



Status & Progress of Fermilab's PIP-II Project

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InPAC2019, IUAC Delhi

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In partnership with:

India/DAE

Italy/INFN

UK/STFC

France/CEA/Irfu, CNRS/IN2P3

Outline

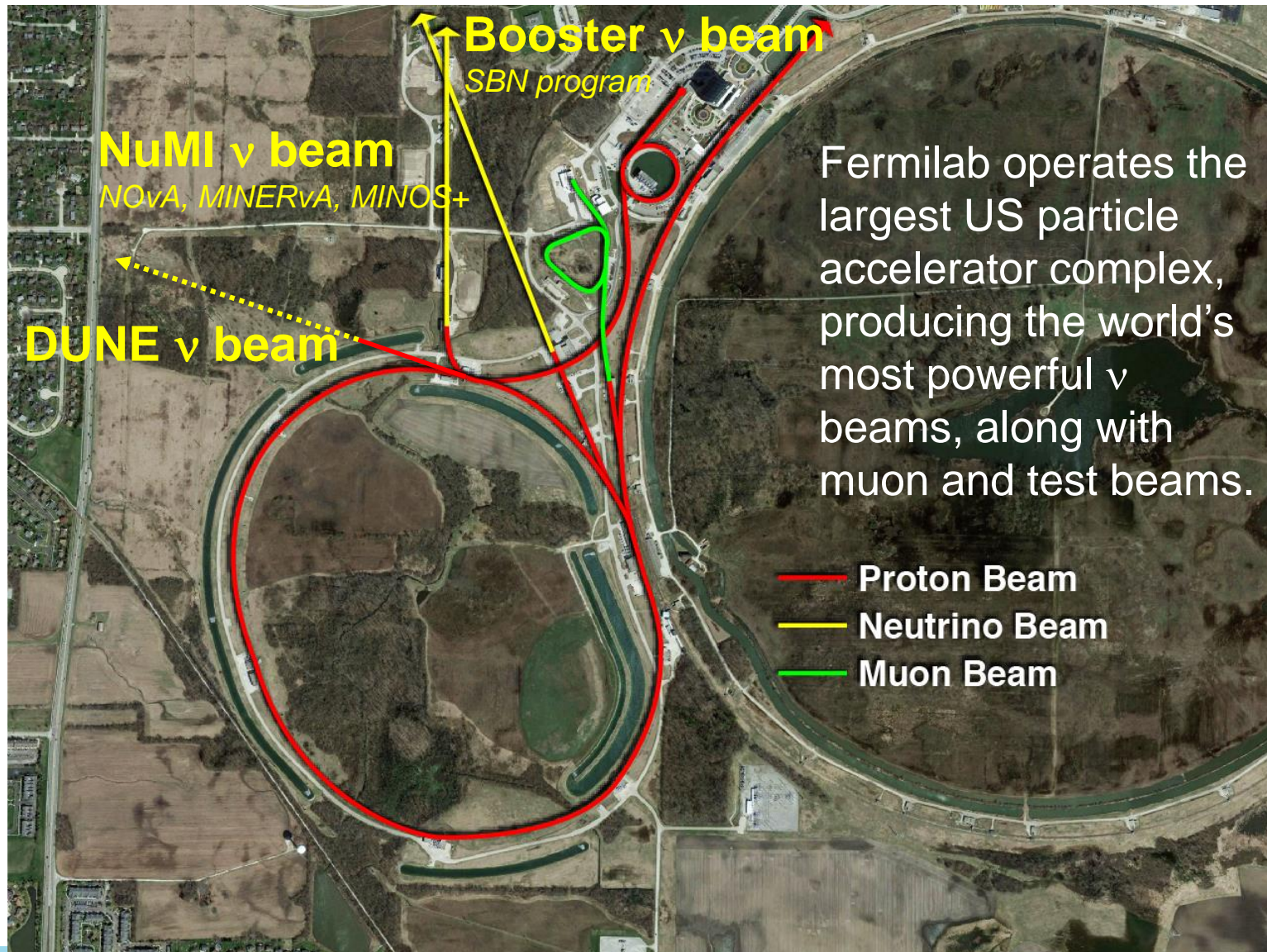
- Fermilab at a Glance
- LBNF/DUNE/PIP-II: Context and Science Objectives
- PIP-II Project Overview & Status
- International Partnerships
- Summary

Fermilab at a Glance

- America's particle physics and accelerator laboratory
- ~1,800 staff at \$550M/yr
- 6,800 acres of federal land
- 4,000 scientists from >50 countries use Fermilab facilities

