BLM quench threshold estimates on the MB magnet

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CERN, Collimation WG, 2009.02.16

Outline

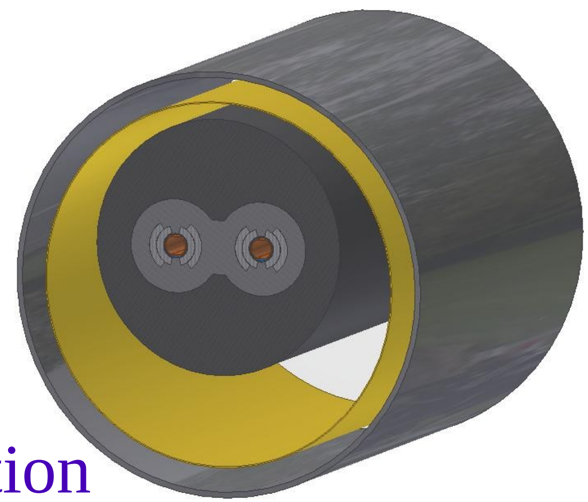
- Geometry and Magnetic Field
- Pointlike vs. distributed losses
- Energy deposit in the coil
- Stability margin
- Particles outside cryostat
- Signals in the BLMs
- Quench-protecting thresholds
- Beam-induced quenches of LHC magnets

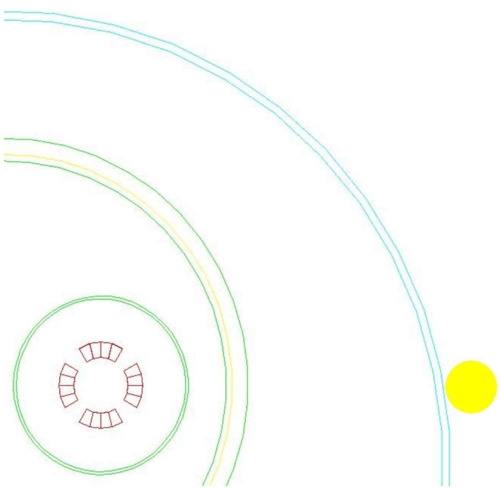
Geometry

- Beam screen, cold bore, coil, yoke, thermal insulation and cryostat
- BLM as a long tube along the cryostat – registering particles entering the tube
- Registering energy deposits in the inner coil, bin size:
  length 4.7 cm

  phi 4 deg

  radial 5.1 mm

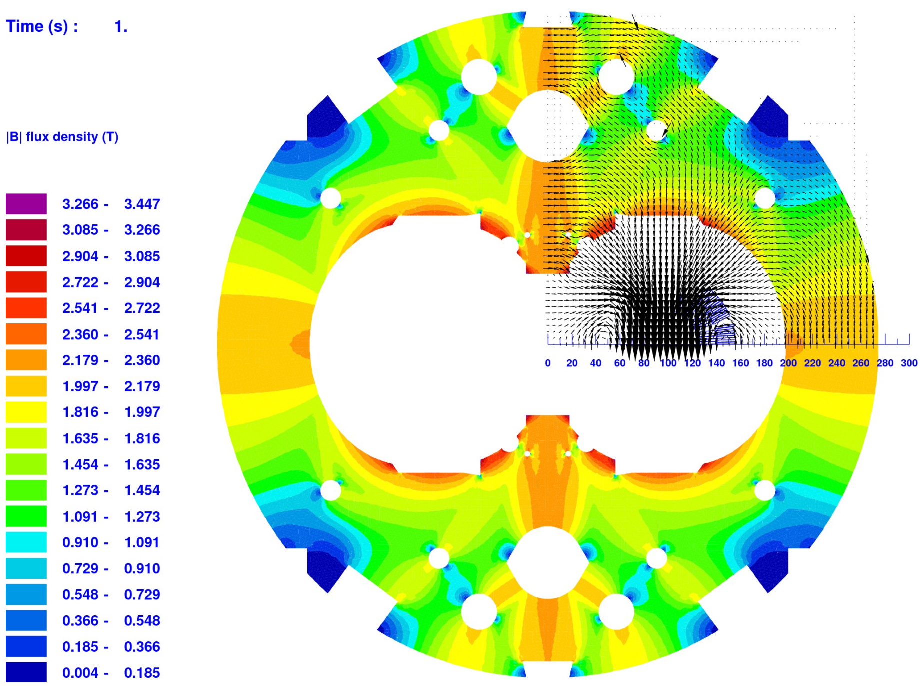




- Geant 4.9.0p01
  with BERTini
  cascade parametrization
  and low energy neutrons.

Magnetic field

- Map covering whole cross section of yoke
- Linear interpolation between mesh points
- Slow dimming of field in zone where coils are bended

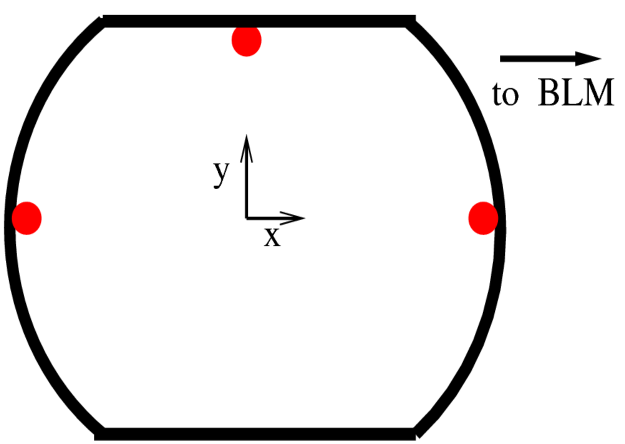


Loss location and distribution

- Three loss locations has been analysed
- Every time a pointlike loss has been simulated
- The distributed loss is obtained by folding pointlike loss results with gaussian loss distribution along the beam screen

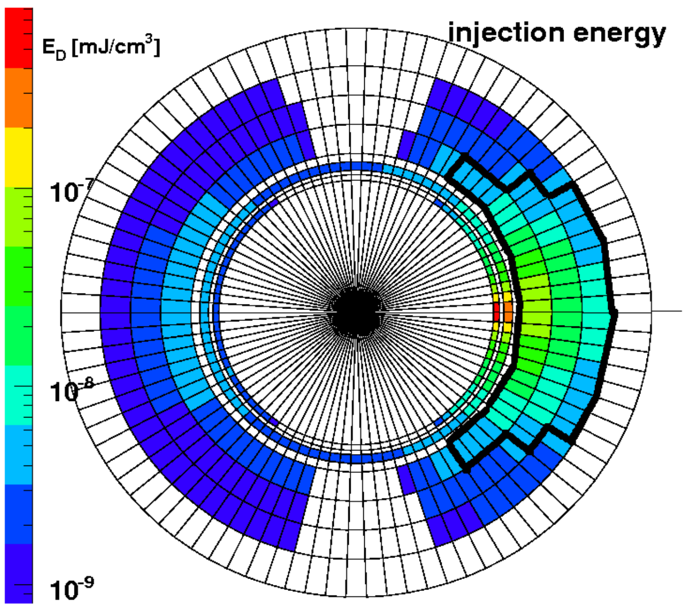
(no distribution in x)

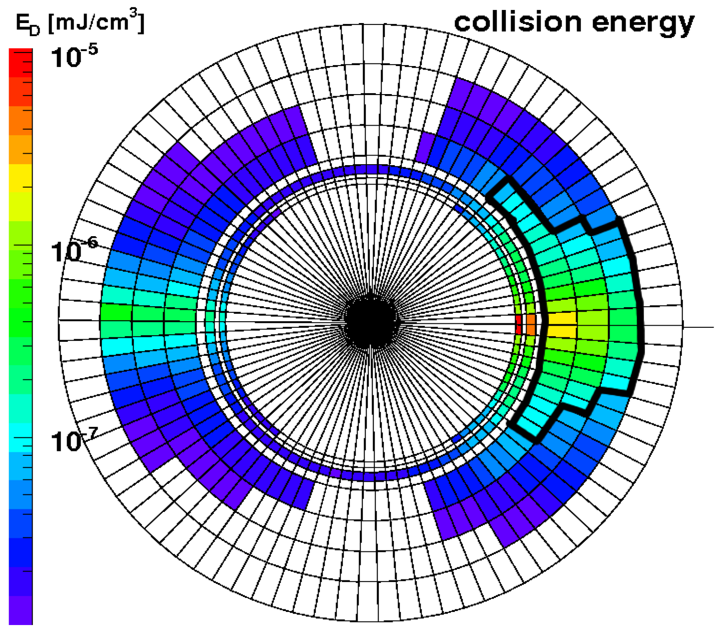
- This approach makes sense
  for losses with
  σ_{loss} << magnet length



