GAMMA BEAM DUMP
AND COLLIMATOR

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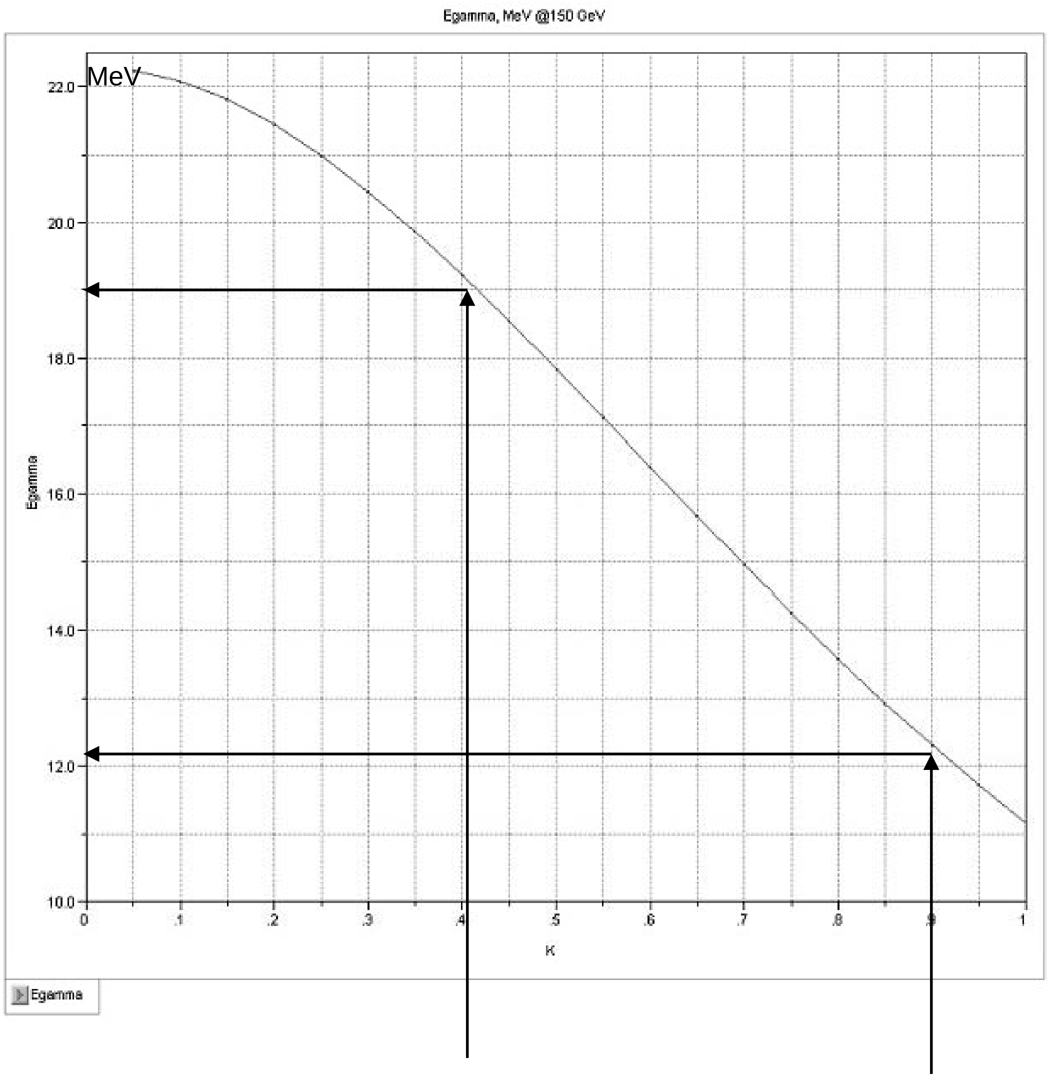
Energy of gamma quanta as function of K factor

Cross section for positron production is higher

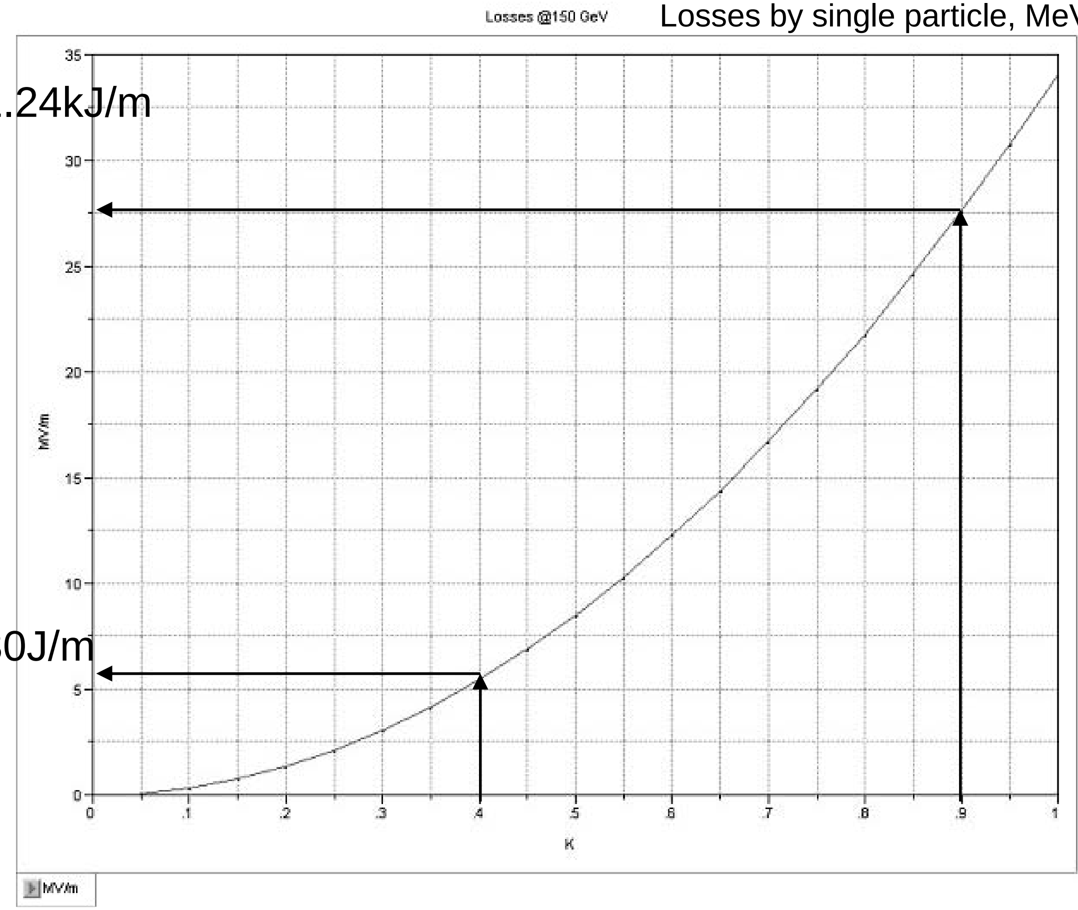


Focusing with Li lens

Baseline TDR

Loss Rate by Undulator Radiation

Losses by single particle, MeV/m



Losses =27.5MVx $4.5\cdot10^{-5}$C~1.24kJ/m

→248 kW/200m

Losses =5.1MVx $4.5\cdot10^{-5}$C~230J/m

→46 kW/200m

Total charge passed in one second is $Q=2\cdot10^{10}$x2820x5x$1.6\cdot10^{-19}$= $4.5\cdot10^{-5}$ Colombs

