Energy deposition with and without IR3 upgrade

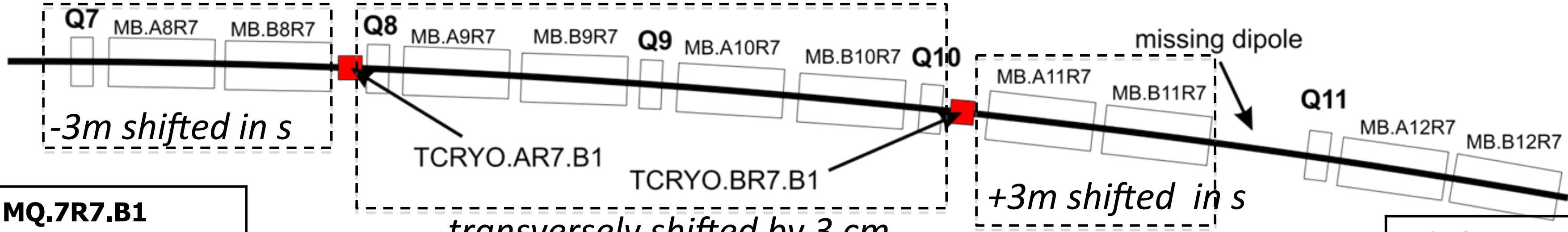
Predicted energy deposition with and without IR3 (IR7) dispersion suppressor collimators. Gain from collimators. Performance reach from comparing peak heat deposition with quench limit. Comparison with MD results.

Outline:

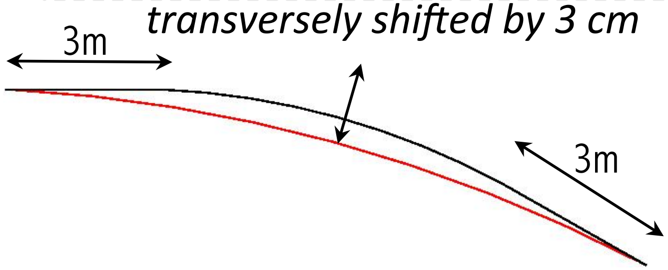
- Benefit of the DS collimator for the (peak) power deposition on the super conductive coils and cables of the magnets in the DS;
- Short discussion of the May 8th/9th MD (quenching test);

Vittorio Boccone for the FLUKA Team (EN/STI)

Impact of the DS-collimator



MQ.7R7.B1
MQTLI.7R7.B1
MCBCH.7R7.B1
MCDO.8R7.B1
MB.A8R7.B1
MCS.A8R7.B1
MB.B8R7.B1
MCS.B8R7.B1



old DS-collimator configuration R. Assmann '09

MCDO.11R7.B1
MB.A11R7.B1
MCS.A11R7.B1
MB.B11R7.B1
MCS.B11R7.B1

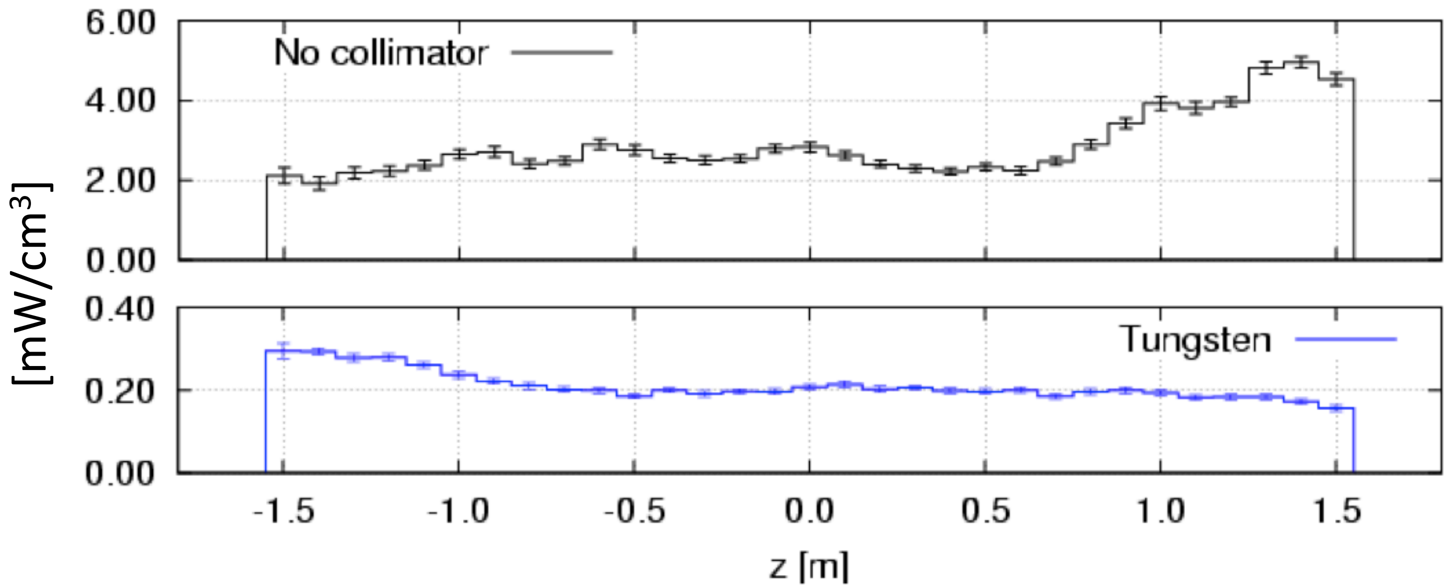
- The impact of the DS collimator (alias TCLD and formerly know as TCryo) as studied in the case of IR7 (2009 and 2010) at 7 TeV, nominal LHC (0.2h lifetime);
- The scenario in IR3 is slightly different as the TCLD and Q10 are now swapped;
- The differences do not change the overall effects of protection of the DS elements. For this reason the results for IR7 can still be considered "valid" from a point of view DS-power load and peak power on the coils of the downstream magnets.

Impact of the DS-collimator

Peak Power on superconductive coils in IR7 (2009)

- The benefits of the DS collimator from the point of view of the reduction of the peak power in the superconductive coils of the magnets were shown by F.Cerutti at the CDR LHC Phase II *Collimation*, April 2nd *2009* (DS in IR7, only horizontal losses)*;*
- The beneficial effect of the DS collimator were quantified. Peak power is below (but not far from) the quench limit. The 1.5 factor for the ultimate intensity does not change the picture.

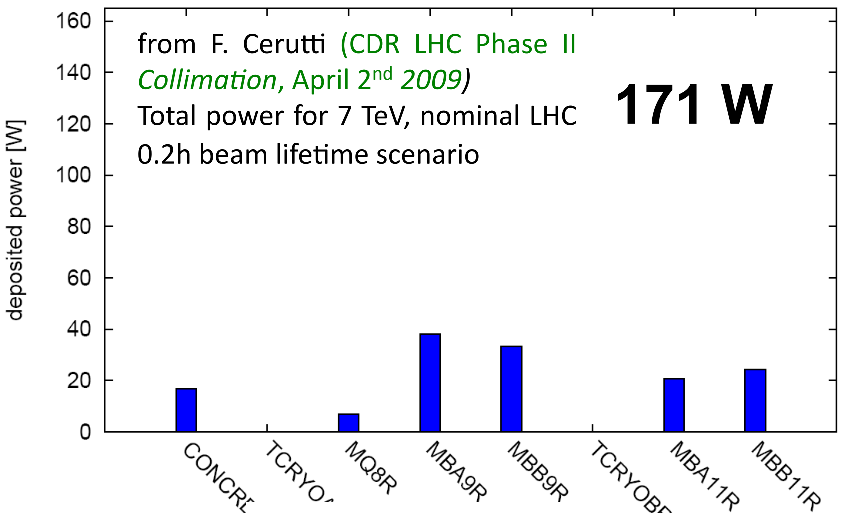
Peak Power along the MQ.8R7 (7 TeV, 0.2h beam lifetime, LHC nominal)



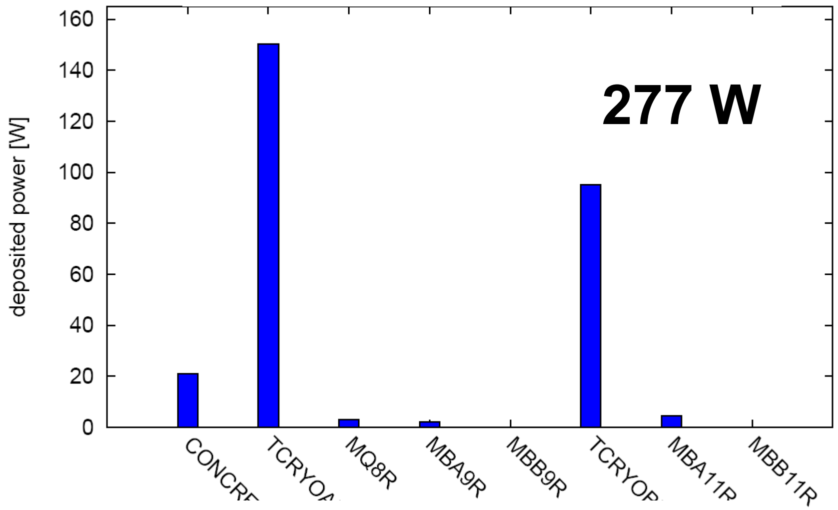
Impact of the DS-collimator

Power Impacting on the DS (IR7)

