

# Beam Diagnostics & Beam Studies at HINS / MDB

Vic Scarpine - Fermilab

Project X Collaboration Meeting

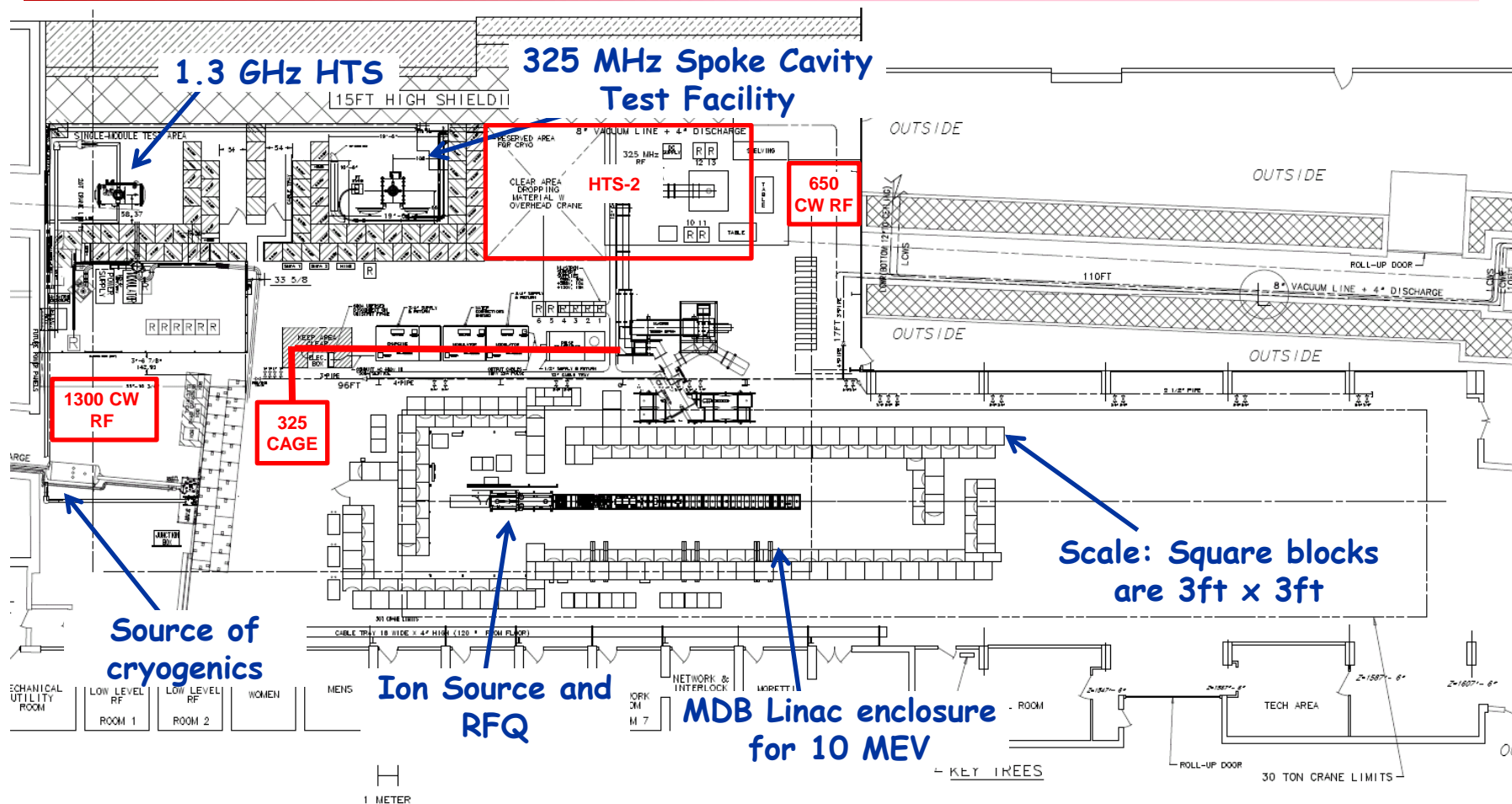
13 Apr 2011



- 
- Motivation
  - HINS Parameters
  - HINS Measurements to Date
  - Beam Diagnostic Projects
  - Collaborations
  - Goals and Timelines
  - Conclusions

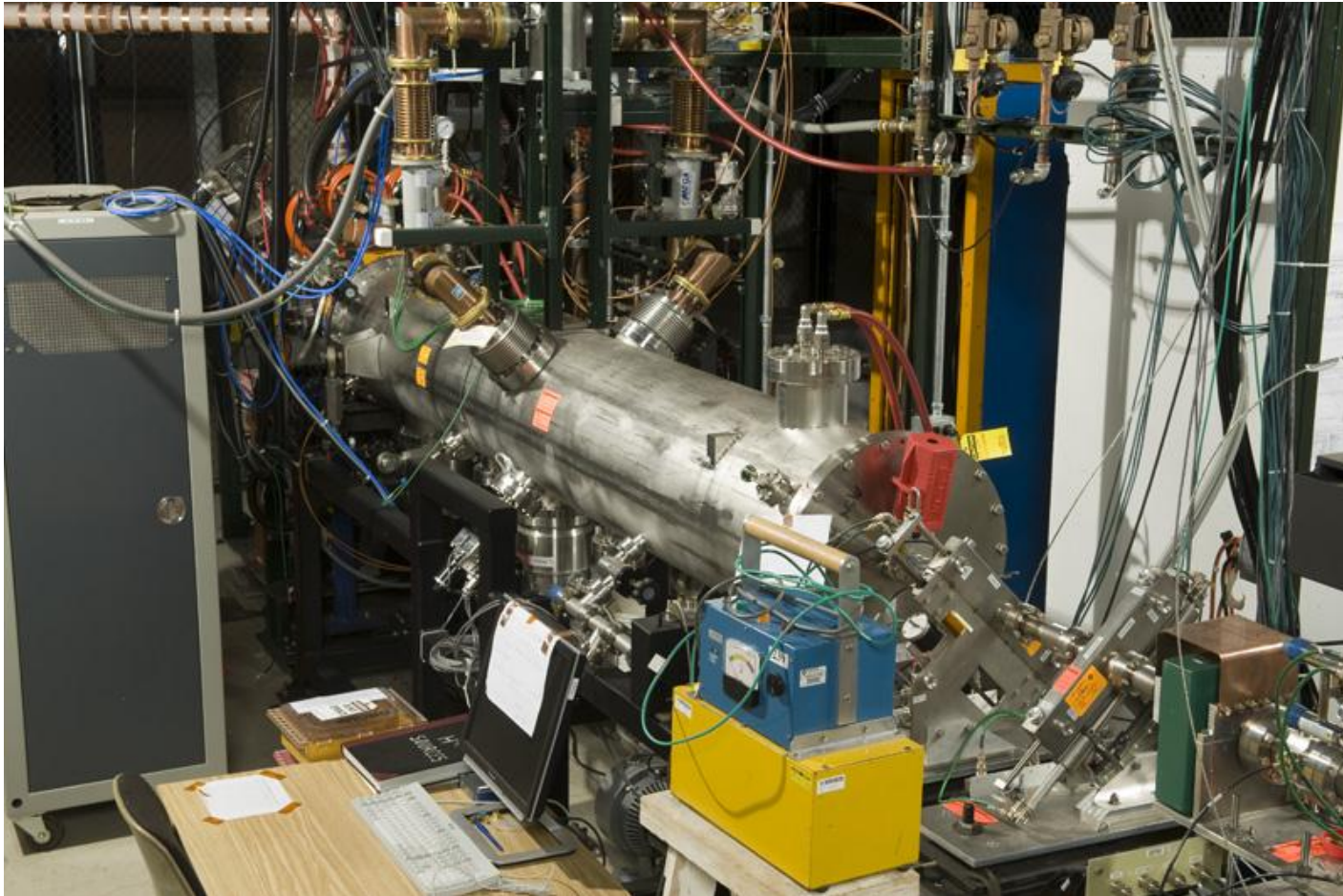


- The Meson Detector Building (MDB) Test Facility (formerly known as HINS – High Intensity Neutrino Source) ultimately comprises:
  - A shielded beam line enclosure with first proton, then  $H^-$ , pulsed 1% duty factor, 3 millisecond beam up to 10MeV
    - For Project X 325 MHz superconducting spoke 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



# MDB Test Facility

## 325 MHz Pulsed RFQ





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 Current	32	mA
Bunch Intensity	6.1 98	E8 pCoul

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



---

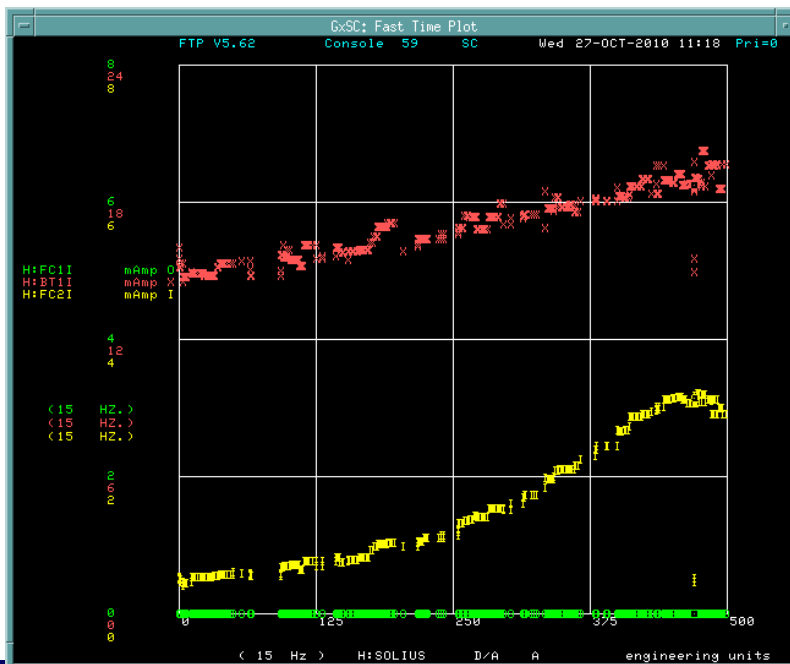
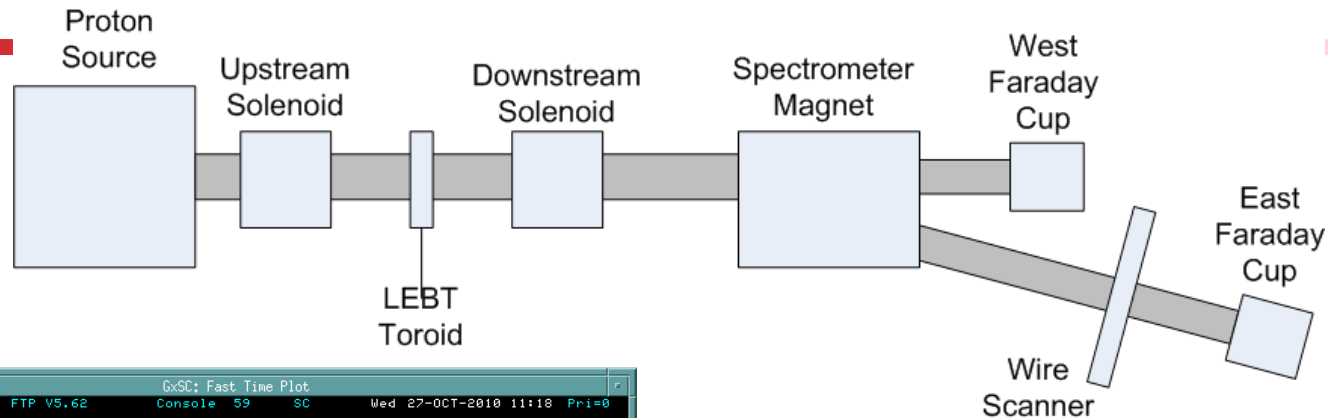
# **Initial Proton Source and RFQ Beam Measurements**



