Beam Loss Patterns at LHC Collimators

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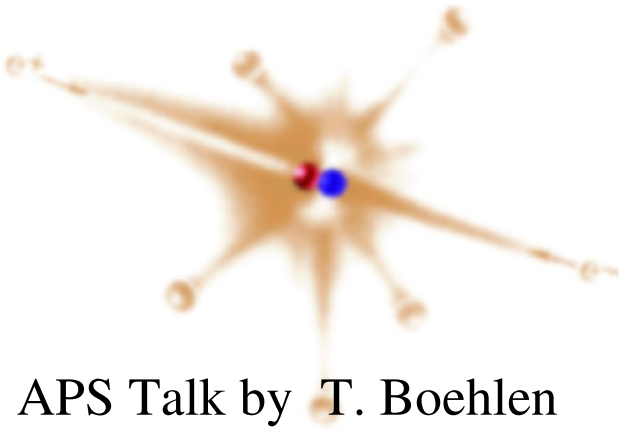
Measurements & Simulations

BLM Team

Till Boehlen



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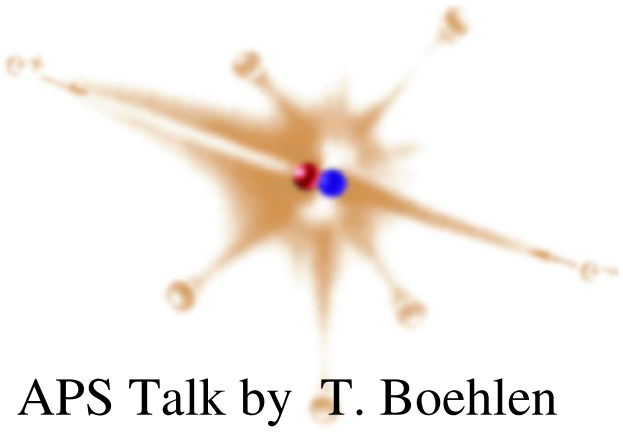
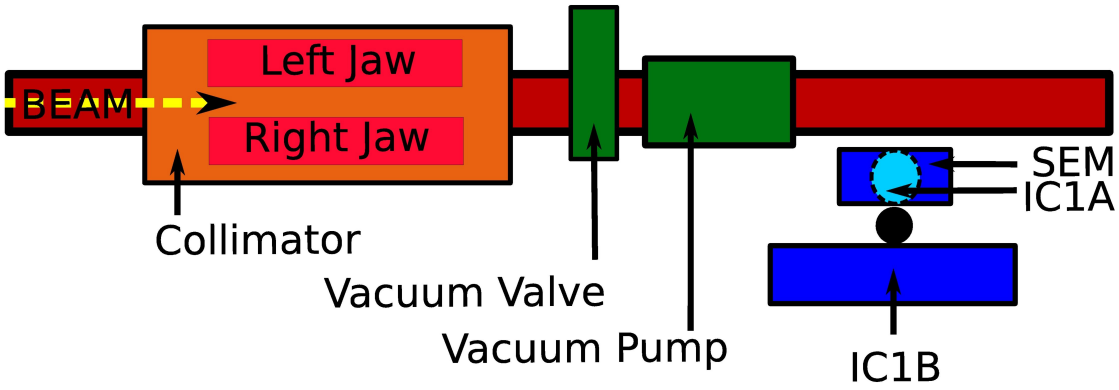


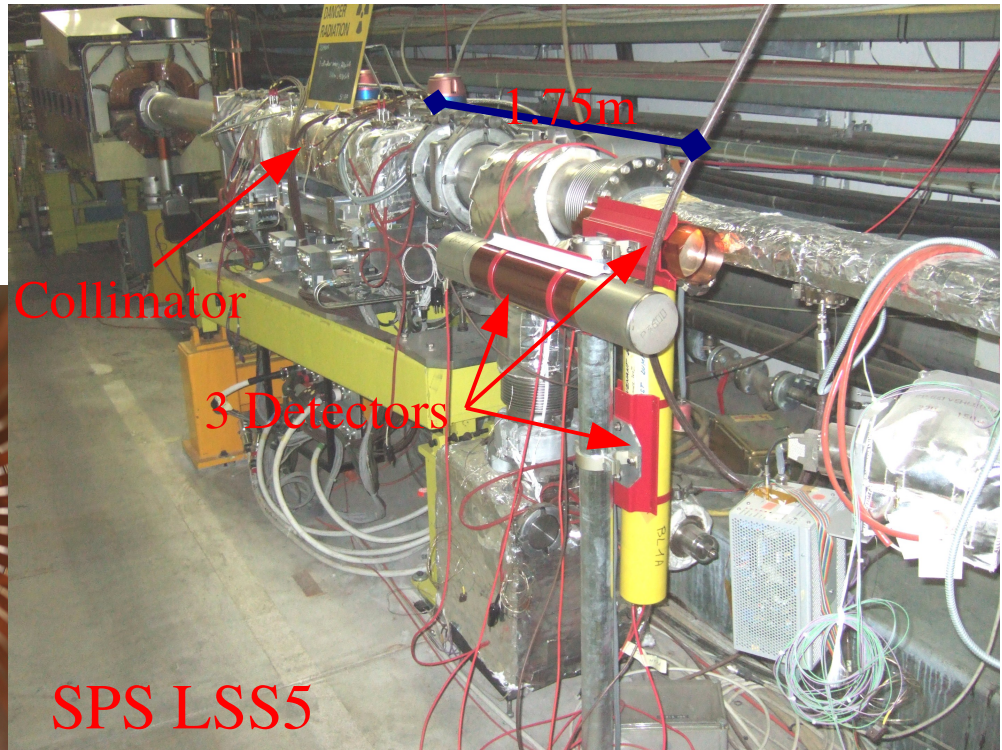
Study Beam Losses at Aperture Limitations in a Setting similar to LHC



