Is the BLM system ready to go to higher intensities?

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F. Zimmermann, A. Guerrero & others

LHC Performance Workshop, 2011/01/26

Outlook

- **Do we understand all beam losses?**

→ examples of not fully understood losses

→ systematic approach: fill-to-fill variation

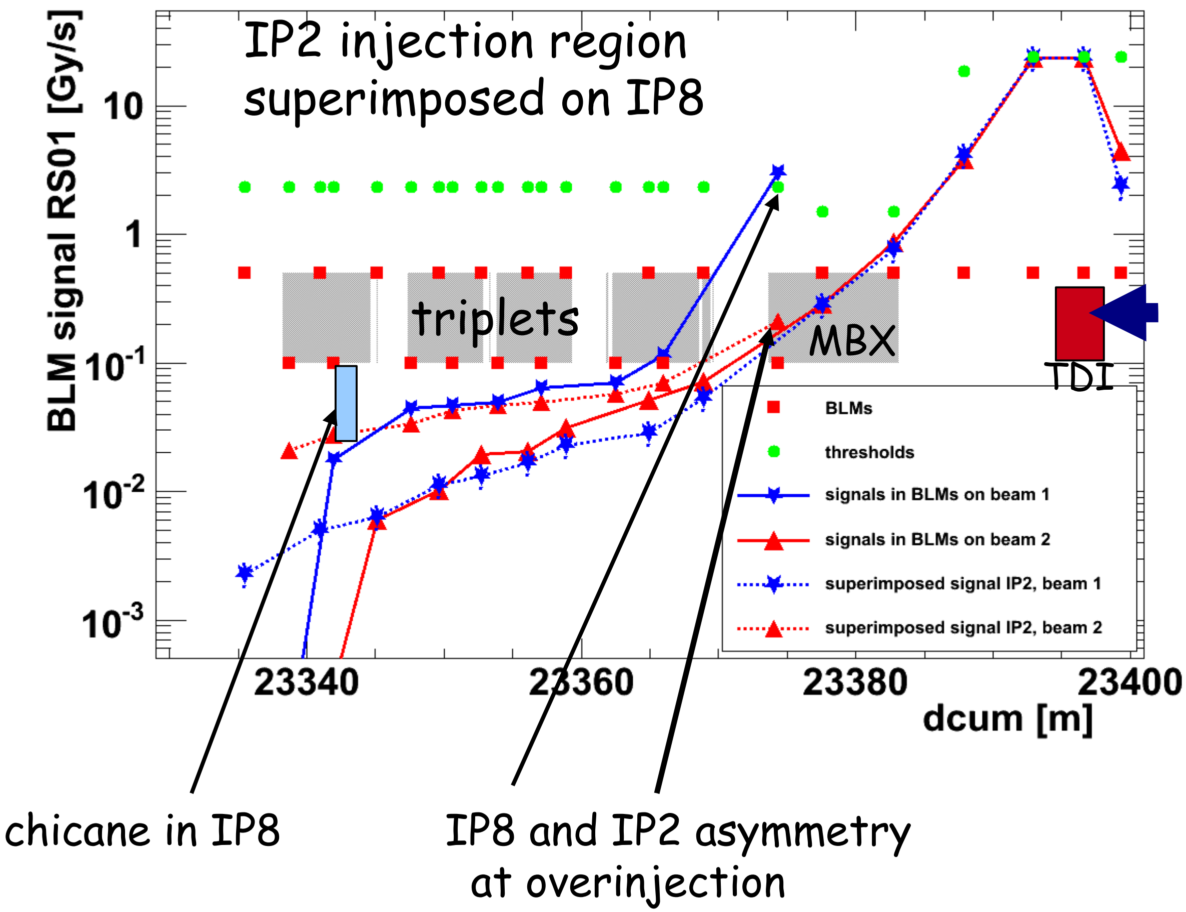
- **UFOs – origin, properties, model, prospects**
- **How correct the thresholds are?**

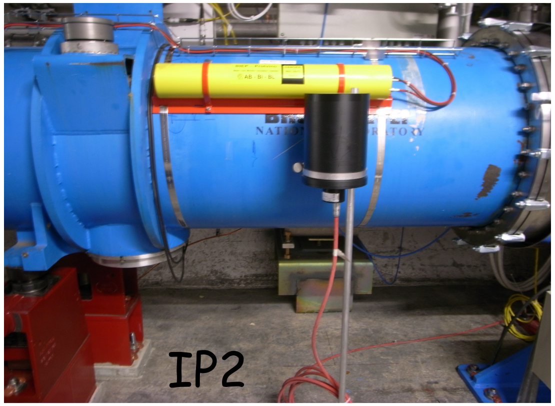
→ cold magnets at ms timescale

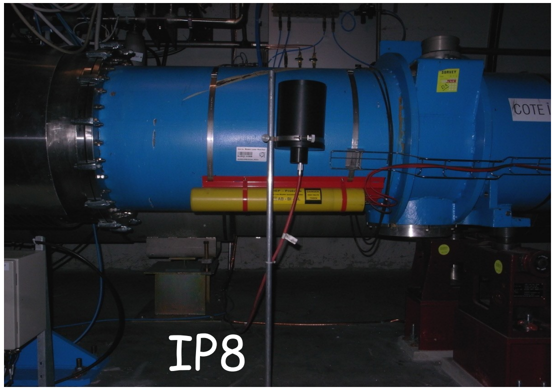
→ cold magnets at second timescale

→ where the threshold values are critical?

Examples of losses not understood yet

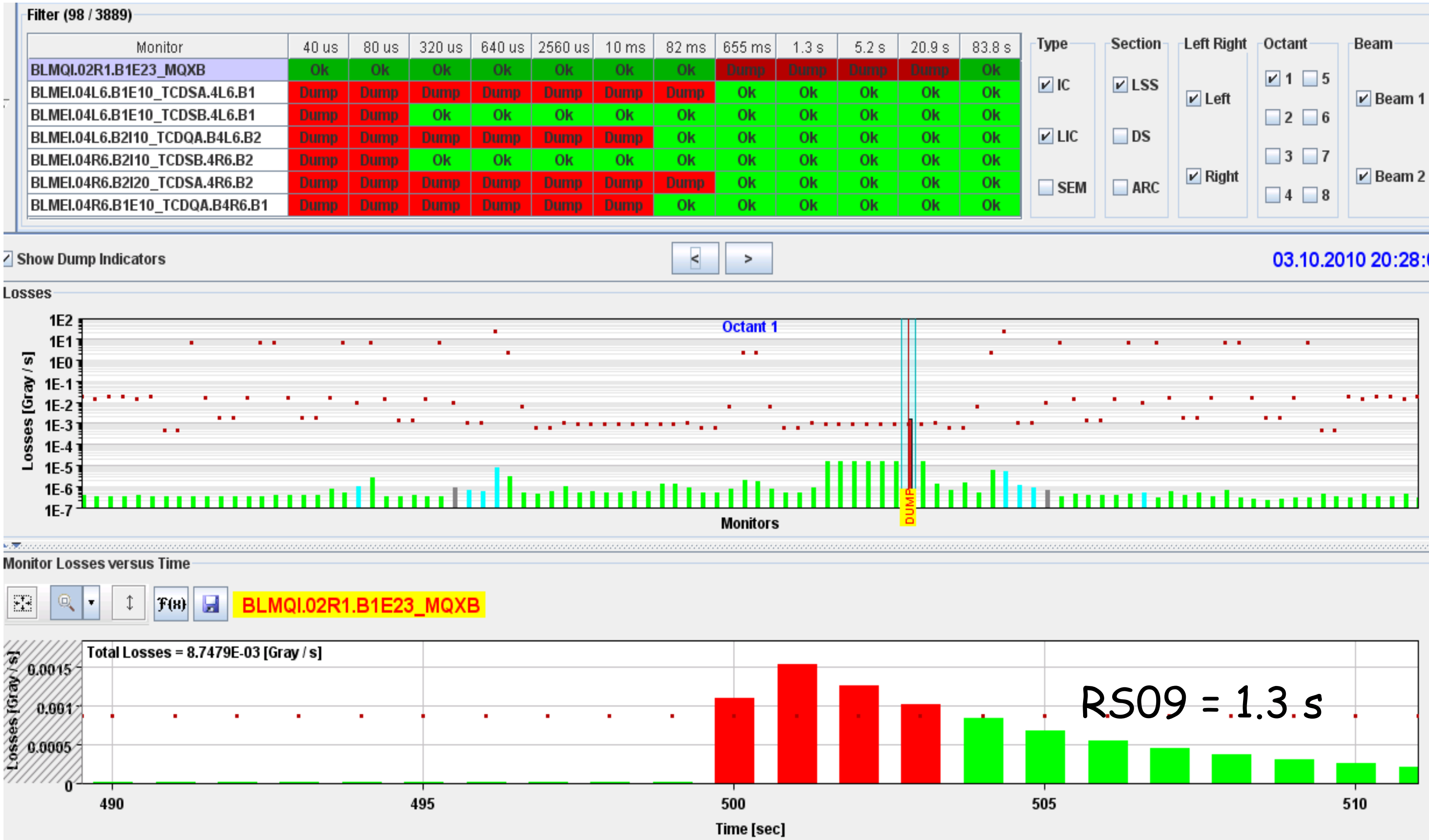






Understanding losses

Loss on triplet: RS08-11 above threshold on one MQXB monitor.



Monitor	40 us	80 us	320 us	640 us	2560 us	10 ms	82 ms	655 ms	1.3 s	5.2 s	20.9 s	83.8 s
BLMQI.02R1.B1E23_MQXB	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Dump	Dump	Dump	Dump	Ok
BLMEI.04L6.B1E10_TCDSA.4L6.B1	Dump	Dump	Dump	Dump	Dump	Dump	Dump	Ok	Ok	Ok	Ok	Ok
BLMEI.04L6.B1E10_TCDSB.4L6.B1	Dump	Dump	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok
BLMEI.04L6.B2I10_TCDQA.B4L6.B2	Dump	Dump	Dump	Dump	Dump	Dump	Ok	Ok	Ok	Ok	Ok	Ok
BLMEI.04R6.B2I10_TCDSB.4R6.B2	Dump	Dump	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok
BLMEI.04R6.B2I20_TCDSA.4R6.B2	Dump	Dump	Dump	Dump	Dump	Dump	Dump	Ok	Ok	Ok	Ok	Ok
BLMEI.04R6.B1E10_TCDQA.B4R6.B1	Dump	Dump	Dump	Dump	Dump	Dump	Ok	Ok	Ok	Ok	Ok	Ok

