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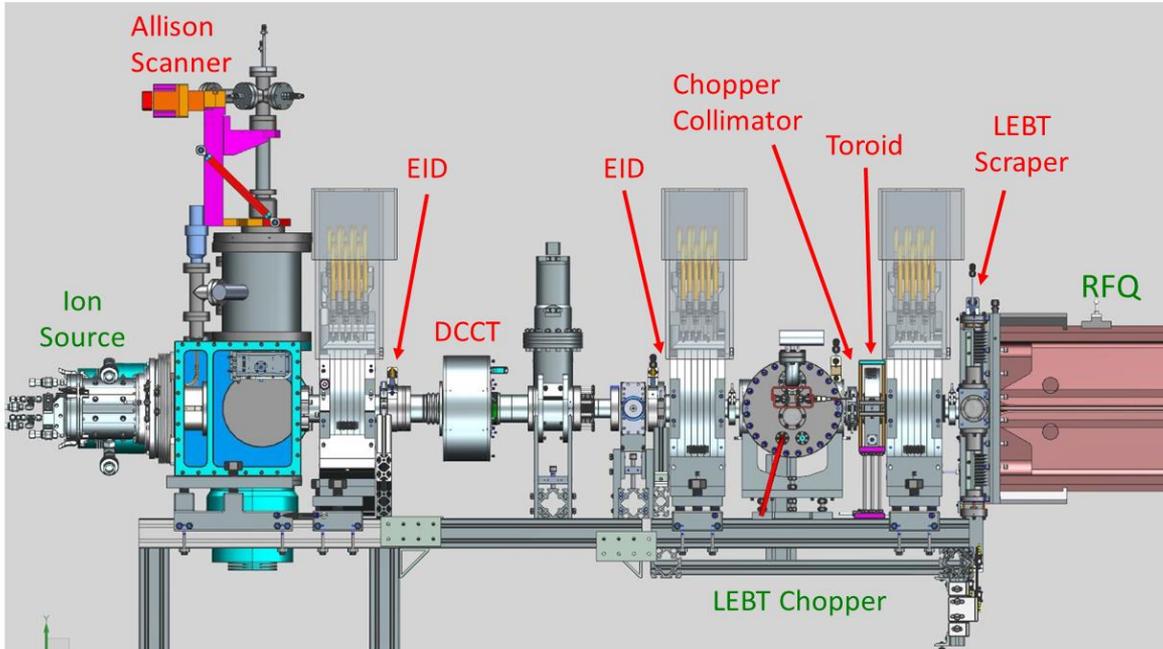
PXIE Beam Instrumentation Status Update

