

Topas Monte-Carlo modelling: Guide and simple techniques

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DTU Health Tech

IMPORTANT

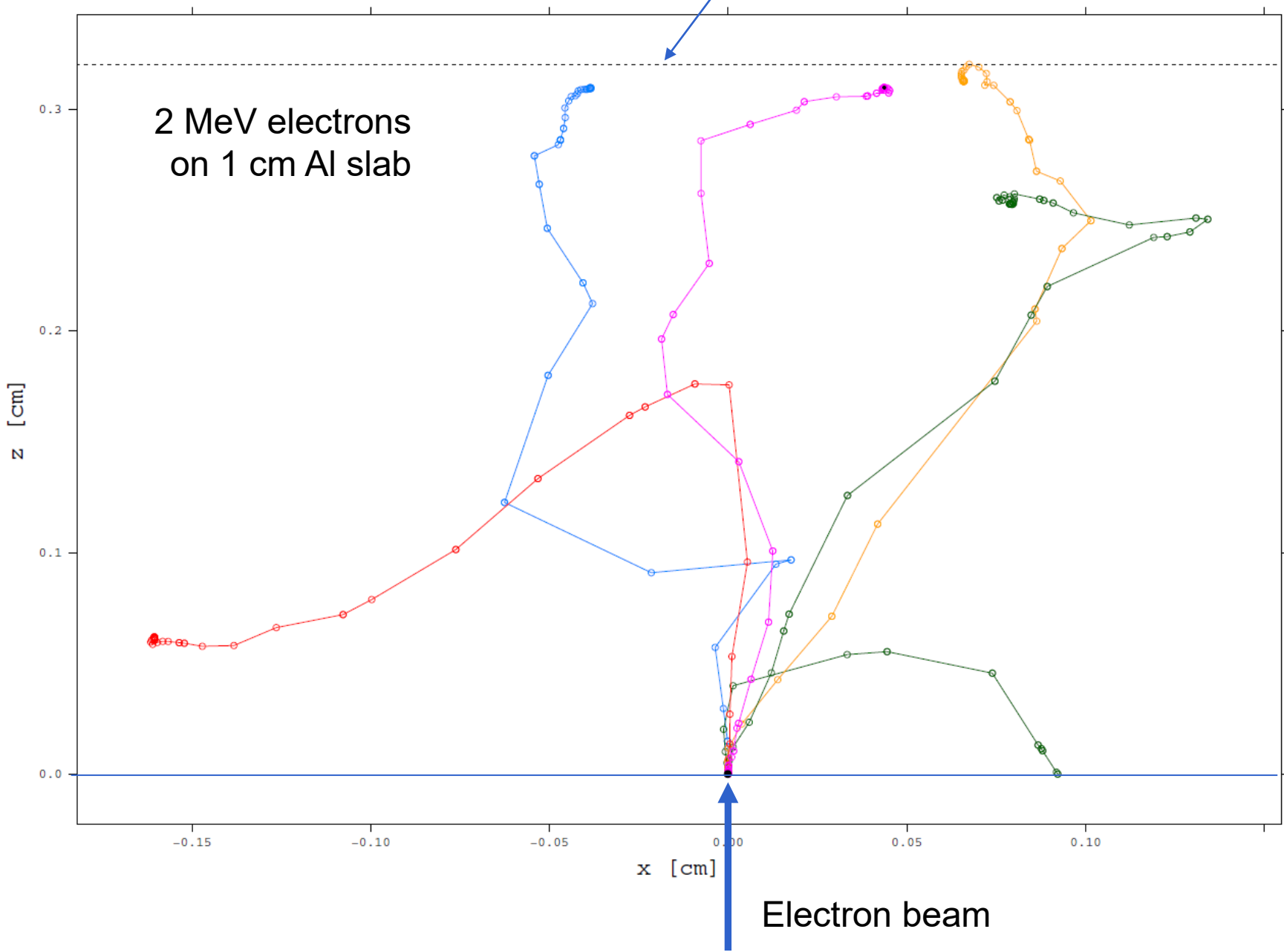
Topas is a research tool.

It cannot be used directly for clinical work.

EGSnrc simulation
(IWATCH analysis)

Computation of projected range

2 MeV electrons
on 1 cm Al slab



What types of sections do we have in Topas parameter files?

Topas Documentation, Release 3.8 by Topas MC Inc :

8.6.5 Quick Ways to Deactivate Parts of the Parameters Files

For most parameter categories, there is one key kind of parameter that triggers creation:

| Parameter object type | Triggering pattern |
|-----------------------|---------------------|
| Element | El/.../Symbol = |
| Material | Ma/.../Components = |
| Component | Ge/.../Parent = |
| Particle Source | So/.../Type = |
| Physics setup | Ph/.../Type = |
| Scorer | Sc/.../Quantity = |
| Graphic | Gr/.../Type = |
| Variance Reduction | Vr/.../Type = |
| Time Feature | Tf/.../Function = |

How to refer to particle types in
Topas?

Particle names used in parameter files

(e.g. for particle sources or filters)

gamma
e-
e+
neutron
proton
...

Main particle codes used in output

(defined by the Particle Data Group, PDG)

22 = photon
11 = electron
-11 = positron
2112 = neutron
2212 = proton
...

What processes do Topas know
about?

What physics is applied?

Selection of physics lists

1. The default, built-in physics list is :

```
sv:Ph/Default/Modules 6 g4em-standard_opt4 g4h-phy_QGSP_BIC_HP  
g4decay g4ion-binarycascade g4h-elastic_HP g4stopping
```

This is what you get if, you do not specify anything.

2. Just electromagnetic interactions:

```
s:Ph/ListName = "MyList"  
sv:Ph/MyList/Modules = 1 "g4em-standard_opt4"
```

To obtain extra accuracy, one can specify that even very low-energetic electrons should be produced and transported. The energy cut is specified as a range in the local material. For example:

```
d:Ph/MyList/CutForElectron = 0.001 mm    # High accuracy
```

```
d:Ph/MyList/CutForElectron = 10 mm        # Low accuracy
```

3. Hadronics, radioactive decay etc. :

```
s:Ph/ListName = "MyList2"  
sv:Ph/MyList2/Modules = 7 "g4em-standard_opt4"  
"g4h-phy_QGSP_BIC_HP" "g4decay" "g4ion-binarycascade"  
"g4h-elastic_HP" "g4stopping" "g4radioactivedecay"
```

Process names (examples)

These names can, e.g., be used by filters to score particles from processes.

| Name | Description |
|------------------------|-------------------------------------|
| "annihil" | Annihilation |
| "compt" | Compton |
| "eBrem" | Bremsstrahlung produced by electron |
| "Decay" | Decay (of sub-atomic particle) |
| "eIoni" | |
| "hadElastic" | Hadronic elastic scattering |
| "hIoni" | |
| "neutronInelastic" | |
| "nCapture" | Neutron capture |
| "phot" | Photoelectric effect |
| "primary" | |
| "protonInelastic" | |
| "RadioactiveDecayBase" | Radiation from radioactive decay |
| "Rayl" | Rayleigh scattering (photons) |

To see what processes you have use:

b:Ph/ListProcesses = "TRUE" and b:Ts/DumpParameters = "True"

Registered Physics Processes for "g4em-standard_opt4":

Transportation, StepLimiter, UserSpecialCut, phot,
compt, conv, Rayl, msc, eIoni, eBrem, ePairProd,
CoulombScat, annihil, muIoni, muBrems, muPairProd,
hIoni, hBrems, hPairProd, ionIoni, nuclearStopping


**Registered Physics Processes for the default built-in physics
list (6 modules):**

Transportation, StepLimiter, UserSpecialCut, phot, compt, conv,
Rayl, msc, eIoni, eBrem, ePairProd, CoulombScat, annihil, muIoni,
muBrems, muPairProd, hIoni, hBrems, hPairProd, ionIoni,
nuclearStopping, neutronInelastic, nCapture, nFission,
protonInelastic, pi+Inelastic, pi-Inelastic, kaon+Inelastic,
kaon-Inelastic, kaon0LInelastic, kaon0SInelastic,
lambdaInelasticanti-lambdaInelastic, sigma-Inelastic, anti_sigma-
Inelastic, sigma+Inelasticanti_sigma+Inelastic,
xi-Inelastic, anti_xi-Inelastic, xi0Inelastic, anti_xi0Inelastic,
omega-Inelastic, anti_omegaInelastic, anti_protonInelastic,
anti_neutronInelastic, anti_deuteronInelastic,
anti_tritonInelastic, anti_He3Inelastic anti_alphaInelastic,
Decay, dInelastic, tInelastic, He3Inelastic, alphaInelastic,
ionInelastic, hadElasticchFritiofCaptureAtRest,
hBertiniCaptureAtRest, muMinusCaptureAtRest

How to estimate the "statistical"
uncertainty of a result?

Statistics for a scorer

Examples of what we can
request Topas to report



sv:Sc/MyScorer/Report = 1 "Sum"

sv:Sc/MyScorer/Report = 4 "Count_In_Bin" "Sum" "Mean" "Standard_Deviation"

Histories, Count_In_Bin,
Sum, Mean,
Variance, Standard_Deviation,
Second_Moment,
Min, Max

Histories = total number of histories (N) that were simulated

Count_In_Bin = number of histories that contributed to the bin
(i.e. excluding histories for which no particles hit this bin).

If we call

Standard_Deviation = SD

then

$u(\text{mean}) = \text{SD}/\sqrt{N}$ = the statistical uncertainty of the mean value

$u(\text{sum}) = u(\text{mean} * N) = u(\text{mean}) * N = \text{SD}/\sqrt{N} * N = \text{SD} * \sqrt{N}$

Sample output and uncertainty statement

```
# TOPAS Version: 3.7
# Parameter File: sandbox-10011.txt
# Results for scorer clanScorer1
# Scored in component: centerrod
# X in 1 bin of 1 cm
# Y in 1 bin of 1 cm
# Z in 200 bins of 0.15 cm
# DoseToMedium ( Gy ) : Count_in_Bin    Sum    Mean    Standard_Deviation
0, 0, 0, 429, 1.478240250207818e-07, 1.478240269572828e-13, 9.802415598904964e-12
0, 0, 1, 403, 1.445507535891011e-07, 1.445507558951234e-13, 9.149940147400391e-12
..
0, 0, 5, 444, 1.635282558254403e-07, 1.635282491183899e-13, 1.000433808080876e-11
0, 0, 6, 449, 1.670288014565813e-07, 1.670288067970067e-13, 1.056387068426724e-11
```

N = 1000'000 histories

Sum

Mean

Standard deviation

So, assume the mean dose for the z=6 voxel is our key result. What is the statistical uncertainty?

$D = 1.670288067970067e-13 \text{ Gy}$

$u(D) = 1.056387068426724e-11 \text{ Gy}/\sqrt{N} = 1.1 \text{ E-14 Gy}$

So, we could write: **$D = (1.67 \pm 0.11) \text{ E-13 Gy (k=1)}$**

The uncertainty $u(D)$ tells us how well we think we know the result D .

The "k = 1" implies that the uncertainty is a standard uncertainty (i.e. expressed as one standard deviation).

Can I have more than one
scorer in a file?

"Multiple scorers" mean "multiple files"

No, there can only be one scorer per output file.

It may therefore be useful to let the names of output files consist of two parts:
(1) a first part common for the given parameter file, and (2) a second part which is specific for each scorer.

One can realize the "common part" by using the "message parameter" as shown below:

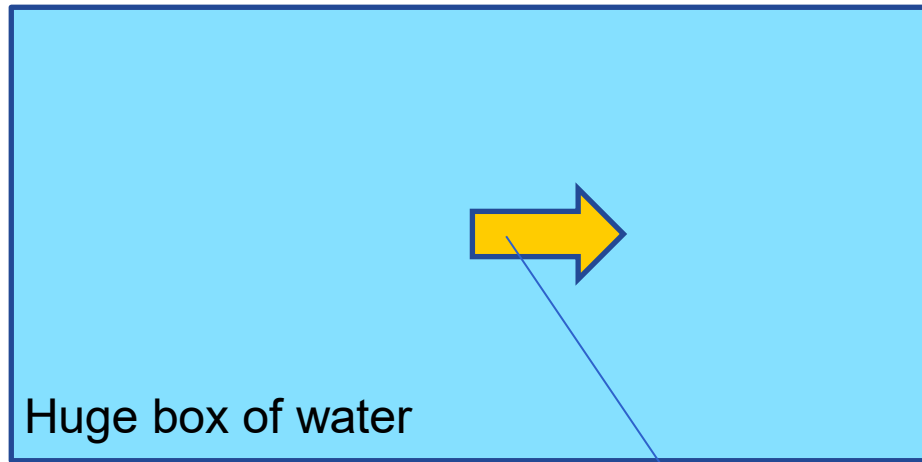
```
s:Ge/World/Message = "flatpanel-10002-"  
s:Sc/clanScorer1/OutputFile = Ge/World/Message + "DoseScorer1"  
s:Sc/clanScorer2/OutputFile = Ge/World/Message + "DoseScorer2"  
s:Sc/clanScorer3/OutputFile = Ge/World/Message + "Phasespace1"
```

which produces output files:

```
flatpanel-10002-DoseScorer1  
flatpanel-10002-DoseScorer2  
flatpanel-10002-Phasespace1
```


Can Topas measure dose?
Let's make a simple test.

Test of dose-to-medium scorer



All particle energy stays within the huge box of water, so we know the mean dose!

Box of water.

Dimensions = 10 m x 10 m x 100 m of water with density 1 g/cm³

Internal source of 1 MeV particles emitted in the z-direction

Score the dose in the box: Energy imparted divided by mass of box

Send off N = 80000 1 MeV particles. What will the mean dose in the box be if we assume that no primaries and secondaries escape the box?

$$D = \frac{80000 \cdot 10^6 \cdot 1.60217649 \cdot 10^{-19} \text{ J}}{10 \cdot 10 \cdot 100 \text{ m}^3 \cdot 10^3 \text{ kg/m}^3}$$

$$D = 1.28174119 \cdot 10^{-15} \text{ Gy}$$

$$\rho = 1 \frac{\text{g}}{\text{cm}^3} = 10^3 \frac{\text{kg}}{\text{m}^3}$$

Test of dose-to-medium scorer

```
# The slab 1
s:Ge/clanSlab1/Type      = "TsBox"
s:Ge/clanSlab1/Material  = "Water_75eV"
s:Ge/clanSlab1/Parent   = "World"
d:Ge/clanSlab1/HLX      = 5 m
d:Ge/clanSlab1/HLY      = 5 m
d:Ge/clanSlab1/HLZ      = 50 m
d:Ge/clanSlab1/TransX    = 0. m
d:Ge/clanSlab1/TransY    = 0. m
d:Ge/clanSlab1/TransZ    = 0. mm
d:Ge/clanSlab1/RotX      = 0. deg
d:Ge/clanSlab1/RotY      = 0. deg
d:Ge/clanSlab1/RotZ      = 0. deg
```

Test of dose-to-medium scorer

```
# Beam position
s:Ge/clanBeamPosition/Parent = "clanslab1"
s:Ge/clanBeamPosition/Type = "Group"
d:Ge/clanBeamPosition/TransX = 0.0 m
d:Ge/clanBeamPosition/TransY = 0.0 m
d:Ge/clanBeamPosition/TransZ = 0.0 m
d:Ge/clanBeamPosition/RotX = 0.0 deg
d:Ge/clanBeamPosition/RotY = 0.0 deg
d:Ge/clanBeamPosition/RotZ = 0.0 deg

# Beam
s:So/clanBeam/Type = "Beam"
s:So/clanBeam/Component = "clanBeamPosition"
s:So/clanBeam/BeamParticle = "e-"
d:So/clanBeam/BeamEnergy = 1 MeV
```

| Particle | Energy | Dose [10^{-15} Gy] | Method |
|----------|--------------|----------------------------------|-----------------------------|
| Anything | 1 MeV | 1.28174119 (hand computation) | Analytical (reference) |
| | | | |
| e- | 1 MeV | 1.28174116 | Topas, OK |
| gamma | 1 MeV | 1.28174116 | Topas, OK |
| proton | 1 MeV | 1.28174116 | Topas, OK |
| | | | |
| neutron | 1 MeV | 4.13712127 | Topas, OK? |
| neutron | 1 eV | 2.8540072 | Topas |
| neutron | 1 MeV – 1 eV | 1.28311 | Difference (probably ok) |

Test of dose-to-medium scorer

Why did the test apparently fail for neutrons?

Topas measured a dose exceeding 2 MeV per particle even when the neutrons only had 1 eV kinetic energy! This must somehow be related to rest mass changes.

The difference between the dose from 1 eV neutrons and 1 MeV neutrons is about 1 MeV. This indicates that the excess energy is released by a process occurring already at thermal neutron energies.

Further investigation using the 4pi-detector (see later) reveals that thermal neutrons undergo **neutron capture with the emission of a prompt 2.22 MeV gamma**. We transform hydrogen to deuterium, and get heavy water! This explains the excess energy absorption. Deuterium is a stable isotope, so there is no activation. We do not get exactly 2.22 MeV in the computation as activation of oxygen can also happen (see next slide), albeit only with a low probability.

What else to consider with neutron modelling?

We need a physics list that handles hadronics. The Topas 3.9 default physics lists were used for these computations. If the physics list had been set to `g4em-standard_opt4` (only electromagnetic interactions = em), for example, Topas would not have known how to transport neutrons and the neutron kinetic energy would be dumped on the spot.

Neutron activation of water?

Progress in Nuclear Energy 117 (2019) 103042



Contents lists available at ScienceDirect

Progress in Nuclear Energy

journal homepage: www.elsevier.com/locate/pnucene

Review

On the dose fields due to activated cooling water in nuclear facilities

Andrej Žohar, Luka Snoj*

Note that the O-18 reactions are possible at thermal neutron energies

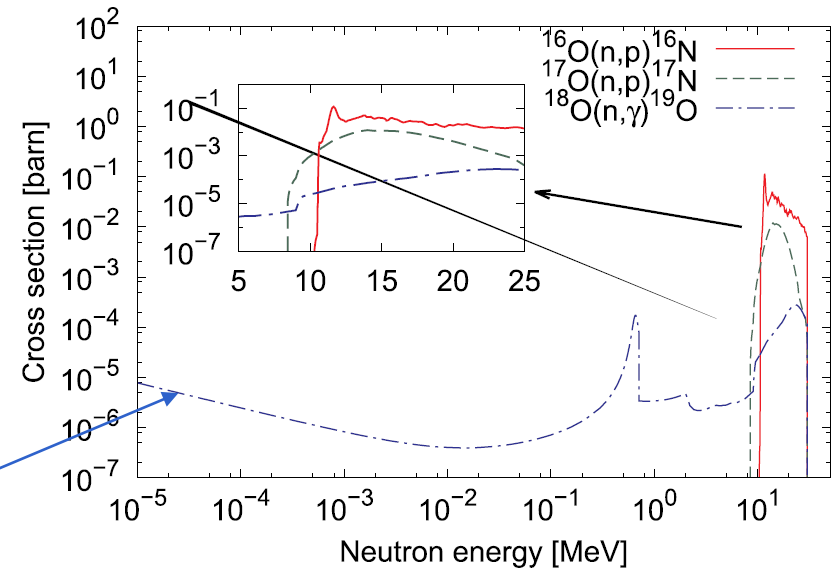


Fig. 1. Cross-section energy dependence for activation of oxygen nuclide taken from the JEFF-3.2 data library (OECD/NEA Data Bank, 2014).

... but it is not very likely

[illegible]

How to apply filters to get
results for certain
particles etc. ?

or

How to find μ for mono-
energetic photon beams?

or

What is a primary photon in
Topas?

