Assessment of shielding for Diamond-II beamlines

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Diamond-II Overview

As with many synchrotron light sources around the world Diamond is planning an upgrade to the storage ring to reduce emittance and increase brightness and coherence.

- The Energy of the storage ring will increase from 3 GeV to 3.5 GeV, the current will remain at 300 mA.
- The lattice will change from a double bend to a muti bend achromat.
- The ‘dark’ period is due to start December 2027 lasting 18 months, finishing June 2029
- First users are scheduled September 2029

Diamond-II Overview

In addition to the changes to the storage ring a large number of beamlines are receiving upgrades (e.g. insertion devices, mirror etc).

In light of multiple changes the shielding of each beamline was assessed using STAC8 summarised in table 1.

As beamlines were designed to shield 500mA stored current, most beamlines have sufficient shielding for an increase in storage ring energy .

Changes to Beamlines

Table 1: Additional BL shielding calculated using STAC8

Beamline	Area 1	Additional Pb	Area 2	Additional Pb	Other areas
I02	EH 2 beamstop	2mm			
B07	Currently soft x-ray, new OH in design phase				
K11	Transport pipe	3mm			
I12	See next slide				
I13	OH1 lat wall, Roof	1mm lat wall, 1mm roof, Restrict access to roof	OH2 end wall	2mm centred on beampipe 575mm diameter	
I14	OH1 lat wall, Roof	4mm lat wall, Restrict access to roof	OH3 upstream wall	1mm centred on beampipe 430mm diameter	3mm Pb beamstop 100mmx100mm EH2, Pb Skirting OH1
B16	OH1 end wall	17+13 (1m^2 centre)	OH1 Lateral wall	2	
B18	OH1 end wall	17+13 (1m^2 centre)	OH1 Lateral wall	2	
I20	OH1 roof	2mm roof, Restrict access			
B21	OH1 end wall	17+13 (1m^2 centre)	OH1 Lateral wall	2	
I24	OH1&2 roof	1mm roof, Restrict access	Transport pipe	3	

Beamline shielding I12

I12 is a 4.2 T Wiggler beamline capable of taking white beam and requires a number of shielding increases:

OH2

Side wall (inboard): additional 3mm Pb in some areas. (Fig 1)

Side wall (outboard) additional 6mm Pb in some areas. (Fig 2)

OH1, SS1, OH2 and EH1 roof 400mm (OH1, SS1, OH2) 391mm (EH1) wide strip from Downstream end wall along entire length of hutch roofs additional 3mm Pb. (Fig 3)

EH1

- Side wall (inboard with search door) additional 9mm Pb over most of the wall. (Fig 4)
- Side wall 2 (inboard wall): 6mm Pb extra, all along. (Fig 5)
- Side wall 3 (outboard wall): 5mm extra all along. (fig 6)

Beamline shielding I12

I12 (OH2 Side walls)

Fig 1.

