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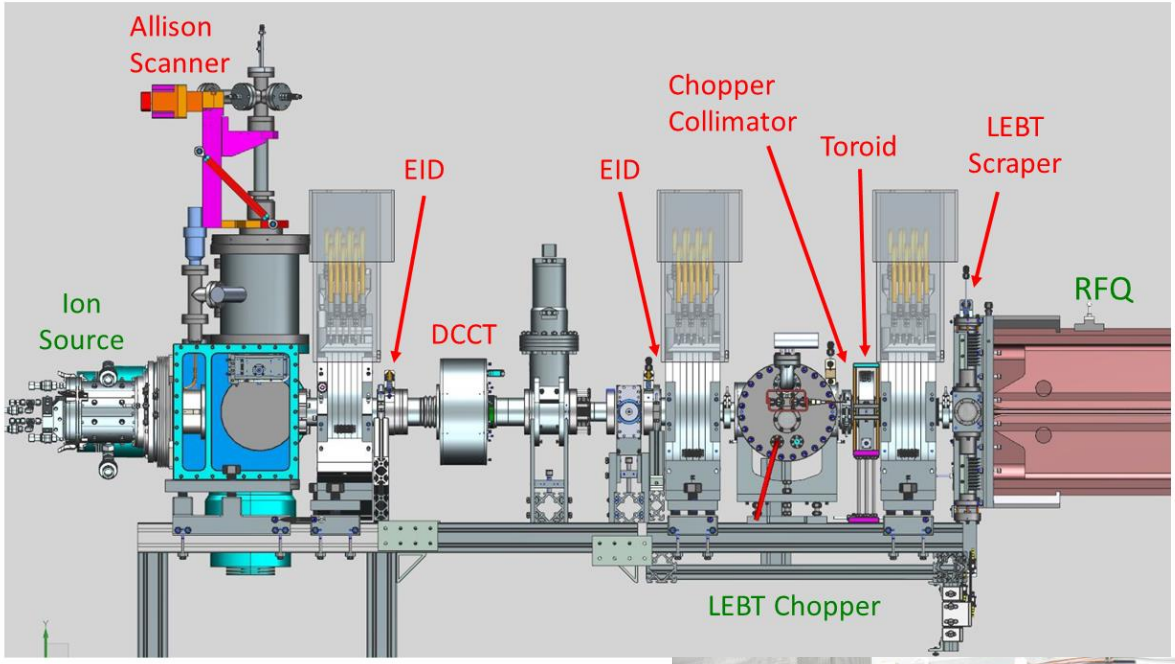
PXIE Beam Instrumentation Status Update

Vic Scarpine

Weekly PIP-II Meeting

June 7, 2016

PXIE LEBT Instrumentation Development

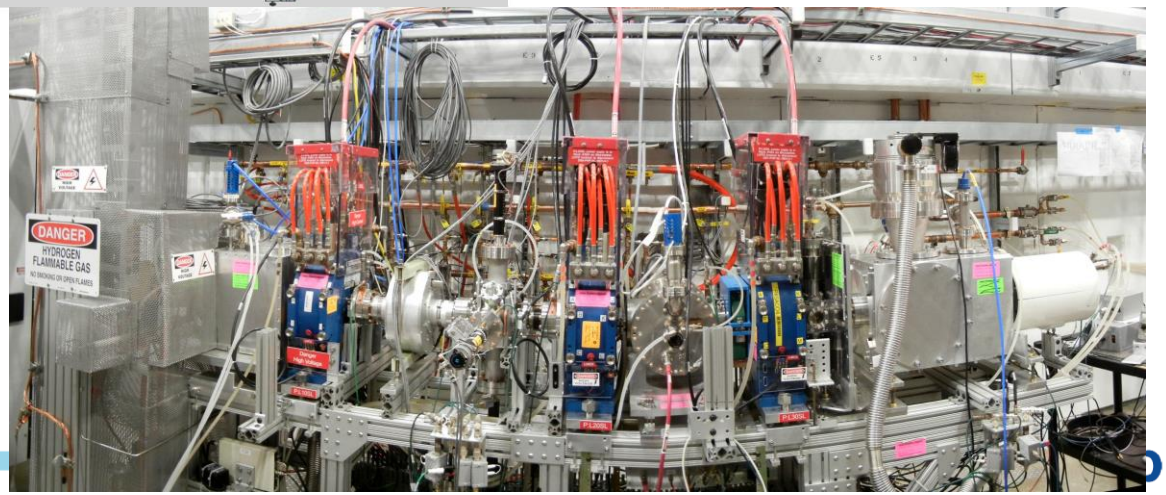


Beam Current Measurements

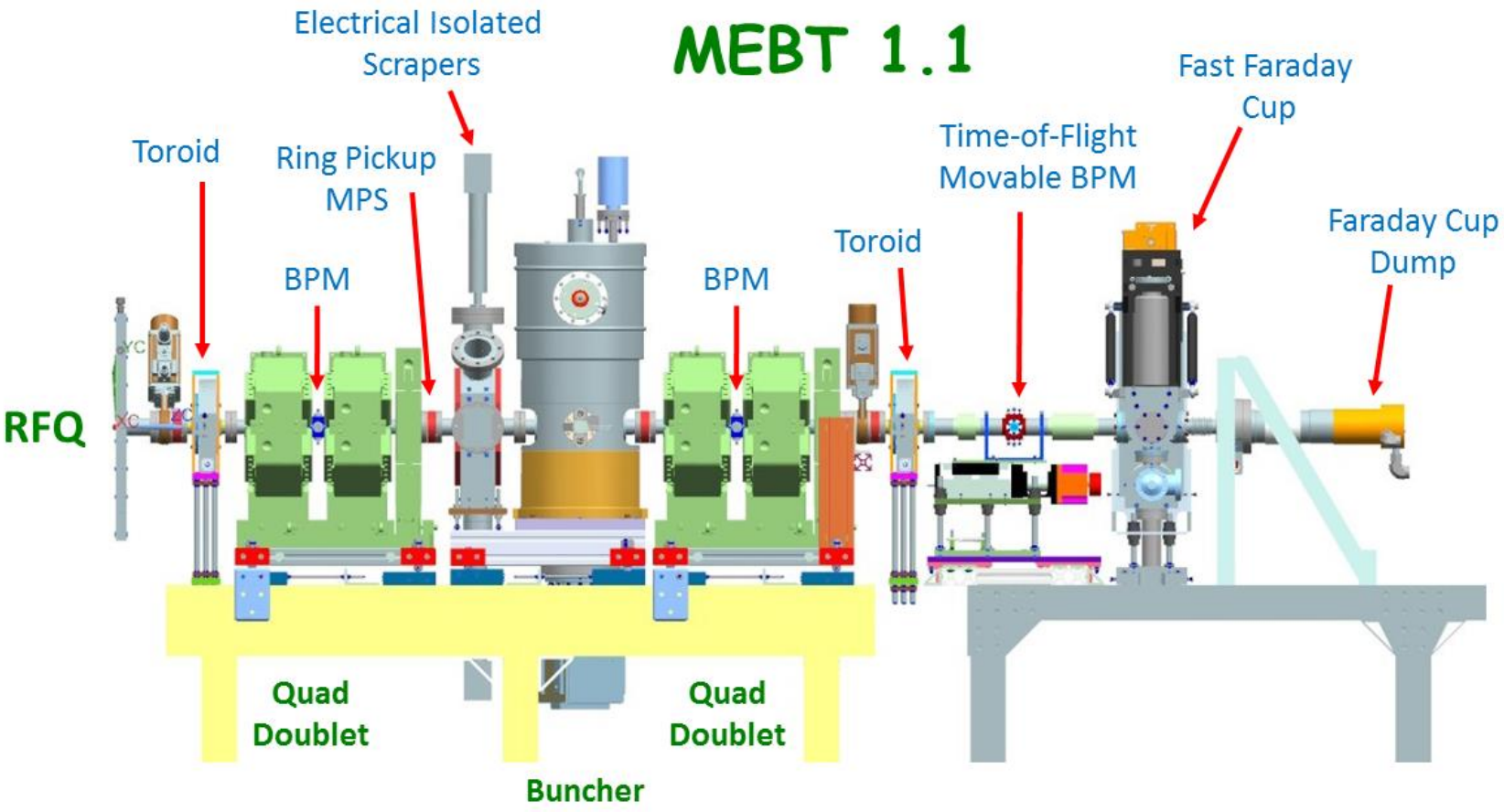
- Upstream of chopper
  - Long pulses - DCCT, EIDs
- Downstream of chopper
  - Short pulses - Toroid, collimator, LEBT scraper
- Digitizer/FPGA DAQ – waveform measurements
  - *Integrated with MPS*

