The Fermilab HINS Test Facility and Beam Measurements of the Ion Source and 325 MHz RFQ

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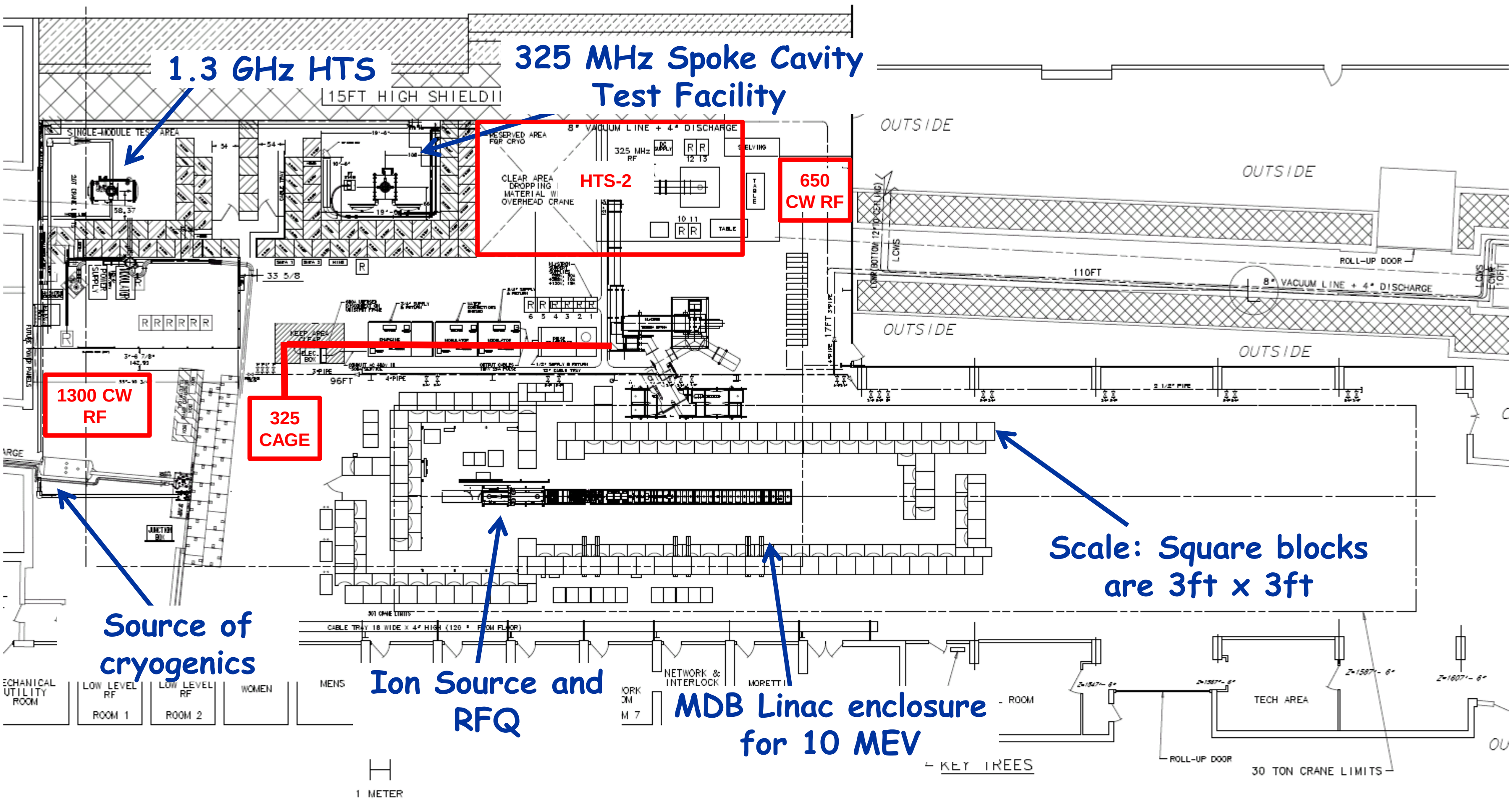
MDB (HINS) Test Facility

The Meson Detector Building (MDB) Test Facility (formerly known as HINS – High Intensity Neutrino Source) ultimately comprises:

- A shielded beam line enclosure with first proton, then H^-, pulsed 1% duty factor, 3 millisecond beam up to 10MeV
  - For Project X 325 MHz superconducting spoke cavity beam tests
  - For Project X chopper tests
  - For Project X H^- beam instrumentation development
- Shielded enclosures and RF power systems for testing individual, jacketed 1.3 GHz, 650 MHz, and 325 MHz superconducting RF cavities (no beam)
  - For ILC
  - For Project X

Project X - Fermilab's proposed superconducting RF, multi-MW, multi-GeV CW proton/H- linac for the Intensity Frontier.

MDB Test Facility Layout

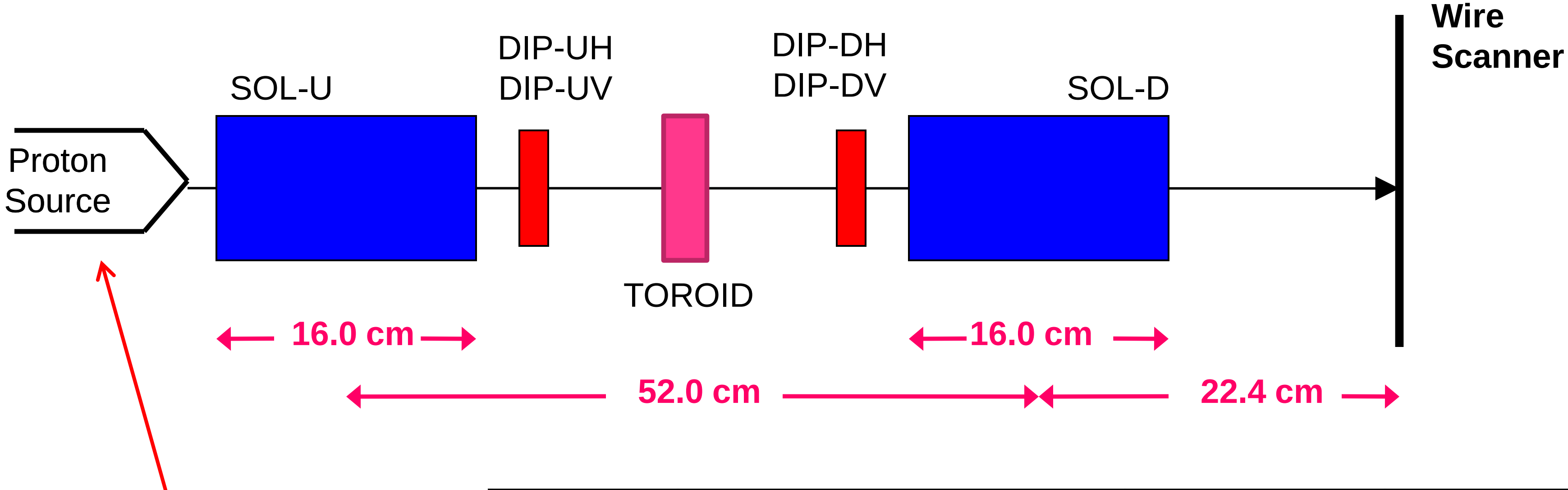


HINS Beam Parameters

Particle	H+ then H-	
Nominal Bunch Frequency/Spacing	325 3.1	MHz nsec
Particles per Pulse	37.5 *	E13
Pulse Length	3/1	msec
Average Pulse Current	~ 20	mA
Pulse Rep. Rate	2.5/10	Hz
Bunch Intensity	6.1 98	E8 pCoul

