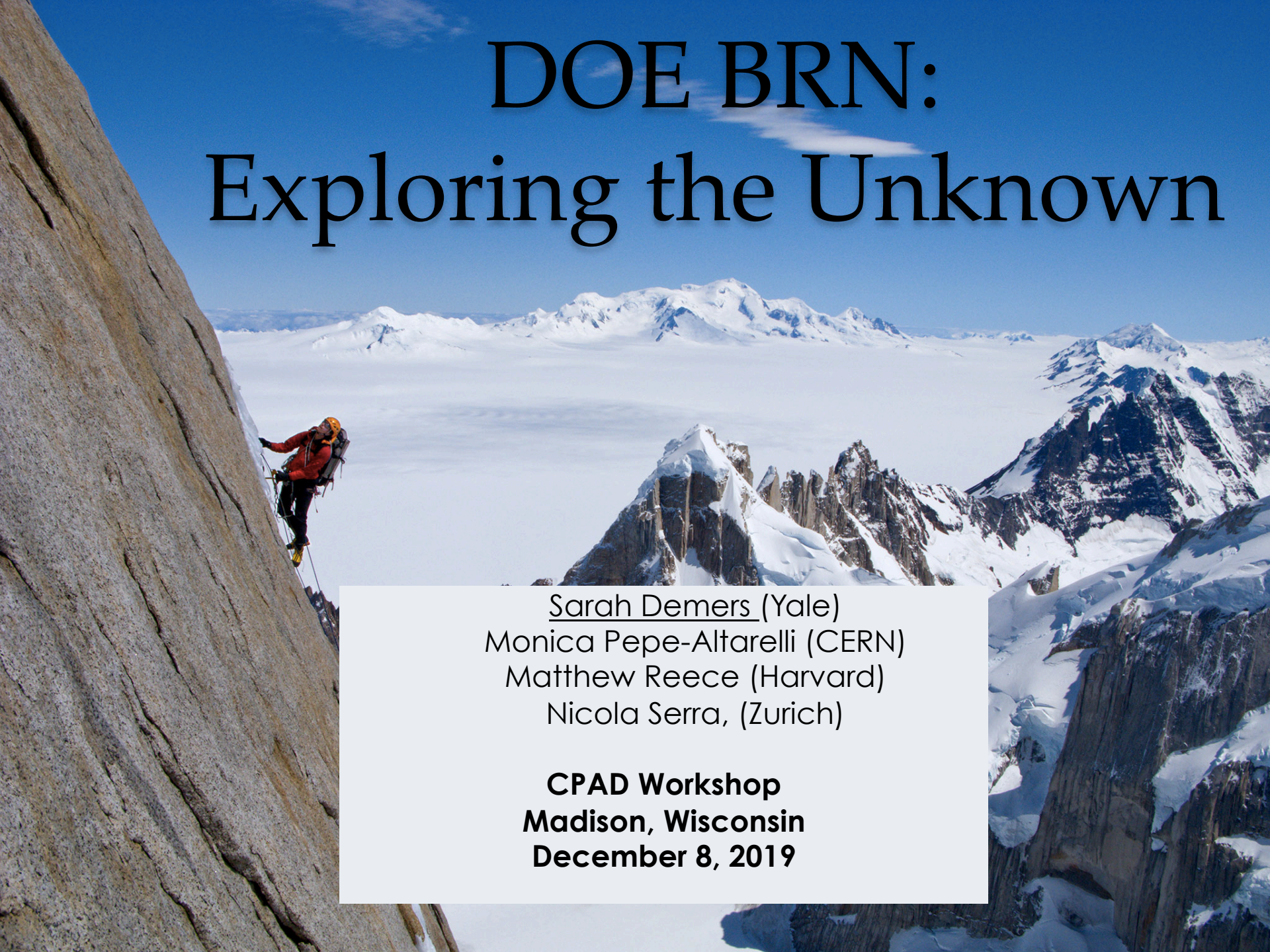
DOE BRN: Exploring the Unknown



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CPAD Workshop
Madison, Wisconsin
December 8, 2019

