HiLumi
HL-LHC PROJECT

Energy deposition in the triplet-D1 region and the matching section: update to v.1.3

A. Tsinganis, F. Cerutti (EN/STI/FDA)

with R. De Maria (BE/ABP)

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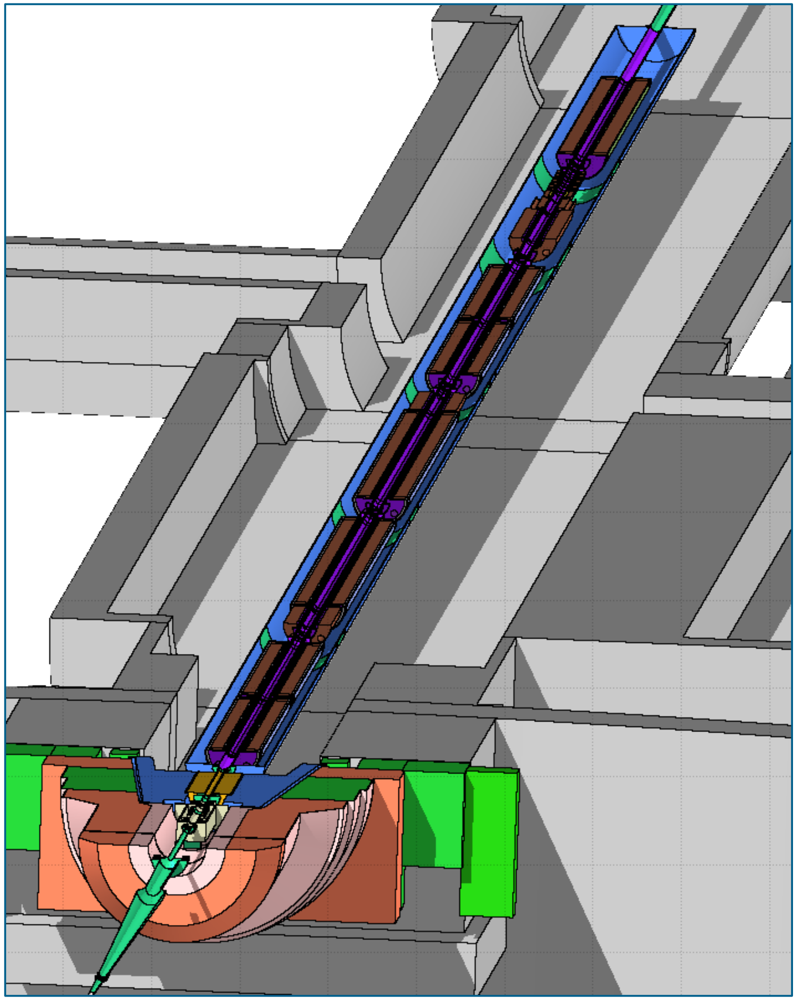
Outline

- Layout and optics
- Triplet interconnects and BPMs
- Results for v.1.3
  - Total power / Peak dose / peak power density
- Radiation in the tunnel
- Summary
- IP displacement

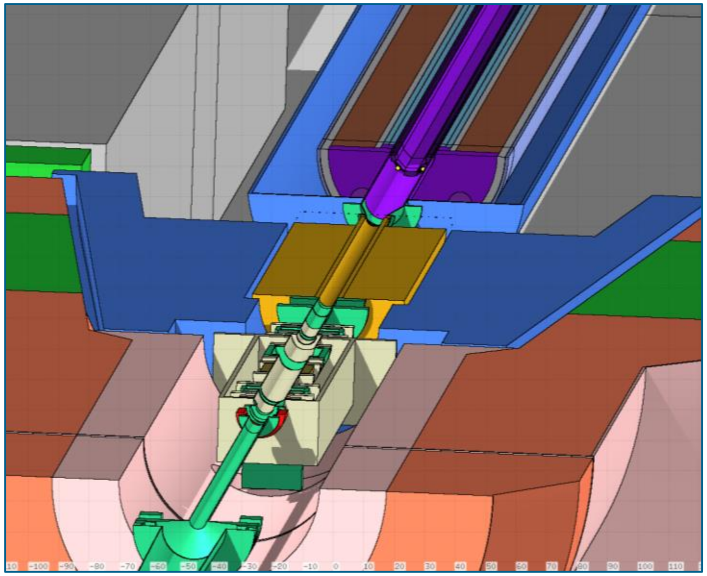
Layout and optics

Simulated geometry (triplet-D1)

- HL-LHCV1.3 (255μrad half crossing angle, β^*=20cm)



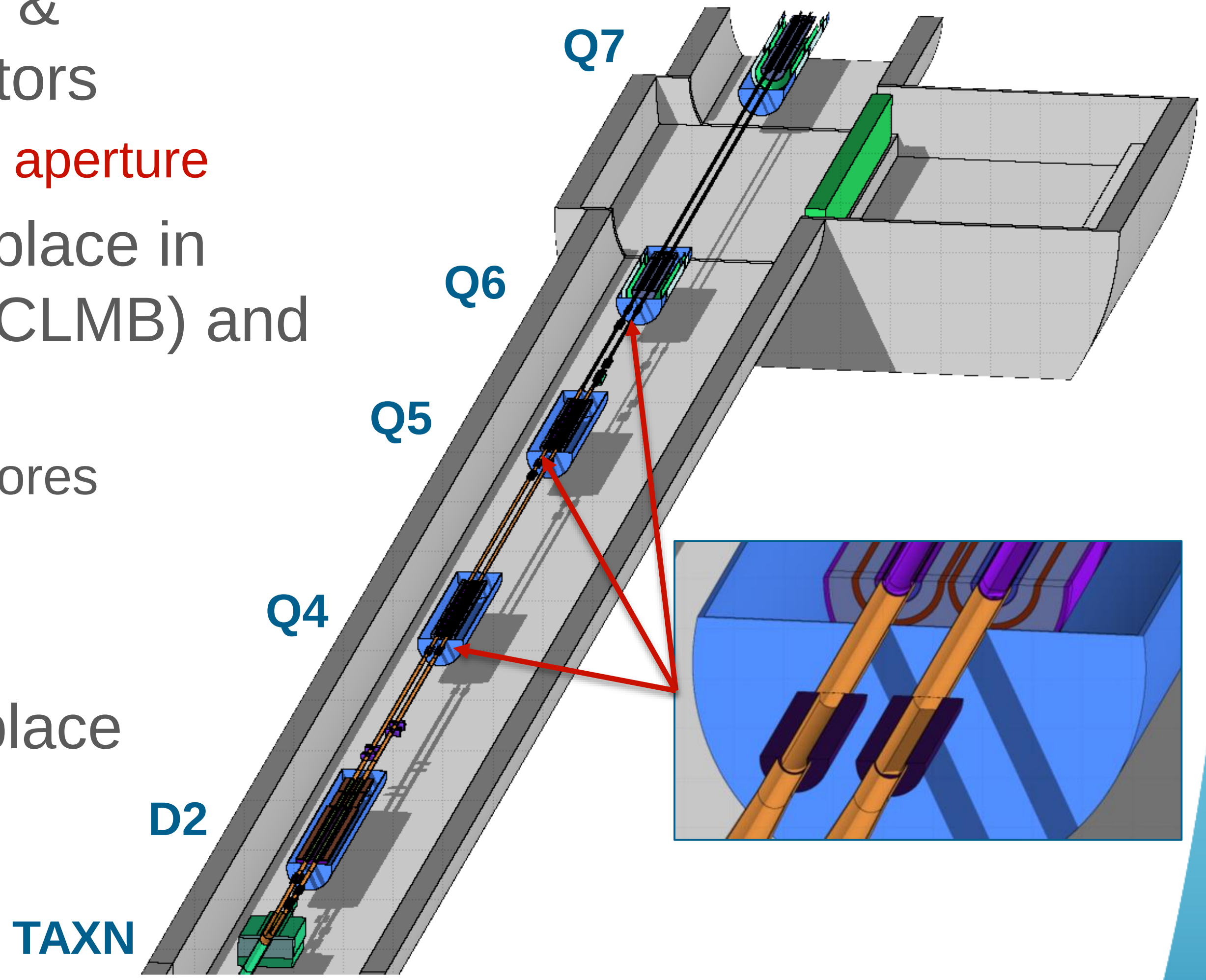
- Various updates:
  - Cryostat (position, composition) *(info from D. Ramos)*
  - Detailed VAX added
  - Realistic BS shielding extension to 45º (20% filling factor, explicitly modelled)
  - Interconnects (see next section)