Not a safety issue

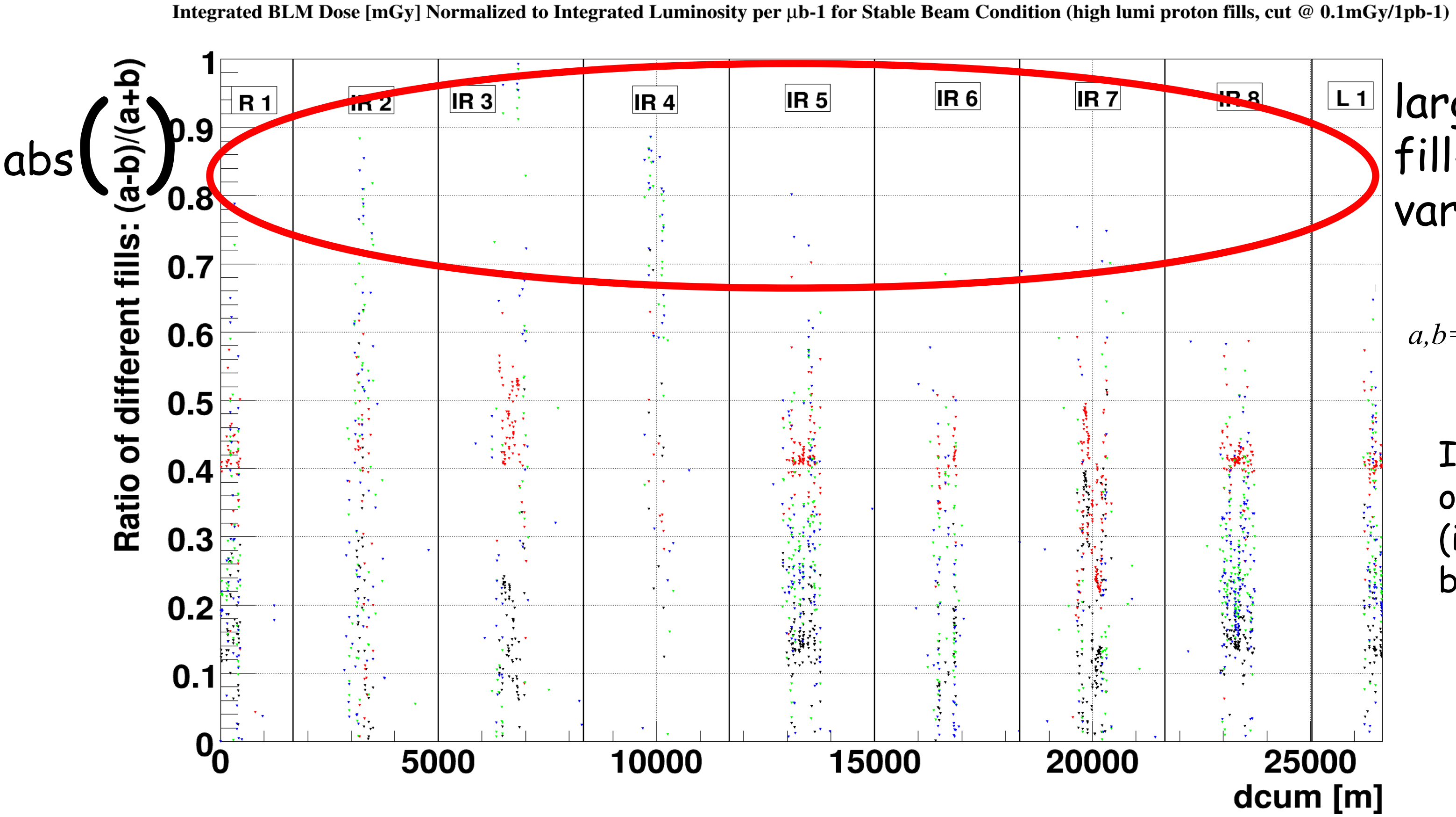
No other signal observed (in BLMs around or in IR3,7, ATLAS BCMs),

but other channels on the triplet went “negative” what means large current flow.

Understanding losses

Systematic approach (Annika Nordt) : total dose over stable beam period normalized to luminosity unit – variations between stable fills.

5 high lumi fills: 1440,1443, 1444, 1450, 1453.



large fill-to-fill variations

$$a,b=\frac{\int S_{BLM}(t)\,dt}{\int L(t)\,dt}$$

Integrals over fills (in stable beams)

Condition: Dose > 0.1 mGy/pbarn^{-1}, offset subtracted.

UFOs

What they are?

How do they manifest?

How they affect operation?

How to deal with them?

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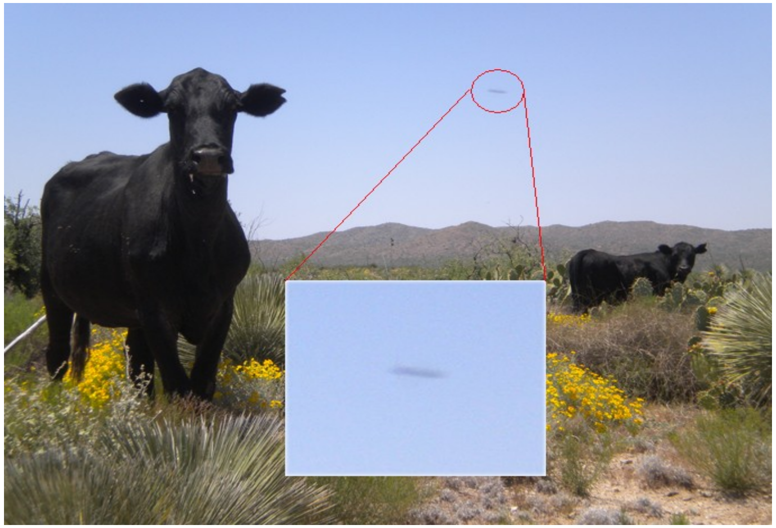
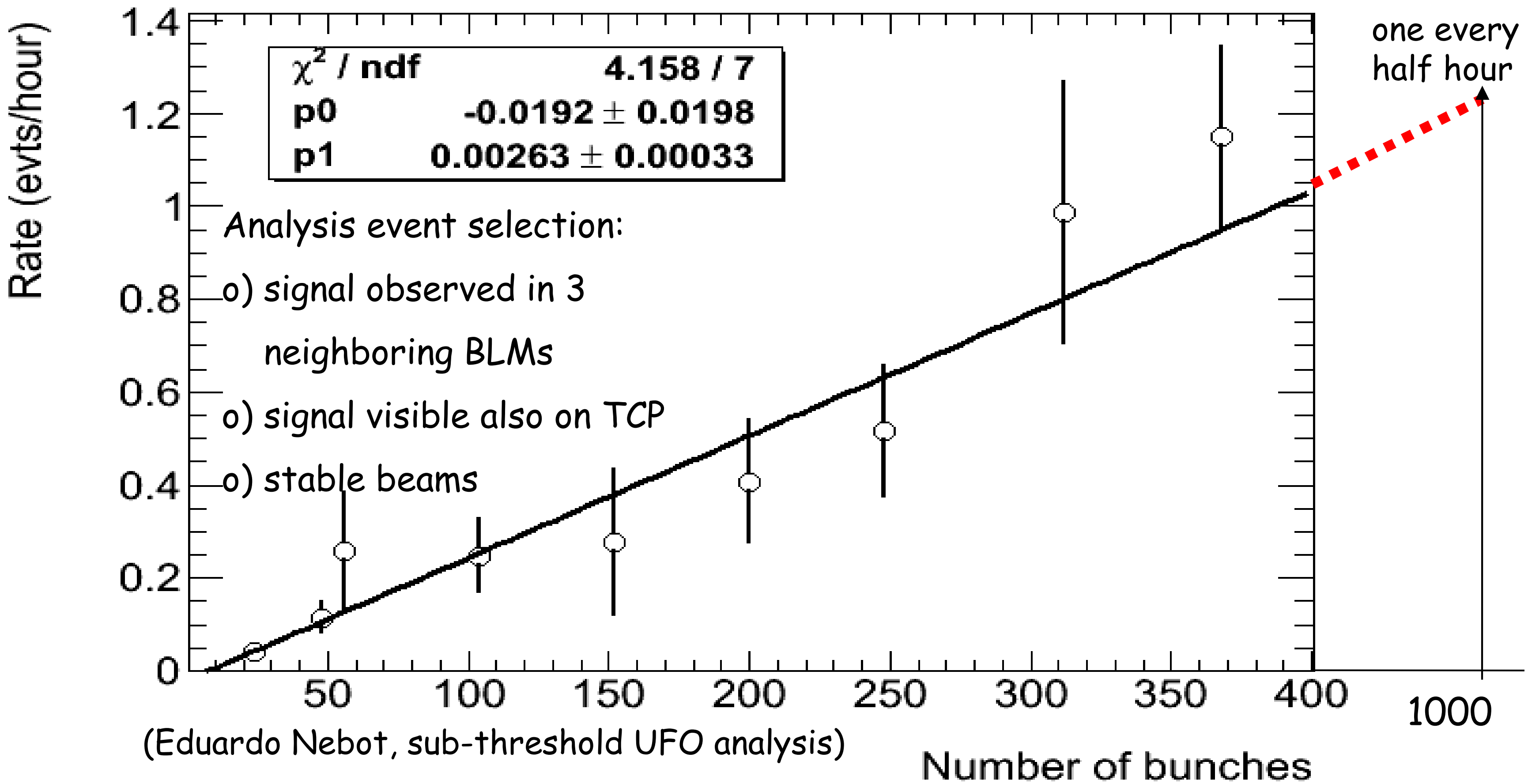


We know that there are more UFOs with higher intensity.

The UFO generation mechanism (dust release) depends on beam intensity.

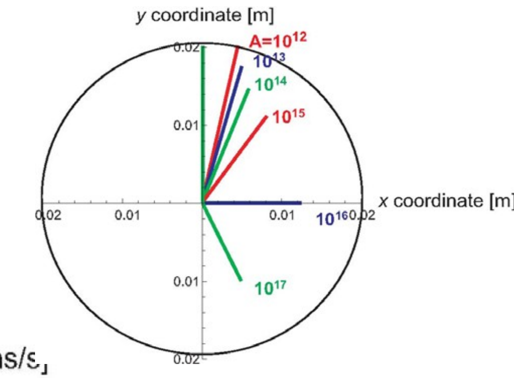


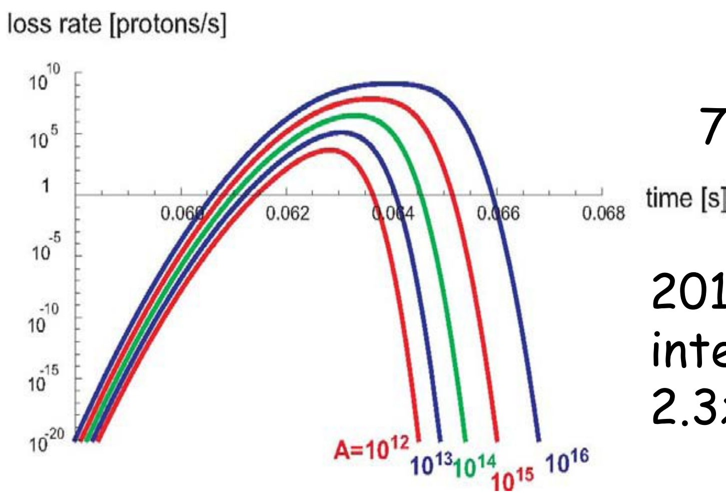
(Eduardo Nebot, sub-threshold UFO analysis)

UFOs – model

Model (Frank Zimmermann): a dust particle (10^{16} Atomic masses), falling into beam, driven by beam field, mirror charge field and gravity.

