LHC Beam loss Monitors

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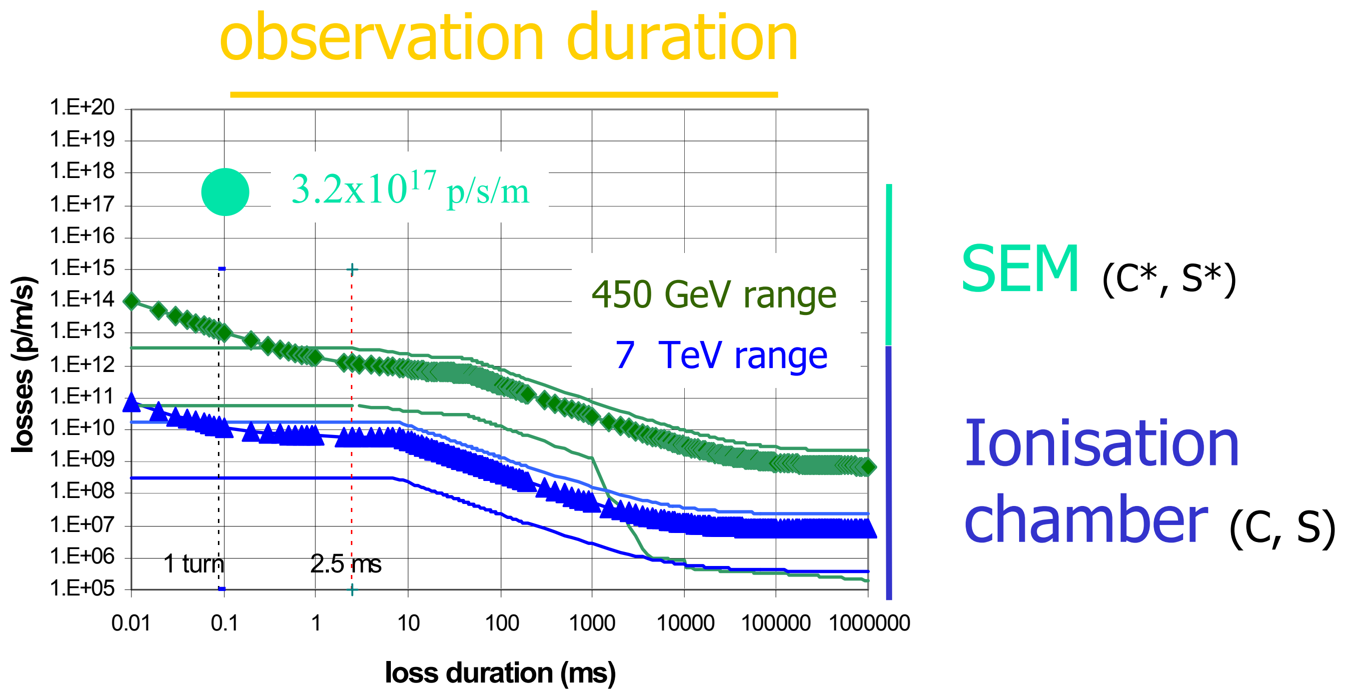
Loss monitor specifications

