Steady State Loss Quench Test

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Quench limits based on GEANT4 simulations

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BE-BI-BL

Experiment: K. Dahlerup-Petersen, B. Dehning,, A.Priebe, M. Sapinski, J. Steckert, A. Verweij

Geant4 simulations: A. Priebe, M. Sapinski

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1. Reminder of the Steady State Loss Quench Test 2010
2. Methodology of performed GEANT4 simulations
3. Energy deposition in the coils
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EXPERIMENT

Methodology of inducing beam losses

- Dynamic three corrector orbit bump

Location: 14R2

Particles: protons

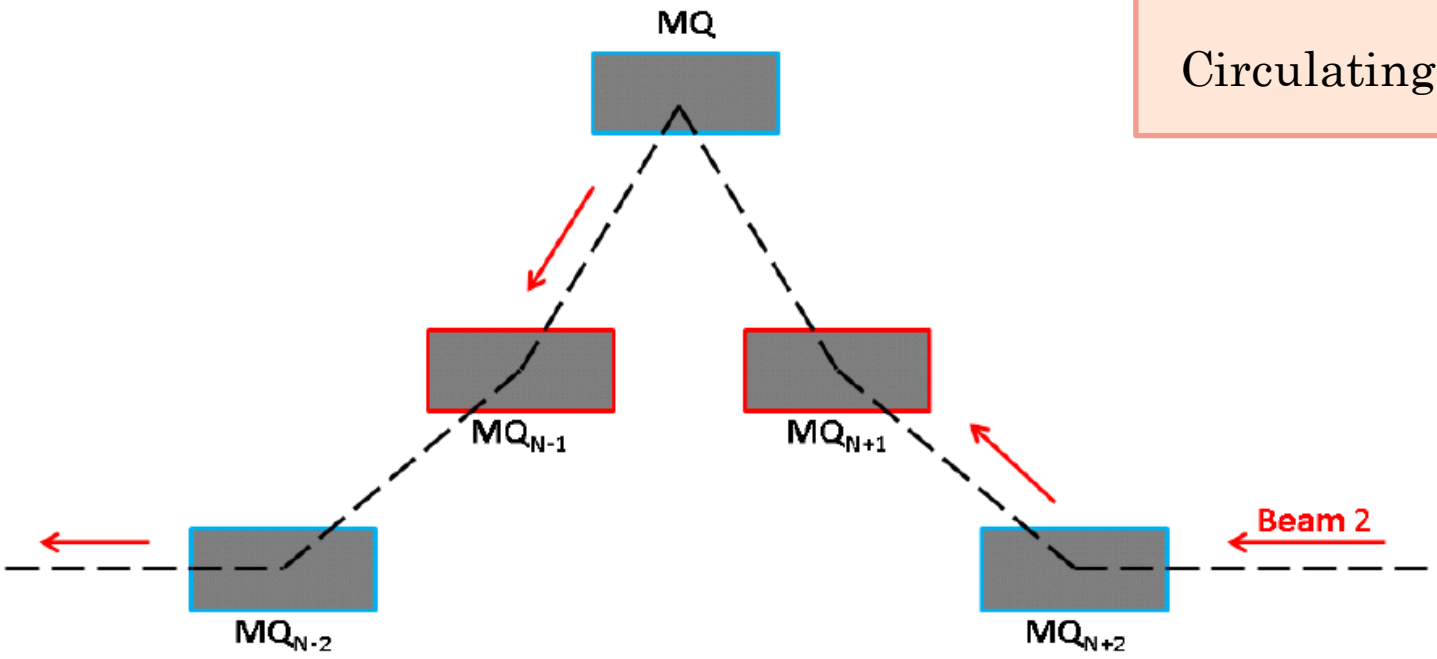
Energy: 3.5 TeV

Beam: 2

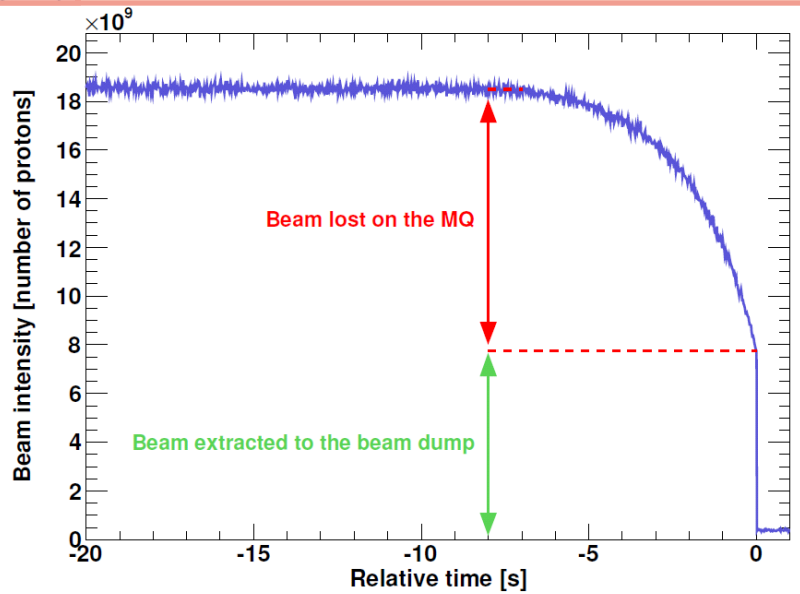
Plane: vertical

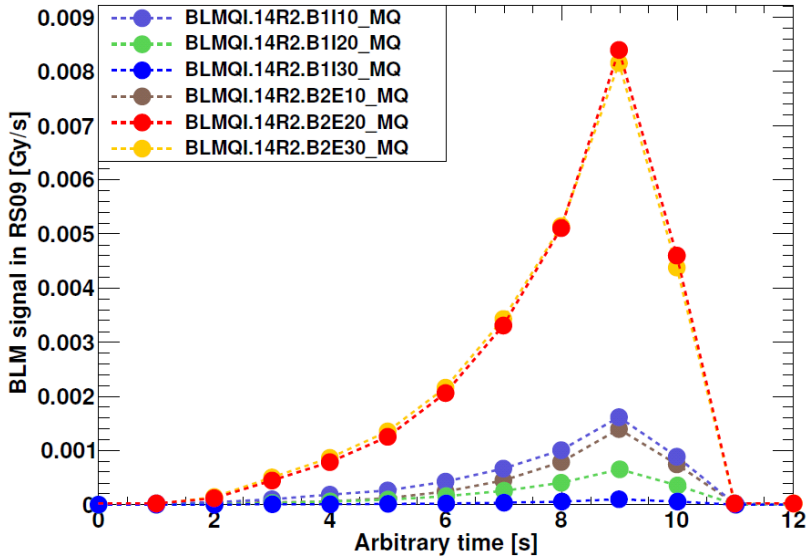
