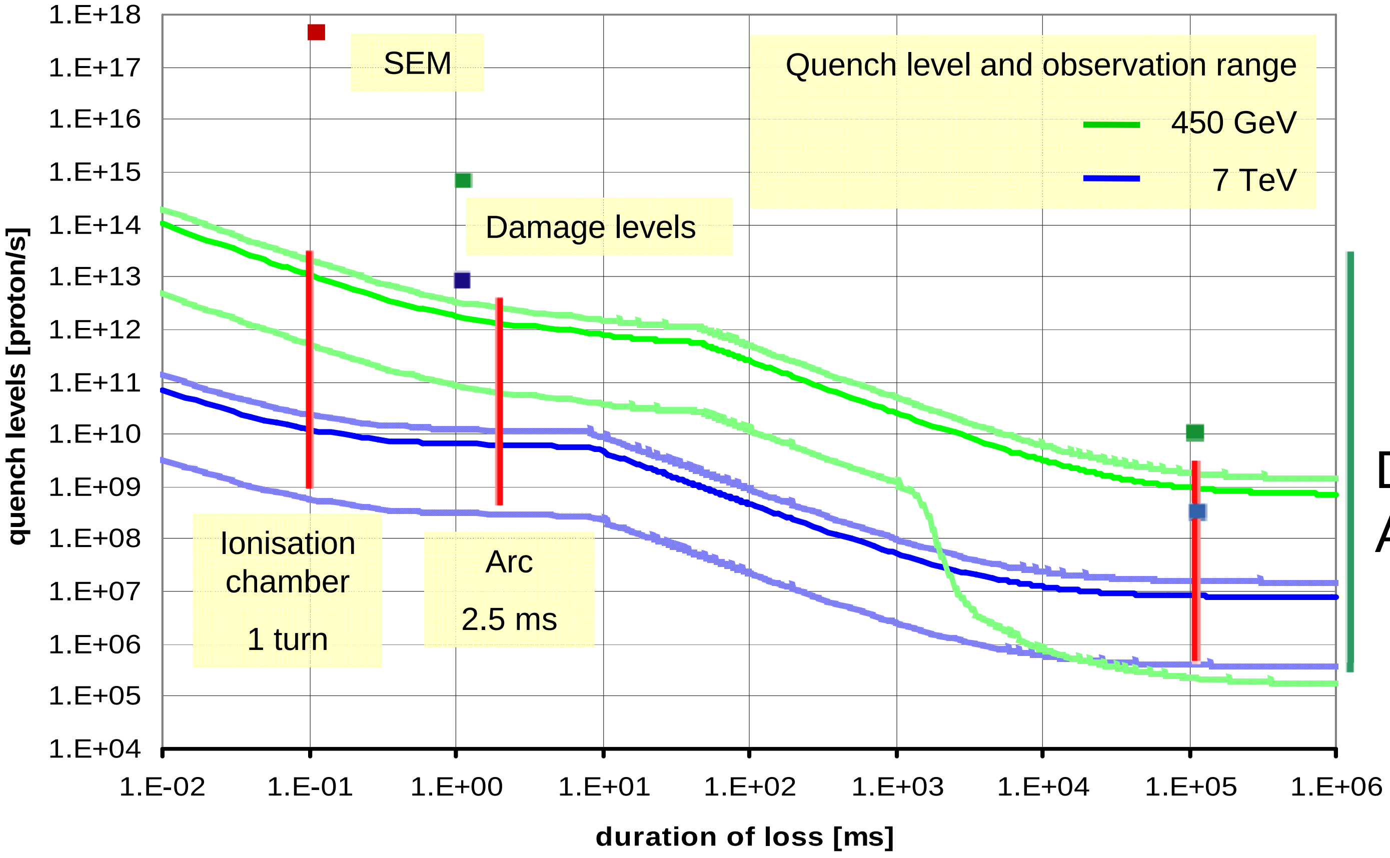
Beam loss monitoring requirements and system description

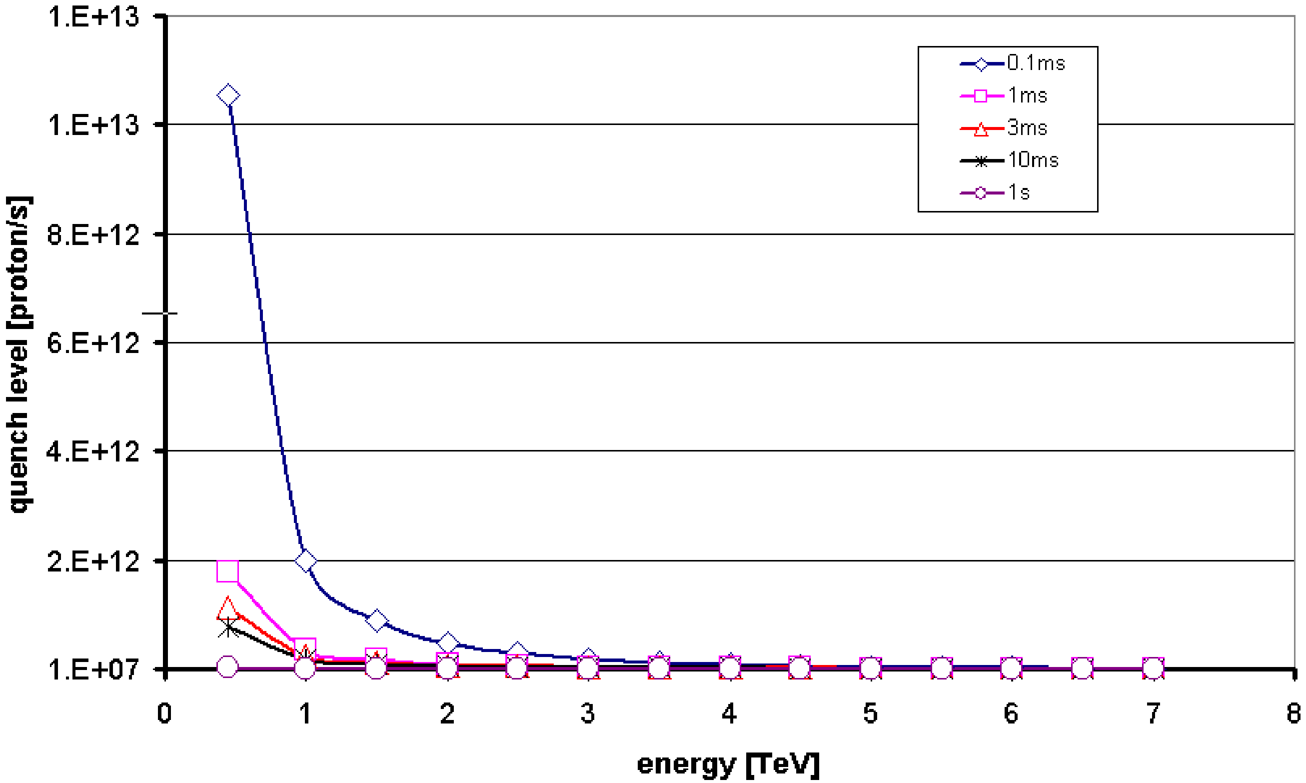
- Introduction
  - Quench and damage levels dependencies
  - System specifications
- Loss location and secondary showers
- Ionisation chambers
- Radiation and electronics
- Collimation areas and beam loss measurements
- Ions

Operational Range of BLMs



Dynamic Arc: 10^8

Quench Levels and Energy Dependence



Fast decrease of quench levels between 0.45 to 2 TeV

Loss Levels and Required Accuracy

Relative loss levels		
	450 GeV	7 TeV
Damage to components	320/5 ***tran./slow***	1000/25 ***tran./slow***
Quench level	1	1
Beam dump threshold for quench prevention	0.3	0.3/0.4 ***tran./slow***
Warning	0.1	0.1/0.25 ***tran./slow***

Specification:

Absolute precision (calibration)	< factor 2 initially: < factor 5
Relative precision for quench prevention	< 25%

Accurately known quench levels will increase operational efficiency

Reliability and Time Resolution

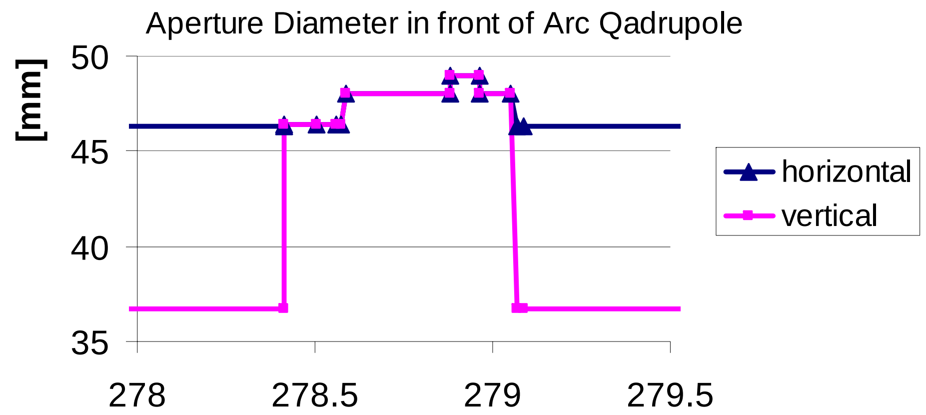
Area of use	*Observation range*	*mask able*	*Time resolution*
Collimation sections	extended	no	1 turn
Critical aperture limits or critical positions	Extended + standard	no	1 turn
All along the rings	standard	yes	2.5 ms
Primary collimators	special	yes	1 turn + Bunch

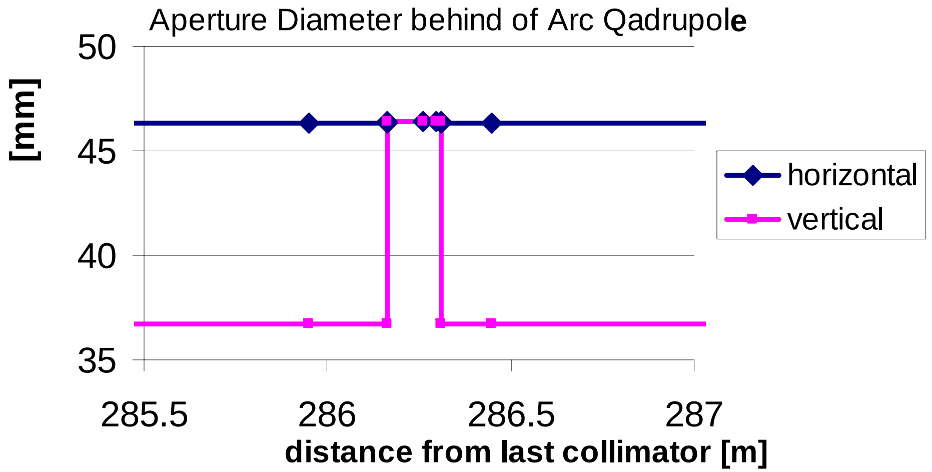
non-mask able: In case of a non working monitor this monitor has to be repaired before the next injection