Vic Scarpine

Weekly PIP-II Meeting

June 7, 2016

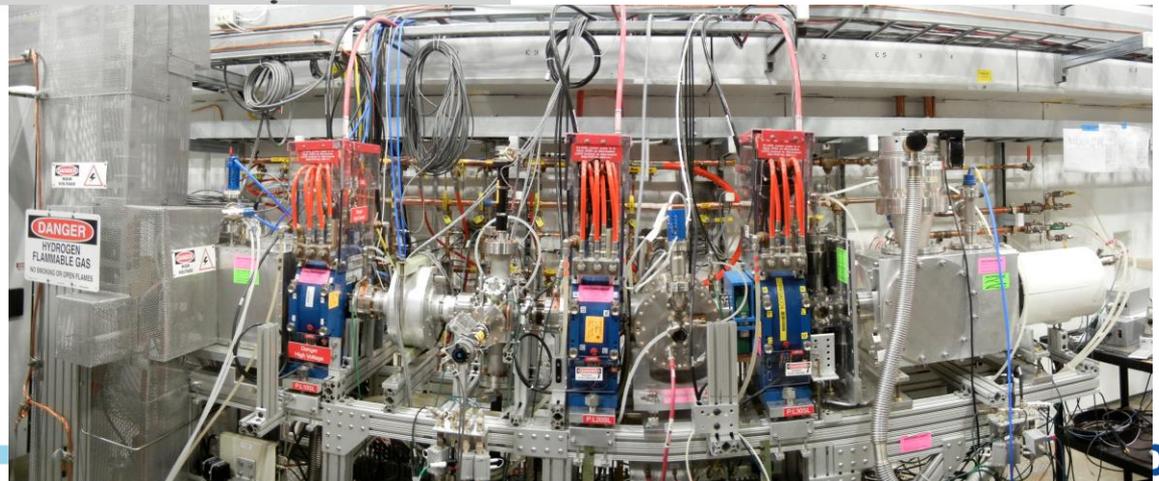
PXIE LEBT Instrumentation Development



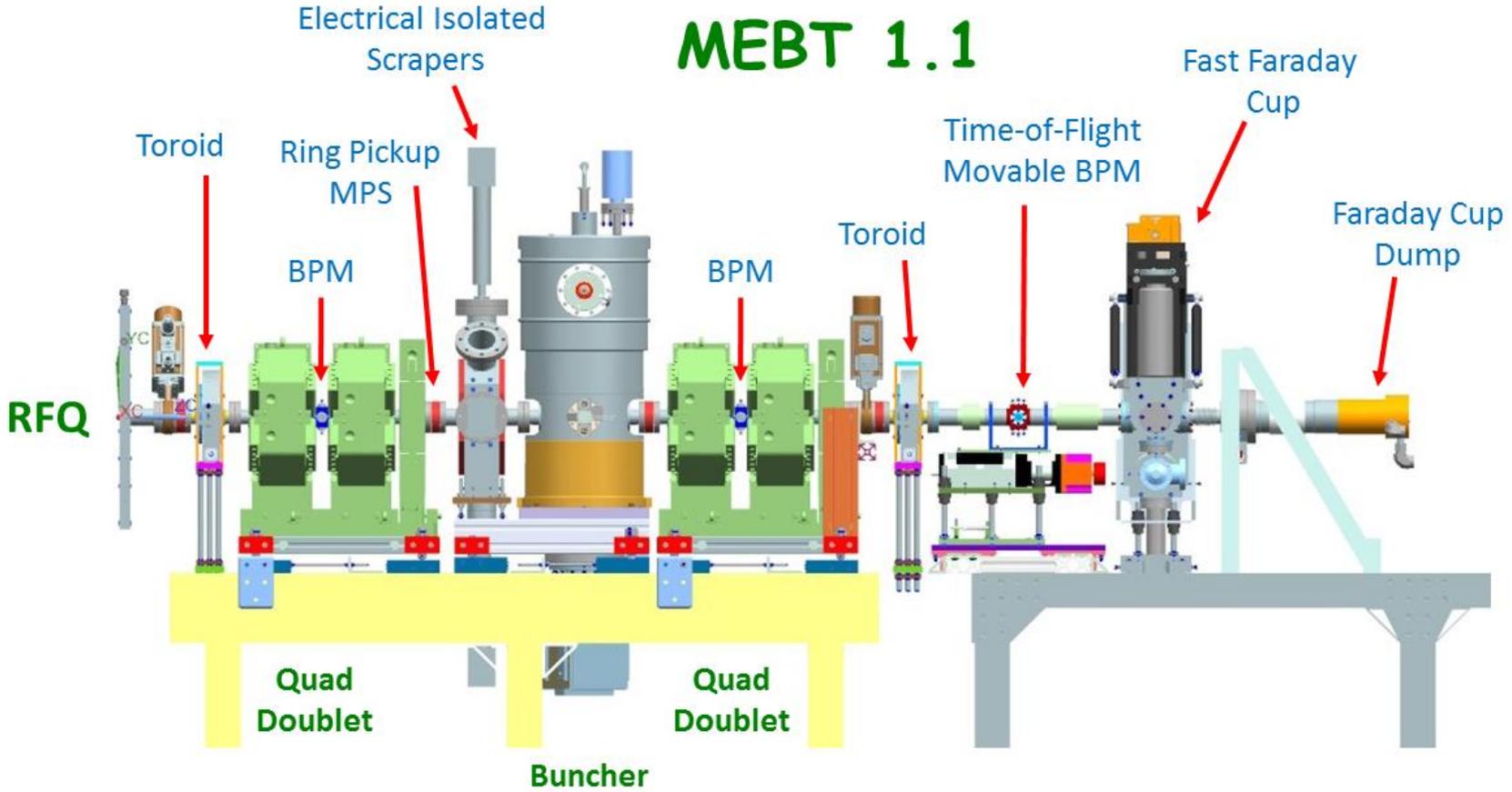
Beam Current Measurements

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

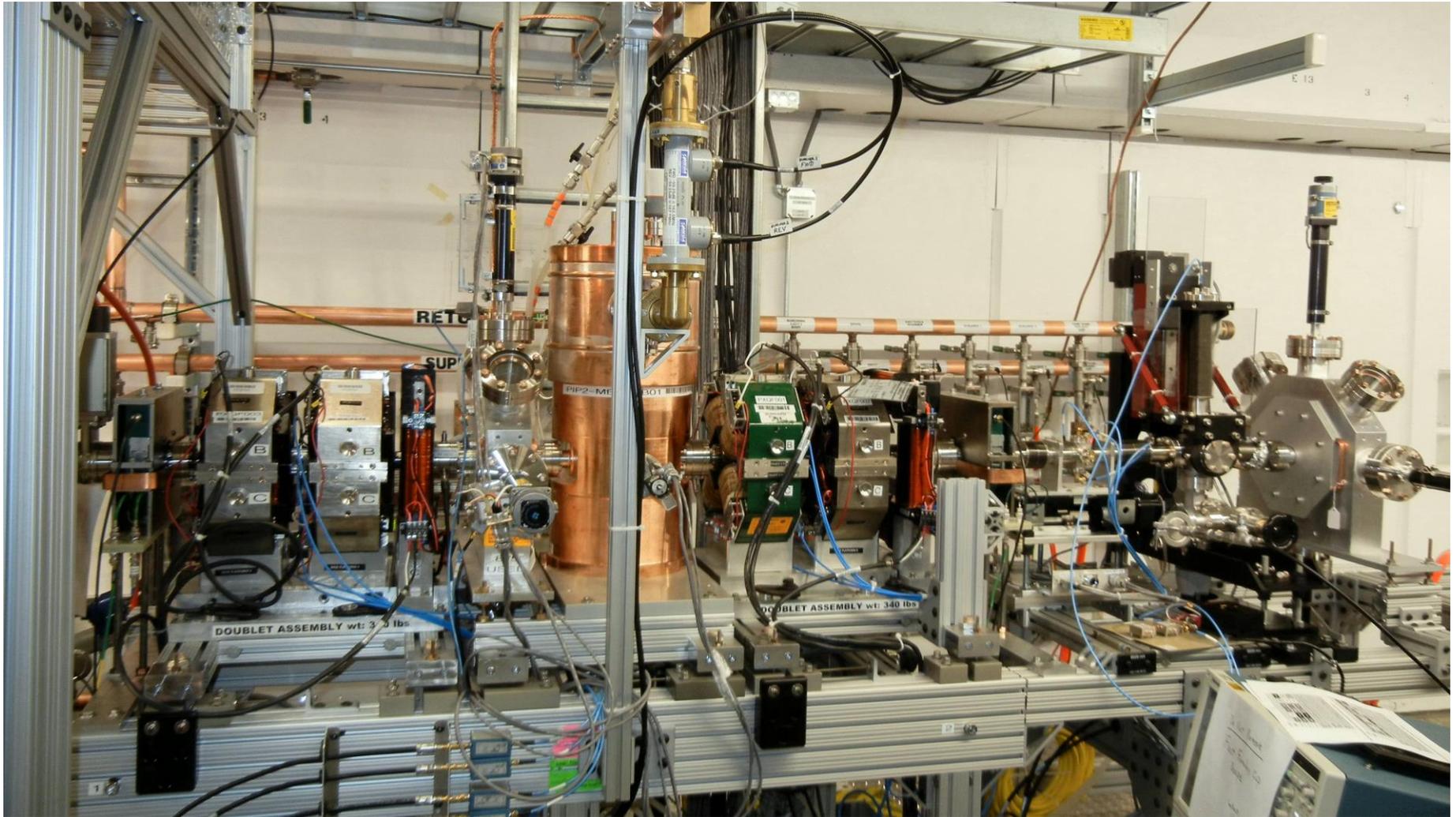
Much of past year has been in the development and support of the PXIE LEBT. Now switching over to MEBT



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 μ sec**
 - **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 μ s
- 50 mV signal
- 60 db gain

PXIE Electrically Isolated Pickups (EIP)

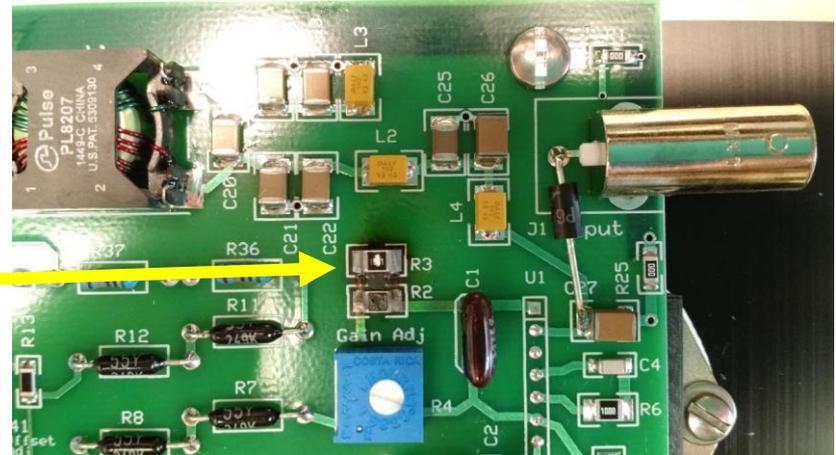
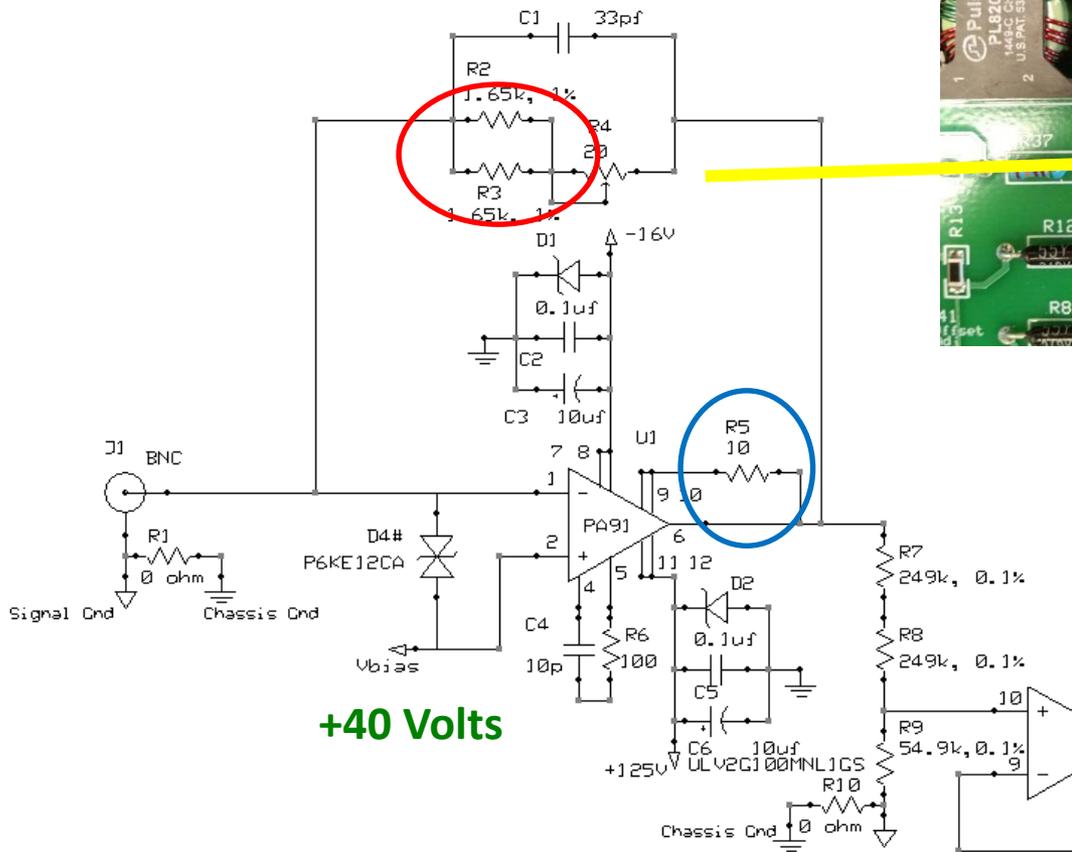
MEBT EIP Update

- 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

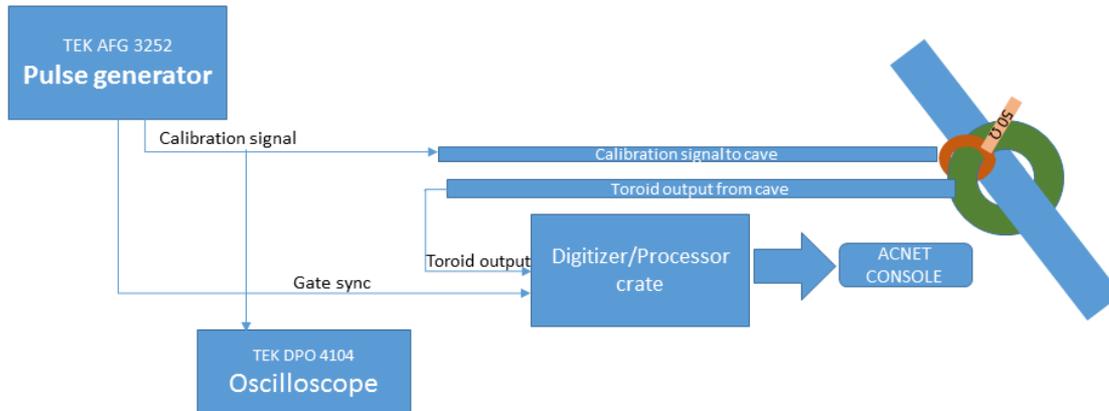
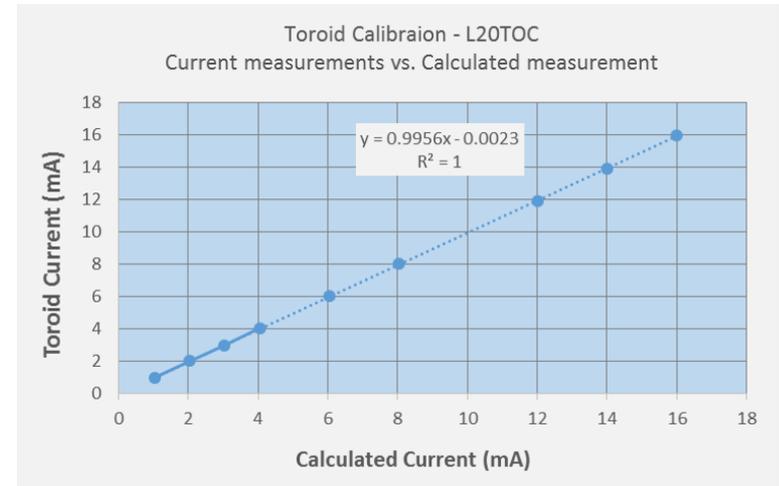
Scraper Short Problem for Bias Electronics



