Beam Instrumentation & Diagnostics for Project X

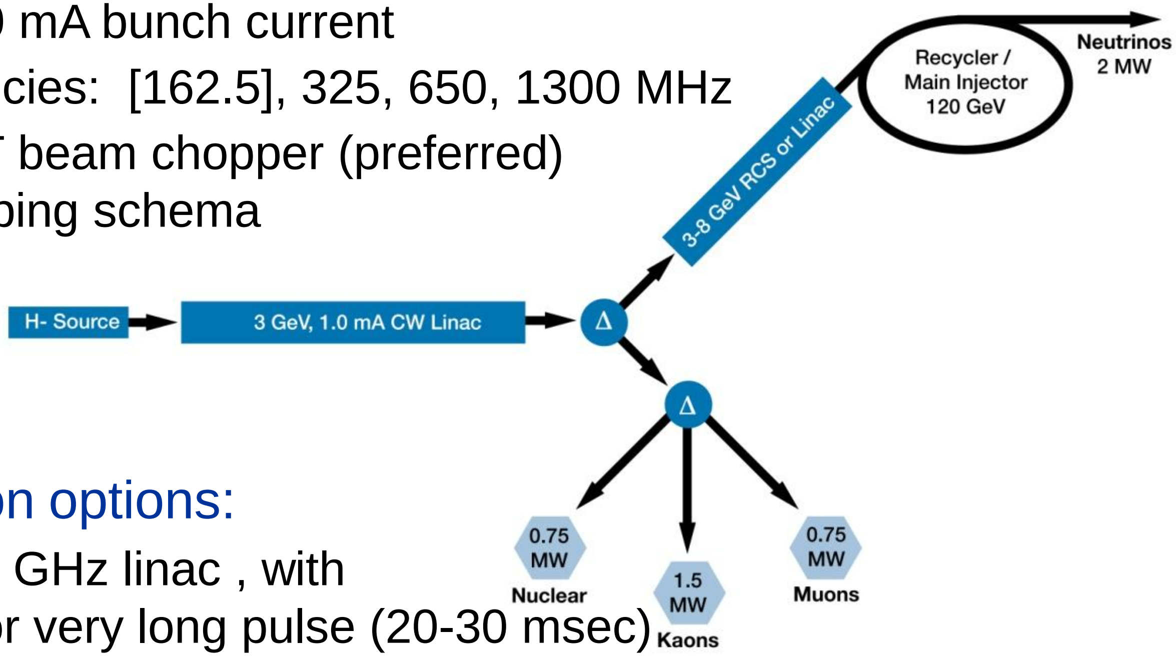
Manfred Wendt

SPL/ESS Collaboration Meeting
Lund
July 1, 2010

Project X in a Nutshell

Project X

- H^- source & 3 GeV / 3 MW CW SCRF linac
  - 1 mA average, 10 mA bunch current
  - (sub) ILC frequencies: [162.5], 325, 650, 1300 MHz
  - broadband MEBT beam chopper (preferred) or resonant chopping schema