- First proton beam through RFQ in Spring 2010
- Beam parameters:
  - Ion source (protons): 500 usec @ 1 Hz
  - RF: 50 usec @ 0.5 Hz
    - RFQ operated without cooling
- Ion Source Toriod ~ 15-20 ma
  - <50%?? protons; >50%?? other (H2+, H3+)
  - Ion source species are being measured
- RFQ Output Toriod Current ~ 3-4 ma
  - Possible beam loss after RFQ but before toroid
- *Basic diagnostics line to make transverse profiles and energy measurements*



# Proton Source Test Setup

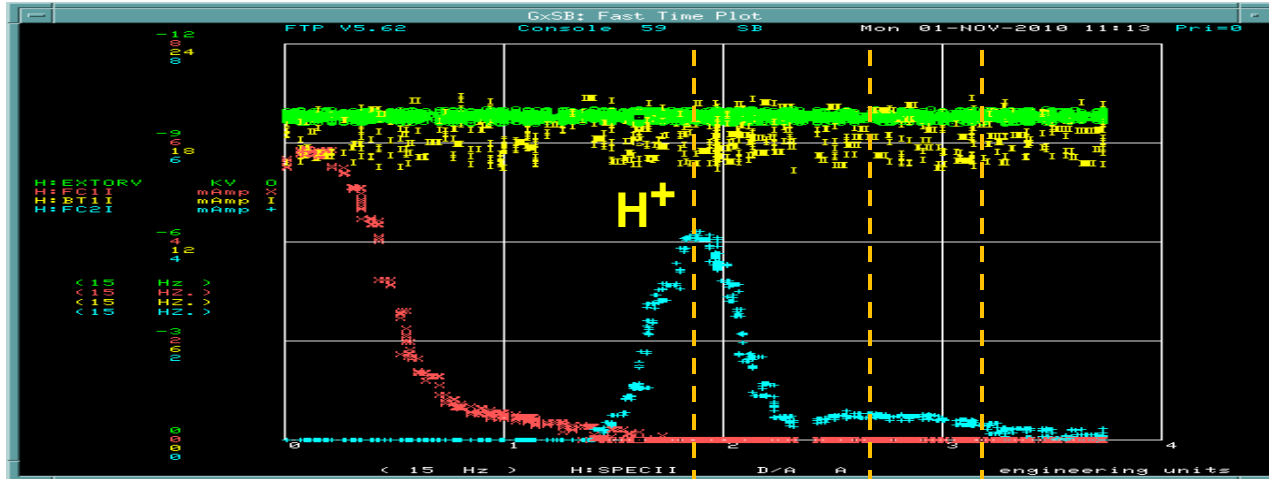


**LEBT Toroid**

**East Faraday Cup**

Optimize Upstream solenoid to transmit  
Max protons to east Faraday cup

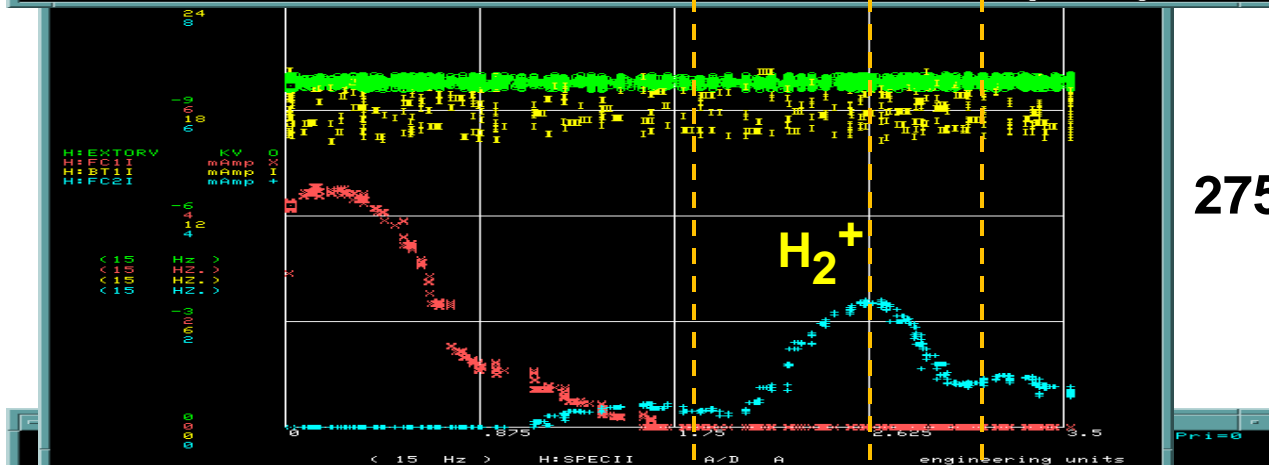
- spectrometer set for protons
- Up solenoid → 470 A



170 A

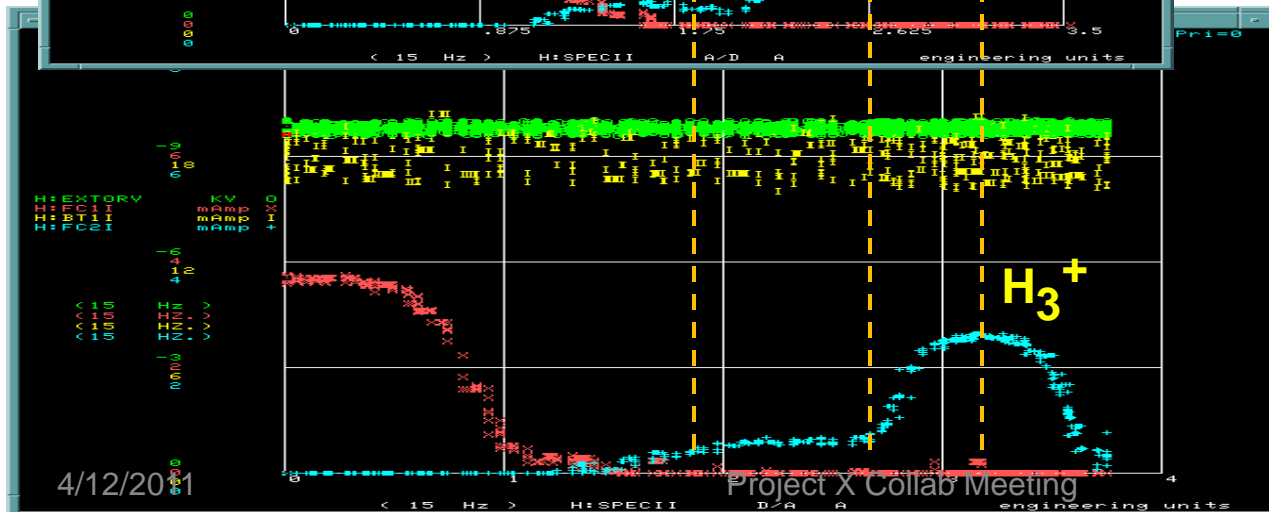
Horz scales aligned

Green – Source  
Extractor Voltage  
Yellow – LEBT Toroid  
Current  
Red – West Faraday  
Cup (straight ahead)  
Blue – East Faraday  
Cup (bend)



