Electron-Cloud Diagnostics at PSR

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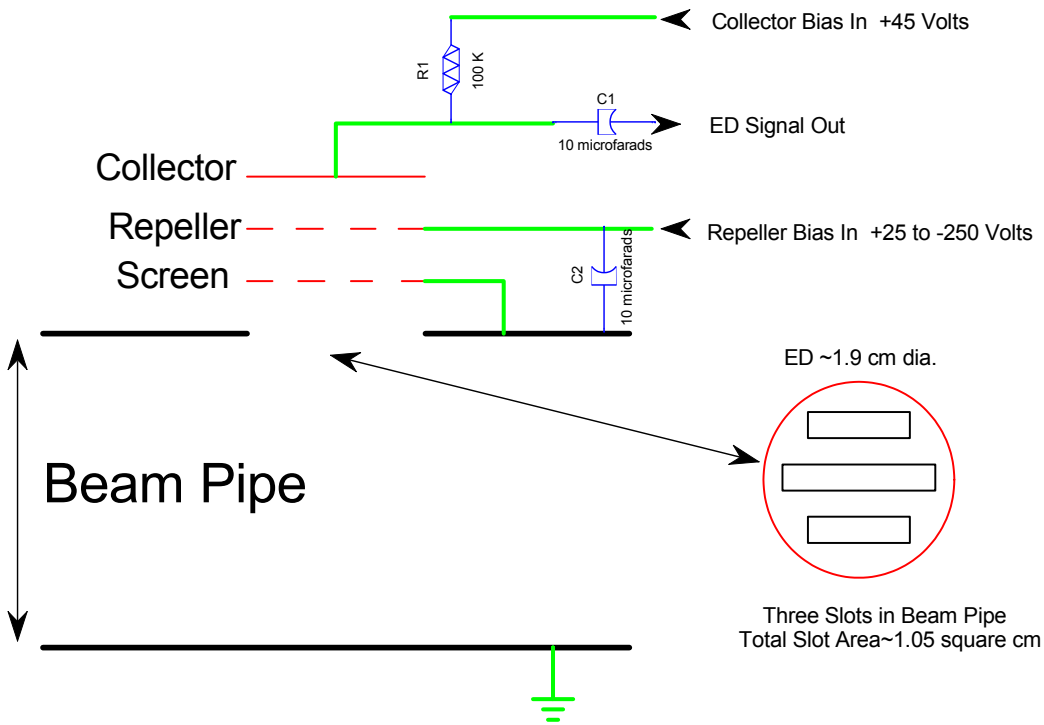
Outline

- Cloud parameters of interest
  - Electron density distribution as function of time, and 6 phase space coordinates of electrons
  - Source strengths of various sources of electrons
  - Much can be learned from flux striking the wall, its time structure and energy spectrum
- Retarding Field Analyzer (RFA)
  - Flux striking the wall
  - Time structure
  - Energy spectrum of electrons striking the wall
- Electron Sweeping Detector (ESD)
  - RFA with pulsed electrode to sweep low energy e's into the RFA
- Ion pump current pulse
- Biased collection electrodes

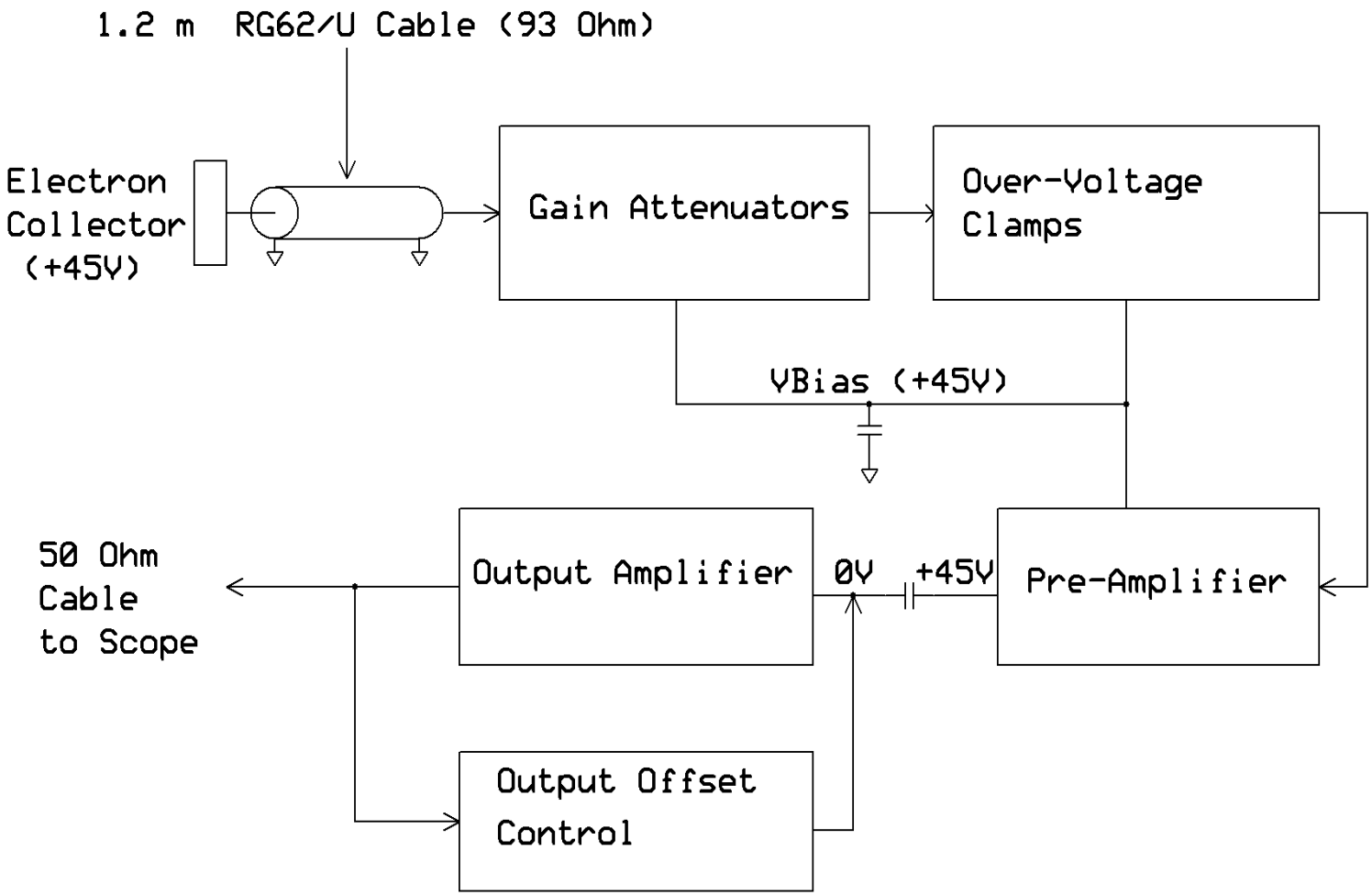
Retarding Field Analyzer

- Described in R. Rosenberg and K. Harkay, NIM A 453 (2000) p507-513.
- LANL augmentation is fast electronics (~80 MHz) on the collector output
- Minimal perturbation of beam/wall environment
- Use of repeller permits collecting a cumulative energy spectrum
- Measures electrons striking the wall, not electrons remaining in the pipe

