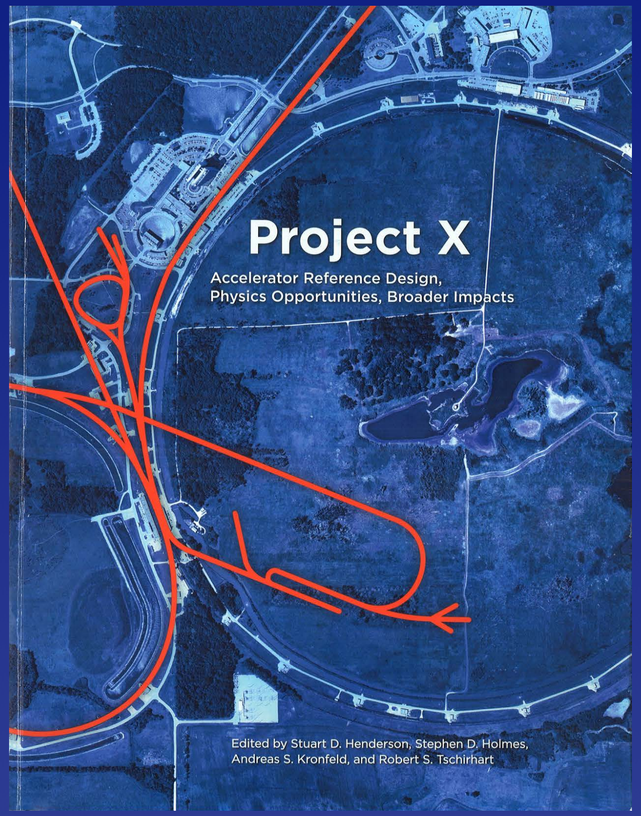
The *Project X* Physics Study at Fermilab

Chris Quigg (FNAL)



New Physics at the Intensity Frontier · CERN · 27 February 2017

Setting the Scene: Fabiola Gianotti at PBC Kickoff

We know there is new physics.

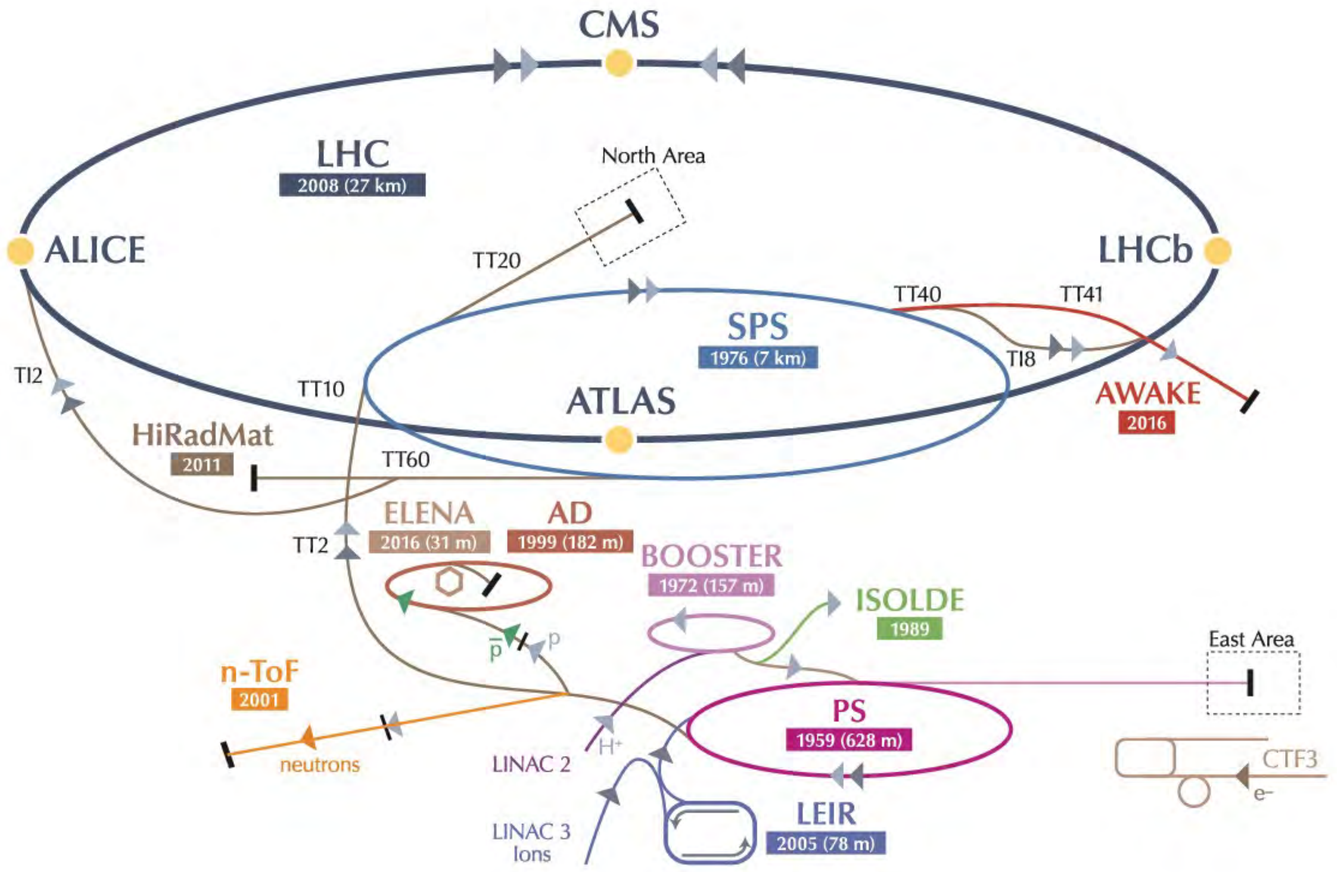
We don't know where it is.

