Position for the European Strategy

LHC network
Flavor network

With the discovery of the Higgs boson in 2012 Particle Physics has entered a new era. The Higgs boson could be the closing piece of the Standard Model (SM), but more likely it opens up the door to physics beyond the Standard Model (BSM), that is known to exist. Consequently, it is of utmost importance to learn as much as possible about the Higgs boson, its interaction to SM particles and to (so far undiscovered) particles beyond the SM.

The first priority of the Spanish groups collaborating in the LHC experiments at CERN is the full exploitation of the data provided by the LHC collider and the participation in the coming upgrade phases of the project.

Spanish HEP groups have made substantial contributions to the LHC experiments since their conceptual phase, participating in the R&D activities for the development of the experimental techniques, to the design studies and taking important responsibilities in the construction, installation, commissioning and operation of the detectors, as well as in the data preparation and data analysis, in many physics areas.

The participation in the LHC project is also well aligned with the Spanish membership of CERN and will help to maximize the scientific, technological and industrial returns.

In the short term, LHC will continue operation in Run 3 in 2021, with already twice the design instantaneous luminosity and possibly an increase in the energy of the collisions to 14 TeV. In the medium term, the already approved high luminosity phase (HL-LHC), which is expected to start by 2026-2027, will bring a major increase in the luminosity, aiming to collect 3000-4000 fb^{-1} of data at 14 TeV by ATLAS and CMS, and 50 fb^{-1} by LHCb. The physics program includes more precise measurements of the Higgs boson properties, SM parameters, physics of the flavour sector of the SM, as well as the direct searches for new phenomena. The expected improvements at the LHC and the HL-LHC in both, precision measurements and searches for BSM physics are significant and will improve our knowledge of nature substantially. They deserve our highest priority now and the corresponding human effort and financial resources.

In order to face the experimental challenges that HL-LHC will impose on the detectors, a major upgrade of their equipment is required. The aim is to cope with the extremely high HL-LHC instantaneous and integrated luminosity, along with the associated radiation levels. There will be major upgrades in tracking detectors, electronics of the calorimeter and muon systems, as well as improved triggers and data acquisition systems. The experiments and their physics potential will benefit of extensions to larger pseudorapidity, particularly in tracking and muon systems. Depending on the upgrade schedule of the individual experiments, some of these activities already took place during the first Long Shutdown period (2013-2014) of the LHC or during the end-of-year maintenance periods. In any case, the bulk of the work is still to be done during the Long Shutdown periods 2 (2019-2020) and 3 (2023-2024). The Spanish LHC groups are participating in detector upgrade activities in ATLAS, CMS and LHCb experiments since day one. The community is

strongly committed to the project and a substantial fraction of their human and financial resources is already dedicated to it.

The LHC Spanish community believes that the new phase of LHC project at CERN (LHC Run 3, detector upgrades and HL-LHC physics exploitation) will be a unique (and the best) opportunity to improve our knowledge of the known and explore the limits of the unknown. We consider LHC should constitute the main path in the European Strategy for Particle Physics for the coming years.

Recently, several observables in the flavour sector of the SM have shown anomalies concerning heavy quarks, which can be pointing out BSM physics. The LHCb experiment, which will be upgraded in the coming years to be operative during Run 3, and the Belle-II experiment at KEKB, which is at present starting to taking data, are of high interest to confirm or refute those possible hints of new physics. The Spanish groups are strongly committed to the LHCb upgrade detector (tracking system and calorimeter) and to the data physics exploitation. Despite the enormous interest of the physics of Belle II, the b-physics Spanish scientific community prioritizes the participation in the LHCb experiment.

Computing activities for HEP are crucial in the next years to cope with the HL-LHC data processing requirements. Spanish ATLAS, CMS and LHCb Tier-1 and Tier-2 infrastructures will need 20 times more resources for HL-LHC with respect to current ones, being storage the main challenge to address. The Spanish LHC computing community is establishing the main guidelines for the next years, moving towards common implementations: Integrated High Performance Computing, Grid resources and increasing network bandwidth. The investment in the computing resources is a strategic point towards the successful exploitation of the LHC data.

Our contribution to LHC and HL-LHC detectors has been based on an extensive R&D program. To maintain and strengthen our position at international level, the R&D program in new detector technologies should be one of our priorities, in particular the development of new tracking devices, very highly segmented calorimeters or more compact electronics for their use at future facilities.

From the theory side, the Spanish HEP community is strongly involved in providing theory predictions for current ATLAS, CMS and LHCb precision measurements and searches. This concerns higher-order corrections for SM processes (e.g. Higgs and top) as well as for BSM physics (Higgs, SUSY, new gauge bosons, vector-like fermions etc.), flavour phenomenology concerning quark and leptons, as well as for heavy ion physics (PbPb and pPb). Furthermore, the Spanish theory community takes a vital role in the planning and the evaluation of the physics potential of future facilities. These efforts ensure that the Spanish theory community also in the future will continue its strong involvement in the ongoing efforts to discover BSM physics.

Going beyond HL-LHC, the way to higher energies in pp colliders has to be paved. We support ongoing R&D efforts that would allow the construction of very high energy pp colliders, such as the HE (High Energy)-LHC (foreseen to reach 27 TeV using the current LHC tunnel, which can be seen as an intermediate step in the road towards higher energies) or the FCC (Future Circular Collider)-hh (foreseen to reach 100 TeV center-of-mass energy in a 100 km circular collider).

Progress in the field of high-energy physics has come in the past from the combination of experiments at hadron colliders as powerful discovery machines and high precision measurements in high-luminosity e^+e^- colliders. For the latter, several proposals are currently discussed: the linear colliders ILC (with the most mature design, starting with a center-of-mass energy of 250 GeV) and CLIC (starting at 380 GeV), as well as circular machines with about 100 km circumference, the FCC-ee (going up to 350 GeV) and the CepC (going up to 250 GeV). These machines would allow high precision and model independent measurements of the Higgs boson, of electroweak precision observables as well as (depending on the center-of-mass energy) of the top quark. It must be emphasized, that it is important that the e^+e^- program must be able to reach at least 500 GeV. That will allow precise measurements of the top quark properties and the Higgs self-coupling, complementing those at hadron colliders. A precise scrutiny of the top quark and Higgs potential is crucial for the completion of our understanding of nature.

The ILC with a center of mass energy of 250 GeV, as currently proposed as a project to be hosted in Japan and upgradable to (at least) 500 GeV is an interesting option. If the Japanese authorities go ahead with the ILC250, our community supports the idea of this new endeavor.