Simplified RFA Installation Sketch



RFA Electronics Block Diagram



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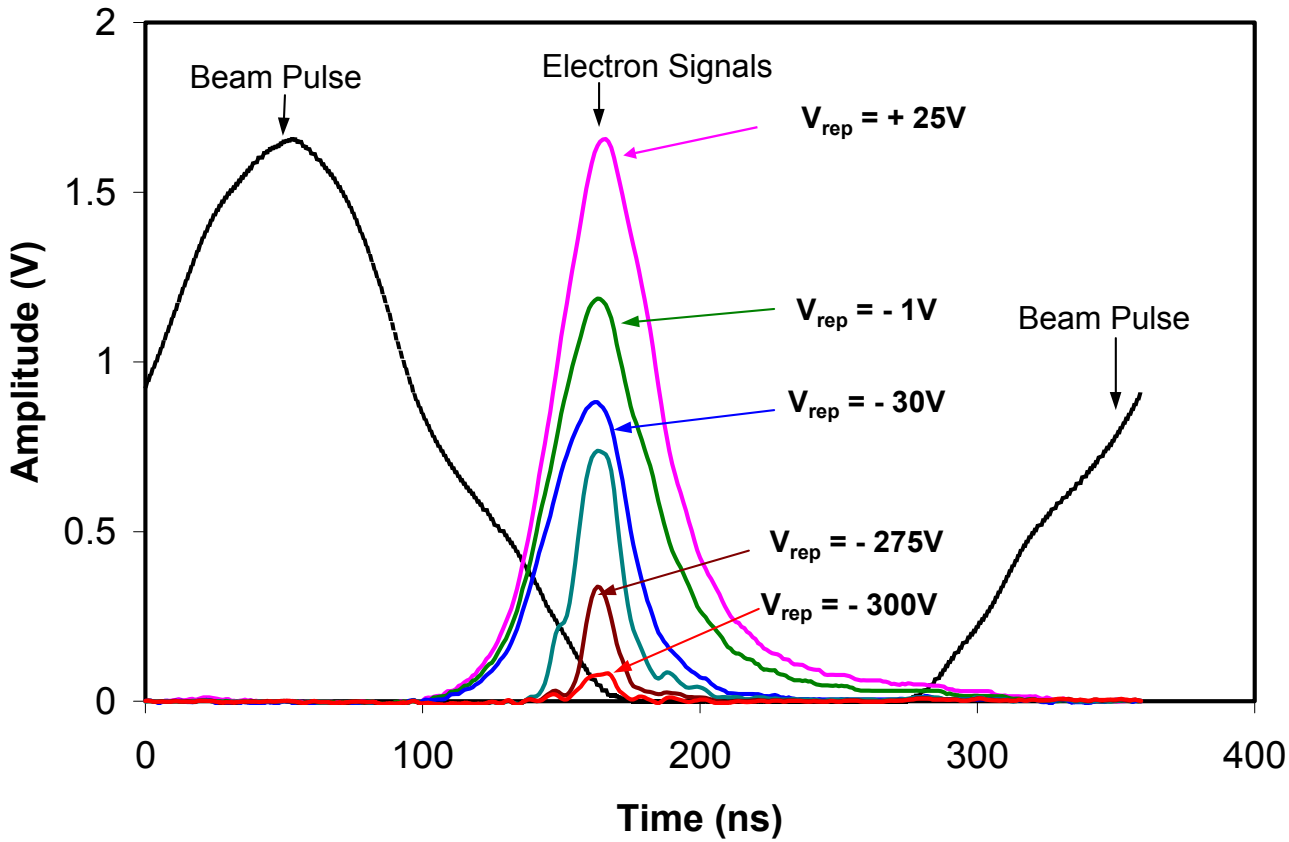
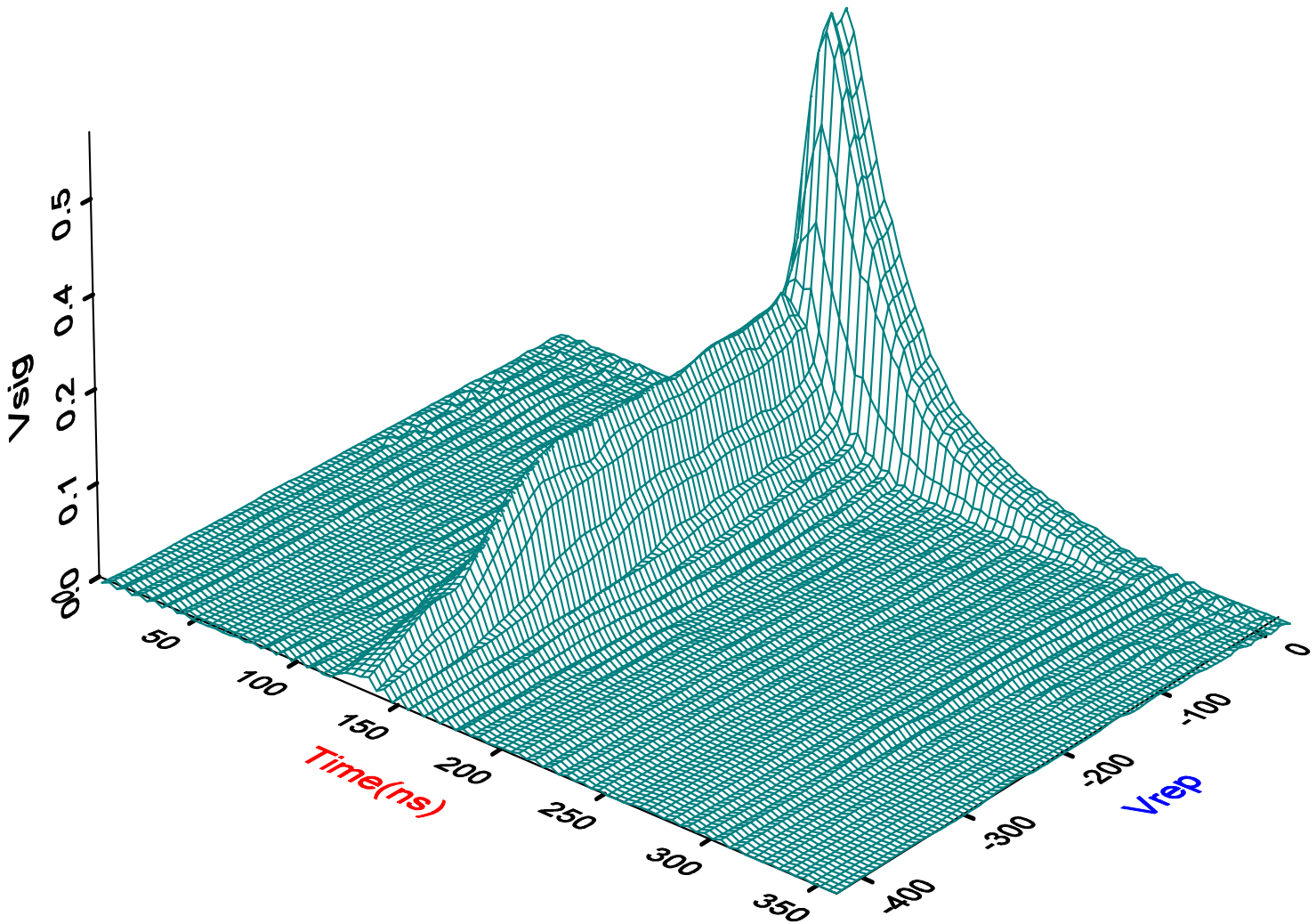
Electron signals from RFA in straight section 4



- **RFA signal has contributions from "trailing edge multipactor" and "captured electrons" released at end of beam pulse plus their secondaries**
- **Key issue is how many electrons survive the gap to be captured by the beam**

Signals averaged for 32 beam macropulses, ~ 8 μC/pulse beam intensity, device is labeled ED42Y, Transimpedance = 3.5 kΩ, opening ~1 cm^2

