Collaboration Opportunities on Project X Beam Instrumentation

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Project X Collaboration Meeting

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Project X Overview of Beam Monitors

ICD-1 Diagnostics	BPM	BLM	Toroid	Laser wire	SEM / Slit	Wirescanner	Screen Monitor	Fast F-Cup	Long. Fiberlaser	e-beam scanner	e-Cloud	IPM	Other Monitors
Injector	32	48	16	8	5	9		5	1	2	2	2	2
1.3 GHz Linac	51	55	3	3				3					
Transport Line	66	88	5	4	23		3						
Recycler (Inj)	1	20	3		5								5
Main Injector										2	2	2	
TOTAL	**150**	**211**	**27**	**15**	**33**	**9**	**3**	**8**	**1**	**2**	**2**	**2**	**7**

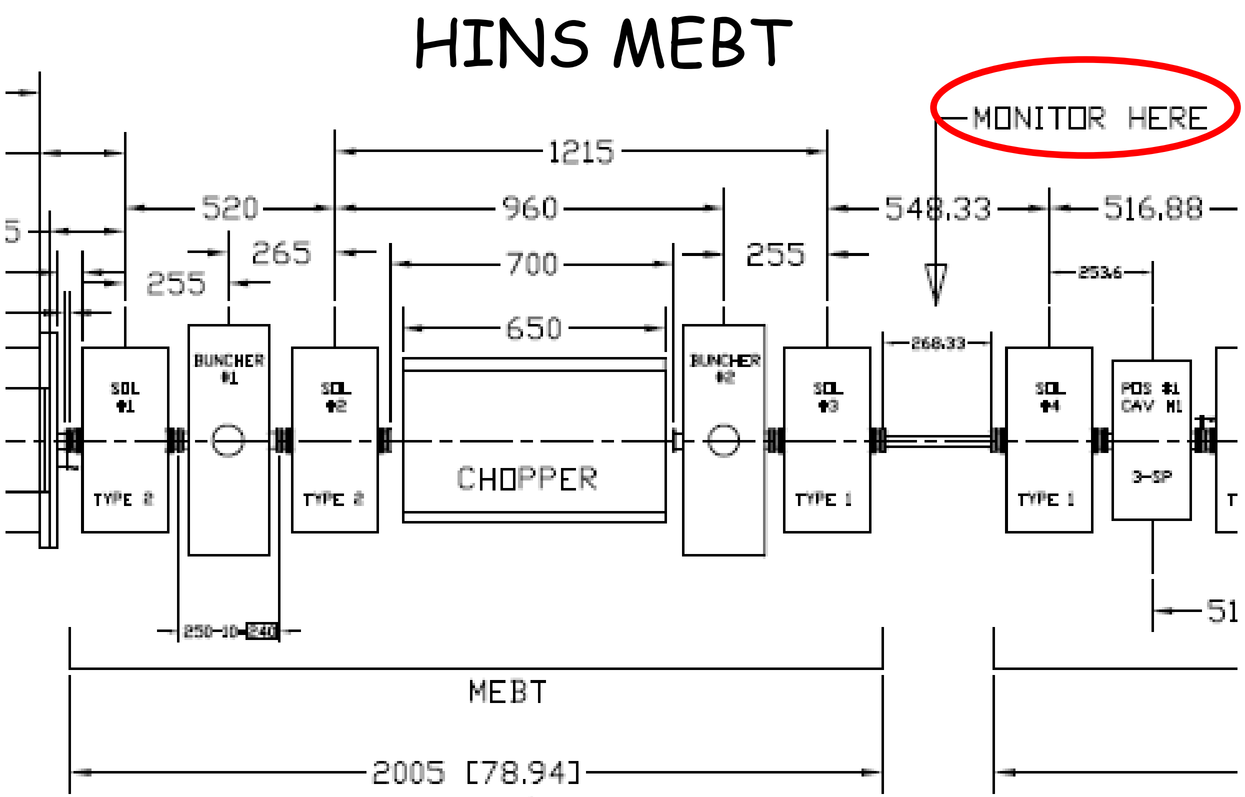
System Requirements

- Detailed requirements and specifications for beam instrumentation systems have NOT yet been established. Need to:
  - Requirements to be derived from beam dynamics and operations aspects (intensity ranges, resolution, precision, operating modes, etc.)
  - Define monitor technologies, e.g. button vs. cavity-style BPM in 1.3 GHz SCRF cryomodules
  - Exact location / layout / space / # of beam detector components. Space limitations: Optics / diagnostics balance (beam quality vs. diagn.)
- Establish a physical layout based on system installation numbers
  - Optimization / distribution of racks/crates vs. cabling, tunnel electronics(?)
  - Standardization of electronics hard- & software (e.g. VME/VXS, TCA, ...)
- Specification of the Machine Protection System (with Controls)
  - Operating modes (long/short pulse), response times, detection elements

Project X (Technical) Issues

- Most technical issues on high-intensity beam instrumentation systems are have been addressed and resolved elsewhere, e.g. SNS, but also DESY FLASH ("cold" beam monitors). However:
  - Exact specifications and the conceptual design has to be worked out.
  - Limited real-estate in MEBT, SCRF spoke-resonator and cryo-modules.
  - Location / type of tr. profile monitors for emittance measurements.
  - Detection of tr. beam halo (vibrating wire, laser wire) and long. beam tails (mode-locked fiberlaser) to prevent beam losses.
- Need onsite development / experience with non-invasive beam diagnostics (laser wire, e-beam scanner)
  - Minimize radiation background, instrument survival.
  - Emittance / profile monitoring in the transport line!
- Infrastructure, integration, standardization, DAQ (Controls)
  - Synchronized time stamping of data, low-jitter (sub-ps) clock signals

