Fast Loss Quench Test

(15.02.2013)

Quench limits based on GEANT4 simulations

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Experiment:
T. Baer, M. Bednarek, B. Dehning, S. Bozyigit, W. Hofle, M. Ludwik, J. Ludwin, E. Nebot del Busto, A.Priebe, B. Salvachua Ferrando, M. Sapinski, D. Valuch

GEANT4 simulations: A. Priebe, M. Sapinski
MAD-X simulations: V. Chetvertkova
FLUKA simulations: N. Shetty, A. Lechner
QP3 calculations: B. Auchmann

CONTENT

1. Reminder of the Fast Loss Quench Test 2013
2. Methodology of performed GEANT4 simulations
3. Energy deposition in the coils
4. BLM signals
5. Comparison of quench limits (GEANT4/FLUKA/QP3)
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EXPERIMENT

Methodology of inducing beam losses

- MKQ kick
- Bunch excitation with the ADT sign flip mode
- Three corrector orbit bump

Location: 12L6

Particles: protons

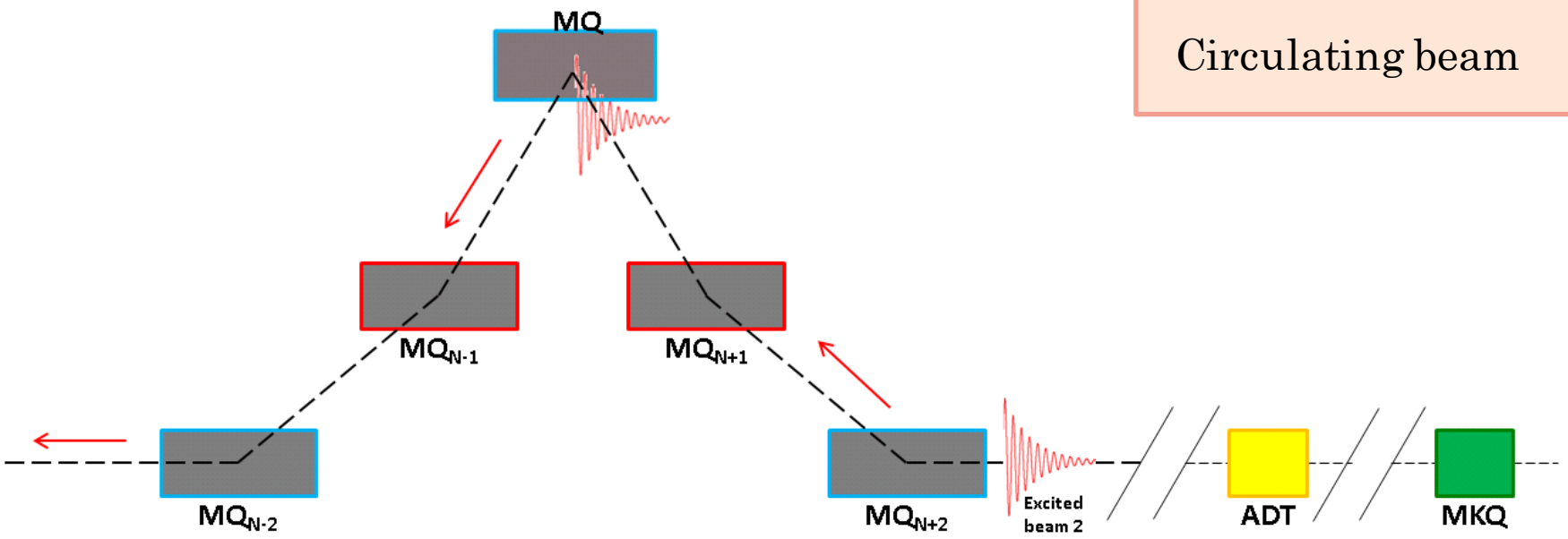
Energy: 4 TeV

Beam: 2

Plane: horizontal

Timescale: ms

Circulating beam



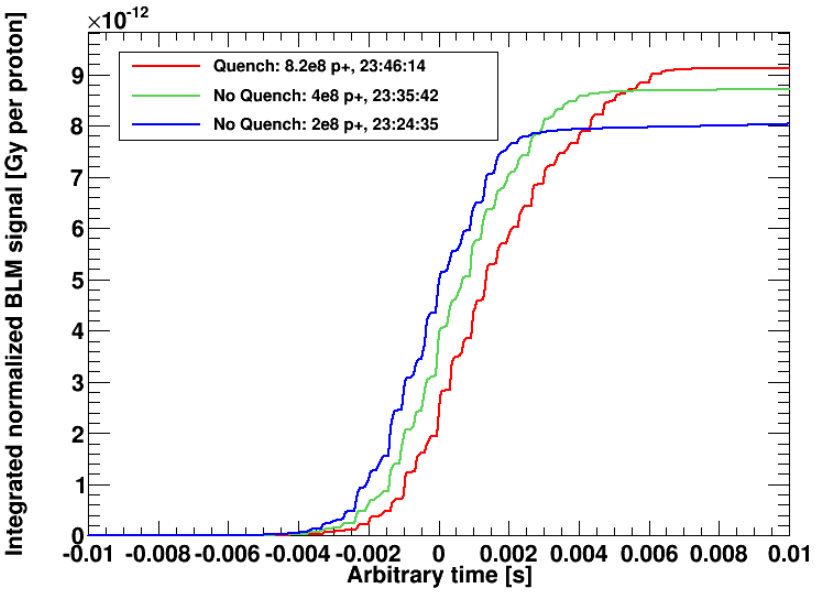
EXPERIMENT

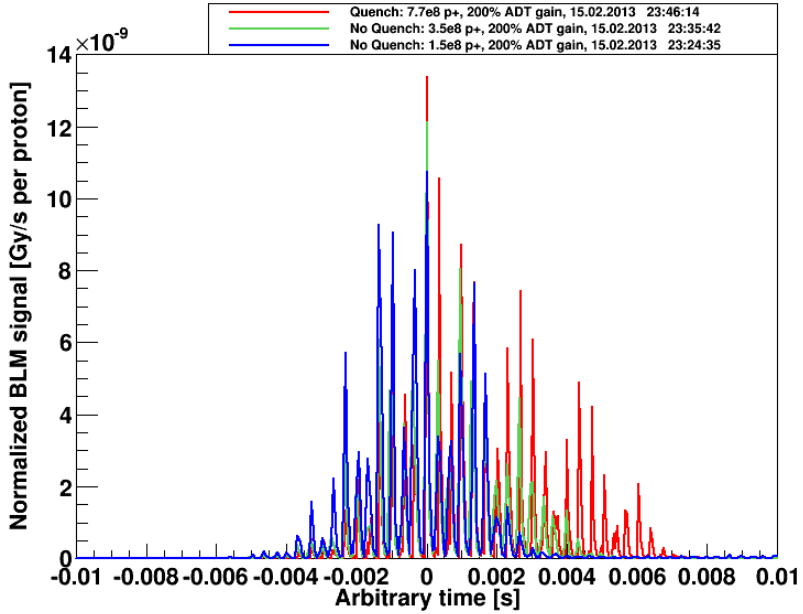
Three bunches excited individually

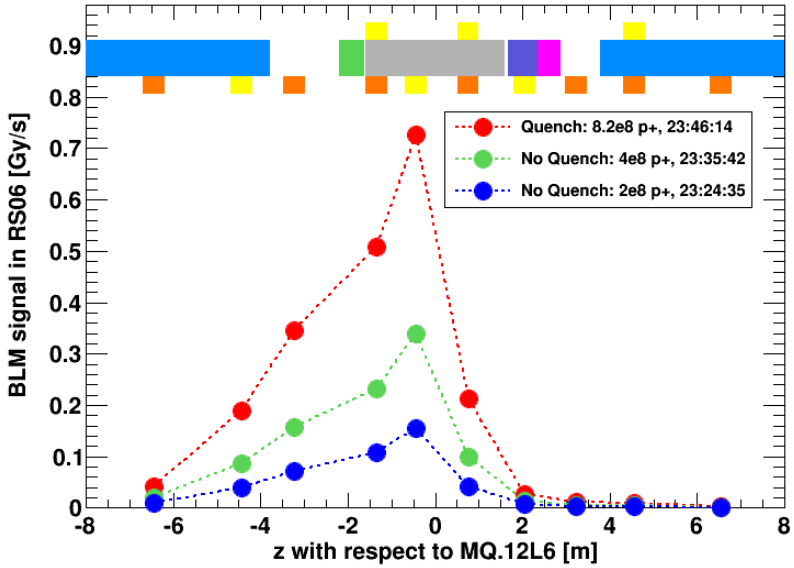
→ the same experimental conditions (200% ADT gain, bump amplitude, MKQ kick)

→ different intensities

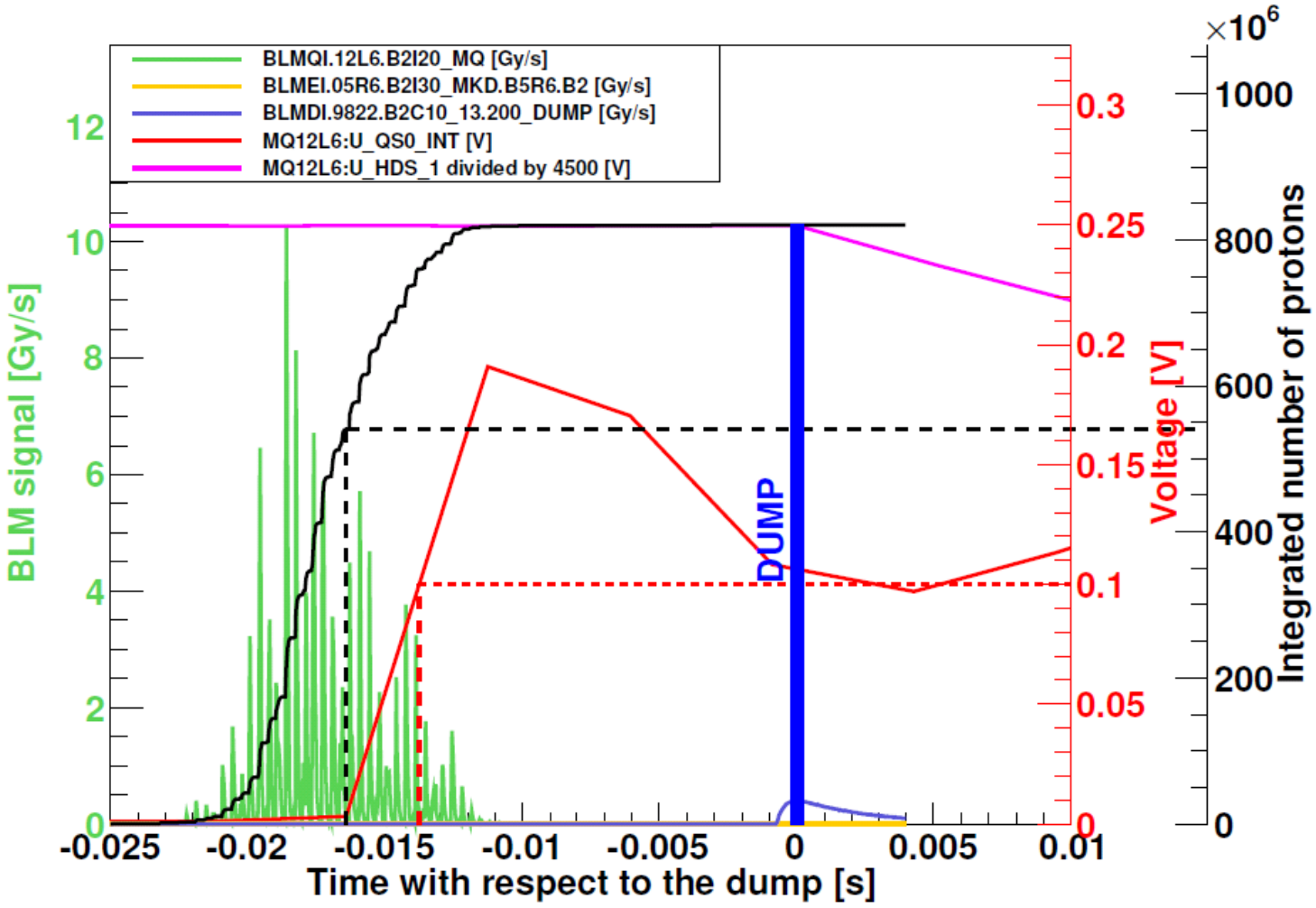
Bunch with initial intensity of $8.2 \cdot 10^8$ p+ caused MQ.12L6 quenching.







EXPERIMENT



About $5.4 \cdot 10^8$ protons caused sudden increase in U_QS0_INT

QPS resolution: 5 ms.

