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PIP-II Beam Instrumentation

Vic Scarpine

PIP-II Machine Advisory Committee Meeting

15-17 March 2016

Outline

- Scope
- Focus on PXIE
  - LEBT and MEBT status
  - Commissioning the PXIE and commissioning of instrumentation
- Beam Diagnostics R&D
- Summary

Scope

The scope of beam diagnostics are to identify and provide the instrumentation systems necessary to successful *commission*, characterize and operate all PIP-II sub-accelerators.
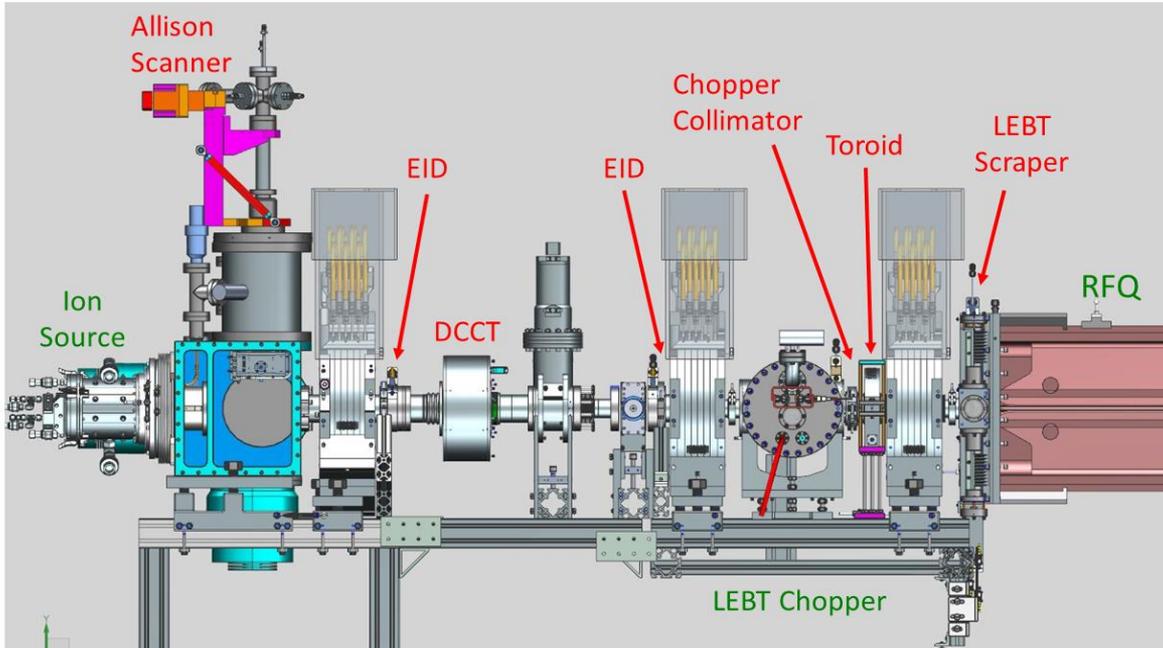
- *Present focus is development of instrumentation for PXIE*
- *PIP-II focus on pulsed operation with an eye toward CW*
  - *Impact on instrumentation choices*

Accelerator instrumentation sections:

