APS physics Division of Particles & Fields

UC San Diego

The View Ahead: A Report from Snowmass 2021

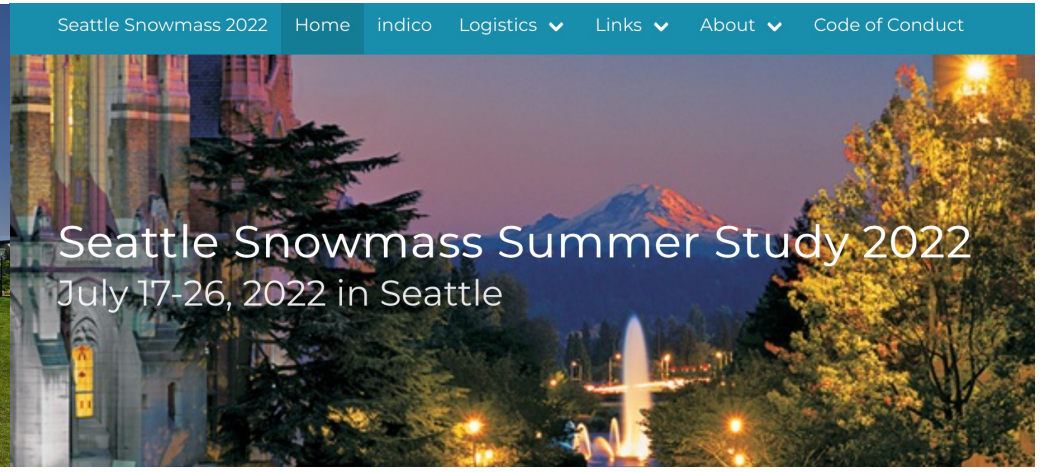
R. Sekhar Chivukula, DPF Chair Elect

Horizons in Accelerators, Particle/Nuclear Physics and Laboratory-Based Quantum Sensors for HEP/NP

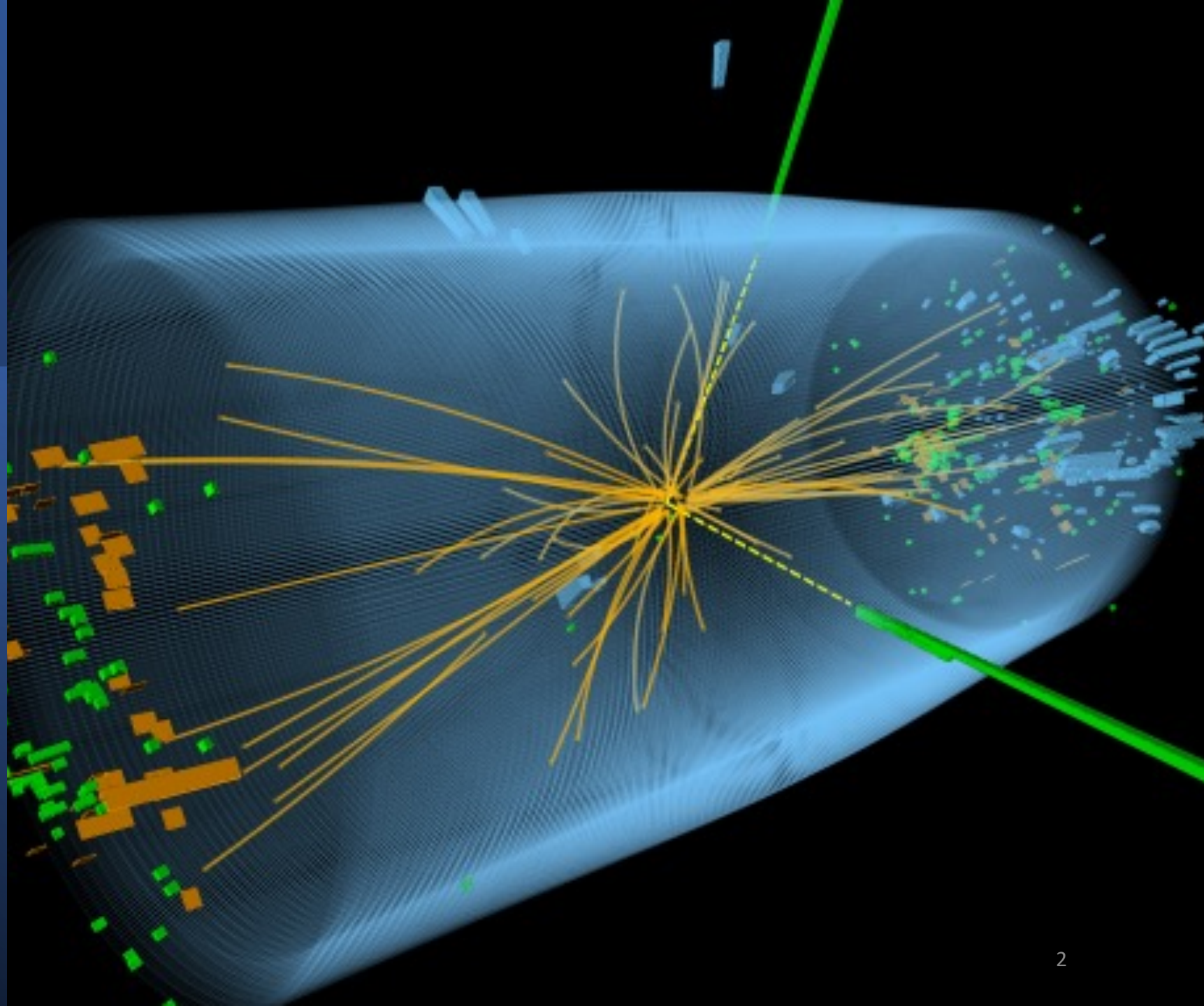
International Centre for Theoretical Science,

November 17, 2022

ICTS



Planning for US High-Energy Physics The "Snowmass/P5 Process"



The last “Snowmass” occurred in 2013

A year-long community-wide effort,
culminating with
“Snowmass on the Mississippi”
July 29 – August 6, 2013

(~700 in-person participants)

Snowmass 2013 highly successful:

(Report by December 2013)

https://www.slac.stanford.edu/econf/C1307292/

The year-long process laid out a roadmap
for **great science opportunities**,
resulted in broad community buy-in.

essential inputs to P5

"Particle Physics Project Prioritization Panel" (P5)

A subpanel of HEPAP (DOE and NSF)

- Projects prioritized according to funding scenarios
- Science research directions in HEP
- Federal funding profile for the current and near-future projects in the decade.

P5 Report, May 2014

Building for Discovery

Strategic Plan for U.S. Particle Physics in the Global Context

Report of the Particle Physics Project Prioritization Panel (P5) May 2014

Distilled from the Snowmass 2013 inputs, five Science Drivers for the field:

- **Use the Higgs boson as a new tool for discovery**
- **Pursue the physics associated with neutrino mass**
- **Identify the new physics of dark matter**
- **Understand cosmic acceleration: dark energy and inflation**
- **Explore the unknown: new particles, interactions, and physical principles.**

- 29 recommendations
- Projects prioritized according to funding scenarios

As a result, highly impactful on the

- Directions/achievements in HEP
- Federal funding profile

for the current and near-future projects in the decade.

And then, after P5, it's important to work together for the whole program in a unified manner.

- https://www.usparticlephysics.org
- https://www.usparticlephysics.org/wp-content/uploads/2022/03/Particle-Physics-Progress-and-Priorities-2022.pdf

- Every year, working with DPF, and Users Groups, and others, materials about the whole field are developed and updated for interactions with decision makers in Washington and elsewhere.

Steve Ritz, P5 Chair

Building for Discovery

Strategic Plan for U.S. Particle Physics in the Global Context

usparticlephysics.org

The P5 Report provides the strategy and priorities for U.S. investments in particle physics for the coming decade.

The top three priorities in 2022

Strengthen support for particle physics research at universities and national laboratories, which includes data analysis, R&D, design of new experiments, and a vibrant theory program. As emphasized in the P5 Report, these activities are essential for the success of the field. They are crucial for extracting scientific knowledge from all the great new data, developing new methods and ideas, maintaining U.S. leadership, and training the next generation of scientists and innovators.

Advance the High-Luminosity Large Hadron Collider (HL-LHC) accelerator and ATLAS and CMS detector upgrade projects on schedule, continuing the highly successful LHC program and bilateral partnership with CERN.

Advance the Long-Baseline Neutrino Facility (LBNF), Deep Underground Neutrino Experiment (DUNE), and Proton Improvement Plan-II (PIP-II), working with international partners on the design, prototypes, initial site construction, and long-lead procurements.

These carefully chosen investments will enable a steady stream of exciting new results for many years to come and will maintain U.S. leadership in key areas.

Particle physics is both global and local. Scientists, engineers, and technicians at more than 180 universities, institutes, and laboratories throughout the U.S. are working in partnership with their international colleagues to build high-tech tools and components, conduct scientific research, and train and educate the next generation of innovators. Valuing equity, diversity, and inclusion, the field is committed to increasing participation of underrepresented groups. Particle physics activities in the U.S. attract some of the best scientists from around the world.

The P5 strategy has been very successful. Even with extraordinary challenges due to COVID-19, there was great progress.