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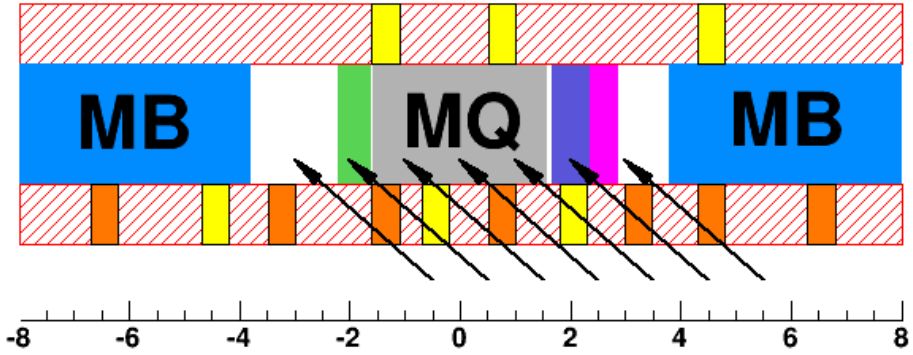
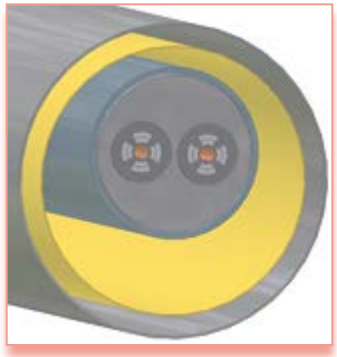
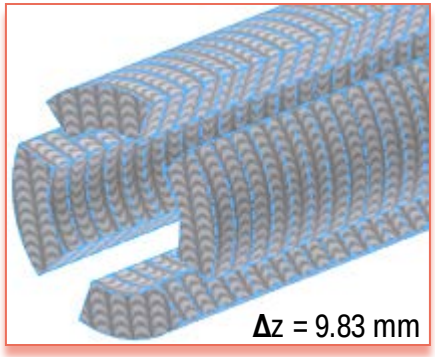
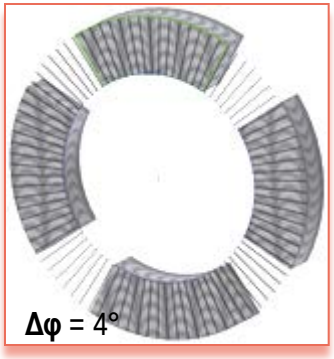
GEANT4 SIMULATIONS

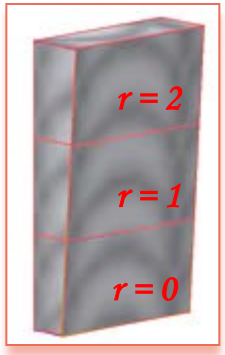
- Detailed magnet representation
- Magnetic field from ROXIE
- Long pseudo-monitors
- Impacting angle: 200 µrad
- 61 point like losses along magnets→ flexibility
- Aim: Correlation E_{dep} = f(BLM)





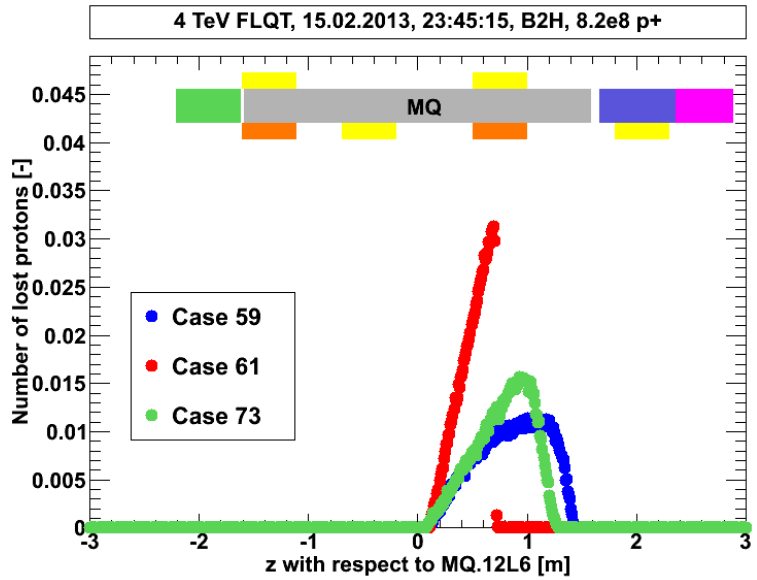






n_r = 3 (2010 QT)
n_r = 4 (2013 QT)

Loss Pattern



← Loss patterns from MAD-X simulations (step of 1 cm). Courtesy of Vera Chetvertkova

Case:

59:

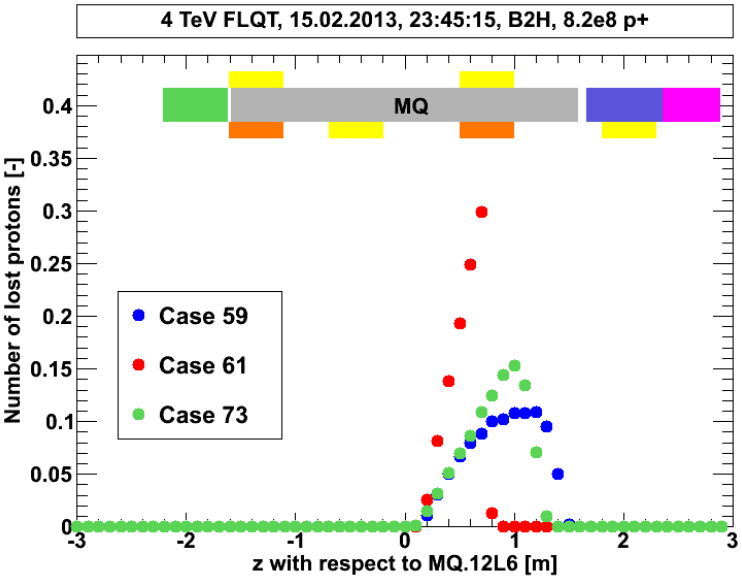
- Bump applied
- Tune matched afterwards (not done in the experiment)

61:

- 64.(3) horizontal tune (3rd order resonance)
- Bump applied

73:

- Tune matched
- Bump applied (order as in the experiment)
- MQ errors taken into account



← Input for GEANT4 simulations (step of 10 cm)