Timescale: s

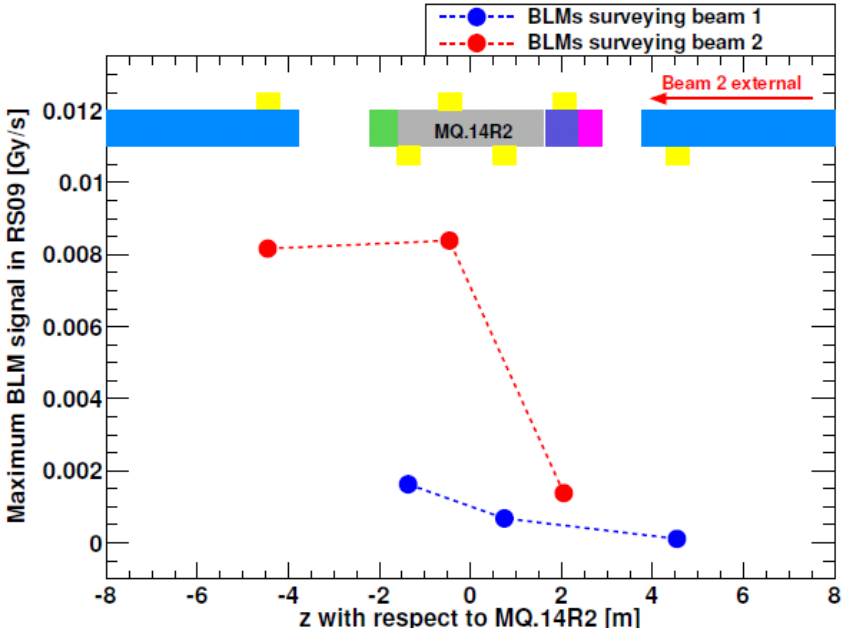
Circulating beam



EXPERIMENT

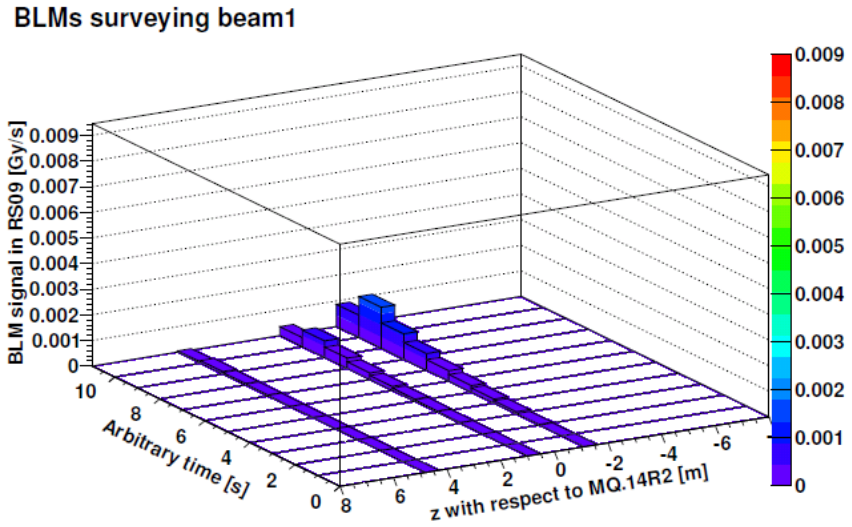


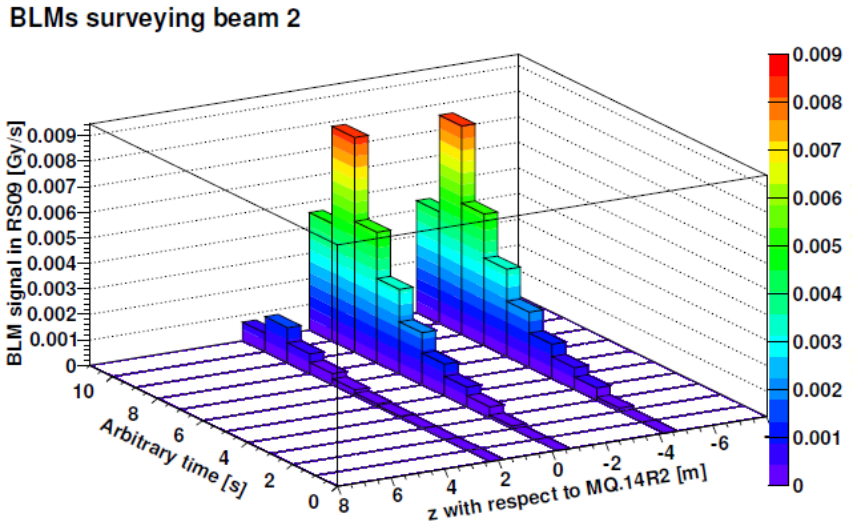


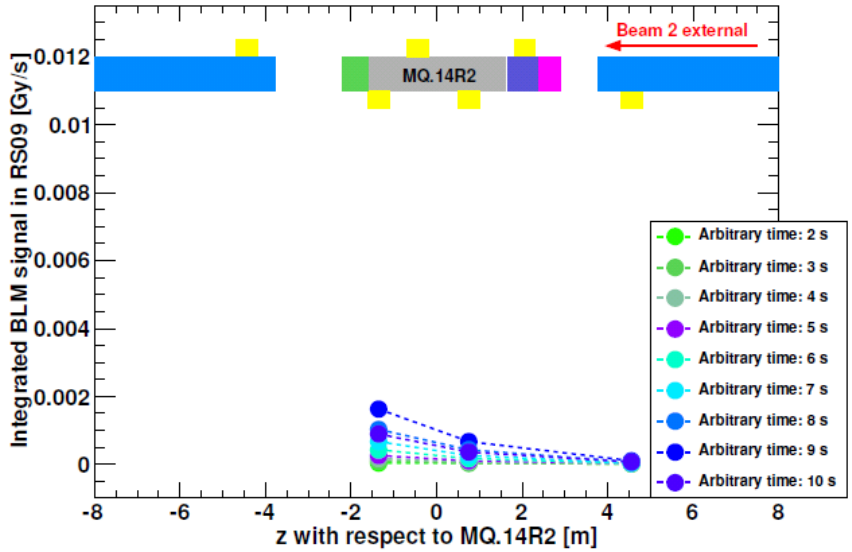


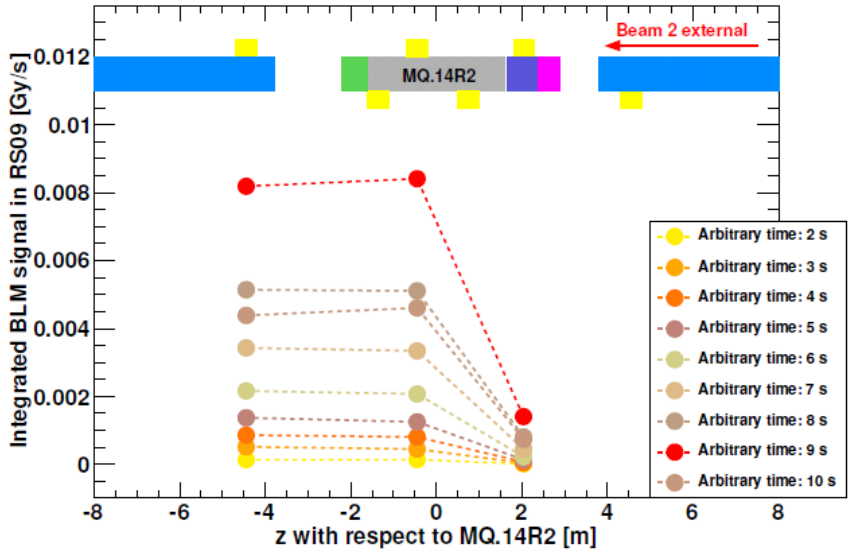
- Three pilot bunches with intensities of (5-6) $\cdot 10^9$ + (total 1.85 $\cdot 10^{10}$ p+)
- Loss rate increasing in time
- Loss duration: around 6 s

