Update of PXIE Beam Instrumentation

Vic Scarpine

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Overview

- Mostly up to now:
  - focus on LEBT instrumentation commissioning and Source/LEBT beam operations
  - Simpler systems:
    - DAQ based on HRM digitizers
    - Simple bias technique for isolated beam pickups
- Now:
  - Focus on MEBT instrumentation development for RFQ commissioning
  - Transition from HRMs to FPGA-based digitizer frontends
    - Allows for more flexibility and dynamic operation
  - Preparing instrumentation for initial pulsed beam operation

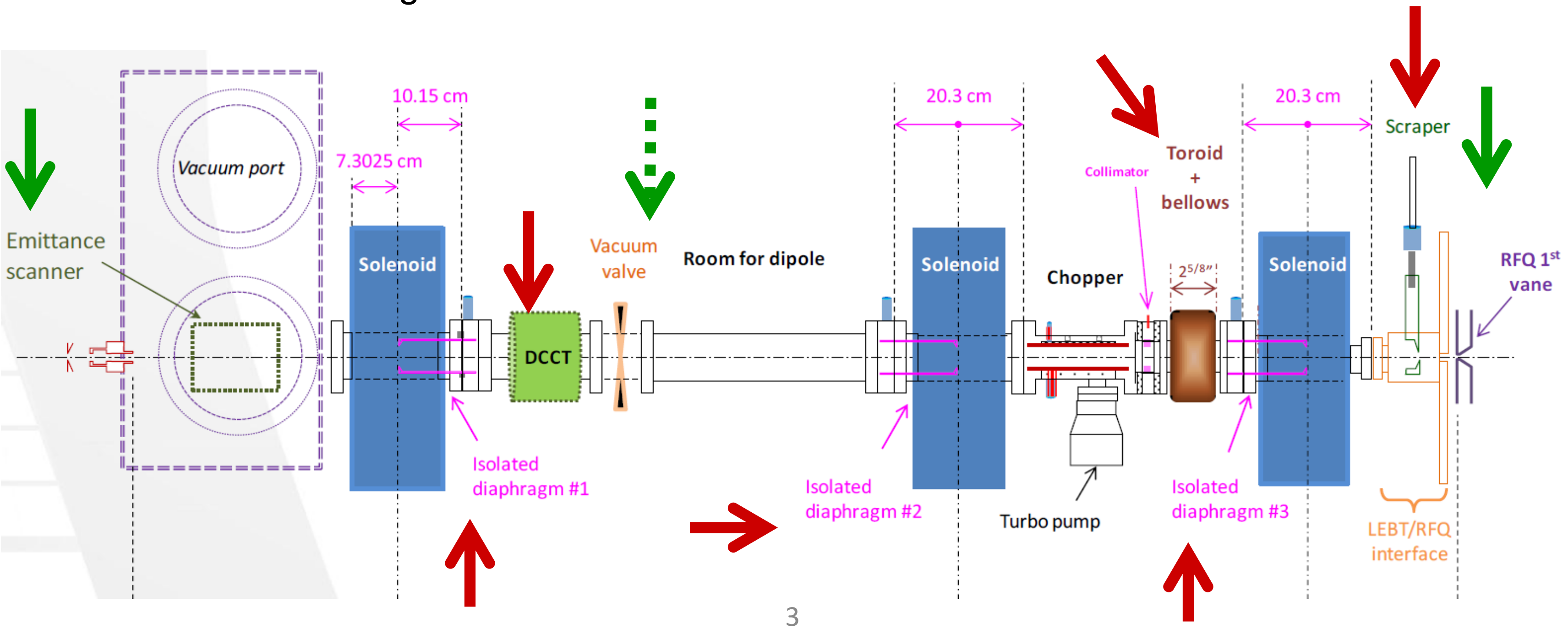
PXIE Source-LEBT Instrumentation

Beam Current

- DCCT
  - Unchopped Beam Current
- Toroid
  - Chopped Beam Current
- Isolated diaphragms
  - Beam tails
  - Beam steering

Beam Emittance

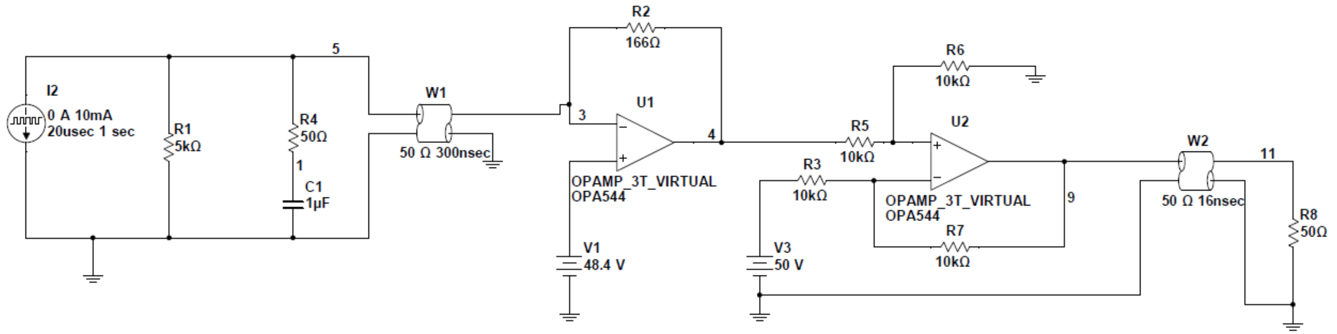
- Water-cooled Allison Scanner
  - Measurements at ion source
  - Measurements in LEBT during commissioning

