PROJECT X INJECTOR EXPERIMENT: GOALS, PLAN, AND STATUS

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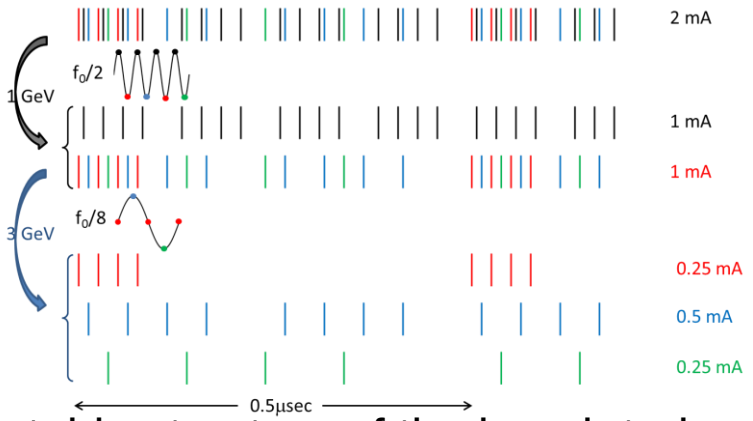
IPAC'13, May 14, 2013

Outline

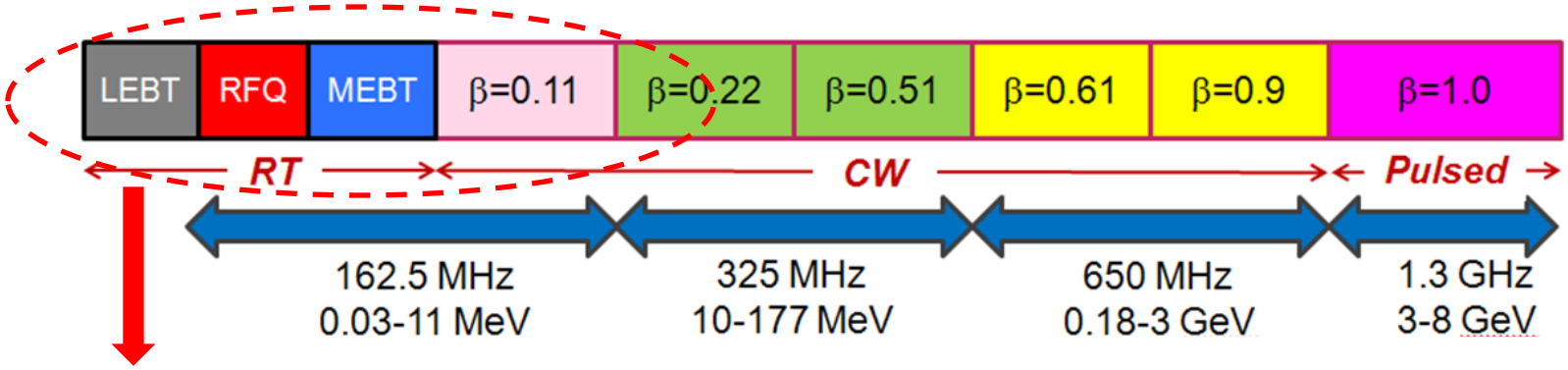
- Project X and PXIE
- Goals
- Status of subsystems
- Plans

Project X and PXIE

- Project X is an Intensity Frontier accelerator providing MW-scale proton beam to many users quasi-simultaneously
  - Acceleration in SRF from low energies

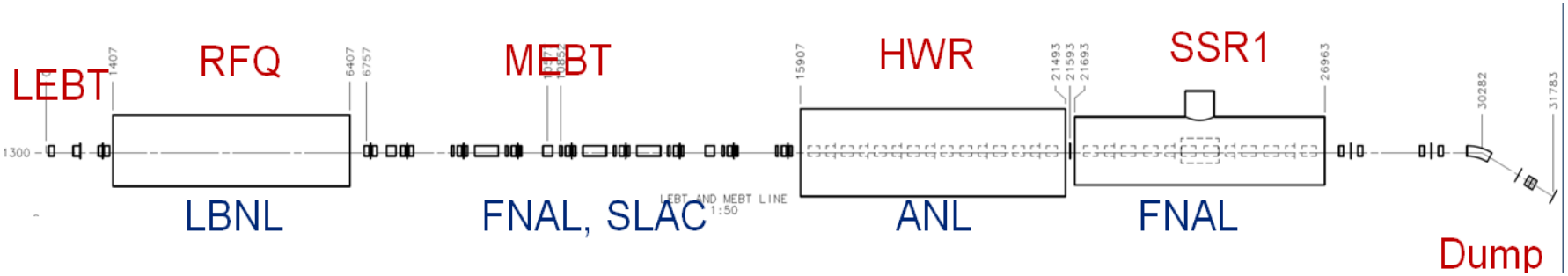


  - Constant power in time scale >μs; adjustable structure of the bunch train
  - Accomplished by bunch-by-bunch chopping in MEBT and RF separation after acceleration to the required energy



