DI: Diagnostic Working Group

Tail measuring devices (part1)

0) Definition of Halo / Required Dynamic Range ?

1) Wire scanners / scrapers

• KEK PS	(profile)	Susumu Igarashi
• LEDA (LANL)	(profile + tails)	J. Douglas Gilpatrick
• AGS (BNL)	(profile + tails)	David Gassner
• PSR (LANL)	(profile + tails)	Robert Macek
• SNS (Oak Ridge)	(profile + tails)	Saeed Assadi
• HERA (DESY)	(profile + tails)	Kay Wittenburg
• Yerevan, DESY	(tails)	Kay Wittenburg

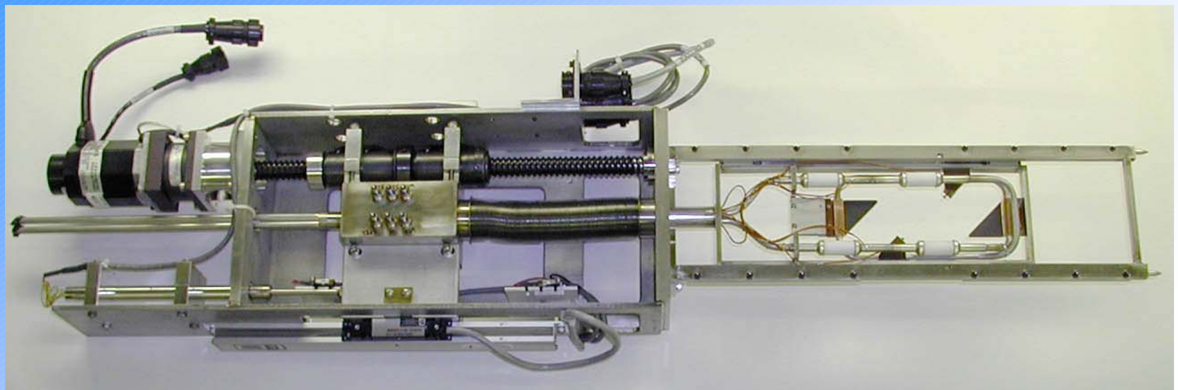
2) IPMs / Others (Thursday)

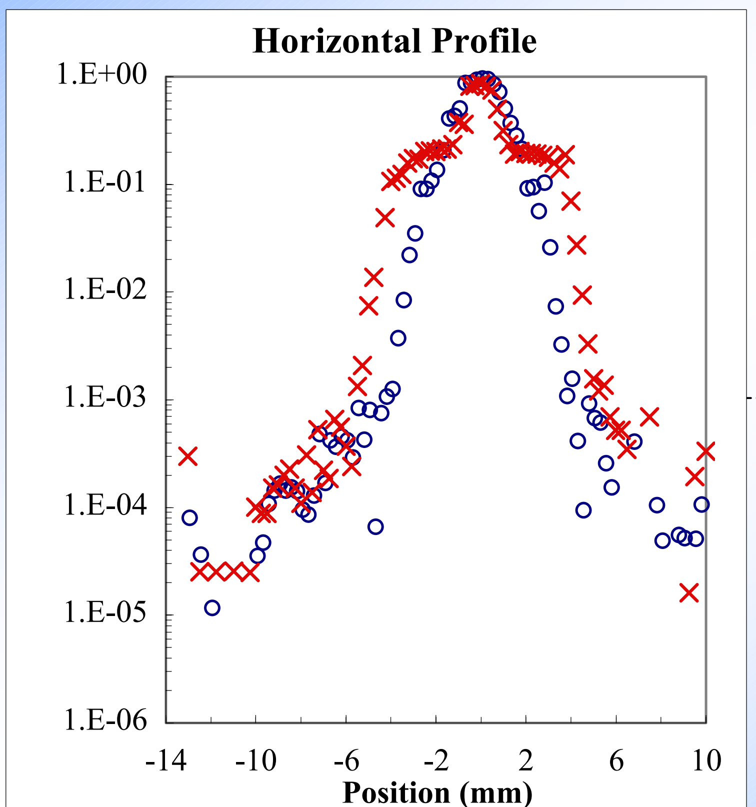
DI: Diagnostic Working Group

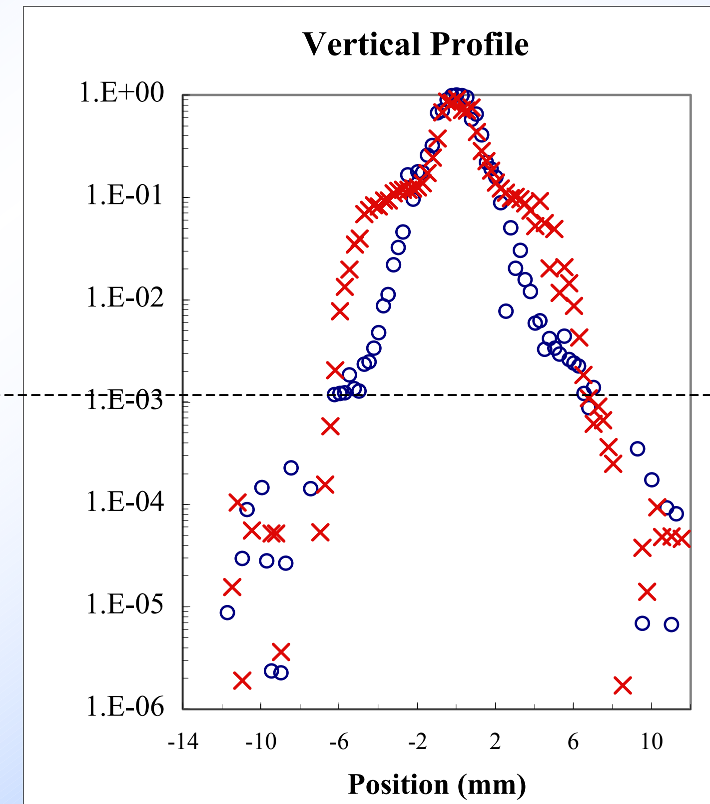
(Tail) measuring devices, part II

1) Wire scanner at KEK PS (emittance) — Susumu Igarashi (We)
2) IPM
   - Discussion (joined with BB)
   - RHIC — Roger Connolly
3) Electron cloud diagnostic at PSR — Robert Macek
4) Beam energy spread measurement — Yun Zou
5) Tail shaping by tune modulation — Christoph Montag
6) Summary

Machine	Type	Signal	Profile	Dynamic range	Status
LEDA (LANL) (6.7 GeV protons)	Scanner+ Scraper	SEM		10^5-10^6	Working in control-system
AGS slow extraction line	Scanning Target	counting mode + SEM		10^4-10^5 10^3-10^4	Was in operation, replaced
PSR extraction line (LANL) (800 MeV p)	thin wire	SEM Log.-amp		10^6	In regular operation
SNS LINAC (200 MeV H^-)	Laser wire	Photo-neutralisation		10^3-10^4	Prototype for production
DESY HERA (40 – 920 GeV p)	Thin wire	Counting mode		10^7-10^8	in operation, readout prototype
Yerivan (20 MeV e^-) DESY PETRA (40 GeV p)	Thin wire	Vibrating wire, natural frequency		10^6-10^7 ??????????	Preliminary tests; more tests planed
KEK PS (12 GeV p)	Thin wire	Scintillators		~10^3	In operation
RHIC	IPM	current		10^2-10^3	Successful tests; upgrade planed



