Beam loss monitoring

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Beam Loss Monitoring @ CTF3

T. Lefevre

- Goal:
  - Beam Loss Monitoring should provide additional monitoring information to the BPMs, in the regime where the BPM's are insensitive (<< % loss of beam current)
  - Detectors should time resolve the losses within the pulse (time energy dependence due to beam loading)
- Simulations work for EM showers in the CTF3 linac (2003)
- Test of different types of detectors installed along the linac
  - Small Ionization Chambers (SICs)
  - Faraday cups
  - Aluminum Cathode Electron Multiplier (ACEM)
  - Cherenkov Fiber coupled to a PMT

Geant3.21 simulation

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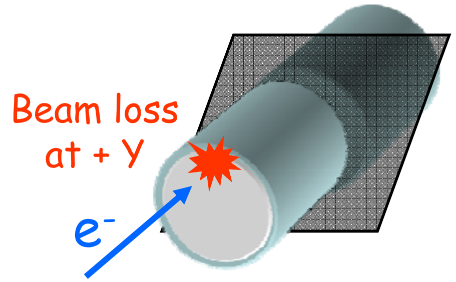
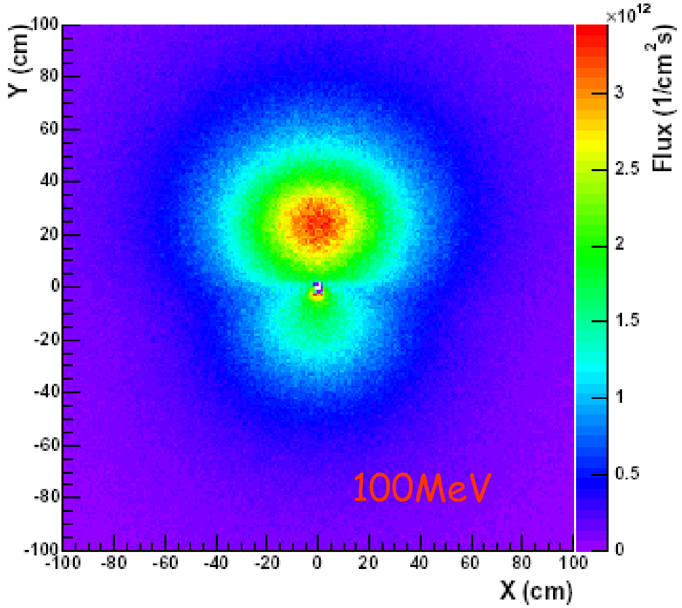
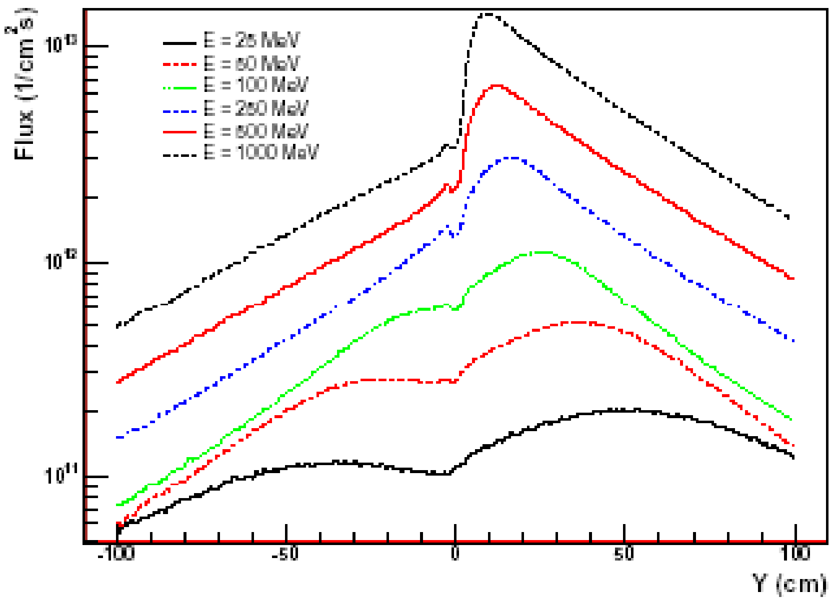
Beam pipe simulations : Transverse distribution of the e⁻/e⁺ shower

Simulations based on a beam loss corresponding to the ‰ of the nominal beam current



Position of observation : 1m dowstream





- The total flux of electrons in the shower is proportional to the electron energy
- With higher beam energies, the shower asymmetry is more pronounced

[1] M. Wood, CTF3 note 064, (2004)