- – Ion source & LEBT
- – MEBT
- – Superconducting linac
- – Transport lines
- – Rings
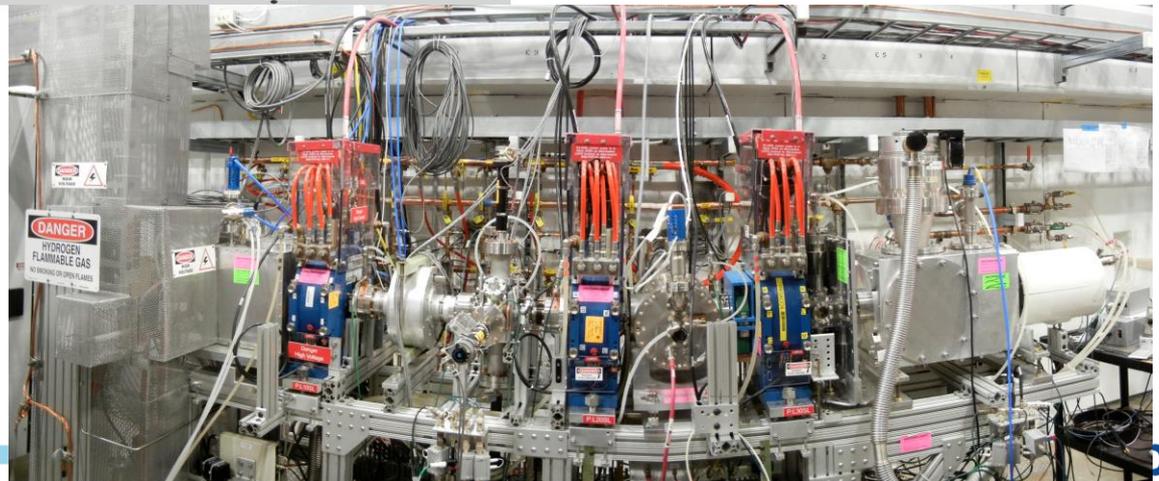
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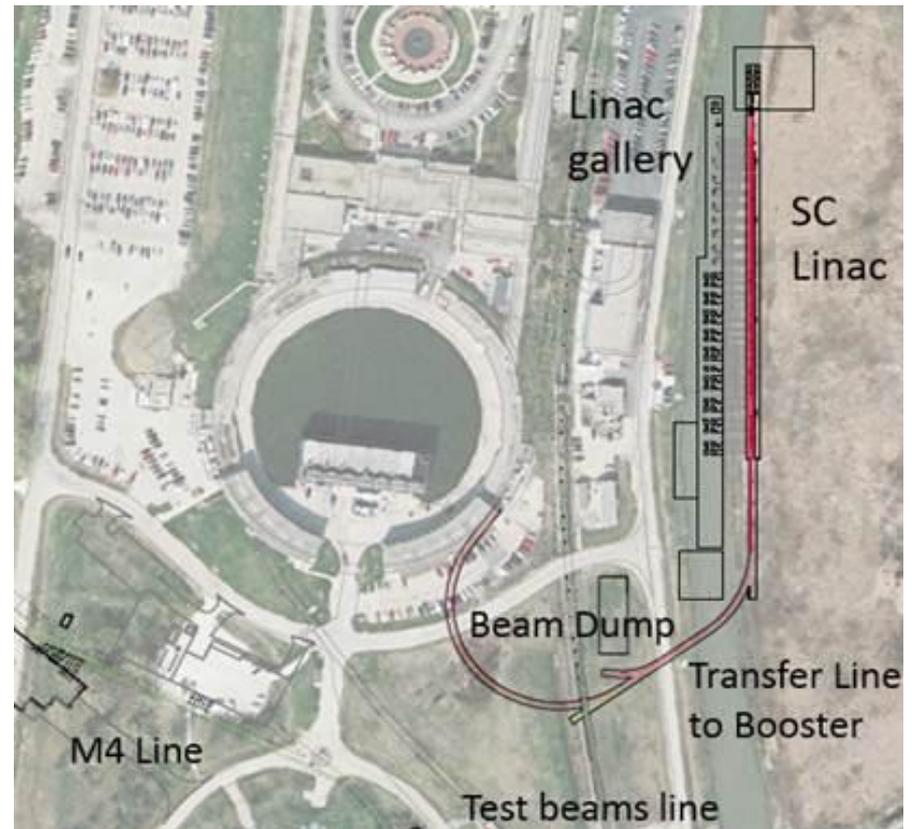
PXIE LEBT Instrumentation Development

Beam Current Measurements

- Upstream of chopper
  - Long pulses - DCCT, EIDs
- Downstream of chopper
  - Short pulses - Toroid, collimator, LEBT scraper
- Digitizer/FPGA DAQ – waveform measurements
  - *Integrated with MPS*

*Much of past year has been in the development and support of the PXIE LEBT*

# MEBT Beam Diagnostics Status

Focus on RFQ commissioning:

- Beam current measurements
  - Toroids, isolated beam dump – being installed at PXIE
  - Integrate into VME-based front-end - under installation and test
- Beam position and phase
  - Warm BPMs - installed in quadrupole doublets
  - DAQ system being installed – based on previous design
- Beam transverse profiles
  - Electrically isolated beam scrapers – one installed in MEBT
  - Integrate into VME-based front-end - under development
- Beam energy
  - Time-of-flight via movable BPM – being installed
    - Phase measurement through BPM system
    - for RFQ/MEBT commissioning only
- Longitudinal bunch shape
  - High-bandwidth Faraday Cup - > 6 GHz BW – being installed

