LHC Beam Loss Monitors

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Content

Purpose of Beam Loss Monitor System

- Protection and Prevention of magnets and other equipment against damage and magnet coil quenches by dump of the beam before thresholds are exceeded
- Beam diagnostic tool: Beam loss monitors can be used to optimise the accelerator tuning

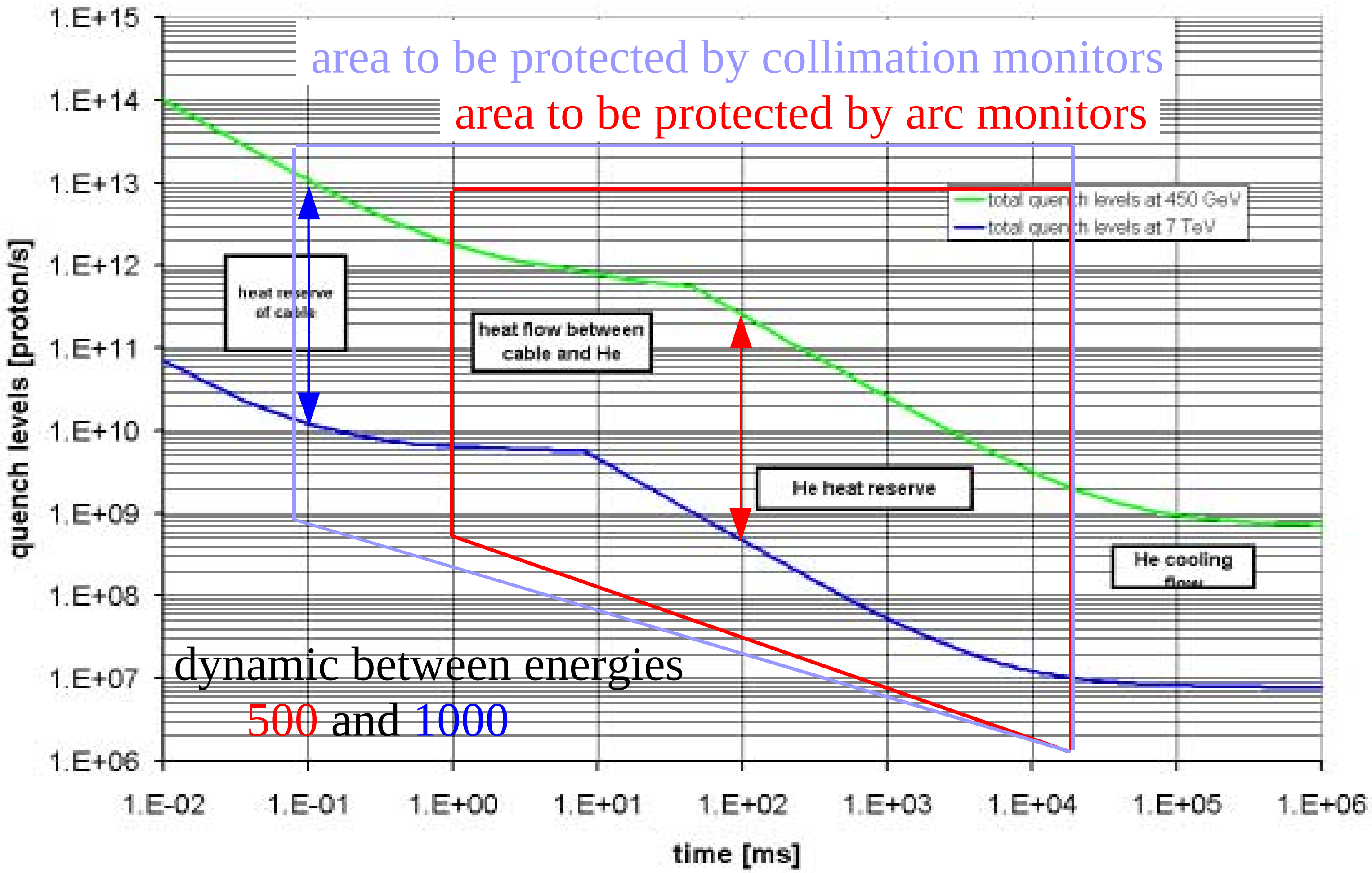
Method

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

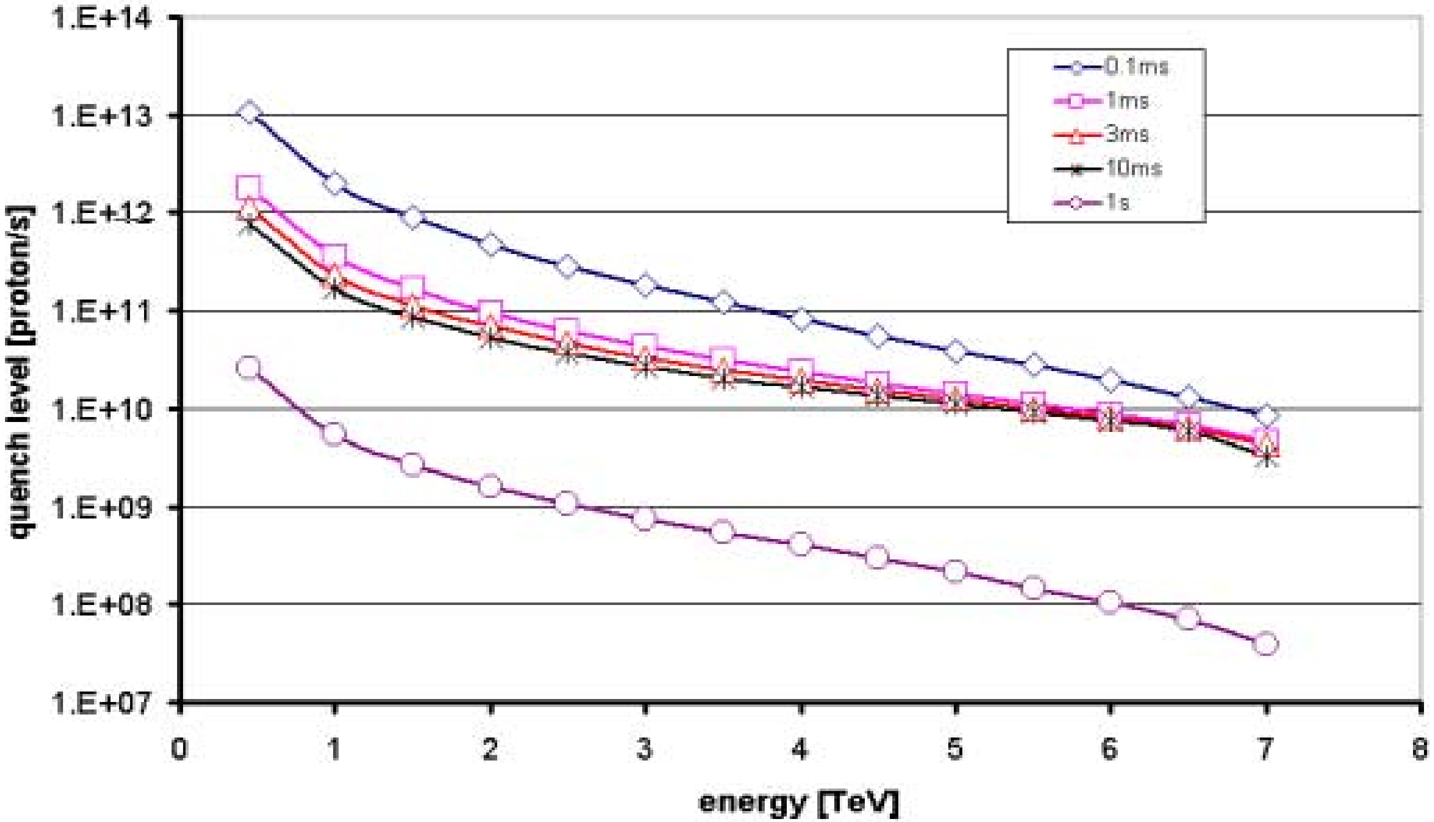
– Relation between loss rate and temperature increase
  quench levels:
  (J.B. Jeanneret et al. LHC Project Report 44)