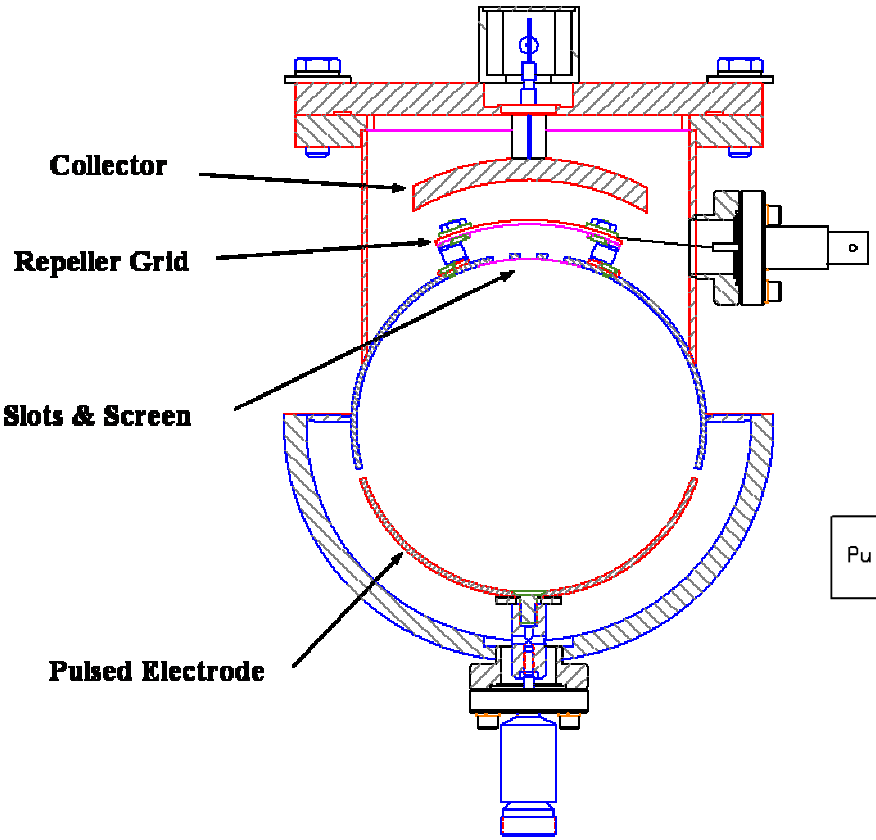
Electron energy cumulative spectrum (3D profile)



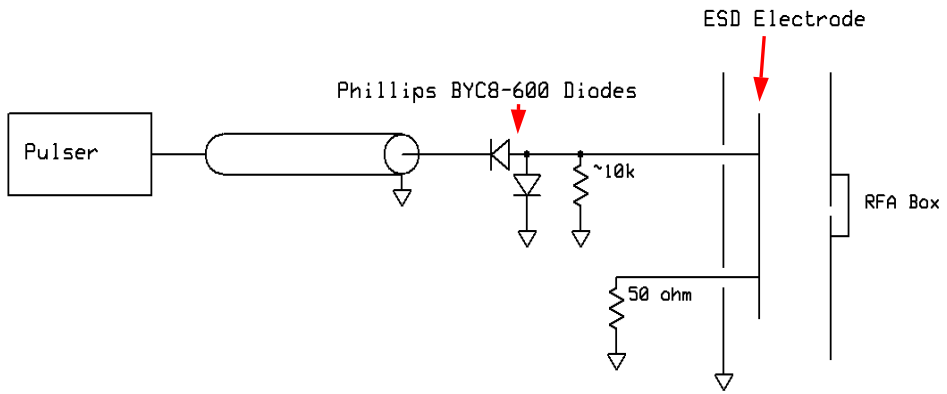
Electron Sweeping Diagnostic (ESD)

- Designed by A. Browman to measure e-cloud surviving passage of the gap
- Short HV (~1kV) pulse is applied to electrode to sweep electrons into RFA

Cross-section



Pulsed Electrode Network



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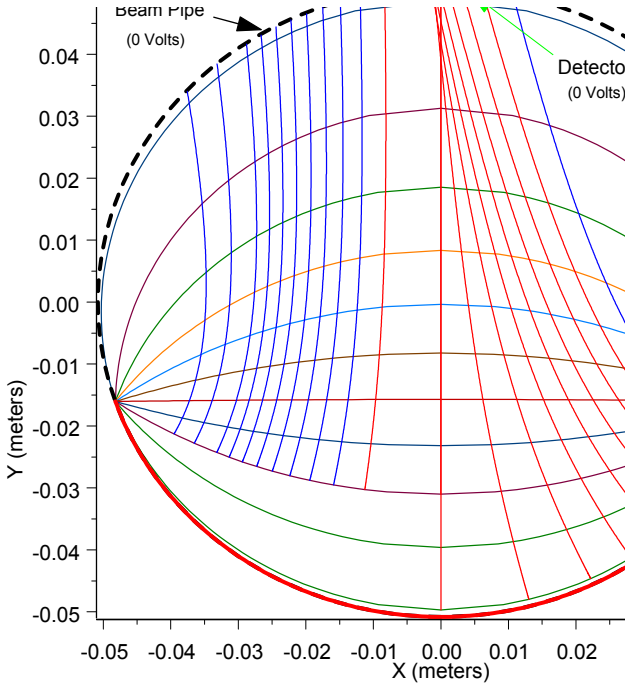
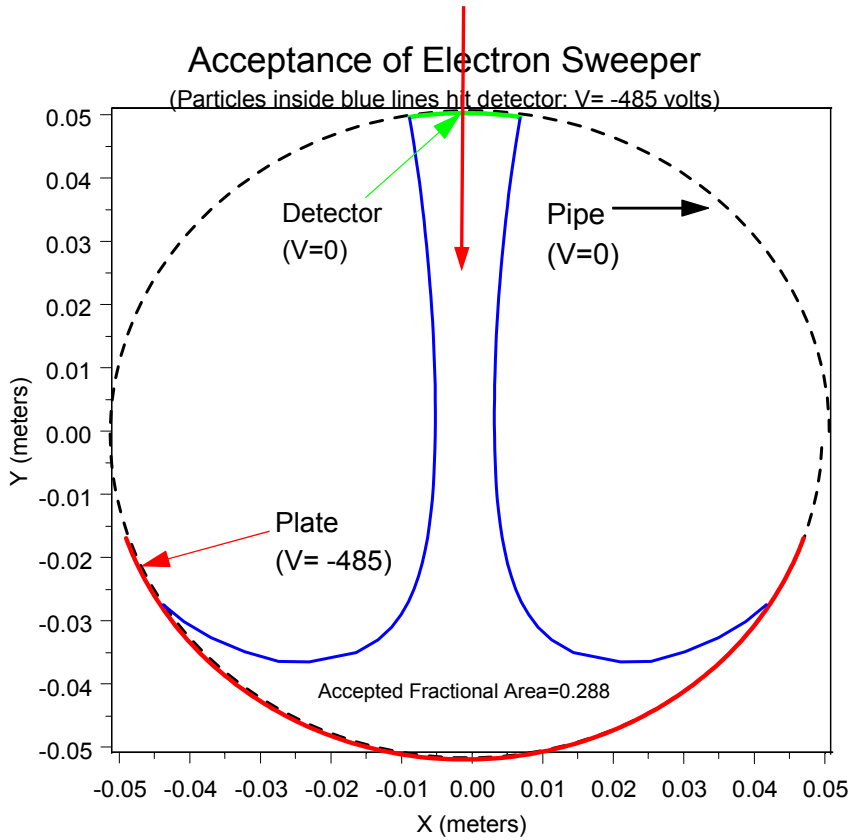
Acceptance of ESD

- **Acceptance mapped by calculating trajectories for thousands of initial positions on a grid in the pipe and selecting those that entered the arc of RFA box**
  - **zero initial velocity (cold electrons)**

