Beam Loss Monitors

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Content

Operating range of monitors

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Collimation detection

Detection monitor system

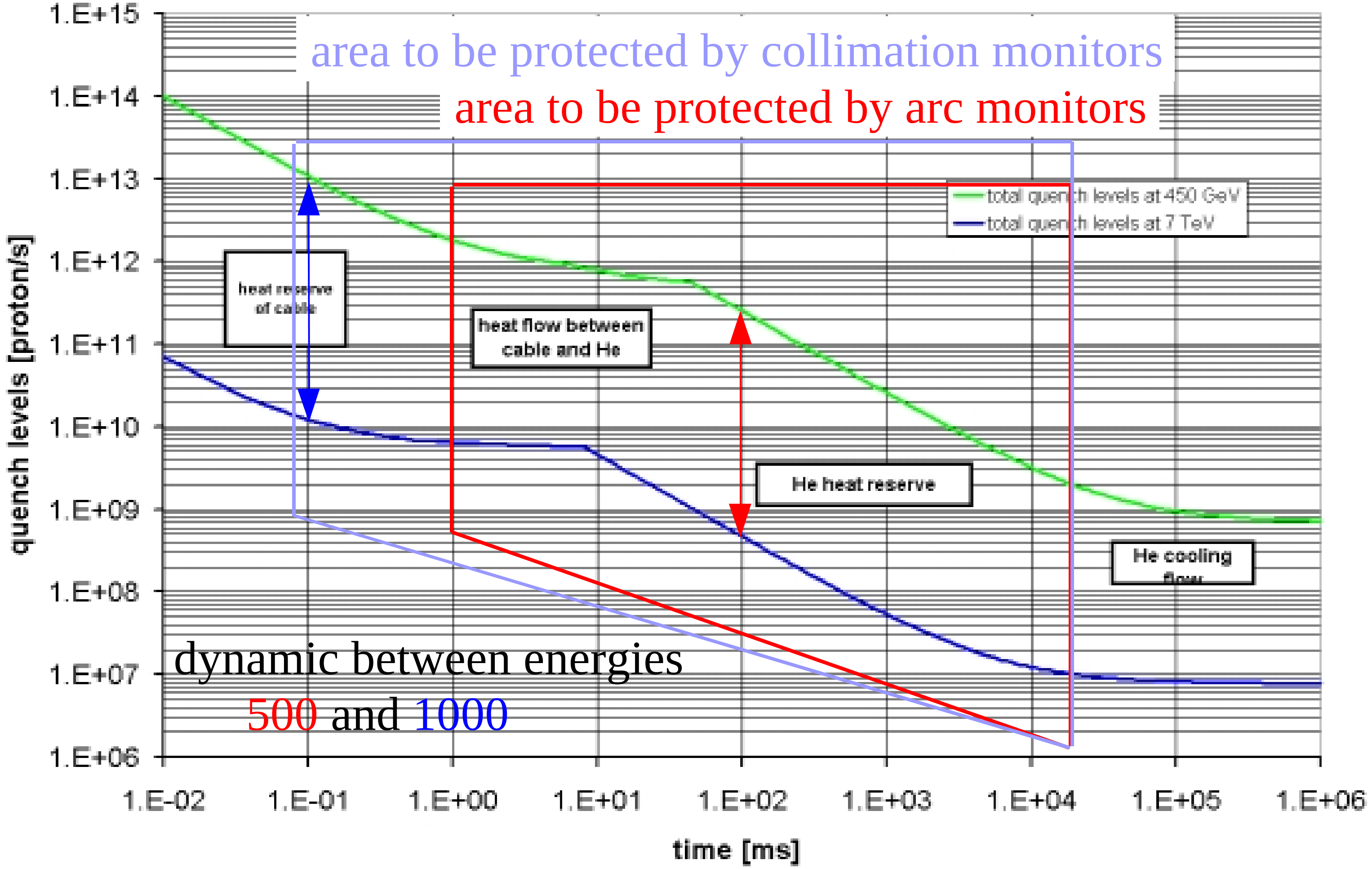
Method

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

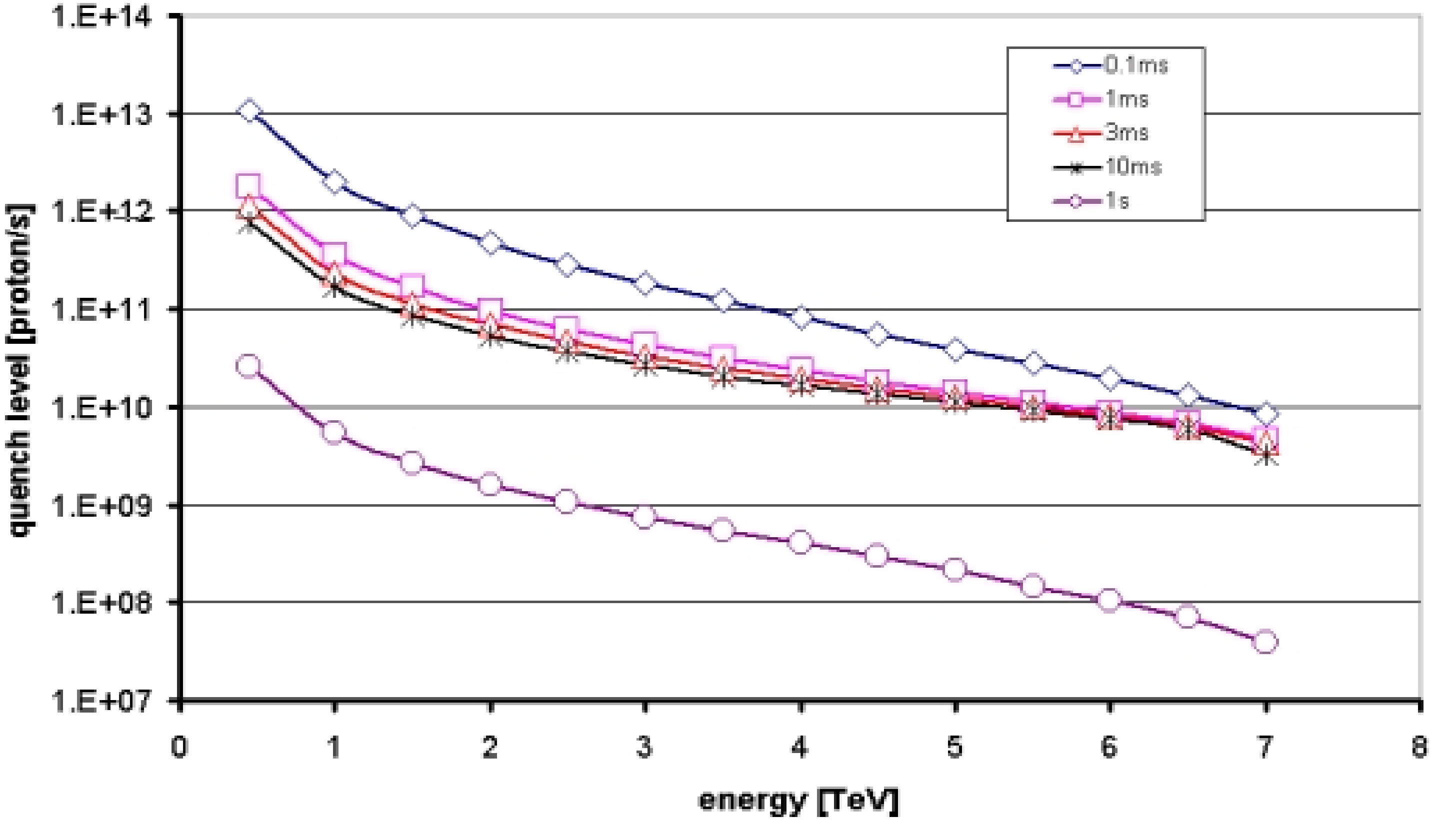
- Relation between loss rate and temperature increase
  quench levels:
  (J.B. Jeanneret et al. LHC Project Report 44)

