Solid and Gas Photon Dump

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Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

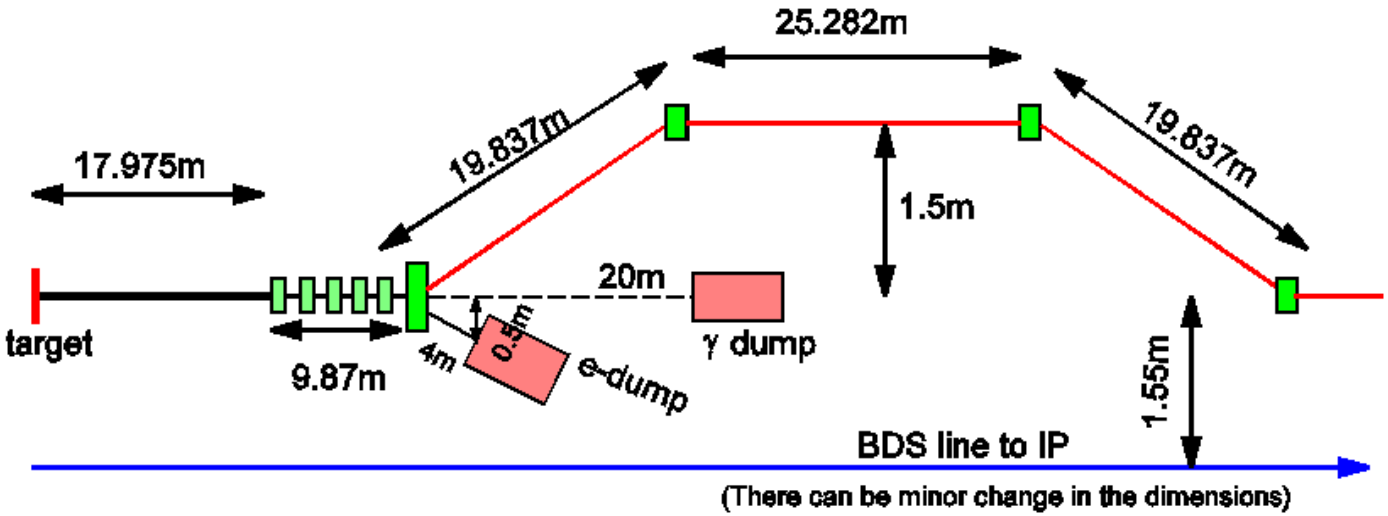
LINEAR COLLIDER COLLABORATION

DESY

Outline

- Considered photon dumps:
  1. Graphite dump at 48 m from e^+ target.
  2. Graphite dump at 1000 m from e^+ target.
  3. Dump starting at 48 m from e^+ target with 60 m 5 atm Ar and 2 m graphite.
  4. Dump starting at 48 m from e^+ target with 300 m 5 atm Ar and Cu- or Al- backstops.
- Radiation levels in “hottest” area of Cu-pipe with 5 atm Ar-gas:
  - during source operation;
  - after beam switched off and different cooling times (residual activity).

Location of Dump and Beam Parameters



Photons:

- 250 GeV e-, 2625 bunches/pulse, K = 0.45, 147 m undulator.
- $\langle P_{ph} \rangle = 86$ kW, 0.961 ms pulse, 5 Hz (366 ns bunch spacing).
- 500 meters distance from middle of undulator to positron target.
- $\approx$48 meters distance from target to photon dump.

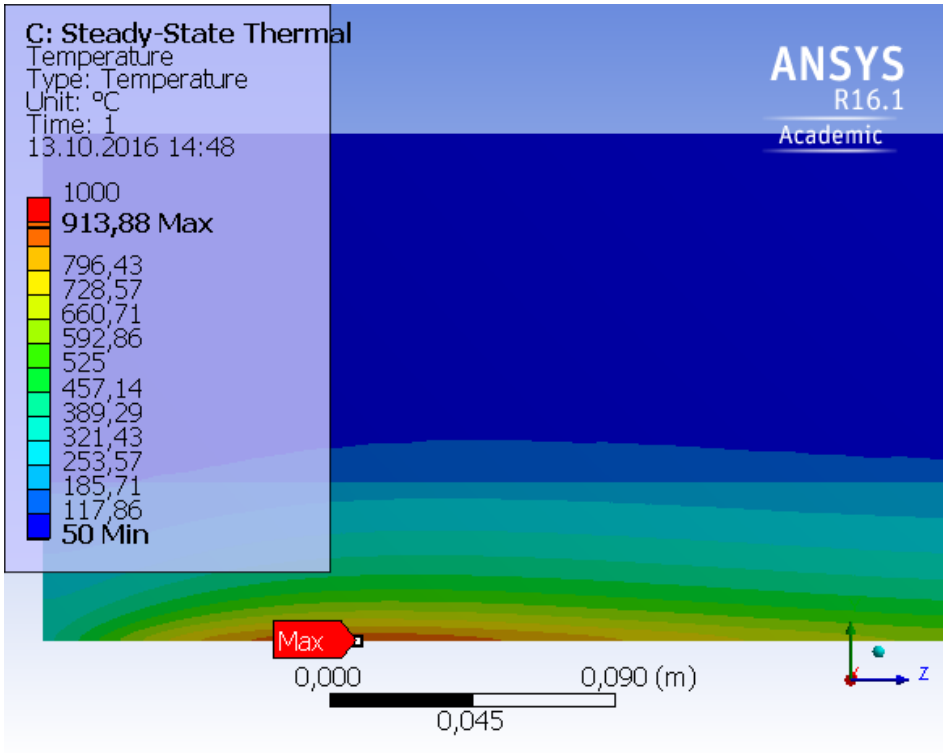
Power, Temperature, Rad. Damage of Photon Dump