Geant3.21 simulation

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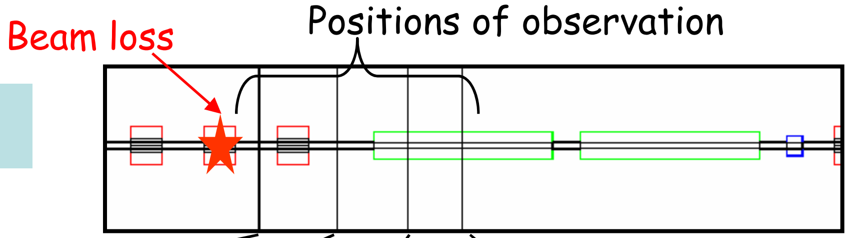
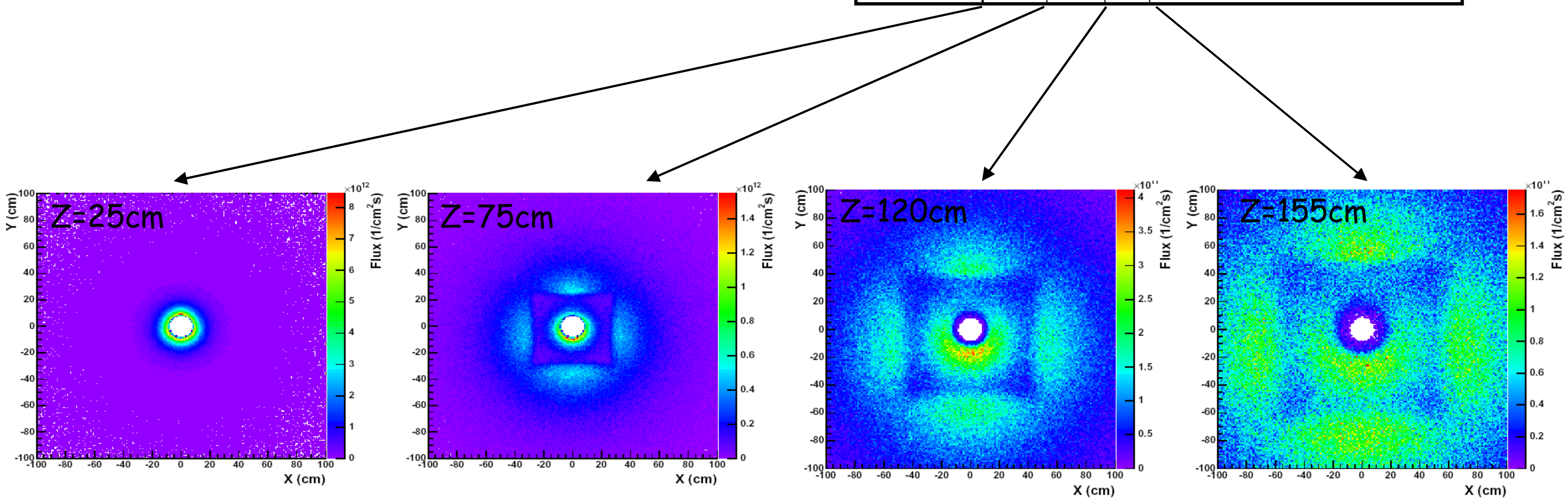
Beam loss in the Central quadrupole



