Target Beamline and “Ring 7” Simulations

KK presenting two aspects of Chandan’s work since the last collaboration meeting

MOLLER

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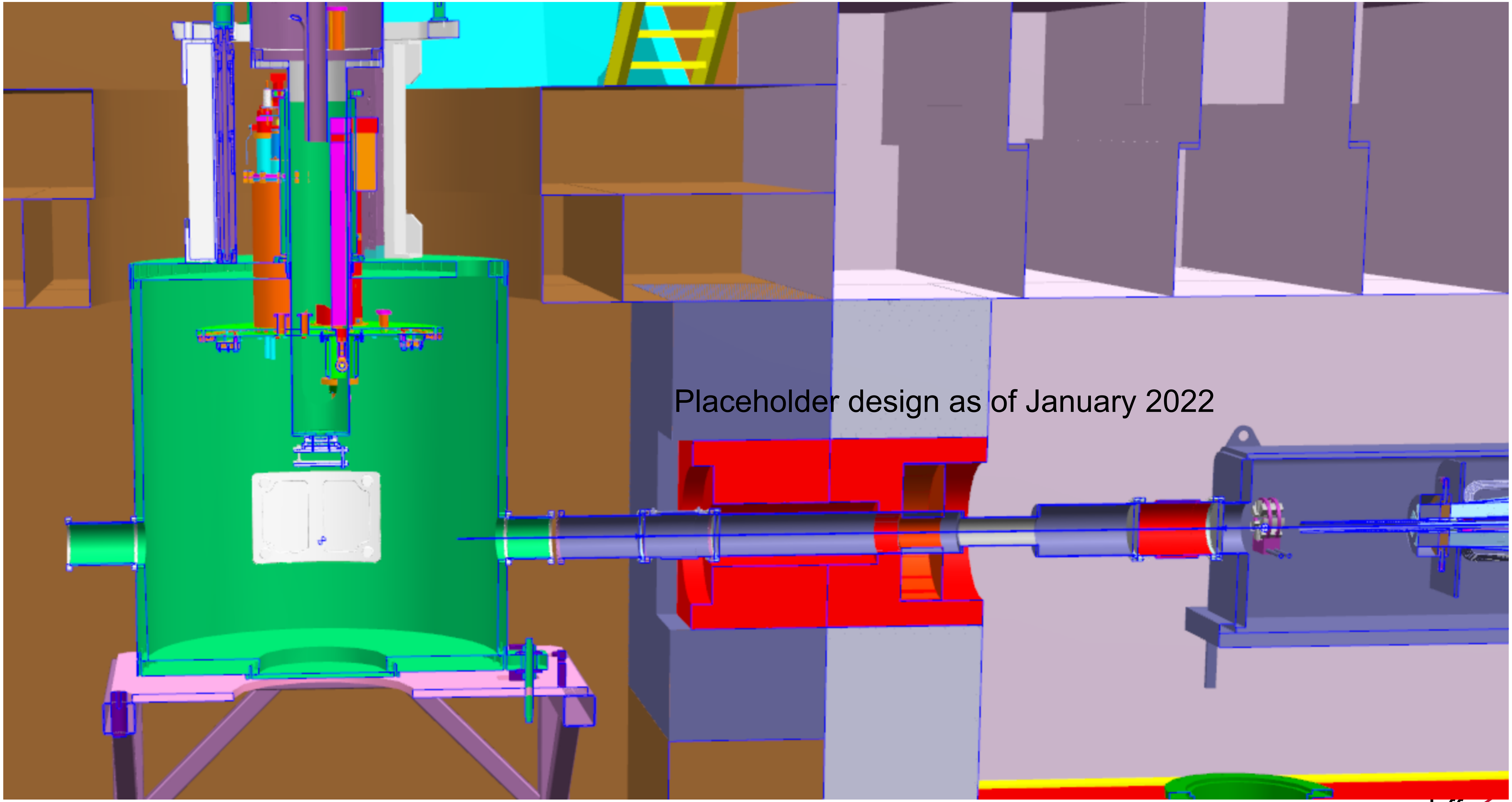
View of the beamline between target chamber and upstream torus chamber

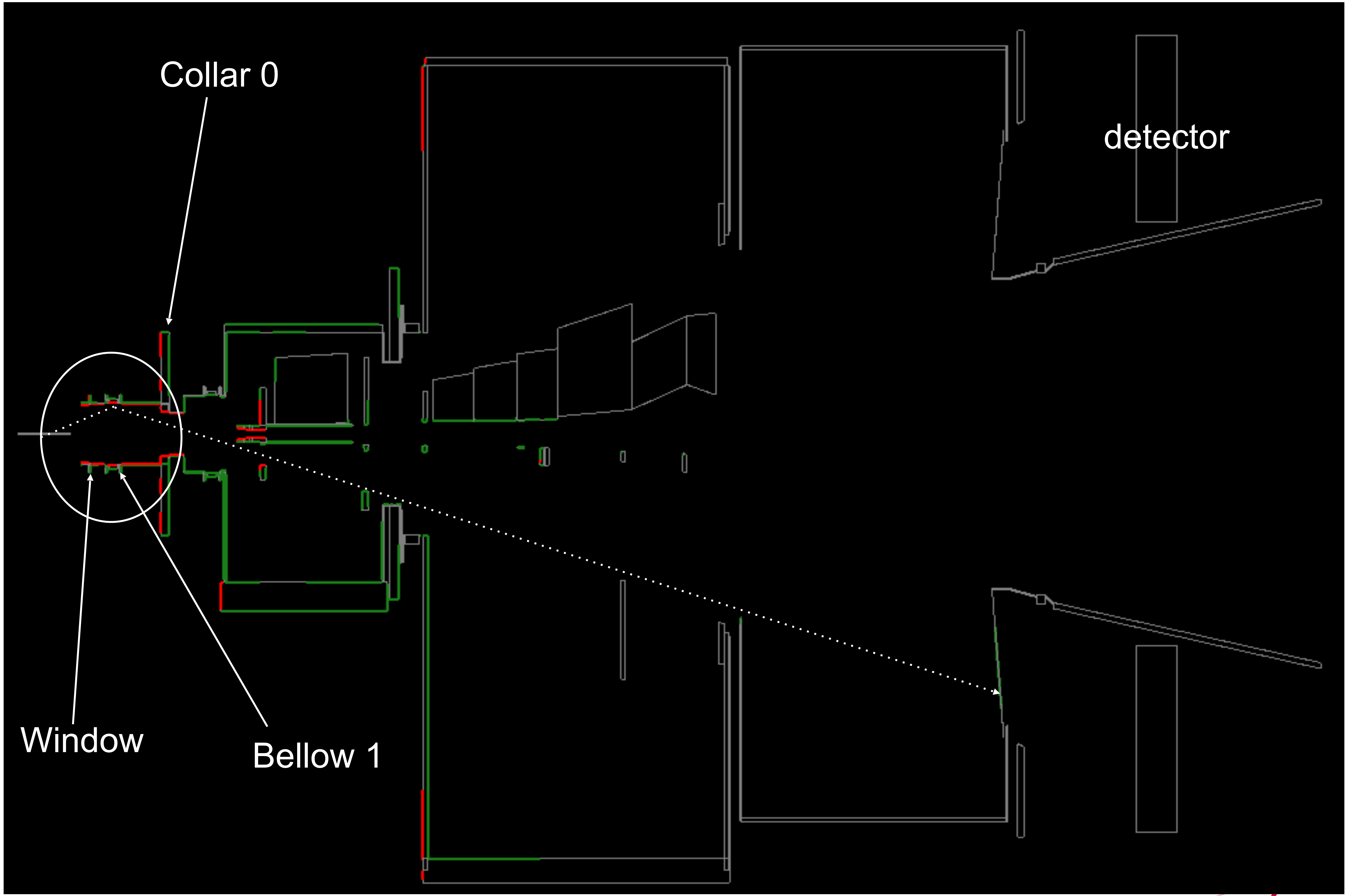


Importing upstream beam pipe from Dave Kashy's placeholder design

Red - direct line of sight to the target
Green - Sees one-bounce photon from the target

We have always known that the region upstream of collar 0 needs scrutiny (source of one-bounce photon to the detector window)

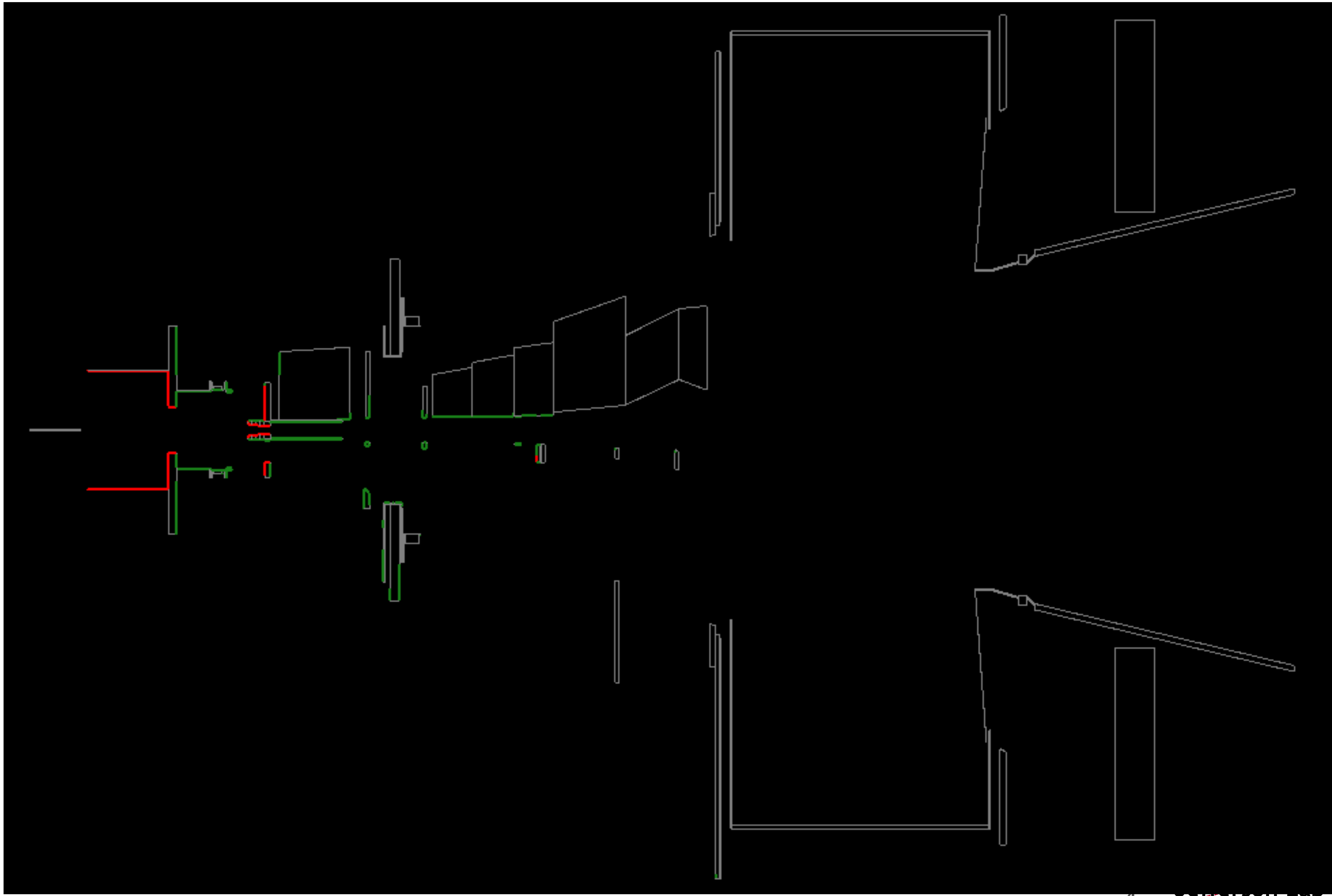
However, these are at fairly large angles (compared to serious 1-bounce sources like collimator 1)



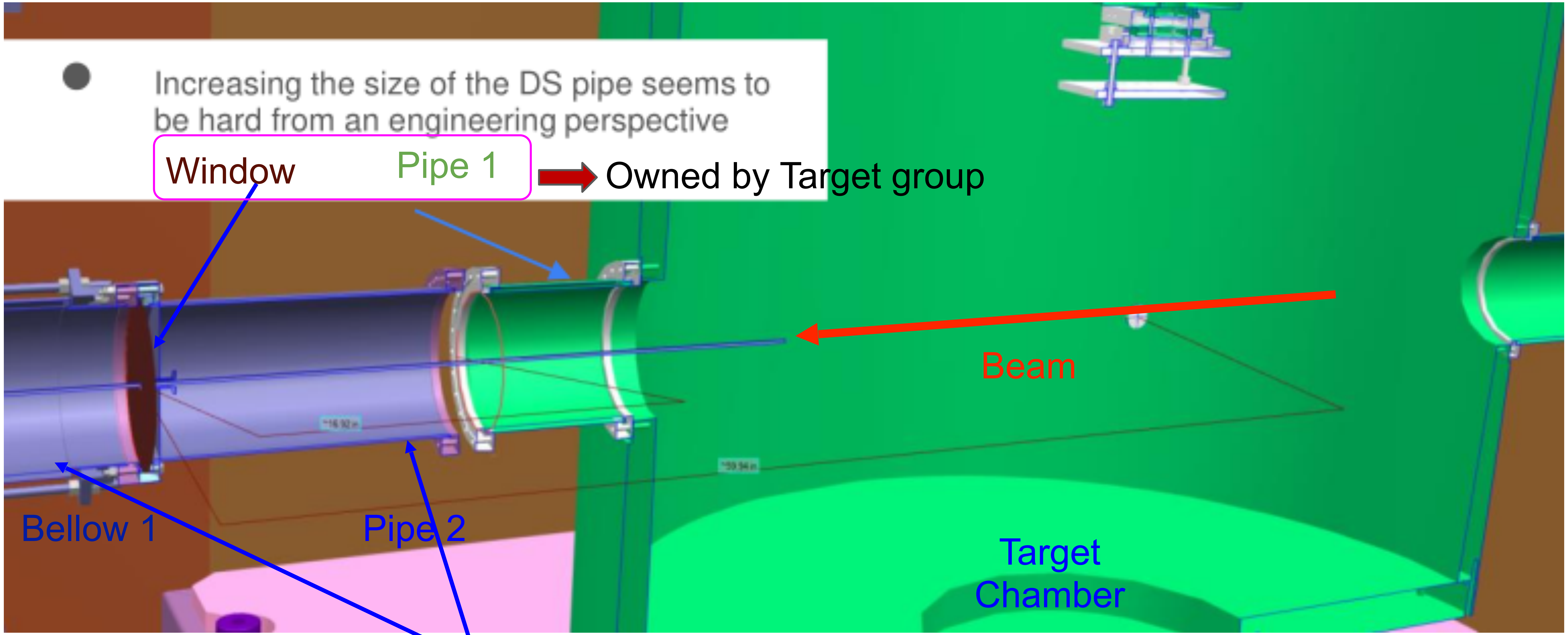
A clean setup would require an upstream beam pipe of IR=185 mm (roughly 15 inch diameter)

