

MR-PET

A new module for the EduGATE Project
part **one**: particle sources

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Basic Paper

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**- *Long is the way of theory,
short and effective by examples –***

(Lucius Annaeus Seneca (the Younger),
Epistulae morales)

MR-PET

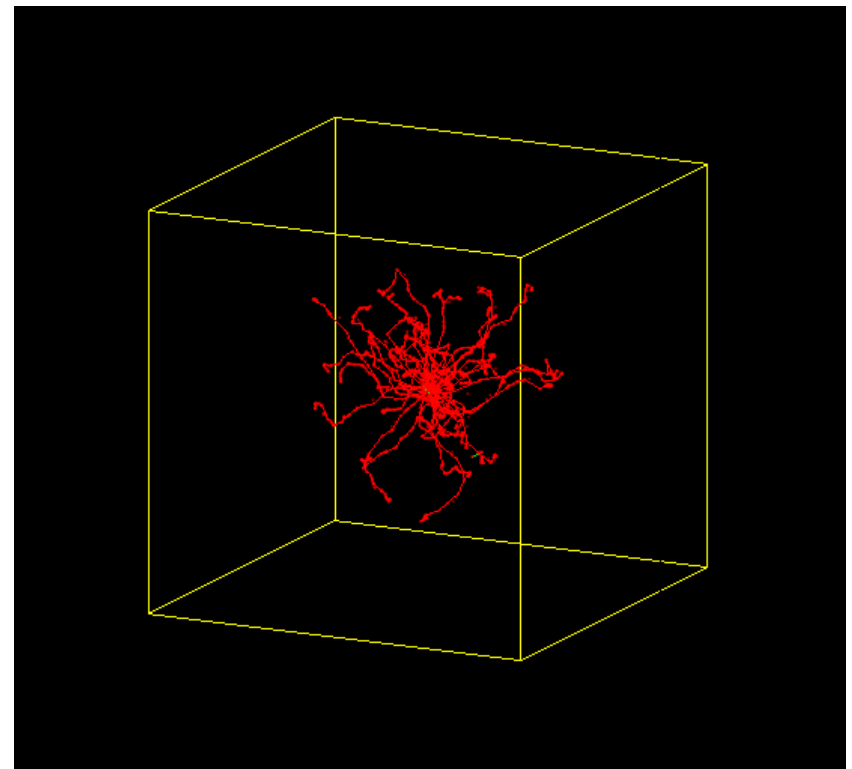
- Introduces to the *basic physical effects* in **MR-PET** hybrid imaging
 - Provides with **GATE**-macros
 - Provides programme code for **ROOT** to visualize basic behaviour of charged particles in the magnetic field of a MR System

general setup of the MR-PET module

- source emits charged particles or photons of defined energy
- particles interact with surrounding medium (impact ionisation, compton scattering,...)
- annihilation of positrons can be enabled (by default disabled)
- additional deviation due to magnetic field (B_0)
- detection of particles in surrounding medium

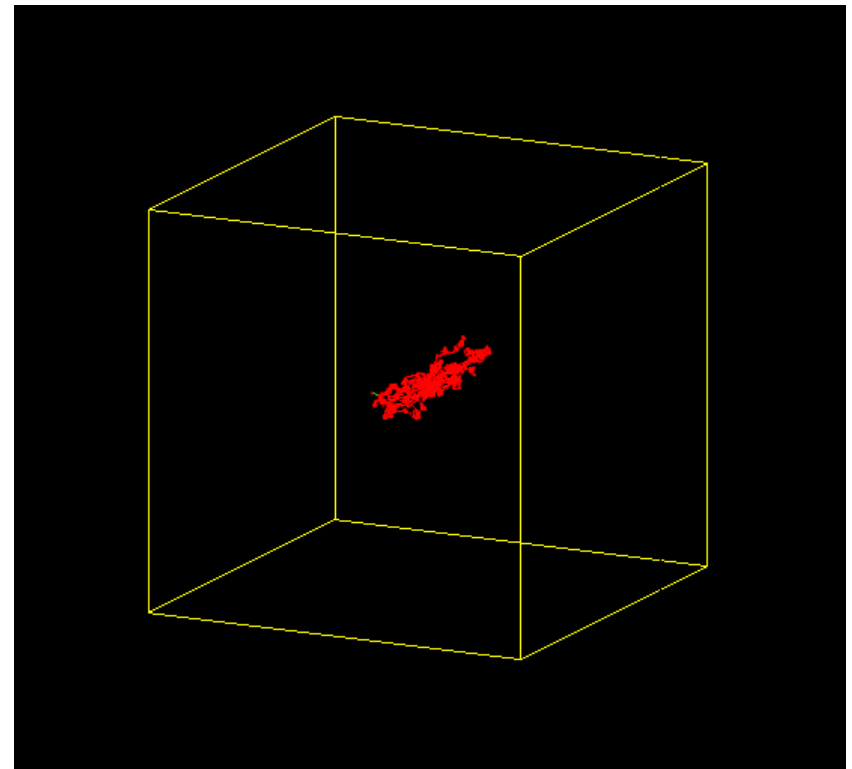
exemplary setup of the MR-PET module

- electrons (80 keV) are emitted isotropically from a point source (positioned at the origin)
- electrons interact with the medium(air), annihilation turned off
- trajectories of electrons are plotted as red lines
- no additional magnetic field

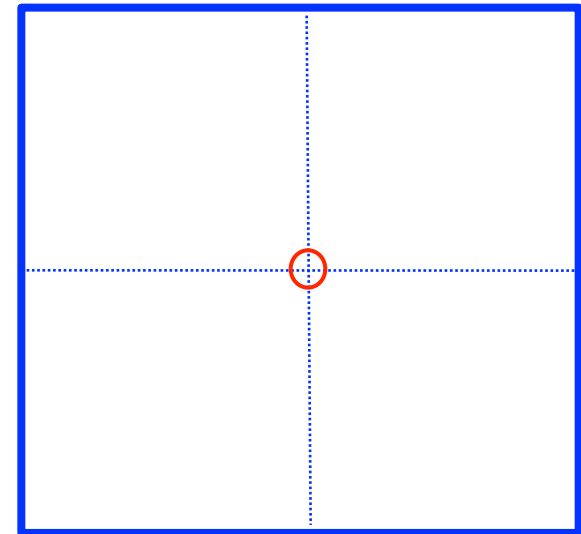
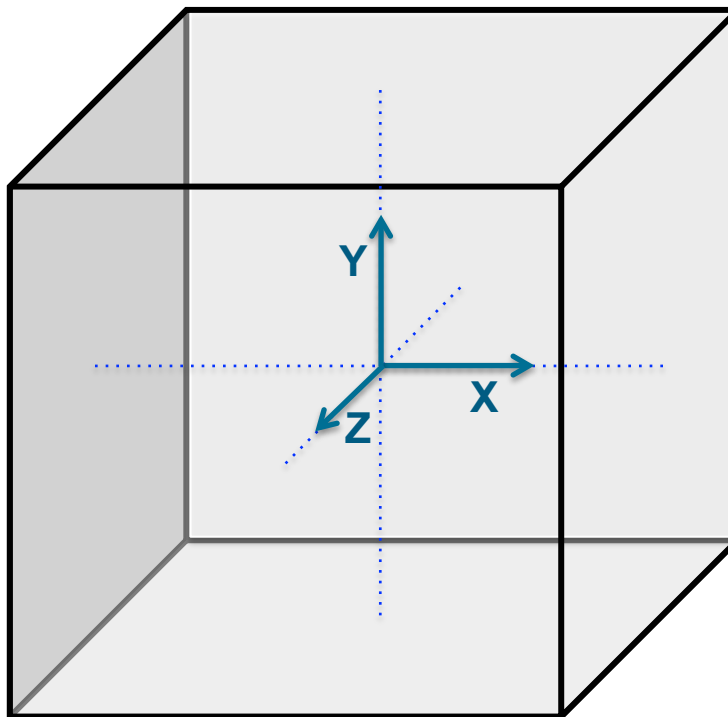


exemplary setup of the MR-PET module

- electrons (80 keV) are emitted from an isotropic source (positioned at the origin)
- electrons interact with the medium (air), annihilation turned off
- trajectories of electrons are plotted as red lines
- magnetic field in z direction: $B_0 = 0.5 \text{ T}$



orientation of the coordinate system



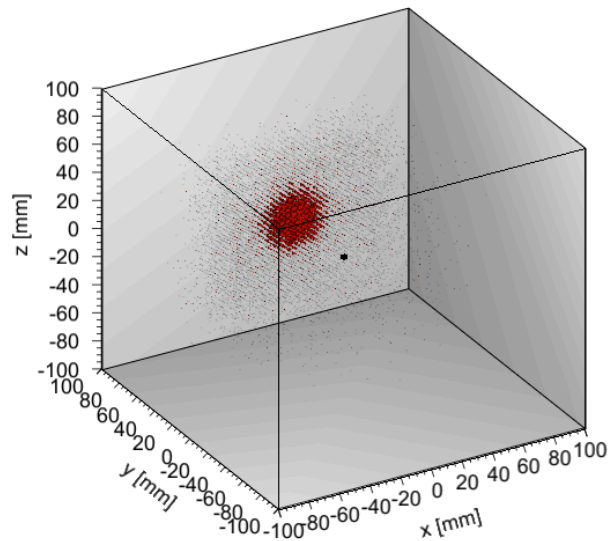
**point-like
source at center
($x = y = z = 0$)**

particle sources

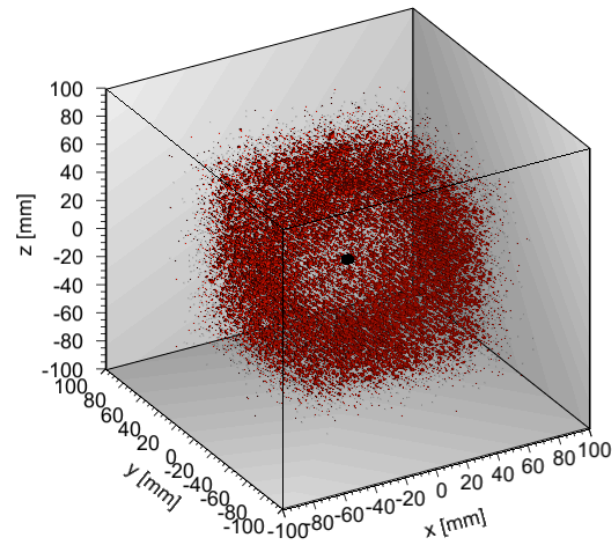
- choose from three different particle sources: electron, positron or gamma^{*)} source
- specify the type of particle propagation (isotropic or beam source)

