

PXIE Beam Instrumentation Update

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07 April 2015

Instrumentation Update

- What has been done for LEBT commissioning
- Instruments planned for RFQ commissioning and initial MEBT configurations

LEBT Commissioning

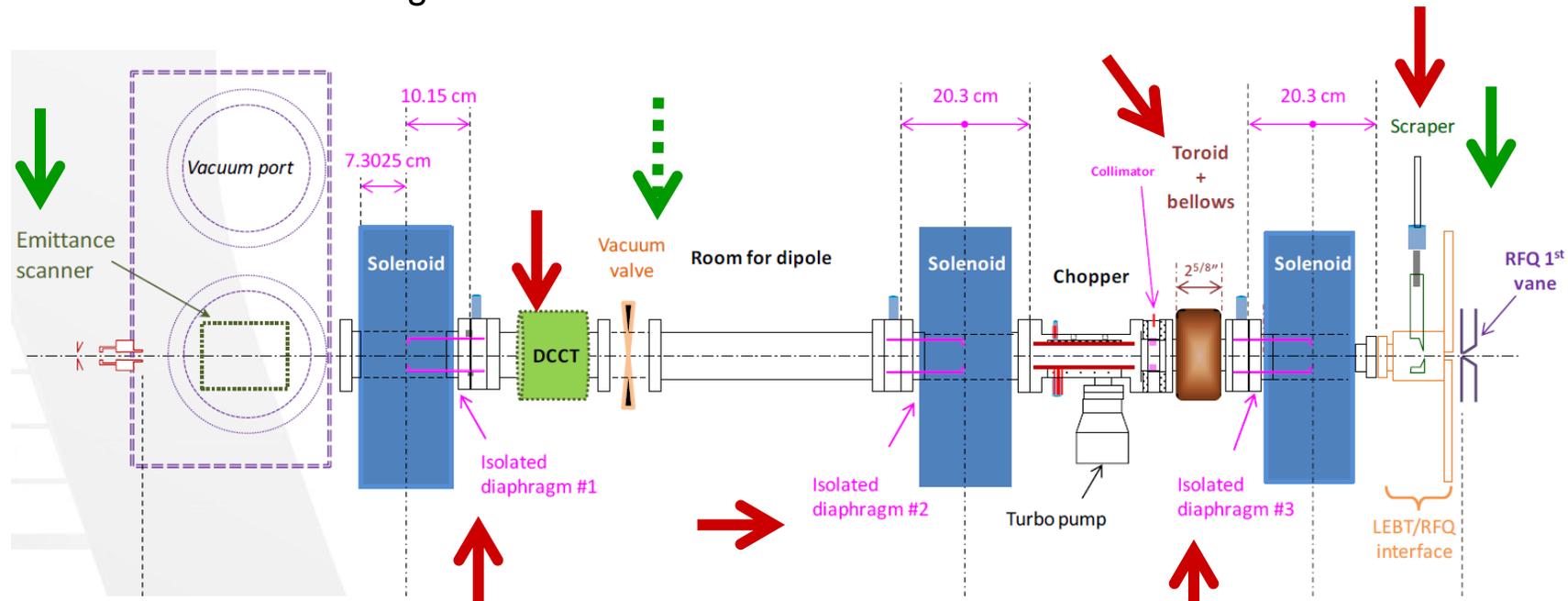
Source-LEBT Instrumentation

Beam Current

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

Beam Emittance

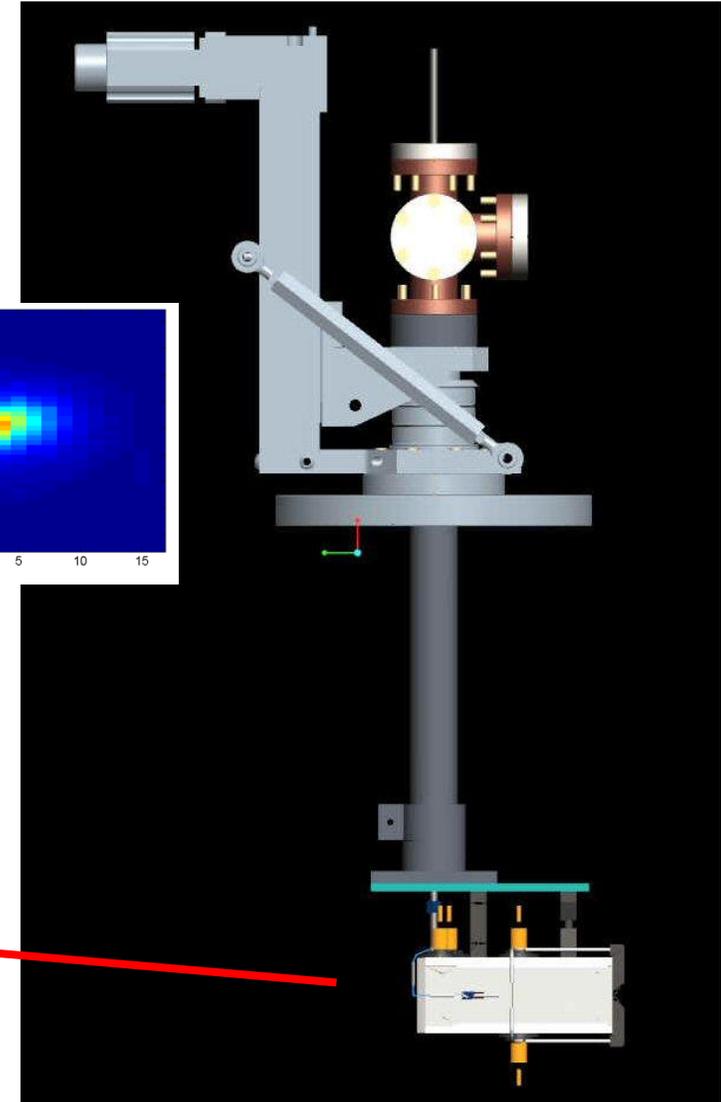
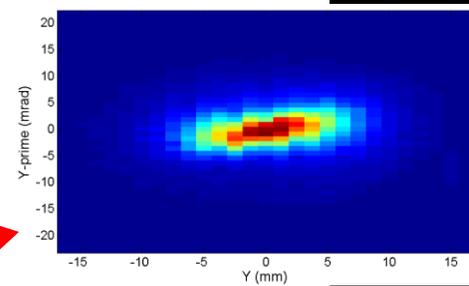
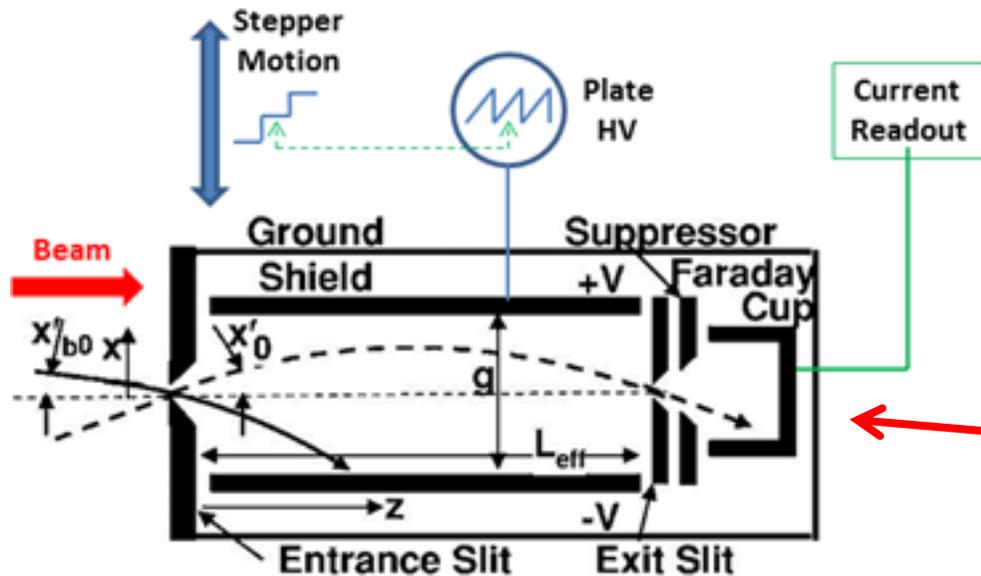
- Water-cooled Allison Scanner
 - Measurements at ion source
 - Measurements in LEBT during commissioning



