Heat Deposition Pre-Evaluation

In the context of the new cryo-collimator and 11-T dipole projects we present a review of the power deposition studies on the DS-collimator performed in the past years.

Outline:

- Impact of the DS-Collimator in the different interaction regions;
- Review of the power deposition in IR7 for protons and ions:
  - Description of beam halo;
  - Total Power impacting the DS-collimator;
  - Effects of the DS-collimator on the peak power in the magnets;
- Conclusions.

Vittorio Boccone **for the** FLUKA Team **(EN/STI)**

Impact of the DS-collimator (I)

The impact of the DS-collimator (alias TCLD and formerly known as TCryo) on the machine protection and its absolute thermal load depend strongly on the "*environment*" where the DS-collimator is inserted:

IR7 (protons/ions) - Effect of the DS-collimator studied:

- Only one horizontal loss case scenario studied (*Conceptual Design Review LHC of the Phase II Collimation)*;
- Effect of jaw length (from 0.5 m to 2 m) and material (W and Cu);
- Effect of collimator aperture;
- Effect of realistic geometry (TCLD-like);

IR3 (protons, combined cleaning) - Effect of the DS-collimator partly studied:

- Vertical and horizontal loss case scenarios;
- Preliminary version of the optics. Scenario later discontinued.

Impact of the DS-collimator (II)

The impact of the DS-collimator (alias TCLD and formerly known as TCryo) on the machine protection and its absolute thermal load depend strongly on the "*environment*" where the DS-collimator is inserted:

IR1/IR5 (protons) - Effect of the DS-collimator not studied:

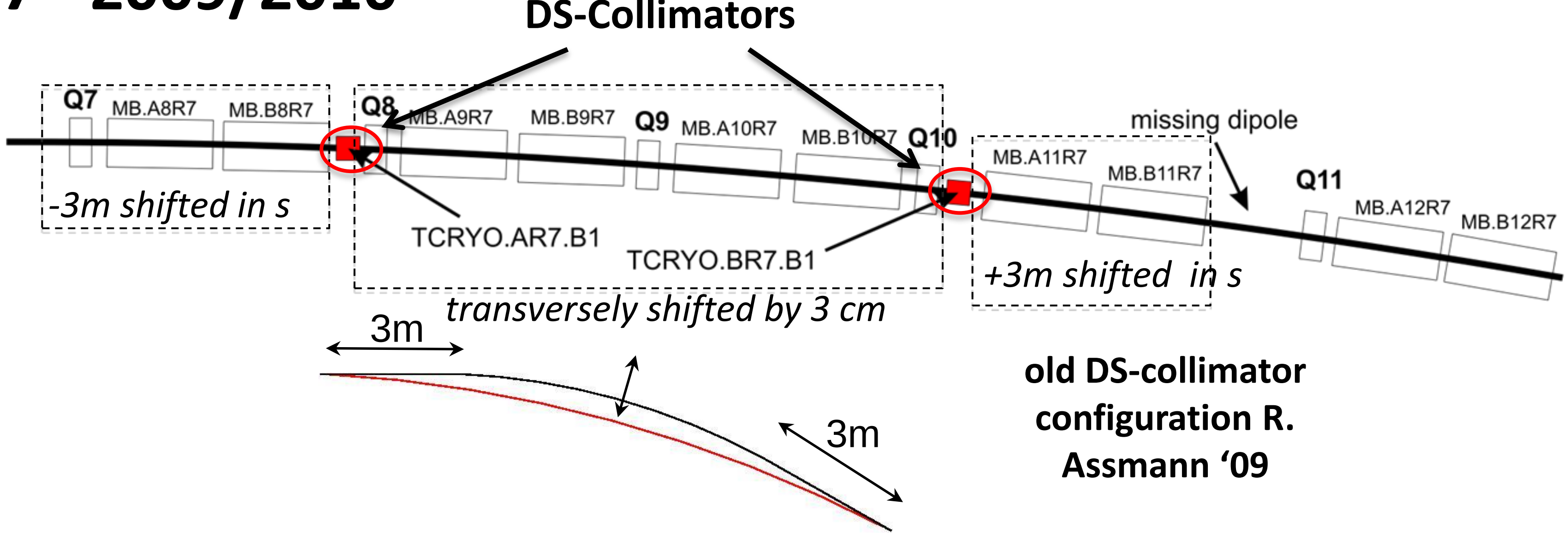
- Simulation stops at Q7 for IR1 and Q4 for IR5.
- Must include the effects of the collision debris on the DS/DS-collimator;
- Not possible to evaluate from IR3/IR7 calculations.

