Bunch Shape Measurement in the Fermilab Linac

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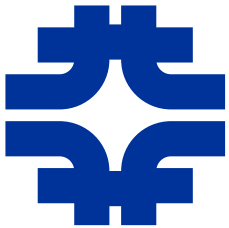

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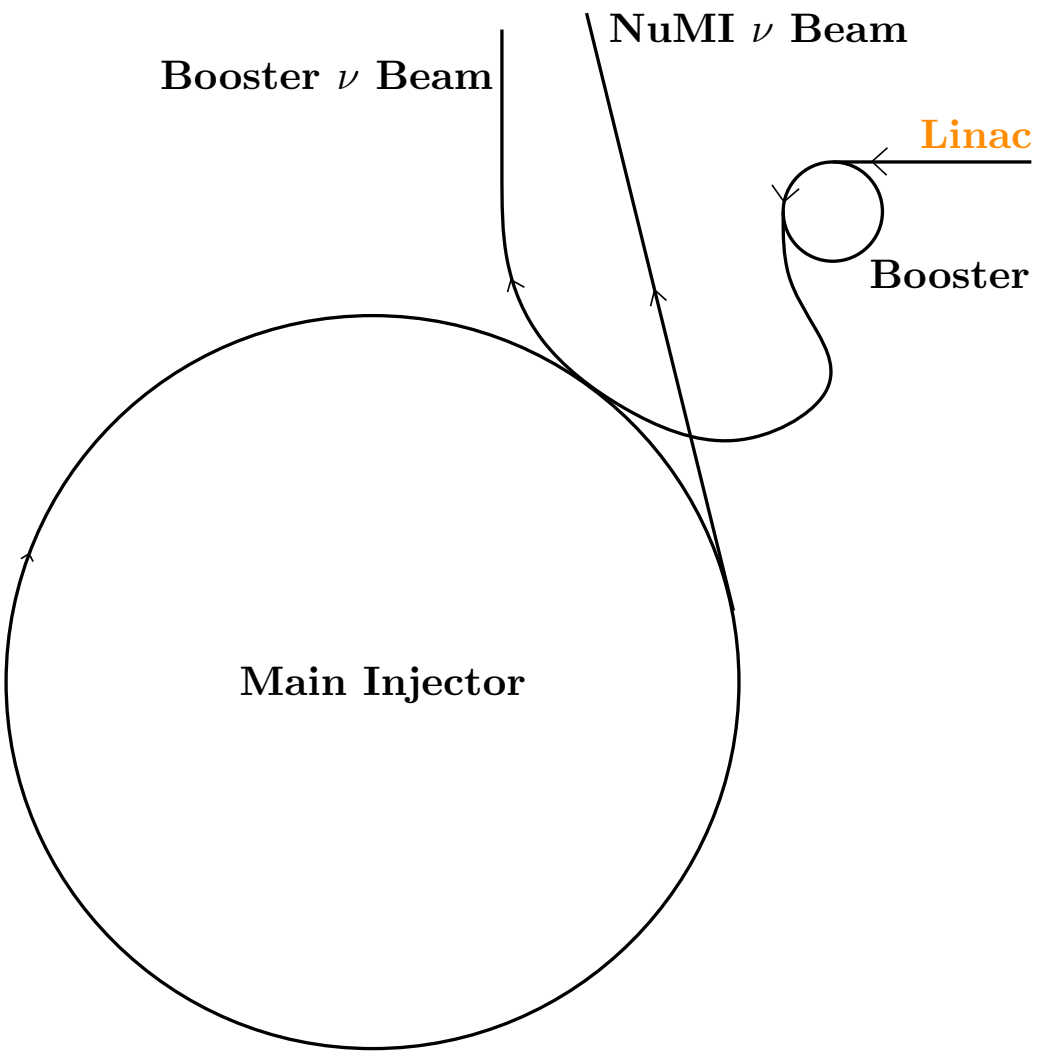
Outline

- **The Fermilab Accelerator Complex**
  - The Fermilab Linear Accelerator
- **Introduction to Bunch Shape Monitors (BSM)**
- **The Fermilab Bunch Shape Monitors**
  - The Radio Frequency (RF) Cavity (RFC)
  - Controlling the BSM
  - Data Acquisition
- **Testing and Calibrating Hardware Devices**
  - Testing Stepper Motors
  - Signal Testing
  - Calibrating the Focussing Lens Plates
- **BSM R&D**
  - X-ray based BSM's

