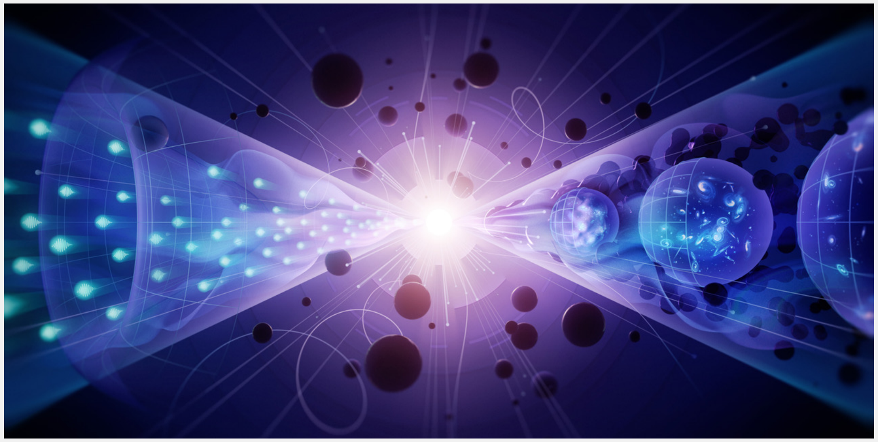
US Planning for a Higgs Factory



Ritchie Patterson, Cornell University

for the US Higgs Factory Steering Committees

10 October 2024

US - CERN Statement of Intent

The US and CERN intend to:

- Enhance collaboration on 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…;**
- Discuss potential collaboration on pilot projects on incorporating new analytics techniques and tools such as artificial intelligence (AI) into particle physics research at scale.

OSTP, April 26, 2024

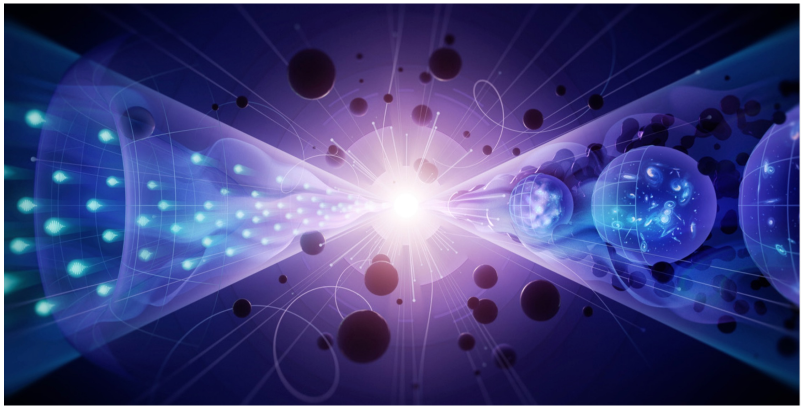
Should the CERN Member States determine the FCC-ee is likely to be CERN's next world-leading research facility following the high-luminosity Large Hadron Collider, the US intends to collaborate on its construction and physics exploitation, subject to appropriate domestic approvals."….

The full statement: https://www.state.gov/joint-statement-of-intent-between-the-united-states-of-america-and-the-european-organization-for-nuclear-research-concerning-future-planning-for-large-research-infrastructure-facilities-advanced-scie/

P5 Report

Recommendation 2: …Plan and start the following major initiatives in order of priority from highest to lowest:

