What is Snowmass all about?

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Snowmass?

"Snowmass" is the Particle Physics Community Planning Exercise, organized by DPF, and originally held in Snowmass, Colorado.

The first Snowmass was held in 1982, with as goal to
"assess the future of elementary particle physics, to explore the limits of our technological capabilities, and to consider the nature of future major facilities for particle physics in the U.S."

Snowmass?

There were many summer studies since the 1982 event. The last one in Snowmass was in 2001, which involved 1200 participants.

In 2013: “Snowmass on the Mississippi” was held at UMN, and was preceded by a year of advance workshops and activities.

For this round the Summer study will be held in Seattle in 2022.

2013 Snowmass report

Scientific study, not yet taking into account available funding etc

Report is a 340 page document summarizing all the studies performed across subjects, including physics goals, instrumentation, computing, accelerator technologies, outreach, …

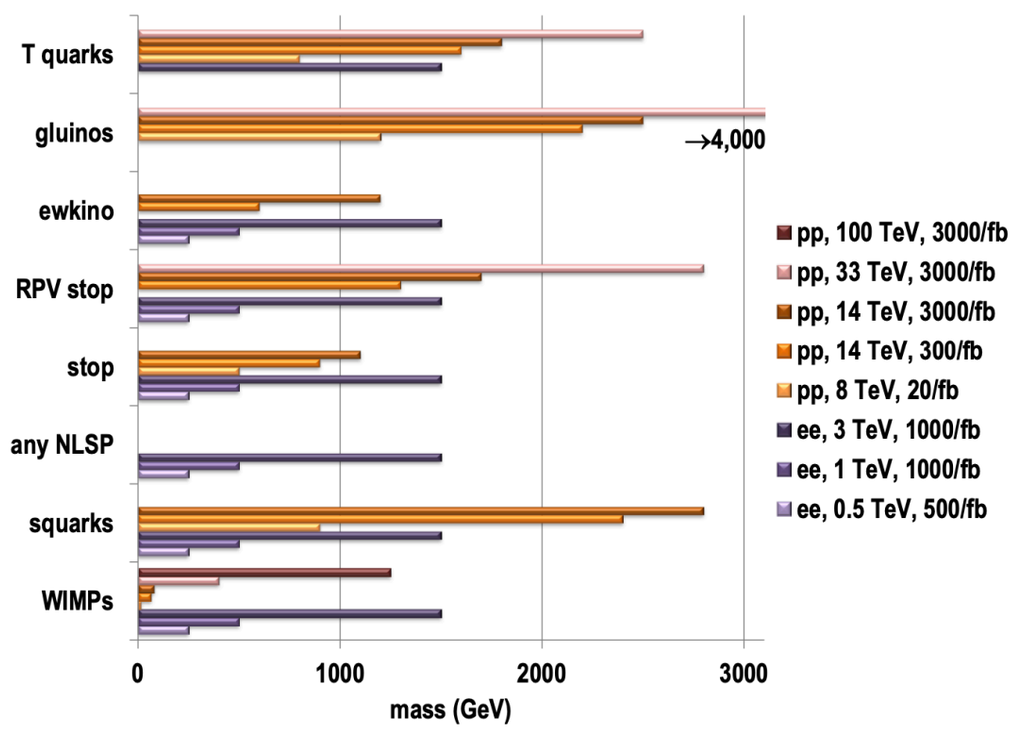
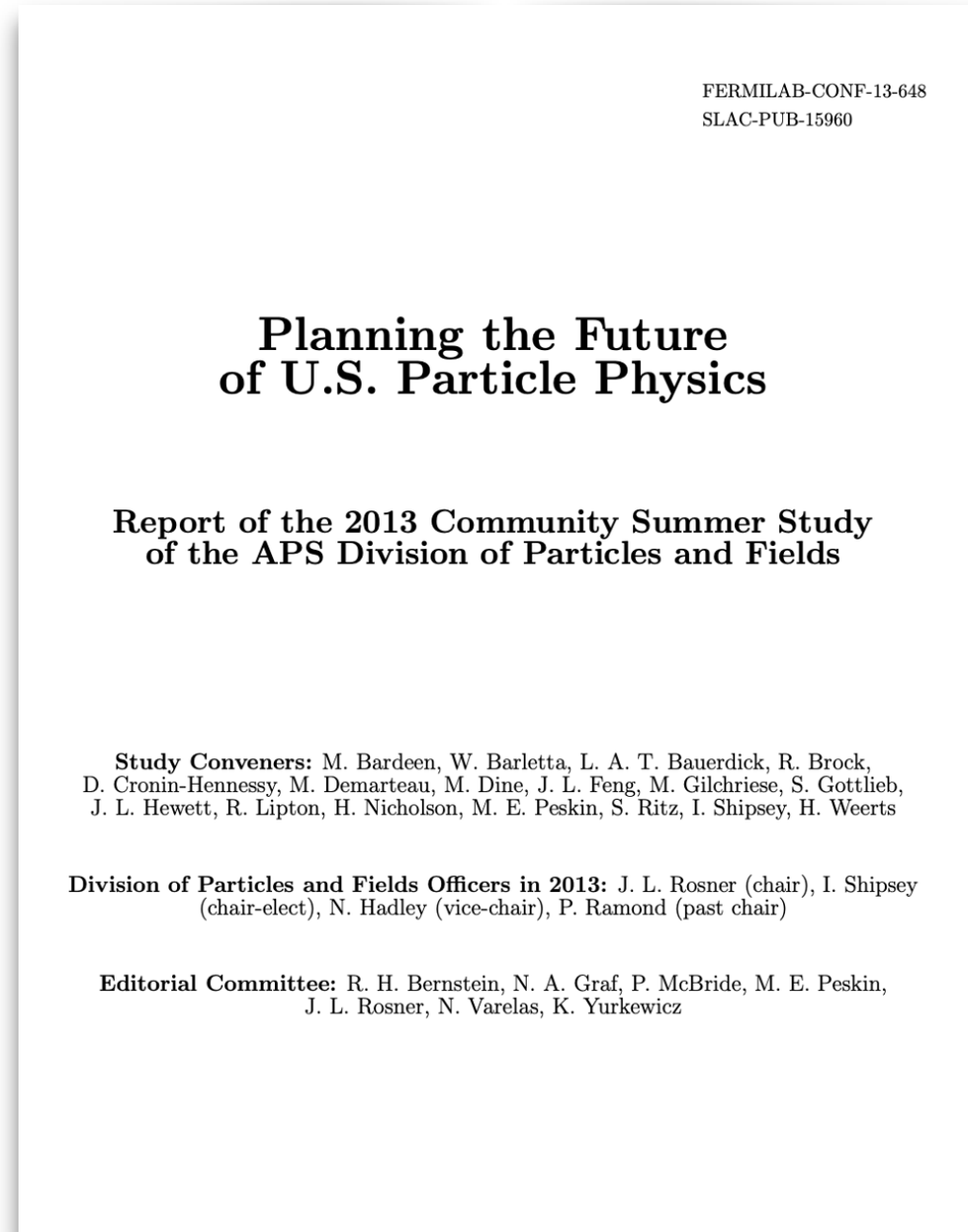


