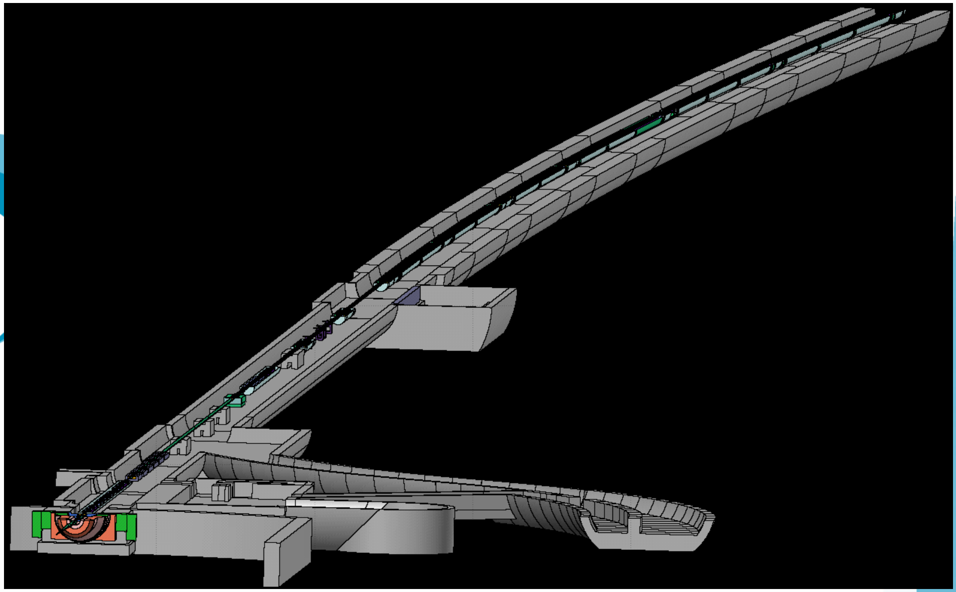
HiLumi HL-LHC PROJECT



IR1/5 COLLIMATION UPGRADES: OUTGOING BEAM

Francesco Cerutti, Luigi S. Esposito, Andrea Tsinganis

CERN EN STI

WP10

Energy deposition & R2E

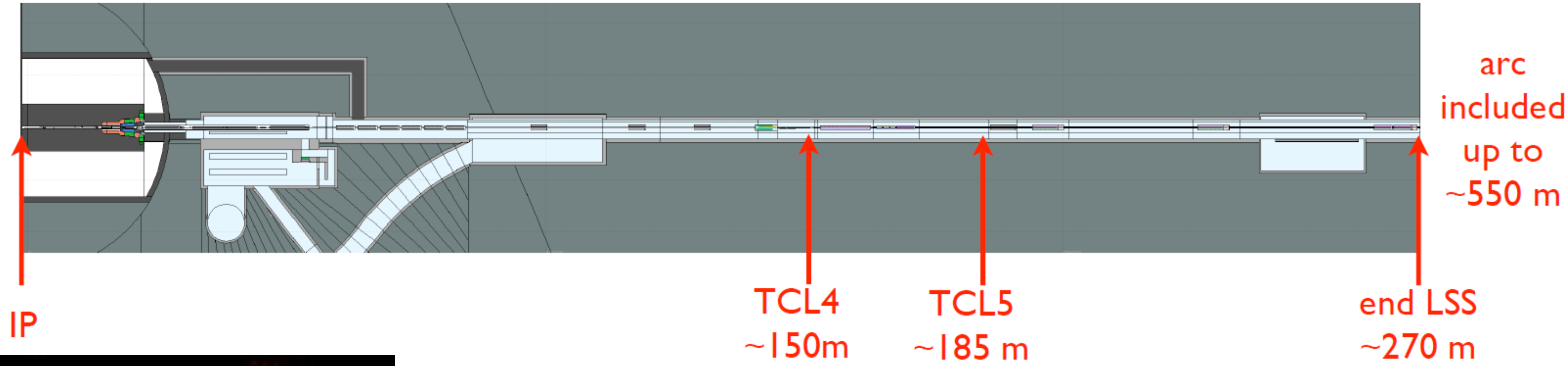
International Review of the HL-LHC Collimation System

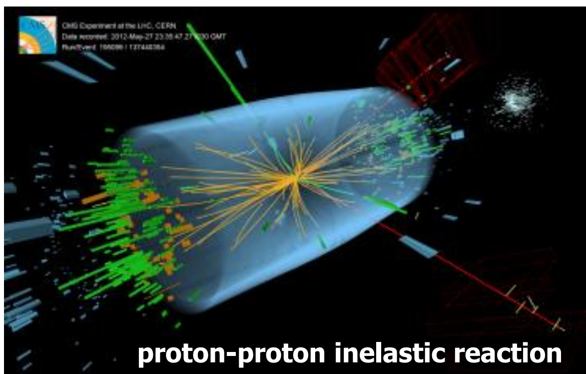
Feb 11th, 2019

OUTLINE

- TCL collimators: why, which
- Another one (TCL6) and its implications wrt forward physics Roman Pots, Dispersion Suppressor magnets and equipment, and RR electronics alcoves
- The new HL Matching Section, implying additional masks (TCLM)
- The DS exposure over the HL era

AN OLD STORY

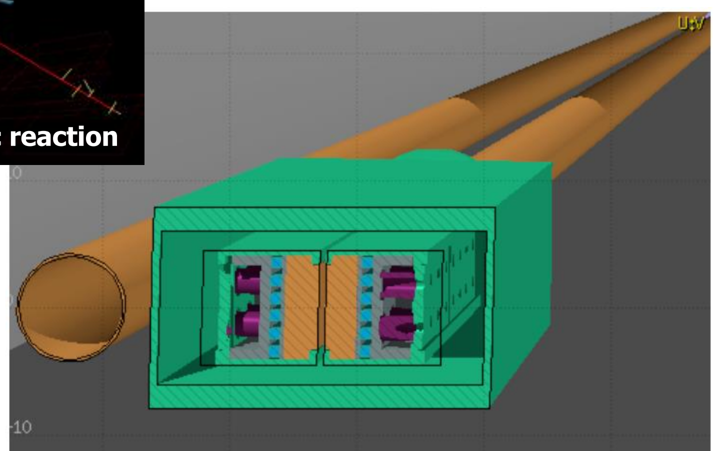




clear evidence of **TCL5** need already in April 2003:

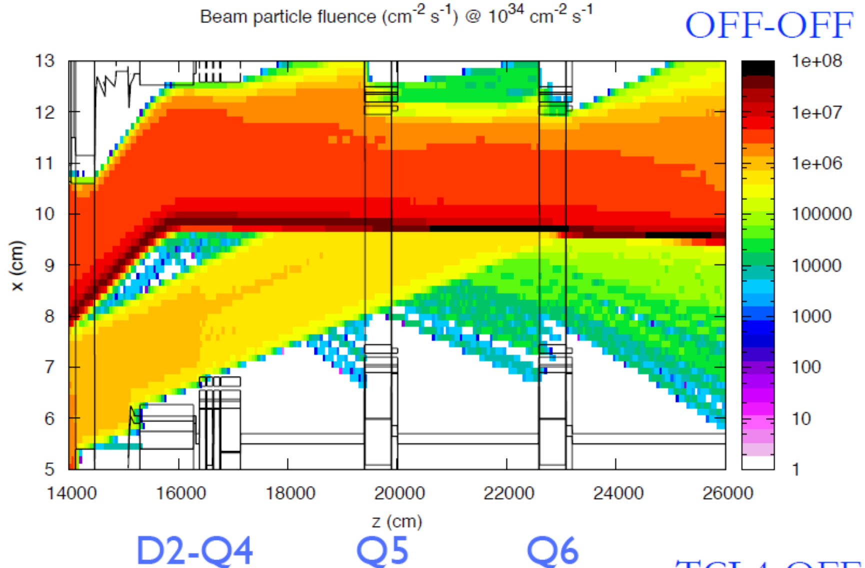
N. Mokhov et al.,
LHC Project Report 633

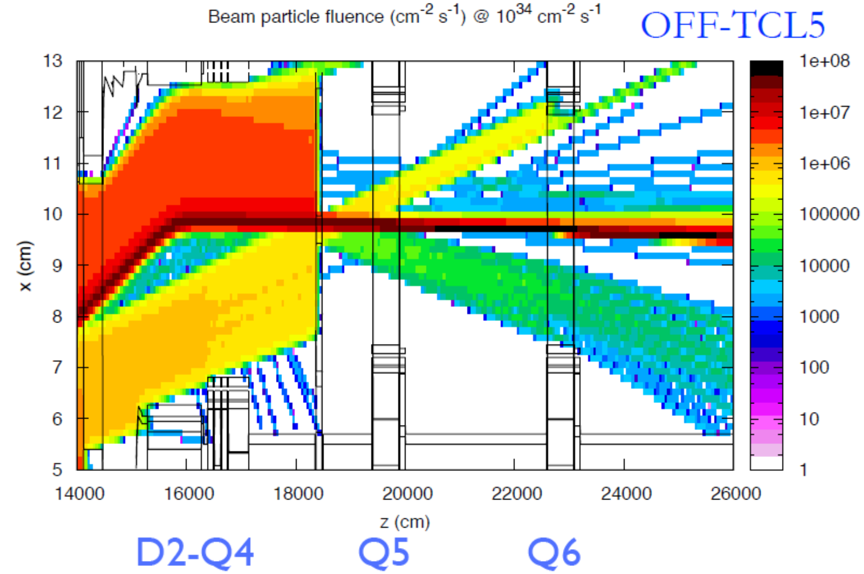
I. Baishev,
Radiation Levels in RR Areas