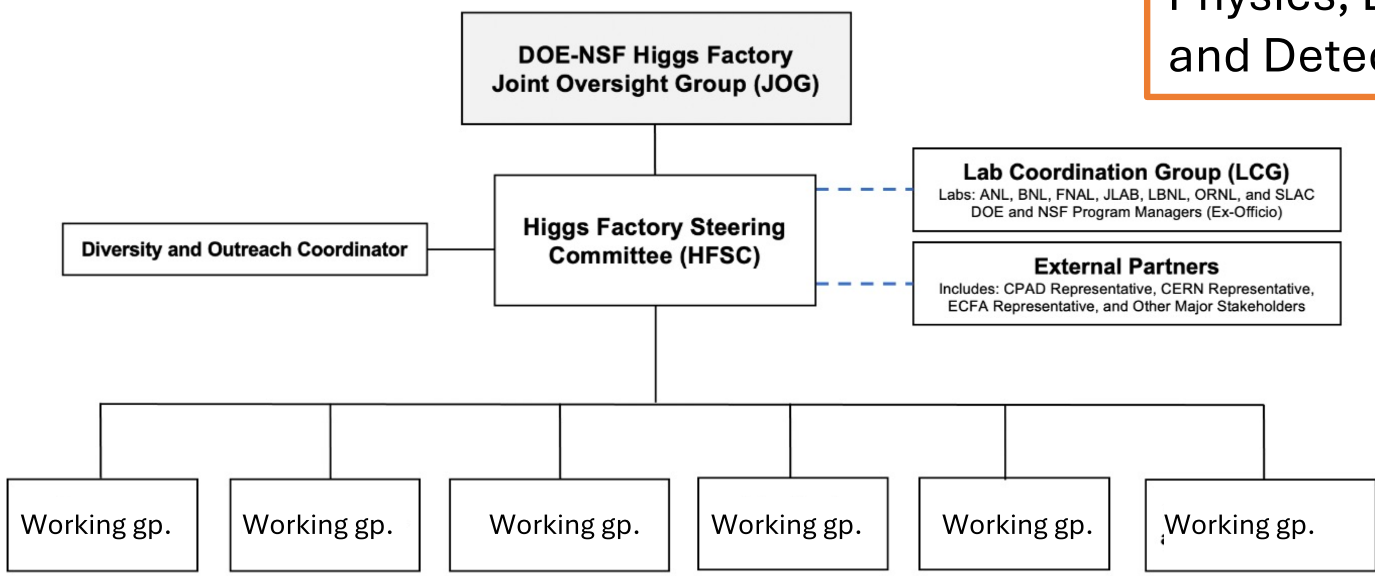
c. **An offshore Higgs factory, realized in collaboration with international partners, in order to reveal the secrets of the Higgs boson.** The current designs of FCC-ee and ILC meet our scientific requirements. **The US should actively engage in feasibility and design studies.** Once a specific project is deemed feasible and well-defined (see also Recommendation 6), the US should aim for a contribution at funding levels com- mensurate to that of the US involvement in the LHC and HL-LHC, while maintaining a healthy US onshore program in particle physics (section 3.2)



DOE/NSF response to P5 recommendation May 2024

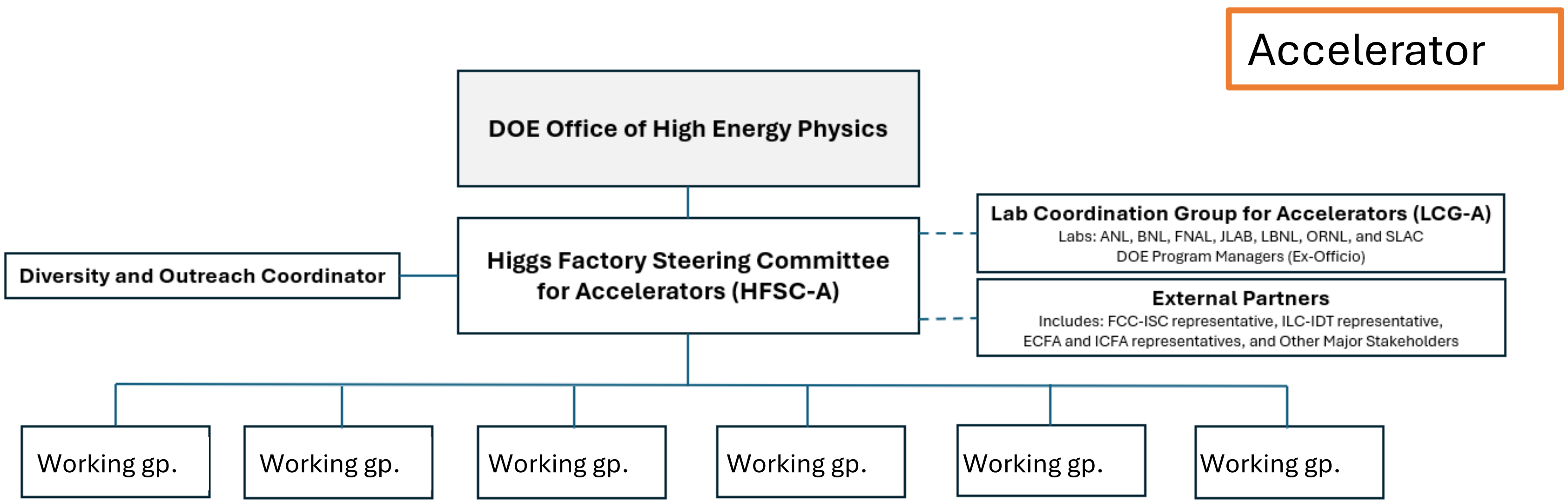
- A national Higgs Factory Coordination Consortium (HFCC)
  - Provide strategic direction and leadership for the U.S. community to engage, shape and thereby advance the development of physics, experiment and detector program for a potential future Higgs factory and to ensure cooperation with our partners in the international program.

