Beam Loss Monitors at LINAC4

Bernd Dehning

Specifications

- Main design parameters considered for BLMs
  - Beam energy
  - Beam Intensity
- Question to be answered:
  - Dynamic range (low and high limit) (SNS max loss 1E-4 of beam intensity)
  - Response time (SNS 40 us)
  - Sampling rate (LHC 40 us)
  - Beam permit signal (use of threshold) to protect against damage of equipment due to beam induced heating
  - Logging rate (Linac 4 2 Hz)
  - Location of detectors
  - Triggered acquisition

LINAC 4 and Beam Loss Parameters

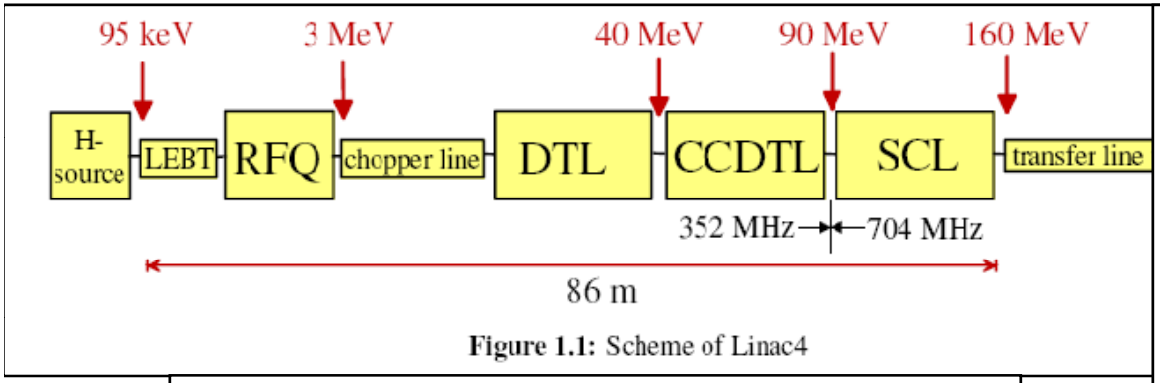


Figure 1.1: Scheme of Linac4

Table 1.2: Linac4 beam parameters

Ion species	H^-
Output energy	160 MeV
Bunch frequency	352.2 MHz
Max. rep.-rate	2 Hz
Beam pulse length	400 μs
Max. beam duty cycle	0.08%
Chopper beam-on factor	62%
Chopping scheme	222/133 full/empty buckets
Source current	80 mA
RFQ output current	70 mA
Linac current	40 mA
Average current	0.032 mA
Beam power	5.1 kW
No. particles per pulse	1.00×10^{14}
No. particles per bunch	1.14×10^{9}
Source transverse emittance	0.2 π mm mrad
Linac transverse emittance	0.4 π mm mrad

