

Global cooperation is key to US high-energy physics strategy

A consensus emerges on which exciting opportunities to pursue under tight budgets.

The High Energy Physics Advisory Panel (HEPAP) unanimously endorsed the Particle Physics Project Prioritization Panel (P5) report when it was released on 22 May. Now the US particle-physics community hopes that NSF and the Department of Energy, the funding agencies that requested the 10-year prioritization strategy, can use the report to help stanch the decline in funding the field has suffered in recent years.

Jim Siegrist, associate director of the DOE Office of Science, says the agency “is very pleased with the report. It pro-

vides an executable plan for high-energy physics in the US in a global context just as requested.” And, he says, it “will affect the details of the execution of our [fiscal year] 2015 budget once appropriated and the formulation of our FY 2016 budget.” The president’s FY 2015 request for high-energy physics is down 6.6% from the previous year. The P5 considered three funding scenarios for the next decade (see the table below). Scenario A assumes flat funding at the FY 2013 level for three years followed by increases of 2% a year; scenario B is also flat for the

first three years but slightly higher, at the president’s FY 2014 budget, and then climbs by 3% annually; scenario C has an unconstrained budget.

Among the highest priorities outlined in the report are that the US be involved in the upgrades of the Large Hadron Collider (LHC) at CERN and that it host as a global project a long-baseline neutrino facility (LBNF) with a large underground detector. Among the casualties are six experiments, including ORKA and NuSTORM—a proposed kaon detector and neutrino beam, respectively, at Fermilab. The report also recommends consulting with partners about an early termination of

Priorities for high-energy physics efforts given various funding scenarios, listed by timing of peak construction

Project/activity ¹	Scenario A	Scenario B	Scenario C
	Least money	↔	Most money
Large projects			
Muon program: Mu2e, Muon $g - 2$	Yes ²	Yes	Yes
High Luminosity Large Hadron Collider	Yes	Yes	Yes
Long-baseline neutrino facility + Proton Improvement Plan-II	Yes ³	Yes	Yes, enhanced
International Linear Collider	R&D only	R&D ⁴	Yes
Neutrinos from Stored Muons (NuSTORM)	No	No	No
R&D argon detector at Ash River	No	No	No
Medium projects			
Large Synoptic Survey Telescope	Yes	Yes	Yes
Dark matter, second-generation experiments	Yes	Yes	Yes
Small projects portfolio	Yes	Yes	Yes
Accelerator R&D and development facilities	Yes, reduced	Yes ⁵	Yes, enhanced
CMB-S4	Yes	Yes	Yes
Dark matter, third-generation experiments	Yes, reduced	Yes	Yes
Precision IceCube next-generation upgrade	Further development of concept encouraged		
Rare kaon decay experiment (ORKA)	No	No	No
Muon accelerator program	No	No	No
Cherenkov detectors in mine pits (CHIPS)	No	No	No
Liquid argon time projection chamber	No	No	No
Additional small projects (beyond the small projects portfolio)			
Dark Energy Spectroscopic Instrument	No	Yes	Yes
Short-baseline neutrino portfolio	Yes	Yes	Yes

¹ Large projects are defined as those exceeding \$200 million, medium projects cost \$50 million to \$200 million, and small projects fall below \$50 million. The P5 study did not consider projects costing less than \$20 million.

² Mu2e needs a small schedule adjustment.

³ LBNF components are delayed relative to scenario B.

⁴ Small hardware contributions may be possible.

⁵ Some reductions are necessary, with redirection to PIP-II development.

Adapted from the Particle Physics Project Prioritization Panel report.

MICE, the International Muon Ionization Cooling Experiment in the UK. The report's most important message is that high-energy physics is a global endeavor, says the University of Tokyo's Toshinori Mori, who served on the 25-member P5. "That is the only way the world of particle physics can survive the future."