Filters for scorers

```
sv:Sc/FS6/OnlyIncludeParticlesNamed = 1 "gamma"
```

```
d:Sc/FS6/OnlyIncludeIfIncidentParticleKEAbove = 9.95 MeV
```

```
s:Sc/FS6/OnlyIncludeParticlesOfGeneration = "Primary"
```

```
s:Sc/FS6/OnlyIncludeParticlesOfGeneration = "Secondary"
```

```
sv:Sc/FS6/OnlyIncludeIfParticleOrAncestorFromProcess = 1 "compt"
```

Compton

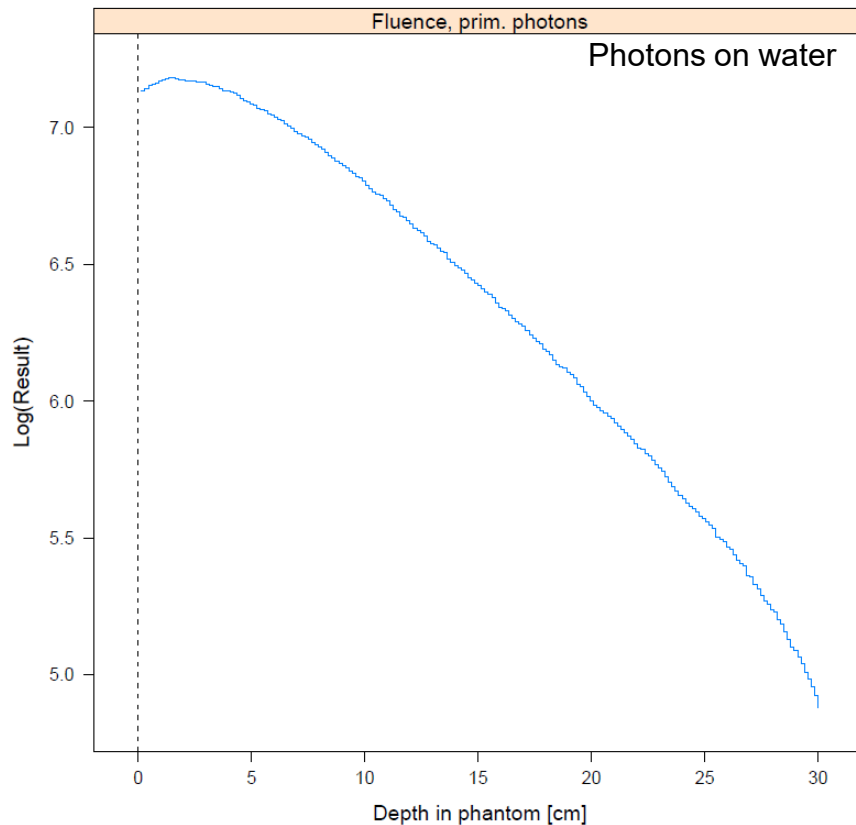


Filters for scorers

Example

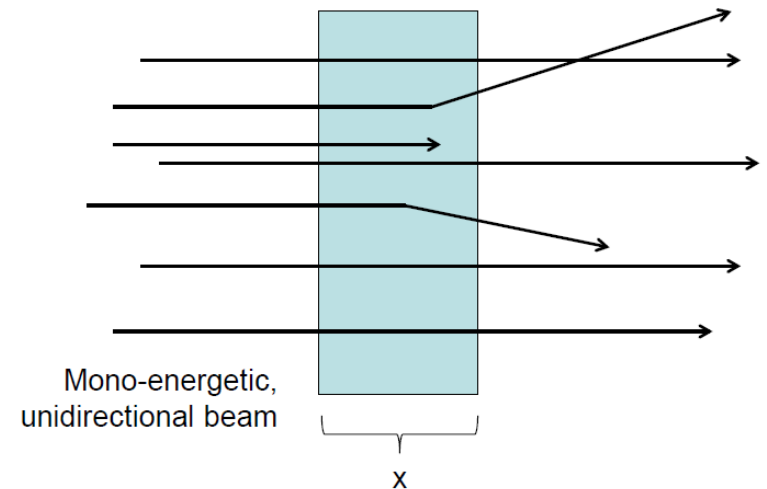
```
# Fluence of primary photons
s:Sc/FluenceScorer3/Quantity = "Fluence"
sv:Sc/FluenceScorer3/OnlyIncludeParticlesNamed = 1 "gamma"
s:Sc/FluenceScorer3/OnlyIncludeParticlesOfGeneration = "Primary"
```

Fluence of "Topas primary photons" vs.
depth in water for 500 keV photons



Exponential attenuation

$$\Phi_0 \quad \Phi(x) = \Phi_0 \exp(-\mu x)$$



μ is the linear attenuation coefficient =
the probability for interaction pr. unit distance pr. photon

Q: Why is the fluence of primary photons **not** governed by exponential attenuation??

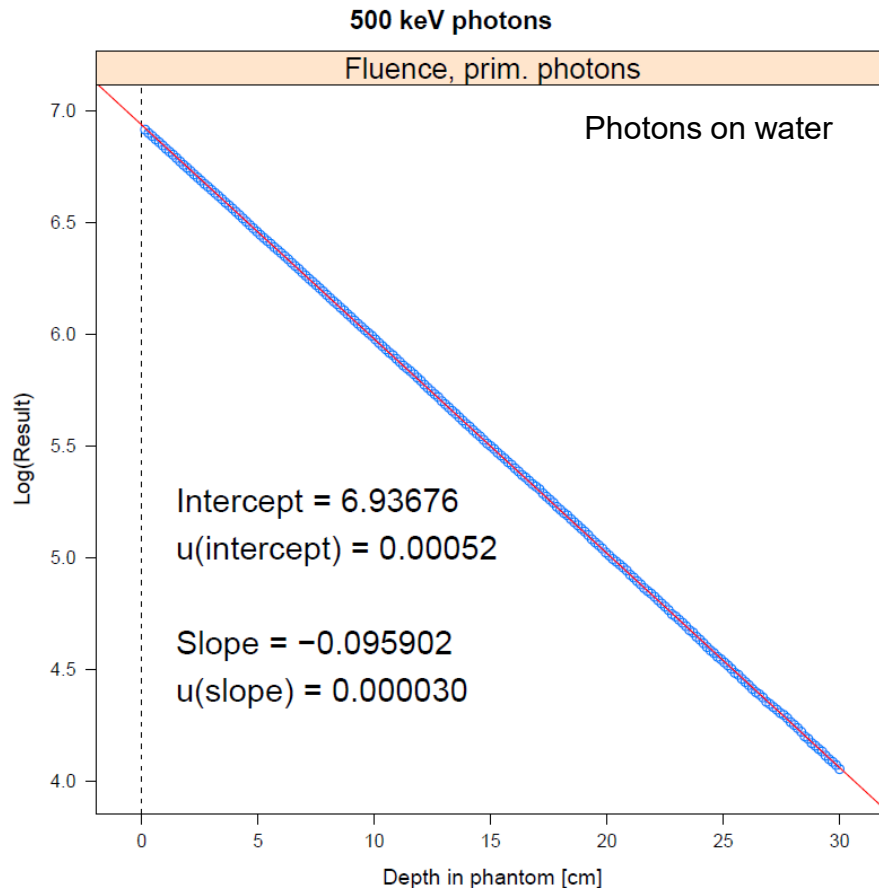
A: Because "primary photons" in Topas terminology is not what is primary in the normal sense that they have not undergone any form of interaction.

So, to get truly "primary" photons it is not enough to request Topas to give primaries.

Filters for scorers

Example

```
# Fluence of primary photons
s:Sc/FluenceScorer3/Quantity = "Fluence"
sv:Sc/FluenceScorer3/OnlyIncludeParticlesNamed = 1 "gamma"
s:Sc/FluenceScorer3/OnlyIncludeParticlesOfGeneration = "Primary"
d:Sc/FluenceScorer3/OnlyIncludeIfIncidentParticleKEAbove = 0.495 MeV
```

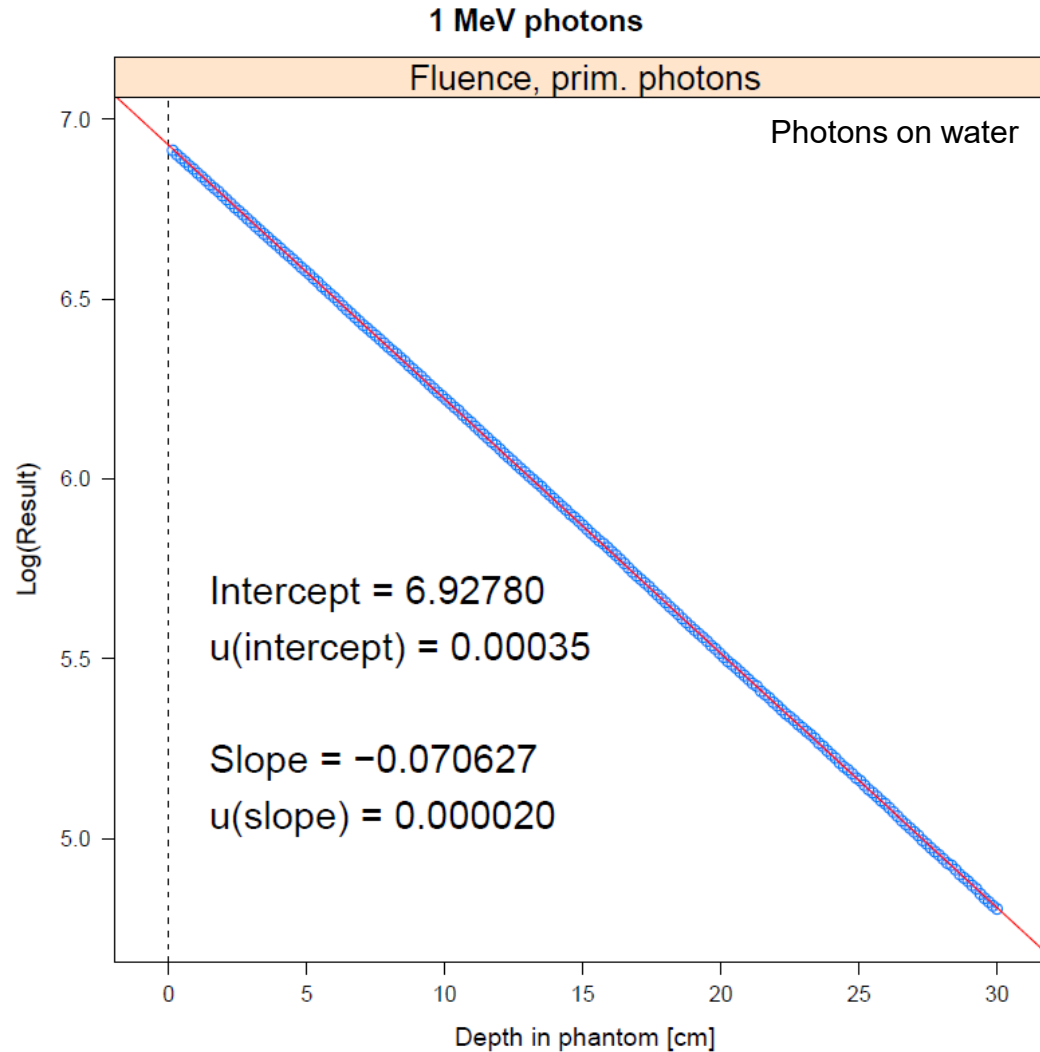


We also filter by energy to get the "true" primaries only.

Now, we can confirm exponential attenuation. The μ for 500 keV photons is the negative slope of the semi-log regression: $\mu = 0.095902 \text{ 1/cm}$ which is in reasonable agreement with the 0.0966 1/cm given by Attix, Appendix D.

Filters for scorers

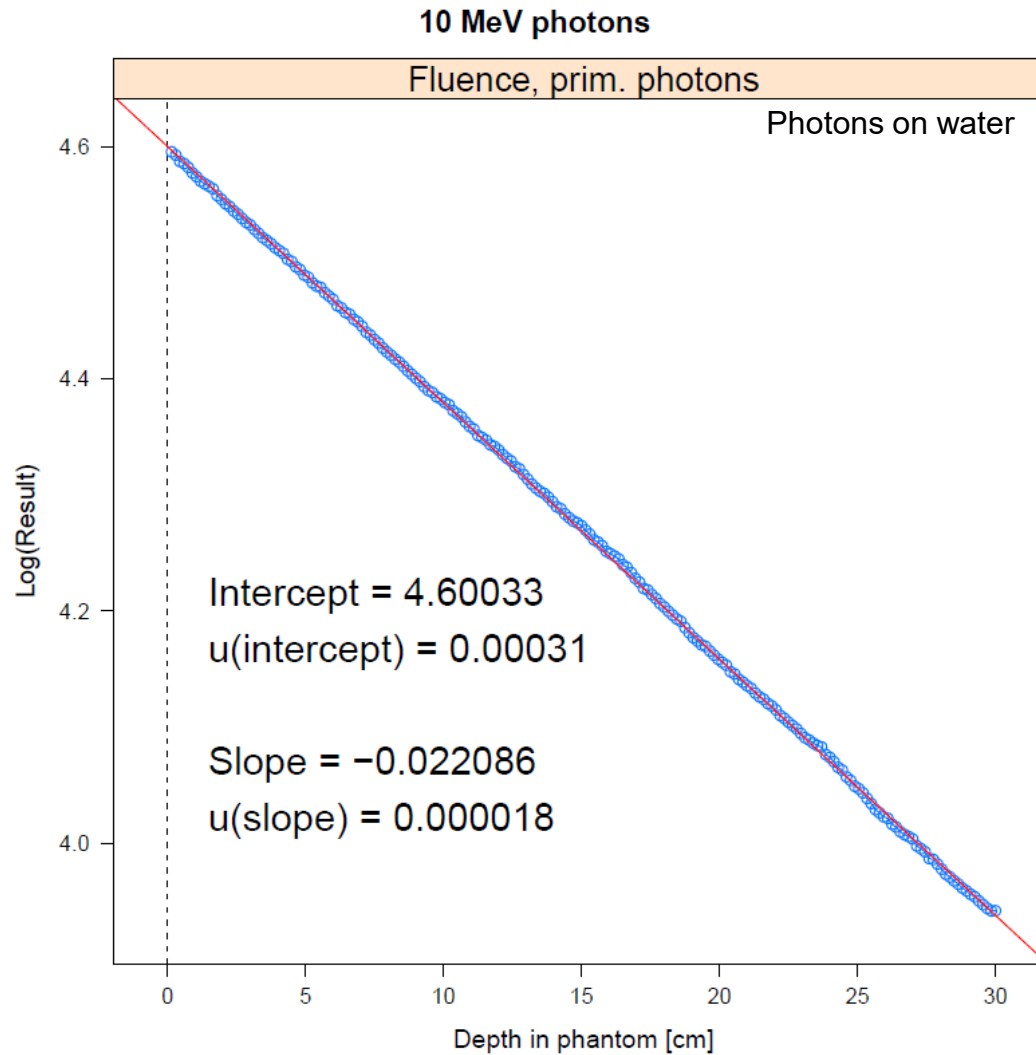
Example



Good agreement with the 0.0706 1/cm given by Attix, Appendix D.

Filters for scorers

Example



Good agreement with the 0.0222 1/cm given by Attix, Appendix D.

In what direction does the
particle source shoot?

Meaning of TransZ and RotX for source components

Beam position, With RotX = 180 deg,
the beam will be in the negative z-axis direction

```
s:Ge/clanBeamPosition/Parent = "World"
```

```
s:Ge/clanBeamPosition/Type = "Group"
```

```
d:Ge/clanBeamPosition/TransX = 0. m
```

```
d:Ge/clanBeamPosition/TransY = 0. m
```

```
d:Ge/clanBeamPosition/TransZ = 0.9 * Ge/World/HLZ m
```

Note the unit




```
d:Ge/clanBeamPosition/RotX = 180. deg
```

```
d:Ge/clanBeamPosition/RotY = 0. deg
```

```
d:Ge/clanBeamPosition/RotZ = 0. deg
```

Rotate with x-axis
as normal vector



```
# Beam
```

```
s:So/clanBeam/Type = "Beam"
```

```
s:So/clanBeam/Component = "clanBeamPosition"
```

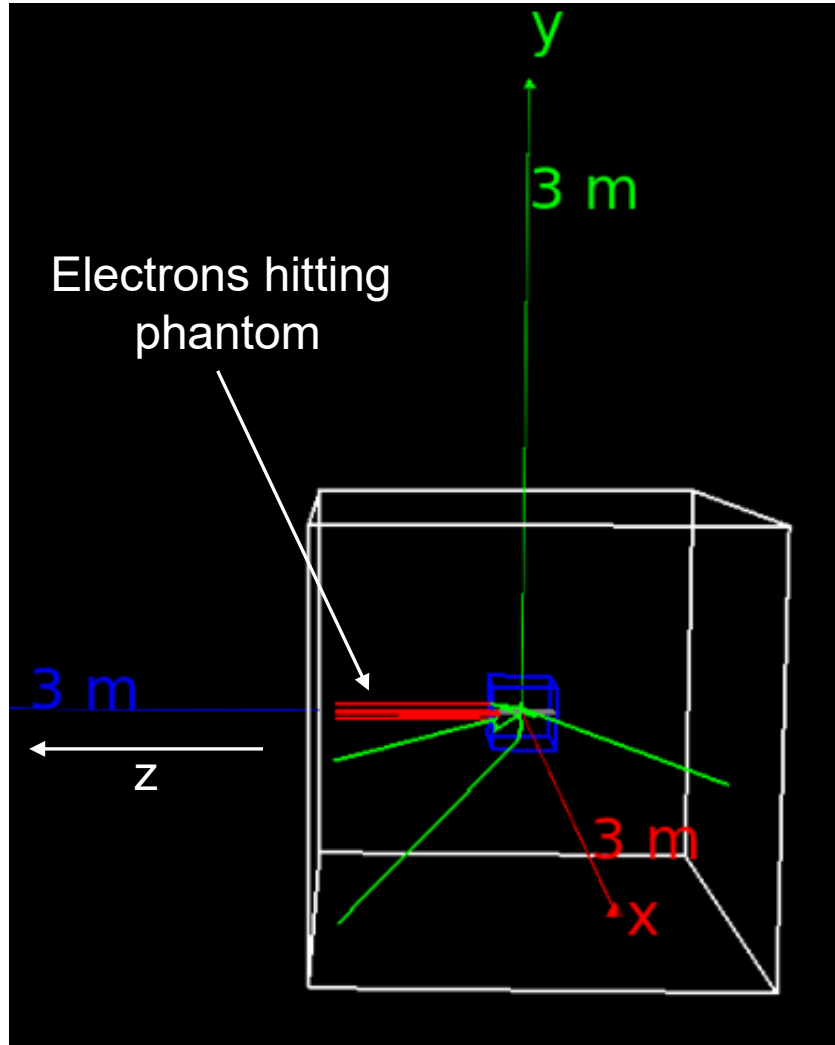
```
s:So/clanBeam/BeamParticle = "e-"
```

```
d:So/clanBeam/BeamEnergy = 10 MeV
```

Case 1 (ok)

d:Ge/BeamPosition/RotX = 180. deg

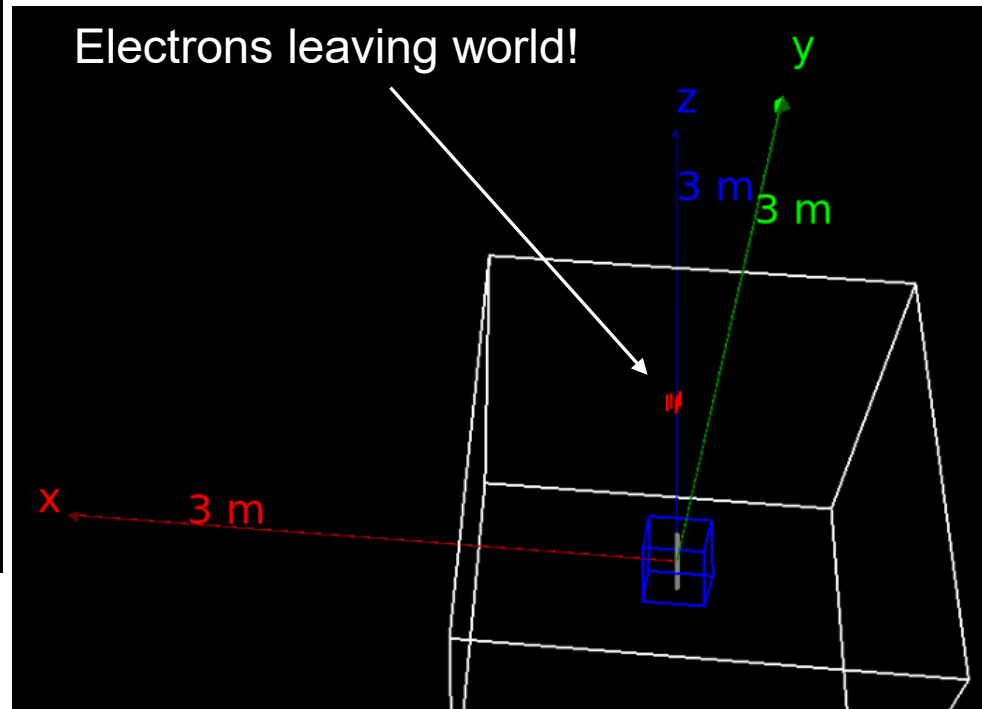
Shooting in negative z-direction



Case 2 (not ok)

d:Ge/BeamPosition/RotX = 0. deg

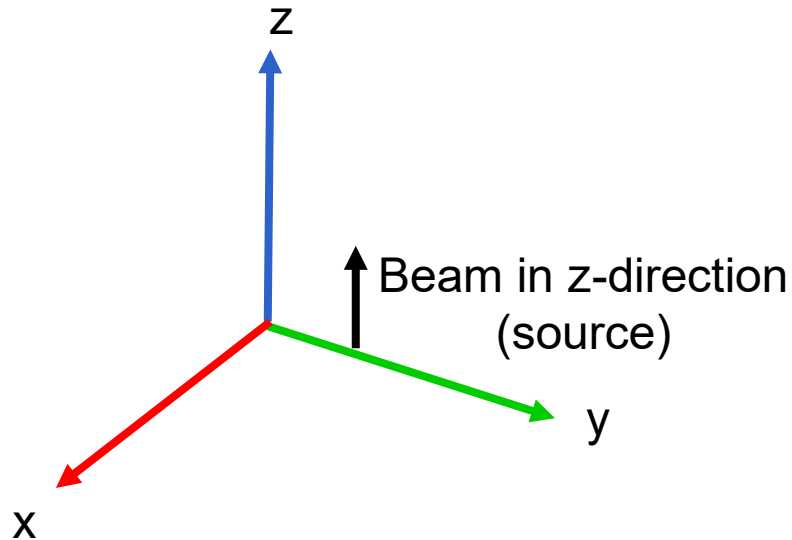
Shooting in positive z-direction.
Since the source is a bit from the world edge, we see small traces of the beam particles before they leave.



