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PXIE Overview

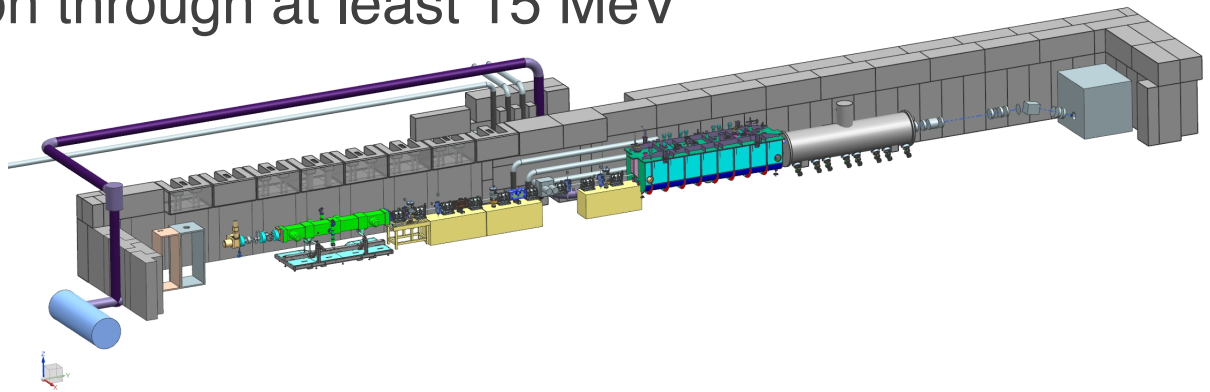
Paul Derwent

PIP-II Collaboration Meeting

9-10 November 2015

PXIE Scope

- Development and integrated systems testing of PIP-II Front End components (PXIE)
  - Deliver 1 mA average current with 80% bunch-by-bunch chopping of beam delivered from the RFQ
  - Demonstrate efficient acceleration with minimal emittance dilution through at least 15 MeV



- All components are being designed and fabricated to PIP-II specifications and our intention is to reutilize as much as possible.

Beam requirements at the end of PXIE

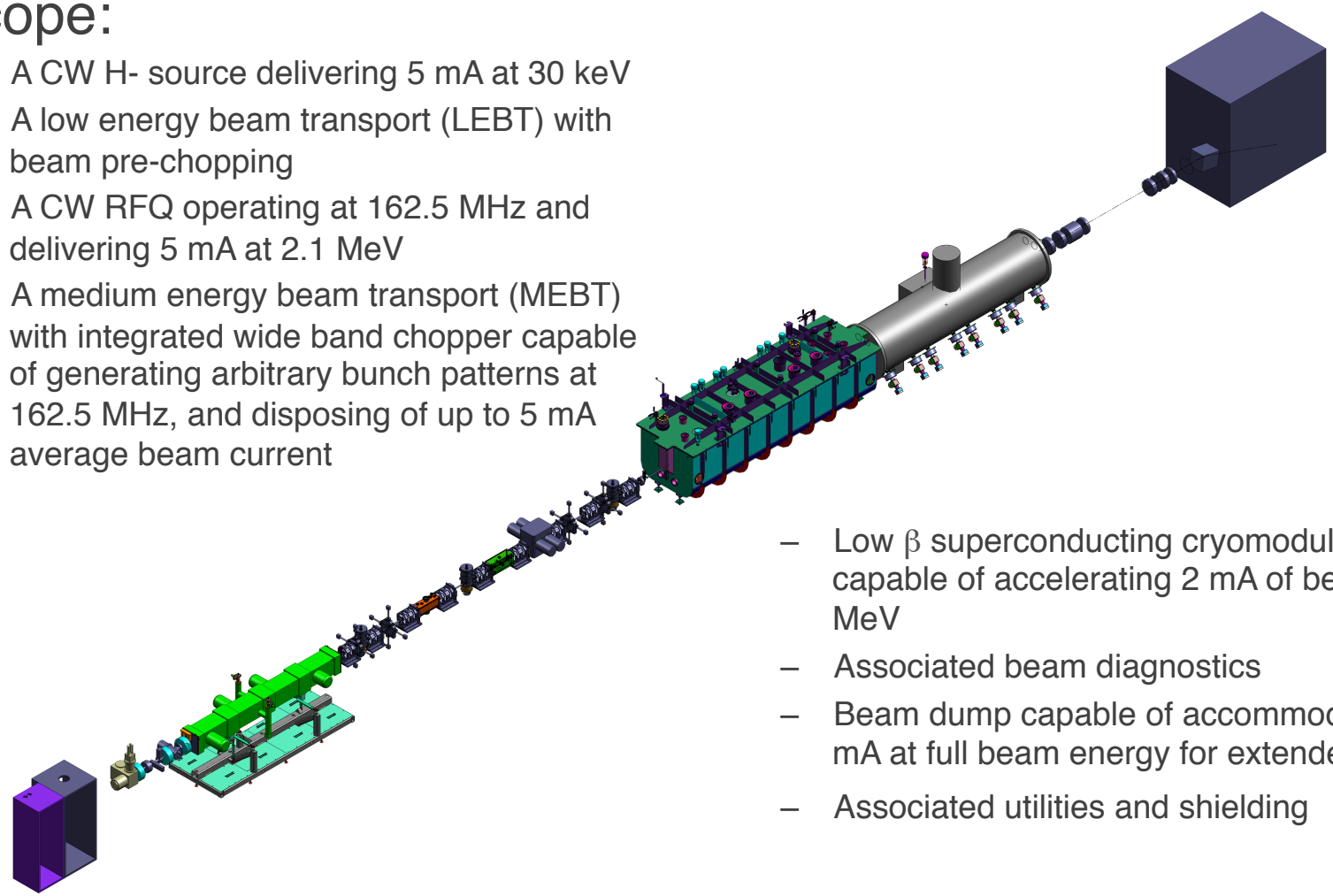
Parameter	Value	Unit
Beam kinetic energy, Min/Max	15/30	MeV
Average beam power	≤ 30	kW
Nominal ion source and RFQ current	5	mA
Average beam current (averaged over > 1μs)	1	mA
Maximum bunch intensity	1.9×10^{8}	
Minimum bunch spacing	6.2	ns
Relative residual charge of removed bunches	$< 10^{-4}$	
Beam loss of pass-through bunches	< 5%	
Nominal transverse emittance*	< 0.25	μm
Nominal longitudinal emittance*	< 1	eV-μs