	Close&Short Dump	Far&Short Dump	Close&Long Dump	
Distance to target	48 m	1000 m	48 m	
Material and Length of Absorber 1	2 m Graphite		60 m 5 atm Ar	300 m 5 atm Ar
Peak Energy Deposition	820 J/g	220 J/g	32 J/g	
Max. ΔT_{pulse}	350 °C	100 °C	62 °C	
Max. Stress or Pressure per Pulse	43 MPa	12.8 MPa	1 atm	
Max. Average T - $T_{cooling\ water}$	950 °C	870 °C	70 °C	
Max. dpa/5000h	16 dpa	3.4 dpa	–	
Material and Length of Absorber 2	–		2 m Graphite	–
Peak Energy Deposition	–		210 J/g	–
Max. ΔT_{pulse}	–		190 °C	–
Max. Stress or Pressure per Pulse	–		23.4 MPa	–
Max. Average T - $T_{cooling\ water}$	–		191 °C	–
Max. dpa/5000h	–		$\sim$ 4 dpa	–
Material and Length of Backstop	–		15 cm Cu	
Peak Energy Deposition	–		8 J/g	5.4 J/g
Max. ΔT_{pulse}	–		20 °C	13.3 °C
Max. Stress or Pressure per Pulse	–		65.8 MPa	43.5 MPa
Max. Average T - $T_{cooling\ water}$	–		3.4 °C	2.7 °C
Max. dpa/5000h	–		$\sim$ 0.5 dpa	$\sim$ 0.3 dpa

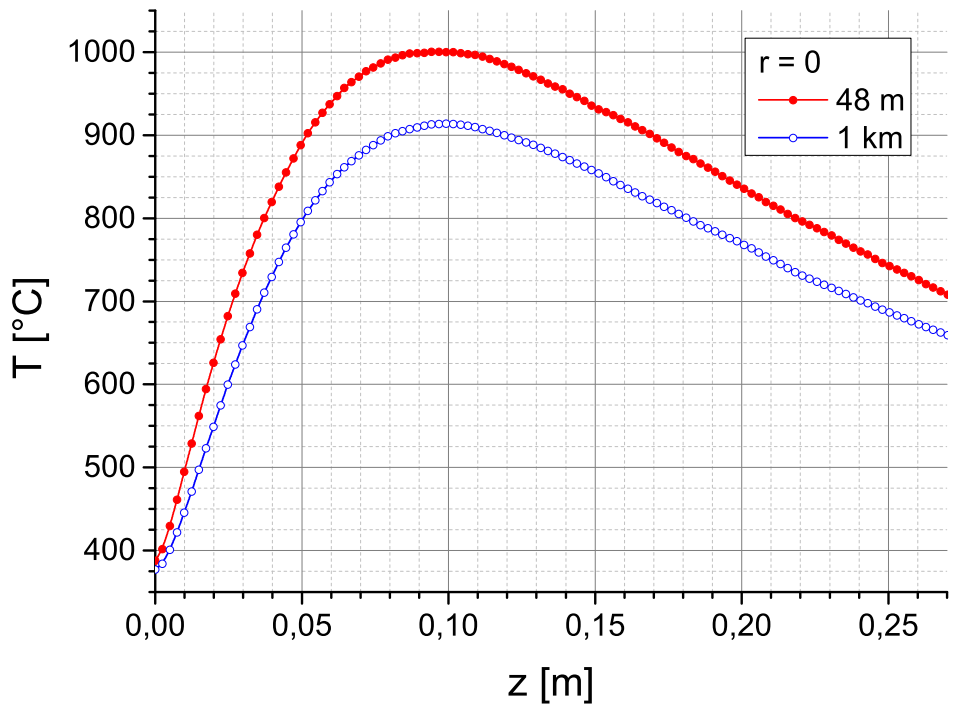
Average Temperature in Close and Far Graphite Dump

86 kW heating power (cw)

