susanne (Vienna University of Technology (AT)); CALVIANI, Marco (CERN); CASOLINO, Marco (INFN); BRUGGER, Markus (CERN); FRASER, Matthew Alexander (CERN); BATTISTIN, Michele (CERN); LAMONT, Mike (CERN); SANTOS DIAZ, Pablo (CERN); NININ, Pierre (CERN); AVIGNI, Pietro (CERN); JACOBSSON, Richard (CERN); MARSH, Simon (CERN); Dr GILARDONI, Simone (CERN); WIJNANDS, Thijs (CERN); KAIN, Verena (CERN); DUTHEIL, Yann (CERN); MUTTONI, Yvon (CERN)

Track Classification: Accelerator Science and Technology

Contribution ID: **130** Type: **not specified**

Input to the Strategy Process from LNF-INFN

Input to the Strategy Process from LNF-INFN

Primary author: Dr CAMPANA, Pierluigi (LNF-INFN)

Track Classification: National road maps

Contribution ID: **131** Type: **not specified**

Enhancing the LBNF/DUNE Physics Program

The Long-Baseline Neutrino Facility (LBNF) offers a unique opportunity for neutrino physics due to the high intensity (anti)neutrino beam with a broad energy spectrum. The possibility to collect unprecedented exposures alleviates one of the primary limitations of past neutrino experiments. An experimental technique has been recently proposed to achieve a control of the configuration, chemical composition, size, and mass of the neutrino targets comparable to the electron scattering experiments. In particular, this technique allows precise measurements of high statistics samples of (anti)neutrino-hydrogen (H) interactions.

The availability of high statistics samples of $\nu(\bar{\nu})$-H interactions addresses three main systematic uncertainties affecting the Deep Underground Neutrino Experiment (DUNE) long-baseline oscillation analyses:
(a) determination of the neutrino and antineutrino fluxes $\Phi(E_\nu)$;
(b) constraint of the nuclear smearing in Ar (response function) entering the event unfolding;
(c) calibration of the reconstructed (anti)neutrino energy scale.
Neutrino flux can be potentially measured at the percent level using various exclusive $\nu(\bar{\nu})$-H topologies. Such a precision cannot be achieved by other techniques.

A control of the neutrino target(s) similar to the one achieved in electron scattering experiments together with an accurate determination of the (anti)neutrino fluxes from $\nu(\bar{\nu})$-H and the unprecedented statistics would enable a sensible program of precision tests of fundamental interactions in the DUNE Near Detector (ND). This program includes a broad mixture of measurements of electroweak parameters, QCD and hadron structure of nucleons and nuclei, form factors, structure functions and cross-sections, as well as searches for new physics or verification of existing outstanding inconsistencies. It would produce hundreds of papers of varying importance and potentially add a substantial discovery potential to the DUNE physics program. This ND program would not require any additional cost with respect to what is needed to address the systematics of the long-baseline analyses. Such a program of precision measurements and searches would nicely complement the ongoing efforts in the collider, fixed-target and nuclear physics communities. In turn, it would elevate the near site of DUNE to a general physics facility much needed for a project of the size and duration of the DUNE experiment.

We propose to integrate the capability to obtain accurate $\nu(\bar{\nu})$-H measurements into the design of the ND complex currently considered in DUNE. The core technology needed for this enhancement of the physics potential is well established and has enough flexibility to be adapted to different detector geometries and configurations. This addition to the ND system can be accomplished either with a new self-contained complementary detector or an integrated sub-detector with minimal variations of the magnetized detector being considered. In particular, an interesting low-cost solution currently being studied for the former option includes the reuse of an existing magnet and electromagnetic calorimeter.

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Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **132** Type: **not specified**

Future Circular Collider - The Lepton Collider (FCC-ee)

This report contains the description of a novel research infrastructure based on a highest-luminosity energy frontier electron-positron collider (FCC-ee) to address the open questions of modern physics. It will be a general precision instrument for the continued in-depth exploration of nature at the smallest scales, optimised to study with high precision the Z, W, Higgs and top particles, with samples of 5·10ˆ12 Z bosons, 10ˆ8 W pairs, 10ˆ6 Higgs bosons and 10ˆ6 top quark pairs. FCC-ee offers unprecedented sensitivity to signs of new physics,appearing in the form of small deviations from the Standard Model, of forbidden decay processes or of production of new particles with very small couplings.
This collider will be implemented in stages, successively spanning the entire energy range from the Z pole over the WW threshold and H production peak to the $t\bar{t}$ threshold. Most of the infrastructure (e.g. underground structures, surface sites, electrical distribution, cooling & ventilation, RF systems) can be directly reused for a subsequent energy-frontier hadron collider (FCC-hh, see FCC conceptual design report volume 3), serving the world-wide particle-physics community in a highly synergetic and cost-effective manner throughout the 21st century.

