Fermilab | U.S. DEPARTMENT OF ENERGY | Office of Science

Fermilab Update

P. Varghese

23 October 2023

LLRF2023
LOW LEVEL RADIO FREQUENCY WORKSHOP 2023
OCTOBER 22-27, 2023
IN GYEONGJU, REPUBLIC OF KOREA

Outline

1. PIP-II Linac Progress
2. LLRF Systems for PIP-II
3. Accelerator Upgrades to Main Injector and Booster
4. Muon g-2 and Mu2e Experiments
5. LBNF-DUNE

PIP-II Linac and Beam Line

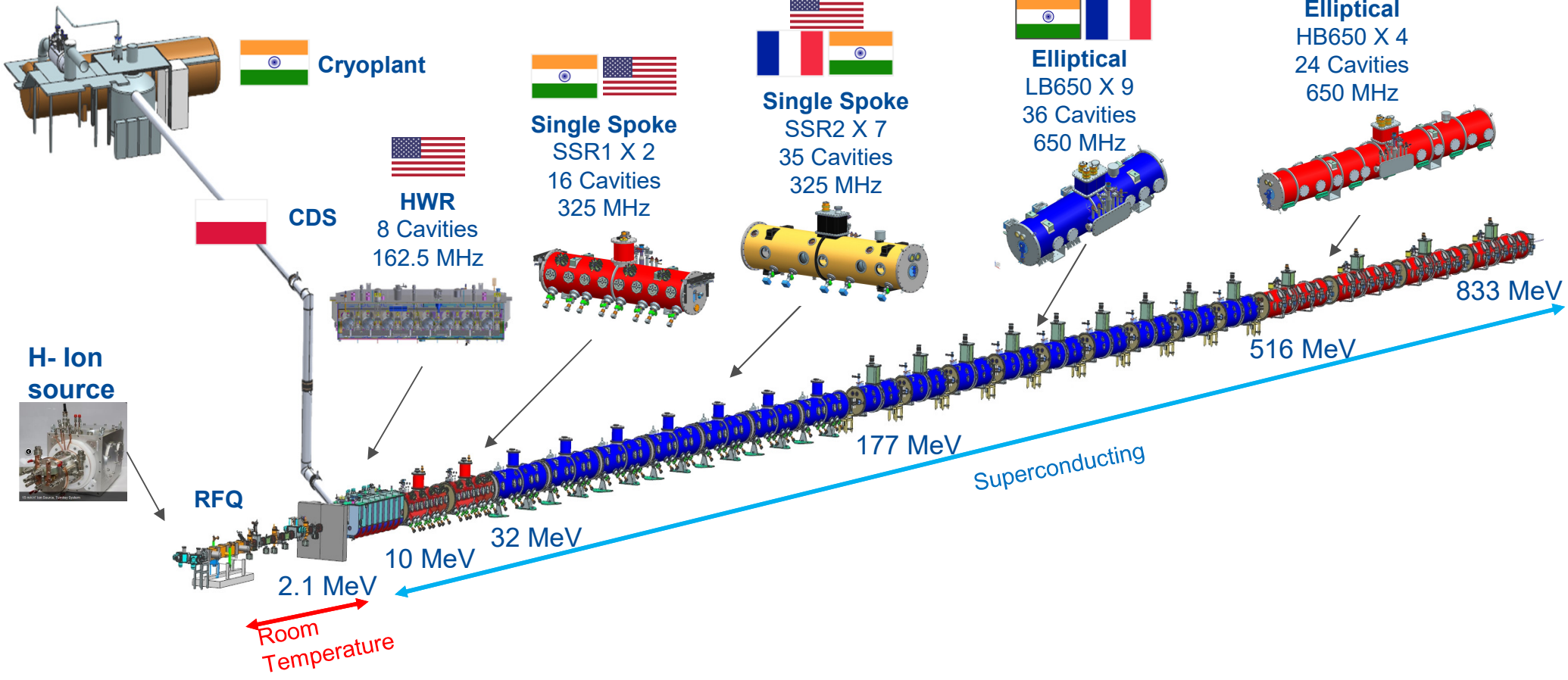
Project received DOE CD-3 approval in 2022