Physics, Experiments and Detectors



DOE response to P5 recommendation Aug 2024

- A national Higgs Factory Coordination Consortium for Accelerators (HFCC-A)
  - Provide strategic direction and leadership for the U.S. community to engage, shape and thereby advance the development of the accelerator program for a potential future Higgs factory and to ensure cooperation with our partners in the international program.



Charge (Physics, Experiments & Detectors)

1. **Physics and technical feasibility studies**, including any associated design and R&D efforts, to **advance various experiment detector concepts** at a future Higgs factory;
2. **Prioritization and stewardship** of the national R&D efforts should funds be identified by DOE and/or NSF;
3. **Development of the pre-project detector R&D scope** that will be required prior to DOE and/or NSF initiating any detector project at a future e+e- collider;
4. Conceptualization of the **software and computing framework** that will be needed to advance physics studies and R&D efforts; and to collect, store, and analyze the large volumes of physics data at future collider experiments;
5. In consultation with DOE and NSF program managers, **develop various funding models** that will be required to support the R&D efforts described in items (3) and (4) above; and
6. **Ensure collaborations** by the U.S. with our partners are cost-effectively carried out to advance the future Higgs factory initiatives. (CPAD, ECFA, DRD, others).

- Prepare the groundwork to respond to the P5 Recommendation 6a: "[Convene a targeted panel to review] 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"

The Accelerator charge is equivalent, addressing accelerator development for an e+e- collider

HF Steering Committees

- Physics, Experiments & Detectors
  - Srini Rajagopalan (BNL); Chair
  - Marcel Demarteau (ORNL)
  - Sarah Eno (Maryland)
  - Ritchie Patterson (Cornell); Deputy chair