Energy deposition in the coil

- Cross section through the internal coil, cold bore and beam screen

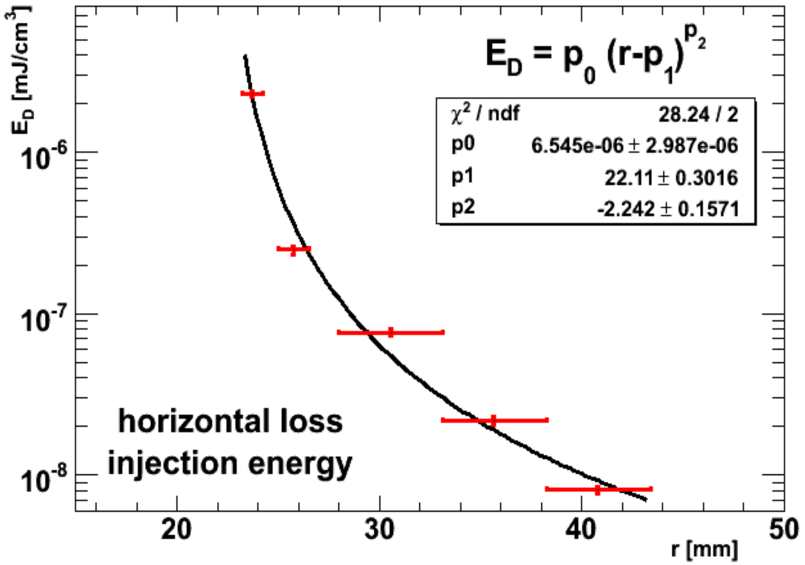


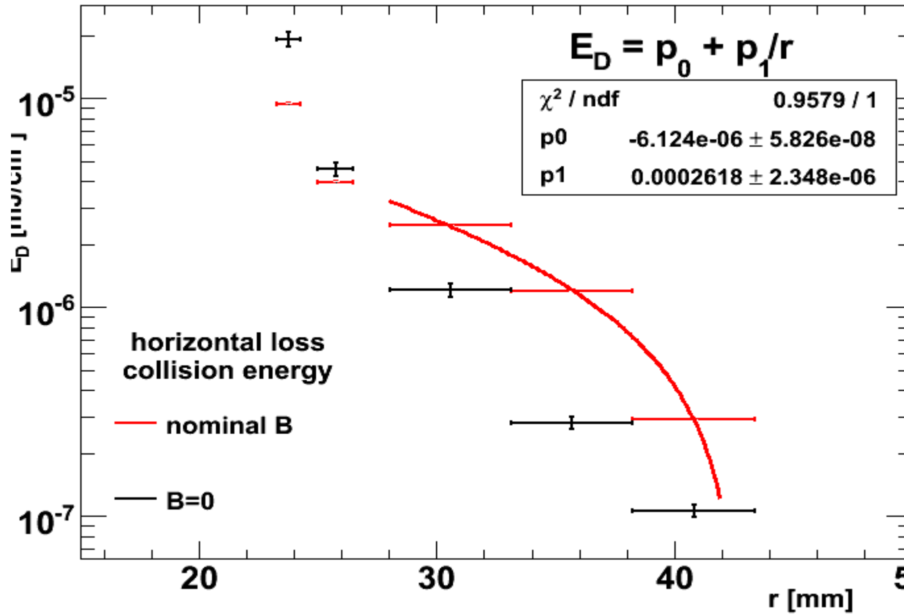


- 90% of energy is the right coil cross section is in:
  63 cells (55%) 46 cells (40%)

Cascade gets narrower due to magnetic field

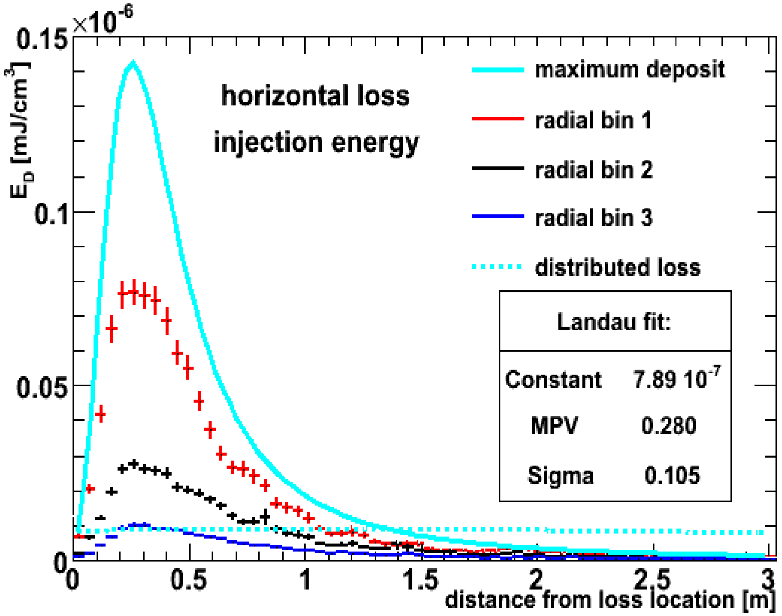
Radial distribution of energy

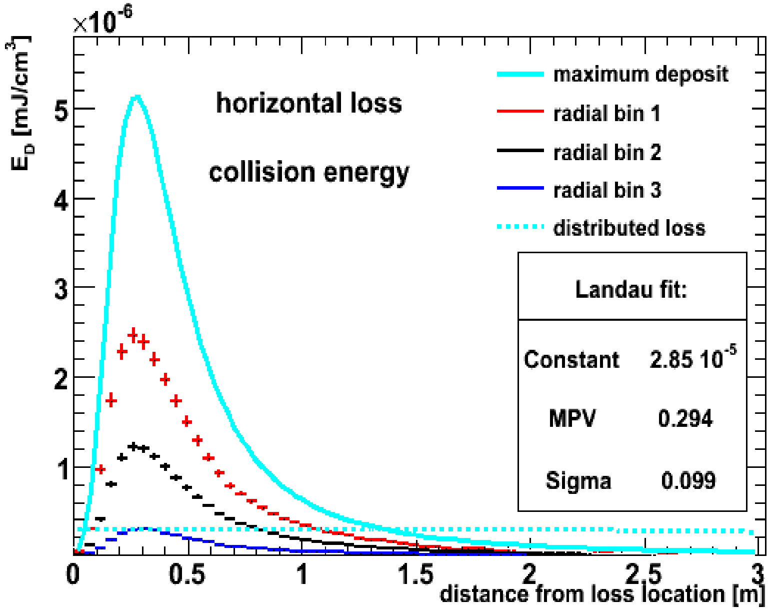




- For injection energy the distribution follows power law as in Note 44
- For collision energy the magnetic field enhances energy density in the inner coil and decreases in the beam screen
- E_D^{max} for threshold analysis is obtained from fits (as in Note 44, different technique used by R. Bruce)