* full un-chopped 3 msec pulse at klystron-limited 20 mA

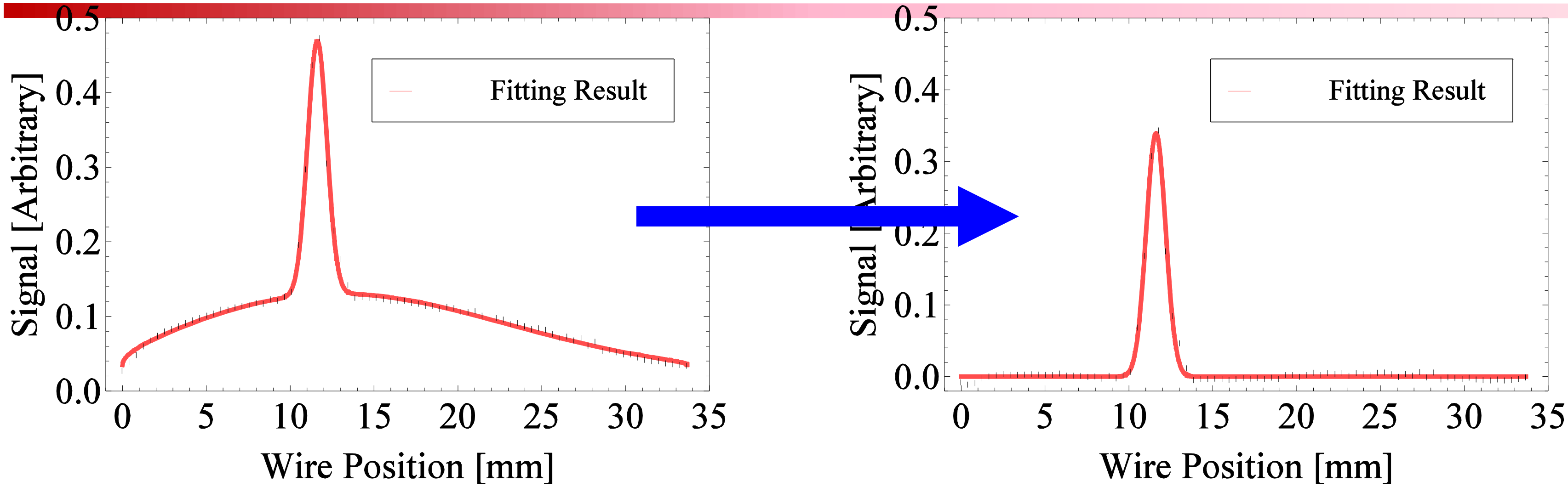
HINS Proton Source and LEBT

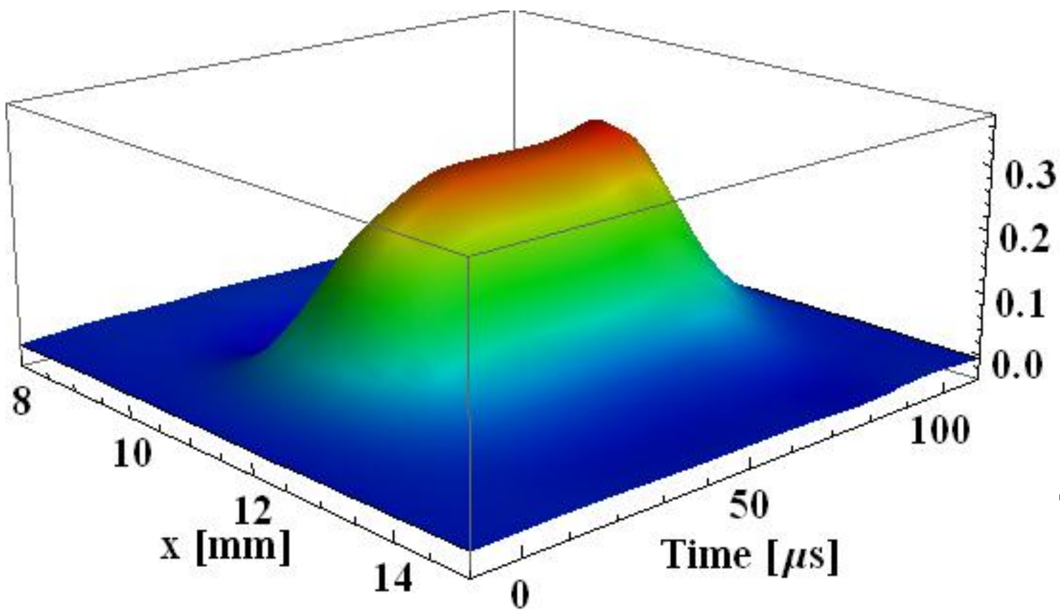


Duo-plasmatron Proton Source	
Energy	50 keV
Peak Current	> 20 mA
Pulse	3 msec
Rep. rate	2.5 Hz

	Name	Current [Amp]	B [Gauss]
SOL-U	Upstream solenoid	850	7900
SOL-D	Downstream solenoid	850	7900
DIP-UH	Upstream horizontal dipole	3	100
DIP-UV	Upstream vertical dipole	3	100
DIP-DH	Downstream horizontal dipole	3	100
DIP-DV	Downstream vertical dipole	3	100