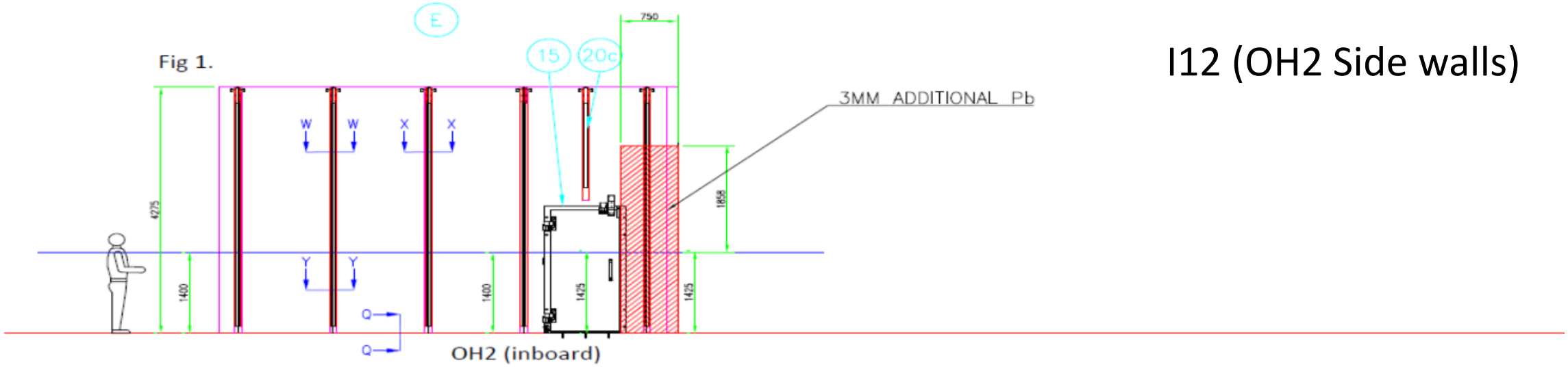
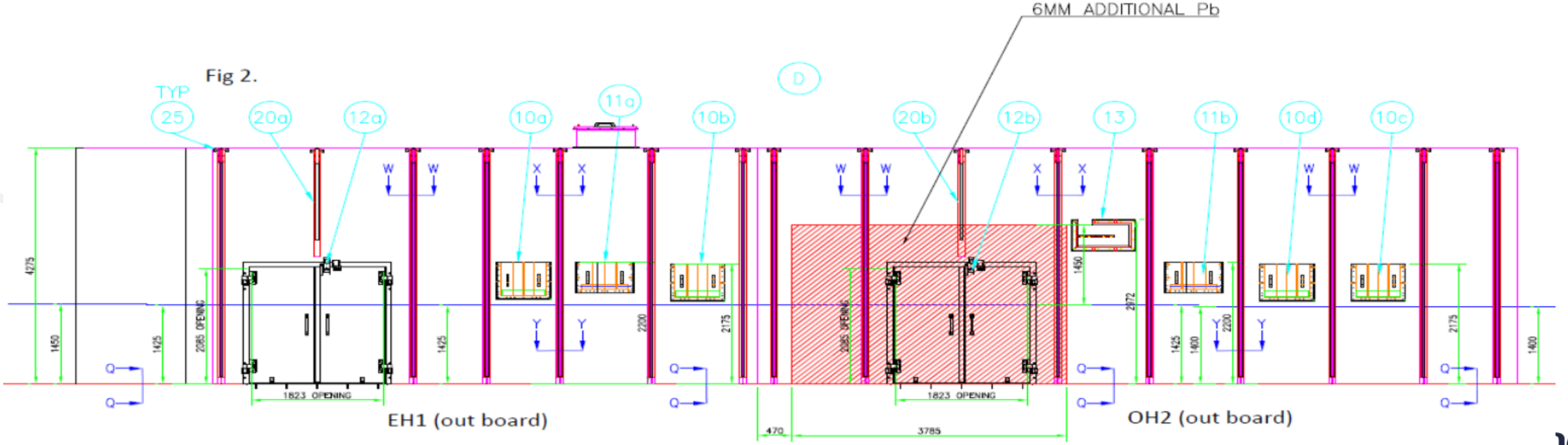
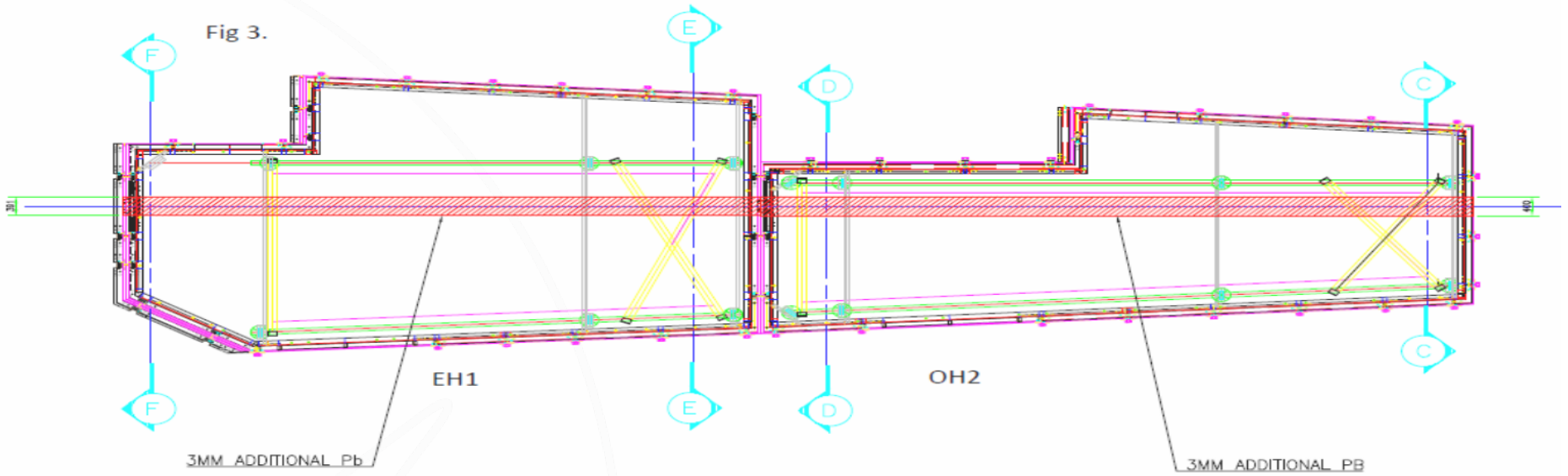


Fig 2.