ATTENUATION OF GAMMAS IN MEDIA

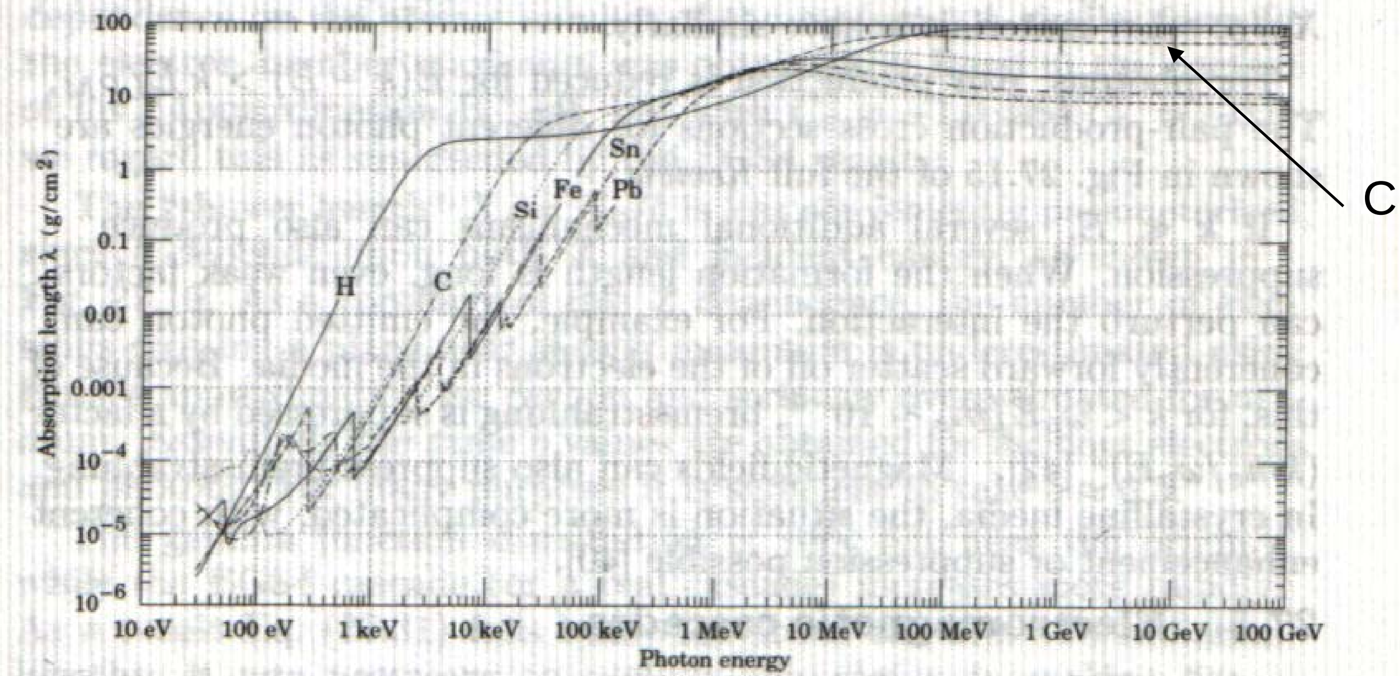


Fig. 27.16: The photon mass attenuation length (or mean free path) $\lambda = 1/(\mu/\rho)$ for various elemental absorbers as a function of photon energy. The mass attenuation coefficient is μ/ρ, where ρ is the density. The intensity I remaining after traversal of thickness t (in mass/unit area) is given by $I = I_0 \exp(-t/\lambda)$. For further data, see `http://www-cxro.lbl.gov/optical_constants` (low energy) and `http://physics.nist.gov/PhysRefData` (high energy).

Losses in Carbon are ~60g/cm^2, which corresponds to the length ~30cm

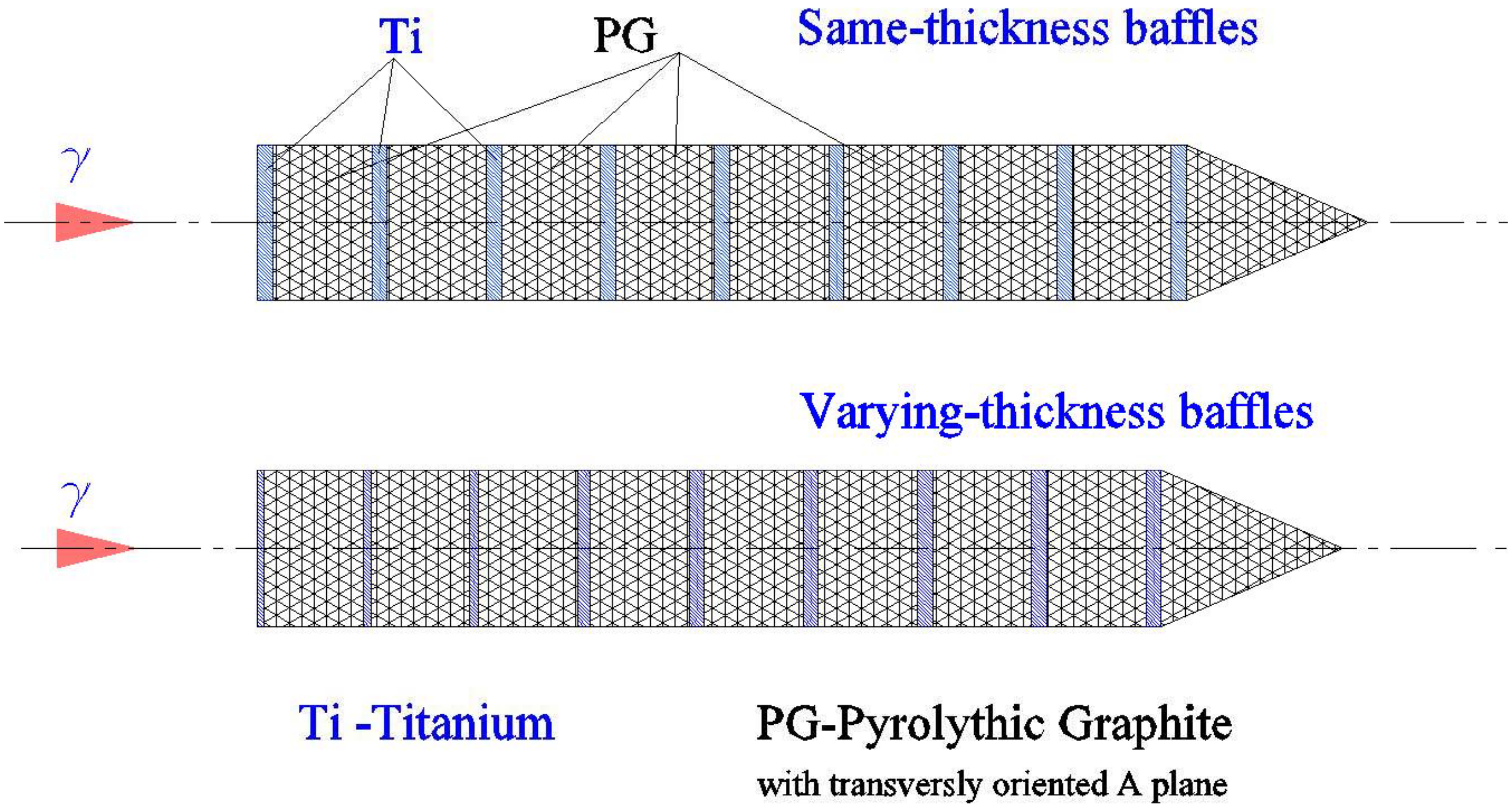
Properties of some materials used in dump/collimator design

