PRELIMINARY RESULTS OF SIMULATIONS OF THE 3.5 TEV QUENCH TEST

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Threshold Working Group Meeting 1 February 2012

Outline

1. Experiment – Quench Test

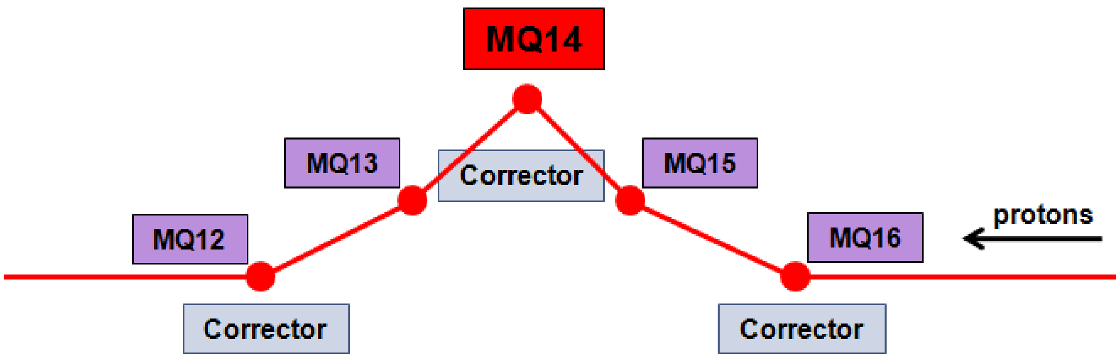
2. Geant4 simulations
    - Geometry
    - Methodology

3. Results
    - Investigations on loss patterns – BLM signal
    - Energy deposition inside the coil and secondary particles in BLMs
    - Geant4 vs experiment
    - Geant4 vs QP3
    - Problems and origin of errors/inconsistency

4. Summary and conclusions

Experiment - Summary

Quench Test on 17 October 2010, 20:23:13



Cell: C14R2

Beam: 2 (circulating)

Energy: 3.5 TeV

Orientation: vertical

Impacting angle: 202 μrad vertically

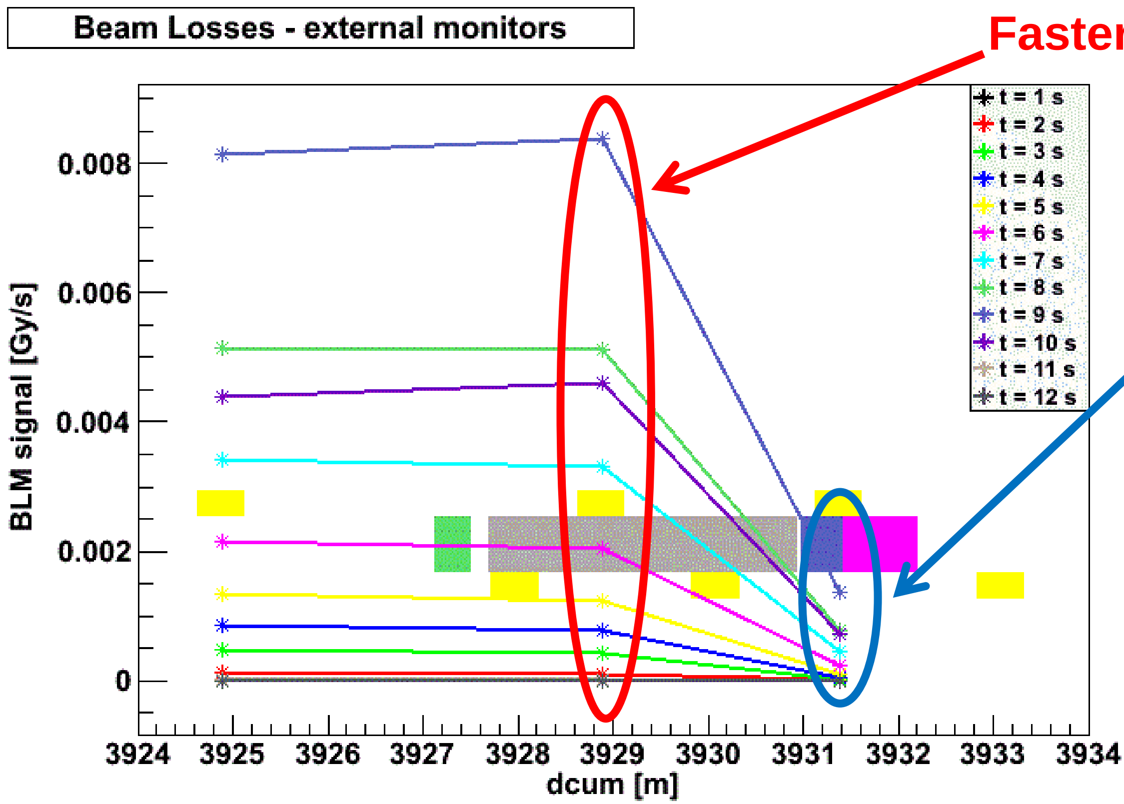
Loss duration: ≈ 5.6 s

Initial intensity: $1.85 \cdot 10^{10}$ protons

Losses: 58% of the initial energy (rest was dumped)

Quenched magnet: MQ

Experiment - Loss evolution in time



Faster growth

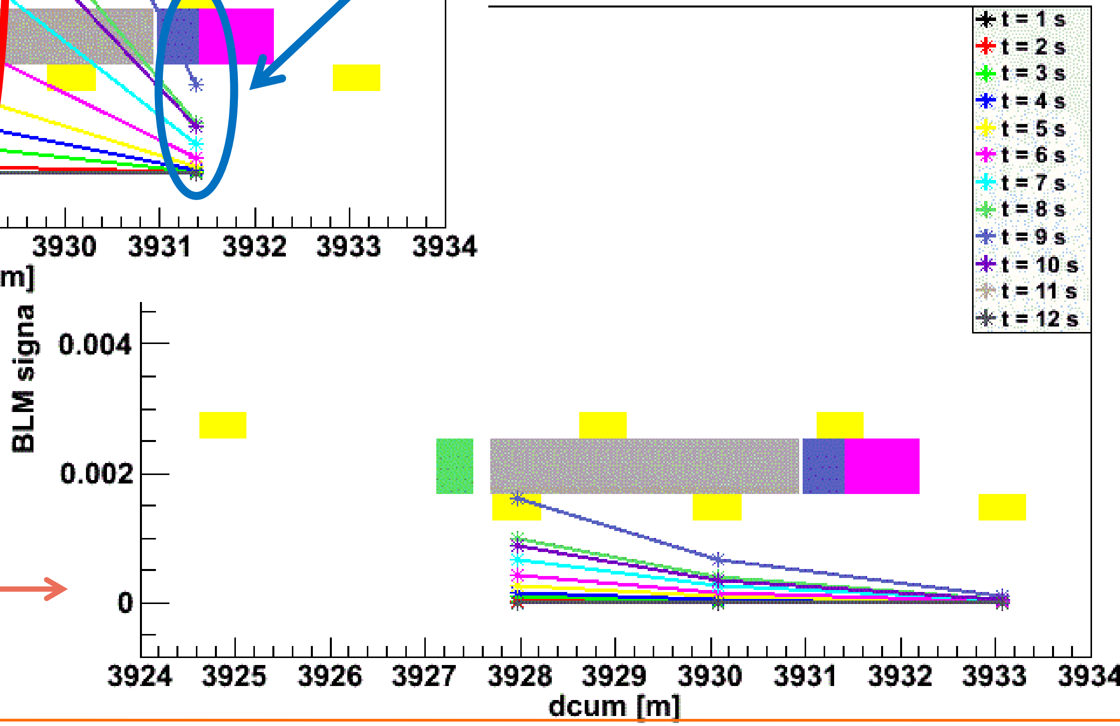
From 3rd s to 9th s signal from B2E20 increases ≈ 5.9 faster than in case of B2E10

