U.S. Higgs Factory Activities and Preparation for ESG input

HEPAP, Dec 5, 2024

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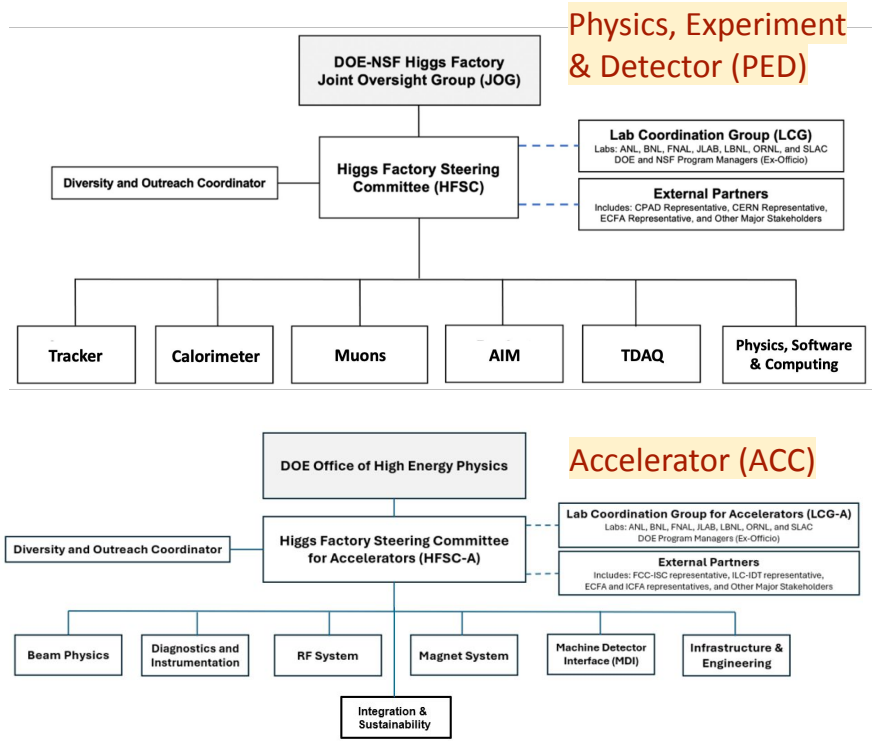
Outline

- What is the HFCC
- Who are the HFCC
  - PED
  - ACC
- European Strategy for Particle Physics
    - State in Europe
    - Considerations for our input to ESG
- HFCC plans for white paper
    - Planned discussions and timelines
- Comments/Summary

U.S. Higgs Factory Consortium Committee (HFCC)

Created by DOE and NSF to provide strategic direction and leadership for the U.S. community to engage, shape, and thereby advance the development of the PED and Accelerator program for a potential future Higgs factory; and to ensure cooperation with our partners in the international program.

Led by Higgs Factory Steering Group (HFSC-PED & HFSC-ACC)



HFCC Charge

- HFCC should coordinate efforts in the following areas:
  - Physics and technical feasibility studies, including any associated design and R&D efforts, to advance detector concepts and accelerator designs for a future e+/e- Higgs factory;
  - Prioritization and stewardship of the national R&D efforts;
  - Development of the pre-project R&D scope that will be required initiate a project;
  - Conceptualization of the software and computing for the experiments and accelerator;
  - Develop various funding models that will be required to support the R&D efforts;
  - Ensure collaborations by the U.S. with our partners are cost-effectively carried out to advance the future Higgs factory initiatives.