Allison Scanner for Source/LEBT Emittance Measurements

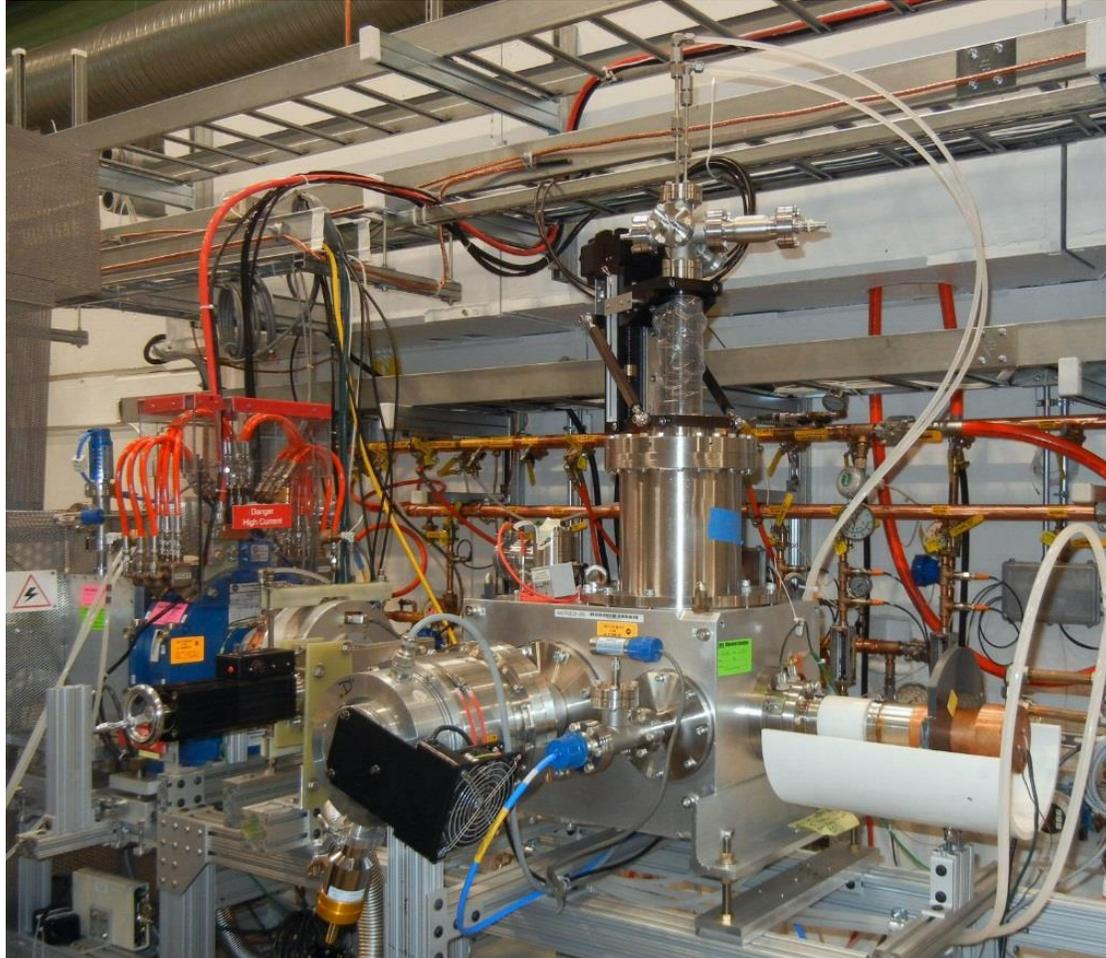
Water cooled Allison scanner – CW operation

- Developed in collaboration with SNS
- Adjustable entrance slits
- Status:
 - Installed in multiple locations in LEBT
 - *Over 1000 phase-space measurements*



