MCNP MODEL OF MEDICAL LINEAR ACCELERATOR TREATMENT HEAD

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Examples in Literature

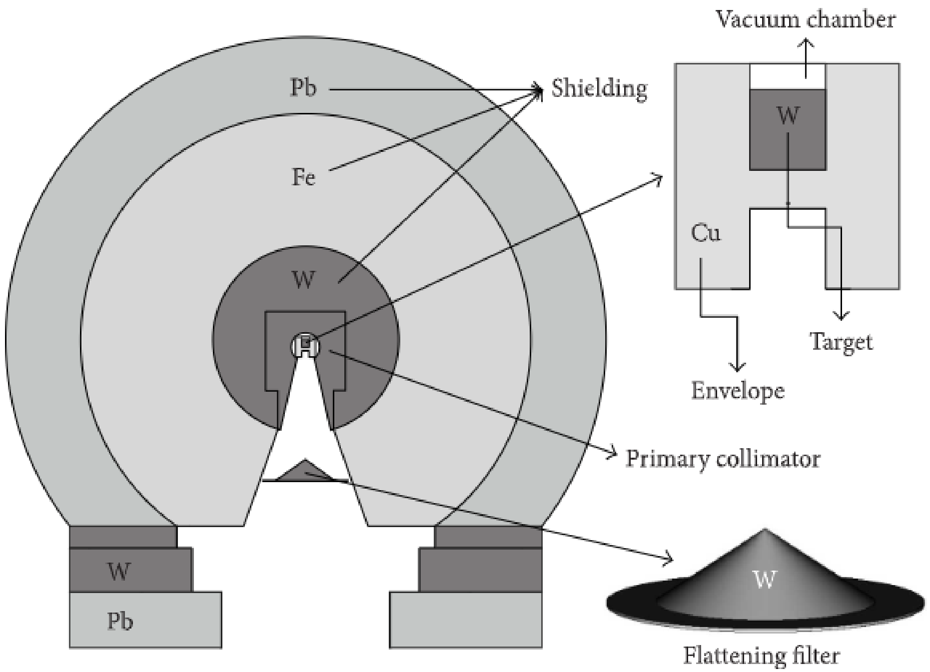


Fig. 1. Linear Accelerator Head model with shielding materials

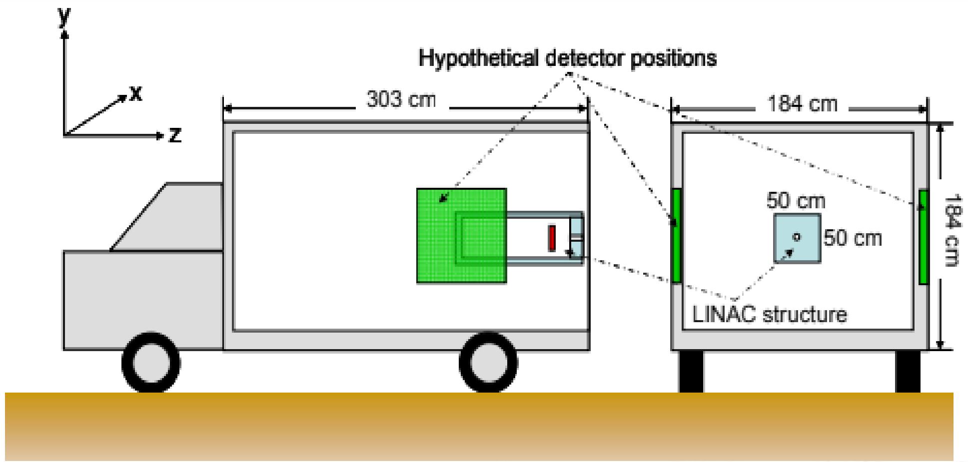


Fig. 2. Linear Accelerator model with shielding materials

Geometry

Examples of surfaces:

Plane:

$$Ax + By + Cz - D = 0 \tag{1}$$

Sphere:

$$(x - A)^2 + (y - B)^2 + (z - C)^2 - R^2 = 0 \tag{2}$$

Cylinder:

On X-axis

$$(y - B)^2 + (z - C)^2 - R^2 = 0 \tag{3}$$

The space surrounded by these surfaces is called a cell. The cell may be: vacuum or any homogeneous materials. The entire space should be subdivided into cells where there are no holes. Cells cannot overlap

More difficult 3D geometries are created by using Boolean algebra element AND and OR and if area is above or right of surface it is noted as”–“and if it is below and in left side “+”.