Graphite Dump at 1 km from Target



Long. Profiles of Temperature on Beam Axis



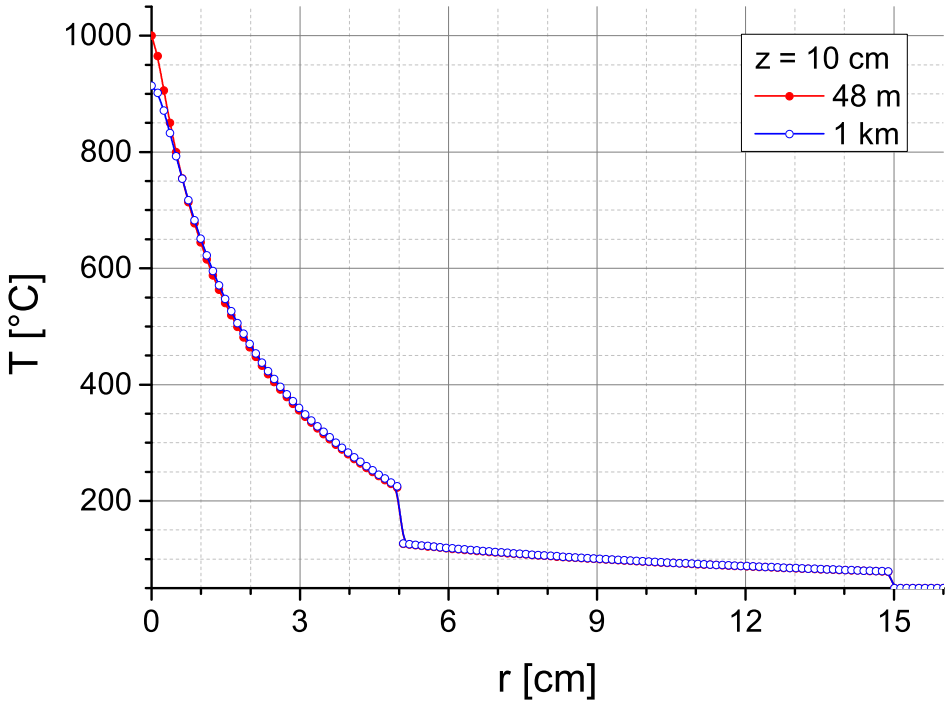
Graphite radius = 5 cm

Wall thickness of Cu-pipe = 10 cm

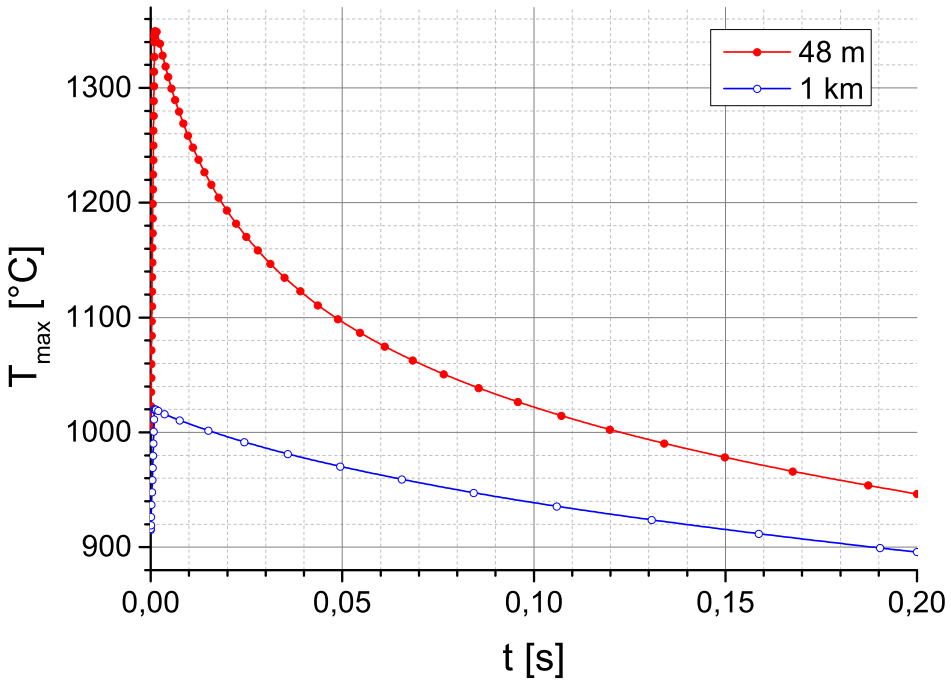
Temperature of cooling water = 50 °C

Radial Temperature Profile and One Thermal Cycle

Radial Profiles of Average T

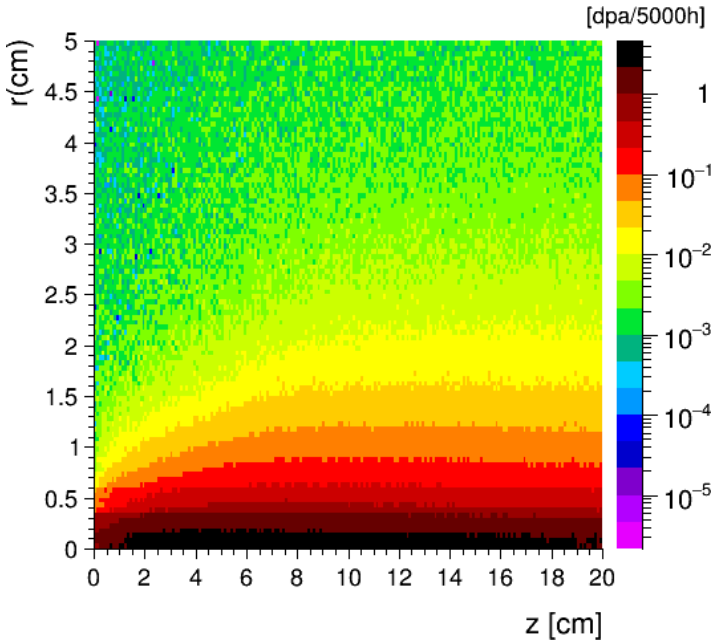


One Cycle (Av. T + Pulse)

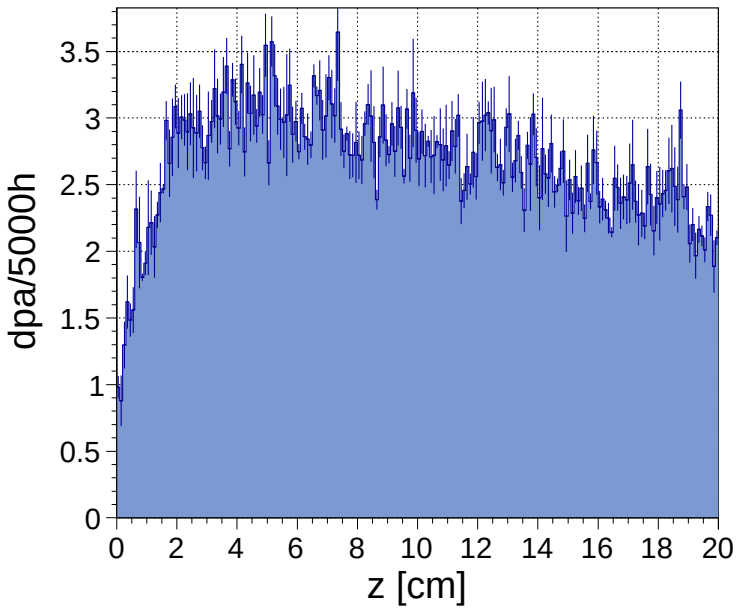


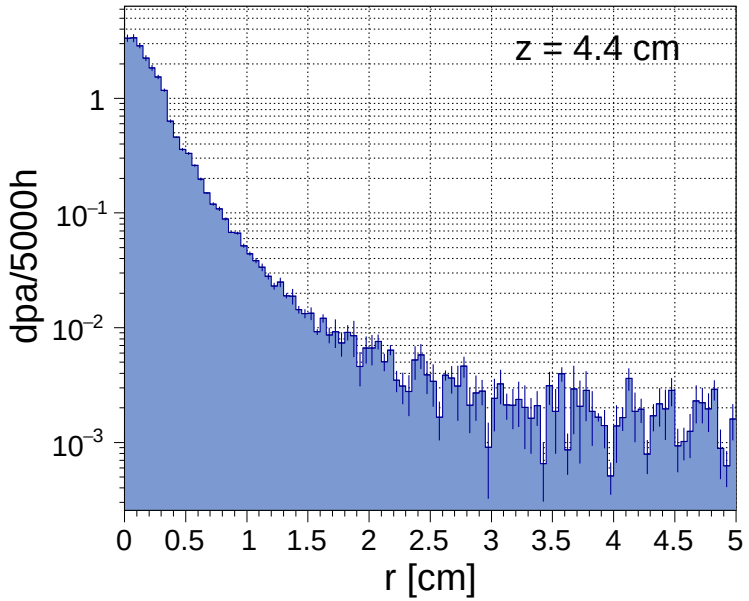
Relocation of graphite dump 1 km downstream reduces ΔT_{pulse} to acceptable level, but average temperature $\langle T \rangle$ is too high.

