Beam Loss Patterns at LHC Collimators

- Measurements & Simulations

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APS Talk by T. Boehlen
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Study Beam Losses at Aperture Limitations in a Setting similar to LHC

- Studying beam loss patterns at a prototype LHC collimator
- Experiment mounted in the SPS

- Simulations with Monte-Carlo particle code FLUKA

- Monitoring signals in the detectors & energy deposition in the jaws

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Purpose & Aims

- Improve Assessment of BLM Thresholds Settings for Collimators
- Study System similar to LHC Setup with Experimental Verification

Establish Relation:
Particles Impacting on Collimator
to Signal seen by BLM Detectors

- As Function of Impact Parameter
  \( \frac{Dose}{Lost Proton} (\Delta x_{\text{impact}}) \)
  (Range: \( \mu m – mm \))

- Misalignment Studies
  BLM Detectors

- Other Parameters
  e.g.: Beam Distribution, Jaw Positions

- Variation of BLM Signal
  uncertainty for BLM Thresholds

Comparison: Exp. to Sim.
Derive Systematic Error for Simulations

Reference Study
For other Simulations for the LHC Setup

Test
LHC BLM Data Acquisition System
Implementation in FLUKA

- Representative geometry:
  - Focus on: Collimator, Detectors, Beam tube
  - Low systematic errors due to simplification
  - Movable collimator jaws

- Dependency on unknown model parameters:
  - Geometry simplification, misalignment, FLUKA physics
  - Systematic errors mostly 1-5%, all < 15%
  - Allows for detailed study of the behavior of such a system

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Measurements (MD45, MD46)

- Until now: 2 Session à 1h
- 0.9 - 1.3x10^13 protons @ 26 GeV, Type: LHC25NS&FT, cycling mode
- Measurements done for varying collimator positions
- Acquisition of: beam current and BLM detector response
- Wire scanner meas. for beam width => beam width at collimator

10 cycles

Injecting
Circulating

07/04/2008

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Preliminary Results

Total loss: killing beam at injection plateau with collimator

Exp.: $L = 3.24 \pm 0.25 \times 10^{-13}$ Gy/Prot.  ($R = 2.31 \pm 0.24 \times 10^{-13}$ Gy/Prot.)

Sim.: $L = 3.30 \pm 0.17 \times 10^{-13}$ Gy/Prot.  ($R = 2.42 \pm 0.10 \times 10^{-13}$ Gy/Prot.)

Data from BLI1A

But: Just 2 experimental values!

Jaw speed ~ 2mm/s

3.2 s integration time

BLM IC Response
Preliminary Results

- IC signal ratio Right/Left Sim: $0.73 \pm 0.05$  Exp: $0.71 \pm 0.09$

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Preliminary Results

Impact parameter scan of a pencil beam @ 26 GeV

- Max. change ~60%
- For LHC energies: additional uncertainty for assessment of thresholds
Method 1: By Wire Scan

Method 2: By Scraping with Collimator

\[ \sigma = \sqrt{\frac{\epsilon \beta}{\pi} + D^2 \left( \frac{\Delta p}{p} \right)^2} \]

**Beam Width** \( B \approx 4.3\text{mm} \)

- **Beam Width** \( B \approx 2.5\text{mm} \)

- **Time Offset** \( \pm 0.5\text{s} \Rightarrow \pm 1\text{mm} \) Impact Parameter

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10/13

07/04/2008
Summary & Outlook

- Implementation of experimental setup in FLUKA
  - Several scans of model parameters => max. systematic error of 15%
- Measurements: few data usable: space-charge effects, missing logging data (software)
- First comparisons between meas. and sim. => agreement within 5% (but low statistics!)
  - Agreement of other meas.-model comparisons 10-50%

- Final determined discrepancy of meas.-model as systematic uncertainty for assessment of LHC BLM detector thresholds by simulations
- Impact parameter studies will be continued at LHC energies
  - Further systematic error for determining thresholds
- Inclusion of determination of peak energy and total energy deposition in collimator
More measurements in May 2008 (2 MDs à 2-4hrs) – optimizing conditions
★ Lower intensities $5 \times 10^9 - 1 \times 10^{11}$ prot (no saturations)
★ Improved calibration of impact parameter (eliminating time offset)
★ Data acquisition with one turn passing (direct extraction)

Using:
★ LHC Collimator
★ 1000 turns closed orbit analysis
★ FBCT (TT10, SPS), BCTDC (SPS)
★ WSCAN (BWSA.51995)
Thanks for attentive ...

Comments and questions welcome!
Related Works

Past
- IR3 Simulation
crosstalk matrices, transversal energy
distribution (MARS, K2)
  I. Kurochkin, 2002-03

Present
- Beam Losses in the whole SPS, relative
  signal height (SixTrack)
  S. Redaelli et al., 2006
- Exp. vs. Sim.
  a validation study,
  investigating a similar system
  My work

Future
- IR7 Simulation
crosstalk matrices, heat in
collimator jaws, ...
  (FLUKA, ANSYS)
  M. Magistris & M. Santana
  Leitner et al., 2006
- tbc ... FLUKA & BLM Team
  Simulations for final LHC layout
  prediction of thresholds for BLMs

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Response Curves (Add.)

Response Curve of LHC BLM IC, by M. Stockner

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Plans for further MDs

- Lower beam intensity $\sim 5 \times 10^9$ to $1 \times 10^{11}$
  (no saturation @ full impact)
- Better statistics: several cycles for each collimator position
- Complete BLM data (ongoing software update (*Fesa 2.10*) => prioritization possible)
- Data acquisition with one turn passing (direct extraction) to eliminate error sources

=> Request: Would require 2 MDs à 2-4hrs (May-June 2008)
Trouble

- Missing BLM data (single threaded front-end CPU => only one data set at a time, MD was dedicated to triggering)

![Graph showing missing data gaps](image)
Particle Interaction with Matter

Task:

Description of interaction of particles in matter, e.g.: scattering events, hadronic & EM showers, energy deposition, ...

Complex geometries!

Examples:

- Energy losses due to EM interaction: Bethe-Bloch ->

- Multiple Coulomb scattering: quantitatively described by
  \[ \theta_{\text{rms}}^{\text{plane}} = \frac{13.6 \text{ MeV}}{\nu p} q_e \sqrt{x/X_0} \]
  \[ X_0 : \text{Radiation Length} \]

Accomplished by:

Monte-Carlo Method for HEP:
  - Random based sampling tracking single particles
  - Allows to derive predictions of fluencies, energy deposition, activation ...
  - Program used: FLUKA

\[ \beta = \frac{p}{M c} \]