



Snowmass and the Future of US HEP

Presented to LISHEP 2023

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Fermilab

Mar. 9, 2023



Outline



- Brief history of US HEP Community Planning Exercise and Prioritization Panel "P5"
- Previous Snowmass 2013 and P5 2014, including outcomes
- Impact of COVID on our plans
- Snowmass 2021, which culminated in a 10-day long workshop, the Community Summer Study, CSS, in Seattle Washington
- Timeline and links to the report, a.k.a. the "Snowmass Book"
- Very brief discussion of some of the conclusions and takeaways messages from the Snowmass Frontiers – **personal viewpoint**
- P5 status
- **Summary and Outlook**

History: US HEP Community Planning Exercise, a.k.a. Snowmass

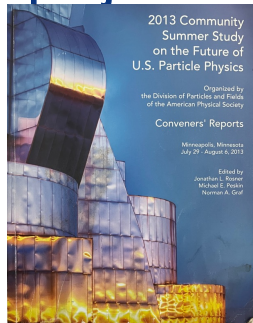


- **Snowmass, the DPF-hosted Community Planning Exercises, started in 1982**
 - The then DPF chair Charles Baltay said: “The 1982 DPF Summer Study was the first attempt in recent years to bring together physicists from the whole country to consider the future of our field from the point of view of the best overall national program. The DPF Executive Committee feels that this summer study was sufficiently useful in this last respect to hold similar summer studies at appropriate times in future years.”
 - The study lasted several months and culminated in a 3-week-long workshop in Snowmass, Colorado
- **Goal: To identify the most important questions in HEP and the tools and infrastructure required to address them**
 - To achieve a broader and deeper understanding of the science in our field
 - To engage junior scientists and foster our community development
 - To reach a compelling vision for the field moving forward
- The 2013 Snowmass
 - Moved outside of Snowmass, Colorado to University of Minnesota
 - **Designed to provide input to the “Particle Physics Project Prioritization Panel” (P5) process**

Snowmass 2013/P5 2014



- In 2013, Snowmass provided input to the High Energy Physics Advisory Panel's (HEPAP) subpanel, the Particle Physics Project Prioritization Panel, a.k.a. P5, charged by DOE and NSF
 - Using Snowmass's scientific input and budget scenarios provided by the funding agency, P5 developed and presented to DOE and NSF, via HEPAP, a 10-year execution plan, with priorities and recommendations, for the field in the US, with an eye also towards the ten years following that
- P5 has a broad mandate but its charge tends to focus it on large projects and facilities



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



P5 Physics Drivers



- **From P5 report:** “Snowmass, the yearlong community-wide study, preceded the formation of our new P5. A vast number of scientific opportunities were investigated, discussed, and summarized in Snowmass reports. **We distilled those essential inputs into five intertwined 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**”

Please look at pages 1 and 2 of the 2013 Snowmass Book

Did Snowmass 2013 have an impact on the P5 outcome?



- **I would say yes!**
- The main recommendations (LHC, neutrinos) needed justification and incorporation into real budgets with timelines
- There were, however, a total of 29 recommendations, including
 - Maintain a program of projects of all scales, from the largest international projects to mid- and small-scale projects.
 - Increase the budget fraction invested in construction of projects to the 20%–25% range.
 - Provide the flexibility to support new ideas and developments
 - Select and perform in the short term a set of small-scale short-baseline experiments
 - Build DESI and complete LSST,
 - Proceed with G2 Dark Matter programs, support one or more G3 dark Matter Programs
 - Complete Mu2e and muon g-2

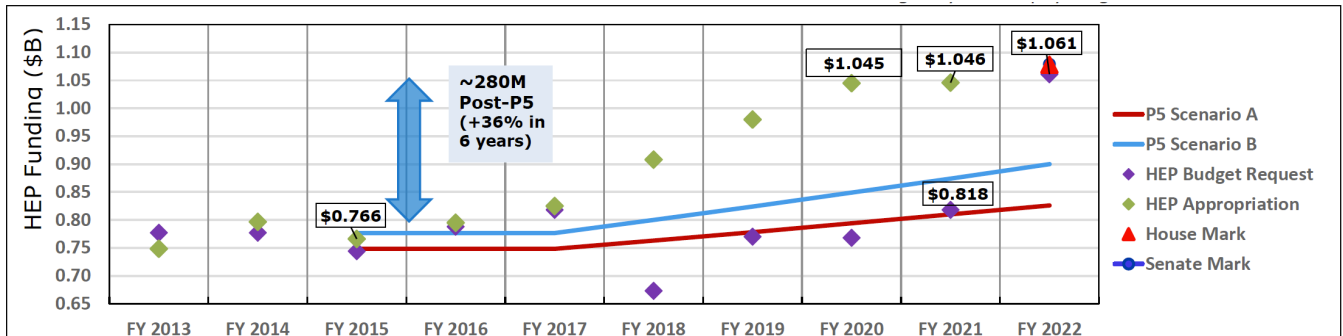
I do not believe that all these would have been included without our strong communities developing excellent proposals

Did P5/2014 have an impact on Funding Outcome



- The U.S. particle physics community enthusiastically supported the P5 plan.
 - 2,331 community members signed a letter of support to DOE and NSF (organized by DPF)

“Four years into executing the P5, the Committee commends the Office of Science and the high energy physics community for achieving significant accomplishments and meeting the milestones and goals set forth in the strategic plan...”



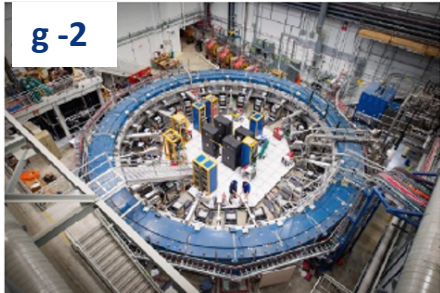
Project Outcome, P5 2014



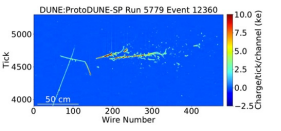
LBNF/DUNE



g -2



ATLAS Upgrade



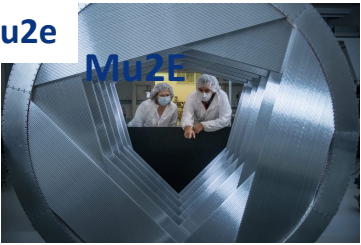
CMS Upgrade



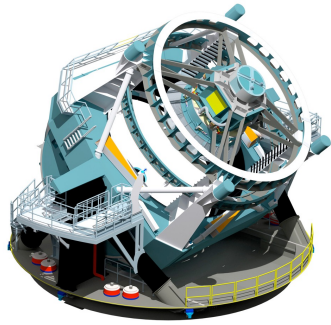
Mu2e



Mu2E



Vera Rubin LSST

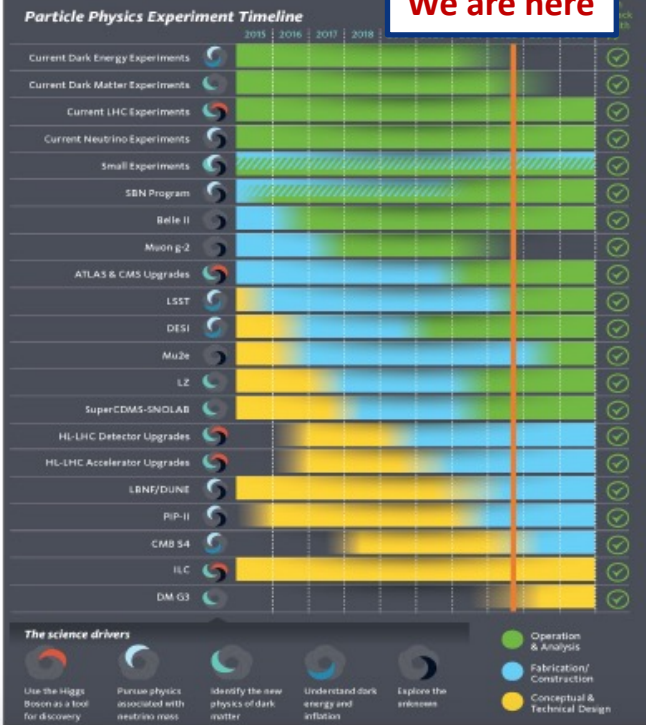


and many other projects, large and small

We are ready for a new Strategic Plan!!



