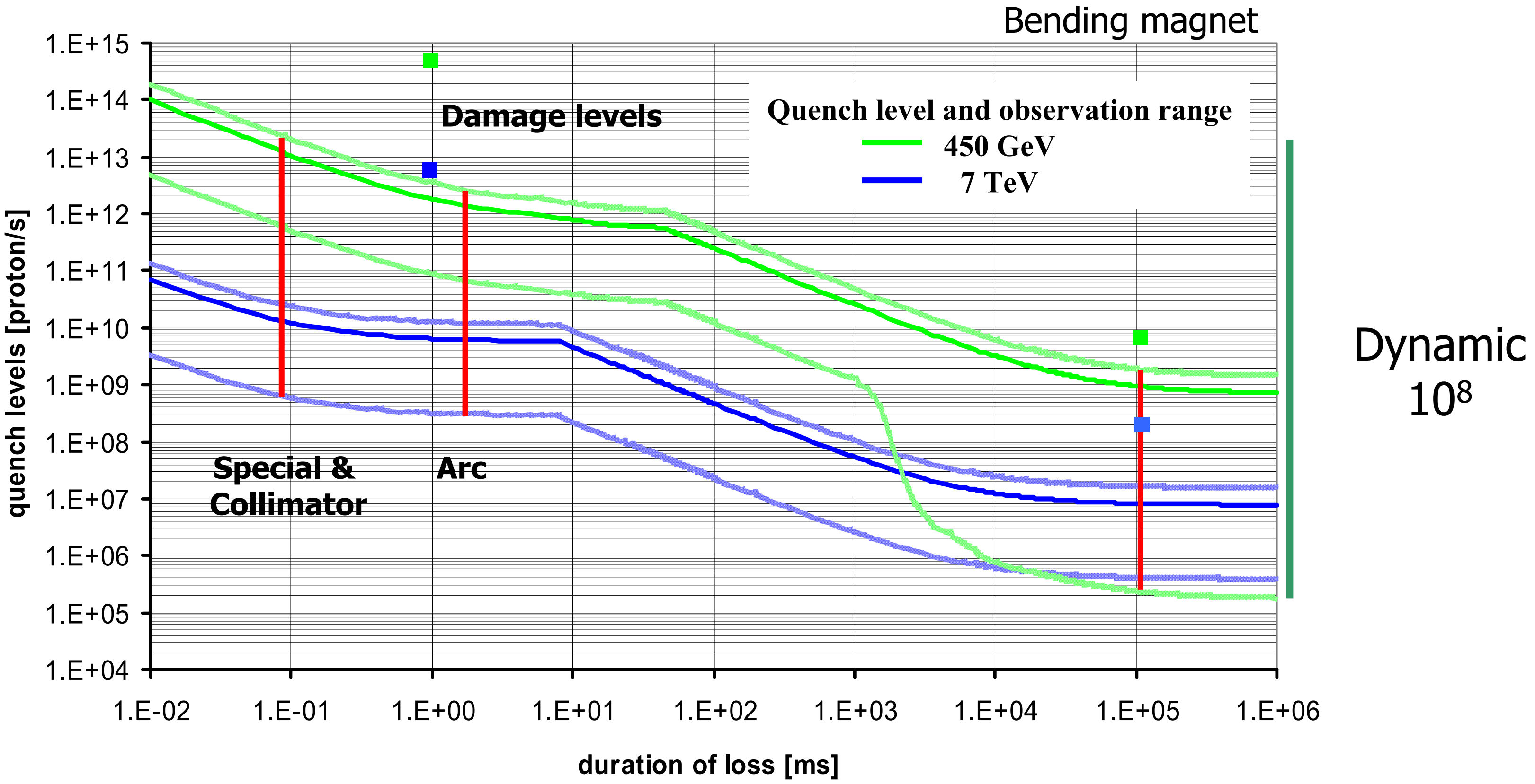
Overview of BLM uses and developments at CERN

- Damage and quench protection
- Beam loss shower distribution
- Detectors
- Ionisation chambers
- Reliability
- Loss signal and background