Recent results

The LHC experiments reported many important and precise results. The remarkably productive ATLAS and CMS experiments have each produced more than 1,000 refereed publications. The advances in precision are represented well by the new measurement of fundamental symmetry properties of **Higgs boson** decays that test the foundations of the underlying theory. The LHCb experiment also published many new results that are sensitive to **new physics**.

The **Muon g-2** fundamental parameter was measured to much greater precision, which represents another success in the program recommended in the P5 report. Remarkably, the value differs significantly from the theoretical prediction, pointing the way to more scientific progress.

Using the high-temperature superconductor, YBCO, researchers at **Fermilab set a new record for a fast-cycling accelerator magnet**.

The **Dark Energy Survey (DES)** announced many results using data from its first three years of operation.

Theoretical physicists have discovered new connections between particle production at **colliders** and fundamental concepts in **quantum field theory**, offering new, more incisive tests. They have also discovered new ways to search for candidate **dark matter** particles.

Intriguing first results from the **MicroBooNE** neutrino experiment, which is a proof-of-principle application of liquid argon for neutrino detectors, tested hypotheses about anomalies from previous neutrino experiments.

Program advances in 2021

Building upon the historic 2015 and 2017 bilateral U.S.-CERN agreements, U.S. and CERN scientists successfully continued their cooperative partnership at the LHC and the international neutrino program hosted by Fermilab. So far, government-to-government agreements with 10 countries have been signed for LBNF/DUNE, PIP-II, and the Short Baseline Neutrino program at Fermilab, with more in progress.

The **Vera C. Rubin/LSST Camera** successfully passed its CD-4 construction completion milestone. The **Dark Energy Spectroscopic Instrument (DESI)**, the world's premiere multi-object spectrometer, began its 5-year survey in May 2021, enabling major advances in the study of the nature of **dark energy** using methods complementary to those of Rubin Observatory's upcoming imaging survey.

The next-generation cosmic microwave background facility, CMB-S4, was ranked highly in the NAS Decadal Survey of Astronomy & Astrophysics, opening the path for a partnership in this interdisciplinary science that was also a priority in the P5 report. CMB measurements uniquely probe **physics of the inflationary era in the early Universe** at energies well beyond those of earth-bound accelerators and can also reveal **neutrino properties**.

Looking forward

All eyes are on the LHC, as its sensitivity to new physics will continue to improve through vastly greater data volumes and new deep-learning data analysis methods. The experiments will extend their discovery reach and probe the Higgs boson's properties with ever greater precision for many years to come. Despite COVID and funding constraints, the HL-LHC upgrade projects are progressing.

Eagerly anticipated new data from operating experiments will advance the understanding of the intertwined Science Drivers identified in the P5 Report. At the LHC, the accelerator is on track to resume operations this spring for data-taking by the successfully upgraded experiments.

Particle physicists are expanding efforts to develop and apply artificial intelligence (AI) techniques to the operation of accelerators and experiments, data analysis, and simulations, opening new avenues for scientific discovery.

Theoretical and experimental particle physicists are advancing Quantum Information Science (QIS), providing solutions to problems in computation, data analysis, sensors, and simulations.

The particle physics theory community will continue to play key roles in interpreting results from current experiments, motivating future experiments, and pursuing answers to the deepest questions.

Looking beyond the current P5 horizon, and guided by new results, the U.S. is currently engaged in the Snowmass community planning process, in which opportunities in all areas of the field are discussed in depth. To inform choices, the U.S. is also working with partners worldwide on the development of concepts for facilities that could be hosted in the U.S. and abroad.

U.S. researchers are pursuing R&D on advanced technologies to enable future generations of accelerators and detectors with a wide variety of applications in science, medicine, and industry.

Building for Discovery

Strategic Plan for U.S. Particle Physics in the Global Context

usparticlephysics.org

The “results” of the last Snowmass/P5 process and follow-up were good!

Spawned numerous U.S. International agreements

- U.S. – CERN Agreement, May 2015
- UK – U.S. Science & Technology Agreement, Sep 2017
- DOE-DAE Project Annex II on Neutrino Research, Apr 2018
- U.S. – Italy Neutrino Agreement, Jun 2018

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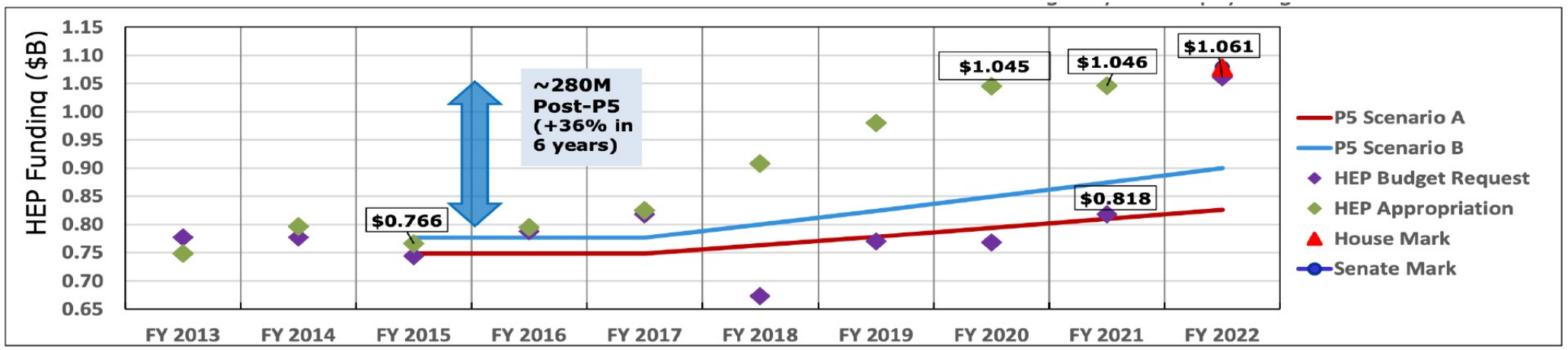
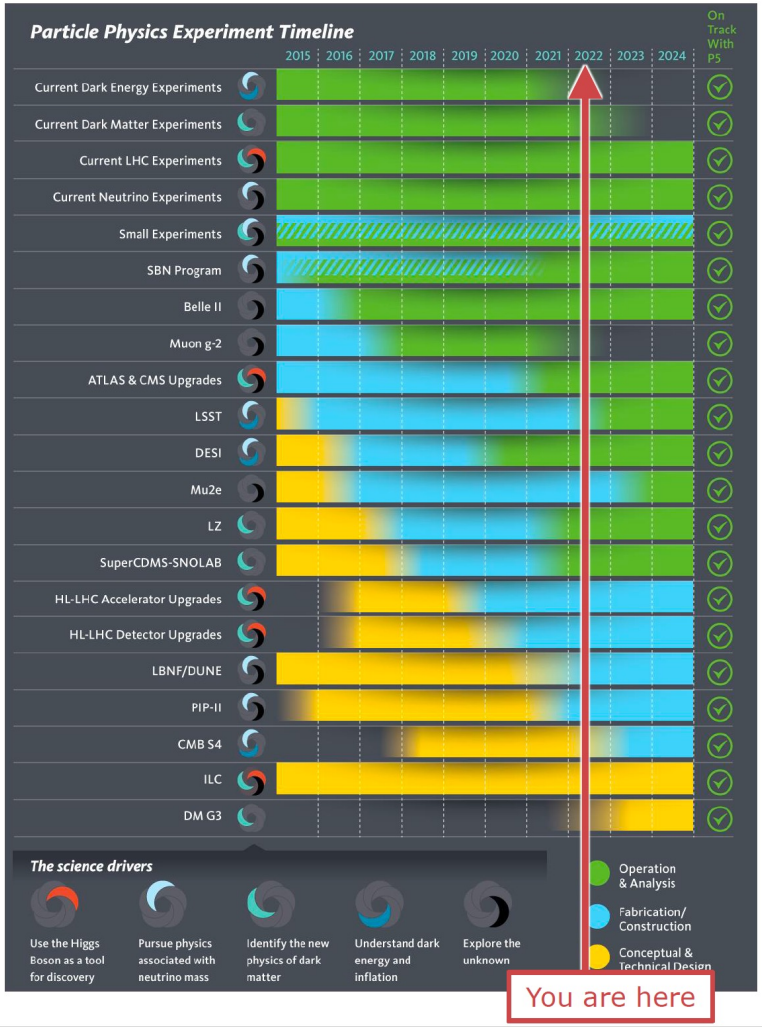
- U.S. – CERN FCC and HL-LHC Agreement, Dec 2020