EXPERIMENT



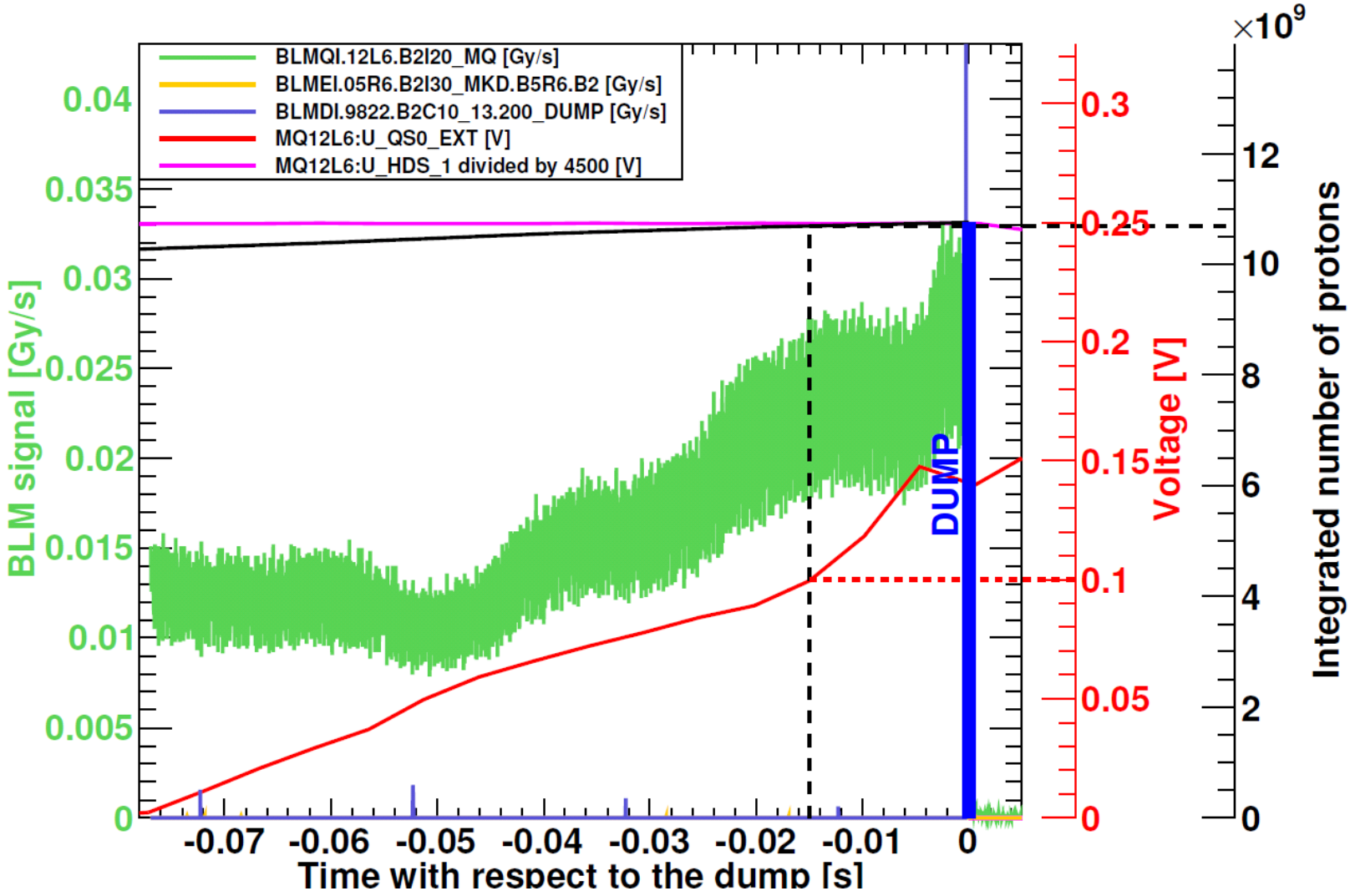






Two BLM monitors record almost the same signal during the total loss duration.

EXPERIMENT


BLMQI.12L6.B2I20_MQ [Gy/s]
BLMEI.05R6.B2I30_MKD.B5R6.B2 [Gy/s]
BLMDI.9822.B2C10_13.200_DUMP [Gy/s]
MQ12L6:U_QS0_EXT [V]
MQ12L6:U_HDS_1 divided by 4500 [V]
BLM signal [Gy/s]
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
DUMP
0.3
0.25
0.2
0.15
0.1
0.05
0
Voltage [V]
×10^9
12
10
8
6
4
2
0
Integrated number of protons
-0.07
-0.06
-0.05
-0.04
-0.03
-0.02
-0.01
0
Time with respect to the dump [s]

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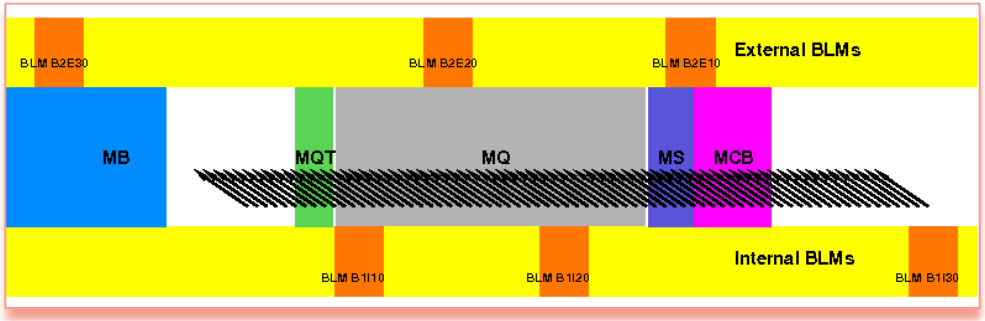
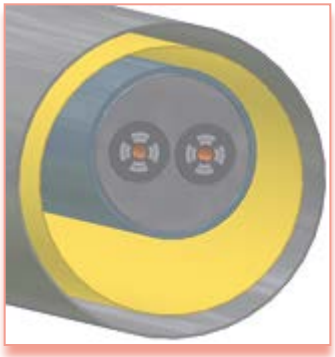
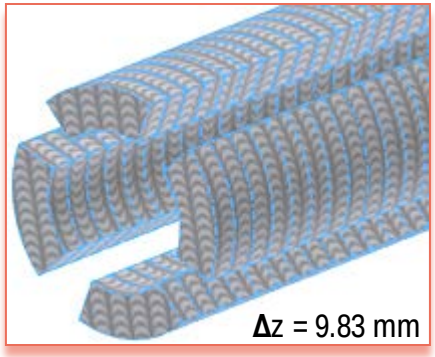
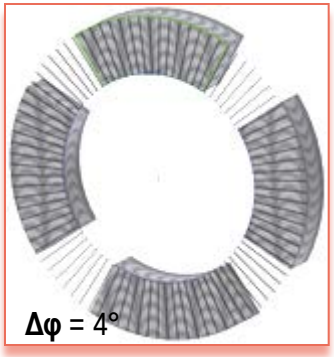
GEANT4 SIMULATIONS