* *RMS, normalized*

- Capability of an arbitrary micro-bunch structure

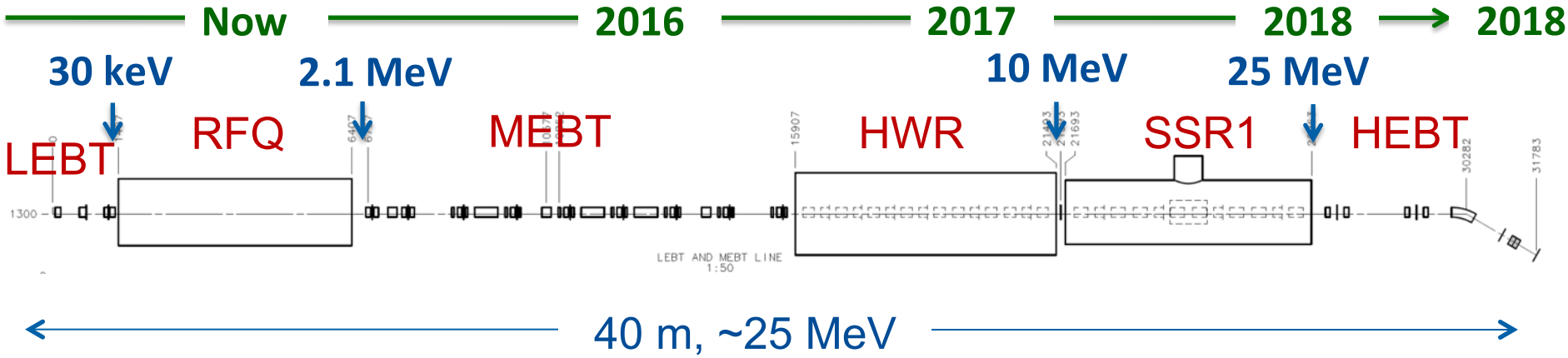
PXIE

- Scope:
  - A CW H- source delivering 5 mA at 30 keV
  - A low energy beam transport (LEBT) with beam pre-chopping
  - A CW RFQ operating at 162.5 MHz and delivering 5 mA at 2.1 MeV
  - A medium energy beam transport (MEBT) with integrated wide band chopper capable of generating arbitrary bunch patterns at 162.5 MHz, and disposing of up to 5 mA average beam current



  - Low β superconducting cryomodules capable of accelerating 2 mA of beam to 25 MeV
  - Associated beam diagnostics
  - Beam dump capable of accommodating 2 mA at full beam energy for extended periods.
  - Associated utilities and shielding

PXIE (PIP-II Injector Experiment)



PXIE will address the address/measure the following:

- LEBT pre-chopping : Demonstrated
- Vacuum management in the LEBT/RFQ region : Demonstrated
- Validation of chopper performance
  - Bunch extinction, effective emittance growth
- MEBT beam absorber
  - Reliability and lifetime
- MEBT vacuum management
- CW Operation of HWR
  - Degradation of cavity performance
  - Optimal distance to 10 kW absorber
- Operation of SSR1 with beam
  - CW and pulsed operation
  - resonance control and LFD compensation in pulsed operations
- Emittance preservation and beam halo formation through the front end

