What's Halo?

… because of the beam distribution's phase-space rotations, the observed halo in 1D oscillates, so that halo at different locations along the beam line is observable in differing degrees. For example, at some locations the halo may project strongly along the spatial coordinate and only weakly along the momentum coordinate, while at others the reverse is true, and the halo can be hidden in the spatial projection. In most circumstances, the beam halo from simulation appears as an irreversible effect, when observed in the 2D phase-space distributions. Therefore, it is also important to search for another definition of halo in the 2D phase-space distributions….

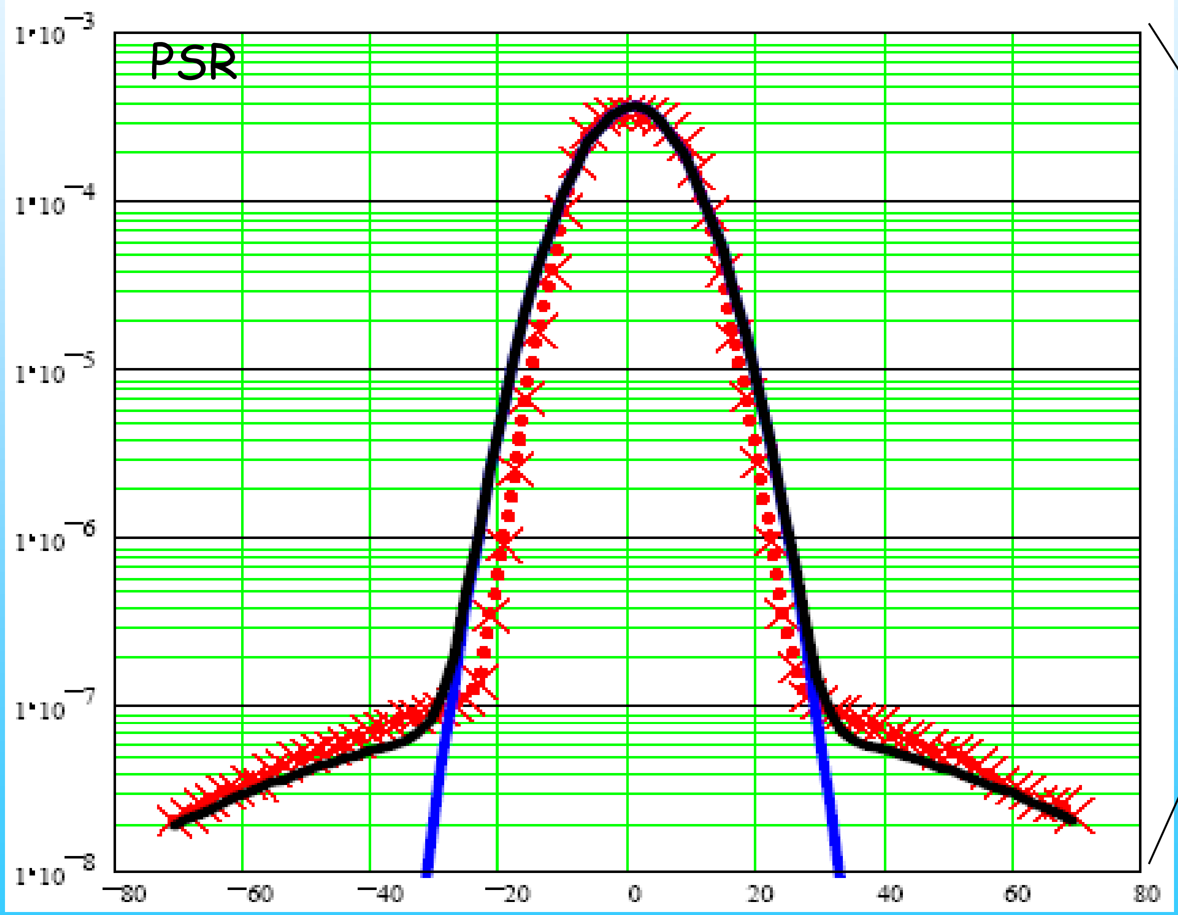
…it became clear that even at this workshop (HALO 03) **a general definition of "Beam Halo" could not be given,** because of the **very different requirements** in different machines, and because of the **differing perspectives** of instrumentation specialists and accelerator physicists.

<u>From the diagnostics point of view, one thing is certainly clear – by definition halo is low density and therefore difficult to measure…</u>

Slides courtesy of Kay Wittenburg (DESY)

What is Halo?

