4th Joint HiLumi LHC-LARP Annual Meeting

Nov 17-21, 2014 KEK

High Luminosity LHC

DEBRIS IMPACT IN THE TAS-TRIPLET-D1 REGION

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CERN EN STI FLUKA

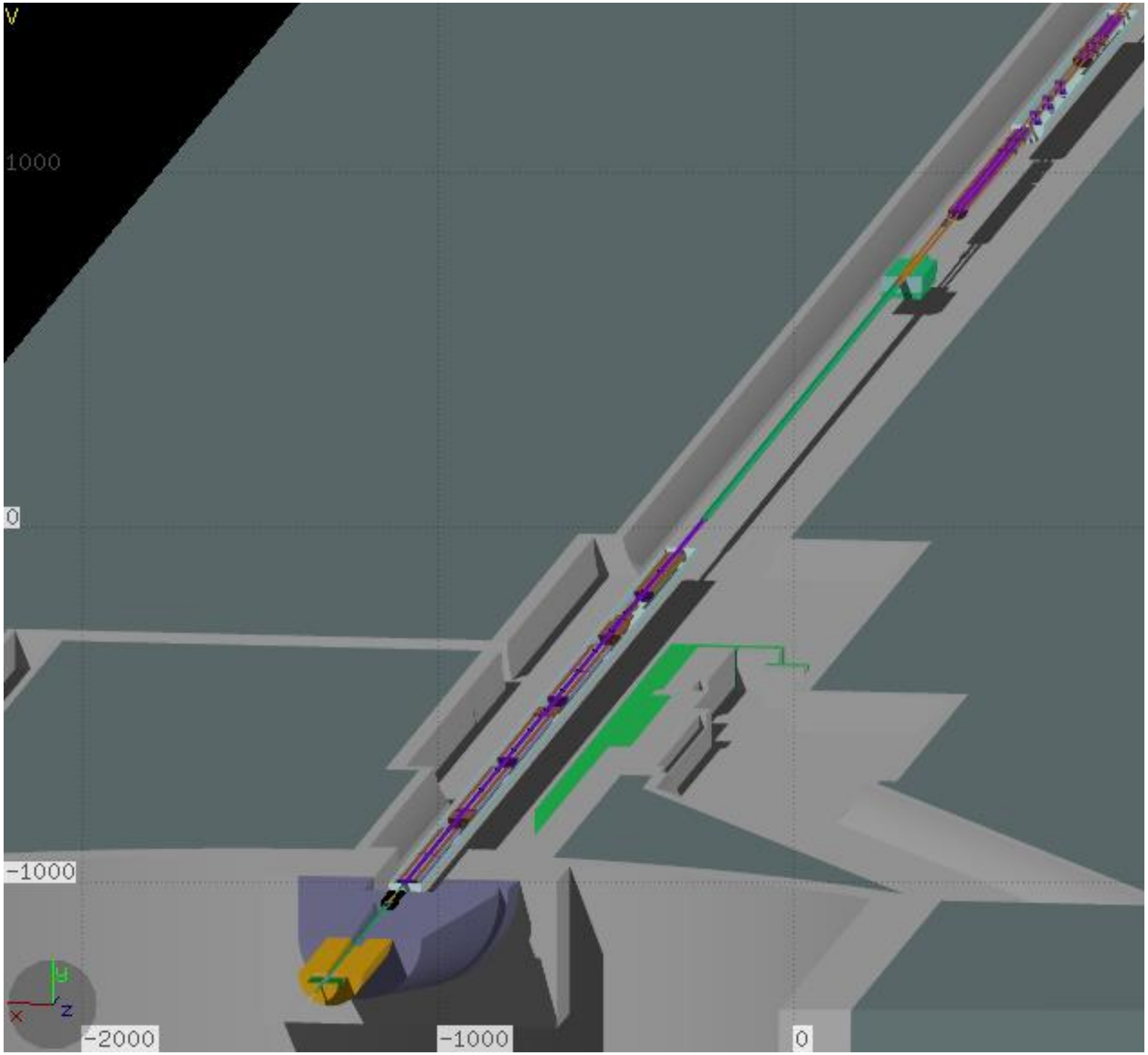
WP10
Energy Deposition & Absorber

The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.

OUTLINE

- radiation source and geometry model
- expected power density and dose – and dpa – in the coils (and outside) and integral power
- effect of beam screen design
- radiation to beam screen
- effect of TAS and crossing angle
- radiation to TAS and TAXS
- radiation in the tunnel
- IR8: impact of LHCb lumi upgrade (LS2)

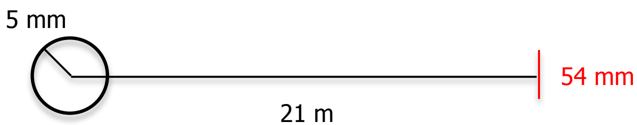
HL-LHC IR



RADIATION SOURCE

700 MJ per beam (7 TeV protons, 2.2 10^{11} p per bunch, ~2800 bunches)

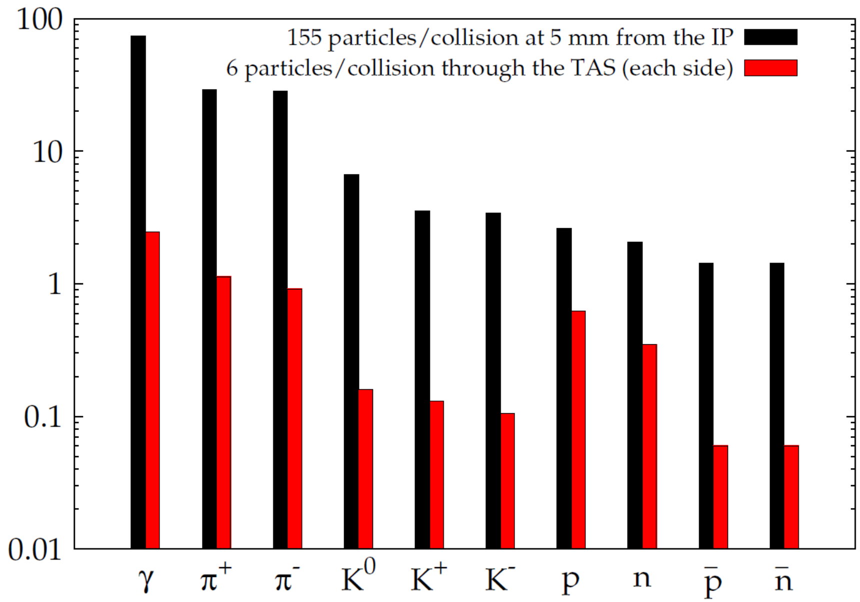
14 kW delivered in collisions ($L=7.5L_0$)



on each side of ATLAS and CMS,

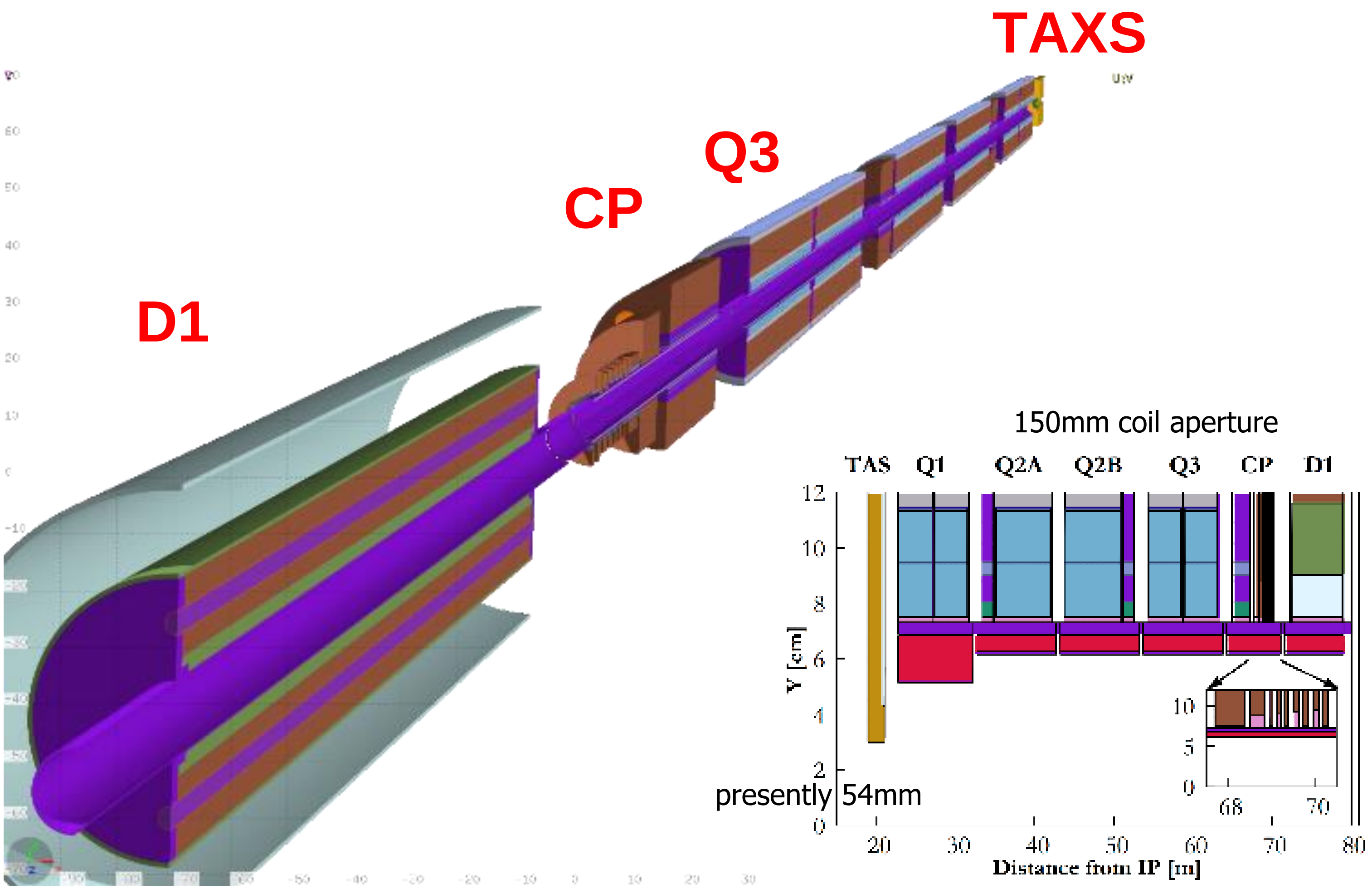
a *54mm aperture TAS* absorber takes 750W