Collaborators

ANL: HWR

LBNL:LEBT, RFQ

SNS: LEBT

IIFC: MEBT, RF, SSR1

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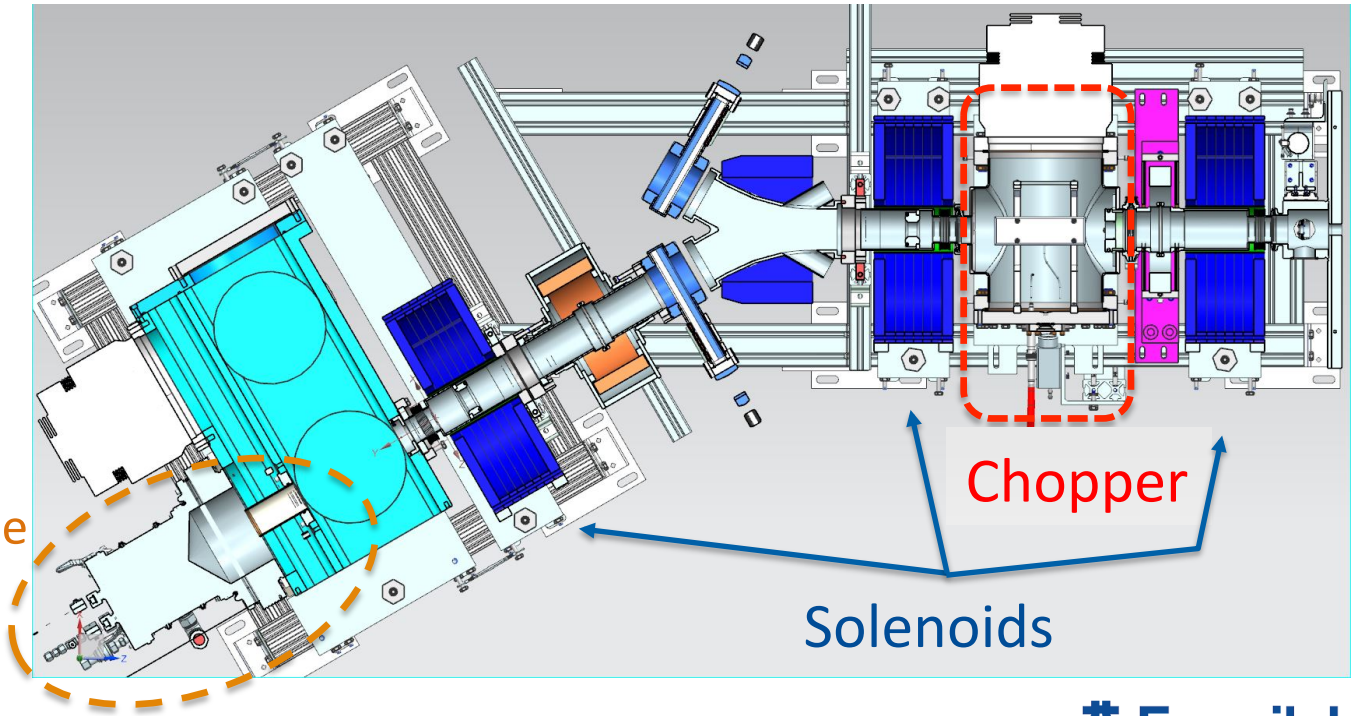
PIP-II

PXIE Ion source and LEBT

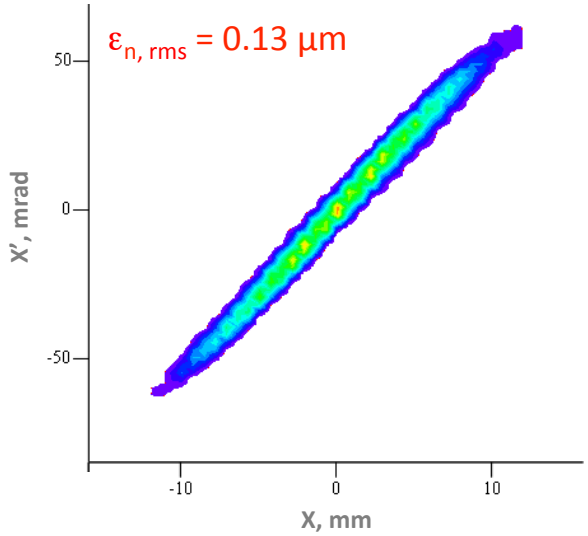
- Commercial ion source
  - D-Pace, Inc.
  - 30 kV, 10 mA DC
- 3 Solenoids
- Bending dipole
  - Accommodate 2 IS for PIP-II
  - Part of Personnel Protection System
  - No direct line of sight between IS and SRF
- Chopper
  - Pre-chopping, MPS, pulse mode
- Possibility of partially un-neutralized transport
- Possibility of scraping the beam at various locations
  - Tail particles management