Radiation tolerant Electronics

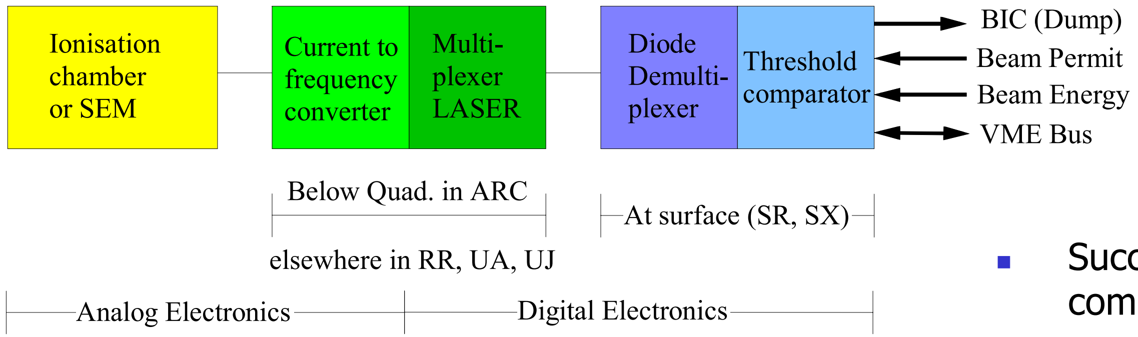
Ionisation chamber development

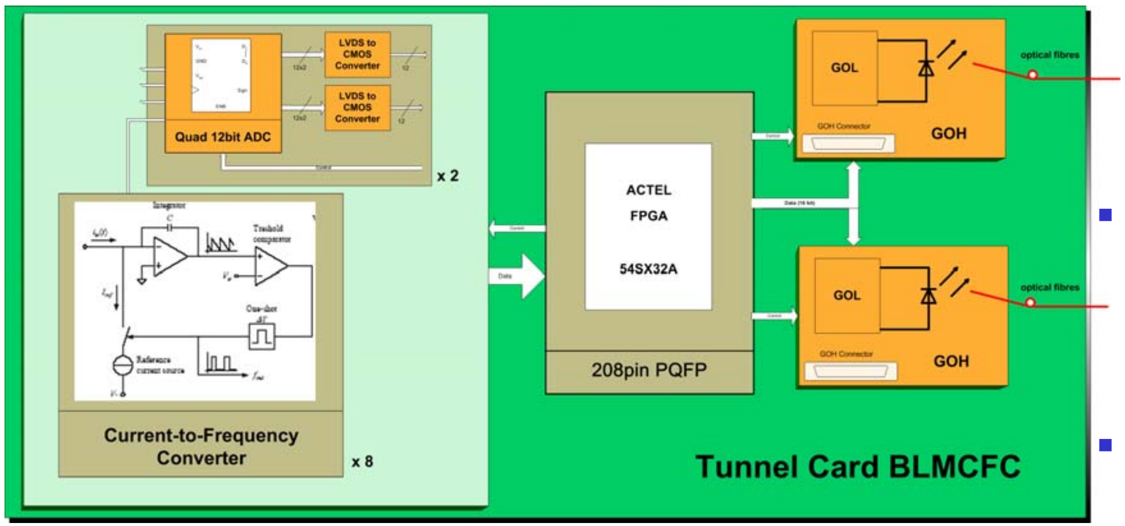
BLM Specifications (Quench Levels)



- Variety of BLM families (A, C, C*, S*), accuracies: rel.: 0.25, absolute 5, later 2
- Identical electronics located near chambers => radiation tolerant design
- Dynamic range in:
  - Time: t_{min} = 89 us – t_{max} = 100 s => response time of ion chambers
  - Intensity: 2.5 pA - 1 mA => linearity of chamber response

