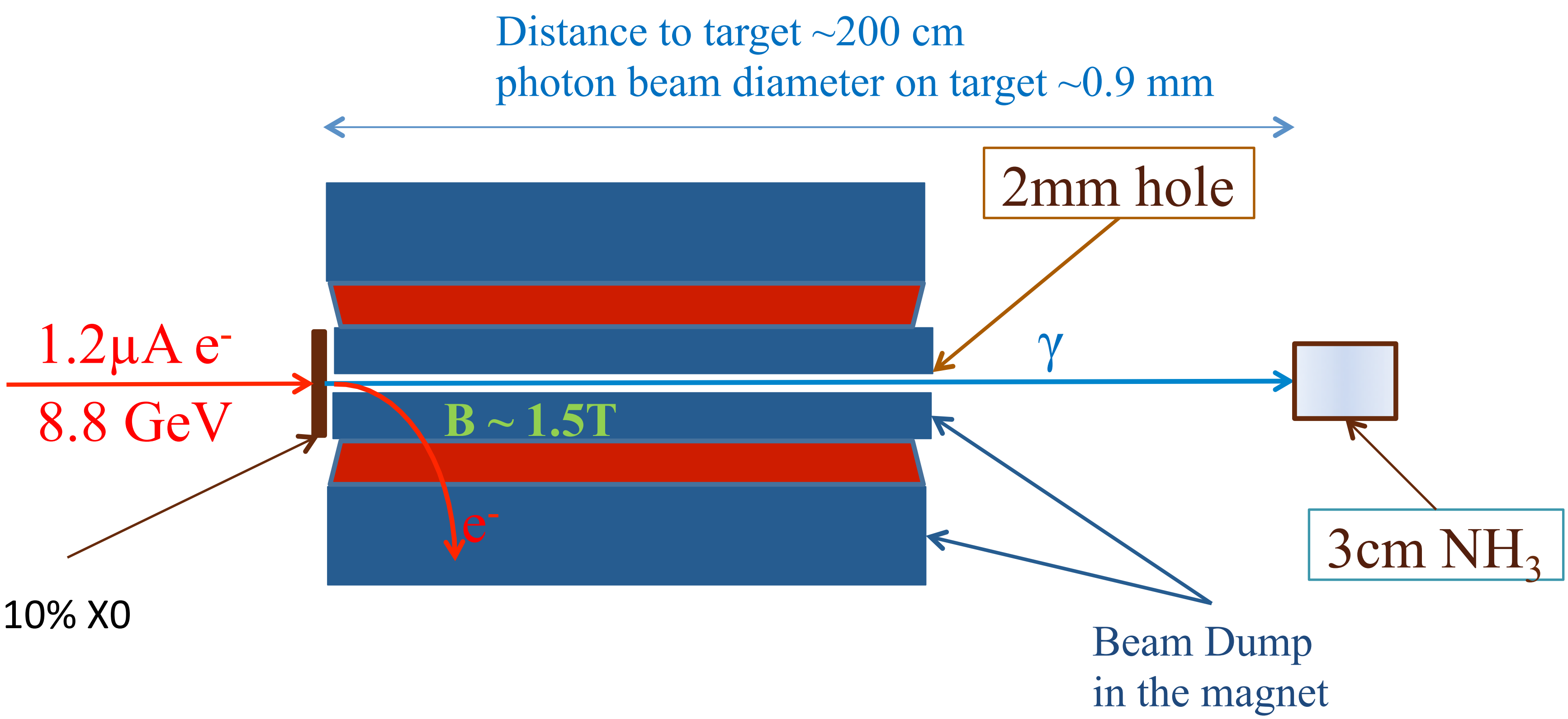
Compact Photon Source

updates&ideas for 10/31/2017

B. Wojtsekhowski for the collaboration

from the November 2014 talk at the NPS meeting

γ-Source



Initial MC simulation shows acceptable background rate on SBS and NPS
Detailed analyses of radiation level are in progress

from the tech note for the 2015 WACS proposal

Conceptual Design Report
A Compact Photon Source

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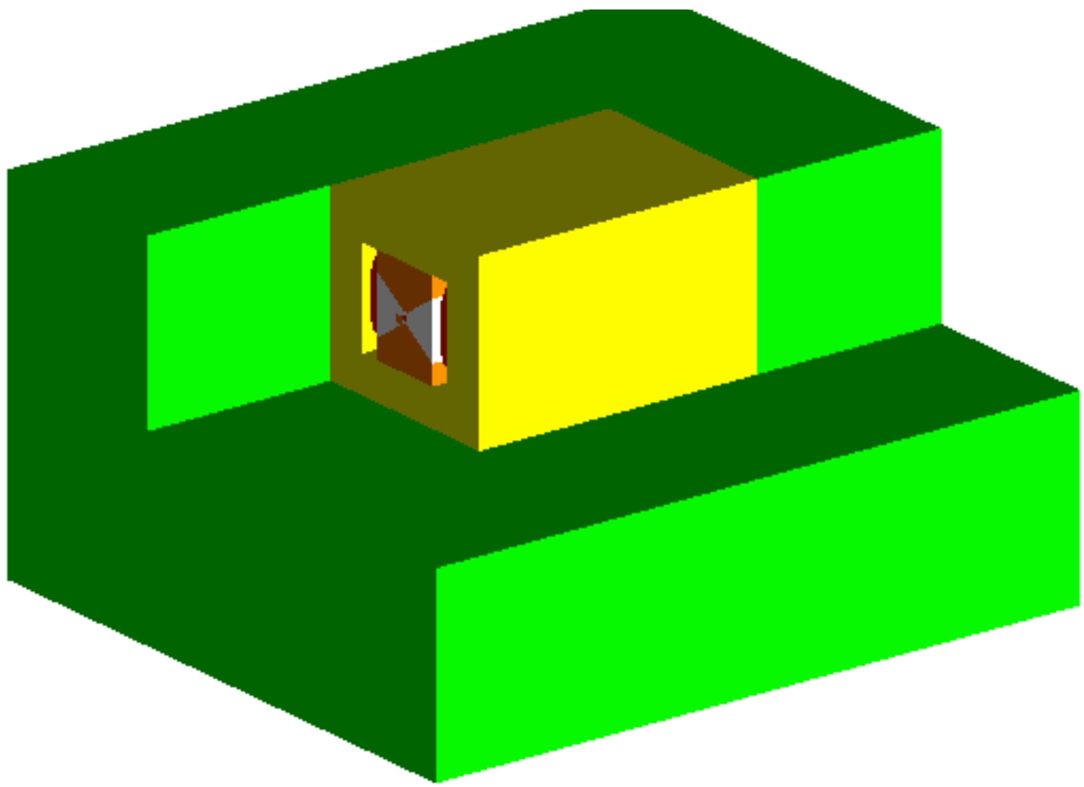
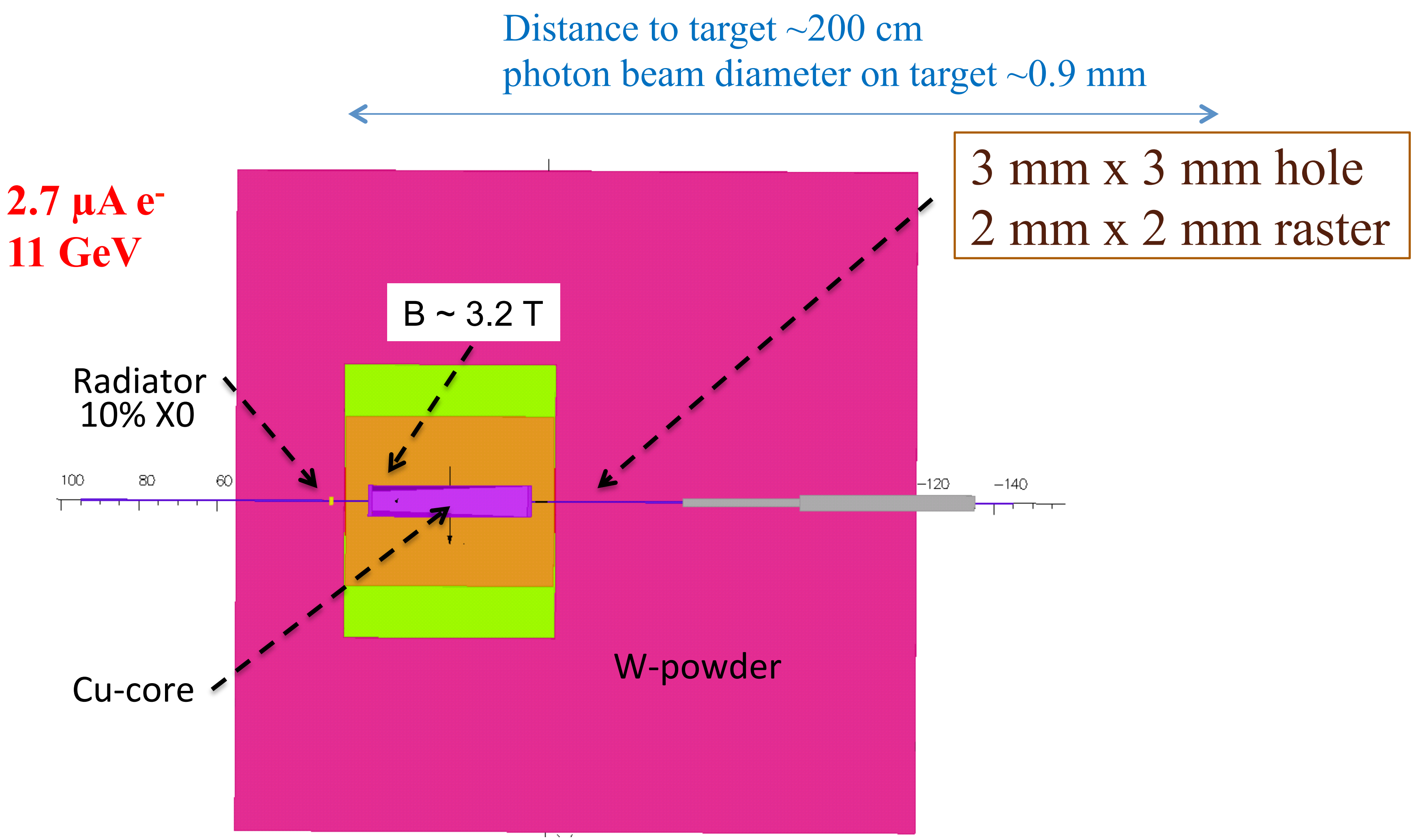
June 22, 2015



