Study the Compact Photon Source Radiation Using FLUKA

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This is a summary of radiation studies done for both the UVa target alone (for electron and photon beams) and with the Compact Photon Source. For more details and plots, see the separate files: Jixie_UVAPolTarget_11302017 and Jixie_CPS_11302017

Outline

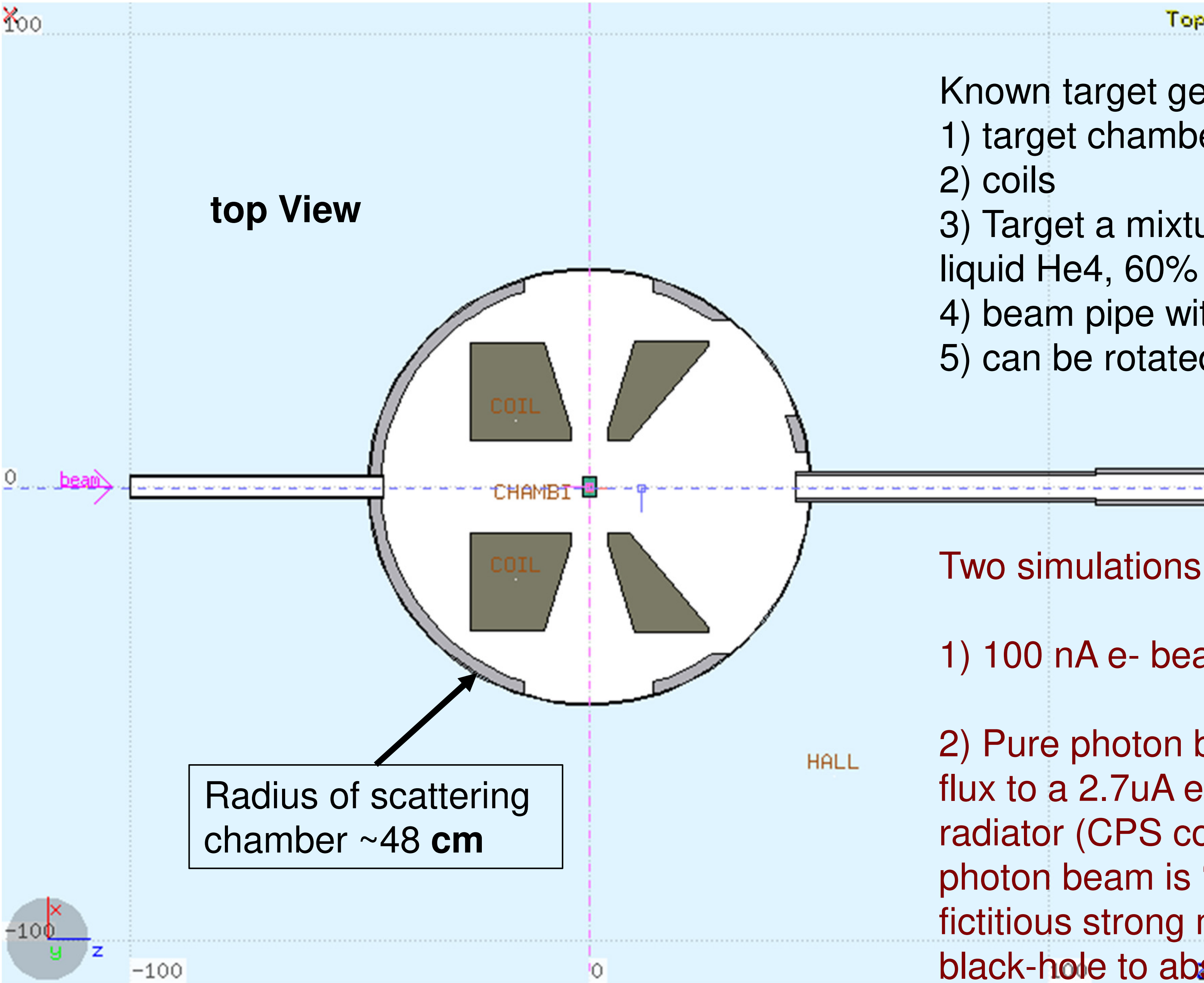
1) Simulations with UVa target alone – electron versus photon beams

2) CPS geometry updated

3) FLUKA simulation results for full setup and comparisons

4) Summary

UVA|Jlab Polarized Target



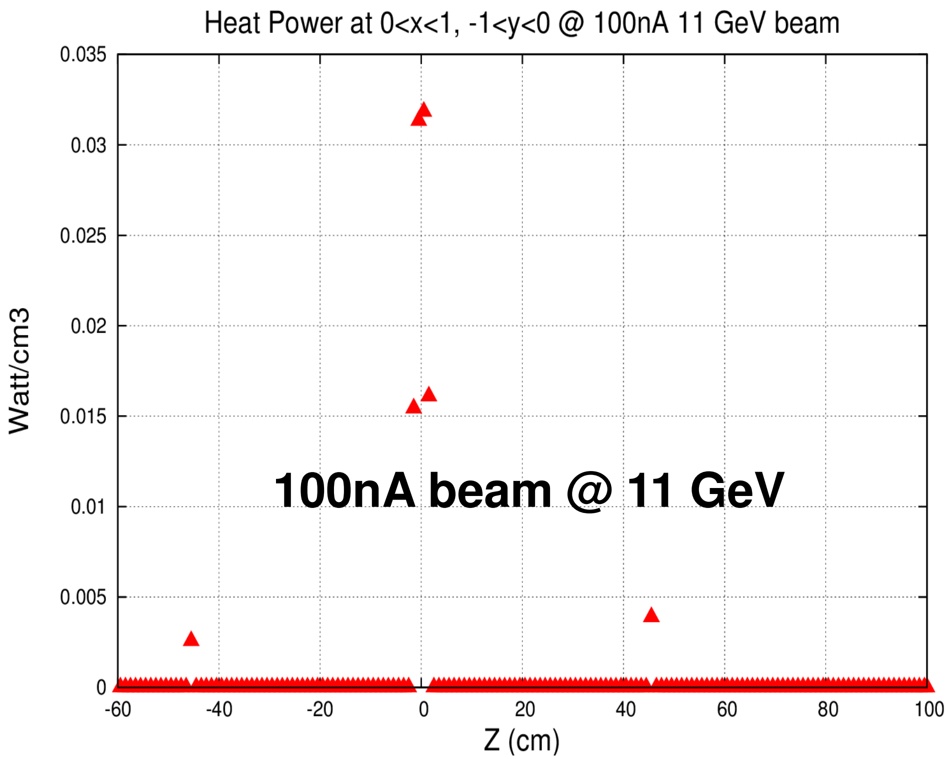
Known target geometry included:
1) target chamber window
2) coils
3) Target a mixture of solid NH3 and liquid He4, 60% packing fraction
4) beam pipe with window (8-10 um)
5) can be rotated

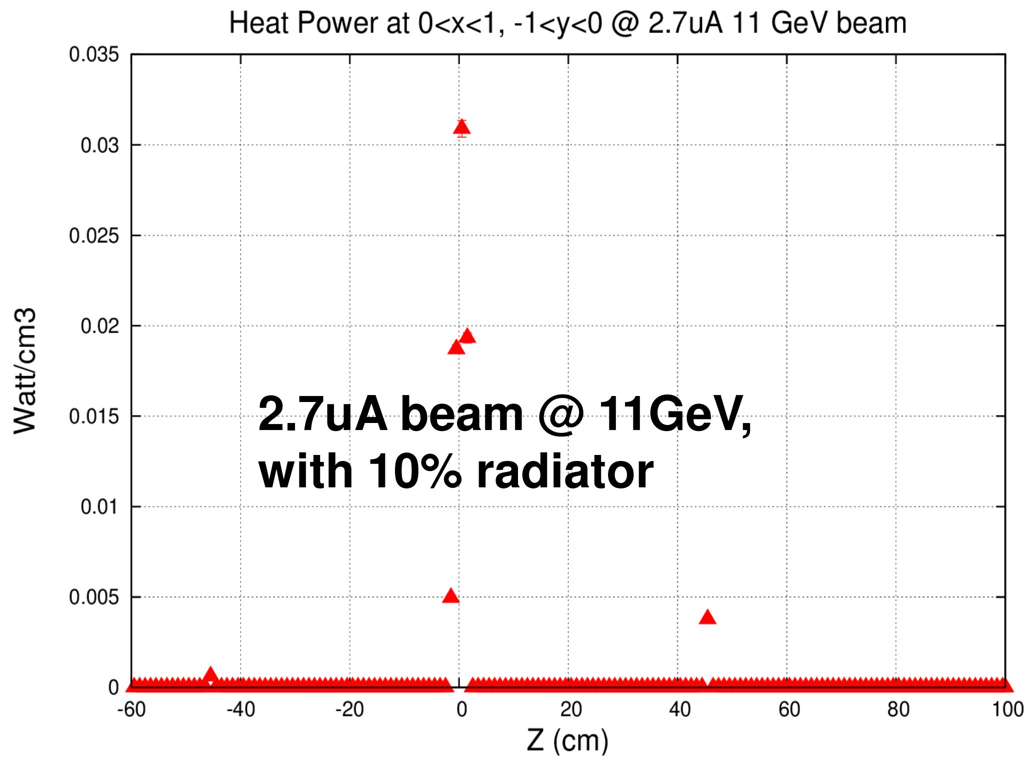
Two simulations have been run:

1) 100 nA e- beam

2) Pure photon beam equivalent in flux to a 2.7uA e- beam on a 10% radiator (CPS conditions). The pure photon beam is “made” using a fictitious strong magnet field and a black-hole to absorb any charged particles coming from the radiator