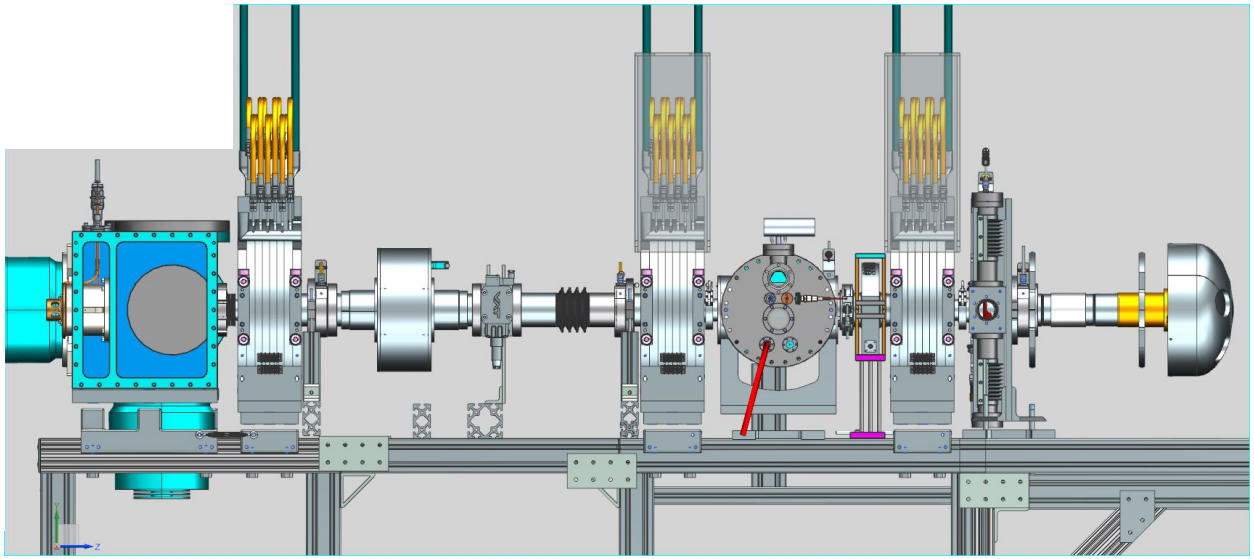


Scheme of
PXIE IS and LEBT
in final configuration

Ion source and LEBT status

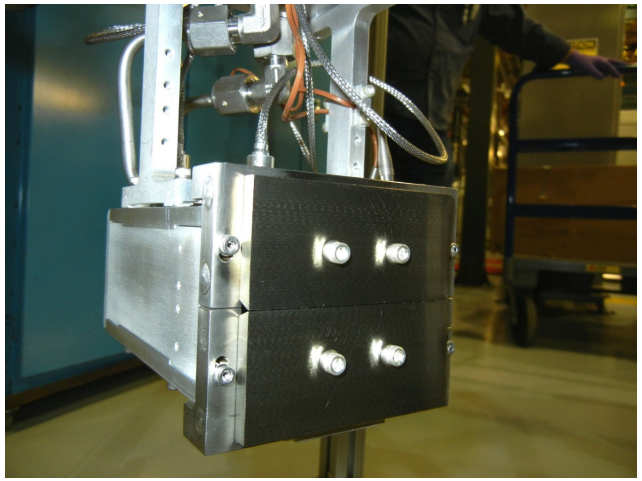
- IS and LEBT are assembled, fully commissioned
  - Straight configuration; dipole will be installed in FY16
  - Beam current up to 10 mA in pulse and DC modes
    - 24 and 72 hrs runs at 5 mA; current stabilization loops
  - At 5 mA, Twiss parameters reconstructed to the RFQ entrance are on target

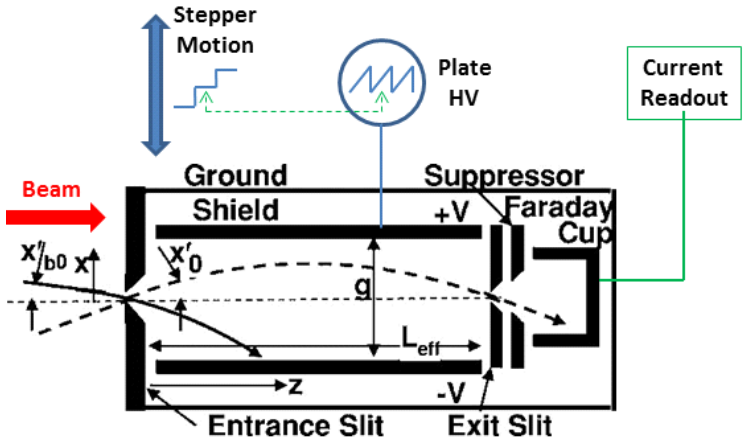




LEBT diagnostics

- DCCT, toroid, electrically isolated electrodes, Faraday cup (not permanent)
  - Beam current, controlled beam loss
- Allison-type emittance scanner
  - Designed and built in collaboration with SNS
    - Front-slit made of TZM pressed against water-cooled aluminum blocks
  - Workhorse for beam measurements
    - Located at the end of the beam line
      - Moves as more elements are added
      - Final permanent location is in the IS vacuum chamber
  - Baseline for MEBT Allison scanner design