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PXIE MEBT Instrumentation Development – Initial RFQ Commissioning
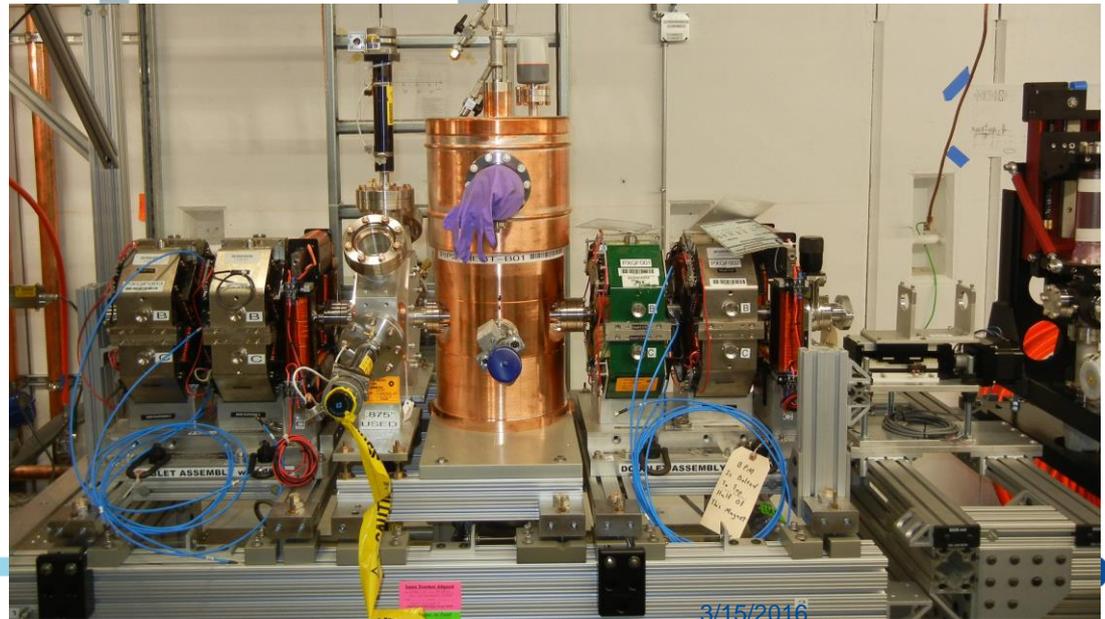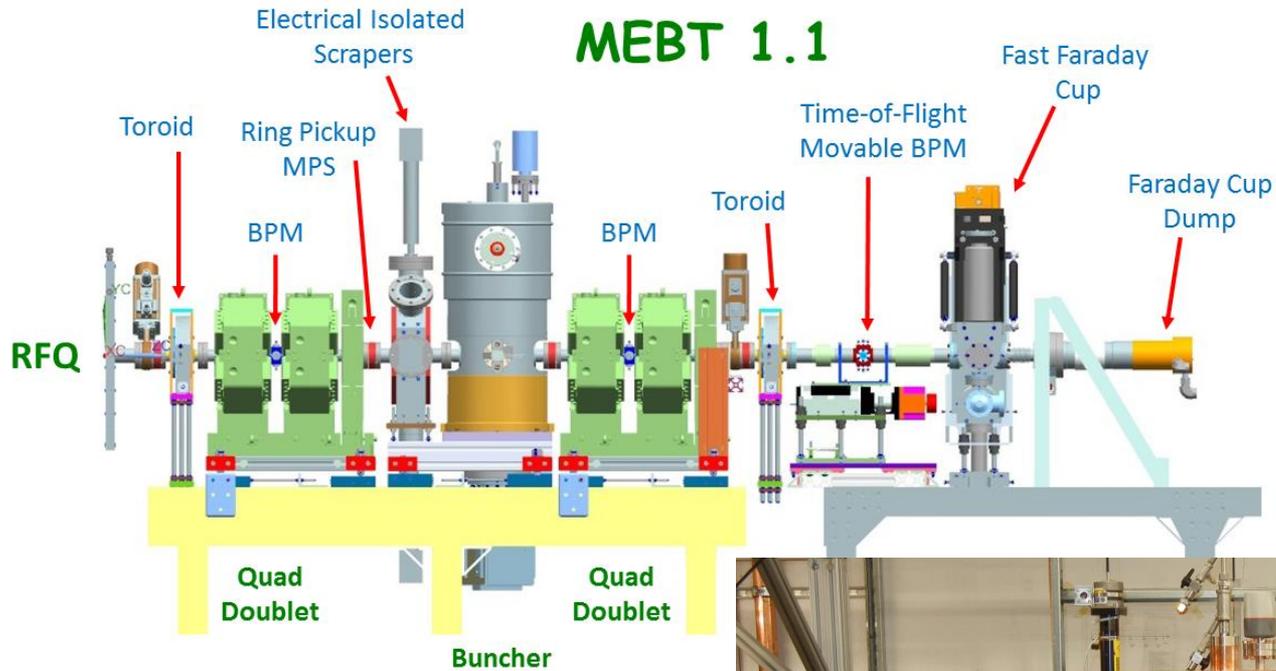
Frontend Electronics for Beam Current Measurements