Figure 3-7. *Examples of 95% confidence upper limits for new particle searches at proposed pp and e^+e^- colliders.*



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Planning the Future of U.S. Particle Physics

Report of the 2013 Community Summer Study of the APS Division of Particles and Fields

Study Conveners: M. Bardeen, W. Barletta, L. A. T. Bauerdick, R. Brock, D. Cronin-Hennessy, M. Demarteau, M. Dine, J. L. Feng, M. Gilchriese, S. Gottlieb, J. L. Hewett, R. Lipton, H. Nicholson, M. E. Peskin, S. Ritz, I. Shipsey, H. Weerts

Division of Particles and Fields Officers in 2013: J. L. Rosner (chair), I. Shipsey (chair-elect), N. Hadley (vice-chair), P. Ramond (past chair)

Editorial Committee: R. H. Bernstein, N. A. Graf, P. McBride, M. E. Peskin, J. L. Rosner, N. Varelas, K. Yurkewicz

P5 process

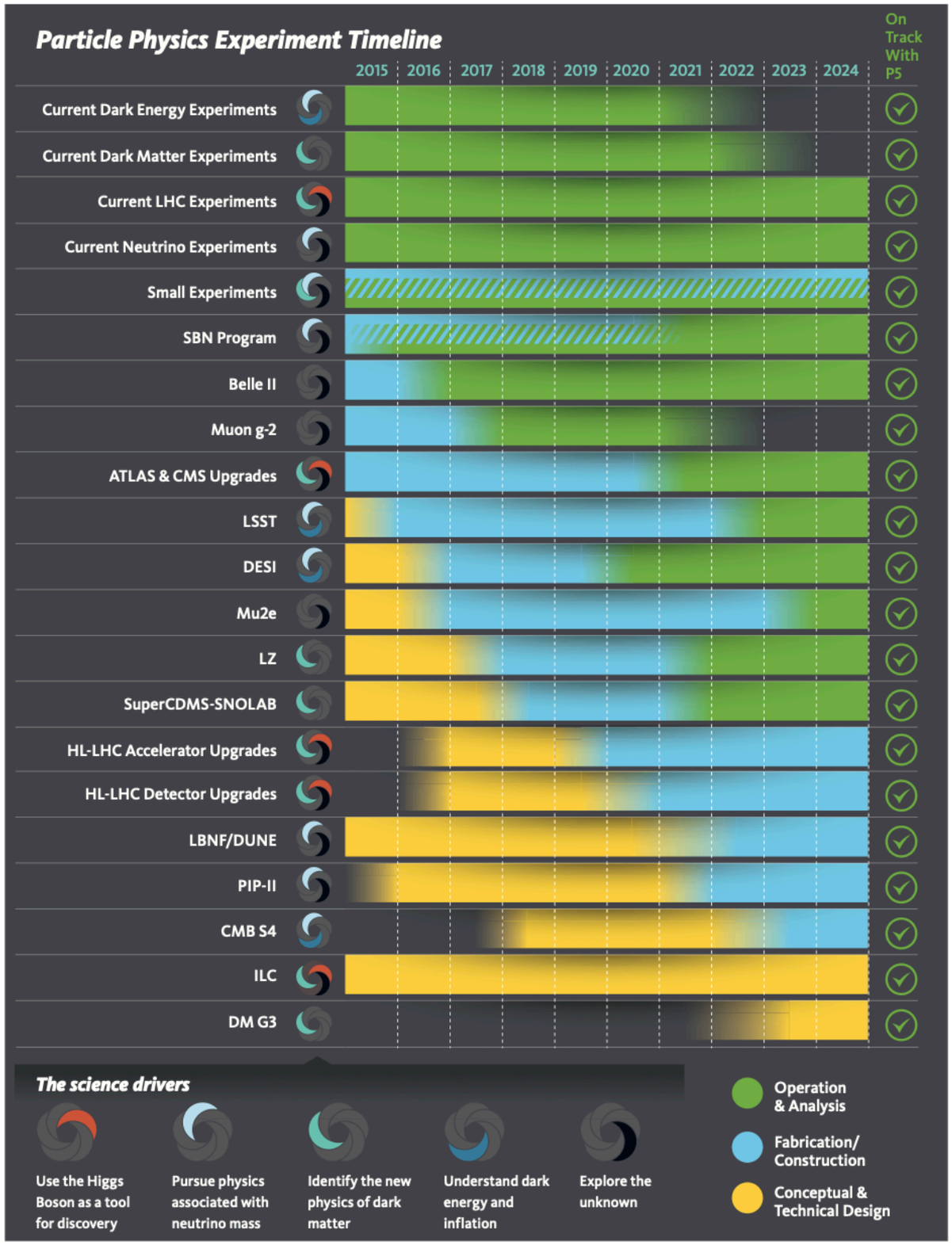
P5 = **P**article **P**hysics **P**roject **P**rioritization **P**anel

- Panel of ~25 HEP scientists tasked by DOE/NSF
- Panel reviews Snowmass scientific study outcomes, along with international studies (e.g. European Strategy Report), and comes up with a prioritized plan for the next 10 years
- P5 takes into account expected costs and available funding
- P5 outcomes are used by DOE and NSF to set funding priorities
- P5 process is very useful when advocating for HEP to members of Congress: we have a community plan, and are sticking to it! (until covid: on time and on budget)

P5 priorities

5 science drivers:

- 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.



Open questions guiding us

- Dark matter? How does it relate to the Standard Model?
- Dark energy??
- What is the origin and size of neutrino masses?
- Is the Higgs boson the Standard Model Higgs? Where does the Higgs potential come from? Is there a problem with “naturalness”?
- CP violation (matter-antimatter asymmetry)?
- Are there more particles/forces/phenomena out there? At what mass scale?

What is the best way to address these questions? What kinds of experiments can give us information? What theory calculations do we need to improve? What computing infrastructure do we need?

Working areas for this Snowmass

Snowmass Frontiers

- Energy Frontier
- Neutrino Physics Frontier
- Rare Processes and Precision
- Cosmic Frontier
- Theory Frontier
- Accelerator Frontier
- Instrumentation Frontier
- Computational Frontier
- Underground Facilities
- Community Engagement

- Process started in 2020 during APS April Meeting
- Letters of Intent submitted by Aug 2020
- Working group activity ongoing, but was put on pause last December due to covid constraints on people's time
- Restarting the process in September, with a "Snowmass Day" on Sept 24

- Lots of involvement of early career physicists, including (under)graduate students and postdocs!