LLRF System final design review in 2024

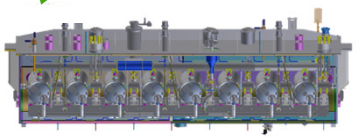
Production stage 2024/25

Upgrades for Booster and Main Injector for higher beam power

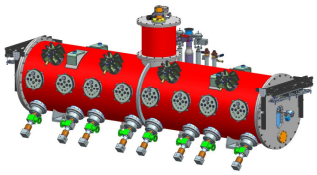
PIP-II Superconducting RF CW Linac, 800 MeV Consists of Five Types of Cryomodules



PIP-II Superconducting Cavities

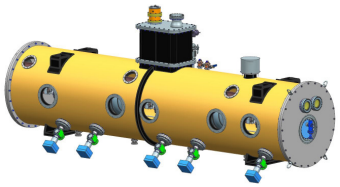


5.9 m



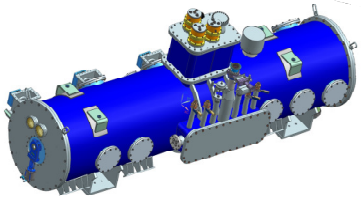
5.3 m

2024/25



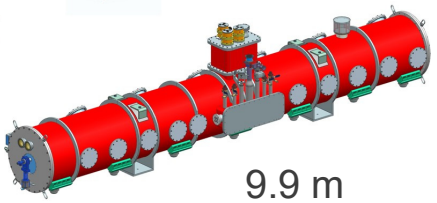
6.5 m

2024/25

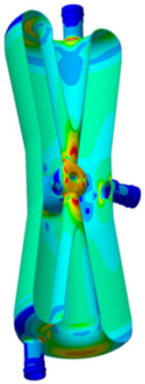


5.5 m

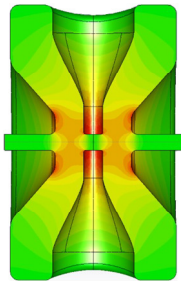
2023



9.9 m

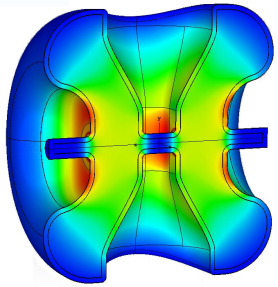


Half Wave Resonator
β=0.11 Q_0 =0.85x10^{10}

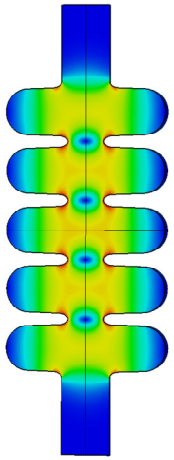


Single Spoke
SSR1
β=0.22 Q_0 =0.82x10^{10}

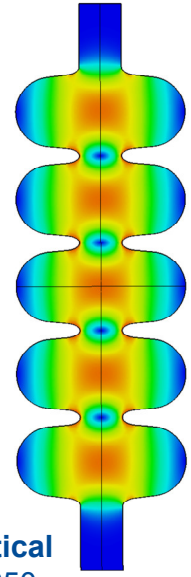
2023



Single Spoke
SSR2
β=0.47 Q_0 =0.82x10^{10}



Elliptical
LB650
β=0.61 Q_0 =2.4x10^{10}

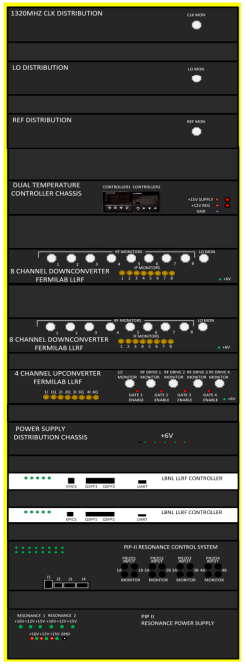


Elliptical
HB650
β=0.92 Q_0 =3.3x10^{10}