HF Steering Committee (HFSC) Composition

HFSC-ACC

Tor Raubenheimer (chair)
Steve Gourlay (deputy)
Matthias Liepe
Jean-Luc Vay

HFSC-PED

Srini Rajagopalan (chair)
Ritchie Patterson (deputy)
Marcel Demarteau
Sarah Eno

HFSC-PED reports to JOG (DOE+NSF)
HFSC-ACC reports to DOE

The state in Europe

Details in P. Sphicas talk

- The 2020 ESPPU declared the "**electron-positron Higgs factory is the highest-priority next collider**".
- In June 2021, CERN council approved and funded the FCC feasibility study with a focus on the first stage (FCC-ee).
- In 2024, mid-term review of FCC Feasibility Study was thought positive enough by CERN Council to accelerate the conclusion of the study.
- European Strategy Group (ESG), chaired by K. Jakobs, has been created to again provide an update to ESPP.
  - "To develop a visionary and concrete plan that greatly advances knowledge in fundamental physics through the realization of the next flagship collider at CERN, and to prioritize alternative options to be pursued if the preferred plan turns out not to be feasible or competitive".
  - Submission of ESG Strategy document to CERN council early 2026.

U.S. input to ESG

- The U.S. is by far the largest national partner in CERN based projects and it is critical that we engage in the ongoing process and provide our comments.

- The U.S. Higgs Factory Coordination Consortia (HFCC-PED & HFCC-ACC) have been requested by DOE and NSF (for PED) to provide our input to the ongoing European Strategy Update.
- Our goal is to build on the P5 recommendations and consult with the U.S. community to deliver a coherent and focused input.
    - We are organizing several meetings with the wider US community to collect input.
- There will be two parts to our input:
    - A **strategic** input partly in response to the questions from ESG (slide 15)
    - A **technical** input highlighting the potential areas of U.S. contribution

Editorial Board

- DOE and NSF have requested an Editorial Board assume the responsibility of preparing the input to the ESG in consultation with the U.S. community.
- ESG consists of the members of the two steering groups (HFSC-PED and HFSC-ACC) and 4 early career scientists appointed by the agencies.
- Current Composition:
  - Josh Bendavid (MIT), Viviana Cavaliere (BNL),
  - Spencer Gessner (SLAC), Kellen McGee (FNAL)
  - Marcel Demarteau (ORNL), Sarah Eno (UMD), Ritchie Patterson (Cornell)
  - Steve Gourlay (FNAL), Matthias Liepe (Cornell), Jean-Luc Vay (LBNL)
  - Srini Rajagopalan (BNL), Tor Raubenheimer (SLAC) - co-chairs

Initial thoughts on U.S. strategic input

Our input should:

- Be consistent with the P5 report
- Seek to engage the broad US HEP community.
- Emphasize P5 statement on current program priorities at CERN:
  - "As the highest priority independent of the budget scenarios, complete construction projects and support operations of ongoing [HL-LHC] experiments and research to enable maximum science." **Re-emphasize this message.**
- Emphasize P5 statement on the need to maintain a vibrant domestic program:
  - Other P5 priorities include DUNE (incl. Phase 2), CMB-S4
  - Support "aggressive R&D program" for a 10 TeV pCM collider
  - "Targeted panel to assess the level and nature of U.S. contribution to specific Higgs Factory".

Initial thoughts on U.S. strategic input (2)

- Ensure coherency with other U.S. national inputs, including
  - Muon Collider community
  - DPF/DPB (non HF, non MuC)
- Recognize developments since P5, notably
  - Progress on the FCC feasibility study
  - Joint CERN/US statement
  - Limited funding allocated in US for HF R&D
- Capture US enthusiasm and ability to make critical technical contributions to both the accelerator and detector grounded on our decades of achievements.
- Respond to the ESG strategic questions, at least in part

U.S. – CERN Statement of Intent

Acknowledged the importance of the European Strategy for Particle Physics Update and the U.S. P5 plan to guide the long-range strategies for Europe, CERN, and the United States; including the leading roles each have played in developing and executing one another's strategy.

The United States and CERN intend to:

- Enhance collaboration in future planning activities for large-scale, resource-intensive facilities.
- Continue to collaborate in the feasibility study of the Future Circular Collider Higgs Factory (FCC-ee), the proposed major research facility planned to be hosted in Europe by CERN
- Should the CERN Member States determine the FCC-ee is likely to be CERN's next world-leading research facility following the high-luminosity Large Hadron Collider, the United States intends to collaborate on its construction and physics exploitation, subject to appropriate domestic approvals.