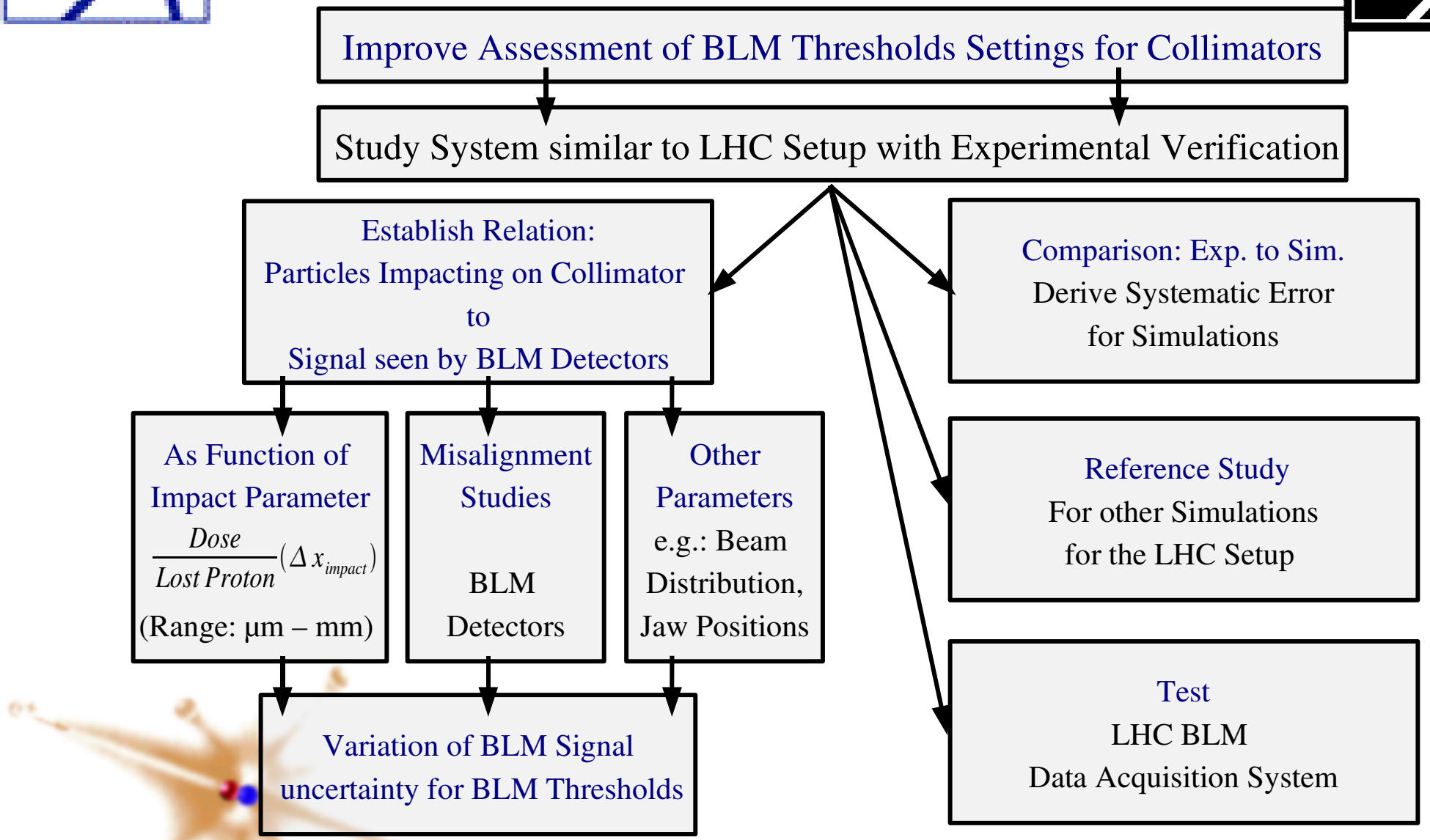
- Studying beam loss patterns at a prototype LHC collimator
- Experiment mounted in the SPS

- Simulations with Monte-Carlo particle code FLUKA

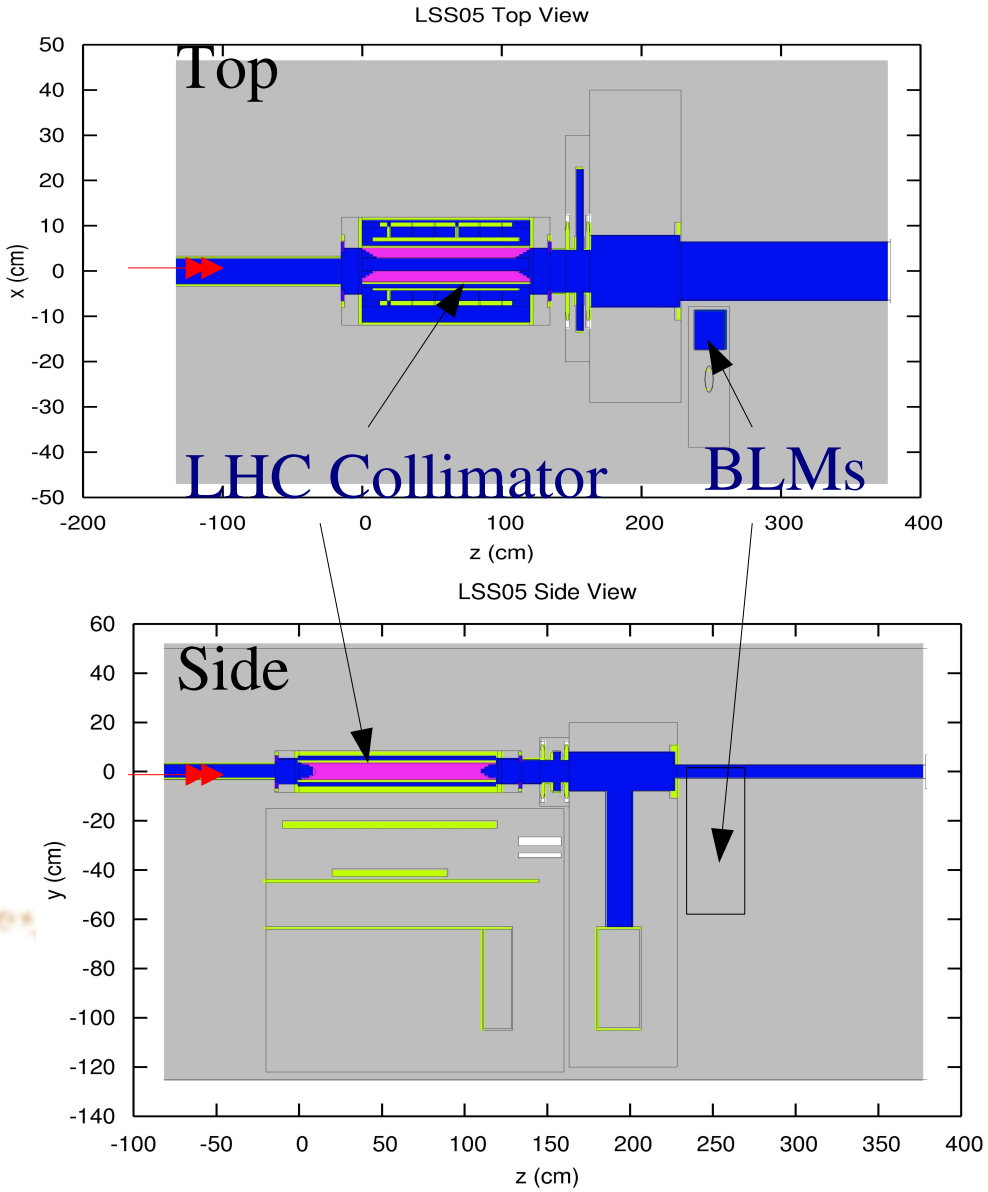
- Monitoring signals in the detectors & energy deposition in the jaws



