~~Input~~ from the US

Hitoshi Murayama, P5 Chair

CEPC Workshop, Edinburgh, July 6, 2023

P5
Particle Physics Project Prioritization Panel

Hitoshi Murayama, P5 Chair

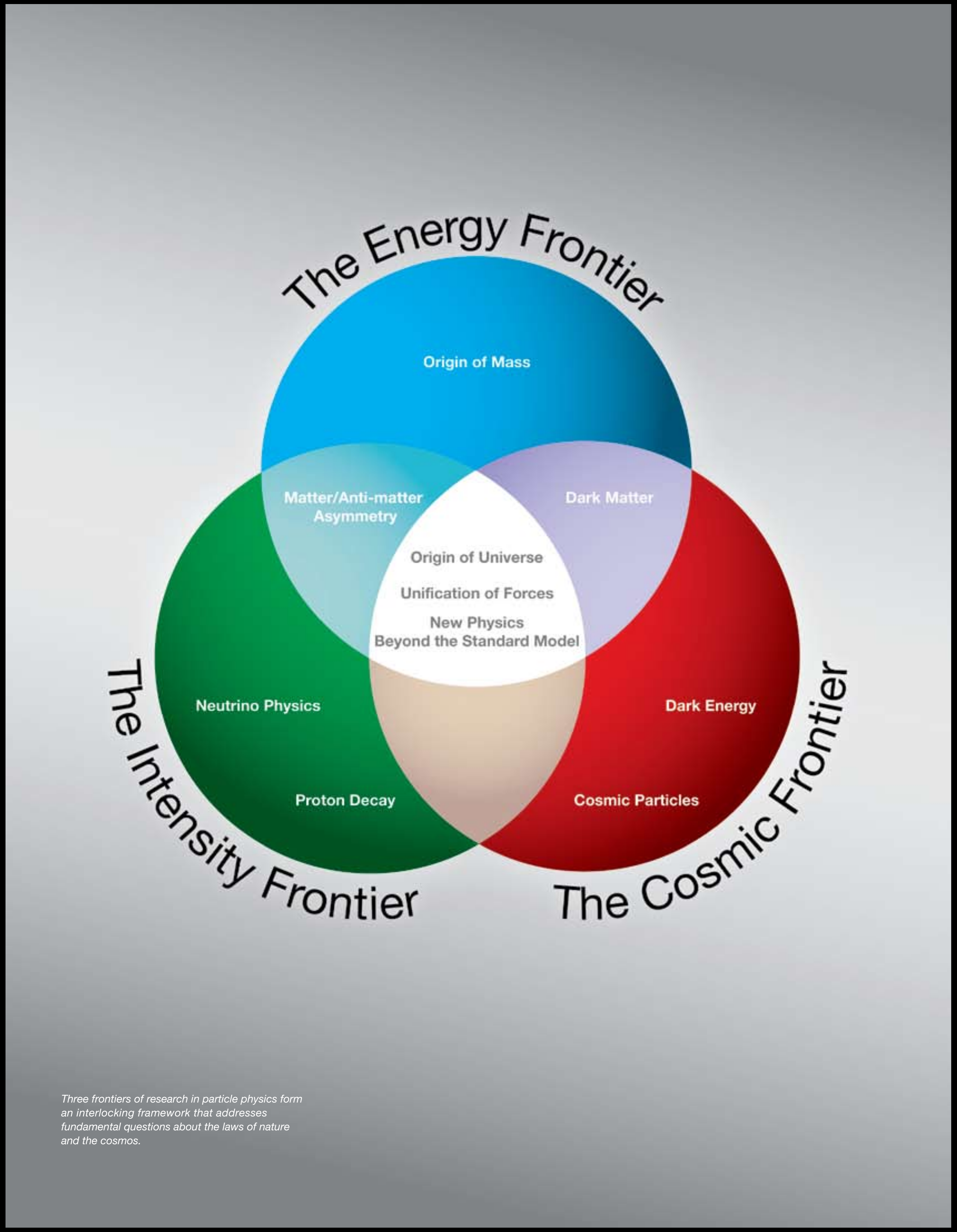
CEPC Workshop, Edinburgh, July 6, 2023

Background

- HEPAP (High-Energy Physics Advisory Panel) advises DOE OHEP and NSF PHY
  - Sunshine law requires such advisory panels are open
  - Impossible to discuss sensitive issues such as prioritization!
- But HEPAP can create a “subpanel” whose meetings can be closed
  - HEPAP subpanels existed for a long time, discussed “big things”
- Individual projects used to be purview of lab PACs
- Around Snowmass 2001, it was becoming increasingly clear that “projects” have become too big to be handled by lab PACs
- Natalie Roe: “national PAC” (Snowmass 2001)
  - A standing committee that handles decisions of mid-size and big projects in particular physics
- Bagger & Barish HEPAP subpanel recommended creation of P5 (2002)