Slower growth

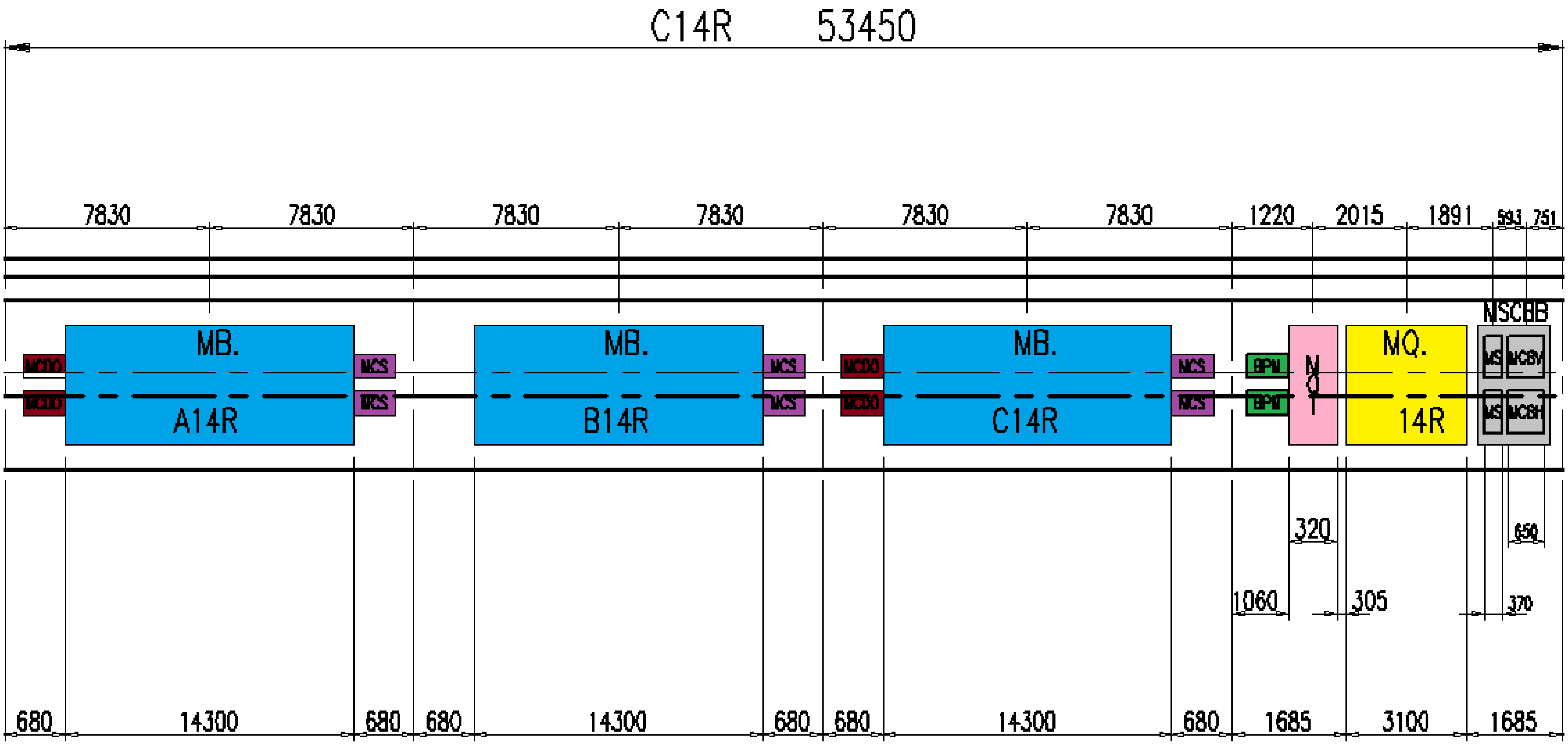
Different loss patterns in time

External monitors for beam 2

Internal monitors for beam 1

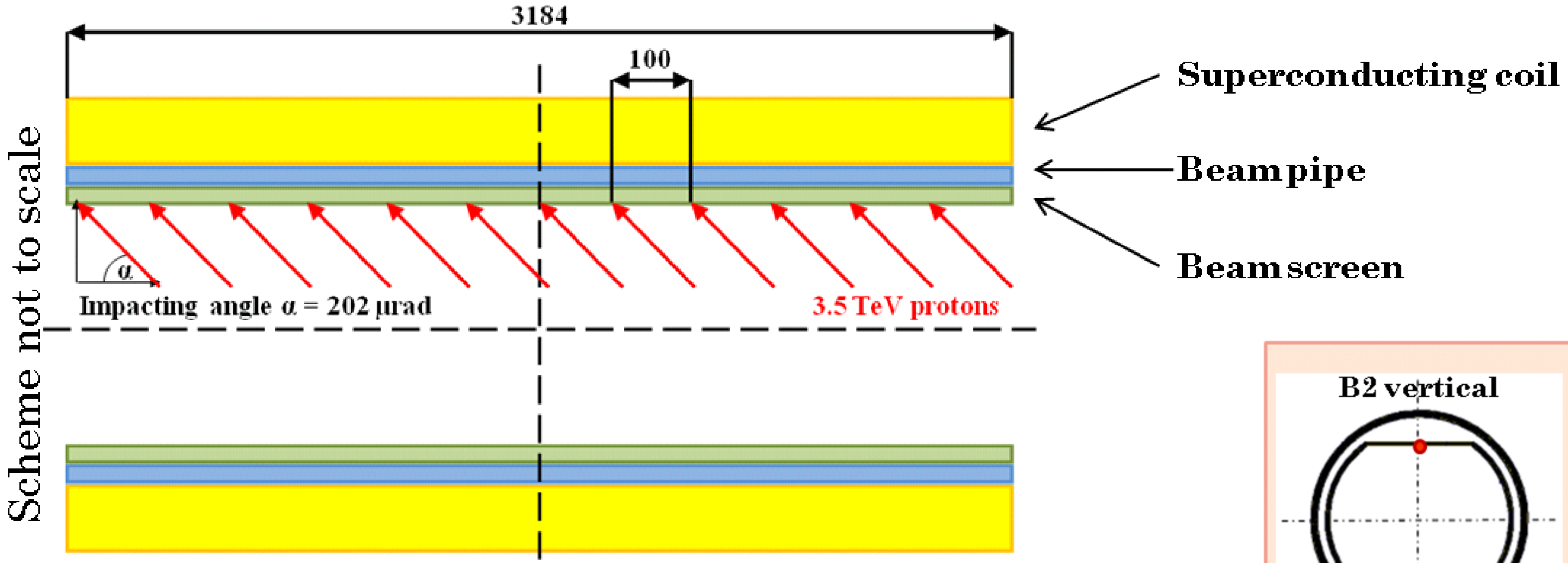


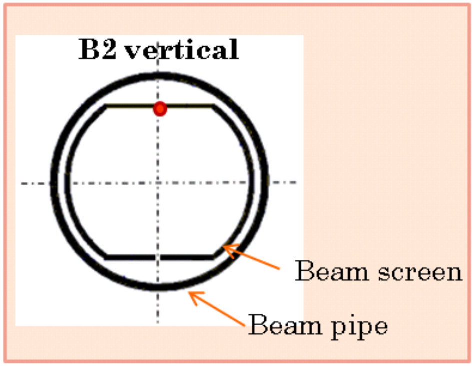
GEANT4 - GEOMETRY

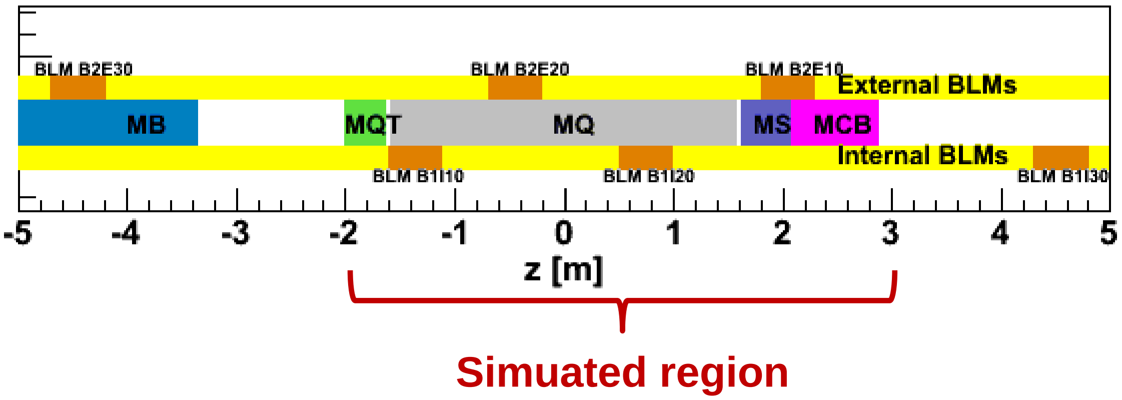


Reconstruction of LHC half-cell where the quench test have been done

GEANT4 - GEOMETRY







Cell: C14R2

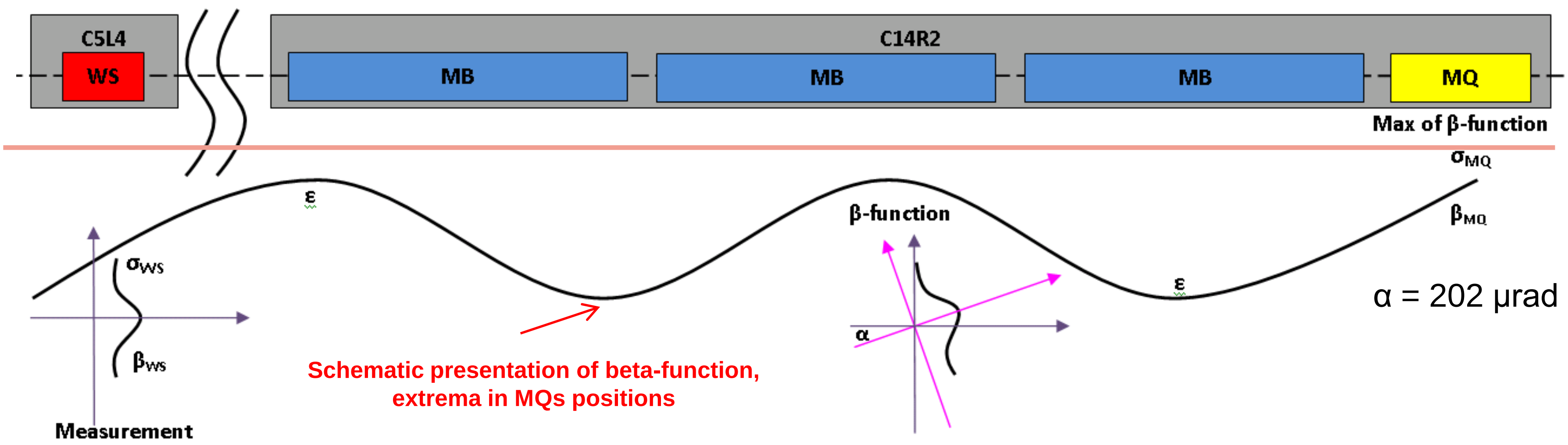
Beam: 2

Plane: vertical

Impacting angle: 202 μrad

51 loss locations, Δz = 100 mm

GEANT4 – LOSS PATTERNS GENERATION



α = 202 μrad

$$\varepsilon = \frac{\sigma_{WS}^{2}}{\beta_{WS}}$$

$$\varepsilon = \frac{\sigma^{2}}{\beta} \Rightarrow \sigma = \sqrt{\beta\varepsilon}$$

	B_x [m]	B_y [m]
MQ.14R2.B1	180.8	32.5
MQ.14R2.B2	29.1	184.0
BWS.5R4.B1	165.5	287.8
BWS.5L4.B2	123.5	404.6
MCBV.14.R2.B2	30.7	175.7
MCBH.14.R2.B1	172.3	34.3

$$\sigma_{beam\,at\,MQ} = \sqrt{\beta_{MQ}\varepsilon}$$

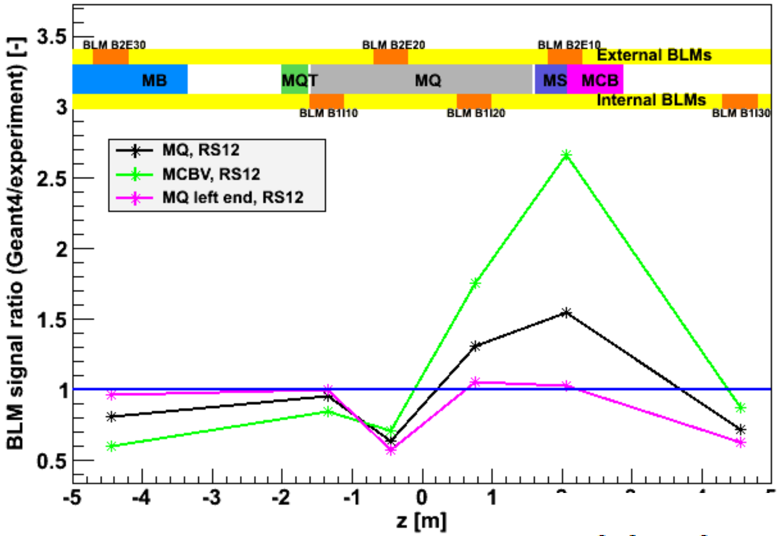
$$\sigma_{loss\,at\,MQ} = \frac{\sigma_{beam\,at\,MQ}}{tg\,\alpha}$$

