Update on the Science Priorities Working Group

Matt Toups

Tues 13 Dec 2022

Particle Physics Project Prioritization Panel ("P5")

- Formed by the High Energy Physics Advisory Panel (HEPAP) at the request of DOE and NSF
- Charged with developing a 10-year strategic plan for US high-energy physics in a 20-year context
- Prioritizes projects within defined budget scenarios
- Uses "Snowmass" community planning reports (but also other reports) as input
- Many additional elements to the charge
  - Recommending strategic actions in support of diversity, equity, inclusion, and accessibility principles
  - Articulating the value of basic research and its benefits to society
- Complete charge can be found at: https://science.osti.gov/hep/hepap/Meetings/202212

Dear Dr. Hewett:

The 2014 report of the Particle Physics Project Prioritization Panel (P5), developed under the auspices of the High Energy Physics Advisory Panel (HEPAP), successfully laid out a compelling scientific program that recommended world-leading facilities with exciting new capabilities, as well as a robust scientific research program. That report was well received by the community, the U.S. Department of Energy (DOE) and the National Science Foundation (NSF), and Congress as a well-thought-out and strategic plan that could be successfully implemented. HEPAP's 2019 review of the implementation of this plan demonstrated that many of the report's recommendations are being realized, and the community has made excellent progress on the P5 science drivers.

As the landscape of high-energy physics continues to evolve and the decadal timeframe addressed in the 2014 P5 report nears its end, we believe it is timely to initiate the next long-range planning guidance to the DOE and NSF. To that end, we ask that you constitute a new P5 panel to develop an updated strategic plan for U.S. high-energy physics that can be executed over a 10-year timeframe in the context of a 20-year, globally aware strategy for the field.

. . .

We would appreciate the panel's preliminary comments by August 2023 and a final report by October 2023. We recognize that this is a challenging task; nevertheless, your assessments will be an essential input to planning at both the DOE and NSF.

Sincerely,

Asmeret Asefaw Berhe
Director, Office of Science
U.S. Department of Energy

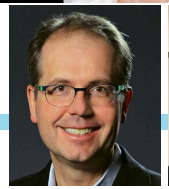
Sean L. Jones
Assistant Director
Directorate for Mathematical and Physical Sciences
National Science Foundation

Fermilab

P5 Committee

Tulika Bose	Wisconsin
Kyle Cranmer	Wisconsin
Francis-Yan Cyr-Racine	New Mexico
Sarah Demers	Yale
Cameron Geddes	LBNL
Patrick Huber	Virginia Tech
Kendall Mahn	Michigan State
Rachel Mandelbaum	Carnegie Mellon
Jelena Maricic	Hawaii
Petra Merkel	Fermilab
Christopher Monahan	William-Mary Coll.
Meenakshi Narain	Brown
Peter Onyisi	Texas Austin
Mark Palmer	Brookhaven
Tor Raubenheimer	SLAC
Mayly Sanchez	Florida State
Richard Schnee	South Dakota School o
Jesse Thaler	MIT
Abigail Vieregg	Chicago
Amanda Weinstein	Iowa State
Lindley Winslow	MIT
Tien-Tien Yu	Oregon
Bob Zwaska	Fermilab
Beate Heinemann	DESY
Christos Touramanis	Liverpool
Shoji Asai	Tokyo
Karsten Heeger	Yale
JoAnne Hewett	SLAC
Hitoshi Murayama	UC Berkeley/LBNL

Deputy Chair



Chair

Fermilab

P5 Schedule

Straw-person schedule

- 4 town halls: LBNL, Brookhaven, SLAC, Fermilab from January to April
- Virtual town halls, especially early career scientists
- 4 in person closed meetings from May to July
  - Make sure to build consensus
- Preliminary version in August
- Final report in October
- Probably need a sub-subpanel for cost and risk evaluations
- Followup with outreach to congress, other fields, public

Hitoshi Murayama, P5 Status, HEPAP Meeting, Dec. 8-9, 2022

Science Priorities Working Group (SPWG)

Set up by the FNAL Director last May to prepare Fermilab's input to P5, chaired by Jim Amundson

- "In advance of the P5 meeting later this year, we are asking that you chair a Fermilab working group to help prepare the laboratory's input to the panel. Your deliverable should be a prioritized set of recommendations for the U.S. particle physics program and Fermilab's role over the next decade to be presented to the P5. The recommendations should integrate the broader community's scientific aspirations set in a global context."