- Toroids, Faraday cup dump, scrapers
- Signal cables being pulled
- Racks being dressed
- Utilize FPGA-based 8-channel, 125 MHz, 14 bit digitizer cards
  - Allows for pipeline or snapshot DAQ and signal processing
  - Only pulsed beam for initial operations
  - Initial FPGA and VME code - reuse FAST code
  - Integrated with MPS
- Need to understand noise and systematic effects
  - Large gain on toroids
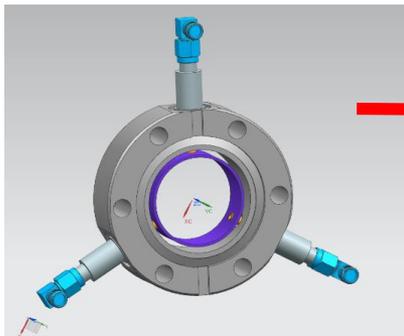 - *Tight beam loss requirements for MPS*
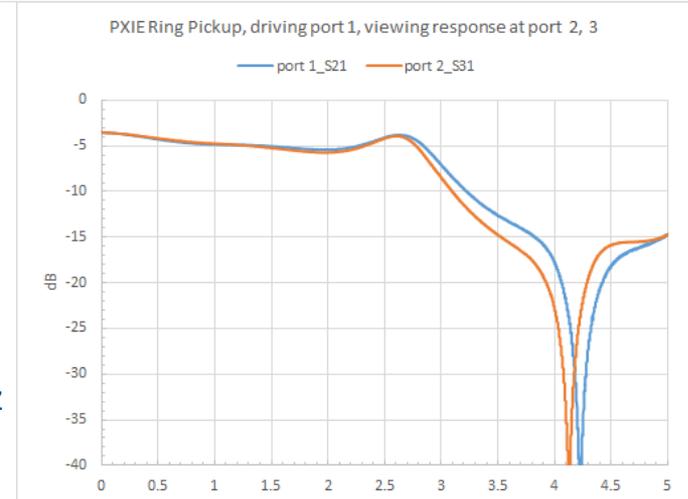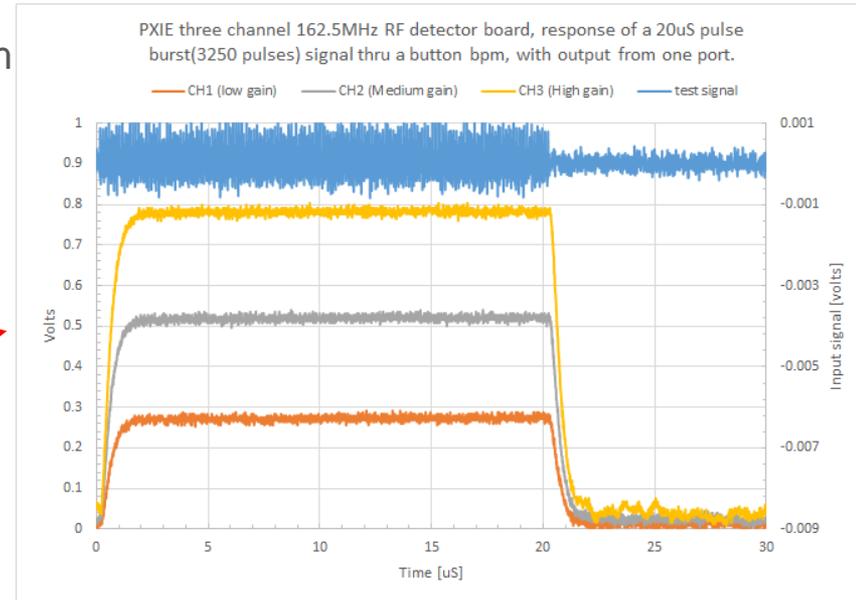 - Needs further study
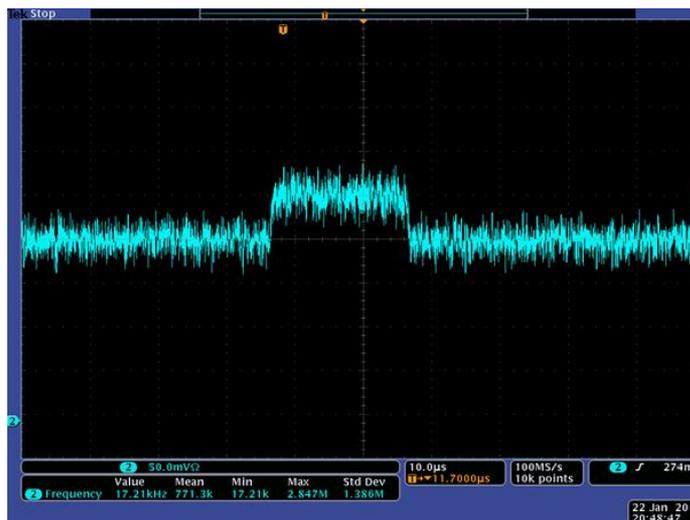
LEBT Toroid
- Calib signal
- 1 mA, 20 µs
- 50 mV signal
- 60 db gain

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Ring Pickup – Beam current for Machine Protection

- Dedicated ring pickup to measure bunched-beam current
  - Wide bandwidth pickup but narrowband electronics
  - Simple analog circuit give rectified signal pulse
- Pickup installed in beamline
- Analog electronics completed and tested
- Signal measured through beam current frontend
- High/Low threshold for MPS
- Short beam pulse software installed and being tested
  - Software for MPS installed
  - Eventual operation with CW beam

PXIE three channel 162.5MHz RF detector board, response of a 20uS pulse burst(3250 pulses) signal thru a button bpm, with output from one port.

Flat response out to ~2 GHz

PXIE Ring Pickup, driving port 1, viewing response at port 2, 3

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MEBT BPM Development

Requirements:

|	Accuracy	Precision
Position, μm	10	30
Phase, degrees of 162.5 MHz	0.05	0.2
Relative intensity, %	1	3

DAQ with FPGA-based electronics for CW and pulsed beam
- 12 channel, 14 bit, 250 MSPS boards

Analog filter & amp boards built and tested
- 162.5 MHz 1st and 3rd harmonics
  - Pseudo bunch length measurements

Status:
- First two BPMs being installed in quads
- Stretched wire measurements performed
- Electronics assembled with initial testing on bench
- Instrumentation rack being filled
- Reuse frontend software from other systems
  - Pulsed beam initially
 - Average position, phase, intensity per pulse