and let 5kW impact the machine

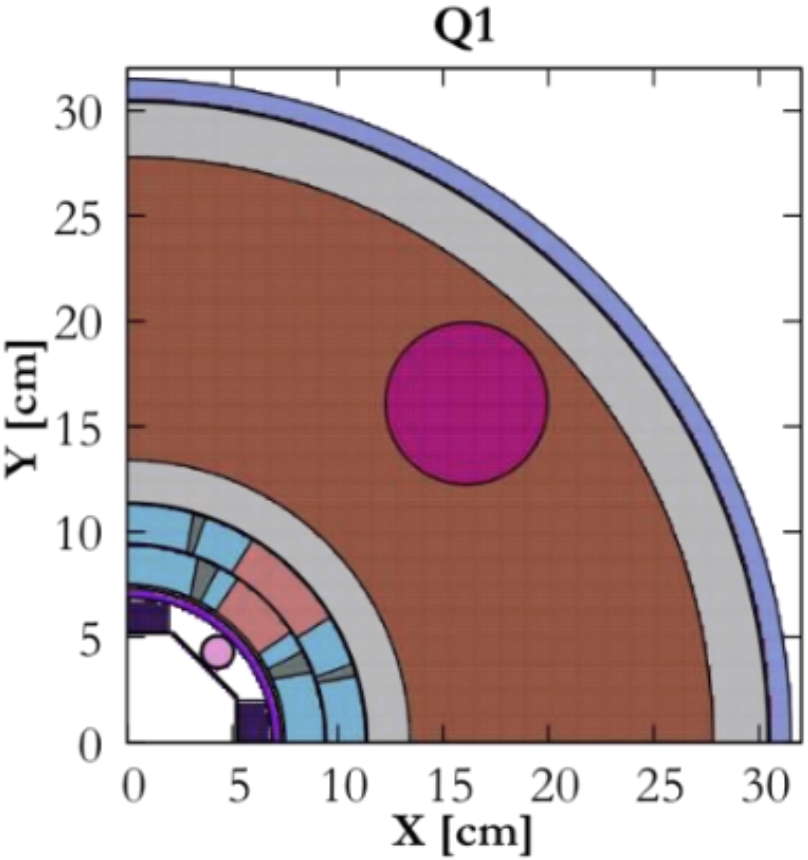


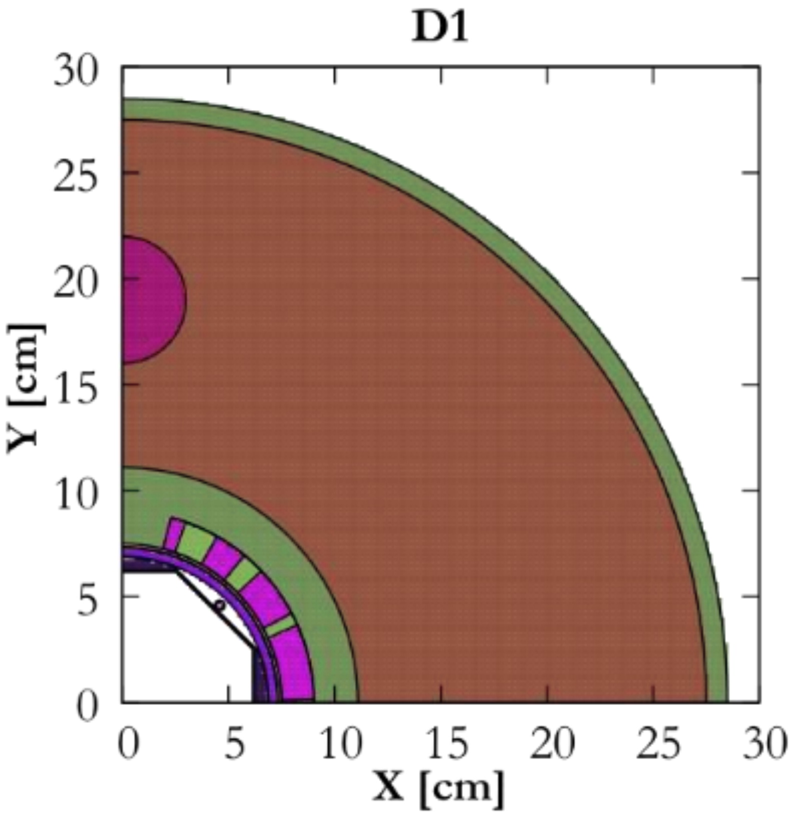
295 urad half vertical crossing angle

SINGLE VACUUM CHAMBER AREA

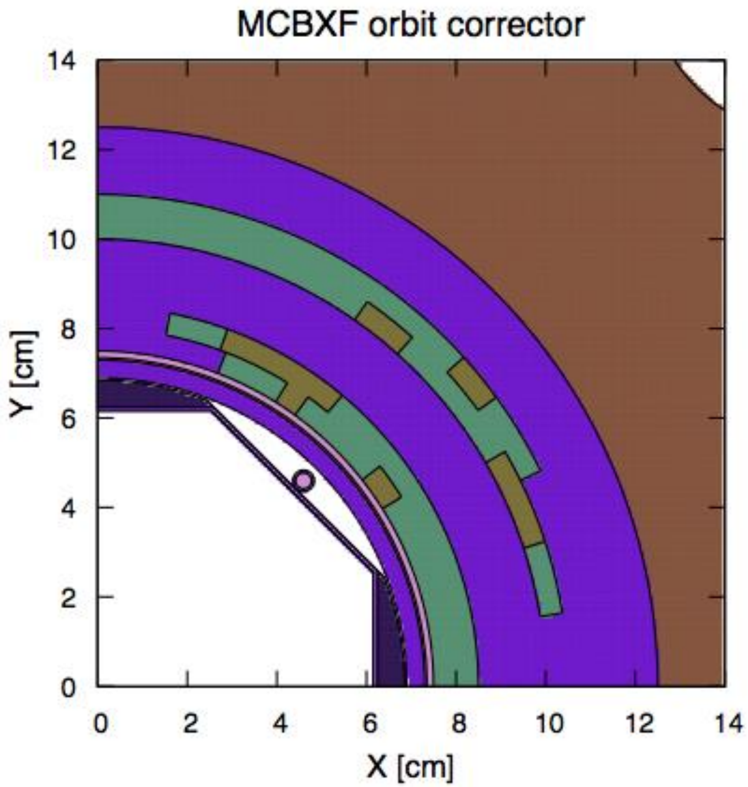


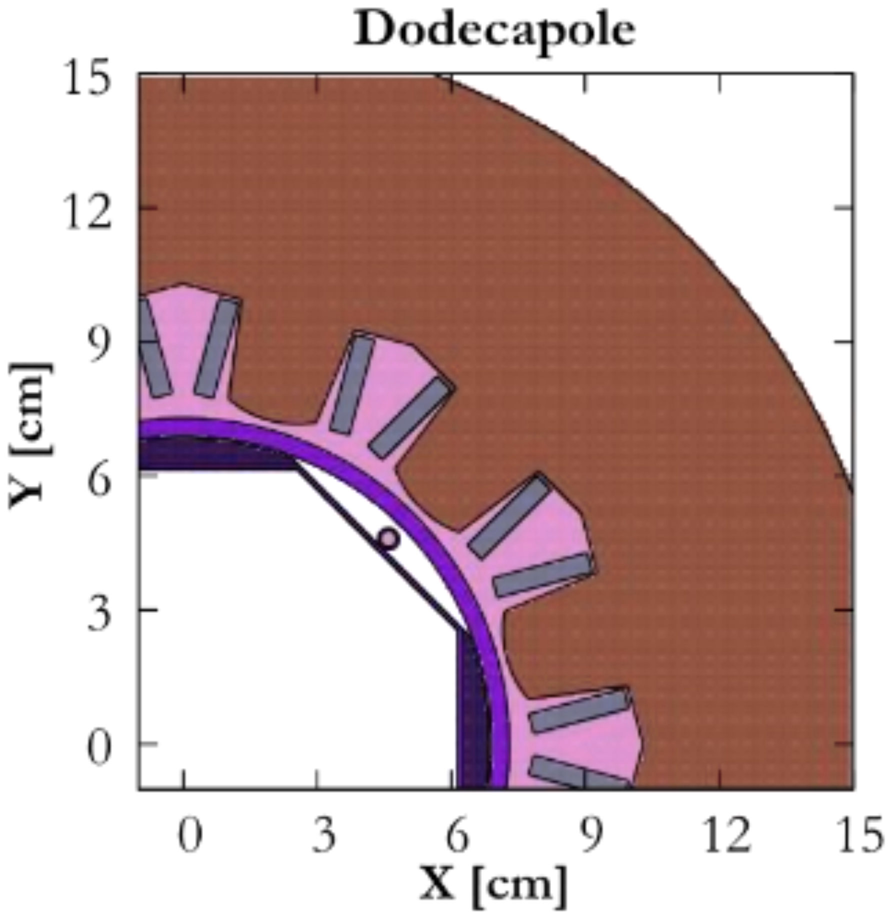
MAGNET MODELS [I]



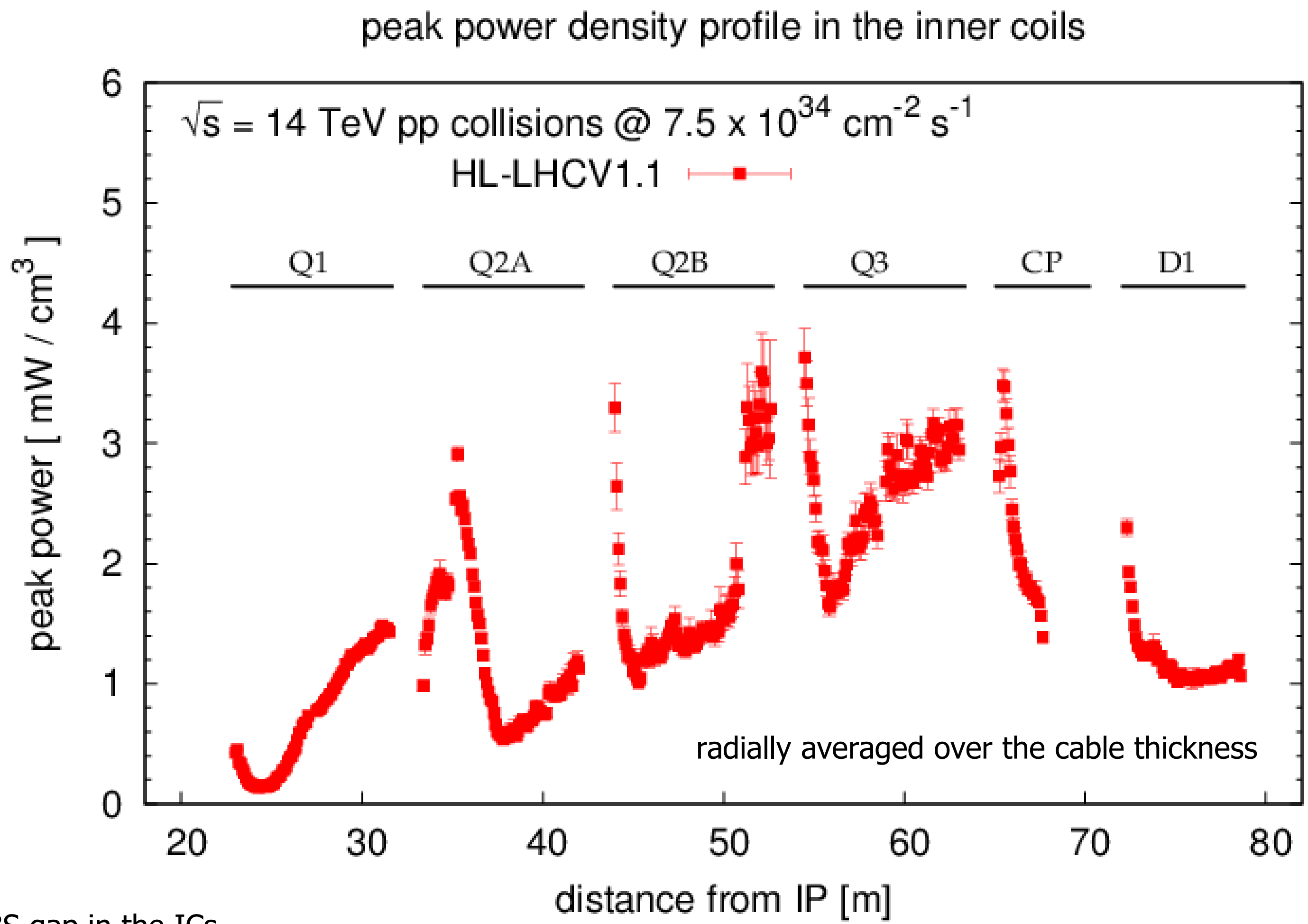


MAGNET MODELS [II]