IR2 (ions) - Effect of the DS-collimator not studied:

- Miss a realistic collimation case to study (optics and loss term).
- Asymmetric case (injection)

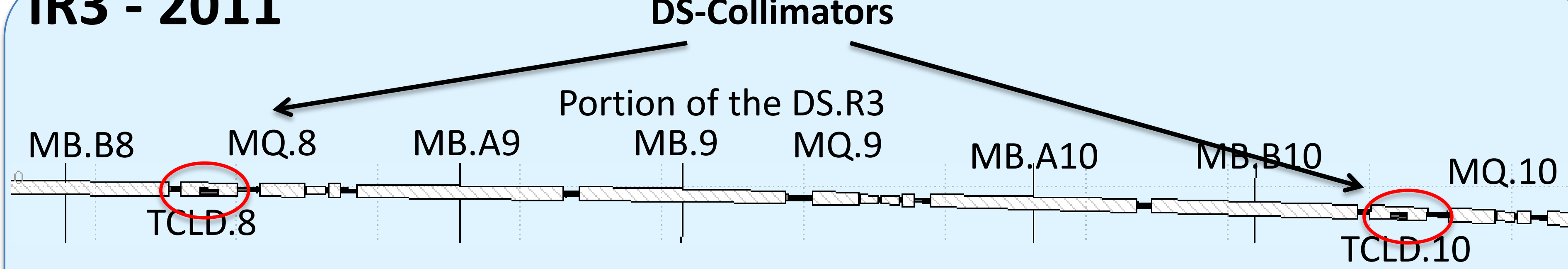
DS-Collimator in IR3 and IR7

IR7 - 2009/2010



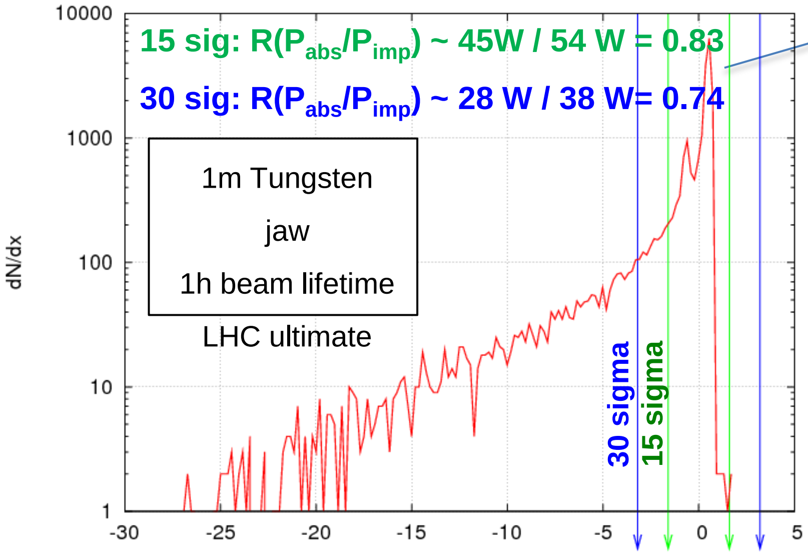
old DS-collimator configuration R. Assmann '09

