Snowmass Report
for
HEPAP Meeting, Dec. 8-9, 2022

Joel Butler, Fermilab
Chairperson, Division of Particles and Fields

Dec. 8, 2022

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 status for 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, so far as I know
- **Summary and Outlook**

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

- **Snowmass, the <u>DPF-hosted</u> 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**
- **<u>Goal: To identify the most important questions in HEP and the tools and infrastructure required to address them</u>**
  - 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**

P5 Physics Drivers

Snowmass 2021

- **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?

Snowmass 2021

- **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

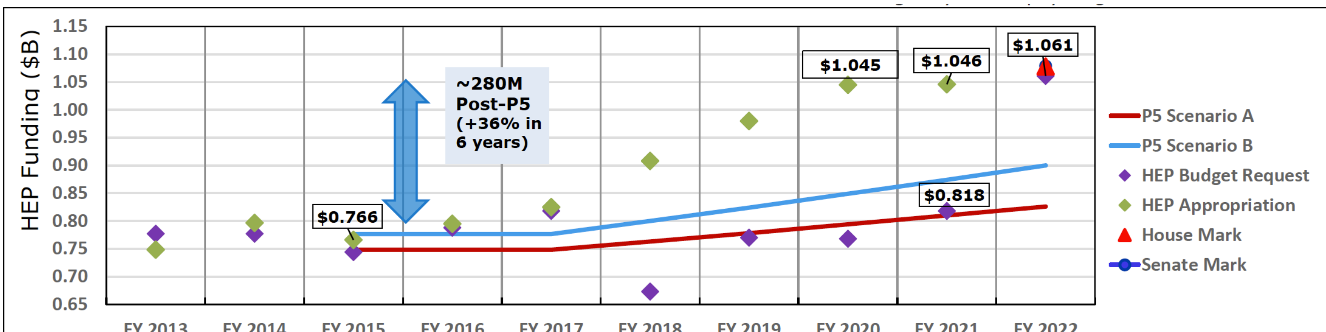
> I do not believe that all these would have been included without our strong communities developing excellent proposals

Did P5/2014 have an impact on Funding Outcome

Snowmass 2021

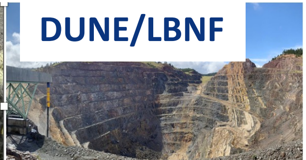
- The U.S. particle physics community enthusiastically supported the P5 plan.
  - 2,331 community members signed a letter of support to DOE and NSF (organized by DPF)

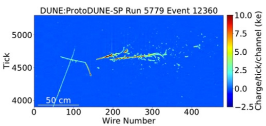
"Four years into executing the P5, the Committee commends the Office of Science and the high energy physics community for achieving significant accomplishments and meeting the milestones and goals set forth in the strategic plan…"



Project Outcome, P5 2014

DUNE/LBNF





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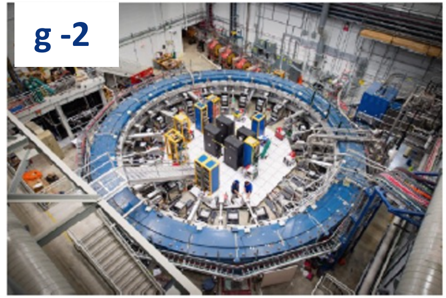
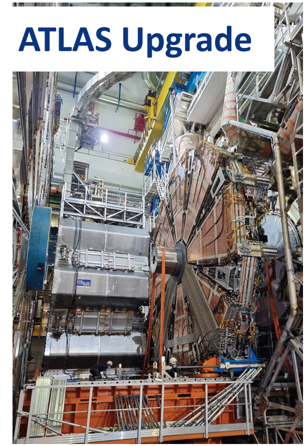
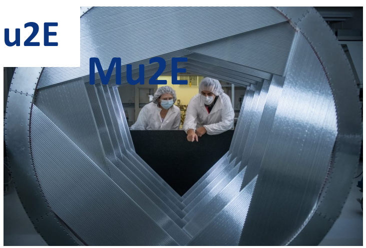