Plane	ε [μm]	σ_{WS} [μm]	$\sigma_{beam\_at\_MQ}$ [μm]	$\sigma_{loss\_at\_MQ}$ [m]	$\sigma_{beam\_at\_MCBV}$ [μm]	$\sigma_{loss\_at\_MCBV}$ [m]
Vertical	0.0019	875.70	590.54	2.92	577.07	2.86

Assumption: beam size is not changed by bump

Loss Pattern Investigations

Geant4 vs. Quench Test 17 Oct 2010 (3.5 TeV, b2, vert)



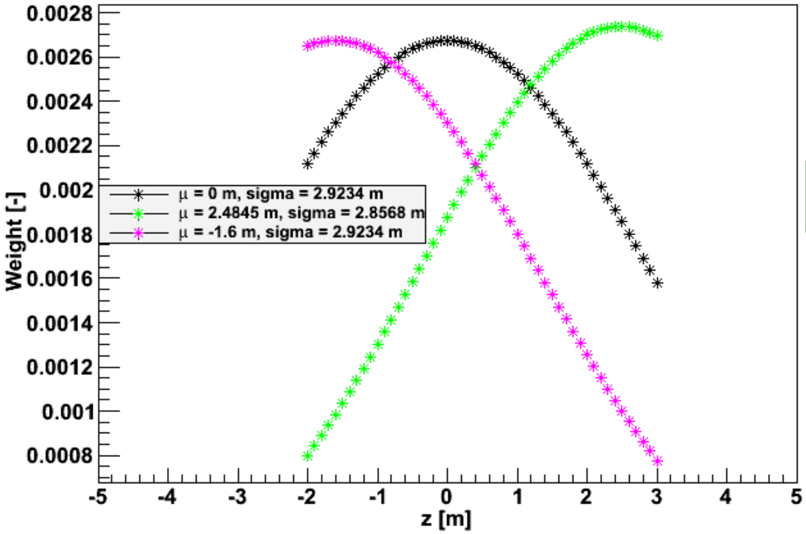
BLM B2E20 is the least sensitive to beam profile changes

Geant4 underestimates the BLM signals?

Experimental BLM signals were integrated over time.

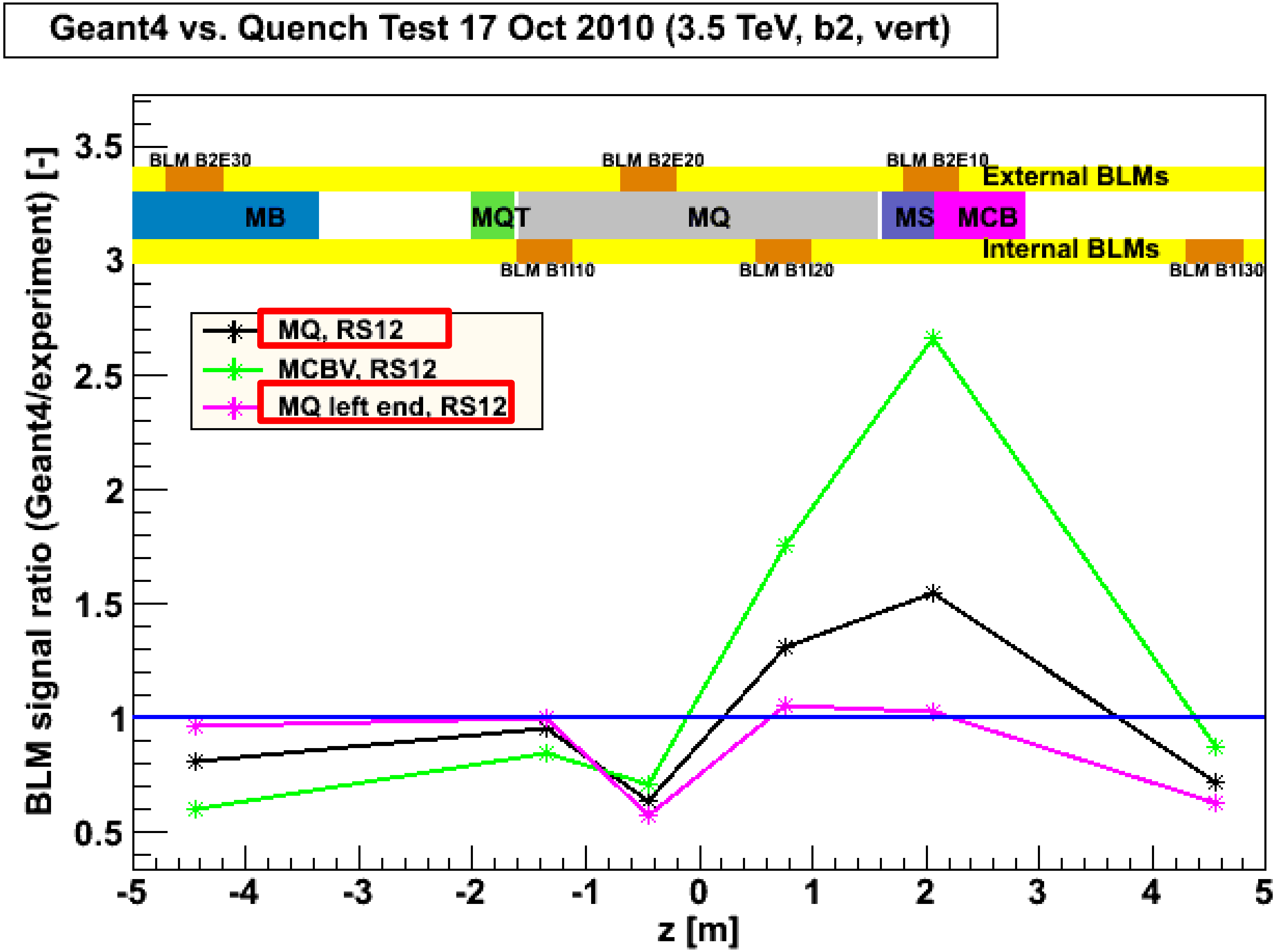
$$Final\_distribution(\mu,\sigma) = \frac{\sum_{i=0}^{50} Gaussian\_weight(\mu,\sigma)\cdot Distribution\_in\_loss\_location_i}{51}$$

