Status of Beam loss Monitoring on CTF3

Results of Tests on LINAC and PETS as R&D for TBL

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(on behalf of all involved in beam monitoring)

CTF3 Collaboration Meeting
24 November 2004

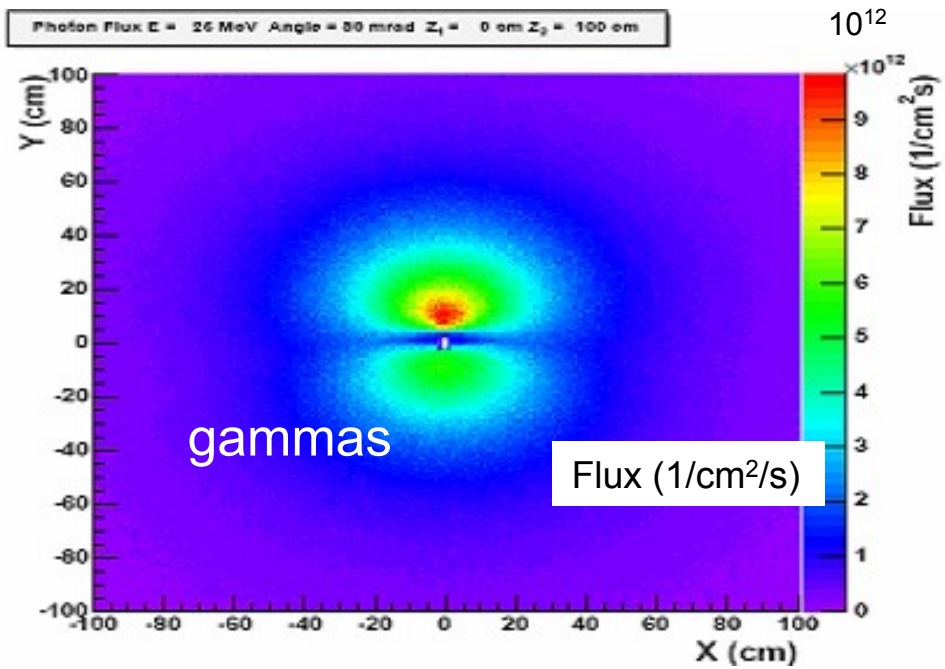
Beam loss monitoring on CTF3

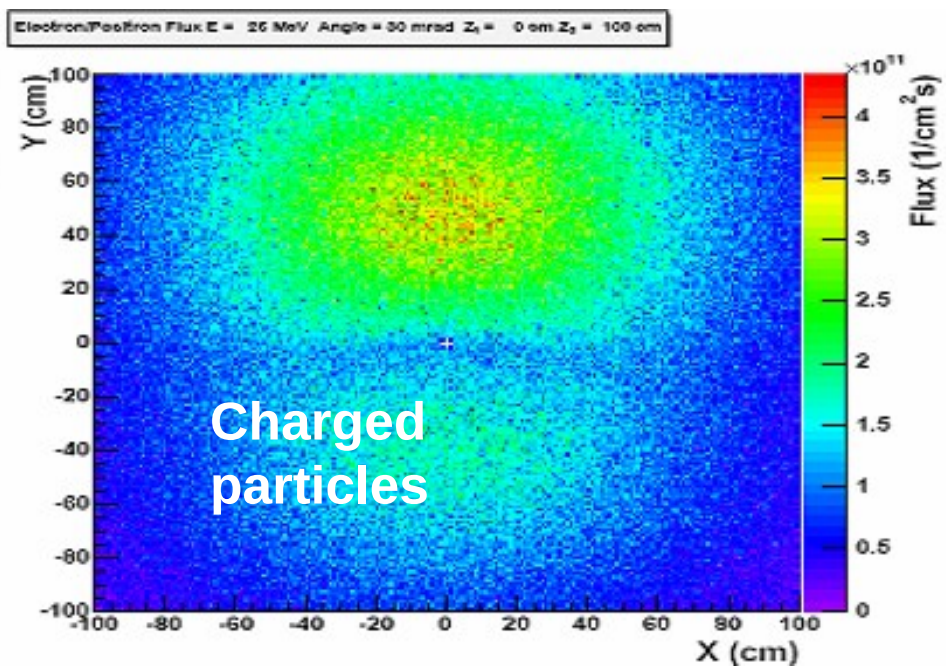
- Goal
  - Map Beam Loss, both in amplitude and within the pulse time along the LINAC and PETS.
- To What precision??
  - Absolute Calibration of the BPMs is %.
  - Must provide detailed information about the **losses along the girder** that the BPM's **can't provide**.
  - For a nominal beam current in the LINAC of 3.5Amps, we need to be sensitive to ‰ of beam loss of at ***least*** 35mA.
  - If sensitive enough → **want** time resolution of the beam loss.
- R&D for TBL:
  - Experience on the LINAC will teach us more about the beam loss environment
    - This environment is different from the high electron / proton flux environment for what the chambers were initially developed for.
  - Future … want at least the ‰ level, to measure beam loss in TBL
    - For nominal beam current in the TBL of 35 Amps, we need to be sensitive to a beam loss of at least 35mA.
    - Require time resolution.
    - Beam loss monitoring will be part of a machine protection system.

Beam Loss from GEANT 3.21 simulation

25 MeV Electron beam

- Flux of photons > charged particles
- Shower shape of Charged particles > shower shape of photons