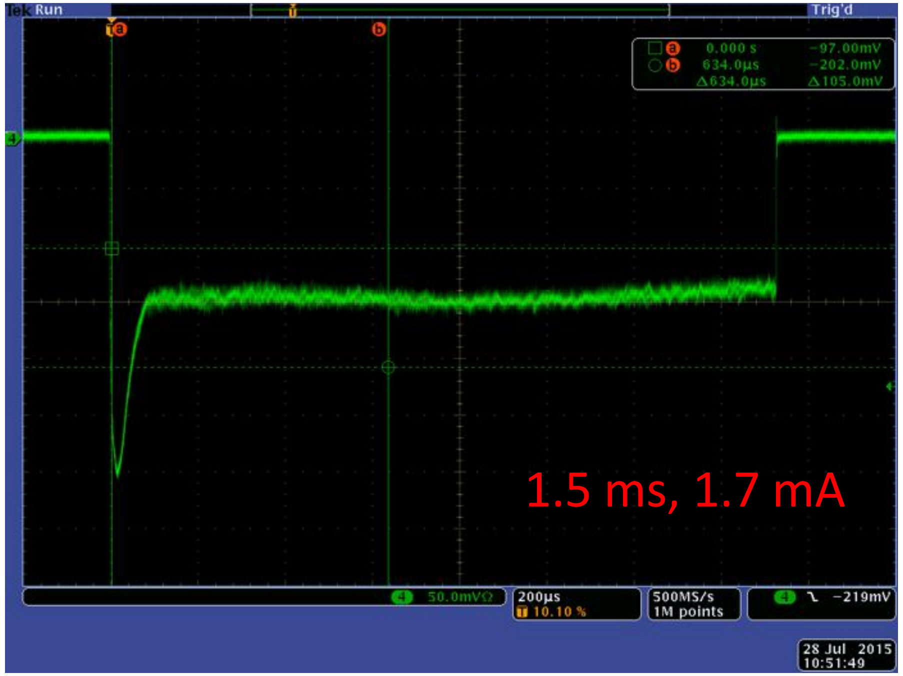


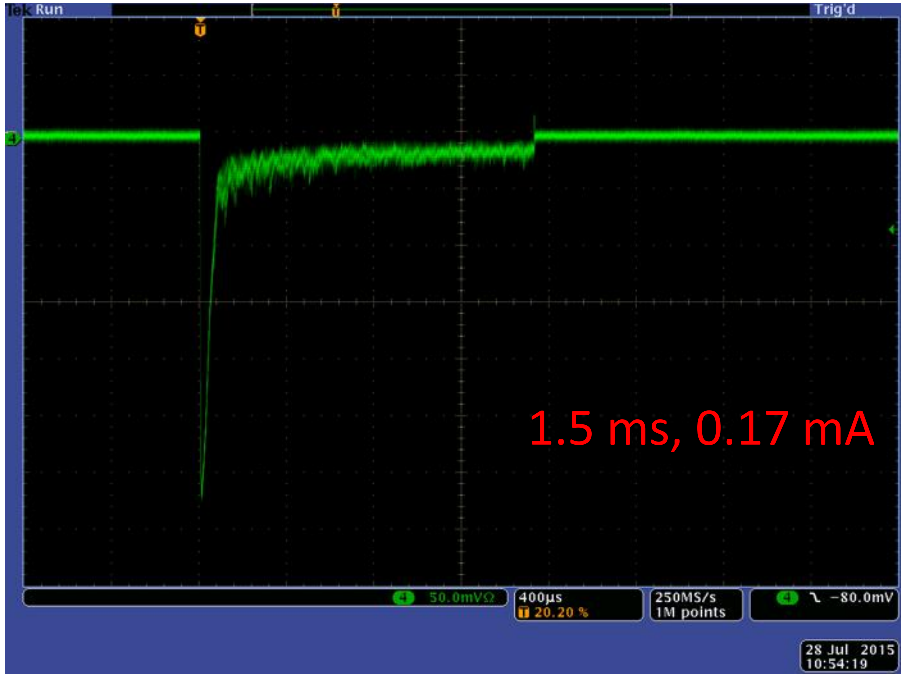
Modified Isolated Pickup Electronics - Update

Replace passive isolated electronics with trans-impedance op-amp circuit design

- Insensitive to cable lengths
- Allows electronics to be moved outside cave into racks







Status

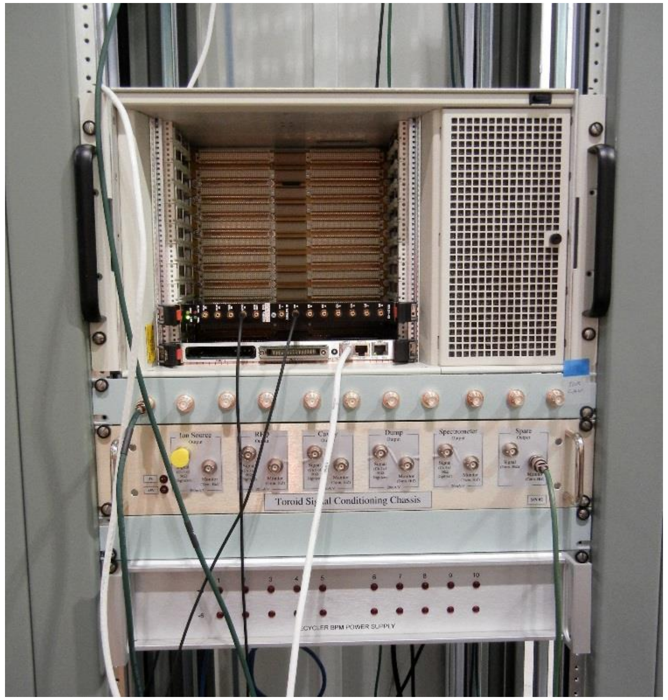
- Prototype circuit has been tested on lab bench
- Prototype tested in PXIE LEBT
- LEBT units under construction

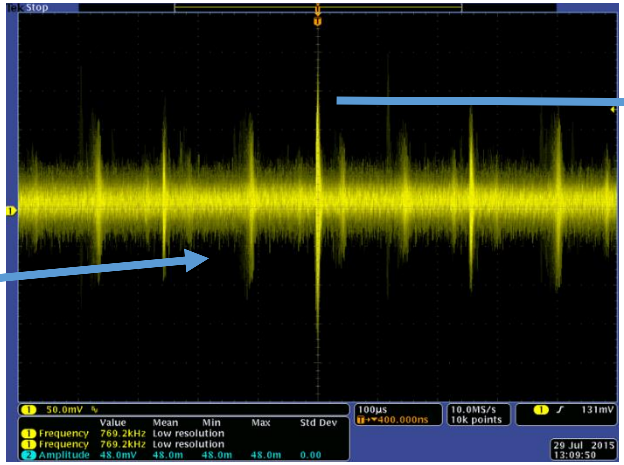
Two models:

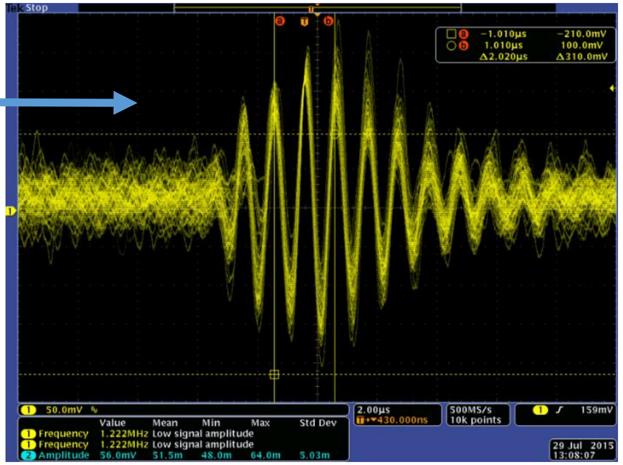
- Up to +100 V for LEBT pickups
- Up to +300 V for MEBT pickups

Frontend Electronics for Beam Current Measurements

- In June, installed first PXIE Instrumentation VME crate for beam current measurements
- Utilize FPGA-based 8-channel digitizer cards for all current measurements – 125 MHz, 14 bit
  - Allows for pipeline or snapshot DAQ and signal processing
  - Only pulsed beam for initial operations
  - Initial FPGA and VME code - reuse FAST code
- Initial operation with LEBT toroid in July
- Picking up coherent, asynchronous burst noise in toroid system
  - Large gain on toroids
  - Needs further investigation