Primary author: BENEDIKT, Michael (CERN)

Track Classification: Large experiments and projects

Contribution ID: **133** Type: **not specified**

Future Circular Collider - The Hadron Collider (FCC-hh)

This report describes a novel research infrastructure, based on a hadron collider with centre-of-mass collision energy of 100 TeV, collecting an integrated luminosity a factor of 5 or more larger than the HL-LHC. It will extend the current energy frontier by almost an order of magnitude. The mass reach for direct discovery will reach several tens of TeV, and allow, for example, to produce new particles whose existence could be indirectly exposed by precision measurements during a preceding e+e- collider phase. This collider will also precisely measure the Higgs self-coupling and thoroughly explore the dynamics of electroweak symmetry breaking at the TeV scale, to elucidate
the nature of the electroweak phase transition. Thermal dark matter WIMP candidates will be discovered, or ruled out. Heavy ion and ep collisions will contribute to the breadth of the programme. As a single project, this particle collider infrastructure will serve the world-wide physics community for about 25 years and, in combination with a highest-luminosity energy frontier lepton collider (FCC-ee, see FCC conceptual design report volume 2), will provide a research tool until the end of the 21st century.

Primary author: BENEDIKT, Michael (CERN)

Track Classification: Large experiments and projects

Contribution ID: **134** Type: **not specified**

UK input to the European Strategy for Particle Physics Update

This document sets out the input from the UK Particle Physics community to the update of the European Strategy for Particle Physics. It is submitted by the UK Particle Physics Advisory Panel and represents the consensus view of the UK community.

Primary author: Prof. SHEPHERD-THEMISTOCLEOUS, Claire (Rutherford Appleton Laboratory)

Track Classification: National road maps

Contribution ID: **135** Type: **not specified**

Future Circular Collider - The Integrated Programme (FCC-int)

The most effective and comprehensive approach to thoroughly explore the open questions in modern particle physics is a staged research programme, integrating in sequence lepton (FCC-ee) and hadron (FCC-hh) collision programmes, to achieve an exhaustive understanding of the Standard Model and of electroweak symmetry breaking, and to maximize the potential for the discovery of phenomena beyond the Standard Model. The project would rely on a shared and cost effective technical and organizational infrastructure, as was the case with LEP followed by LHC. This integrated programme is complementary to other ongoing research activities and leverages cross-disciplinary synergies to expand our understanding of the universe. It cements and enlarges Europe's leadership in particle and high-energy physics for decades to come. This document provides an overview of the physics potential of the integrated FCC programme and outlines its implementation scenario.

Primary author: BENEDIKT, Michael (CERN)

Track Classification: Large experiments and projects

Contribution ID: **136** Type: **not specified**

Future Circular Collider - The High-Energy LHC (HE-LHC)

This report contains the description of a novel research infrastructure based on a high-energy hadron collider, which extends the current energy frontier by almost a factor 2 (27 TeV collision energy) and an integrated luminosity of at least a factor of 3 larger than the HL-LHC. In connection with four experimental detectors, this infrastructure will deepen our understanding of the origin of the electroweak symmetry breaking, allow a first measurement of the Higgs self-coupling, double the HL-LHC discovery reach and allow for in-depth studies of new physics signals arising from future LHC measurements. This collider would directly produce particles at significant rates at scales up to 12 TeV. The project re-uses the existing LHC underground infrastructure and large parts of the injector chain at CERN. This particle collider would succeed the HL-LHC directly and serve the world-wide physics community for about 20 years beyond the middle of the 21st century.

Primary author: BENEDIKT, Michael (CERN)

Track Classification: Large experiments and projects

Contribution ID: **137** Type: **not specified**

The Short-Baseline Neutrino Program at Fermilab

Attachments

Primary author: RAMEIKA, Regina Abby (Fermi National Accelerator Lab. (US))

Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **138** Type: **not specified**

INFN National Scientific Committee for High Energy Particle Physics with Accelerators

High energy colliders offer the opportunity to widen our investigation of sub-nuclear phenomena to the highest unexplored energy regimes and shortest interaction scales. They consequently have the strongest potential for discovering new heavy particles and forces, allowing more accurate precision tests of Standard Model objects, and detecting new elusive signatures like the ones associated with dark matter particles.
In 2014-2015 the INFN National Scientific Committee for High Energy Physics with Accelerator (CSN1) discussed and prepared an extensive document 1 to describe the present understanding of the scientific scenarios and to propose recommendations towards future experiments at high energy particle accelerators.
Dedicated physics studies and R&D on innovative technologies are longstanding activities for the CSN1 community of over one thousand physicists and engineers. This valuable work has been exploited as a contribution in the context of international collaborations, preparing the dedicated inputs for the update of the European Strategy for Particle Physics.
The present document is the outcome of several workshops and discussions, during the past three years, devoted to study different opportunities both at the high energy and high intensity frontiers.

Primary author: PASTRONE, Nadia (INFN - Torino)

Track Classification: National road maps

Contribution ID: **139** Type: **not specified**

Birmingham Particle Physics Group Submission

This document is sent on behalf of the academic faculty members of the Birmingham Particle Physics Group. We begin by summarising our view of the most significant physics questions driving our field and go on to argue how we think they can best be addressed through new facilities, before ending with a few comments on maintaining our community and its wider impact.

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Track Classification: National road maps

Contribution ID: **140** Type: **not specified**

Energy frontier lepton-hadron colliders, vector-like quarks/leptons, preons and so on

First of all, an importance of the LHC/FCC based energy frontier lepton-hadron and photon-hadron colliders is emphasised. Then arguments favoring existence of new heavy isosinglet down-type quarks and vector-like isosinglet or isodoublet leptons are presented, following by historical arguments favoring new (preonic) level of matter. The importance of Super-Charm factory and GeV energy proton linac for Turkey's national road map is argued. Finally, several recommendations for ESPP2020 are suggested.