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

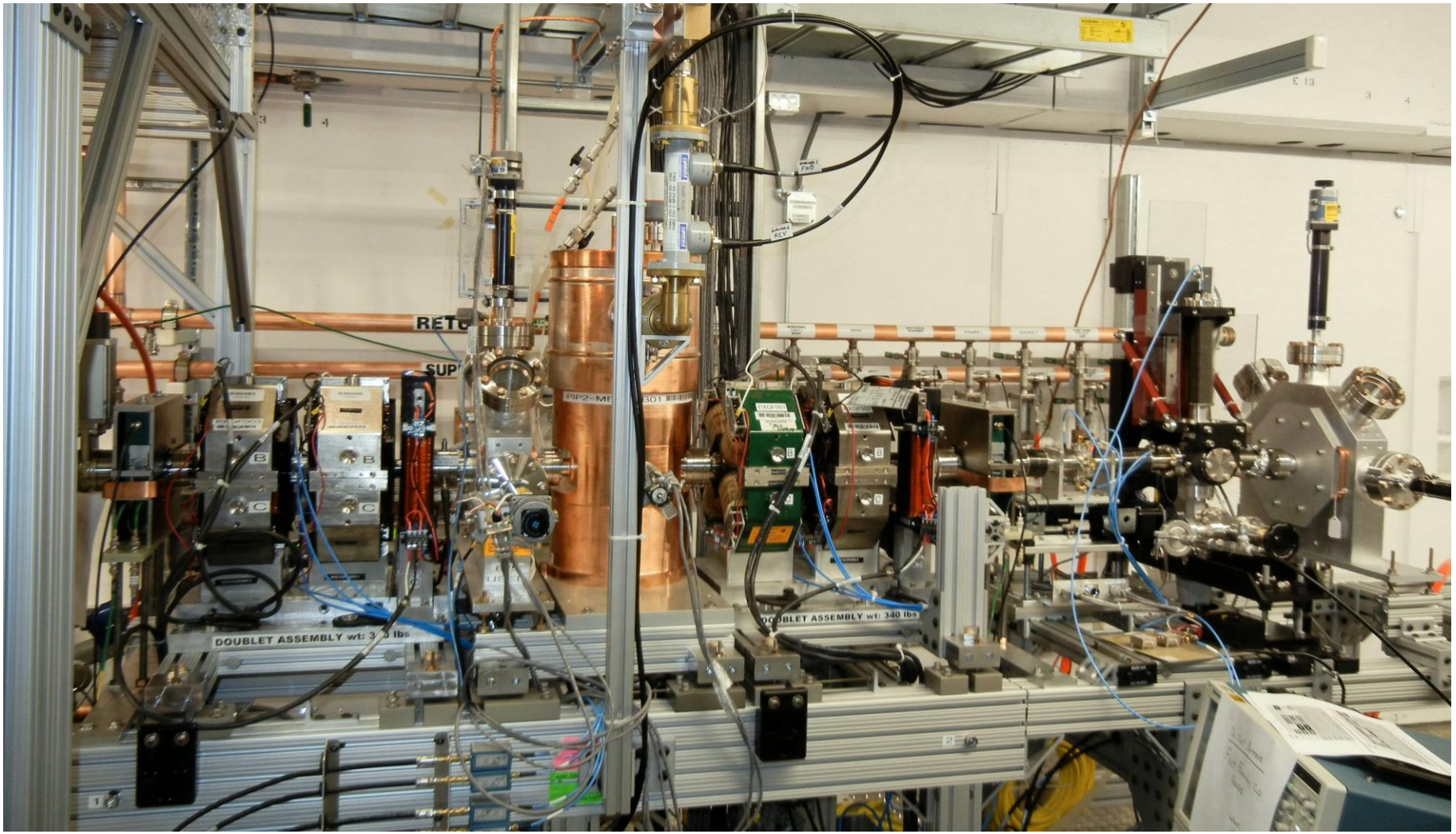
Now switching over to MEBT



PXIE MEBT Instrumentation Development – Initial RFQ Commissioning



MEBT 1.1

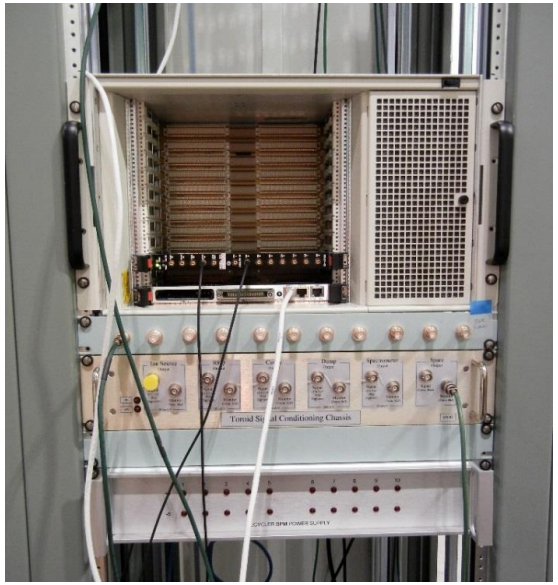


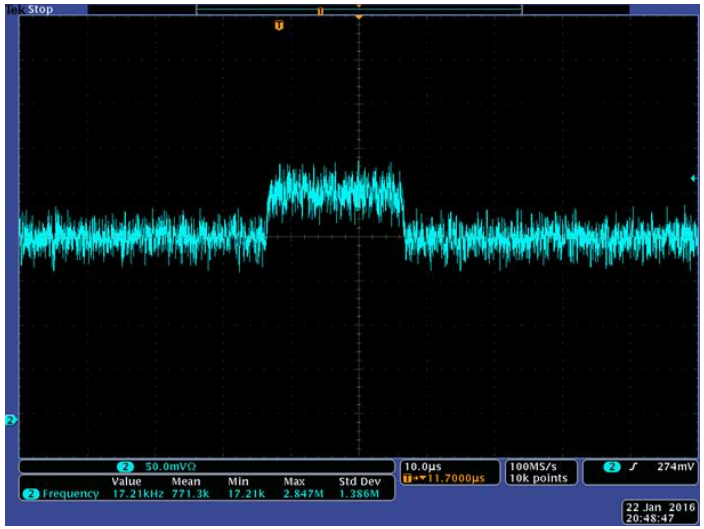
MEBT Beam Diagnostics Status

- Beam current measurements
  - Toroids, isolated beam dump, ring pickup
  - Installed and Integrate into VME-based front-end – under test
- Beam position and phase
  - Warm BPMs - installed in quadrupole doublets
  - DAQ system running and under test
- Beam transverse profiles
  - Electrically isolated beam scrapers – two installed in MEBT
  - Integrate into VME-based front-end - under test
  - Prototype wire scanner under design
- Beam energy
  - Time-of-flight via movable BPM – installed
  - System under test – manual measurements made
- Longitudinal bunch shape
  - High-bandwidth Faraday Cup - > 6 GHz BW – installed
  - First measurement attempt yesterday

Frontend Electronics for Beam Current Measurements

- Toroids, Faraday cup dump, scrapers
- 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 – 20 μsec
  - Upgrading to longer pulses
  - 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

PXIE Electrically Isolated Pickups (EIP)

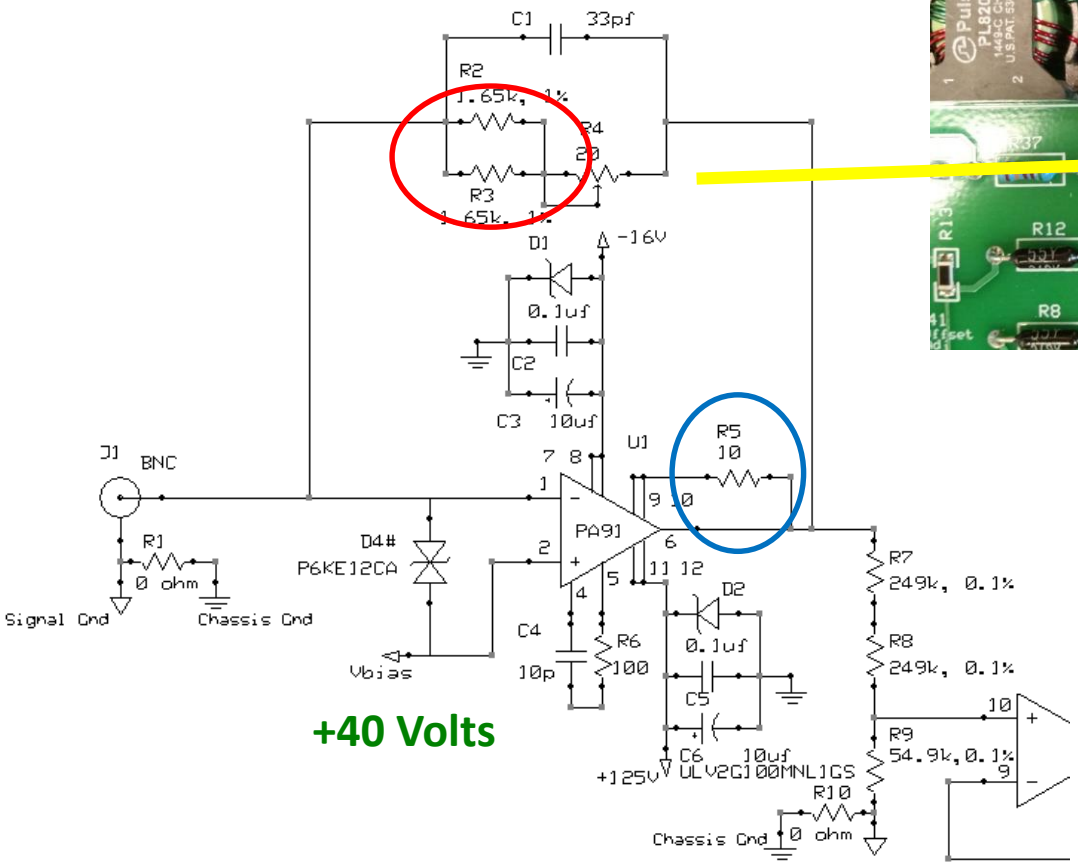
MEBT EIP Update

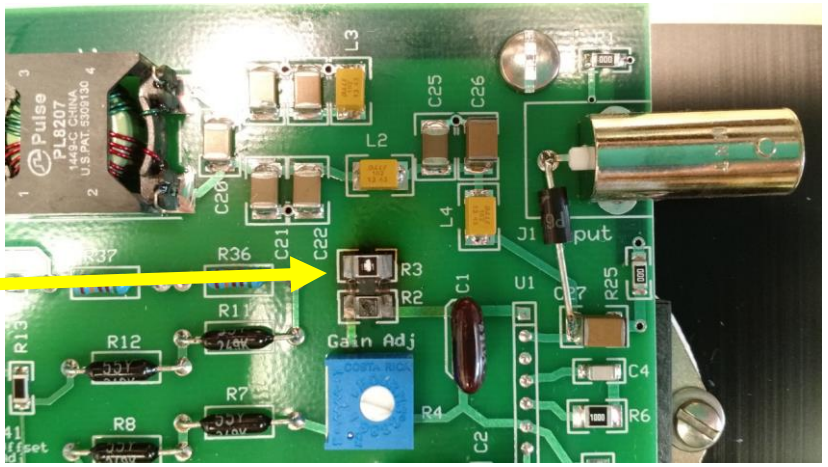
- EIPs biased (up to +100 volts)
- Two scrapers (8 channels) plus SNS dump and halo fingers (5 channels)
- Bias boards connected (excepted shorted scraper channel)
- Signals readout thru beam current DAQ FPGA board and into ACNET
- All channels calibrated – gain and offset
  - Offset coarse correction in electronics
  - Offset fine correction in DAQ processing – only for pulsed beam
  - Gain correction in ACNET

