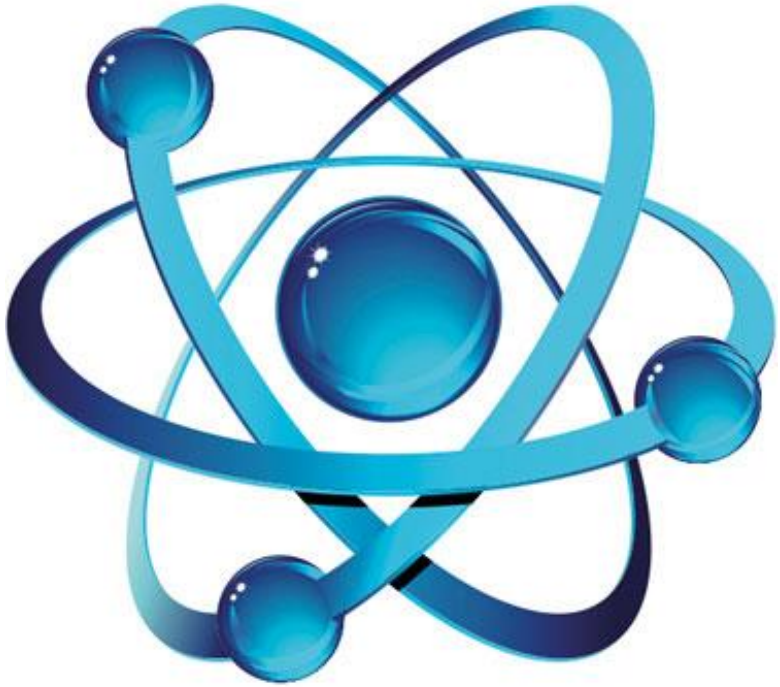
Geant4 for Nuclear Medicine



Mariam Abuladze
(Free University,
Tbilisi State University)

Supervisor:
Prof. Revaz Shanidze
(Tbilisi State University)

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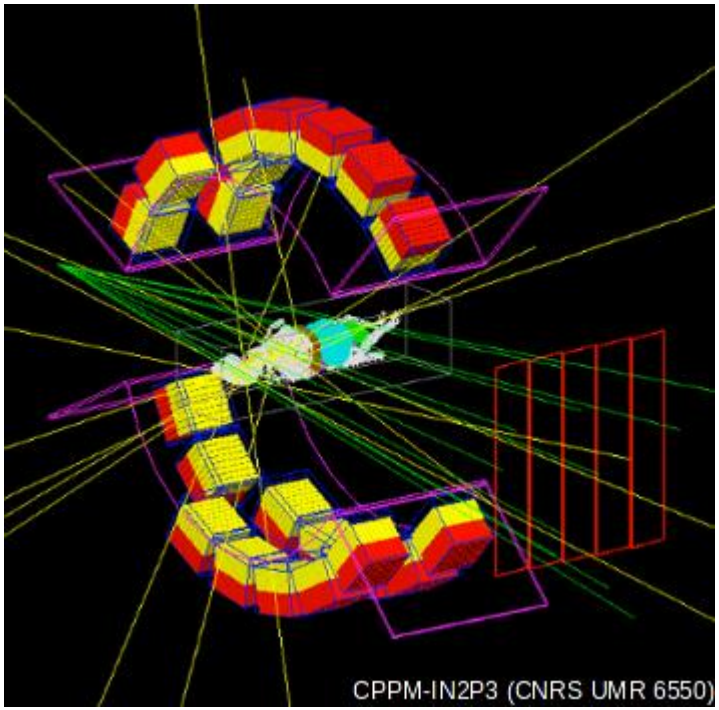
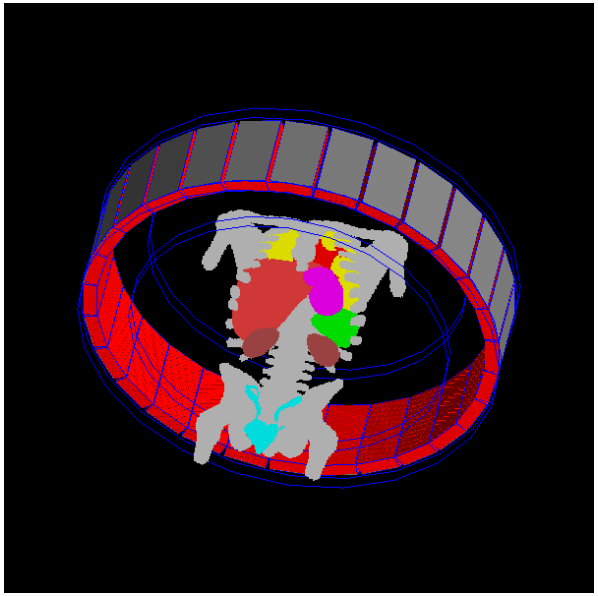
- ✓ Geant4 (Brief introduction)
- ✓ Positron Emission Tomography
- ✓ G4 basic examples B3:
  structure and illustrations.
- ✓ Summary