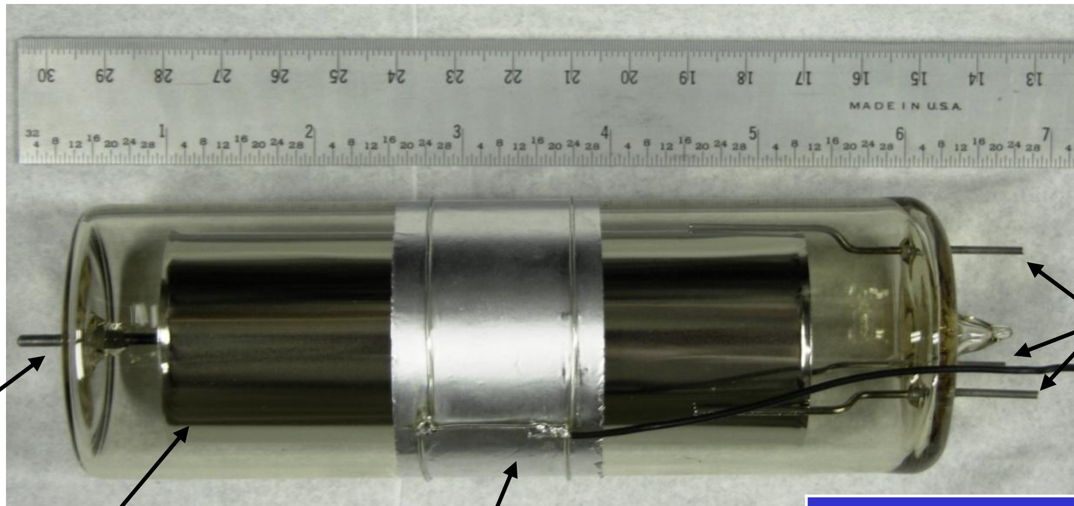


- 3-8 GeV acceleration options:
  - Pulsed SCRF 1.3 GHz linac , with short (<5 msec) or very long pulse (20-30 msec)
  - Rapid cycling synchrotron
- 8-120 GeV acceleration in existing Main Injector (2 MW beam power)

Project X Beam Instrumentation R&D

- Standard Beam Diagnostics
  - Toroids
  - BLMs
  - BPMs (cold and warm), including beam phase and TOF
  - Wirescanners and multiwires (invasive, temporary)
- Advanced Beam Instruments
  - LPM, laser slit (emittance) monitor, longitudinal laser scanner
  - E-beam scanner
  - Beam halo diagnostics (vibrating wire, time resolved SEM)
  - Invasive long. bunch diagnostics (Feschenko, fast Faraday cup)
- Related Issues
  - SCRF segmentation (location of complex beam detectors)
  - Beam detectors inside the cryostat, BPMs, what else?
  - Minimum-invasive beam profile measurements (“pollution-free”)
  - Protons vs. H^- beams (photo detachment methods)
- Beam diagnostics is close connected to beam optics / dynamics / simulations
  - Definition of requirements, e.g. resolution, precision, dynamic range, locations,…