Primary author: Prof. SULTANSOY, Saleh (TOBB University of Economics and Technology)

Track Classification: Beyond the Standard Model at colliders (present and future)

Contribution ID: **142** Type: **not specified**

Swiss input for the discussion on the European Strategy for Particle Physics

The position of the Swiss particle physics community towards the update for the European Strategy for Particle Physics compiled by the Swiss Institute for Particle Physics (CHIPP).

Primary author: CHIPP, (Swiss Institute for Particle Physics)

Track Classification: National road maps

Contribution ID: **143** Type: **not specified**

A New QCD Facility at the M2 beam line of the CERN SPS

This document summarises the physics interest, sensitivity reach and competitiveness of a future general-purpose fixed-target facility for Particle Physics research. Based upon the versatile M2 beam line of the CERN SPS, a great variety of measurements is proposed to address fundamental issues of Quantum Chromodynamics.

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Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **144** Type: **not specified**

European Particle Physics Strategy: Input from UK National Laboratories

This document supplements the main scientific input from the UK particle physics community, and sets out the position of the UK national laboratories on points of European collaboration and organisation.

Primary author: Prof. NEWBOLD, Dave (STFC Rutherford Appleton Laboratory (GB))

Track Classification: National road maps

Contribution ID: **145** Type: **not specified**

The Compact Linear e^+e^- Collider (CLIC): Physics Potential

The Compact Linear Collider, CLIC, is a proposed e^+e^- collider at the TeV scale whose physics potential ranges from high-precision measurements to extensive direct sensitivity to physics beyond the Standard Model. This document summarises the physics potential of CLIC, obtained in detailed studies, many based on full simulation of the CLIC detector. CLIC covers one order of magnitude of centre-of-mass energies from 350 GeV to 3 TeV, giving access to large event samples for a variety of SM processes, many of them for the first time in e^+e^- collisions or for the first time at all. The high collision energy combined with the large luminosity and clean environment of the e^+e^- collisions enables the measurement of the properties of Standard Model particles, such as the Higgs boson and the top quark, with unparalleled precision. CLIC might also discover indirect effects of very heavy new physics by probing the parameters of the Standard Model Effective Field Theory with an unprecedented level of precision. The direct and indirect reach of CLIC to physics beyond the Standard Model significantly exceeds that of the HL-LHC. This includes new particles detected in challenging non-standard signatures. With this physics programme, CLIC will decisively advance our knowledge relating to the open questions of particle physics.

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Track Classification: Electroweak physics (physics of the W, Z, H bosons, of the top quark, and QED)

Contribution ID: **146** Type: **not specified**

The Compact Linear e^+e^- Collider (CLIC): Accelerator and Detector

The Compact Linear Collider (CLIC) is a TeV-scale high-luminosity linear e^+e^- collider under development by international collaborations hosted by CERN. This document provides an overview of the design, technology, and implementation aspects of the CLIC accelerator and the detector. For an optimal exploitation of its physics potential, CLIC is foreseen to be built and operated in stages, at centre-of-mass energies of 380 GeV, 1.5 TeV and 3 TeV, for a site length ranging between 11 km and 50 km. CLIC uses a two-beam acceleration scheme, in which normal-conducting high-gradient 12 GHz accelerating structures are powered via a high-current drive beam. For the first stage, an alternative with X-band klystron powering is also considered. CLIC accelerator optimisation, technical developments, and system tests have resulted in significant progress in recent years. Moreover, this has led to an increased energy efficiency and reduced power consumption of around 170 MW for the 380 GeV stage, together with a reduced cost estimate of approximately 6 billion CHF. The detector concept, which matches the physics performance requirements and the CLIC experimental conditions, has been refined using improved software tools for simulation and reconstruction. Significant progress has been made on detector technology developments for the tracking and calorimetry systems. The construction of the first CLIC energy stage could start as early as 2026 and first beams would be available by 2035, marking the beginning of a physics programme spanning 25-30 years and providing excellent sensitivity to Beyond Standard Model physics, through direct searches and via a broad set of precision measurements of Standard Model processes, particularly in the Higgs and top-quark sectors.

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Track Classification: Large experiments and projects

