Beam-machine interaction: simulation benchmarking vs first LHC experience

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LHC Collimation Review
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Introduction

FLUKA is extensively used for energy deposition/particle fluence studies in many regions of the LHC, i.e. collimation and experimental insertions

Simulation benchmarking

First LHC operation with 3.5 TeV protons provides input for Monte Carlo benchmarking of beam-machine interaction

- The reliability of the shower development description by FLUKA in the LHC energy regime is examined for **two distinct experimental scenarios**
- In both cases, predictions by FLUKA are compared against **Beam Loss Monitor (BLM)** response measured throughout last year's operation

Scenario I

Analysis of a **controlled** beam loss event

- Quench test with the beam wire scanner

Scenario II (preliminary)

Stable beams

- p–p collisions in IP1

Benchmark I: Losses induced by beam wire scanner

Experimental scenario

Quench test of superconducting magnets at 3.5 TeV (performed in Nov 2010)

- Controlled beam losses induced by beam wire scanner

Wire:	Carbon fibre
Diameter:	30 μm
Location:	left of IR4, ≈33 m upstream of MBRB.5L4 (D4)

- Horizontal scans of beam 2 at various speeds (from **1 m/sec** to **5 cm/sec**)

Horizontal beam size:	280 μm
Number of bunches N_b:	144
Number of protons per bunch N_p:	1.05×10^{11}

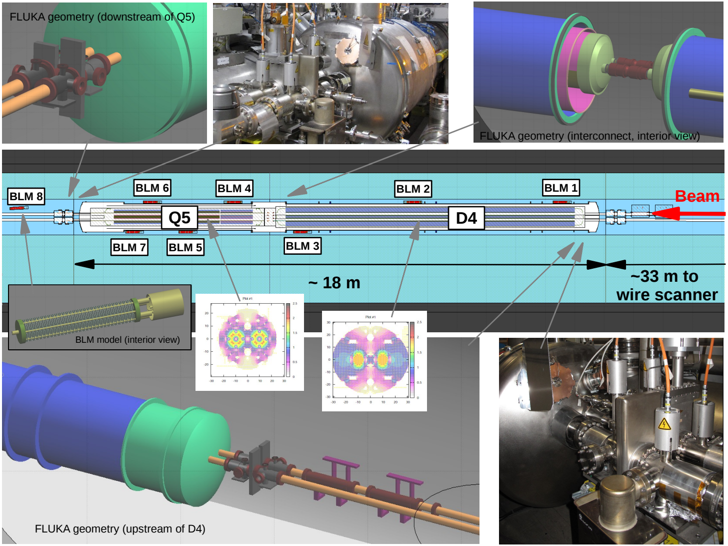
→ **Dipole quenched during scan at 5 cm/sec**

Monte Carlo

Accurate knowledge of source term: experiment provided suitable conditions to validate FLUKA predictions

- Monte Carlo was compared against measured BLM response **along the most impacted magnet string** (MBRB (D4) and MQY (Q5))
- Complex geometry was accurately rendered in the simulation setup

FLUKA geometry: magnets, cryostat, BLMs, etc.



Normalization factor

- Only protons simulated which impinge on wire: normalization applied to account for the **total number of protons** N_w traversing the wire throughout a scan

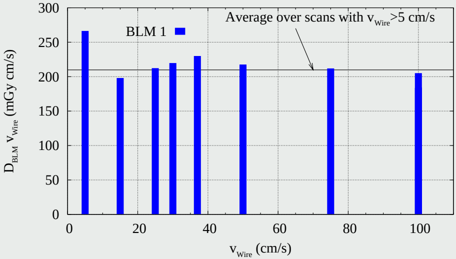
$$N_w = N_b N_p \frac{f_{rev}}{v_w} d_w$$

N_b/N_p=Bunches/protons per bunch

f_{rev}=LHC revolution frequency,

v_w/d_w=wire speed/diameter

- Factor implies that the product $N_w \cdot v_w$ (and hence $D_{BLM} \cdot v_w$) is constant for scans performed at different speeds
- Expected behaviour is largely confirmed by measurements, except for $v_w =$ 5 cm/s, where wire oscillation, wire sublimation, etc. occurred:

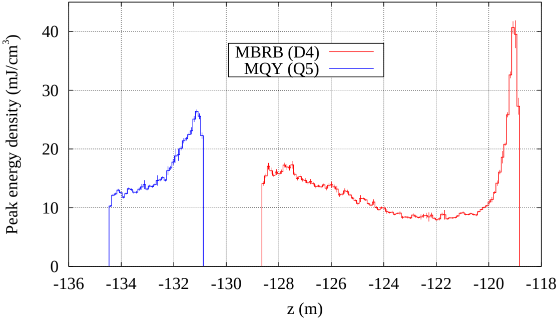


- **For the purpose of the benchmark, we compare against the average measured value over all scans with v_w >5 cm/s**

Peak energy density in coils of D4 and Q5

Time-integrated (≈40 msec) peak energy density for a scan at 5 cm/sec

- Represents scan during which **D4 quenched**
- Results compatible with expectations



Dedicated normalization applied taking into account wire oscillations, wire sublimation, etc.