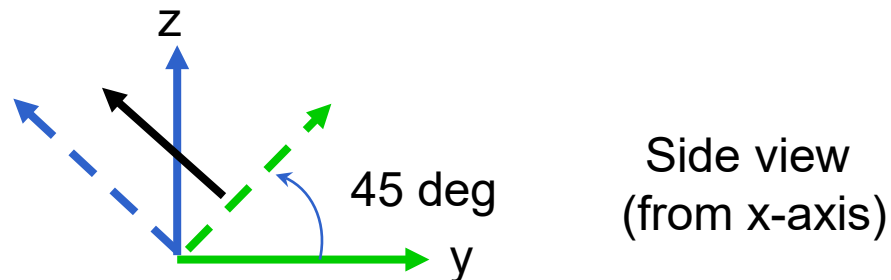
White box = world

Source is at $z = 0.9 \times \text{HLZ}$ for world

Meaning of RotX = 45.0 deg?



Rotate source 45 deg around the x-axis (i.e. the x-axis as normal vector and then rotate 45 deg following the right-hand-rule).



Rotated beam $x_{rot} = 45$ deg (still perpendicular with x-axis).

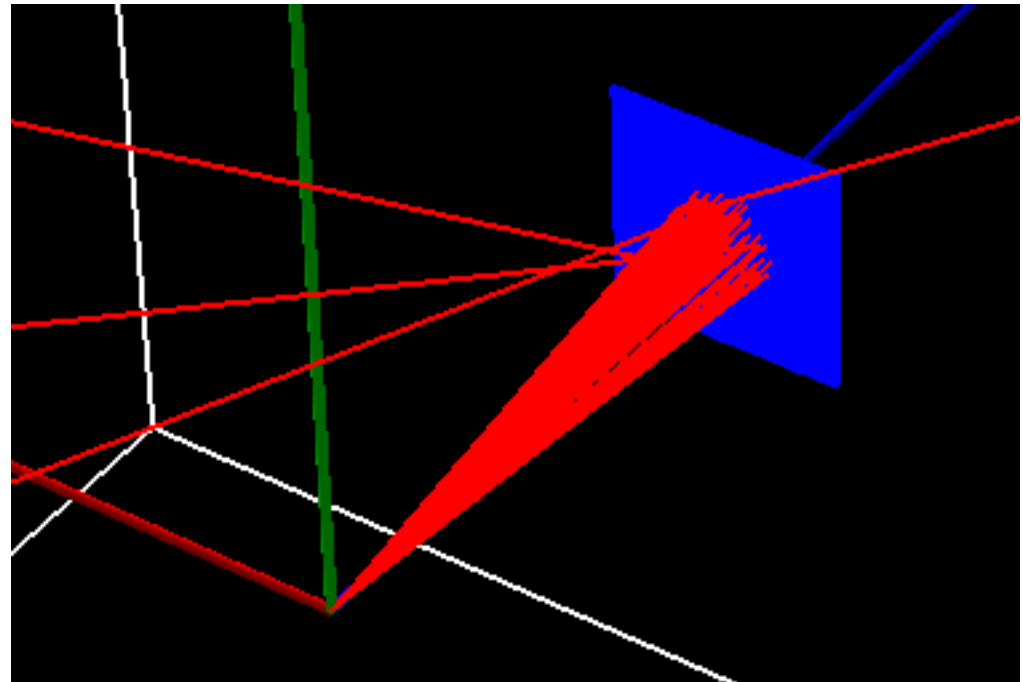
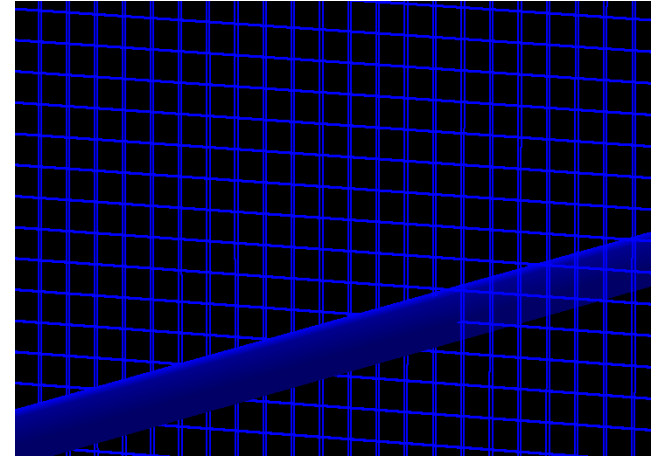
Rotating source RotX = 180 deg means that the source emits in the negative z-direction.

Beam shape parameters

Scoring beam intensity using a 40 cm x 40 cm "flatpanel detector" 1 m from the source

```
# The flatpanel (40 x 40 resolution)
s:Ge/flatpanel/Type      = "TsBox"
s:Ge/flatpanel/Material  = "Water_75eV"
s:Ge/flatpanel/Parent    = "World"
d:Ge/flatpanel/HLX       = 20 cm
d:Ge/flatpanel/HLY       = 20 cm
d:Ge/flatpanel/HLZ       = 1 mm
d:Ge/flatpanel/TransX    = 0. m
d:Ge/flatpanel/TransY    = 0. m
d:Ge/flatpanel/TransZ    = 1. m
d:Ge/flatpanel/RotX      = 0. deg
d:Ge/flatpanel/RotY      = 0. deg
d:Ge/flatpanel/RotZ      = 0. deg
s:Ge/flatpanel/color     = "blue"
i:Ge/flatpanel/XBins     = 40
i:Ge/flatpanel/YBins     = 40
```

The "flatpanel" scorer will give
a $40 \times 40 = 1600$ (voxels) array
of dose values.



NOTE: This gives a parallel beam, 20 cm x 20 cm

Case 1

```
s:So/clangBeam/BeamPositionDistribution = "Flat"
```

```
# Flat or Gaussian
```

```
s:So/clangBeam/BeamPositionCutoffShape = "Rectangle"
```

```
# Ellipse, Rectangle
```

```
d:So/clangBeam/BeamPositionCutoffX = 100.0 mm
```

```
d:So/clangBeam/BeamPositionCutoffY = 100.0 mm
```

```
d:So/clangBeam/BeamPositionSpreadX = 0.0 mm
```

```
d:So/clangBeam/BeamPositionSpreadY = 0.0 mm
```

```
s:So/clangBeam/BeamAngularDistribution = "None"
```

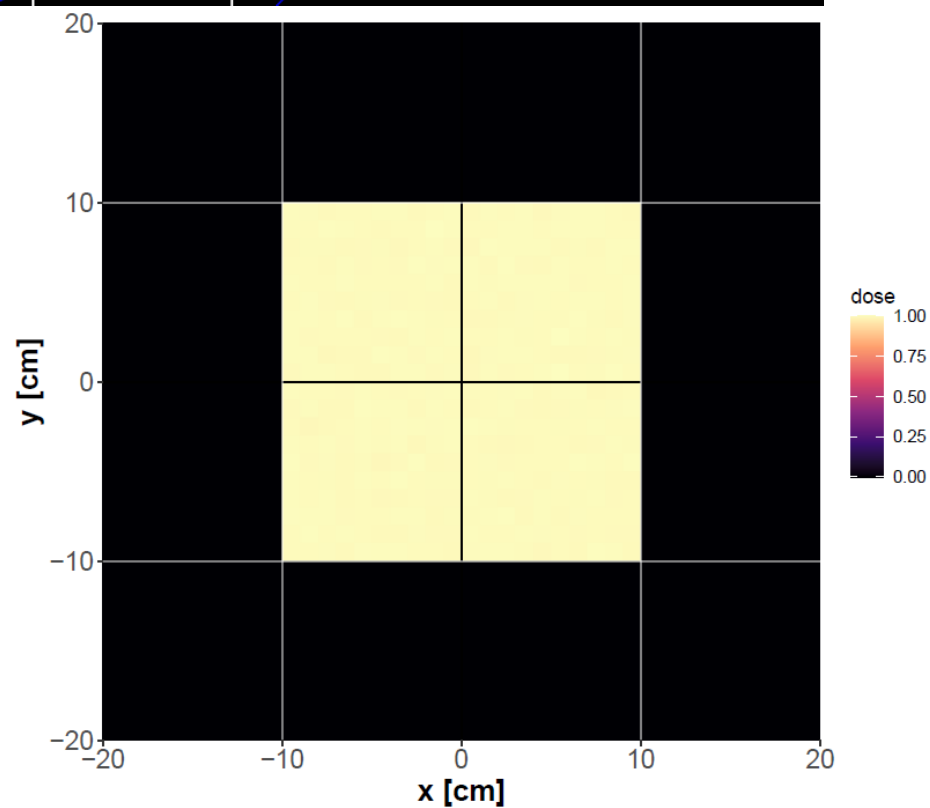
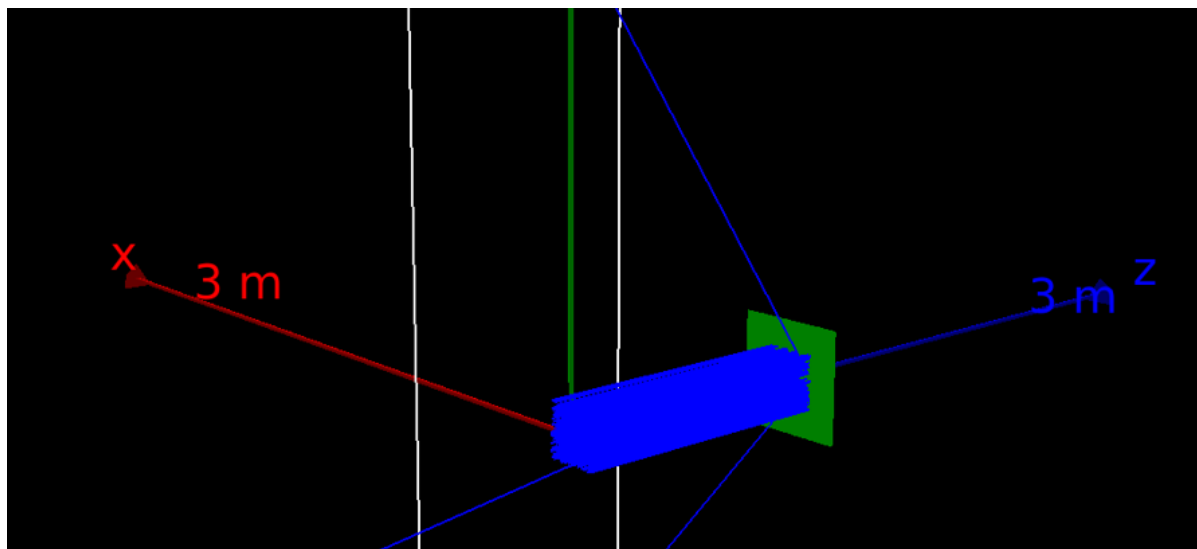
```
d:So/clangBeam/BeamAngularCutoffX = 0.0 deg
```

```
d:So/clangBeam/BeamAngularCutoffY = 0.0 deg
```

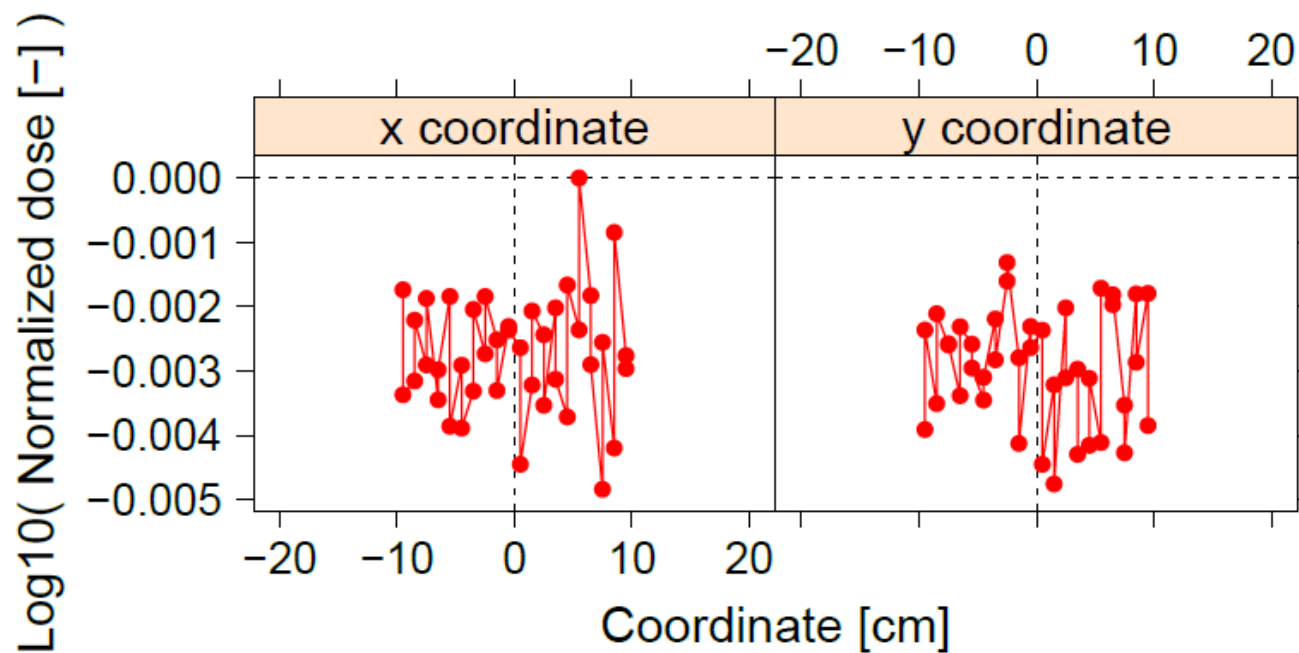
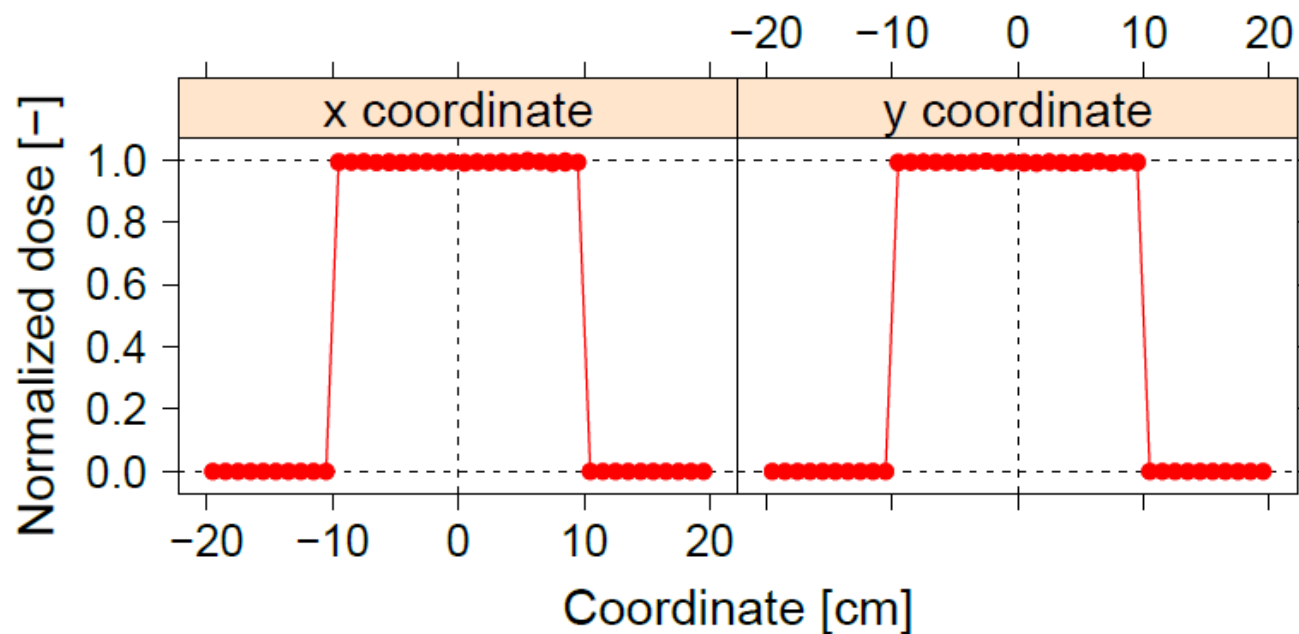
```
d:So/clangBeam/BeamAngularSpreadX = 0.0 deg
```

```
d:So/clangBeam/BeamAngularSpreadY = 0.0 deg
```

Case 1



Case 1



NOTE: This gives a parallel beam, circular beam w. 20 cm diameter

Case 2

```
s:So/clanBeam/BeamPositionDistribution = "Flat"
```

```
# Flat or Gaussian
```

```
s:So/clanBeam/BeamPositionCutoffShape = "Ellipse"
```

```
# Ellipse, Rectangle
```

```
d:So/clanBeam/BeamPositionCutoffX = 100.0 mm
```

```
d:So/clanBeam/BeamPositionCutoffY = 100.0 mm
```

```
d:So/clanBeam/BeamPositionSpreadX = 0.0 mm
```

```
d:So/clanBeam/BeamPositionSpreadY = 0.0 mm
```

```
s:So/clanBeam/BeamAngularDistribution = "None"
```

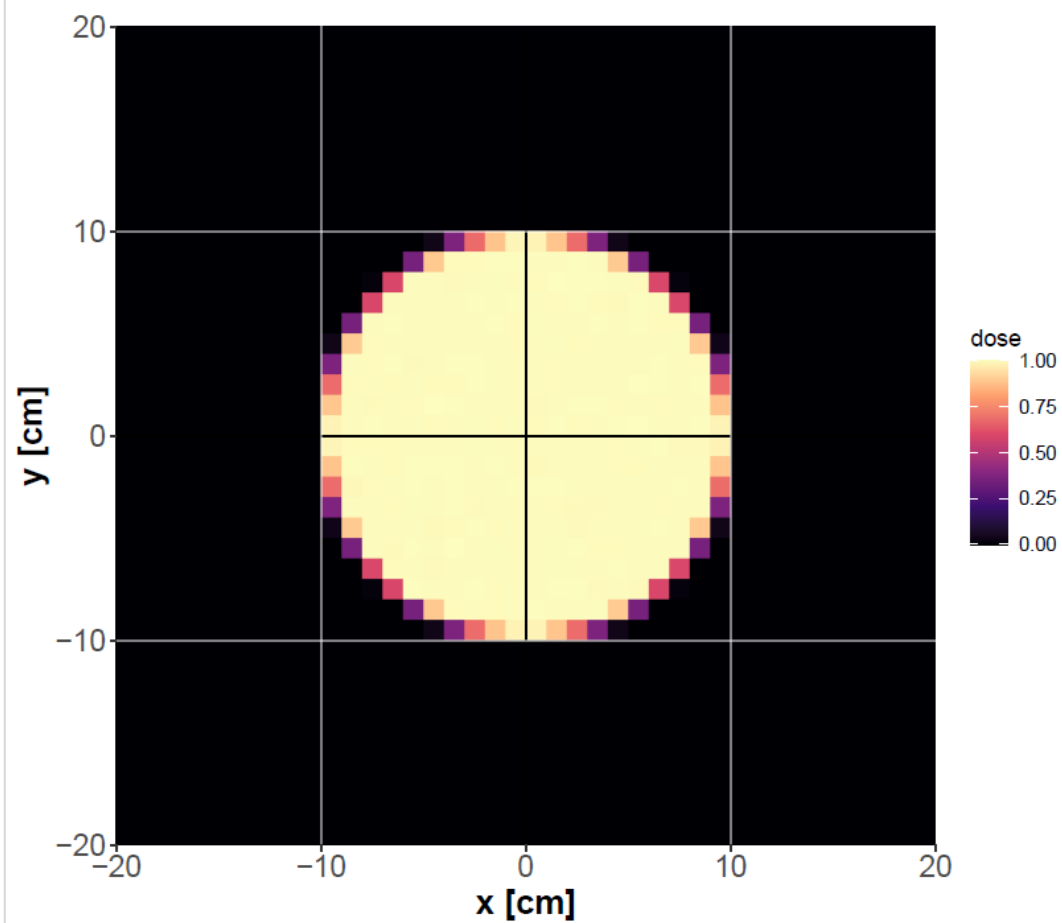
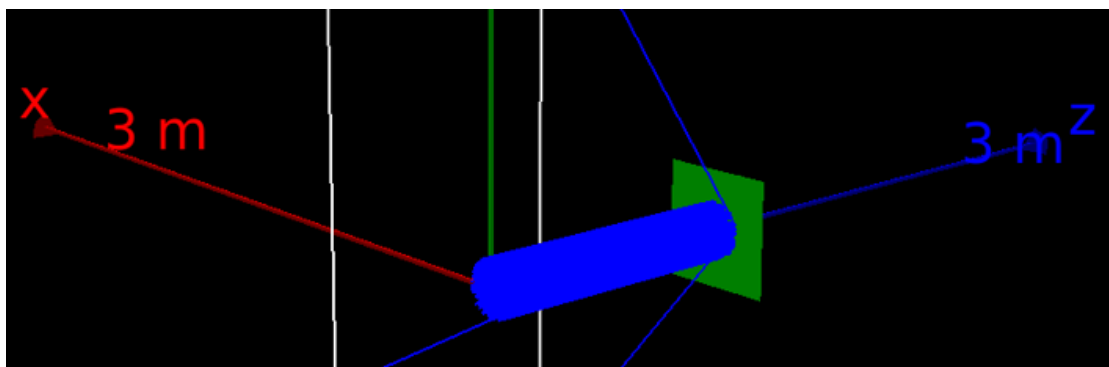
```
d:So/clanBeam/BeamAngularCutoffX = 0.0 deg
```

```
d:So/clanBeam/BeamAngularCutoffY = 0.0 deg
```