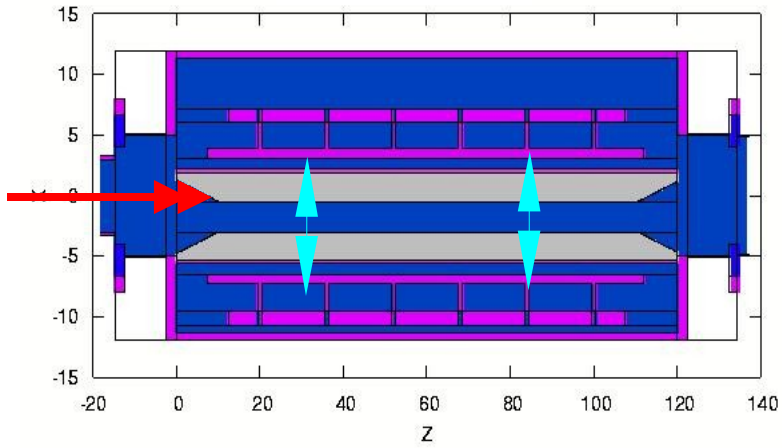
Purpose & Aims



Implementation in FLUKA



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

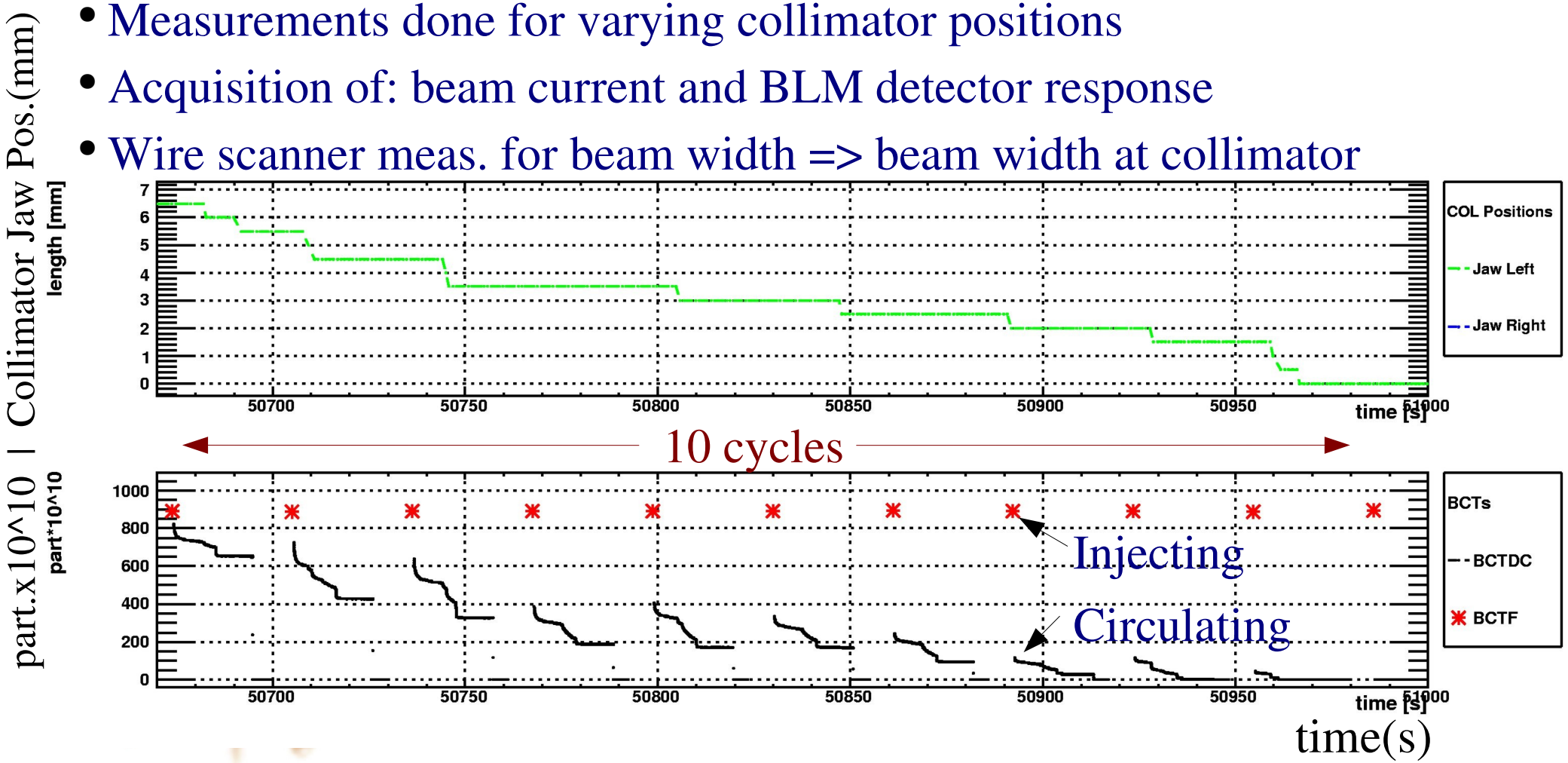


- Dependency on unknown model parameters:
  - Geometry simplification, misalignment, FLUKA physics
- Systematic errors mostly 1-5%, all < 15%
- ☆ Allows for detailed study of the behavior of such a system

Measurements (MD45,MD46)