A Typical Wire Scan

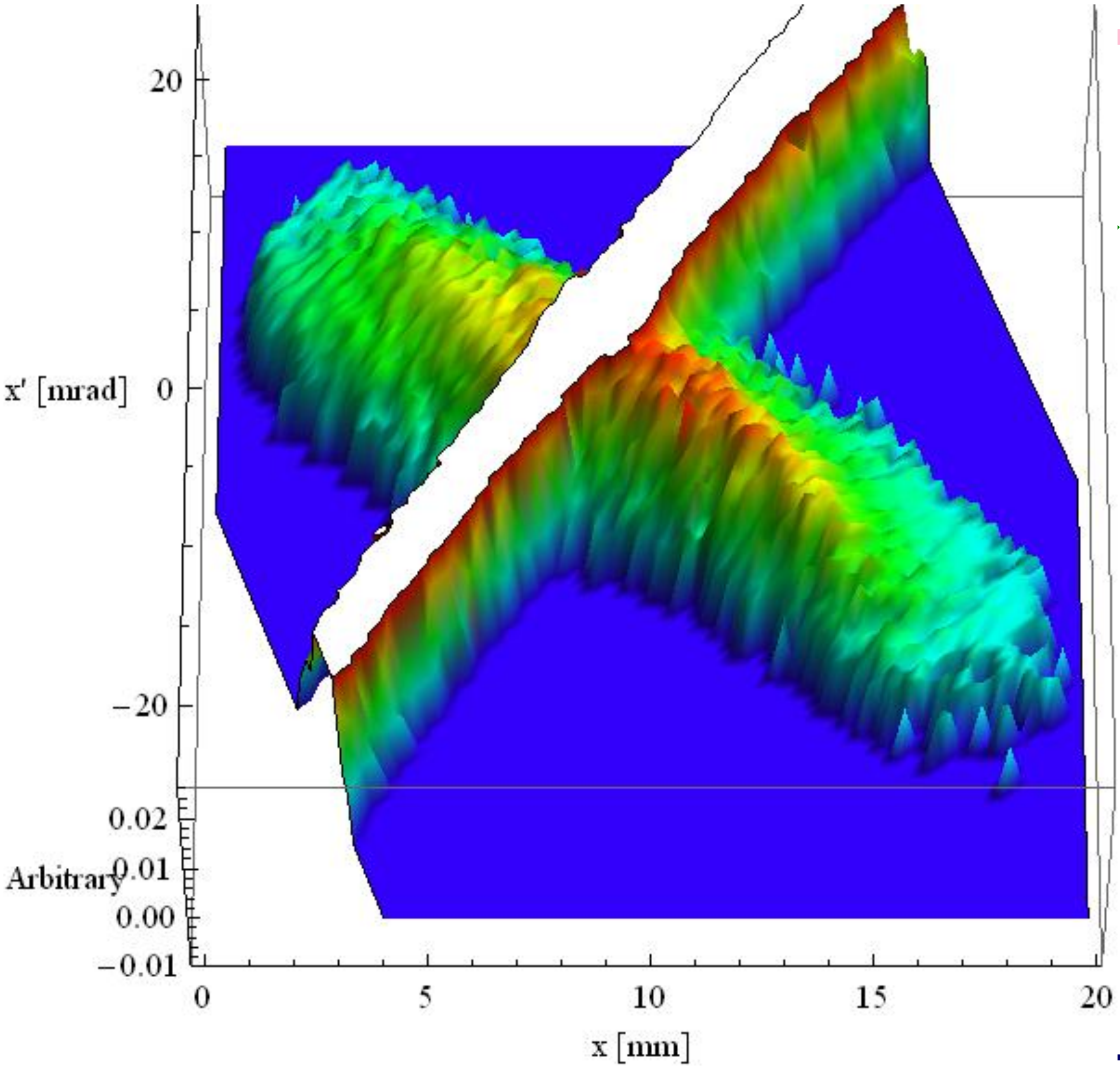




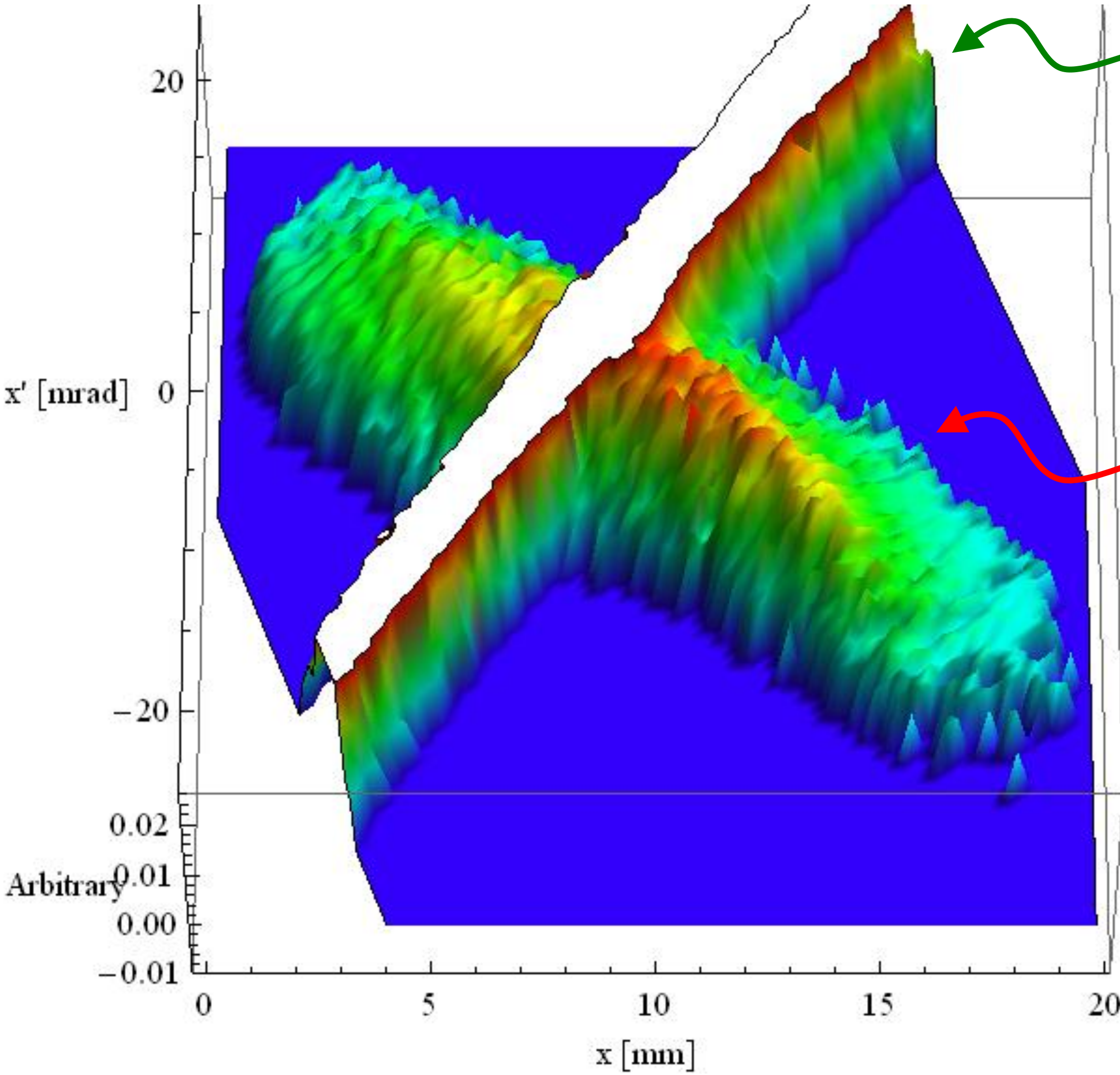
Signal with background subtracted.

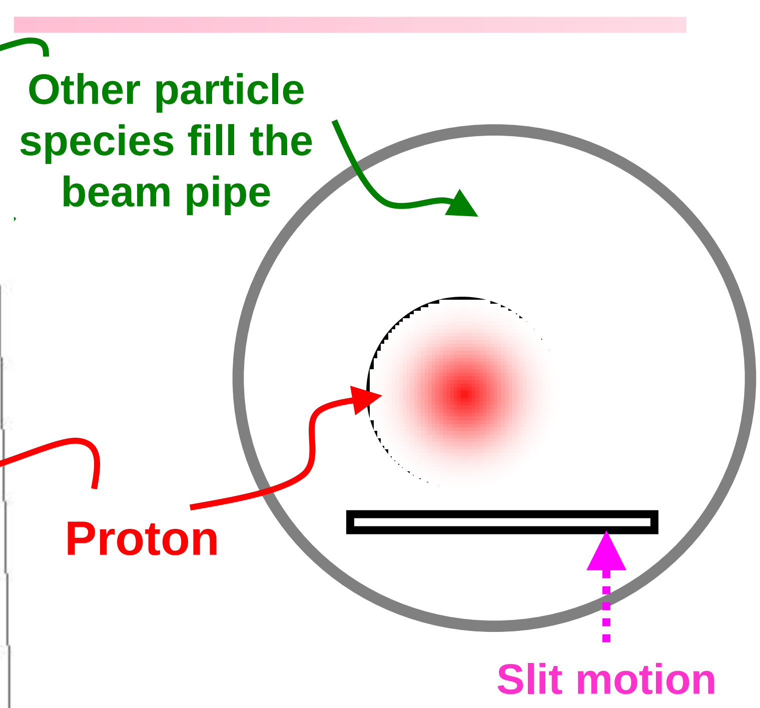
The time structure of a 100 μs pulse. The flattop is about 50 μs.