Investigating bias electronics damage caused by scraper short

- Need to modify electronics to protect against shorts

Scraper Short Problem for Bias Electronics



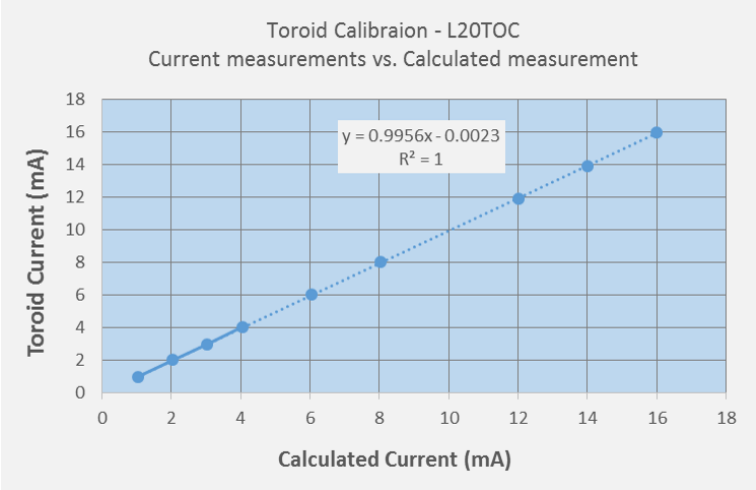


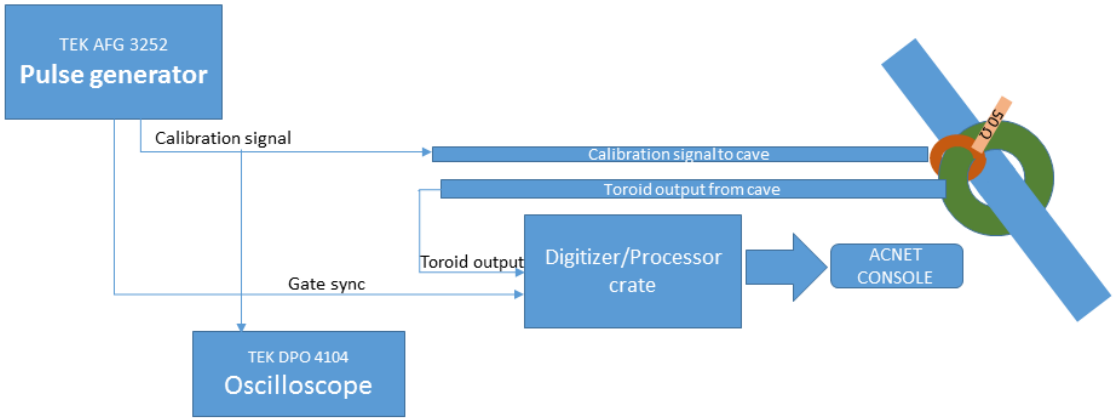
- Feedback loop tries to keep op-amp negative port at same voltage as Vbias
- Short at scraper drives op-amp feedback current to max and burns out ½ watt resistors
- ***Change current limiting resistor to limit feedback current***

PXIE Toroid Calibrations

1) Measure resistance of calibration port with ohm-meter or multi-meter
2) Instrumentation trigger is used to trigger pulse generator, oscilloscope and instrumentation crate.
3) Use pulse generator to generate calibration signal and gate sync signal (currently 20usec pulse used – could change for longer pulses)
4) Sweep calibration signal from 0mV in 50-100mV steps until toroid current reads 10-12mA (linear portion)
5) Measure voltage of input signal on oscilloscope
6) Measure toroid current on ACNET using the average current devices
7) Linear curve-fit of data is taken and used to generate new coefficients

- Averaging devices used to measure toroid output signal
- *Calibration seems to be repeatable to ~ +/- 0.5%*

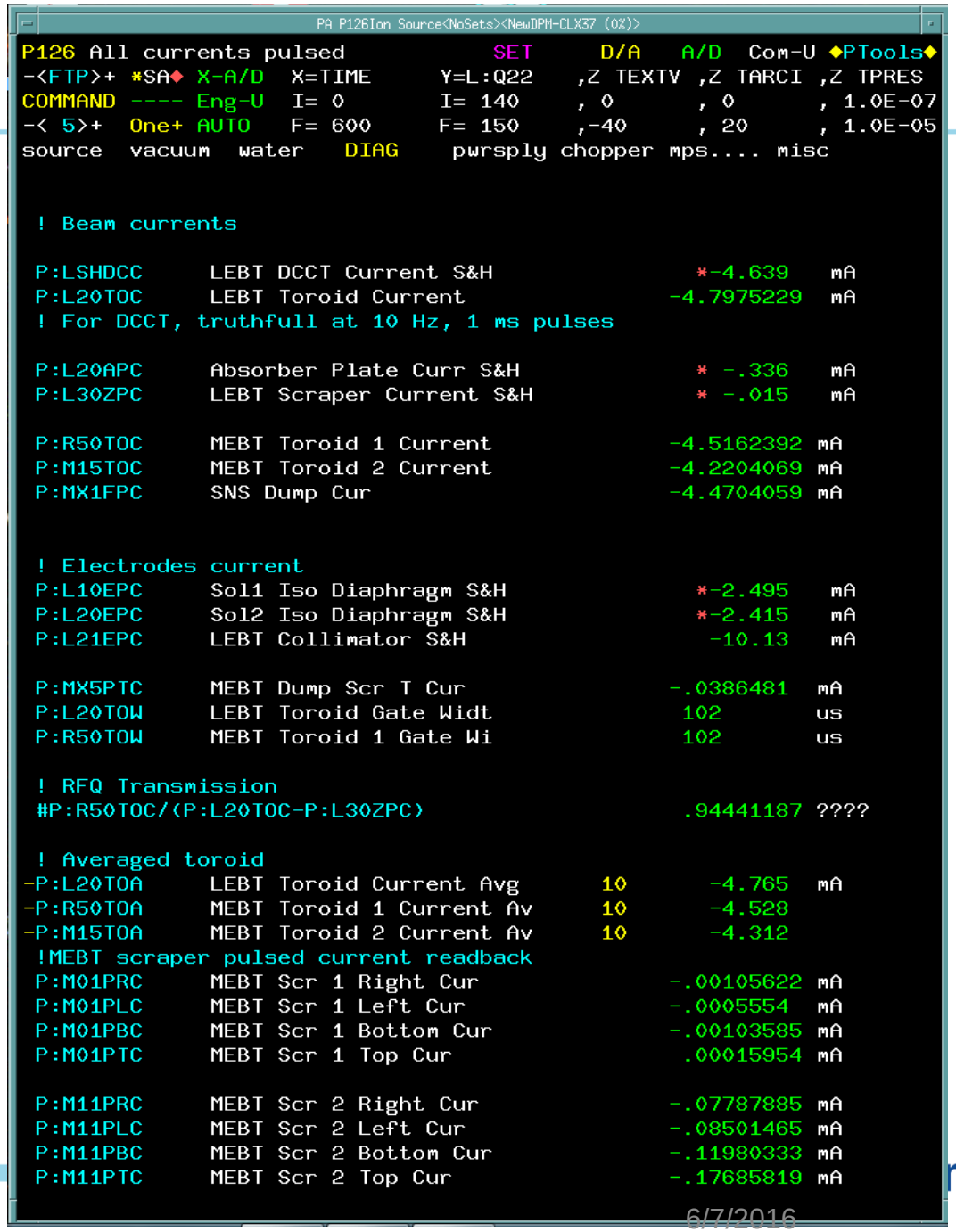




Work to be done

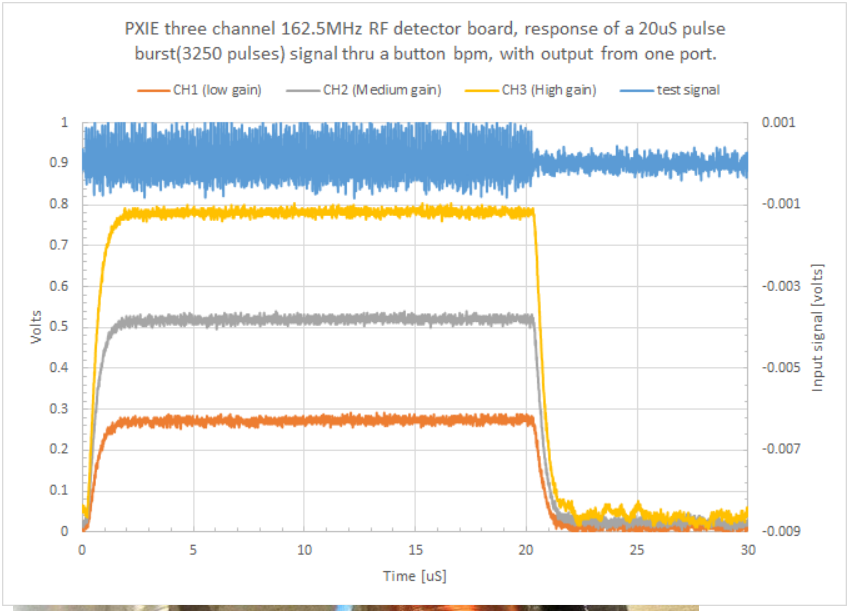
- Investigate noise on LEBT toroid
- MEBT 1 toroid still reads around 1% less current than MEBT 2 toroid
- Investigating a more automated calibration sequence

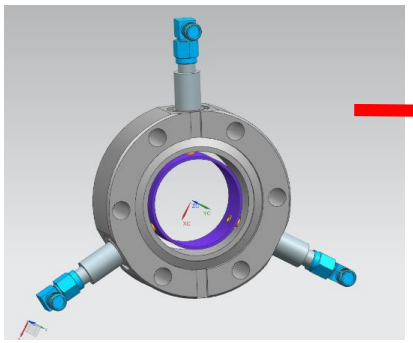
Beam Current Devices in ACNET

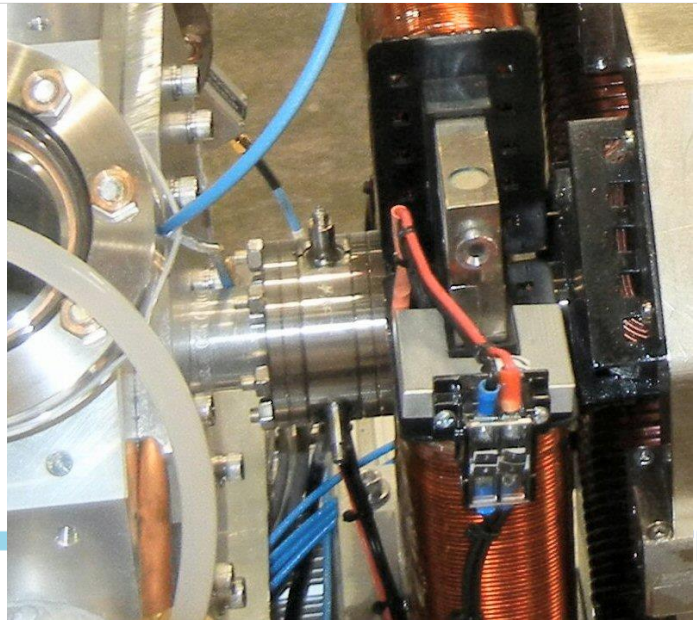


Ring Pickup – Beam current for Machine Protection

- 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 – under test
  - Eventual operation with CW beam