✓ Performance validated ✓ Testing in progress Dates: component built

LLRF Station Configurations For PIP-II

4-Cavity Station Control Rack



1320 MHz Clock Distribution

LO Distribution

Reference Distribution

Dual Temperature Controller

8-Channel Downconverter

8-Channel Downconverter

4-Channel Upconverter

UC/DC Power Supply

LLRF Controller

LLRF Controller

Resonance Controller

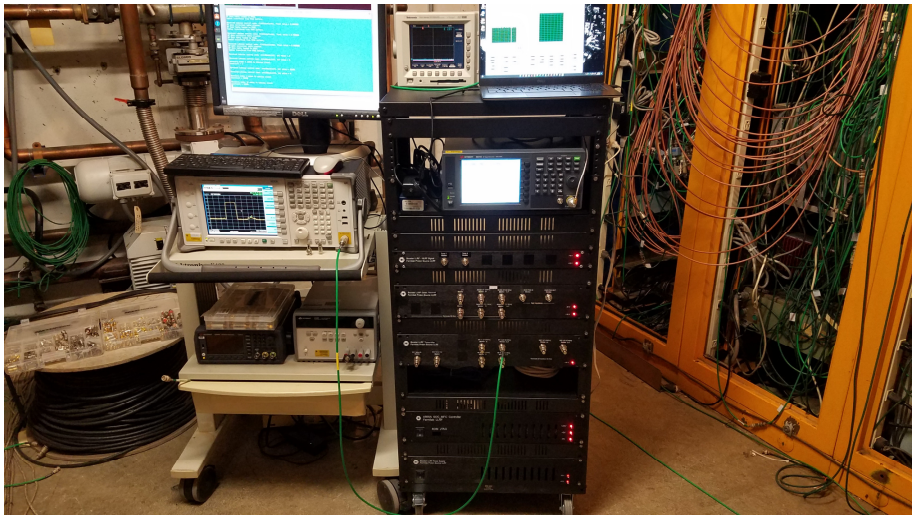
RCC Power Supply

See Posters ID-26,27,64
For PIP-II related topics

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9	Station 10	Station 11	Total
	RFQ, B1-4	HWR	SSR1-1,2	SSR2-1,2,3	SSR2-4,5	SSR2-6,7	LB650-1,2,3	LB650-4,5,6	LB650-7,8,9	HB650-1,2	HB650-3,4	
Number of cavities	6	8	16	15	10	10	12	12	12	12	12	125
RF Freq (MHz)	162.5	162.5	325	325	325	325	650	650	650	650	650	

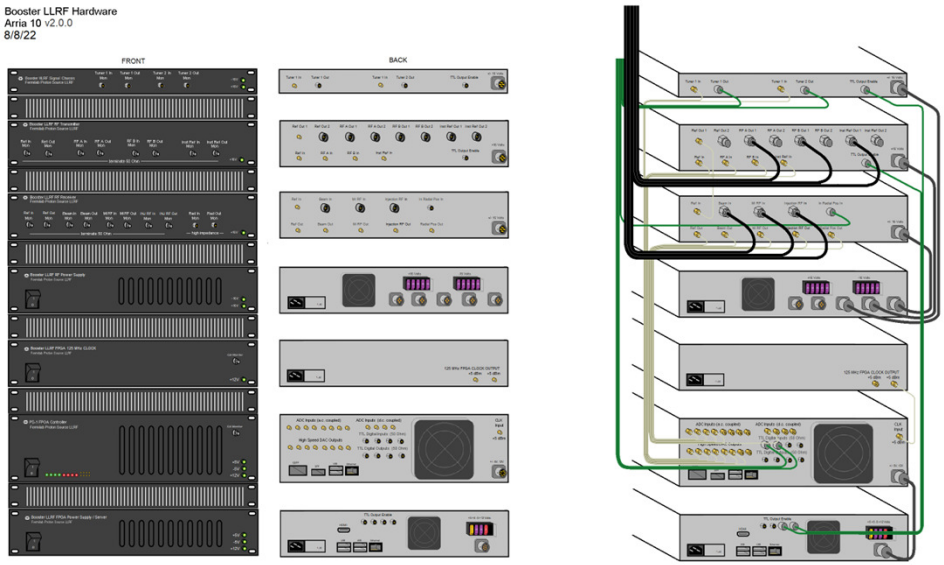
Booster Upgrades

Prototype LLRF System



New FPGA board being developed will be used by the PIP-II warm front-end LLRF systems