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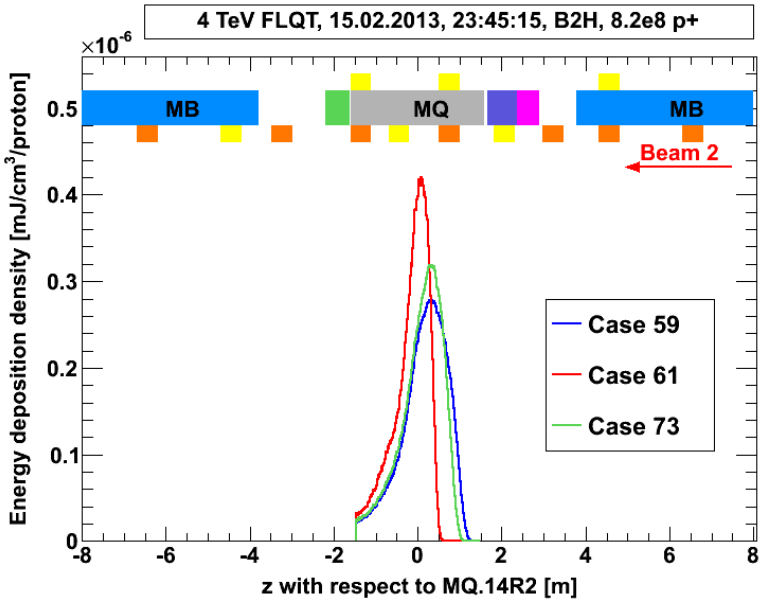
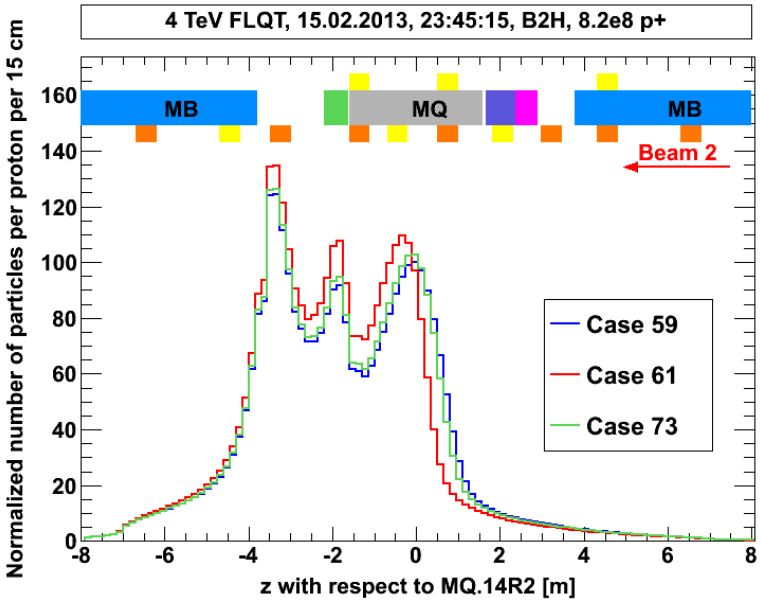
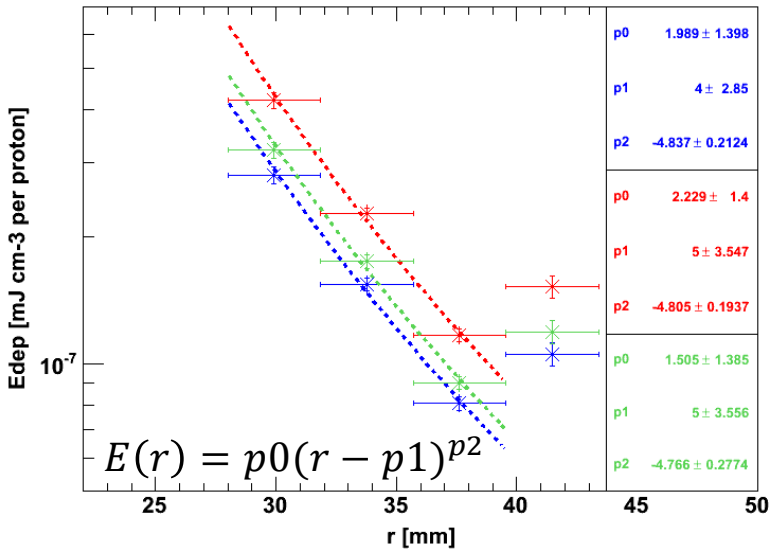
GEANT4 SIMULATIONS







Average energy in first bins:

Case:

59:

$E_{dep} = (2.8 \pm 0.2) \cdot 10^{-7}$ mJ/cm^3

61:

$E_{dep} = (4.2 \pm 0.2) \cdot 10^{-7}$ mJ/cm^3

73:

$E_{dep} = (3.2 \pm 0.2) \cdot 10^{-7}$ mJ/cm^3

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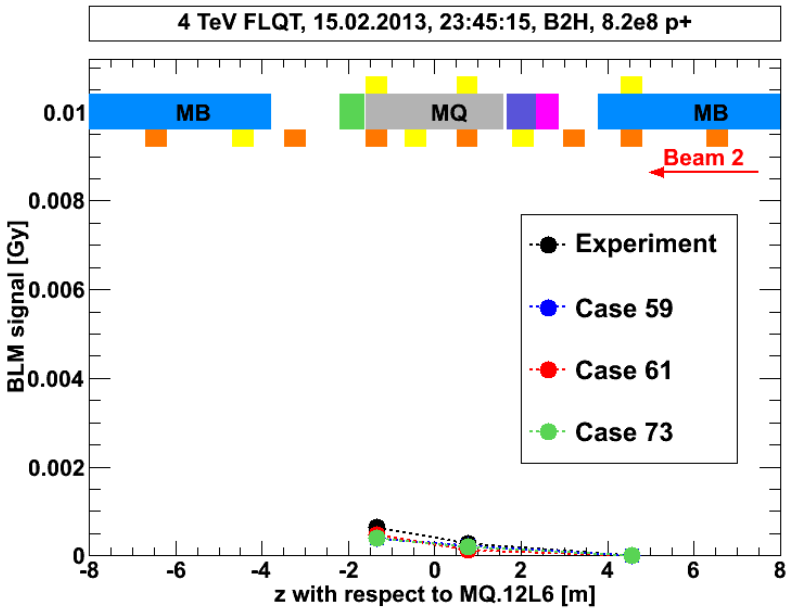
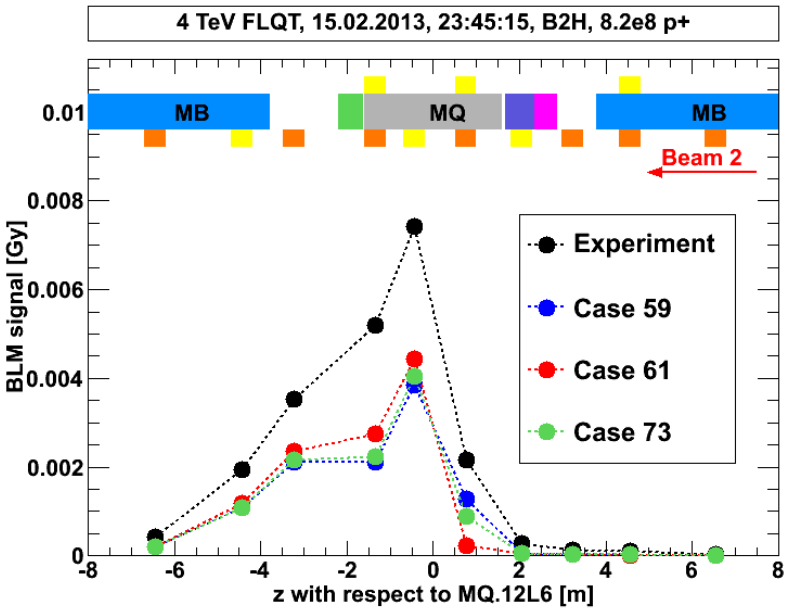
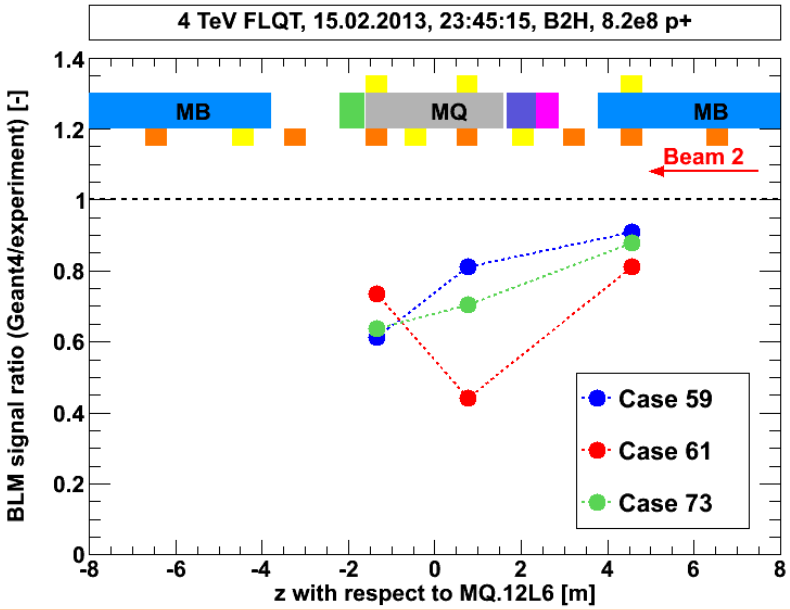
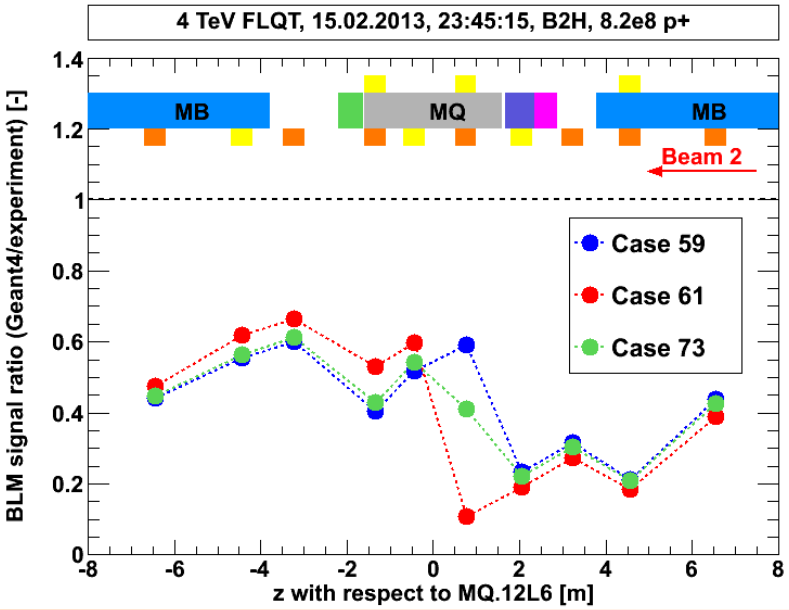
SIGNALS IN BLMS