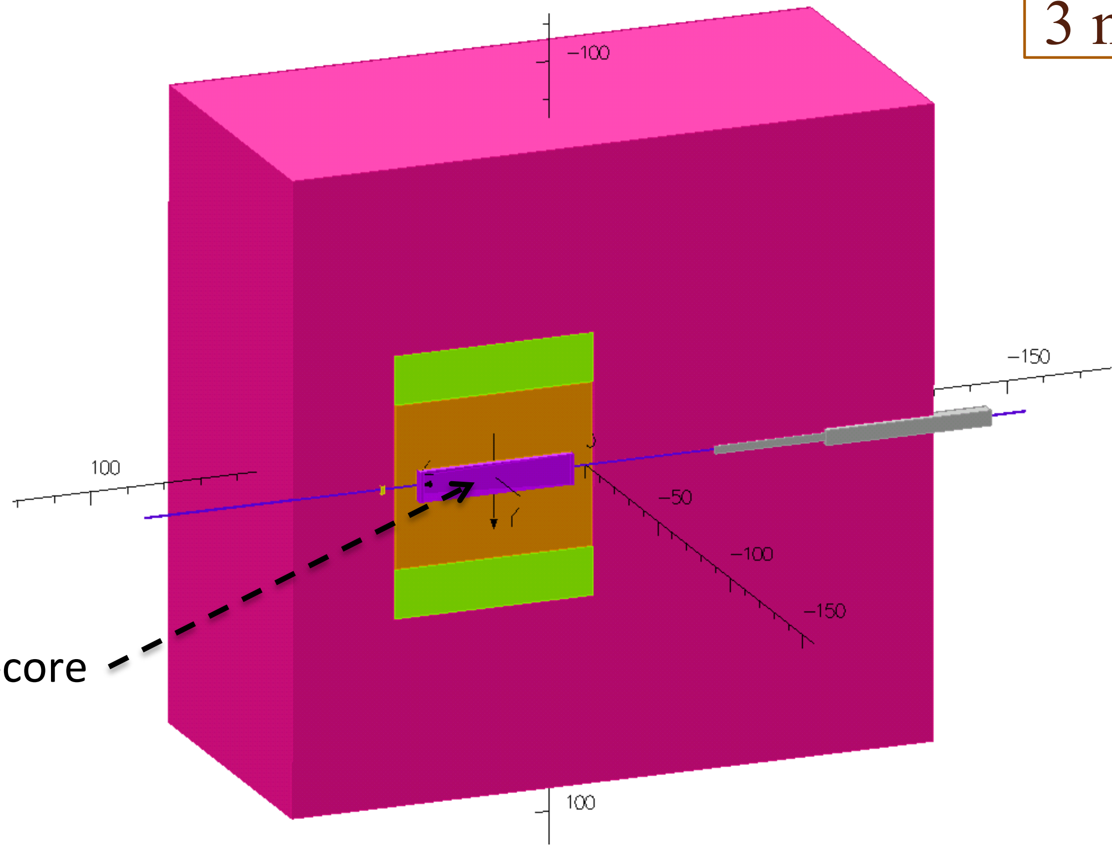
Current model of the γ-Source



Current model of γ-Source

Distance to target ~200 cm
photon beam diameter on target ~0.9 mm

3 mm x 3 mm hole

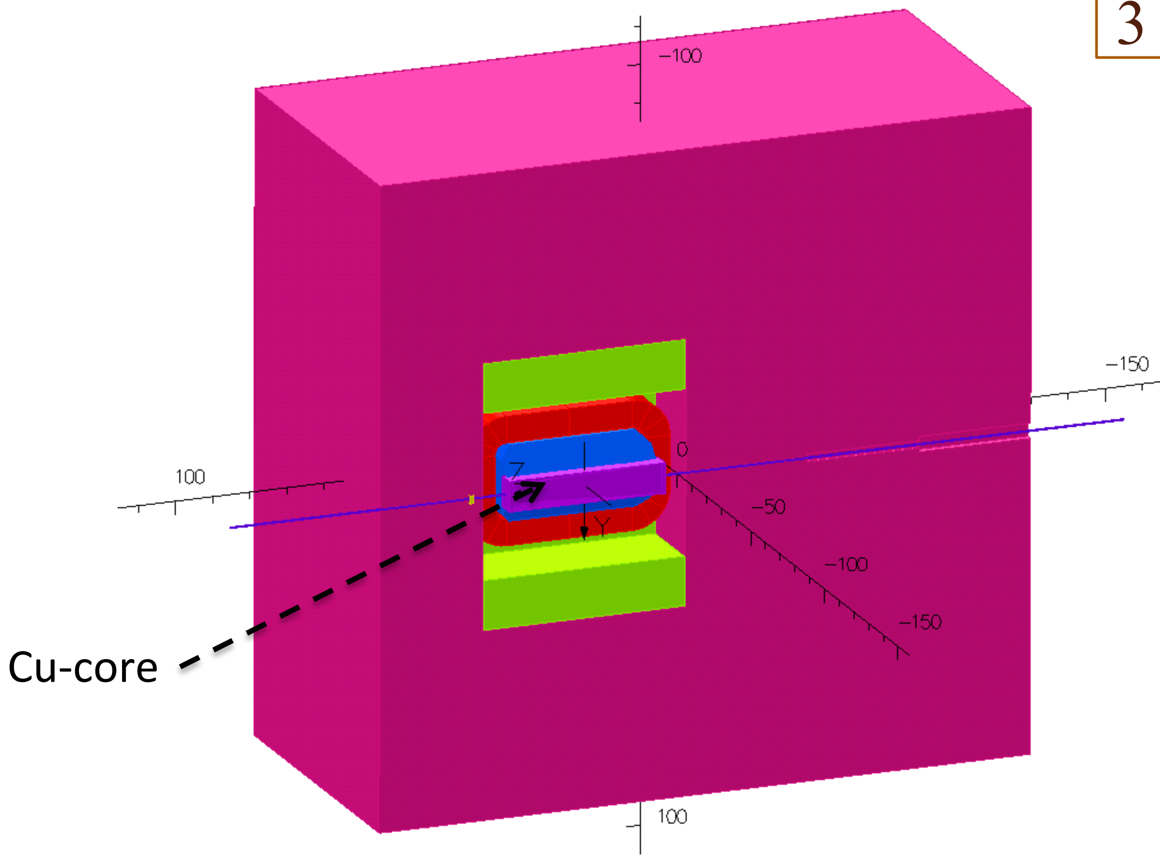


Cu-core

Current model of γ-Source

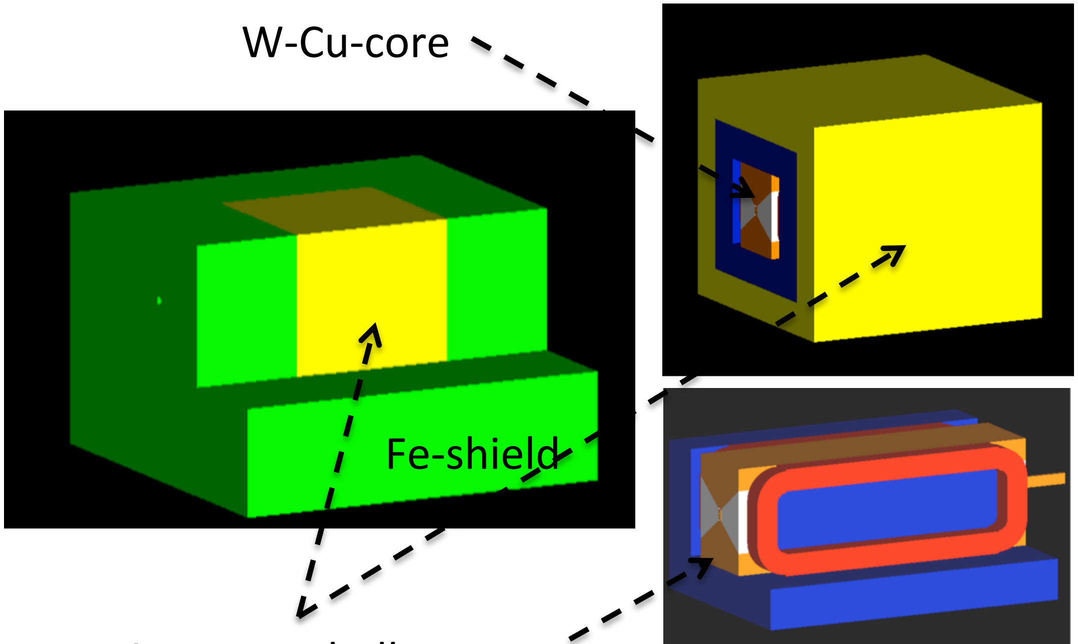
Distance to target ~200 cm
photon beam diameter on target ~0.9 mm

3 mm x 3 mm hole



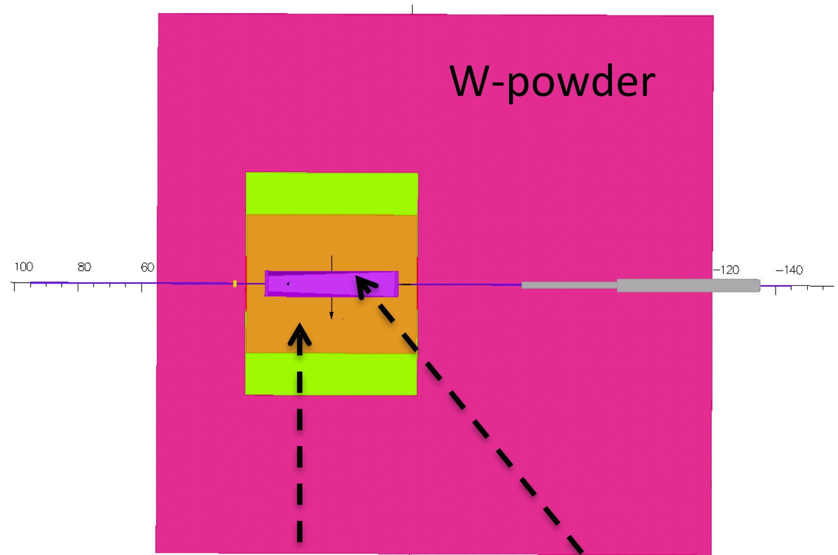
Graphical view of changes in the source

2015 model



$1.2\ \mu A\ e^-$ 8.8 GeV

2017 model



$2.7\ \mu A\ e^-$ 11 GeV

New developments

the list from our previous meeting

1. The raster is 2 mm x 2 mm (requires pol. target rotation)
2. The magnet pole is shaped to boost the B field to 3.2 T -> length reduction which allows a longer front shield and a wedged absorber.
3. The central absorber of Cu has 1.9 x better heat conductivity, 4.2 x longer radiation length than the W-Cu (20%) alloy.
4. W-powder external shield (16 g/cm^3 density) for better shielding.
5. Gradual “stepped” opening of the beam line for rad. leak reduction
6. Shielding requirement logic: The radiation from the source should be a few times lower than that from the photon beam interaction with the material of a polarized target.

Considerations for a 6-point list

1. The raster is 2 mm x 2 mm (requires pol. target rotation)

