Meeting on the European Strategy for Particle Physics Update

Milano, October 29, 2024

A meeting was held in Milano on October 29, 2024, to discuss the on-going process of the update of the European Strategy for Particle Physics. The meeting was organized by the local coordinators of CSN1 (G. F. Tartarelli), CSN4 (G. Ferrera) and CSN5 (F. Groppi) with the following agenda:

- Introduction (G. F. Tartarelli)
- High Luminosity LHC: ATLAS e LHCb, status and perspectives (T. Lari, N. Neri)
- FCC-ee/hh: status of machine and detectors studies (A. Andreazza)
- High Field Magnets (L. Rossi, M. Sorbi)
- Precision theoretical predictions for future colliders (A. Vicini)
- Accelerators R&D (A. R. Rossi)
- Scientific studies, technological developments and experimental facilities for RF electrical fields embedded in high DC magnetic fields for advanced accelerating structures (D. Giove)
- HighQ/HighG SRF R&D for ESPPU: extension proposal (L. Monaco)
- Perspectives for HEP computing: from LHC to FCC (L. Carminati)
- The ECFA Early Career Research Meetings (M. Rossetti Conti)

A good portion of time was devoted to the discussion of the points in the agenda.

HL-LHC

It was emphasized the importance of fully exploiting the HL-LHC program as foreseen today, without any descoping or shortening. The machine and detector upgrade are still a very challenging task but the luminosity increase and the improvements in the detectors will result in a huge increase in physics potential from LHC to HL-LHC. This is true for both the high-p_T and flavor physics programs. Current estimates are mainly based on the increase of statistics available, in several cases performed with fast simulation, and do not include any possible improvement in the analysis techniques.

HL-LHC will still be competitive and complementary with FCC-ee in many Higgs property measurements. There is good complementarity between FCC-ee precision measurement and high mass direct searches at HL-LHC. FCC-ee will improve over HL-LHC discovery potential only for weakly coupled light particles.

LHCb will be able to perform ultimate tests of the CKM mechanism for CP violation in beauty and charm sector, benefiting from the larger statistics available, and constraints SM extension with

Right-Handed currents in rare decays. LHCb will also have a unique discovery potential for the understanding of exotic hadrons: tetra quarks, pentaquarks, ...

FCC-ee/hh

The FCC two-stage program (FCC-ee followed by FCC-hh) represents a unique and comprehensive long-term program that maximizes the physics opportunities after the completion of the HL-LHC program. The FCC-ee great improvement on the measurement of electro-weak and Higgs observables, the increase statistics of light leptons and the direct/indirect discovery potential are well complemented by the huge direct discovery potential of FCC-hh at the highest energy and the precision measurement of rare processes (Higgs self-couplings, rare decays, ...). The possibility to instrument up to four interaction points will also provide robustness, additional statistics, and the possibility of specialized detectors to maximize the physics output. This program, if found feasible by the on-going studies, will guarantee CERN (and Europe) leadership in this field in future years.

In the discussion the current schedule for the start of the FCC program appears too optimistic, considering that this could jeopardize the resources to carry out the HL-LHC program successfully. Studies for FCC detectors are on-going (like the IDEA detector concept proposed by the Italian community) and should continue to be supported.

The collaborative and coherent detector R&D effort (DRD) called for in the last ESPP update has slowly started and the collaborations have been formed and are preparing MoU. A final model is not defined yet and will require further work and discussion to be fully operative.

HFM

High-field magnets (HFM) R&D was given high priority in the current ESPP and this should be also true for the current Strategy Update. Studies for both Nb_3Sn and HTS (High Temperature Superconductor) magnets should be intensively pursued. The main focus is the R&D for magnets in the 12-20 T range for FCC-hh with the goal of building prototypes (smaller length prototypes possibly operating at 4.2 K to reduce consumption, Two-In-One dipoles like in LHC...) and then a full-length prototype to show that the magnet is ready for industrialization. Moreover, HTS magnet studies for FCC-ee (both machine and detector magnets) and for a future Muon Collider are also considered, a great step in the direction of reducing power consumption and of the sustainability of future machines.