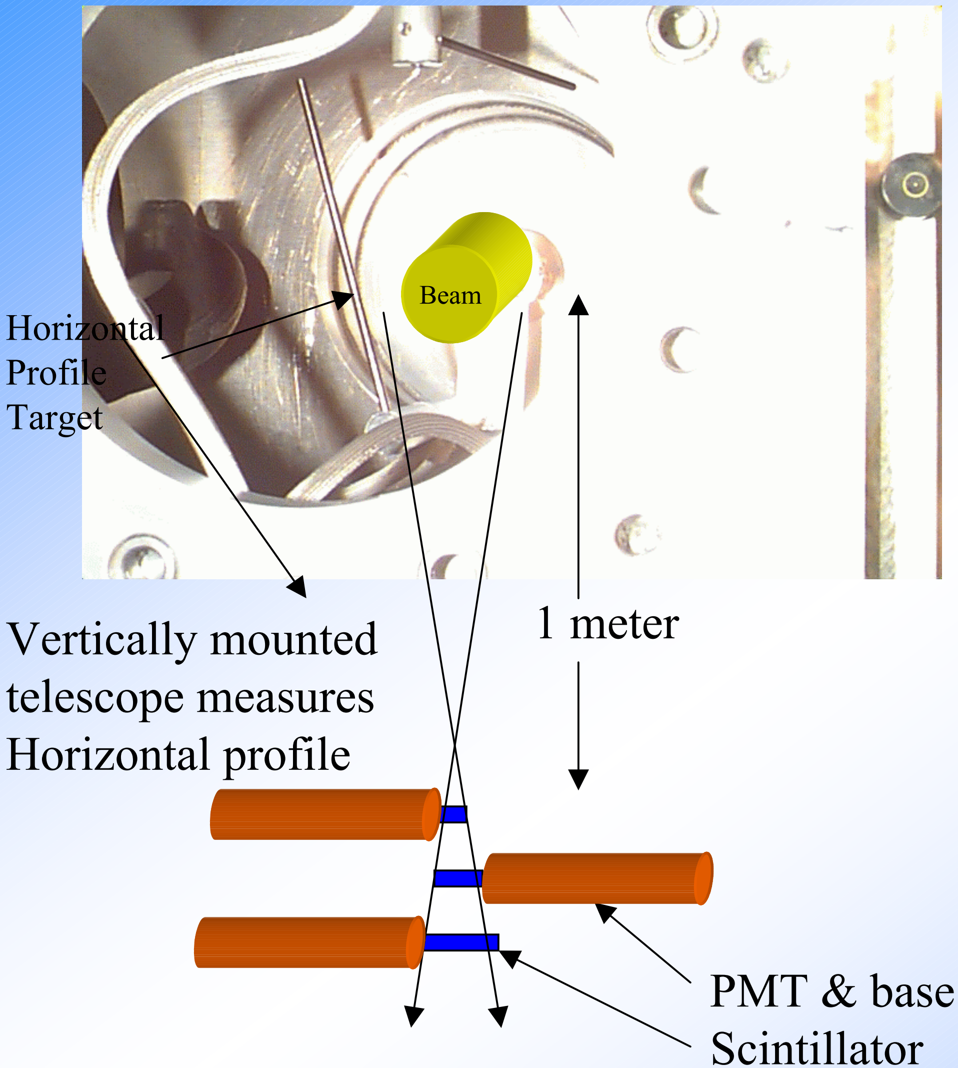




Scanning

Scraping

Tungsten targets, 2.5mm



Log scale

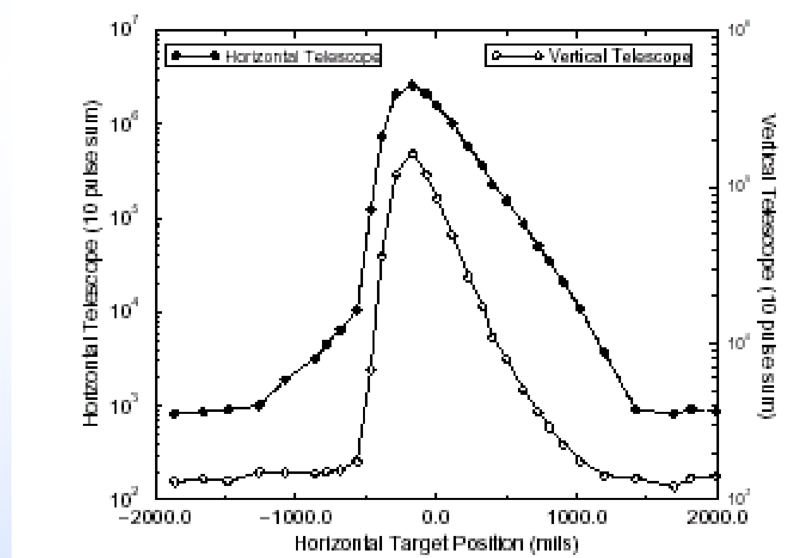
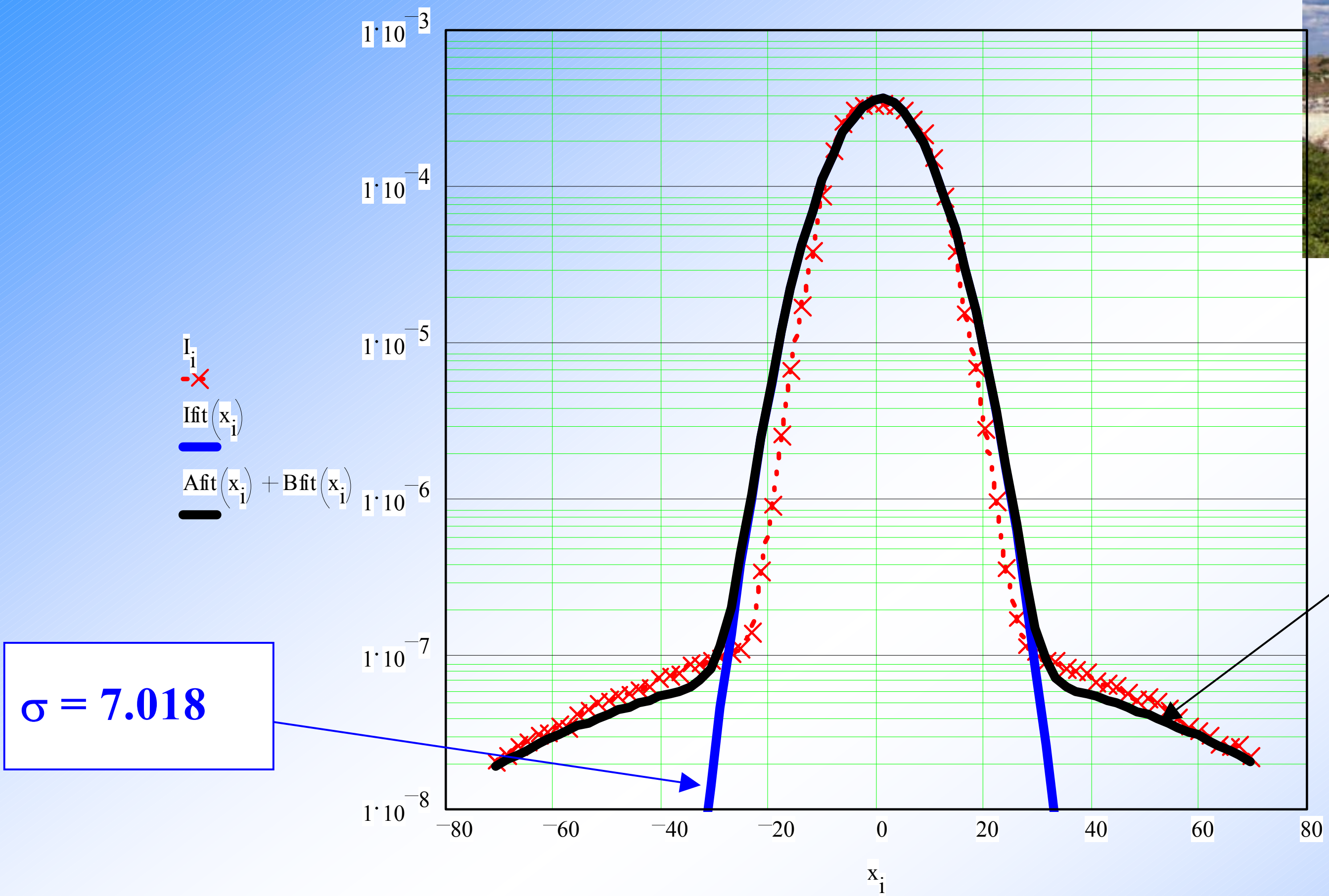
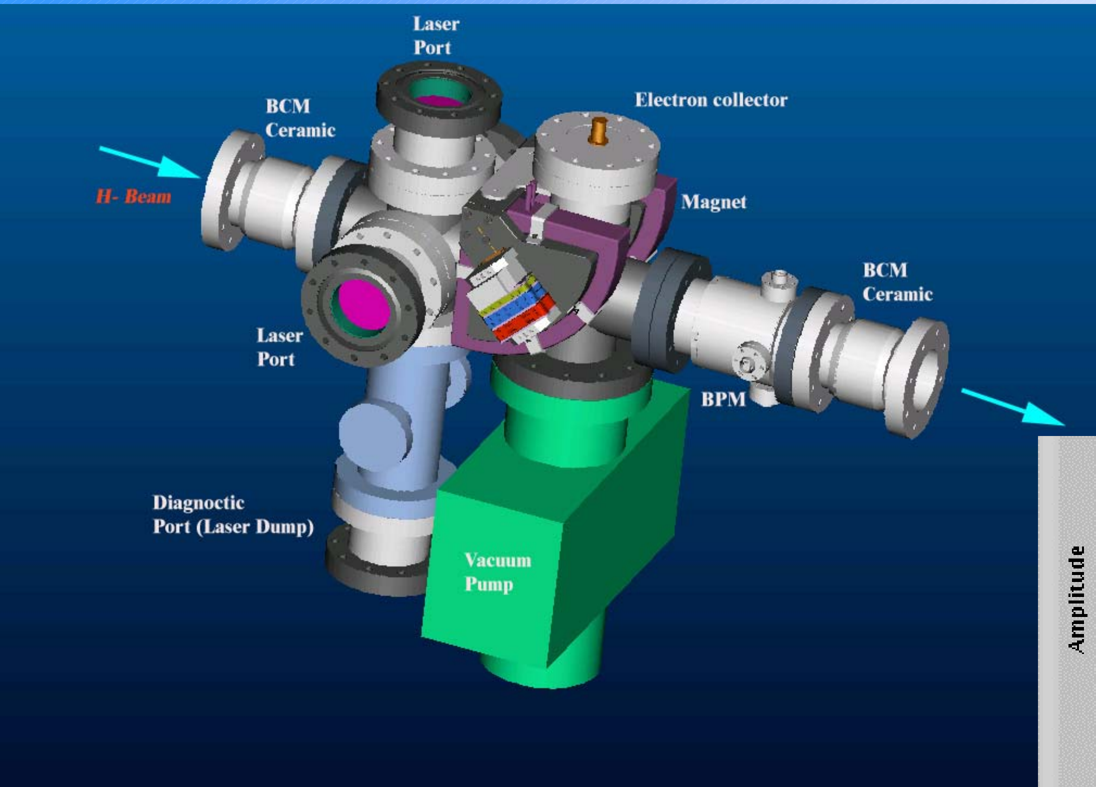
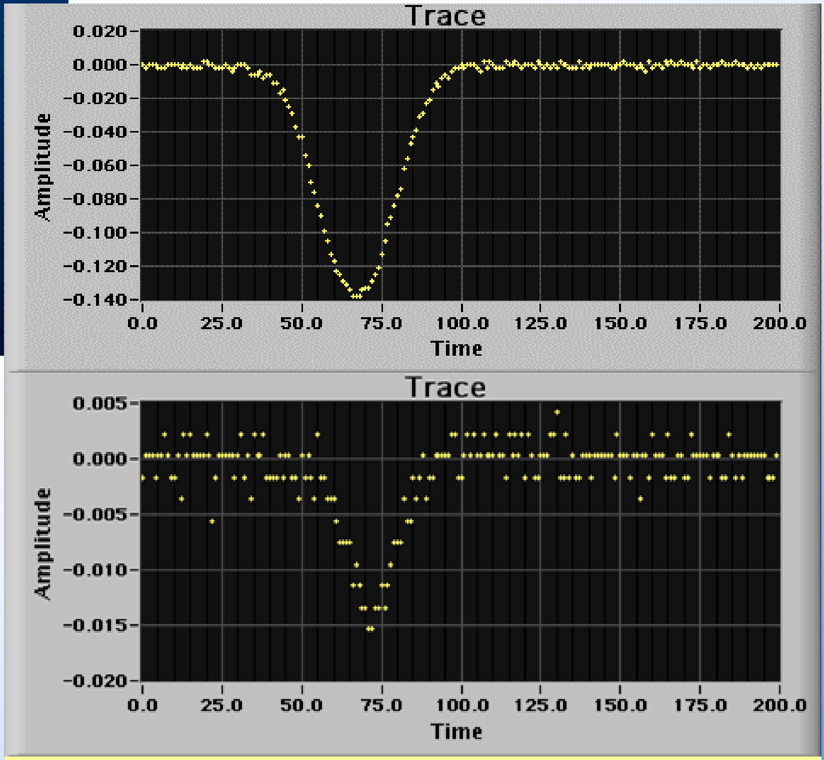


Figure 2: Horz. and Verti. Telescope triples for Horz. Scan



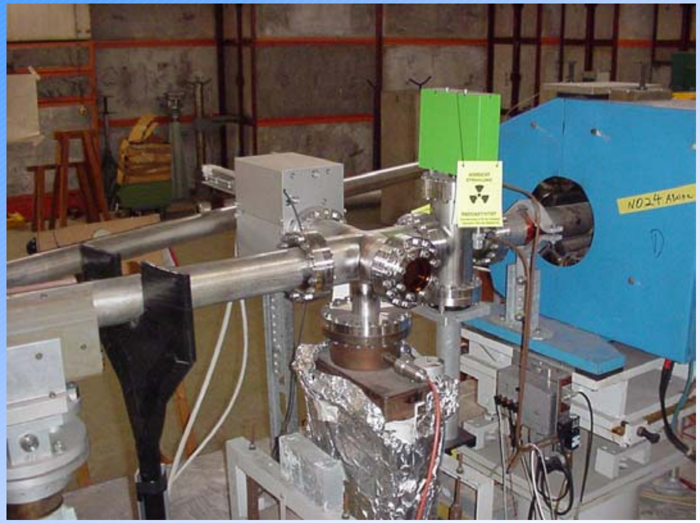
The nature of the beam "halo" has not yet been determined. A normal function shown in solid blue has been fit to the data (red x's). A sum of two normal functions is shown in solid black. The X-axis is scaled as scanner position in mm's and the Y-axis is log-amp input current in Amps.