Example

```
surface wizard: MCNPX Visual Editor Version 740X_23z
c      Created on: Tuesday, April 23, 2019 at 12:04
    1      0          -1
    2      0          -2
    3      0          -3
    4      0          -4
    5      0          1 2 3 4 -6 -7
    6      0          (-5 6 ):(-5 7 )
    7      0          5

c     Elipsoid
    1         sq 0.0025000001769513 0.0011111112544313 0.00062500004423782 0 0 0
                  -1 0 0 0
c     X torus
    2         tx 0 0 0 70 10 20
c     Y torus
    3         ty 0 0 0 120 20 10
c     Z torus
    4         tz 0 0 0 170 15 25
c     sphere
    5         so 300
c     Uppercone
    6         kz 250 0.99999999991021 -1
c     Lowercone
    7         kz -250 0.99999999991021 1

mode  n
imp:n   1 5r         0             $ 1, 7
sdef
nps 100000
```

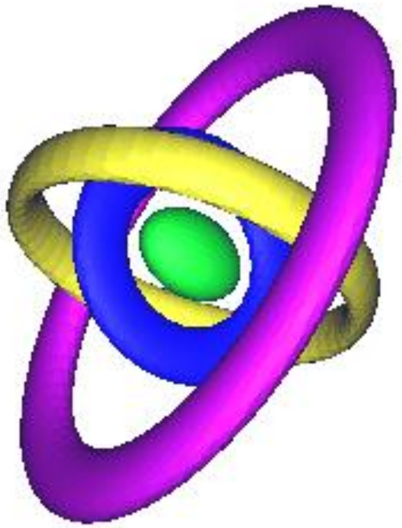


Fig. 3. Cells and surfaces example

Source

The sources described by MCNP codes can localized in one cell or distributed in many cells, or described as a point, line, or plane. The emitted energy from the source may be discrete (usually gamma rays) or have spatial distribution.

Example of source description:

sdef cel=9 erg=d1 par=p pos=1.6 1.6 1.6 wgt=1

si1 H 23.75 26.25

sp1 D 0 1

Using Janis software was obtained the Tungsten spectrum provided by the ENDF/B-VIII library

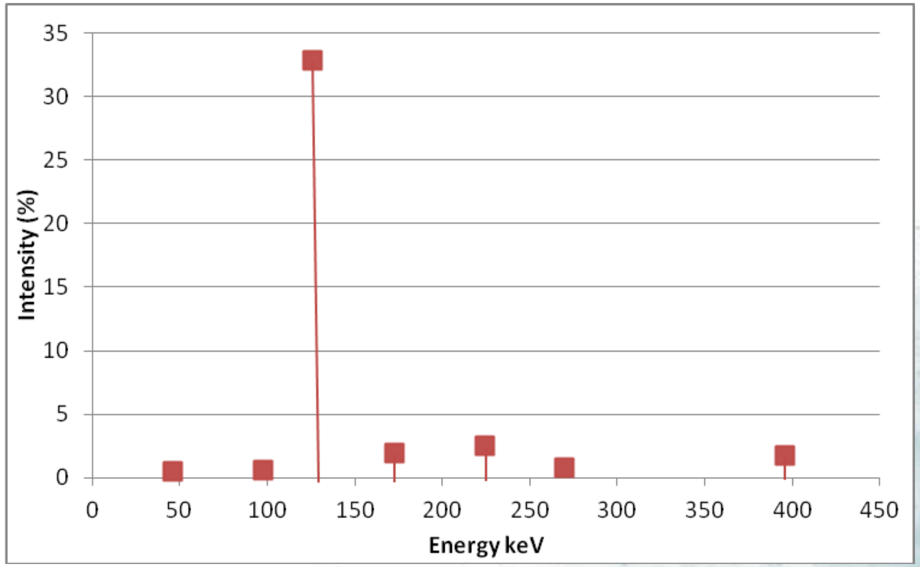


Fig. 4. Discrete photons spectrum of Tungsten

Flux to dose rate conversion factors

Table 1 Conversation factors

Energy Mev	Doze rate rem/h	Dose rate Sv/h
0.01	2.78E-06	6.10E-02
0.015	1.11E-06	8.30E-01
0.02	5.88E-07	1.05
0.03	2.56E-07	0.81
0.04	1.56E-07	6.40E-01
0.05	1.20E-07	5.50E-01
0.6	1.11E-07	5.10E-01
0.08	1.20E-07	5.30E-01
0.1	1.47E-07	6.10E-01
0.15	2.38E-07	8.90E-01
0.2	3.45E-07	1.20E+00
0.3	5.56E-07	1.80E+00
0.4	7.69E-07	2.38
0.5	9.09E-07	2.93E+00
0.6	1.14E-06	3.44E+00
0.8	1.47E-06	4.38E+00
1	1.79E-06	5.20E+00
1.5	2.44E-06	6.90E+00
2	3.03E-06	8.60E+00
3	4.00E-06	1.11E+01
4	4.76E-06	1.34E+01
5	5.56E-06	1.55E+01
6	6.25E-06	1.76E+01
8	7.69E-06	2.10E+01
10	9.09E-06	2.56E+01

MCNP software package can count photon fluxes, but it cannot provide dose rate, but by entering conversation coefficients into grid parameters, we can calculate dose rate for calculated particle fluxes.