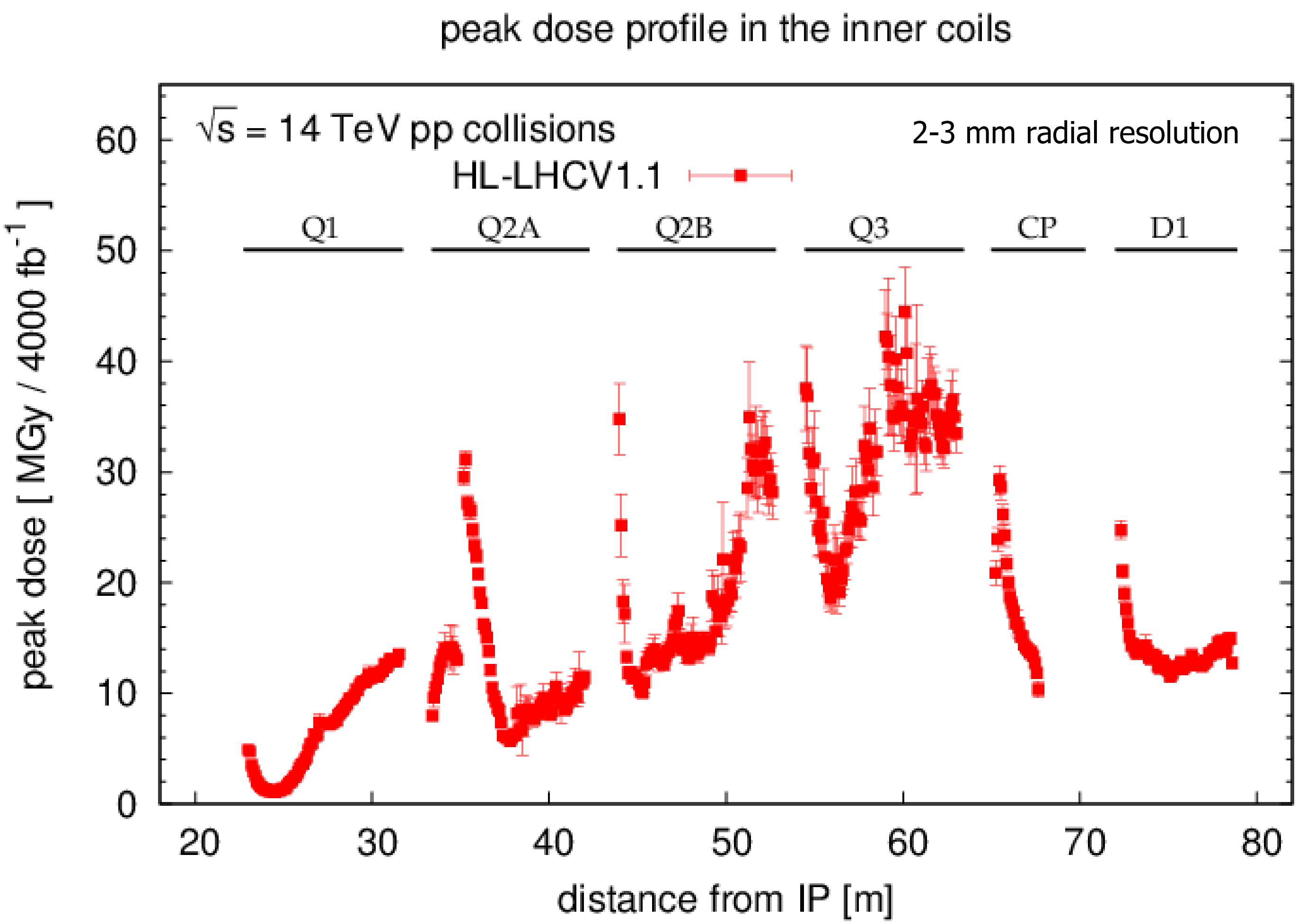


MARGIN TO QUENCH



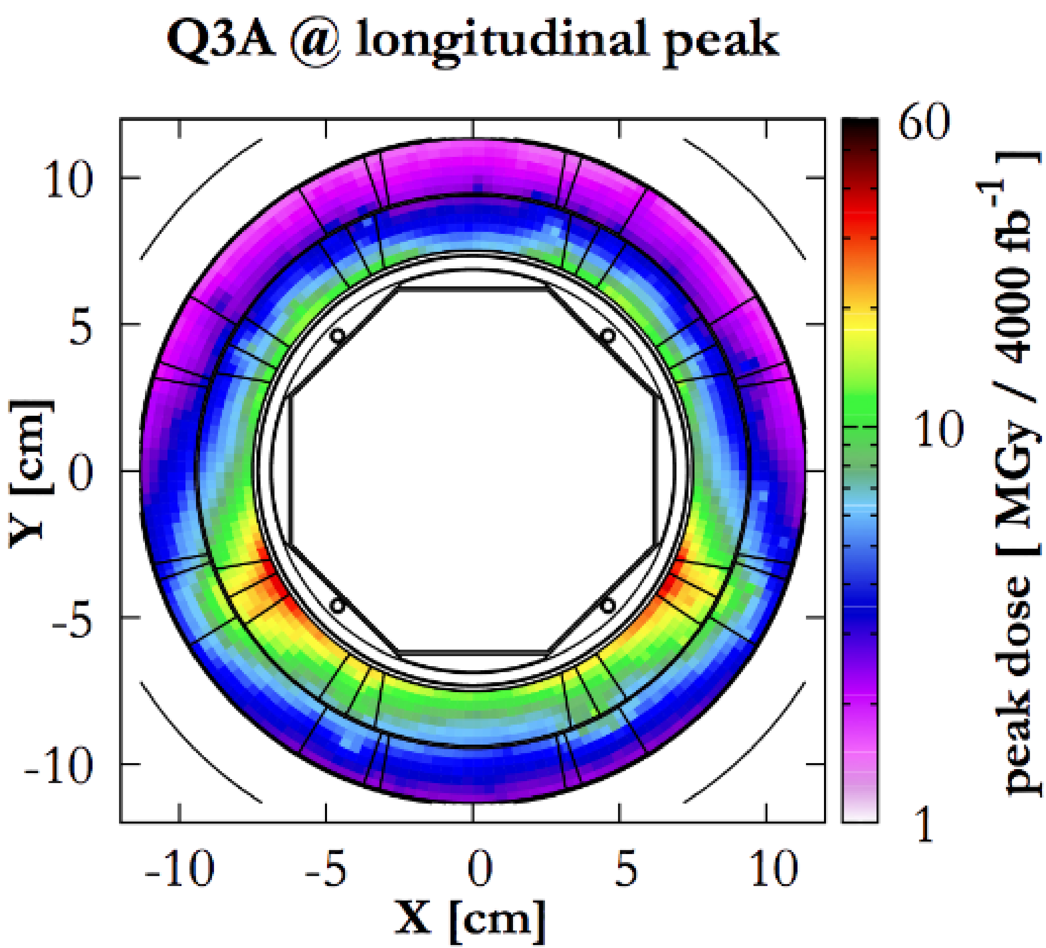
50cm BS gap in the ICs

LIFETIME



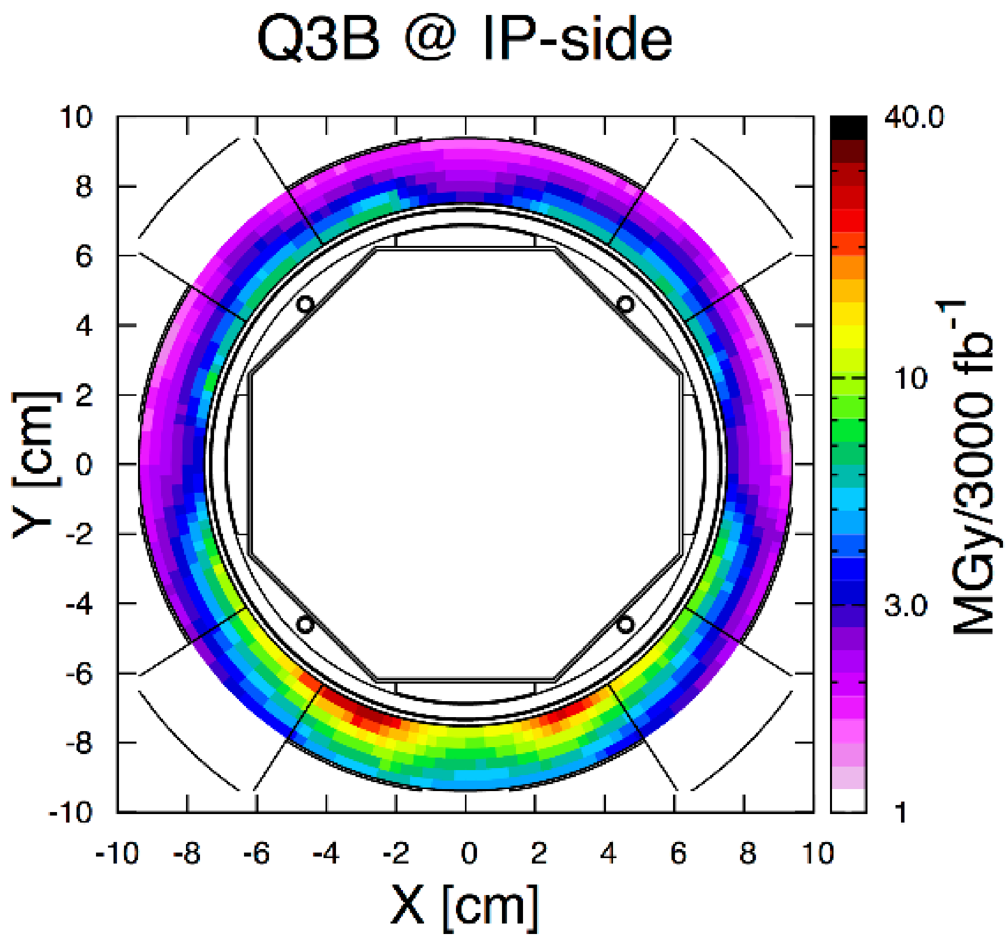
50cm BS gap in the ICs

2D VIEW [I]



Q3A @ longitudinal peak
Y [cm]
10
5
0
-5
-10
X [cm]
-10
-5
0
5
10
60
10
1
peak dose [MGy / 4000 fb-1]

2D VIEW [II]



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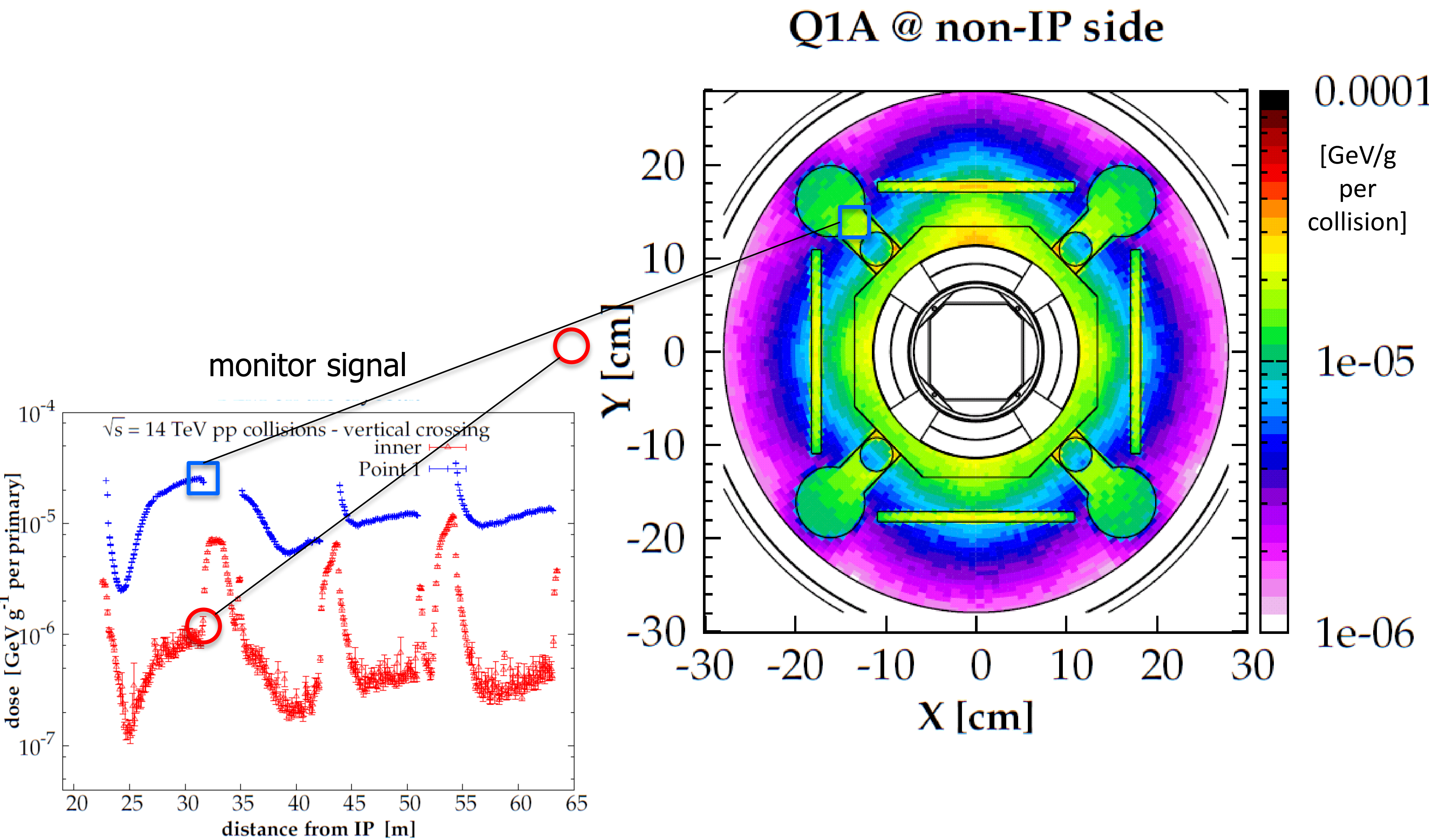
2D VIEW [III]

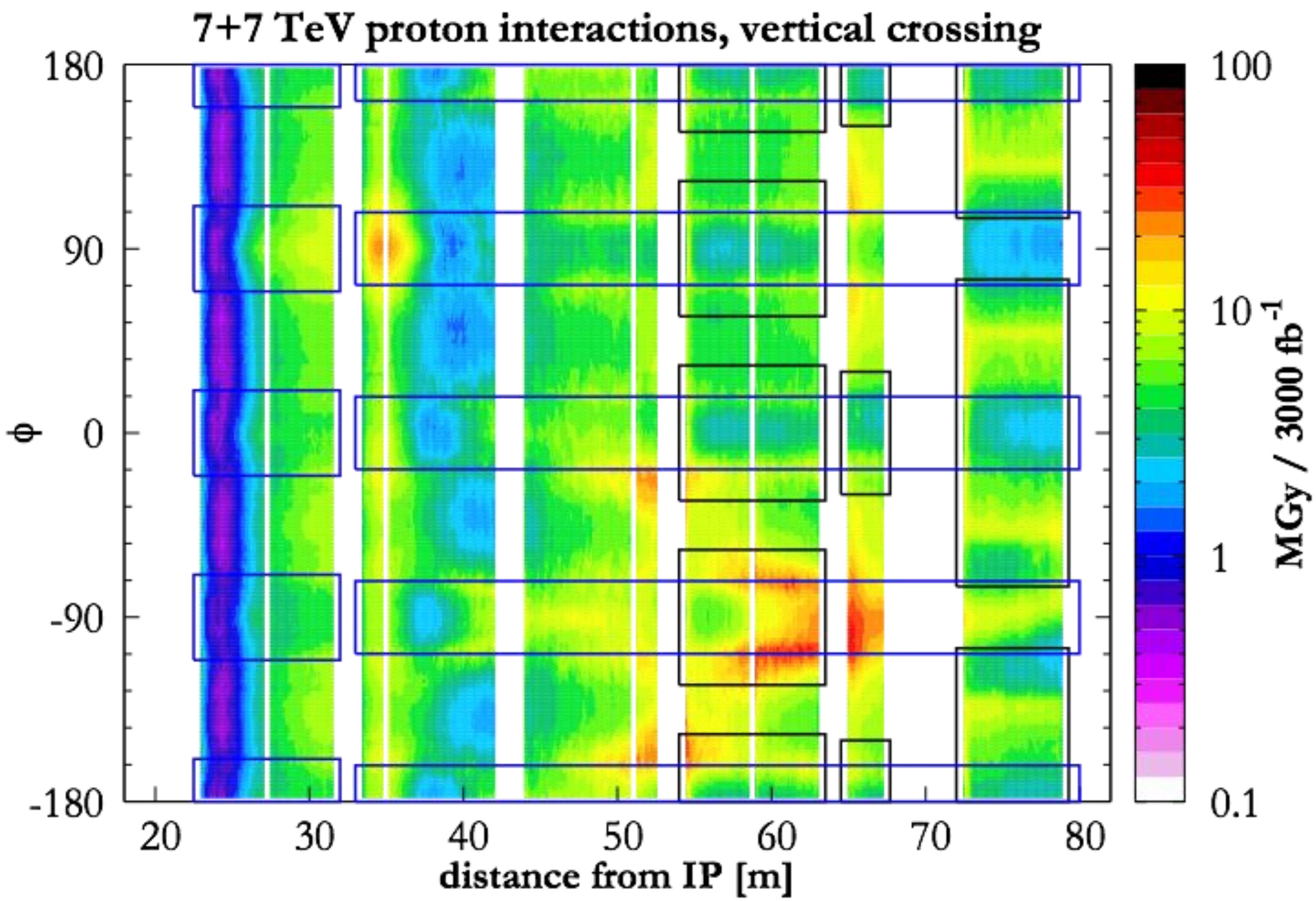


Q1A @ non-IP side
monitor signal
√s = 14 TeV pp collisions - vertical crossing
inner
Point 1
dose [GeV g⁻¹ per primary]
distance from IP [m]
Y [cm]
X [cm]
0.0001
[GeV/g per collision]
1e-05
1e-06

2D VIEW [IV]

Blue rectangles indicate the azimuthal regions shielded by the tungsten absorbers

