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Particle Physics in Finland

On behalf of the particle physics community in Finland:

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

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Contribution to the update of the European Strategy of Particle Physics:

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Finland has a long-standing tradition in internationally high-quality research in theoretical and experimental high-energy physics. The research in experimental particle physics started in Finland in 1965 and a theory institute was founded in 1964. The experimental activities began on an ad hoc basis at CERN, which Finland then joined in 1991. Finland has also participated in the physics programme of Fermilab's Tevatron-collider.

Since 1996 the Helsinki Institute of Physics (HIP) has had a national mandate to coordinate Finland's research related to CERN, and recently also to the Facility for Antiproton and Ion Research (FAIR). HIP is a joint institute of five Finnish universities: the Universities of Helsinki and Jyväskylä, Aalto University, and the Lappeenranta and Tampere Universities of Technology. The role of HIP is essential in creating cohesion and focusing resources in both theoretical and experimental research in Finland. The HIP theory programme is instrumental in supporting and coordinating research in both particle physics and cosmology in the member Universities. This enables research in Finland to have much greater impact than would be possible without HIP.

Currently the main research focus is on three of the LHC experiments: ALICE, CMS and TOTEM, where Finnish scientists contribute significantly to ultra-relativistic heavy ion physics, new physics searches, standard model measurements and forward physics. The full physics exploitation of these, including the preparation of their high luminosity phase, constitute at the time being the highest priority of the Finnish high-energy physics community. Computing and data access are an integral part of this physics exploitation. HIP participates in the Worldwide LHC Computing Grid (WLCG) through the Nordic Tier-1 (NGDF) and the HIP Tier-2 (T2_FI_HIP) centers. Securing and developing further the WLCG resources will be essential to fully take advantage of the LHC data. In parallel, continued detector R&D is equally important. Common focused European and/or global efforts on semiconductor and gas detector development for the upgrades of the LHC experiments, and also at future linear collider experiments, is crucial. Finland expresses support for the continuation of heavy ion collisions at the LHC beyond 2029.

Instrumentation of particle physics means designing, constructing and testing scientific instruments needed for measuring and recording physical properties of particles created in high energy physics experiments. Participation in instrumentation is a prerequisite in experimental particle physics for accessing scientific data and for producing new physics. Thus, also in the future, we plan to

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maintain the Detector Laboratory infrastructure at HIP for high-quality instrumentation with appropriate laboratory premises, cutting-edge equipment, skillful teams and wide networks.

The HIP Technology Programme promotes research, development, innovation, technology transfer and pre-commercialization activities with links to the CERN experiments. Synergies with other international big science initiatives are actively sought. HIP is a part of the CERN Business Incubation Center network and collaborates closely with Business Finland, the Finnish agency for supporting and funding innovations with the aim of enabling companies to grow, through specific actions focused on CERN-related new business ideas.

Regarding particle accelerator development, Finland is actively contributing to the CLIC R&D programme. This activity is multidisciplinary and intersectorial, and includes material physics and engineering aspects as well as collaboration with the industry. An international linear collider is a definitive option for the next step in the high-energy frontier, besides the high-energy hadron collider possibility. The development and preparation of the CLIC option as the possible next high-energy frontier facility should continue in parallel with other options until a physics driven decision based on the LHC results can be taken. We emphasize that CERN, as the European Particle Physics Laboratory, should play a key role in any international post-LHC high-energy facility. Finland supports particle physics programmes also in other international laboratories, like ESS in Sweden.

FAIR is an international facility and chosen by NuPECC as a top priority for the European Nuclear Physics Community. FAIR will provide unique experimental opportunities with antiproton and relativistic heavy ion beams as well as secondary radioactive ion beams for a broad range of studies in atomic and plasma physics, hadron and nuclear physics and in astrophysics. Since 2010 Finland has belonged to FAIR in a consortium with Sweden, participating in the NUSTAR Collaboration. The main civil construction works of FAIR started in July 2017 aiming at the target completion of the facility in 2025. The Phase-0 experiments utilizing the upgraded GSI accelerators and storage rings will start in 2019. At start, the main contribution of Finland to FAIR accelerator construction is the beam tracking instrumentation for the Superconducting Fragment Separator (S-FRS). Finland is also involved in other experimental activities at CERN, such as ISOLDE and CLOUD, expanding the activities to other fields. Similarly, the JYFL Accelerator Laboratory in Finland remains strong also in future as a leading European stable-beam facility in nuclear physics.