VAX model by I. Efthymiopoulos & I. Bergstrom

Simulated geometry (matching section)

- Major change: Q4 & associated correctors
  - Now at 70mm coil aperture
- Masks already in place in front of Q4, Q5 (TCLMB) and Q6 (TCLMC)
  - Present on both bores
- Updated RR shielding
- All collimators in place
  - TCLs @ 13.5σ (instead of 12σ)
  - TCTs @ 12σ (instead of 10.9σ)

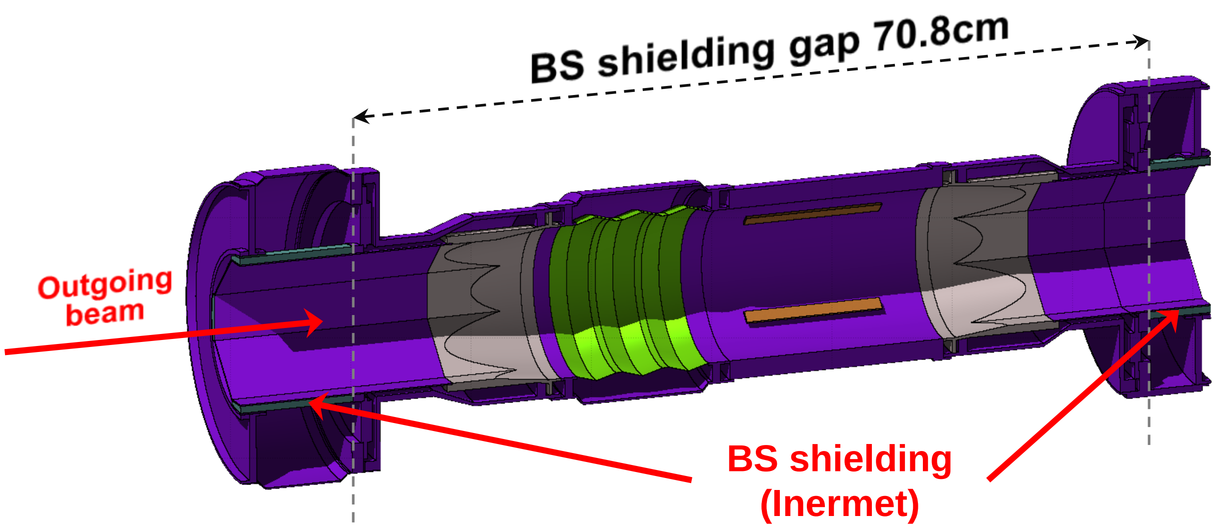


Triplet interconnects and BPMs

with T. Lefevre, R. Jones, D. Draskovic (BE/BI)
C. Garion, R. Kersevan, R. Fernandez-Gomez (TE/VSC)

Triplet interconnects and BPMs

- Peak dose values in the triplet using the first FLUKA implementation of the interconnects with incorporated BPM were presented at last annual meeting (October 2015)
  - https://indico.cern.ch/event/400665/contributions/1843468/
- A peak value of 48MGy at the IP face of Q2B was predicted for 4000fb^{-1} (36MGy after re-baselining to 3000fb^{-1}) for horizontal crossing
- The interruption of the Inermet BS shielding in the interconnect was indicated as the primary cause of this localised problem

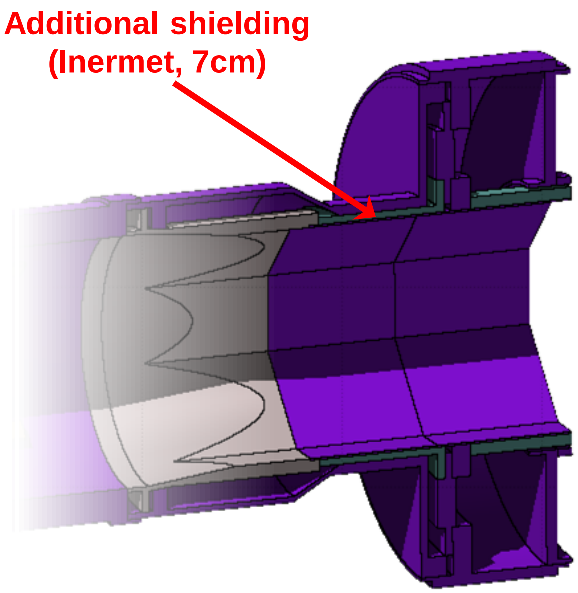


Proposed cure

- It was shown that alternative optics and crossing scenarios could significantly reduce the peak value
  - **HOWEVER**, some of these solutions are dependent on specific hardware availability (e.g. wire compensation)
- It was proposed to investigate local design improvements with the view of reducing the shielding interruption
- **Constraint:** any additional shielding element would only be effective if its radial position matches that of the BS shielding
- Improvements to the interconnect design in the direction of increasing the shielding were investigated
  - Results presented at Sep. 1st TCC meeting
    - https://indico.cern.ch/event/559125/contributions/2268948/

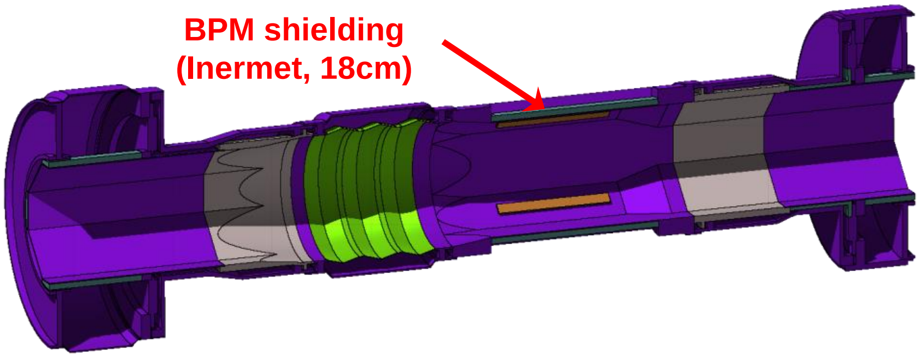
Shielding improvements

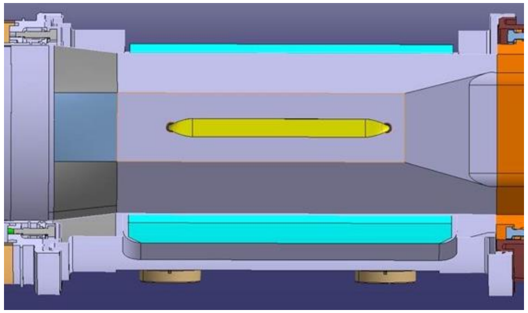
- “Circular” BPM
- Addition of 7cm Inermet insert on non-IP side