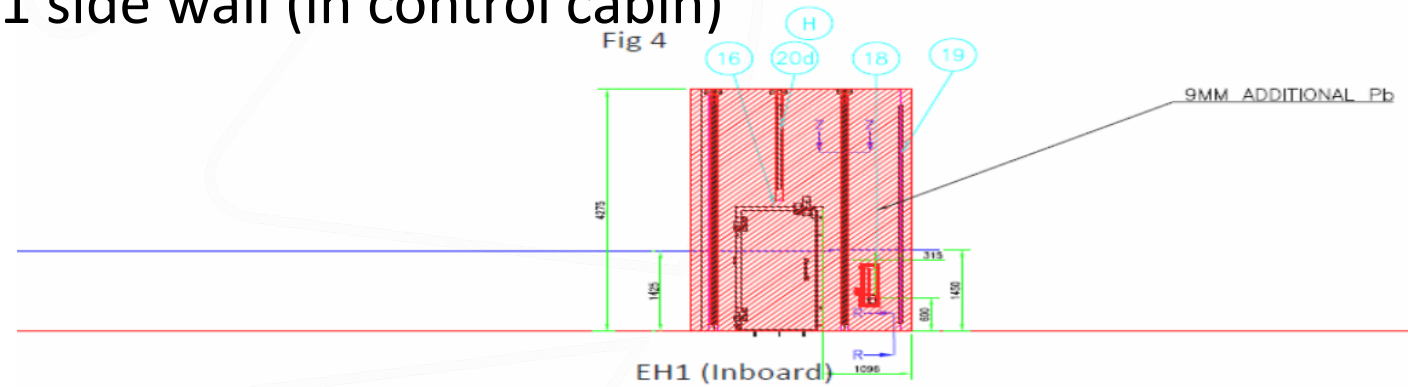


Beamline shielding I12

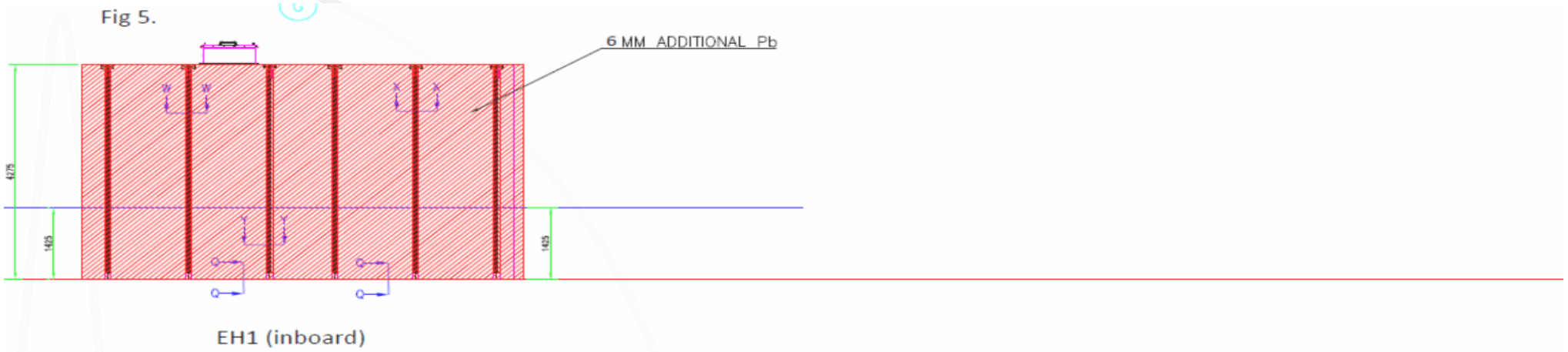
I12 (roof)



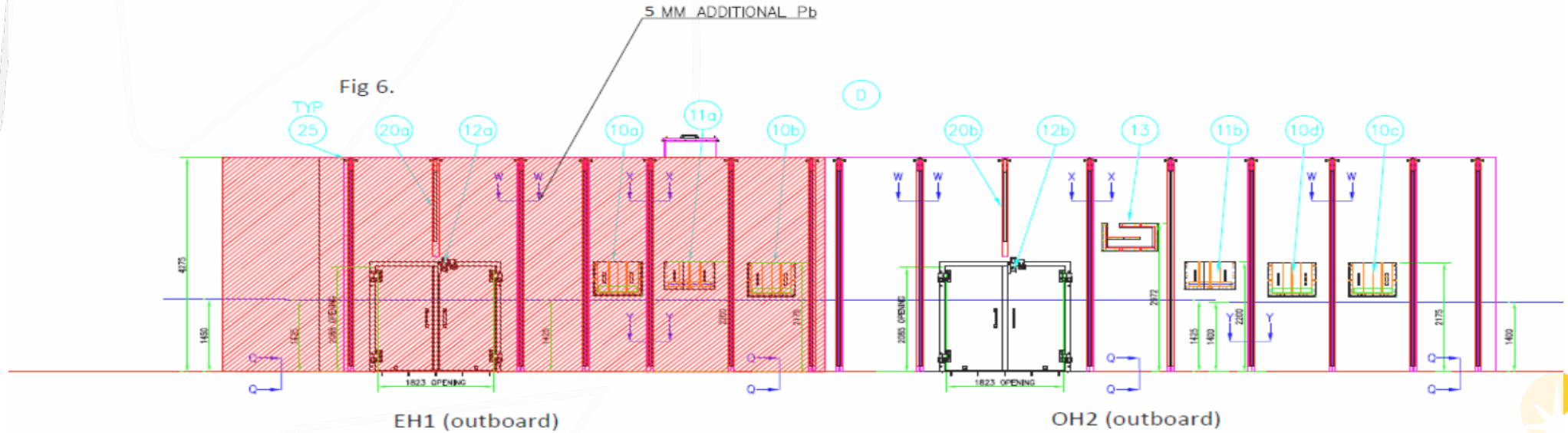
I12 EH1 side wall (in control cabin)



Beamline shielding I12



I12 EH1 side walls (outside control cabin)

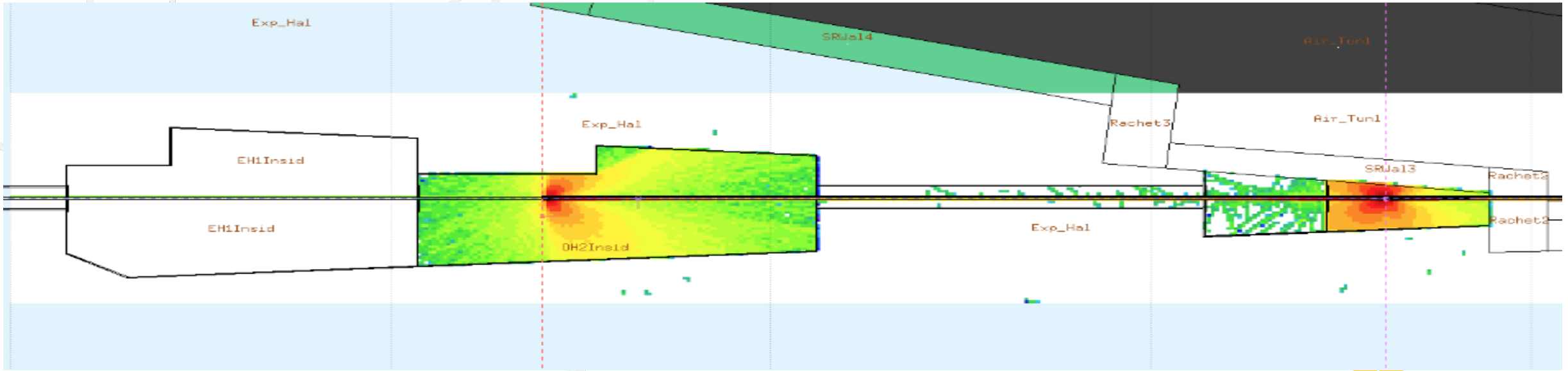


To check if the increases are really needed, we constructed a FLUKA model of the BL. Several modes were considered:

- White Beam, terminated at shutter in OH2 and sample target and shutter EH1
- Mono Beam, terminated at shutter in OH2 and sample target and shutter EH1
- GB, terminated at shutter in OH2 and sample target and shutter EH1

No doses above 0.5 µSv/h were calculated outside the shielding…However

Fig 7: Layout of I12 with SR terminating in OH2



if the beam was missteered by a mono crystal there could be a leak thought the closed shutter (30µSv/h).