High-energy physics and cosmology are closely connected, which is particularly reflected in theoretical research. Finland has long traditions in theoretical high-energy physics and cosmology, with groups in Helsinki, Jyväskylä and Turku. The links between theory and particle physics experiments are closest in particle physics phenomenology. In Helsinki the research in this area is concentrated on BSM phenomenology, both for collider experiments (at LHC or at future collider experiments) and for cosmology. Particle theory and phenomenology in Jyväskylä has an emphasis

on QCD, especially in the context of heavy ion physics. Here there is a close and fruitful collaboration with the local ALICE experimental group and also a strong interest in the physics explored at a future electron-ion collider.

In neutrino physics, the newly-formed CERN Neutrino Platform contributes with R&D to long baseline neutrino experiments to which Finnish physicists also contribute. In Finland, the Pyhäsalmi mine offers a prospect of observing ultra-high energy neutrinos by acoustic detection of particle showers in the rock in a similar fashion as in ANTARES/AMADEUS and KM3NeT. This would benefit from the greater density, larger speed of sound and higher neutrino interaction rate in rock compared to water. There is a proposal for a pilot project to study this, and on a longer term the Pyhäsalmi mine could be converted into the largest acoustic observatory in the world. The nuclear-theory group at the University of Jyväskylä develops nuclear-structure models needed for the two-neutrino and neutrinoless double beta decay studies. It contributes to two major European underground experiments SUPERNEMO and COBRA, which are measuring these extremely rare processes.

The research in cosmology at Helsinki, Jyväskylä and Turku is broad, including inflation, structure formation, and implications of BSM physics scenarios for cosmology. A new initiative is to investigate how gravitational waves can be used to directly observe physical processes in the very early universe. Gravitational waves in the relevant frequency range can be observed with the ESA's LISA (Laser Interferometer Space Antenna) gravitational wave satellite mission, scheduled for launch in 2034. The University of Helsinki is a member of the LISA consortium and an active participant to the LISA Cosmology Working Group.

After the now completed successful ESA Planck mission, there is a need for a next generation satellite mission (or missions) for studying the cosmic microwave background (CMB) polarization and electromagnetic spectrum, to extract the remaining cosmological and high-energy physics information in the CMB. The accelarated expansion of the Universe requires an explanation beyond the standard model of particle physics. Finland participates in the ESA Euclid satellite mission, which for the next decade will be the most important relevant cosmology mission to study large scale structure and dark energy. USA is participating in Euclid and there is an upcoming NASA mission with possibility of European participation: WFIRST, which includes dark energy cosmology as part of the mission. Reciprocal European participation in the cosmology part of WFIRST should be a goal.

Finland is committed to promoting and implementing open science, and has been very active in the field of high energy physics through important contributions to data preservation and open access in the CMS experiment. Support from the highest level for these activities is a key success factor and

stable long-term support is needed to keep LHC legacy data available and in widest possible use in different domains, also in the distant future.

These measures foster collaboration between scientific domains, and bring needed expertise for example in machine learning and artificial intelligence from which particle physics can greatly benefit. Furthermore, open data in a simplified format has been used in secondary level education with great success, increasing interest in particle physics, data analysis, computing and STEM field in general through concrete access to authentic data. Similarly, the Detector Laboratory will continue to provide hands-on education by pedagogically competent teachers who are specialists both in instrumentation and in particle physics. These kind of actions and other outreach activities should be considered as an integral part of research work. The continuation and development of outreach is important in order to encourage children and youth from all backgrounds to pursue careers in particle physics and its instrumentation.

Addendum

Interested community: particle physicists, cosmologists, and nuclear physicists