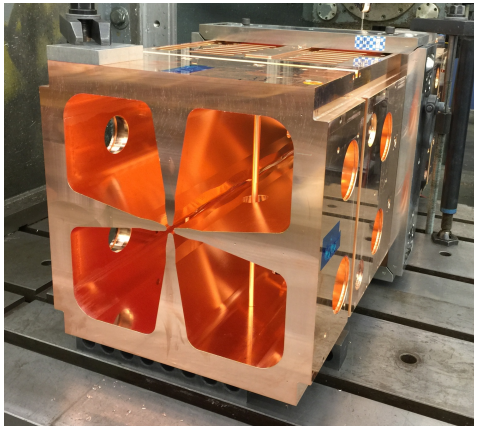


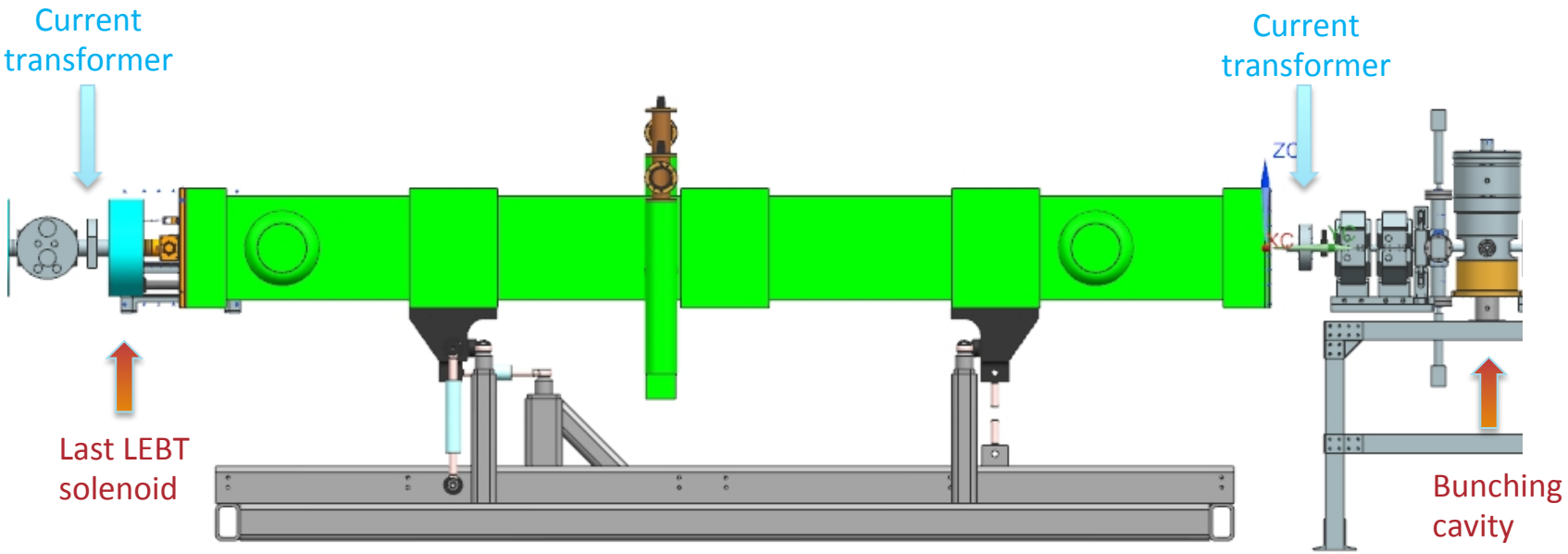
RFQ

- Designed and fabricated by LBNL
  - 4 vane, 4 module brazed copper body
  - Fixed tuners
  - Output energy: 2.1 MeV
    - Below neutron production level
  - Similar RFQ has been commissioned at IMP (Lanzhou, China) with 10 mA CW
  - Delivered beginning of September
- Two 75 kW 162.5 MHz solid-state amplifiers are installed and partially commissioned

RFQ setup

- Installation in progress
- Resonance control via cooling water circuit
- Identical and cross-calibrated current transformers before and after RFQ to directly measure transmission





MEBT

- Goals for PXIE MEBT
  - Demonstrate creation of an arbitrary bunch pattern from initially CW 5-10 mA, 2.1 MeV H^- beam
  - Compatible with SRF downstream
- All major components have been prototyped and most have been ordered or in fabrication
  - Except for some of the diagnostics
  - Mechanical design of the integrated beam line is in progress
- Parts of MEBT will be used to characterize the beam from the RFQ