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

Quench levels

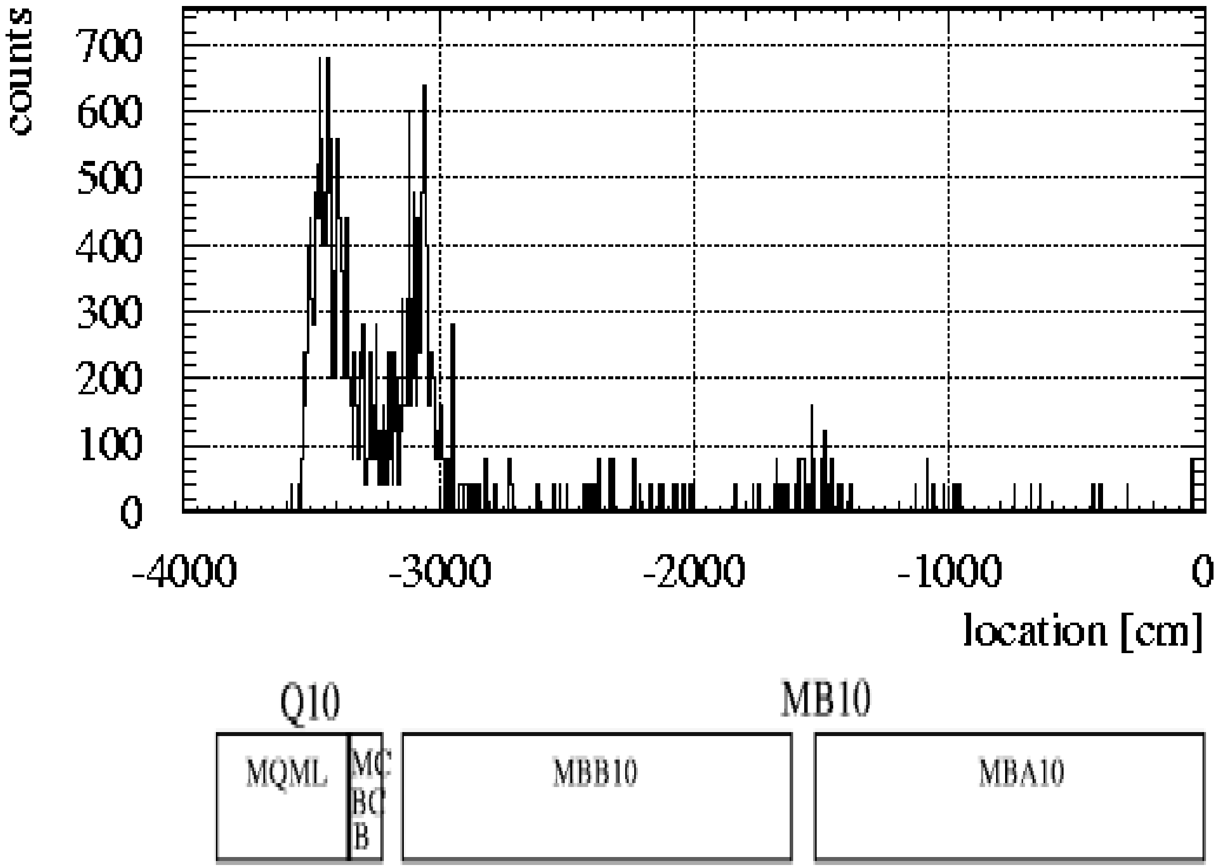


Quench Level Rate and Energy



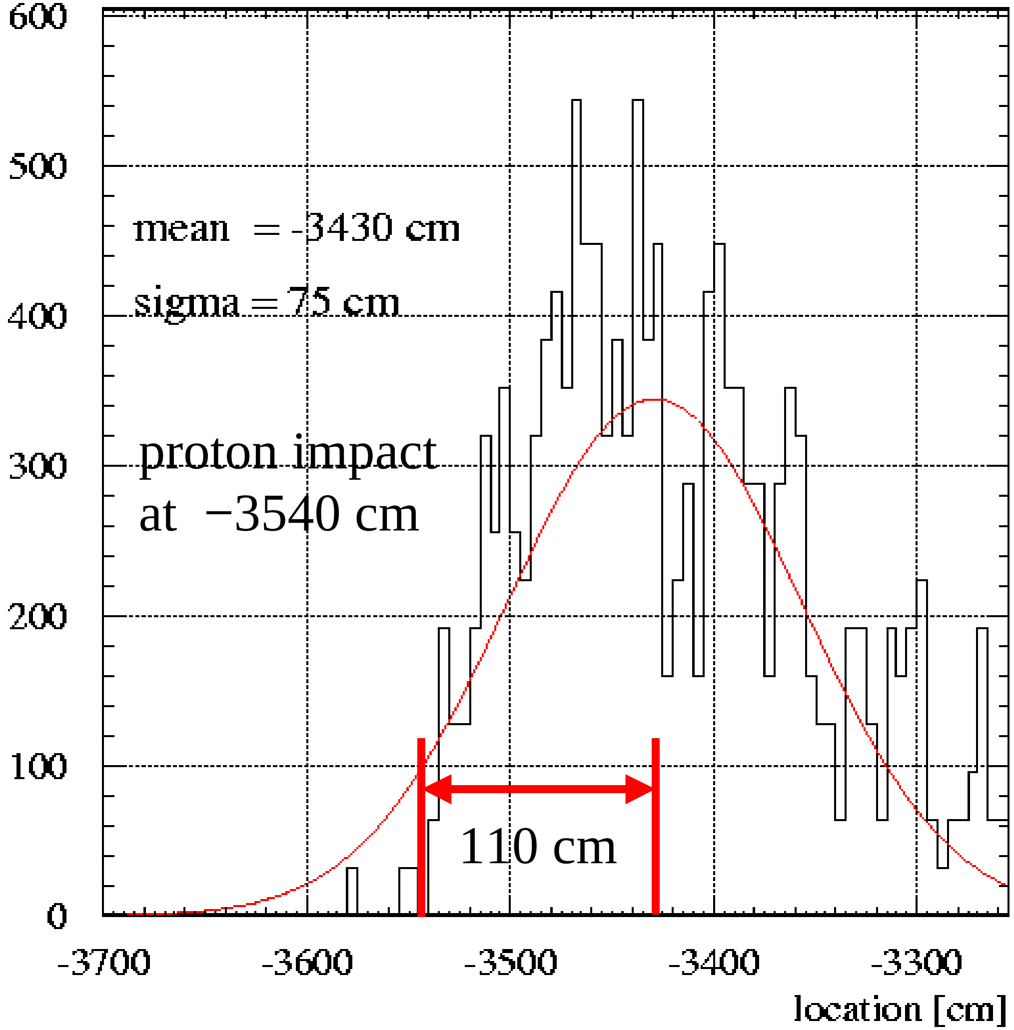
Factor 10 reduction between 0.45 and 1.5 TeV

Proton Shower Distribution (1)



