U.S. Plans

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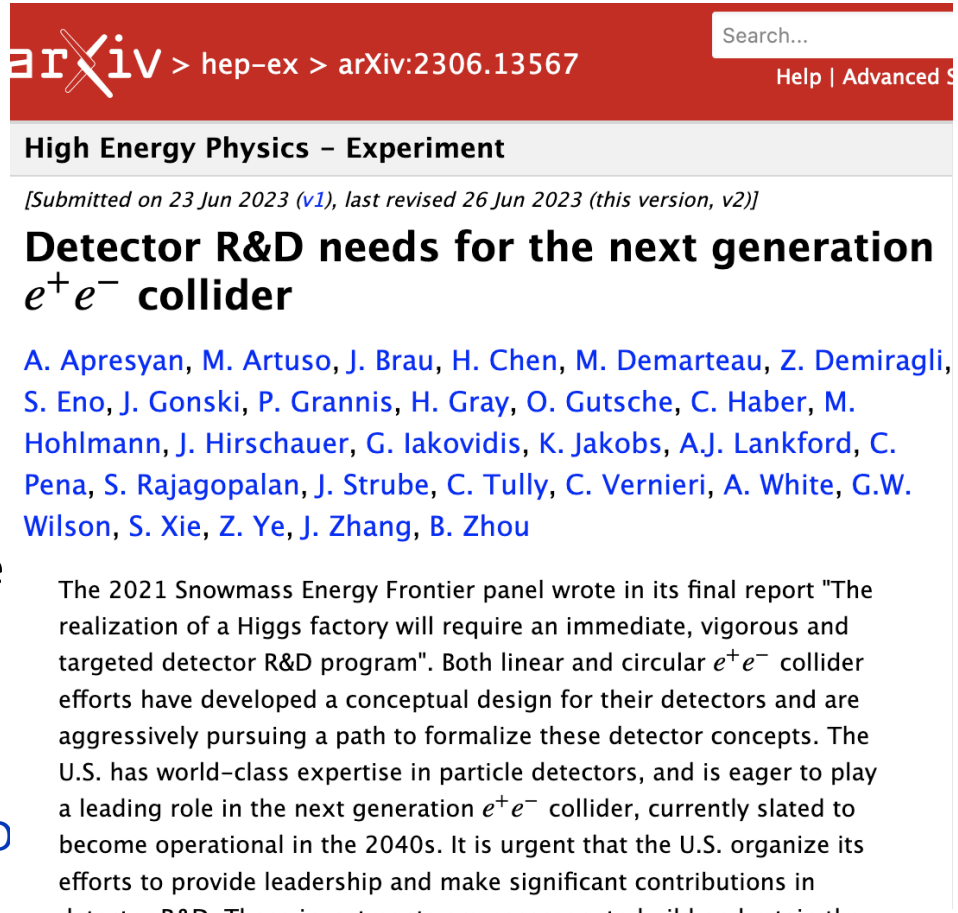
on behalf of
The U.S. Higgs Factory Steering Committee
for Physics, Experiments & Detectors

June 10, 2024

U.S. efforts toward P5

- The Snowmass process highlighted the critical need for constructing a future e+e- collider, that can:
  - Measure a comprehensive set of electroweak and Higgs observables with high precision,
  - Tightly constrain a large number of SM parameters,
  - Unveil, if any, small but significant deviations from SM
  - Direct evidence for rare processes/particles beyond SM.
- Building on the Snowmass efforts, a bottom-up community driven process was launched to communicate the need for a coherent and focused U.S. effort.
- A joint effort between Circular and Linear collider communities.
  - Focus on developing a scope/ask for targeted detector R&D toward detectors for e+e- colliders
  - Documented scope, priorities, and an Ask
  - submitted to P5 (https://arxiv.org/abs/2306.13567)
- Similar efforts for accelerator R&D.



