Energy Deposition Simulation and Measurements in a LHC Collimator and Beam Loss Monitors

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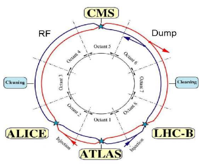
Abstract: *The LHC collimators are protected against beam-caused damages by measuring the secondary particle showers with beam loss monitors. Downstream of every collimator an ionisation chamber and a secondary emission monitor are installed to determine the energy deposition in the collimator. The relation between the energy deposition in the beam loss monitor and the collimator jaw is based on secondary shower simulations. To verify the FLUKA simulations the prototype LHC collimator installed in the SPS is equipped with beam loss monitors. The results of the measurements of the direct impact of the 26 GeV proton beam injected in the SPS onto the collimator are compared with the predictions of the FLUKA simulations. In addition simulation results from parameter scans and for mean and peak energy deposition with its dependencies are shown.*

LHC: Machine Protection Systems



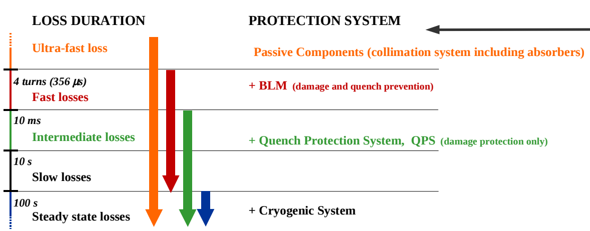
Large Hadron Collider (LHC):

Circumference: 26.7 km, **Injection energy:** 450 GeV

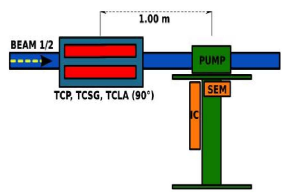
Top energy: 7 TeV in two counter rotating beams

Superconducting magnets: ~ 11 GJ stored energy in the magnet system + **365MJ** in beam

Different **protection systems** (passive and active) needed



Collimators and Design Specifications



Name	Active Jaw	Material	ϱ [g/cm□]
TCP	60cm	CC	1.77
TCSG	100cm	CC	1.77
TCLA(TCT)	100cm	W/Cu	19.3/8.96

Collimators:

- Robust and movable beam line components
- Different materials and geometries
- About 80% (initial Phase I) of collimators in loss-intensive cleaning insertions: multi stage cleaning (TCP, TCSG, TCLA)

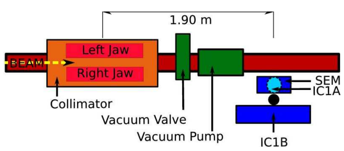
Protection against beam caused damages:

- Secondary particle showers measured with BLM detectors (determine energy deposition)
- Impact parameters vary considerably (TCP)
- Estimation of damage limits as function of BLM detector signals
- Total energy deposition on collimator
- Maximum energy density in jaws to determine damage limits

Measurements vs Simulation for LHC-like Set-Up

Experimental set-up in SPS (LSS 5):

- LHC prototype collimator (TCSG),
- 2 Ionisation Chambers (IC1A, IC1B)
- 1 Secondary Emission Monitor (SEM)



Measurements @ injection energy 26GeV:

- High dose rates (larger impact parameters)
- Low dose rates (small impact parameters)

Simulation tool:

- Monte Carlo particle code FLUKA (version 2006.3b, NEW-DEFAULTS physics settings)

Aim:

- Determine accuracy of predicting BLM signals by simulations for an LHC collimation scenario

Results:

- Reproduction of IC measurements within ±21%
- SEM: maximum deviations of +73% and -30%

Deviations due to uncertainties in:

- Precise impact parameter distribution
- Surface structure
- Beam jaw angle
- Space charge effects for the IC
- Calibration uncertainty of IC and SEM
- Fraction of returning protons that were not removed from beam estimated only roughly

Prediction of BLM Signals

Implementation:

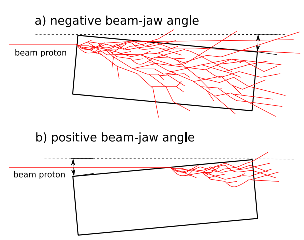
- A cell consisting of a (exchangeable) collimator and IC-SEM detector pair

Aim:

- Predicting ratios of BLM-signal to energy deposition in the collimator for TCP, TCSG and TCLA
- Determination of BLM-signal per proton on collimator (normalized BLM signal)

Focus:

- Variation of BLM signals and energy deposition due to BLM misalignment (±3cm trans., ±5cm long.),
- Different beam impact parameters,
- Different energies (26, 450, 7000 GeV)
- Beam-jaw angles (variation ±300µrad)
- Different jaw tilt angles with respect to coll. with horizontal jaw



Results:

- Relative particle fluence spectra **independent** of energy
- Jaw angles: signal change **max. -36%** (IC), **-19%** (SEM)
- Detector misalignment: **±21%**
- Simplifications in geometry: **16%**

Cross Talk & Peak ED

Higher Order Particle Halos

Aim:

- Mixed particle shower generated at particle collimator upstream impinge on collimator (second & third order halos)

Simulations:

- 3 TCP collimator detector cells
- Protons impacting on cell1, particles exiting through beam pipe propagated through cell2 and cell3

Results:

- Ratio of BLM signal to total energy deposition in jaw for cell 3 is **25%** of cell 1
- Systematic studies needed (IR3+7 implementation by FLUKA team)

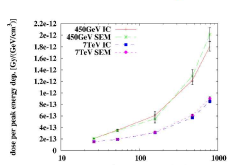
Peak Energy Deposition

Assumption:

- Gaussian tails as part. distributions on collimators (typical for failure scenarios)
- Typical mean impact parameter: 25-800µm

Results:

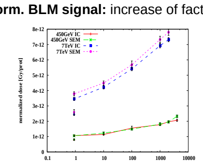
- Graphite collimators: max. **variation factor of 10**
- TCLA: signal **variation** much **higher**



Scans and Results

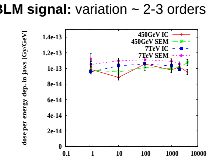
Impact Parameter Scan (pencil beam)

Norm. BLM signal: increase of factor 2

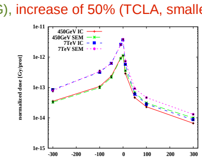


Beam-Jaw Angle Scan (penc.beam, 2µm imp.par.)

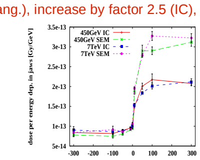
Norm. BLM signal: variation ~ 2-3 orders of mag.



Signal-to-energy deposition ratio: constant (TCP, TCSG), increase of 50% (TCLA, smaller imp.par.)



Ratio of BLM signal to tot. energy dep.: constant (neg. ang.), increase by factor 2.5 (IC), 4 (SEM)



presented at PAC07