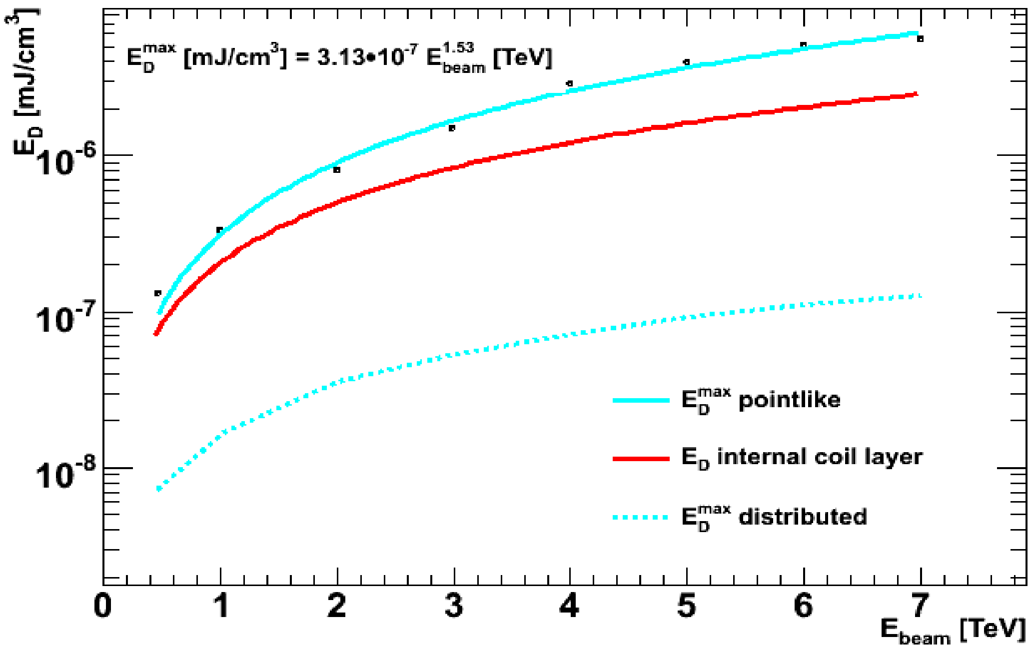
Longitudinal distribution of energy





- Maximum is about 20-30 cm after loss location
- Width (FWHM) is about 50 cm
- Agreement with FLUKA for pointlike loss

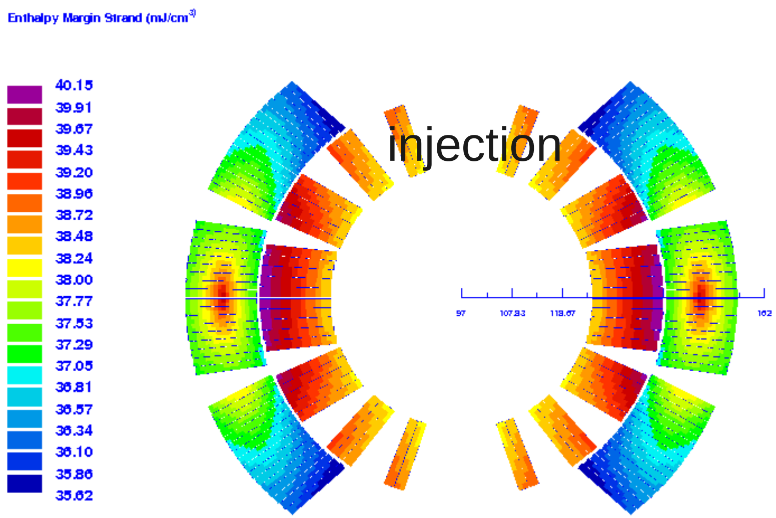
Energy in the coil vs. beam energy

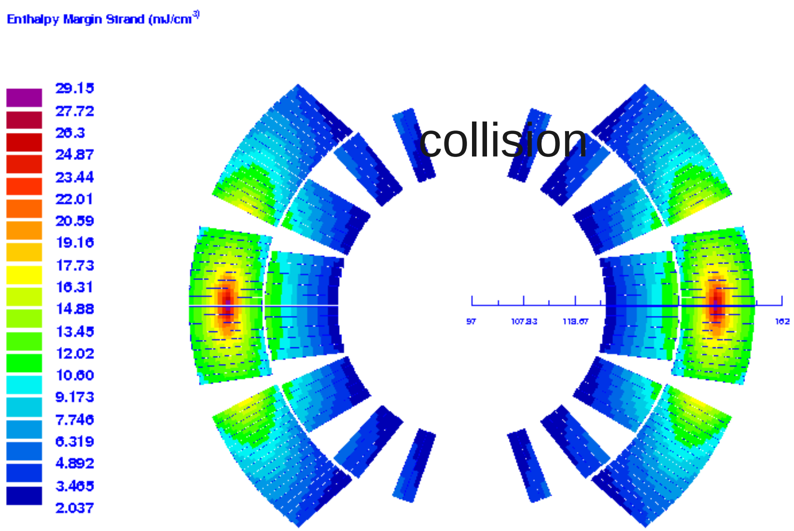


- Maximum energy density follows the power law
- Old fit with E_{beam} log(A E_{beam}) is also a good fit (E. Wildner, J. Jeanneret, VLHC workshop 1999)

Enthalpy density limit

- For fast losses the cable quenches when reaching the enthalpy density limit $H_{strand}=H_{strand}(J,B)$

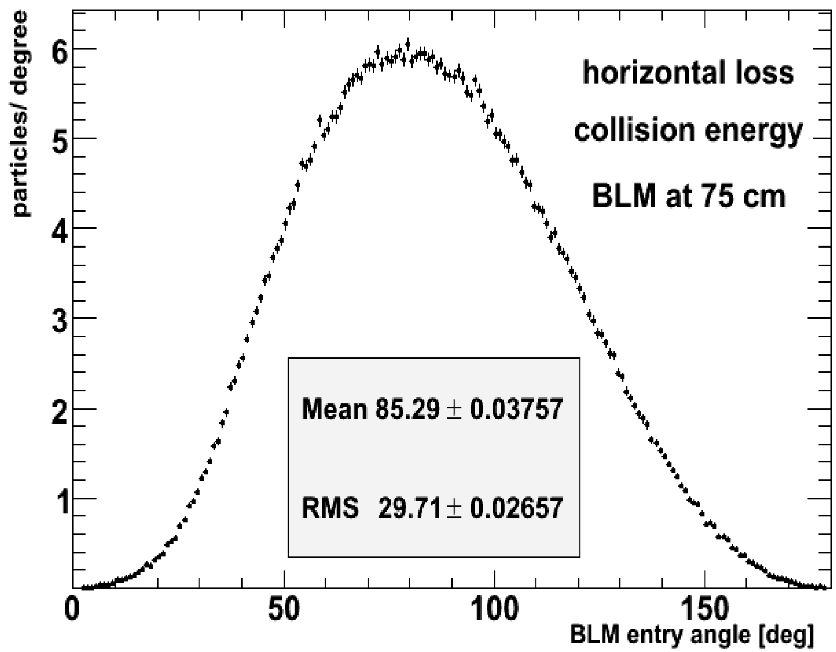


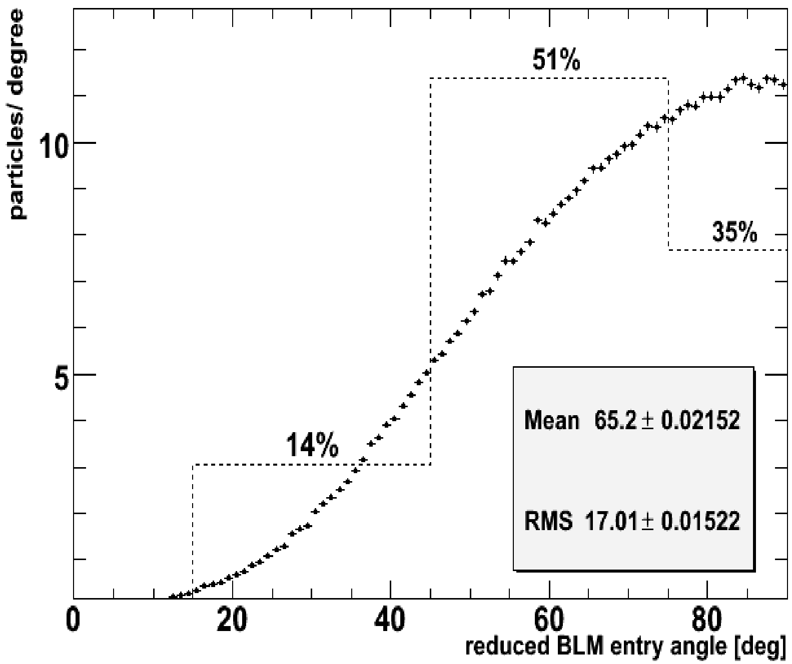


- Note 44: 38 mJ/cc 0.8 mJ/cc
- D. Bocian (EDMS 750204): 31.3 mJ/cc 0.93 mJ/cc
- ROXIE (N. Schwerg): 38 mJ/cc 2.04 mJ/cc