Contribution ID: **147** Type: **not specified**

PERLE : A High Power Energy Recovery Facility for Europe

The efficient recovery of power, to re-excite cavities from the used beam, was proposed in 1965. Major advances in superconducting RF technology, as quantified by cavity quality factors Q0 in excess of 1010, and the consideration of multi-turn recirculator passages, have opened the door to the green generation of high energy, high brightness, high current electron beams. The facility PERLE, here presented to the formation of the European Strategy for Particle Physics, is being designed as a new generation facility reaching for the first time into the 10MW power regime of beam current and energy. The PERLE Collaboration comprises currently ten institutions. With Daresbury (UK), Darmstadt (D), Jlab (US) and Novosibirsk (Ru) there are four laboratories, which have been pioneering the development of ERL technology, together with three leading laboratories on superconducting RF (SRF) technology, CERN, Orsay (LAL and IPN) and Saclay CEA, and others. PERLE has been designed in support of the LHeC development, which defines its configuration (3 turn recirculator), its frequency (802 MHz, synergetic with FCC requirements) and electron current (20mA or 500pC in the LHC, 40MHz time structure). This contribution, based on the 2017 PERLE CDR 1 and recent progress, describes the purpose, the parameters and configuration as well as the main components, including the successfully built first 802MHz SC Niobium cavity with a large dynamic range and a Q0 exceeding 3·1010. Based on in-kind contributions including re-use of existing components, especially the source (Daresbury, ALICE) and cryomodule (CERN, SPL), PERLE is expected to be operational at Orsay in the early twenties in an initial configuration subsequently upgradeable to full energy. The facility has the main goal of developing ERL technology, especially SRF, for application in high energy colliders, especially LHeC and FCC, as well as to develop techniques for multi-turn, high current ERL operation, complementary to and collaborating with the upcoming 1.3 GHz facilities CBETA at Cornell and bERLinPro and others. As such it represents a major contribution to the development of energy and intensity frontier accelerators, the innovation through technology of which compares well with plasma wakefield R&D for high gradient acceleration. The uniquely demanding parameters of PERLE make it a most powerful facility for lower energy precision electron beam physics in the areas of electroweak interactions, proton radius, search for dark bosons, or for the investigation of the unknown charge density of heavy nuclei such as the magic 132Sn as a striking example for a PERLE nuclear physics programme. From PERLE a 5 MeV energy photon beam can be derived of an intensity more than a factor of 100 higher than at ELI, which is a base for novel photo-nuclear physics or the production of medical radio-isotopes. As this paper is being submitted, the leading laboratories are signing Memoranda of Understanding for the foundation of the PERLE Collaboration. Being hosted at Orsay, in one of Europe's larger national laboratories, PERLE is ideally suited to support our joint particle physics future at CERN and to also maintain more than one of our larger associated research infrastructures at the highest level, for Europe and beyond.

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Track Classification: Accelerator Science and Technology

Contribution ID: **148** Type: **not specified**

Nuclear physics and the European Particle Physics Strategy Update 2018

This document provides input to the update of the European Strategy for Particle Physics in fields that are related to Nuclear Physics as described in the NuPECC Long Range Plan 2017.

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Track Classification: Other (communication, outreach, strategy process, technology transfer, individual contributions,...)

Contribution ID: **149** Type: **not specified**

APS Division of Particles and Fields Response to European Strategy Group Call for White Papers: Community Planning and Science Drivers

This white paper describes the community strategic planning process organized by APS DPF, and summarizes U.S. particle physics community input on activities and aspirations. This is the first of two documents, covering the five P5 Science Drivers.

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Track Classification: National road maps

Contribution ID: **150** Type: **not specified**

APS Division of Particles and Fields Response to European Strategy Group Call for White Papers: Tools for Particle Physics

The U.S. particle physics strategy process is summarized in a companion white paper that also describes U.S. activities related to the five P5 science drivers. Additional activities within the U.S. particle physics program that are critical to progress in our field are described here.

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Track Classification: National road maps

Contribution ID: **151** Type: **not specified**

New physics searches with heavy-ion collisions at the LHC

This document summarizes proposed searches for new physics accessible in the heavy-ion mode at the LHC, both through hadronic and ultraperipheral $\gamma\gamma$ interactions, and that have a competitive or, even, unique discovery potential compared to standard proton-proton collision studies. Illustrative examples include searches of new particles — such as axion-like pseudoscalars, radions, magnetic monopoles, new long-lived particles, dark photons, and sexaquarks as dark matter candidates — as well as new interactions, such as non-linear or non-commutative QED extensions. We argue that such interesting possibilities constitute a well-justified scientific motivation, complementing standard quark-gluon-plasma physics studies, to continue running with ions at the LHC after the Run-4, i.e. beyond 2030, including light and intermediate-mass species, accumulating nucleon-nucleon integrated luminosities in the accessible fb^{-1} range per month.

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Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **152** Type: **not specified**

The physics potential of HL-LHC

This document presents the executive summary of the findings of the Workshop on "The physics of HL-LHC, and perspectives on HE-LHC", which has run for over a year since its kick-off meeting on 30 October – 1 November 2017.
We discuss here the HL-LHC physics programme. As approved today, this covers {\it (a)} pp collisions at 14~TeV with an integrated luminosity of 3 ab^{-1} each for ATLAS and CMS, and 50 fb^{-1} for LHCb, and {\it (b)} Pb–Pb and p–Pb collisions with integrated luminosities of 13 nb^{-1} and 50 nb^{-1}, respectively. In view of possible further upgrades of LHCb and of the ions programme, the WG reports assume 300 fb^{-1} of luminosity delivered to an Upgrade II of LHCb, 1.2 pb^{-1} of integrated luminosity for p–Pb collisions, and the addition of collisions with other nuclear species.
A separate submission covers the HE-LHC results.

The activity has been carried out by five working groups (WGs): Standard Model" (WG1),Higgs" (WG2), Beyond the Standard Model" (WG3),Flavour" (WG4) and "QCD matter at high density" (WG5). Their reports, extending this executive summary with more results and details, are available on the CERN Document Server, and will appear on arXiv. The WG results include both phenomenological studies and detailed simulations of the anticipated performance of the LHC detectors under HL-LHC conditions. These latter studies implement the knowledge acquired during the preparation of the technical design reports for the upgraded detectors, and reflect the experience gained by the experiments during the first two runs of the LHC.
The documents describing in full detail the HL-LHC studies performed by the experiments are also available.

Three goals have been set for the Workshop: (i) to update and extend the projections for the precision and reach of the HL-LHC measurements, and for their interpretation; (ii) to highlight new opportunities for discovery of phenomena beyond the Standard Model (BSM), in view of the latest theoretical developments and of recent data; (iii) to explore possible new directions and/or extensions of the approved HL-LHC programme, particularly in the area of flavour, in the search for elusive BSM phenomena, and in the study of QCD matter at high density.

