Looking Forward with Some Personal Perspectives From Past Snowmass-P5 Processes

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The Previous Snowmass Was Essential to P5

Snowmass Questions

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

1. How do we understand the Higgs boson? What principle determines its couplings to quarks and leptons? Why does it condense and acquire a vacuum value throughout the Universe? Is there one Higgs particle or many? Is the Higgs particle elementary or composite?
2. What principle determines the masses and mixings of quarks and leptons? Why is the mixing pattern apparently different for quarks and leptons? Why is there CP violation in quark mixing? Do leptons violate CP?
3. Why are neutrinos so light compared to other matter particles? Are neutrinos their own antiparticles? Are their small masses connected to the presence of a very high mass scale? Are there new interactions that are invisible except through their role in neutrino physics?
4. What mechanism produced the excess of matter over anti-matter that we see in the Universe? Why are the interactions of particles and antiparticles not exactly mirror opposites?
5. Dark matter is the dominant component of mass in the Universe. What is the dark matter made of? Is it composed of one type of new particle or several? What principle determined the current density of dark matter in the Universe? Are the dark matter particles connected to the particles of the Standard Model, or are they part of an entirely new dark sector of particles?
6. What is dark energy? Is it a static energy per unit volume of the vacuum, or is it dynamical and evolving with the Universe? What principle determines its value?
7. What did the Universe look like in its earliest moments, and how did it evolve to contain the structures we observe today? The inflationary Universe model requires new fields active in the early Universe. Where did these come from, and how can we probe them today?
8. Are there additional forces that we have not yet observed? Are there additional quantum numbers associated with new fundamental symmetries? Are the four known forces unified at very short distances? What principles are involved in this unification?
9. Are there new particles at the TeV energy scale? Such particles are motivated by the problem of the Higgs boson, and by ideas about space-time symmetry such as supersymmetry and extra dimensions. If they exist, how do they acquire mass, and what is their mass spectrum? Do they provide new sources of quark and lepton mixing and CP violation?
10. Are there new particles that are light and extremely weakly interacting? Such particles are motivated by many issues, including the strong CP problem, dark matter, dark energy, inflation, and attempts to unify the microscopic forces with gravity. What experiments can be used to find evidence for these particles?
11. Are there extremely massive particles to which we can only couple indirectly at currently accessible energies? Examples of such particles are seesaw heavy neutrinos or grand unified scale particles mediating proton decay. How can we demonstrate that these particles exist?

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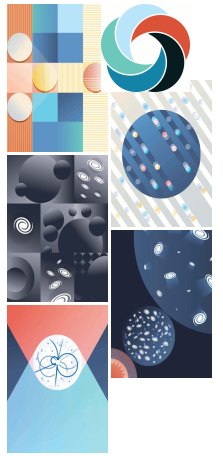
P5: Science Drivers of Particle Physics

P5 distilled the 11 groups of physics questions from Snowmass into 5 compelling lines of inquiry that show great promise for discovery over the next 10 to 20 years:

- 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



- The Drivers are deliberately **not prioritized** because they are **intertwined**, probably more deeply than currently understood.
- A selected set of different experimental approaches that reinforce each other is required. **Projects are prioritized**.
- The vision for addressing each of the Drivers using a selected set of experiments is given in the report, along with their approximate timescales and how they fit together.

P5 Strategic Planning Process 8

P5 distilled the Snowmass questions (>30) into something more actionable and explainable to people outside the field, the 5 Science Drivers. Could be done by Snowmass this time.

The Previous Snowmass Was Essential to P5

- The Snowmass documents enabled P5 to write a much shorter report.
  - A short report is actually more difficult to write than a long report, but it is usually **much more effective**.

The Importance of Showing Up

- Ideas and questions given to the next P5 will be shaped by those who participate in the Snowmass process.
  - **Early career voices are especially important**
    - **Long-term choices most strongly affect younger colleagues.**
  - Snowmass ideally a process in which ideas are discussed, vigorously debated, and refined by everyone together.

- We should not hesitate to ask the tough questions (in good faith).

The essential importance of diversity, equity, inclusion, and climate in everything we do

- The persistent lack of diversity in our field won’t be fixed just by individuals trying to be unbiased.
- Systemic issues must be addressed, and we have work to do.
- Yes, this is an important part of the Snowmass Process.

The Importance of Theory

The following is obvious, but worth stating here:

- An essential focus in its own right:
  - Reveals important questions and issues
  - Provides the intellectual underpinning, new ways of thinking, and new frameworks for a deeper understanding of Nature

As well as…

- Necessary for success -- essential part of the ecosystem of projects in all stages.
- Gives meaning to the data
- Ties the field together
- Points in new directions

International Connections

- The previous P5 was an outward-facing panel, with a large number of members from other countries, by design
  - thoughtful leaders of strategic planning and those familiar with U.S. program.
- Therefore, welcome our thoughtful colleagues from other regions into the Snowmass process, too.

The Opportunity of Cross-roads

- Snowmass is an excellent chance to broaden our own research, to reassess directions, and to make connections.
- Also, how can we expect others to become interested in our own subfields if we don't become interested in theirs?

Beyond particle physics, too

"*More generally, we strongly affirm the essential importance of fundamental research in all areas of science.*"

-2014 P5 Report Executive Summary

https://www.usparticlephysics.org/wp-content/uploads/2018/03/FINAL_P5_Report_053014.pdf