First configuration of the MEBT to commission the RFQ is being assembled

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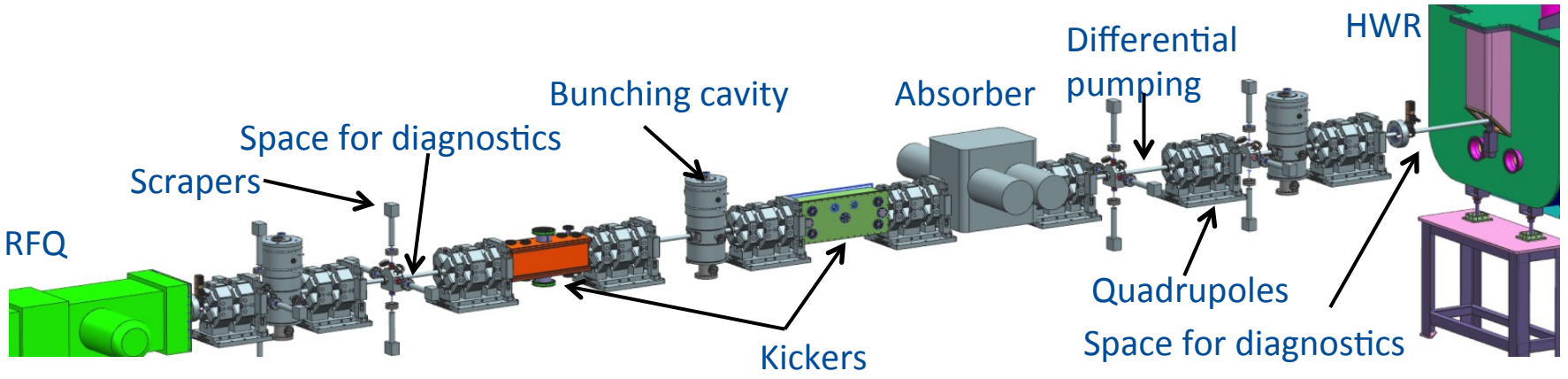
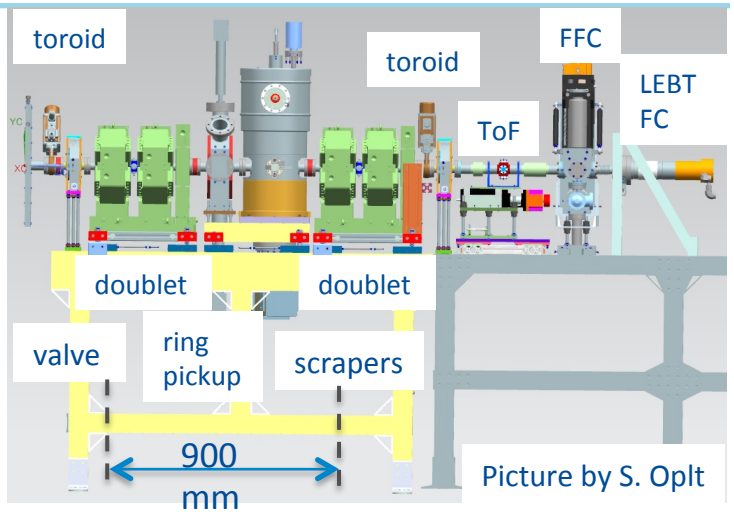
MEBT concept

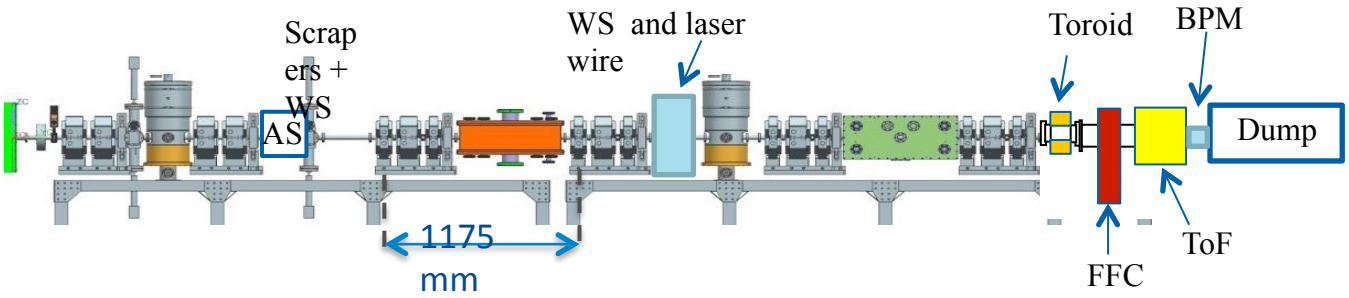
- Transverse focusing with 2 doublets and 7 triplets
  - First short section for beam matching; 1.14 m period after
- Longitudinal focusing with 3 bunching cavities
- Chopping system: Two TW kickers in sync + absorber
- Last ~2 m are particle-free, UHV
- Scrapers: 4 sets by 4 jaws in each
  - Independently moving, electrically isolated, radiation- cooled plates