We must explore as broadly as possible.

Optimize the resources of our discipline globally.

« Diversity and scale diversity »

CERN Accelerator Complex

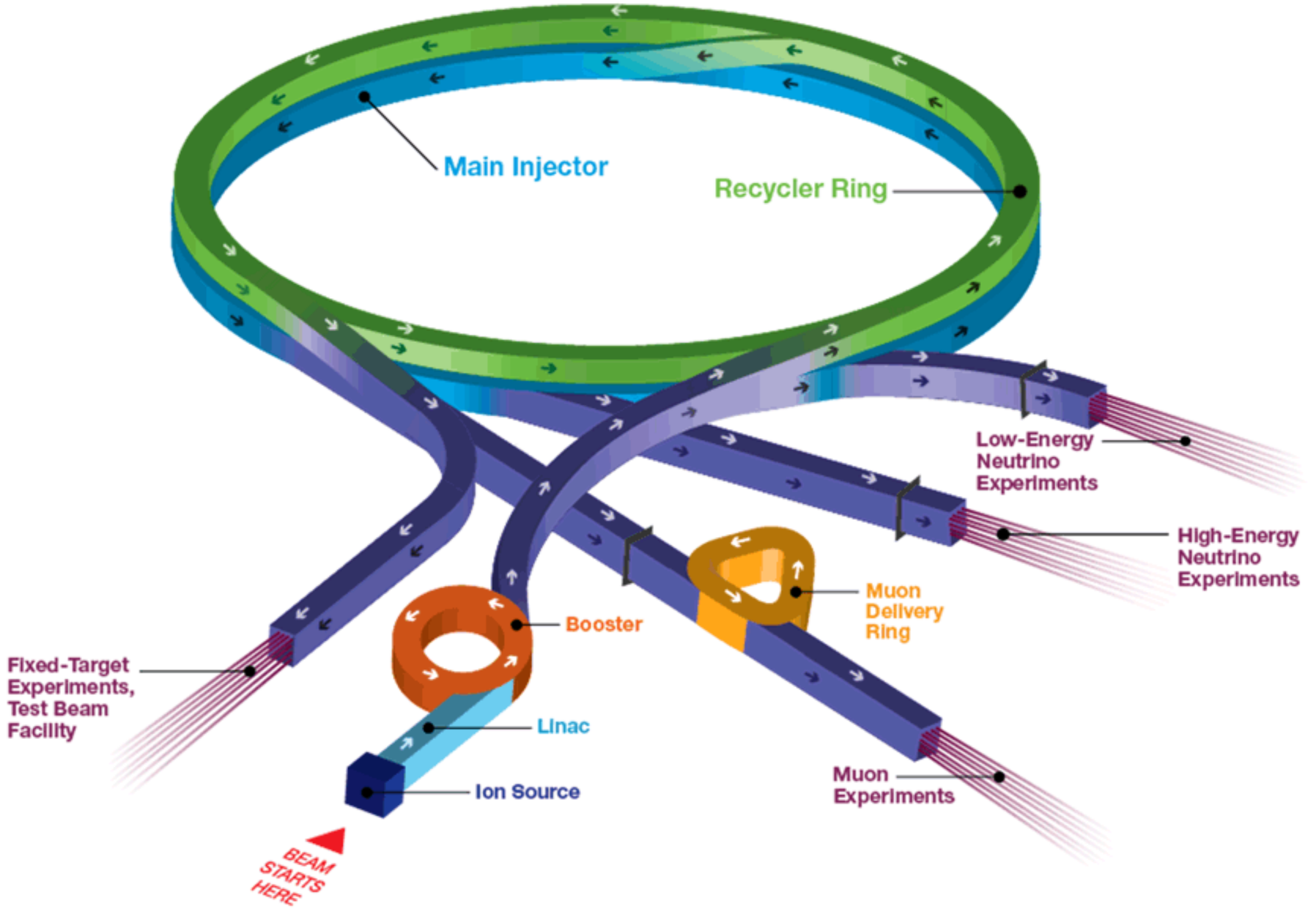


LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF3 Clic Test Facility AWAKE Advanced WAKefield Experiment ISOLDE Isotope Separator OnLine DEvice

LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight HiRadMat High-Radiation to Materials

Fermilab Accelerator Complex



What is / was *Project X*?

ν *Experiments:* Studies of ν oscillations and ν interaction physics with ultra-intense ν beams provided by a high-power proton source with energies up to 120 GeV, with near and far detectors.

Goal: ≳ 2 MW of proton beam power at any energy between 60 to 120 GeV; several hundred kW of proton beam power on target at 8 GeV.

What is / was *Project X*?

K, μ, N, and n Precision Experiments: World-leading experiments studying ultra-rare *K* decays, searching for μ→e conversion and nuclear electron dipole moments, and exploring neutron properties at very high precision.

Goal: MW-class proton beams supporting multiple experiments at 1 and 3 GeV, with flexible capability for providing distinct beam formats to concurrent users while allowing simultaneous operations with the ν program.

What is / was *Project X*?

Material Science and Nuclear Energy Applications: High-intensity accelerator, spallation, target, and transmutation technology demonstrations. Applications of μ spin rotation techniques probe the magnetic structure of materials.

Goal: Provide MW-class proton beams at 1 GeV, coupled with novel targets required to support a broad range of materials science and energy applications.

What is / was *Project X*?

Platform for Future Frontier Facilities: A high-intensity proton source will strengthen and modernize the Fermilab injector complex, providing a robust platform upon which to build future frontier facilities. The Neutrino Factory and Muon Collider are examples that would provide world-leading capabilities at the Intensity and Energy Frontiers for many decades to come.

Goal: Provide a straightforward upgrade path for a 4 MW, low-duty-factor source of protons at energies between 5 and 15 GeV.

Project X: Physics Opportunities (2012–2013)

Neutrino Physics
Rare *K* Decays
Muon experiments (CLFV & *g*–2)
Electric Dipole Moments
Neutron–antineutron oscillations
Light, weakly coupled particles
Hadron structure
Hadron spectroscopy
Lattice QCD calculations