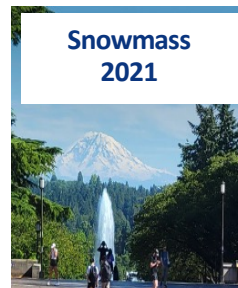
We are here



When most projects have gone into operation (**green**) or are solidly into construction/fabrication (**blue**) and there are too few in the design stage, (**orange**) it is time to develop the next plan!!



Time for a new Snowmass/P5 Working towards:



Impact of COVID on Snowmass



- 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 in Seattle**
- 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 Snowmass and 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 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 plans for completing the work in for the July 2022 meeting
- We hoped that vaccination and mitigation would enable us to have a large face-to-face component to our planned hybrid meeting in UW

Community Summer Study (CSS) and Workshop



- Community Planning Meeting on Oct 5-8, 2020 (Official planned start)
- **Snowmass Day (post-pause restart): September 24, 2021**
- **Snowmass Community Summer Study started (July 17, 2022)**
[Home Page for Seattle, July 17-26, 2022](#)



Evolution of the Frontier Structure



- In 2013, we had
 - THREE “cutting edge scientific working groups”, a.k.a. **Frontiers**: Energy, Intensity, and Cosmic; and
 - FIVE cutting edge supporting and infrastructure working groups, a.k.a. **Capability Groups**.
- In 2021, we have **TEN Frontiers**
 - The Intensity Frontier split into two
 - Neutrinos
 - Rare Decays and Precision Measurements
 - Theory became a full activity
 - The **FIVE Capability groups** were transitioned to Frontiers, since they all have major R&D and scientific components
 - The “Communication, Education, and Outreach” group was renamed the “Community Engagement Frontier”

Organization in Ten "Frontiers" - I



Accelerator



Steve Gourlay
(LBNL)



Tor Raubenheimer
(SLAC)



Vladimir Shiltsev
(FNAL)

Cosmic



Aaron Chou
(Fermilab)



Marcelle Soares-Santos
(U.Michigan)



Tim Tait
(UC Irvine)

Community Engagement



Kétévi Assamagan
(BNL)



Breese Quinn
(Mississippi)

Computing



Steven Gottlieb
(Indiana U.)



Ben Nachman
(LBNL)



Daniel Elvira
(FNAL)

Energy



Meenakshi Narain
(Brown U)

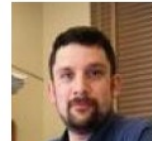


Laura Reina
(FSU)



Alessandro Tricoli
(BNL)

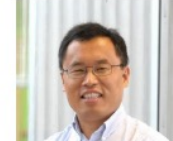
Instrumentation



Phil Barbeau
(Duke)



Petra Merkel
(FNAL)



Jinlong Zhang
(ANL)

Organization in Ten "Frontiers" - II



Neutrino



Patrick Huber
Virginia Tech



Kate Scholberg
Duke University



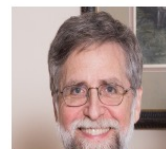
Elizabeth Worcester
BNL



Marina Artuso
(Syracuse U.)



Alexey Petrov
(Wayne State U.)



Bob Bernstein
(FNAL)

Rare Processes & Precision Measurements

Theory



Nathaniel Craig
(UCSB)



Csaba Csaki
(Cornell)



Aida El-Khadra
(UIUC)

Underground Facilities and Infrastructure



Laura Baudis (U. Zurich)



Jeter Hall (SNOLAB)



Kevin Lesko (LBNL)



John Orrell (PNNL)

All frontiers have topical subgroups (details on Twiki)

Accelerator:	7	Instrumentation:	10
Cosmic:	7	Neutrino:	10
Community Engagement:	7	Rare Processes:	7
Computing:	7	Theory:	11
Energy:	10	Underground:	6

More than 1500
people have
signed up to
participate in
Snowmass!

10 Frontiers

80 Topical Groups

Snowmass 2021 organization

Energy	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
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
Rare Processes	Weak Decays of b and c, Strange and Light Quarks, Fundamental Physics and Small Experiments. Baryon and Lepton Number Violation, Charged Lepton Flavor Violation, Dark Sector at Low Energies, Hadron spectroscopy
Cosmic	Dark Matter: Particle-like, Dark Matter: Wave-like, Dark Matter: Cosmic Probes, Dark Energy & Cosmic Acceleration: The Modern Universe, Dark Energy & Cosmic Acceleration: Cosmic Dawn & Before, Dark Energy & Cosmic Acceleration: Complementarity of Probes and New Facilities
Theory	String theory, quantum gravity, black holes, Effective field theory techniques, CFT and formal QFT, Scattering amplitudes, Lattice gauge theory, Theory techniques for precision physics, Collider phenomenology, BSM model building, Astro-particle physics and cosmology, Quantum information science, Theory of Neutrino Physics
Accelerator	Beam Physics and Accelerator Education, Accelerators for Neutrinos, Accelerators for Electroweak and Higgs Physics, Multi-TeV Colliders, Accelerators for Physics Beyond Colliders & Rare Processes, Advanced Accelerator Concepts, Accelerator Technology R&D: RF, Magnets, Targets/Sources
Instrumentation	Quantum Sensors, Photon Detectors, Solid State Detectors & Tracking, Trigger and DAQ, Micro Pattern Gas Detectors, Calorimetry, Electronics/ASICS, Noble Elements, Cross Cutting and System Integration, Radio Detection
Computational	Experimental Algorithm Parallelization, Theoretical Calculations and Simulation, Machine Learning, Storage and processing resource access (Facility and Infrastructure R&D), End user analysis
Underground Facilities	Underground Facilities for Neutrinos, Underground Facilities for Cosmic Frontier, Underground Detectors
Community Engagement	Applications & Industry, Career Pipeline & Development, Diversity & Inclusion, Physics Education, Public Education & Outreach, Public Policy & Government Engagement
Snowmass Early Career	Snowmass Early Career to represent early career members and promote

From the US and many other nations. From HEP and many related disciplines.

Snowmass Early Career (SEC) - I



- Early Career physicists have been formally represented at Snowmass since 2001 and gained even more formal recognition in 2013 and now in 2021/22
- This Snowmass they were treated ~ as a full frontier
 - Many problems have been exposed and HEP will have to develop the means to make progress faster
 - The EC physicists have a writeup in the Snowmass book
- The issues addressed by the Community Engagement frontier and the SEC are now at the forefront of our agenda and those of the DOE and NSF
 - Possible roles for funding agencies and national organizations such as DPF, AAAS have been identified

Snowmass Early Career (SEC) - II



- Key Initiatives:
 - **Snowmass Coordination:** Coordinate with the Snowmass frontiers and help get EC members involved in the process
 - **In-reach:** Professional development and building cohesion within the early career community
 - **Diversity, Equity, and Inclusion (DEI):** Initiatives to make HEP more representative, welcoming, inclusive, and equitable.
 - **Survey:** Collect data on the early career membership
 - **Long-Term Organization:** There is interest in defining an early career organization to continue after Snowmass

Letters of Intent



- **Letters of Interest (April 1 – August 31, 2020) – <https://snowmass21.org/loi>**
 - Two pages
- Not done in 2013 (or previously)
- >1500 submitted
- These resulted in the writing of over 500 contributed papers (white papers)

Participation in this CSS Hybrid Meeting



■ Participants

- Number of in-person participants: 743
- Number of virtual participants: 654
- Local Organizing Committee/Volunteer/Press: 58

■ Total number of participants: 1397



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*

- This is close to the largest in-person attendance ever but is certainly the largest if remote participation is included.
- Its execution is a story by itself, which I hope will be written
- Special precautions were taken by the community to limit the spread of COVID. Our Community did amazing job of complying with voluntary measures to keep us all safe!