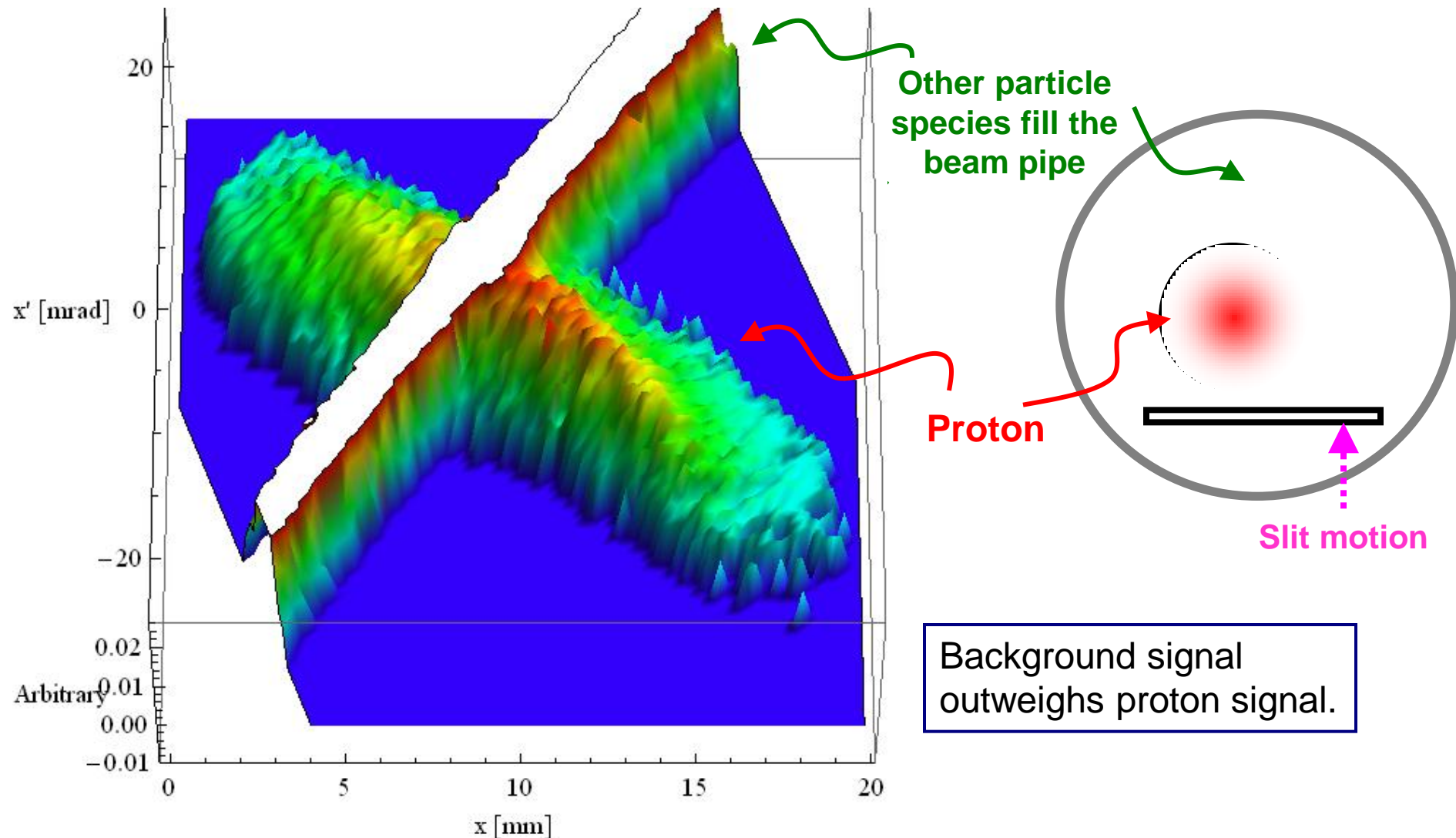
275 A

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

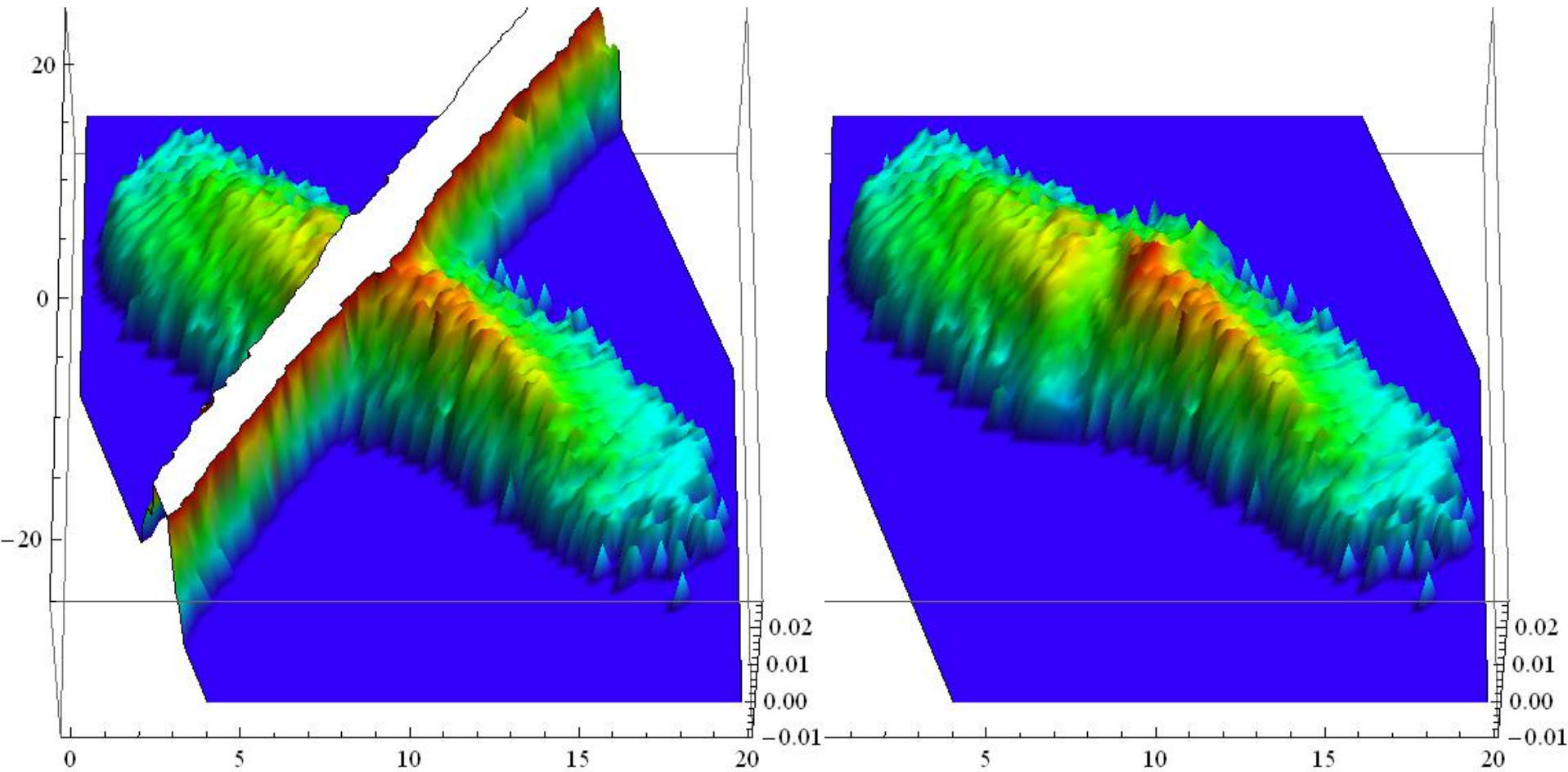


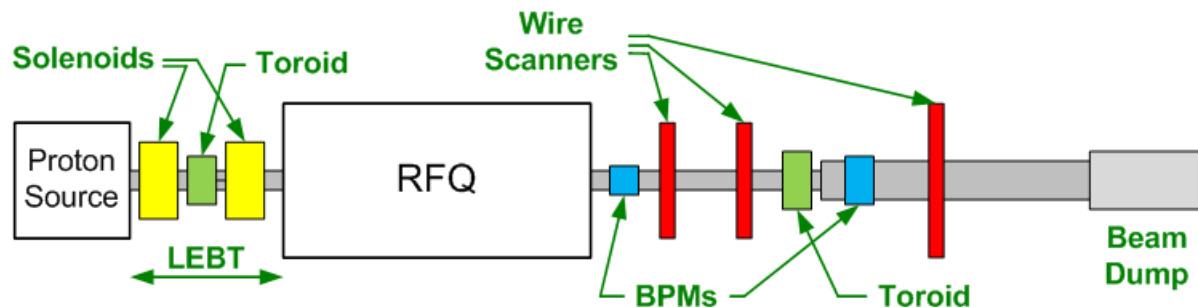
335 A

# Proton Source Slit-WS Emittance Measurement



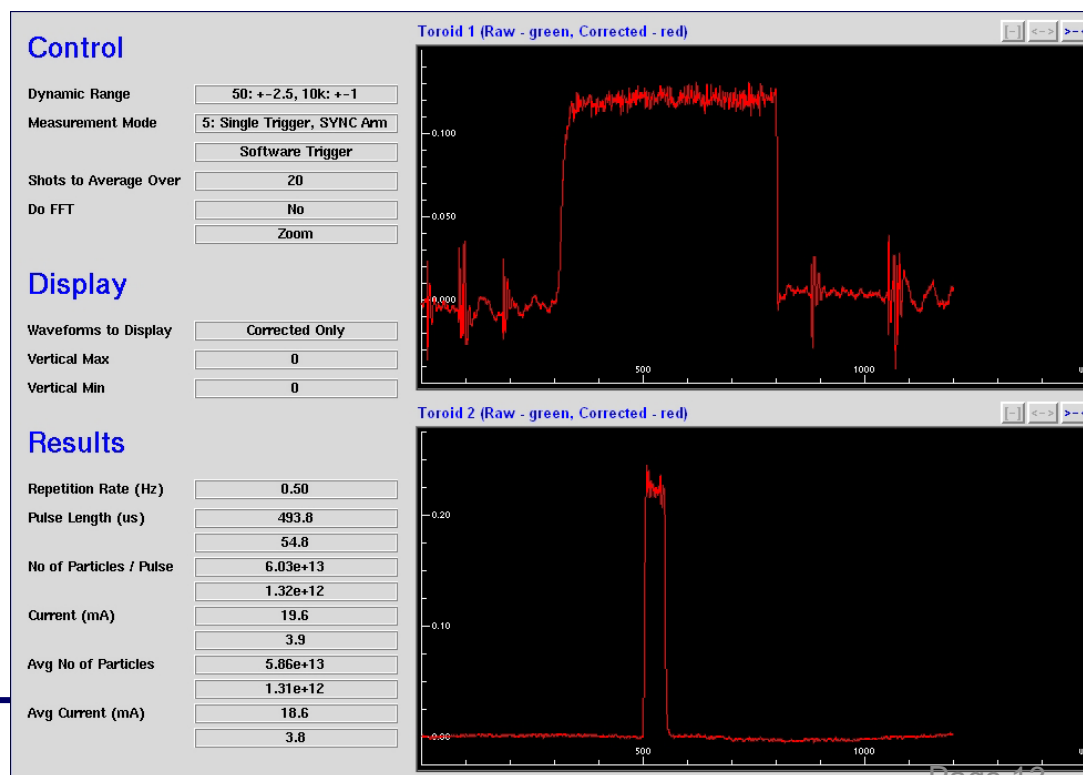
# Signal Cleaning





Initial Diagnostics Line

## Initial Beam Currents

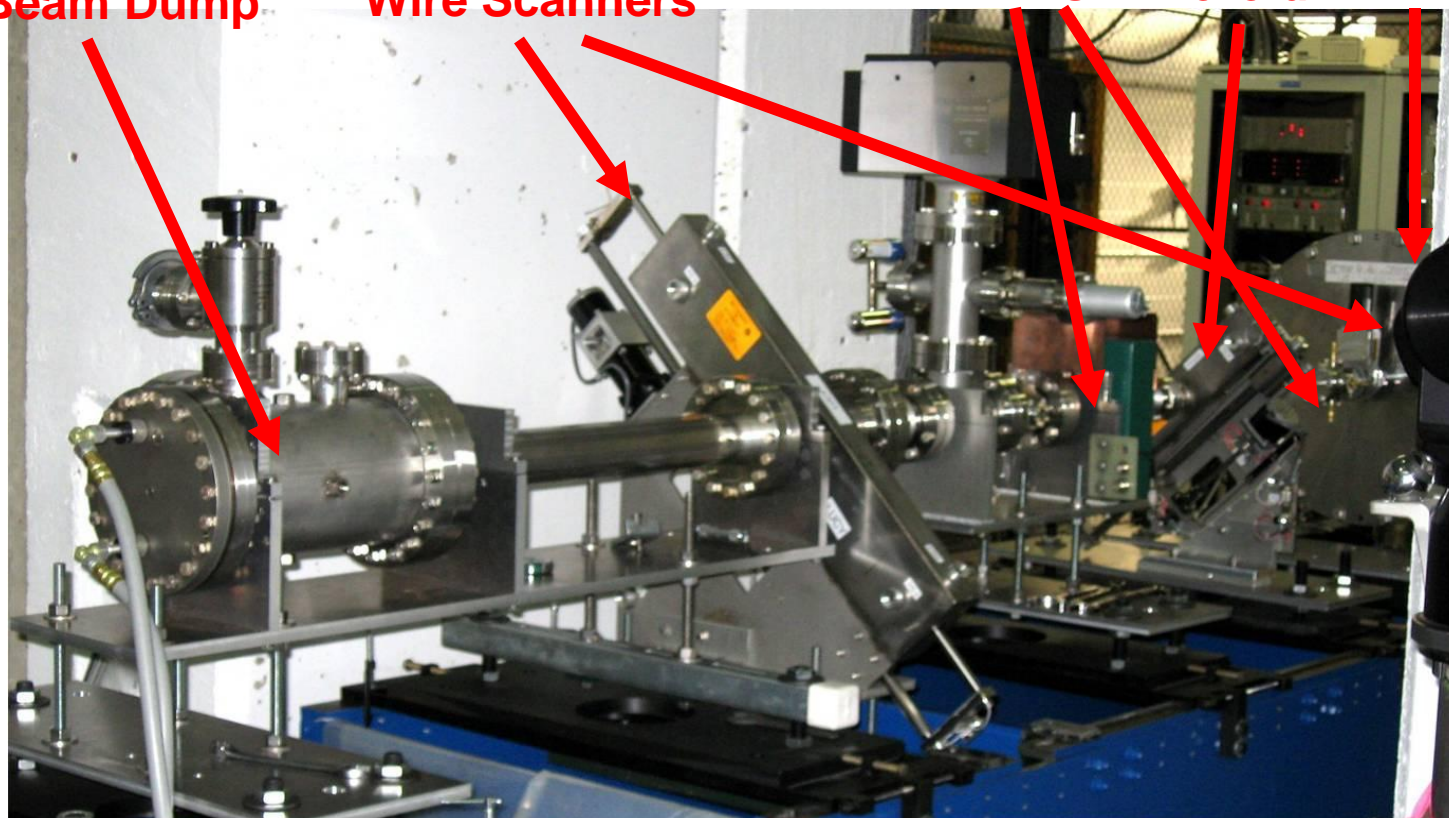


# Initial RFQ Beam Diagnostics



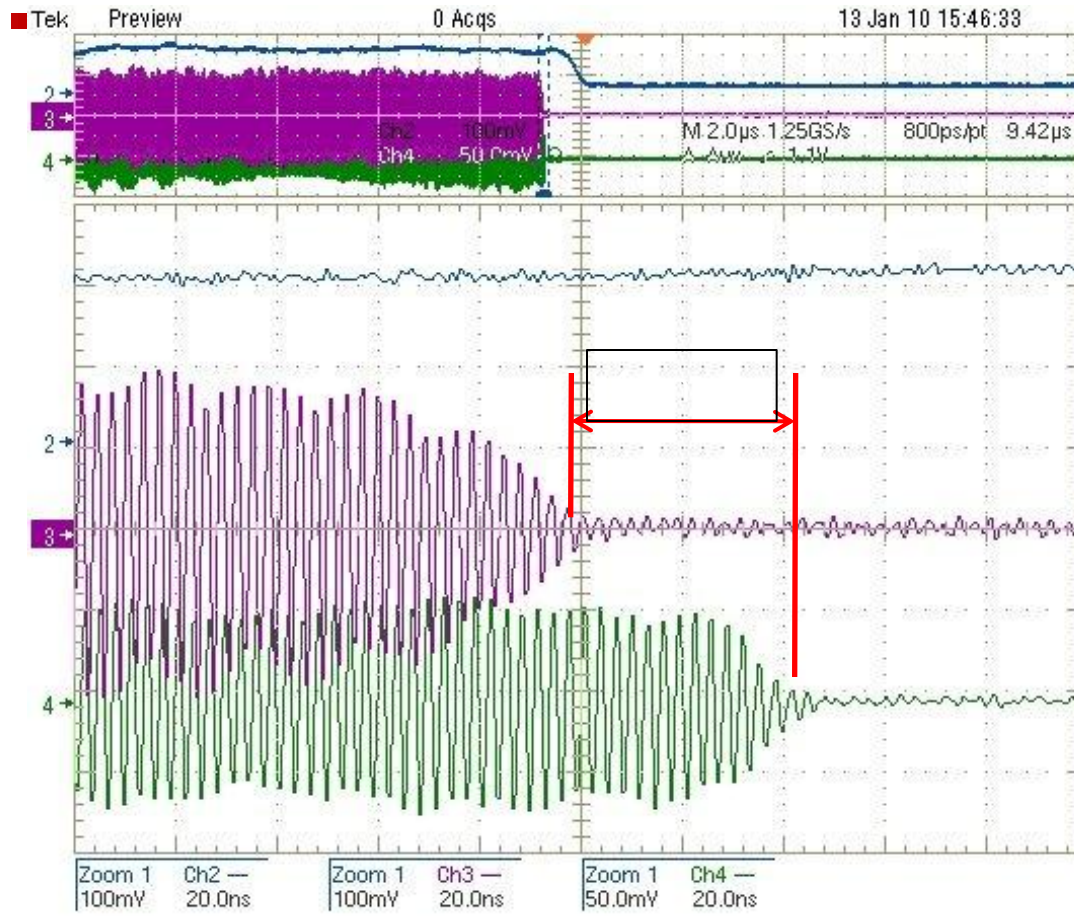
The HINS linac was equipped with a reconfigurable, movable diagnostics station at the end of the linac

**Beam Dump**      **Wire Scanners**      **BPMs**      **Toroid**      **RFQ**





# RFQ Energy Measurement – First Beam on 1/13/2010



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

Upper display: 2  $\mu$ sec/div

Lower display: 20 nsec/div

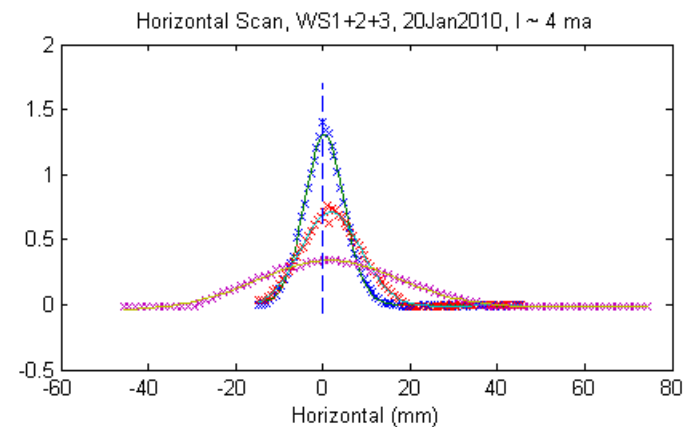
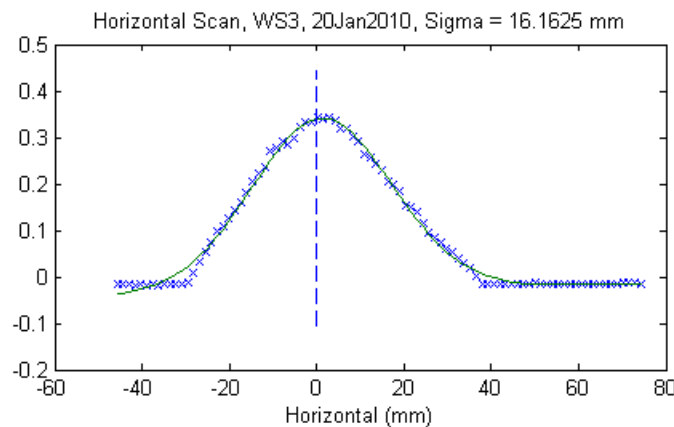