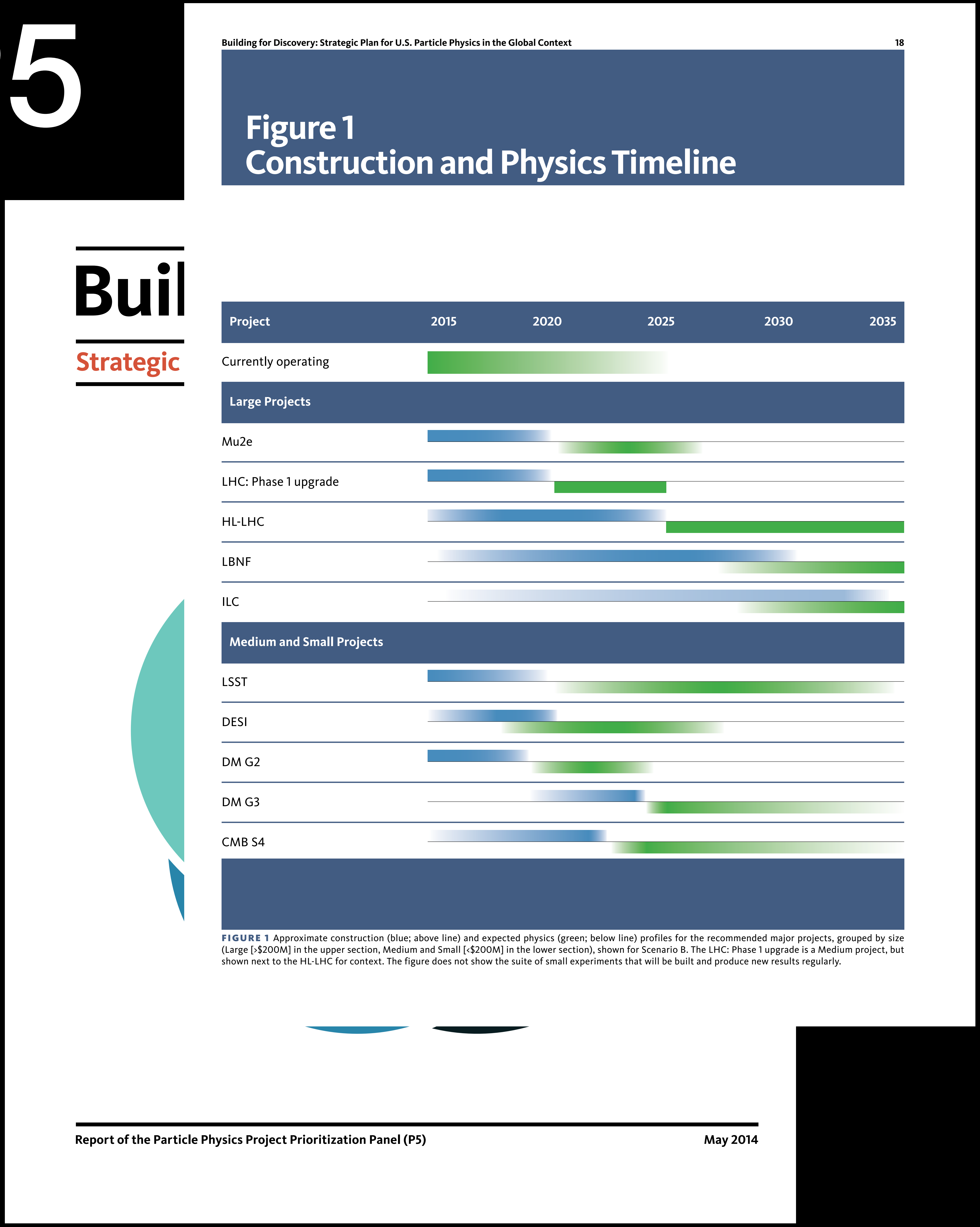
2008 P5

- 2008 P5 (Charles Baltay)
  - First “modern” P5 with budget scenarios
  - Tevatron for one to two more years
  - World-class neutrino program
  - Dark matter & dark energy, LSST
- *US Particle Physics: Scientific Opportunities A Strategic Plan for the Next Ten Years*
- Followed by specific 2010 P5 on Tevatron that recommended additional 2-3 years