Proton Source Slit-WS Emittance Measurement

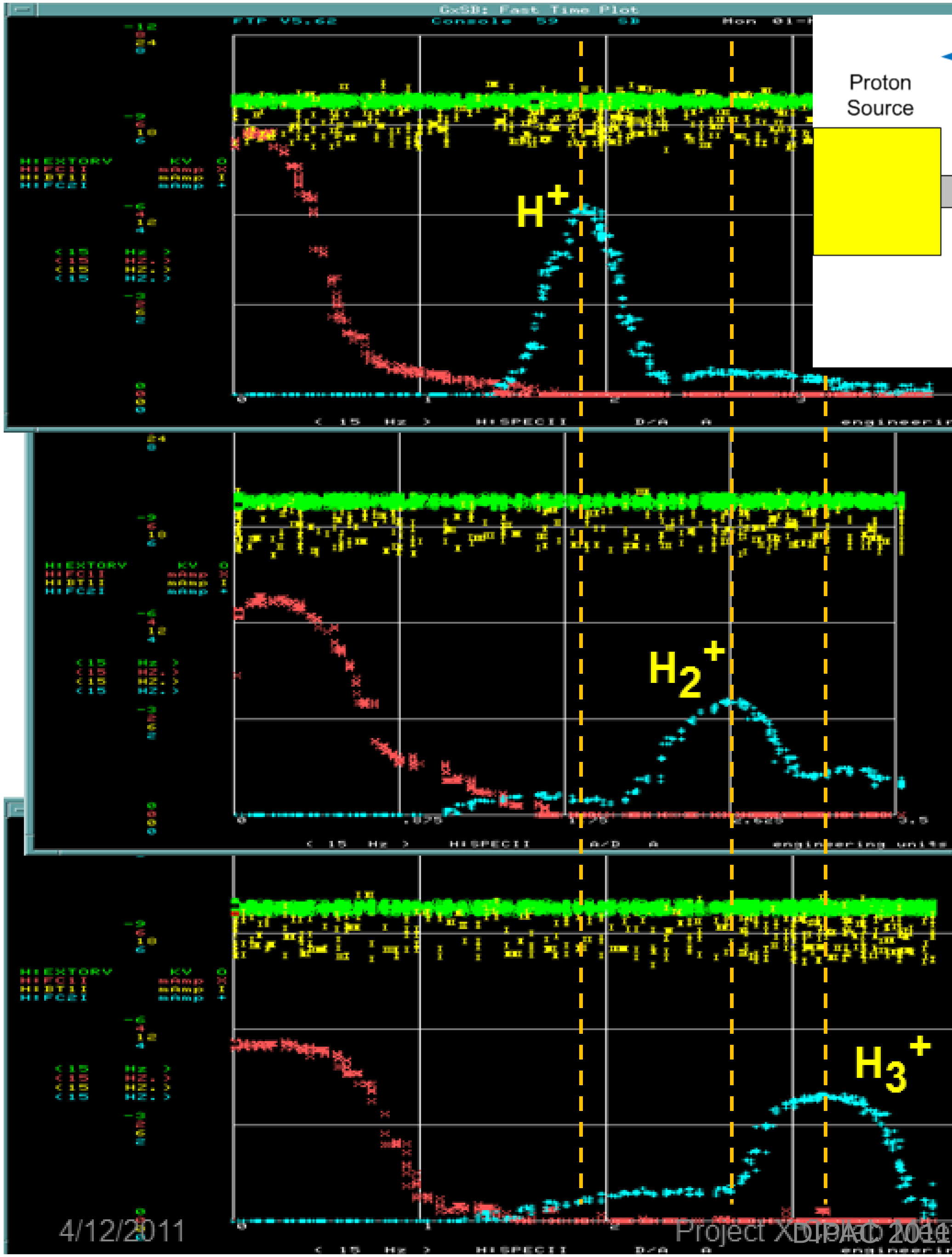


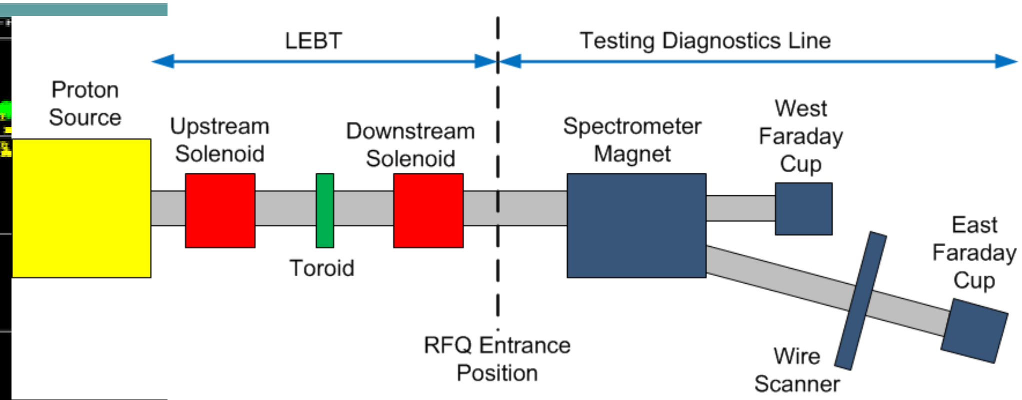
Proton Source Slit-WS Emittance Measurement





Background signal outweighs proton signal.