This is at the exit of the target chamber, so we had an exchange with Dave Meekins and he expressed serious concerns:

"Incorporating this request to the present design of target chamber would be very challenging" and needs serious physics justification



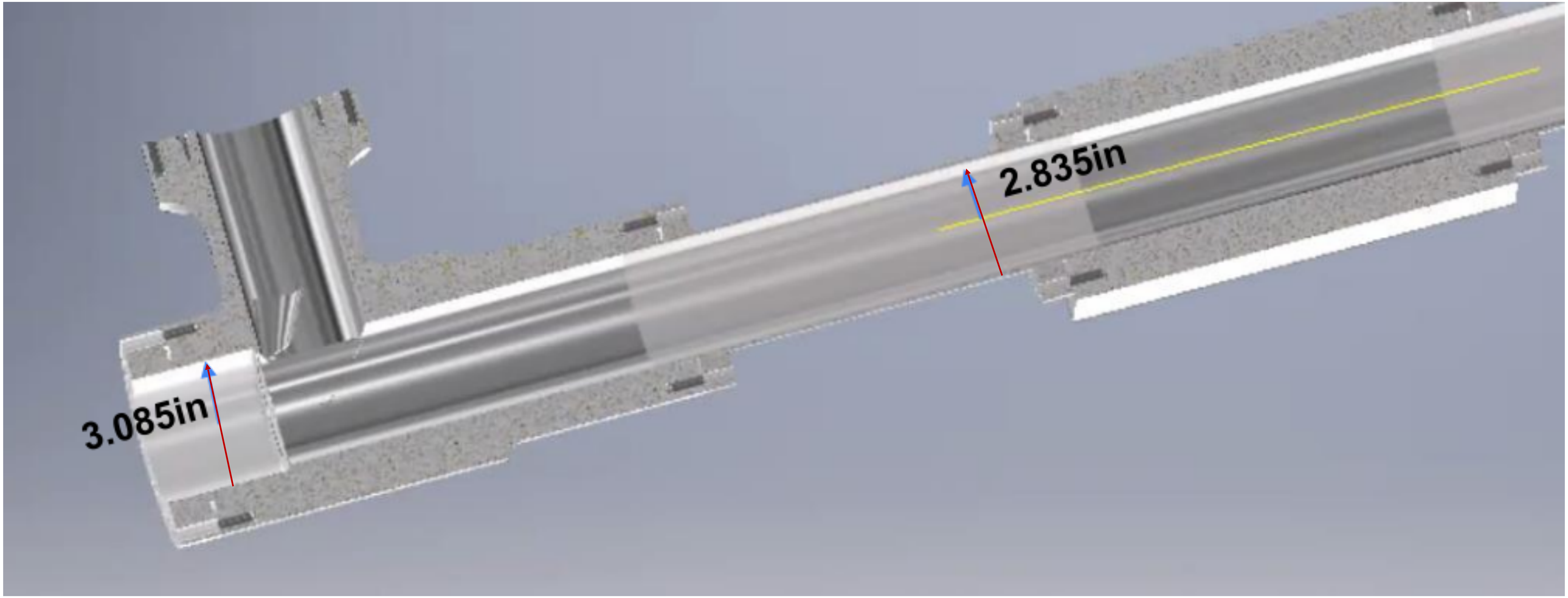
Discussion with Dave Meekins



Own by Spectrometer group

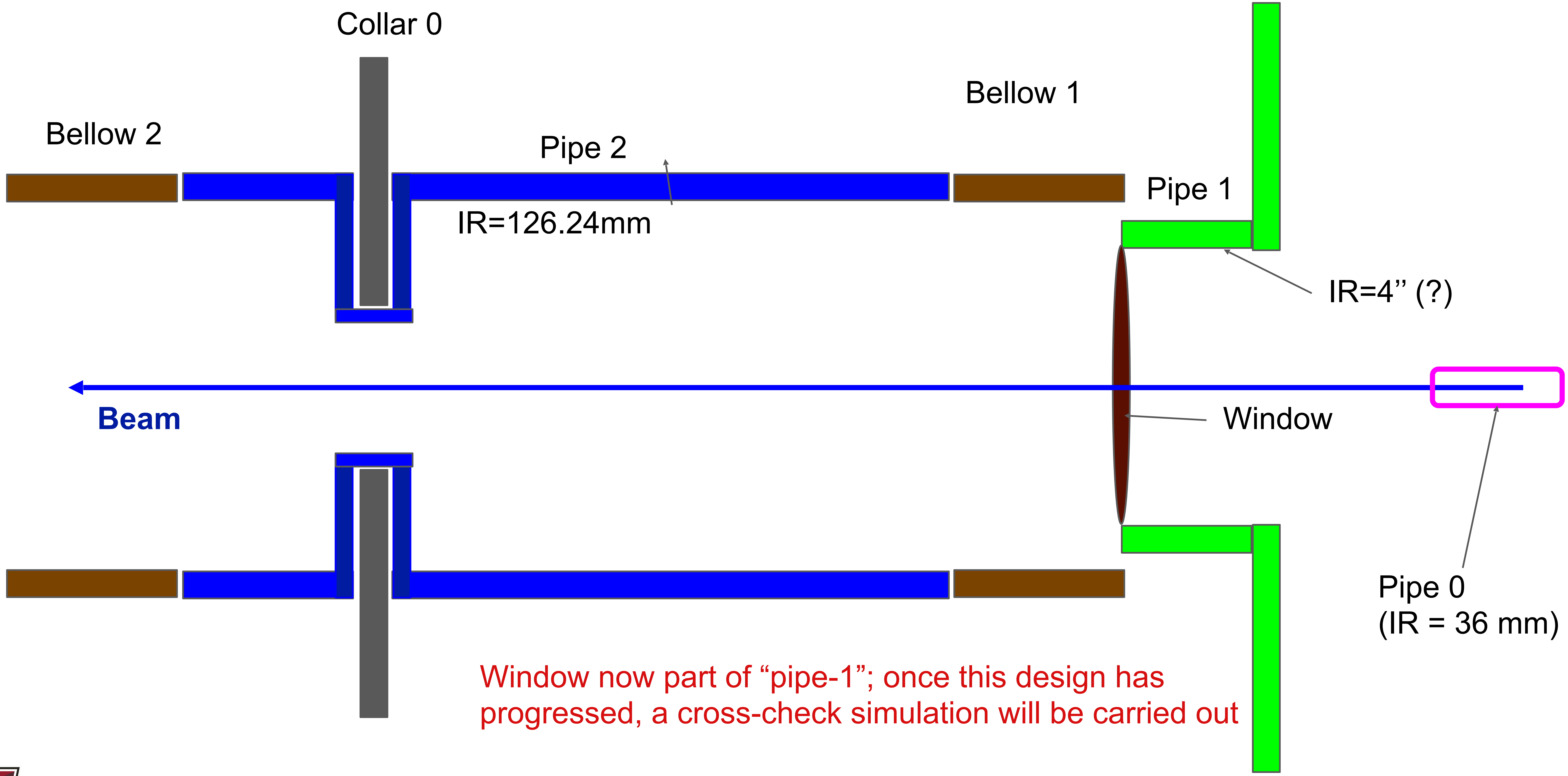
- In the above picture: Pipe 1 IR = 4'' (101.6 mm)
- The two-bounce code prediction for pipe 1 IR = 185 mm - Dave Meekins said it would be very challenging to adopt these changes (from engineering perspectives)

Additional source of one-bounce photon: Al-tube around the target Cell



The current target design has a tube of IR=72.009 mm - Would this tube be a significant one-bounce source?

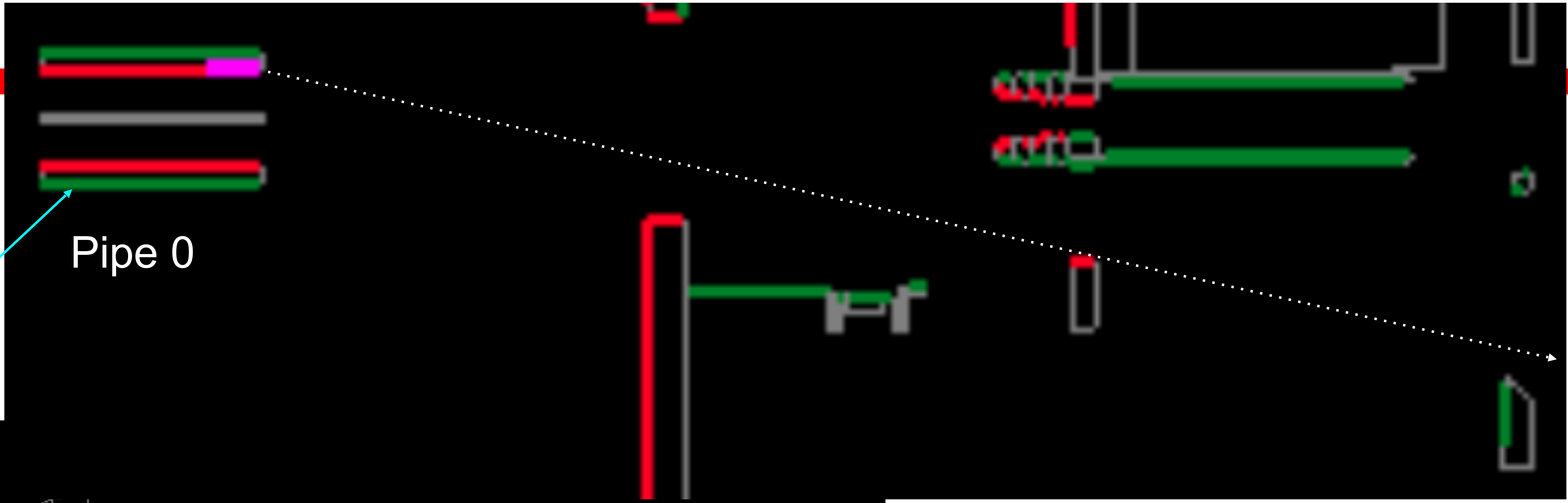
Proposed beam pipe near the target chamber exit: 8 inches at target exit going to 10 inches

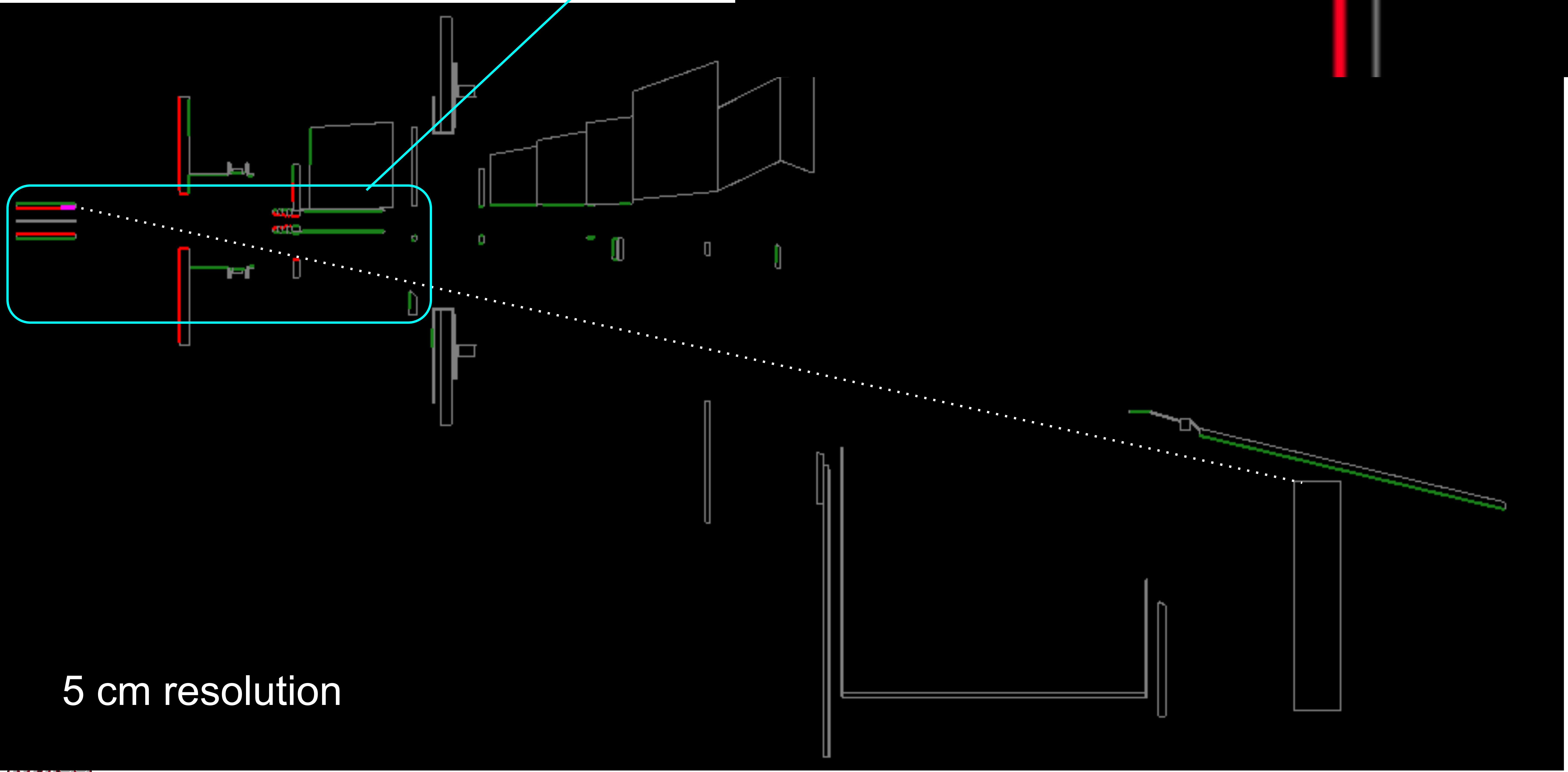


Window now part of "pipe-1"; once this design has progressed, a cross-check simulation will be carried out

