HiLumi HL-LHC PROJECT

Simulation of ion losses around IR2 with TCLD collimators

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6th HL-LHC Collaboration Meeting – Paris – November 15th

CERN FLUKA EN STI

Outline

- **Background and motivation**
  - Beam losses during ion runs in the LHC
- **Mitigation strategies**
  - IR2 particularities
- **HL-LHC baseline for IR2**
  - TCLD collimator inside empty cryostat
- **Feasibility study**
  - Quench risk, cryogenics, radiation to electronics
- **Conclusions and outlooks**

Beam losses during ion runs in the LHC

Pb runs have intrinsic beam losses around the Interaction Points ATLAS, ALICE, CMS, LHCb (IP1, IP2, IP5, IP8) due to electromagnetic interactions

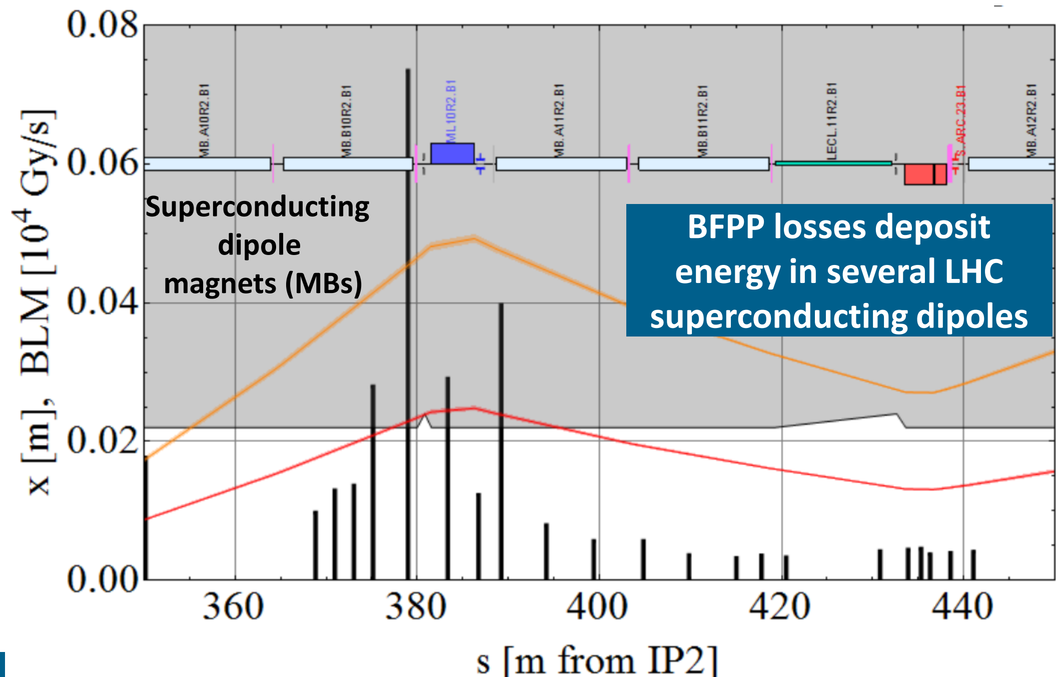
$$\text{BFPP1: } {}^{208}\text{Pb}^{82+} + {}^{208}\text{Pb}^{82+} \longrightarrow {}^{208}\text{Pb}^{82+} + {}^{208}\text{Pb}^{81+} + e^{+}, \quad \sigma = 281\ \text{b}, \quad \delta = 0.01235$$

$$\text{BFPP2: } {}^{208}\text{Pb}^{82+} + {}^{208}\text{Pb}^{82+} \longrightarrow {}^{208}\text{Pb}^{82+} + {}^{208}\text{Pb}^{80+} + 2e^{+}, \quad \sigma \approx 6\ \text{mb}, \quad \delta = 0.02500$$

$$\text{EMD1: } {}^{208}\text{Pb}^{82+} + {}^{208}\text{Pb}^{82+} \longrightarrow {}^{208}\text{Pb}^{82+} + {}^{207}\text{Pb}^{82+} + n, \quad \sigma = 96\ \text{b}, \quad \delta = -0.00485$$

$$\text{EMD2: } {}^{208}\text{Pb}^{82+} + {}^{208}\text{Pb}^{82+} \longrightarrow {}^{208}\text{Pb}^{82+} + {}^{206}\text{Pb}^{82+} + 2n, \quad \sigma = 29\ \text{b}, \quad \delta = -0.00970$$