^{*)} use the gamma source to investigate effects of secondary electrons

particle sources

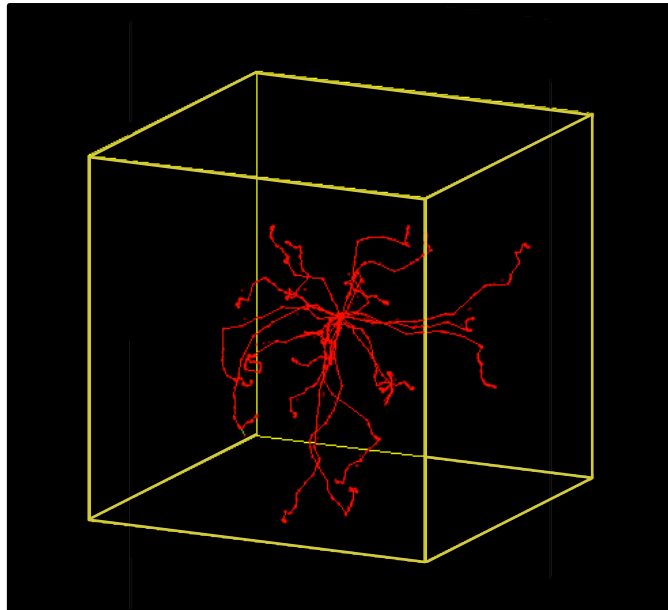


beam
direction: +y



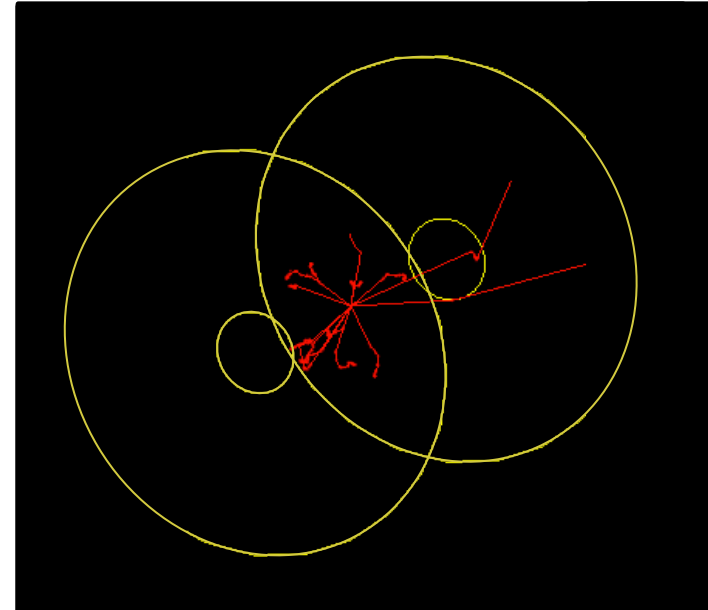
isotropic

shapes of surrounding medium



cube

particles interact immediately within medium



cylinder

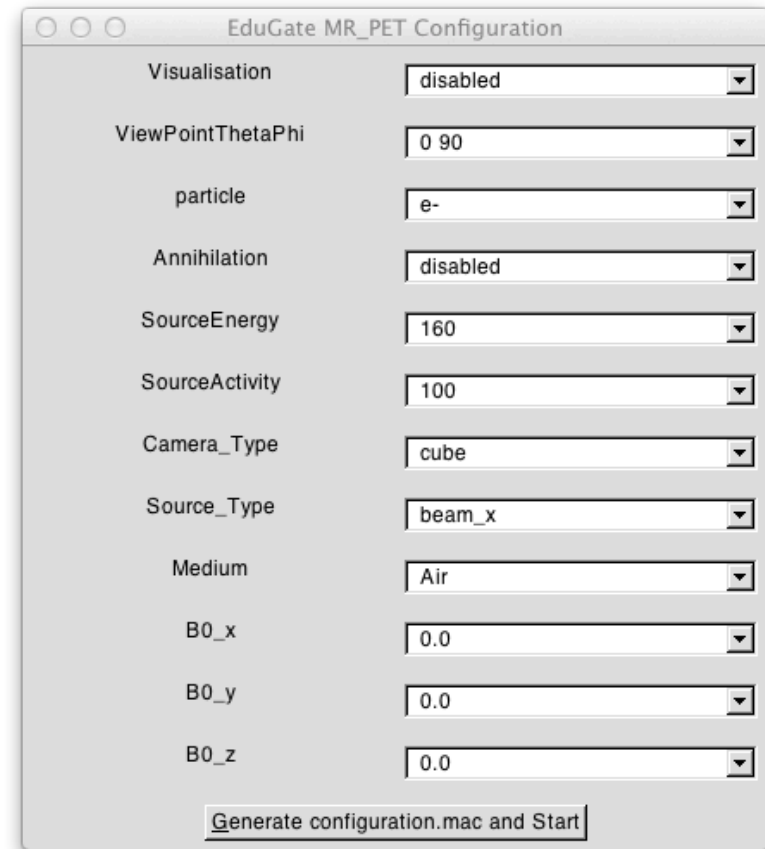
initial deviation due to magnetic field visible (if enabled), followed by interaction within medium

Please note:

- Within **GATE**, **crystal** denotes the volume in which particles are **detected**
- it does not have to be a crystal (like a scintillator) but consists of air, water or lung tissue, etc.
- to prevent misunderstanding the '**crystal**' is called '**medium**' in this macro

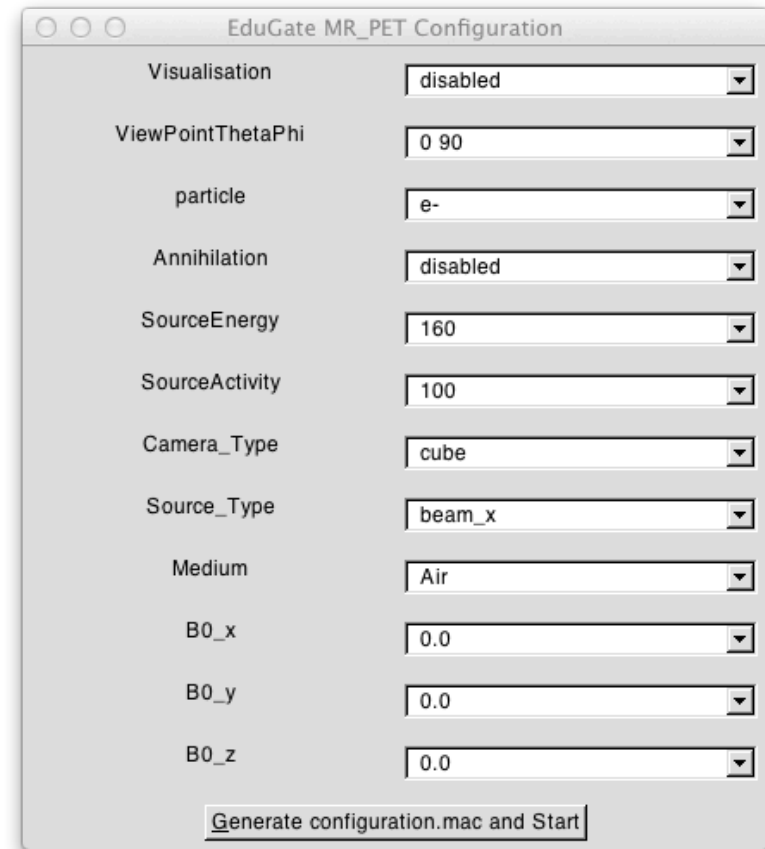
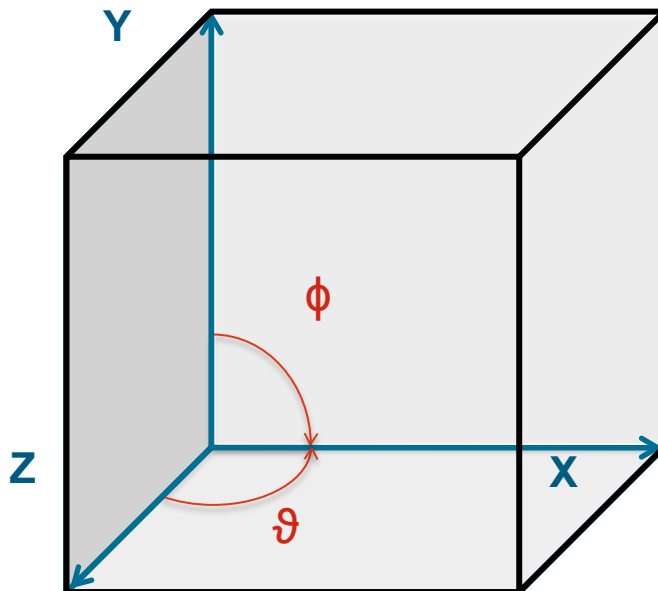
user interface (Gate_v7.0 or 7.1)

- type
„./config_starter_mac_70.csh“
in a terminal window
- specify parameters like
source energy, source
activity, medium etc.
- choose point of view if
visualisation is enabled
- generate configuration and
start simulation



user interface (Gate_v7.0 or 7.1)

- take a look at the scene under different angles by changing (ϑ, ϕ)



user interface (Gate_v7.0 or 7.1)

selection presets can be modified in „MR_PET.txt“

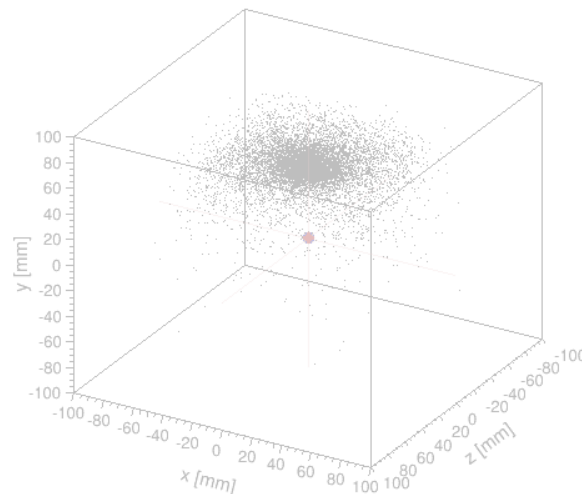
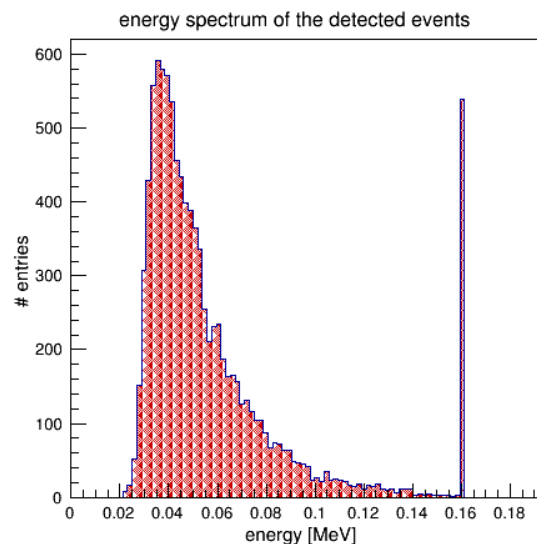
```
Visualisation: disabled; enabled;  
ViewPointThetaPhi: 0 90; 30 30; 90 0; -90 0; 89 90; 15 30; 30 30; 45 45; 60 60;  
particle: e-; e+; gamma;  
Annihilation: disabled; enabled;  
SourceEnergy: 10; 30; 50; 80; 90; 100; 120; 140; 160; 200; 240; 400; 600; 800; 1000; 1600;  
SourceActivity: 100; 1000; 10000; 100000;  
Camera_Type: cube; cylinder;  
Source_Type: beam_x; beam_y; beam_z; iso;  
Medium: Air; Water; Lung; Liver;  
B0_x: 0.0; 0.1; 0.2; 0.3; 0.4; 0.5; 1.0; 3.0; 7.0; 9.4; 12.0; 15.0; 20.0;  
B0_y: 0.0; 0.1; 0.2; 0.3; 0.4; 0.5; 1.0; 3.0; 7.0; 9.4; 12.0; 15.0; 20.0;  
B0_z: 0.0; 0.1; 0.2; 0.3; 0.4; 0.5; 1.0; 3.0; 7.0; 9.4; 12.0; 15.0; 20.0;
```

user interface (Gate_v7.0 or 7.1)