Ionization Chamber BLM



Signal Out

Guard Lead

Cathode @ +2000 V

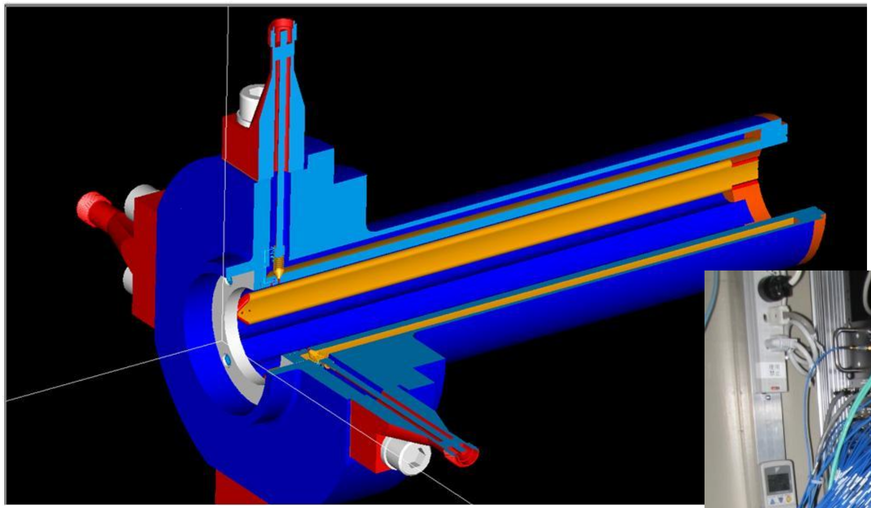
1.5” ANODE

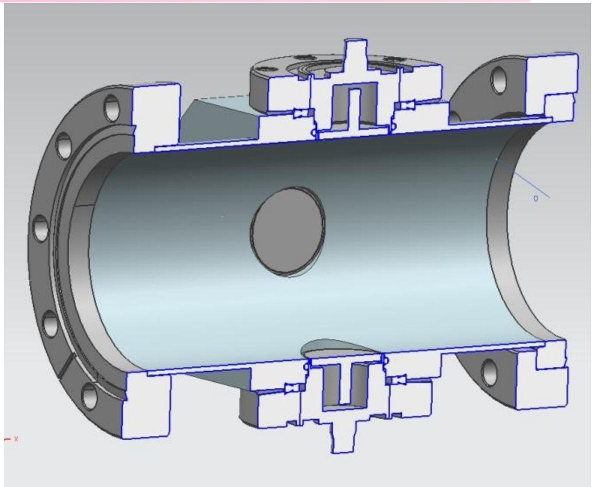
Guard to reduce Leakage current

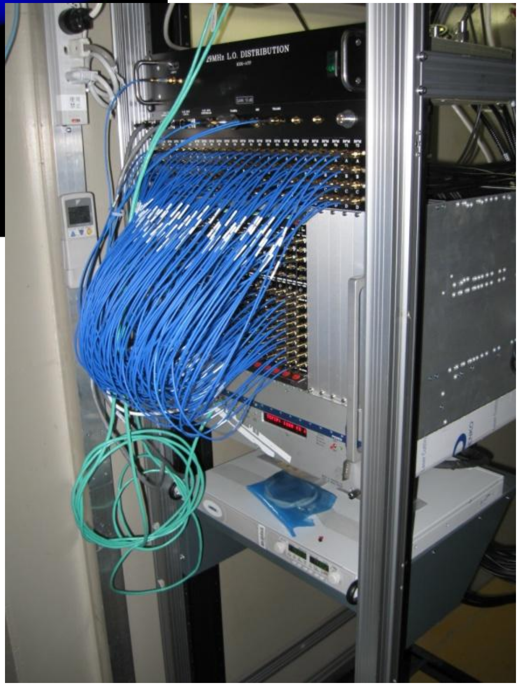
Specifications	
Materials	Glass, Nickel
Volumen	110 ccm Argon gas at 1 Atm
Calibration	70 nC / rad
Response time	1-2 µsec
Leakage current	< 10 pA
Operating range	1 mrad – 100 rad

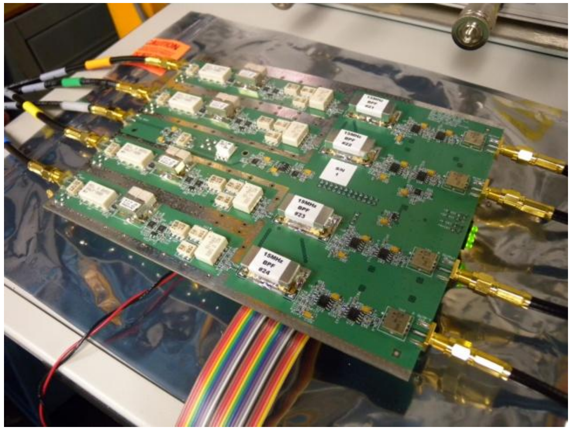
Project X

BPM R&D (KEK Collaboration)



