

Towards an update of the European Strategy for Particle Physics

(29 Sept 2019)

With a view to update the European Strategy for Particle Physics, the Briefing Book compiled by the Physics Preparatory Group (PPG), based on the submitted inputs and the discussions during the Open Symposium in Granada, provides a summary of the present landscape in the field. It summarises the scientific aspirations, opportunities, as well as technical challenges. Revolving around future major colliders in Europe, at this stage, five scenarios are defined to initiate the discussions within the European Strategy Group (ESG).

| | 2020-2040 | 2040-2060 1st gen technology | 2060-2080 2nd gen technology |
|--------------------|---------------|---------------------------------|---------------------------------|
| CLIC | HL-LHC | CLIC380-1500 | CLIC3000 |
| CLIC-FCC-mixed | HL-LHC | CLIC380 | FCC-h/e/A (Adv HF magnets) |
| FCC | HL-LHC | FCC-ee (90-365) | FCC-h/e/A (Adv HF magnets) |
| LE-to-HE-FCC-h/e/A | HL-LHC | LE-FCC-h/e/A (LF magnets) | FCC-h/e/A (Adv HF magnets) |
| LHeC+FCC-h/e/A | HL-LHC + LHeC | LHeC | FCC-h/e/A (Adv HF magnets) |

All elements related to the CLIC and FCC proposals are discussed in their respective CDRs. The LE-to-HE-FCC-h/e/A scenario moves from initially lower-field magnets in the window of 6-10T (e.g. adiabatically) to higher-field magnets, potentially HTS magnets. The LHeC+FCC-h/e/A scenario assumes that an electron-positron collider is built outside Europe and that the time gap between the end of HL-LHC and the realisation of the high-energy FCC-h/e/A can be used for the LHeC programme, potentially even starting in parallel with the HL-LHC.

For each scenario a new collider would be operational in Europe in the 2040-2060 era, i.e. as short as possible after the HL-LHC or for the scenario including LHeC even before. The community needs to provide guidance for this strategy update for the technology it favours for the 1st generation collider at CERN, leaving options for the 2nd generation open. In general, around 2045 the community will have to consider which technologies are available for high-energy and high-luminosity colliders in the 2060-2080 era and plan accordingly. No firm technology decision for the 2060-2080 era is required today.

The chosen scenario will have to be reassessed at the time of the next strategy update, typically 7 years after the current one, taking into account the global context (e.g. ILC, CEPC, EIC, etc).

Given significant investments in Accelerator R&D at CERN and elsewhere towards the 1st and 2nd generation technologies, as well as adequate investments in a Scientific Diversity Program at CERN and elsewhere, the annual additional structural and/or in-kind financial effort required to realize the first three collider scenarios is equivalent to 10-13% of the CERN budget in the period from 2025 to about 2045. This assumes that the civil engineering of each scenario is funded from outside the regular CERN budget. For the LE-to-HE-FCC-h/e/A scenario the required investment is not fully understood at this stage, but initial studies indicate that in the period 2025-2045 an additional annual budget equivalent to 20%

of the CERN budget is needed for the deployment of a collider with 6T magnets. The 1st phase of the scenario involving LHeC would fit within the regular CERN budget.

To realize a particular scenario, the following objectives should be considered in the overall strategy update.

1. Main expectations of the next Strategy update (in about 7 years)

- Observe the global status of major colliders outside Europe, and decide to concretely engage in the 1st generation of the scenario, or to revive another option
- Receive the TDR for 1st generation of the scenario for final approval, or commission a TDR for an alternative option
- Decide on the strategy for further development of high-field magnets
- Decide on the basis of CDRs to construct a muon and/or plasma-based collider demonstration facility

2. Goals to reach by the time of the next Strategy update (within ~7 years)

- Concrete technical and administrative plans for the civil engineering for the 1st generation scenario, including cost optimization studies
- Concrete financial organization plan for civil engineering, accelerator and experiments for 1st generation scenario, including cost optimization studies
- In the context of the particular scenario, set up proto-collaborations for experiments to propose initial detector designs
- Verify the technical feasibility and cost optimization for alternative scenarios
- CDRs for demonstration collider facilities for a muon collider and a plasma-based collider

3. Would require from the 2020 Strategy update

- Strong statement to investigate the full program of the scenario, including technical and administrative plans, and commission a TDR for the 1st generation of the scenario
- Commission CDRs for demonstration facilities for a muon collider and a plasma-based collider, and support statements for the development of high-field magnets
- Openness towards opportunities for a major collider outside Europe

Considering the information summarized in the Physics Briefing Book, we seek input for each of the five scenarios on the following aspects:

- Arguments pro & con on the physics program
- Arguments on the technical, financial and organization feasibility
- Arguments on the community support
- Verification if we collect with the above list, adequate and sufficient elements to be considered for this and the next strategy update

Additionally, we seek to collect pro/con arguments that are to be considered for discussion by the European Strategy Group in answering the following questions and with a view to update the 2013 European Strategy for Particle Physics¹.

1. In the absence of clear indications for new physics, is a broad exploration an adequate approach for our global field? Do we want to move forward in the largest variety of directions?
2. Would it be appropriate/sufficient to move the scientific diversity program to among the highest priorities for Europe? Should the strategy engage in ranking proposals according to priority? Which are the key proposals?
3. Should we consider statements to strengthen the LHC and HL-LHC program? Should we stimulate the creation of coordinated programs at CERN and/or in Europe, e.g. AI@LHC for both data analysis and for control of instruments, etc?
4. Should we also support the fixed-target projects at (HL-)LHC?
5. Because of the competition for the Interaction Region at Point-2@LHC, should we consider for the period beyond LS4 a choice between the next generation heavy-ion experiments at the HL-LHC and the LHeC?
6. Do we remain open towards strong participation in future collider programs outside Europe? Should such a statement remain among the highest priorities? Should we extend the scope to include a variety of options like ILC@Japan, EIC@US, CEPC@China, ... ?
7. Anno 2013: *“CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan.”* Is the continuation of the CERN Neutrino Platform appropriate? Should we propose to extend the scope of the Neutrino Platform beyond long-baseline neutrino projects?
8. Anno 2013: *“Europe should support a diverse, vibrant theoretical physics programme, ranging from abstract to applied topics, in close collaboration with experiments and extending to neighbouring fields such as astroparticle physics and cosmology. Such support should extend also to high-performance computing and software development.”* Should we strengthen this statement? Should we provide guidance how to achieve this?
9. Anno 2013: *“Detector R&D programmes should be supported strongly at CERN, national institutes, laboratories and universities. Infrastructure and engineering capabilities for the R&D programme and construction of large detectors, as well as infrastructures for data analysis, data preservation and distributed data-intensive computing should be maintained and further developed.”* Should we strengthen this

¹ Link to 2013 strategy document: <https://cds.cern.ch/record/1567258/files/esc-e-106.pdf>

statement? Should we provide guidance how to achieve this? For example, related to new R&D cluster programs at CERN and in Europe, and related to the balance between blue sky R&D versus focused R&D.

10. Should we make concrete the technology collaboration with the gravitational wave community?
11. Should the HE-LHC feature in our strategy update?
12. In the context of the LE-to-HE-FCC-h/e/A scenario, would an adiabatic evolution from 6T to 16T/HTS magnets for FCC-h/e/A be an avenue to explore?

Figure 1 Timeline of Future Colliders (by U. Bassler)