- use „MR_PET.C“ to evaluate a specific .root file
(file browser opens automatically after simulation)
- further information in terminal window

```
[Acquisition-0] ===== Acquisition starts! =====  
[Acquisition-0] Simulation start time = 0 sec  
[Acquisition-0] Simulation end time   = 100 sec  
[Acquisition-0] Simulation will have  = 10 run(s)  
...  
##### Reading from file: MR_PET_cube_Water_800_e-_10_beam_x_0.0_0.4_0.0_enabled  
...  
##### Number of emitted particles : 990  
##### Number of detected events   : 990  
##### ratio detected/emitted      : 100 %
```

analysis with „MR_PET.C“

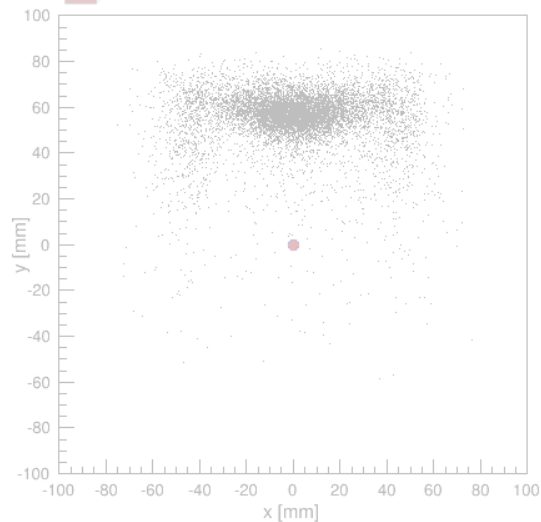


- particle: e-
- camera type: cube
- medium: Air
- source energy: 160 keV
- source activity: 100 Bq
- source type: beam (y)
- $B_{0,x}$: 0.0 T
- $B_{0,y}$: 0.0 T
- $B_{0,z}$: 0.0 T

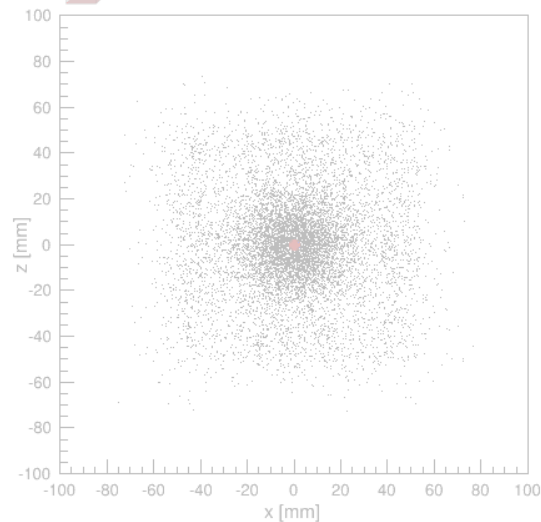
● source position



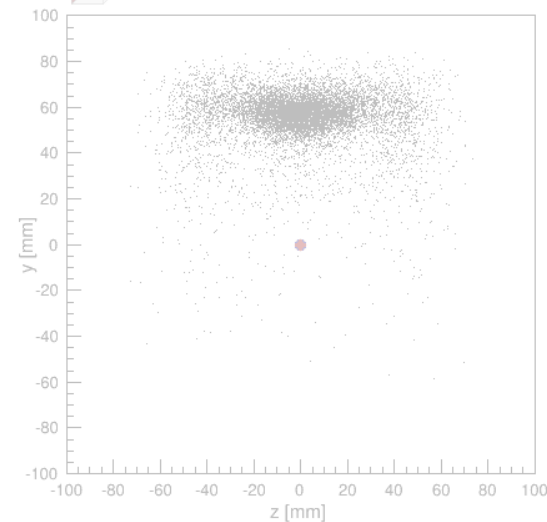
projection onto xy plane



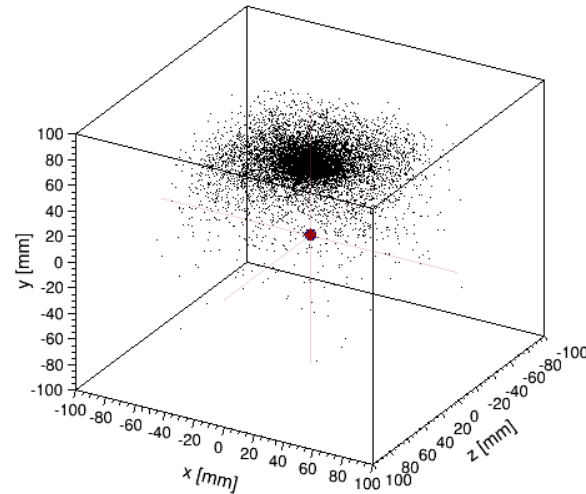
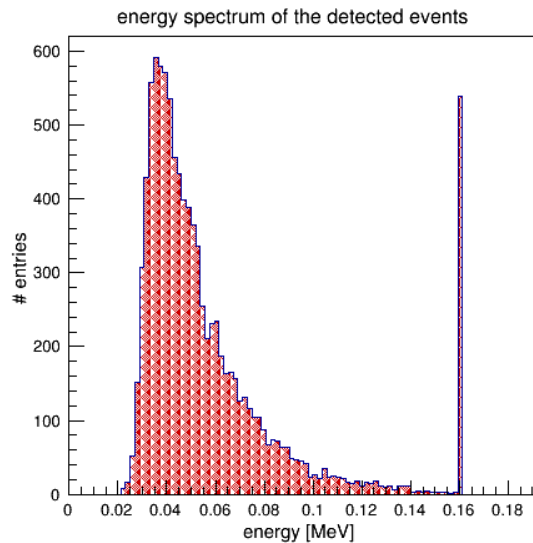
projection onto xz plane



projection onto zy plane

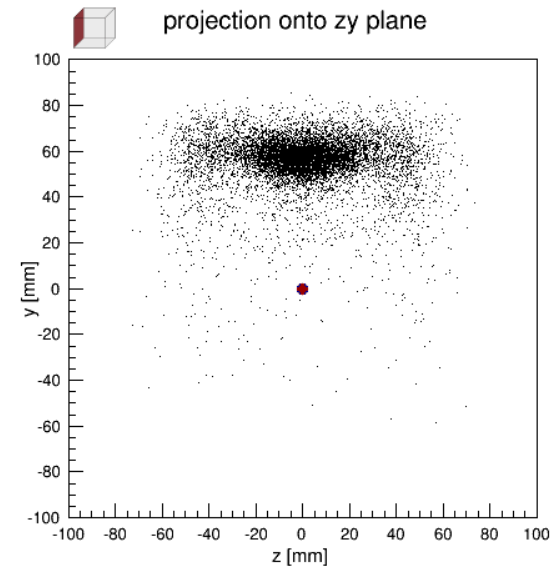
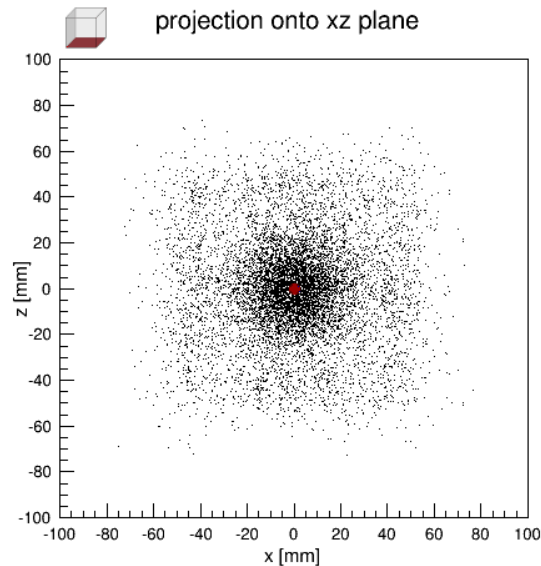
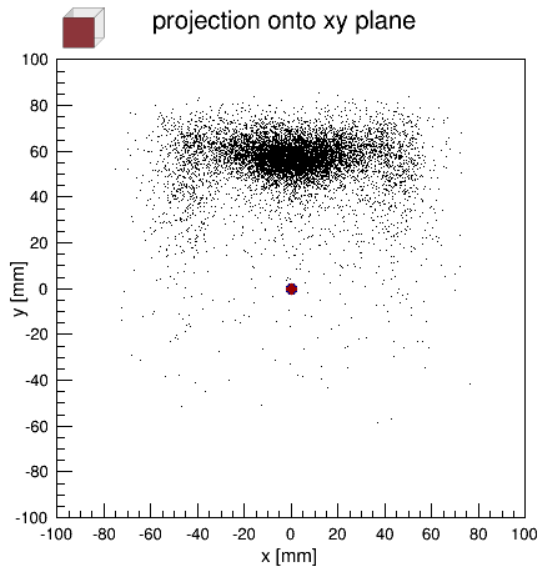


no magnetic field

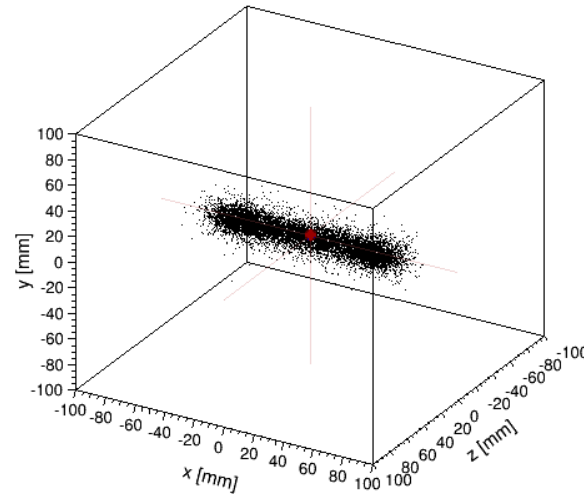
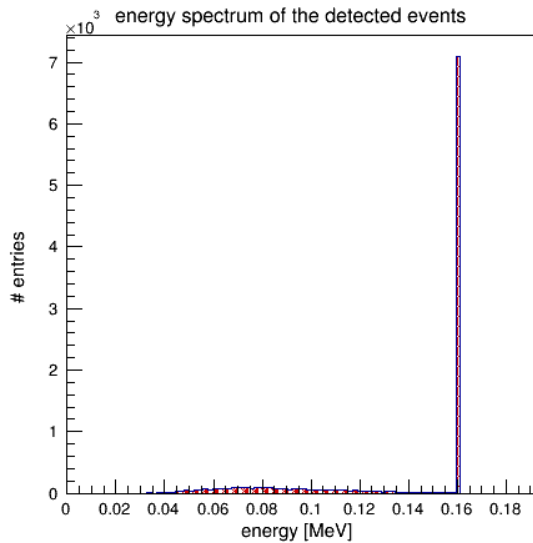