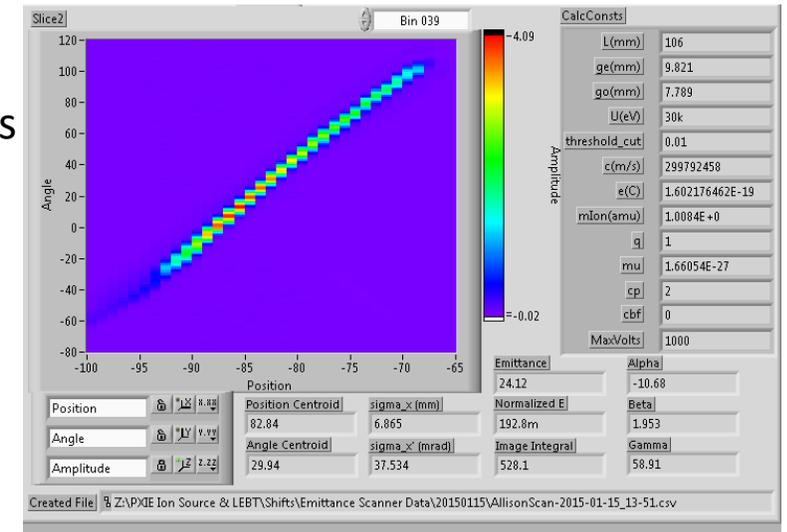
Allison Scanner Installation

Installation after 1st Solenoid – May 2014

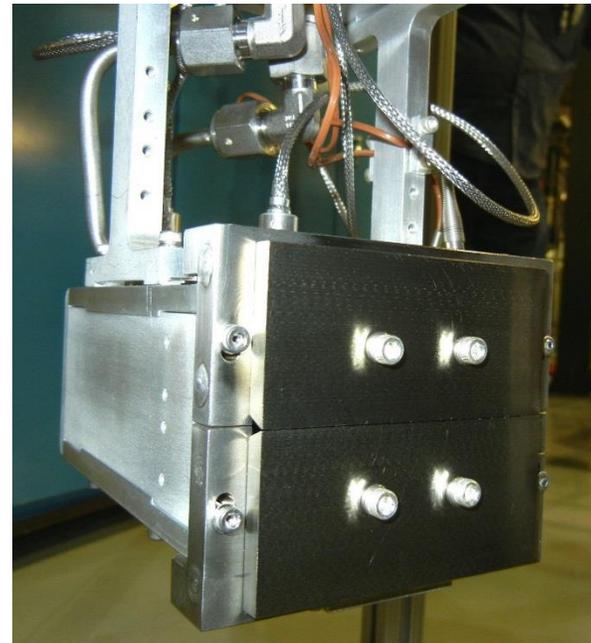


Labview-based
DAQ and analysis
software

Operated in both
vertical and horizontal
orientations



Front-slit made of TZM pressed
against water-cooled blocks



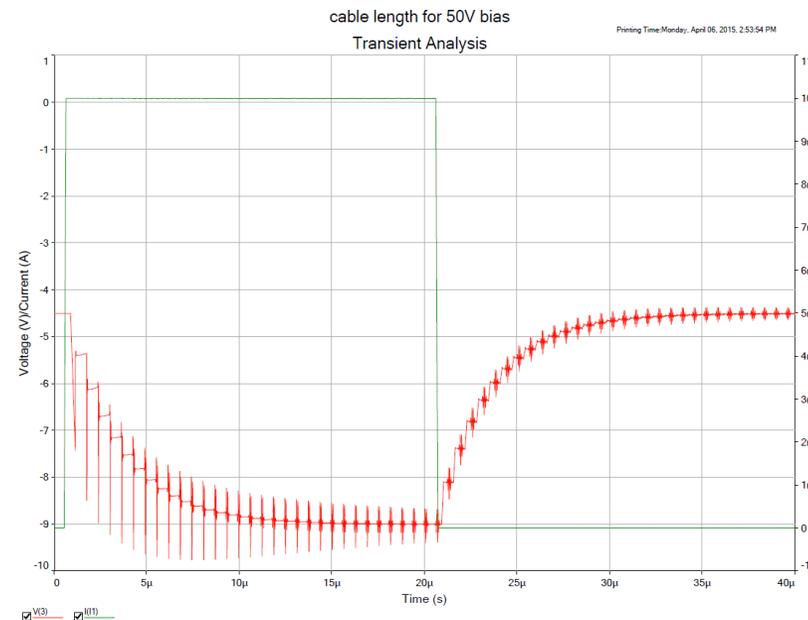
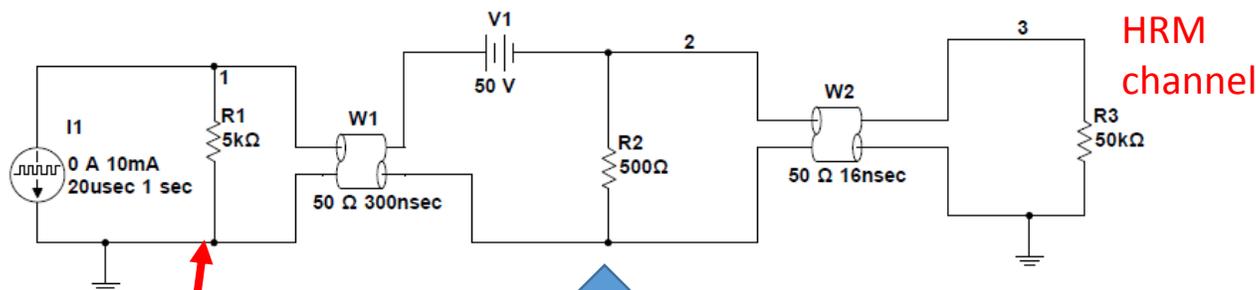
Electronics rack



Isolated Electrode Beam Current Measurements

Various isolated electrodes in LEBT and MEBT

- LEBT diaphragms, Faraday cup, chopper
- MEBT scrapers, Faraday cup
- Individually biased (+50 volts)
- Present circuit has mis-matched impedances – problem for longer cables



Electrode and safety 5K ohm



+50 V bias and termination boxes



+50 V bias

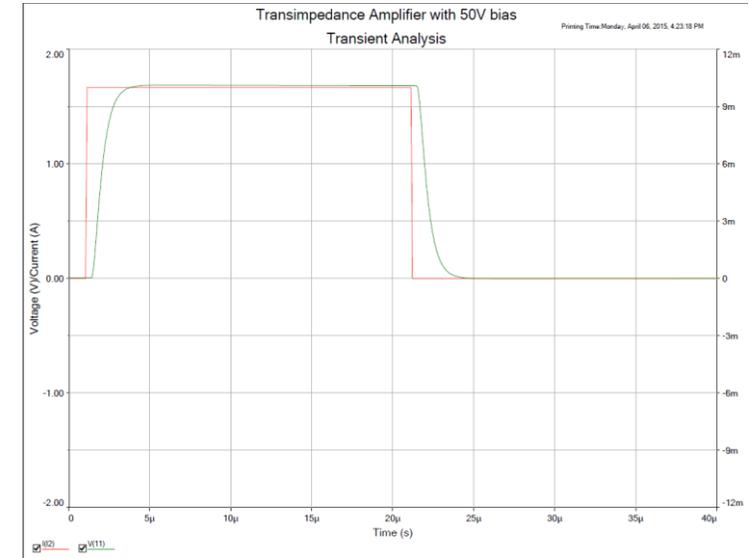
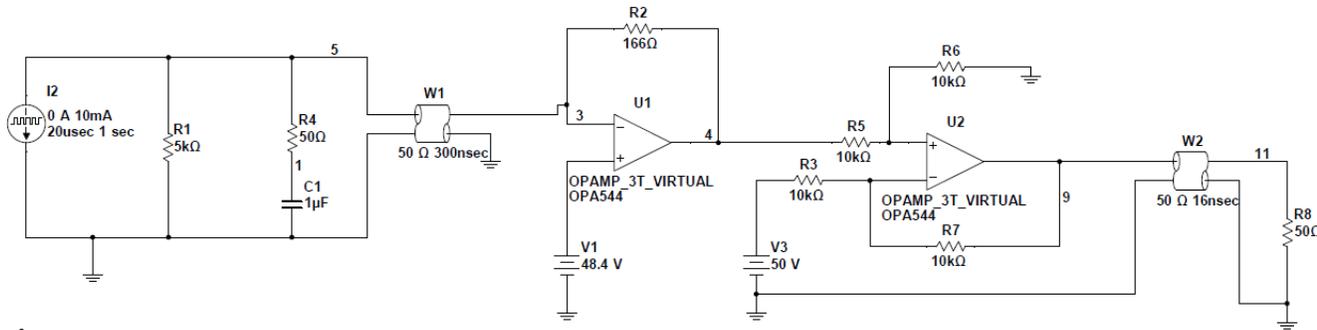
OK for few LEBT channels and bias supplies in PXIE cave