Particles outside cryostat

- Angular distribution (collision energy)

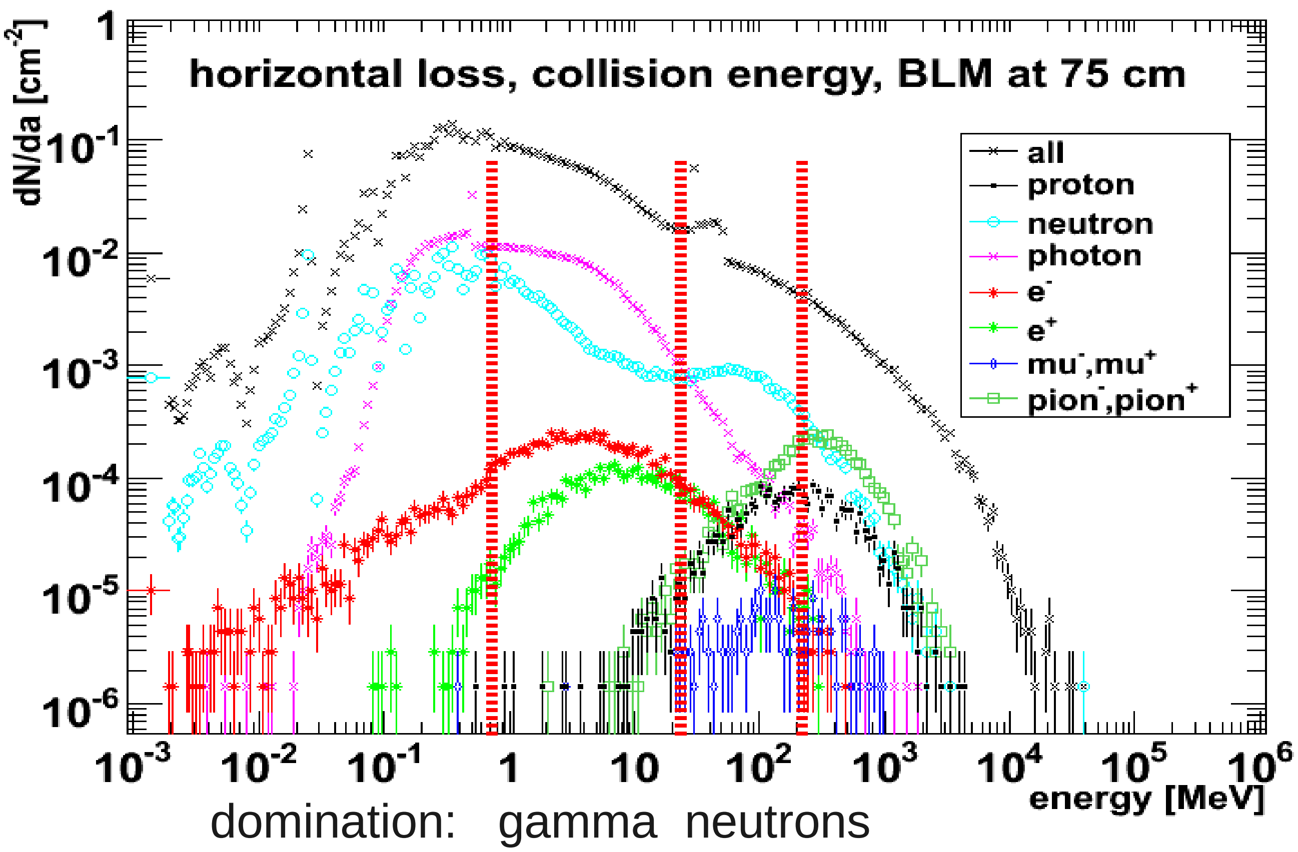




- Tail of the cascade: particles are coming out of Cryostat with almost normal angle
- Response functions for: 2, 30, 60 and 88 deg

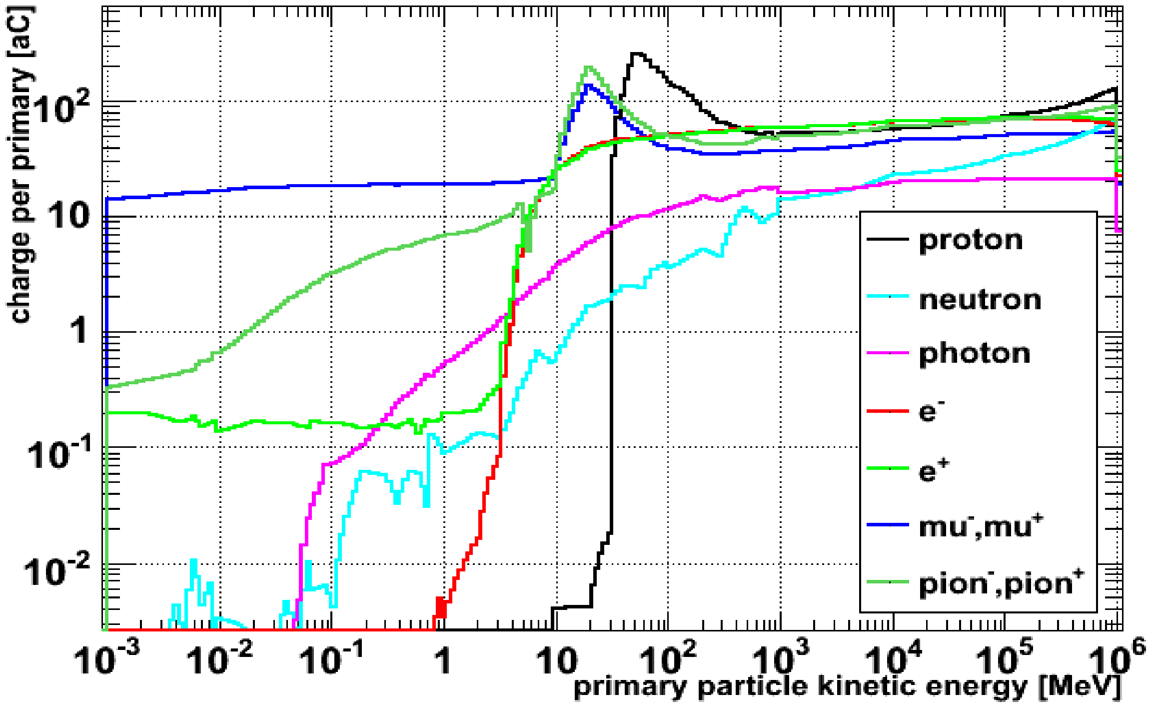
Particles outside cryostat

- Spectra: domination of photons and neutrons



Response functions

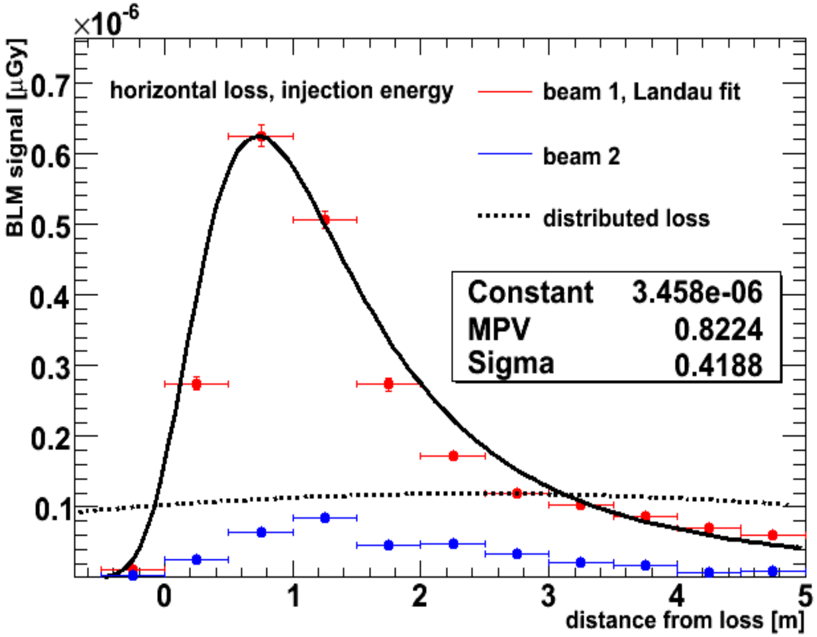
- Prepared using G4 and tested on various beams (M. Stockner thesis, 2007)