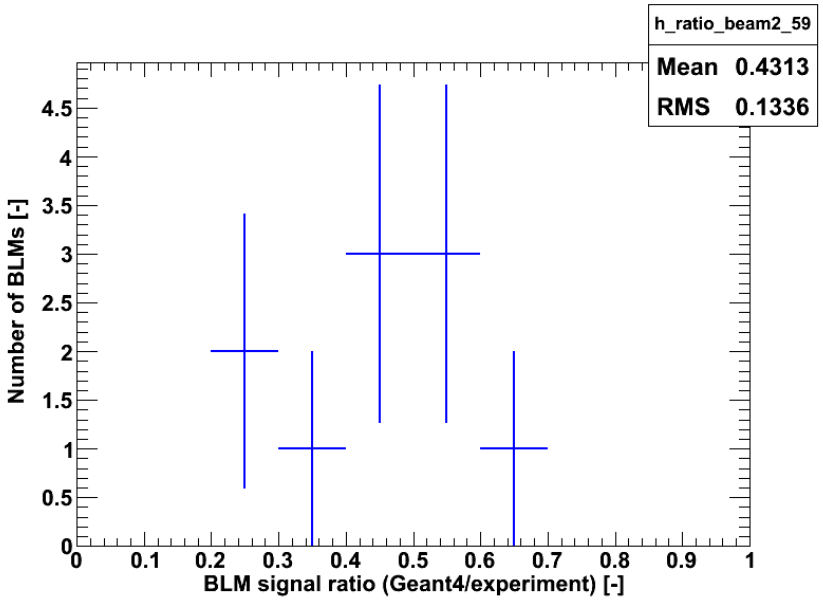


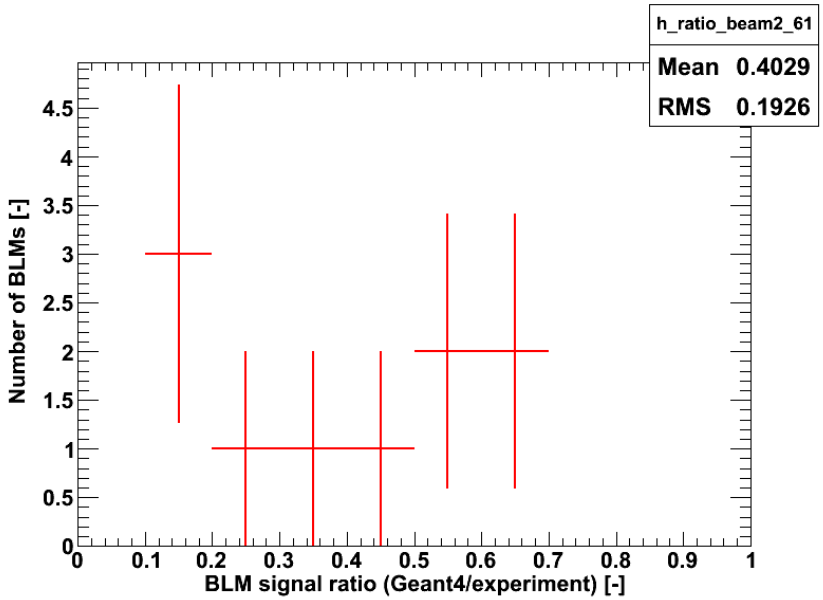


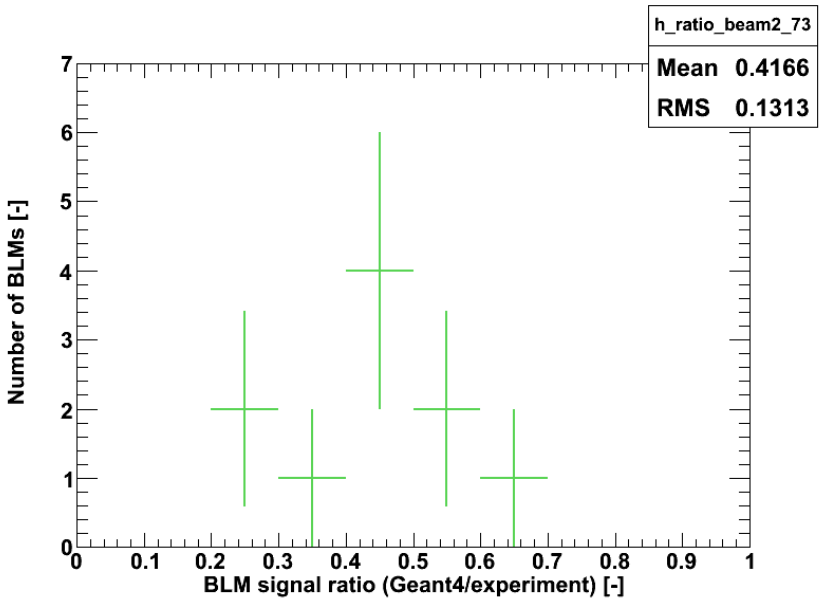




GEANT4: Error estimation







- The mean value of ratios is around 0.4 and RMS is about 0.1-02.
- GEANT4 underestimated BLM signals by a factor of ≈2.

