U.S. DEPARTMENT OF ENERGY | Office of Science

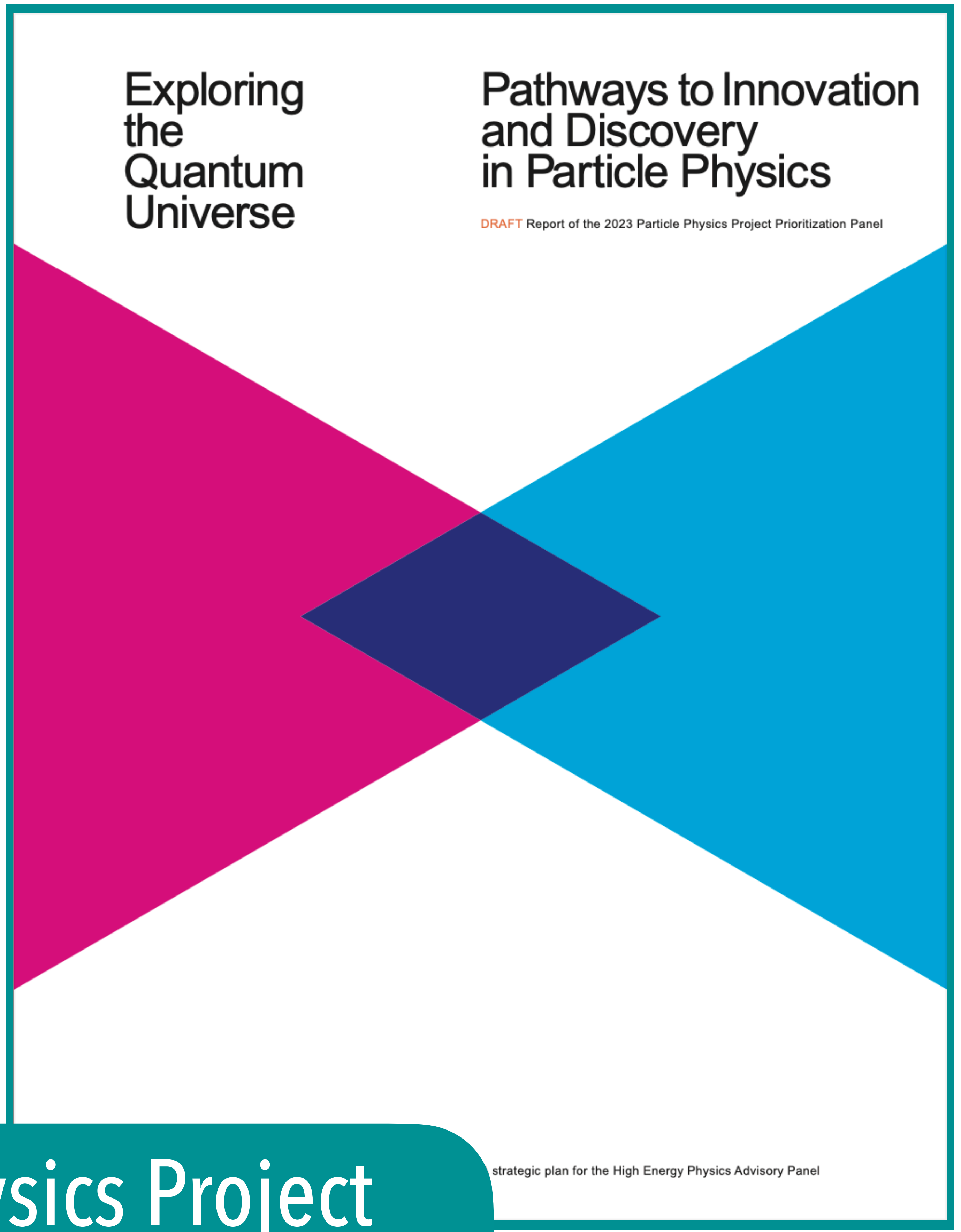
THE FUTURE OF HIGH ENERGY PHYSICS:
A NEW GENERATION, A NEW VISION

INTERNATIONAL BENCHMARKING

IN HIGH ENGERY PHYSICS

TOVA HOLMES, U. OF TENNESSEE
MARCH 28, 2024
ASPEN CENTER FOR PHYSICS

The lesser-known HEPAP panel…



Particle Physics Project Prioritization Panel

Live as of today!!

International Benchmarking

The lesser-known HEPAP panel…

(many summaries borrowed from Patty McBride's much more comprehensive slides!)

- Tasked with "international benchmarking", or more specifically asked about these three areas:

U.S. as a leader, at home and abroad	Innovative and transformative capabilities	Workforce
How can we cooperate and compete? How do we attract the best partners? How can we be a partner of choice? What barriers are preventing effective partnerships?	What are the key areas where we have or could have leadership roles? How can our leadership be strategically maintained? Are there other technical areas we could be leveraging better?	How do we attract and retain talented people? What barriers are there for this? How do we recruit, train, and mentor the best talent from all over the world, and from traditionally underrepresented groups in the US?

The lesser-known HEPAP panel…

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U.S. as a leader, at home and abroad	Innovative and transformative capabilities	Workforce
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Co-Chairs: Patricia McBride (FNAL), Bonnie Fleming (FNAL/UChicago)

Members: Mei Bai (SLAC), Marcela Carena (FNAL), Scott Dodelson (CMU), Dan Dwyer (LBL), Tova Holmes (UTK), Tsuyoshi Nakaya (Kyoto), Andy Lankford (UCI), Wim Leemans (DESY), Reina Maruyama (Yale), Sekazi Mtingwa (NRC), Brian Nord (FNAL), Ian Shipsey (Oxford), Stefan Soldner-Rembold (Manchester), Lindley Winslow (MIT)

Ex -Officio: JoAnne Hewett (SLAC) → Sally Seidel (UNM)

The lesser-known HEPAP panel…

- How did we organize our work?