The conversion factors used in this work are the conversion table ICRP213 created in 1977

Shielding Materials

Lead: it the most commonly chosen shielding material because of it density, high atomic number, stability, easy production, high flexibility. Mass attenuation coefficient when photon energy varies from 1-30MeV is about 0.12 cm^2*g, and the linear attenuation coefficient decreases as the energy varies from 1MeV to 4MeV from 0.79 cm^{-1} to 0.48 cm^{-1} and as the energy increases to 30MeV it reach around 0.807cm^{-1}.[9]

Tungsten: these alloys very dense, so because of good ionizing radiation damping makes them ideal for radiation protection in nuclear medicine. Mass attenuation coefficient of tungsten is about 0.112 cm^2 *g then energy changes from 1-30 MeV. [9].

Stainless steel: The steels contain heavy elements such as Cr, Fe, Ni and Cu, which have good shielding properties in the medium energies. Therefore, these materials are widely used in radiation protection in medicine. As the photon energy varies from 1-6Mev the linear attenuation coefficient varies from 0.46 to 0.23 cm^2 *g

Results

- Medical linear accelerator treatement head was created using the MCNP-VIS software package visedX_23Z_740. It is easier to create models, but later for calculation was used version vised61_24j.23. Because MCNP6 is a newer and more reliable version than MCNPX.
- Source is in the middle of this model. It is square with diemensions of 40X48mm an its made of tungsten. In the upper part there are 1 cm empty space left for electrons interact with the target.
- The primary collimator is a sphere with a radius of 43 cm. made out of tungsten.
- Shielding was created as spheres with radius of 95 cm. and 120 cm.

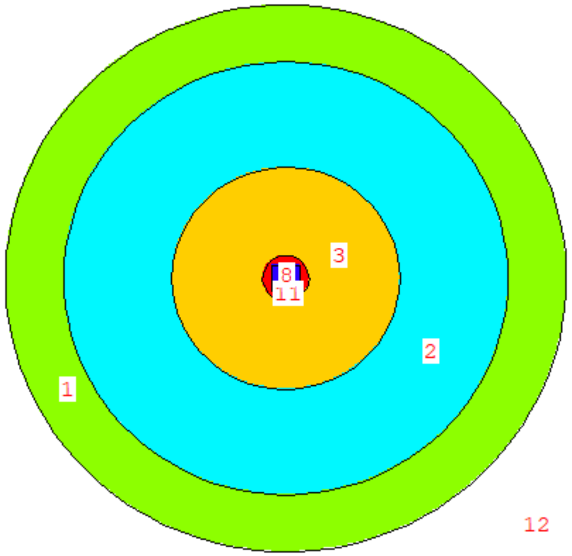
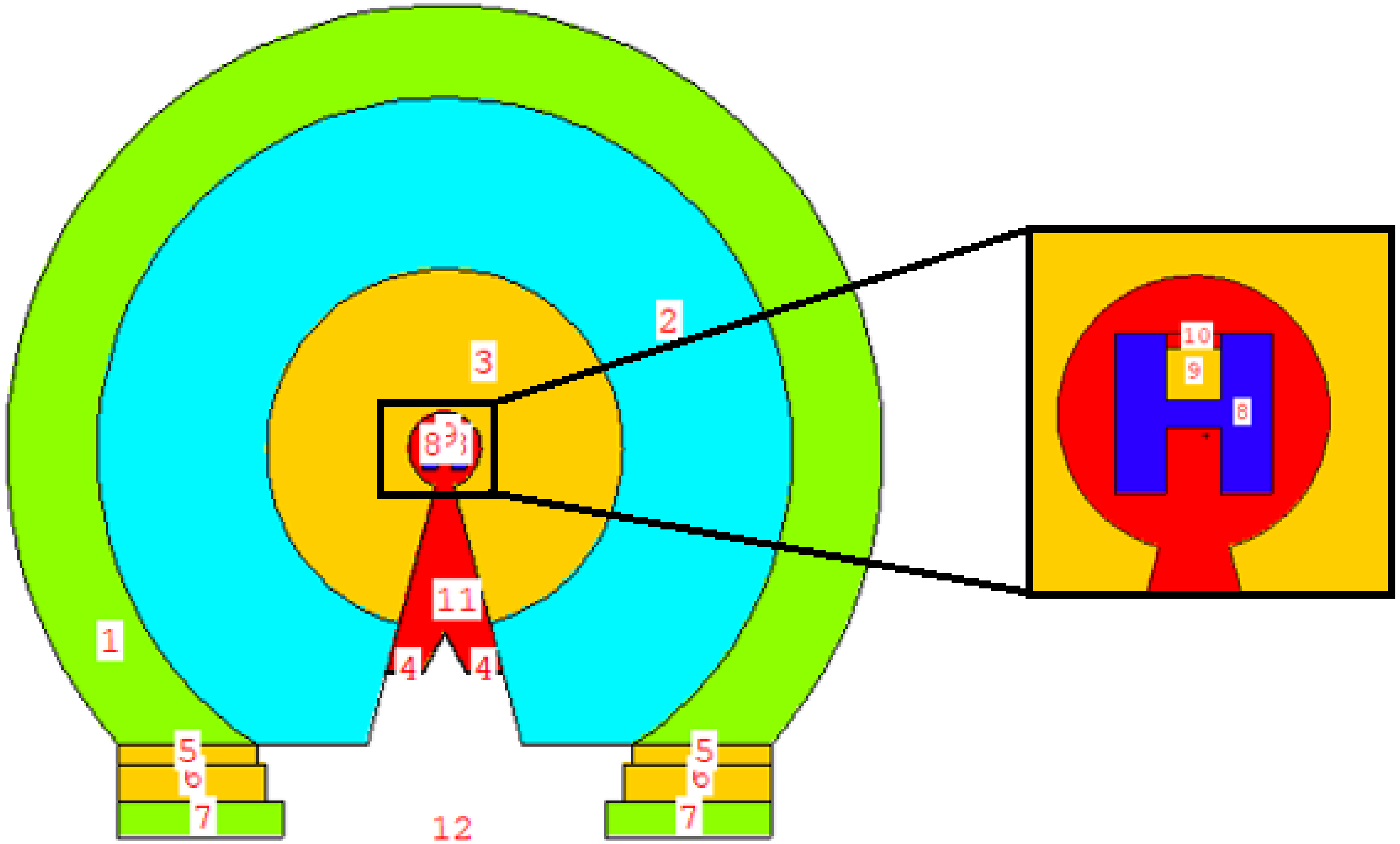