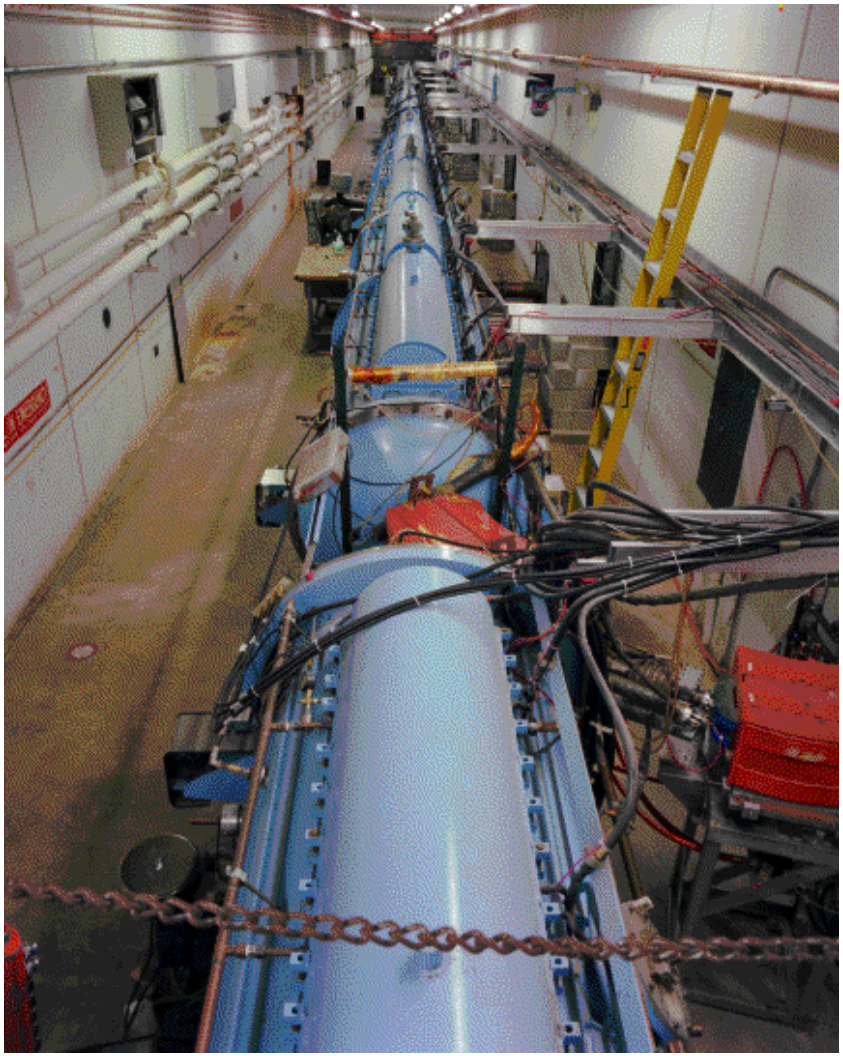
Fermilab Accelerator Complex



A simple model of the Fermilab Accelerator Complex for the current run. Energies:

- Linac: 400 MeV
- Booster: 8 GeV
- Main Injector: 120 GeV
- *Tevatron (RIP):* $\sqrt{s} = 1.96$ TeV

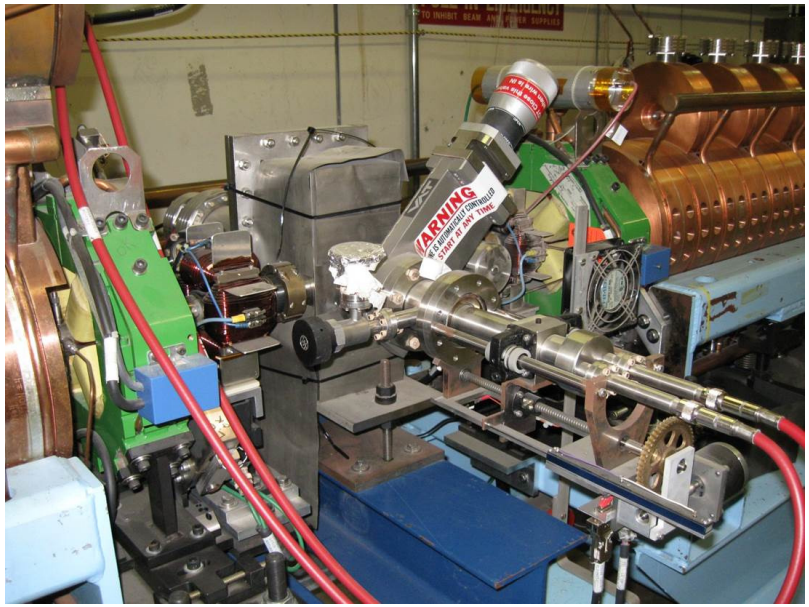
The Fermilab Linac

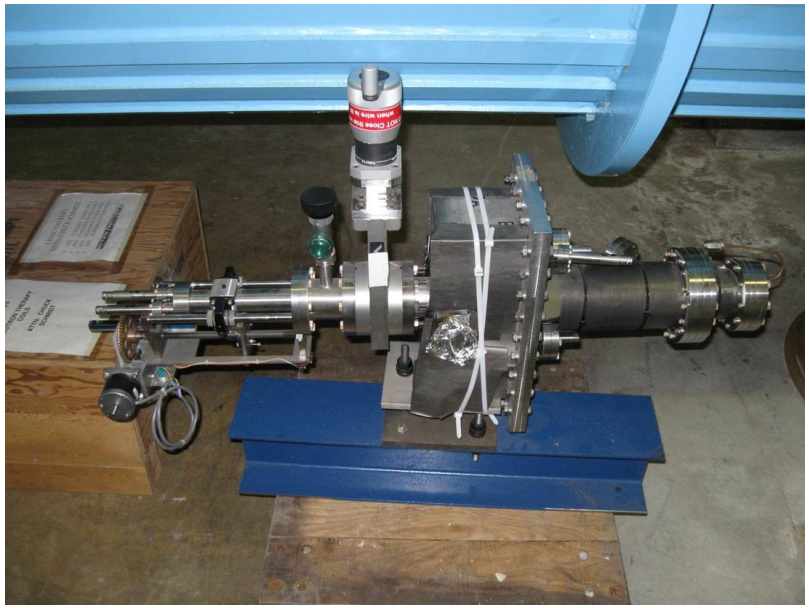


- The Linac has two main section.
- First section: Drift tube linac operating at a bunching frequency of 201.25 MHz. Accelerates H^- beam to 116 MeV.
- Second section: Side-couple cavity linac operating at 805 MHz bunching frequency. Accelerates beam to 400 MeV.
- The BSM is installed in the transition area (between the two main sections) where the bunching frequency is 805 MHz.