Community Summer Study Hybrid Workshop



Organization of the meeting -



	Sunday, July 17 Day 1	Monday, July 18 Day 2	Tuesday, July 19 Day 3	Wednesday, July 20 Day 4	Thursday, July 21 Day 5	Friday, July 22 Day 6	Saturday, July 23 Day 7	Sunday, July 24 Day 8	Monday, July 25 Day 9	Tuesday, July 26 Day 10	Wednesday, July 27 Day 11
07:30 - 08:00 AM	Registration										
08:00 - 08:30 AM											
08:30 - 09:00 AM											
09:00 - 09:30 AM	Introductory Plenary	Parallel Sessions							Snowmass Frontier Summaries		
09:30 - 10:00 AM											
10:00 - 10:30 AM											
10:30 - 11:00 AM											
11:00 - 11:30 AM											
11:30 - 12:00 PM											
12:00 - 12:30 PM	Lunch	Lunch, Poster & Exhibit	Lunch, Poster & Exhibit, and FOA/DOE General Meeting	Lunch, Poster & Exhibit and NSF General Meeting	Lunch, DOE Prgm Managers ,Astrophysics,2) NSF Special PI meeting	Lunch,DOE Prgm Managers 1) Energy 2) Theory	Lunch and Roundtables, Communicating HEP to the public and the gov	Lunch and COV Roundtables, lessons to be learned			
12:30 - 01:00 PM											
01:00 - 01:30 PM											
01:30 - 02:00 PM											
02:00 - 02:30 PM	Introductory Plenary	Parallel 1: AIML Parallel 2: Underground Science	Panel: Careers and Training the Next Generations	Parallel 1: Neutrino; Parallel 2: Rare processes	Colloquium on Rare Processes and Precision Measurements	Colloquium on Underground Physics	Colloquium on Energy Frontier	Presentation: Snowmass Early Career	Panel: Interconnections with other fields		
02:30 - 03:00 PM											
03:00 - 03:30 PM											
03:30 - 04:00 PM	Coffee	Parallel 1: The next accelerators; Parallel 2: LQCD	Parallel 1: Neutrino Colliders; Parallel 2: Cosmic	Colloquium on Instrumentation	Colloquium on new Accelerators and R&D	Colloquium on Theory	Colloquium on Computing	Parallel 1: Underrepresented Minorities; Parallel 2: Instrumentation project	Coffee		
04:00 - 04:30 PM											
04:30 - 05:00 PM	If	Coffee	Coffee		Coffee	Coffee	Coffee	Coffee			
05:00 - 05:30 PM											
05:30 - 06:00 PM											
06:00 - 06:30 PM		DE: Talks and Panel	Colloquium on Community Engagement		Colloquium on Cosmic Frontier	Colloquium on Neutrino Physics	Quantum Information Science in HEP	talks: DOE, NSF, FNAL Director other US labs	Panel International Status and Plans		
06:30 - 07:00 PM											
07:00 - 07:30 PM											
07:30 - 08:00 PM	Reception and Poster and Industry			Adam Riess Public Lecture	Physics Slam						
08:00 - 08:30 PM		Industry Networking									
08:30 - 09:00 PM											
09:00 - 09:30 PM						Conference Dinner		ColliderScope			
09:30 - 10:00 PM											
10:00 - 10:30 PM											

in the schedul and afor the mtend

Parallel Sessions



Timetable

Mon 18/07 Tue 19/07 Wed 20/07 Thu 21/07

Print

08:00 Accel. Frontier: AFx Internal (TBD) (AF) 242, Kane MGH 08:00 - 12:00

09:00 Accel. Frontier: AF3 Report (AF) 220, Kane Hall 08:00 - 12:00

09:00 Accel. Frontier: (AF) reser... 238, MGH 08:00 - 12:00

09:00 Cosm. Hugh... 08:00 - 12:00

09:00 Com. Front. End 08:00 - 12:00

Sat 16/07

08:00 Acce. Front. Intern AF7 (AF) Emilio Nann...

13:00 Social: Remotely Green Virtual

13:00 Kane Hall

Poster Session: Poster S...

17/07 Mon 18/07 Tue 19/07 Wed 20/07 Thu 21/07 Fri 22/07 Sat 23/07 Sun 24/07

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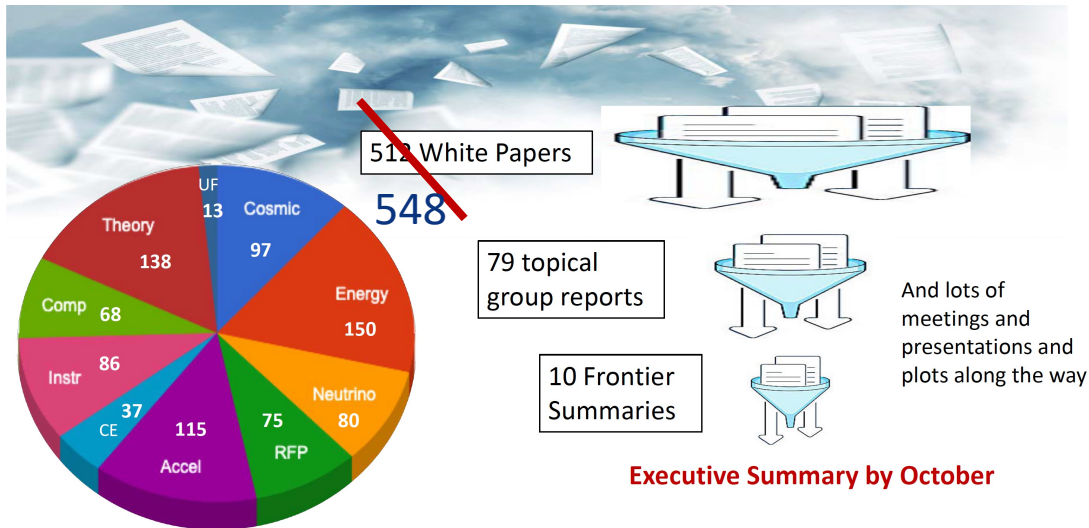
Acc. Fron... AF-wide	Acc. Fran...	Ener... Fron... Disc... and Sum... (EF) Alex... Tricol...	Neut... Phys... Fron... BSM... & Sect... & Rea... Neut... Early Career Pres... (NF) Jacob Zettl... Steven	Neut... Phys... Fron... DUNE & Inter... (Early Career Pres... (NF) Jacob Zettl... Steven	Rare... Proc... and Prec... Fron... All- Fron... Disc... (RF)	Theory Fron... String theory, qua... grav... black holes (TF01); CFT and formal QFT (TF03)	Theory Fron... BSM Model Buil... (TF08); Qua... infor... Scie... (TF) Grah... Kribs, simon	Cross Fron... Sess... IF-UF Cross-cutting Instr... for Neut... Exp... (XF)	Cross Fron... Sess... IF-UF Cross-cutting Instr... for Neut... Exp... (XF)	Cross Fron... Sess... TF-CF Cos... Fron... Theory Exp... (XF) Prof. Daniel Green, Flip Tane... Tracy
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July 26,