Applied Gaussian weights



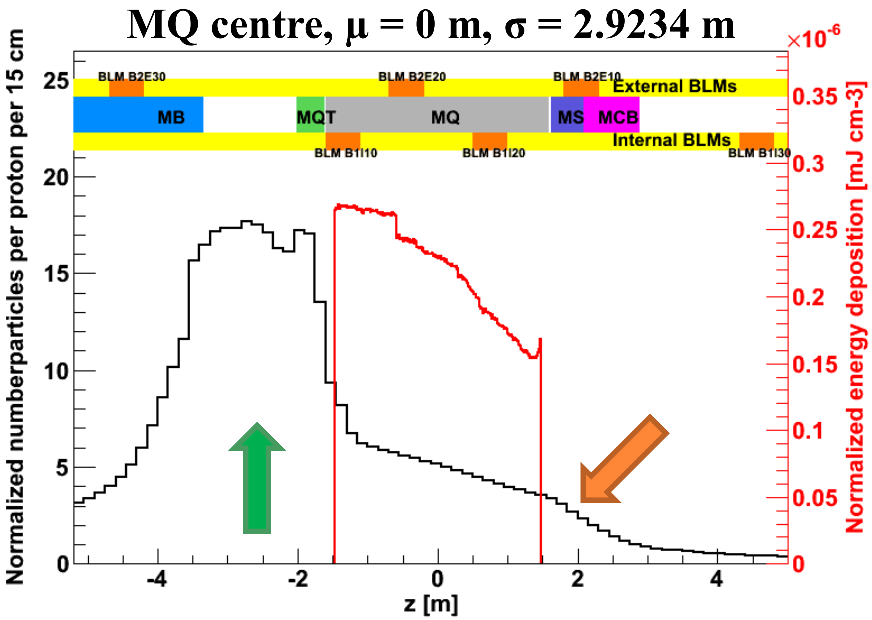
Applied beam shape plays a crucial role

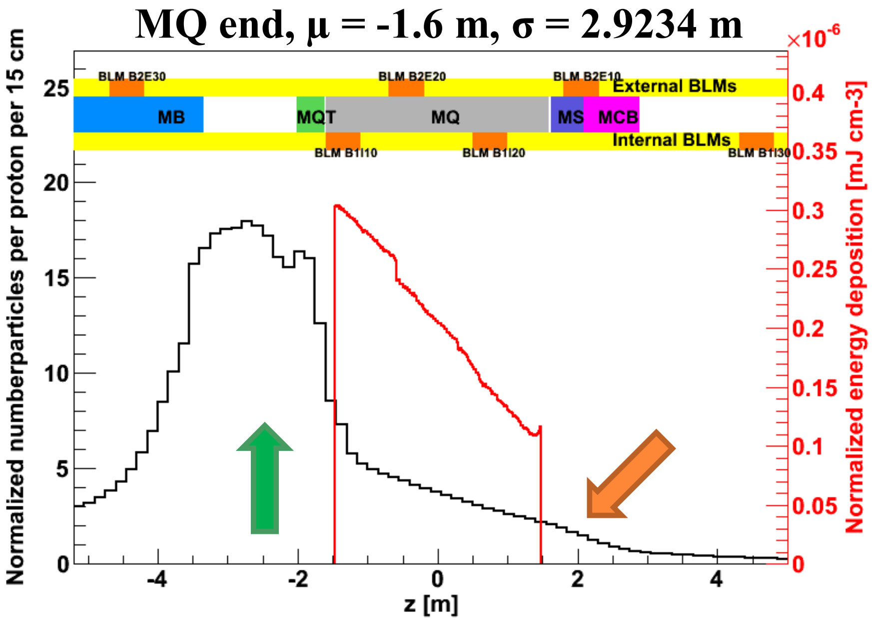
Loss Pattern Investigations

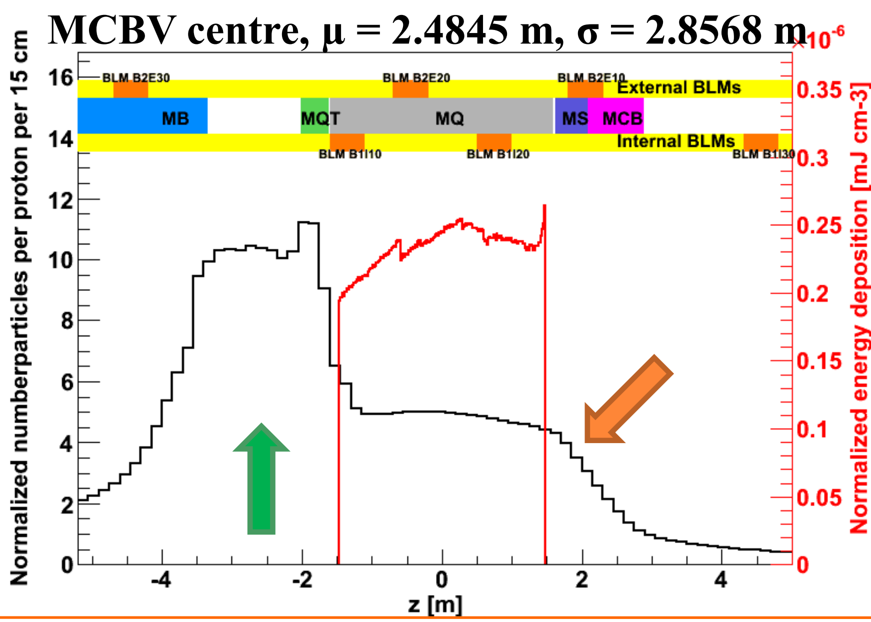


Comparison of integrated signals (RS12=sum over all signal [Gy/s]*84 [s])

E_{DEP} INSIDE A COIL & SECONDARIES IN BLMS

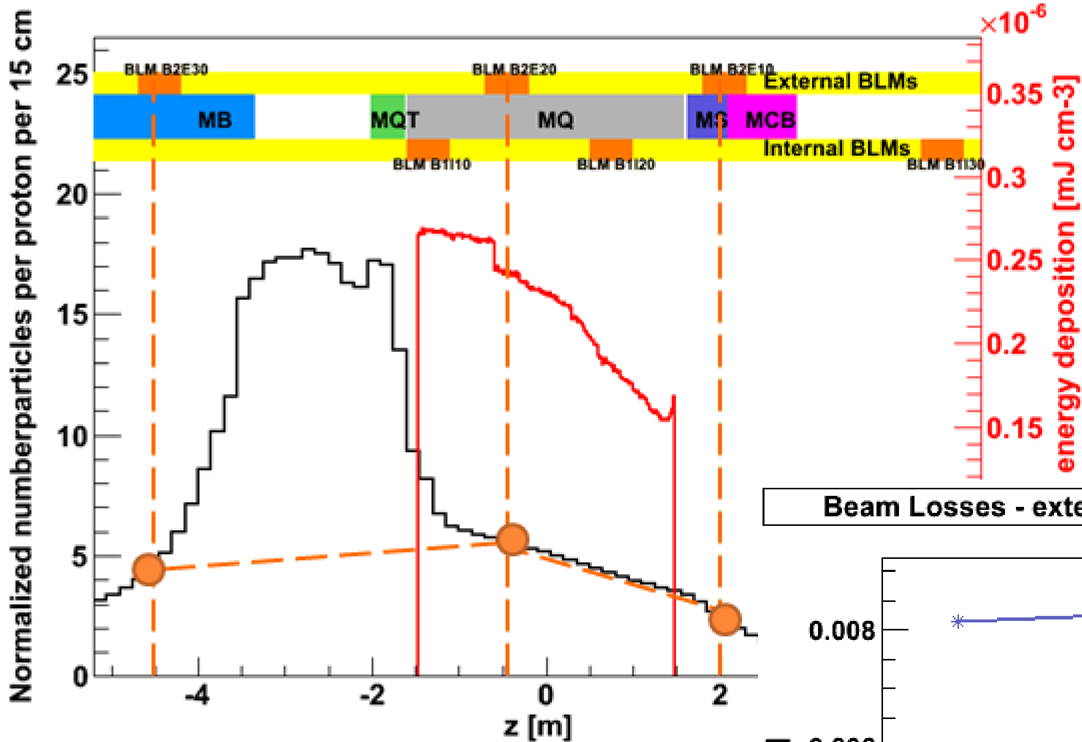






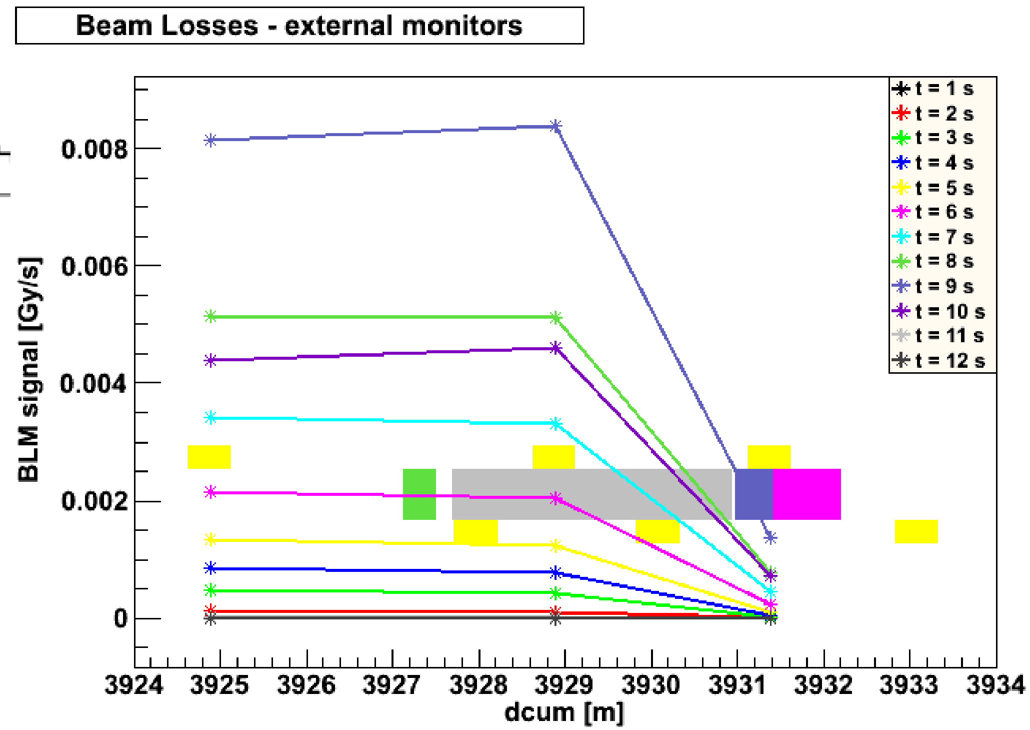
Maximum of secondary particles appears between 1.5 and 3.5 m from the centre of MQ

External monitors (for beam 2)