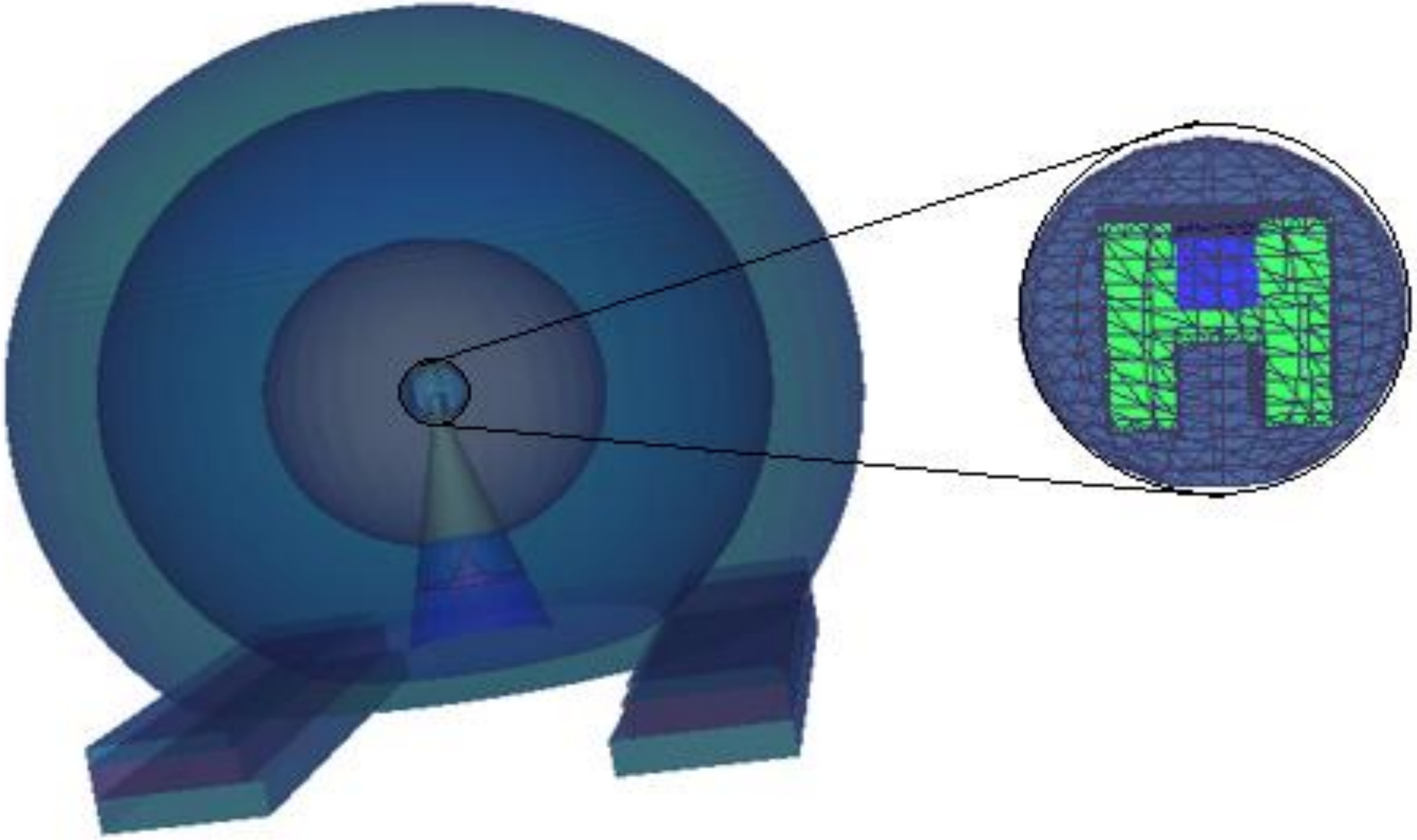
Fig. 5. Created linear accelerator treatment head model in the Y-X plane. Colors: Green: Lead Pb, Blue: Stainless Steel (SS-316L), Yellow: Tungsten, Dark Blue: Copper, Red: Air.