In addition to enriching and consolidating the physics plans for HL-LHC, and highlighting the significant advances that the full HL-LHC programme will bring relative to today's landscape, this contribution to the European Strategy for Particle Physics Update process is intended to help put in perspective the physics potential of future projects beyond HL-LHC.

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Track Classification: Beyond the Standard Model at colliders (present and future)

Contribution ID: **153** Type: **not specified**

KLEVER: An experiment to measure BR(KL -> pi0 nu anti-nu) at the CERN SPS

Precise measurements of the branching ratios for the flavor-changing neutral current decays $K \to \pi\nu\bar{\nu}$ can provide unique constraints on CKM unitarity and, potentially, evidence for new physics. It is important to measure both decay modes, $K^+ \to \pi^+\nu\bar{\nu}$ and $K_L \to \pi^0\nu\bar{\nu}$, since different new physics models affect the rates for each channel differently. The goal of the NA62 experiment at the CERN SPS is to measure the BR for the charged channel to within 10%. For the neutral channel, the BR has never been measured. We are designing the KLEVER experiment to measure BR($K_L \to \pi^0\nu\bar{\nu}$) to ∼20% using a high-energy neutral beam at the CERN SPS starting in Run 4. The boost from the high-energy beam facilitates the rejection of background channels such as $K_L \to \pi^0\pi^0$ by detection of the additional photons in the final state. On the other hand, the layout poses particular challenges for the design of the small-angle vetoes, which must reject photons from K_L decays escaping through the beam exit amidst an intense background from soft photons and neutrons in the beam. Background from $\Lambda \to n\pi^0$ decays in the beam must also be kept under control. We present findings from our design studies for the beamline and experiment, with an emphasis on the challenges faced and the potential sensitivity for the measurement of BR($K_L \to \pi^0\nu\bar{\nu}$).

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Track Classification: Flavour Physics and CP violation (quarks, charged leptons and rare processes)

Contribution ID: **154** Type: **not specified**

nuSTORM at CERN: Executive Summary

The Neutrinos from Stored Muons, nuSTORM, facility has been designed to deliver a definitive neutrino-nucleus scattering programme using beams of (anti-)electron and (anti-)muon neutinos from the decay of muons confined within a storage ring. The facility is unique, it will be capable of storing muon beams with a central momentum of between 1 GeV/c and 6 GeV/c and a momentum spread of 16\%. This specification will allow neutrino-scattering measurements to be made over the kinematic range of interest to the DUNE and Hyper-K collaborations. At nuSTORM, the flavour composition of the beam and the neutrino-energy spectrum are both precisely known. The storage-ring instrumentation will allow the neutrino flux to be determined to a precision of 1% or better. By exploiting sophisticated neutrino-detector techniques such as those being developed for the near detectors of DUNE and Hyper-K, the nuSTORM facility will:

- Serve the future long- and short-baseline neutrino-oscillation programmes by providing definitive measurements of electron-neutrino-nucleus and muon-neutrino-nucleus scattering cross-sections with percent-level precision;
- Provide a probe that is 100\% polarised and sensitive to isospin to allow incisive studies of nuclear dynamics and collective effects in nuclei;
- Deliver the capability to extend the search for light sterile neutrinos beyond the sensitivities that will be provided by the FNAL Short Baseline Neutrino (SBN) programme; and
- Create an essential test facility for the development of muon accelerators to serve as the basis of a multi-TeV lepton-antilepton collider.

To maximise its impact, nuSTORM should be implemented such that data-taking begins by ˜2027/28 when the DUNE and Hyper-K collaborations will each be accumulating data sets capable of determining oscillation probabilities with percent-level precision.

With its existing proton-beam infrastructure, CERN is uniquely well-placed to implement nuSTORM. The feasibility of implementing nuSTORM at CERN has been studied by a CERN Physics Beyond Colliders study group. The muon storage ring has been optimised for the neutrino-scattering programme to store muon beams with momenta in the range 1 GeV to 6 GeV. The implementation of nuSTORM exploits the existing fast-extraction from the SPS that delivers beam to the LHC and to HiRadMat. A summary of the proposed implementation of nuSTORM at CERN is presented below. An indicative cost estimate and a preliminary discussion of a possible time-line for the implementation of nuSTORM are presented the addendum.

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Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **155** Type: **not specified**

CEA-Irfu contribution to the 2020 update of the European Strategy for Particle Physics

This document summarizes the scientific and technological position of CEA-Irfu teams on the main projects for particle physics, including neutrino physics and QGP physics.
The achievement of the HL-LHC and its scientific exploitation is the immediate priority. The crucial question is therefore the definition of the next generation of collider able to pursue an ambitious search for new physics.

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Track Classification: National road maps

Contribution ID: **156** Type: **not specified**

The HIBEAM/NNBAR Experiment for the European Spallation Source

The HIBEAM/NNBAR experiment is a two stage experiment for the European Spallation Source (ESS) to search for baryon number violation. The experiment would make high sensitivity searches for baryon number violating processes: n $\longrightarrow$ nbar (neutron to antineutron) and n $\longrightarrow$ n′ (neutron to sterile neutron), corresponding to the selection rules in baryon number $\Delta B = 2, 1$, respectively. The experiment addresses topical open questions such as baryogenesis and dark matter, and is sensitive to a scale of new physics substantially in excess of that available at colliders. This is a cross disciplinary experiment with a clear particle physics goal. The community encompasses physicists from large collider experiments and low energy nuclear physics experiments, together with scientists specialising in neutronics and magnetics. European, US and Asian communities are represented. The experiment would increase the sensitivity to neutron conversion probabilities by three orders of magnitude compared with previous searches. The opportunity to make such a leap in sensitivity in tests of a global symmetry is rare and should not be missed.