Project X: Accelerator Reference Design

Project X: Broader Impacts

Contents

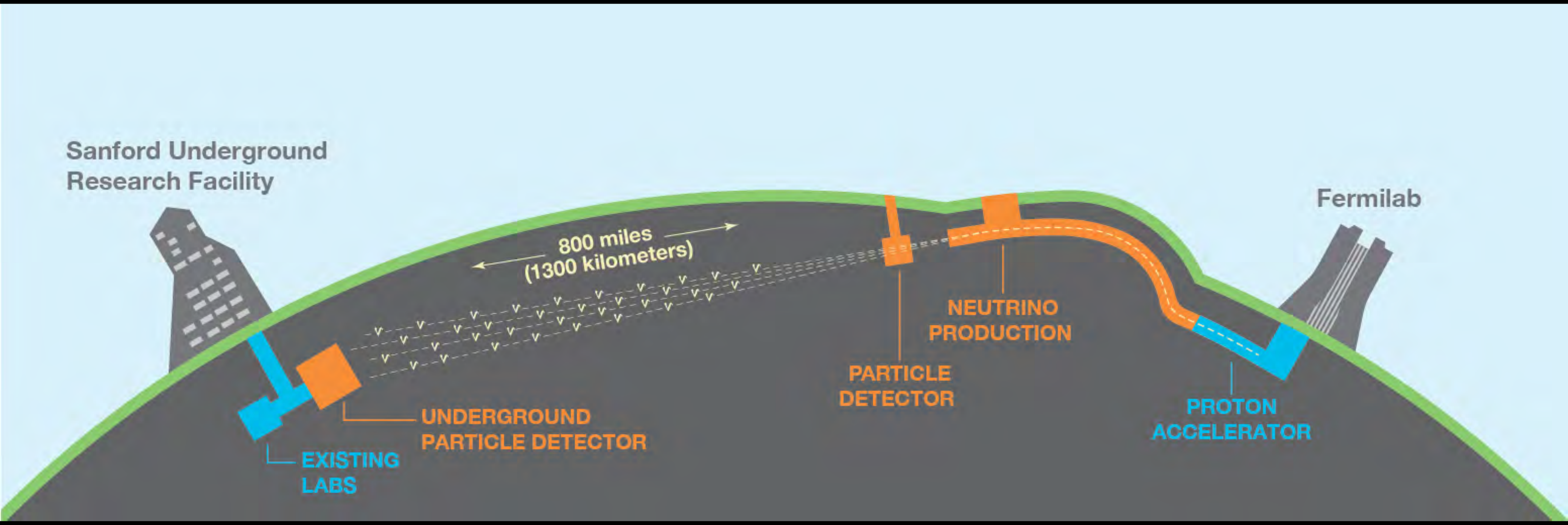
FERMILAB-TM-2557
ANL/PHY-13/2
BNL-101116-2013-BC/81834
JLAB-ACP-13-1725
PNNL-22523
SLAC-R-1029
UASLP-IF-13-001

June 2013

2013–2014 Academic Lectures: The Allure of Ultrasensitive Experiments

Muon Anomalous Magnetic Moment: 2 theory / 2 experiment
Lepton Flavor Violation: 1 theory / 3 experiment
Ultrasensitive Measurements with Electrons: 2 experiment
Dark Matter: 2 theory / 2 experiment
Neutrinos: 5 theory / 8 experiment
The Cosmic Microwave Background: 2 theory / 2 experiment
Electric Dipole Moments: 2 theory / 1 experiment
Quark Flavor Physics: 2 experiment