Some more Specification Requirements

- DATA FOR THE CONTROL ROOM AND THE LOGGING SYSTEM
  - Loss rates normalized quench level, (energy and integration time-independent)
  - Updated every second
  - Coincidence of several close-by quadrupoles
  - Allow frequency spectrum analysis
  - Long term summation for comparisons with dose detectors
- POST-MORTEM ANALYSIS
  - Store data 100 - 1000 turns before post mortem trigger
  - Average rates few seconds to 10 minutes before a beam-dump
- False dumps
  - less than one per month
- BEAM 1/BEAM 2 DISCRIMINATION
  - If possible, higher tuning efficiency
- A set of movable BLM's

Change of Aperture at Quadrupoles



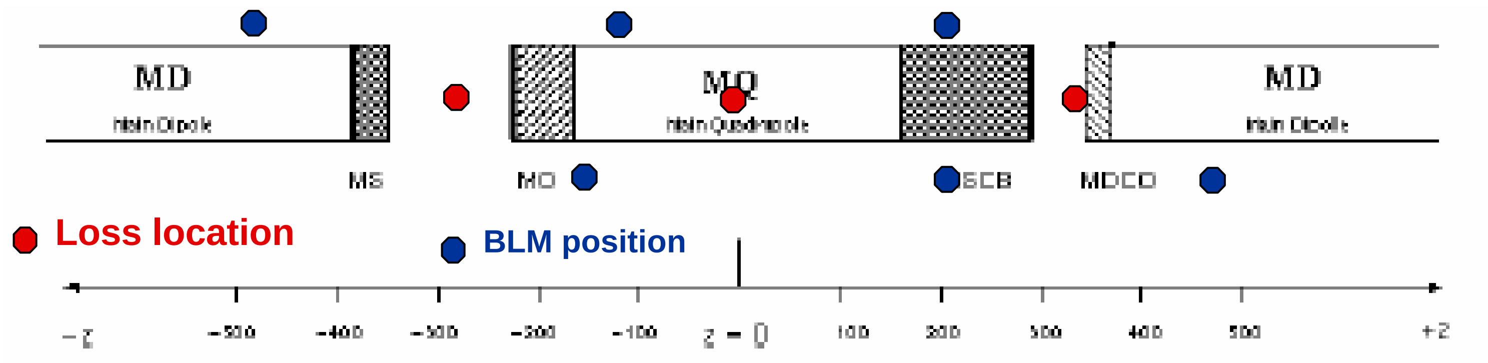


Secondary and tertiary halo tracking
=> proton loss location
(talk S. Redaelli)

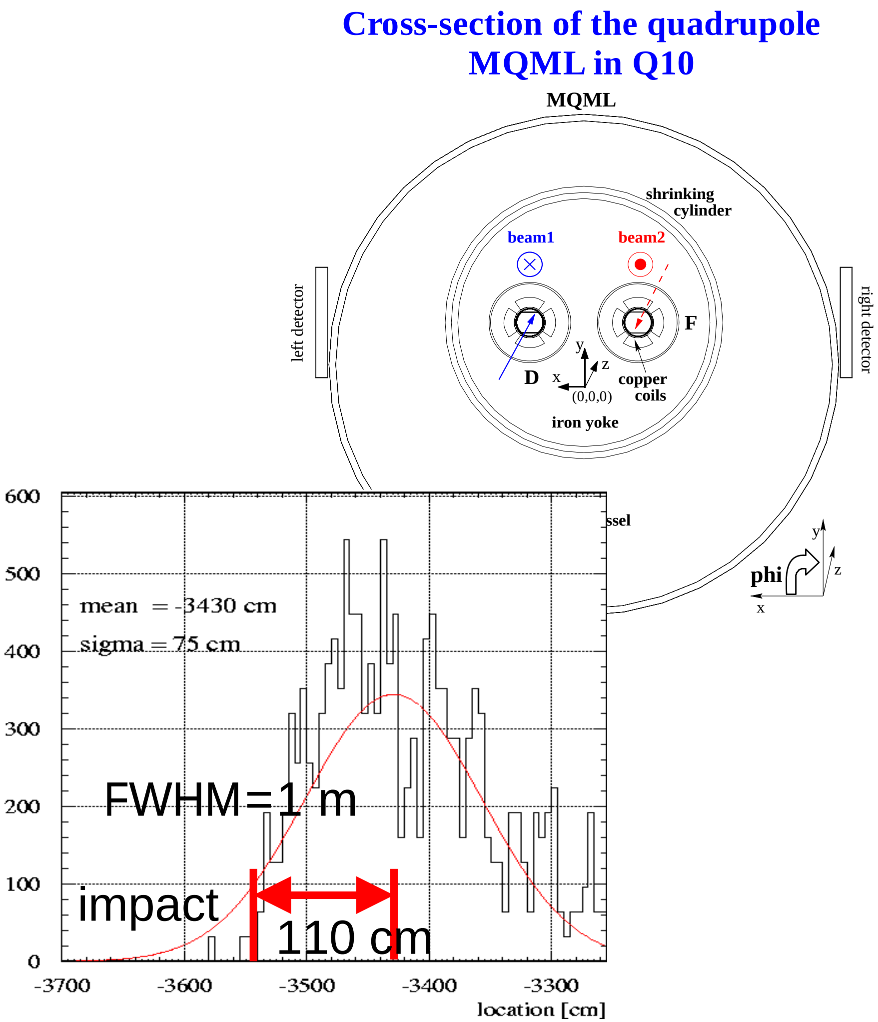
- Losses enhanced at beginning of quadrupole, due to:
  - Beta function maximums
  - Dispersion function maximums
  - Misalignments (location of bellows
  - Beam kings (quadrupole + cor. dipole location)
  - Change in aperture

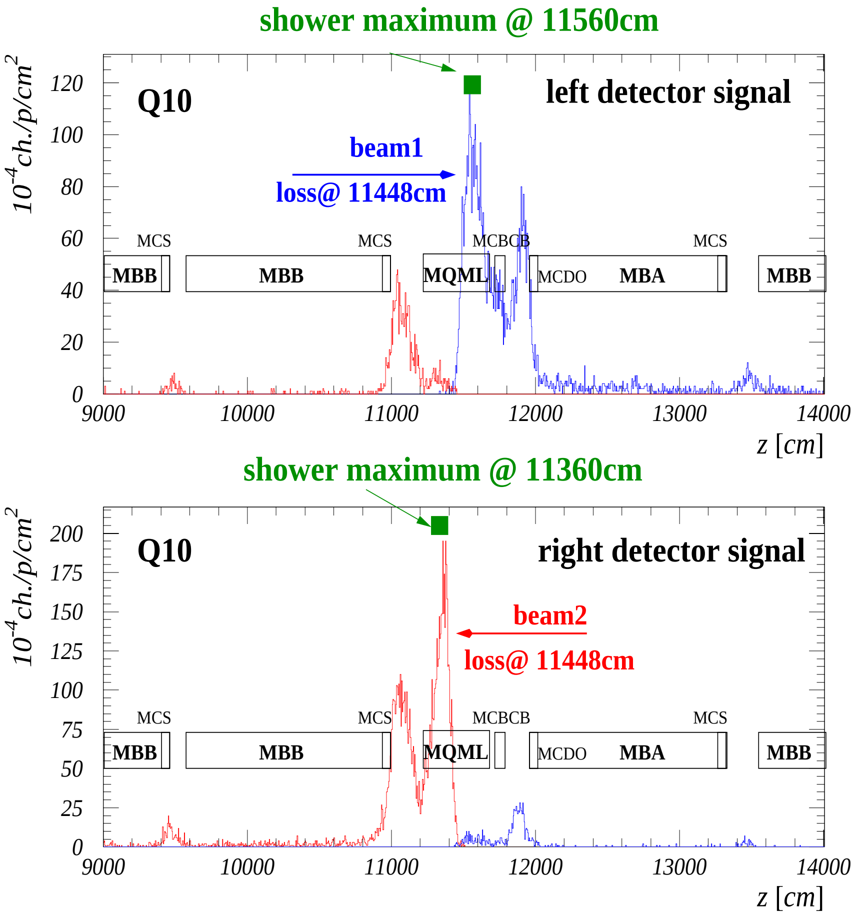
BLM Locations in the Arcs

- **3 loss locations simulated: shower development in the cryostat, GEANT 3.**
- **The positions of the BLMs are chosen to:**
  - minimize crosstalk
  - reduce difference between inside and outside loss
  - difference with and without MDCO.