Digitalisation Electronics



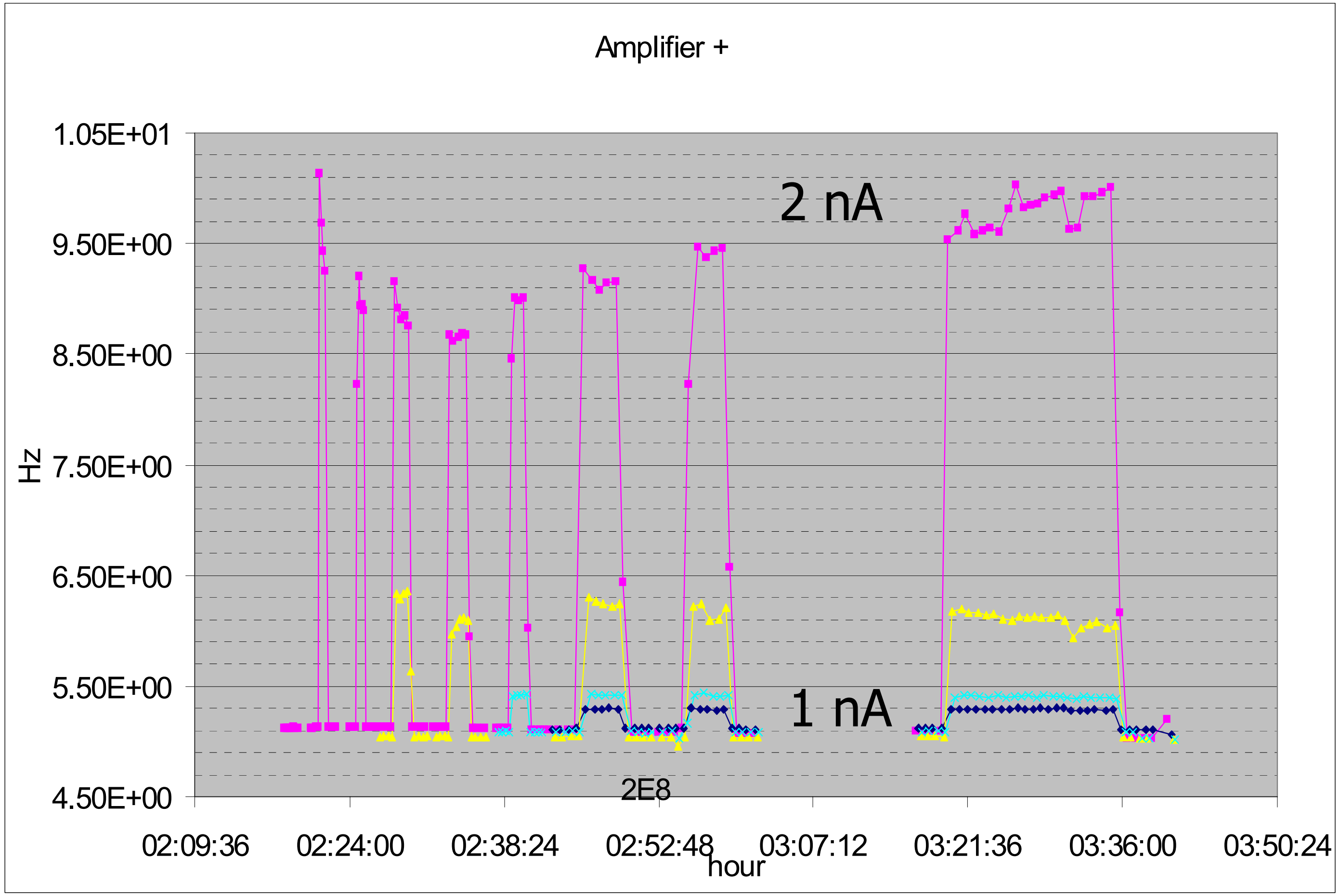


- Successful test of radiation tolerant components (> 500 Gy)
  - FPGA (ACTEL, anti fuse)
  - GOL/GOH (CMS, 3 kGy)
  - ADC (CMS, AD 41214, 12 bit)
  - Level converter (CMS Ecal LVDS_RX, 100 Gy)
  - Current to frequency integrator (OPA627)
- Partially tested
  - Current to frequency converter
    JFET, diodes, DAC (offset compensation)
  - FPGA (with program)
  - Ionisation chamber, SEM
- No successful
  - ADC (AD 7492, 12 bit)

Ionisation chamber currents (1 litre)

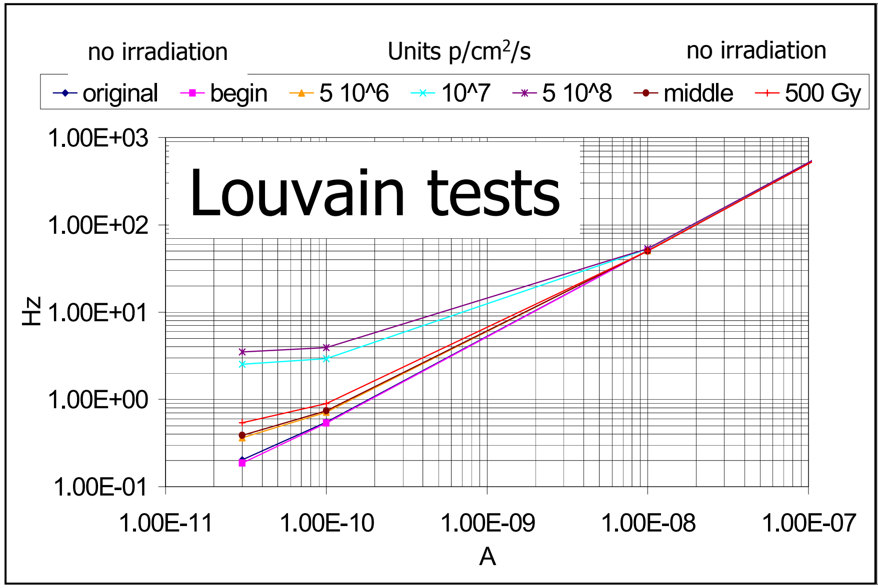
450 GeV, quench levels (min)	100 s	60 nA
7 TeV, quench levels (min)	100 s	10 nA
Required 25 % rel. accuracy, error small against 25% => 5 %		100 pA
450 GeV, dynamic range min.	10	10 pA
	100	2.5 pA
7 TeV, dynamic range min.	10 s	160 pA
	100s	80 pA