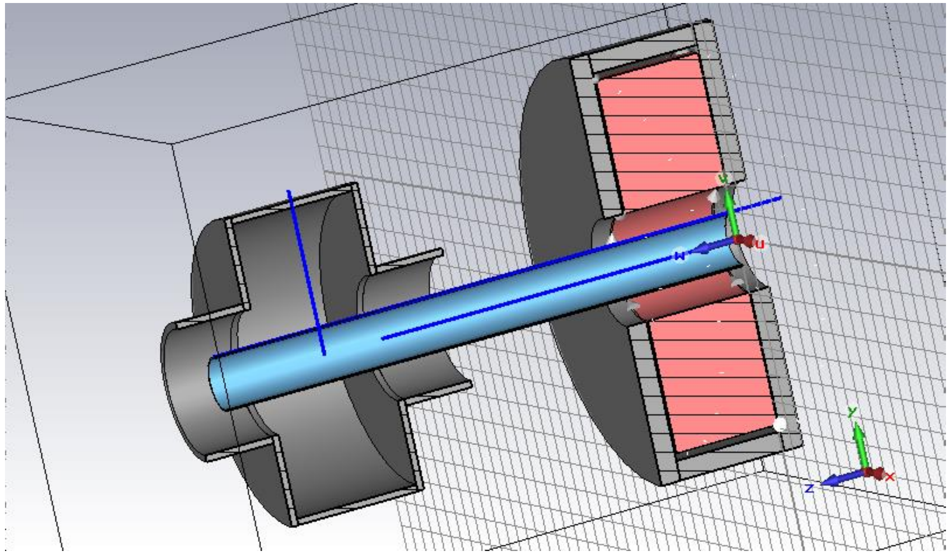


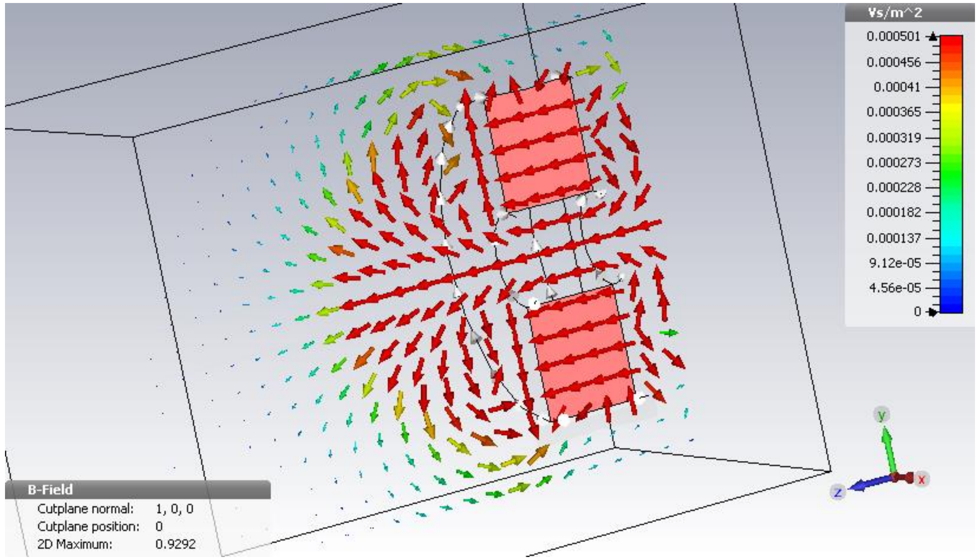
1 MHz burst noise

DCCT Shielding Studies

- With the new LEBT design, the DCCT will need to move closer to the first solenoid
  - What effects may this have one DCCT operation?
  - DCCT is manufactured by Bergoz
    - Sensor saturation: ~ 100 G (axial), ~ 20 G (radial)
    - Sensor sensitivity: ~ 1 μA/G (axial), ~ 100 μA/G (radial)
- No magnetic shielding at present location
- Add magnetic shielding (steel) in new location
  - Shield also is electrical bypass
  - Perform simulation studies in Microwave Studio (Randy Thurman-Keup)

DCCT MWS Modeling with No Shield

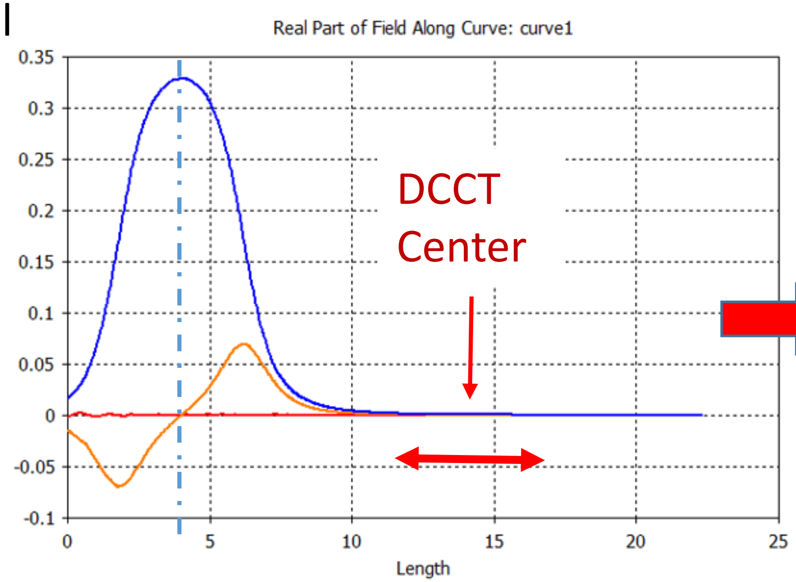


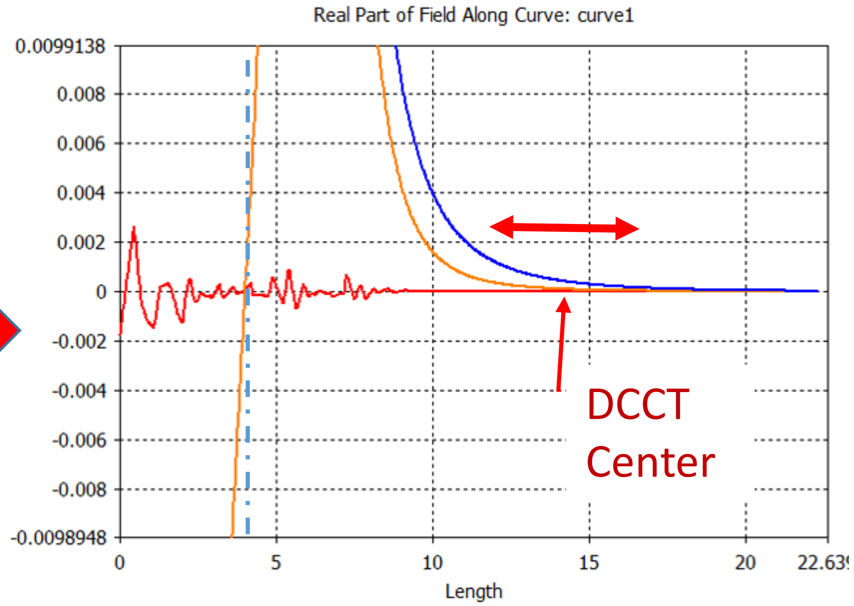


Fields along horizontal blue line on top of beam pipe.