- Problem to remove bias supplies from cave and mis-matched impedances
- Mis-match causes reflections

Modified Isolated Electronics

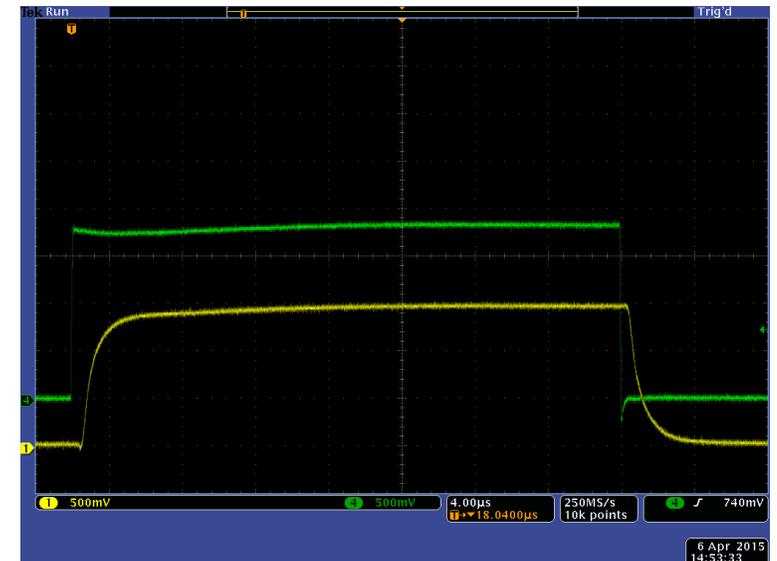
Replace passive isolated electronics with trans-impedance op-amp circuit design

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



Status

- Prototype circuit has been tested on lab bench
- Next, will test design in PXIE LEBT
- In addition, installing first PXIE Instrumentation VME crate for beam current measurements - End of April
- Utilize FPGA-based 8-channel digitizer cards for all current measurements – 125 MHz, 14 bit
 - Allows for pipeline or snapshot DAQ and signal processing
 - Initial FPGA and VME code - reuse ASTA code
- Initial operation in May



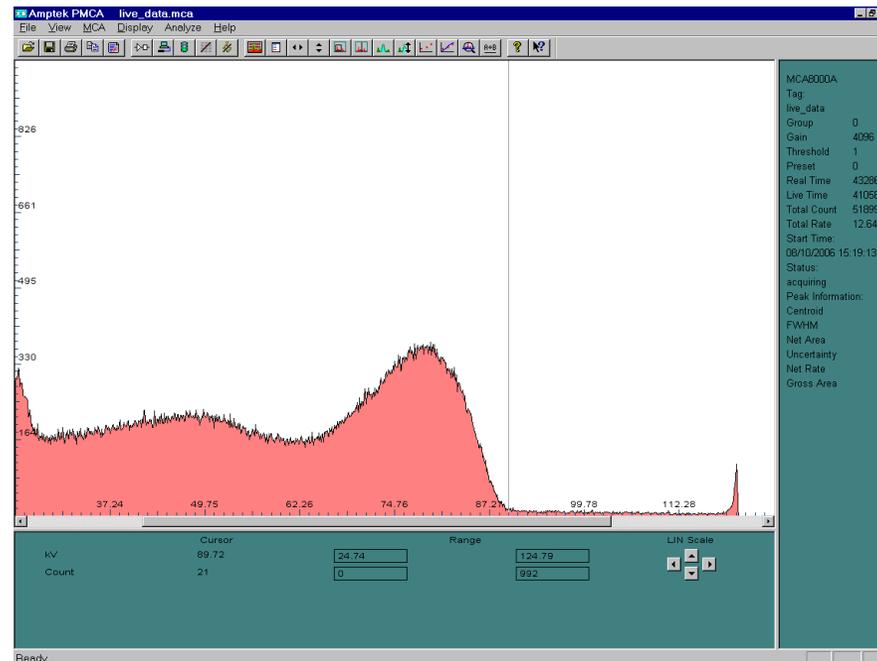
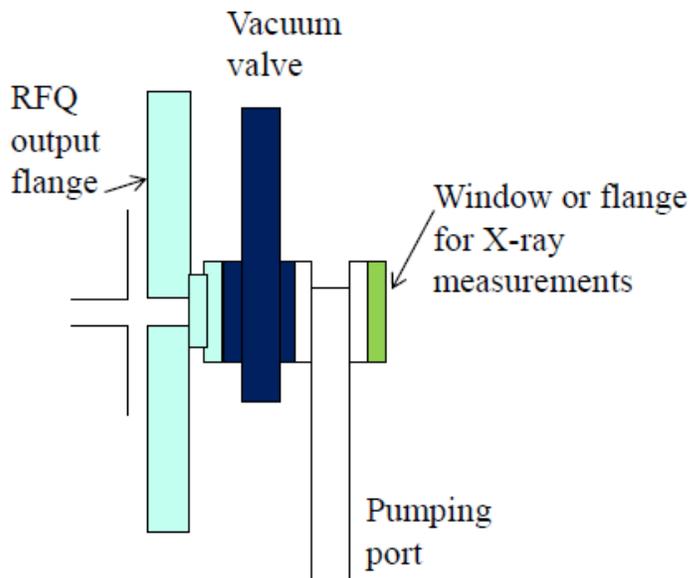
RFQ Commissioning

RFQ RF Testing - Configuration 1.0

Inter-vane voltage calibration from X-ray end-point energy measurement.