Engineers are looking at a redesign of the shutter

Fig 8: Leak from mono beam missteer (Plan view)

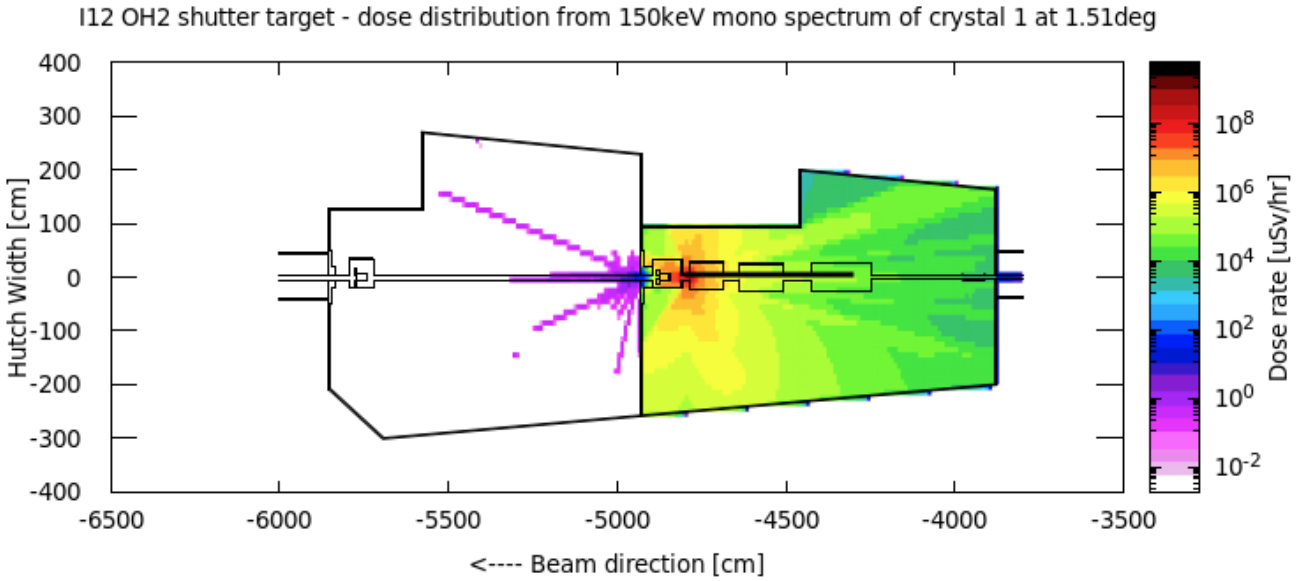
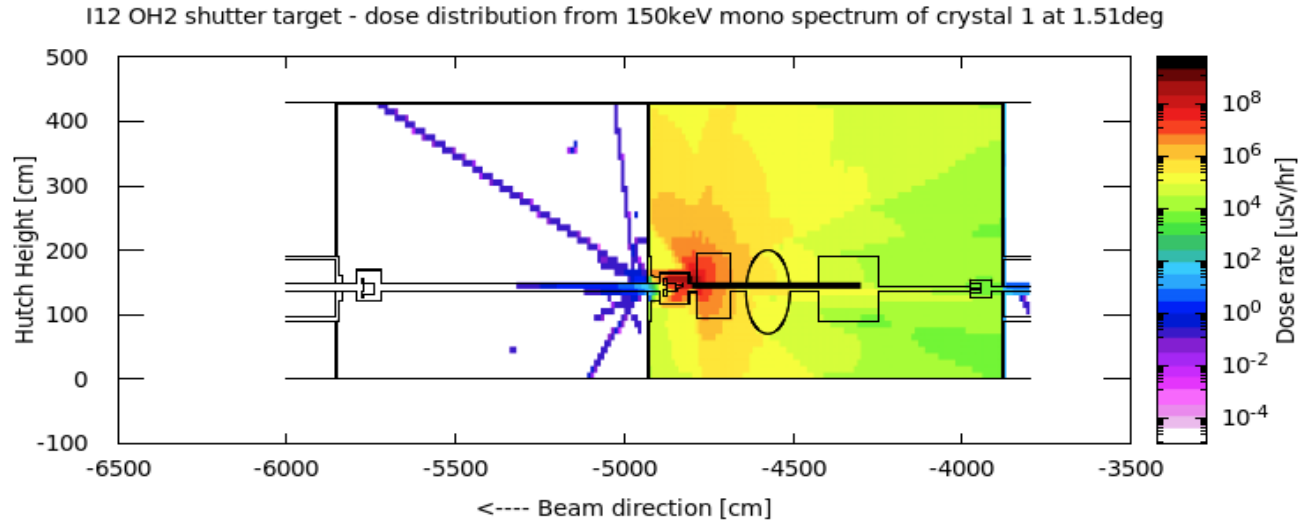
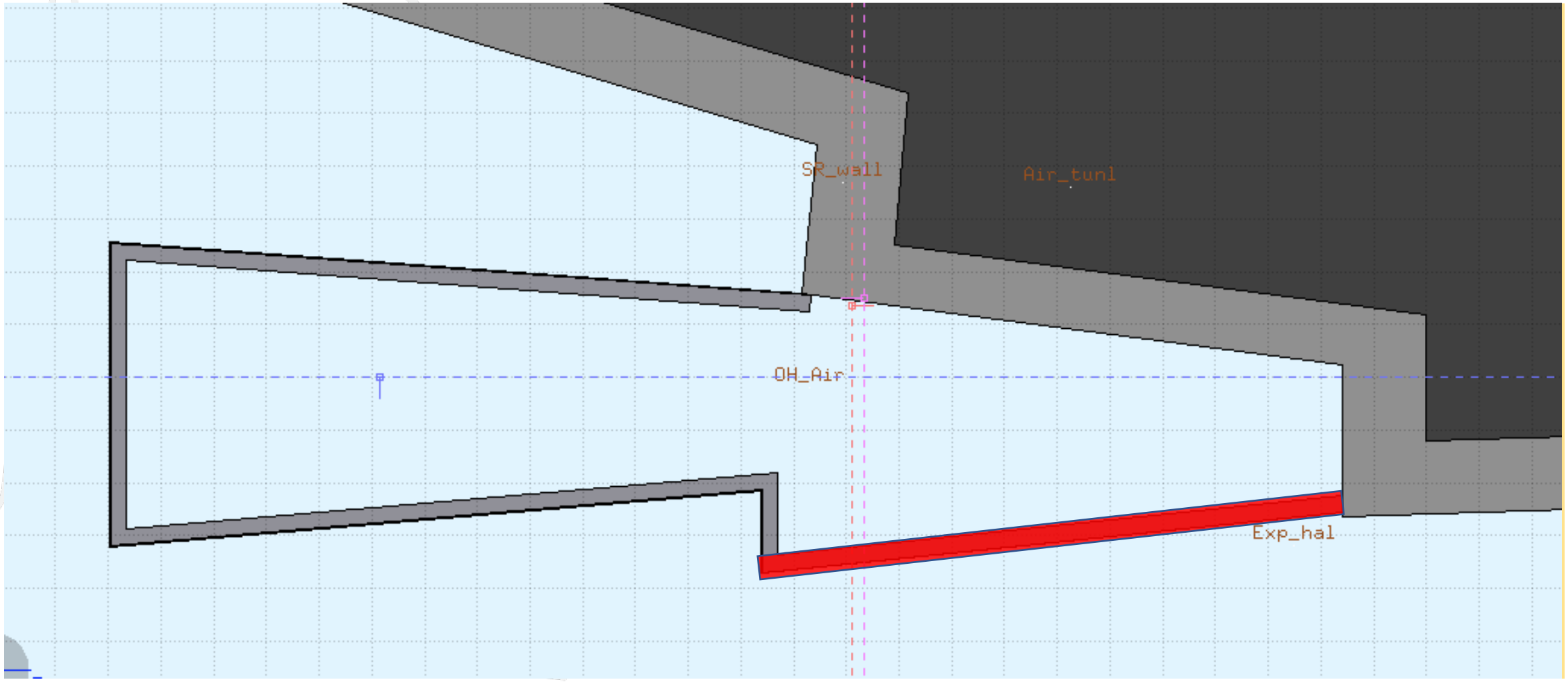