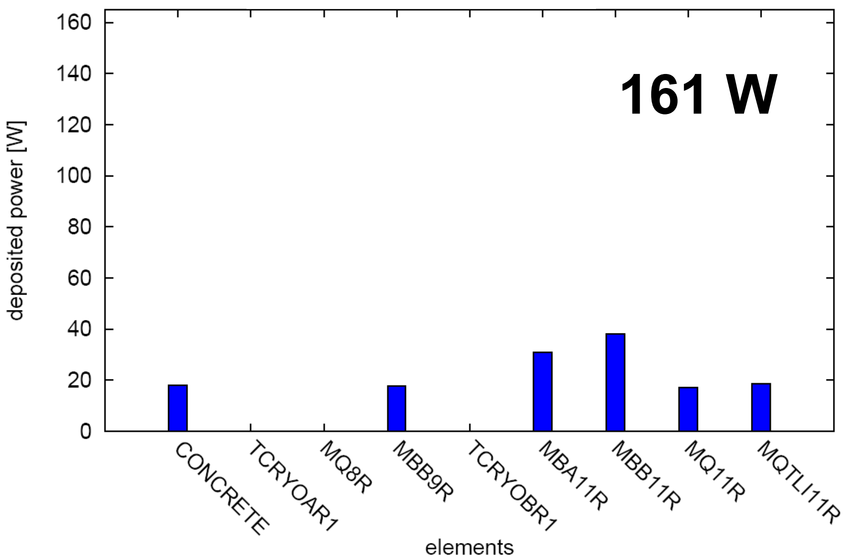
protons, no DS coll.



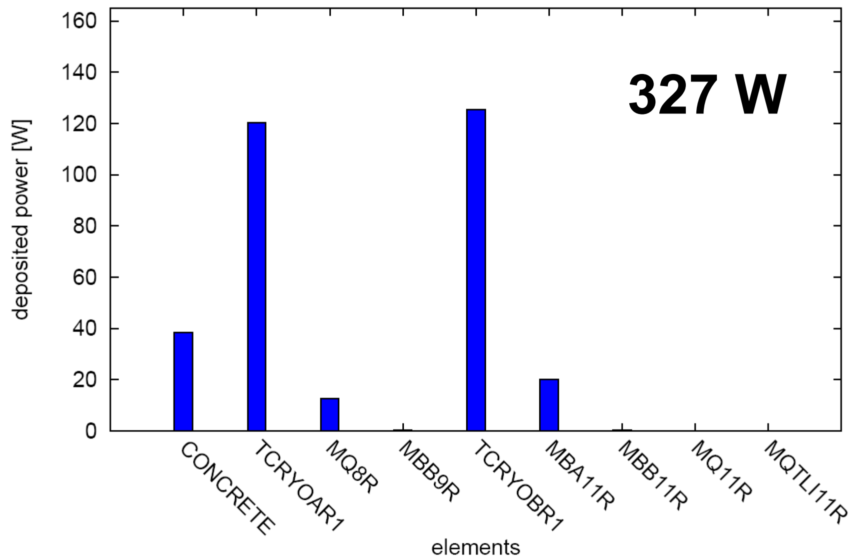
protons, DS coll. in tungsten @15σ



Pb-ions, no DS coll.



Pb-ions, DS coll. in copper @15σ



A recall to the conclusions of 2009

- For the LHC proton beam, the addition of the TCLDs is expected to decrease the predicted peak power in the superconducting coils of the DS magnets by a factor from 5 (1m copper jaws) to 15 (1m tungsten jaws), which is critical for quench occurrence;
- The total load on the cold magnets is decreased as well;
- The benefits are not strongly dependent on the TCLD aperture (provided that it is not too large);
- The reduction is even more significant for the lead beam (a factor of 10 with 1m Cu jaws);

Possible issues:

- The 2009 loss maps (IR7) was only including protons SD from the horizontal TCP;
- The 2011 loss maps (IR3) show a non negligible contribution of vertical component.

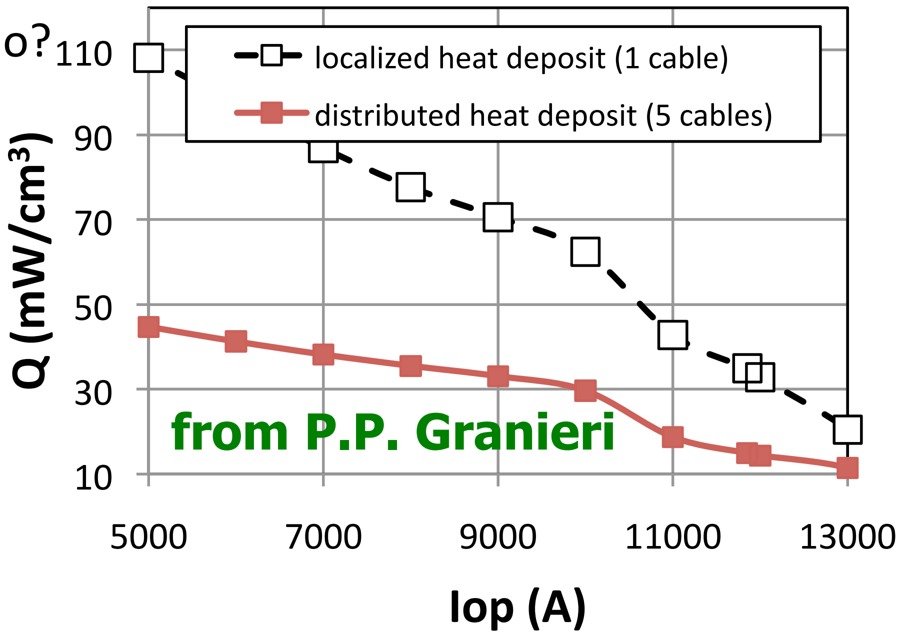
Few consideration about the May 8th/9th MD

For a detailed analysis, description and discussion of the May 8th/9th MD
- D.Wollman "Collimation setup and performance" (morning session);
- A.Rossi "Proton beam performance with and without IR3 upgrade" (about an hour ago).

MD was on beam2 and (DS.left) but we have only the loss maps for beam1 (DS.right).
Question we try to answer only using FLUKA and the collimator loss map from SixTrack:
- Where do we lose the protons?
- Which was the power deposited on the magnets?
- Are we compatible with the non quench scenario?

Quenching limits assumptions (MB/MQ)?
- 3.5 TeV (I=6 kA) $P_{peak} \approx 41$ mW/cm^3;
- 7 TeV (I=12 kA) $P_{peak} \approx 15$ mW/cm^3;