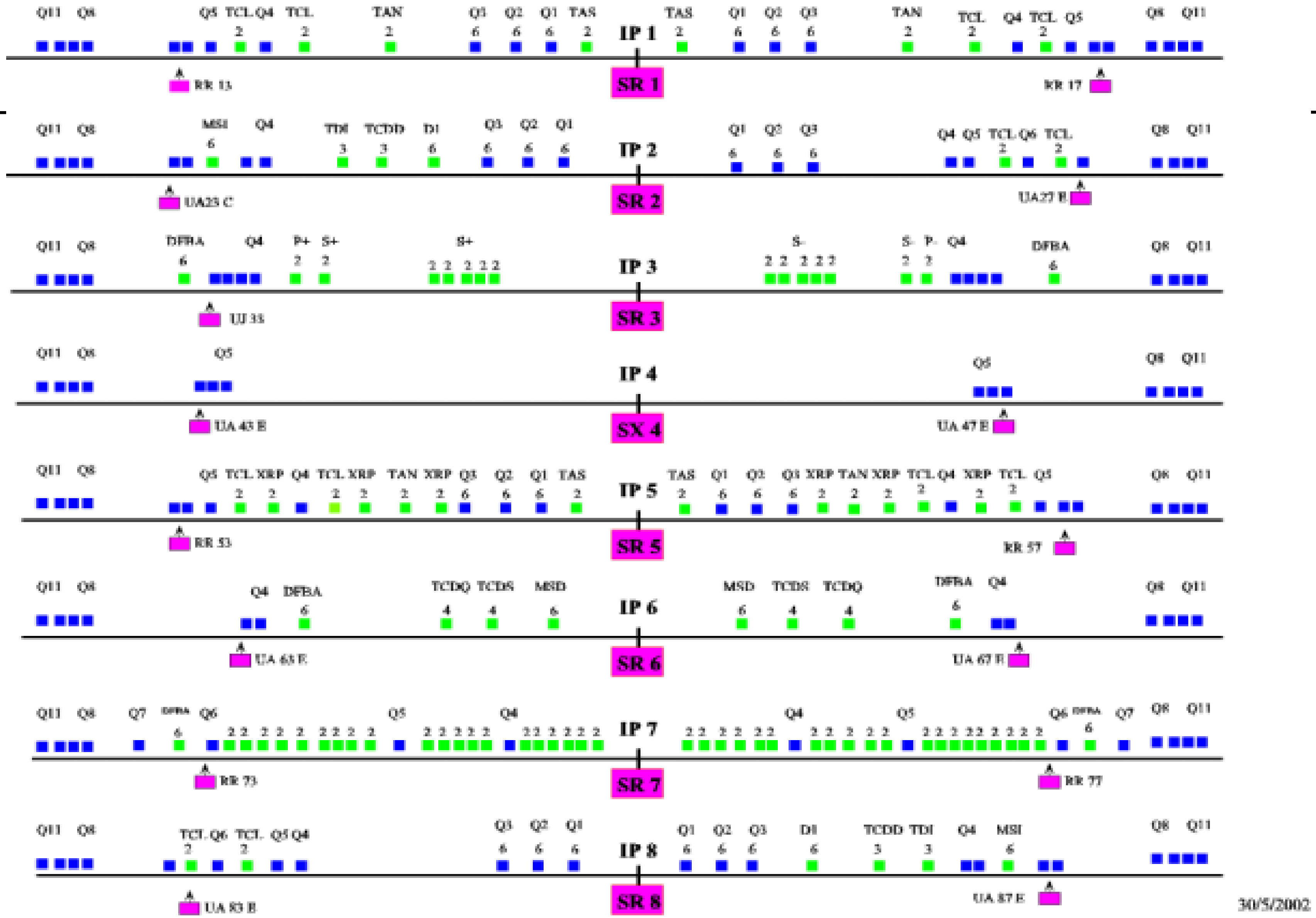
- impact of the protons at the centre of Q10
- first maximum due to shower in the cold mass
- second maximum due to gap between MQ and MB magnet
- third maximum due to gap between two MB magnets
- reduction of shower particles by a factor of over 100 after a few meters

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

Beam Loss: BLM (876), BLMC (240)



Main Monitor System Parameters

The monitor system dynamic range will be between 10^6 to several 10^7.

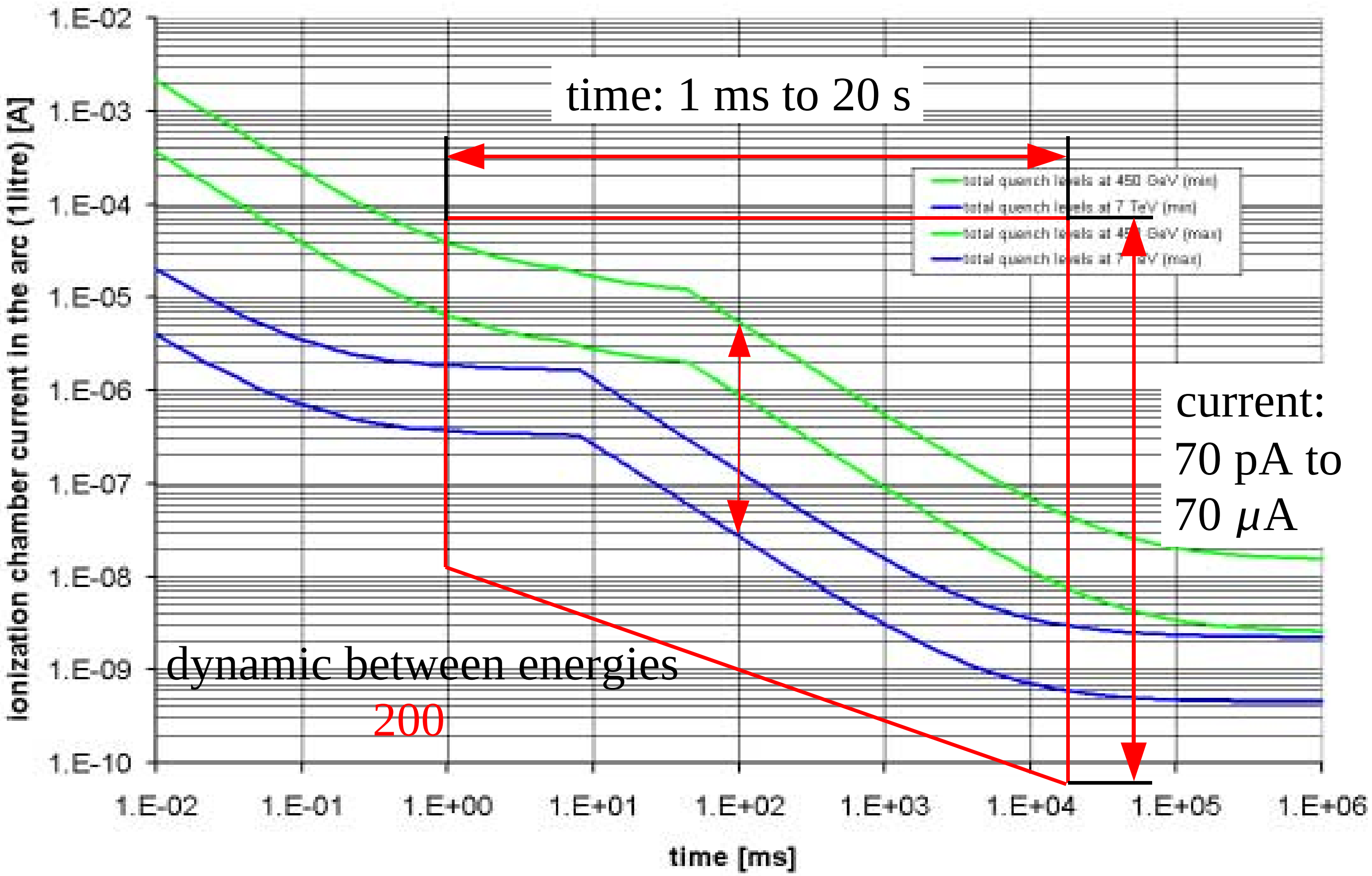
The update rate of the system will be 1 turn (89 us).