Elements →	C	W	Cu	Al	Ti	Fe
Z	6	74	29	13	22	26
A	12	183.8	63.5	27	47.9	55.8
E_c, *MeV*	84.2	8.1	20.2	42.8	26.2	22.4
X_0 g/cm^2	43.3	6.8	13	24.3	16.1	13.84
l_{X_0} , *cm*	19.2	0.35	1.45	9	3.58	1.75
R_M/X_0 ($=E_s/E_c$)	0.25	2.57	1.05	0.49	0.7	0.95
l_M, *cm*	4.8	0.9	1.5	4.4	2.5	1.65

Threshold energy for neutron photo-production

Elements →	C	W	Cu	Al	Fe	Pb	U
$E_{\gamma th}(\gamma, n)$, *MeV*	18.72	6.19	9.91	13.03	11.21	6.73	6.04

Concept: controllably transform gammas into electron/positron pairs, which deposit theirs energy by ionization losses in low Z media



As the critical energy in Carbon is high (84 MeV) ionization losses are dominant

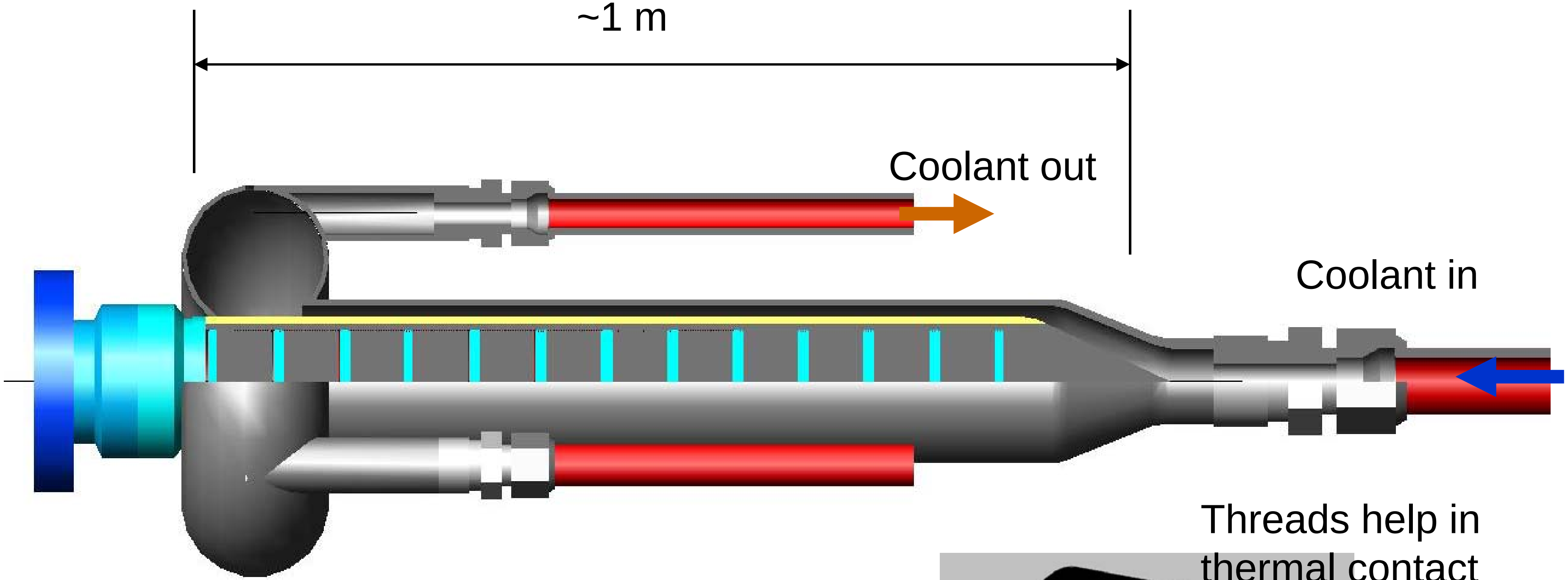
Properties of Pyrolithic Graphite

Graphite →	PG SN	PG HT
Density	2.18 - 2.22 *g/cm*^{3}	2.22 *g/cm*^{3}
Flexural Strength (A* plane)	18k *psi* (120 *M Pa*)	4.8k *psi*
Tensile Strength (A plane)	12k *psi* (80 *M Pa*)	4.2k *psi*(29 *MPa*)
Compressive Strength (A plane)	15k *psi* (105 *M Pa*)	
Young's Modulus (A plane)	3 x 10^6 *psi* (20 *GPa*)	7.2 x 10^6 *psi* (50 *GPa*)
Thermal Exp. Coeff. (A plane)	0.5 x 10^{-6} *cm/cm/*^{o}C	-0.6·10^{-6} *cm/cm/*^{o}C
Thermal Exp. Coeff. (C* plane)	6.5 x 10^{-6} *cm/cm/*^{o}C	25·10^{-4} *cm/cm/*^{o}C
Thermal Conductivity (A plane)	400 W/m/ ^{o}C	1400 *W/m/* ^{o}C
Thermal Conductivity(C plane)	3.5 W/m/ ^{o}C	7 *W/m/* ^{o}C
Electrical Resistivity (A plane)	5 10^{-4} *ohm·cm*	5 10^{-4} *ohm·cm*
Electrical Resistivity(C plane)	0.5 *ohm·cm*	0.6 *ohm·cm*
Crystal Structure	Hexagonal	
C/2 Spacing):	3.42 Å)	
Outgassing	non	non

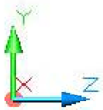
Extremely high conductivity across plane A, in radial direction here;