U.S. Coordination group during P5 process

- The efforts of the coordinators during the P5 process must be commended, they put in significant work and engaged the community in the process:
  - Solid State: A. Apresyan, C. Haber, C. Vernieri
  - Calorimeter: H. Chen, C. Tully, A. White
  - Gaseous Detector: M. Hohlmann, G. Iakovidis, B. Zhou
  - Readout/ASICs: J. Gonski, J. Hirshchauer
  - Trigger/DAQ: Z. Demiragli, J. Zhang
  - Particle ID: M. Artuso, G. Wilson, Z. Ye
  - Quantum: M. Demarteau, C. Pena, S. Xie
  - Software: H. Gray, O. Gutsche, J. Strube
  - ex-officios: J. Brau, A. Canepa, D. Denisov, S. Eno, P. Grannis, K. Jakobs, A. Lankford
    - plus representation from DOE and CPAD.
  - Chair: S. Rajagopalan

P5 Recommendation

Our organization and efforts during the P5 process paid off!

❖Recommendation 2c:

[Plan and start] an off-shore 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 commensurate to that of the US involvement in the LHC and HL-LHC, while maintaining a healthy US on-shore program in particle physics.

❖Recommendation 6a

[Convene a targeted panel that would consider] 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.

U.S. – CERN Statement of Intent

The Government of the United States and CERN, as an intergovernmental organization, signed a Statement where – among the topics – the U.S. and CERN intend to:

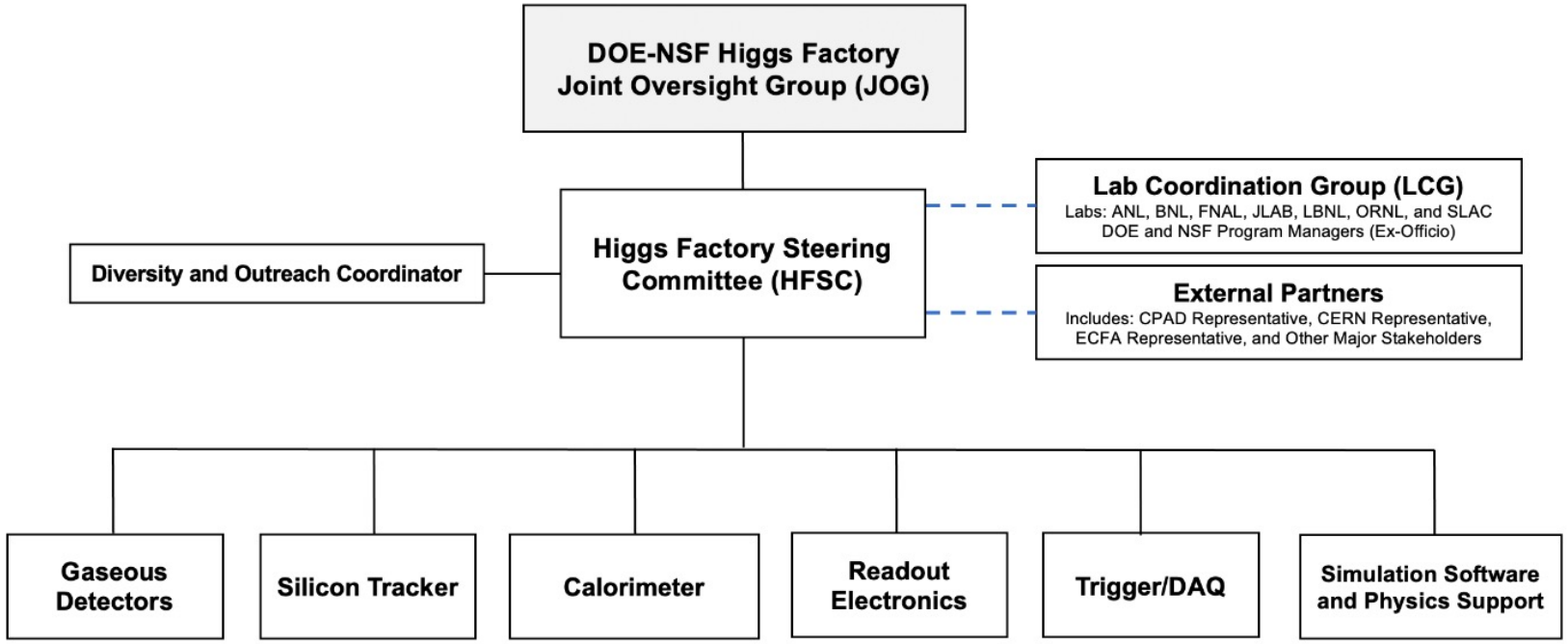
- Enhance collaboration in future planning activities for large-scale, resource-intensive facilities.
- Continue to collaborate in the feasibility study of Future Circular Collider Higgs Factory (FCC-ee)

Should the CERN member states determine the FCC-ee is likely to be the next world-leading research facility following HL-LHC, the U.S. intends to collaborate on the construction and physics exploitation, subject to appropriate domestic approvals.