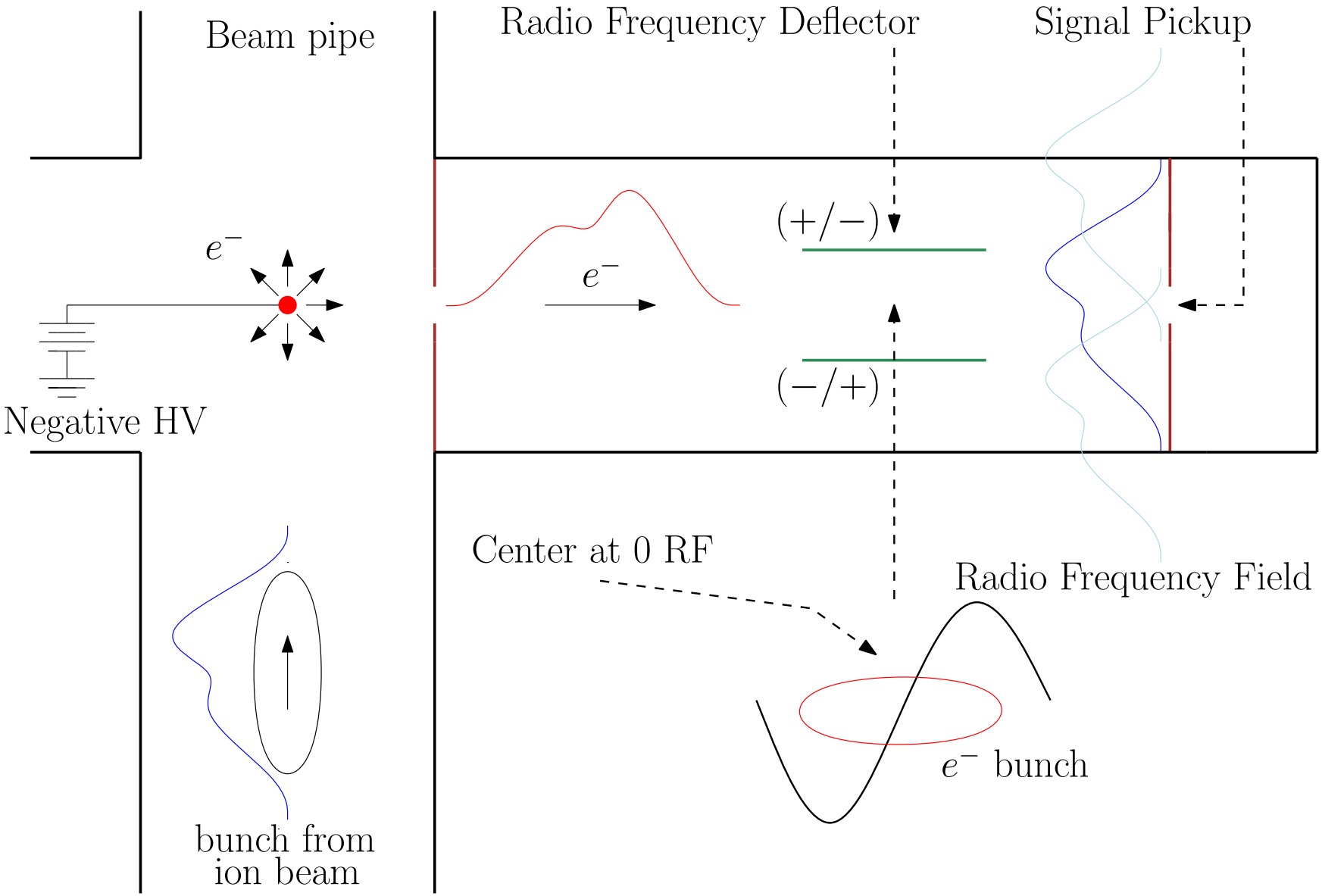
Intro to Bunch Length Detection

- Method developed in the late ‘80s at INR in Russia.
- BSM built at Fermilab in early ‘90s.
- Place thin filament at -HV in beam; secondary electrons ejected from the wire with same time structure as the beam.
- e^- propogate through slit and into radio frequency cavity.
- e^- structure in time transformed to a spacial structure.
- e^- impinge on an electron multiplier tube (EMT).
- RF cavity phase shift to sample entire beam structure.