Heat Load in Target



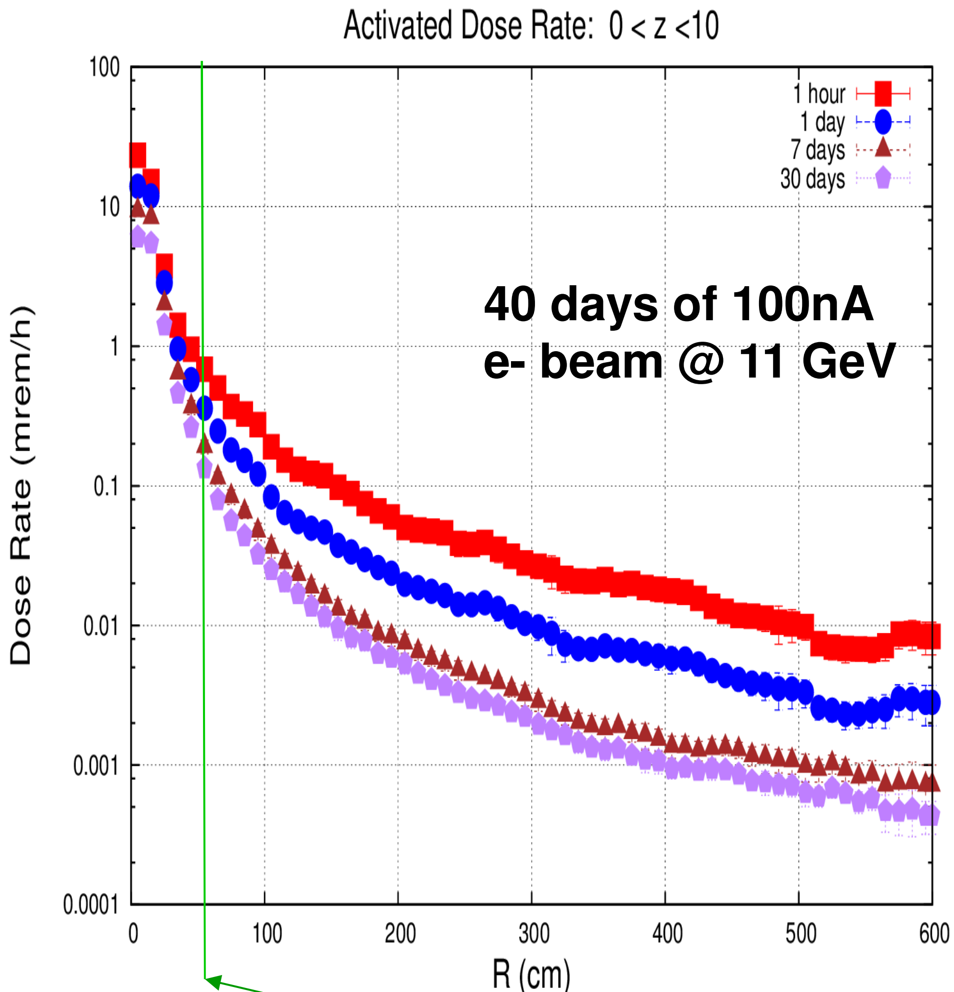


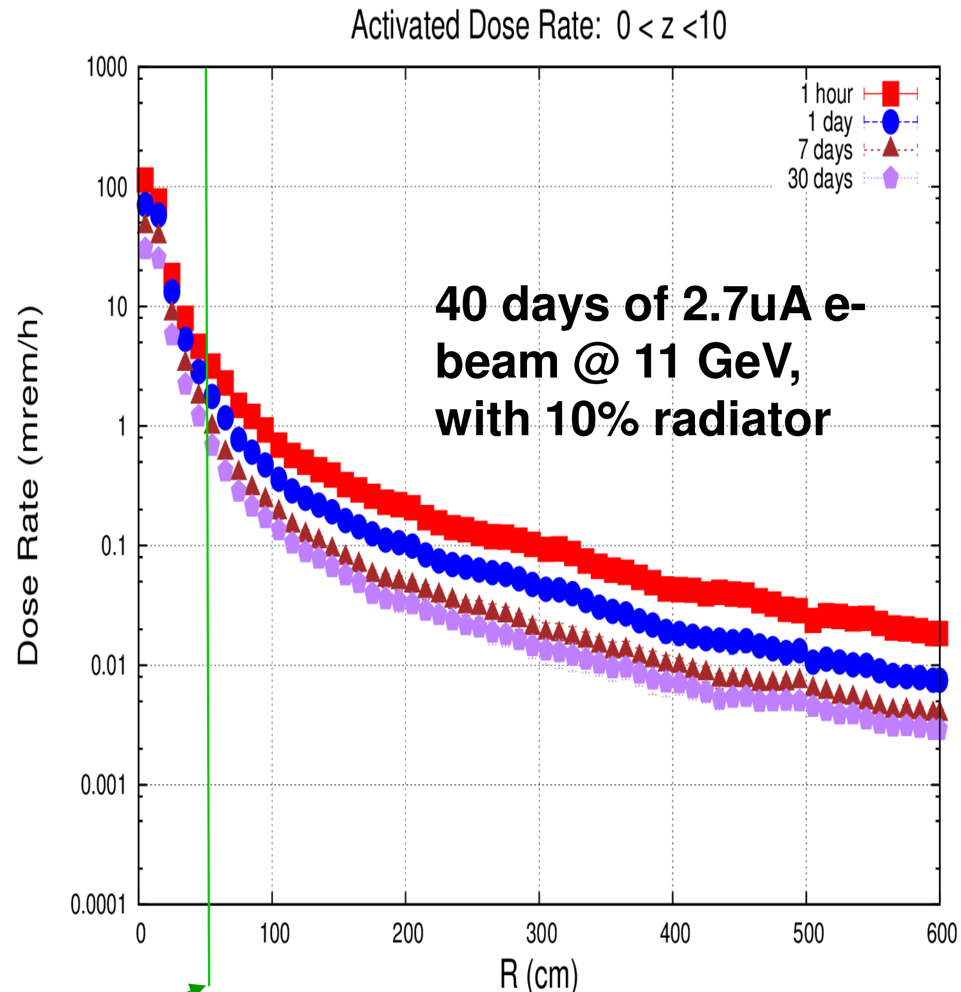
Only with UVA|JLab target

The linear heat density in target is ~0.033 W/cm^2/bin, total heat power is ~0.3W. A Bremsstrahlung photon beam created from 2.7uA 11GeV electron beam on 10% radiator will have equivalent deposited heat power in target.

This was per design: the heat load for the 100 nA electron beam and the photon beam as envisioned with a CPS was to be balanced.

Activated Dose Rates in Target





target chamber boundary

Only with UVA|JLab target

A Bremsstrahlung photon beam created from 2.7uA 11GeV electron beam on 10% radiator will always have more activated dose in the target than a 100 nA electron beam as one has more photons activating.

Summary of electron vs photon beam, only with UVA/JLab Target (no CPS)

1) FLUKA simulation has been performed for UVA|JLab polarized target assuming 11 GeV beam with 10% radiator or 100nA electron beam current for 40 days.

2) The accumulated 1MeV neutron equivalent damage to silicon for area 20cm away from beam pipe is below 10^11 for 100nA electron beam, and below 10^13 for brem. photon beam.

3) Heat load in target is about 0.033 watt per cm^2 and total heat power is about 0.1 watt, for both cases.

4) Dose rate from activation at target chamber boundary: below 1mrem/h for 100nA electron beam, and ~4mrem/h for brem. photon beam.

5) Need shielding behind the radiator to protect beam line equipment.

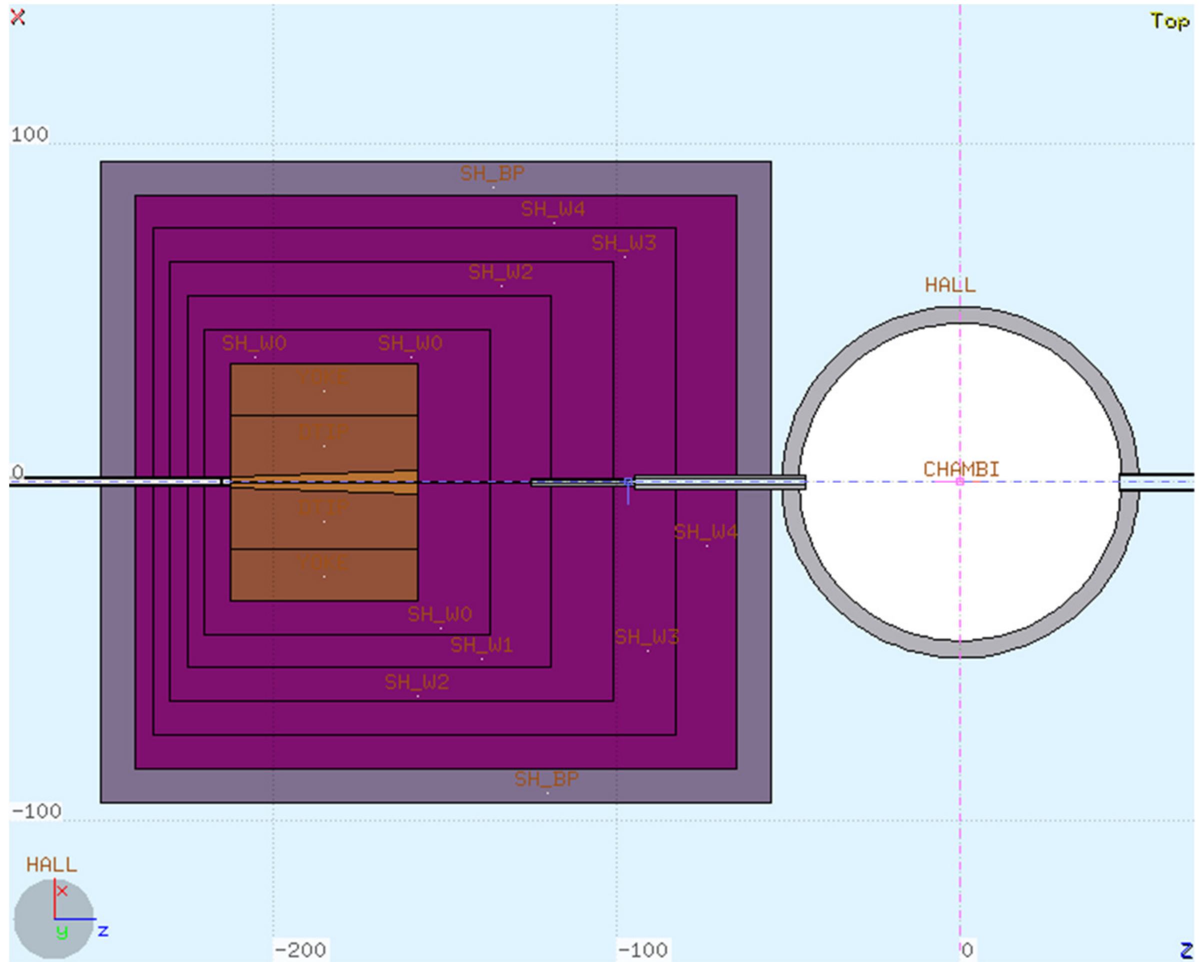
CPS + UVA/JLab Target Geometry: Top View