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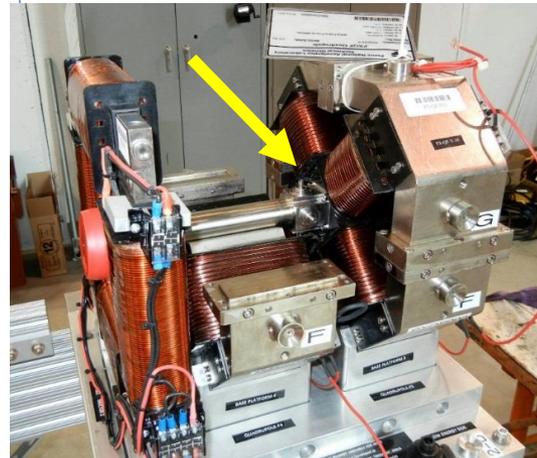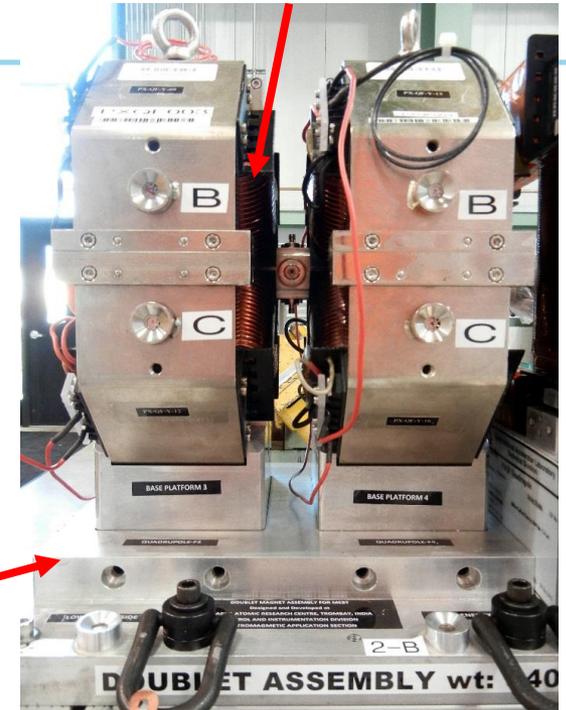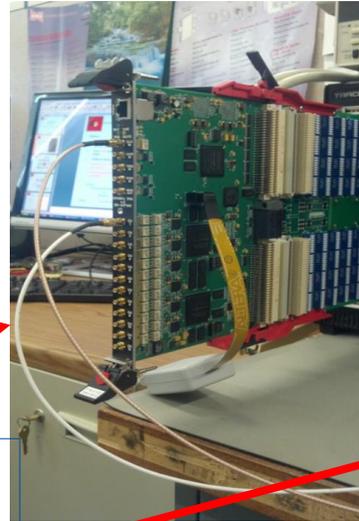
Beam Energy - Time of Flight (ToF) Movable BPM

Measure beam velocity (→ energy) via ToF

- Utilize movable BPM to minimize systematics
    - e.g. BPM response, bunch shape effects
- Use HINS BPM on linear stage
    - ~ 1" of travel; ~10 μm resolution
    - Allows for "continuous" phase measurements
   - Expected MEBT energy resolution: 0.1% @ 2.1 MeV

Status:

- Motion stage installed; BPM ready for installation
- Use MEBT BPM electronics to acquire phase
- DAQ and energy scan software under development

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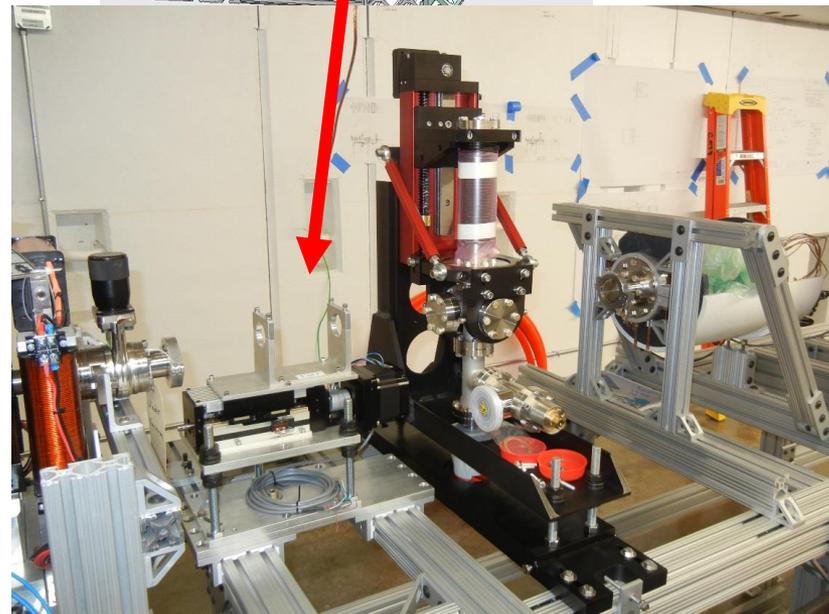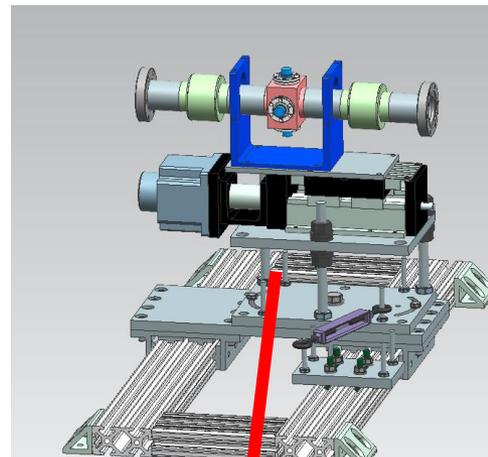
Bunch Length Measurements - New Fast Faraday Cup