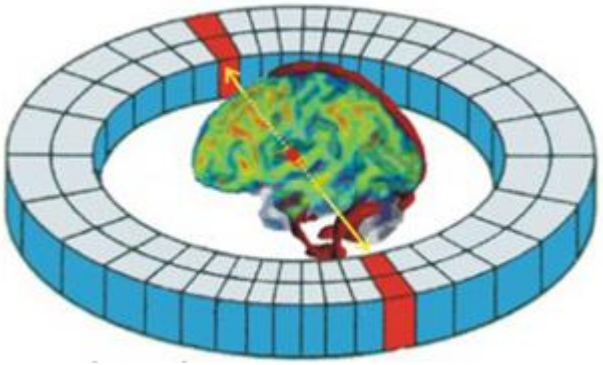
What is Geant4?
Medical application

- ✓ Particle Tracking
- ✓ Geometry
- ✓ Physics models
- ✓ Hits



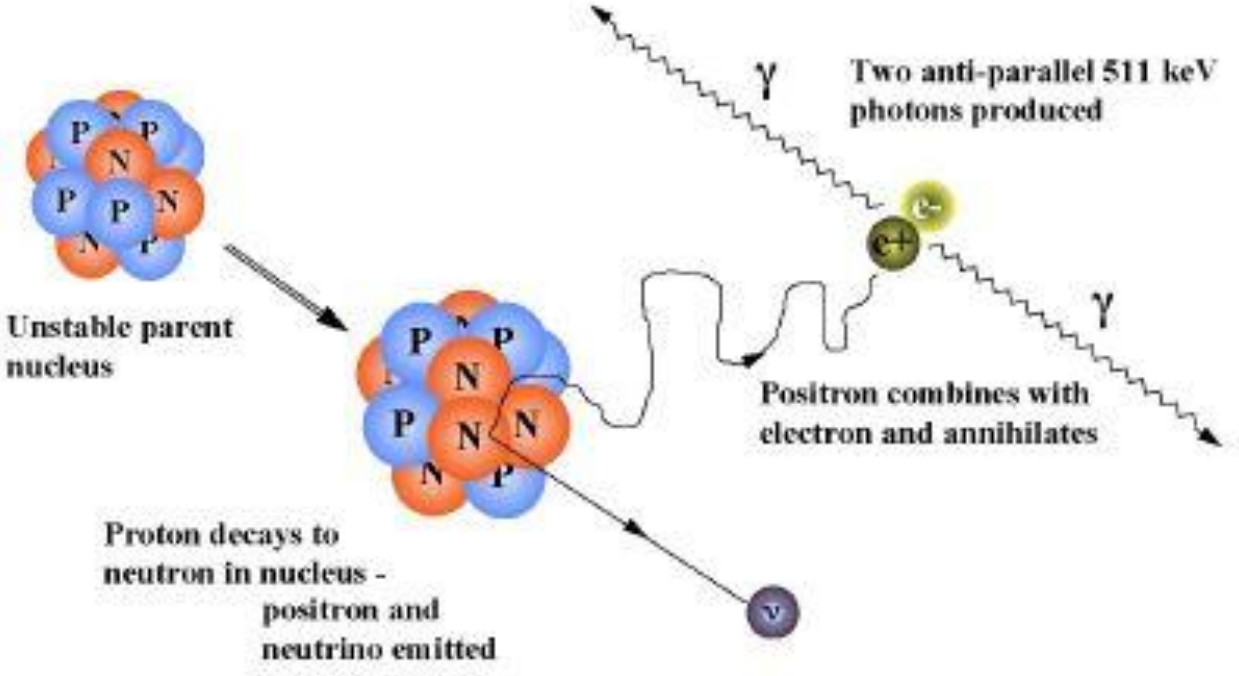


Position Emission Tomography

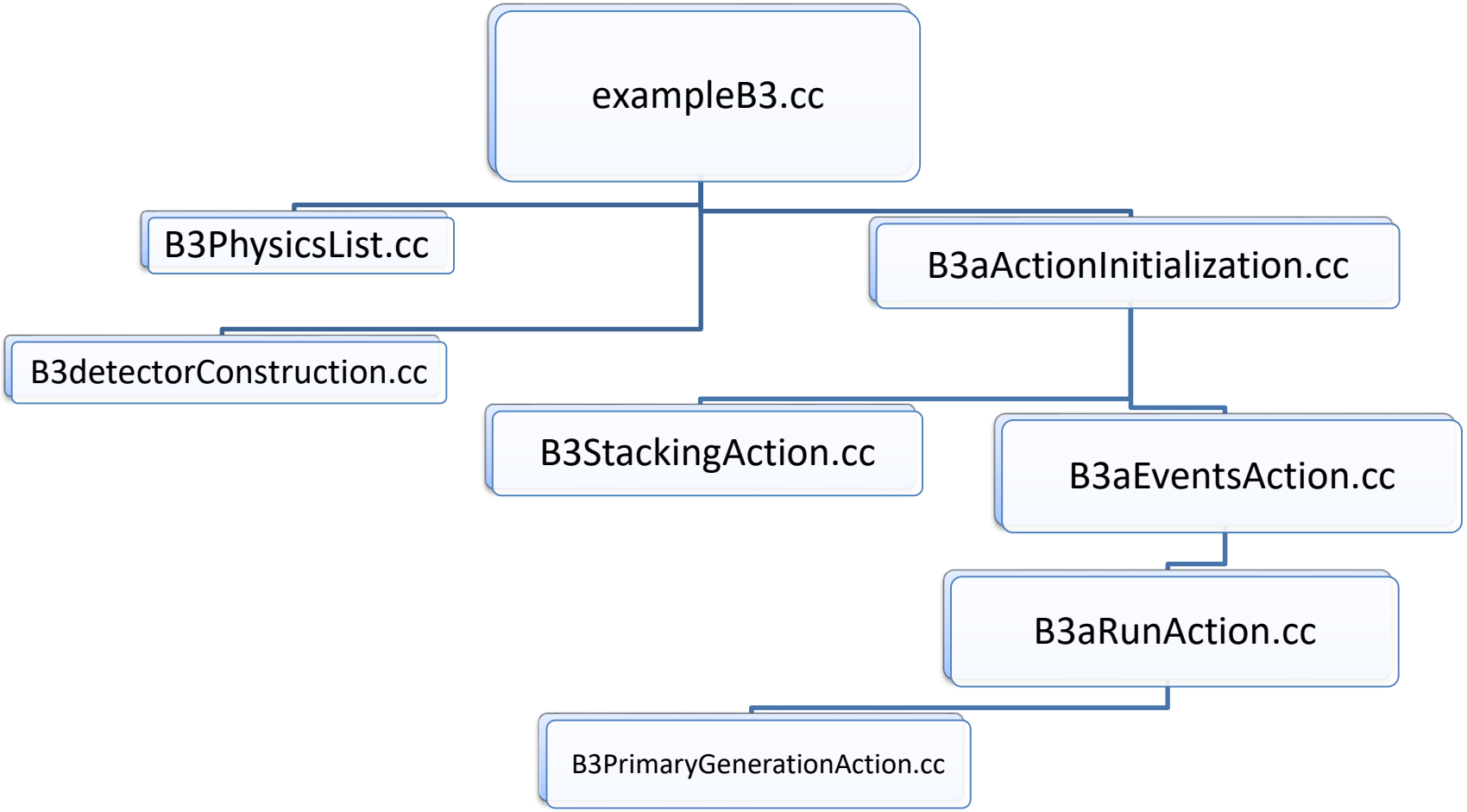


$$^{18}\mathrm{F} \rightarrow {}^{18}\mathrm{O} + \nu_e + e^+$$

- Positron production and annihilation

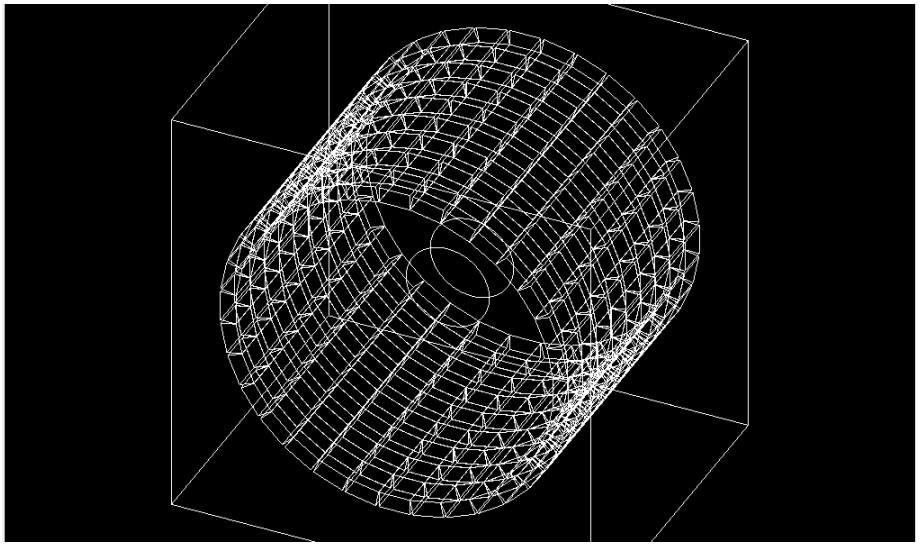


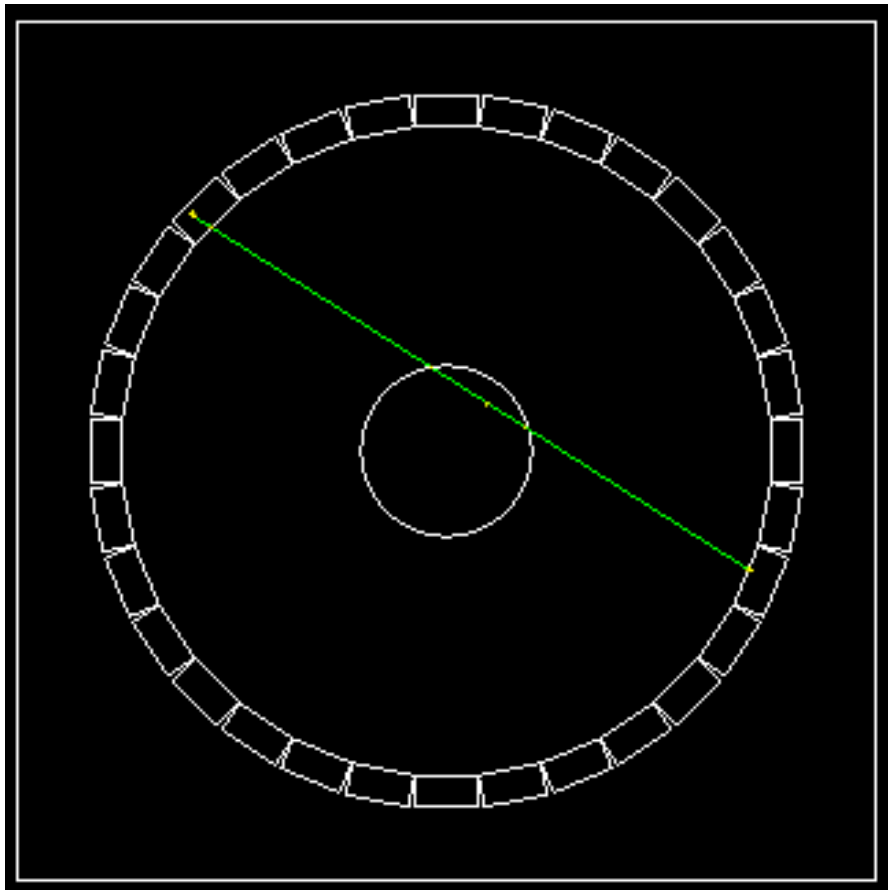