New LLRF System

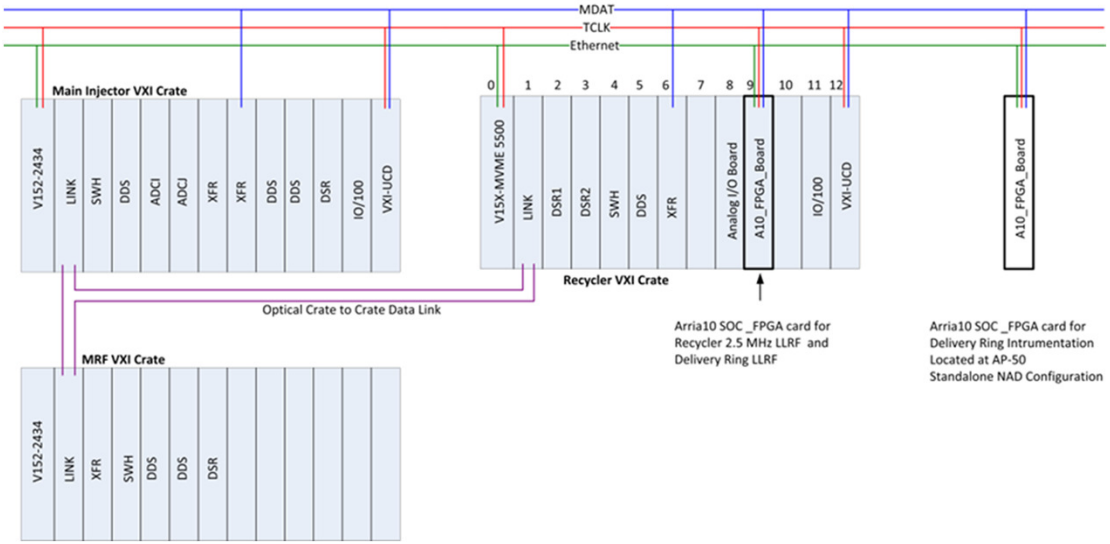


Single SoC FPGA controller for vector control of 19 NC RF cavities
And 1 controller per cavity for Cavity control

MI Cavity Upgrades

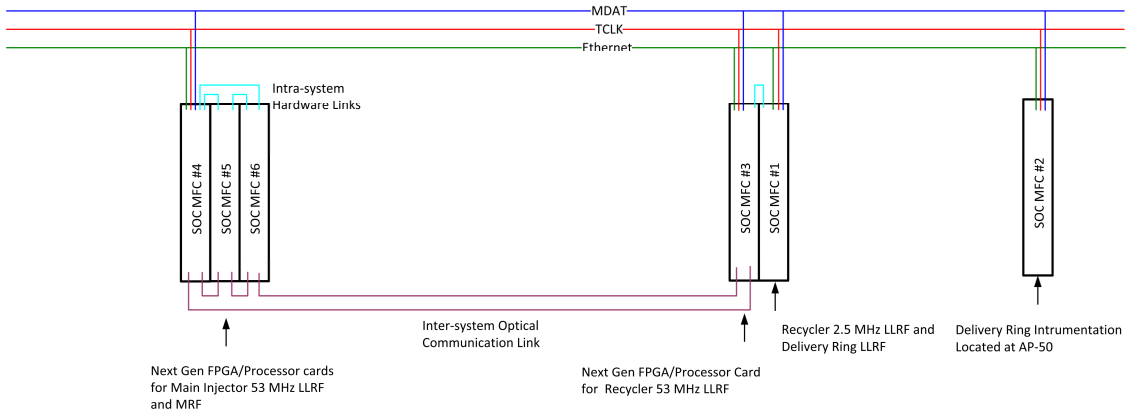
Cavities are being upgraded during annual shutdowns