Some corrections implemented:

1) Add 10 cm thick of borated plastic on each side to reduce neutron flux

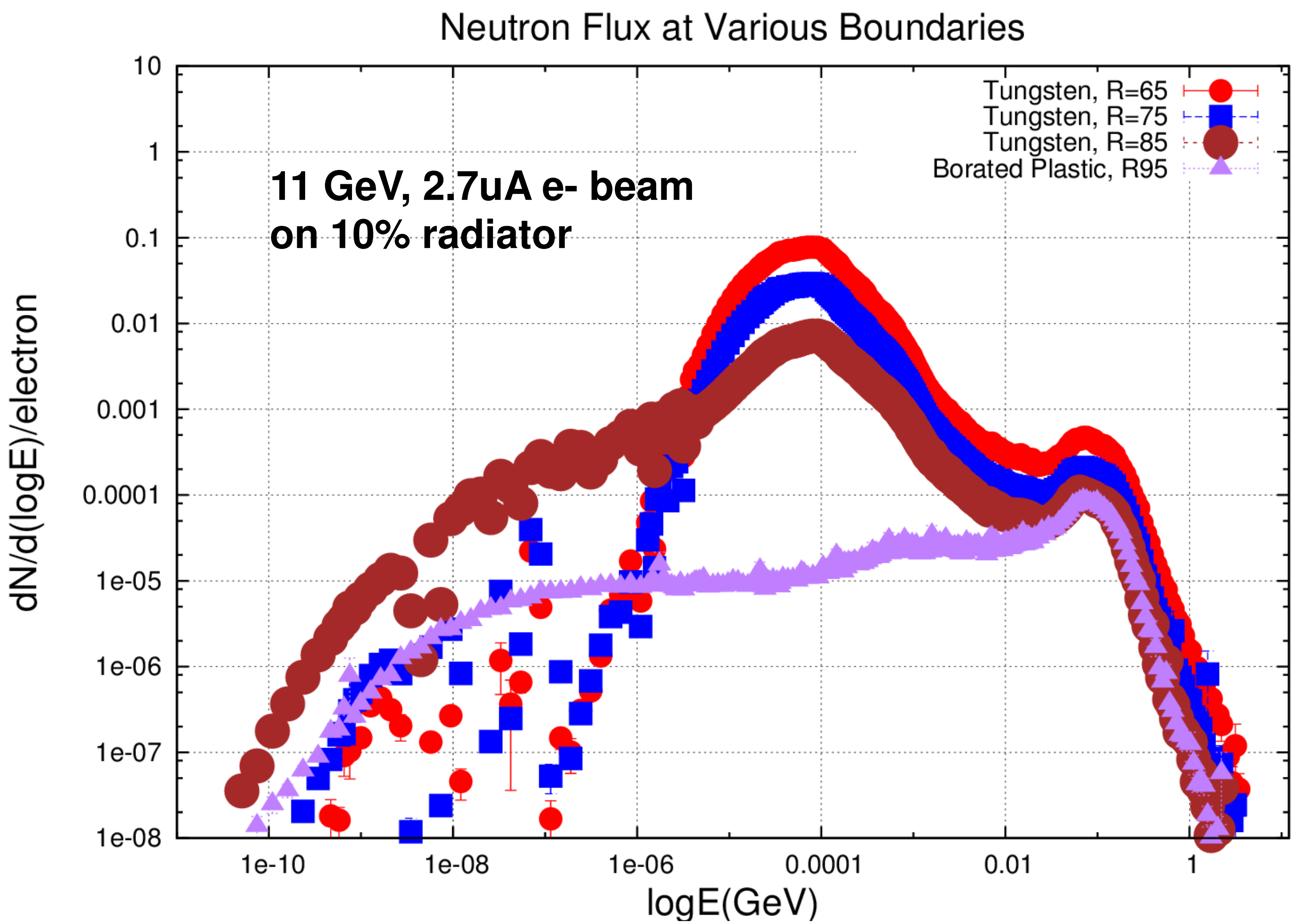
2) The size of target chamber (or the distance of entrance window to target center) was slightly underestimated, also leaving no space for the plastic layer.
→ Move the whole thing **15** cm upstream. Radiator is now at a distance of **215** cm from the target.

3) (with respect to the simulations shown last time: add tungsten-cupper alloy, add beam hole in scattering chamber)



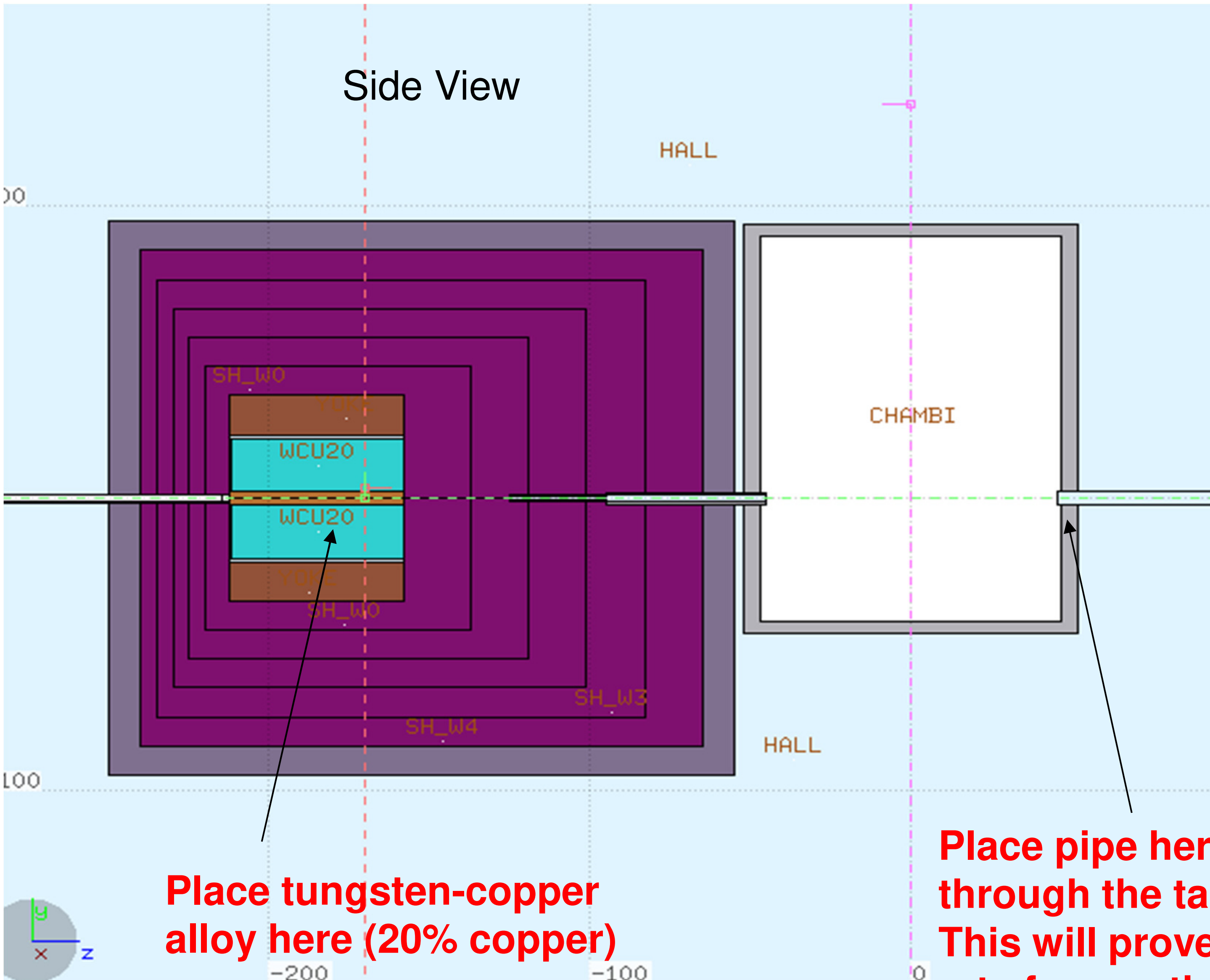
Design assumptions:
Dipole Yoke: (70.5cm x 70.5cm x 54.5cm)
Core: pure copper
Slot: 3mm(width) x 3mm(height)
Shielding: tungsten powder, 16g/cm^3, (5 layers)+ 10cm 30% borated plastic (1 layer). Shielding thickness is 92.75cm, 49.75cm and 27.75cm in downstream, side and upstream direction.
Radiator: 10%, copper, located at z=-215cm
Beam raster: 2mm x 2mm

Neutron Fluence at Various Boundaries



Addition of 10 cm thick 30% borated plastic layer will reduce neutron flux a lot.