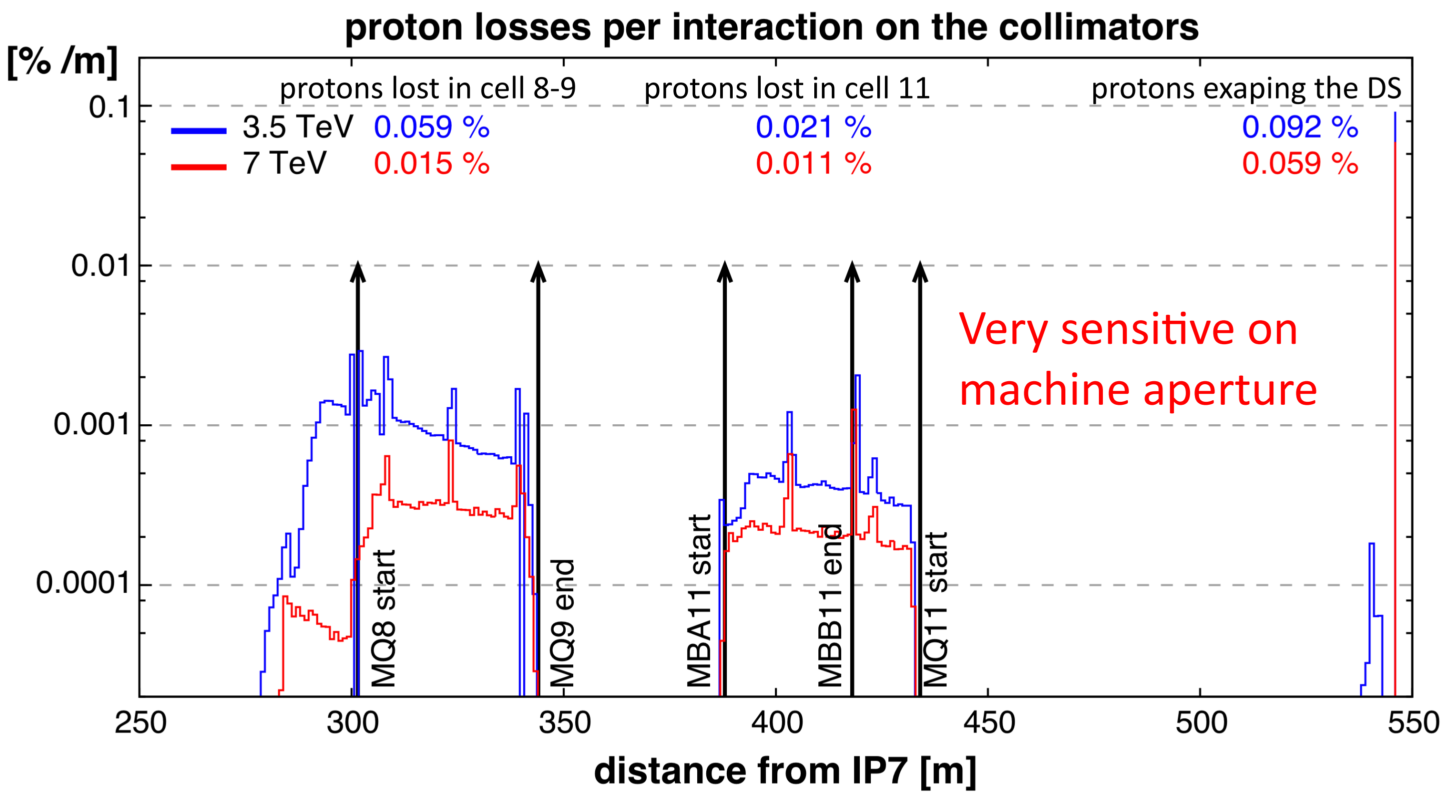
Estimated through the results of heat transfer measurements, in case of localized and distributed loss (courtesy of P.P. Granieri and E. Todesco).



Proton loss pattern in IR7 DS.R

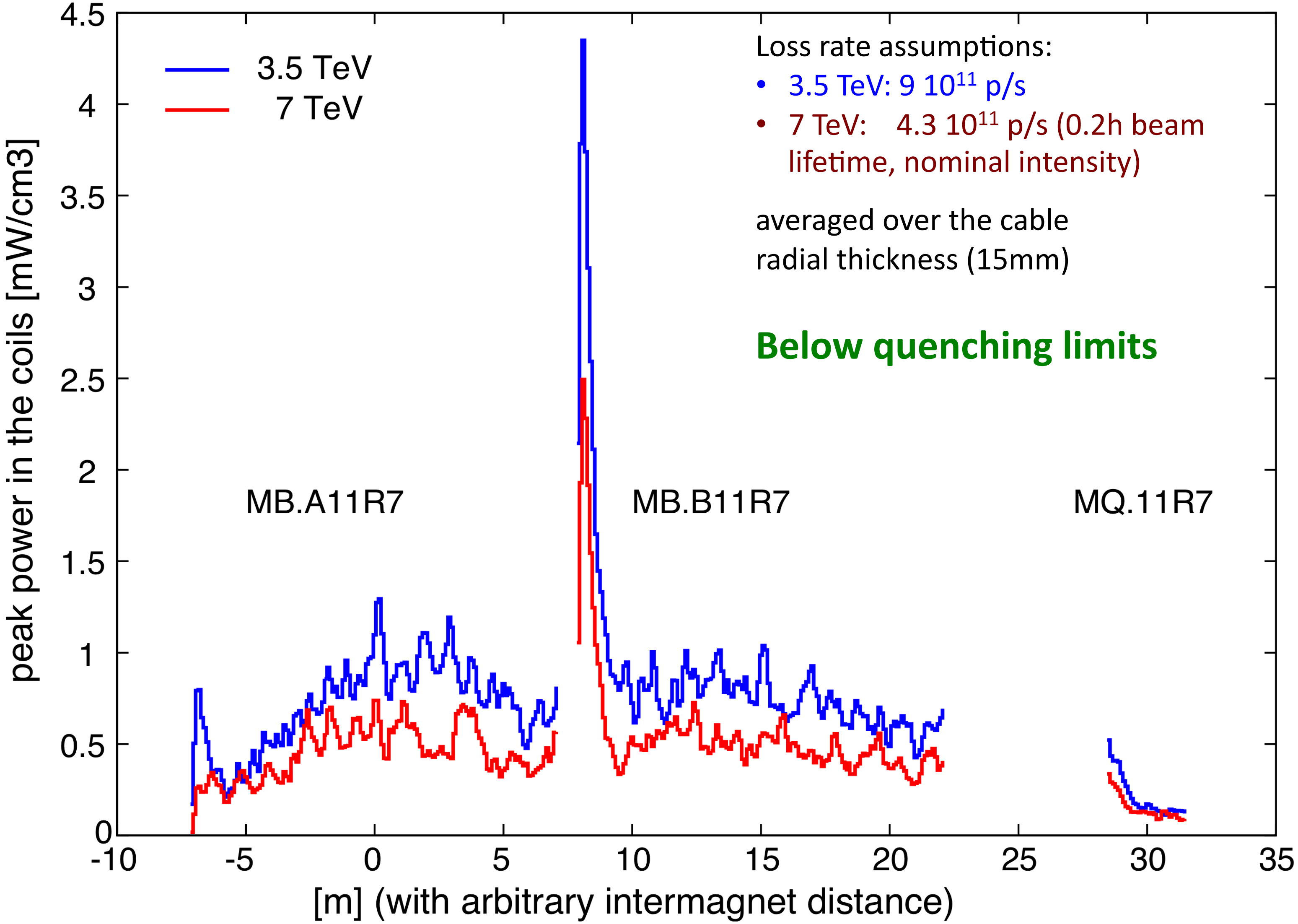
FLUKA tracking from the impact maps on the primary collimators (provided by SixTrack only horizontal halo):

- E=3.5 TeV intermediate collimator settings (R. Bruce, Nov. 2010), 10 μm mean impact parameter in the TCP.C6L7.B1
- E=7 TeV nominal (tight) collimator settings (Jul. 2009), 20 μm mean impact parameter in the TCP.C6L7.B1



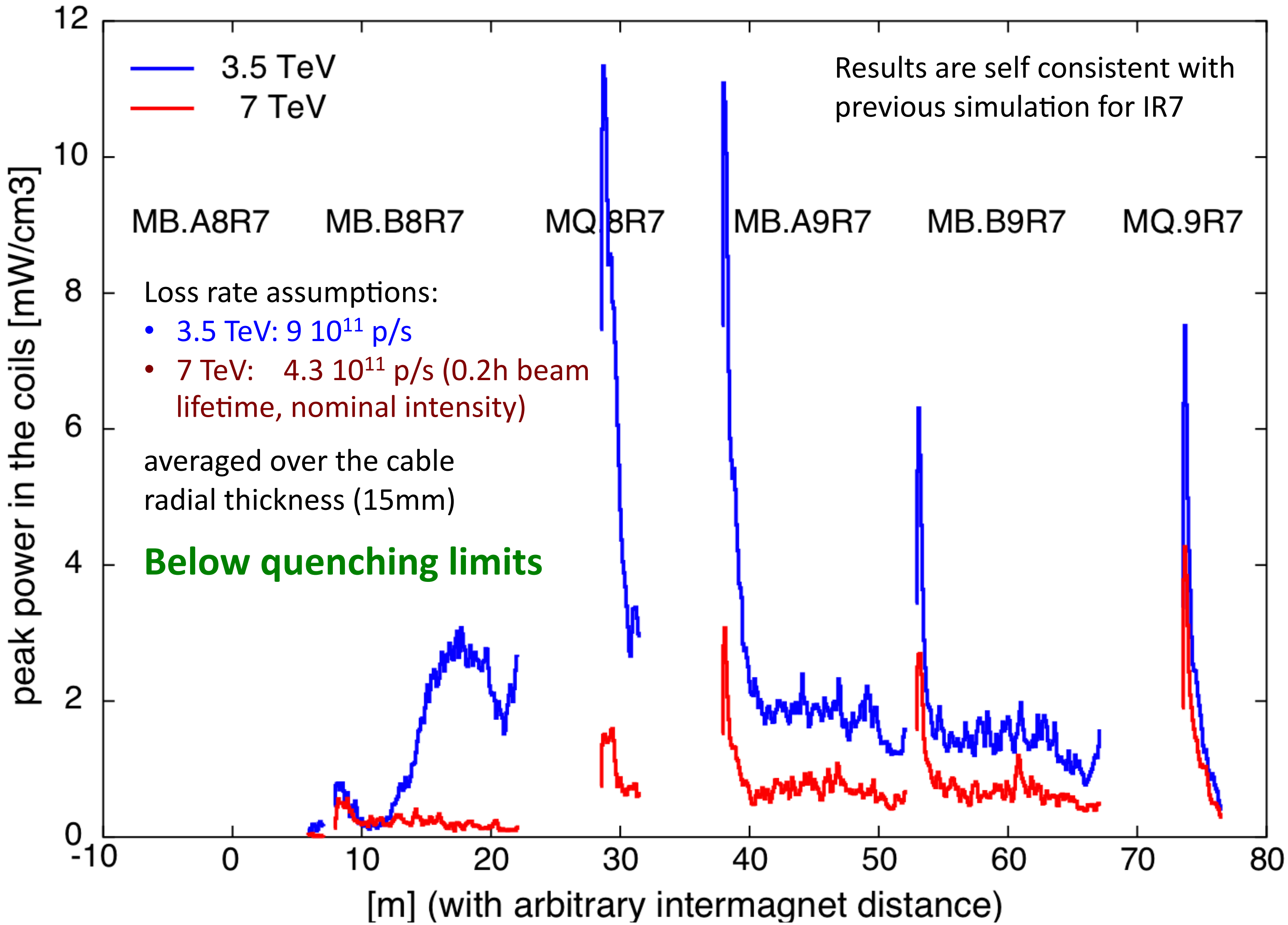
Few consideration about the May 8th/9th MD (3/5)