- Relation between loss rate and particle flux outside the cryostat
  fluence:
  (A. Arauzo Garzia et al. LHC Project Note 238)

Quench levels

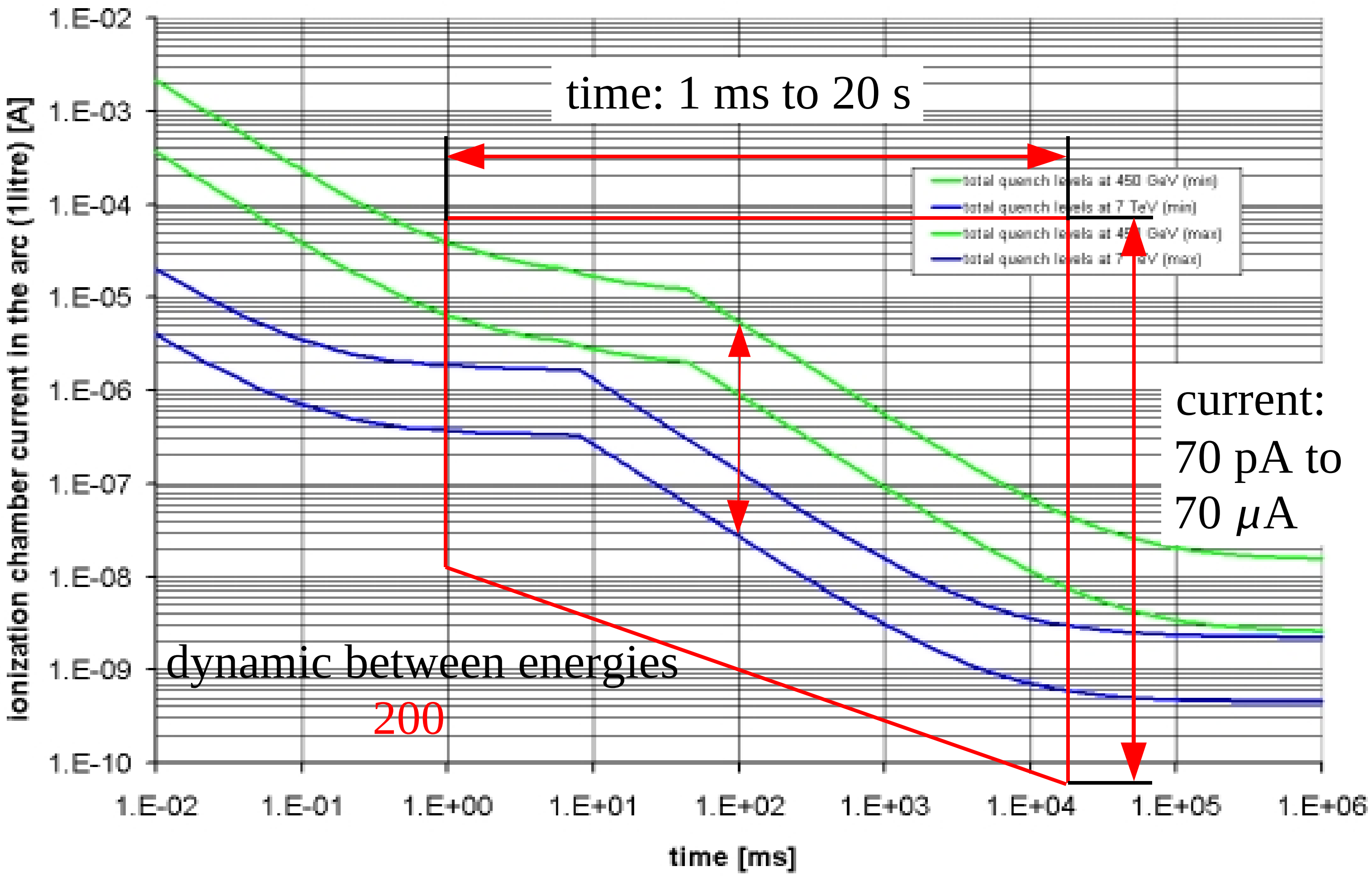


Quench Level Rate and Energy