- Embedded 50 Ω stripline – initially designed by SNS
- High Bandwidth (> 6 GHz) – need scope DAQ
  - Beam damage at HINS (2.5 MeV protons)
  - We redesigned with better thermal properties
  - Limit beam to 20 μs pulses and < 0.1 Hz
- Old model tested at HINS and Linac
- Prototype new design tested in PXIE LEBT
- Assembly into beamline occurring now
- DAQ via scope – manual operation
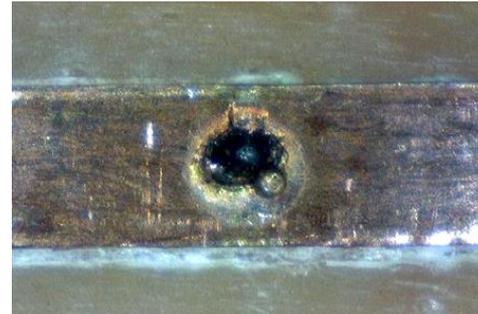
Old design - Damage with HINS beam

New design
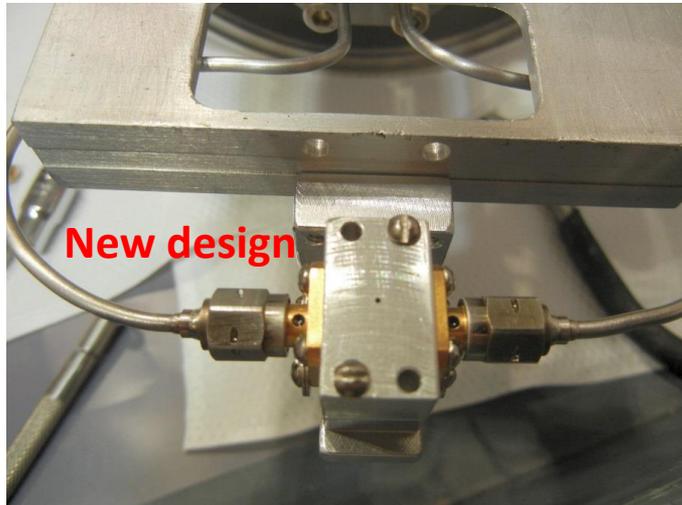
Linac MEBT Measurements

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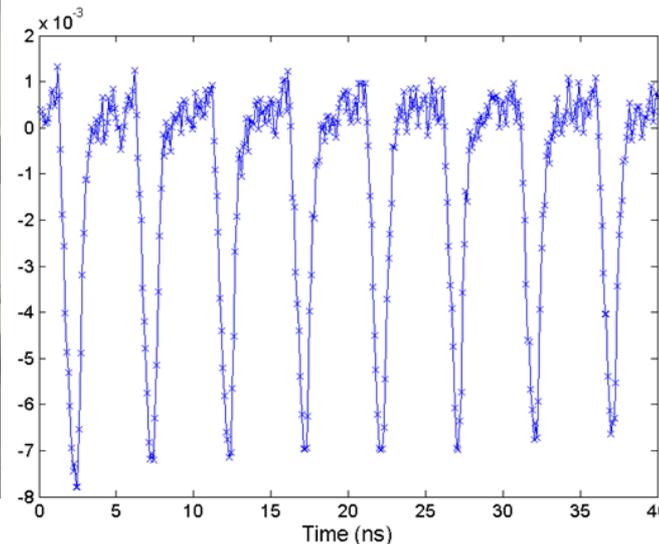
Allison Scanner for MEBT Emittance Measurements

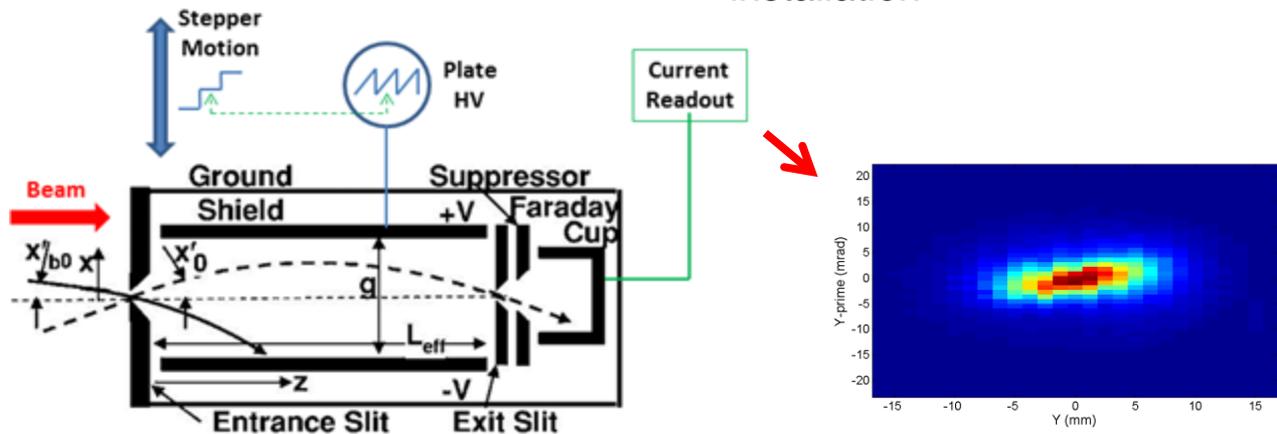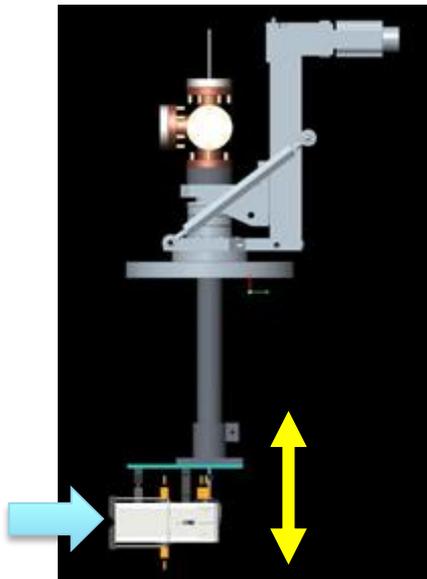Design a water cooled Allison-style MEBT emittance scanner based on LEBT scanner