- 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

```

PA P126Ion Source<NoSets><NewDPM-CLX37 (0%)>
P126 All currents pulsed          SET      D/A    A/D    Com-U  ♦PTools♦
-<FTP>+ *SA♦ X-A/D X=TIME          Y=L:Q22 ,Z TEXTV ,Z TARCI ,Z TPRES
COMMAND ---- Eng-U I= 0          I= 140 , 0 , 0 , 1.0E-07
-< 5>+ One+ AUTO F= 600          F= 150 , -40 , 20 , 1.0E-05
source vacuum water DIAG        pwrsply chopper mps.... misc

! Beam currents

P:LSDCC      LEBT DCCT Current S&H          * -4.639 mA
P:L20TOC     LEBT Toroid Current          -4.7975229 mA
! For DCCT, truthfull at 10 Hz, 1 ms pulses

P:L20APC     Absorber Plate Curr S&H      * -.336 mA
P:L30ZPC     LEBT Scraper Current S&H     * -.015 mA

P:R50TOC     MEBT Toroid 1 Current        -4.5162392 mA
P:M15TOC     MEBT Toroid 2 Current        -4.2204069 mA
P:MX1FPC     SNS Dump Cur                -4.4704059 mA

! Electrodes current
P:L10EPC     Sol1 Iso Diaphragm S&H      * -2.495 mA
P:L20EPC     Sol2 Iso Diaphragm S&H      * -2.415 mA
P:L21EPC     LEBT Collimator S&H         -10.13 mA

P:MX5PTC     MEBT Dump Scr T Cur         -.0386481 mA
P:L20TOW     LEBT Toroid Gate Wid        102 us
P:R50TOW     MEBT Toroid 1 Gate Wi       102 us

! RFQ Transmission
#P:R50TOC/(P:L20TOC-P:L30ZPC)          .94441187 ???

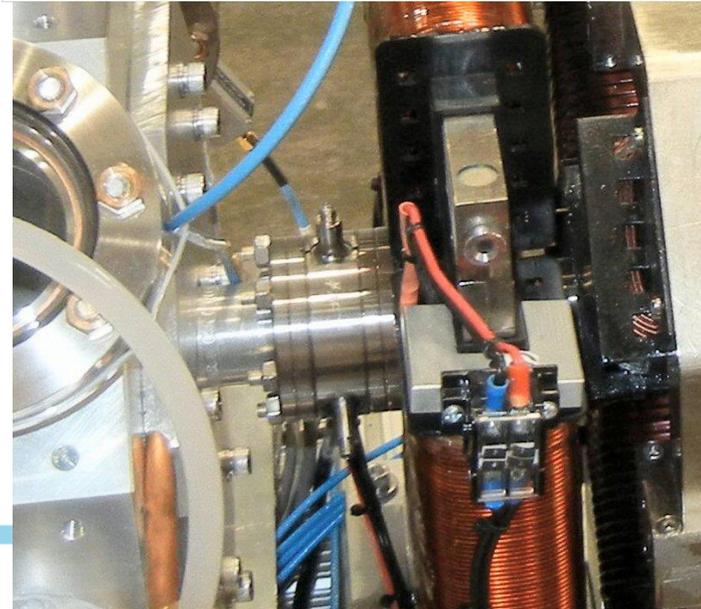
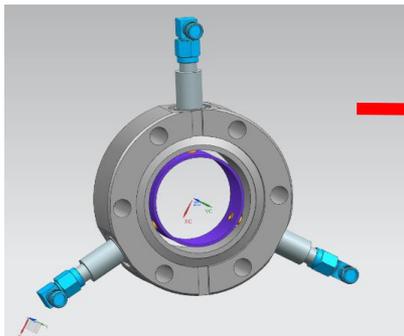
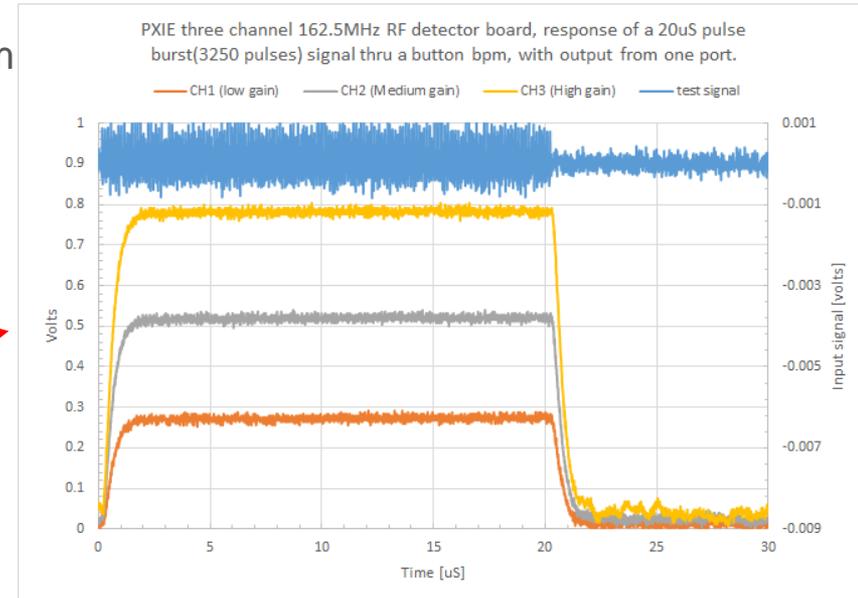
! Averaged toroid
-P:L20TOA    LEBT Toroid Current Avg      10 -4.765 mA
-P:R50TOA    MEBT Toroid 1 Current Av     10 -4.528 mA
-P:M15TOA    MEBT Toroid 2 Current Av     10 -4.312 mA
!MEBT scraper pulsed current readback
P:M01PRC     MEBT Scr 1 Right Cur          -.00105622 mA
P:M01PLC     MEBT Scr 1 Left Cur          -.0005554 mA
P:M01PBC     MEBT Scr 1 Bottom Cur       -.00103585 mA
P:M01PTC     MEBT Scr 1 Top Cur          .00015954 mA

P:M11PRC     MEBT Scr 2 Right Cur          -.07787885 mA
P:M11PLC     MEBT Scr 2 Left Cur         -.08501465 mA
P:M11PBC     MEBT Scr 2 Bottom Cur       -.11980333 mA
P:M11PTC     MEBT Scr 2 Top Cur          -.17685819 mA

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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 – under test**
 - Eventual operation with CW beam



MEBT BPM Development

Requirements:

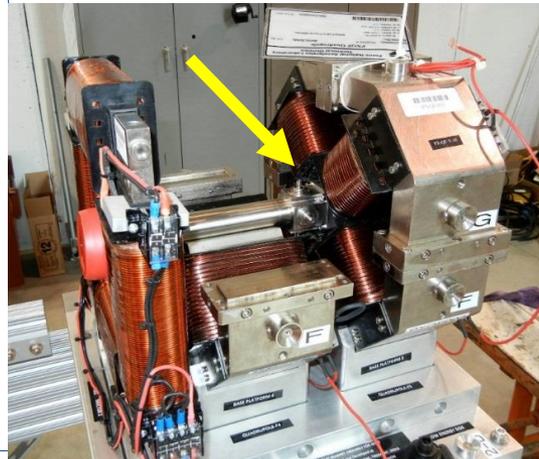
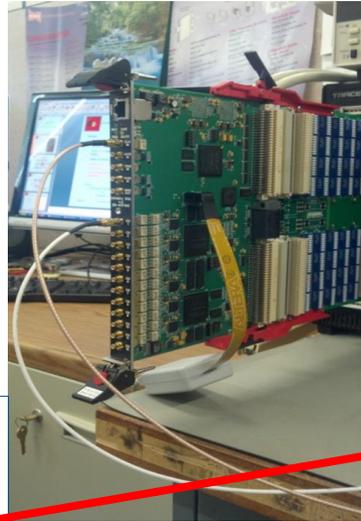
	Accuracy	Precision
Position, μm	10	30
Phase, degrees of 162.5 MHz	0.05	0.2
Relative intensity, %	1	3

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**



BPM Readings in ACNET

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

```

PA P126Ion Source<NoSets><NewDPM-CLX37 (0%)>
P126 MEBT BPM                               SET      D/A      A/D      Com-U  ♦PTools♦
-<FTP>+ *SA♦ X-A/D  X=TIME      Y=L:Q22  ,Z TEXTV ,Z TARC1 ,Z TPRES
COMMAND ---- Eng-U  I= 0      I= 140   , 0      , 0      , 1.0E-07
-<12>+ One+ AUTO  F= 600    F= 150   ,-40     , 20     , 1.0E-05
source vacuum water  DIAG      pwrsply chopper mps.... misc