Source Species

Green – Source Extractor Voltage

Yellow – LEBT Toroid Current

Red – Straight ahead Faraday Cup

Blue – Spectrometer Faraday Cup (bend)

- Downstream solenoid optimized for each species
- Upstream solenoid fixed at 470 A

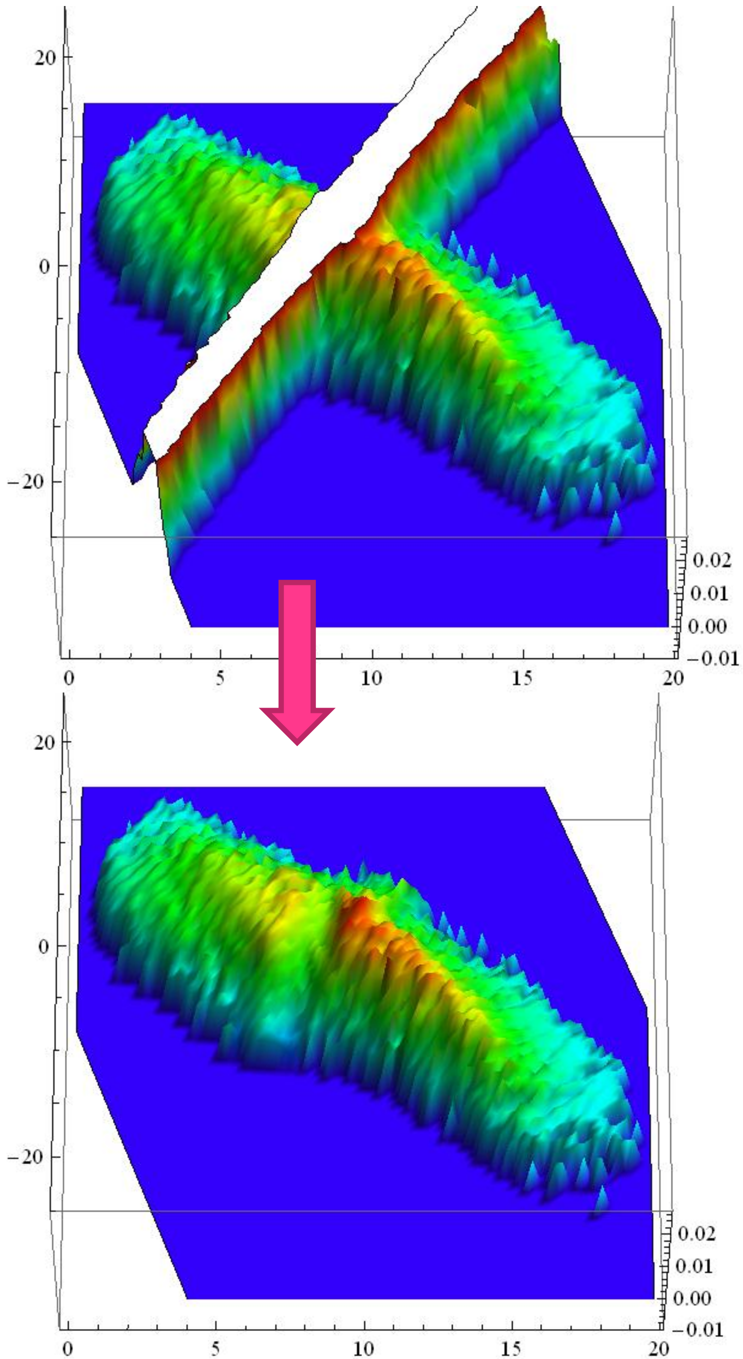
~ 40% Protons

~ 30% H2+

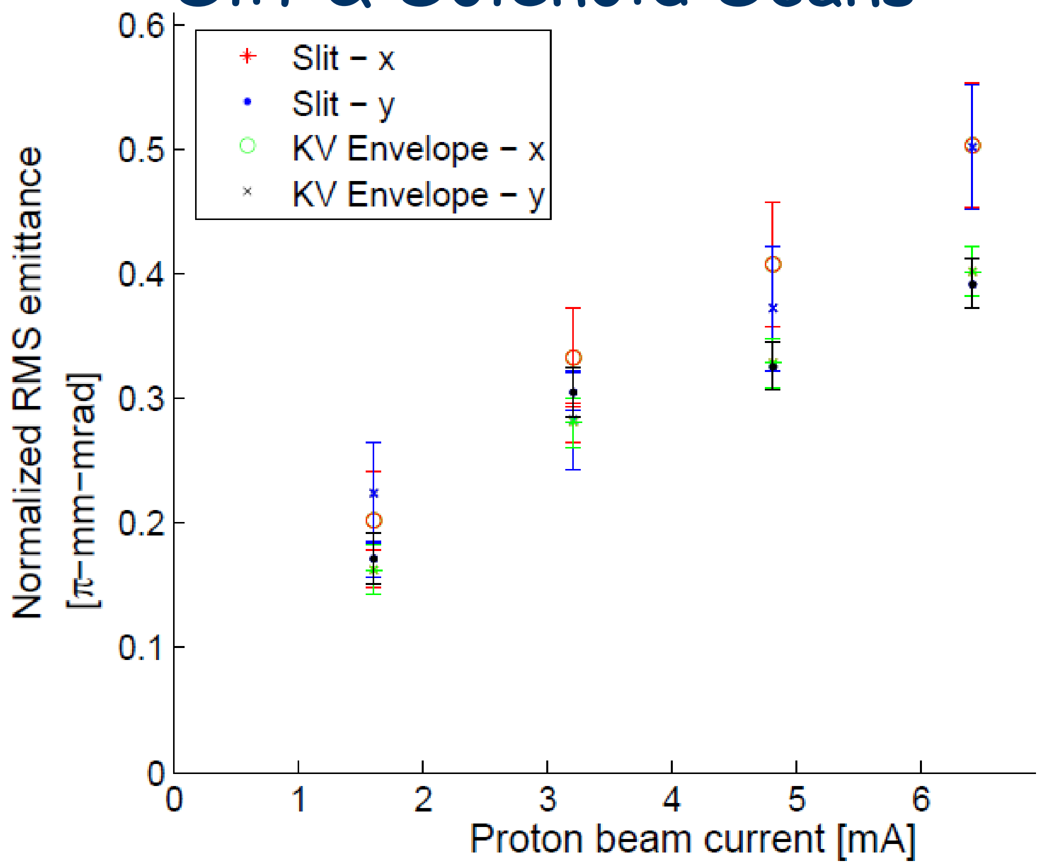
~ 30% H3+

- ***As measured by LEBT toroid***

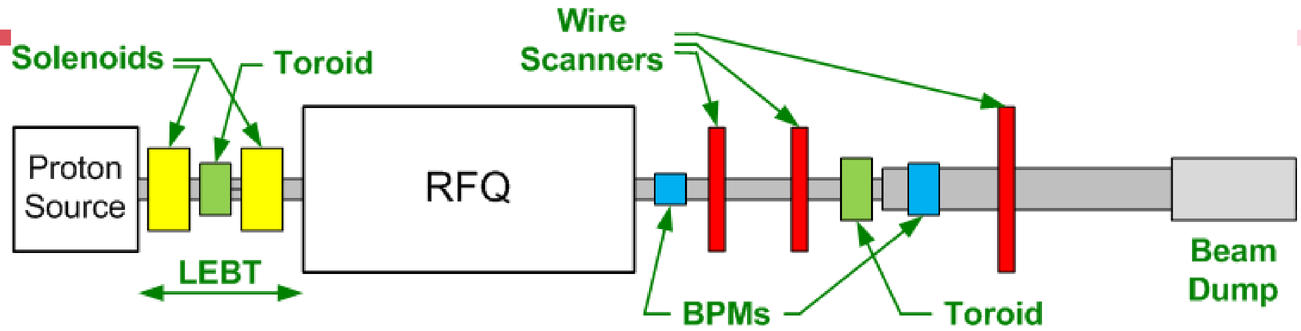
Phase Space Signal Cleaning



Source Emittance Slit & Solenoid Scans



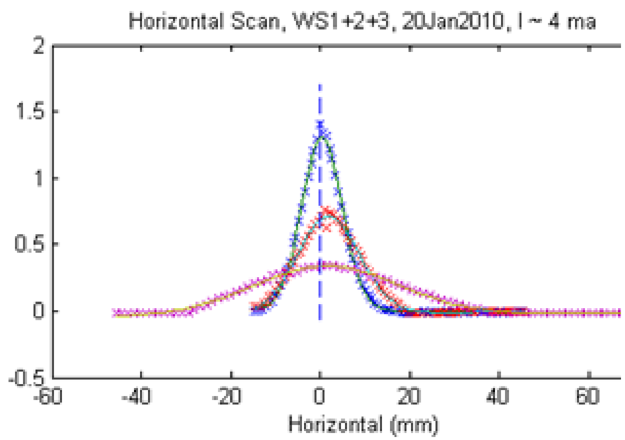
Initial RFQ Beam Measurements



RFQ design:

- 2.5 Mev
- 325 MHz
- Peak power up to 450 KW
- 1 ms pulses at 10 Hz

RFQ suffered from detuning problems and water leaks → 50 μs pulses at 1 Hz



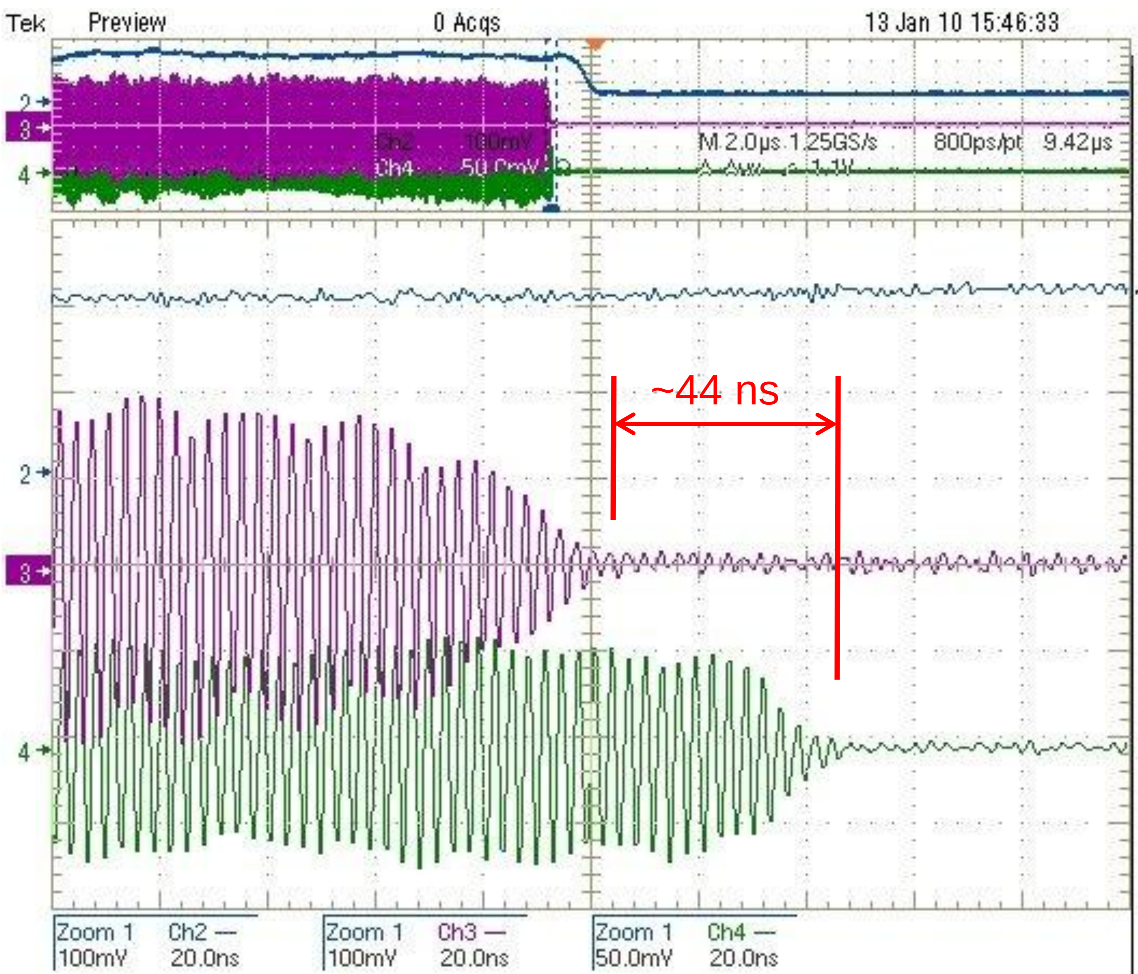
Profile Sigmas and Integrals ; I ~ 4 mA

Sigmas	Horizontal	Vertical	Diagonal
Scanner 1	4.5 mm	4.2 mm	4.3 mm
Scanner 2	7.0 mm	6.8 mm	6.2 mm
Scanner 3	16.2 mm	13.2 mm	13.4 mm

Integrals	Horizontal	Vertical	Diagonal
Scanner 1	14.8 V*mm	14.9 V*mm	14.7 V*mm
Scanner 2	11.8 V*mm	10.5 V*mm	10.2 V*mm
Scanner 3	11.6 V*mm	10.1 V*mm	10.7 V*mm