09/03/23 LISHEP 2023-JB



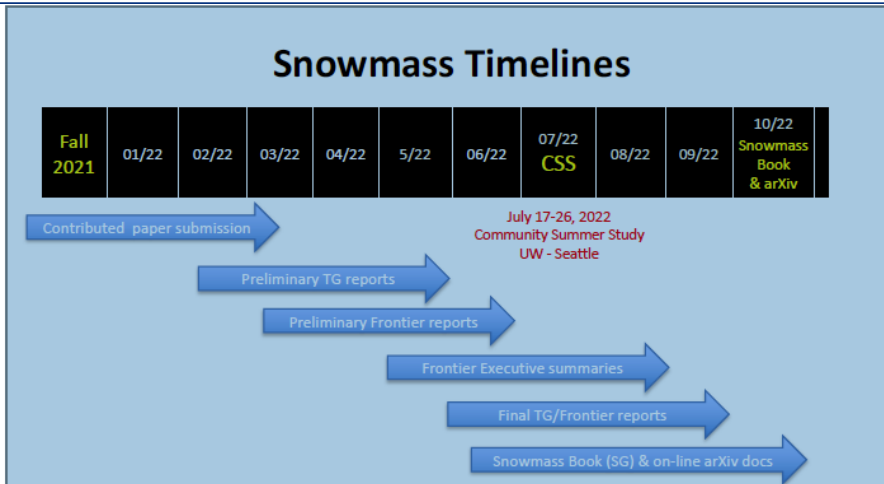
Converging to Consensus



Prisca Cushman

We are grateful for the large number of international participants and participants from outside HEP

Aspirational Timeline for Snowmass Report/Book

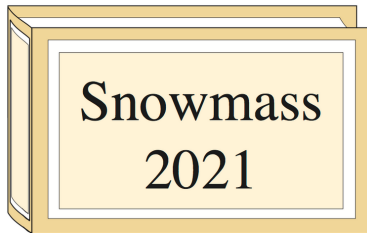


- **March 15: Contributed papers (a.k.a. White Papers)**
- **May 31: Preliminary Topical Group Reports**
- **June 30: Preliminary Frontier Reports**
- **July 17 – 26: Converge on reports for all the frontiers and produce executive summaries representing the views of their communities and providing the basic input needed for P5**
- **September: draft Executive Summary and Report Summary**
- **November: Report finalized and ready for submission (now end of Dec.)**

Snowmass Proceedings



- <https://www.slac.stanford.edu/econf/C210711/>



Proceedings of the 2021 US Community Study on the Future of Particle Physics

(Snowmass 2021)

organized by the APS Division of Particles and Fields

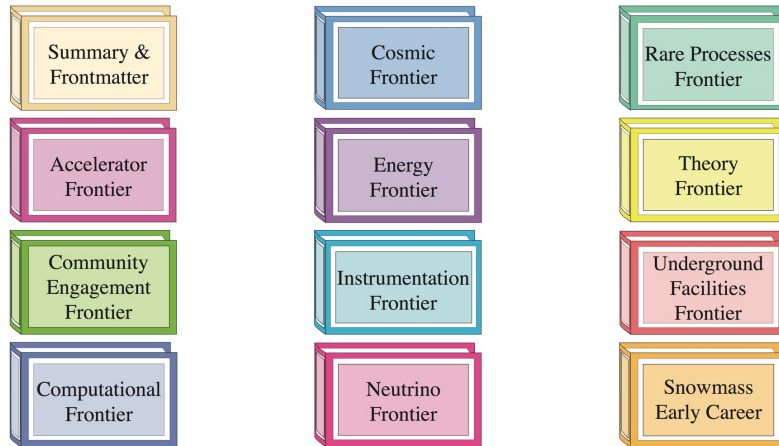
**These proceedings are dedicated to the memory of [Meenakshi Narain](#) (1964-2023),
in honor of her many contributions to Snowmass 2021.**

The US Community Study on the Future of Particle Physics (Snowmass 2021) was a grassroots study to plan for US particle physics in the decade 2025-2035 with an eye towards the following decade. Snowmass 2021 was organized by the APS Division of Particles and Fields, with input and collaboration from the Divisions of the Physics of Beams, Astrophysics, Nuclear Physics, and Gravitational Physics. It began with a kick-off meeting at the 2020 APS April Meeting and a Community-wide Planning Meeting in October of 2020. Because of the COVID pandemic, the study was paused between January and September 2021. The study finally concluded at the Community Summer Study meeting at the University of Washington, July 17-26, 2022.

The Summary and Frontier Reports are also available as a 700-page book. [This link will give you a pdf version of the Snowmass Book.](#)

We hope that this compendium of reports will be a useful source of background material in planning the future of our field over the next decade.

- Editors of these pages: Joel N. Butler, R. Sekhar Chivukula, Michael E. Peskin



Home

Other Products: Full Report: 750 pages; Report Summary: 70 pages

Topical Group Reports:

[Higgs Boson Physics](#)

Conveners: Sally Dawson, Patrick Meade, Isobel Ojalvo,
Caterina Vernieri

[arXiv:2209.07510](#)

[Heavy Flavor and Top Quark Physics](#)

Conveners: Reinhard Schwienhorst, Doreen Wackerath

[arXiv:2209.11267](#)

[Electroweak Precision Physics and Constraining New Physics](#)

Conveners: Alberto Belloni, Ayres Freitas, Junping Tian

[arXiv:2209.08078](#)

[Quantum Chromodynamics](#)

Conveners: Michael Begel, Stefan Hoeche, Yen-Jie Lee
Huey-Wen Lin, Swagato Mukherjee, Pavel M. Nadolsky
Christophe Royon, Michael Schmidt

[arXiv:2209.14872](#)

[Beyond the Standard Model](#)

Conveners: Tulika Bose, Antonio Boveia, Caterina Dogliani,
Simone Pagan Griso, James Hirschauer, Elliot Lipeles,
Zhen Liu, Nausheen R. Shah, Lian-Tao Wang

[arXiv:2209.13128](#)

Cross-Frontier Reports:

T. Roser et al.

[Report of the Snowmass 2021 Collider Implementation Task Force](#)

[arXiv:2208.06030](#)

K. M. Black et al.

[Report of the Snowmass 2021 Muon Collider Forum](#)

[arXiv:2209.01318](#)

M. Chamizo Llatas et al.

[Report of the Snowmass 2021 Electron-Positron Collider Forum](#)

[arXiv:2209.03472](#)

A. Boveia et al.

[Snowmass 2021 Dark Matter Complementarity Report](#)

[arXiv:2210.01770](#)

Contributed Papers:

General - centered on this frontier

A. Blondel et al.

[FCC-ee: Your Questions Answered](#)

[arXiv:1906.02693](#)

A. Blondel, P. Janot.

[Circular and Linear e+e- Colliders: Another Story of Complementarity](#)

[arXiv:1912.11871](#)

L. A. Anchordoqui et al.

[The Forward Physics Facility: Sites, Experiments, and Physics Potential Modern and Future Colliders](#)

[arXiv:2109.10905](#)

Personal and Preliminary View of Outcomes

Current Status and Outlook

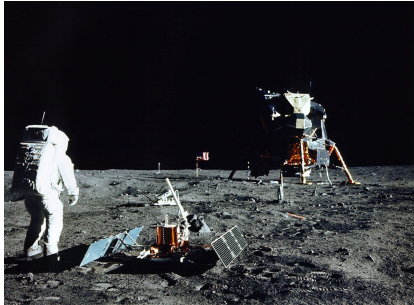


- No mass/energy scale for BSM physics
- Many new ideas have expanded the search space, e.g. for Dark Matter, but also in other topics as well
 - Huge mass range: **arguably 90 orders of magnitude**
 - Possibility of complex physics in hidden sectors
- **Some hints exist that may point us in a particular direction, e.g. flavor anomalies, g-2**
- Calls for a new strategy
 - More diverse, with large, medium, and small experiments
 - More interconnected – use all available information from all Frontiers, scales of experiments, theory, ...

