MD10724:
BFPP Quench Test 2023

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Based on slides shown by C. Bahamonde Castro, R. Bruce, M. Jebramcik, J. Jowett, A. Lechner, M. Schaumann at rMPP 20/11/2018 for MD4746 (which did not happen …)

Goal

Use BFPP beams to induce a quench in a main dipole magnet

Information on **steady state quench limit in a clean loss scenario**:

- Impact point in magnet can be controlled by orbit bumps avoiding magnet ends, which would return less accurate quench level estimates

- Quench limit can be approached gradually by anti-levelling the luminosity of the IP, since the power of BFPP beams is directly proportional to luminosity and can therefore be controlled by changing the beam separation

Proposed magnet for MD: MB.B11R1.B1

Motivation

First test performed on 8 Dec 2015 (Fill 4707) on **MB.B11L5.B2**

Location chosen due to observed loss situation

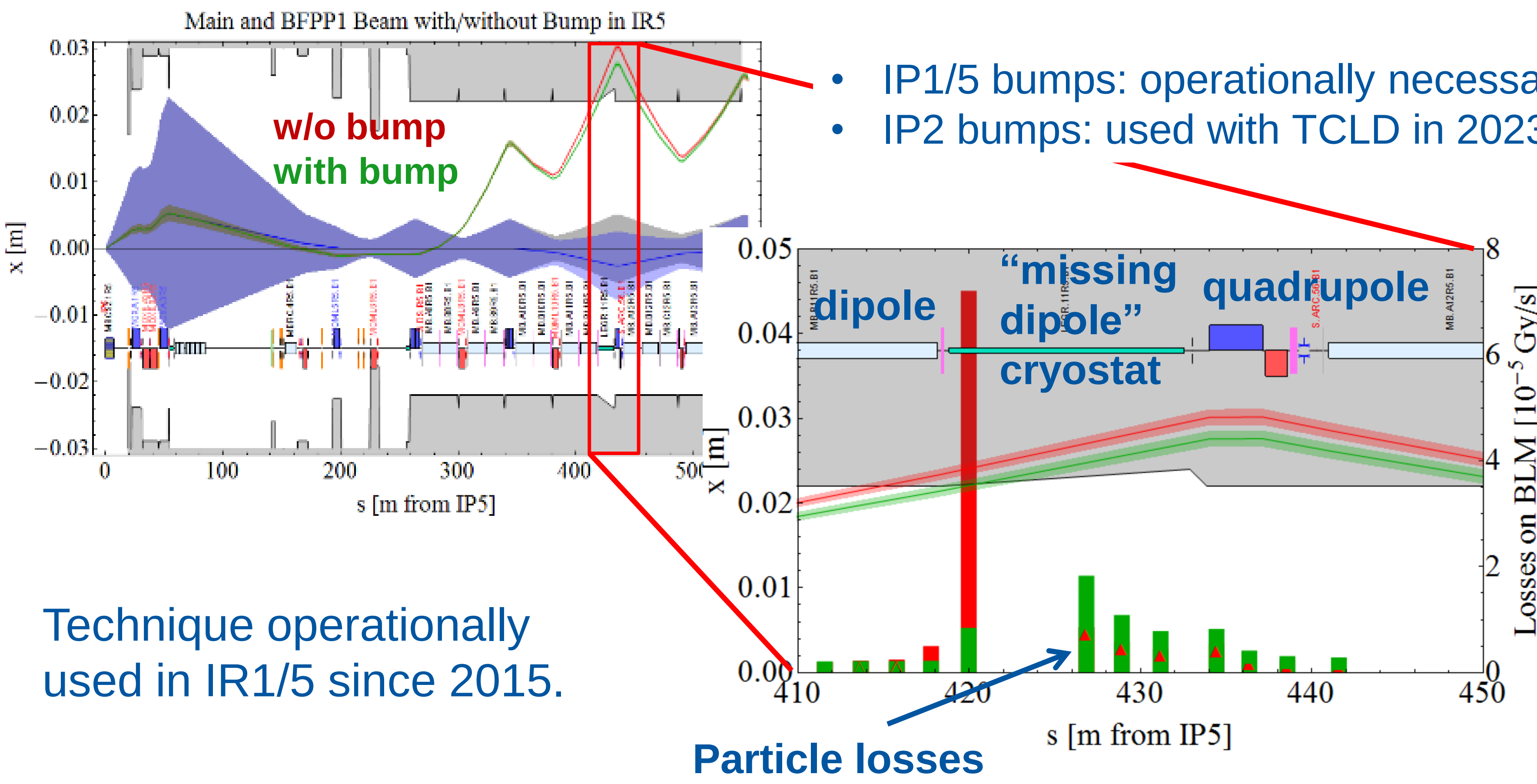
- Losses still in the MB during regular operation with -3mm bump
- Could easily move losses deep into the MB by inverting the bump for QT