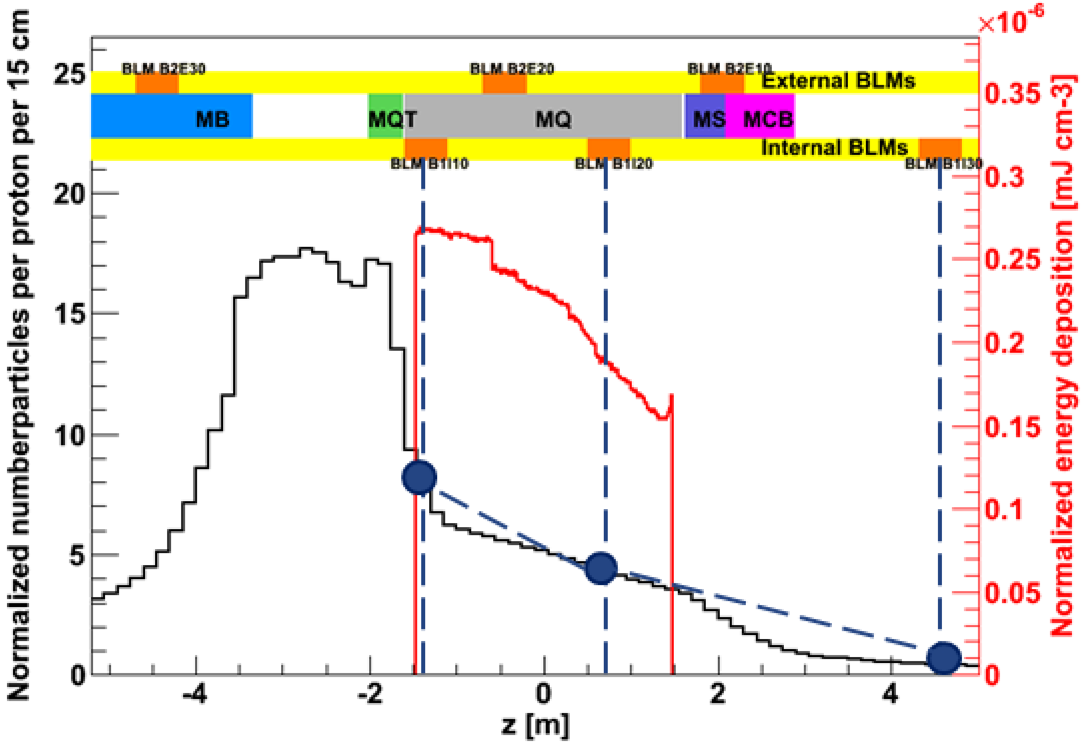
Geant4 simulations

Experimental data

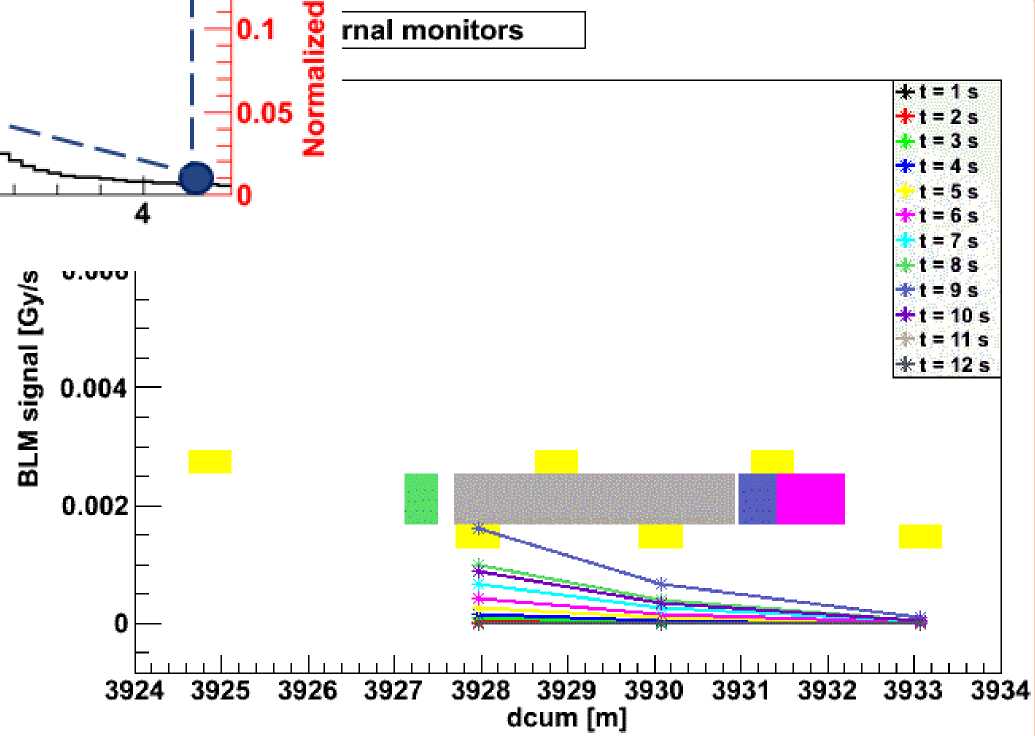


New BLMs will be installed.

INTERNAL MONITORS (FOR BEAM 1)



Geant4 simulations



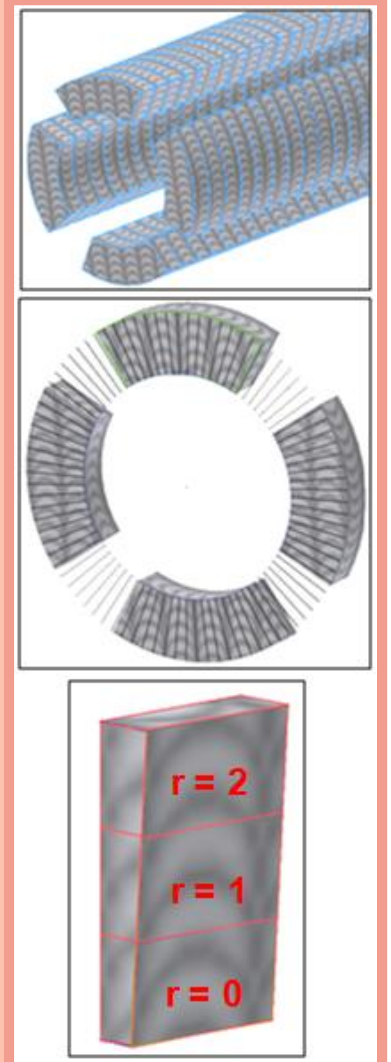
Experimental data

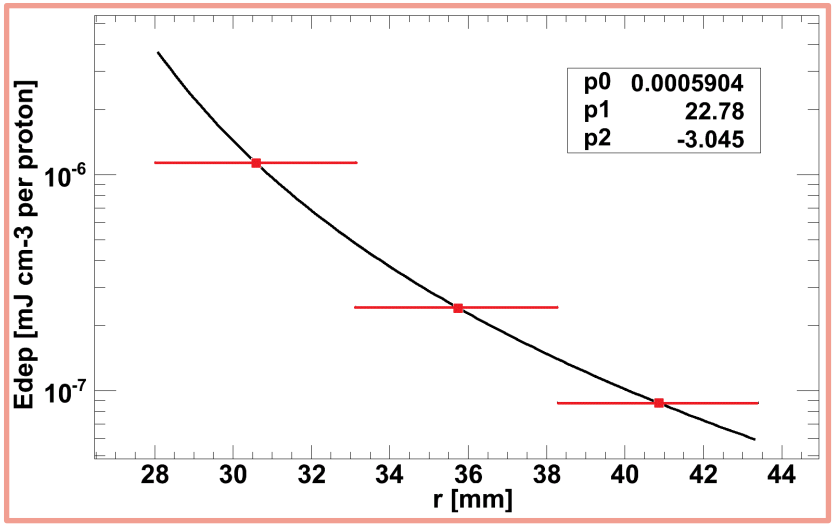
BLM SIGNALS

Chi-squared distribution $$\chi^2 = \sum_{BLM=1}^{6} \frac{\left(S_{sim_i} - S_{exp_i}\right)^2}{S_{exp_i}}$$

Loss pattern	BLM signal [Gy]						χ^2
	B2E30	B1I10	B2E20	B1I20	B2E10	B1I30	
Experiment (RS12)	2,76E-02	5,50E-03	2,71E-02	2,22E-03	3,89E-03	4,39E-04	-
MQ centre	2,25E-02	5,26E-03	1,74E-02	2,91E-03	6,02E-03	3,16E-04	5,86
MCBV centre	1,65E-02	4,66E-03	1,93E-02	3,88E-03	1,04E-02	3,84E-04	18,85
MQ centre 1/2 Gaussian	1,08E-02	4,35E-03	2,64E-02	4,47E-03	9,99E-03	4,14E-04	22,36
MCBV centre 1/2 Gaussian	9,79E-03	3,88E-03	2,40E-02	4,94E-03	1,37E-02	4,52E-04	40,48
MQ left end	2,67E-02	5,51E-03	1,55E-02	2,34E-03	4,01E-03	2,77E-04	5,07

Energy inside the coil – Geant4

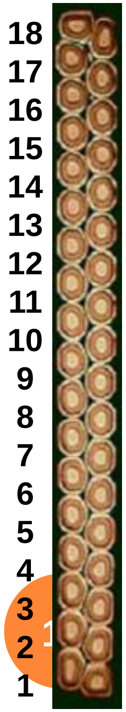




Power law function:

$$E_{deposition} = p_0(r - p_1)^{p2}$$

Superconducting cable with strands



- The coil is divided to 3 layers in r
- The radial distribution is fitted to power law function
- Based on the fit parameters, an averaged energy deposition is recalculated for 18 strands (E_{dep} is calculated in the centre of each strand)

$$E_{avg} = \frac{\sum_{i=1}^{18} E_{deposition}}{18}$$

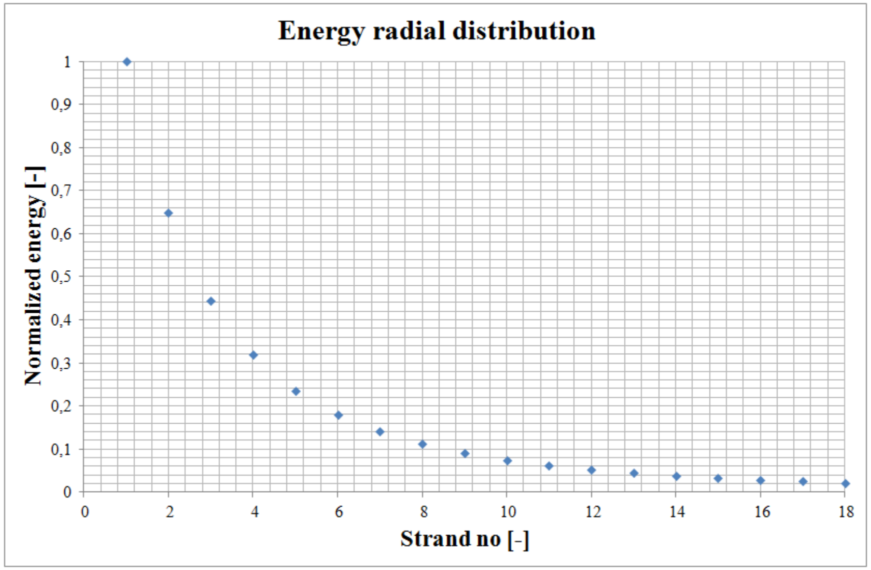
Energy inside the coil – QP3

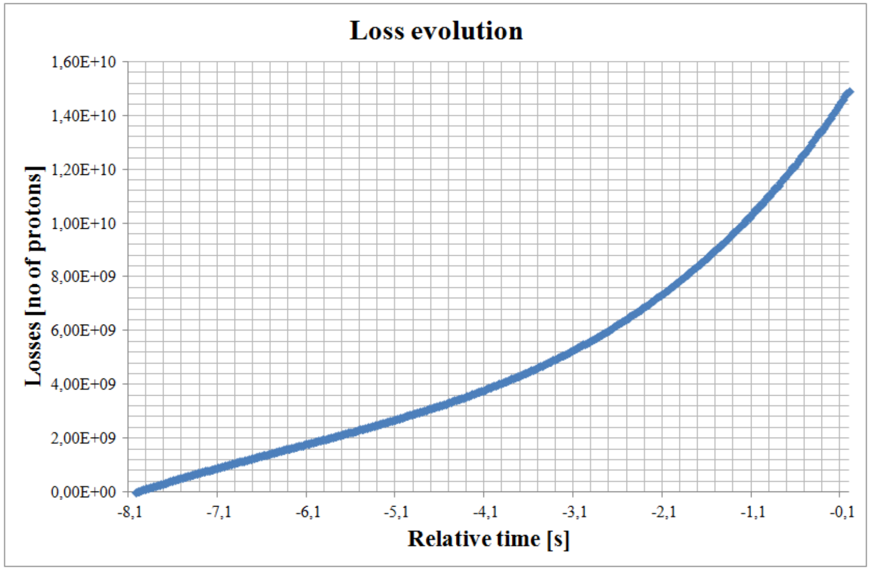
INPUT:

- Radial distribution (from Geant4, normalized to 1)
- Evolution of losses in time (from Quench Test)

OUTPUT:

- E_{peak}
- E_{avg}



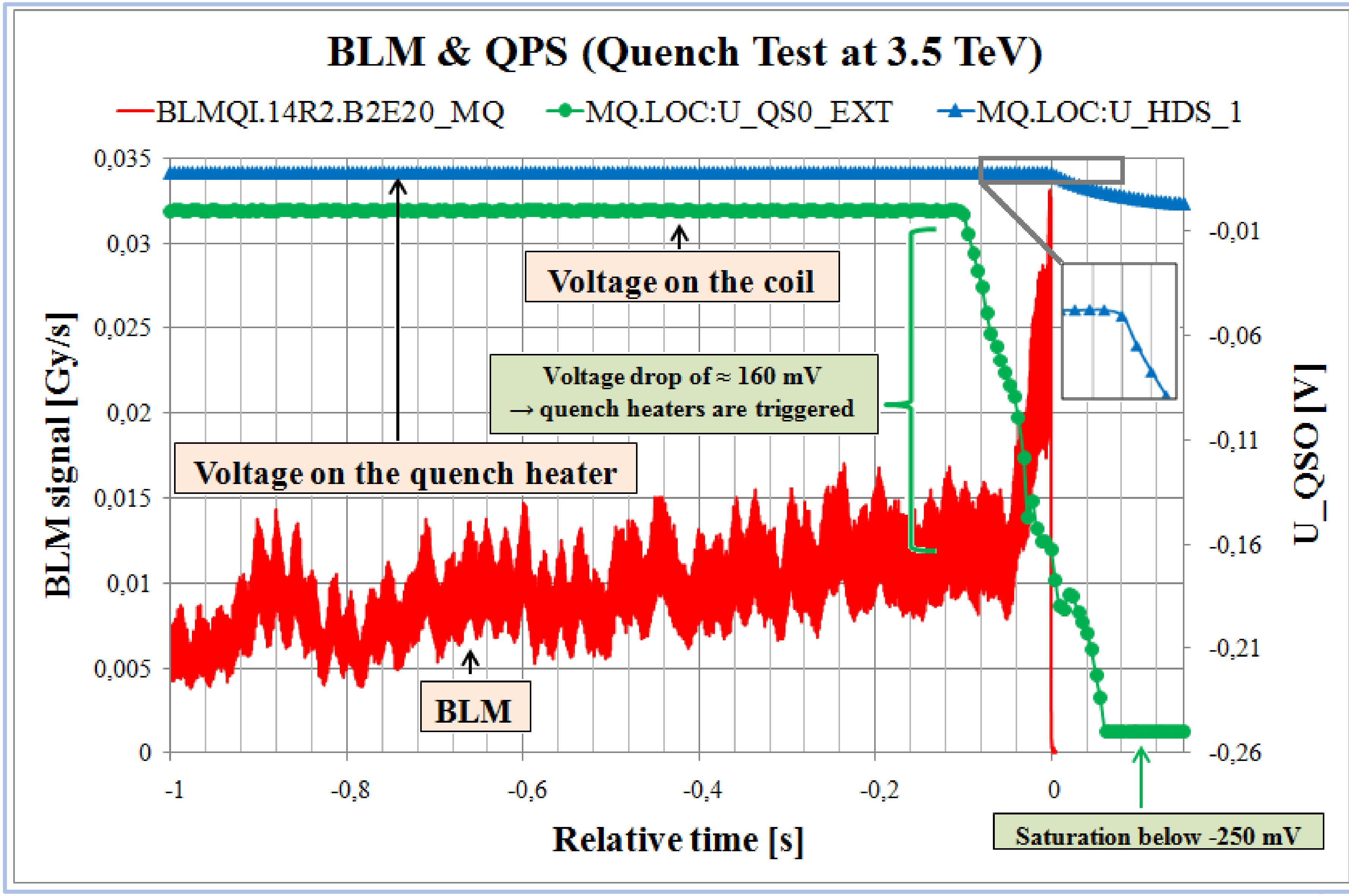


Energy inside the coil – Geant4 vs QP3

	Geant 4 [mJ/cm^3]	QP3 [mJ/cm^3]	Geant4/QP3 [-]
MQ centre	1369.55	549.80	2.49
MQ end	1526.24	550.93	2.77
MQ centre ½ Gaussian	2002.11	547.78	3.65
MQ end 90% of losses (=>48%)	1248.74	543.62	2.30
MQ end 80% of losses (=>38%)	971.24	537.07	1.81
MQ end 70% of losses (=>28%)	693.75	523.97	1.32
MCBV	1333.64	548.48	2.43
MCBV ½ Gaussian	1825.92	548.52	3.33

Last 0.1s corresponds to 3.3% of losses

Energy inside the coil – Geant4 vs QP3



QP3 calculates average energy at 0.1 s before a quench.

Problems and origin of errors/inconsistency

Problem:		Proposed solution:
❖ Fitting E_{dep} in radial distribution	→	❖ Increase of coil bins in r-direction
❖ Unknown loss pattern	→	❖ Investigations of deduced patterns
❖ Impact of missing dipole on the right of MQ (in Geant4)	→	❖ Improved simulated geometry
❖ Low statistics of experimental data	→	❖ Requested Quench Test during MD
❖ Underestimated signal of B2E30 (Geant4)	→	❖ Simulations of losses on the left of MQ cryostat

Summary & Conclusions

- ✓ Preliminary analysis of 3.5 TeV Quench Test in vertical directions was done.
- ✓ Prepared method allows efficiently obtain results for proposed loss patterns.
- ✓ Discrepancy between QP3 program and Geant4 simulations estimations of E_{dep} inside the superconducting coils of a factor $\approx$ 2.5.

- Improved Geant4 geometry is foreseen (MB right of MQ, greater binning in *r*-direction)
- Investigations of loss patterns must be done (GPS, SixTrack)
- Simulations of loss locations situated on the left side of MQ cryostat

- ❑ Simulations for Quench Test at injection energy (0.45 TeV, beam1, horizontal direction) are ongoing.

Thank you for your attention !!!!

Questions?

Comments?

Hints?

Back Up slides

Comparison

Quench Test: 17 Oct 2010
Beam: 2
Energy: 3.5 TeV
Orientation: Vertical
Loss Location z=0 (centre of MQ)

1

Old Physics (without low energy neutrons)

	B2E30	B1I10	B2E20	B1I20	B2E10	B1I30
Geant4/Exp	0.6143	1.3827	1.0338	0.4173	0.1115	0.7105

2

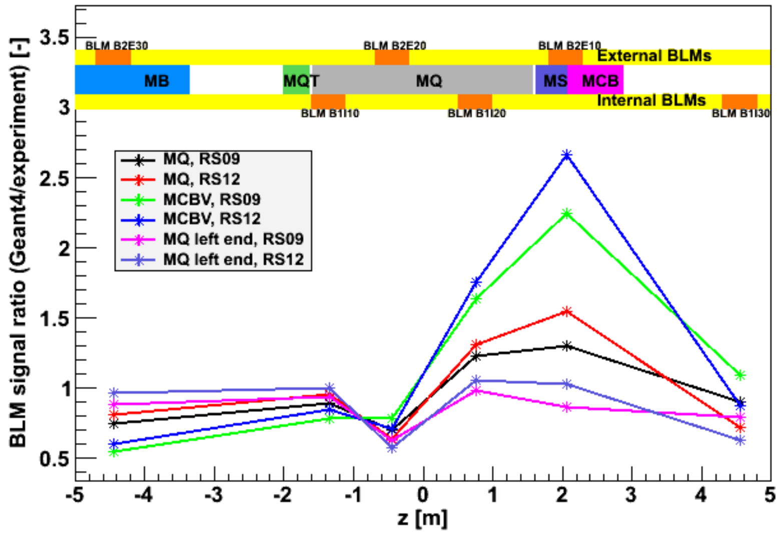
New Physics (with low energy neutrons)

	B2E30	B1I10	B2E20	B1I20	B2E10	B1I30
Geant4/Exp	0.6413	1.3454	1.0385	0.4120	0.1039	0.6920

	B2E30	B1I10	B2E20	B1I20	B2E10	B1I30
1- 1 / 2	4.2 %	-2.8 %	0.5 %	1.3 %	-0.73	-2.7 %

Loss Pattern Investigations

Geant4 vs. Quench Test 17 Oct 2010 (3.5 TeV, b2, vert)



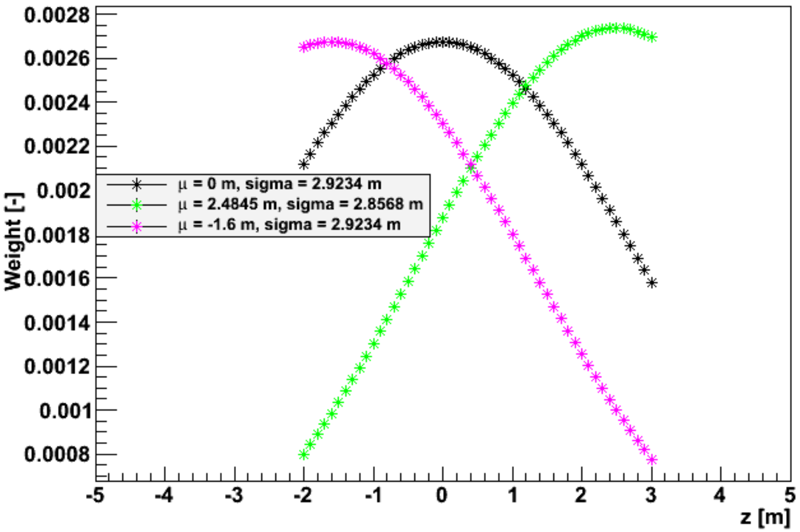
BLM B2E20 is the least sensitive to beam profile changes

Geant4 underestimates the BLM signals?