For Copper heat conductivity ~400 W/m/ ^{o}C

Gamma dump with PG and Ti baffles

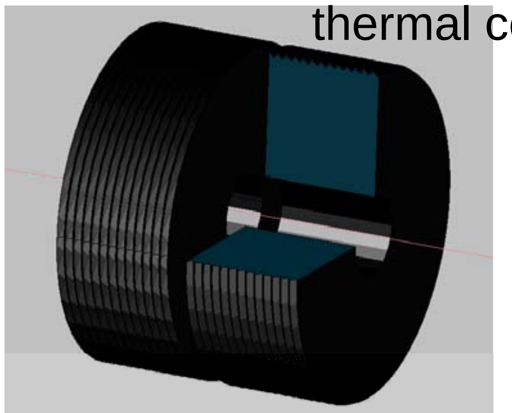


Threads help in thermal contact

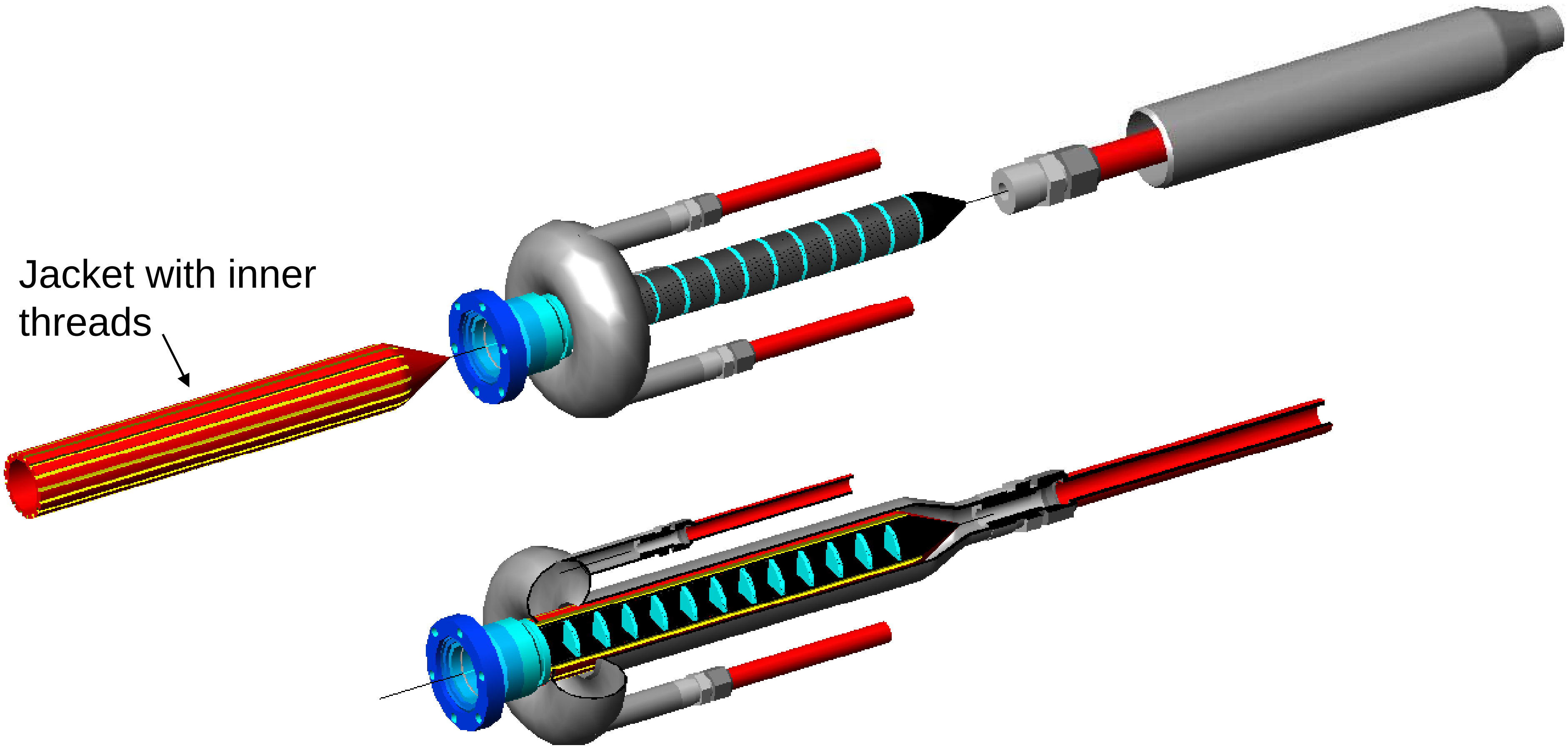


Power 200kW requires coolant flow rate for temperature jump 20^{o}C

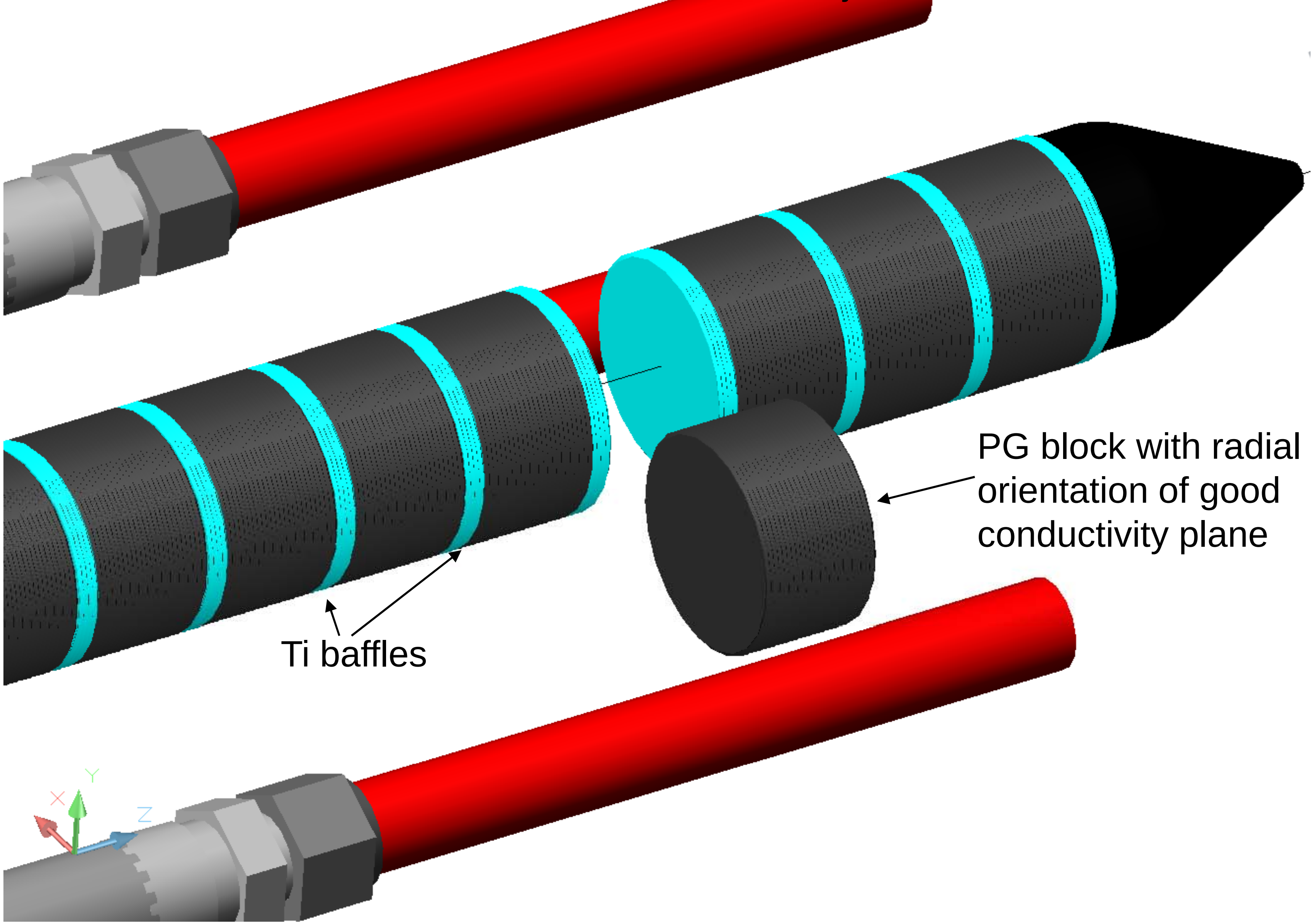
$$\dot{m} \cong \frac{E_{tot}}{\Delta T C_p} \cong \frac{2 \cdot 10^5}{20 \cdot 4.18 \cdot 10^3} \cong 2.4 L / \sec$$