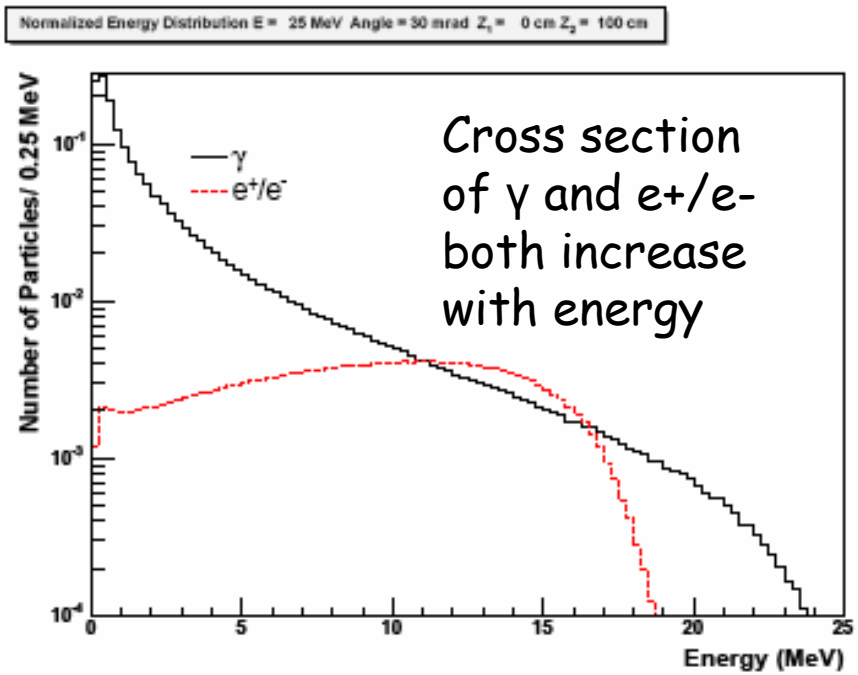




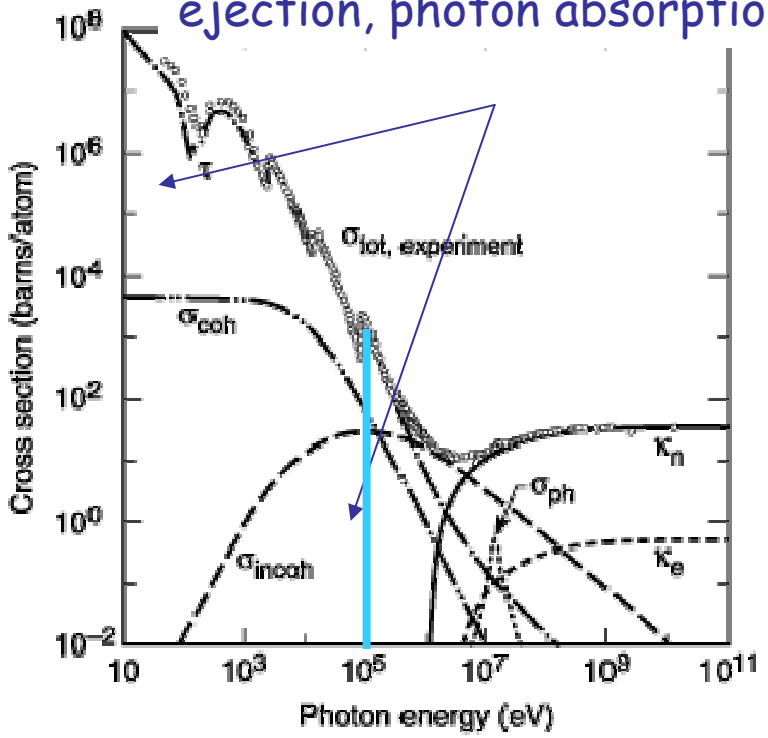
M. Wood note 061, (2004)

A. Dabrowski, November 24 2004

Photon cross sections dominate at low energy



τ, atomic photo-effect (electron ejection, photon absorption);



The **photon production cross section**, and the interaction cross section with matter (photo-electric type effect) make this the dominant process at low energy

Efficiency for 100keV photon 0.33, but at 1keV, the efficiency is 2000

SEM efficiency is 5%, linear with energy

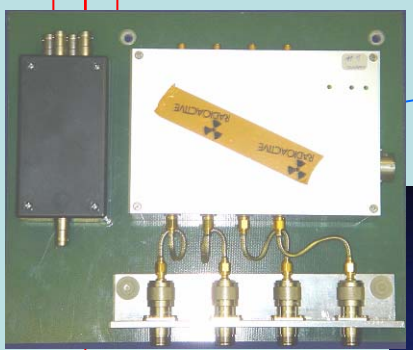
Ionization signal efficiency 8/94 for He/Argon gas …and independent of energy

Design of Detector Tested in October

- SEM (vacuum) gas sealed, radiation hard, high rate chamber.
  - Since the environment is dominated by photon and secondary emission cross-sections, these processes provide a signal higher than ionization.
  - The SEM is the main chamber, and the SIC (Helium/Argon filled) is almost equivalent device.

- Faraday Cup tested as cross-calibration device (Aluminum block sensitive to charged particles) : designed to measure the ‰ beam loss (μA)

HV to chamber

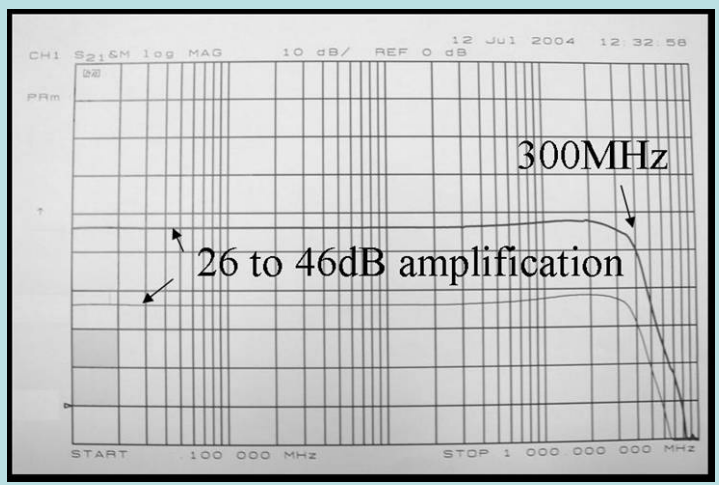


Amplifier

(gain of x20 or x200, switchable)

HV from Gallery

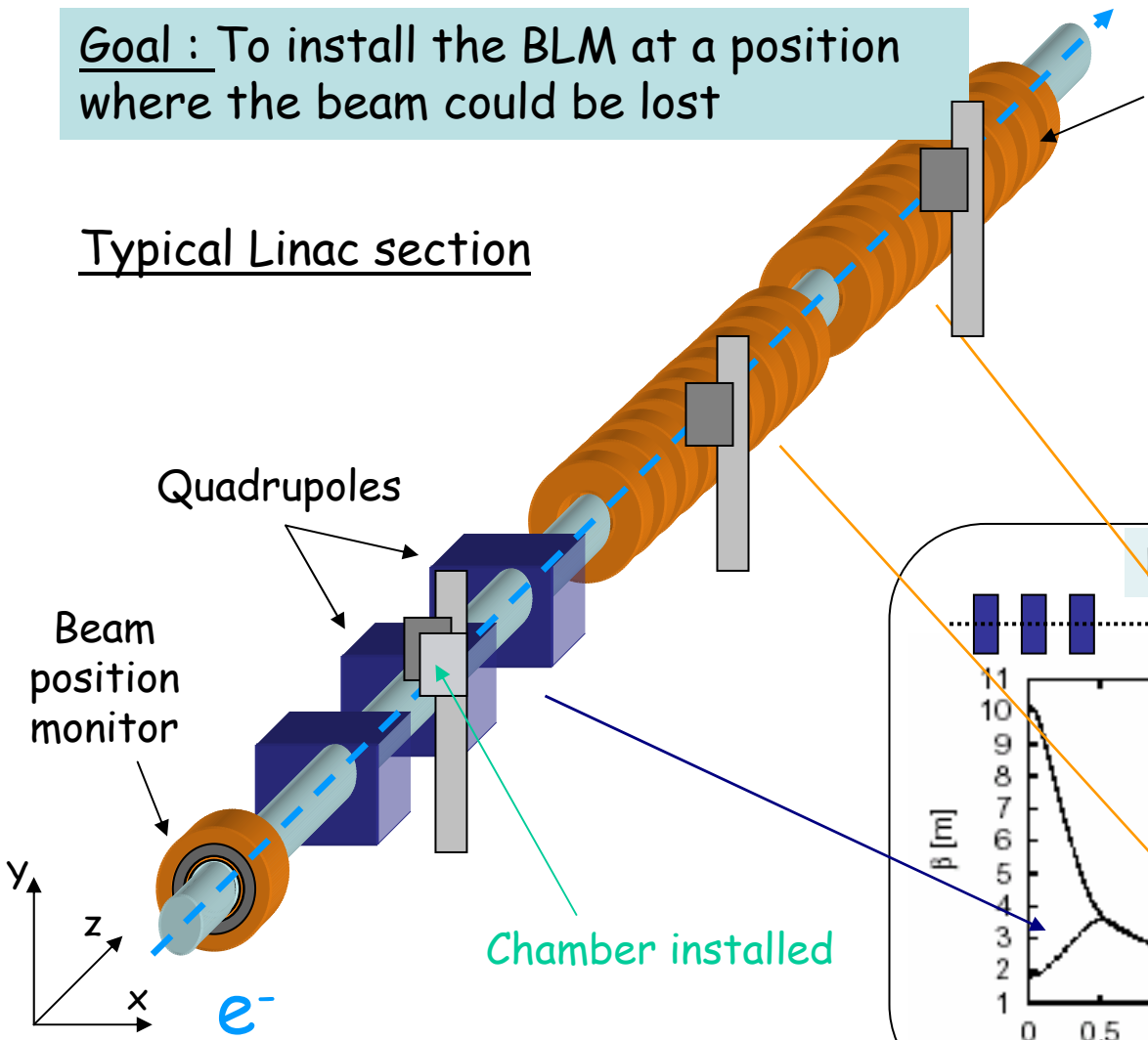
Chamber mounted in metal box for shielding