ECFA Guidelines for input to ESG

a) Which is the preferred next major/flagship collider project for CERN?

b) What are the most important elements in the response to (a)?
   - Physics potential; Long-term perspective; Financial and human resources; Requirements and effect on other projects; Timing; Careers and training; Sustainability

c) Should CERN/Europe proceed with the preferred option set out in (a) or should alternative options be considered:
   - if Japan proceeds with the ILC in a timely way?
   - if China proceeds with the CEPC on the announced timescale?
   - if the US proceeds with a muon collider?
   - if there are major new (unexpected) results from the HL-LHC or other HEP experiments?

d) Beyond the preferred option in (a), what other accelerator R&D topics (e.g. high field magnets, RF technology, alternative accelerators/colliders) should be pursued in parallel?

e) What is the prioritized list of alternative options if the preferred option set out in (a) is not feasible (due to cost, timing, international developments, or for other reasons)?

f) What are the most important elements in the response to (e)? (Considerations in (b) should be used).

Community Input and Process

- The US HFCC white paper will be written by the Editorial Board as requested by DOE/NSF
- We will have three open meetings to collect community input:
  - HFCC-PED SLAC, December 19-20, 2024
  - HFCC-ACC FNAL, January 15-16, 2025
  - HFCC-PED/ACC TBA, probably late Feb. 2025, joint with MuC, DPF/DPB, CPAD
- We will also send emails requesting electronic input and will post draft versions of the white paper for comment by the community
- Coordinate with other efforts, incl. MuC and DPF/DPB to assure coherency between inputs.
  - Trying to coordinate to have joint sessions during the February meeting
- Timeline:
  - Paper outline December 18, 2024
  - 1st complete draft January 31, 2025
  - Final draft for review February 29, 2025
  - White paper submission March 28, 2025

Engagement of Early Career Scientists

- A Higgs Factory will be built and operated by early career scientists
- Critical to engage the early career scientists who will be working on the experiments and accelerator and we need to think about how to engage the pre-scientists who could be early career scientists in 20 years
- Will have some direct input into the white paper through the EC members of the editorial board
- Arranging Early Career sessions in each of the open meetings
- Suggestions for additional input would be appreciated.
    - A web form is being constructed to gather input, will be distributed soliciting input from Early Careers.

Comments

- We can provide limited strategic responses to ESG query
  - There is consensus within our community to support an e+/e- Higgs Factory at CERN as recommended by P5, including FCC-ee if it is approved by CERN Council. To be further deliberated in our open meetings.
  - ILC in Japan would be an option but is not thought to be likely on the timescale of an FCC-ee decision.
  - P5 believed that funding for Muon Collider Demonstration is compatible with US contribution to Higgs Factory.
  - Geopolitical tensions may limit U.S. ability to participate in CEPC. Maybe true for several countries.
  - P5 emphasized the need to maintain a strong domestic program while contributing to an off-shore Higgs Factory.

Comments (2)

- Possible challenges to the FCC program include funding.
  - ESG will evaluate the technical feasibility and will be provided with cost/timeline, and the final FCC Feasibility Study Report (available March 2025).
  - CERN Council will evaluate the viability of the financial model.
- If FCC is found not feasible for various reasons, CERN could pivot in many directions incl. (lower Energy) FCC-hh, LC, MuC, HE-LHC, or an extension of HL-LHC.
  - A pivot will likely delay the CERN Council approval of the next project.
- Technical input will be provided for both detector & accelerator (bulk of white paper)
  - Identify potential areas where US can make leading and significant contributions.
  - Grounded on our historical achievements and our expertise and capabilities.
  - Collecting input from community; however we will largely provide examples and possibilities of the scope of technical contribution.