Beam loss after first wire scanner → need focusing

RFQ Energy Measurement by Time of Flight



Signals from toroid and two BPM buttons, all downstream of the RFQ

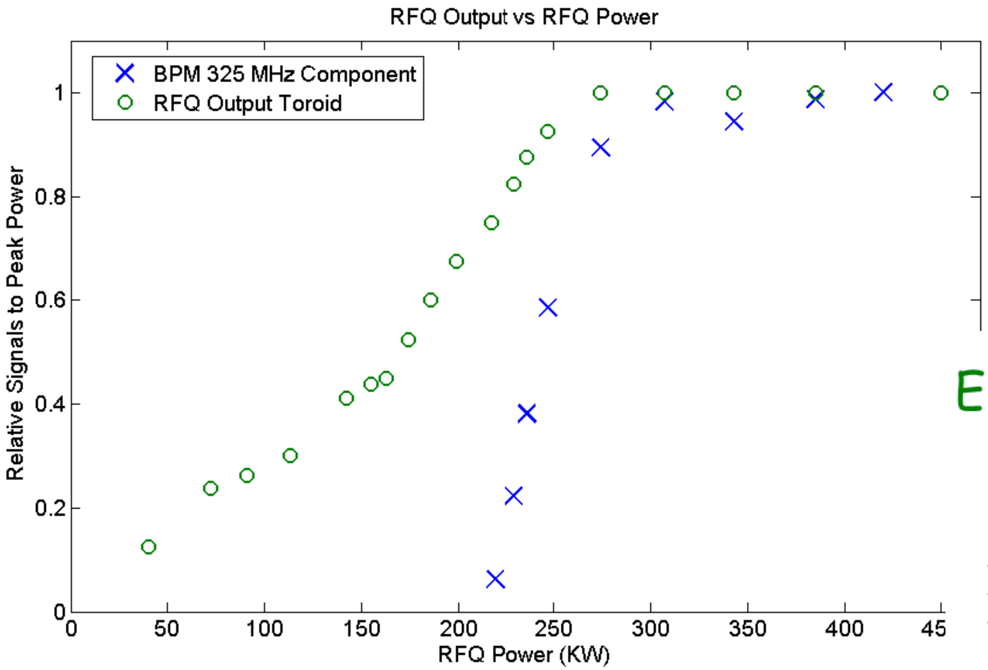
Upper display: 2 μsec/div

Lower display: 20 nsec/div

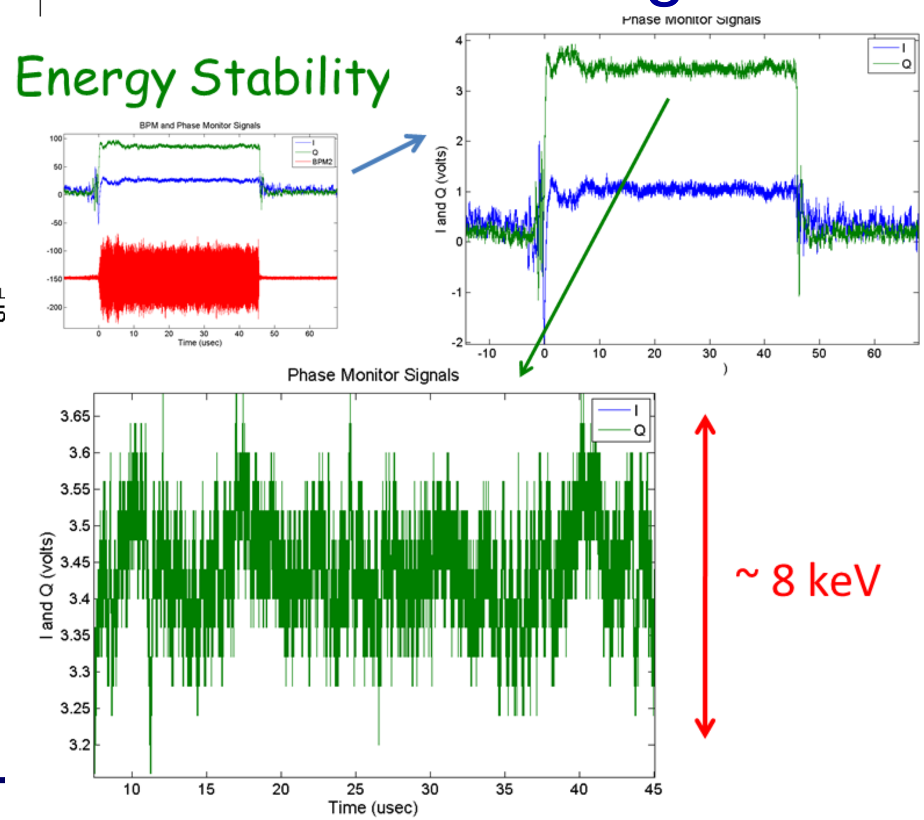
Lower display shows the 44 ns delay expected for transit of 2.5 MeV beam between the BPM two buttons separated by 0.96 meters

Beam current is about 3 mA

RFQ Stability



Phase variation from time-of-flight



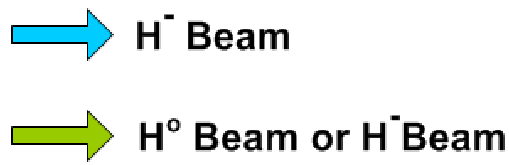
Relative RFQ output beam vs. RF Power

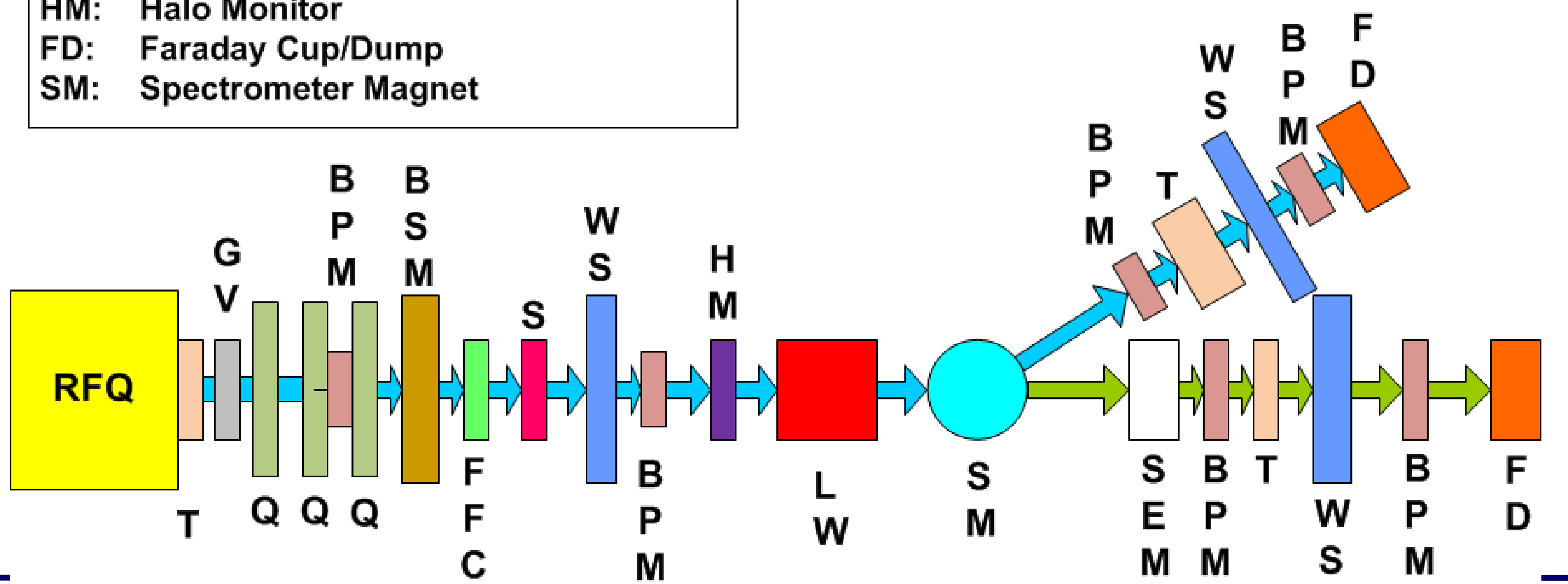
Next Iteration of RFQ Beam Measurements

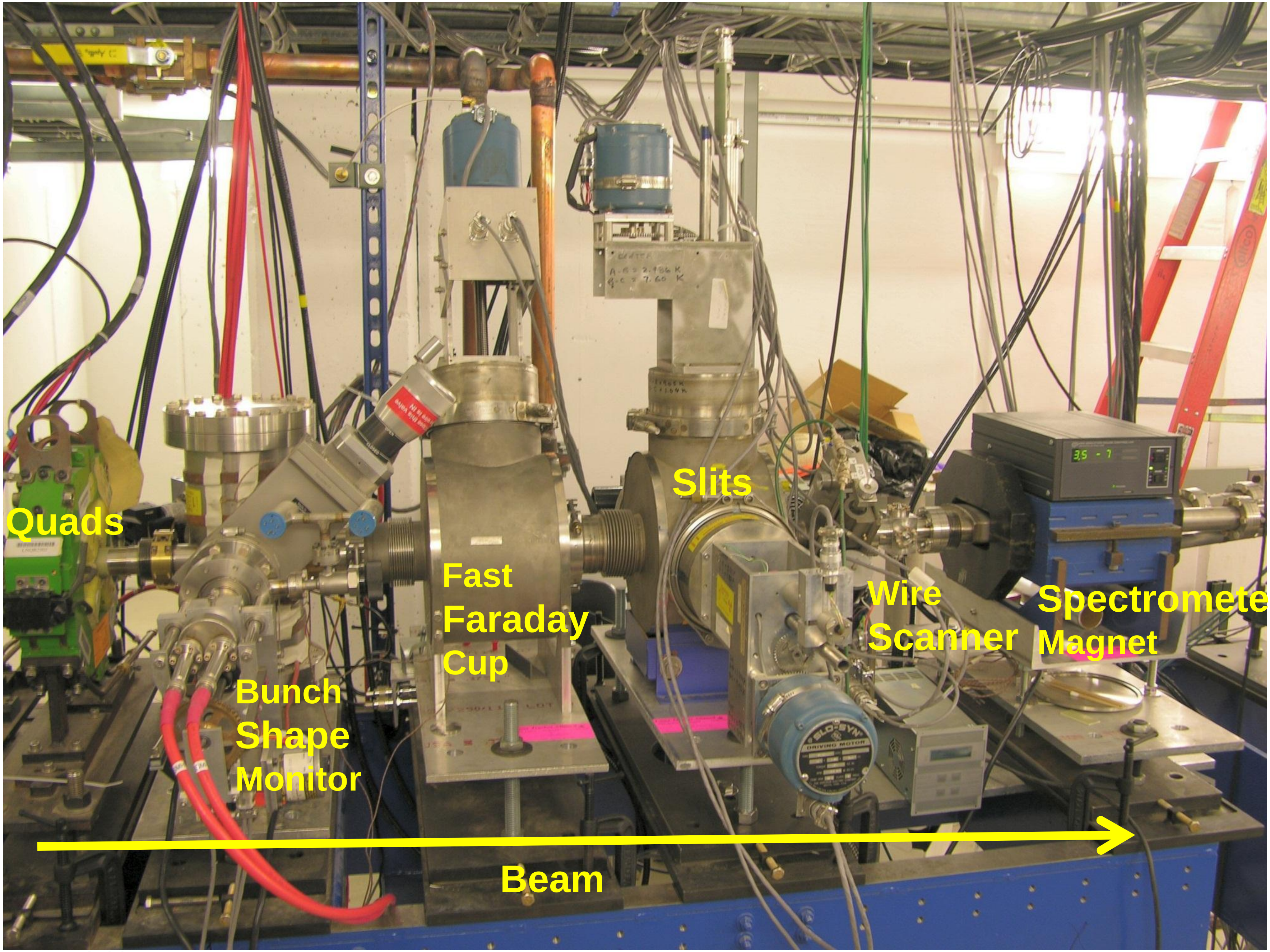
- Initial measurements suffered from RFQ water leak problems
  - RFQ limited to 50 μsec pulses
  - RFQ has been repaired and reinstalled at the Meson test facility
- Initial RFQ measurements suffered many issues
  - No transverse focusing → Quadrupoles added
  - No longitudinal measurements → FFC and BSM
  - No transverse emittance measurements → Quad-Wire, Slit-Wire
  - Energy measurement was not precise → Spectrometer magnet
  - RFQ efficiency not accurately measured → Toroid at RFQ output
- New diagnostics line has been install
  - Reconfigurable, movable
  - ***Space available for R&D projects***