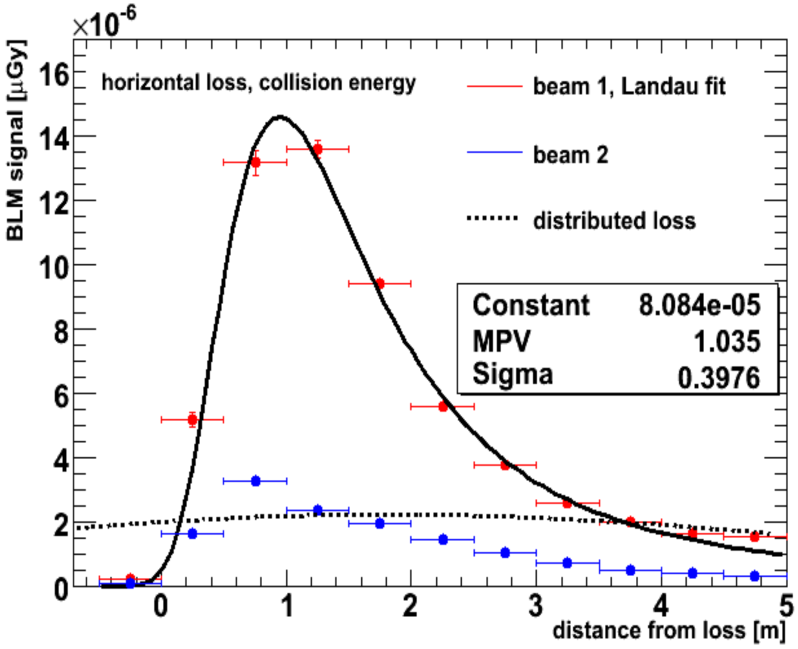


Signal in the BLMs (1)

- Signal [aC] =

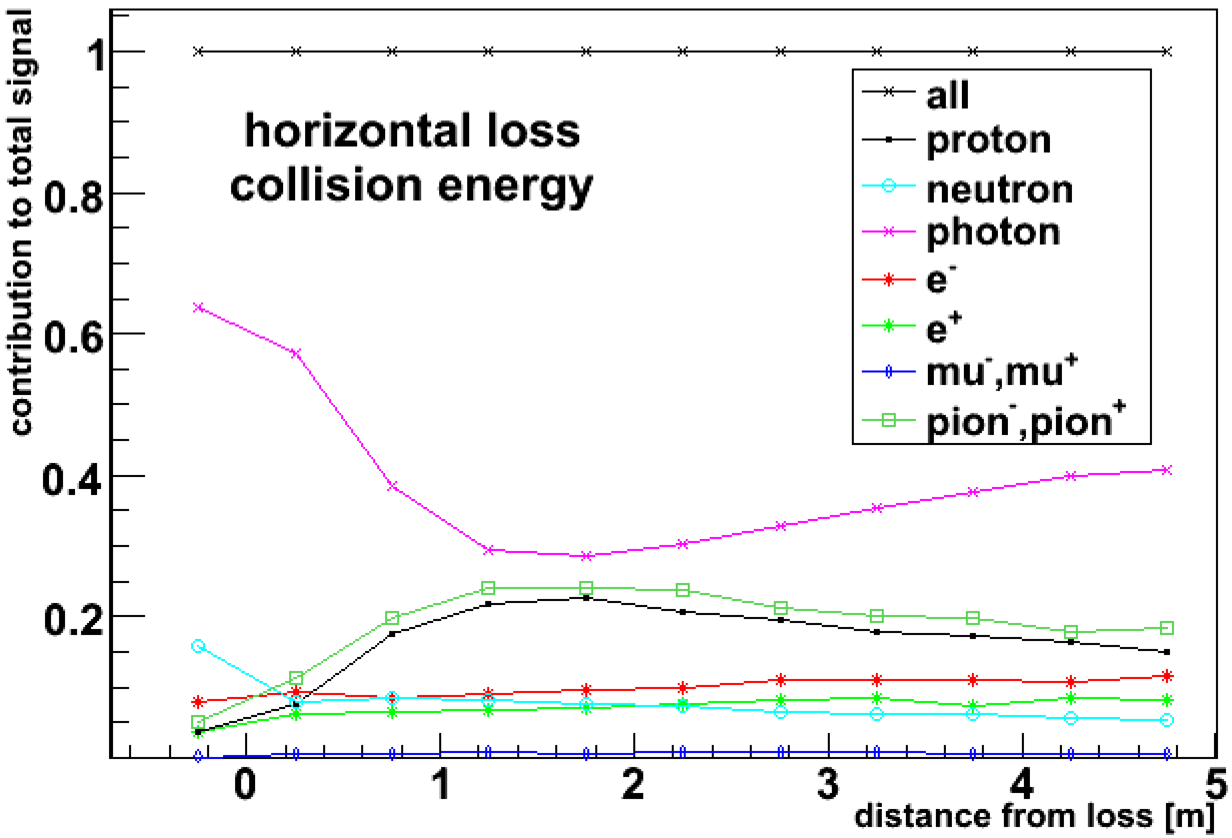
$$\Sigma_{r=1..4}(w_r (\Sigma_{p=p,n,e+,e-,\gamma,\mu} \Sigma_{e=1..240} R_{r,p,e}\, \Phi_{p,e}))$$





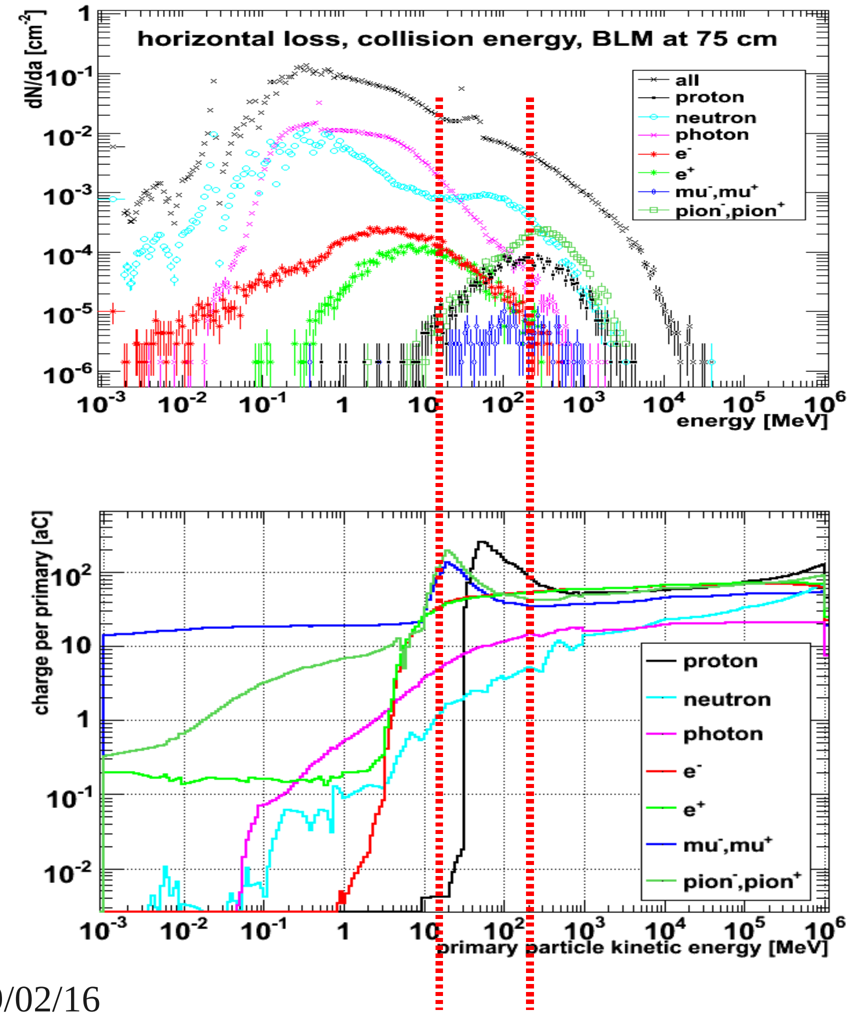
Signal in the BLMs (2)