Proton Intensity Upgrade (PIU) Central Design Group (CDG) set up at the same time, co-chaired by Steve Brice & Brenna Flaugher

- Define a strategy for providing 2.4 MW to LBNF to be presented to P5, coordinating with SPWG
  - Assumed to require a new machine to replace the Booster
  - Consider Rapid Cycling Synchrotron and Superconducting RF Linac options

Note that Fermilab's input to the last P5 consisted of a 14-slide presentation by Gina Rameika

SPWG Organization

- Split into 12 subgroups:
  - Experiment-driven
    - Neutrino
    - Rare and Precision
    - Energy
    - Cosmic
  - Theory
  - Diversity, Equity, & Inclusion
  - Technologies
    - Materials
    - Accelerator S&T
    - Microelectronics
    - Quantum
    - Detector R&D
    - Computing/AI
- Kick-off meeting prior to Snowmass
- Afterwards, meetings 1-2 times per week
  - Initially focused on collecting input from subgroups
  - Now focused on crafting the overall message

LAST NAME	FIRST NAME	DIVISION	CHAIR	SCIENCE THEME
Valishev	Sasha	AD		Acc S&T
Posen	Sam	APS-TD		Acc S&T
Pellemoine	Frederique	AD		Acc S&T
Boffo	Cristian	APS-TD		Acc S&T
Berry	Doug	PPD		Collider
Canepa	Anadi	PPD		Collider
Ngadiuba	Jennifer	PPD		Collider
Amundson	Jim	SCD	X	Computing
Tran	Nhan	SCD		Computing, AI
Walton	Tammy	SCD		Computing, Precision
Spentzouris	Panagiotis	FQI		Computing, Quantum
Benson	Brad	PPD		Cosmic
Drlica-Wagner	Alex	PPD		Cosmic
Estrada	Juan	PPD		Detector R&D, Cosmic
Merkel	Petra	PPD		Detector R&D, Collider
Fahim	Farah	FQI		Detector R&D, Quantum
Schukraft	Anne	ND		Neutrino
Fava	Angela	ND		Neutrino
Toups	Matt	ND		Neutrino
Polly	Chris	PPD		Precision
Gaponenko	Andrei	PPD		Precision
Grassellino	Anna	SQMS		Quantum, Acc S&T
Carena	Marcela	THD		Theory
Harnik	Roni	THD		Theory
Machado	Pedro	THD		Theory
Sonnenschein	Andrew	PPD		Cosmic

Ex-officio: Steve Brice, Brenna Flaugher

Neutrino Subgroup

Subset of SPWG responsible for preparing neutrino science input

- S. Brice, A. Fava, P. Machado, F. Pellemoine, A. Schukraft, P. Spentzouris, M. Toups (lead), T. Walton

Met separately from SPWG every other week between Labor Day and Thanksgiving

Initial presentation to SPWG on 9/14/22 based largely on Snowmass Neutrino Report

Collect & incorporate feedback from FNAL scientists at Neutrino Town Hall on 10/28/22

Final presentation to SPWG on 11/2/22

- Copy of final presentation to SPWG can be found at https://indico.fnal.gov/event/57199/

The Neutrino Subgroup's Message

Build DUNE Phase I with all haste and commit to DUNE Phase II

- DUNE is a best-in-class neutrino experiment with a rich portfolio of compelling science
- DUNE is the culmination of a multi-decade, global program to develop the modern, LArTPC ν detector

Evolve Fermilab's program of short-baseline, accelerator ν experiments in light of upcoming results

- SBN results will inform the future direction of the field, including the DUNE physics program
- Decay-at-rest ν experiments are a complementary probe of new physics at short baselines
- Smaller experiments provide a pipeline of talent trained in all experiment stages: design, execution, analysis

Establish funding mechanism for directed R&D for DUNE Phase II detector upgrades

- R&D for technologies that will enable future physics programs beyond the next P5 should also be backed

Provide support for theory, including in ν interaction modeling, generator development, and pheno

Demand leadership in HEP-wide EDI efforts from Fermilab, as host of the international ν community

LBNF/DUNE Phases I and II

From the 2014 P5 Report

Recommendation 12: In collaboration with international partners, develop a coherent short- and long-baseline neutrino program hosted at Fermilab.