HINS MEBT Real Estate



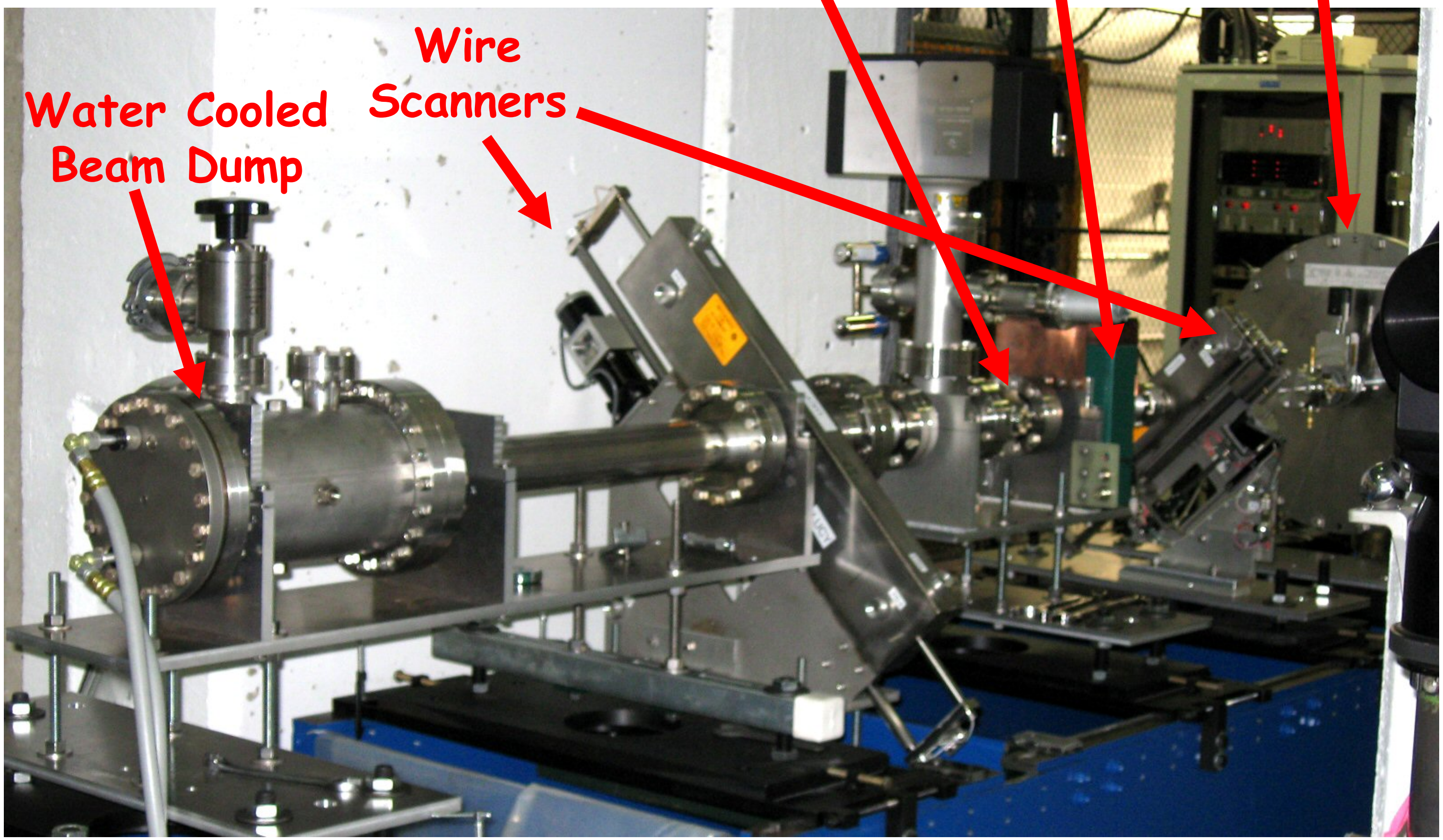
- SNS MEBT Diagnostics:
  - 6x BPMs
  - 2x Beam current
  - 5x Wire scanner
  - Diagnostics “Tank”
    - 2x Multiwire / slit
    - Beamstopper
    - Mode-locked laser
  - 3x BLM

Project X Technical Strategy

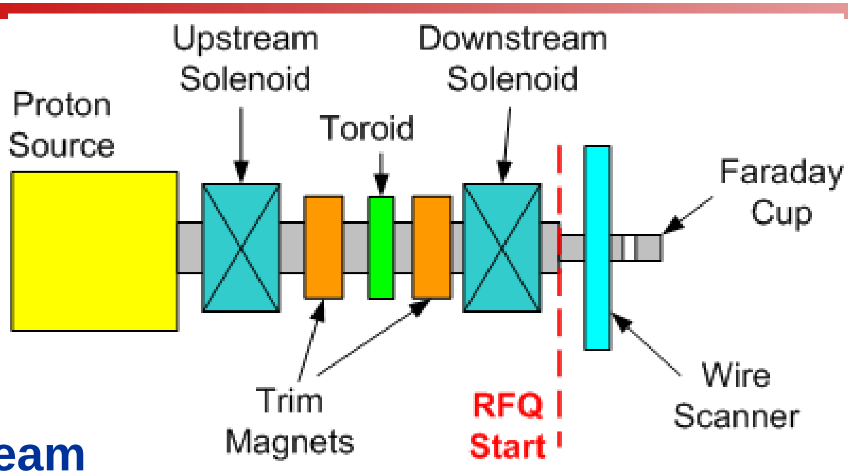
- Collect information
  - Workshop participation (HB, BIW, DIPAC, Care) information exchange
  - Visit of potential collaborators, e.g. SNS, BNL, LBNL, SLAC
  - Meetings, meetings, meetings,…(requirements & specifications!)
  - Review of specific instrumentation systems,
    e.g. HINS MEBT diagnostics, cryomodule BPMs, etc.
- Instrumentation RD&D targets (need beam!)
  - HINS H^- front-end (various linac instrumentation)
  - Main Injector (e-cloud, e-beam scanner, IPM)
  - NML test accelerator (cryomodule BPMs)
- Develop, build and test mission critical beam instruments, e.g.
  - MEBT diagnostics (orbit, emittance & phase monitors)
  - “Cold” BPMs, phase pickups (1.3 GHz cryomodule, spoke-resonators)
  - Non-invasive beam instruments