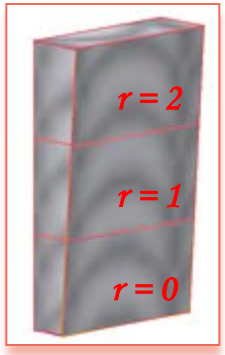


- Detailed magnet representation
- Magnetic field from ROXIE
- Long pseudo-monitors
- Impacting angle: 202 µrad
- 71 point like losses along magnets→ flexibility
- Aim: Correlation E_{dep} = f(BLM)









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

LOSS PATTERN

Assessing loss patterns:

1) MAD-X simulations (Vera Chetvertkova)

2) Imposing expected loss pattern and verifying agreement with experimental data (min of similarity estimator)

Simulation-experiment similarity estimator:

$$\Sigma^{norm}_{\mu,\sigma_r,\sigma_l} = \sum_{i=1}^{6} \left(\frac{BLM_i^{sim} - BLM_i^{exp}}{BLM_i^{sim}} \right)^2$$

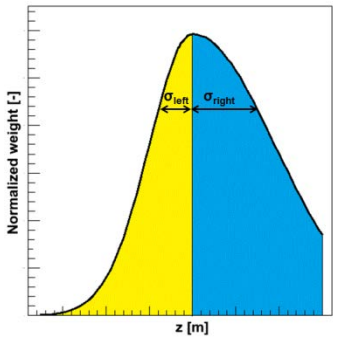
BLM_i^{sim} - simulated signal of i-th BLM

BLM_i^{exp} - measured signal of i-th BLM

3.5 TeV Steady State Quench Test 2010

- B2V
- No of lost protons: $1.1 \cdot 10^{10}$
- Loss duration: 5.6 s
- Cell: 14R2

Optimized parameters:



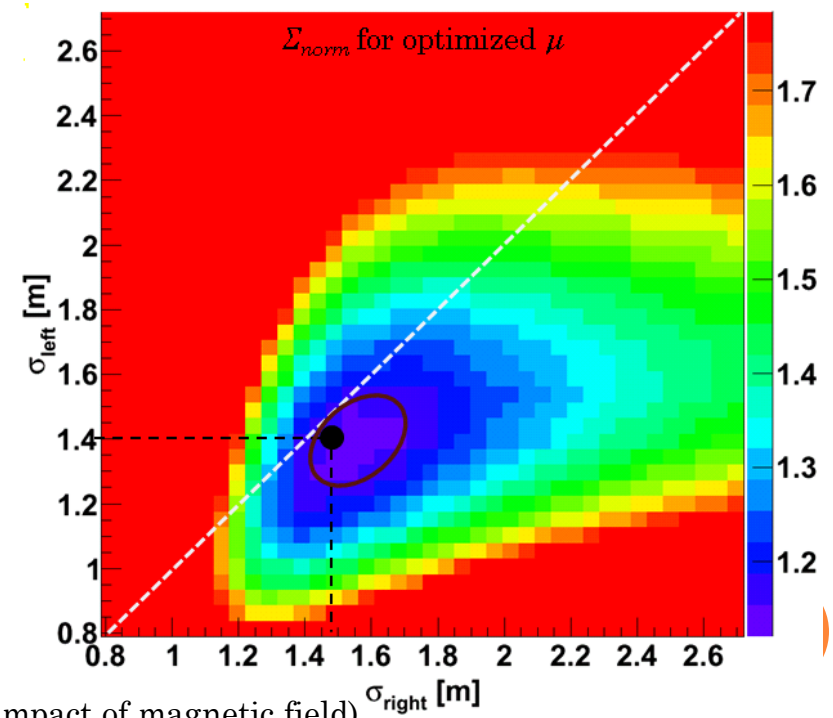
Asymmetrical Gaussian

- $\Sigma_{norm} = 1.12$

→ $\mu = (0.4 \pm 0.1)$ m

→ $\sigma_{right} = (1.54 \pm 0.15)$ m

→ $\sigma_{left} = (1.40 \pm 0.14)$ m



➢ $\sigma_{right} > \sigma_{left}$ (reasonable due to the impact of magnetic field)