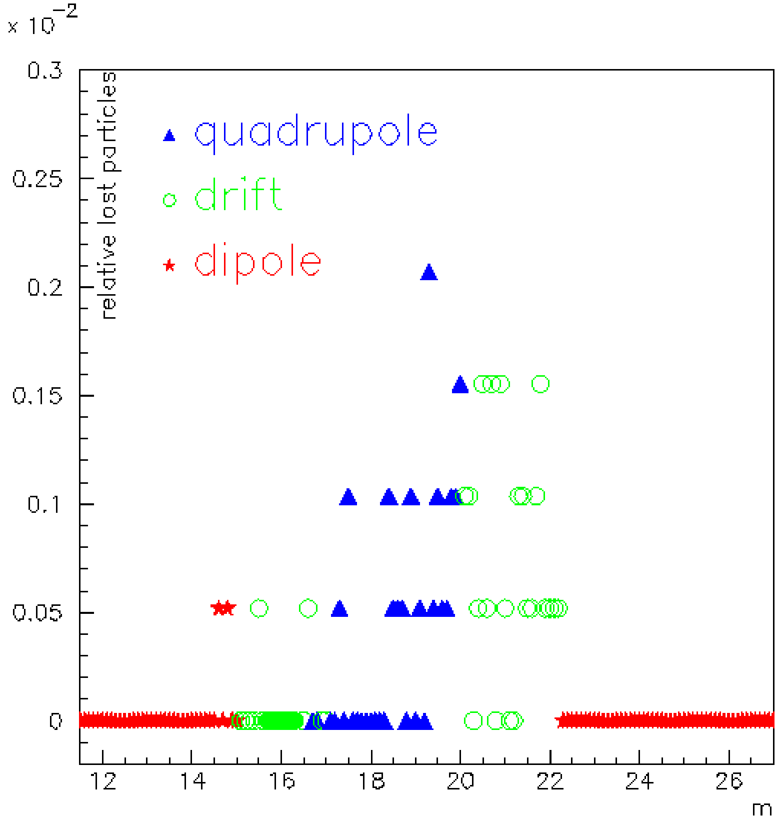
Quench and damage levels

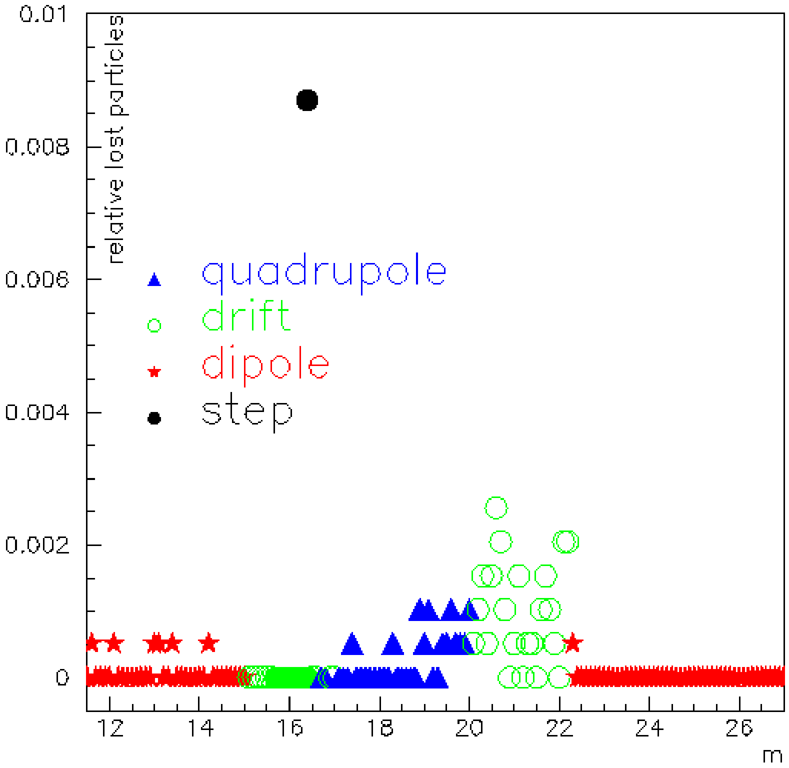
Detection of shower particles outside the cryostat or near the collimators to determine the coil temperature increase due to particle losses



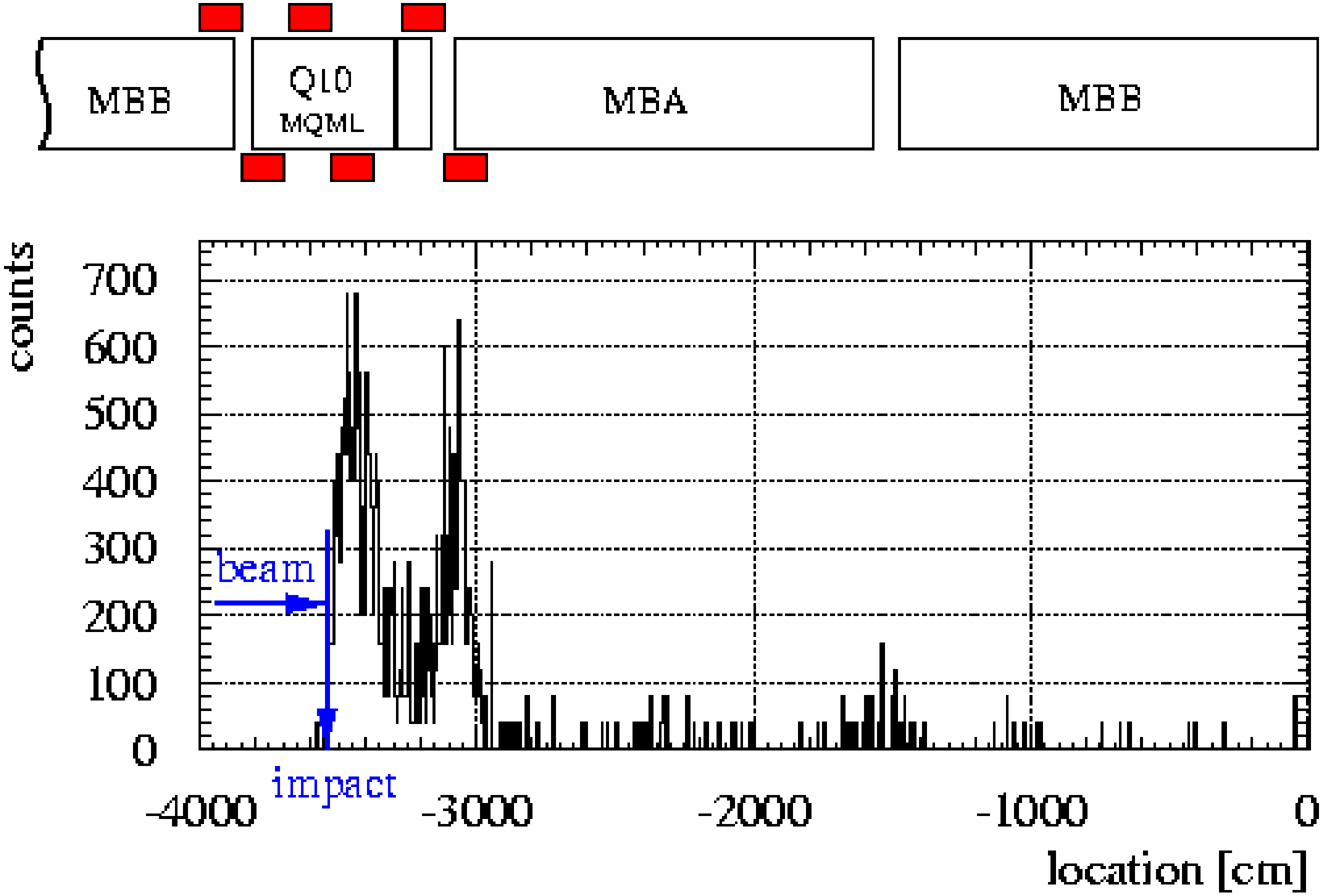
Loss distribution along the magnets

- Shower simulation; aims:
  - Determination of best monitor location
  - Determination of best shower integration (length of chamber)



