Beam Instrumentation for Future High Intensity Hadron Accelerators at Fermilab

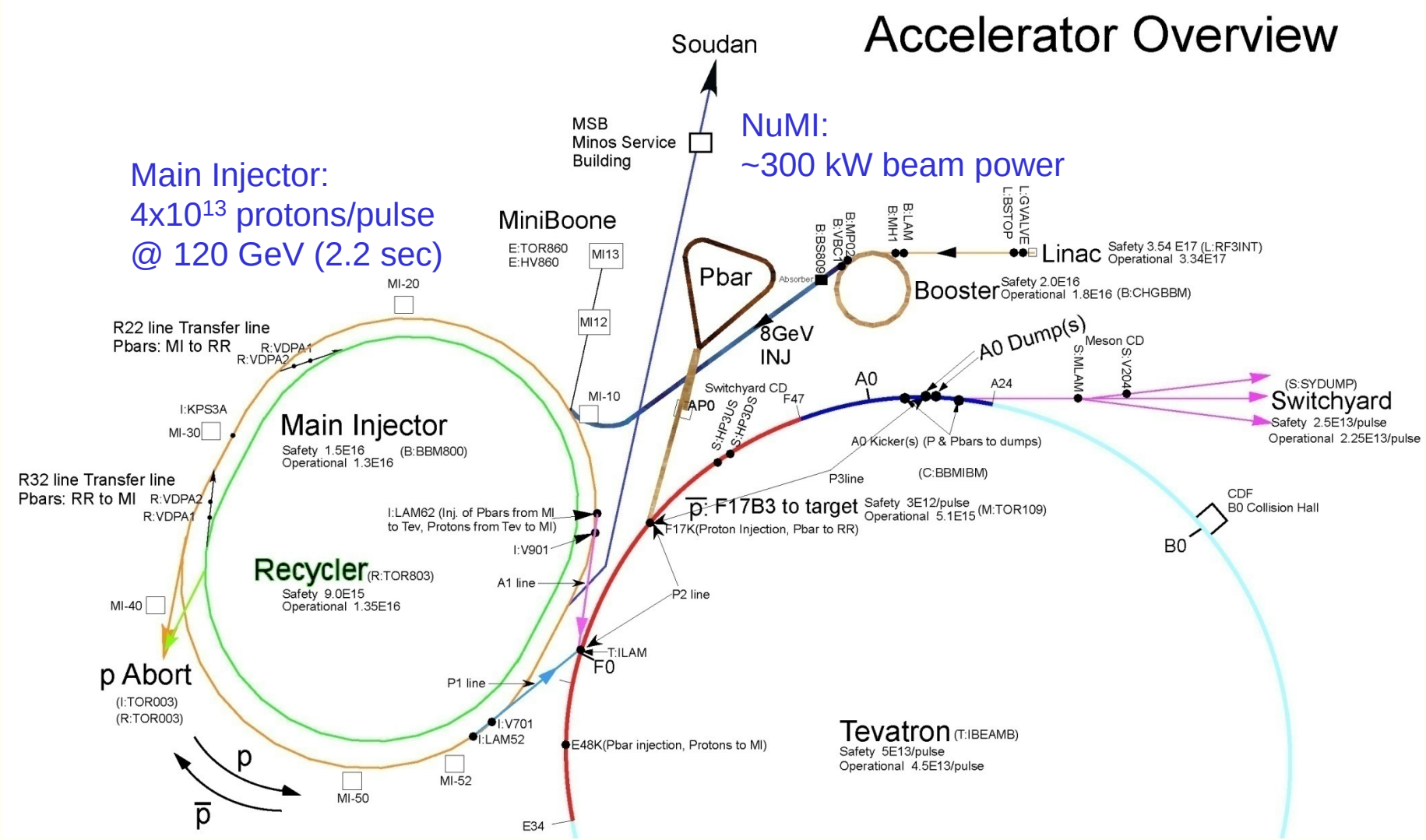
Manfred Wendt

Fermilab

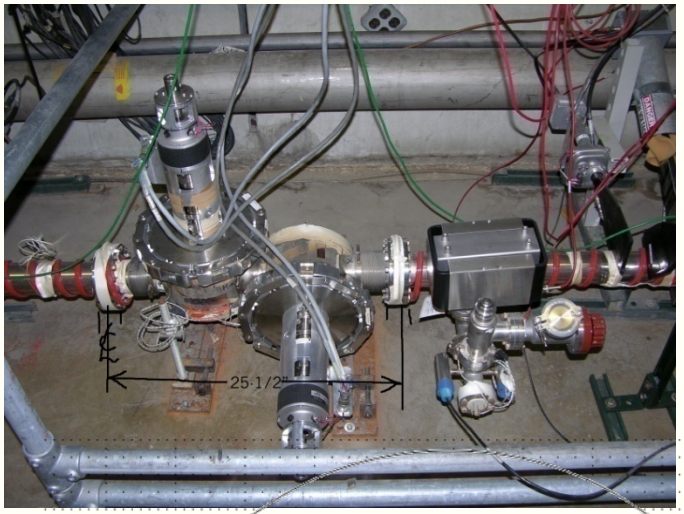
Fermilab Hadron Activities

- **Current HEP hadron accelerator activities**
  - Tevatron: p -> pbar collider Run II (until September 2010)
  - NuMI: 120 GeV beam-line for neutrino experiments (290 kW)
  - 8 GeV beam-line to MiniBooNE, microBooNE
  - Switchyard beam-lines, e.g. MTest
- **Beam Instrumentation**
  - Stripline or split-plate BPM pickups, Echotek-based digital read-out electronics in most areas.
  - Transverse beam profile/ emittance characterization using flying wires, IPMs, OTRs, multi-wires, SWICS, SyncLight (TeV),...
  - Longitudinal beam monitors (WCM, read-out by high speed oscilloscopes or digitizers)
  - Beam halo characterization (crawling wire)
  - Beam loss detection (ionization chamber, scintillators & PMT)