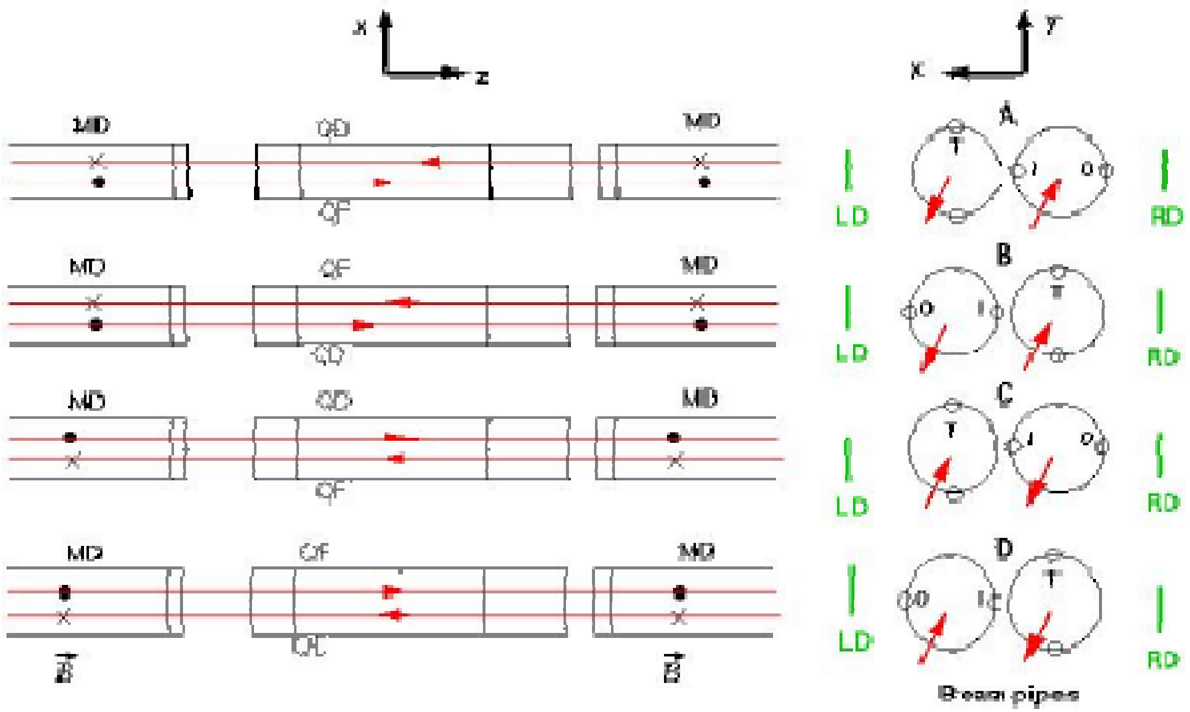


Shower Development in Dispersion Suppressor Magnets



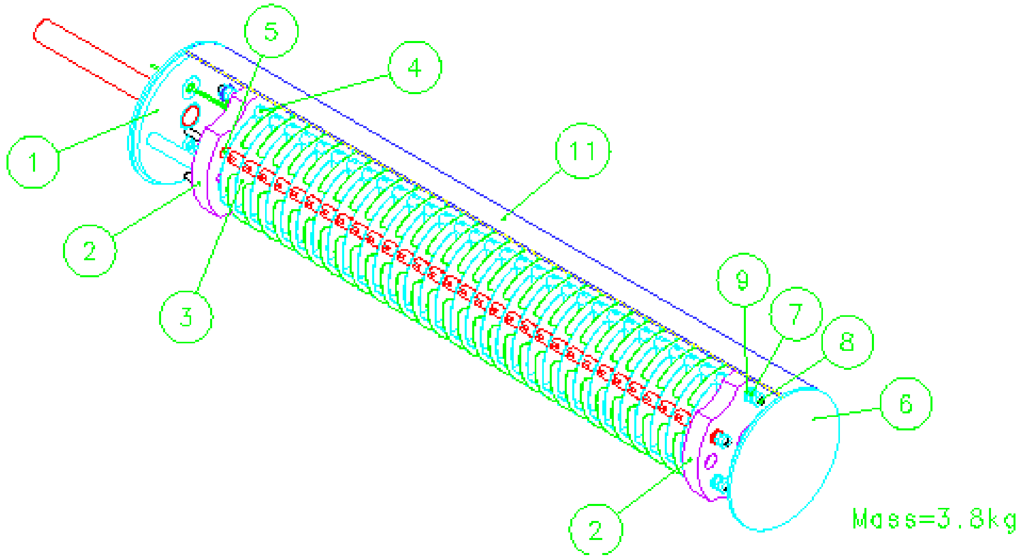


Beam and Magnetic Field Directions



- 4 combinations of beam directions and magnetic fields.
- 3 loss locations: inside and outside of beam screen and top of beam screen (bottom is about the same as top).

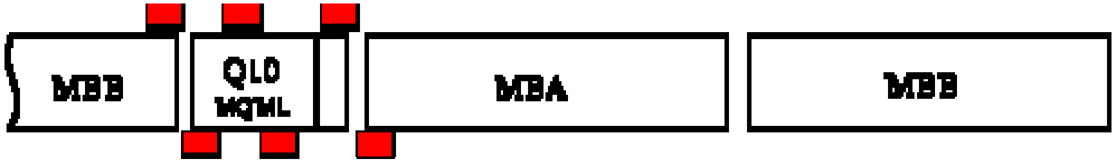
Ionisation chamber



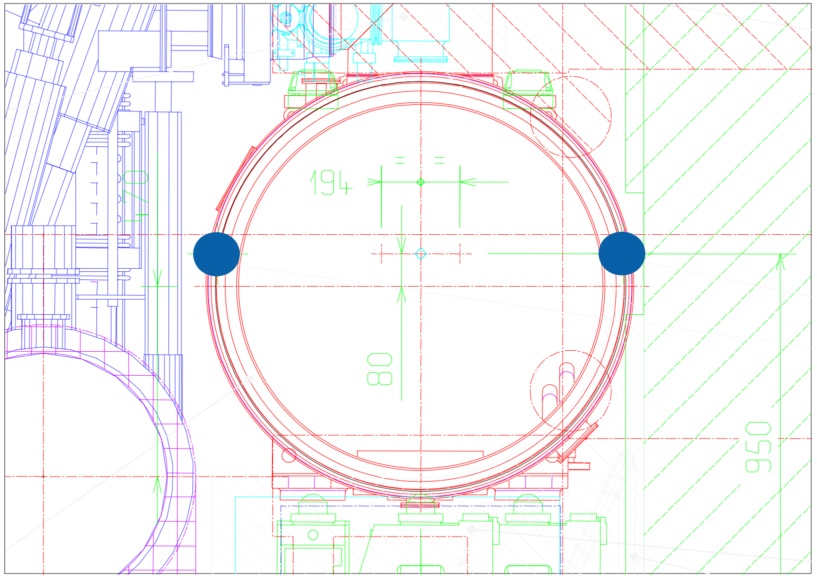
- LHC design
  - Parallel electrodes separated by 0.5 cm
  - Stainless steel cylinder
  - Al electrodes
  - Low path filter at the HV input
  - N_2 gas filling at 100 mbar over pressure

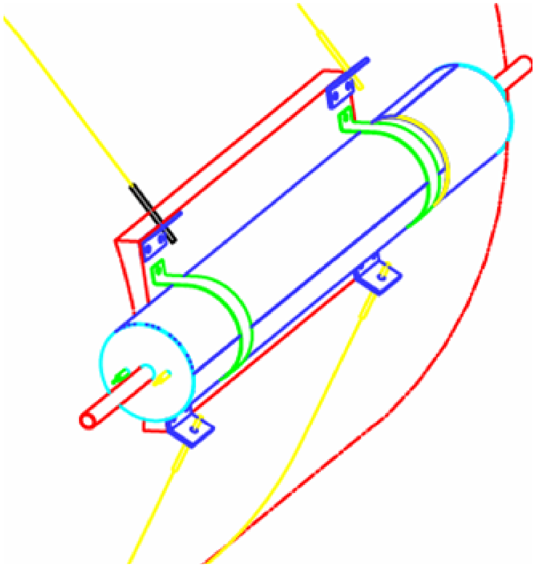
diameter = 8.9 cm, length 60 cm, 1.5 litre

Location of Detectors



Installation with a small support and straps or cables on the cryostats

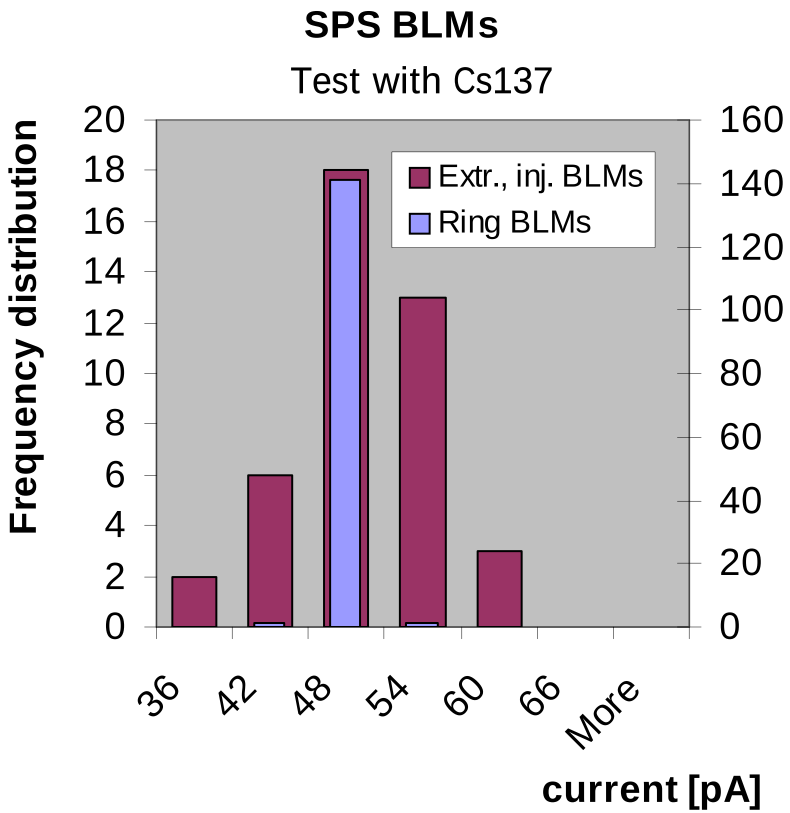




Ionisation chamber currents (1 litre)

		Collimation	All others
450 GeV, quench levels (min)	100 s	3.3 mA	12.5 nA
7 TeV, quench levels (min)	100 s	100 uA	2 nA
Required 25 % rel. accuracy, error small against 25% => 5 %			100 pA
450 GeV, dynamic range min.	10 s		10 pA
	100 s	33 nA	2.5 pA
7 TeV, dynamic range min.	10 s		160 pA
	100s	1.1 nA	80 pA

Gain Variation of SPS Chambers



Total received dose:

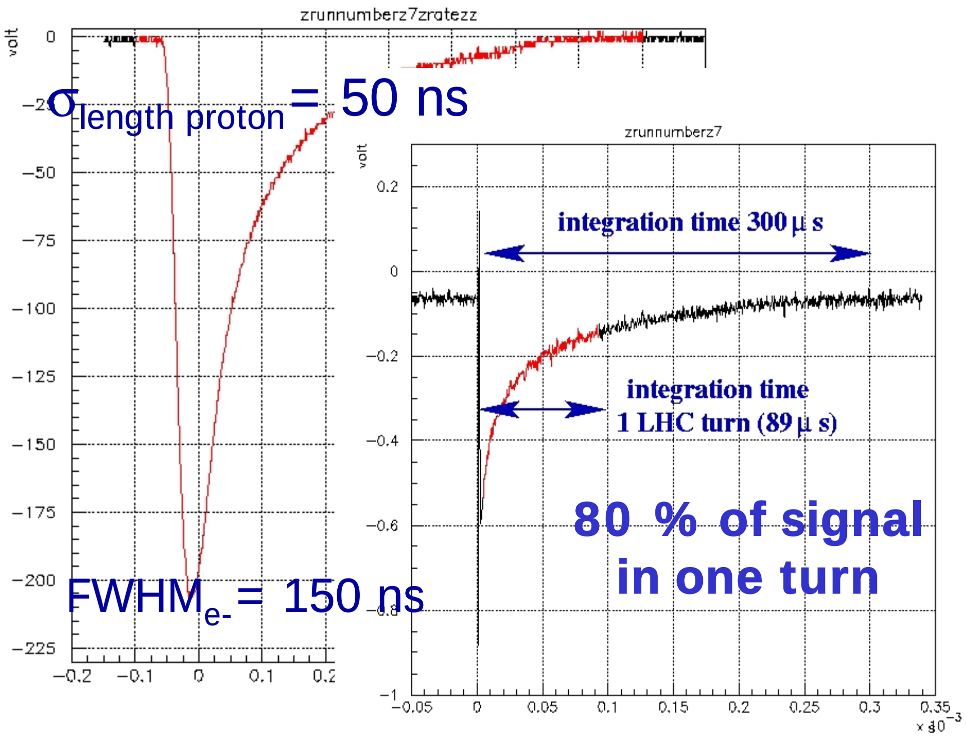
ring 0.1 to 1 kGy/year

extr 0.1 to 10 MGy/year

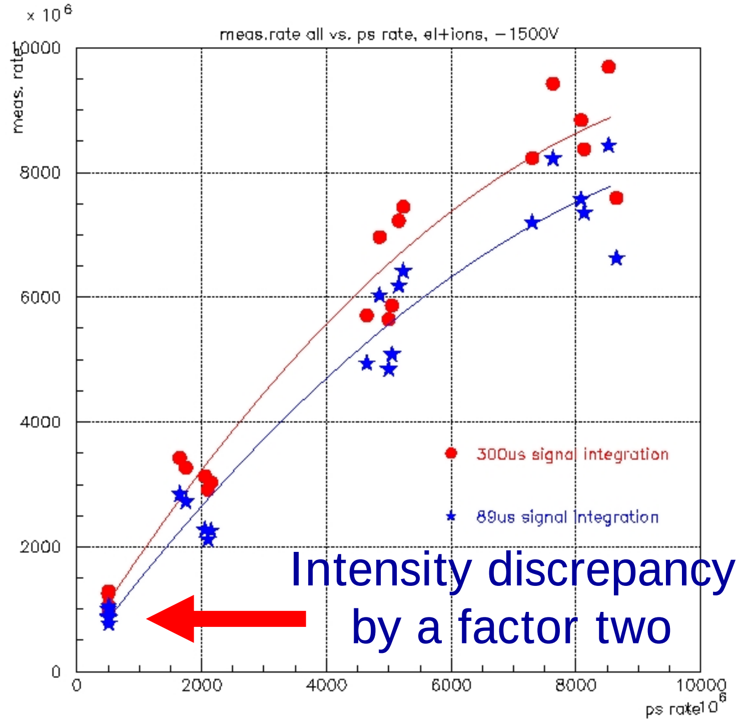
- 30 years of operation
- Measurements done with installed electronic
- Relative accuracy
  - $\Delta\sigma/\sigma$ < 0.01 (for ring BLMs)
  - $\Delta\sigma/\sigma$ < 0.05 (for Extr., inj. BLMs)
- Gain variation only observed in high radiation areas
- Consequences for LHC:
  - No gain variation expected in the straight section and ARC
  - Variation of gain in collimation possible for ionisation chambers (SEM foreseen for dump signal generation)

Ionisation Chamber Time Response Measurements (BOOSTER)

Chamber beam response

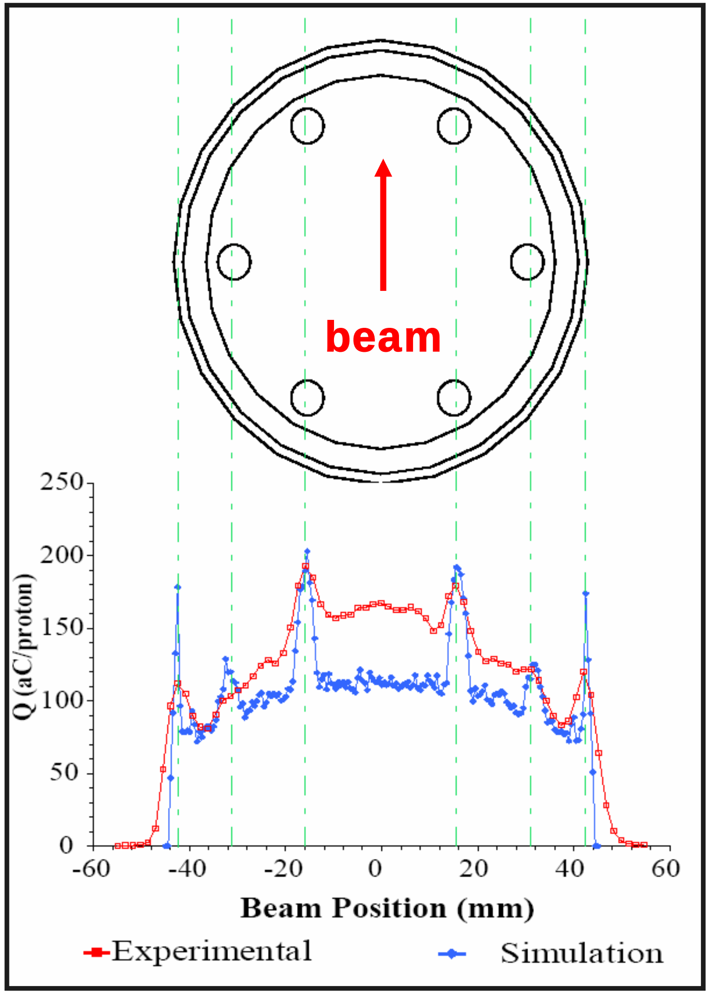


Chamber current vs beam current



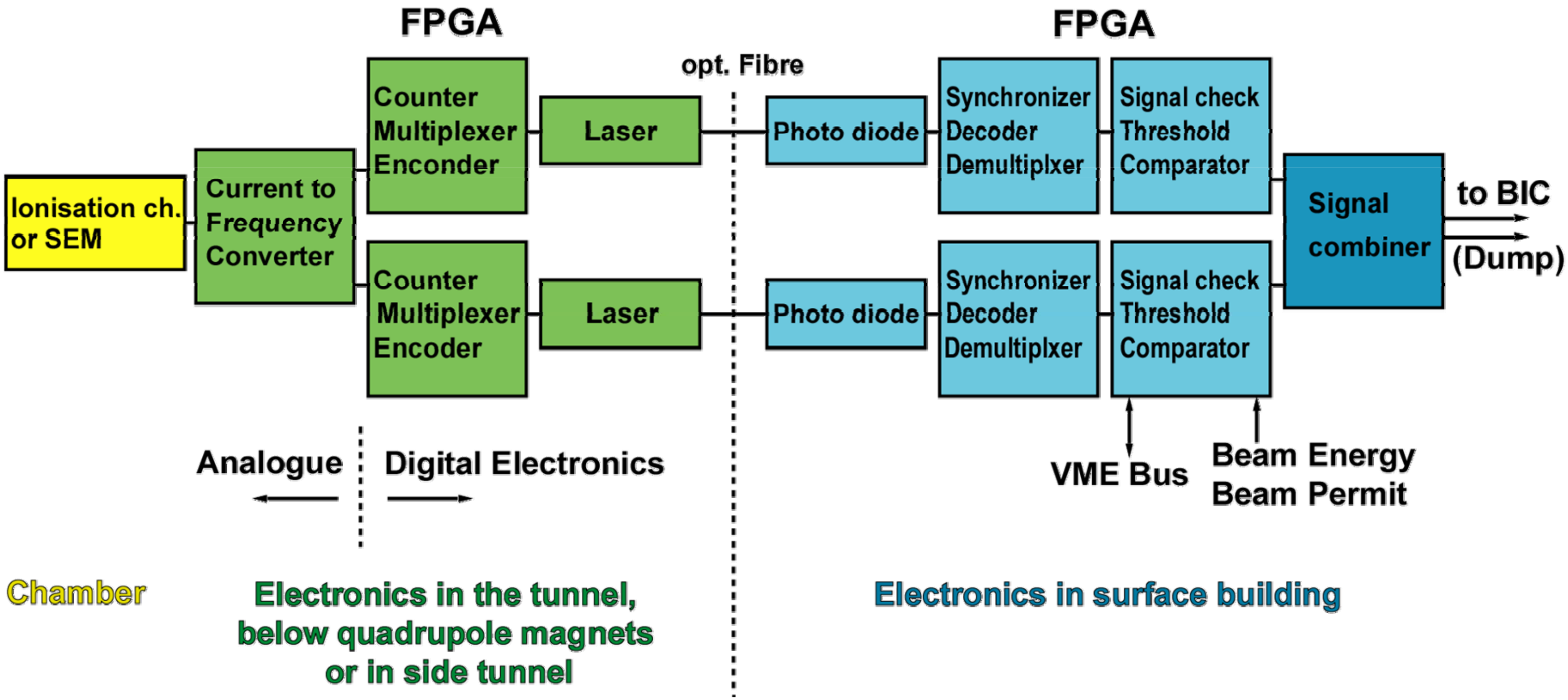
Intensity density: - Booster 6 10^9 prot./cm^2, two orders larger as in LHC

Ionisation Chamber Energy Deposition Measurements and Geant4 Simulation



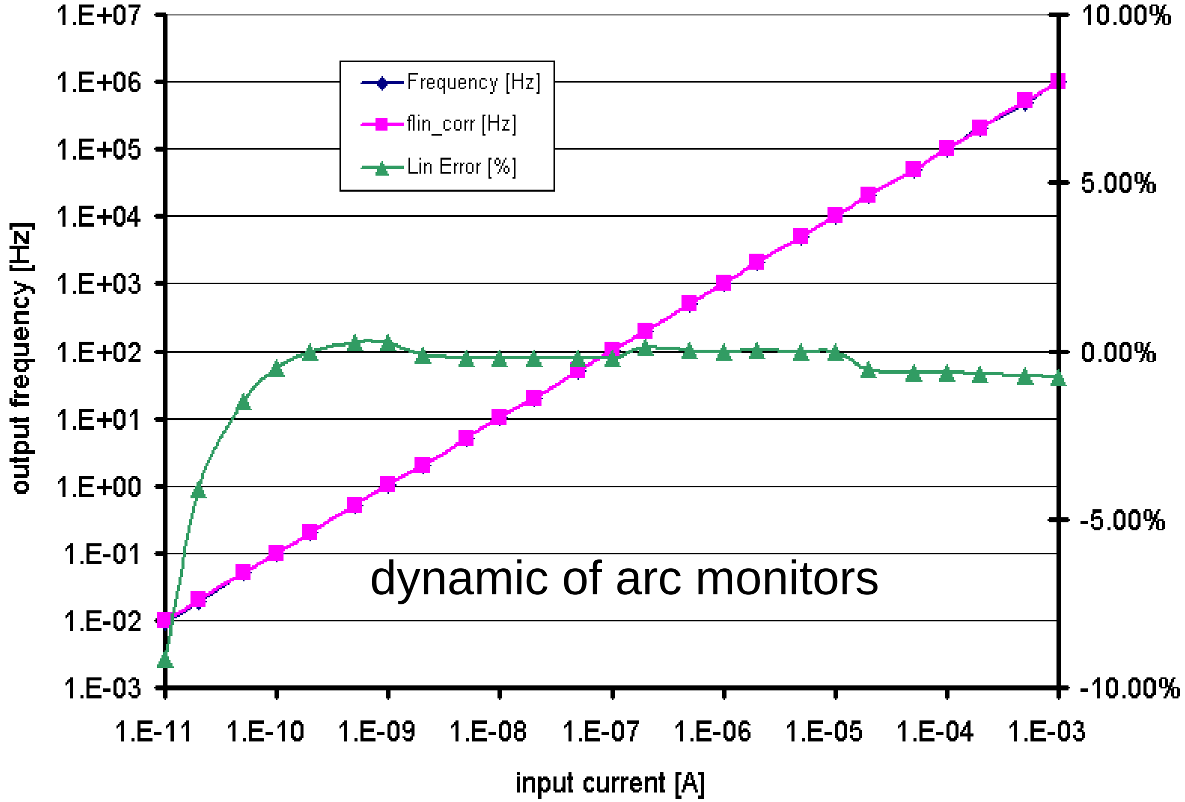
- Test in SPS T2 extraction line 400 GeV protons, medium intensity (quench levels)
- Chamber moved through the beam
- Structure of chamber reproduced
- Integral difference between measurements and simulation about 25 %