BLM s installed along the Linac

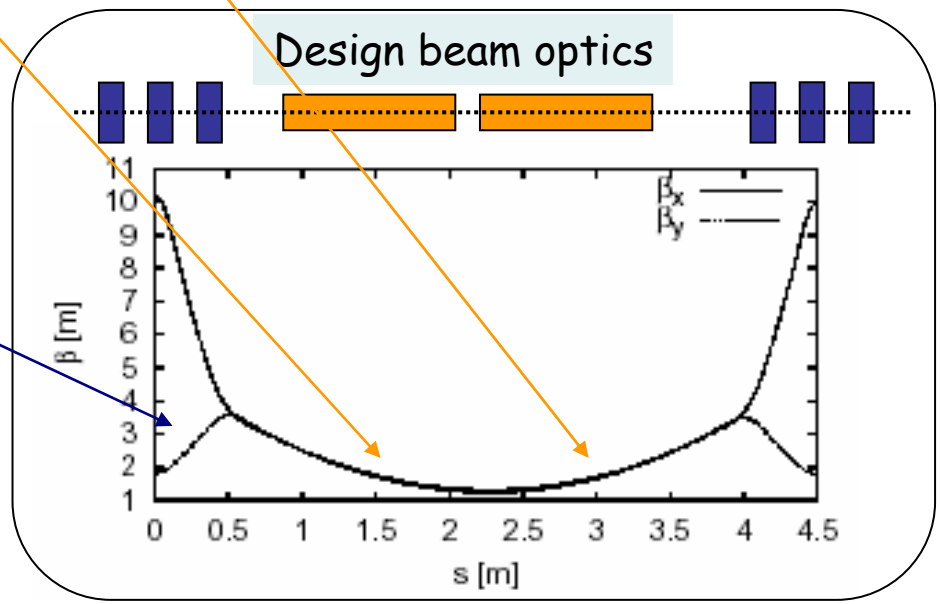
Goal : To install the BLM at a position where the beam could be lost

Typical Linac section



Install 3 chambers and 1 Faraday Cup per Girder which have an accelerating structure

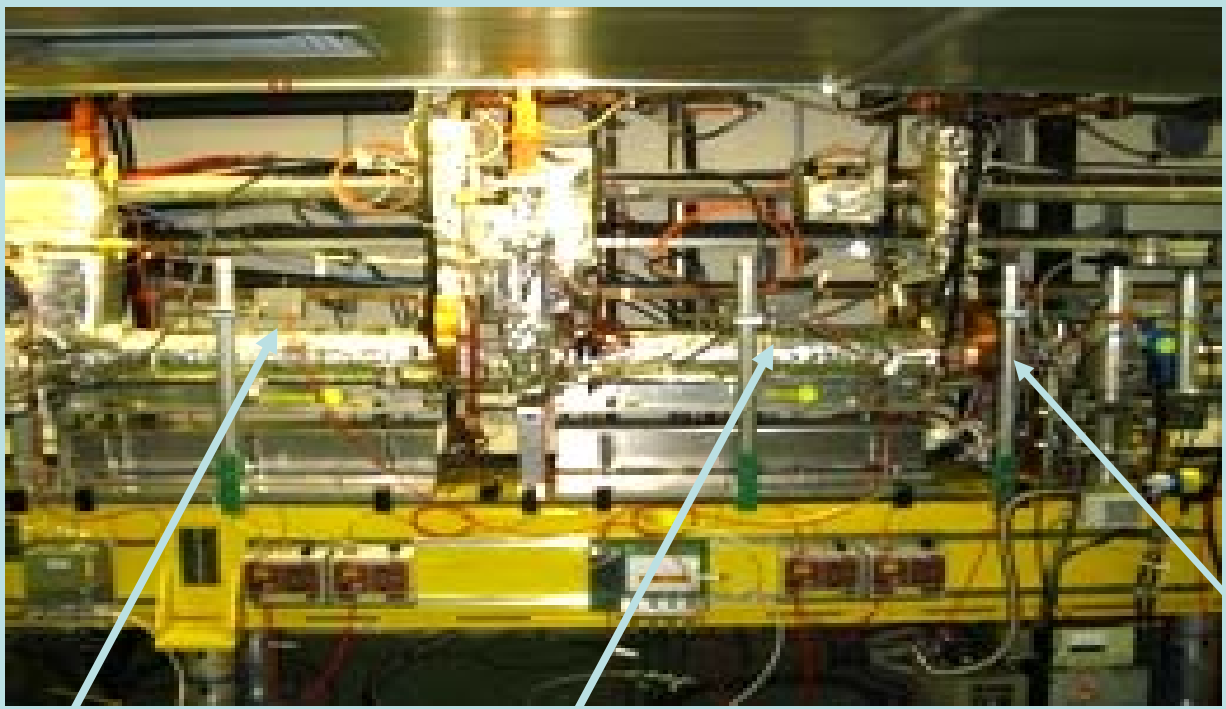
Design beam optics



Chambers installed along the Girder

Example below of Setup on Girder 5 with 30 MeV electrons

(Similar setups on Girders 6,11,12)