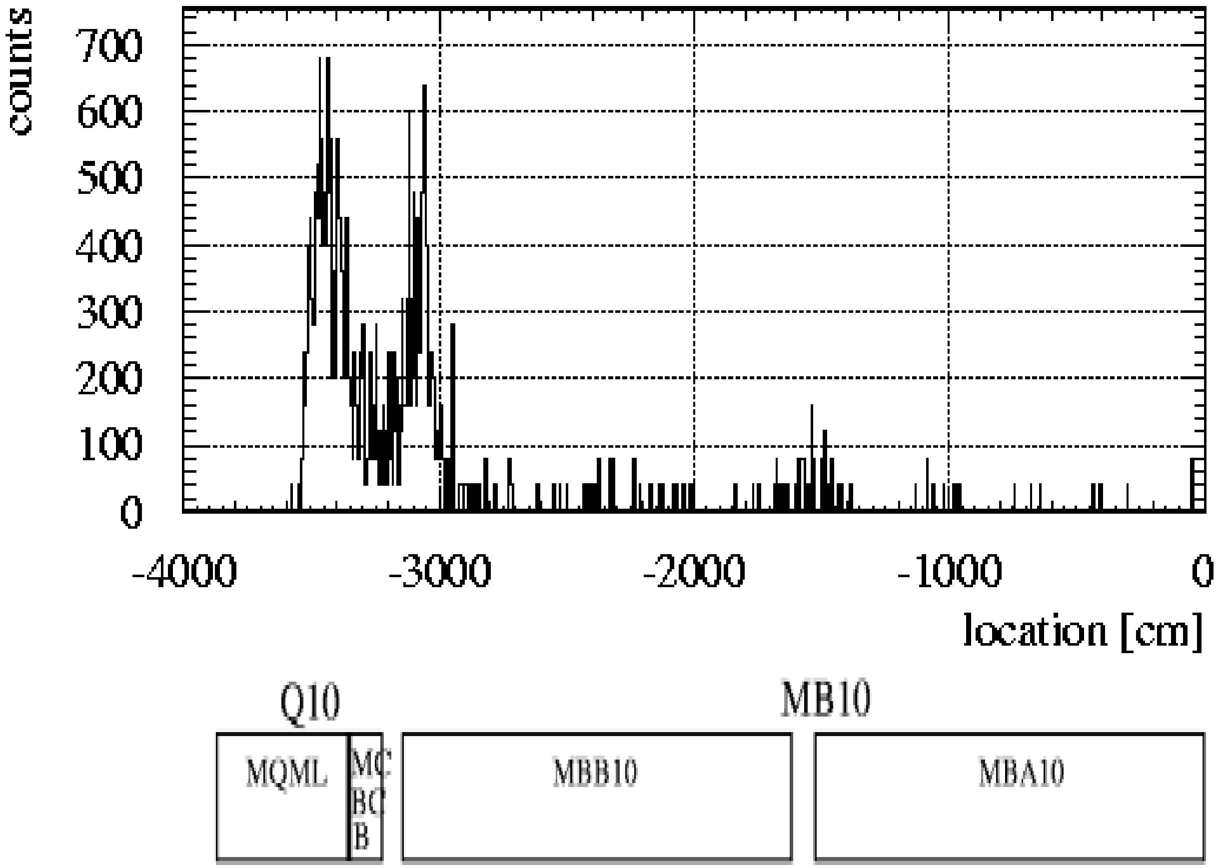


Factor 10 reduction between 0.45 and 1.5 TeV

Arc Ionisation Chamber Current

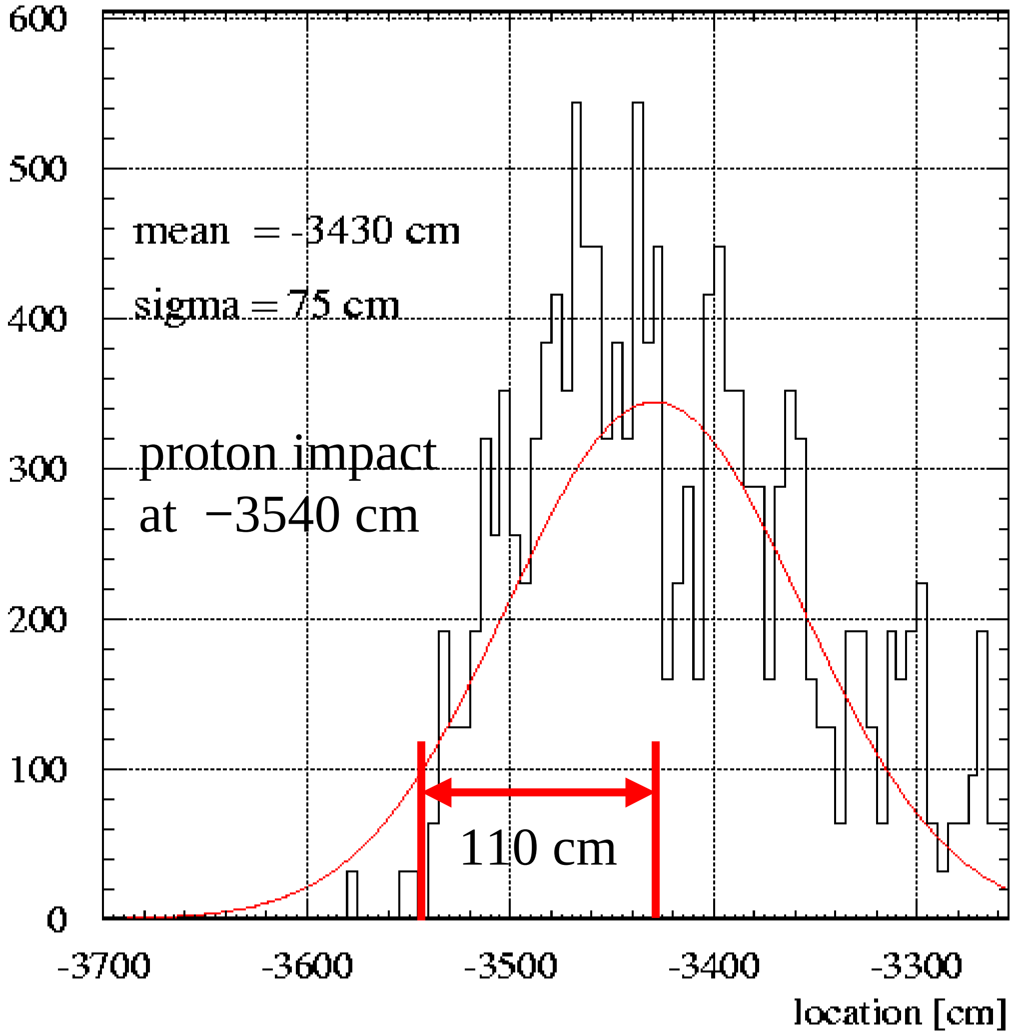


Proton Shower Distribution (1)