Addressed by the Project X Injector Experiment, PXIE

PXIE structure



- Standard scheme for proton (H-) acceleration
  - Ion source and LEBT (30 keV, 5 mA nominal/ 10 mA max DC)
    - Beam pre-chopping for machine tuning
  - 162.5 MHz RFQ (2.1 MeV, 5/10 mA CW)
  - MEBT (chopping, 5mA CW->1mA Repetitive Structure)
  - 2 SC cryomodules accelerating the beam to 20-30 MeV
  - HEBT (beam diagnostics)
  - 50 kW beam dump
- Total length ~ 40 m
- Collaboration between Fermilab, ANL, LBNL, SNS, SLAC, and Indian institutions

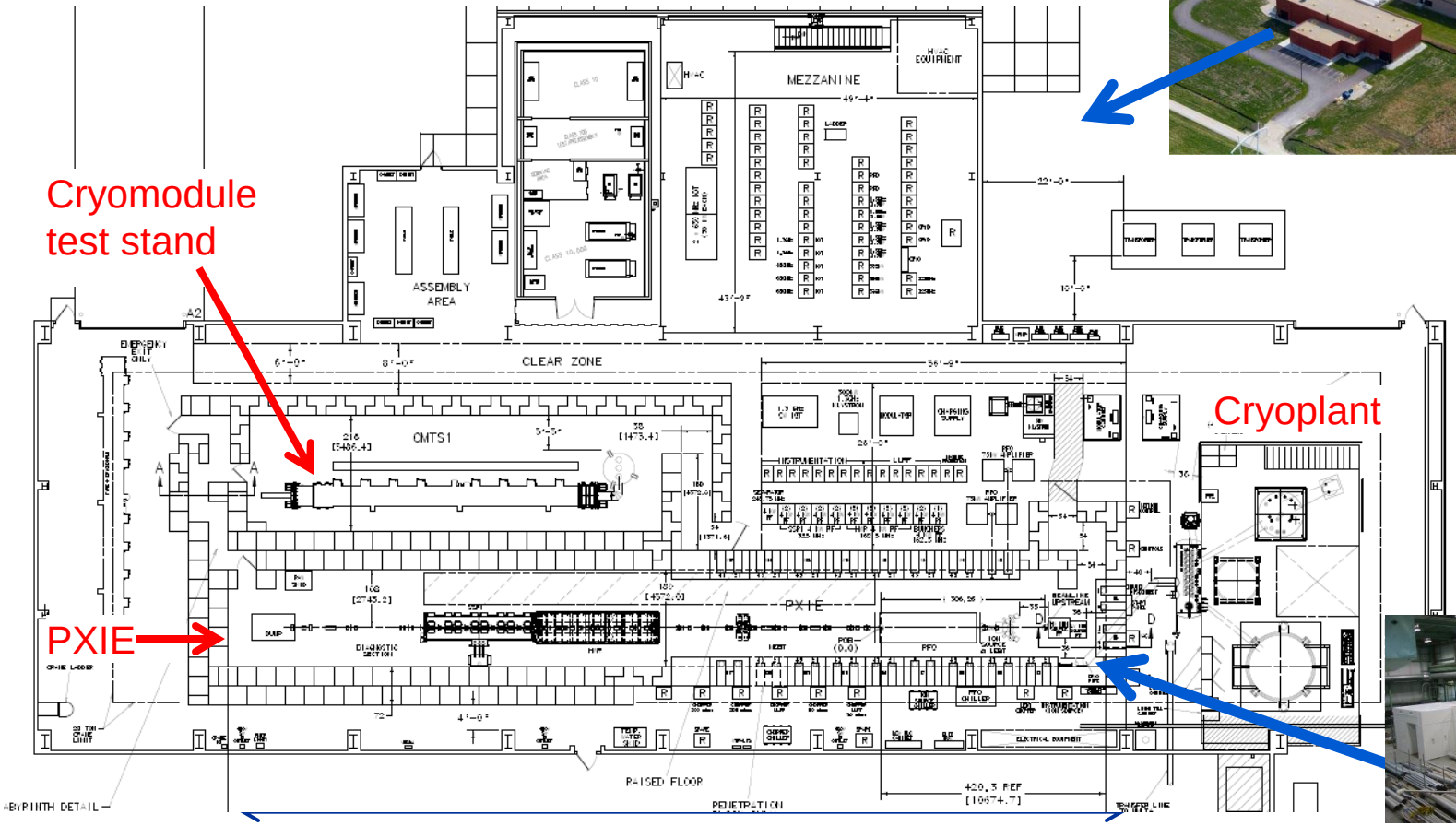
Optics: see PXIE end-to-end Simulations, TUPWA054