Only Pipe 0 is enabled

Without detector window





Projection to the detector plane: OR of the green patch is 728.1 mm

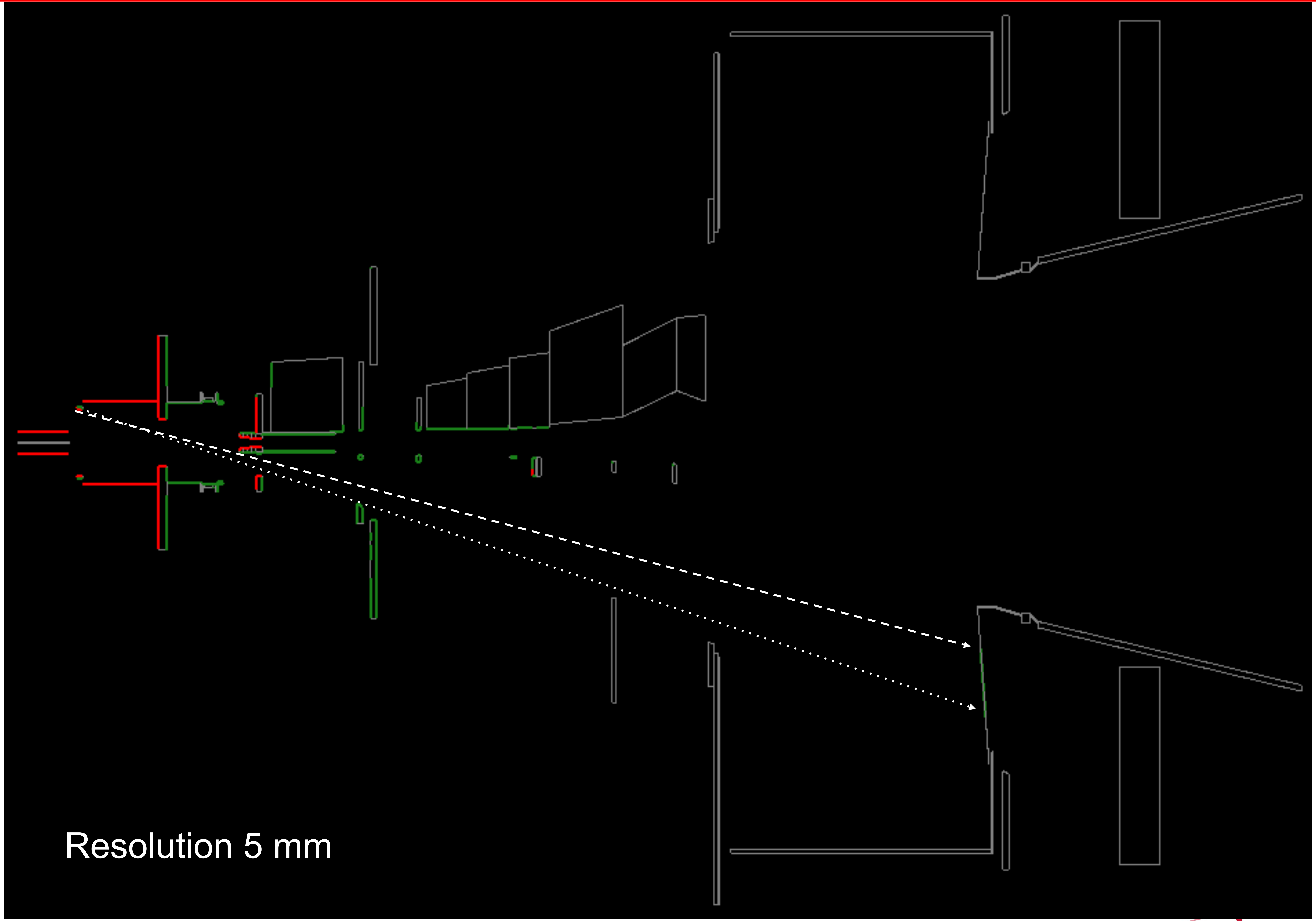
The main detector range
R1 (660-690); R2 (690-750);

So, Ring 1 and 2 would see one-bounce particles from the pipe 0.

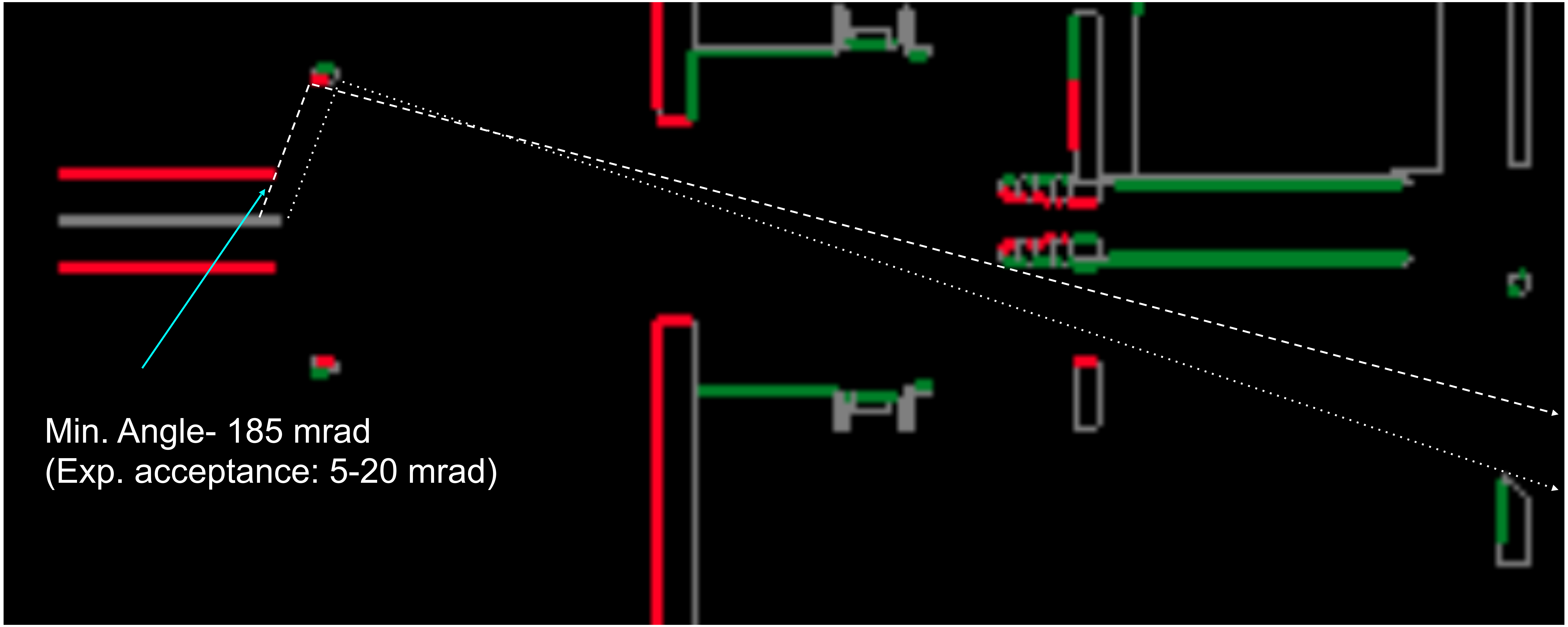
With pipe 1 and detector window

Only pipe 1 is enabled for one-bounce source.
Pipe 0 and (pipe 2+ bellow 1) are disabled

A section of the main detector sees the pipe 1



Zoomed version of previous slide



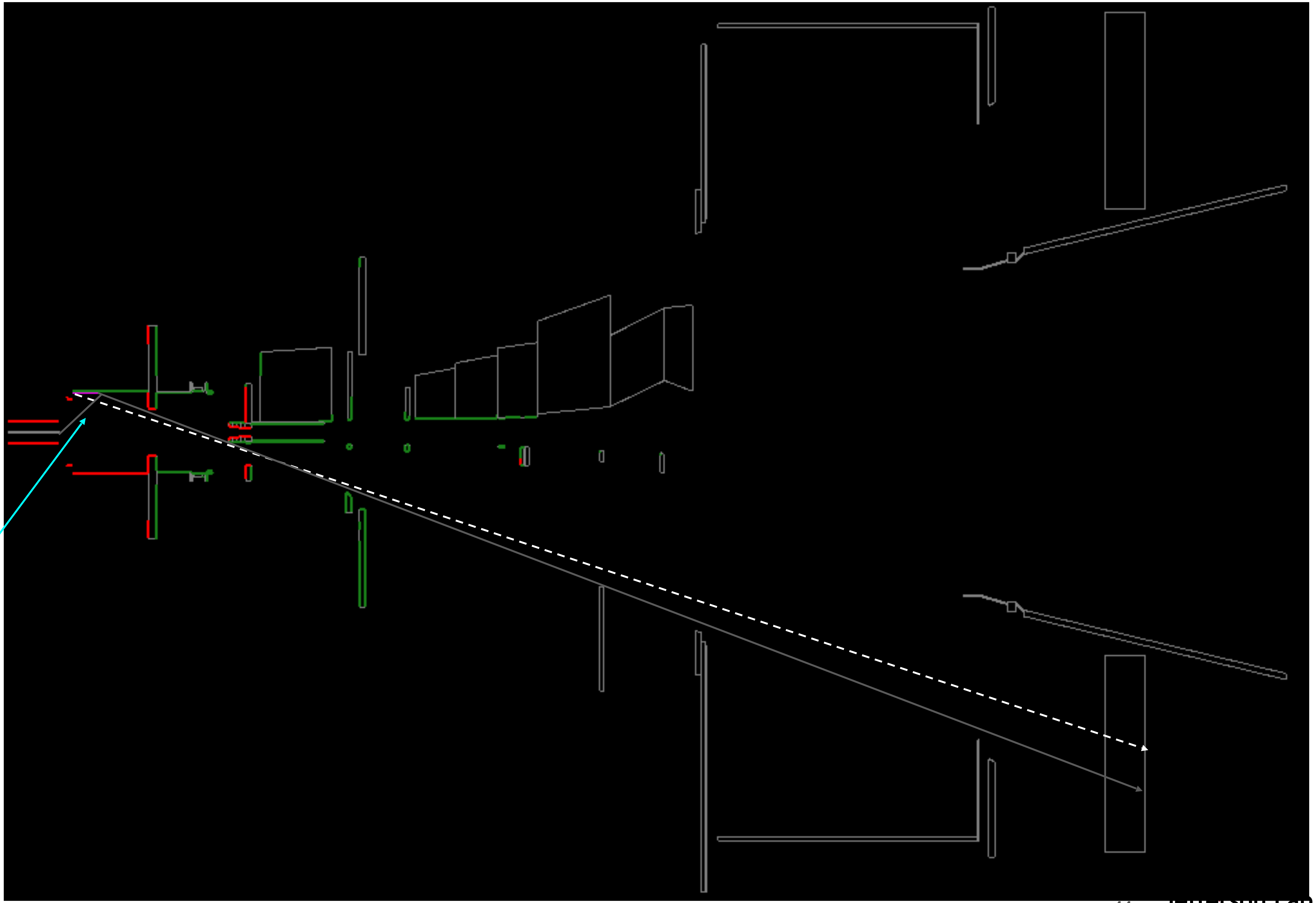
- At the detector ring (z=26.7 m), the radial range that can see the pipe 1 is 747.7 mm to 983 mm.
- The main detector range R1 (660-690); R2 (690-750); R3 (750-810); R4 (810-930); R5 (930-1070); R6 (1070-1170) (all in mm).
- Ring 2, 3, 4, & 5 will see one-bounce source from the pipe 1 (4'' long after the target chamber).

Full pipe with 2 mm resolution without detector window

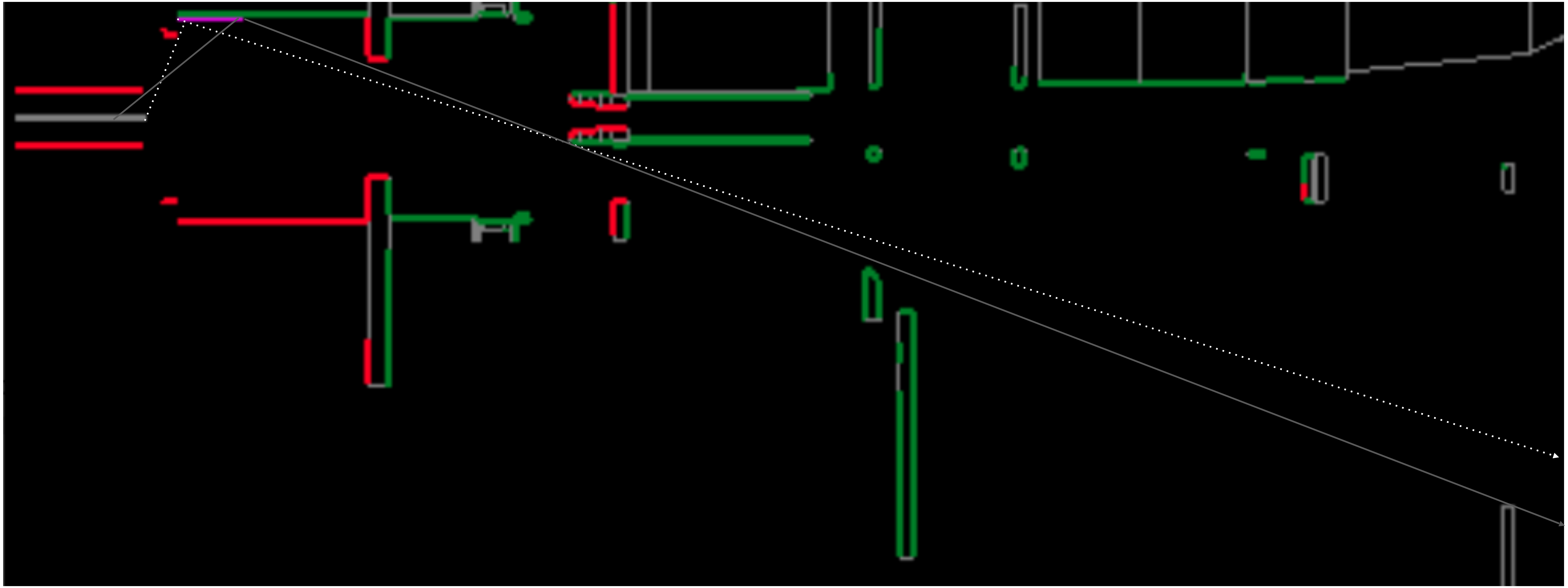
Pipe 2 IR = 126.24 mm
Z(US) = 977.9 mm from target center
Z(DS) = 2851 mm