2014 P5

- 2014 P5 (Steve Ritz)
  - 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.
- Finally “got it right”
  - Well received in Washington
  - “*Made many hard choices*”
  - 3000 signatures from the community
  - Increased HEP budget ~45%



s Process for Future Planning

Community

“Snowmass”
Community Study

Organized by
APS / DPF

Snowmass 2021

Particle Physics Project
Prioritization Panel (P5)

Organized by
HEPAP

Charge
Budget scenario

DOE HEP
NSF PHYS

DOE HEP
NSF PHYS

OMB
OSTP
Congress

Key Elements of a Successful P5

- Well informed by the science community
- Set a grand long-range vision for U.S. particle physics
- Faced budget constraints realistically
  - “Community made tough choices.”
- Balanced portfolio
  - Domestic and international
  - Small, mid-scale, and large projects
- Community engagement critical to success
  - “Bickering scientists get nothing.”

Harriet Kung, Snowmass in Seattle
Then interim director of HEP
Now deputy director for Science Programs

Changing landscape

- 125 GeV Higgs does look like standard model
  - Previous P5: “Higgs as a new tool for discovery”
- Recognition that dark matter parameter space is *big*
  - Growing in interest in low-energy weakly coupled sector
- **Λ**CDM + inflation is the new Standard Model
  - But H_0, $\boldsymbol{\sigma}_8$ tension
  - Inflation, cosmological constant vs swampland?
- DUNE moving ahead
  - Now Hyper-Kamiokande is also happening
- Lattice vs g-2?
- Interesting anomalies in flavor physics
- Gravitational wave! High-energy neutrinos!
- Now 10 frontiers (+costing frontier?)
- National Initiatives: Quantum, AI/ML, microelectronics
- Field is more global than ever, yet geopolitical challenges, climate change

Snowmass 2021

Decadal Overview of Future Large-Scale Projects		
Frontier/Decade		
Energy Frontier	U.S. Initiative for the Targeted Development of Future Colliders and their Detectors	
	US role?	Higgs Factory Scope? Technology? Complementarity?
Neutrino Frontier	LBNF/DUNE Phase I & PIP- II	DUNE Phase II (incl. proton injector)
Cosmic Frontier	Cosmic Microwave Background - S4 Spectroscopic Survey - S5* Scope?	Next Gen. Grav. Wave Observatory* Line Intensity Mapping* Do we embrace them?
	Big, small, new? Multi-Scale Dark Matter Program (incl. Gen-3 WIMP searches)	
Rare Process Frontier		Advanced Muon Facility Scope? Other science?

How do we develop enabling technology for long-term vision in a fashion executable in 20 years?

Table 1-1. *An overview, binned by decade, of future large-scale projects or programs (total projected costs of $500M or larger) endorsed by one or more of the Snowmass Frontiers to address the essential scientific goals of the next two decades. This table is not a timeline, rather large projects are listed by the decade in which the preponderance of their activity is projected to occur. Projects may start sooner than indicated or may take longer to complete, as described in the frontier reports. Projects were not prioritized, nor examined in the context of budgetary scenarios. In the observational Cosmic program, project funding may come from sources other than HEP, as denoted by an asterisk.*

Balance

- Project vs research
- Large (>$200M), medium ($50-200M), small (<$50M) (previous P5)
  - Collection of small may be medium
- Science vs R&D
  - Instrumentation, computing, theory
- National initiatives
  - AI/ML, microelectronics, QIS
  - How do we capitalize on it? How do we contribute to justify it?
- DEI
  - What can agencies do?
  - Mentoring statement in grant proposals (done!)

P5 Charge (dated November 2, 2022) 1/8

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.

- The 2014 report was successful
- 2019 implementation review by HEPAP showed progress on the plan

- 2023 P5 to update strategic plan over 10-year timeframe in 20-yr context

P5 Charge 4/8

- A successful plan should maintain a balance of large, medium, and small projects that can deliver scientific results throughout the decadal timeframe. We do not expect the panel to consider the large number of possible small-scale projects individually, but advice on research areas where focused investments in smallscale projects can have a significant impact is welcome.
- There are elements of DOE HEP-operated infrastructure that are a stewardship responsibility for HEP. Investments to maintain that infrastructure in a safe and reliable condition are an HEP responsibility and are outside the scope of the panel. Major infrastructure upgrades that create new science capabilities are within the scope of the charge and should be considered by the panel.
- Successfully exploiting a newly built project requires funding for the commissioning and operation of the project and to support the researchers who will use these new capabilities to do world-leading science. Funding is also needed for research and development (R&D) that develops new technologies for future projects. Scientists and technical personnel working in experimental particle physics often contribute to all these project phases, while theoretical physics provides both the framework to evolve our fundamental understanding of the known universe as well as the innovative concepts that will expand our knowledge into new frontiers. The panel should deliver a research portfolio that will balance all these factors and consider related issues such as training and workforce development.