Radiation Damage of Graphite at 1 km from Target

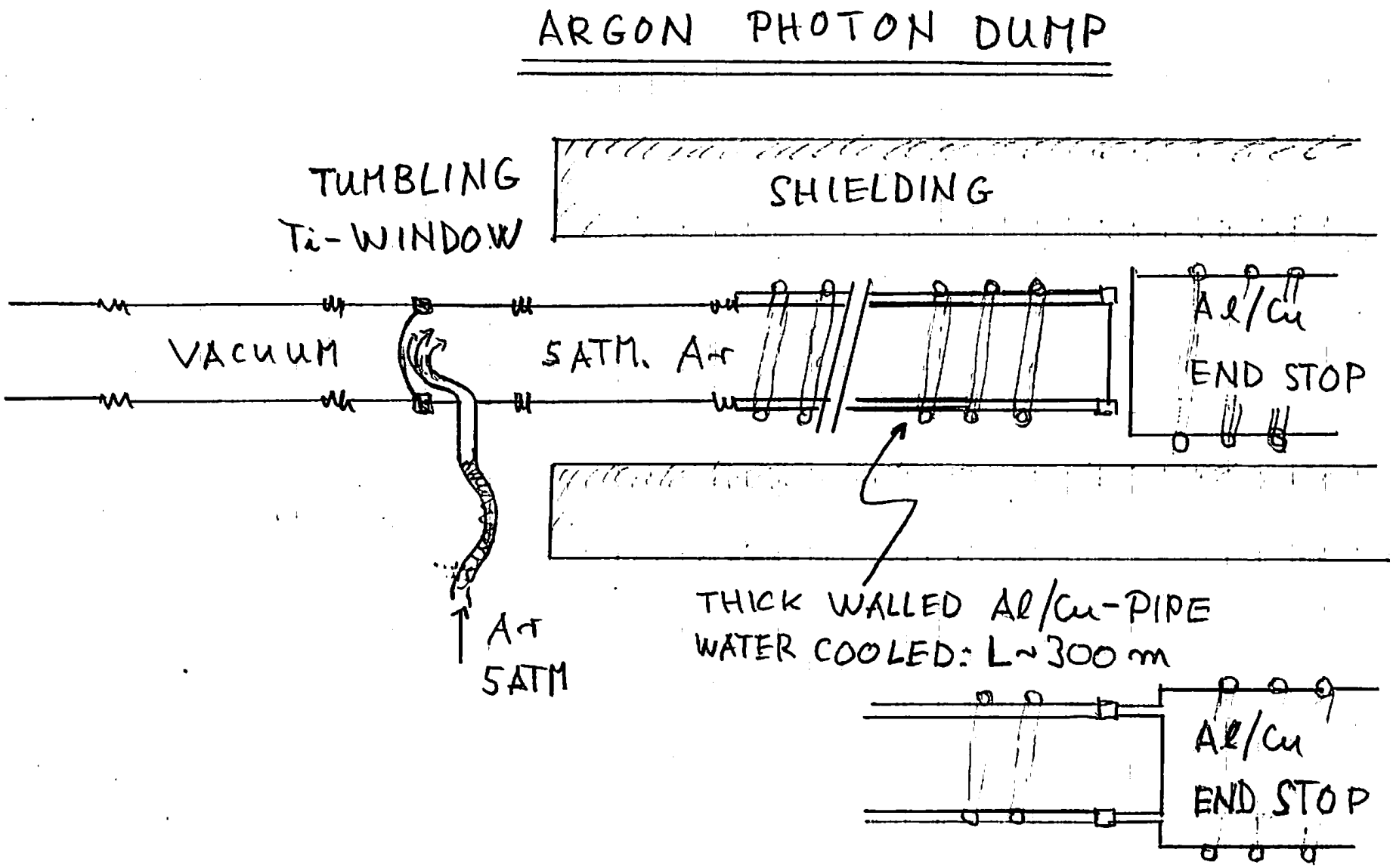


Peak damage: $\approx$3.4 dpa after 5000 hours of irradiation



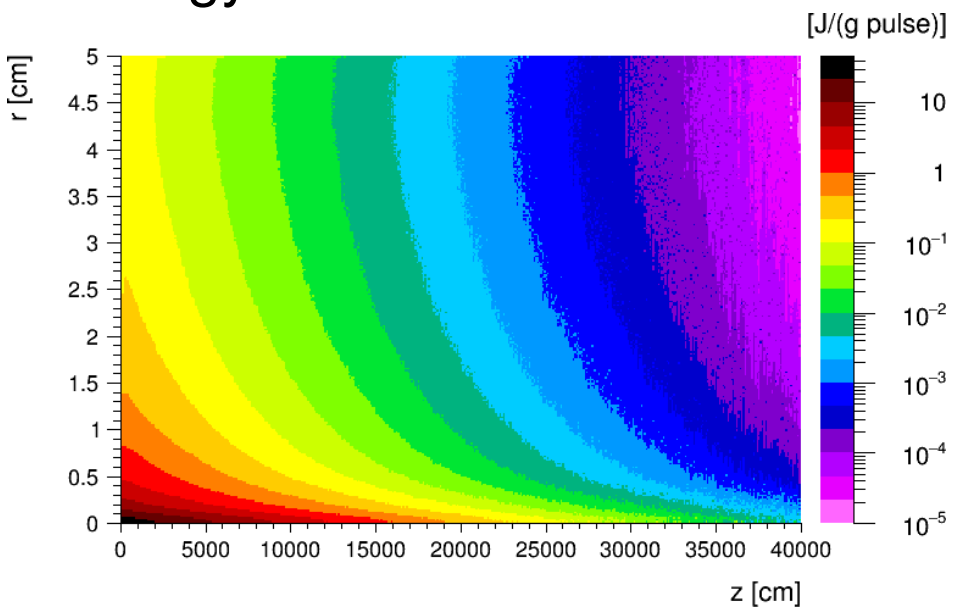


Sketch of Ar-Gas Dump

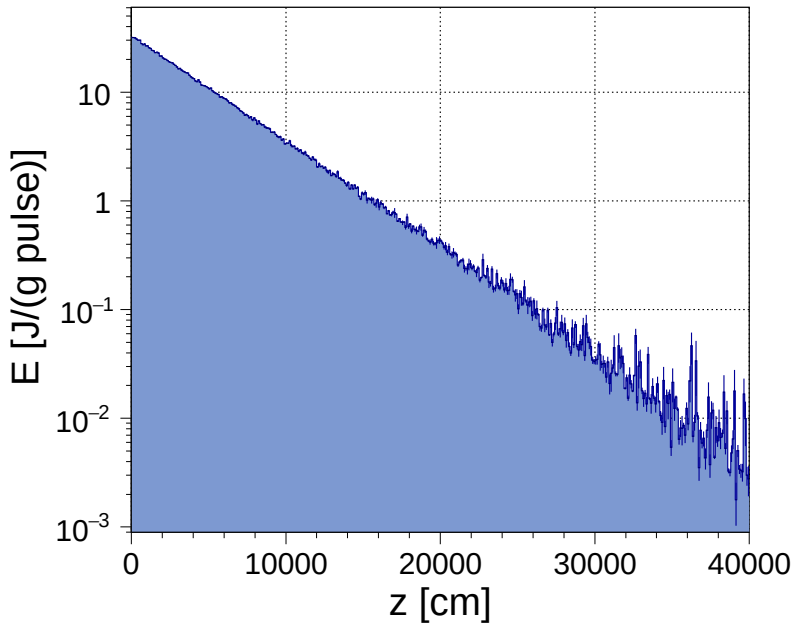


Energy Deposition in 5 atm Ar-Gas

Energy Distribution in 400 m Ar