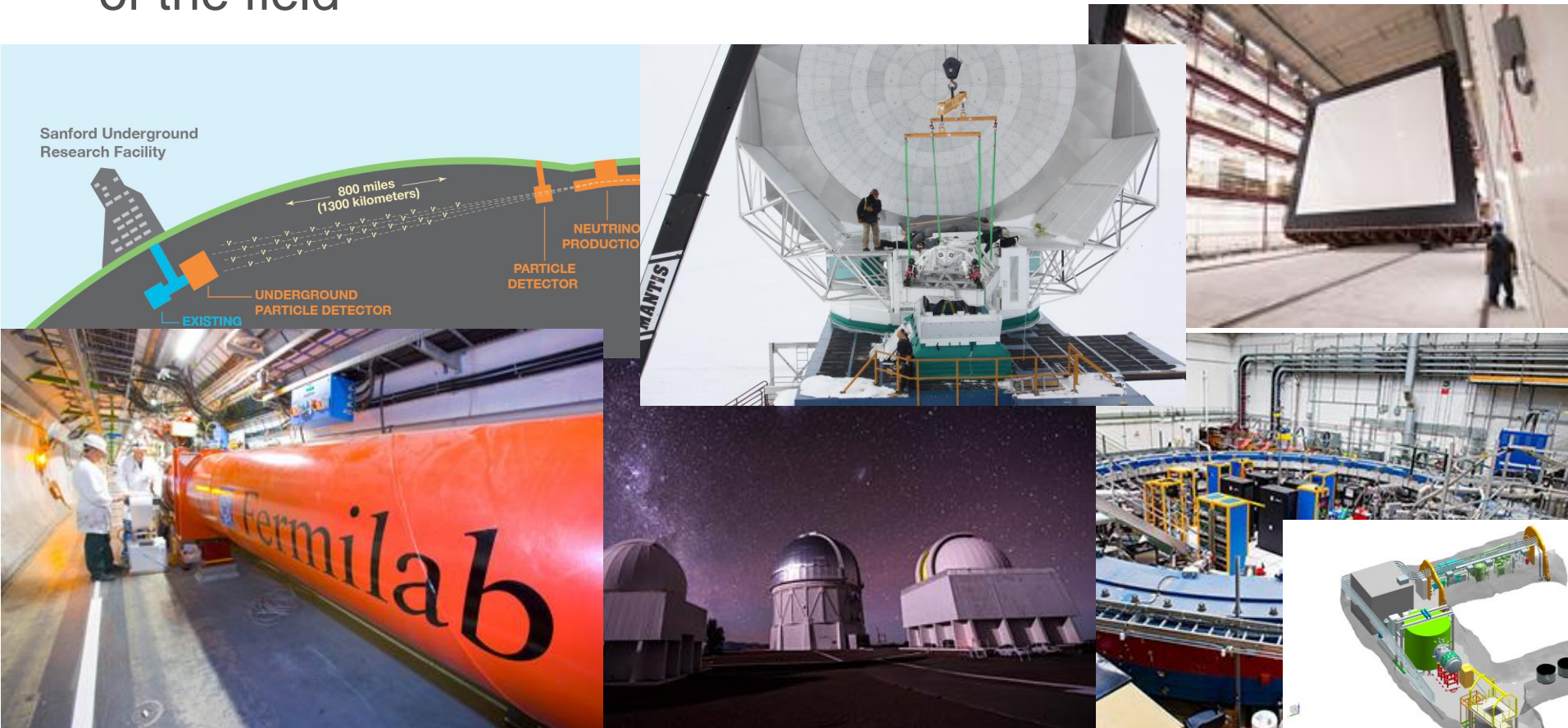
As we move into the next 50 years,
our vision remains to solve the mysteries of
matter, energy, space, and time
for the benefit of all.

Fermilab accelerator complex: operating at >750 kW now



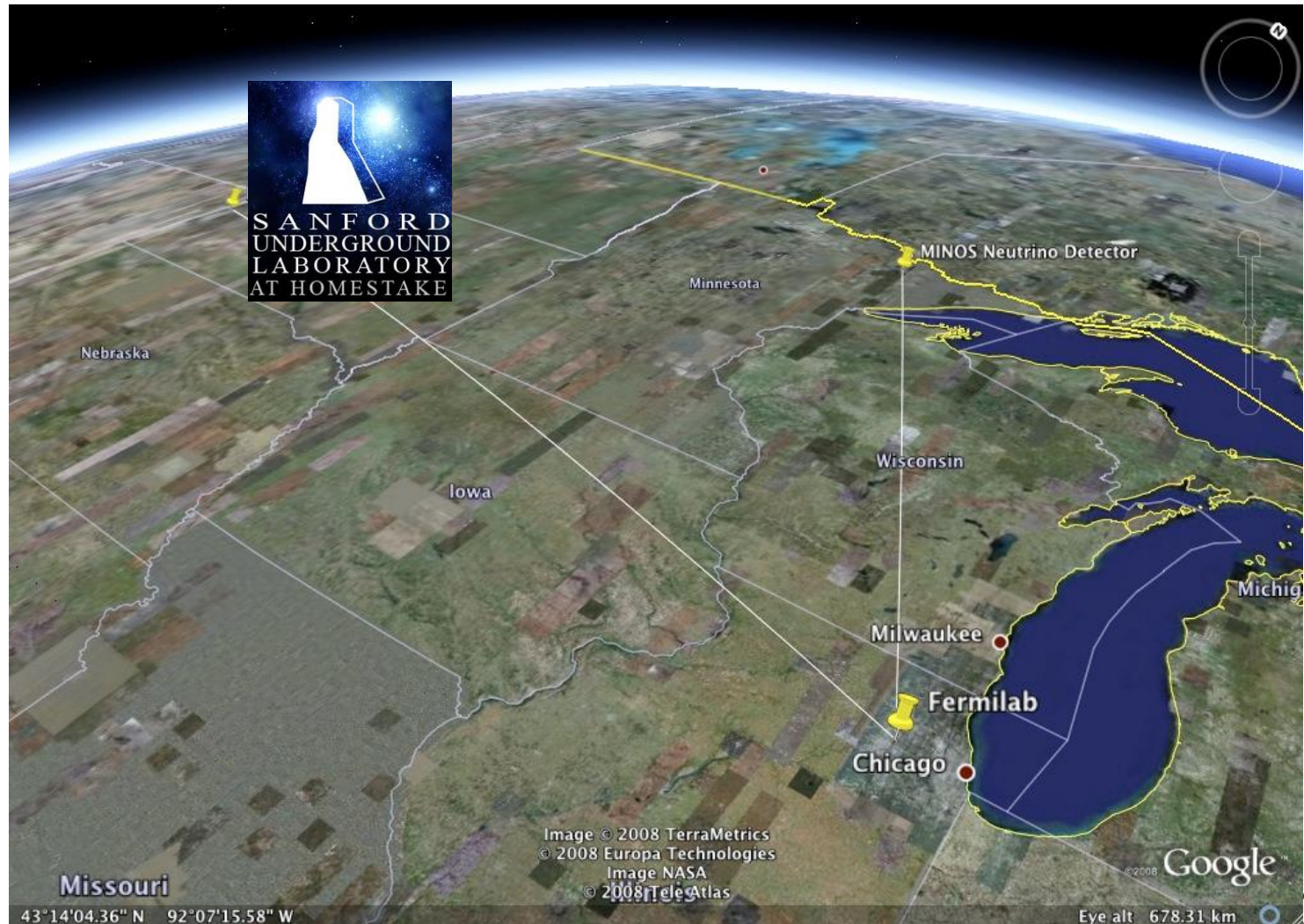
Diverse Particle Physics Program with a Flagship