Somewhat inconclusive results *Phys. Rev. Accel. Beams* 23 (2020) 121003 **require second test at different location**

- Discrepancy between the expected & the actual loss location→ analysis revealed aperture misalignment in this zone
- Quench limit lower than expected
  - Power density reconstructed with FLUKA was factor ~ 2 lower than the quench level predicted by electro-thermal models.
  - Quench happened at $2.3\times10^{27}cm^{-2}s^{-1}$ but max. luminosity reached during 2015 run 3.6e27 $cm^{-2}s^{-1}$ and no other BFPP induced quenches occurred (bump in L5 still left some losses inside MB)

Quench Risk Mitigation with Orbit Bumps

Orbit bumps are used to move the secondary beam losses to a less vulnerable location in order to reduce risk of quench.

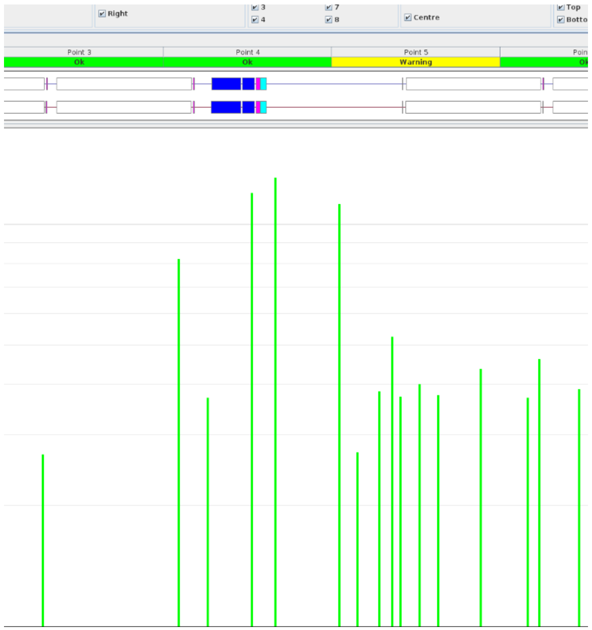


- IP1/5 bumps: operationally necessary
- IP2 bumps: used with TCLD in 2023

Technique operationally used in IR1/5 since 2015.

Operational bump in 2023

- BFPP bump Setup evening of 21/9/2023
- Initial amplitude in R1 (-2.5 mm) did not require much further adjustment
- Works well in physics with luminosity up to 6× 10^{27}cm^{-2}s^{-1}



Procedure

① BLM MFs =1 at MB.B11R1 (and L1/R5) with thresholds increased to allow 6× $10^{27}cm^{-2}s^{-1}$ (to check with BLM team, similar to 2018 plan)

② Prepare beam as for **standard physics fill** until collisions.