Power deposition in the polarized target for a high energy photon beam defined by photon intensity is 160 mW per 1 μA electron beam (10% X0 radiator and no loss due to collimation), see p.18 in PR12-15-003 to PAC43 and p.21 in the TN on CPS for Geant4 calculations.

The projected 2.7 μA beam on a 0.1 X0 radiator leads to a power deposition of 0.43 Watt which also corresponds to an 80 nA electron beam on the polarized target - almost at the limit for the UVa NH3 target for the optimum Figure-of-Merit. FOM enhancement due to the CPS could be calculated as: R = 2.7 x 0.10/ [0.08 x (0.10+0.02)] = **28,**

where we used the same radiation length of the convertor (+ 1/2 target)

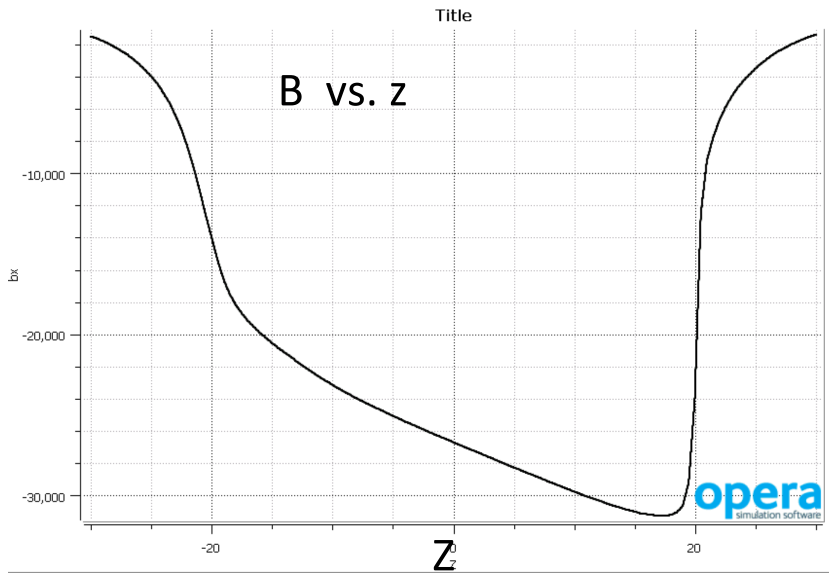
and included an effective flux of virtual photons (0.02) for electron beam.

Considerations for a 6-point list

2. The magnet pole is shaped to boost the B field to 3.2 Tesla -> length reduction, which leads to a better front shield and wedged absorber.

This optimization took into account that for a small horizontal raster size the distance between the magnet poles near the radiator could be reduced. However, the distance needs to be much larger in the area of the beam power deposition to allow for heat transfer in the absorber.

The wedge shape of the pole leads to concentration of the magnetic flux at the front of the magnet and helps faster deflection of the used beam to the absorber. The space between magnet poles is filled with a wedged cooper absorber.