Subcommittees	How to benchmark?	Data collection
Big Experiments (LHC, DUNE, Cosmic), Chair: A. Lankford Small Experiments & Instrumentation, S&C, QIS, AI/ML, Chair: I. Shipsey Accelerator Program, Chair M. Bai Workforce, Chair: S. Mtingwa Theory distributed throughout subcommittees.	Collaboration is key to progress. International collaboration complicates benchmarking the U.S. role. Metrics are not easy to evaluate (e.g., scientific papers, citations). Other possible metrics: Nobel prizes, investment per capita, leadership roles. More productive to focus on the benefits of collaboration and the advantages of the partnerships that advance our science globally.	Community interviews Townhall at Snowmass Demographics collected from diverse sources Feedback through our website and surveys from subcommittees

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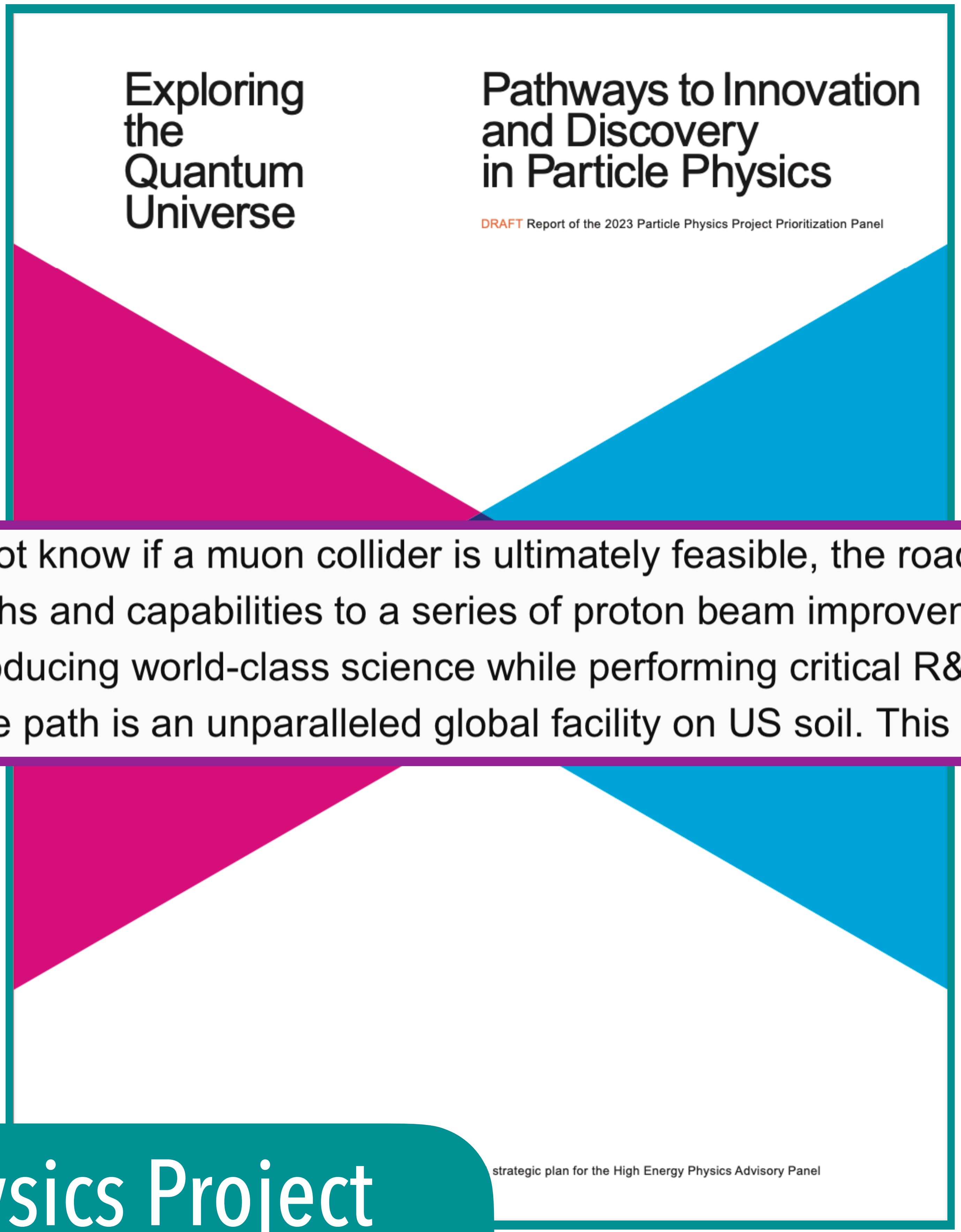
Theory distributed throughout subcommittees.	and the advantages of the partnerships that advance our science globally.	

My perspective:

Worked on the "big experiment" and workforce subcommittees

My personal lens



Although we do not know if a muon collider is ultimately feasible, the road toward it leads from current Fermilab strengths and capabilities to a series of proton beam improvements and neutrino beam facilities, each producing world-class science while performing critical R&D towards a muon collider. At the end of the path is an unparalleled global facility on US soil. This is our Muon Shot.

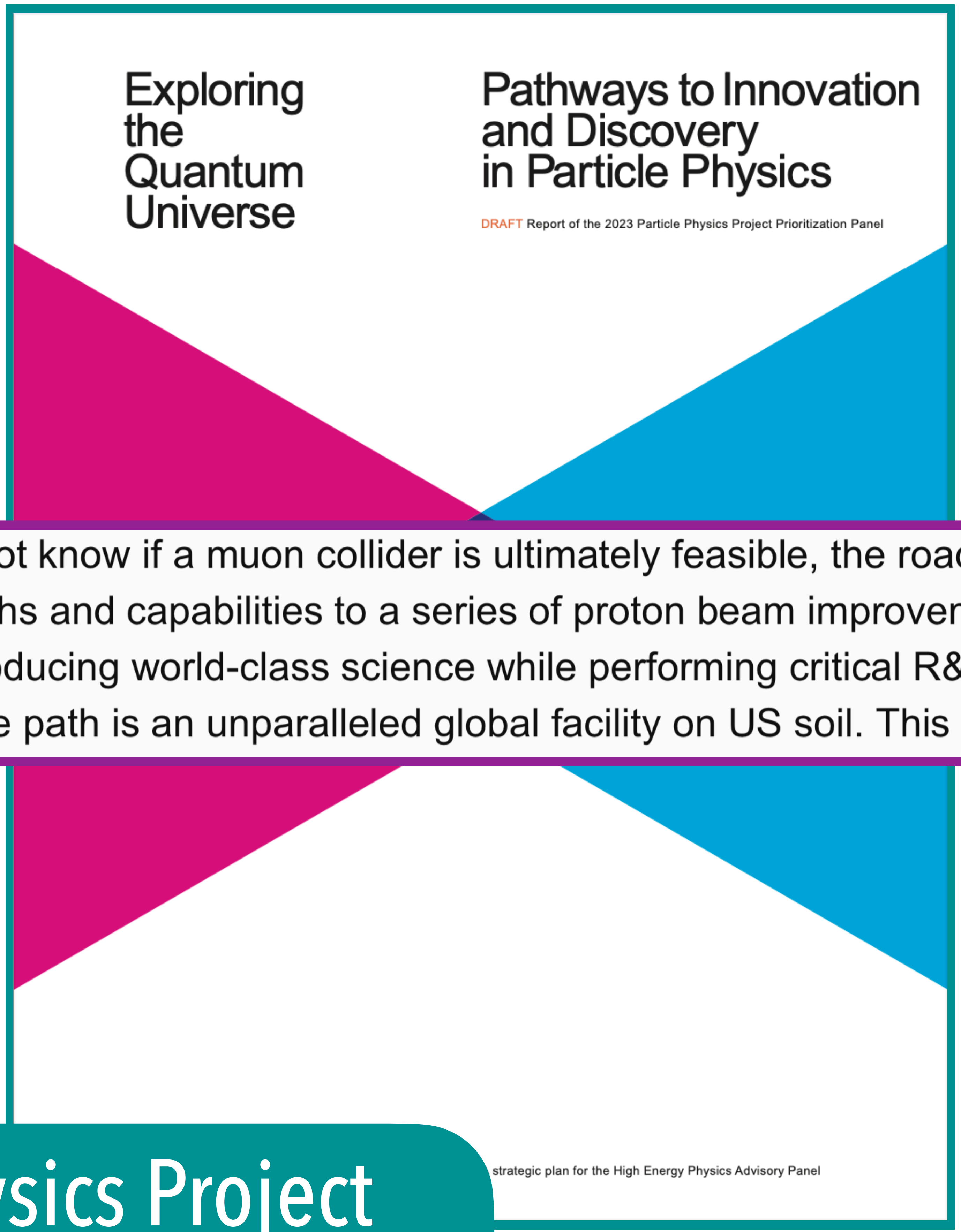
Particle Physics Project Prioritization Panel