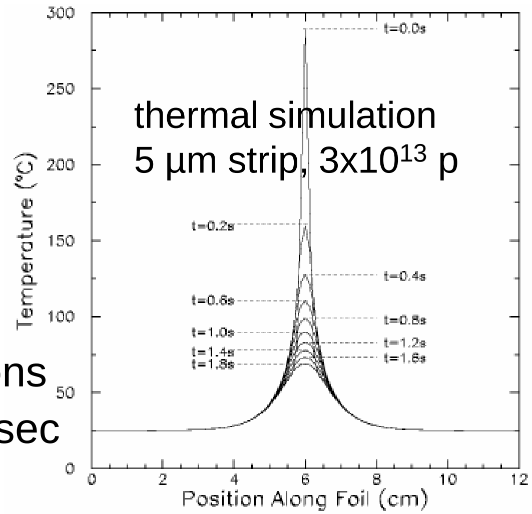






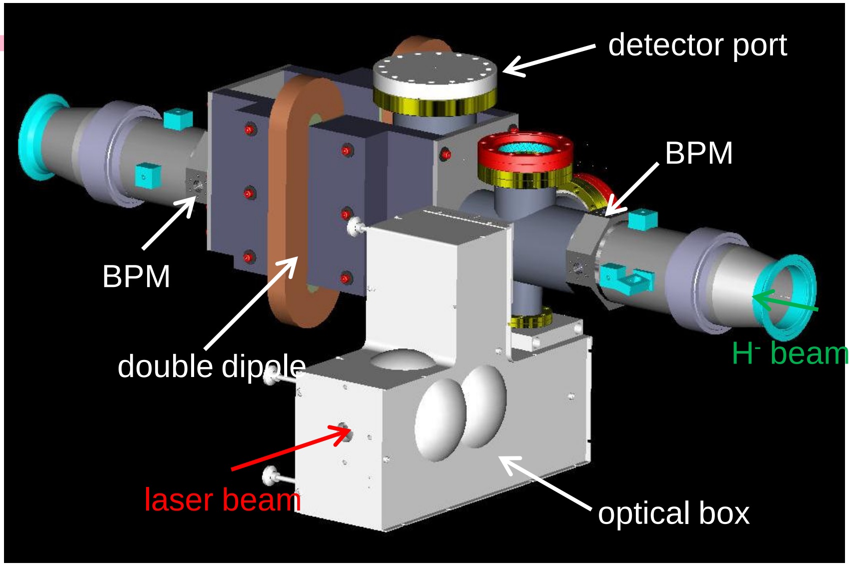
Multiwire/Foil SEM (UTA Collaboration)

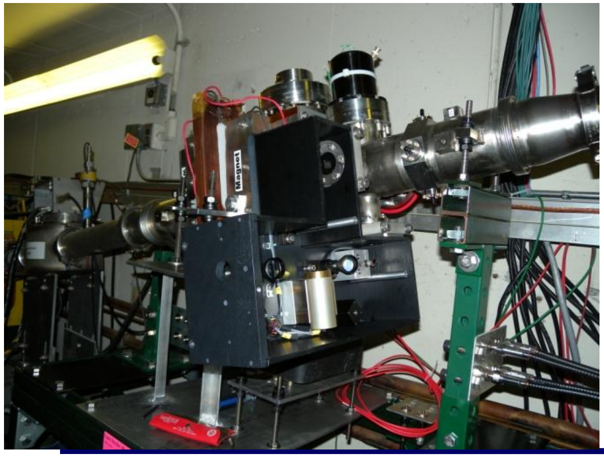
- FNAL type
  - Wire: 25 µm Ti (before W/Au)
  - Ceramic substrate, w beam gap, wires epoxied to pads.
- University of Texas type
  - 100x5 µm Ti strips
- NuMI beam
  - Energy: 120 GeV
  - Intensity/pulse: 3×10^{13} protons
  - Beam time: 8.56 µsec / 2.2 sec
  - Power/spill: 140 kJoule
  - Σ total: > 3×10^{20} protons
- Extrapolation
  - 5 µm Ti strip (1660 degC – 10 %): ~1.6×10^{14} protons (max)

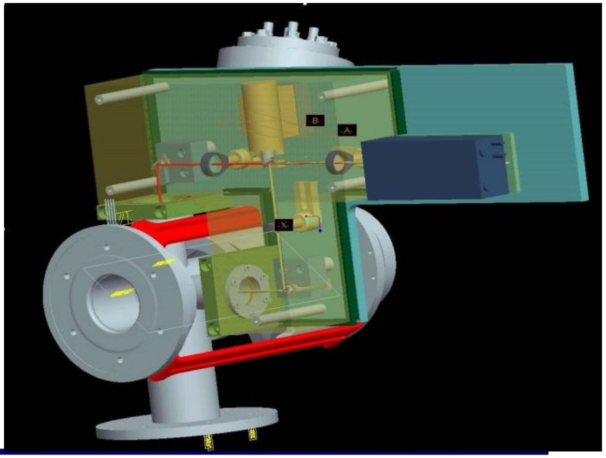


LPM R&D (BNL & LBNL Collaborations)

- Laser Profile Monitor details
  - Q-switch laser
  - Laser energy: 50 mJoule
  - Wavelength: 1064 nm
  - Pulse length: 9 nsec
  - Fast rotating mirrors ($\pm 4^0$ / 100 µsec)
  - e^- detector: scintillator & PMT





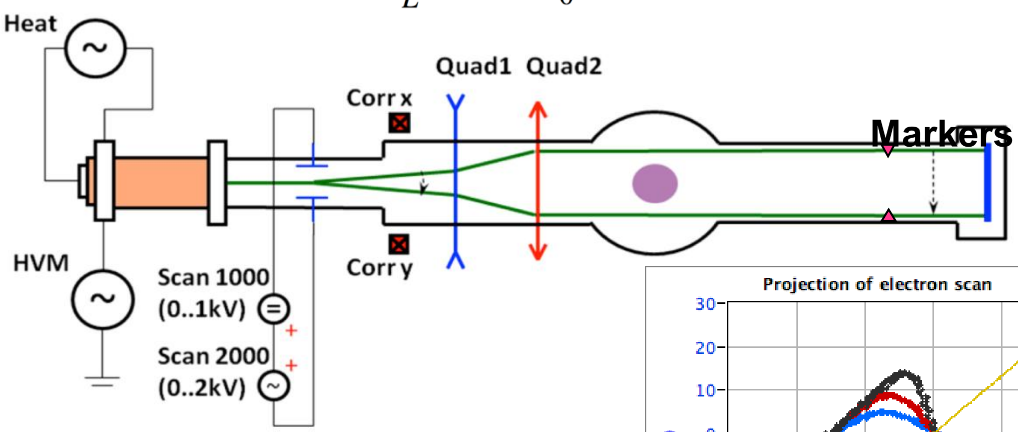


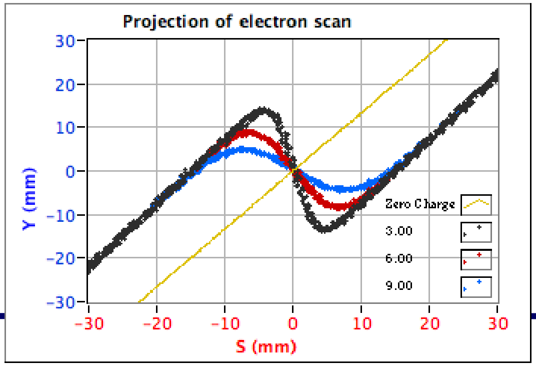
Electron Beam Scanner (SNS Collaboration)

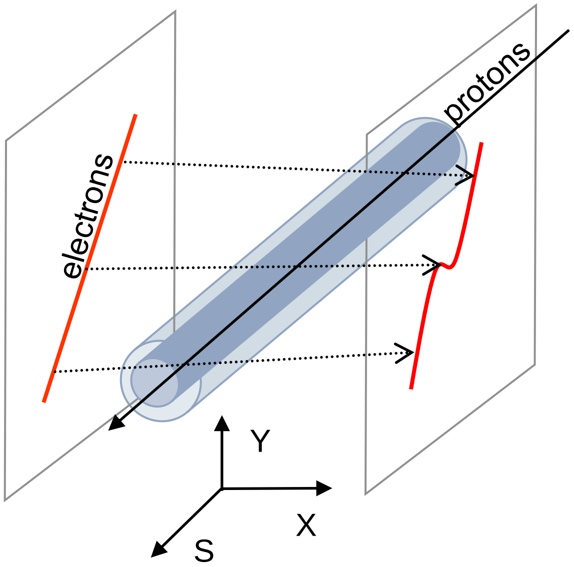
- Look at the deflected projection of a tilted sheet of electrons due to the proton beam charge
  - Neglect magnetic field (small displacement of projection)
  - Assume path of electrons is straight (they are almost straight)
  - Assume net electron energy change is zero (if symmetric).

→ $$\frac{d\theta_0(x)}{dx} = \int_L \frac{e}{mv^2}\frac{\delta(x,y)}{\varepsilon_0}dy$$ or, take the derivative to get the profile

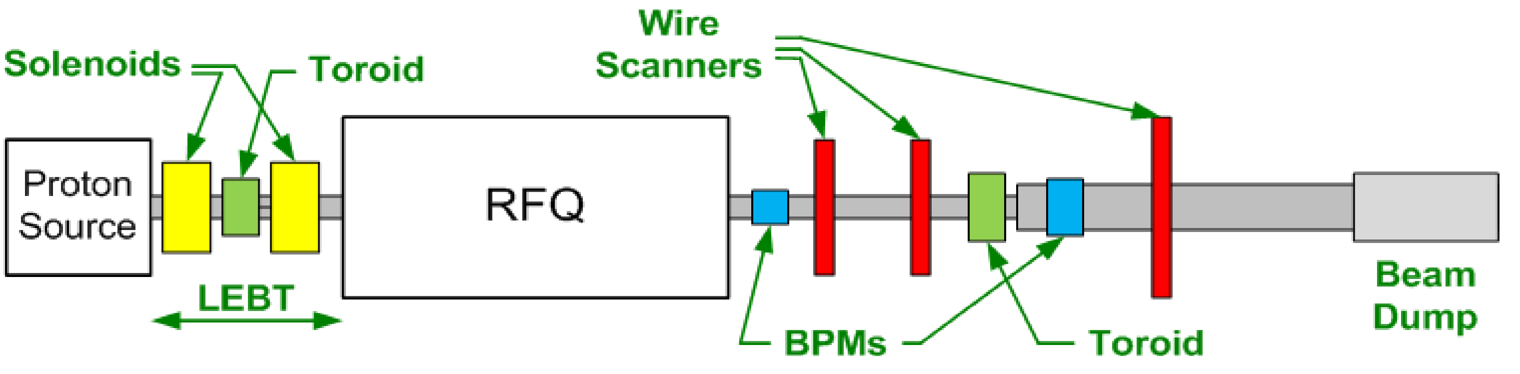
Kimball Physics e- Gun
- 60 KeV
- 6 mA
- Focusing and steering elements built in

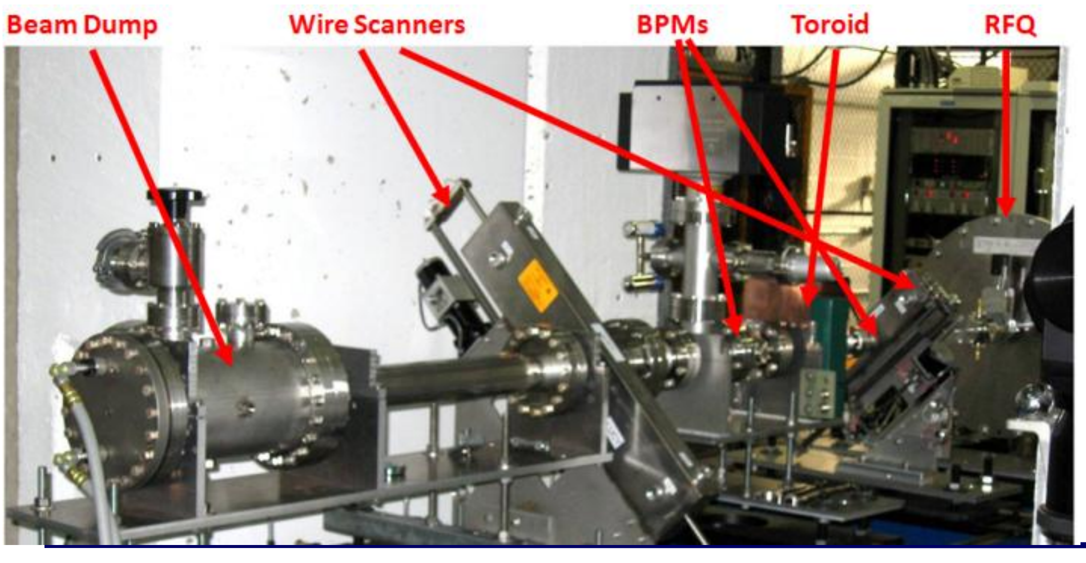






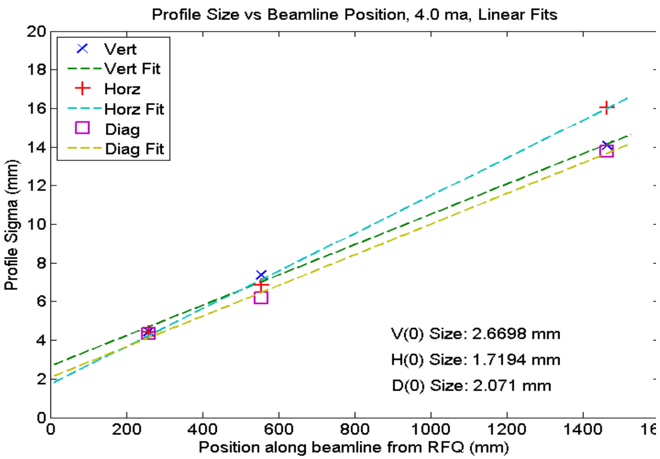
HINS Beam Studies

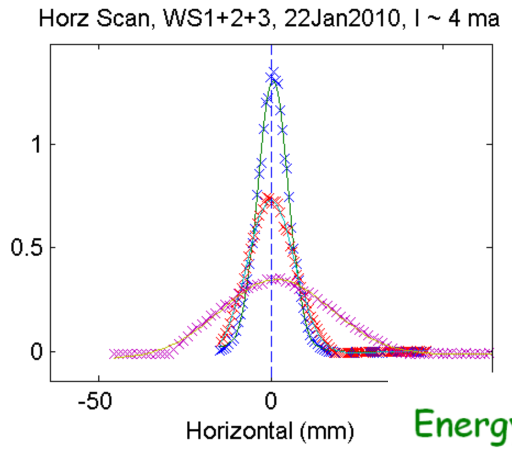




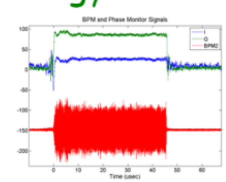
- HINS: High Intensity Neutrino Source
  - Initial Setup with p-source & RFQ
  - Temporary diagnostics beam-line
  - Beam dynamics & instrumentation playground

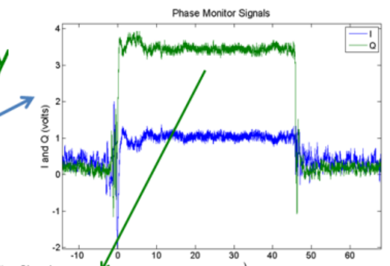
HINS Beam Studies (cont.)