Monitor Signal Chain



More details, see talk Christos Zamantzas

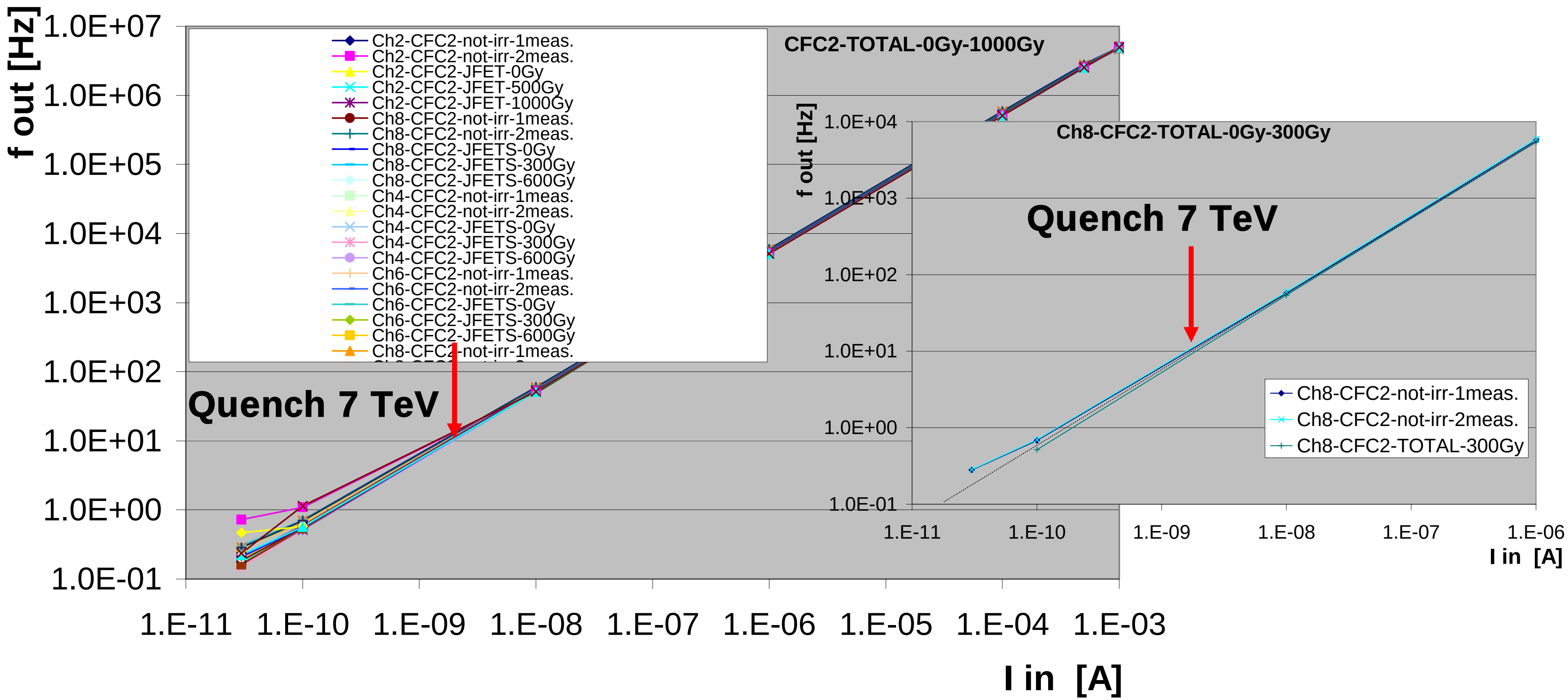
Current to Frequency Converter



circuit limited by:

1. leakage currents at the input of the integrator (< 2 pA)
2. fast discharge with current source (<500 ns)

Current to Frequency Converter and Radiation



- Variation at the very low end of the dynamic range
- Insignificant variations at quench levels

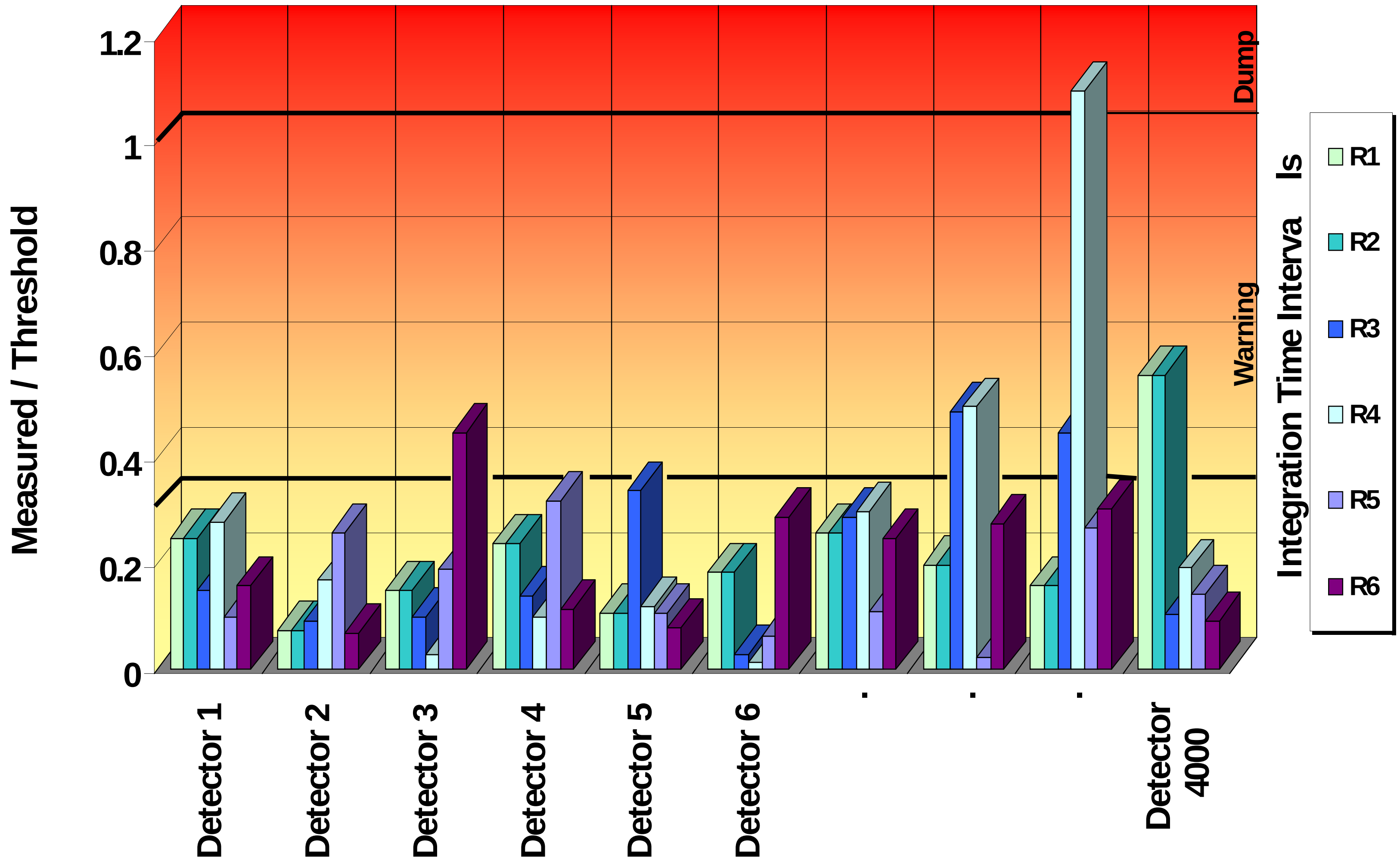
Test Procedure of Analog Signal Chain

- Basic concept: Automatic test measurements in between of two fills
  - Measurement of 10 pA bias current at input of electronic
  - Modulation of high voltage supply of chambers
    - Check of components in Ionisation chamber (R, C)
    - Check of capacity of chamber (insulation)
    - Check of cabling
    - Check of stable signal between few pA to some nA (quench level region)
  - Not checked is the gas gain of chamber (in case of leak about 50 % gain change, signal speed change – to be checked)