Fig 9: Leak from mono beam missteer (Side view)



I13 and I14

Fig 10: Layout of I13 and I14 optics hutches (Plan view)



Adding 1mm of lead to the whole area of the existing wall would have been difficult as there are pipes and other services that would need to be removed.

Initially we used FLUKA simulation to possibly narrow down where additional lead was needed, however the results show that dose rates outside the shielding are less than 0.5µSv/h.

Fig 11: (Plan view) SR dose rate contribution in I13 OH

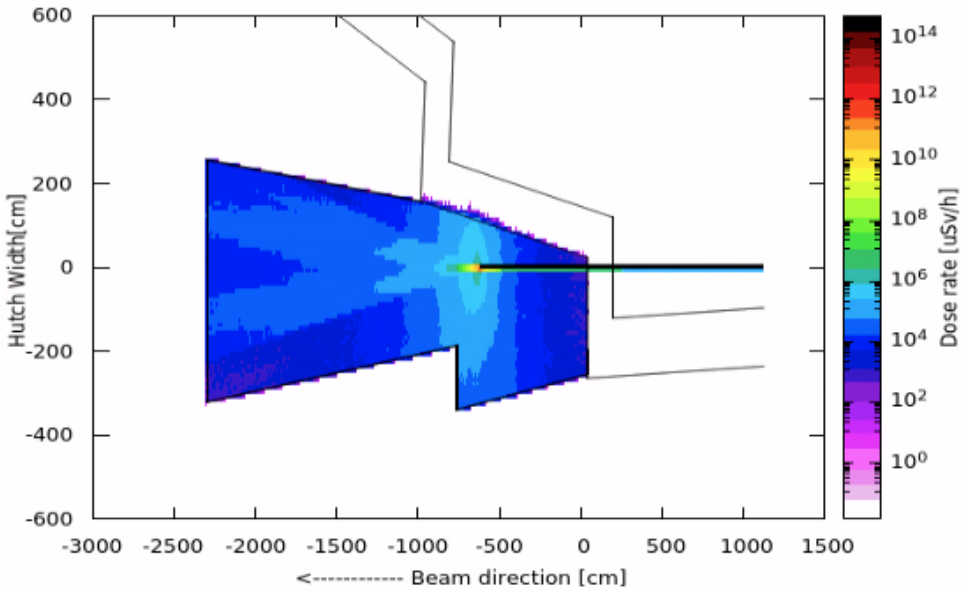
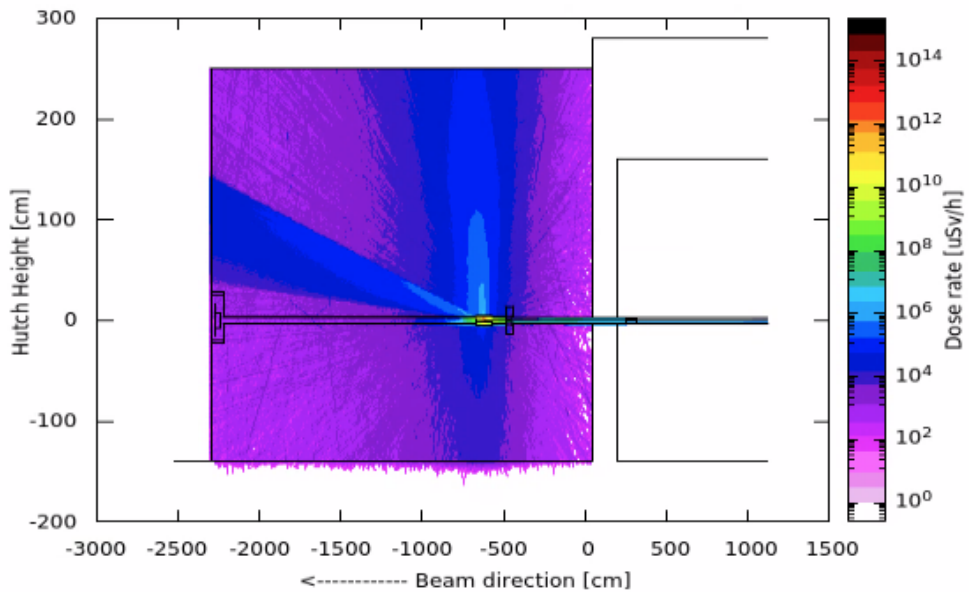