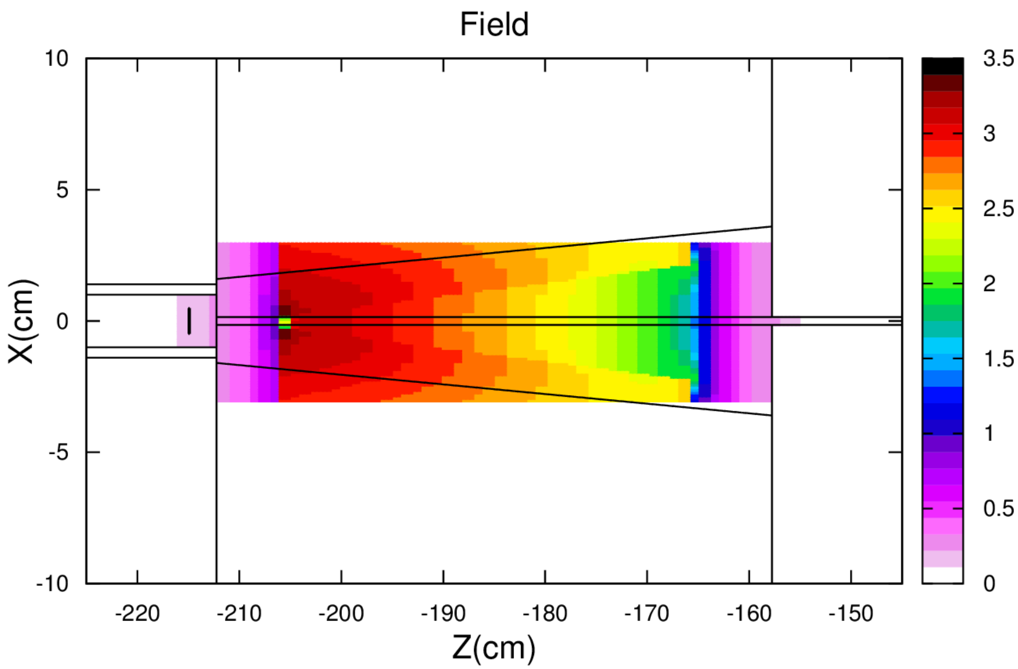
Geometry: What is New?

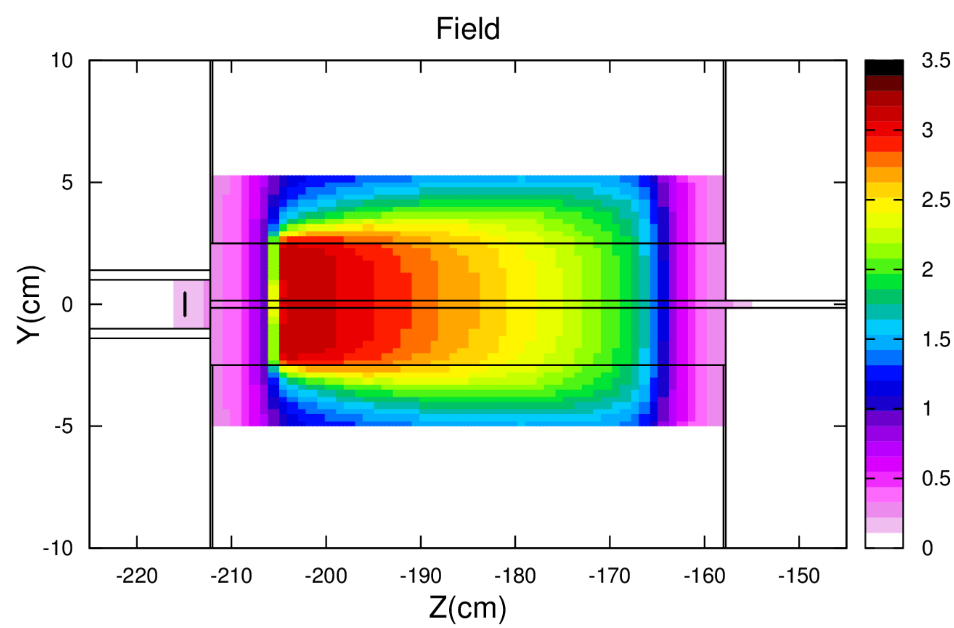


Place tungsten-copper alloy here (20% copper)

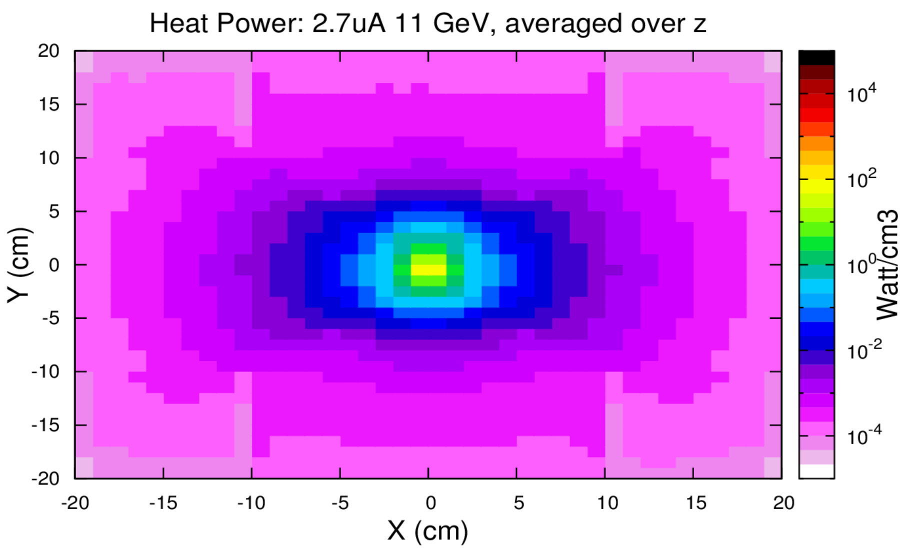
Place pipe here, so photon can go through the target chamber.
This will prove the estimation of dose rate from activation.

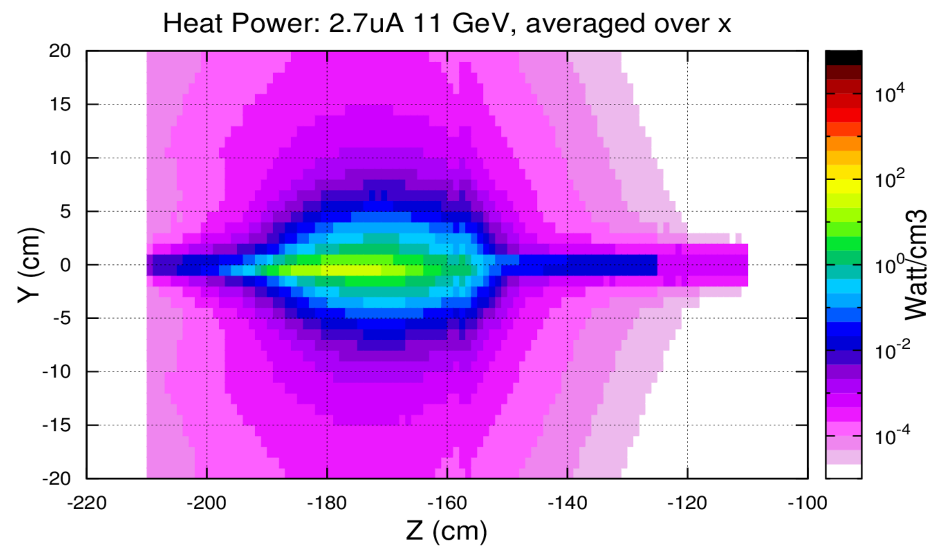
(Tapered) Dipole Field Included in simulations