- Maintain balance of large, medium & small projects
- Advise on science topics to focus small projects
- Assess infrastructure upgrades that create new science capabilities
- Remember costs of R&D, commissioning, and operations for future projects
- Remember that a balanced core research budget is paramount to producing science from current projects and developing ideas for new ones

P5 Charge 5/8

- Both NSF and DOE are deeply committed to diversity, equity, inclusion, and accessibility principles in all the scientific communities they support. Creating a more diverse and inclusive workforce in particle physics will be necessary to implement the plan that this panel recommends, and the panel may further recommend strategic actions that could be taken to address or mitigate barriers to achieving these goals.
- Broad national initiatives relevant to the science and technology of particle physics have been developed by the administration and are being implemented by the funding agencies. These include, but are not limited to, investments in advanced electronics and instrumentation, artificial intelligence and machine learning, and quantum information science. Potential synergies between these initiatives and elements of the recommended portfolio should be considered.

- Remember that a diverse workforce results in improved science

- Address synergies with broad national initiatives

P5 Charge - budget scenarios 6/8

We request that the panel include these considerations in their deliberations and discuss how they affect their recommendations in the report narrative.

The panel's report should identify priorities and make recommendations for an optimized particle physics program over 10 years, FY 2024–FY 2033, under the following budget scenarios:

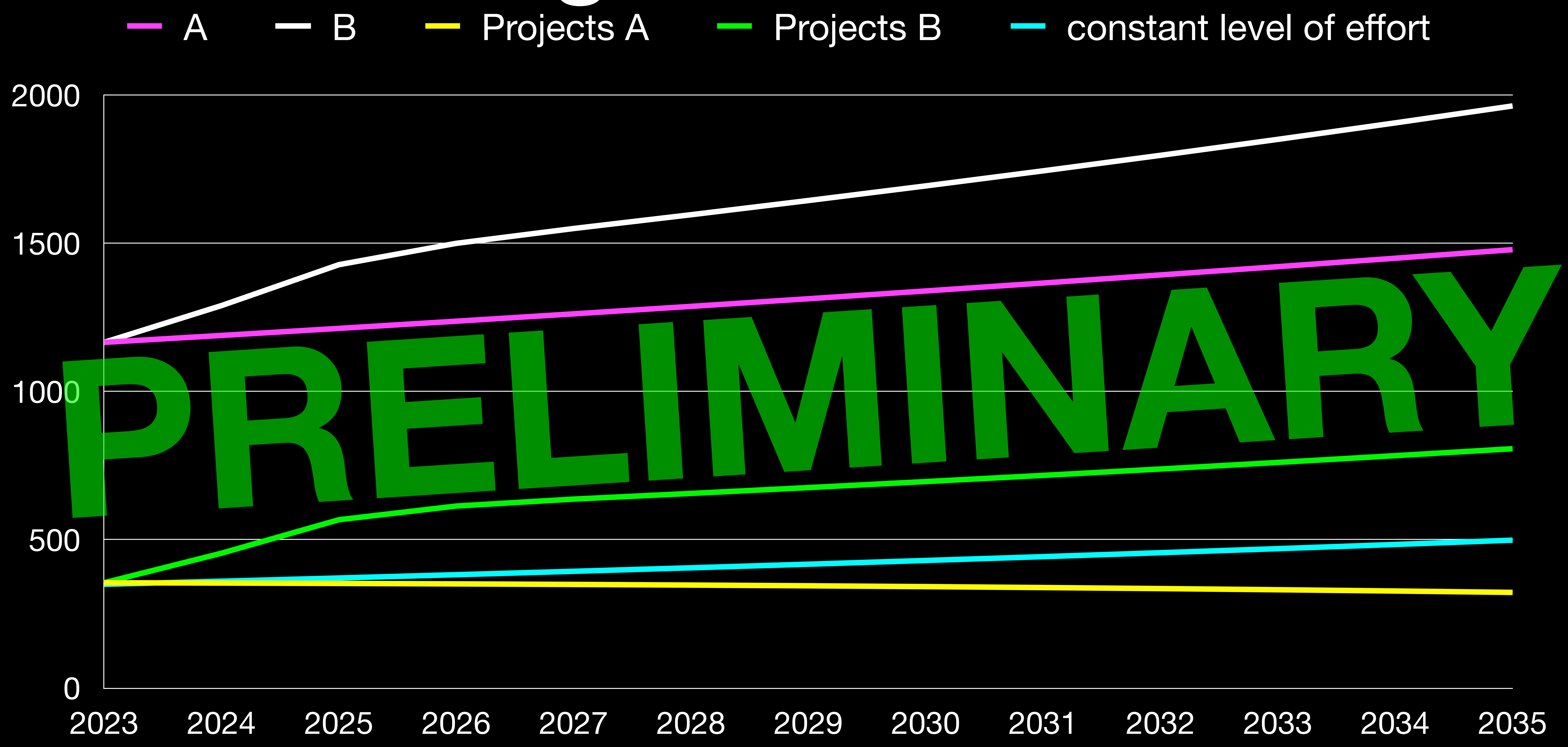
1) Increases of 2.0 percent per year during fiscal years 2024 to 2033 with the FY 2024 level calculated from the FY 2023 President's Budget Request for HEP.
2) Budget levels for HEP for fiscal years 2023 to 2027 specified in the Creating Helpful Incentives to Produce Semiconductors and Science Act of 2022, followed by increases of 3.0 percent per year from fiscal years 2028 to 2033.