Fig 12: (Side view) SR dose rate contribution in I13 OH



I14

I14 had similar results to I13, dose rates outside the shielding below 0.5 µSv/h. However as we analysed the results we found some radiation leaking through the lateral wall, on further investigation we found this was groundshine, as there is no lead ‘skirt’ along this section of wall.

Fig 13: Radiation distribution at beam height (Plan view)

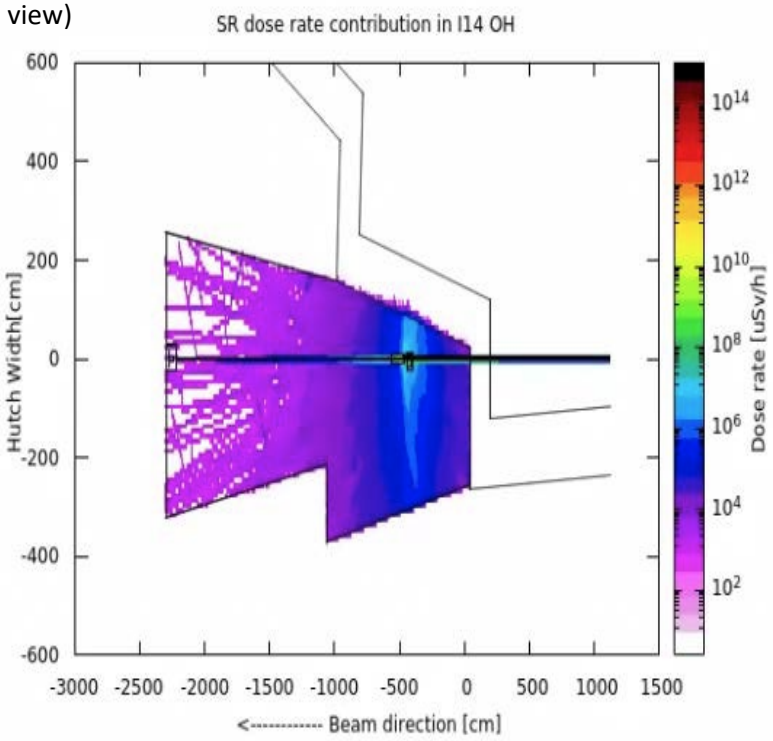


Fig 14: Radiation distribution at floor level (Plan view)