Table 2 From the output file information of the occurrence and loss of photons

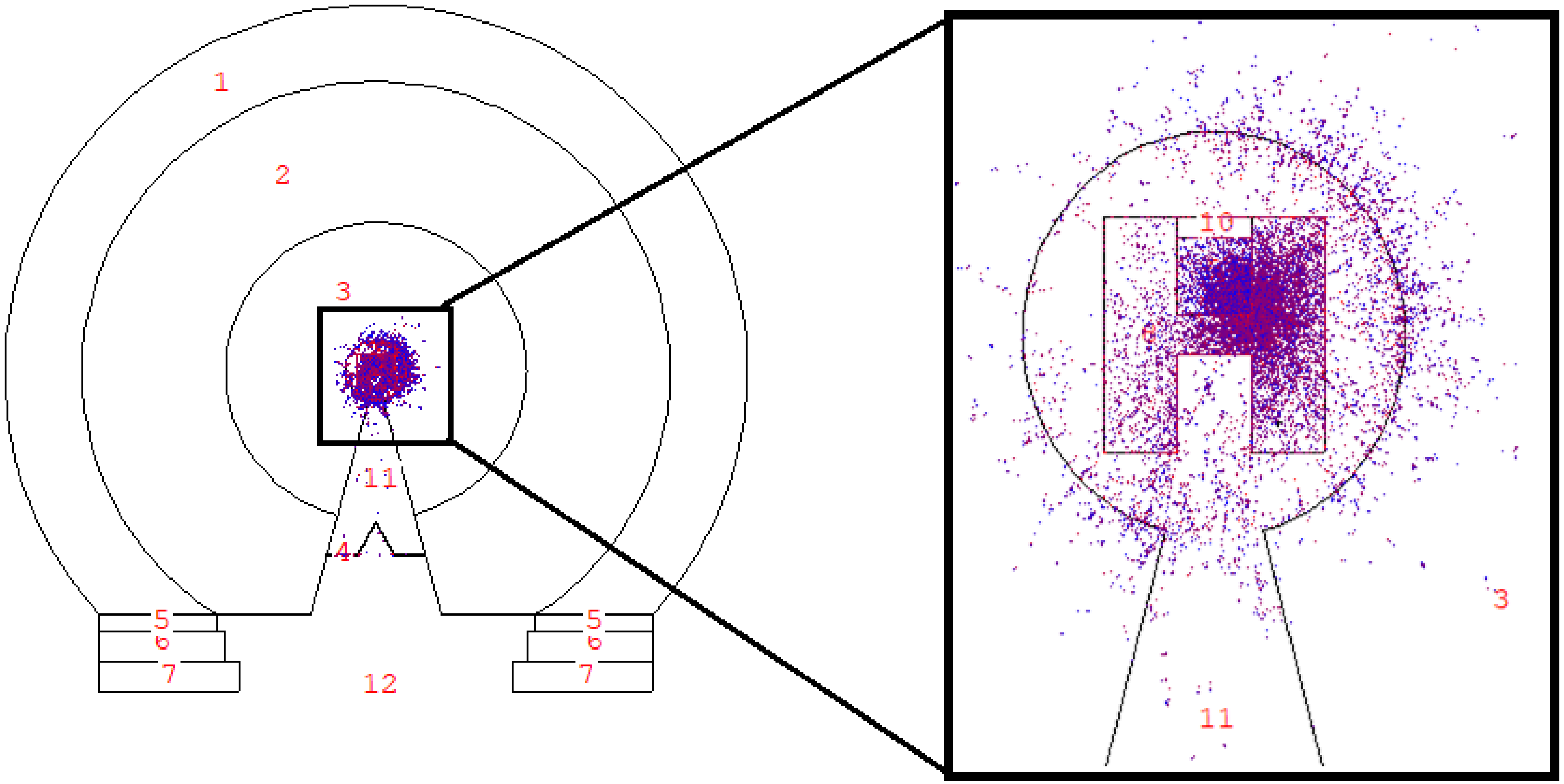
Photons occur	Amount	Energy MeV
Source	1000010	25
Bremsstrahlung	28248718	9,4831
Photon fled away	2824646	1,44
Single fluorescence	11920712	0,5
Double fluorescence	1574960	0,1
total	45569046	36,4
Photon lost	Amount	Energy MeV
Go away from mesh	17445	0,05
Energy loss	-	0,0046
Compton scattering	-	6,84
Electron capture	44139011	4,26
Pair creation	1412323	25,296
total	45568779	36,441