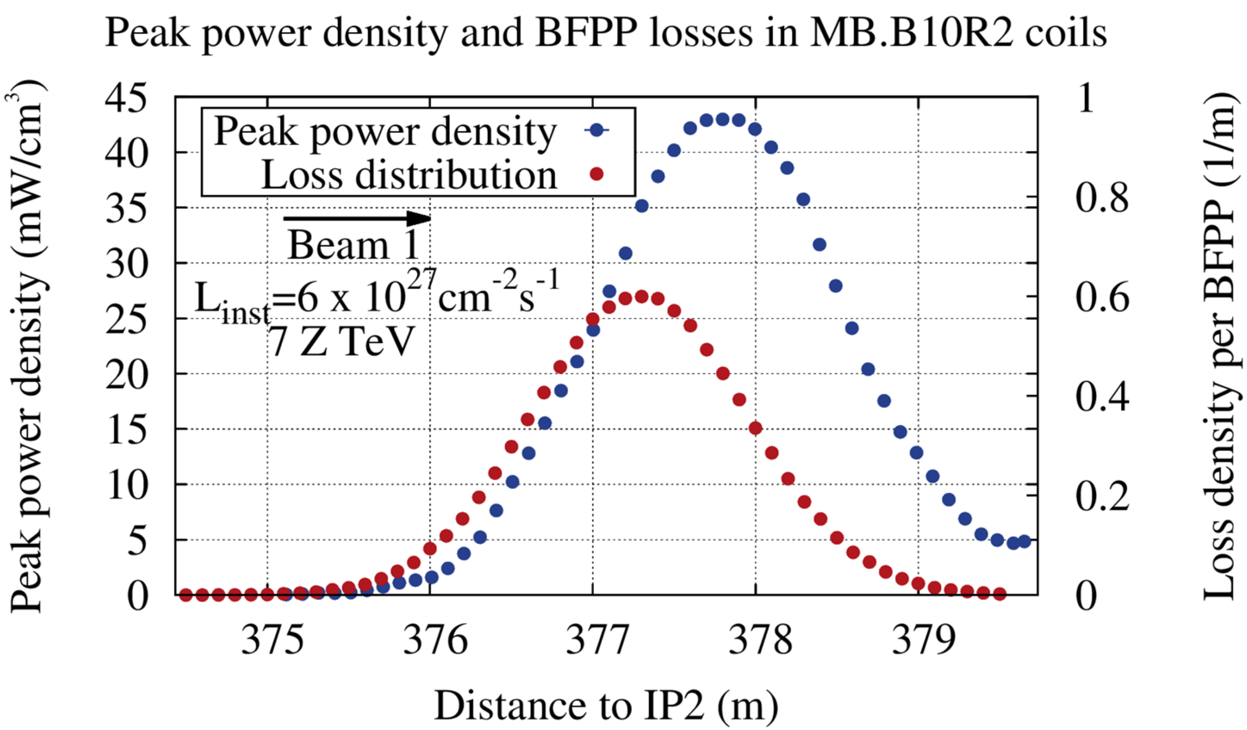
Bound- Free Pair Production (BFPP) is the main contribution to fast Pb-Pb beam burn-off



J.M. Jowett, Dispersion Suppressor Collimators for Heavy-Ion Operation, LHC Collimation Review 2013

Present and future LHC ion runs need to protect superconducting magnets from quenches due to BFPP losses

Expected peak power density for HL-LHC



Peak power density in MB coils ~44 mW/cm^3

Quench risk in HL-LHC!

Remark → 2015 BFPP quench test at 2.3 x 10^{27}cm^{-2}s^{-1} shows quench limit could be as low as 15 mW/cm^3 [3]

[1] BFPP Quench Test Analysis Meeting https://indico.cern.ch/event/496892/

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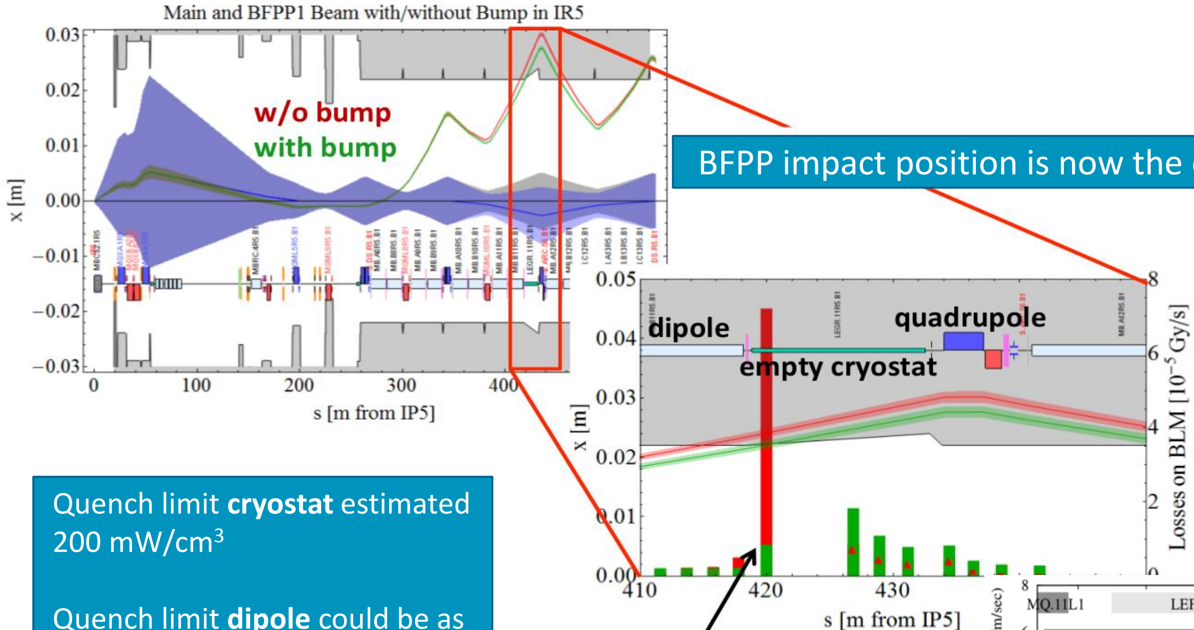
Displacing BFPP losses to less sensitive locations: IR1 and IR5