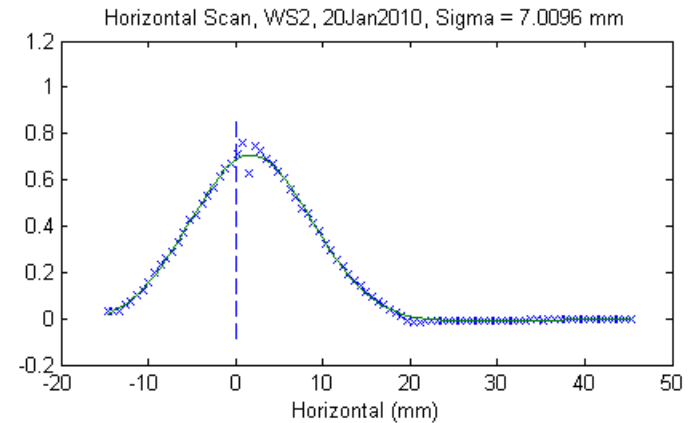
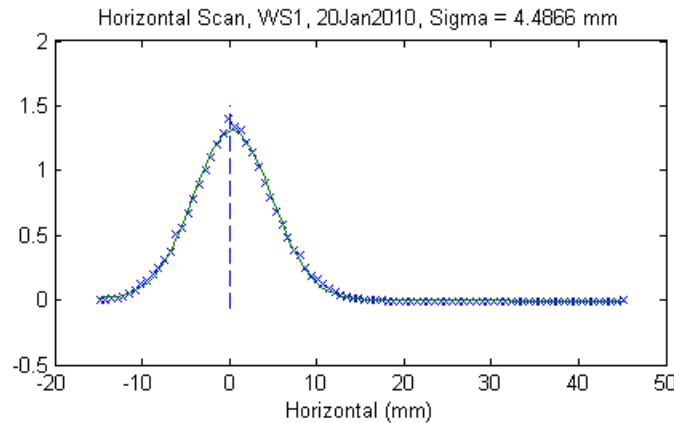
Lower display shows the 44nsec delay expected for transit of 2.5 MeV beam between the BPM two buttons separated by 0.96 meters

Beam current is about 3 mA

# Early 2.5 MeV Beam Profiles – Horizontal at 4 mA

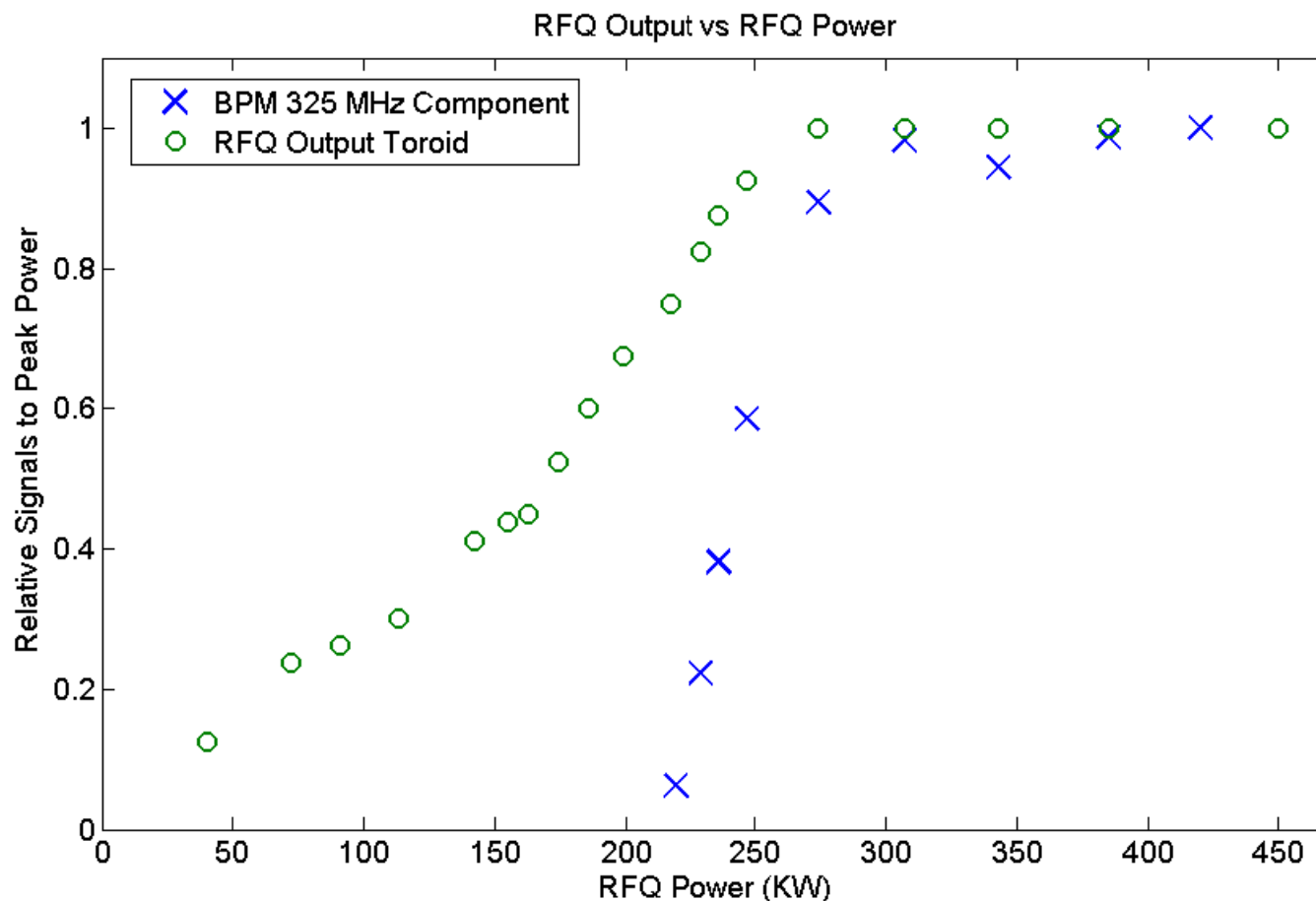


Note: Beam  
loss  
after first  
wire  
scanner





# 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  $\mu$ sec pulses
  - RFQ has been repaired and reinstalled at the Meson test facility
- Initial RFQ measurements suffered many issues
  - No longitudinal measurements → FFC and BSM
  - No transverse emittance measurements → Quad-Wire, Slit-Wire
  - Energy measurement was not precise → spectrometer magnet
  - RFQ transmission efficiency not measured
    - Toroid not close enough to RFQ output
- New diagnostics line has been install
  - Reconfigurable
  - Space for R&D projects