Adjusted hybrid wall and removed the upstream end of the drift pipe

Scattering angle ~ 125 mrad
-very large angle scattered particles - may be benign
Our accepted scattering angle (5-20 mrad)



Full pipe with 2 mm resolution - zoomed

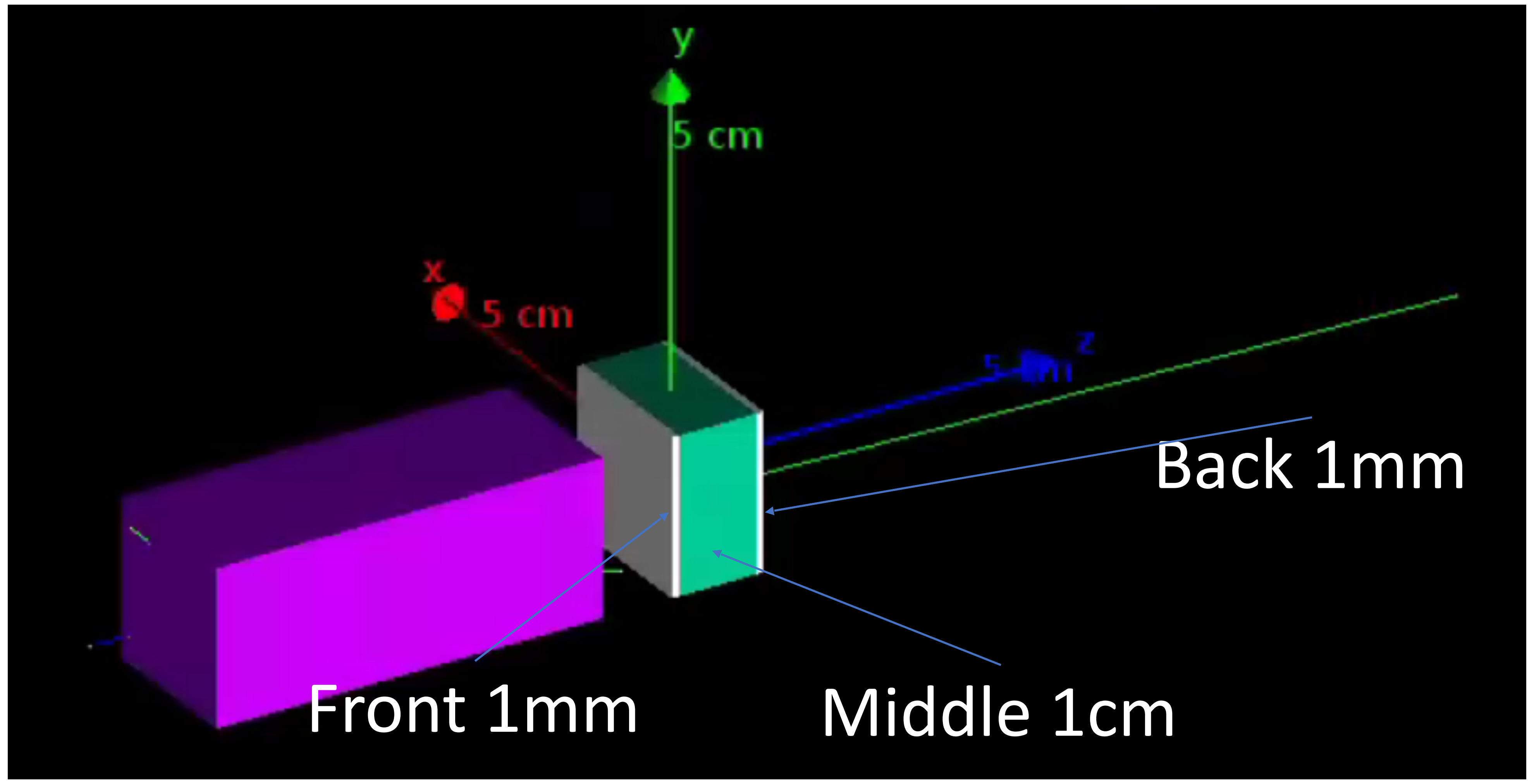


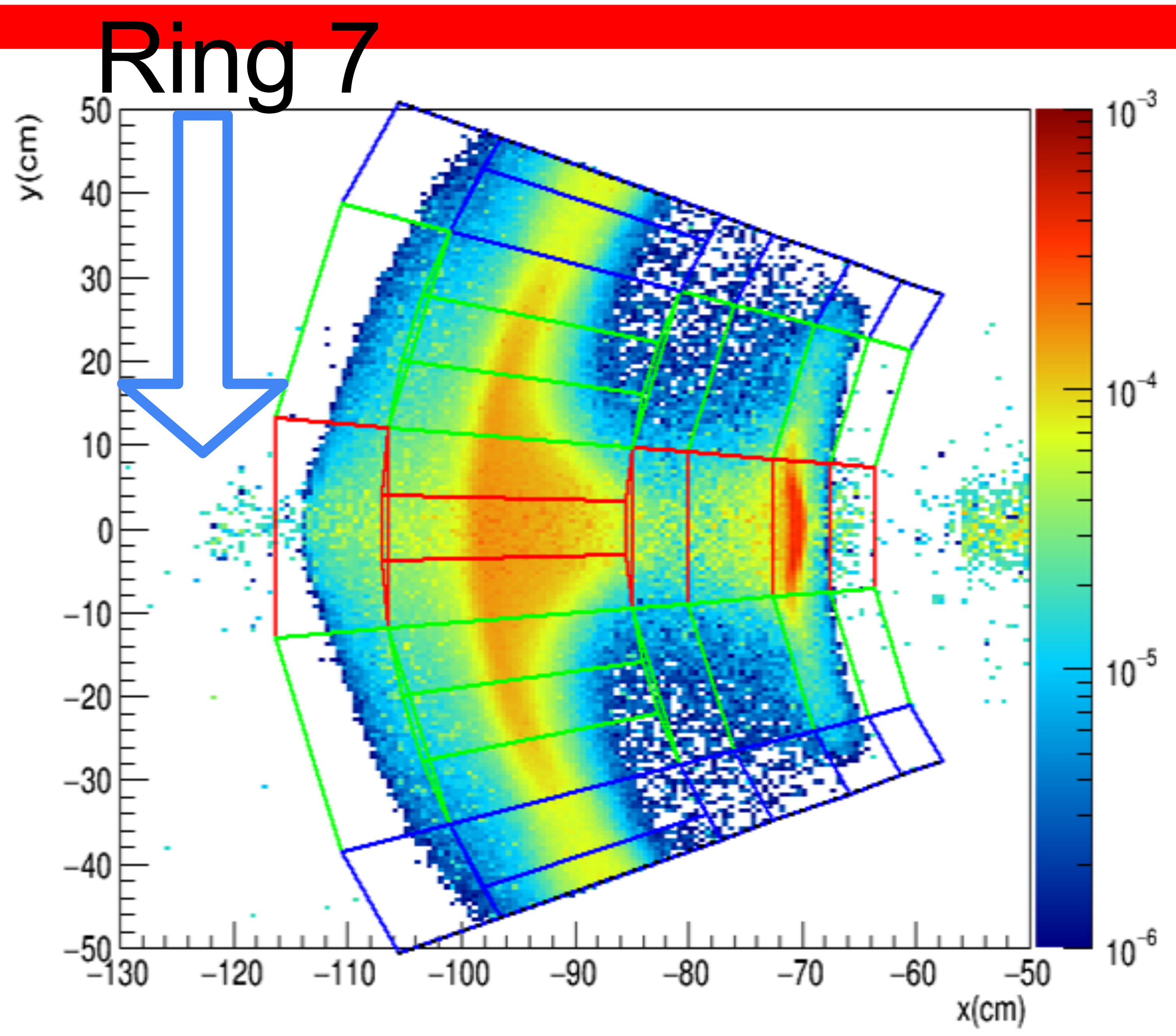
- The projected radial range at the main detector plane (z=26700mm) is: 915 - 1086 mm.
- The main detector range: R1 (660-690); R2 (690-750); R3 (750-810); R4 (810-930); R5 (930-1070); R6 (1070-1170) (all in mm)
- R4 to R6 will see the one-bounce sources from (pipe 2+bellow 1) region.

Summary on target to upstream torus 2-bounce study

- A new design of upstream region beam pipe has been checked with the two-bounce code.
- Ring 1–2 would see one-bounce particles from the pipe 0.
- Ring 2–5 would see one-bounce particles from the pipe 1.
- Ring 4–6 would see one-bounce particles from (pipe2+bellow1) region.
- In the above cases: one-bounce particles are be generated by LARGE-angle-scattered particles from the target. We dont think this is a problem for beam-halo induced helicity correlations.
- Ultimately, a full simulation of the photon backgrounds will be carried out with final beam pipe and beam window designs but it is not expected to add significantly to the photon background budget at the main detector rings

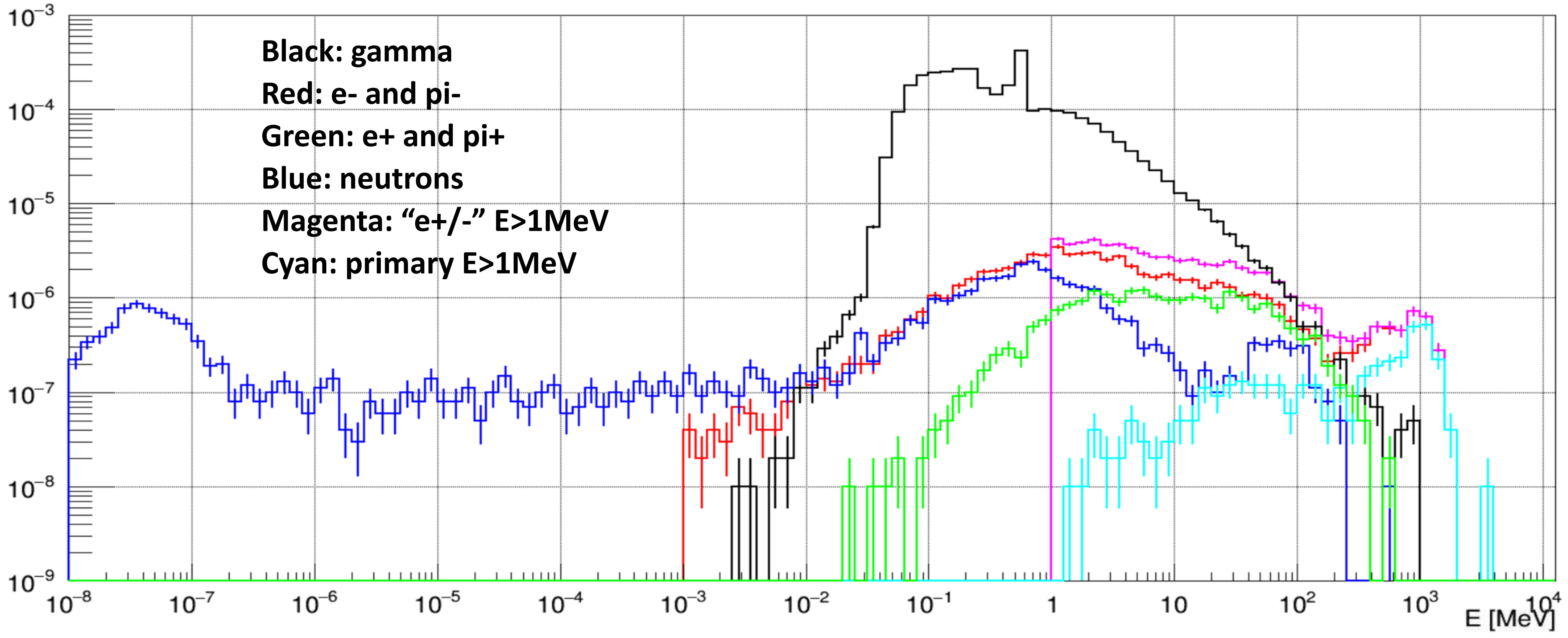
"Ring 7" Radiation Load: Estimate from summer 2020 by Ciprian





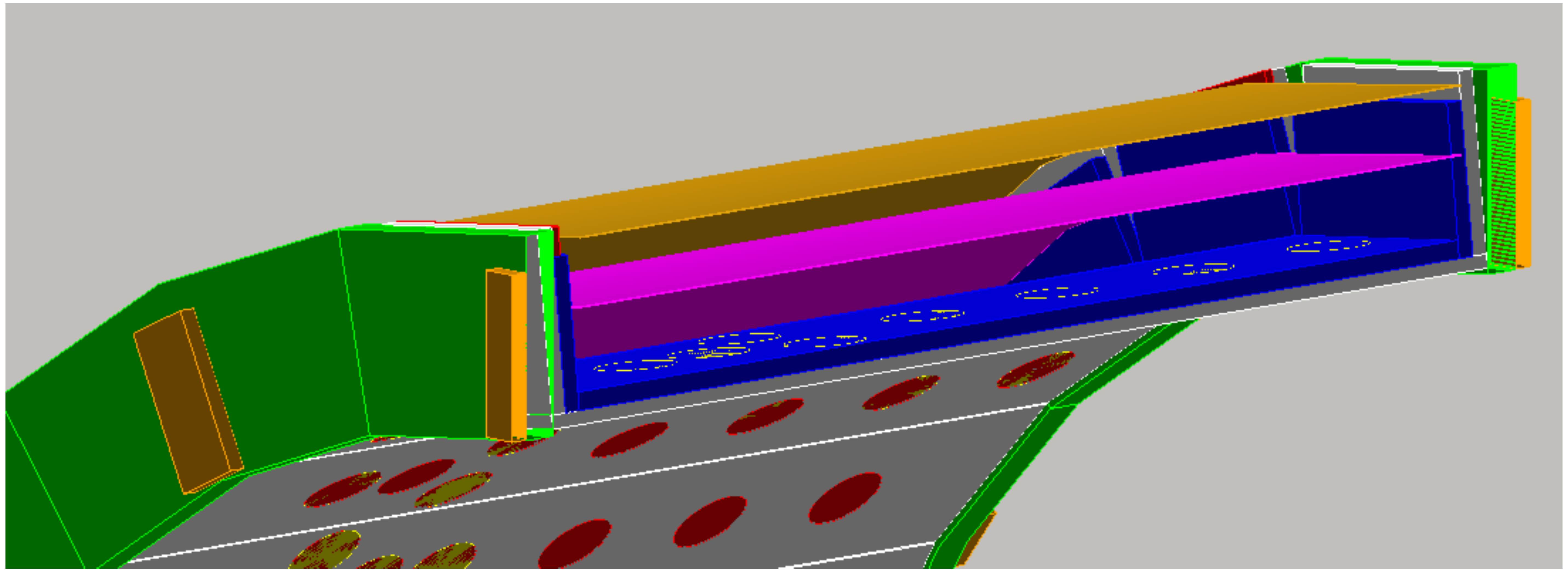
- *•No shielding: ~ 900 kRad —> motivated the lead shield for holding structure*
- *•With 5 cm of Pb: 60 kRad; this is the conceptual design at the time of the CD-1 review*