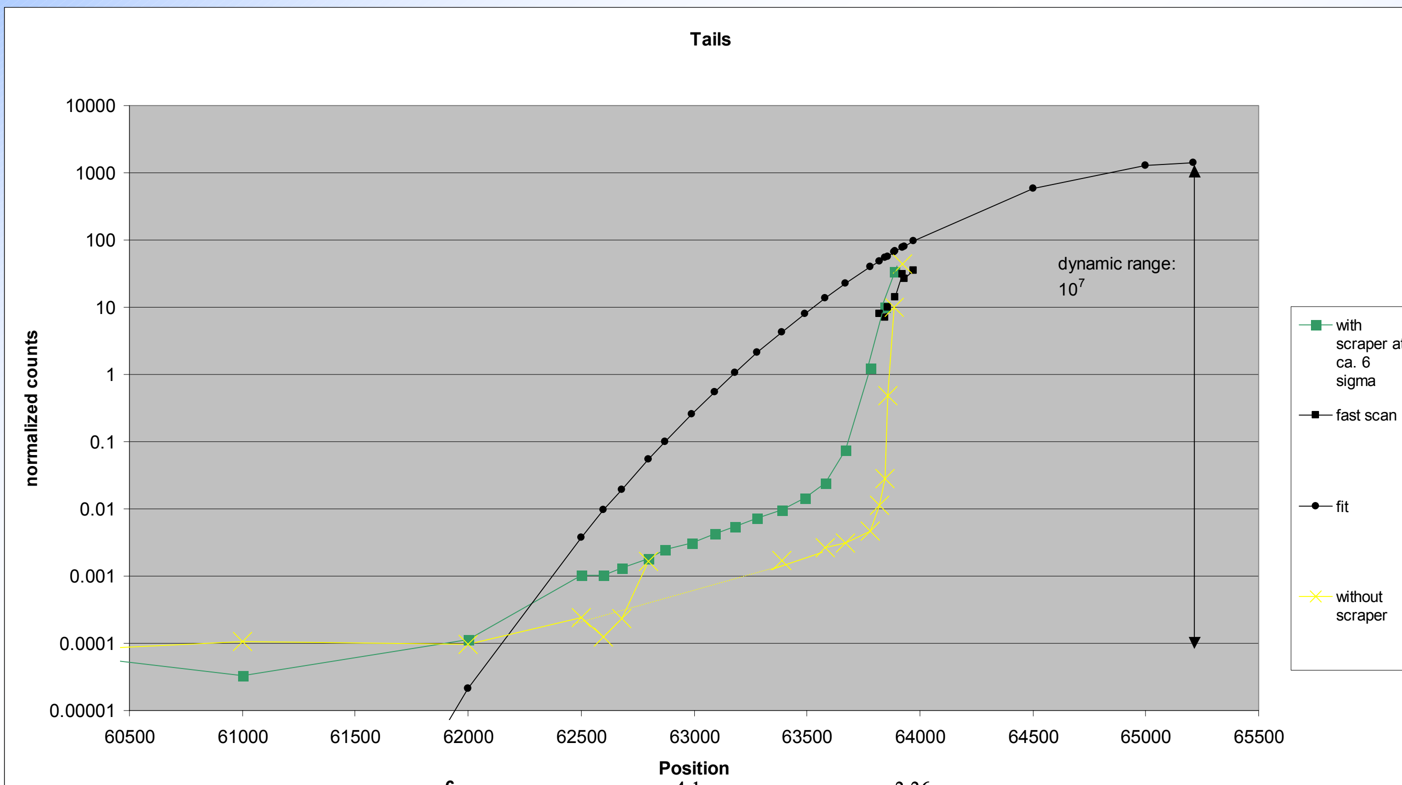


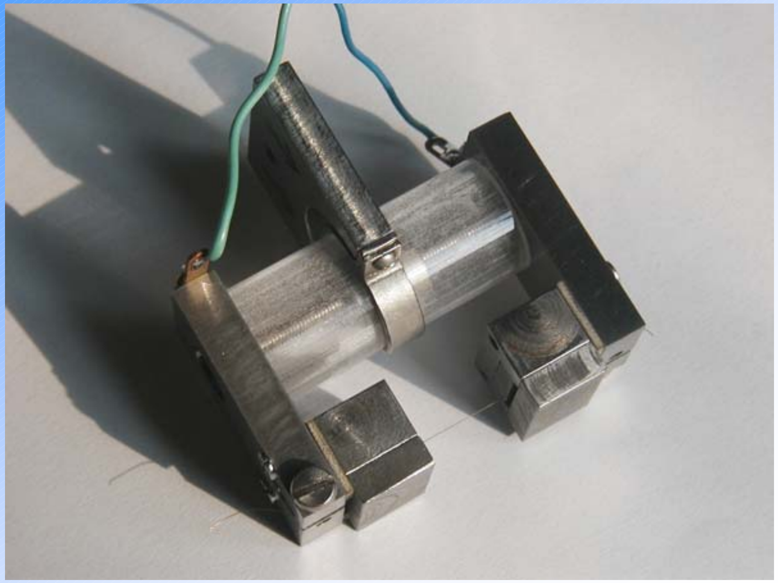
Signal from electron collector
Top: laser intercepting beam core
Bottom: laser intercepting beam tail

- Reliable measurements to about **3 sigma**

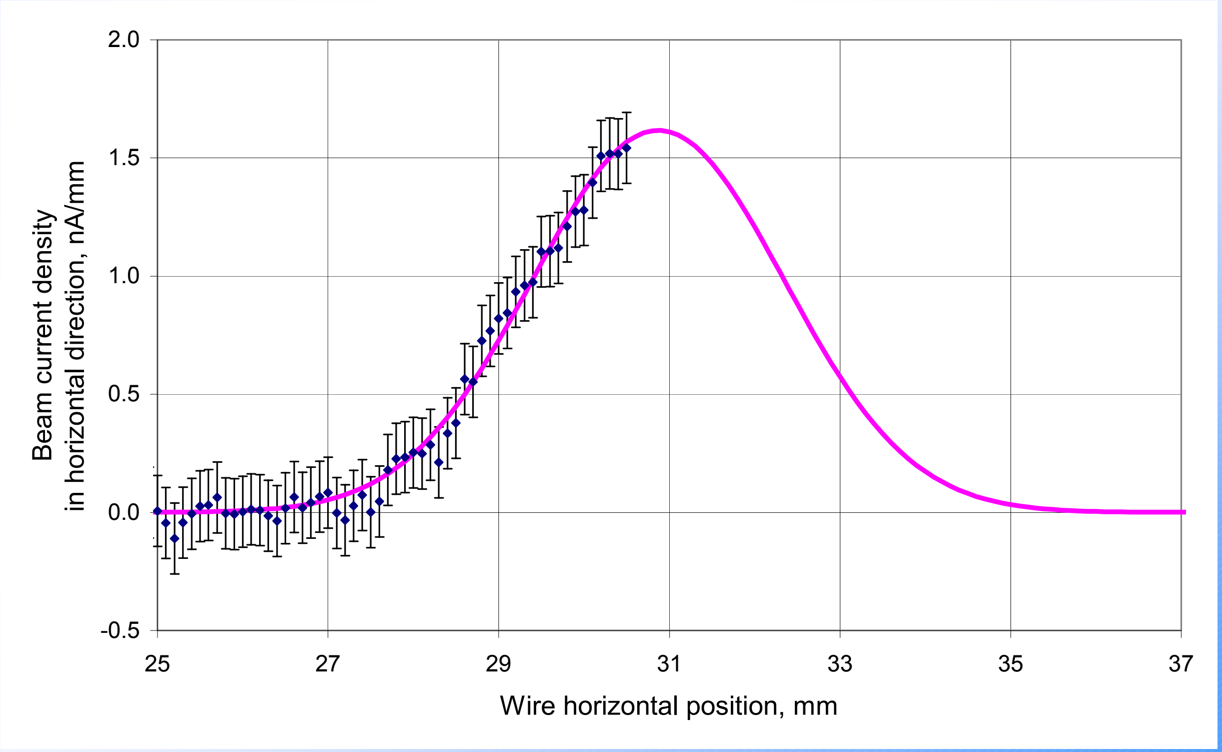



HALO'03


Tails
normalized counts
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001
60500
61000
61500
62000
62500
63000
63500
64000
64500
65000
65500
Position
dynamic range: 10^7
with scraper at ca. 6 sigma
fast scan
fit
without scraper
6 σ
4.1 σ
2.26 σ