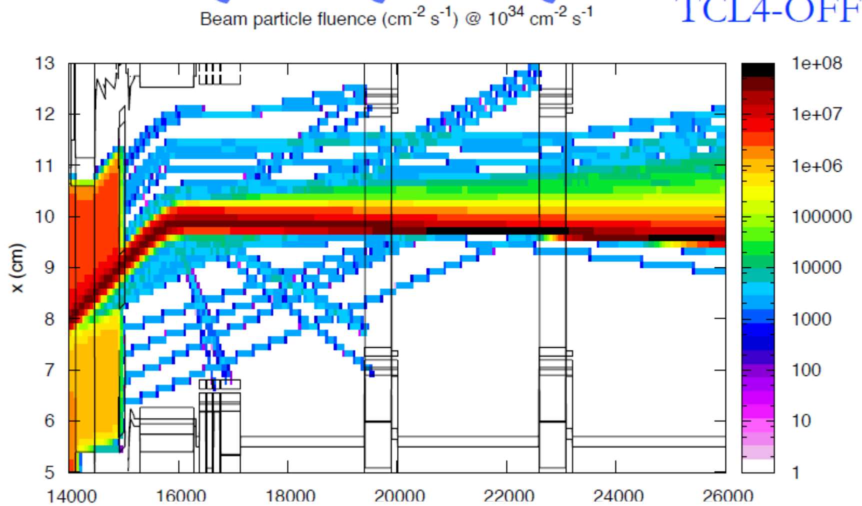


1 m long copper jaws

THE TCL4 APPRECIATION





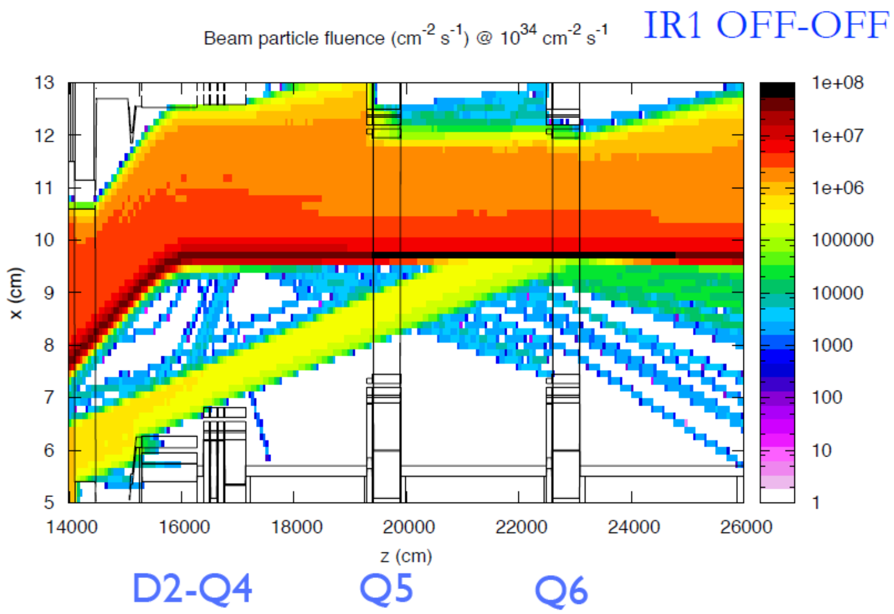


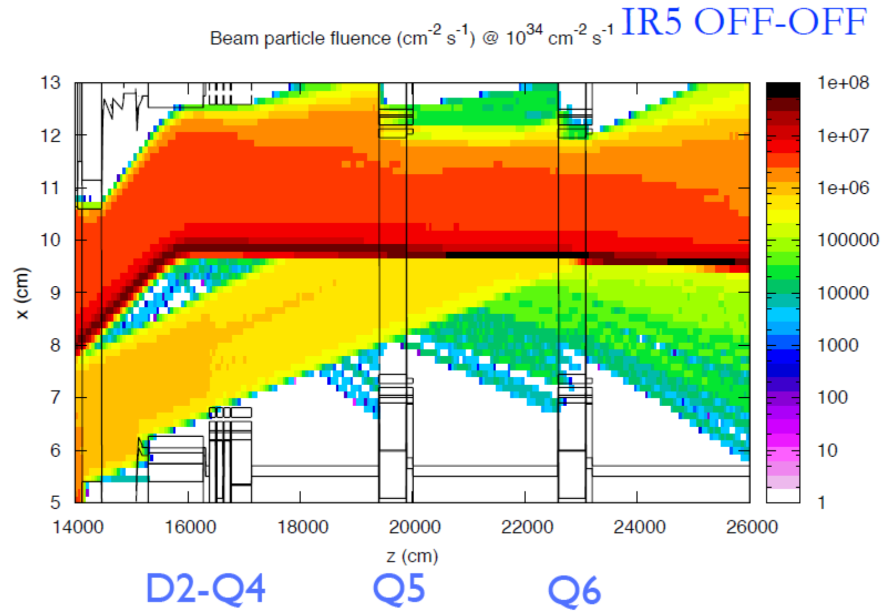
vertical average over 6 cm at beam height

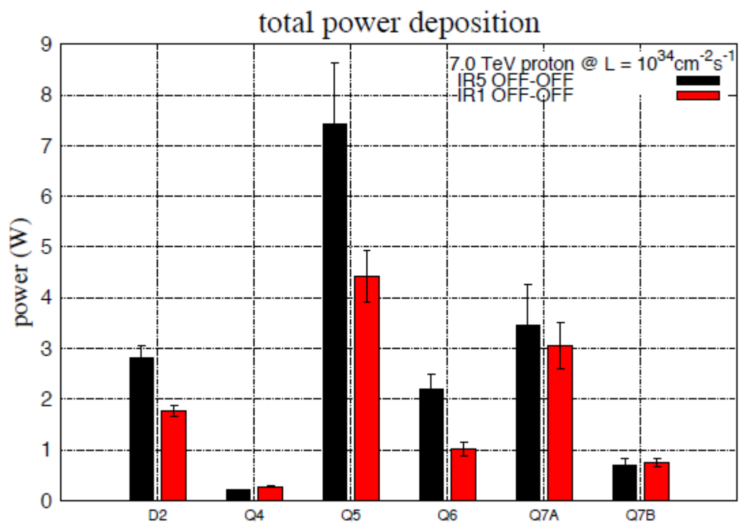
better cleaning of collision product by TCL4

- TCL4 is more efficient in catching the neutrals coming from IP, that are mainly responsible for energy deposition in the Matching Section elements, because of the maximum separation of the neutral beam from the circulating proton trajectory

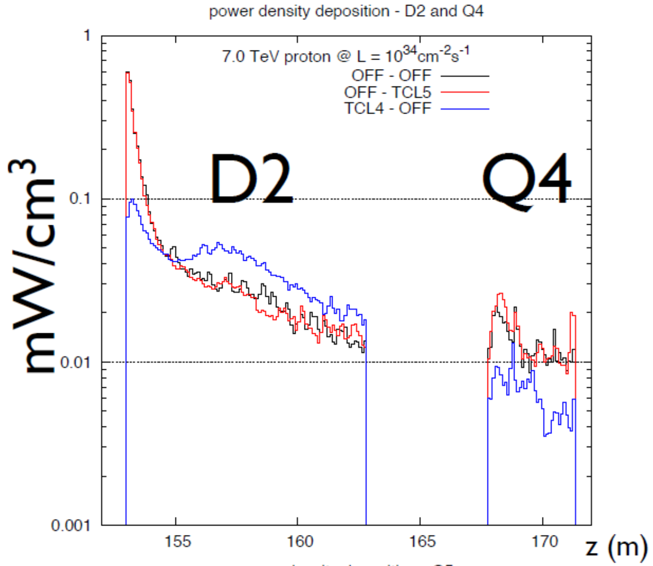
CROSSING PLANE EFFECT





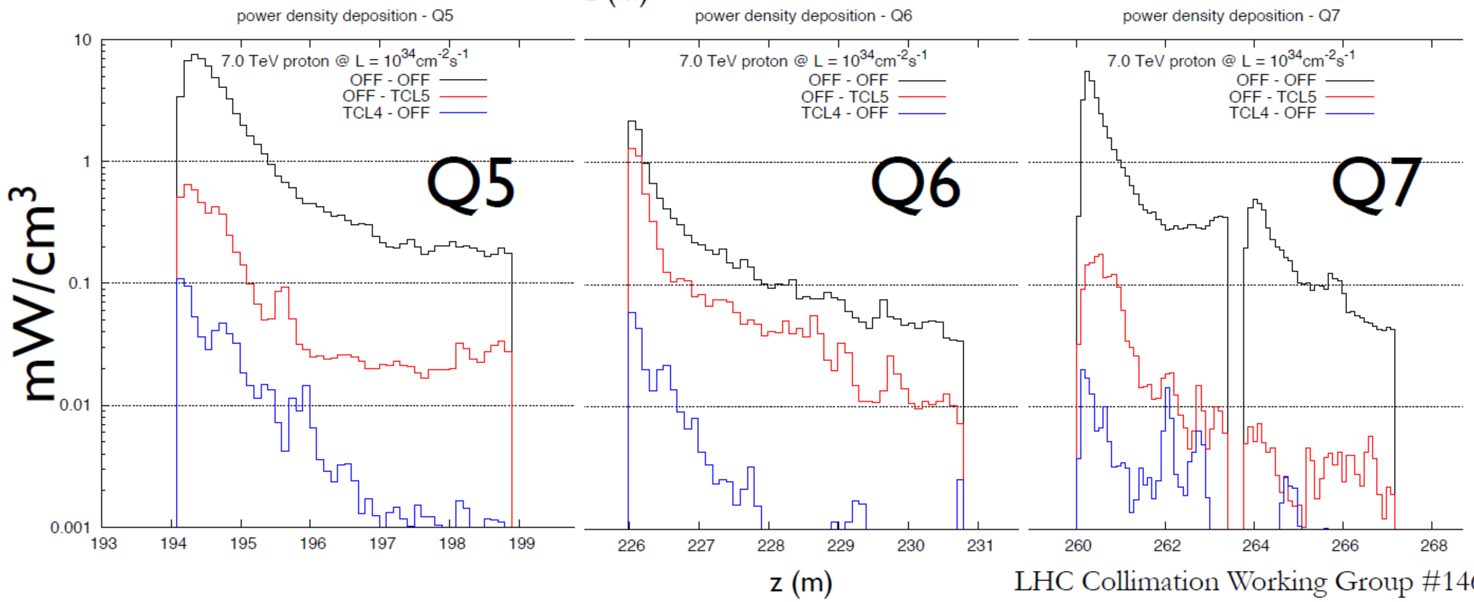


MATCHING SECTION MAGNET PROTECTION



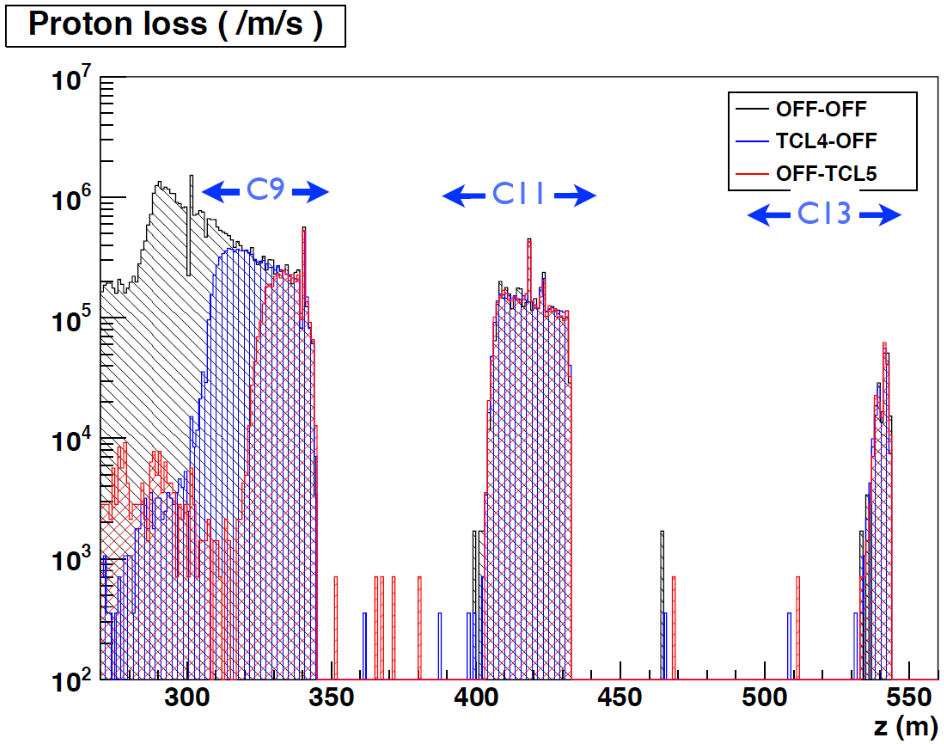
- Binning scoring: $\Delta z = 10$ cm, $\Delta\phi = 2$ deg averaged radially on the entire coil

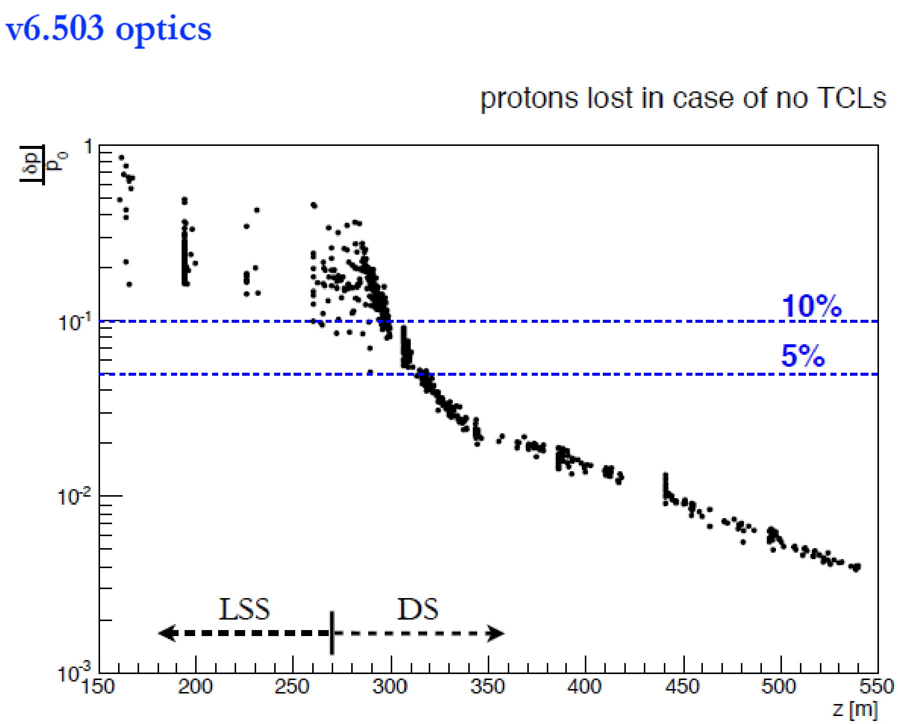
- D2 not an issue
- Q5 and Q7 protection required
- power peaks of about same order in IR1