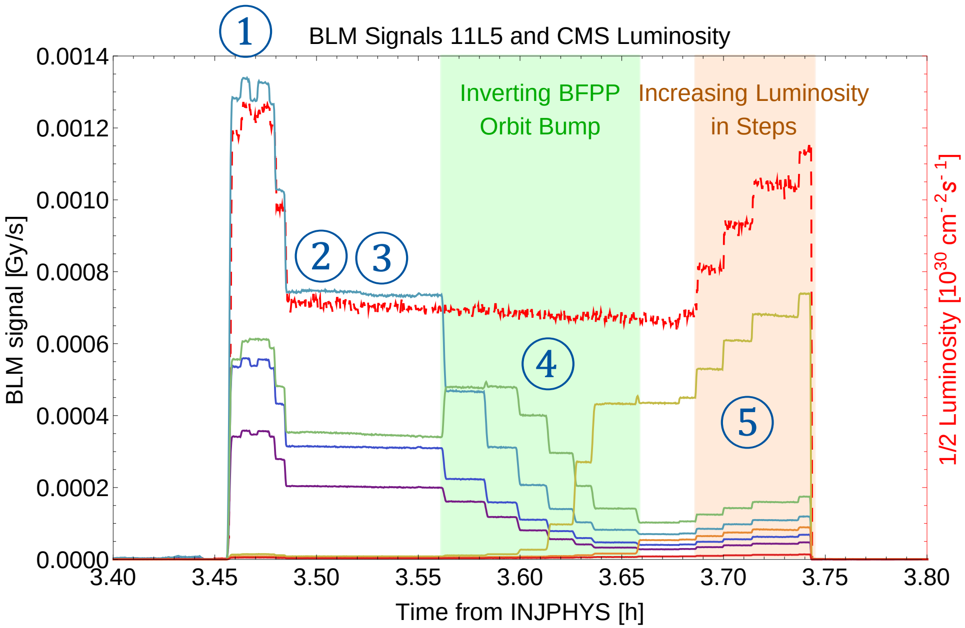
③ Re-separation of the beams to reduce burn-off, and to about 2σ in IP1

④ Reduce beam separation in steps at IP1 to have enough luminosity to determine the impact point of the BFPP beam in the MB based on the BLM signals.

⑤ **Invert BFPP orbit bump R1** from operational setting (-2.5 mm) until losses are fully in the MB (expect slightly positive bump around +1 mm).

⑥ **Reducing the separation in IP1** in 5 or 10 µm steps until quench occurs (wait 0.5-1min/step) ~30 min total to quench

Time evolution of the 2015 test



Other considerations **in 2018**

QPS crates

New patched nQPS boards installed during TS3 in cell 11 L/R of IR1 & IR5 in anticipation of the ion run.

Losses during intensity ramp up and high intensity EOF tests will be closely monitored to spot potential issues triggered by R2E.

MP3

No special constraints for quenching MB.B11 in L1/R1 according to magnet experts

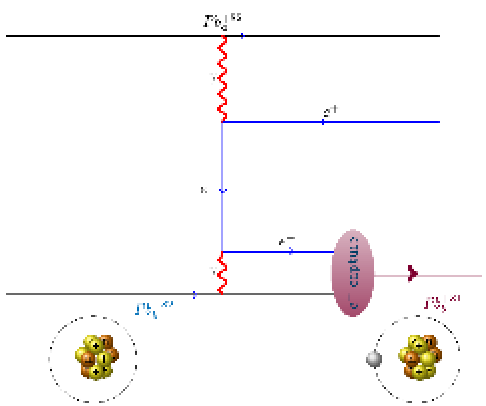
In 2023, verify with cryo …

Backup

Secondary Beams created in the Collision

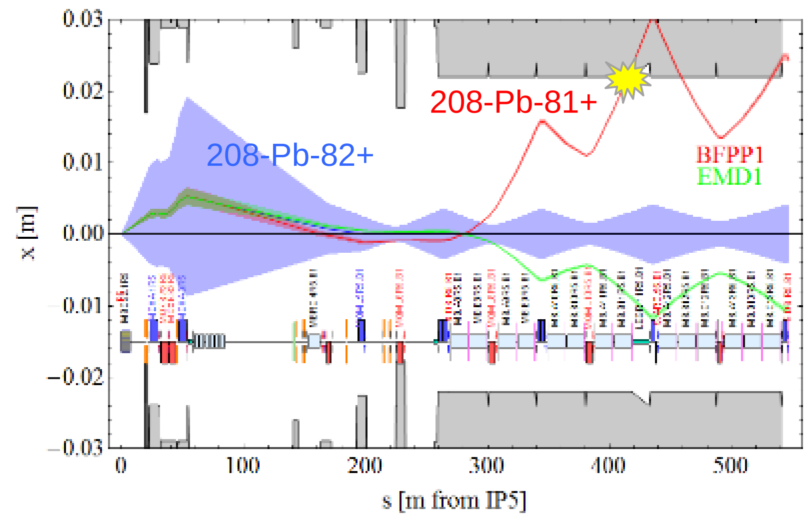
Bound-free pair production (BFPP)