MEBT plan: upcoming year

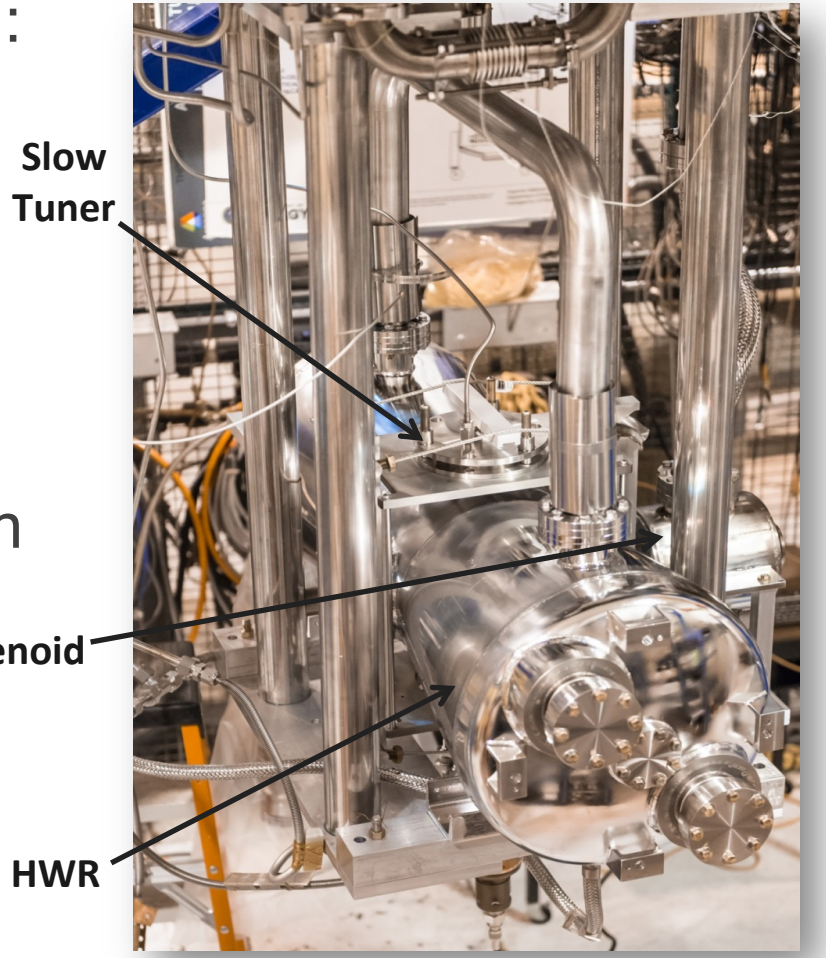
- Build it out in sections
  - MEBT 1:
    - 2 doublets + 1 buncher
    - diagnostics section varies for different measurement
  - MEBT-2:
  - add 4 triplets, 1 buncher, kicker prototypes





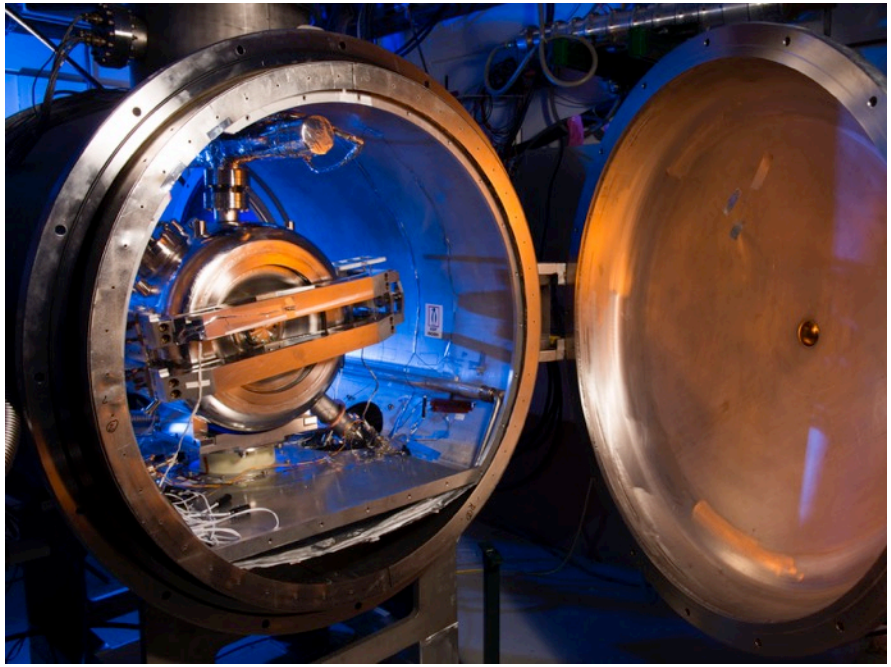
PXIE: HWR

- Half Wave Resonator Cryomodule:
  - 8 162.5 MHz β=0.11 Half Wave cavities
  - 8 SC focusing solenoids (&BPM)
  - 2.1 MeV -> 11 MeV
- In collaboration with Argonne
- Design complete, under fabrication at Argonne
  - Testing of all production components in 2016
  - Assembly in 2017
  - Delivery/Installation Q3s 2017



PXIE: SSR1

- Single Spoke Resonator Cryomodule:
  - 8 325 MHz β=0.22 Single Spoke cavities
  - 4 SC focusing solenoids (& BPM)
  - 11 MeV -> 25 MeV