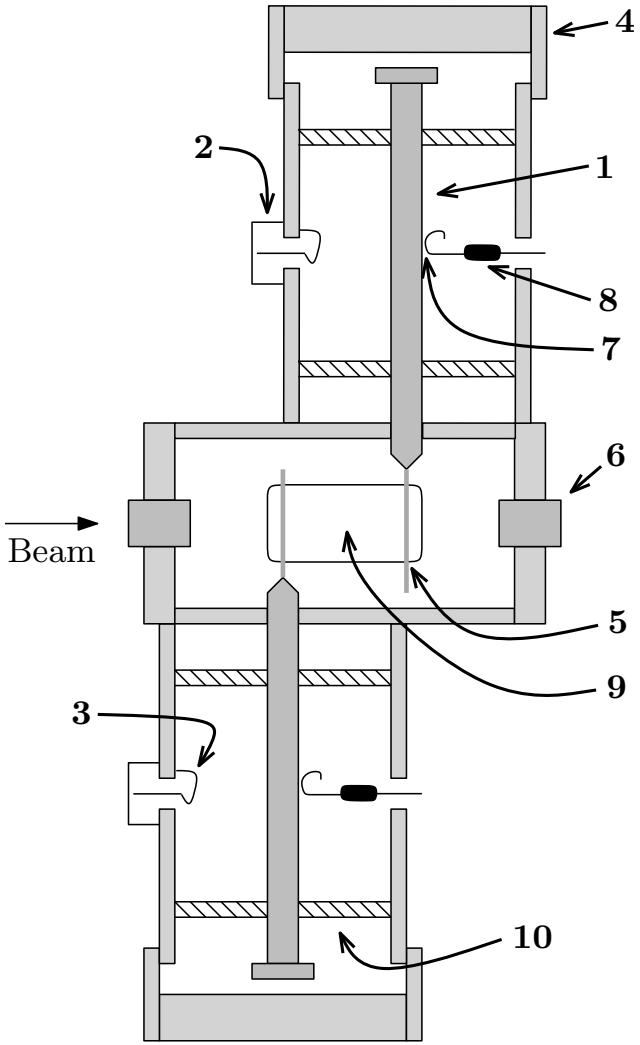
BSM Diagram


Beam pipe
Radio Frequency Deflector
Signal Pickup
e^-
e^-
(+/−)
(−/+)
Negative HV
Center at 0 RF
Radio Frequency Field
e^- bunch
bunch from
ion beam

Radio Frequency Cavity

The RFC is the most important part of the BSM

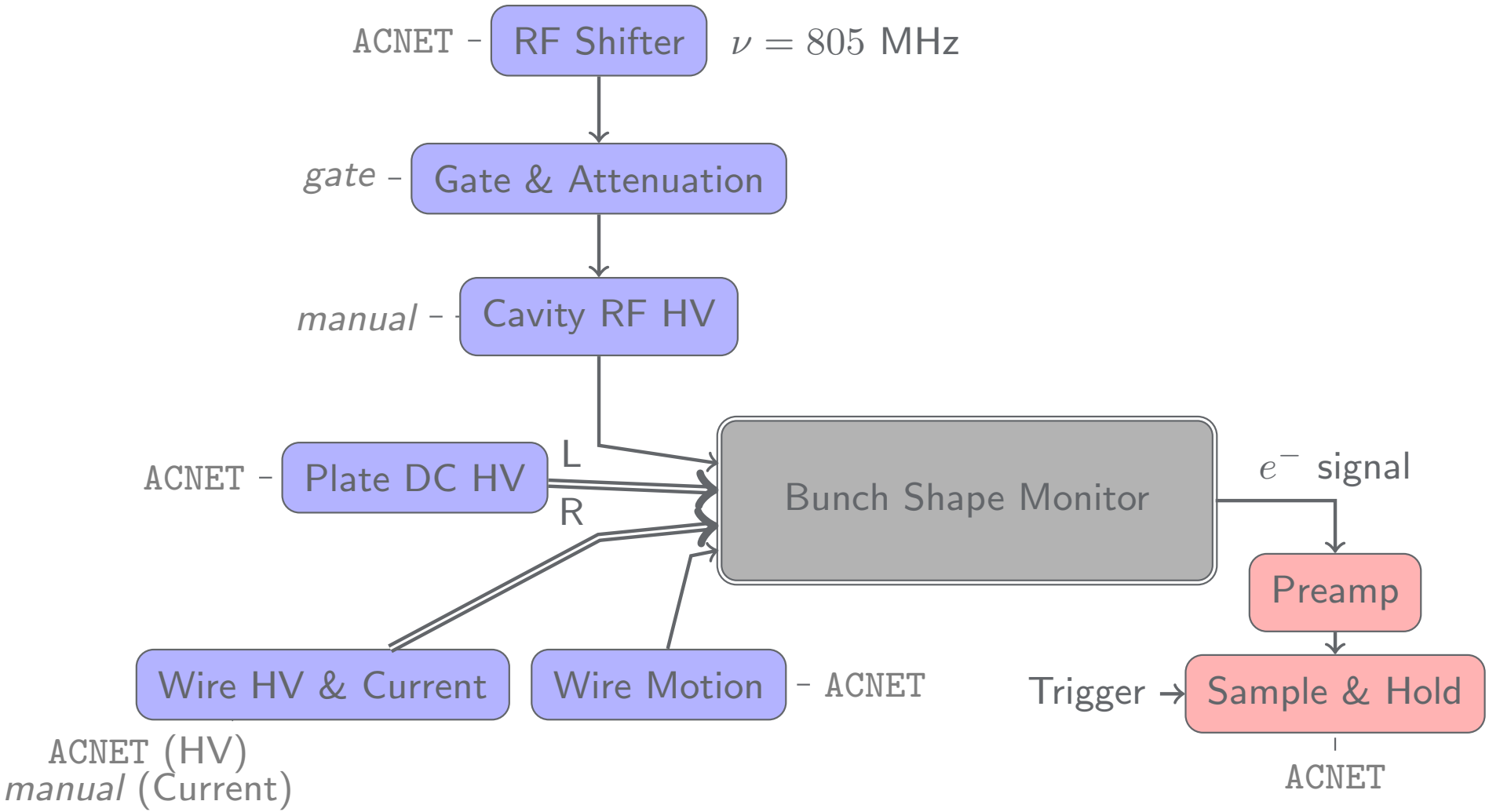
Time distribution $\Rightarrow$ Spacial distribution.