Peak Power profile in sector 11



Few consideration about the May 8th/9th MD (4/5)

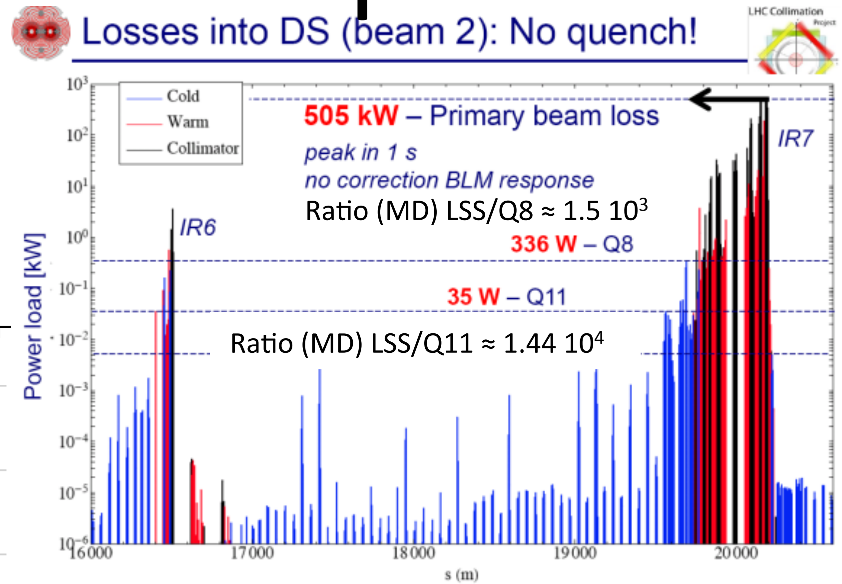
Peak Power profile in sector 8-9

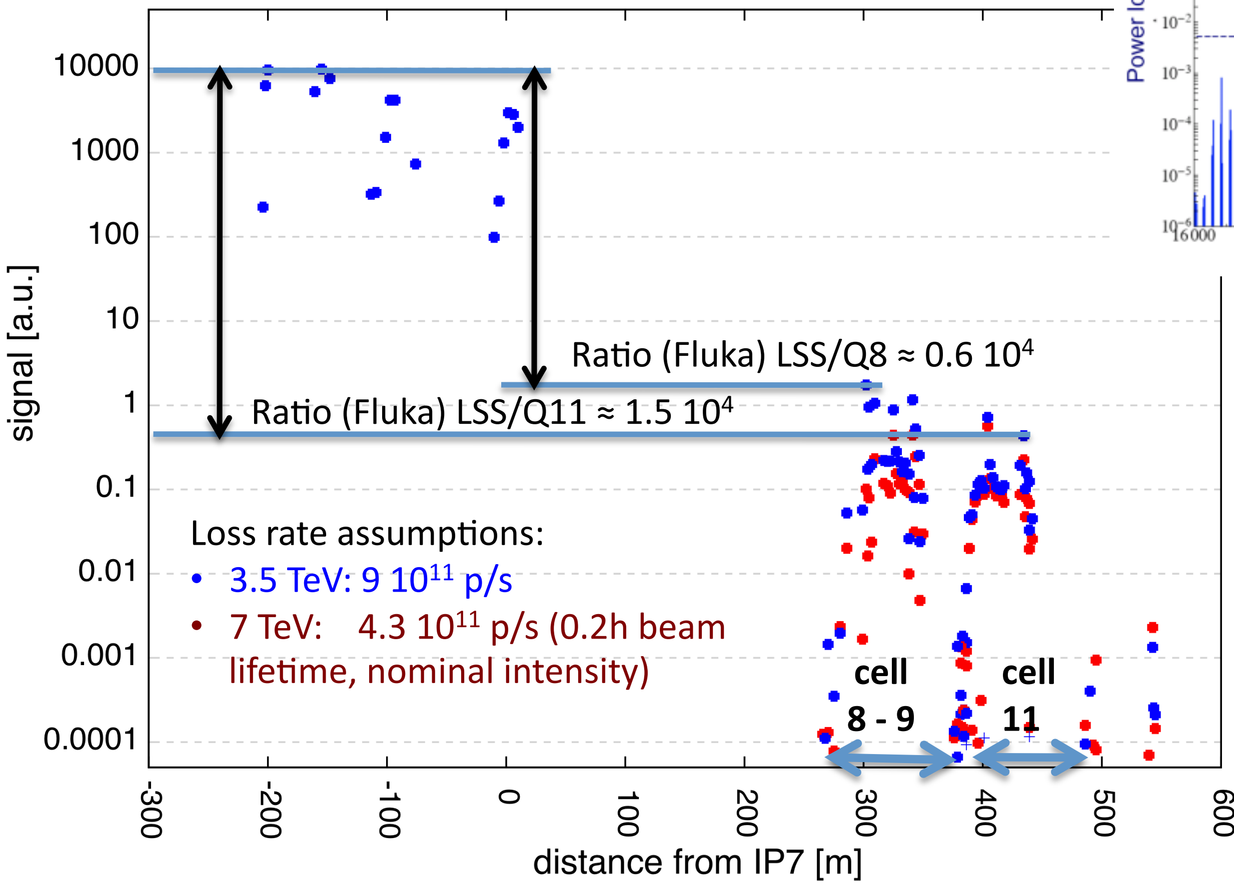


Losses in the DS and BLM pattern

Preliminary comparison (only local proton power deposition) between BLM pattern and Fluka calculation.

- MD was on B2 (IR7 left) while we had loss maps only for B1 (IR7 right) => Possible issues with asymmetry in BLM positions.





BLM signal Ratio	MD 8th/9th May '11	Fluka Calculations
LSS/Q11	$1.44\ 10^4$	$1.5\ 10^4$
LSS/Q8	$1.5\ 10^3$	$6.0\ 10^3$