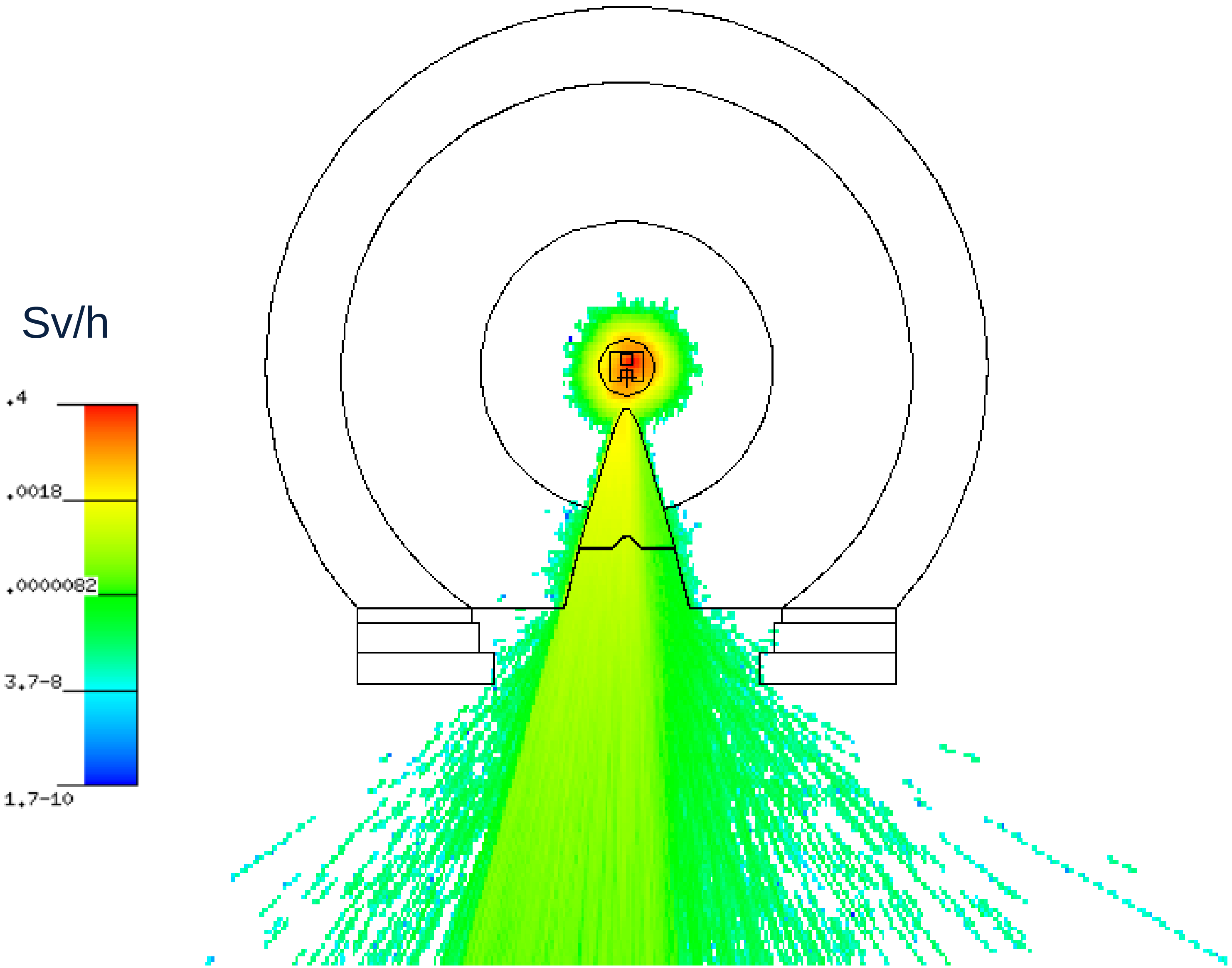
6 Pav. Created linear accelerator treatment head model in the Y-Z plane. Colors: Green: Lead Pb, Blue: Stainless Steel (SS-316L), Yellow: Tungsten, Dark Blue: Copper, Red: Air.