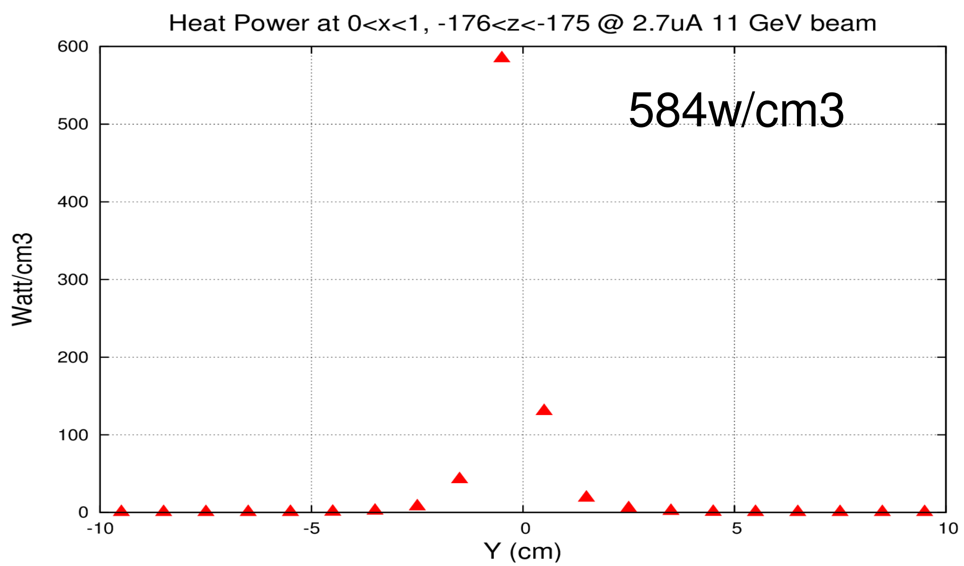


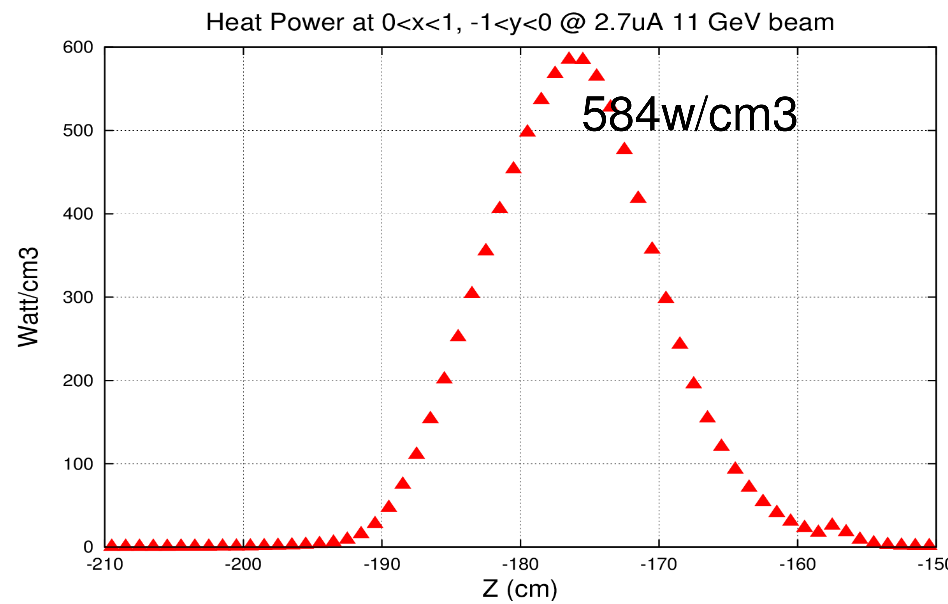


Heat Power, CPS Setup



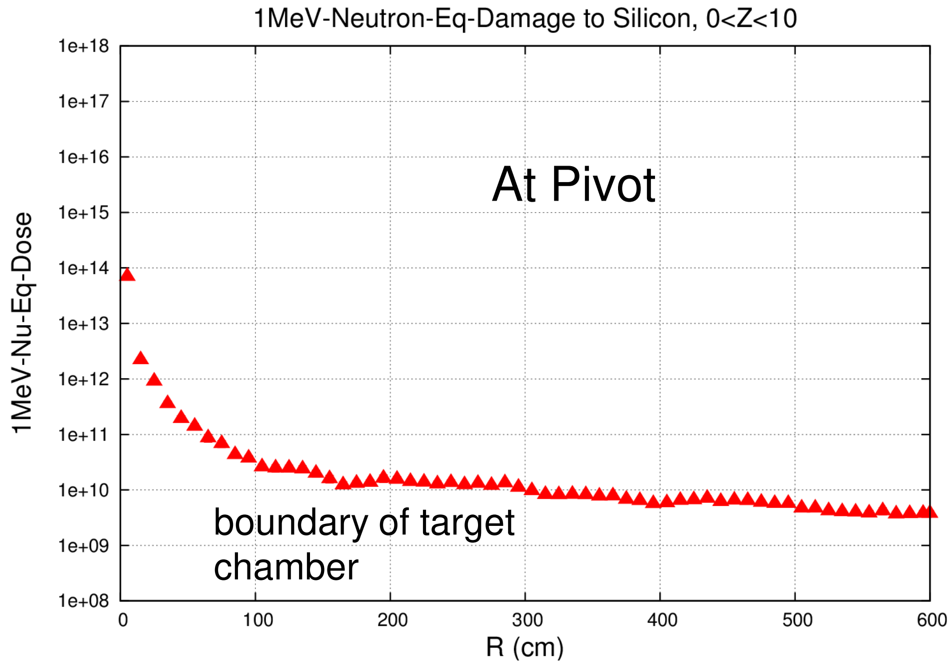


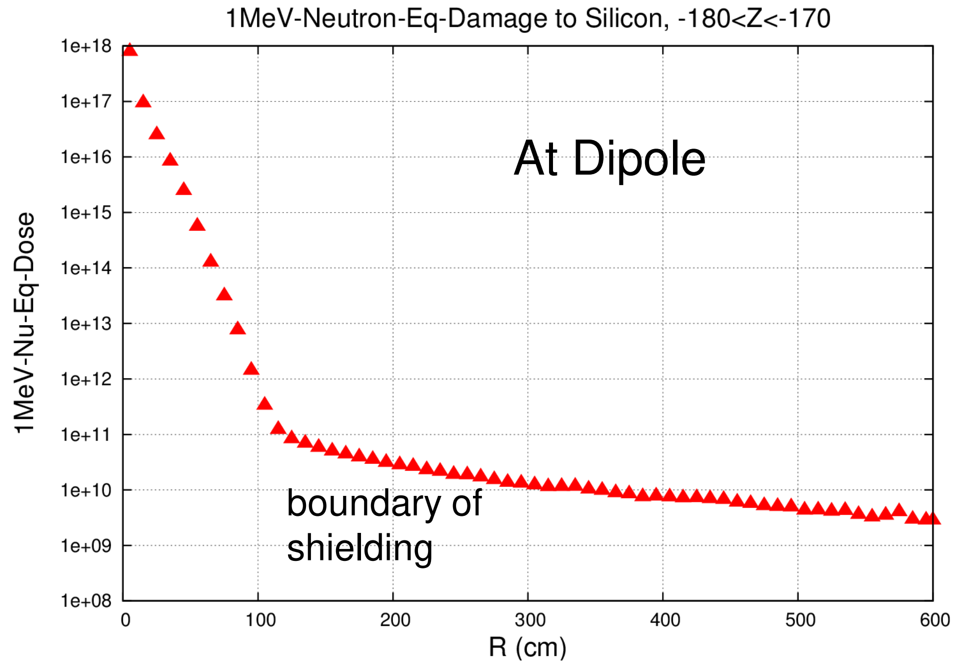


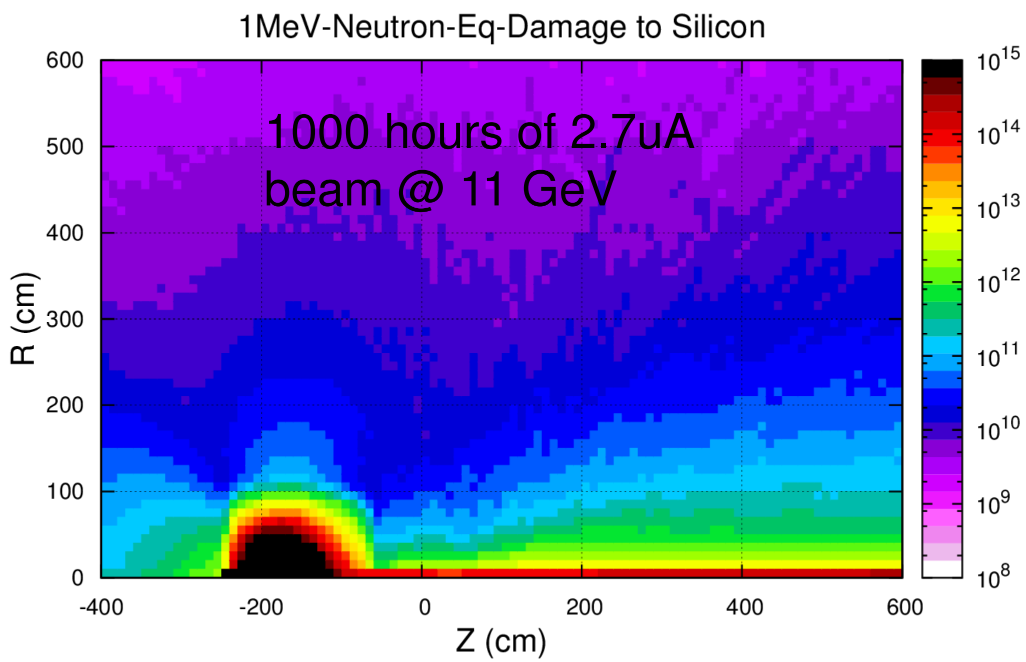


2.7uA beam @ 11 GeV

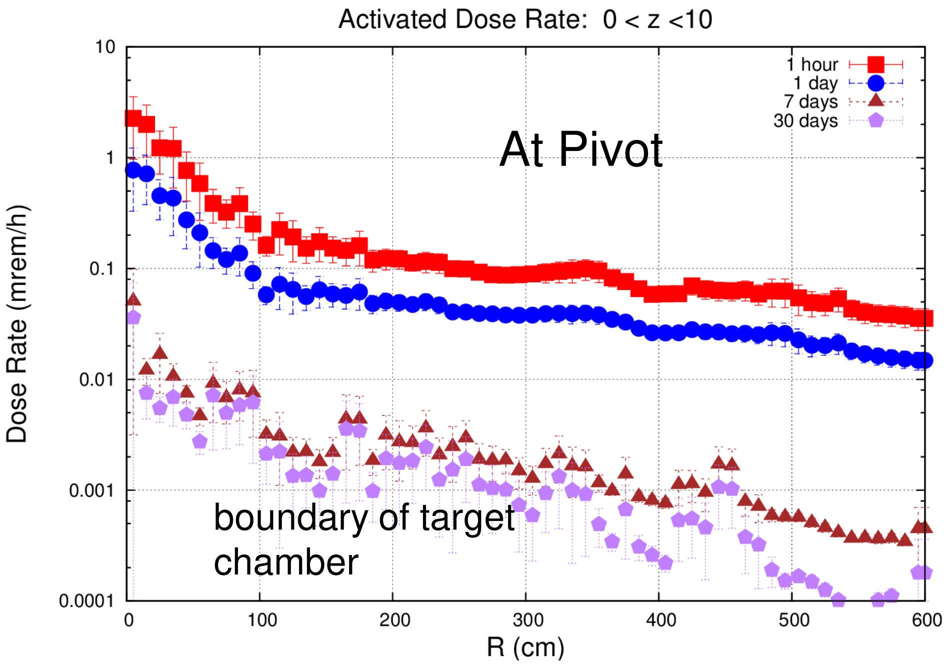