Can the US host a global, mega-scale collider?

International Benchmarking

My personal lens

Also live as of today!!



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Particle Physics Project Prioritization Panel

Can the US
mega-sca

International Benchmarking

My personal lens

- This is very much not representative of the full report!
    - (but in 20 minutes…)

Diversity across scales and stages

KEY FINDING

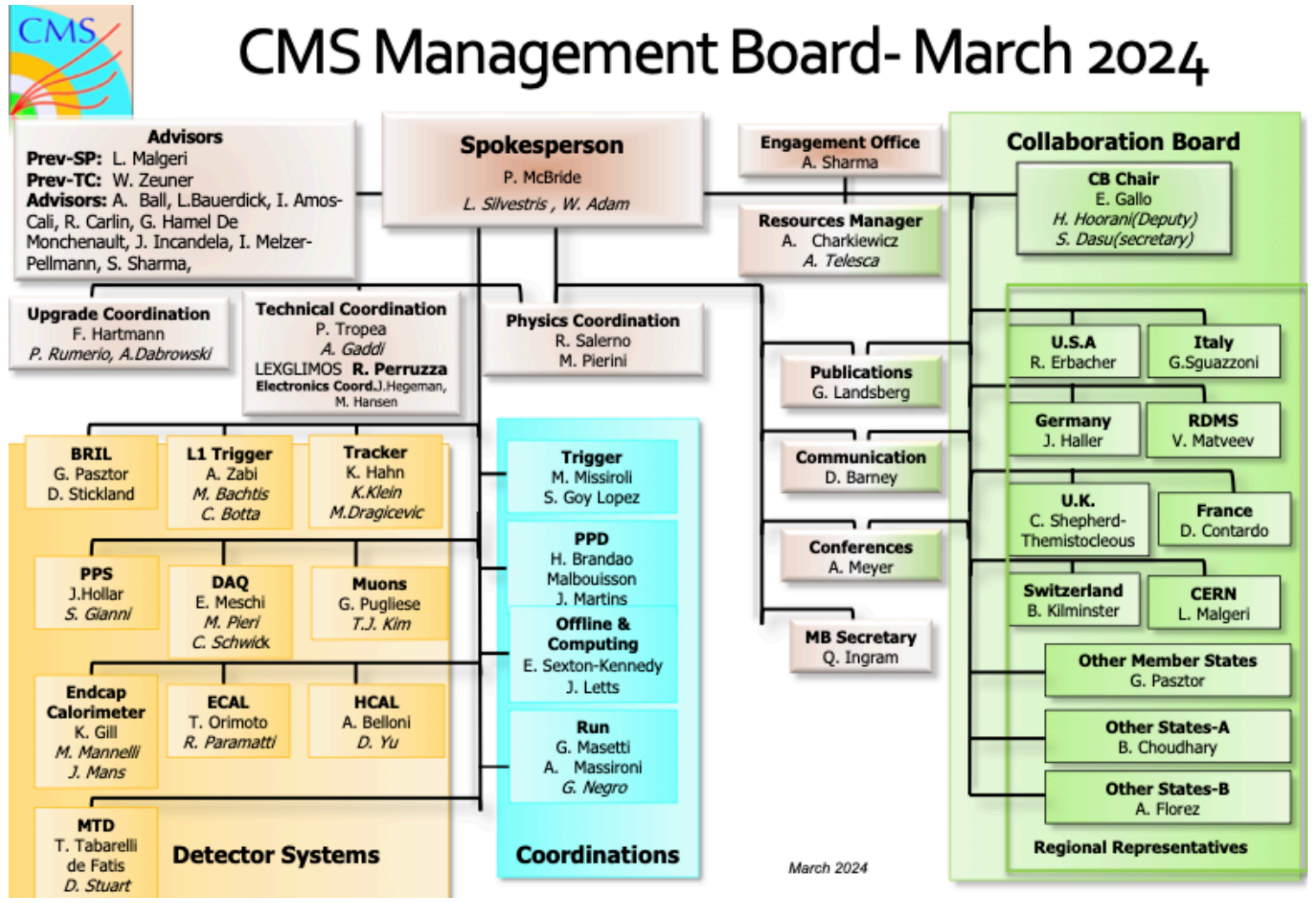
The field of particle physics is a vibrant research ecosystem, built by an international network of partnering nations, facilities, experiments, and people. To be a leader, the U.S. must continuously produce scientific results, build facilities and experiments for the future, and advance new ideas and technologies that enable the discoveries of tomorrow.