- Peak value reduction by ~15%

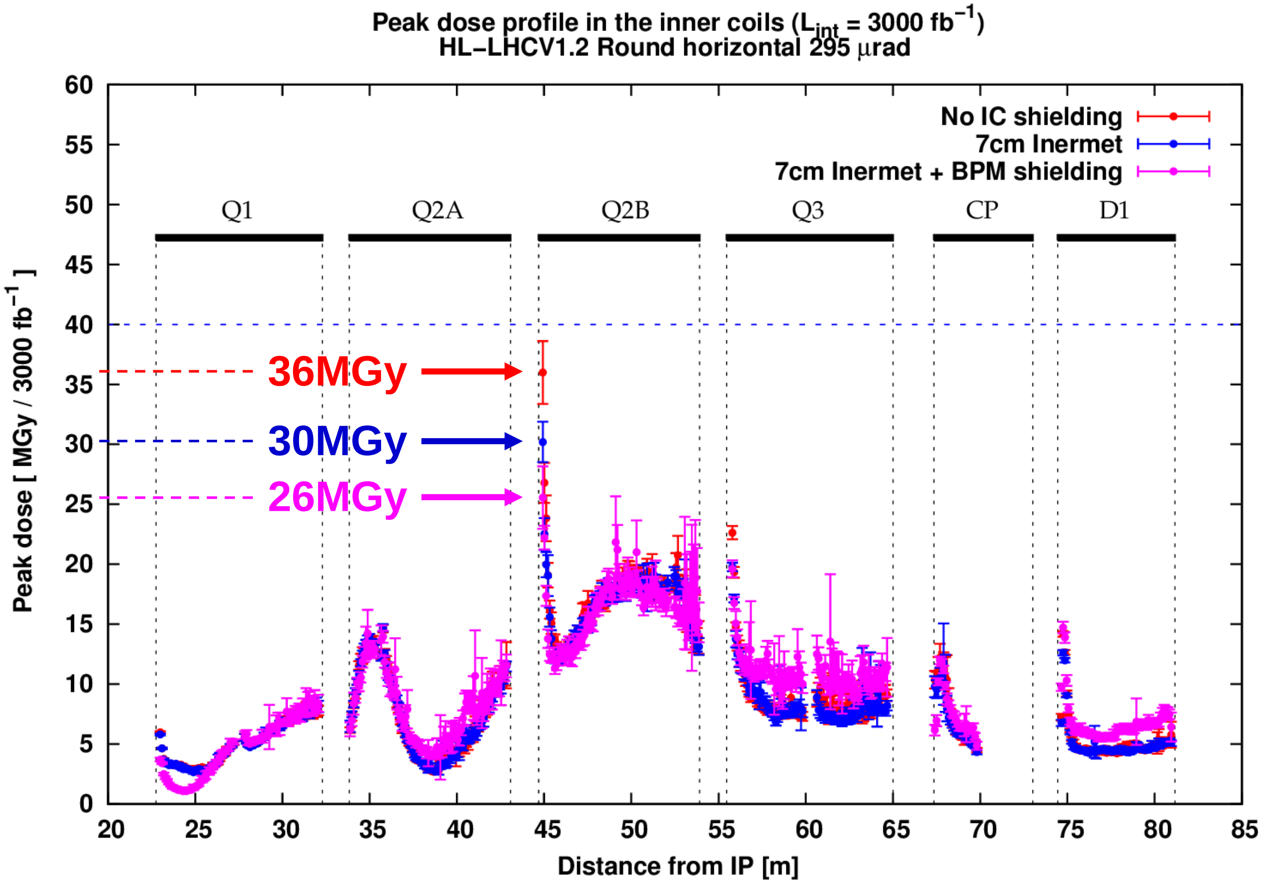
- “Octagonal” BPM with incorporated 18cm Inermet pieces on the mid-planes (retaining 7cm insert)





- Further ~15% reduction

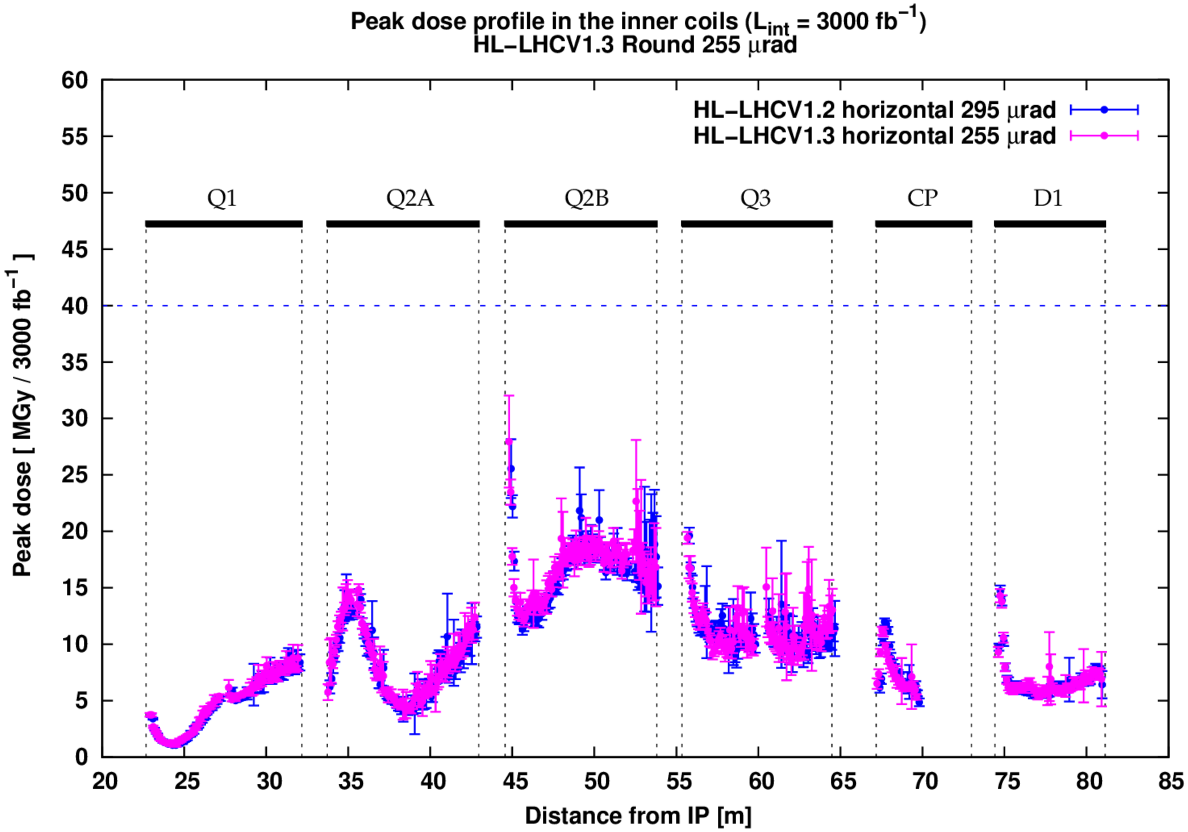
Summary of results



- TCC decision (used for v.1.3 calculations):
  - Interconnect with shielded BPM only before Q2B (for now)
  - Interconnect with 7cm insert kept elsewhere