The recommended projects and initiatives should be implementable under reasonable assumptions and be based on generally accepted estimates of science reach and capability. Estimated costs for future projects and facility operations should be given particular scrutiny and may be adjusted if the panel finds it prudent to do so. Given the long timescales for realizing these initiatives, we expect the funding required to enable the priorities the panel identifies may extend well past the 10-year budget profile, but any recommendation should be technically and fiscally plausible to execute in a 20-year timeframe.

- Scenario A: 2% increase per year
- Scenario B: Budgets in Chips and Science Act, followed by 3% increase per year

- Evaluate projected project costs
- Plan should be executable in 20-yr timeframe

Budget Scenarios



From the budget scenarios, research, facilities & ops are subtracted at the current level + 3% escalation to estimate project funds

Leadership team

JoAnne Hewett
HEPAP chair, ex officio

Hitoshi Murayama
P5 chair

Karsten Heeger
P5 Deputy chair


It is a great panel!

sts/Risks/Schedule Committee

- One lesson from the previous P5 was some of the costs were off by a factor of ~π
- Need to understand maturity of cost estimates better
- Jay Marx (Caltech), Chair
  - Gil Gilchriese, Matthaeus Leitner (LBNL)
  - Giorgio Apollinari, Doug Glenzinski (Fermilab)
  - Norbert Holtkamp, Mark Reichanandter, Nadine Kurita (SLAC)
  - Jon Kotcher, Srini Rajagopalan (BNL)
  - Allison Lung (JLab)
  - Harry Weerts (Argonne)

Jay Marx

Charge to P5 cost committee (Draft - 3/1/2023)

The cost/schedule/risk subcommittee to P5 is asked to obtain and clarify the cost/schedule/risk information from the proponents of high cost (>250M FY23$) HEP projects funded or being considered for funding by the DOE and/or NSF. The subcommittee will not prepare its own estimates. The committee should assess this information at a high level, noting key assumptions, risks and cost and schedule uncertainties including the risk from non-DOE/NSF funding sources, international partners making in-kind contributions and collaborations and missing costly items, if any. The committee is also asked to comment on the operation costs for projects for during commissioning and when the resulting facilities are in steady-state operation. This committee will provide P5 with the expert opinions on the uncertainty ranges for the projects that P5 needs to develop a strategy for the field within assumed budgetary constraints. The subcommittee will submit their preliminary report to P5 in early summer.