- particle: e-
- camera type: cube
- medium: Air
- source energy: 160 keV
- source activity: 100 Bq
- source type: beam (y)
- $B_{0,x}$: 0.0 T
- $B_{0,y}$: 0.0 T
- $B_{0,z}$: 0.0 T

● source position



magnetic field in x direction

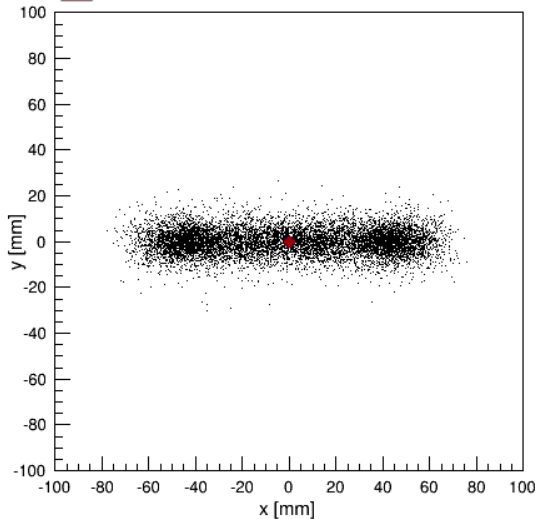


- particle: e-
- camera type: cube
- medium: Air
- source energy: 160 keV
- source activity: 100 Bq
- source type: beam (y)
- $B_{0,x}$: 0.5 T
- $B_{0,y}$: 0.0 T
- $B_{0,z}$: 0.0 T

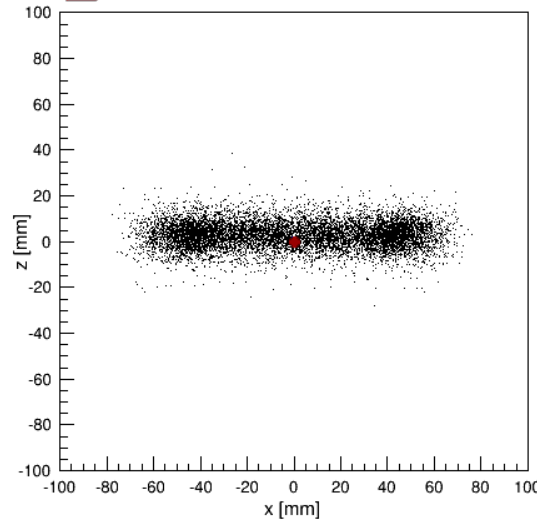
● source position



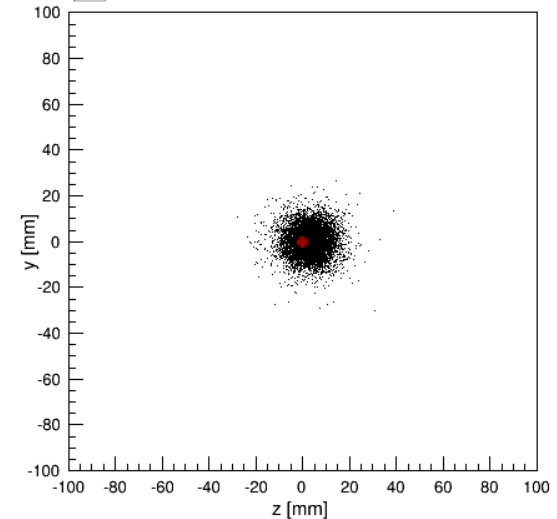
projection onto xy plane



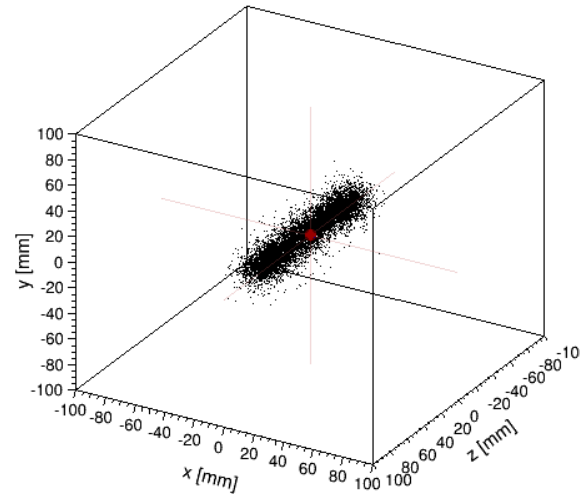
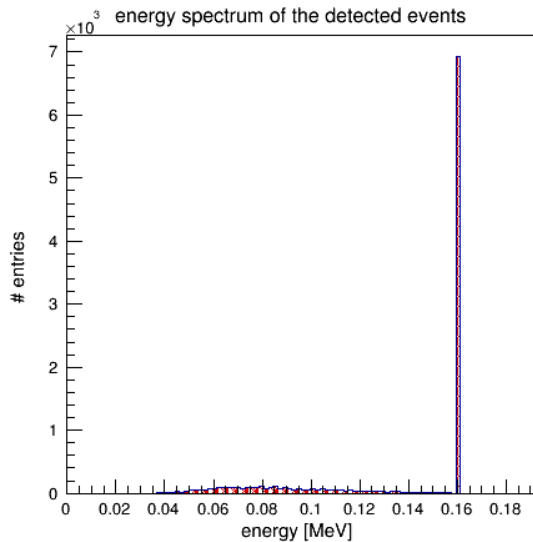
projection onto xz plane



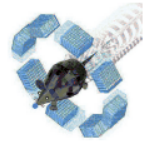
projection onto zy plane



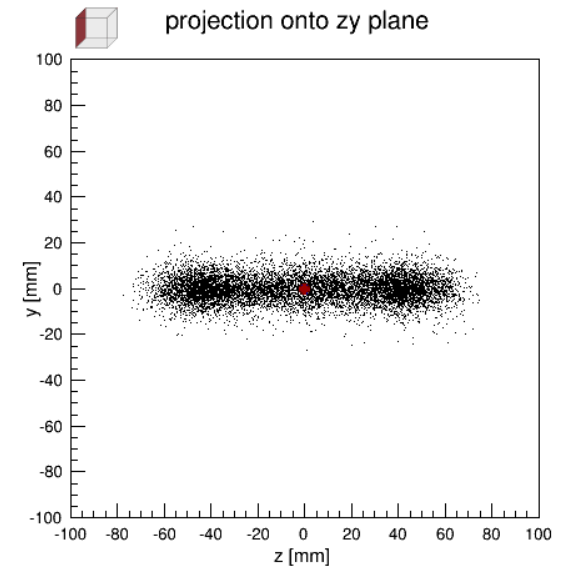
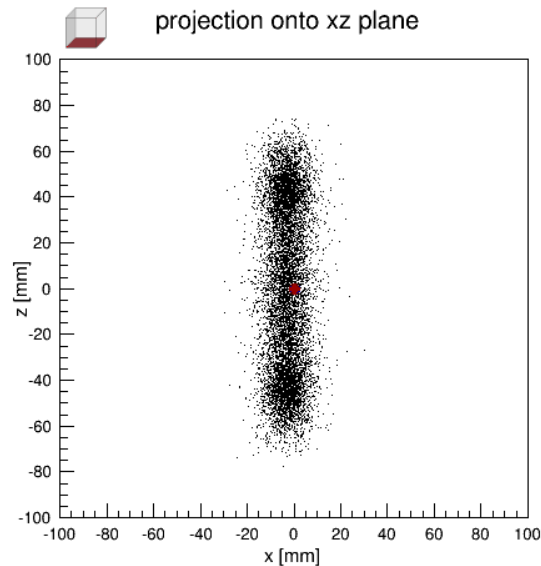
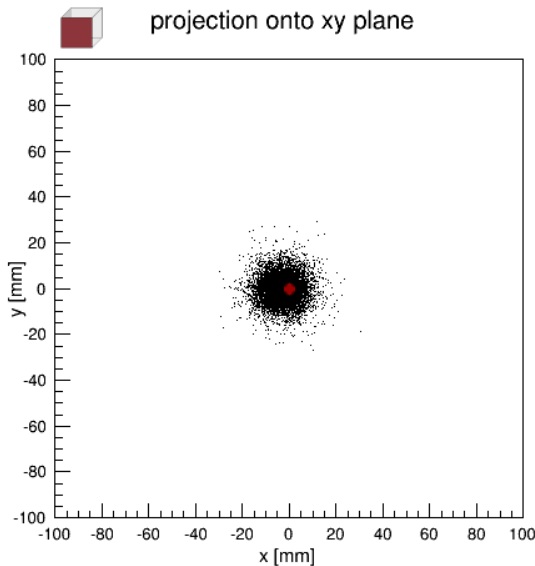
magnetic field in z direction