1. Resonant Cavity Forming Arms
2. RF Power Coupling Loop
3. RF Readback Loop
4. Endcaps (tuning)
5. Plate Size Trimming (tuning)
6. Slug Tuners
7. 0 RF – DC Voltage applied here
8. 1 MΩ Resistor
9. Focussing area
10. Nylon Support

Controlling the BSM

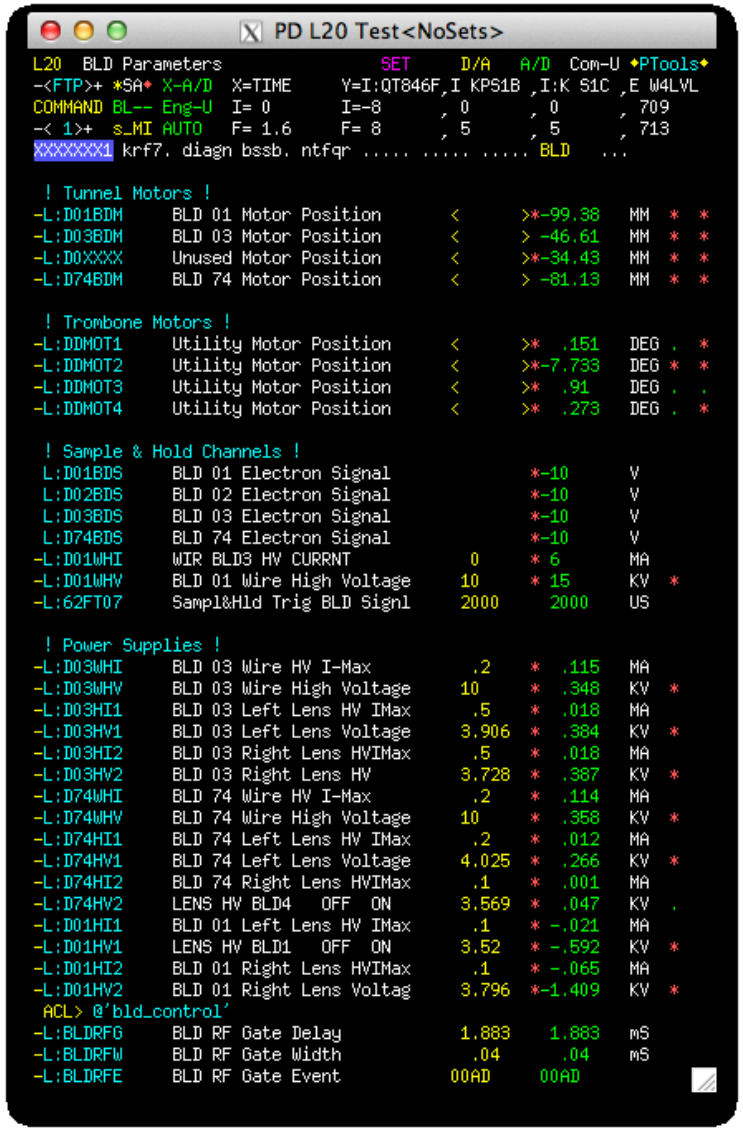
A simple block/flow diagram for the Linac BSM system:



Controlling the BSM, DAQ: ACNET, ACL

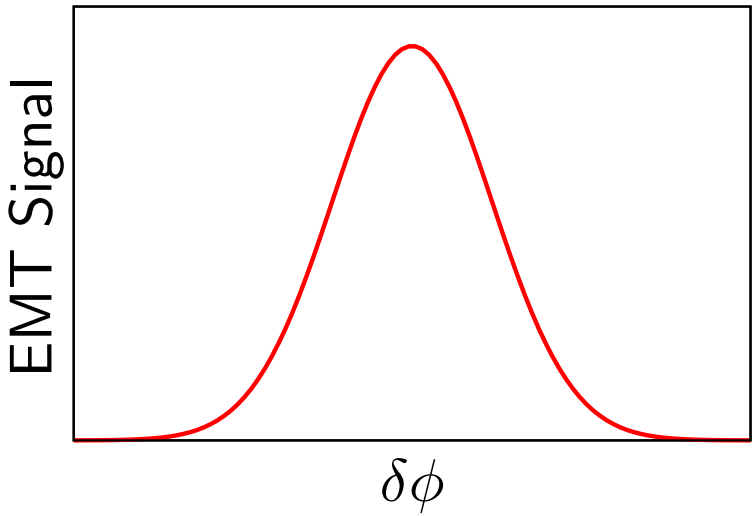
We use ACNET and ACL for setting and reading back BSM parameters.
ACL scripting language used for DAQ

- Set RF phase limit
- Set Starting RF starting phase
- Step RF phase
- Wait for a Linac pulse
- Readback phase value and EMT signal (10x)
- Step RF phase ...