Iterating with “big” projects
Will also ask for information from medium and small soon

P5 tentative logo

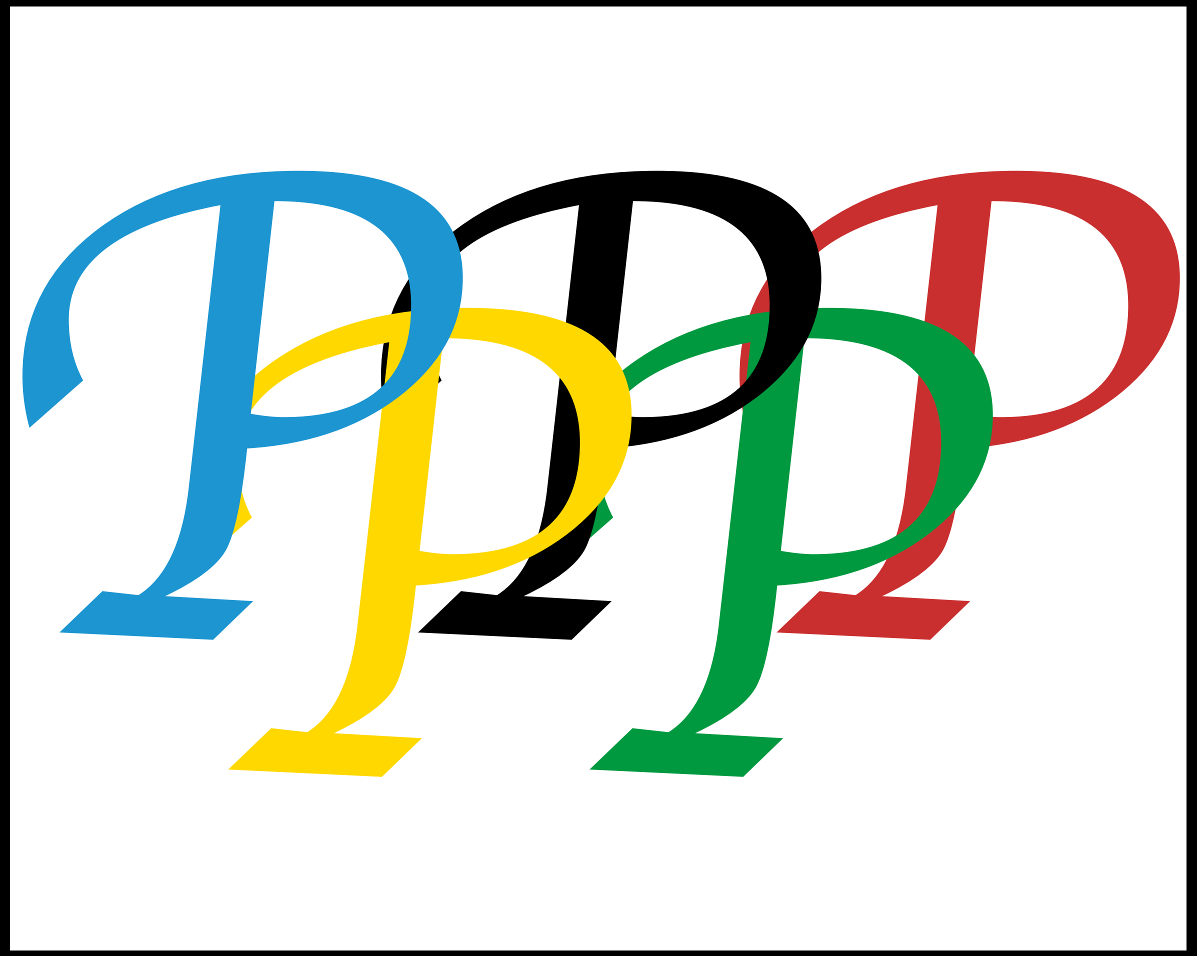
Apologies to Antarctica! CMB and IceCube

Time Table

- Information Gathering phase
  - Open Town Halls (finished)
    - LBNL: Feb 22, 23. 513 participants
    - Fermilab/Argonne: March 21, 22, 23. 797 participants
    - Brookhaven: April 12, 13. 666 participants
    - SLAC: May 3, 4. 512 participants
    - All with short remarks (x3 oversubscription)
  - Virtual Town Halls: June 5 (UT Austin), June 27 (Virginia Tech) (finished)
  - DPF session on P5 (April 15), Early Career Network Workshop (June 8,9), ACE Science Workshop (June 14, 15), CEPC Workshop (July 6)

Now

- Deliberation Phase
  - Four closed meetings from May to July, two more to go
  - Preliminary recommendations to agencies August
- Final report due October, subject to approval by HEPAP



Maximize science!

Higgs factory summary table

- Main parameters of the submitted Higgs factory proposals.
- The cost range is for the single listed energy.
- The superscripts next to the name of the proposal in the first column indicate:
  - (1) Facility is optimized for 2 IPs. Total peak luminosity for multiple IPs is given in parenthesis;
  - (2) Energy calibration possible to 100 keV accuracy for MZ and 300 keV for MW ;
  - (3) Colli... longitud... lepton b... substan... effective... for certa...