Potentials and Trajectories

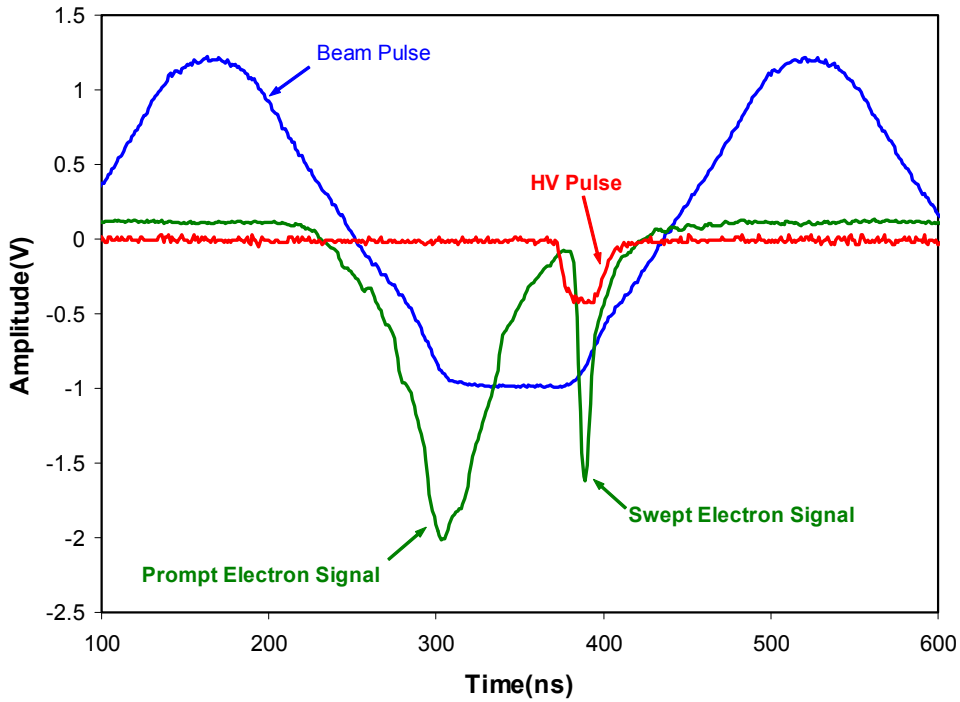


Collection Region



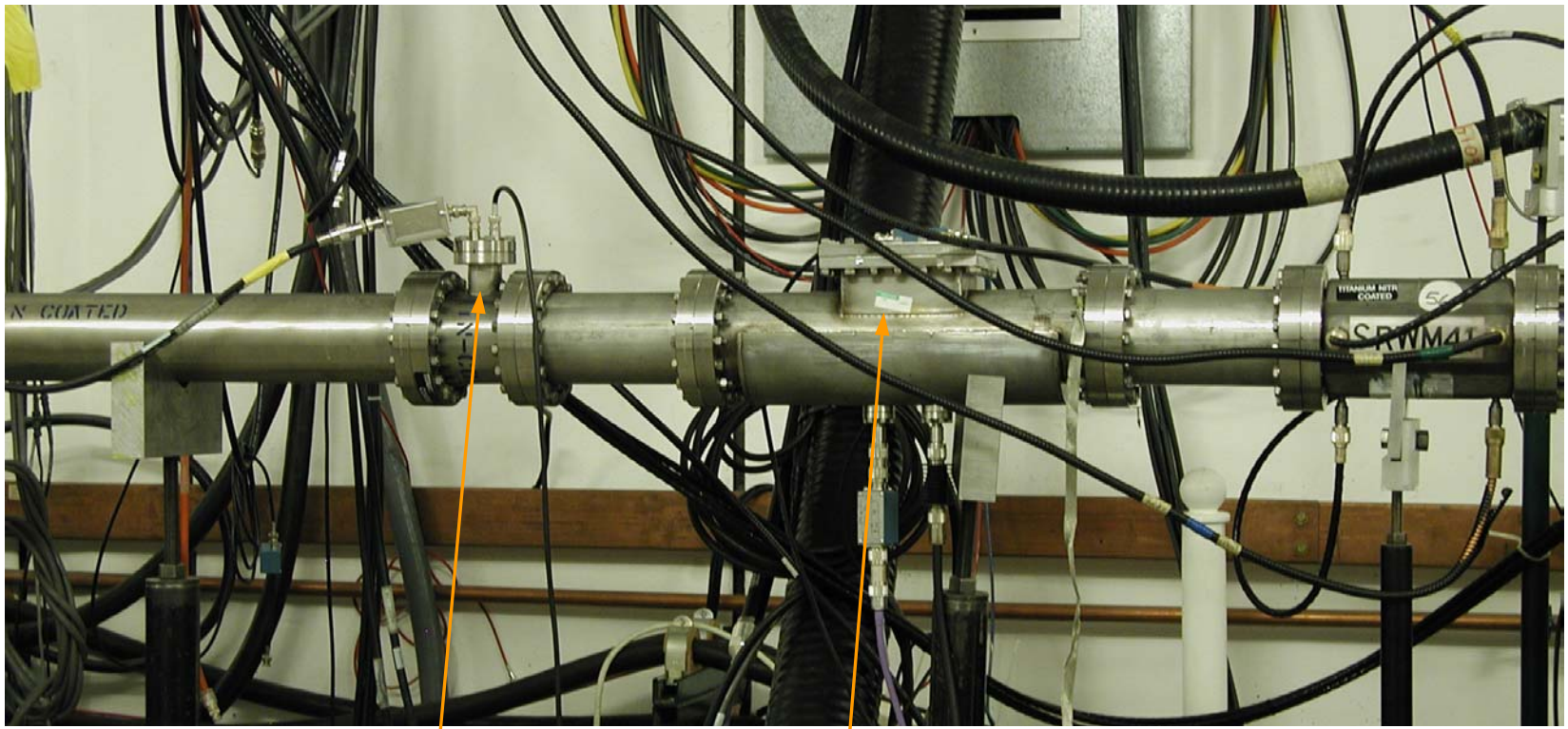
Sample Electron Data from Electron Sweeper

- Signals have been timed correctly to the beam pulse
- "Prompt" electrons strike the wall peak at the end of the beam pulse. Contributions from:
  - Trailing edge multipactor
  - Captured electrons released at end of beam pulse
- Device basically acts a large area RFA until HV pulse applied
- ~10 ns transit time delay between HV pulse and swept electron signal is expected
- "Swept" electron signal is narrow (~10 ns) with a tail that is not completely understood



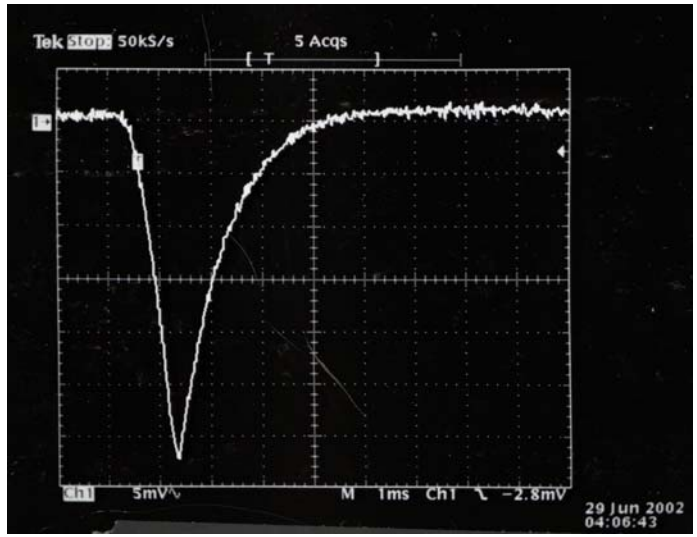
7.7 μC/pulse, bunch length = 280 ns, 30 ns injection notch, signals averaged for 32 macropulses, repeller = - 25V, HV pulse = 500V

Picture of installed electron sweeper

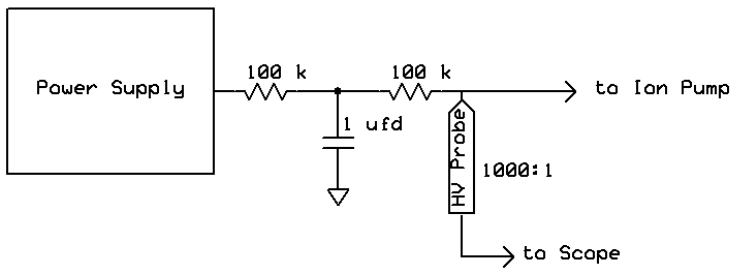


Ion pump current pulse

- A vacuum pressure rise was historically one of the first indicators for beam-induced multipacting
  - Multipacting electrons striking the wall desorb gases
- An ion pump current pulse is observed during accumulation of intense beam pulses in PSR
- Pulse amplitude tracks the peak RFA signal amplitude e.g.,
  - When it changes with beam intensity
  - As the cloud diminishes over time with beam scrubbing
- Simple diagnostic to implement