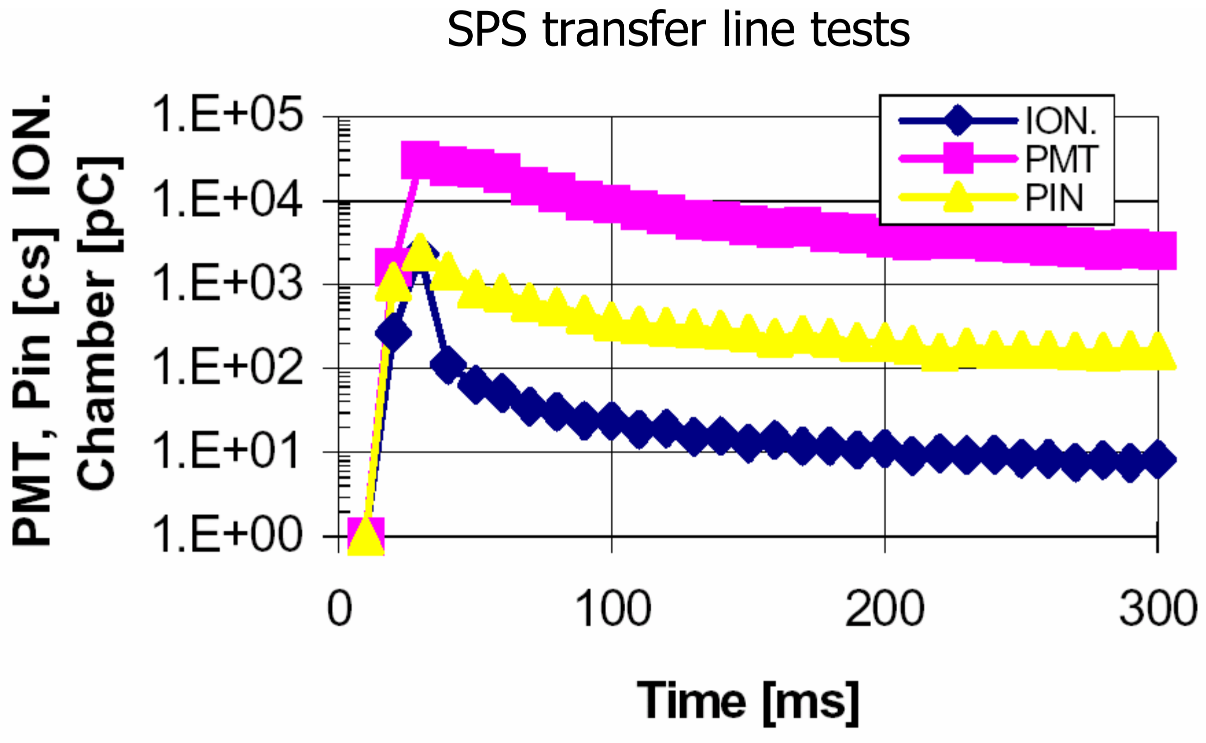


Detector locations and shower distribution

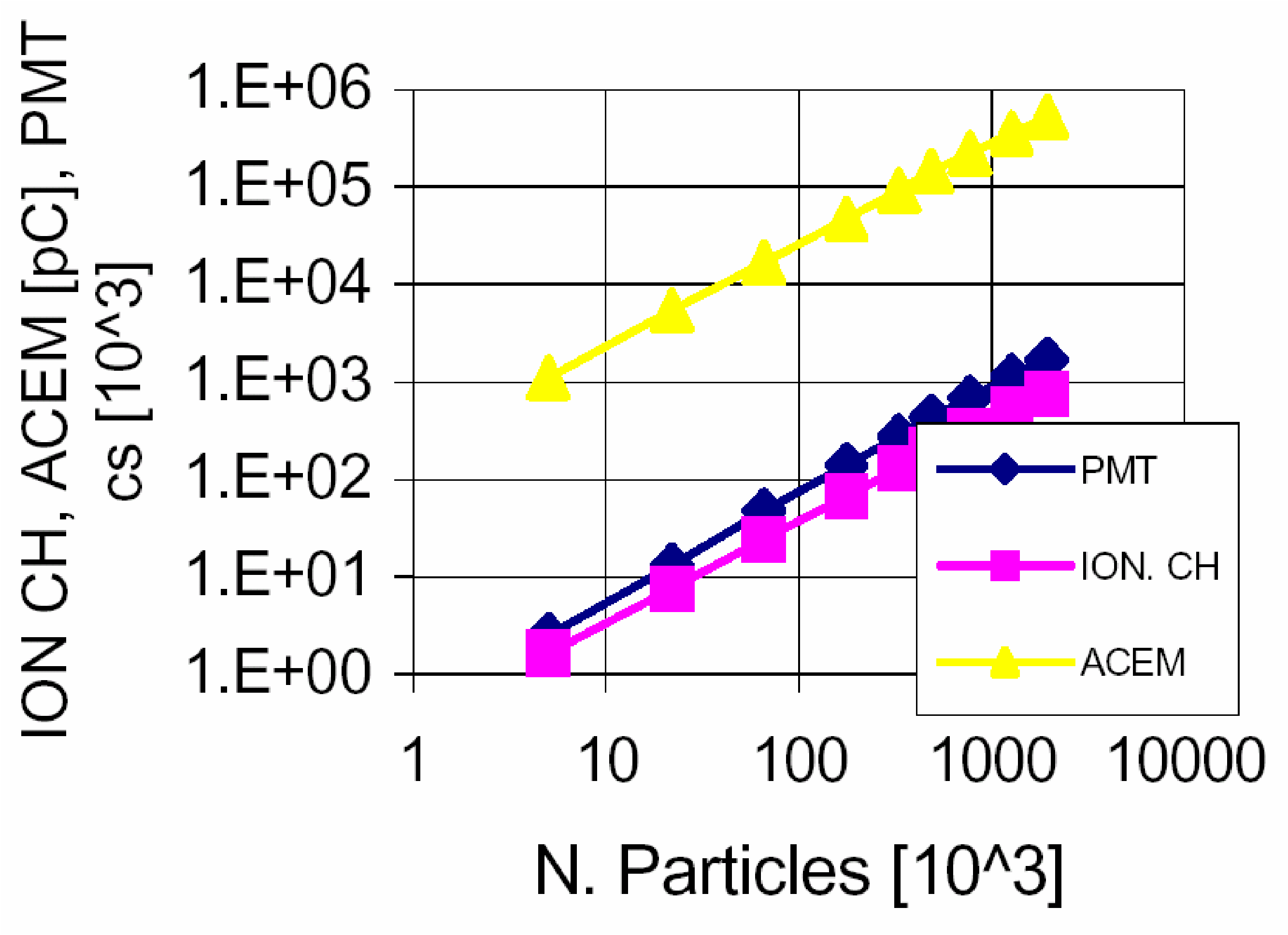


Comparison of different detectors

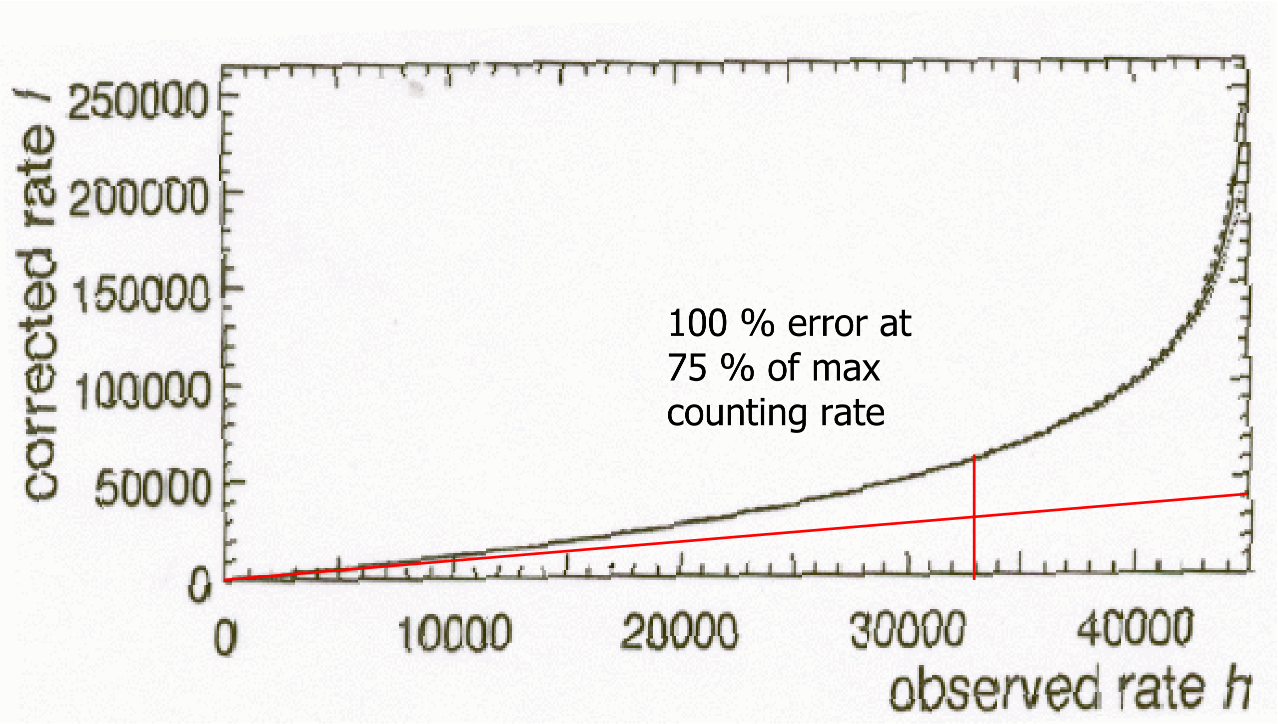
- Ionisation chamber (1l)
  - Dark current < pA
  - Analog dynamic > 10^7
  - Time response few 100 ns
  - Ion tail several 100 us
- Scintillator + PMT
  - Time response few ns
  - Gain calibration
  - Radiation sensitive
  - Counting dynamic 10^7
- Pin diodes
  - MIPS sensitivity 0.3
  - Counting dynamic 10^7
- ACEM
  - Time response few ns
  - Analog dynamic > 10^3