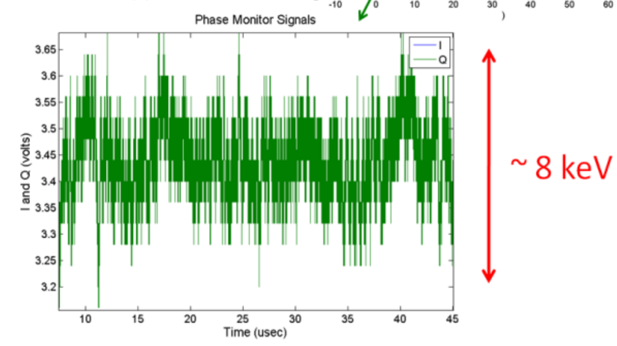




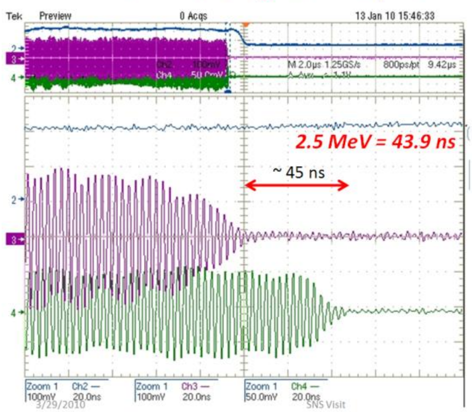
Energy Stability







Time of Flight – Sparked RFQ



- Toroid
- Up BPM
- Down BPM

- Up BPM

- Down BPM

Project X

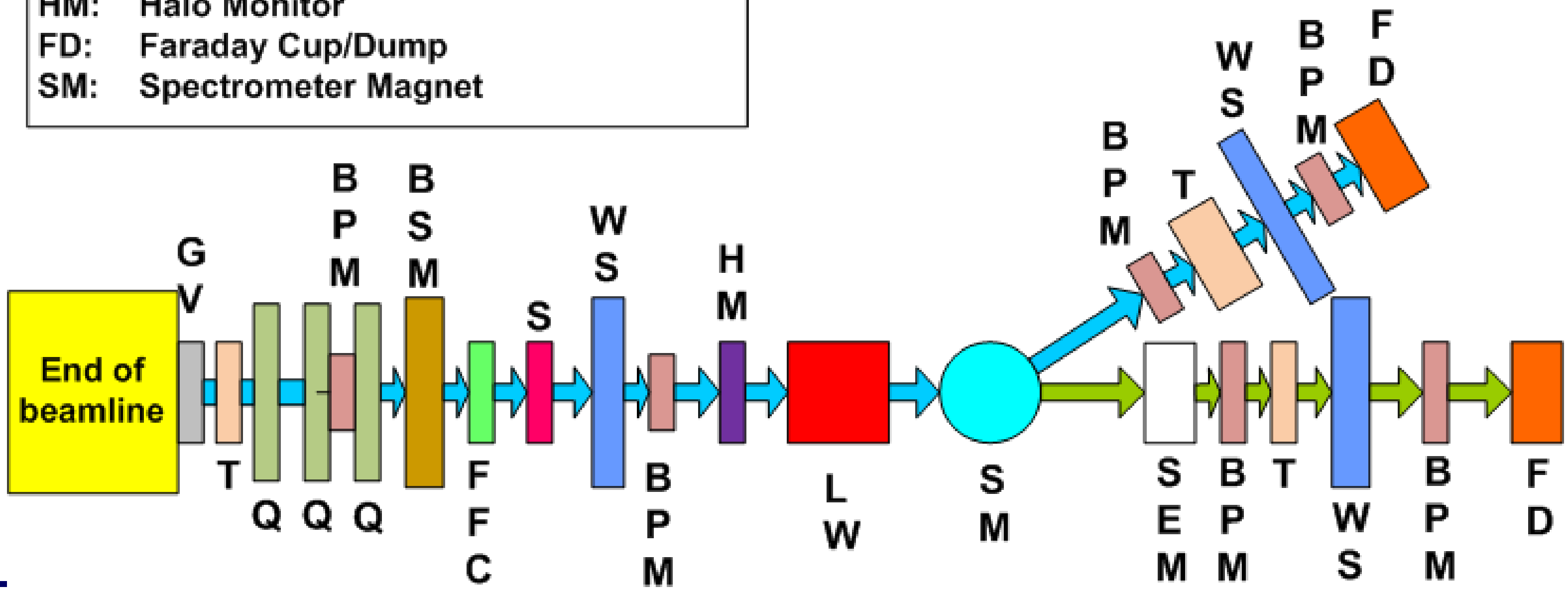
HINS Diagnostics R&D

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^o Beam or H^- Beam



Miscellaneous Diagnostics

- Other beam diagnostics R&D include
  - Monitoring of HOM coupler signals as BPM, also bunch-by-bunch. Read-out electronics and algorithms in collaboration with DESY.
  - Electron cloud beam studies applying the RF transmission method. Collaboration with LBNL.
  - Electron beam diagnostics for the NML test facility, e.g. screen monitors (OTR, YaG), EOS, interferometer techniques, fiber laser TOF, etc.
- Various (non-beam) instrumentation needs are supported, e.g.
  - Faraday cups for high power cryomodule tests
  - Wire position monitor (WPM) system inside the cryomodule
  - Machine protection system electronics
  - Klystron protection interlock system, also in test stands
  - 2nd sound & temperature monitoring
  - …

Summary & Remarks

- Beam instrumentation & diagnostics R&D needs beams(!), i.e. beam test facilities (HINS, NML).
  - The beam is the ultimate test to verify guide and acceleration fields.
  - Beam dynamic issues are expected in the low energy, space charge driven part of the hadron linac.
- SCRF based linacs may have issues operating invasive diagnostics, e.g. wires, slits, and other physical targets.
  - H^- beams offer the use of photo detachment techniques, e.g. laser wire profile monitor, longitudinal LW, laser slit
  - Invasive beam diagnostics can be installed temporary at the end of the linac, or in long warm sections (segmentation).
- Fermilab invites ESS & SPL for fruitful collaborations!
  - Use upcoming events to strengthen the discussions, e.g. HB2010 ICFA workshop in Switzerland end of September.