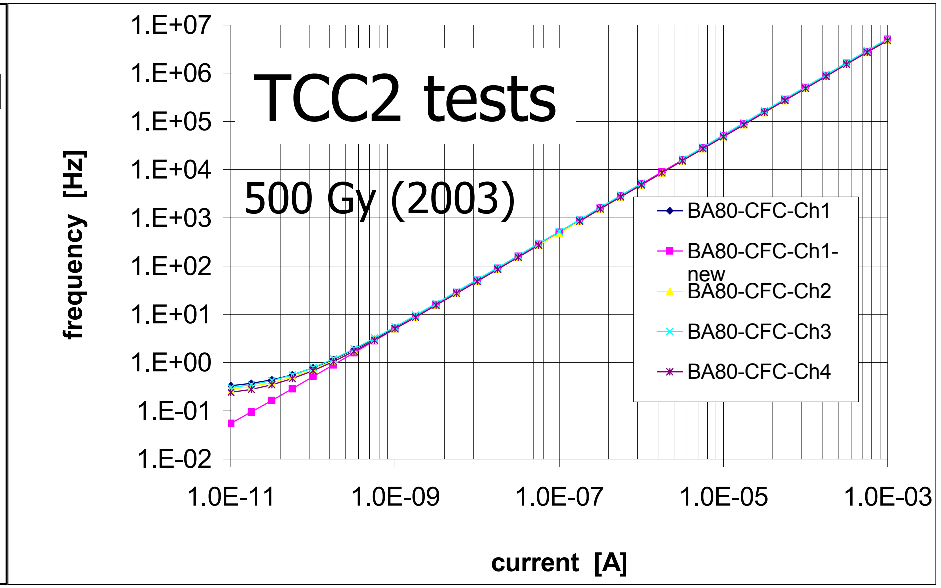
AMPL+JFETs



Irradiation of Amplifier and JFET results in an increase of the output signal

Component Irradiation JFET integral dose





Observation: Increasing of (low current) signal during irradiation and integral dose effect.

Irradiation of Single Components

Component	Supplier	Name	Integral dose (effects after irradiation)	Single event (5E8 p/s/cm^2)
CFC JFET (switch)	TEMIC	J176	70 pA after 500 Gy ($\rightarrow$ calibration)	+700 pA (dark current)
CFC JFET + diode (switch)	TEMIC, ?	J176	< 10 pA	to be tested
CFC Amplifier	BURR-BROWN	OPA627	30 pA	-800 pA (current into the component)
CFC threshold comparator	PHILIPS	NE521	No	~+100 pA (threshold value is lower)
CFC monostable	PHILIPS	74HCT123	No	Small

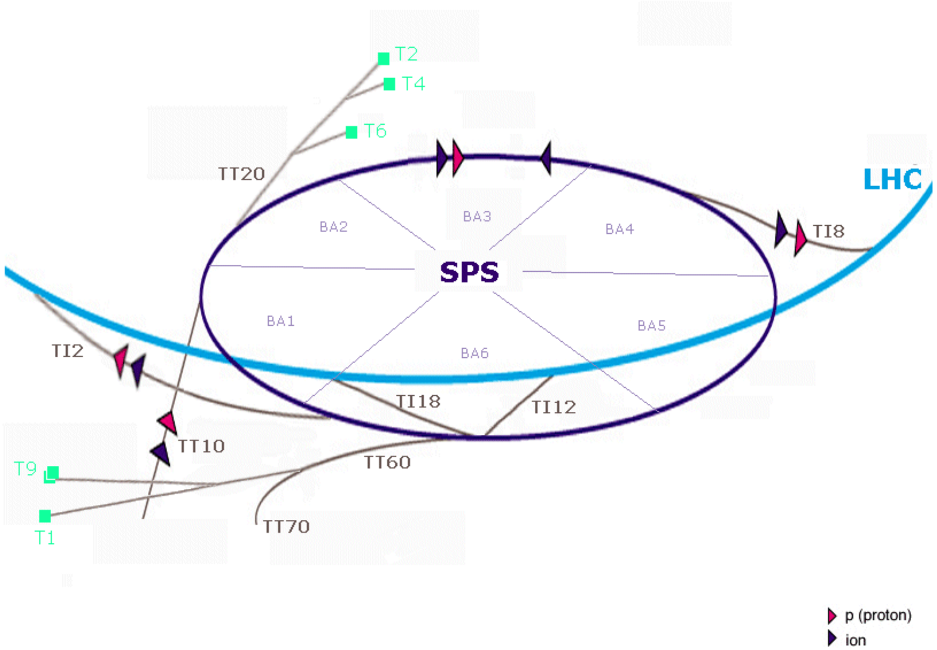
- Successful change of JFET switch circuit
- Offset current variation of amplifier compensated by DAC (to be tested)