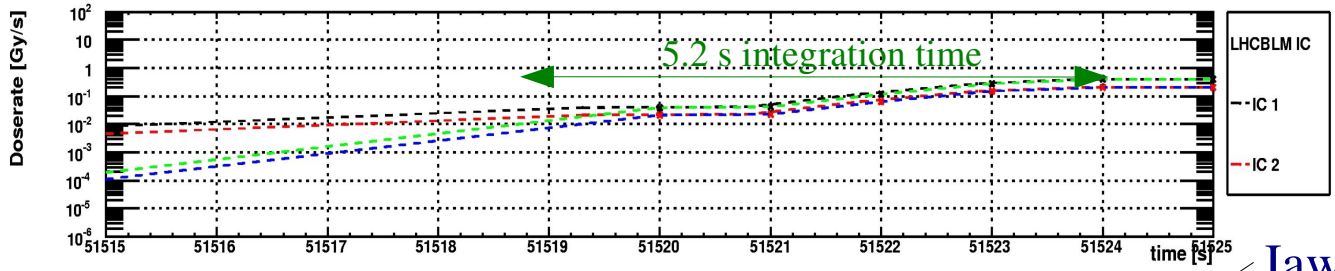
08/11/07 12/11/07

- 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

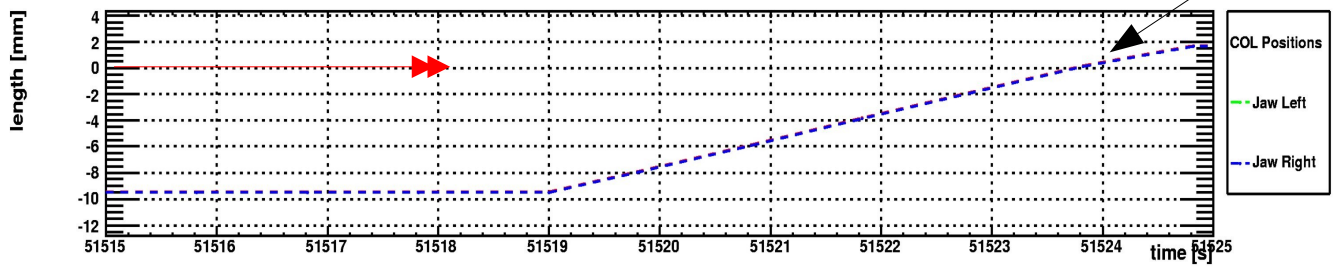


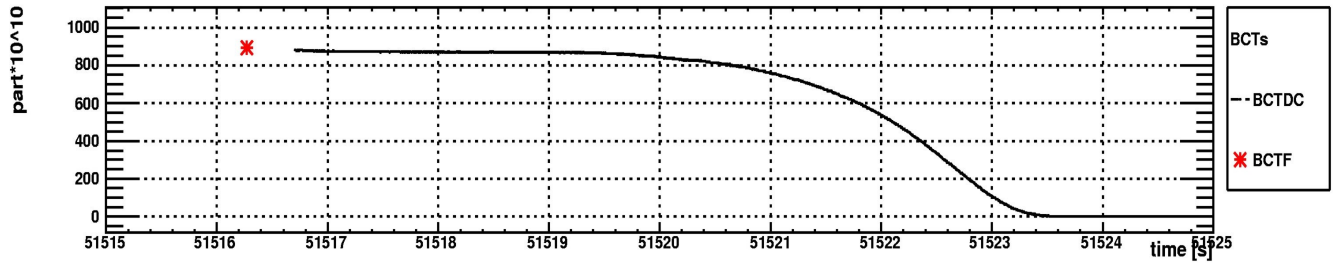
Preliminary Results

Total loss: killing beam at injection plateau with collimator



Jaw speed ~ 2mm/s





But: Just 2 experimental values!

BLM IC Response

Exp.: L $3.24\pm0.25\times10^{-13}$ Gy/Prot. (R $2.31\pm0.24\times10^{-13}$Gy/Prot.)

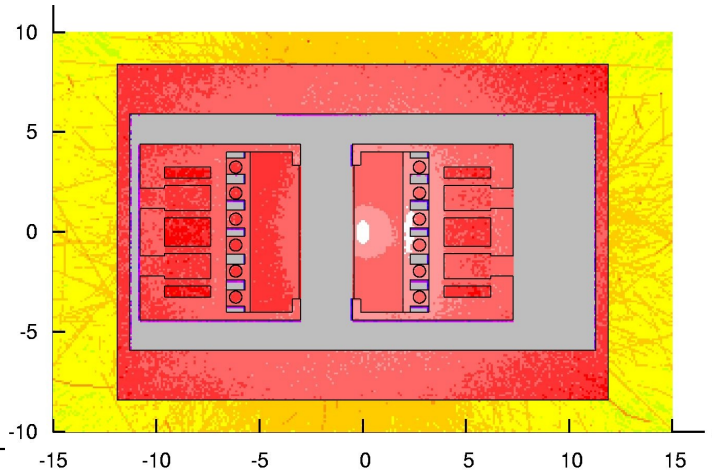
Sim.: L $3.30\pm0.17\times10^{-13}$ Gy/Prot. (R $2.42\pm0.10\times10^{-13}$Gy/Prot.)