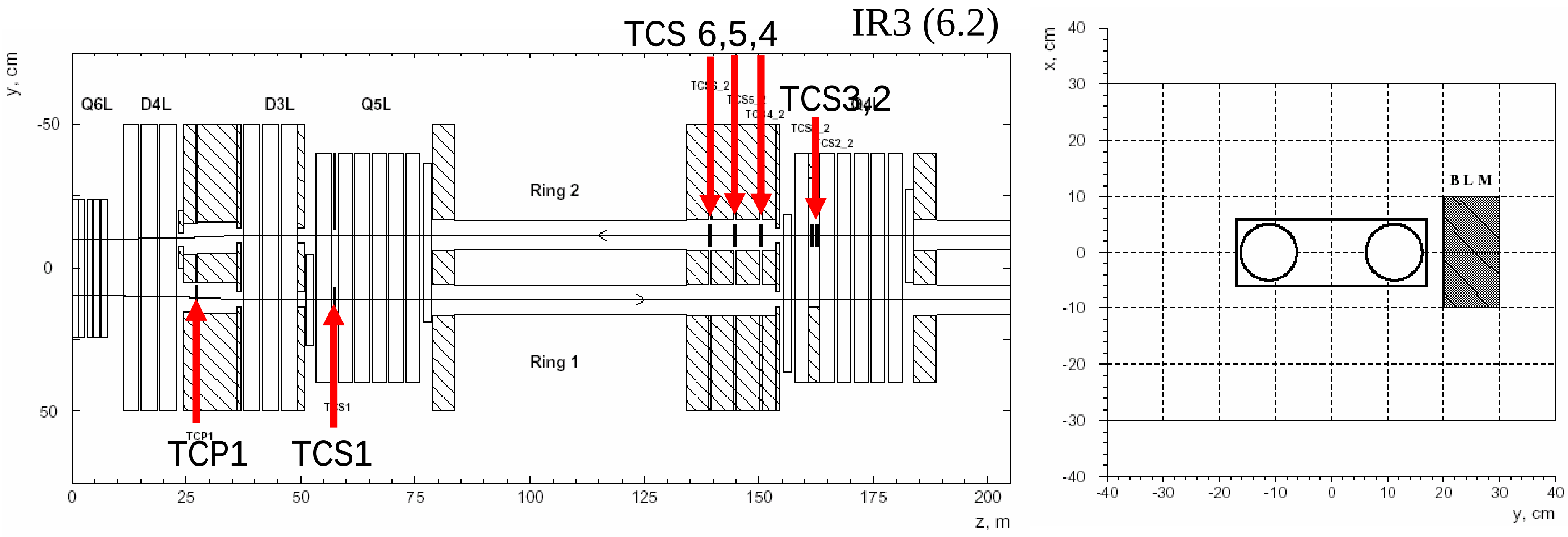
Systematic Uncertainties at Quench Levels

	relative accuracies	Correction means
Electronics	< 10 %	Electronic calibration
Detector	< 10 – 20 %	Source, sim., measurements
Radiation & analog elec.	about 1 %	
fluence per proton	< 10 - 30 %	sim., measurements with beam (sector test, DESY PhD)
Quench levels (sim.)	< 200 %	measurements with beam (sector test), Lab meas., sim. fellow)
Topology of losses (sim.)	?	Simulations

Beam Loss Display

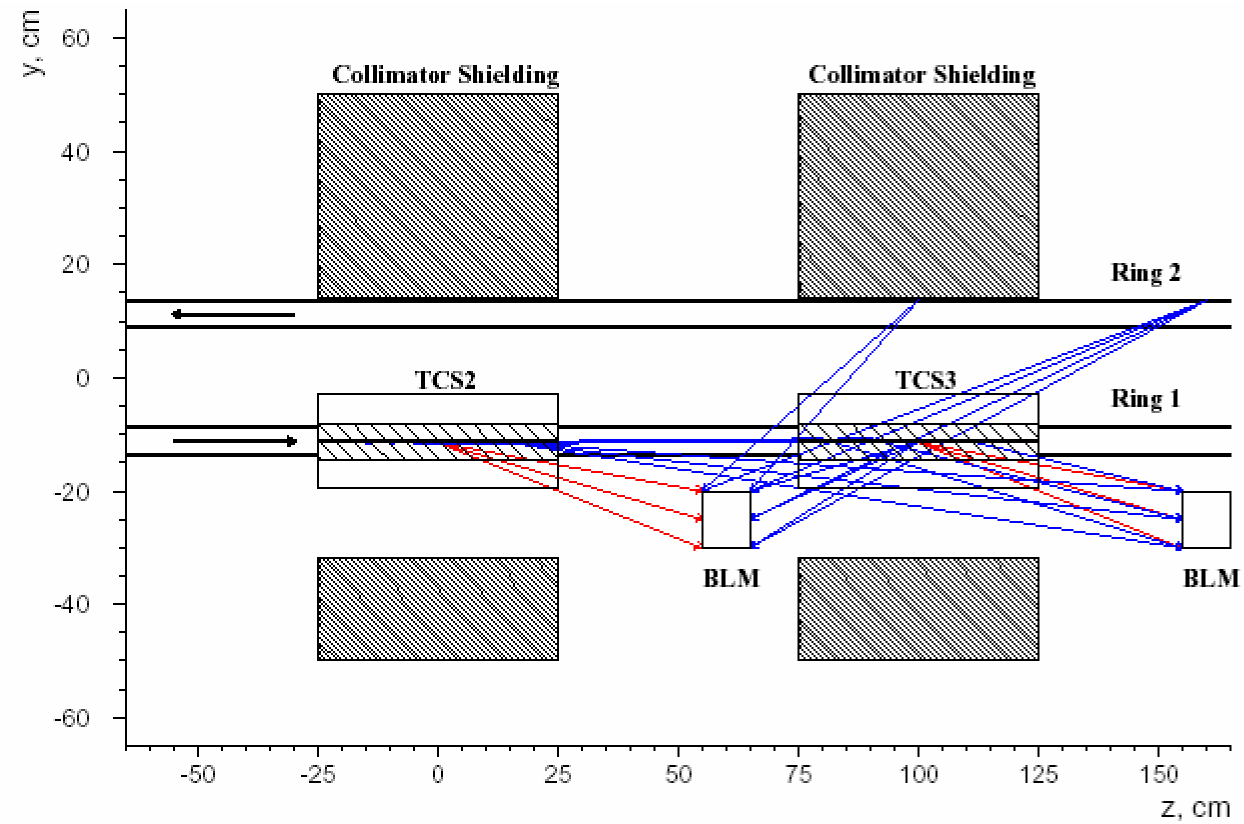


IR 3 Cleaning



- Loss rate at the collimators 3 to 4 orders of magnitude higher as at the ARC locations
- Instead of gas ionisation detection secondary electron emission detection will be used

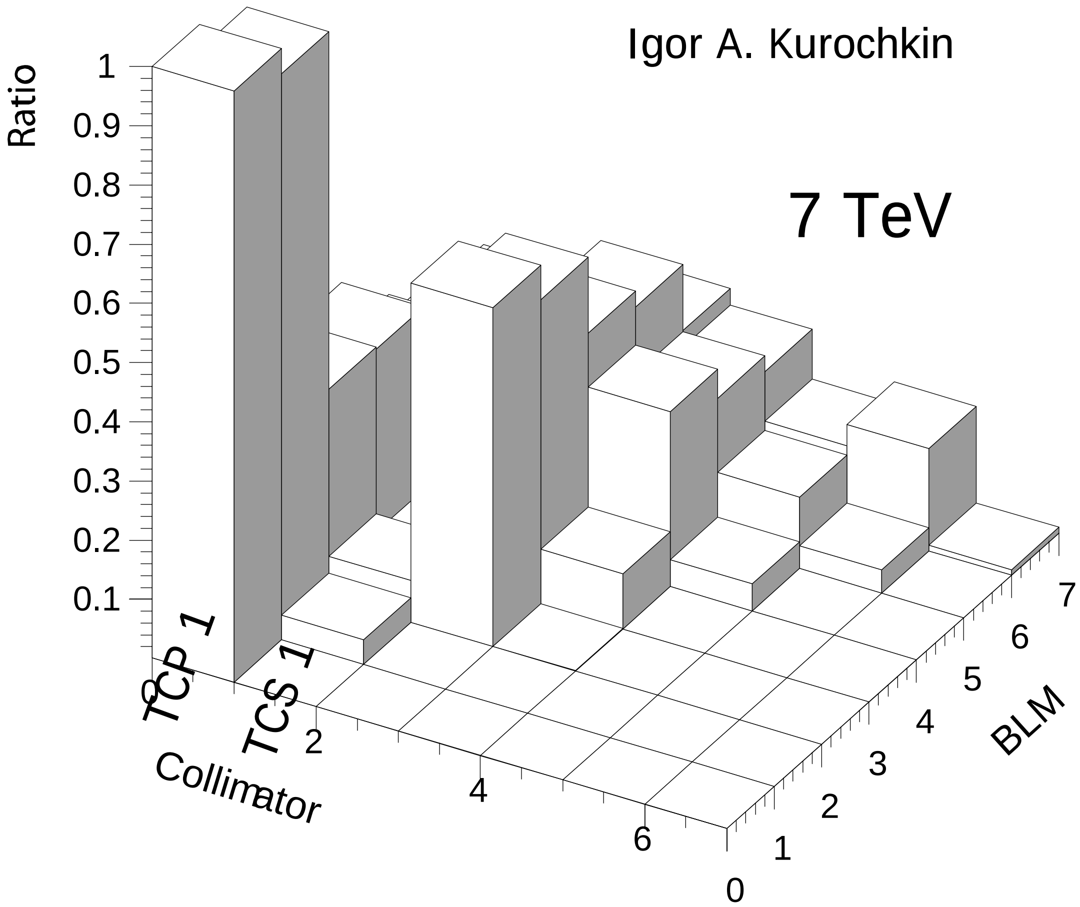
Simulated BLM Signals at Collimators (IP3)



- Simulation of monitor signals taking background and cross talk effects into account (collimator C/C 20/50 cm, new C/C 20/ 100 cm)

Order of magnitude of the effect is to be expected identical to old/new, IR3/IR7

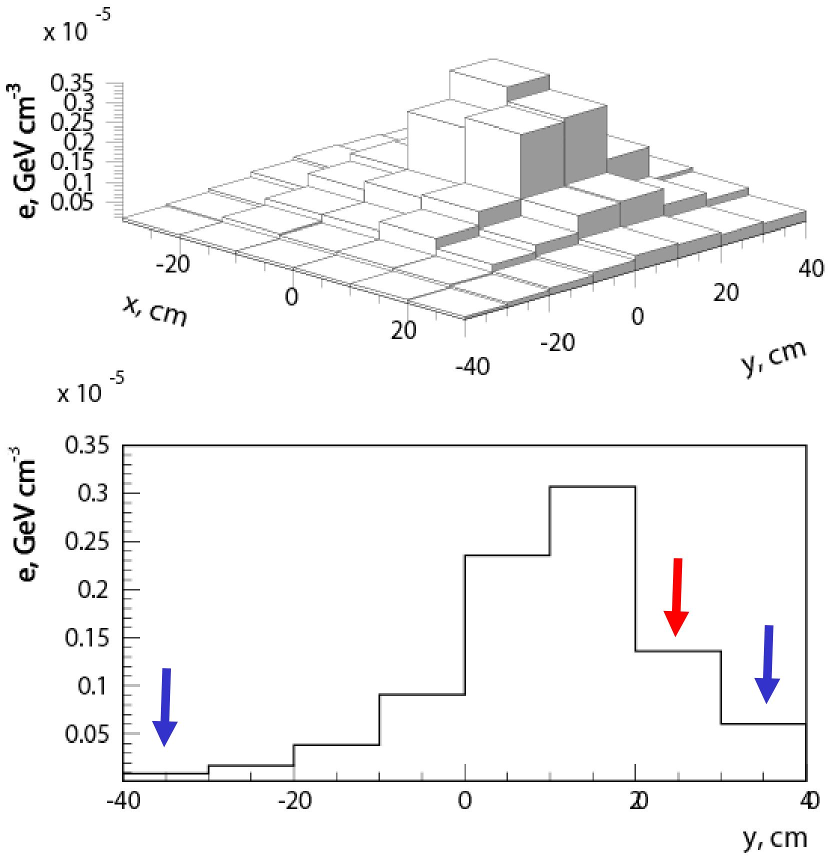
BLM Signal from Upstream Collimator



- BLM3 (close to TCS2) – only 57.4% “Good” signal
- BLM2 – 4%
- BLM4 – 9%
- BLM5 – 5%
- BLM6 – 4%
- BLM7 – 1%
- TCP1 - major contributor to background
- BLM2 – 96%
- BLM7 – 20%