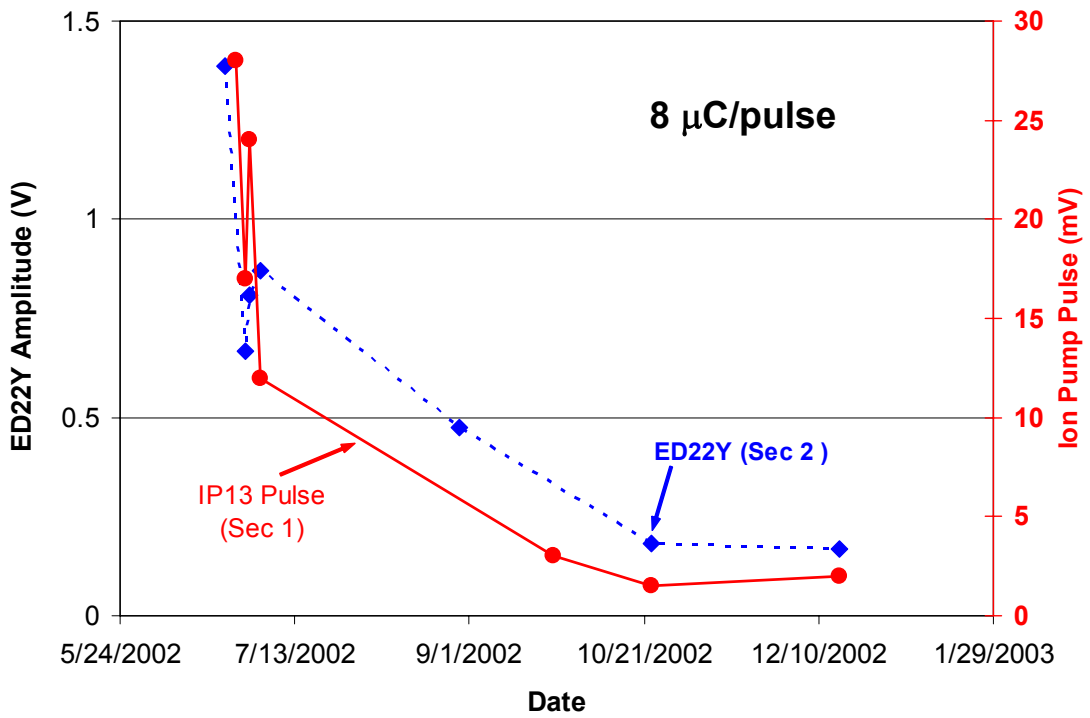


Gas pulse for 8 μC/pulse stable beam

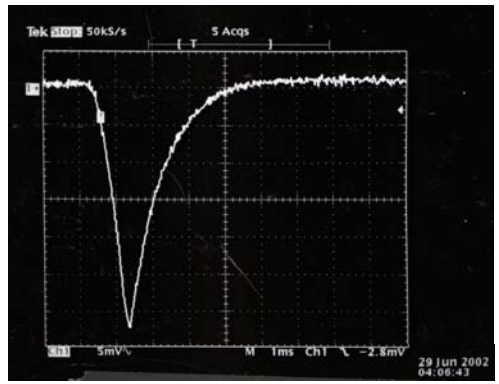


Correlation of Gas Pulse with Electron Signal

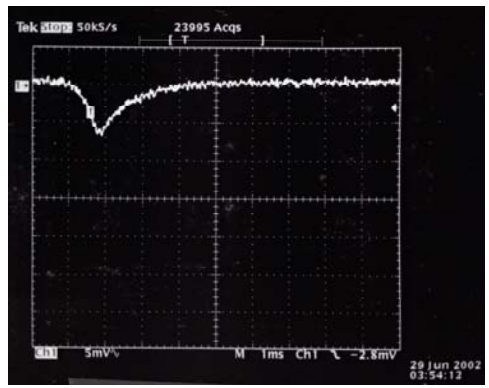
Correlation with beam scrubbing



Effect of Intensity



8 μC/pulse 6/29/02



5 μC/pulse 6/29/02

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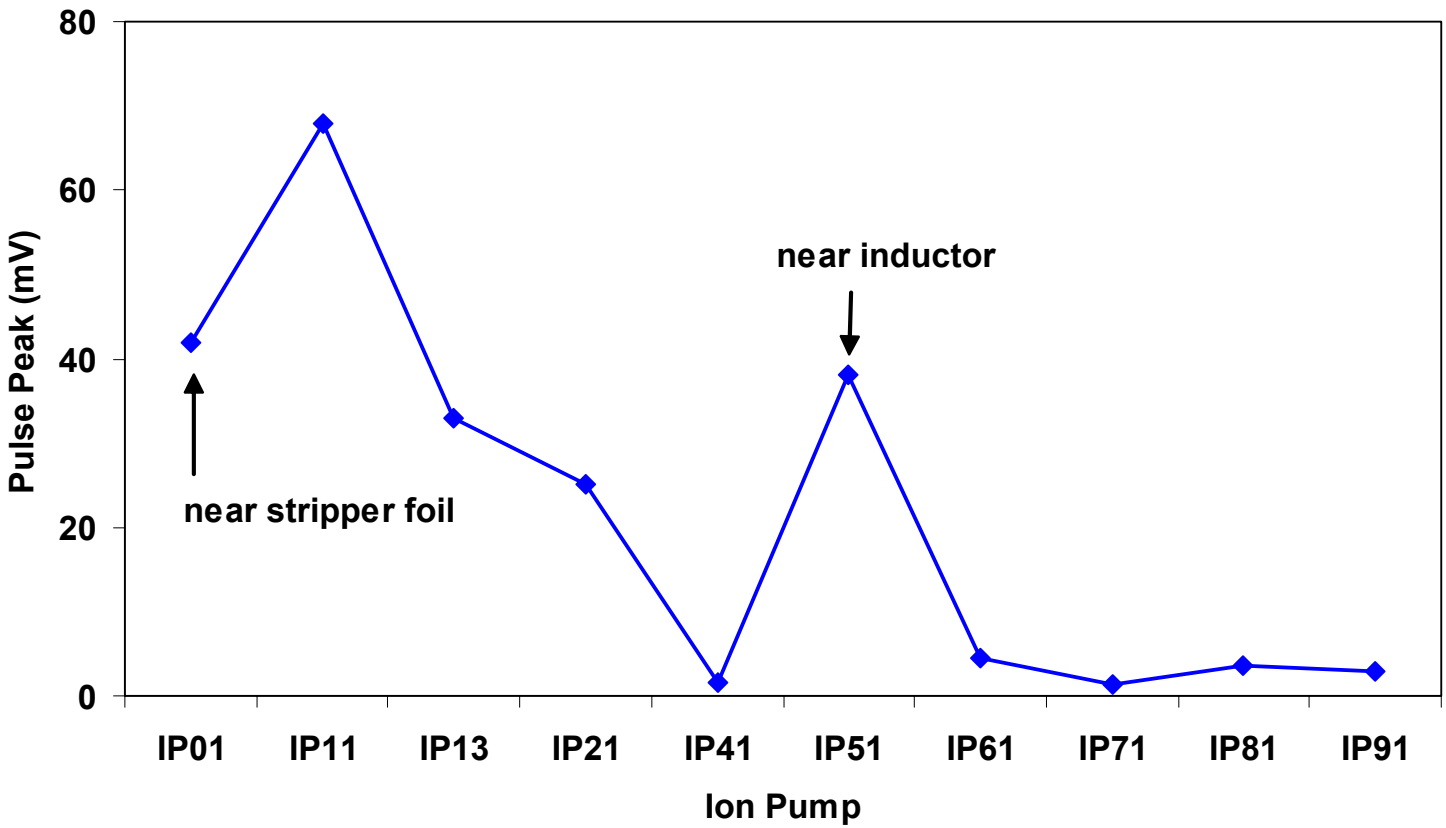
Pump signal at various locations in PSR