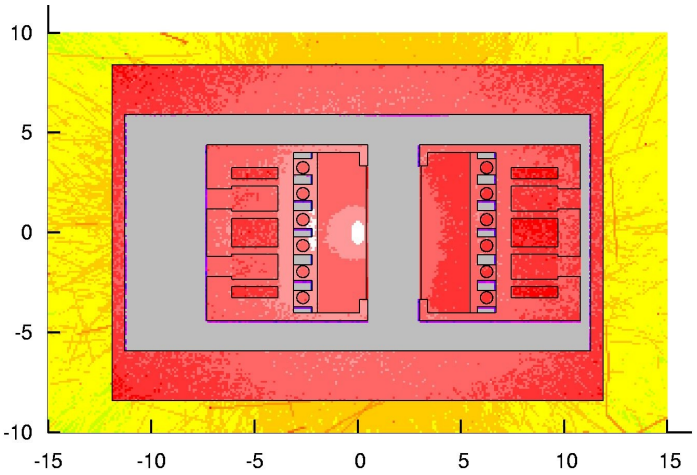
Data from BLI1A

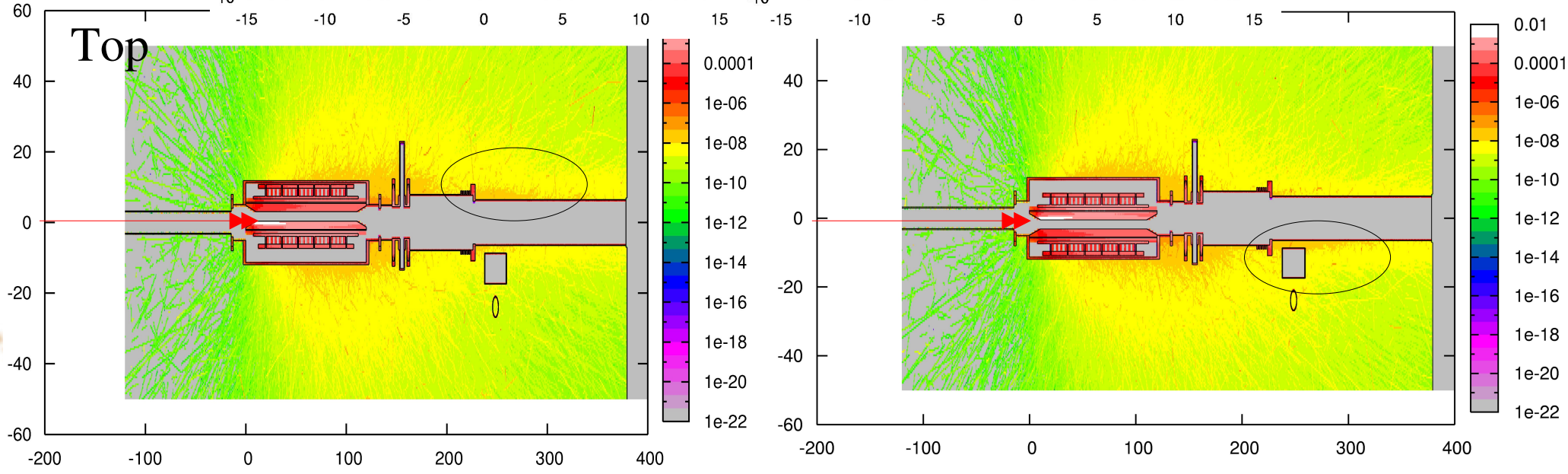
Preliminary Results

Right jaw in

Left jaw in



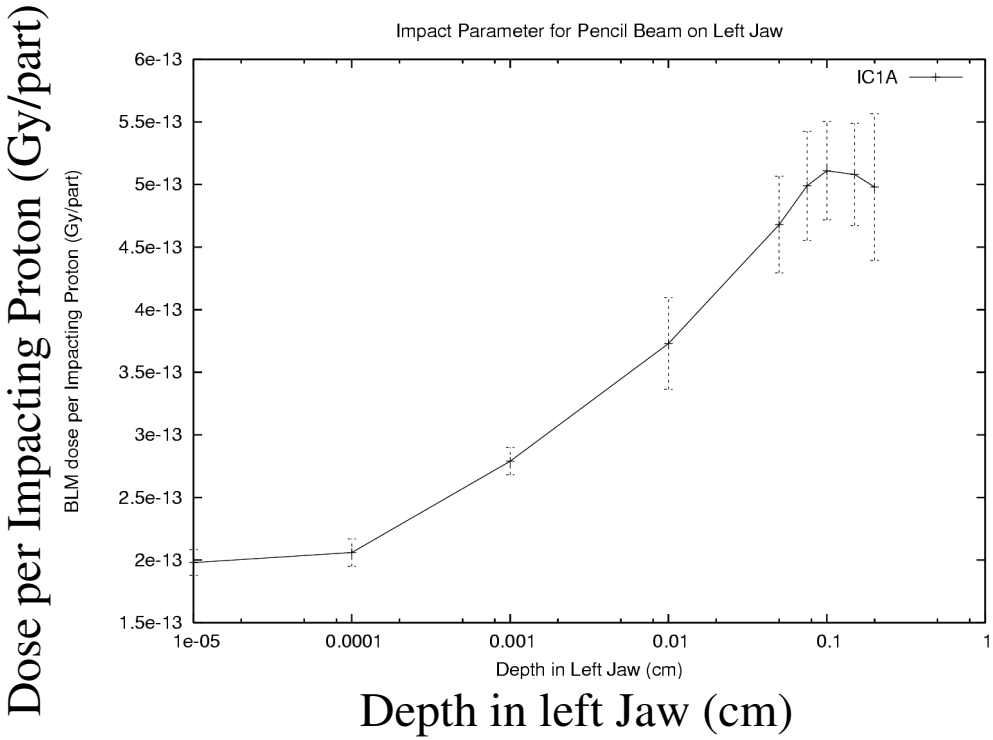




- IC signal ratio Right/Left Sim: 0.73±0.05 Exp: 0.71±0.09

Preliminary Results

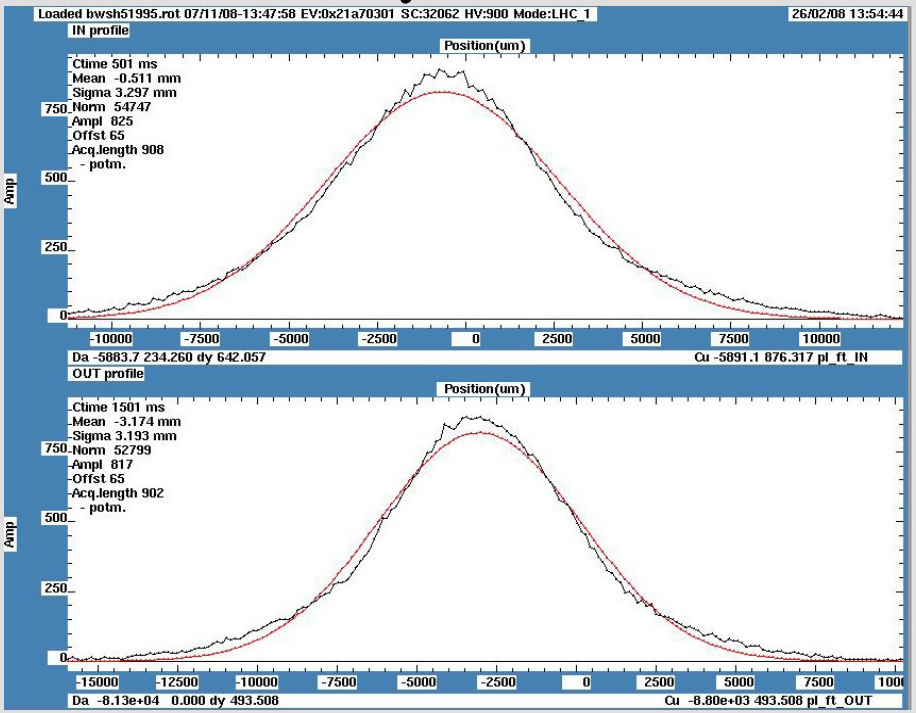
Impact parameter scan of a pencil beam @ 26 GeV



- Max. change ~60%
- For LHC energies: additional uncertainty for assessment of thresholds