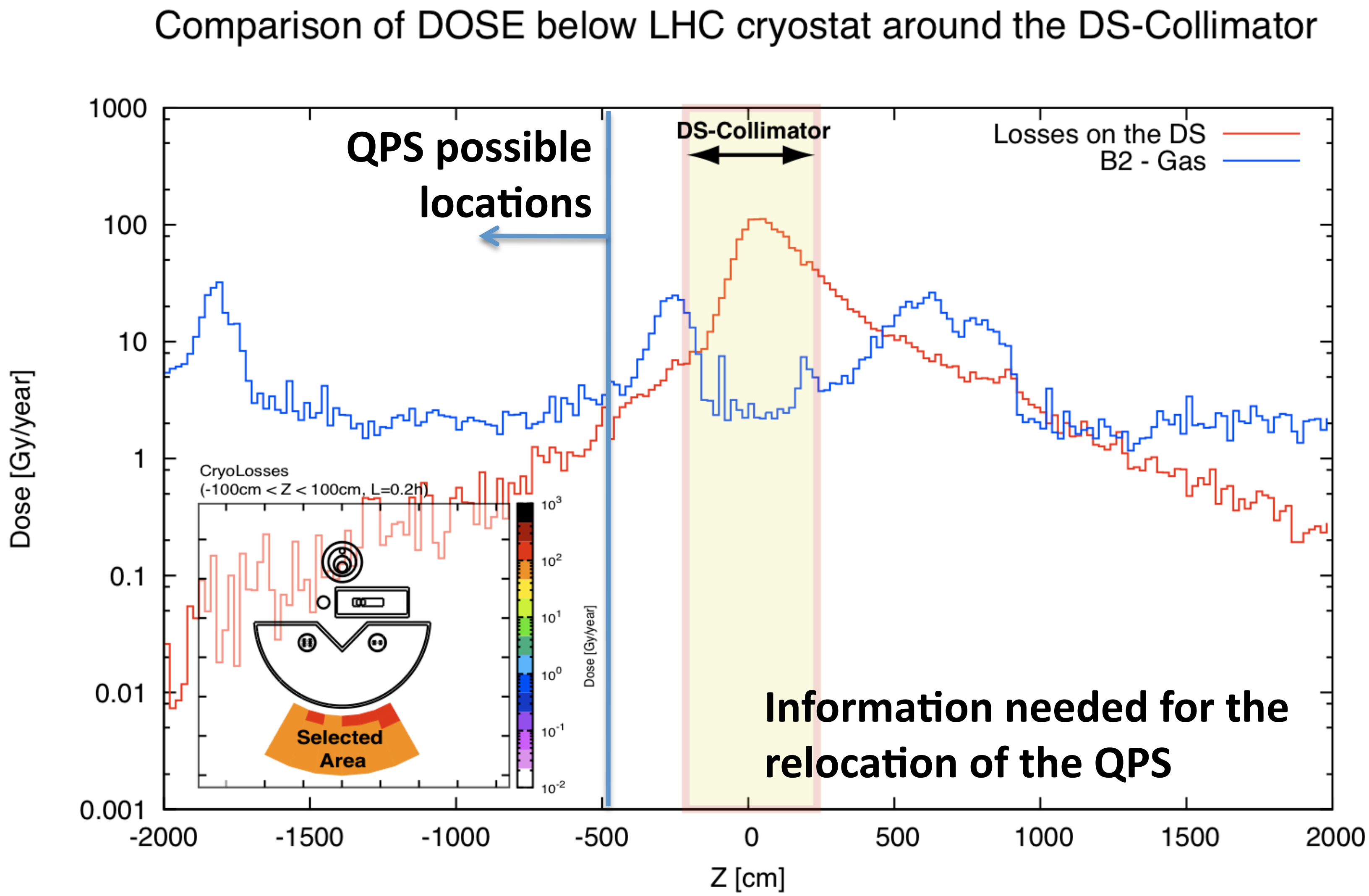
The difference for Q8 is explained by the asymmetry of the BLM position and by the secondary particles leaking from the LSS (not considered in this preliminary results because of the short timescale of the simulation)

Conclusion

- We recall the results of the DS-collimator simulation for the IR7 case. The addition of the TCLDs is expected to decrease the predicted peak power in the superconducting coils of the DS magnets up to a factor of 15 (1m tungsten jaws).
- Peak power is below (but not far from) the quench limit. The 1.5 factor for the ultimate intensity does not change the picture.
- Few consideration about the May 8th/9th MD:
  - Simulated peak power in the elements of cell 8-9 and cell 11 were below the quenching limits for the MD at 3.5 TeV and for the 0.2h scenario at 7 TeV;
  - Preliminary comparison of the BLM loss pattern with the one measured in the MD.

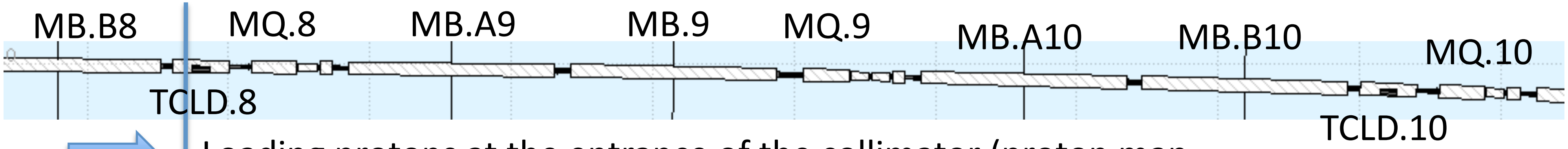
BACKUP SLIDES

Dose on the tunnel floor



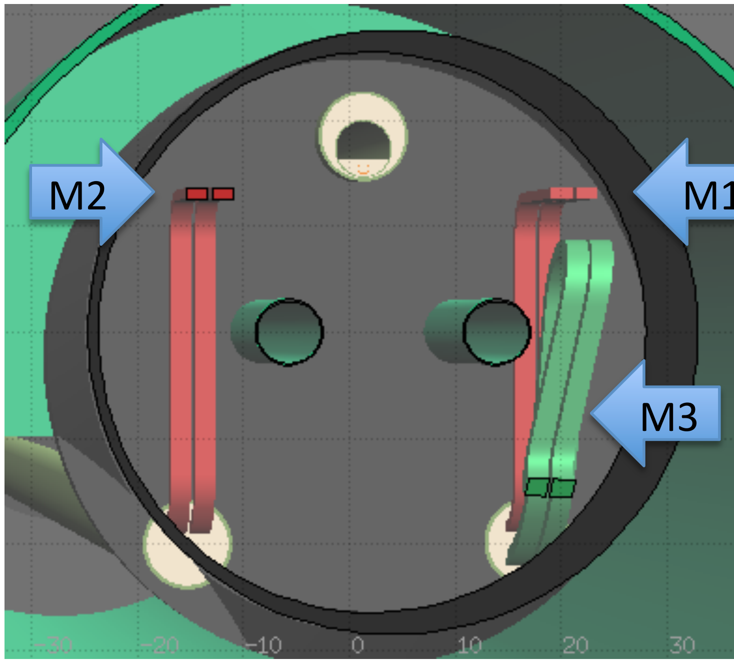
TCLD model in the IR3 layout

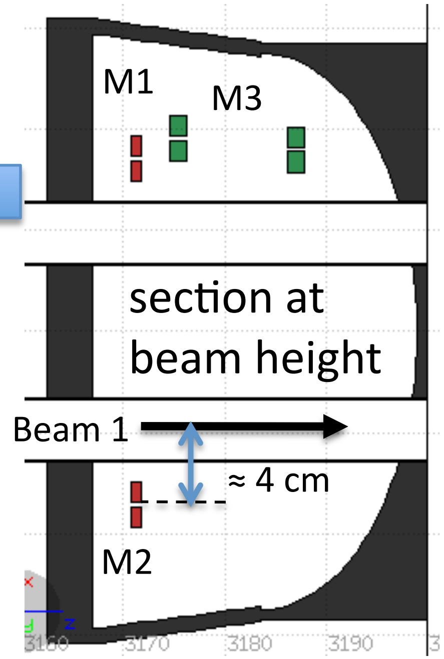
Portion of the DS.R3



Loading protons at the entrance of the collimator (proton map from SixTrack simulation by A.Rossi D.Wollmann)

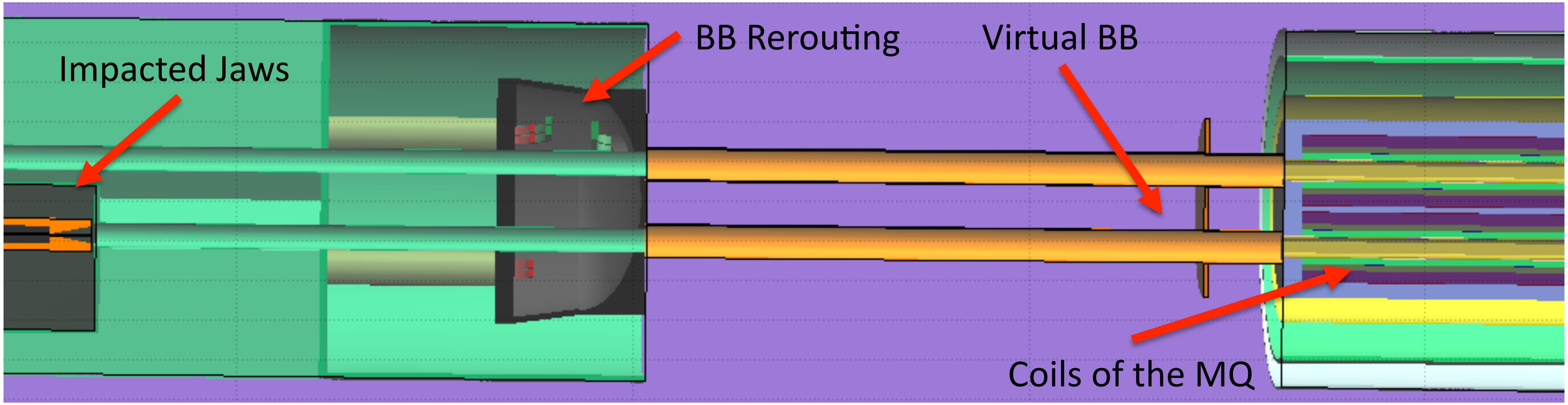
- The new DS-collimator optics (IR3) layout for the was implemented
- The TLCD FLUKA model includes the BB rerouting in the cryogenic bypass (very close to Beam Pipe);
- Implement a virtual BB rerouting in front of the MQ downstream the TCLD collimator;
- TLCD Collimators opened at 15 sigma;
- Two loss maps corresponding to the interaction of the horizontal and vertical primary collimators;





Calculation are ongoing.