Linearity of beam loss monitors



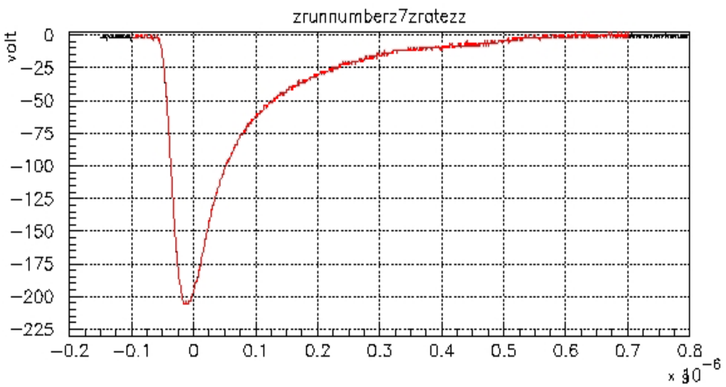
Saturation in counting mode



100 % error at
75 % of max
counting rate

Electron & ion induced signal

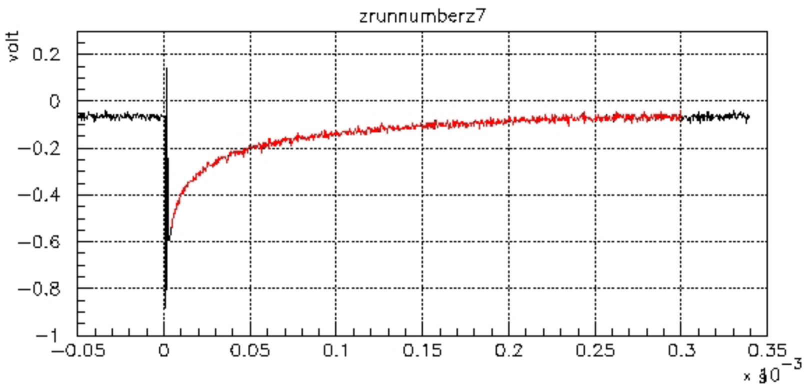
Booster intensity: ~ 8 10^9 protons



Model:

τel =270ns

(for v_{el}=20.2 ·10^5 cm/s at E=3000V/cm)

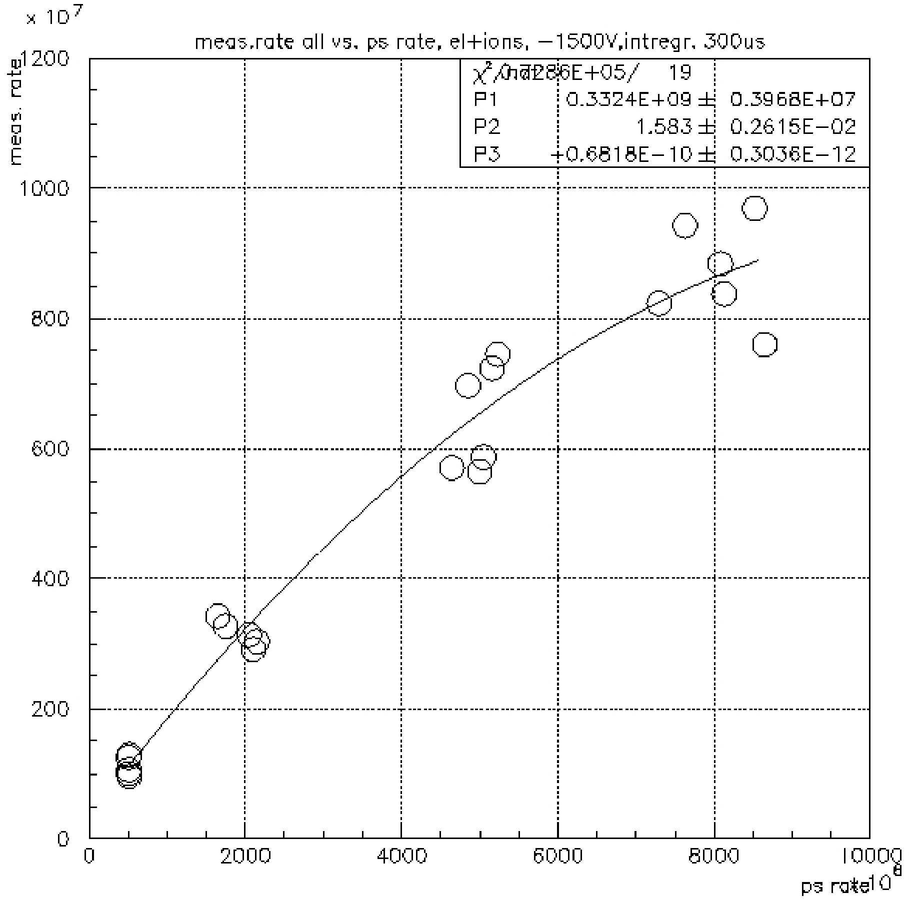


Model:

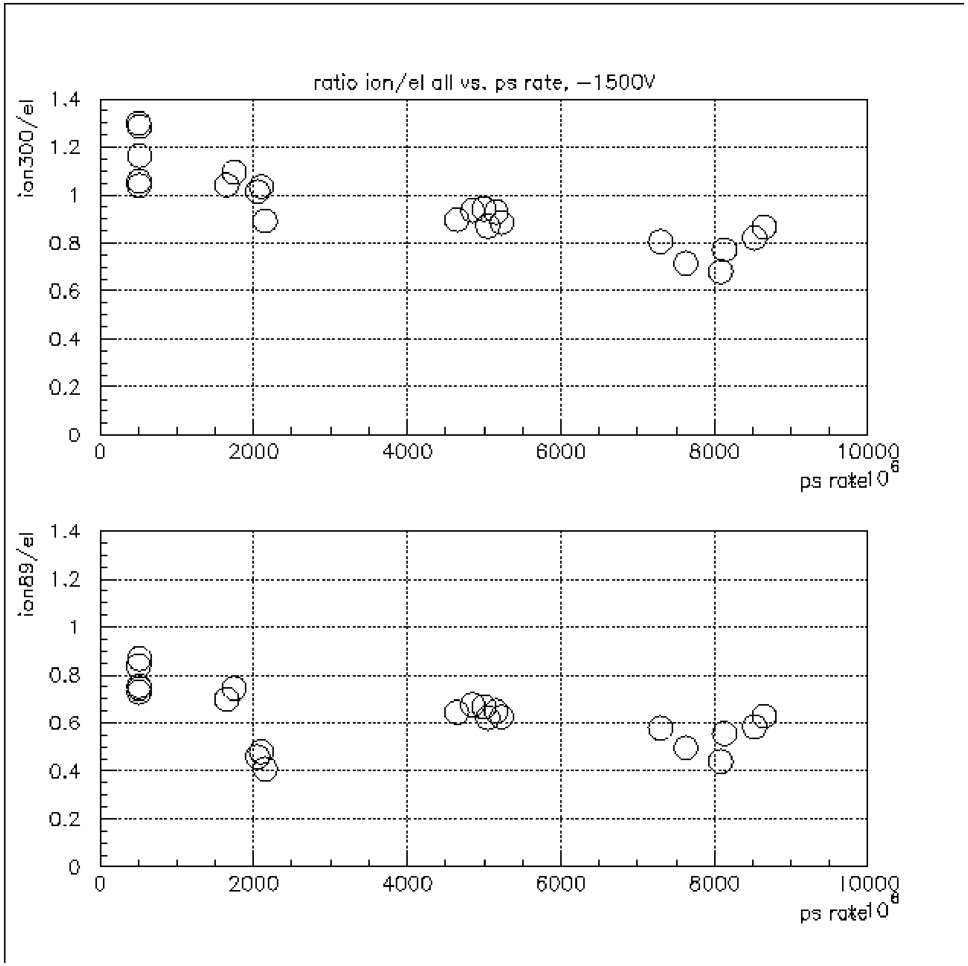
τ_{ion} = 69µs

(for v_{ion}=µE=8010 cm/s, µ=2.67cm²/Vs)

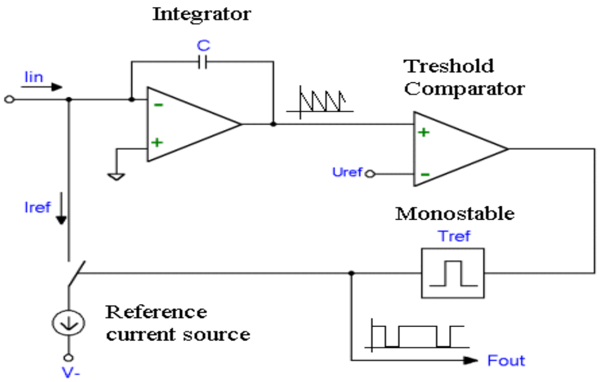
Meas. protons vs Booster protons ($t_{int}=300\mu s$)

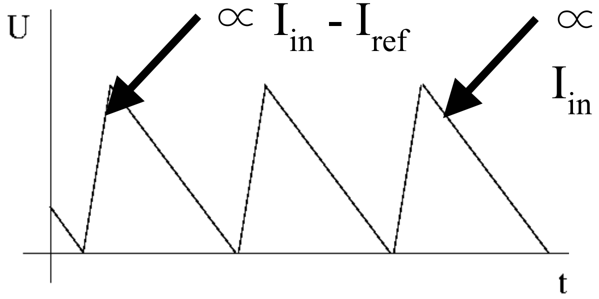


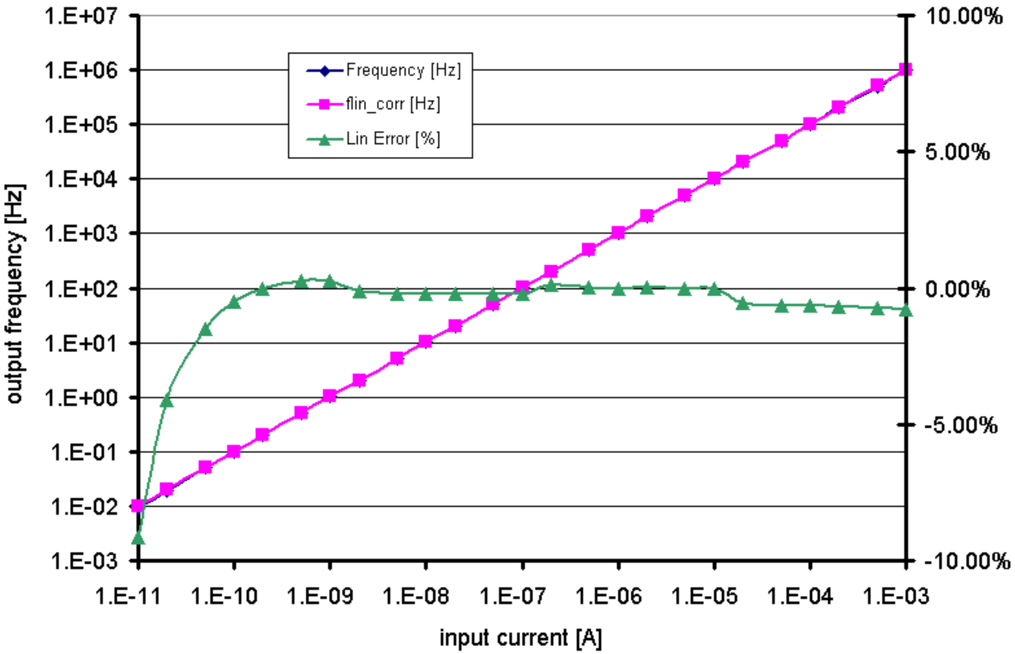
Ratio ion300(89)μs el-ion. vs Booster proton