***Cf.* LHC ~ 120MW**

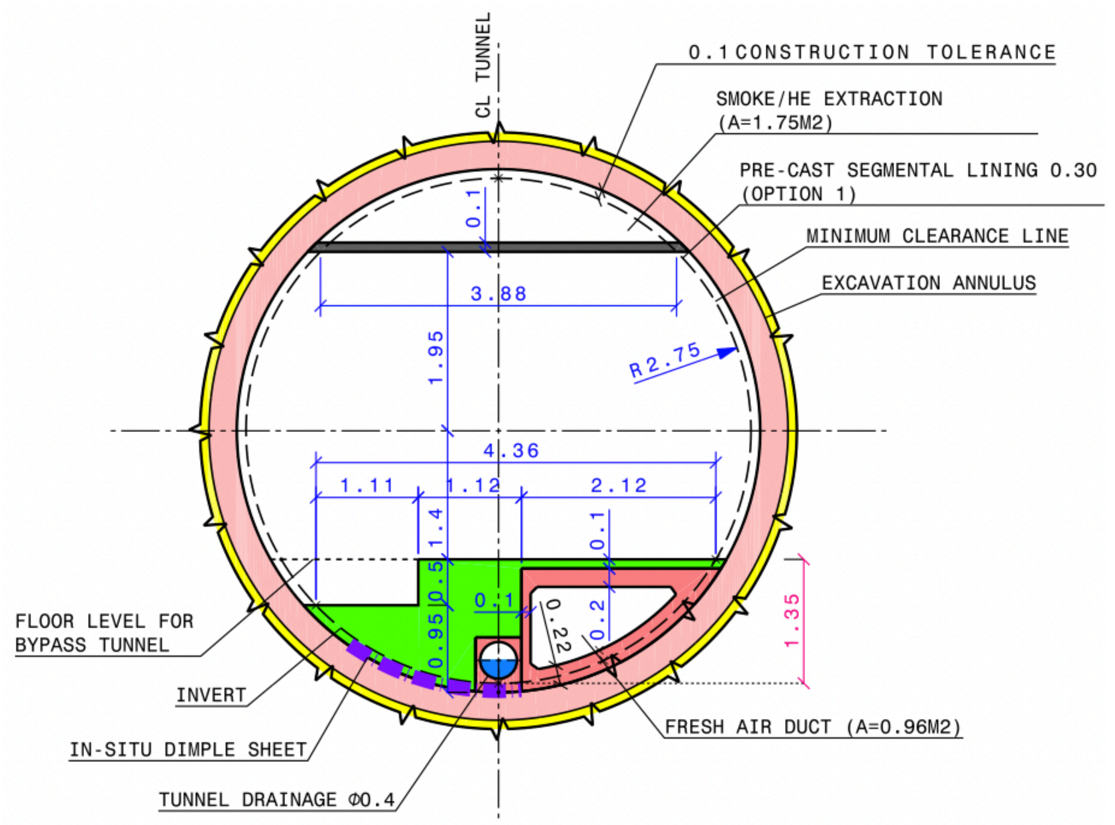
Proposal Name	CM energy nom. (range) [TeV]	Lum./IP @ nom. CME [10^{34} cm^{-2}s^{-1}]	Years of pre-project R&D	Years to first physics	Construction cost range [2021 B$]	Est. operating electric power [MW]
FCC-ee[1,2]	0.24 (0.09-0.37)	7.7 (28.9)	0-2	13-18	12-18	290
CEPC[1,2]	0.24 (0.09-0.37)	8.3 (16.6)	0-2	13-18	12-18	340
ILC[3] - Higgs factory	0.25 (0.09-1)	2.7	0-2	<12	7-12	140
CLIC[3] - Higgs factory	0.38 (0.09-1)	2.3	0-2	13-18	7-12	110
CCC[3] (Cool Copper Collider)	0.25 (0.25-0.55)	1.3	3-5	13-18	7-12	150
CERC[3] (Circular ERL Collider)	0.24 (0.09-0.6)	78	5-10	19-24	12-30	90
ReLiC[1,3] (Recycling Linear Collider)	0.24 (0.25-1)	165 (330)	5-10	>25	7-18	315
ERLC[3] (ERL linear collider)	0.24 (0.25-0.5)	90	5-10	>25	12-18	250
XCC (FEL-based $\gamma\gamma$ collider)	0.125 (0.125-0.14)	0.1	5-10	19-24	4-7	90
Muon Collider Higgs Factory[3]	0.13	0.01	>10	19-24	4-7	200