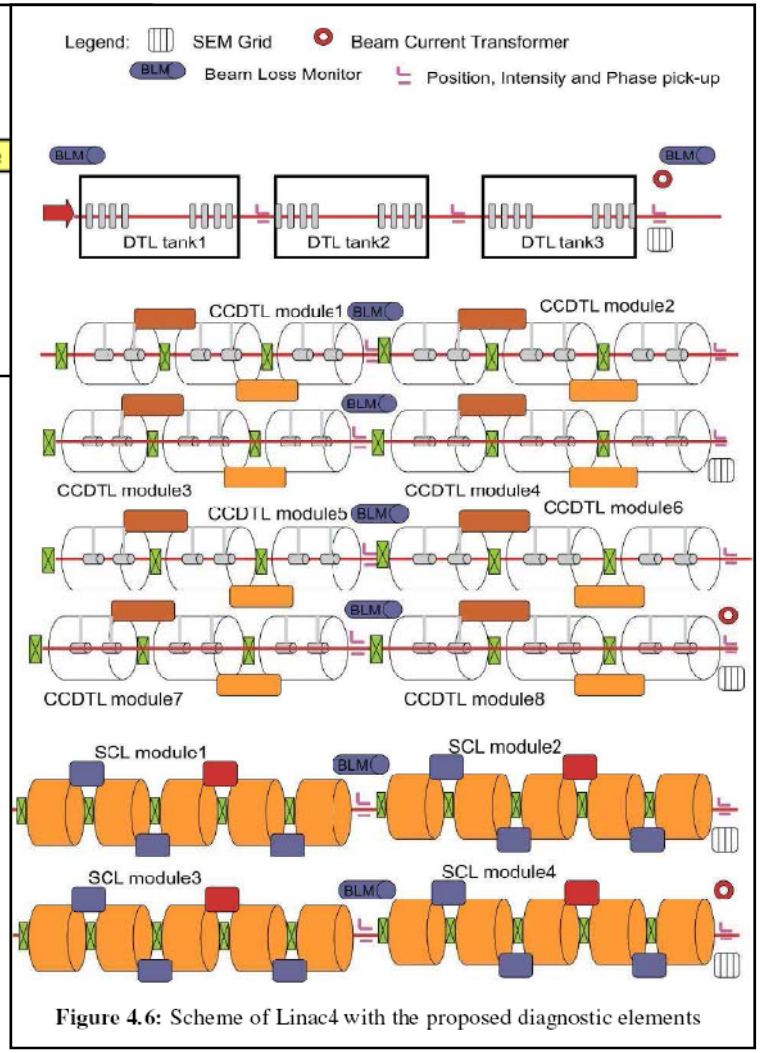
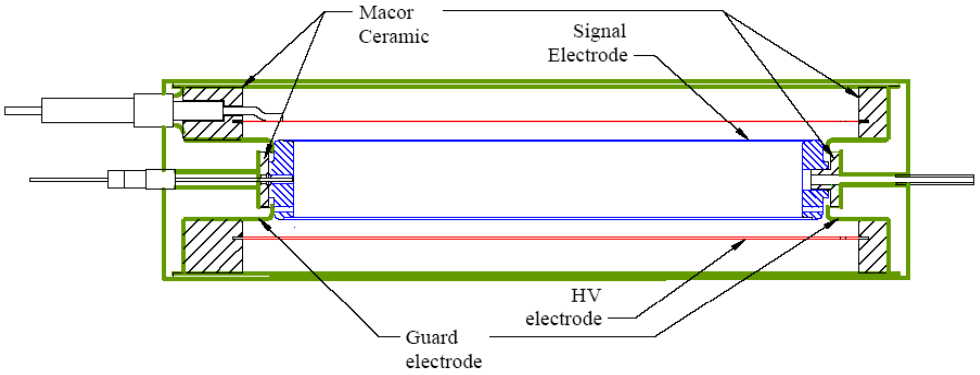
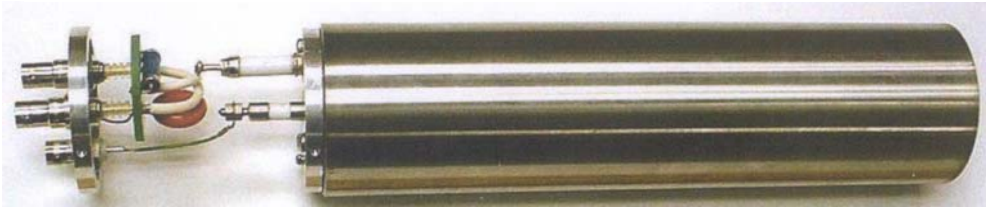