DEEP UNDERGROUND NEUTRINO EXPERIMENT



Desired sensitivity requires decades of running without accelerator improvements

Physics Goals for DUNE

Oscillation parameters

Search for CPV phase

Mass hierarchy

Test 3-flavor paradigm

Search for proton decay to $\tau/B \approx 3\times10^{34}$ y

Sensitive to ν_e from core-collapse supernova

Search for nonstandard interactions

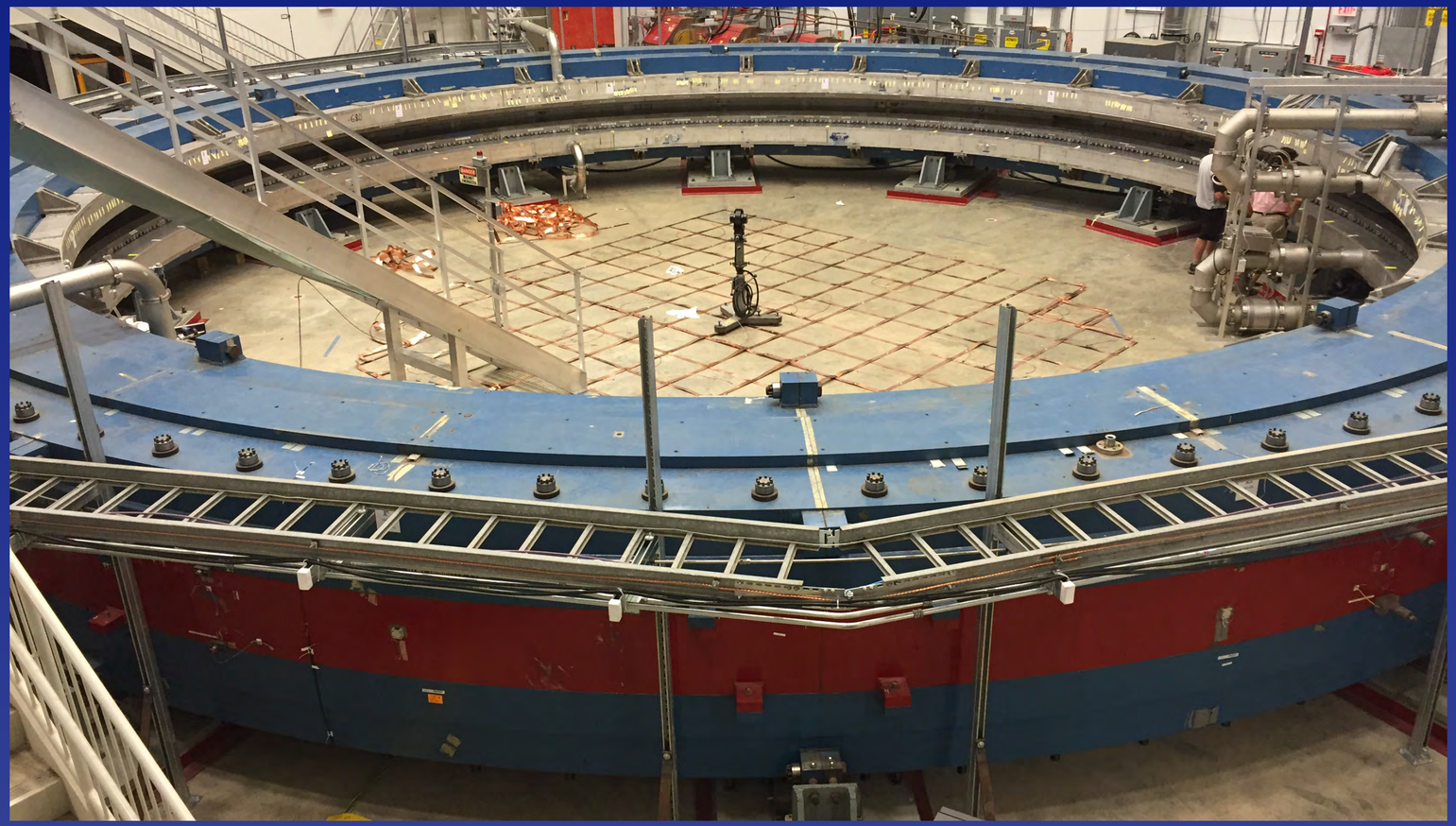
Precision measurements with near detector

…

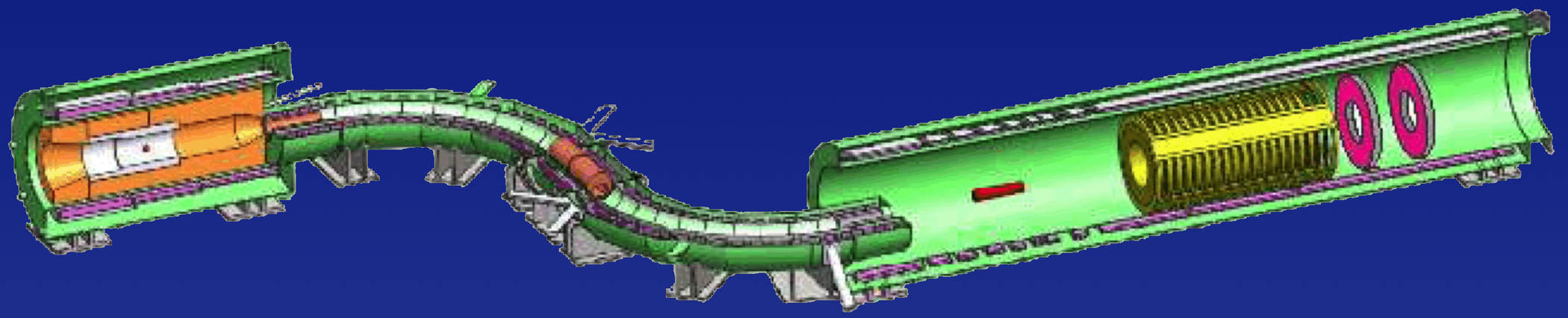
Muon g-2

Match BNL μ^+ sample by FY 2018, 20x by 2019

↳ 140 ppb measurement of a_μ (BNL errors / 4)