Thomas Roser (Brookhaven)
P5 Town Hall at Brookhaven

Yifang Wang couldn't get a visa to come to this meeting

Emissions from construction

- Carbon impact of main tunnel?
- Bottom up: calculate volume of tunnel walls, concrete is 15% cement → ~240 kt CO_2.
- Top down: studies of road tunnel construction give rule of thumb of 5,000-10,000 kg CO_2/km of tunnel → > ~500 kt CO_2.
- 6 million trees required for carbon offset!



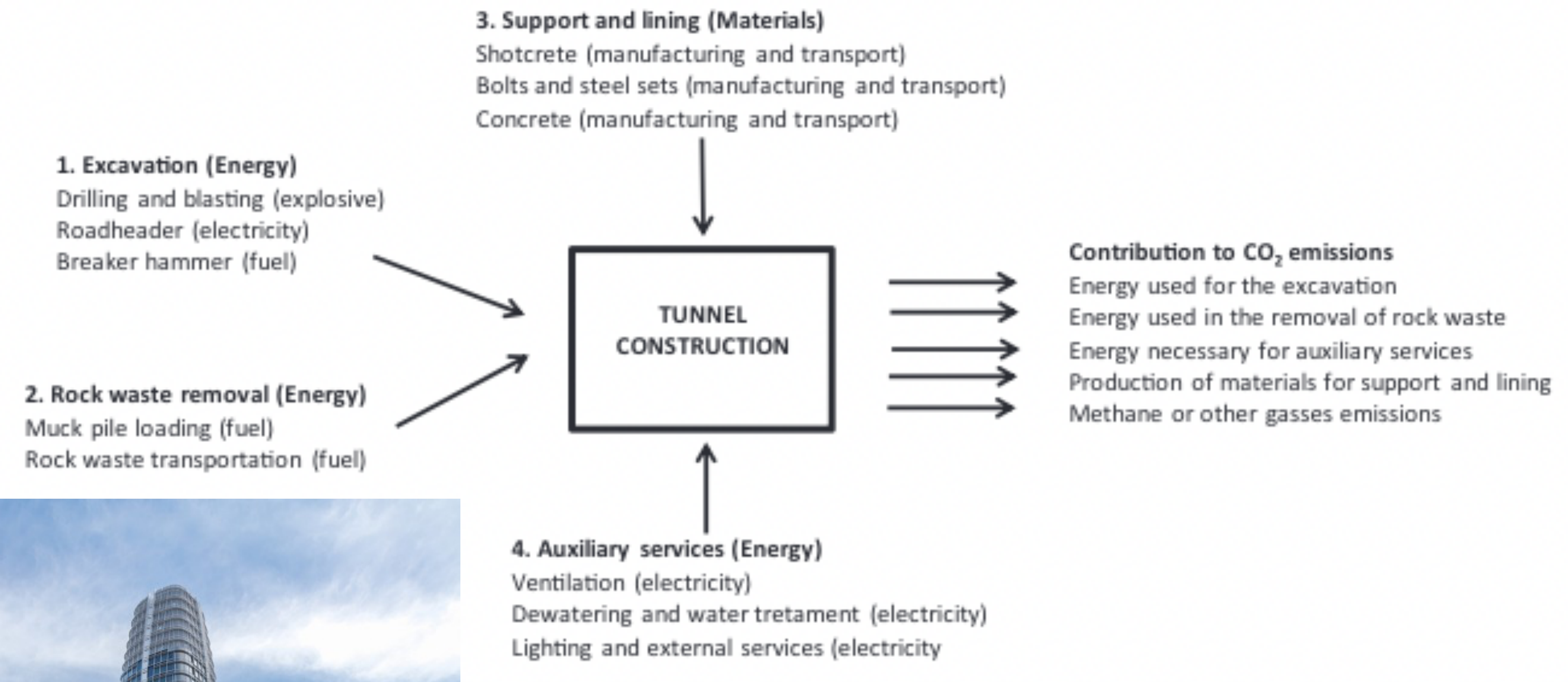


Fig. 1. Schematic overview of the system boundary.

- Salesforce Tower: 1.4M ft², ~550 kg embodied carbon/m² → ~79 kt CO2e.

Ken Bloom (Nebraska)
P5 Town Hall at SLAC