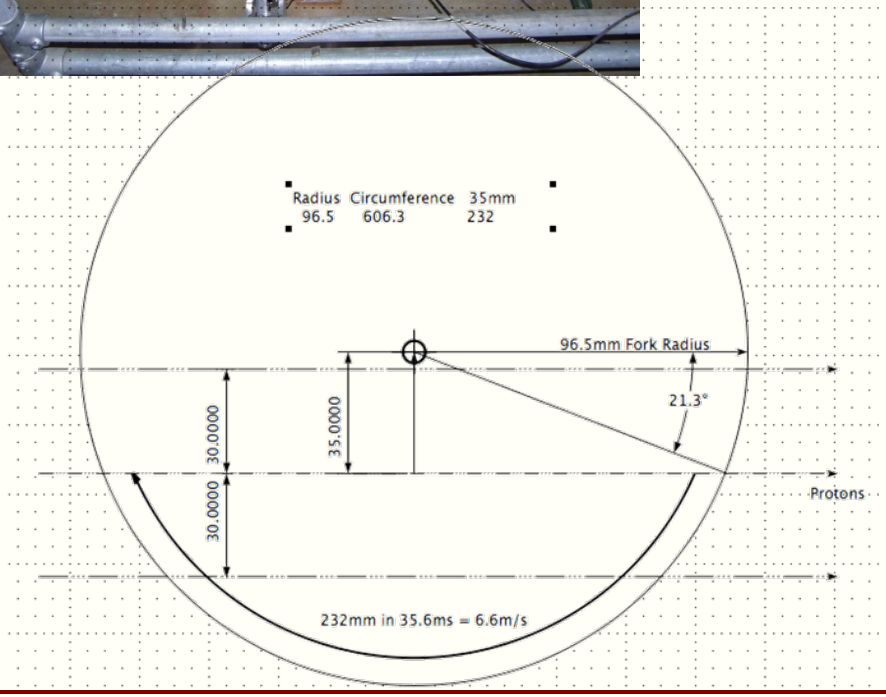
Accelerators at Fermilab



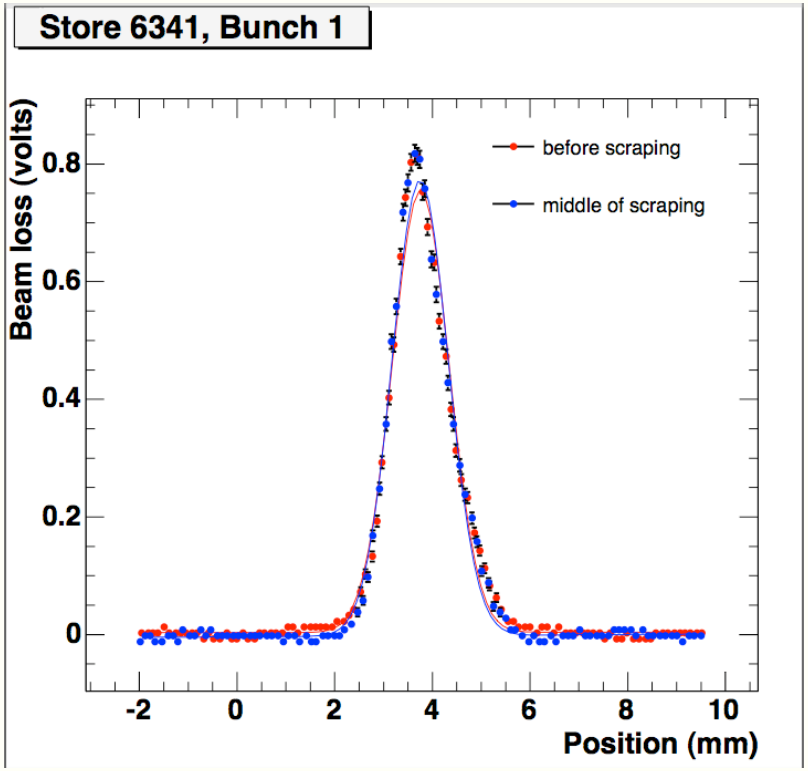
Flying Wire Monitor



- **Wire: 5 μm carbon**
- **Speed: 6.6 m/sec**
- **Max. beam intensity: < 4x10^{13} p (NuMI)**

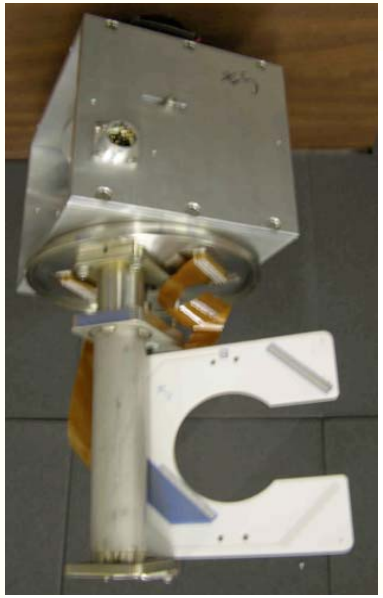


Scraping Losses (TeV)

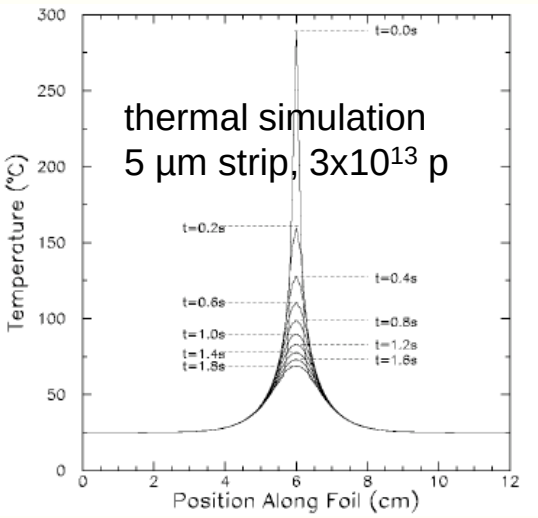


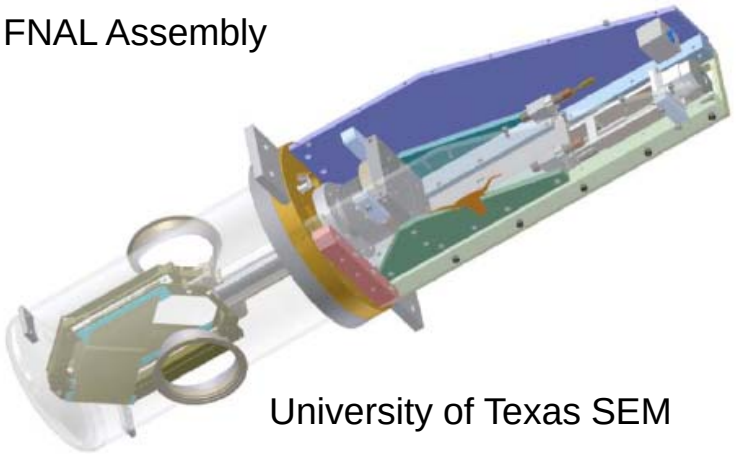
Multiwire (or SEM)