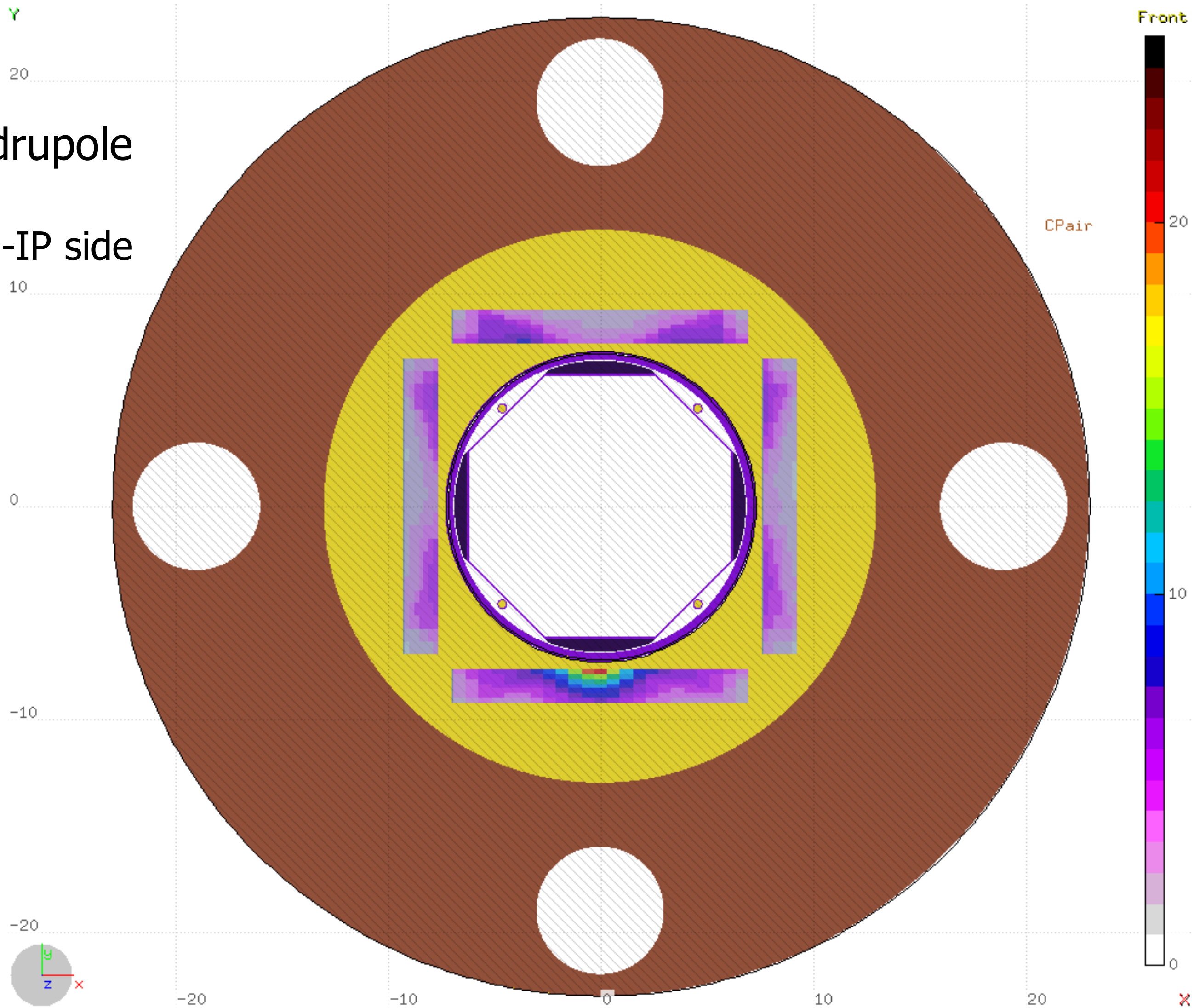
Black rectangles indicate the azimuthal regions covered by coils



2D VIEW [V]

skew quadrupole

non-IP side



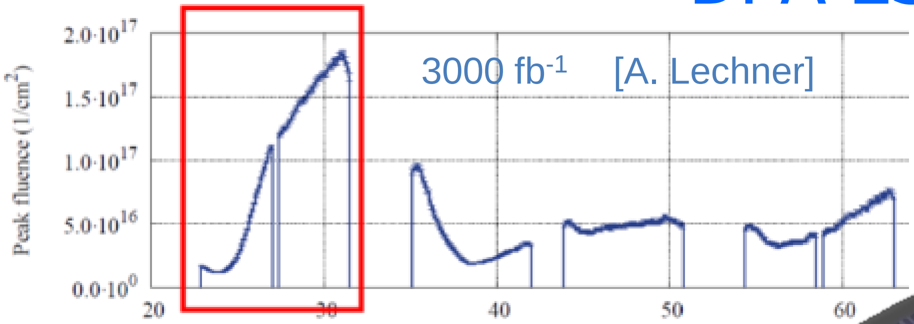
[MGy /4000fb^{-1}]

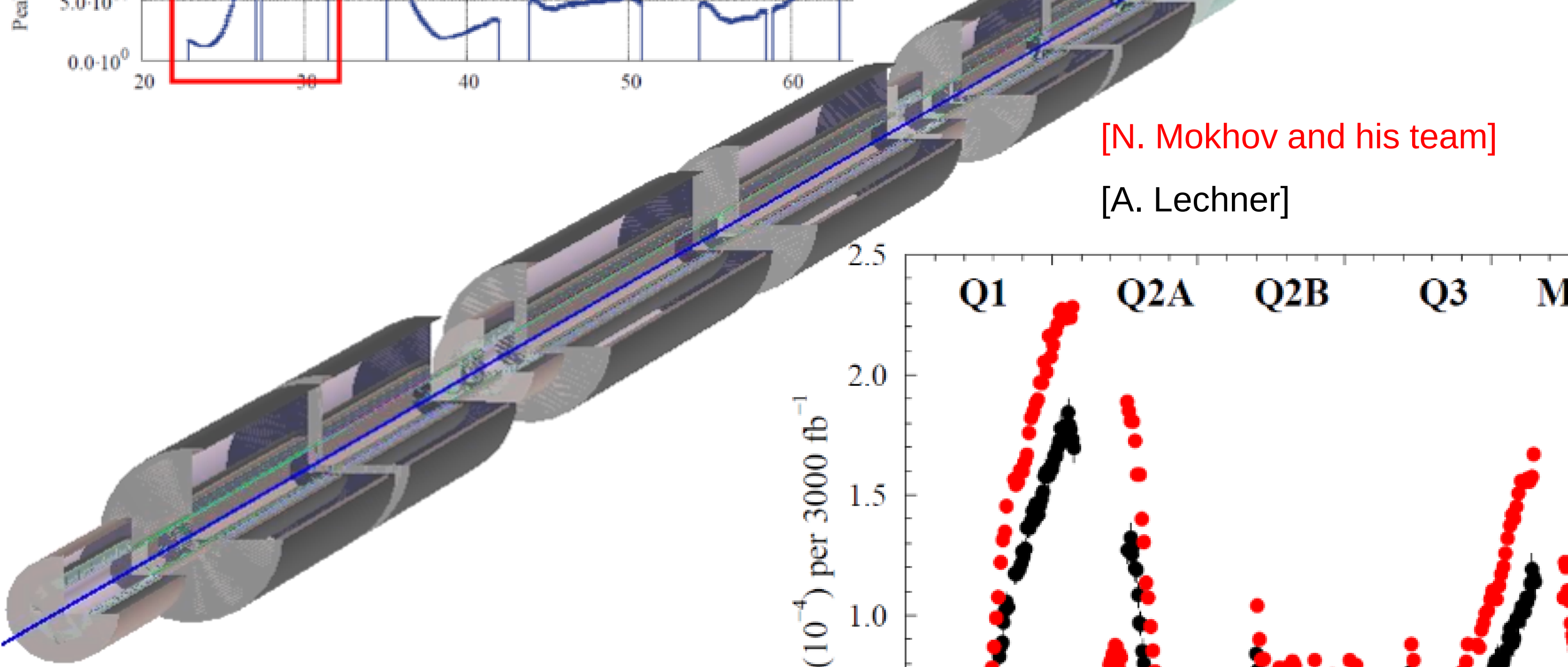
INTEGRAL POWER

@ 7.5 L_0	HL-LHCV1.1	
Power [W]	**Magnet cold mass**	**Beam screen**
Q1A + Q1B	140	210
Q2A + corr	150	90
Q2B + corr	165	100
Q3A + Q3B	220	105
CP	105	90
D1	135	80
Interconnects	30	110
Total	**945**	**780**

Values for horizontal crossing are about 10% lower

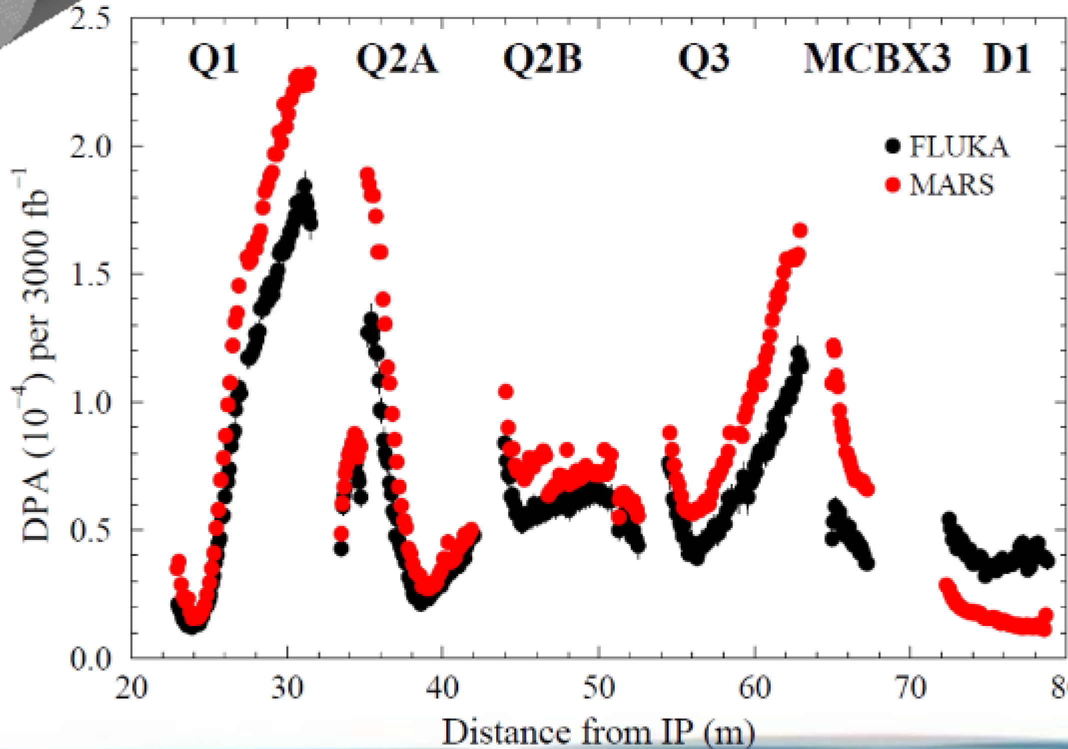
DPA ESTIMATE





[N. Mokhov and his team]

[A. Lechner]



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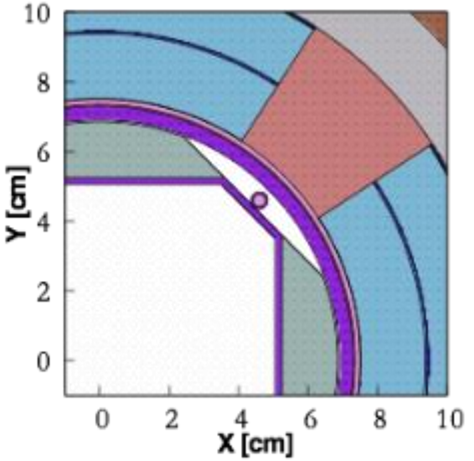
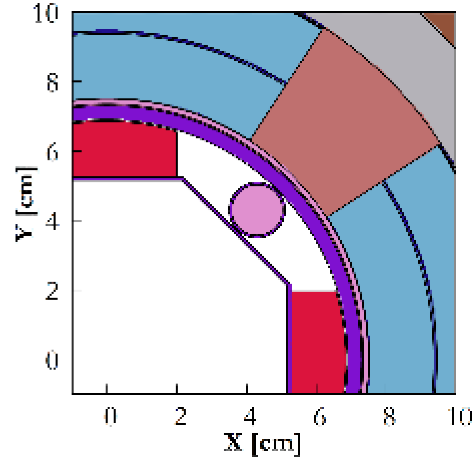
BEAM SCREEN AND ABSORBER DESIGN

conceptual version (BS #1) | **executive version (BS #2)** | **revisited version (BS #3)**