Practical Activities

HINS Temporary Diagnostics



1st HINS Beam Measurements



Beam

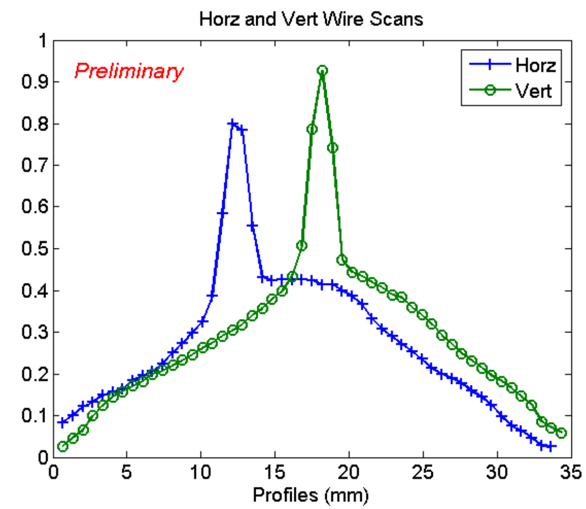
- 45 kV Protons
- 2-3 mA
- 100 μs pulse
- 0.1 Hz

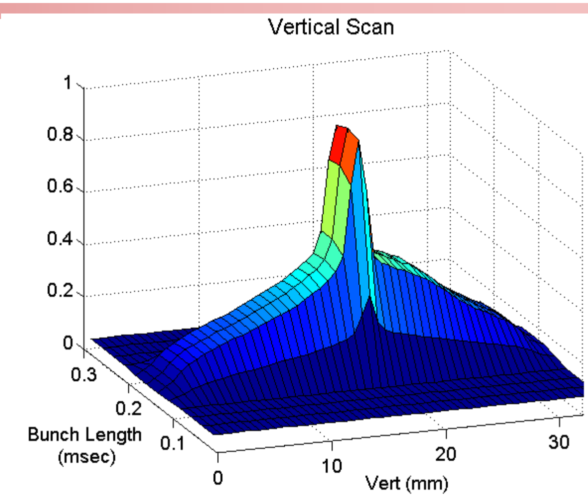
Solenoids

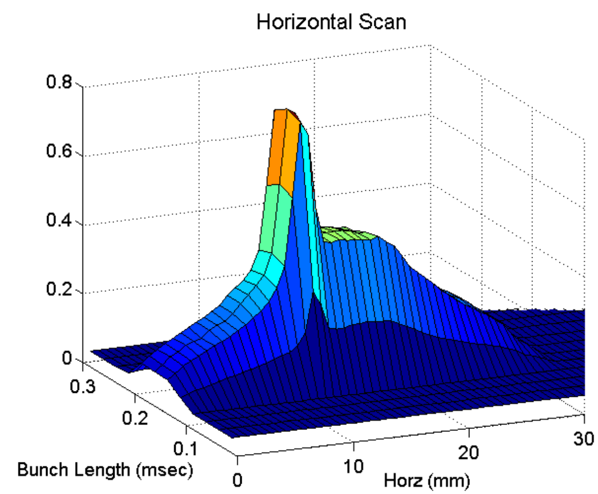
- Up to 7.8 kG

Trim Dipoles

- Up to 100 G





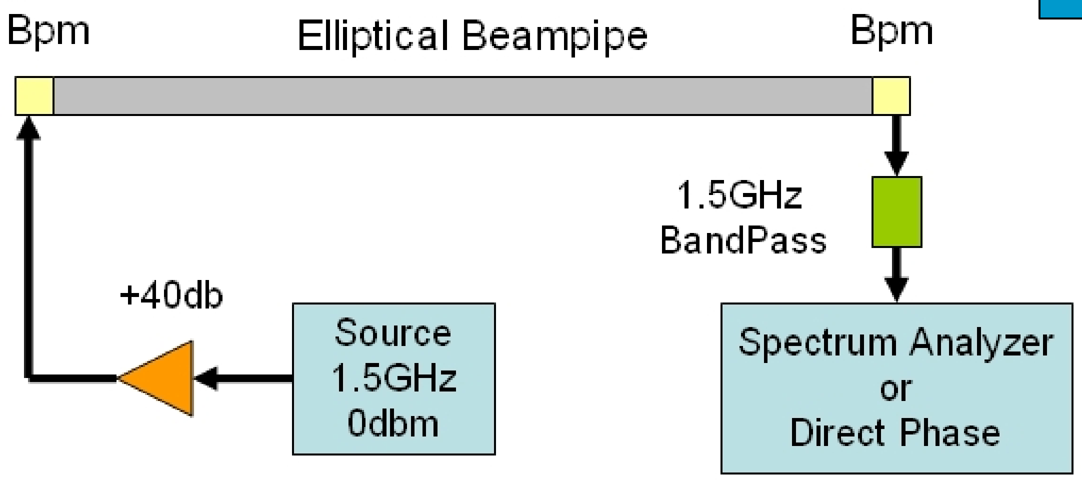


e-Cloud Measurements

- Microwave transmission (phase velocity) measurement:
  - From plasma physics, microwaves travelling along a waveguide (vacuum chamber)
  - Phase shift due to a homogeneous plasma
  - Microwave dispersion relation:

$$k^2 = \frac{\omega^2 - \omega_c^2 - \omega_p^2}{c^2}$$

$$\frac{\Delta\phi}{l} = \frac{\omega_p^2}{2c\sqrt{\omega^2 - \omega_c^2}}$$



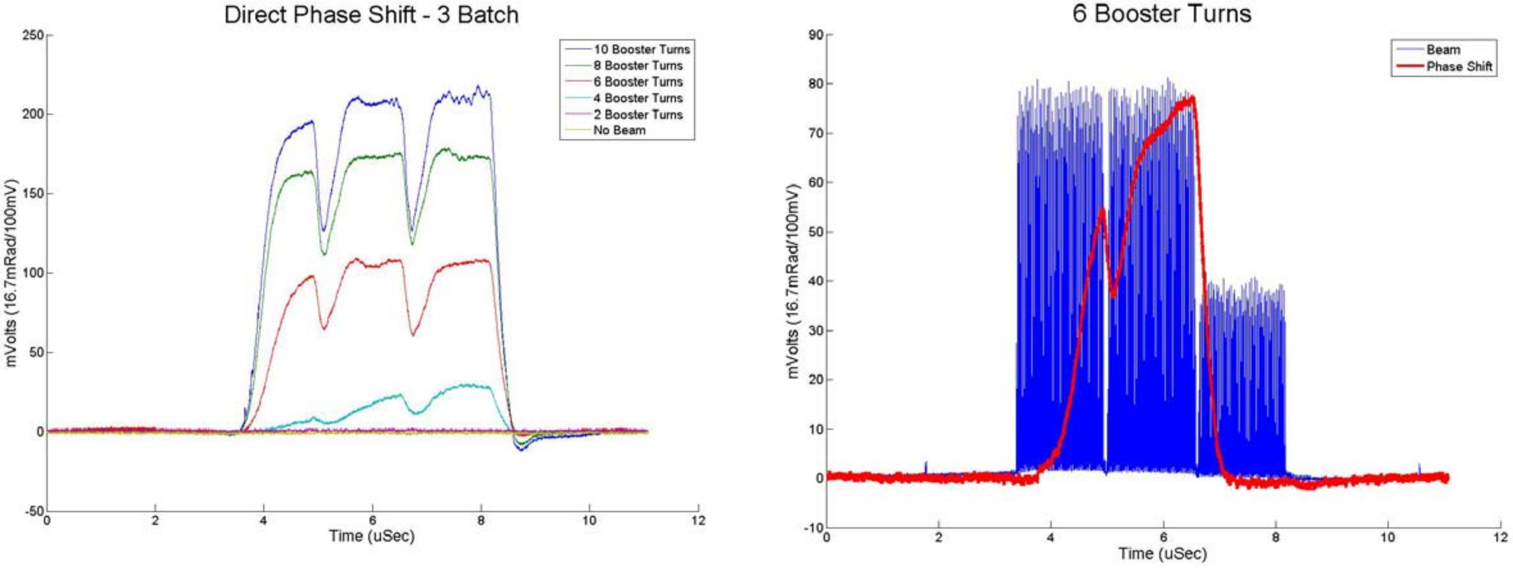
For an electron cloud

$$\omega_p^2 = 4\pi\rho_e r_e c^2$$

is proportional to e density

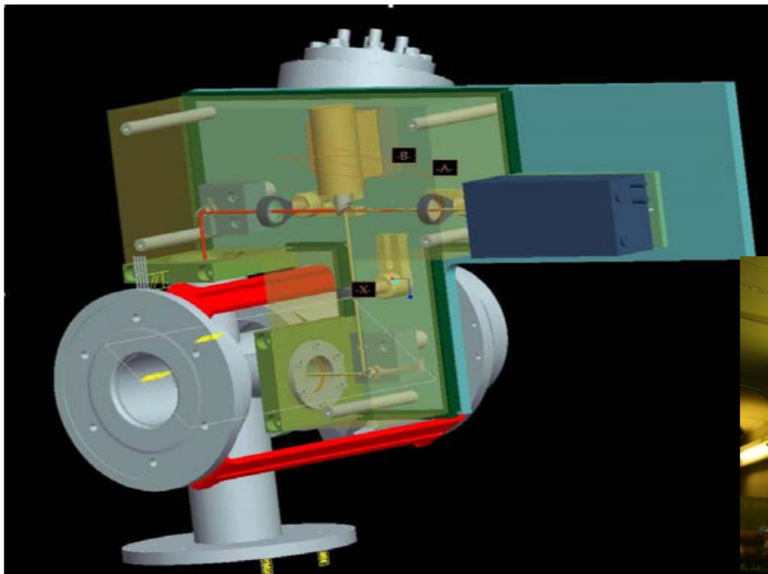
Project X Time Resolved Measurements

- Direct Phase e-Cloud Measurements
  - Mix the transmitted signal with the source and measure the baseband component.
  - The phase difference translates into a DC offset at the mixer output.



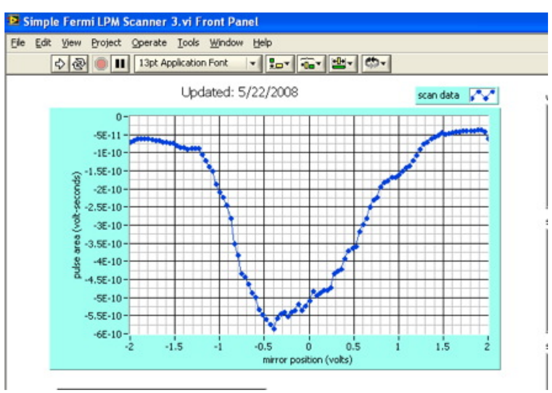
  - We can observe the development of the e-Cloud as the beam passes!
  - Data shown represents one machine turn (TbT time resolution).