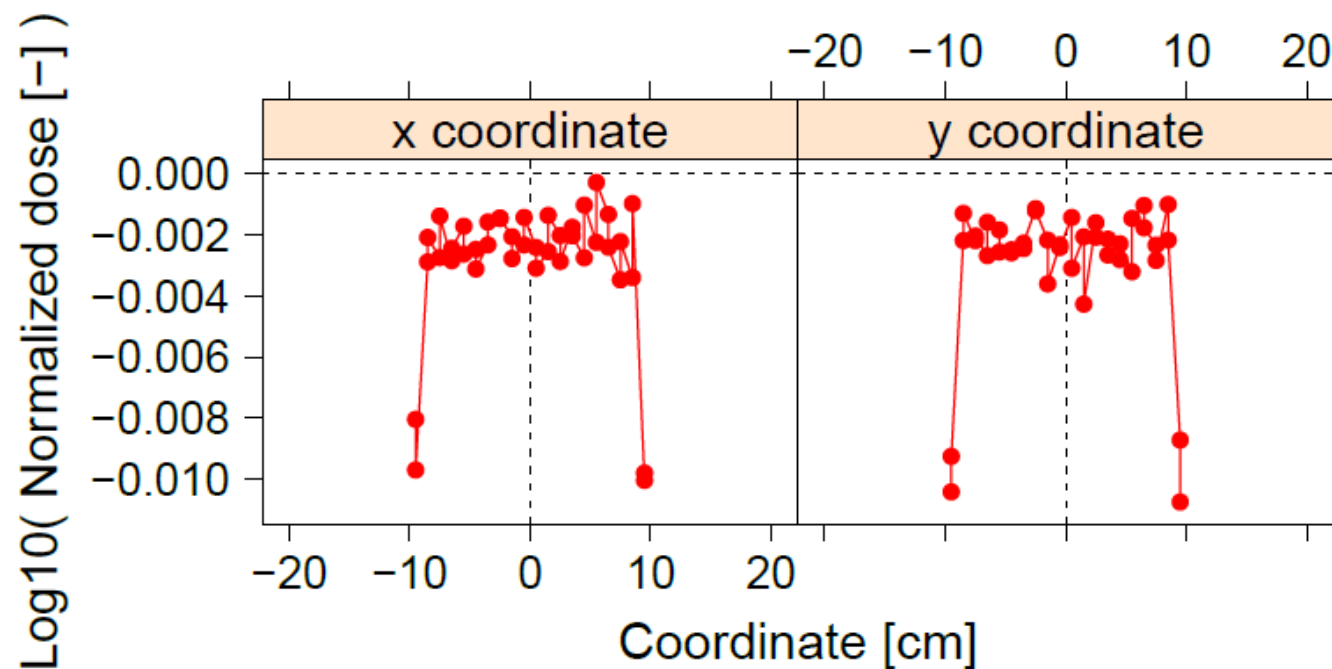
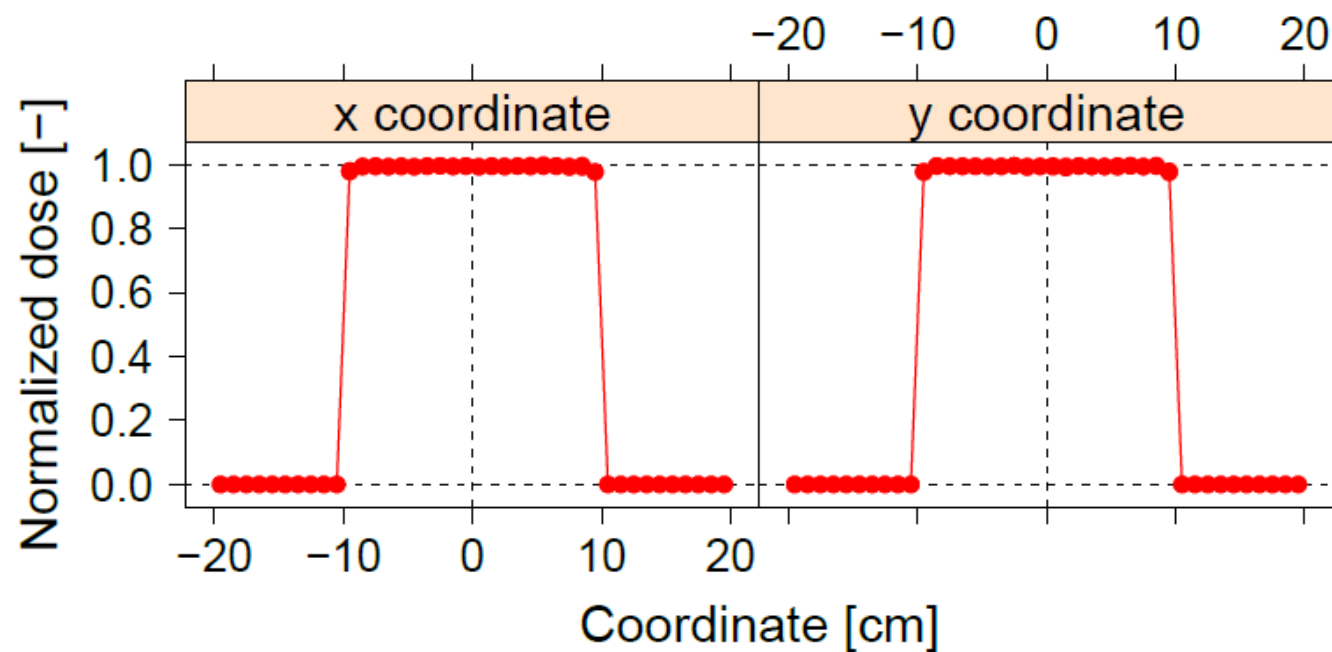
```
d:So/clanBeam/BeamAngularSpreadX = 0.0 deg
```

```
d:So/clanBeam/BeamAngularSpreadY = 0.0 deg
```

Case 2



Case 2



NOTE: Beam intensity described by gaussian parameters

Case 3

s:So/clangBeam/BeamPositionDistribution = **"Gaussian"**

Flat or Gaussian

s:So/clangBeam/BeamPositionCutoffShape = "Rectangle"

Ellipse, Rectangle

d:So/clangBeam/BeamPositionCutoffX = 100.0 mm

d:So/clangBeam/BeamPositionCutoffY = 100.0 mm

d:So/clangBeam/BeamPositionSpreadX = **20.0 mm**

d:So/clangBeam/BeamPositionSpreadY = **70.0 mm**

s:So/clangBeam/BeamAngularDistribution = "None"

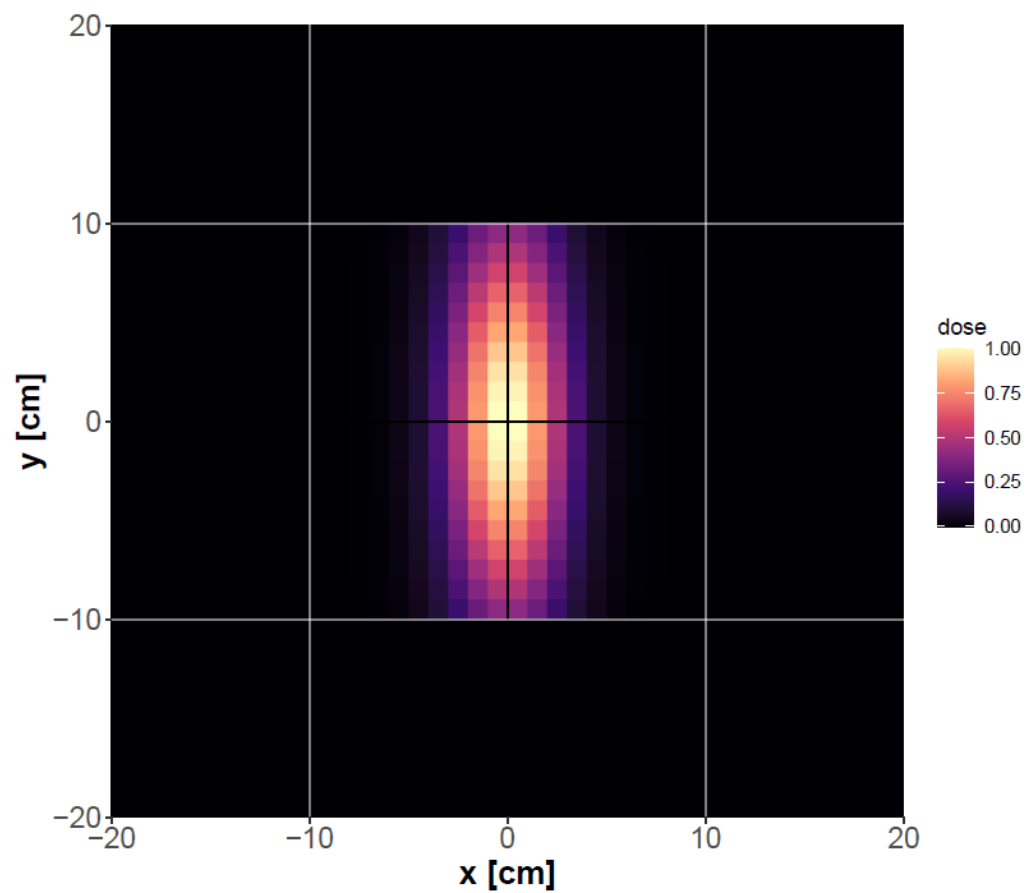
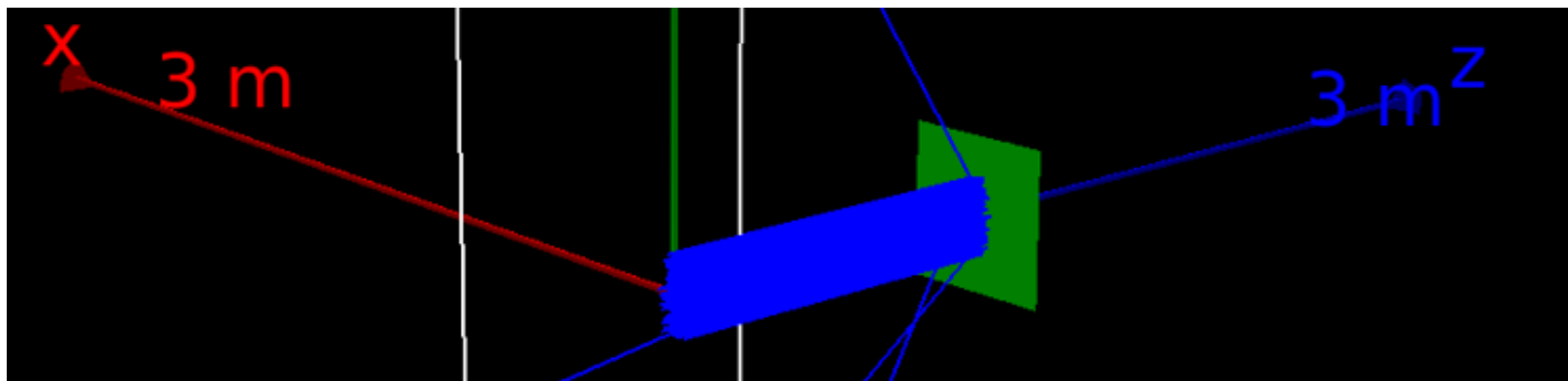
d:So/clangBeam/BeamAngularCutoffX = 0.0 deg

d:So/clangBeam/BeamAngularCutoffY = 0.0 deg

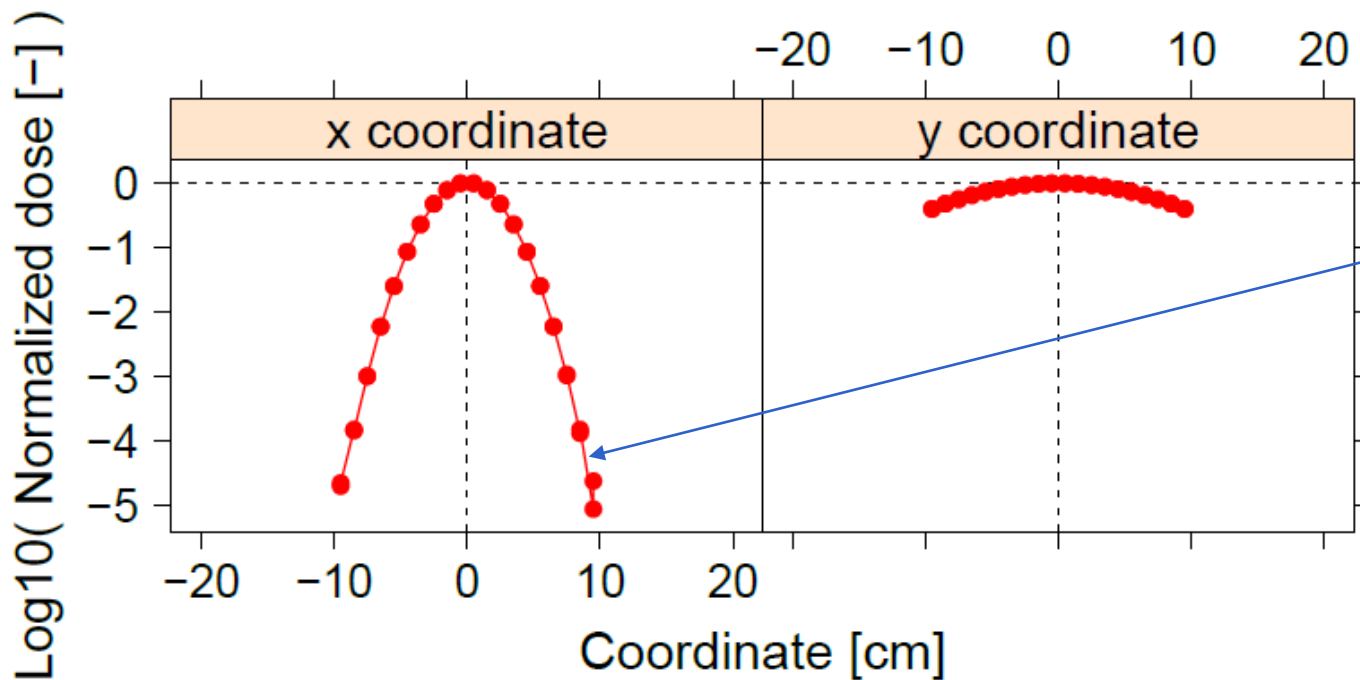
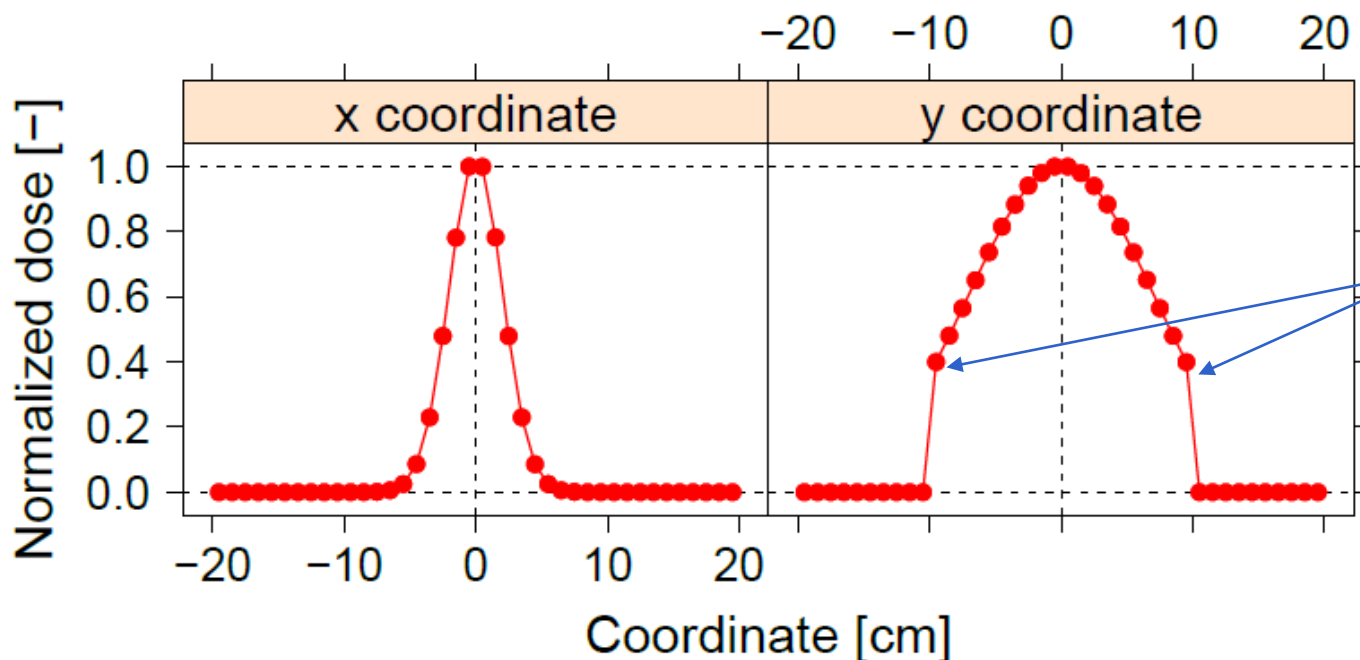
d:So/clangBeam/BeamAngularSpreadX = 0.0 deg

d:So/clangBeam/BeamAngularSpreadY = 0.0 deg

Case 3



Case 3



NOTE: Diverting point source

```
s:So/clanBeam/BeamPositionDistribution = "Flat"
```

```
# Flat or Gaussian
```

```
s:So/clanBeam/BeamPositionCutoffShape = "Rectangle"
```

```
# Ellipse, Rectangle
```

```
d:So/clanBeam/BeamPositionCutoffX = 0.000001 mm
```

```
d:So/clanBeam/BeamPositionCutoffY = 0.000001 mm
```

```
d:So/clanBeam/BeamPositionSpreadX = 0.0 mm
```

```
d:So/clanBeam/BeamPositionSpreadY = 0.0 mm
```

```
s:So/clanBeam/BeamAngularDistribution = "Flat"
```

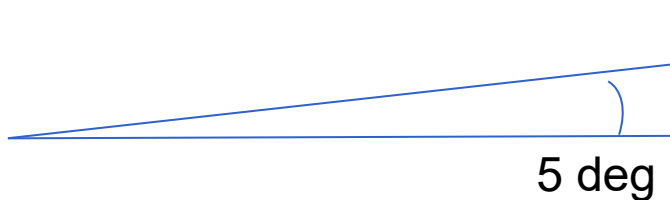
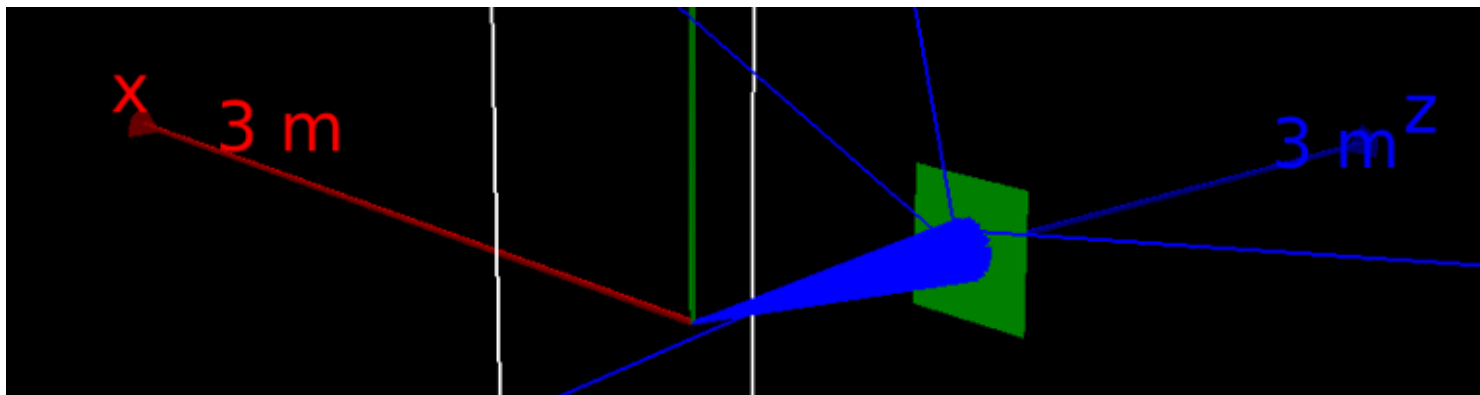
```
d:So/clanBeam/BeamAngularCutoffX = 5.0 deg
```

```
d:So/clanBeam/BeamAngularCutoffY = 5.0 deg
```

```
d:So/clanBeam/BeamAngularSpreadX = 0.0 deg
```