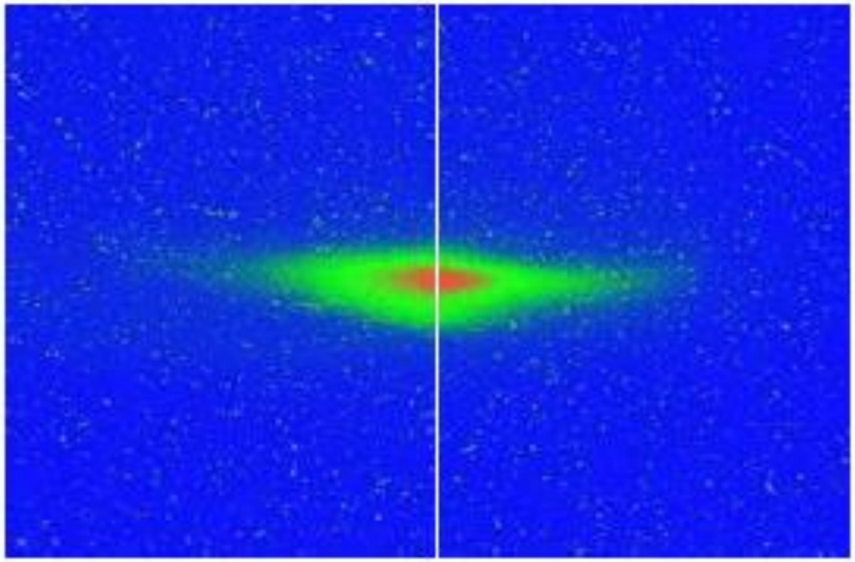
From the diagnostics point of view, one thing is certainly clear – by definition halo is low density and therefore difficult to measure…

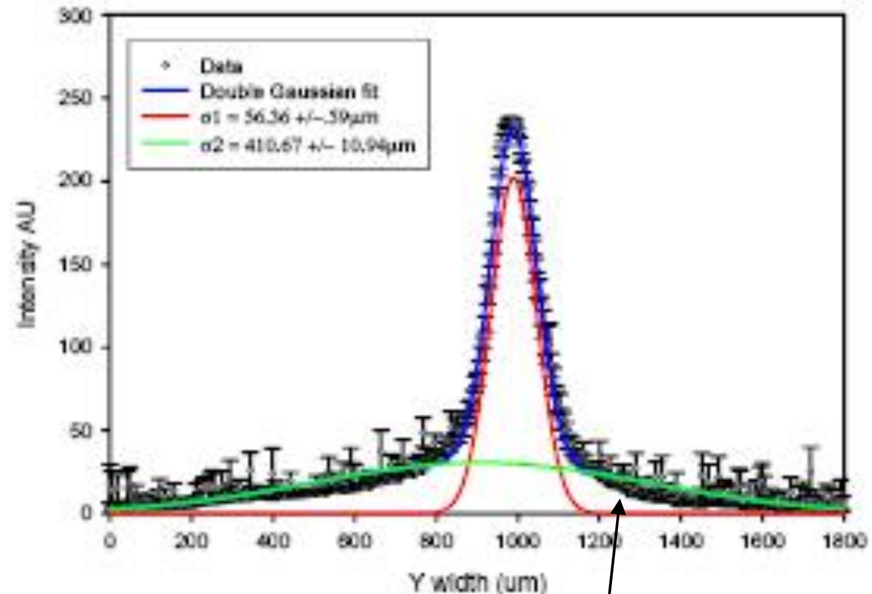


Halo measurements require **high dynamic range instruments** and methods

Dynamic range > 10^5

What is Halo?

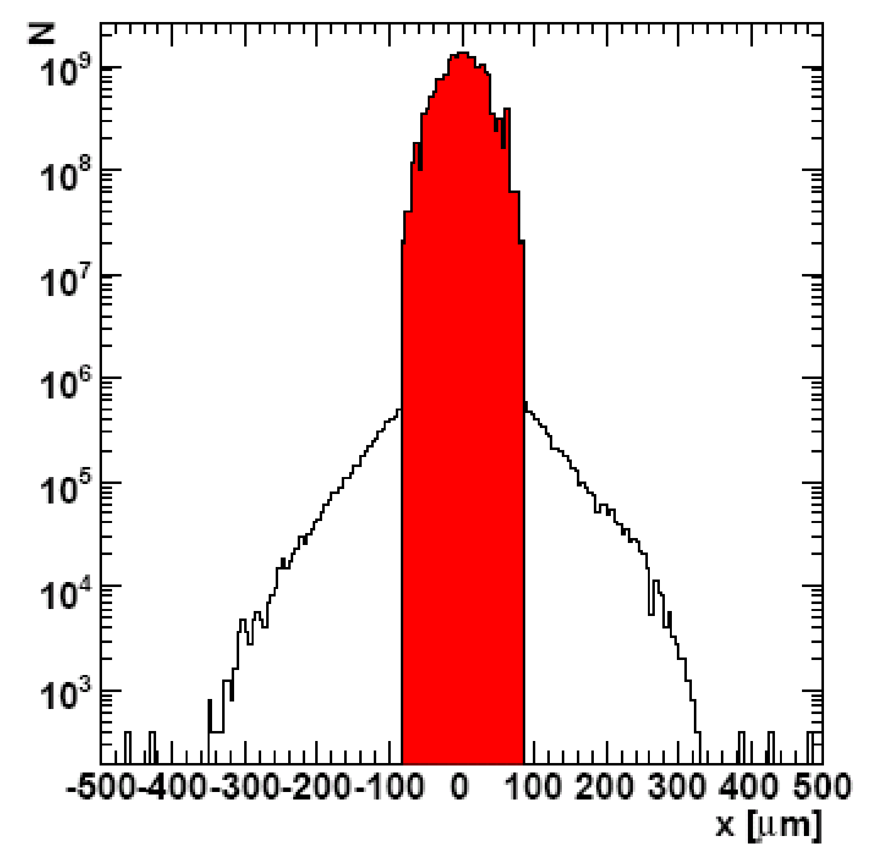




That's not a halo,
that's a tail!
Dynamic range $<10^3$

What is Halo?