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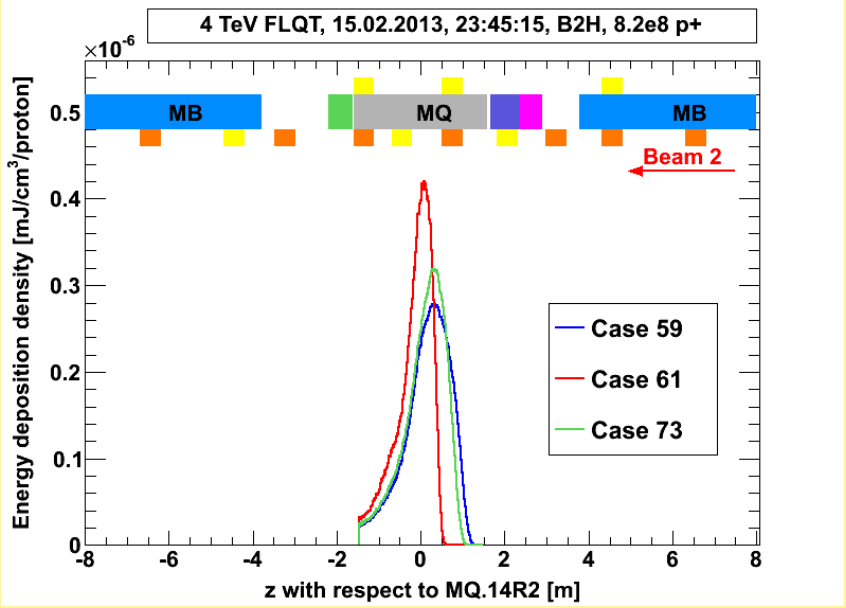
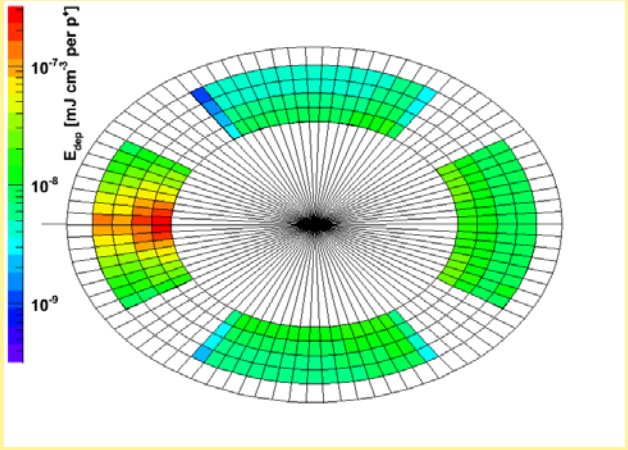
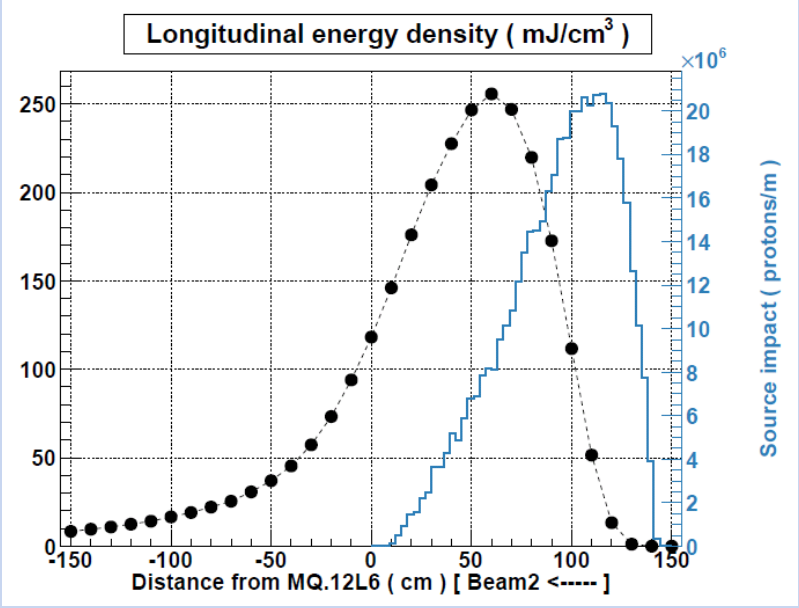
RESULTS