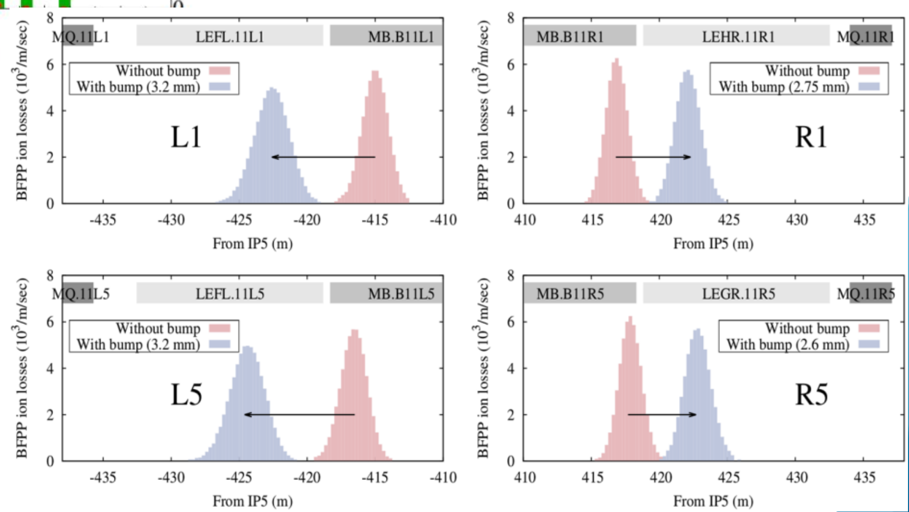
BFPP impact position is now the empty cryostat

Quench limit **cryostat** estimated 200 mW/cm^3

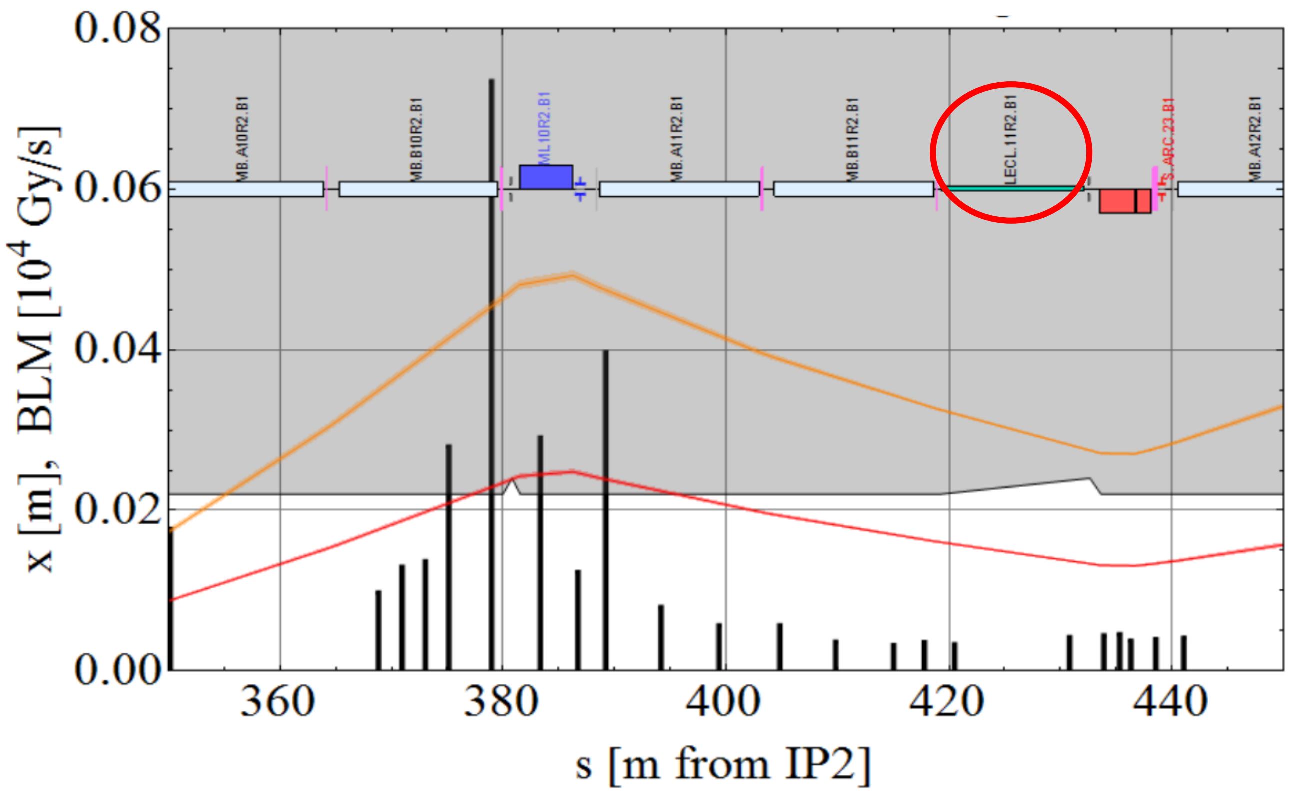
Quench limit **dipole** could be as low as 15 mW/cm^3

M. Schaumann, ColUSM #66, 2015

Tom Mertens



IR2 particularities



Optics in IR2 do not allow a selective displacement of the BFPP losses to an adjacent empty connection cryostat