Goals

- PXIE is a program to validate the concept for the Project X front end, thereby minimizing primary technical risks
- The main specific goals
  - Demonstrate the bunch-by-bunch chopping
    - Kicker and absorber
  - Efficient acceleration of 1mA beam in SRF to at least 15 MeV
    - Emittance dilution; halo generation and management
- Also, address
  - Emittance issues and pre-chopping in LEBT
  - Reliable CW RFQ
  - MEBT/SRF interface (vacuum, microparticle migration)
  - Diagnostics for testing the extinction of the removed bunches to ~10^{-9}
  - Gain experience in design and operation of SC cryomodules
    - SSR1 cryomodule will be designed and built by Fermilab

PXIE layout

- PXIE will be assembled in the existing Cryo Module Test Facility building

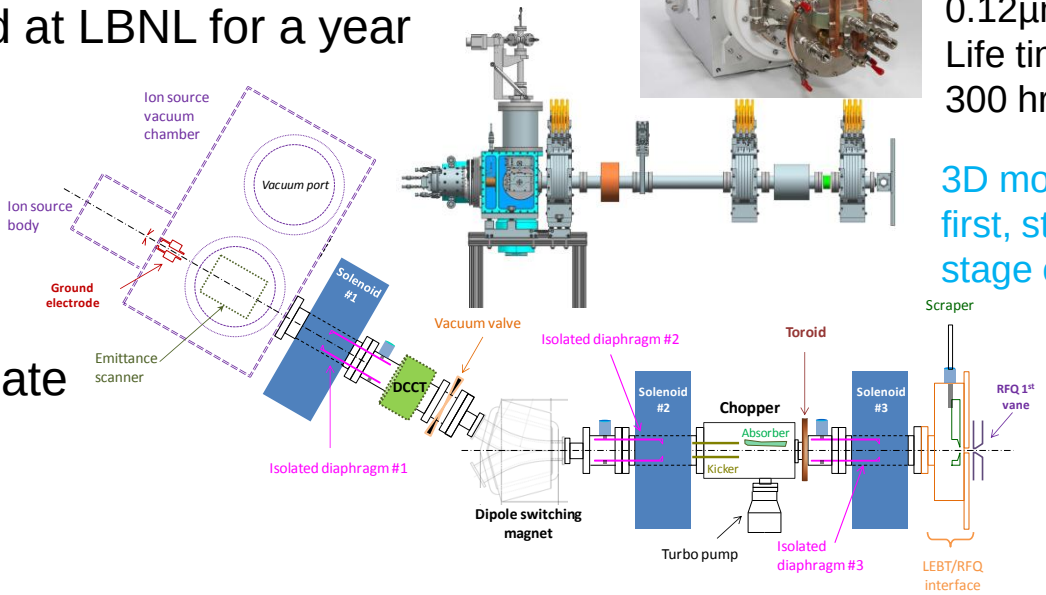


Ion source and LEBT

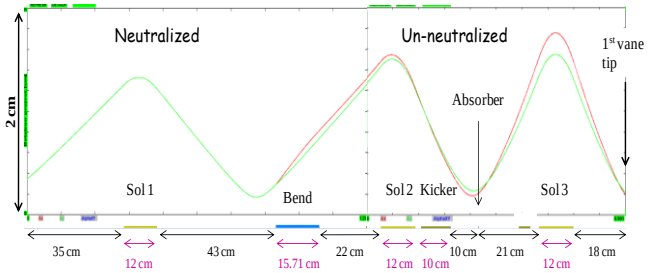
- H- ion source
  - Purchased from D-Pace Inc
  - Was tested and used at LBNL for a year