$$^{208}\mathrm{Pb}^{82+} + ^{208}\mathrm{Pb}^{82+} \longrightarrow ^{208}\mathrm{Pb}^{82+} + ^{208}\mathrm{Pb}^{81+} + e^{+}$$



Has large interaction cross-section (>200b) in Pb-Pb collisions and is the main contribution to fast luminosity burn-off.

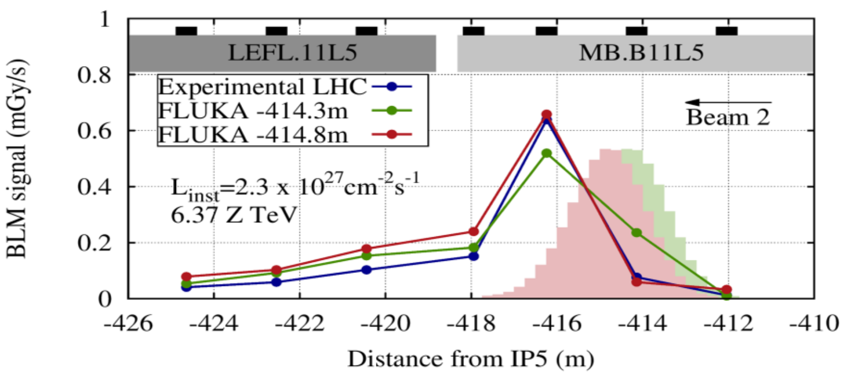
Secondary beams impact in superconducting magnets downstream the interaction points.



Deposited power exceeds quench limit.
Luminosity limit found at L≈2.3e27cm^{-2} s^{-1} in 2015 quench test (≅40W into magnet)

FLUKA Results of 2015 test

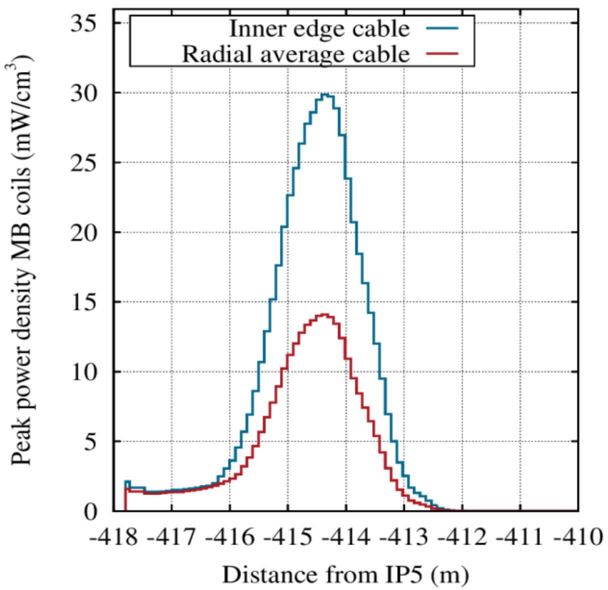
BLM signals can be accurately reproduced with FLUKA, but strongly depend on the longitudinal loss location.



Inconsistencies found. **A second test in a different location is required to understand and confirm the results.**

Power deposition in the MB coils is **lower than expected***,

- strongly depends on shape of loss distribution
- shape effect is washed out in the BLM signals.



*power density reconstructed with FLUKA is about a factor of two lower than the quench level predicted by electro-thermal models

courtesy of C. Bahamonde