- Simple simulation setup
  - We use SiO2 as a material
  - Run with and without a 5cm Pb shield
  - Shoot gammas, electrons, positrons based on kinetic energy distributions at Ring 7
  - Score energy deposition (divided by mass)

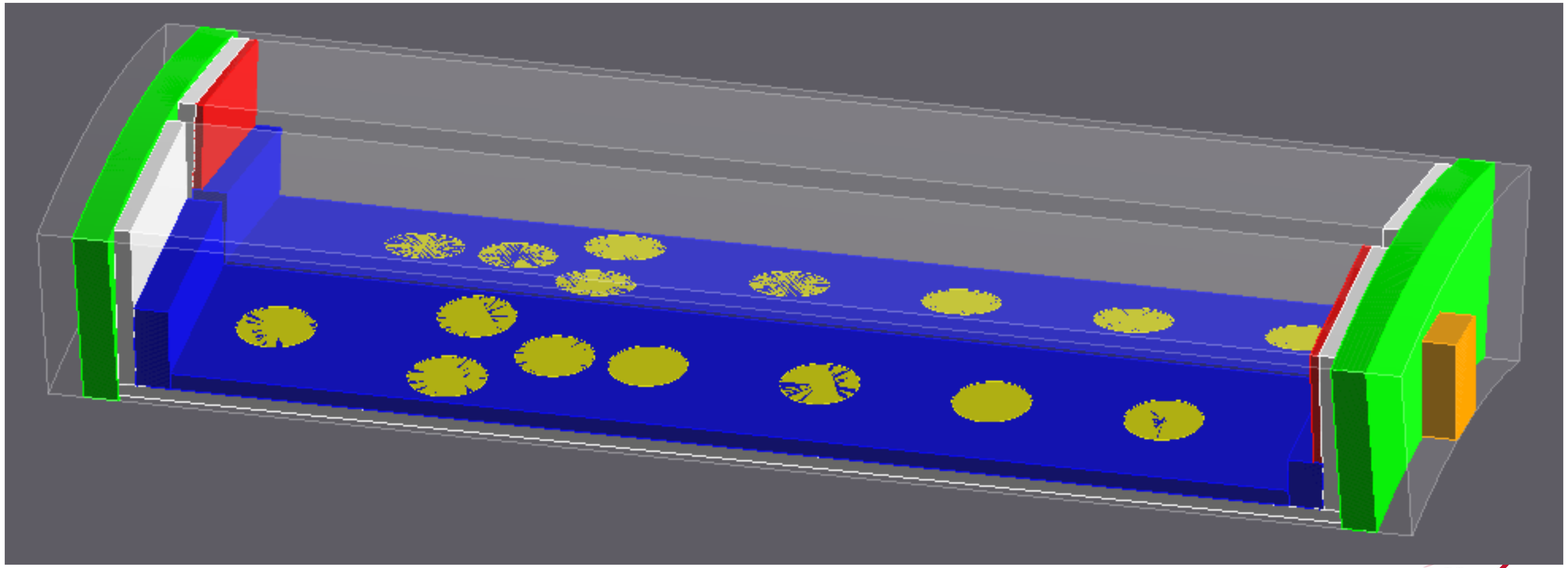


Simulations with the existing detector Shielding & support structure

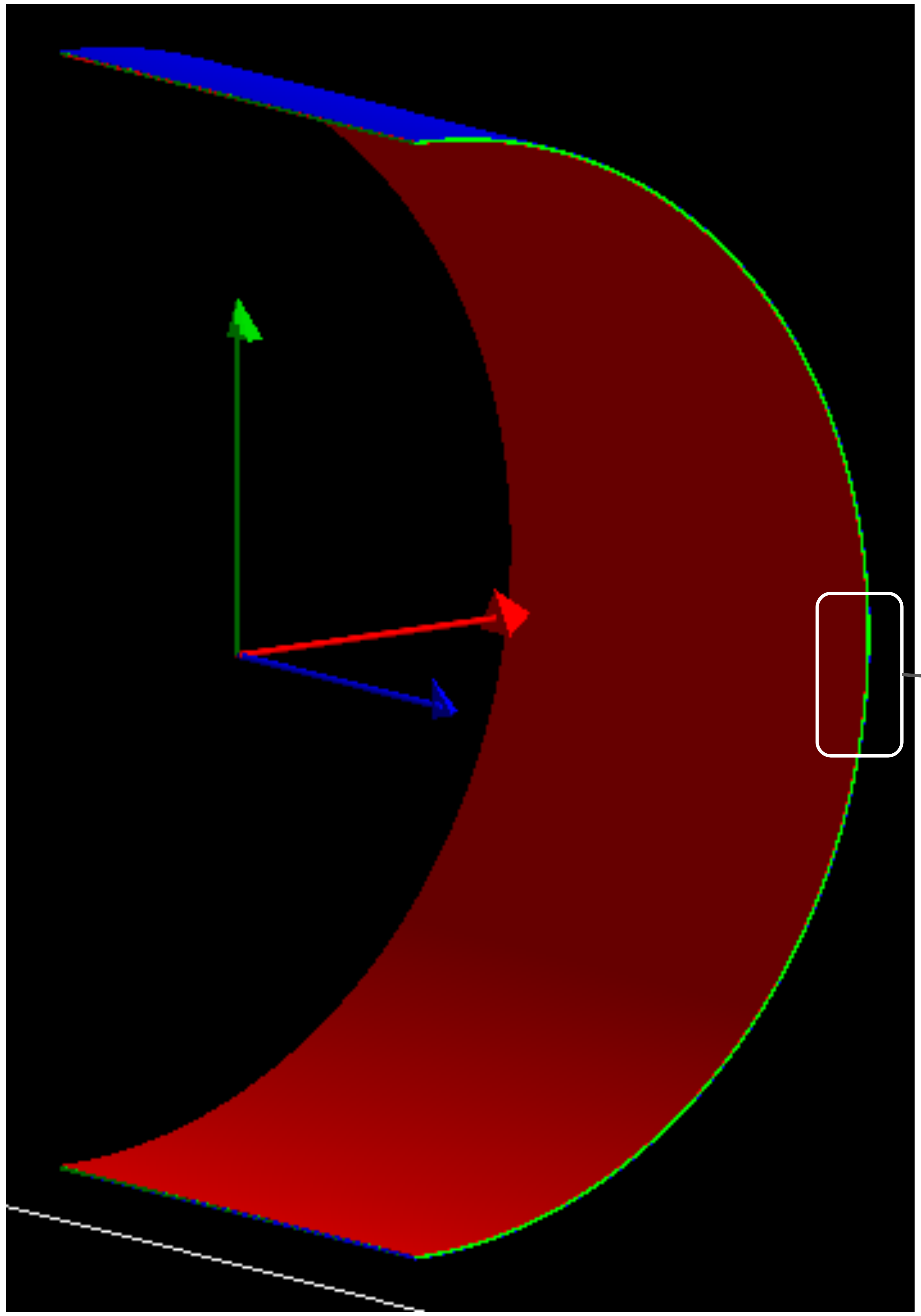
•Early in engineering design with Bartoszek: 5 cm of Pb was making the the detector structure very large with just Aluminum
•Executive decision: 2.5 cm barrel shield should do the job, endcap “lips” kept at 5 cm

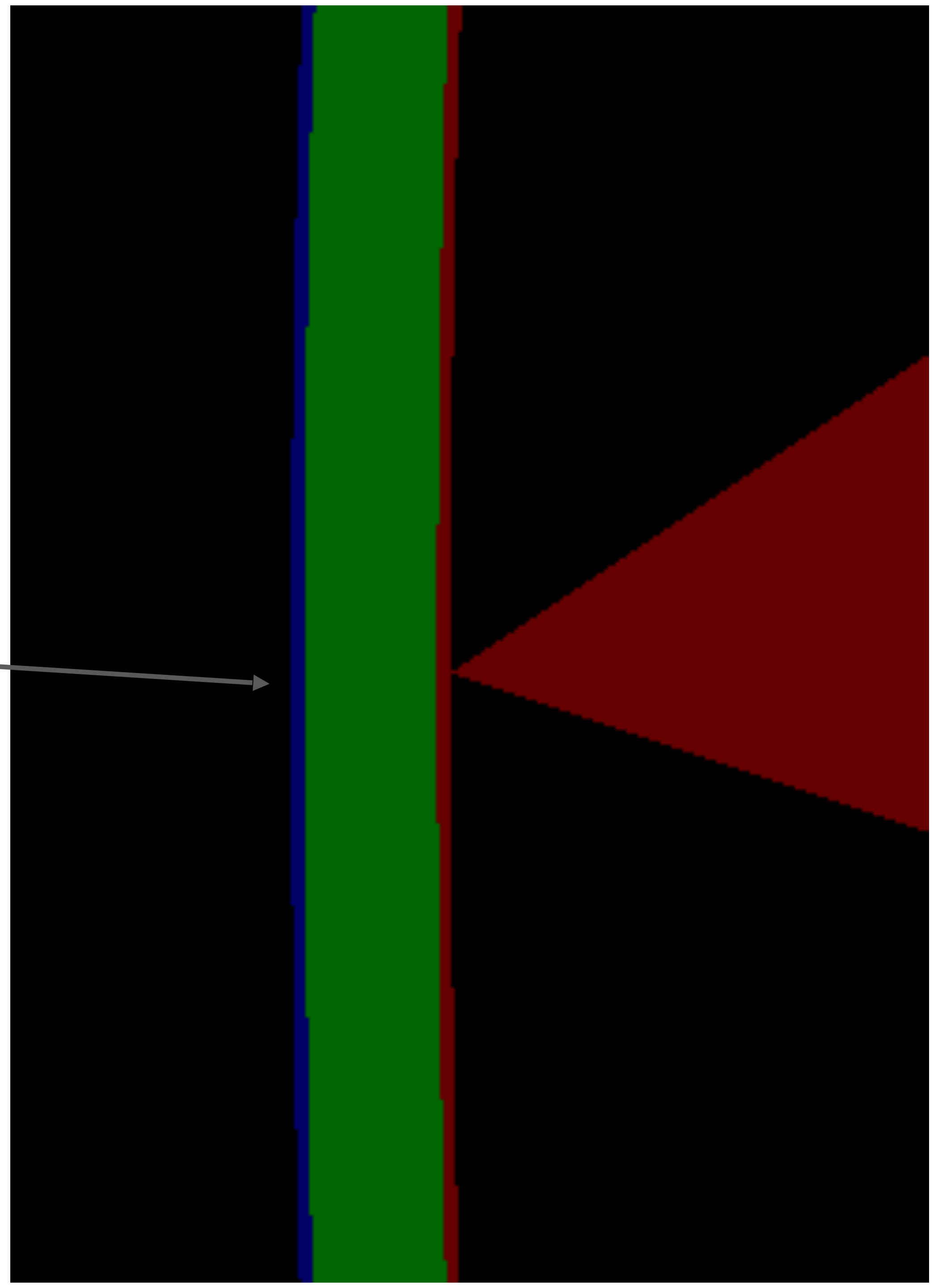


- Used beam generators for primary simulations and scored particles on PreAmp1 (r=1542 mm) and PreAmp2 (r=1602 mm) detectors
- Simulations were performed with and without the detector shielding and support structure



Secondary simulations for radiation dose on PreAmp1 & 2





Unshielded

Similar to what was done before: take the scored particles and then have 3 layers: 1-10-1 mm

Radiation dose on PreAmp1 & 2

SiO2 placement (radially)	PreAmp 1 (r=1542-1554 mm)		PreAmp 2 (r=1602-1614 mm)	
	*Total Energy deposition (MeV) [bare (with the existing shielding)]	Dose (krad) [bare (with the existing shielding)]	*Total Energy deposition (MeV) [bare (with the existing shielding)]	Dose (krad) [bare (with the existing shielding)]
Front 1 mm	2.93e18 (4.06e17)	1294 (180)	2.82e18 (4.30e17)	1197 (183)
Middle 10 mm	1.37e19 (1.71e18)	602 (75)	1.32e19 (1.91e18)	561 (81)
Back 1 mm	8.89e17 (1.24e17)	390 (55)	8.65e17 (1.43e17)	365 (61)

