EPICS for Fermilab's Flagship Project – PIP-II

E. Harms, PIP-II Accelerator Systems L2 Manager

EPICS collaboration meeting

25 April 2023 harms@fnal.gov

PIP-II is a partnership of:

- US-DOE
- India-DAE
- Italy-INFN
- UK-STFC-UKRI
- France-CEA, CNRS/IN2P3
- Poland-WUST, WUT, TUL

About me

Role

- L2 manager for Accelerator systems
- MPS CAM
- WUT & TUL IKCs
- >5 years direct involvement with PIP-II

Relevant Experience

- Senior Engineering Physicist
- LCLS-II cryomodule testing (Fermilab lead)
- FAST/IOTA cryomodule commissioning
- Deputy leader: FLASH 3rd harmonic SRF system delivered to DESY
- Leader/coordinator various SRF SRF test stands
- AD department head: Antiproton source, SRF electron linac
- Building, commissioning, **operations**, and training/education/outreach
- TTC Technical Board (Integration & Operation)
- USPAS instructor

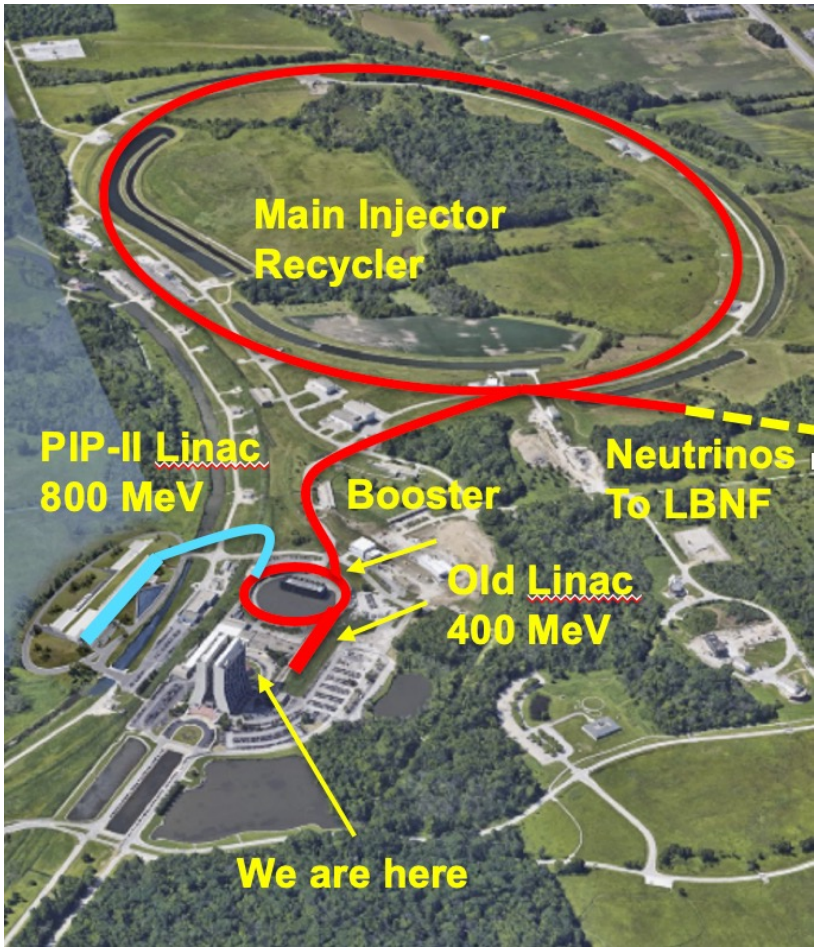
Outline

- PIP-II Mission
- Layout
- In-Kind Contributions
- Status
- EPICS
  - Why for PIP-II?
  - progress to date
- Summary

PIP-II = Proton Improvement Plan Phase II
yes, Phase-I is complete: upgrades to the existing linear accelerator