Dose at Quench Levels below Quadrupole Magnets and Single Event Effect

Energy	Steady state loss [p/m/s]	Geometrical factor	Loss FWHM [m]	MIP/p/cm^2	MIP/s/cm^2 on the CFC	quench limits current	Gy/y	weights	range (at dump limit)
450 GeV	7.00E+08	1.00E-01	3	3.00E-03	6.30E+05	60 nA	5.59E+02	0.3	max Gy/y
				5.00E-04	1.05E+05	10 nA	9.32E+01	0.3	7.26E+01
7 TeV	7.00E+06	1.00E-01	3	4.00E-02	8.40E+04	8 nA	7.46E+01	0.7	min Gy/y
				8.00E-03	1.68E+04	1.6 nA	1.49E+01	0.7	1.27E+01

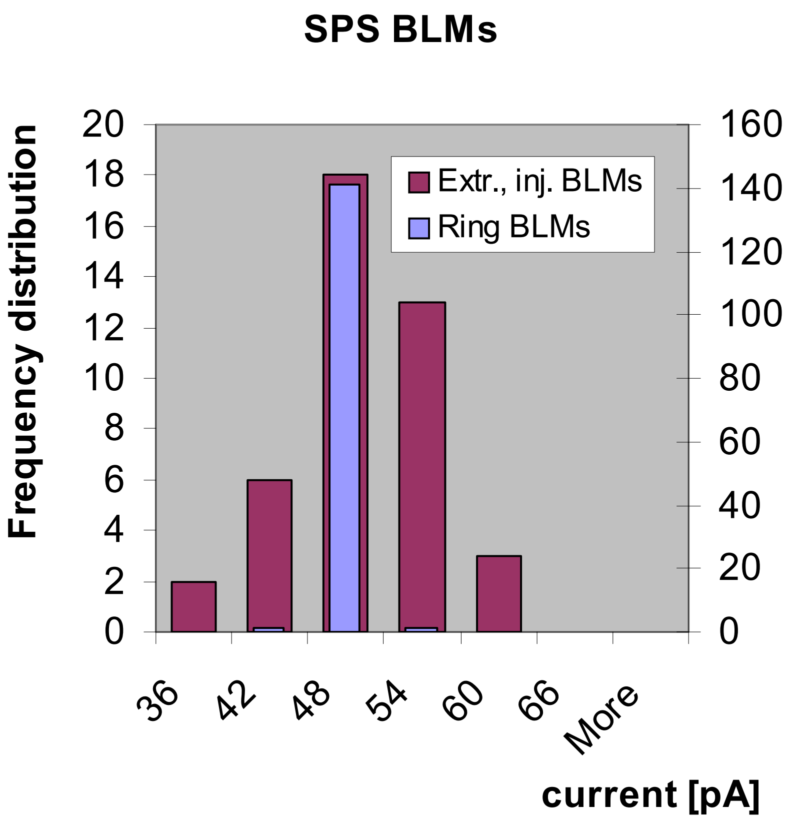
- Offset current increase due to SEE
  - offset current proportional to loss rate
  - ratio: offset current to loss rate, location and energy dependent
  - Effect blow < 1% of loss rates (negligible error)

Ageing Test of Ionisation Chamber in the SPS (I)



- SPS system:
  - Ionisation chambers with parallel plate geometry (0.5 cm separation)
  - Electronics in surface buildings with a analog signal transmission of about 1.5 km
  - Operation time:
    - chambers over 20 years
    - electronics 10 years
  - Total received dose:
    - ring 0.1 to 1   kGy/year
- Test method:
  - Chamber gas ionised with Cs source
  - Observation of created charges with installed electronics (about 180 chambers)

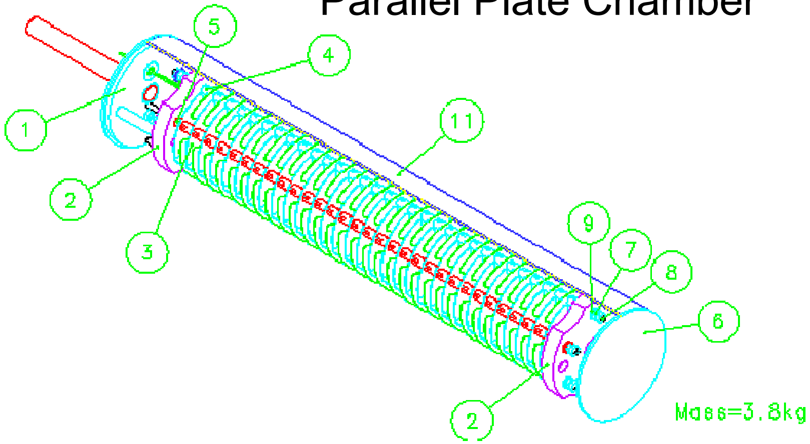
Ionisation Chamber and Electronics Tests SPS (II)