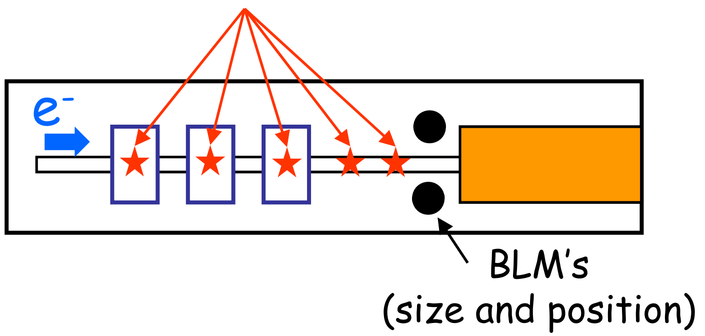


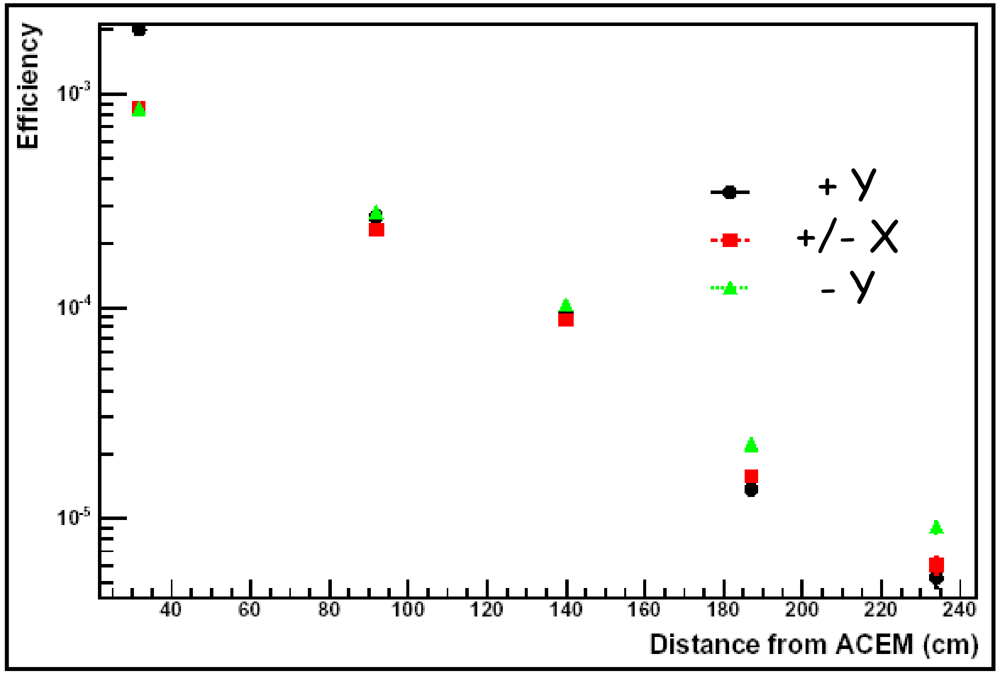
⇨ Screening effect of the 3rd quadrupole which reverses the transverse distribution of the e^-/e^+ Shower

[1] M. Wood, CTF3 note 064, (2004)

Geant3.21 simulation

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





Simulations

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

⇨

- The shower transverse distribution is affected by the presence of Quadrupoles
- For losses on the beam pipe the asymmetry corresponds to 50%
- Beam loss position → more than 2 orders of magnitude difference in the shower efficiency
- For losses > 1‰ of beam current → Detector must be able to measure currents > 100nA

[1] M. Wood, CTF3 note 064, (2004)

Data collected @ CTF3

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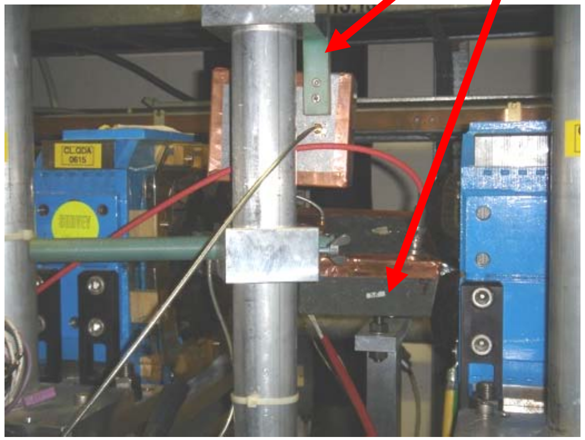
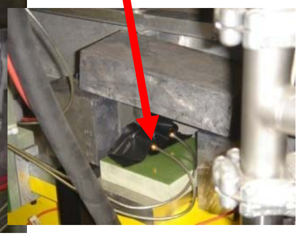
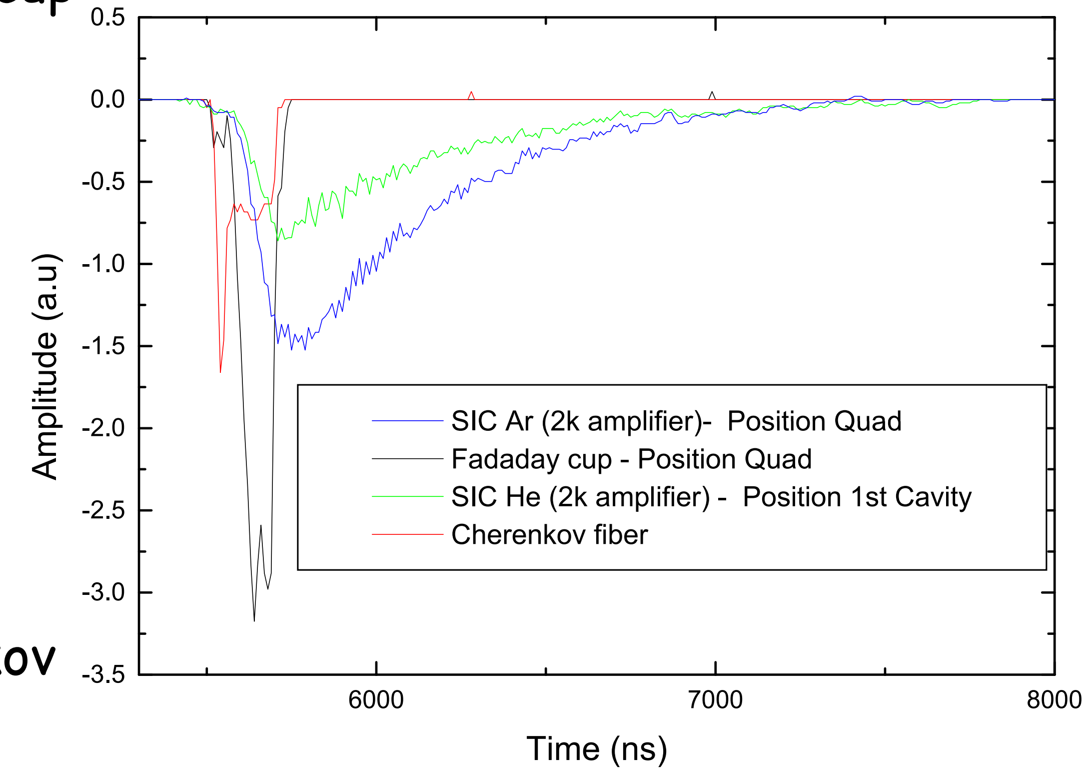