KEY RECOMMENDATION

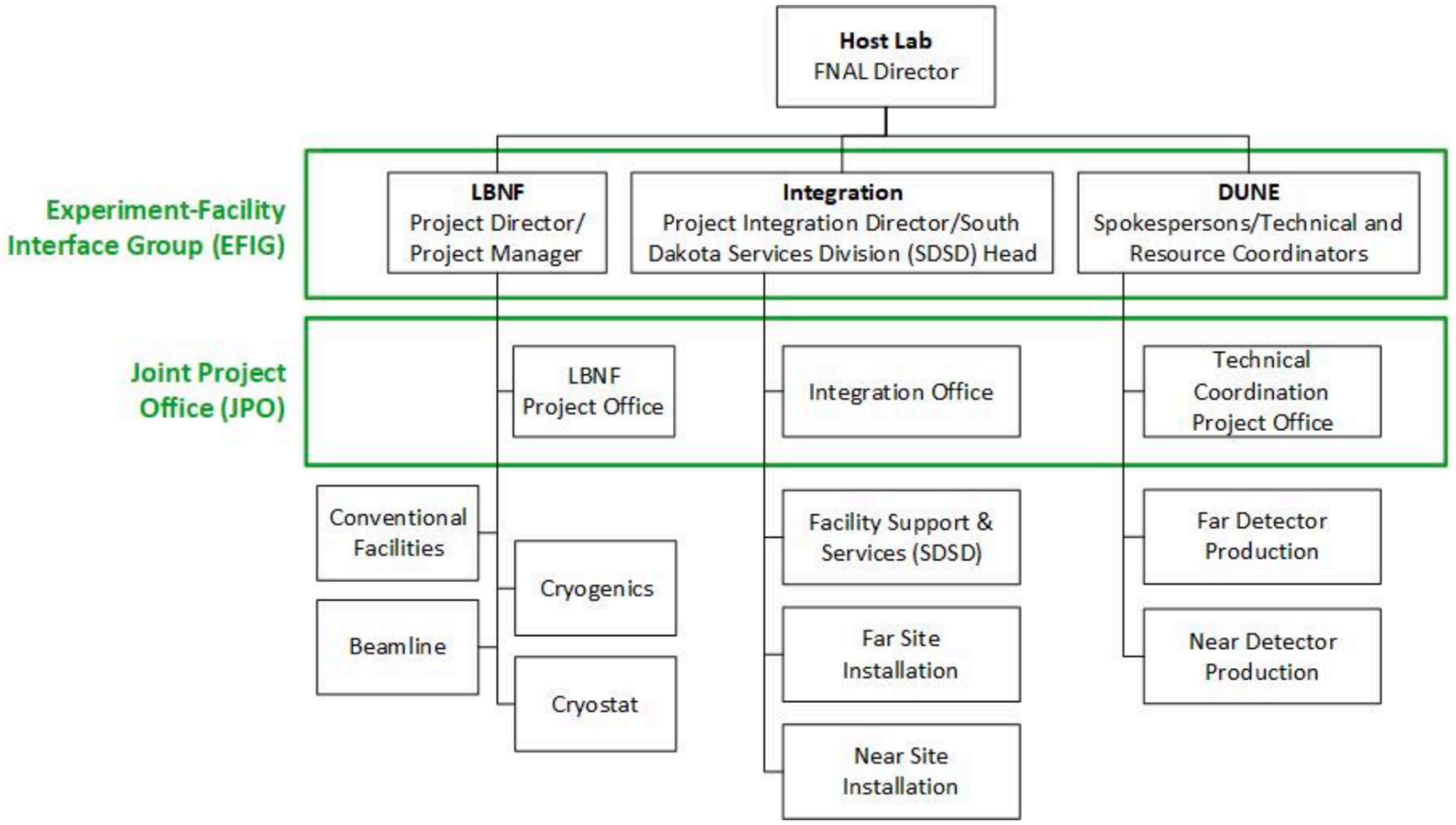
Maintain a comprehensive program at home and abroad, with a range of experiment scales and strategic balance among construction projects, operations of experiments and facilities, and core research activities, including the development of future facilities.

How are experiments organized?