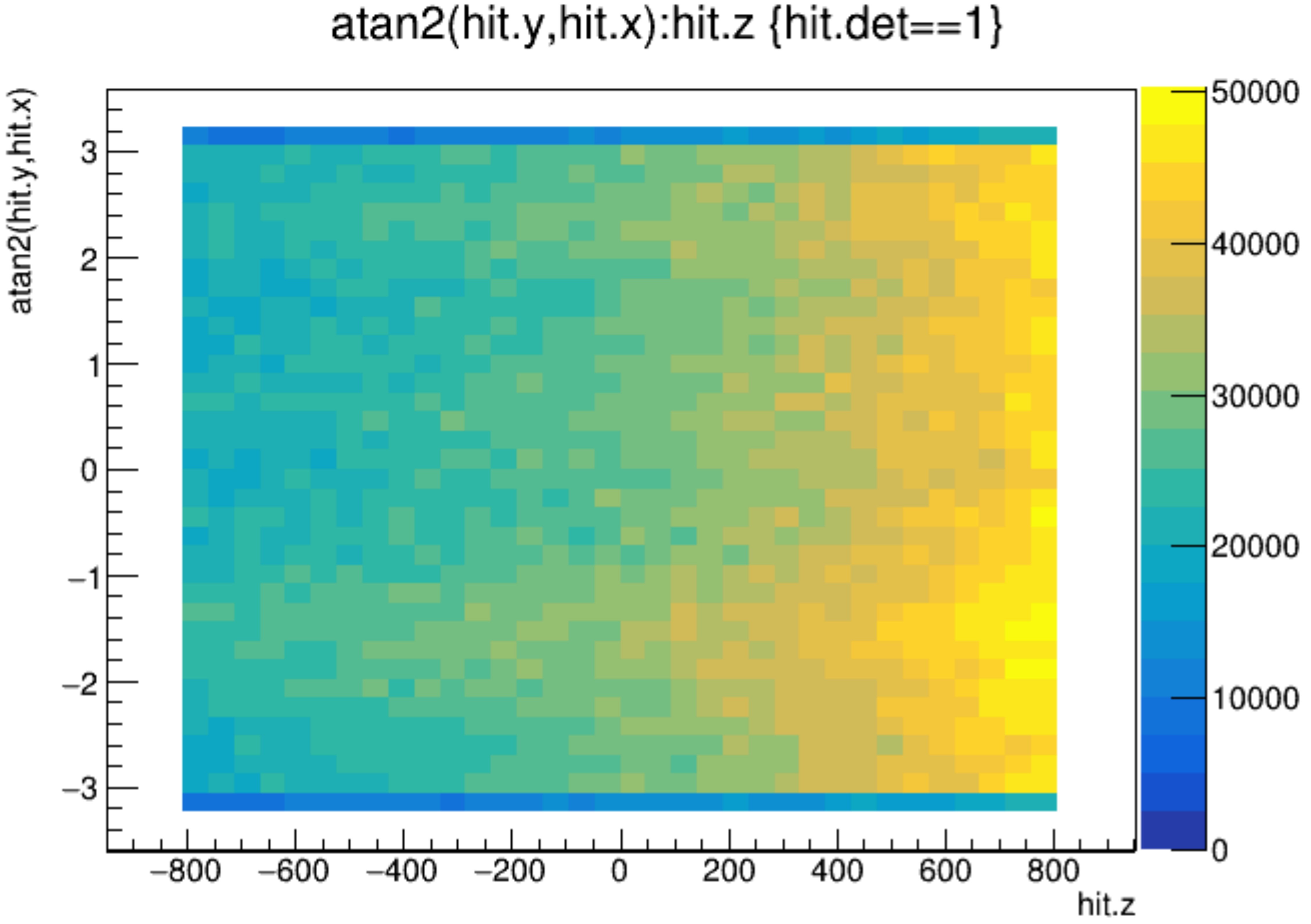
- These numbers are without quartz, light guide and PMT assembly - there are holes on the Pb plates
- Does the presence of those elements increase of decrease radiation load to the preAmps?
- If 1 mm thick SiO2 can stop low-energy particles, then those elements too would work as shielding

*With 70uA 344 days, SiO2 density = 2.32 g/cc

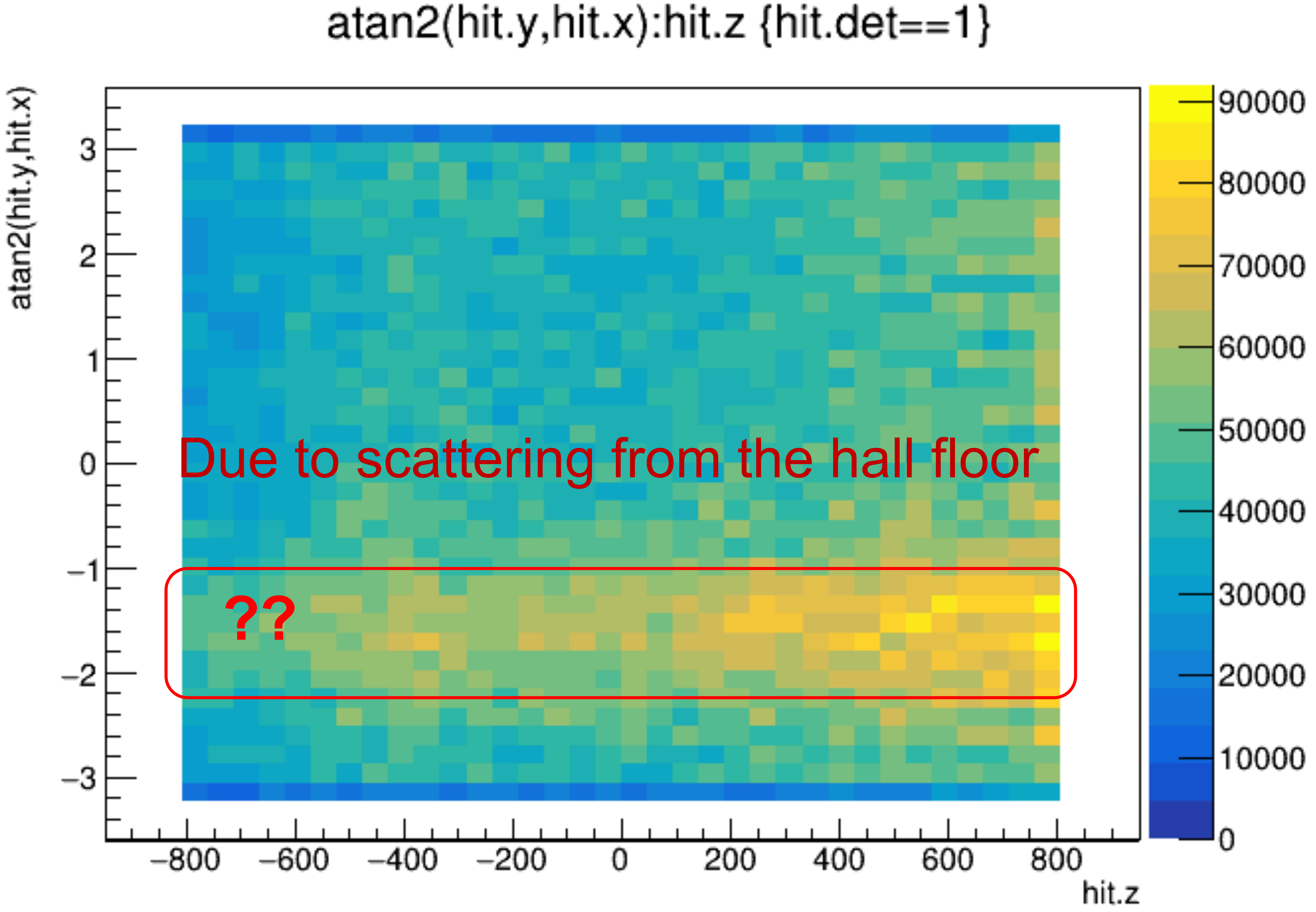
Phi vs z plot : Unshielded vs Shielded (not scaled)

- These plots shows hit distributions on the inner 1 mm SiO2 cylinder
- It is clear that the ring 1 region would be the hottest in terms of radiation.

Unshielded



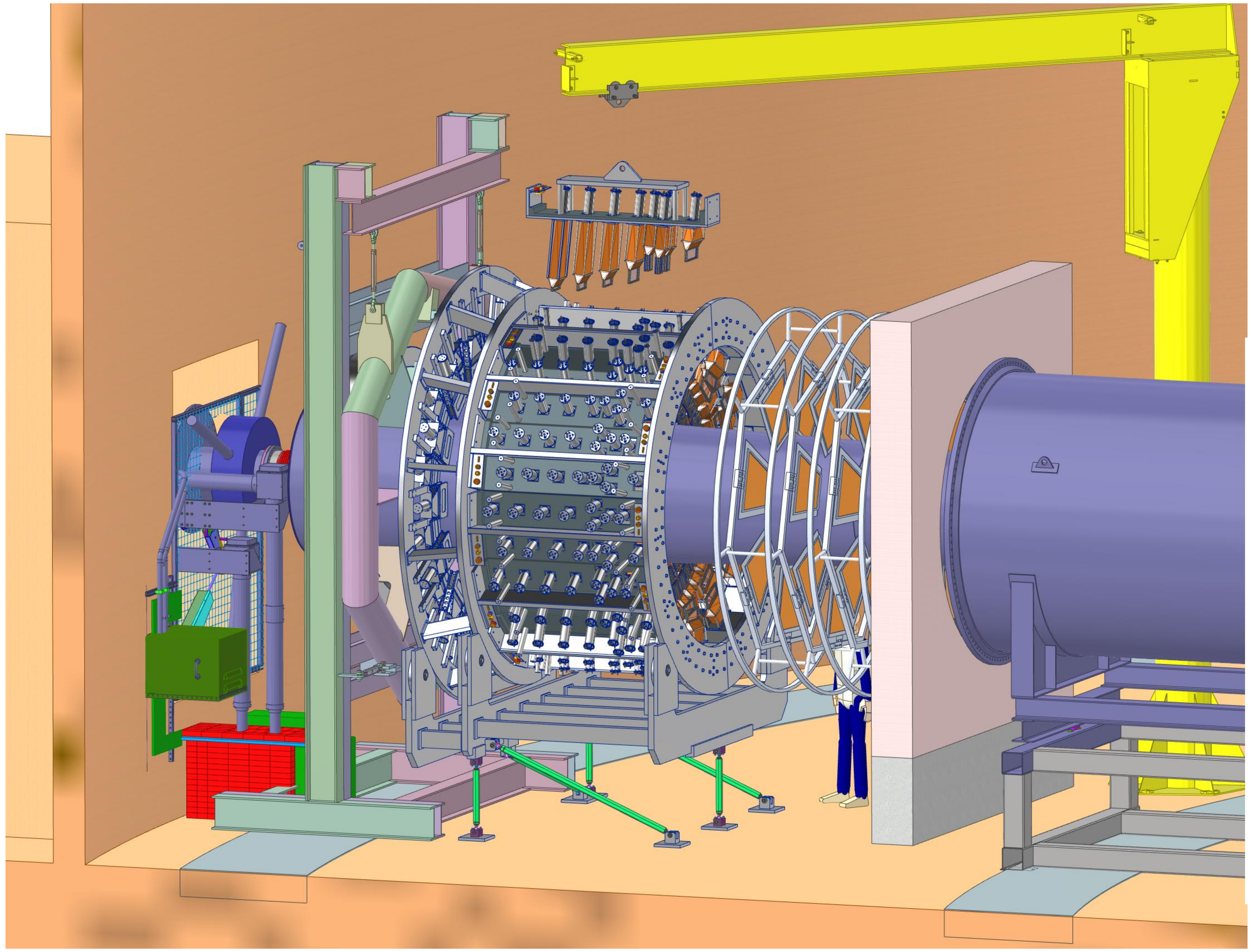
Shielded with existing PMT region design

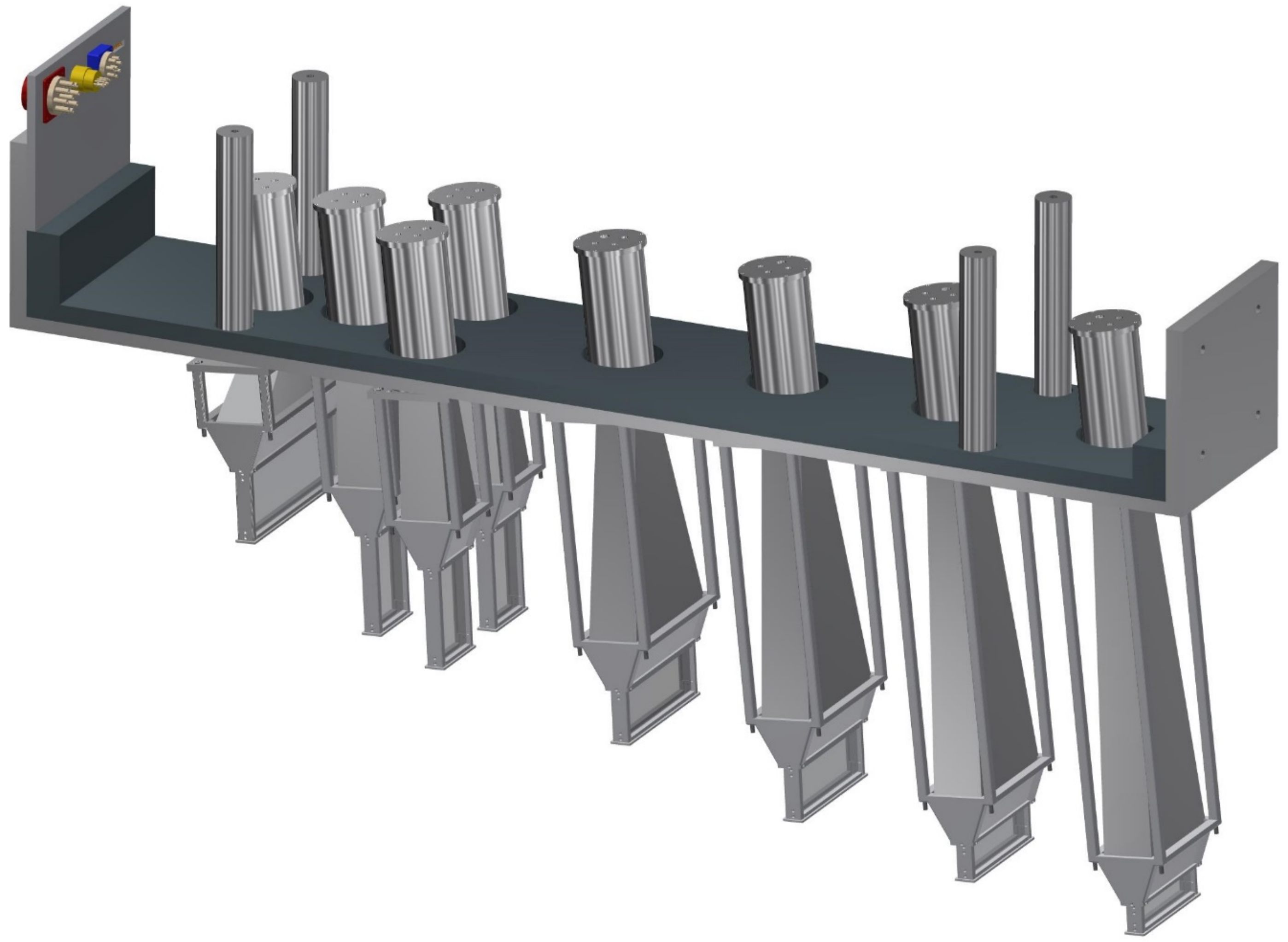


Phi = 0 deg:: beam left horizontal; phi = 90 deg (1.57 radian):: Vertically upward
Phi = 180 deg (3.14 radian):: beam right horizontal; phi = 270 deg (-1.57radian)::vertically downward