- **Sources of halo are:**
  - space charge
  - mismatch
  - beam beam forces
  - instabilities and resonances
  - RF noise
  - Scattering (inside beam, residual gas, macroparticles, photons, obstacles (stripping foil, screens), …)
  - nonlinear forces
  - misalignments
  - electron cloudes
  - etc.



Calculated transverse beam halo
at the ILC-BDS entrance

One of our aims was to assemble a comprehensive list of potential halo production pro-cesses. We find it useful to subdivide this list in three categories.

Particle processes:

- Beam Gas elastic scattering and multiple scattering
- Beam Gas inelastic scattering, bremsstrahlung
- Synchrotron radiation, incoherent and coherent
- Scattering off thermal photons
- Intrabeam and Touschek scattering
- Ion or electron-cloud effects

Optics related:

- Mismatch
- Coupling
- Dispersion
- Non-linearities

Collective and equipment related:

- Wake-fields
- Beam Loading
- Noise and vibration
- Dark currents
- Space charge effects close to source
- Bunch compressors

This list was presented and discussed at several conferences including EPAC'06 [4] and PAC'07 [5] and in various EuroTeV meetings. It can be considered as a rather complete, agreed basis.

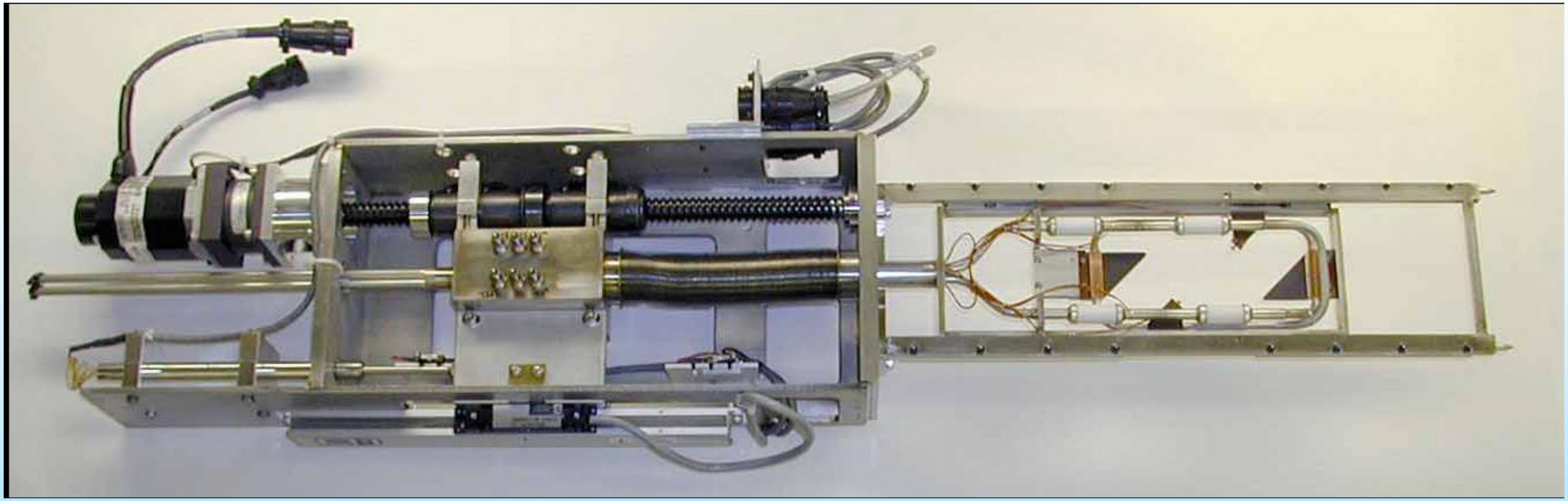
2008-076
Halo and Tail Generation Computer Model and Studies for Linear Colliders
Phys. Rev. ST Accel. Beams 12, 032801 (2009) [9 pages]
H. Burkhardt, I. Ahmed, M. Fitterer, A. Latina, L. Neukermans, D. Schulte
December 19, 2008

What is Halo?

- In storage synchrotrons, **background** due to halo can mask the **rare physics processes** and the experiment detectors are often the most **radiation sensitive components** in the accelerator. The beam loss threshold imposed by the most sensitive of the several experiments is often far below that imposed by activation of machine components.
- A number of < 0.1‰ lost particles /bunch appears sometimes to be already critical (e.g. can cause harmful beam loss). We therefore require a beam monitor capable of measuring the transverse beam halo better than this. **The required dynamic range is therefore of the order of 10^5 or better**.