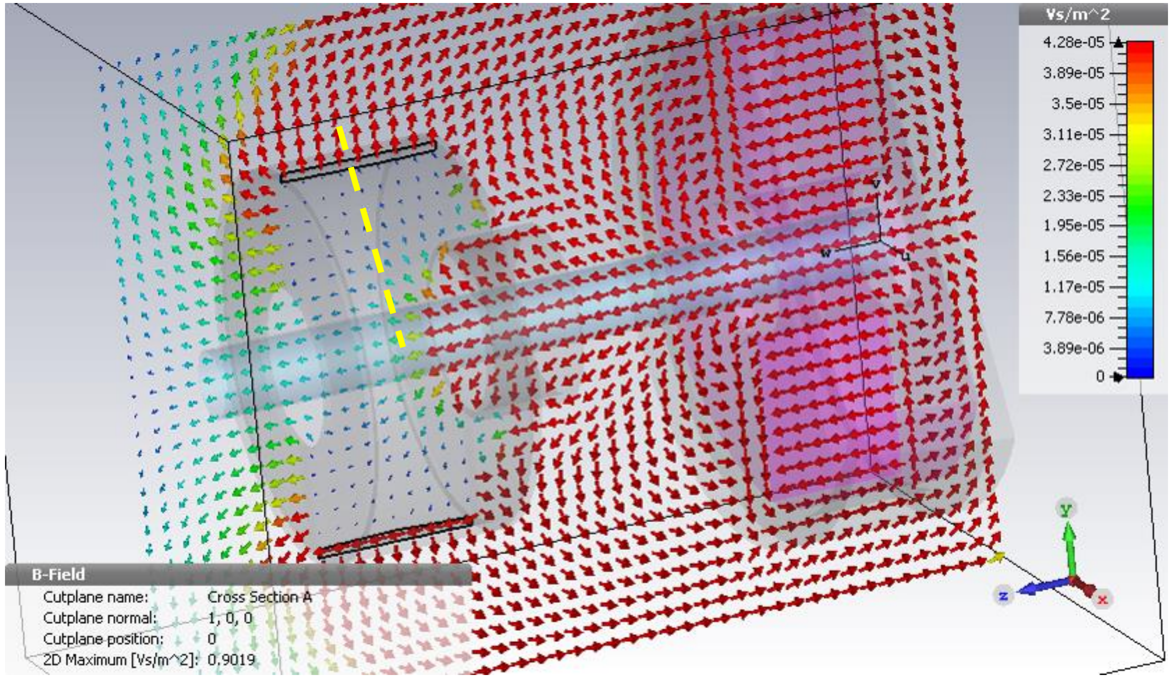
Units in plot are Tesla and inches.

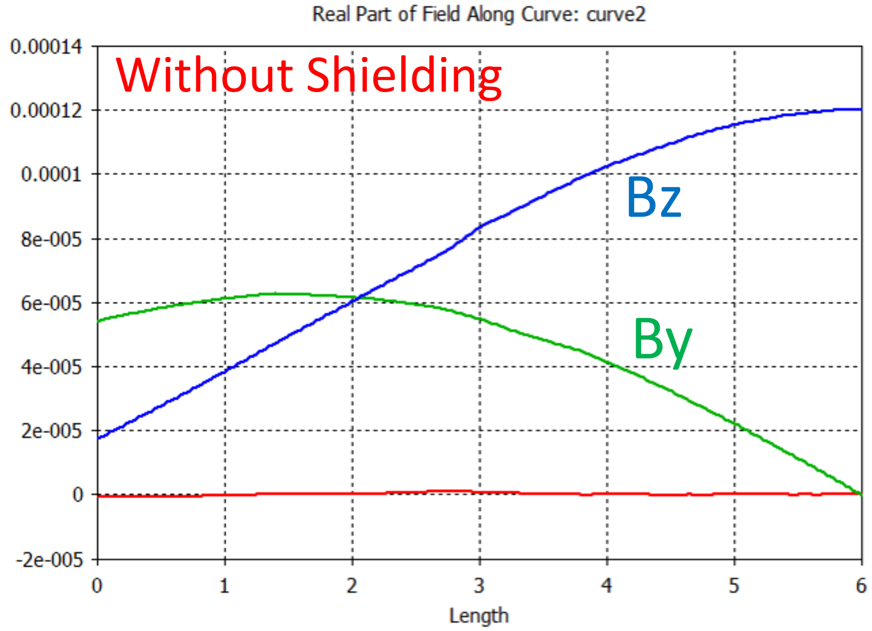
No DCCT shielding in place for this calculation.