Structure for exampleB3



Geant4 example B3: Geometry

B3DetectorConstruction.cc





"$Patient$" (Phantom) : $Radius = 8\ cm,$
$length = 10cm$

$PET\ detector : 32\ \frac{Cristal}{Ring}, 9\ Ring$

$Cristal\ box:\ 6 * 6 * 3cm^3$

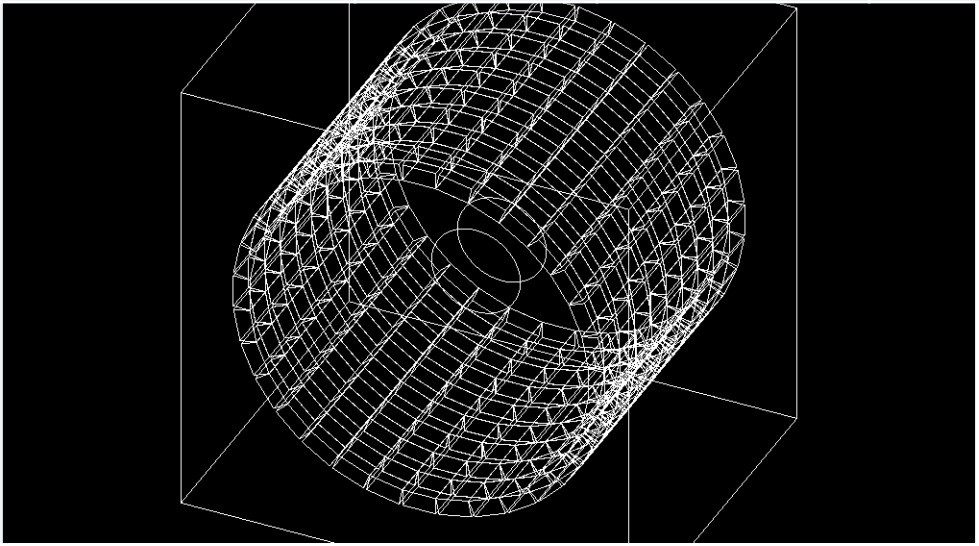
$World : length = 18\ cm, radius = 30cm$

$Volume = 5 * 10^4 cm^3$

Geant4 example B3

B3DetectorConstruction.hh

Substance	Density ($^{g}/_{cm^3}$)	Radiation Length(cm)	Nucl.Int.L (cm)	I.Mean (eV)	Temperature (K)	Preasure (atm)
Lu_2SiO_5	7.4	1.143	20.920	418.807		
G4-Air	$1.205\ 10^{-3}$	$3.0392\ 10^{5}$	$7.101\ 10^{5}$	85.700	293.15	1.0
G4_BRAIN_ICRP	1.04	35.403	72.156	73.300		



G4_air:
C(0.02) N(78.44) O(21.07) Ar(0.47)

G4_Brain_ICRP:
H(64.44) C(7.33) N(0.95)
O(27.01) Na(0.05) P(0.08)
S(0.04) Cl(0.05) K(0.05)

^{18}F Decays in Geant4

Initialization

β^+ $^{18}F \rightarrow {}^{18}O + \nu_e + e^+$ (0.97)