30 kV;
15 mA DC;
$\varepsilon_{rms,n\_x} \approx$ 0.12μm;
Life time 300 hrs

- LEBT
  - 3 solenoids
  - Dipole to accommodate two IS for PX
    - Only one at PXIE
  - Chopper
    - Pre-chopping, MPS, pulse mode
  - Possibility of partially un-neutralized transport
  - Beam halo scraping

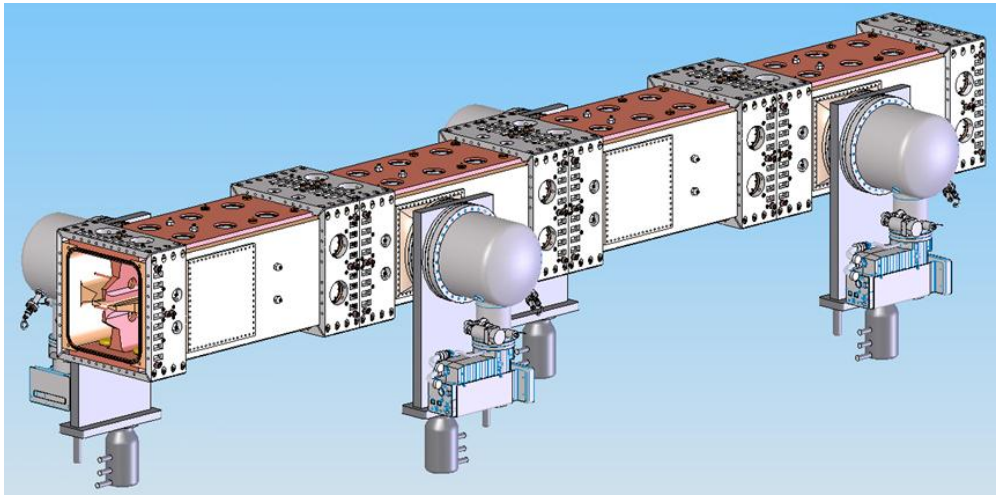


3D model of the first, straight stage of LEBT



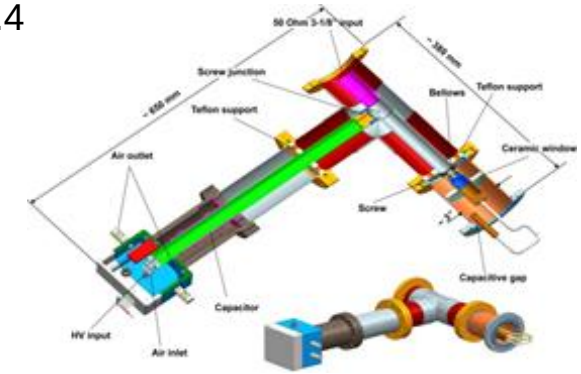
RFQ

- Design (LBNL): 4 vanes CW RFQ
  - 162.5 MHz frequency to make bunch-by-bunch chopping possible
  - 2.1 MeV energy to exclude residual radiation in the MEBT



See THPME047 Progress of the RFQ Accelerator for PXIE

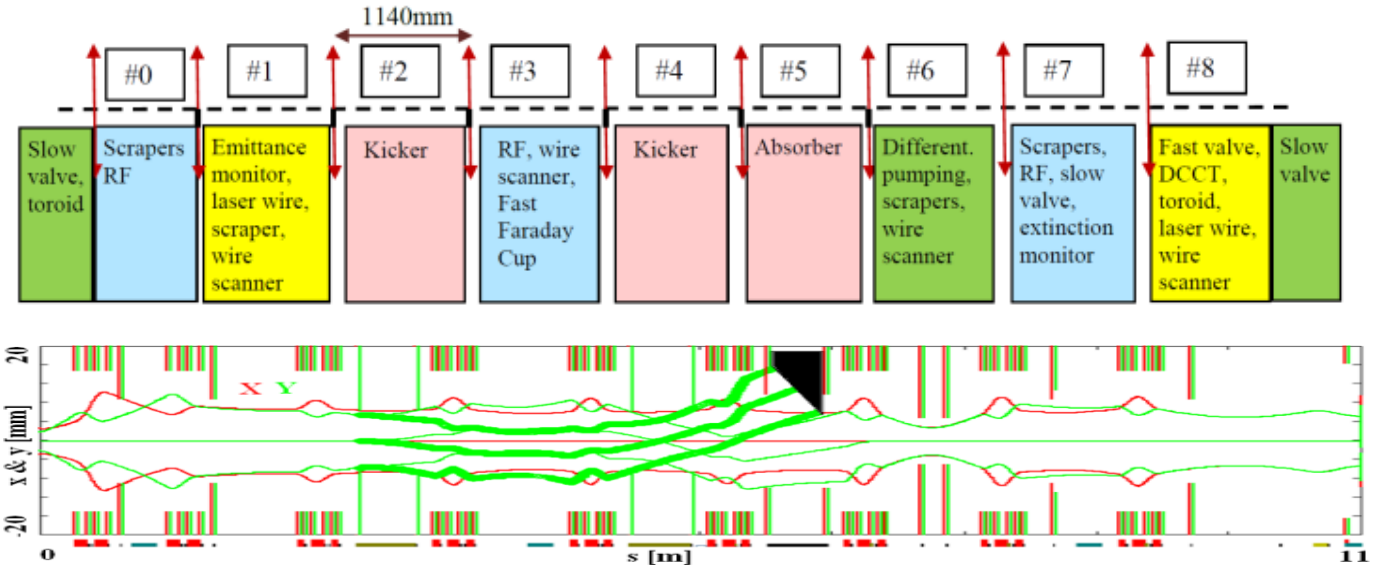
Beam current: 1 – 10 mA;
$\varepsilon_{\perp n,rms}$ < 0.25 μm
$\varepsilon_{\|n,rms}$ ≤1.0 keV-ns
Length: ~4.4



