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

Swiss Institute for Particle Physics (CHIPP)

18 December 2018

1 Introduction

The Swiss Institute for Particle Physics (CHIPP) is an association of particle physicists (experimental and theoretical). It coordinates the activities in particle and astroparticle physics in Switzerland.

In order to produce the Swiss input for the update of the European Strategy for Particle Physics (ESPP), CHIPP held two workshops in 2018. In the first workshop in April, the status of the field was reviewed and discussed. The CHIPP input for the discussion of the ESPP update was then agreed during the second workshop held in September. This document describes the CHIPP position on the ESPP update focused on the scientific issues and, in order to facilitate the discussion to follow, it starts with recapitulating the main points of the current ESPP (CERN-Council S/106; 7 May 2013).

The current ESPP was produced in May 2013 soon after the discovery of the Higgs particle with four high priority items, which can be summarised as:

- Exploitation of the LHC as the highest European priority.
- Research and Development (R&D) of accelerators including the design studies in order to ensure Europe to remain at the forefront of the high energy frontier.
- Importance of e^+e^- colliders for the Higgs studies complementing the LHC.
- Developing a neutrino programme at CERN which allows the European groups to play a leading role in long baseline experiments in Japan and the US.

In addition, the ESPP notes theory, precision physics, detector R&D and computing, and exploring further collaboration with astroparticle physics and maintaining the CERN support for nuclear physics as important scientific items.

2 Developments since the May 2013 update of the European Strategy

Since the last update of the European Strategy, the LHC has been running very successfully at a centre of mass energy of 13 TeV. Its luminosity upgrade project (HL-LHC) was approved and has started. No new particles outside of the Standard Model have been discovered by the LHC experiments so far. However, the LHC has still plenty of room for discoveries. The energy of the LHC will be increased to its design value of 14 TeV in the near future and the HL-LHC will boost the event statistics by more than an order of magnitude for the ATLAS and CMS experiments, while the LHCb experiment will continue to explore flavour physics with larger event statistics.

The R&D and design studies for the future high-energy frontier machines at CERN have intensified over the past years and groups working on the Future Circular Collider (FCC) and Compact Linear Collider (CLIC) are providing their input to the ESPP update.

The FCC consists of a circular tunnel with a circumference of 100 km. It can start as an e^+e^- collider (FCC-ee), followed by a pp collider (FCC-hh), as it was done for LEP and LHC. Furthermore, heavy ions and the possibility for a $pe^\pm$ option are also investigated. The centre of mass energy for the FCC-ee covers the energy range from the Z^0 production to beyond the $t\bar{t}$ threshold, i.e. $\sqrt{s} \approx 90$ to 365 GeV, whereas the FCC-hh foresees $\sqrt{s} \approx 100$ TeV.

CLIC is a linear collider, starting at $\sqrt{s} = 380$ GeV to cover Higgs and top physics, with a goal to extend its energy to the 3 TeV range.

CERN has constructed a facility, the so-called CERN neutrino platform, where large scale prototype detectors for neutrino experiments can be tested with charged particle beams. Various prototype detectors for the US and Japanese neutrino programmes are being tested.

Overall, the development of European particle physics activities during the last five years are in line with the ESPP priorities.

3 Swiss community consideration for the European Strategy

A: LHC exploitation and next high-energy frontier machine at CERN

With the HL-LHC, new physics will be fully probed up to an energy scale of at least $\sim$1 TeV in the near future. The next step has to include decisive studies of the properties of the Higgs and the top quark. This should then be followed by the exploration of an energy scale that is an order of magnitude higher than what can be reached with the LHC in the years to come.

For this reason, the Swiss community considers the FCC to be the most promising project for the next high-energy frontier machine at CERN. The FCC would start as an e^+e^- collider. It is a challenging project that requires R&D, but does not need the technically very demanding superconducting high field magnets. Multiple experiments can be operated simultaneously with luminosities significantly larger than those at future linear colliders. The FCC-ee would be able to explore the presence of new physics through tests of the electroweak theory with one to two order of magnitudes better precision than now. It would also extend heavy flavour physics and searches for extremely rare processes. Furthermore, FCC-ee would provide many more Higgs particles than CLIC or ILC and an interesting opportunity for $t\bar{t}$ studies near threshold.