7 Pav. Created linear accelerator treatment head 3D model



8 Pav. Particle distribution in medical treatment head in the Y-Z plane. Minimum Energy: 0.001MeV, Maximum Energy: 26,248MeV



9 Pav. Distribution of the dose rate of the created linear accelerator treatment head in the Y-Z plane

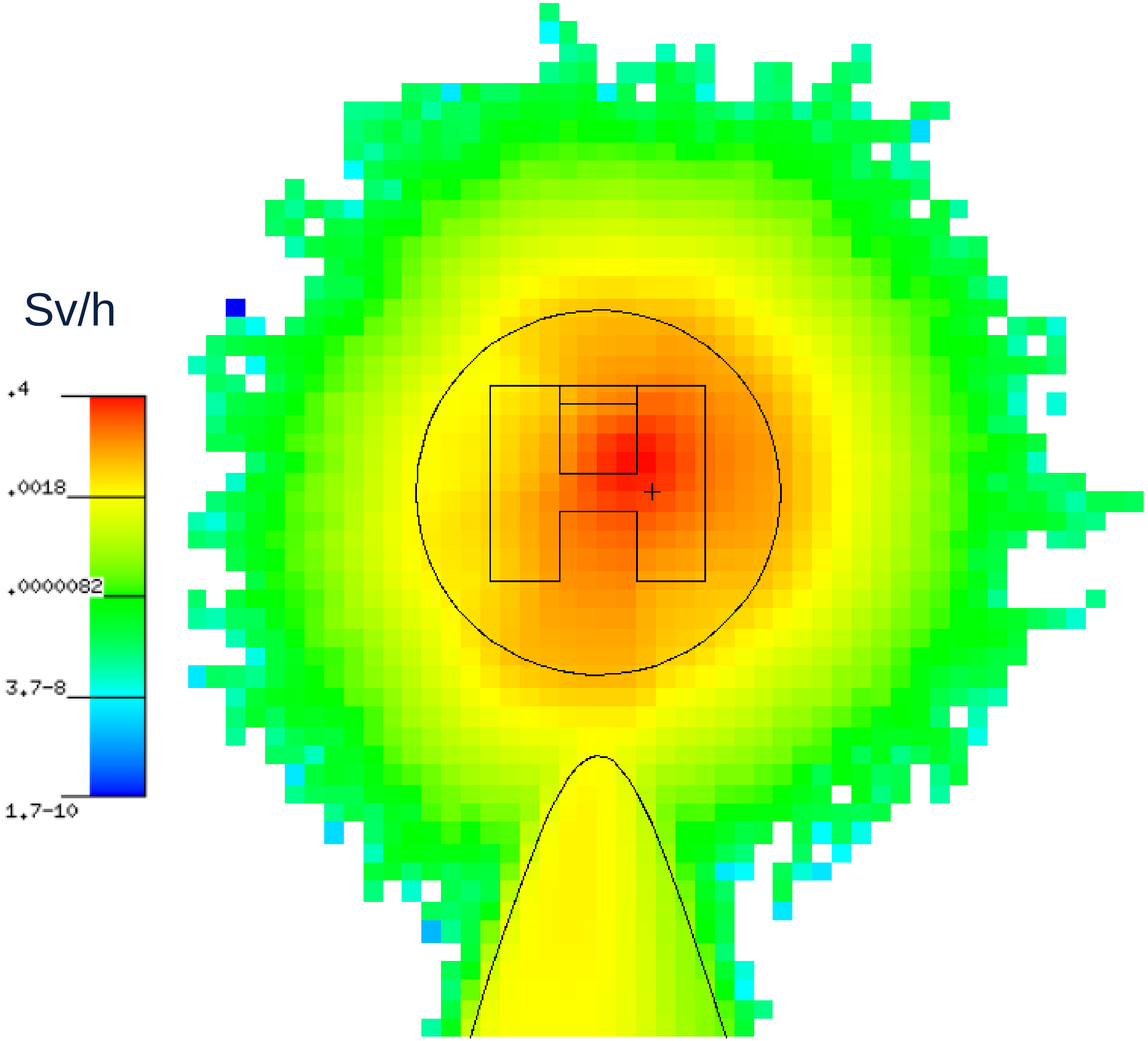


Fig. 10. Distribution of the dose rate of the created linear accelerator treatment head in the Y-Z plane near source