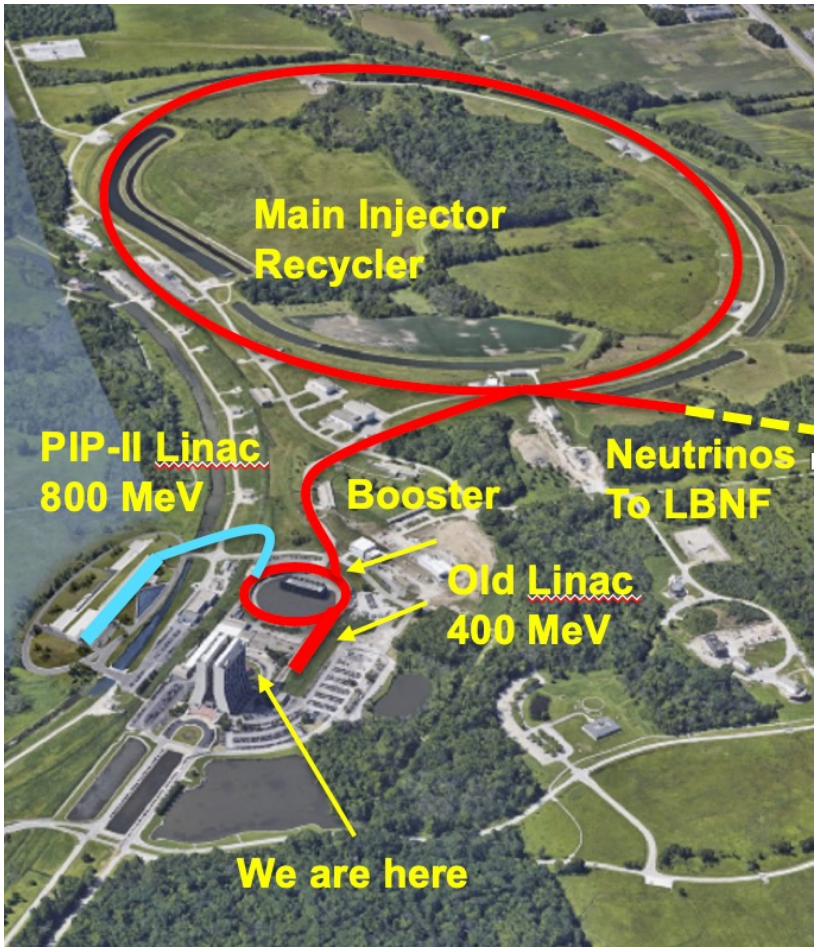
Mission

Mission (2)



- An 800-MeV superconducting H^-, CW-compatible Linac
- Beam transport of 800-MeV H^- from the SRF Linac to the Booster.
- A new injection area in the Booster.
- Modifications to the Booster, Main Injector, and Recycler Ring to enable >1 MW power on LBNF target for 60-120 GeV.
- Associated conventional facilities. The linac enclosure is compatible with upgrades.
- Tailoring strategy
- Beam parameters
  - 2 mA beam current
  - 550 μs pulse width
  - 20 Hz repetition rate
- **PIP-II is the first US/DOE accelerator to be built with significant international contributions/partnerships.**

Mission (2)