Organization

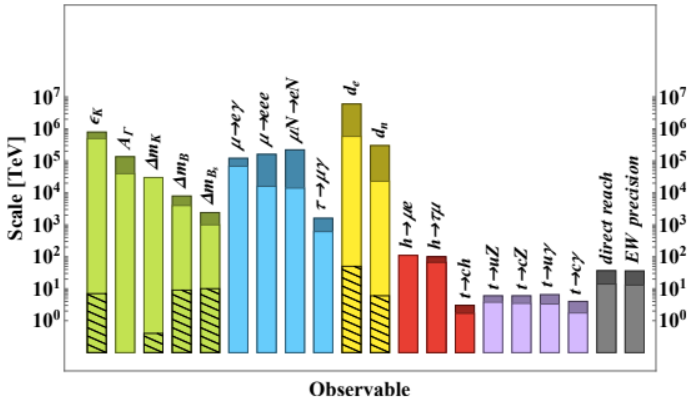
- Physics Groups
  - Higgs and other Energy Frontier
  - Neutrinos
  - Dark Matter
  - Dark Energy and Inflation
  - **Explore the Unknown**
- Technology Groups
  - Quantum Sensors
  - Noble Liquids
  - Calorimetry
  - Solid state and tracking
  - Photodetectors
  - Trigger and Data Acquisition
  - Readout and ASIC
- Cross-Cutting Group

<u>Goals this morning:</u>
Communicate the scope of the group
Share our identified key challenges
Enable Feedback from this group!

More information in this PDF:
https://info.aps.org/e/640833/r-Research-and-Development-pdf/9hvh8/190837603?h=x3IAj1VgI4ALXG1jtdRw0QmslKkWg05S1rPmejfRGLI

Explore the Unknown

The Standard Model of particle physics and general relativity describe the known universe over a vast range of scales, allowing accurate calculations at distances as small as 10^{-18} meters and as large as 10 billion light years, **however**…



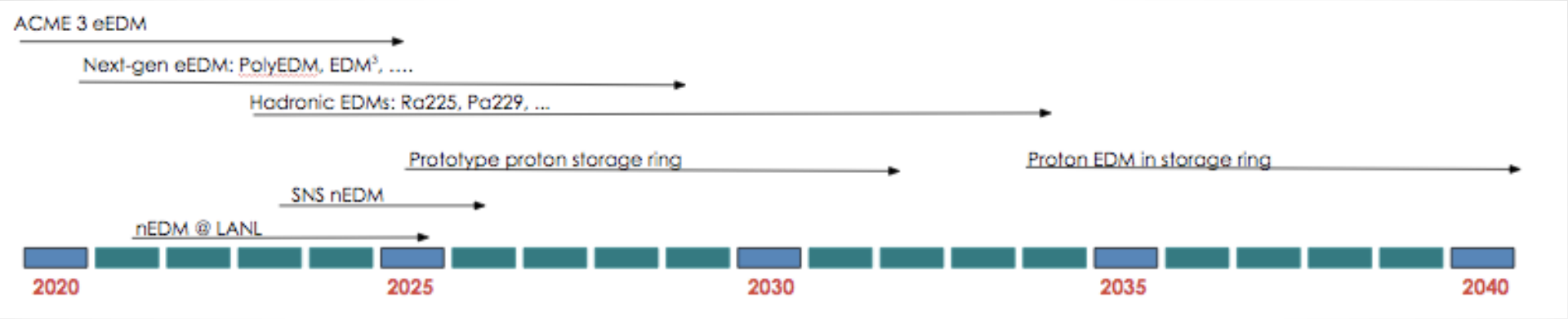
"Explore the Unknown" is a very broad group, with topics that include

- EDMs
- Heavy Flavor
- Rare Muons and Kaons
- Dark Sector & Axions

Process

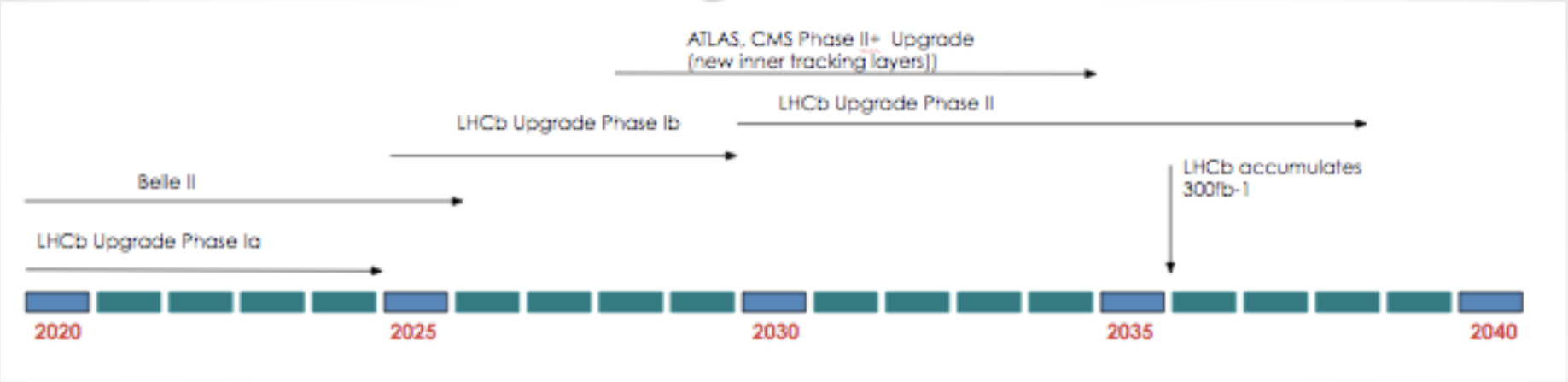
- Starting point was the "New Technologies for Discovery" Document: from this community: https://arxiv.org/abs/1908.00194
- The group scope, both in physics reach and large range of types of experiments, has resulted in our needing to consult with many experts and groups beyond the make-up of our committee.
  - THANKS to those who have contributed, many of whom are mentioned in the following slides.
- We reached out to experiments via email and with dedicated presentations
- We hope to gather feedback via this meeting
- We will circulate a draft of a 6-page document in December for community feedback