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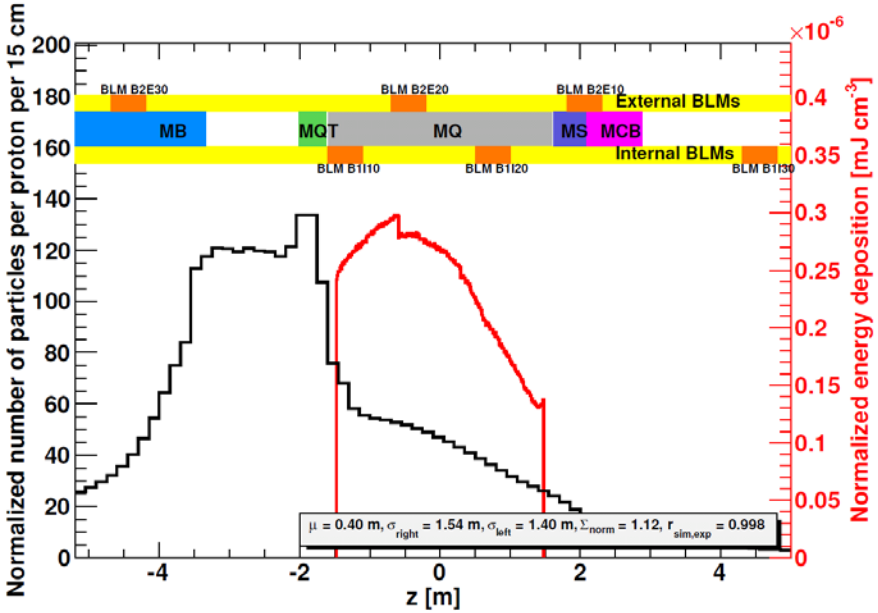
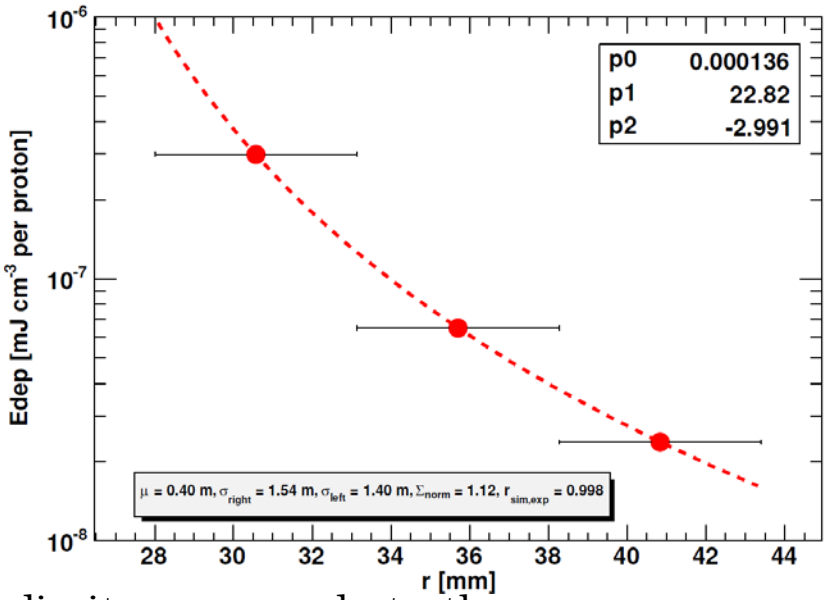
ENERGY DEPOSITED INSIDE THE COIL





In the case of steady state regime, the quench limit corresponds to the average energy deposited along the cable.

In order to compare Geant4 and QP3 results, average over 18 strands was considered.

Quench limit: Geant4: $1.56 \cdot 10^{-7}$ mJ/cm^3 per proton

Quench limit for steady state regime was estimated to be

for $1.1 \cdot 10^{10}$ lost protons

- Geant4: 1.7 J/cm^3
- QP3: 0.5 J/cm^3 (0.4 J/cm^3 ←B. Auchmann)

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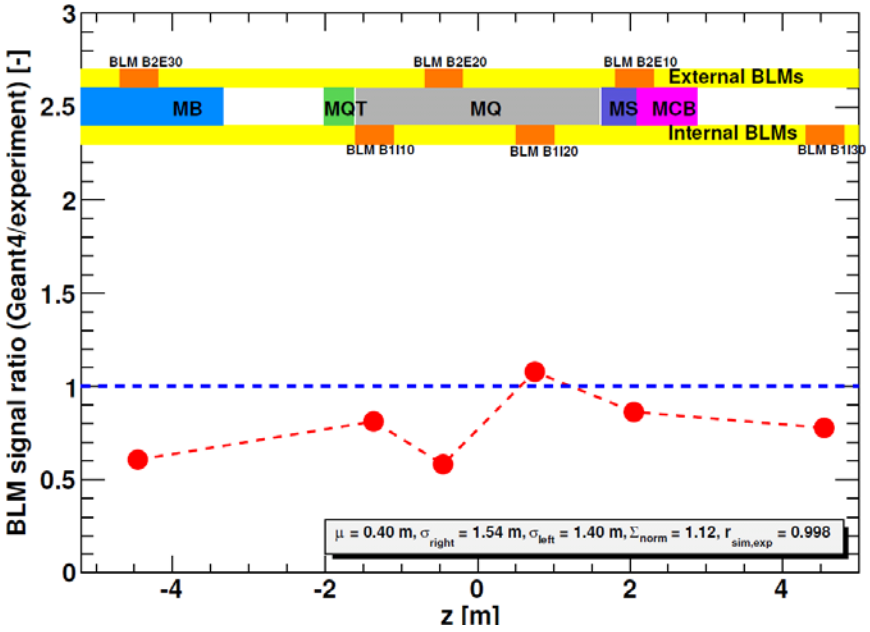
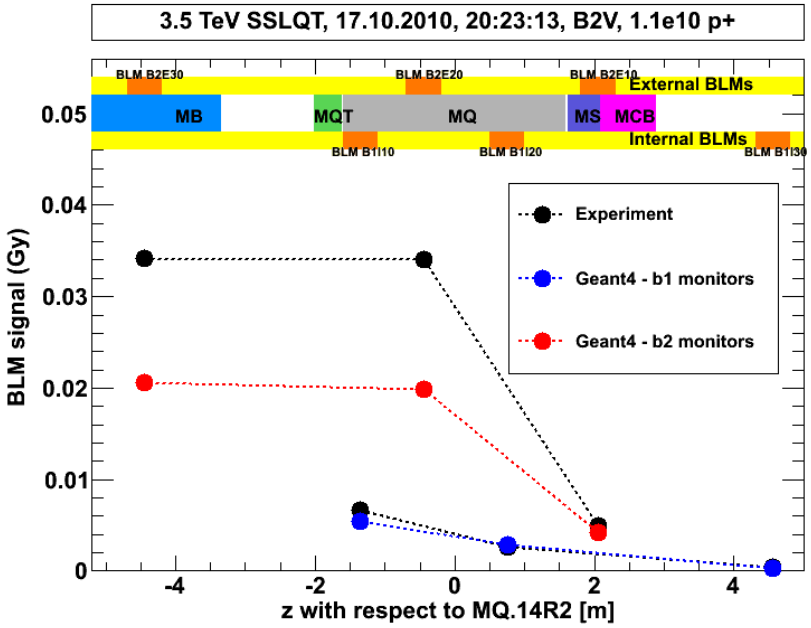
BLM SIGNALS