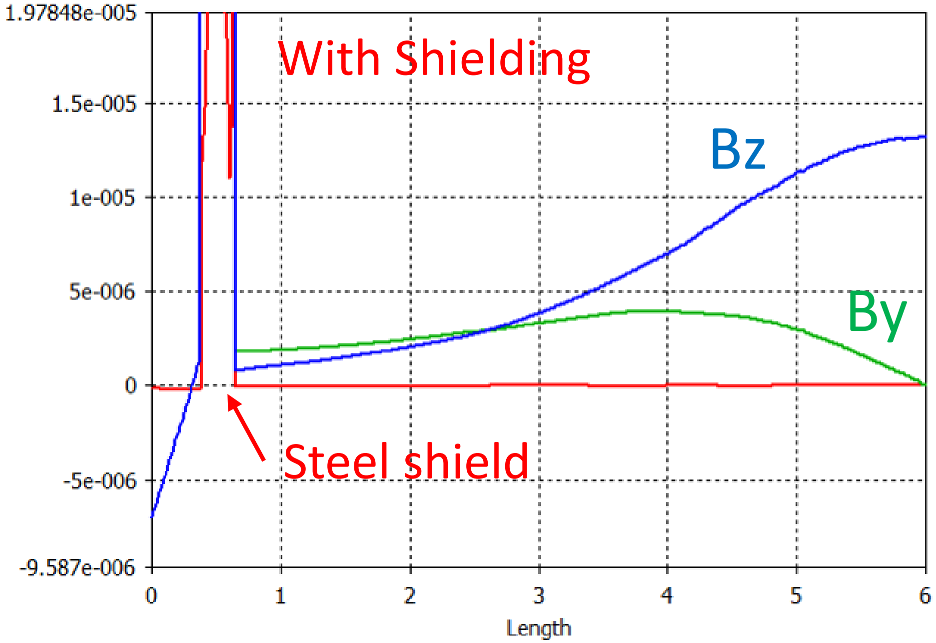




DCCT MWS Modeling with Shielding







Steel shielding reduces fields in DCCT by about x10

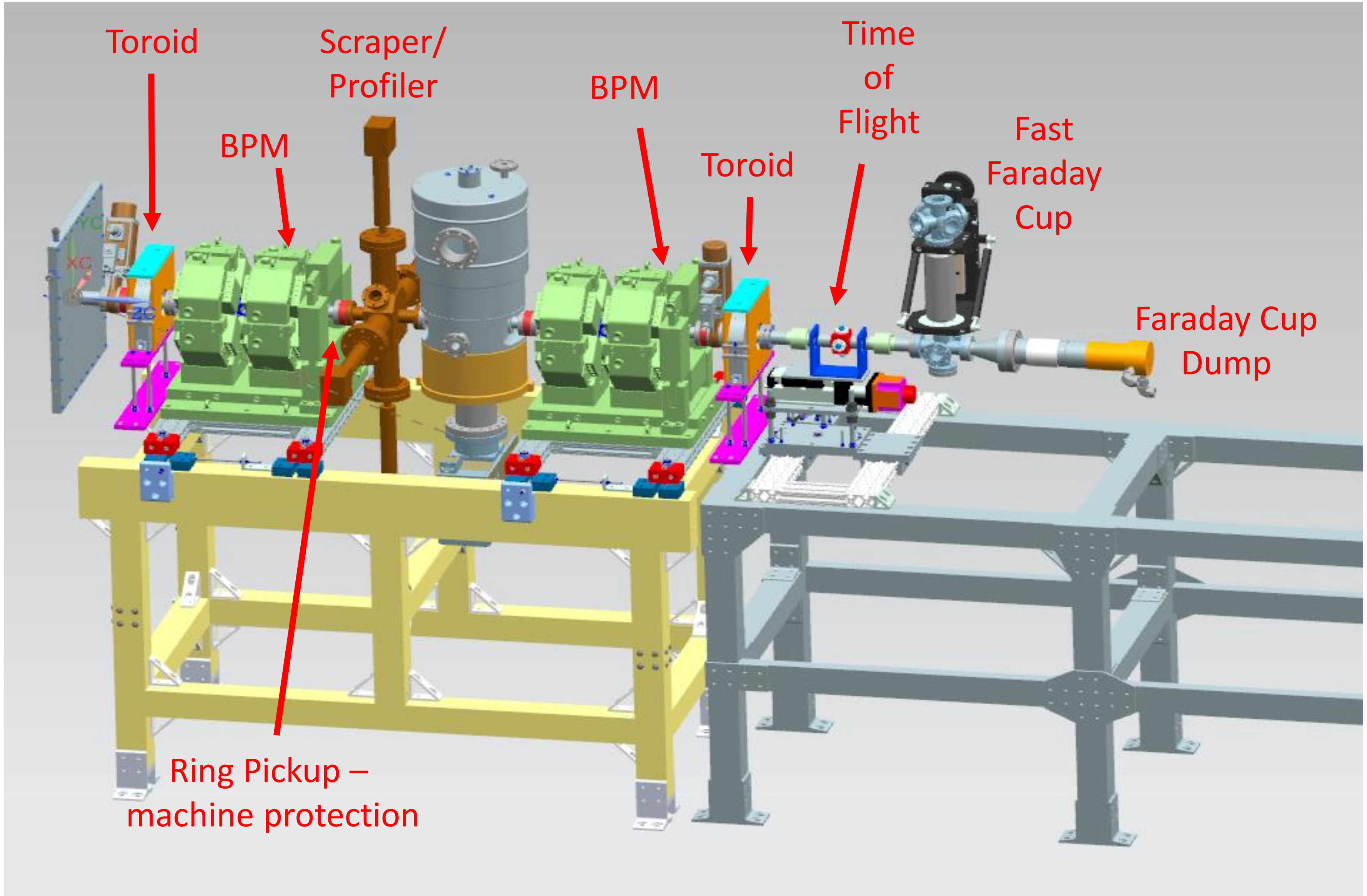
- Radial fields now < ~50 mG
- Should be OK for DCCT

PXIE MEBT Beam Instrumentation

Focus on RFQ commissioning and early MEBT configurations:

- Beam current measurements
  - Toroids, isolated beam dump
  - Integrate into VME-based front-end - initial system installed at PXIE
- Beam position and phase
  - Button BPMs - Installation into quad doublets
  - DAQ system under development – based on previous design
- Beam transverse profiles and emittance
  - Electrically isolated beam scrapers for profile measurements
  - Integrate into VME-based current front-end
  - rms emittance measurements via quadrupole scans
  - Prototype wire scanner work underway
  - Developing MEBT version of Allison-type emittance scanner
- Beam energy
  - Time-of-flight via movable BPM – under installation
- Machine protection
  - Isolated ring pickup – constructed
- Longitudinal bunch shape
  - High-bandwidth Faraday Cup - > 5 GHz BW
  - DAQ thru high-bandwidth scope
  - Prototype tested in LEBT

Initial MEBT Configuration 1.1



MEBT BPMs

Requirements:

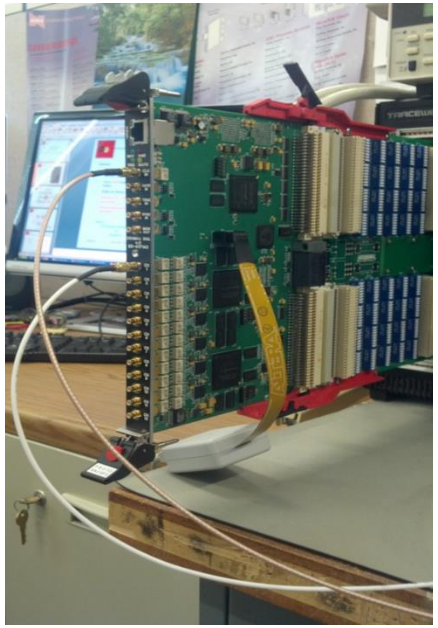
	Accuracy	Precision
Position, μm	10	30
Phase, degrees of 162.5 MHz	0.05	0.2
Relative intensity, %	1	3

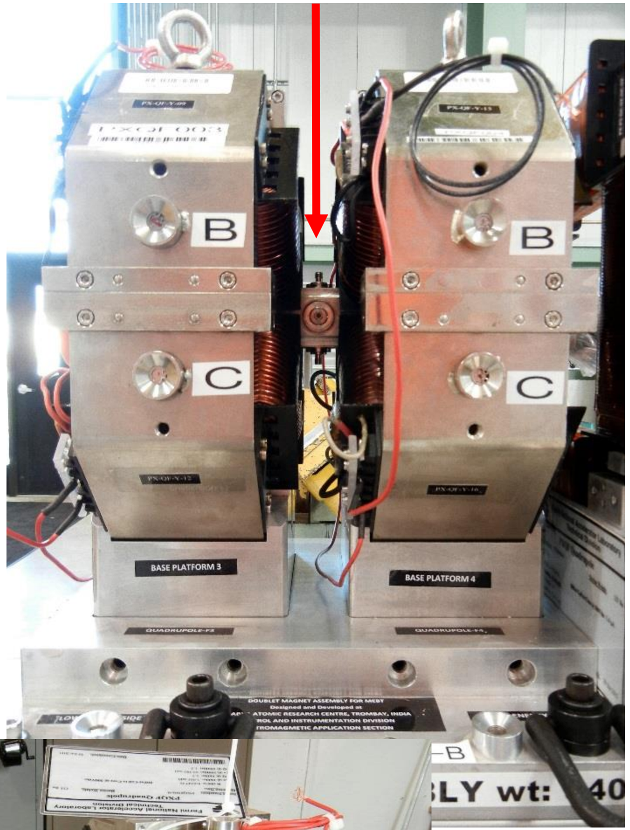
DAQ with FPGA-based electronics for CW and pulsed beam

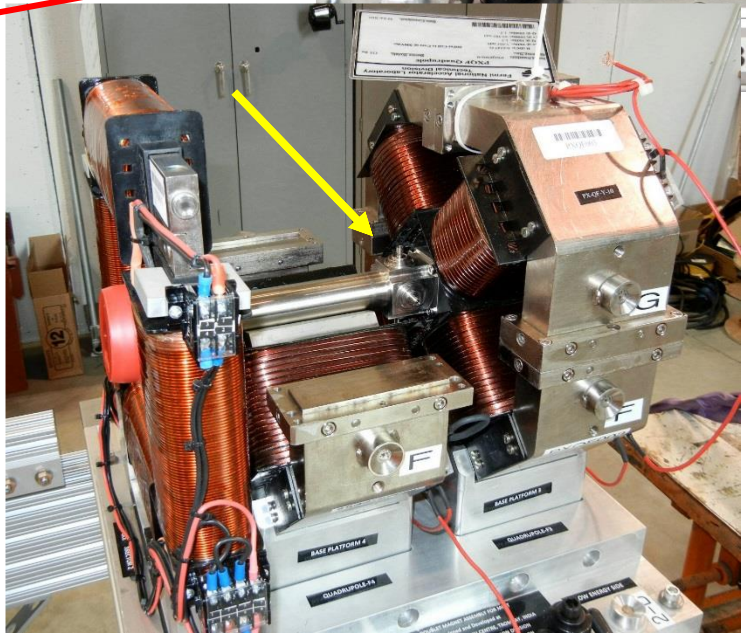
- 12 channel, 14 bit, 250 MSPS boards

Analog filter & amp board under development

- 162.5 MHz 1st and 3rd harmonics
  - Pseudo bunch length measurements







Status:

- First two BPMs being installed
- Stretched wire measurements performed
- Electronics assembled with initial testing on bench
  - Installation at PXIE in November
- Reuse frontend software from other systems
  - Pulsed beam initially
  - Average position, phase, intensity per pulse
- Initial system ready by first beam

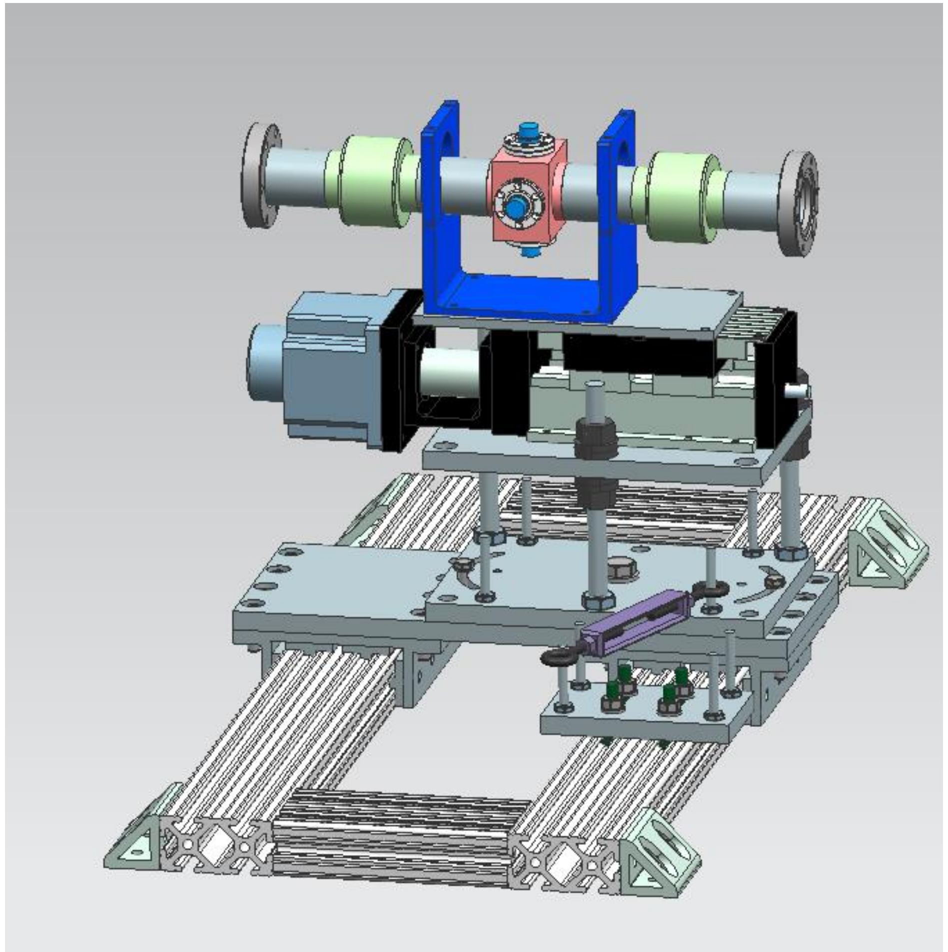
Time of Flight (ToF) Movable BPM

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
  - MEBT energy resolution: 0.1%

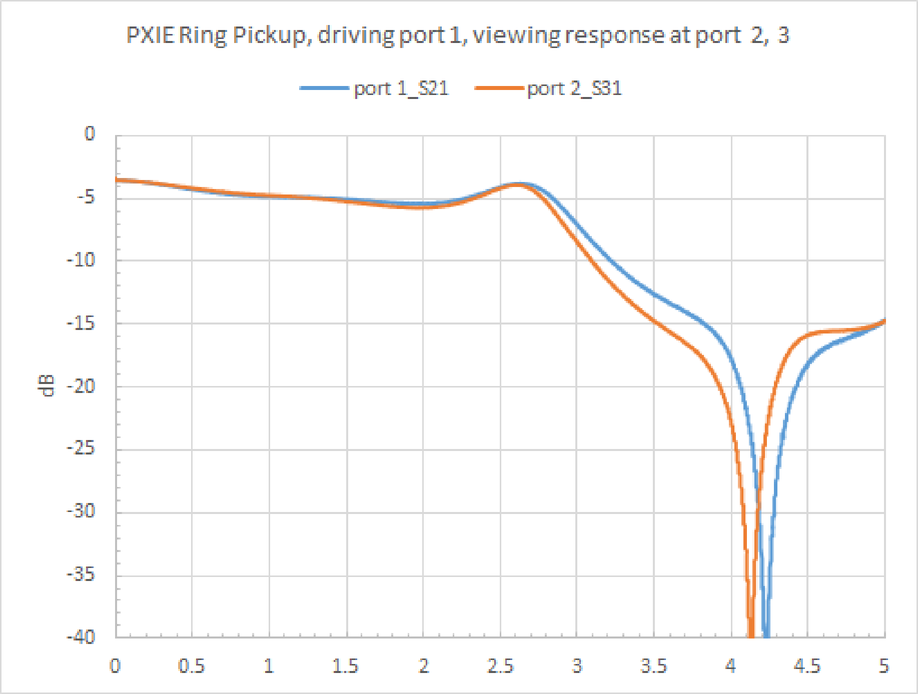
Status:

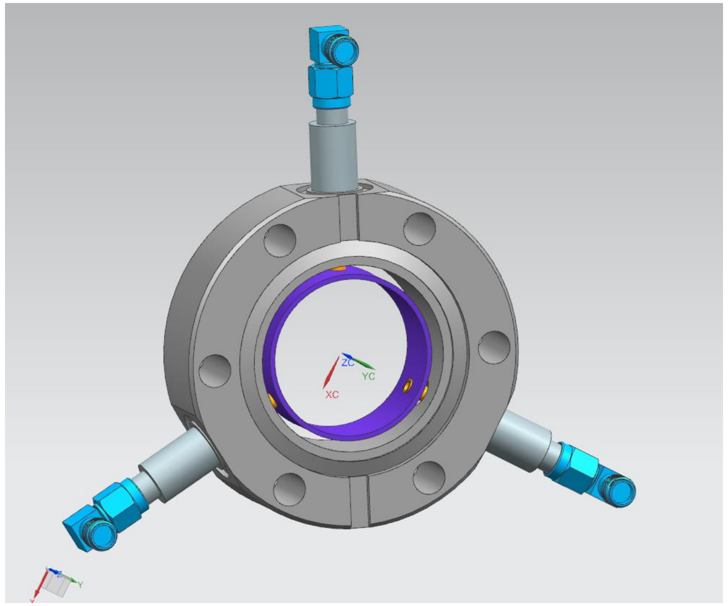
- All components in hand
- Installing stage in beamline girder
  - Waiting on BPM stretched-wire mapping
- Use MEBT BPM electronics to acquire phase