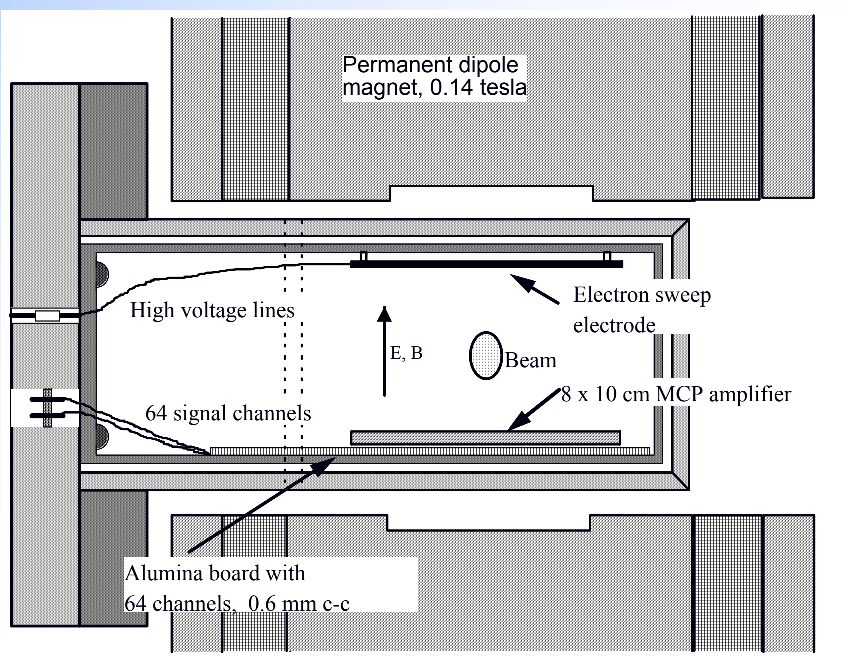
Profile of a **<u>10 nA (!)</u>** beam



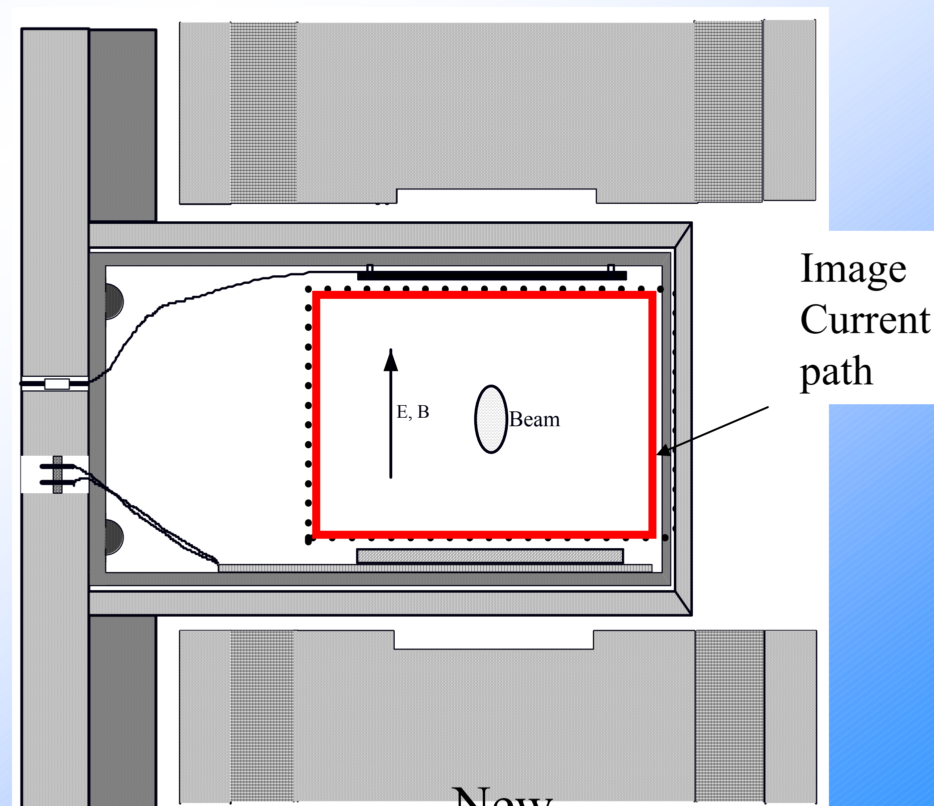
The original detector was sensitive to noise sources.

1. Rf coupling to beam
2. Radiation spray from beam loss
3. Secondary electrons

The new IPMs (horizontal in both rings) are designed to be immune from these background sources. Rf coupling and electron clouds are greatly reduced from original design.

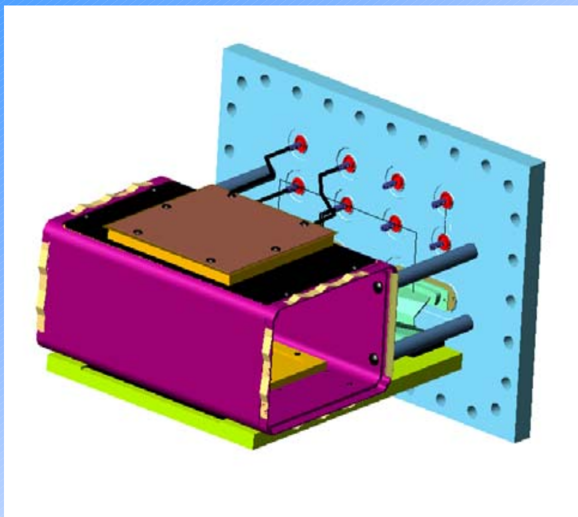


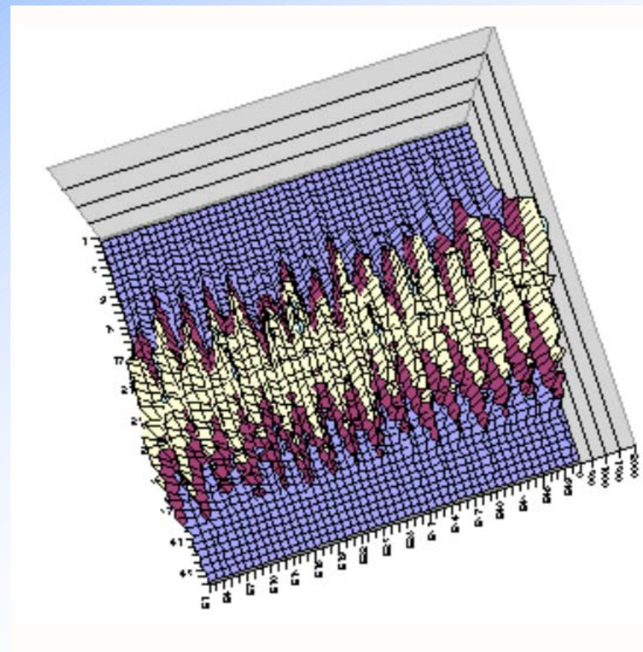
Old



New

Typical proton profile with new IPM





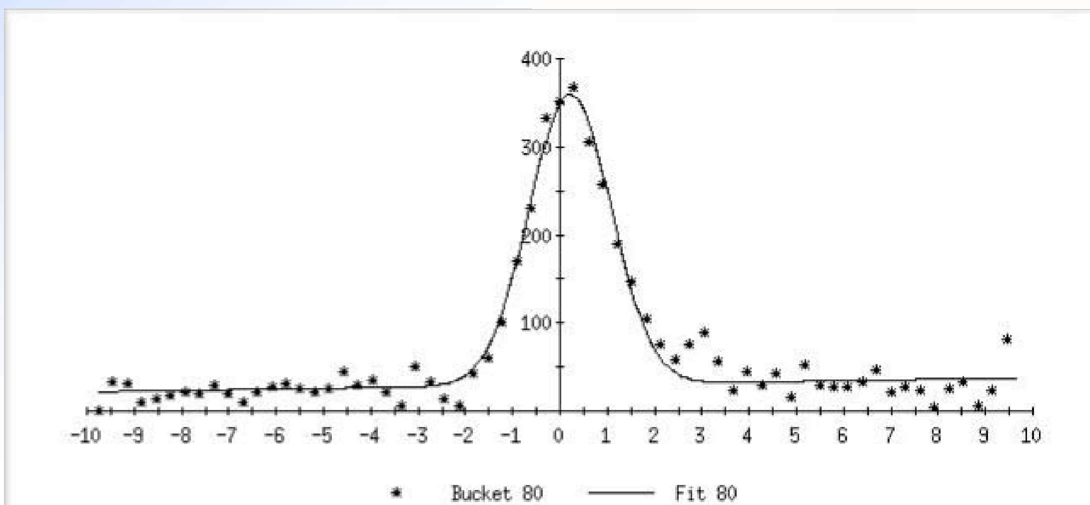
Profile from single measurement with polarized proton beam. Detector pressure is ~2×10^{-9} torr. With protons at this pressure background is about 10% of profile peak.

NEXT IPM

Sweep field will be increased. This will increase sensitivity to signal electrons and further suppress background electrons.

Internal calibration source will allow channel-channel gain uniformity.

Accurate transverse sweep field will permit collections of ions in event of large electron backgrounds.