Configuration during RFQ RF conditioning

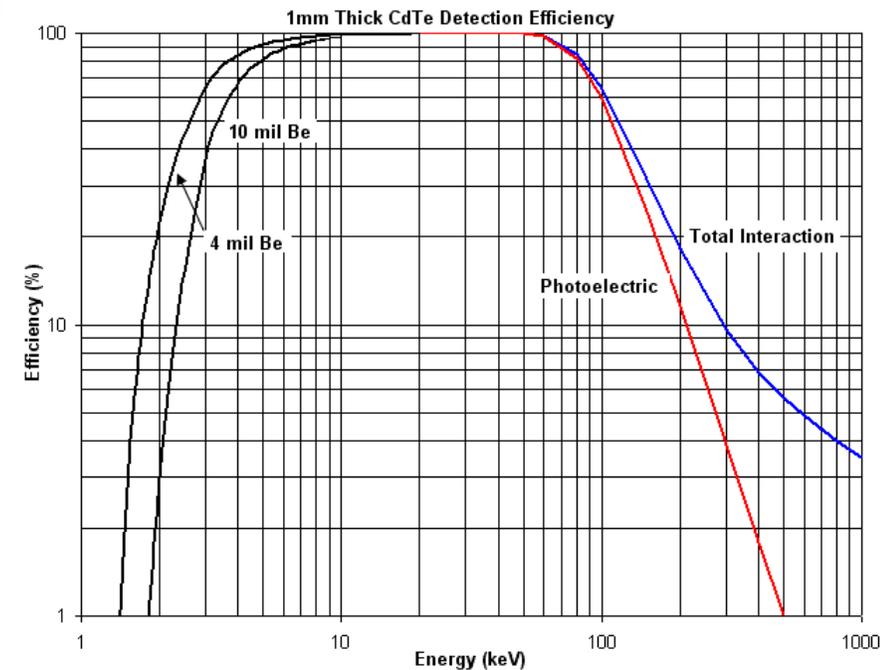
- Measure X-rays longitudinally out of RFQ



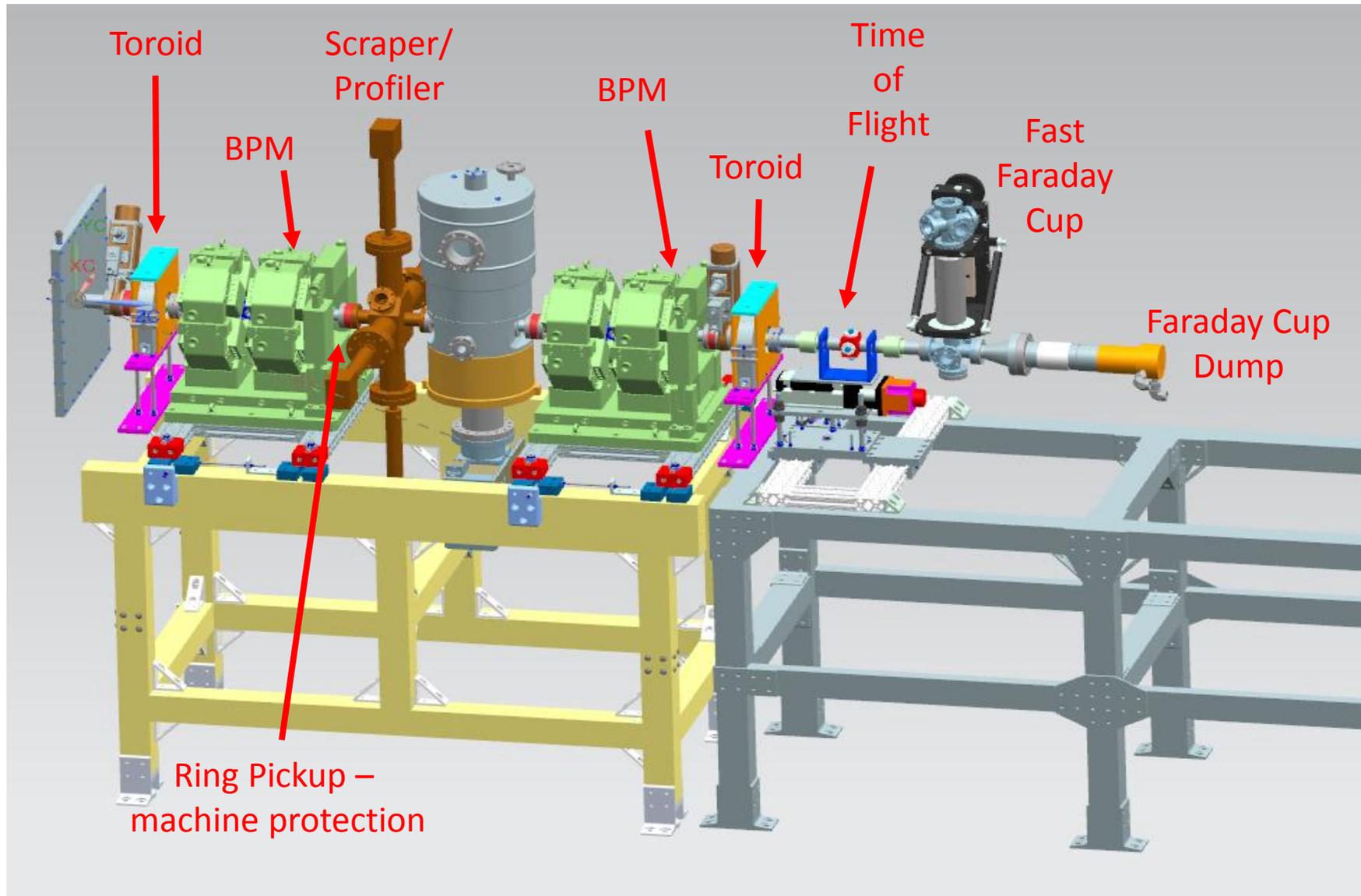
ANL, Ostroumov, LINAC06

Amptek CdTe X-ray detector

- Resolution: < 1.2 keV (@ 122 keV)
- Energy range: 5 to 150 keV
- Max count rate: $\sim 2e5$ cps



Initial MEBT Configuration 1.1



MEBT Beam Instrumentation

Focus on RFQ commissioning and early MEBT configurations:

- Beam current measurements
 - Toroids, isolated beam dump – purchased or have
 - Integrate into VME-based front-end - under development
- Beam position and phase
 - Button BPMs - designed and being fabricated
 - DAQ system under development – based on previous design
- Beam transverse profiles and rms emittance
 - Electrically isolated beam scrapers – prototype under test in LEBT
 - Integrate into VME-based Current front-end - under development
 - rms emittance measurements via quadrupole scans
- Beam energy
 - Time-of-flight via movable BPM – under design
 - for RFQ/MEBT commissioning only
- Machine protection
 - Isolated ring pickup – constructed
- Longitudinal bunch shape
 - High-bandwidth Faraday Cup - > 5 GHz BW – under design
 - DAQ thru high-bandwidth scope

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 boards
- 14 bits, 250 MSPS
- Different operational modes
- Adding lock-in synchronous signal detection capability
 - For laser wire development
- **8 channel, 125 MHz board as fallback**