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MEBT BPM Development

Requirements:

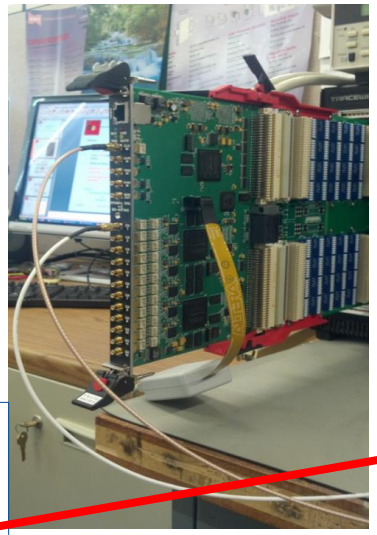
	Accuracy	Precision
Position, μm	10	30
Phase, degrees of 162.5 MHz	0.05	0.2
Relative intensity, %	1	3

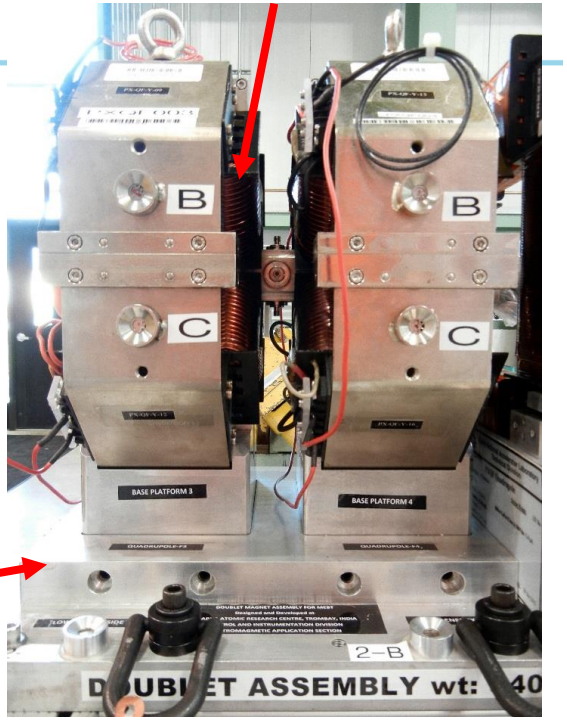
DAQ with FPGA-based electronics for CW and pulsed beam

- 8 channel, 14 bit, 125 MSPS boards

Analog filter & amp boards built and tested

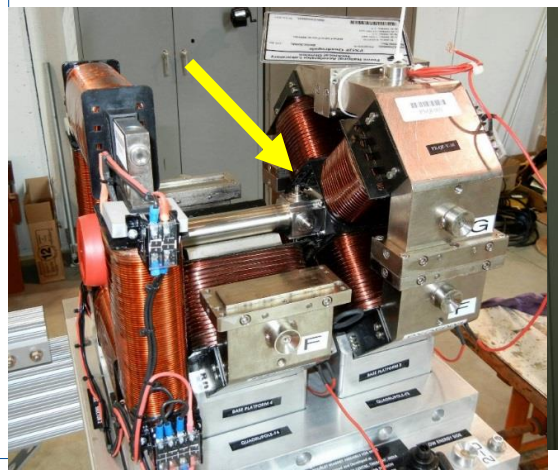
- Ring bunches – No bunch-by-bunch measurements





Status:

- First two BPMs being installed in quads
- ToF BPM installed
- Stretched wire measurements performed
  - Low-beta correction added
- Reuse frontend software
  - Pulsed beam initially
  - Average position, phase, intensity per pulse
- ***BPM System installed and under test***
- ***Change to 250 MSPS system soon***



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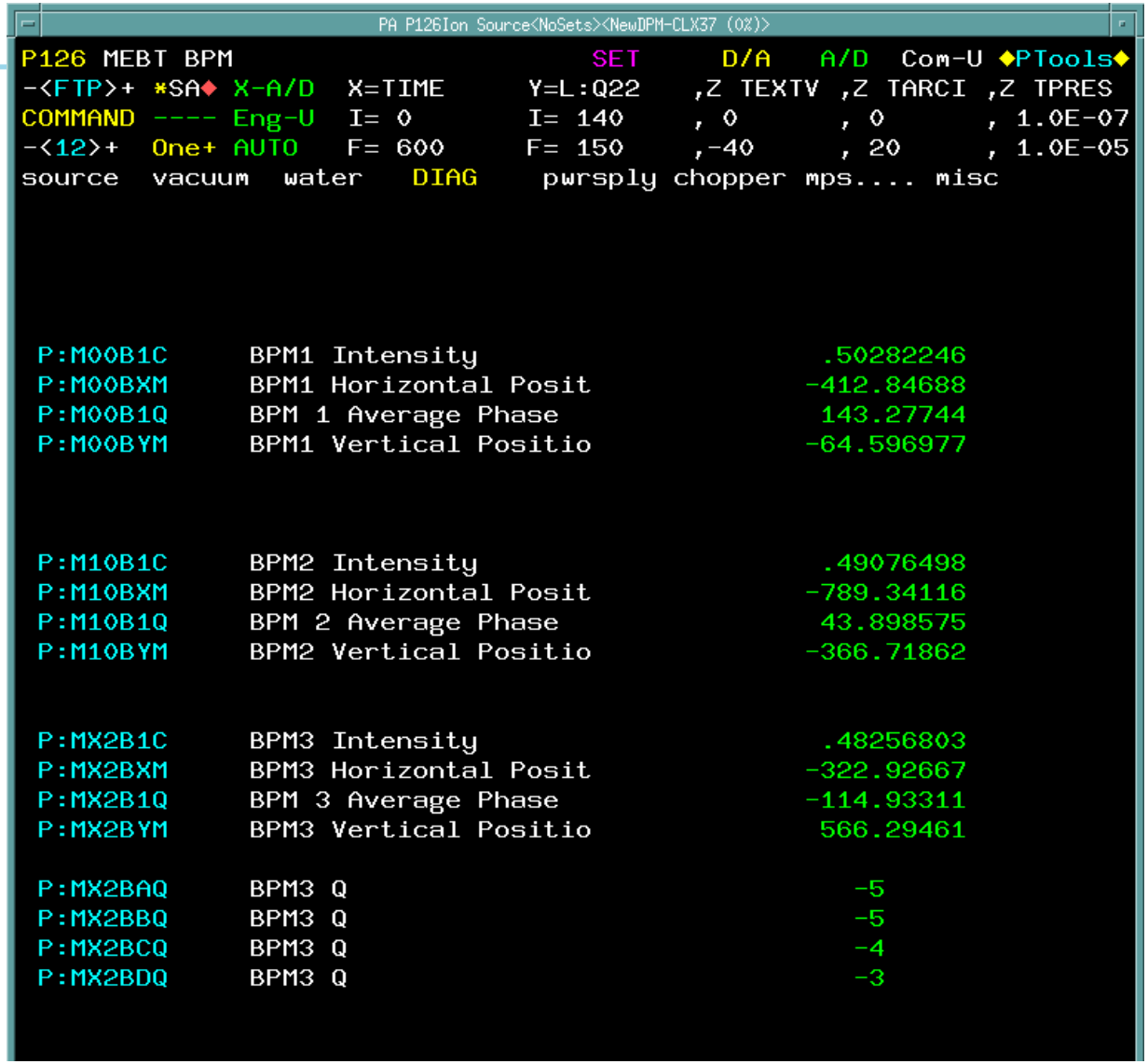
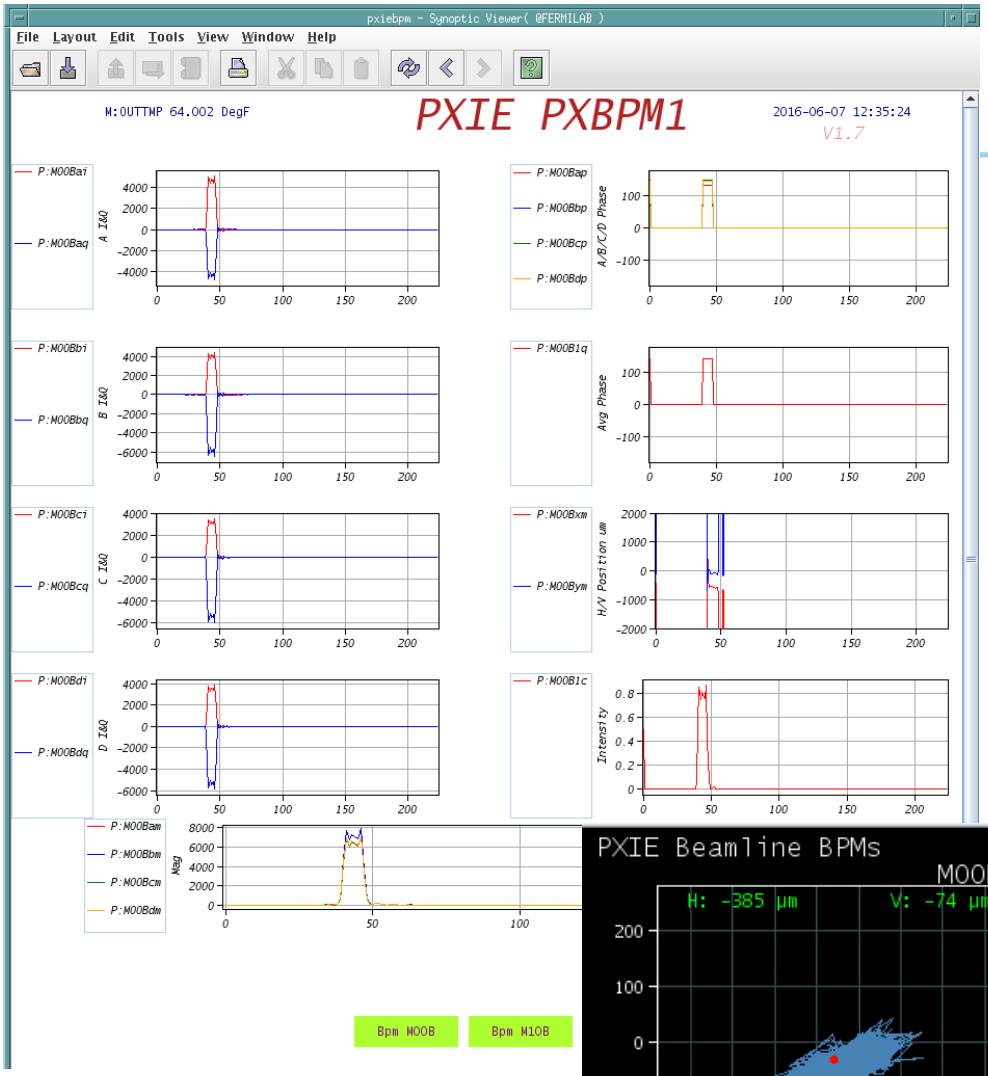
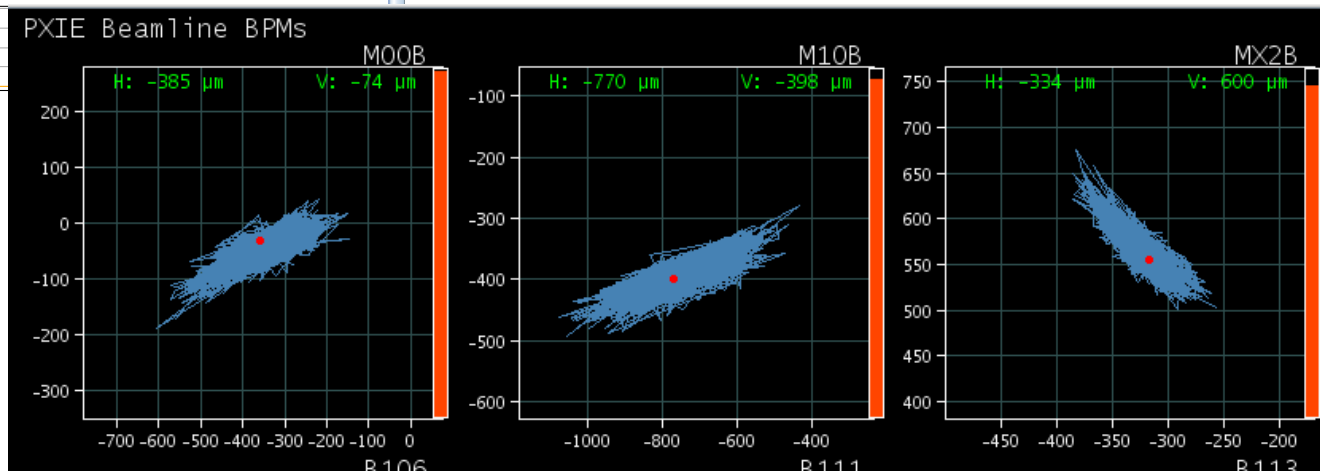
BPM Readings in ACNET