Components of gamma dump

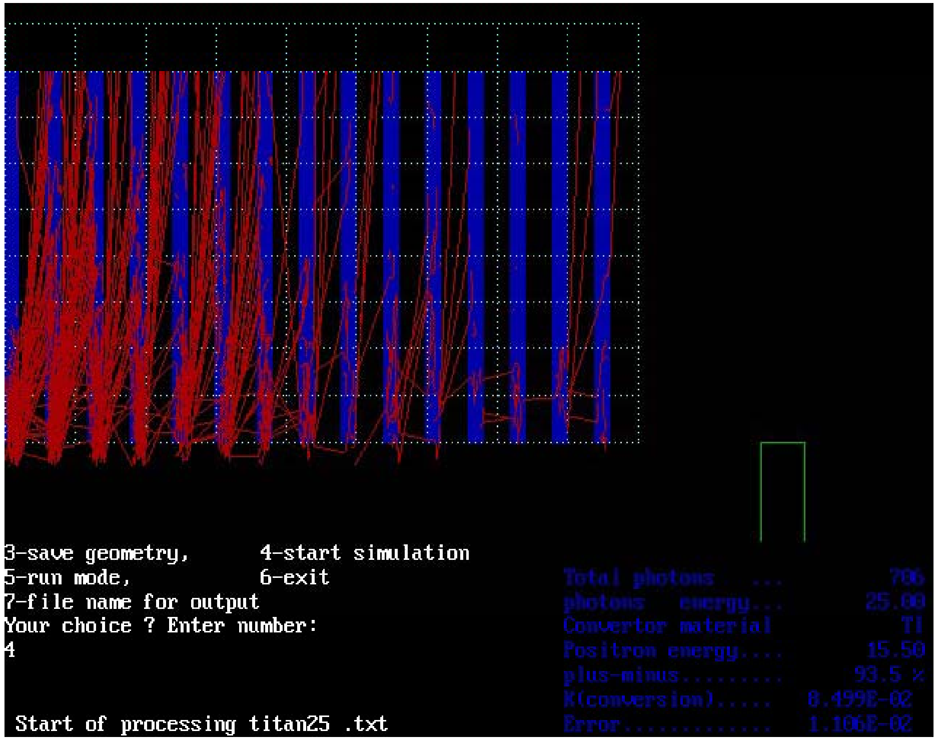


Zoomed view to the core with removed jacket

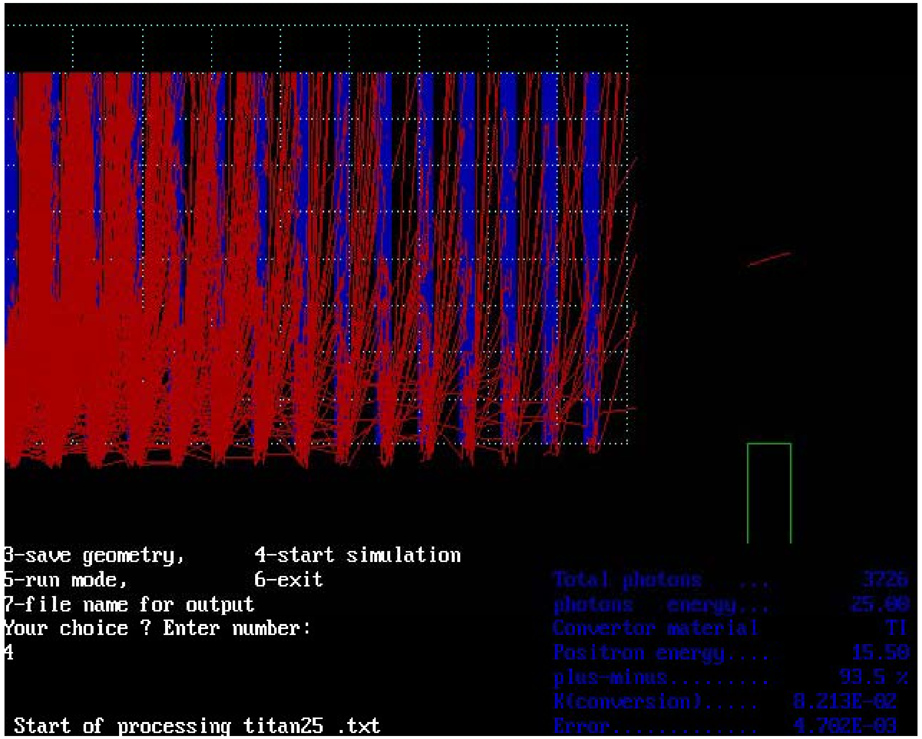


Ti baffles has the same thickness here

At start



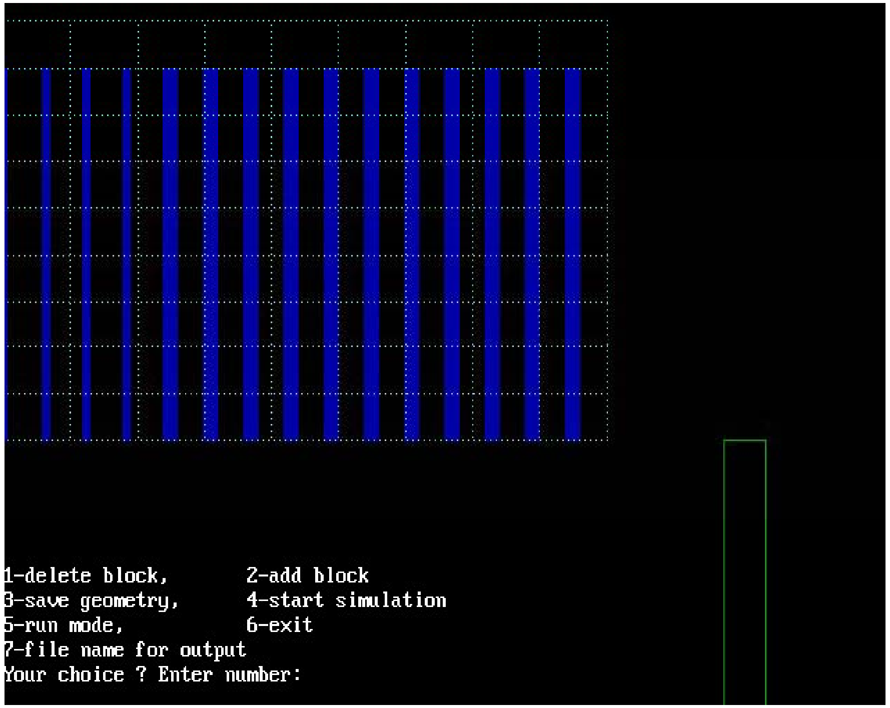
Later

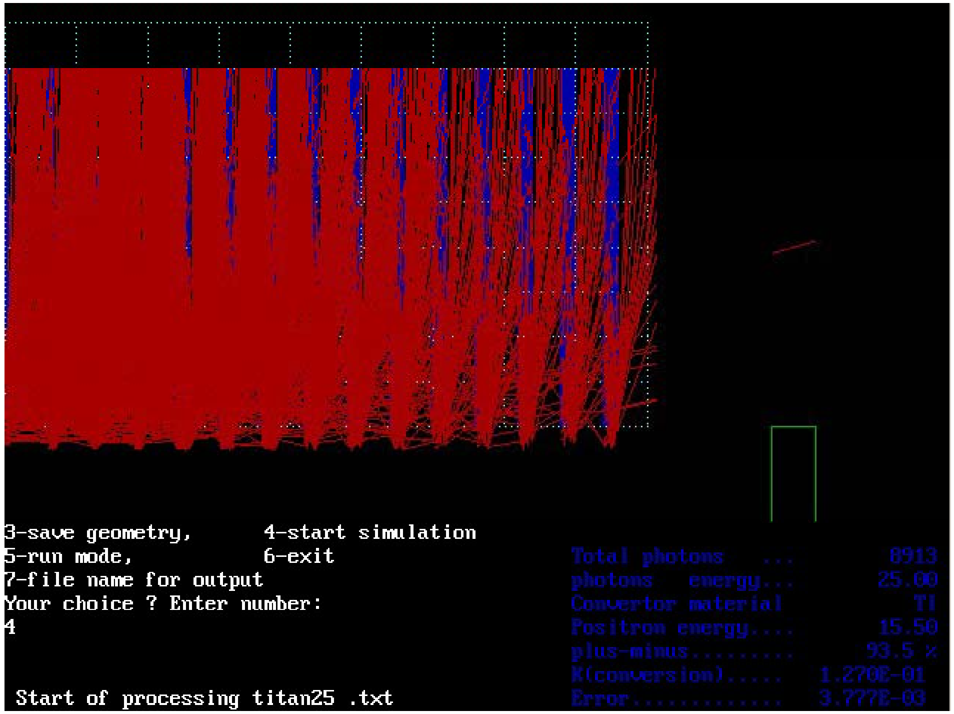


Positron trajectories marked by red; Figure enlarged in radial direction

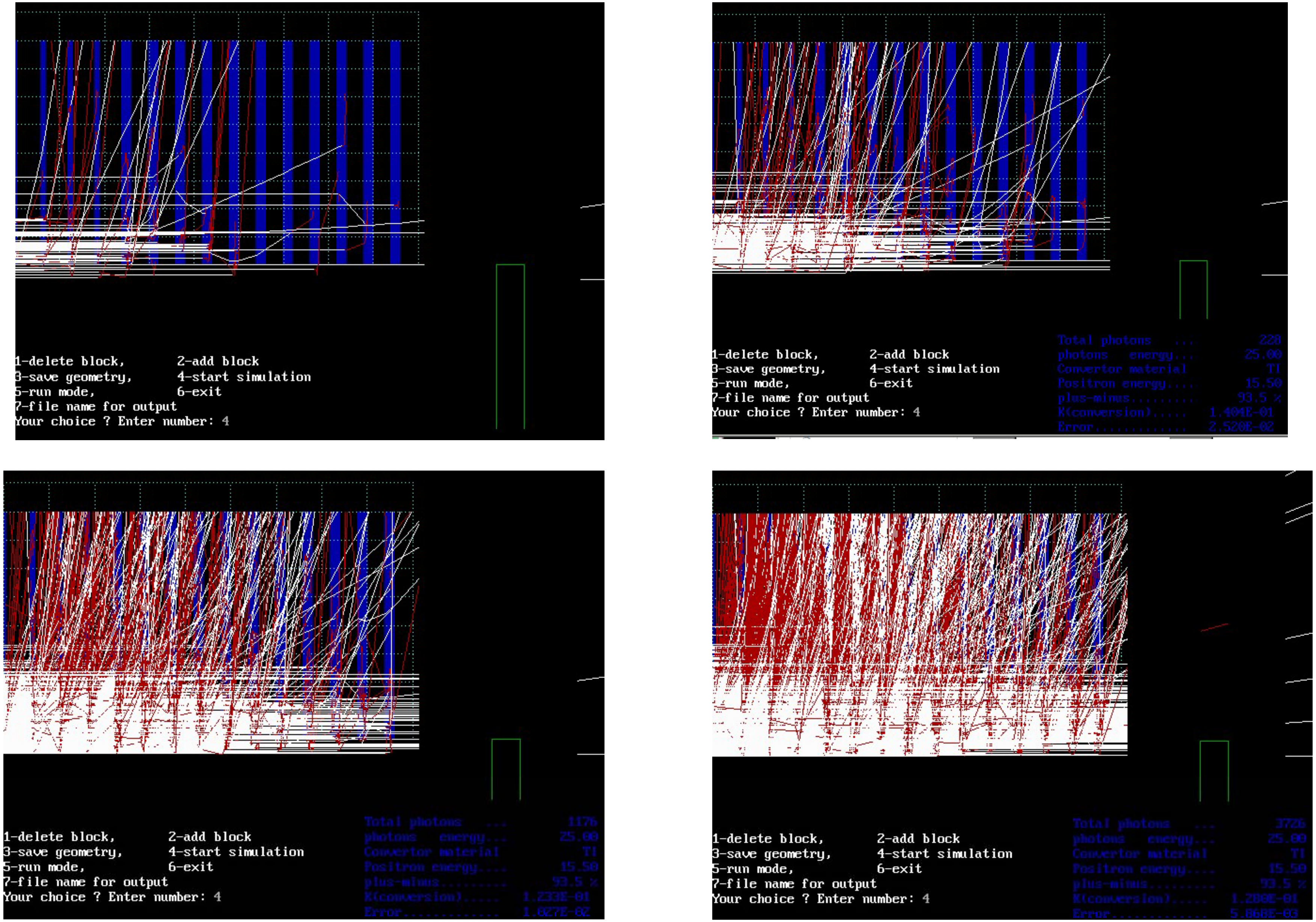
Code CONVER by A.Bukin, BINP

Ti baffles start thin, grow toward the end





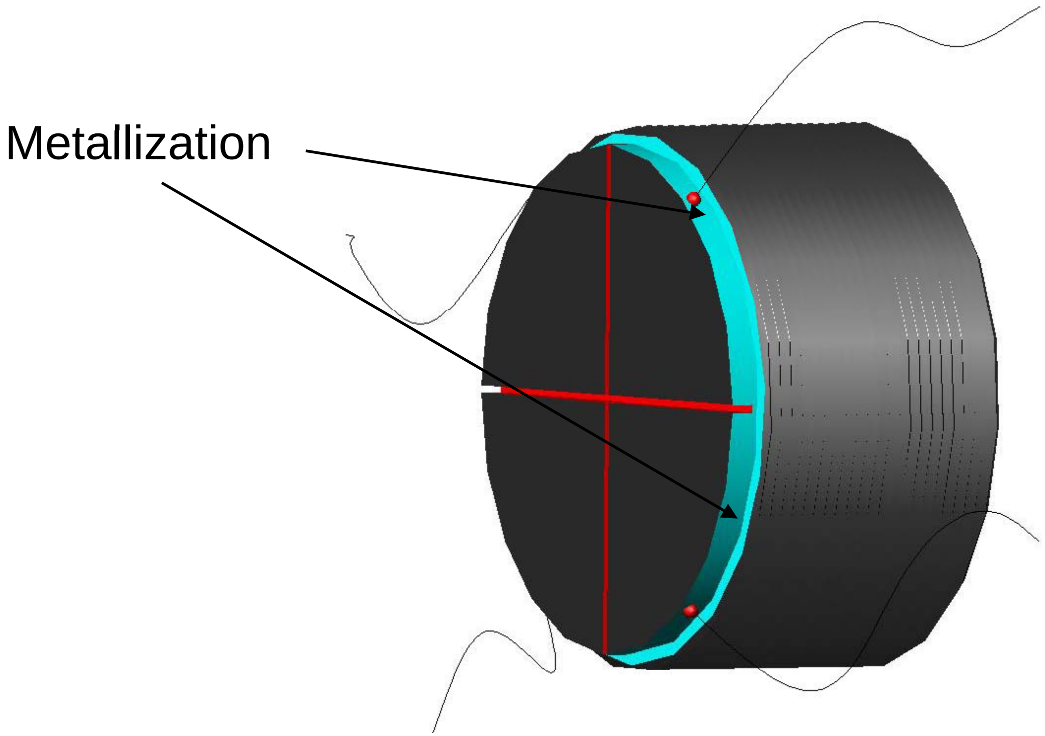
By this way one can even energy losses along the dump system