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Track Classification: Accelerator Science and Technology

Contribution ID: **157** Type: **not specified**

Canadian Submission to the European Particle Physics Strategy Update

This document provides input from the Canadian subatomic physics community to the European Particle Physics Strategy 2020-2025 and is based on the 2017-21 Canadian Subatomic Physics Long Range Plan (www.subatomicphysics.ca). This submission provides an overview of the major projects in which the Canadian community is participating, and discusses connections to the European Particle Physics Strategy and prospects for further collaboration.

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Track Classification: National road maps

Contribution ID: **158** Type: **not specified**

Opportunities in Accelerator-based Neutrino Physics in Japan

This document provides the inputs to the ongoing European Particle Physics Strategy based on the opportunities offered by the accelerator-based neutrino programme in Japan to which the 2013 European Strategy recommended due to the "Rapid progress in neutrino oscillation physics, with significant European involvement", "CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments", that led to the establishment of the CERN neutrino platform and that "Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan", that supported the expansion of the already substantial European presence in the Japanese long baseline neutrino programme to encompass Hyper-Kamiokande in addition to T2K.
There have been significant developments since the publication of the European Particle Physics Strategy with the establishment of the Hyper-K collaboration, whose far detector will start to be constructed in 2020, and the prospect of the T2K running beyond 2021, with increasing beam power due to an upgrade of the J-PARC Main Ring accelerator, up to the start of data taking for Hyper-K, thus assuring a continuous period of data taking in Japan in the next decades. There is significant European participation in both experiments and an already ongoing engagement from CERN through the Neutrino Platform and the registered-experiment status of T2K.
Recommendations to the European Particle Physics strategy are presented on the accelerator-based neutrino programme of those facilities, based upon the foundations of the current and past work and future opportunities offered by the accelerator neutrino programme in Japan.

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Track Classification: Neutrino physics (accelerator and non-accelerator)

Contribution ID: **159** Type: **not specified**

Exploring the Energy Frontier with Deep Inelastic Scattering at the LHC

The Large Hadron Collider determines the energy frontier of experimental collider physics for the next two decades. Following the current luminosity upgrade, the LHC can be further upgraded with a high energy, intense electron beam such that it becomes a twin-collider facility, in which ep operates concurrently with pp. A joint ECFA, CERN and NuPECC initiative led to a detailed conceptual design report (CDR) 1 for the Large Hadron Electron Collider (LHeC) published in 2012. The LHeC uses a novel, energy recovery linear (ERL) electron accelerator which enables TeV energy electron-proton collisions at high luminosity, exceeding that of HERA by nearly three orders of magnitude. The discovery of the Higgs boson and the surprising absence of BSM physics at LHC demand to extend the experimental base of particle physics suitable to explore the energy frontier, beyond pp collisions at the LHC. Following a mandate of the CERN Directorates and guided by an International Advisory Committee, this motivated representatives of more than 100 institutes to proceed, as sketched here, with the development of the accelerator, physics and detector prospects for the LHeC with the intention to publish an update of the CDR in early 2019 [2].
The very high luminosity and the substantial extension of the kinematic range in deep inelastic scattering (DIS) compared to HERA, make the LHeC a uniquely powerful TeV energy collider, which rests on a maximal exploitation of the LHC infrastructure. Realising an "Electrons for LHC" [3] programme would create the cleanest, high resolution microscope accessible to the world, one may term a "CERN Hubble Telescope for the Micro-Universe". It is directed to unravel the substructure of matter encoded in the complex dynamics of the strong interaction, a necessary input for future hadron colliders, including HL- LHC. Being complementary to the LHC and a possible future e+e− machine, the LHeC would scrutinise the Standard Model (SM) deeper than ever before, and possibly discover new physics in the electroweak and chromodynamic sectors. Adding ep transforms the LHC into an outstanding, high precision Higgs facility. Through the extension of the kinematic range by about three orders of magnitude in lepton-nucleus (eA) scattering, the LHeC is the most powerful electron-ion research facility one can build in the next decades, for elucidating the chromodynamic origin of the Quark-Gluon-Plasma and clarifying the partonic substructure and dynamics inside nuclei for the first time.
The LHeC physics programme reaches far beyond any specialised goal, it complements and sustains the physics at HL-LHC by providing new discovery potential in its final phase of operation. The LHeC represents a unique opportunity for CERN and its associated laboratories to build a full, new accelerator using modern technology. The ERL has major future applications, with ep at HE-LHC and FCC-eh, as an injector for FCC-ee, as a $\gamma\gamma$ Higgs facility [4, 5] or, beyond particle physics, as the highest energy XFEL of hugely increased brightness [6]. The main LHeC innovation is the first ever high energy application of energy recovery technology, based on high quality superconducting RF developments, a major contribution to the development of green collider technology. A novel ep experiment enables modern detection technology, such as HV CMOS Silicon tracking, to be further developed and exploited in a new generation, 4π acceptance, no pile-up, high precision collider detector in the decade(s) hence.
This paper focuses on physics providing also an overview on the machine. It is complemented by an Addendum describing further aspects of the LHeC project such as the operation and timelines for the accelerator and the detector. The development of multi-turn, high current, 802MHz ERL technology, required for the LHeC, is described in an accompanying, separate strategy contribution of the PERLE Collaboration [7] on a 500 MeV ERL facility at Orsay, based on its CDR [8]

published in 2017.