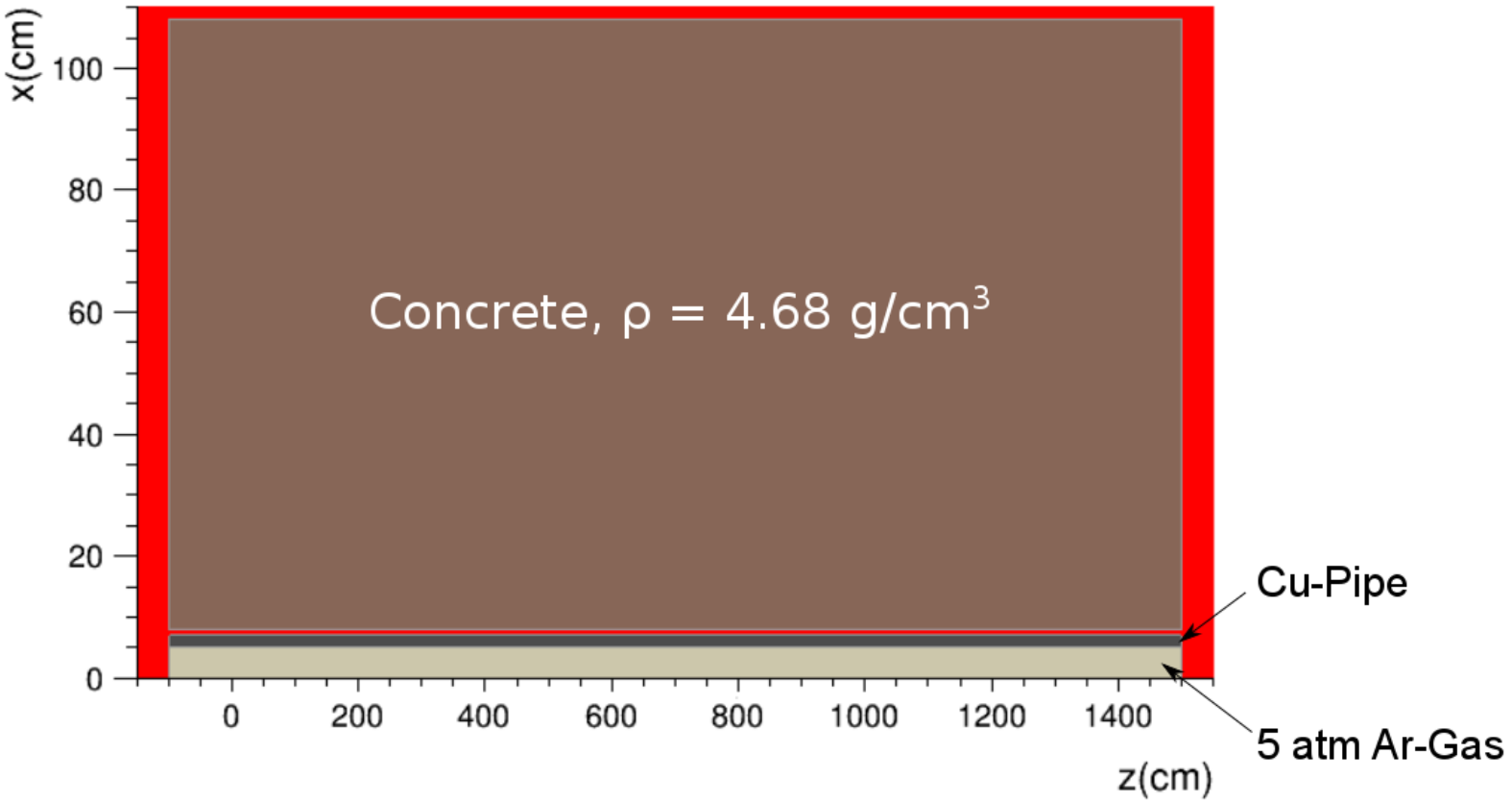
Long. Energy Deposition Profile



- 60 m 5 atm Ar reduces energy deposition density $\sim$ 4 times
- 300 m 5 atm Ar reduces energy deposition density $\sim$ 1000 times

What **thickness of concrete shielding** has to be used around dump pipe at hottest first few meters of the dump?