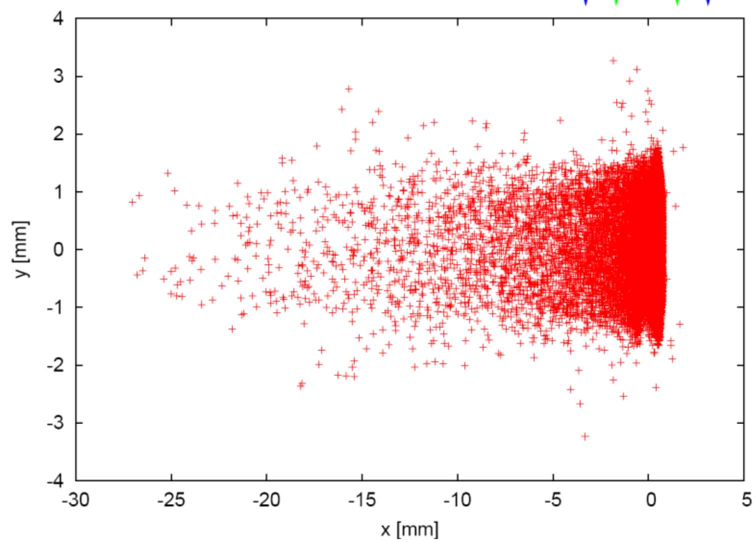
IR3 - 2011



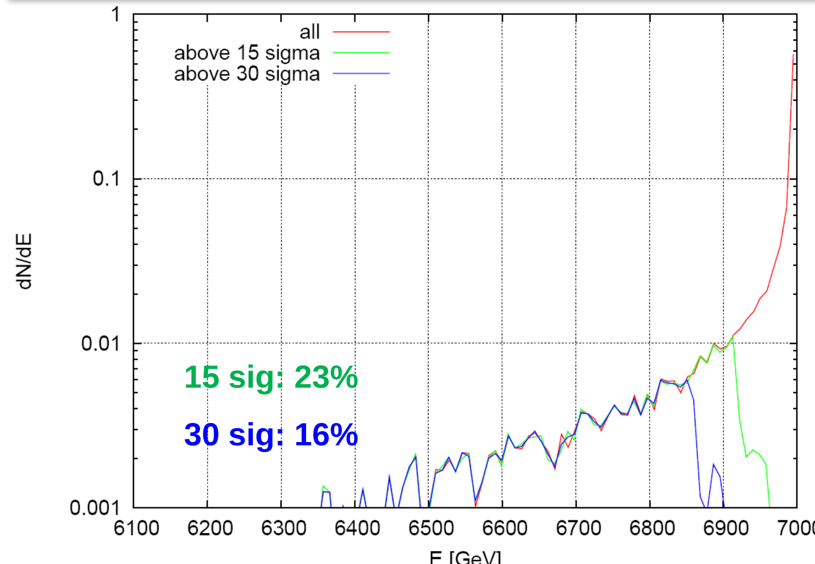
Beam Halo at the DS (IR7) - protons

at the entrance of TCRYO.AR7.B1





This Ratios stay the same but the absolute values of the power depend on the losses



LHC ultimate = LHC nominal x1.5

1h beam lifetime = 0.2h beam lifetime / 5

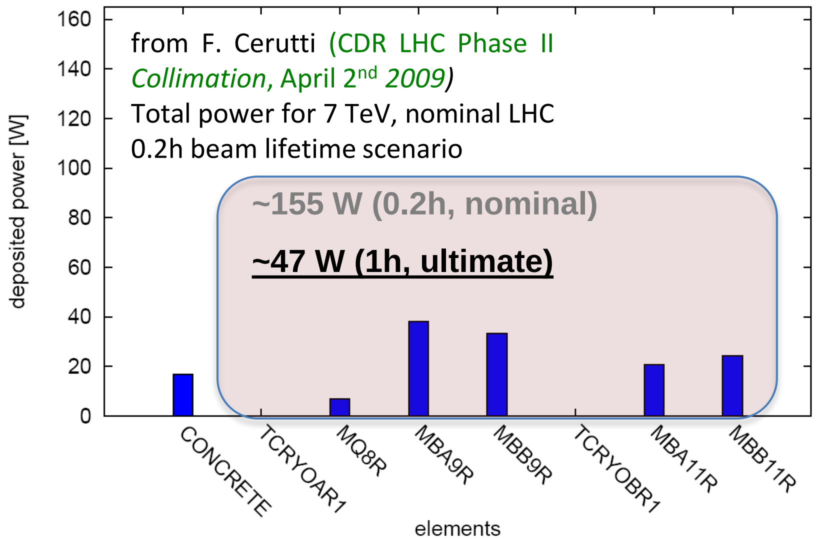
Losses (LHC ultimate, 1h beam lifetime):

- All LHC = 1.3×10^{11} p/s (tot);
- DS-coll = 1.4×10^{8} p/s.