Details of the geometry



Uncertainties

Only statistical errors are calculated and shown.
On top of them there are the systematic ones:

factor for integral quantities	factor for point quantities	origin	reason
0.5–2	0.5–2	single diffractive x-section	almost no data for p-A collisions
0.7–1.5	0.7–1.5	grazing impact	jaw roughness dependence on the angular distribution at zero degrees
0.8–1.3	0.8–1.3	SixTrack / beam model	beam halo description
0.8–1.2	0.5–2	FLUKA / physics	interaction extrapolation at 7 TeV (p_t/p)
0.9–1.1	0.7–1.5	FLUKA / machine model	description of a large sector (including material implementation)

But…. We must consider the effect of imperfections …

10 ?	10 ?	**Imperfections**	collimator tilting, magnet displacement, field accuracy (from present experience)

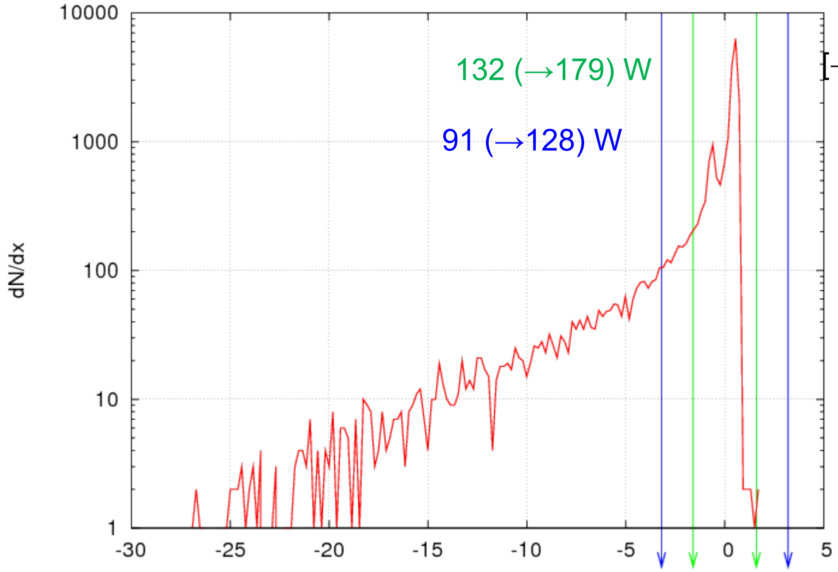
as shown in:
V. Vlachoudis + A. Ferrari, LCWG meeting, Mar 2nd 2009
F. Cerutti, CDR LHC Phase II Collimation, April 2nd 2009
F. Cerutti, LCWG meeting, May 10th 2010

Chiara Bracco, Commissioning scenarios and tests for the LHC collimation system. Thèse EPFL, no 4271 (2009).

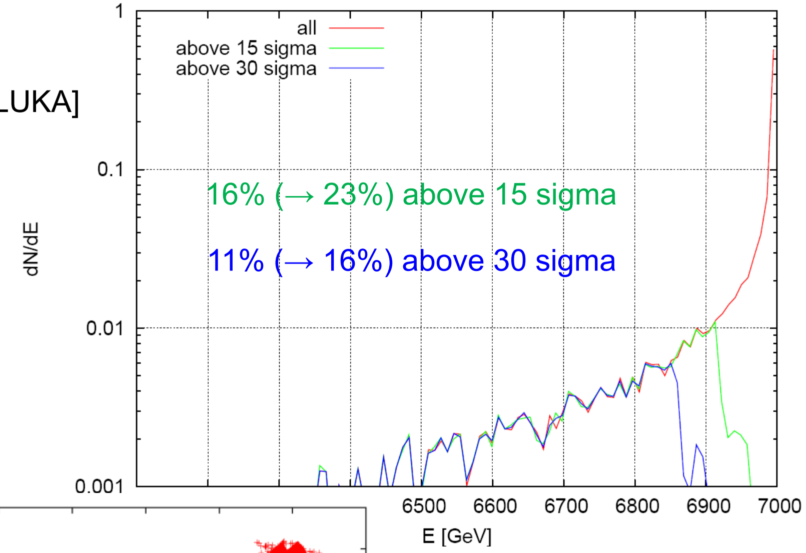
Slide from: F. Cerutti, LCWG meeting, May 10th 2010

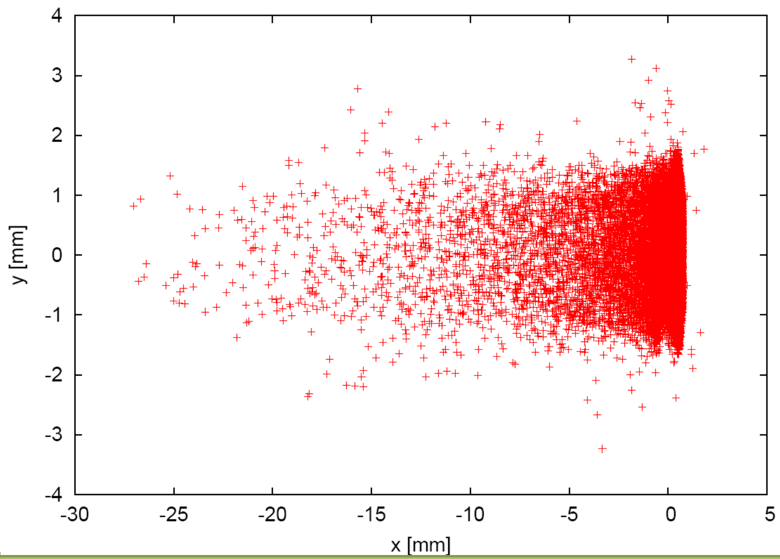
Beam Halo (protons)

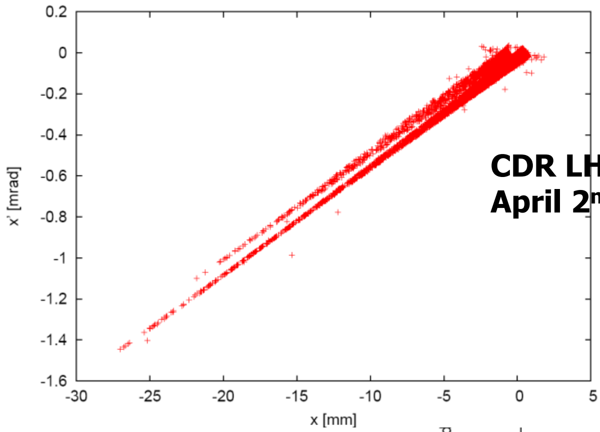
at the entrance of TCRYO.AR7.B1



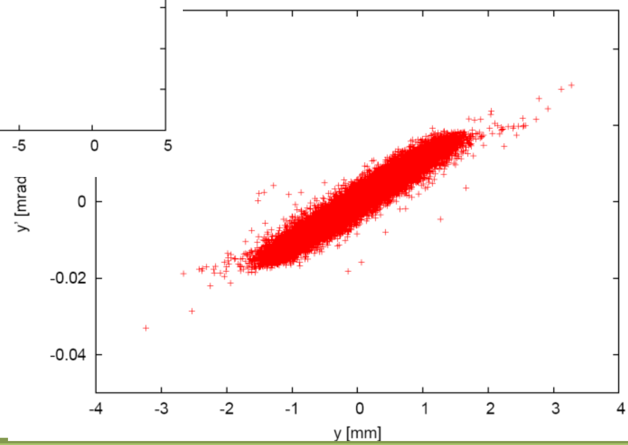
[→ correction by FLUKA]