- Fermilab performs experiments around the globe
- Experiments are interrelated and address the main questions of the field



Neutrinos to Minnesota...generation 2 → 3 (DUNE)

NOvA...our present flagship neutrino experiment



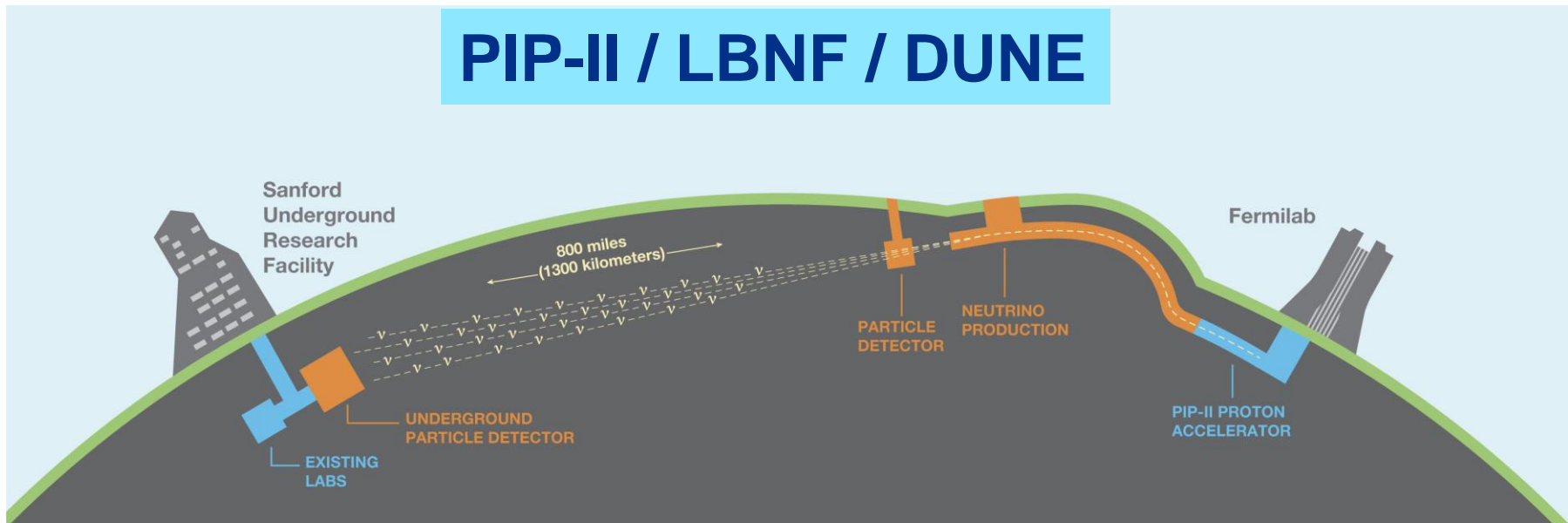


Building for Discovery

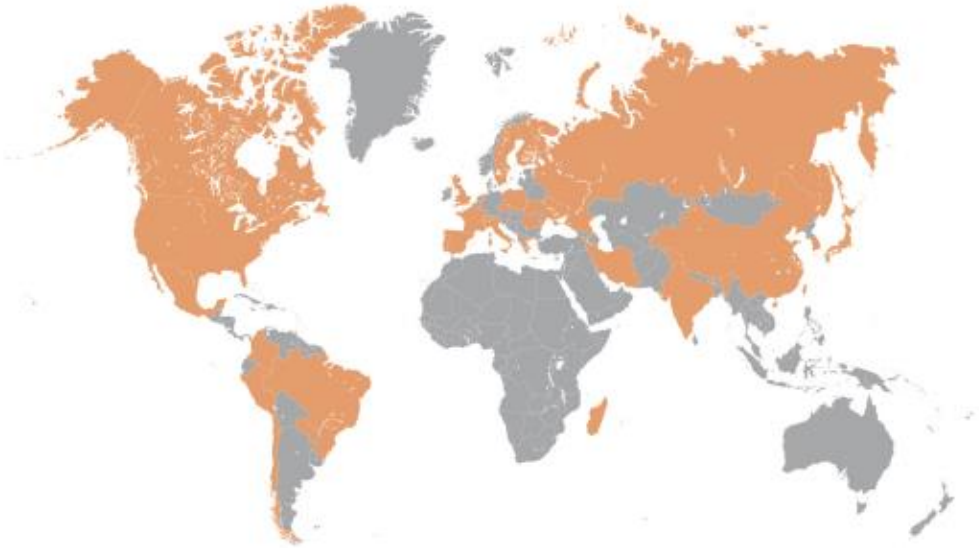
Strategic Plan for U.S. Particle Physics in the Global Context

- 2014 P5 Report:
 - Build a world-class neutrino program
 - Host it as a global project
 - Upgrade Fermilab accelerator complex for higher intensity beams

PIP-II / LBNF / DUNE



DUNE – A Global Collaboration



1075 collaborators from
184 institutions in
31 countries + CERN



DUNE Science Objectives

Neutrinos – most ubiquitous matter particle in the universe, yet the least understood. Opportunities for game changing physics discoveries:



- **Origin of matter**

Investigate leptonic CP violation, mass hierarchy, and precision oscillation physics

- Discover what happened after the big bang: Are neutrinos the reason the universe is made of matter?