Loss map from T.Weiler for the *Conceptual Design Review LHC of the Phase II Collimation*

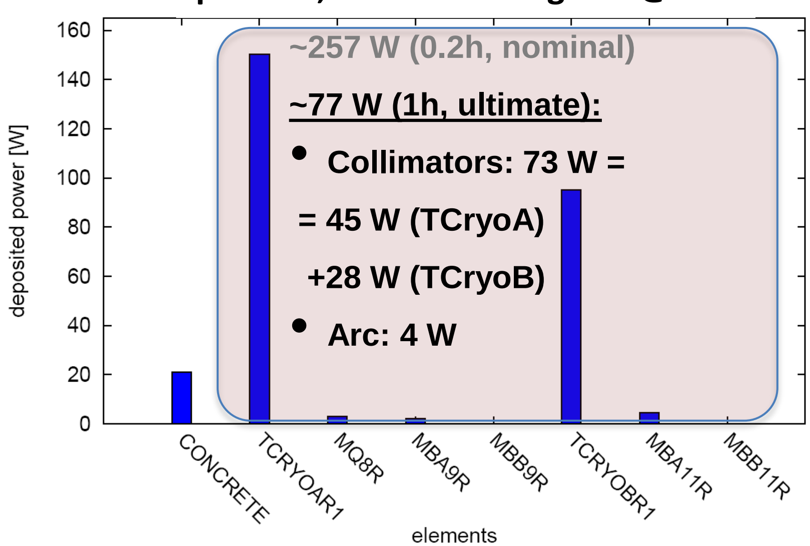
Power Impacting on the DS (IR7) - protons

protons, no DS coll.



- Without the collimator (for protons) the power lost in the DS (only elements) is quantified in about **47 W** (1h beam lifetime, LHC ultimate);

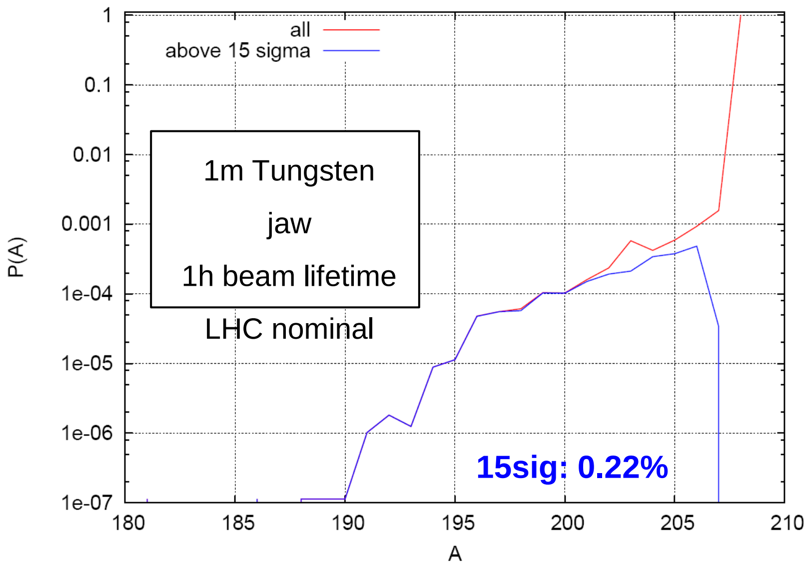
protons, DS coll. in tungsten @15σ

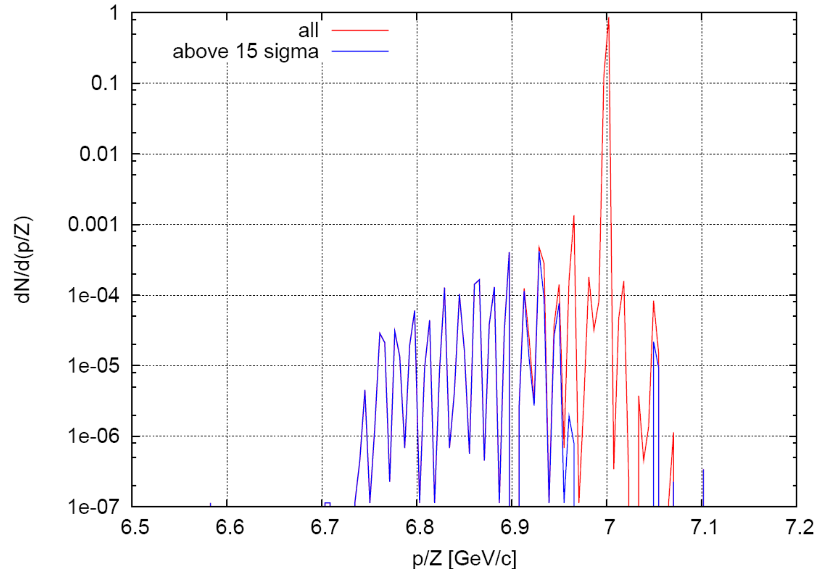


- The presence of the DS-collimator increases the power deposited in the DS to **77 W** (1h beam lifetime, LHC ultimate) but at the same time it reduces the fraction of the power deposited in the arc from **47 W** to about **4 W**;