Machine Protection

- Dedicated ring pickup to measure bunched-beam current
  - Wide bandwidth pickup but narrowband electronics
- Simple analog circuit to generate 162.5 MHz RMS spectral power level

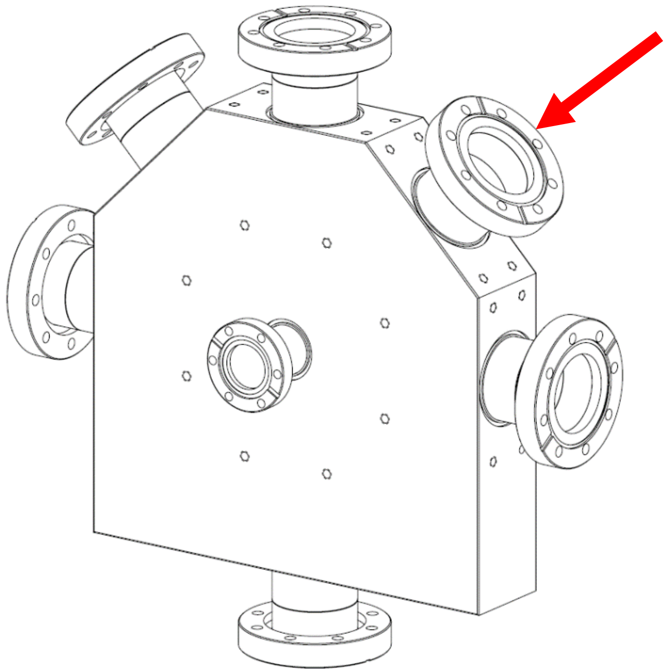


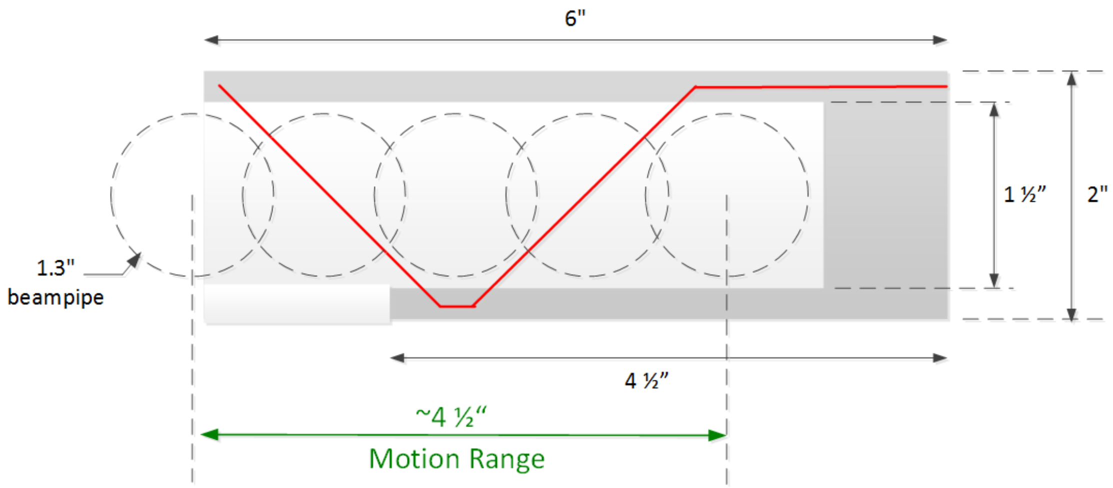


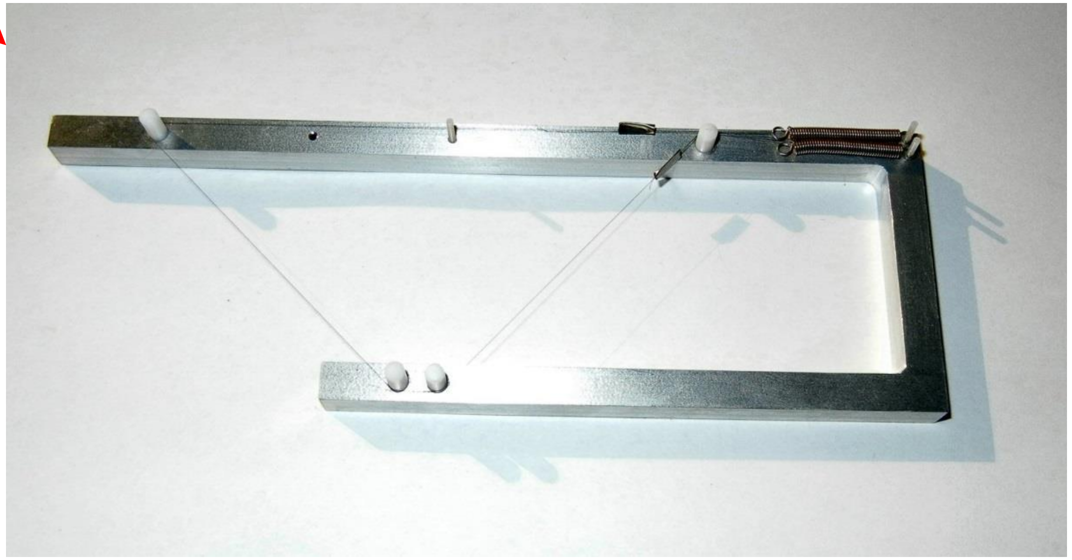
Prototyping Wire Scanner

Developing prototype wire scanner for profile measurements

- Test in diagonal port of MEBT scraper
- Constructed mock-up to test wire stretching and mounting issues