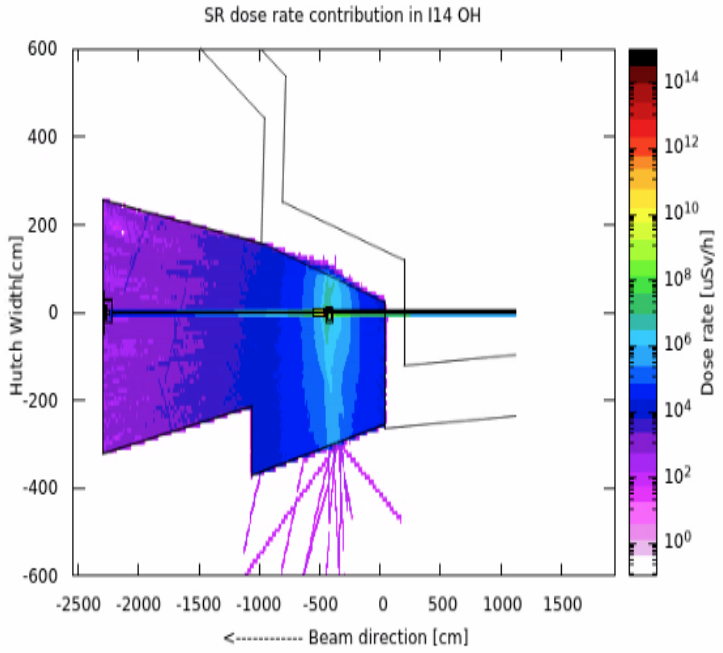
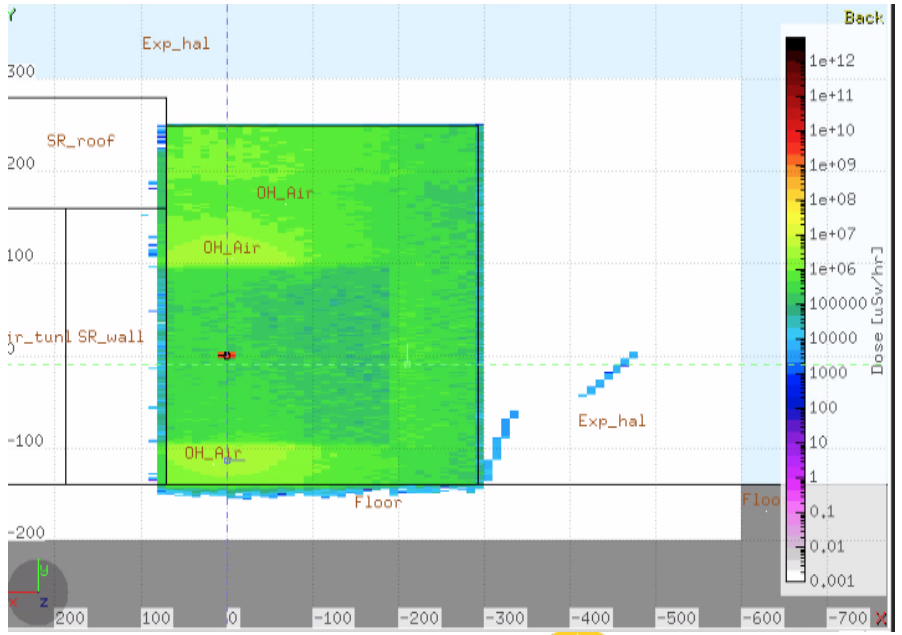


Fig 15: Groundshine looking upstream (end view)

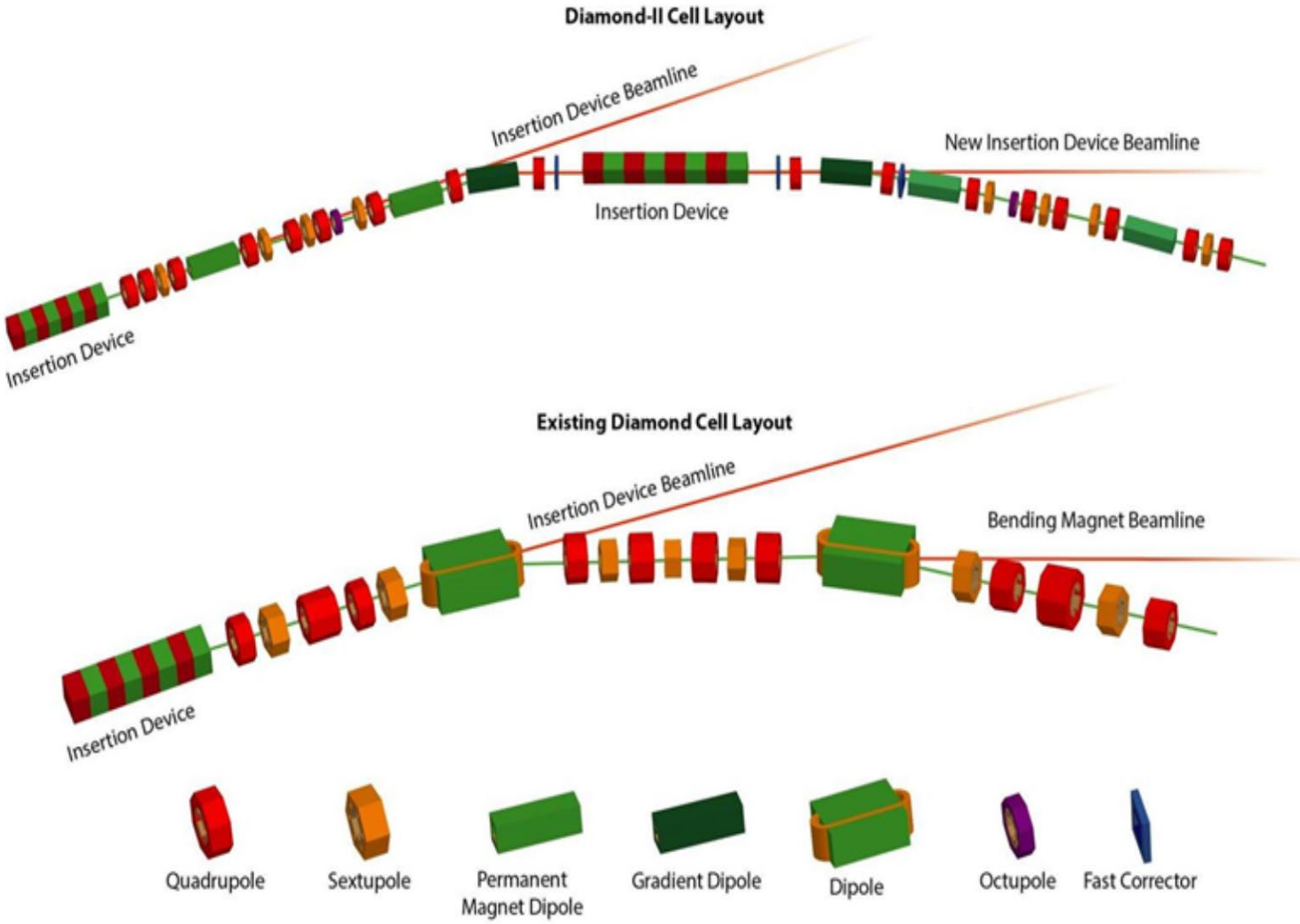


Impact of new ‘mid-straights’

This schematic shows the change from double bend to a six bend achromat. This change allows beamlines formerly receiving light from bending magnets to now have insertion devices on the new ‘mid-straights’.