Main Injector/Recycler LLRF Upgrade

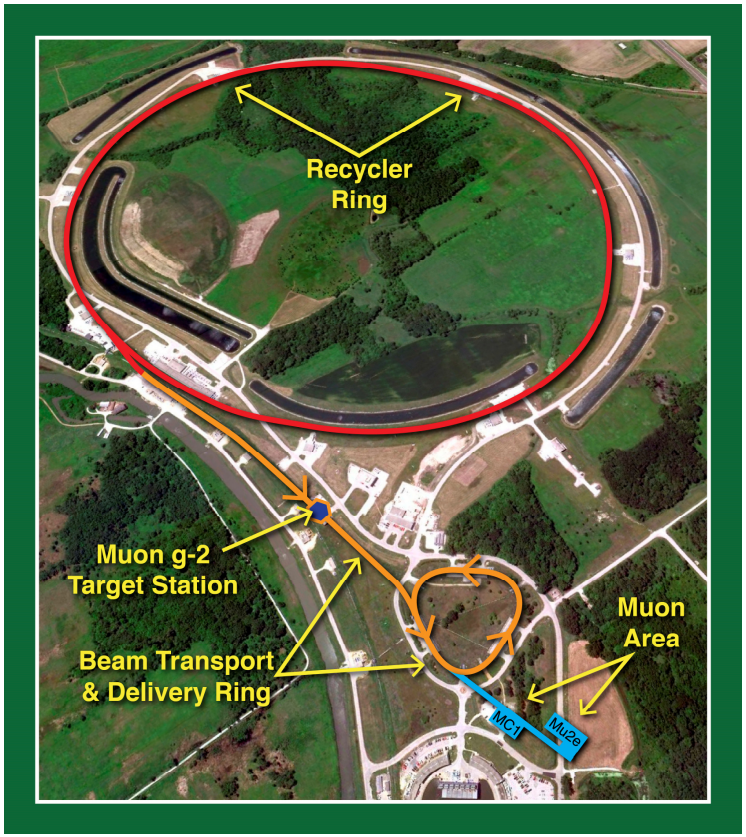


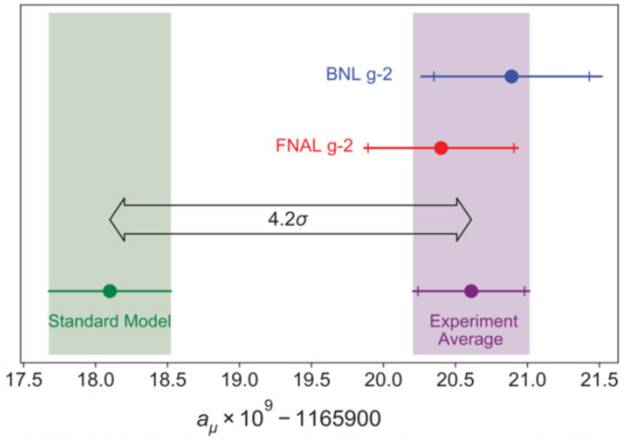
Existing VXI Crate based LLRF systems to be upgraded

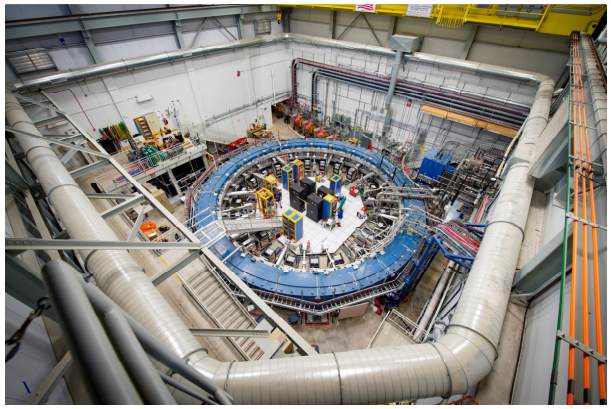
Network Attached Device(NAD) Hardware a possible alternative