- Simulations completed
  - RF, beam, thermal, stress
- Finalizing the production drawings
- Manufacturing tests

RF coupler has been designed. See WEPFI070 Design of RFQ Coupler for PXIE Project

MEBT



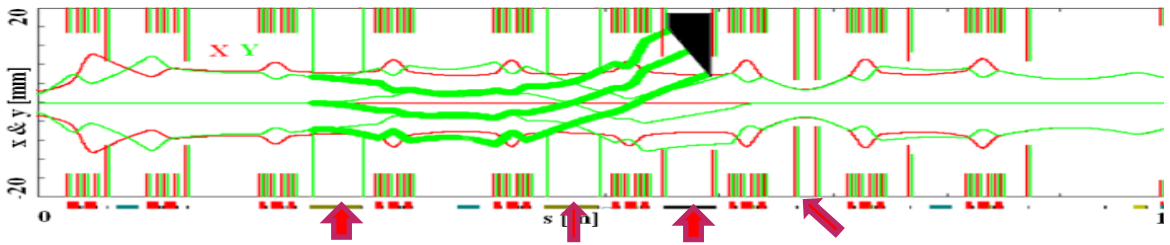
MEBT sections and optics. 3σ envelopes of passing bunches – thin lines, removed bunches- thick lines. Red squares- quads, blue – bunching cavities.

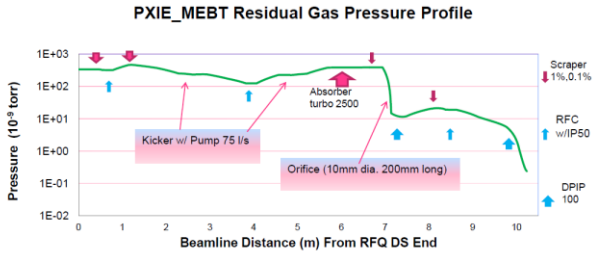
Design: I. Terechkine et al.

- Transverse focusing – 9 quadrupole doublets/triplets
  - Small β-function variation
  - Quads/dipole correctors are being designed by BARC, India
- Longitudinal focusing – 3 bunching cavities
  - Production drawings preparation

Frequency	162.5 MHz
Max voltage	100 kV
Gap	2x23 mm
Max power loss	1.5 kW

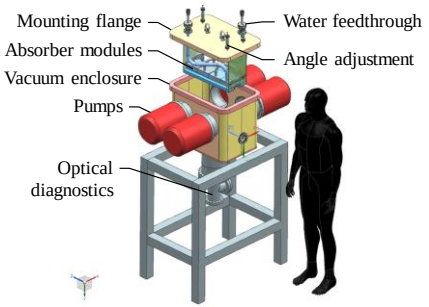
Chopping system





Two kickers separated by 180º Absorber Differential pumping

- Undesired bunches are removed by the MEBT chopper
  - Two kickers separated by 180º and working in sync (next slide)
  - Removed and passing bunches are separated at the absorber by $6\sigma_y$
  - Large gas load from absorber, ~1 mTorr·l/s
    - 2500 l/s turbo pumping at the absorber and differential pumping
- Developed a concept of a 21 kW absorber (x2 full nominal power)
  - 29 mrad incident angle
  - Mo alloy TZM
  - Testing ¼ size prototype with e-beam