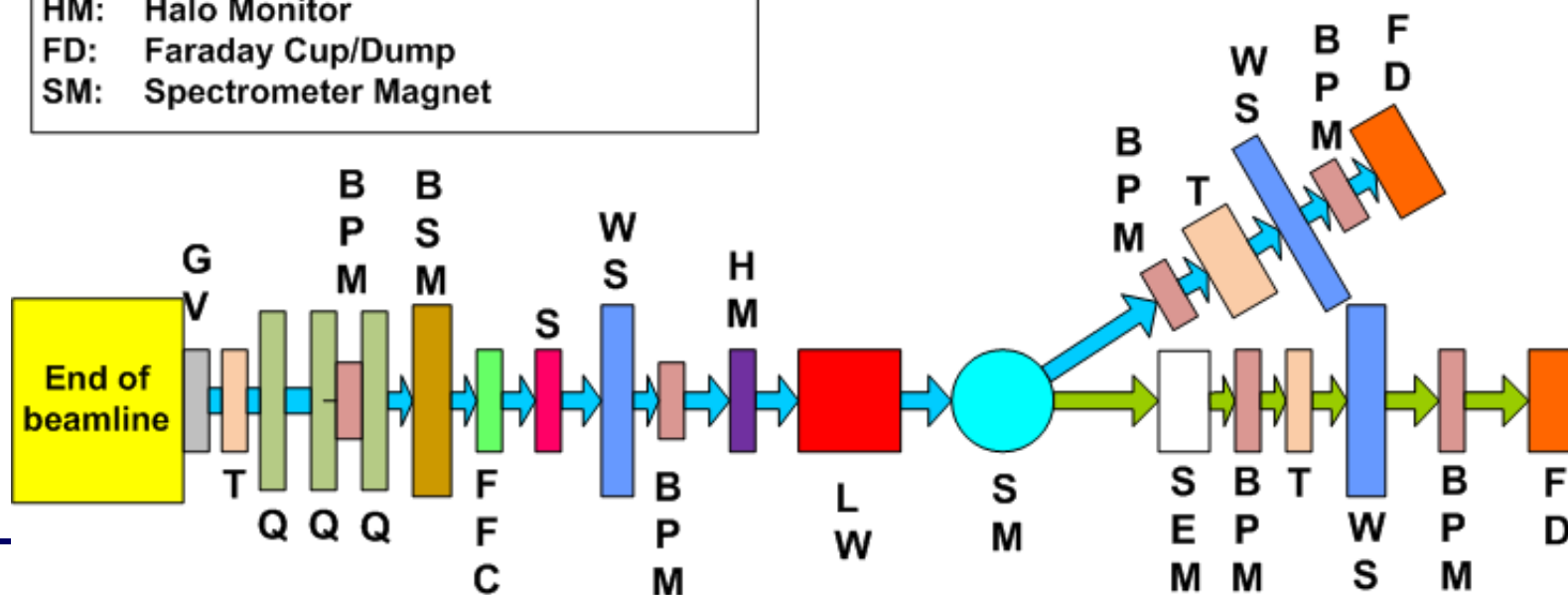
# Advanced HINS Diagnostics Line

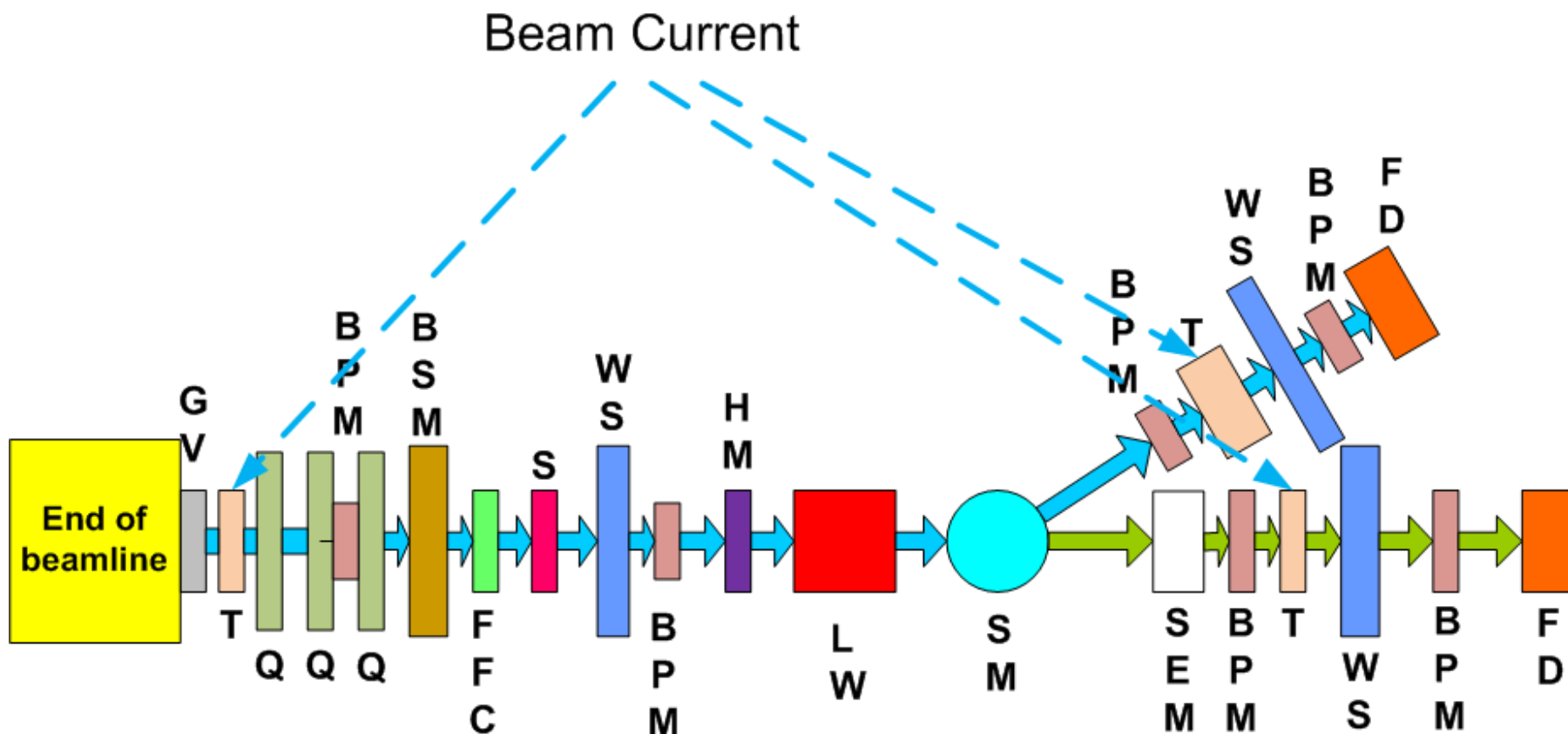


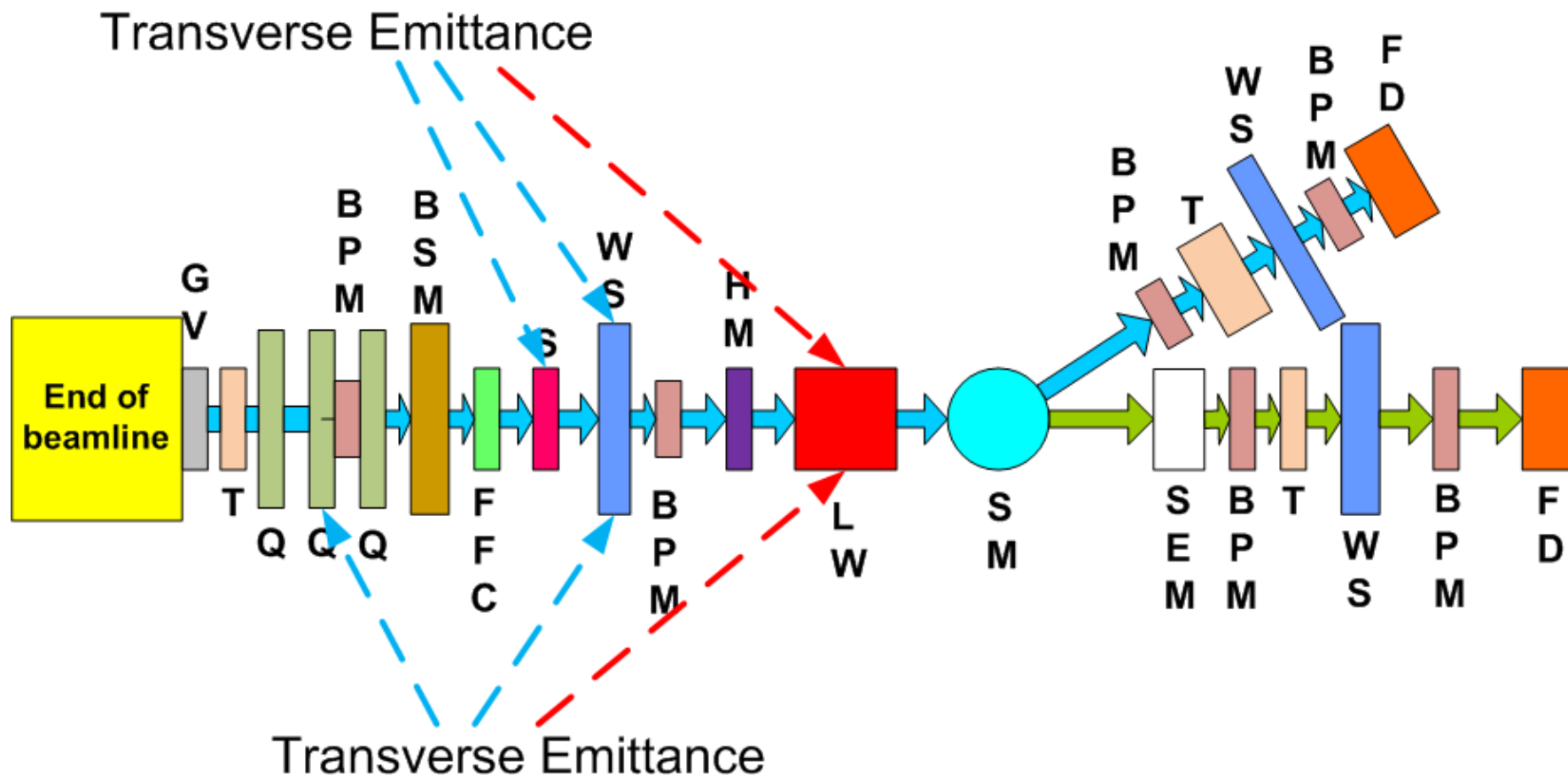
**T:** Toroid  
**GV:** Gate Value  
**Q:** Quadrupole  
**LW:** Laser Wire  
**SEM:** Secondary Emission Monitor  
**BPM:** Beam Position Monitor  
**WS:** Wire Scanner  
**S:** Horz and Vert Slits  
**BSM:** Bunch Shape Monitor (Longitudinal)  
**FFC:** Fast Faraday Cup  
**HM:** Halo Monitor  
**FD:**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