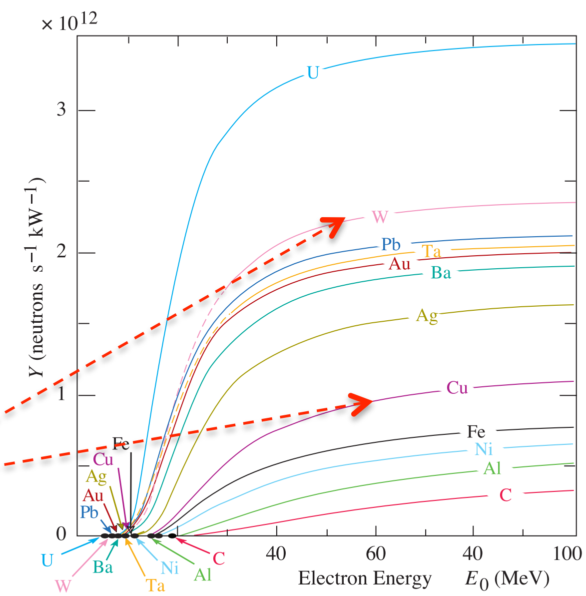
Considerations for a 6-point list

3. The central absorber of Cu has 1.9 x better heat conductivity, 4.2 x longer radiation length than the W-Cu (20%) alloy.

In the original design we used the WCu(20%) alloy for faster absorption of the beam energy and secondary neutrons. The original 2015 CPS scheme assumed 10 kW beam power and a 20 mm x 2 mm raster pattern with several slots. However, the current plan requires a power of 30 kW and reduced raster size to 2 mm x 2 mm.

Higher heat conductivity and longer radiation length of the pure copper absorber allows us to achieve acceptable power density in the absorber.

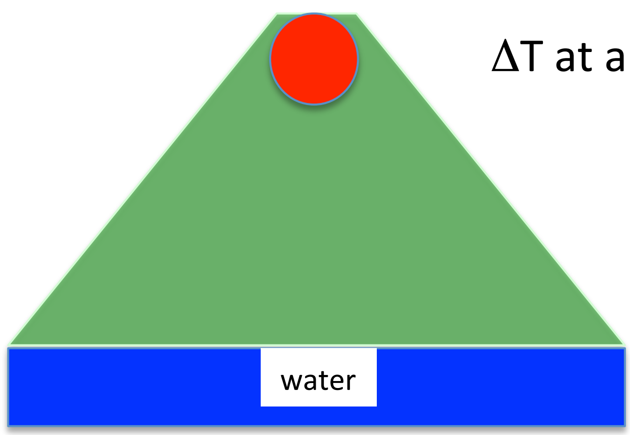
Also the neutron yield per kW is lower in Cu relative to W by a factor of two.



Considerations for a 6-point list

3. The central absorber of Cu has 1.9 x better heat conductivity, 4.2 x longer radiation length than the W-Cu (20%) alloy.

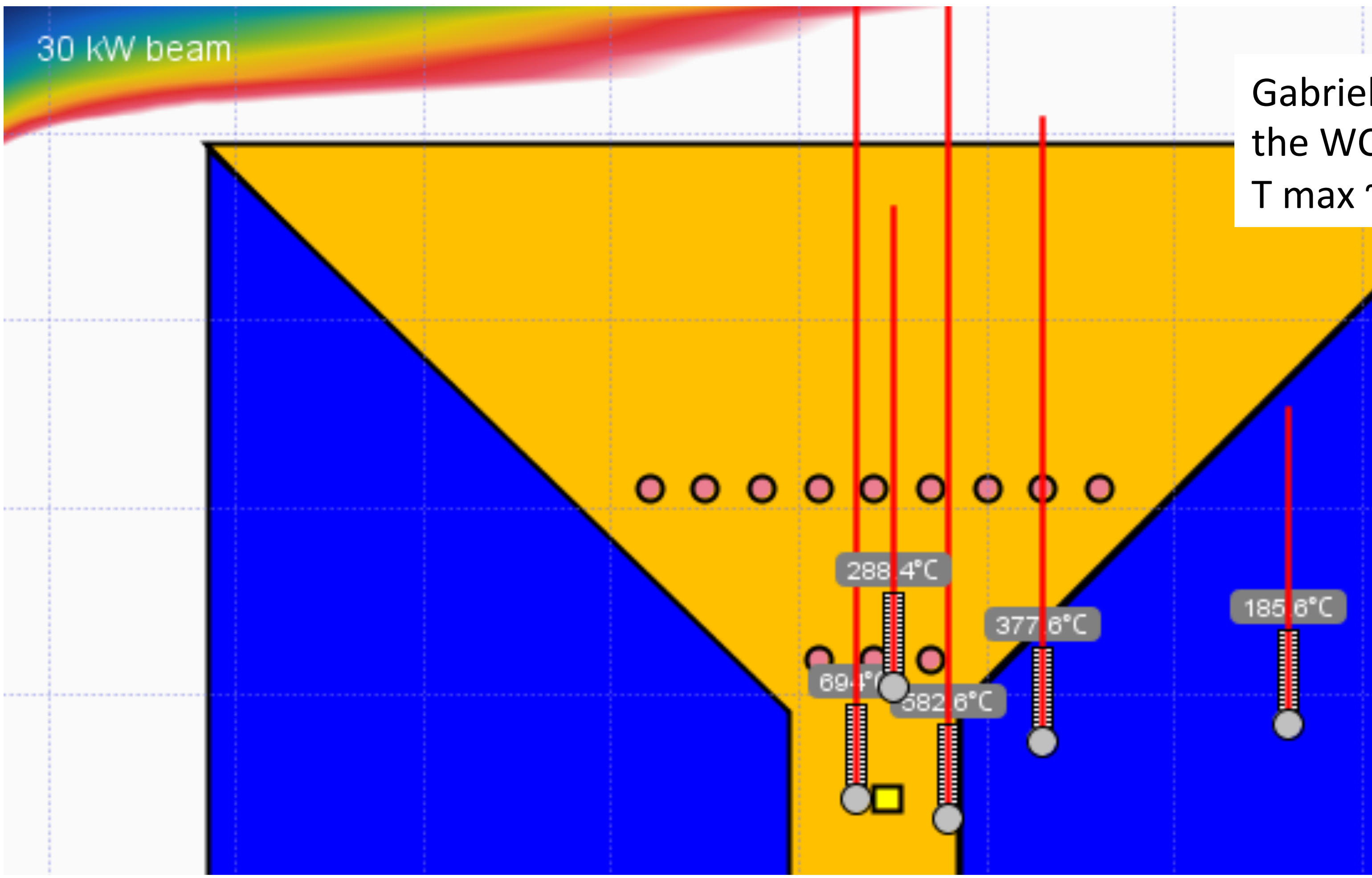
An estimate: The power distributed over 30 cm with diameter of 2 cm. Using a wedge shape of the Cu (in x-y plane) with angle of 90 degrees and cooling at 12 cm distance from the power source we can estimate the temperature profile: 600+ 140 x $(1-r^2)$ for r<1 cm and a log. profile for r>1 cm 240 ln(12/r).
A 3D calculation would be useful.



ΔT at a hot center = 600 + 140 C

Considerations for a 6-point list

3. The central absorber of Cu has 1.9 x better heat conductivity, 4.2 x longer radiation length than the W-Cu (20%) alloy.