16 mm absorbers





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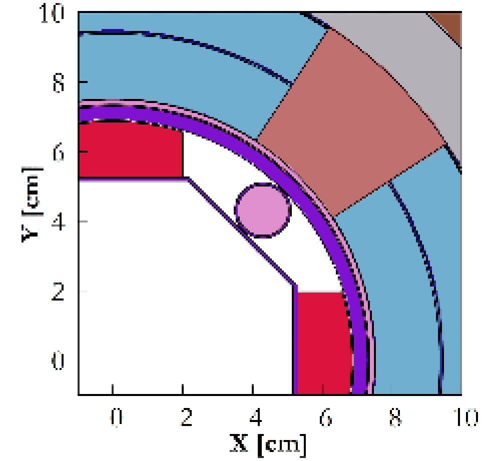
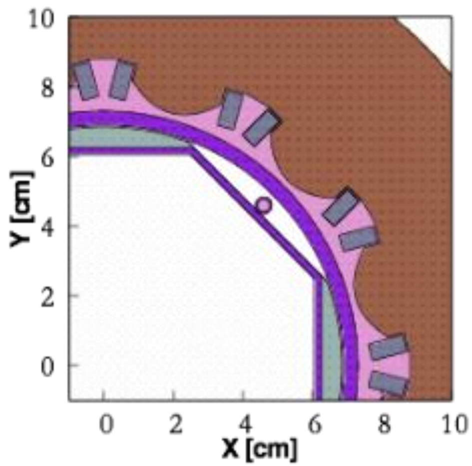
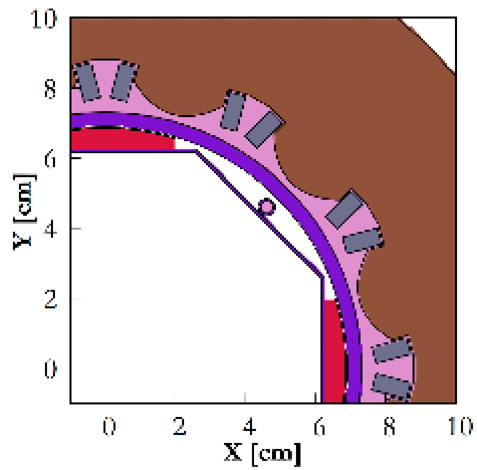
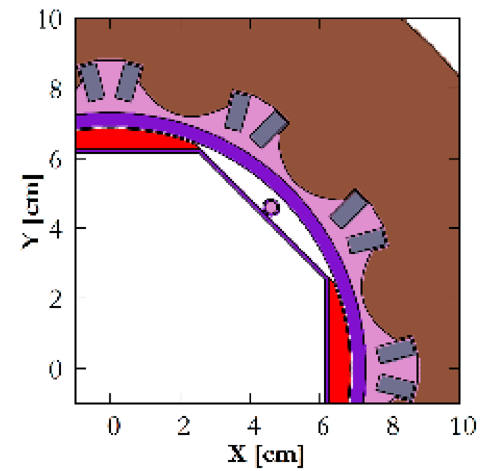


6 mm absorbers







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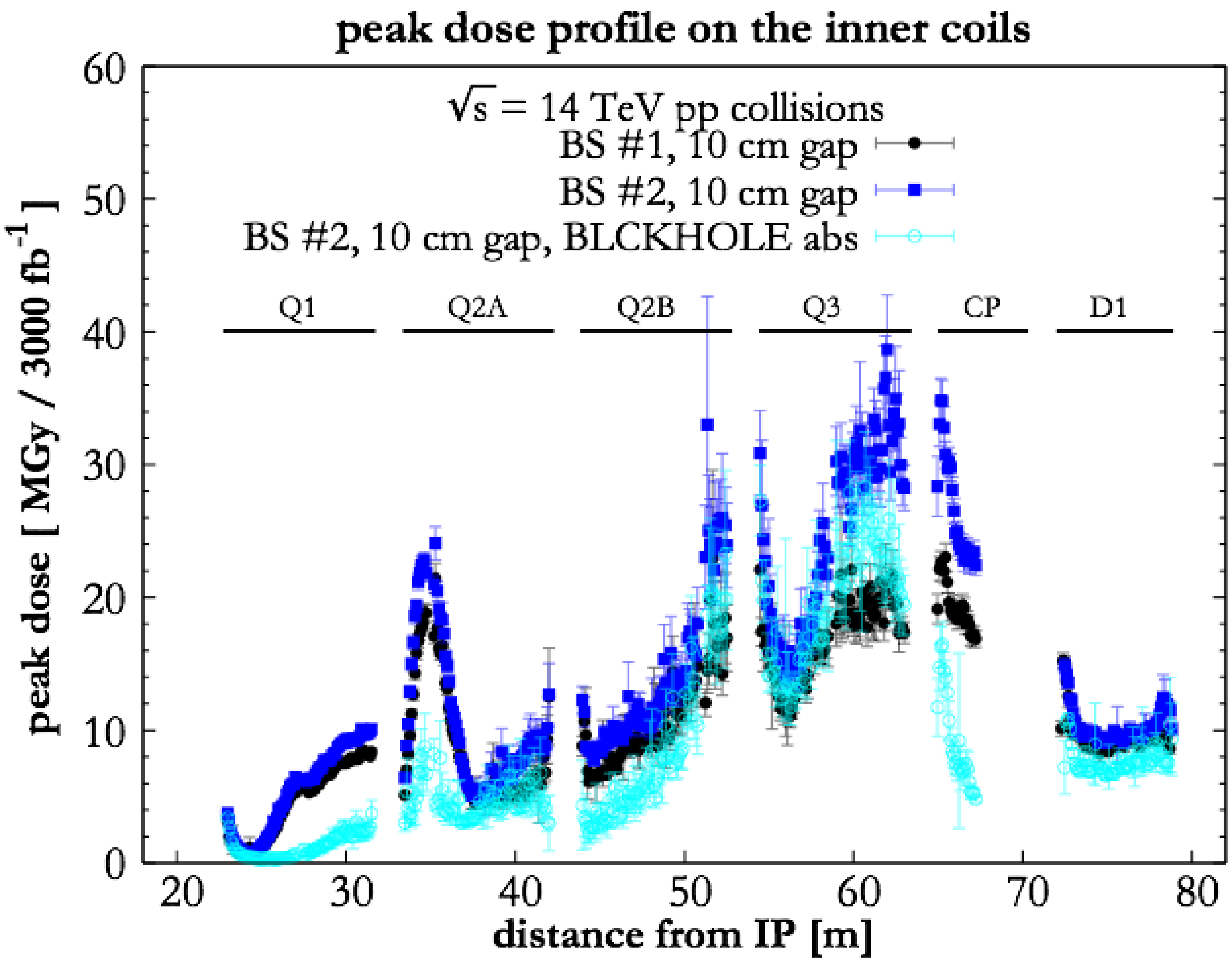
DESIGN WEAKNESS



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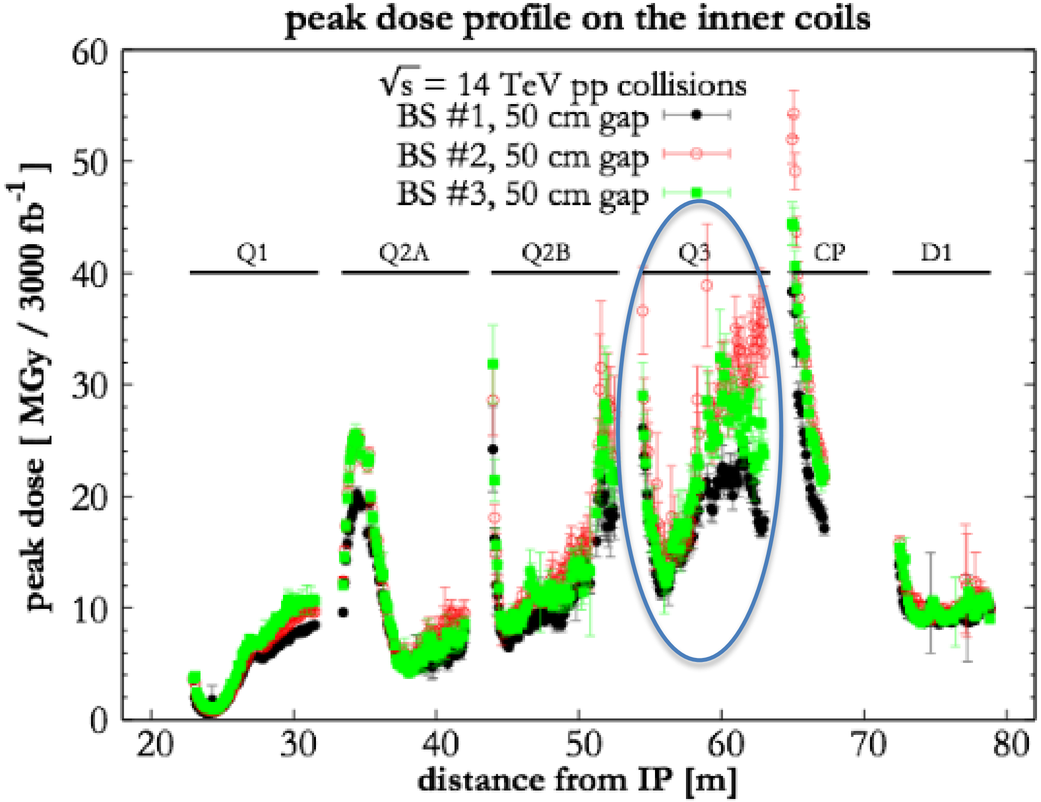
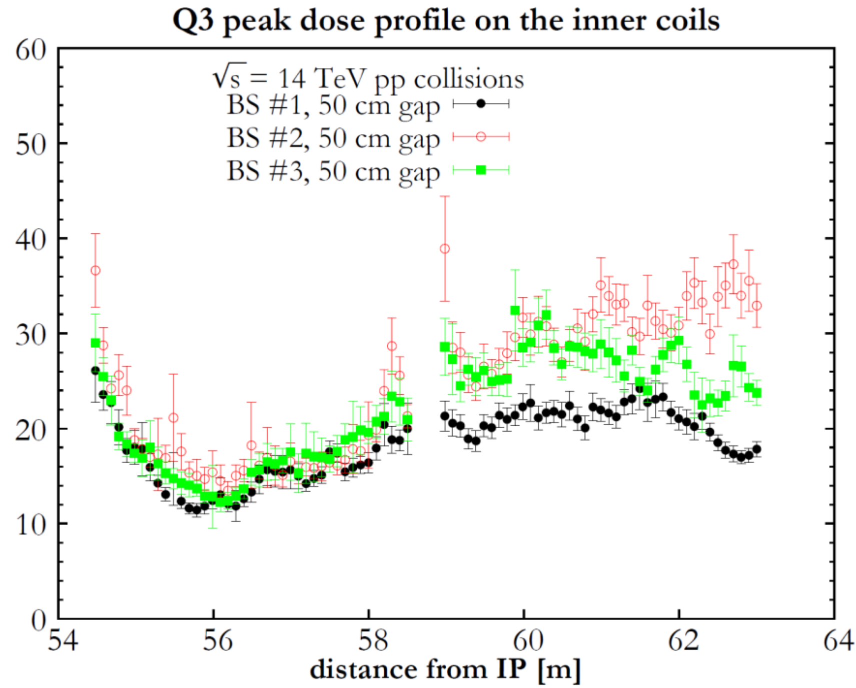
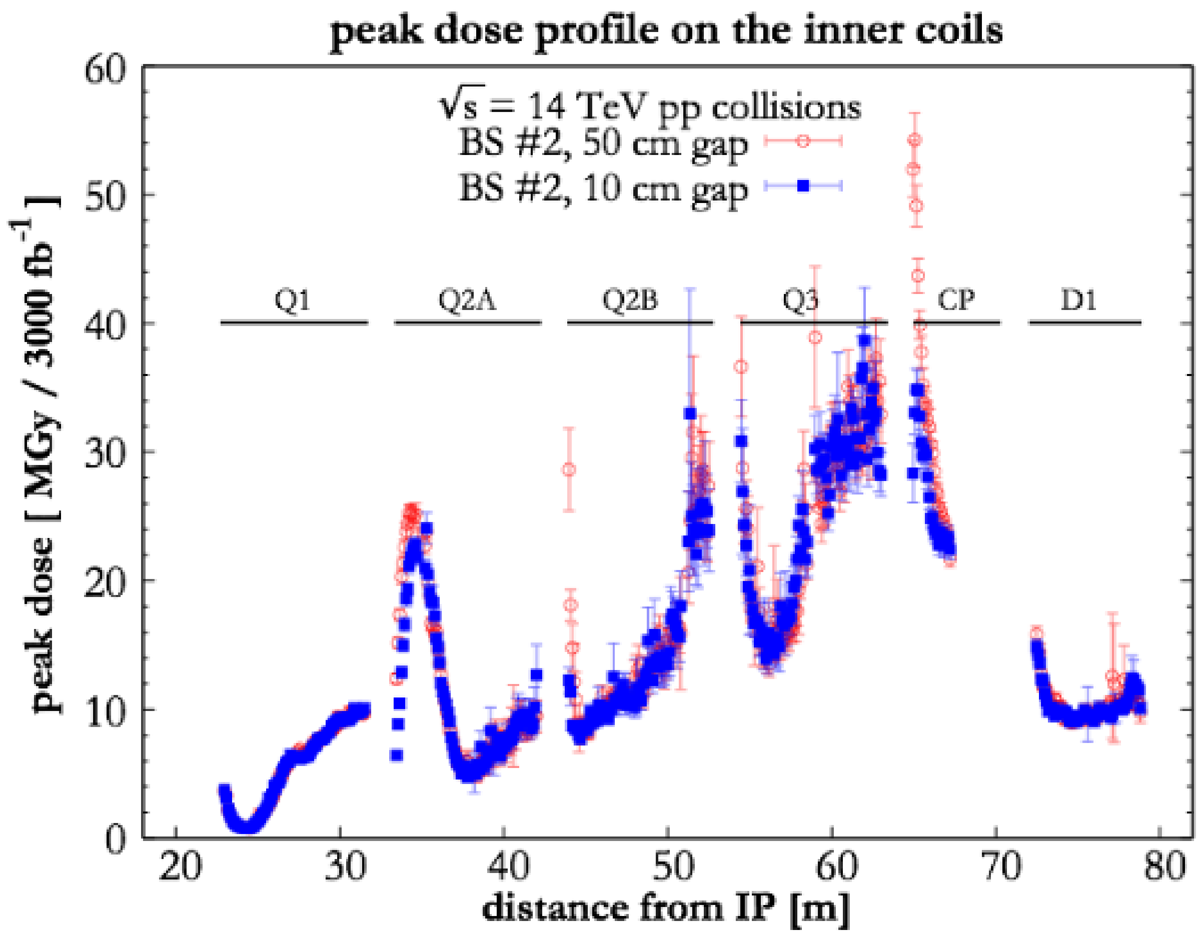
INERMET WEAKNESS