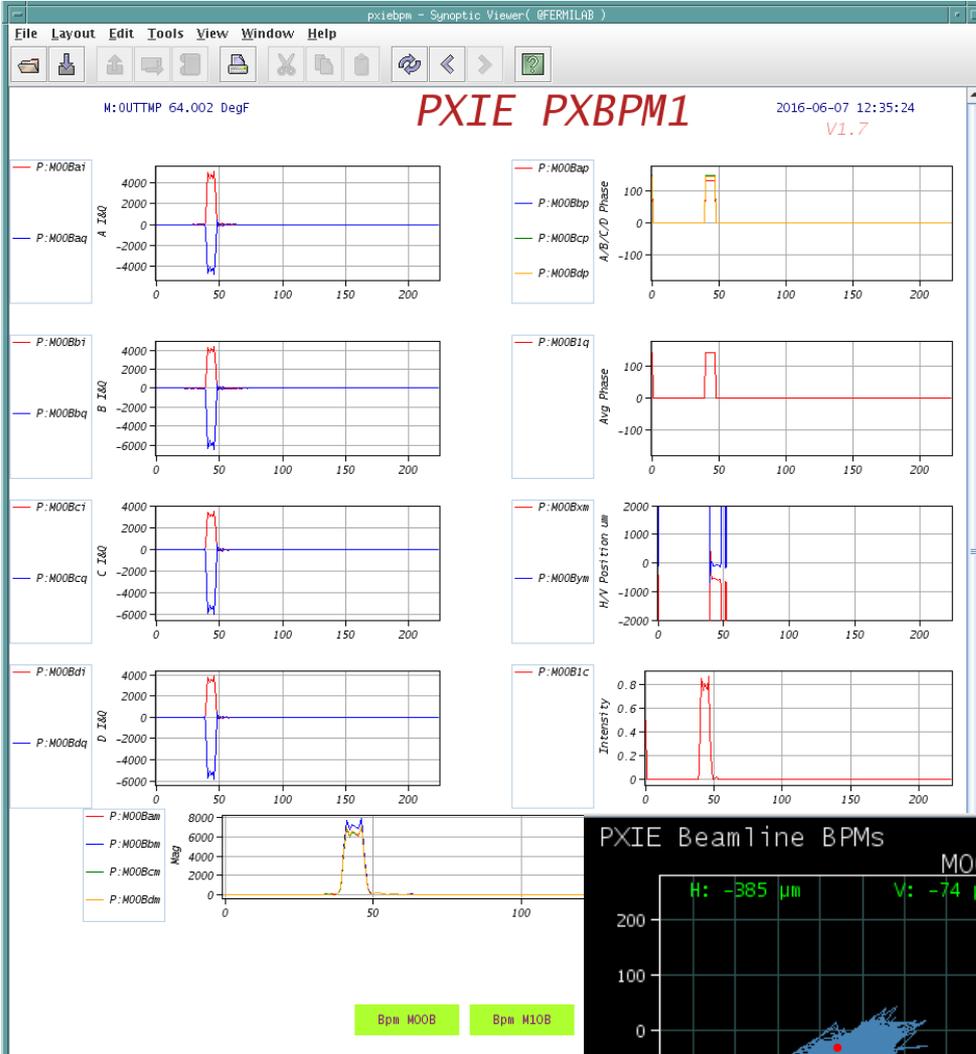
P:M00B1C      BPM1 Intensity                .50282246
P:M00BXM      BPM1 Horizontal Posit       -412.84688
P:M00B1Q      BPM 1 Average Phase         143.27744
P:M00BYM      BPM1 Vertical Positio      -64.596977

P:M10B1C      BPM2 Intensity                .49076498
P:M10BXM      BPM2 Horizontal Posit       -789.34116
P:M10B1Q      BPM 2 Average Phase         43.898575
P:M10BYM      BPM2 Vertical Positio      -366.71862

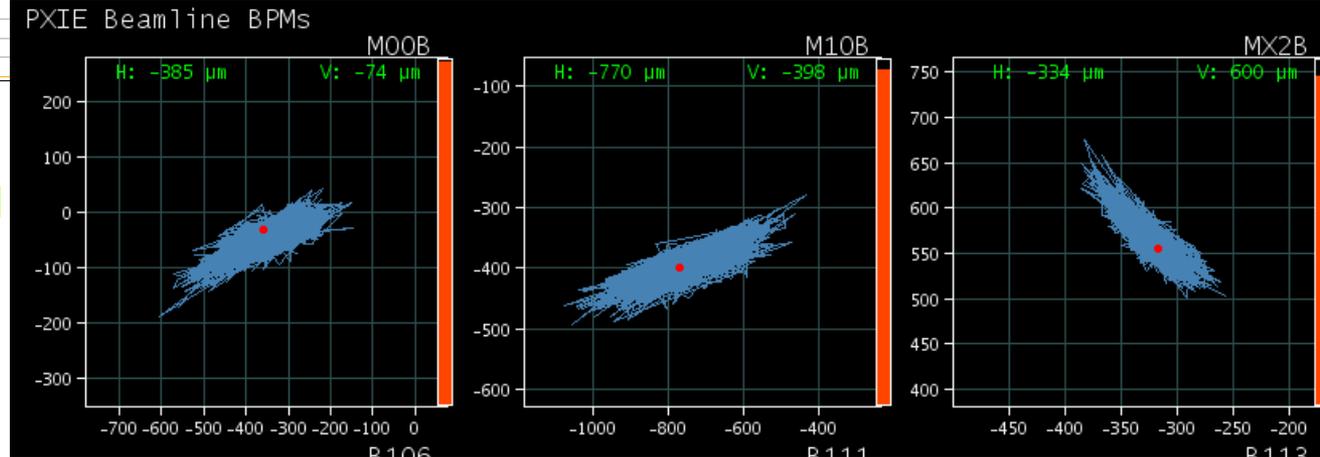
P:MX2B1C      BPM3 Intensity                .48256803
P:MX2BXM      BPM3 Horizontal Posit       -322.92667
P:MX2B1Q      BPM 3 Average Phase        -114.93311
P:MX2BYM      BPM3 Vertical Positio         566.29461