CERN – FNAL HL LHC Agreement, Mar 2021



JoAnne Hewett, HEPAP Chair

P5 8 Years in: Many projects completed/in progress



Successful implementation of the 2014 P5 strategy continues

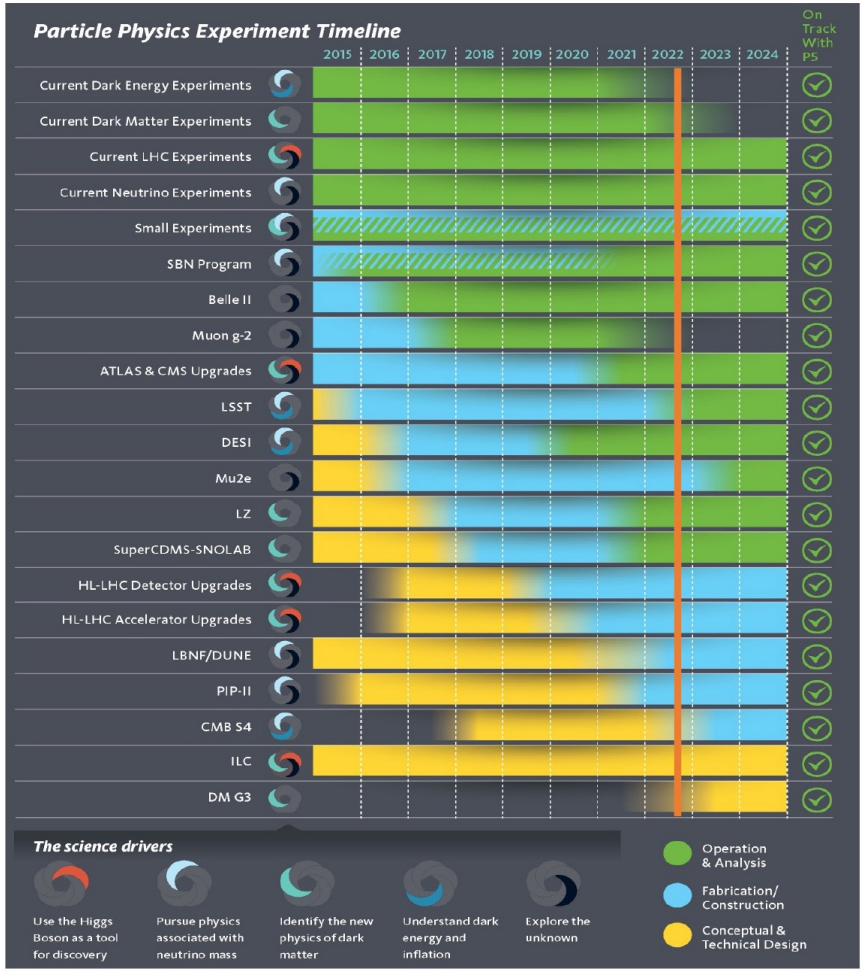
Continuous physics analyses and output throughout the "P5 envisioned" 10-year plan

Even with extraordinary challenges due to COVID-19, there was great progress!

- **Projects fully funded or ongoing as of FY 2022:**
  - **Initial Phase-1 LHC detector upgrades: ATLAS and CMS**
  - **Mu2e**
  - **SuperCDMS at SNOLAB (DM-G2)**
- HL-LHC accelerator and detector upgrade projects underway
- LBNF/DUNE & PIP-II schedules advanced due to strong support by the U.S. Administration & Congress; Muon g-2 is operating
- DESI, LZ and LSSTCam (for Rubin Observatory) projects completed; CMB-S4 in concept planning
- Broad portfolio of small projects running

Harriet Kung
Deputy Director
DOE Office of Science

We've succeeded … time for a new plan



Healthy HEP program requires a mix of project stages

Yesterday's projects lead to today's science

Today's projects lead to tomorrow's science

Planning for the next decade(s)

JoAnne Hewett


Snowmass 2021

Impact of COVID

- This edition of Snowmass was planned to run from the summer of 2020 to a final get-together in July of 2021 at the University of Washington
- By early 2021, it became clear that COVID would have a major impact on our ability to carry out the necessary work because of
  - Lack of face-to-face meetings reduced efficiency
  - Heavy burdens fell on our young physicists, who do many of the studies
    - **Especially young physicists with children, who now had care for them all day and school them at home**
- In consultation with **DOE, which agreed to delay P5 by one year, to 2022/23**, we decided to take a ~7month pause/slowdown with the expectation that conditions would improve because of vaccines and other mitigation measures
  - **The meeting at University of Washington was delayed until July of 2022**
- The pause/slowdown began in January of 2021
- The startup dates varied among the frontiers, but by September everything was restarted and there was a **"Snowmass Day" on September 24, 2021**, to review the status and plans for completing the work in for the July 2022 meeting

Snowmass 2021 organization

10 Frontiers	80 Topical Groups
Energy Frontier	Higgs Boson properties and couplings, Higgs Boson as a portal to new physics, Heavy flavor and top quark physics, EW Precision Phys. & constraining new phys., Precision QCD, Hadronic structure and forward QCD, Heavy Ions, Model specific explorations, More general explorations, Dark Matter at colliders
Frontiers in Neutrino Physics	Neutrino Oscillations, Sterile Neutrinos, Beyond the SM, Neutrinos from Natural Sources, Neutrino Properties, Neutrino Cross Sections, Nuclear Safeguards and Other Applications, Theory of Neutrino Physics, Artificial Neutrino Sources, Neutrino Detectors
Frontiers in Rare Processes & Precision Measurements	Weak Decays of b and c, Strange and Light Quarks, Fundamental Physics and Small Experim… …pton Number Violation, Charged Lepton Flavor Violation, Dark Sector at Low Energies, Had…
Cosmic Frontier	Dark Matter: Particle-like, Dark Matter: Wave-like, Dark Matter: Cosmic P… …ion: The Modern Universe, Dark Energy & Cosmic Acceleration: Cosmic … Acceleration: Complementarity of Probes and New Facilities
Theory Frontier	String theory, quantum gravity, black holes, Effecti… …mal QFT, Scattering amplitudes, Lattice gauge theory, Theory t… …phenomenology, BSM model building, Astro-particle physics and c… …ce, Theory of Neutrino Physics
Accelerator Frontier	Beam Physics and Accele… …inos, Accelerators for Electroweak and Higgs Physics, Multi-TeV … …nd Colliders & Rare Processes, Advanced Accelerator Concepts, A… …ets, Targets/Sources
Instrumentation Frontier	…, Solid State Detectors & Tracking, Trigger and DAQ, Micro Pattern Gas …onics/ASICS, Noble Elements, Cross Cutting and System Integration, Radio Detection
Computational Frontier	…lgorithm Parallelization, Theoretical Calculations and Simulation, Machine Learning, Storage and …ng resource access (Facility and Infrastructure R&D), End user analysis
Underground Facilities and Infrastructure Frontier	Underground Facilities for Neutrinos, Underground Facilities for Cosmic Frontier, Underground Detectors
Community Engagement Frontier	Applications & Industry, Career Pipeline & Development, Diversity & Inclusion, Physics Education, Public Education & Outreach, Public Policy & Government Engagement

30 Frontier conveners, ~250 Topical Group conveners,
>40 Inter-Frontier Liaisons, ~25 Early Career Liaisons.

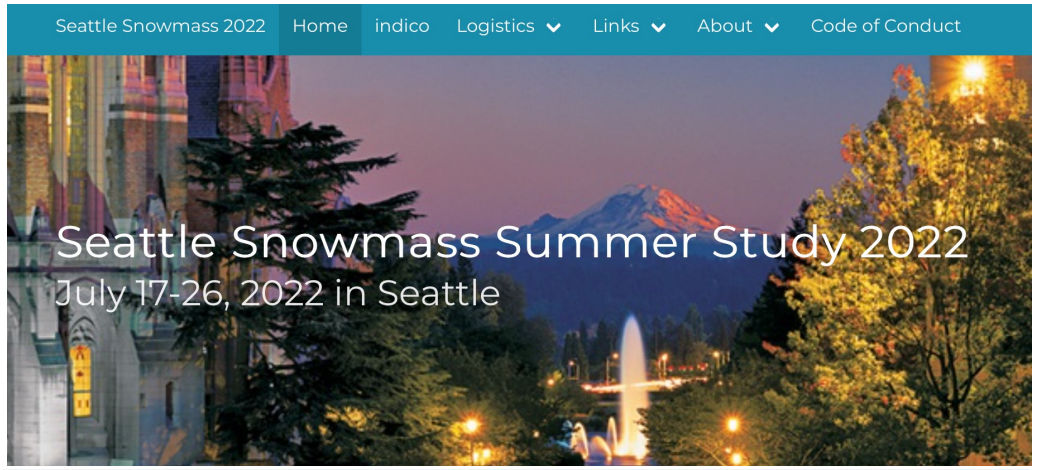
Snowmass Early Career — to represent early career members and promote their engagement in the Snowmass 2021 process; to build a long-term HEP early career community

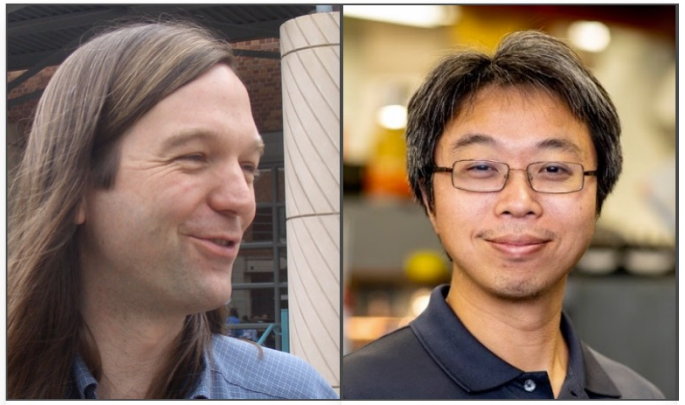
Broad coverage and connection to global science community!