- The best fitting results (not necessarily the most probable ones)

- Geant4 simulations underestimate BLM signal (based on 2013 QT experience) so this approach has to be compared with loss patterns from MAD-X.

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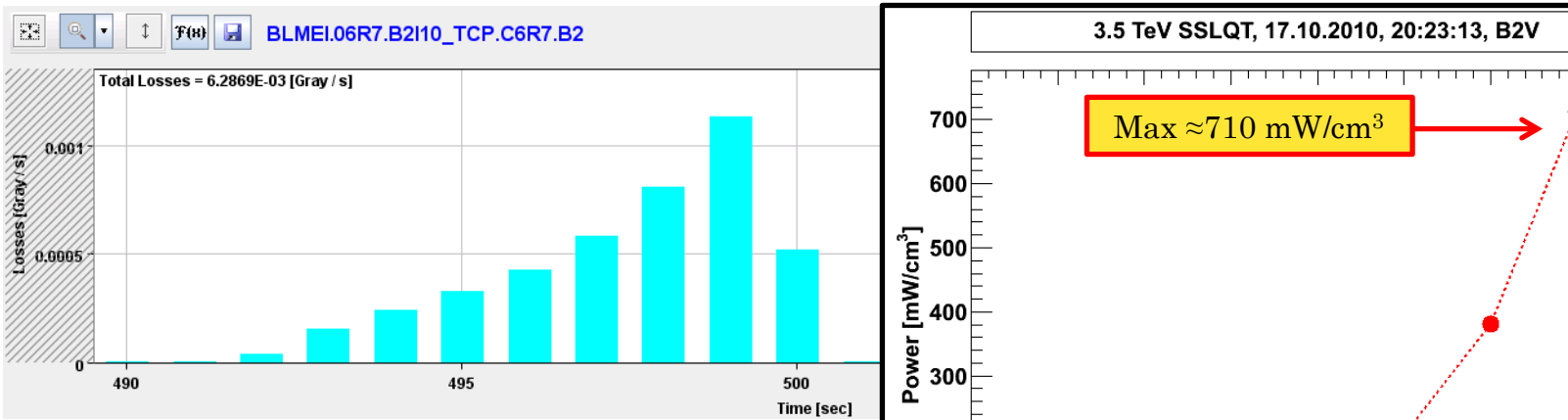
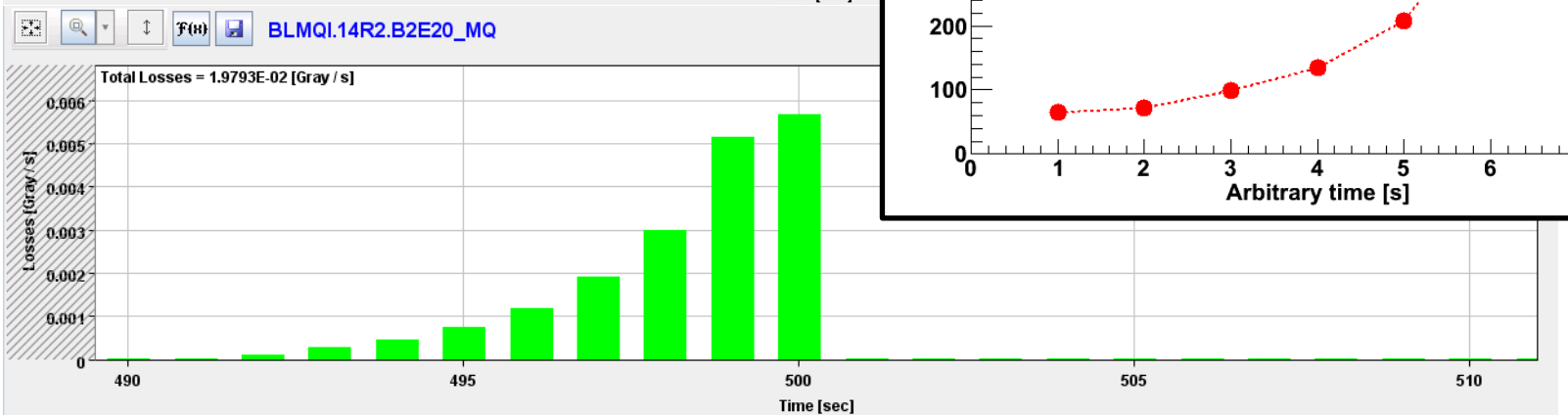
POWER





Power load is calculated based on BCT data and estimated Geant4 quench limit assuming that all protons were lost on MQ.14R2. The max value ≈710 mW/cm^3 is huge.