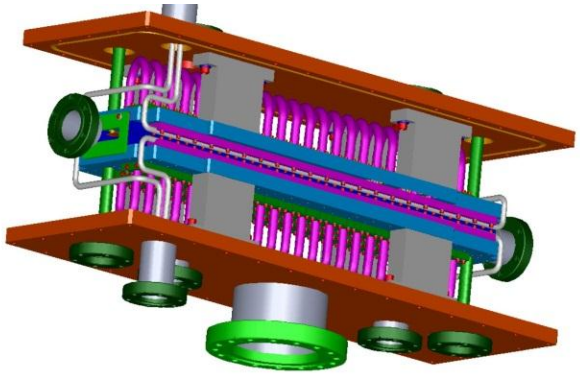


See THPFI085 Status of PXIE MEBT Absorber Development

Kicker

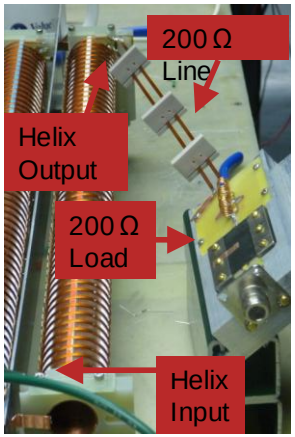
- Travelling – wave, broadband kickers: 50 and 200 Ohm versions
  - 0.5m, ±250V on each plate, 16mm gap; 6σ beam length is 1.3 ns

- 50 Ohm
  - 25 electrodes per plate connected in vacuum by cables
    - Finalizing the production drawings
  - Commercial linear amplifier and pre-distortion
    - Lower power driver successfully tested



3D model
A.Chen, D.Sun

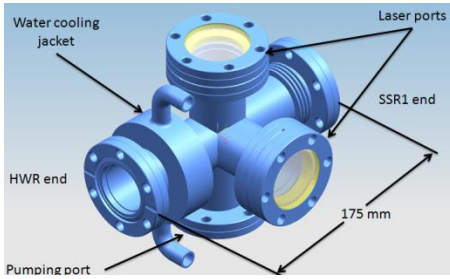
- 200 Ohm
  - Helix as travelling-wave structure
    - RF simulations, modeling, concept development
      - Driver: broadband, DC coupled switches in push-pull configuration
        - Fermilab development
        - Single switch: tested to 0-500V
        - Complete driver: tested to 0-100 V



RF model G. Saewert

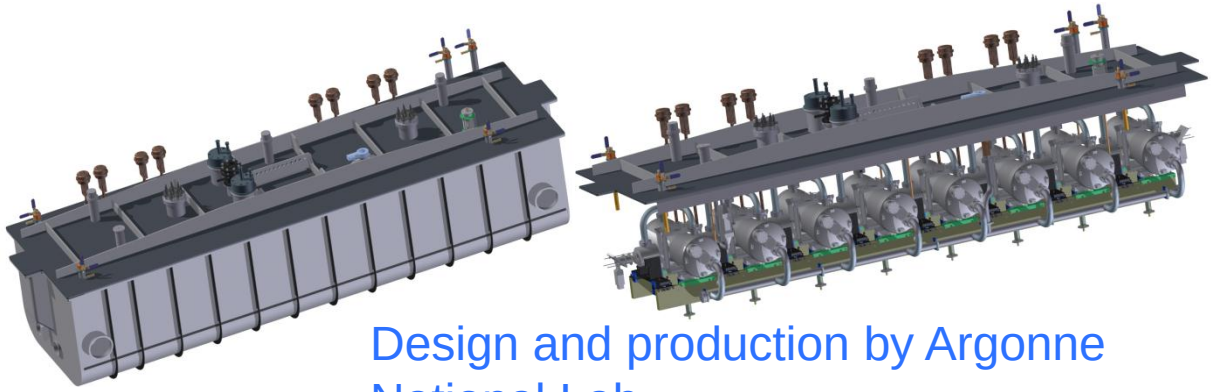
SRF cryomodules

- Two cryomodules operating at 2K, HWR and SSR1
  - Half Wave Resonators (HWR) and Single Spoke Resonators (SSR1)
  - Warm gap between cryomodules; fast vacuum valves on both sides
- In both cryomodules
  - Solenoidal focusing
    - No magnetic steel; backing coil to reduce fringe field
  - BPM and dipole correctors in each solenoid
- Structure of HWR cryomodule
  - 8 cavities, 8 solenoids arranged as 8x (S C)
  - Starts with a solenoid to mitigate H_2 influx from MEBT
- Structure of SSR1 cryomodule
  - 8 cavities, 4 solenoids arranged as 4x (C S C)
  - Separated coils of dipole correctors allow creating of skew-quads
  - The first upstream element is a cavity to improve longitudinal dynamics