$1 \rightarrow 2 + 3 + 4$

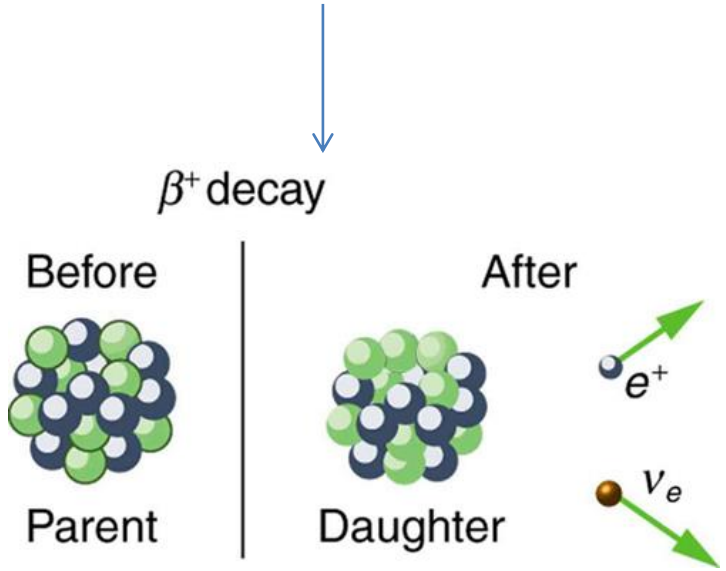
EC $^{18}F + e^- \rightarrow {}^{18}O + \nu_e$ (0.03)

$1 \rightarrow 2 + 3$

B3PrimaryGenerationAction.hh

B3ActionInitialization.hh

- B3aEventAction.hh
  - B3aRunAction.hh
    - B3PrimaryGeneratorAction.hh
- B3StackingAction.hh



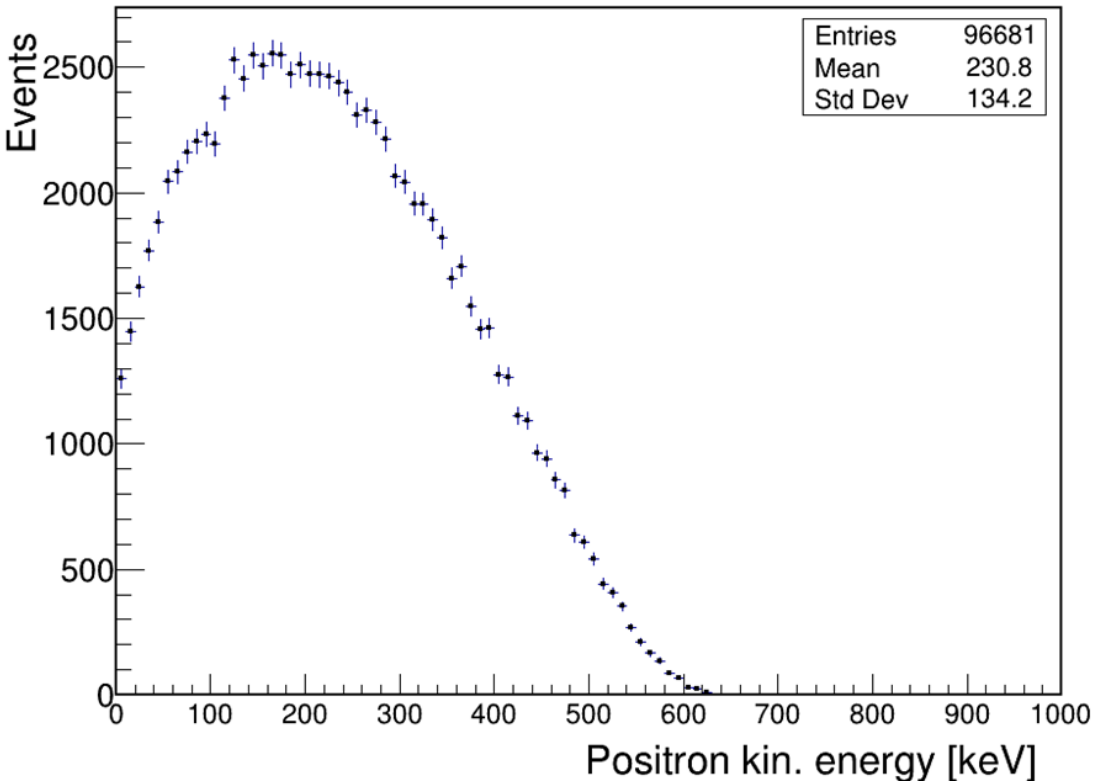
Spectrum of e^+

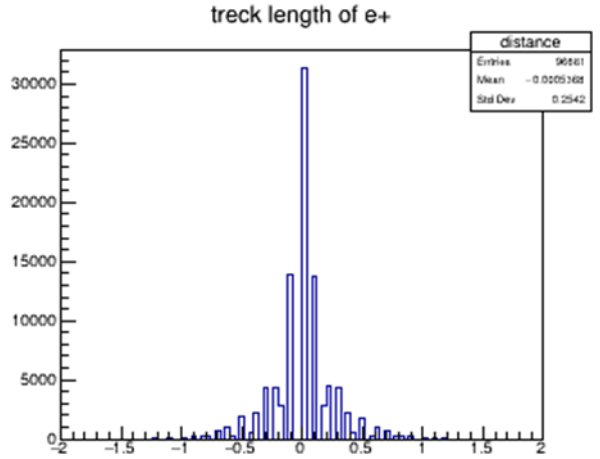
β^+ $^{18}F \rightarrow {}^{18}O + \nu_e + e^+$ (0.97)