LHC Collimation Working Group #146, 30 July 2012

DISPERSION SUPPRESSOR





TLC4 provides less protection in the dispersion suppressors
Shower effects in the arc might be evaluated starting from loss map
TCL6 role should be taken into account

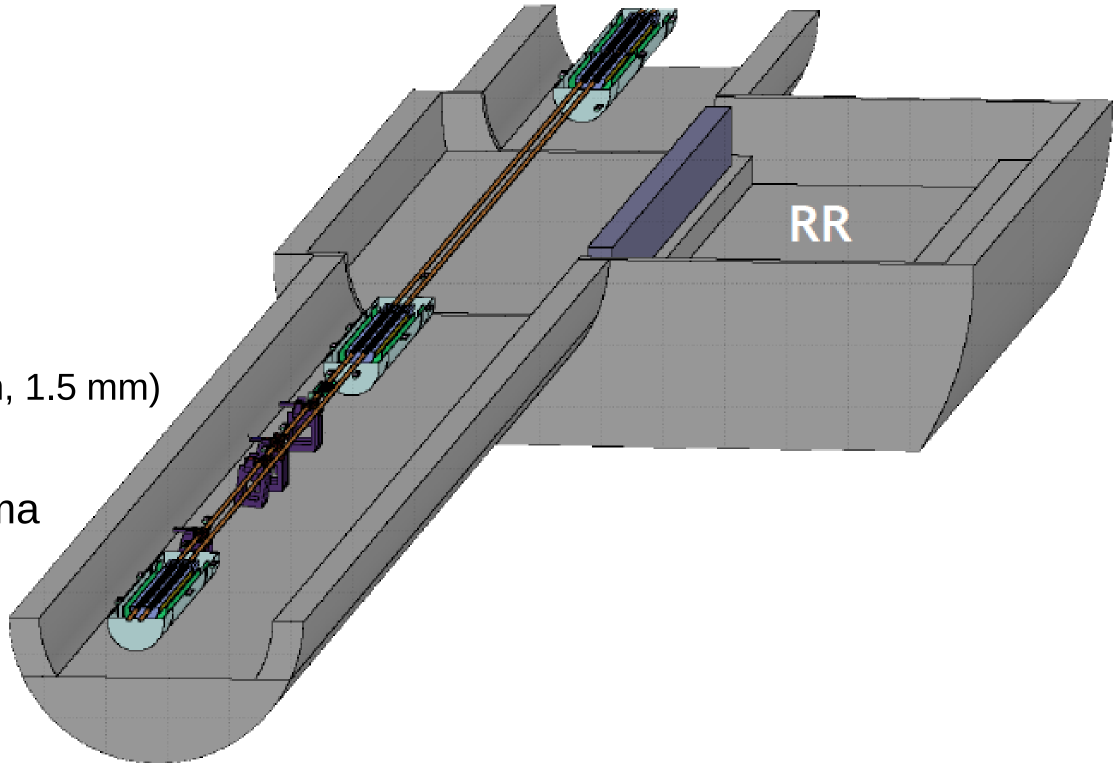
LHC Collimation Working Group #146, 30 July 2012

THE NEWCOMER: TCL6

forward physics Roman Pots

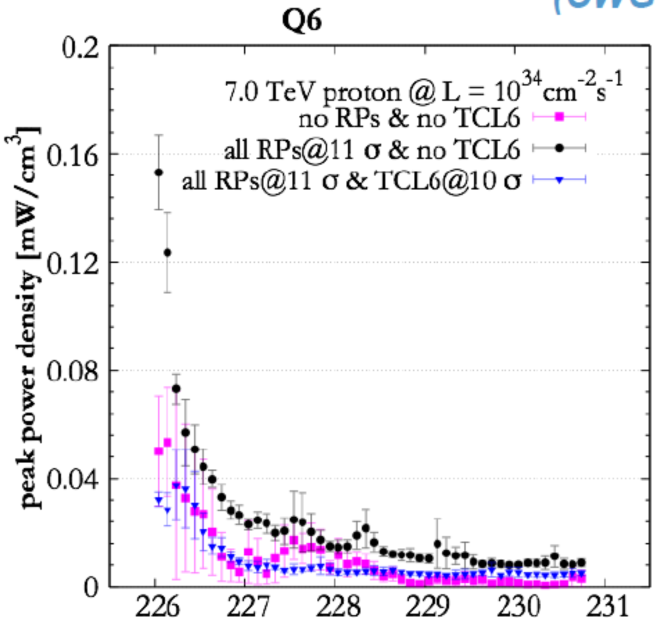
TOTEM at max (12 sigma + 0.3 mm, 1.5 mm)

with TCL4, 5, 6 at 15-18, 35, 20 sigma

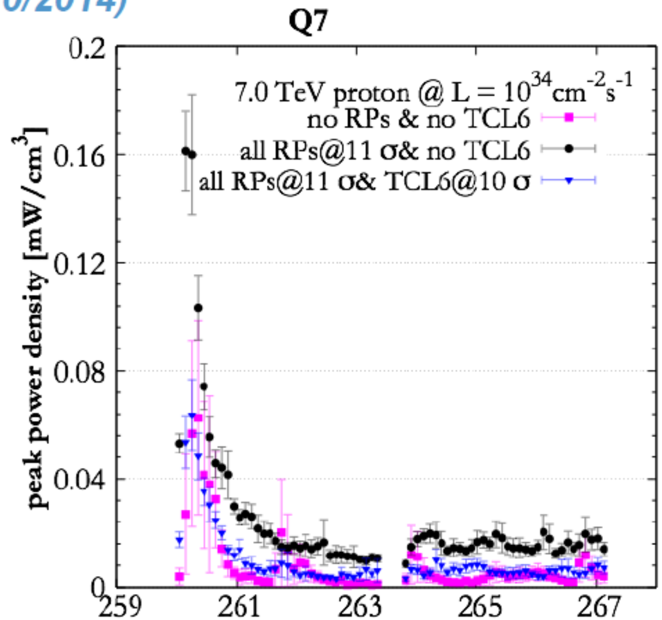


Q6/Q7 PROTECTION AND BLM SIGNALS

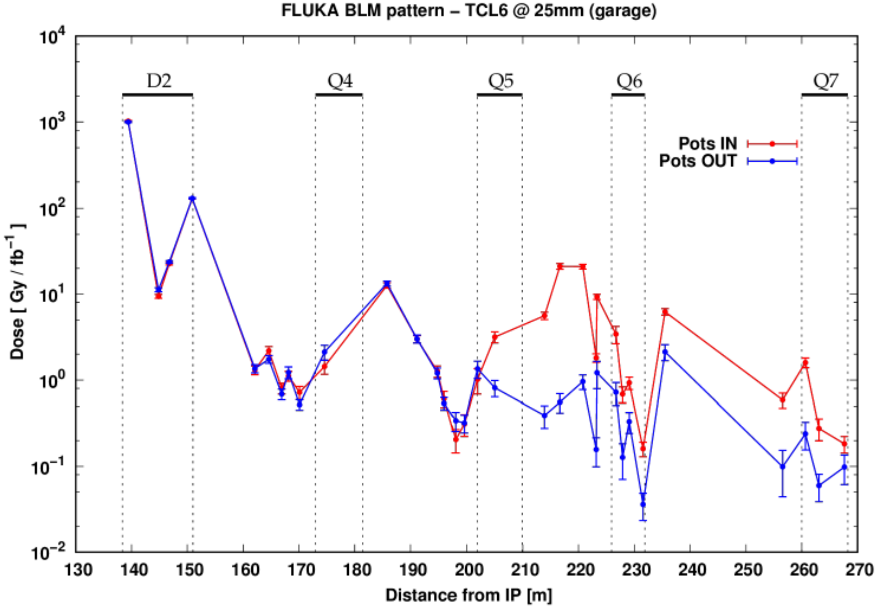
(CWG #182, 27/10/2014)

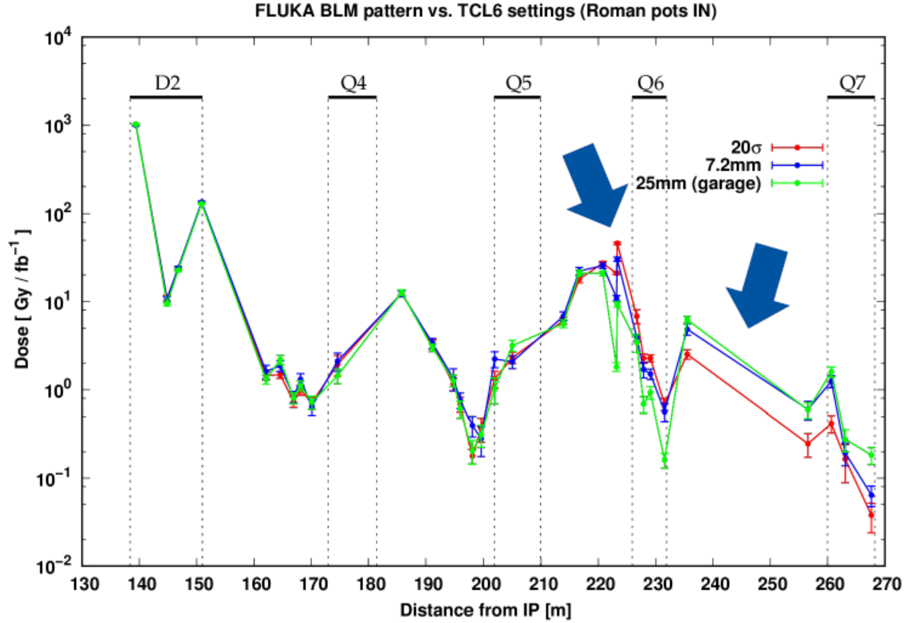


FLUKA BLM pattern – TCL6 @ 25mm (garage)

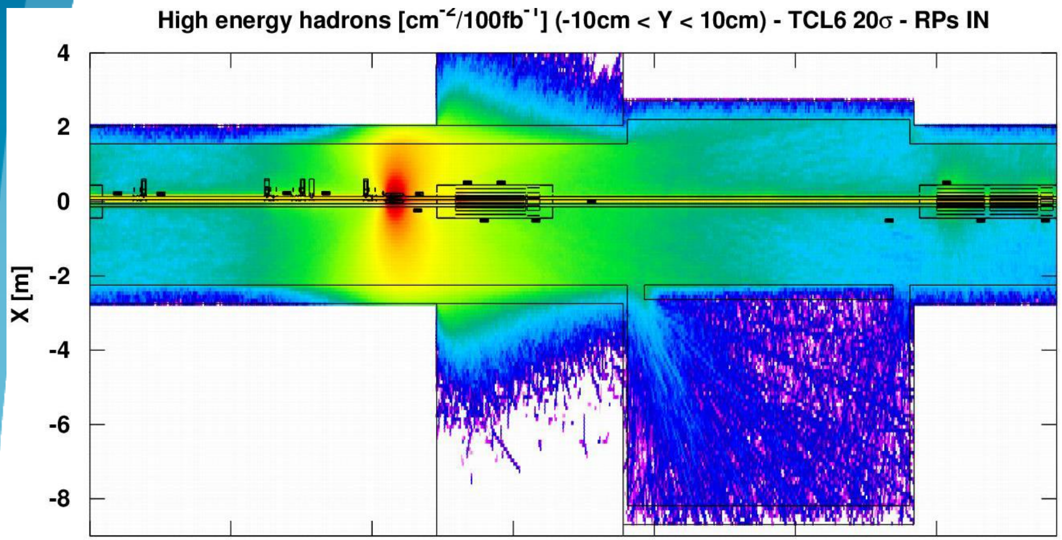


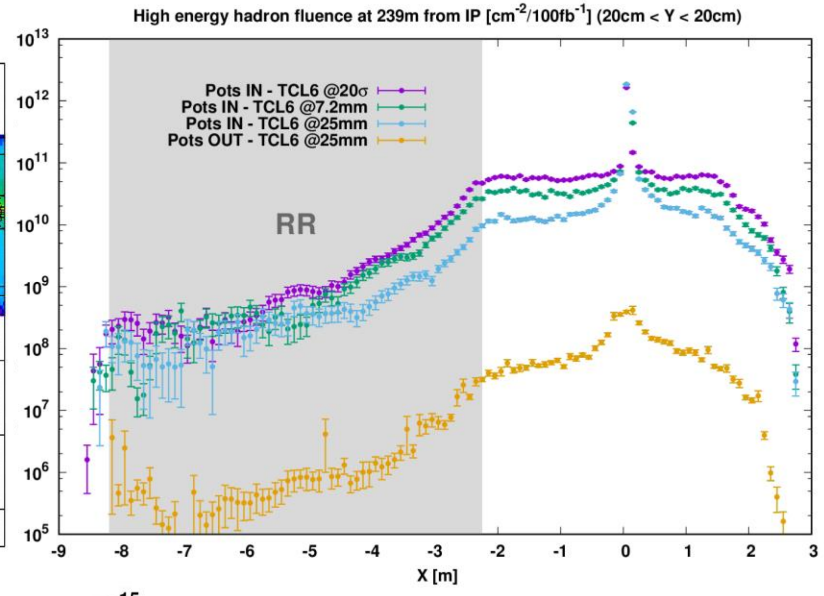
FLUKA BLM pattern vs. TCL6 settings (Roman pots IN)