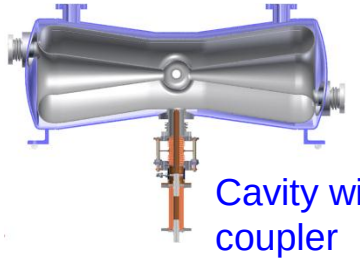
Warm transition box between CMs

HWR



Beam energy: 2.1-11MeV
Frequency 162.5 MHz
CM length (flange-to-flange): 5.9 m
β_g 0.11
Cavity voltage 1.7 MV

Design and production by Argonne National Lab

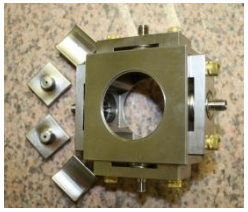


Cavity with coupler

Cavity parts

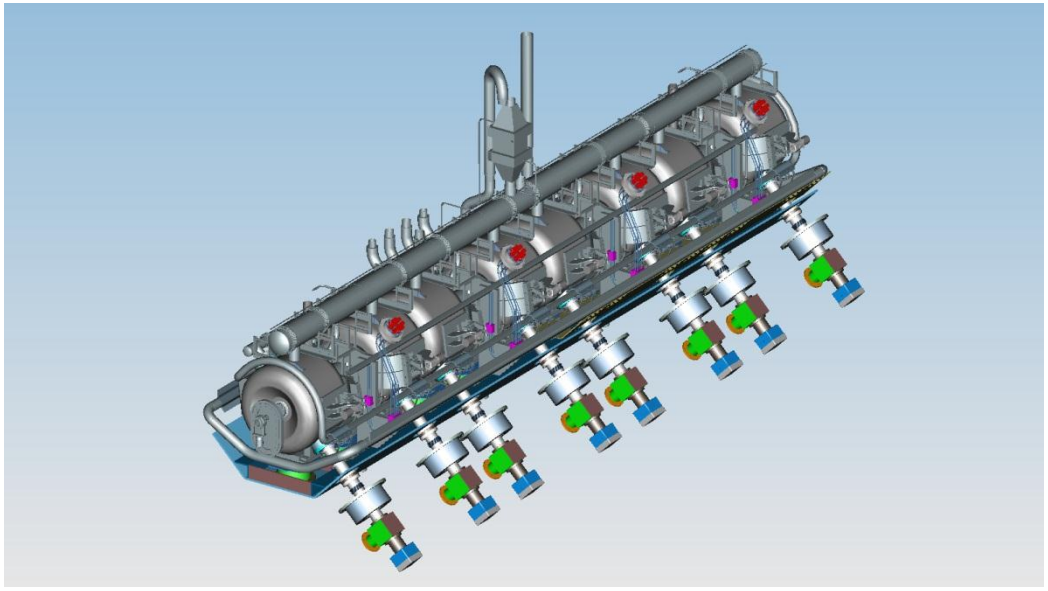
- Cavity and cryomodule design is complete
- Prototypes of 10-kW RF coupler and SC solenoid with steering coils have been built and successfully tested
- BPM prototype has been built and will be tested with beam in FY13
- Nb parts for all cavities will be fabricated in FY13
- Two prototype SC cavities will be tested in FY14

