Input of Joint Institute for Nuclear Research to European Strategy for Particle Physics Update

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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.

Introduction

JINR particle physics community considers itself an integral part of European and world-wide community and is committed to work together towards new discoveries. We consider highly valuable the mutual observer status of CERN and JINR. 2010 CERN and JINR have concluded the Co-operation Agreement and a number of Protocols for the implementation of their co-operation, covering areas of particle physics, accelerator physics and technologies, educational programs, administrative and financial tools as well as publication policies. Of great importance are also bilateral agreements at governmental and institutional levels between JINR and European countries and institutions. Over last year's JINR has taken a number of steps to become integrated into the landscape of European research infrastructure in the framework of the ESFRI.

Recommendation. This ESPP Upgrade should emphasize the diversity of research in particle physics, the complementarity of studies at international laboratories (CERN, JINR), the integrity of particle and astroparticle physics.

I. Heavy ion physics

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

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Abstract

The NICA (Nuclotron-based Ion Collider fAcility) project is now under realization at the Joint Institute for Nuclear Research (JINR) - international intergovernmental scientific research Laboratory established in 1956 in Dubna town near Moscow. The main goal of the project is extension of the existing relativistic ion facility Nuclotron to the world level research infrastructure facility NICA aimed at study of hot and dense nuclear and baryonic matter in heavy ion collisions and spin physics research with polarized proton and deuteron beams. The centre-of-mass energies $\sqrt{s_{NN}}$ from 4 to 11 GeV will be available in heavy ion research mode. Polarized proton collisions can be studied over energy range up to $\sqrt{s_{NN}}$ = 27 GeV. Physics detector setups MPD, SPD and BM@N are under design and construction. An average luminosity in the collider mode is expected to reach 10^{27} cm^{-2} s^{-1} for Au (79^+) collisions and 10^{32} cm^{-2} s^{-1} in pp mode. Extracted beams of various nucleus species with maximum momenta of up to 13 GeV/c (for protons) will be available. The proposed program allows to search for possible signs of phase

transitions and critical phenomena as well as to shed light on the problem of the nucleon spin structure. The particle beams of the NICA complex will be used not only for fundamental research but also for innovation and technological activities aimed at obtaining of new knowledge in modern areas of nuclear and space technologies; medical and biological technologies; higher education and information technologies as well.

Recommendation. The Strategy Update should give high priority to the NICA project in the domain of heavy ion physics and particle physics and support strong participation of European physics community in this project.

II. Neutrino physics

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Abstract

JINR physics community has strong involvement in experiments in neutrino physics ranging from search for neutrinoless double beta decay (in particular, with germanium detectors) to neutrino mass measurement (KATRIN) to reactor and accelerator long baseline experiments (JUNO, DUNE) and search for sterile neutrinos (DANSS experiment at Kalinin Nuclear Power Plant,). This area of research is of great interest not only for particle physics but also for cosmology (neutrino masses are of direct relevance to structure formation in the Universe; CP-violation in neutrino transitions would support, albeit in a model-dependent way, the leptogenesis mechanism for the generation of baryon asymmetry, etc.). The world-wide neutrino program is reasonably well defined and has ambitious, but well identified targets, among which particularly challenging but extremely important are the determinations of the type (Majorana or Dirac) and values of neutrino masses.

Recommendation. The Strategy Update should support long baseline experiments and at the same time give high priority to neutrinoless double beta decay search and direct measurement of neutrino mass.

III. Astroparticle physics

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Abstract

The field of astroparticle physics is tightly connected with particle physics – both are aiming at discovering the most fundamental properties of our world; both have much common in the experimental methods they use, both require development of

large scale infrastructure, as well as computer resources. Particle physics and astroparticle physics communities have substantial overlap.