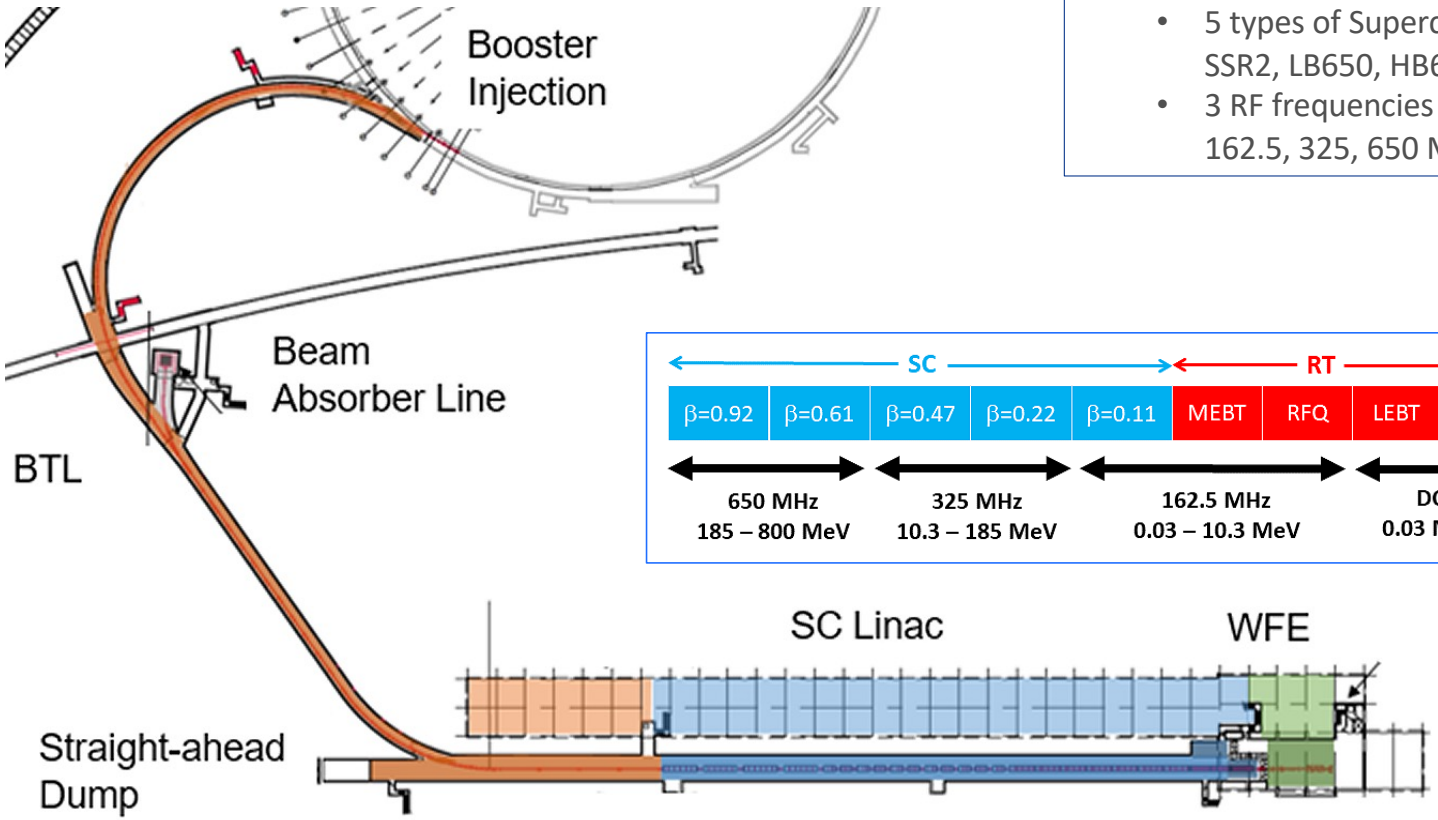
- An 800-MeV superconducting H^-, CW-compatible Linac
- Beam transport of 800-MeV H^- from the SRF Linac to the Booster.
- A new injection area in the Booster.
- Modifications to the Booster, Main Injector, and Recycler Ring to enable >1 MW power on LBNF target for 60-120 GeV.
- Associated conventional facilities. The linac enclosure is compatible with upgrades.
- Tailoring strategy
- Beam parameters
  - 2 mA beam current
  - 550 μs pulse width
  - 20 Hz repetition rate
- **PIP-II is the first US/DOE accelerator to be built with significant international contributions/partnerships.**

#	Scope	Threshold KPPs	Objective KPPs
1	Linac Beam Energy	Accelerate H- beam to 600 MeV	1. Accelerate H- beam to 700 MeV 2. Linac systems required to accelerate beam to 800 MeV installed and tested
2	Linac Beam Intensity	Beam delivered to Beam Dump at the end of Linac	Beam with intensity of 1.3E12 particles per pulse (H-) at 20 Hz delivered to Beam Line Dump
3	Booster/ Recycler/ Main Injector upgrades	Booster, Recycler, and Main Injector Upgrades to support operations with beam power of 1.2 MW on the LBNF target are installed and tested without beam	Linac beam injected and circulated in Booster

Objective KPPs are aligned with the baseline project scope and assure that the accelerator facility, as constructed, is capable of meeting the scientific needs of the Fermilab program (Project Execution Plan, PIP-II DocDB #3036)

PIP-II Layout

Linac consists of:
- Room temperature front end (up to 2.1 MeV)
- Superconducting (cold) linac
  - 5 types of Superconducting cavities: HWR, SSR1, SSR2, LB650, HB650
  - 3 RF frequencies are used for acceleration: 162.5, 325, 650 MHz



PIP-II Layout (2)

PIP2IT successfully demonstrated 17 MeV beam with parameters required for LBNF/DUNE operations