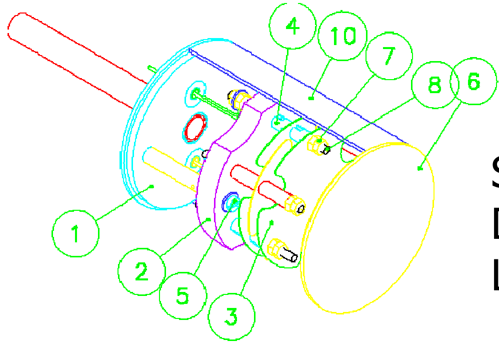


- SPS Results:
  - Relative variation between:
    - successive acquisitions
      σ/mean < 0.005
    - between different monitors
      σ/mean < 0.01 (for ring BLMs)
      σ/mean < 0.05 (for Extr., inj. BLMs)
- LHC:
  - Ionisation chamber material choice very close to SPS materials
  - Gas likely N_2 (SPS ring chambers N_2, others air)

Ionisation Chambers and SEM Detector for the LHC

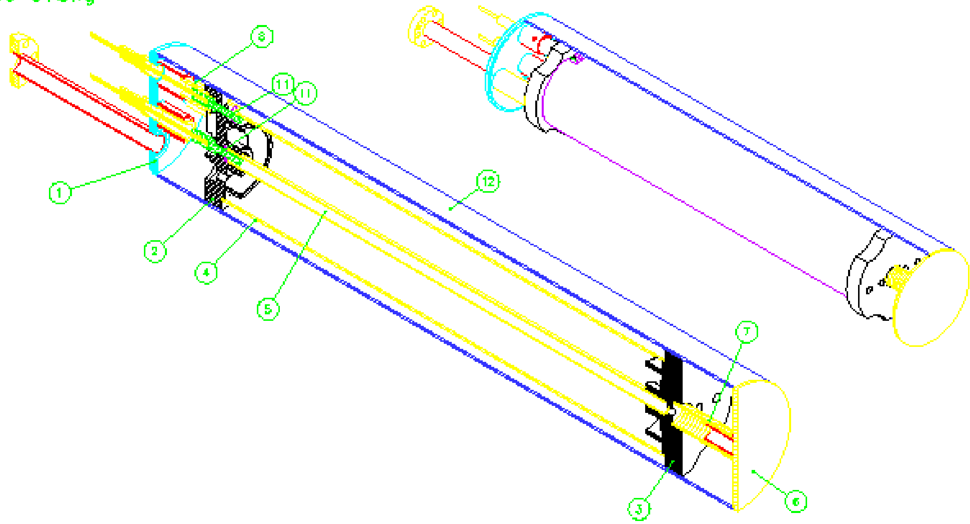
Parallel Plate Chamber





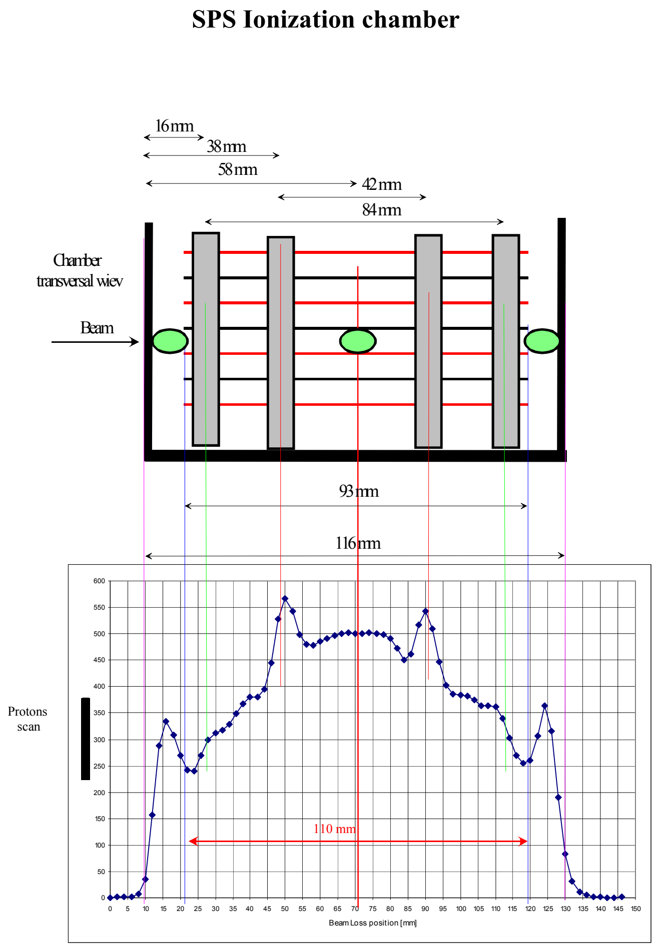
SEM
Diameter = 8.9 cm
Length 15 cm

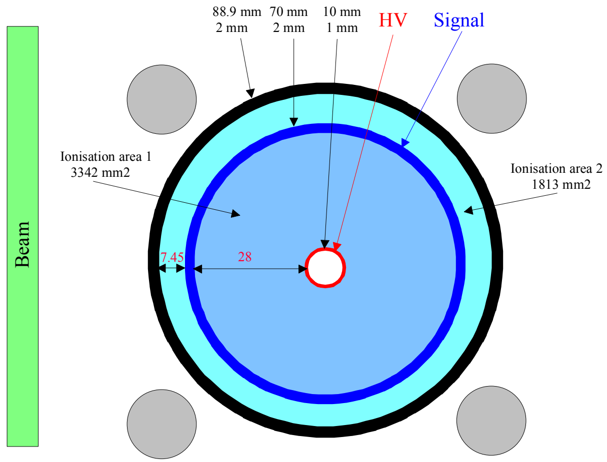
Coax Chamber

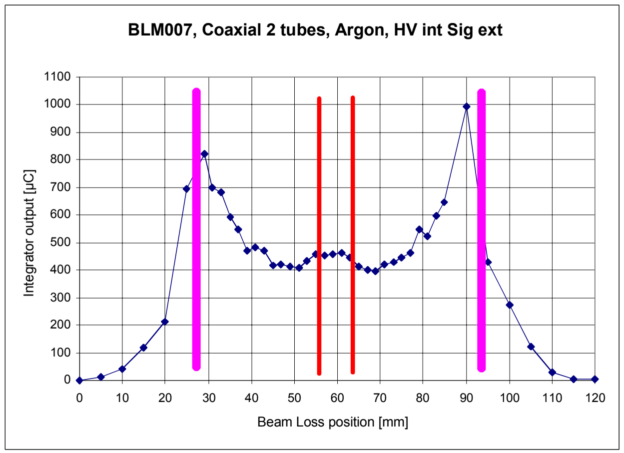


Diameter = 8.9 cm,
Length 60 cm, 1.5 litre,
Filled with likely N_2