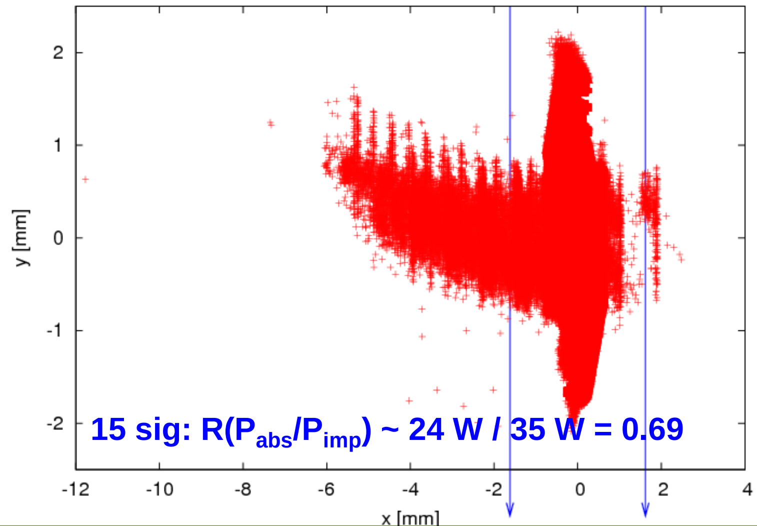
Beam Halo at the DS (IR7) - ions

at the entrance of TCRYO.AR7.B1



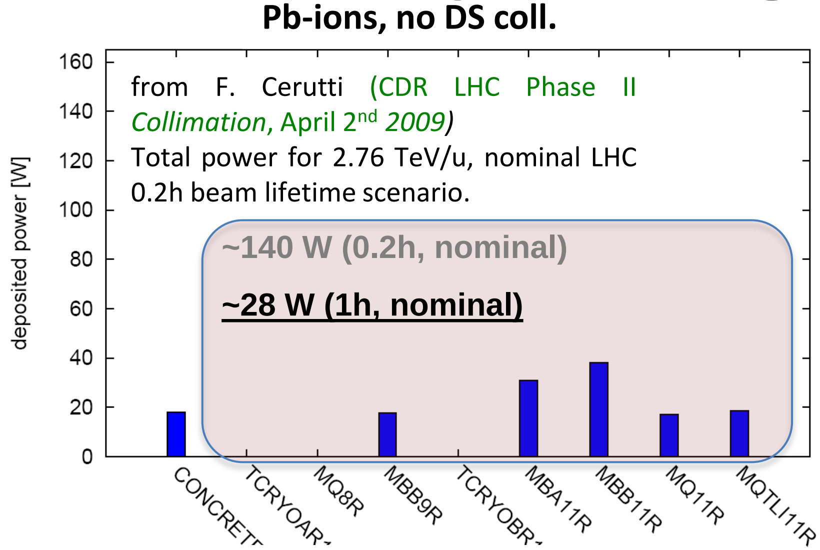


CDR LHC Phase II Collimation, April 2nd 2009

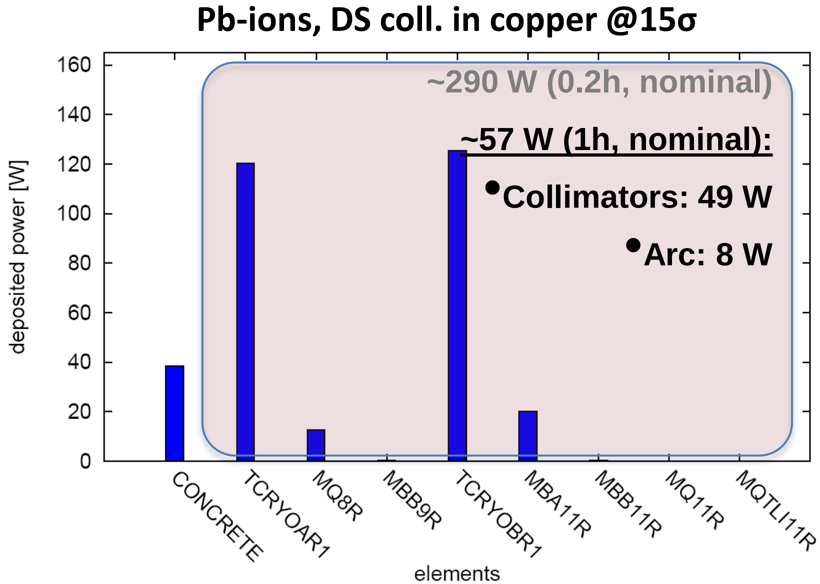


Loss map from G.Bellodi, J.Jowett for the *Conceptual Design Review LHC of the Phase II Collimation*