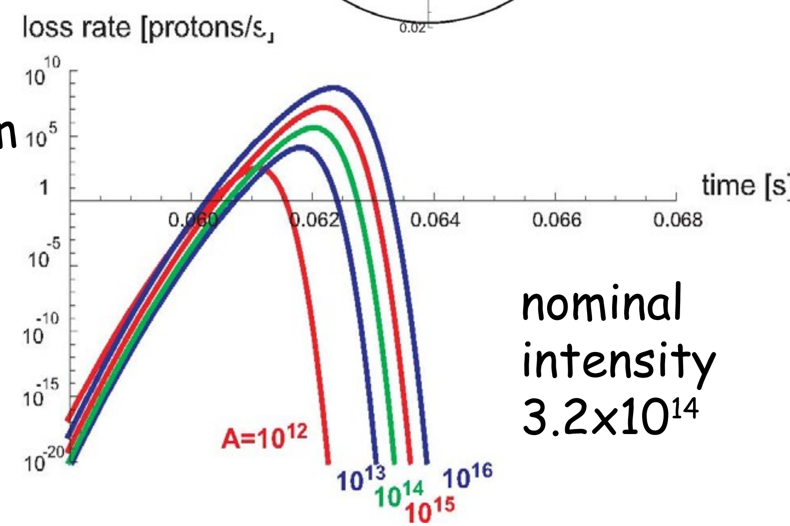
Dust is positively charged and repelled from the beam (which might result in "precursor event")





7 TeV beam

2010 intensity 2.3×10^{12}



nominal intensity 3.2×10^{14}

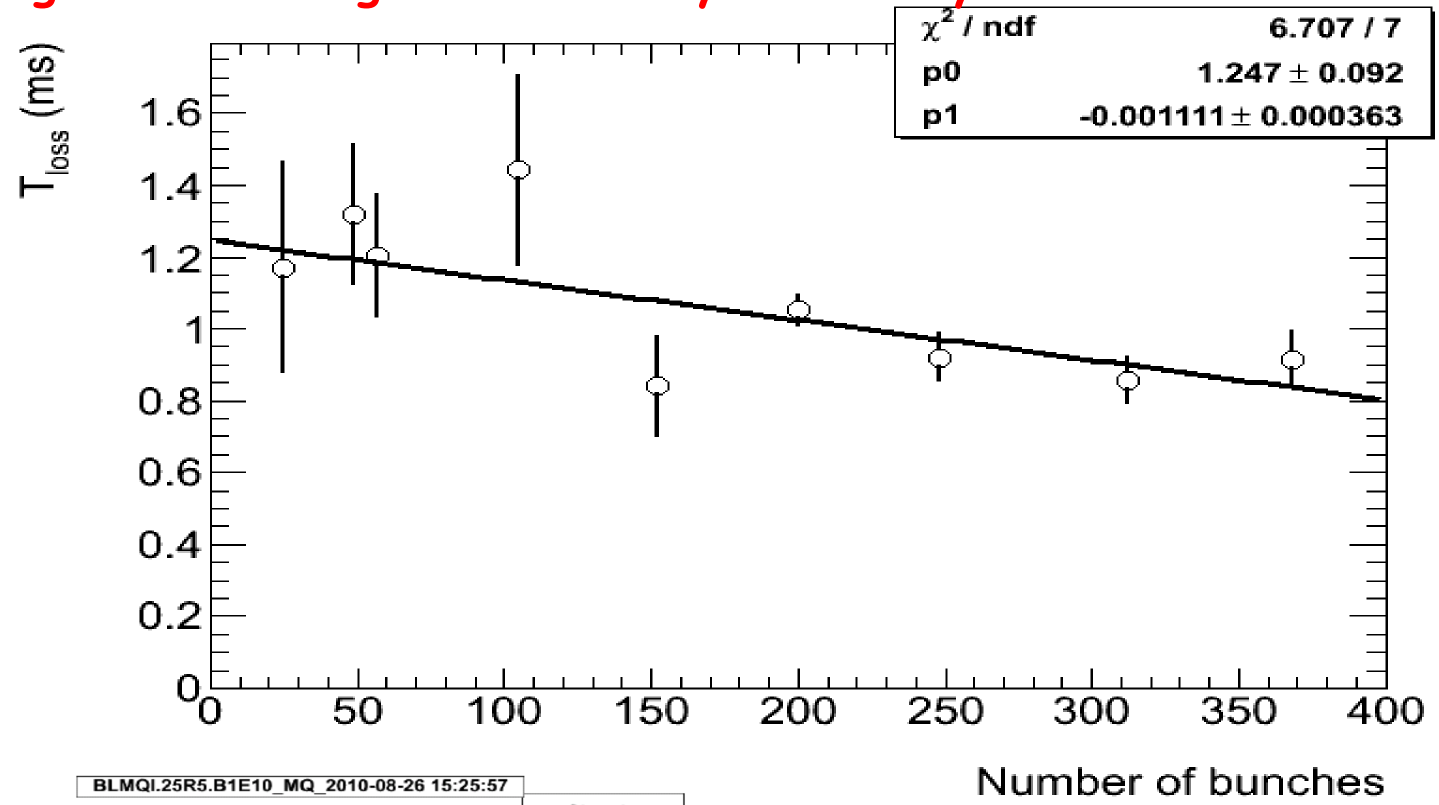
predictions

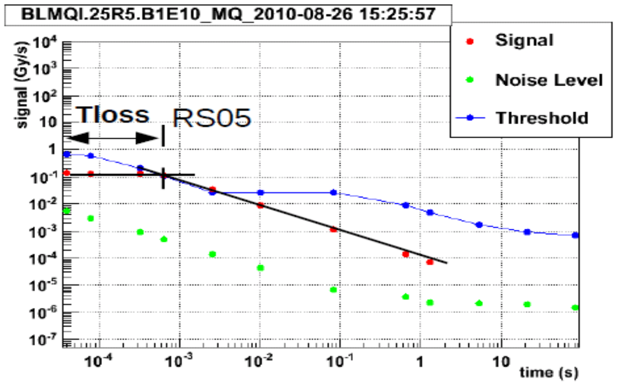
o) shorter signal at higher beam intensity,

o) no dependence of the maximum loss amplitude on beam intensity (depends only on dust size).

UFOs – loss duration

Signal shortening with intensity is actually observed:

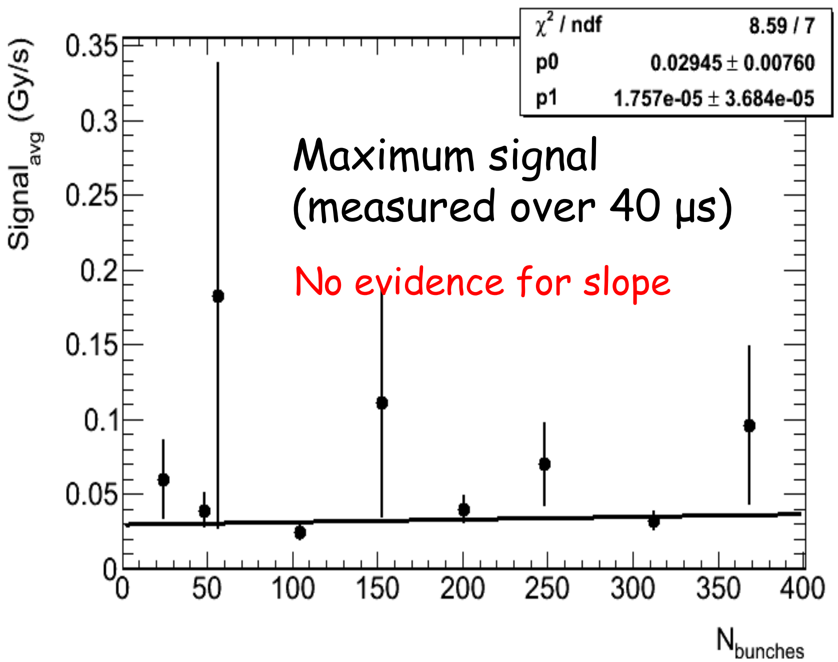


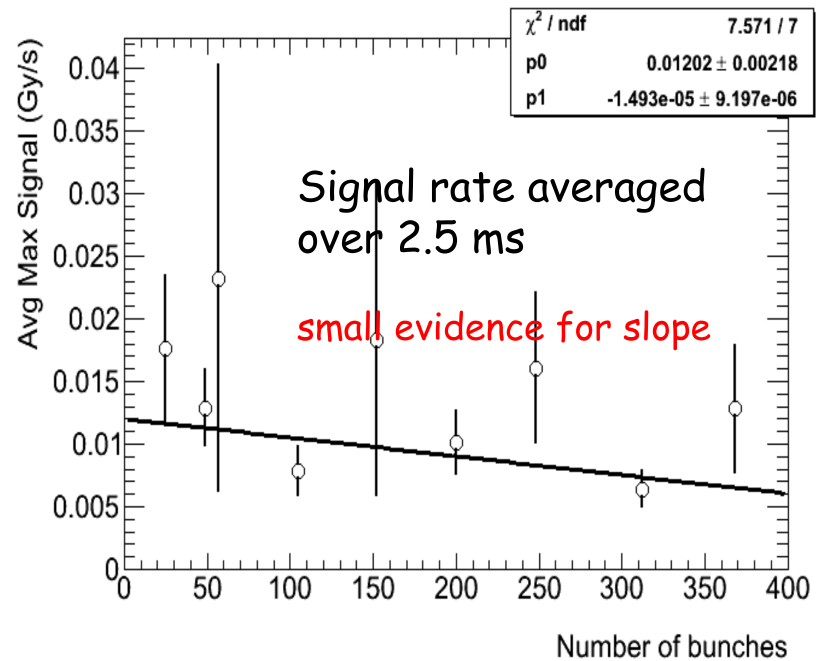


T_{loss} definition, proportional to loss duration measurements in postmortem

UFOs – signal amplitude

No dependence of maximum loss amplitude on beam intensity:





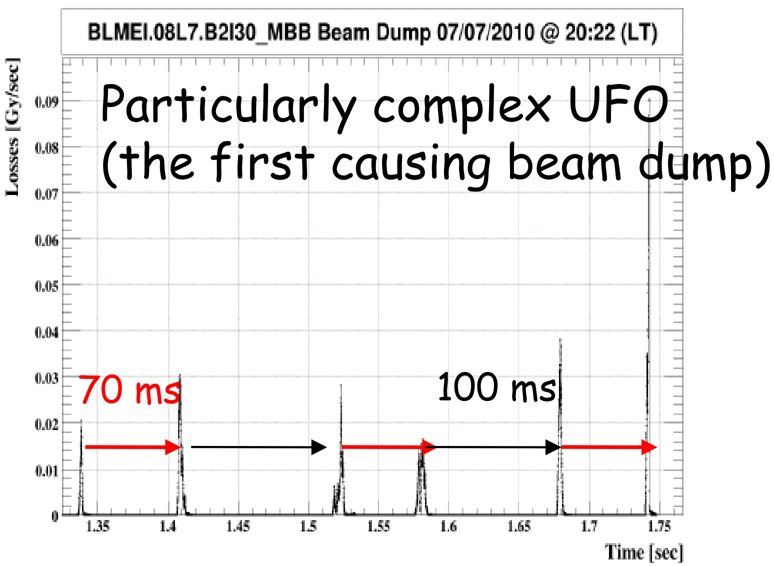
Maximum signal and average signal tendencies seem to agree with model.

Model gives predictions for higher intensities.

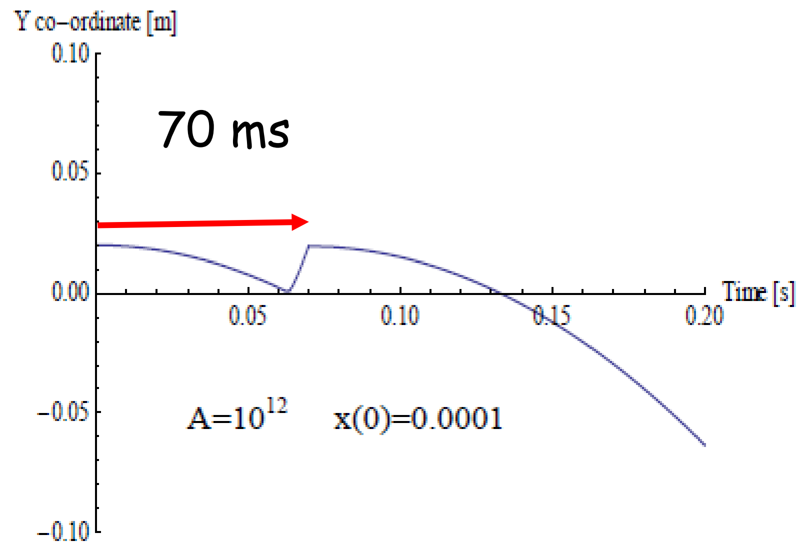
We need (and will get) more statistics!.