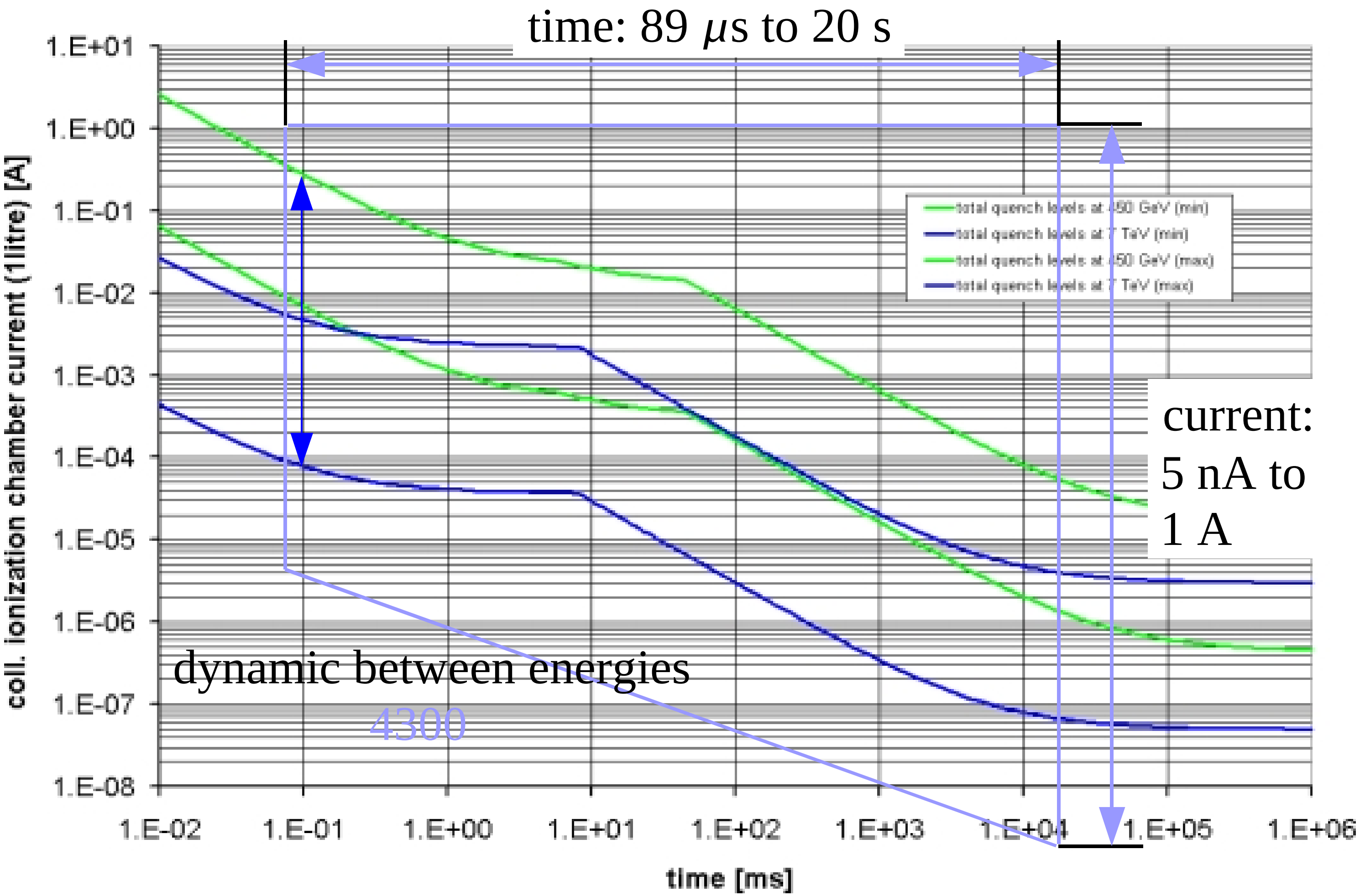
- impact of the protons at the centre of Q10
- first maximum due to shower in the cold mass
- second maximum due to gap between MQ and MB magnet
- third maximum due to gap between two MB magnets
- reduction of shower particles by a factor of over 100 after a few meters

Proton Shower Distribution (2)



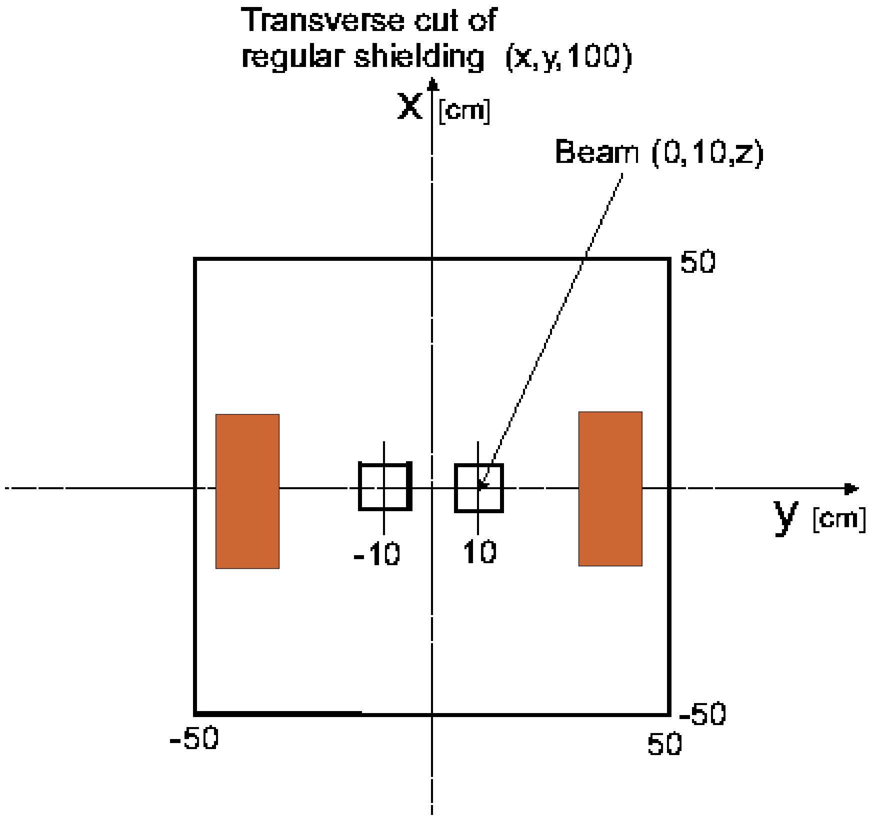
- distance between proton impact and shower maximum 110 cm
- shower width σ = 75 cm
- longitudinal proton loss distribution will modify shower distribution significantly