- **Neutron Star and Black hole formation**

Ability to observe supernovae events

- Use neutrinos to look into the cosmos and watch the formation of neutron stars and black holes in real time



- **Unification of forces**

Investigate nucleon decay targeting SUSY-favored modes

- Move closer to realizing Einstein's dream of a unified theory of matter and energy

Proton Improvement Plan – II (PIP-II)





P5 Report defines PIP-II Mission



***PIP-II** will enable the world's most intense beam of neutrinos to the international LBNF/DUNE project, and a broad physics research program, powering new discoveries for decades to come.*

PIP-II linac will provide:

Beam Power

- Meeting the needs for the start of DUNE (1.2 MW proton beam)
- Upgradeable to multi-MW capability

Flexibility

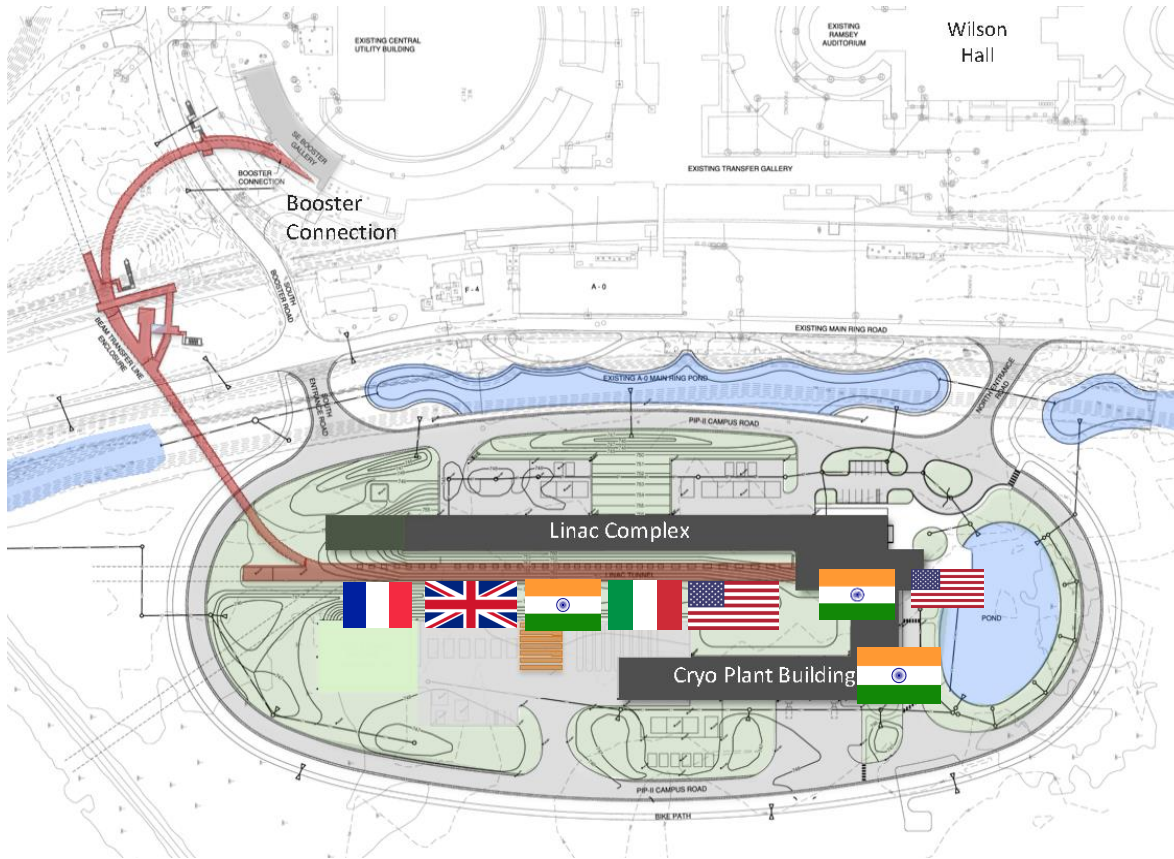
- Compatible with CW-operations which greatly increases the linac output
- Customized beams for specific science needs
- High-power beam to multiple users simultaneously

Reliability

- Fully modernizing the front-end of the Fermilab accelerator complex



PIP-II Scope Overview



800 MeV H⁻ linac

- Warm Front End
- SRF section

Linac-to-Booster transfer line

- 3-way beam split

Upgraded Booster

- 20 Hz, 800 MeV injection
- New injection area

Upgraded Recycler & Main Injector

- RF in both rings

Conventional facilities

- Site preparation
- Cryopant Building
- Linac Complex
- Booster Connection

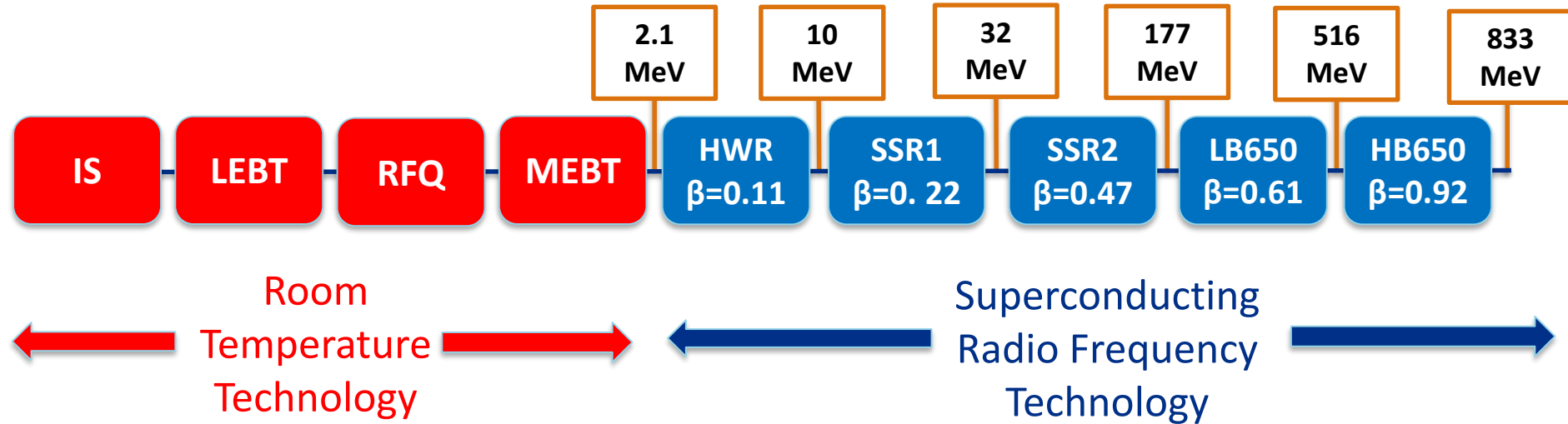
The PIP-II scope enables the accelerator complex to reach 1.2 MW proton beam on LBNF target.