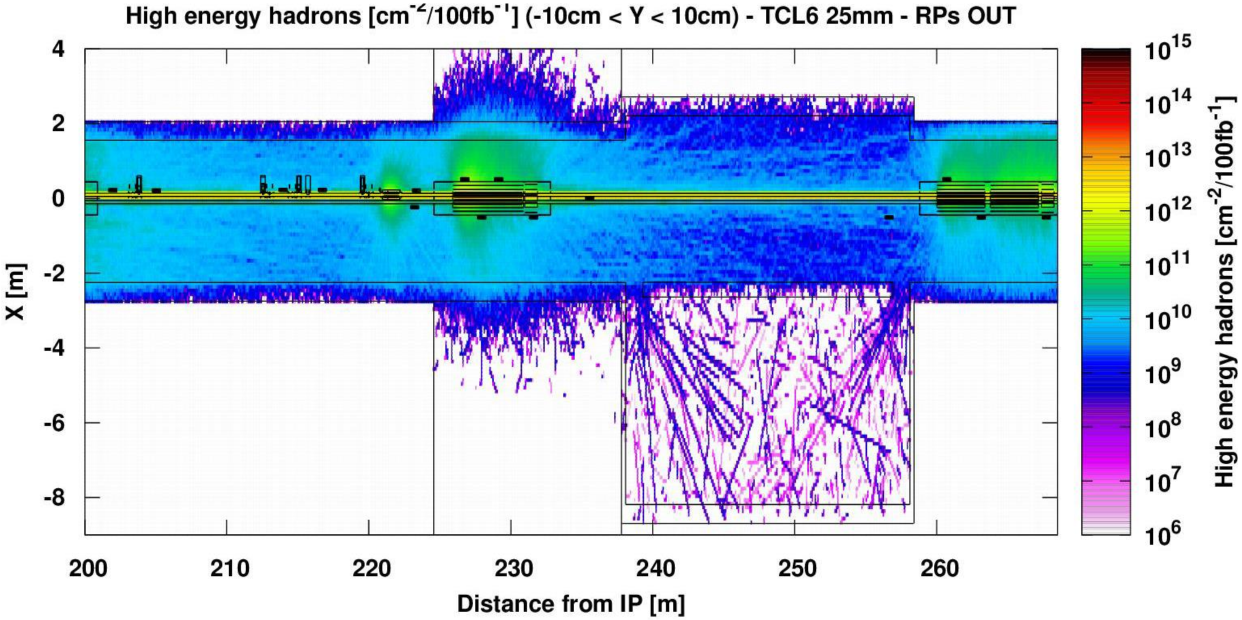




RADIATION LEVEL IN THE RR

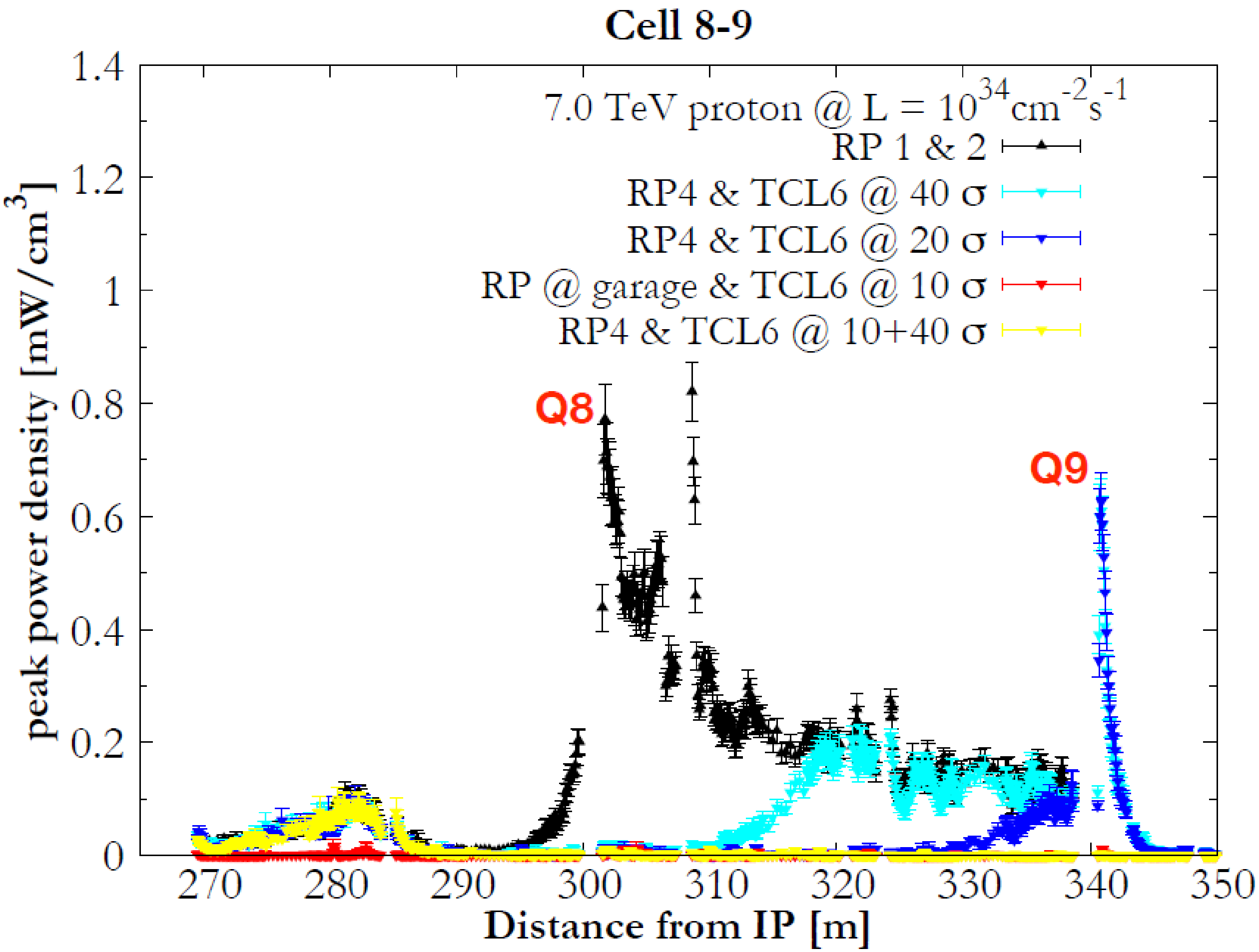






with RPs out and TCL6 in garage position, the actual levels get dominated by the *beam-gas* contribution

DISPERSION SUPPRESSOR CLEANING



10 σ aperture of the TCL6 external jaw is **necessary to protect Q9**

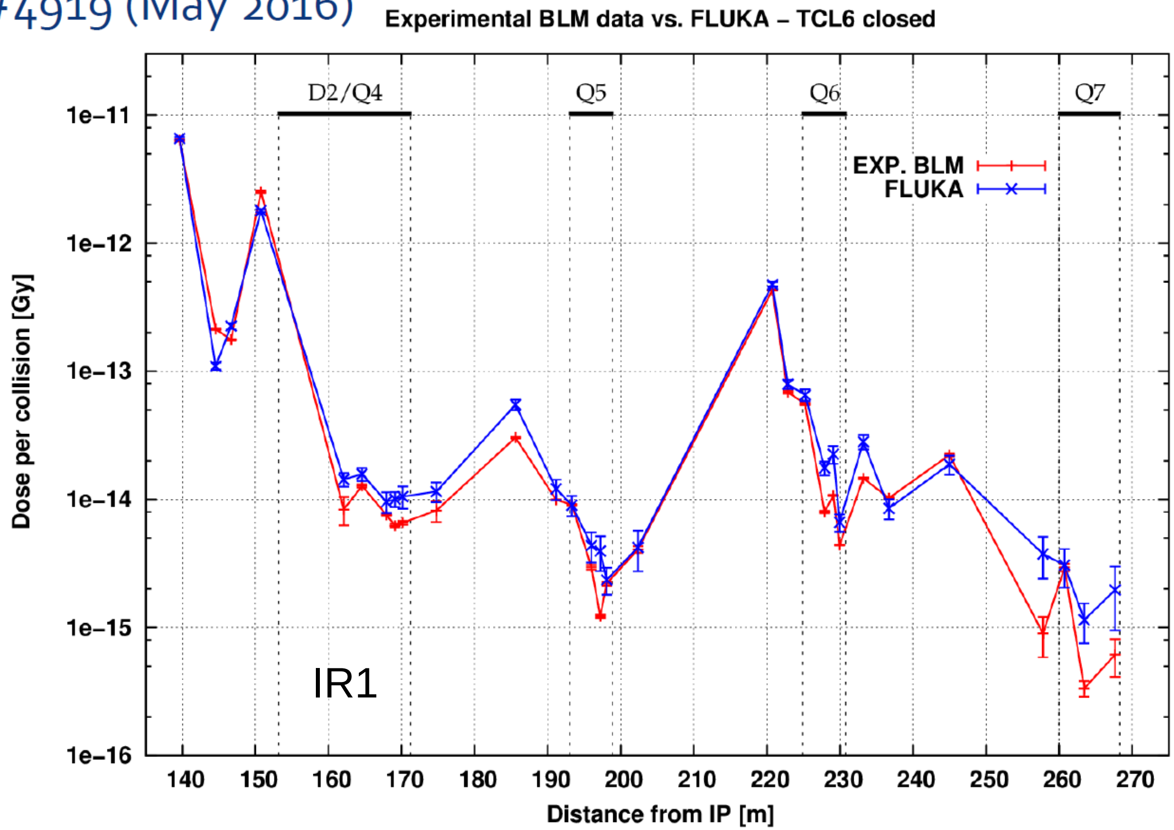
but cannot be applied for impedance reason (< 1 mm halfgap)

L.S. Esposito, LHC Collimation Working Group #174

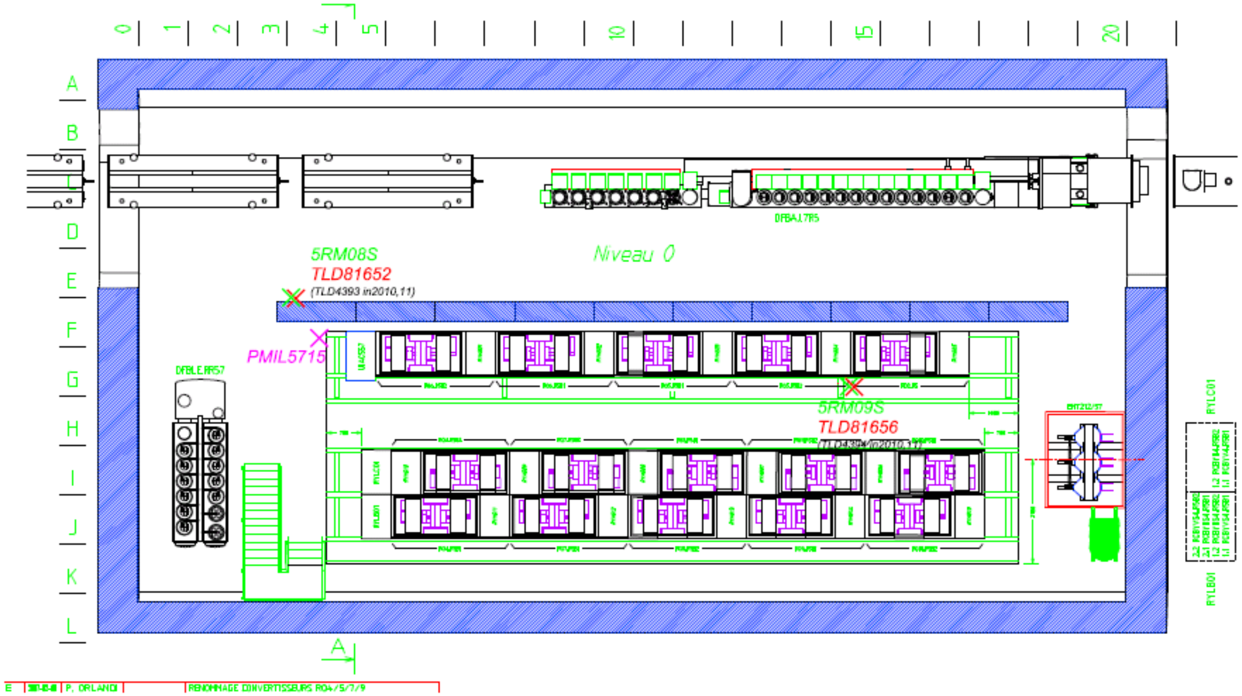
BLM BENCHMARKING [I]