This SOI represents a major step to enhance cooperation and collaboration between U.S. and CERN.

DOE/NSF response to P5 recommendation

- Constructive engagement with DOE & NSF following the release of the P5 report.
- A national Higgs Factory Coordination Consortium (HFCC) has been formed by DOE & NSF
  - 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.



Charge (Physics, Experiments & Detectors), 5/28/2024

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"

Appointments

- Membership to the U.S. HFSC is appointed by DOE & NSF:
  - Marcel Demarteau (ORNL)
  - Sarah Eno (Maryland)
  - Ritchie Patterson (Cornell); Deputy chair and NSF contact
  - Srini Rajagopalan (BNL); Chair and DOE contact
- Specifically:
  - Eno/Rajagopalan will serve as national contacts to FCC-ee
  - Patterson/Demarteau will serve as national contacts to ILC
- Membership of the Lab Coordination Group, an integral group in the HFCC, is to be defined by the respective lab management. (ANL, BNL, FNAL, JLAB, LBNL, ORNL, SLAC)
  - That process will take place over the next ~weeks.
- A well-defined process is being laid out for the appointment of the coordinators of the various activity areas (aka L2 coordinators), including defining their roles and responsibilities.
  - Process will engage the broader U.S. HEP community. Call for coordinator nominations is forthcoming.
- Engagement with external partners: CPAD, DRDs, ECFA and other stakeholders will be clarified soon.

The U.S. community is strong

- Universities and National Labs with existing interests/efforts in e+e- Collider (60+ institutes):
  - **Argonne**, Arizona, Brandeis, **Brookhaven**, Brown, Boston, Caltech, Carnegie Melon, Chicago, Colorado, Colorado State, Columbia, Cornell, Duke, Florida Tech, Florida, **Fermilab**, Florida State, Hawaii, Indiana, Iowa, Iowa State, **Jefferson Lab**, Johns Hopkins, Kansas, Kansas State, **LBNL**, Louisiana State, Maryland, U Mass Amherst, Michigan, Michigan State, Minnesota, MIT, Mississippi, Nebraska, New Mexico, Northeastern, Northern Illinois, Notre Dame, **Oak Ridge**, Ohio State, Oregon, Pennsylvania, Pittsburgh, Princeton, Purdue, Riverside, Rochester, **SLAC**, SMU, Stony Brook, Syracuse, Texas Arlington, Texas Austin, Texas Tech, Tufts, UC Berkeley, UC Davis, UC Irvine, UC Los Angeles, UC Santa Barbara, UC Santa Cruz, Virginia, Washington, Wayne State, Wisconsin, Yale …
- Community interests is expected to grow with time
  - Growing interest among the early-stage scientific members of the community.
  - Significant pool of resources/expertise, primarily engaged in the ongoing LHC/HL-LHC program, who can seamlessly transition and contribute to the next generation Higgs Factory collider at the conclusion of the ongoing HL-LHC upgrades.
    - We must ensure that the ongoing high priority efforts in HL-LHC are not impacted, but we need to create a balanced program to invest in the future.

U.S. is already engaged

Second annual U.S. FCC workshop in MIT earlier this year drew 209 participants incl. our international colleagues as well as our Linear Collider community given the synergies between the two efforts.

Expression of Interests presented by 45 institutes to contribute to near term effort in Detector R&D and/or software/simulation studies.

- LC and CC communities working together
- We encourage other US institutes to become engaged and submit an EOI.