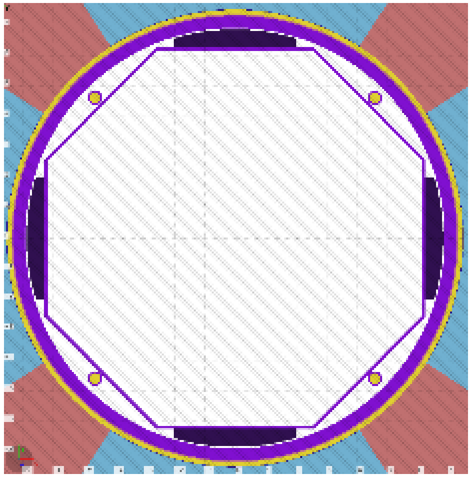


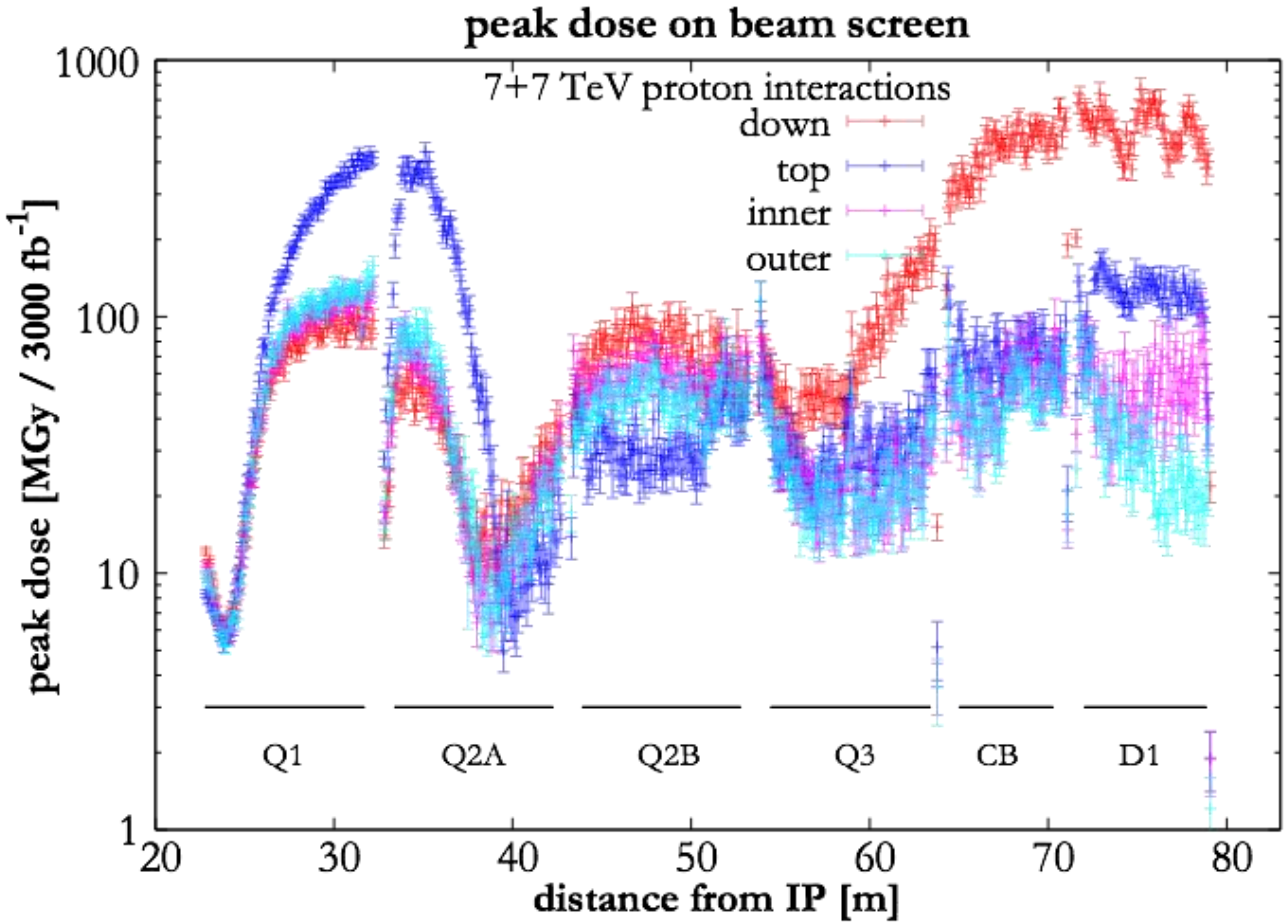


ABSORBERS IN THE INTERCONNECTS (BPMs)



DOSE TO BEAM SCREEN





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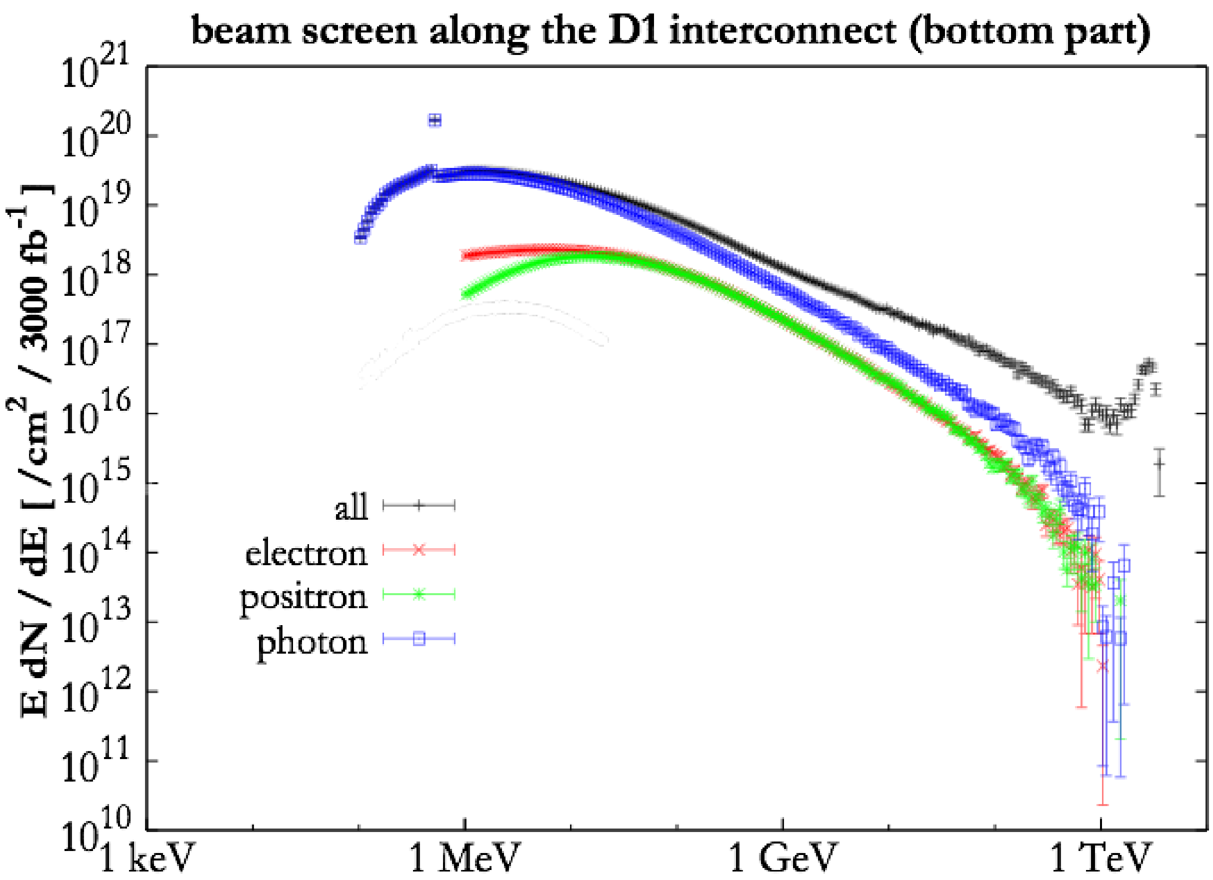
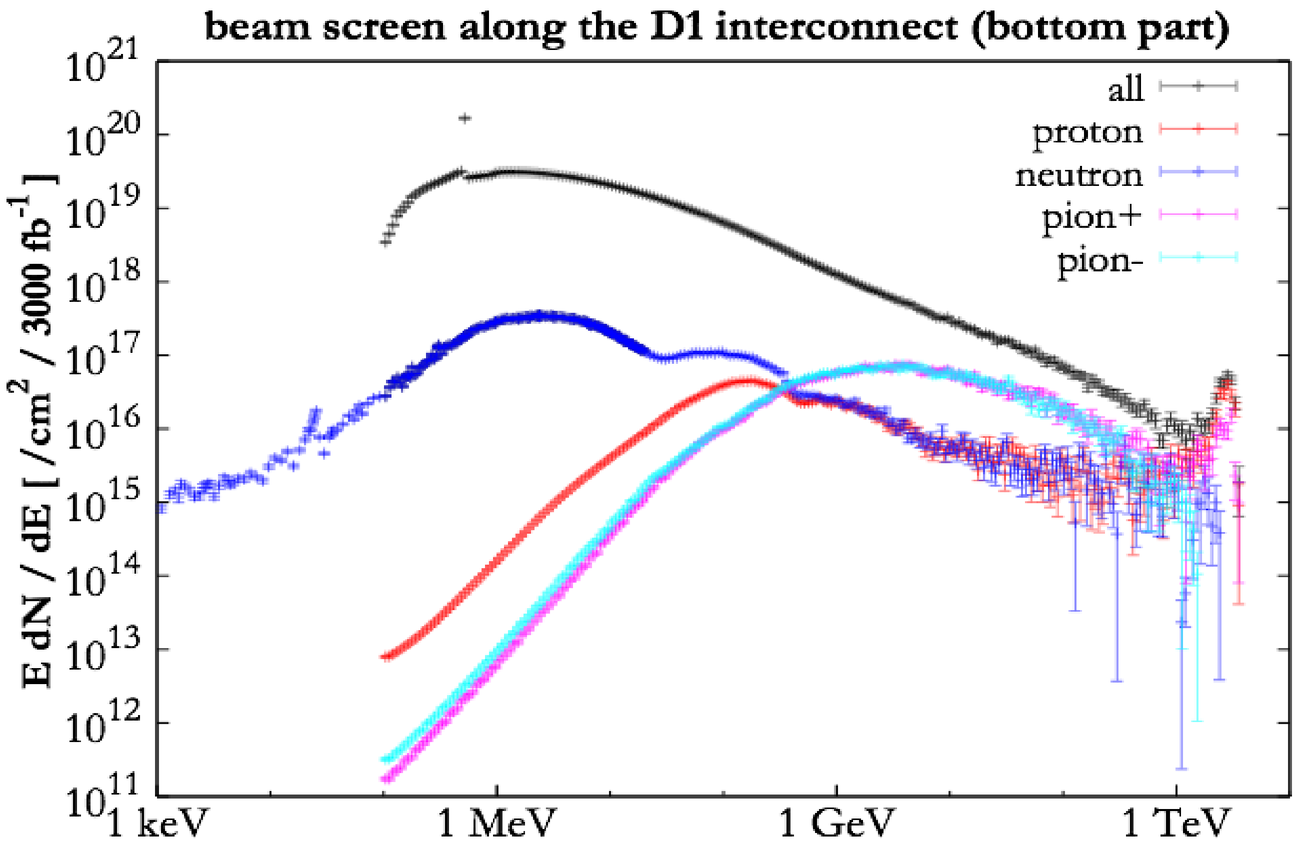
PARTICLE FIELD [I]

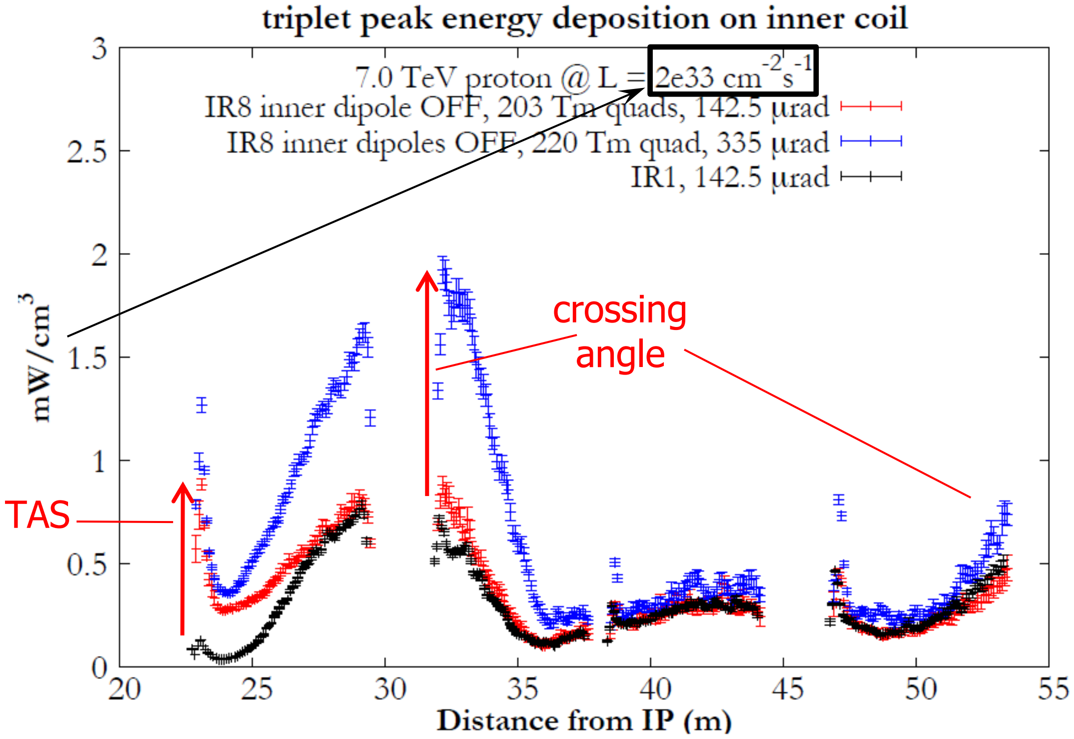


PARTICLE FIELD [II]