A threshold scaling during beam energy changes will be implemented

Several average loss values will be compared with the loss duration depending quench values

Each beam loss monitor channel will be connected to the beam abort system

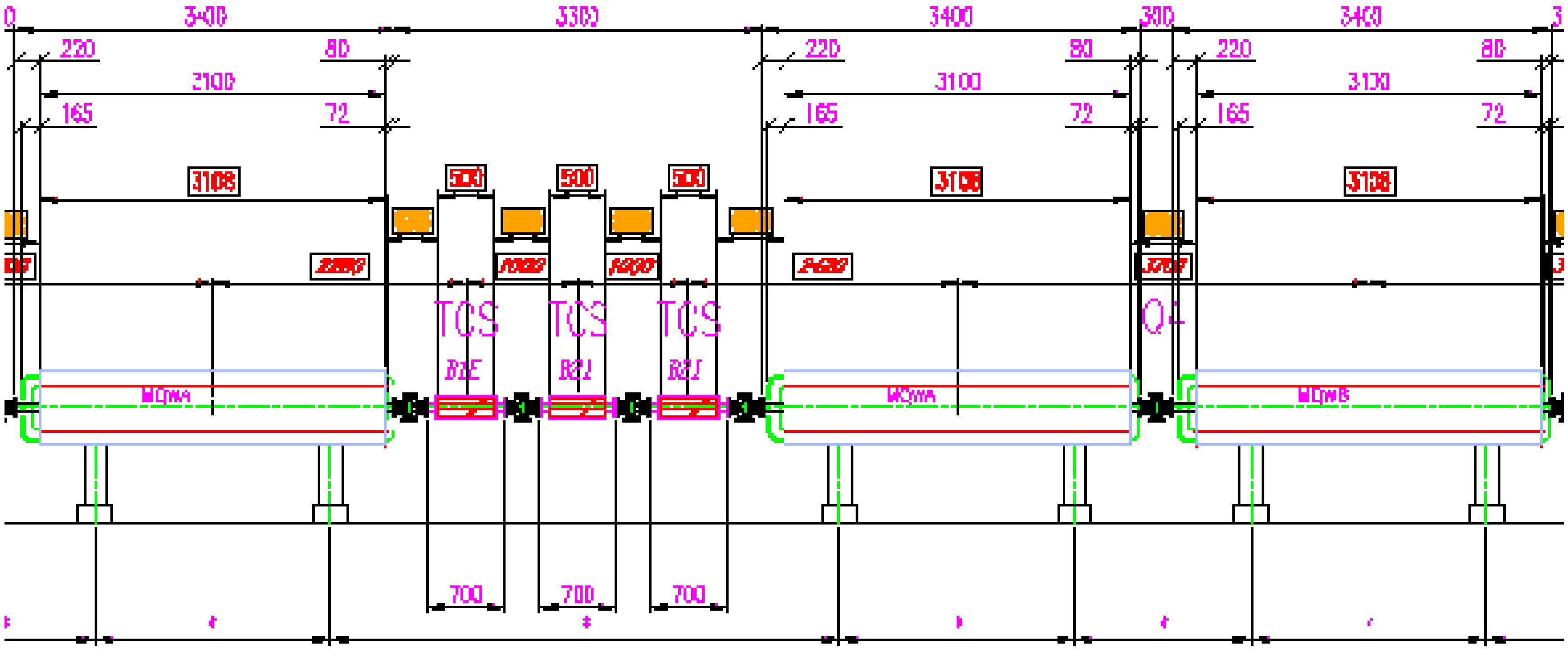
Arc Ionisation Chamber Current



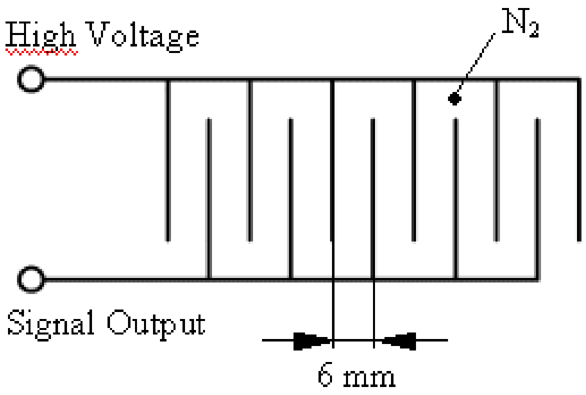
Proposed Collimator Locations IP7

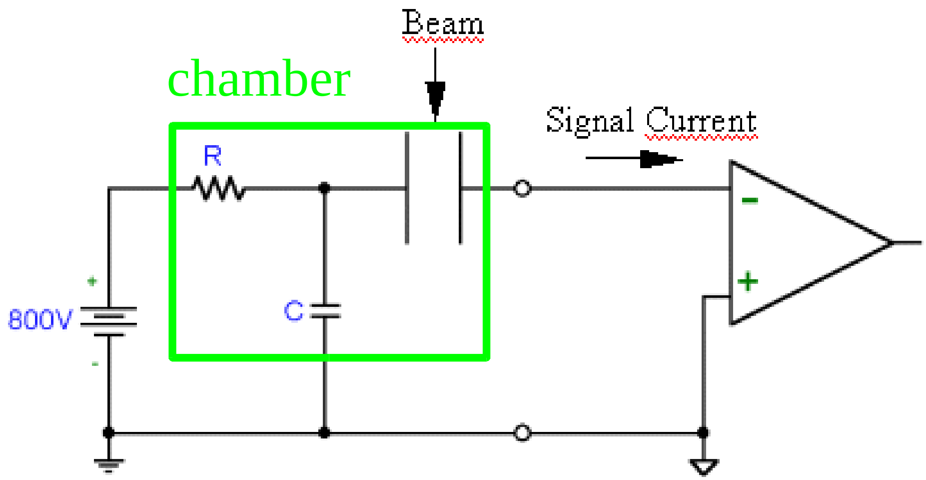
Collimators are about 1m apart and some arrangements are composed

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



Ionisation Chamber Monitor