Goal of the EOIs was to build on the P5 process and:

- Understand the community interests
- Assess the available short-term resources
- The EOIs will provide the initial input to define the scope, prioritize and implement a coherent US effort

Expertise in detector R&D and Software

- U.S. community has been engaged in the ongoing detector benchmarks for both FCC-ee (CLD, IDEA, ALLEGRO) and ILC (ILD, SiD) and corresponding physics/simulation studies.
- Significant experience in U.S., demonstrated through our contributions to LHC and HL-LHC upgrades as well as other HEP/NP experiments.
- Well positioned to contribute in a number of areas, including:
  - Large area MAPS detectors, Low-Mass lightweight support structures
  - LGAD based timing layers to support particle ID.
  - Lightweight large areas gaseous detectors offering fast readout
  - Calorimeter design and development incl: SiW, Dual Readout and Nobel Liquids
  - ASIC development and related readout electronics
  - Machine Detector Interfaces
  - Software development and simulation studies
- We must strengthen our engagement in the ongoing feasibility studies and the newly formed DRD collaborations.

US R&D on semiconductor tracking and timing

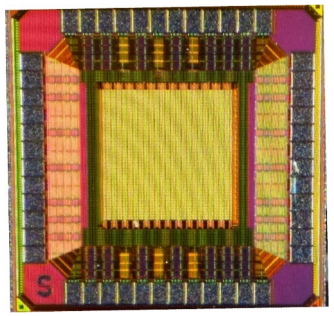
Significantly informed by the DOE BRN, CPAD, and ECFA R&D Roadmaps

- Important synergies with RHIC, LHC, EIC heavy ion programs, which have important US based components.

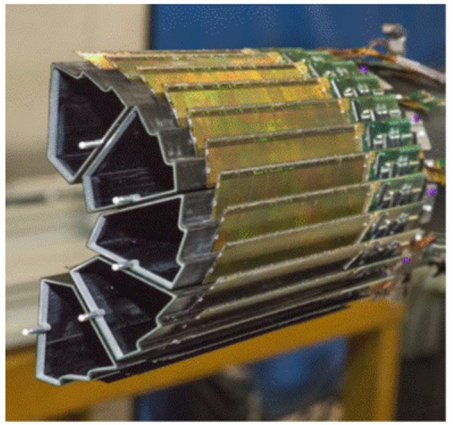
EIC is the prototype for FCC-ee

- **Large Area MAPS:**
  - SLAC pursuing O(ns) timing, low mass, fault tolerance
  - FNAL pursuing U.S. based foundries
  - SLAC/FNAL/ORNL : 3D integrated sensors to achieve high spatial and timing resolution
- **Low mass mechanics:**
  - Carbon fiber engineering for LHC and RHIC programs
  - Low mass air cooled support for the STAR→ FCC-ee
  - System integration: MAP staves for sPHENIX and ALICE
- **LGADs:**
  - Broad R&D program to achieve high spatial resolution
  - Development of LGADs in silicon carbide alternatives

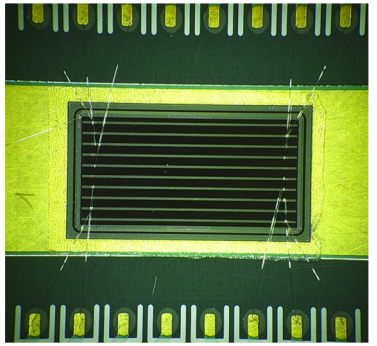
Significant interests and expertise in many Labs/Universities
Discussions on all these topics this week in parallel sessions

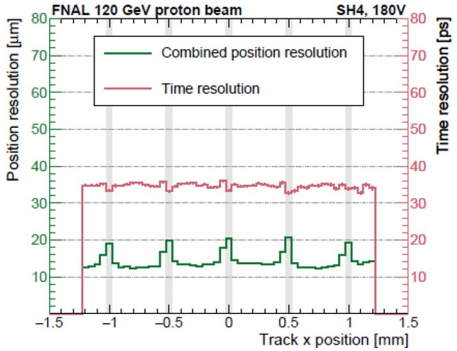


SLAC: Picture of NAPA-p1 prototype through DRD3 (WP1.2)