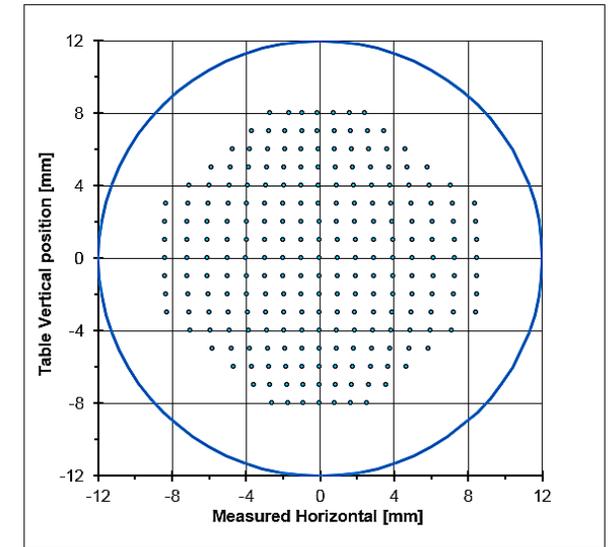
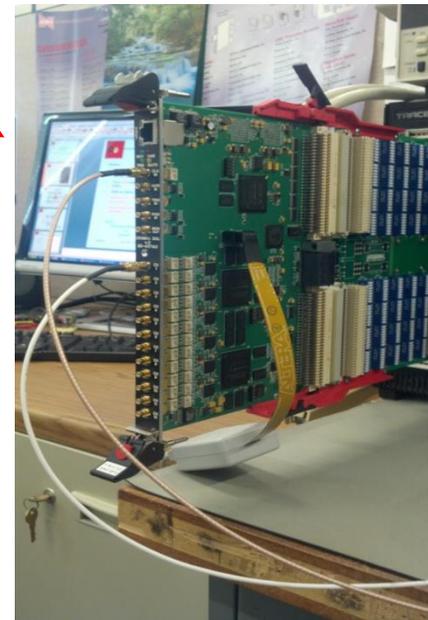
Status:

- All BPM buttons and housing purchased
- Two complete BPMs by early May
- Stretched wire measurements performed
- Simulations of low- β corrections getting started
- Electronics assembled with initial testing on bench
 - Installation at PXIE in September
- Reuse frontend software from other systems
- Initial system ready by first beam