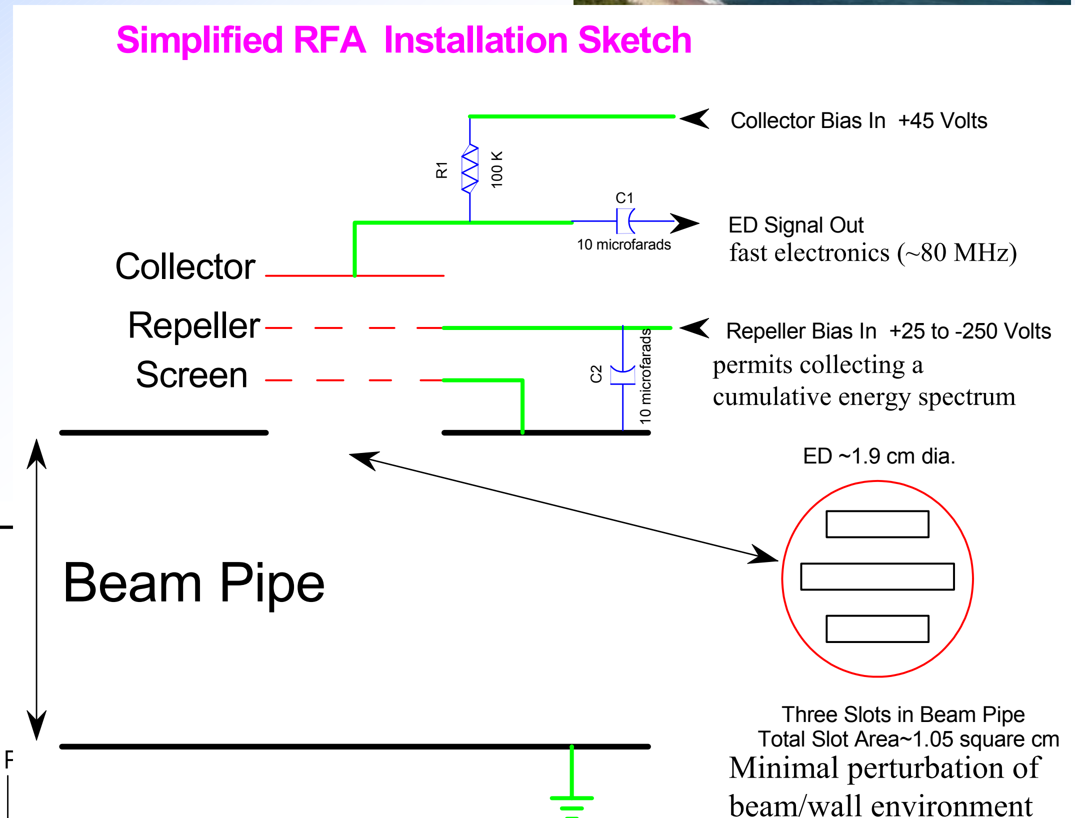


e^- - Cloud diagnostics in PSR

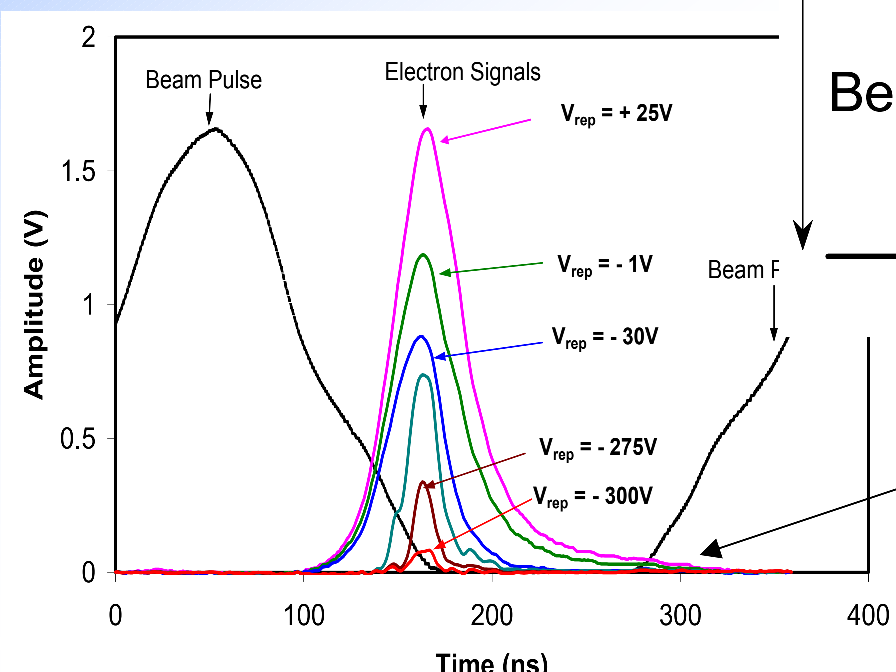
- Retarding Field Analyzer (RFA)
  - Flux striking the wall
  - Time structure
  - Energy spectrum of electrons striking the wall
- Electron Sweeping Detector (ESD)
  - RFA with pulsed electrode to sweep low energy e's into the RFA
- Ion pump current pulse
- Biased collection electrodes

Retarding Field Analyzer

Measures electrons striking the wall, not electrons remaining in the pipe

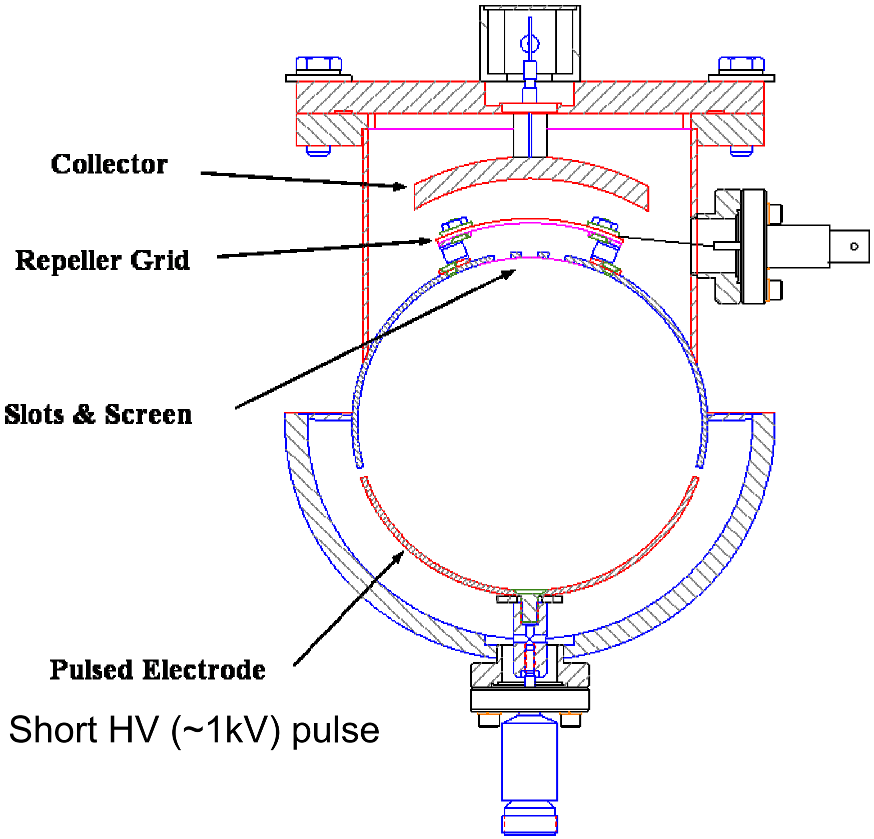


RFA signal has contributions from "trailing edge multipactor" and "captured electrons" released at end of beam pulse plus their secondaries



How many electrons survive in the pipe?
Important for driving e-p instability.

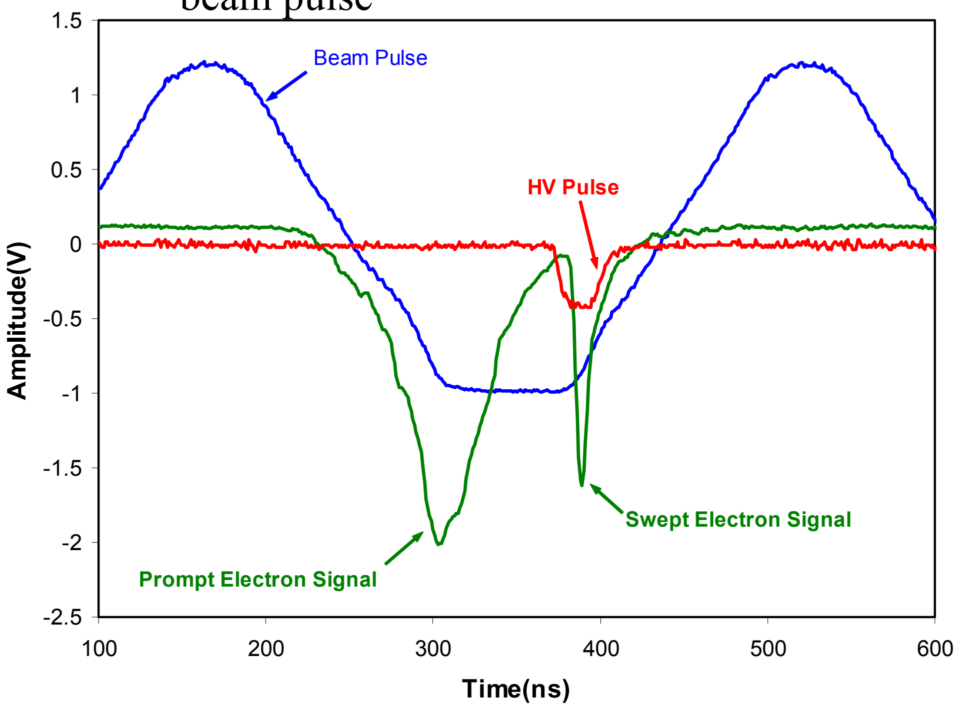
Electron Sweeping Diagnostic (ESD)



Short HV (~1kV) 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

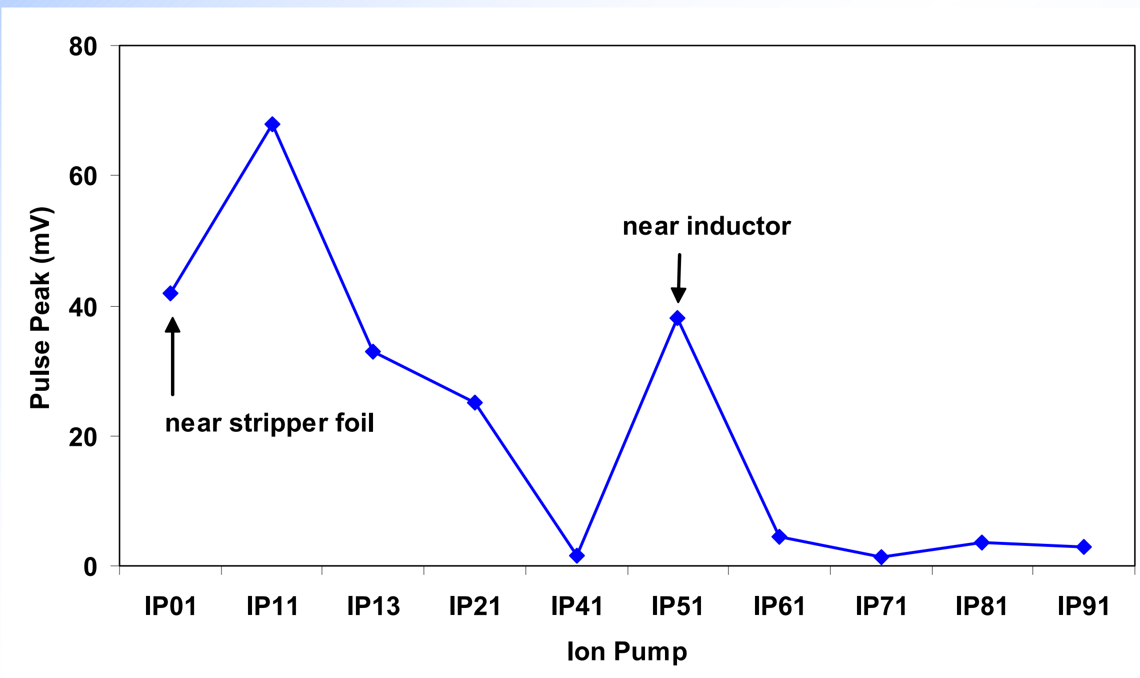


"Swept" electron signal is narrow (~10 ns) with a tail that is not completely understood

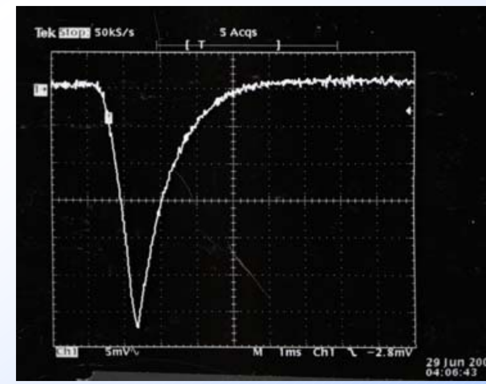
Ion pump current pulse

Multipacting electrons striking the wall desorb gases

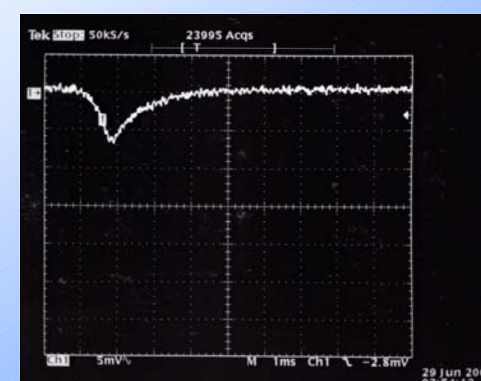
- An ion pump current pulse is observed during accumulation of intense beam pulses in PSR
- Simple diagnostic to implement