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Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **160** Type: **not specified**

The physics potential of HE-LHC

This document summarizes the physics potential of the High-Energy LHC (HE-LHC), under consideration as a possible future project at CERN. The HE-LHC is a 27 TeV pp collider, to be installed in the LHC tunnel, relying on the 16 T magnet technology being developed for the 100 TeV Future Circular Collider (FCC-hh). The HE-LHC is designed to deliver 10-15 ab^{-1} of integrated luminosity to two general purpose detectors, during 20 years of operation. As for the LHC, the facility could host a dedicated interaction point focused on flavour physics, delivering 3 ab^{-1} of integrated luminosity to an upgraded LHCb detector, and would continue the programme of heavy ion collisions. The results presented here were obtained in the context of the Workshop on "The physics of HL-LHC, and perspectives on HE-LHC", which ran for over a year after its kick-off meeting on 30 October – 1 November 2017. These studies complemented those focused on the engineering and technological aspects of the project, performed in the context of the FCC conceptual design report (CDR) for the HE-LHC, and documented elsewhere.

The activity has been carried out by five working groups (WGs): Standard Model (WG1), Higgs (WG2), Beyond the Standard Model (WG3), Flavour (WG4) and QCD matter at high density (WG5). The reports from the WGs, extending this executive summary with much more detail and many more results, are available on the CERN Document Server, and will appear on arXiv. The documents describing in full detail the HL-LHC and HE-LHC studies performed by the ATLAS and CMS Collaborations will be available in early 2019.

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Track Classification: Beyond the Standard Model at colliders (present and future)

Contribution ID: **161** Type: **not specified**

MAGIS-1K: A 1000 m Atom Interferometer Device for Searches in Dark Matter and Gravity Waves

MAGIS-1K: A 1000 m Atom Interferometer Device for Searches in Dark Matter and Gravity Waves

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On behalf of the MAGIS-100 collaboration

This document is responding to the call for input collaboration to the update of the European Strategy for Particle Physics from the MAGIS collaboration.

Atom interferometry can be used to answer basic science questions in quantum mechanics, dark sector physics, and 'mid-band' gravitational wave detection, due to its exquisite sensitivity to distortion of space-time. It will be able to detect well-motivated ultra-light dark matter candidates several orders of magnitude beyond current bounds.

The Matter-wave Atomic Gradiometer Interferometric Sensor (MAGIS) collaboration seeks to connect two quantum sensors across a long baseline to perform fundamental physics measurements. The phase in each device is compared across this baseline, enabling broad applications for fundamental physics. The science is enabled by the ongoing advances in atomic clocks and atom interferometry.

This scheme will be implemented in the configuration proposed for the MAGIS-100 experiment 1 by taking two atom interferometers and separating them across the baseline of the vertical 100-meter-deep NuMi access shaft at Fermilab. MAGIS-100 will combine the unique physical features of the Fermilab site with the laboratory expertise in vacuum and magnetics fields to give a high level of support to the physics collaboration.

Design, construction, and integration of the main components of MAGIS-100 is expected to take approx. three years. The initial science program will then take an additional three years. It will provide an increase of two orders of magnitude in sensitivity of a dark matter field in the mass region 10−15 eV and four orders of magnitude increase in sensitivity to B-L coupled new forces over eight orders of magnitude in mass. The experiment will also yield sensitivity to pseudoscalar dark matter. MAGIS-100 is the precursor to a proposed 1000 m baseline experiment which will provide leading sensitivity to gravitational waves in the mid-band frequency range. The project will advance the frontier of quantum sensor technologies and the physics that can be pursued with these technologies, including quantum tests on record-setting macroscopic scales.

To reach its full potential the MAGIS experiment will be extended to the km-scale, to provide sensitivity to physics of the early universe and the dark-sector. The program of R&D for such a device adds to the diversification of the community and experimental techniques for exploring fundamental physics and providing leading sensitivity to gravitational waves in the mid-band frequency range. The project will advance the frontier of quantum sensor technologies ensuring that US and Europe work in partnership to stay at the frontier of the second quantum revolution [2].

Currently there are several efforts within Europe, including the MIGA (France) experiment, the proposed AION (UK) initiative, and the UKs contribution to the MAGIS-100 experiment. There exists substantial benefit for Europe to contribute to the MAGIS programme, and the development of this technology for km scale experiments, and realisation of this experiment on a decadal timescale

Recommendation:
It is important for Europe to collaborate in the new field of quantum sensors for fundamental physics in the search for dark matter across unexplored parameter-space, such as the MAGIS experiment. The opportunity to explore sub-eV territory is not generally

accessible through the Higgs portal and the LHC, quantum sensors provide a complimentary effort enabling access to this mass range.