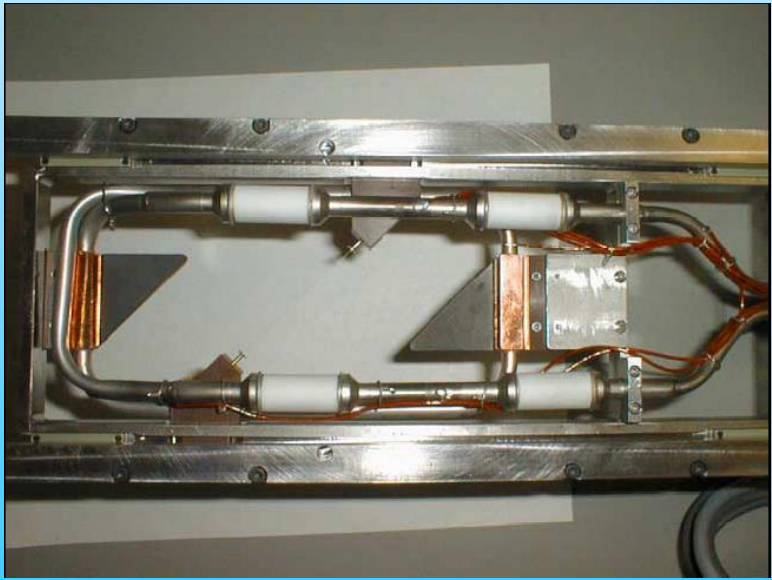
- **Profile measurements are often questioned at the level of a few percent**, the difficulty is easily seen in making halo measurements already at the level of 10^{-4} and beyond.

Wire Scanners at LEDA
(Proton LINAC, SEM readout)



WS can move a 33-µm carbon mono filament and two halo scraper consisting of two graphite scraping devices (one for each side of the distribution).

The high-heat flux testing performed on the prototype scrapers revealed that the design can withstand the thermally induced fatigue loading. The peak heat flux that these scrapers have experienced in actual service is approximately 600 kW/cm^2



Wire Scanners

To plot the complete beam distribution for each axis, the **wire scanner and two scraper data sets must be joined**. To accomplish this joining, several analysis tasks are performed on the wire and scraper data including:

1. Scraper data are spatially differentiated and averaged,
2. Wire and scraper data are acquired with sufficient spatial overlap (where the wire scanner signal rises above the noise),
3. Differentiated scraper data are normalized to the wire beam core data,
4. Normalize data to axis (simple if on same fork)
5. Normalize data to beam current and beam position (true for all kind of halo measurements)!!!!

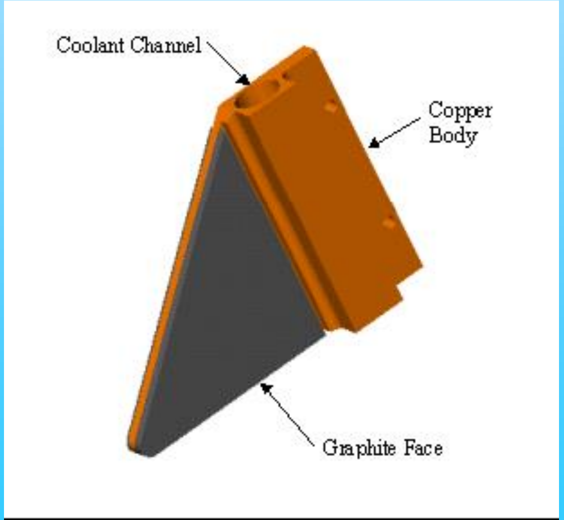
Before scan: define safe scraper insertion limits (avoid too much heat load) by wire scan data. In SEM mode avoid thermal electron emission!

Procedure explained in:

ANALYSIS OF DATA FROM THE LEDA WIRE SCANNER/HALO SCRAPER*
J. H. Kamperschroer,† General Atomics, Los Alamos,
J. F. O'Hara, Honeywell, L. A. Day, J. D. Gilpatrick, and D. M. Kerstiens, Los Alamos National Laboratory
PAC2001

Wire Scanners

To 1: **<u>Scraper data are spatially differentiated and averaged</u>**
As the scraper marches inward, it intercepts an ever increasing segment of the beam. It is therefore necessary to **differentiate the scraper signal** to determine the transverse distribution. Take scraper data with N-times finer steps than used for the wire scan. This finer stepping allows the **differentiation algorithm to smooth the data**. The numerical derivative can be computed as the difference between two N-point averages on either side of the point in question divided by the spatial separation between them. Larger values of N improve the signal-to-noise ratio, but at the cost of additional time to complete the scrapes.