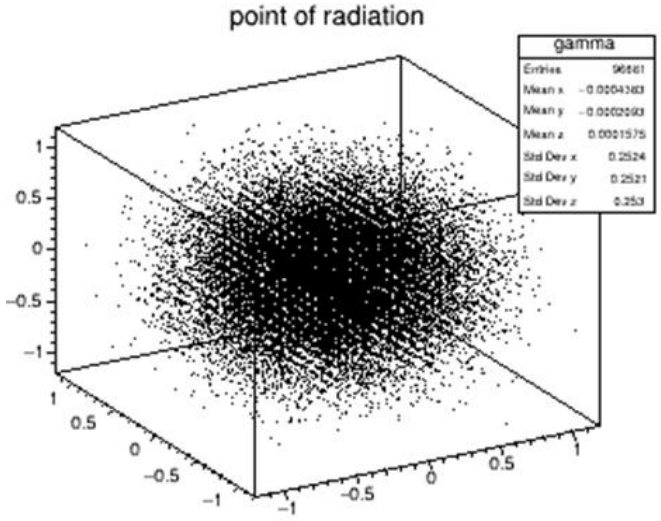
$1 \rightarrow 2 + 3 + 4$

EC $^{18}F + e^- \rightarrow {}^{18}O + \nu_e$ (0.03)