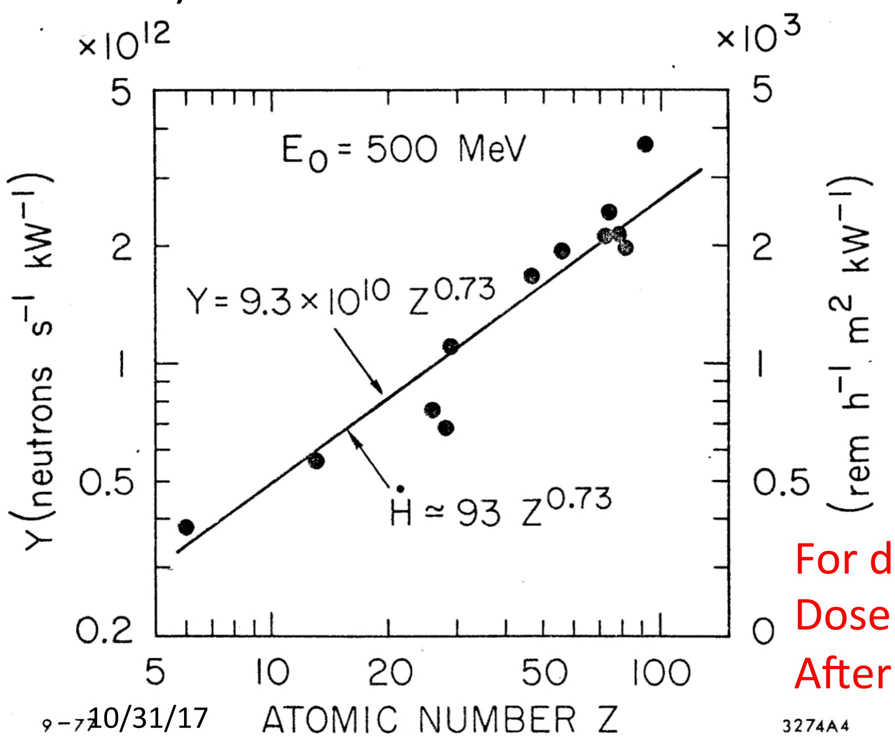
Gabriel found for the WCu absorber:
T max ~ 700 C

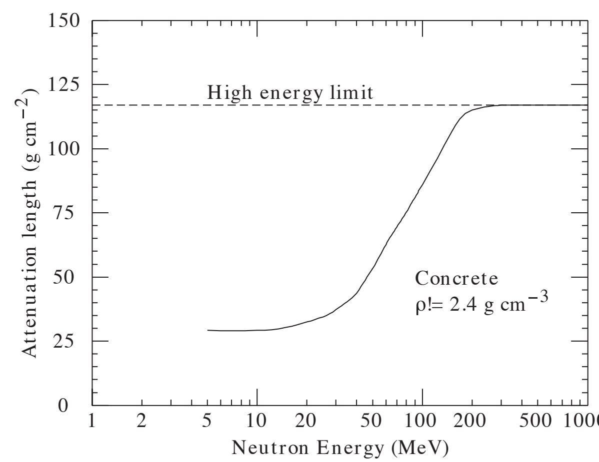
Considerations for a 6-point list

4. W-powder external shield (16 g/cm^3 density) for better shielding.

Optimization of the CPS shielding will continue until full engineering is completed. There are several general considerations:

a) The total thickness needed for neutron absorption is about 1000 g/cm^2





For distance 2 meter from the source and 30 kW beam
Dose rate is 1 krem/kW*30 kW / (4π r^2)=0.60 krem/h
After applying a shielding factor of 1000 => 0.60 rem/h

Considerations for a 6-point list

4. W-powder external shield (16 g/cm^3 density) for better shielding.

Optimization of the CPS shielding will continue until full engineering is completed. There are several general considerations:

a) The total thickness needed for neutron absorption is about 1000 g/cm^2 .

b) The total weight is lower for the higher material density.

c) The cost of the material will be the main factor for the CPS project. Solid tungsten is too expensive for the outer shielding; W-powder is more affordable and its density (16 g/cm^3) is still higher than for iron by a factor of two.

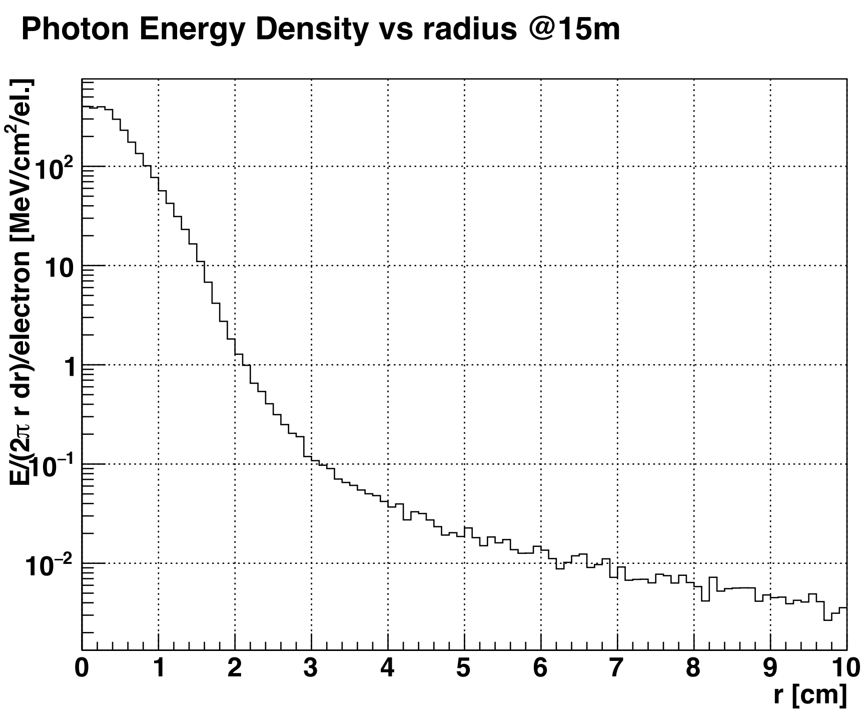
d) There is a significant surplus (200 tons) of lead bricks at SLAC which could be obtained for a very low cost (mainly transportation).

e) There is a possibility of using iron plates e.g. for KL case (no weight limit).

Considerations for a 6-point list

5. Gradual "stepped" opening of the beam line for rad. leak reduction.

The profile of the opening is the subject currently ongoing work. The Geant4 MC presented in the CPS TN (see p. 24-25) is shown below:



Power density at an angle > 0.4 degree (distance is above 10 cm from beam axis) is lower by a factor of 10^5 than in the center, but it is still lead to radiation on the level of several kRad/hour.

The recent study shows that a stepped profile of the gamma-beam exit line helps to reduce radiation level.

Considerations for a 6-point list

6. Shielding requirement logic: The radiation from the source should be a few times lower than from the photon beam interaction with the material of a polarized target.

With the gamma-beam on the polarized target, significant radiation will be produced in beam-target interaction which defines the unavoidable radiation level.

Radiation level is proportional to $\mathcal{L}_{\gamma\ n}$ = photon flux \times target mass.

In the TN for 2015 proposal (p. 26) we provided a comparison of the CPS operation on the UVa target with the radiation level during GEP/SBS and GEn E02-013 experiments:

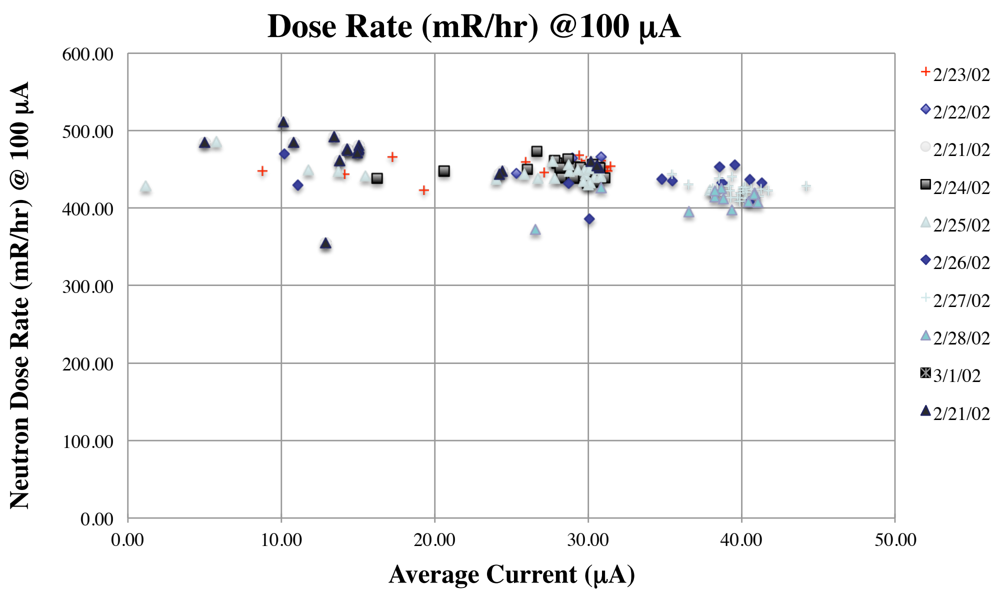
After correction for the higher power (30 kW) of the present plan, the radiation level estimated to be 10 times lower than in the GEp experiment and 2.5 times higher than in the 2006 GEn experiment.