Advanced HINS Diagnostics Line

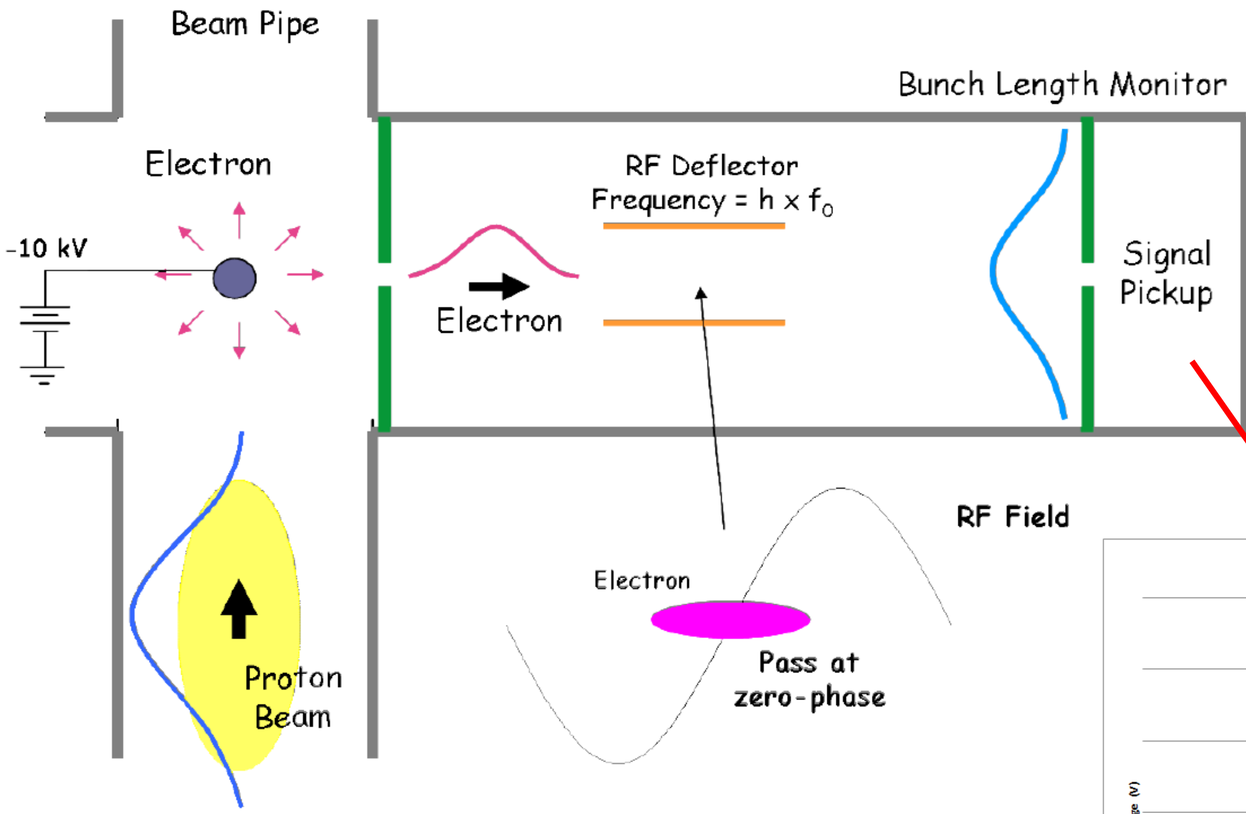
- T: Toroid
- GV: Gate Value
- Q: Quadrupole
- LW: Laser Wire
- SEM: Secondary Emission Monitor
- BPM: Beam Position Monitor
- WS: Wire Scanner
- S: Horz and Vert Slits
- BSM: Bunch Shape Monitor (Longitudinal)
- FFC: Fast Faraday Cup
- HM: Halo Monitor
- FD: Faraday Cup/Dump
- SM: Spectrometer Magnet



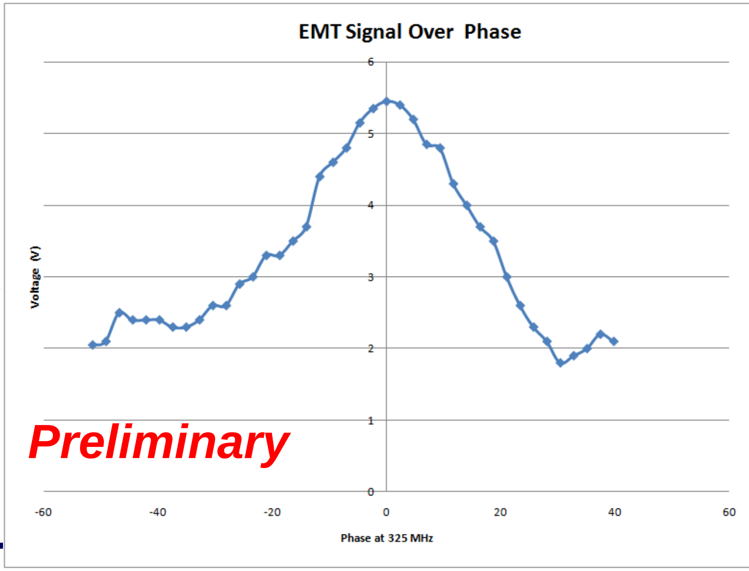



Quads
Bunch
Shape
Monitor
Fast
Faraday
Cup
Slits
Wire
Scanner
Spectrometer
Magnet
Beam