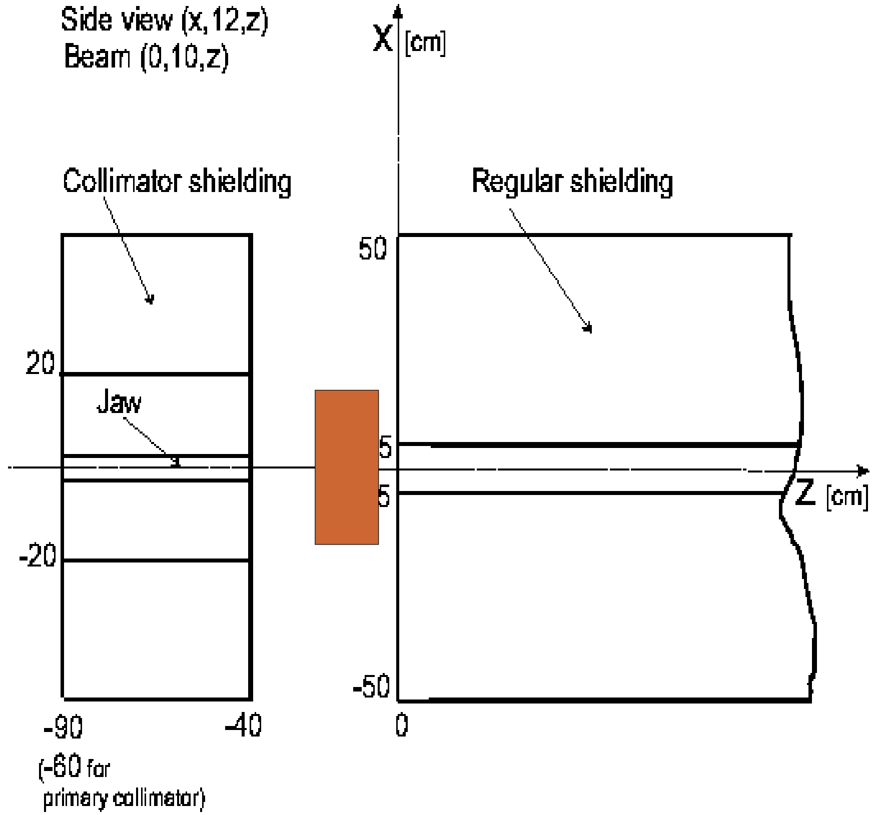
Collimation Ionisation Chamber Current



Location of Monitors at Betatron Collimation

First layout of a IP7 shielding. The beam loss monitors are placed in the gap between collimator shielding and regular shielding

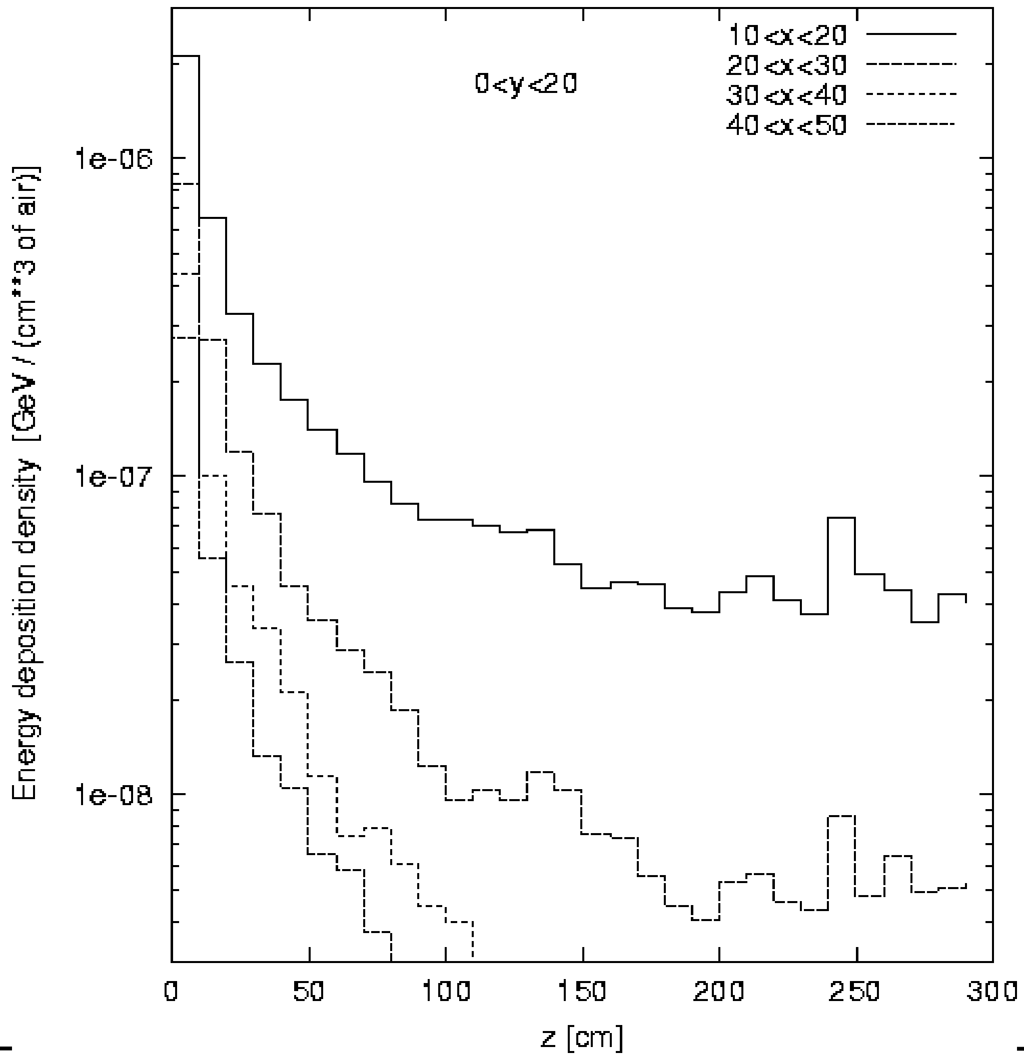




Longitudinal Energy Deposition

I. Baichev

1. secondary particle energy deposition along the regular shielding
2. loss monitor location z=0
3. at 100 cm (location of foreseen second collimator in some arrangements) the energy deposition is only reduced by a factor of 10 (10<x<20)