Charge Balanced Converter





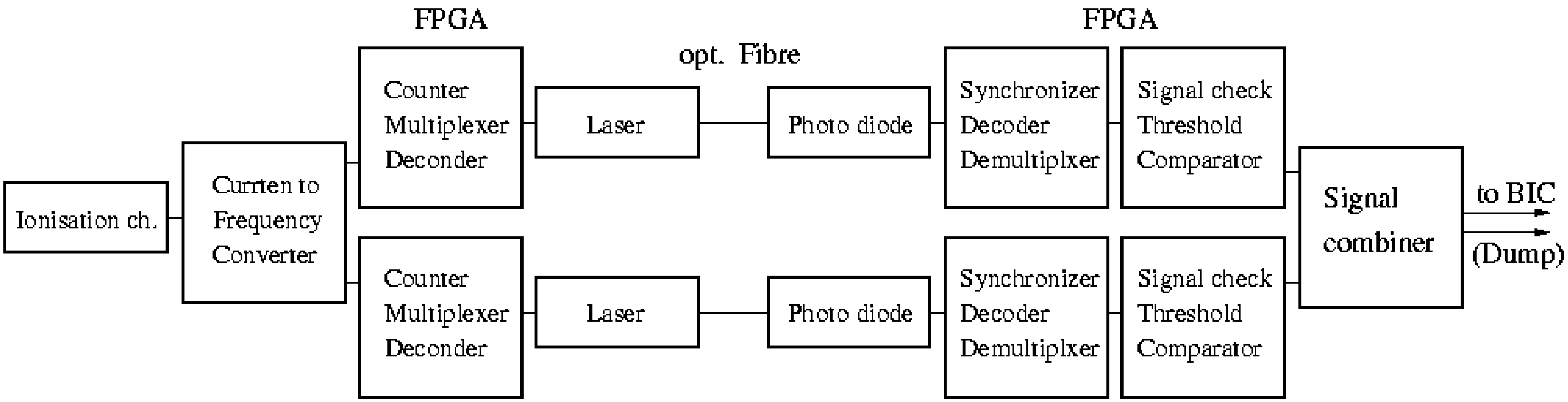


- Every f_{out} period is proportional to the average input current during the period
- f_{out} independent of capacitor
- relative error $\Box f_{out}/f_{out}$ proportional to relative error of $\Box I_{ref}/I_{ref}$ and $\Box T_{ref}/T_{ref}$

SIL Approach

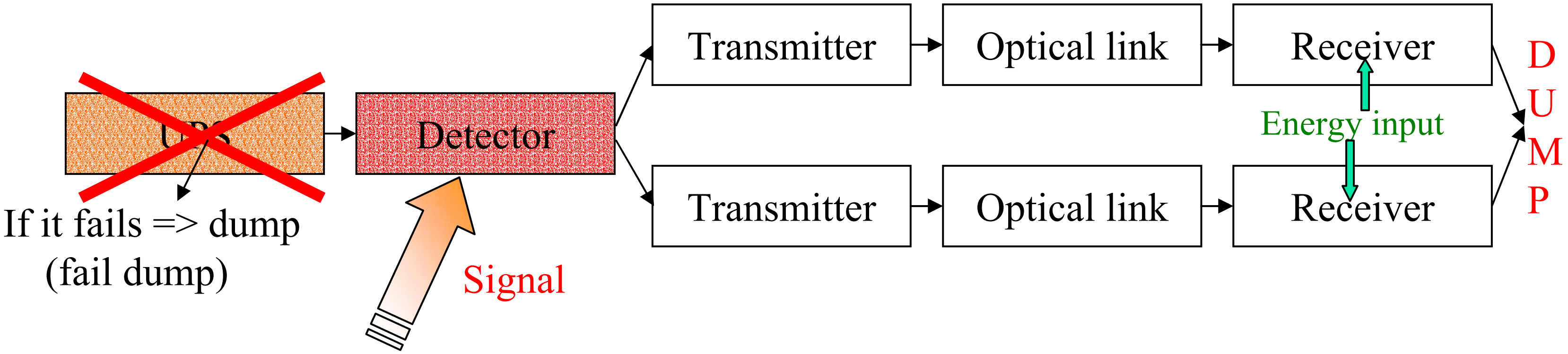
- Magnet damage:
    - Event likelihood (assumption):
      100 losses which could lead to a damage per year => frequent event
    - Consequences:
      Costs: 10^6 – 5 10^7 SFr or 20 days to 6 months down time => major
    - => needed failure probability: 10^{-7} – 10^{-8} /hours (=>250 y 1 damage)
- Failure to dump:
    - Event likelihood (assumption):
      10 wrong dumps per year => frequent event
    - <1 day down time => minor
    - => needed failure probability: 10^{-6} – 10^{-7} /hours

BLM Signal Transmission Chain



- Detector:
  - Ionisation chamber
  - 3 on either side of the quadrupole magnets
- Signal:
  - Current to frequency conversion (max 400 m distance to ionisation chamber)
  - redundant transmission to threshold comparator in surface buildings

Magnet Damage



~~UPS~~

If it fails => dump
(fail dump)