FLUKA Geometry of Shielding

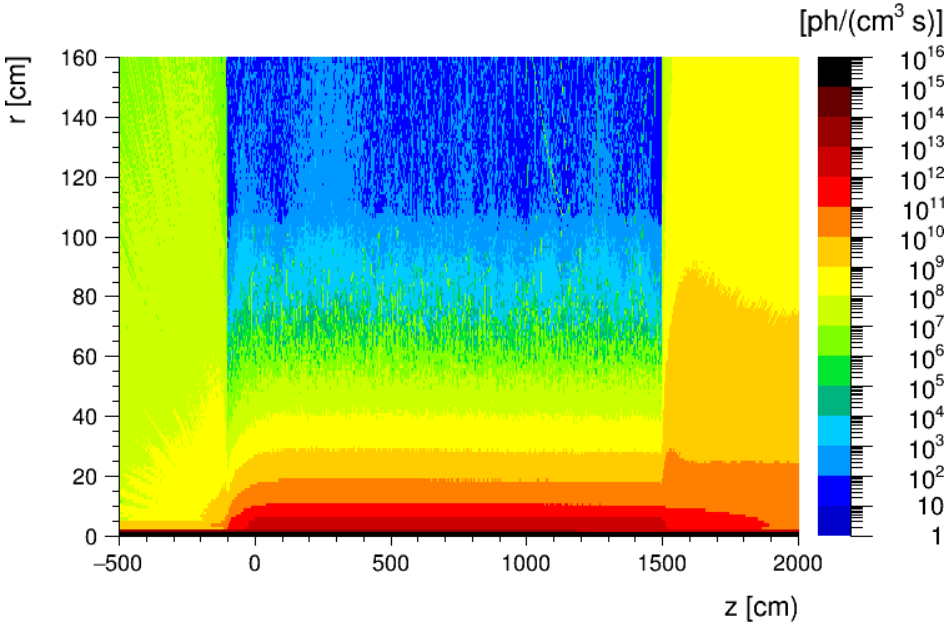


Thickness of Cu-pipe: 2 cm

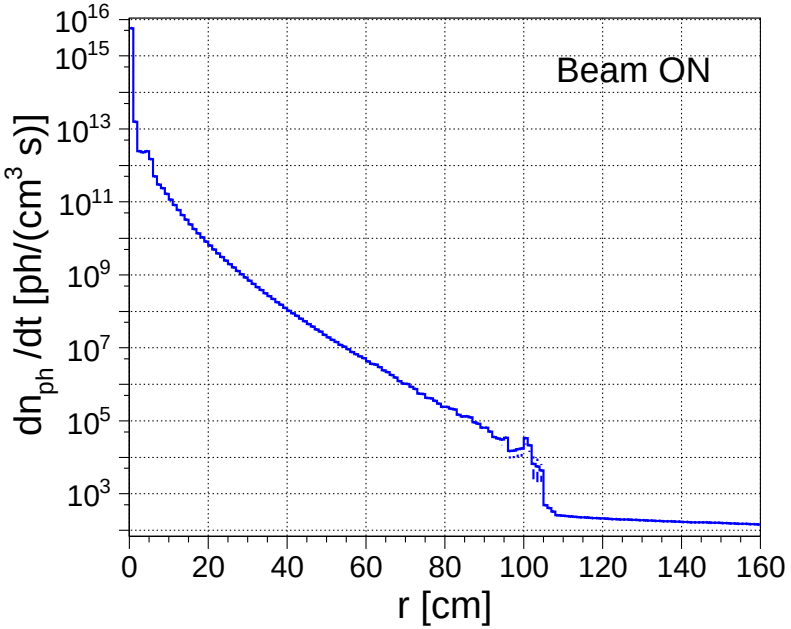
Thickness of concrete wall: 1 m

Photon Distribution at the Beginning of Dump

Distribution of Photon Rate Density at Beginning of Dump

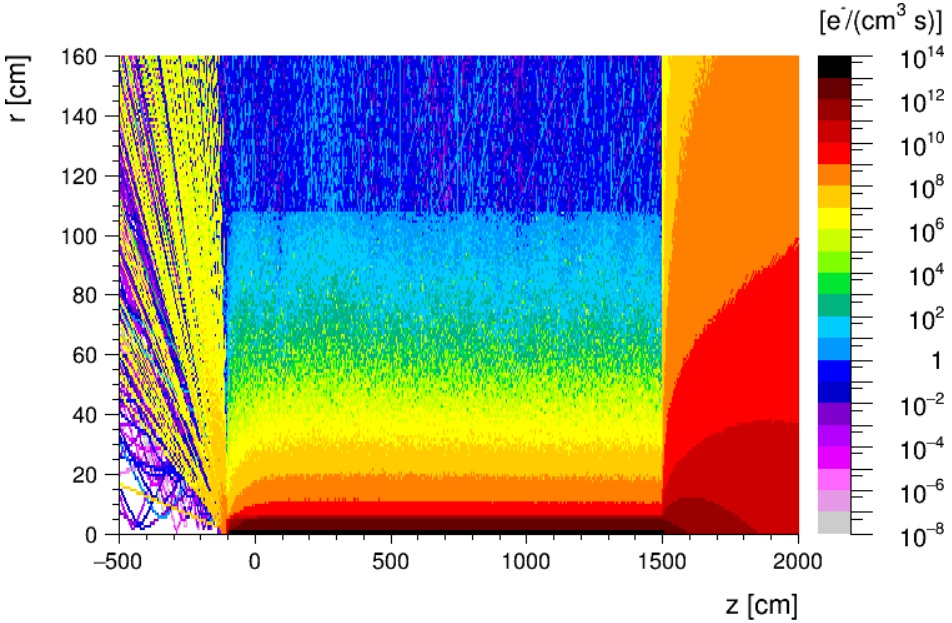


Photon Rate Density vs Radius in “Hottest” Area (3–4 m from Window)