JINR physics community is particularly strongly involved in multimessenger astrophysics. One of the messengers – high energy neutrinos – is studied at large scale under-water and under-ice detectors Baikal-GVD (Gigaton Volume Detector), KM3Net and IceCube. These three are integrated into Global Neutrino Network. In particular, Baikal-GVD collaboration. Activities of JINR together with INR RAS include a number of institutes and universities from Russia, Slovakia, Czech Republic and Germany.

The km3-scale neutrino telescope - Gigaton Volume Detector (GVD) in lake Baikal

The ultimate goal of the Baikal-GVD project is the construction of a km3-scale neutrino telescope with implementation of about ten thousand light sensors. The array construction was started by deployment of reduced-size demonstration cluster named "Dubna" in 2015, which comprises 192 optical modules (OM). The first cluster in its baseline configuration was deployed in 2016 and the second one in 2017. After deployment of the third GVD-cluster in April 2018 Baikal-GVD comprises the total of 864 OMs arranged at 24 strings and becomes, at present**, the largest underwater neutrino telescope.** The modular structure of Baikal-GVD design allows studies of neutrinos of different origin with early stages of construction. Analysis of data collected in 2015-2017 allows for extraction of a sample of upward through-going muons as clear neutrino candidates and the identification of the first two promising high-energy cascade events - candidates for events from astrophysical neutrinos. The search for neutrinos associated with GW170817 with Baikal-GVD allows deriving upper limits on the neutrino spectral fluence from this source. The commissioning of the first stage of the Baikal neutrino telescope GVD-1 with an effective volume 0.4 km3 is scheduled for 2020-2021. Baikal-GVD construction is well underway, with 3 of its clusters already in operation and the first phase totaling 8 clusters (volume 0.4 cubic kilometers) planned for 2020. The second phase is foreseen in 2021-2025 at which the number of clusters will increase to 20 and volume to 1 cubic kilometer. Together with KM3Net, Baikal-GVD will have excellent opportunities to study high energy neutrinos, in particular to determine their arrival directions with high precision.

Recommendation. The Strategy Update should include astroparticle physics section as its integral part. In particular, Baikal-GVD should be supported.

IV. Precision frontier

4.1. Rare decays

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NA62 experiment allows to clarify CP-violation problem, to measure precisely very rare charged kaon decay to carried out a search for supersymmetry with a goal to observe a physics beyond the Standard Model. JINR physists deeply involved in this project currently taking part in detector support, data taking and analysis.

Recommendation: The continuation of NA62 experiment at CERN, is promising from the viewpoint of the search for New Physics and has to be strongly supported at the Strategy Update.

4.2. Search for weakly interacting particles

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Currently, there are solid arguments to assume that the Standard Model (SM) is not complete and there are some particles in Nature, which are not described in it. It comes from astronomical observations which are telling us that the known matter composes only a few percent of the overall "mass" of matter in the Universe. Theoreticians propose an explanation of the missing "mass" by two sources: the existence of an unknown form of the energy called "dark energy", the nature of which today is a puzzle, and unknown neutral particles that are responsible for the mass of about 5 times greater than that associated with the ordinary matter. These particles form the so-called "dark matter", they are massive and interact, besides gravity, with the ordinary matter very weakly which significantly complicates their discovery. The NA64 experiment, which main objective is to search for particles of the hidden sector in the interactions of electrons, muons or hadrons of high energy with an active target, is under realization at CERN. The JINR team is responsible for the drift chambers made of straw tubes. These detectors are key elements of the facility as they have a high-speed performance, good spatial resolution and are almost transparent for the passing particles.

Recommendation: The Strategy Update should emphasize the importance of this area and support projects within NA64 experiment.

V. Energy frontier

JINR physicists are contributed to the success of the LHC and its experiments. JINR team isinvolved in the ATLAS, CMS and ALICE project and interested in the continuation of the participation in the experiments. JINR look forward to making substential contributions to the upgrade towards HL-LHC and participating at the HL-LHC phase.

Recommendation. This Update of ESPP should support continuation LHC experiments with the highest priority.