PIP-II Site - Aerial View



The PIP-II 800 MeV Linac



PIP-II Injector Test Facility (PIP2IT)



PIP-II Injector Test Facility retires a significant number of technical risks – complete in FY20

PIP-II Injector Test Facility (PIP2IT)



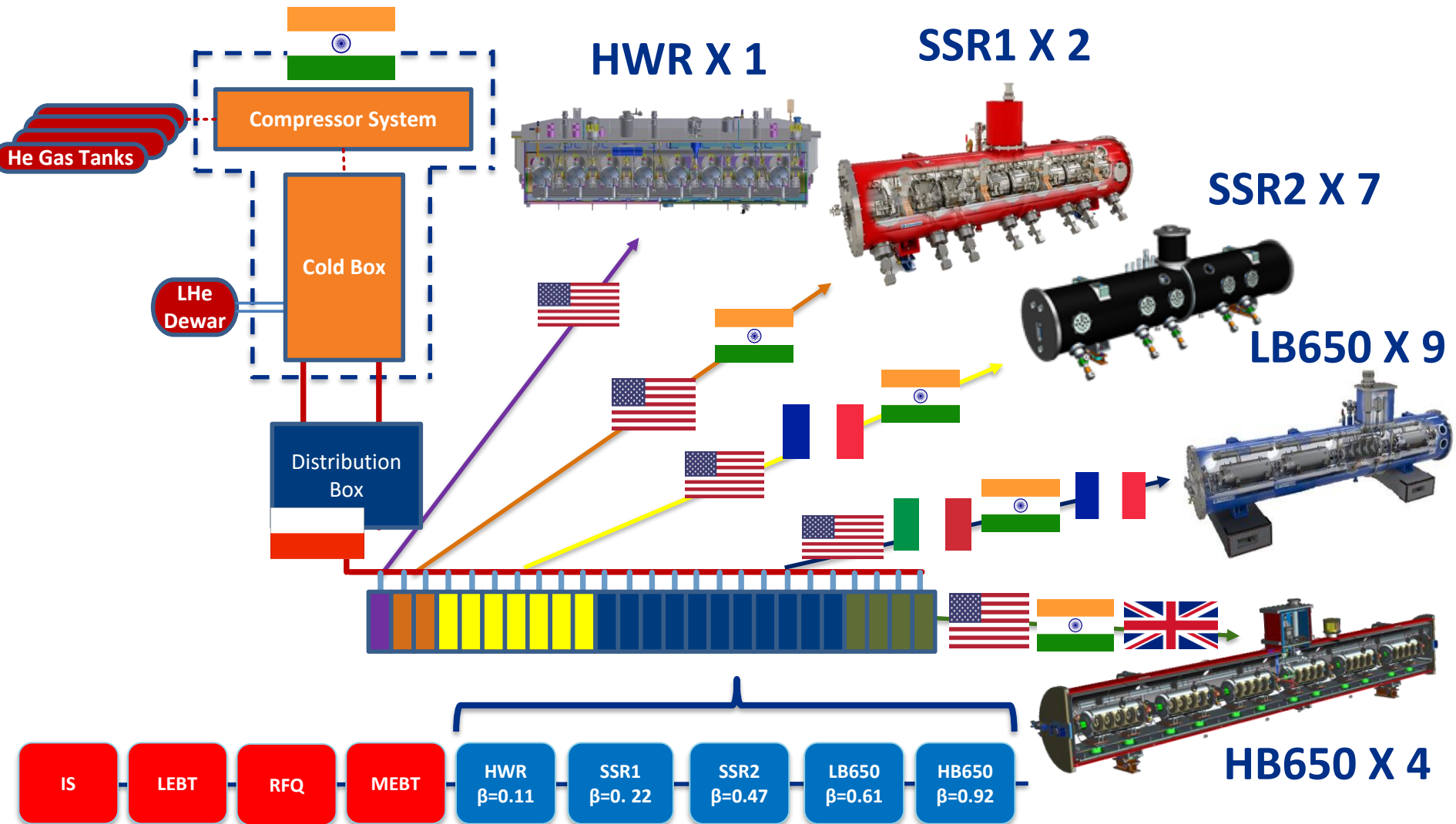
Beam through full length MEBT
“CDR parameters” for 24 hours
 $5 \text{ mA} \times 0.55 \text{ ms} \times 20 \text{ Hz} \times 2.1 \text{ MeV}$

Magnets provided by

RFQ designed by



PIP-II SRF Linac & Areas of International Interest



PIP-II is the first U.S. accelerator project to be built with major international contributions

Half-Wave Resonator Cryomodule Fabrication by Argonne



HWR cryomodule arrived at Fermilab 16-Aug-2019.