Cryoplant
2.5kW @ 2K

HWR
162.5 MHz

Single Spoke 1
SSR1 x (1 + 2)
325 MHz

Single Spoke 2
SSR2 x (1 + 7)
325 MHz

Elliptical
LB650 x (1 + 9)
650 MHz

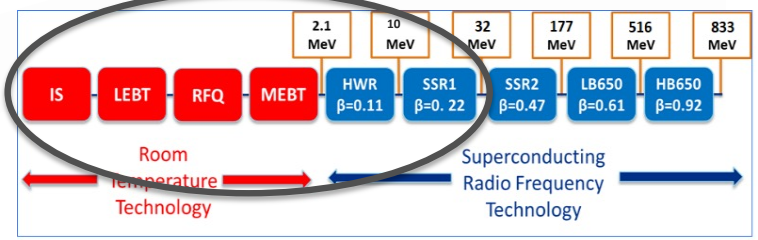
Elliptical
HB650 x (1 + 4)
650 MHz

CD S

SRF technology

Room temperature technology

Tested at PIP2IT



PIP-II technology map

9

Other In-kind Contributions

- DAE
  - All 325 MHz, 650 MHz Solid State Amplifiers
    - SSR1 325 MHz, 7 kW – FDR conducted
    - 9 prototype units *delivered & operated* at PIP2IT
    - 9 more production ones to be provided
    - SSR2 325 MHz, 20 kW – PDR conducted, FDR soon
      - 40 total units; design based on 7 kW; prototype @ BARC
  - LB650 650 MHz, 40 kW – PDR conducted, FDR this summer
    - 39 units total
    - 2 units *delivered; first one powered & meets specs; 2nd one at PIP2IT run continuously for ~900 hours*
  - HB 650 MHz, 70 kW – PDR conducted, FDR late this summer
    - 40 units total; design based on 40 kW system
  - Magnets
  - 35 MEBT quadrupoles; 27 in hand (PIP2IT)
  - Warm Unit elements: 47 Quadrupoles, 44 Correctors
    - 2 prototypes delivered
  - LLRF/RF Protection systems
    - 23 units: SSR1/SSR2/LB650

PIP-II will provide a highly capable, reliable, upgradeable and expandable scientific infrastructure with significant savings to DOE

India, Department of Atomic Energy (DAE) (started 2009)
BARC, RRCAT, VECC; and 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, STFC UKRI (started 2017)

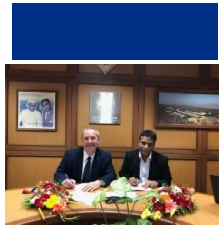
Substantial engineering and manufacturing experience; Construction, operation of synch light & neutron sources SRF cavity processing and testing for ESS

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, WUT, TUL (started 2018)

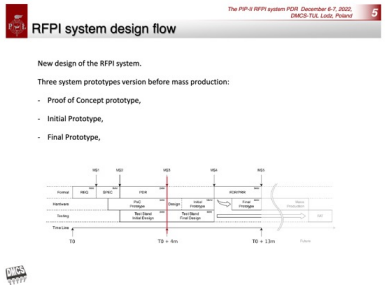
Substantial engineering / manufacturing experience; CDS, LLRF, QC for XFEL, ESS

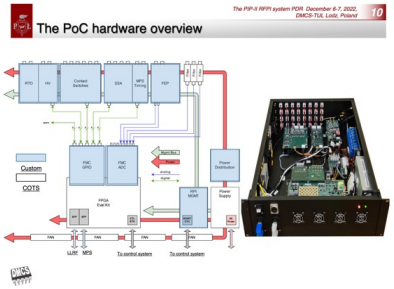


PIP-II is the U.S. first accelerator project to be built with major international contributions; benefits from world-leading expertise, capabilities

In-kind Opportunities

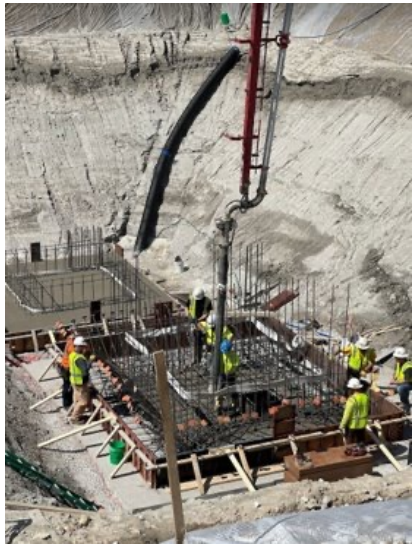
- Warsaw University of Technology/Institute of Electronic Systems
  - LLRF Phase Reference Line design & installation
    - System enhancements
  - Cavity Simulators
  - Build on ESS IKCs
  - Request to funding ministry pending (March?)
- Lodz University of Technology/DMCS
  - Subcontract for LLRF RF Interlocks Design
    - PDR conducted 6-7 December at TUL
  - Pursue IKC funding this summer
- Joint ICRADA executed (2021) and basis for IKCs
  - PPDs and ICRADA Annexes in draft
- Regular (weekly) meetings with both teams
- Regular visits