6.5 TeV beams

- Fill #4919 (May 2016)



RADMON BENCHMARKING

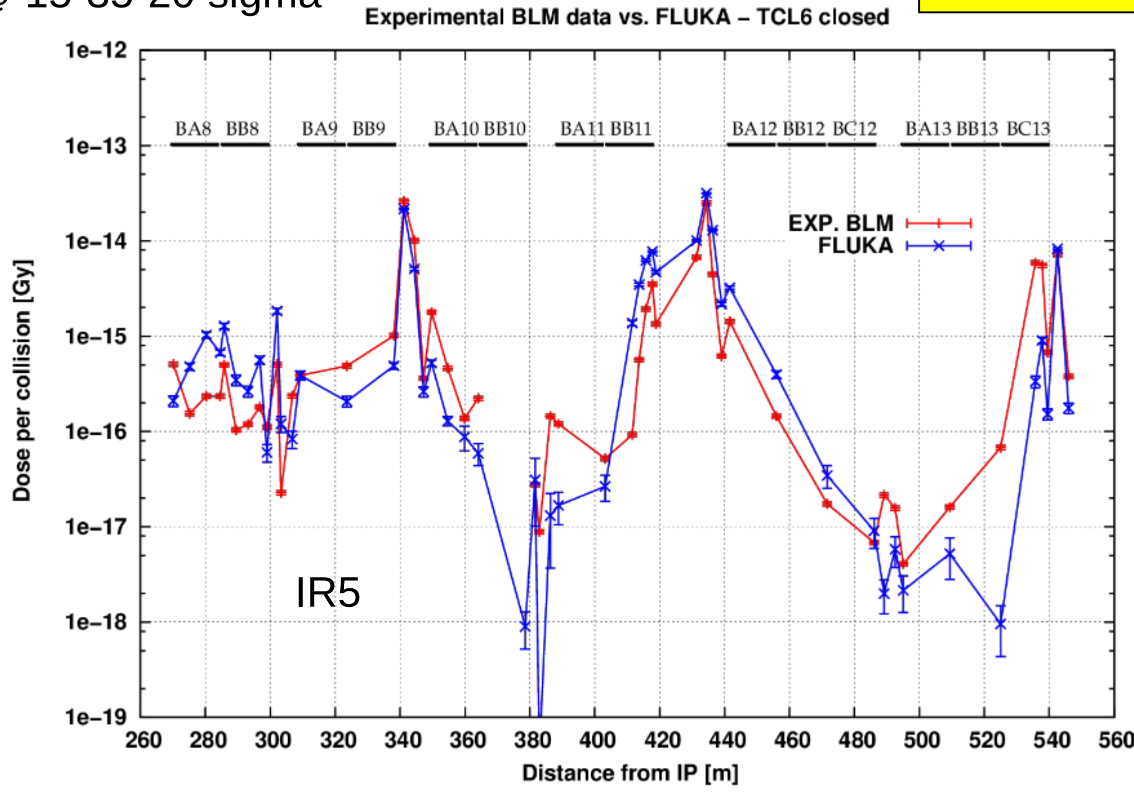


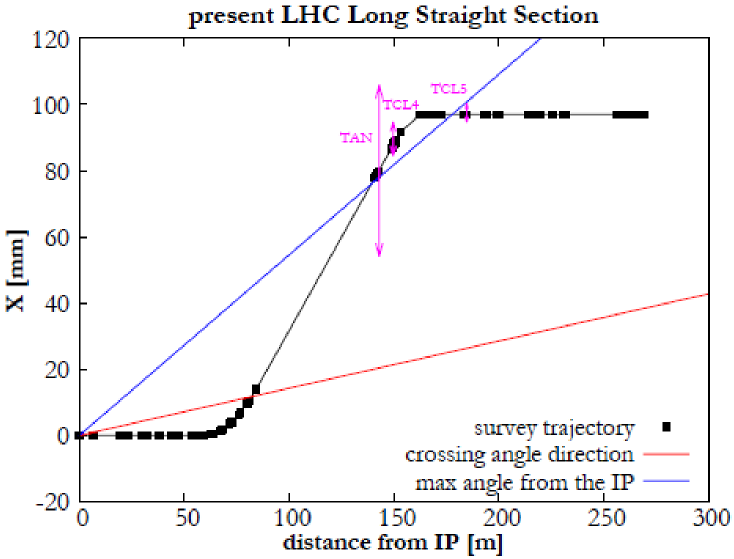
$F_{H>20MeV}$ [cm^{-2}] (L_{2012})	5RM08S	5RM09S
FLUKA	$6.1\ 10^{8}$	$3.0\ 10^{7}$
DATA	$4.56\ 10^{8}$ (256 upsets)	$4.32\ 10^{7}$ (25 upsets)

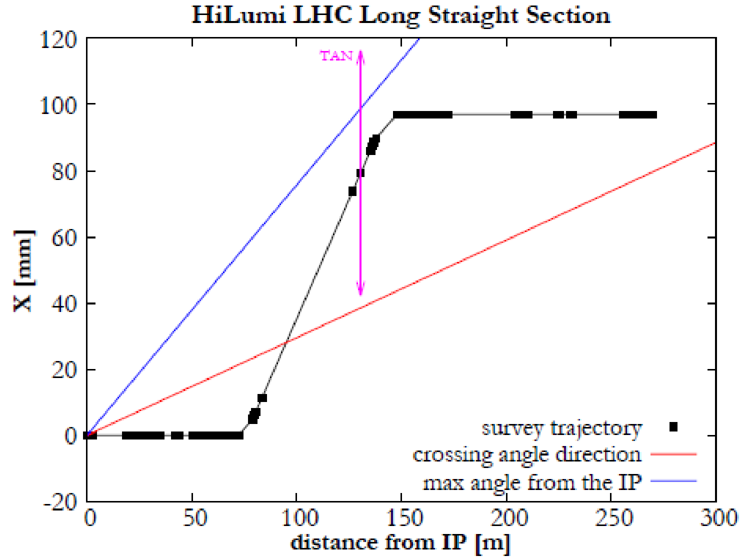
BLM BENCHMARKING [II]

Fill #5401 (October 2016)
TCLs @ 15-35-20 sigma

6.5 TeV beams

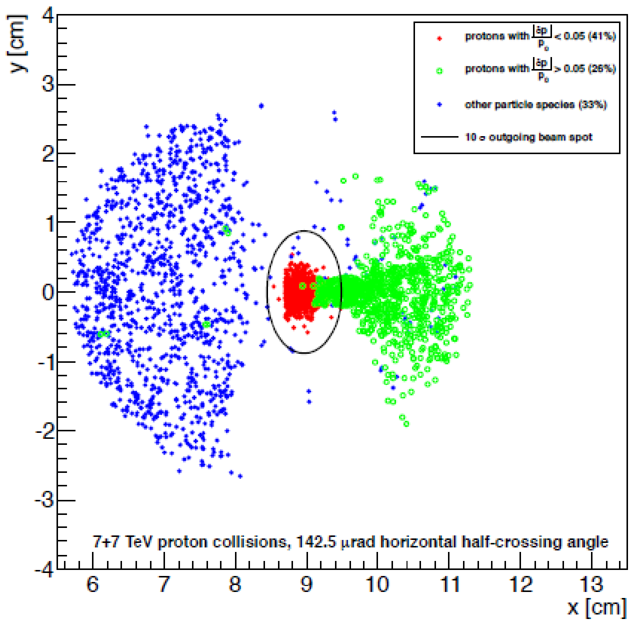




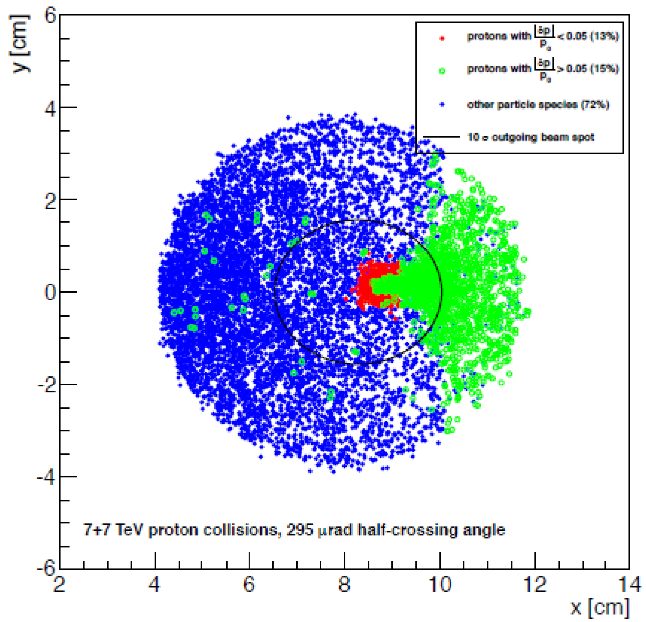


LHC **VS.** **HL-LHC**

debris distribution at TCL.4R5 entrance



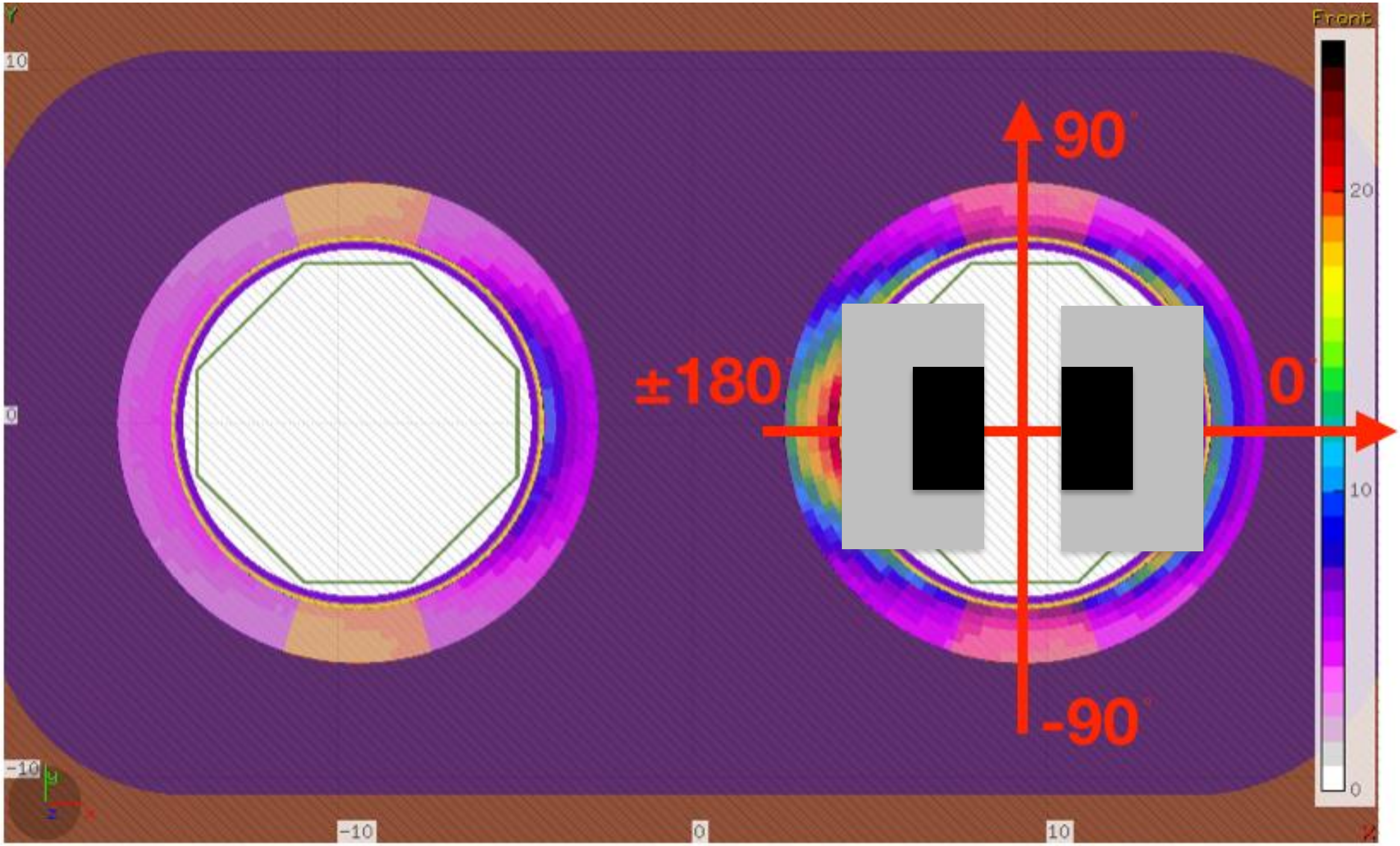
debris distribution at TAN.4R5 exit (truncated cone)