Figure 4.6: Scheme of Linac4 with the proposed diagnostic elements

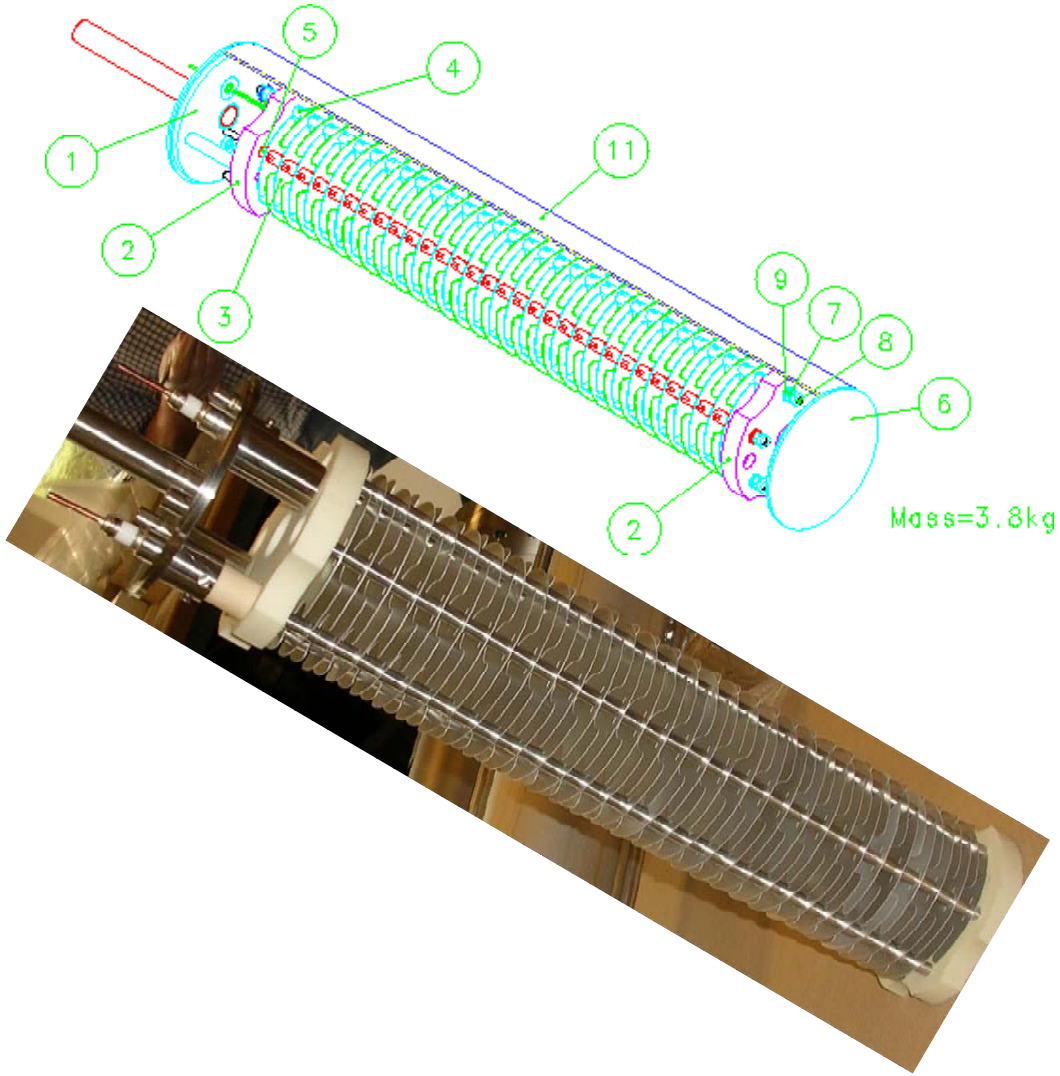
Ionisation chamber SNS





- Stainless steal
- Coaxial design, 3 cylinder (outside for shielding)
- Low pass filter at the HV input
- Ar, N_2 gas filling at 100 mbar over pressure
- Outer inner electrode diameter 1.9 / 1.3 cm
- Length 40 cm
- Sensitive volume 0.1 l
- Voltage 2k V
- Ion collection time 72 us