Effect of Intensity



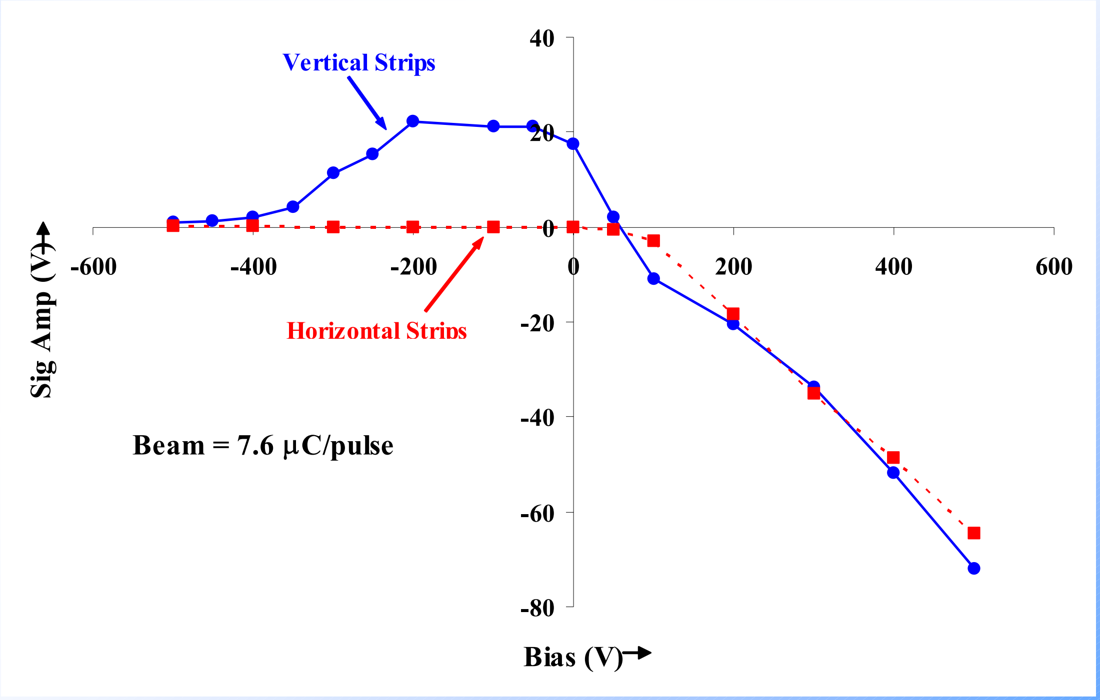
8 μC/pulse 6/29/02

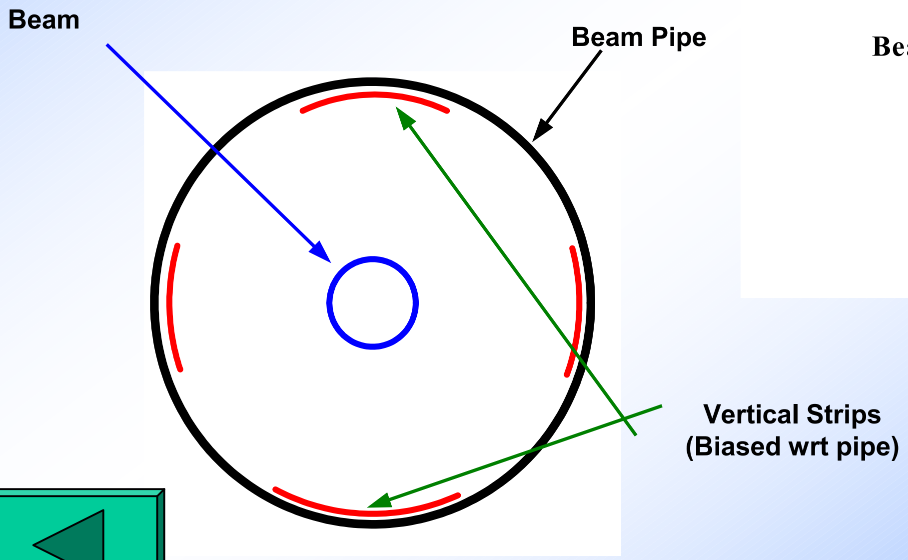


5 μC/pulse 6/29/02

Biased Strips in a Dipole

- Signal is heavily filtered to suppress large induced AC signals from beam (up to 100 V)
- Signal is integrated by the filter

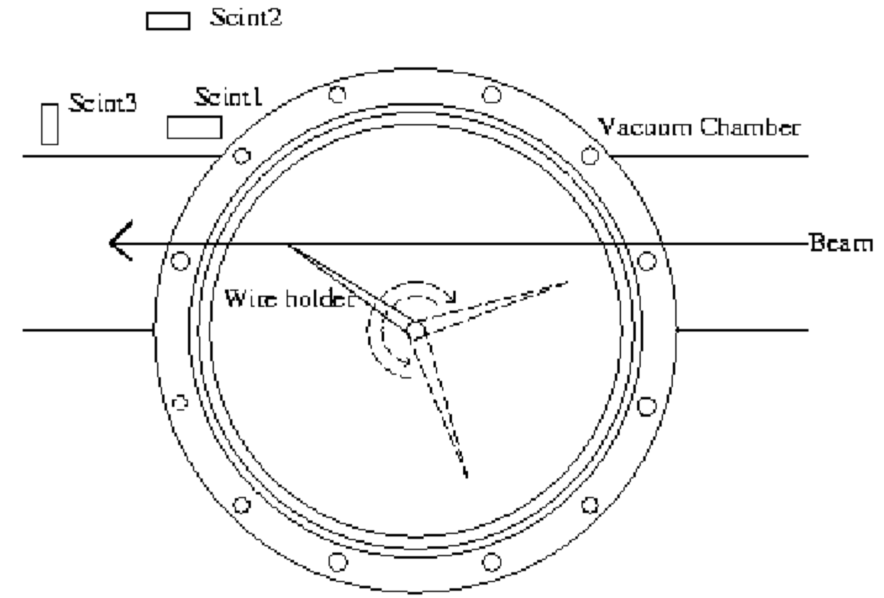


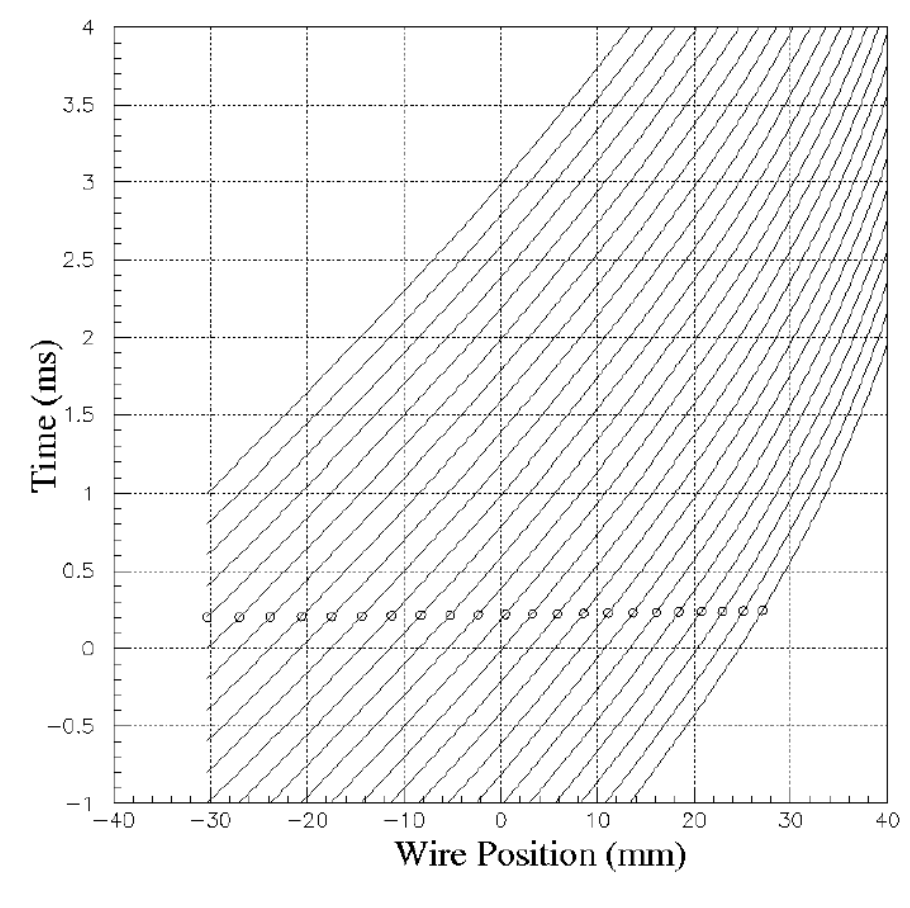


Biased electrode signals provide some information but are difficult to understand and interpret

- **Only devices in magnetic field regions**

Flying Wire Transverse Beam Profile Monitors





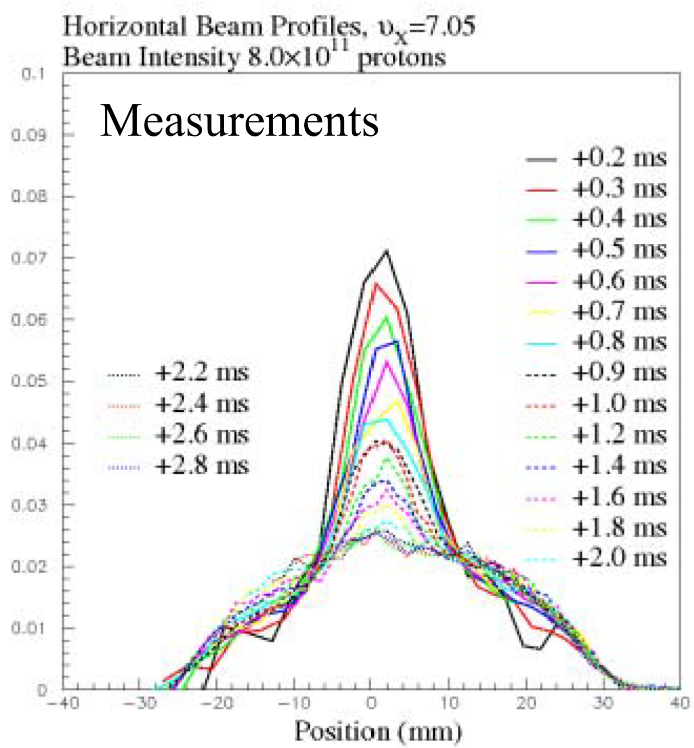
- An analysis procedure is developed to reconstruct beam profiles that rapidly change with a time scale of 1 ms or less.
- A series of profile data are acquired by changing the trigger setting with an increment of 0.2 ms.