Community Summer Study (CSS): Snowmass 2021

July 17 – 26, 2022 @ UW – Seattle

http://seattlesnowmass2021.net





Gordon Watts
email
Co-Chair of Local Organizing Committee, Co-Chair of Program Committee

Shih-Chieh Hsu
email
Co-Chair of Local Organizing Committee, Co-Chair of Program Committee

Participants

Number of in-person participants: 743

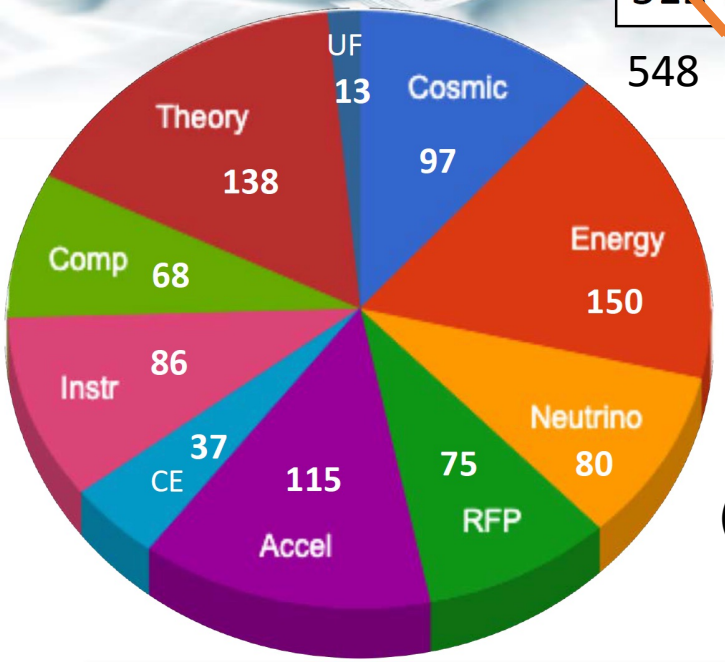
Number of virtual participants: 654

Local Organizing Committee/Volunteer/Press: 58

Total number of participants: 1397

Covid Cases: ~35

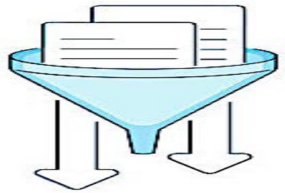
Output of Snowmass – referenced at PAQS



512 White Papers

548

79 topical group reports



And lots of meetings and presentations and plots along the way

10 Frontier Summaries

(Plus 2 additional reports…)

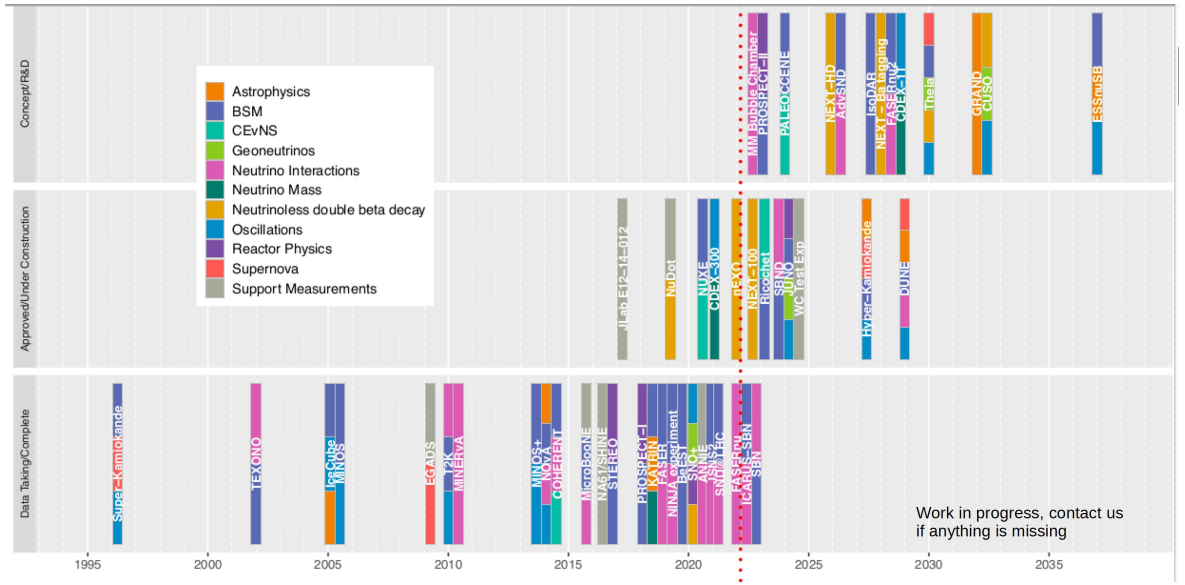
Executive Summary by October

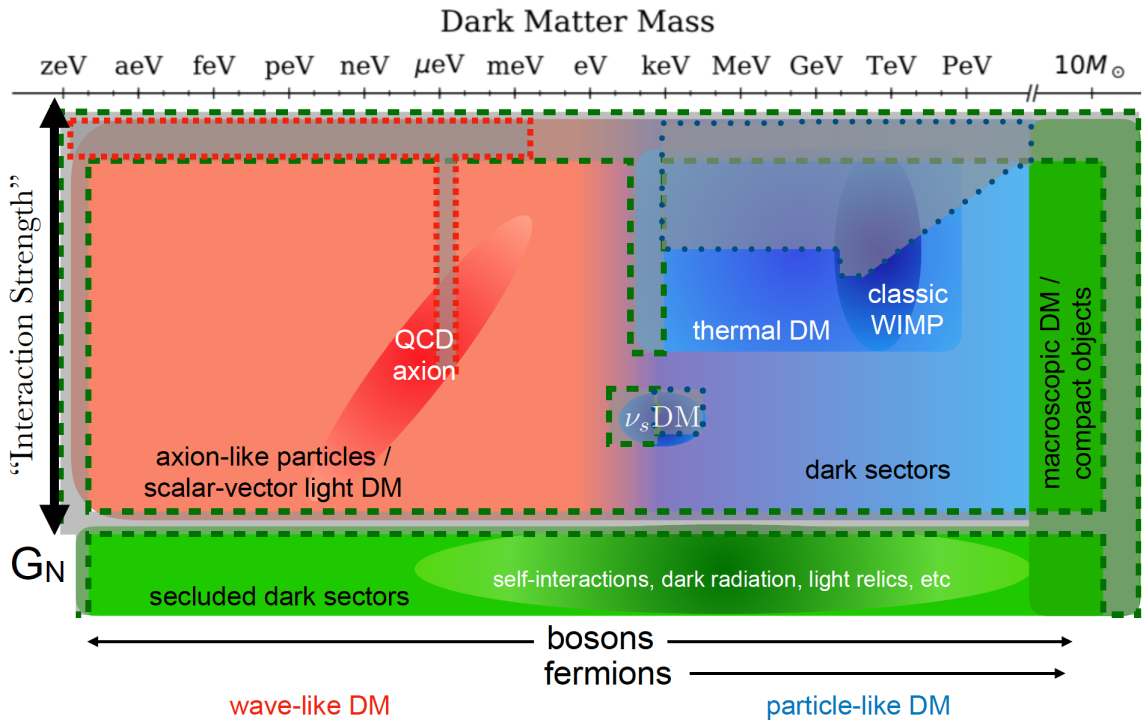
Coming soon…

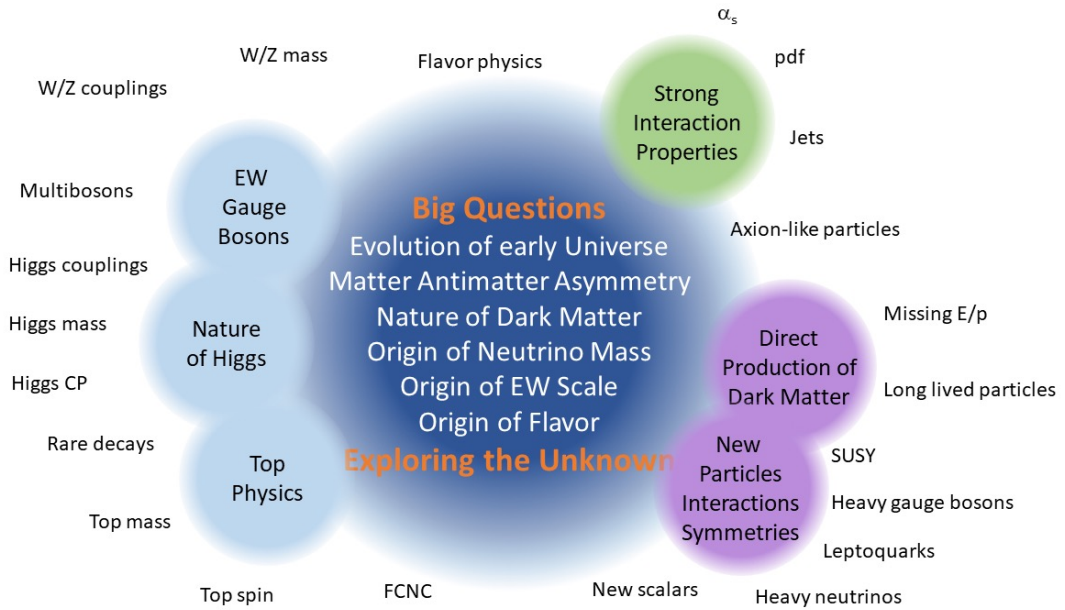
We are grateful for the large number of international particpants – including many from India!