Summary

- The HFCC has been asked to provide the ESG with input
- An Editorial Board was anointed by DOE/NSF consisting of the HFSC-PED, HFSC-A, and 4 early career members + ex-officio's.
- Arranging three open meetings to collect input and comments on the white paper
- Will coordinate with CPAD, US Muon Collider effort and DPF/DPB
- Working to engage early career scientists and engineers in the process
- Have an aggressive timeline to complete the white paper

Backup

Laboratory Coordination Group (LCG)

LCG-ACC

ANL: Philippe Piot
BNL: Wolfram Fischer
FNAL: Sam Posen
JLAB: Andrei Seryi
LANL: Steve Russell
LBNL: Cameron Geddes
ORNL: Fulvia Pilat
SLAC: Mei Bai

LCG-PED

ANL: Rik Yoshida
BNL: Dmitri Denisov
FNAL: Kevin Burkett
LBNL: Natalie Roe
ORNL: Fulvia Pilat
SLAC: Dan Akerib

Quoting from the 2020 ESPPU

An **electron-positron Higgs factory is the highest-priority next collider**. For the longer term, the European particle physics community has the ambition to operate a proton-proton collider at the highest achievable energy. Accomplishing these compelling goals will require innovation and cutting-edge technology:

- the particle physics community should **ramp up its R&D effort focused on advanced accelerator technologies**, in particular that for high-field superconducting magnets, including high-temperature superconductors;
- Europe, together with its international partners, should **investigate** the technical and financial feasibility of a **future hadron collider at CERN** with a center-of-mass energy of at least **100 TeV** and with an **electron-positron Higgs and electroweak factory as a possible first stage**. Such a feasibility study of the colliders and related infrastructure should be established as a global endeavor and be completed on the timescale of the next Strategy update.
- The timely realization of the electron-positron International Linear Collider **(ILC) in Japan would be compatible with this strategy** and, in that case, the European particle physics community would wish to collaborate.

P5 on HL-LHC

- **“As the highest priority independent of the budget scenarios, complete construction projects and support operations of ongoing experiments and research to enable maximum science.:**

We reaffirm the previous P5 recommendations on major initiatives:

1. HL-LHC (including the ATLAS and CMS detectors, as well as the Accelerator Upgrade Project) to start addressing why the Higgs boson condensed in the universe (*reveal the secrets of the Higgs boson*, section 3.2), to *search for direct evidence for new particles* (section 5.1), to *pursue quantum imprints of new phenomena* (section 5.2), and to *determine the nature of dark matter* (section 4.1).

P5 on Future Colliders

- P5 20-year vision statement:
  - In 20 years, the HL-LHC program will be completed, a Higgs factory will be preparing to take data, and a vigorous R&D program will be paving the path to a 10 TeV pCM collider [FCC-hh, muon-collider, …]. Each of these projects will fill in the map of the Higgs boson's behavior in complementary ways: The HL-LHC will deliver the first draft, the Higgs factory will provide incredible detail in key areas of the landscape, and the 10 TeV pCM collider will reveal the challenging heights of the Higgs boson's interaction with itself.
- Recommendation 2c:
  - **Construct a portfolio of major projects that collectively study nearly all fundamental constituents of our universe and their interactions, as well as how those interactions determine both the cosmic past and future.**
  - An offshore Higgs factory, realized in collaboration with international partners, in order to reveal the secrets of the Higgs boson. The current designs of FCC-ee and ILC meet our scientific requirements. The US should actively engage in feasibility and design studies. Once a specific project is deemed feasible and well-defined, the US should aim for a contribution at funding levels commensurate to that of the US involvement in the LHC and HL-LHC, while maintaining a healthy US onshore program in particle physics.

P5 recommended targeted panel

Recommendation 6: Convene a targeted panel with broad membership across particle physics later this decade that makes decisions on the US accelerator-based program at the time when major decisions concerning an offshore Higgs factory are expected, and/or significant adjustments within the accelerator-based R&D portfolio are likely to be needed. A plan for the Fermilab accelerator complex consistent with the long-term vision in this report should also be reviewed.

The panel would consider the following:

1. *The level and nature of US contribution in a specific Higgs factory including an evaluation of the associated schedule, budget, and risks once crucial information becomes available.*
2. Mid- and large-scale test and demonstrator facilities in the accelerator and collider R&D portfolios.
3. A plan for the evolution of the Fermilab accelerator complex consistent with the long-term vision in this report, which may commence construction in the event of a more favorable budget situation