- SIC Argon
- Faraday cup

-Cherenkov fiber
- PMT





BLM devices Tested at CTF3

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Device	Type of Signal	Sensitivity	Timing	Radiation Hardness	Spatial coverage	Cost
SICs	Ionization in Argon	0.1% of be 10^5 - p/cm				500CHF
Faraday Cup	Stopping charged particles	0.01 % of beam current	Fast	Very	Small	00CHF
ACEM	Secondary Electron Emission & amplification	<0.01% current				1000CHF
Optical Fiber connected to PMT	Cherenkov Light	<0.01% curren				00CHF

Good for integrated measurements
(can we improve the spatial coverage)

Limited to low beam energy (<200MeV)

Limited by their size

Looks quite promising

Beam loss @ CLIC

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•In terms of machine protection system, both beams need to be carefully monitored at all times. Even though the Drive Beam has a relatively low energy of 2.4 GeV, it carries a high average current of 94 A. During nominal operation, it would thus contain a total beam power of 86 MW which has to be compared to the 30 MW carried by the beams to collide. (*Identify the Beam loss tolerances*)

• An additional complexity in CLIC comes from the fact that the two beams propagates at the same time at a short distance the one from the other. The design of the beam loss monitors must ensure that the two beams are monitored accurately. (*Develop monitors capable to disentangle losses from the Main or/and the Drive Beams*)

• One technical solution would be to design the BLMs of the Main Beam with an energy threshold slightly higher than the Drive Beam energy. The detector could be based on the Cherenkov effect.

• The Two-Beam Test Stand in CLEX is the natural place to test and develop the detectors

Conclusions @ CTF3

- Several detectors have been tested on CTF3 with success
  - Radiation hard system
  - Azimutally distributed system to localize the loss and minimize the measurement error
  - Preferably with a fast time response (not necessary everywhere)

- **The beam losses along the CLIC tunnel must be studied very carefully.**
  - **Simulations effort to be done**
  - **The CLEX-TBL and TBTS would be the ideal place to test the monitor**