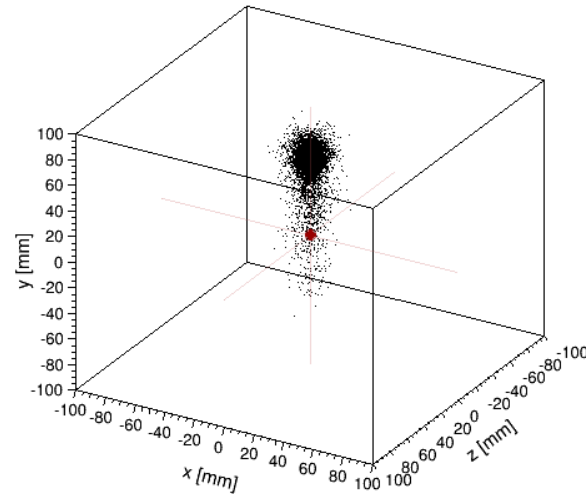
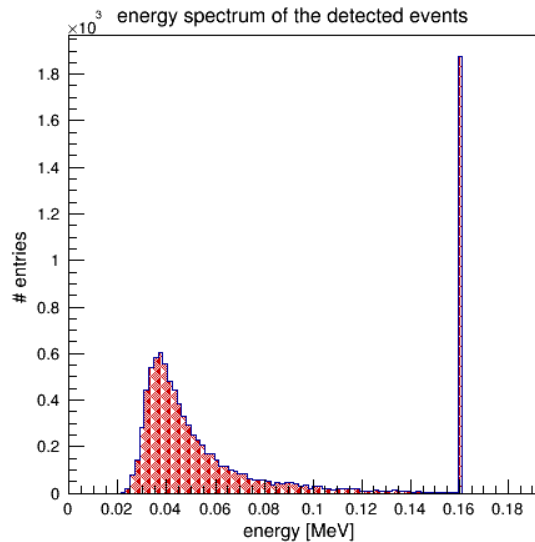
- particle: e-
- camera type: cube
- medium: Air
- source energy: 160 keV
- source activity: 100 Bq
- source type: beam (y)
- $B_{0,x}$: 0.0 T
- $B_{0,y}$: 0.0 T
- $B_{0,z}$: 0.5 T



● source position



magnetic field in y direction

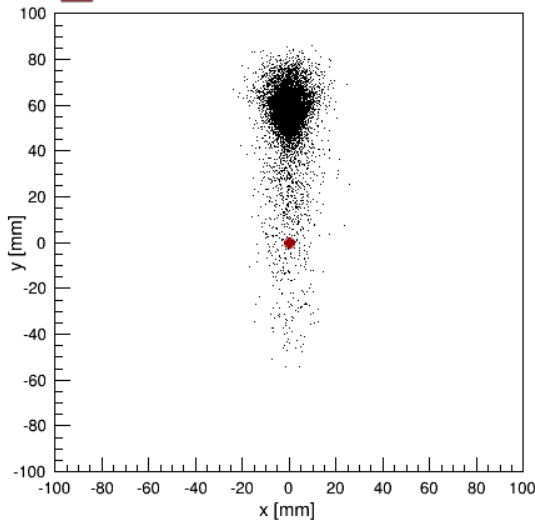


- particle: e-
- camera type: cube
- medium: Air
- source energy: 160 keV
- source activity: 100 Bq
- source type: beam (y)
- $B_{0,x}$: 0.0 T
- $B_{0,y}$: 0.5 T
- $B_{0,z}$: 0.0 T

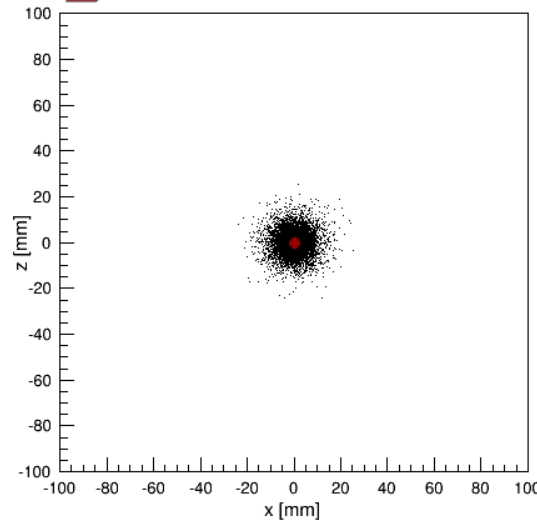
● source position



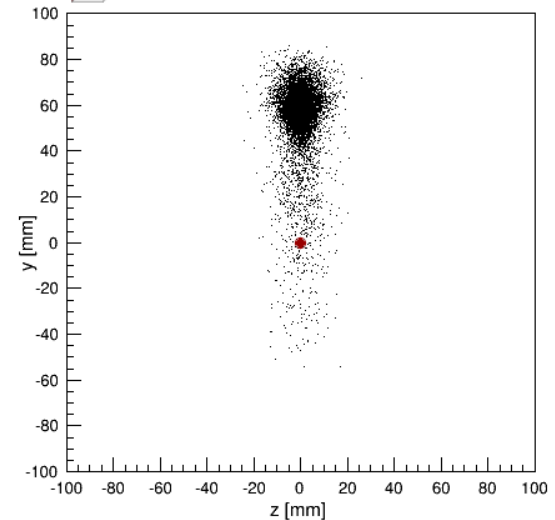
projection onto xy plane



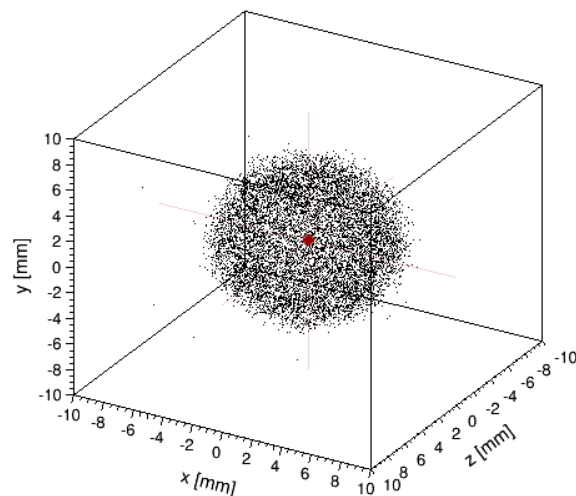
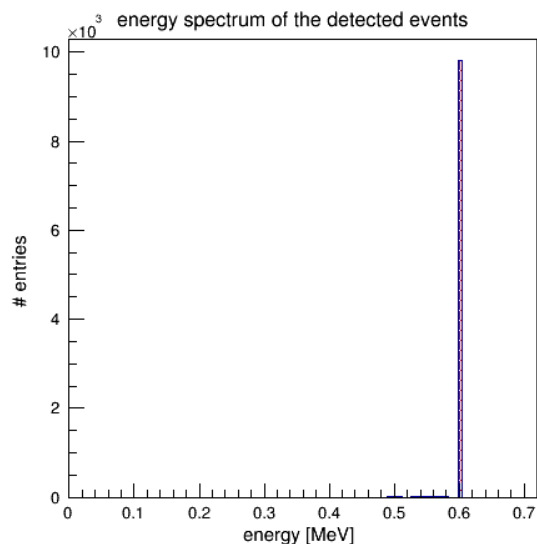
projection onto xz plane



projection onto zy plane



electron source in lung tissue

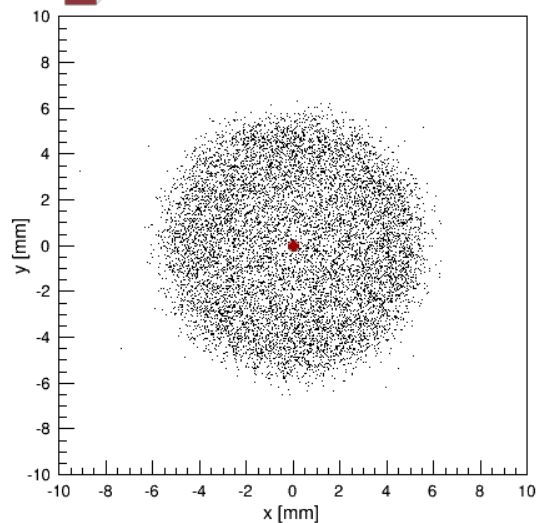


- particle: e-
- camera type: cube
- medium: Lung
- source energy: 600 keV
- source activity: 100 Bq
- source type: isotropic
- $B_{0,x}$: 0.0 T
- $B_{0,y}$: 0.0 T
- $B_{0,z}$: 0.0 T

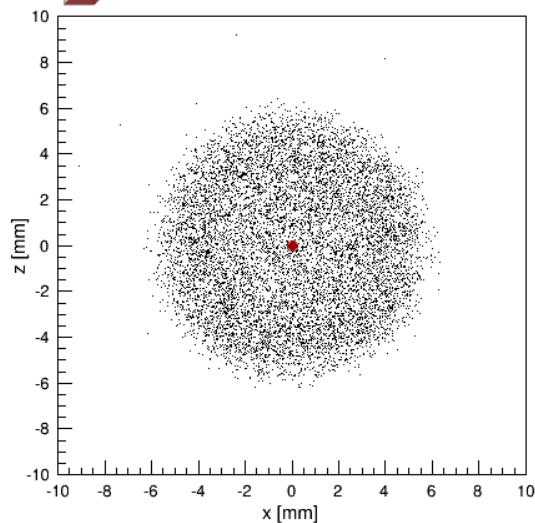
● source position



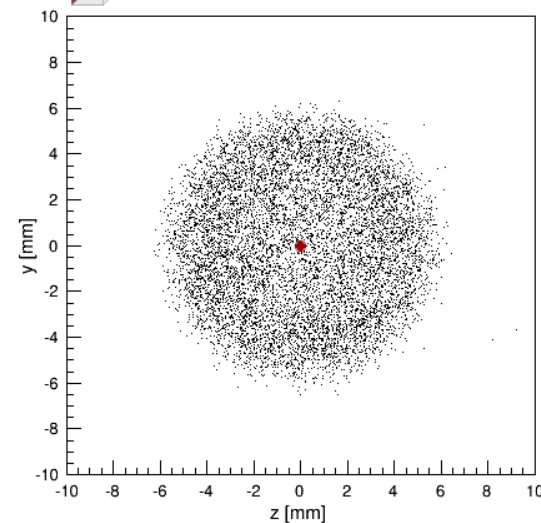
projection onto xy plane



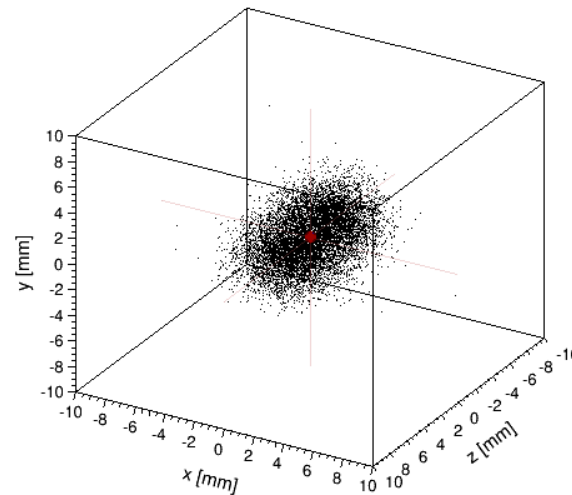
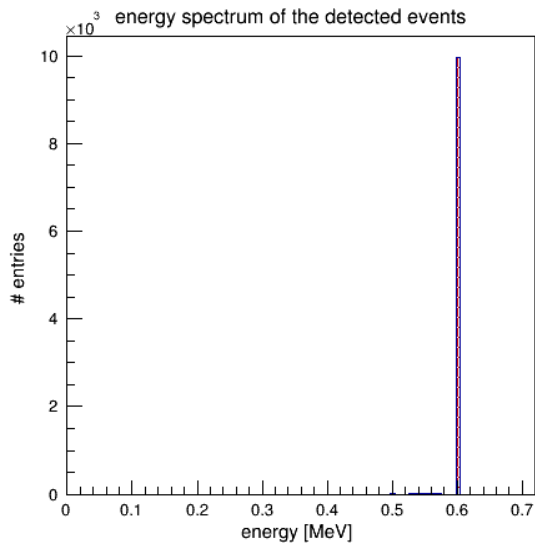
projection onto xz plane