Impact Parameter & Beam Width

Method 1: By Wire Scan

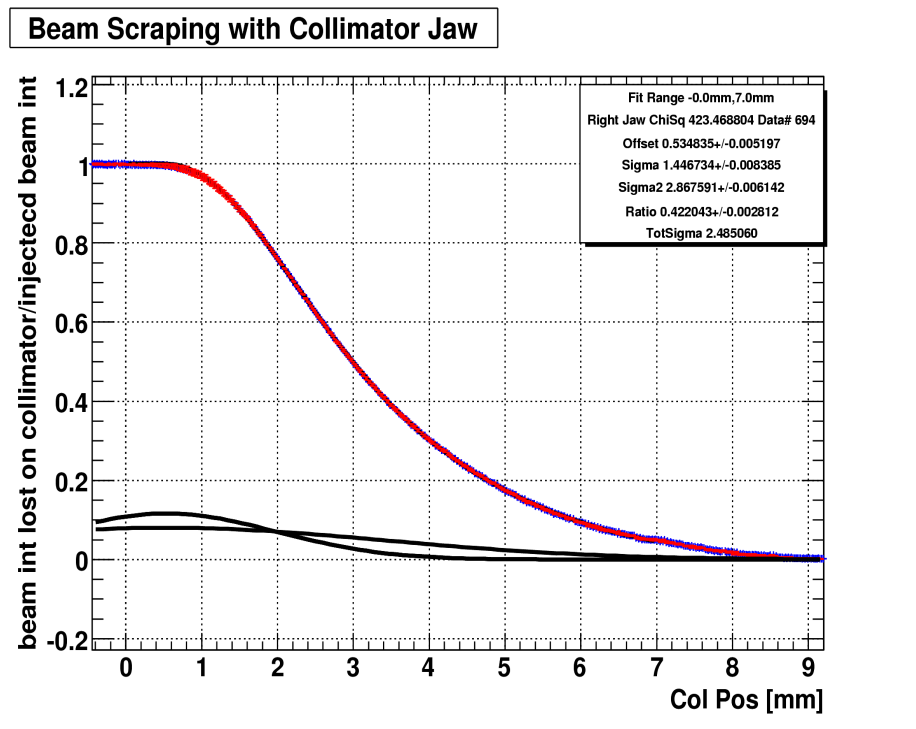


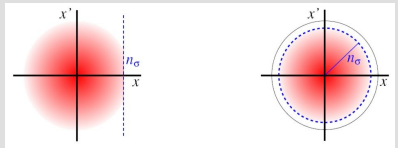
$$\sigma = \sqrt{\frac{\epsilon\beta}{\pi} + D^2\left(\frac{\Delta p}{p}\right)^2}$$

- Beam Width B ≈ 4.3mm

40%

Method 2: By Scraping with Collimator



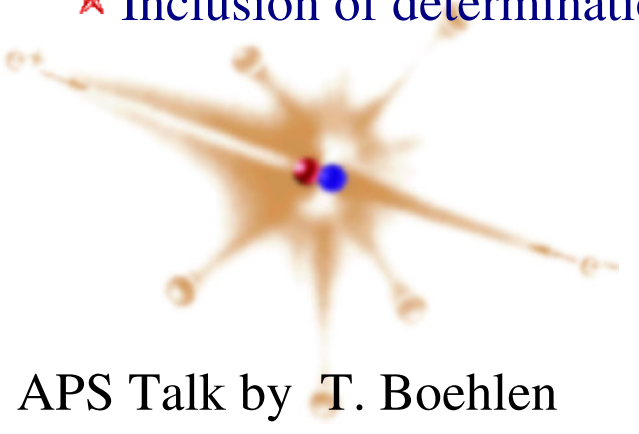


- Time Offset ±0.5s => ±1mm Impact Parameter
- Beam Width B ≈ 2.5mm

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%

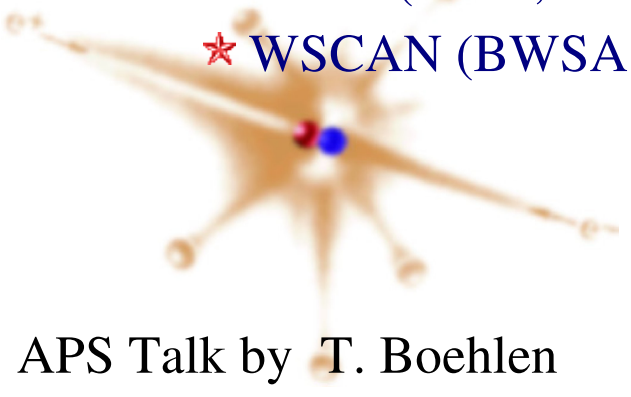
- Final determined discrepancy of meas.-model as systematic uncertainty for assessment of LHC BLM detector thresholds by simulations
- Impact parameter studies will be continued at LHC energies
  - Further systematic error for determining thresholds
- Inclusion of determination of peak energy and total energy deposition in collimator



Summary & Outlook

- More measurements in May 2008 (2 MDs à 2-4hrs) – optimizing conditions
  - Lower intensities $5*10^{9}$-$1*10^{11}$ prot (no saturations)
  - Improved calibration of impact parameter (eliminating time offset)
  - Data acquisition with one turn passing (direct extraction)

- Using:
  - LHC Collimator
  - 1000turns 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

Beam Losses in
the whole SPS, relative
signal height (SixTrack)
S. Redaelli et al.,
2006

IR7 Simulation
crosstalk matrices, heat in
collimator jaws, ...
(FLUKA,ANSYS)
M. Magistris & M. Santana
Leitner et al., 2006

Present

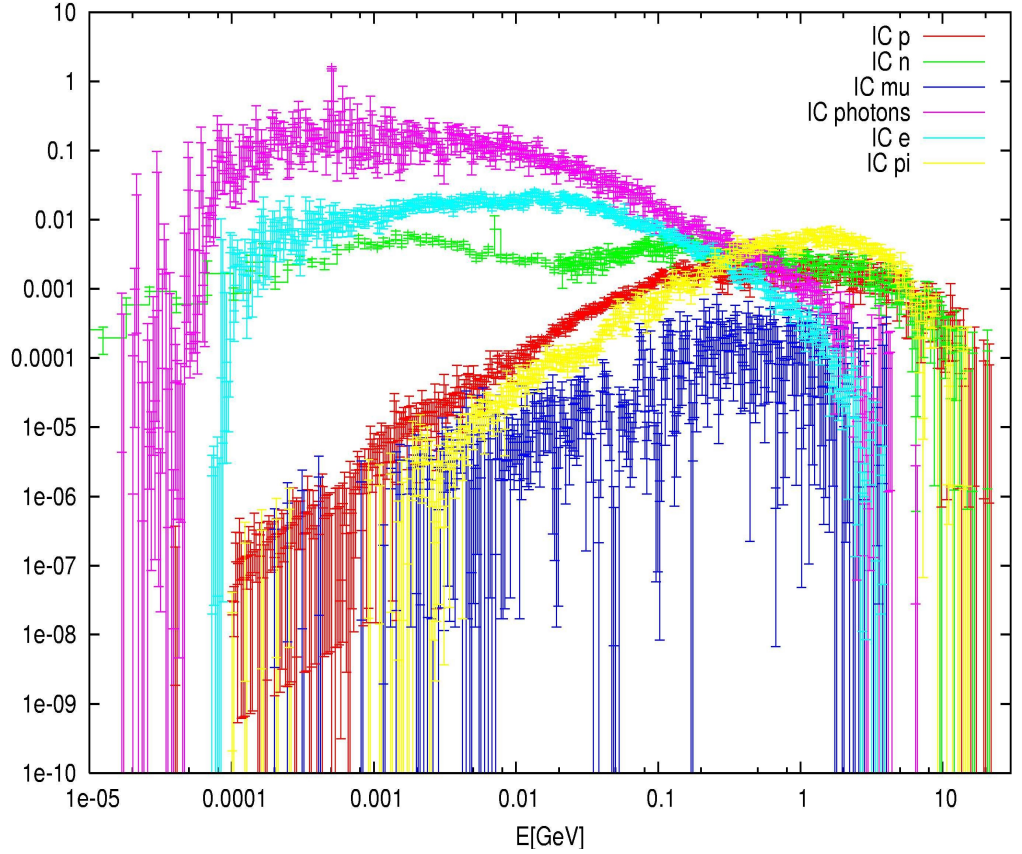
Exp. vs. Sim.
a validation study,
investigating a similar system
My work