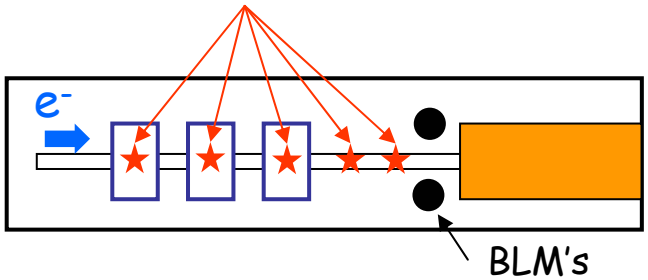
Middle of second cavity

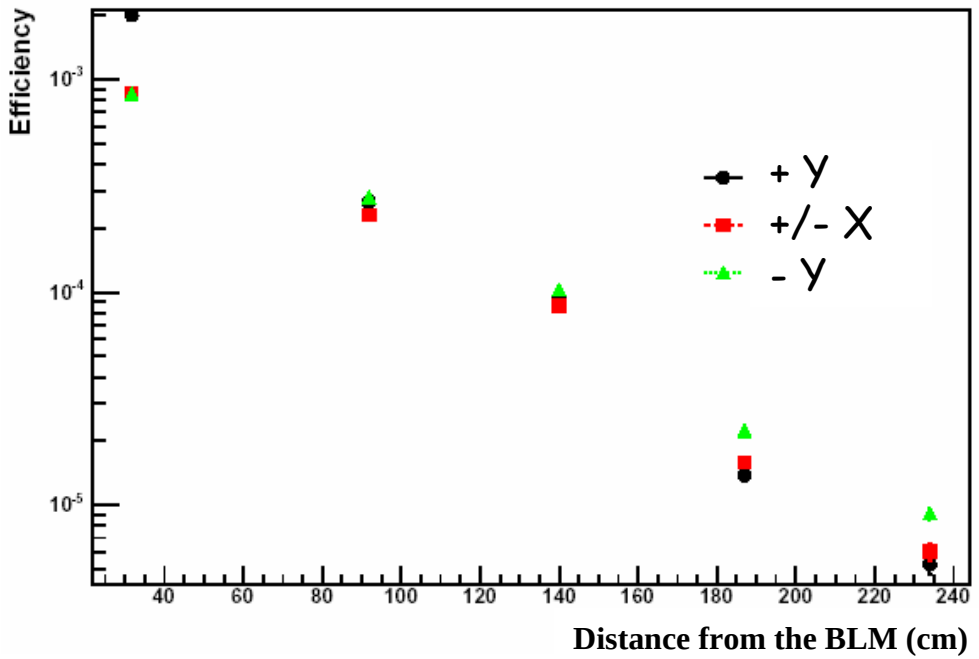
Middle of first cavity

After the quadruple

e⁻ shower efficiency : Number of particles detected / Number of particles lost

Positions of the beam loss





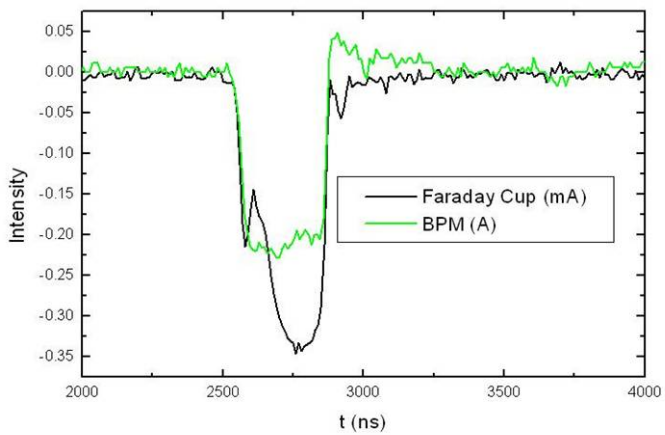
Simulations with Geant 3.21

- 35MeV, 0mm beam size, 3mrad beam angle
- Beam loss at + Y
- Ø40mm detector (~Faraday Cup) installed at 15cm from the beam axis

Measurements made on girder 5

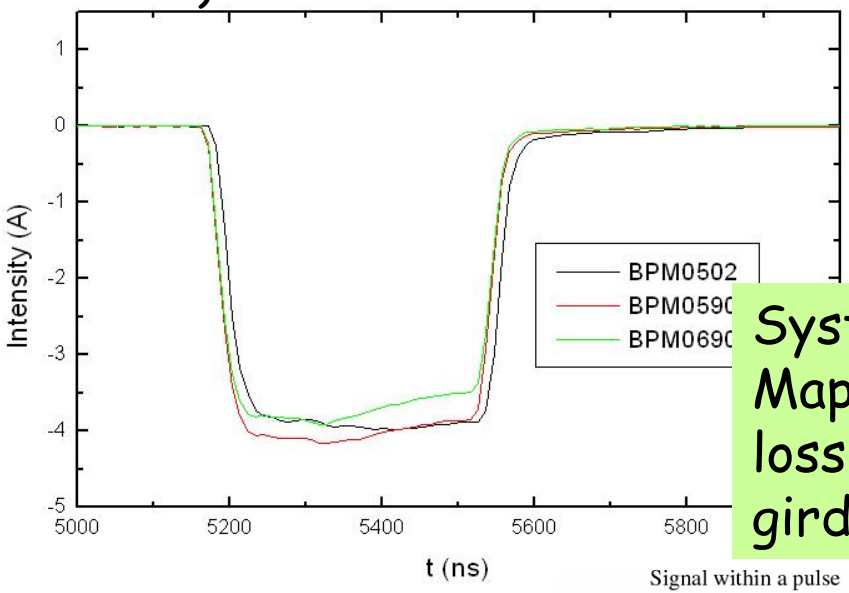
- beam current lost between two BPM
- beam loss measurement using faraday cup

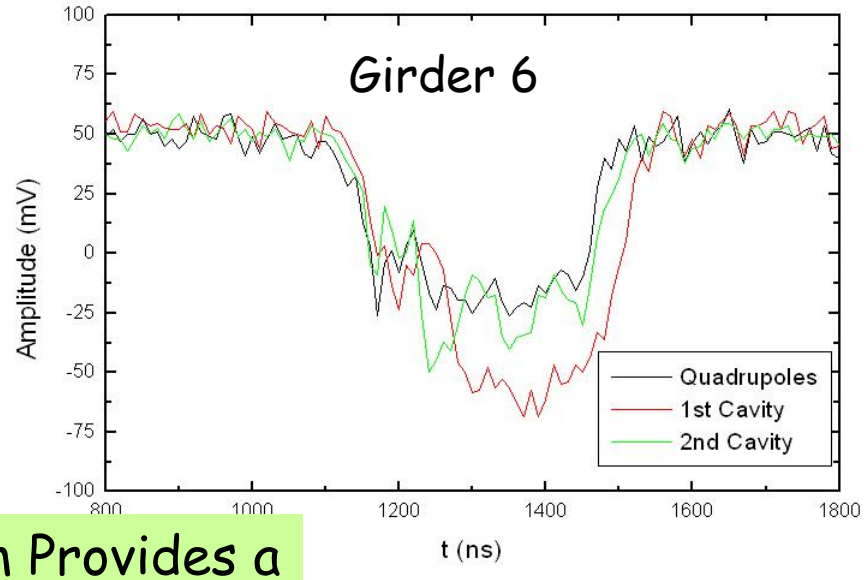
- Efficiency of 10^{-3} : ~ loss at 20cm far from the detector