- Gives faster phase-space measurement
- Reuse most LEBT hardware except scanner head
- 2.1 MeV → requires longer deflector plates → requires more beam line space
- Higher beam power → no CW operation

- Design numbers:
  - HV plate length: 300 mm
  - Flange-to-flange: < 450 mm
  - HV plate separation: 6 mm
  - Plate HV: ± 1 kV
  - ~ ± 10 mrad angular range

- Status:
  - Vacuum enclosure under design
  - Sensor design mostly finished
  - Ordering hardware
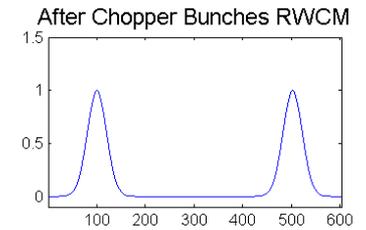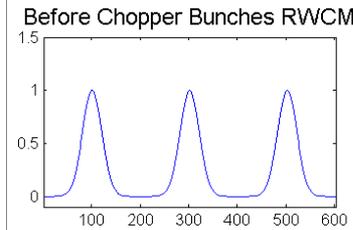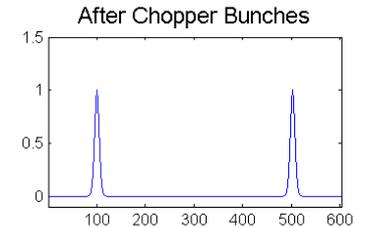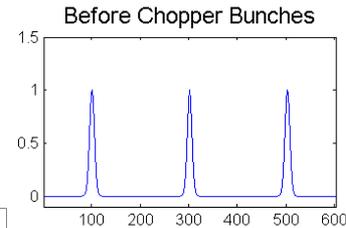 - Estimate May/June for MEBT installation

MEBT Chopper Extinction Measurement – Under Design

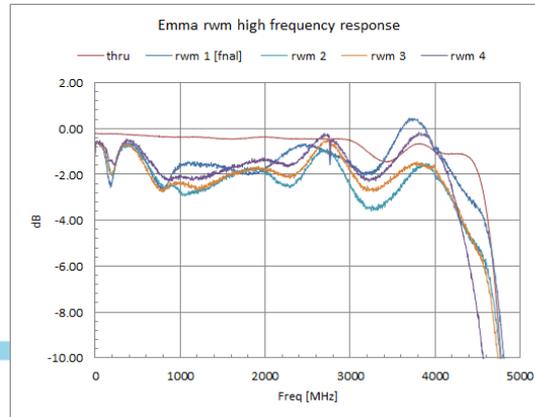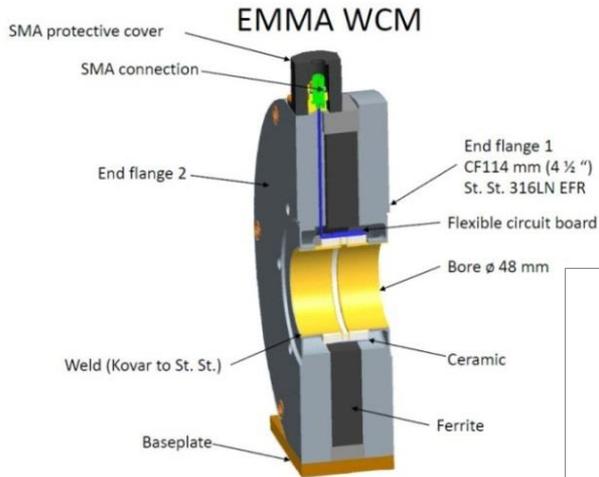RFQ — Kickers, RF, Absorber — RWCM — HW

Fast Scope
Bunch-by-Bunch Extinction Measurement

Integrator
Beam Current
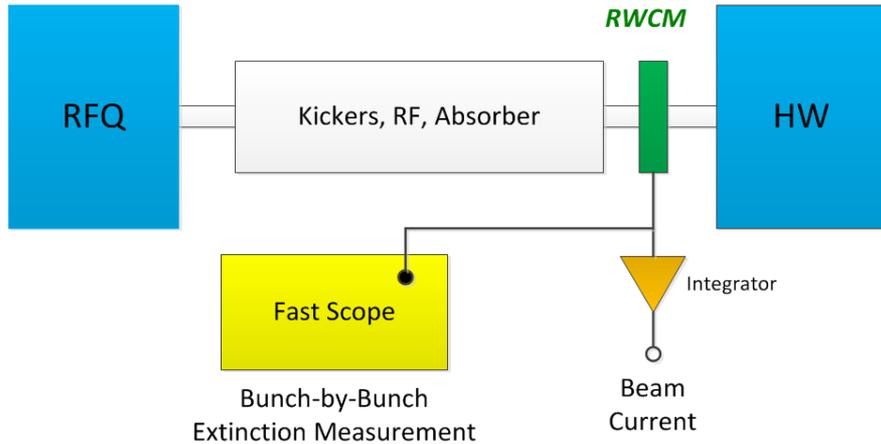
Use downstream Resistive Wall Current Monitors (RWCM)