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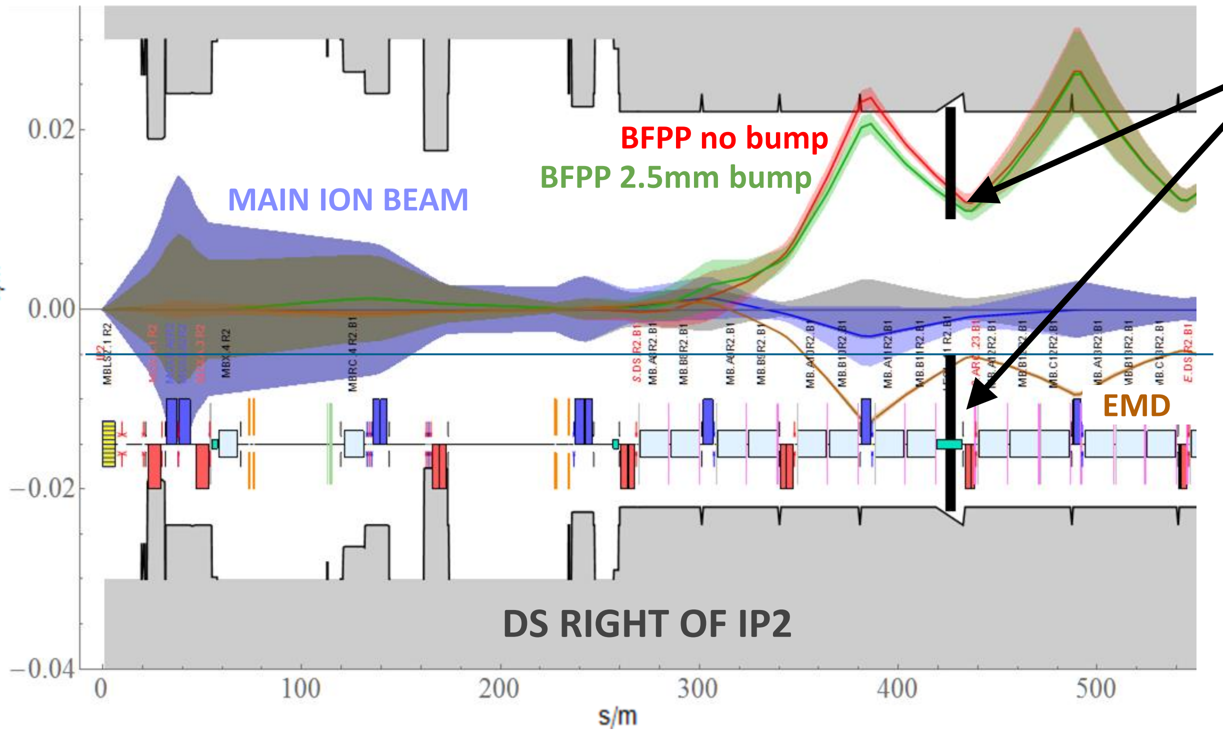
HL-LHC baseline: intercepting losses with TCLD collimator



J.M. Jowett, LHC Performance Workshop, Chamonix, 28/01/2016

TCLD.11R2 settings

60 cm tungsten jaws

Upper jaw 10.53 mm
Lower jaw -4.65 mm

Asymmetric setting to intercept BFPP and EMD with an impact parameter of 2 mm

Half gap ~30 sigma
(lower jaw)

T. Mertens

Other minor EM interactions could increase results ~10%

BFPP: $^{208}Pb^{82+} + {}^{208}Pb^{82+} \rightarrow {}^{208}Pb^{82+} + {}^{208}Pb^{81+} + e^{+}$

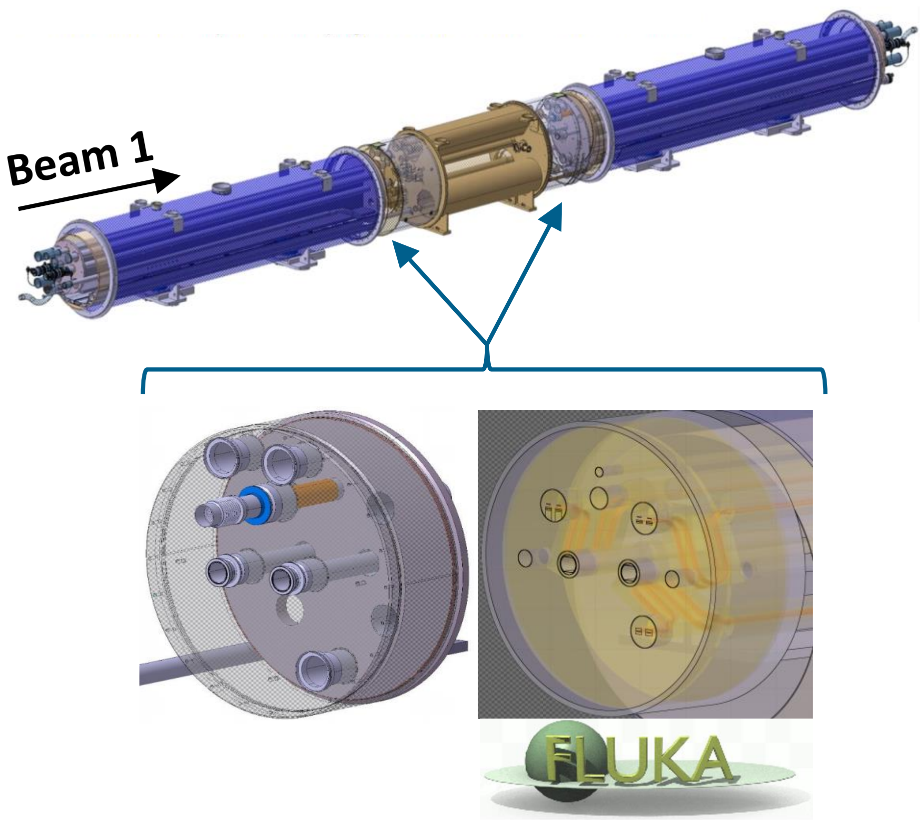
For HL-LHC conditions Estimated beam power ~155W