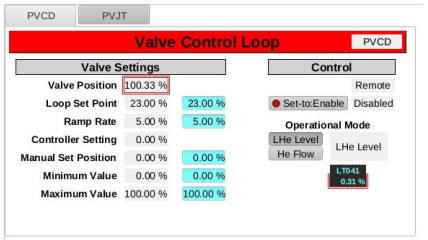
Status

- Project Execution (CD-3)
- Technical Designs nearing completion
- Civil construction in progress

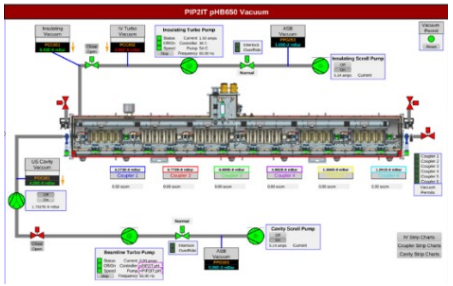


EPICS & PIP-II

- Mandate to adopt EPICS for PIP-II
- Some, but minimal previous experience
  - Test beams & detectors
  - SRF test stands
  - LCLS-II LLRF
- PIP2IT reconfiguration to cryomodule test stand determined to be the ‘right’ time to implement EPICS-based controls
- Achieved: LLRF, HPRF, Controls, Vacuum, Cryo
  - Supports pHB650 testing: in progress
  - Development test bed
- More from Pierrick to follow

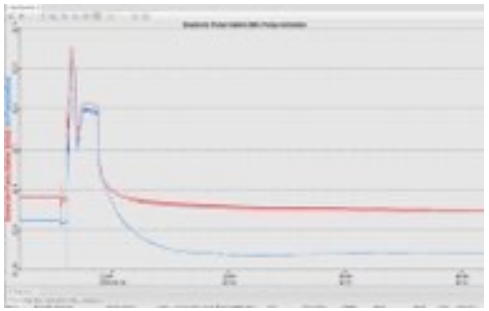


Cryo Valve Control

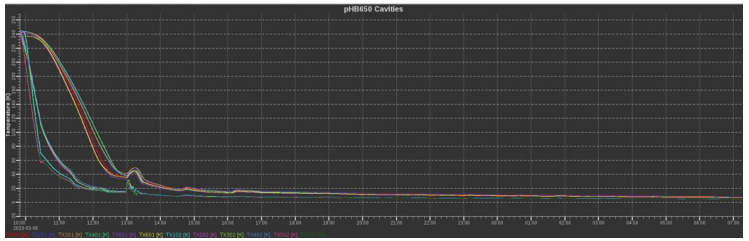


PIP2IT Vacuum layout

SRF cavity performance



PIP2IT Vacuum pump down



PIP2IT Initial Cooldown (EPICS archiver)

PIP-II & EPICS

- IDIQ contractors fully engaged – Osprey and Cosylab
  - 5 tasks completed to date, 2 in progress, 2 pending
- EPICS collaboration
  - Presence at most recent *codeathon* and collaboration meeting
  - Invited to a seat at the collaboration table
  - Bilateral work
    - Drawing on EPICS resources
    - Identifying legacy capabilities that can be shared with EPICS community
    - This meeting
  - Open to other opportunities & partnerships

	Task	Duration	Contractor
✓	TCLK Multicast	Jan – Mar 2021	Osprey
✓	MODBUS IOCs	May – July 2021	Cosylab
✓	PV Access Multicast	July – Oct 2021	Osprey
✓	Enet protocol drivers	Oct 2021 – Jan 2022	Cosylab
✓	EPICS training	Mar – Apr 2022	Osprey
	High Power RF EPICS interface	**in progress**	Cosylab
	Low Level RF EPICS interface	**In progress**	Osprey
	Waveform handling	pending	tbd
	Sequencer	pending	tbd

Summary

- PIP-II allows Fermilab to embark on a new chapter of science
  - Neutrino physics +
- Construction has begun on Fermilab's new flagship accelerator
  - SRF technology
  - Modern front end of the accelerator complex
  - Provide high power beams
- EPICS is the basis for PIP-II's controls
  - PIP2IT/cryomodule test stand is already realizing this path forward
  - Expanding in-house capabilities and drawing on external capabilities
  - Exploring/open to other opportunities
- In the words of a recent reviewer:
  - 'never expected to hear Fermilab and EPICS uttered at once'
  - A new reality!


PIP-II
Follow us:
www.pip2.fnal.gov
@PIP2accelerator
/showcase/pip-ii/