More info on https://snowmass21.org

Energy Frontier topics

Goals:

- Understanding the heaviest particles of the Standard Model (SM)
- Exploring physics beyond the SM to discover new particles and interactions
- Unraveling the mystery of dark matter

Approach:

- Detailed studies of Electroweak (EW) physics, QCD and strong interactions, and Beyond-Standard-Model (BSM) physics under different future accelerator scenarios, including lepton-lepton, hadron-hadron, and lepton-hadron colliders.
  - EW: focus on Higgs sector, e.g. Higgs boson properties and couplings, SM gauge boson scattering, using Higgs boson as portal to new physics
  - BSM: model-dependent and model-independent searches

New collider options

Machine	Energy						
Circular ee	m_Z	$2m_W$	240	$2m_t$			GeV
ILC	250	350	500	1000			
CLIC					1500	3000	
HL-LHC/FCC-hh	14	75	100	150			TeV
LHeC/FCC-eh	1.3	3.5					
μμ	3	10	14	30			

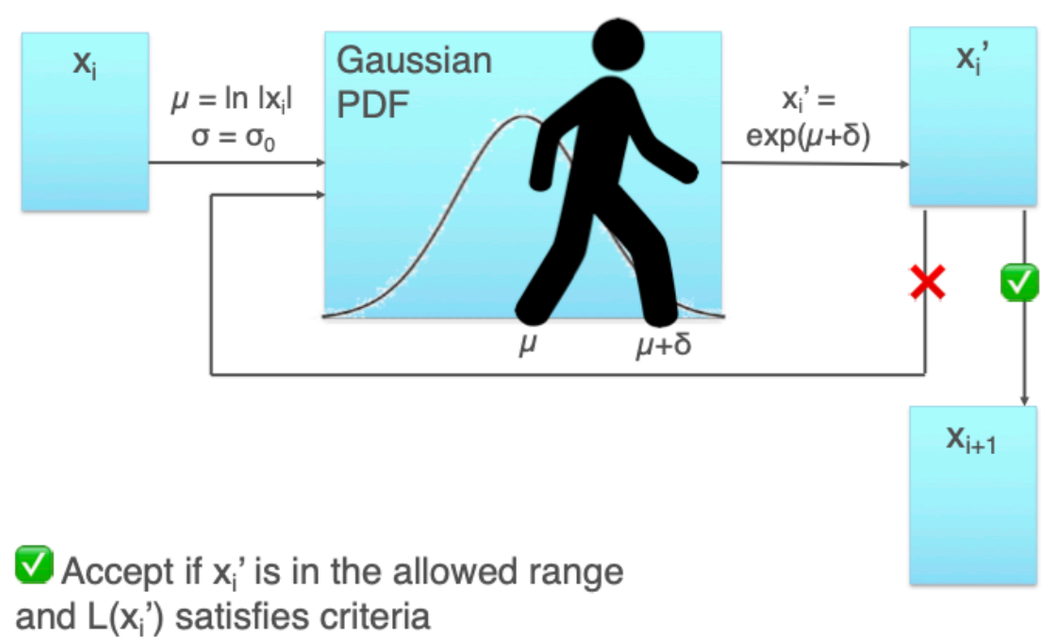
- Interest in e+e- colliders for precision measurements of Higgs properties and other EW processes
- Interest in hadron colliders at very high energies to push the boundaries of our direct reach for discovery of new particles
- Renewed interest in exploration of muon collider

Example study

- Supersymmetry is a proposed extension of the SM
  - New symmetry between fermions and bosons
  - Doubles # of particles by introducing partner particles to known SM particles that differ in spin by 1/2
- Has some nice properties
  - Possible dark matter candidate
  - Possible unification of coupling constants
  - Partial explanation for the “hierarchy problem” of the Higgs mass
  - Seems needed for theories of quantum gravity
- Downside: large number of free parameters
  - ~120 in the “Minimal” Supersymmetric Standard Model
  - only 19 in the phenomenological MSSM

Example study: pMSSM scan

- Understand the physics potential of different future experiments in the context of the pMSSM
  - How will SUSY sensitivity from various collider scenarios overlap/ complement each other?
  - What interesting pMSSM models have limited coverage, and how can we expand this coverage?
- Approach:
  - Use a Markov Chain Monte Carlo method to scan the 19-parameter model space, taking into account existing measurements
  - Pick set of benchmarks
  - Generate events (including detector simulation) for the variety of collider options considered
  - Explore sensitivity to these models using a range of reference physics analyses



REU project working on aspects of this

Big questions also guide our research

The science drivers also guide our research at CMS and LDMX

- 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
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Higgs measurements

Dark matter searches

Supersymmetry searches

And more!