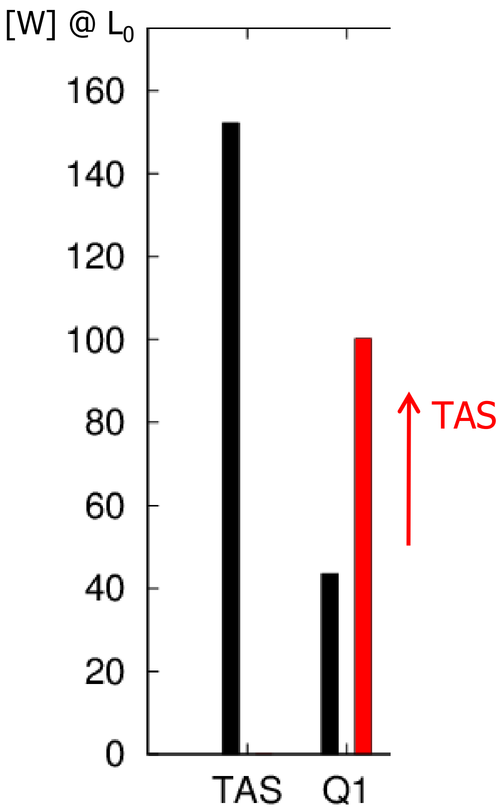
TAS AND CROSSING ANGLE EFFECT

for quench risk



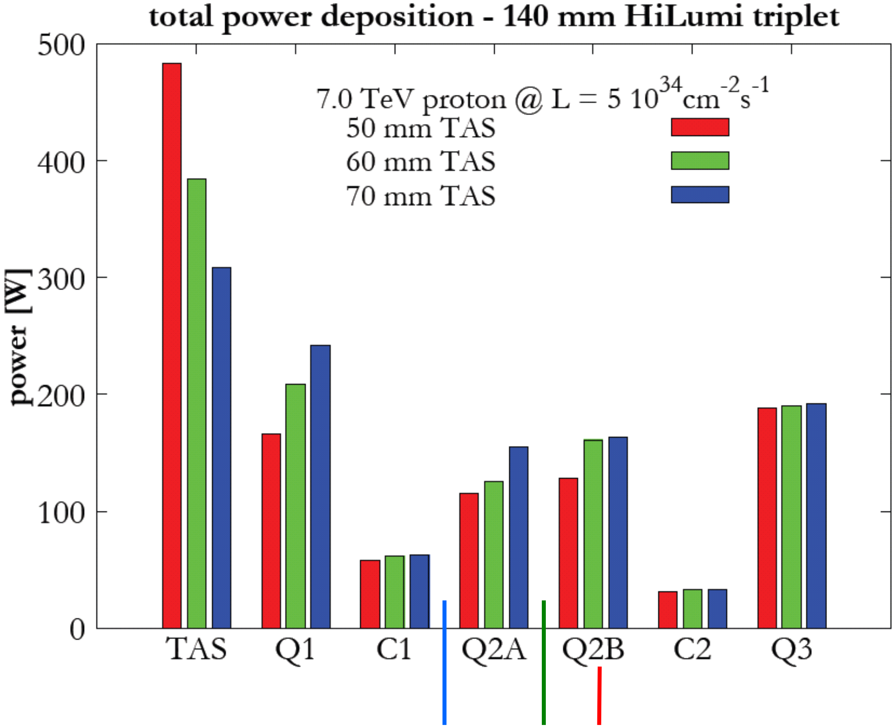
- the TAS has meaning only for (the first half of) of Q1!
- the crossing angle plays a significant role

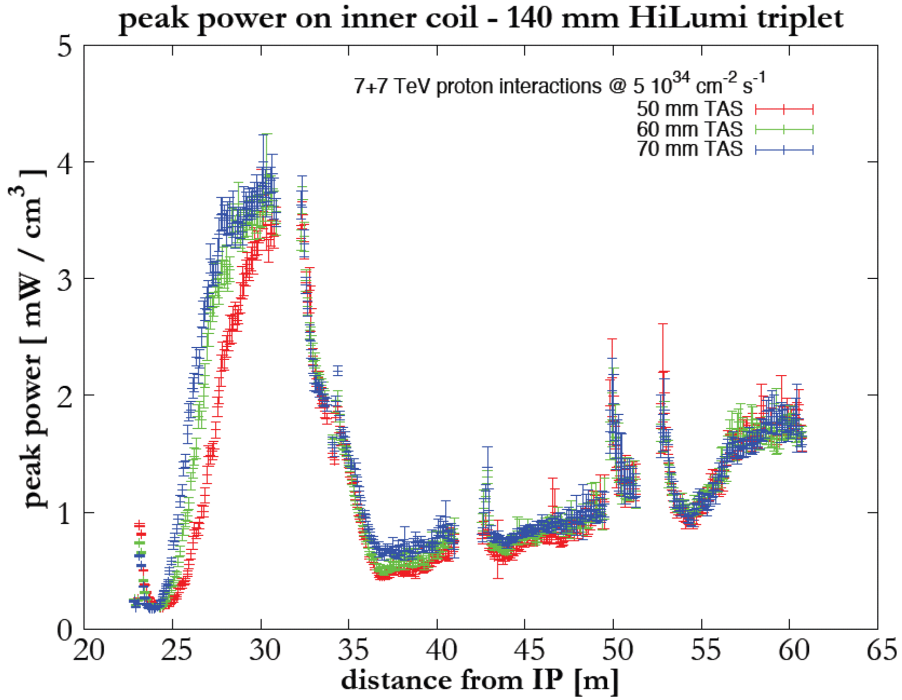
for cryogenic load



- the TAS absence redoubles (+130%) the Q1 load

TAS APERTURE EFFECT

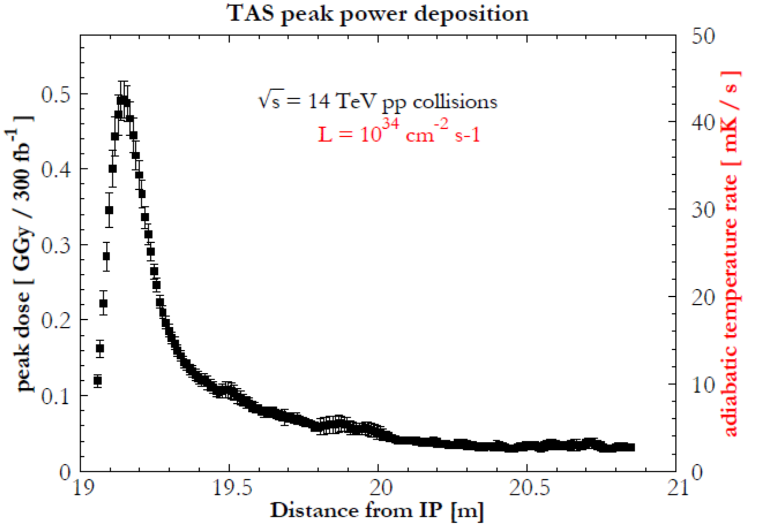


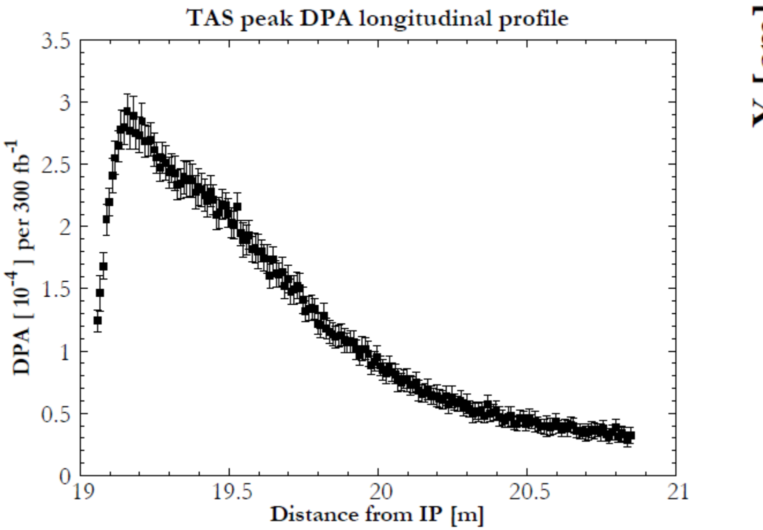


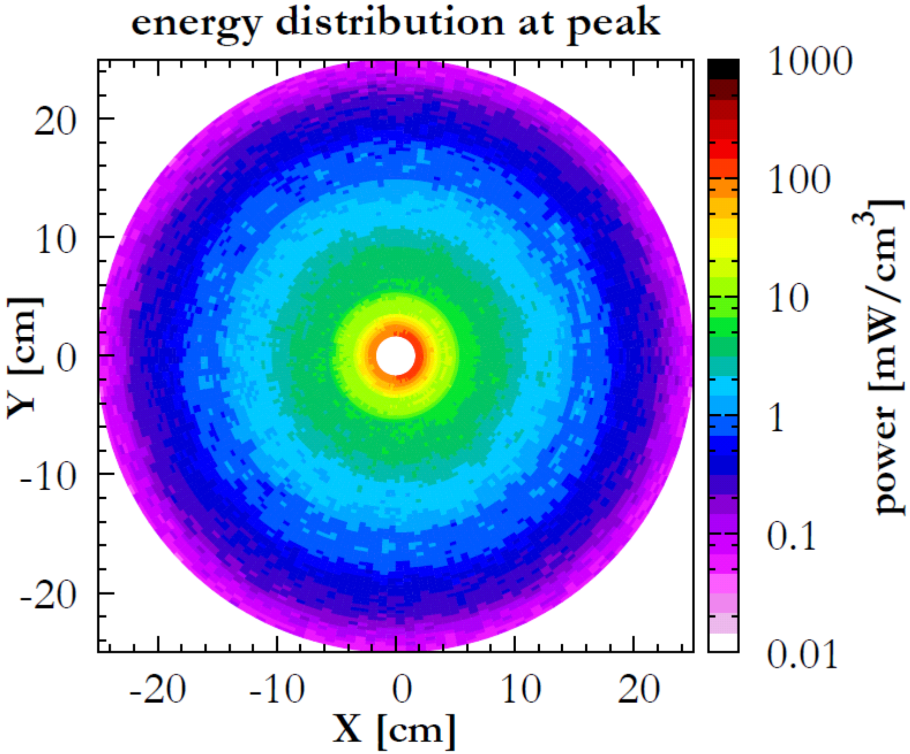
TAS aperture [mm]	TAS shadow [m]	
50	47	mid-Q2B
60	39	end-Q2A
70	33.5	end-C1

for increasing TAS aperture, the power no longer intercepted is collected in the triplet (mainly in Q1)
but with no impact on quench risk and lifetime