Longitudinal Bunch Shape Monitor



FWHM: (prelim)
~ 40^o @325 MHz
~ 340 ps

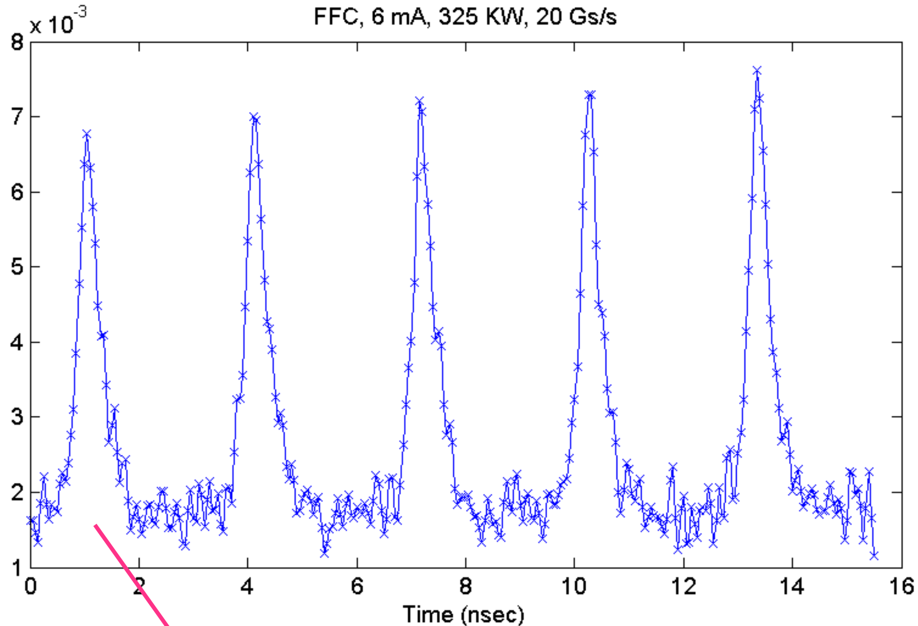


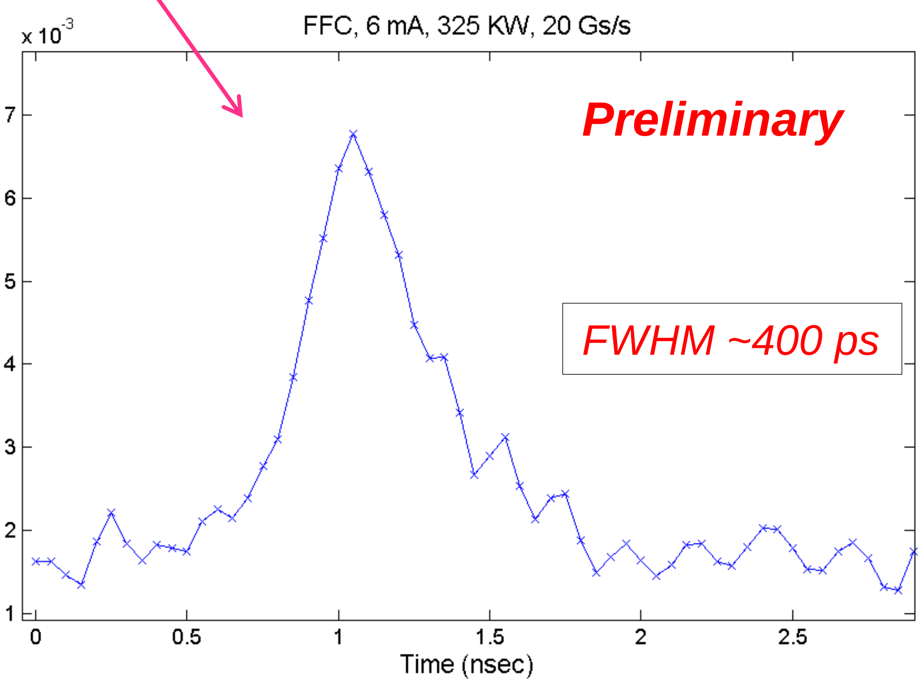
Translate time coordinate into space coordinate using RF deflector cavity

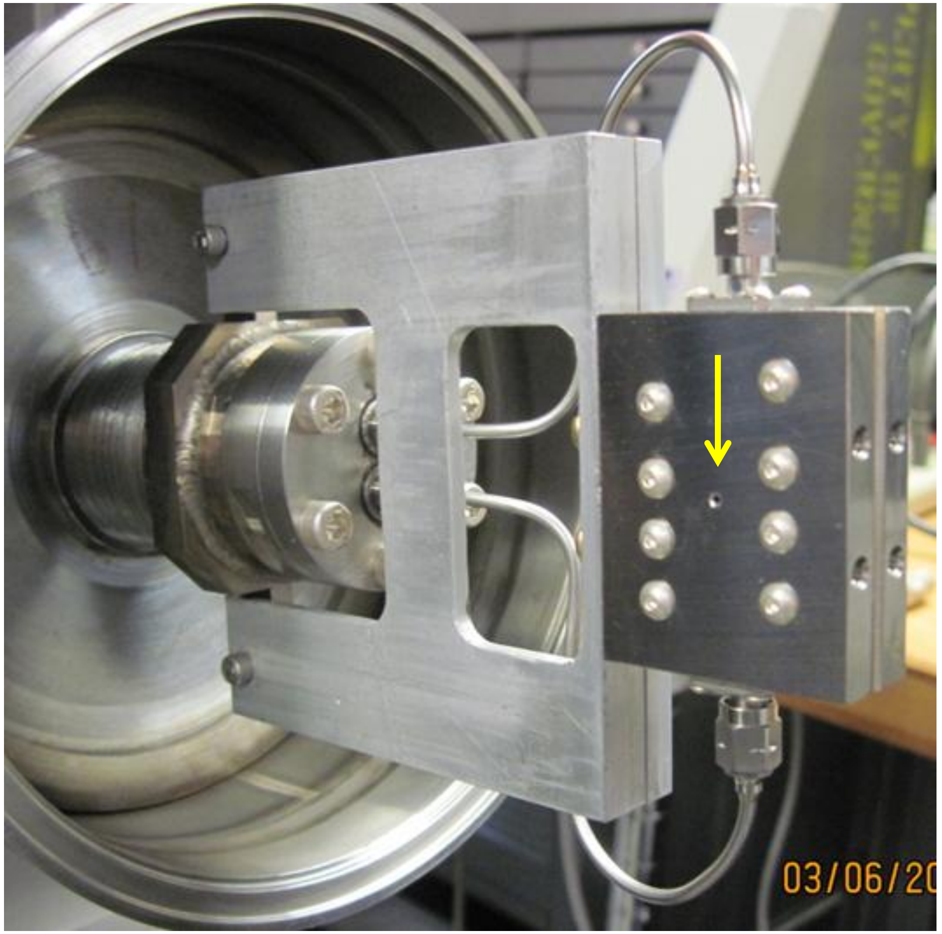
- like a streak camera

Systematics need to be understood

Longitudinal Bunch Shape – Fast Faraday Cup







Beam Diagnostic Projects for Project X

Transverse Diagnostics

- Laser Transverse Profile Monitor*
- Ionization Profile Monitors
- Electron Wire Transverse Profile Monitor – with SNS

Longitudinal Diagnostics

- Wire Longitudinal Profile Monitor*
- Laser Longitudinal Profile Monitor* - with LBNL
- Broadband Faraday-cup – with SNS*****

Halo Monitoring – transverse and longitudinal

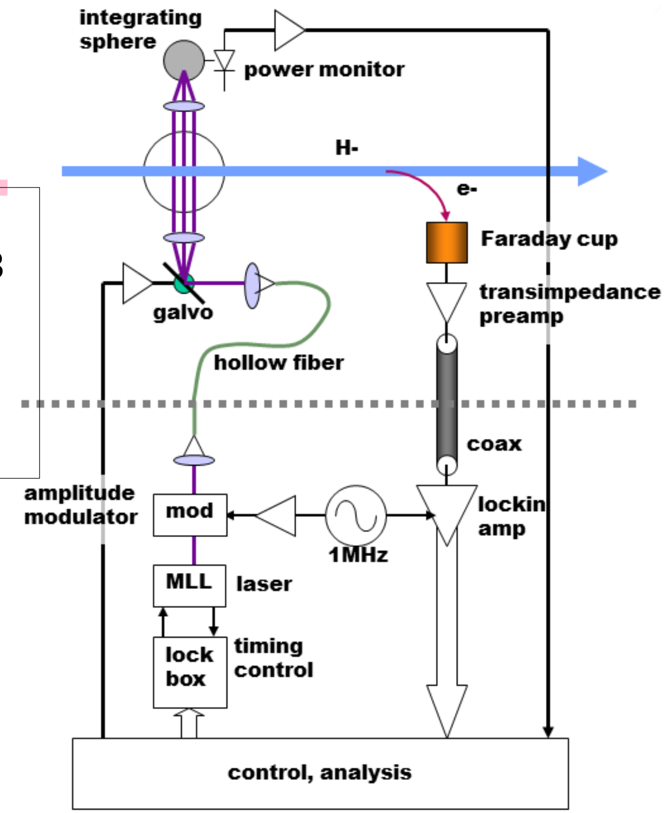
- Vibrating wire* - *from Bergoz Instrumentation*
- Laser wire* - with LBNL

MEBT Emittance station

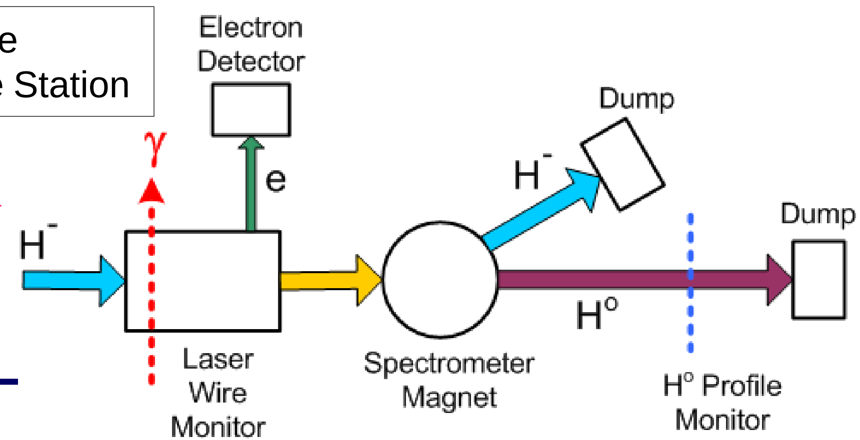
- Slit-collector*
- Laser Slit*

** Project X related instrumentation to be tested at HINS*

See R. Wilcox Poster TUPD53 “A Low-Power Laser Wire with Fiber Optic Distribution”



Laser Wire Emittance Station



Conclusion

- MDB Test Facility (HINS) has taken initial proton source and RFQ beam measurements
- RFQ has been repaired and reinstalled at MDB
- New diagnostics line has been installed
- RFQ Beam measurements have started
- Six cavity to be installed this year – accelerator and buncher cavities
  - H^- to be installed later this year
- The MDB test facility HINS will be key to future Project X front-end testing
- ***Outside collaborators invited and encouraged to use MDB and HINS for diagnostic instrumentation R&D***