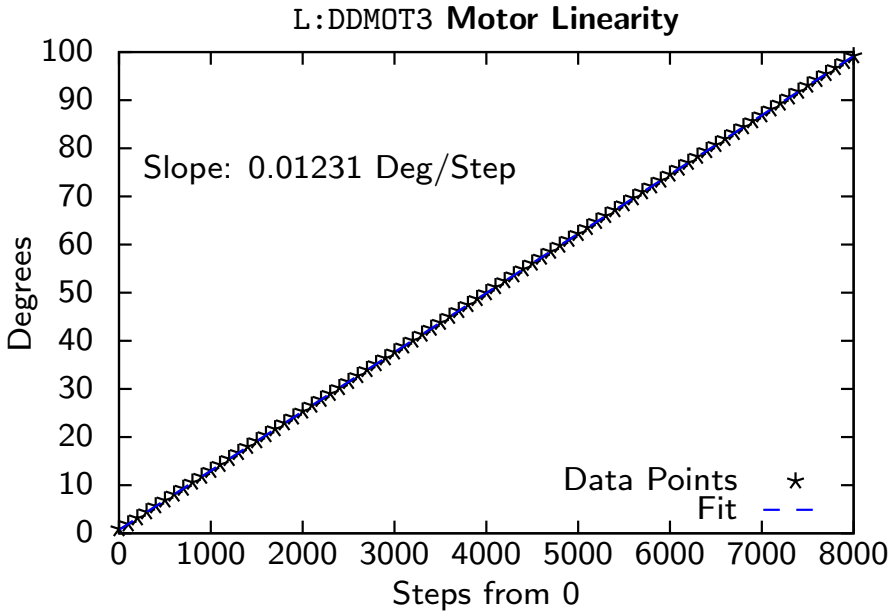


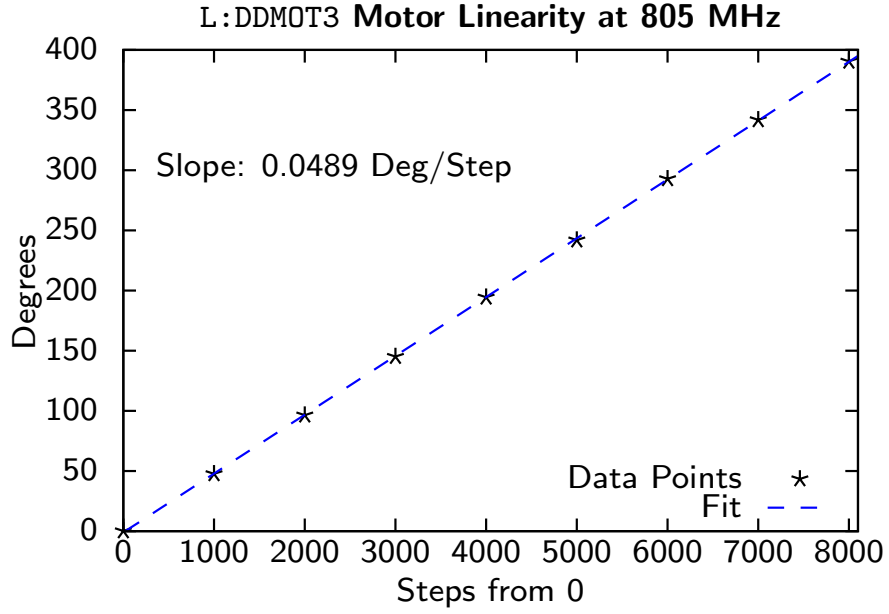
How the Shape is Determined

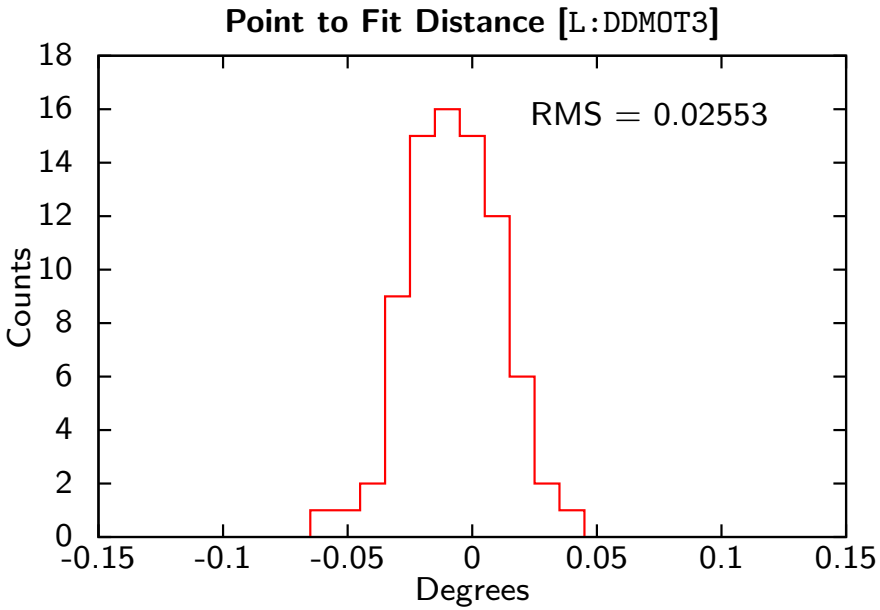
- Each Linac pulse (15 Hz) gives signal to the EMT. Many pulses contribute to one measurement
- As the phase is shifted, different segments of the spatial profile propogate through the second slit
- The measurement is then a function of the shift in phase.
- A theoretical bunch shape measurement, as a function of phase difference $\delta\phi$; real measurements would not be as perfectly Gaussian.