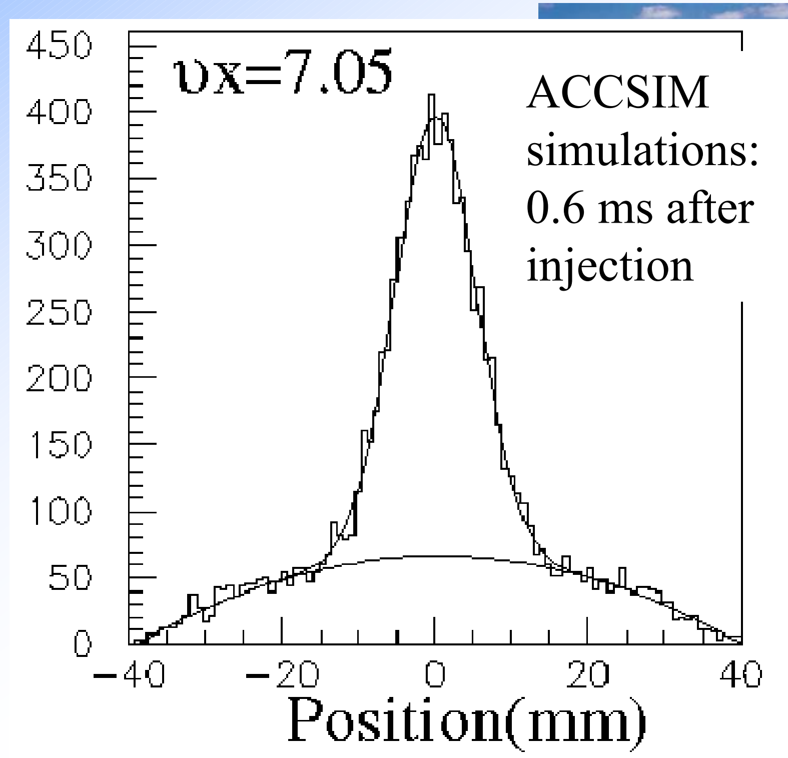
•Carbon fiber of 7 μm in diameter.

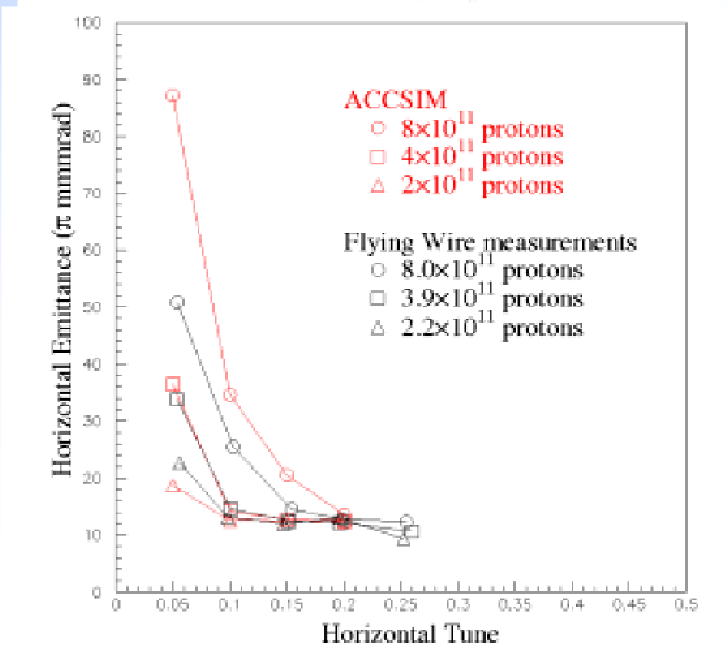
•Maximum wire scanning speed of 20 m/s.

•Secondary particles from the beam-wire scattering are detected to reconstruct the beam profile.

•About 4 ms is necessary to scan the







Modulations of the transverse beam profiles depending on the intensity and tune have been observed during the injection period of the KEK PS main ring.

Fourth order resonance created by the space charge force causes the modulations.

The effects have been qualitatively reproduced by the ACCSIM simulations.

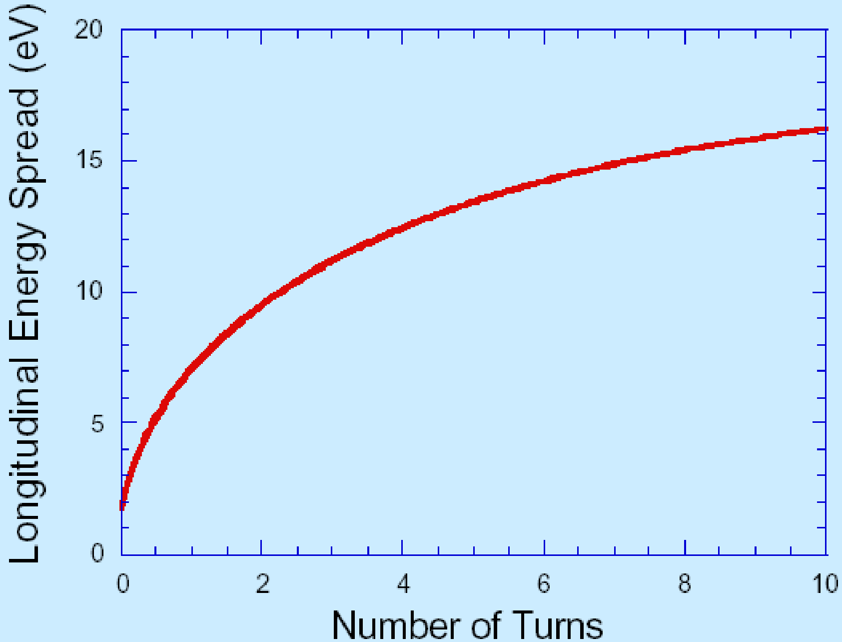
Energy Spread Growth in UMER

- University of Maryland Electron Ring (UMER) project
- Nominal beam parameters:

  Energy: 10 keV, Current: 100 mA,

  Average radius: 0.01 m,

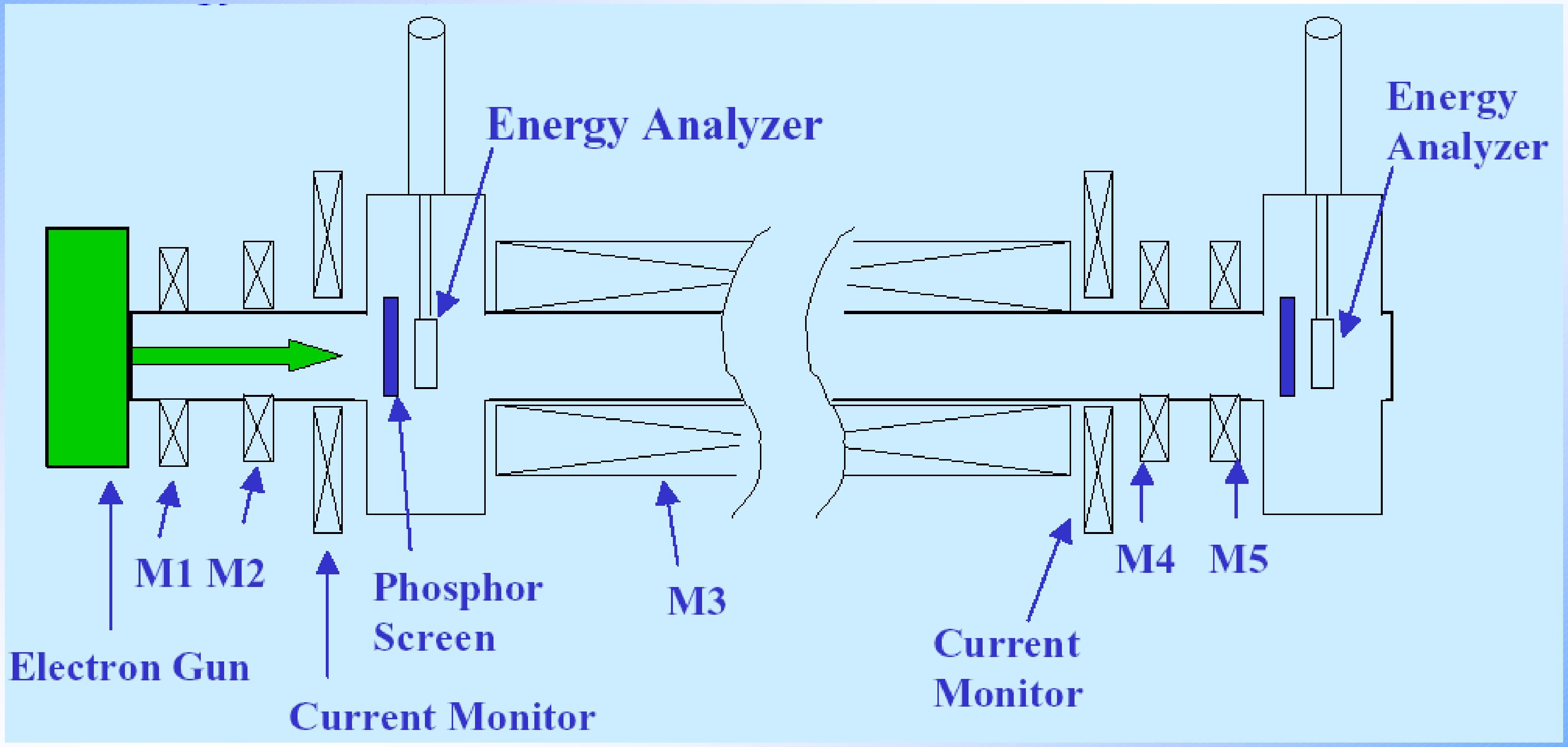
Theoretical Calculation of Energy spread due to L-T and L-L effects