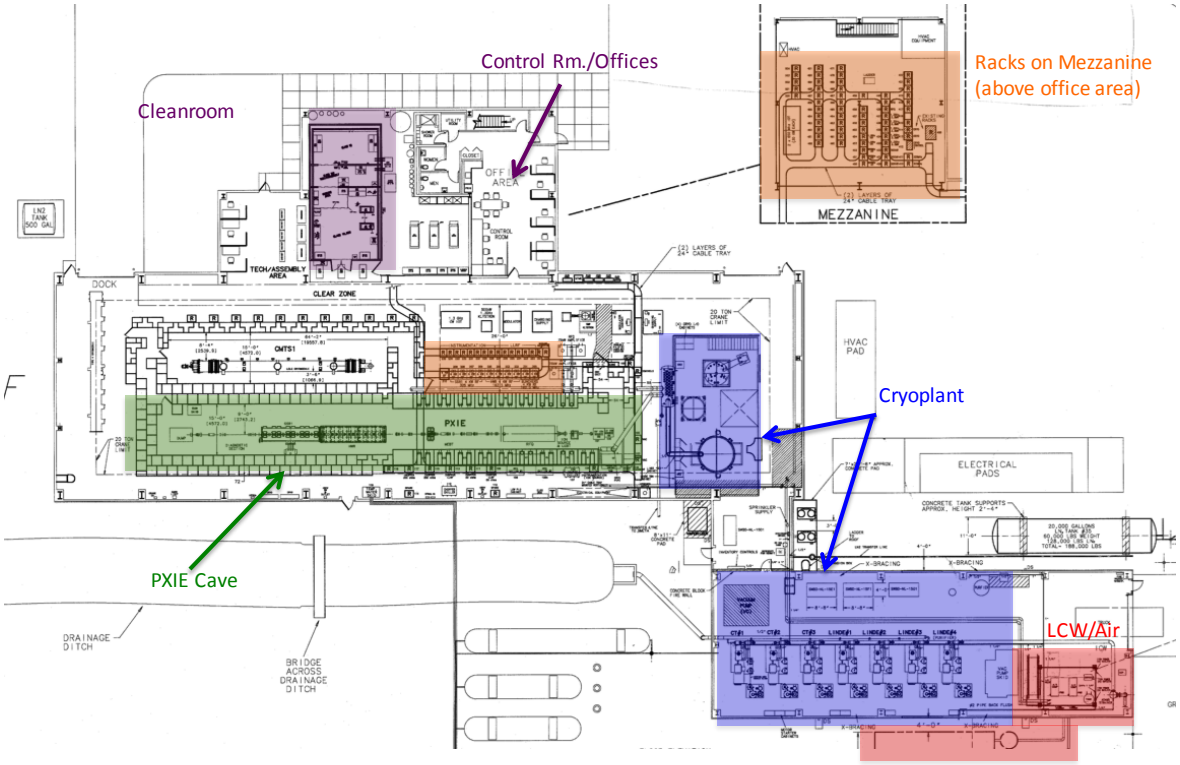


- India Institutes Fermilab Collaboration (IIFC)
  - Cavity and Solenoid Design (FNAL) complete
    - 12 cavities fabricated (10 FNAL, 2 IUAC New Delhi)
  - CM design underway
  - Fabrication/Assembly 2017

dressed SSR1 cavity in test cryostat

PXIE infrastructure

- CMTF building, housing PXIE, has all required capacity
  - Cryo, power, water
  - Distribution systems are being designed and implemented
- All components for the PXIE cave are on hand



PXIE plan

- FY16
  - Commission RFQ (RF and beam)
  - Install most of the MEBT magnets
  - Install and test kicker prototypes

- FY17
  - Finalize design of all MEBT components
  - Receive HWR
  - Installation of Cryo distribution, HWR, MEBT 3
- FY18
  - RF commissioning of HWR,
  - Installation of SSR1 & HEBT
  - RF Commissioning of SSR1
  - Beam operation?
- FY19
  - Final beam parameters

Collaborations in PXIE

- LBNL: Ion source, RFQ
- SNS: Emittance Scanner

} In hand

- ANL: HWR Cryomodule – FY17
  - delivery dependent on funding availability

- IIFC:
  - MEBT magnets: Quad and Dipole delivery through FY16 & 17
  - SSR1 cavities/He vessel/Tuners: FY16
  - SRF Interlocks, 325 MHz amplifiers, LLRF system
    - FY16, 17, 18

- WG1: address opportunities for additional collaboration

Working group 1: PXIE

- We would like to focus on the plan for the next three years:
  - What are the goals and deliverables of the R&D phase of PXIE during this time frame?
  - What are the identified responsibilities among collaborators and where are opportunities for additional collaboration?

12:30 - 17:15 **Working Group Meetings: Working Group 1**

Location: Floating Point

12:30 **PXIE Plan: 2016, 2017, 2018** *30'*
Speaker: Paul Derwent (Fermilab)

13:00 **RFQ Commissioning Plan** *30'*
Speaker: Mr. James Steimel (Fermilab)

13:30 **MEBT Components: Buncher cavities, kicker/absorber, vacuum system** *30'*
Speaker: Alexander Shemyakin (Fermilab)

14:00 **Instrumentation Development** *30'*
Speaker: Vic Scarpine (Fermilab)

14:30 **HWR** *30'*
Speaker: Dr. Peter Ostroumov (Argonne National Laboratory)

15:00 **Break** *30'* (IARC Auditorium)

Joint with WG2

15:30 **LLRF and Resonance Control for PXIE: RFQ, HWR, SSR1** *30'* (IARC Auditorium)
Speaker: Mr. Brian Chase (FNAL)

16:00 **PXIE Cryo Distribution** *20'*
Speaker: Michael White (Fermilab)

16:20 **Integration of HWR, SSR1, and Cryo Distribution into PXIE enclosure** *20'*
Speaker: Mr. Curtis Baffes (Fermilab)

16:40 **Discussion / Preparation for WG1 Report** *20'*

Summary