Transversal Variation of Monitor Location

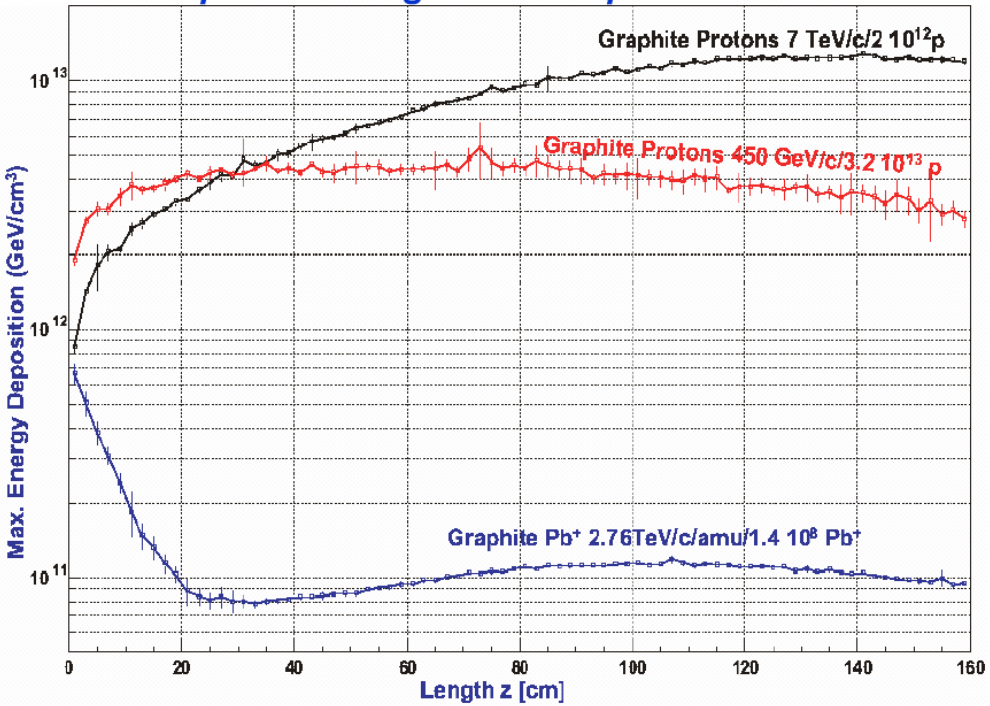
TCS1 Igor A. Kurochkin



- Best signal to background and signal to cross talk at position near to the beam
- It is expected that additional absorbers near to the vacuum chamber are not significantly improving the situation

Ions Energy Loss

FLUKA calculations from Vasilis Vlachoudis for dump kicker single module prefire



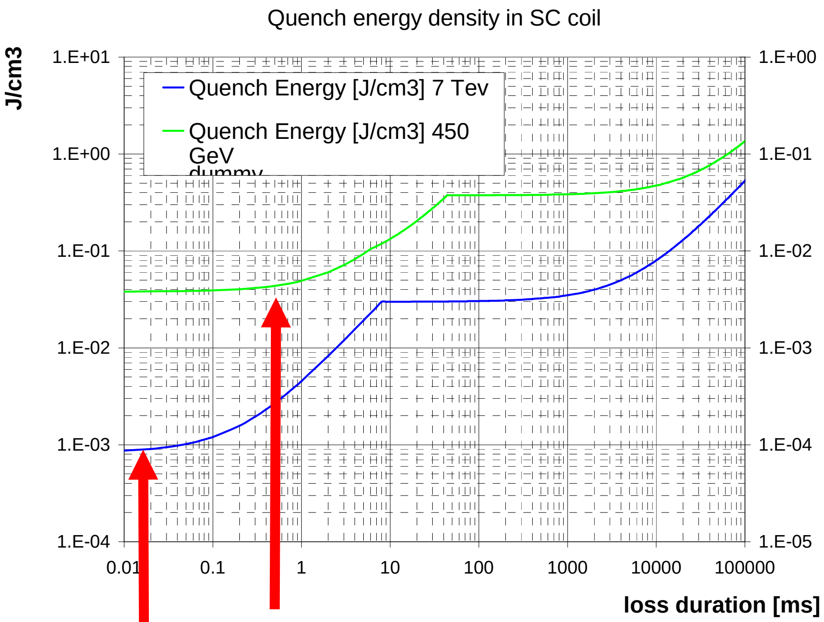
Specification:

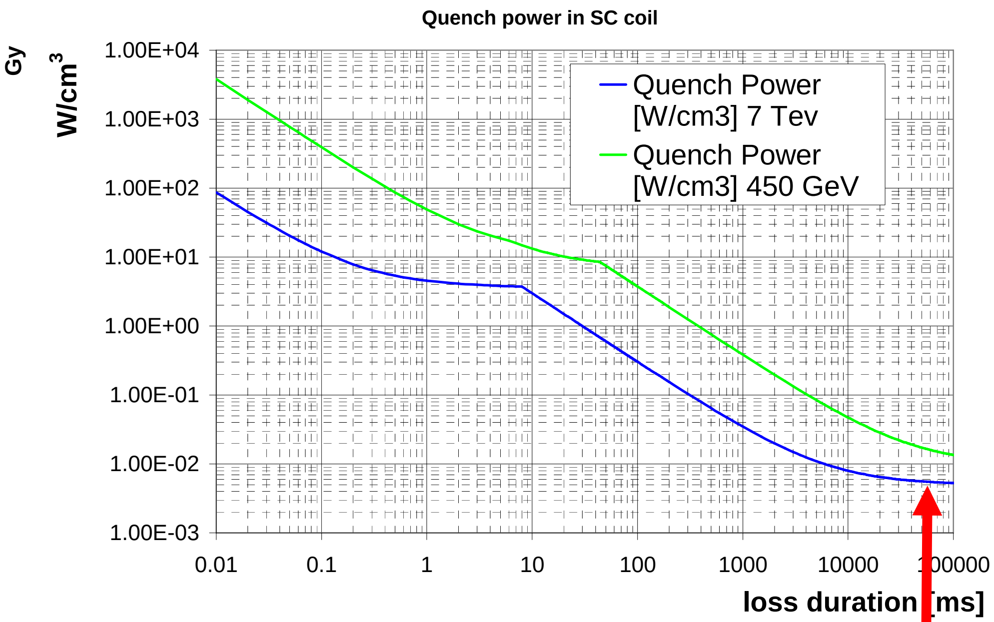
- **PROTONS VERSUS IONS**
  - **These two quantities (Ion bunch and ion beam energy) are very close to respectively a pilot bunch and a proton beam of intermediate intensity (5 10^9 and 2.2 10^{12}). It can be concluded that no particular properties need be added to the present specification with respect to ion beams.**

- **Ion loss and fluence calculation before final decision on detector location, ...**
- **Ongoing simulations (**R. Bruce, S. Gilardoni, J.Jowett)