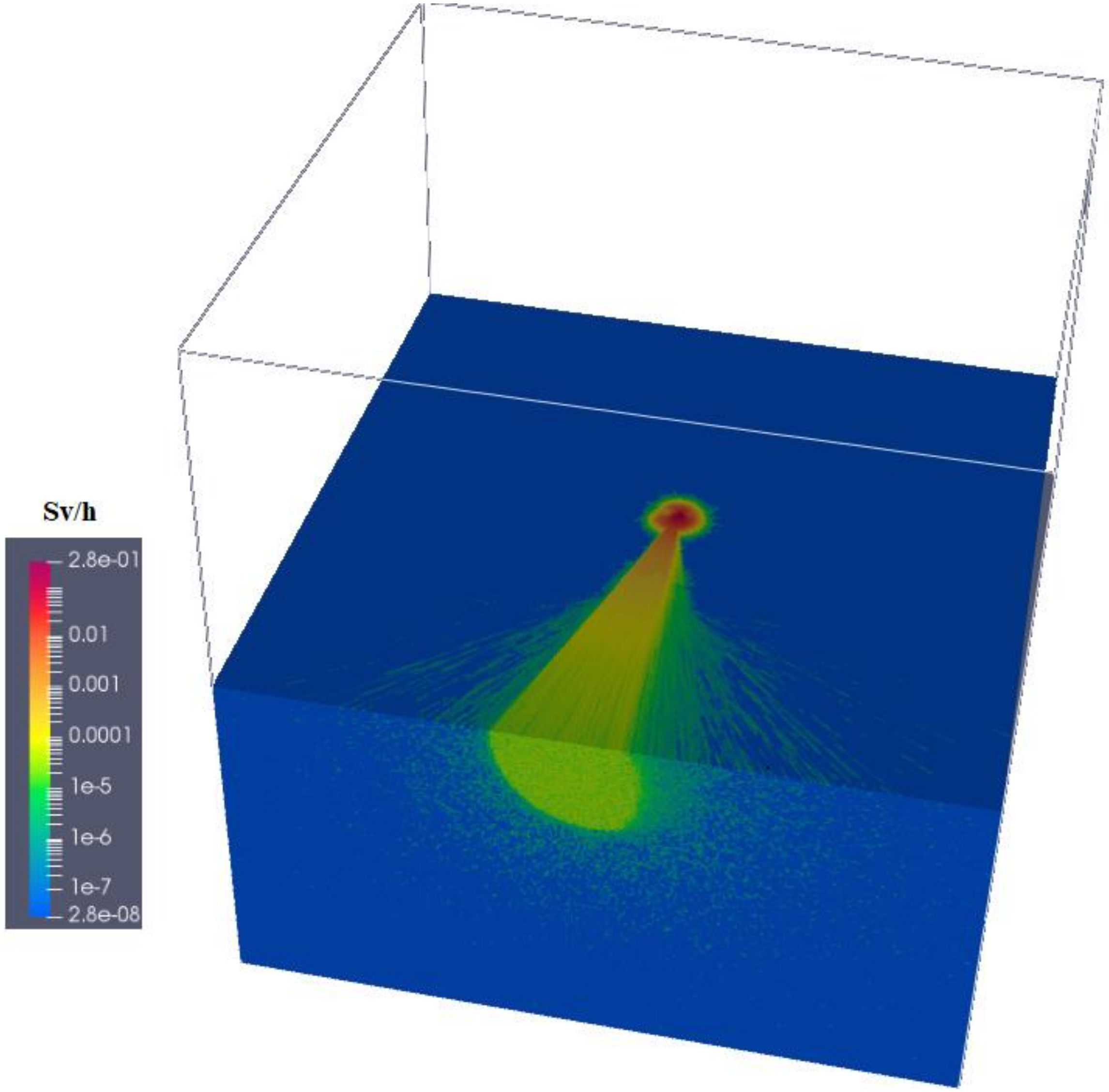


Fig. 11. 3D distribution of the dose rate in the created treatment head.

Conclusion

Using MCNP-VIS were performed photon distribution in device geometry. The MCNP- VIS analysis showed that the generated photons are located in cells near the source and in air-filled space. Minimum Energy: 0.001MeV, Maximum Energy: 26,248MeV

For dose rate calculations, 10^7 particle transfer calculations were performed, which showed that the dose rate varied from $1.7 \cdot 10^{-10}$ Sv/h to 0.4 Sv/h. Most of the dose rate is in the source area and the distribution is down streaming direction.

Despite that Linac‘s uses high atomic number shielding materials, with high density, it was shown that some penetration happens and nonetheless and that may cause additional dose to the patient.

Any Questions?

Thank you for your attention ☺