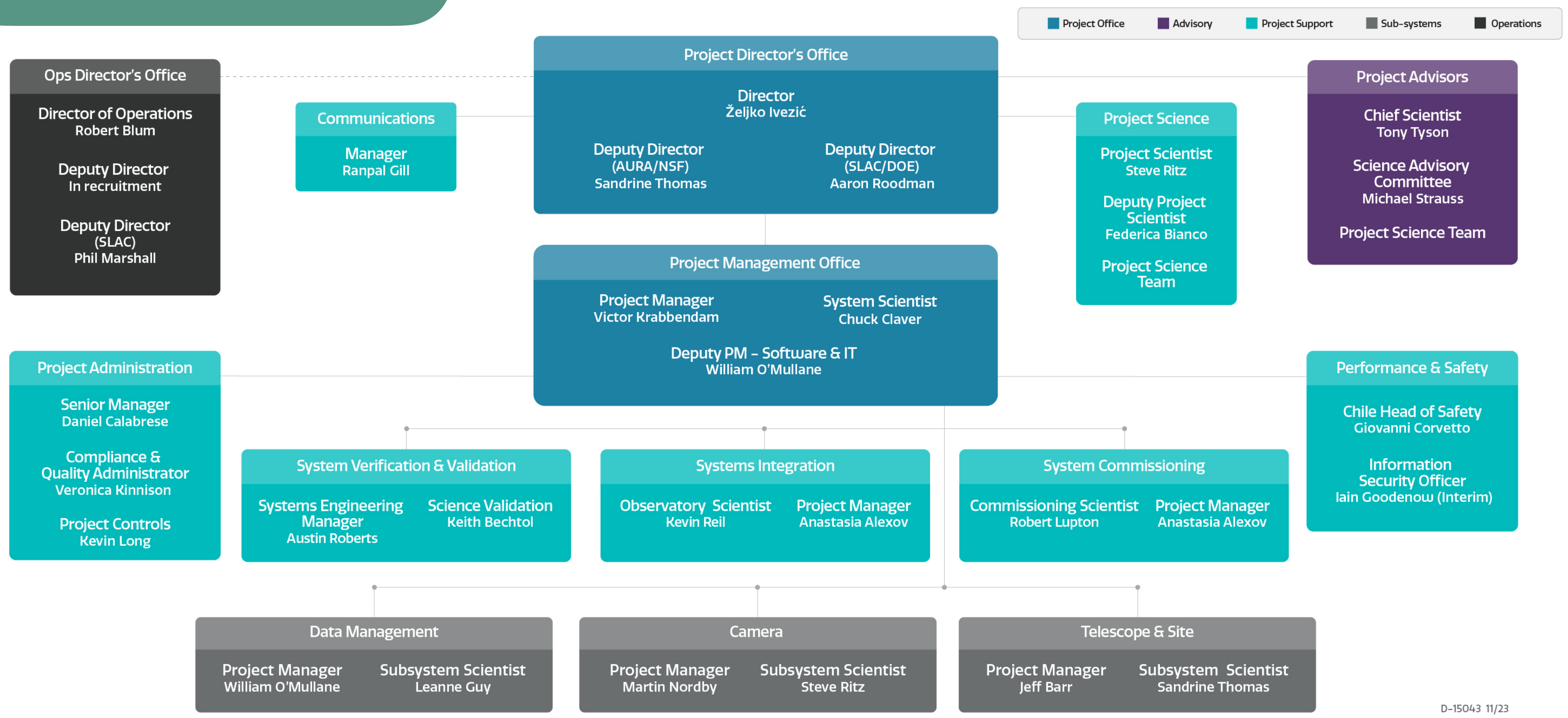
CMS Experiment



LBNF/DUNE



Vera Rubin



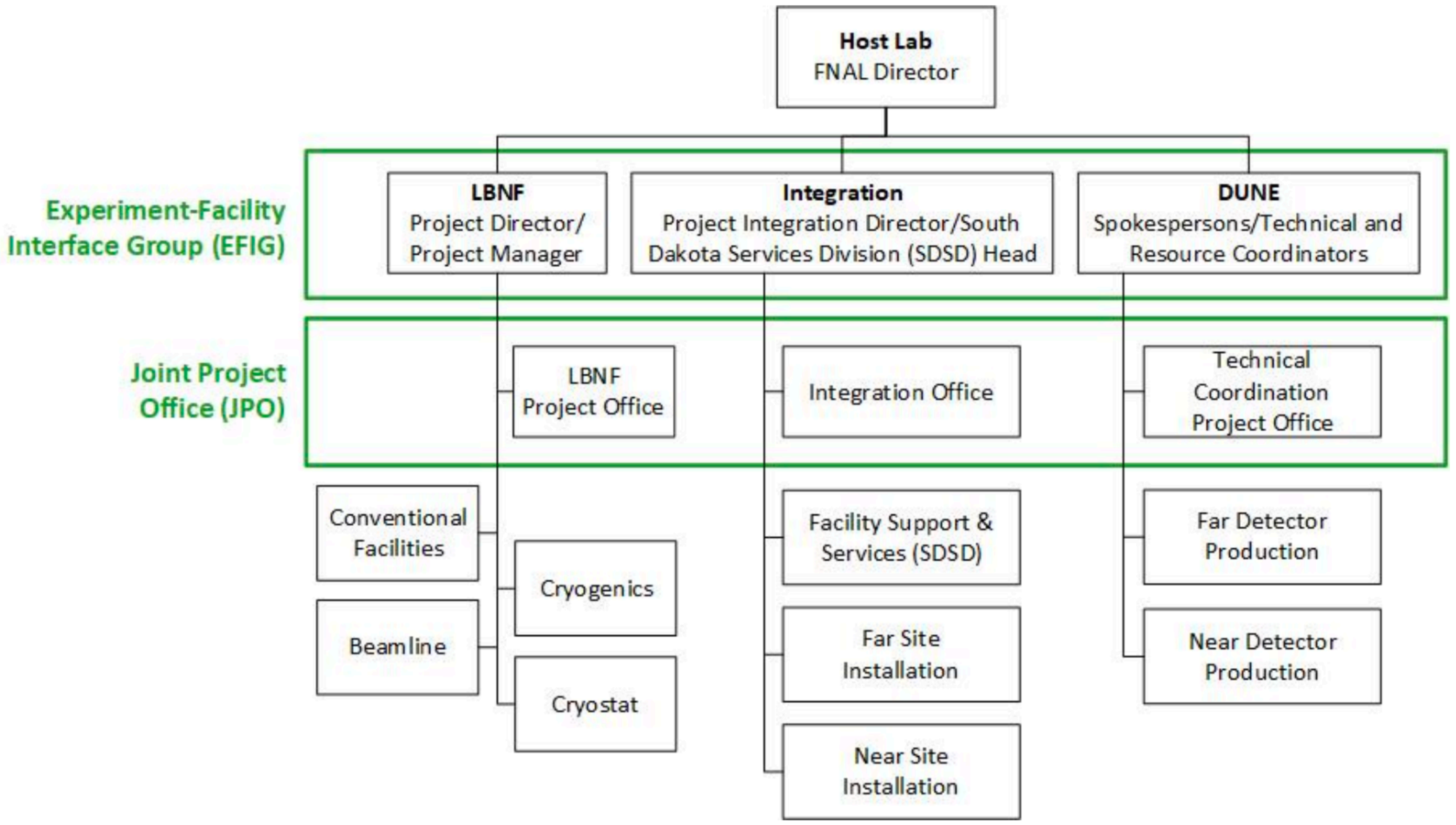
Taken from experiment websites, TDRs…

An attempt at a glossary:

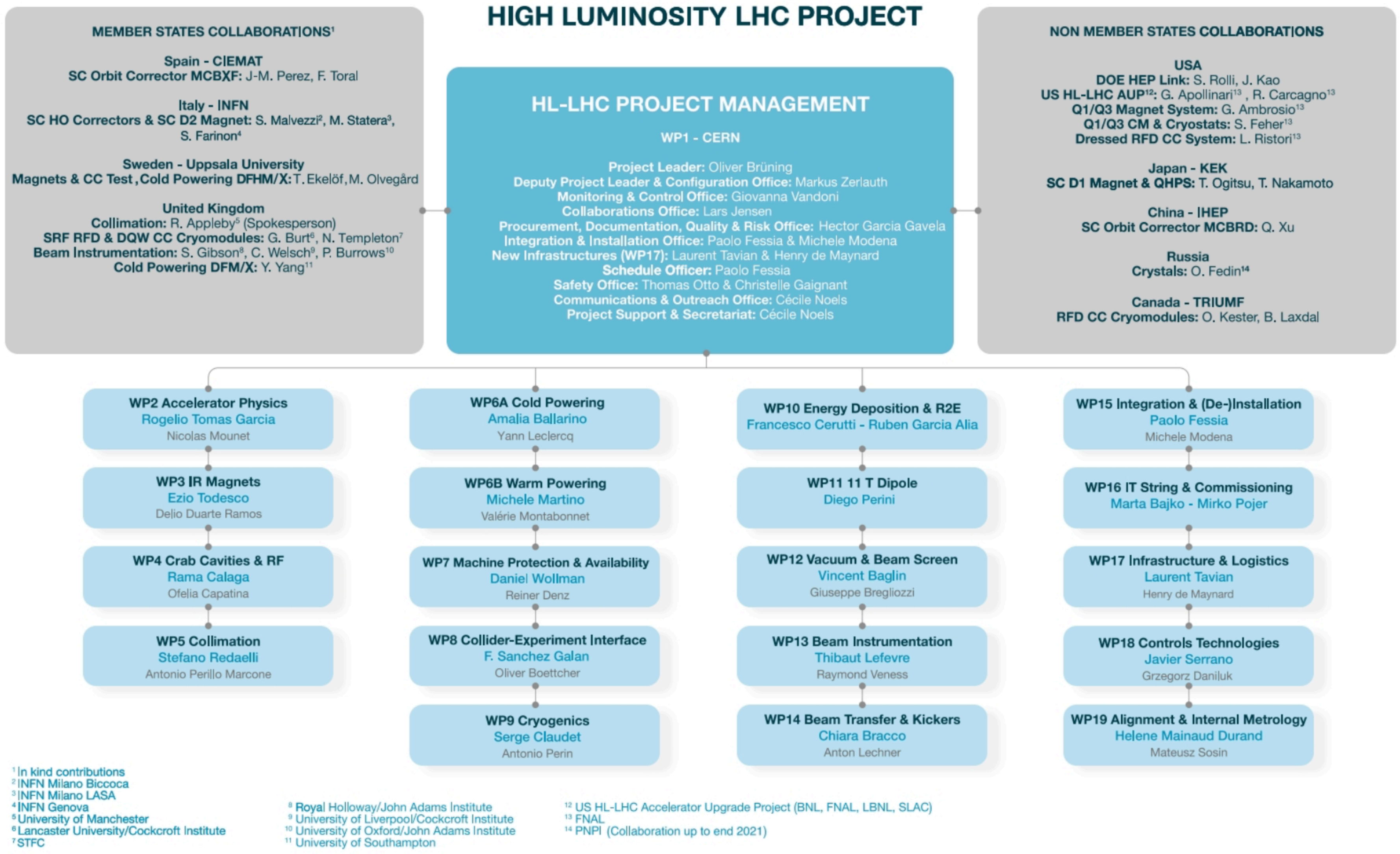
- **Experiment**
  - An apparatus used to take data. Typically there is a one-to-one relationship between an experiment and a collaboration.
- **Facility**
  - The physical infrastructure (and personnel) required to operate an experiment, including accelerators. Depending on experiment, this can also components closer to the experiment, like cryogenics and supports for detectors.
- **Collaboration**
  - The group that determines governance over an experiment, its members, and the analysis and publication of its data.
- **Project**
  - The scope covered by a specific funding agency's contribution to the construction, upgrade, or operation of an experiment or facility.

How are experiments organized?

LBNF/DUNE



HL-LHC Upgrade



An attempt at a glossary:

- **International [experiment, facility, collaboration]**
  - Primarily executed by a single nation, but with significant contributions and participation from others. Another name: "host-led"
- **Global [experiment, facility, collaboration]**
  - Fundamentally a partnership; no single nation dominates. Agreements are multilateral rather than bilateral. Another name: "CERN model"

Both strategies can work, but the larger the experiment/facility the more need for international buy-in.

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Finding: International partnership on construction of major particle physics accelerator facilities is growing. International partnerships yield more powerful capabilities for scientific discovery.

Recommendations:

The U.S. particle physics program should: 1) strive to engage as partners in the construction and operation of major future particle physics accelerator facilities constructed outside the U.S. and 2) actively seek international partners to engage in the construction and operation of major future particle accelerator facilities constructed in the U.S.

Establish a collaborative U.S. national accelerator R&D program on future colliders to coordinate the participation of U.S. accelerator scientists and engineers in global energy frontier collider design studies as well as maturation of technology.

An attempt at a glossary:

- **International [experiment, facility, collaboration]**
  - Primarily executed by a single nation, but with significant contributions and participation from others. Another name: "host-led"
- **Global [experiment, facility, collaboration]**
  - Fundamentally a partnership; no single nation dominates. Agreements are multilateral rather than bilateral.

Finding: Shared governance and shared responsibility are principles observed in successful partnerships and large collaborations.

Recommendation: Formally agree among partners on an international governance structure early during the formation of the international project.

What makes for a strong collaboration?

Finding: Strong collaborations exhibit common characteristics. Shared scientific objectives and a shared sense of responsibility are overarching common characteristics.

Recommendation: Collaborations should strive to establish an organizational structure and governance model that enables and cultivates the shared characteristics of current and past successful strong collaborations.

- shared scientific objective(s)
- shared decision making
- shared governance
- shared sense of ownership
- shared sense of responsibility
- shared problem solving
- shared credit
- shared authorship
- shared sense of success
- shared values
- shared culture
- shared respect

Lessons from the past

BABAR:

Host-led, international experiment

Engaged partners from the onset, including developing the conceptual design and governance structure

"International Finance Committee" brought together partnering funding agencies

Partners paid into a common fund that in some cases handled infrastructure

Lessons from the past/present

DESI:

International partners were engaged at an early stage

Multiple competing designs were created, and the down-selection was managed by the collaboration

Also made use of a common fund, and construction was completed early and under-budget

Scientific collaboration is now approximately half non-US

Lessons from the past/present

PIP-II:

Approximately 75% US, 25% international

Technical organization directly incorporates funding agencies and international projects

Managed by International Neutrino Council, which is chaired by the DOE Associate Director for High Energy Physics

Lessons from the past/present

LBNF/DUNE:

Dramatic increase in scale, and faced several specific challenges.

With some growing pains, is nonetheless on a track for succes, and has built an international governance structure similar to the LHC experiments.

Formed when a US experiment (LBNE) was directed to reformulate itself as an international collaboration, and and set on a tight timescale - governance structure not yet in place as it ramped up

Prevented international input in early stages, and decreased ability for scientific collaboration to influence key decisions

LBNF is ~80% US, while DUNE is ~50% US, but the two are under the same US project umbrella

Overall, international contributions are O($1B), and were viewed as "risk"

Lessons from the past/present

LBNF/DUNE:

Dramatic increase in scale, and faced several specific challenges.

With some growing pains, is nonetheless on a track for succes, and has built an international governance structure similar to the LHC experiments.

Recommendation:

DOE and NSF should convene a task force to study and recommend project management and oversight procedures that facilitate and cultivate international and inter-agency partnerships on large scientific research infrastructures for particle physics.

Can we achieve a “global” collaboration?