HWR Transported to PIP2IT



HWR Transported to PIP2IT



HWR Installed at PIP2IT



SSR1 Cold Mass Assembly Complete – Inserted in cryostat



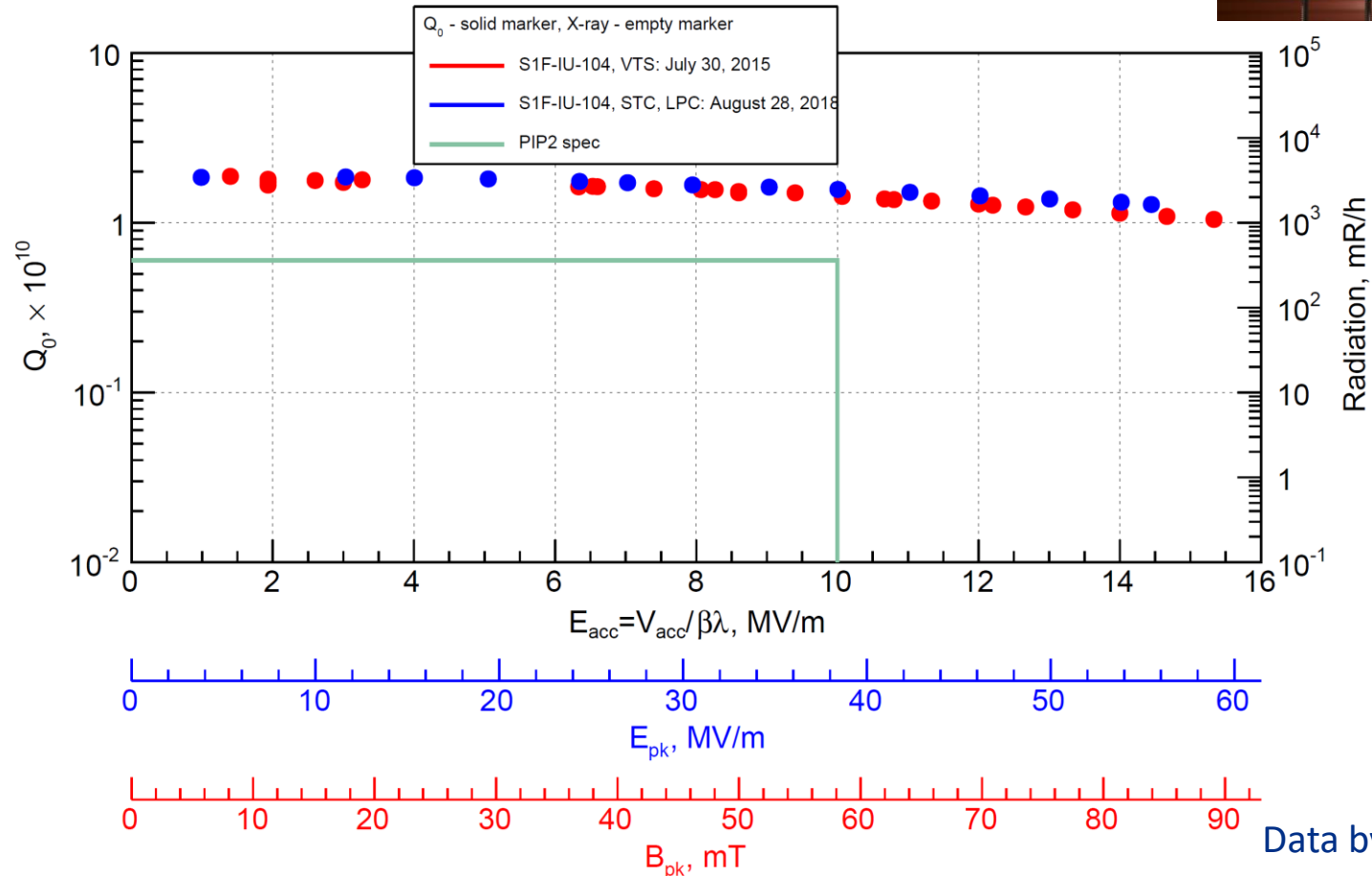


Scheduled to be transported to PIP2IT November 2019

SSR1 – Indian Cavity Performance



STC* test with low power coupler

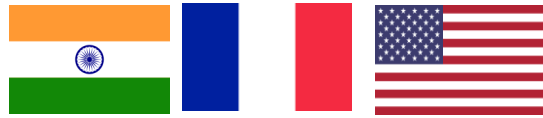


Data by A. Sukhanov

High Q at high gradient and field emission free
BARC cavity has the best cavity Q performance up to date



SSR2



- Cavity RF and mechanical design complete
 - Nb ordered
- Prototype cavities expected in FY20

LB650

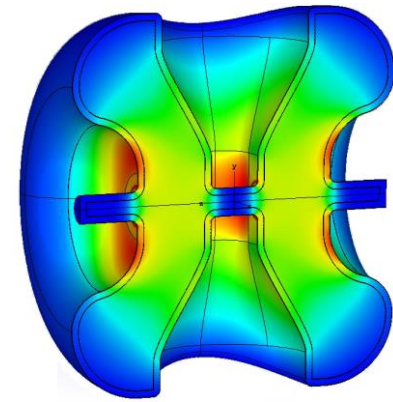


- Cavity RF and mechanical design complete
- Two prototype cavities will be delivered in 2019