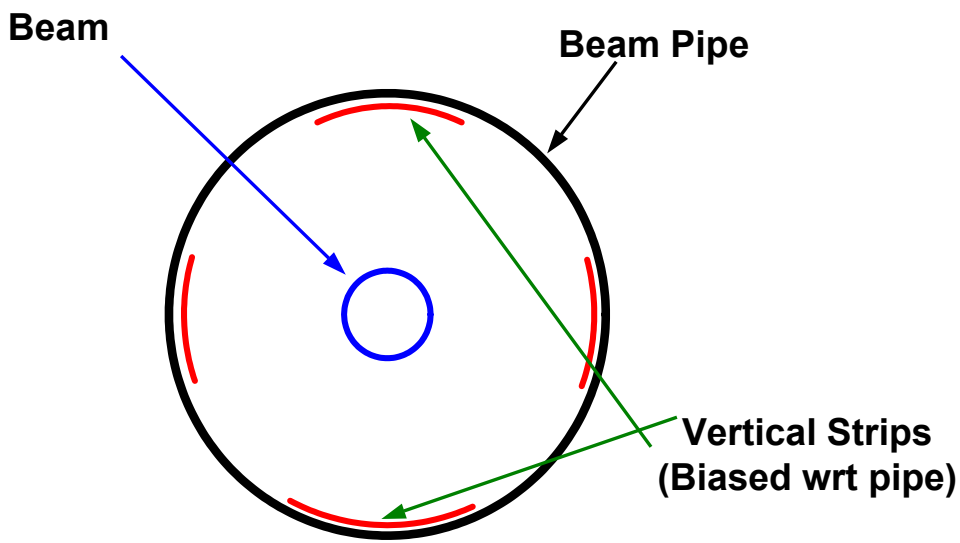
8 μC/pulse beam @ 1Hz, 6/29/02

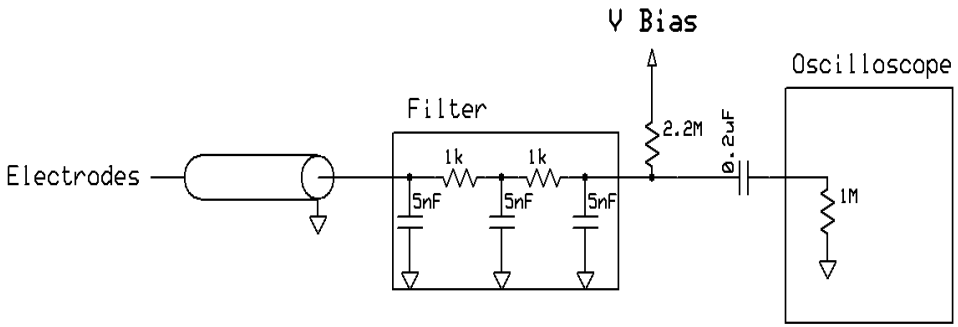
Biased collection electrodes

- We have tried a variety of biased electrodes over the last decade
  - parallel and curve plates, BPM striplines, split cylinders etc in drift regions, quadrupoles and thin striplines in a dipole
  - various combinations of bias fields
- Many puzzling features emerged during their use
  - Peculiar voltage plateau curves
  - Electrons seen in the plane transverse to a dipole field
- Complicated situation to interpret
  - Signal is net charge collected i.e., incoming – outgoing (secondary emission)
  - Bias electric field dominates during the gap passage and can collect electrons during the gap
  - Beam electric field dominates during bunch passage
  - Electrodes in the pipe see large induced signals (100-200 V) from coupling to the beam that must be filtered out to see the electron cloud signal
  - Biased electrodes change the beam-wall environment and can alter the multipacting process
  - An exquisitely detailed simulation might provide some insight
- They did provide our first evidence for a flood of electrons for high intensity beams
- RFA and electron sweeper are better devices for measuring the electron cloud

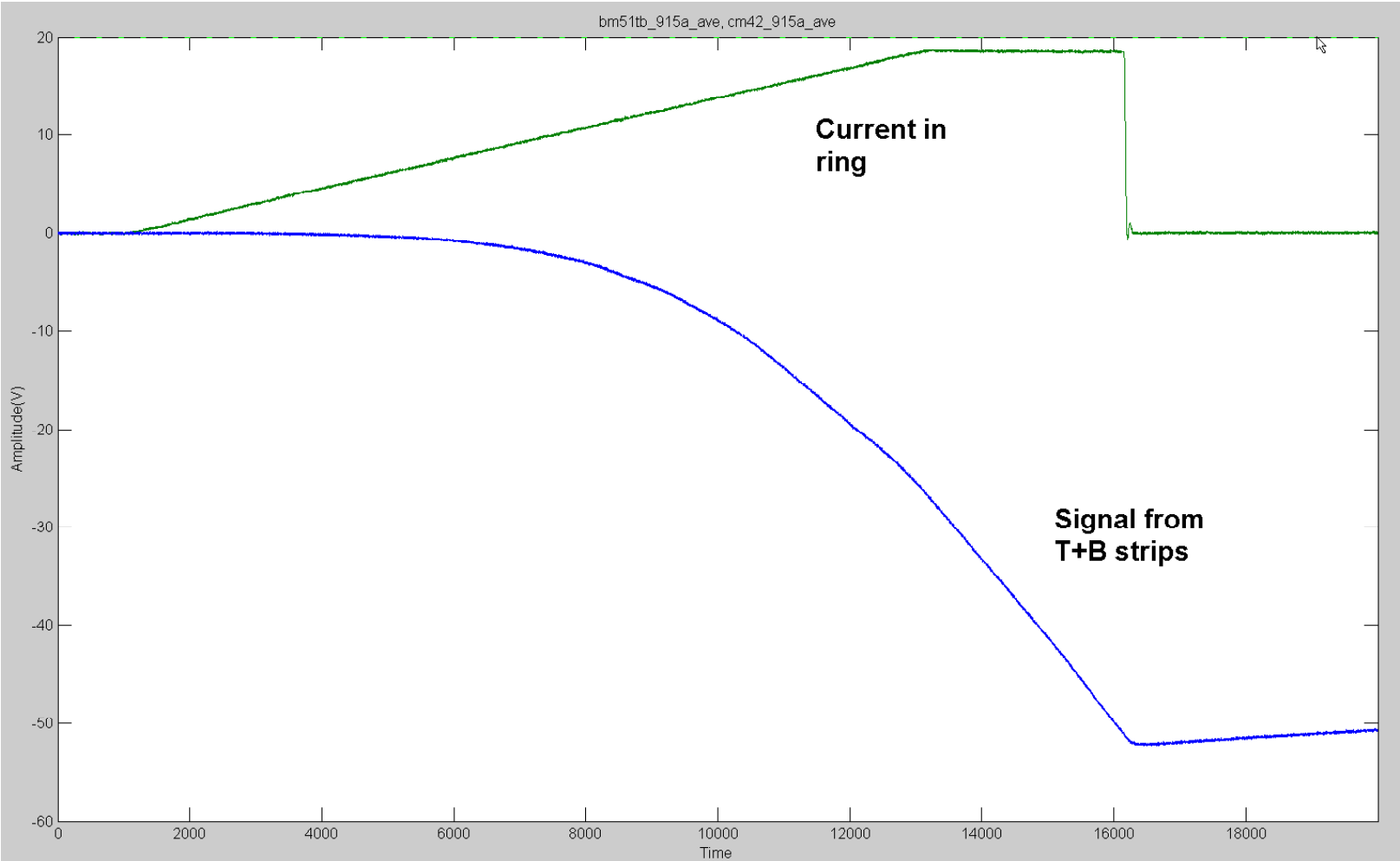
Biased Strips in a Dipole

- 4 copper strips on kaptan tube (0.010” thick)
- Leads brought out through the nearby quad to vacuum feed throughs
- Vertical and horizontal connected in pairs
  - One set biased
  - The other grounded
- Signal is heavily filtered to suppress large induced AC signals from beam (up to 100 V)
- Signal is integrated by the filter