Power Impacting on the DS (IR7) - ions



- Without the collimator (for ions) the power lost in the DS (only elements) is quantified in about **28 W** (1h beam lifetime, LHC nominal);



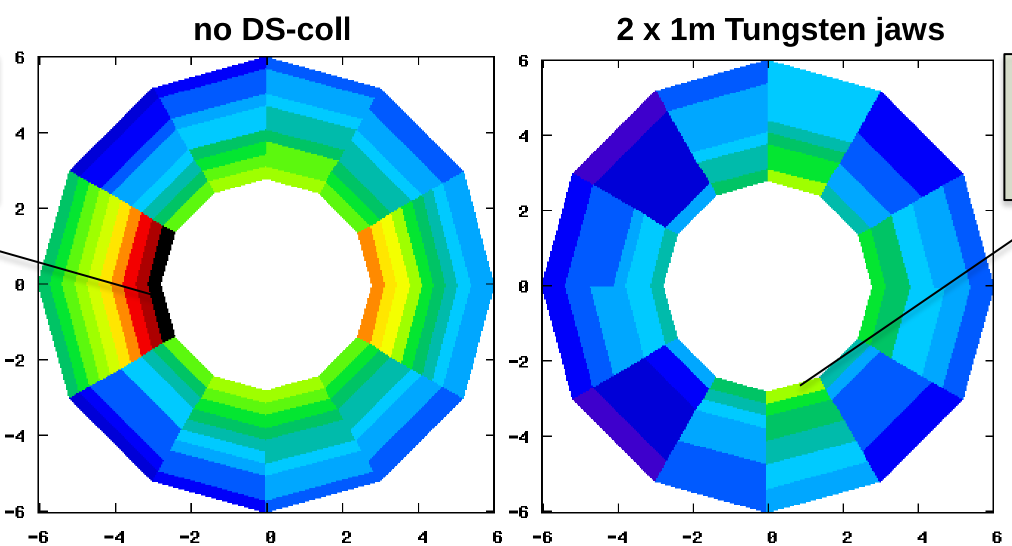
- The presence of the DS-collimator increases the power deposited in the DS to **57 W** (1h beam lifetime, LHC nominal) but at the same time reduces the fraction of the power deposited in the arc from **28 W** to about **8 W**;

Peak Power on superconductive coils (IR7)

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)*;*

Peak Power on the MQ.8R7 coils (7 TeV, 1h beam lifetime, LHC ultimate)

P_{peak}^{MQ} ~1.5 mW/cm^3 (1h, LHC ultimate)

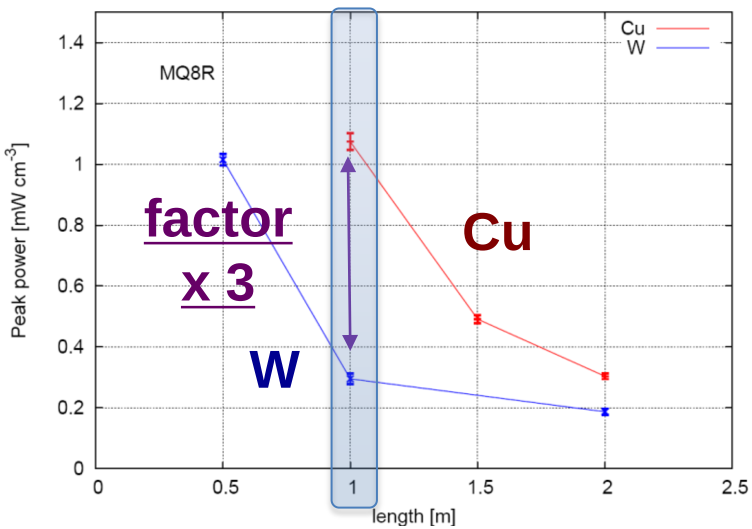


P_{peak}^{MQ} ~ 0.09 mW/cm^3 (1h, LHC ultimate)

factor x15!