Science drivers

The P5 took up where Snowmass, a nearly year-long brainstorming process, left off (see PHYSICS TODAY, October 2013, page 18). The 11 groups of physics questions that came out of Snowmass fed into the P5 report's five intertwined "compelling lines of inquiry that show great promise for discovery over the next 10 to 20 years." Those "science drivers" inform the P5 recommendations and also give the high-energy physics community a more descriptive way to talk about its science than the "frontier" categories—energy, intensity, and cosmic—that were adopted by the last P5 in 2008. The drivers are

- 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 report makes 29 recommendations. They span specific facilities, R&D, timing of projects, redirection of money, and a reminder to remain flexible so that the field can respond to future findings and to decisions in other countries. (The 65-page report is available at <http://www.usparticlephysics.org/p5>.) The P5 recommends pursuing small- and medium-scale projects in addition to large ones. The report gives high marks to completing the Large Synoptic Survey Telescope and two muon experiments, Mu2e and Muon $g-2$, and also says it's "urgent" to move forward with next-generation dark matter experiments at a higher level of funding than NSF and DOE proposed in 2012.

The report says that the fraction of the US high-energy physics budget devoted to construction should increase from 16% to 20–25%. "If we don't make more money available to build things, there won't be a future," says Ian Shipsey of Purdue and Oxford Universities, who is a member of HEPAP and the current chair of the American Physical Society's division of particles and fields. The increase would come at

the expense of the research and operations budgets. But research could still get at least 40% of the total, which the panel "calculated would maintain a strong community at universities," Shipsey says.

For large-scale facilities, in addition to the LHC upgrades and LBNF, the report says the science case is strong for the International Linear Collider (ILC), a 500-GeV electron-positron accelerator upgradable to 1 TeV. Japan is expected to decide in the next five years whether to proceed with the ILC (see PHYSICS TODAY, March 2013, page 23). "The US role depends on lots of things outside of P5," says P5 chair Steve Ritz of the University of California, Santa Cruz. "But we voiced strong endorsement [of the ILC]." And, he adds, "Our overall global vision is that the US and other major world players can address the breadth of questions only if each region hosts a major unique facility and also partners in the major facilities elsewhere."

Neutrino facility

The vision for a major international US-based facility is the LBNF, with neutrinos from Fermilab zipping 1300 km to a large detector deep in the Sanford Underground Research Facility in



We machine all kinds of complex shapes

When precision machining, extremely tight tolerances, and on-time delivery matters

sapphire, ceramics and glass

- Ability to machine complex geometry – up to 5-axis
- Machined to customer specs at extremely tight tolerances
- Unbiased guidance and technical assistance on material selection
- Outside and inside diameter polishing
- Machine automation allows for prototype to high volume production



Insaco's inspection and lean manufacturing processes deliver bottom line customer benefits

www.insaco.com

Phone 215.536.3500



Earning your trust since 1947

South Dakota. Consensus for the scheme emerged last year at the Snowmass meeting after DOE had trimmed the project to a smaller, aboveground detector (see PHYSICS TODAY, February 2013, page 19).

Going forward with the LBNF will require that some \$600 million of the total \$1.5 billion tab come from other countries. "We have to figure out what to change at Fermilab so that this looks not like a national project with international participation, but like an international project hosted at Fermilab," says Fermilab director Nigel Lockyer. For starters, new governing structures, likely modeled on CERN, will be needed. With the green light from P5, says Lockyer, "I am working to collect together funding agencies and leaders of particle physics from around the world to have discussions as to how we can proceed as one team."

Europe and Japan both have their own concepts for long-baseline neutrino experiments. "We're sticking our necks out and saying, Let's do it here," Lockyer says. "We can't easily change the baseline or the beam. But everything [about the design] is on the table." And, he adds, "I am quite excited that P5 endorsed in no uncertain terms upgrading [the neutrino source] to have higher power. Once we have the world's best neutrino beam, it sets things up perfectly for getting everybody here."

Small change, big effects

Scenario B has about \$30 million a year more than scenario A until 2018, and then the gap grows, reaching \$95 million in 2024. Summed over the decade, the difference comes to \$500 million. With the annual DOE budget for high-energy physics hovering around \$750 million, the difference between the two scenarios may seem small. But, says Ritz, "the bang for the buck for the investment is huge."