- Contribution from various particles: domination of photons, protons and pions

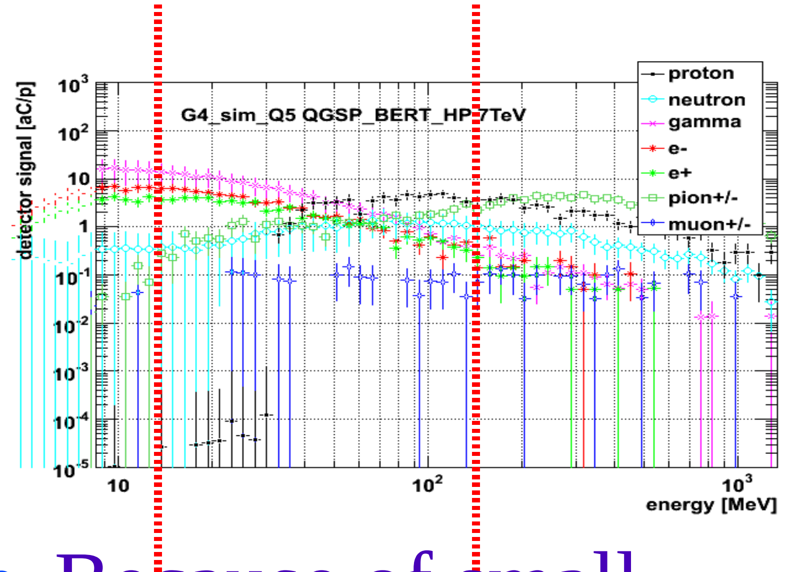


Signal in the BLMs (3)

- Doubt about neutron contribution (Markus Brugger)



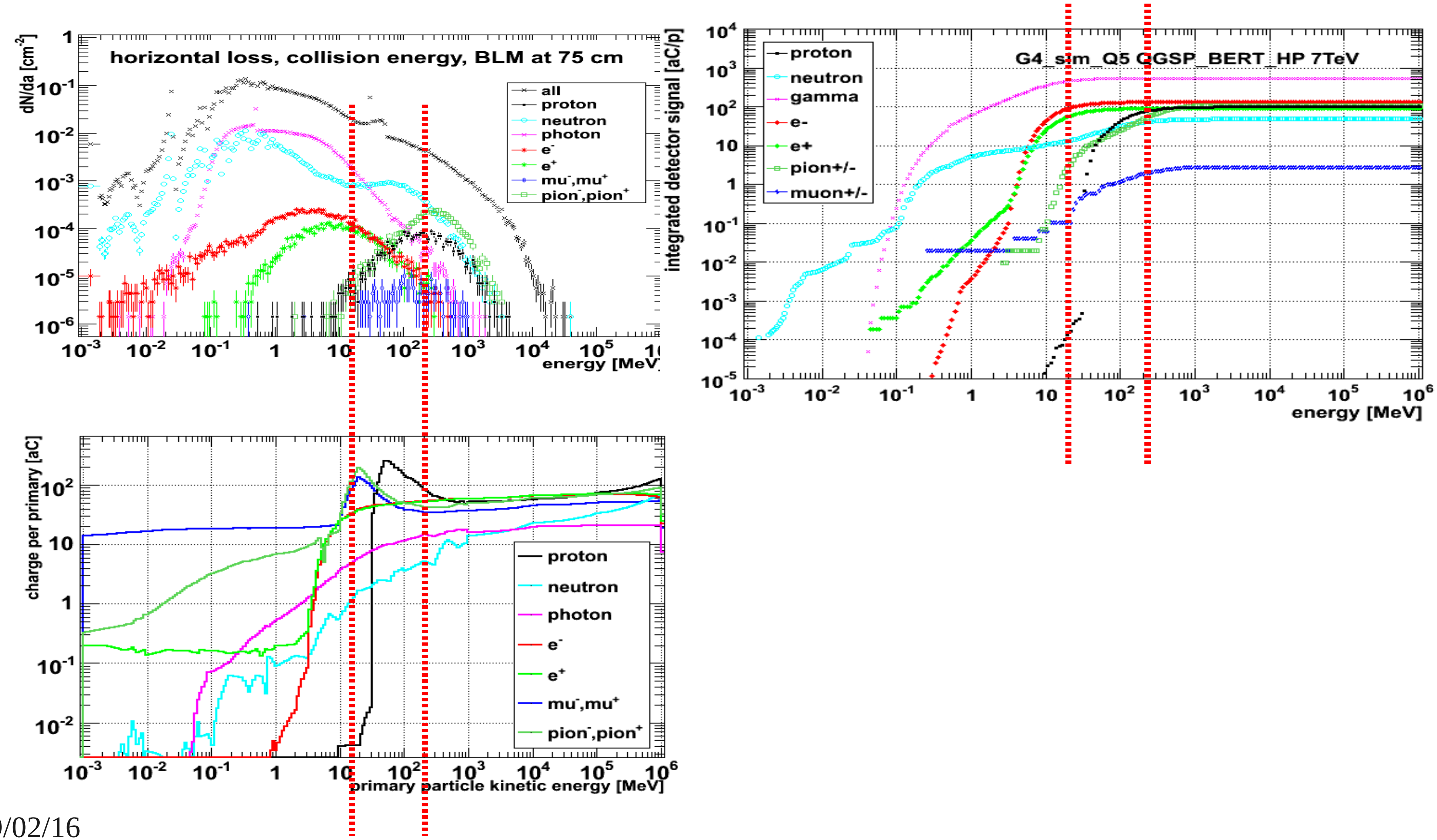
20-200 MeV neutrons



- Because of small response function neutrons are not dominant here
- sensitive region

Signal in the BLMs (4)

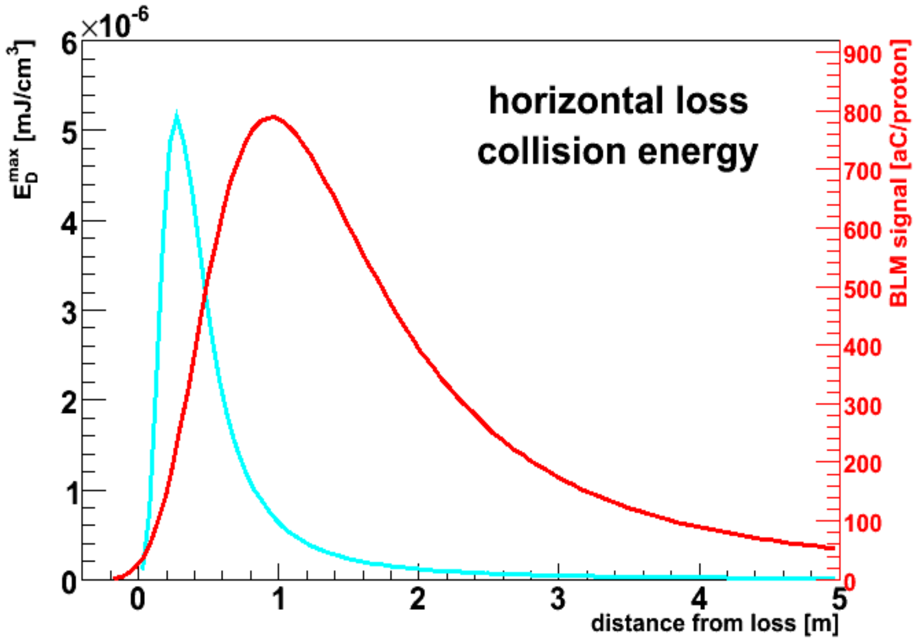
- Doubt about neutron contribution (Markus Brugger)



20-200 MeV neutrons

Quench-protecting threshold (1)

- $D\ [Gy] = Q_{BLM}\ H_{strand}\ /\ E_D^{max}$
- Two inputs from this analysis: E_D^{max} and Q_{BLM}



