Quench test with LHC wire scanner: Update on FLUKA simulations

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Beam wire scan: Quench test

Recall of experimental scenario

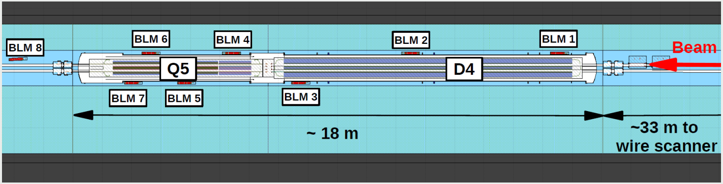
- **Beam Wire Scanner (BWS.5L4.B2)**
  - Wire made of **Carbon**, with a diameter d_W of **30**μ**m**
  - Position: **left of IR4**, ≈32 m upstream of MBRB.5L4 (D4)
- **Quench test conducted by BLM team (01/11/2010)**
  - Horizontal scans at various speeds (**1 m/sec** to **5 cm/sec**)
  - Dipole (MBRB) quenched during last scan
  - For details, see presentation given at MPP, 12/11/2010

Simulation benchmark

- Experiment provided **suitable conditions to validate FLUKA predictions** of shower development in the LHC energy regime
- Monte Carlo compared against measured **Beam Loss Monitor (BLM) response** along the most impacted magnet string
- First results were presented at MPP, 21/01/2011

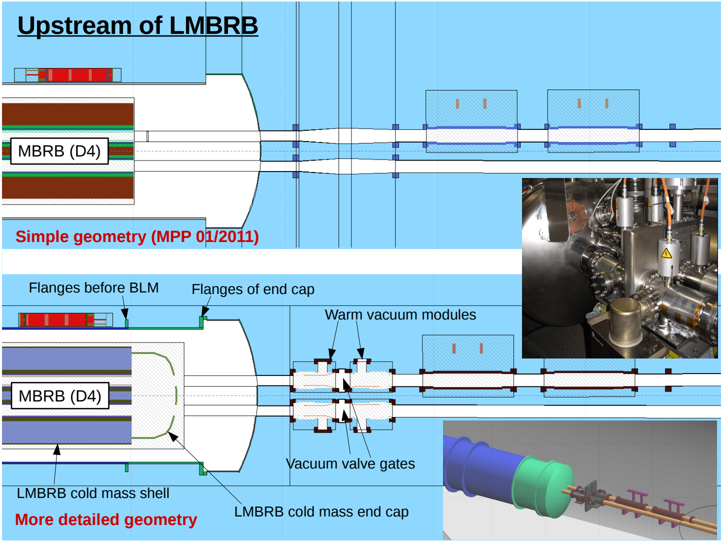
Simulation update

- **Geometry more accurately rendered**
  - Improvements particularly concerned **cryostat**, **interconnect** LMBRB/LMQYH, **warm vacuum modules** up-/downstream of LMBRB/LMQYH, as well as **BLM positioning**
  - Additional details resulted in enhanced shielding effects or shower build-up → significant changes in BLM signals were observed in some cases