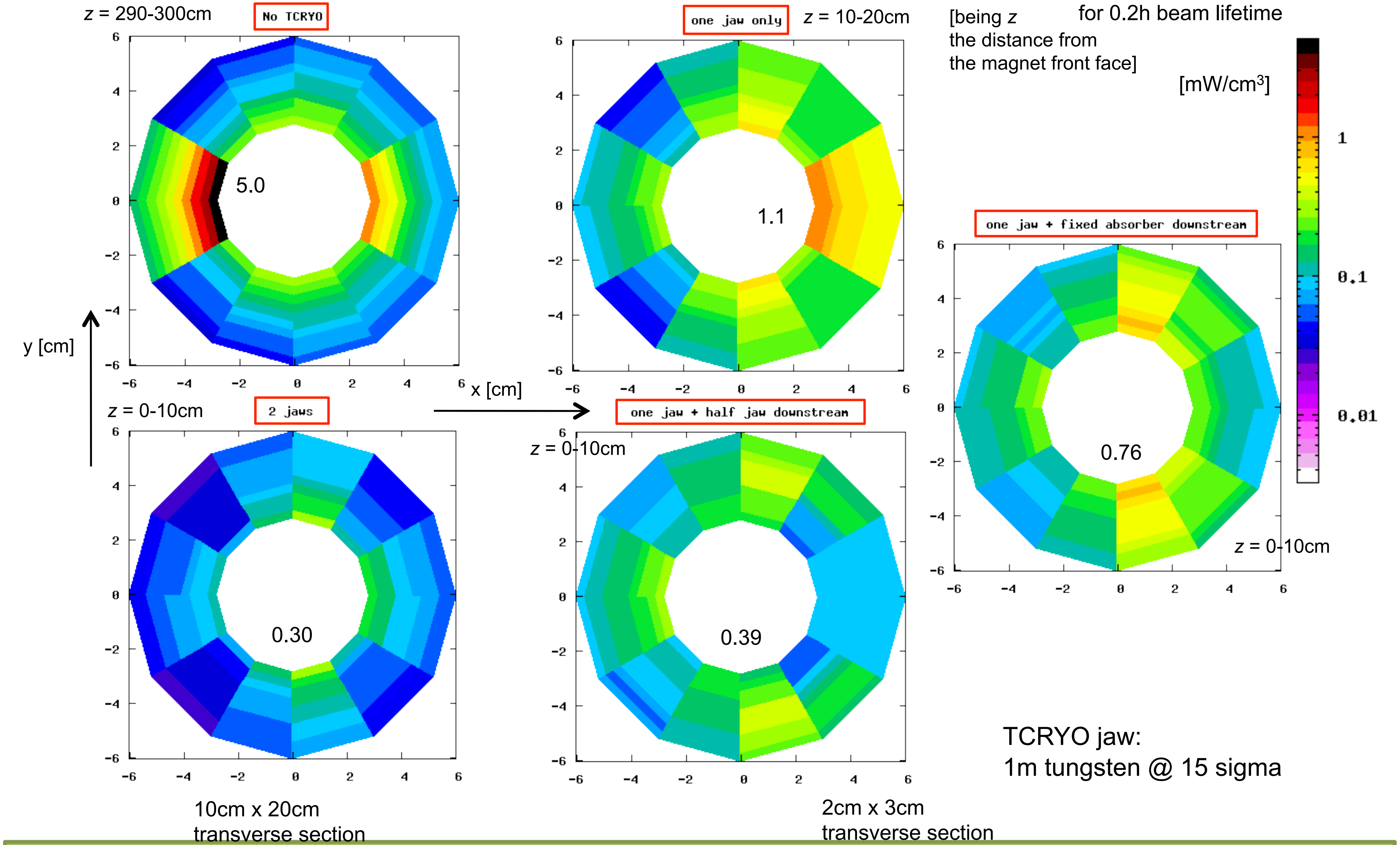


CDR LHC Phase II Collimation, April 2nd 2009



[T. Weiler]

Power deposition in the MQ.8R7.B1 coils

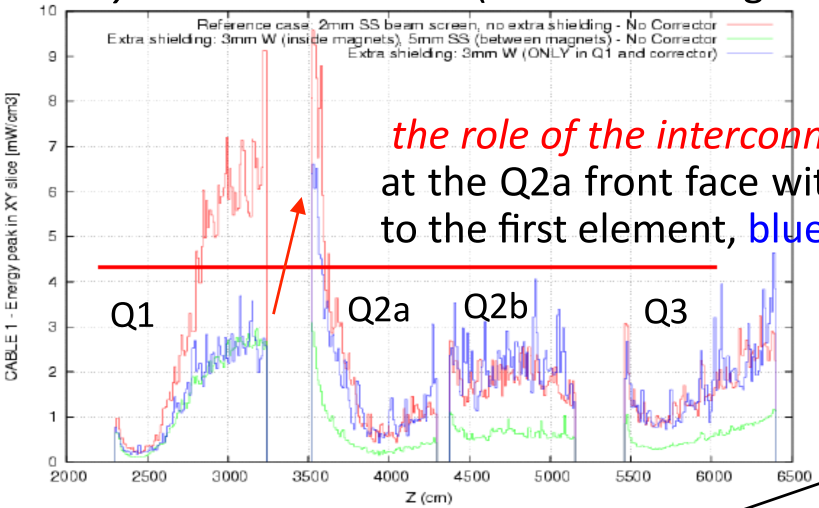


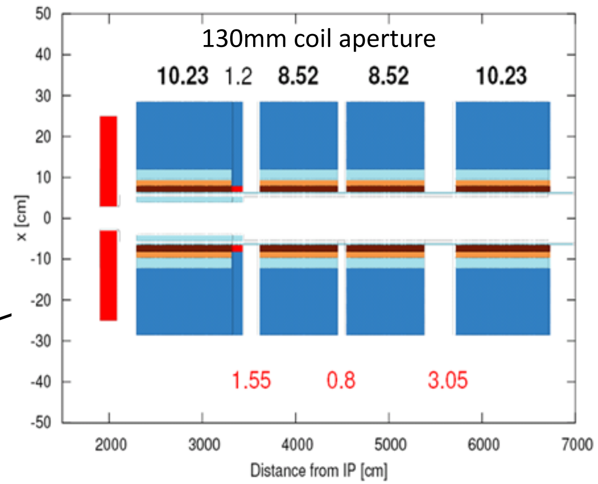
Shielding options

- *ideally* a continuous liner (here 3mm tungsten, green curve) is quite effective

$L=2.5L_0$

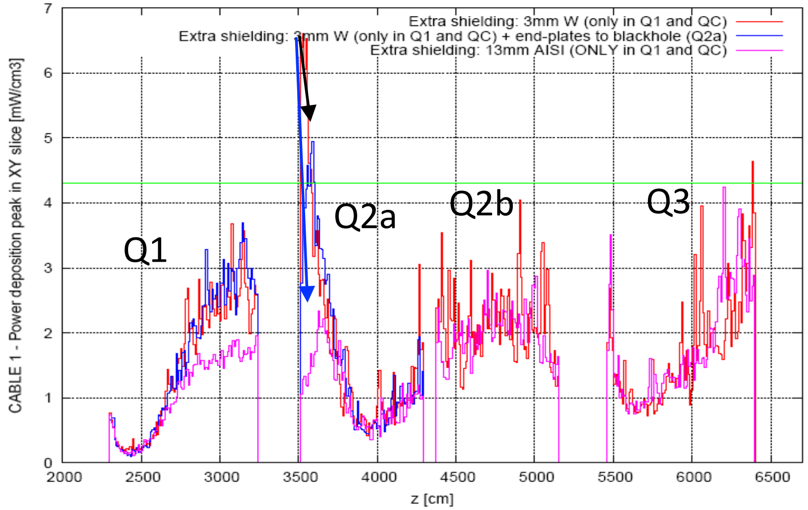
the role of the interconnections! jump at the Q2a front face with liner limited to the first element, blue curve

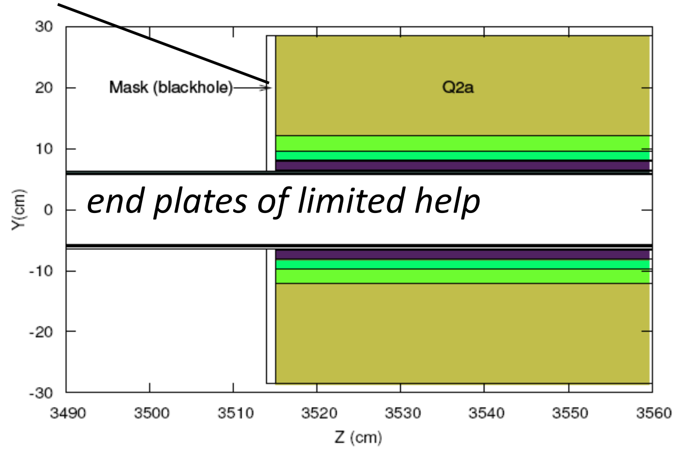




- as an alternative, a thick liner in Q1 (here 13mm stainless steel, purple curve) casting a **shadow** over Q2a

