# The particle physics program in the next decade

Gina Rameika for the

*The Fermilab Science Priorities Working Group*



Fermilab

# Summary in Advance

- **We recommend the following elements as priorities for the U.S. Particle Physics Program**

  - U.S. High Energy Physics community continues to play a leading role in LHC operations and upgrades
  - Fermilab hosts a world-class accelerator-based neutrino program
  - The next generation rare process experiments will take place within this decade
  - Continue to explore new particles and forces with a community selected set of experiments in the cosmic frontier
  - Participation in the ILC as an international partner when the concept matures to the appropriate level
  - Plans for an upgrade of the accelerator complex to deliver multi-megawatt beam power are developed
  - Work with the world community on longer term accelerator technology options

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# Basis for Planning

- Our community has identified many exciting, well-motivated, new or upgraded experiments to pursue
- The Snowmass Outcome
  - Hundreds of  pages of white papers and reports
  - General support and enthusiasm from all frontiers for all frontiers
- Funding is not available to do everything
- There are three regions internationally which host major facilities : Europe, Asia and the Americas
  - Large programs  are expensive and will require global planning and collaboration

Need to plan with a global view of the future

# Fermilab Science Priorities Working Group

- Following Snowmass, the Fermilab Director formed a *Science Priorities Working Group* to analyze scenarios for new projects and programs to see what fits within realistic budget constraints and timelines

- Charge was to deliver a set of recommendations on the Fermilab role in an optimized particle physics program over the next ten years, aligned with the community's scientific aspirations and examining the needed laboratory infrastructure to deliver the science results.

- 28 scientists from across the laboratory's divisions and sectors, both experimentalists and theorists

- Discussions informed by input from the entire scientific staff through three retreat session

# Fermilab Scientific Priorities Working Group

- Giorgio Apollinari
- Greg Bock (Chair)
- Steve Brice
- Kevin Burkett
- Joel Butler
- Keith Ellis
- Brenna Flaugher
- Fernanda Garcia
- Douglas Glenzinski
- Roni Harnik
- Jim Hirschauer
- Craig Hogan
- Steve Holmes
- Hugh Lippincott
- Ron Lipton
- Patricia McBride
- Shekhar Mishra
- Sergei Nagaitsev
- Cathy Newman-Holmes
- Mark Palmer
- Stephen Parke
- Regina Rameika
- Alex Romanenko
- Marcelle Soaros-Santos
- Jim Strait
- Alvin Tollestrup
- Robert Tschirhart
- Geralyn Zeller

- Ex-officio :
  - Steve Geer
  - Stuart Henderson
  - Mike Lindgren
  - Rob Roser
  - Katie Yurkewicz

# Criteria for a strong science program

- The program addresses critical and exciting scientific questions
- The program is bold and establishes world leadership in this area
- The program is so compelling that physicists from all 3 regions want to participate in this science
- The program fits within a global strategy for the field and within reasonable funding expectations
- The program is focused, yet flexible enough to be resilient in the face of unexpected physics discoveries and funding fluctuations

# We recommend an accelerator-based neutrino program

- Build on the **existing** Fermilab complex to deeply explore the neutrino sector
  - Short and long baseline, three neutrino mixing, sterile neutrinos, anomalous behaviors ….
- Build **new** neutrino **detectors** to fully develop the liquid argon TPC detector technology
- Build a **new neutrino beam** to a longer baseline (LBNE) to make a definitive determination of the neutrino mass hierarchy and precise measurement of the CP-violating phase
  - **Underground detector** has multi-purpose potential for many physics topics
- Upgrade of the accelerator complex to deliver >1MW **beam power**

# Why Neutrinos ?

- Neutrinos are fundamental particles that have played critical roles in the evolution of our universe
- Non-zero neutrino masses have already told us that there *is* physics beyond the Standard Model
- Many questions remain about these elusive particles :
  - Why are the masses so small?
  - What is the neutrino mass ordering?
  - Are neutrinos their own anti-particle?
  - Do neutrinos violate CP?
  - Are there more than three neutrino mass states?

# Current Fermilab-based Neutrino Program

- DATA from NOvA, Minerva, MINOS+ and MicroBooNE!
- PHYSICS
  - neutrino mass and mixing, mass hierarchy
  - cross-sections
  - sterile neutrinos
  - anomalies
- LAr Technology Development leading to VERY large detectors
  - Prototypes
  - Test beams

If you'd like more detailed discussion of any of these, just ask. There are many of us around who would be happy to talk about this exciting program

# Why LBNE ?

- LBNE will be a world-class accelerator-based neutrino experiment for CP violation searches and more!
  - **Baseline** of 1300 km
    - For the determination of the mass hierarchy AND measuring the CP violating phase
  - **High Power Wide-band beam**
    - Enough statistics to fit event spectra for both neutrinos AND anti-neutrinos
  - **Liquid Argon Detector (>30kT)**
    - Excellent signal efficiency and background rejection
- The combination of these three components make LBNE the most effective way to get to neutrino CP-violation physics
- Underground for extended physics capabilities (supernova, proton decay, ….)

# Protons for Neutrinos

- We are reorienting the Project X program to have a goal of delivering >1MW on day one of LBNE operations
- To achieve >1MW an upgrade to the proton complex is required
  - Start by upgrading the linac
  - Develop high power target capability
  - Build a platform for multi-megawatt future

Details under development

To be presented at the BNL P5 Meeting

# Elements for Ensuring Success

- The U.S. particle physics community has a strong commitment for global programs
- Fermilab and the U.S. neutrino community commit to focus their efforts on this program
- Demonstrate that we are reliable partners by delivering beam to running experiments and remaining committed to projects that are already underway
- Attract international project partners to our neutrino program within two years
- Develop a coherent, affordable plan for increasing beam power to neutrino targets

# Summary in Conclusion

- **We recommend the following elements as priorities for the U.S. Particle Physics Program**
  - U.S. High Energy Physics community continues to play a leading role in LHC operations and upgrades
  - Fermilab hosts a world-class **accelerator-based neutrino program**
    - Full scope LBNE, deep underground with >1MW beam power
    - Active program in short baseline LArTPC experiments
  - The next generation rare process experiments will take place within this decade
  - Continue to explore new particles and forces with a community selected set of experiments in the cosmic frontier
  - Participation in the ILC as an international partner when the concept matures to the appropriate level
  - Plans for an upgrade of the accelerator complex to deliver multi-megawatt beam power are developed
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Requires major investments by non-DOE and international partners