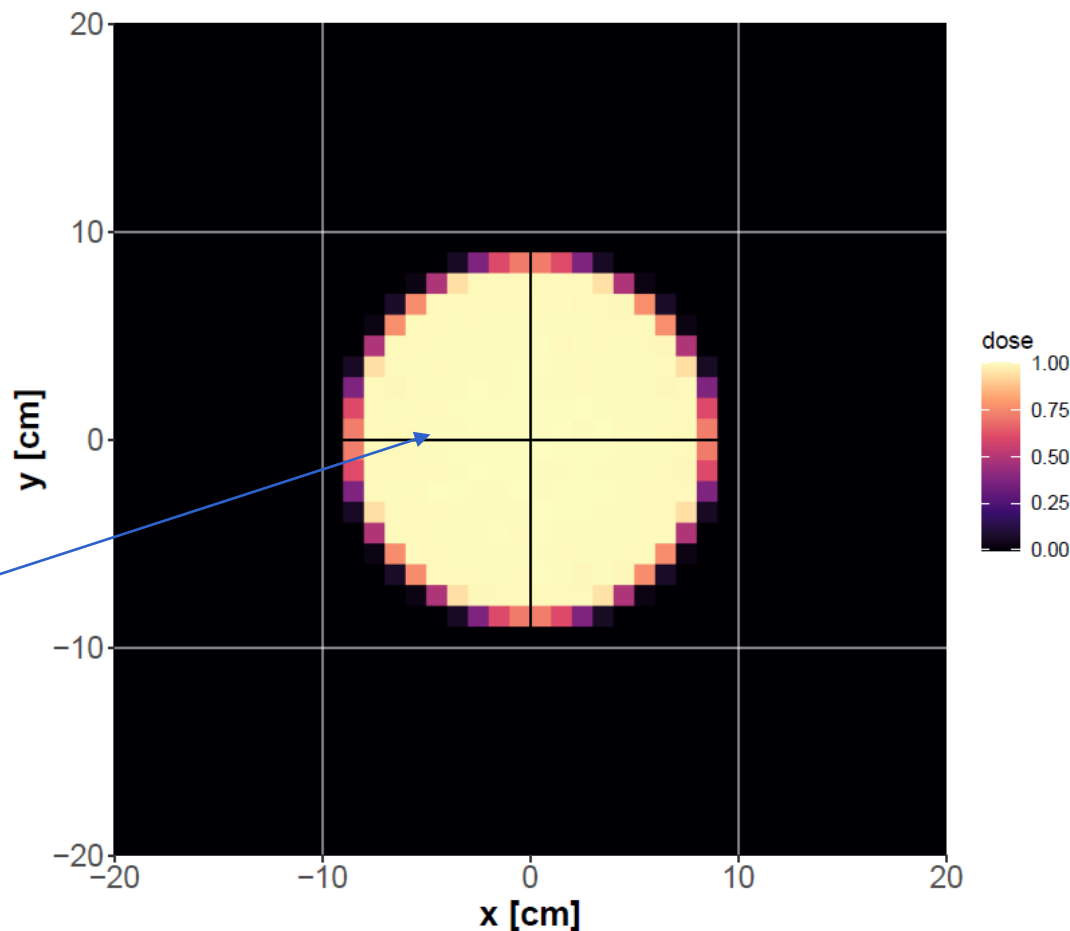
```
d:So/clanBeam/BeamAngularSpreadY = 0.0 deg
```

Case 4

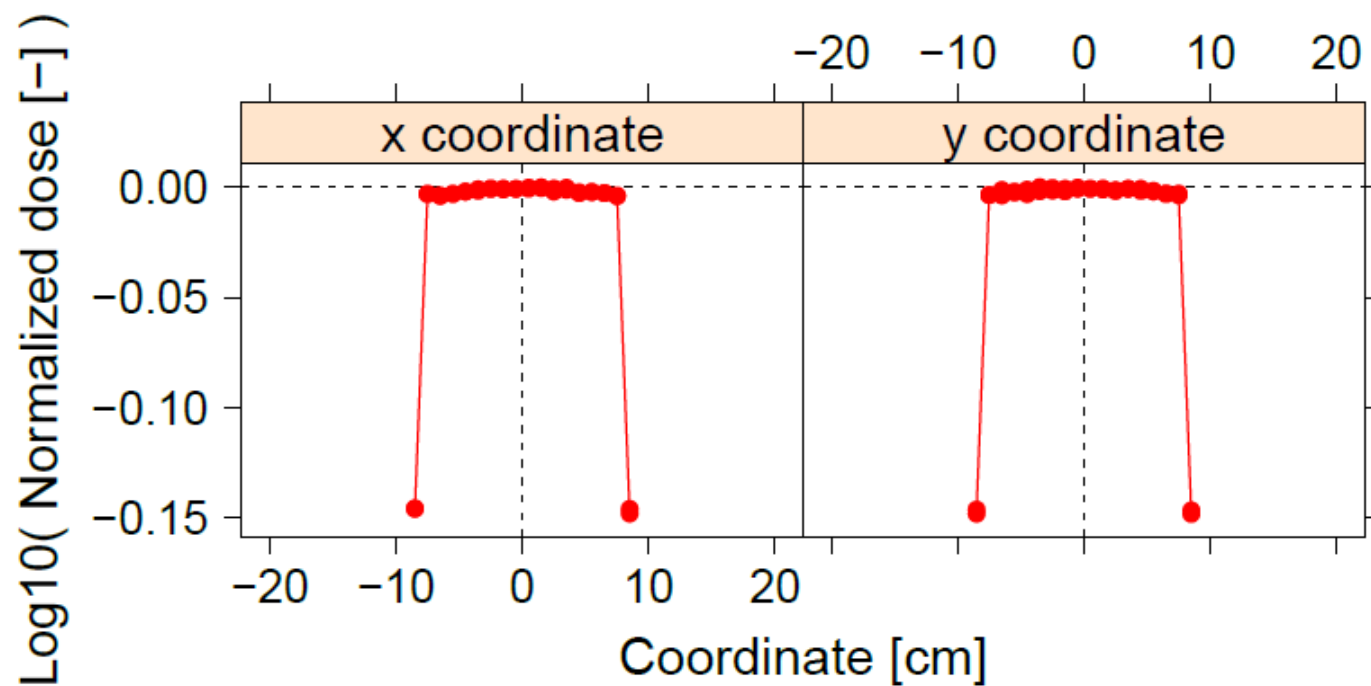
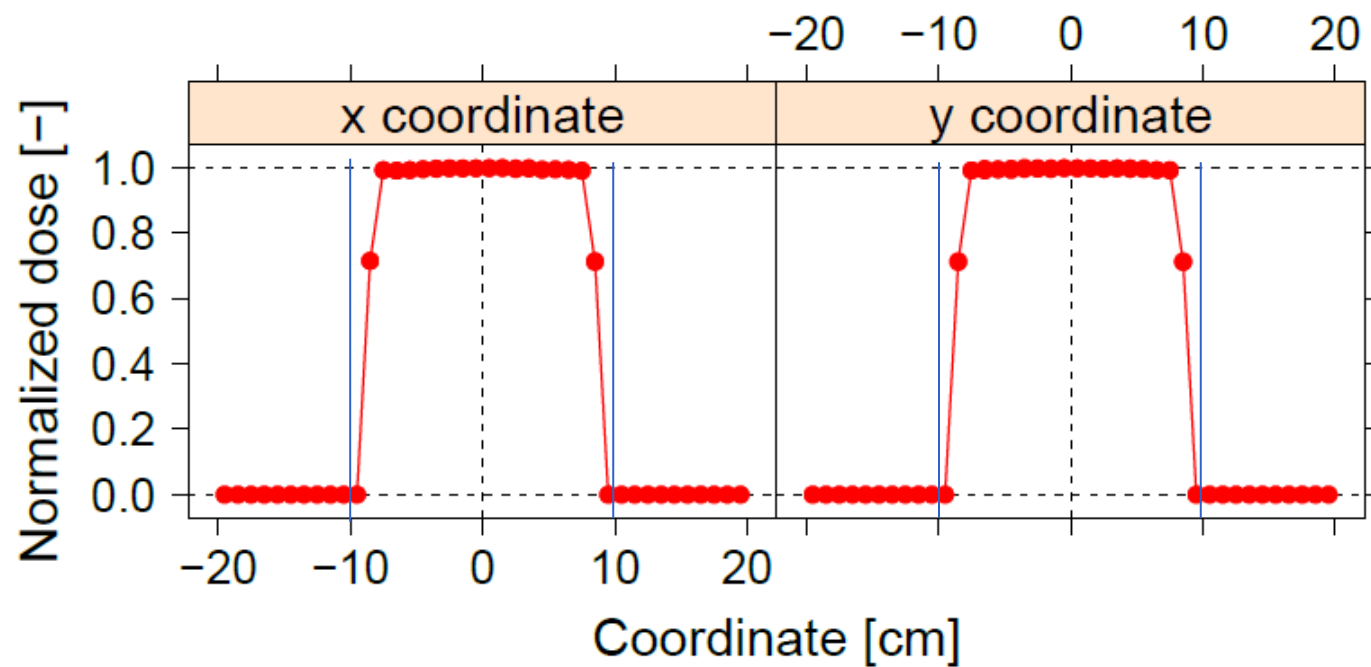


Radius at flatpanel =
 $1 \text{ m} \times \tan(5 \text{ deg}) = 8.75 \text{ cm}$

NOTE:
The beam shape is
not a rectangle !!!
(important for
simple MV linac
simulations)



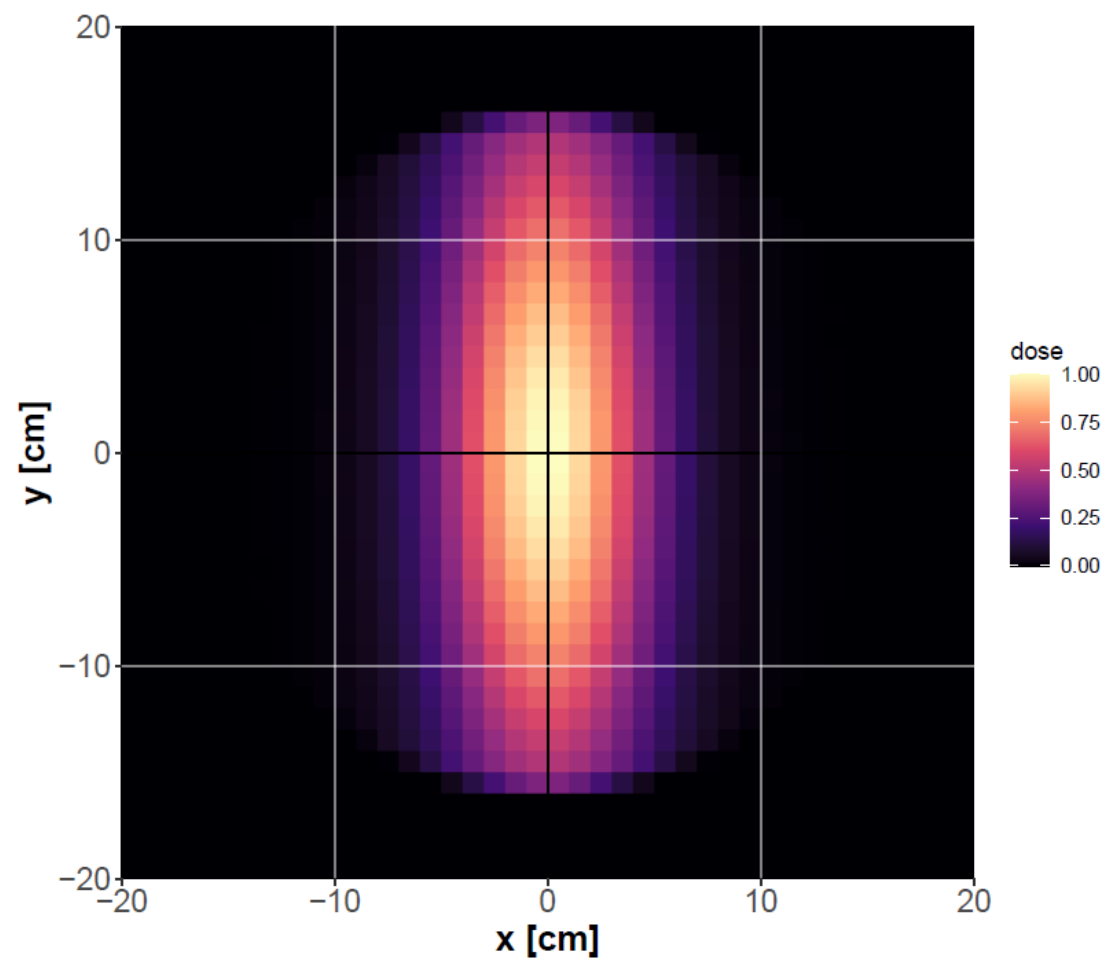
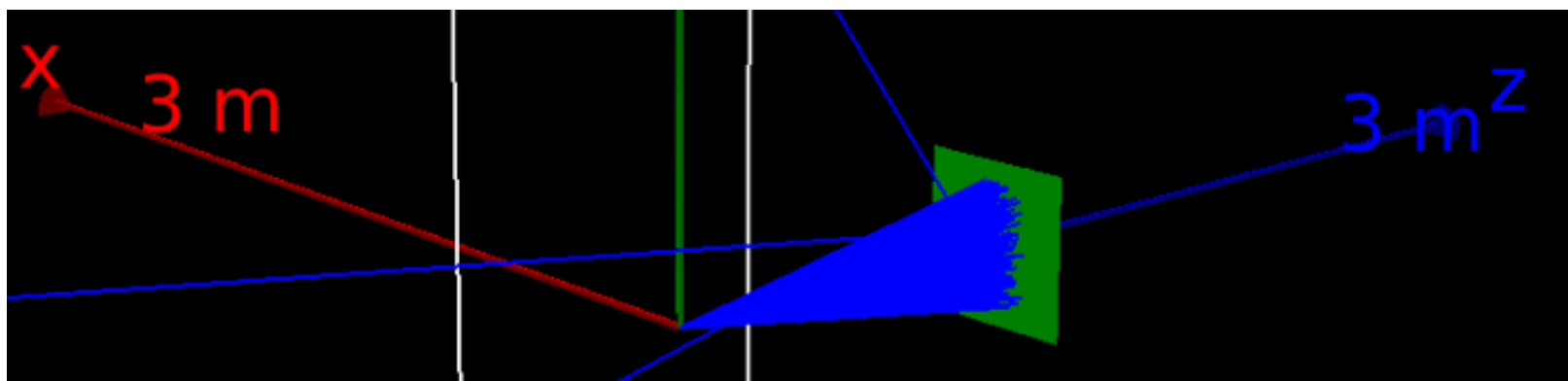
Case 4



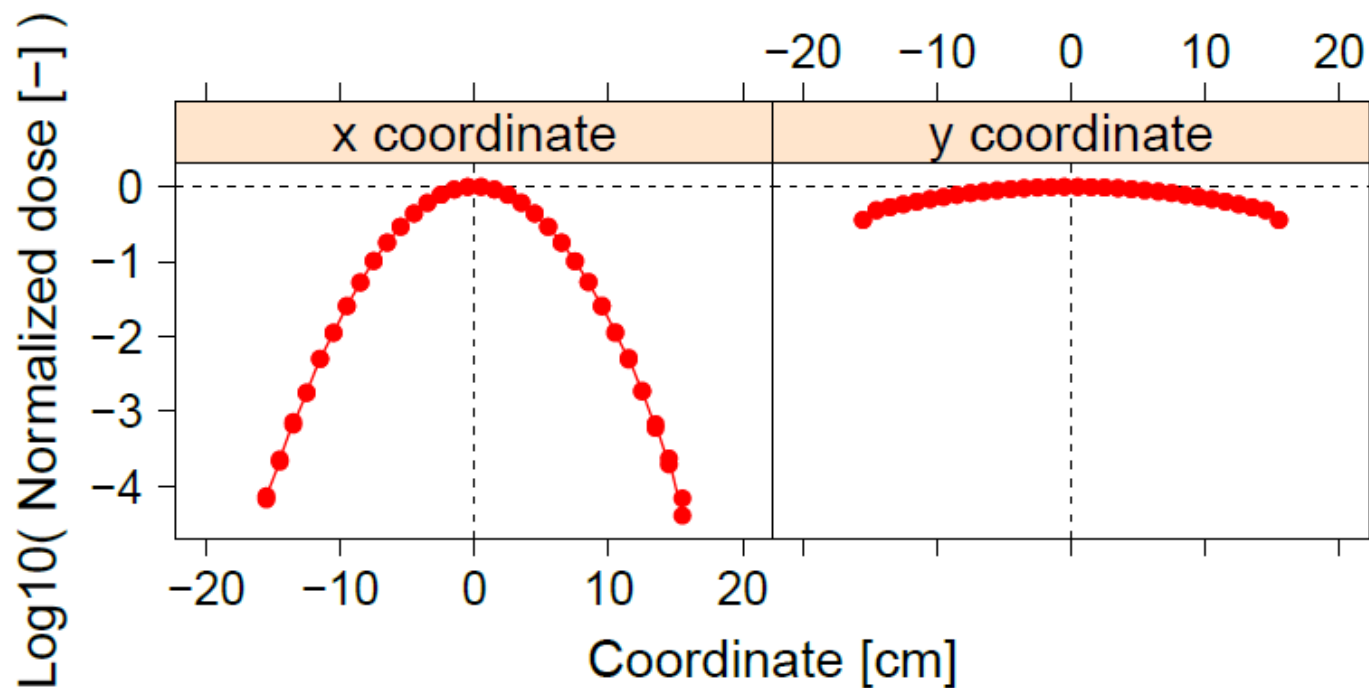
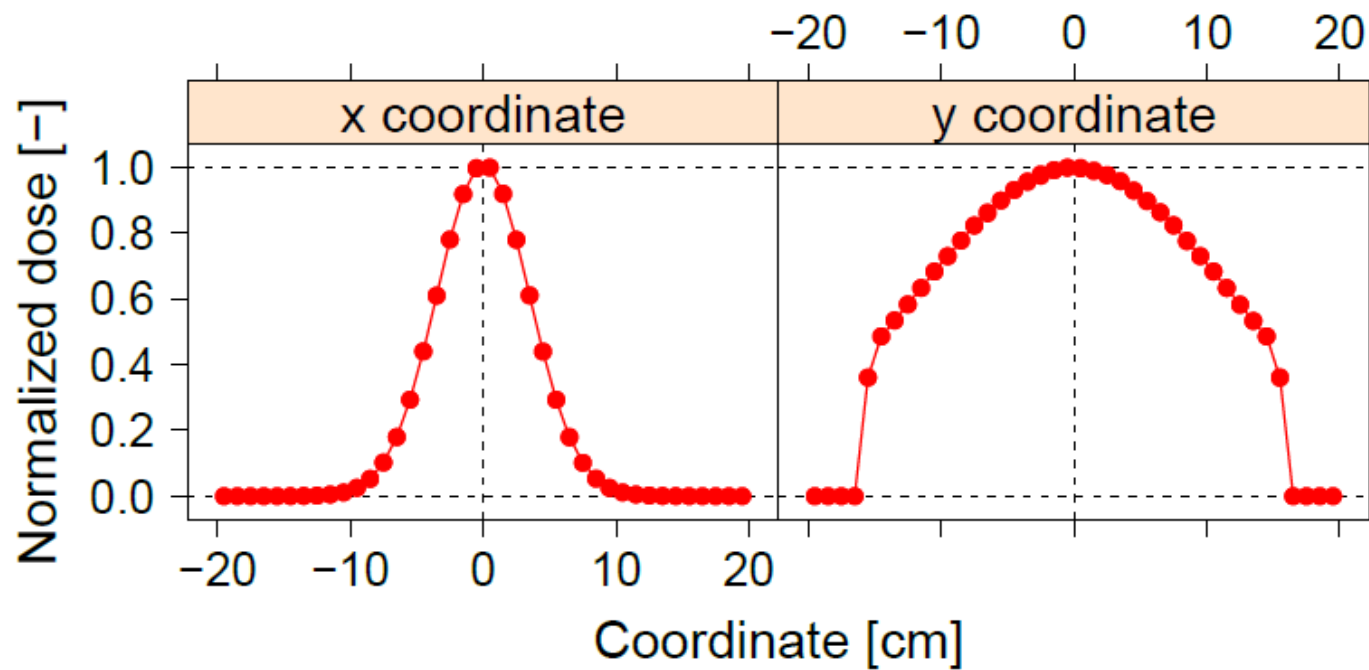
NOTE: Diverting point source

```
s:So/clangBeam/BeamPositionDistribution = "Flat"  
# Flat or Gaussian  
  
s:So/clangBeam/BeamPositionCutoffShape = "Rectangle"  
# Ellipse, Rectangle  
  
d:So/clangBeam/BeamPositionCutoffX = 0.000001 mm  
d:So/clangBeam/BeamPositionCutoffY = 0.000001 mm  
  
d:So/clangBeam/BeamPositionSpreadX = 0.0 mm  
d:So/clangBeam/BeamPositionSpreadY = 0.0 mm  
  
s:So/clangBeam/BeamAngularDistribution = "Gaussian"  
d:So/clangBeam/BeamAngularCutoffX = 9.0 deg  
d:So/clangBeam/BeamAngularCutoffY = 9.0 deg  
  
d:So/clangBeam/BeamAngularSpreadX = 2.0 deg  
d:So/clangBeam/BeamAngularSpreadY = 7.0 deg
```


Case 5



Case 5



NOTE: Diverting point source

```
s:So/clanBeam/BeamPositionDistribution = "Flat"
```

```
# Flat or Gaussian
```

```
s:So/clanBeam/BeamPositionCutoffShape = "Rectangle"
```

```
# Ellipse, Rectangle
```

```
d:So/clanBeam/BeamPositionCutoffX = 0.000001 mm
```

```
d:So/clanBeam/BeamPositionCutoffY = 0.000001 mm
```

```
d:So/clanBeam/BeamPositionSpreadX = 0.0 mm
```

```
d:So/clanBeam/BeamPositionSpreadY = 0.0 mm
```

```
s:So/clanBeam/BeamAngularDistribution = "Gaussian"
```


```
d:So/clanBeam/BeamAngularCutoffX = 100.0 deg
```

```
d:So/clanBeam/BeamAngularCutoffY = 100.0 deg
```