projection onto zy plane



magnetic field in z direction

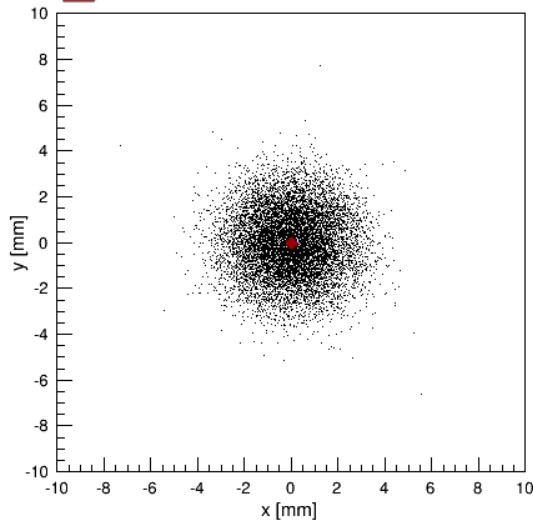


- particle: e-
- camera type: cube
- medium: Lung
- source energy: 600 keV
- source activity: 100 Bq
- source type: isotropic
- $B_{0,x}$: 0.0 T
- $B_{0,y}$: 0.0 T
- $B_{0,z}$: 3.0 T

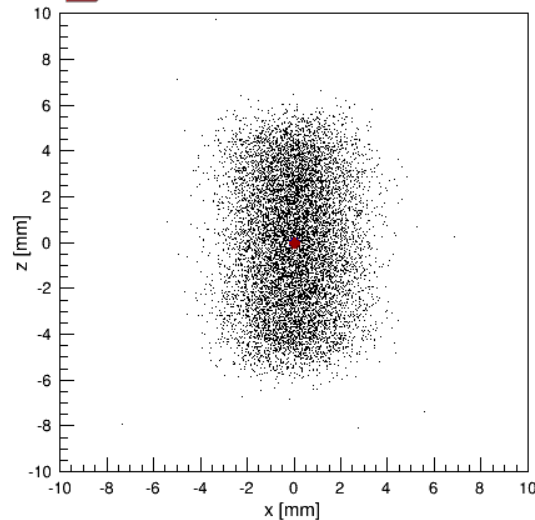
● source position



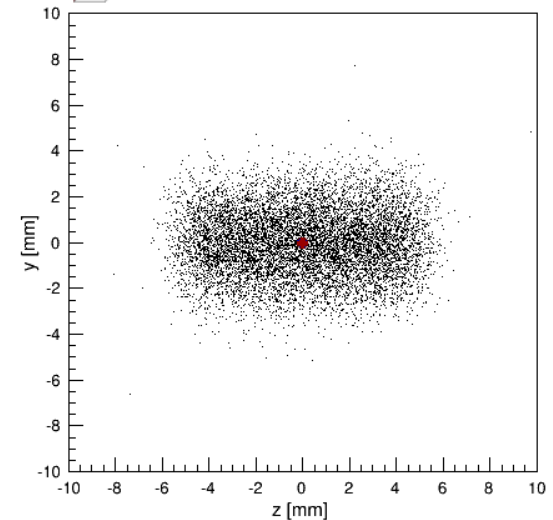
projection onto xy plane



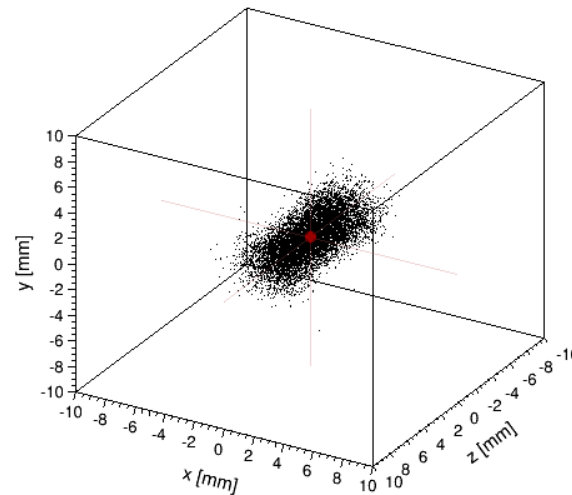
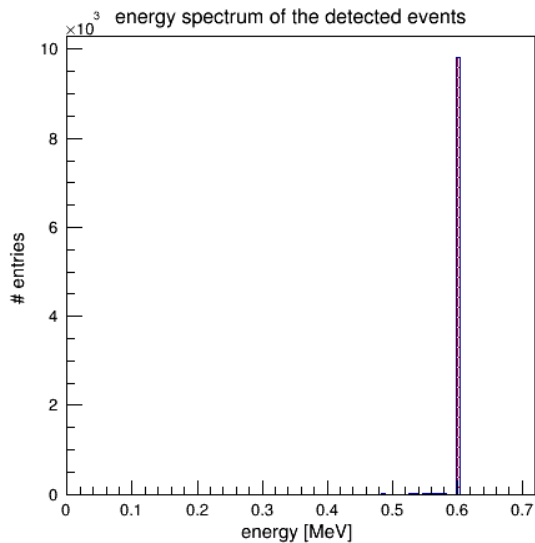
projection onto xz plane



projection onto zy plane

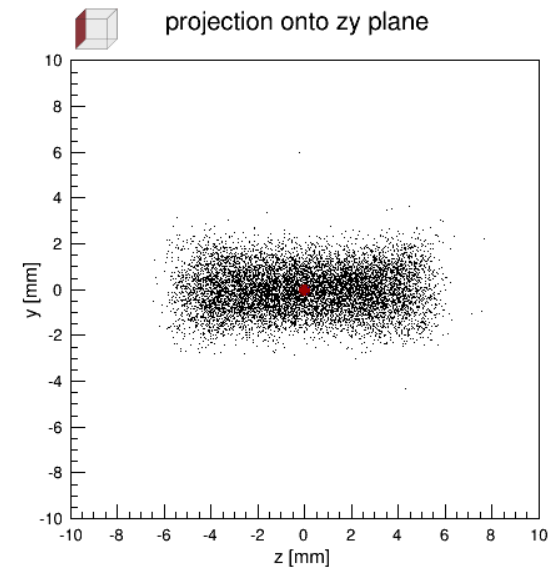
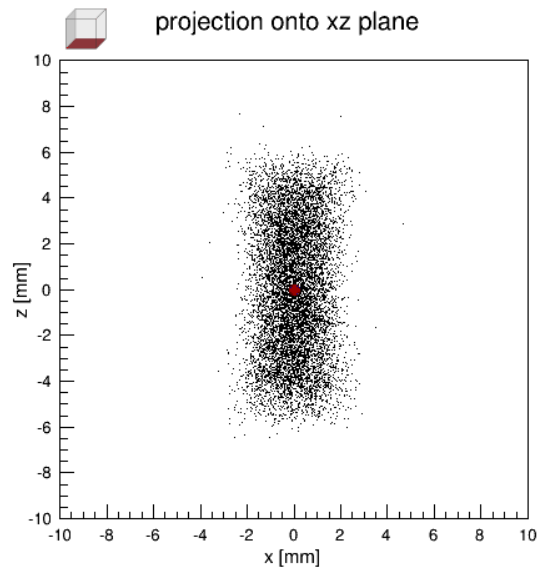
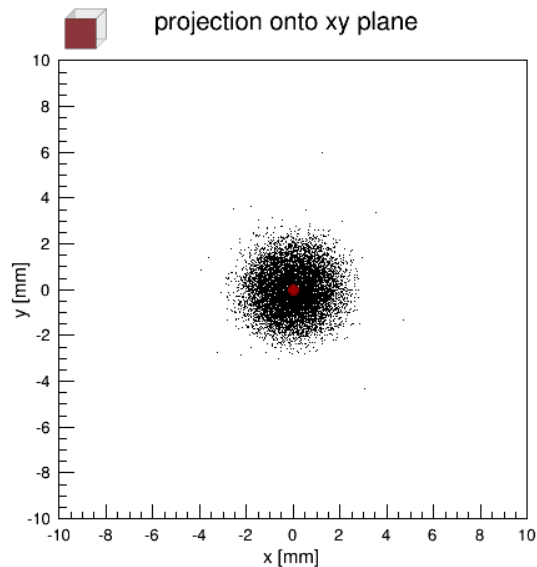


magnetic field in z direction

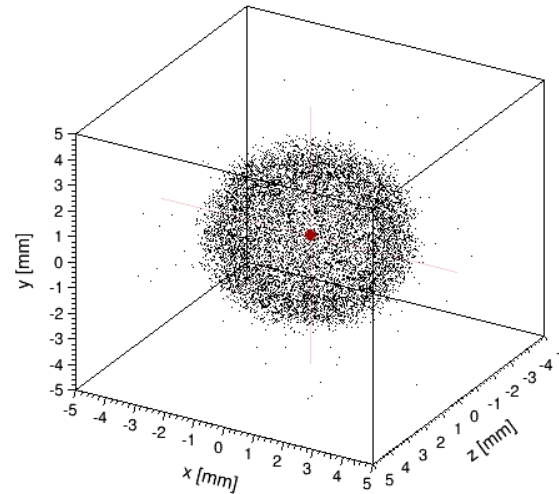
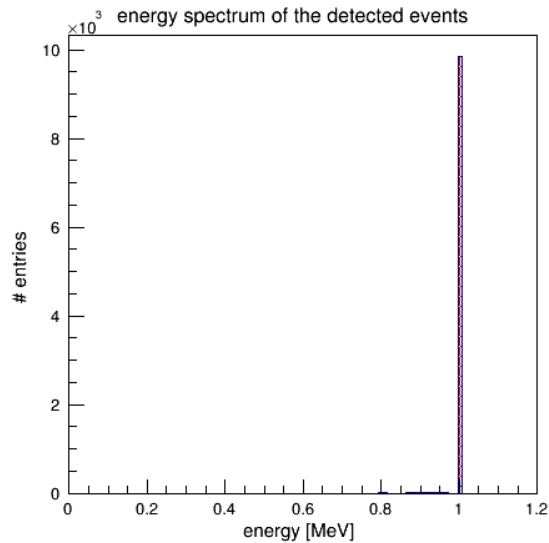


- particle: e-
- camera type: cube
- medium: Lung
- source energy: 600 keV
- source activity: 100 Bq
- source type: isotropic
- $B_{0,x}$: 0.0 T
- $B_{0,y}$: 0.0 T
- $B_{0,z}$: 7.0 T