1 MeV Neutron Equivalent Damage

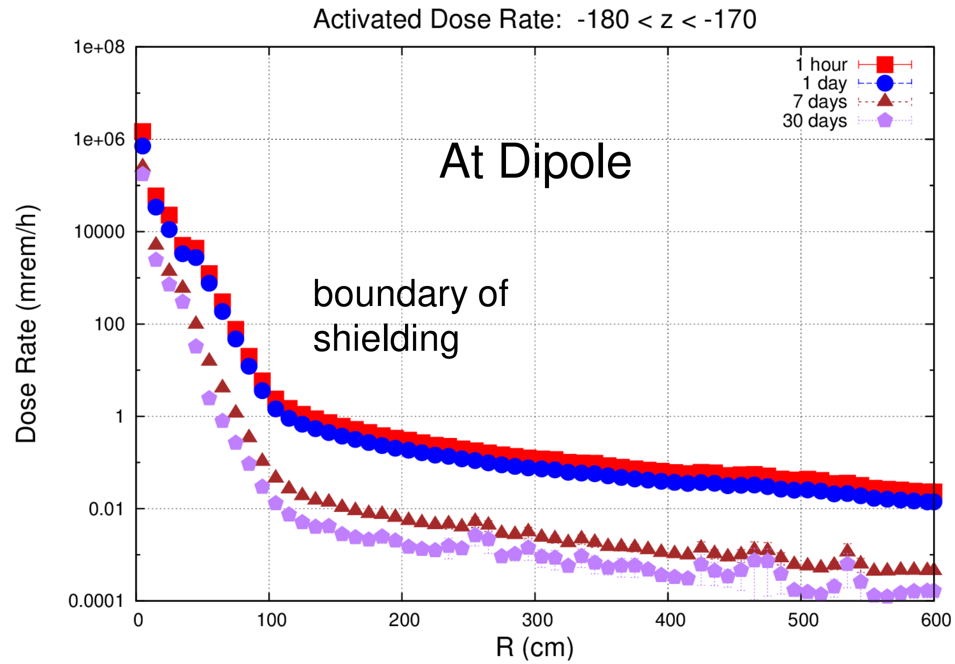




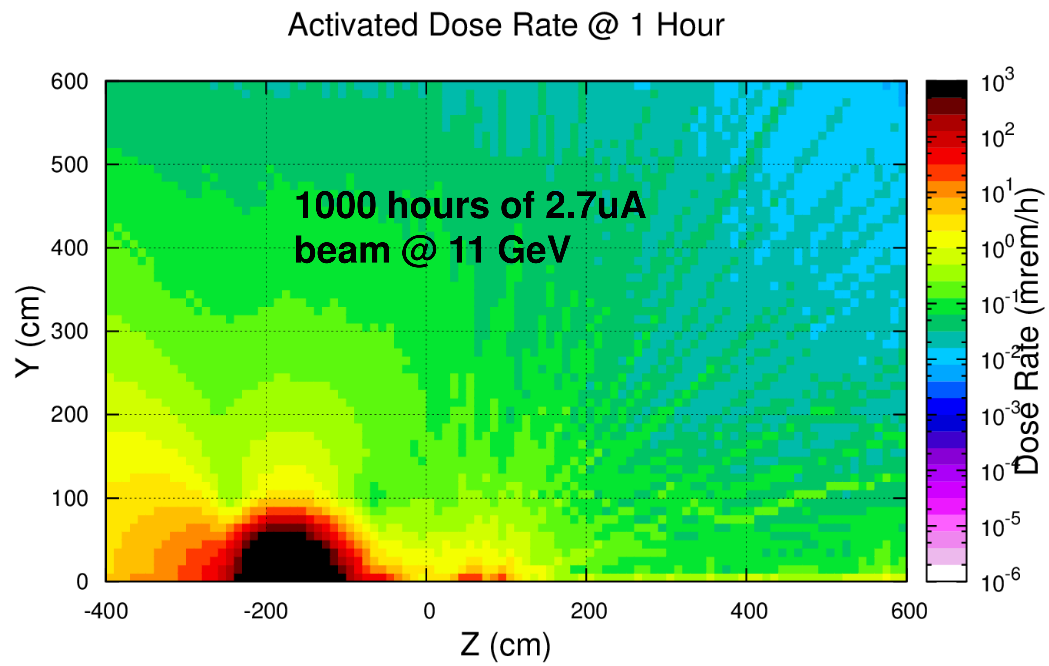


Dose Rate from Activation

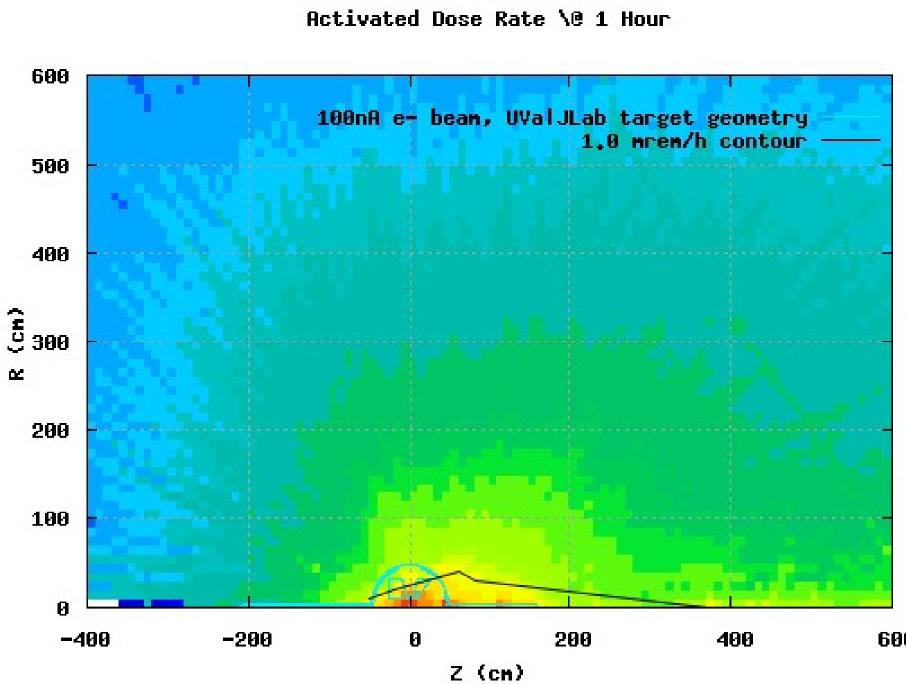


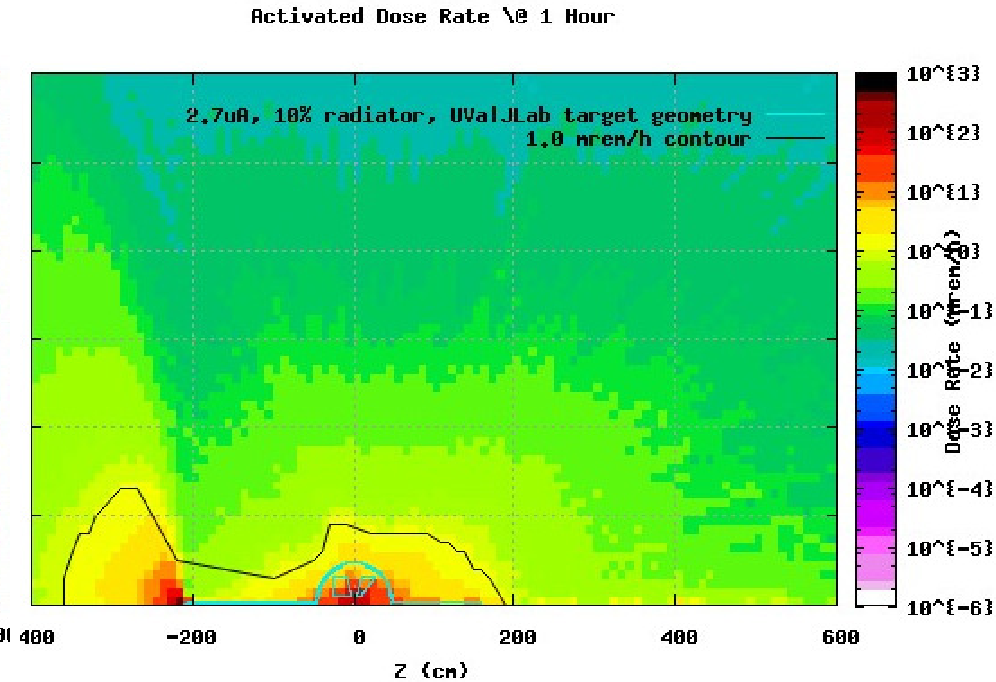


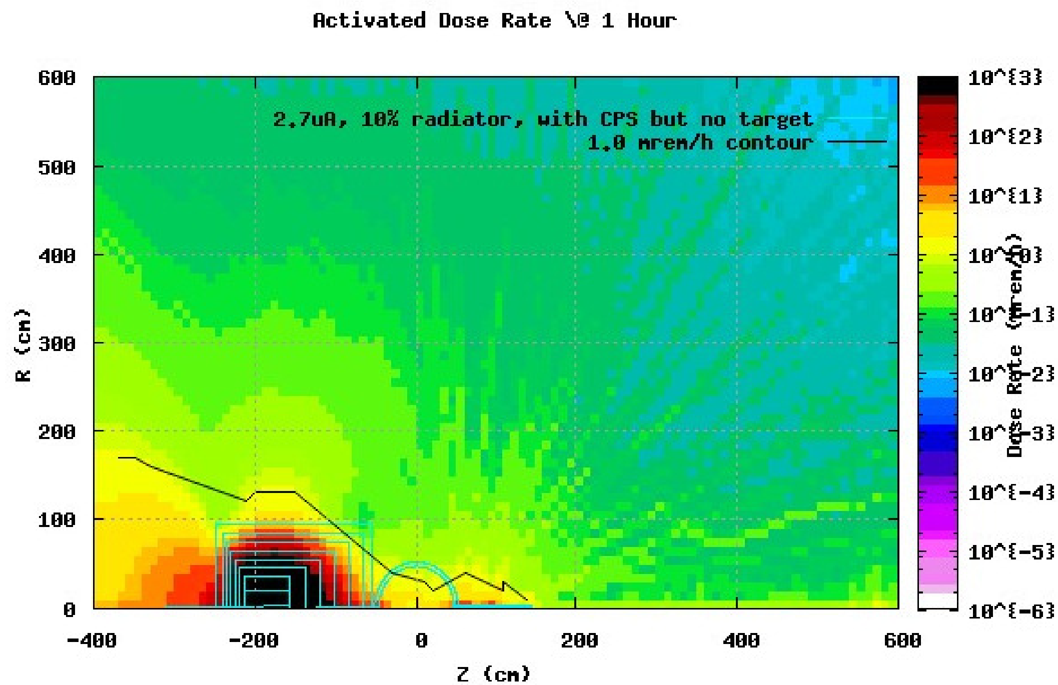
High radiation!!!
Need more shielding in backward CPS