Muon g-2 Experiment





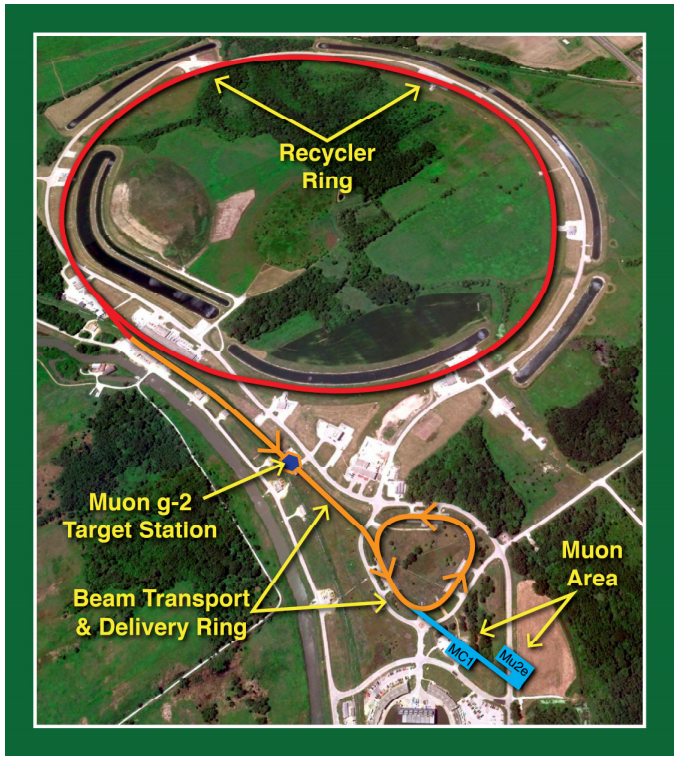


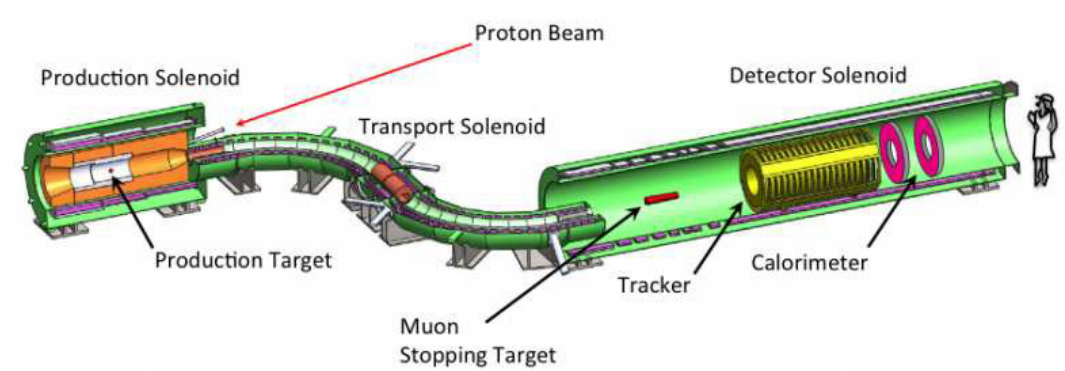
Muon g-2 run has ended
Data from first two years has
Provided a measurement that
is accurate to about 5.3 σ

Physicists Move One Step Closer to a Theoretical Showdown

The deviance of a tiny particle called the muon might prove that one of the most well-tested theories in physics is incomplete.