- Position in microns
- Phase in degrees of 162.5 MHz
- Intensity is relative intensity of 162.5 MHz signal component



BPM Diagnostic Tools

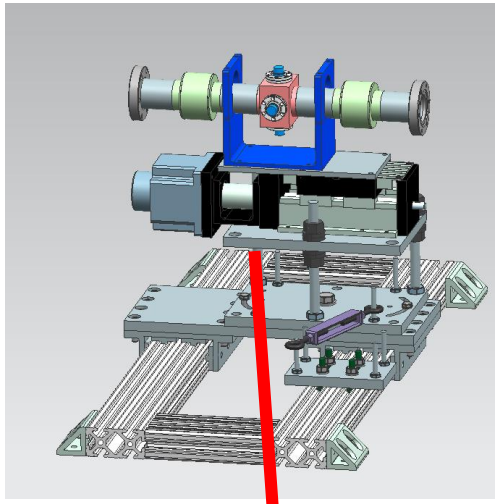


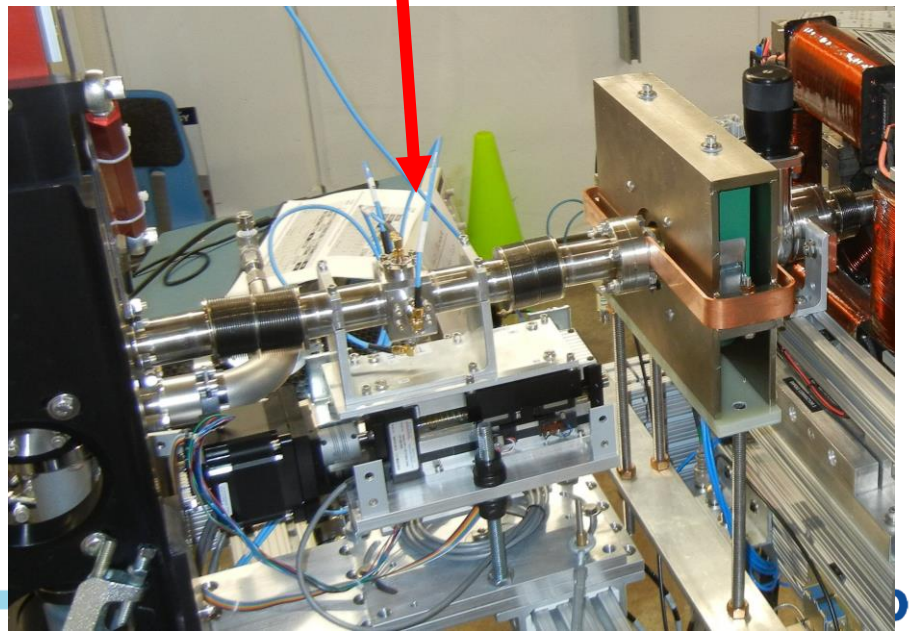


Beam Energy - Time of Flight (ToF) Movable BPM

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

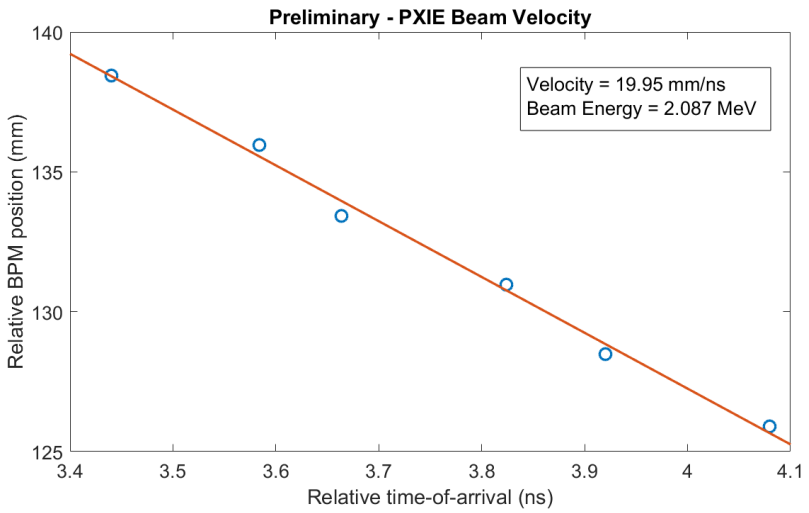


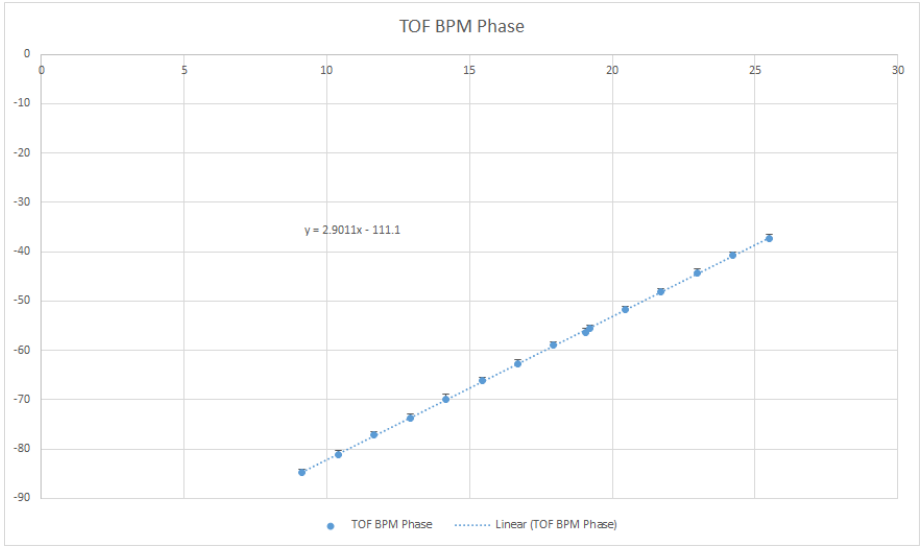


Status:

- Motion stage installed and operational
- BPM electronics returning phase
- DAQ and automatic energy scan software under test
- Initial energy measurements made manually

Preliminary RFQ Beam Energy Measurements



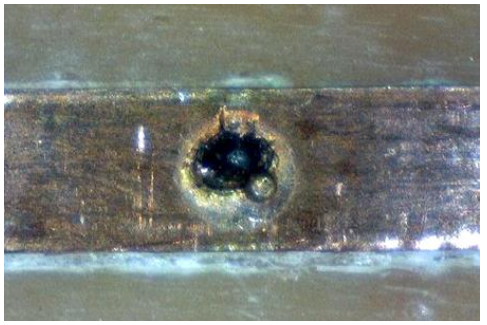


- Buncher cavity off
- Manual measurement
- Phase from raw waveforms
- Energy = 2.087 MeV