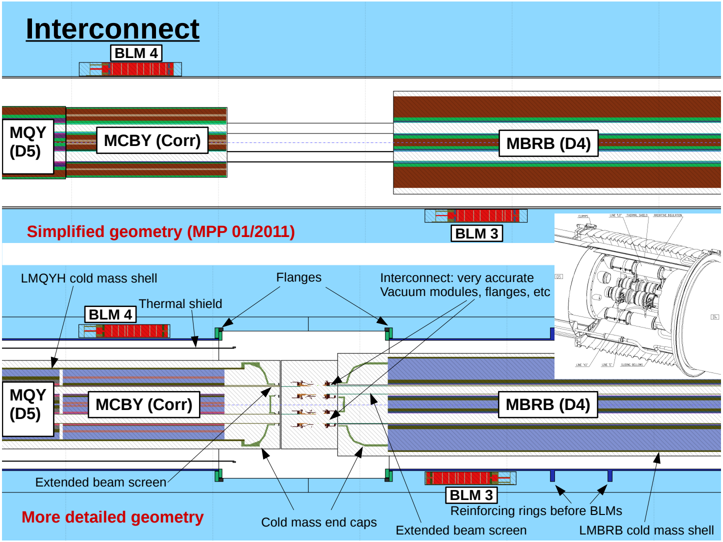


- **Re-evaluation of results in view of normalization**

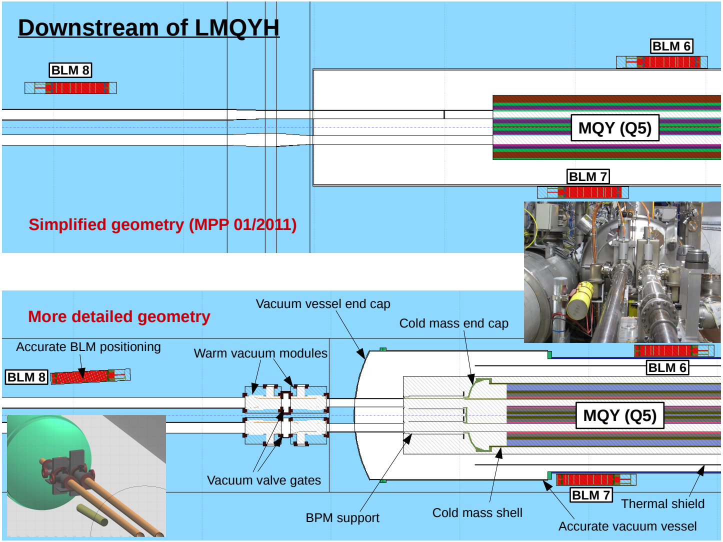
Geometry details upstream of LMBRB



Geometry details around interconnect



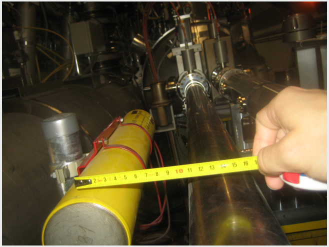
Geometry details downstream of LMQYH

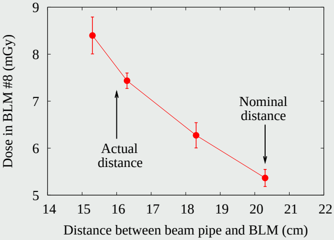


Geometry details downstream of LMQYH

Impact on signal in BLM #8

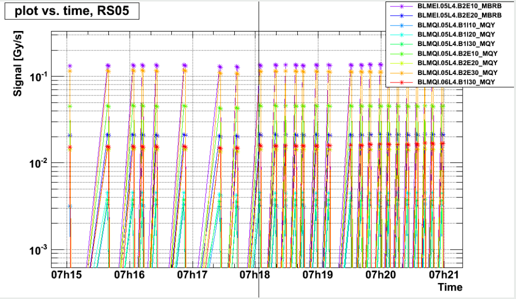
- Additional components (in particular warm vacuum modules and cold mass end cap) partially shield radiation field
  $\longrightarrow$ **Dose decrease of ≈40%**
- Actual distance between BLM and beam pipe significantly smaller than nominal value in layout database
  $\longrightarrow$ **Accounting for actual position yields dose increase of ≈30% due to strong radial field gradient (see plot)**





Static wire and initial proton distribution

- **Basics assumption:** Static wire position at nominal beam center
- Only protons simulated which impinge on the wire (flat distribution to cover wire laterally)
- Plot (by Mariusz) shows measured BLM signals for scans performed in case of different orbital bumps (difference from shot to shot was 0.5 mm):



- Bump has (almost) no effect on the shape of the loss as seen by BLMs
  → Confirms the validity of our assumption of a static wire position

Normalization factor

Recall

Simulation delivers results **per proton impinging on the wire**
→ Normalization required to account for the total number of protons N_W traversing the wire throughout a scan

Model solution

Supposing the wire moves with constant velocity v_W, one obtains following expression:

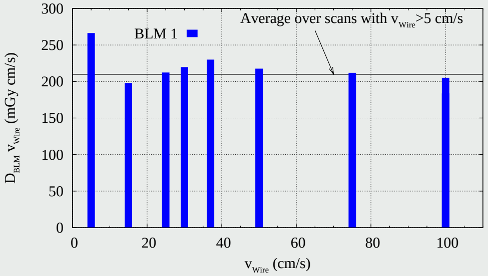
$$N_W = N_b N_p \frac{f_{LHC}}{v_W} d_W, \quad (1)$$

where N_b refers to the **number of bunches**, N_p indicates the **number of protons per bunch**, f_{LHC} is the **LHC revolution frequency**, and d_W is the **wire thickness**.