For a long-baseline oscillation experiment, based on the science Drivers and what is practically achievable in a major step forward, we set as the goal a mean sensitivity to CP violation[2] of better than 3σ (corresponding to 99.8% confidence level for a detected signal) over more than 75% of the range of possible values of the unknown CP-violating phase δ_{CP}. By current estimates, this goal corresponds to an exposure of 600 kt*MW*yr assuming systematic uncertainties of 1% and 5% for the signal and background, respectively. With a wideband neutrino beam produced by a proton beam with power of 1.2 MW, this exposure implies a far detector with fiducial mass of more than 40 kilotons (kt) of liquid argon (LAr) and a suitable near detector. **The minimum requirements to proceed are the identified capability to reach an exposure of at least 120 kt*MW*yr by the 2035 timeframe, the far detector situated underground with cavern space for expansion to at least 40 kt LAr fiducial volume, and 1.2 MW beam power upgradable to multi-megawatt power. The experiment should have the demonstrated capability to search for supernova (SN) bursts and for proton decay, providing a significant improvement in discovery sensitivity over current searches for the proton lifetime.**

Phase II (future):

- Increased mass at Far Detector
- More Capable Near Detector (MCND)
- Increased beam power by Booster replacement

Phase I (current):

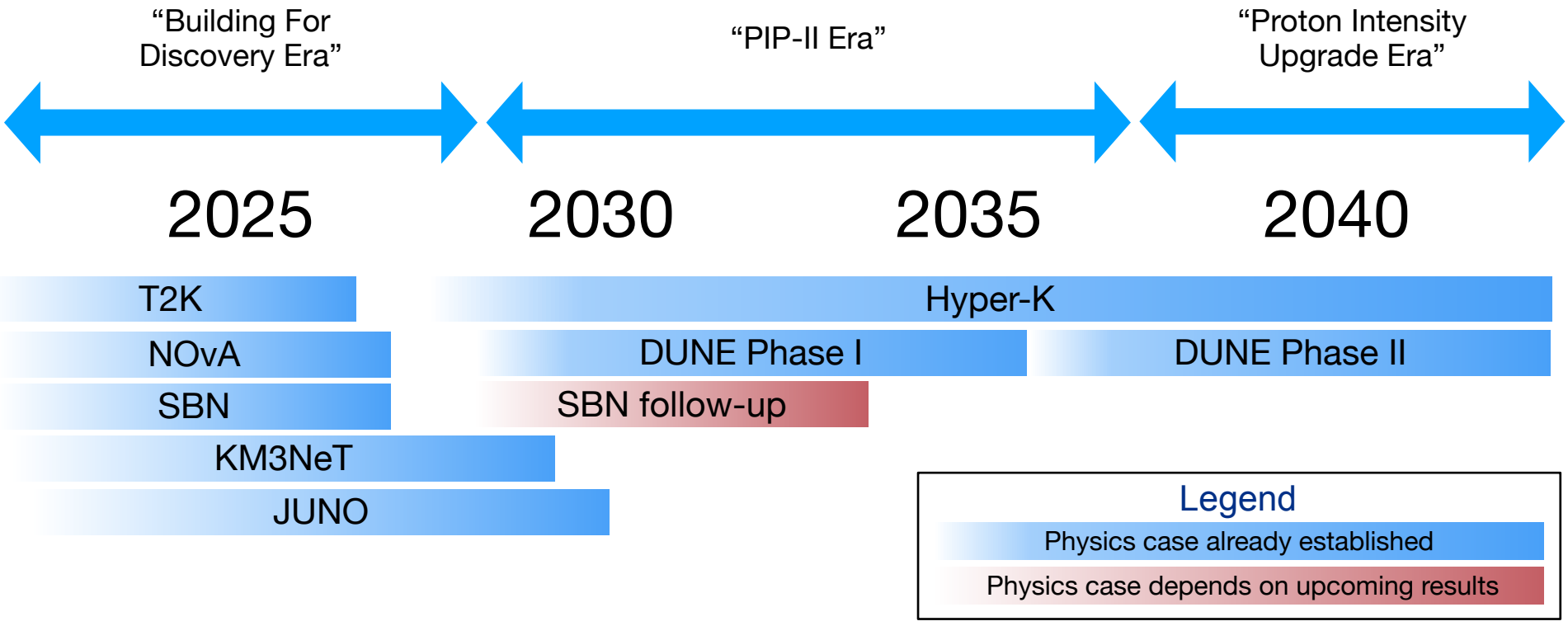
- Accomplished with PIP-II, LBNF/DUNE-US, and DUNE International Partners
- Meets P5 minimum requirements to proceed by 2035 timeframe
- Same project scope as proposed at CD-1R in July 2015

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

DUNE Timeline



The SPWG's Message

Still under development

High-level summary currently leads with neutrino physics:

- **"Fermilab's highest priority is the successful execution of DUNE and DUNE Phase 2 on a timescale that enables world-first measurements as laid out by the 2014 P5**
  - Short-baseline neutrino experiments are an important complement to the long-baseline program with their own compelling physics"

Also lists priorities from the other 11 subgroups

- Ongoing and proposed projects in all frontiers, including developing a path for the R&D, design, and construction of a muon collider and an Advanced Muon Facility (AMF) at FNAL

Must be further consolidated into a crisp message for P5

Upgrading the Current Complex

- In addition to Booster replacement the PIU CDG reported on 12/2 that it is considering what upgrades to the current complex would make sense prior to Booster replacement
- Currently 3 areas being looked at
  - **PIP-II Accumulator Ring (PAR)**
    - Would aid in loading the Booster with PIP-II beam
    - Would provide a 0.8GeV pulsed proton beam program
      - beam dump, dark matter experiments
      - experiments with neutrinos from stopped pions and muons
  - **Upgrades to the present Booster**
    - Probably only small increases in intensity can be facilitated here unless a lot of money is spent
  - **Reducing the Main Injector cycle time**
    - This looks extremely promising
    - Potential to increase the power to LBNF
    - Compatible with all upstream upgrades being considered

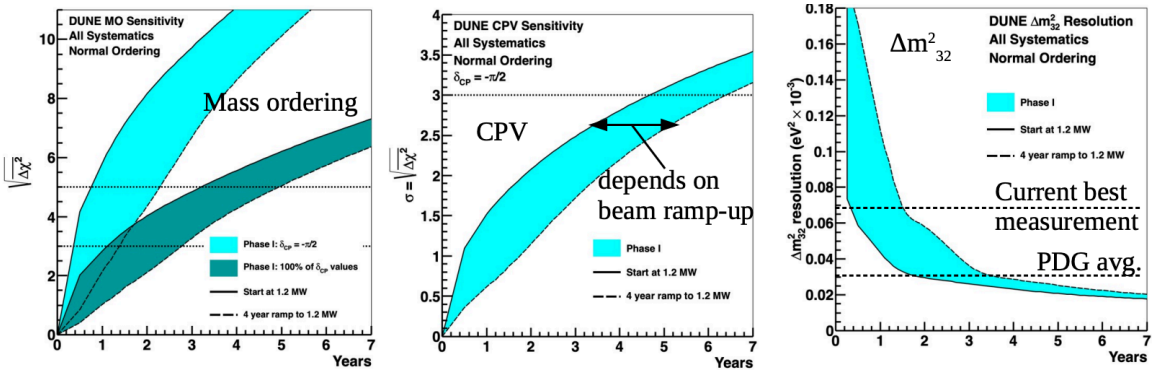
“Proton Economics”

Scenario	Present	PIP-II	MI cycle time reduction	units
MI 120 GeV ramp period	**1.2**	**1.2**	**0.7**	s
Booster ring intensity	**4.5**	**6.5**	**6.5**	10^{12} p
Booster repetition rate	15	20	20	Hz
Number of batches	12	12	12	
MI power	0.865	1.25	**2.142**	MW
cycles for 8 GeV	6	12	2	
Available 8 GeV power	29	83	24	kW

- Accelerating an additional 59 kW of 8 GeV protons to 120 GeV
  - Results in 1.25 MW + 59 kW * (120 GeV / 8 GeV) = 2.14 MW of 120 GeV protons

Reducing the Main Injector Cycle Time

- Capable of delivering >2MW to LBNF much sooner than a full booster replacement
- Considerably cheaper than a new accelerator
- Executable in a series of summer shutdowns rather than needing a long shutdown
  - Some improvements possible by the end of the long shutdown, full benefit likely by ~2035



- Workshop/internal review in Jan. will develop full technical scope, cost and schedule for the MI cycle time reduction and associated required improvements

Summary

- P5 charge, committee makeup, and rough schedule have been announced
- The FNAL SPWG is currently crafting its overall message to P5, leading with DUNE
  - "Fermilab's highest priority is the successful execution of DUNE and DUNE Phase 2 on a timescale that enables world-first measurements as laid out by the 2014 P5"
- This messaging is supported by the exciting prospect of delivering >2MW to LBNF more cheaply and faster than originally envisioned with an MI cycle time reduction
  - Path also implies that the justification for new accelerators replacing the Booster will be driven by physics programs other than LBNF/DUNE, whose beam delivery requirements will nonetheless remain a design requirement for any future machine
- Based on P5's "straw-person schedule", expect to present Fermilab's message to P5 sometime in February

Thank you for your attention

Discussion/feedback