Cherenkov in gases

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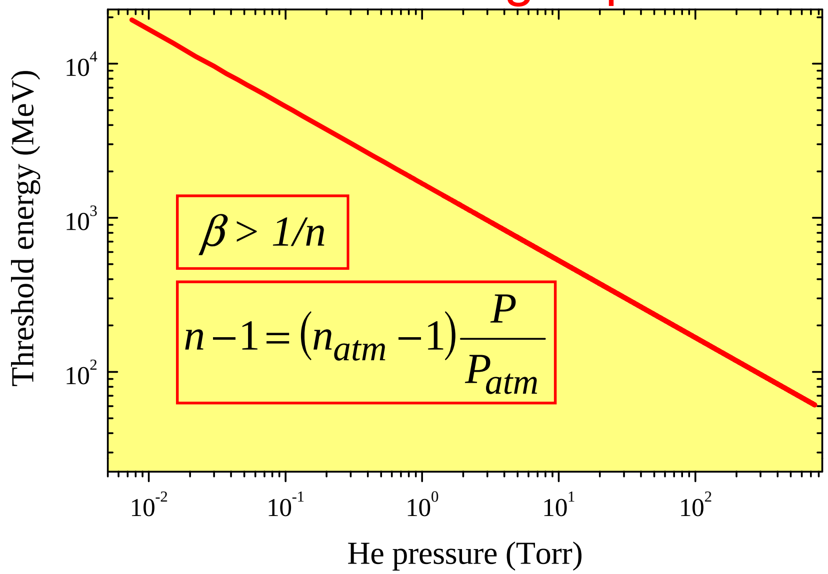
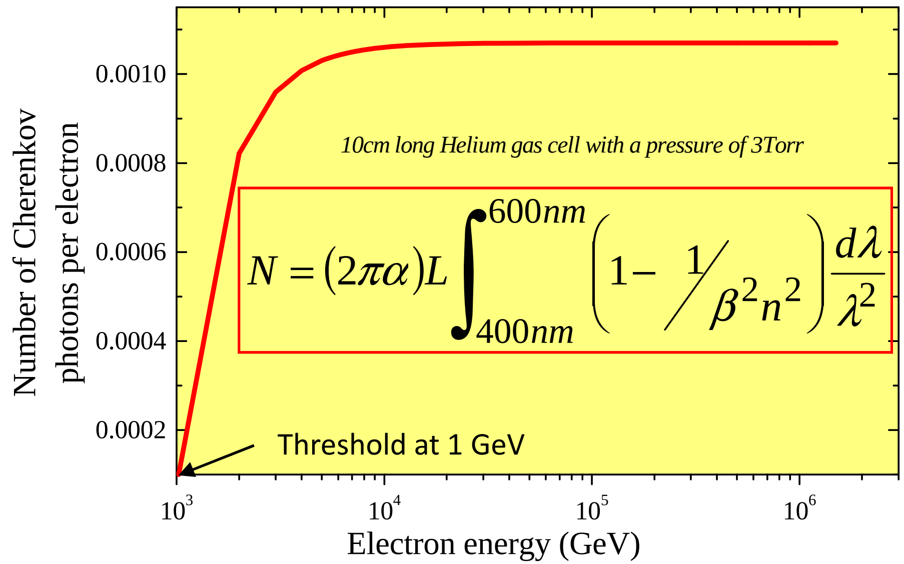
Threshold Cherenkov detector : $\beta > 1/n$

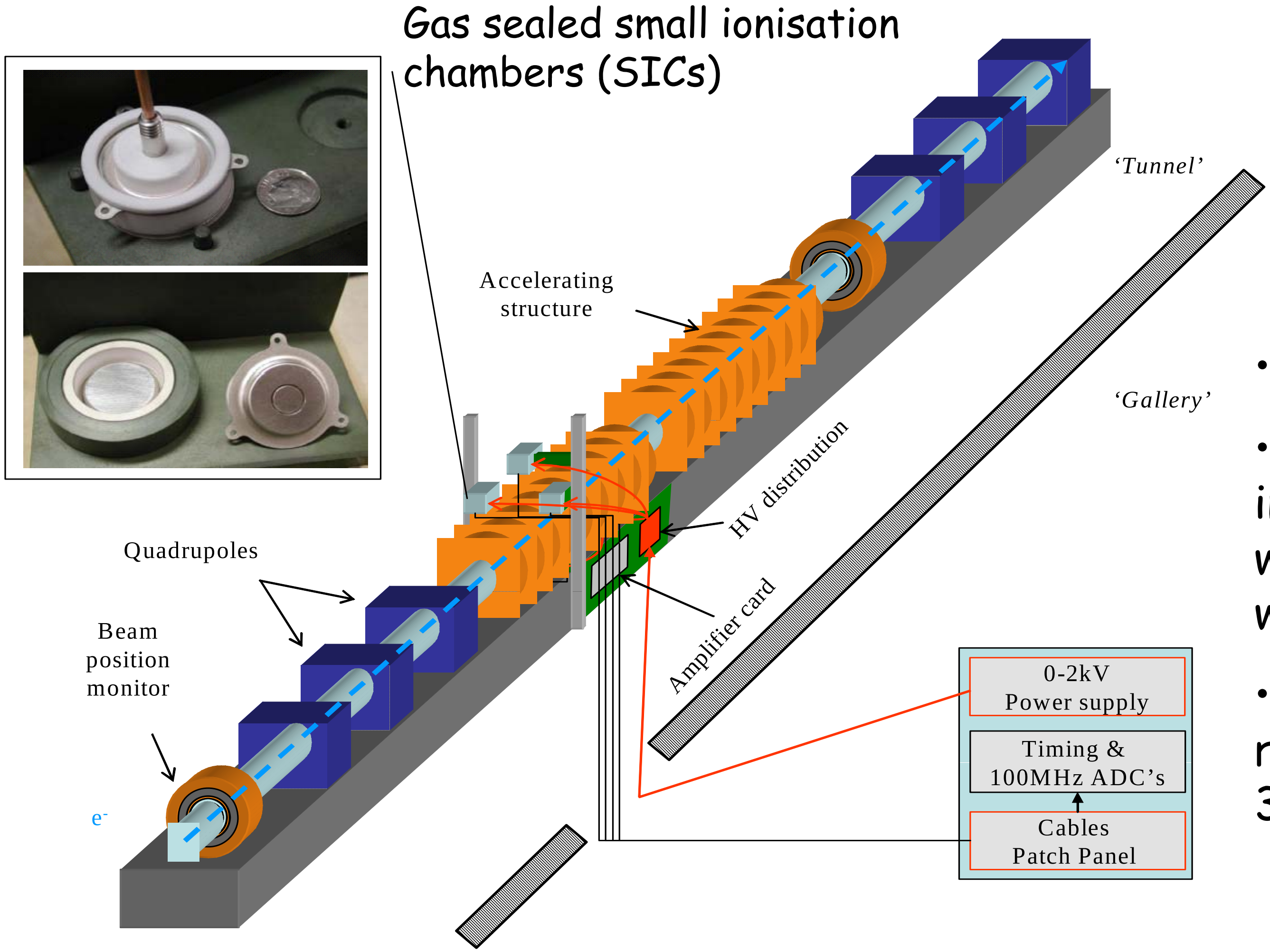
Cherenkov radiator (1atm)	Silica aerogel	Pentane C_5H_{12}	Ethane C_2H_6	Argon Ar	Neon Ne	Helium He
Index of refraction (n-1)	$8.4\ 10^{-3}$	$1.7\ 10^{-3}$	$7.1\ 10^{-4}$	$2.8\ 10^{-4}$	$6.7\ 10^{-5}$	$3.5\ 10^{-5}$
Cherenkov threshold (MeV)	3.5	8.2	13.1	20.9	43.5	60.4