Under scenario A, not only would the Dark Energy Spectroscopic Instrument be sacrificed, but R&D for dark matter and other experiments would get reduced funding and the long-baseline neutrino program would progress more slowly. "As valuable as each of these items is, they simply do not fit in Scenario A," the report says.

Moreover, funding at the scenario A level would send the rest of the world a danger signal, says Shipsey. "Scenario A is at the edge of not being able to deliver. It might create the impression that the US is teetering on the brink. If the rest of the world sees the US choose scenario A, it will think we are not commit-

ted. The US has not always been a reliable partner. We need to look like we are the real deal."

Unconstrained funding

The P5 members didn't go wild with scenario C, which removes financial constraints. Instead the report focuses on "a few high-priority opportunities that would each dramatically enhance key elements of the strategic plan recommended for Scenarios A and B." The recommendations for increased accelerator R&D are "transformational," says Ritz. With a larger investment, experiments will be affordable sooner. "As work proceeds worldwide on long-term future-generation accelerator concepts, the U.S. should be counted among the potential host nations," says the report. And if Japan does go ahead with the ILC, scenario C "would enable the U.S. to play world-leading roles in the detector program as well as provide critical expertise and accelerator components."

Also, with more money, the LBNF could expand to host both a Cherenkov water detector and a liquid argon detector. They are sensitive to different attributes of neutrinos and proton decay, and having both would incorporate aspects of the visions for neutrino experiments in Japan, Europe, and the US. The combination might make it easier to get everyone on board for a single global facility in the US, notes Lockyer.

But getting enough money to realize scenario C, says Shipsey, "would require working together with the other sciences. I don't think the government would pick out particle physics and give us a boost. In the end, biologists, chemists, zoologists all have much in common. We need to convince the government to invest more in research."

Getting their act together

Future budgets aside, the P5 report has already resulted in a significant gain for the US high-energy physics community. In building a strategy that the community as a whole is behind, the report should help dispel a perception of fractiousness. Among the theories for how that reputation came about are that the field has become very broad, which has led to subgroups competing with each other; that the community has asked for all manner of projects to be funded without heed to tight budgets; and that in debates about new ideas, sore losers have been vocal.

Whatever the source of the reputation, the consensus is that speaking in a unified voice is necessary to combat eroding budgets and realize big plans. Lockyer recalls that when he interviewed for Fermilab's top job last year, a DOE official told him that the field "has to get its act together." The P5 report does that, he says.

Toni Feder

Lasers will shine in future warfare

High-power radio and microwave beams join cost-effective, solid-state lasers on US military's horizon.

Later this year the US Navy will deploy a laser weapon aboard a ship in the Persian Gulf. Slated to be installed on the USS *Ponce*, an amphibious transport dock, the laser weapon system will be capable of shooting down the unmanned aerial vehicles (UAVs) and disabling the small attack boats that officials say are rapidly increasing threats.

"This is a revolutionary capability," Matthew Klunder, chief of naval research, said in a statement. "This very affordable technology is going to change the way we fight and save lives."

The 30-kW weapon system is a prototype that bundles six commercial fiber lasers. Their noncoherent beams converge at the target, which they burn or ablate, explains Peter Morrison, manager of the Solid-State Laser Technol-

ogy Maturation Program at the Office of Naval Research. In tests, earlier versions of the system successfully defeated several UAVs and small boats.

Three navy contractors—Raytheon, Northrop Grumman, and BAE Systems—are now developing different versions of laser weapon prototypes in the 100- to 150-kW range. In two or three years, some of those systems could be demonstrated on destroyers or on combat ships close to shore, Morrison says. If all goes well, full-scale deployment of onboard weapons could begin as soon as 2020.

The US military has experimented with laser weapons since the late 1970s, says Richard De Fatta, director of the emerging technology directorate at the US Army Space and Missile Defense Command. It was a carbon dioxide