Prisca Cushman, UMinn, DPF Chair 2019

A *Sample* of Snowmass Frontier Recommendations







“Large” Experiments

Cosmic:

Timeline of CF large projects

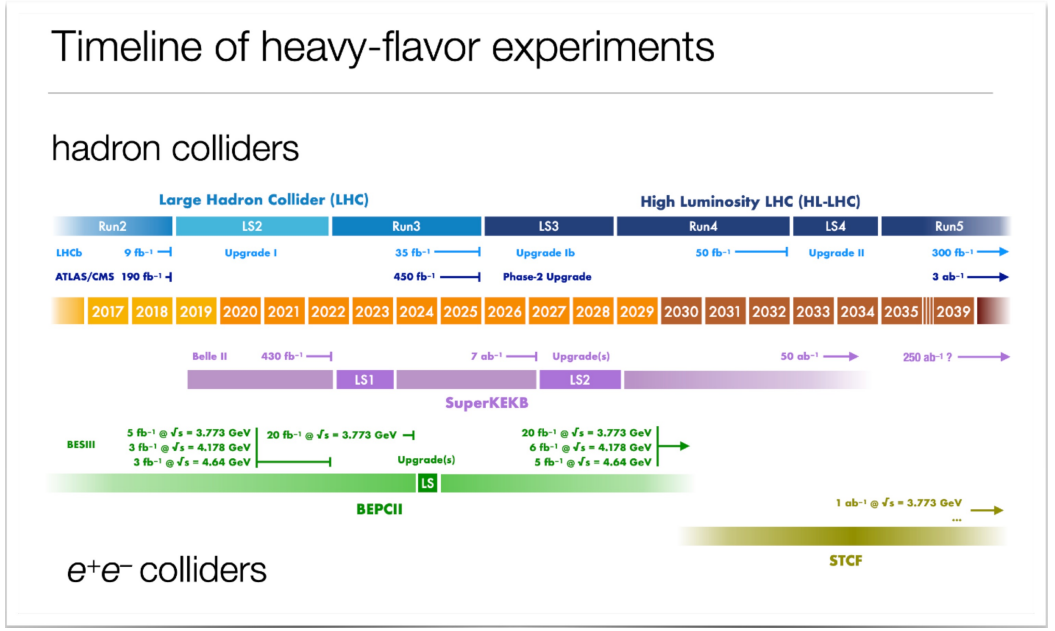
- **2022-2036: Build & operate CMB-S4 (current large project)**
- 2022-2036: Science with DESI, LSST, CMB-S4
- 2022-2025: Pathfinder for 21cm (LuSEE-Night)
- 2024-2027: Pathfinder for Spec-S5 target selection (DESI-II)
- **2024: Target date for CD-0 for Spec-S5 (next large project)**
- 2025-2029: Pathfinders for next-generation GW Observatory
- 2027-2029: Pathfinders for 21cm/mm-wave line intensity mapping
- **2029: Begin CD process for LIM, GWO (future large project)**

Energy:

- US EF community strongly supports

1. A fast start of construction of an e+e- Higgs Factory (FCC-ee, ILC, C^3, CLIC) [Large Project]
2. Request for targeted detector R&D for Higgs Factory [in the range of small project costs]
3. Request for investment in R&D towards lowering of costs for Higgs Factory [lower end of medium project costs]
   a. interest in new technologies from early career scientists
4. Request for investment in R&D towards multi-TeV colliders
   a. significant interest for adding muon collider R&D. [lower end of medium project costs]

Rare and Precision: Heavy flavor factories: medium size, large scope



Neutrino:

Takeaways

- DUNE Phase I should be realized in this decade
- Realization of the full DUNE Phase II should be the highest priority
  - Pursue upgrades aggressively such that the full DUNE scope is achieved in the 2030s
- R&D work to design detectors that broaden the physics scope while fulfilling the core goals of DUNE should be supported
- There are unique opportunities for NF to contribute to leadership of a cohesive, HEPwide strategic approach to DEI and community engagement, which is urgently needed.
  - As the flagship domestic experiment DUNE should be at the center of these efforts
- A healthy portfolio of small and midscale NF experiments is vital to the field and to the success of DUNE (C.F. SBN and DUNE)

Theory, AF, and UF

Critical Needs

1. Support for the essential role of theory similar to (and at least as strong as) recommended by the European Strategy Update, both in relation to projects and in its own right.

European Strategy Update

4 Other essential scientific activities for particle physics

B. Theoretical physics is an essential driver of particle physics that opens new, daring lines of research, motivates experimental searches and provides the tools needed to fully exploit experimental results. It also plays an important role in capturing the imagination of the public and inspiring young researchers. The success of the field depends on dedicated theoretical work and intense collaboration between the theoretical and experimental communities. ***Europe should continue to vigorously support a broad programme of theoretical research covering the full spectrum of particle physics from abstract to phenomenological topics. The pursuit of new research directions should be encouraged and links with fields such as cosmology, astroparticle physics, and nuclear physics fostered. Both exploratory research and theoretical research with direct impact on experiments should be supported, including recognition for the activity of providing and developing computational tools.***

AF Messages #2-4 for Large-Scale Facilities

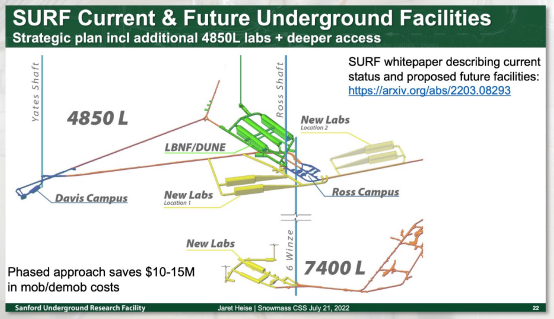
Snowmass 2021

- #2: We need an integrated future collider R&D program (a focused R&D program in OHEP) to engage in the design and to coordinate the development of next generation collider projects such as: ILC, CLIC, FCCee, CCC/HELEN, multi-TeV Muon Collider. We (the US) have few new proposals ready for P5 evaluation.
- #3 & #4 We have an active R&D program in labs and universities aimed at general accelerator R&D that is critical in developing technologies and options for future HEP accelerators (but does not develop accelerator proposals).

Sanford Underground Research Facility

The ambitious Snowmass community vision requires additional underground facilities and infrastructure over the next decade

- Neutrinos, rare processes, and cosmic frontier experiments and enabling R&D require more space than available
  - Expanding SURF represents an opportunity to expand US leadership in discovery science
- **Leverage the LBNF excavation enterprise to increase underground space at SURF** in a ***timely*** and cost-effective way to allow the US to compete for siting next-gen WIMP dark matter experiments
- Additional space and facilities for research and development will enable the program including particle and nuclear physics and others like QST R&D, engineering, geology, biology, etc.
  - **Make SURF an SDSTA-managed DOE User Facility** to foster cross-cutting underground science in the US
- Invest in the diversity of people and expertise required for the design, installation, integration, and operations of this increasingly complex program



SURF expansion would enable US leadership in many aspects of underground science

IF Key Message #1

IF-1 Double the US Detector R&D budget over the next five years and modify existing funding models to enable R&D Consortia along critical key technologies for the planned long term science projects, sustaining the support for such collaborations for the needed duration and scale.

Since last Snowmass funding for Detector R&D in the US has been on the decline. Detector R&D shares pot of money (DOE) with detector facilities operations, which need to be protected at all cost. Any decline in research funds for detectors has direct hit on R&D.

CERN RD Collaborations for targeted and coordinated detector R&D wildly successful. We recommend the establishment of a similar model of R&D Consortia in the US, along strategic technological directions, and perhaps under the guidance of CPAD. We recommend a strong link to the newly formed R&D collaboration model at CERN, following the ECFA Roadmap.

Computation and Instrumentation

We recommend the creation of a standing **Coordinating Panel for Software and Computing (CPSC)** under the auspices of DPF mirroring the panel for advanced detectors (CPAD) established in 2012.

Promote, coordinate, and assist the HEP community on Software and Computing, working with scientific collaborations, grassroots organizations, institutes and centers, community leaders, and funding agencies on the evolving HEP Software and Computing needs of experimental, observational, and theoretical aspects of the HEP programs. The scope should include research, development, maintenance, and user support.