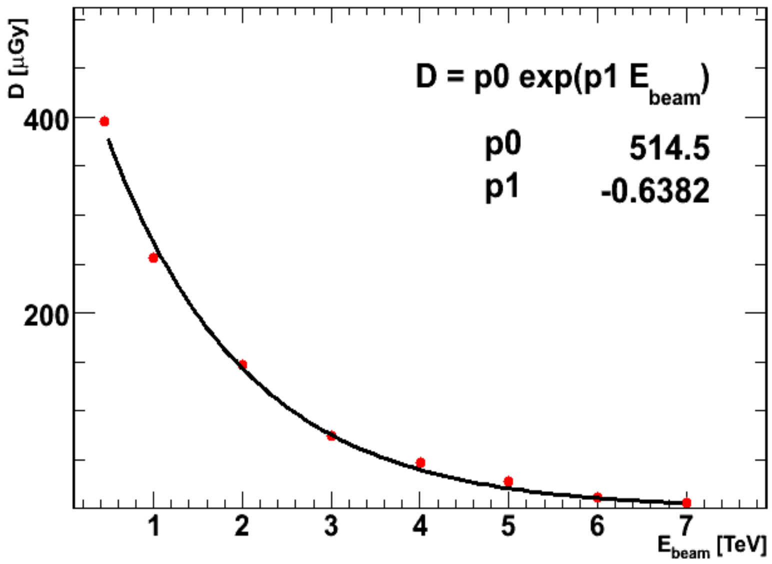
Horizontal loss	injection	collision
BLM at:	[μGy]	[μGy]
25 cm	37.5	0.2
75 cm	93.7	0.7
125 cm	93.2	0.7
175 cm	62.6	0.5
distributed loss	395	6.9

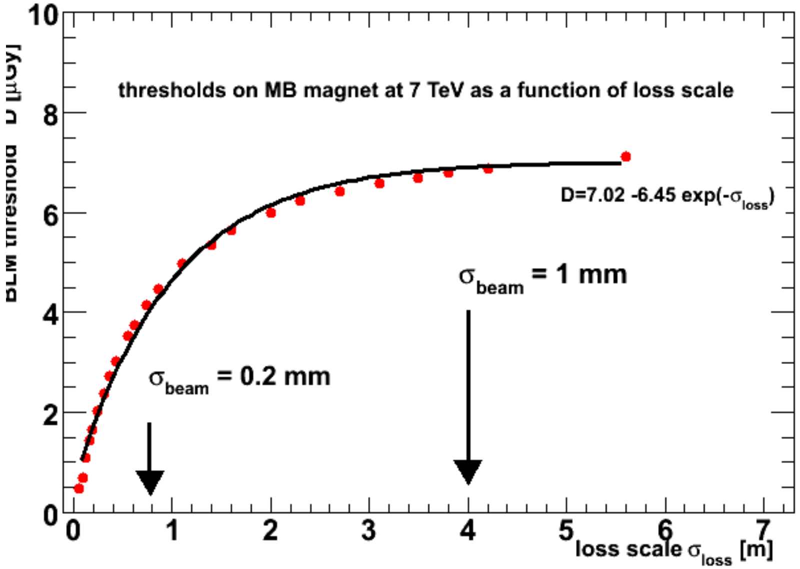
- SS case (assuming 12 mW/cc at collision and 320 mW/cc at injection)

200 mGy/s   4 mGy/s

Quench-protecting threshold (2)

- In function of beam energy and loss size



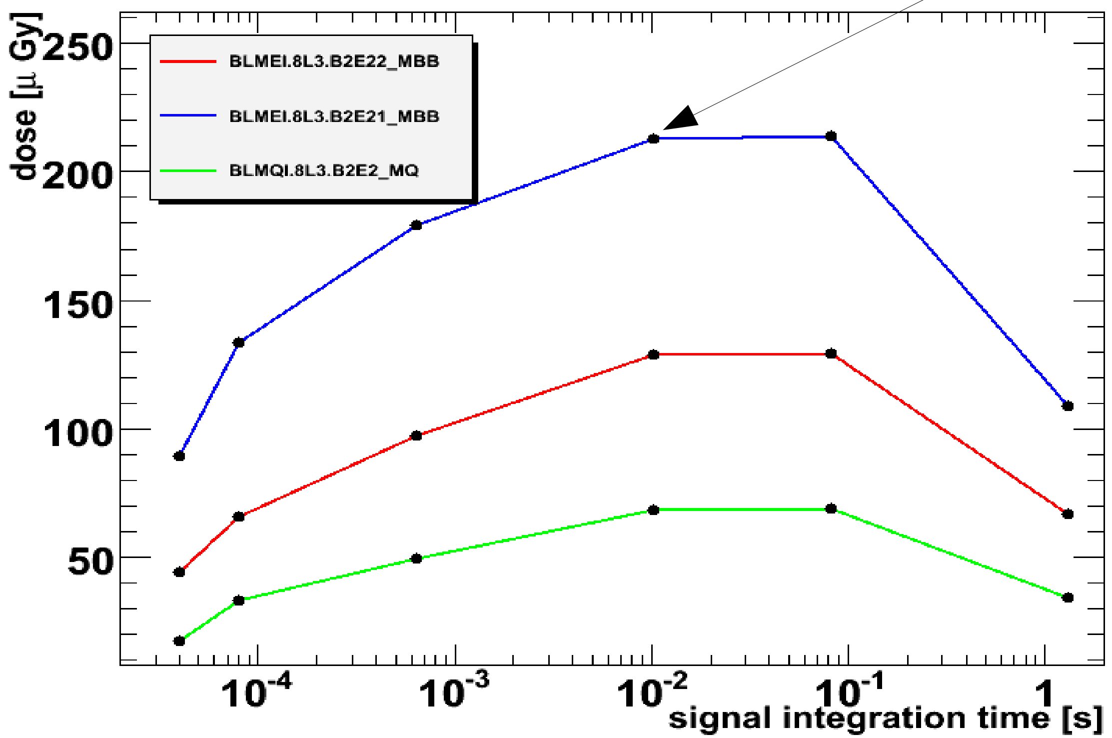


- In case of localized losses (aperture limit, obstacle in the beam pipe) the energy concentration in the coil raises fast and threshold becames lower even if BLM is placed in the signal maximum

Quenches of LHC magnets (1)

- Observation: time of charge collection from chambers is longer then expected.

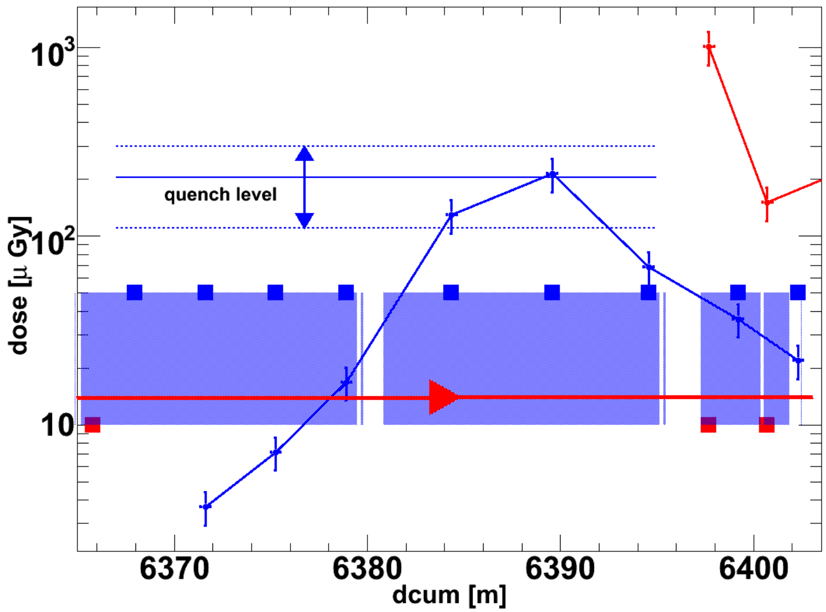
RS06 which is: 10 ms



This effect was expected to be smaller: it is stronger in Straight Sections where the cables are longer.