Detector

Signal

Transmitter

Optical link

Receiver

Energy input

Transmitter

Optical link

Receiver

DUMP

$$P_{MaDa} \sim P_S + Q_{BLM} + P_{en-} + Q_{DUMP}$$

Probability to have a Magnet Damage

Probability not to detect the dangerous loss

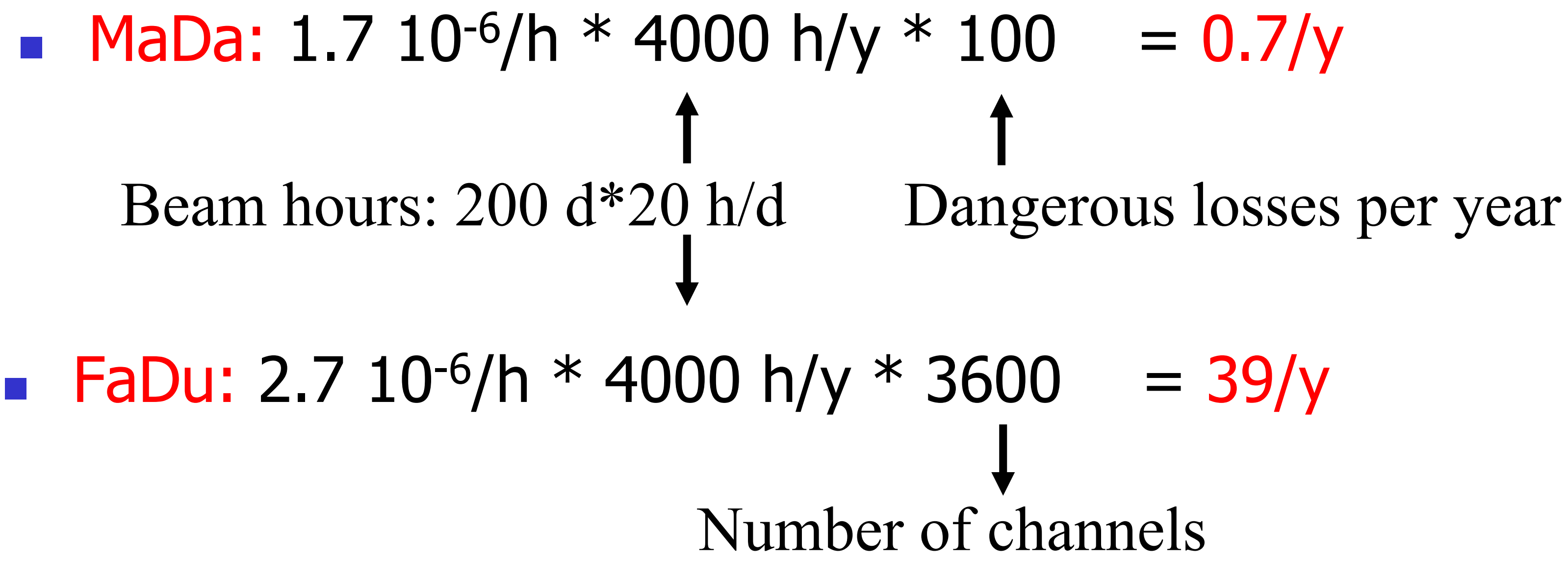
Unavailability of the BLM system

Probability to underestimate the beam energy

Unavailability of the DUMP system

$$\Sigma < 10^{-7}\ /h \Rightarrow \text{single } 1\ 10^{-8}\ /h$$

Damages and Failures per Year



- MaDa: 1.7 10^{-6}/h * 4000 h/y * 100 = 0.7/y

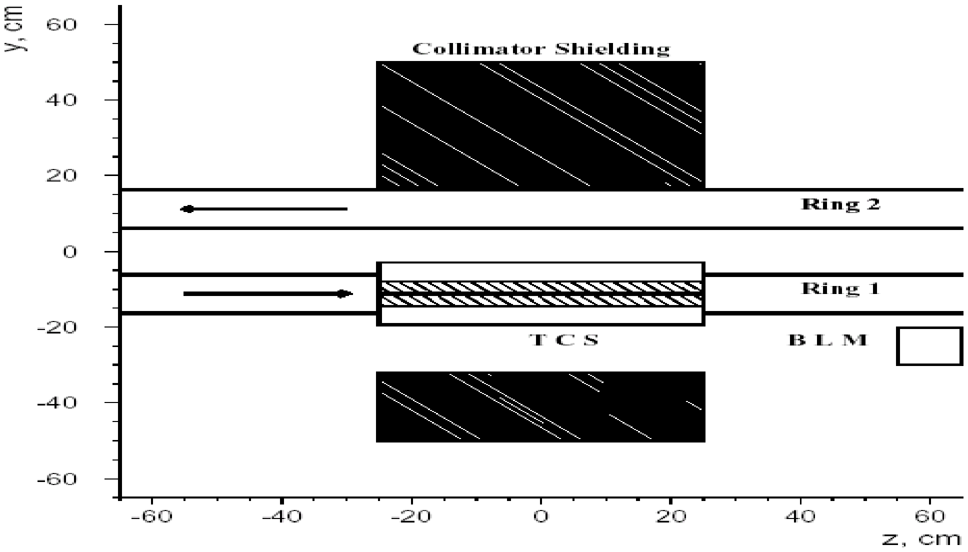
Beam hours: 200 d*20 h/d

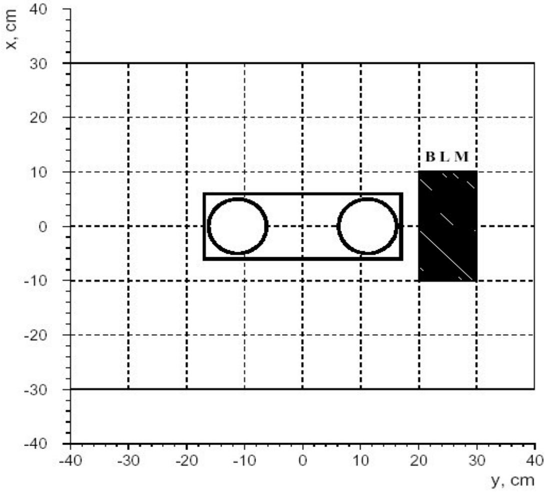
Dangerous losses per year

- FaDu: 2.7 10^{-6}/h * 4000 h/y * 3600 = 39/y

Number of channels

BLM in the Collimation Insertions

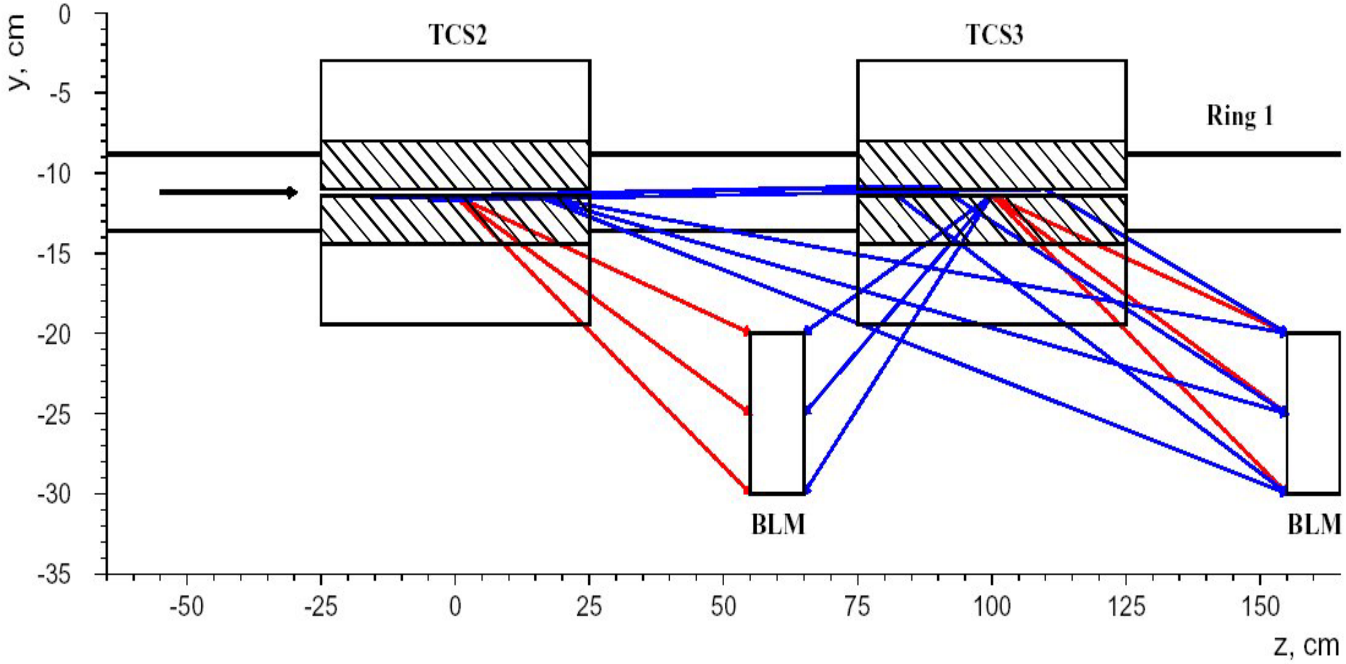




- Every collimator is equipped with one ionisation chamber
- The combined signal of the cleaning insertion has to be compared with the quench level thresholds