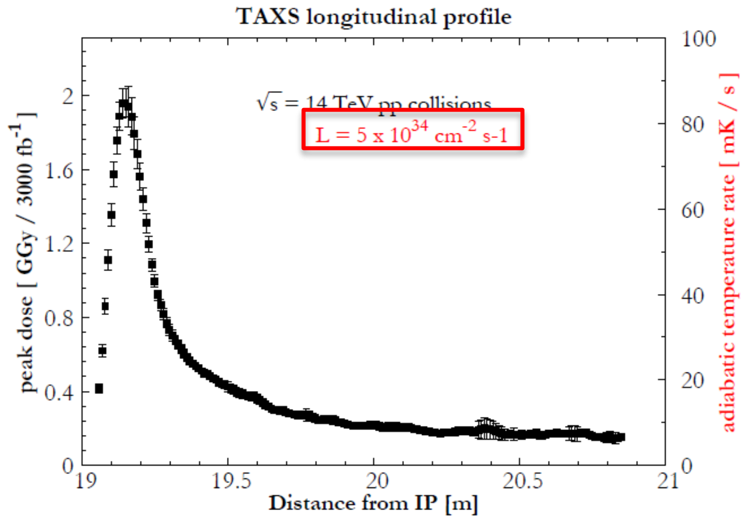
RADIATION TO PRESENT TAS

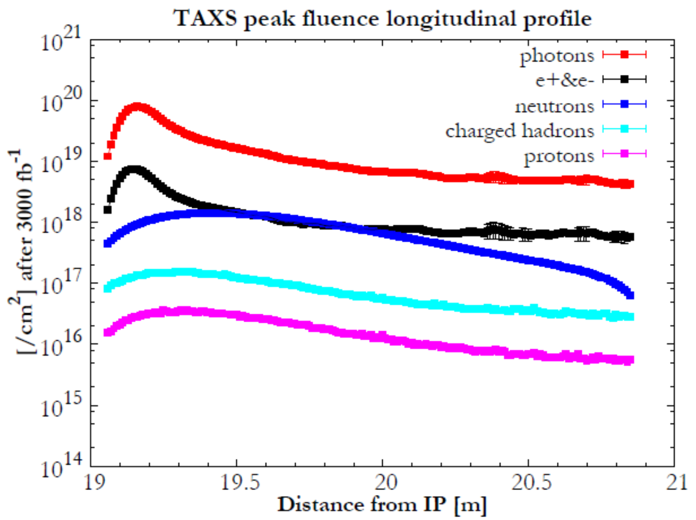


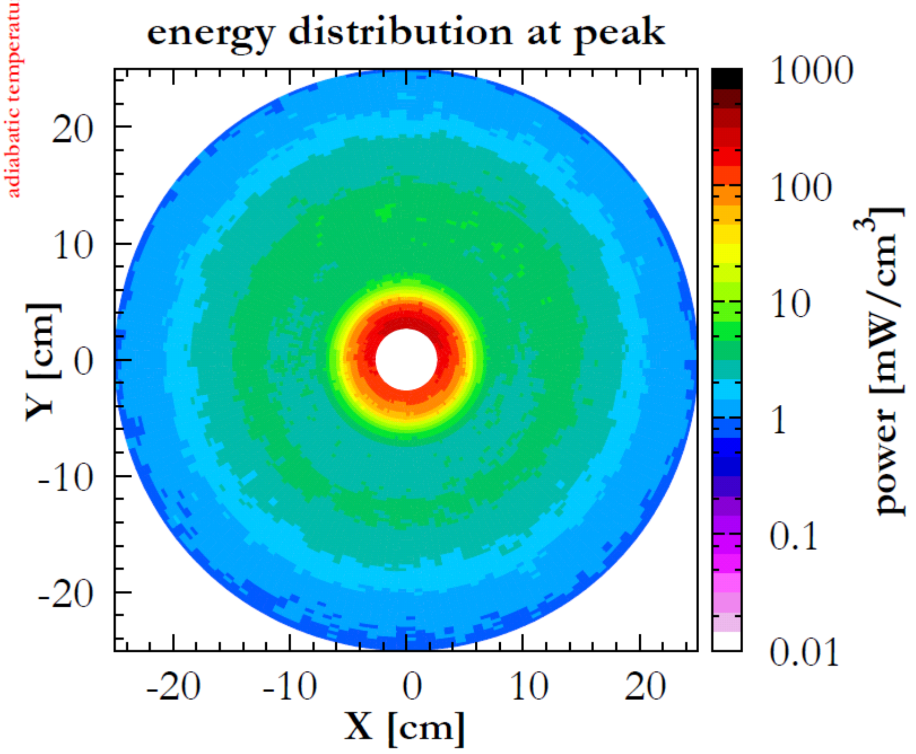




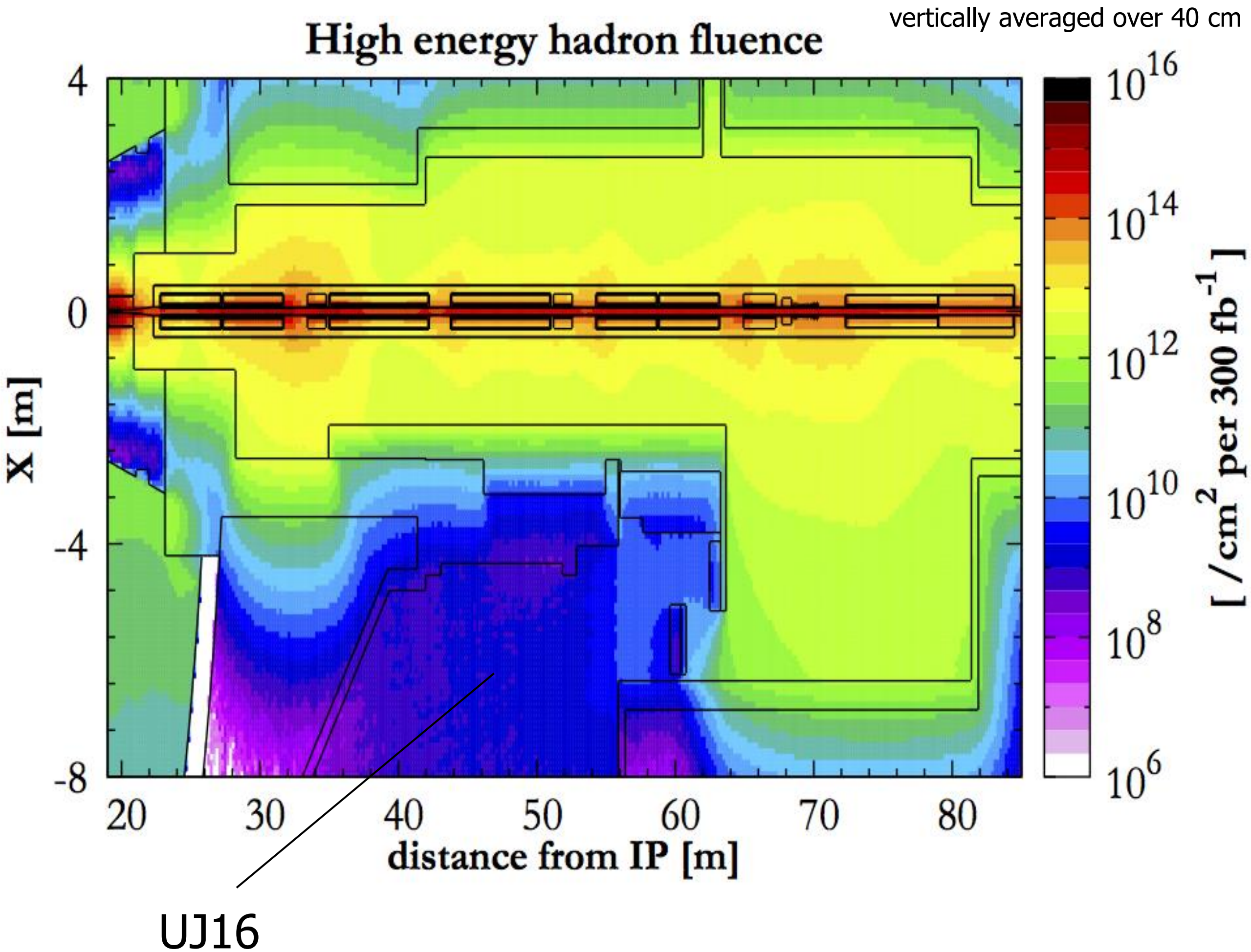
RADIATION TO TAXS





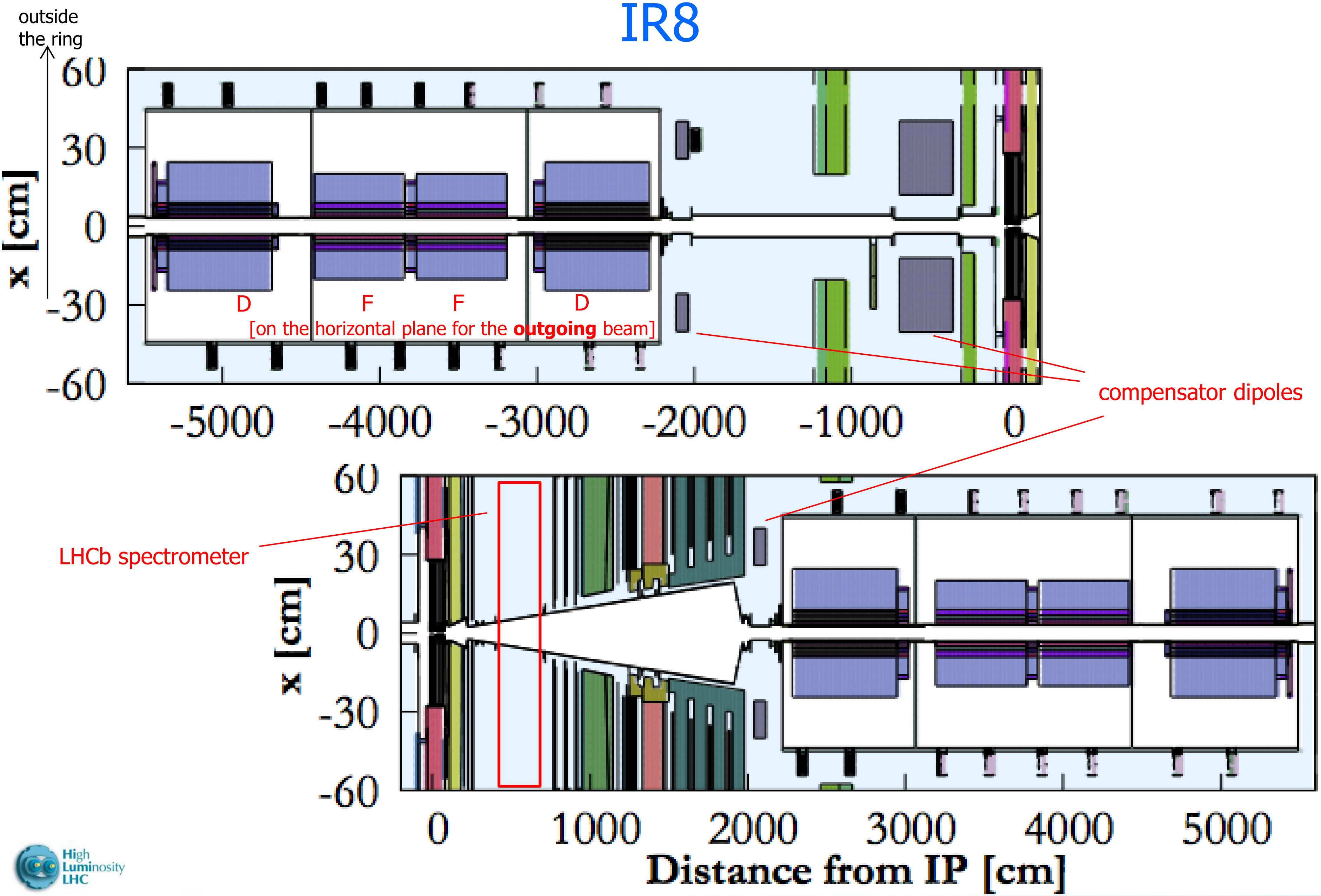


RADIATION TO EQUIPMENT



2 10^9 per year

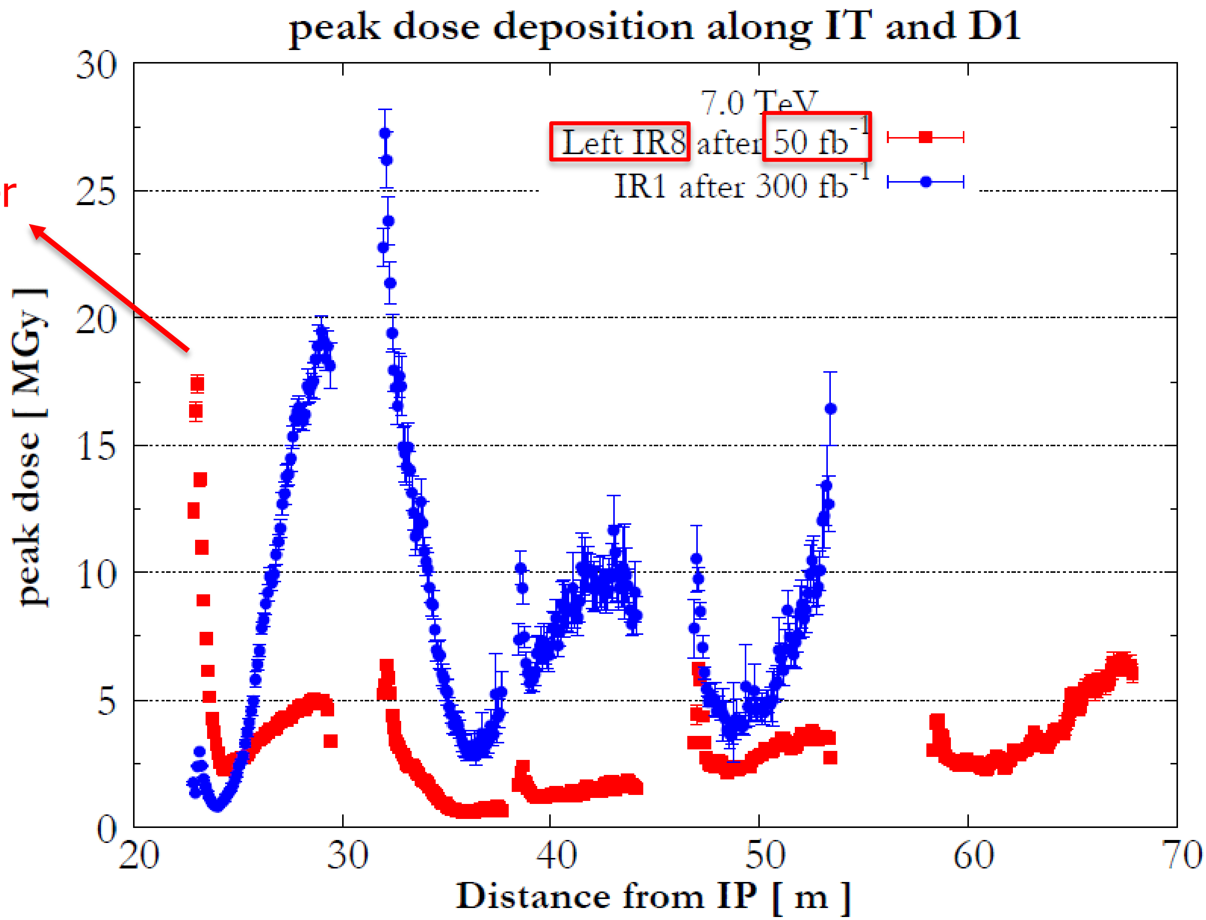
IR8


outside the ring
x [cm]
60
30
0
-30
-60
D
F
F
D
[on the horizontal plane for the **outgoing** beam]
-5000
-4000
-3000
-2000
-1000
0
compensator dipoles
LHCb spectrometer
1000
2000
3000
4000
5000
Distance from IP [cm]

Q1 COIL EXPOSURE AFTER LHCb LUMI UPGRADE

385 urad half horizontal crossing angle

25% higher
on Q1.R8



3 - 3.5 mW/cm³ @ 2 10³³ cm⁻² s⁻¹ on Q1.R8

CONCLUSIONS

• *HL-LHC IR model* kept being updated: orbit corrector design progress, quad coil refinement, beam screen evolution (waiting for shielded BPMs), …, TAXS aperture reduction.

• **Ultimate lumi** targets yield < 4 mW/cm^3 and < 40-50 MGy, with <u>Q3</u> especially hit.
20 MGy in the high order correctors. 1 kW in the cold masses and 800 W in the beam screen.

• Details of the **beam screen design** have a measurable impact on the coil protection.
BPMs embedding absorbers are clearly beneficial in the Q2a-Q2b and Q2b-Q3 (and Q3-CP) interconnects.

• <u>In the beam screen dose up to GGy</u>, dominated by <u>electromagnetic</u> component.

• Important dependence on **crossing angle**, whereas the **TAS aperture** is not critical with respect to triplet (Q1) protection.

• Thermal load specs made available for *TAXS design* development.

• High energy hadron fluence in the <u>UJ</u> exceeding 10^9 cm^{-2} per year (300 fb^{-1}).

• Triplet (Q1) exposure in IR8 (without TAS) after the **LHCb luminosity upgrade** does not exceed the IR1 levels at nominal lumi.

MORE