Mu2e Experiment

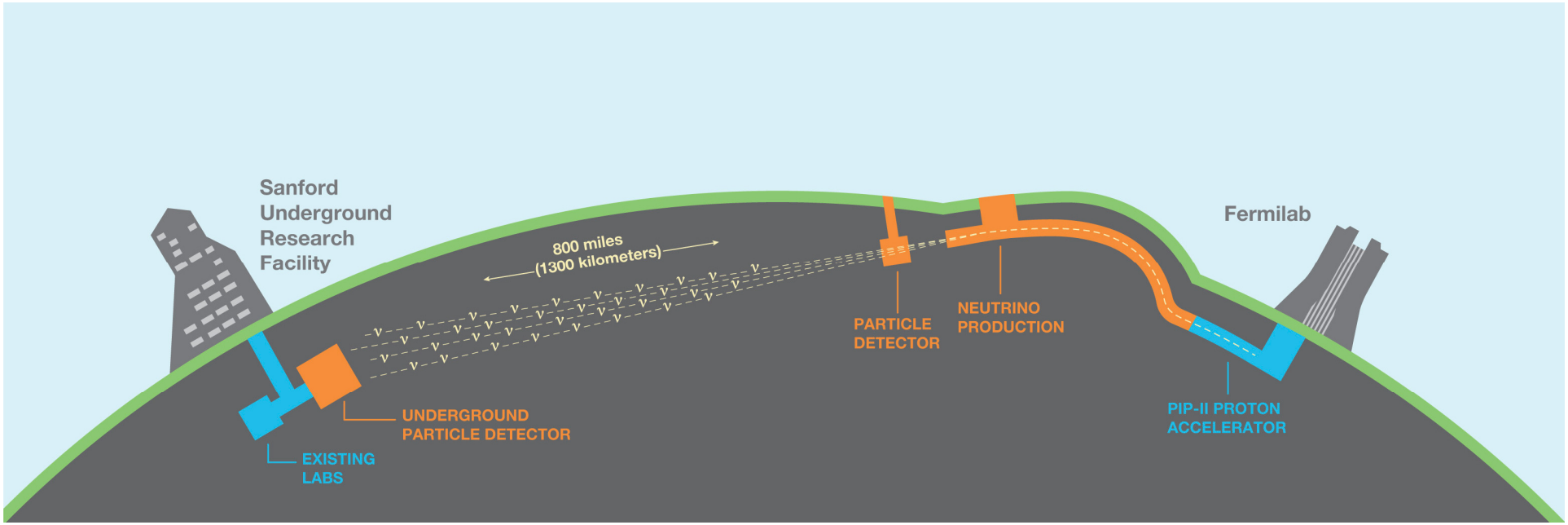




Mu2e construction is under way. A first run in 2025-2026 is expected. A second run will follow PIP-II installation, starting in 2029.

See Poster ID-65

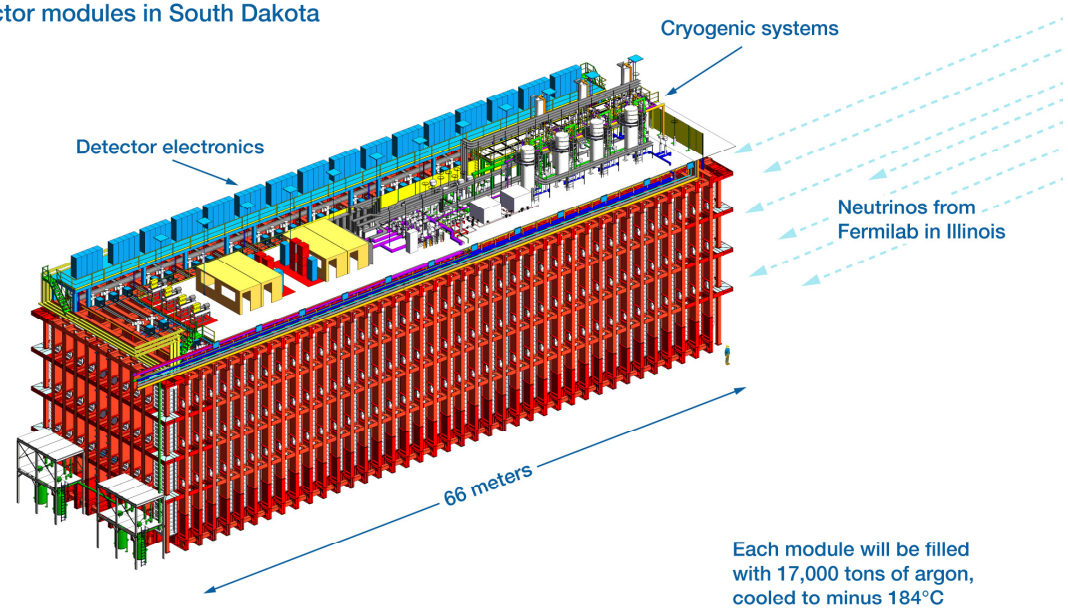
LBNF - DUNE



- The 1.2 MW proton beam on a graphite target produce other particles with electric charge that are focused into a tight beam by a series of magnets called horns
- The DUNE near detector is 60 meters (200 feet) underground at the Fermilab site

LBNF - DUNE

Deep Underground Neutrino Experiment
One of four detector modules in South Dakota



Detector located 1.5 kilometers underground at Sanford Lab

Each module will be filled with 17,000 tons of argon, cooled to minus 184°C

- DUNE will compare the rates of neutrino and antineutrino oscillations
- Recent contracts signed with CERN and Unniversity of Campinas for LBNF participation

Conclusion

- PIP-II LLRF systems will enter the production phase in 2024
- Initial assessments to replace LLRF systems for Main Injector and Recycler
- Mu2e experiment construction is in full swing

Thank You !