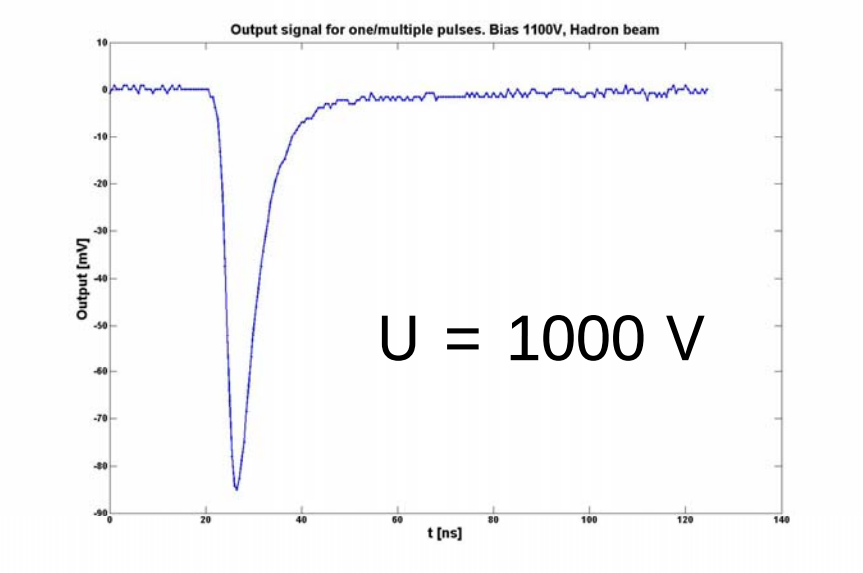
Ionisation chamber LHC

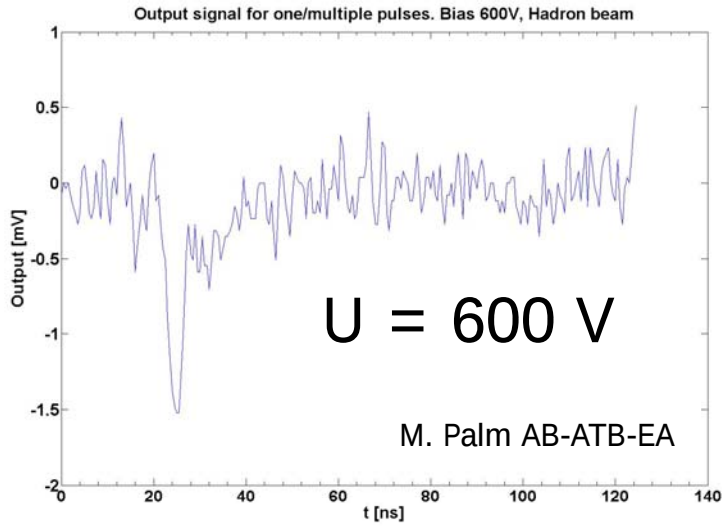


- Stainless steal cylinder
- Parallel electrodes separated by 0.5 cm
- Al electrodes
- Low pass filter at the HV input
- N_2 gas filling at 100 mbar over pressure
- Diameter 8.9 cm
- Length 60 cm
- Sensitive volume 1.5 l
- Voltage 1.5 kV
- Ion collection time 85 us

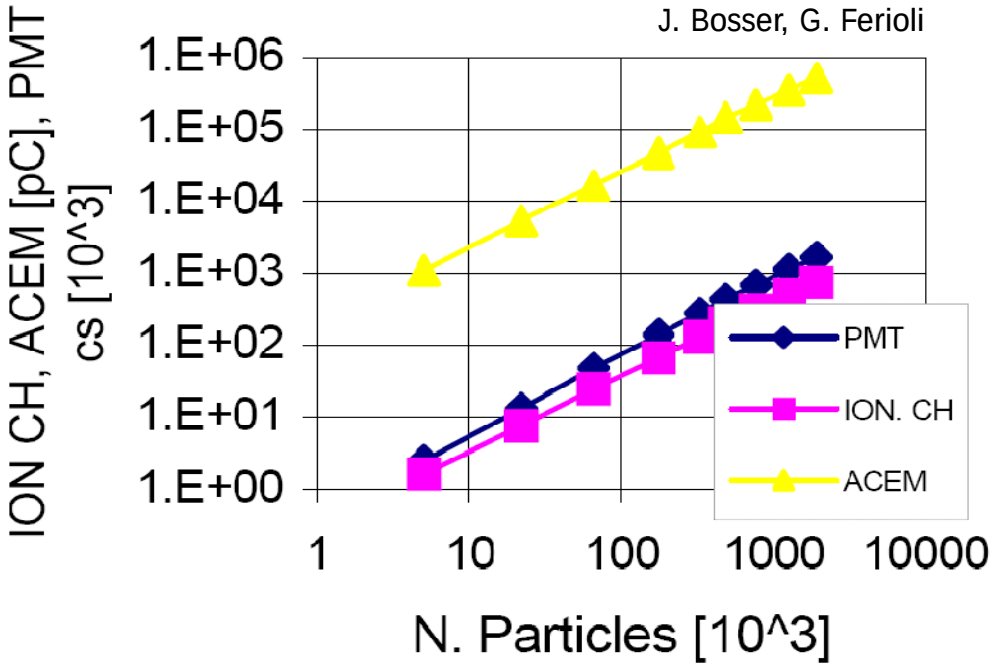
ACEM

- Regular photomultiplier, with an aluminum foil as cathode (secondary electron emitter when irradiated).
  - 10 dynodes
  - High voltage: 0.5-1.5 kV
  - Max. current: 20 mA for short pulses
  - Electron transit time: 40 ns
  - Cathode surface area: 7 cm^2
  - Gain variation 1E3