- **How has CERN been so successful?**
  - by default international; organizational structures are natively set up to support this
  - manages its own relatively stable budget (and can borrow against future budget)
  - able to streamline the process of visas and residency for international visitors
- **In the US:**
  - international participation is often seen as a type of “risk” – must be prepared to compensate if they don’t deliver
  - budget is set year-to-year (at best!)
  - visa processes, lab access, lab housing can all be unreliable

Is the US a reliable partner?

- **Being a reliable partner is essential to international collaboration.**
  - The U.S. has not always been viewed as a reliable partner.
  - Such perceptions can be an obstacle to consideration of the U.S. as a partner of choice.
- We find that this issue arises largely because of inadequate communication between U.S. decision makers and international partners.
- **Some historical incidents giving rise to the view that the U.S. not a reliable partner:**
  - 1993 – termination of the SSC
  - 2003 – termination of the CDF & D0 silicon tracker upgrade projects
  - 2005 – termination of BTeV
  - 2008 – termination of the SLAC B-factory program
  - 2011 – decision not to extend Tevatron running

Nonetheless, respect for technical abilities and scope that US can carry out means that we're still sought-after partners.

Is the US a reliable partner?

- **Finding:** Being a reliable partner is essential to international collaboration, and especially to hosting international partnerships.
    - **Recommendation:** Discuss and communicate with international partners before making decisions that affect partners. Seek ways to mitigate the impact of necessary U.S. decisions on international partners.
- **Finding:** The uncertainty of the annual U.S. appropriations process is an impediment to good international partnership, whether the partnership's project is hosted in the U.S. or abroad. Continuity of funding is especially important for U.S.-hosted experiments in both the construction and operations phases because of its importance to international partners.
    - **Recommendation:** Stakeholders in the U.S. executive branch and in Congress should understand the negative consequences – both immediate and long term – of abrupt reductions in funding, including the negative impact on international partners.

A welcoming environment is critical

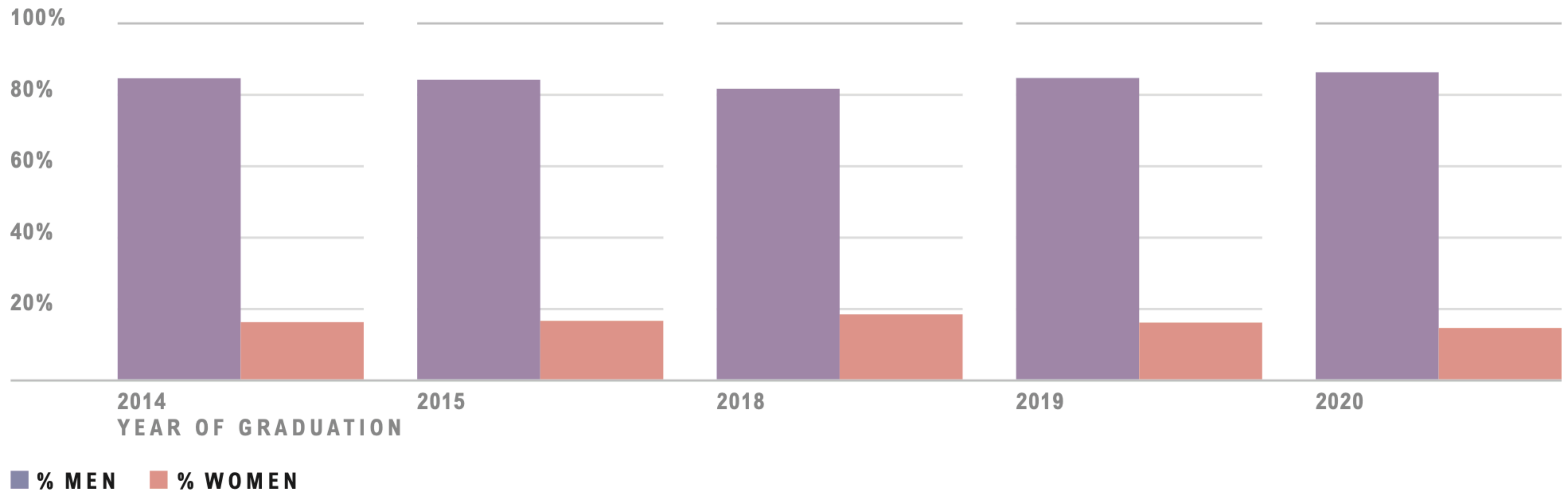
- **The host laboratory has a special responsibility** to provide an environment that encourages and supports international collaboration.
    - Facilities for international collaborators, e.g., offices and onsite accommodation
    - Support for visas
    - Unhindered access to the laboratory.
    - Fellowship and associate programs, accessible to collaborators independent of background and nationality
    - A vibrant community that encourages cross-topic communication
- **The principles of equity, diversity, and inclusion should govern the policy of both the host laboratory and the international collaboration.**