New calculations are needed for the current design of the outer shielding.

Considerations for a 6-point list

6. Projected radiation in the hall due to a photon beam and target interaction

RCS - Feb. 2002: $E_{e-} = 3.48$ GeV



Radiation monitor ~ 15 m from the target in 120 deg. direction

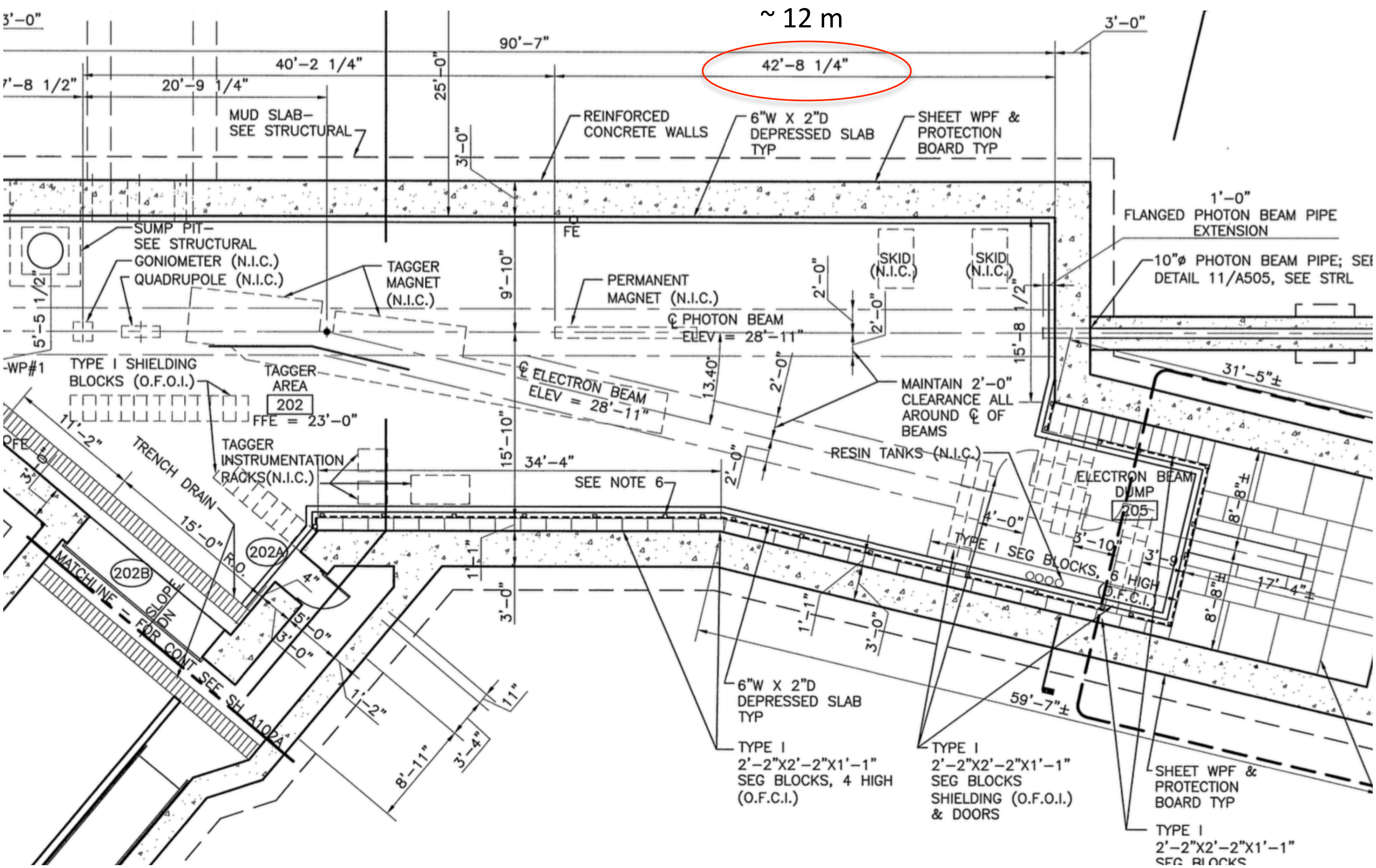
From this 4 mrem/h/μA for
1) effective target - 1.7 g/cm^2
2) effective radiator – 7%

projected level for WACS for
1) target – 3 g/cm^2
2) radiator 10%

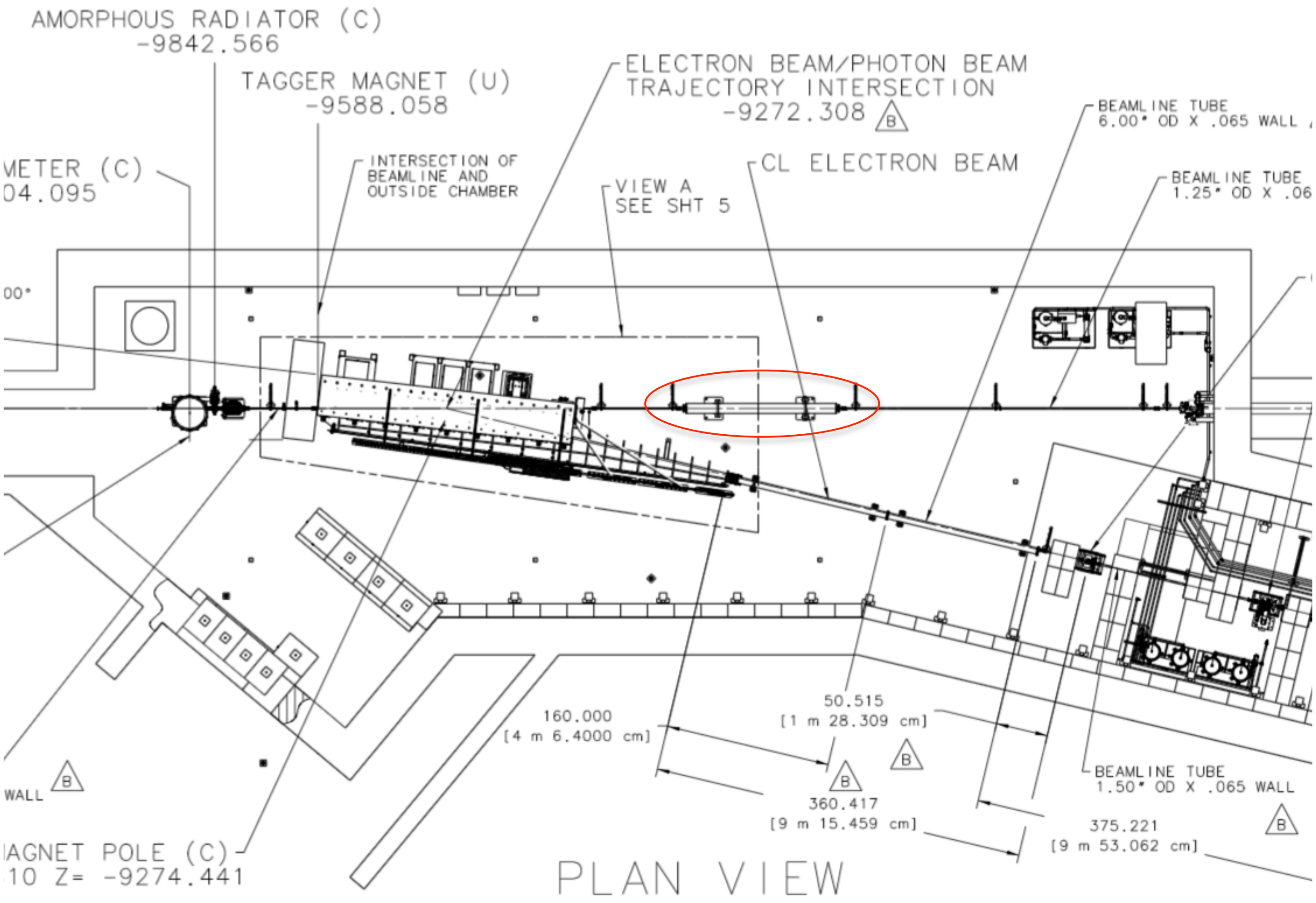
is 10 mrem/h/μA at 15 m
or at 2 m from target ~
500 mrem/h/μA =>
total 1.5 rem/h