Reserve Slides

LHC Bending Magnet Quench Levels,
LHC Project Report 44





38 mJ/cm3 = 5 mJ/g

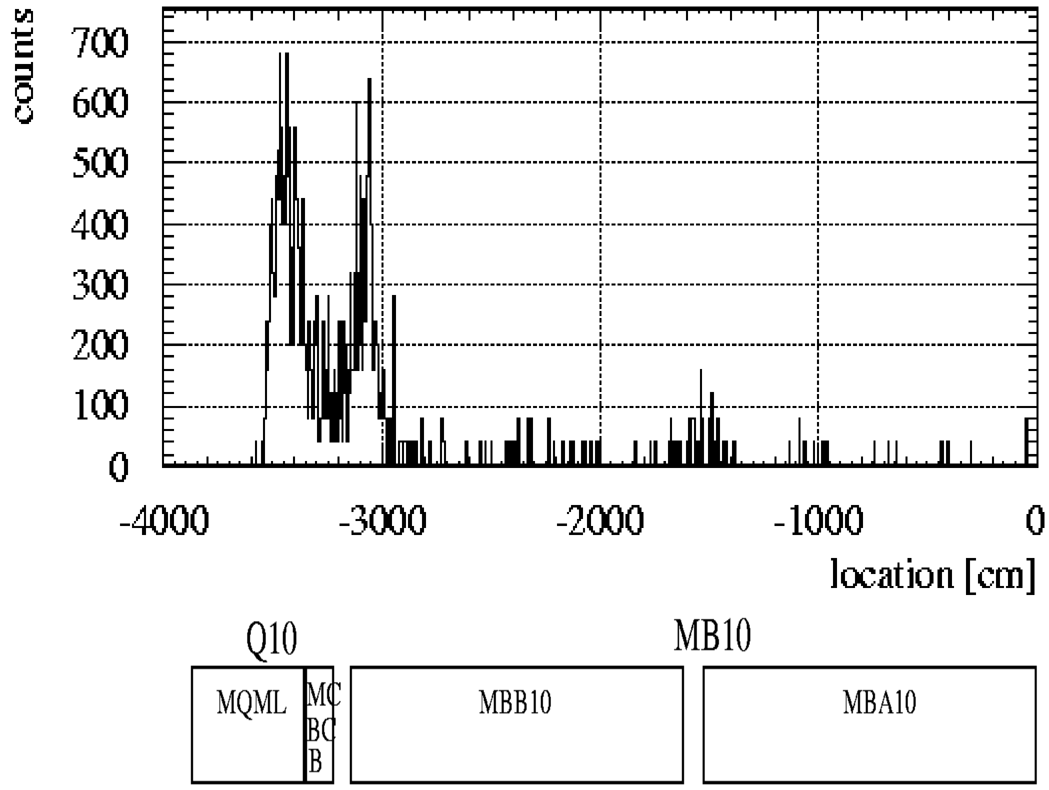
5 mW/cm3 = 0.6 mW/g

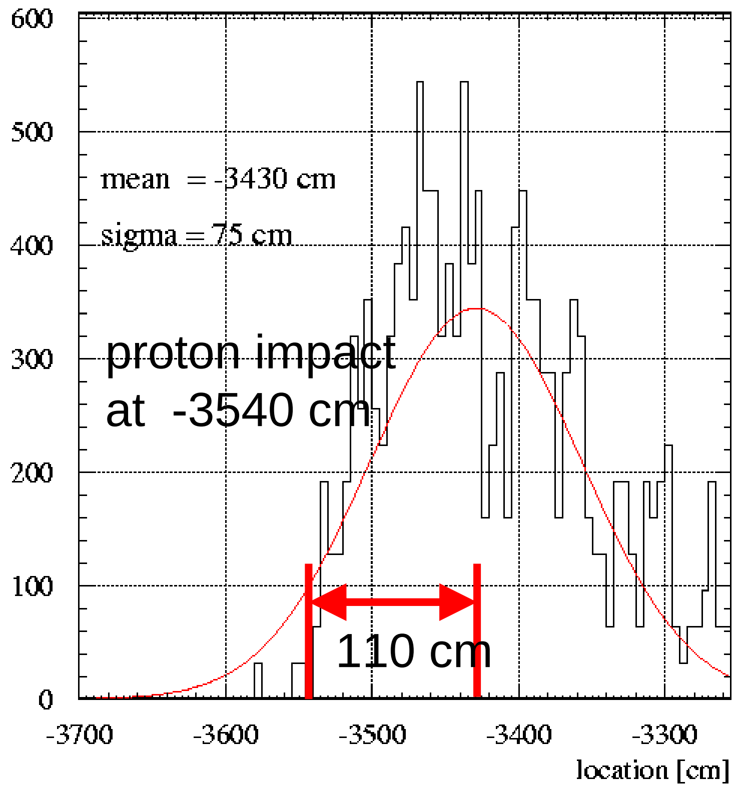
0.8 mJ/cm3 = 0.09 mJ/g,

(RHIC=2 mJ/g, Tevatron=0.5mJ/g)

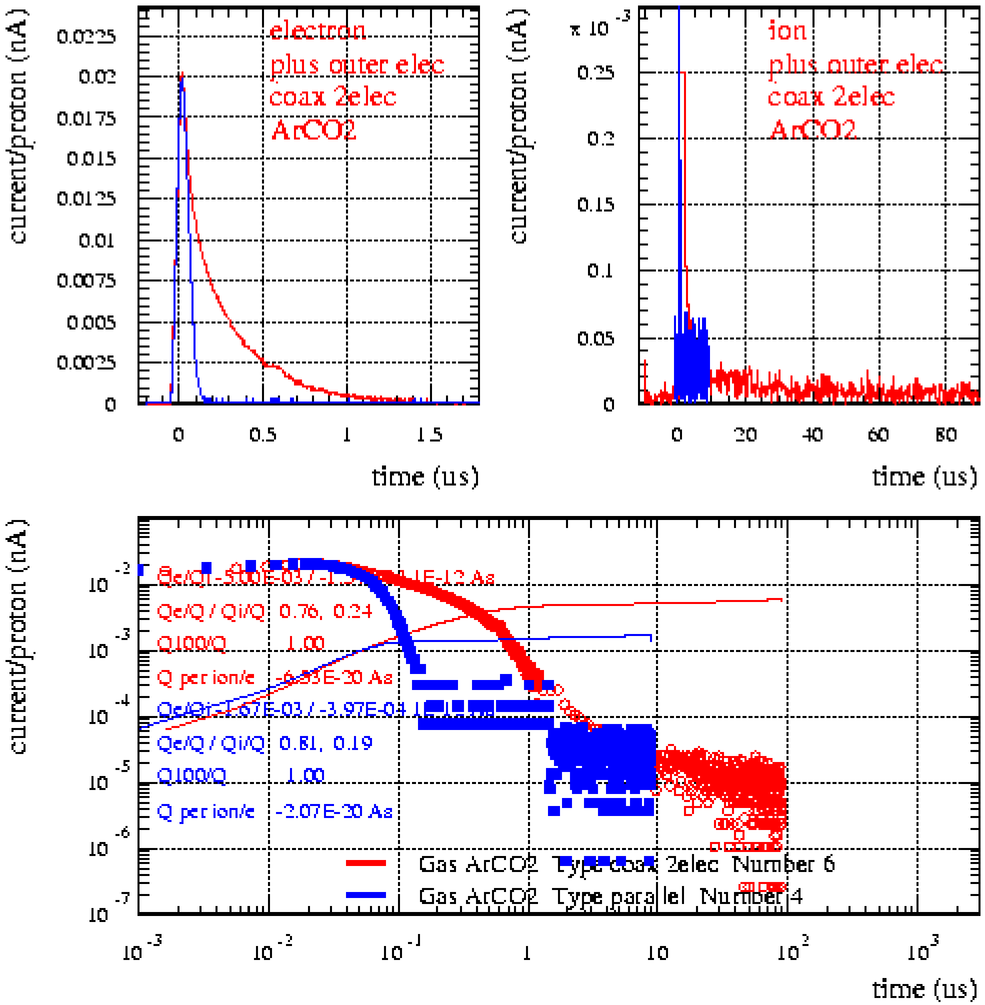
(RHIC = 8 mW/g, Tevatron = 8mW/g)

Proton Shower Distribution (1)



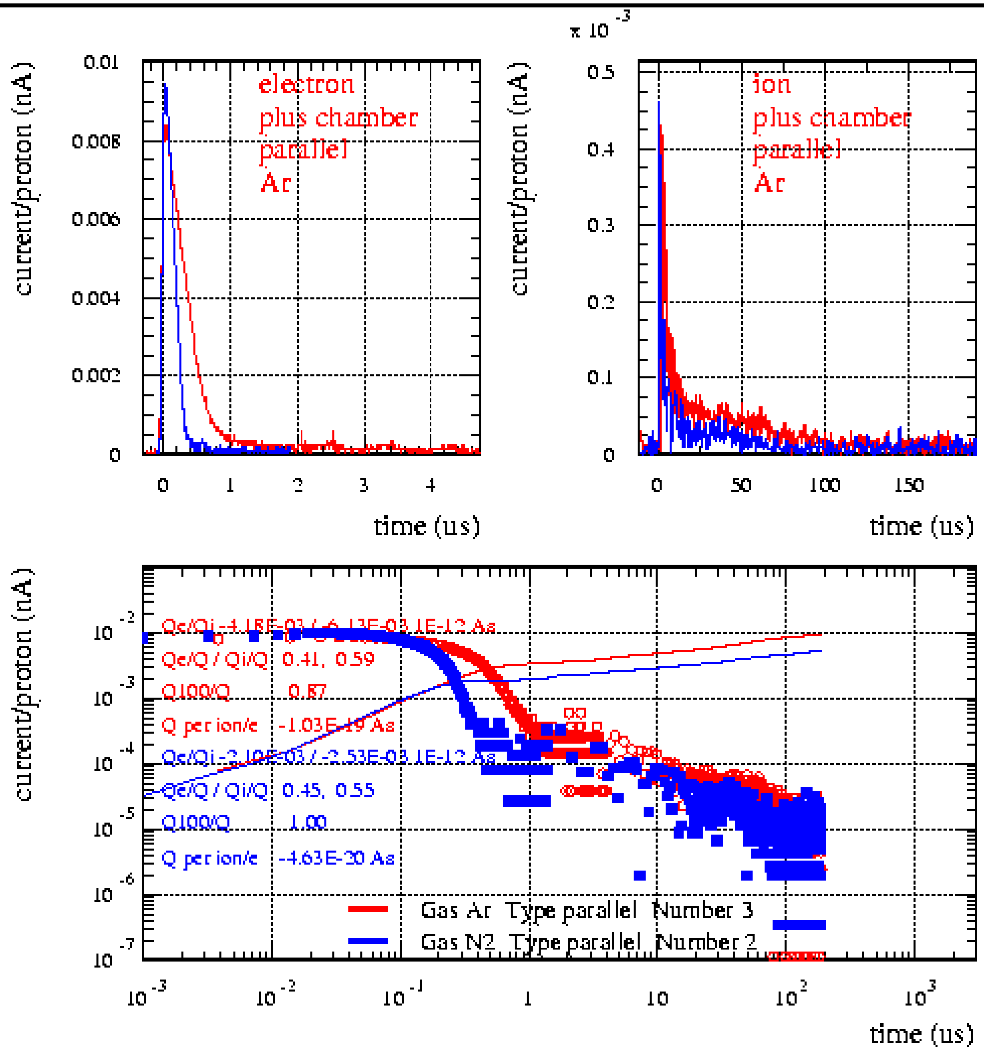


Ionisation Chamber Time Response Measurements

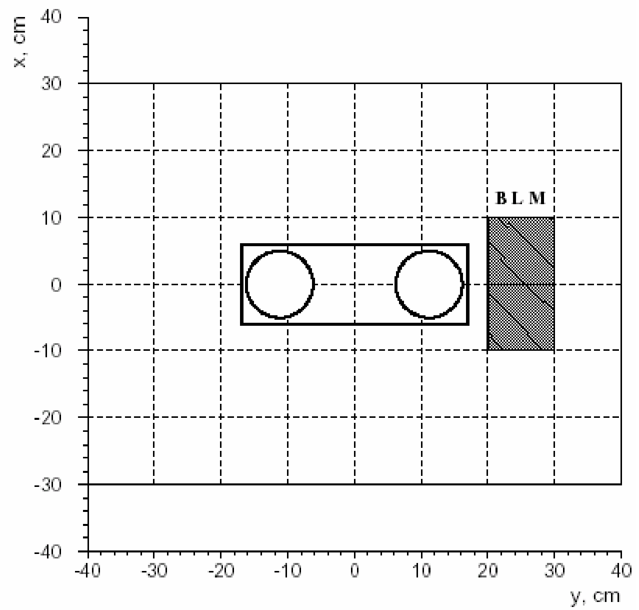


- Booster Pluses
  - Duration σ_t = 50 ns
  - Intensity 2 10^8 – 1 10^{10} prot./cm2
- Comparison of parallel and cylindrical geometry
  - Parallel chamber 10 times faster
- Simulation (Garfield) agree with measurements

Comparison Parallel Plate Chambers Ar – N2



Activation – Background of Monitors



1. Due to continuous high loss rate activation of materials

2. Due to background and cross talk monitor position near to the vacuum chamber

Activation and therefore reduction of monitor sensitivity will depend on: individual loss rates, materials, geometry

(Activation: 1e-4 of mean loss rate (SPS fast extraction)

Consequence: beam tuning with low intensities will be difficult