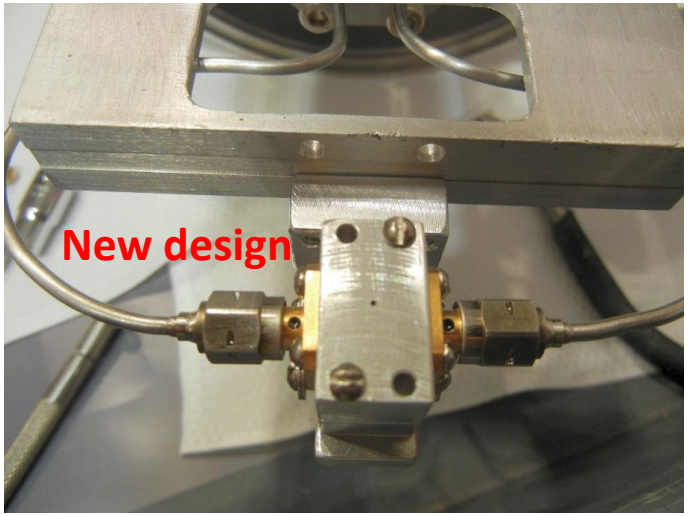
- Buncher cavity off
- Manual measurement
- Phase from BPM system
- Energy = 2.129 MeV

Bunch Length Measurements - New Fast Faraday Cup

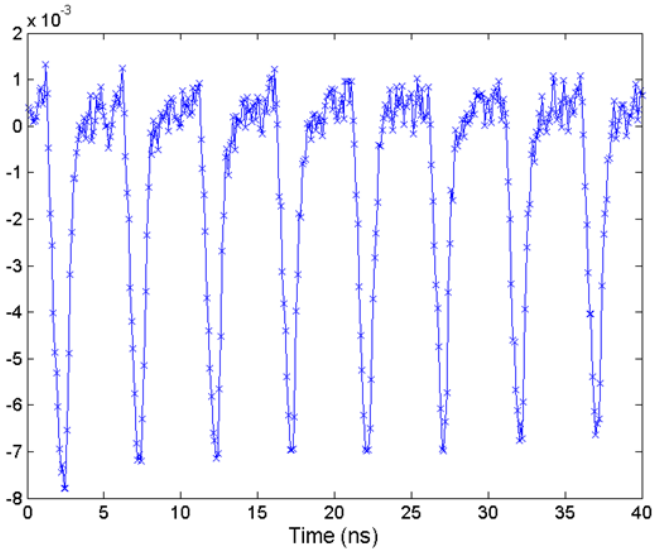
- Embedded 50 Ω stripline – initially designed by SNS
- High Bandwidth (> 6 GHz) – need scope DAQ
  - Beam damage at HINS (2.5 MeV protons)
  - We redesigned with better thermal properties
  - Limit beam to 20 μs pulses and < 0.1 Hz
- Old model tested at HINS and Linac
- Prototype new design tested in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

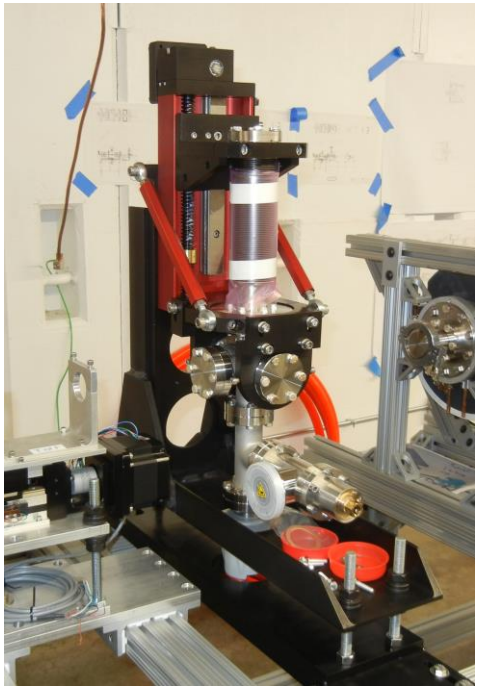


Old design - Damage with HINS beam



Linac MEBT Measurements



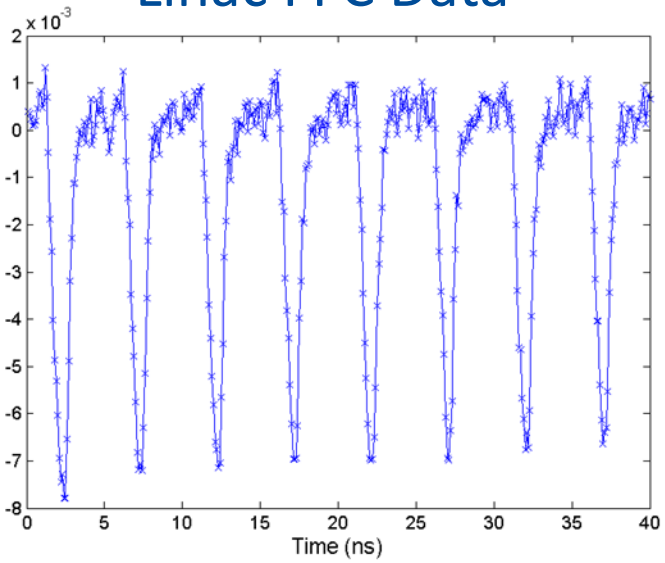


Initial FFC Measurements – Needs study

Red: FFC

Blue: ToF BPM Plate

Linac FFC Data



What's going on here? Looks like capacitive coupling.

Did we burn out stripline?

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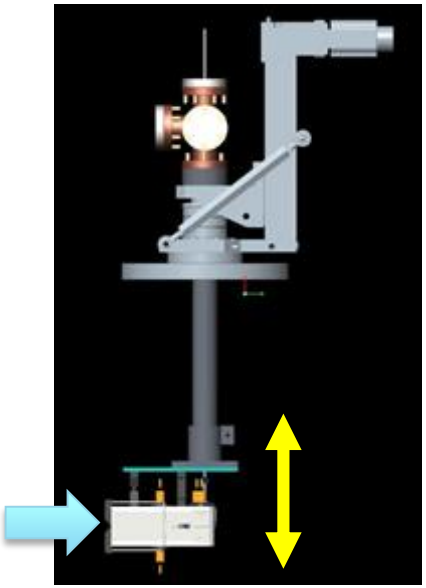
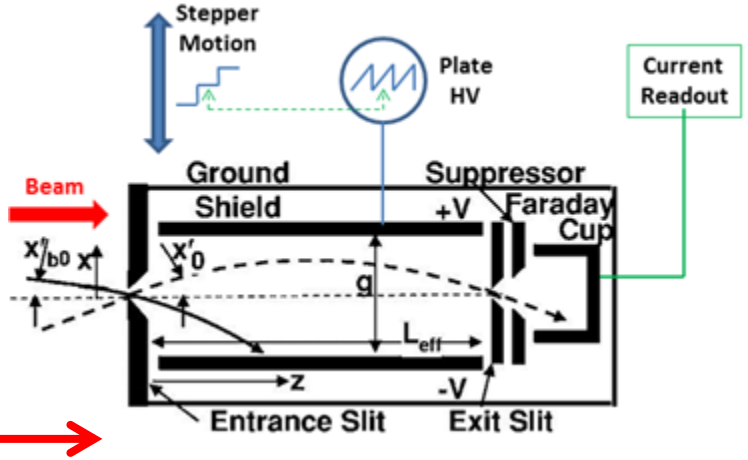
Allison Scanner for MEBT Emittance Measurements

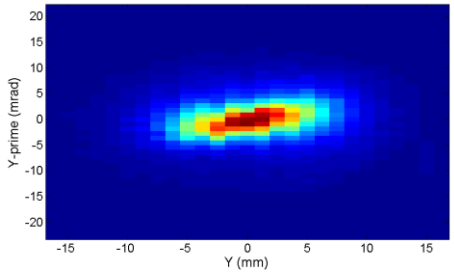
Design a water cooled Allison-style MEBT emittance scanner based on LEBT scanner

- Gives faster phase-space measurement
- Reuse LEBT electronics
- 2.1 MeV → requires longer deflector plates → requires more beam line space
- Tight alignment requirements
- Higher beam power → no CW operation

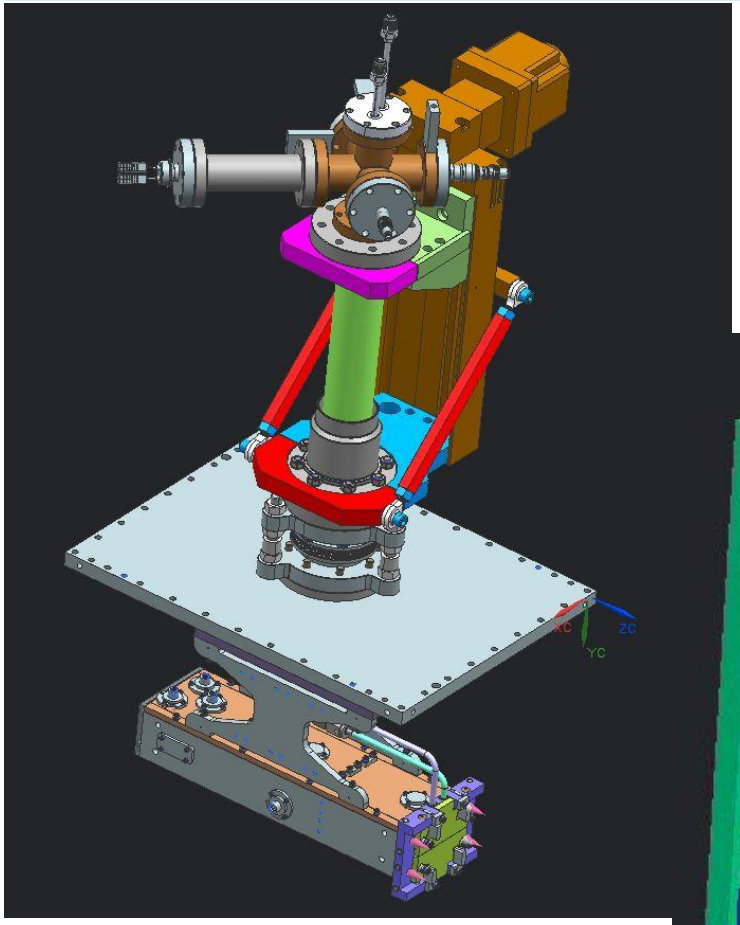
- Design numbers:
  - HV plate length: 300 mm
  - Flange-to-flange: < 450 mm
  - HV plate separation: 6 mm
  - Plate HV: ± 1 kV
  - ~ ± 10 mrad angular range
- Status:
  - Vacuum enclosure designed
    - Out for bids
  - Sensor design finished
  - Hardware coming in
  - Estimate August completion
  - Matt Alvarez lead engineer