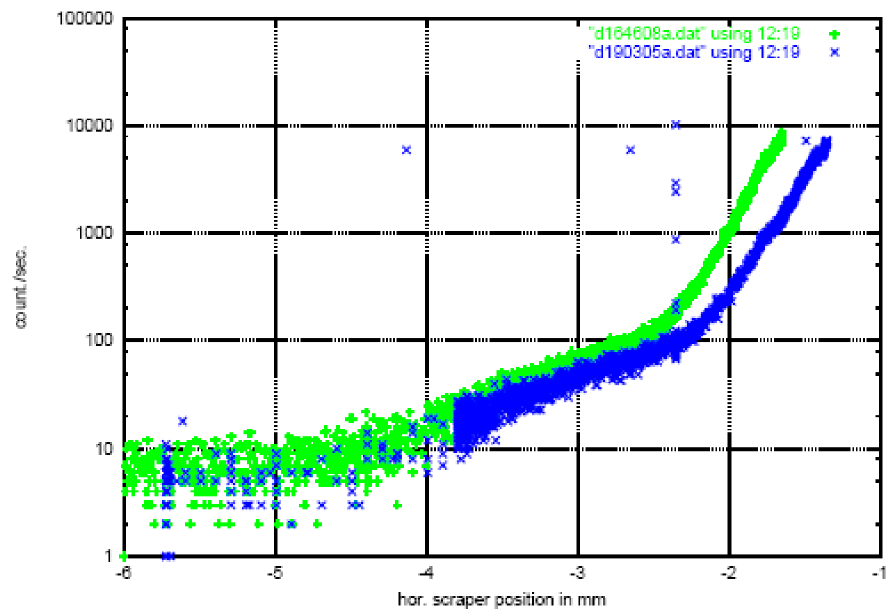
Wire Scanners

to 2: **Wire and scraper data are acquired with sufficient spatial overlap**
The first step in joining the scraper data to the wire scanner data is determining where the data sets overlap. The overlap region consists of wire scanner locations ranging from where the wire scanner signal-to-noise ratio is greater than 2 to the maximum insertion location of the scraper.

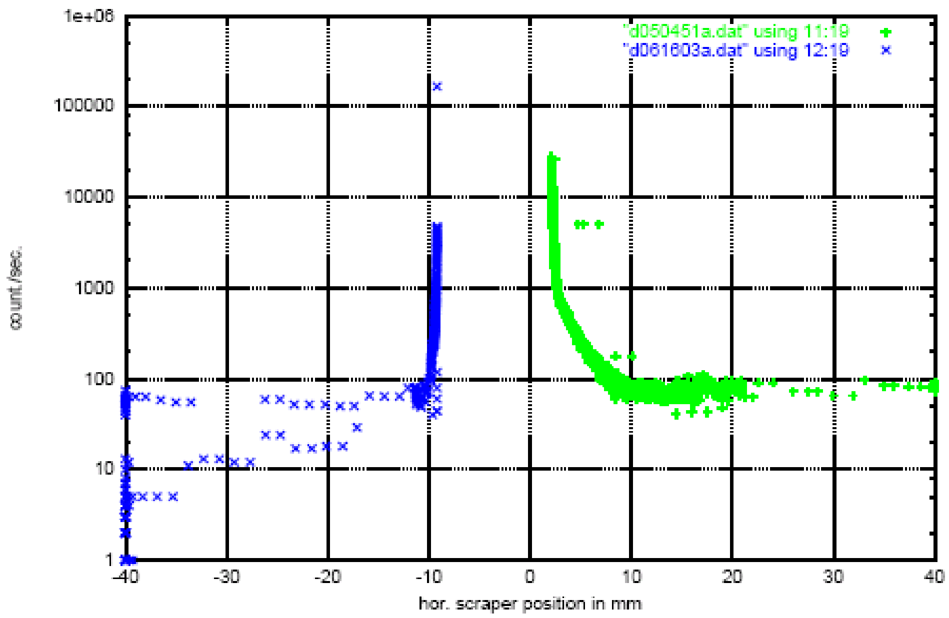
to 3 and 4: **Differentiated scraper data are normalized to the wire beam core data and**
Normalize data to axis
Once the region of overlap has been determined, the scraper data must be normalized to attach it to the wire scanner data. The scaling factor is the average of wire scanner to halo scraper signal ratios at two of the three most-inboard points in the overlap region (the most inboard point is excluded). Once scaled, the entire scraper data set is thinned by keeping only every N^{th} scraper point and attached at the connecting points.
Measurements of wire to scraper distances were carried out in Lab. with an uncertainty of 0.25 mm. This implies a positional attachment uncertainty of 0.25 mm. At this point, the resulting three distributions have been combined into a single distribution with uniform step size.

Wire Scanners **and others**

to 5: **Normalize data to beam current and beam position**
Each data point has to be normalized to the measured **beam current and beam position** for each measurement.

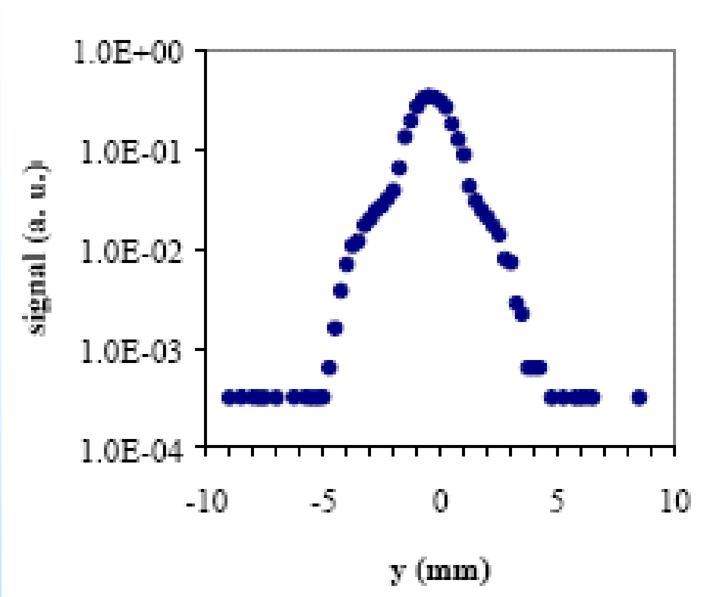


Beam loss rates versus scraper position, black: first measurement, grey: second measurement. During the second measurement the orbit moved about 0.30 mm in 4721 s.