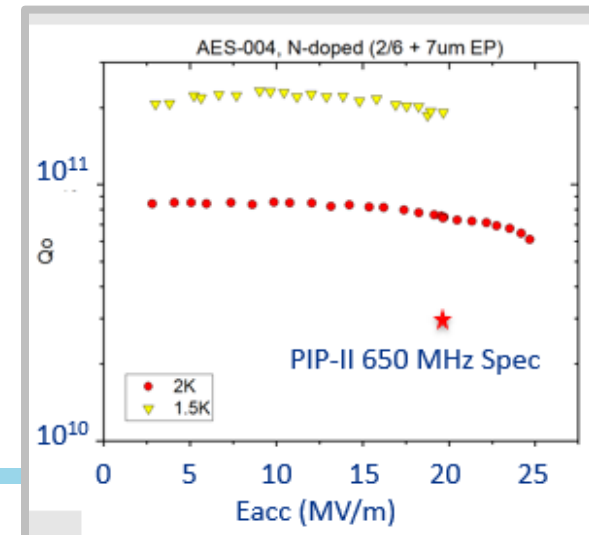
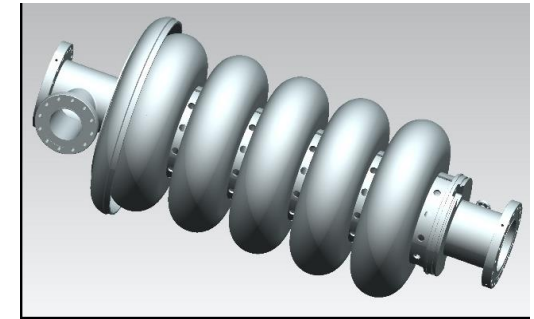
HB650



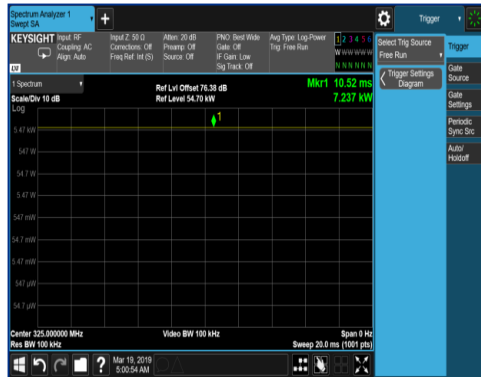
- First HB650 jacketed cavity
- HB650 high Q R&D completed, design validation started
- Cryomodule design is in progress



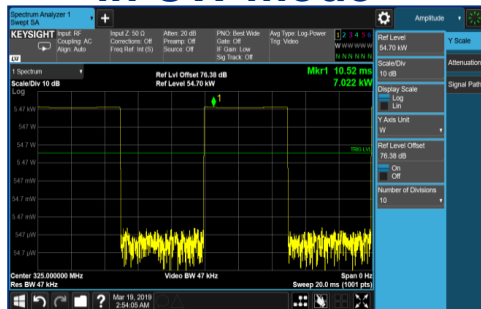
INFN 3D model of LB650 cavity



Indian Institutes and Fermilab Collaboration: 325 MHz, 7 kW Solid State Power Amplifiers @ ECIL



RF power waveform
in CW mode



RF power waveform
in pulse mode

Slide from M. Pande



BARC, ECIL & FNAL team at ECIL



Officials of BARC, ECIL & FNAL at ECIL



RF power amplifier,
qualified and tested @ ECIL

Most of the components, bias supplies and sub systems of this amplifier are indigenously designed and developed except few RF power devices

First ECIL 325 MHz, 7 kW Solid State Amplifier arrives at Fermilab



Flag Off of 1st RFPA at ECIL



Amplifier crates at Fermilab

Slide from M. Pande

Conventional Facilities



Site Clearing Complete

Under special authorization
prior to CD-2/3a granted by DOE



Cryogenics Plant Building

Design Complete;
Ready for Procurement

Linac Complex

Conceptual Design update underway, scheduled for completion in
November 2019. Will form the basis of final design