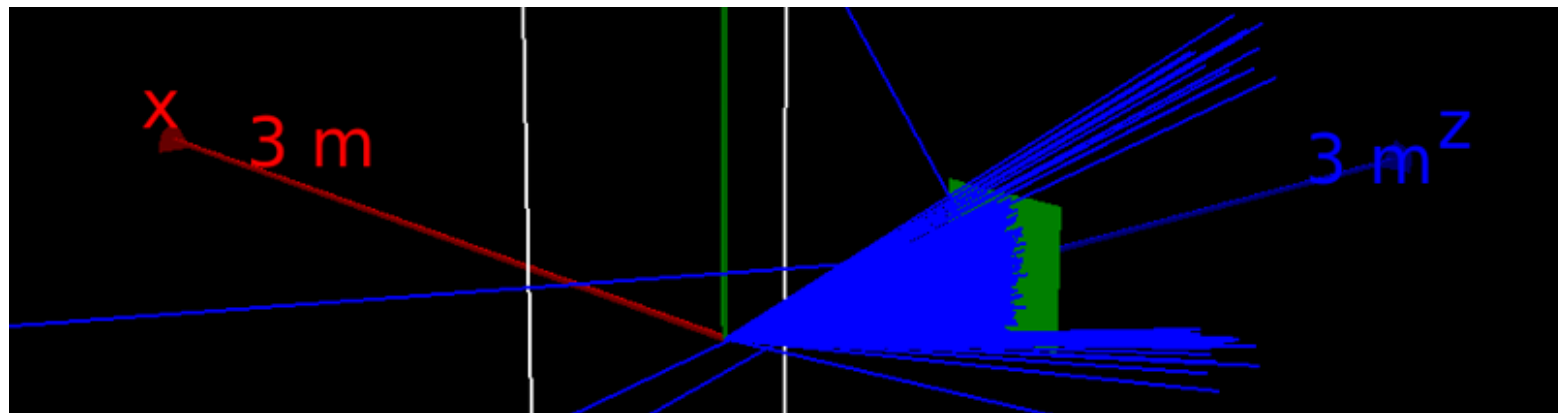
```
d:So/clanBeam/BeamAngularSpreadX = 2.0 deg
```

```
d:So/clanBeam/BeamAngularSpreadY = 6.0 deg
```

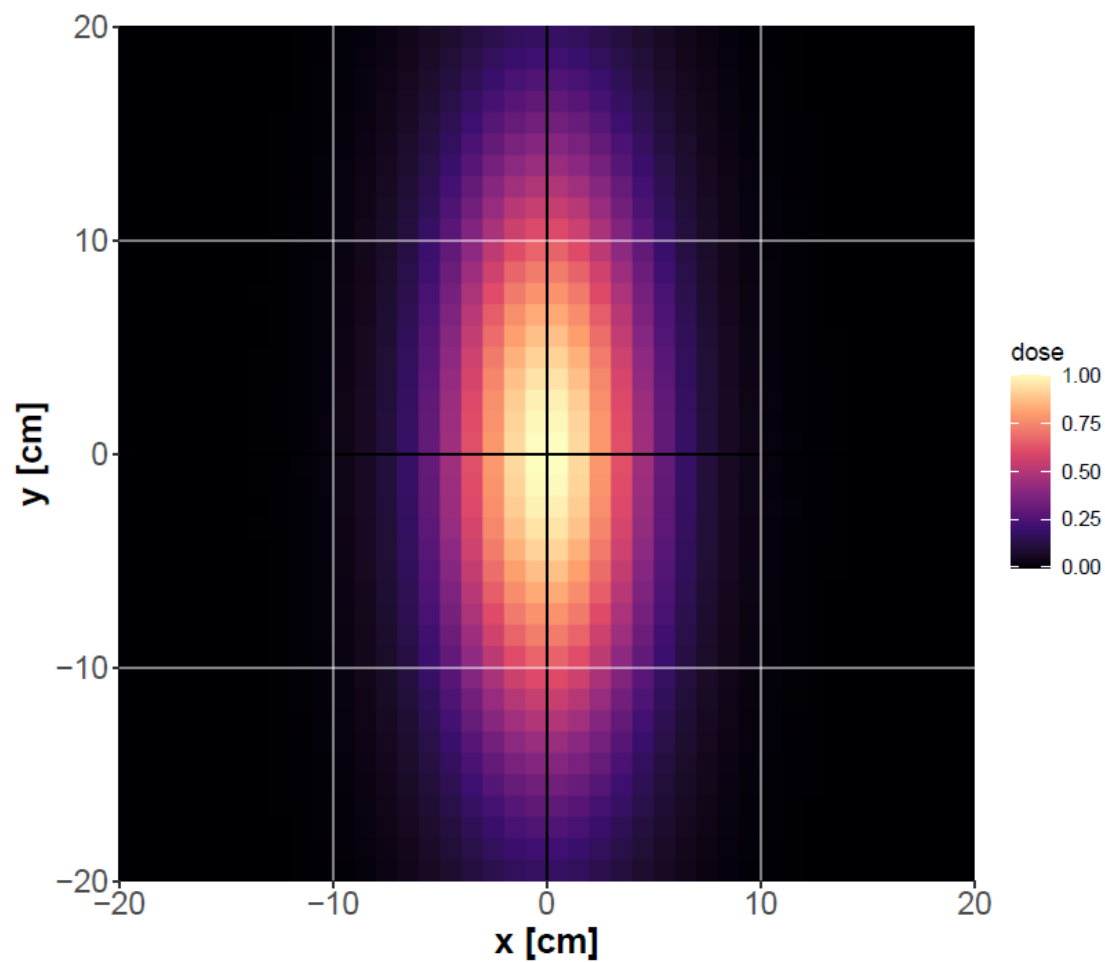
Now, essentially
no truncation
of beam.



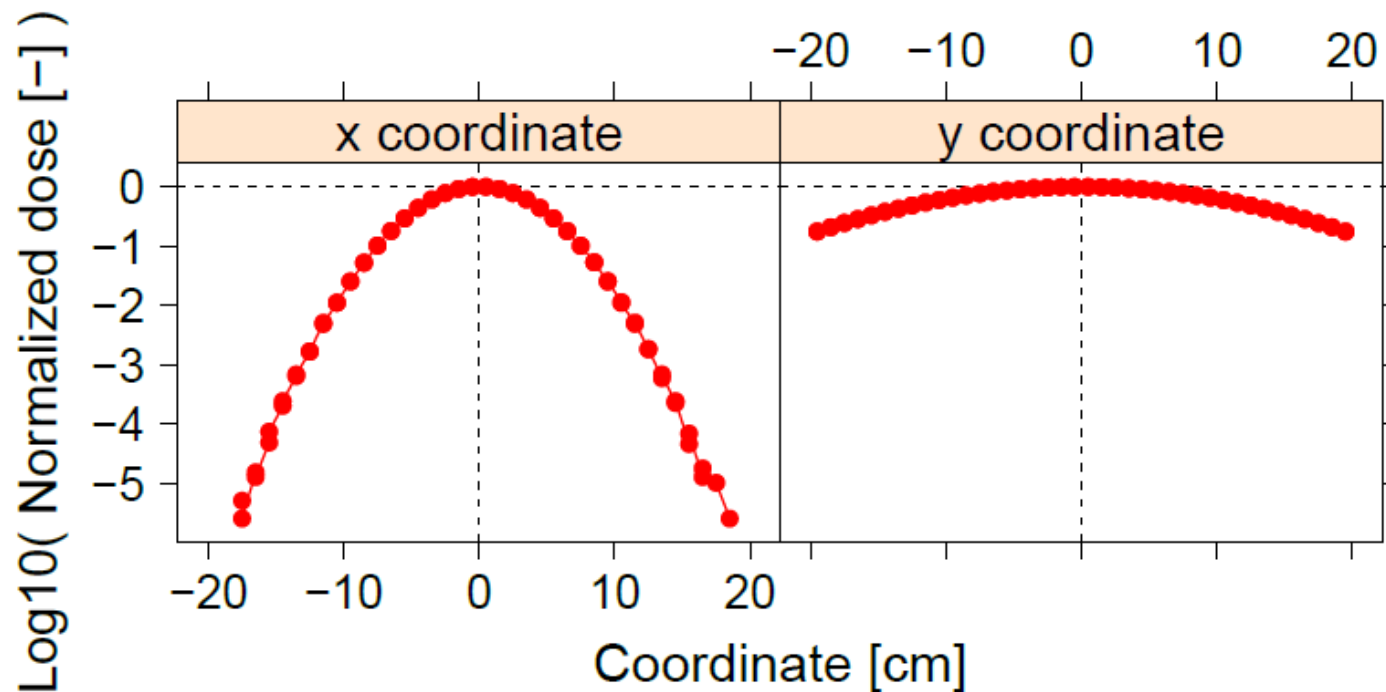
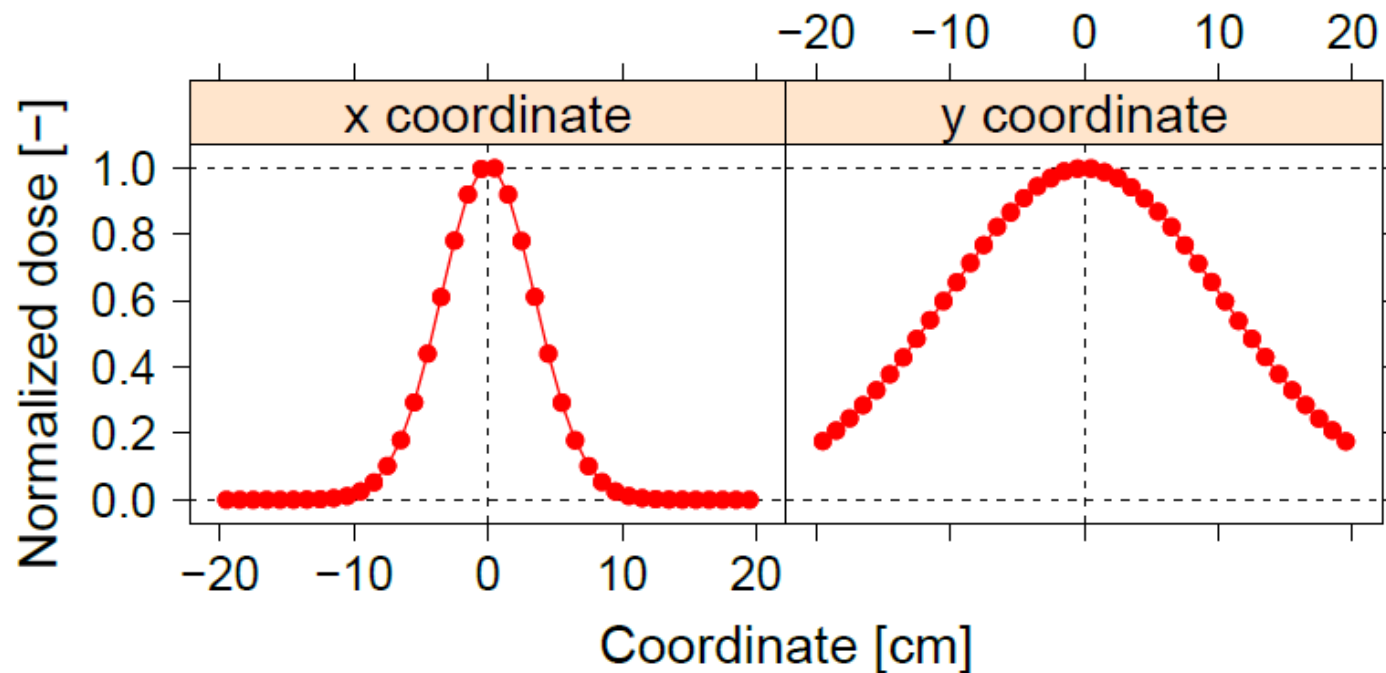
Case 6



Beam extends outside
the flatpanel detector



Case 6



Welcome to "parallel worlds" !

You can now score with
different resolutions and
across components.

Wonderful !!!

How to score multiple quantities in a component using different resolutions?

Answer: Use a parallel-world component without mass or material:

```
# Flatpanel2 (10 x 10 resolution)
b:Ge/flatpanel2/IsParallel = "True"
s:Ge/flatpanel2/Type        = "TsBox"
s:Ge/flatpanel2/Parent      = "World"
d:Ge/flatpanel2/HLX         = 20 cm
d:Ge/flatpanel2/HLY         = 20 cm
d:Ge/flatpanel2/HLZ         = 1 mm
d:Ge/flatpanel2/TransX      = 0. m
d:Ge/flatpanel2/TransY      = 0. m
d:Ge/flatpanel2/TransZ      = 1. m
d:Ge/flatpanel2/RotX        = 0. deg
d:Ge/flatpanel2/RotY        = 0. deg
d:Ge/flatpanel2/RotZ        = 0. deg
s:Ge/flatpanel2/color       = "blue"
i:Ge/flatpanel2/XBins = 10
i:Ge/flatpanel2/YBins = 10
```

(The "real-world" flatpanel has
40 x 40 resolution)

When we make a scorer, we just refer to this "parallel world" component:

```
s:Sc/SomeScorerName/Component = "flatpanel2"
```

How about time-of-flight?

What is phase-space scoring?

How to score time of flight of particles?

Answer: One possibility is to use a phasespace scorer.

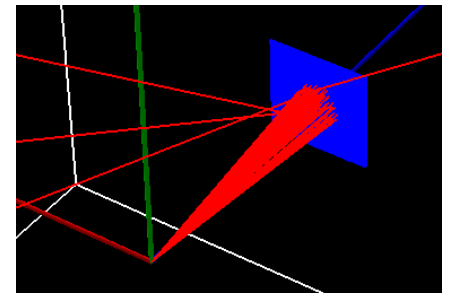
```
s:Sc/clanScorer3/Quantity = "Phasespace"  
s:Sc/clanScorer3/Surface= "flatpanel/ZMinusSurface"  
b:Sc/clanScorer3/IncludeTimeOfFlight = "True"  
b:Sc/clanScorer3/IncludeRunID      = "True"  
b:Sc/clanScorer3/IncludeEventID   = "True"  
b:Sc/clanScorer3/IncludeTrackID   = "True"  
b:Sc/clanScorer3/IncludeParentID  = "True"  
    # Track ID of parent particle  
b:Sc/clanScorer3/IncludeCharge     = "True"  
b:Sc/clanScorer3/IncludeCreatorProcess = "True"  
b:Sc/clanScorer3/IncludeVertexInfo = "True"  
    # Initial KE, Position and Momentum  
b:Sc/clanScorer3/IncludeSeed = "True"  
s:Sc/clanScorer3/OutputType = "ASCII"  
b:Sc/clanScorer3/PropagateToChildren = "True"  
s:Sc/clanScorer3/Component = "flatpanel2"  
s:Sc/clanScorer3/IfOutputFileAlreadyExists = "Overwrite"  
b:Sc/clanScorer3/OutputToConsole = "False"  
s:Sc/clanScorer3/OutputFile = Ge/World/Message + "Phasespace1"
```

Phasespace file with 28 columns:

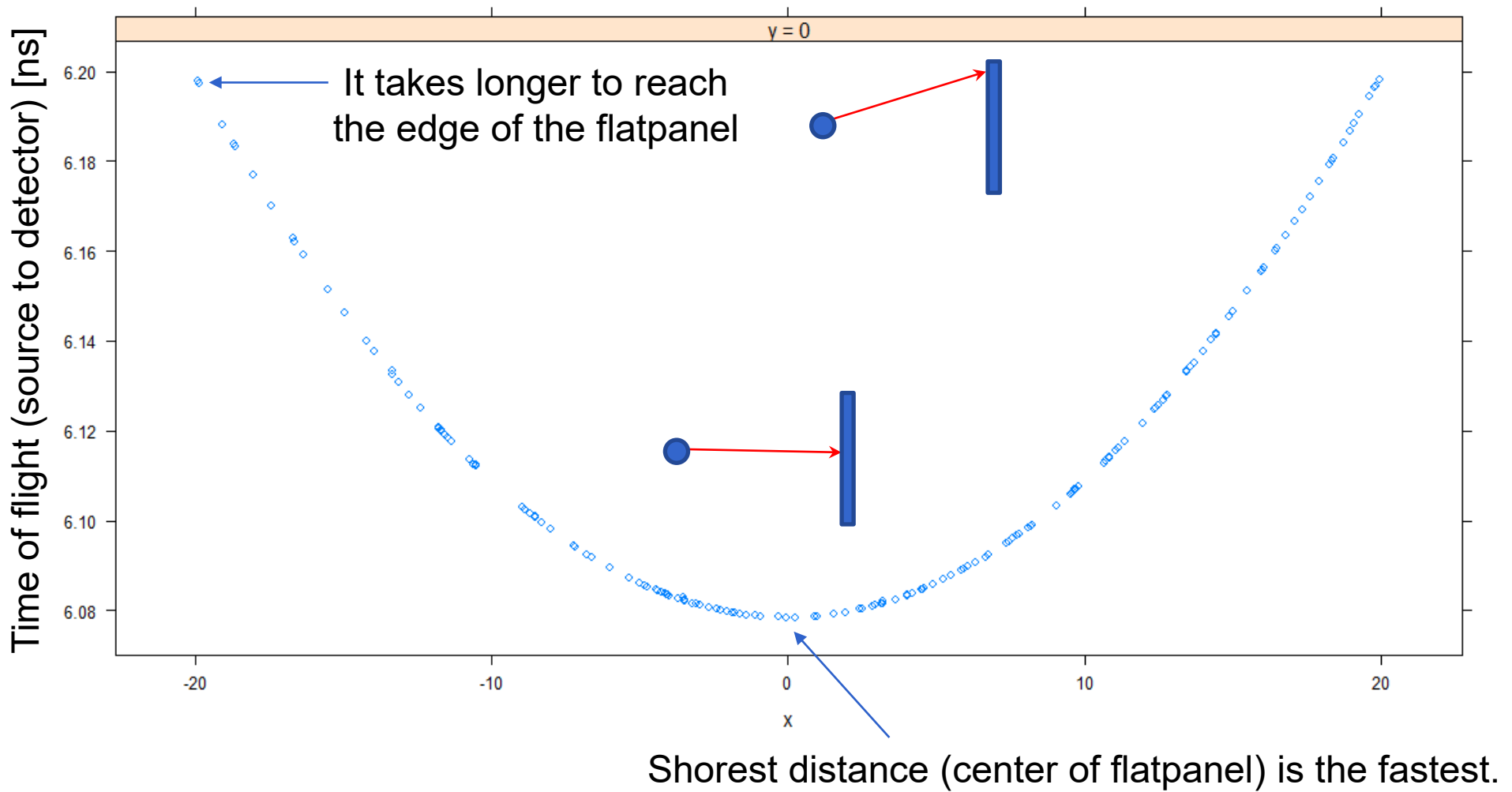
#1: Position X [cm]
#2: Position Y [cm]
#3: Position Z [cm]
#4: Direction Cosine X
#5: Direction Cosine Y
#6: Energy [MeV]
#7: Weight
#8: Particle Type (in PDG Format)
#9: Flag to tell if Third Direction Cosine is Negative (1 means true)
#10: Flag to tell if this is the First Scored Particle from this History (1 means true)
#11: Time of Flight [ns]
#12: Run ID
#13: Event ID
#14: Track ID
#15: Parent ID
#16: Charge [e+]
#17: Creator Process Name
#18: Initial Kinetic Energy [MeV]
#19: Vertex Position X [cm] #20: Vertex Position Y [cm] #21: Vertex Position Z [cm]
#22: Initial Direction Cosine X #23: Initial Direction Cosine Y
#24: Initial Direction Cosine Z
#25: Seed Part 1 #26: Seed Part 2 #27: Seed Part 3 #28: Seed Part 4

Point source with 15 deg angle (not 5 deg as in the picture)

$1\text{m} / 6.08\text{ ns} = 1.64\text{E}8\text{ m/s}$ (approx. 50% speed of light)



Time of flight in ns for point source of 100 keV electrons vs. flatpanel x coordinate at $y = 0$

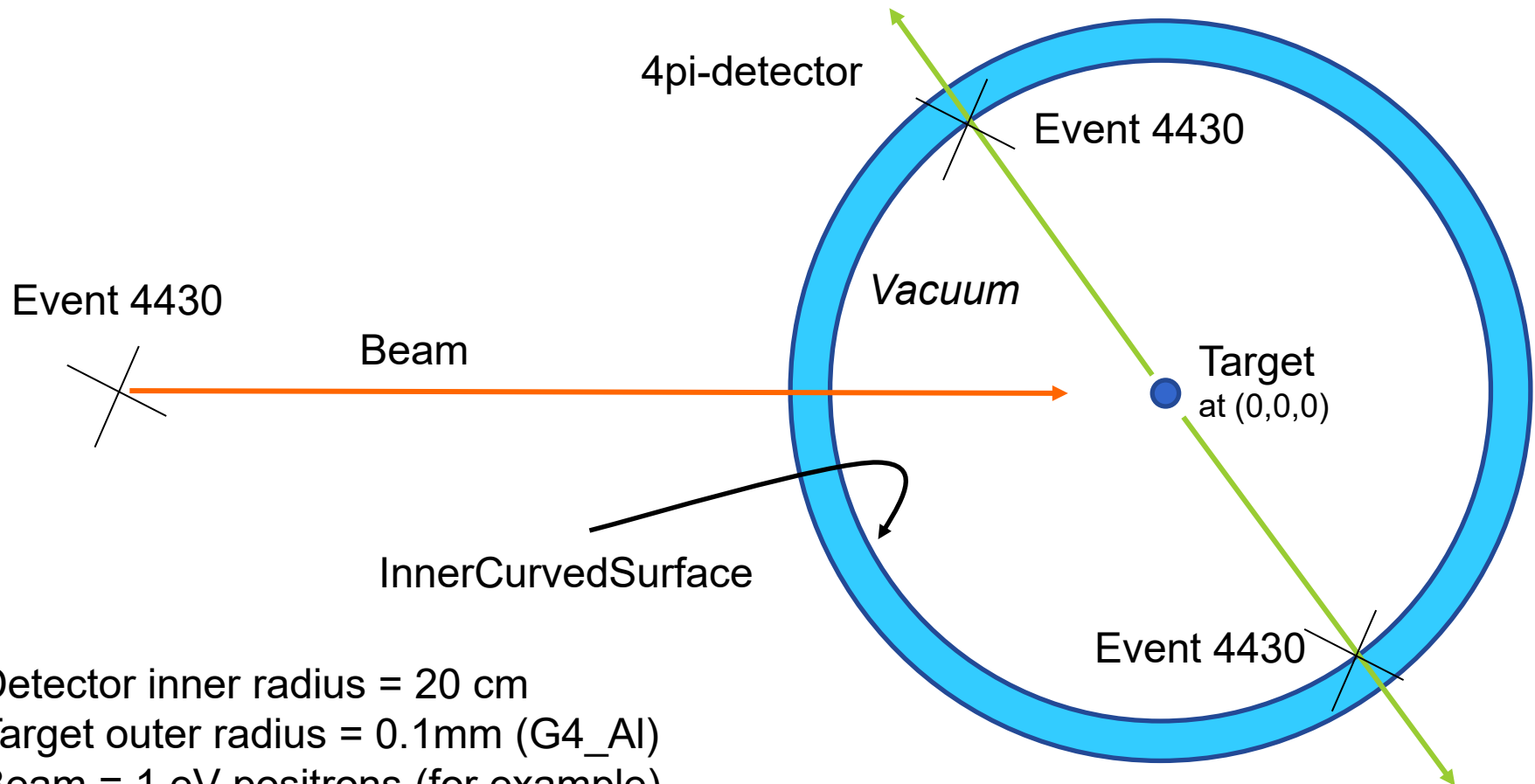


More about phase-space scoring

Using 4pi detector and phase space scoring

Each particle history from the beam source is associated with an event id. These are unique within each run.