EDM Experiments



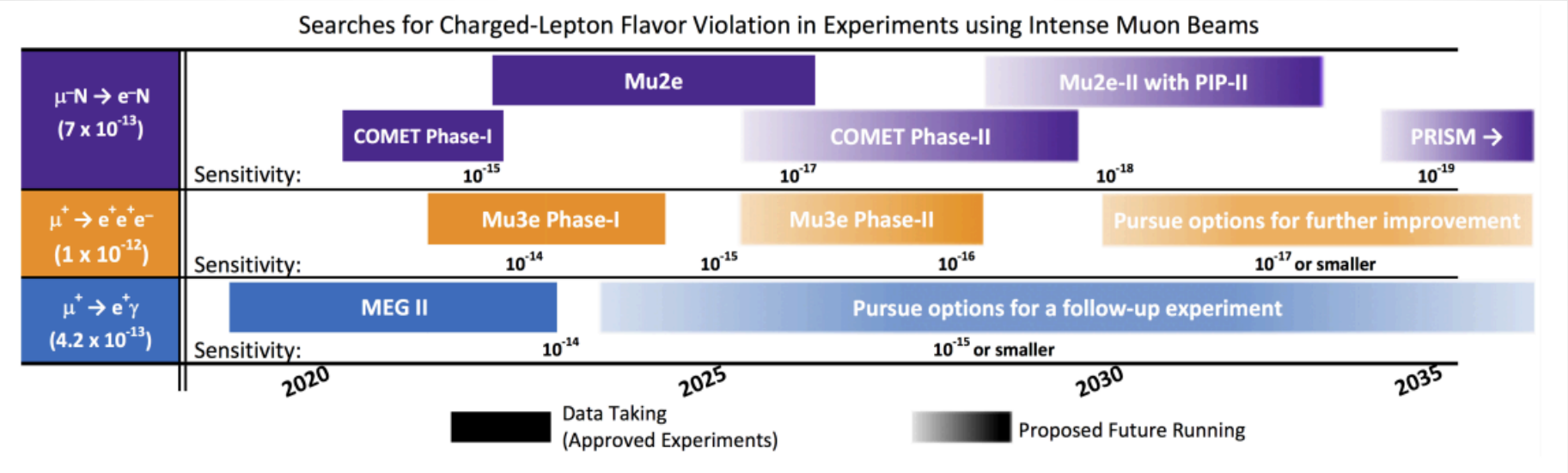
- Measuring Flavor-conserving, CP-violating processes like EDMs provide access to energy scales that greatly exceed our capabilities of direct probing at the LHC
- Transformation advances would come from
  - improved quantum control
  - molecular enhancements
  - exotic nuclei
- Many thanks to
  - Nick Hutzler for telling us about atomic and molecular EDM experiments
  - Takeyasu Ito for telling us about neutron EDM experiments
  - Ed Stephenson for telling us about storage ring EDM experiments (including oscillating EDM/axion searches.)