$1 \rightarrow 2 + 3$







E_{max}=640KeV

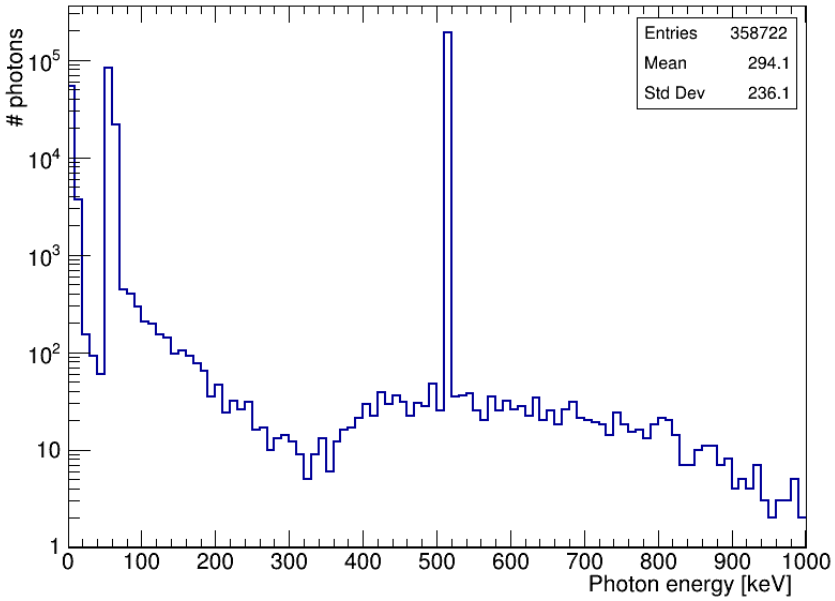
$\nabla\bar{R} = 0.04cm$

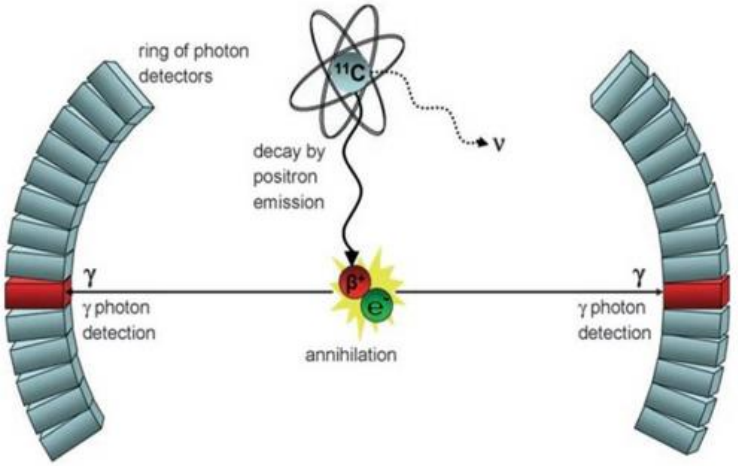
Photon Energy

B3ActionInitialization.hh

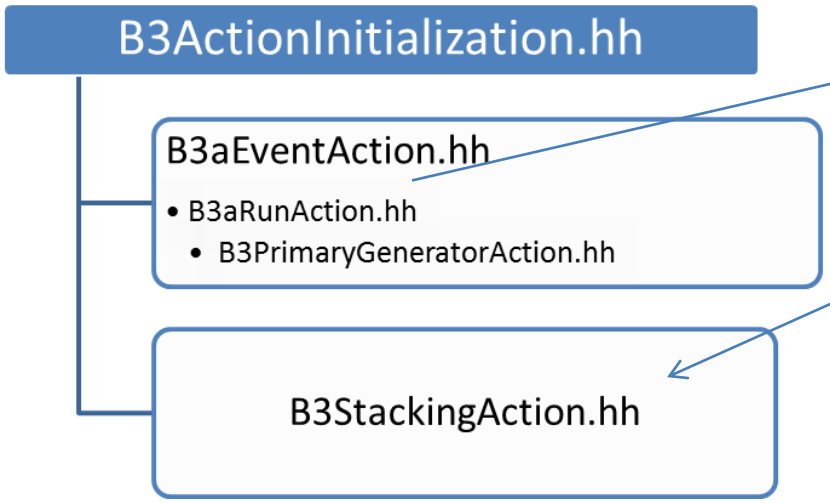
- B3aEventAction.hh
  - B3aRunAction.hh
    - B3PrimaryGeneratorAction.hh
- B3StackingAction.hh

B3aEventAction.hh



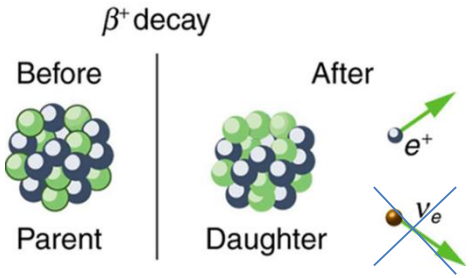


Efficiency of PET method



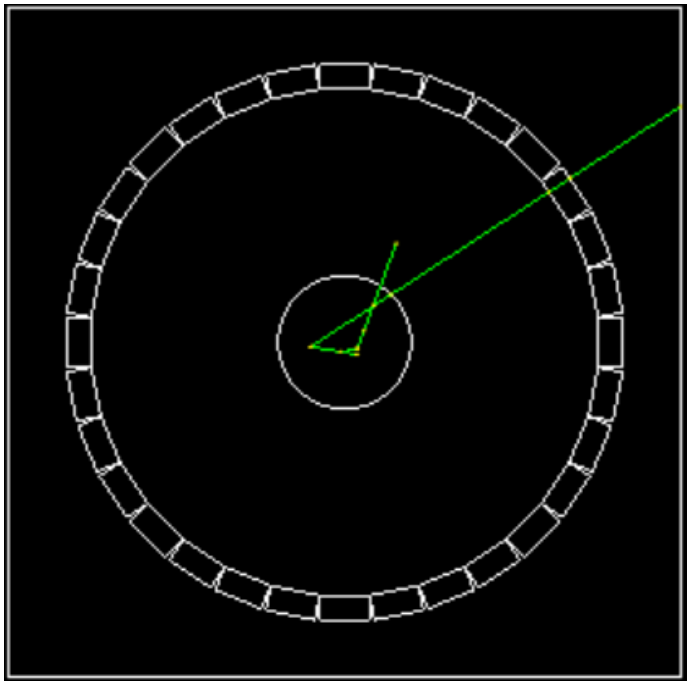
B3aRunAction.hh

Avoids tracking of neutrino



Conditions for successful run

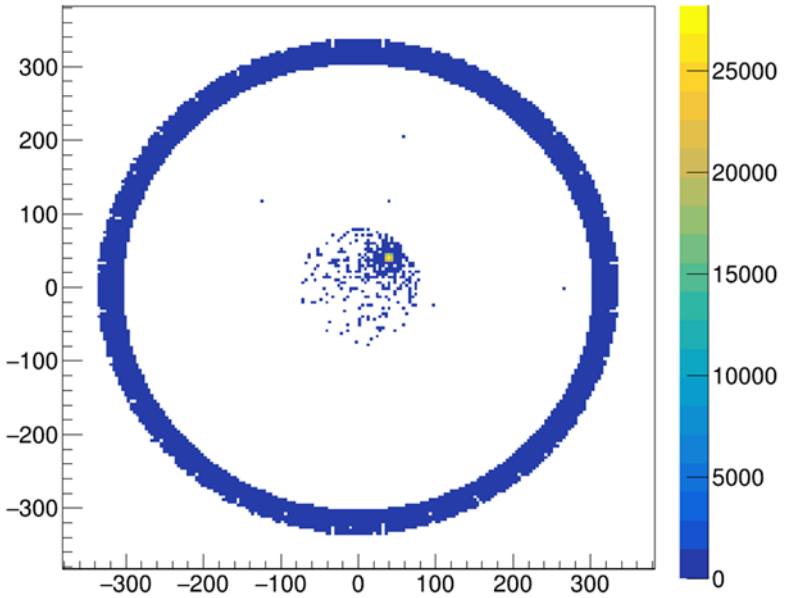
- ✓ $E_p(energy\ of\ detected\ photon) \geq 511\ keV$
- ✓ A couple of photons are detected by the detected by two separated detectors
- ✓ Detected couple of photons should have equal energies