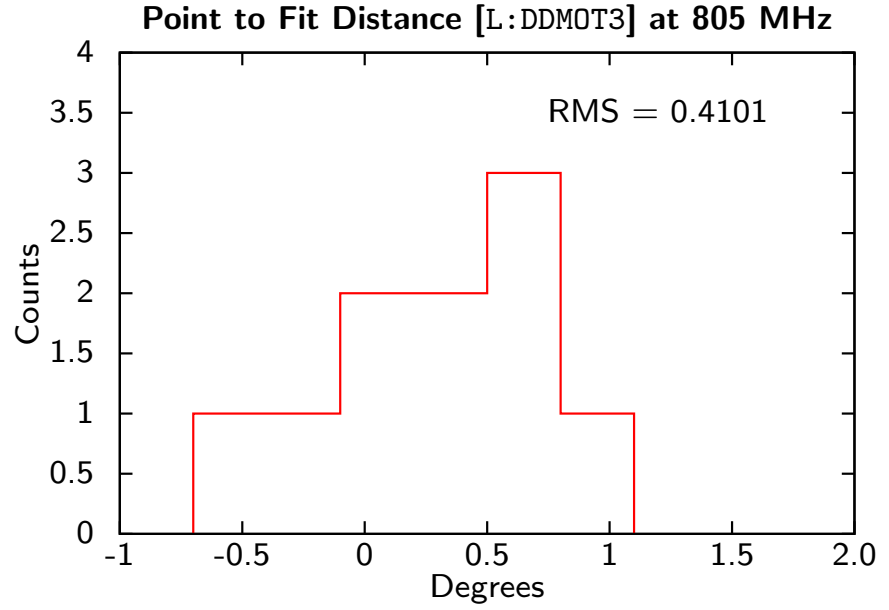


Stepper Motor Testing



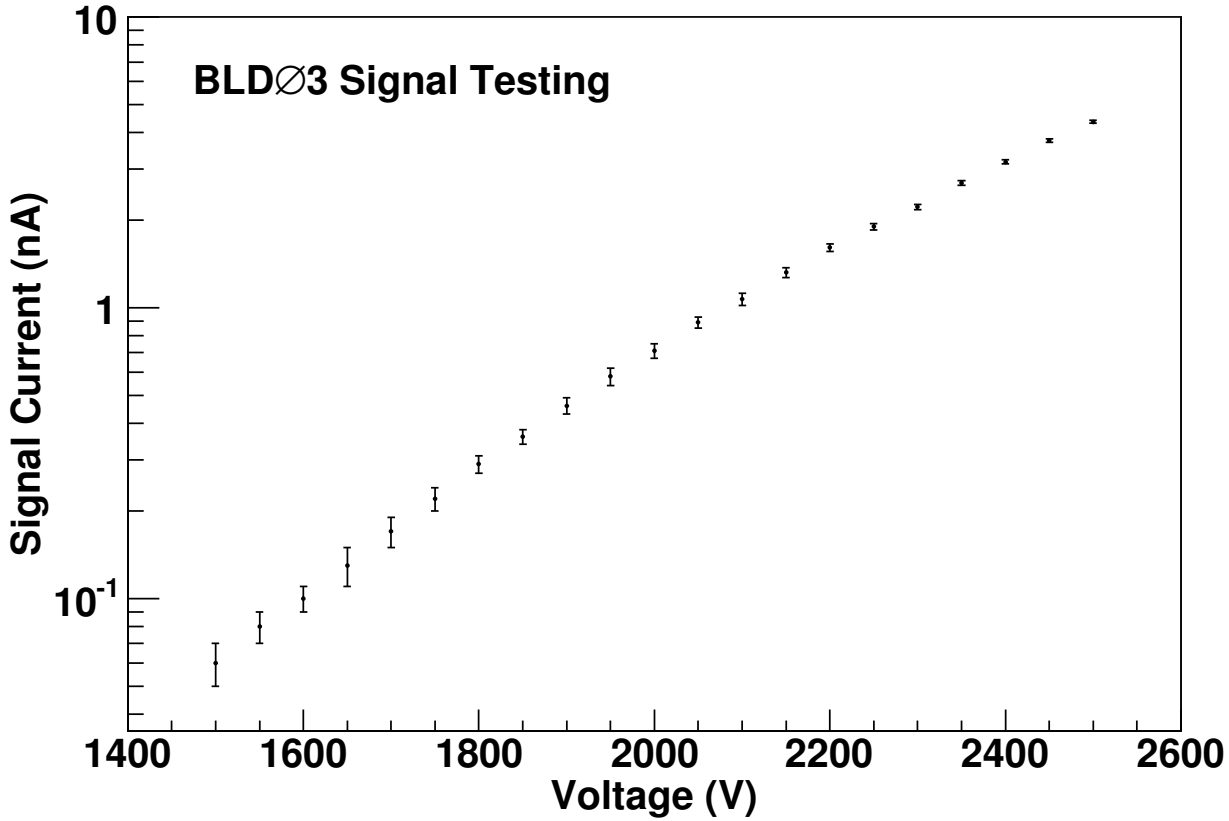






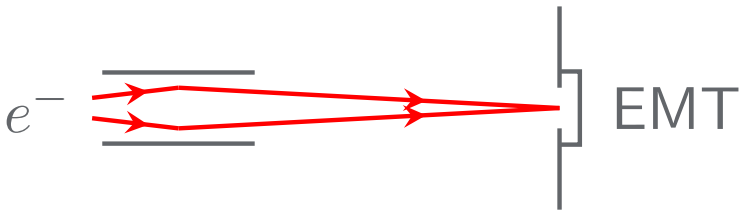
Successful Signal

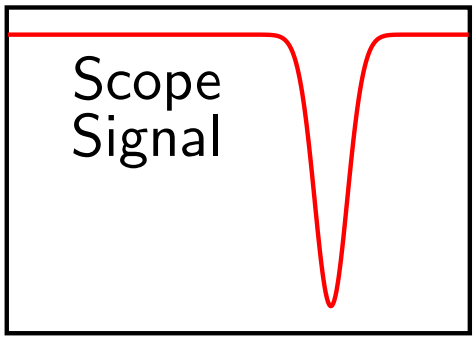
Very recently we have been able to generate a successful signal of electrons from the filament on the EMT. Applying approximately 1 A to the filament:



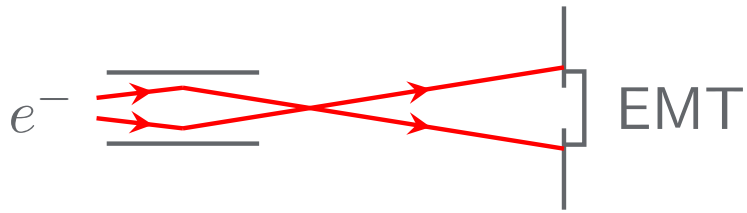
Calibrating the Focussing Plates

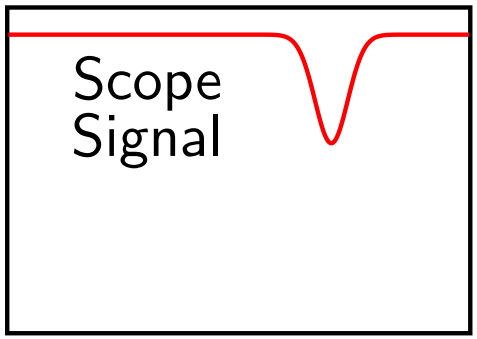
The tungsten wire can emit electrons when not impinged on by beam by applying a current to the wire; we can calibrate how to apply voltage to the lenses in the RF Cavity without beam running.