10cm x 20cm transverse section

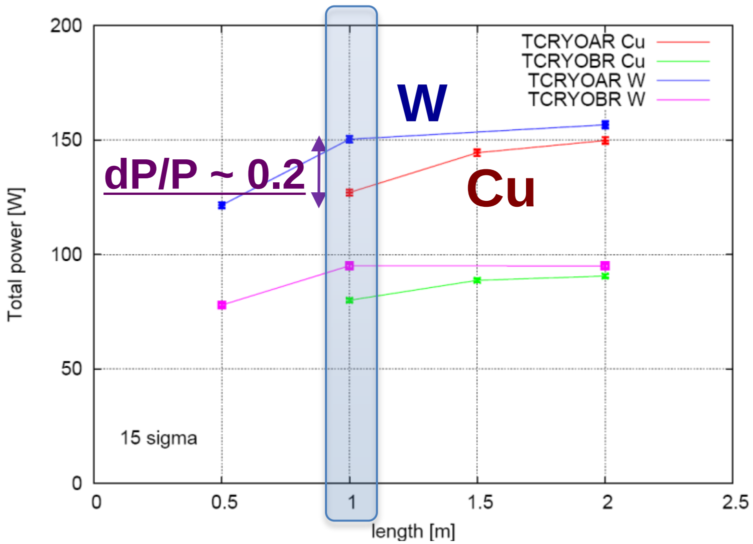
Material for the DS-collimator



Tungsten ensures the protection of the downstream magnets by reducing the peak power on the coils

Peak power on the MQ8R for a 2x 1 m Jaws:

- Tungsten: $P_{peak}^{MQ} \sim 0.3\ mW/cm^3$ (0.2h, nominal)
  $P_{peak}^{MQ} \sim 0.09\ mW/cm^3$ (1h, ultimate)
- Copper: $P_{peak}^{MQ} \sim 1\ mW/cm^3$ (0.2h, nominal)
  $P_{peak}^{MQ} \sim 0.3\ mW/cm^3$ (1h, ultimate)