- **FNAL type**
  - Wire: 25 μm Ti (before W/Au)
  - Ceramic substrate, w beam gap, wires epoxied to pads.
- **University of Texas type**
  - Signal planes: 5 μm Ti strips
  - Bias planes: 2.5 μm Ti foil
- **NuMI beam**
  - Energy: 120 GeV
  - Intensity/pulse: 4×10^{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)



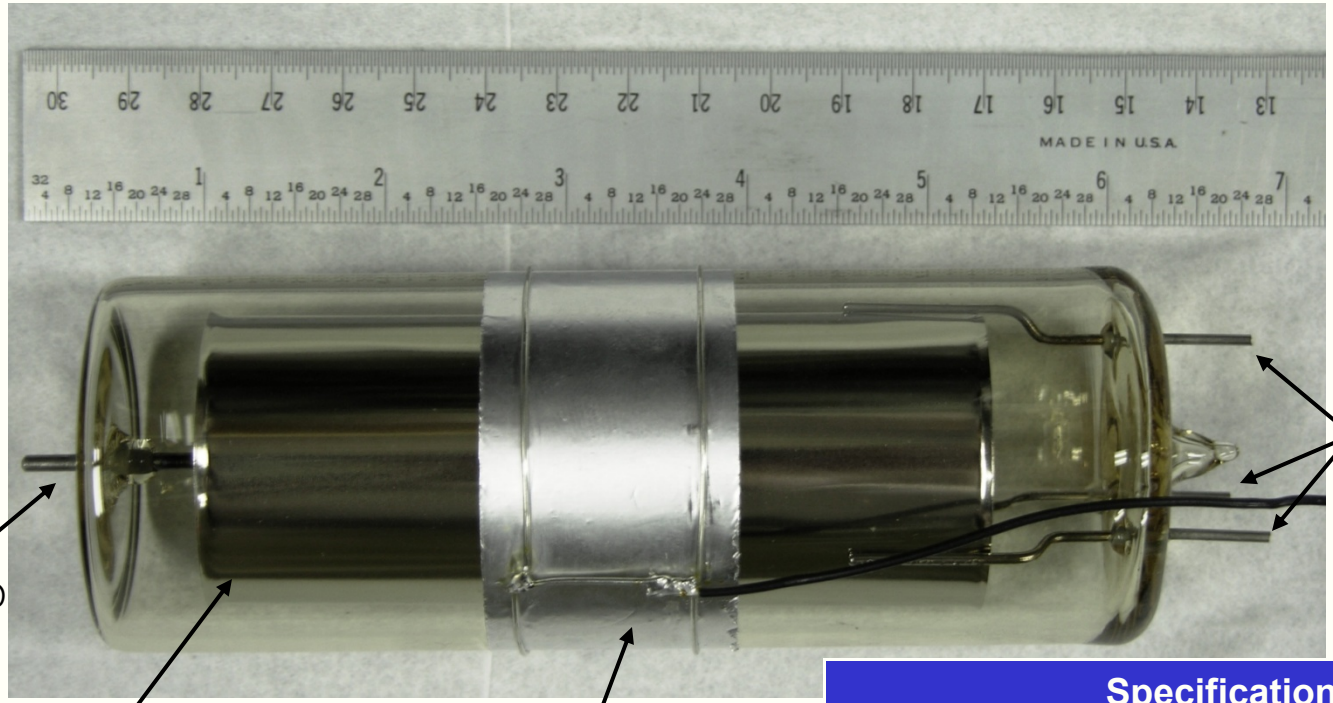
FNAL Assembly





University of Texas SEM

Ionization Chamber BLM

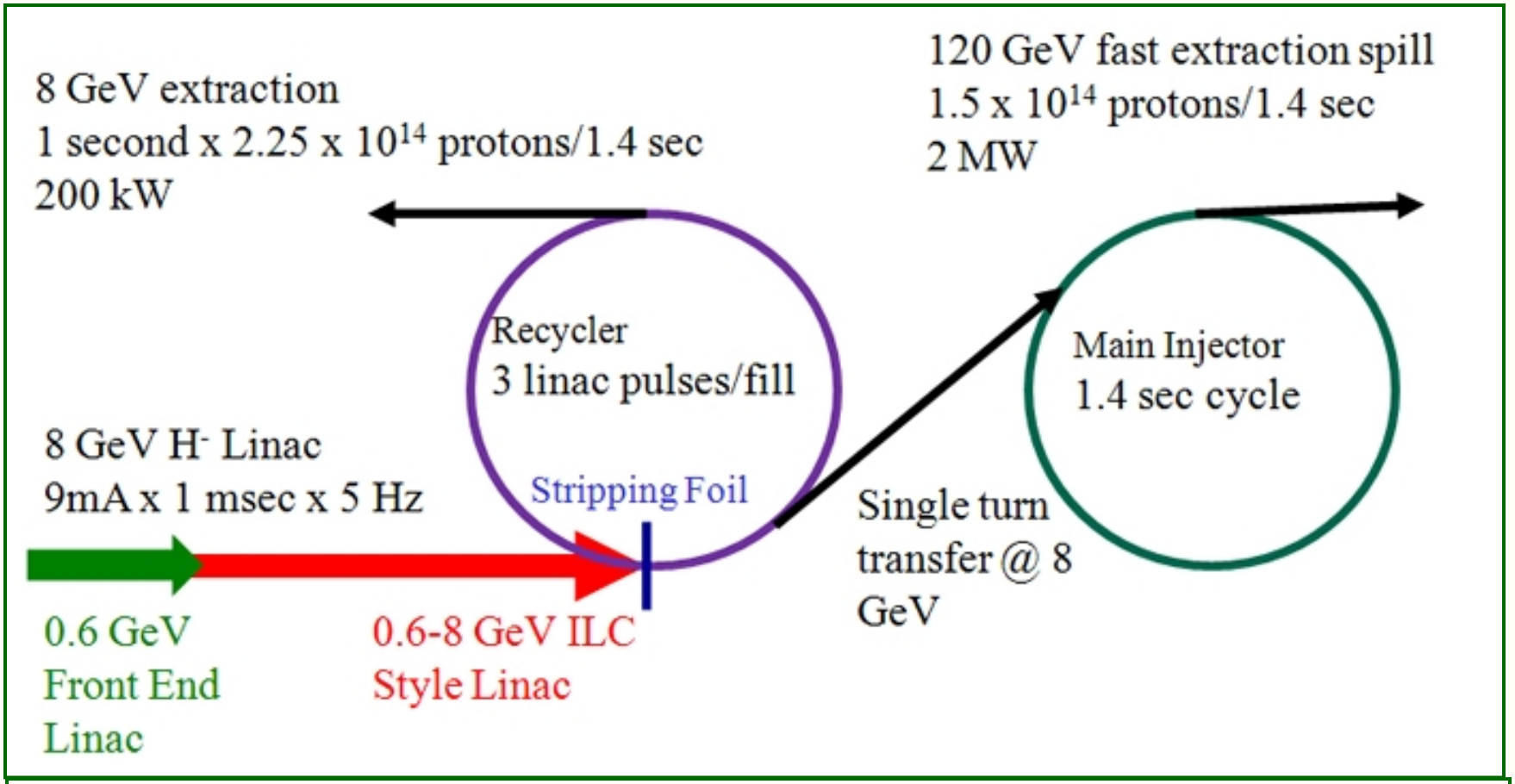


Specifications	
Materials	Glass, Nickel
Volumen	110 ccm Argon gas at 1 Atm
Calibration	70 nC / rad
Response time	1-2 µsec
Leakage current	< 10 pA
Operating range	1 mrad – 100 rad

Project X Fermilab Upcoming Activities

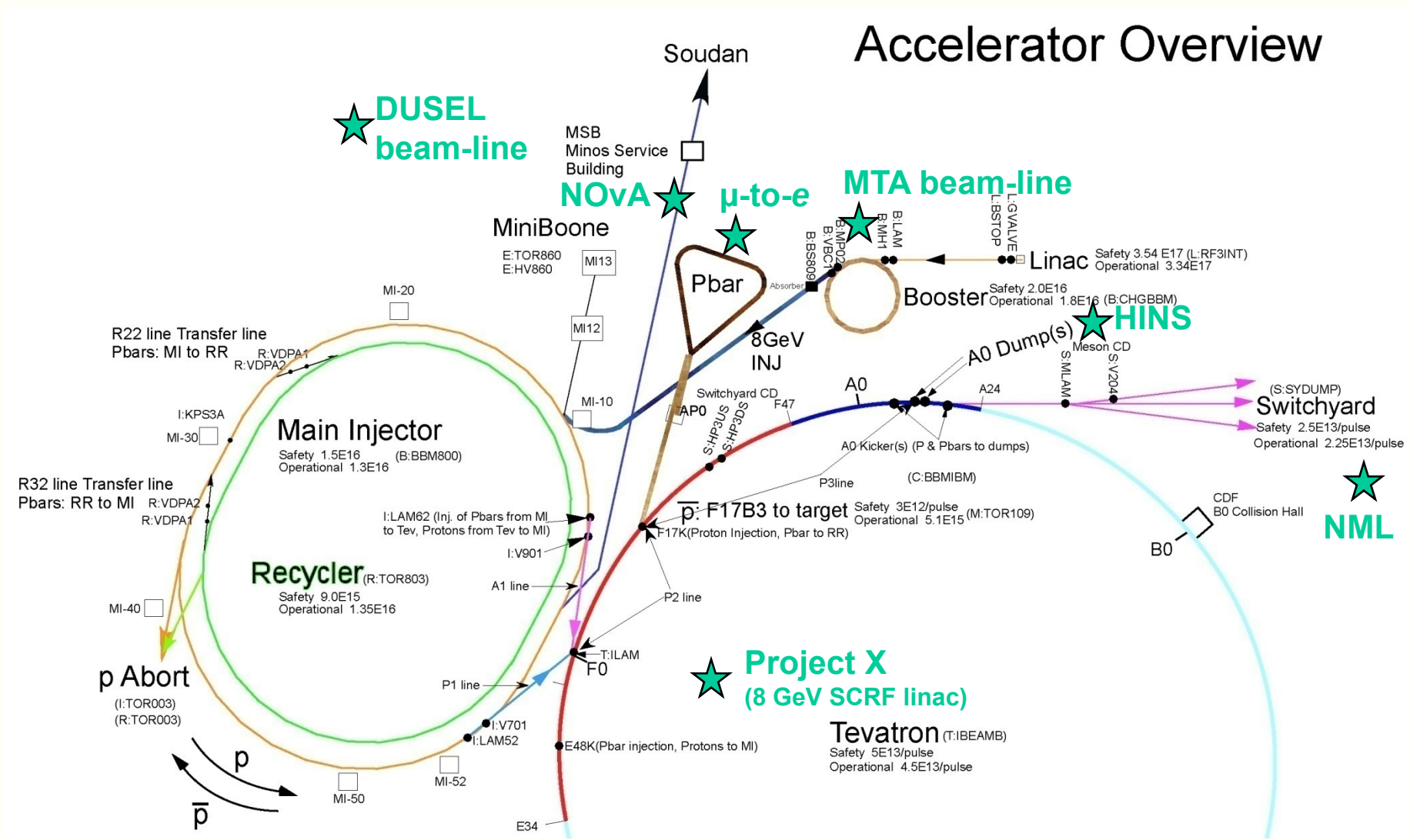
- **Future hadron accelerator activities**
  - 400 MeV MTA beam-line (muon cooling experiments, FY09)
  - NOvA upgrade for up to 700 kW beam power (120 GeV)
  - HINS: High intense SCRF H- injector (60 MeV) R&D
  - NML: SCRF beam test facility (runs with electrons, 750 MeV)
  - μ-to-e experiment, needs 8 GeV slow spill
  - Project X, based on a new SCRF 8 GeV H^- linac & HINS injector, 2 MW beam power (or more) @ 120 GeV
  - New 120 GeV beam-line to DUSEL (Homestake)
  - -…
- **Most project are pre-CD0 (beam parameters not final)**
- **Instrumentation requirements need to be specified**

Fermilab's Project X



- **High beam intensities call for non-intercepting beam diagnostics**

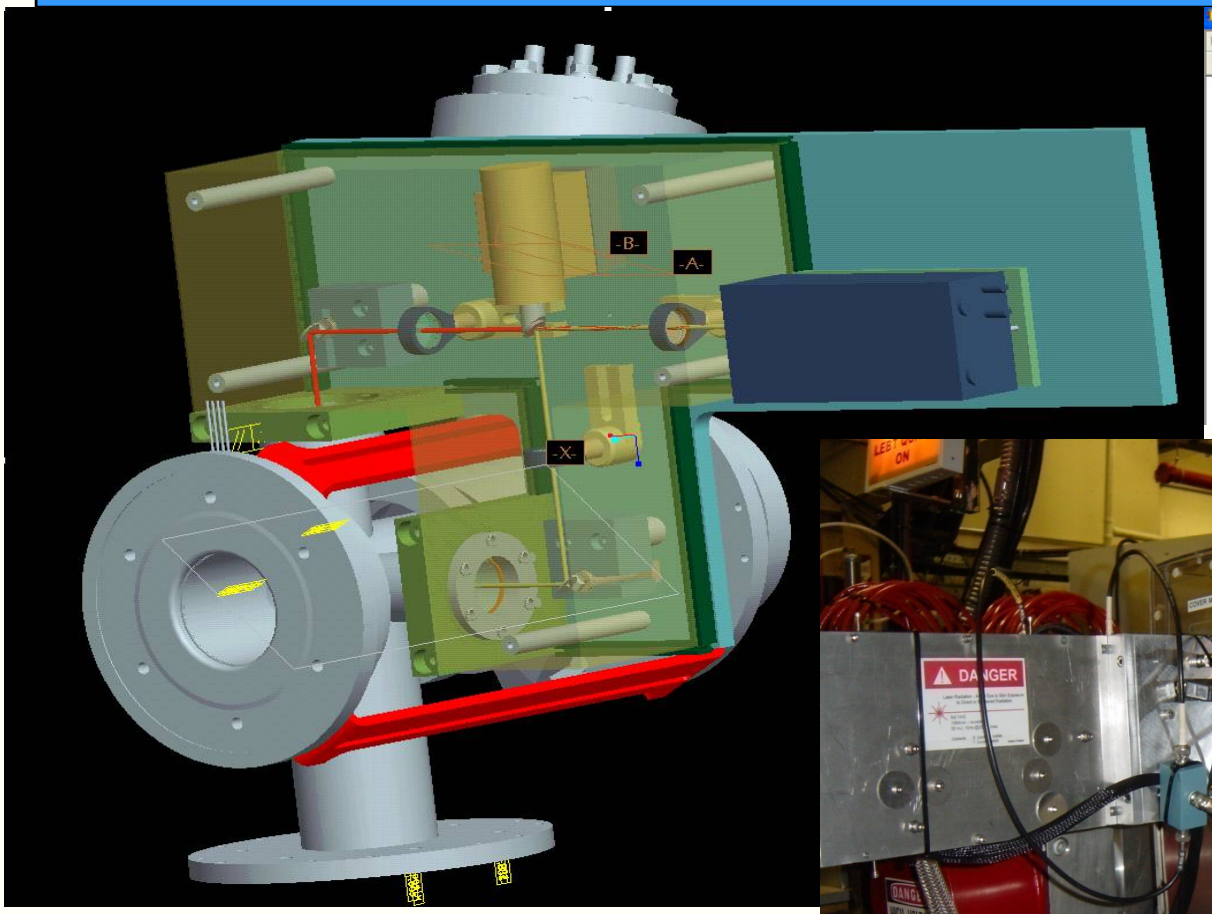
Accelerators at Fermilab

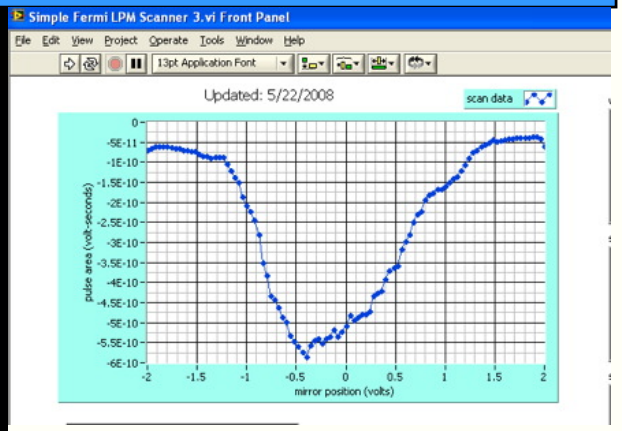


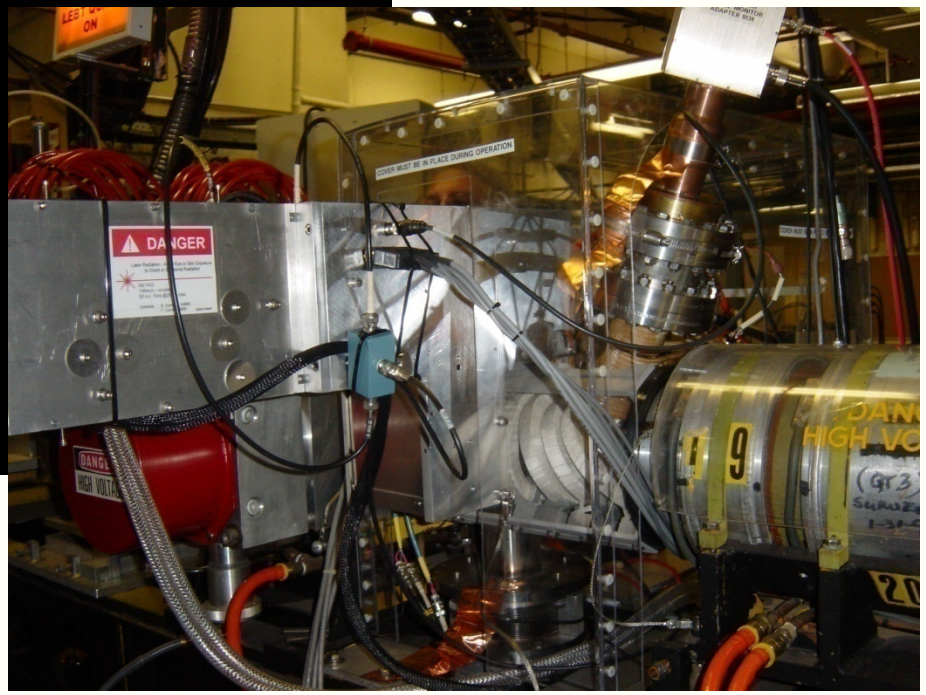
Challenges (for discussion)

- Transverse beam size / emittance
  - Physical (intercepting) wires?
  - Laser wire (only H- beams)
  - Ionization profile monitors (calibration)
  - e-beam wire???
- Beam halo characterization (sensitivity, safety)
  - crawling wire, laser wire, vibrating wire
- Resonant extraction feedback systems
- Beam gap instrumentation (dynamic range 1:10^9)
- Diagnostics for low energy beams (BPMs, emittance)
- Beam monitors as part of SCRF cryostats
  - BPM pickup (button or RF cavity style)
  - Use of HOM coupler signals
- Machine protection systems
  - BLM-based system with minimal response time (5-10 μsec total)
  - Reliability, absolute calibration
- Other challenges…?!

BNL Laser Wire for HINS



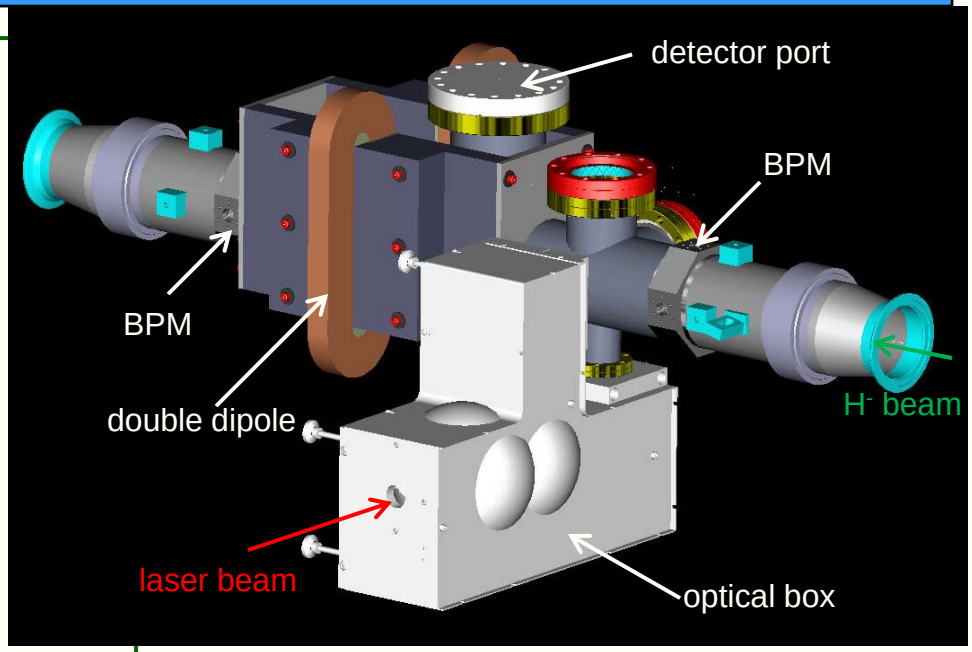


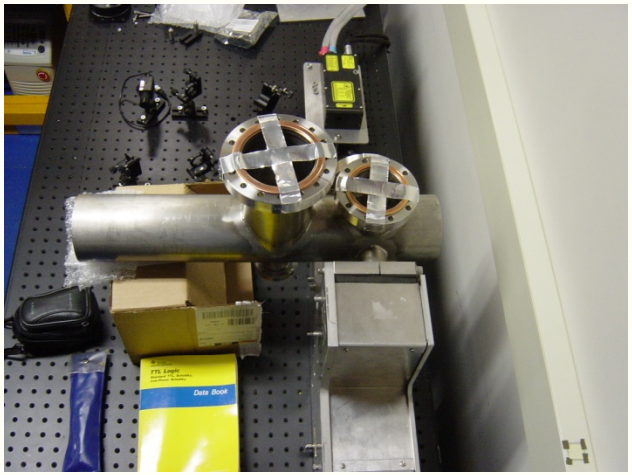


- **BNL test:**
  - **750 keV H^- beam**
  - ***Faraday*-cup e^- detector**

Fermilab LPM Test Setup

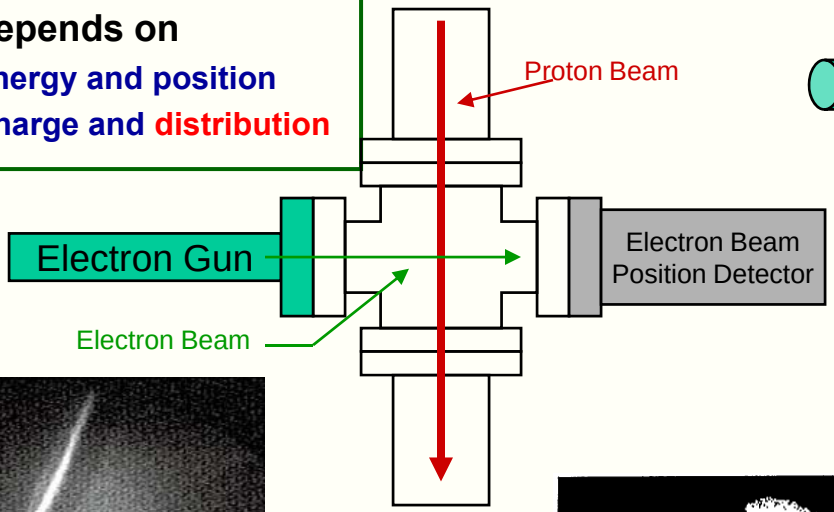
- **Laser Profile Monitor details**
  - Q-switch laser
  - Laser energy: 50 mJoule
  - Wavelength: 1064 nm
  - Pulse length: 9 nsec
  - Fast rotating mirrors ($\pm 4^0$ / 100 µsec)
  - e^- detector: scintillator & PMT
- **Installation:**
  - 1st Test with 400 MeV H^-
  - HINS: 2.5 & 60 MeV
- **Upgrades & issues**
  - CW laser for single macro pulse sweep
  - Detector system for 8 GeV setup