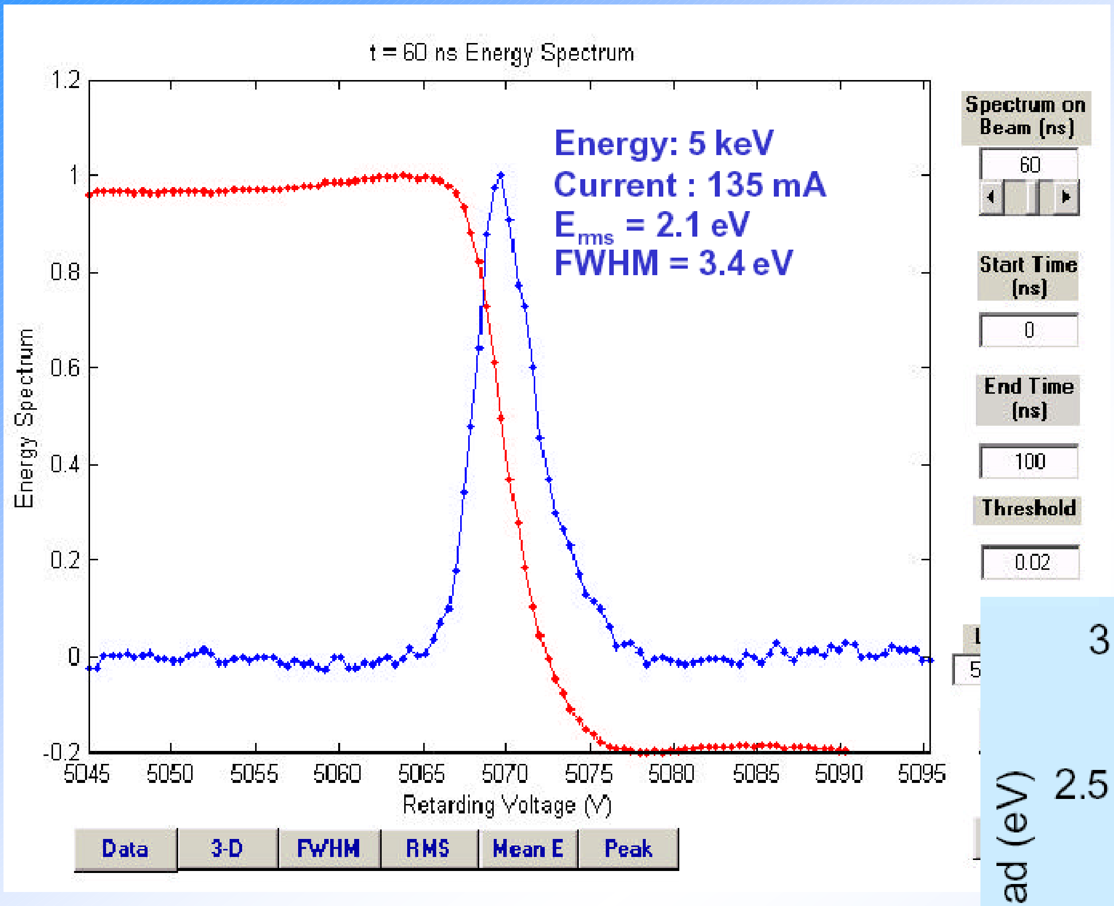


which may create halo

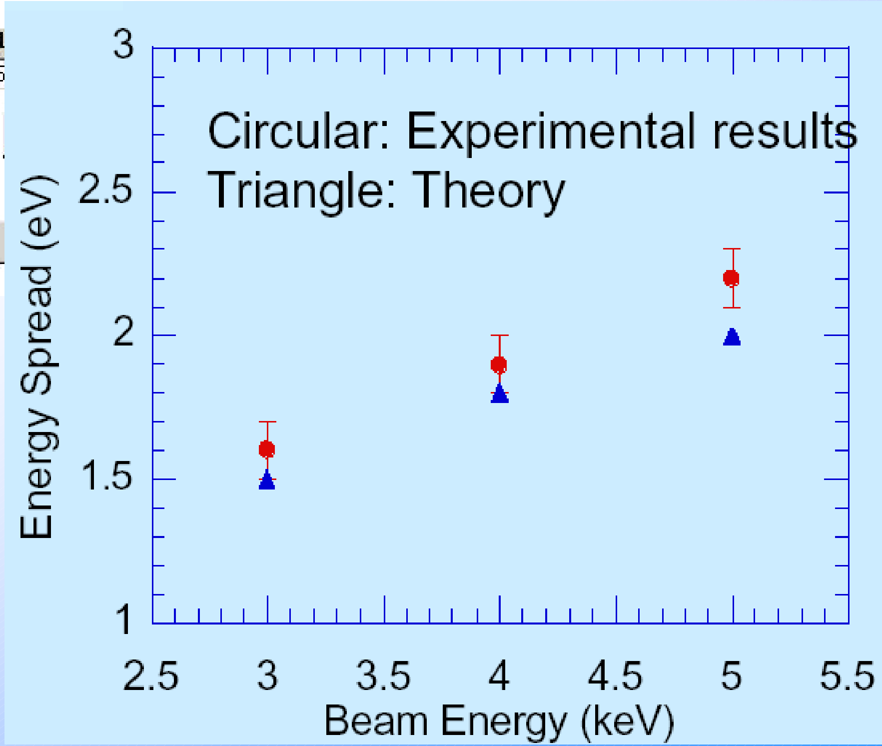
High space charge regime

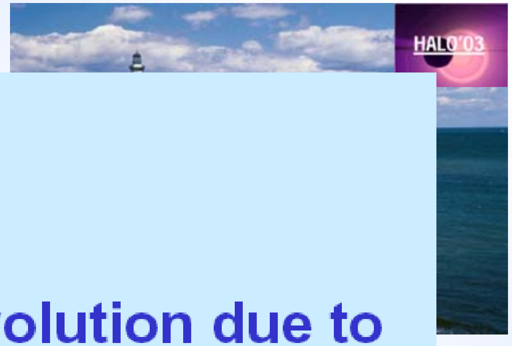

HALO'03


Energy Analyzer
Energy
Analyzer
M1 M2
Electron Gun
Current Monitor
Phosphor
Screen
M3
Current
Monitor
M4
M5


t = 60 ns Energy Spectrum
Energy: 5 keV
Current : 135 mA
E_rms = 2.1 eV
FWHM = 3.4 eV
Energy Spectrum
Retarding Voltage (V)
Spectrum on Beam (ns)
60
Start Time (ns)
0
End Time (ns)
100
Threshold
0.02
Data
3-D
FWHM
RMS
Mean E
Peak


HALO'03


Circular: Experimental results
Triangle: Theory
Energy Spread (eV)
Beam Energy (keV)



Summary

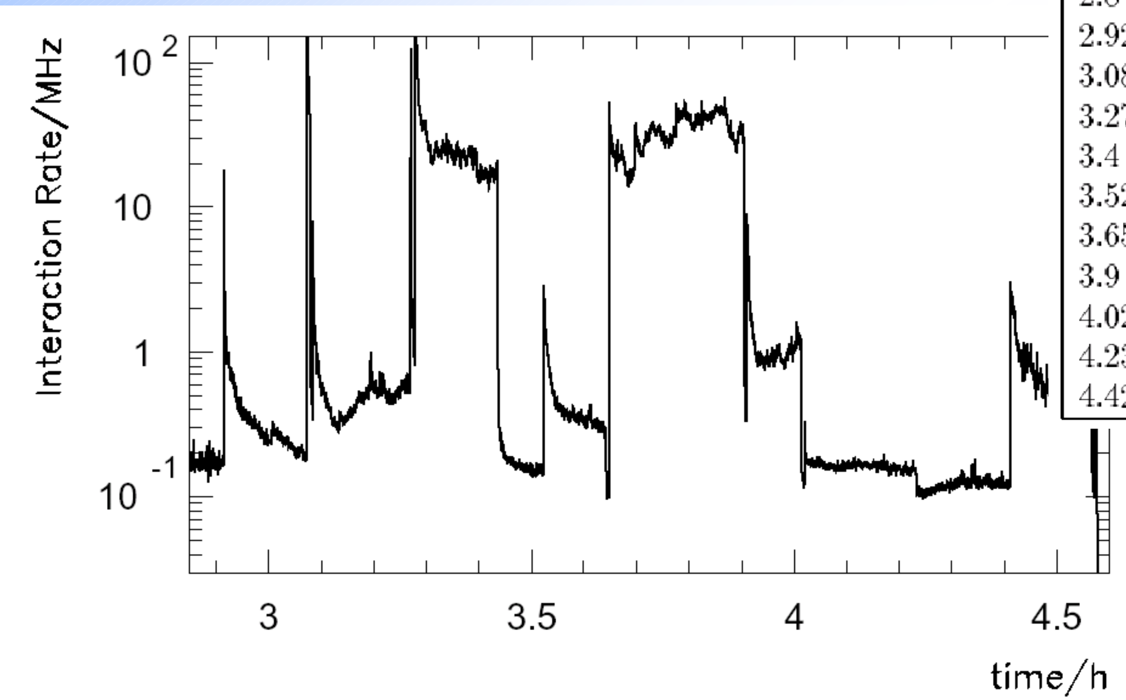
- An experiment to study the energy spread evolution due to the intra beam scattering and other mechanisms in the space-charge dominated beam has been designed and is being carried out.

- A compact, high-precision retarding field energy analyzer system has been designed and tested. Understandings of several issues inside the device have significantly improved the device resolution.

- The results of phase I experiment show excellent agreement between the experiments and the theory (Boersch effect and Longitudinal-Longitudinal effect).

- The phase II experiment is under way to measure the energy spread increase in longer distance.

The HERA–B experiment [43] uses an internal wire target inserted into the halo of the stored HERA proton beam. While machine performance was improved during recent years, this halo practically vanished. Therefore the wire target has to be moved close to the beam core at about 3 to 4 σ in order to keep the actual rate constant at the design rate of five interactions per bunch crossing. As it was observed, this leads to a high sensitivity of the interaction rate to beam orbit jitter of very small amplitudes. To overcome this situation, it has been suggested to artificially create some beam halo by means of tune modulation [42].



time/h	f_1/Hz	U_1/V	f_2/Hz	U_2/V	rate/MHz
2.8	0	0	0	0	0.18 ± 0.03
2.92	40	2.5	190	2.5	0.27 ± 0.03
3.08	20	2.5	190	2.5	0.35 ± 0.04
3.27	10	2.5	190	2.5	23 ± 5
3.4	0	0	0	0	0.16 ± 0.02
3.52	10	2.5	0	0	0.35 ± 0.05
3.65	10	2.5	190	2.5	30 ± 0.8
3.9	10	1.875	190	1.875	0.9 ± 0.15
4.02	10	1.25	190	1.25	0.17 ± 0.02
4.23	10	0.625	190	0.625	0.12 ± 0.015
4.42	10	2.5	0	0	0.6 ± 0.1

Summary
(instrumentation point of view)

Wire scanners/scrapers are state of the art in measuring tail with a huge dynamic range

IPM has to be improved, but is okay for continuous beam (turn by turn) observation

KEK PS technique shows that a wire scanner may measure fast profile changes

Other nice/fancy instruments exist to measure parameters which may drive beam tails

AC dipole: Waiting for ideas to make use of for tail measurements

Questions like: turn by turn (bunch by bunch) measurements of
Tune / chromaticity (on ramp) / coupling / halo etc.
where not answered yet, no instruments available.

Thanks to all contributors, have a nice trip home
Kay