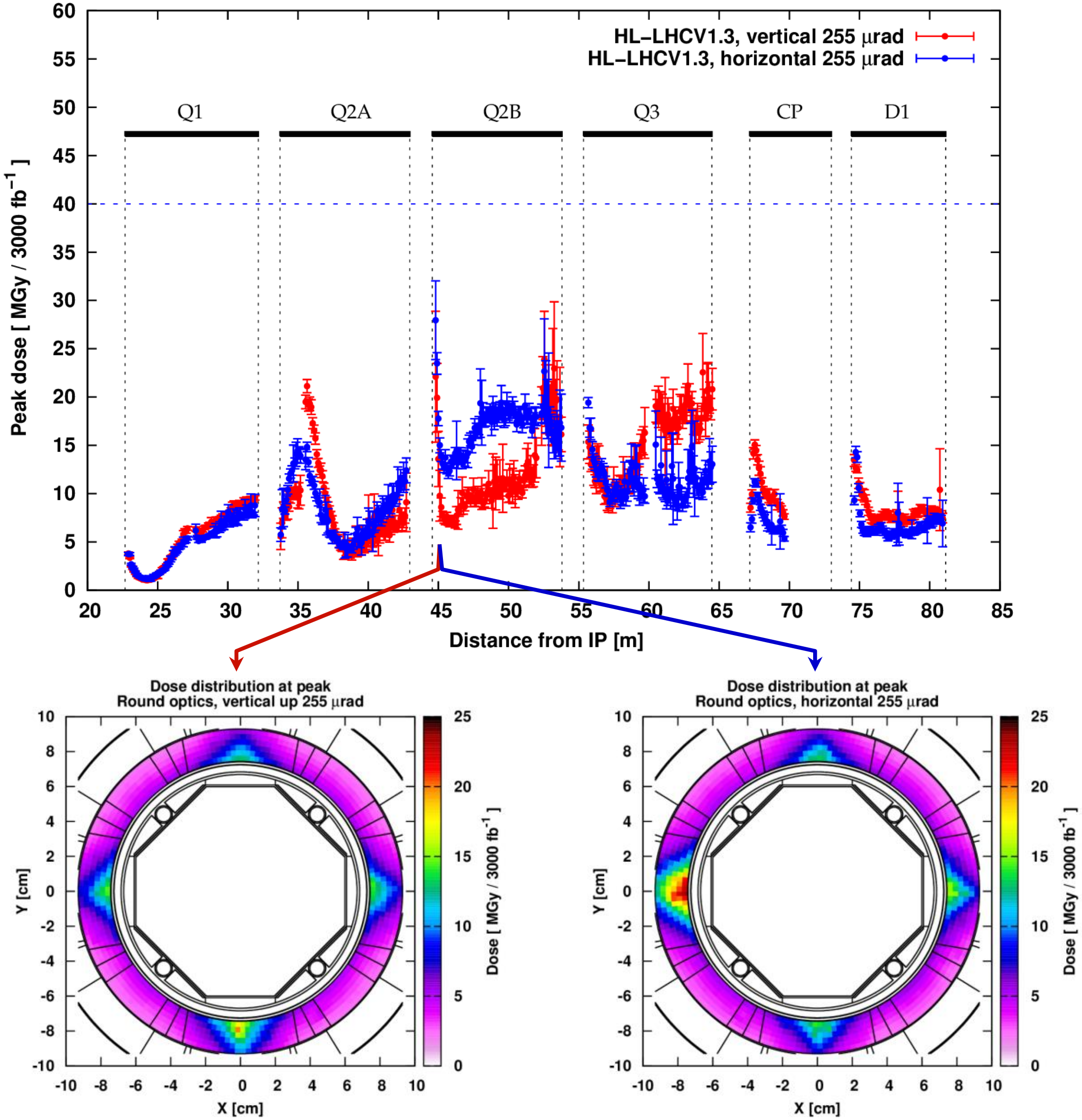
Results for v.1.3

Comparison with v.1.2: peak dose in the triplet

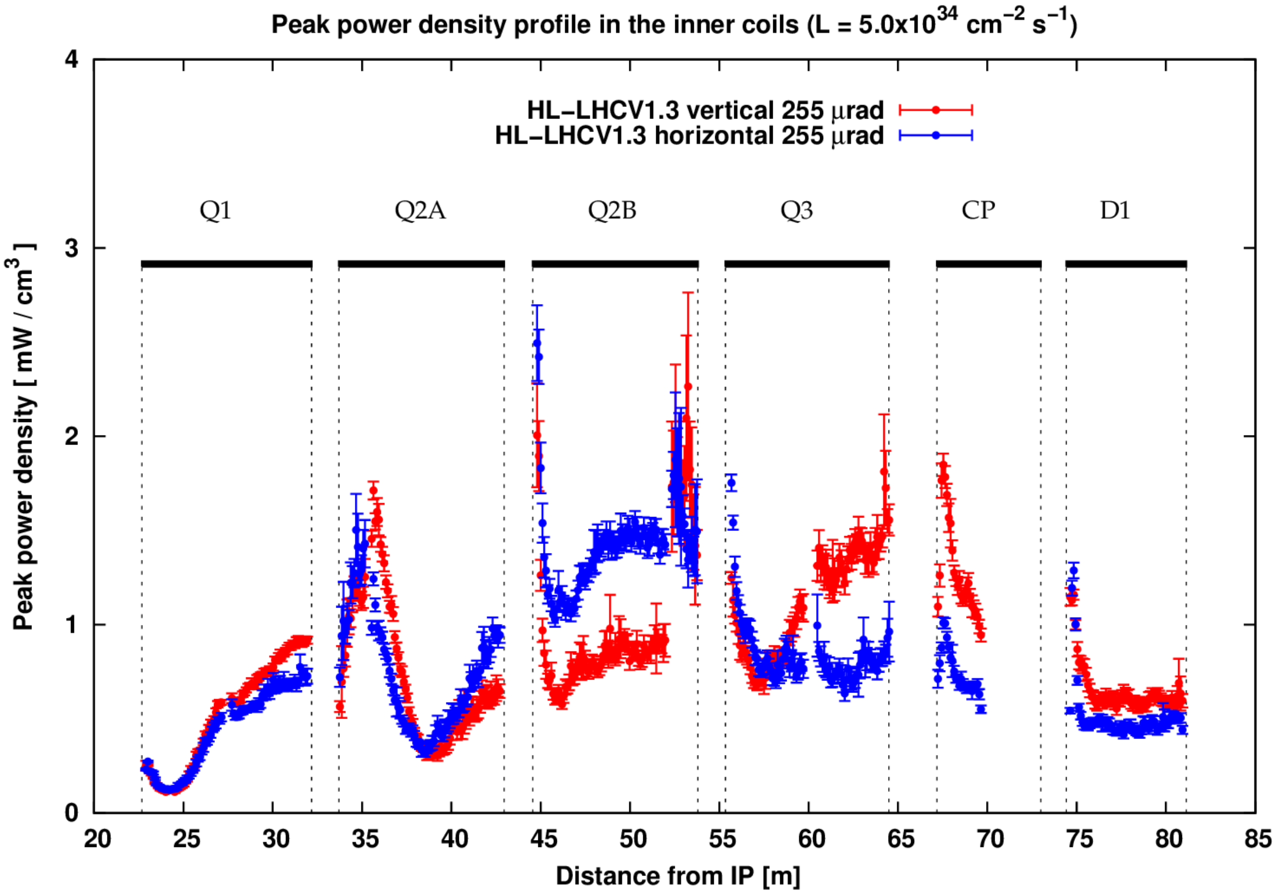


- The situation does not change significantly
- The decrease of the crossing angle (295→255μrad) is in principle expected to contribute beneficially, but not noticeably (<10% decrease in peak dose)

Triplet-D1: Peak dose profile



Triplet-D1: Peak power density profile ($L=5.0x10^{34}$ cm^{-2} s^{-1})



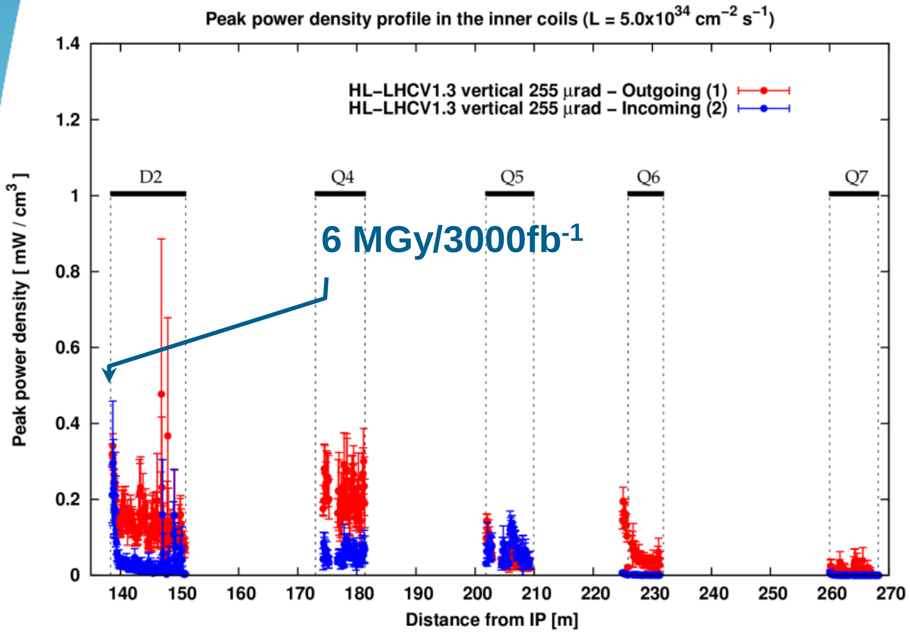
- Peak power density values below $3mW/cm^3$ everywhere