P:MX2BAQ      BPM3 Q                        -5
P:MX2BBQ      BPM3 Q                        -5
P:MX2BCQ      BPM3 Q                        -4
P:MX2BDQ      BPM3 Q                        -3

```



BPM Diagnostic Tools



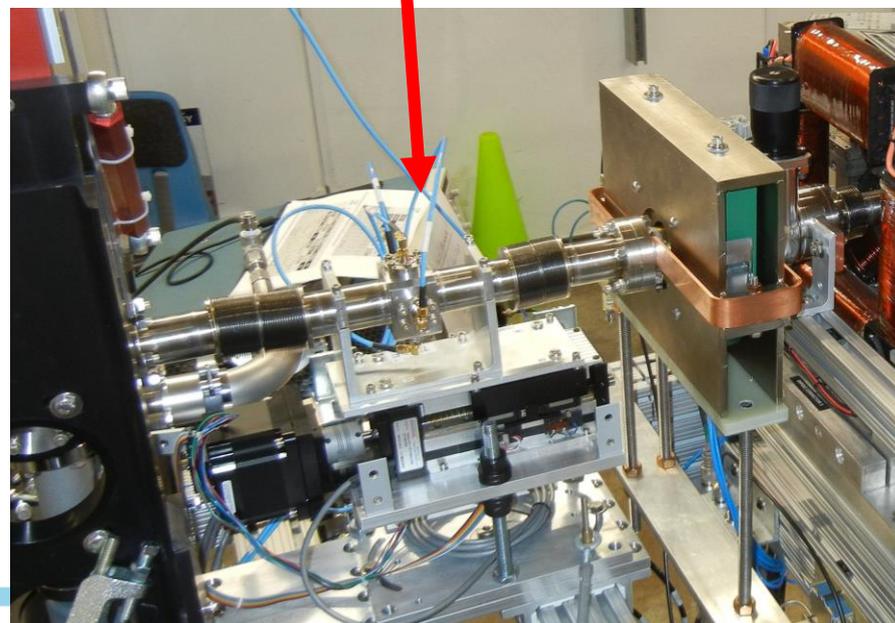
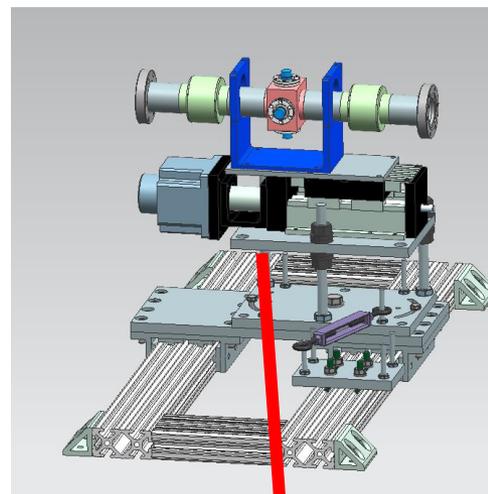
Beam Energy - Time of Flight (ToF) Movable BPM

Measure beam velocity (\rightarrow energy) via ToF

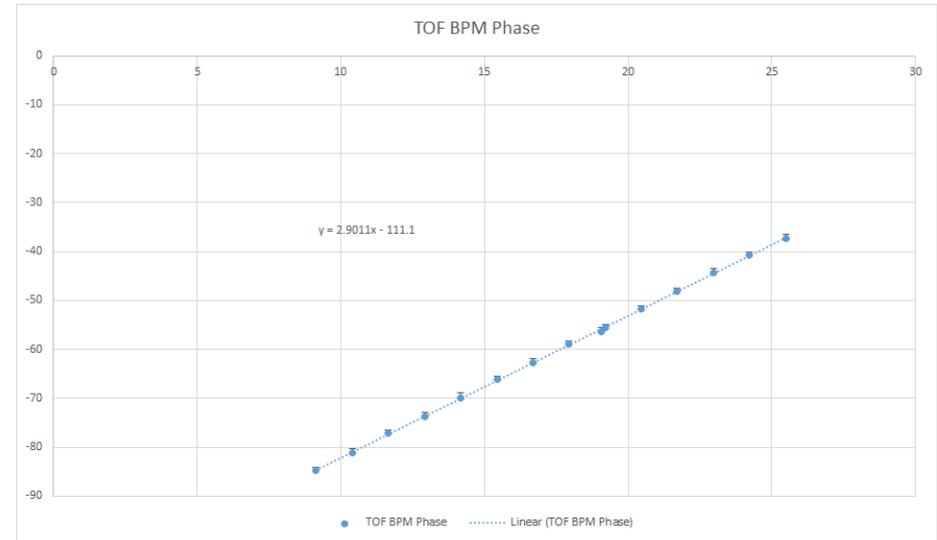
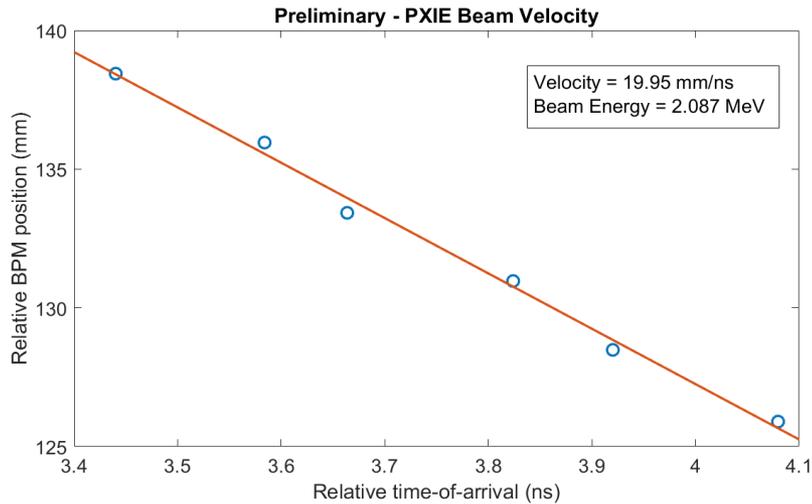
- Utilize movable BPM to minimize systematics
 - e.g. BPM response, bunch shape effects
- Use HINS BPM on linear stage
 - $\sim 1''$ of travel; $\sim 10 \mu\text{m}$ resolution
 - Allows for “continuous” phase measurements
 - **Expected MEBT energy resolution: 0.1% @ 2.1 MeV**

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