Evolution with the gas pressure





Beam Loss monitoring



- Full setup since 2004
- 3 detectors (SICs) installed per girder, with a cross calibration with Faraday cup
- Electronics with 2 gain ranges (26/46dB 300MHz from CERN)

SIC signals: Calibration Plateau

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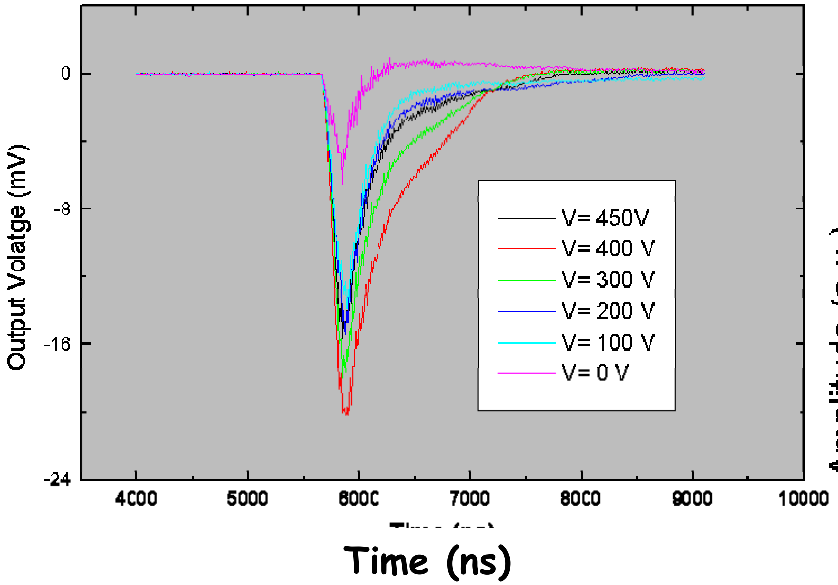
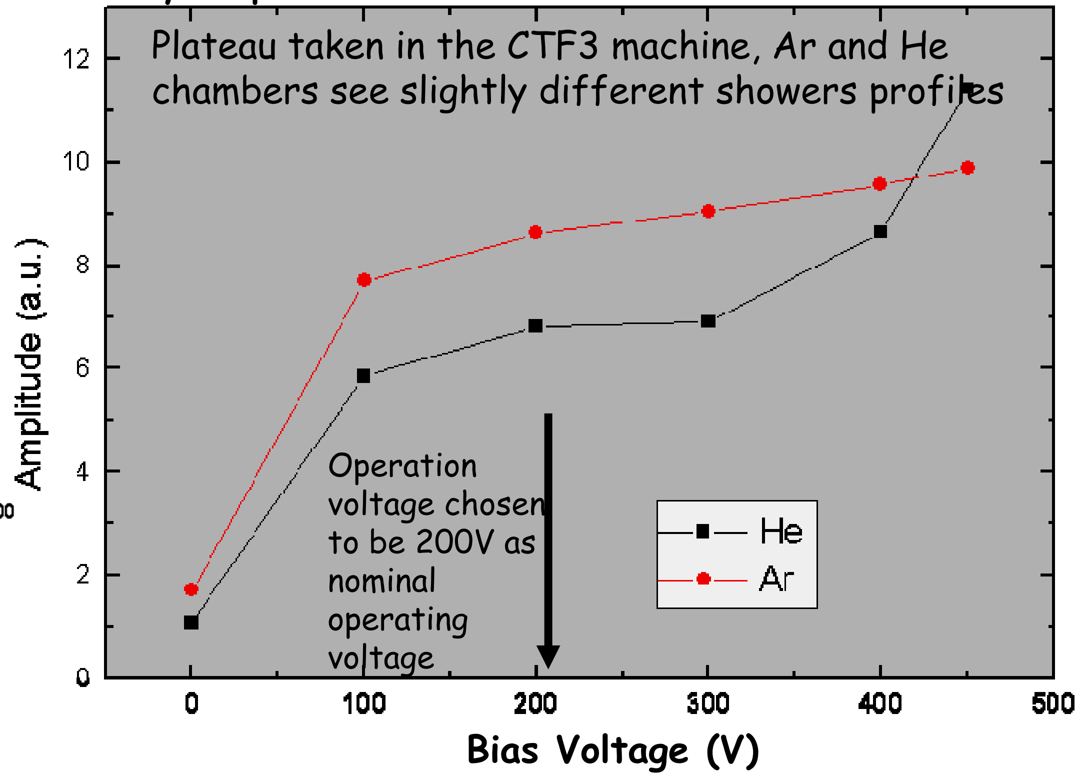
Calibration Plateau for chambers (SIC) filled with He or Ar gas taken in the CTF3 machine, normalized to the Faraday cup