● source position

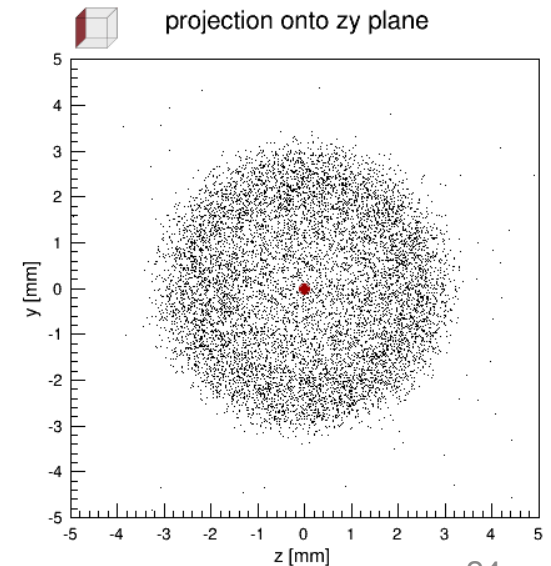
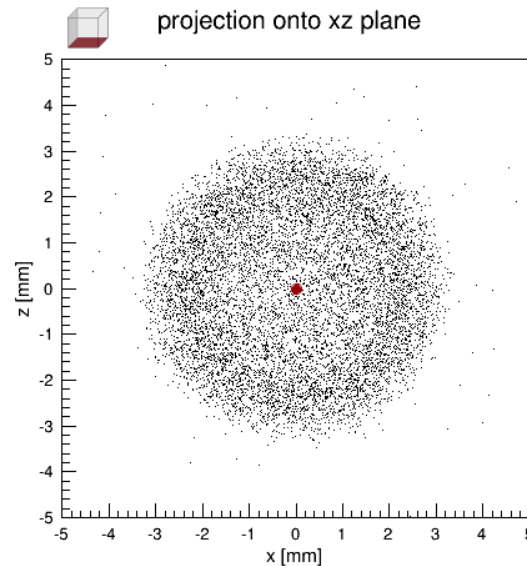
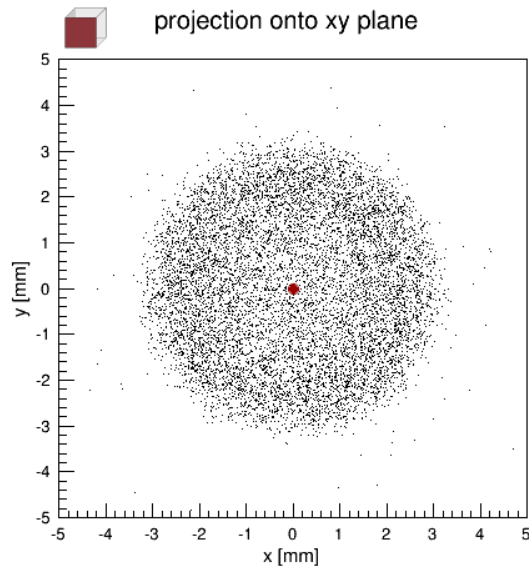


positron source in water

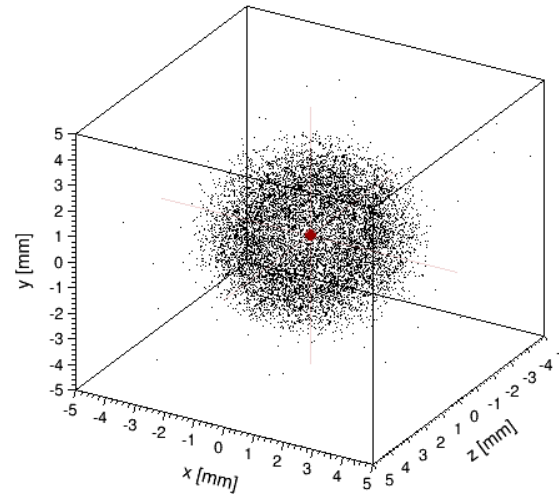
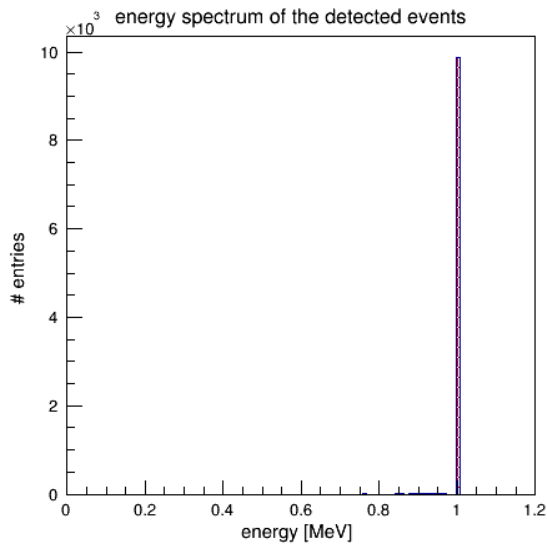


- particle: e^+
- camera type: cube
- medium: Water
- source energy: 1000 keV
- source activity: 100 Bq
- source type: isotropic
- $B_{0,x}$: 0.0 T
- $B_{0,y}$: 0.0 T
- $B_{0,z}$: 0.0 T
- positron annihilation: disabled

● source position



magnetic field in z direction

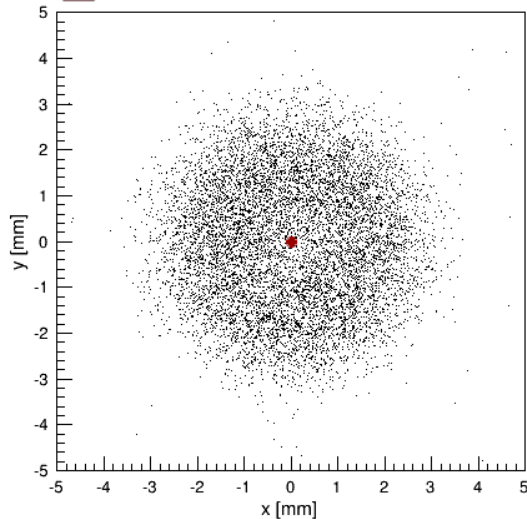


- particle: e^+
- camera type: cube
- medium: Water
- source energy: 1000 keV
- source activity: 100 Bq
- source type: isotropic
- $B_{0,x}$: 0.0 T
- $B_{0,y}$: 0.0 T
- $B_{0,z}$: 3.0 T
- positron annihilation: disabled

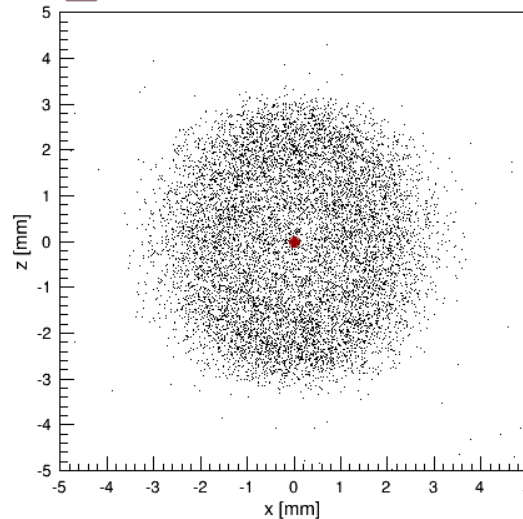
● source position



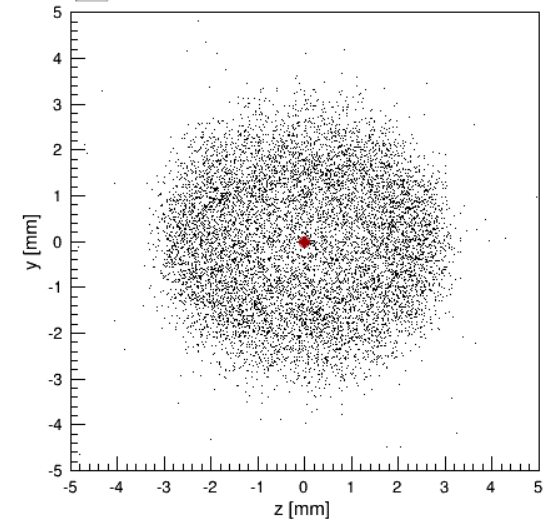
projection onto xy plane



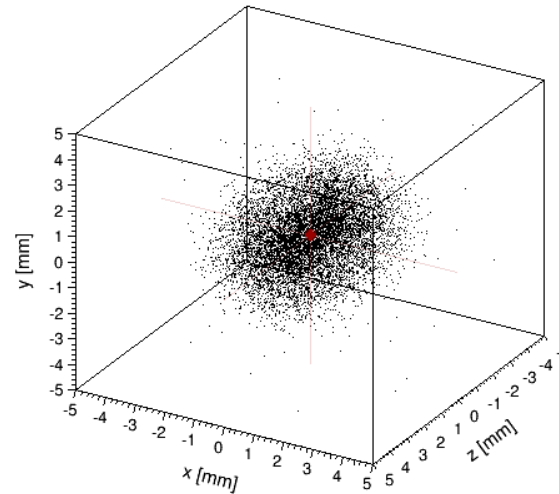
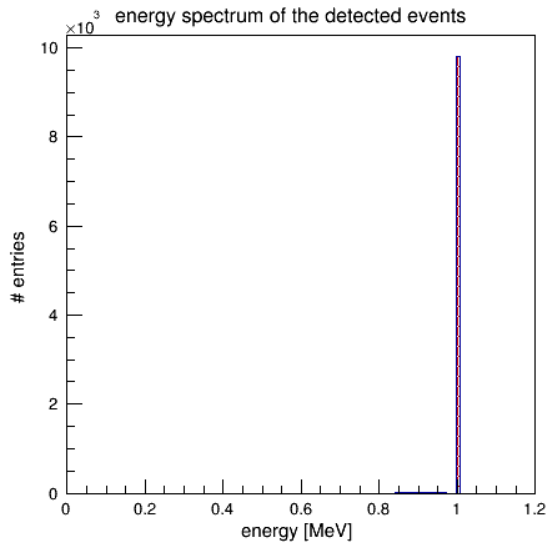
projection onto xz plane