- Extinction
  - Can average over many bunches or take a single shot measurement
  - Measurement BW < 1 Hz
  - Fits to bunch shape
  - Measure impact on adjacent bunches

EMMA WCM

SMA protective cover
SMA connection
End flange 2
End flange 1
CF114 mm (4 ½ ")
St. St. 316LN EFR
Flexible circuit board
Bore ø 48 mm
Weld (Kovar to St. St.)
Ceramic
Ferrite
Baseplate

Emma rwm high frequency response

Before Chopper Bunches

After Chopper Bunches

Before Chopper Bunches RWCM

After Chopper Bunches RWCM

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R&D – Laser Diagnostics Development – Low-power transverse and longitudinal laser wire

$$H^- + \gamma \rightarrow H^0 + e^-$$

162.5 MHz, psec mode-locked laser (MML) used to measure both transverse and longitudinal profiles

- Laser rep-rate is locked to accelerator RF
- Amplitude modulate laser pulses
- Distribute modulated laser pulses via fibers
- Measure profiles by either:
  - Collection of electrons
  - Use BPM as reduced-beam pickup
    - Allows laser monitor to fit between cryomodules
- Narrow-band lock-in amp detects modulated signal

Status
- Test system at PXIE - infrastructure development underway
- Laser design/development underway
- Vacuum hardware design underway
- Initial installation goal end of 2016

R. Wilcox, LBNL

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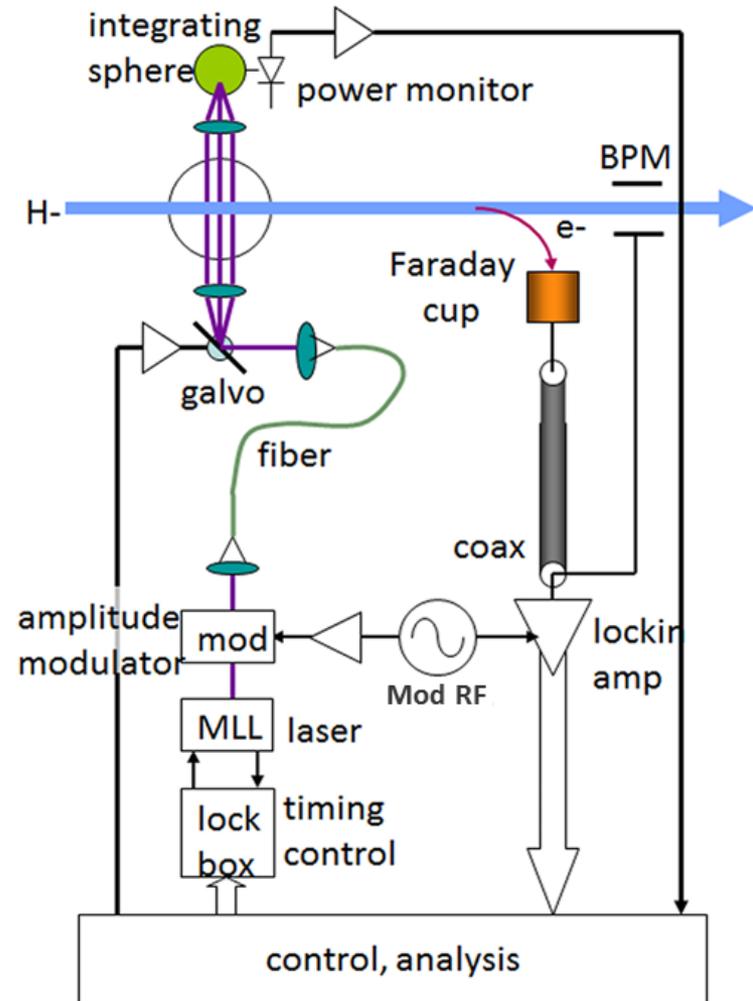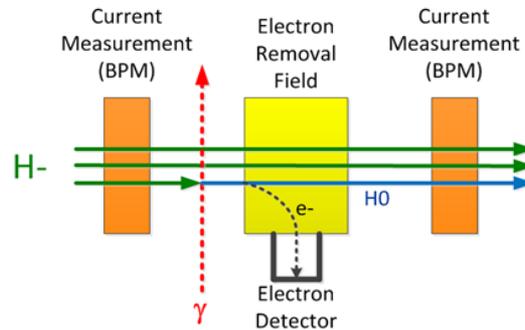
Summary

- Instrumentation focus now is on preparation for first RFQ beam
  - All MEBT configuration 1.1 instruments proceeding
  - No perceived delays for beam line installation
  - Initial instrumentation software for pulsed mode only
  - Commissioning of instrumentation help study systematic effects
- India to eventually deliver BPM system
  - Initial PXIE system for prototyping and development studies
- Strong competition for manpower resources
  - Limits focus to present PXIE commissioning needs
  - Effects timeline of diagnostics development

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