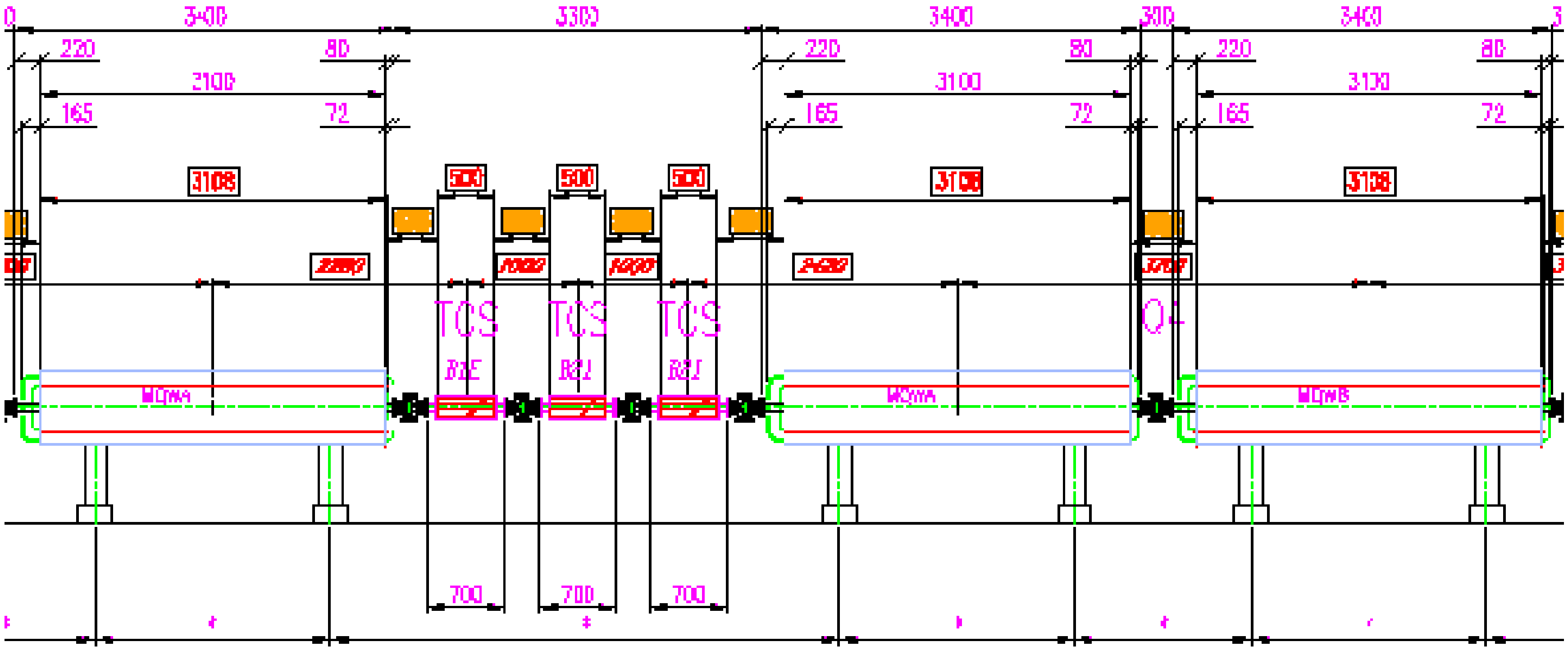


Result: crosstalk between monitors, reduction of collimation adjustment accuracy=>
careful investigations needed

Proposed Collimator Locations IP7

Collimators are about 1m apart and some arrangements are composed

of beam 1 and beam 2 collimators (distinction between losses of different beams will not be possible).



Collimation Counting Rates

1. Collimation (basic definitions):

$$n_{primary} * \eta = n_{tertiary}$$

η : *collimation inefficiency;*

2. Losses at collimation:

$$n_{col} = n_{prim}(1-\eta) = \sum_{i=1}^{4} N_{primary\ i} * \alpha_i + \sum_{i=1}^{16} N_{secondary\ i} * \beta_i$$

n_{col}: *loss rate at collimators;* $N_{primary}$, $N_{secondary}$: *counting rates at the collimator monitors;* α, β : *monitor sensitivity*

3. Losses at other locations:

$$n_{tertiary} = n_{col} \frac{\eta}{1+\eta} = \sum_{i=1}^{N} quench\ level_i * \overline{safety}$$

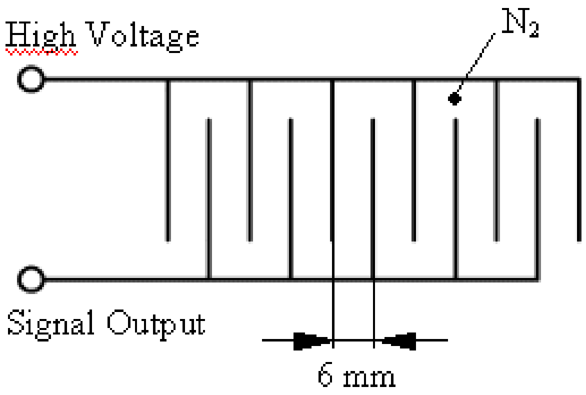
$\overline{safety}$: *ratio of maximal safe losses to quench level; N: number of locations where losses will occur*

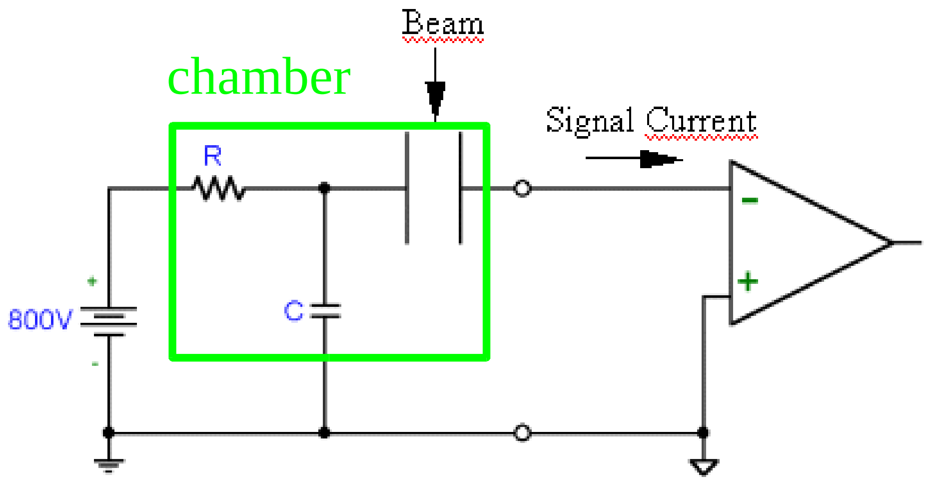
4. Aim: predict accuracy of quench levels with an error of 2

Beam Loss Simulations

1. How to combine the ionisation chamber signals (and, or, ...)?
   i. Between two primary chambers
   ii. Between two secondary chambers
   iii. Between primary and secondary chambers
   iv. Between betatron and momentum cleaning
2. What is the number of location where particle losses will occur (in the arc and in the long straight sections)?
3. At which location losses are expected?
4. What is the length of the losses (relevant for design of chambers)?
5. Do we need to combine signals from loss detectors in the arc (correlation of losses)?

Ionisation Chamber Monitor





ionisation chamber:

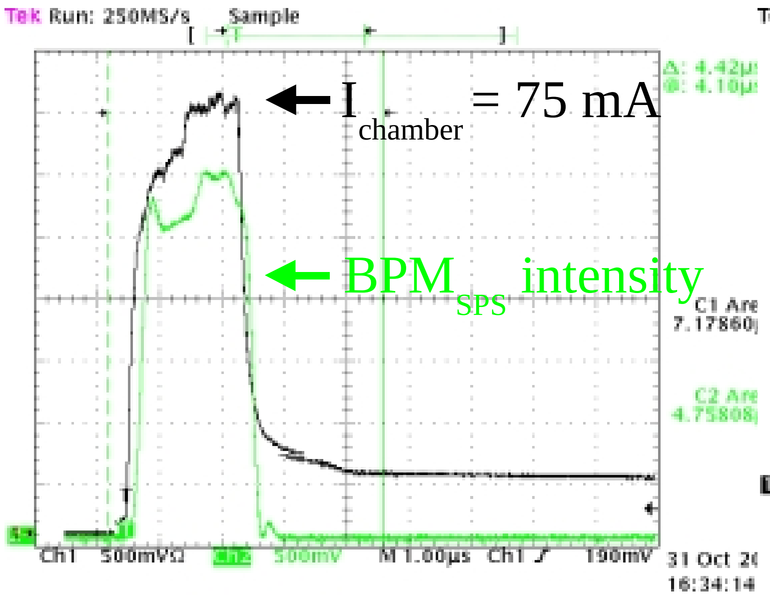
- gas: N_2
- pressure: normal
- voltage: 800 to 1800 V
- # of electron/ion pairs 50 − 70 1/MIP/cm