Trajectories of positrons (red) and gammas (white) in baffled absorber as they developed it time (from left to right, from top to bottom)

Electron and gamma position monitor could be implemented into PG absorbers

Anisotropic electric conductivity of PG allows elegant solution for gamma position monitor. Standard PG disc has a cross, milled to some depth~2mm. As the electric conductivity of PG in radial direction is 1000 times bigger, than along axis, such grooves arrange segmented monitor.



Analyzing the difference in signals from all wires, one can restore the center of gravity of the beam centroid. The similar device could be implemented in collimator as well.

W.P.Swanson, "*Calculation of Neutron Yields Released by Electrons Incident on Selected Materials*", Health Physics, Vol.35, pp.353-367, 1978.

$$\dot{D}(rem/hour) \cong 93 \cdot Z^{0.73} \frac{P[kW]}{R[m]^2}$$

For total power of deposition 200 kW this gives

$$\dot{D}(rem/hour) \cong 93 \cdot 22^{0.73} \frac{200[kW]}{1[m]^2} = 178k \cdot rem/hour$$

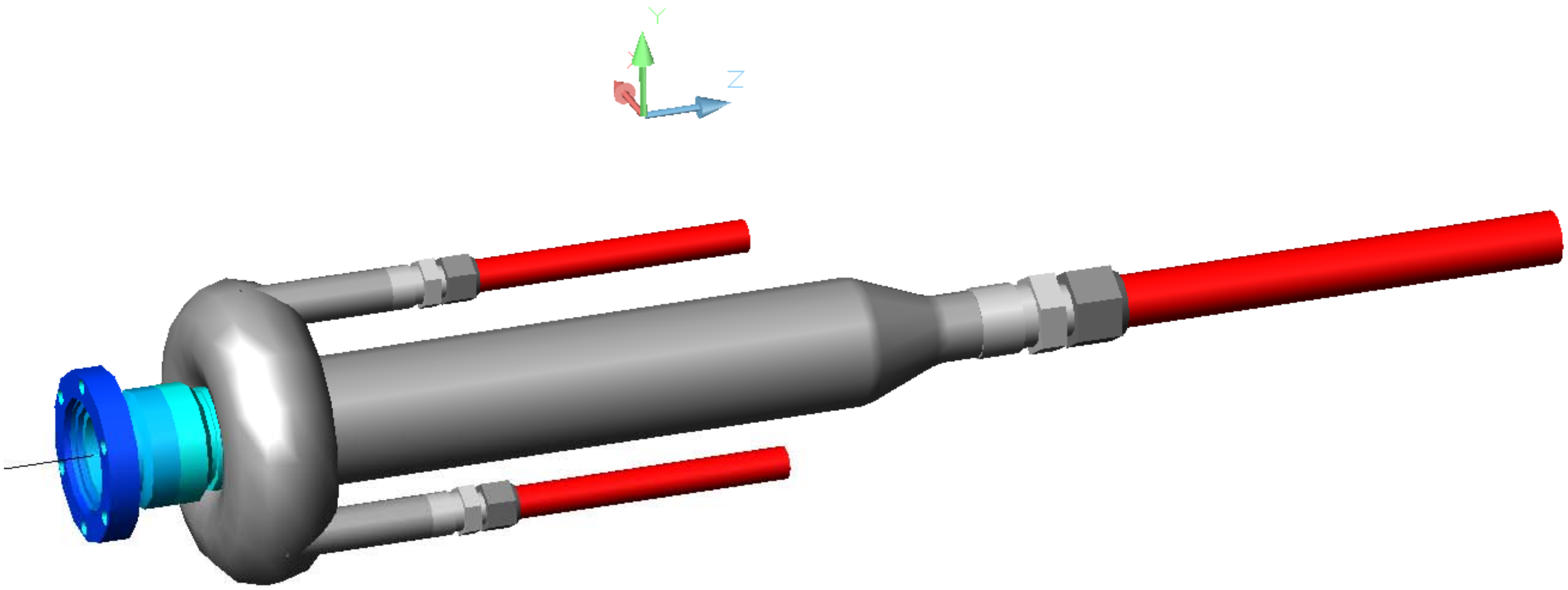
For reference

$$\dot{D}_{safe} \leq 0.1/7/24 \cong 6 \cdot 10^{-4} rem/hour$$

Personnel will not be present during operation;