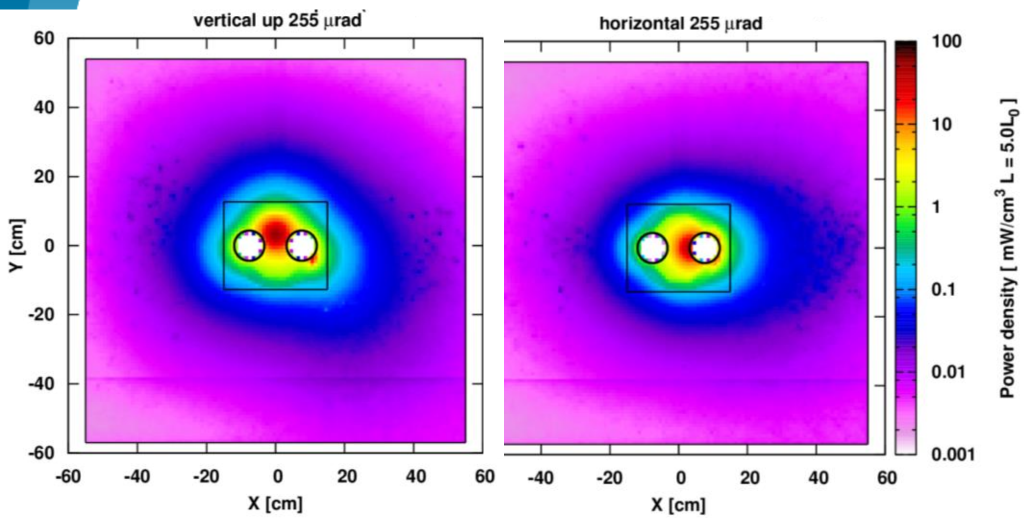
Same number of events

HiLumi HL-LHC PROJECT

WHY A NEW DESIGN: TCLX4



THE NEW MATCHING SECTION



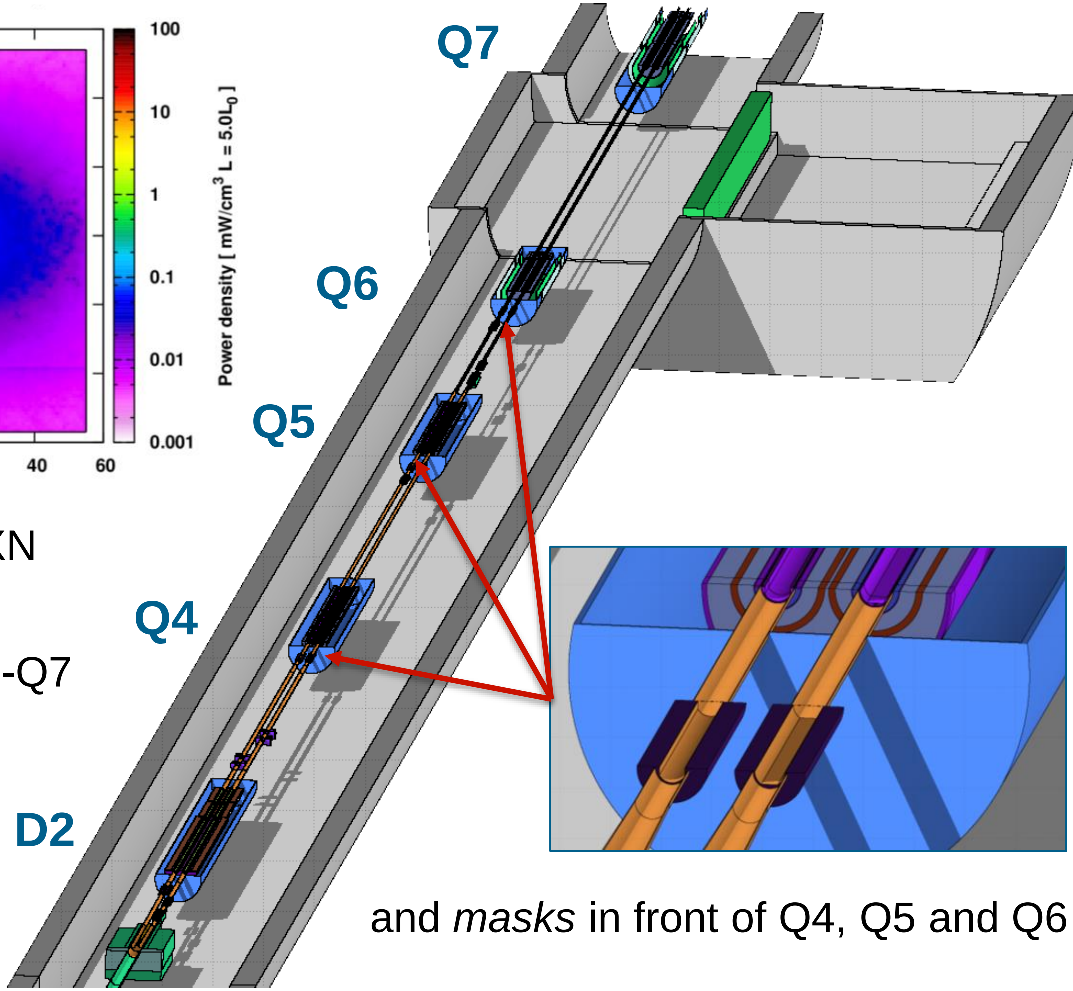
behind the 85 mm twin bore TAXN

with the old 70 mm Q4 and 56 mm Q5-Q7

3 TCLs @ 14 σ* and

4 TCTs @ 10.5 σ*

* *for 2.5 µrad emittance*



and *masks* in front of Q4, Q5 and Q6

33 W in the D2 cold mass for **hor** crossing, 155 W in the most exposed TCL4 jaw

@ $5L_0$ peak power density < 1 mW/cm³ everywhere (D2-Q7 cold coils)

HL MATCHING SECTION MAGNET PROTECTION

	Horizontal crossing	
Magnet assemblies	power density [mW/cm^3 @ 5L$_0$]	dose [MGy after 3 ab^{-1}]
D2	**0.8**	**12**
Q4	**0.5**	**7**
Q5 (70 mm)	**0.2**	**3** (4 W)*
Q6	**0.2**	**3**
Q7	**0.5**	**7**

*with TCL at 14 σ for 15 cm β**

(21 – 7 – 3 mm halfgaps)

	Horizontal crossing		
	dose [MGy after 3 ab^{-1}]		power density [mW/cm^3 @ 5L$_0$]
	12		**0.4**
	7		***1.1***
(56 mm)	**6** (4 W)*		**0.3** (2 W)*
	3		**< 0.2**
	7		**~ 0.2**

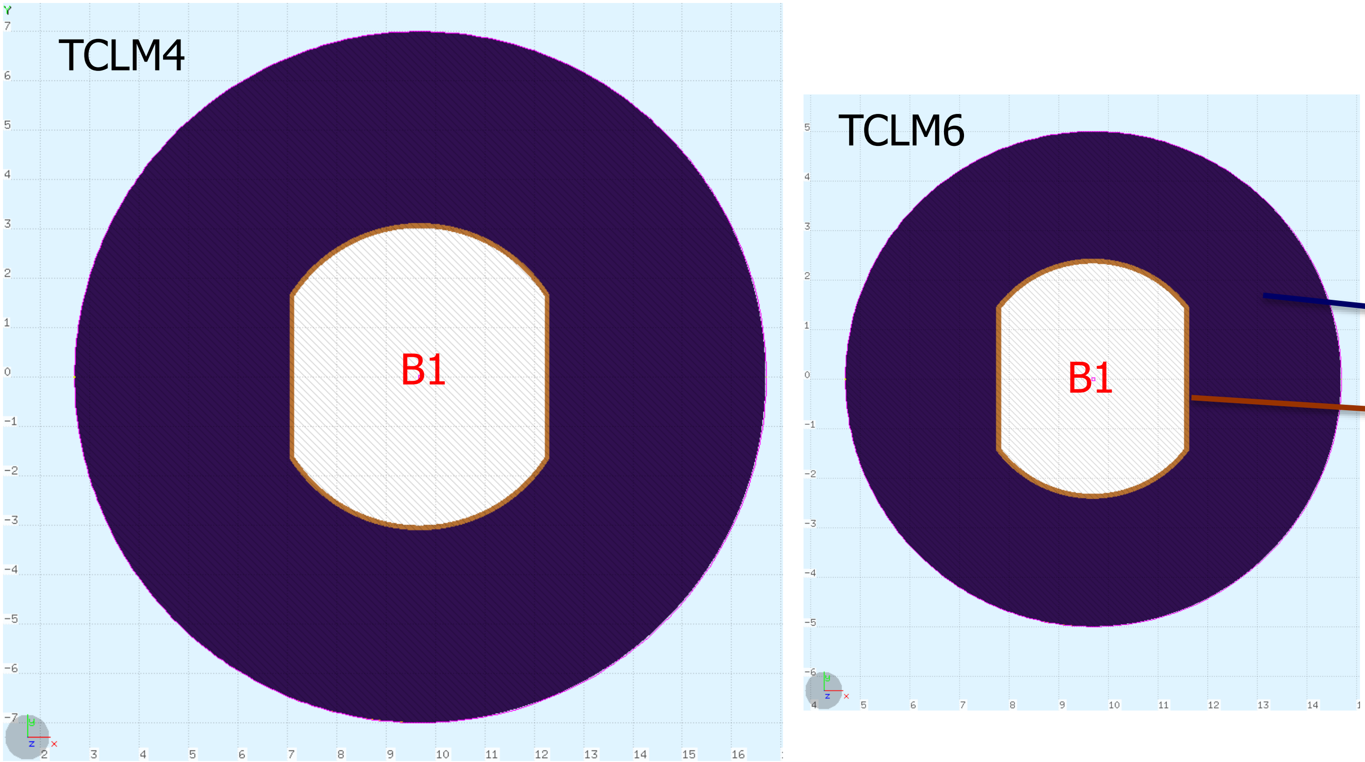
*for 50 cm β**

(TCL gap decreased by a factor 1.8)