GEANT4

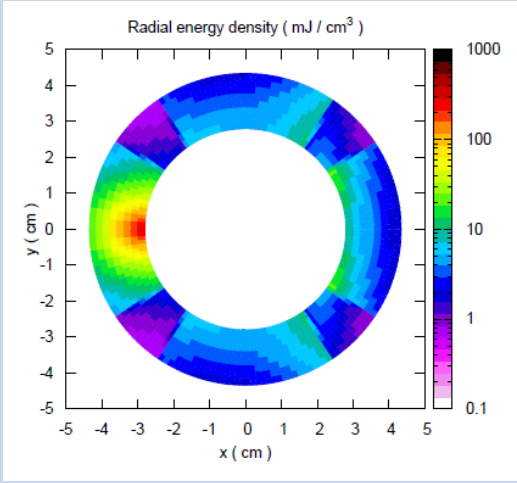




FLUKA



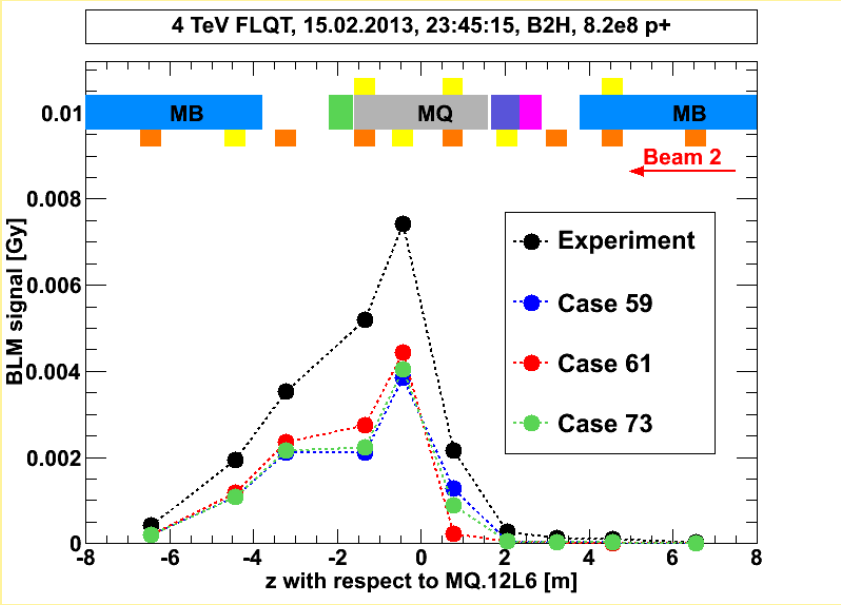
Note different units



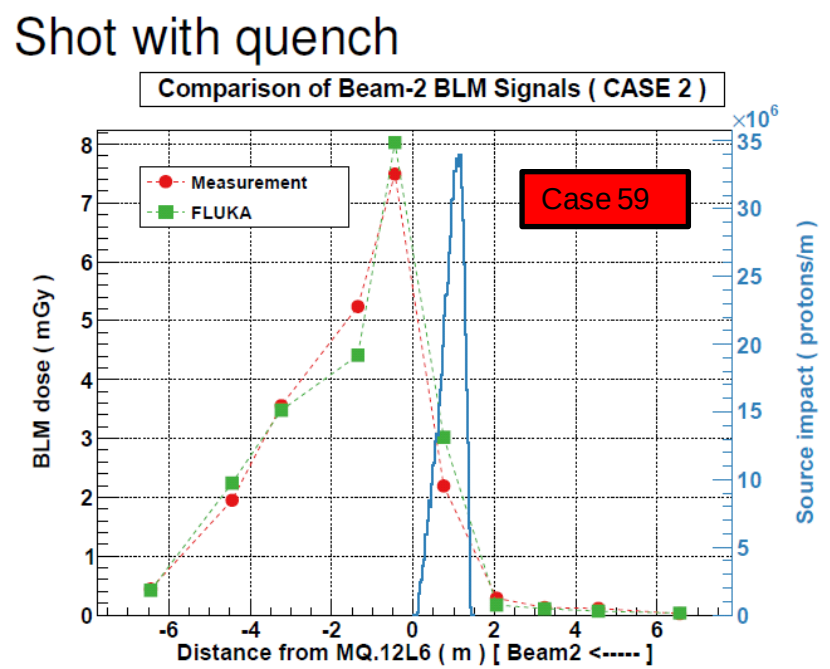
FLUKA results – courtesy of N. Shetty

RESULTS

GEANT4



FLUKA

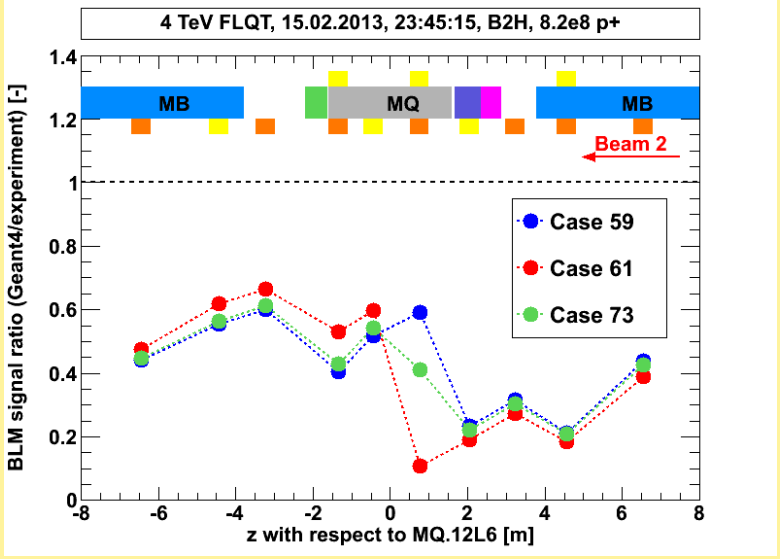


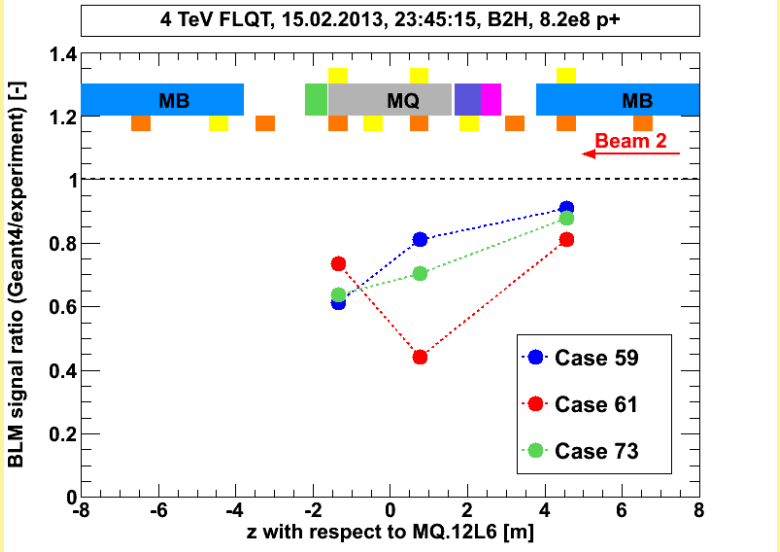
FLUKA results – courtesy of N. Shetty

- Good agreement (in shape) between simulated and measured BLM signals
- Both simulations show underestimated signal in the BLM behind the most exposed BLM
- GEANT4 simulations underestimate BLM signals by a factor (2-3)
- Tendency of FLUKA results varies depending on monitor location