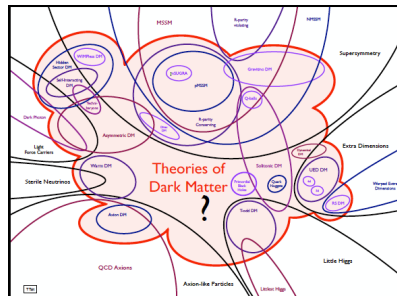
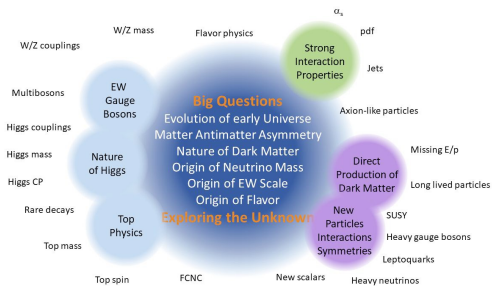
Every frontier is seeking BSM physics:

From Cosmic on DM: Delve deep, search wide! Search wide, aim high! Talk to each other, use all connections to gain insight!

Campaigns vs Explorations



1. Have a goal that you know is achievable
2. Have the means to carry it out
3. Have the determination and support to do it



In 2013/2014 with the Higgs newly discovered and the first 13 TeV run coming up, it was possible to imagine we would find specific targets and mass scale for BSM to shoot at that was accessible .

This has not happened yet

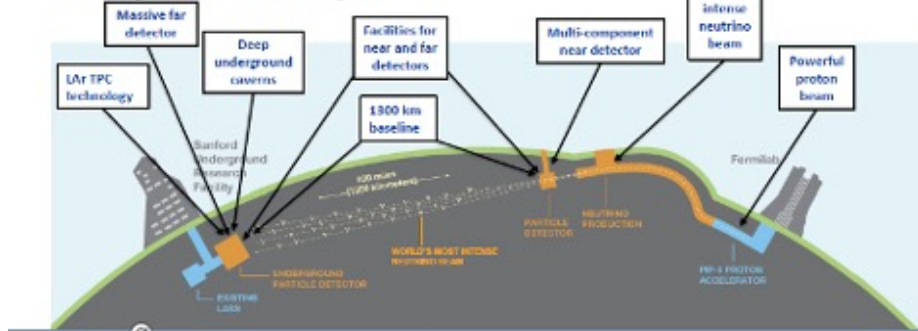
In many cases, we are not doing campaigns but “explorations” or “investigations. No “no lose” theorems. **This will be FUN!**

Large Projects: Neutrino Frontier



Deep Underground Neutrino Experiment (DUNE)

- The next-generation neutrino experiment



LBNF/DUNE-US Project + DUNE Int'l Project

Capability Description	Phase I	Phase II
Beamline		
1.2MW (includes 2.4MW infrastructure)	X	
2.4MW		X ¹
Far Detectors		
FD1 – 17 kton	X	
FD2 – 17 kton	X	
FD3		X ²
FD4		X ²
Near Detectors		
ND LAr	X	
TMS	X	
SAND	X	
MCND (ND GAr)		X

Note 1: requires upgrades to LBNF neutrino target and upgrades to Fermilab accelerator complex. The LBNF facility is built to support 2.4MW in Phase I.
 Note 2: Caverns and cryo-infrastructure built in Phase I

Neutrino Frontier Message

- A future program with a healthy breadth and balance of physics topics, experiment sizes, and timescales, supported via a dedicated, deliberate, and ongoing funding process, is highly desirable.
- Completion of existing experiments and execution of **DUNE in its full scope** are critical for addressing NF science drivers
- To exploit these new opportunities directed R&D needs to be supported.
- Strong and continued support for neutrino theory is needed.
- There are unique opportunities for NF to contribute to leadership of a cohesive, HEP-wide strategic approach to DEI and community engagement, which is urgently needed.

Energy Frontier



It is essential to

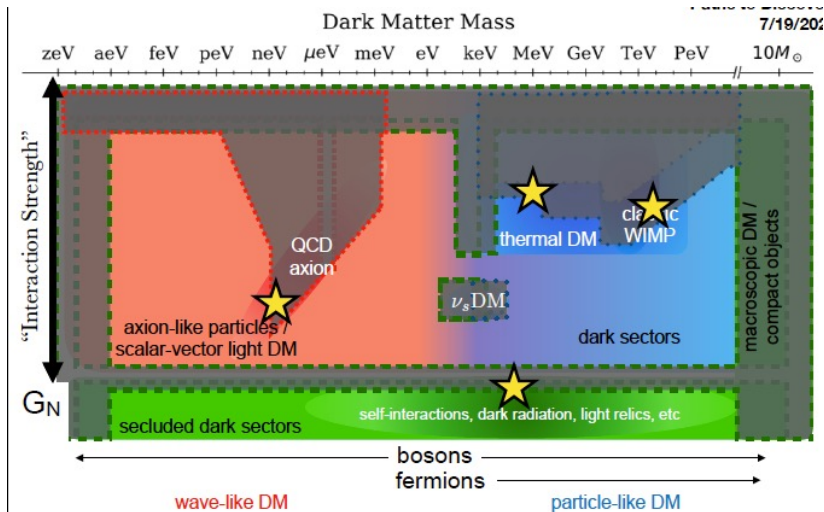
- Complete the LHC and HL-LHC program,
- Start now a targeted program for detector R&D for Higgs Factories
 - Support a **fast start** of the construction of a Higgs factory
- Ensure the long-term viability of the field by developing a **multi-TeV energy frontier facility such as a muon or hadron collider.**
- The US EF community has a renewed interest and ambition to bring back energy-frontier collider physics to US soil while maintaining its international collaborative partnerships and obligations, e.g. with CERN.
 - A US-sited linear e+e- collider (ILC/CCC) (**Cold Copper Collider**)
 - Exploring other e+e- collider options to fully utilize the Fermilab site
 - I sense that elements of the community at Snowmass are frustrated by a timeline which now appears to produce the next new collider about 25 years from now
 - Hosting a 10-TeV range Muon Collider
- Instrumenting uncovered parts of phase space in ATLAS and CMS (e.g. Faser, MATHUSLA) provides a “mid-scale” addition to the program and new opportunities for innovation and leadership

Cosmic Frontier/Dark Matter



- The space of dark matter models encompasses a dizzying array of possibilities, representing many orders of mass and couplings.
- But there is a plan: **'Delve Deep, Search Wide'** employs a range of direct searches for WIMPs interacting with targets on Earth, indirect searches for annihilation products, and cosmic probes based on structure, to scrutinize priority targets such as WIMPs and QCD axions, while broadly scanning parameter space, leaving no stone unturned.