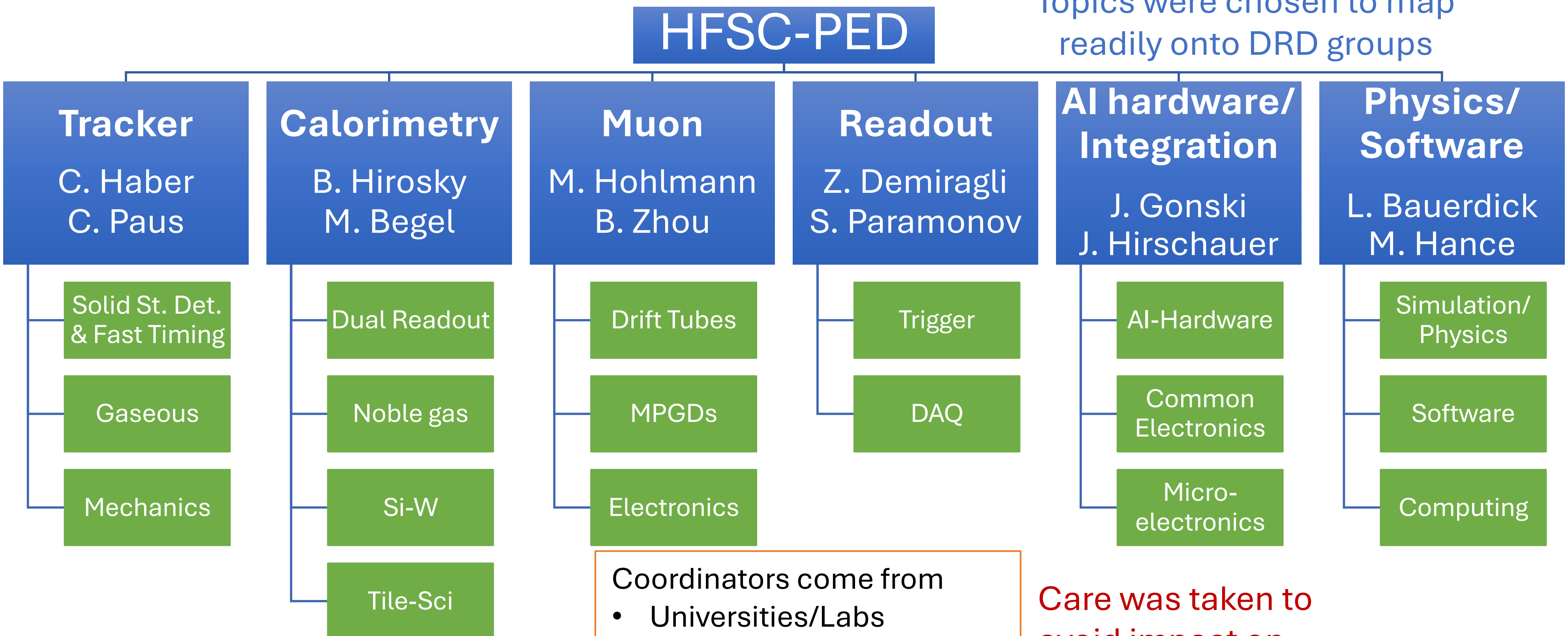
- Accelerator
  - Tor Raubenheimer (SLAC); Chair
  - Steve Gourlay (FNAL); Deputy chair
  - Matthias Liepe (Cornell)
  - Jean-Luc Vay (LBNL)

Lab Coordination Groups (LCGs)

	PED	Accelerator
ANL	Rik Yoshida	Philippe Piot
BNL	Dmitri Denisov	Wolfram Fischer
FNAL	Kevin Burkett	Sam Posen
JLAB	TBA	Andrei Seryi
ORNL	Fulvia Pilat	Fulvia Pilat
LBNL	Natalie Roe	Cameron Geddes
SLAC	Dan Akerib	Mei Bai
LANL	-	Steve Russell

Structure – Phys., Expts & Detectors

Topics were chosen to map readily onto DRD groups



Coordinators come from
- Universities/Labs
- ATLAS/CMS/other
- Early career/not so early…

Care was taken to avoid impact on HL-LHC upgrades

L2 and L3 Coordinators - PED

Tracking
L2: Carl Haber (LBNL),
Christoph Paus (MIT)
Solid State Tracking & Fast Timing Caterina Vernieri (SLAC), Artur Apresyan (FNAL)
Gaseous Tracking Junjie Zhu (U Michigan), George Iakovidis (BNL)
Mechanics Andy Jung (Purdue)

Calorimetry
L2: Bob Hirosky (U Virginia),
Michael Begel (BNL)
Dual Readout Grace Cummings (FNAL)
Noble gas Erich Varnes (U Arizona)
Si-W Jim Brau (U Oregon)
Tile-Scintillator Vishnu Zutshi (NIU)

TDAQ
L2: Zeynep Demiragli (Boston U),
Sasha Paramonov (ANL)
Trigger TBA
DAQ TBA

Physics, Software and Computing
L2: Lothar Bauerdick (FNAL),
Mike Hance (UC Santa Cruz)
Simulation/physics TBA
Software TBA
Computing TBA

AIM (AI, Integration, & Microelectronics)
L2: Julia Gonski (SLAC),
Jim Hirschauer (FNAL)
AI driven hardware TBA
Integration/common electronics Liza Brost (BNL),
Loukas Gouskos (Brown U)
Microelectronics Tim Andeen (U Texas)

Muons
L2: Marcus Hohlmann (Flor. Inst. Tech.),
Bing Zhou (U. Michigan)
Drift tubes Reinhard Schwienhorst (Mich. St. U)
MPGDs Klaus Dehmelt (JLAB)
Electronics Verena Martinez Outschoorn (U. Mass Amherst)