TCL4 jaw up to 215 W

** total power in the Q5 assembly cold masses at 5L$_0$*

MASK CONCEPTUAL DESIGN



90 deg rotation on the B2 aperture

1 m length

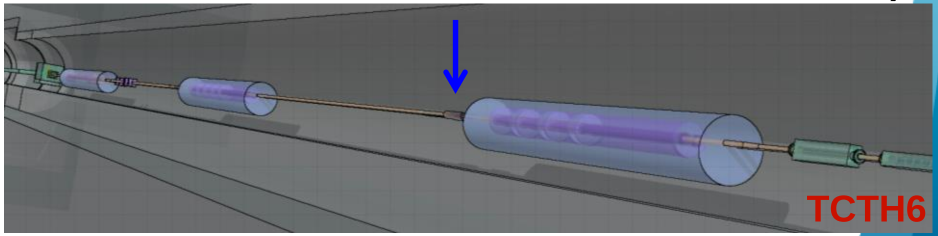
@ $5L_0$ 20 W in TCLM4, 5% on B2

8 W in TCLM5, 20% on B2

1.5 W in TCLM6, 5% on B2

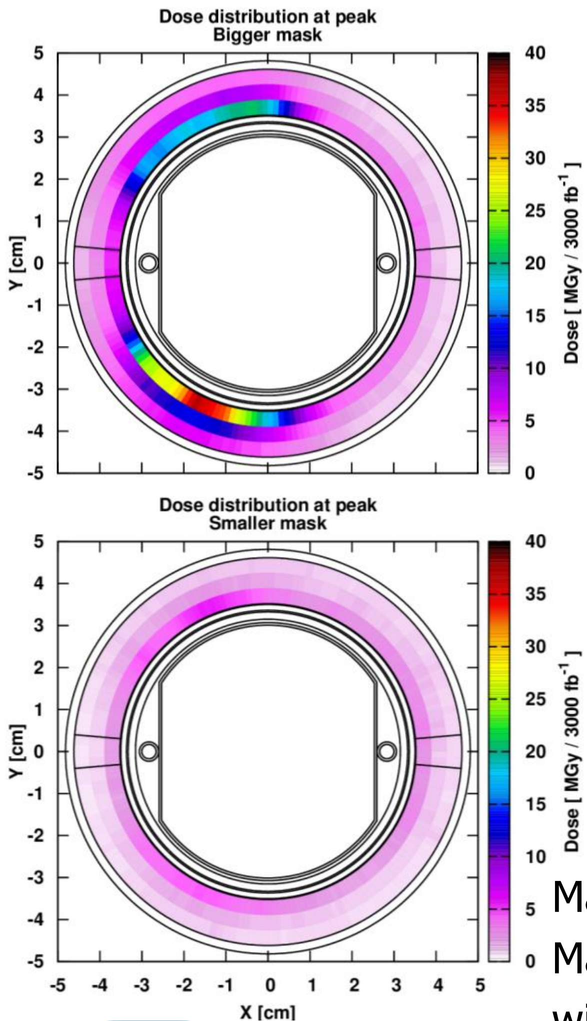
up to 10% in the 1 mm Cu chamber

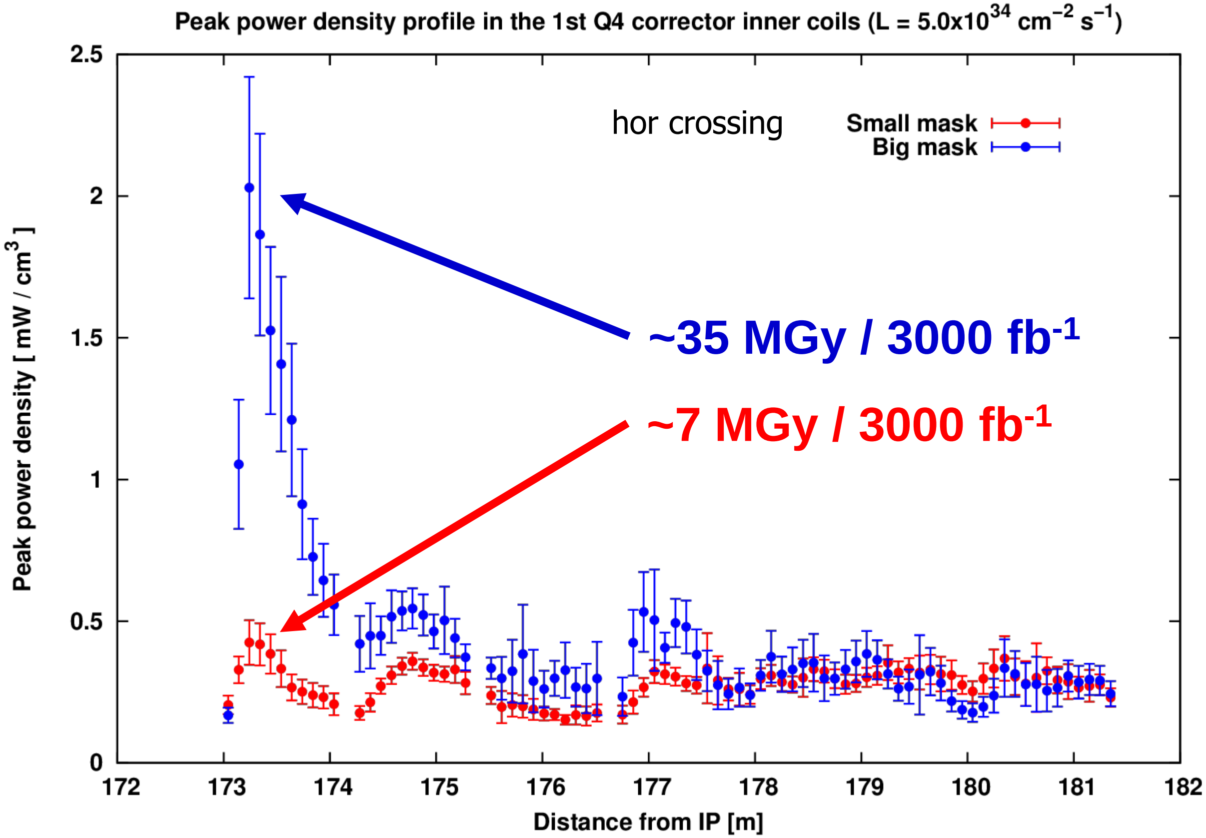
(some role for Q4 protection in case of asynchronous beam dump)



ALIGNMENT REQUIREMENTS

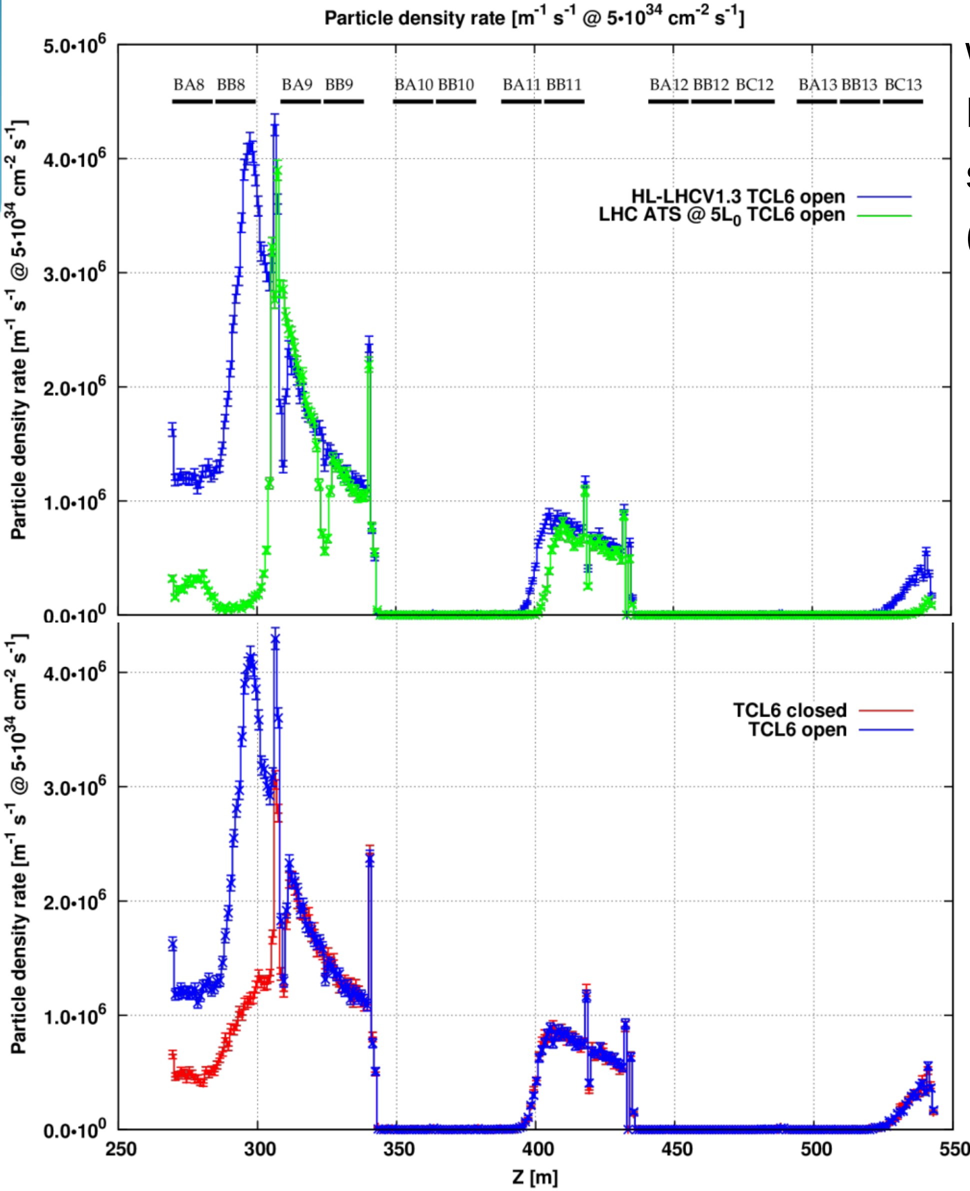
The warm masks are designed to match the beam screen aperture of the respective magnet
Assuming a 2 mm radial enlargement:



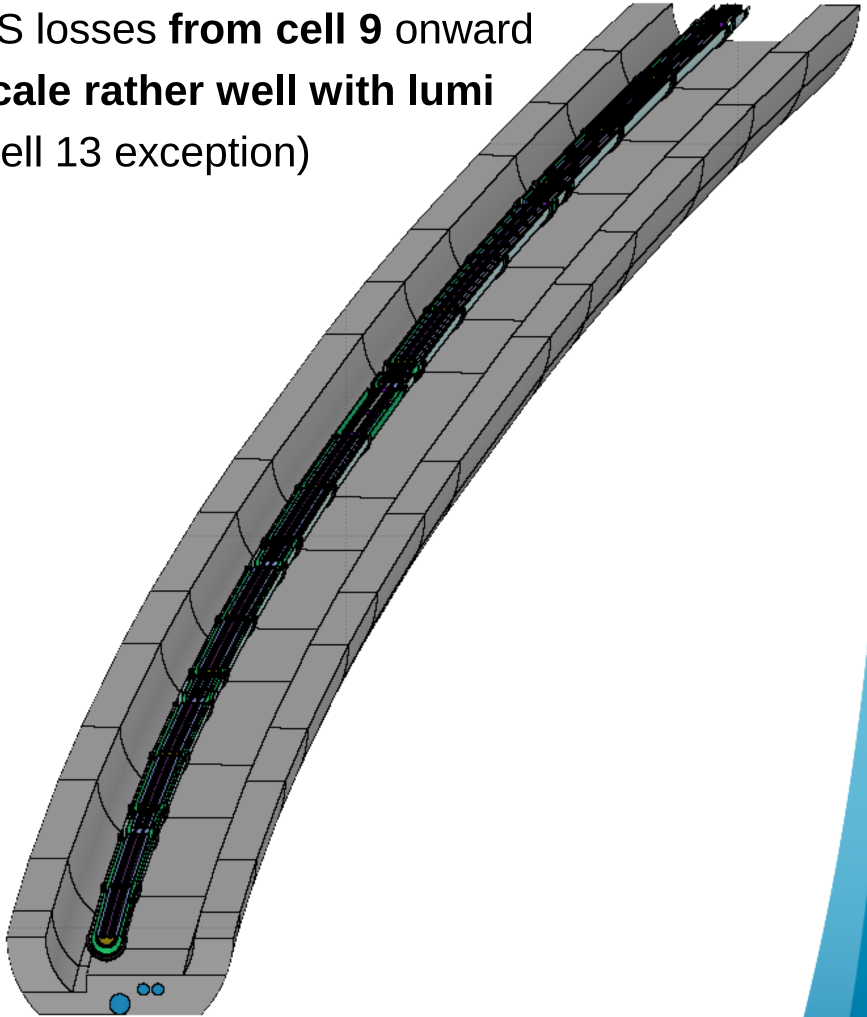


Major increase of the peak dose on the IP face of the first Q4 MCBYV
Max power density value of 2 mW/cm^3 @$5L_0$ still acceptable, with small impact on the total heat load