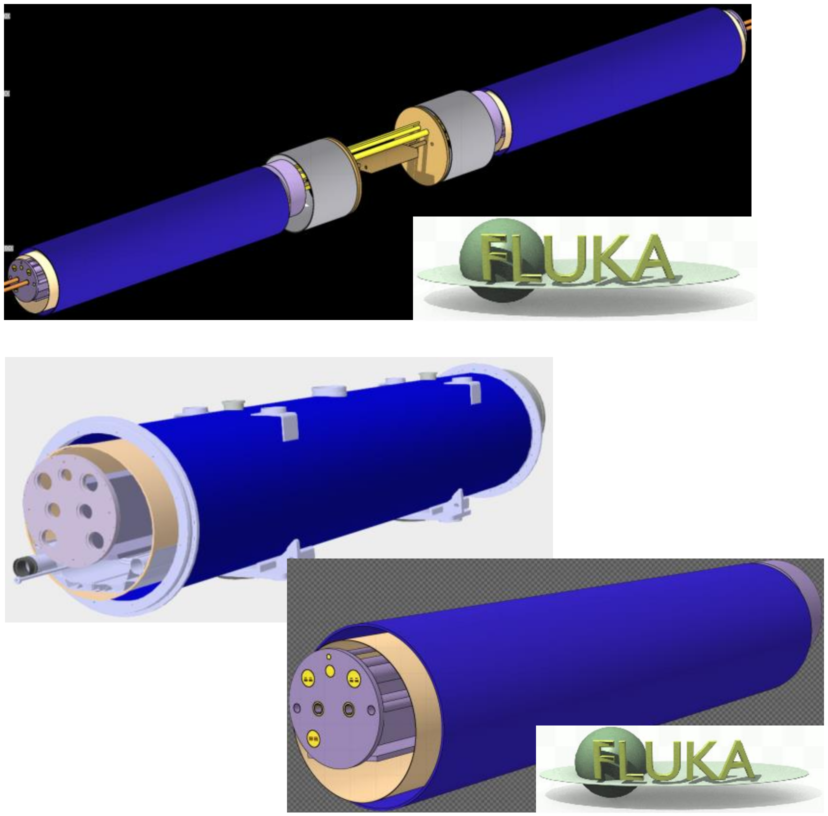
EMD: $^{208}Pb^{82+} + {}^{208}Pb^{82+} \rightarrow {}^{208}Pb^{82+} + {}^{207}Pb^{82+} + n$

For HL-LHC conditions Estimated beam power ~56W

Particle showers from TCLD intercepting these secondary beams could damage electronics or quench sensitive parts of magnets and bus bars further downstream