1 P. Adamson, et al., “PROPOSAL: P-1101 MAGIS-100”, FERMILAB-TM-2700-PPD
[2] Z. Ahmed, et al., “Quantum Sensing for High Energy Physics”, https://arxiv.org/abs/1803.11306

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Track Classification: Dark matter and dark sector (accelerator and non-accelerator dark matter, dark photons, hidden sector, axions)

Contribution ID: **162** Type: **not specified**

The Importance of Research-Industry Collaborations on Emerging Technologies towards Exascale Computing

High Energy Physics is facing a shortage in computing power that has been evaluated between one and two orders of magnitude in the next ten years. To preserve the physics discovery potential and make the best use of the data that will be collected at great cost, it will be essential to explore emerging Information and Communication Technologies (ICT) in close collaboration with leading industry partners. CERN openlab has adopted a unique approach to foster this collaboration by defining and coordinating innovative projects between industry, HEP users and other research entities in hardware, software, algorithms, and education. We propose that the European Strategy for Particle Physics should consider the CERN openlab collaborative R&D model and support the establishment of collaborative programmes as efficient tools in the development of the future computing strategies for HEP.

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Track Classification: Instrumentation and computing

Contribution ID: **163** Type: **not specified**

Quantum Chromodynamics: Theory - Input for the European Particle Physics Strategy Update

This contribution highlights the role of QCD theory in studying the physics of the Standard Model and beyond, as well as opportunities and challenges,
as an input to the preparation of the European Particle Physics Strategy Update (EPPSU).

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Track Classification: Strong interactions (perturbative and non-perturbative QCD, DIS, heavy ions)

Contribution ID: **164** Type: **not specified**

The European Spallation Source ERIC - Input for European Strategy

The European Spallation Source ERIC is a joint European organization committed to building and operating the world's leading facility for research using neutrons. The facility uses a 2 GeV proton beam hitting a tungsten target to produce neutrons (predominately boil off neutrons at about 2MeV and spallation product). A recent document from ESS (The ESS Instrument Suite – A Capability Gap Analysis) has analysed the capability gaps remaining after construction of the first 15 instruments, and the result of this analysis has shown that one of the community that is most obviously not catered is the particle physics community. For this reason the wording of the European Strategy should take into account that non-collider fundamental physics experiments in Europe outside of CERN

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Track Classification: Accelerator Science and Technology

Contribution ID: **165** Type: **not specified**

Initial INFN input on the update of the European Strategy for Particle Physics - The Astroparticle Physics Commission 2

This document contains some initial input from the INFN Astroparticle Physics Commission 2 (CSN2) to the update of the European Strategy for Particle Physics.

It does not aim at providing a comprehensive overview of the CSN2 activities nor to cover all possible relevant aspects of the Strategy: this will be defined with the other actors all along the update process, from the Open Symposium of May 2019 to the Strategy Drafting Session of January 2020. It aims instead at emphasising the CSN2 activities which are or might be connected in the near future to Particle Physics programs and to CERN activities. In particular, is therefore devoted to a short description of the activities on: the study of neutrino oscillations by means of neutrino beams; the direct search of dark matter in underground laboratories, particularly by means of noble liquid detector; the observation of Gravitational Waves sources in the Universe and the study of fundamental laws of physics by means of Gravitational Waves.

The content of this document takes into account the information presented and the extensive discussions held at a National INFN "Town Meeting", which took place in Rome on 6-7 September 2018: https://agenda.infn.it/conferenceOtherViews.py?view=standard&confId=15968 and the content of a document that is currently in preparation and that will be made public well before the May 2019 Symposium. This document will cover in details all scientific activities supported by the CSN2.

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Track Classification: National road maps

Contribution ID: **166** Type: **not specified**

Input from the Netherlands for the European Strategy for Particle Physics – Update 2020

Input from the Netherlands for the European Strategy for Particle Physics – Update 2020

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Track Classification: National road maps

Contribution ID: **167** Type: **not specified**

Status of Fermilab's Neutrino Facilities

Fermilab is the only laboratory in the world that operates two accelerator-based neutrino beams simultaneously. These intense neutrino sources enable an important collection of experi- ments that are studying neutrinos over both short and long distances, allowing the experiments to address questions such as the neutrino mass ordering, whether additional (sterile) neutrinos exist, and whether neutrinos violate matter-antimatter (CP) symmetry. The 8 GeV protons from the Booster are supplied to the Booster Neutrino Beam (BNB), which serves ANNIE, MicroBooNE and MiniBooNE and will soon serve ICARUS and SBND. The 120 GeV proton beam from the Main Injector supports neutrino experiments at NuMI (MINERvA and NOvA) and will support the Long Baseline Neutrino Facility (LBNF)/Deep Underground Neutrino Experiment (DUNE) in the future. The NOvA experiment explores the details of neutrino flavor transformation. DUNE will push beyond the precision achievable by NOvA in a new beamline created as part of the LBNF and powered by the Proton Improvement Plan II (PIP-II) accelerator upgrades. MINERvA, scheduled to cease data taking in 2019, enables these measurements with precision measure- ments of neutrino interactions with various nuclear targets. The Short Baseline Neutrino (SBN) Program on the low-energy BNB is designed to definitively address the question of sterile neu- trinos through a suite of three experiments: MicroBooNE, that began operating with beam in 2015; ICARUS, that will begin operating in 2019; and SBND, the Short-Baseline Near Detec- tor that will follow in 2020. Experience with these liquid argon detectors will also inform the future flagship international LBNF/DUNE program.

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Track Classification: Neutrino physics (accelerator and non-accelerator)