With proton-proton collisions at $\sqrt{s} = 100$ TeV as the next phase, the FCC-hh probes a completely new energy regime, which is the right next step for the exploration of the 10 TeV mass scale. In order to achieve this goal, R&D efforts must be intensified with a focus on high-field magnets.

Full exploitation of the LHC should remain as the first priority for the European particle physics programme, in parallel with an intensified R&D and design effort to realise the next large project at CERN in the future, namely FCC. The Swiss particle physics community considers that Europe should pursue an ambitious plan to lead high energy frontier physics.

For the long term future of particle physics, R&D for innovative concepts for acceleration technology is crucial in order to reach an energy scale far beyond 10 TeV, which is currently out of scope. *Current R&D efforts for novel acceleration and other accelerator technologies must continue and be strengthened.*

B: Other high priority items

Neutrino physics

The CERN neutrino platform is now working smoothly, and enabling the neutrino community in Europe and worldwide to advance with intensive detector R&D work. *CERN should envisage a long-term support for the neutrino platform ensuring a substantial European participation in long-baseline neutrino projects worldwide to continue.* It is worth noting that experimental search for neutrino-less double beta decay addresses one of the most fundamental questions of the neutrino properties and should be further supported.

Exploiting high intensity facilities at national laboratories and CERN

Search for phenomena beyond the Standard Model should not be restricted to the experiments at high energy colliders. There are great opportunities for the facilities at lower energies at national laboratories performing precision physics. In this context, the Swiss community would like to highlight the facilities at PSI that deliver the most intense pion and muon beams in the world, in particular the HiMB (next generation High-intensity Muon Beam facility) project under development, as well as ultra-cold neutrons, providing unique opportunities for experiments in CP violation and lepton flavour physics. This also generates a welcome diversity in the field. *Continuation of precision physics with facilities at national laboratories, such as PSI, must be strongly encouraged.*

Similarly, the CERN accelerator complex can provide unique opportunities with a modest investment. *CERN should explore the possibility of constructing well motivated non-collider facilities that are unique to CERN.* The Swiss community considers a beam dump facility with the SPS beam particularly interesting. The SPS provides a high intensity high energy proton beam which can be used in a beam dump mode, a unique place to look for rare phenomena in the low mass range. The SHiP experiment could be a possible user of such a facility.

Astroparticle physics

Astroparticle physics is still an expanding field producing many remarkable results and addresses some of the key open questions in particle physics relevant for the CERN programme in a complementary way, the search for Dark matter being a notable example. Astroparticle physics also creates important links to cosmology and astronomy. CHIPP members play leading roles in gamma-ray and neutrino observatories, dark matter search, as well as in the APPEC Consortium. There are many commonalities in the development of detector technologies between astroparticle and particle physics and close collaboration of the two is mutually beneficial. Although the core mission of CERN lies on the accelerator based facilities, CERN's expertise in engineering and detector construction, computing, and know-how to manage large facilities could make a significant impact for astroparticle physics experiments. *CERN should explore contributing to well selected astroparticle physics experiments where CERN participation can make a unique contribution.*

Theoretical physics

Theory, from the foundation to phenomenology, is the backbone of the particle physics activities. It provides a framework for understanding nature and tools essential for the analysis of data. In some cases, current theoretical limitation does not allow the full exploitation of experimental data. In other cases, theory provides a guidance for the data analysis. Balanced activities covering all those areas are essential to the field. *A strong and diverse theoretical physics programme should be fully supported on the European scale.*

Instrumentation and computing

An equally important item for the future of particle physics is the advancement in computing capability, in both hardware and software, and in detector technology. Significant progress will be needed in both fields for realising the next generation of the experiments. *Particle physics should remain the driving force in the development of those areas.*