However, the collimators were not open completely(!) and losses occured there as well.

This gives an uncertainty of 50% (→difficult to estimate exact number of protons lost on the MQ+ what time exactly should be taken as loss duration?).

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SUMMARY

1. Quench limit for steady state regime was estimated to be
   - Geant4: 1.7 J/cm^3 for $1.1 \cdot 10^{10}$ lost protons
   - QP3: 0.5 J/cm^3 (0.4 J/cm^3 ←B. Auchmann)
2. The maximum power load on MQ was around 710 mW/cm^3 (calculated from BCT data) which is huge and due to losses on collimators, biased with 50% of uncertainty.
3. The results are based on finding "the best fitting" scenario (not necessarily the most probable one).
4. Loss pattern from orbit simulations (Vera) will be used soon, the results will be compared.

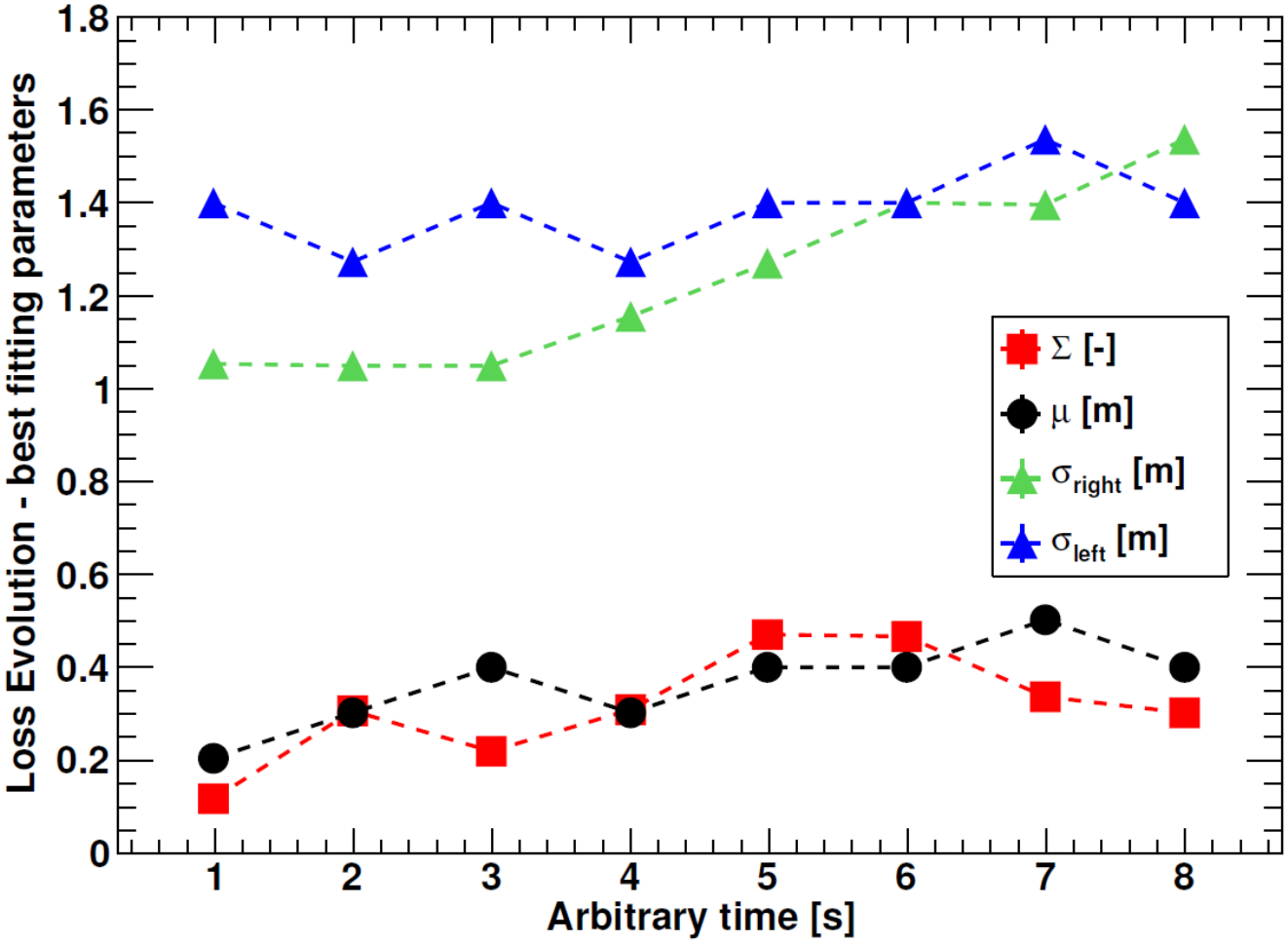
THANK YOU FOR YOU ATTENTION !

Questions?

Comments?

Remarks?

SIMULATIONS



SIMULATIONS