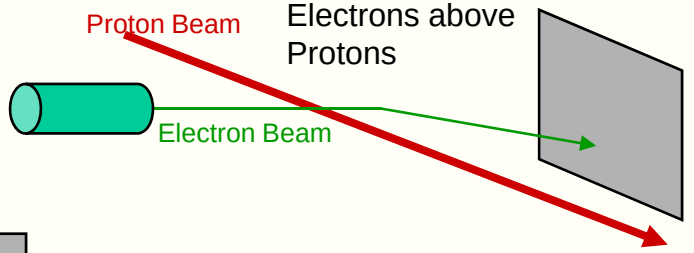


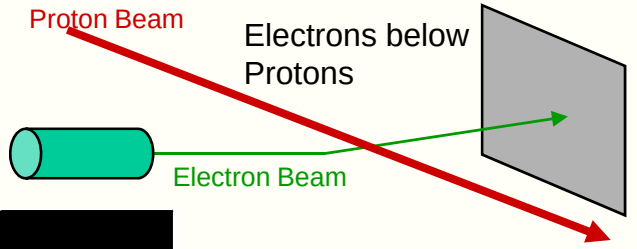


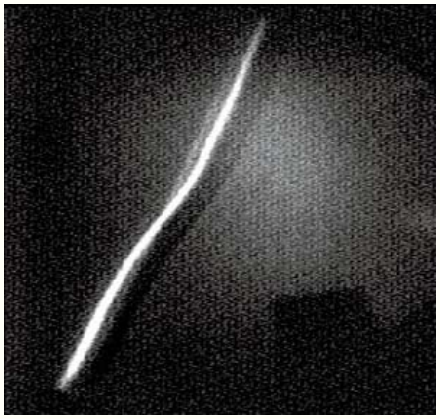
Electron Beam Profiler

- **e-beam get deflected by the p-beam**
- **Defection depends on**
  - **e-beam energy and position**
  - **p-beam charge and distribution**



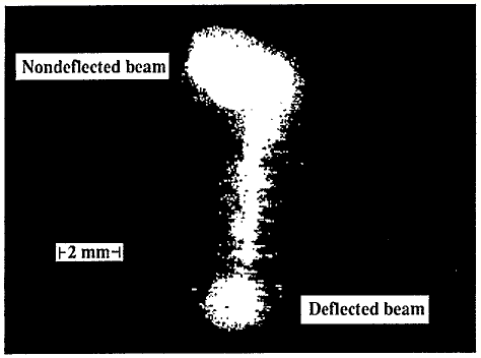






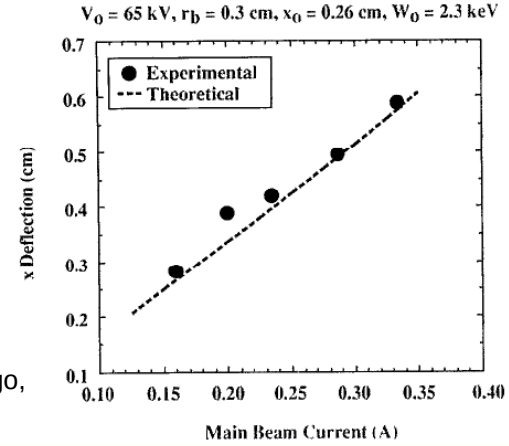
Deflection of ion beam curtain observed at CERN SPS

- *Transverse profile monitor using ion probe beams*. J.Bosser, *et.al*. CERN-PS-2000-071-BD, Nov 2000. 28pp.
  - W. Nexsen *et al*., SSCL-631, May 1993.
  - E. Tsyganov *et al*., Proc. 1993 PAC.