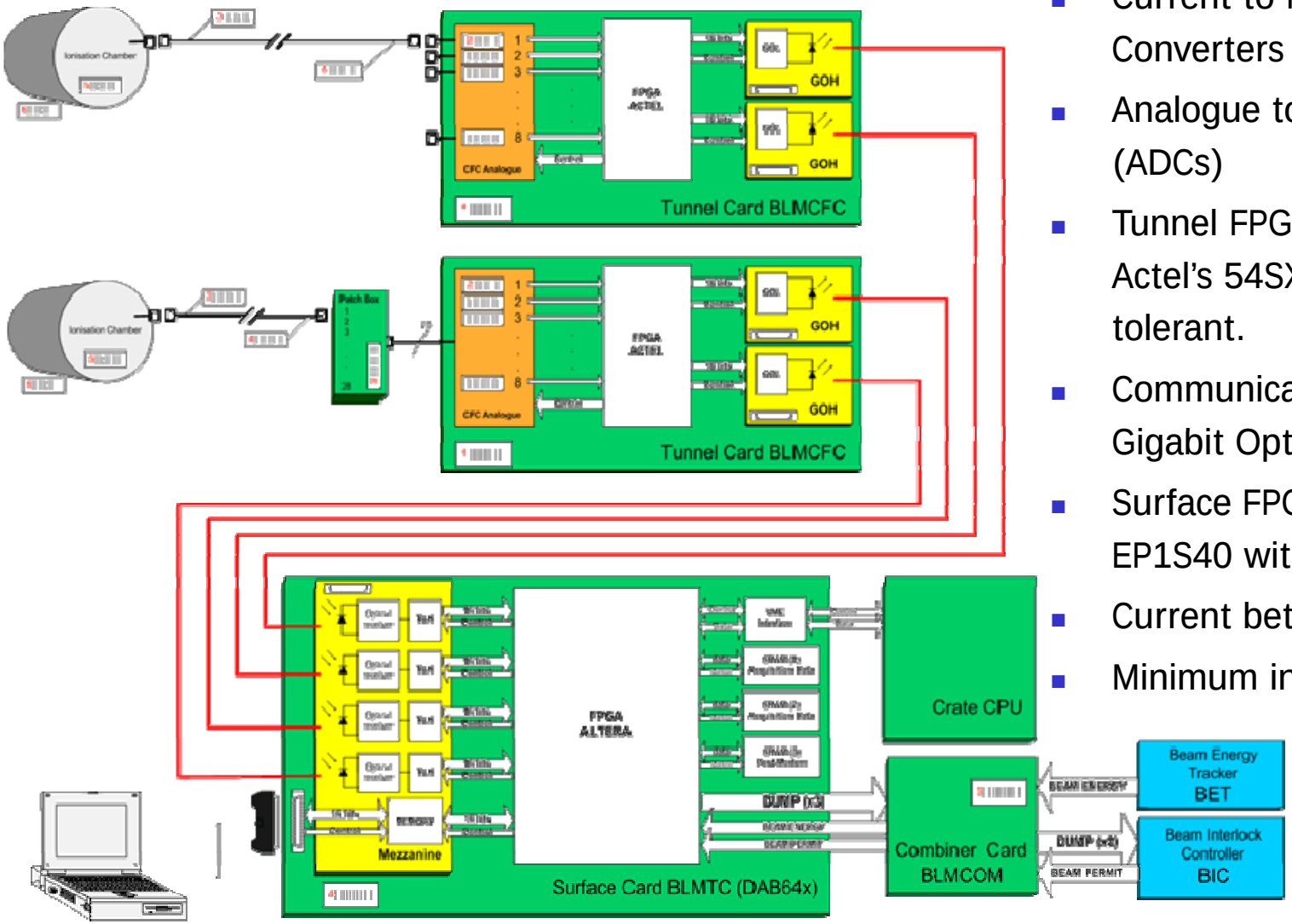


Comparison of ACEM and Ionisation Chamber



- ACEM 3 orders of magnitude more sensitive
- ACEM disadvantage: gain depending on environmental B field