The phasespace scorer can give us detailed information about the recorded hits, for example, at the inner curved surface of the detector.



Results from phasespace scorer in 4pi detector

Beam = positrons, target = Al

| Run | event | | | | MeV | Particle | Creator | MeV.sum |
|---|-------|-------------|------------|--------------|----------|----------|---------|----------|
| id | | x | y | z | | type | process | |
| name | | | | | | | | |
| <u>Shooting 1 eV positrons into target:</u> | | | | | | | | |
| 0-0 | | 1.2537300 | -5.880420 | -19.07480000 | 0.510999 | 22 | annihil | 1.021998 |
| 0-0 | | -1.2537300 | 5.880420 | 19.07480000 | 0.510999 | 22 | annihil | 1.021998 |
| 0-1 | | 6.4156800 | -13.075500 | 13.70660000 | 0.510999 | 22 | annihil | 1.021998 |
| 0-1 | | -6.4156800 | 13.075500 | -13.70660000 | 0.510999 | 22 | annihil | 1.021998 |
| 0-2 | | 18.1159000 | 8.357020 | 1.40523000 | 0.510999 | 22 | annihil | 1.021998 |
| 0-2 | | -18.1159000 | -8.357020 | -1.40523000 | 0.510999 | 22 | annihil | 1.021998 |

Run 0, event 2

Note the perfect symmetry around (0,0,0). These annihilations are perfect back-to-back gammas.

Note, as an example, that the distance from (x,y,z) to (0,0,0):

$((-18.1159000 \text{ cm})^2 + (-8.357020 \text{ cm})^2 + (-1.40523000 \text{ cm})^2)^{0.5} = 20.000 \text{ cm}$
which verifies that these points are actually located on the detector sphere.

Note that the sum of energy for particles hitting the detector is always 1.021998 MeV.

Results from phasespace scorer in 4pi detector

Beam = positrons, target = Al

Run event

| id | x | y | z | MeV | Particle type | Creator proce | MeV.sum |
|---|------------|------------|-----------|-----------|------------------|------------------|----------|
| Shooting 1 MeV positrons into target: | | | | | | | |
| 0-412 | -5.4949400 | 7.855230 | 17.552800 | 1.2307200 | 22 | annihil | 2.017131 |
| 0-412 | 9.0652200 | -15.725900 | 8.397520 | 0.7864110 | 22 | annihil | 2.017131 |
| 0-882 | -3.8491100 | -7.544530 | 18.118100 | 1.3963700 | 22 | annihil | 2.006963 |
| 0-882 | -7.3570100 | 18.521900 | 1.677870 | 0.6105930 | 22 | annihil | 2.006963 |
| 0-1882 | 1.3758200 | 3.614410 | 19.622500 | 1.5717700 | 22 | annihil | 2.005375 |
| 0-1882 | -1.6320100 | -18.778200 | -6.686900 | 0.4336050 | 22 | annihil | 2.005375 |

Note that the sum of energy hitting the detector pr. event (MeV.sum) is now variable and always less than 2.021998 MeV. Why?

Answer: The positron loses a variable amount of energy in the target before annihilation. The secondaries from these interactions stay in the target and the secondaries are therefore not captured by the detector.

Note that the annihilation photons are not back-to-back in the frame of the laboratory coordinate system (lack of symmetry around (0,0,0)).

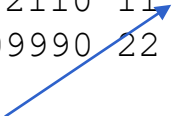
Results from phasespace scorer in 4pi detector

Beam = positrons, target = Al

Shooting 1 eV positrons into target.

Events with 3 detector hits:

| Run event id | x | y | z | MeV init | MeV | Particle type | Creator process name | MeV sum |
|--------------------|--------------|------------|------------|-------------|-----------|------------------|----------------------------|------------|
| 0-115 | -1.54866000 | -0.868451 | -19.921000 | 0.5109990 | 0.5109990 | 22 | annihil | 0.94165 |
| 0-115 | -3.19828000 | -19.569600 | -2.607920 | 0.5109990 | 0.2348890 | 22 | annihil | 0.94165 |
| 0-115 | 2.51310000 | -1.207900 | 19.804700 | 0.2760280 | 0.1957640 | 11 | compt | 0.94165 |
| 0-452 | 8.47510000 | 14.092200 | -11.383500 | 0.5109990 | 0.5109990 | 22 | annihil | 1.00087 |
| 0-452 | -3.49529000 | -18.041100 | -7.893080 | 0.5109990 | 0.3317510 | 22 | annihil | 1.00087 |
| 0-452 | -3.91598000 | -6.506080 | 18.502300 | 0.1791660 | 0.1581270 | 11 | compt | 1.00087 |
| 0-947 | 18.88940000 | -5.398080 | 3.748680 | 0.5109990 | 0.2034750 | 22 | annihil | 0.95168 |
| 0-947 | -16.03400000 | 3.532880 | 11.420600 | 0.3074050 | 0.2372110 | 11 | compt | 0.95168 |
| 0-947 | 13.90580000 | 3.755140 | -13.875400 | 0.5109990 | 0.5109990 | 22 | annihil | 0.95168 |



Note that the annihilation photons that underwent Compton scattering are classified as annihilation photons. Only the electrons from the Compton interactions, are classified as being created by the Compton.

Phasespace scorer in 4pi detector

Topas parameters

The 4pi-detector

```
s:Ge/detector/Type      = "TsSphere"  
s:Ge/detector/Material  = "G4_Galactic"  
s:Ge/detector/Parent    = "World"  
d:Ge/detector/RMin      = 20.0 cm  
d:Ge/detector/RMax      = 20.1 cm  
d:Ge/detector/TransX    = 0. m  
d:Ge/detector/TransY    = 0. m  
d:Ge/detector/TransZ    = 0. m  
d:Ge/detector/RotX      = 0. deg  
d:Ge/detector/RotY      = 0. deg  
d:Ge/detector/RotZ      = 0. deg  
s:Ge/detector/color     = "blue"
```

The target

```
s:Ge/target/Type       = "TsSphere"  
s:Ge/target/Material   = "G4_Al"  
s:Ge/target/Parent     = "world"  
d:Ge/target/RMax       = 0.01 cm  
d:Ge/target/TransX     = 0. m  
d:Ge/target/TransY     = 0. m  
d:Ge/target/TransZ     = 0. m  
d:Ge/target/RotX       = 0. deg  
d:Ge/target/RotY       = 0. deg  
d:Ge/target/RotZ       = 0. deg  
s:Ge/target/color      = "blue"
```

Phasespace scorer in 4pi detector

Topas parameters

Beam

```
s:So/clanBeam/Type = "Beam"
s:So/clanBeam/Component = "clanBeamPosition"
s:So/clanBeam/BeamParticle = "e+"
d:So/clanBeam/BeamEnergy = 1 eV
u:So/clanBeam/BeamEnergySpread = 0.0
s:So/clanBeam/BeamPositionDistribution = "Flat"
s:So/clanBeam/BeamPositionCutoffShape = "Rectangle"
dc:So/clanBeam/BeamPositionCutoffX = 0.000001 mm
dc:So/clanBeam/BeamPositionCutoffY = 0.000001 mm
dc:So/clanBeam/BeamPositionSpreadX = 0.000001 mm
dc:So/clanBeam/BeamPositionSpreadY = 0.000001 mm
s:So/clanBeam/BeamAngularDistribution = "Flat"
dc:So/clanBeam/BeamAngularCutoffX = 0.000001 deg
dc:So/clanBeam/BeamAngularCutoffY = 0.000001 deg
dc:So/clanBeam/BeamAngularSpreadX = 0.000001 deg
dc:So/clanBeam/BeamAngularSpreadY = 0.000001 deg
i:So/clanBeam/NumberOfHistoriesInRandomJob = 0
```

Phasespace scorer in 4pi detector

Topas parameters

Phasespace scorer

```
s:Sc/clanScorer3/Quantity = "Phasespace"
s:Sc/clanScorer3/Component = "detector"
s:Sc/clanScorer3/Surface = "detector/InnerCurvedSurface"
s:Sc/clanScorer3/OnlyIncludeParticlesGoing = "In"

b:Sc/clanScorer3/IncludeTimeOfFlight = "True"
b:Sc/clanScorer3/IncludeRunID = "True"
b:Sc/clanScorer3/IncludeEventID = "True"
b:Sc/clanScorer3/IncludeTrackID = "True"
b:Sc/clanScorer3/IncludeParentID = "True"
b:Sc/clanScorer3/IncludeCharge = "True"
b:Sc/clanScorer3/IncludeCreatorProcess = "True"
b:Sc/clanScorer3/IncludeVertexInfo = "True"
b:Sc/clanScorer3/IncludeSeed = "True"

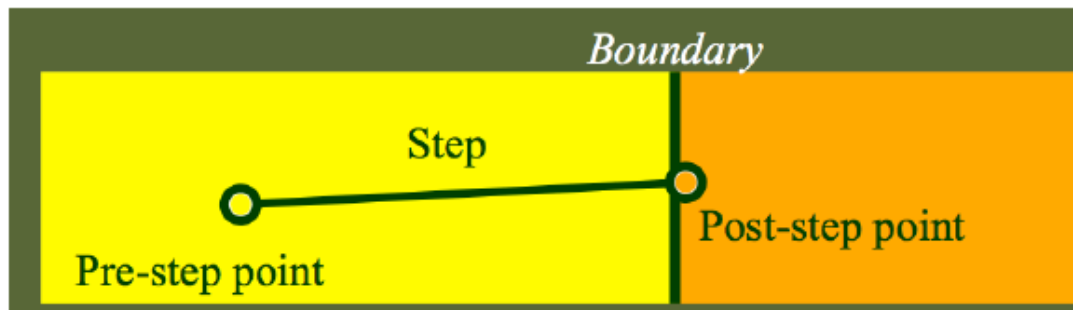
s:Sc/clanScorer3/OutputType = "ASCII"
b:Sc/clanScorer3/PropagateToChildren = "True"
s:Sc/clanScorer3/IfOutputFileAlreadyExists = "Overwrite"
b:Sc/clanScorer3/OutputToConsole = "False"
s:Sc/clanScorer3/OutputFile = Ge/World/Message + "Phasespace1"
```

GEANT4 terminology

- **Events** are the basic units of a simulation (G4Event)
- At the beginning of an event, **primary tracks** are generated and stored in a **stack**
- The track is a snapshot of a **particle**, and it keeps its current information: energy, momentum, etc.
- GEANT4 gets a track from the stack and follows it in the geometry, until it exits the world or stops
 - If **secondary tracks** are produced in this process, they are also stored in the stack
 - When the stack is empty the event is completed
- A **run** is a collection of events all with the same detector setup and physics settings

GEANT4 terminology

- Tracks are divided in **steps**
- A new step occurs every time the particle crosses a border or has an interaction
- A step has two points (**pre-step** and **post-step**) and G4Step stores information about both and the deltas (e.g. energy loss in the step)
- If a step is limited by a volume boundary, the post-step point is physically at the border, and associated with the next logical volume



How to score a fluence
spectrum differential in energy?

Fluence spectra scoring

Unless you score the fluence in vacuum, you normally need to select the "PreStep" energy for binning:

```
i:Sc/MyScorer/EBins = 10
# defaults to 1, that is, un-binned

d:Sc/MyScorer/EBinMin = 0. MeV
# defaults to zero

d:Sc/MyScorer/EBinMax = 100. MeV
# must be specified if EBins is greater than 1


s:Sc/MyScorer/EBinEnergy = "PreStep"
# "IncidentTrack" # "IncidentTrack", "PreStep" or
# "DepositedInStep"
```

Note that if you create particles inside your scoring volume (volume source), then they have no incident energy, and they will not be considered if you select "IncidentTrack" for binning. This is another reason to select "PreStep".

How to score kerma?

Topas manual (3.9) section 12.2.1

Cuts do not affect all processes, but only those listed below:

- *Energy thresholds for gamma are used in Bremsstrahlung*
 - *Energy thresholds for electrons are used in ionization and e^+e^- pair production processes*
 - *Energy thresholds for positrons are used in e^+e^- pair production process*
 - *Energy thresholds for gamma and electrons are **used optionally** in all discrete processes*
 - *Photoelectric effect*
 - *Compton*
 - *gamma conversion*
 - *Energy thresholds for protons are used in processes of elastic scattering for hadrons and ions defining the threshold for kinetic energy of nuclear recoil*
-  **Unknown what this means or how this is controlled**

BE CAREFUL HERE: This does not work in general!!!!

We cannot simply force all electrons **not** to be transported if they have an energy below say 10 MeV (specified by an equivalent range in the medium):

```
d:Ph/Default/cutforelectron = 10 m
```

So, unfortunately, we cannot score kerma using the dosetomedium scorer by simply stopping electrons from moving after photons have undergone, for example, photoelectric effect or Compton scattering.

Collision-kerma scorer

```
##### Collion-kerma scoring using the TLE (see paper by Berumen et al. (2020))
s:Sc/kerma/Quantity = "TrackLengthEstimator"
b:Sc/kerma/PropagateToChildren = "True"

sv:Sc/kerma/Report = 5 "Count_In_Bin" "Sum" "Mean" "Standard_Deviation" "Histories"
s:Sc/kerma/InputFile = "Muen.dat"
s:Sc/kerma/Component = "centerrod"
b:Sc/kerma/OutputToConsole = "False"
s:Sc/kerma/IfOutputFileAlreadyExists = "Overwrite"
s:Sc/kerma/OutputType = "csv"
s:Sc/kerma/OutputFile = Ge/World/Message + "DoseScorer2"
sv:Sc/kerma/OnlyIncludeParticlesNamed = 1 "gamma"
```

You need to copy this file from the examples/Brachytherapy folder (or make a direct link)

DO NOT FORGET THIS!

Essentially, this is just the photon fluence times the mass energy absorption coefficient (μ_{en}/ρ) from the `Muen.dat` file.

Berumen et al. (2020):

"Validation of the TOPAS Monte Carlo toolkit for HDR brachytherapy simulations"
Medical Physics

The TLE technique approximates the absorbed dose as electronic (collisional) kerma. For a photon traversing a voxel, the absorbed dose is

$$D = \Phi E \frac{\mu_{en}}{\rho} = \frac{L}{V} E \frac{\mu_{en}}{\rho},$$

where L is the track length (the distance traveled in the voxel), V is the voxel volume, E is the photon energy, and μ_{en}/ρ is the mass energy absorption coefficient.

The Muen.dat file contains photon interaction data.

The source of data is not clear.

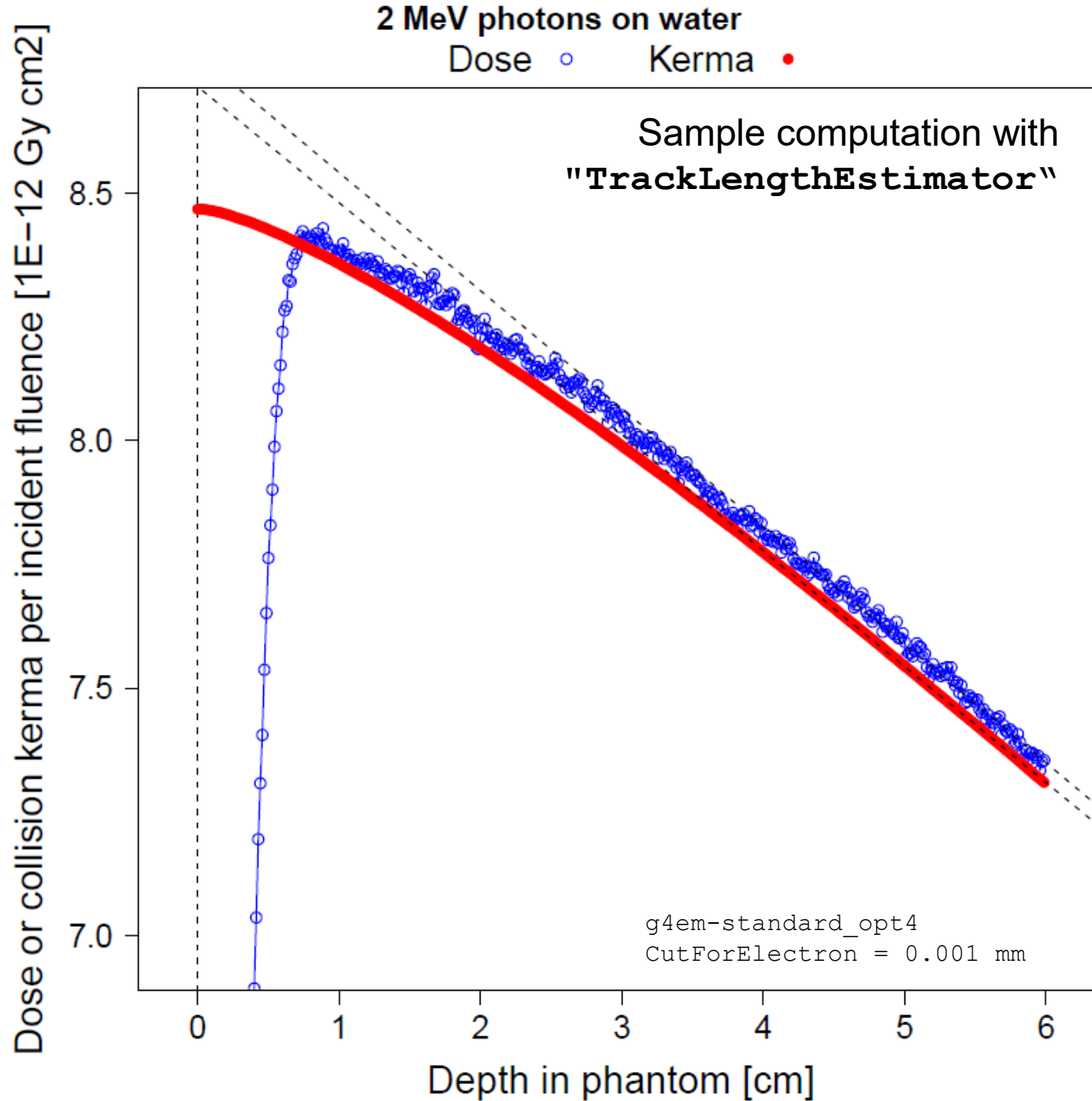
```
1 36
1.00000E-03 7.217E+00 6.820E+00
1.50000E-03 2.148E+00 1.752E+00
2.00000E-03 1.059E+00 6.643E-01
3.00000E-03 5.612E-01 1.693E-01
4.00000E-03 4.546E-01 6.549E-02
5.00000E-03 4.193E-01 3.278E-02
6.00000E-03 4.042E-01 1.996E-02
8.00000E-03 3.914E-01 1.160E-02
1.00000E-02 3.854E-01 9.849E-03
...
1.00000E-01 2.944E-01 4.063E-02
1.50000E-01 2.651E-01 4.813E-02
2.00000E-01 2.429E-01 5.254E-02
3.00000E-01 2.112E-01 5.695E-02
4.00000E-01 1.893E-01 5.860E-02
5.00000E-01 1.729E-01 5.900E-02
6.00000E-01 1.599E-01 5.875E-02
8.00000E-01 1.405E-01 5.739E-02
1.00000E+00 1.263E-01 5.556E-02
1.25000E+00 1.129E-01 5.311E-02
...
1.00000E+01 3.254E-02 2.247E-02
1.50000E+01 2.539E-02 1.837E-02
2.00000E+01 2.153E-02 1.606E-02
```