BPMs pickups prototyped

**Four button
Warm BPM**



Stretched wire mapping

- Simulating low- β corrections

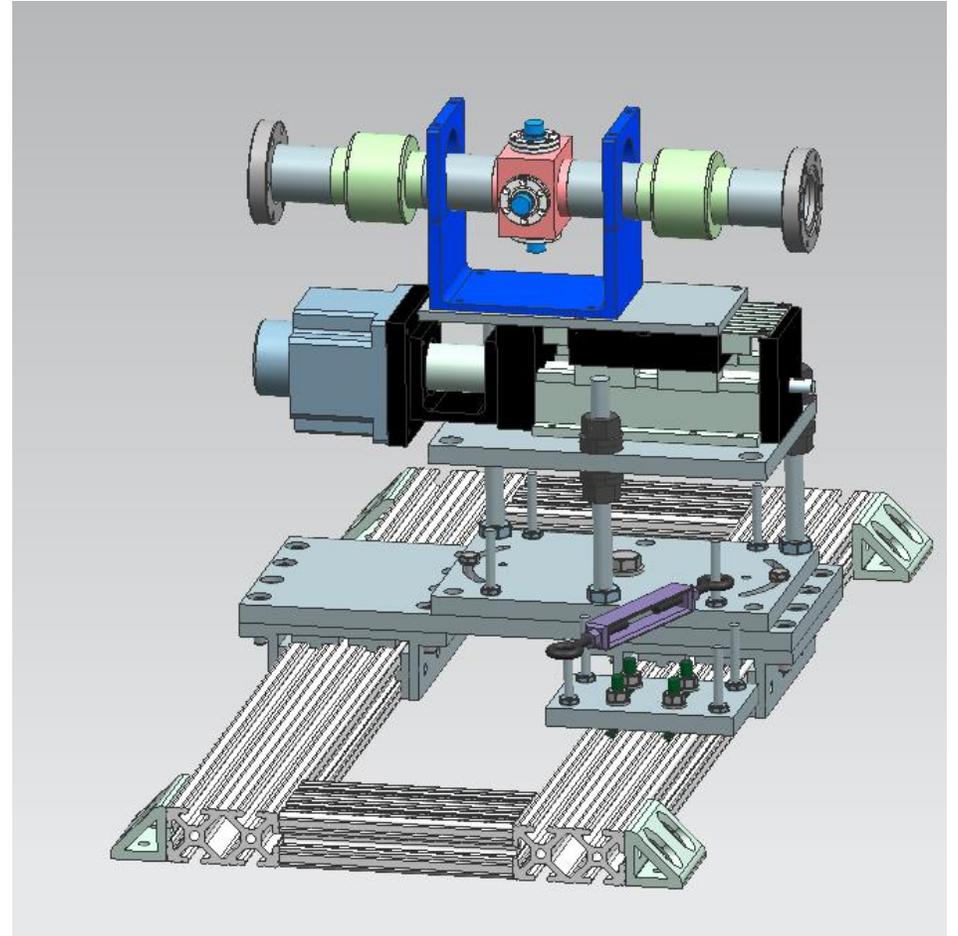
Time of Flight (ToF) Movable BPM

Measure beam velocity 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%

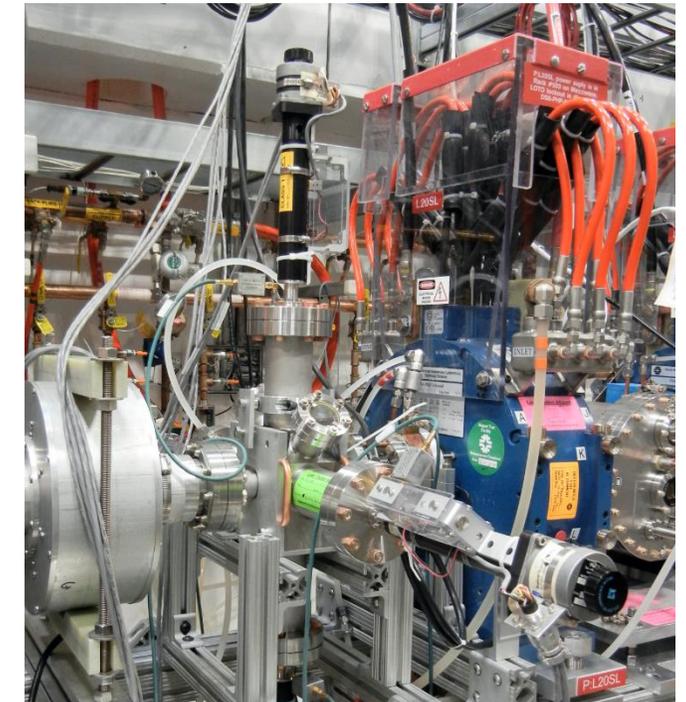
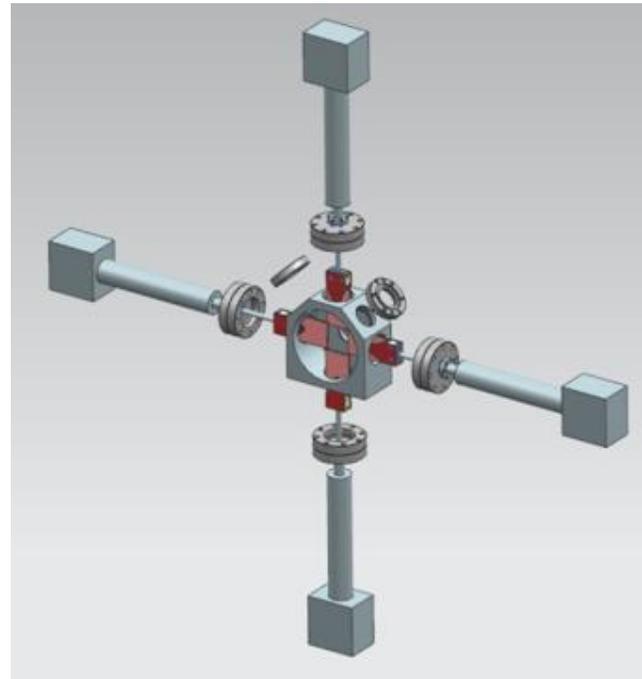
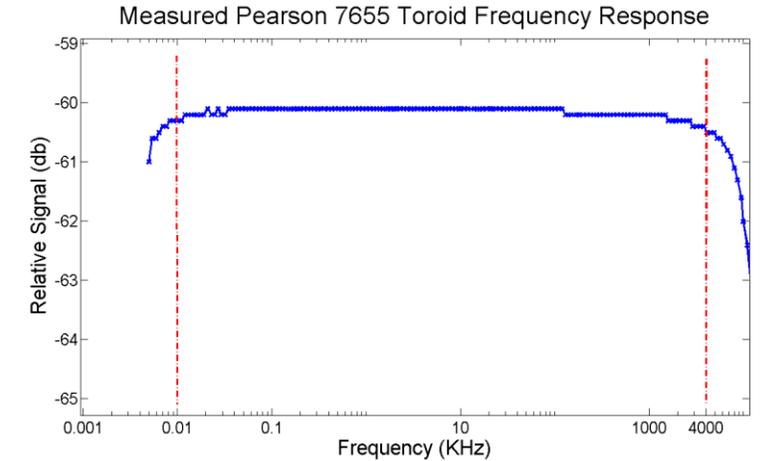
Status:

- Design is in drafting stage – early May
- Have motion stage and BPM in-hand
- Trying to complete assembly before shutdown
- Use MEBT BPM electronics to acquire phase



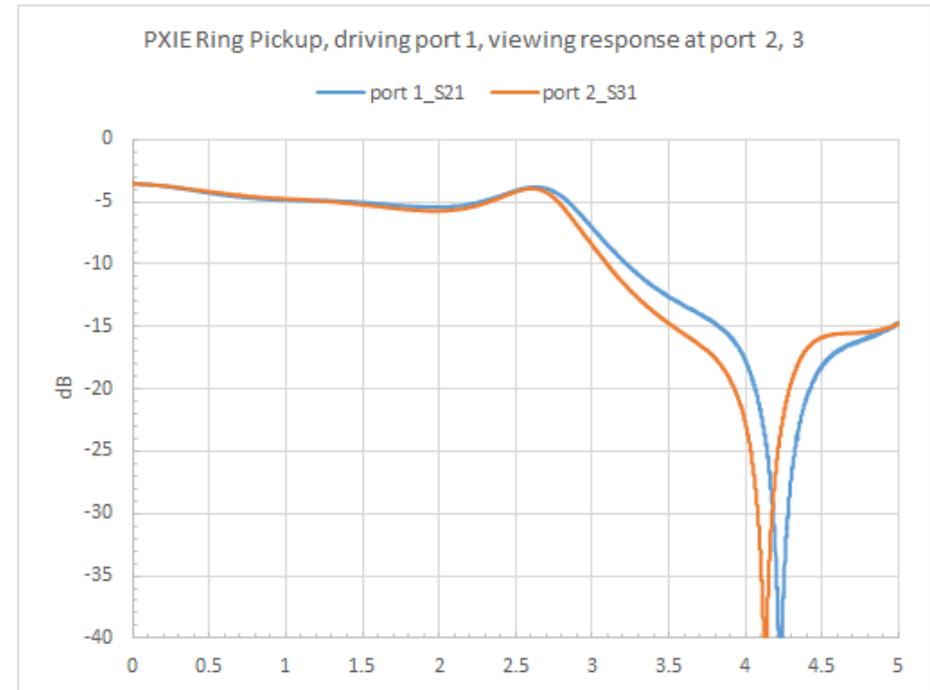
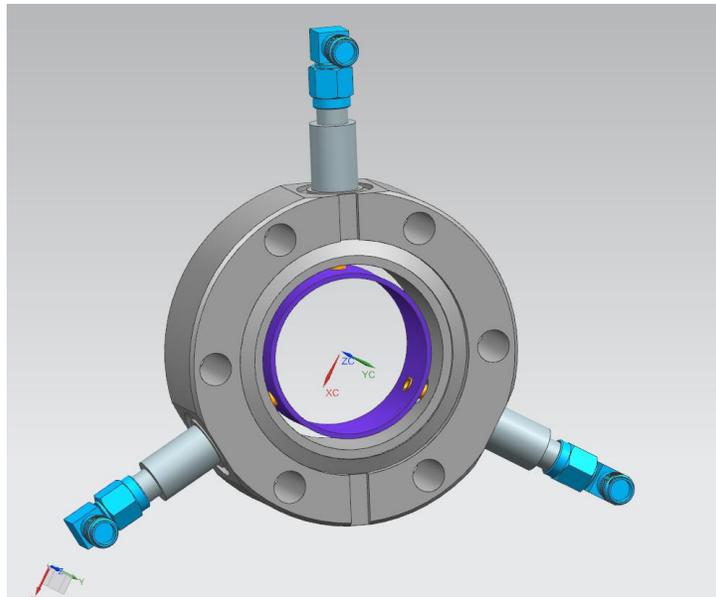
Beam Current and Profiles