UFO – time structure

Some UFOs should have complex time structure, model predicts that UFO might be repelled and come back:



Long PM, Annika Nordt



<u>Plans to ameliorate the model:</u> Lorentz force, beam energy dependence

<u>Plans to for data analysis:</u> reduce condition to 2 BLMs, correlate with beam emittance, dispersion, beta-function, analysis of non-stable beams periods, correlate with vacuum (Brennan – no vacuum activity),

online analysis (UFO fixed display)

UFO – velocity

Using UFOs which dumped the beam and gave PM (18 events):

o) some have very gaussian shape (10 events)

o) gaussian fitted and assuming dust is smaller than the beam

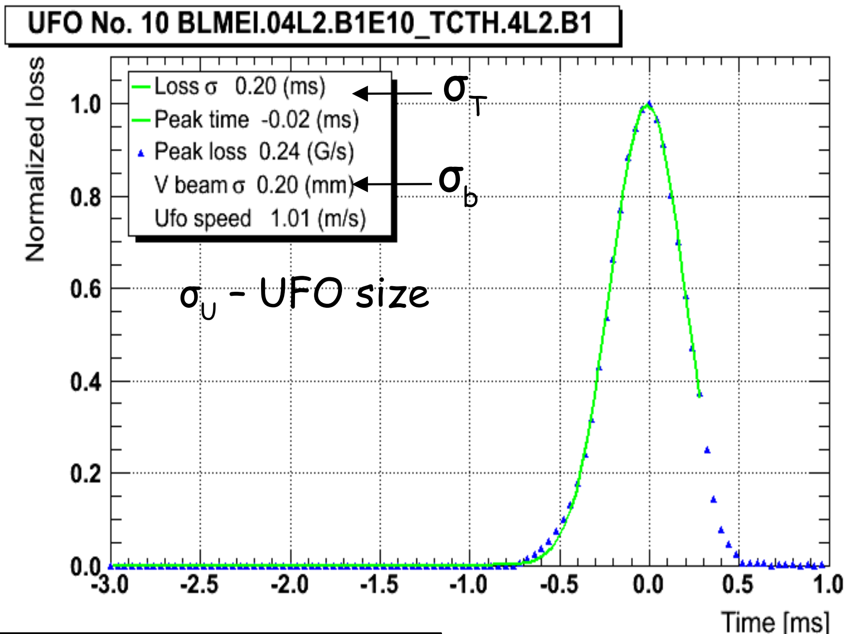
(UFOs are probing beam shape – like wire scanner - not inverse).

o) UFO speed:

$$v_U = \frac{\sigma_b}{\sigma_T} < \frac{\sqrt{\sigma_b^2 + \sigma_U^2}}{\sigma_T}$$

o) assumed emittance 3.5 μm

o) beta-function from loss location



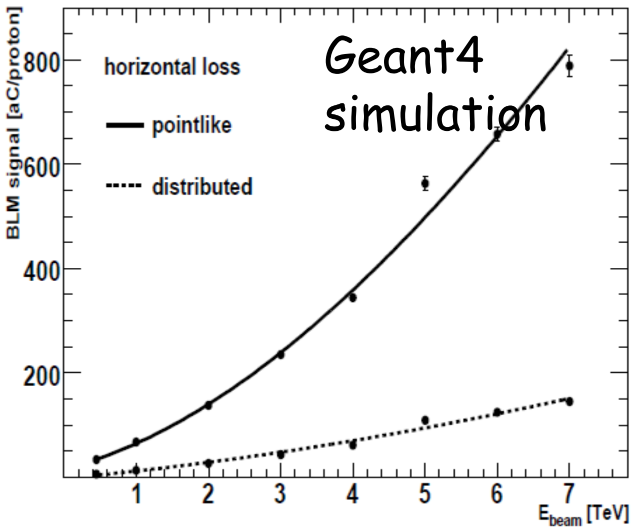
(Jorg Wenninger)

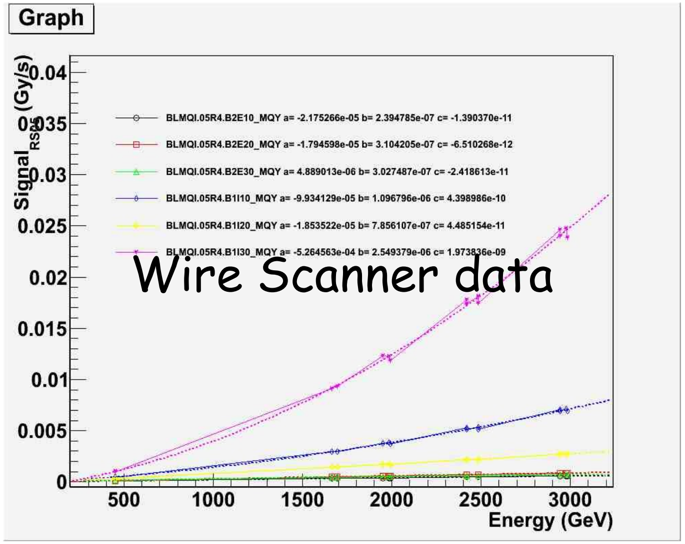
Estimated UFO speed is typically 0.4-4.5 m/s
(free fall speed 0.63 m/s)
- evidence of electromagnetic forces acting on dust?

UFO – avoiding beam dumps

Two possibilities:

o) scrubbing at 450 GeV – only 1 UFO has been detected at injection energy (680 bunches run), but it might be due to lower signal from UFO expected at lower beam energies (threshold effect in the analysis procedure):





o) increasing BLM thresholds for ms-scale losses

(last year the thresholds were already increased by factor 5 what allowed to avoid many dumps due to UFOs and did not lead to any quench)

UFO – BLM thresholds

BLM thresholds on cold elements:

quench limit — BLM signal — energy deposited in coil

$$T\,(E_b,L_s(x,y,z),L_t(t)) = \Delta Q\,(E_b,L_t(t)) * S_{BLM}\,(E_b,L_s(x,y,z))/E_d(E_b,L_s(x,y,z))$$

$L_s(x,y,z)$ – spatial distribution of loss
$L_t(t)$ – loss duration (or evolution timescale)
E_b – beam energy

o) S_{BLM} is measured and simulated, E_d is only simulated, but accuracy of this simulation is controlled by S_{BLM}.

o) quench limits ΔQ are best known for fast transient losses (cable enthalpy) and steady state losses (heat evacuation to cryogenic system) –

ΔQ in milisecond scale? →

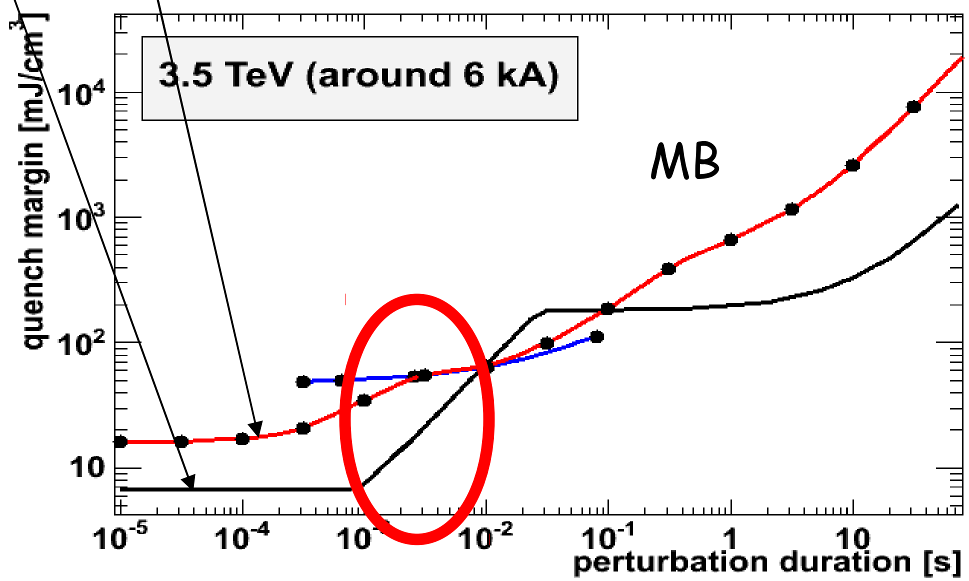
o) $L_s(x,y,z)$ corresponds beam impacting on the beam screen over many meters (240 μrad) – UFO is similar to loss generated by Wire Scanner →

UFO – quench limit at ms loss

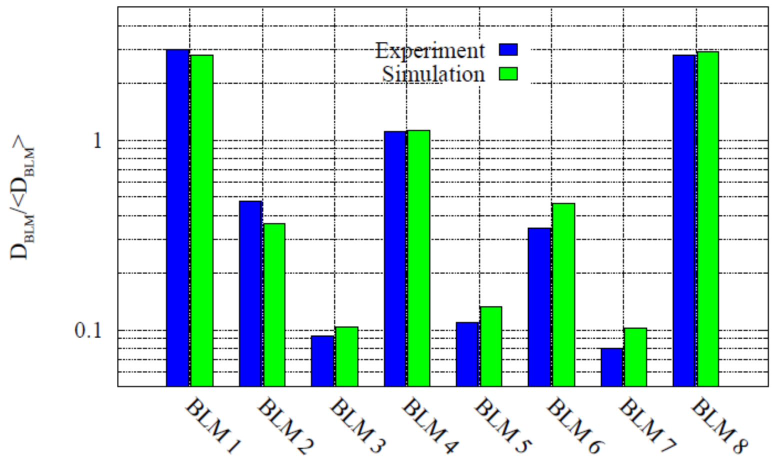
o) 2 models investigated: Note44 and QP3 (Arjan Verweij)

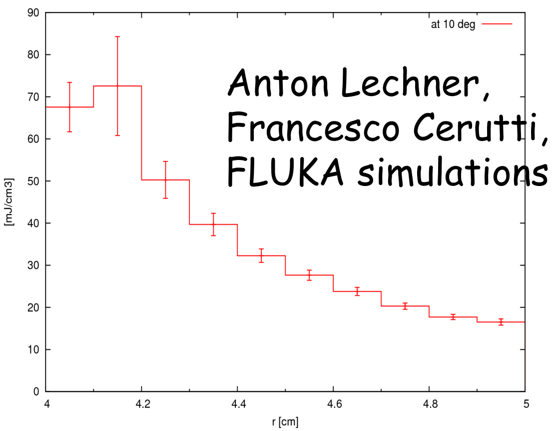
o) QP3 code introduces Helium cooling faster than Note44 parametrization

o) in order to check that: quench test with wire scanner, but the quench occured after about 20-45 ms...



very good agreement





Anton Lechner, Francesco Cerutti, FLUKA simulations

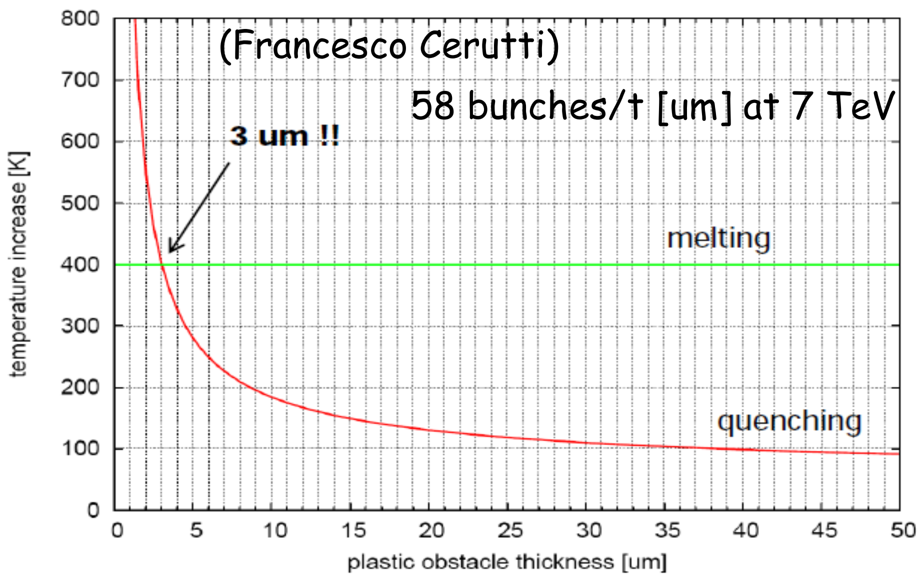
analysis ongoing but it would be very useful to repeat this test!