Community Engagement

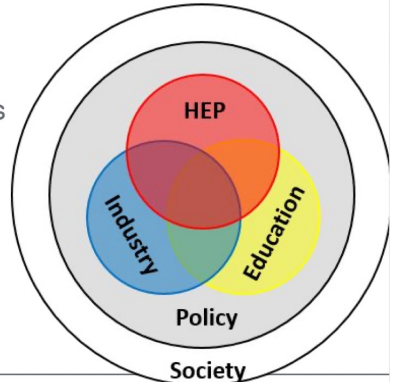
CEF: Frontier-wide

Major Goals

- It is critical that we all agree on the importance of *everyone* working together to organize and develop our ongoing efforts in CE in a *coherent* manner focused on improving our HEP community and achieving the vision for our field
- A *structure* must be established within HEP for taking ownership and responsibility for *implementing* CEF recommendations and *monitoring* their progress across the entire field

Structural Change

- All stakeholders form a P5-equivalent panel to shepherd CEF recommendations
  - Must have direct connection to multiple streams of resources
  - As opposed to P5: agencies fund/implement projects, so P5 lives within DOE/NSF
- Review CEF integration in Snowmass
  - Perhaps do major work on field-wide CEF planning asynchronously, enhance participation
  - Other Frontiers could still report on CEF activities during Snowmass



- Applications and Industry
- Career Pipeline and Development
- Diversity, Equity, & Inclusion
- Physics Education
- Public Education and Outreach
- Public Policy & Government Engagement
- Environmental & Societal Impacts

On to P5

Snowmass was WONDERFUL!!!

Snowmass results will be critical input to P5

- The hard work was impressive and is an important documentation of visions for our field

Turning towards P5

- Every idea presented at Snowmass will receive due consideration

(P5)

- Report is not written
- Decisions are not made
- P5 will take a fresh look at our project program
- P5 is a process and the process will be followed

Next P5 chair:

JoAnne Hewett

Considerations for the Next P5

- Grand, long-term, and global vision for U.S. particle physics
- Realistic budget scenarios
- Balanced portfolio of small/mid-scale/large projects
- Must consider a holistic view of program
  - Project costs
  - Operations costs
  - Research program to deliver the science
  - Technology R&D for the future
- Community engagement, including this week's Snowmass study process, remains critical to success

Note added – recent good funding news:

IRA - $304M APPROPRIATION to HEP

CHIPS and Science Act – recommends increases to NSF/DOE

Harriet Kung

Delayed: P5 Charge unveiled at Dec. 8 HEPAP meeting

Preliminary P5 Timeline

JoAnne Hewett

- Form panel by early Fall
  - Call for nominations for P5 members in early Aug 2022
  - Panel members wear a community hat
- Hold hybrid in-person/virtual townhalls in Fall 2022
  - Aim for further community input and further information on potential future projects
  - Opportunity for each panel member to start with equal footing covering all frontiers
- Deliberations Winter/Spring 2023
  - Will provide ample opportunity for further community input
- Aim for report late Spring/Early Summer 2023 for HEPAP to approve and submit to DOE/NSF

Gina Rameika named the new associate director for high-energy physics at DOE

November 3, 2022 | edited by Lisa Roberts

Share Tweet Email

In her new role with the DOE's Office of Science, Gina Rameika will oversee all high-energy physics research activities in the United States. Photo: Gina Rameika.

The U.S. Department of Energy's Office of Science recently announced that Regina "Gina" Rameika has accepted the role of associate director for its Office of High Energy Physics. In her new role, Rameika will oversee all high-energy physics research activities in the United States at both national laboratories as well as universities. She joins the DOE Office of Science on Nov. 7.

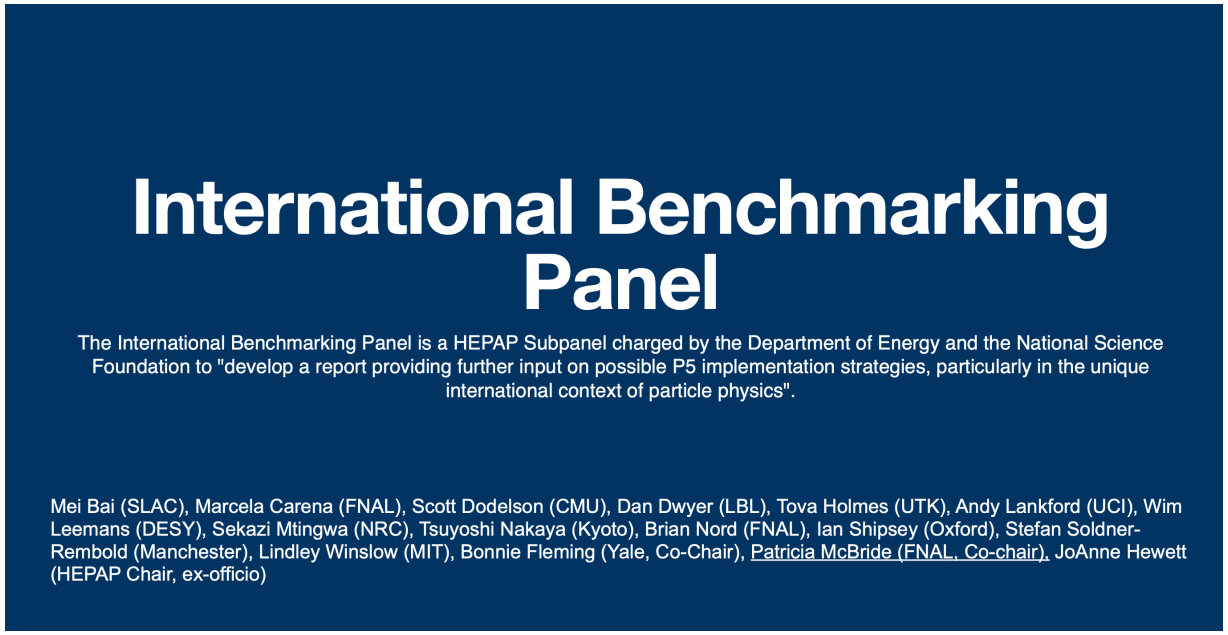
"Gina has demonstrated tremendous leadership in the national laboratory environment with DOE projects and with international science collaborations," said Asmeret Asefaw Berhe, director of the Office of Science. "We are thrilled to have Gina join the Office of Science, given her vast experience and skilled leadership."

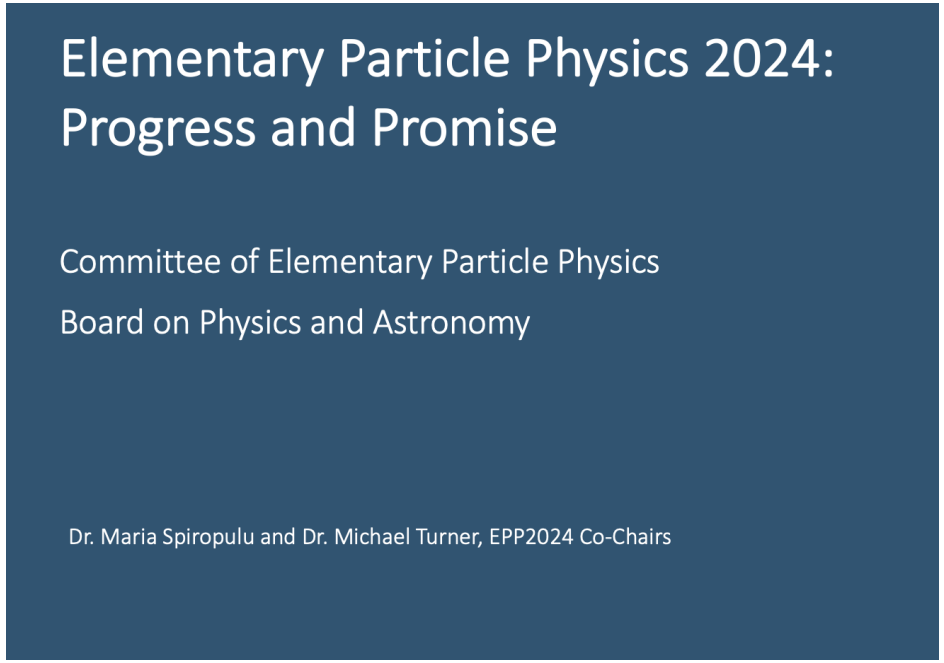
Rameika hails from the DOE's Fermi National Accelerator Laboratory where, as a distinguished scientist, she spent much of her career in neutrino science and experimental particle physics. Her responsibilities have ranged from managing particle detector construction projects to leading the Deep Underground Neutrino Experiment, the international science collaboration that plans to carry out the world-leading experiment currently under construction as part of the DOE Long-Baseline Neutrino Facility/DUNE-US Project.