The shielding factor of CPS needs to be 1000 to keep CPS contribution of 1/3 comp. unavoidable 1.5 rem/h

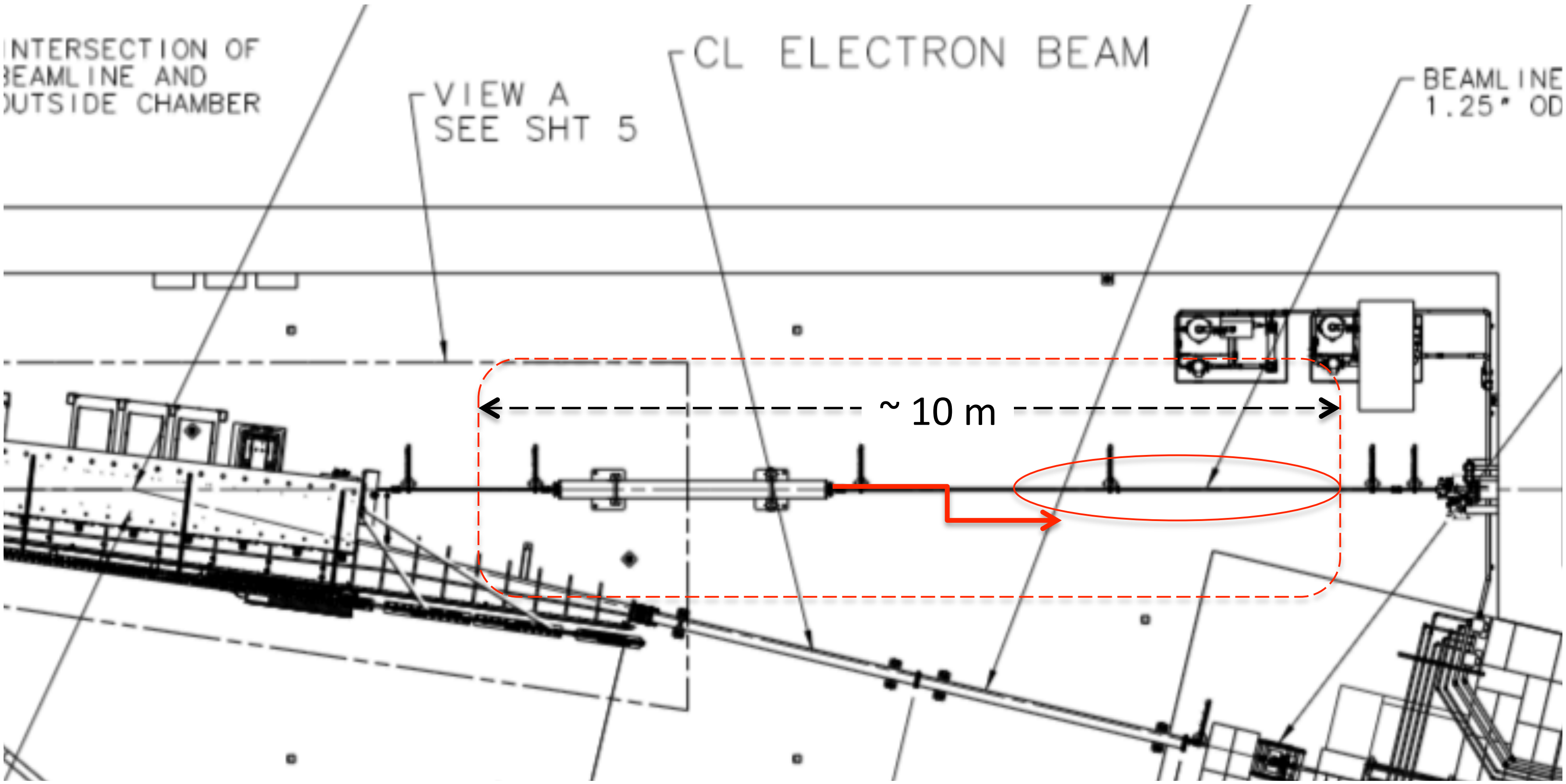
KLong CPS area



KLong CPS area

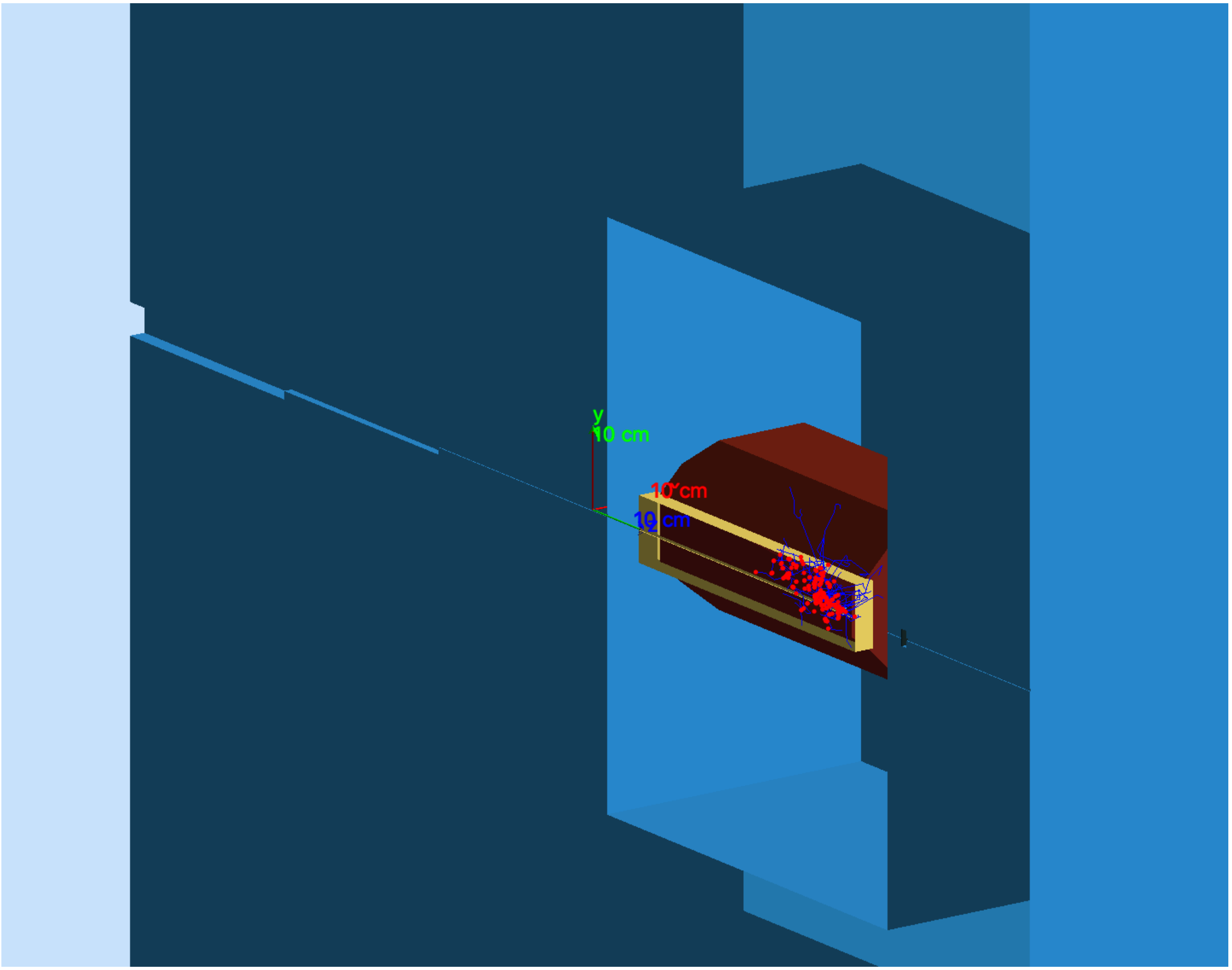


KLong CPS area



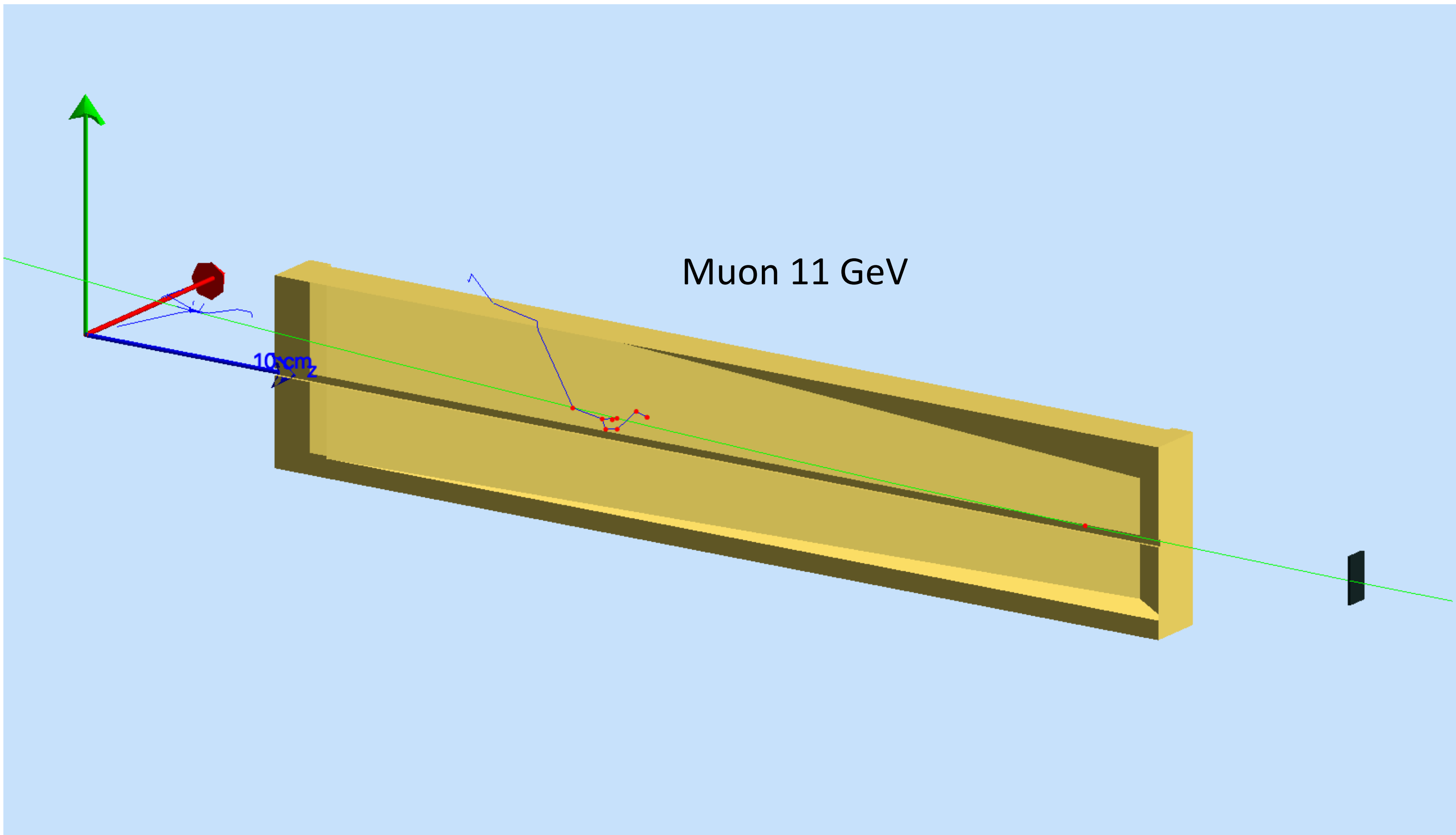