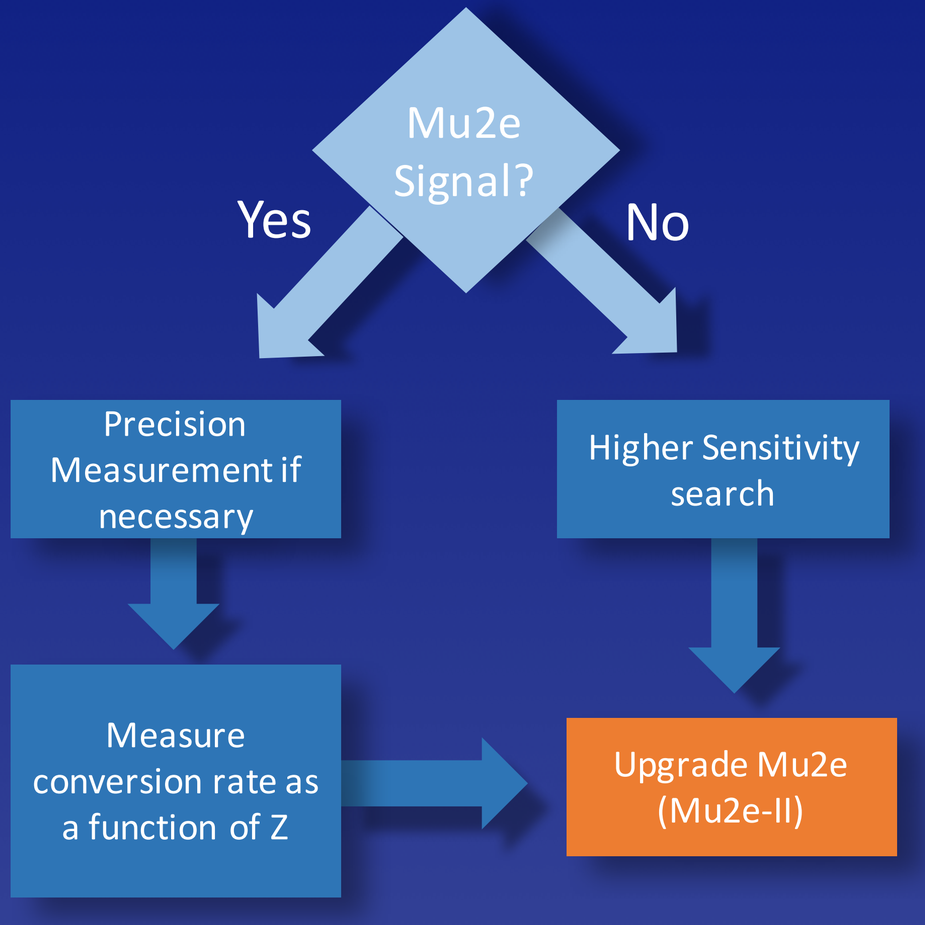
Mu2e (muon–electron conversion)



Aim to improve $R_{\mu e}$ by 10^{-4}: 6×10^{-17}
standard model: 10^{-54}

Mu2e (muon–electron conversion)

Mu2ell would reach $R_{\mu e} \approx 6 \times 10^{-18}$



mu2e-spokespersons@fnal.gov

Proton Improvement Plan

Now routine operation at 700 kW @ 120 GeV for NOvA

PIP-II

New 800-MeV SCRF CW Linac to enable
1.2 MW @ 60–120 GeV
for DUNE (2026)
and 100 kW @ 800 MeV for Mu2eII
joint work with India & INFN, others

Under development: PIP-III

Booster replacement (2030?) to enable >2 MW @ 120 GeV

Currently running Fermilab accelerator experiments

LArIAT

MicroBooNE

MINERvA (E938)

MINOS/MINOS+ (E875/E934/E1016)

NOvA

SeaQuest (E906)

Approved future Fermilab accelerator experiments

LBNF / DUNE

ICARUS / SBND

Mu2e

Muon g-2

What next?