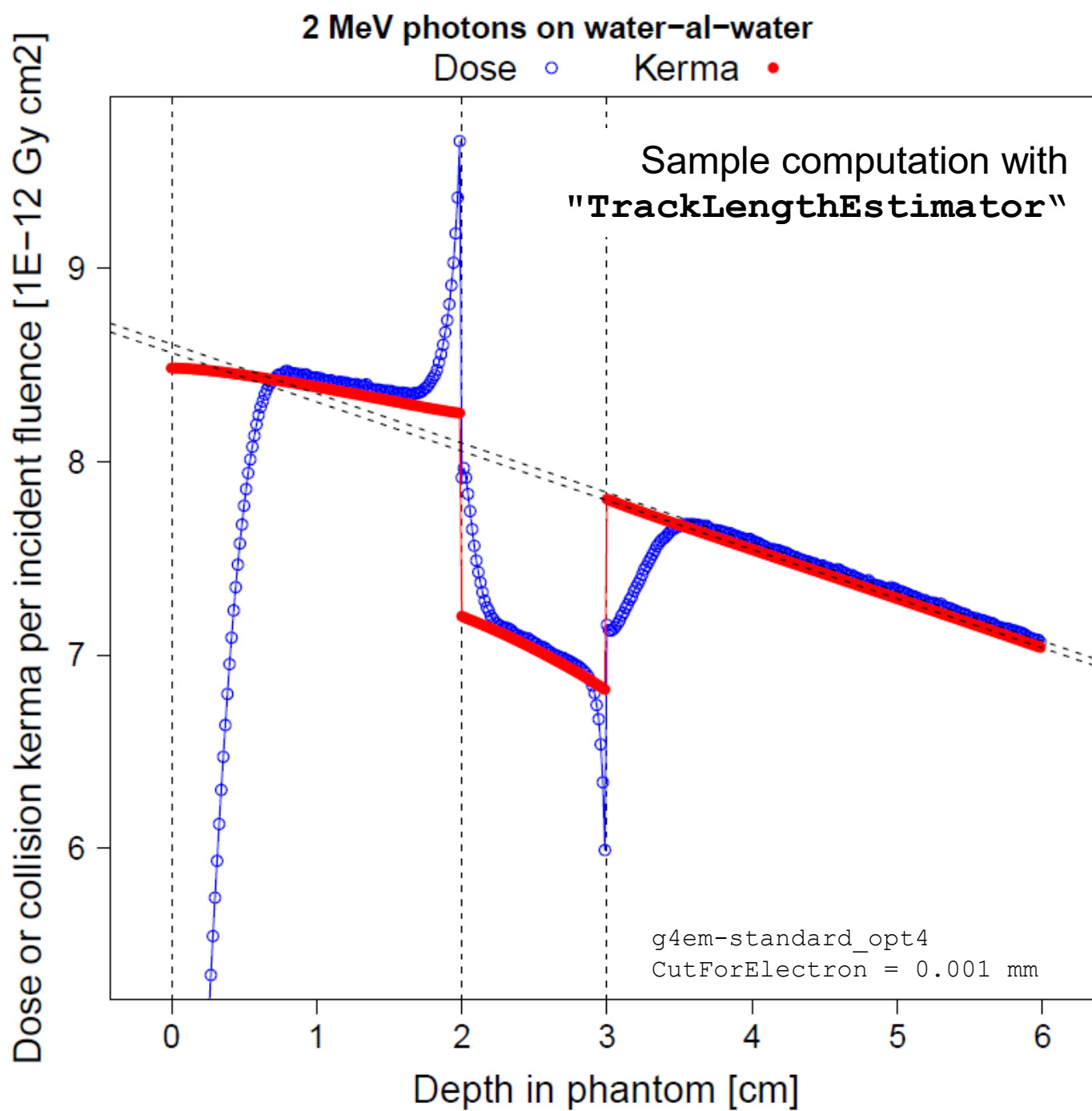
The data to the left is the initial part of the file. The data appears to be in the format:

$\langle \text{MeV} \rangle$ $\langle \mu/\rho \rangle$ $\langle \mu_{\text{en}}/\rho \rangle$

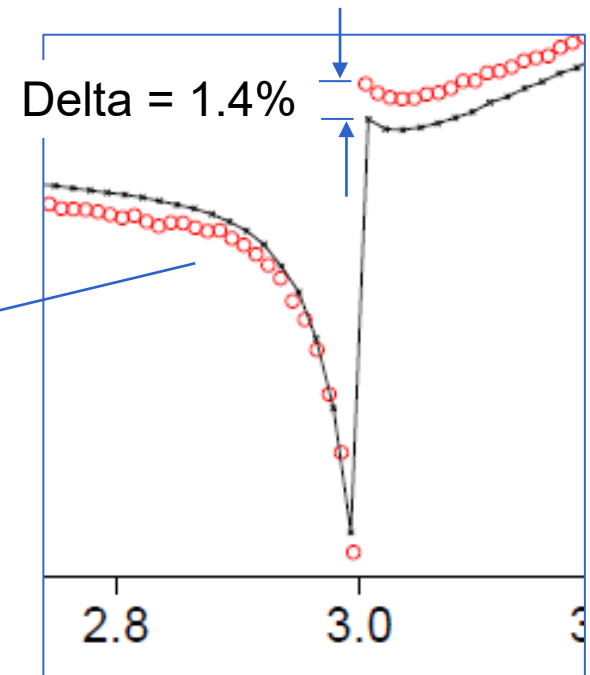
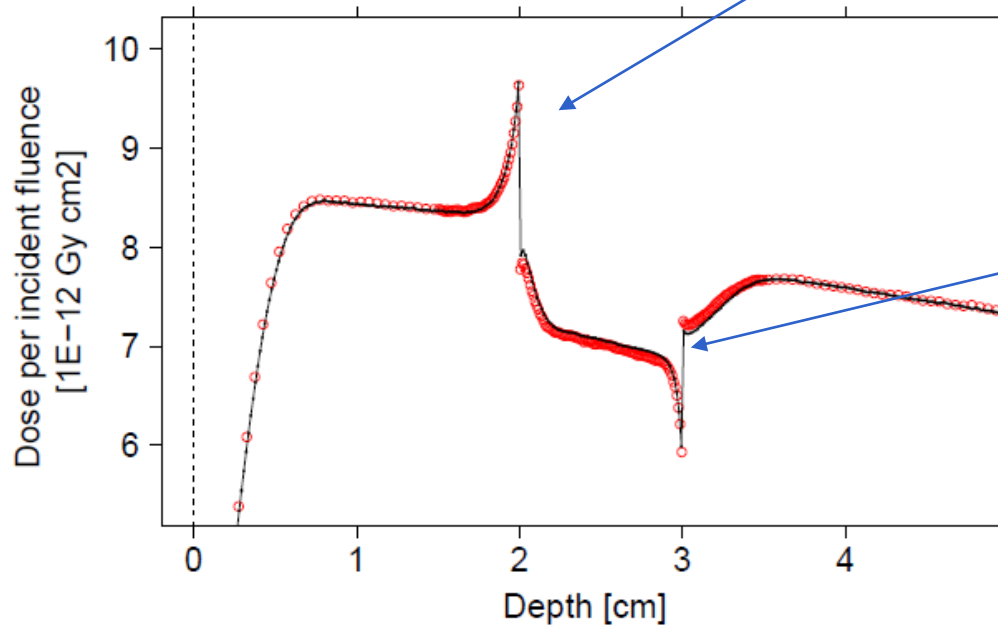
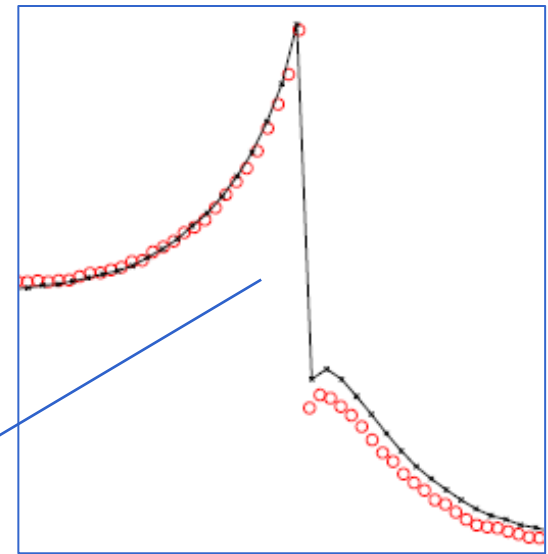
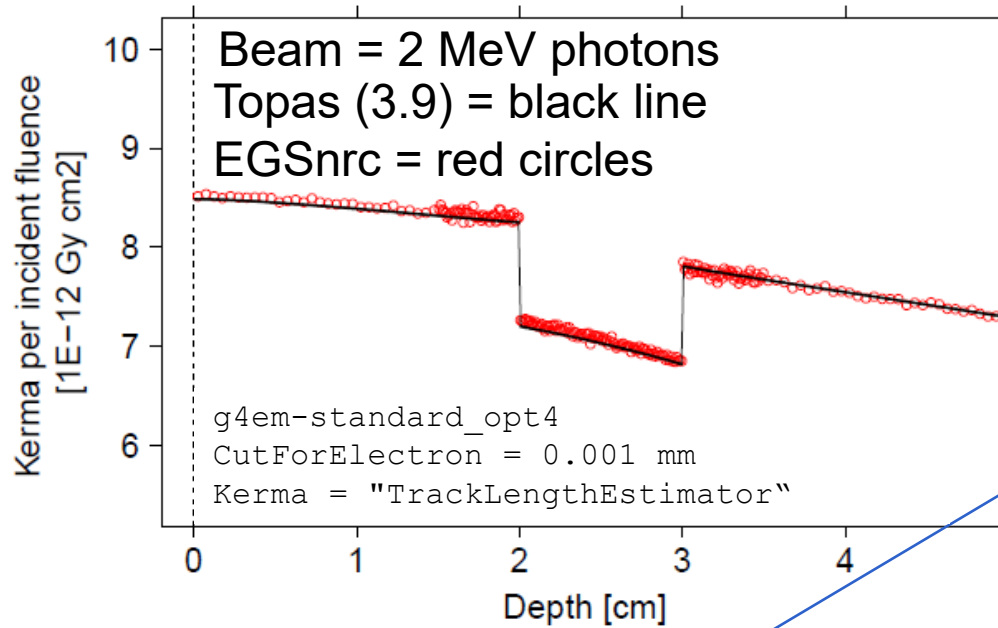
for hydrogen ($Z = 1$ in the (1, 36) opening line) with 36 data points in the range from 1 keV to 20 MeV.

If, so, then the file contains data for elements 1 to 92.





Topas vs. EGSnrc for the water-aluminium-water interface



Topas :

How to represent the spectral
distribution of photons from a
Varian medical linac ?

The Topas-VarianBeamAR.txt file on GitHub

Using the data in Table 5 of the Ali & Rogers (2012) paper:

IOP PUBLISHING

Phys. Med. Biol. 57 (2012) 31–50

PHYSICS IN MEDICINE AND BIOLOGY

doi:10.1088/0031-9155/57/1/31

Functional forms for photon spectra of clinical linacs

E S M Ali and D W O Rogers

Carleton Laboratory for Radiotherapy Physics, Department of Physics, Carleton University,
1125 Colonel By Drive, Ottawa, ON K1S 5B6, Canada

E-mail: eali@physics.carleton.ca and drogers@physics.carleton.ca

Received 26 May 2011, in final form 18 September 2011

Published 29 November 2011

Online at stacks.iop.org/PMB/57/31

Simple histograms representing the
Varian Clinac 4 MV, 6 MV, 10 MV, 15 MV and 18 MV

The spectra are in the file: [Topas-VarianBeamAR.txt](#)

available here:

<https://github.com/claus-e-andersen/topas>

Use of the Topas-VarianBeamAR.txt file

1. Put the following text in your parameter file.
2. Copy the Topas-VarianBeamAR.txt file to the folder of your parameter file.
3. Modify the source name and select the beam quality as indicated below:


```
includeFile = Topas-VarianBeamAR.txt

s:So/clanBeam/BeamEnergySpectrumType = "Continuous"
# None, Continuous or Discrete

# Code for selection of spectra:
VarianBeamxxMV where xx = 04, 06, 10, 15, or 18

dv:So/clanBeam/BeamEnergySpectrumValues =
    So/VarianBeam04MV/BeamEnergySpectrumValues MeV

uv:So/clanBeam/BeamEnergySpectrumWeights =
    So/VarianBeam04MV/BeamEnergySpectrumWeights
```

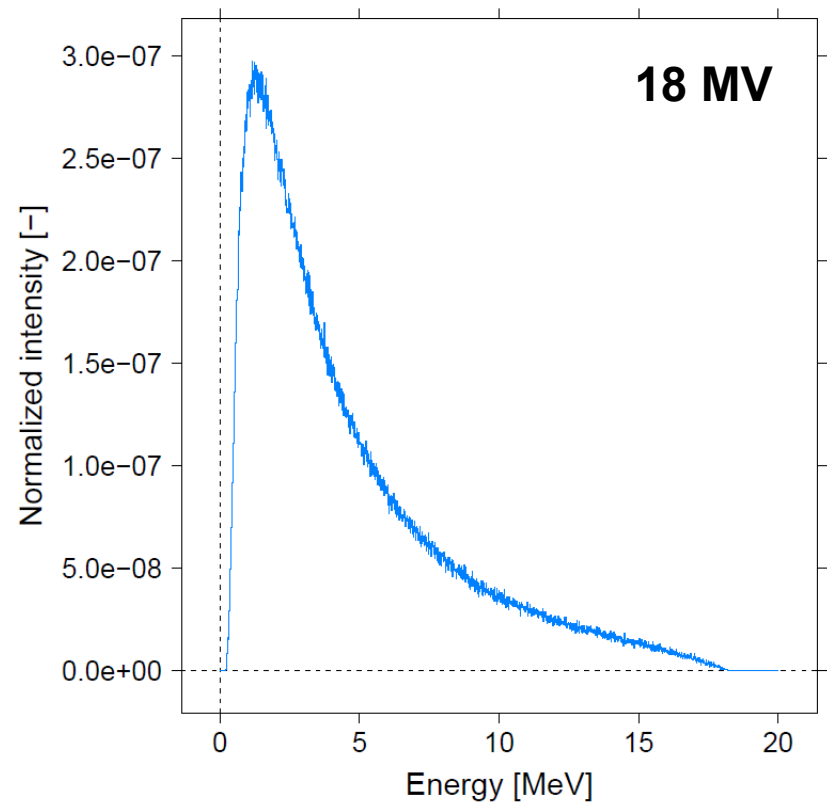
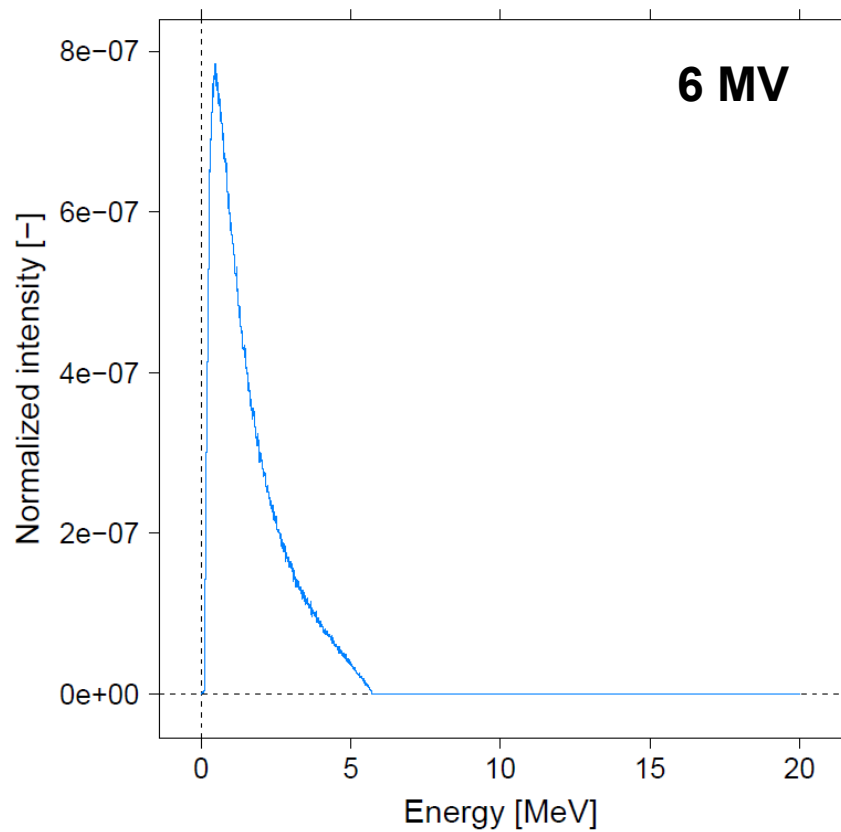


Write the specific name
of your gamma source here.



This is where you select the beam quality

Topas-VarianBeamAR.txt file examples



How to make radioactivity in
Topas?

Radioactive decay

Select a proper physics list:

```
sv:Ph/Default/Modules = 7 "g4em-standard_opt4"  
"g4h-phy_QGSP_BIC_HP" "g4decay" "g4ion-binarycascade"  
"g4h-elastic_HP" "g4stopping" "g4radioactivedecay"
```

If you shoot neutrons into a big lump of aluminum sitting in a 4pi-detector phasespace scorer, you can see if you get any photons out that were created by the process "RadioactiveDecayBase".

If it works, you may want to limit the scorer only to record photons from this process.

From their initial kinetic energy, you can see if they are the same as you measured (1.7 MeV) and from the time-of-flight data, you can see if they arrive at the detector as expected from exponential decay and the half-life specific for Al-28.

How to make Topas do
photonuclear reactions?

Photonuclear reactions

Select a proper physics list:

```
sv:Ph/Default/Modules = 8 "g4em-standard_opt4"  
"g4h-phy_QGSP_BIC_HP" "g4decay" "g4ion-binarycascade"  
"g4h-elastic_HP" "g4stopping" "g4radioactivedecay" "g4em-extra"
```

Add the g4em-extra to your physics list.

Jan Won Shin “A data-based photonuclear reaction model for GEANT4” Nuclear Instruments and Methods in Physics research B (2015) write:

G4EmExtraPhysics: For photonuclear interactions, GEANT4 uses the “G4EmExtraPhysics” class, which include the “G4PhotoNuclearCrossSection” class [\[47\]](#) and the “G4CascadeInterface” [\[48\]](#) class. G4PhotoNuclearCrossSection provides the total inelastic cross-sections for photonuclear interactions with nuclei. For simulating final states for photonuclear reactions, G4EmExtraPhysics uses the Bertini-style cascade model, the “G4CascadeInterface”. Even though the Bertini model is available for the region of incident photon energy $0.6 \text{ Ec} < 3.5 \text{ GeV}$ in GEANT4 (v10.1), the model has been tested in a energy range $60 \text{ MeV} - 3 \text{ GeV}$ [\[48\]](#). The above mentioned classes are described in detail in the Physics Reference Manual [\[49\]](#).

If you run Topas within
VirtualBox and need more hard
disk space?

How to expand your hard disk in VirtualBox

1. Make a clone of your machine (right-click and select clone ctrl+0).

2. Expand disk on VB:

Menu: File / Tools / Manage Virtual machine (“Håndtering af virtuel medie”) Ctrl-D

Get properties on machine <name... vdi>

Adjust slider to 49.01 Gb or whatever space you want to expand to.

Apply.

3. Open machine in VB.

Open terminal

Run df (to get an overview of your disks.). Typically the disk with data will be /dev/sda3

```
sudo cfdisk
```

(sudo password = cavity)

Choose partition (e.g. /dev/sda3)

RESIZE

(select new size, e.g. 49.01 Gb)

WRITE

(write new partition to disk)

QUIT (cfdisk)

Sudo reboot

df (new overview, nothing has happened yet)

```
sudo resize2fs /dev/sda3 (or whatever the name of the disk is)
```

(resize2fs = resize to free space)

df (now something has happened, hopefully)

4. If all is good you can now delete the machine that you cloned.

If you run bash under linux

Include Topas in you path
(.bashrc changes)

If you run bash under linux

To include topas in your path, do the following:

Add the following lines to .bashrc in your home-folde:

```
export TOPAS_G4_DATA_DIR=~/.G4Data  
export PATH=~/.topas/bin:$PATH
```

(just put them at the end as the last lines).

Close / open terminal to start using your revised bash profile.

Write:

```
echo $PATH
```

from terminal to verify the status of your path or simply write topas.

Ressources

[TOPAS MC](#)

<http://www.topasmc.org/>

[TOPAS MC Users - Google Grupper](#)

<https://groups.google.com/g/topas-mc-users>
(require registration)

[Geant4 Forum \(cern.ch\)](#)

<https://geant4-forum.web.cern.ch/>

List of materials:

[Geant4 Material Database — Book For Application Developers 11.1 documentation \(cern.ch\)](#)

<https://geant4-userdoc.web.cern.ch/UsersGuides/ForApplicationDeveloper/html/Appendix/materialNames.html>

Ressources on Github

[topasmc \(github.com\)](https://github.com/topasmc)

<https://github.com/topasmc>

<https://github.com/jschuemann/extensions>

“Dirty dose extension etc.:

[Villadslj/Topas-Extension: Different kind of TOPAS extensions \(github.com\)](https://github.com/Villadslj/Topas-Extension)

Varian spectra:

[claus-e-andersen/TopasTools: Tools for Topasmc \(Topas Monte-Carlo\) modelling \(github.com\)](https://github.com/claus-e-andersen/TopasTools)

<https://github.com/claus-e-andersen/TopasTools>