Total power (triplet-D1) (L=5.0x10^{34} cm^{-2} s^{-1})

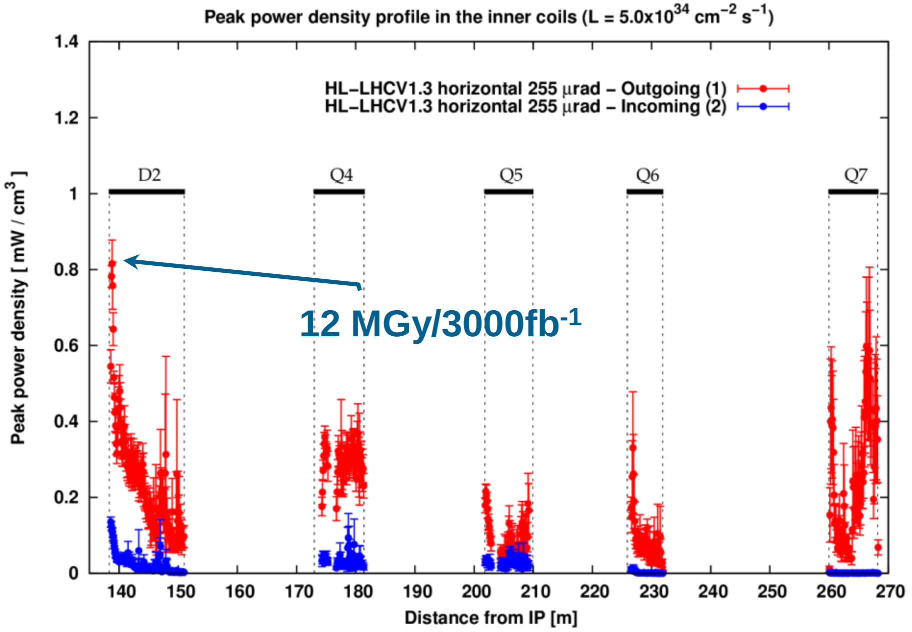
	Vertical		Horizontal	
Magnets	**Magnet cold mass**	**Beam screen**	**Magnet cold mass**	**Beam screen**
	Power [W]			
Q1A + Q1B	114	170	113	169
Q2A + corr.	101	68	99	65
Q2B + corr.	126	87	136	100
Q3A + Q3B	134	80	119	70
CP	54	62	42	46
D1	79	56	67	46
Beam pipe extensions	21	72	21	64
TOTAL	**629**	**595**	**597**	**560**

Matching section: peak power density profile ($L=5.0x10^{34}$ cm^{-2} s^{-1})

Vertical crossing



Horizontal crossing



- Peak power density values well below $1mW/cm^3$ in the matching section
- Dose values $/3000fb^{-1}$ up to 12MGy in front face of D2 (for horizontal crossing)
- CRITICAL POINT: the overall good result (despite the significant restriction of the Q4 aperture) is expected to be largely due to the beneficial presence of the masks on the outgoing beam bore (especially before Q4), as well as the TCLs and the TCTs on the incoming beam bore

Total power (matching section) (1/2)

	Vertical		Horizontal	
Magnets	Magnet cold mass	Beam screen (b1/b2)	Magnet cold mass	Beam screen (b1/b2)
	Power [W]			
D2 + corr.	17	1.0 / 0.1	36	2.2 / <1mW
Q4 + corr.	6.4	1.3 / 0.8	9.0	2.2 / 1.0
Q5 + corr.	0.8	<1mW	1.0	0.04 / <1mW
Q6 + corr.	0.9	<1mW/0.03	2.4	<1mW / 0.1
Q7 + corr.	0.1	<1mW	1.3	0.2 / <1mW
Other				
TAXN (85mm)	1087		736	
Crab cavities	40-60mW (b1) / 15mW (b2)		130-190mW (b1) / 30mW (b2)	

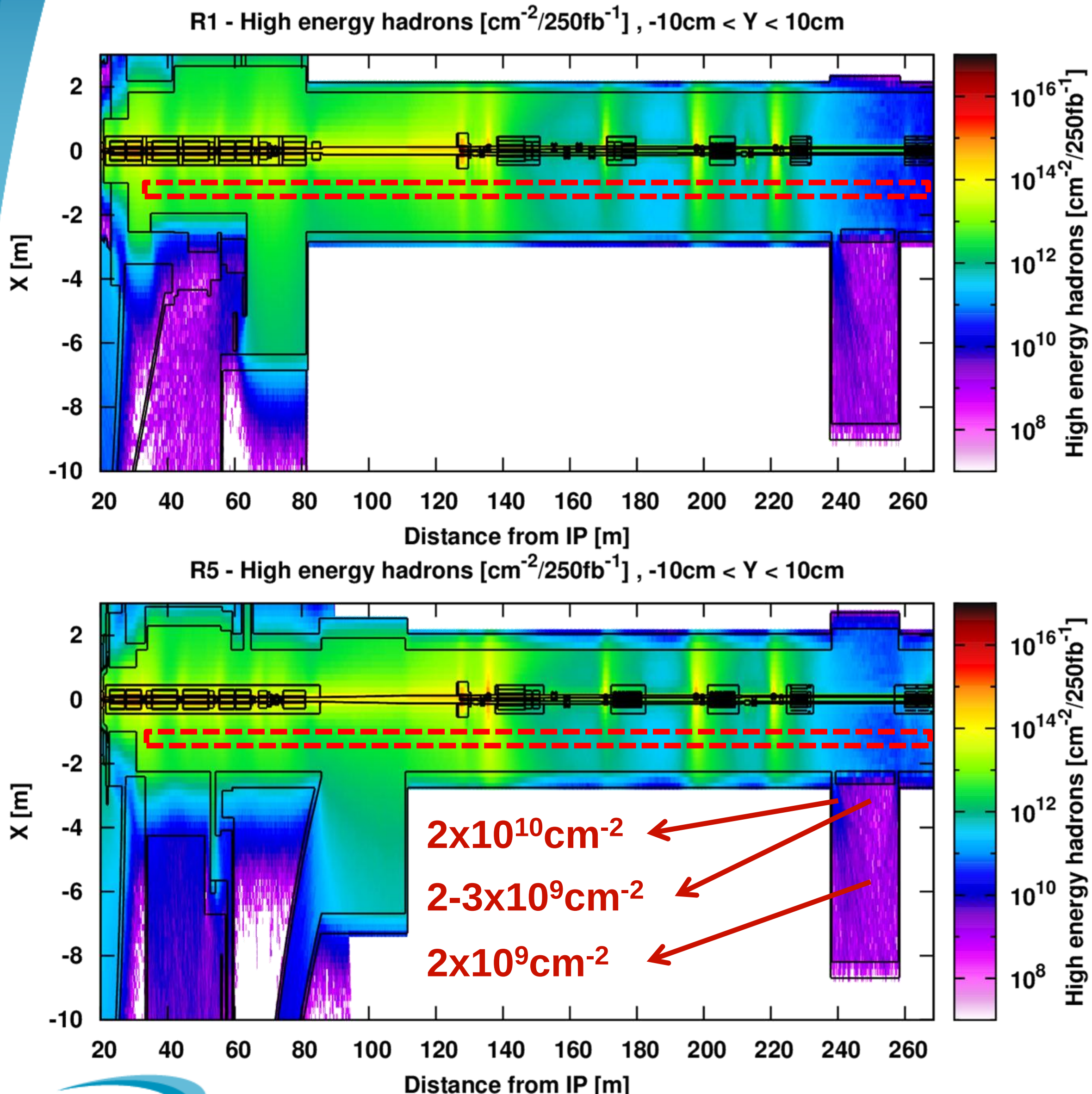
Total power (matching section) (2/2)