ionisation chamber:

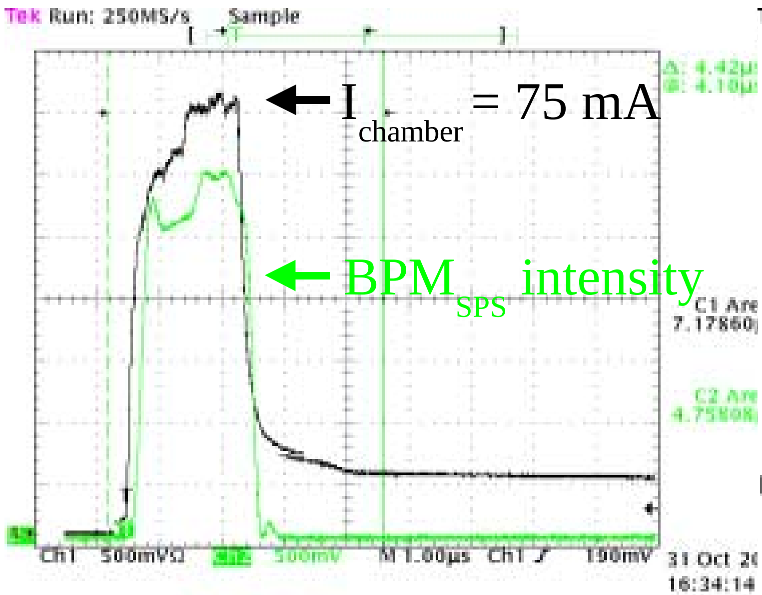
- gas: N_2
- pressure: normal
- voltage: 800 to 1800 V
- # of electron/ion pairs 50 − 70 1/MIP/cm

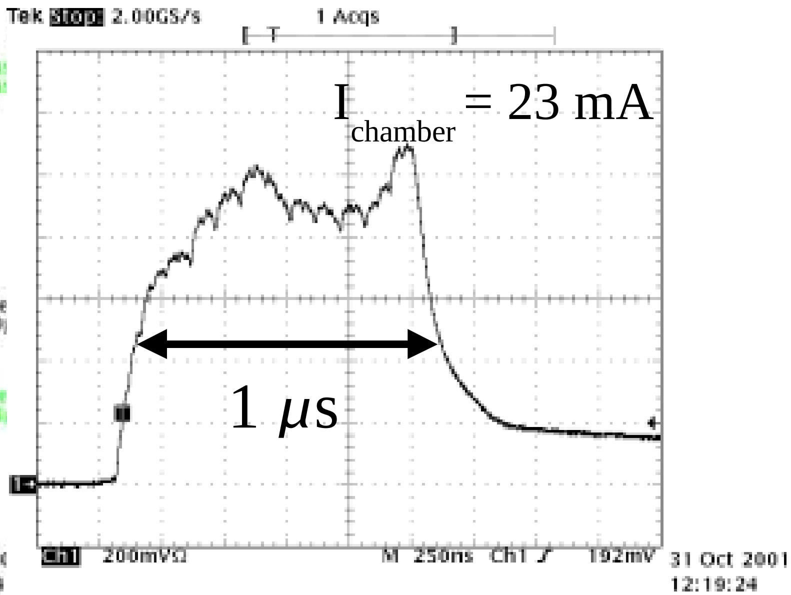
current to frequency converter:

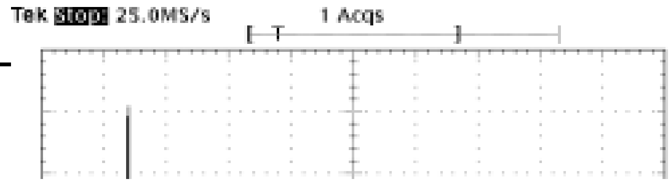
- first stage (input cable length up to 400 m):
  - dynamic: about 10^7
  - input current: 30 pA to 50 mA
  - output frequency: 0.05 to several MHz
- second stage (input cable length up 1.5 km)
  - every channel with micro controller
  - several mean loss values in parallel
  - energy tracking