Heavy Flavor



- This broad and aggressive physics program includes:
  - precision access to CP-violating phases
  - tests of minimal flavor violation
  - probing charm CP violation
  - hadron spectroscopy to probe low-energy QCD
- Transformational advances would come from:
  - precision timing, improved particle identification, advances in TDAQ, advances in computing/simulation capabilities
- Many thanks for information/discussions to:
  - Paula Collins (Silicon vertex detectors and tracking, timing)
  - Andrey Golutvin (Calorimeters)
  - Mike Williams (ML and data science tools)
  - Francesco Forti (Belle II upgrade)

Rare Muons and Kaons



- Probes of charged lepton flavor violation provide access to energy scales of new physics beyond what can be probed directly
- Transformational advances would come from
  - precision timing
  - low mass tracking detectors and fine granularity, fast calorimetry
  - more stopped particles! (muon storage beam)
- Many thanks to:
  - Augusto Ceccucci (NA 62)
  - Pasha Murat and Giani Pezzullo (Mu2e)

Current areas of focus for "Explore the Unknown"

- Precision timing
- Low mass tracking detectors
- High-granularity and fast calorimeters
- Real-time processing of a large amount of data
- Magnetic fields
- Controlled preparation of many coherent particles

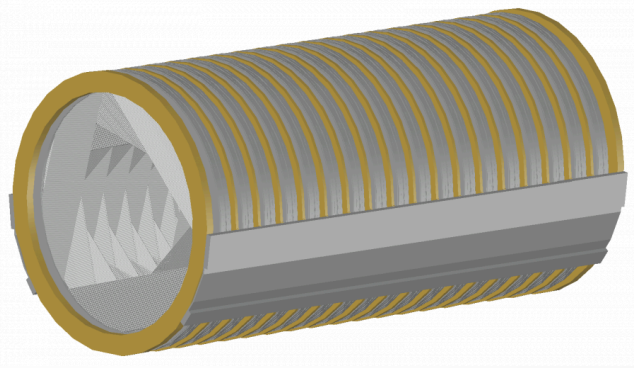
Precision Timing

- Transformational advances in heavy flavor and searches for rare decays in muons and kaons will require intense beams of particles
- The detector performance requirements (position, energy, momentum, object classification, vertex association, etc) will remain stringent in spite of higher luminosities.
- Precision timing for 4D tracking can
  - mitigate the background combinatorics
  - allow physics objects to be assigned to the correct vertex

Massless Tracking Detectors

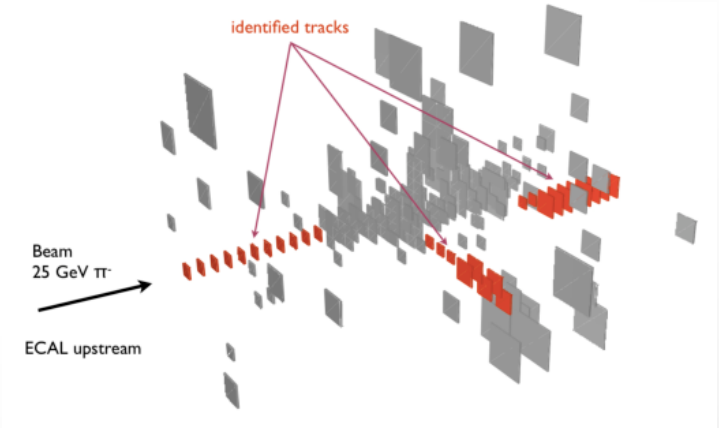
- The next generations of experiments like NA62, SHiP, Mu2e, and COMET will require excellent particle identification and momentum resolution while minimizing multiple scattering.
- Massless tracking detectors could be transformational in delivering physics in these environments.

Current Generation:
straw tube trackers



Fast, High-Granularity Calorimeters

- Future experiments like NA62 and Koto, or a τ ->eγ CLFV experiment will require excellent photon identification, π^0 reconstruction and electron reconstruction.
- Vetoing backgrounds and excellent pointing capabilities to tag photon vertex position will be critical for axion searches, in addition to π^0 identification.



Real-time Processing of a Large Amount of Data

- A paradigm shift is already underway at experiments like LHCb, where sophisticated analysis is done online, allowing event selection and paring down of event size to allow for storage of the events that provide access new physics parameter space.
- If the ongoing revolution in deep learning could be ported to online infrastructure, this would be transformational.
- Real-time calibration and data quality control would be necessary.

Controlled Preparation of many coherent particles

- Extending quantum control of systems from atoms to polyatomic molecules would be transformational for EDM measurements.
- A candidate molecule, YbOH, would provide a target for laser cooling with another part of the molecule providing EDM sensitivity.
- A dedicated ultracold neutron source would be transformational for neutron EDM experiments.
- A muon storage ring would be transformational for CLFV searches in muon decays.

Conclusions

- The "Explore the Unknown" physics group covers a wide range of physics experiments and represents access to a huge range of energy scales of potential new physics.
- In spite of this diversity, a number of R&D paths could prove to be transformation across the entire program.
- We look forward to your input and ideas as we think about the physics opportunities and implications of these potentially transformational developments.