Low Z materials reduce the activation after machine stops;

Isometric view

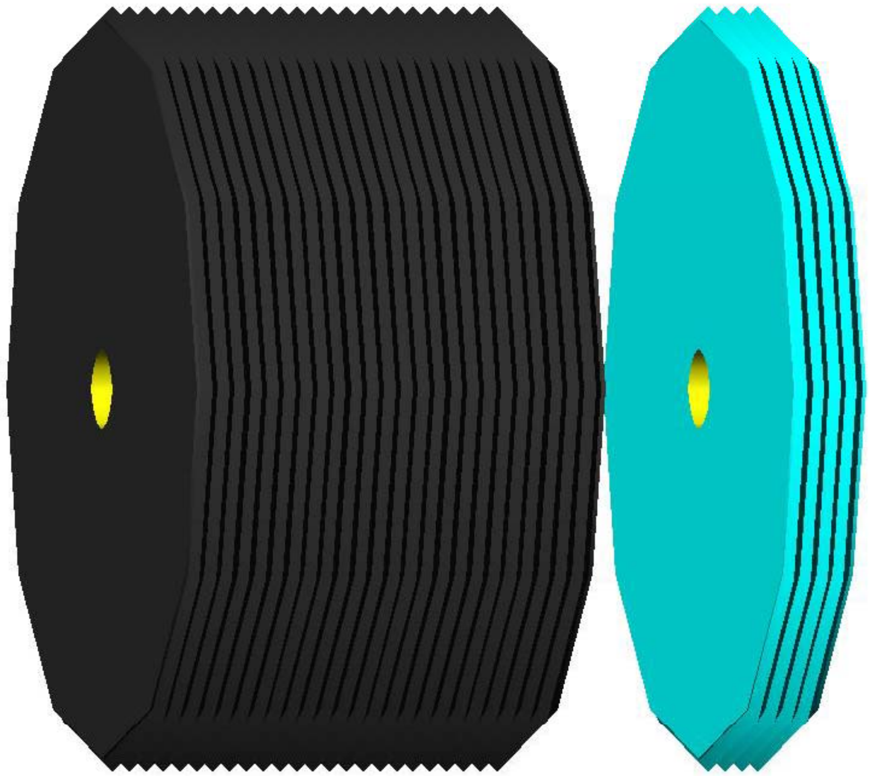


This dump surrounded by multi-layer neutron-protection shield which may include paraffin, Boron Carbide, Lead and Iron bricks

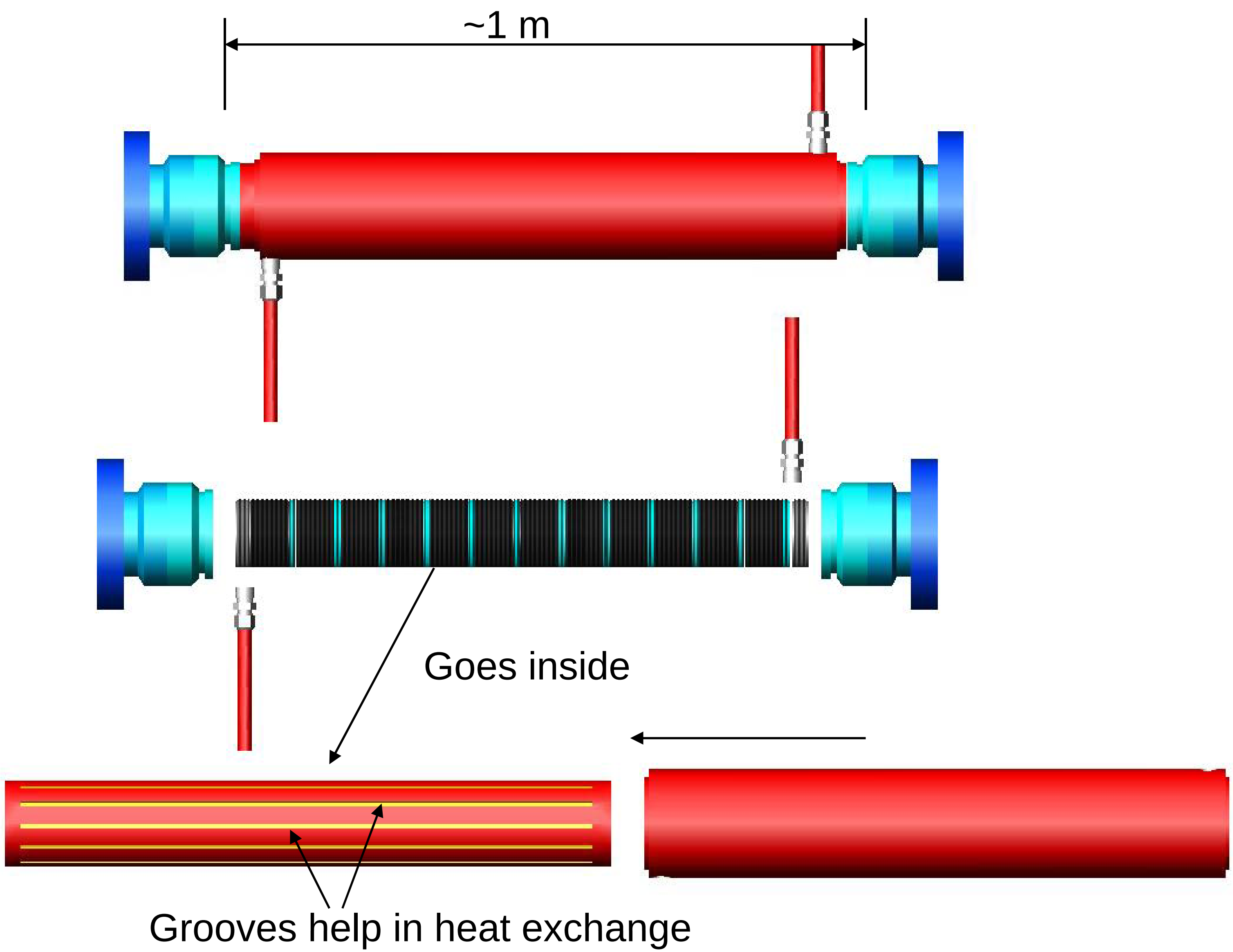
The same ideas used for design of high power collimator

Pyrolithic Graphite disc (nut)

Ti disc



Components of Collimator



SUMMARY

Usage of Pyrolithic Graphite with Ti baffles allow compact design of dump and collimator for photons;

Usage of low Z PG and Ti helps in reduction of neutron flux and activation;

Utilization of Li lens allow more efficient collection of positrons which reduces the power deposited in collimator and dump (low K <0.3 allows operation without collimator at all);

A.Mikhailichenko,” Physical Foundations for Design of High Energy Beam Absorbers”, CBN 08-8, Cornell, LEPP, 2008.