Advanced HINS Diagnostics Line  
 V 1.0  
 May 19, 2010

  $H^-$  Beam  
  $H^0$  Beam or  $H^-$  Beam

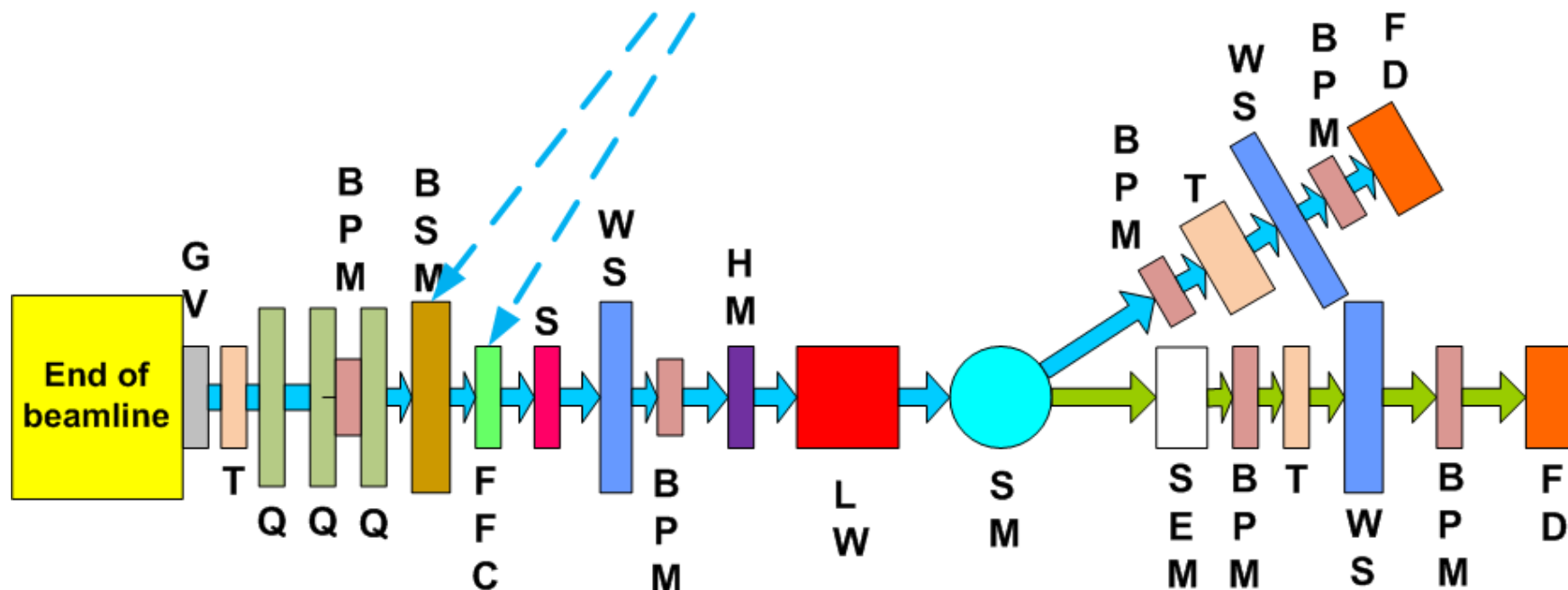






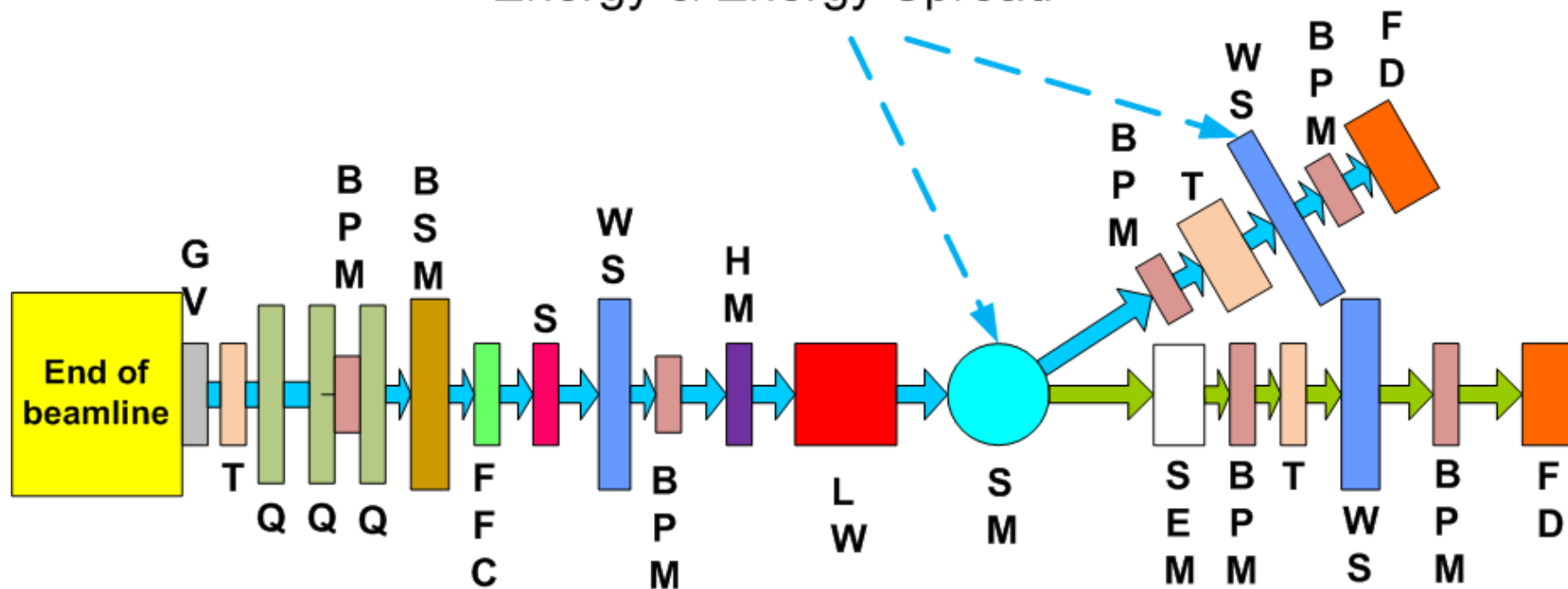


## Longitudinal Bunch Shape





## Energy & Energy Spread



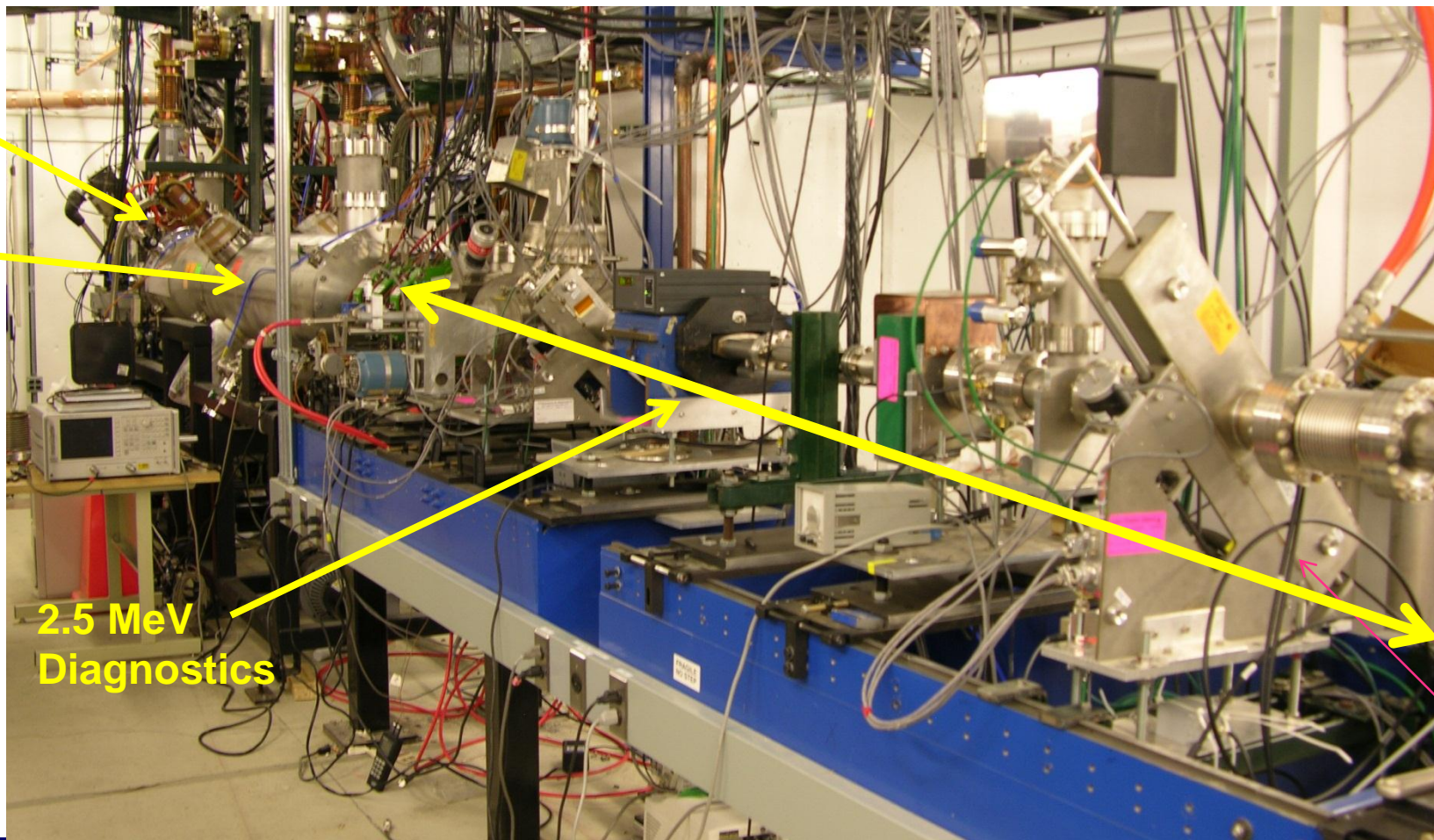




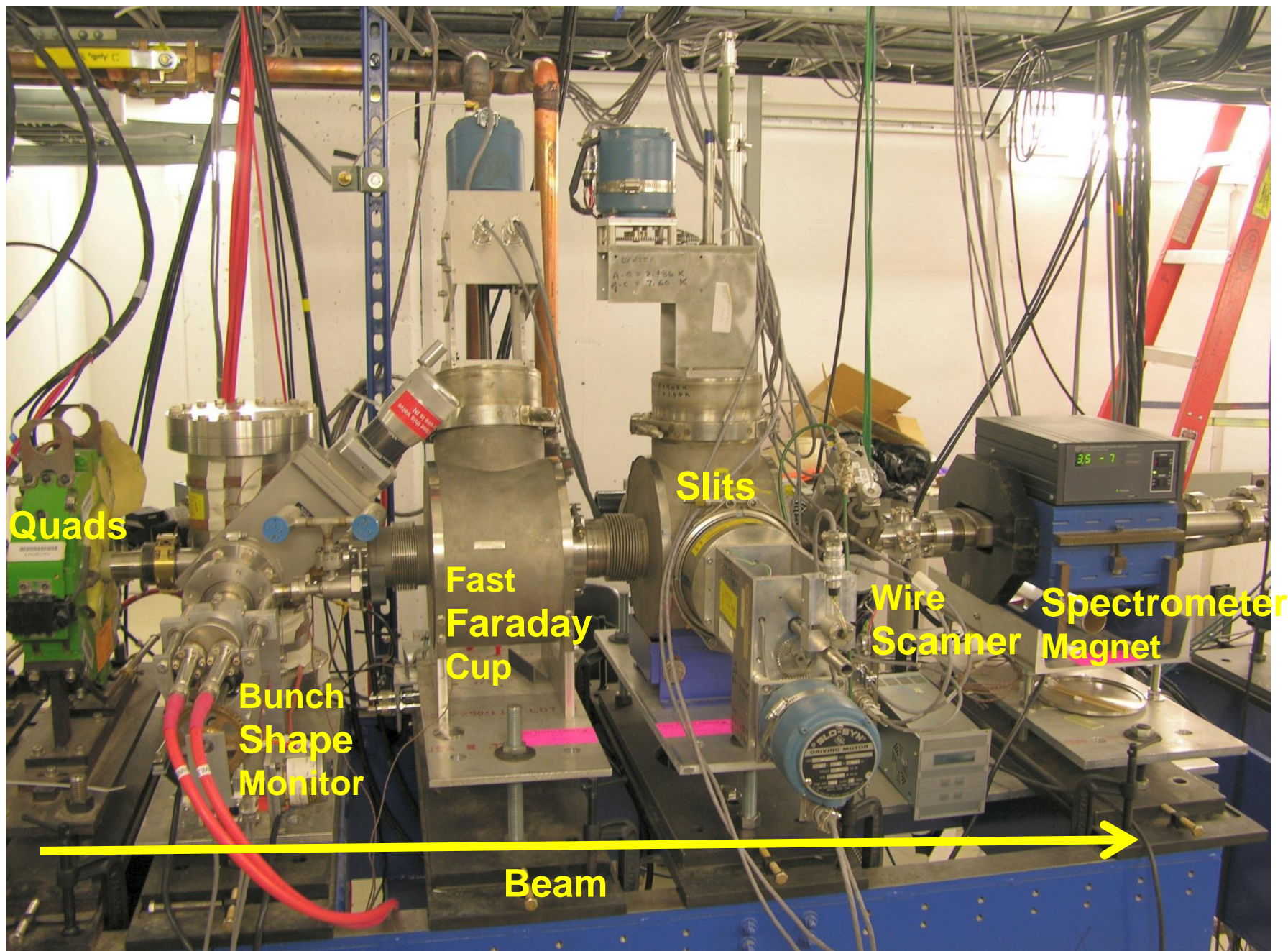
**Source  
/LEBT**

**RFQ**

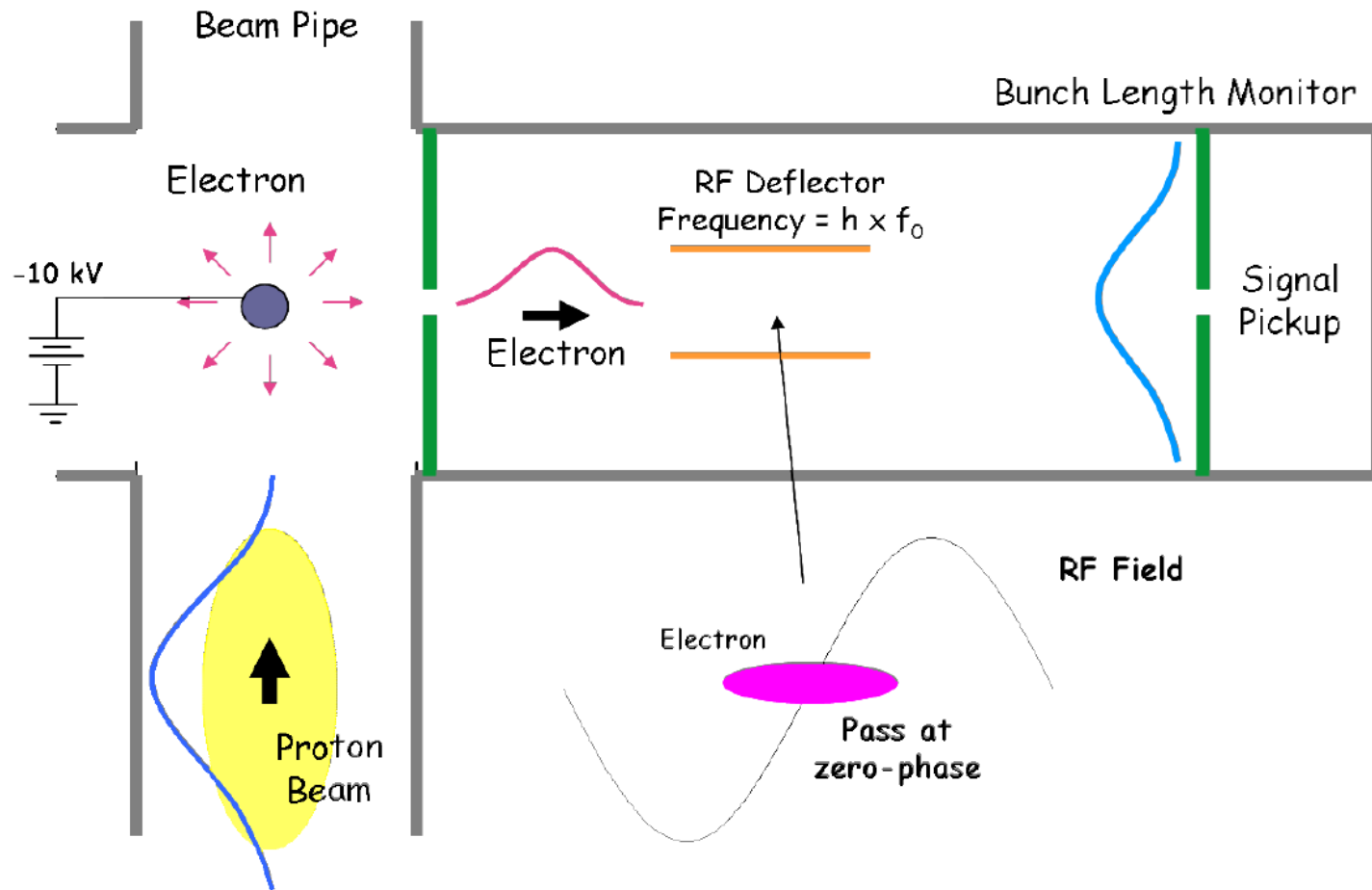
**2.5 MeV  
Diagnostics**







# Longitudinal Bunch Shape Monitor



# Beam Diagnostic Projects for Project X



- *Transverse Diagnostics*
  - Laser Transverse Profile Monitor\*
  - Ionization Profile Monitors
  - Electron Wire Transverse Profile Monitor
- *Longitudinal Diagnostics*
  - Wire Longitudinal Profile Monitor\*
  - Laser Longitudinal Profile Monitor\*
  - Broadband Faraday-cup\*
- Halo Monitoring – transverse and longitudinal
  - Vibrating wire\* - *from Bergoz Instrumentation*
  - Laser wire\*
- MEBT Emittance station
  - Slit-collector\*