- Faraday cup and two toroids
 - Pearson 7655 split toroids
 - Identical to LEBT toroid
 - Toroids in-hand
 - Signal DAQ thru VME FPGA-based digitizers
 - Same as LEBT digitizers
 - Same software as LEBT isolated diaphragms
- Beam profiles via scraper scans
 - Scrapers isolated and biased
 - Prototype scraper installed in LEBT
 - Signal DAQ thru VME FPGA-based digitizers
 - Same as LEBT digitizers
 - Same software as LEBT isolated diaphragms
 - Profile reconstruction via Controls application

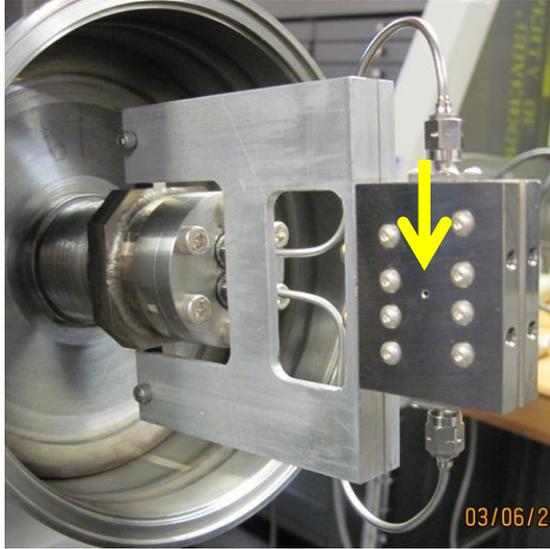


Machine Protection

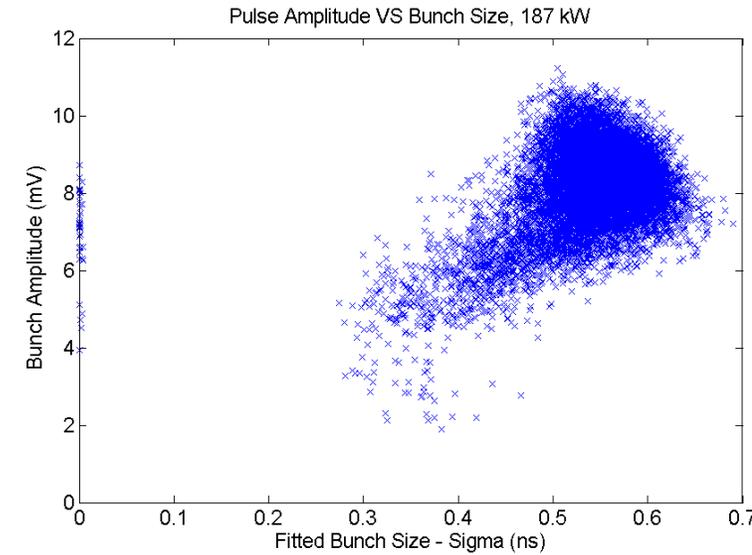
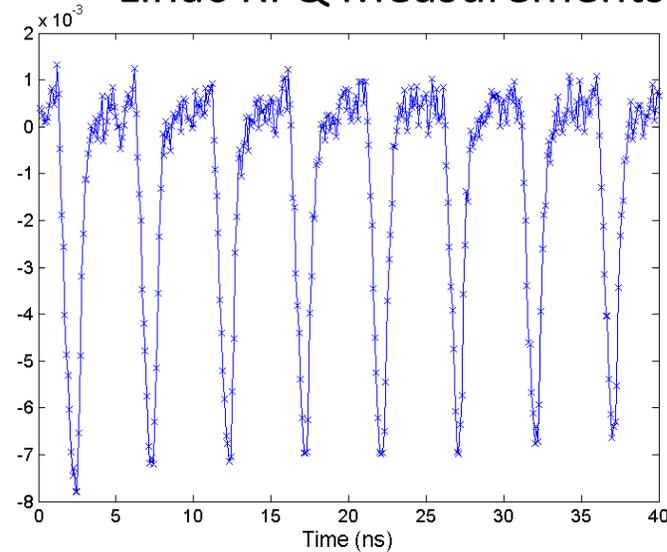
- Dedicated ring pickup to measure bunched-beam current
 - Wide bandwidth pickup
- Simple analog circuit to generate beam intensity



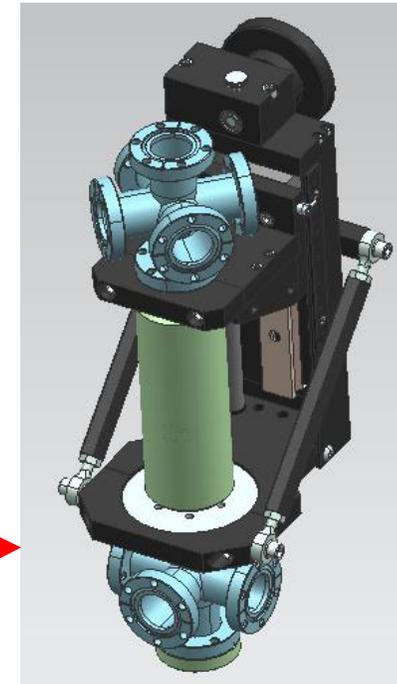
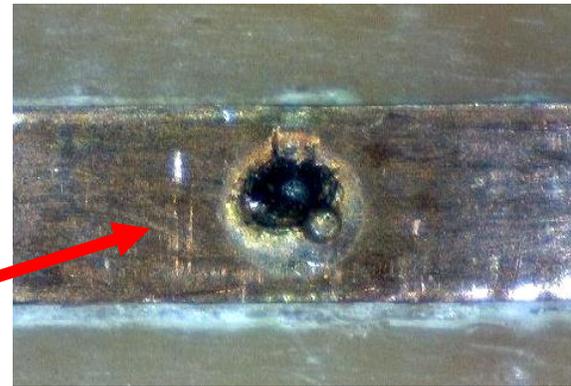
Longitudinal Bunch Length - Fast Faraday Cup



Linac RFQ Measurements



- Embedded 50 Ω stripline – designed by SNS
- Tested at HINS and Linac
- High Bandwidth (> 6 GHz) – need scope DAQ
 - Beam damage at HINS (2.5 MeV protons)
 - We are redesigning with better thermal properties
- Vacuum hardware under design
- Prototype ready by September



Summary

- LEBT commissioning continuing
 - Allison scanner operational and a success
 - Current measurements continue through HRMs
 - Transitioning over to VME FPGA digitizers
- RFQ and initial MEBT
 - Focusing effort on initial MEBT 1.1 configuration
 - Beam current, BPM, ToF, profile systems and machine protection ring pickup hardware proceeding
 - Longitudinal Fast Faraday Cup still in design
 - Front-end software development needs more support