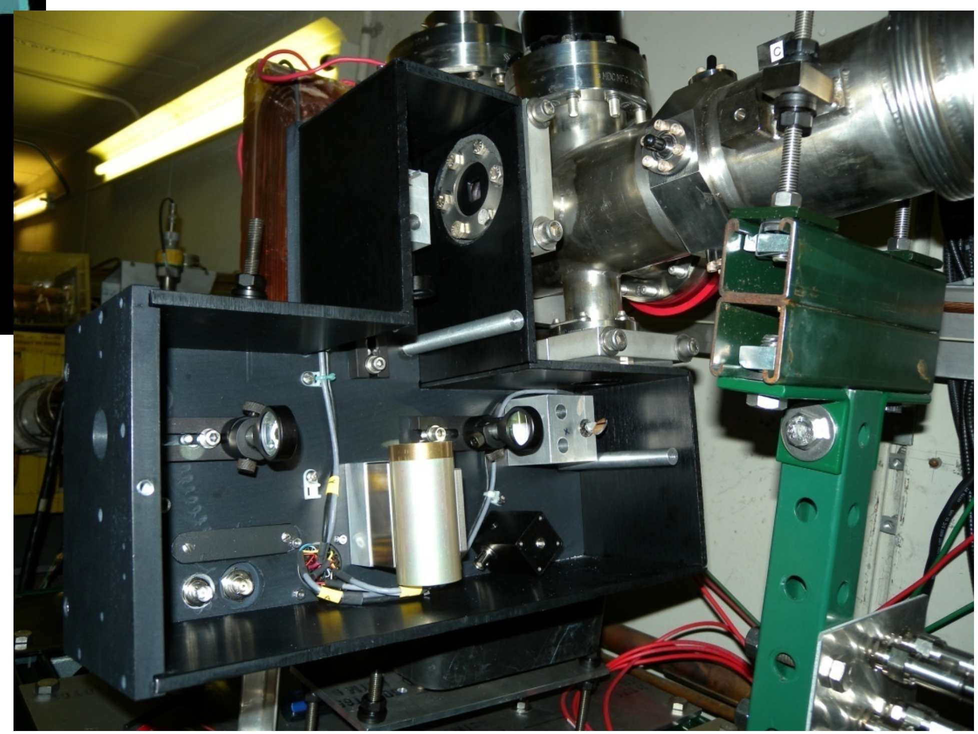
BNL Laserwire Collaboration



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

Fermilab:
- 400 MeV H^- beam
- Scintillator/PMT e^- detector





Project X Collaboration Opportunities

- **Laser-based, non-invasive beam diagnostics – formal collaboration (MoU) with LBNL, J. Byrd.**

- MEBT emittance monitor, e.g. mulitwire/slit apparatus. (UT?).
- LEBT emittance diagnostics, e.g. *Allison* scanner.
- Collaboration on a e-beam scanner for non-invasive beam profile monitoring of high intensity proton beams (SNS?).
- Collaboration of a high power version of a fast *Faraday* cup as invasive longitudinal beam profile monitor (SNS?).
- Collaboration on beam halo diagnostics, e.g. vibrating wire (*Bergoz* offers now a “commercial” version of this instrument).
- Need to set up a formal plan and scope (MoU) of the collaboration!

Collaborations

- The scope of a formal collaboration can be wide:
  - Time frame from 6 month to several years
  - From conceptual design study to a complete turn-key instrumentation system (however, the latter may be limited by available funds).
- The Project X R&D collaboration has to be based on a MoU, which includes:
  - Definition (exact specifications) and scope of the R&D activity.
  - Schedule & milestones.
  - Oversight, reviews and good communication, based on transparency and trust (this includes some travel and visits).
- Project X information:
  - http://projectx.fnal.gov
  - Document database (private DocDB):
    Username: collaborators, Password: xcoll