UFO – loss scenario

Nominal loss scenarios, used to compute current thresholds, are protons impacting on beam screen, stretched over many meters.

UFO: source very localized, but secondary particles travel far before hitting beam pipe.

Some studies done assuming objects falling through the beam



→ 1000 bunches/t [um] at 3.5 TeV (assuming only enthalpy margin)

368 bunches → t < 0.3 um

Studies ongoing to determine quench-protecting threshold in case of UFO losses.

Question: are BLMs installed only on quads enough to protect from UFOs once they start quenching?

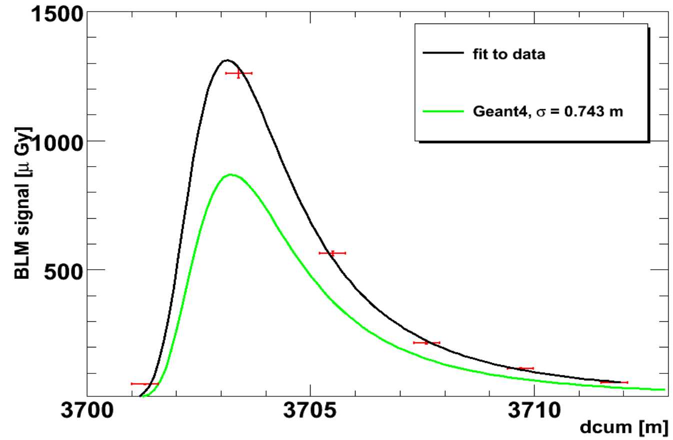
Thresholds – simulations and measurements

There were quench tests in 2008: for MB at 450 GeV and fast transient losses (injection and dump):

o) BLM signal underestimated by 50%

o) thresholds corrected for this discrepancy

o) need for test with longer losses, where heat transfer to helium is complex to model

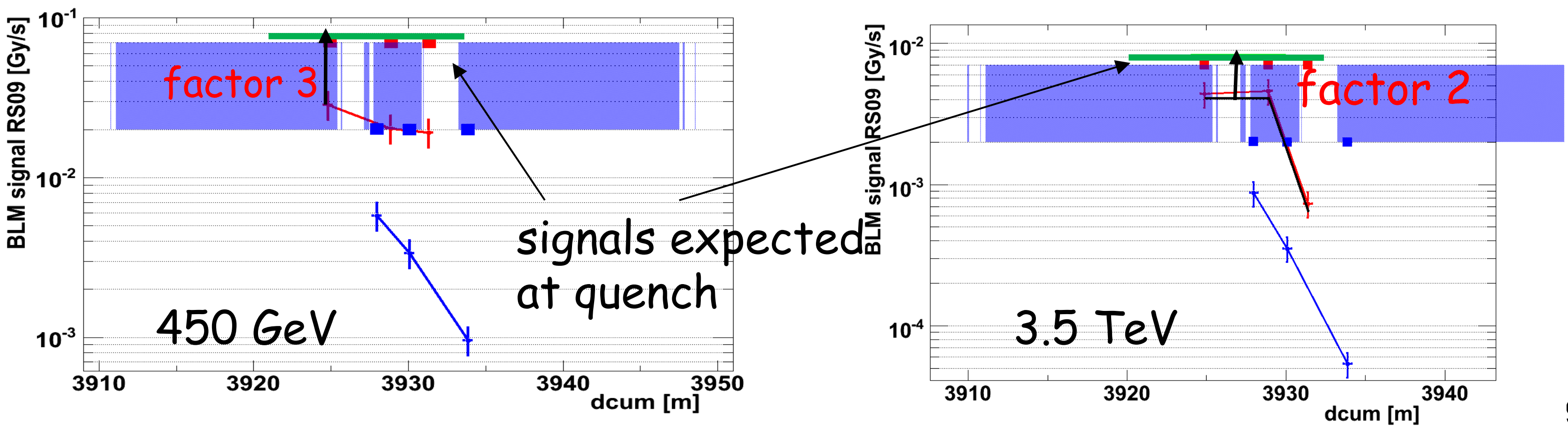


Quench tests 2010:

o) orbital bump technique

o) 1.5 s loss at 450 GeV and 5 s loss at 3.5 TeV

o) quenched MB and MQ at 450 GeV and MQ at 3.5 TeV



Thresholds - summary

Main conclusion:

o) thresholds for long losses on MQ magnets are underestimated by factor 2-3

o) detailed analysis ongoing (Agnieszka Priebe), because this effect is maybe due to different loss distribution assumed in threshold calculations

o) nevertheless we plan to revise thresholds on superconducting magnets, lowering thresholds for losses longer than 1 s and increasing the thresholds for ms-scale losses

(empirical corrections to existing model or follow QP3 quench margin calculations, if they agree with quench tests).

Thresholds - summary

<u>Main conclusion:</u>

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due to diffe alculations

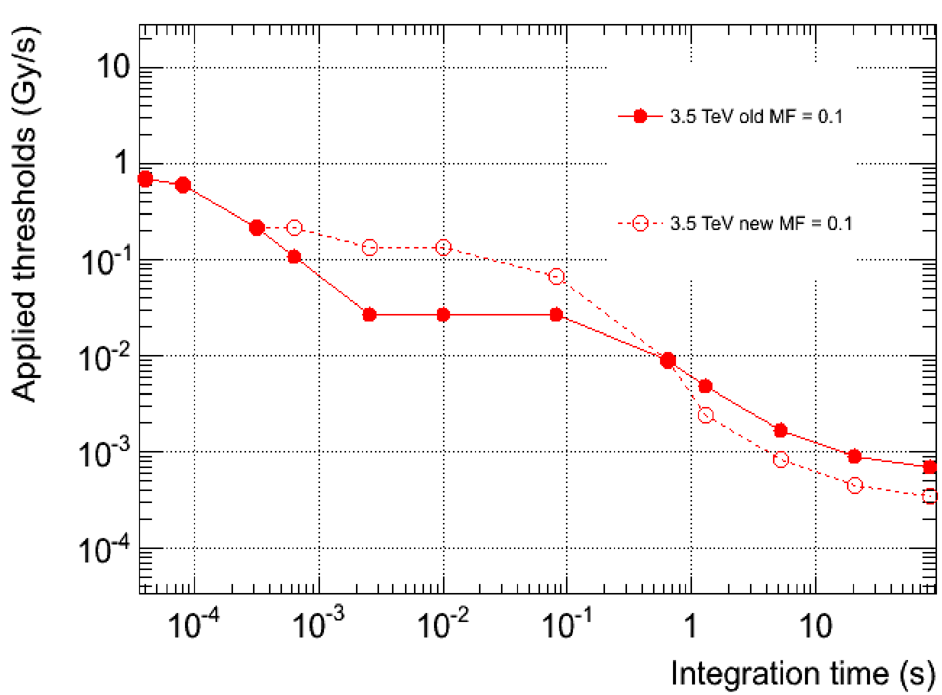
o) neverthieles cting

magnets, lowe increasing

the thresholds

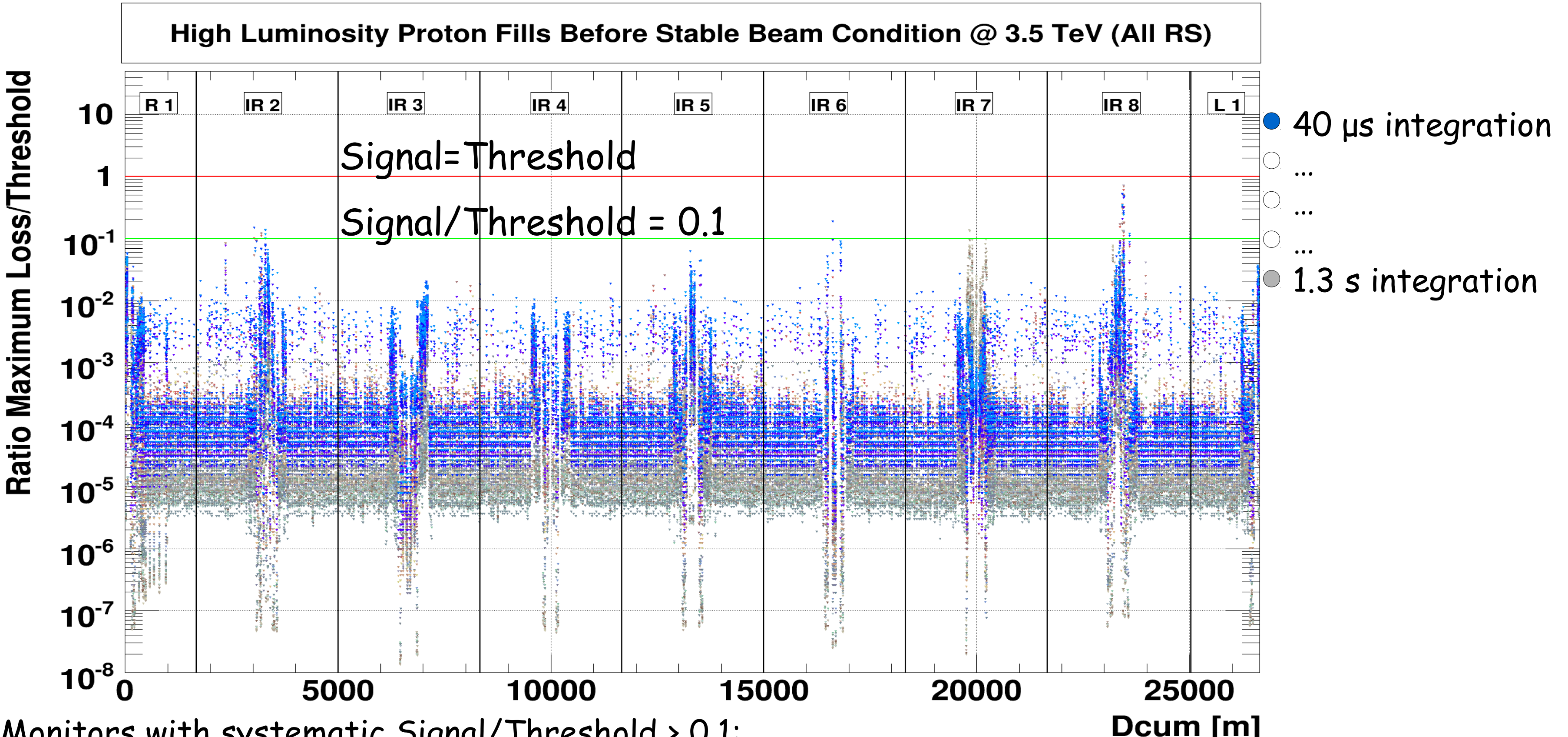
(empirical cor ich margin

calculations,



Thresholds

Max loss signal versus applied threshold before stable beams (Annika Nordt).
5 high lumi fills (1440, 1443, 1444, 1450 and 1453), 3.5 TeV.