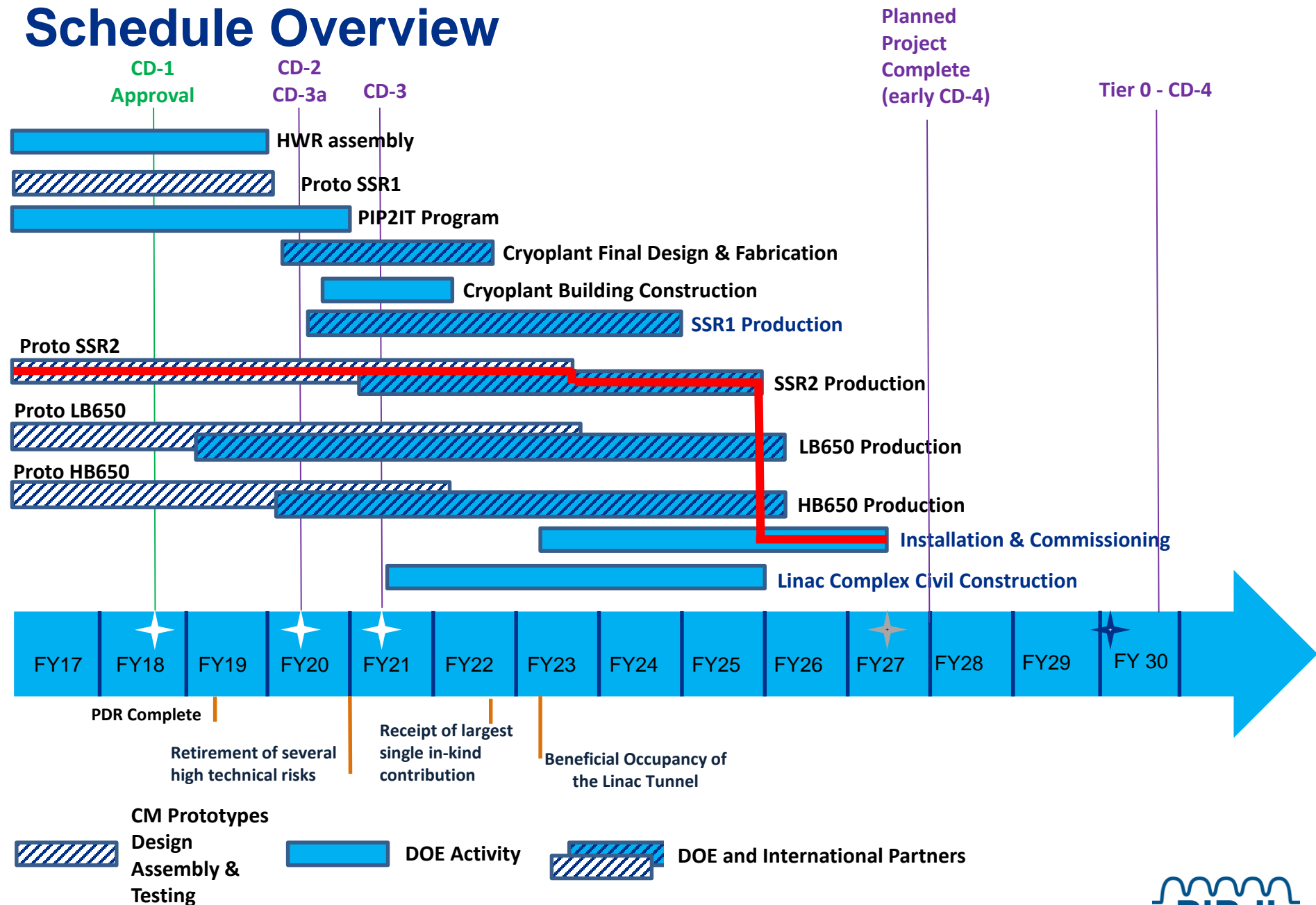


PIP-II Groundbreaking – 15 March 2019

Ms. Neeta Bhushan,
Consul General of India,
Chicago, Jan 2017 – Mar 2019



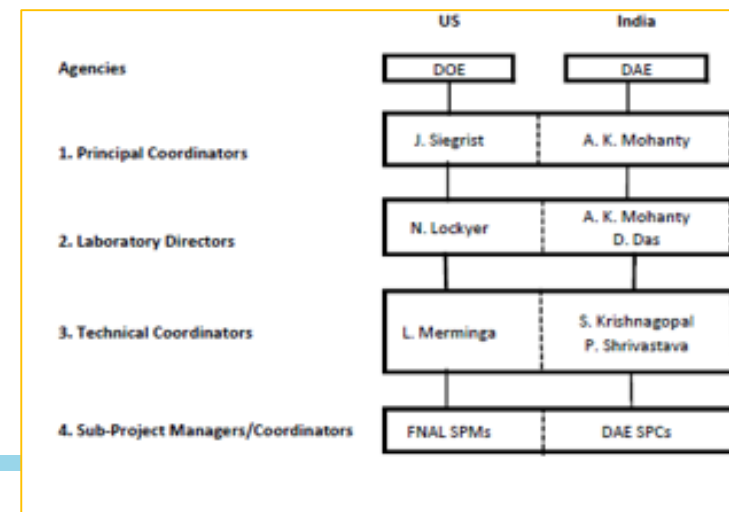
Schedule Overview



International Partnerships

PIP-II International Partnership Principles

- Pursue partnerships where broader interests are aligned, specifically technology (SRF) and science (DUNE)
- Bring international institutions in early as Partners
 - Share project planning, R&D to provide joint sense of ownership
- Integrate Partners in PIP-II project management principles
- Establish International Agreements
- Establish a multi-layered governance structure



PIP-II International Partners, Expertise and Capabilities



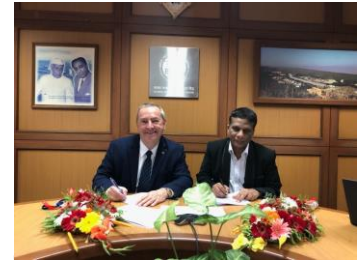
India, Department of Atomic Energy (DAE) (started 2009)
BARC, RRCAT, VECC; also IUAC

Substantial engineering/manufacturing experience
Superconducting magnets for LHC; 2 GeV synch light source



Italy, INFN (started 2016)

Internationally recognized leader in superconducting RF technologies
SRF cavity and cryomodule fabrication for XFEL; SRF cavities for ESS



UK, UKRI (started 2017)

Substantial engineering and manufacturing experience
Construction, operation of synch light & neutron sources
SRF cavity processing and testing for ESS



France, CEA, CNRS/IN2P3 (started 2017)

Internationally recognized leader in large-scale CM assembly
CM assembly for European XFEL and ESS
SSR2 cavities and couplers for ESS

























Poland, WUST (started 2018)

Substantial engineering and manufacturing experience
CDS, LLRF, QC for XFEL and ESS



PIP-II Project benefits from world-leading expertise, facilities.

Major In-Kind Contribution Production Deliverables

Subsystem (count)	Cavities		Cryomodules		RF & Cryo Systems
HWR (1)					
SSR1 (2)					
SSR2 (7)					
LB650 (11)					
HB650 (4)					
Cryoplant (1)					
CDS					

International partnerships are essential for the success of the PIP-II Project

First PIP-II Project Executive Board Meeting – 3/14/2019



Third PIP-II Project Executive Board Meeting – 10/11/2019

IPNO France



PIP-II 2020 Priorities

1. Successfully complete CD-2/3a review

- Baseline PIP-II

2. Complete beam tests at PIP-II Injector Test Facility, incl. HWR and SSR1

- Demonstrate key technologies: CM strong back, LLRF/Resonance Control, SSAs, absorber,

3. Advance HB650 proto cryomodule design/construction

- High level R&D goal of Indian Institutions and Fermilab Collaboration

3. Advance CF designs

- Launch cryoplant building construction



Summary

- PIP-II is breaking new ground
 - First DOE accelerator to be built with significant international contributions
 - Highest energy CW SRF proton linac
- PIP-II is the “heart and soul” of Fermilab, and critical to the success of the international neutrino program
- Baseline review is scheduled January 28-30, 2020
 - Highly talented Fermilab and international team is ready
- We greatly appreciate the enduring support from DOE and international Partners, and their commitment to our joint success and furthering neutrino science

Thank you BARC, RRCAT, VECC, IUAC Teams for your expertise, experience, commitment and great contributions to the PIP-II Project!

धन्यवाद!