  - Laser Slit\*

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

# Project X Beam Diagnostics Collaborations

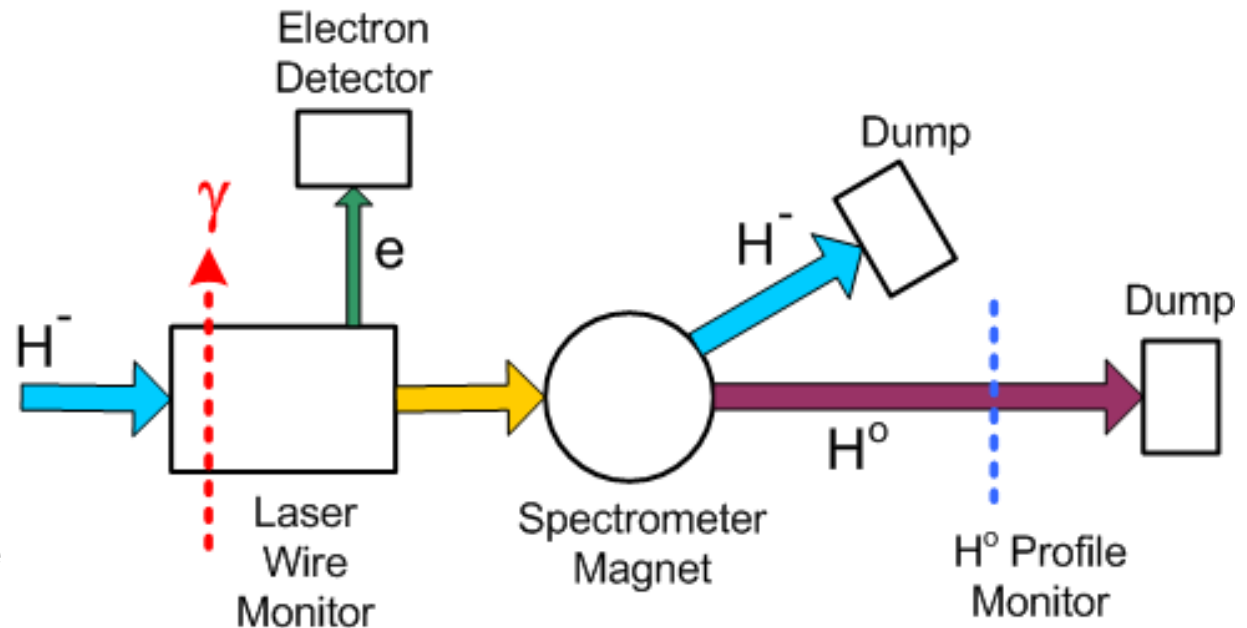


- Project X Collaboration Initiative (November 2008):
  - Present beam instrumentation collaboration projects with SNS, LBNL, and SLAC
- SNS
  - Various advanced diagnostics systems (**broadband Faraday-cup**, e-beam scanner, **MEBT beam instrumentation**, **laser wires**, etc.)
  - Support, information exchange, R&D help, visits, reviews, etc.,
- LBNL
  - Development of a mode-locked fiber laser system for longitudinal bunch profile measurements (also bunch tails), distribution of laser light with fiber optics
    - Byrd & Wilcox – see Wilcox talk this meeting
    - Critical to use HINS at testing facility



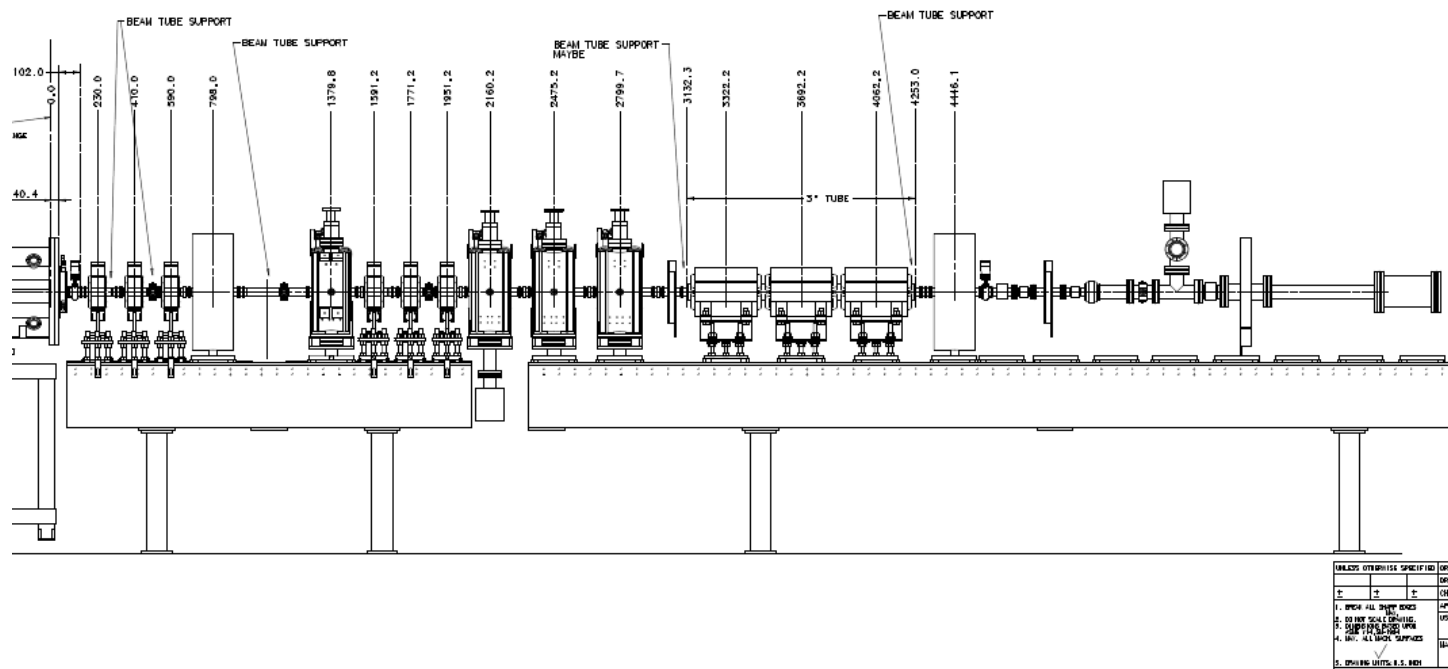


Transverse Beam Profiles using Laser Wire and electron detector



Transverse Emittance using Laser Wire, electron detector and  $H^0$  profile monitor