	Vertical		Horizontal	
Collimators	Inner/ upper jaw	Outer/ lower jaw	Inner/ upper jaw	Outer/ lower jaw
	Power [W]			
TCLX4.B1	25	53	190	88
TCTPV4.B2	11	6	3.6	3.6
TCTPH4.B2	5	19	1.6	8.6
TCL5.B1	7	45	14	81
TCL6.B1	10	32	13	24
TCTV6.B2	0.9	0.9	0.3	0.4
TCTH6.B2	0.4	0.05	0.3	0.03
Masks	Beam 1	Beam 2	Beam 1	Beam 2
TCLM4	**19**	1.3	**22**	0.6
TCLM5	2.6	1.3	4.3	0.8
TCLM6	0.7	0.06	1.8	0.06

Radiation in the tunnel

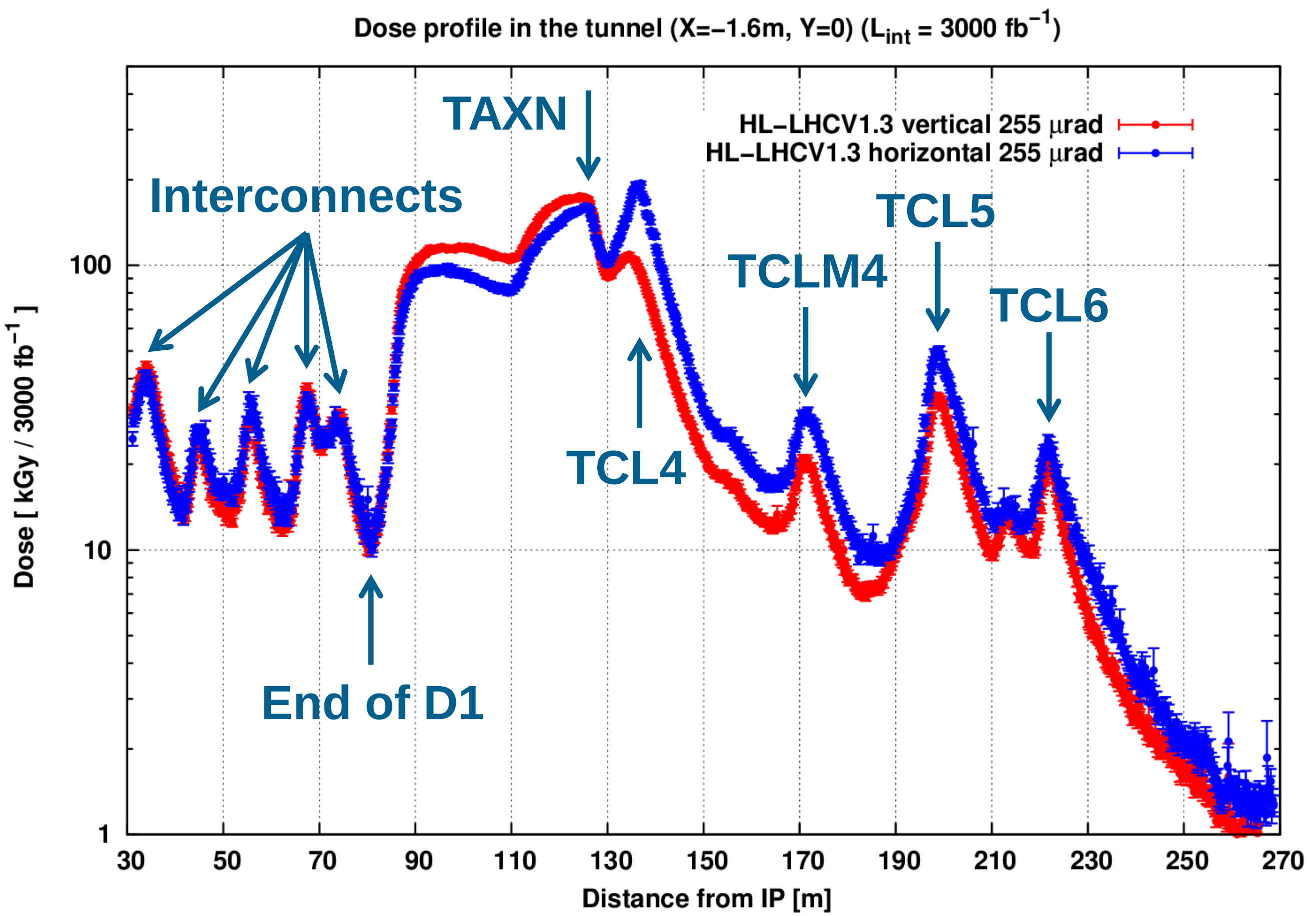
with R. Garcia Alia (EN/EA)

Radiation in the tunnel (250fb^{-1})



- Dose, thermal and 1MeV neutron equivalent fluence & high energy hadron fluence estimated
- HE hadron fluence in RRs:
  - Up to 2×10^{10}cm^{-2} near entrance
  - few x 10^{9}cm^{-2} elsewhere

Peak dose profile in the tunnel (x=-1.6m, y=0)



- In general, higher levels in the matching section for horizontal crossing
  - Locally due to greater impact on TCL4, overall due to greater leakage through the TAN and subsequent losses on various elements

Summary

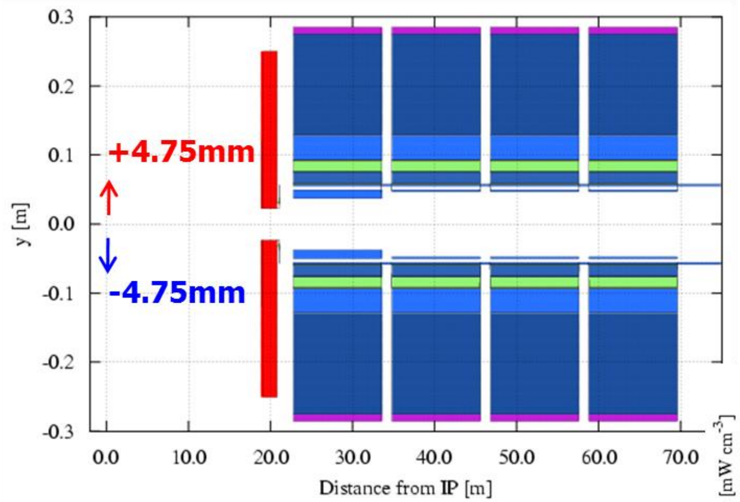
- Situation in the triplet-D1 region remains largely unchanged in v.1.3 (no major changes in the layout)
- Use of shielded BPM in interconnect before Q2B is important
- Despite reduced Q4 aperture, peak dose and peak power density values in the matching section remain acceptable, largely due to the presence of masks on the outgoing beam (especially before Q4), as well as TCLs and TCTs
- Usefulness of masks on incoming beam is more debatable
  - Could become more important for accident scenarios (e.g. asynchronous beam dump on TCT6)
- Quantities relevant for R2E, instrumentation, VAX area etc. are available
- Further studies: IP displacement