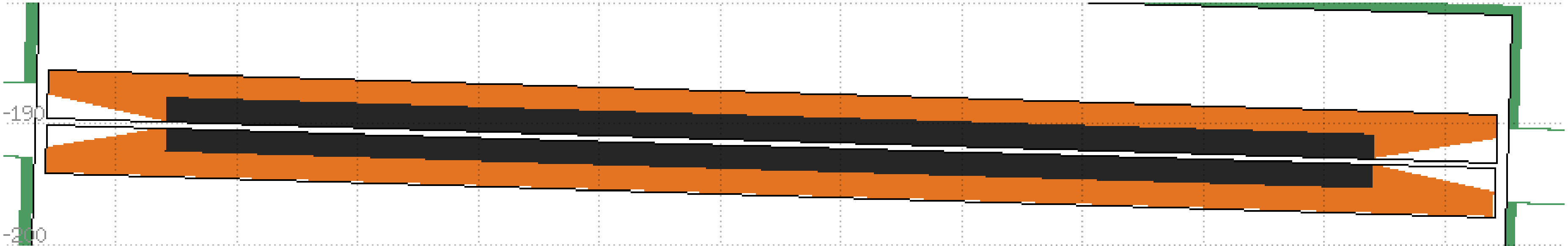


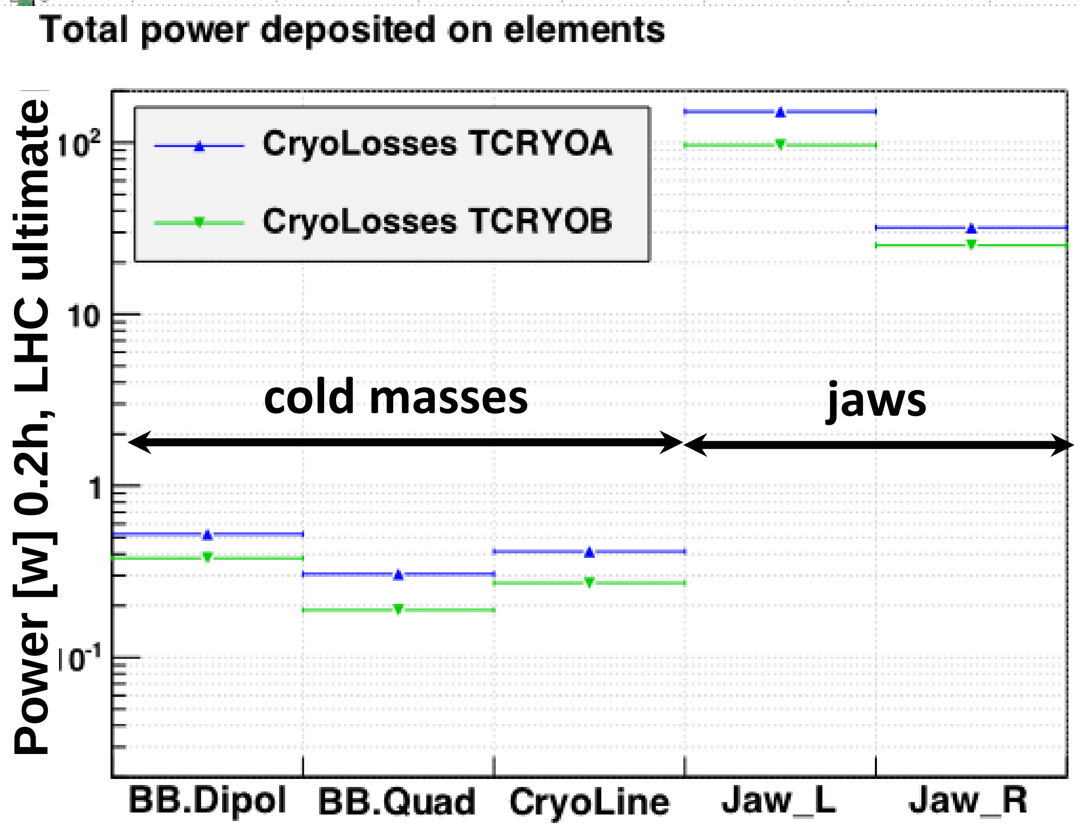
Tungsten reduces the total load on the arc by intercepting more power.

Total power on first collimator for a 2x 1 m Jaws:

- Tungsten: $P_{col} \sim 150$ W (0.2h, nominal)
  $P_{coll} \sim 45$ W (1h, ultimate)
- Copper: $P_{col} \sim 125$ W (0.2h, nominal)
  $P_{coll} \sim 38$ W (1h, ultimate)

Realistic Collimator Model





The TCLD design fix the transversal dimension of the jaw (LxWxH)

- Stiffener (Cu) - (1000 x 40 x 40) mm^3
- Inset (W) - (1000 x 20 x 30) mm^3

this allows to better evaluate the power deposited on the jaws in a realistic case:

P_{TCRYOA}= ~180W (0.2h, ultimate)

~36 W (1h, ultimate)

P_{TCRYOB}= ~120 W (0.2h, ultimate)

~24 W (1h, ultimate)

Conclusion (I)

We recalled the past results of the DS-collimator studies in the case of the IR7 phase II upgrade, horizontal loss scenario, LHC ultimate and 1h beam lifetime:

- **Under those assumptions** we expect a **maximum power <50 W** for a DS-collimator with 2x 1 m tungsten jaws;
- A correct evaluation of the absolute value relies on:
  - The collimator settings;
  - The proton/ion loss scenario considered;
  - The material and the real dimensions of the jaw inset and its stiffener;
- The ratio between the impacting and absorbed power could be prudently used to evaluate the load on the collimator in similar cases;

Nevertheless the presence of such a collimator in IR7 reduces:

- the total power deposited in the arc decreased by a factor of 10-12 for protons and by a factor of 3 for ions;
- the peak power on the downstream magnets by a factor of 15 (protons).

Conclusion (II)

Which is the total power deposited in the DS-collimator in the other cases?

A possible roadmap to answer to this question must include:

- IR1/IR5: define and study collision debris down to the DS;
- IR2: define and study a realistic collimation scenario for the ions;
- IR3/IR7: define and study the impact of the vertical scenario in the overall cleaning scheme.

However - as always - we must take in account the uncertainties.

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).

BACKUP SLIDES

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

Power deposition in the MQ.8R7.B1 coils

[Z is the distance from the magnet front face]

LHC nominal, 0.2h beam lifetime

TCRYO jaw:
1m tungsten @ 15 sigma