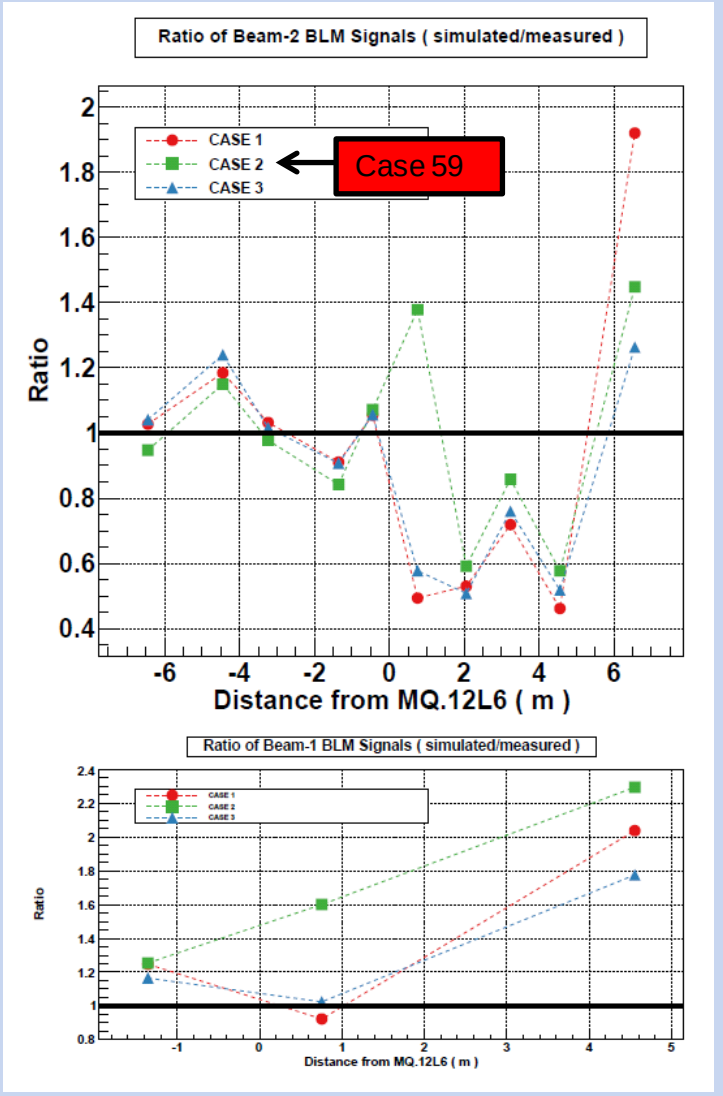
RESULTS

GEANT4





FLUKA



FLUKA results – courtesy of N. Shetty

COMPARISON OF OBTAINED QUENCH LIMITS

Method		Lost $4 \cdot 10^8$ protons	Lost $8.2 \cdot 10^8$ protons
GEANT4	Case 59	170 mJ/cm^3	340 mJ/cm^3
	Case 61	260 mJ/cm^3	520 mJ/cm^3
	Case 73	200 mJ/cm^3	400 mJ/cm^3
FLUKA	Case 59	200 mJ/cm^3	420 mJ/cm^3
QP3		(70±40) mJ/cm^3	

Estimated quench limits

- Dependency on a moment of quenching (number of lost protons)
- Accuracy of MAD-X simulations
- Methodology of GEANT4/FLUKA (different approaches of simulating losses and recording signals, geometry, density of materials)
- QP3 uses radial distribution from Monte Carlo simulations

FLUKA results: N. Shetty

QP3 results: B. Auchmann

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SUMMARY

1. GEANT4 simulations consider weighting of point-like losses depending on loss pattern (fixed impacting angle)
2. FLUKA simulations are based on direct implementation of loss pattern to the code (angle variation taken into account)
3. Both Monte Carlo simulation techniques give similar quench limits (for $5.4 \cdot 10^8$ protons):
   - GEANT4: 260 mJ/cm3
   - FLUKA: (250-280) mJ/cm3
4. Although GEANT4 FLUKA use different approaches, they provide similar quench limits.
5. Quench limit based on QP3 code is (70±40) mJ/cm^3

THANK YOU FOR YOU ATTENTION !

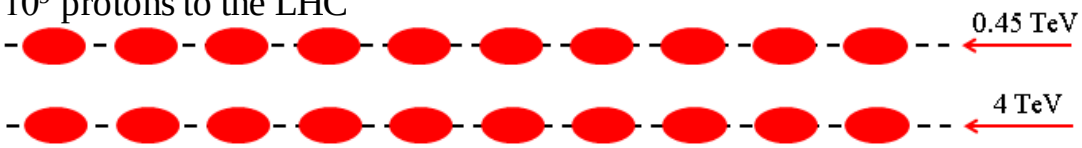
Questions?

Comments?

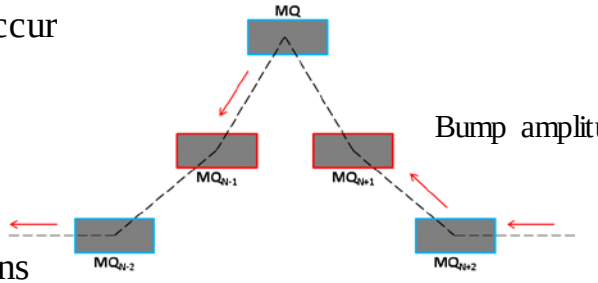
Remarks?

FAST LOSS QUENCH TEST PROCEEDING

1. Injecting 10 bunches with intensity of (4-6)·10^9 protons to the LHC
2. Ramping to nominal energy

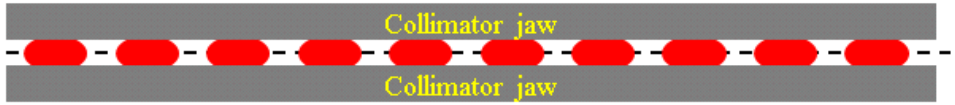


3. Increasing a dynamic three corrector orbit bump until losses occur



Bump amplitude = 21.61 mm

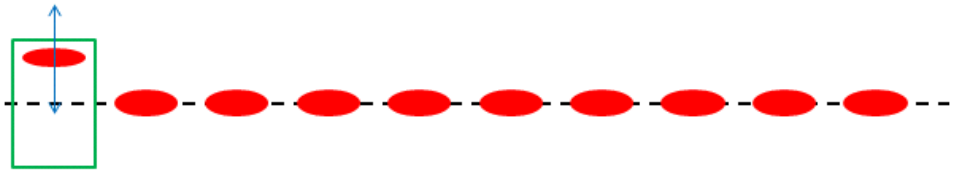
4. Reducing the bump by 2 mm
5. Beam scraping on horizontal collimators to (1.4-2.0)·10^9 protons

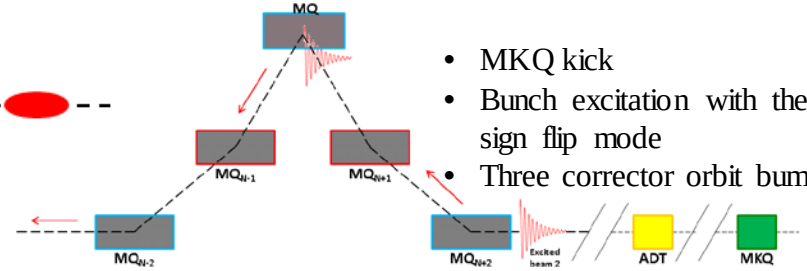


6. Setting the ADT to "ultra low intensity" mode
7. Opening the horizontal and skew collimators
8. Gating the ADT on one bunch only

9. Blowing up the bunch slowly in the vertical plane to reduce its intensity
10. Setting the bump to 21.61 mm
11. Losing the bunch on the MQ

ADT white noise mode





- MKQ kick
- Bunch excitation with the ADT sign flip mode
- Three corrector orbit bump

Diagram not to scale