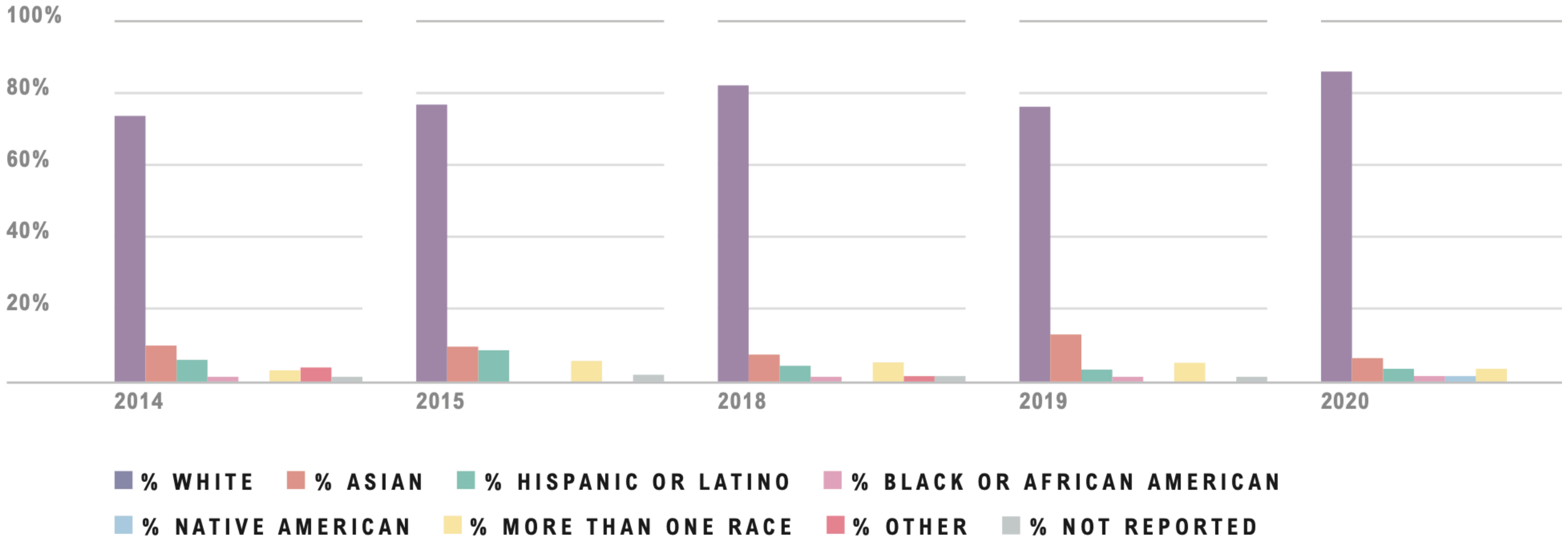
Workforce

Key finding: Attracting, inspiring, training, and retaining a diverse workforce is vital to the success of all particle physics endeavors and more broadly to U.S. science and technology. A robust particle physics workforce will both leverage and be representative of the diversity of the nation.

Key Recommendation: Explore frontier science using cutting-edge technologies to inspire the public and the next generation of scientists while opening new pathways to diversify the workforce and realize the full potential of the field.

Workforce

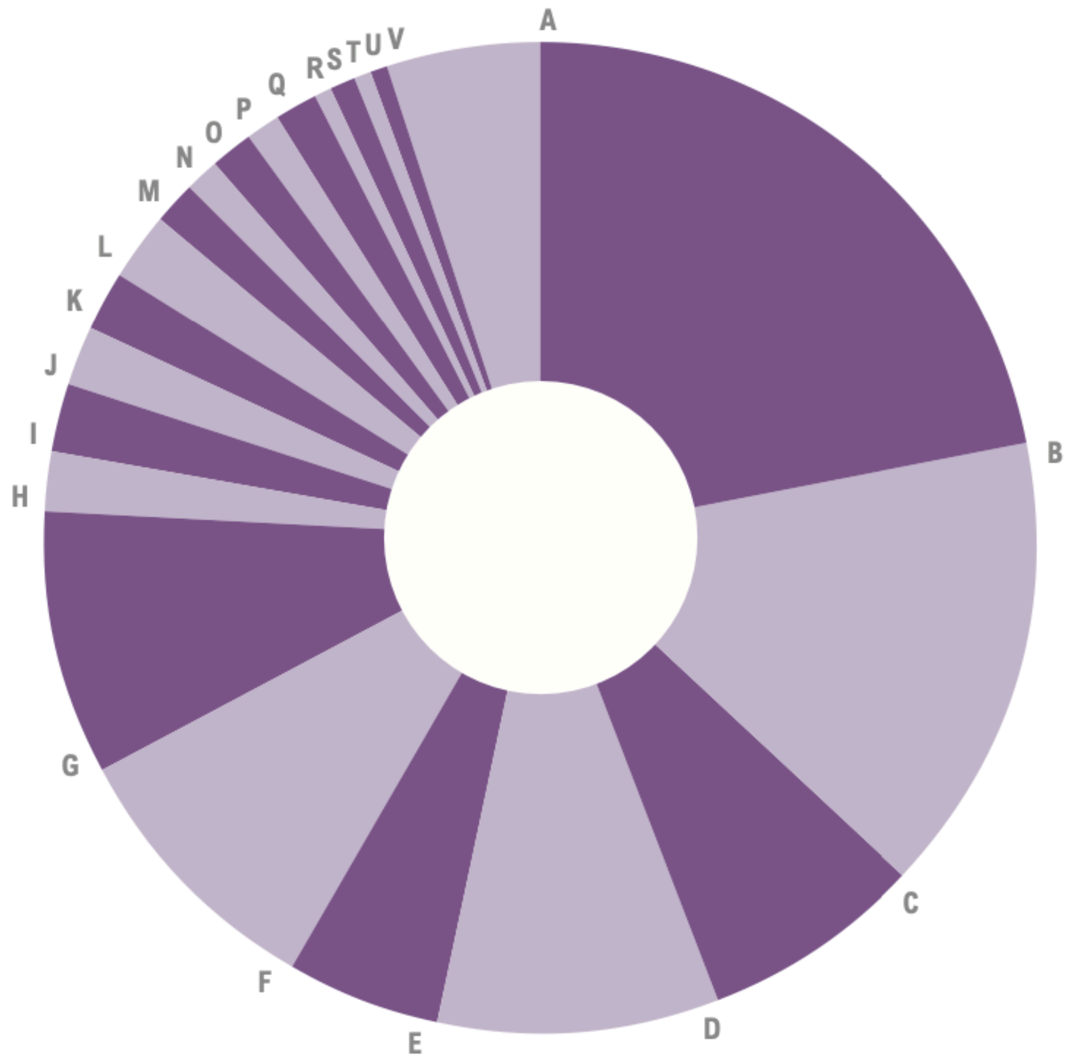




Demographics of particle physics PhD recipients

PhD Institution for Accelerator Physicists

A Cornell University 65
B Indiana University 45
C Stanford University 21
D Stony Brook University 27
E University of Maryland 15
F Northern Illinois University 26
G UCLA 26
H University of Colorado 6
I University of Chicago 6
J UC Berkeley 6
K Duke University 6
L Old Dominion University 6
M University of Tennessee 4
N University of New Mexico 4
O Michigan State University 4
P UT Austin 3
Q MIT 4
R Florida State University 2
S Carnegie Mellon University 2
T UC Irvine 2
U University of Mississippi 2
V Other 14



The best thing you can do for workforce overall…

Finding: Frontier large-scale research facilities offer the most comprehensive method of answering fundamental questions while exciting and inspiring a whole new STEM workforce.

Recommendation: A next-generation international flagship particle physics facility based in the U.S. would attract a whole new generation of scientists while boosting opportunities to train students and sustain a leading scientific workforce. The U.S. should not wait until DUNE is commissioned to embark upon its next major particle physics initiative but should move quickly to intensify its R&D program with the aim of accelerating progress in this direction to enable a timely decision.

In conclusion…

Frontier research in particle physics necessitates international collaboration and cooperation. The combined expertise and resources from nations around the world enable discoveries and technological advances impossible to achieve by any single nation. **It is the global particle physics program that collectively addresses the burning scientific questions across the breadth of the field.**

To be a leader in particle physics, the US must also be a leader in global collaboration.

Thank you!