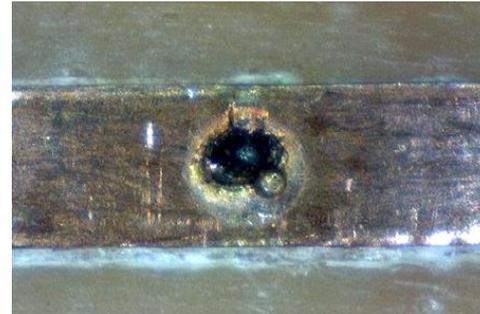


- Buncher cavity off
- Manual measurement
- Phase from raw waveforms
- Energy = 2.087 MeV

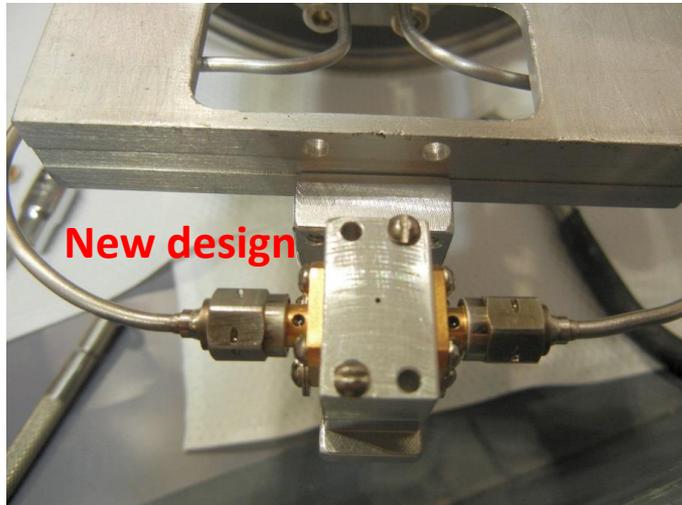
- Buncher cavity off
- Manual measurement
- Phase from BPM system
- Energy = 2.129 MeV

Bunch Length Measurements - New Fast Faraday Cup

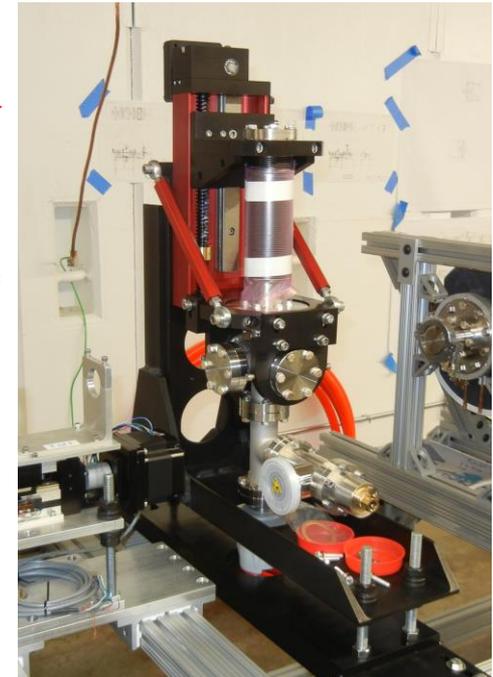
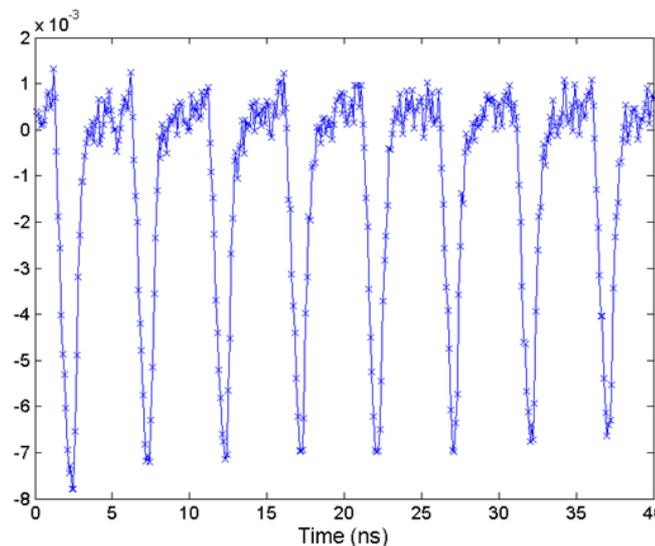
- Embedded $50\ \Omega$ stripline – initially designed by SNS
- High Bandwidth ($> 6\ \text{GHz}$) – need scope DAQ
 - Beam damage at HINS (2.5 MeV protons) →
 - We redesigned with better thermal properties
 - **Limit beam to $20\ \mu\text{s}$ pulses and $< 0.1\ \text{Hz}$**
- Old model tested at HINS 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



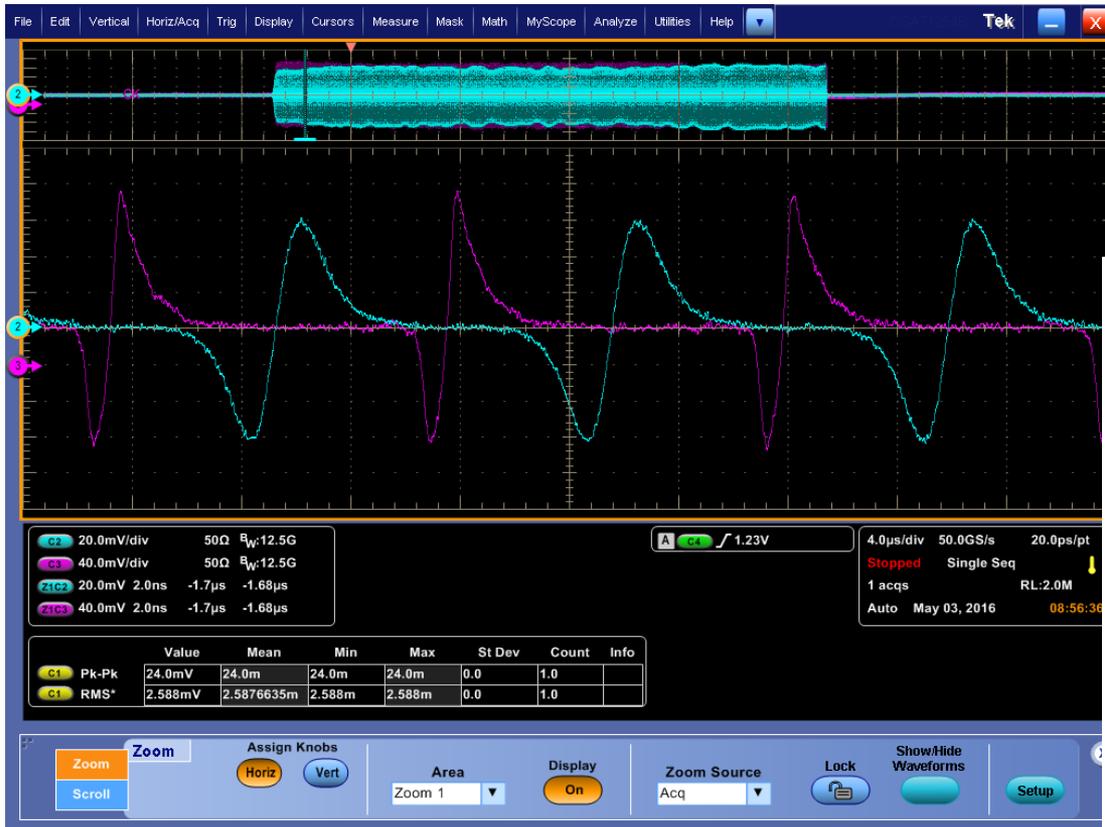