Implementation of the cryostat model in FLUKA





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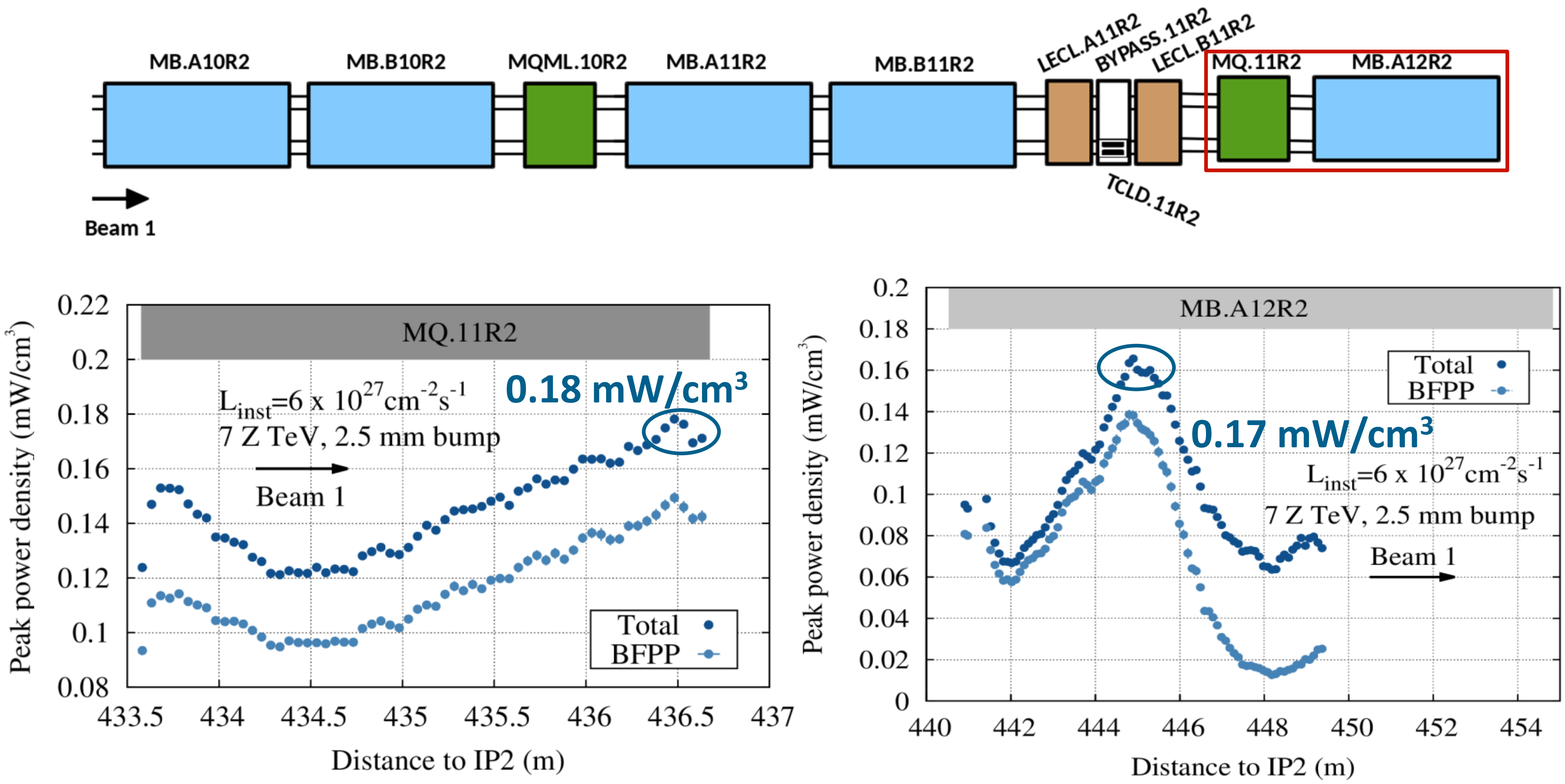
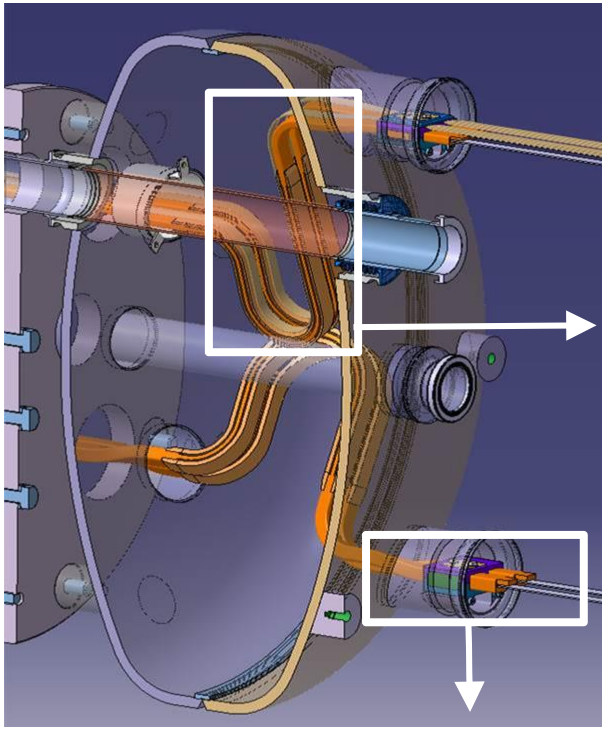
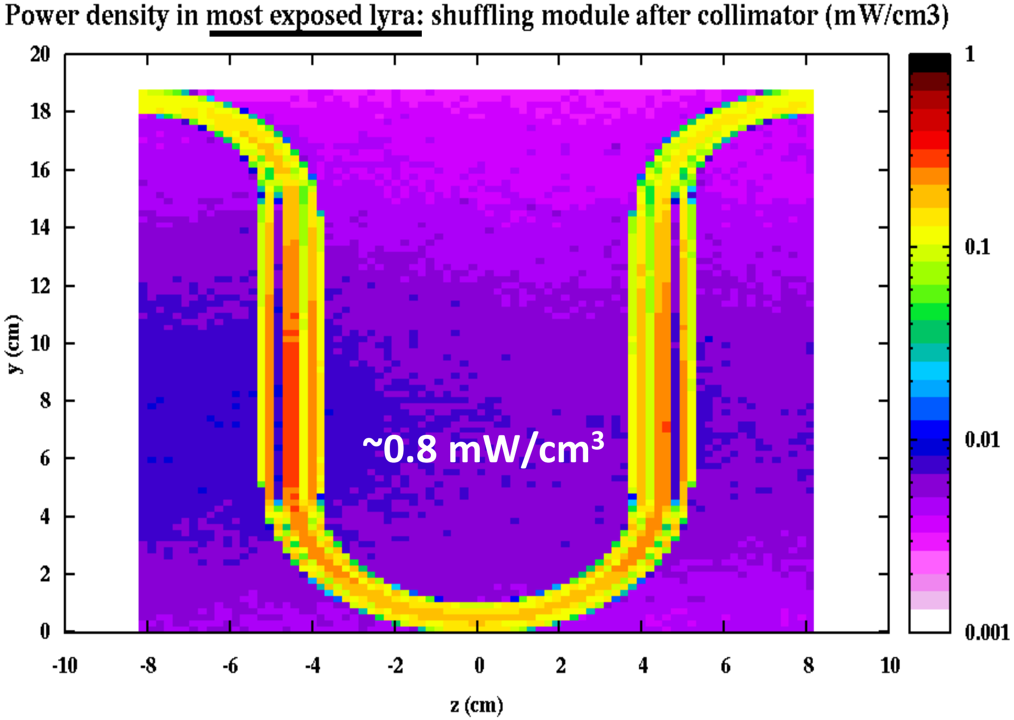
Quench risk: superconducting magnet coils



Collimator maintains the peak power density in the magnet coils at least a factor 10 below their estimated quench limit

Quench risk: lyras & M lines of the cryostat





Most exposed M line ~2 mW/cm³

Current cryostat design gives a peak power density in the bus bars of at least a factor 100 lower than their estimated quench limit

Cryogenics: heat load to the cold elements

In the DS is potentially possible to extract 150W (120W dynamic plus static loads) from magnet cold mass elements at 1.9K. However, with a high dynamic load, the operational redundancy of the cooling loops becomes questionable.