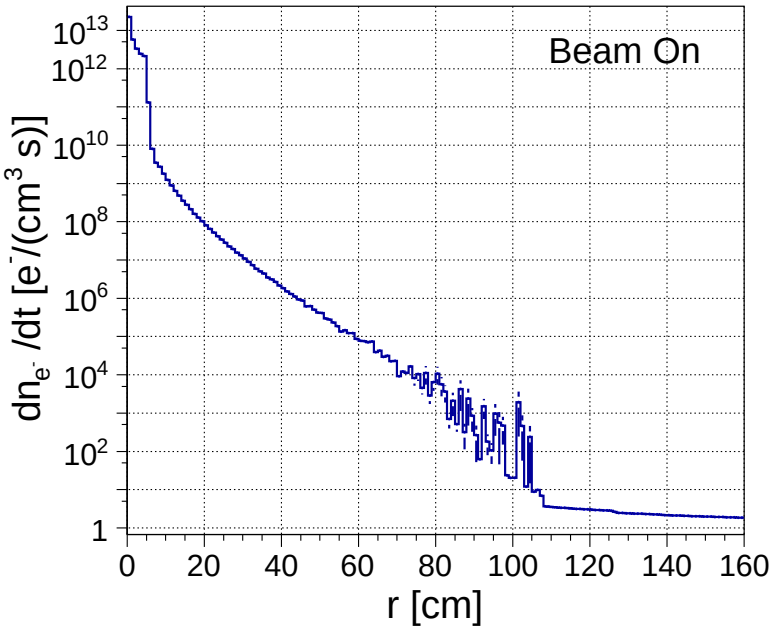


Electron Distribution

Distribution of Electron Rate Density

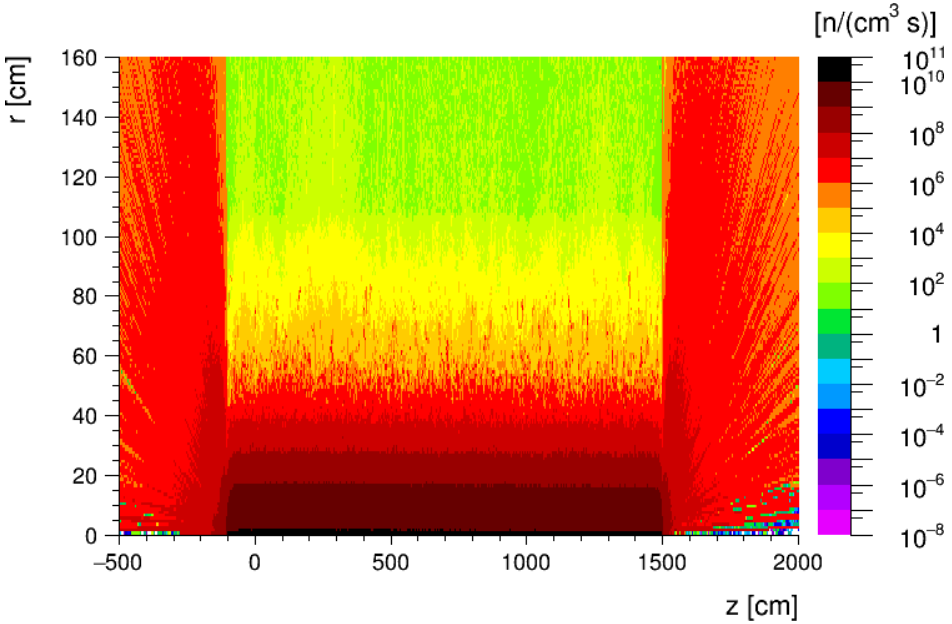


Electron Rate Density vs Radius

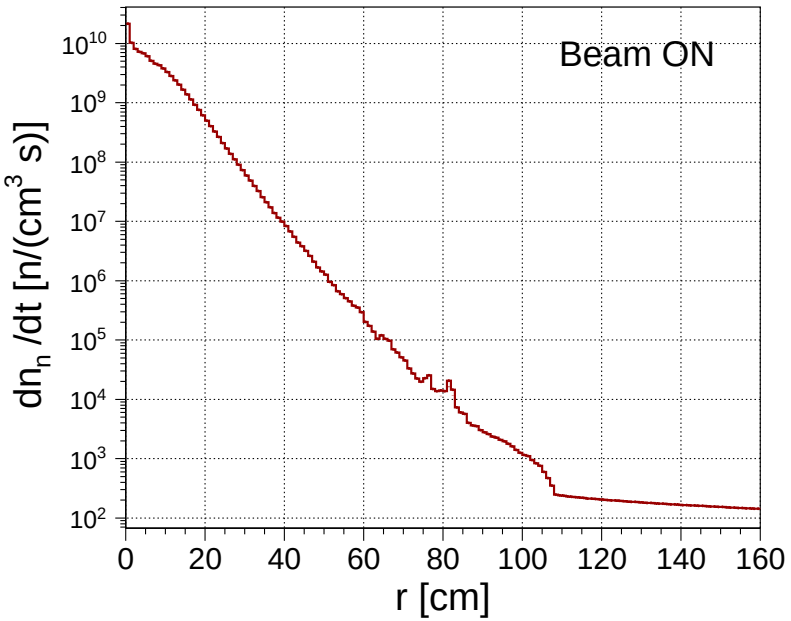


Neutron Distribution

Distribution of Neutron Rate Density

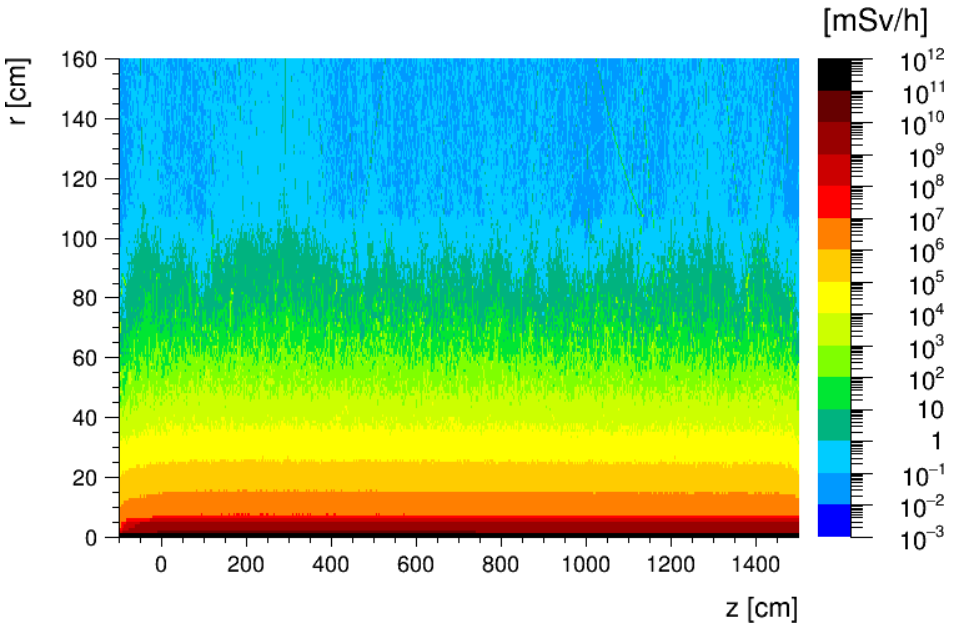


Neutron Rate Density vs Radius

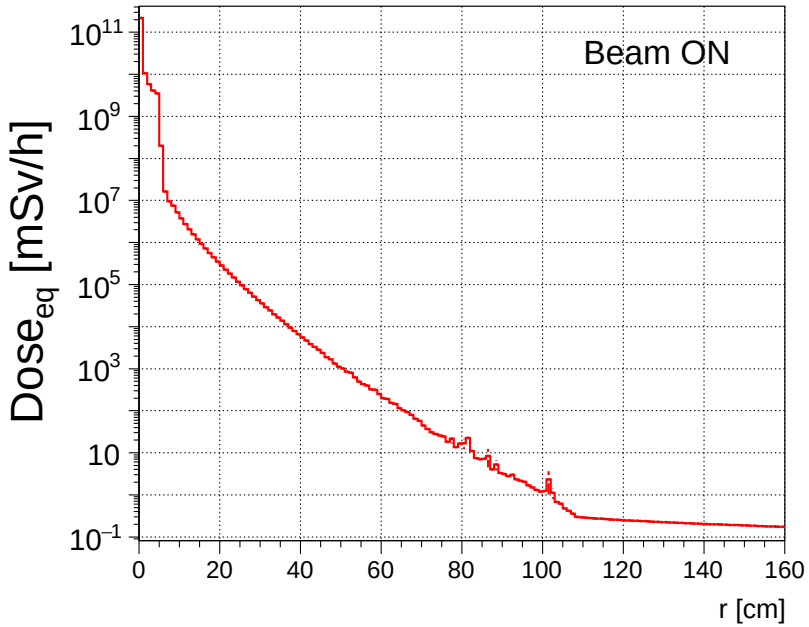


Dose Equivalent Rate during Source Operation

Distribution of Dose Equivalent Rate



Dose Equivalent Rate vs Radius



"Hottest" area (3–4 m from dump window):

To reduce dose rate down to 1 mSv/h approx. 1 m thickness of heavy concrete is needed.

Remanent Dose Equivalent Rate

Remanent dose equivalent rate at

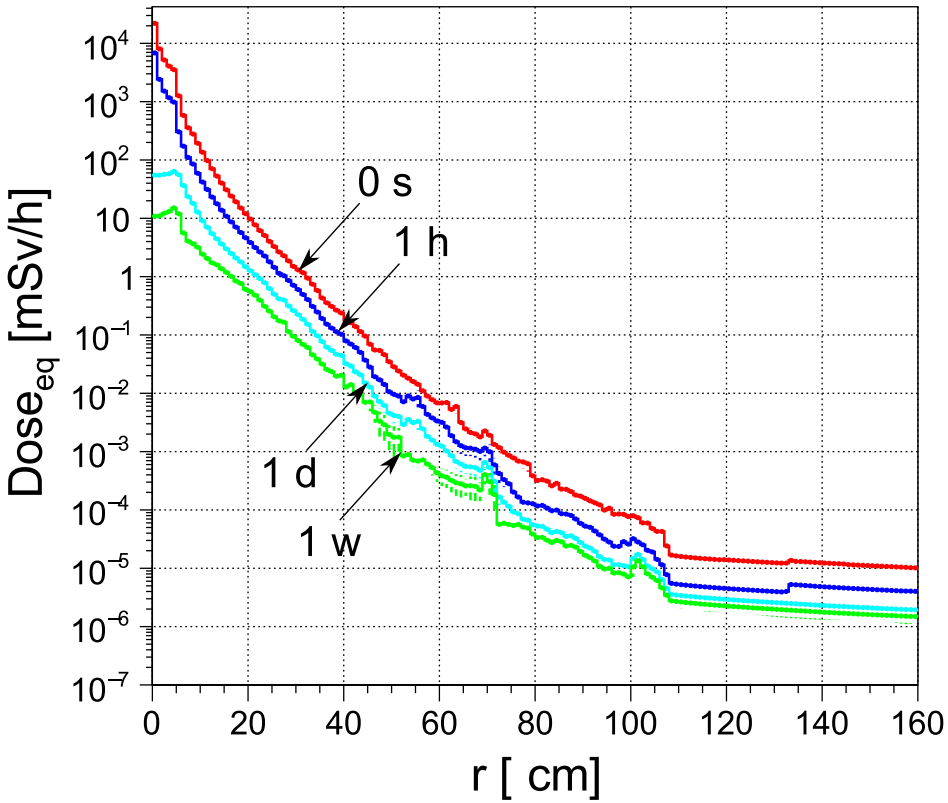
0 s – beam off,

1 h – after 1 hour of cooling,

1 d – after 1 day of cooling,

1 w – after 1 week of cooling.

Remanent Dose Equivalent vs Radius



"Hottest" area (3–4 m from dump window):

To reduce dose equivalent rate down to 10 μSv/h approx. 50 cm thickness of heavy concrete is needed.

Summary

- Stationary graphite placed at distance of ≈48 m from positron target **can not withstand** the heat induced by photon beam.
- Slowly tumbling graphite dump at 1 km from target could be an option.
- 60 m 5 atm Ar-gas upstream of 2 m graphite reduces heat load in graphite to acceptable levels. Radiation damage (4 dpa/5000h) is relatively high, therefore, shifting dump laterally ($\sim$ 1 cm) several times per year is needed.
- 300 m 5 atm Ar-gas dump with Cu- or Al- backstop can be used.
- Radiation levels at the beginning of Ar-gas dump have been calculated.