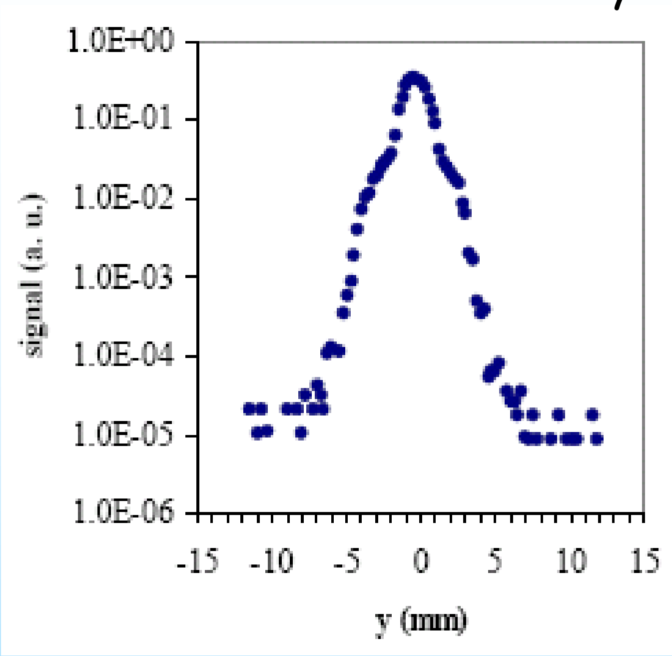
Beam loss rates versus scraper position. The orbit movement causes an artificial asymmetry in the measurement results

Y-axis wire scan



=>

Combined distribution in y.



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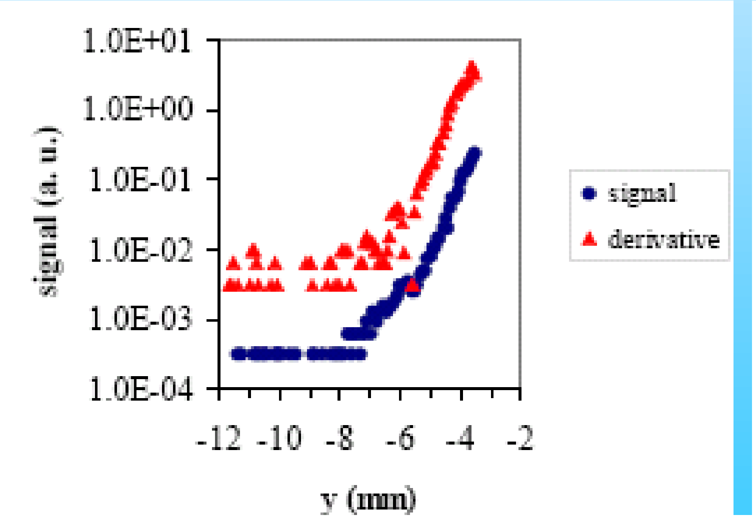
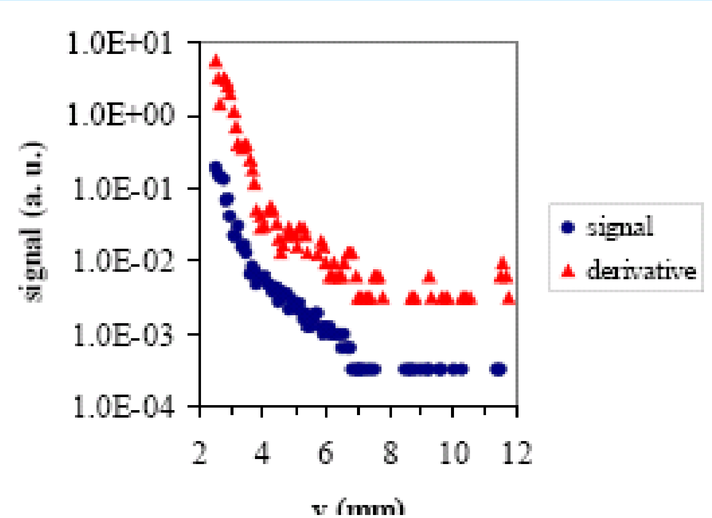




-Y and + Y scrape signal and derivative. The derivative has been multiplied by ten.

Wire Scanners at LEDA

A lossy integrator is used to detect the replacement charge flowing to the wire and scraper (SEM). Independent programmable dc-bias voltages are applied to the wire and the scraper through the analog electronic interface to optimize charge capture from the two sensors. A programmable guard voltage is applied to isolate the scraper from the resistivity of the cooling system. Programmable gain provides a total dynamic range in the analog electronics of greater than about one part in 10^6. The analog signal is digitized to 14 bits plus sign, and the equivalent input noise is nominally 30fC.

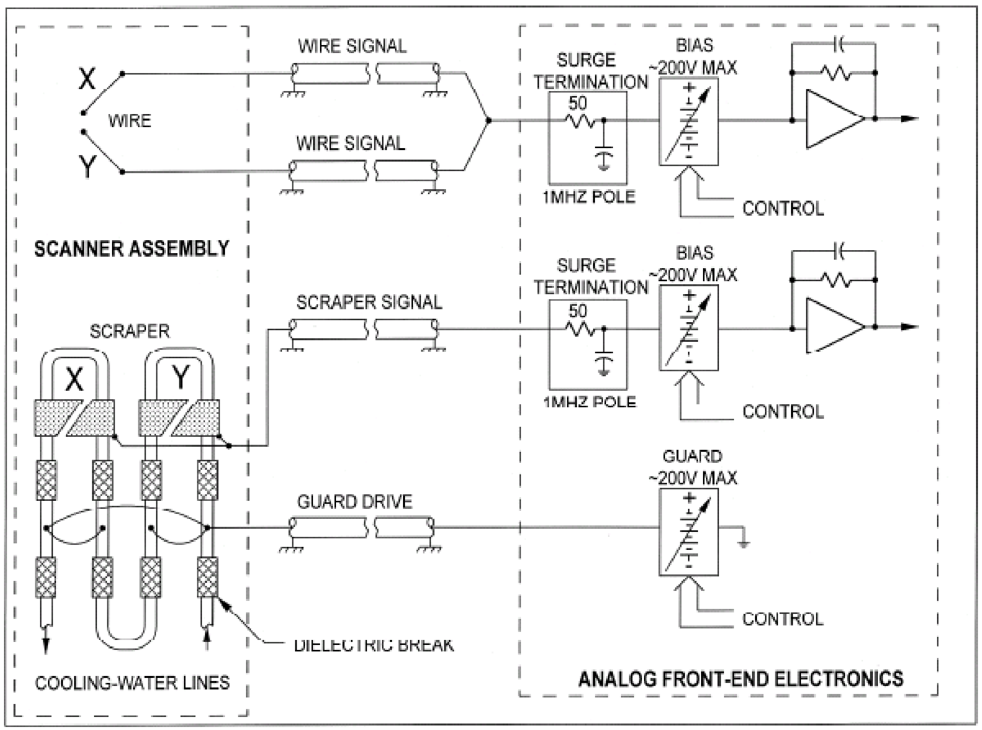
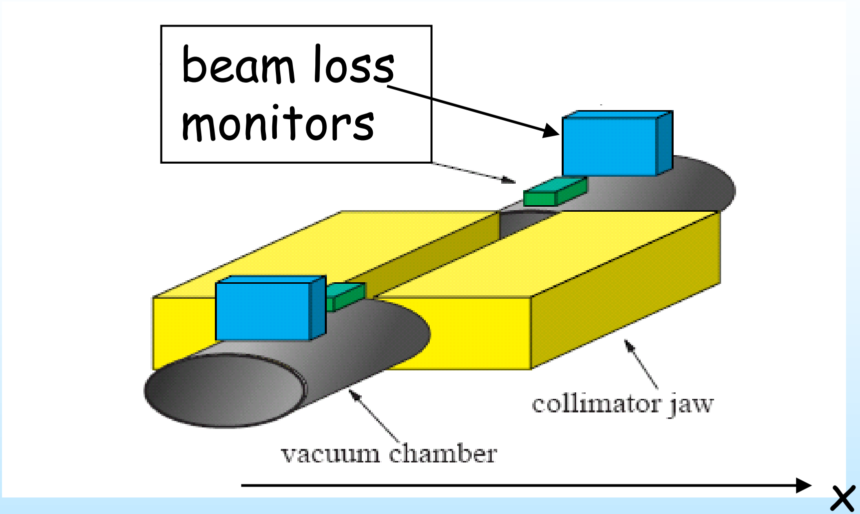
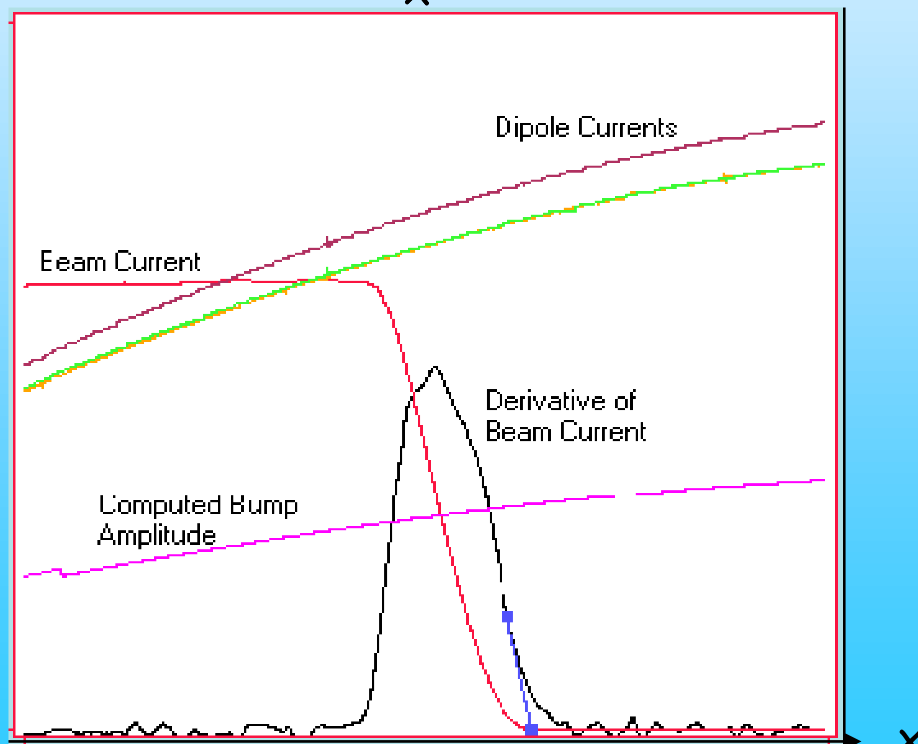


Figure 1. LEDA Wire-Scanner/Halo-Scraper AFE Block Diagram

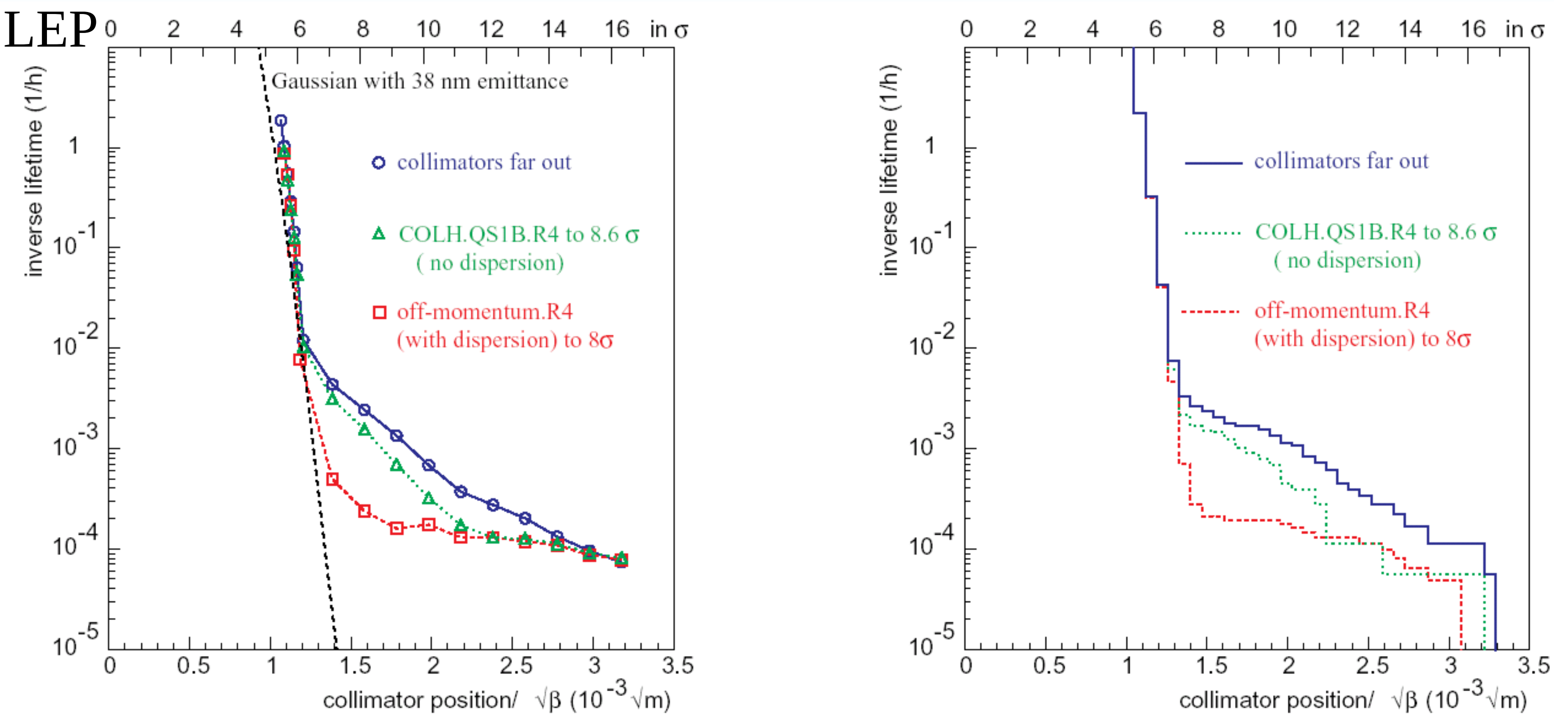
Scraping by collimators



In a synchrotron one jaw will scrape both sides of the beam distribution (β-oszillation)
=> meas. symmetric halo
Such a tail scan yields information about particles which oscillate with an amplitude larger than the position of the collimator



Scraping by collimators + BLM



Measurement (left) and simulation (right) of the horizontal beam tails for a beam energy of 80.5 GeV and for different collimator settings at LEP. The simulation is the result of tracking particles after Compton scattering on thermal photons (black body radiation of vacuum chamber).

Measurements were performed by moving one jaw of a collimator closer to the beam in steps. Beam current and beam size measurements were recorded for each collimator setting. The collimators were moved closer until significant lifetime reductions were observed. Lifetimes calculated from beam currents for these points were used to calibrate the loss monitors. This allows to give loss rates directly in terms of equivalent lifetimes