But wait, there's more…

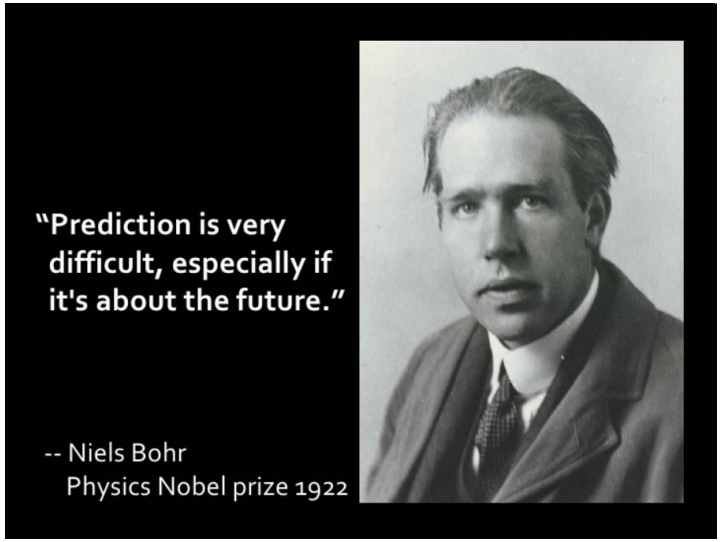
International Benchmarking Subpanel &

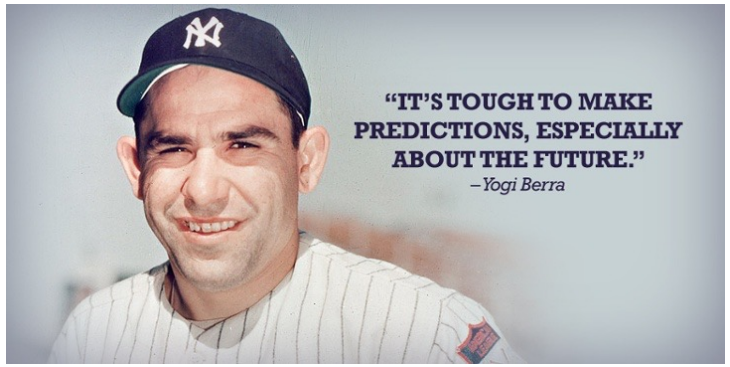
NAS Elementary Particle Physics 2024 (EPP 2024)

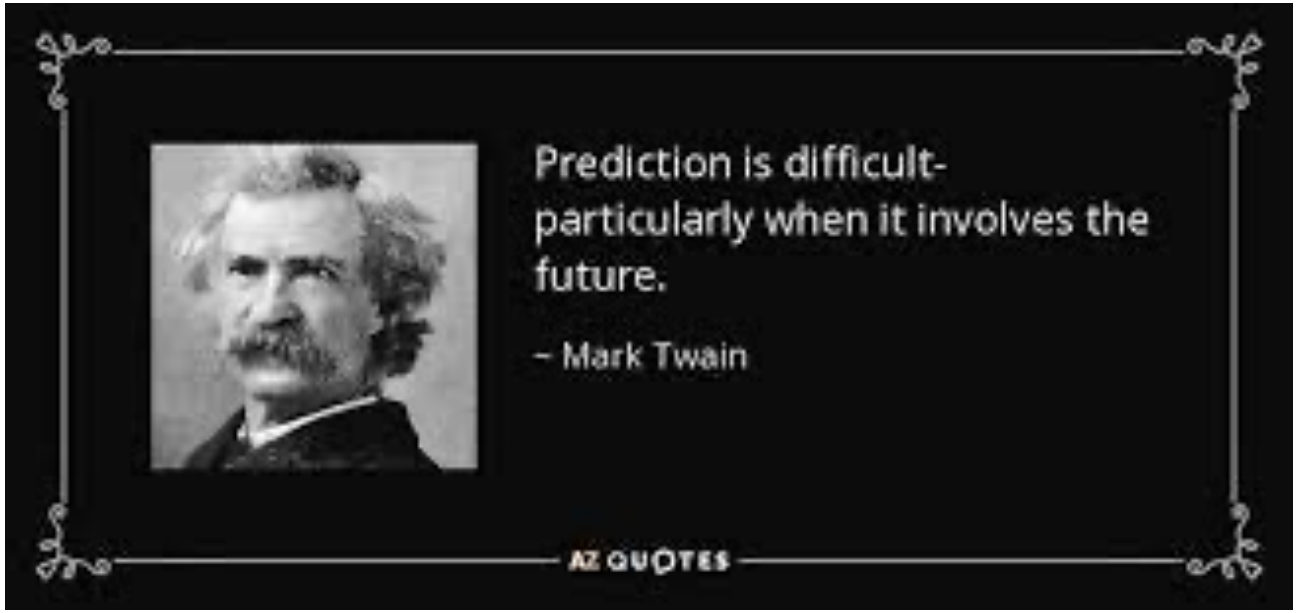




Personal Observations







Lessons from the Last Snowmass/P5 Process

- Collaboration with our agency (DOE and NSF) and global partners is essential.
- A coherent and balanced plan is essential.
  - Across “subfields”
  - Small, Medium, and Large Experiments
  - Fund “enabling” subfields
  - **Research and Projects?**
- A consistent message from our community is helpful.

There continues to be strong support for carrying through on the elements of the previous plan: HL-LHC, Dune Phase 1, LSST/Vera Rubin, etc.

The last plan succeeded – and the elements of a new successful plan exist!

“NEW” (US) issues we must address…

- **Balance support for projects and R&D** (Kung: “holistic” approach)
  - Theory, Accelerator, Detectors
  - R&D trains and supports students and postdocs … the future of US HEP
- **Mix of short-term and long-term, small, medium, and large, projects.**
  - Need a continuous stream of opportunities for young scientists, even though the time-scales of our large projects continue to increase!
- **We need sustained and impactful outreach to the public and to government engagement, to create excitement and justify support.**
- **Address the (lack of) Diversity, Equity, and Inclusion in our field.**
  - If US particle physics is to be healthy in 10 years, let alone for the balance of the century, we must do a better job of including people from all backgrounds.

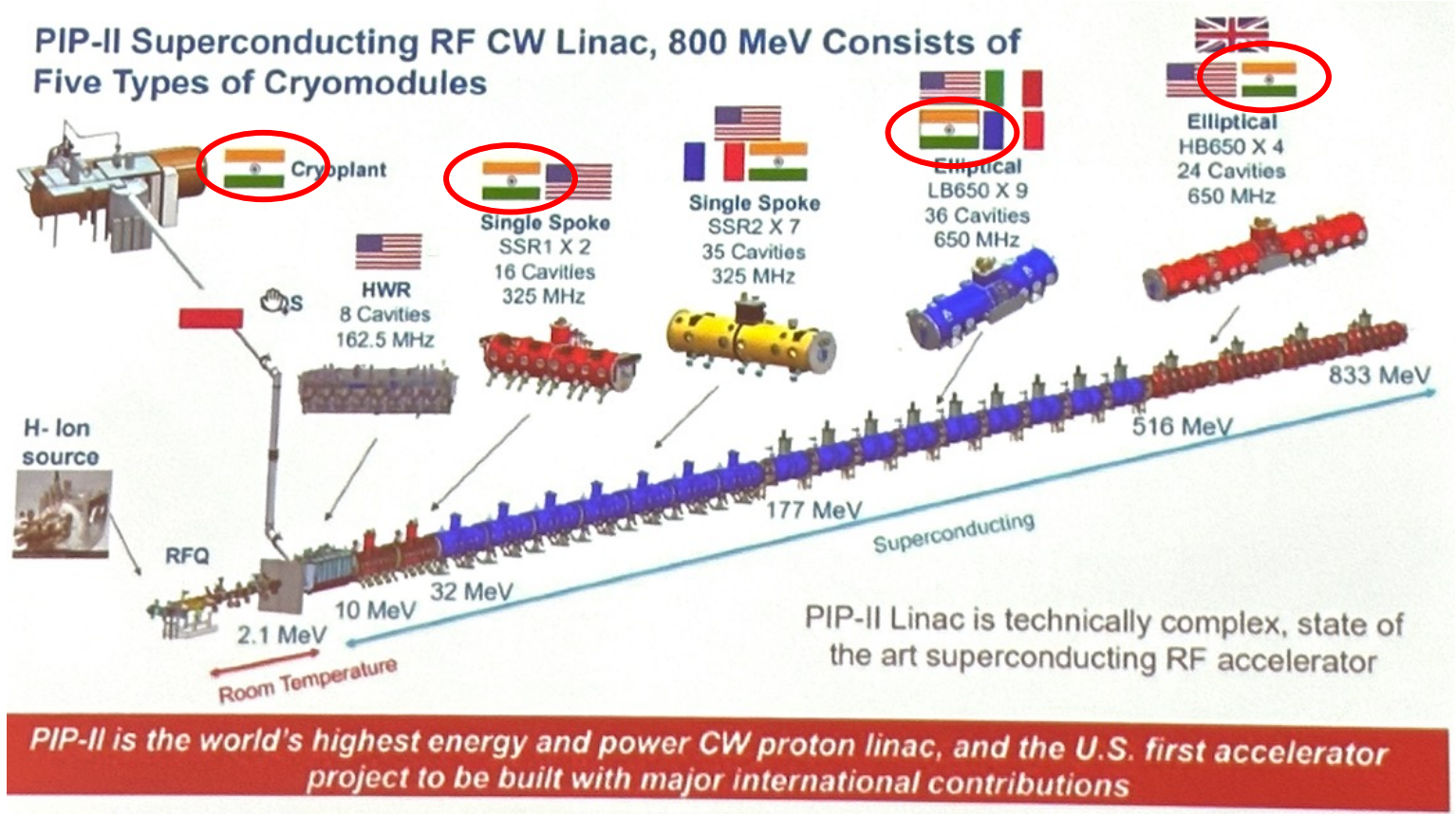
Snowmass Summary and Outlook

- The Seattle meeting was a success, with a large in-person and remote presentation, with a total of over 1300 participants.
  - **The US HEP community showed great commitment and resilience to complete the process to this point – and did so in the face of great challenges!**
- We have the input needed to complete a final Snowmass document, which will be completed by the Steering Committee SOON!
- We plan to give P5 a thorough picture of the most important physics opportunities, and the capabilities needed to achieve them.
- **We expect that we will emerge from this 2022/23 Snowmass/P5 process with a program that will enable us to do great physics and will have the same or higher level of community support than we achieved in 2013/14.**