Linac MEBT Measurements



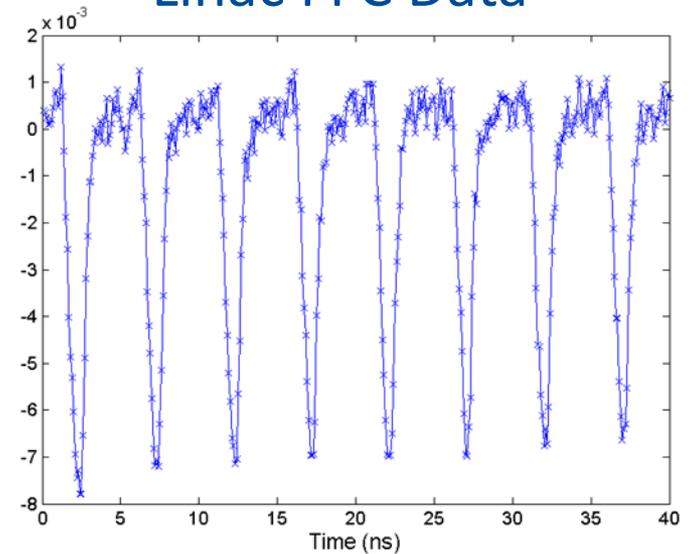
Initial FFC Measurements – Needs study

Red: FFC

Blue: ToF BPM Plate



Linac FFC Data



What's going on here? Looks like capacitive coupling.
Did we burn out stripline?

Allison Scanner for MEBT Emittance Measurements

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

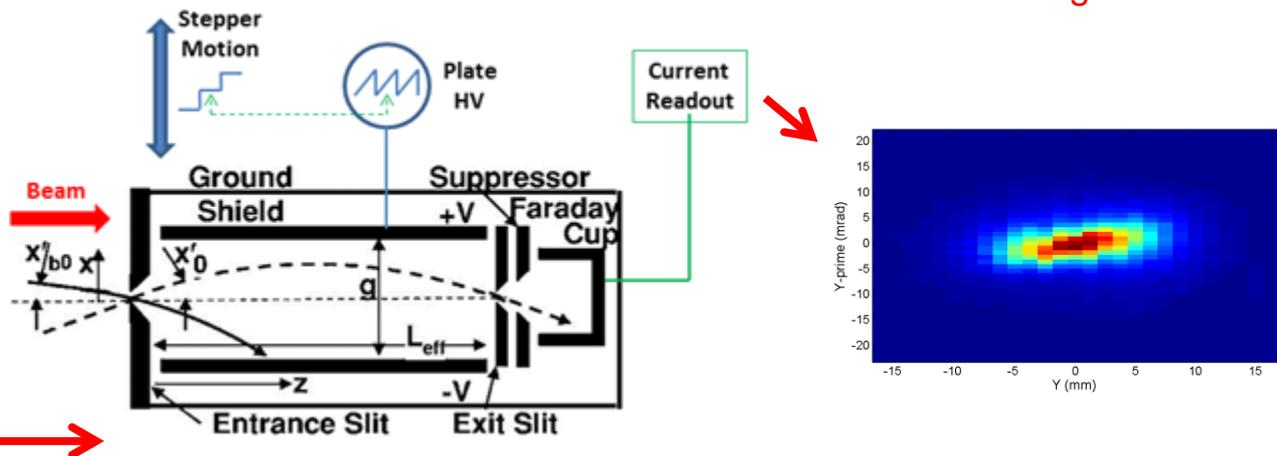
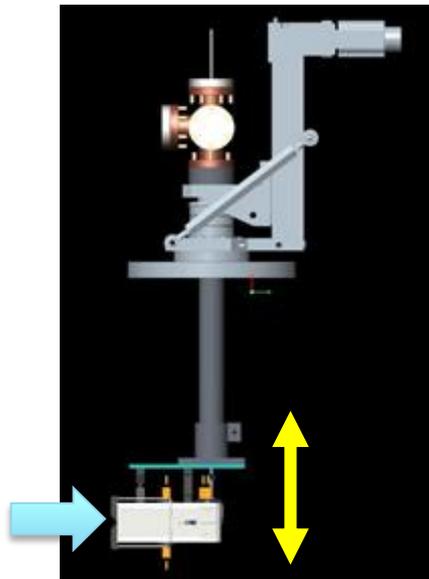
- Gives faster phase-space measurement
- Reuse LEBT electronics
- 2.1 MeV → requires longer deflector plates → requires more beam line space
- Tight alignment requirements
- Higher beam power → no CW operation

• Design numbers:

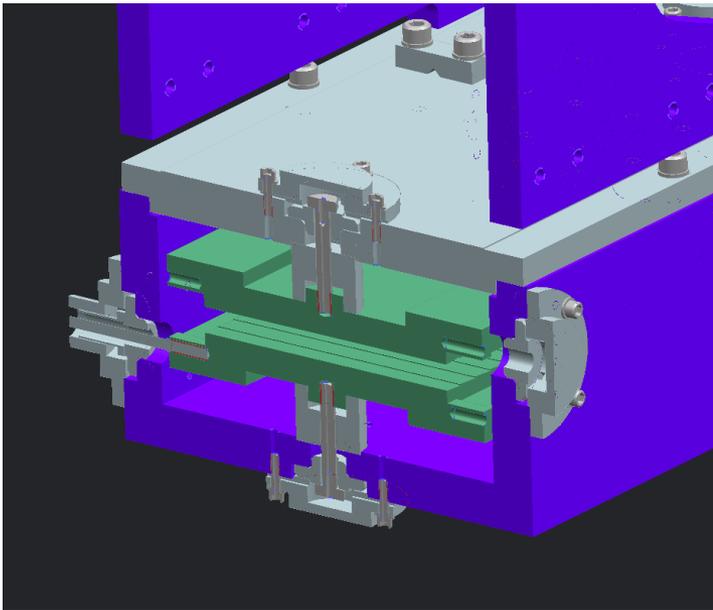
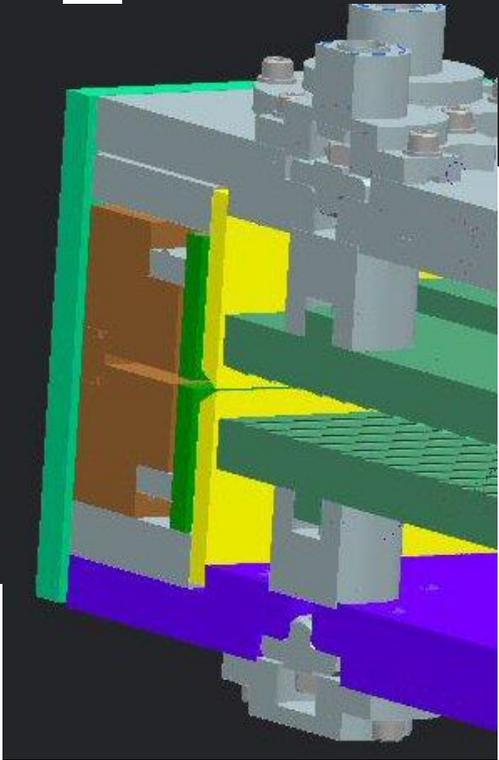
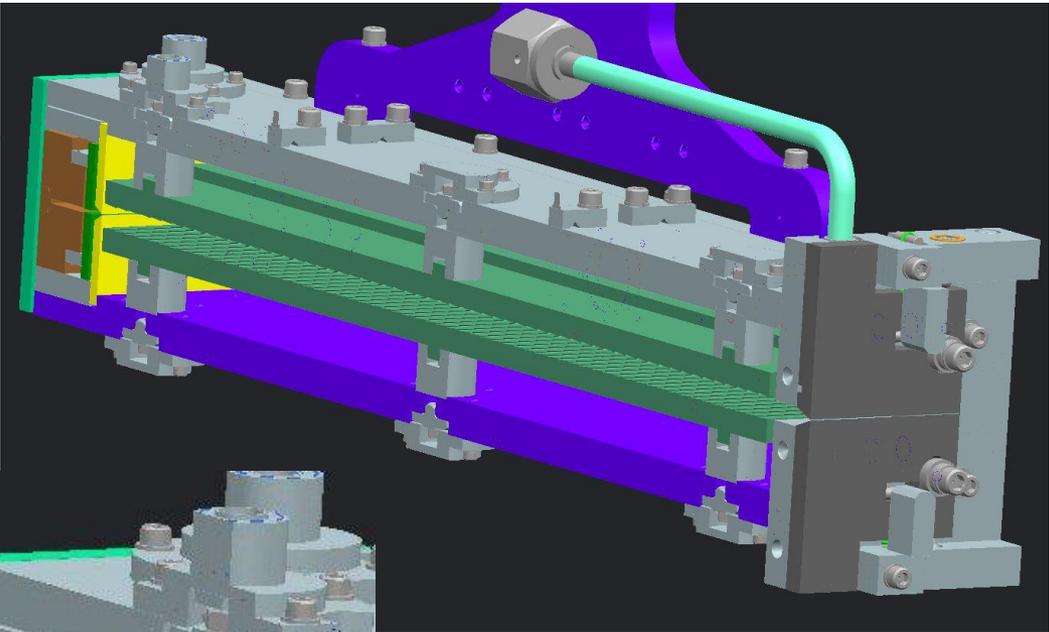
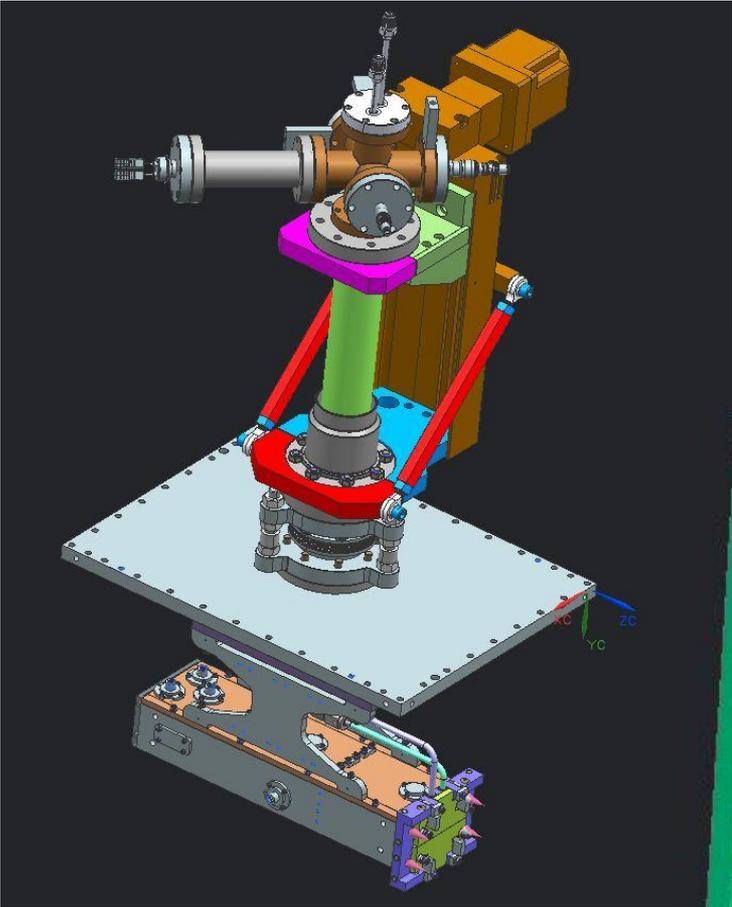