A high-energy LHC (HE-LHC) with the highest field magnets available should be also prioritized as an alternative to the FCC program, if this turns out not to be feasible or financially sustainable.

Precision theoretical predictions

Testing the Standard Model and searching for new physics will be complementary perspectives at HL-LHC and at future colliders. The huge data samples that will be collected and so the extremely small statistical errors on many observables will require SM predictions at the 0.01% level.

This poses severe theoretical challenges. Multi particle final states and large phase-spaces represent big challenges for numerical integration algorithms: machine-learning techniques and use of GPU for calculations at NLO and higher orders should be intensively pursued. Fixed-order calculations depend on the number of energy scales (external legs + internal masses) and the size of the analytical amplitudes can easily reach the gigabyte level: new mathematical ideas are advisable to complement the "brute force" approach. Moreover, there is always the risk of absorbing a small New Physics signals in the proton parameterization, as the non-perturbative component of the proton is obtained with a fit to collider data: systematic studies of all the parton densities (e.g. antiquark at large-x) may help to disentangle the BSM signal.

Accelerator R&D

The current ESPP recommended the particle physics community to intensify and sustain accelerator R&D studies. This should also be the case for the next update. ERL technology for future colliders can provide high beam intensity and low emittance beams while at the same time maintaining operation sustainability and reducing the environmental impact. Other improvements for future e^+e^- colliders include study of the positron source, of the capture line and of use of inverse beam scattering for beam control. An adequate support to Eupraxia should allow to resolve still open issues relevant for the use of plasma acceleration to a future collider.

Muon Collider

Studies for a Muon Collider (MC) and support for its realization have increased in the last years. The MC demonstrator project is a crucial step towards the assessment of the feasibility of such a machine and should be given great support. One of the key points to be studied in the MC demonstrator is the cooling cell, which provides a reduction of the emittance of the muon beam. Studies (geometry, materials, surface treatments, breakdown rates, frequencies…) of the magnet assemblies and of normal conducting RF cavities should be pursued to arrive to a prototype of a single cooling cell first and later to a prototype of a full cooling cell as basic building block of the MC demonstrator. These studies are also relevant for other accelerating machines.

HighQ/HighG SRF R&D

Superconducting RF cavities (SRF) with high quality factor and high gradient allow to obtain power savings and build shorter machines so providing cost reduction and sustainability. R&D for the design, optimization and test of SRF are crucial for future accelerators. Particulars focus should be put on innovative surface treatments and on cold tests that also require setting up adequate infrastructures (cryogenic facilities). Results obtained on single cells first and on multicells later need to be carefully checked for stability and robustness in order to allow a smooth transition from prototyping stage to industrial production.

Perspectives for HEP computing: from LHC to FCC

The projections of computing requirements from LHC to HL-LHC are challenging. This is even more evident if we consider that at the same time the HEP community is asked to enter a path of greenhouse gas emission reduction in the coming years. Mitigation strategies should address both optimization of the software used by the experiment (uses of fast simulations, improved analysis models…) and the hardware (low power architectures, use of accelerators, optimization of the power consumption of the computing centers…). Although Machine Learning (ML) has been used in HEP for many years, it has been making a huge leap forward recently (driven by industry) and will surely represent a paradigm shift also in our field. Also, Quantum Computing progress should be followed actively. New actors are on the scene as alternatives to the present WLCG model and should be evaluated in view of the future accelerators computing requirements: supercomputers (like the ones in the EuroHPC network: ICSC, Vega, Leonardo, Jupiter…) and commercial resources (like Google Cloud, AWS…).

ECFA-INFN Early Career meetings

It was soon noticed the scarce participation of young researchers and students to this meeting… Every initiative, like the series of meetings of the INFN Early Career Researchers (ECR) should be pursued and reinforced. A report from the first two meetings was presented. The uncertainties on the post-HL-LHC collider(s), on how these activities are evaluated in selection boards, and the recruitment policy in Italy are among the main concerns. Young researchers also ask for establishing coordination between the various ECR communities, and better communication and representation inside INFN.