BLM Signal Simulation for the Cleaning Insertion I

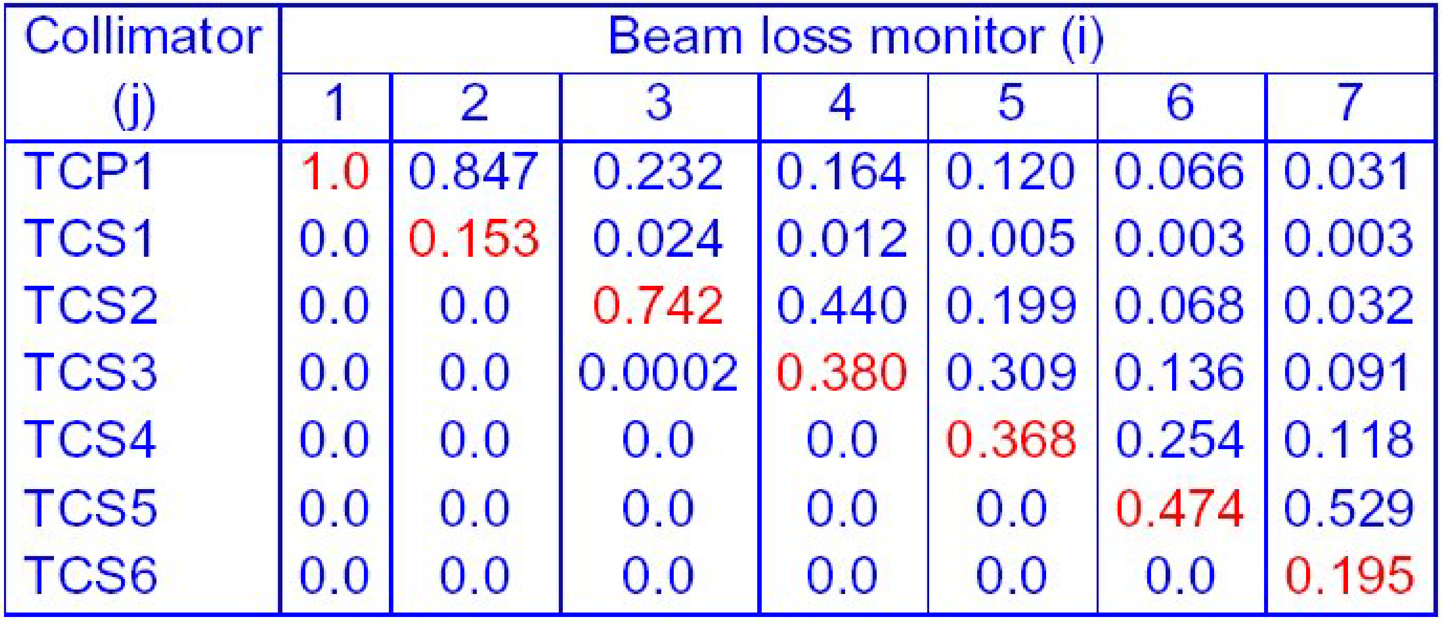
- Aims:
  - Minimisation of cross talk
  - Optimisation of BLM signal
  - Definition of total loss estimator



BLM Signal Simulation for the Momentum Cleaning Insertion II

- First simulation result (Igor Kourotchkine, Protvino)
  - Momentum cleaning, IP3
  - Collimator material: AL/CU
  - Collimator length: 20/50 cm

E = 7 TeV

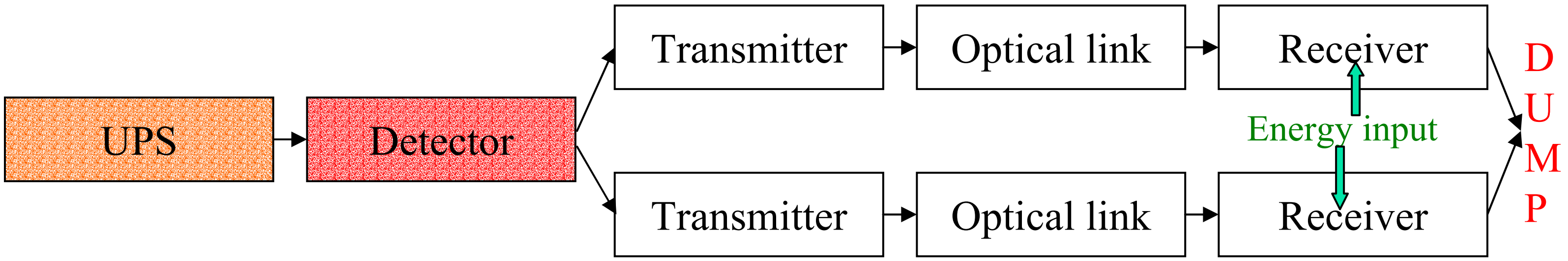


Collimator (j)	Beam loss monitor (i)						
	1	2	3	4	5	6	7
TCP1	1.0	0.847	0.232	0.164	0.120	0.066	0.031
TCS1	0.0	0.153	0.024	0.012	0.005	0.003	0.003
TCS2	0.0	0.0	0.742	0.440	0.199	0.068	0.032
TCS3	0.0	0.0	0.0002	0.380	0.309	0.136	0.091
TCS4	0.0	0.0	0.0	0.0	0.368	0.254	0.118
TCS5	0.0	0.0	0.0	0.0	0.0	0.474	0.529
TCS6	0.0	0.0	0.0	0.0	0.0	0.0	0.195

Literature

- http://ab-div-bdi-bl-blm.web.cern.ch/ab-div-bdi-bl-blm/Ionisation_%20chamber/Literature

False Dump



$$P_{\mathrm{FaDu}} \sim \left(P_{\mathrm{THR}} + Q_{\mathrm{BLM}} + P_{\mathrm{en+}} \right) * 3600$$

Probability to have a False Dump

Probability to have a false dump signal

Unavailability of the BLM system+UPS

Probability to overestimate the beam energy

Number of channels

$$1*10^{-6}\,/\mathrm{h} = \left(3*10^{-10}\,/\mathrm{h} \right) * 3600$$

Pin diode versus Ionisation chamber

- In pilot bunch operation no quench protection
- Very fast loss detection (0.1 to 10 ms) difficult (may not needed)
- First turn detection not possible (1 count, 100 % error, BPM will deliver no intensity information)
- Single bunch loss detection possible

- All possible operation ranges are covert (0.1 ms to several seconds,
  dynamic of 10^7)
- First turn sensitivity
- No single bunch loss detection possible (min time resolution batch)

Basic Concepts

- System fault events:
  - BLM are designed to prevent the Magnet Damage (MaDa) due to a high loss of protons (~ 30 downtime days).
  - BLM should avoid false dumps (FaDu) (~ 6 downtime hours).
  - Use of Safety Integrity Level (SIL).