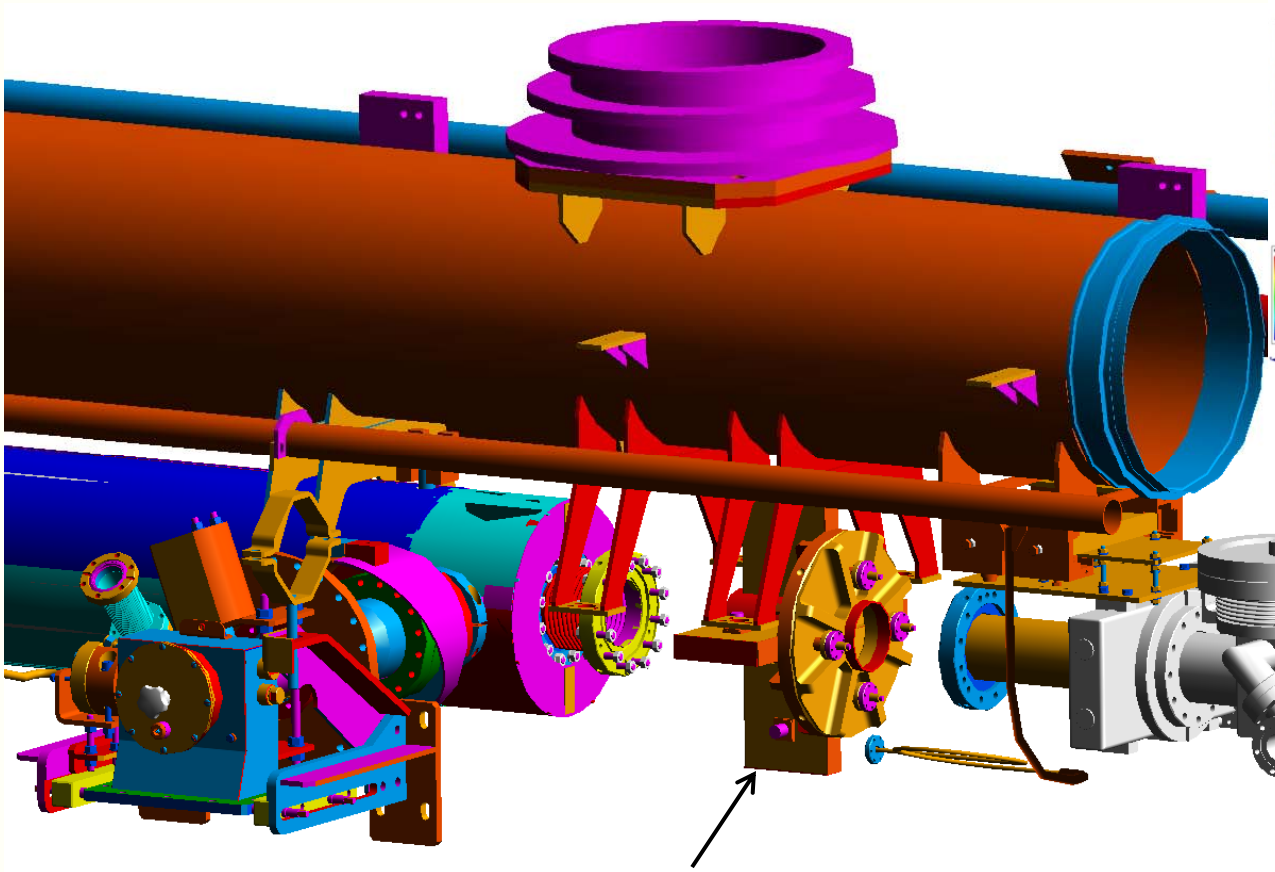


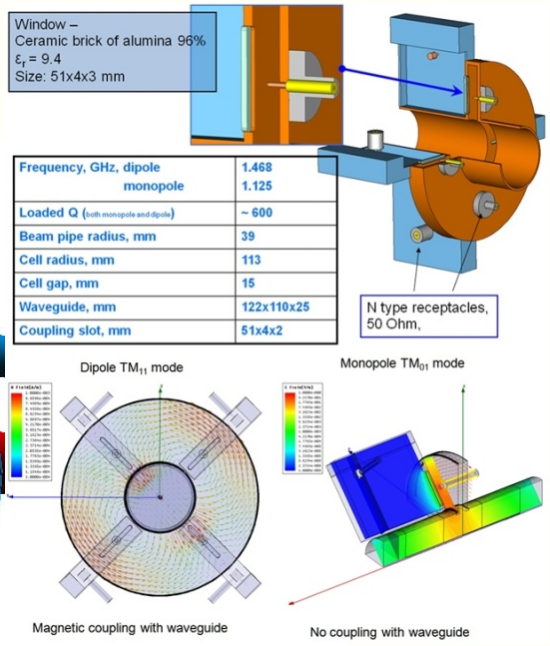
Deflection of ~2 keV e^- beam by 65 keV e^- beam

- *Nonperturbing electron beam probe to diagnose charged-particle beams*. J.A.Pasour and M.T.Ngo, Rev. Sci. Instrum. **63** (5), May 1992.



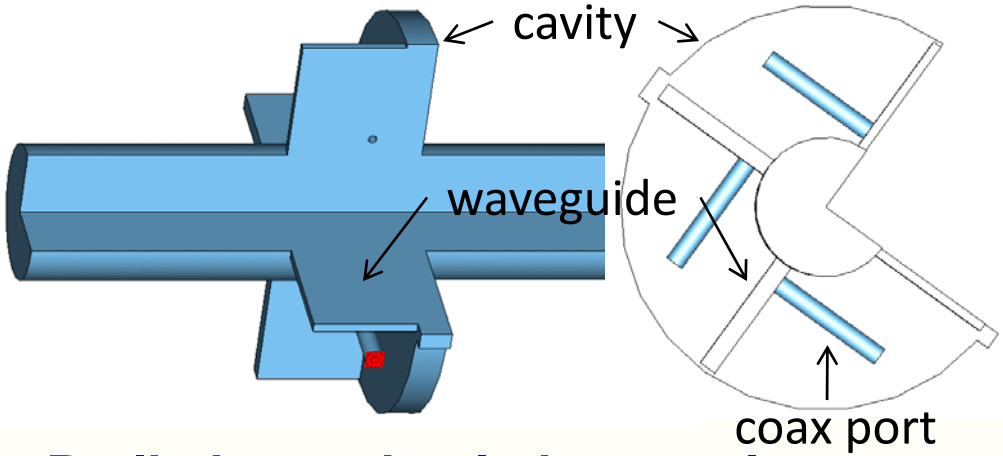
Cold BPM for NML / Project X





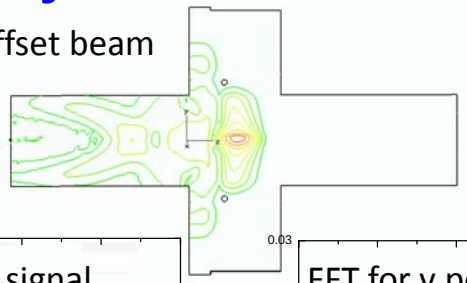
ILC type cold CM-free L-Band cavity BPM

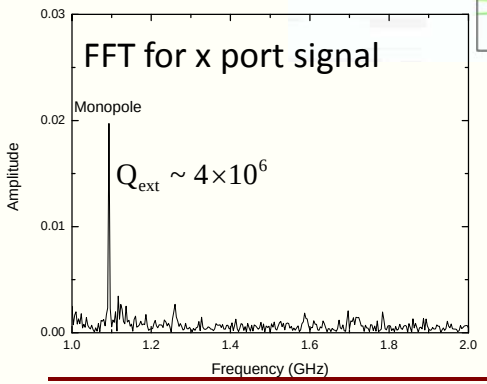
Cold BPM (cont.)

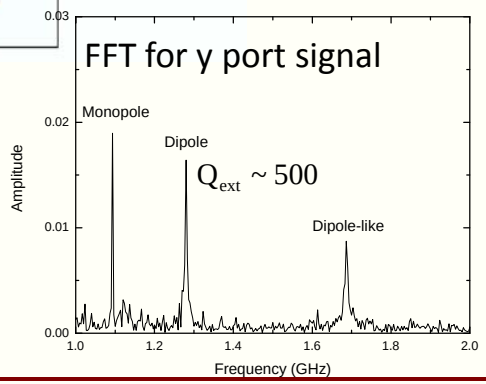


Preliminary simulation results

Field from 1mm y offset beam







- High resolution (~1 μm) CM-suppressed cavity BPM
- Simple structure to get cryogenic and cleanroom certification
- Fit into ILC cryomodule
- Operation at NML with
  - Project X CW-like beam (325 or 1300 MHz bunched)
  - ILC-like beam (~300 ns bunch spacing) single bunch acquisition
- f_{110} = 1.3 GHz, Q_L ~ 500
- Design needs more investigation on CM suppression.