Ionisation Chamber Signal

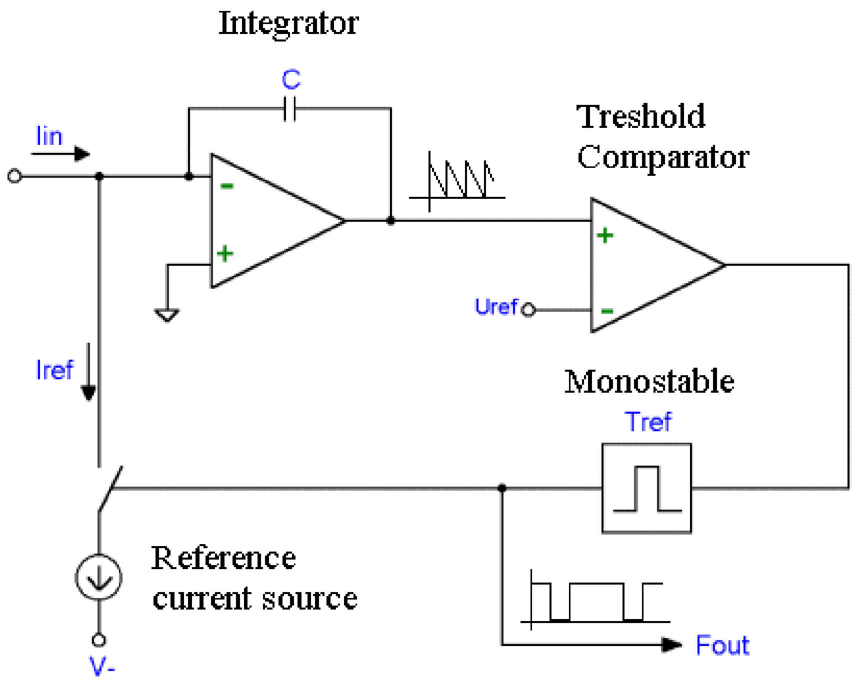
- High intensity test measurements with standard SPS ionisation chamber near SPS dump
- Rise time of the signal 300ns (limited by electron drift speed, electrode distances and pressure)
- Fall time of the signal 200 μs (limited by positron drift speed, “ “ “ “)
- Measurements: scope directly connected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