projection onto zy plane

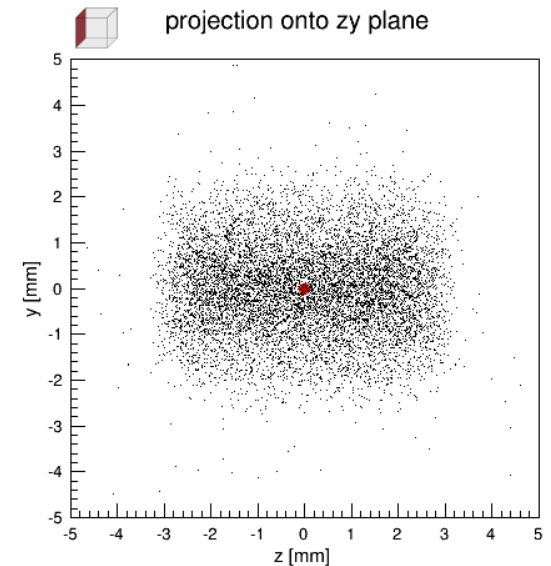
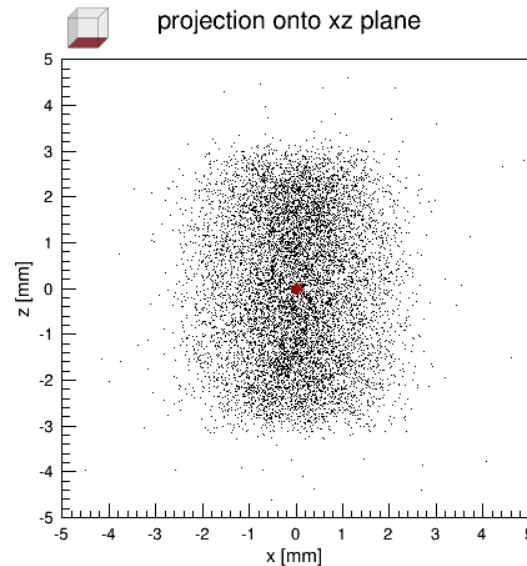
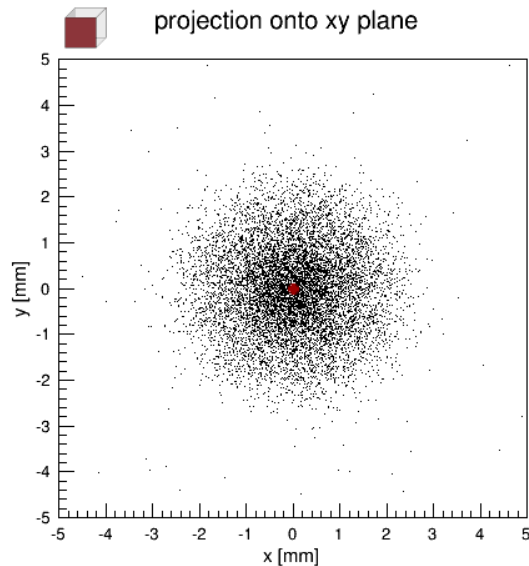


magnetic field in z direction

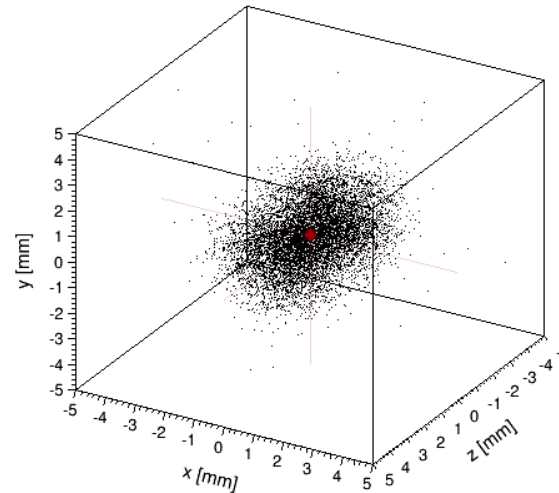
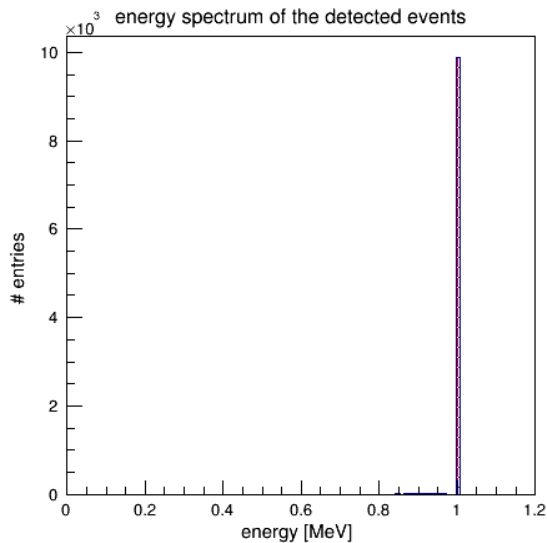


- particle: e^+
- camera type: cube
- medium: Water
- source energy: 1000 keV
- source activity: 100 Bq
- source type: isotropic
- $B_{0,x}$: 0.0 T
- $B_{0,y}$: 0.0 T
- $B_{0,z}$: 7.0 T
- positron annihilation: disabled

● source position



magnetic field in z direction

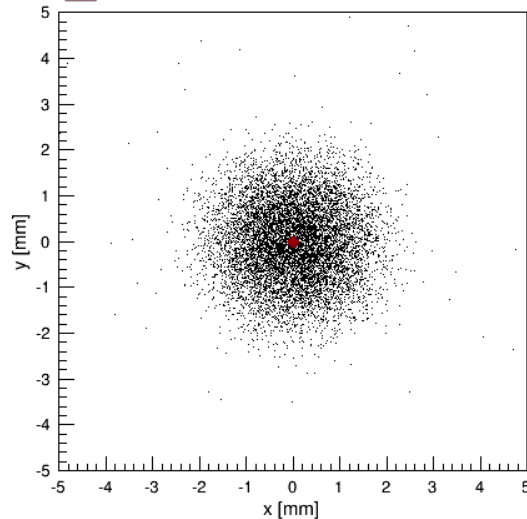


- particle: e^+
- camera type: cube
- medium: Water
- source energy: 1000 keV
- source activity: 100 Bq
- source type: isotropic
- $B_{0,x}$: 0.0 T
- $B_{0,y}$: 0.0 T
- $B_{0,z}$: 9.4 T
- positron annihilation: disabled

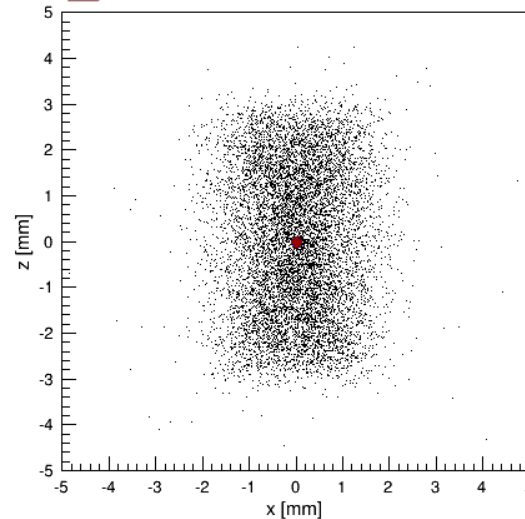
● source position



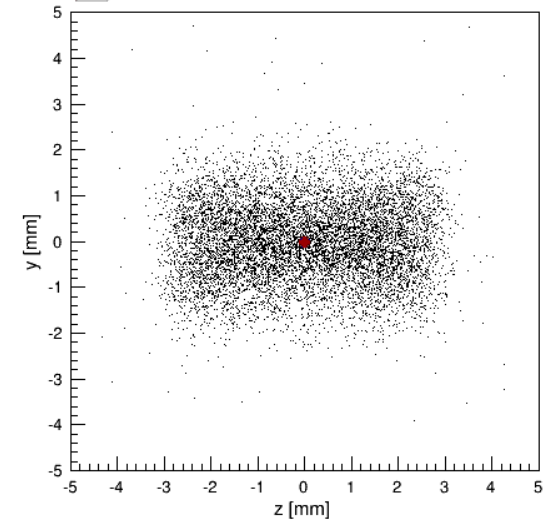
projection onto xy plane



projection onto xz plane



projection onto zy plane

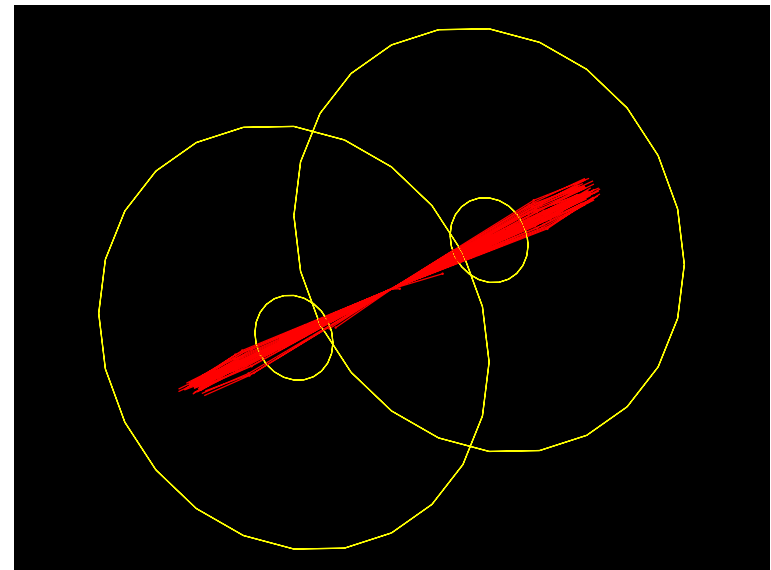
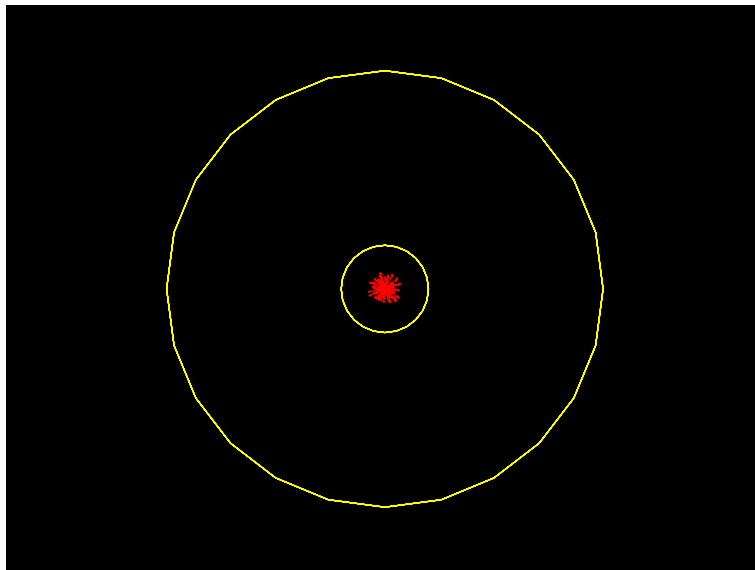


troubleshooting

```
Error: illegal pointer to class object hi_energy 0x0
157 MR_PET.C:172
```

The leaves of the branch you are investigating seem to have no content.

Check your simulation settings: can particles be stopped within the medium or can they leave the medium without being detected?



Example: electron source (100 keV) within a cylindrical medium (Air), magnetic field in z direction (0.3 T). The electrons can't even enter the medium due to deviation caused by presence of magnetic field.