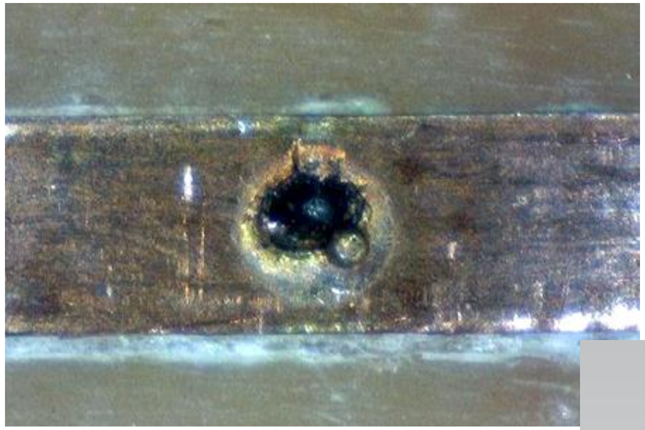




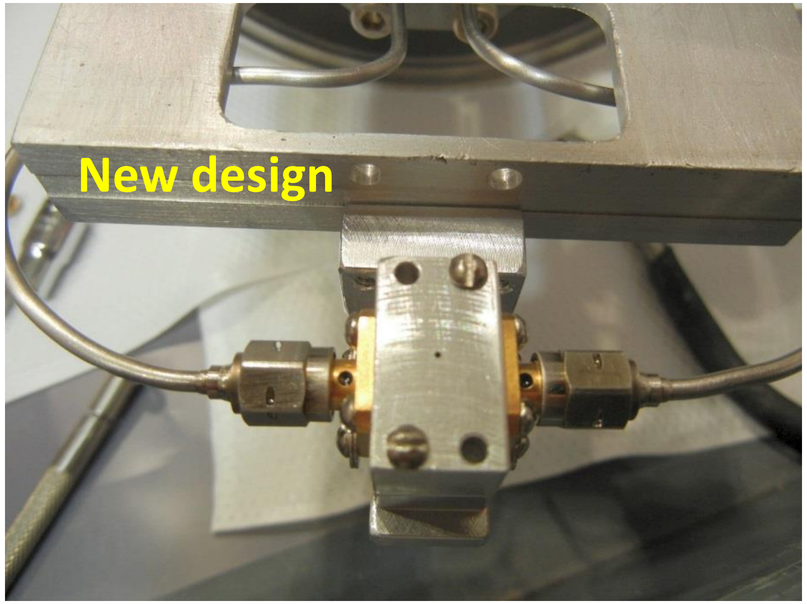


Bunch Length - New Fast Faraday Cup

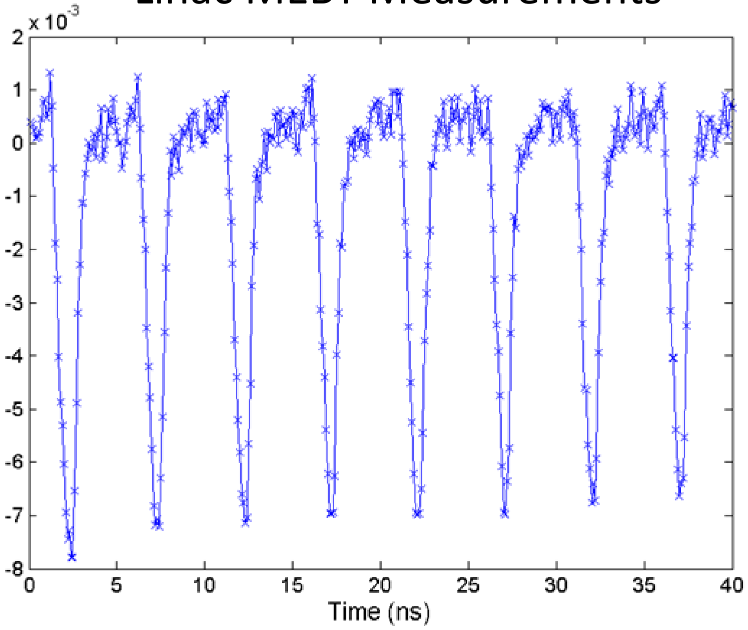
- Embedded 50 Ω stripline – initially designed by SNS
- High Bandwidth (> 6 GHz) – need scope DAQ
  - Beam damage at HINS (2.5 MeV protons)
  - We are redesigning with better thermal properties
- Old model tested at HINS and Linac
- Prototype new design tested in PXIE LEBT
- Vacuum hardware design complete
- Ready for beamline installation in November

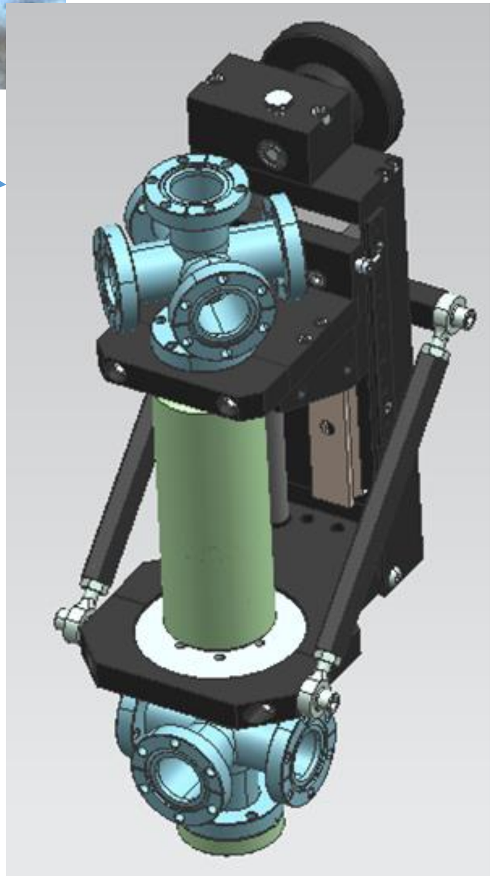


Old design - Damage with HINS beam



Linac MEBT Measurements

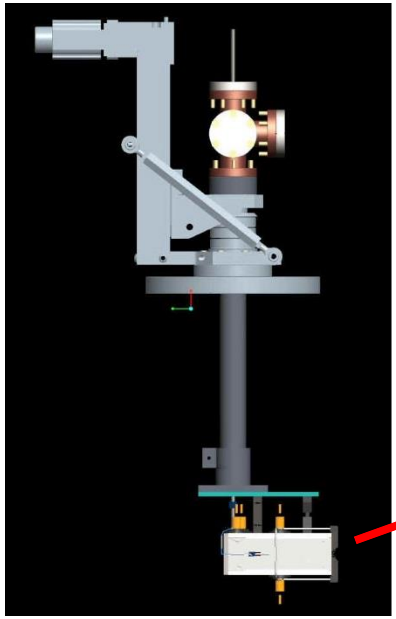


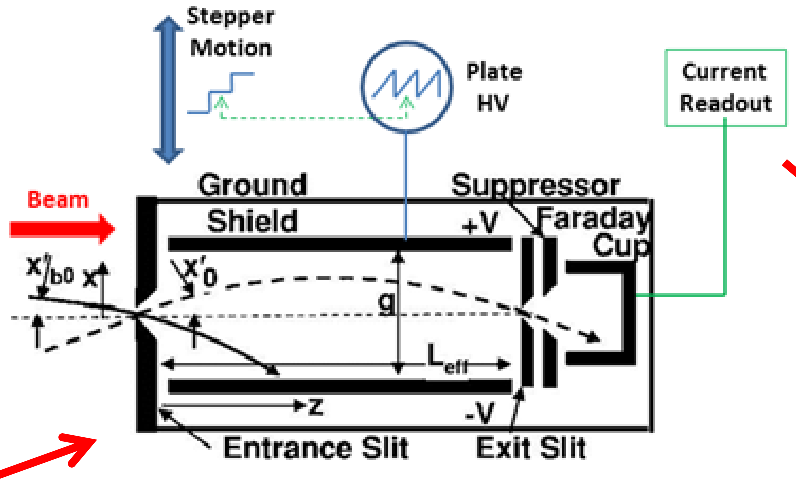


Allison Scanner for MEBT Emittance Measurements

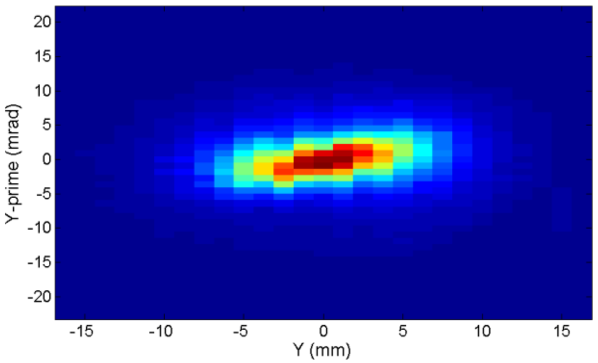
Design a water cooled Allison-style MEBT emittance scanner based on LEBT scanner

- 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





- Preliminary 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
  - Modified scanner head under design
  - Estimate spring FY16 for MEBT installation



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
    - Average values per pulse
  - Basic beam measurements at first beam
  - Electrical noise may be a issue → filters, averaging, signal processing
- Integration of instrumentation signals into MPS proceeding and added as needed