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

Introduction

Particle physics research based on accelerators has led to key discoveries in the past 50 years that have shaped the development of the fundamental theory of the elementary building blocks of matter and their interactions - the Standard Model of particle physics (SM). Europe played a leading role within this international field of research. Highlights such as the discoveries of the fundamental bosons of the theory: the gluon, the Z and the W bosons, and – ultimately – of a Higgs boson at the Large Hadron Collider (LHC) at CERN were provided by European laboratories. The particle content and the structure of basic interactions of the SM have been tested and verified with ever increasing precision at energies up to the TeV scale.

Limitations of the SM in explaining the astrophysical evidence for Dark Matter and Dark Energy, the observation of massive neutrinos and many other open questions of fundamental nature strongly indicate the existence of New Physics beyond the Standard Model (BSM). The exploration of these puzzles, at all accessible energy and precision scales, is the goal of ongoing and future projects in experimental and theoretical particle physics.

The German Committee for Particle Physics, KET[1], arranged, jointly with the Committees of the neighbouring fields for astroparticle physics, KAT, and for hadronic and nuclear physics, KHuK, a series of workshops where the current status and future plans for the wider scientific field were evaluated and discussed. 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.

Running and approved Collider Projects

The physics potential of the experiments at the LHC and its upgrade, the HL-LHC, as well as at SuperKEKB must be fully exploited.

These projects provide now, and for the medium-term, the energy-, luminosity- and precision-frontier of high energy particle physics. Operation of the LHC has already been a great success with the Higgs boson discovery being the most visible example. Its high luminosity upgrade, the HL-LHC, will yield at least an order of magnitude more data recorded with significantly improved detectors. Belle II will complement the physics reach of the LHC through its access to rare processes in a particularly clean environment. The excellent discovery potential of these projects, both through precision measurements and through the search for new particles, must be fully exploited. The results acquired will provide insight for the planning

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of upgrades beyond the approved program as well as for future collider projects and their optimal specifications.

Future Collider Projects

An electron-positron collider, upgradeable to a centre-of-mass energy of at least 500 GeV, should be realised, with the highest priority, as the next international high-energy project.

The physics case for such a project is well defined and underlined by the state-of-the-art results from collider experiments. The SM, and possible deviations from it, will be probed to unprecedented precision with an electron-positron collider by operating it as a Higgs factory and by studying the top quark, W and Z boson production, and the Higgs potential.

We strongly support the Japanese initiative to realise, as an international project in Japan, the ILC as a "Higgs-Factory" with an initial centre-of-mass energy of about 250 GeV.

An energy of 250 GeV is regarded to be appropriate for an initial precision Higgs program. Concurrent running with the HL-LHC is highly desirable. Upgradeability to 500 GeV and beyond should be foreseen from the beginning.

Continuation of the development of accelerator and detector technologies and studies for a next-generation hadron collider, at the highest possible centre-of-mass energies beyond the LHC, should be pursued with high priority.

Hadron colliders explore the highest energies in direct searches for BSM physics. Theoretical guidance and experimental evidence for optimal specifications of a future hadron collider are currently not available. They are expected to emerge from ongoing and future projects and from theoretical developments. New insights may well allow to discriminate between the two scenarios that have been evaluated most thoroughly in Europe: the high energy (HE-)LHC, offering up to 27 TeV p-p centre-of-mass energies, and the FCC-hh (up to 100 TeV). Further development of required technologies, such as of high-field superconducting bending magnets, is recommended with high priority. A heavy flavour program at high energy hadron colliders should be pursued. Design studies of complementary collider options or extensions, for example a next generation high energy lepton-hadron collider, are supported.

Future non-Collider Projects

Experiments searching for WIMPs and axion-like particles, and experiments searching for light very weakly interacting particles at a high-intensity proton beam-dump are strongly recommended.

Experiments using natural particle sources or performed at accelerators in fixed-target or beam-dump setups are able to address fundamental questions that are complementary to collider experiments. Various SM problems are addressed by BSM theories predicting very weakly interacting particles (neutral leptons, dark photons/scalars, ALPs, WIMPs, but also light dark matter). The German particle physics community is particularly interested in the experiments IAXO at DESY, SHiP at CERN's SPS and DARWIN.

Accelerator based Neutrino Projects

A visible European participation in long-baseline neutrino experiments, in particular at LBNF/DUNE, is strongly recommended.

Neutrino physics is a dynamic field with strong discovery potential providing a unique window to physics beyond the SM. The major scientific questions include the hierarchy and absolute scale of neutrino masses as well as their particle-antiparticle properties. The measurements of mass hierarchy, oscillation parameters and leptonic CP violation require complementary experiments using neutrinos from reactors and accelerators as well as atmospheric neutrinos. For the long-term future, a precise measurement of leptonic CP violation is a key scientific objective in particle physics.

Theory

A strong theory program is essential both for strategic decisions and for the success of experiments. Substantial support is therefore mandatory.

All projects discussed above will provide important - sometimes even crucial - input to advancing the theoretical foundations of particle physics. In turn, the interpretation of the experimental results is based on an ever deepening theoretical understanding. Close collaboration between experiment and theory is therefore a prerequisite to advance the field of particle physics. Theory also establishes the links between the various topics and identifies opportunities for future experiments at an early stage.

Advances in Technology

Research and development in accelerator and detector technologies, as well as in computing and software, are a prerequisite for all future projects.

Many of the topics and projects discussed above require substantial developments in the areas of accelerator, detector, computing and software technology. Examples in accelerator R&D are high field magnets, energy recovery structures and plasma wake field acceleration. Examples in detector R&D are extremely fast, radiation hard and cost-effective detectors with high granularity. Unprecedented data rates and volumes will require the exploitation of state of the art computer science methods to develop adequate computing concepts and innovative algorithms for data handling, reconstruction and analysis. Due to the very long time scales of many of the currently proposed projects, it will be essential to keep and further develop the technological expertise within the community.

Research Infrastructure

CERN must maintain its leading role in particle physics, and further develop its potential. This requires the continued close collaboration with national laboratories, institutions and universities.

The large-scale projects of particle physics build on infrastructures that are only available in the major international and national laboratories. For particle physics in Germany, DESY and its infrastructure are of particular importance. The success of experiments and the progress in theoretical particle physics depend decisively on collaboration on the international and national level. The further development of these structures is a prerequisite to maintain world-class research in Europe. The coordination in Europe is and should be firmly established through CERN.

Research Conditions - Promoting Young Scientists

The research conditions must guarantee the maintenance and further evolution of expertise during the long project lifetimes and be attractive for junior scientists.

An outstanding European research landscape in particle physics is the basis to ensure scientific progress and the attractiveness of the field. In order to guarantee the continuity and evolution of indispensable expertise in computing, software, detectors and accelerators, the personnel structures must be adapted to the long-term duration of projects. Young scientists are often the source of new ideas and have the cutting-edge competence in many areas. Their scientific and technical contributions should be given high visibility and they need promotion and predictable career prospects.

Outreach

The commitment of scientists to activities that create public awareness and support is crucial and must be recognized as beneficial to their career record. Inspiring the next generation through outreach activities is an indispensable task.

Outreach and science communication aim at communicating current research questions and results, thereby raising public awareness of the societal benefits of particle physics and enhancing the support by the general public. Outreach programs also create opportunities for young people to encounter role models and to obtain insight in the research process. Access to open data online or in masterclass programs enable participation of the public in scientific research. Scientists have the opportunities to share their enthusiasm in outreach and communication efforts worldwide.