- The next big project is CMB-S4
 - Endorsed as a "start" by P5 in 2014
 - Has CD-0 from DOE
- 2022-2036: Build and operate CMB-S4 (current large project)
- 2024: Target date for CD-0 for Spec-S5 (next large project)
- 2029: Begin CD process for LIM, GWO (future large project)



Rare Processes and Precision Measurements Frontier



- B- physics:
 - Strong support for US participation in LHCb and its next upgrade, Upgrade II.
 - Strong support for continued participation in BELLE
- Beam dump searches for Dark Matter
- Possible light quark physics experiments, e.g. REDTOP
- Possible Muon Facility (AMF) at FNAL
 - Would employ PIP-II and additional machine upgrades to enable a world-leading facility to study **Charged Lepton Flavor Violation** in all three muon modes: $\mu^-N \rightarrow e^-N$; $\mu \rightarrow e\gamma$; and $\mu \rightarrow 3e$
 - Two new small rings for $\mu^-N \rightarrow e^-N$ and $\mu^-N \rightarrow e^+N'$ and at high-Z and additional x100 in rate
 - x100-1000 more beam for $\mu \rightarrow e\gamma$ and $\mu \rightarrow 3e$ than are possible at PSI
 - a possible DM experiment
 - possible muonium-antimuonium oscillation experiment
 - possible atomic physics studies with muonia
 - possible muon EDM experiment

Would like the PHYSICS of FLAVOR to be a SIXTH “DRIVER”

Overview of the Large Scale Projects For the Four Experimental Physics Frontiers



Decadal Overview of Future Large-Scale Projects		
Frontier/Decade	2025 - 2035	2035 -2045
Energy Frontier	U.S. Initiative for the Targeted Development of Future Colliders and their Detectors	
		Higgs Factory
Neutrino Frontier	LBNF/DUNE Phase I & PIP- II	DUNE Phase II (incl. proton injector)
Cosmic Frontier	Cosmic Microwave Background - S4 Spectroscopic Survey - S5*	Next Gen. Grav. Wave Observatory* Line Intensity Mapping*
	Multi-Scale Dark Matter Program (incl. Gen-3 WIMP searches)	
Rare Process Frontier	Advanced Muon Facility	

Table 1-1. *An overview, binned by decade, of future large-scale projects or programs (total projected costs of \$500M or larger) endorsed by one or more of the Snowmass Frontiers to address the essential scientific goals of the next two decades. This table is not a timeline, rather large projects are listed by the decade in which the preponderance of their activity is projected to occur. Projects may start sooner than indicated or may take longer to complete, as described in the frontier reports. Projects were not prioritized, nor examined in the context of budgetary scenarios. In the observational Cosmic program, project funding may come from sources other than HEP, as denoted by an asterisk.*

Theory Frontier



- Support 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.
- Support for a balanced program of Projects and Research, as both are essential to the health of the field.
- Support for people, especially early career, who are the key “infrastructure” of Research.
- Support for targeted funding advancing the physics goals. (E.g. LQCD Project, LHC Theory Initiative, Neutrino Theory Network, QIS, AI/ML, Exascale Computing Project, SciDAC...)

Accelerator Frontier



- To enable the near-to medium-term future, AF needs
 1. An integrated **National Future Collider R&D Program** in OHEP to engage in the design and to coordinate development of the next generation collider projects such as: ILC, CLIC, FCC-ee, CCC/HELEN, a multi-TeV Muon Collider, or hadron collider.
- To enable medium- and long-term future, we 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), e.g.
 1. General Accelerator R&D (GARD)
 2. Accelerator and Test facilities

Computational Frontier



- With the end of the Moore's Law era, we will be using accelerators (GPUs, FPGAs, Vector units), parallelism within events, common systems, High Performance Computing Centers for production
 - There will be many changes
- CompF recommends 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.'*
- Long-term development, maintenance, and user support of essential software packages cutting across project or discipline boundaries is largely unsupported.
- Research and development (R&D) for software and computing cutting across project or discipline boundaries receive insufficient support.
- Scarcity of personnel and expertise jeopardizes the ability for full and optimal use of heterogeneous and high performance computing (HPC) resources

Instrumentation Frontier



- 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
 - 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,
- Advance performance limits of existing technologies and push new techniques and materials
- Develop and maintain the critical and diverse technical workforce, and enable careers for technicians, engineers and scientists across disciplines working in HEP instrumentation, at laboratories and universities
- Expand and sustain support for blue-sky, table-top RD, and seed funding.
- Develop and maintain critical facilities, centers and capabilities for the sharing of common knowledge and tools, as well as develop and maintain close connections with international technology roadmaps, other disciplines and industry.

Community Engagement Frontier

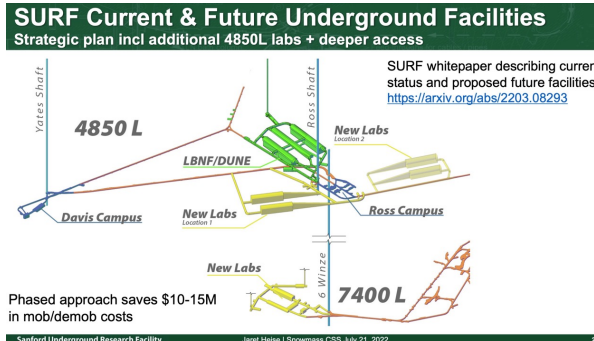


- Major Goals
 - It is critical that we all agree on the importance of everyone working together in CEF to organize and develop our ongoing CE efforts in a coherent manner focused on improving our HEP community and achieving the vision we are defining for our field.
 - A structure must be established 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
- Nevertheless, significant work was done over a very wide range of topics:
- Applications and Industry
 - Career Pipeline and development
 - Diversity, Equity, and Inclusion
 - Physics Education
 - Public Education and Outreach
 - Public Policy and Government Engagement
 - Environmental and Societal Impacts (sustainability)

By far the most disturbing problem the conveners encountered was the extremely low participation in CEF by members of our field.

Underground Frontier

- Neutrinos, rare processes, and cosmic frontier experiments and enabling R&D require more space than available
- 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 generation WIMP dark matter experiments
- 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



Some High-level Conclusions - I



- The science questions that HEP seeks to answer continue to be the ones identified in the 2013 Snowmass Report and so eloquently and succinctly summarized by P5 in the formulation of its Five HEP Science Drivers. These five drivers have guided US HEP for nearly a decade with great success. There was a consensus in Snowmass that these drivers were still relevant for the next decade.
 - There was a suggestion that the physics of flavor, currently included under the fifth driver, be more specifically recognized given the current tensions between recent results in this area and the Standard Model. An assessment of the current and projected status of HEP relative to the P5 Drivers is given below.
- The portfolio of projects should continue to include a healthy breadth and balance of physics topics, experiment sizes and timescales, supported via a dedicated, robust, ongoing funding process.
- Completion of existing experiments and operation of DUNE and the HL-LHC programs, priorities of the 2104 P5 are critical for addressing the science drivers for the near term and for much of the next two decades.
- Strong, robust support for the research program is essential to analyze the data from the existing and planned experiments, plan upgrades and future programs and projects, and educate the next generations of researchers and technical experts.
- Strong and continued support for formal theory, phenomenology and computational theory is needed, as are stronger, targeted efforts connecting theory to experiment.

Some High-level Conclusions - II



- Both R&D directed to specific future projects and generic research needs to be supported in critical enabling technologies such as accelerators, instrumentation/detectors and computation, and in new ones such as quantum science and machine learning.
- An overall strategy, with overarching goals, for HEP engagement with five interrelated communities: HEP itself and the broader academic community, K-postdoc education, private industry, government policy makers, and the broader society, should be formulated. A structure for achieving these goals should be provided, along with the necessary resources, should be provided.
- The HEP community should institute a broad array of practices programs to reach and retain the diverse talent pool needed for success in achieving our scientific vision.
- A cohesive, strategic approach to promoting diversity, equity and inclusion in high-energy physics, and to improving community outreach and engagement, is required

A Partial List of Key Issues



- How to promote and advance DEI?
- How to provide better support the members of our HEP Community, especially EC scientists
 - How can we support the requested Early Career organization?
 - How can we provide career opportunities for careers for our young people in and outside of HEP?
- How can we stay a vibrant field with the long timelines and few big projects?
- What opportunities will there be for small and mid-size projects and leadership positions for young scientists?
- How can we improve support for IF, CF, and AF to ensure continued development and transfer of expertise?
- Quantum Science and Technology appeared for the first time. Where does it fit into HEP – will it be the 11th Frontier for Snowmass 203X?

Snowmass Scope vs P5 Scope



- Snowmass discussed many issues that extend beyond P5s charge
 - Small scale experiments - P5 may prioritize directions, but not specific experiments
 - Connections to other efforts that are not funded in HEP budgets, but are crucial to carrying out the P5 agenda
 - Accelerators, Computing, Instrumentation all might like more guidance concerning priorities of the kind that P5 provides for the scientific program and perhaps more coherent direction
 - Career issues for young scientists
 - Quality of life and life-work balance for HEP scientists
 - Outreach and engagement
 - DEI, now a DOE and NSF priority
 - Connection to other fields beyond what DOE and NSF currently consider
- In some cases, DOE and NSF cannot address these issues
 - HEPAP may be able to help here
 - Organizations like APS/DPF or AAAS may provide some assistance
 - Many of the issues require actions by universities

We now have the new P5 charge, which may enable it to address some of these issues

P5 is Launched!



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
- 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



2023 P5 chair:



JoAnne Hewett, HEPAP Chair

<http://hitoshi.berkeley.edu/P5/>

Summary and Outlook



- Despite all the challenges, an amazing amount of outstanding work has been done by this large US, international, and interdisciplinary community and we emerged from the July meeting, with the needed input to the Snowmass Book and P5.
- We will give P5 a thorough picture of the most important physics opportunities, and the capabilities needed to achieve them
- We hope and expect that we will emerge from this 2021-22/2023 Snowmass/P5 process with a program that will enable us to do great physics and will have the same or a higher level of community support than we achieved in 2013/2014!

Thank you for your attention!
Questions/Comments?

Additional Information

Status of the Snowmass Report



- All ten Frontier reports are now available publicly in the arXiv.
 - Two additional reports that will appear in the Snowmass Report (11-12) are also available
 - The actual “freezing” of the report for the Snowmass Book will occur next week
 - Links to Frontier reports:
1. Energy Frontier
 - <https://arxiv.org/abs/2211.11084>
 2. Neutrino Physics Frontier
 - <https://arxiv.org/abs/2211.08641>
 3. Rare Processes and Precision
 - <https://arxiv.org/abs/2210.04765>
 4. Cosmic Frontier
 - <https://arxiv.org/abs/2211.09978>
 5. Theory Frontier
 - <https://arxiv.org/abs/2211.05772>
 6. Accelerator Frontier
 - <https://arxiv.org/abs/2209.14136>
 7. Instrumentation Frontier
 - <https://arxiv.org/abs/2209.14111>
 8. Computational Frontier
 - <https://arxiv.org/abs/2210.05822>
 9. Underground Frontier
 - <https://arxiv.org/abs/2211.13450>
 10. Community Engagement Frontier
 - <https://arxiv.org/abs/2211.13210>
 11. Snowmass Early Career
 - <https://arxiv.org/abs/2210.12004>
 12. Dark Matter Complementarity
 - <https://arxiv.org/abs/2211.07027>

Resources



- Some Resources for Snowmass 2021:
 - Link to conference homepage for Community Summer Study: <http://seattlesnowmass2021.net/>
 - Link to CSS agenda
 - List : <https://indico.fnal.gov/event/22303/timetable/?view=standard>
 - Block: <https://indico.fnal.gov/event/22303/timetable/#20220726.detailed>
 - CSS SLACK: snowmass2021 – snowmass2021.slack.com
 - Link to Snowmass 2021 portal twiki: <https://snowmass21.org/>
 - Link to Contributed papers: <https://snowmass21.org/submissions/>
 - Snowmass Early Career 2021: <https://snowmass21.org/start/young>
- Historical overview – Snowmass 2013/P5 2014
 - “How to Snowmass (article by C. Quigg)”: https://indico.fnal.gov/event/45207/attachments/133652/164937/How_to_Snowmass-final-links.pdf
 - Snowmass 2013 Book: <https://tinyurl.com/ypfd679z>
 - Link to material and report of P5, 2014: <http://usparticlephysics.org/p5/>

Considerations for Next P5 – H. Kung

(Deputy Director for Science Programs Office of Science)



- Grand, long-term, and global vision for the 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.

DPF Oversight and Coordination



- Snowmass includes all aspects of high energy physics and takes an interdisciplinary and international approach
 - **Snowmass Steering Group [met weekly]**
 - DPF Chair line + representatives of four closely associated APS Divisions: Astrophysics, Nuclear Physics, Gravitational Physics, Physics of Beams
 - **Snowmass Advisory Group [met monthly]**
 - DPF Executive Committee + representatives of major regional and international organizations
 - **Snowmass All-Conveners Group [met monthly]**
 - DPF chair line, 30 frontier conveners, the UW chair and deputy chairs of the CSS
 - **Community Summer Study (CSS) Program Committee [met weekly]**
 - One convener chosen by each frontier, Steering Committee, Early Career scientist representatives, UW chairs of CSS
 - **CSS Local Organizing Committee [endless meetings]**

DPF Oversight and Coordination: Snowmass Steering Group



DPF:

Joel Butler (chair, Fermilab)
Sekhar Chivukula (chair-elect,
University of California,
San Diego)
Andre de Gouvea (vice chair,
Northwestern University)
Tao Han (past chair, University
of Pittsburgh)
Young-Kee Kim (recent chair,
University of Chicago)
Priscilla Cushman (recent chair,
University of Minnesota)

APS Divisions with strong cross-disciplinary links:

Particle Beams: Sergei Nagaitsev (FNAL)
Nuclear Physics: Yury Kolomensky (University
of California, Berkeley)
Astrophysics: Glennys Farrar (New York
University)
Gravitational Physics: Nicolas Yunes
(University of Illinois, Urbana-
Champaign)

The Steering Group Ensures a multi- and cross- disciplinary focus.
Each frontier also has a liaisons to all other associated frontiers

DPF Oversight and Coordination: Snowmass Advisory Group (2021)



- Chair (Joel Butler)
- The Snowmass Steering group
- Additional DPF Executive Committee members:
 - Secretary/Treasurer: Tulika Bose, University of Wisconsin
 - Councilor: Bob Bernstein, FNAL
 - Member-at-Large: Kendall Mahn
 - Member-at-Large: Heather Gray
 - Member-at-Large: Mary Raafat Mikhail Bishai, BNL
 - Member-at-Large: Lauren Tompkins, Stanford University
 - Member-at-Large: Mayly Sanchez, Iowa State University
 - Member-at-Large: Gordon Watts, University of Washington - Seattle
 - Early Career Member-at-Large: Julia Gonski, Columbia University
- Representatives of the International Community
 - Claudio Dib, Universidad Tecnica Federico Santa Maria, Chile
 - Rainer Wallny, ETH (Val Gibson, Cavendish Laboratory, UK)
 - Berrie Giebels, CNRS, France
 - Atsuko Ichikawa, Kyoto University, Japan
 - Rob McPherson, Victoria (Heather Logan, Carleton University, Canada)
 - Xinchou Lou, IHEP, China
 - Michelangelo Mangano, CERN
 - Azwinndini Muronga, Nelson Mandela University, South Africa
- Editor
 - Michael Peskin, SLAC National Laboratory
- Communications Liaison
 - Robert Bernstein, Fermilab
- Technical Liaison
 - Sergei Chekanov, Argonne National

The Advisory Group ensures awareness of international plans and opportunities for collaboration. **HEP is Global!!**



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/w-p-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.



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 measurements of fundamental symmetry properties of Higgs boson decays that test the foundations of the underlying theory. The LHC experiments 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.

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 50 countries have been signed for LBNF/DUNE, PIP-II, and the Short Baseline Neutrino program at Fermilab, with more to come.

The Vera C. Rubin/LSST Camera successfully passed its CD-4 construction completion milestone. The Dark Energy Spectroscopic Instrument (DESI), the world's premier multi-object spectroscopic

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 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 to a wide variety of applications in science, medicine, and industry.

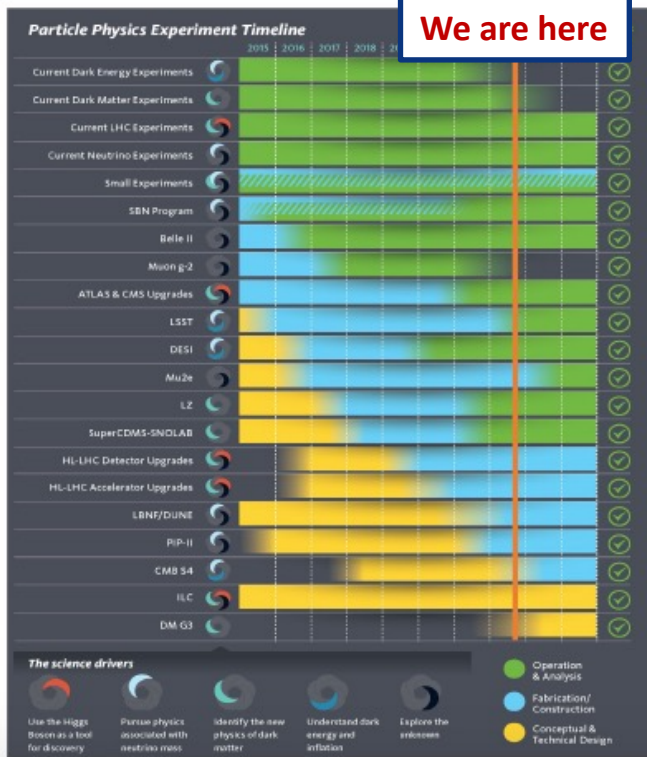


Building for Discovery

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

Steve Ritz, P5 Chair

We are ready for a new Strategic 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)

From JoAnne Hewett

General Conclusions



There was broad agreement at Snowmass 2021 on the general principles needed to have a successful US HEP program in the future.

- The science questions that HEP seeks to answer continue to be the ones identified in the 2013 Snowmass Report and so eloquently and succinctly summarized by P5 in the formulation of its Five HEP Science Drivers. These five drivers have guided US HEP for nearly a decade with great success. There was a consensus that these drivers were still relevant for the next decade. There was a suggestion that the physics of flavor, currently included under the fifth driver, be more specifically recognized given the current tensions between recent results in this area and the Standard Model.
- The portfolio of projects should continue to include a healthy breadth and balance of physics topics, experiment sizes and timescales, supported via a dedicated, robust funding process.
- Completion of existing experiments and operation of DUNE and the HL-LHC programs, are critical for addressing the science drivers for the near term and for the next two decades.
- Strong, robust support for the research program is essential to analyze the data from the existing and planned experiments, plan upgrades and future programs and projects, and educate the next generations of researchers and technical experts.
- Strong and continued support for formal theory, phenomenology and computational theory is needed, as are stronger, targeted efforts connecting theory to experiment.
- Both R&D directed to specific future projects and generic research needs to be supported in critical enabling technologies such as accelerators, instrumentation/detectors and computation, and in new ones such as quantum science and machine learning.
- A cohesive, strategic approach to promoting diversity, equity and inclusion in high-energy physics, and to improving community outreach and engagement, is required.
- An overall strategy, with overarching goals, for HEP engagement with five interrelated communities: HEP itself and the broader academic community, K-postdoc education, private industry, government policy makers, and the broader society, should be formulated. A structure for achieving these goals should be provided, along with the necessary resources, should be provided.

AF: Fermilab Proton Source Upgrade



- PIP-II SRF linac for 1.2 MW for DUNE in Main Injector
 - 800 MeV protons
 - Beam ops in 2028-29
 - 162.5 MHz bunches
 - Up to 2mA → 1.6 MW possible
 - ~17 kW for LBNF/DUNE v's
- PIP-II enables the accelerator complex to reach design proton power on LBNF (MI) target of 2.4 MW, but still leaves 98.8% of the beam for other users!
 - The “Booster upgrade/replacement” can be designed to provide the necessary factor of two in beam power for DUNE (2.4 MW out of Main Injector) **and a variety of beam conditions to enable small and mid-size experiments described in the Rare Processes Frontier with e.g. the addition of an accumulator ring**

Does the potential of the physics program described in the RPF support the extra cost of a versatile proton source?

P5 Recommendations for Energy Frontier



Snowmass 2013 Outcomes

- **Recommendation 10:** The LHC upgrades constitute our highest-priority near-term large project.
- **Recommendation 11:** Engage in modest and appropriate levels of ILC accelerator and detector design ... Consider higher levels of collaboration if ILC proceeds.
- **Recommendation 24:** Participate in global conceptual design studies and critical path R&D for future very high-energy proton-proton colliders. Continue to play a leadership role in superconducting magnet technology
- **Recommendation 26:** Pursue accelerator R&D. Focus on outcomes and capabilities that will dramatically improve cost effectiveness for mid-term and far-term accelerators.

Goal of Snowmass 2021



- This Snowmass Community Planning exercise is again organized by the Division of Particles and Fields (DPF) of the American Physical Society as
 - A ~ year-long “Science” study in which the entire HEP community comes together to identify opportunities and, to the extent possible, document a vision for the future of particle physics in the U.S. and its international partners.
 - Its narrative will communicate the opportunities for discovery in particle physics to the broader scientific community and to the government.
 - It will provide a validated set of inputs to the next P5, which is expected to begin its work in the late fall of 2022 and produce a report in the spring of 2023.
- Young-Kee Kim, DPF Chair, 2020: “DPF aims for everyone's voice to be heard. Your contributions and participation are critical for the success of Snowmass and they will naturally occur as part of one or more working groups directed by the conveners of the now 10 Frontiers”

For Snowmass 2021, the final meeting of Community Planning Exercise just took place at the **University of Washington in Seattle from July 17 to 26 in 2022**

P5 Report, May 2014



Building for Discovery

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



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

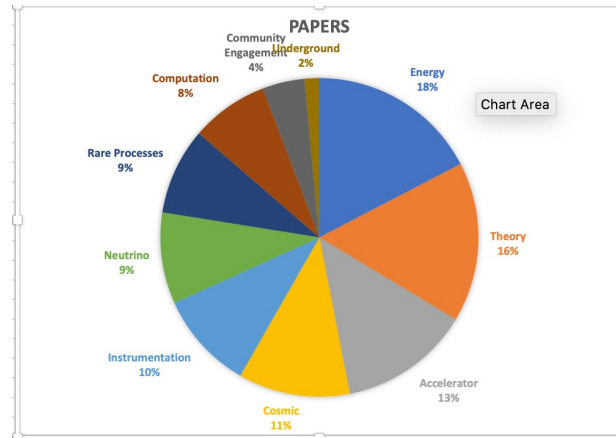
- Directions/achievements in HEP
- Federal funding profile for the current and near-future projects in the decade.

Contributed Papers, a.k.a. White Papers



These were due March 5, 2022

- [Links to Submitted Papers, by Frontier](#)
- [Energy Frontier \(EF\)](#) (150)
- [Neutrino Physics Frontier \(NF\)](#) (80)
- [Rare Processes and Precision Measurements \(RF\)](#) (76)
- [Cosmic Frontier \(CF\)](#) (98)
- [Theory Frontier \(TF\)](#) (140)
- [Accelerator Science and Technology Frontier \(AF\)](#) (115)
- [Instrumentation Frontier \(IF\)](#) (86)
- [Computational Frontier \(CompF\)](#) (68)
- [Underground Facilities and Infrastructure \(UF\)](#) (13)
- [Community Engagement Frontier \(CommF\)](#) (37)



total submissions: 515
[Contributed paper submission database compiled by SEC](#)