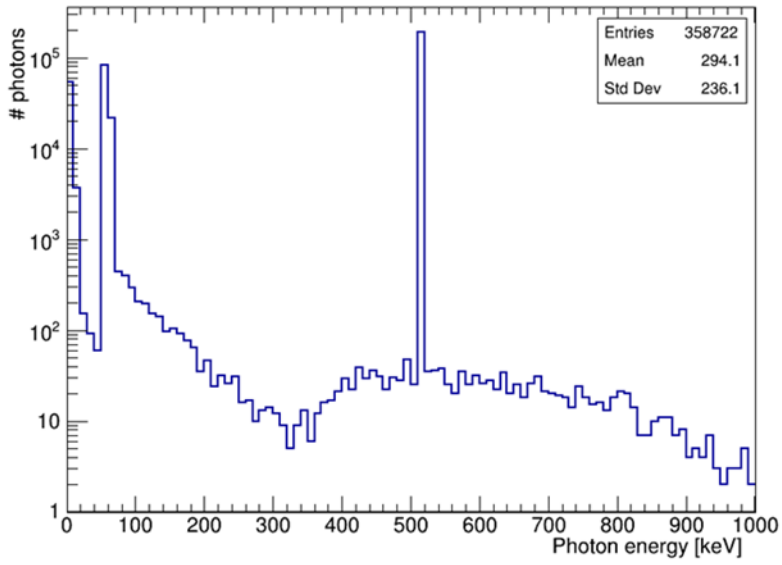


Photons

Data_2.txt: 100 000 events (100 000 ^{18}F decays)

(358 722 photons/100 000 events)





Efficiency of PET method

$$\beta^+ \quad {}^{18}F \rightarrow {}^{18}O + \nu_e + e^+ \quad (0.97)$$
$$1 \rightarrow 2 + 3 + 4$$

$$EC \quad {}^{18}F + e^- \rightarrow {}^{18}O + \nu_e \quad (0.03)$$
$$1 \rightarrow 2 + 3$$

$$\frac{Photons\ detected}{Photons\ emmited} = \varepsilon_{PET}$$

Nuclide	ε_{PET}	PROP. For dose (nGy)	Dose in patient (nGy)	Max. Energy of positron
RB82	13.08%	12x	12.02	3.15
O15	12.94%	6x	6.7	1.7
F18	12%	3x	2.9	0.65

summary

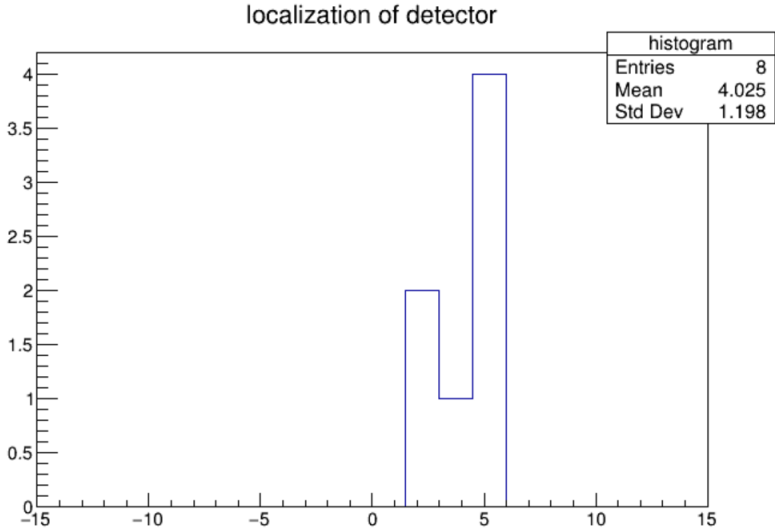
- ✓Geant4 exampleB3 is a good tool make real calculations
- ✓ ExampleB3 was considered for positron emission tomography
- ✓Small addition of software was made to calculate efficiency of PET method for some nuclides.

Thank you

- I am open to your questions ☺

Calculate the resolution PET scanner having particular parameters

- ✓ $detector\ size:\ R_i = 3\ cm$
- ✓ $positron\ range: R_p = 0.04cm$
- ✓ $non-colinearity:\ R_a = 0.066cm$
- ✓ $localization\ of\ detector =\ R_l$= 4.02 cm



$$R_t{}^2 = \sum R_i{}^2$$

$$R_t = 5.1\ cm$$

Dose Calculation

Dose = Energy / mass

M= ρV

patient density = 1.040 g/cm^3

patient volume = $\pi R^2 L$ (R=8 cm, L=10 cm, about 2 L)

patient mass = about 2 kg

$$total\ dos \approx 10 * (Dose\ of\ detector + energy\ of\ electrons\ )$$ + error

$$dose\ of\ patient\ \approx 20 * dose\ of\ detector$$