Priorities

- **Engage the U.S. community**
  - Recently collected EOIs identified the interests of the U.S. institutes.
  - Regular meetings with community to define and prioritize the U.S. scope.
  - Oversee the U.S. effort to meet the respective objectives and milestones.
- **Engage the external partners**
  - Coordinate the efforts with the respective DRD coordinators to lay out a unique and cost-effective U.S. scope that relies on the U.S. strengths.
  - Collaborate and work with the international partners.
  - Collaborate and communicate with CPAD/RDC and DRD groups.
- **Coordinate and Plan**
  - Define, prioritize and justify scope and seek appropriate funding.
  - Contribute to the U.S. input to the European Strategy Feasibility studies.

R&D support - PED

- DOE authorized $0.5M in support of FY24 R&D.
- The HF Steering Committee allocated funds to the following **FY24** activities needing short-term support in areas including:
  - MAPS
  - TCAD simulations
  - Straw tubes
  - Gaseous tracker
  - Eco-friendly gases
  - LAr demonstrator modules
  - Low power TDC
  - Software development
- Moving forward, we will use a bottom-up process to allocate funding, similar to those of US ATLAS and US CMS.

Coordination: DRD

- HFSC-PED charge from DOE/NSF states:

  "The U.S. HFSC members will serve as the national contacts to various international bodies, …, and thereby help advocate for the U.S. interests for the Higgs factory."

  "**Ensure collaborations** by the U.S. with our partners are cost-effectively carried out to advance the future Higgs factory initiatives. (CPAD, ECFA, DRD, others)."

- DOE and HFSC-PED are currently engaging with CERN management to formalize the engagement with the DRD collaborations.
- Each PED Working Group (Tracker, Calorimetry, etc.) will have a DRD point-of-contact. Announcements in the next few weeks

DRD and Community Themes

Gaseous	DRDT 1.1	Improve time and spatial resolution for gaseous detectors with long-term stability
	DRDT 1.2	Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out schemes
	DRDT 1.3	Develop environmentally friendly gaseous detectors for very large areas with high-rate capability
	DRDT 1.4	Achieve high sensitivity in both low and high-pressure TPCs
Liquid	DRDT 2.1	Develop readout technology to increase spatial and energy resolution for liquid detectors
	DRDT 2.2	Advance noise reduction in liquid detectors to lower signal energy thresholds
	DRDT 2.3	Improve the material properties of target and detector components in liquid detectors
	DRDT 2.4	Realise liquid detector technologies scalable for integration in large systems
Solid state	DRDT 3.1	Achieve full integration of sensing and microelectronics in monolithic CMOS pixel sensors
	DRDT 3.2	Develop solid state sensors with 4D-capabilities for tracking and calorimetry
	DRDT 3.3	Extend capabilities of solid state sensors to operate at extreme fluences
	DRDT 3.4	Develop full 3D-interconnection technologies for solid state devices in particle physics
PID and Photon	DRDT 4.1	Enhance the timing resolution and spectral range of photon detectors
	DRDT 4.2	Develop photosensors for extreme environments
	DRDT 4.3	Develop RICH and imaging detectors with low mass and high resolution timing
	DRDT 4.4	Develop compact high performance time-of-flight detectors
Quantum	DRDT 5.1	Promote the development of advanced quantum sensing technologies
	DRDT 5.2	Investigate and adapt state-of-the-art developments in quantum technologies to particle physics
	DRDT 5.3	Establish the necessary frameworks and mechanisms to allow exploration of emerging technologies
	DRDT 5.4	Develop and provide advanced enabling capabilities and infrastructure
Calorimetry	DRDT 6.1	Develop radiation-hard calorimeters with enhanced electromagnetic energy and timing resolution
	DRDT 6.2	Develop high-granular calorimeters with multi-dimensional readout for optimised use of particle flow methods
	DRDT 6.3	Develop calorimeters for extreme radiation, rate and pile-up environments
Electronics	DRDT 7.1	Advance technologies to deal with greatly increased data density
	DRDT 7.2	Develop technologies for increased intelligence on the detector
	DRDT 7.3	Develop technologies in support of 4D- and 5D-techniques
	DRDT 7.4	Develop novel technologies to cope with extreme environments and required longevity
	DRDT 7.5	Evaluate and adapt to emerging electronics and data processing technologies
Integration	DRDT 8.1	Develop novel magnet systems
	DRDT 8.2	Develop improved technologies and systems for cooling
	DRDT 8.3	Adapt novel materials to achieve ultralight, stable and high precision mechanical structures. Develop Machine Detector Interfaces.
	DRDT 8.4	Adapt and advance state-of-the-art systems in monitoring including environmental, radiation and beam aspects
Training	DCT 1	Establish and maintain a European coordinated programme for training in instrumentation
	DCT 2	Develop a master's degree programme in instrumentation