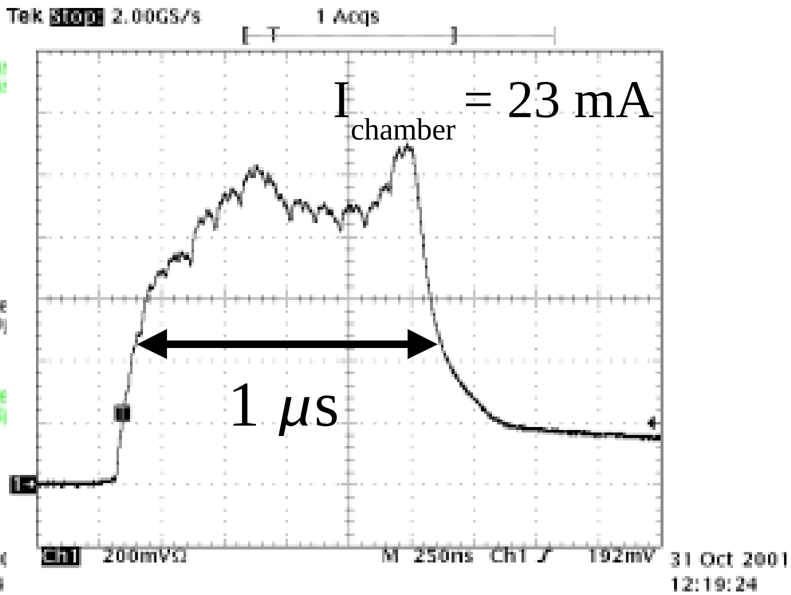
current to frequency converter:

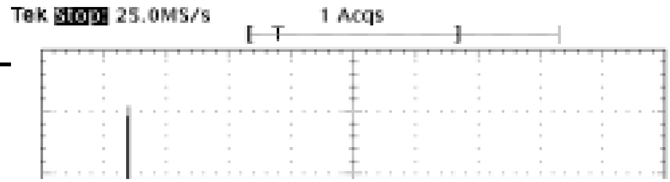
- first stage (input cable length up to 400 m):
  - dynamic: about 10^7
  - input current: 30 pA to 50 mA
  - output frequency: 0.05 to several MHz
- second stage (input cable length up 1.5 km)
  - every channel with micro controller
  - several mean loss values in parallel
  - energy tracking

Ionisation Chamber Signal

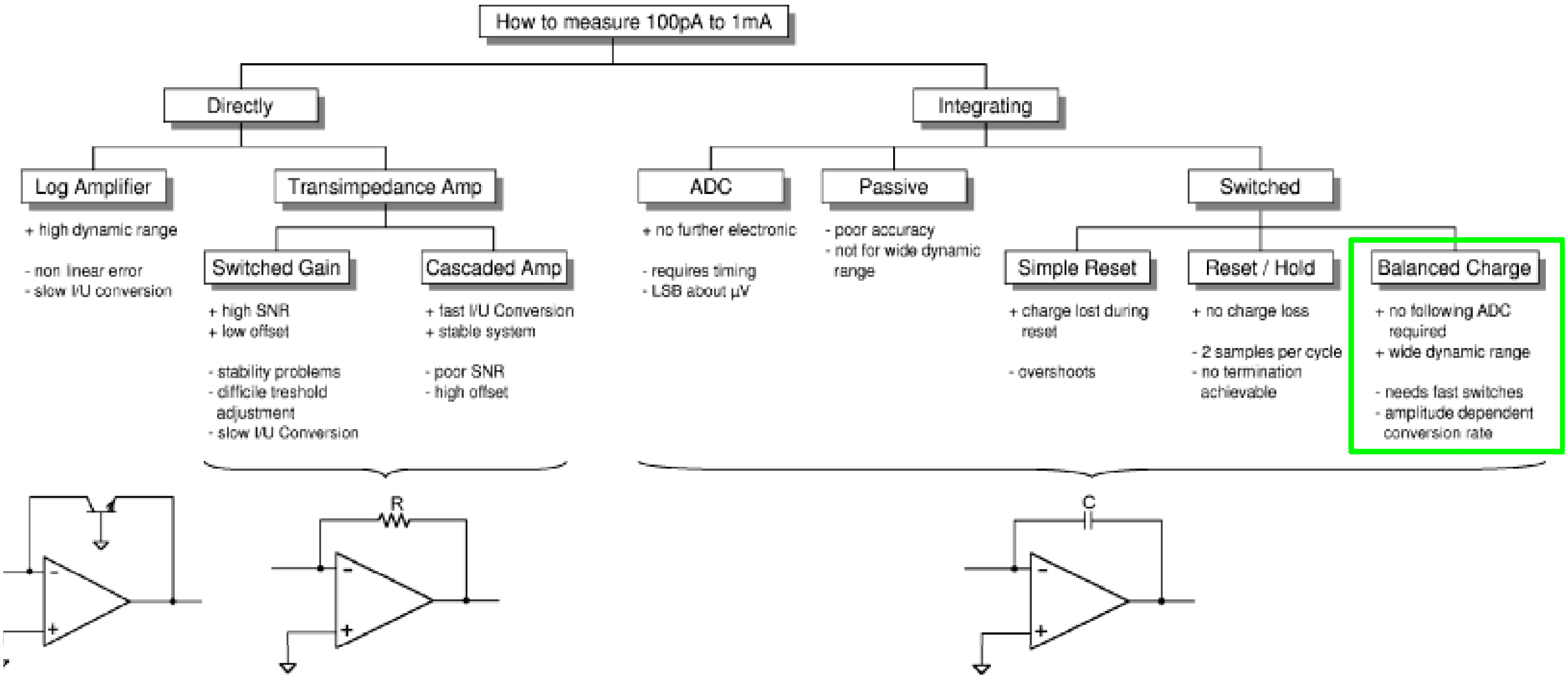
- High intensity test measurements with standard SPS ionisation chamber near SPS dump
- Rise time of the signal 300ns (limited by electron drift speed, electrode distances and pressure)
- Fall time of the signal 200 μs (limited by positron drift speed, “ “ “ “)
- Measurements: scope directly connected (50 Ω) to the ionisation chamber