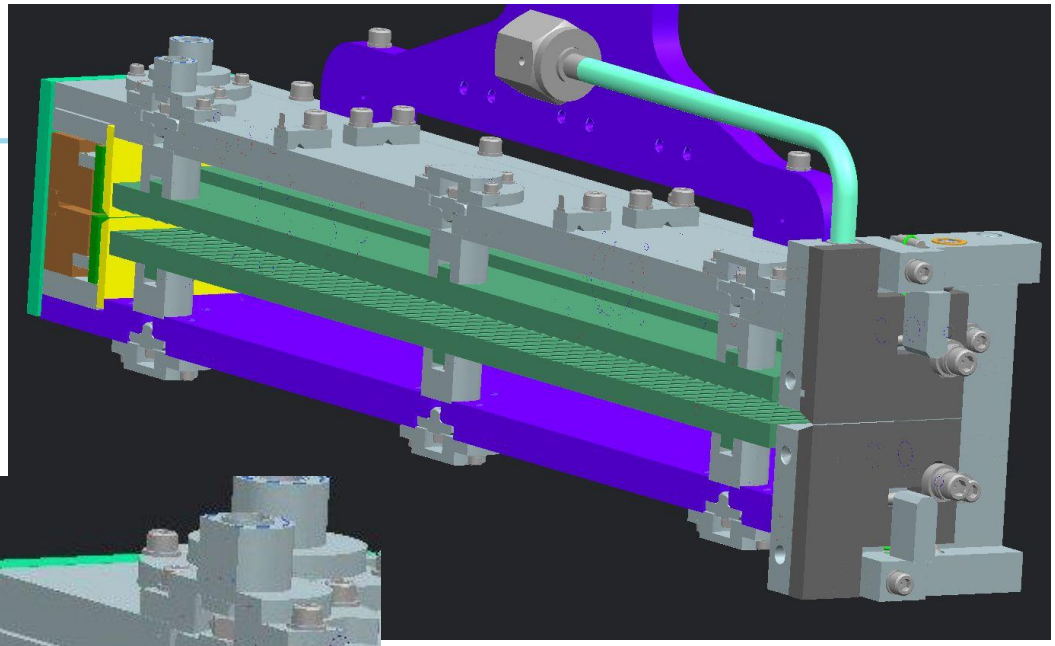


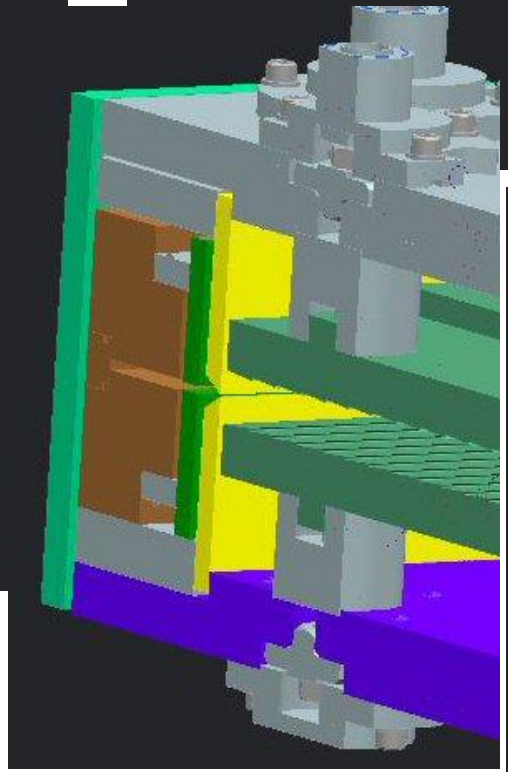


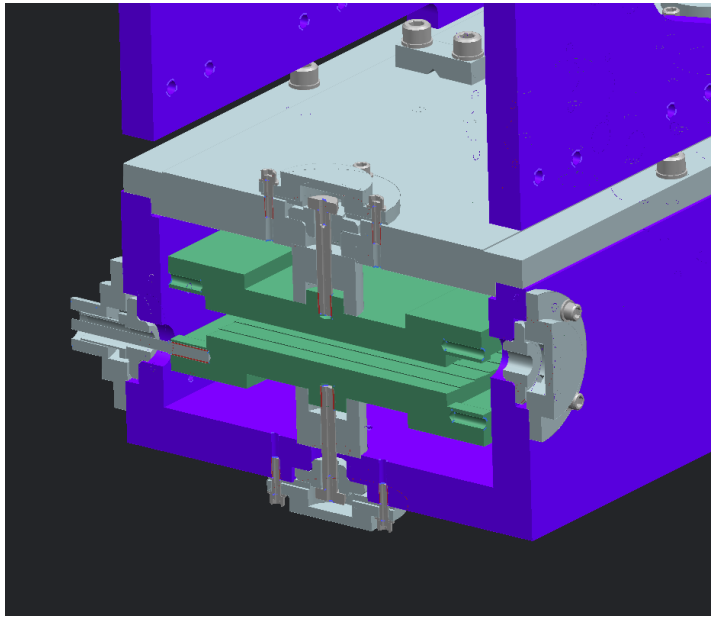


MEBT Emittance Scanner









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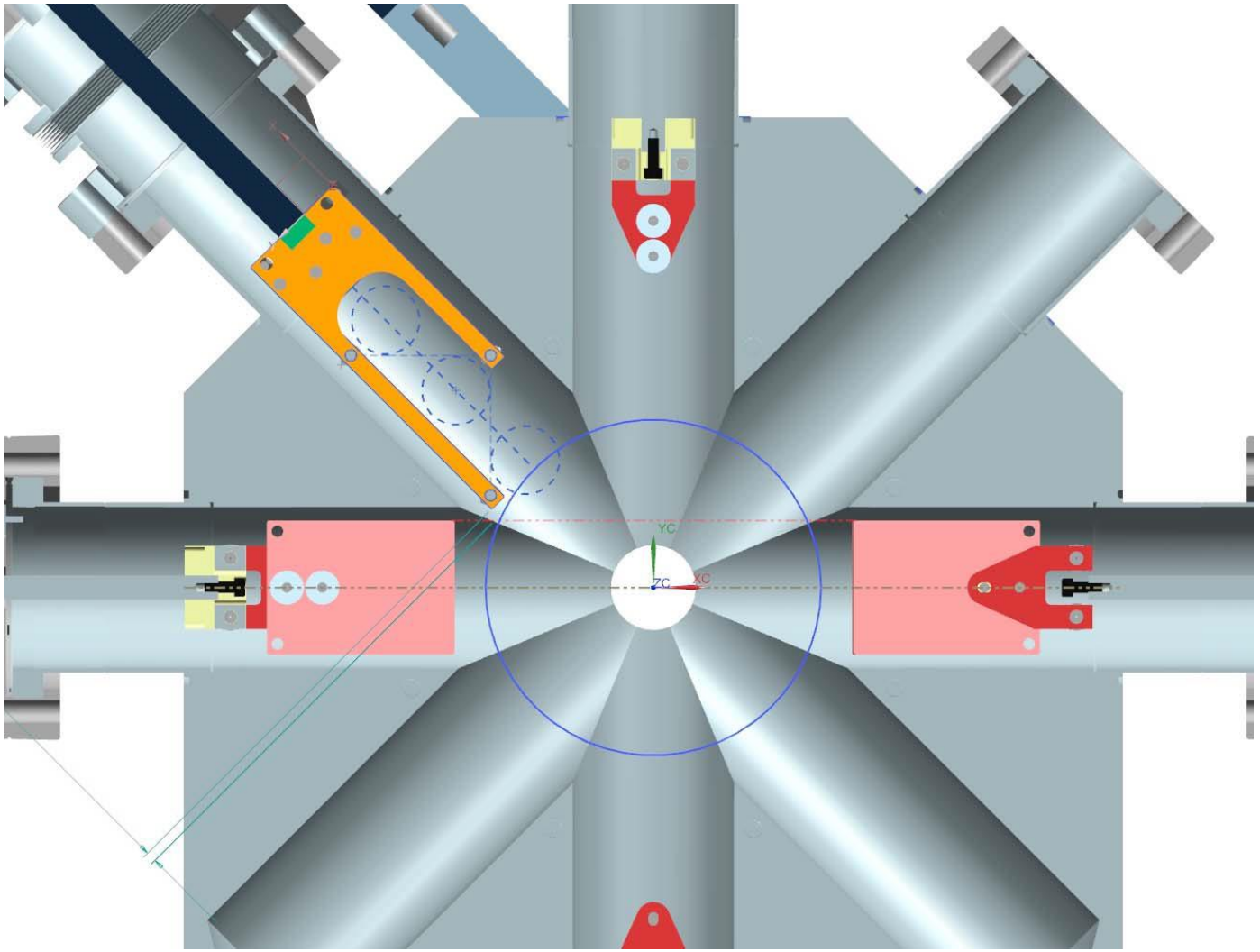
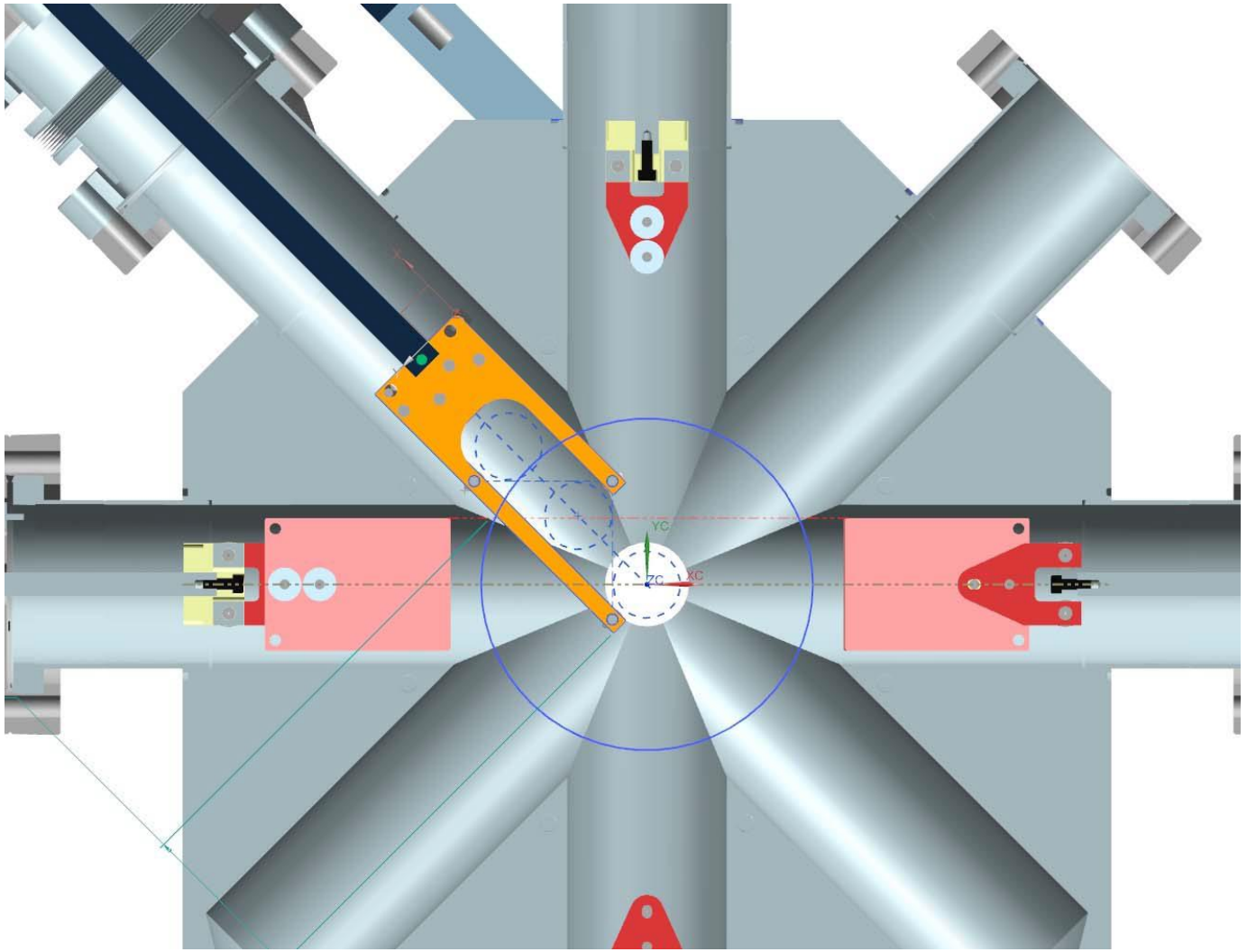
Prototype Wire Scanner