New PreAmplifier locations -latest design from Michael

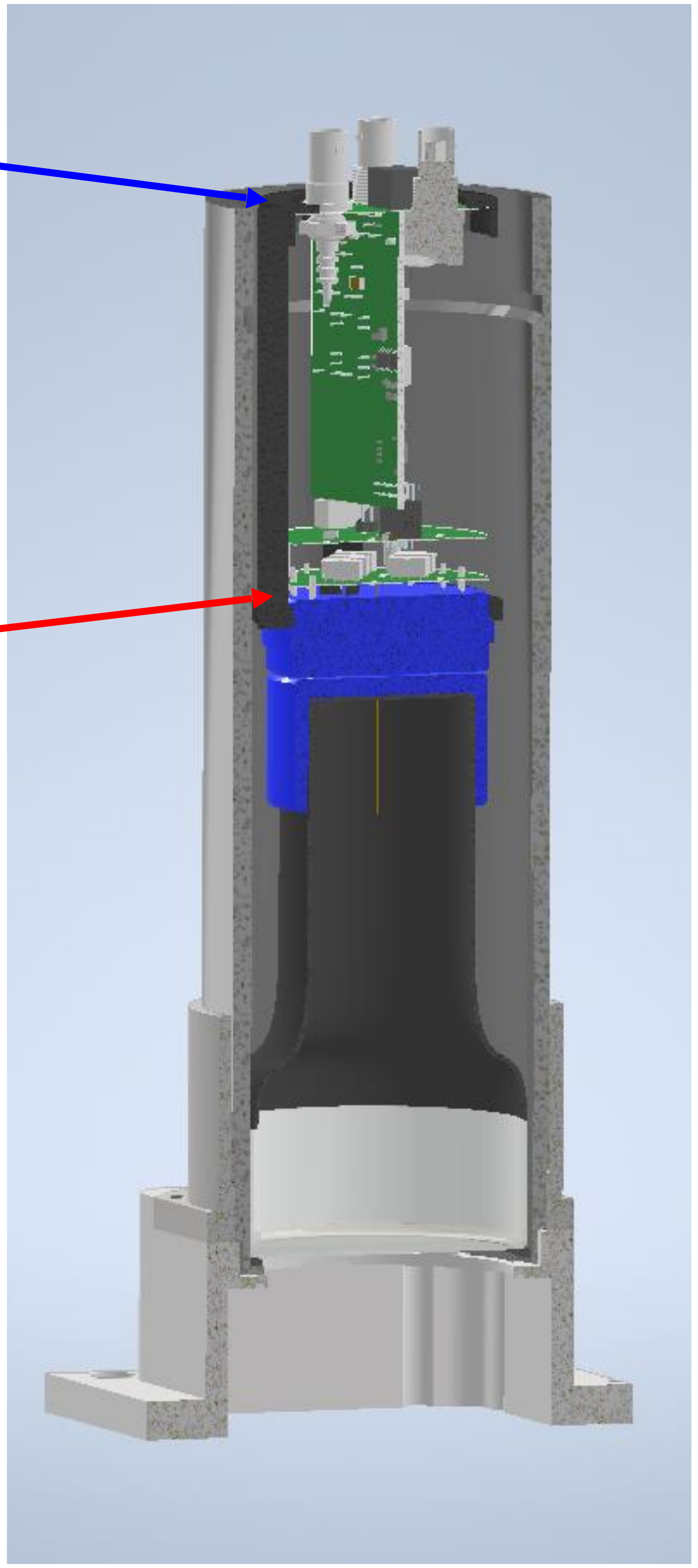
All previous simulation were performed for preamplifier at r=1542 mm and r=1602 mm, which are close to the latest preamplifiers' locations.





Outer PreAmp (r=1635 mm)

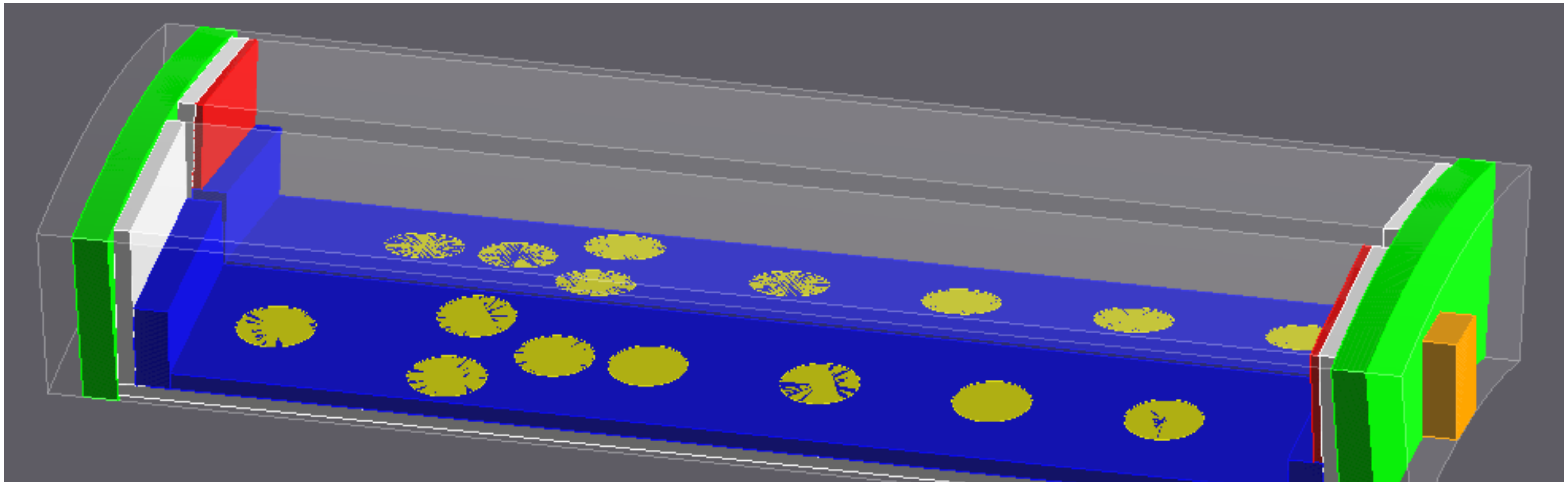
Inner PreAmp (r=1540 mm)



Do we really need 5 cm in the upstream and downstream discs or “lips”?

The thickness of Pb lips placed upstream and downstream of the main detector shielding are reduced from 5 cm to 2.5 cm.

Also the placement of the virtual detectors are adjusted according to the latest voltage divider and preamplifier design from Michael’s group.
Inner virtual detector placed earlier at r=1542 -1543 mm & the new placement is r=1540-1541 mm
Outer virtual detector placed earlier at r=1602 -1603 mm & the new placement is r=1635-1636 mm



Picture is before modification

Radiation dose on PreAmp1 & 2

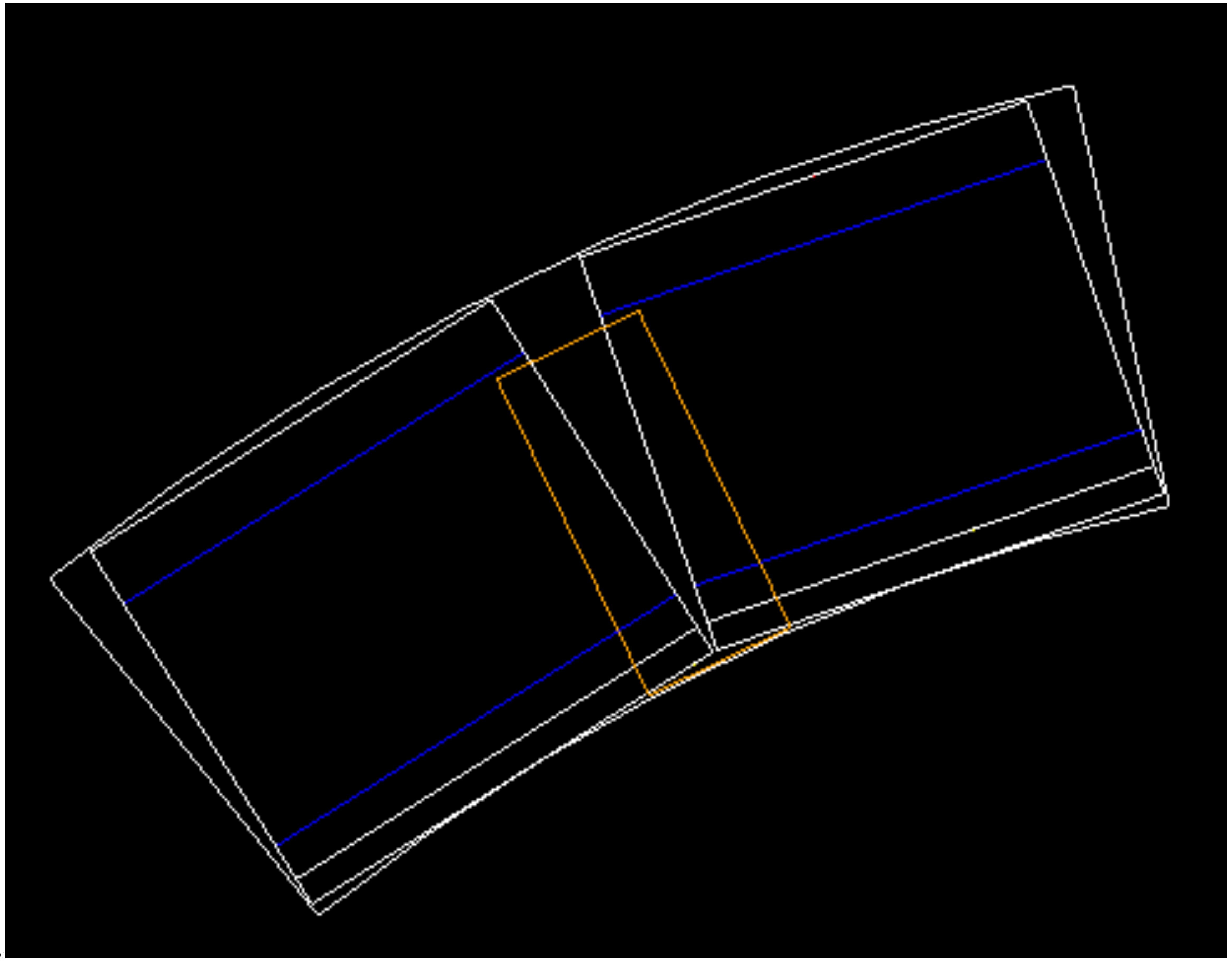
Si placement (radially)	PreAmp 1 (r=1540-1552 mm)		PreAmp 2 (r=1635-1647 mm)	
	*Total Energy deposition (MeV) [2.5 cm lips (5cm lips)]	Dose (krad) [2.5 cm lips (5cm lips)]	*Total Energy deposition (MeV) [2.5 cm lips (5cm lips)]	Dose (krad) [2.5 cm lips (5cm lips)]
Front 1 mm	4.01e17 (4.06e17)	177 (180)	4.44e17 (4.30e17)	184 (183)
Middle 10 mm	1.74e18 (1.71e18)	76 (75)	2.12e18 (1.91e18)	88 (81)
Back 1 mm	1.23e17 (1.24e17)	54 (55)	1.54e17 (1.43e17)	64 (61)

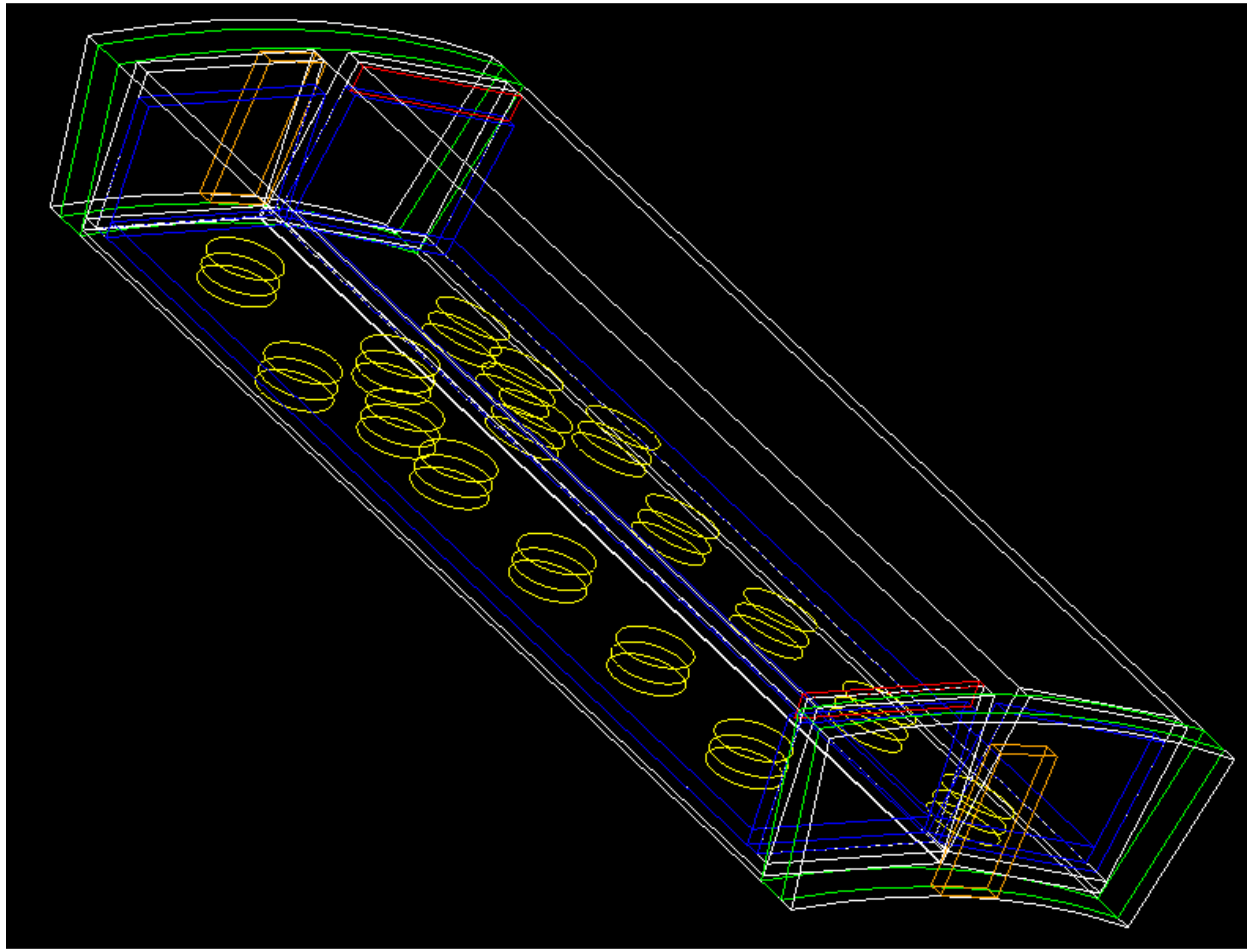
- Two small changes between simulations with 5 cm and 2.5 cm lips -
  - The material changed from SiO_2 (for 5 cm case) to pure Si (for 2.5 cm case)
  - The preamplifiers' locations changed little bit: for 5 (2.5) cm case the radial locations used 1542-1554 (1540-1552) mm for inner preAmp and 1602-1614 (1635-1647) mm for outer preAmp.