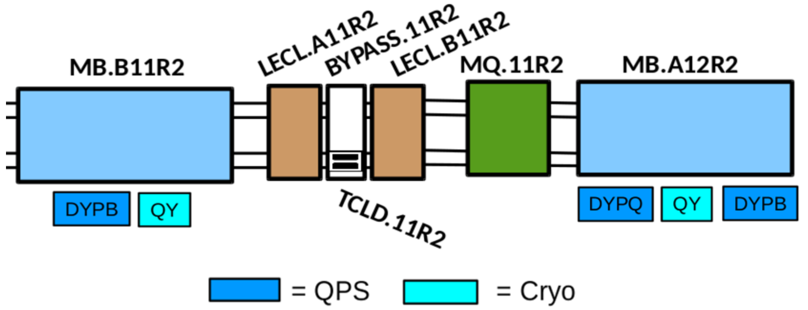
R. Van Weelderen

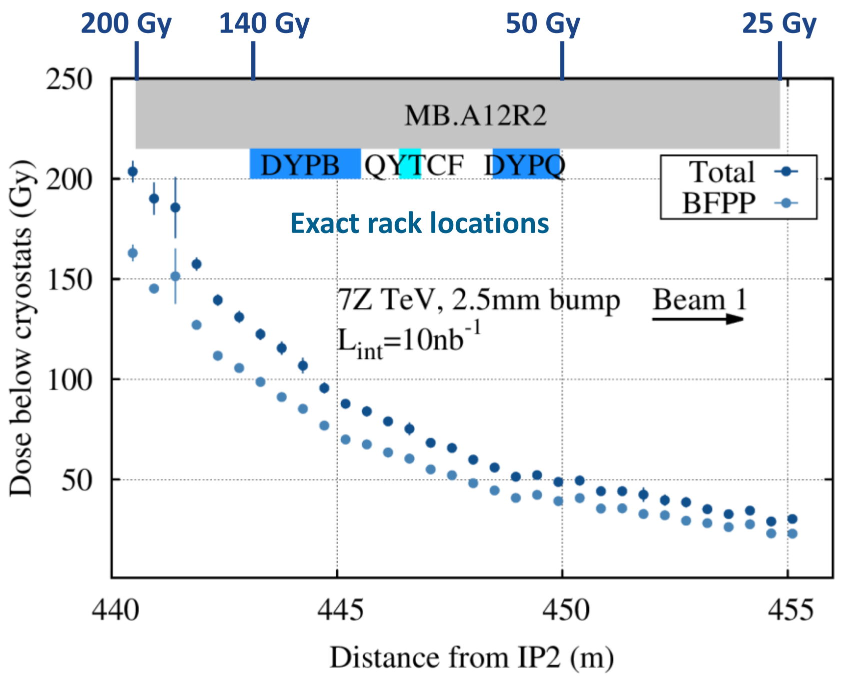
	MQ.11R2	MB.A12R2	Collimator impacted jaw	Collimator non-impacted jaw	Collimator tank	Cryostat
Total power	2 W	2 W	71 W	11 W	10 W	16 W

Factor 60 reduction compared to using only an orbit bump

The implementation of a TCLD collimator helps to evenly distribute the heat load among different components → facilitated evacuation by cryogenics.

Radiation to Electronics: cumulative damage (dose)





Results normalized to 10 nb^{-1}(target integrated luminosity for ALICE during **the whole HL-LHC ion period**)

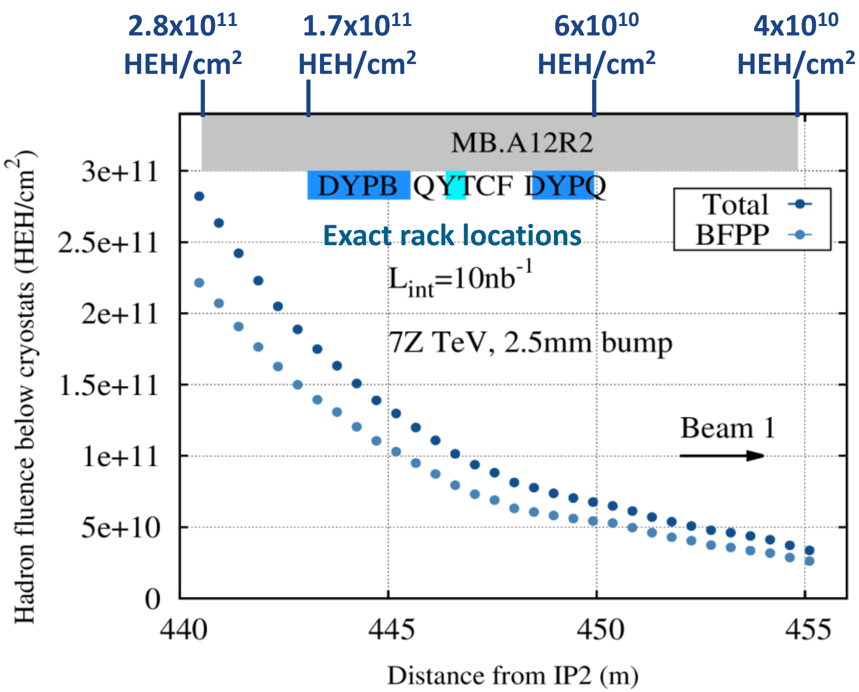
Dose accumulated during ion runs over <u>all</u> years of HL-LHC operation