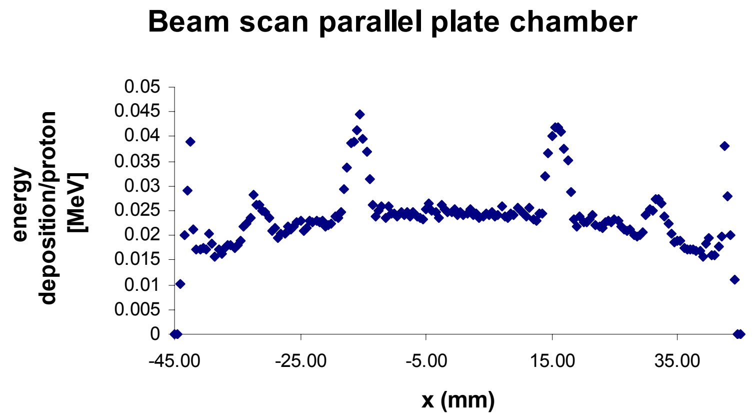
T2 Beam Tests

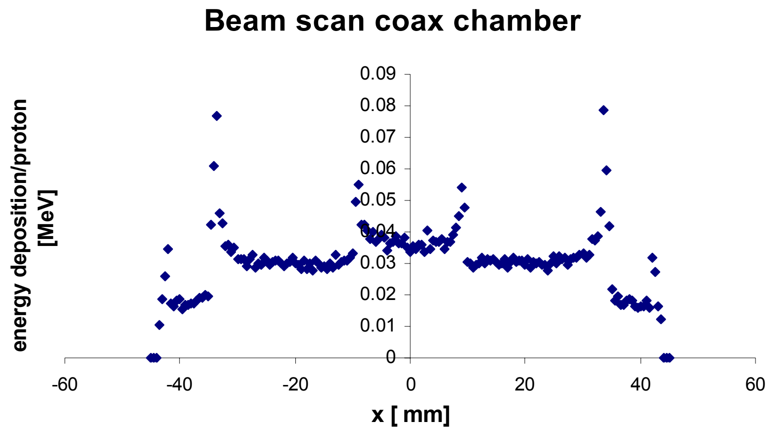






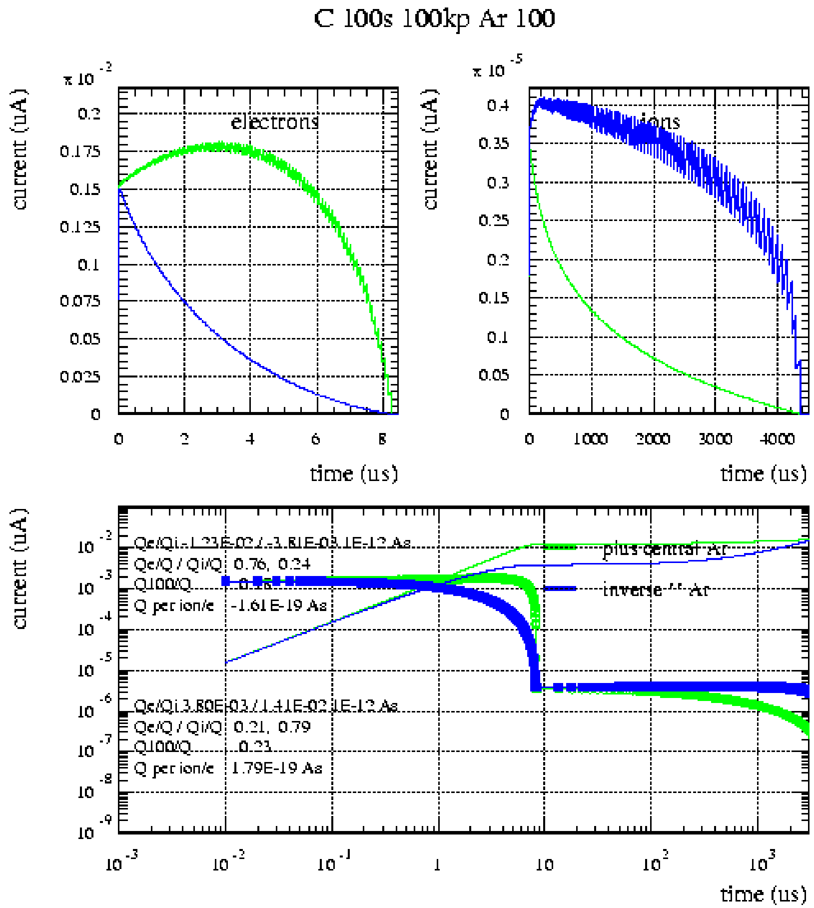
Geant Energy Loss Simulation





- Motivation for test measurements and simulations
  - required absolute accuracy (2) over large dynamic range (7 – 8 order of magnitude)
  - Detectors sensing far shower tails (trans. distance 38 cm) of the proton loss shower (inaccuracy of simulations, particle spectrum energy below 100 MeV @ 450 GeV)
  - test measurements only with proton beams
- Ongoing studies

Time Response Simulations (Garfield)



- Motivation: time response time optimization of coax chamber geometry, depending on:
  - Chamber geometry
  - Drift voltage polarity
  - Homogenous or non homogenous charge creation in volume
- Check with measurements in the BOOSTER (50 ns pulse, 5 10^8 prot. 1.4 GeV), ongoing

Summary

- Radiation tolerant design of BLM tunnel electronics almost finished, To be done:
  - Test of modified circuit
  - Test of FPGA with final program
- Ageing test of ionisation chambers in the SPS show small degradation of monitors (few exceptions, high dose area, …), chamber gas analysis ongoing
- Design of new LHC prototype ionisation chamber
  - Chambers are test
    - with different gases (N_2 Ar, $ArCO_2$)
    - in different beams (H6, T2, BOOSTER dump line)
  - Energy deposition and time response simulation are almost finished.
- SEM proto type detector
  - next year to be tested in BOOSTER dump line