Assuming $N_b = 131$, $N_p = 1.15 \times 10^{11}$, $f_{LHC} = 11245$ Hz and $d_W = 0.003$ cm, Equation (1) yields $N_w = 5.082 \times 10^{14}/v_w$ (with v_w in cm/s).

Normalization factor

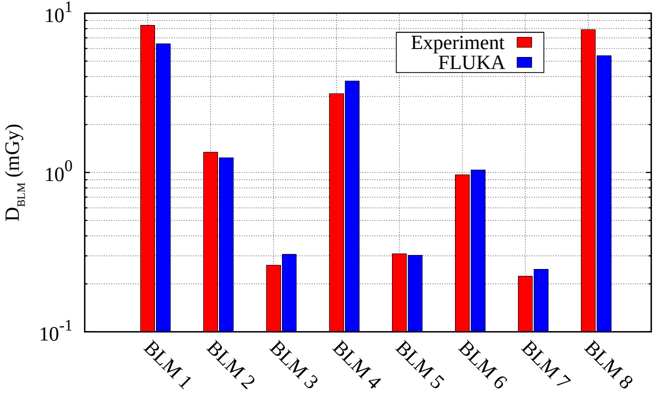
- Model solution implies that the product $N_W \cdot v_W$ (and hence $D_{BLM} \cdot v_W$) is constant for scans performed at different speeds
- Expected behaviour is largely confirmed by measurements, except for $v_W =$ 5 cm/s, where wire oscillation, wire sublimation, etc. occurred (see presentation at MPP, 01/2011):



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

Time-integrated dose in BLMs

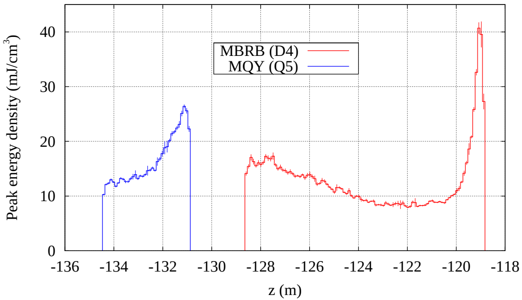
Experiment vs FLUKA (v_W=25 cm/sec):



Agreement of absolute dose within ±30%

Peak power density in coils of D4 and Q5

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



To account for experimental conditions at 5 cm/sec (e.g. wire oscillations etc.) an empirical factor was applied on top of the described normalization: $N_W^{5\ cm/sec} = N_W \cdot 1.27$ (this factor derives from a comparison of experimental dose values obtained at different speeds)

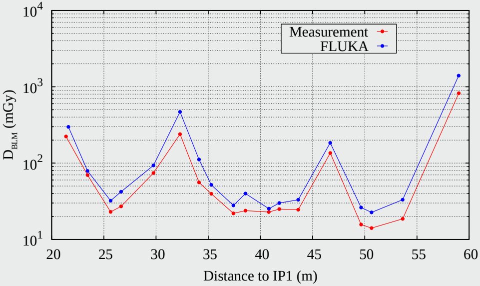
Summary and conclusions

- Shower development descriptions by FLUKA and accompanying energy deposition/particle fluence predictions are used in many LHC-related studies (e.g, collimation, ...)
- By comparing simulated and measured BLM response, the presented work examined the reliability of FLUKA for predicting beam-machine interaction effects in the LHC energy regime
- Geometry details in the vicinity of BLMs proved to be particularly important in cases where BLMs were located after an interconnect or in the proximity of the beam pipe
- **Measured dose values could be well reproduced – with discrepancies amounting to less than 30% in all individual cases**
- The experimental setup allowed for a benchmark under controlled conditions, with accurate knowledge of the source term
  - In other experimental scenarios, larger uncertainties may occur if the information available (e.g. loss distribution) is limited

Outlook

Upcoming benchmark

- Stable beams: FLUKA vs dose measured in BLMs around triplet right of IR1
- **Preliminary comparison** of time-integrated dose for Fill #1450:



- 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), ...