Experimental BLM signals were integrated over time.

$$Final\_distribution(\mu,\sigma) = \frac{\sum_{i=0}^{50} Gaussian\_weight(\mu,\sigma) \cdot Distribution\_in\_loss\_location_i}{51}$$

Applied Gaussian weights



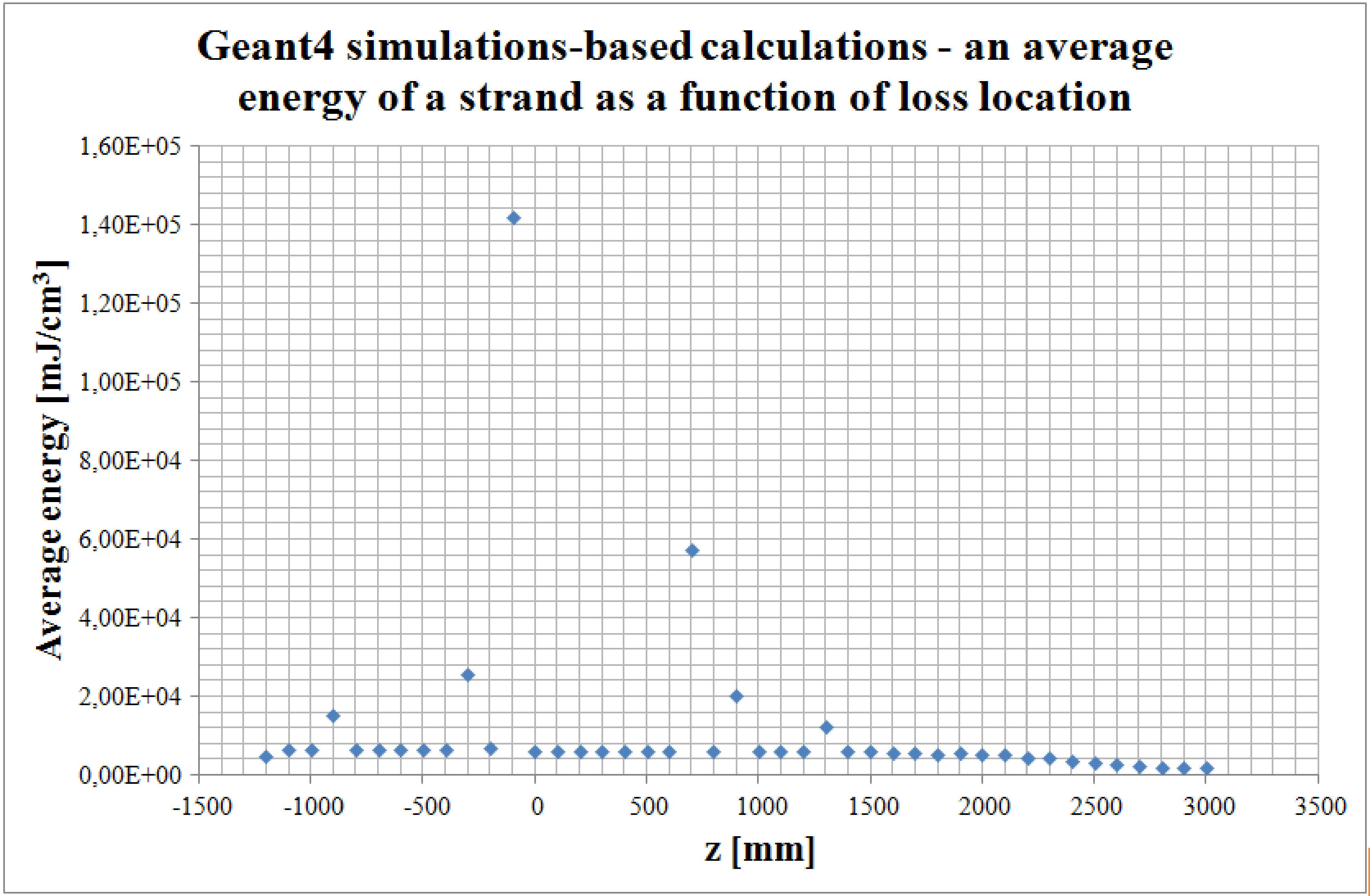
Applied beam shape plays a crucial role

Chi-squared distribution

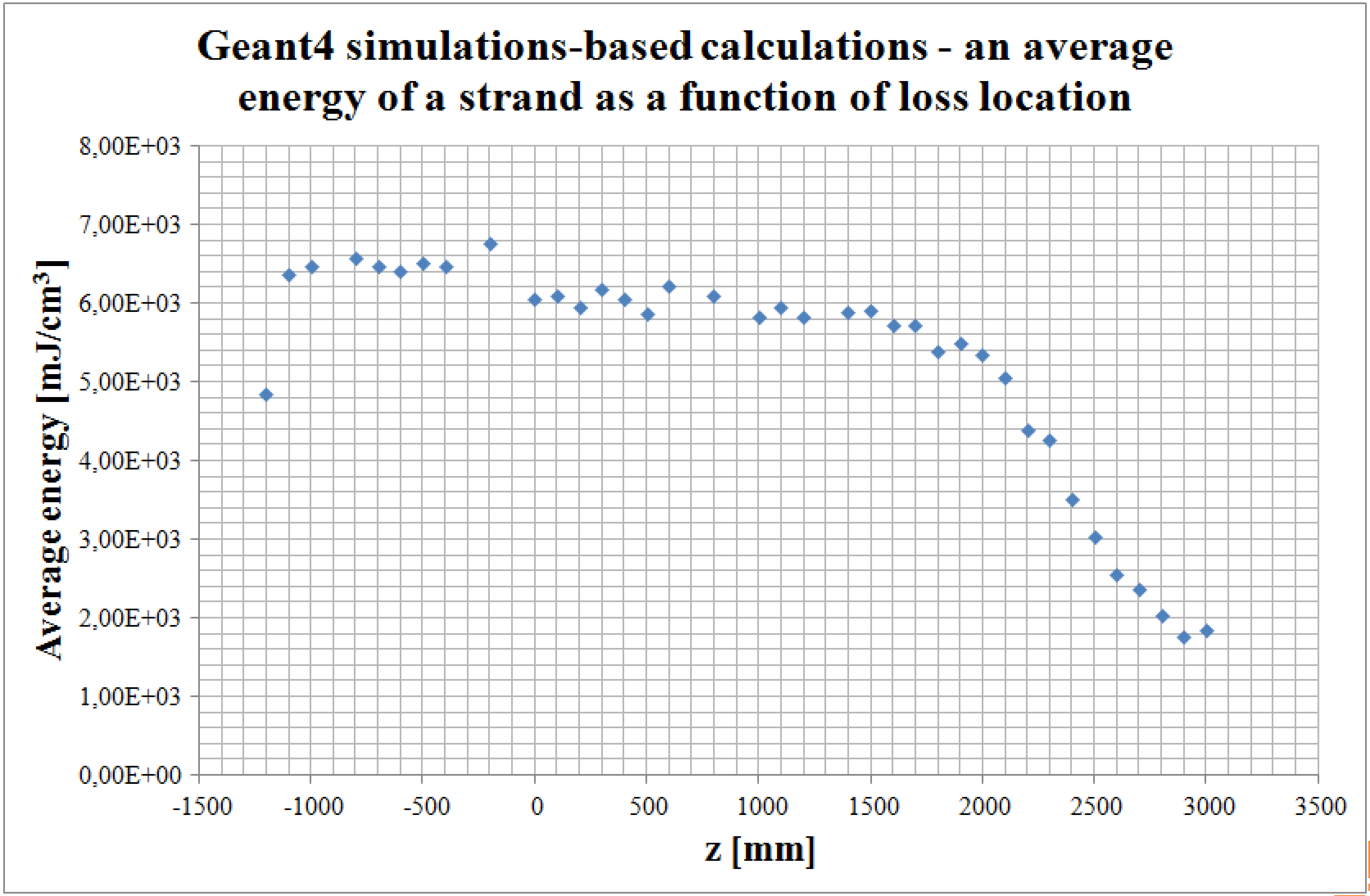
$$\chi^2 = \sum_{BLM=1}^{6} \frac{\left(S_{sim_i} - S_{exp}\right)^2}{S_{exp}}$$

Loss pattern	BLM signal [Gy]						χ^2
	B2E30	B1I10	B2E20	B1I20	B2E10	B1I30	
Experiment (RS12)	0,02763117	0,00550247	0,02714754	0,002218087	0,003888595	0,000438572	-
MQ centre	0,022489	0,005262	0,017445	0,002912	0,006023	0,000316	5,86
MCBV centre	0,016546	0,004656	0,019324	0,003883	0,010358	0,000384	18,85
MQ centre 1/2 Gaussian	0,010810	0,004345	0,026409	0,004473	0,009987	0,000414	22,36
MCBV centre 1/2 Gaussian	0,009794	0,003883	0,023970	0,004945	0,013702	0,000452	40,48
MQ left end	0,026667	0,005515	0,015535	0,002338	0,004010	0,000277	5,07

E_{DEP} AS A FUNCTION OF LOSS LOCATION (GEANT4)