*With 70uA 344 days, Si density = 2.33 g/cc;

GDL geometry for extended limits

The radial dimensions of the upstream and downstream lips are extended upto r=1600 mm & thickness of the lips are kept at 2.5 cm
The brick's dimensions are also extended to cover the gap between the two adjacent lips





Radiation dose on PreAmp1 & 2

Si placement (radially)	PreAmp 1 (r=1540-1552 mm)		PreAmp 2 (r=1635-1647 mm)	
	*Total Energy deposition (MeV) [2.5 cm lips (with extended 2.5 cm lips)]	Dose (krad) [2.5 cm lips (with extended lips)]	*Total Energy deposition (MeV) [2.5 cm lips (with extended 2.5 cm lips)]	Dose (krad) [2.5 cm lips (with extended lips)]
Front 1 mm	4.01e17 (3.64e17)	177 (160)	4.44e17 (3.93e17)	184 (163)
Middle 10 mm	1.74e18 (1.58e18)	76 (69)	2.12e18 (1.73e18)	88 (71)
Back 1 mm	1.23e17 (1.12e17)	54 (49)	1.54e17 (1.24e17)	64 (51)

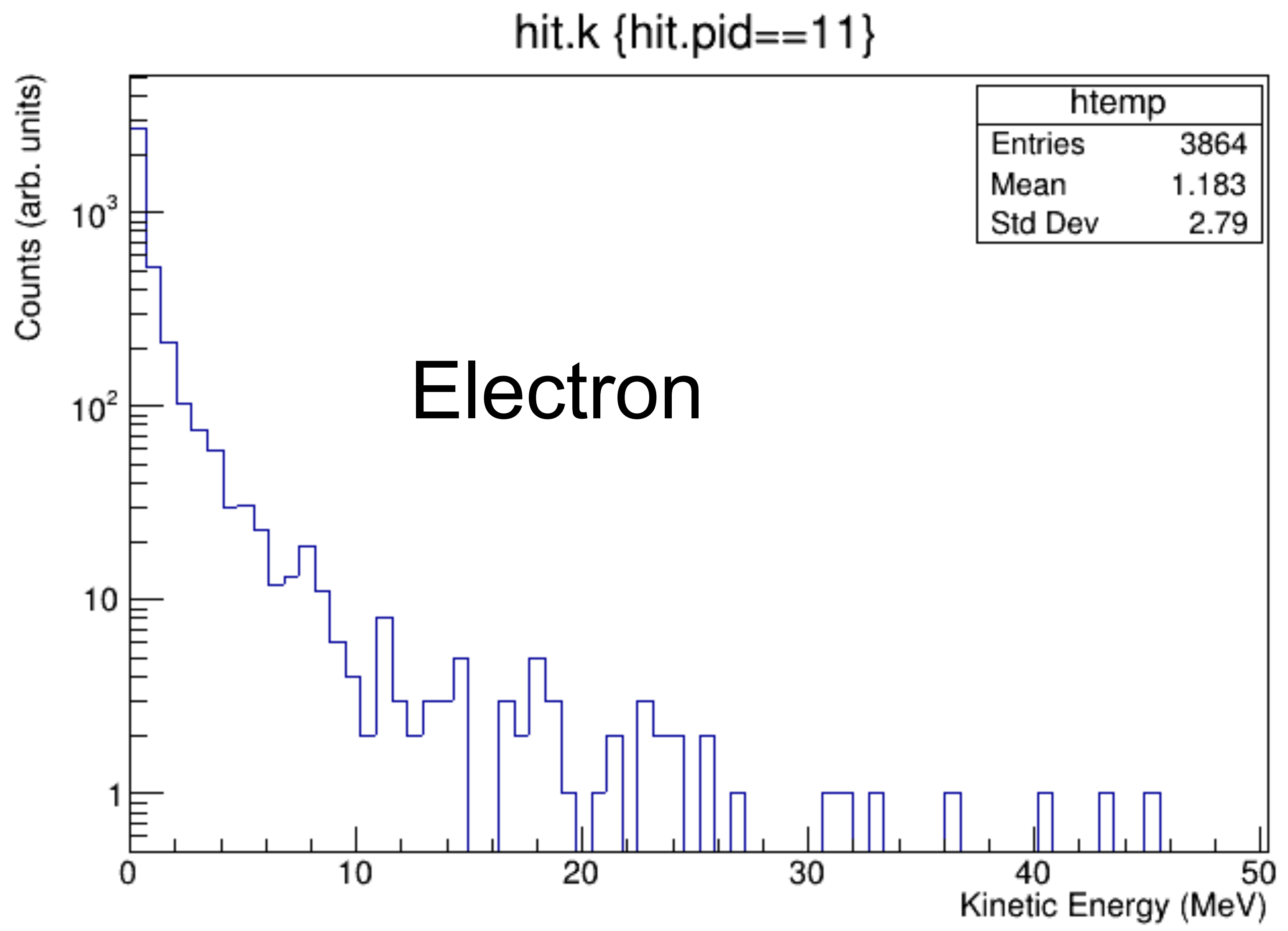
With the radially extended lips, dose on preAmp 1 decreased by ~10% and that for preAmp 2 ~20%.

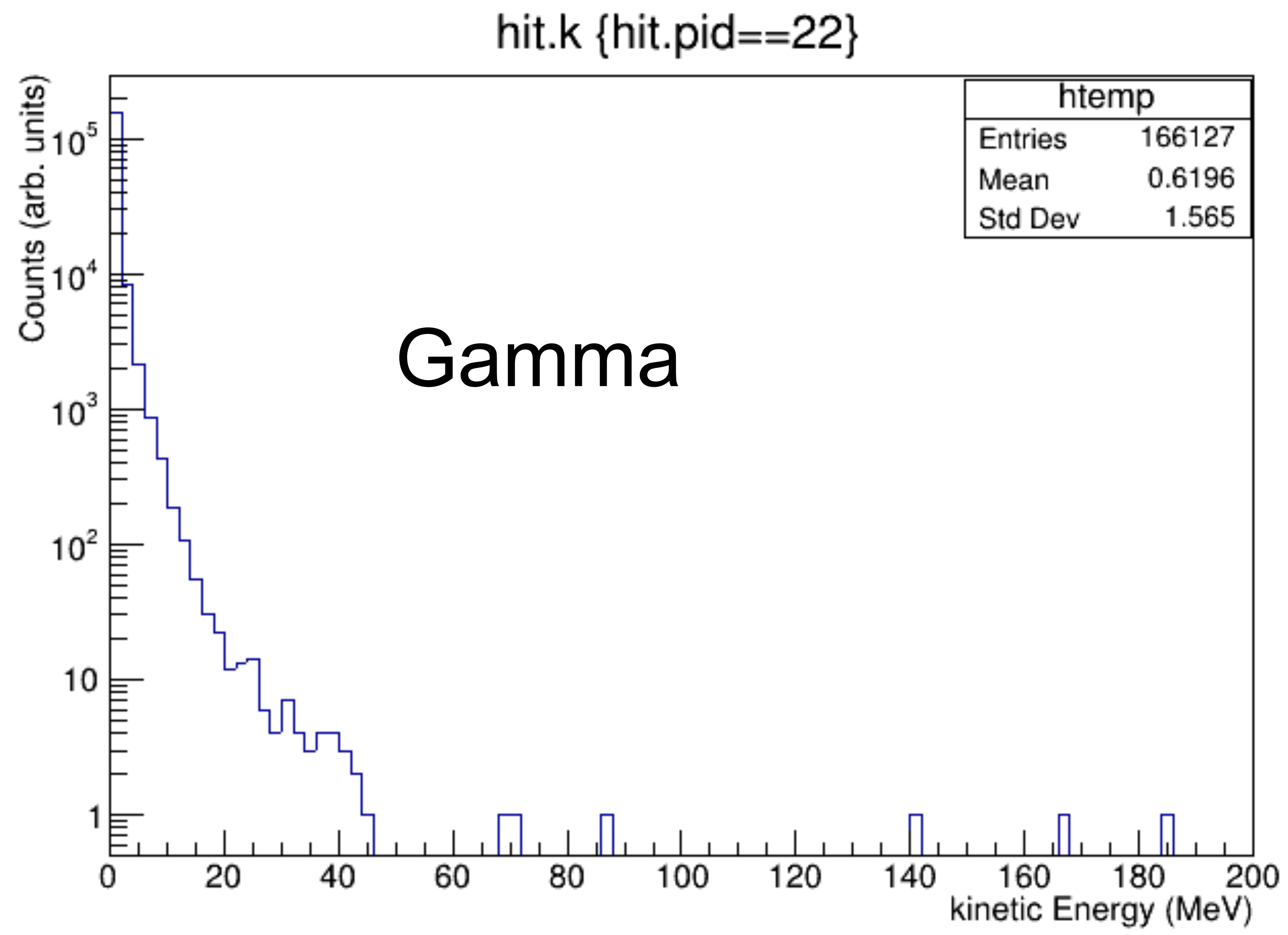
So, if you compare the unshielded dose values from slide 17, then it will be clear that the majority of the dose is coming from the barrel section of the shielding.

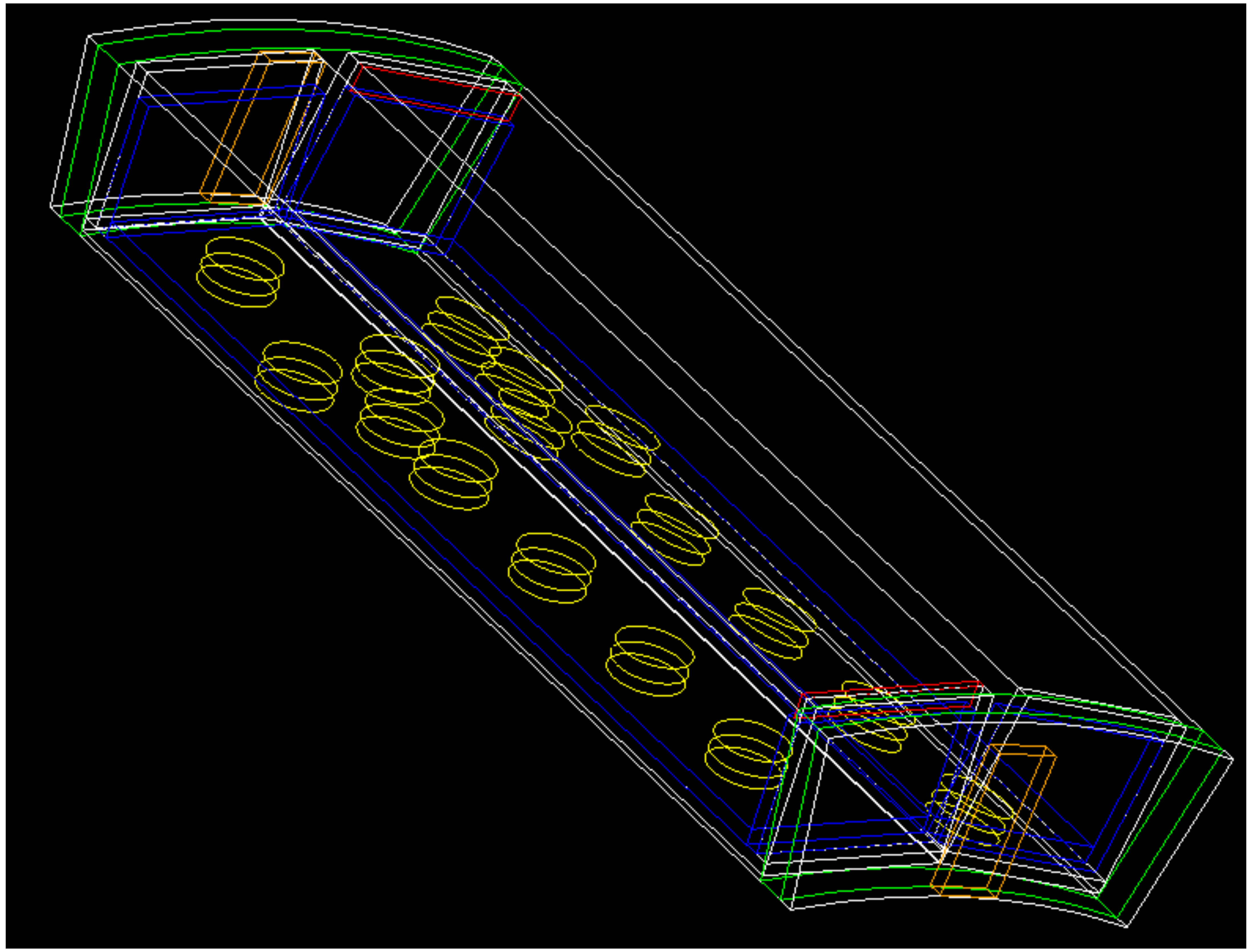
*With 70uA 344 days, Si density = 2.33 g/cc;

The lips and the bricks are set to G4_AIR

The green ring is 50.8 mm thick Al & the rectangular plate between green ring and lip is 25.4 mm Al







Radiation dose on PreAmp1 & 2

Si placement (radially)	PreAmp 1 (r=1540-1552 mm)		PreAmp 2 (r=1635-1647 mm)	
	*Total Energy deposition (MeV) [Extended Air lips (with extended 2.5 cm pb lips)]	Dose (krad) [Extended Air lips (with extended pb lips)]	*Total Energy deposition (MeV) [Extended Air lips (with extended 2.5 cm lips)]	Dose (krad) [Extended Air lips (with extended pb lips)]
Front 1 mm	4.87e17 (3.64e17)	215 (160)	5.23e17 (3.93e17)	217 (163)
Middle 10 mm	2.39e18 (1.58e18)	105 (69)	2.76e18 (1.73e18)	114 (71)
Back 1 mm	1.74e17 (1.12e17)	76 (49)	2.08e17 (1.24e17)	86 (51)

The above table says that it would be better to have the lips.

*With 70uA 344 days, Si density = 2.33 g/cc;

Conclusions and Future work

- The radiation load on the preamplifiers (placed between r=1685 mm to 2640 mm) is ~ 100 krad which is lesser than rated values (~300 krad).
- The detector, light-guide and PMT assembly most likely decrease this radiation load further.
- The hall floor produces enhanced radiation (x2) for preamplifiers near the hall floor - but still well within the 300 kRad canonical limit
- We can probably get away with 2.5 cm Pb all around (including the lips), reducing the weight slightly and the extent of the lips can stay the same
- We need to explore a bit what the material of the modules and the PMT housing will do to the first mm radiation load