Solenoid installed in He vessel



BPM parts

SSR1

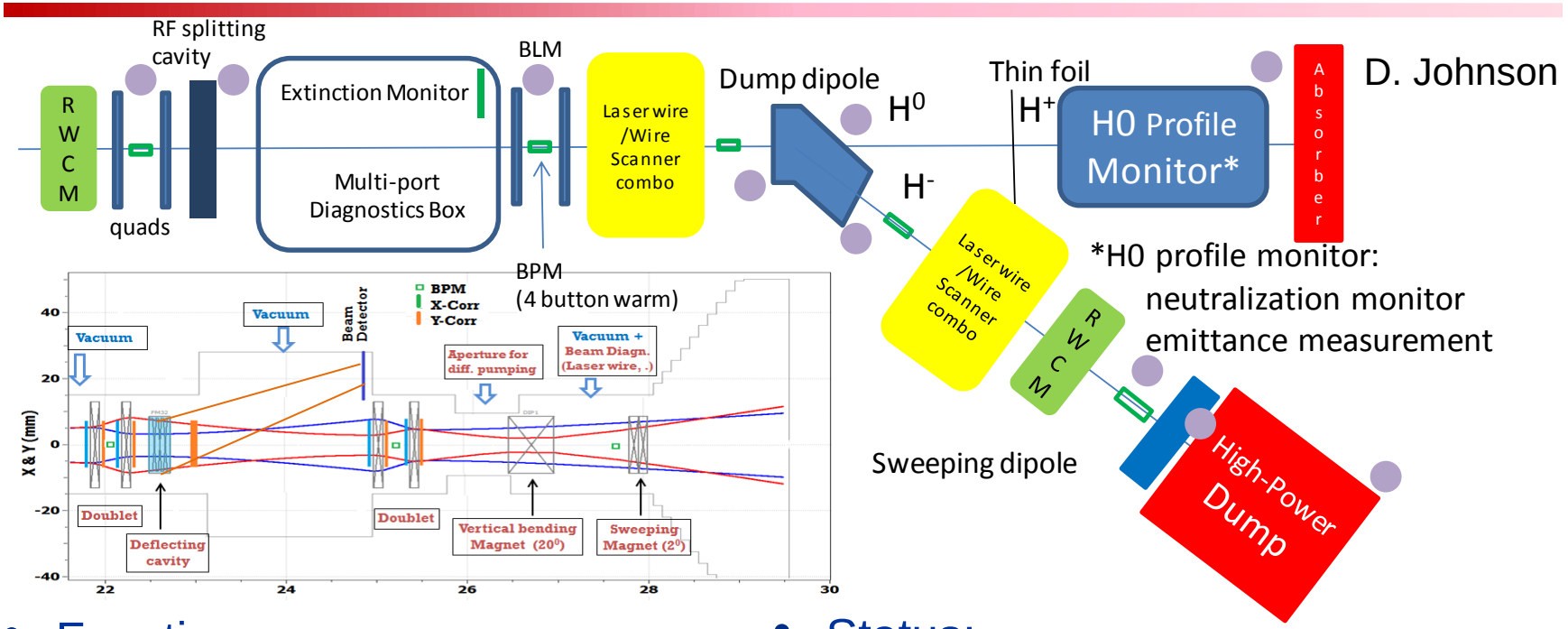


Beam energy: 11-25 MeV
Frequency 325 MHz
CM length (flange-to-flange): 5.4 m
β_g 0.22
Cavity voltage 2 MV

3D model of cavity with tuners

- Design of major components is complete
  - Cavity, tuner, coupler, solenoid, current leads, helium vessel, support
- Design of cryomodule to be complete in Fall 2013
- First production batch of 10 cavities is complete
  - Tests proceed well- see WEPWO055 Fabrication and Testing of SSR1 Resonators for PXIE
  - Prototypes of coupler, solenoid, and helium vessel are close to production

HEBT



- Functions:
  - Primary 50 kW beam dump
  - Instrumentation to characterize beam parameters and measure efficiency of MEBT bunch-by-bunch chopper
- Status:
  - Preliminary design of optics, absorber, and shielding complete
  - deflecting cavity is being designed
  - Instrumentation specifications in progress

Plans

- FY2013 – beam from ion source (at Fermilab)
- FY2015 – beam from RFQ
- FY2017 – Stage 1
  - Ion source, LEBT, RFQ at full power
  - Full MEBT with prototype kickers, prototype absorber, temporary dump, bunchers, some diagnostics
  - Cryo system
  - SSR1 CM – cold and RF powered, no beam
- Aug 2017- Stage 2
  - HWR CM – cold and RF powered, no beam
- Aug 2018- Stage 3
  - HEBT, final MEBT kickers, final 50 kW beam dump, 1-mA beam with required structure delivered to the dump

PXIE- related posters

- J.-F.Ostiguy et al., PXIE End-to-end Simulations, TUPWA054
- D. Li et al., Progress of the RFQ Accelerator for PXIE, THPME047
- S.Kazakov et al., Design of RFQ Coupler for PXIE Project, WEPFI070
- A. Shemyakin et al., Status of PXIE MEBT Absorber Development, THPFI085
- L. Ristori et al, Fabrication and Testing of SSR1 Resonators for PXIE, WEPWO055