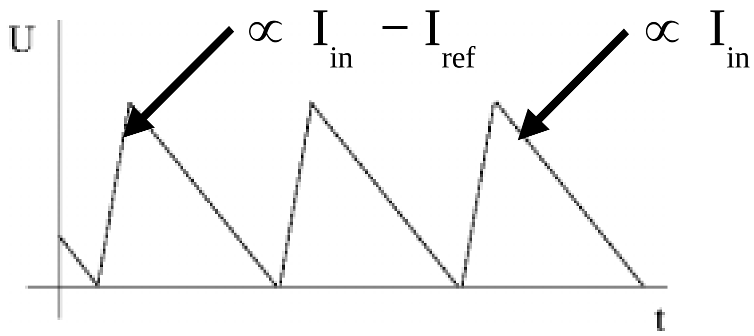






Charge Balanced Converter

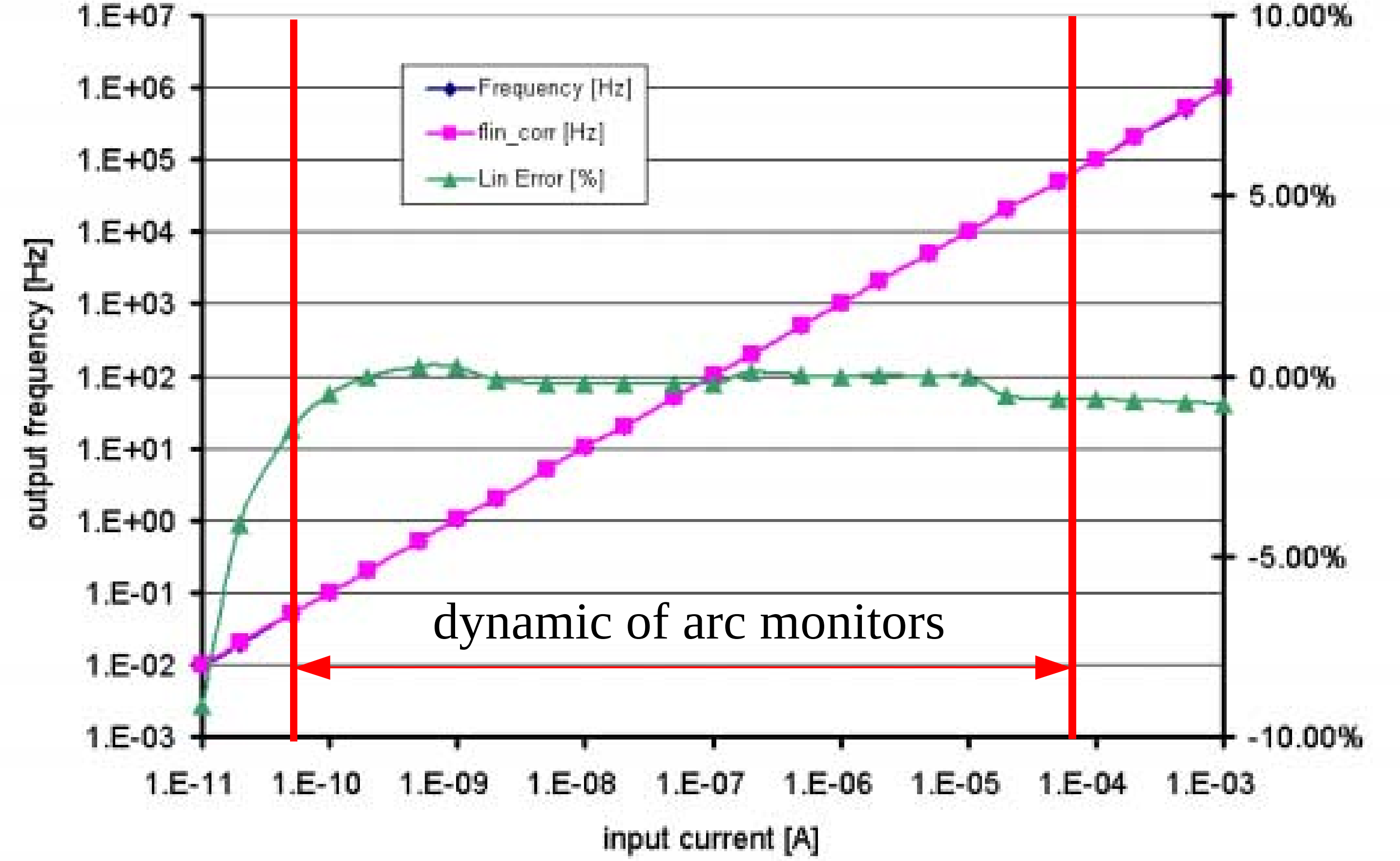




$$f_{out} = I_{in} \frac{1}{I_{ref} * T_{ref}}$$

- 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).