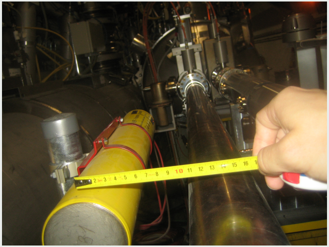
Geometry impact on simulated BLM signal

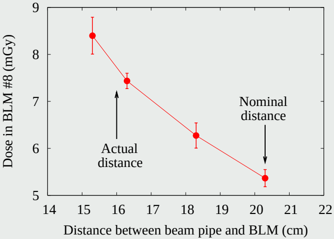
Geometry details (e.g. warm vacuum modules, cold mass end caps) proved to be important due to **enhanced shielding effects** or **shower build-up**

- Significant changes in BLM signals (up to ≈40%) were observed in some cases if these components were neglected

Accurate BLM positioning relevant if BLM was located in proximity of beam pipe

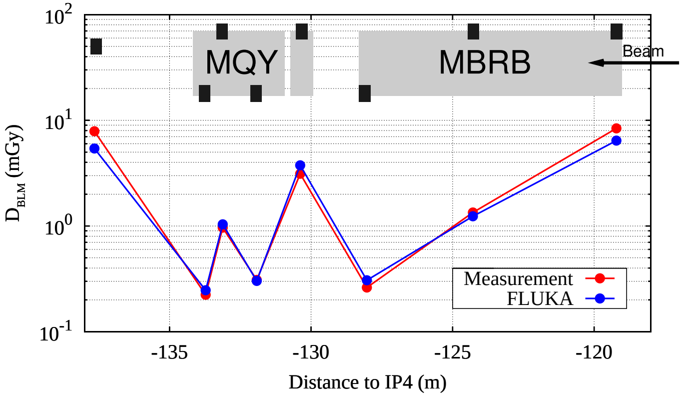
- **Case of BLM #8**: Actual distance between BLM and beam pipe significantly smaller than nominal value in layout database
- Accounting for actual position yielded dose increase of ≈30% due to strong radial field gradient (see plot)





Time-integrated dose in BLMs

Experiment vs FLUKA (v_w=25 cm/sec):



Absolute comparison!

Benchmark II: Proton–proton collisions in IR1

Experimental scenario

Proton–proton collisions in IR1 (Oct 28, 2010)

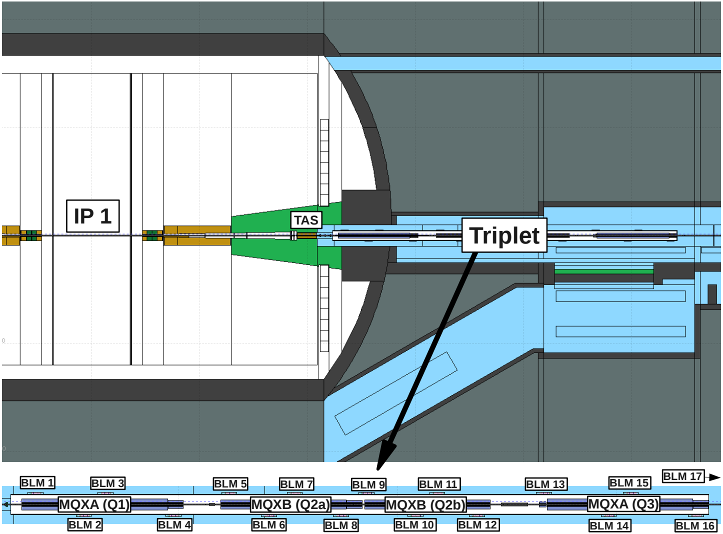
- Stable beams fill #1450

Time period:	more than 14h
Number of bunches N_b:	364
Integrated luminosity:	$>$ 6200 nb^{-1}

Monte Carlo

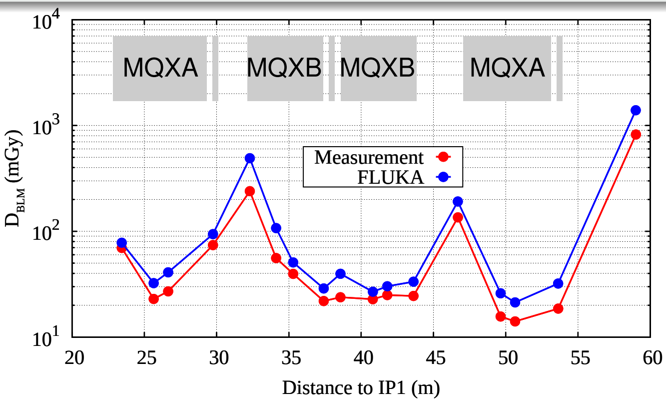
- p–p collisions simulated by means of DPMJET-III (through FLUKA)
- FLUKA prediction of dose deposition compared against measured BLM response **along triplet right of IR1**
- Normalization based on **nominal ATLAS luminosity**, assuming a total cross section of 80 mb
- Geometry still sketchy
- **Work in progress: preliminary results available**

FLUKA geometry



Time-integrated dose in BLMs

Measurement vs FLUKA (for an integrated luminosity of 6255.71 nb^{-1}):



- Relative pattern well reproduced, some discrepancies can be ascribed to missing geometry details (lessons learned from wire scanner simulations)
- **Systematic offset to be understood**, possible source of differences could be normalization (luminosity, total cross section), ...

Summary & conclusions

- By comparing simulated and measured BLM response, the presented work examined the reliability of FLUKA simulations for predicting beam-machine interaction effects in the LHC energy regime (p@3.5 TeV)
- Benchmark I: Controlled beam losses by means of wire scanner
  - **Absolute BLM dose values could be well reproduced**
  - In other loss scenarios, larger uncertainties may occur if the information available (e.g. loss distribution) is limited
    $\rightarrow$ Uncertainty depends on individual scenario, cannot be easily quantified
- Benchmark II (work in progress): p–p collisions in IP1
  - Relative BLM dose pattern in good agreement with measurement
- Geometry details in the vicinity of BLMs particularly important in cases where BLMs are located after an interconnect or in the proximity of the beam pipe
  - Uncertainties up to 30%–40% could be observed if details were neglected