IP displacement

- Possibility of IP displacement by few mm is foreseen
- Not studied yet for HL-LHC, but results exist for a previous upgrade scenario

IP displacement

COLLISION POINT DISPLACEMENT



vertical axis

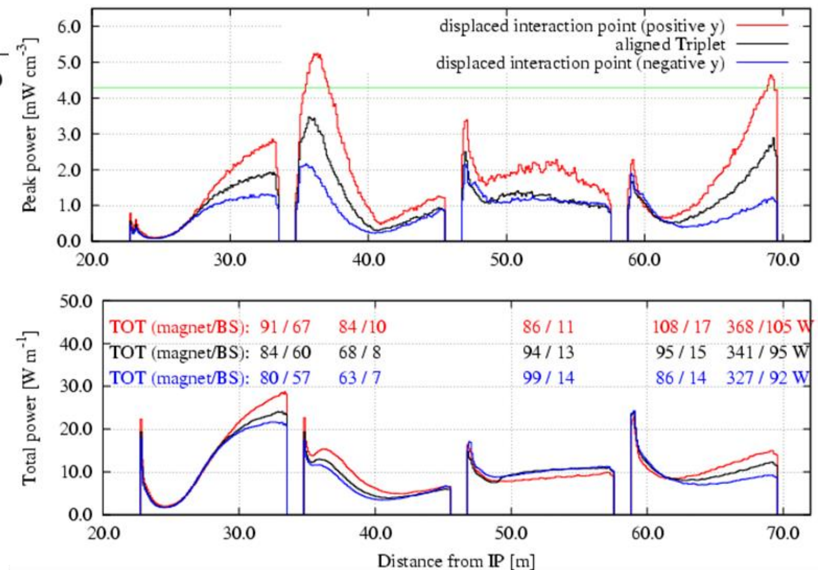
vertical crossing

(+225 urad half crossing angle)

+50% for peaks

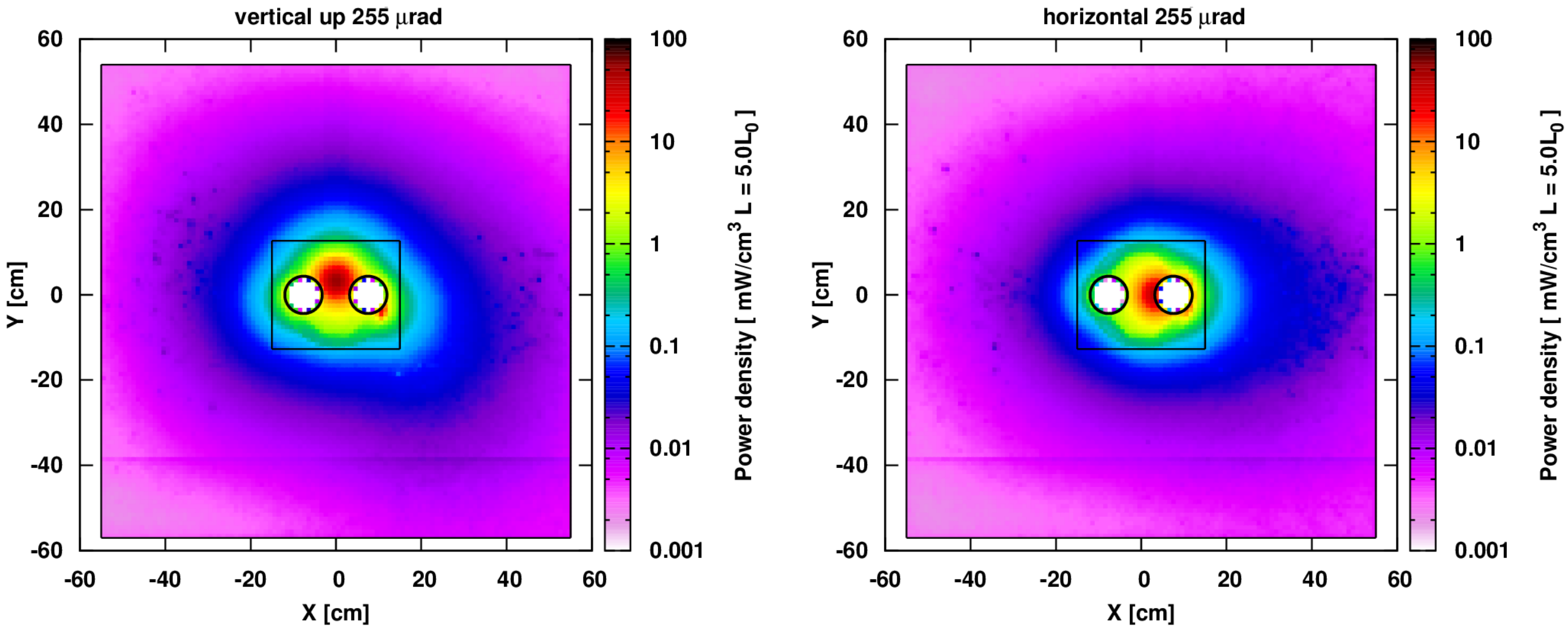
+10% for totals

when the debris cone is moved to a higher field region at the triplet entrance



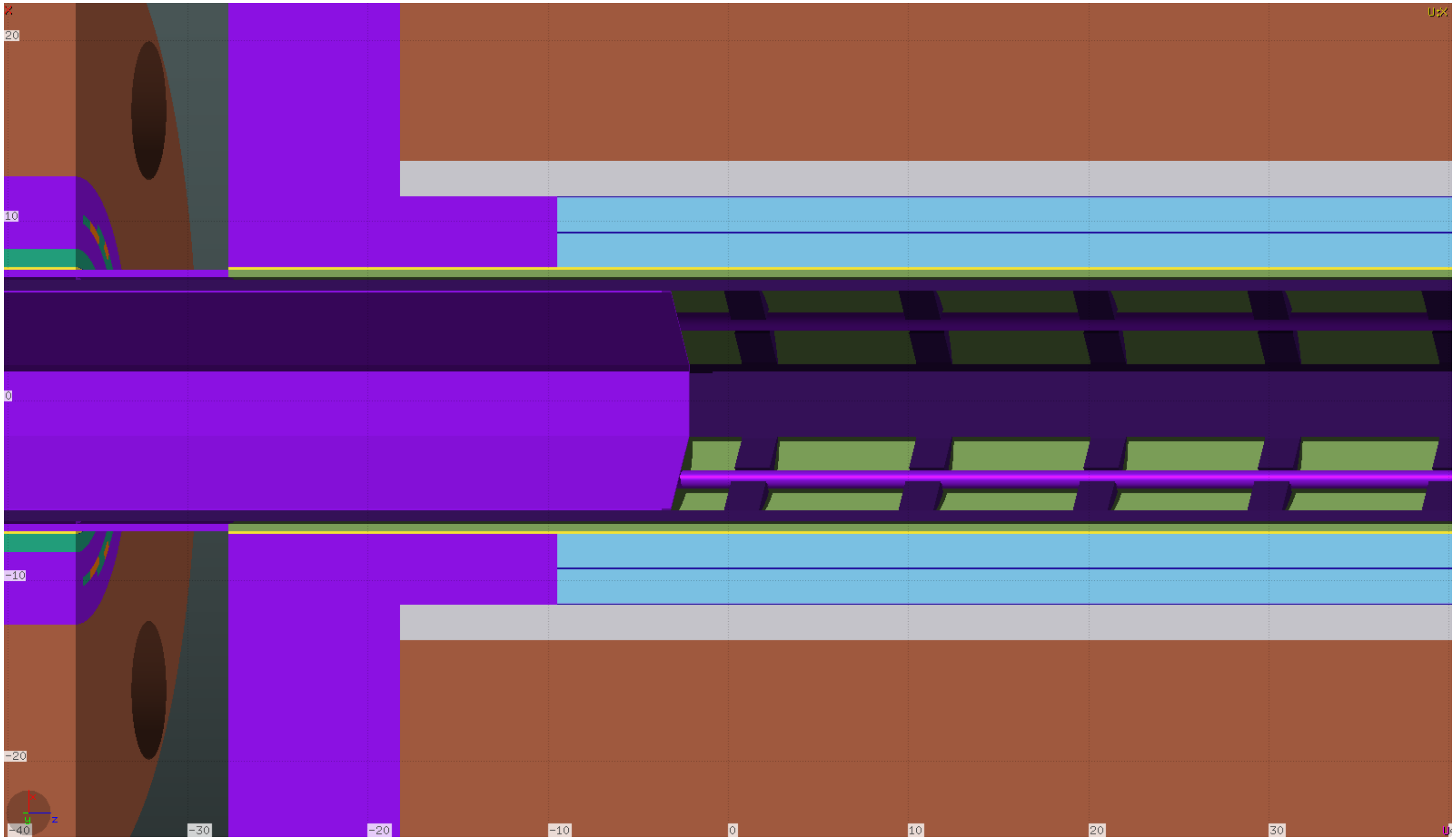
SLHC-IRP1, TDG Meeting, June 4th 2009 F.Cerutti 3