- HV plate length: 300 mm
- Flange-to-flange: < 450 mm
- HV plate separation: 6 mm
- Plate HV: ± 1 kV
- $\sim \pm 10$ mrad angular range

• Status:

- Vacuum enclosure designed
 - Out for bids
- Sensor design finished
- Hardware coming in
- Estimate August completion
- Matt Alvarez lead engineer



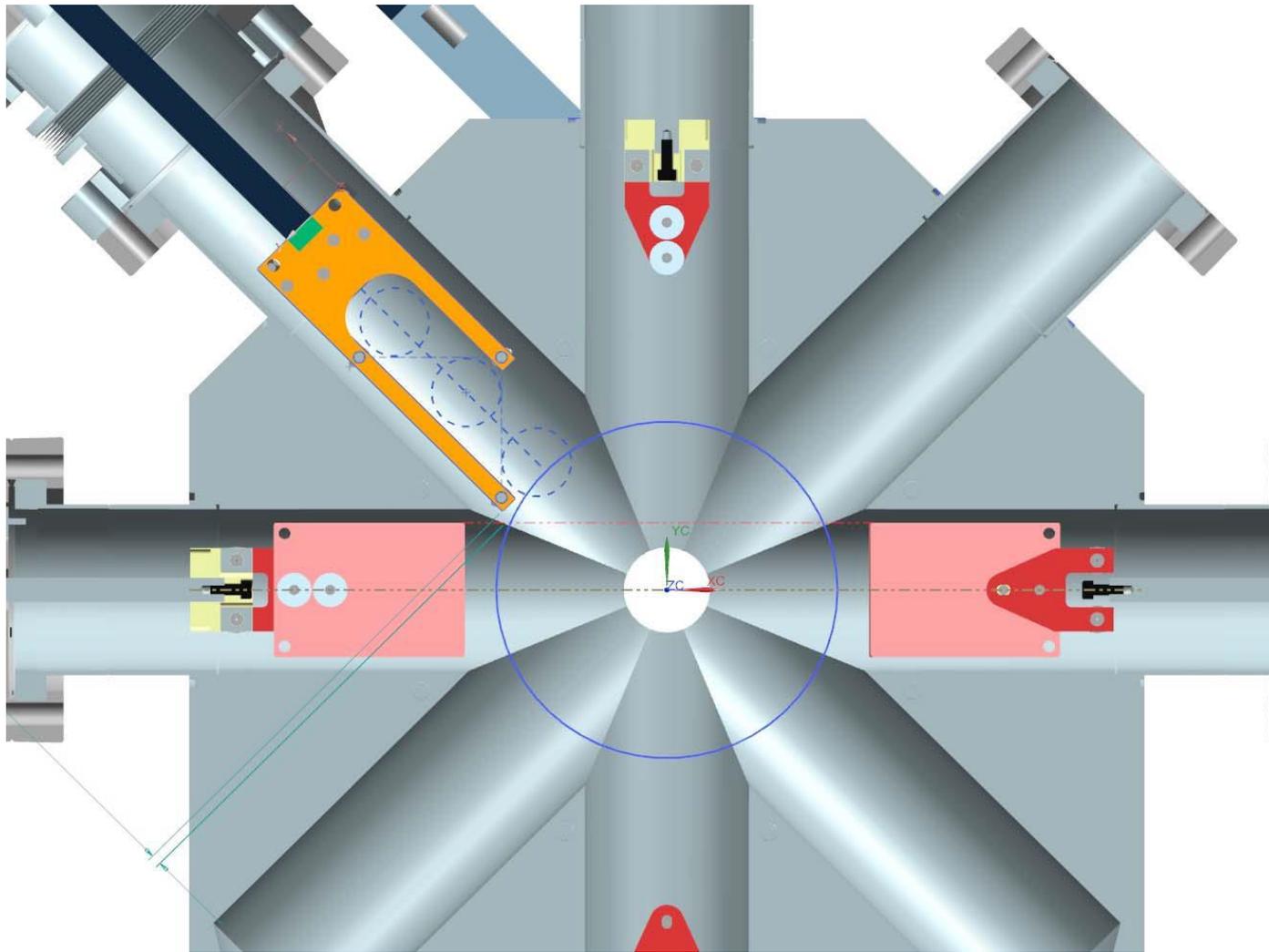
MEBT Emittance Scanner



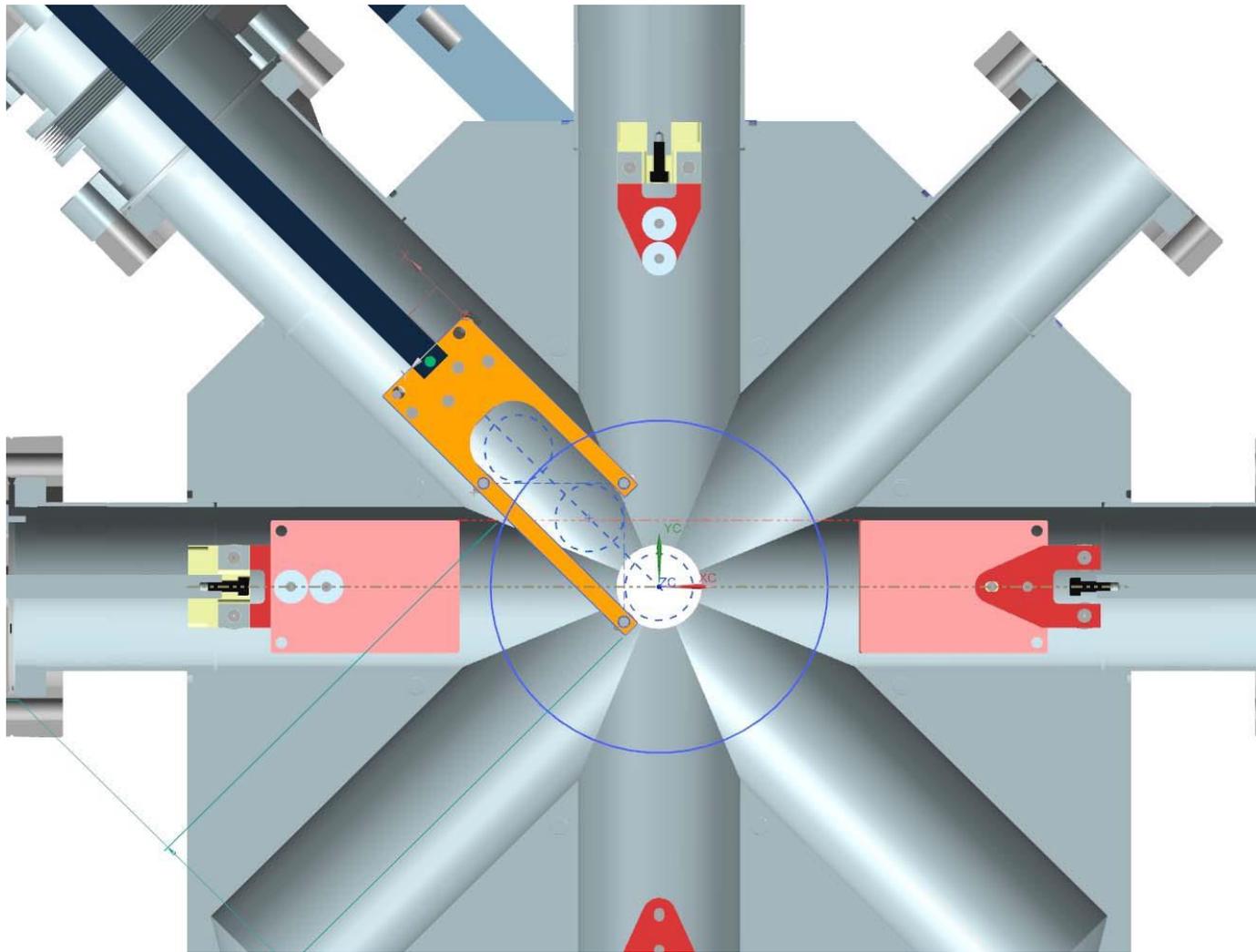
Prototype Wire Scanner

- Single wire scan – step transversely through beam
- Test in diagonal (45°) 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

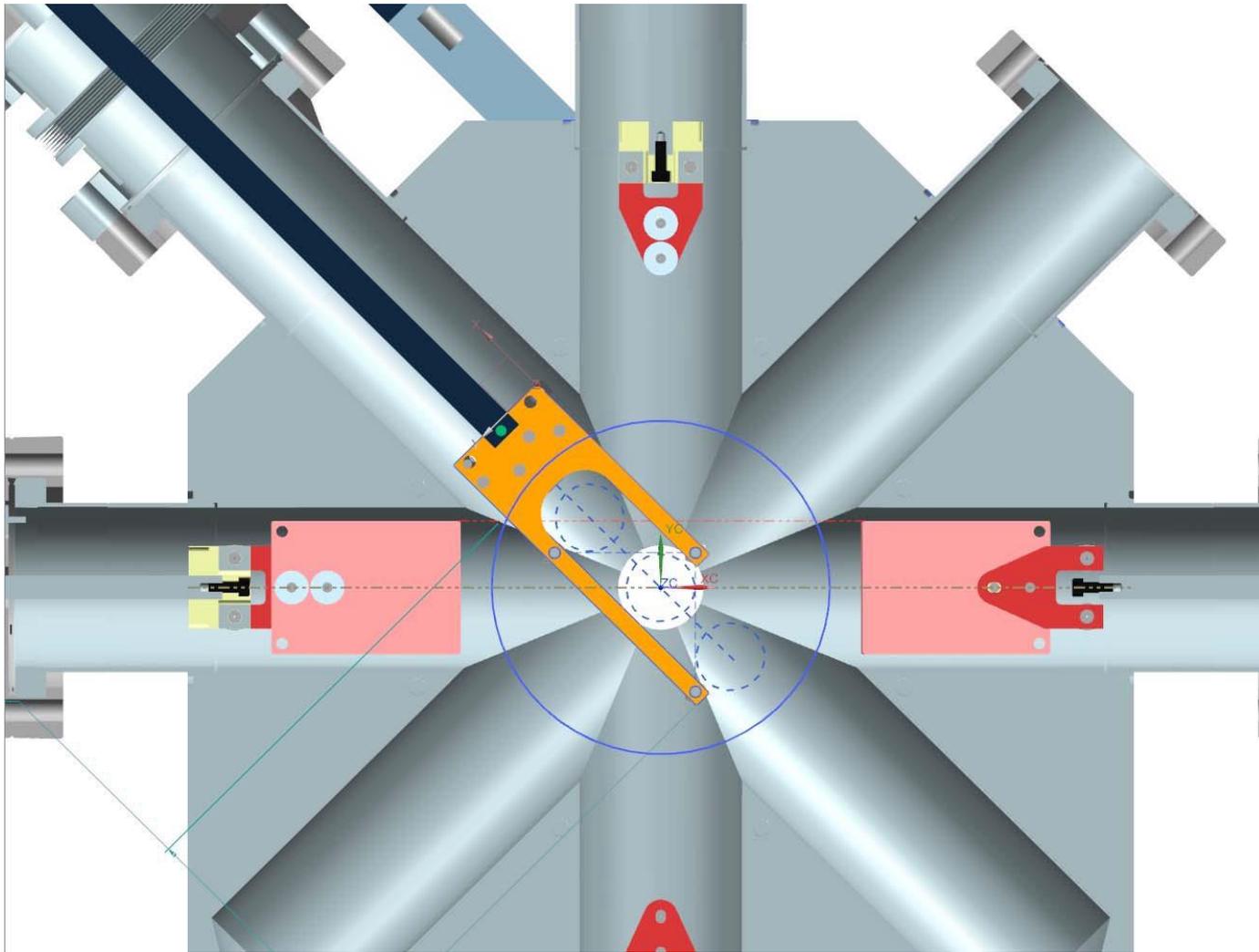
Prototype Wire Scanner



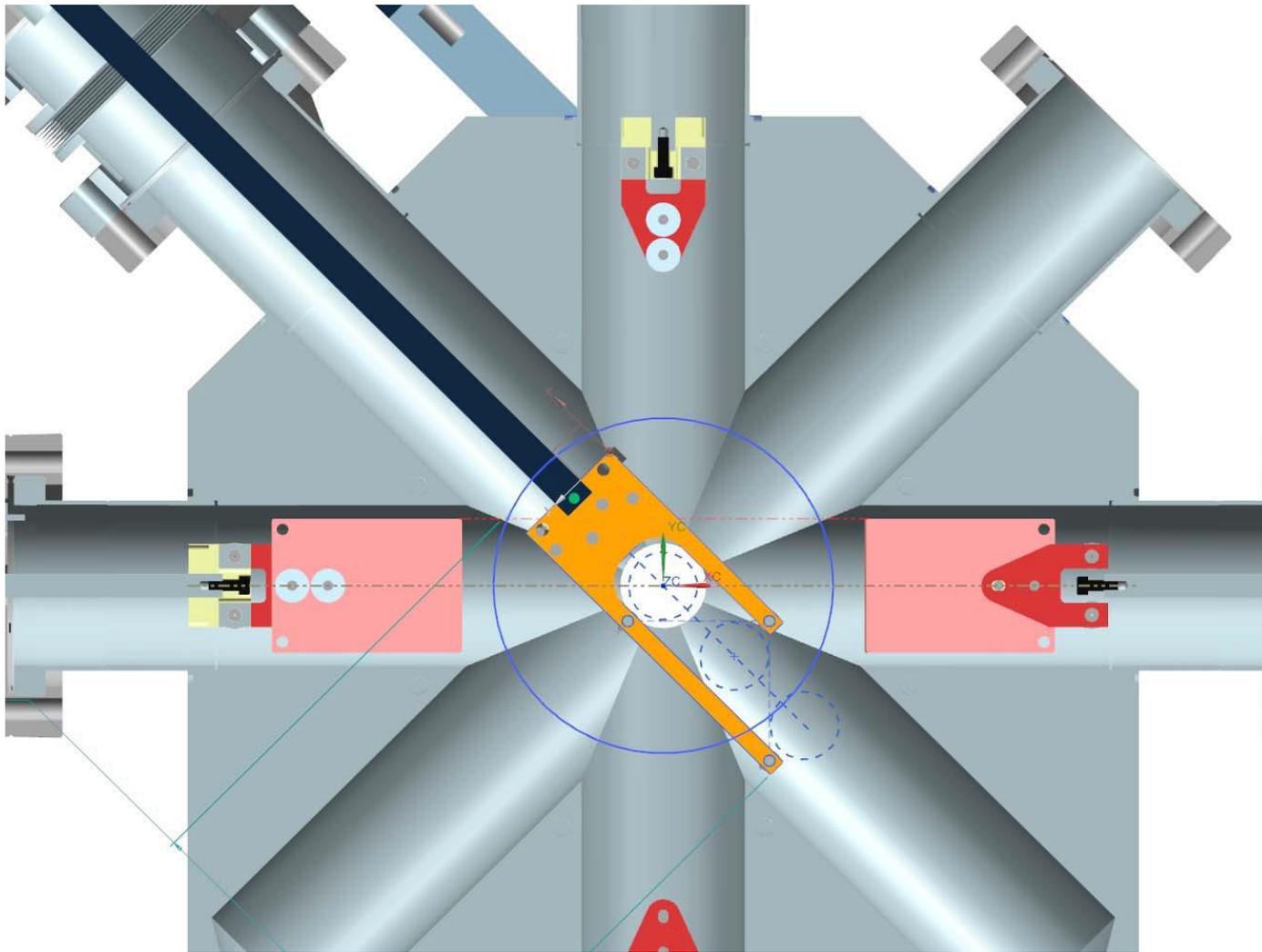
Prototype Wire Scanner



Prototype Wire Scanner



Prototype Wire Scanner



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