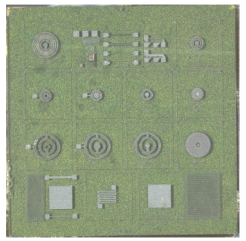


STAR Heavy Flavor Tracker with MAPS staves and gas cooling channels





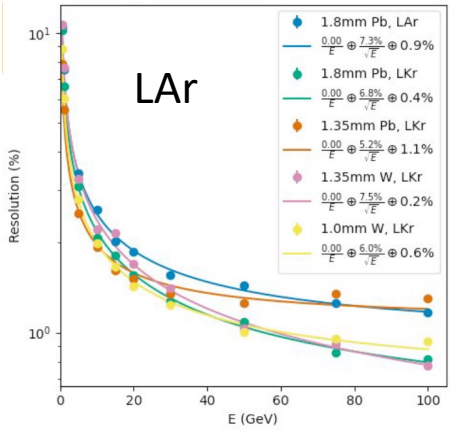
BNL/FNAL: AC coupled LGAD

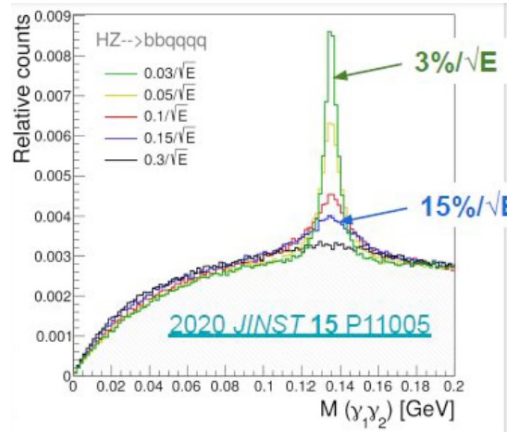


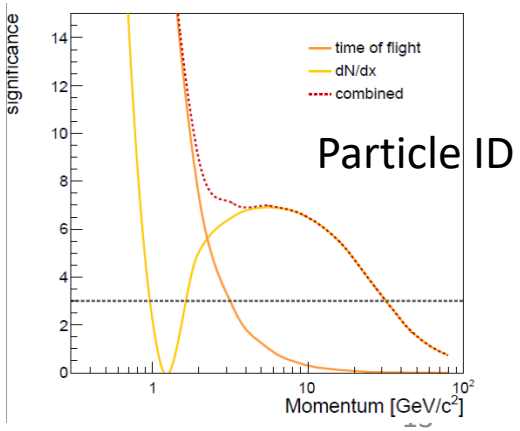
LBNL/NCSU: Array of SiC LGAD and test structures

Others

- Calorimeters: (Long established U.S. expertise)
  - LAr: Finer longitudinal segmentation and superior (~5x) SNR with cold electronics offers better performance
  - Dual Readout Fiber calorimeter:
    - Exploiting Cerenkov and scintillation light to achieve superior hadronic resolution. Dedicated U.S. R&D funding line.
    - EM crystal calorimeters offer excellent EM resolution
  - Si-W EM calorimeters and Tile-Scintillator hadronic calorimeter with SiPM readout. (CALICE style proposed for both CLD and ILC.)
- Gaseous Detectors
  - Gaseous tracker options have the potential to offer better momentum resolution (minimize multiple scattering).
  - Particle ID through dE/dx and cluster counting allows pi/K separation in a wide momentum range.
- U.S. is in a unique position to make leadership contributions to these and many other efforts in collaboration with international partners.







Next Steps

- Our immediate priority:
  - Work with the U.S. community, national laboratories, DOE/NSF and other stakeholders to build the U.S. organization and begin to address/implement the charge.
  - Define, prioritize and engage in critical near-term R&D (subject to available funds)
  - Engage in the ongoing feasibility studies and the European Strategy process in advancing experimental detector concepts.
  - Define the unique U.S. detector R&D scope in the international context and support community engagement in the newly formed DRD collaborations
- Initial ramp-up of our efforts will take time due to limited funding available in the near-term; the priority is to complete the HL-LHC accelerator and (Phase-II) detector upgrades (P5 Recommendation 1a)
- We value the importance of early engagement and intend to work with our international partners to build a strong foundation that is required to constructively move forward in the realization of a future e+e- collider.