Estimated length of 10 meters allows the CPS type source with the beam power of 60+ kW

Geant4 model (GEMC framework)



Marco,
Maurizio
BW

Geant4 model (GEMC framework)



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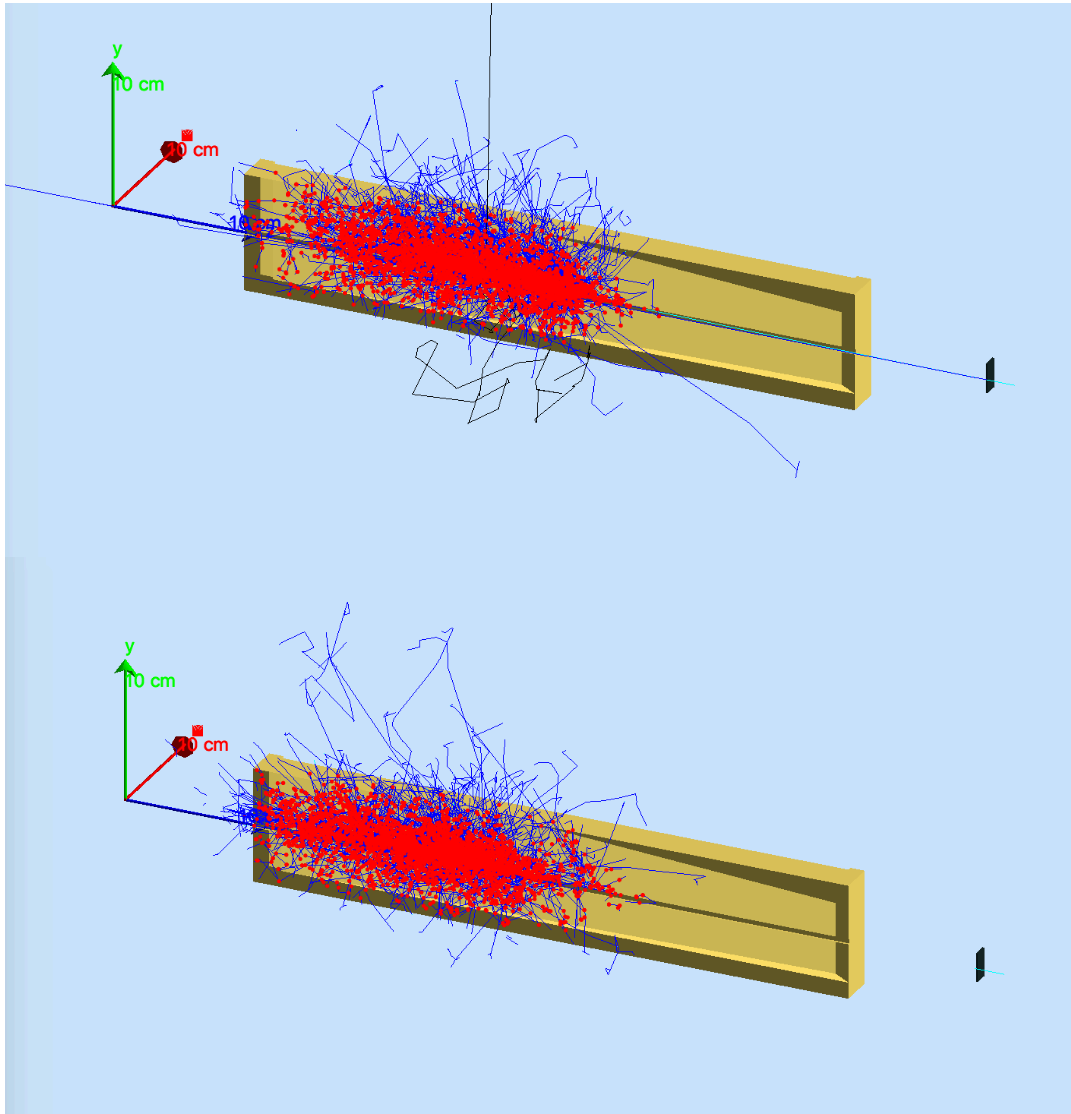

11 GeV e-
and a photon

11 GeV e-
Yv = -1 mm