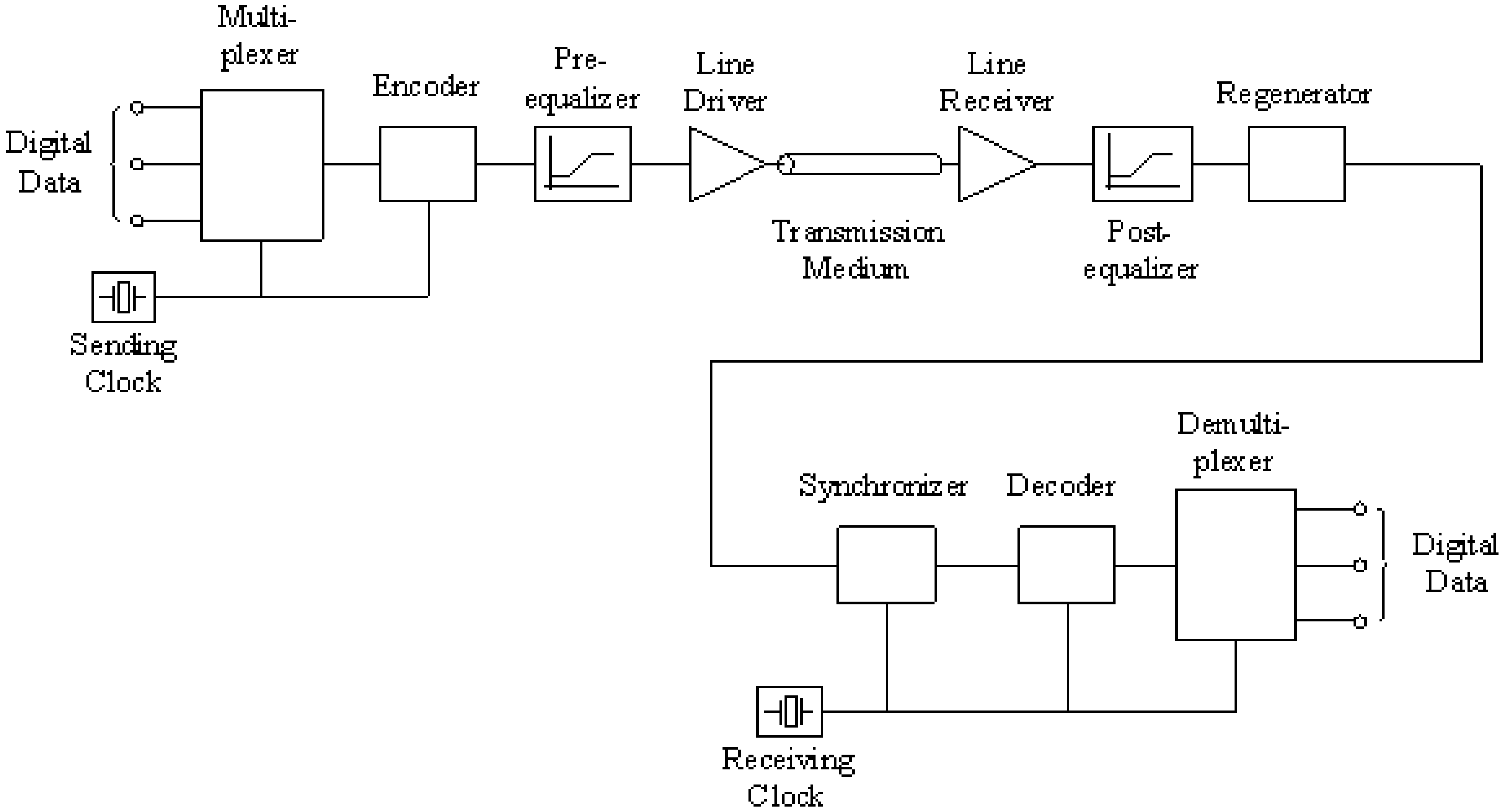
Collimation monitor system needs detailed analysis of particle contamination.

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.

Data Transmission Principle



Front End Circuit