For currently envisaged lifetimes <20 Gy/year or rack rotation *(M. Brugger)*

Rack rotation or non-electronic zone foreseen

Moving the electronic racks towards the end of the MB would halve the dose they are exposed to

Radiation to Electronics: Single Event Effects (HEH fluence)



Results normalized to 10 nb^{-1}(target integrated luminosity for ALICE during the whole HL-LHC ion period)

HEH fluence during ion runs over all years of HL-LHC operation

Probabilities of SEE failure for a certain HEH fluence are calculated for the total number of units in the machine

Probability of SEE failure may increase in these racks but not in the rest of the LHC areas: the overall probability of failure would not be significantly affected

No risk of compromising the machine operation due to HEH fluence levels

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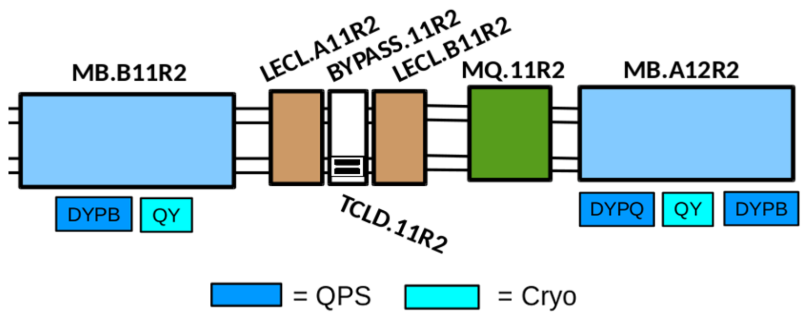
Conclusions and outlooks

For target instantaneous luminosities during ion operation ($6x10^{27}cm^{-2}s^{-1}$), installing a collimator in the DS of IR2 (provided it intercepts the 2^{ary} beams with a 2mm impact parameter):

- eliminates the risk of quenching any downstream magnets
- does not introduce a risk of quenching M lines or lyras in the shuffling module
- does not pose a challenge for the cryogenic system

For a target integrated luminosity of 10 nb^{-1} over the whole HL-LHC ion operation, no added shielding around the collimator and cryostat is required as long as:

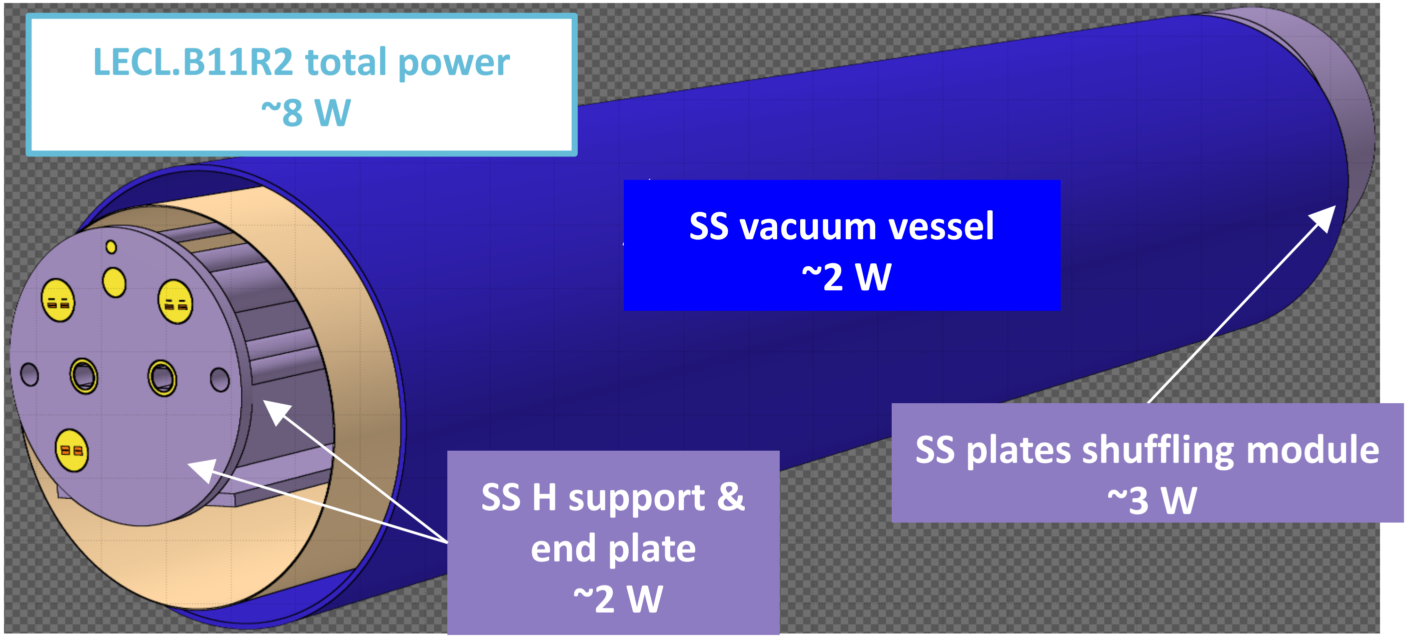
- the electronic racks under the MB.A12 are displaced towards the end of the magnet. This way the dose they are exposed to would get halved
- a rack rotation or a non-electronic zone is foreseen



Thank you for your attention

Back-up

Cryogenics: power deposition distribution



BYPASS.11R2 total power
~5 W