ATLAS Upgrade

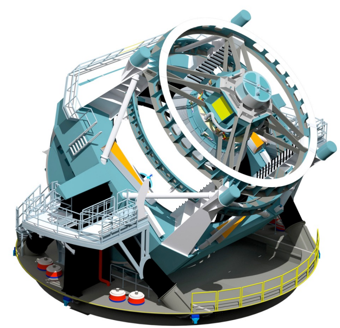


CMS Upgrade

Mu2E



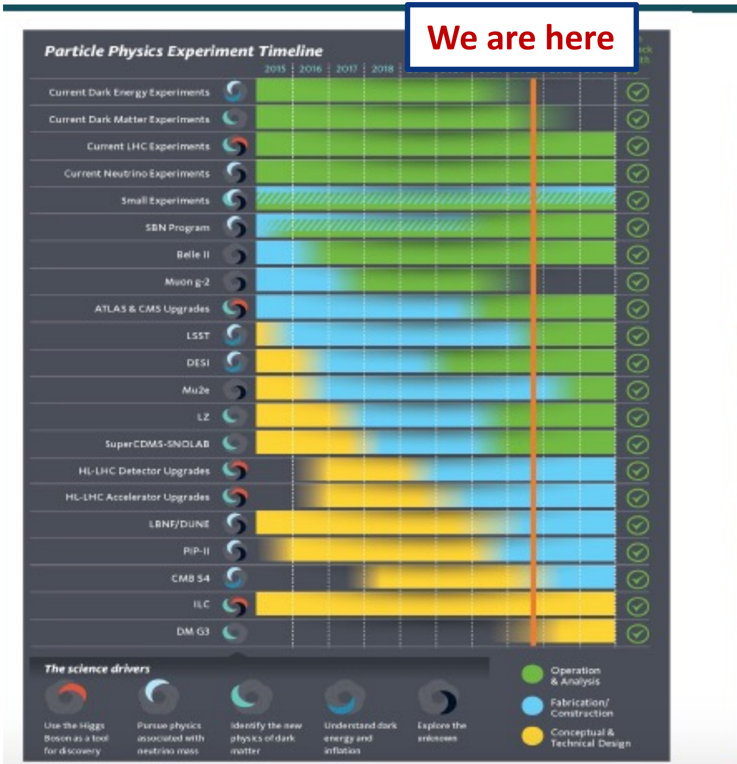
Vera Rubin LSST



and many other projects, large and small

We are ready for a new Strategic Plan!!

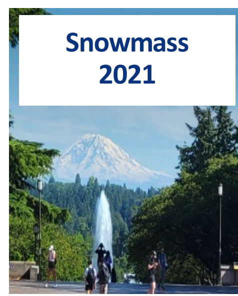
Snowmass 2021

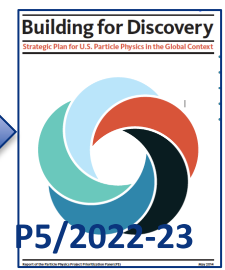


When most projects have gone into operation (green) or are solidly into construction/fabrication (blue) and there are too few in the design stage, (orange) it is time to develop the next plan!!

Time for a new Snowmass/P5

Working towards:





Impact of COVID on Snowmass

Snowmass 2021

- 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

Snowmass 2021

- 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

Snowmass 2021

- 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

Snowmass 2021

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)

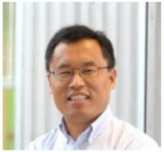
Laura Reina
(FSU)

Alessandro Tricoli
(BNL)

Instrumentation

Phil Barbeau
(Duke)

Petra Merkel
(FNAL)



Jinlong Zhang
(ANL)

Organization in Ten "Frontiers" - II

Snowmass 2021

Neutrino


Patrick Huber
Virginia Tech


Kate Scholberg
Duke University


Elizabeth Worcester
BNL

Rare Processes & Precision Measurements


Marina Artuso
(Syracuse U.)


Alexey Petrov
(Wayne State U.)


Bob Bernstein
(FNAL)

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!

Snowmass 2021 organization

10 Frontiers	80 Topical Groups
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.

DPF Oversight and Coordination: Snowmass Steering Group

Snowmass 2021

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)

Snowmass 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!!

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

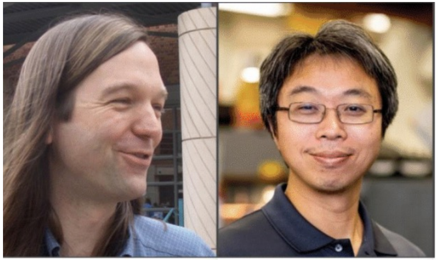
- Key Initiatives:
  - **Snowmass Coordination:** Coordinate with the Snowmass frontiers and help get EC members involved in the process
  - **In-reach:** Professional development and building cohesion within the early career community
  - **Diversity, Equity, and Inclusion (DEI):** Initiatives to make 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

Snowmass 2021

Organization of the meeting -

Snowmass 2021

Parallel Sessions

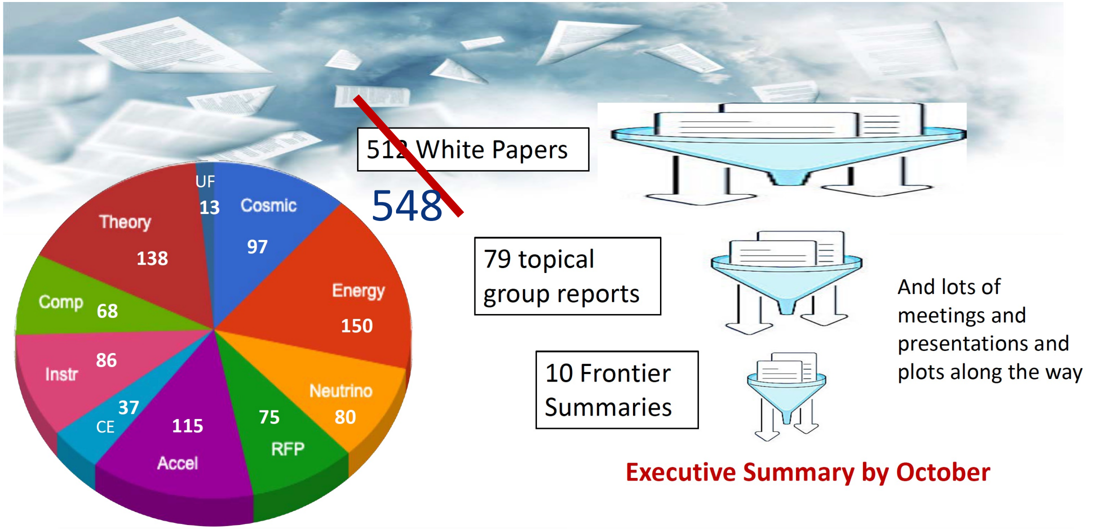
	Sunday, July 17	Monday, July 18	Tuesday, July 19	Wednesday, July 20	Thursday, July 21	Friday, July 22	Saturday, July 23	Sunday, July 24	Monday, July 25	Tuesday, July 26	Wednesday, July 27
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	
07:30 - 08:00 AM	Registration										
08:00 - 08:30 AM		Parallel	Parallel	Parallel	Parallel	Parallel	Parallel		Snowmass Frontier Summaries	Benchmark	
08:30 - 09:00 AM										NAS EPP Decadal Stud	
09:00 - 09:30 AM	Introductory Plenary									Snowmass Frontier Summaries	
09:30 - 10:00 AM								Parallel			
10:00 - 10:30 AM											
10:30 - 11:00 AM											
11:00 - 11:30 AM										Snowmass Workshop Summary	
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, 1) DOE Prgrm Managers ,Astrophysics,2) NSF Special PI meeting	Lunch,DOE Prgrm Managers 1) Energ 2) Theory	Lunch and Communicating HEP to the publ and the govt	Lunch and COV Roundtable; lessons (to be learned		Closing remarks	
12:30 - 01:00 PM											in the scheduel and afor the mttend
01:00 - 01:30 PM											
01:30 - 02:00 PM											
02:00 - 02:30 PM	Introductory Plenary	Parallel 1: AI/ML Parallel 2 : Undergroun 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 Ear Career	Panel: Interconnections with other fields		
02:30 - 03:00 PM											
03:00 - 03:30 PM											
03:30 - 04:00 PM		Parallel 1: The next accelerators; Parallel 2: LQCD	Parallel 1: Lepton 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 projec	Coffee		
04:00 - 04:30 PM	Coffee								Talks: national, International Leaders		
04:30 - 05:00 PM	If										
05:00 - 05:30 PM		Coffee	Coffee		Coffee	Coffee	Coffee	Coffee	Panel International Status and Plans		
05:30 - 06:00 PM		DEI: 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			
06:00 - 06:30 PM											
06:30 - 07:00 PM											
07:00 - 07:30 PM		Reception and Poster and Industry									
07:30 - 08:00 PM			Industry Networking	Adam Riess Public Lecture	Physics Slam						
08:00 - 08:30 PM						Conference Dinner	ColliderScope				
08:30 - 09:00 PM											
09:00 - 09:30 PM											
09:30 - 10:00 PM											
10:00 - 10:30 PM											

Parallel Sessions

Snowmass 2021

Converging to Consensus

Snowmass 2021

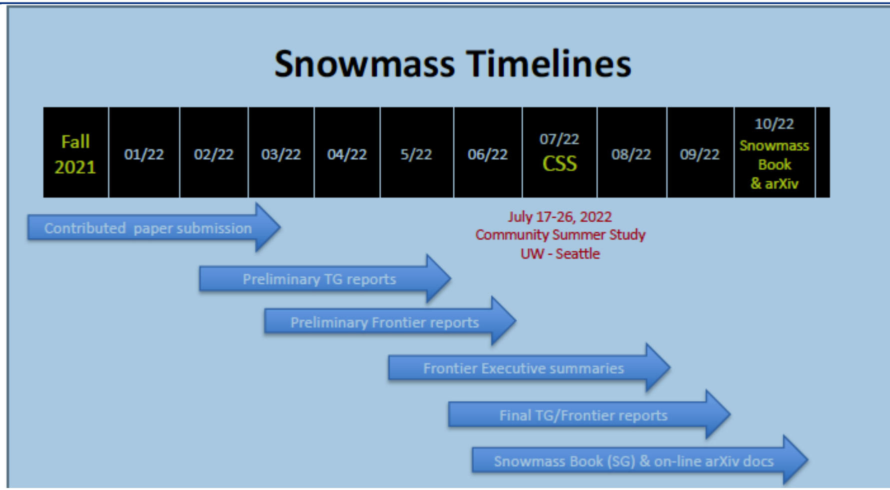


Prisca Cushman

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

Aspirational Timeline for Snowmass Report/Book

Snowmass 2021



- **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.)**

Personal and Preliminary View of Outcomes

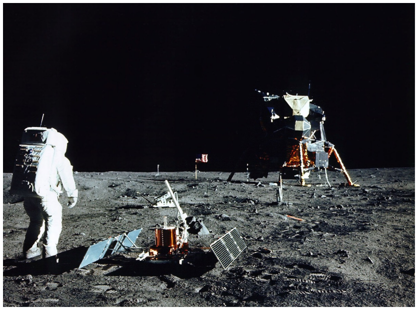
Current Status and Outlook

Snowmass 2021

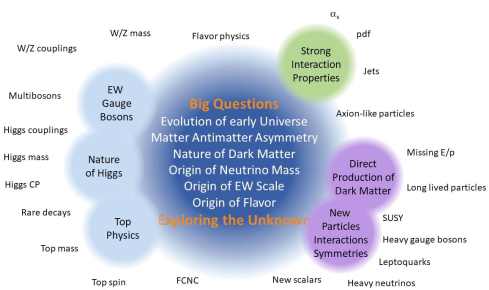
- No mass/energy scale for BSM physics
- Many new ideas have expanded the search space, e.g. for Dark Matter, but also in other topics as well
  - Huge mass range: **arguably 90 orders of magnitude**
  - Possibility of complex physics in hidden sectors
- **Some hints exist that may point us in a particular 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, …

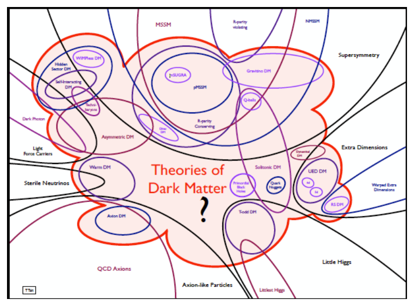
Every frontier is seeking BSM physics:
From Cosmic on DM: Delve deep, search wide! Search wide, aim high! Talk to each other, use all connections to gain insight!

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





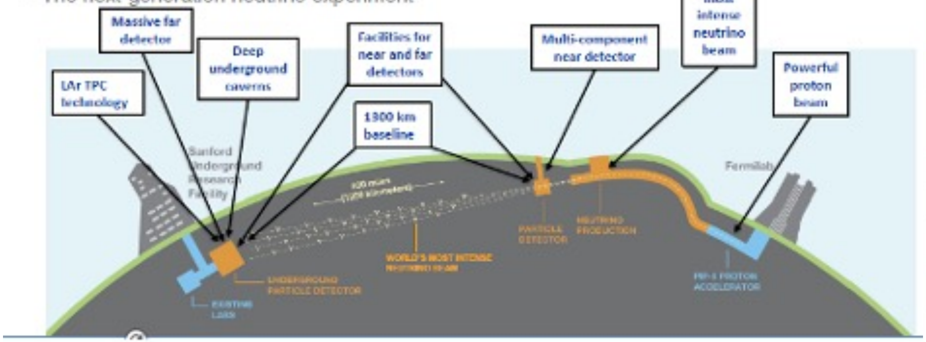
In 2013/2014 with the Higgs newly discovered and the first 13 TeV run coming up, it was possible to imagine we would find specific targets and mass scale for BSM to shoot at that was accessible .
This has not happened yet

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

Large Projects: Neutrino Frontier

Snowmass 2021

Deep Underground Neutrino Experiment (DUNE)
- The next-generation neutrino experiment



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.

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 1

Energy Frontier

Snowmass 2021

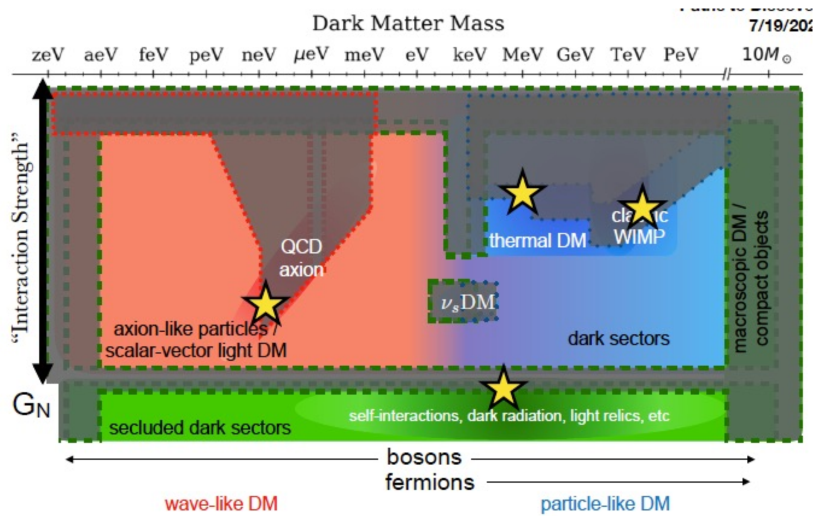
It is essential to

- 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

Snowmass 2021

- **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"

Theory Frontier

Snowmass 2021

- 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

Snowmass 2021

- 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

Snowmass 2021

- 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

Snowmass 2021

- 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

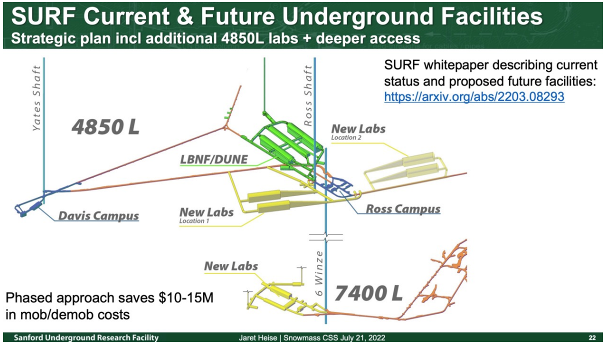
Nevertheless, significant work was done over a very wide range of topics:

- 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

Snowmass 2021

- 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.
- 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

Snowmass 2021

- 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 the11th Frontier for Snowmass 203X?

Status of the Snowmass Report

Snowmass 2021

- 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

Snowmass Scope vs P5 Scope

Snowmass 2021

- 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

On to P5

Snowmass 2021

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

Next P5 chair:

JoAnne Hewett

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!

Snowmass 2021

Stoppage Time

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]

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

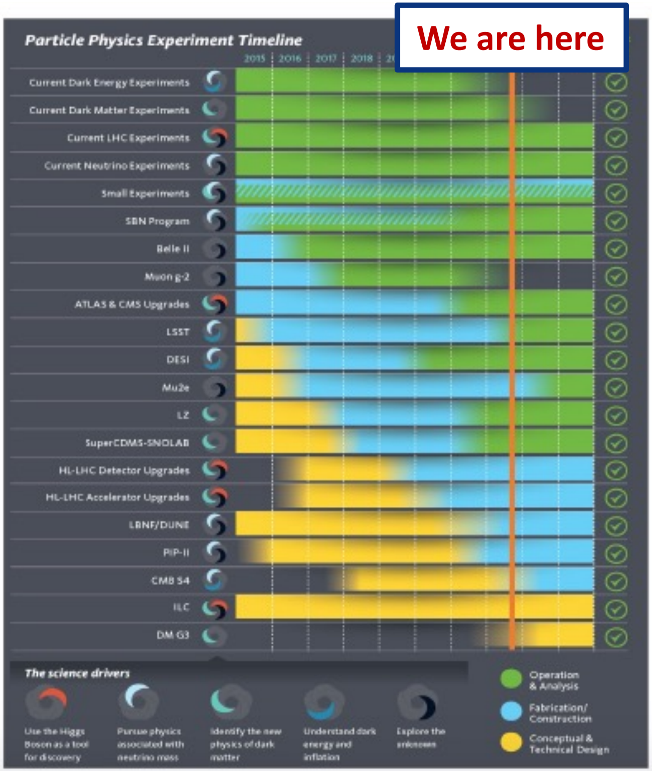
usparticlephysics.org

6

Extra Slides

We are ready for a new Strategic Plan!!

Snowmass 2021



Healthy HEP program requires a mix of project stages

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 ithat 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.
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- 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

- PIPII 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 ν'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 2021

Snowmass 2013 Outcomes

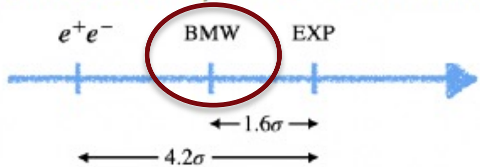
- **Recommendation 10: The LHC upgrades constitute our highest-priority near-term large project.**
- **Recommendation 11**:Engage in **modest** and appropriate levels of **ILC** accelerator and detector **design** … Consider higher levels of collaboration if ILC proceeds.
- **Recommendation 24:** Participate in global conceptual **design stud**ies 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.**

Muon g-2

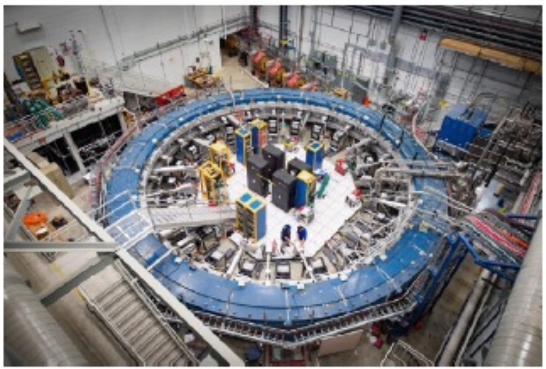
Snowmass 2013 Outcomes

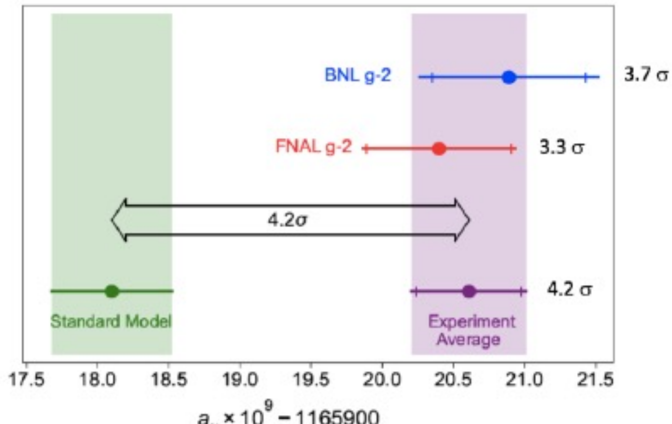
★ Muon's magnetic properties (g-2): $a_\mu = (g-2)/2$ with $\vec{\mu} = g\frac{e}{2m}\vec{s}$

discrepancy



Di Luzio, et al.





FNAL (g-2): $a_\mu(\mathrm{Exp}) = 116592061(41) \times 10^{-11}$

$a_\mu(\mathrm{Theory}) = 116591810(43) \times 10^{-11}$

$a_\mu(\mathrm{BMW}) = 116591954(55) \times 10^{-11}$

Goal of Snowmass 2021

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

Snowmass 2021

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.

Aspirations over Time

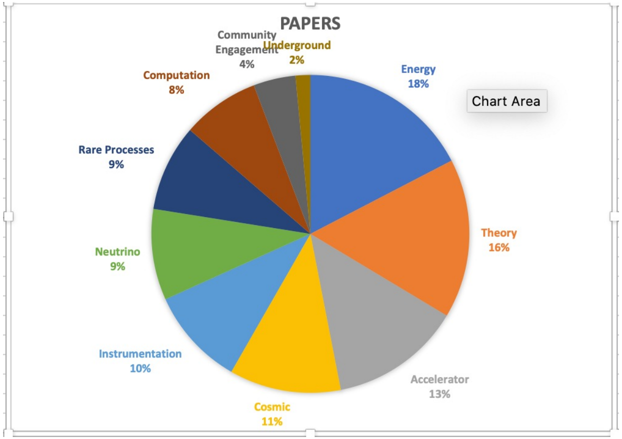
- At Snowmass **2001**, goals were to discover the **Higgs**; detect **SUSY whose lightest members would be accessible at a 500 or 800 GeV linear collider**, explore the SUSY spectrum up to ~20TeV, where the heaviest members were expected to provide insight into the SUSY-breaking interactions.
- When the LHC was starting in 2010, **SUSY was considered the low-hanging fruit, observable in a few hundred pb^{-1}**
- By Snowmass 2013, the **Higgs was found** (7, 8 TeV), **SUSY not!**
- By **2015 -2018:** The LHC showed it **could study the Higgs at an unexpected level of precision,**
  - **still no SUSY and no new mass scale**

Current aspirations for many are to study the Higgs much better than we can at the HL-LHC and search for new particles, interactions at >~ 10 TeV

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

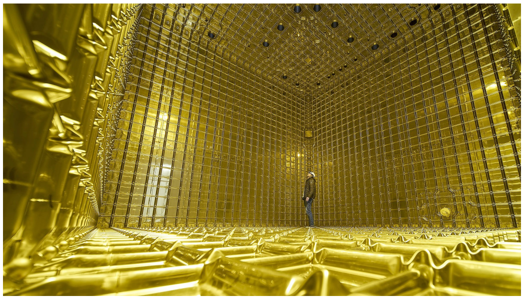
Contributed paper submission database compiled by SEC

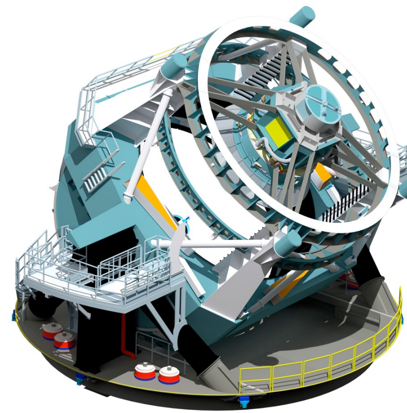
Personal (JB) View of a Vision

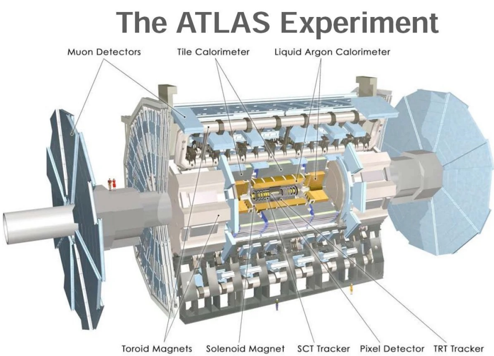
- *While we know there is BSM physics, we have only a few clues about where to look for it*
  - *The landscape has changed, since 2014, with no clear evidence to BSM physics seen at the LHC **so far** at 13 TeV.*
- *We now have a huge space of possibilities to investigate with no guarantees that if we embark in any direction, it will pay off in a discovery, unlike previous campaigns to fill out the SM*
    - *New ideas, new search strategies are needed*
    - This can be terrifying, but it is, in many ways, it is exciting and exhilarating
- *Efforts in every Frontier are necessary to discover, and eventually to characterize, BSM physics and all recognize this and are adjusting their outlook accordingly*

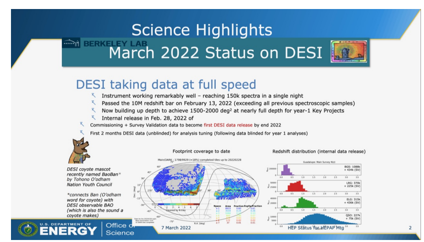
We have not discussed a Snowmass "Vision Statement", but there is a clear theme, summarized in the inspiring Snowmass Seattle meeting Conference Synthesis talk. I am not good at these exercises, but if you asked me to make an attempt at one, it might look like:

- *The US HEP/Elementary Particle Physics Community that participated in Snowmass 2021, together with its many international and interdisciplinary contributors, recognizes the challenge of the large, still mostly uncharted, terrain in which physics beyond the standard model (BSM) can reside. We enthusiastically embrace the global search for BSM physics, and with our existing and planned experiments, theoretical expertise, accelerators, instrumentation, and computing, and our passionate, committed, and increasingly diverse community of physicists, engineers, technicians, and computer scientists, we are confident that in the next decade and beyond US HEP will make major progress in identifying BSM physics or cornering it in a narrow search space that will tell us clearly what path to follow to discovery.*






The ATLAS Experiment
Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker


Science Highlights
BERKELEY LAB
March 2022 Status on DESI
DESI taking data at full speed
Instrument working remarkably well – reaching 150k spectra in a single night
Passed the 10M redshift bar on February 13, 2022 (exceeding all previous spectroscopic samples)
Now building up depth to achieve 1500-2000 deg² at nearly full depth for year-1 Key Projects
Internal release in Feb. 28, 2022 of
Commissioning + Survey Validation data to become first DESI data release by end 2022
First 2 months DESI data (unblinded) for analysis tuning (following data blinded for year 1 analyses)
Footprint coverage to date
Redshift distribution (internal data release)
DESI coyote mascot recently named BaoBan* by Tohono O'odham Nation Youth Council
*connects Ban (O'odham word for coyote) with DESI observable BAO (which is also the sound a coyote makes)
U.S. DEPARTMENT OF ENERGY
Office of Science
7 March 2022
HEP Status for HEPAP Mtg
2