- Good focussing $\Rightarrow$ Good signal

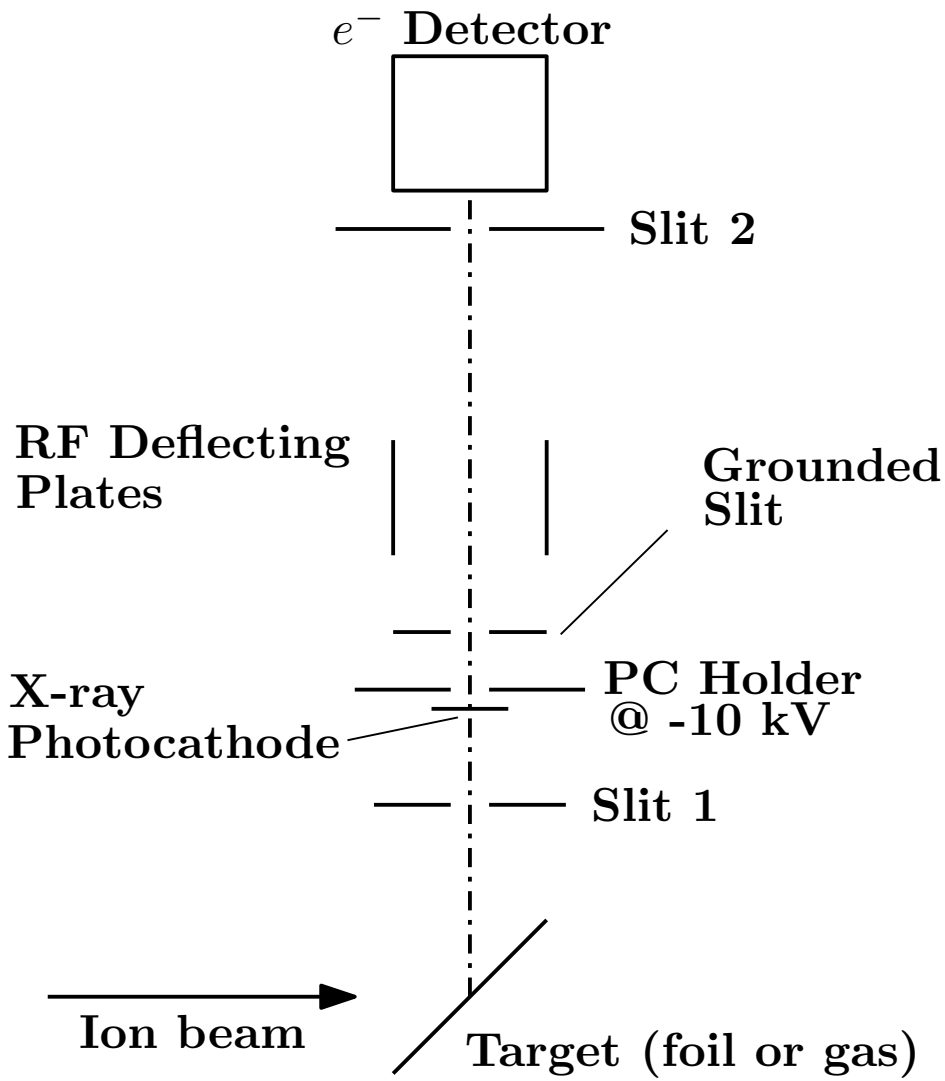




- Over focussed $\Rightarrow$ Bad signal

X-ray based BSM

- X-ray based BSM has been commissioned at ANL by Peter Ostroumov.
- Place foil in the beam line (or gas) as target. Beam-Target collisions create inner shell vacancies in target atoms. Allows for emission of X-ray photons.
- Photocathode converts X-rays into low energy electrons.
- Like the secondary electron based BSM, the X-rays and electrons in the X-ray version have the same time structure as the bunched ion beam.
- Better time resolution (10 ps vs. 5 ps) & no effect from 2 e^- from the H^- beam.



Summary and Conclusions

- Secondary electron based BSM has existed at Fermilab since the 400 MeV upgrade.
- Recommissioning of this detector has begun this summer and will continue.
  - Components of the Fermilab BSM have been tested and more will be tested
  - New data acquisition method has been developed.
  - Unfortunately, we were not able to access the Linac to diagnose problems until very recently – *but* we have been able to diagnose some problems outside of the tunnel, and we have now identified some issues in the tunnel.
- An X-ray based BSM has been commissioned at ANL and Fermilab will begin R&D on an X-ray based BSM for the PXIE effort.
- After successful measurements with the current BSM, it will be removed to install the X-ray based BSM into the Linac to prepare for one in PXIE.

Acknowledgements

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Backup

Previous BSM Measurements

The original developer of the Fermilab BSM, Elliott McCrory, has made measurements in the past.