TAXN effectiveness



- Greater leakage in the horizontal case, hence the lower power on the TAN itself and higher radiation in the matching section

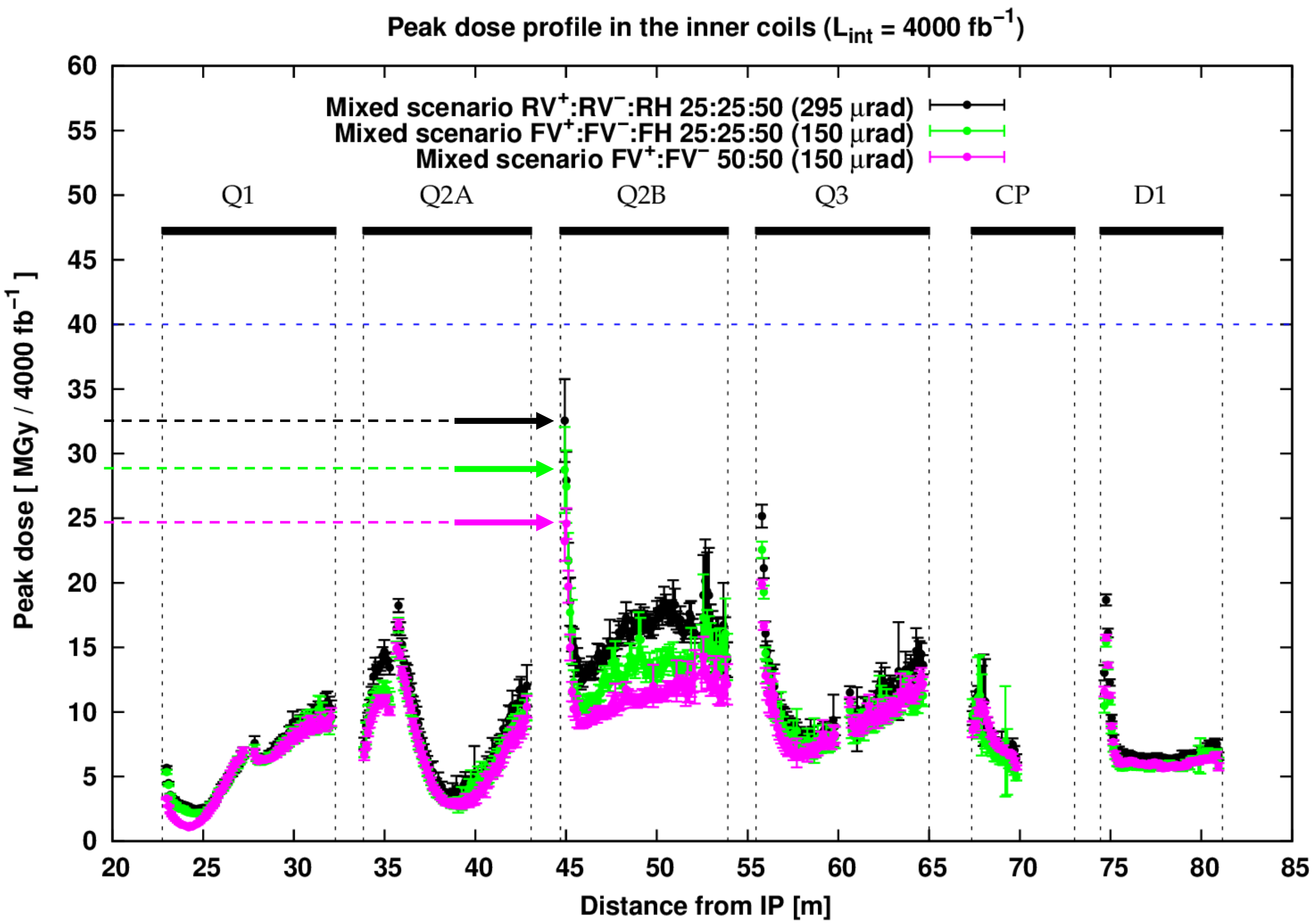
Triplet-D1 BS shielding



- Extension of shielding to 45º explicitly modeled

Peak dose minimisation scenarios

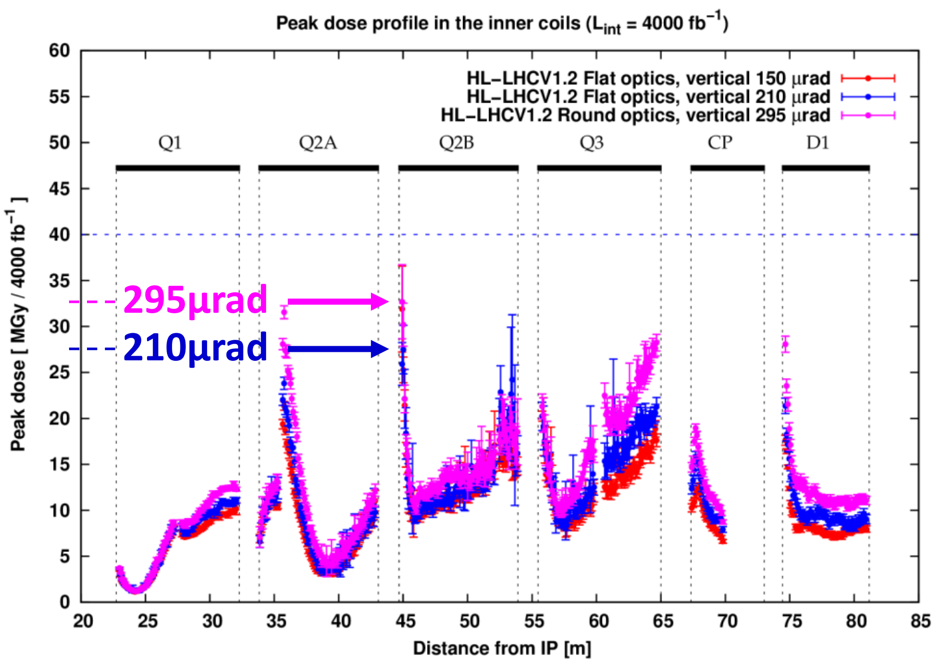
- Comparison of three mixed scenarios:



Further studies: flat optics

- Two flat optics scenarios were also studied for both vertical and horizontal crossing
  - 150μrad half-crossing angle, β^*_x / β^*_y = 40 / 10 cm
  - 210μrad half-crossing angle, β^*_x / β^*_y = 40 / 10 cm
- Sensitivity of results to changes in bunch length and beam divergence is limited
- On the contrary, the crossing angle plays an important role
  - Lower dose for lower crossing angle

Vertical crossing



Horizontal crossing