Bending magnet beamlines were built with thinner shielding than the ID beamlines, However this new straight generates more gas bremsstrahlung, replacing or retrofitting all shielding is not financially viable so we are using FLUKA to assess where current shielding is sufficient and where additional shielding is needed.

Fig 16: Comparison of Diamond-II and Diamond lattice



B21, OH1

B21, High-throughput SAXS Beamline. The Optics hutch currently has the following shielding:
End wall, Side Wall and roof all 8mm Pb
Additional 25mm Pb on end wall, 1m^2 centred on beampipe
Experiments shutter 12 mm Tungsten Alloy

The following Shielding was added to the FLUKA model:
Front end: 3 custom apertures
End wall: 50mm Pb, 2m^2 centred on beampipe, 40 mm Pb 1m^2 centred on beampipe
Outboard perpendicular wall 25mm Pb full width 2m high from floor.
Experiments shutter increase to 65 mm Tungsten Alloy

Fig 17: (Plan view) K21 OH GB dose contribution

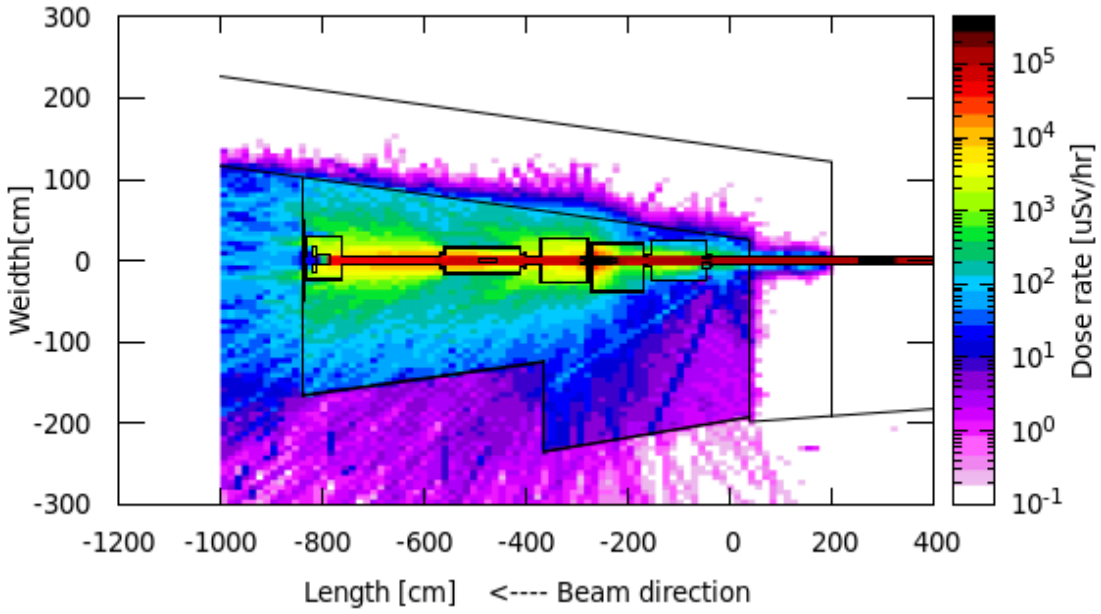
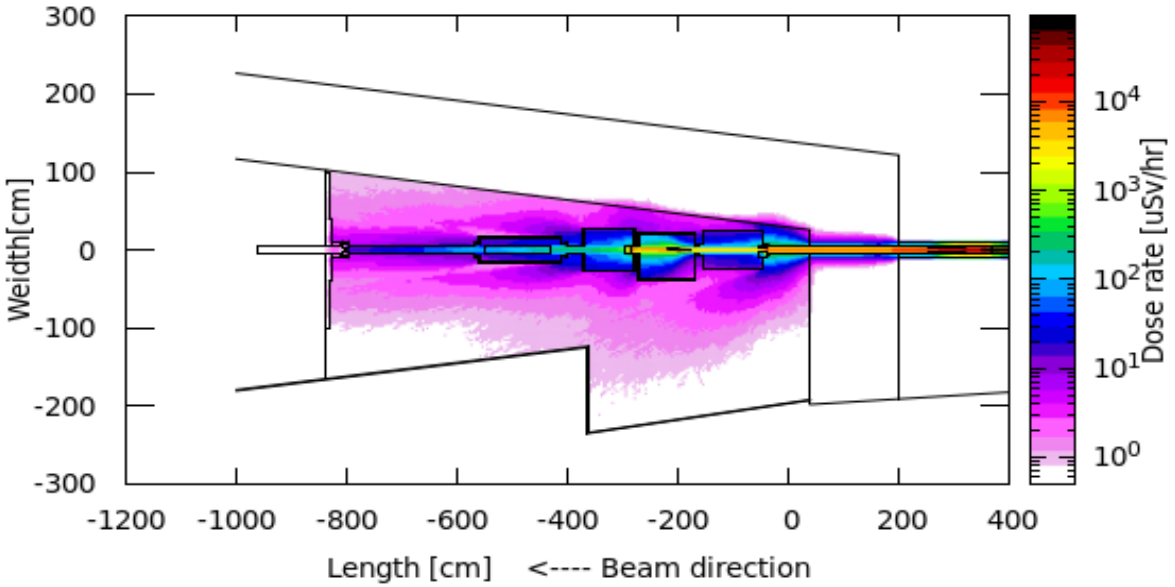


Fig 18: (Plan view) K21 OH GB dose contribution with recommended change



Special Thanks

I would like to say a special thank you to my colleague Sanjeev Faruk who spent many hours building the FLUKA models, running them and writing the reports.

Thank you

Any Questions ?