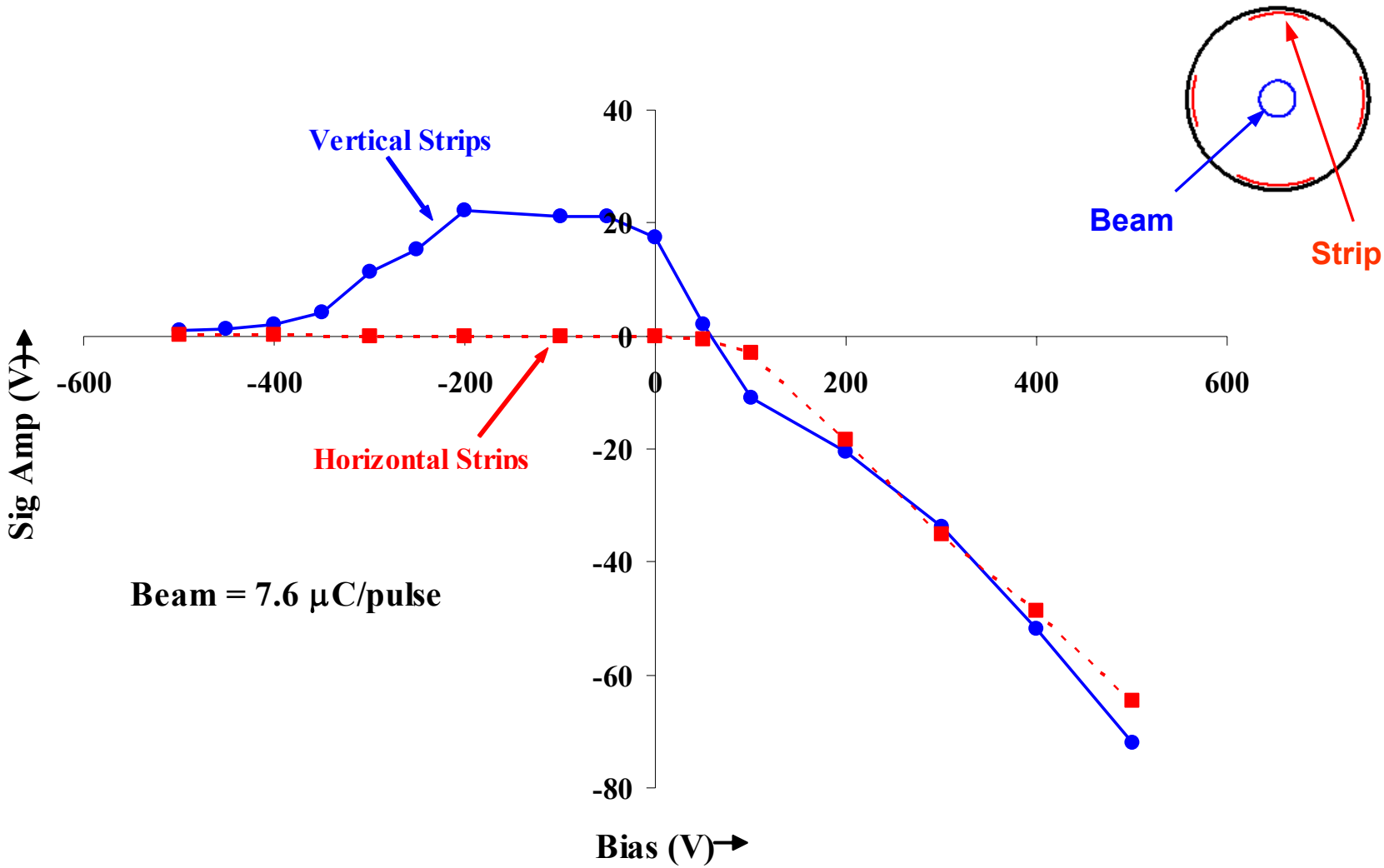




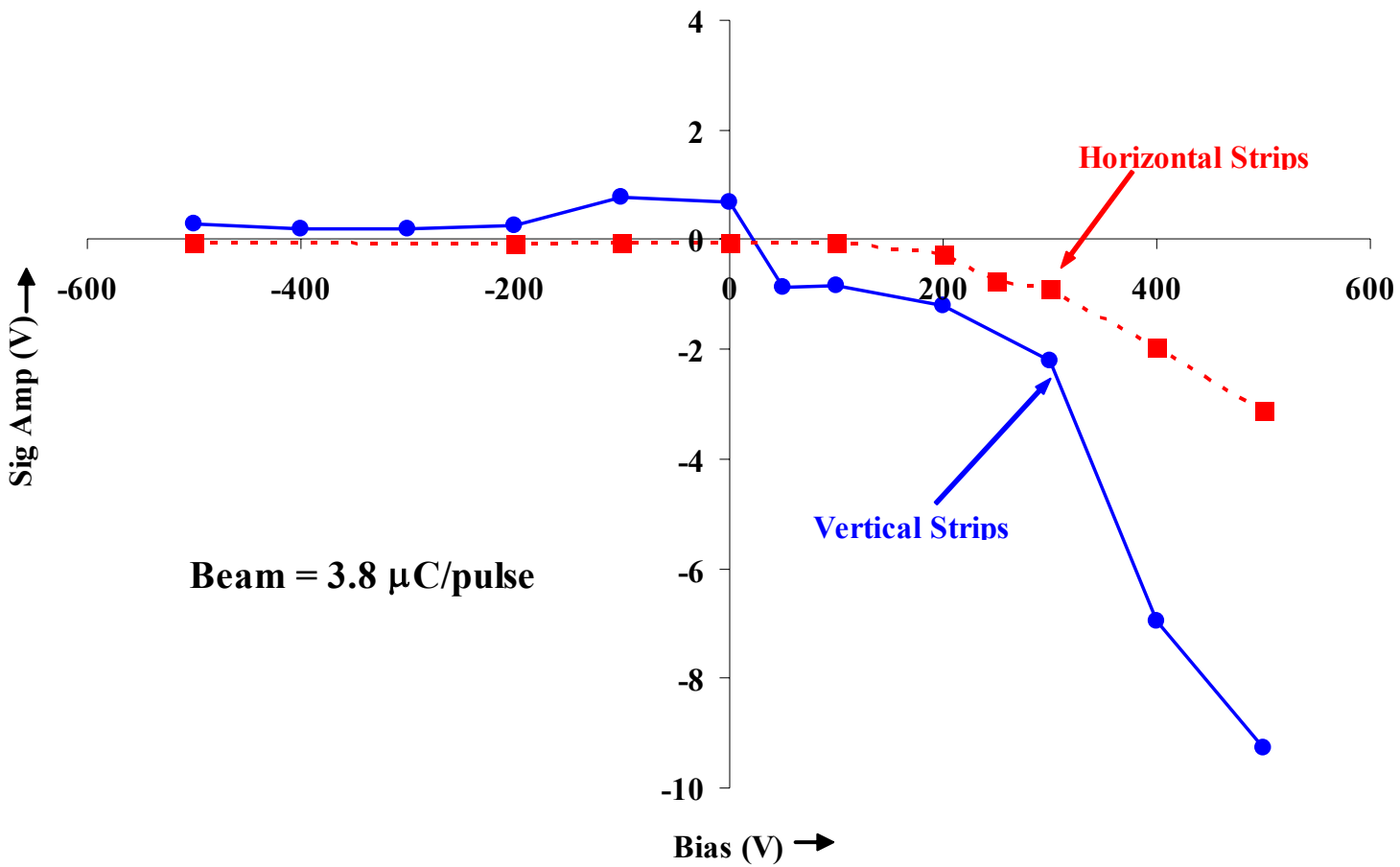
Sample signal from strips in dipole



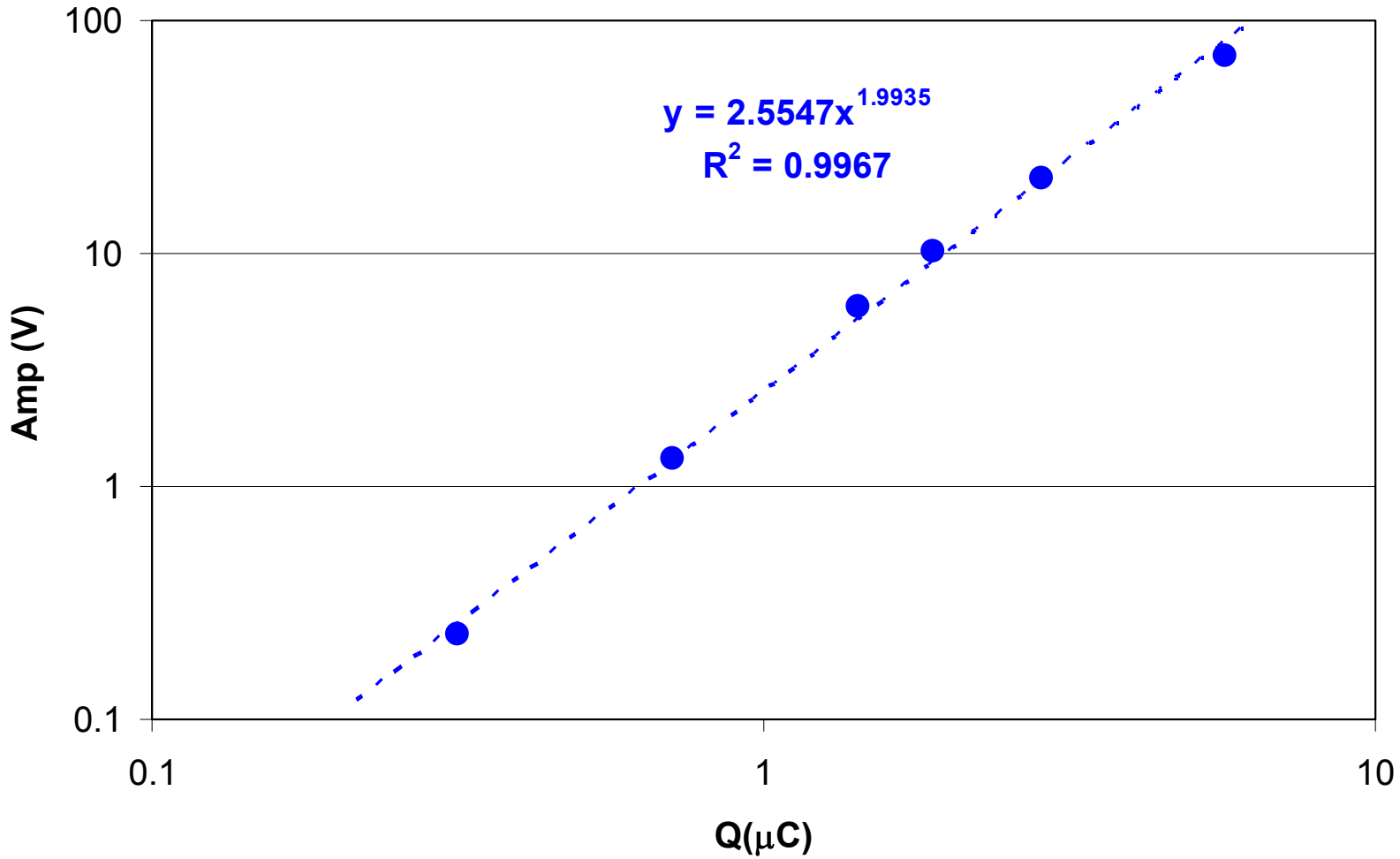
Biased Strips in Dipole at 7.6 μC/pulse



Biased Strips in Dipole at 3.8 μC



Electron Signal from Biased BPM Striplines in Quad

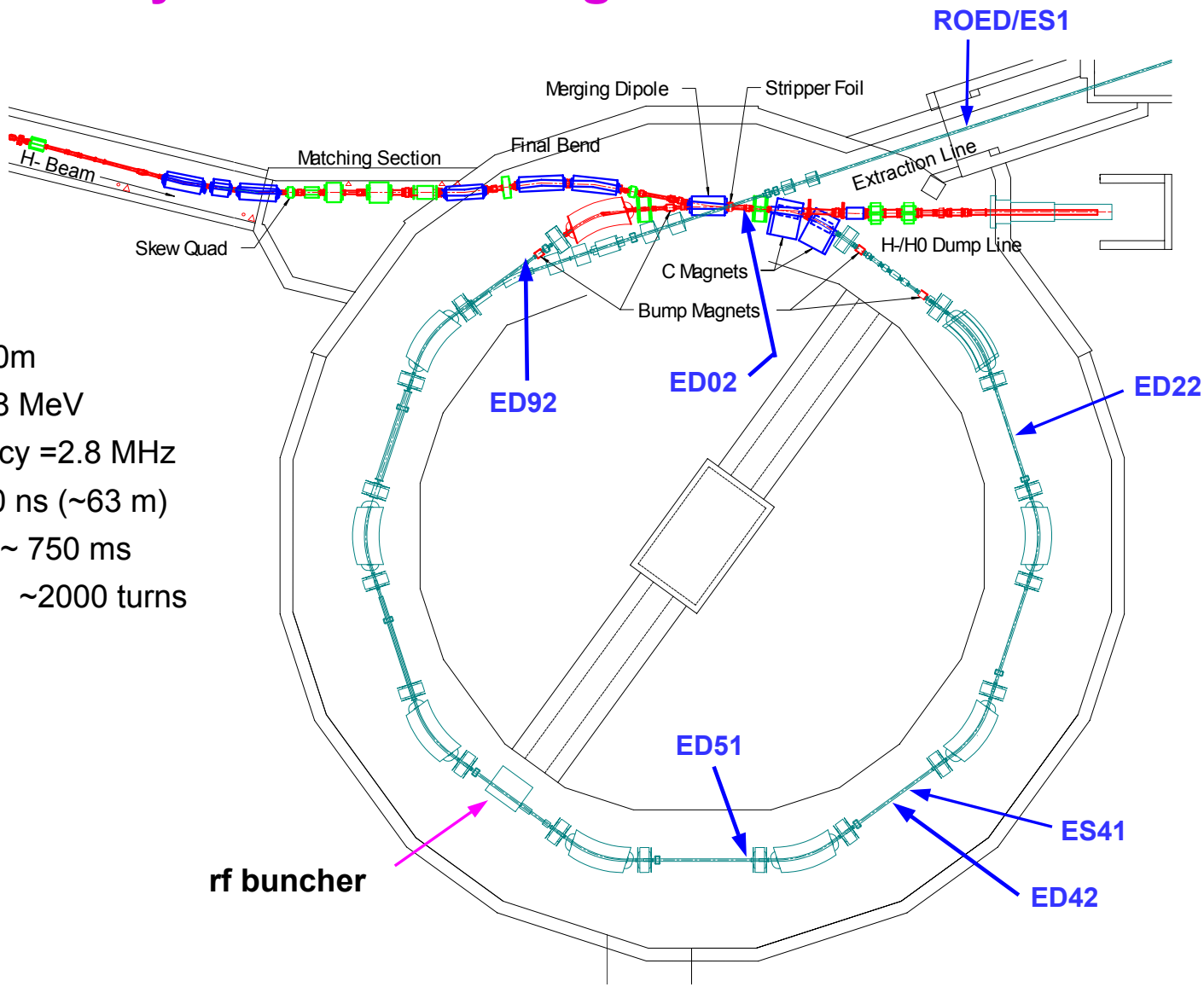


Conclusions

- **The RFA and ESD are our most useful EC diagnostics and have provided immensely useful information on the EC in PSR**
  - **RFA provides data on flux, energy spectra and time structure of electrons striking the wall with minimal perturbation of the EC**
  - **ESD is an RFA that can also measure electrons swept from a beam-free time interval**
- **Biased electrode signals provide some information but are difficult to understand and interpret**
  - **Only devices we have in magnetic field regions**
- **Ion pump gas pulse signal provides a useful relative measure of gas desorption and correlates well with other measures of the EC**
  - **Simple to implement**
  - **More informative than the DC average pump current**
  - **Provides good sampling over all regions of the ring**

Backups

PSR Layout with EC Diagnostics



Circumference = 90m

Beam energy = 798 MeV

Revolution frequency =2.8 MHz

Bunch length ~ 250 ns (~63 m)

Accumulation time ~ 750 ms

~2000 turns

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RFA electronics