IR1/5 DISPERSION SUPPRESSOR IN THE HL ERA

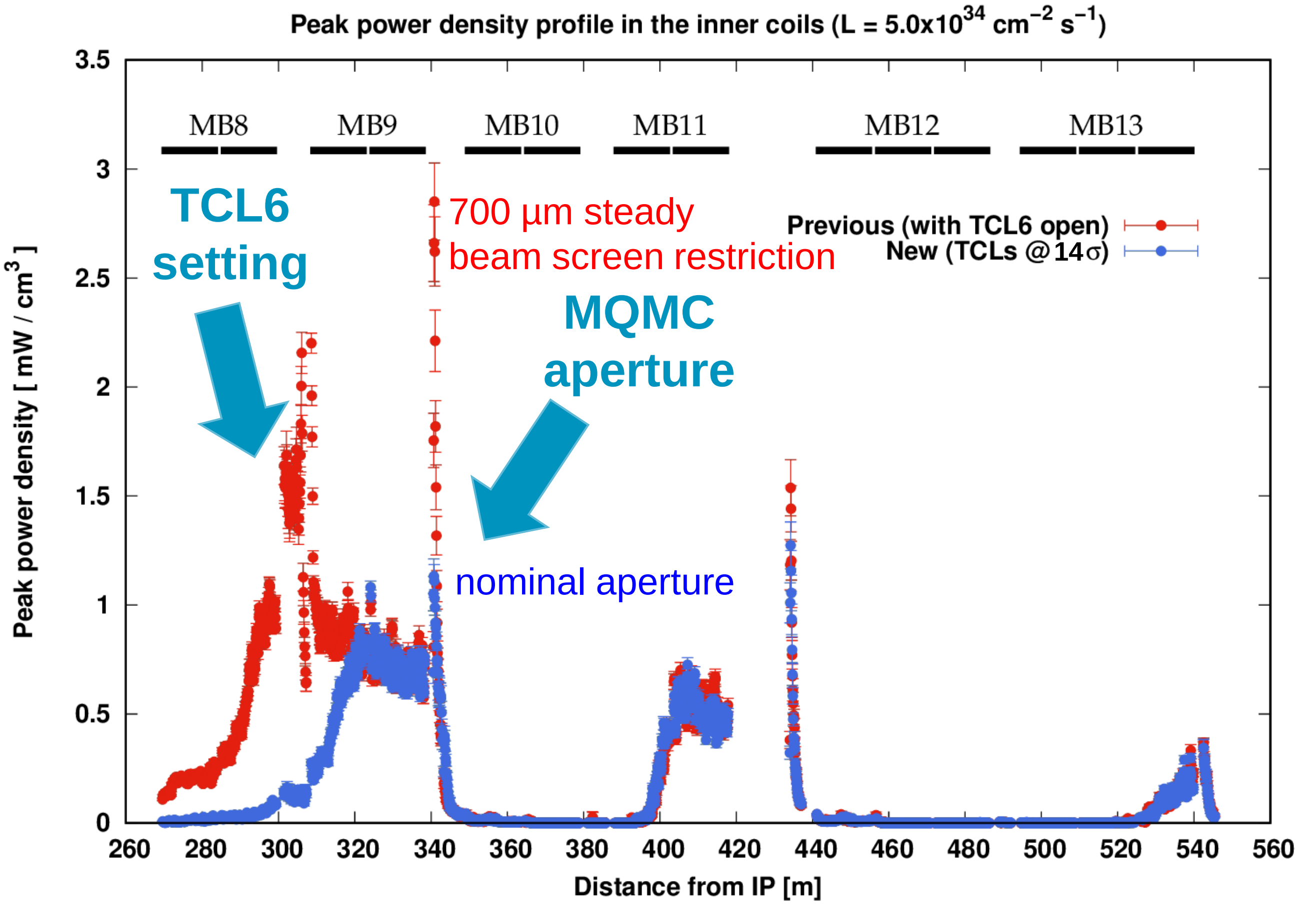


wrt present LHC ATS optics, DS losses **from cell 9** onward **scale rather well with lumi** (cell 13 exception)



TCL6 has a noticeable impact only up to cell 8

DS COILS IN THE HL-LHC ERA [I]

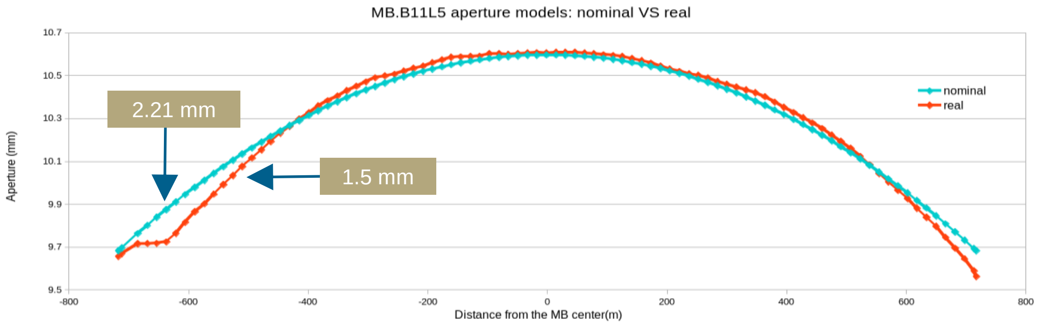


Maximum peak power density values in the coils around 1-2 mW/cm^3 @ $5L_0$

Pronounced sensitivity to aperture imperfections

REAL APERTURE EFFECT

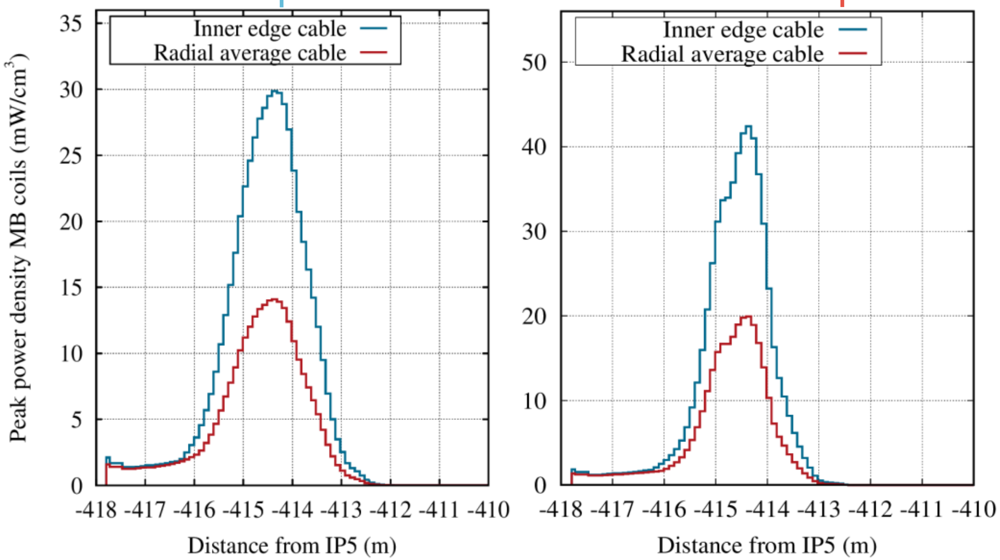
by C. Bahamonde
and A. Lechner



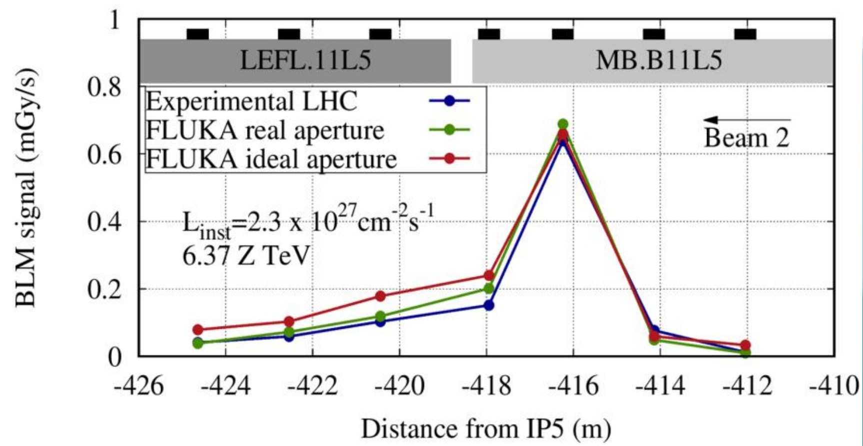
BFPP losses on

nominal aperture

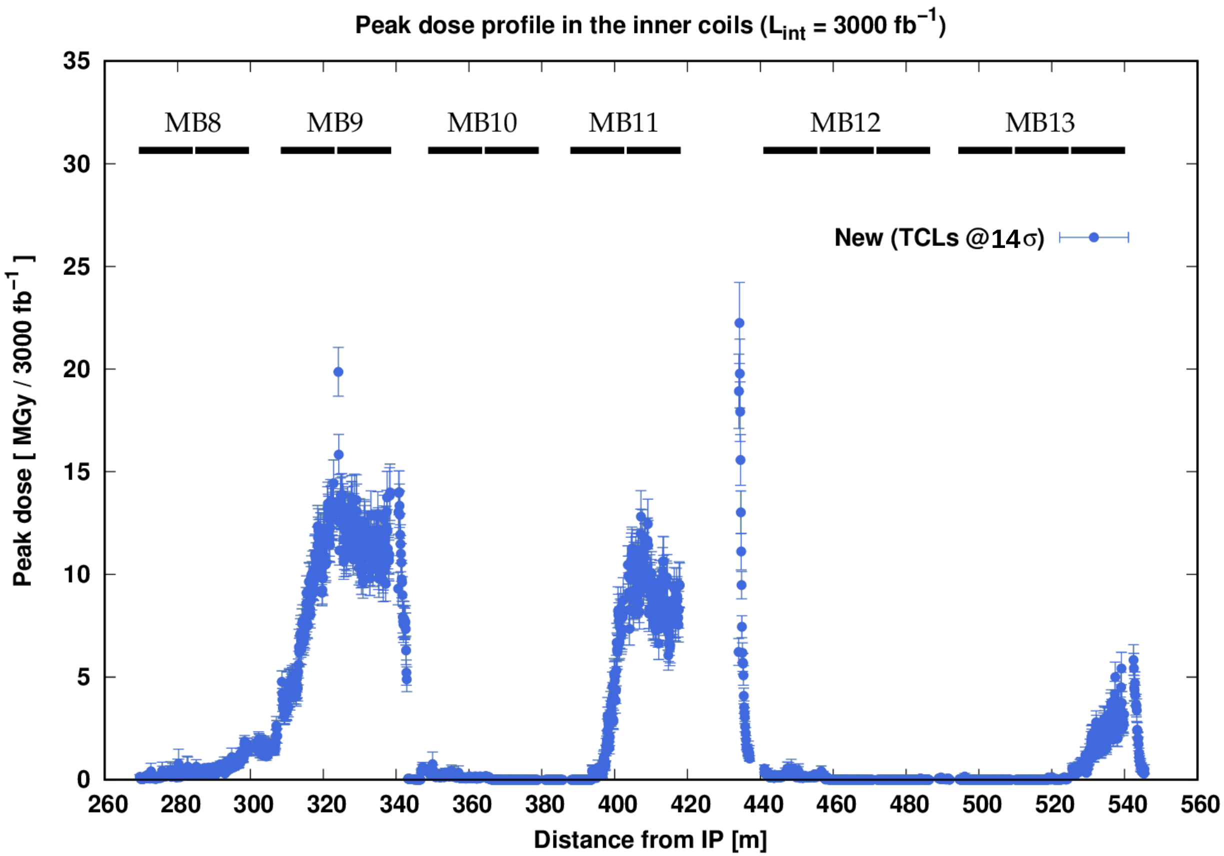
real aperture



35% increase in peak dose



DS COILS IN THE HL-LHC ERA [II]



Maximum dose below 20 MGy for 3000 fb^{-1} (MQ11 peak estimation is conservative due to the absence of the specific LEGR-to-MQ interconnect)

Measures are envisaged for the MCBC corrector in cell 9L, due to its lower radiation resistance

CONCLUSIONS

Despite the weaker TAXN effectiveness, collimators and masks can offer a reasonable protection to the matching section.

TCLX4 settings are prone to be optimized in mm rather than σ.

TCTs play a role in protecting the incoming beam bore from the collision debris too.

Dispersion suppressor losses are expected to mainly display the expected lumi scaling, inducing for an ideal aperture profile a local max dose of about 20 MGy after 4 ab^{-1}, still subject to a pronounced sensitivity to aperture imperfections.

TCL6 allows for an effective cleaning of cell 8, with the correlated increase of RR levels compensated by the limitation to radiation hard electronics.

Peak power densities of few mW/cm^3 at nominal HL lumi offer a good operational margin.

Possible forward physics stations will require a careful layout revision (TCL7?).