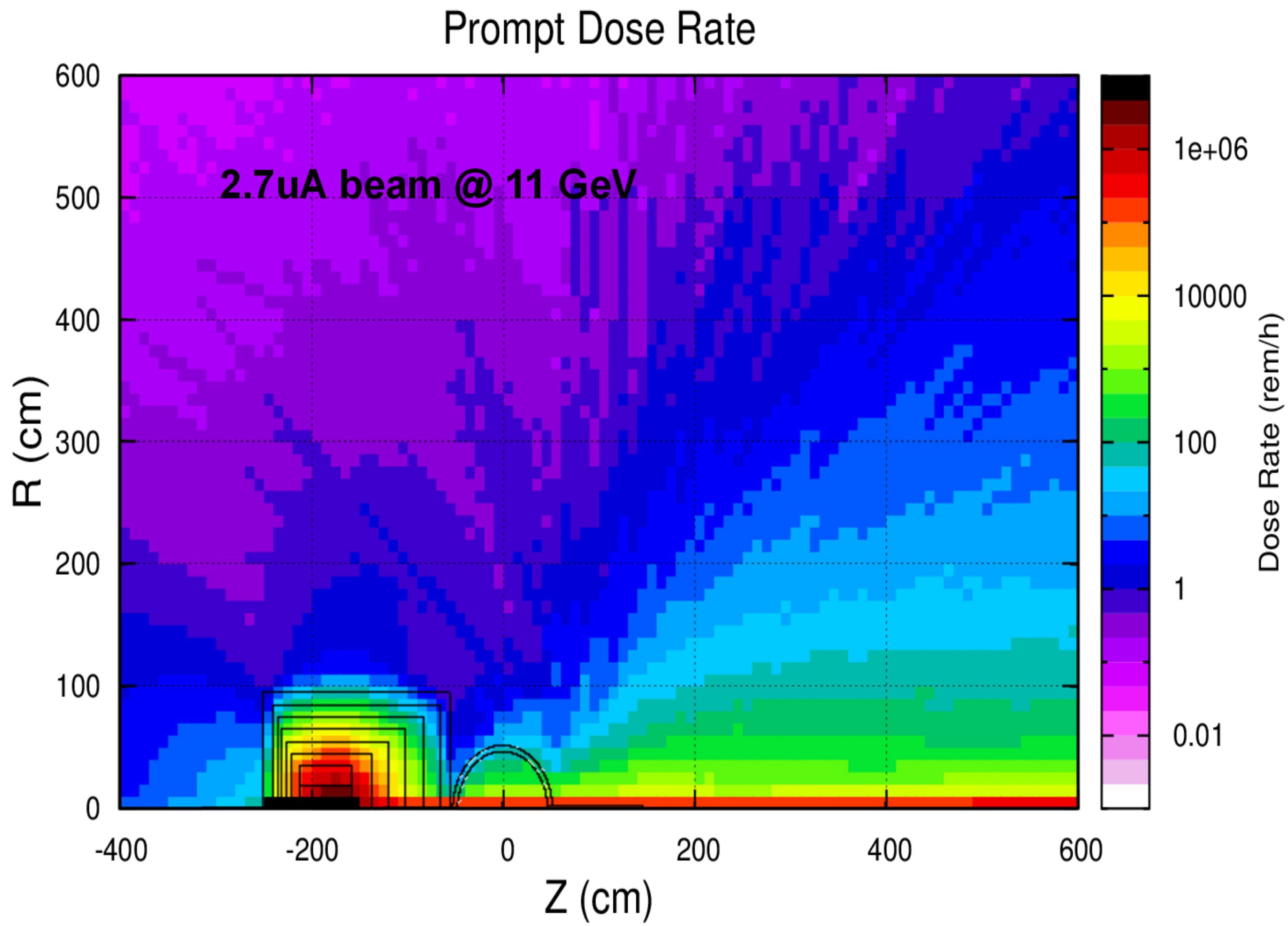
Compare Activated Dose Rate





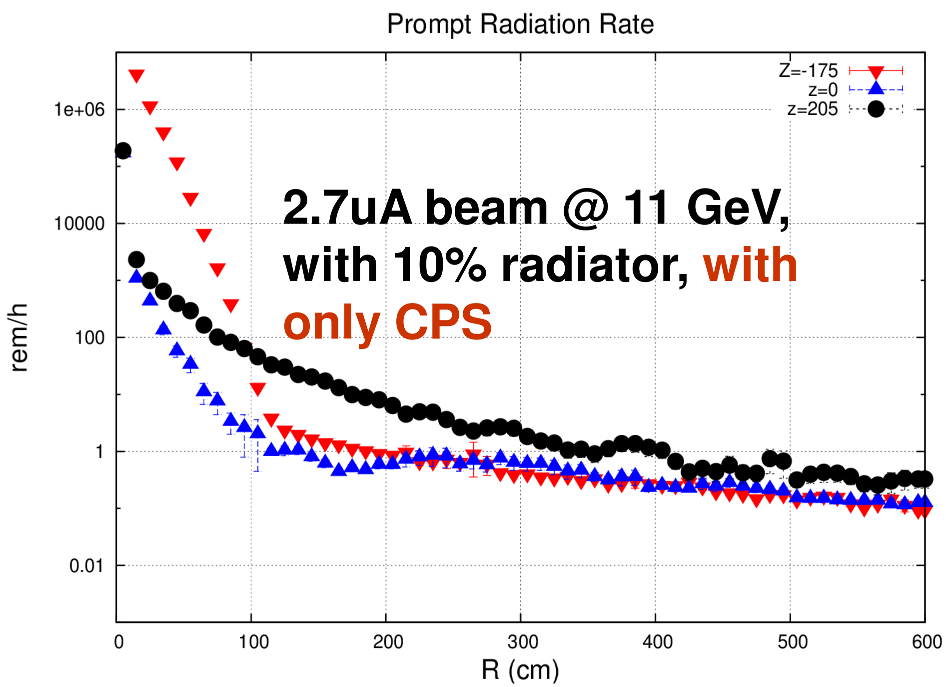


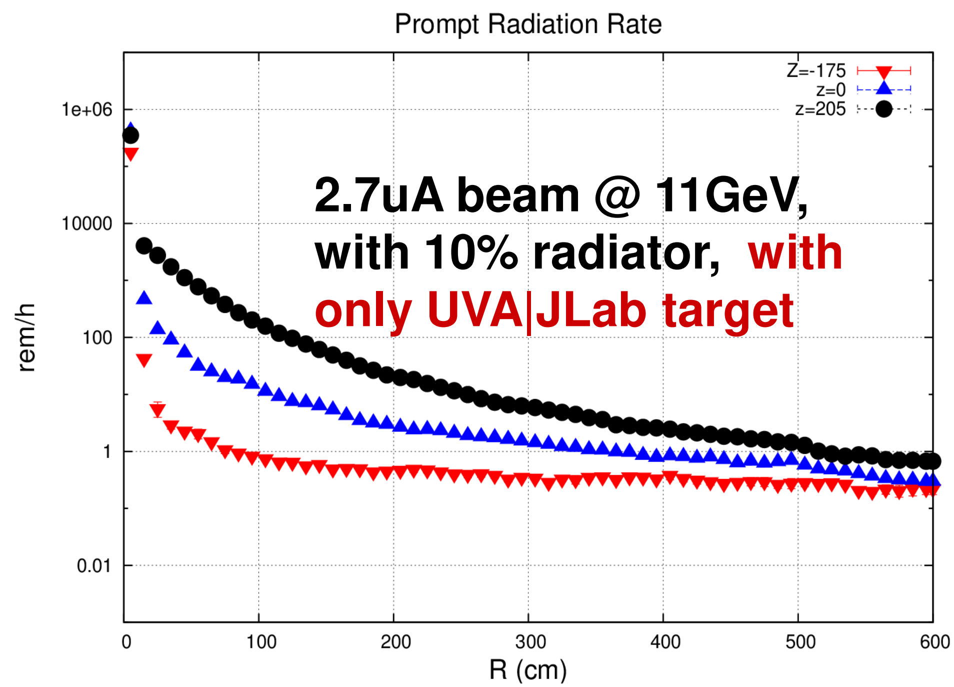
Prompt Dose Rate, CPS setup

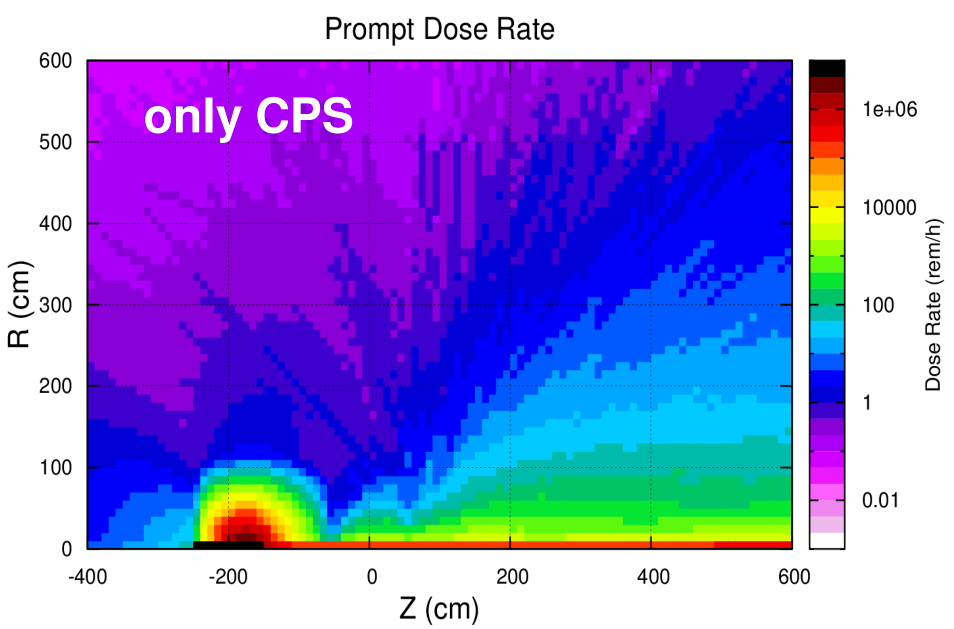


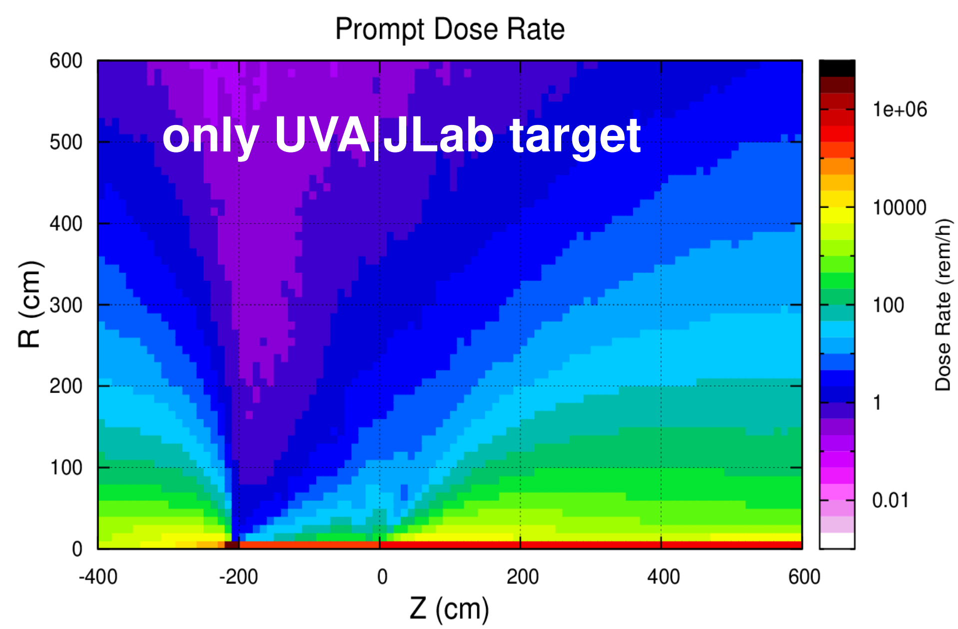
Magnet and shielding target chamber

Compare Prompt Dose Rate

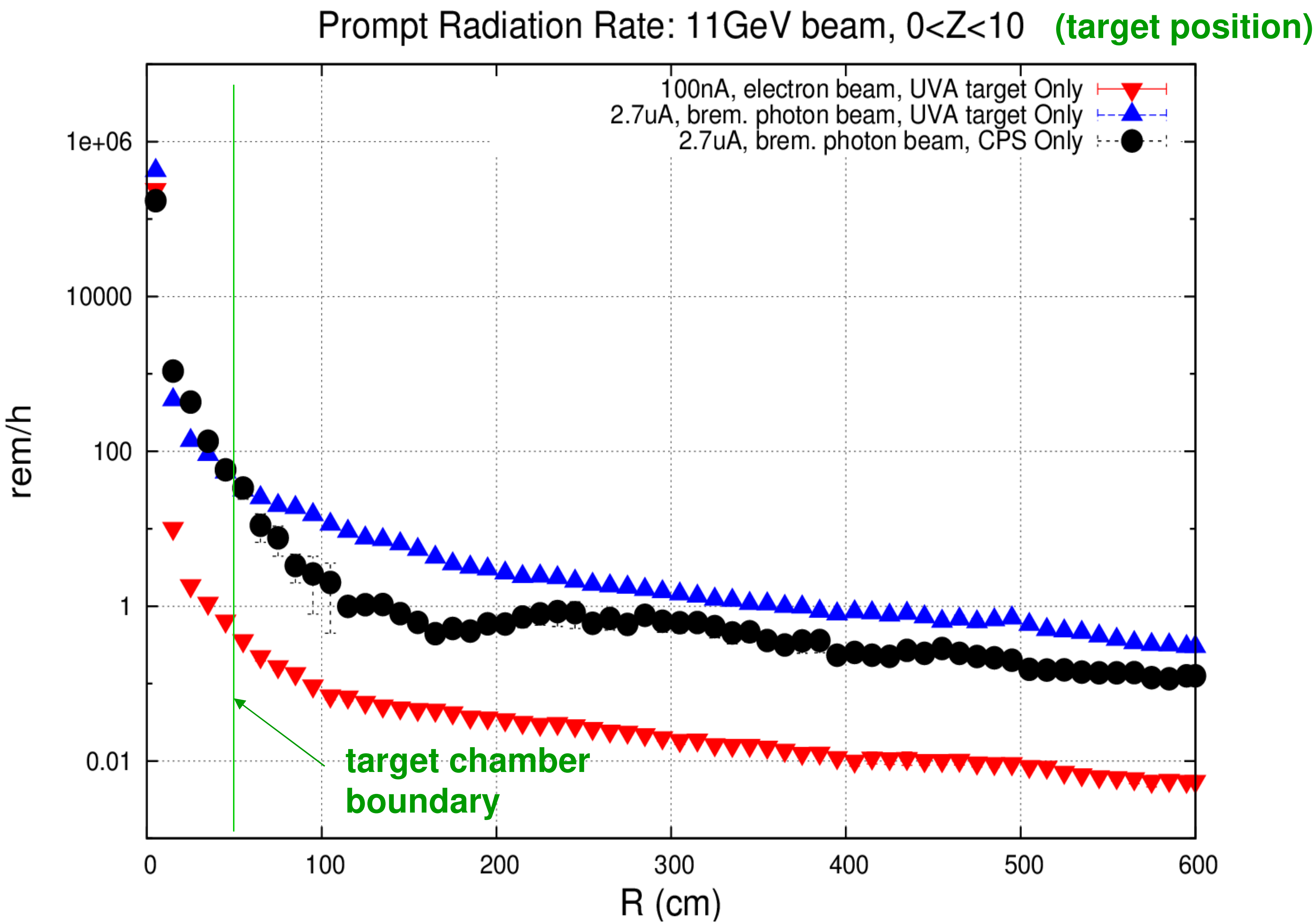








Compare Prompt Dose Rate (II)



Summary

1) FLUKA simulation has been performed assuming 1000 hours of 2.7 uA electron beam at 11.0 GeV. In this setup, the distance from the pivot to the 10% radiator is 215 cm. *The core is made of pure copper. Tungsten-Copper(20%) alloy is filled in between the coils. UVA/JLab target and beam pipe is added in downstream of the target chamber to properly simulate the activation.*

2) For CPS setup, the maximum heat density in the core is ~584 watt/cm^3, located at z=-176 cm (magnet center is at z=-185cm).

3) 10 cm borated plastic shielding is very helpful to reduce neutron flux.

4) After 1000 hours, the accumulated 1-MeV-Nu damage to silicon at pivot (z=0) is less than 10^12 at 20cm away from beam line. Outside the borated plastic layer is several 10^11.

5) Dose rate from activation after 1 hour the beam is shut down: at the target chamber boundary is ~1 mrem/h, at 1.0m away from the dipole is ~6 mrem/h. Need more shielding in upstream of the radiator!

6) The indirect effect of the CPS on the pivot area is small as compared to the direct activation associated with a pure photon beam ♦♒♋♦ CPS design concept is maturing!