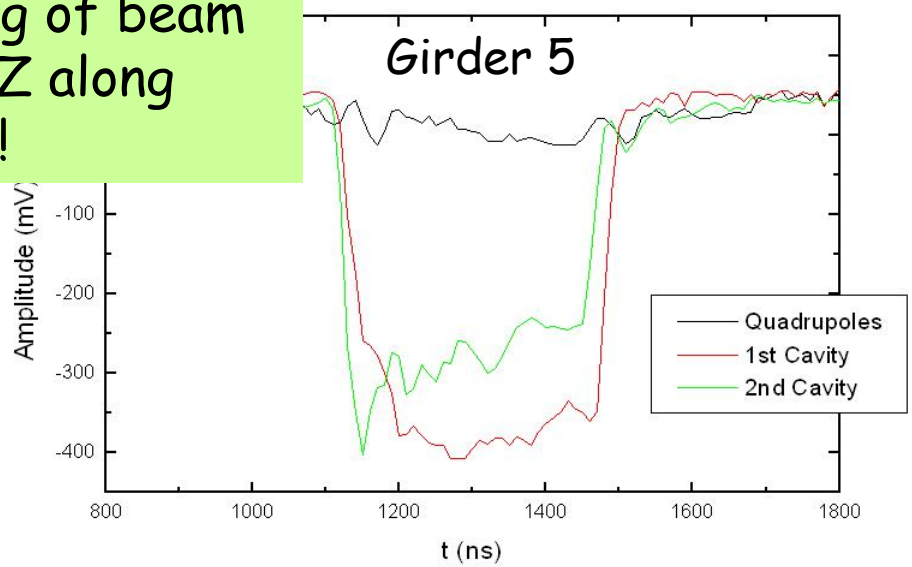
Beam loss with nominal beam optics

Chamber signals for nominal beam optics have good signal and time response with only low x20 gain amplifier (and 50 Ω resistor)



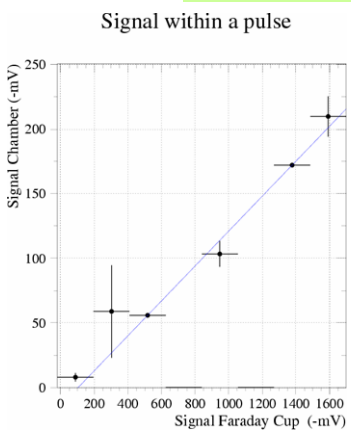


System Provides a Mapping of beam loss in Z along girder !



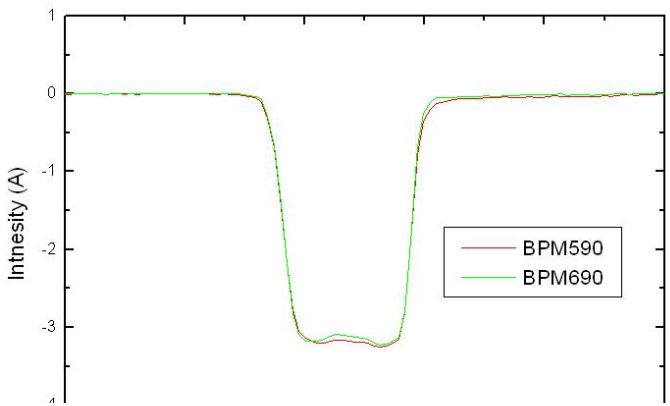
Linear response between Chamber and Faraday cup

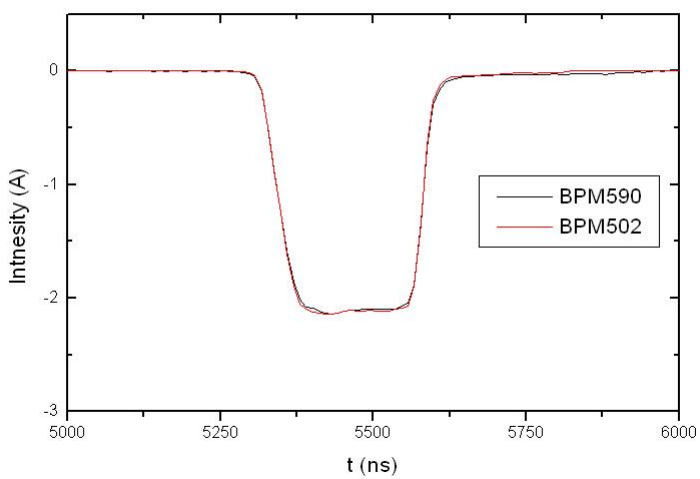
Calibration Factor ~ 6 depending on beam loss shower shape



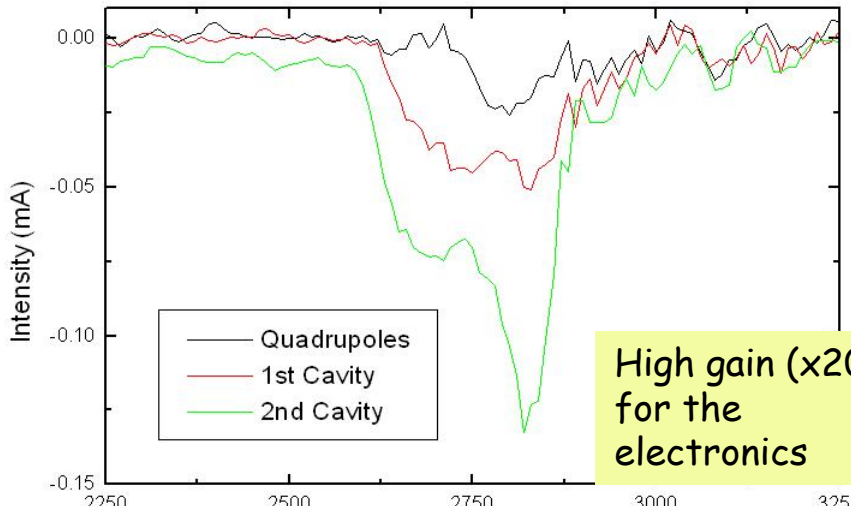
Relatively low losses on Girder 5 /6

Losses at the limit of the BPM resolution … signals on Girder 6 visible with high gain electronics, but on Girder 5 we are not sensitive to losses