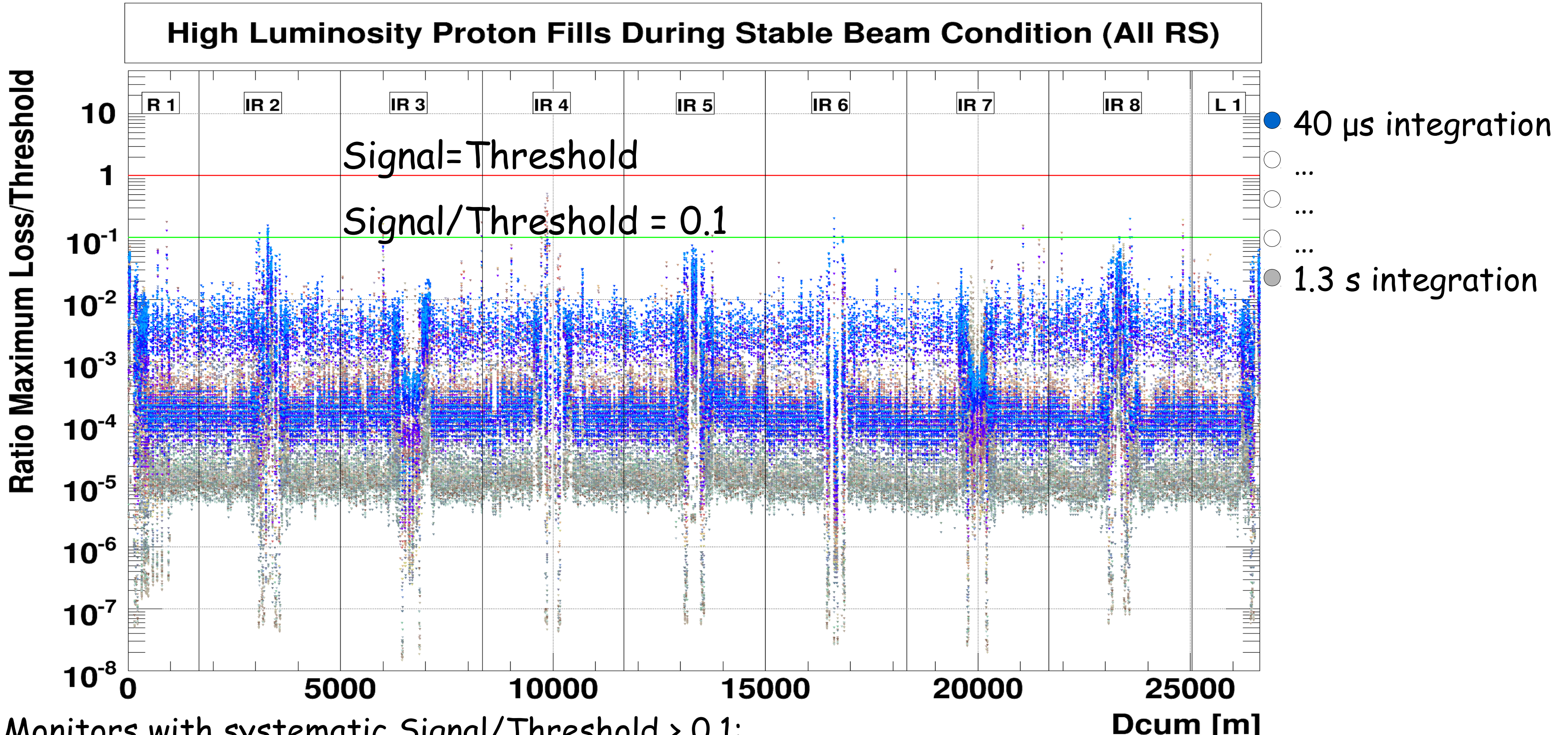
Monitors with systematic Signal/Threshold > 0.1:

BLMQI.02L2.B1E21_MQXB, BLMQI.07R8.B2E20_MQM, BLMQI.04R8.B2E20_MQY

BLMEI.04R8.B2E10_TCTH.4R8.B2

Thresholds

Max loss signal versus applied threshold during stable beams (Annika Nordt).
5 high lumi fills (1440, 1443, 1444, 1450 and 1453), 3.5 TeV.



Monitors with systematic Signal/Threshold > 0.1:

BLMEI.04L6.B1E10_TCDSA.4L6.B1, BLMEI.04R6.B1E10_TCDQA.B4R6.B1

Triplet monitors in 01L2, 02L2 and 03L2

for ion beam situation looks better

Conclusions

Losses are generally understood, but:

o) There are single cases of not understood high losses – regular (overinjection) or irregular

o) There are locations where small, accumulated losses vary between stable fills - not understood

o) In general they should not affect 2011 operation from BLM point of view

UFOs:

o) UFO signal amplitude: no dependence on beam intensity therefore it should be possible to run LHC at 2011 intensities with increased cold magnets threshold in ms scale

o) In case of beam energy increase (4TeV) we might get UFOs which quench (ΔQ down by 15%, Edep up by 20%, margin to quench down by 30%)

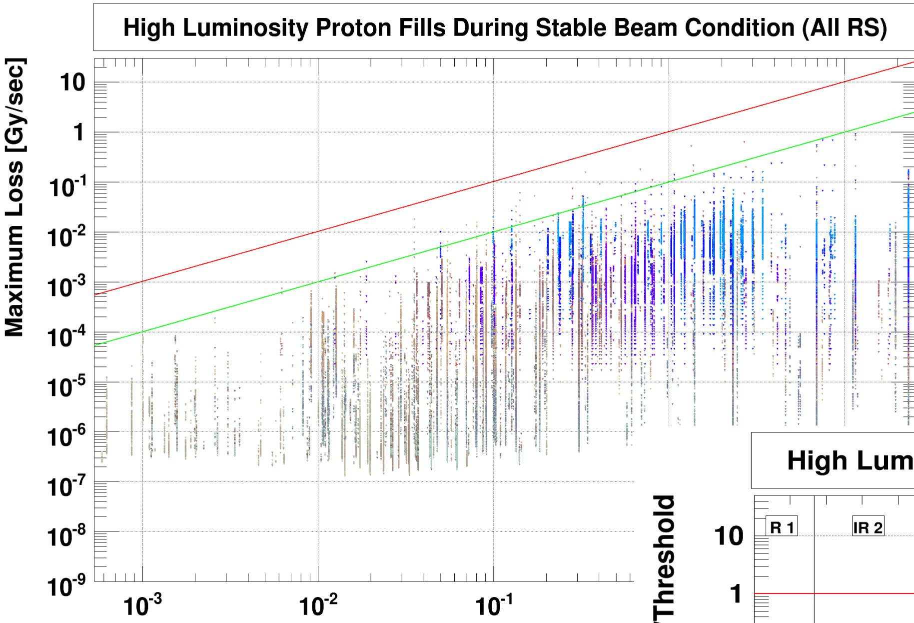
BLM thresholds:

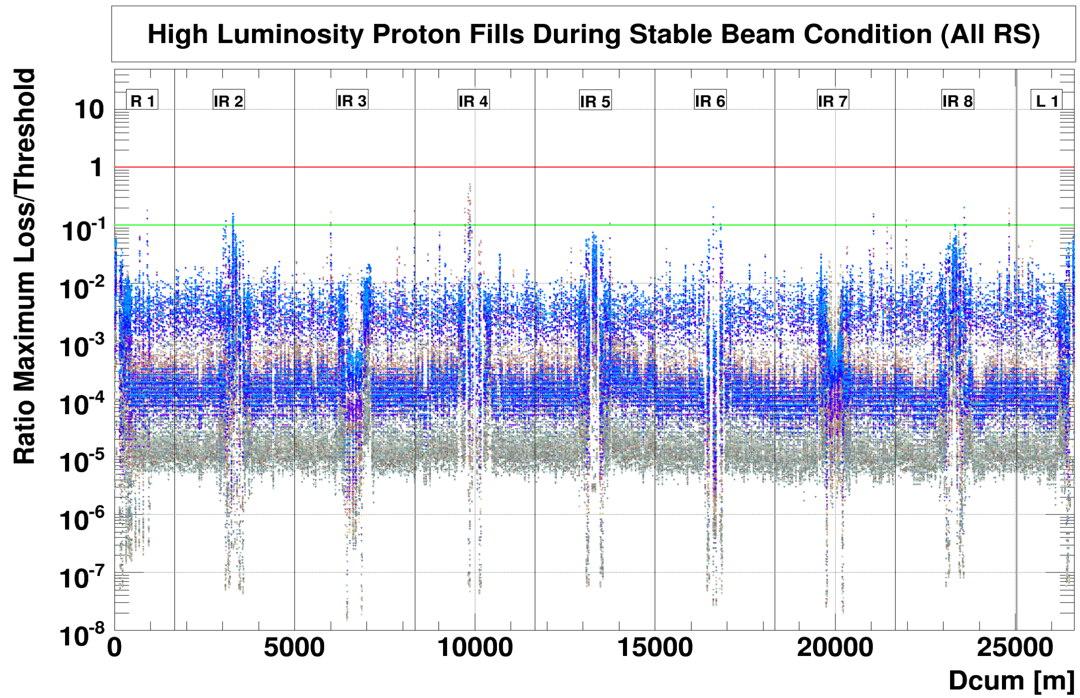
o) Some close to losses especially before stable beam period

o) Cold magnets – modified to accommodate quench test results and UFO losses.