Linear response between Chamber and Faraday cup

Calibration Factor ~ 6 depending on beam loss shower shape

Length of Plateau greater for Ar as expected. He breaks down at > 450 V

Ionization signal efficiency 8/94 for He/Argon gas …and independent of energy. Chambers designed for high rate environment and saturate (with Argon) at ~ 10^{11}cm^2/μs pulse

ACEM / PMT

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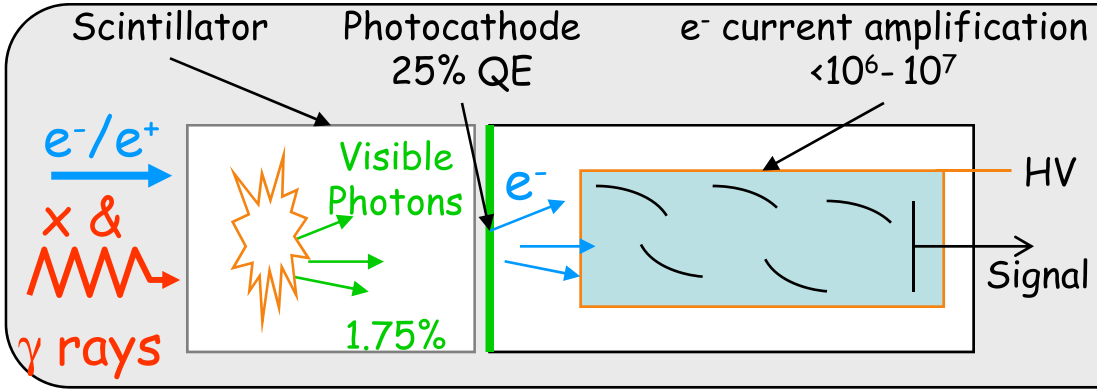
Two different types of detectors (ns time response) have been tested in parallel

- A 4mm thick **plastic scintillator** (Ø40mm) coupled to XP2020 **photomultiplier tube**

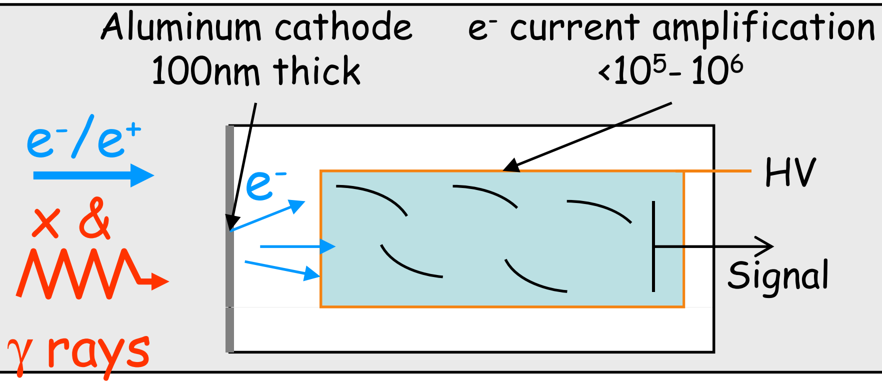


• e- / e+ :
[1, 20]MeV → 500 - 1000 photo-e-

• γ & x rays :
[10keV,20MeV] → 4 - 100 photo-e-

50mV/50Ω → μA-pA

- An **Aluminum Cathode Electron Multiplier** (ACEM) (Ø38mm)