US HF PED workshop

- December 19 & 20 at SLAC
- Physics, Experiments and Detectors for a Higgs Factory
- Purpose:
  - Engage the US community in discussions of the scope and progress of our R&D efforts
  - Engage the US community to prepare our input to the ESPPU
- Almost a full day of parallel sessions, to:
  - Further develop the US R&D priorities
  - Define the potential scope of US contribution to an overseas Higgs Factory, based on past experience and available resources and expertise.

ESPPU input

HFCC has been requested by DOE and NSF to prepare input to ESPPU

Elements of input :

- US interest in an overseas Higgs Factory as laid out by P5
- Technical input on

  1) U.S. capabilities and expertise

  2) potential scope of its contribution to the Accelerator and Detectors of a future Higgs Factory located at CERN

Conclusions

- US Higgs Factory effort is taking shape

- Near-term priorities
  - Cost-effective and coordinated R&D program directed at a future Higgs Factory
  - Coordination with parallel efforts in Europe and elsewhere
  - Preparation of input to EPPSU

Backups

P5: Higgs Factory R&D

Exploring the Quantum Universe

Pathways to Innovation and Discovery in Particle Physics

Report of the 2023 Particle Physics Project Prioritization

Accelerator R&D

Engagement with FCC-ee specifically should include design and modeling to advance the feasibility study, as well as R&D on **superconducting radio frequency cavities** designed for the ring and **superconducting magnets** designed for the interaction region. These efforts benefit from synergies in workforce development through participation in SuperKEKB and the EIC.

Maintaining engagement with ILC accelerators through the ILC Technology Network can include **design updates** and **cryomodule construction**, which will support significant US contributions to potential projects. A global framework for future collider development, such as the ILC International Development Team as implemented by ICFA for the ILC, is relevant for all future colliders.

Detector R&D

For Higgs factory detectors, a concerted effort of targeted R&D synchronized with the targeted accelerator R&D program is needed. The US should **engage in international design efforts for specific collider detectors**. To achieve the scientific goals, several common requirements apply to the detectors of the various collider options, including **vertexing, tracking, timing, particle identification, calorimetry, muon detection, and triggering**. Central coordination of these requirements is crucial.

Charge (Accelerator), 8/28/2024

1. **Physics and technical feasibility studies, including any associated design and Research & Development (R&D) efforts**, to continue to advance the accelerator designs for a future e+e -collider;
2. **Prioritization and stewardship of the national accelerator R&D efforts** should funds be identified by DOE;
3. **Development of the pre-project accelerator R&D scope** that will be required prior to DOE initiating any accelerator project at a future e+e -collider;
4. **Conceptualization of the accelerator controls software and computing framework** that will enable highly automated and remote operation while maintaining appropriate security;
5. In consultation with DOE program managers**, develop various funding models** that will be required to support the R&D efforts described in items (3) and (4) above; and
6. **Ensure collaborations by the U.S. with our partners are cost-effectively carried out** to advance the future Higgs factory initiatives. Such partner efforts include, but are not limited to, those being undertaken by a) the DOE Office of High Energy Physics (HEP) General Accelerator R&D program; b) the CERN-hosted Future Circular Collider (FCC) Feasibility Study; c) the International Committee for Future Accelerators; d) the International Linear Collider (ILC) International Development Team (IDT); e) the European Committee for Future Accelerators; and f) other major stakeholders.