assumed as totally absorbing! blue curve

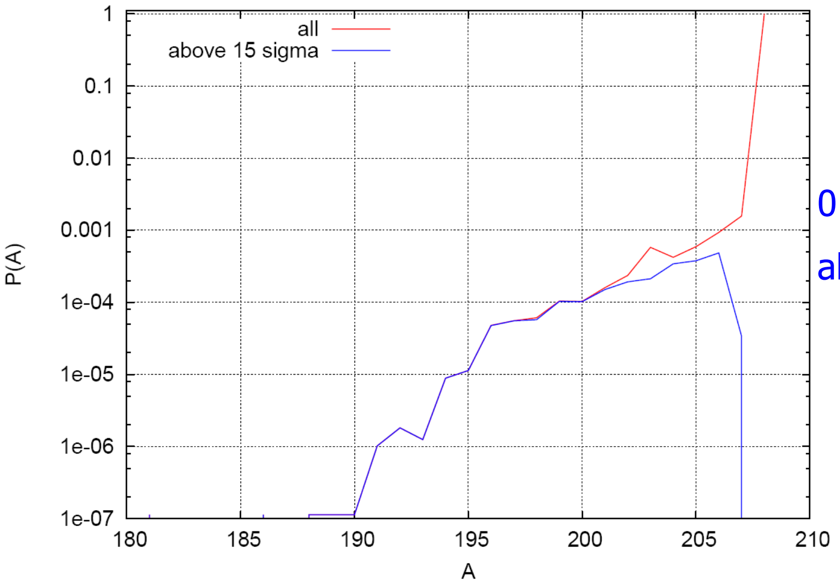




Slide from: F. Cerutti, LCWG meeting, May 10th 2010

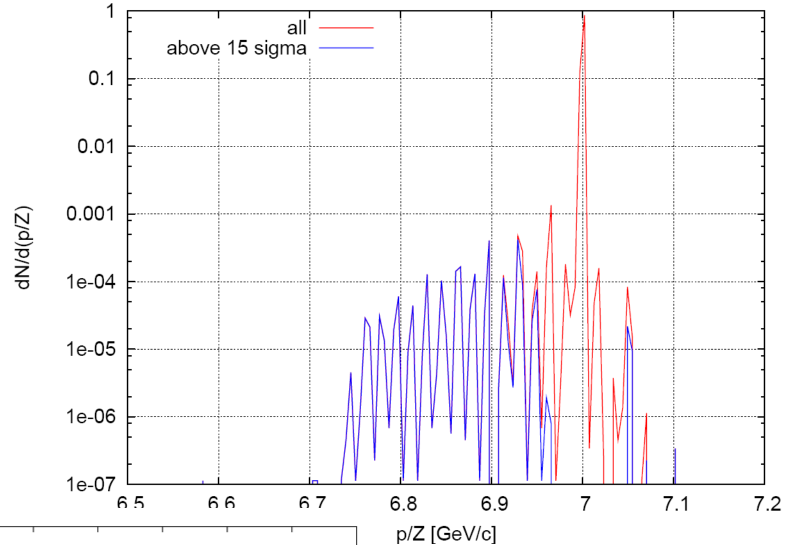
The Pb beam Halo

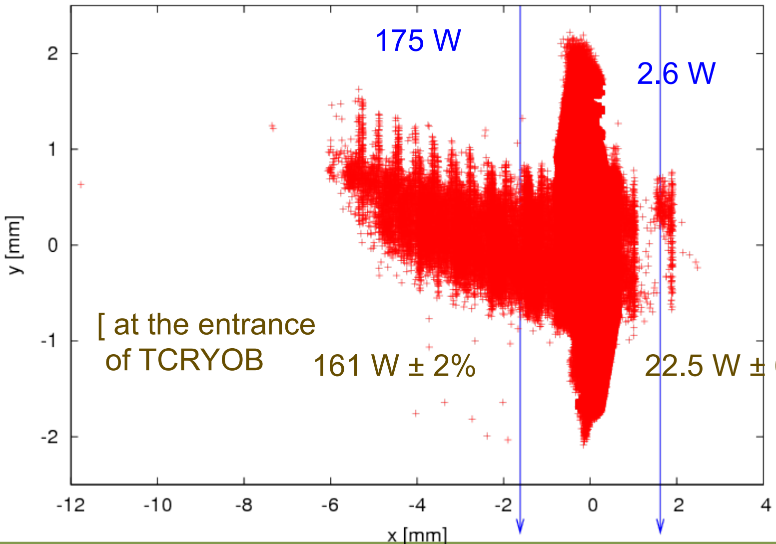
at the entrance of TCRYO.AR7.B1

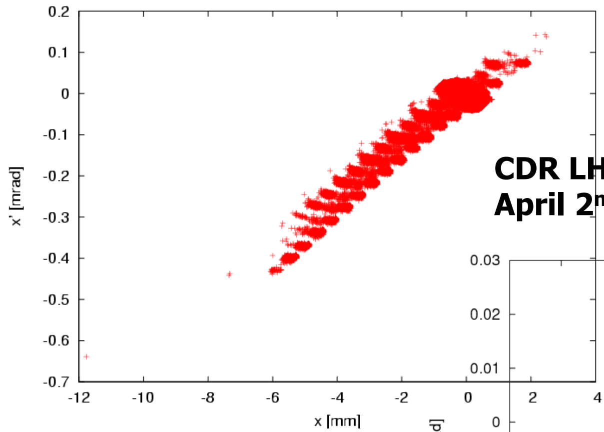


0.22%

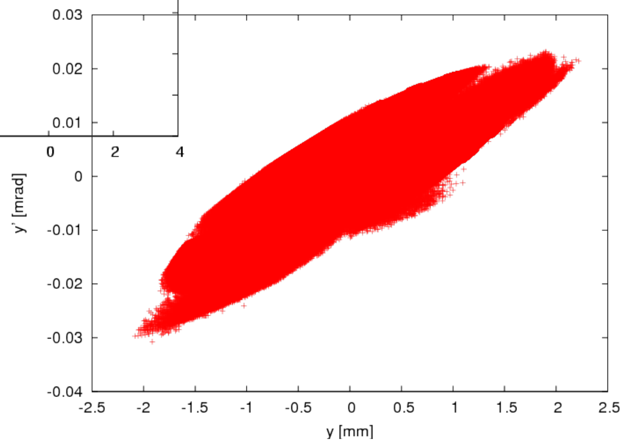
above 15 sigma







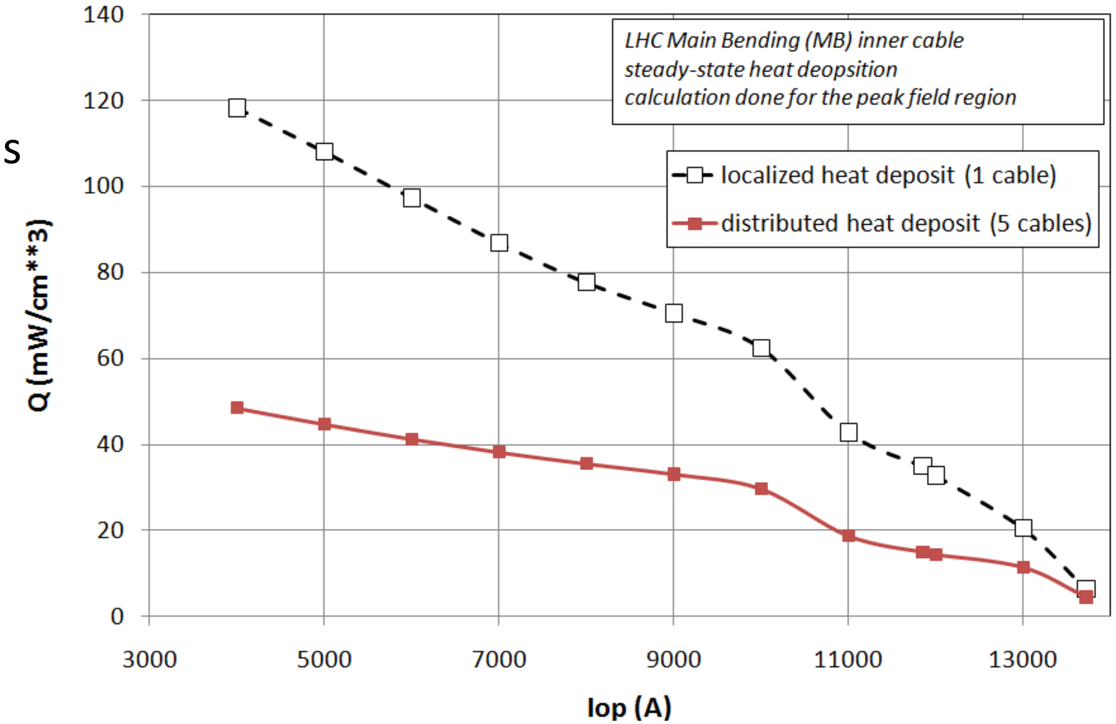
CDR LHC Phase II Collimation, April 2nd 2009



[G. Bellodi]

MB Quench Limit

- The steady-state heat deposit the MB cables can withstand is estimated through the results of heat transfer measurements, in case of localized and distributed loss
- The driving mechanism is indeed the heat transport through the cable electrical insulation. (Slightly) conservative assumptions are considered to account for the differences between the experimental setup and the real magnet
- The considered heat deposit is uniform in the cable cross-section, as well as in the longitudinal direction
- Further analyses are ongoing to model the heat flux distribution in the coil, thus allowing to improve the quench limit estimation



MB Stability

- The stability of the MB cables with respect to transient heat deposit is estimated through numerical calculation
- The mechanism that confers stability is the transient heat transfer between strands and helium in the cable. Hence the model pays particular care to its definition, considering the different helium phases
- Strands and cable enthalpy represent lower and upper limit for stability
- The considered heat deposit is uniform in the cable cross-section, as well as in the longitudinal direction
- Experimental tests would be needed to obtain a deeper insight of the stability underlying mechanisms