• e- / e+ :
[1, 20]MeV → 1 - 5% SEM e-

• γ & x rays :
[10keV,20MeV] → 4.10^{-6} - 2.10^{-9} SEM e-

50mV/50Ω → 100mA-100nA

Localizing the beam loss

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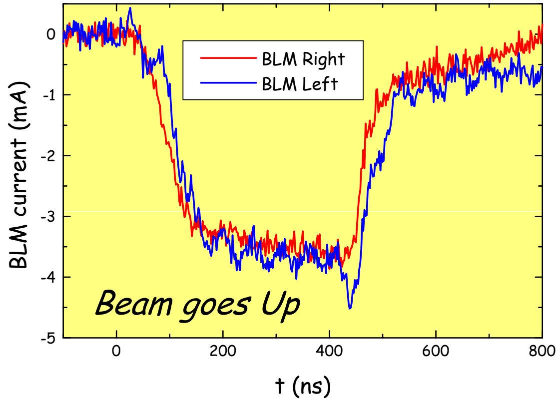
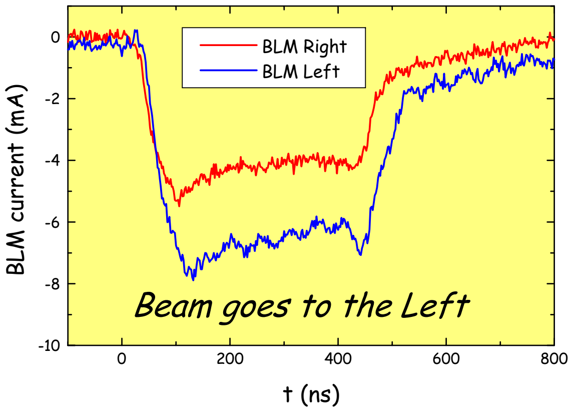
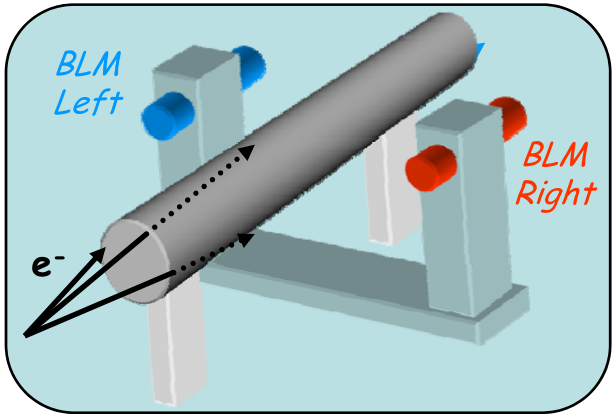
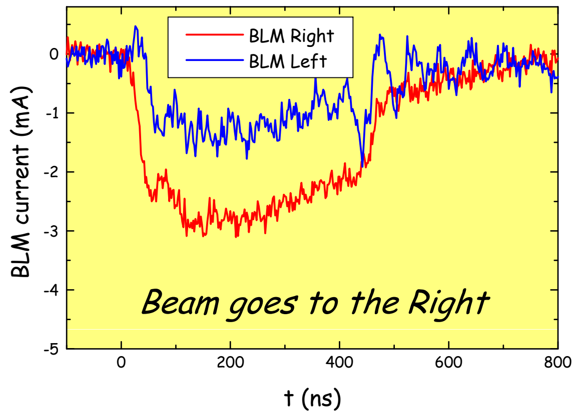
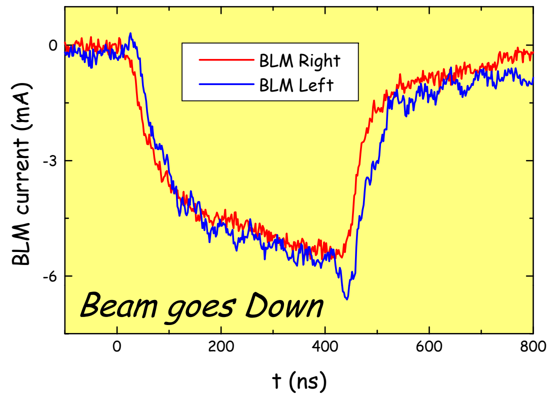
Localizing the beam loss transversely ?











- In vertical scans the beam loss is equally distributed on the two detectors and their output signals are equivalent (<5% difference)

- In horizontal scans the BLM output signals are different in a ratio of 2 (40-60%)