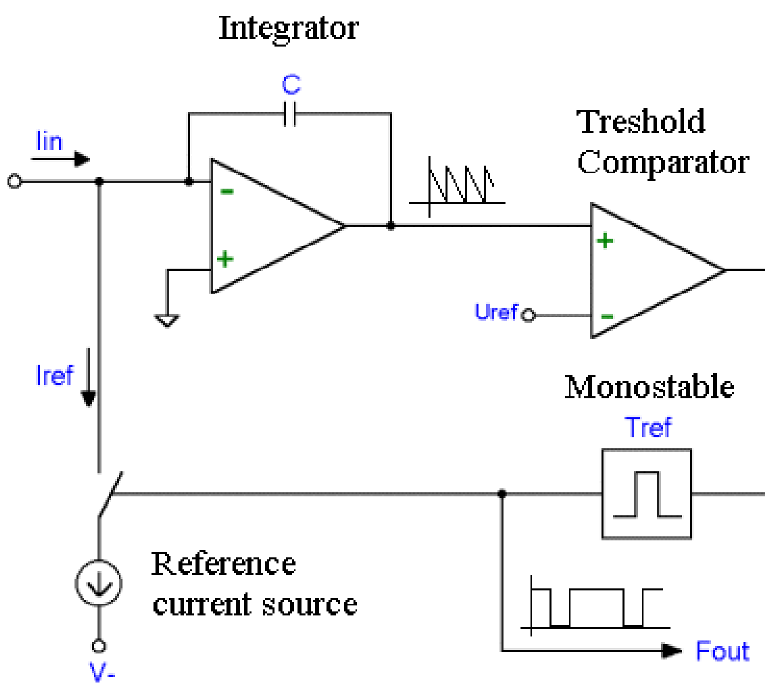


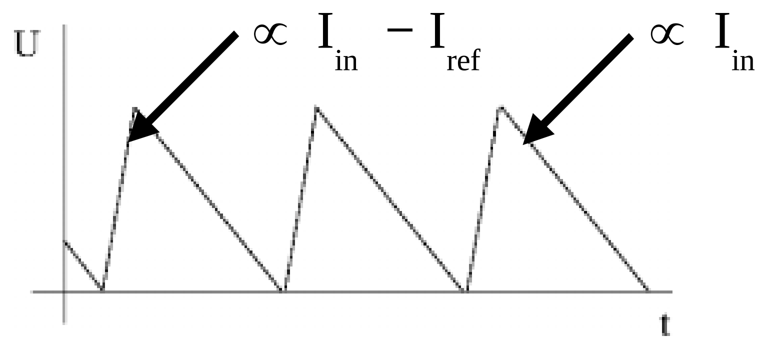


Acquisition Circuit Principles



Charge Balanced Converter

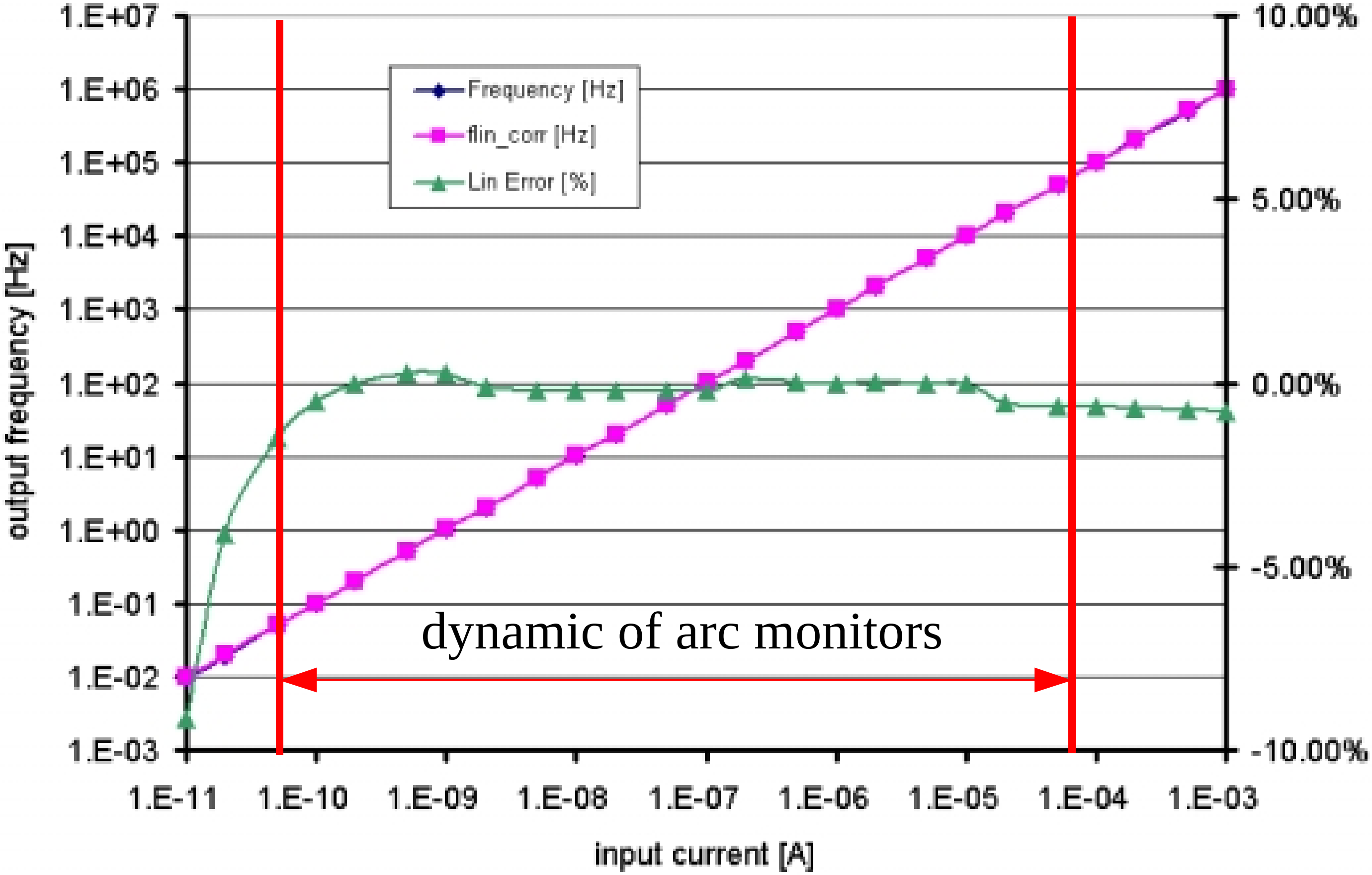




$$f_{out} = I_{in} \frac{1}{I_{ref} * T_{ref}}$$

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

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)

Summary

A monitor dynamic of 10^6 to several 10^7 is required.

A calculation of several average loss rates between 89 μs and 20 s is required.

Proton shower simulations partially done (arc).

Collimation monitor system needs detailed analysis of particle contamination.

Several simulations are needed to determine the combination rules of loss informations.

First tests with ionisation chambers indicate a high intensity limit.

The charge balanced converter has the required dynamic range.