- Single wire scan – step transversely through beam
- Test in diagonal (45º) port of MEBT scraper
- Horizontal and vertical transverse profiles in one scan
- Can test different wire materials
  - Start with 50 micron tungsten-rhenium
- Mayling working on wire scanner design
- Motion stage ordered
  - Need to make motion test
- Completion date unclear - Funding limited

Prototype Wire Scanner



Prototype Wire Scanner



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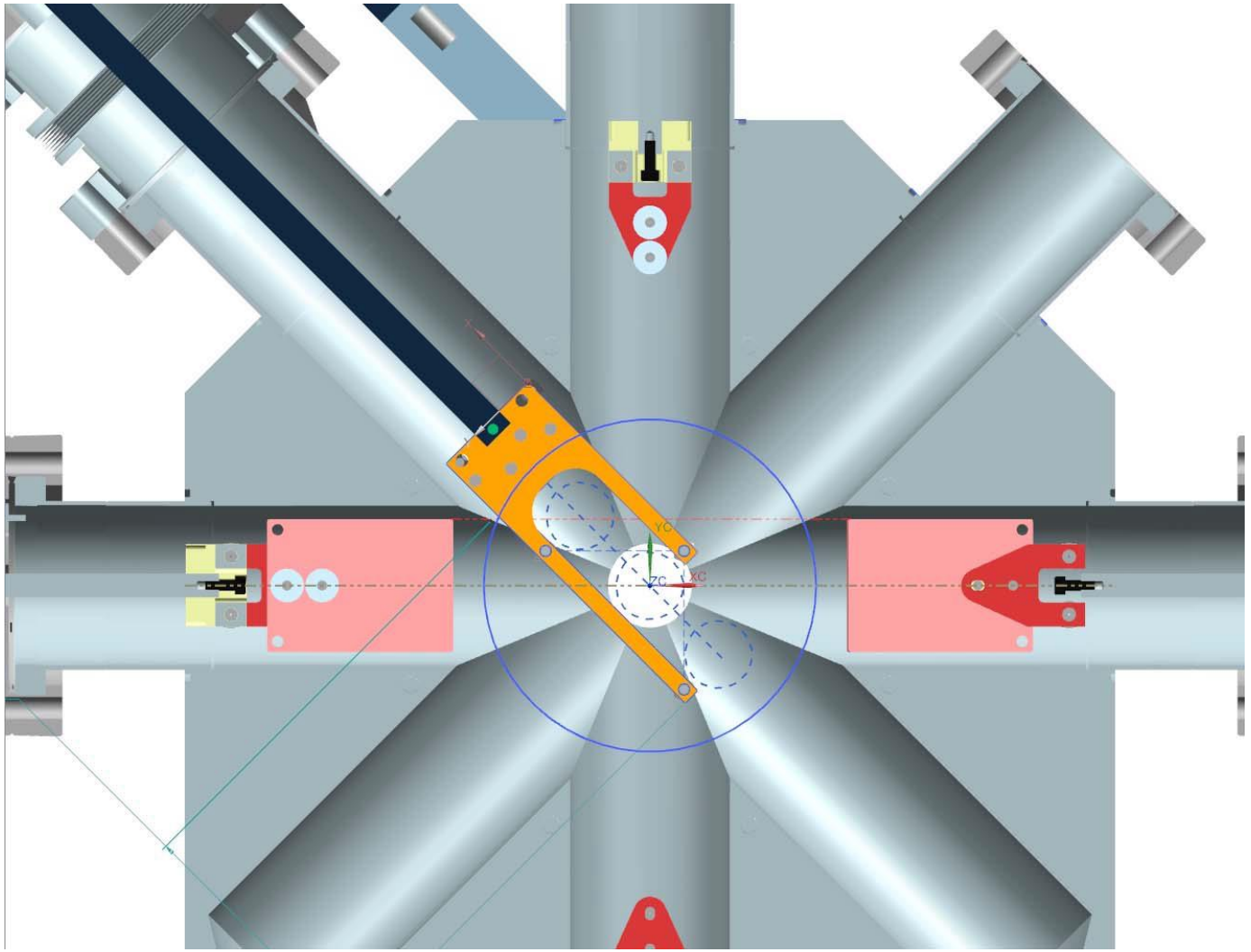

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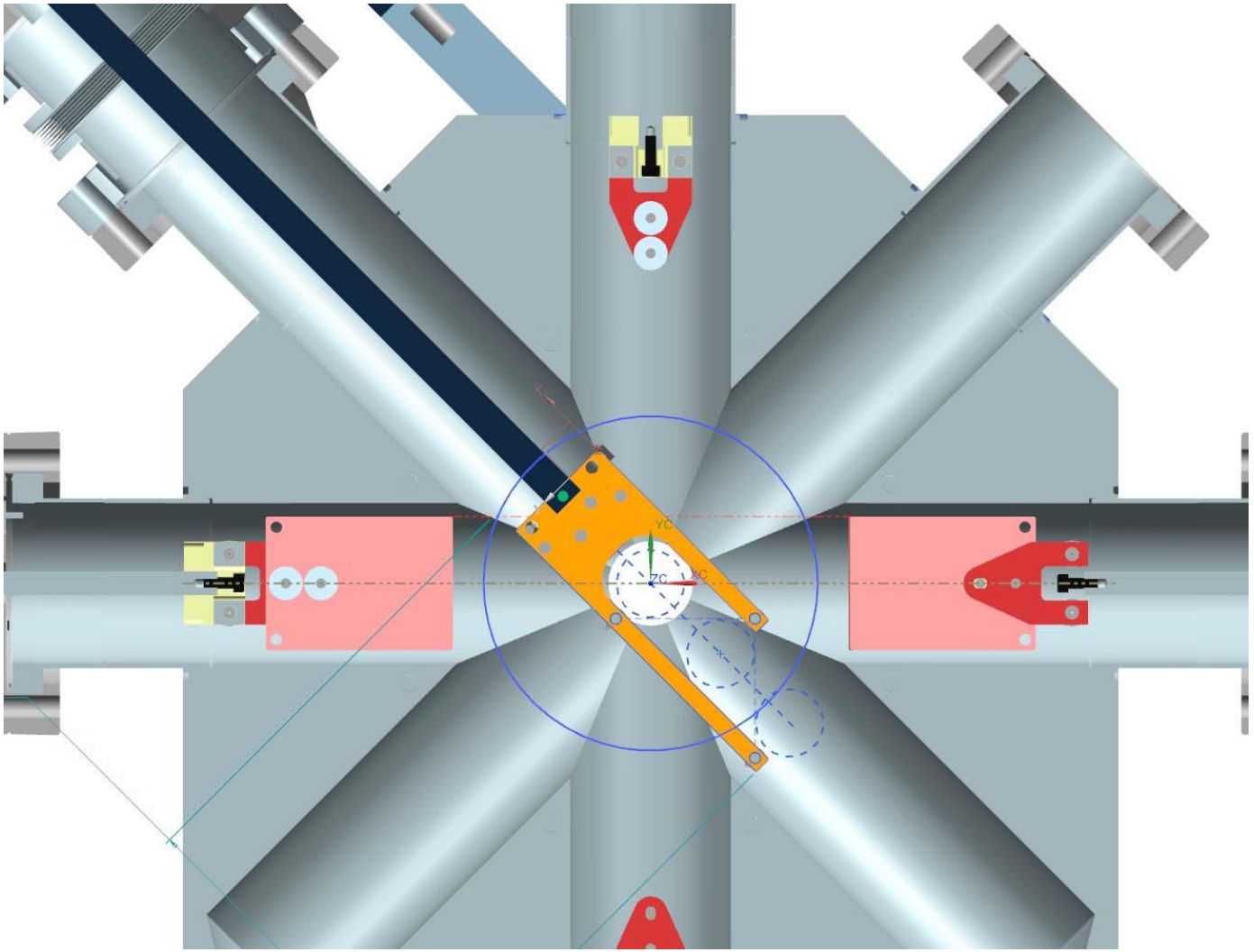

Summary

- All initial MEBT 1.1 instruments installed in beamline
- All instruments into ACNET readout – *except FFC*
- Integrating necessary devices into MPS
- Systems in commissioning phase
  - Need to verify operations and understand systematics