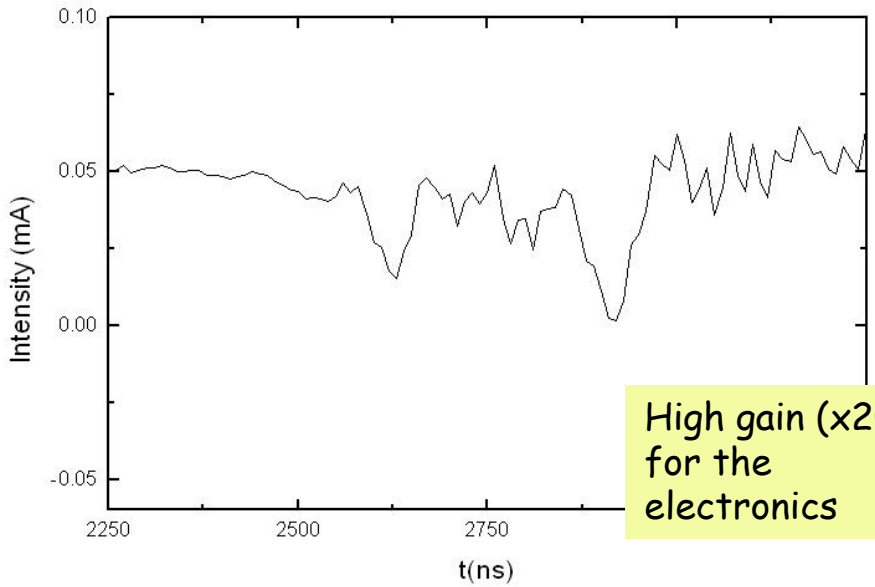


Girder 6



High gain (x200) for the electronics

Girder 5



High gain (x200) for the electronics

A. Dabrowski, November 24 2004

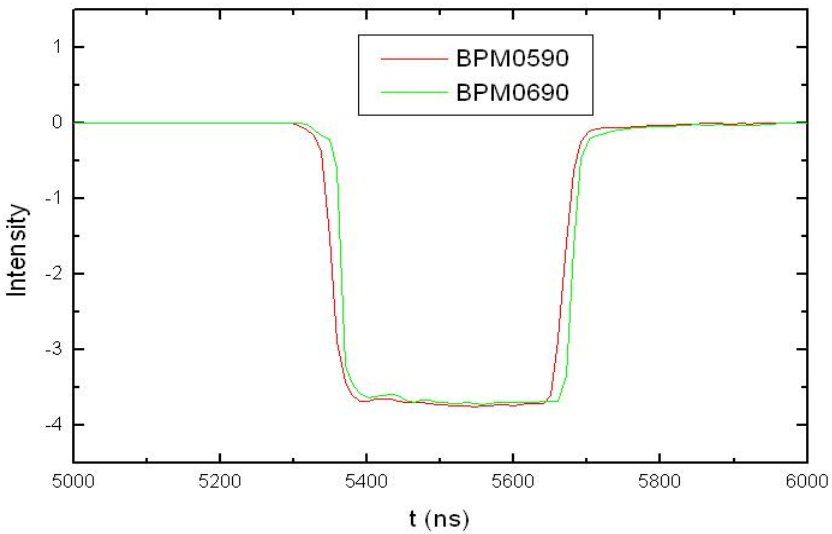
Very Low Losses on Girder 6

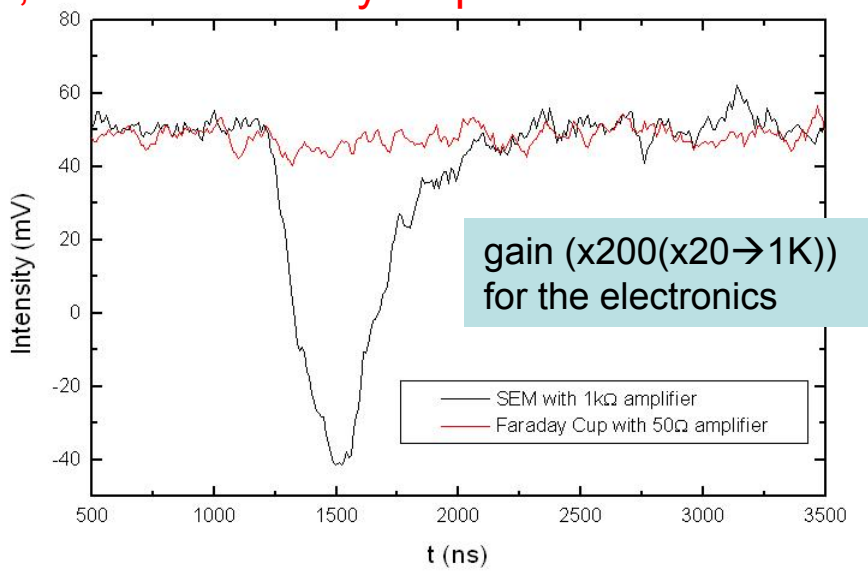
Data taken with very low loses in the beam …

Modified the electronics to increase the sensitivity… 50Ω input impedance to the amplifier replaced by 1kΩ (x20 more)

- still with the amplifier gain of x20 or x200
- Drawback : we loose the time resolution (x20 slower)

In this condition… SEM sees the beam loss, but the Faraday Cup in the noise.





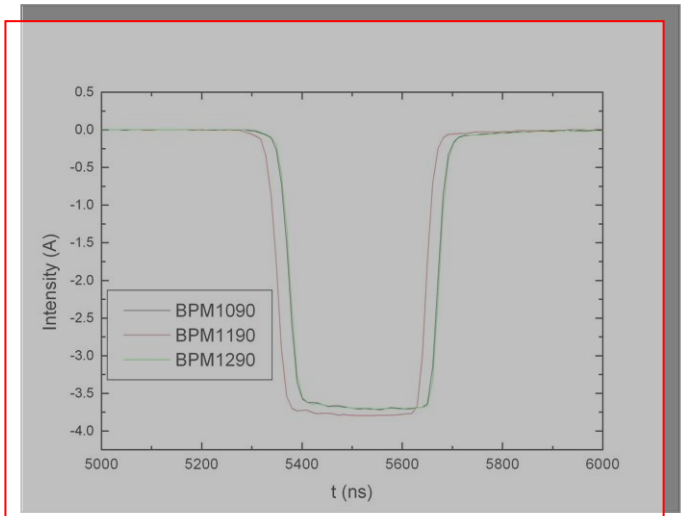
Since the Calibration Factor between SEM and Faraday cup X5, and input impedance factor is x20, here we are in the less than ‰ region of beam loss

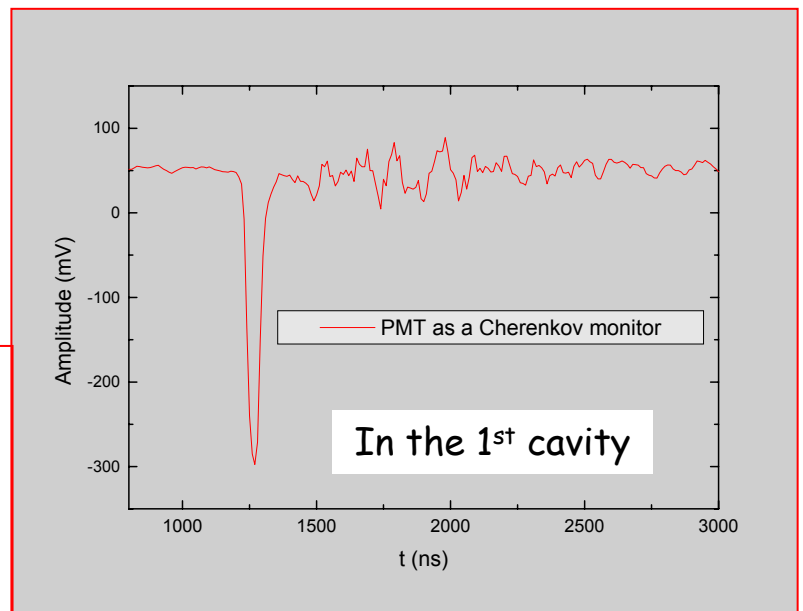
Alternative detector for region of low beam loss

Girders 11/12 …

Energy ~ 60-100 MeV

- From Simulation, beam loss is more collimated at higher energy …
- A PMT as Cherenkov detector was installed in the 1st Cavity, together with a Faraday Cup.
- Change PMT voltage, depending of sensitivity required
- PMT have relatively low dynamic range (10^3) within a given voltage gain





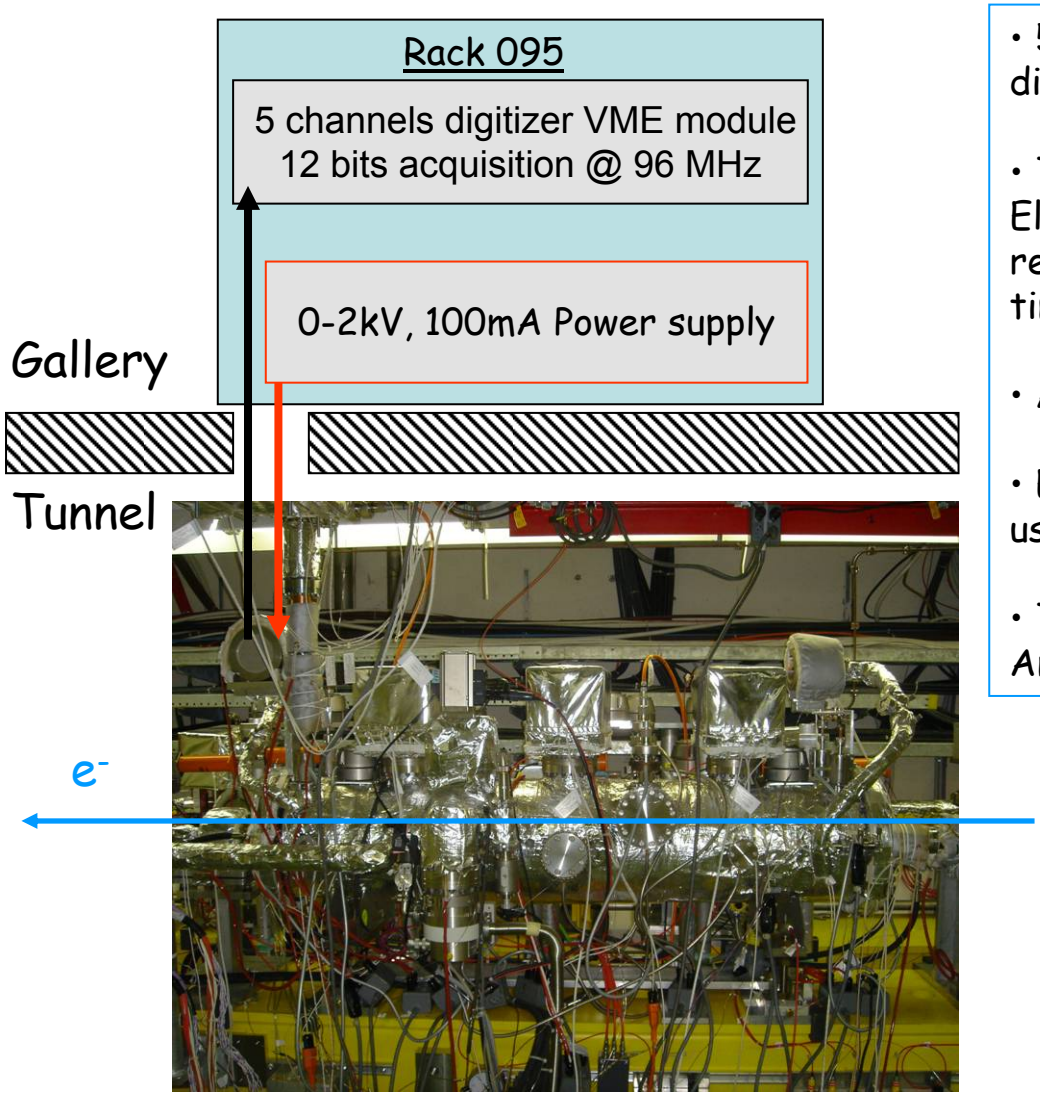
- At 300V bias voltage, the PMT is x200 more sensitive than the Faraday cup
- Here we estimated the loss to be lower than 10^{-4} of the beam current

Summary … Beam Loss on Linac

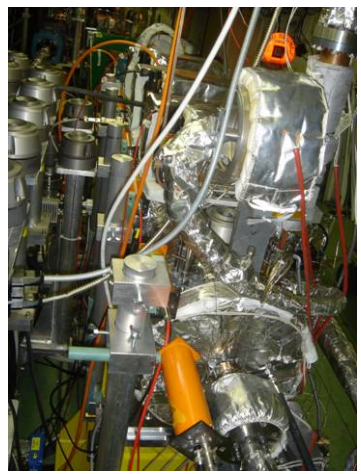
- This has been a valuable exercise to learn about beam loss environment in LINAC … to translate to the TBL.
- Chambers are sensitive to beam loss along the girder …. Additional monitoring complementary to BPM available today!
- Chambers are most sensitive to Photo-electric / Secondary emission signal … fast time resolution, and no need to apply voltage
- In regions of very low loss, Chambers sensitive if one sacrifices resolution, and integrates over large impedance.
- For TBL, beam currents will be 10X larger … but we need to investigate all possible devices
  - SEM chamber
  - PMT as a Cherenkov monitor

  find the best range of sensitivity to the desired level of beam loss

BLM system for the PETS in 2004

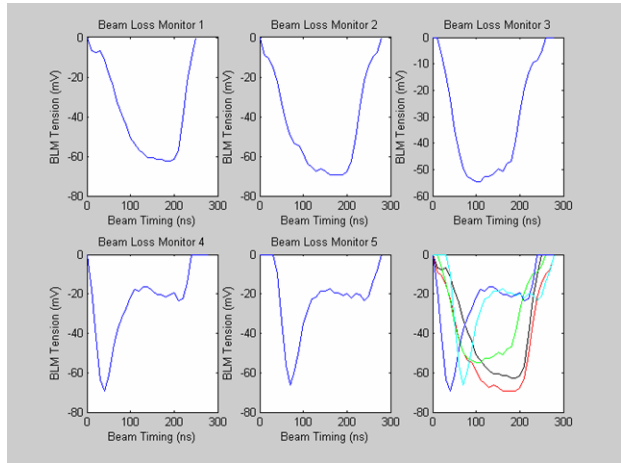


- 5 Beam Loss Monitors are installed and distributed along the PETS Tank
- The detectors are Aluminum Cathode Electron Multipliers. They have a fast time response (2ns) which allows to observe the time evolution of the beam losses.
- All the BLM's are supplied in parallel
- Every signal can be amplified in the tunnel using a 26/46dB 300MHz amplifier card.
- The output signals are then sent to fast Analog to Digital converters

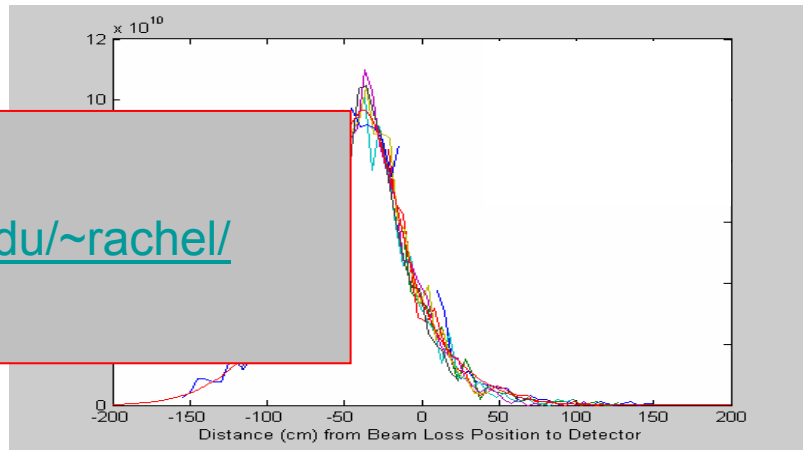


PETS Beam Loss Analysis Tool
Work done by Rachel Scheidegger

- **Beam Loss Analysis tool written to be incorporated in the control system**
- Signal Processing
- Suggest amplifier gain and ACEM polarization to optimize measurements
- Warn about detector saturation or long decay time
- Find general beam loss signal patterns to estimate position of loss, search for beam loss at a single position and intensity, search for constant beam loss all along the PETS
- Compare signals to Geant3 simulations to find ex
  intensity
- Relate be
  beam inte



Smooth Noise
Correct offset
Synchronize detectors



Work ongoing ….

http://diablo.phys.northwestern.edu/~rachel/

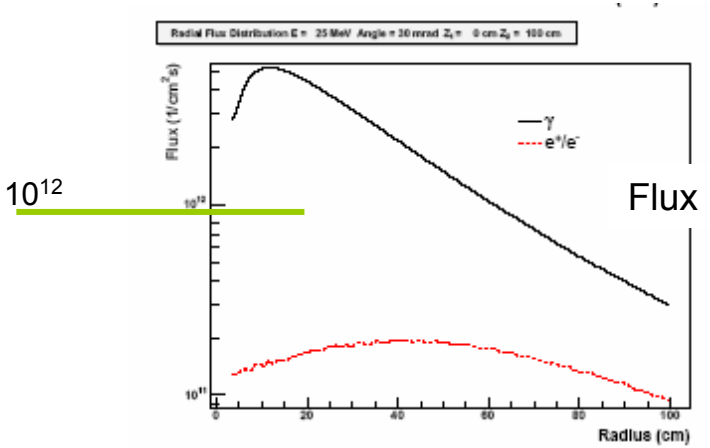
For updated status

Beam Loss from simulation … cont

25 MeV electrons

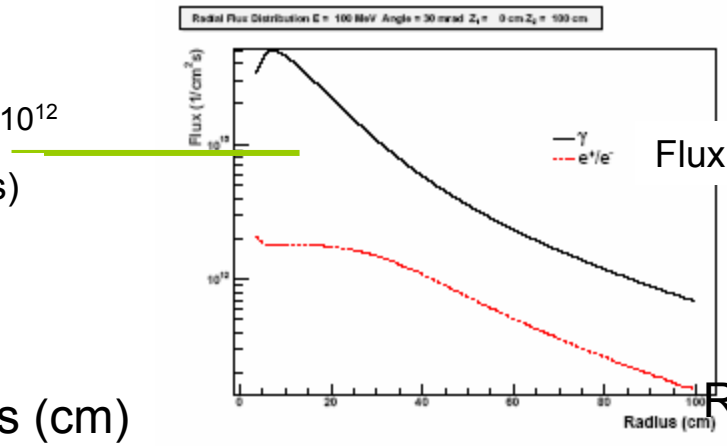
100 MeV electrons

Radial distribution of beam loss



10^{12}

Flux (1/cm²/s)



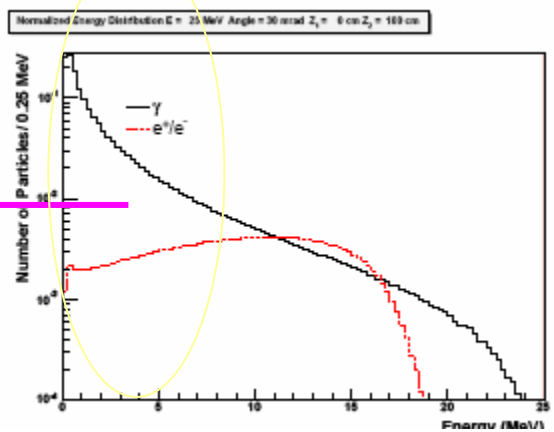
10^{12}

Flux (1/cm²/s)

Radius (cm)

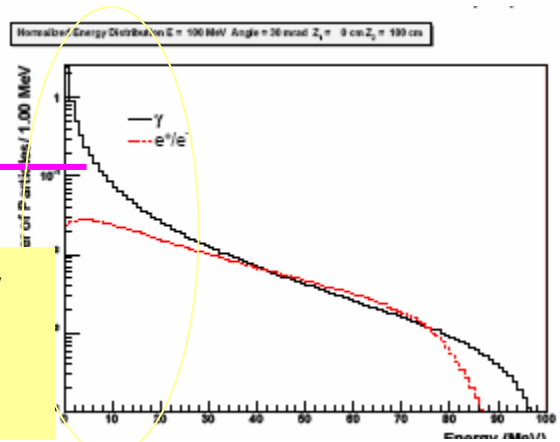
Radius (cm)

Energy Distribution of secondary particles at a distance of 100 cm from beam loss



10^{-2}

0 Energy (MeV) 25



10^{-2}

Dominated by low energy photons

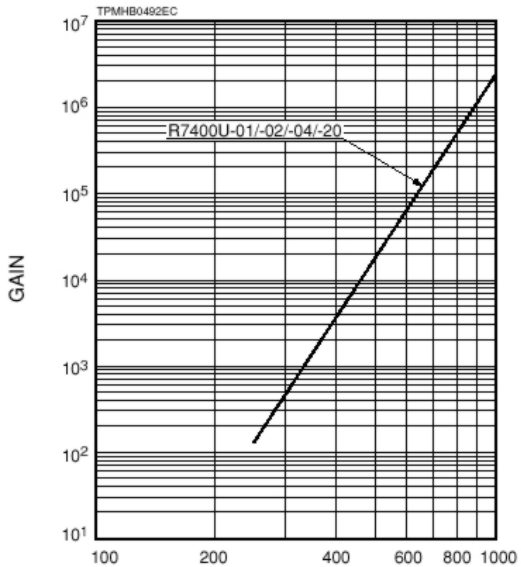
0 Energy (MeV) 100

M. Wood CTF3 note 061, (2004)

A. Dabrowski, November 24 2004

PMT used Hamamatsu R7400U series

Figure 5: Typical Gain Characteristics



Left: R7400U Right: R7401/R7402

At a given voltage the dynamic range is limited