Thresholds

Max signal vs. threshold during stable beams (Annika Nordt)

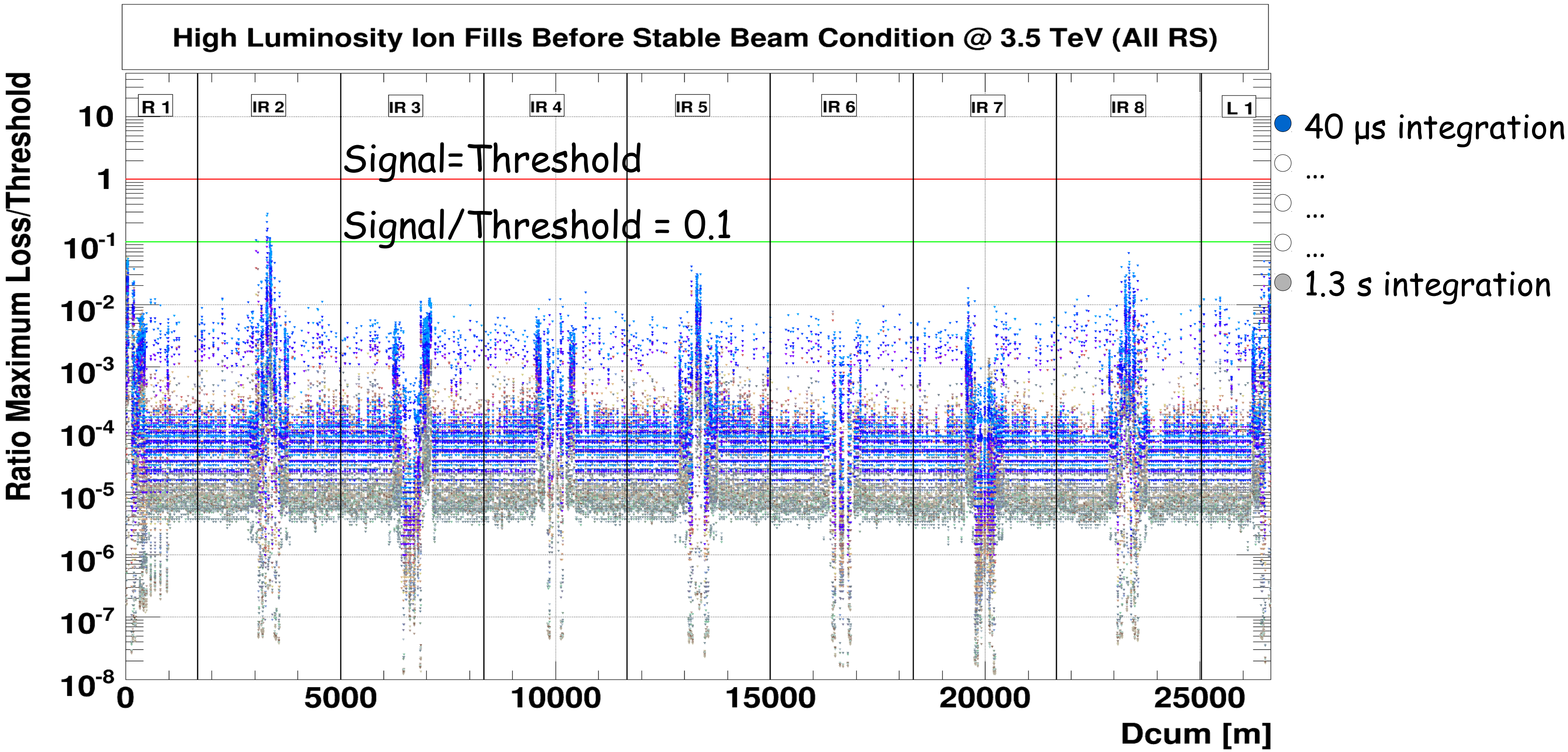




for ion beam
situation looks better

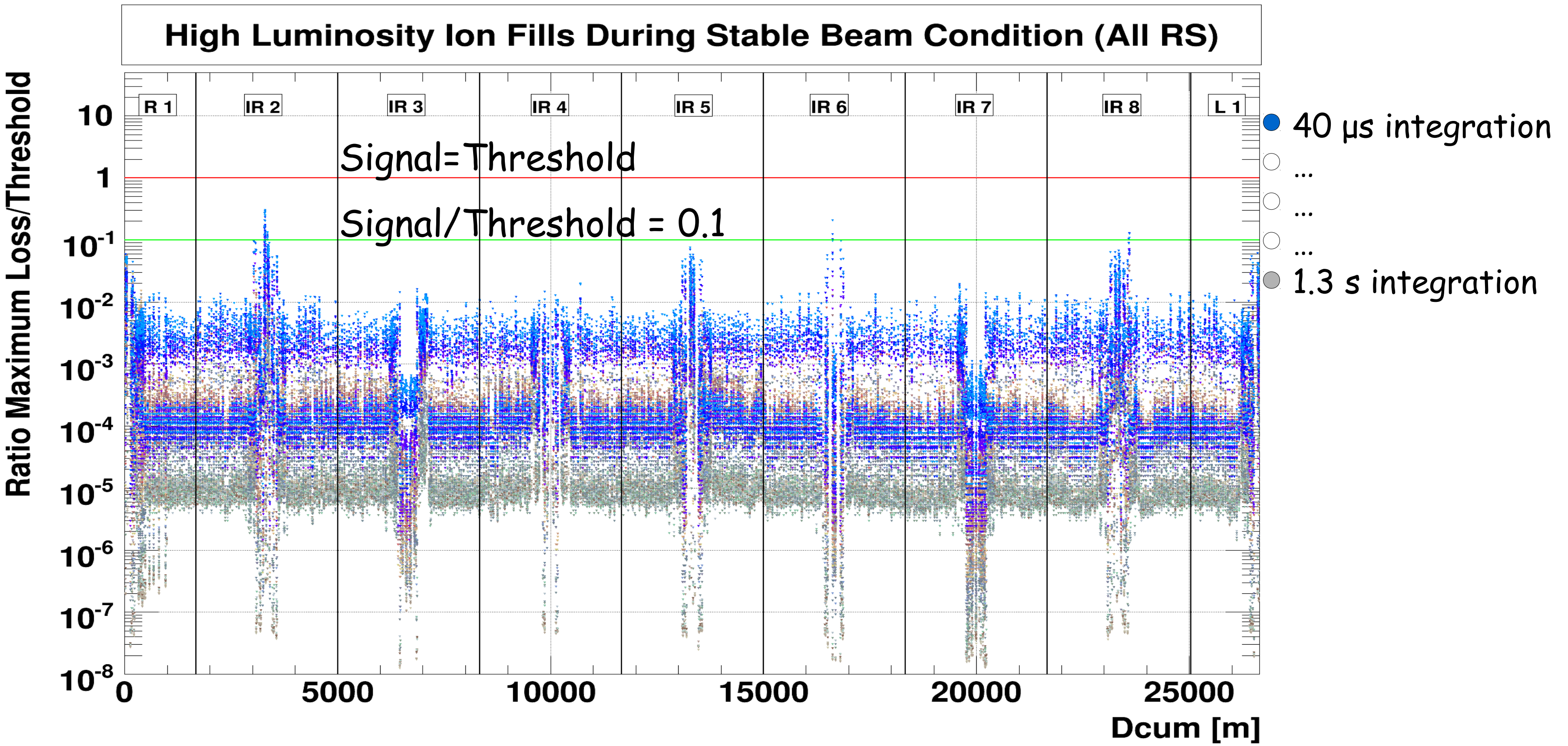
Thresholds - ion beams

Max loss signal versus applied threshold before stable beams (Annika Nordt).
High lumi fills, 3.5 ZTeV.

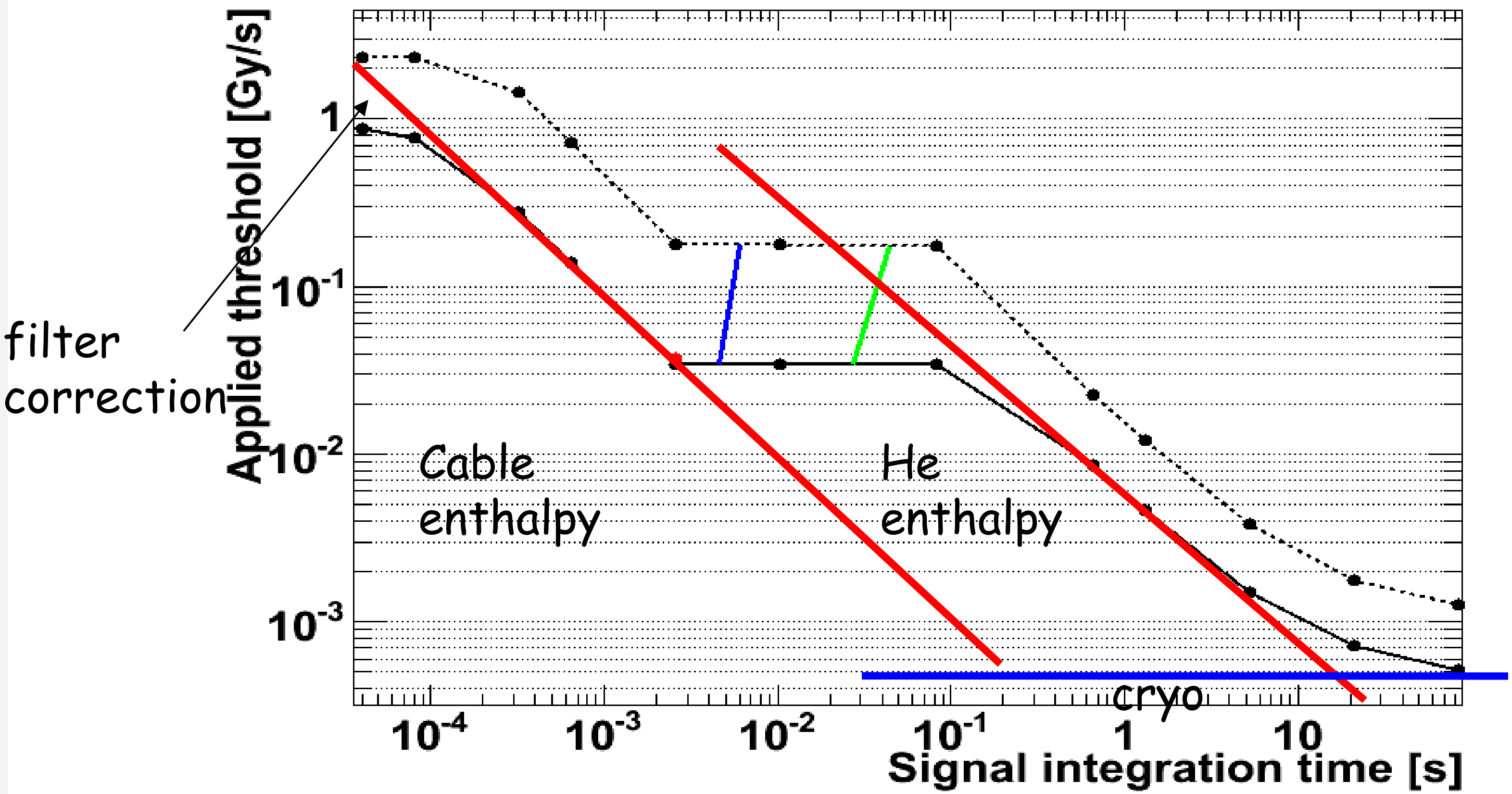


Thresholds - ion beams

Max loss signal versus applied threshold during stable beams (Annika Nordt).
High lumi fills, 3.5 ZTeV.