Preliminary Thoughts/Questions on the HEP Program in India … based on the excellent presentations at PAQS

Look forward to learning/hearing more at today's panel…

Near Term: The US and Indian HEP Programs are very well-aligned: LHC/HL-LHC, LBNF/DUNE, Belle II, …

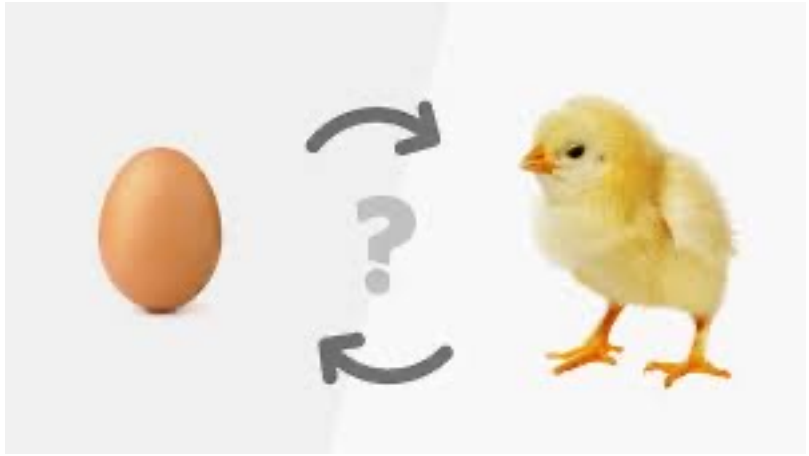


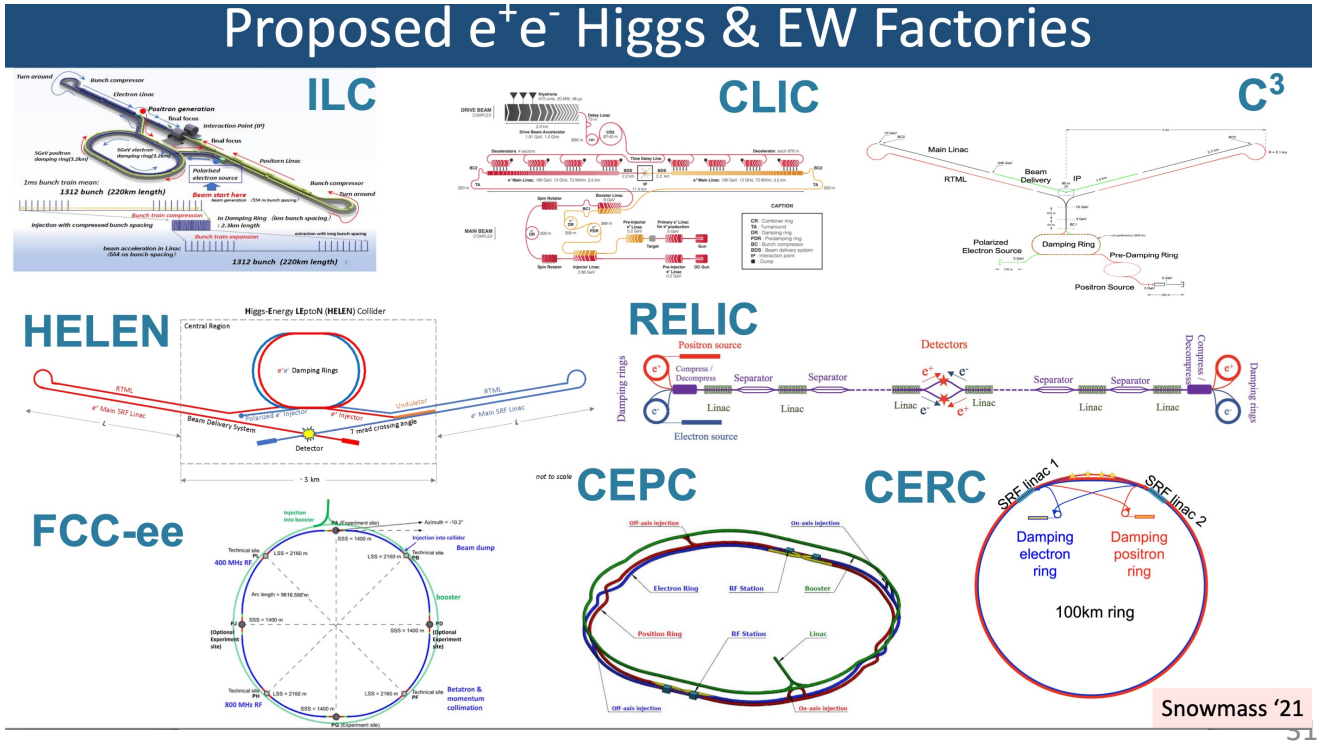
How do we maintain and grow fruitful global collaborations in the face of rapidly changing/fluctuating domestic and international conditions?

Intermediate Term: Global Higgs Factory

- How do we, as a global HEP community, take the next step at the Energy Frontier – which will require a thoroughly global effort?
  - Can we resolve the “chicken and egg problem” that has plagued the ILC?

Our future depends on it…





Plan now for mid-century … and beyond

FCC Feasibility Study 2021-2025

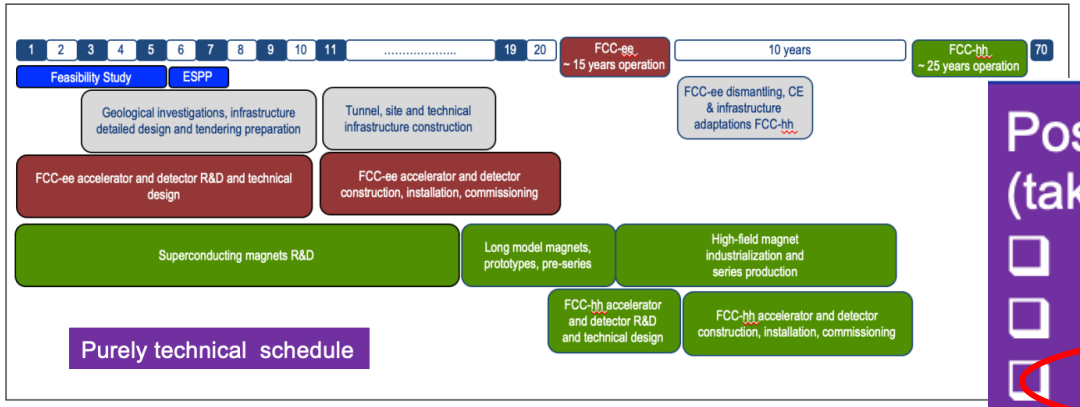
FUTURE CIRCULAR COLLIDER

Numbers are for 100 km ring

	√s	L /IP ($cm^{-2}\,s^{-1}$)	Int. L /IP(ab^{-1})	Comments
e^+e^- FCC-ee	~90 GeV Z 160 WW 240 H ~365 top	230 x10^{34} 28 8.5 1.5	75 5 2.5 0.8	2-4 experiments Total ~ 15 years of operation
pp FCC-hh	100 TeV	5 x 10^{34} 30	20-30	2+2 experiments Total ~ 25 years of operation
PbPb FCC-hh	$\sqrt{s_{NN}}$ = 39TeV	3 x 10^{29}	100 nb^{-1}/run	1 run = 1 month operation
ep Fcc-eh	3.5 TeV	1.5 10^{34}	2 ab^{-1}	60 GeV e- from ERL Concurrent operation with pp for ~ 20 years
e-Pb Fcc-eh	$\sqrt{s_{eN}}$ = 2.2 TeV	0.5 10^{34}	1 fb^{-1}	60 GeV e- from ERL Concurrent operation with PbPb

Potentially a multi-stage facility with immense physics potential (energy and intensity).

Feasibility Study:
- ❑ Focus is on FCC-ee and magnet R&D
- ❑ ~ 40 MCHF/year from CERN budget (half for magnet R&D)
  Additional funding from EU and collaborating institutes (e.g. CHART)
- ❑ Results will be summarised in Feasibility Study Report end 2025



Possible schedule
(taking into account resources constraints):
- ❑ project's approval by end of decade
- ❑ construction's start early 2030s
- ❑ FCC-ee operation: 2048-2063
  (10 years Z, W, H and 5 years tt)

Technical schedule: operation starts early 2040s

How do we collaborate to create a vibrant global program that retains the brightest scientists, providing them continuous scientific and professional opportunities over 50+ years?

Fabiola Gianotti, Snowmass

These are difficult questions to answer … but we don’t have to do so today!

- The future is built incrementally.
- The path taken will depend on the contingencies of the future.
  - COVID & the invasion of Ukraine, for example, will have large, lasting, and unforeseen consequences.
- Our past successes was built on global scientific and human connections.
  - CERN: DAE agreement 1991, Associate Membership 2016
  - FNAL: "Fermilab's strong partnership with Indian institutions in particle physics research dates back to 1986.” Project X collaborative agreement 2011.
- This workshop is a great example of the work needed to build, maintain, and expand these needed connections.

The Beginning of a New Era?