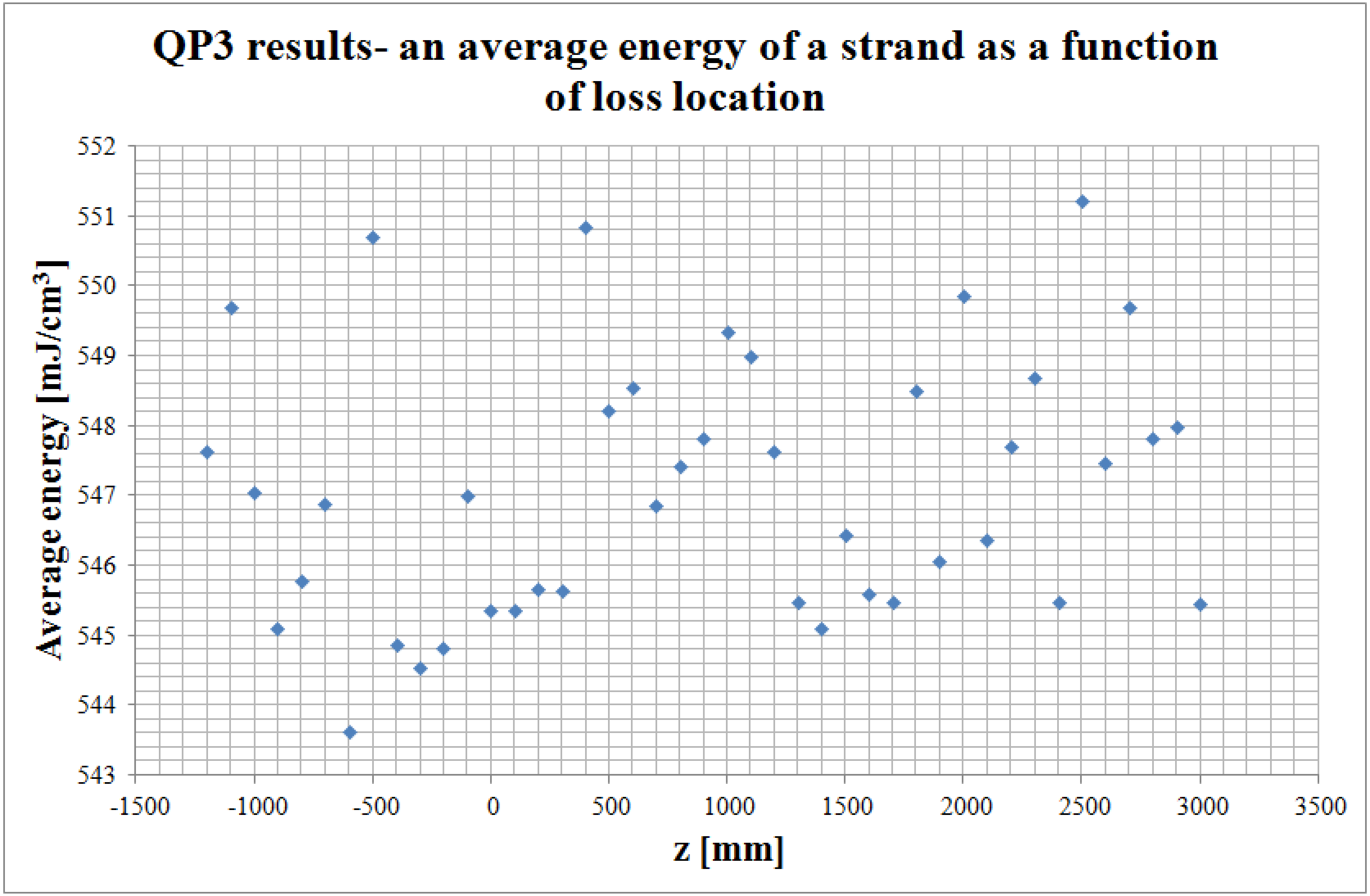


E_{DEP} AS A FUNCTION OF LOSS LOCATION (GEANT4)



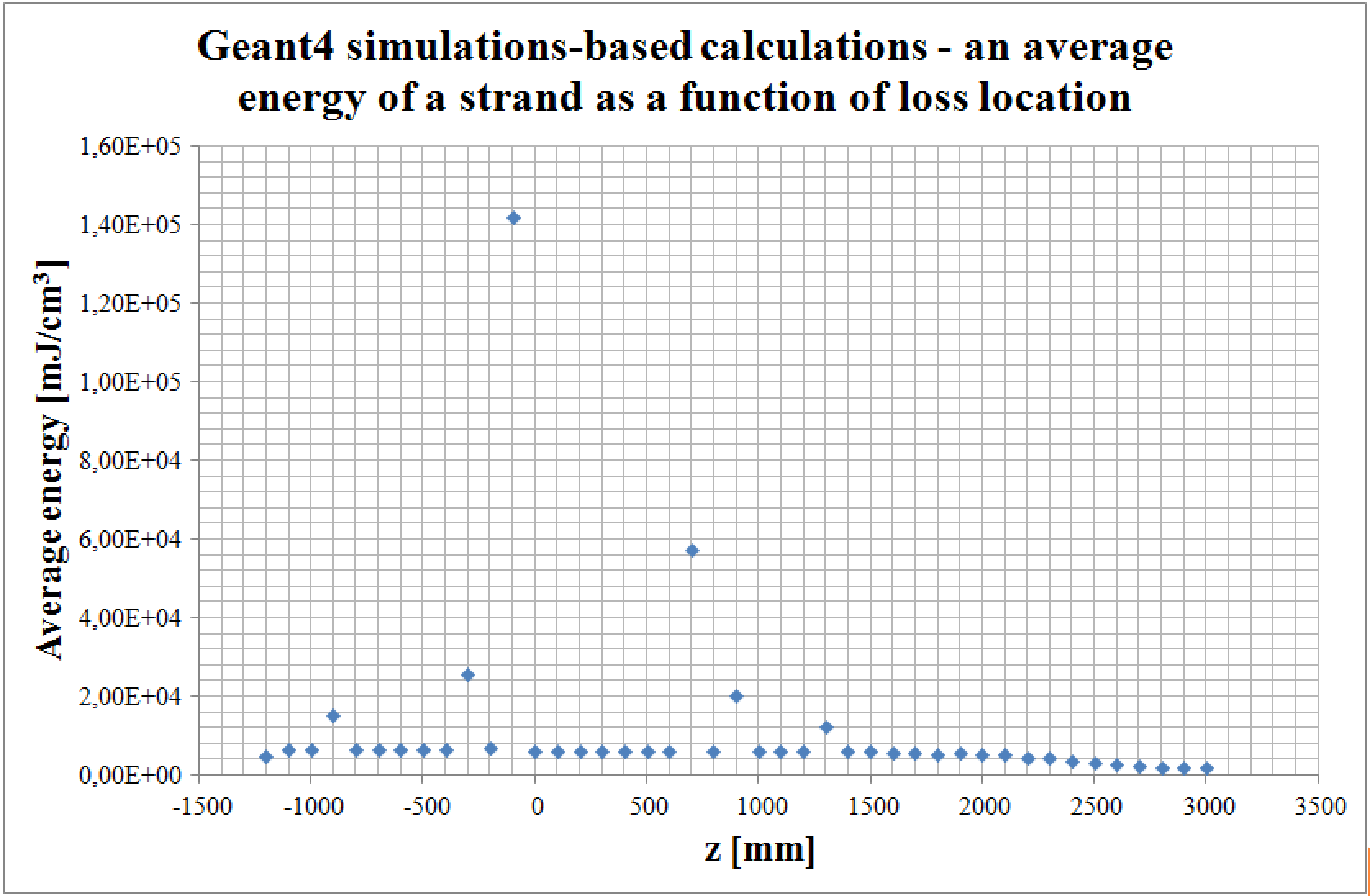
Geant4 results strongly depend on a loss location.

E_{DEP} AS A FUNCTION OF LOSS LOCATION (QP3)

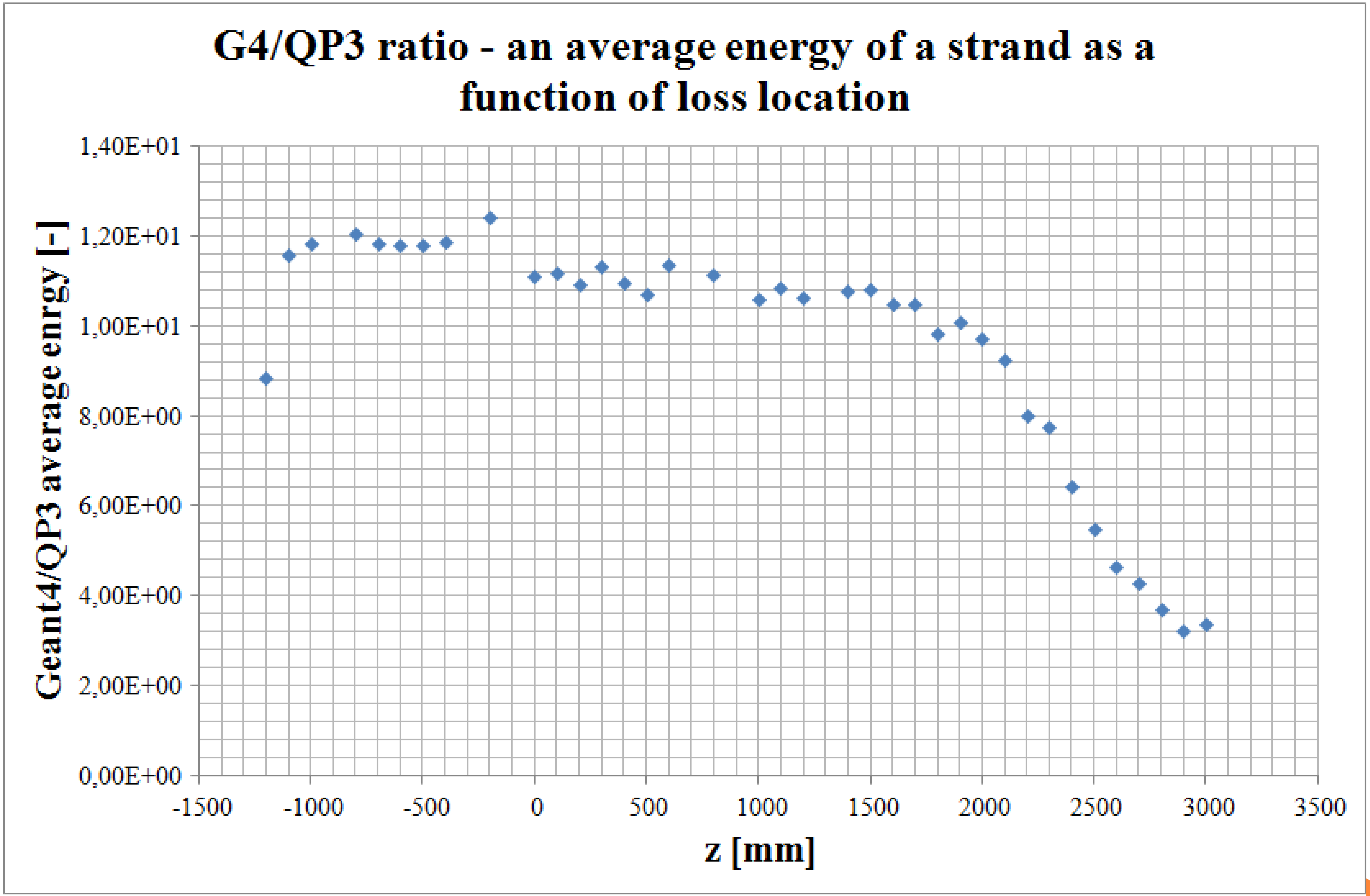


QP3 program is insignificantly sensitive to a loss location.

E_{DEP} AS A FUNCTION OF LOSS LOCATION (RATIO)



E_{DEP} AS A FUNCTION OF LOSS LOCATION (RATIO)



Ratios are determined by the results of Geant4 simulations

(small changes in QP3 results)

Energy inside the coil – Geant4 vs QP3

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MQ centre	1369.55	549.80	2.49
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ENERGY INSIDE THE COIL – GEANT4 VS QP3