LHC acquisition board

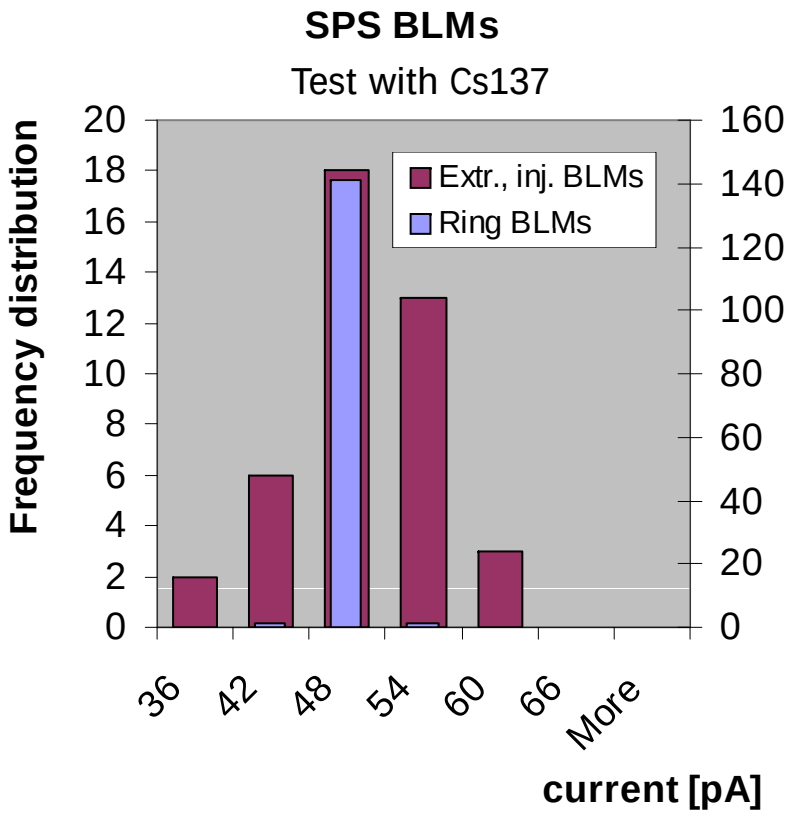


- Current to Frequency Converters (CFCs)
- Analogue to Digital Converters (ADCs)
- Tunnel FPGAs: Actel's 54SX/A radiation tolerant.
- Communication links: Gigabit Optical Links.
- Surface FPGAs: Altera's Stratix EP1S40 with 780 pin.
- Current between 5 pA to 1mA
- Minimum integration time 40 us

Summary

- Beam loss and shower simulation are needed to make the choice for the detector and the locations
- Definition of machine protection procedure needs to be done
- Detector type: ionisation chamber or ACEM
- LHC type electronics: main feature are appropriate
- Definition of post mortem and logging, specifications are needed

Gain Variation of SPS Chambers



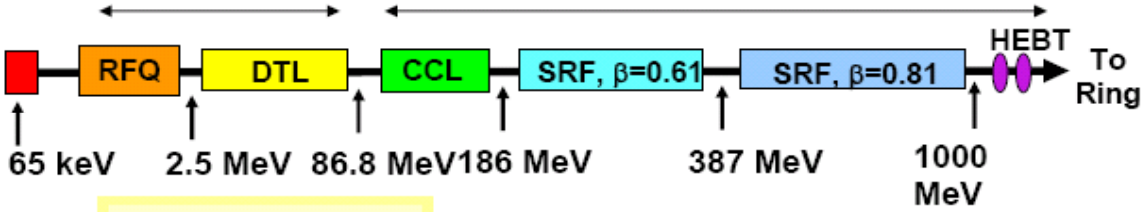
Total received dose:

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 of LHC
  - Variation of gain in collimation possible for ionisation chambers

SNS



Proton energy on target		1.0 GeV
Power on target		1.4 MW
Pulse repetition rate		60 Hz
Macro-pulse length		1 ms
Ave. current in macro-pulse		26 mA
H^- peak current front end	>	38 mA
Peak current in ring		52 A
Proton pulse width on tgt		695 ns
Energy per Pulse		>17 kJ
Uncontrolled beam loss		<1 W/m

Ionisation chamber currents (1 litre, LHC)

450 GeV, quench levels (min)	100 s	12.5 nA
7 TeV, quench levels (min)	100 s	2 nA
Required 25 % rel. accuracy, error small against 25% => 5 %		100 pA
450 GeV, dynamic range min., used for tuning	10 s	10 pA
	100 s	2.5 pA
7 TeV, dynamic range min.	10 s	160 pA
	100s	80 pA