Quenches of LHC magnets (2)

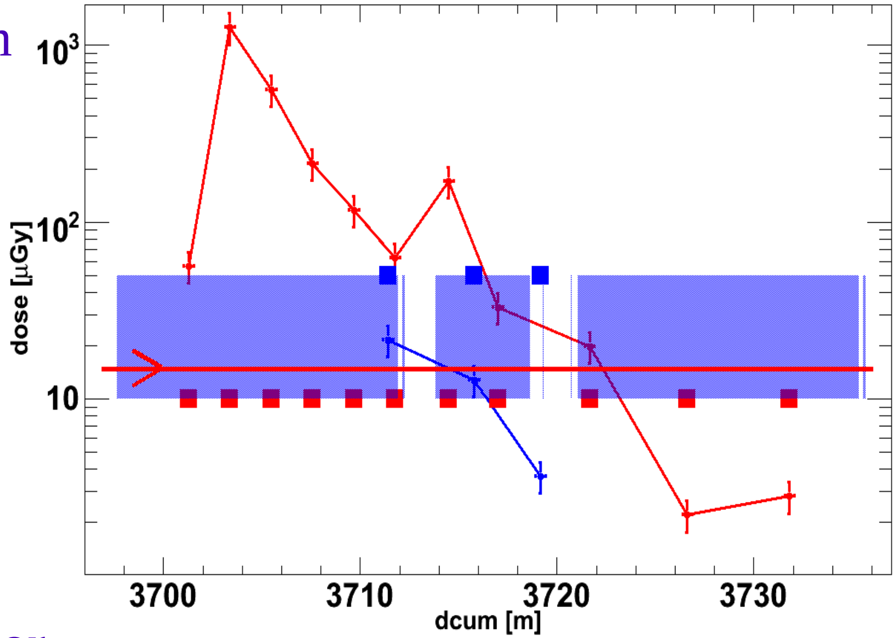
- 1^{st} quench: MB.A8L3, dcum~6385 m
- UTC timestamp: 2008-08-09 00:19:51
- Bunch intensity: $4 \cdot 10^9$ protons
- Not-intentional quench during aperture scan
- Source of beam deflection: corrector MCBV.9R2.B1, 2.7 km before MBB, deflection angle set to 80 μrad
- Last BPM measurement on BPM.8L3.B1 (dcum= 6357.23 m, about 25 meters from quench position): Vpos = 10mm
- Between this BPM and MBB there is MQ.8 (defocusing, dcum=6361) and MBA plus correctors – orbit uncertainty



- Modeling the beam trajectory (Elena) failed to hit the magnet – not all data are available.
- From beam position at BPM.8L3.B1 and distance to quenched magnet the impact angle is 260-300 μrad.
- BLMs on Beam2 are distributed every about 5 m

Quenches of LHC magnets (2)

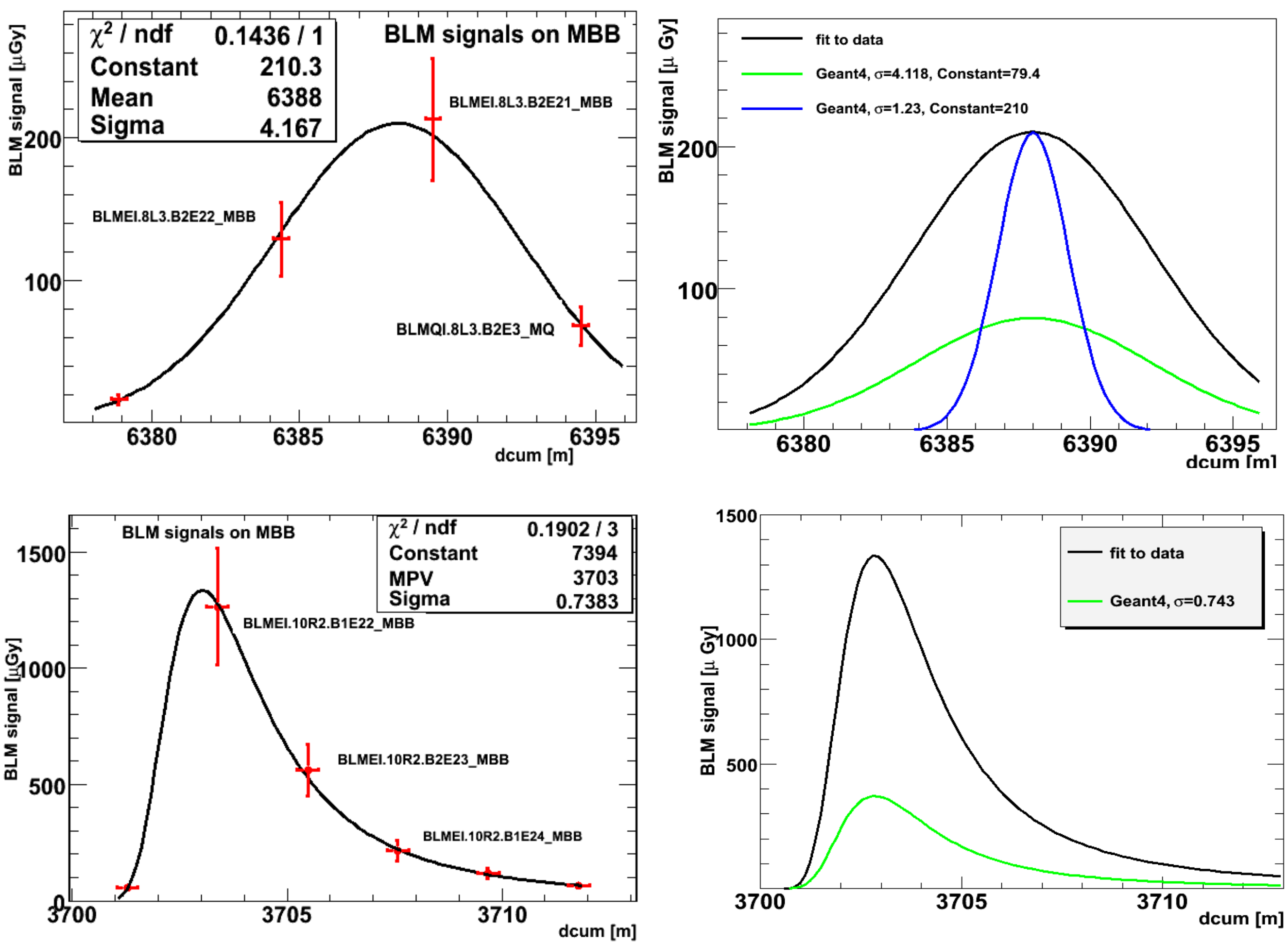
- 2^{nd} quench: MB.B10R2, dcum~3700 m
- UTC timestamp: 2008-09-07 15:34:05
- Bunch intensity: $2 \cdot 10^9$ protons
- Intentional quench
- Source of beam deflection: corrector MCBV.9R2.B1, 17.4 m before MBB, deflection angle set to 750 μrad
- No BPM measurement berween corrector and quenched magnet
- Between the corrector and MBB there is NO MQ - no orbit deflection
- The distribution of signal in BLMs is not gaussian – it looks more like pointlike distribution



- Modeling the beam trajectory not done but beam conditions are much simpler: deflection angle stays 750 μrad.
- BLMs on Beam1 are distributed every about 3 m

Quenches of LHC magnets - simulation

- The technique used is the same as for thresholds determination – folding signal from pointlike loss with gaussian loss distribution



- In both cases simulation underestimates signal by factor 2-3
- In both cases the maximum energy density estimation in the coil is only 50% of theoretical strand enthalpy (*)
- Estimated loss profiles agree with expected from beam size and impacting angles

What is next

- Detailed comparison with FLUKA (ongoing, Markus Brugger): preliminary agreement is E_D^{max} for pointlike loss in the coil
- Better understanding the discrepancy in the BLM signal (maybe reevaluation of response functions)
- Analysis of various geometries:
  MB/MQ interconnection – Christoph Kurfuerst
  Triplets – Alessio Mereghetti
  new fellow – new geometries
- More experimental data (quenches) needed but also analysis of existing data (not quenches but well defined loss conditions)

Conclusions

- Simulation to estimate quench-protecting thresholds in BLMs presented (in case of MB magnet)
- The two beam – induced quenches have been analyzed
- Simulation underestimates signal in BLMs by factor 2-3 (similar results seen before in HERA beam dump analysis by Markus Stockner)
- Simulation foresees that strand enthalpy limit is 50% of calculated one OR it underestimated the maximum energy deposition in the coil by factor 2
- Both above effects (accidentally) cancel and give correct threshold
- Thanks to Jorg Wenninger for real quenches and Markus Brugger for discussions and FLUKA results