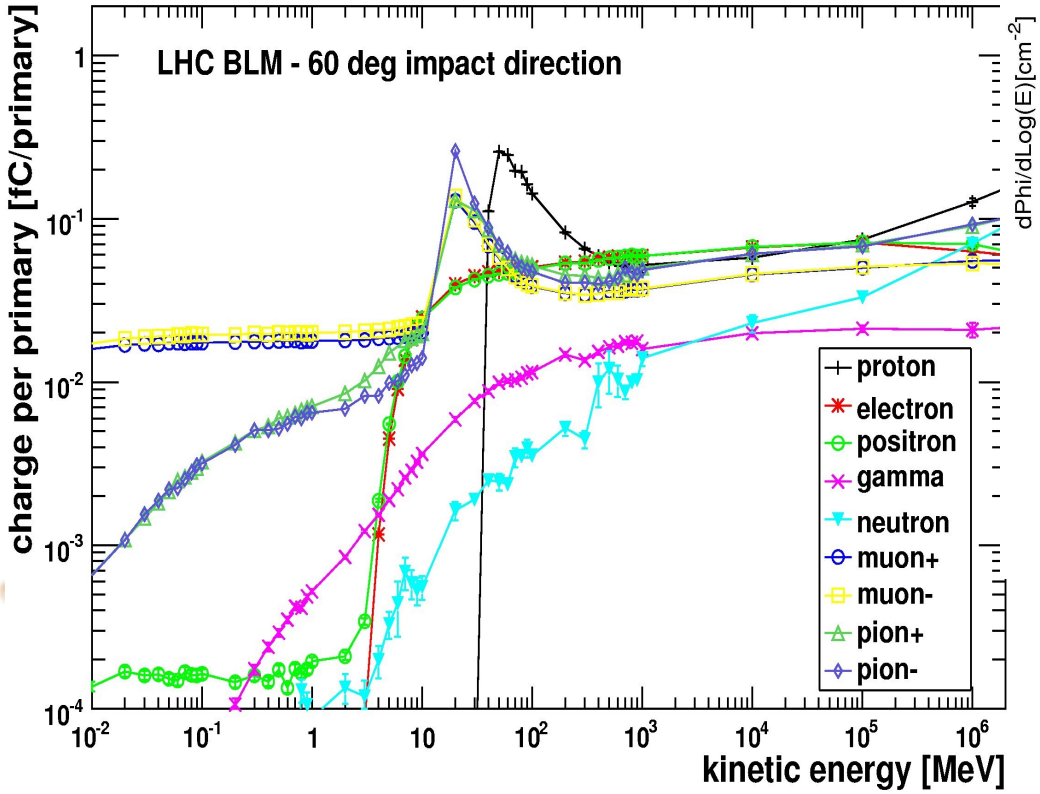
Future

tbc ... FLUKA & BLM Team
Simulations for final LHC layout
prediction of thresholds for BLMs

Response Curves (Add.)

BLI1A Lethargy BLMIC1ATrFluLeth





Response Curve of LHC BLM IC, by M. Stockner

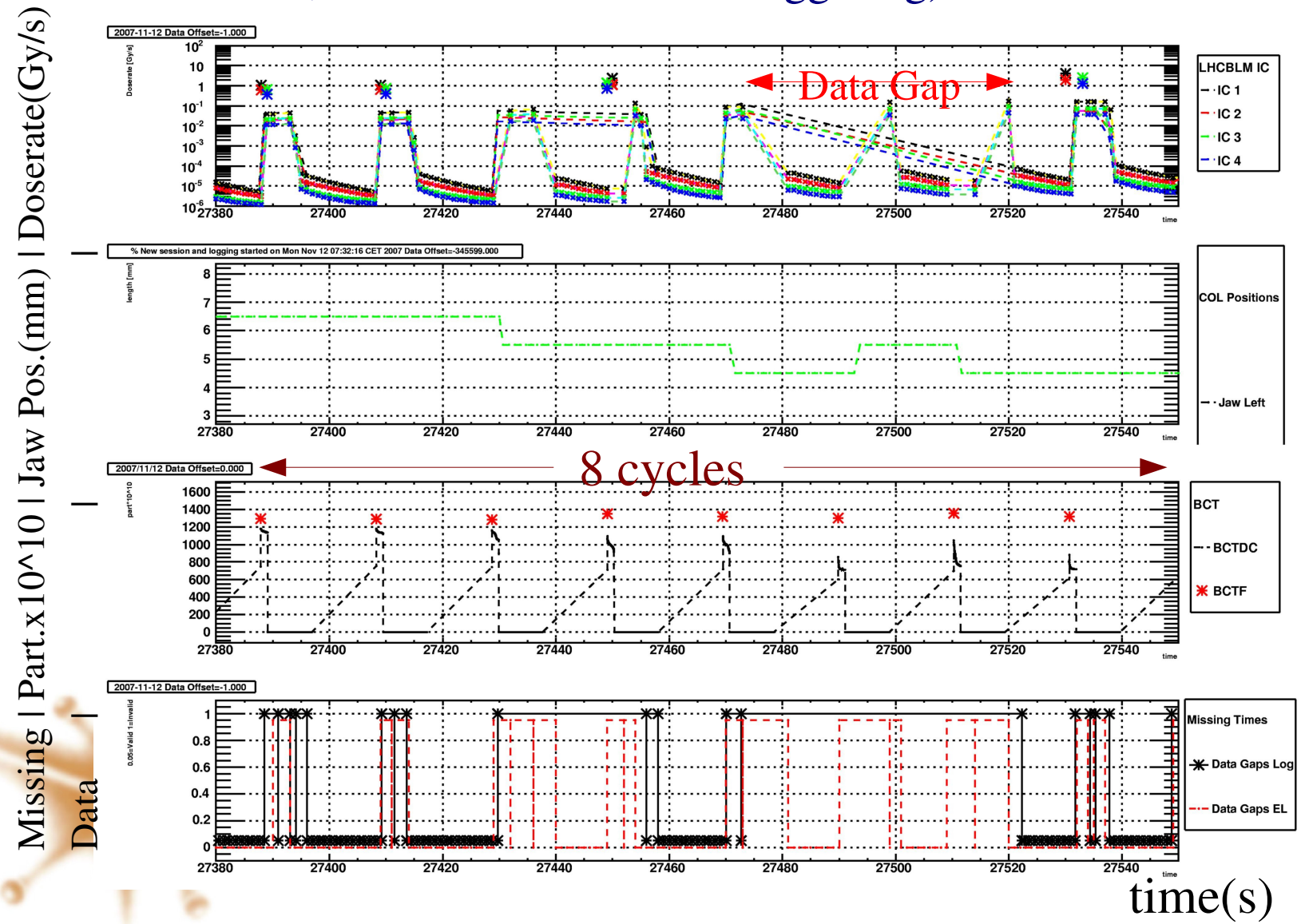
Plans for further MDs

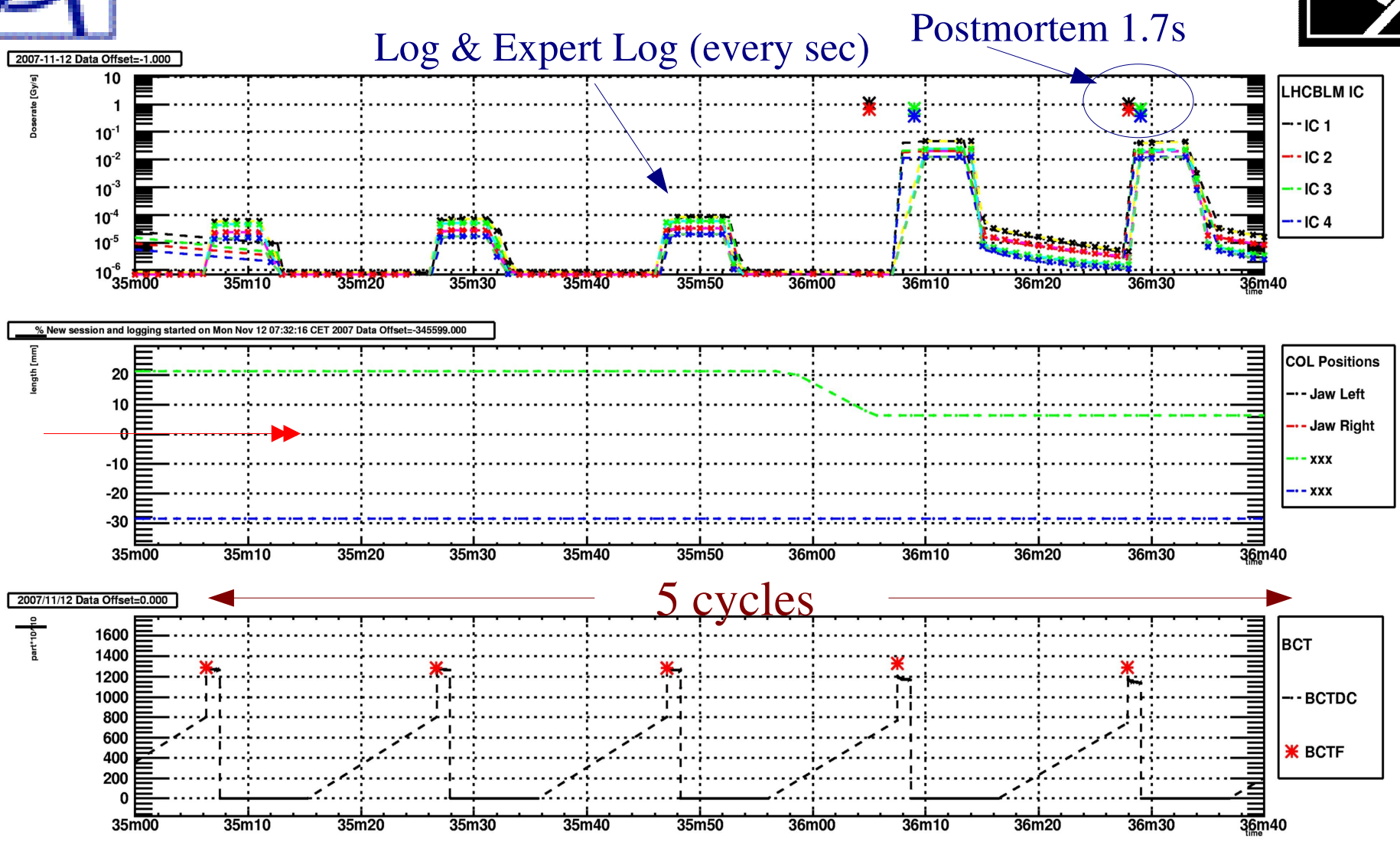
- Lower beam intensity ~5x10^9 to 1x10^11 (no saturation @ full impact)
- Better statistics: several cycles for each collimator position
- Complete BLM data (ongoing software update (*Fesa 2.10*)=> prioritization possible)
- Data acquisition with one turn passing (direct extraction) to eliminate error 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)





Part.x10^10 | Jaw Pos.(mm) | Doserate(Gy/s)

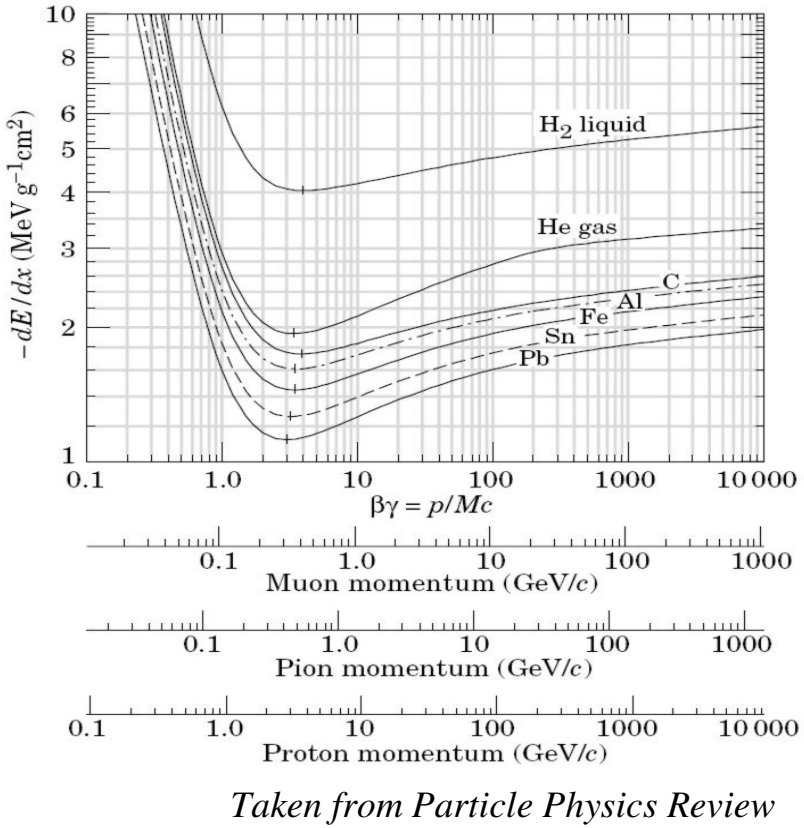
time(s)

Particle Interaction with Matter

Task:

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

Complex geometries!



Taken from Particle Physics Review

Examples:

- Energy losses due to EM interaction: Bethe-Bloch ->
- Multiple Coulomb scattering:

quantitatively described by $\theta^{rms}_{plane} = \frac{13.6\,MeV}{v\,p} q_e \sqrt{x/X_0}$

X_0 : *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