# MDB Test Facility Six-Cavity Test



- Demonstrate use of high power RF vector modulators to control multiple RF cavities driven by a single high power klystron
  - Summer 2011

# Partial Installation of Six-Cavity Test



RF distribution system  
in background and one  
RF cavity in foreground  
inside HINS beam  
enclosure

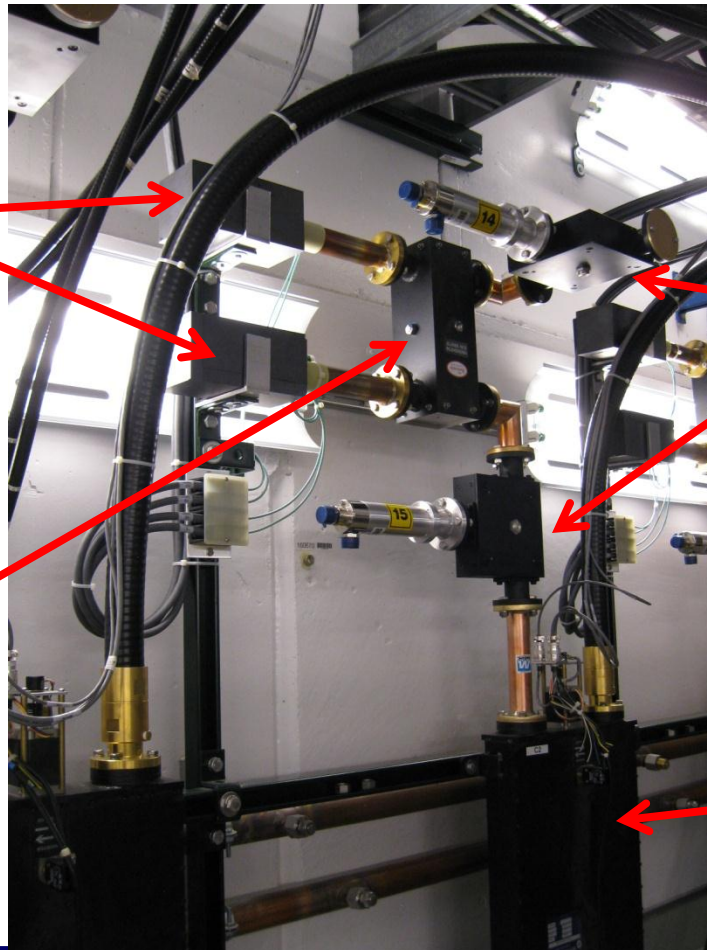


**Ferrite Phase Shifters**

**Circulators**

**Hybrid**

**Trumbone**



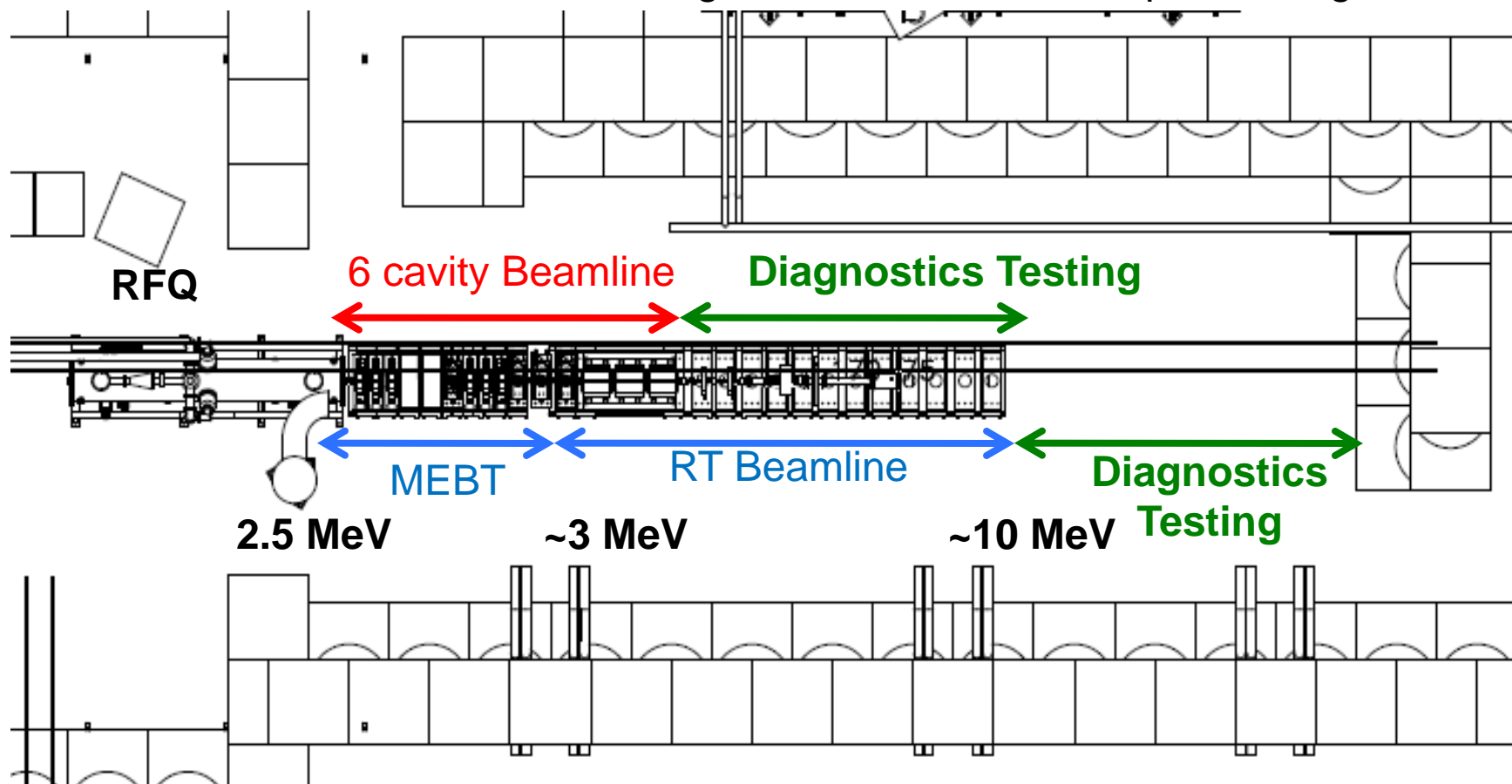




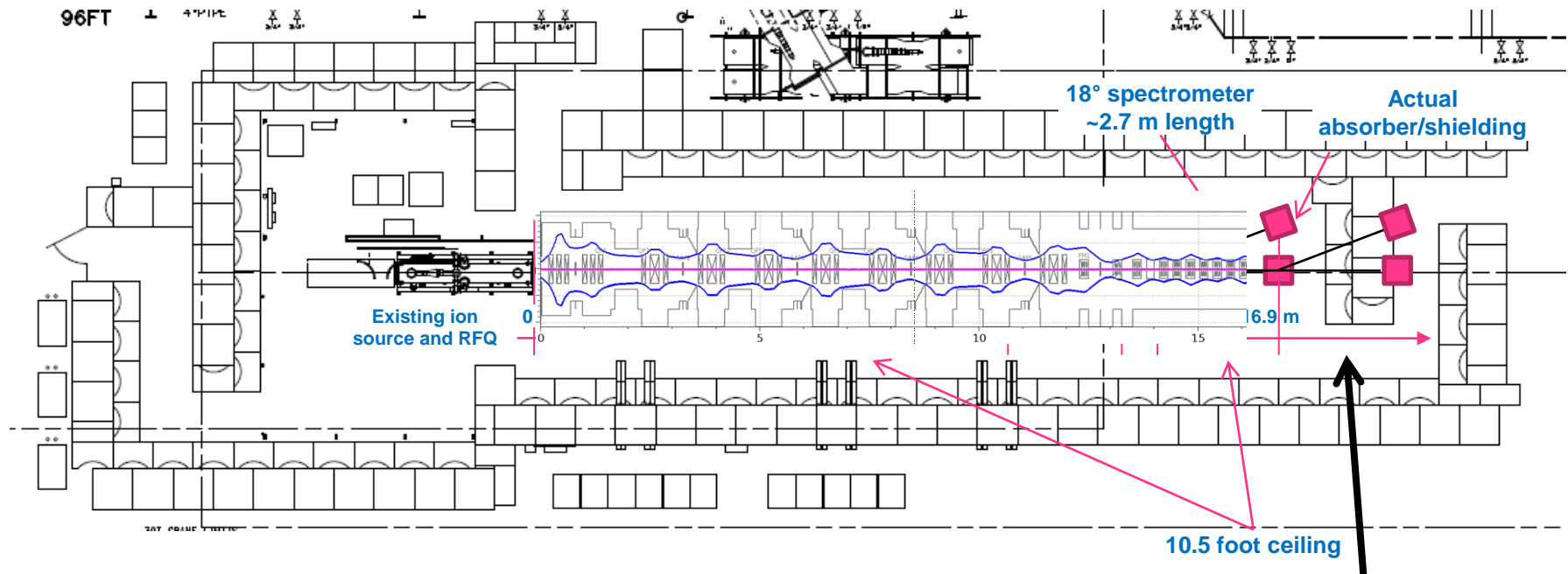
- 
- FY11
    - Complete Linac enclosure electrical, water, and safety interlock system infrastructure installations
    - Re-commission RFQ with beam
    - Begin Six-Cavity Test beam line installation
    - Install H- source
  - FY12
    - Complete beam line installation
    - Install and commission beam line controls, LLRF, and RF interlocks
    - Commission beam line and commence test plan
  - FY13
    - Successfully complete Six-Cavity vector modulator/beam tests
    - Decommission test set-ups as required
    - Complete final technical papers and reports
-



HINS beamline will evolve – diagnostics section will adapt to changes



# MDB Long Term Plan Chopper and 4-Cavity CM



With cryomodule need  
additional 3+ meters cave  
length pending spectrometer  
line optics design



- 
- 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 to start shortly
  - Six cavity (and  $H^-$  source?) to be installed this year
    - *Laser diagnostic projects need  $H^-$*
  - Success with HINS measurements will allow for future Project X front-end testing and characterization at Meson

End