Note44 algorithm:



Extra slides

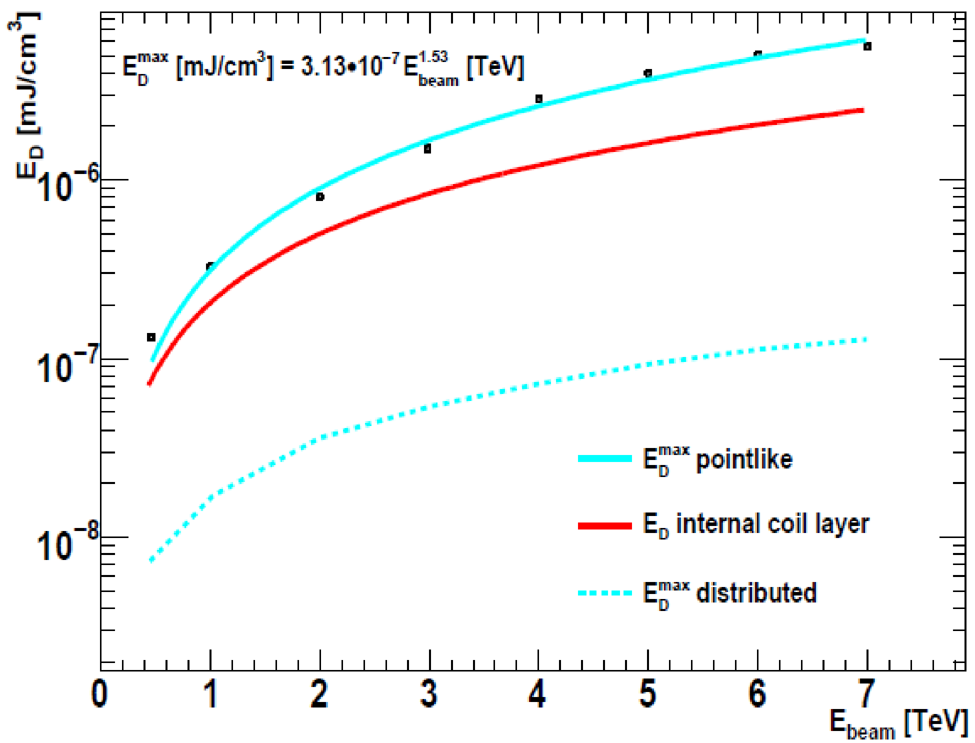
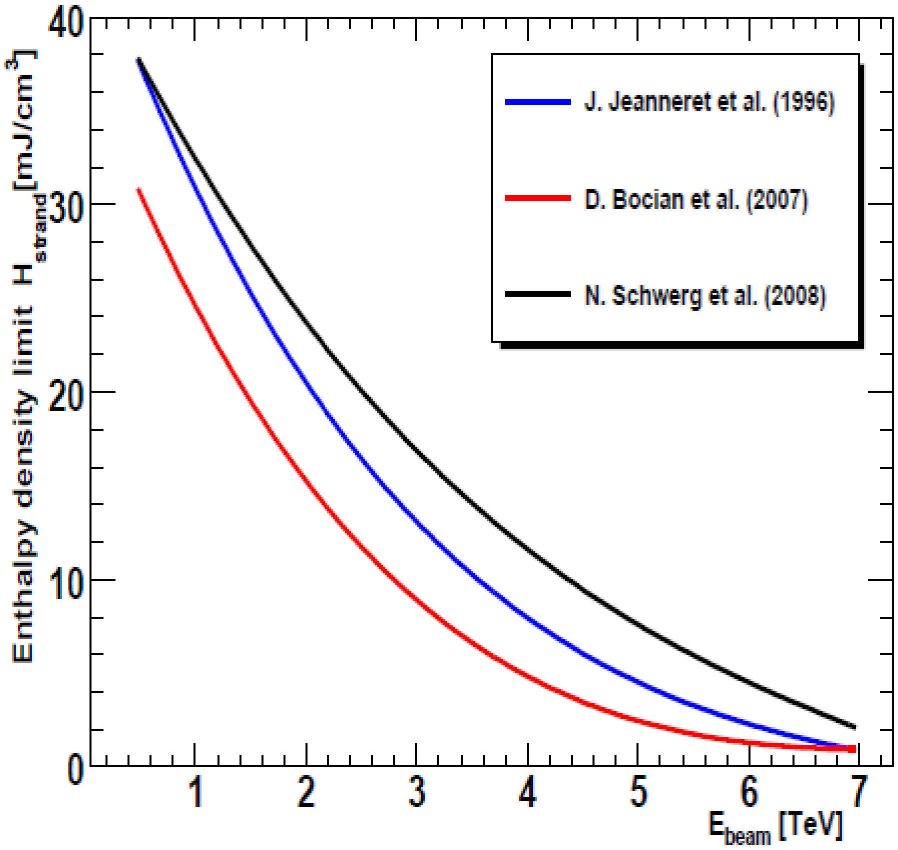
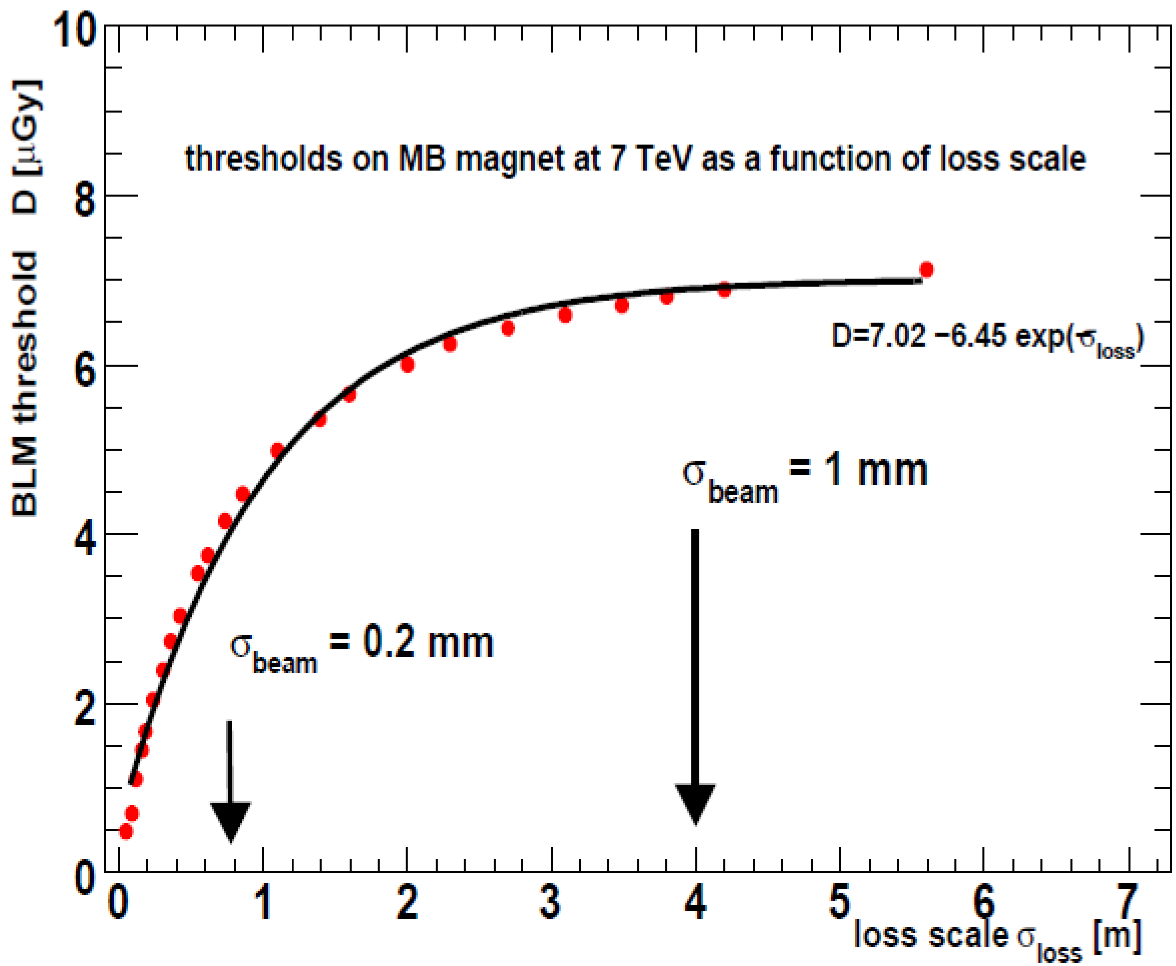


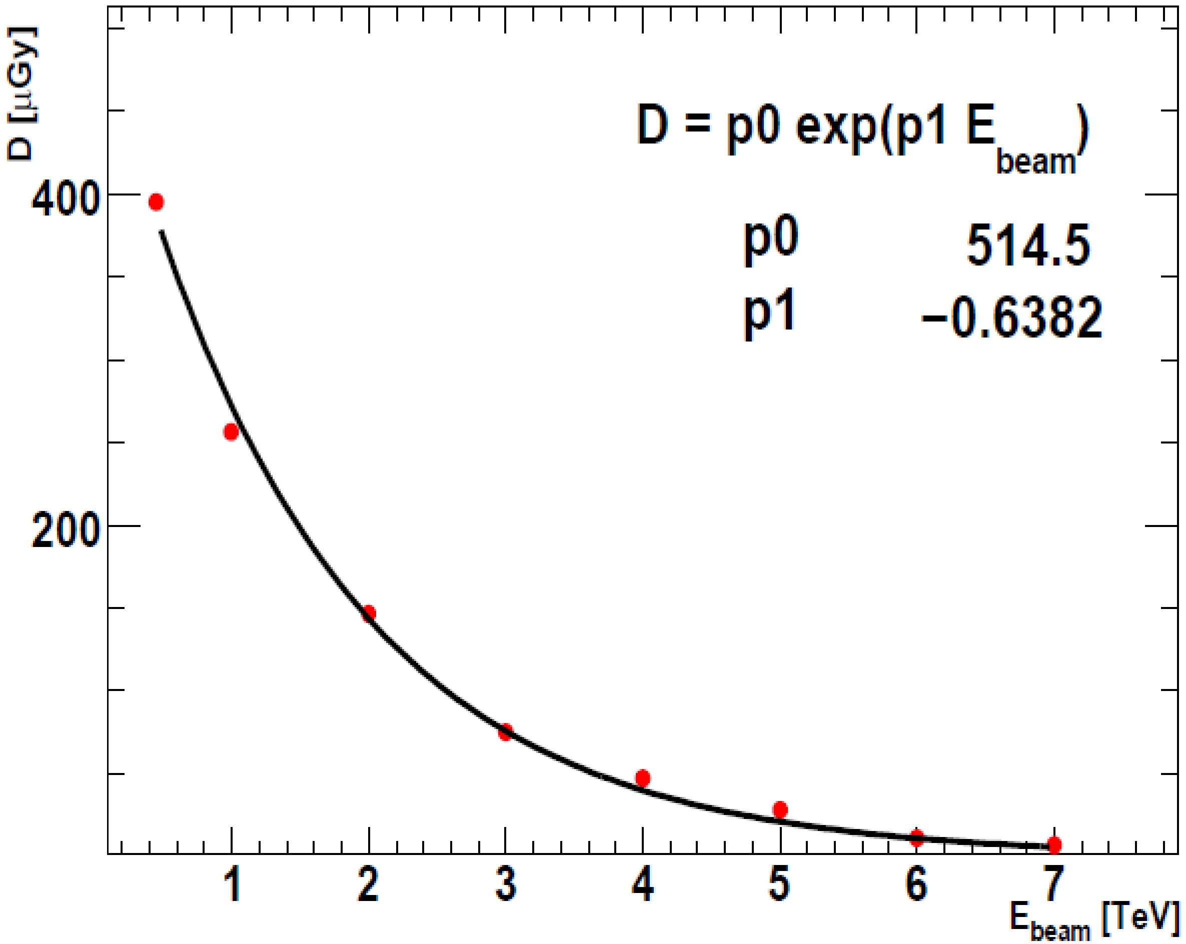
Figure 7: *The plot shows the evolution of the energy deposition in the coil with the impacting proton energy. The red curve presents the evolution in the most inner bin of the coil, the blue shows the extrapolated maximum energy deposition which takes place at the inner surface of the coil and the dashed line shows the deposition for the distributed losses.*

Extra slides




thresholds on MB magnet at 7 TeV as a function of loss scale
BLM threshold D [μGy]
D=7.02 −6.45 exp(σloss)
σbeam = 1 mm
σbeam = 0.2 mm
loss scale σloss [m]
0
2
4
6
8
10
1
3
5
7

Extra slides



Empirical correction to Note44 algorithm: