MOLLER Pion Detector Design: Progress Update

Modification of the Showermax wall thickness and the Lead donut support thickness for the new geometry with shielding in the Moller and Pion generator

The MOLLER Project
Measurement **O**f a **L**epton **L**epton **E**lectroweak **R**eaction

Elham Gorgannejad

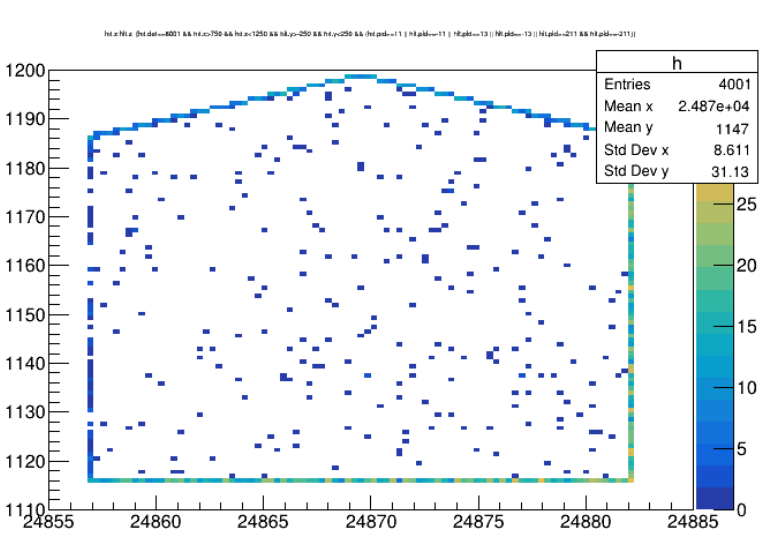
Dr. Wouter Deconinck

March 26th, 2021

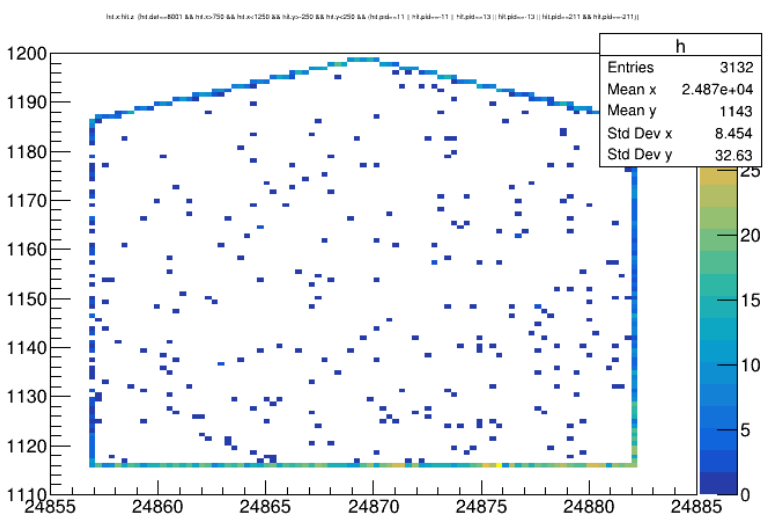
University of Manitoba

Comparison of hits at the Lucite plane for 5,000,000 events

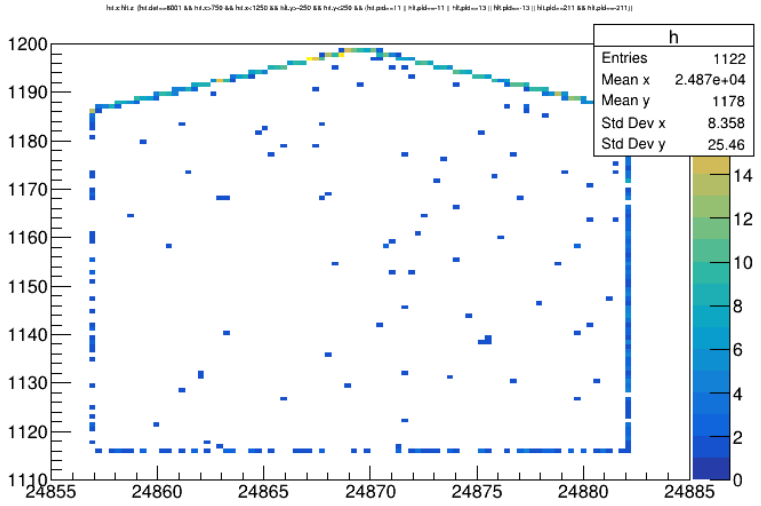
(without shielding)



(with downstream shielding)



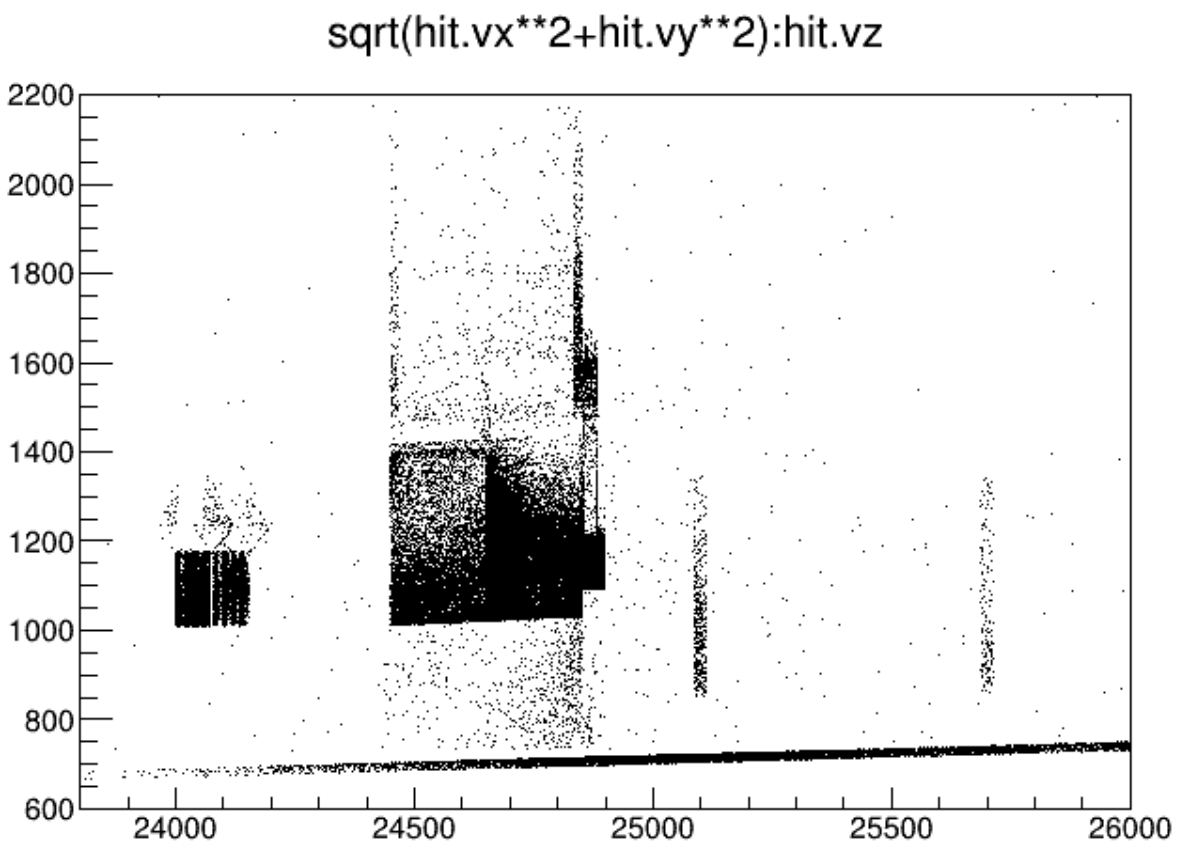
(with inner radial shielding)



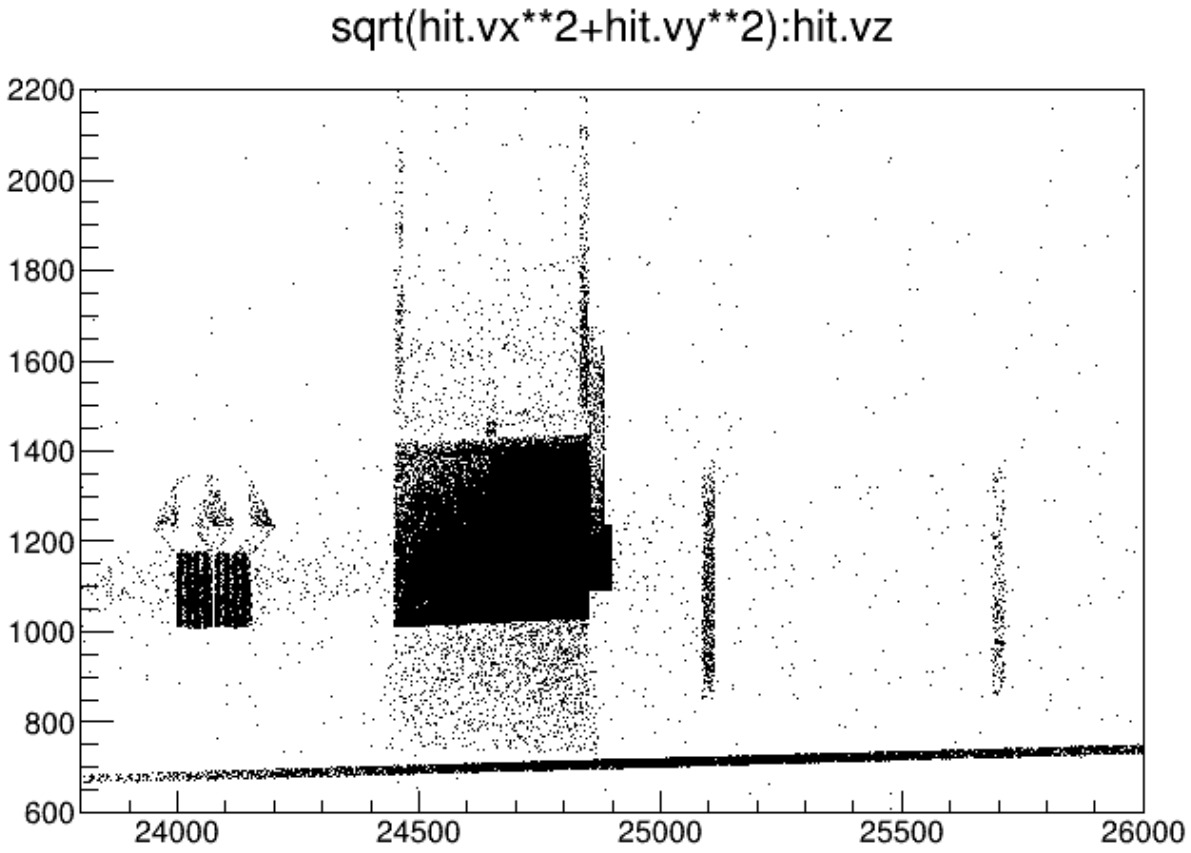
Changing the radial and longitudinal thickness of Concrete and Lead

The origin location of all the secondaries anywhere for 5,000,000 events

Moller



Pion

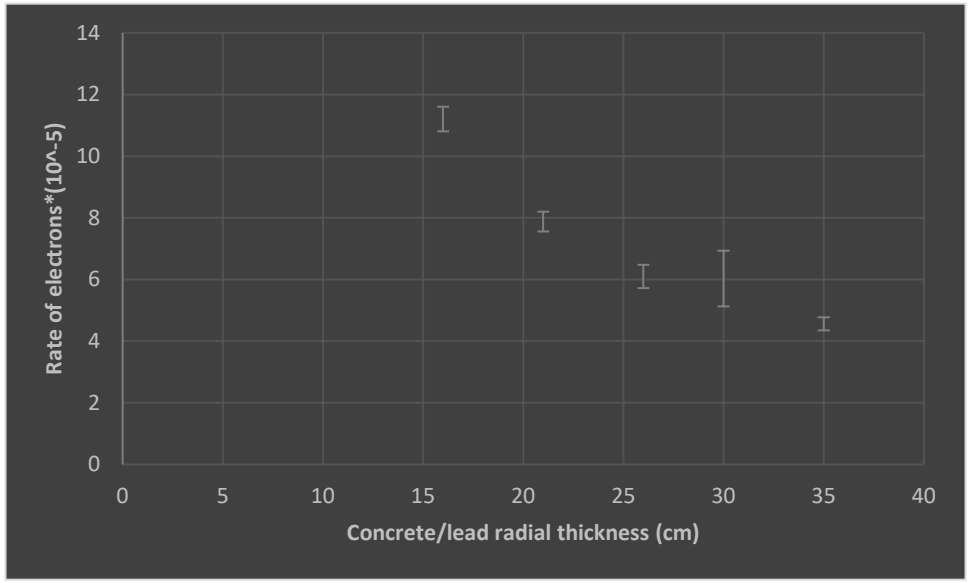


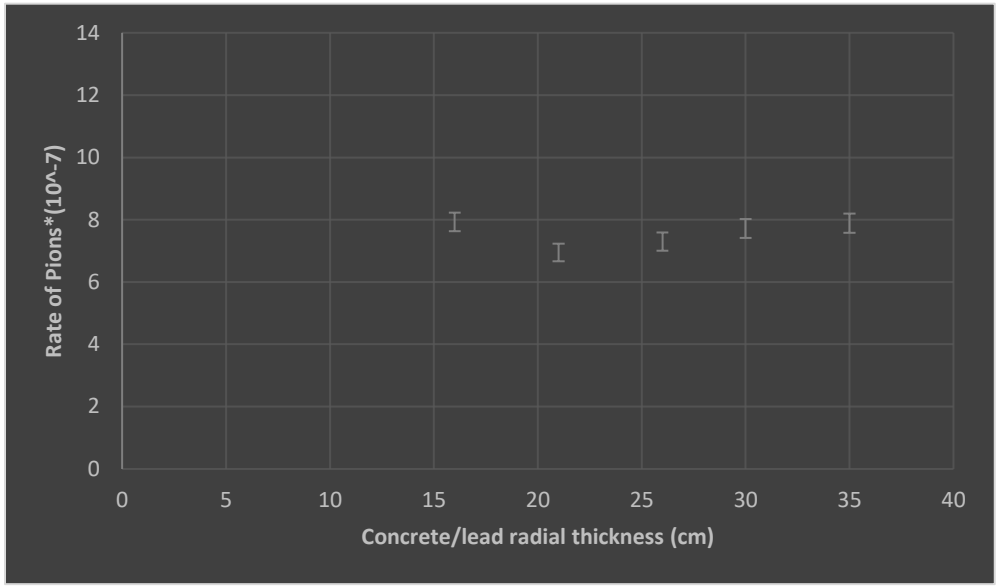
Comparison of rates at the Lucite and PMT for 5,000,000 events (Low energy particles, hit.p<2*MeV)

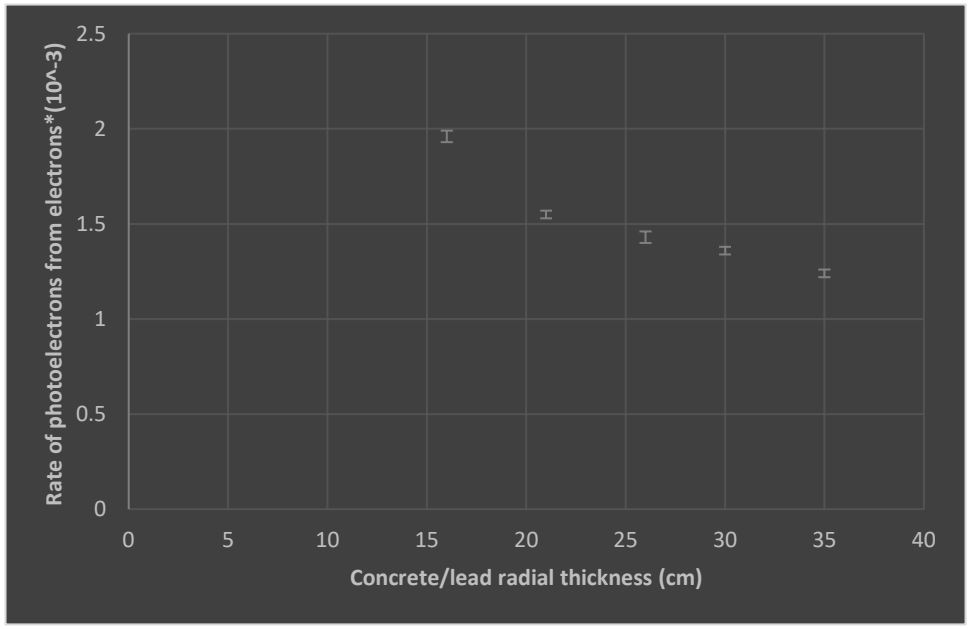
Rates $GHz/\mu A$ /Detector	Rate of electrons	Rate of pions	Pi/e	Rate of photoelectrons from electrons	Rate of photoelectrons from pions	Pi/e
Concrete and Lead at 16cm	$(1.12 \pm 0.04) \times 10^{-4}$	$(7.93 \pm 0.30) \times 10^{-7}$	0.71%	$(1.96 \pm 0.03) \times 10^{-3}$	$(7.54 \pm 0.03) \times 10^{-5}$	3.85%
Concrete and Lead at 21cm	$(7.88 \pm 0.32) \times 10^{-5}$	$(6.95 \pm 0.28) \times 10^{-7}$	0.88%	$(1.55 \pm 0.02) \times 10^{-3}$	$(7.46 \pm 0.03) \times 10^{-5}$	4.81%
Concrete and Lead at 26cm	$(6.10 \pm 0.38) \times 10^{-5}$	$(7.30 \pm 0.29) \times 10^{-7}$	1.20%	$(1.43 \pm 0.03) \times 10^{-3}$	$(7.43 \pm 0.03) \times 10^{-5}$	5.20%
Concrete and Lead at 30cm	$(6.03 \pm 0.90) \times 10^{-5}$	$(7.72 \pm 0.30) \times 10^{-7}$	1.28%	$(1.36 \pm 0.02) \times 10^{-3}$	$(7.34 \pm 0.03) \times 10^{-5}$	5.40%
Concrete and Lead at 35cm	$(4.56 \pm 0.21) \times 10^{-5}$	$(7.89 \pm 0.31) \times 10^{-7}$	1.73%	$(1.24 \pm 0.02) \times 10^{-3}$	$(7.89 \pm 0.03) \times 10^{-5}$	6.36%

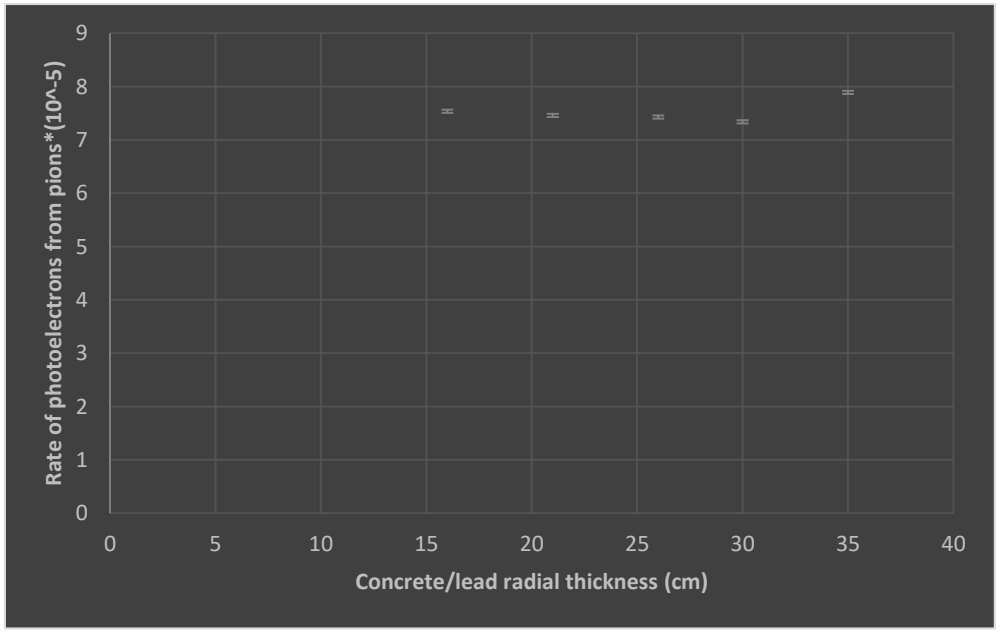
Note: Inclusion of electron, positron, pion, and (anti) Muon (hit.pid==11, -11, 211, -211, 13, -13)

Comparison of rates at the Lucite and PMT for 5,000,000 events (Low energy particles, hit.p<2*MeV)





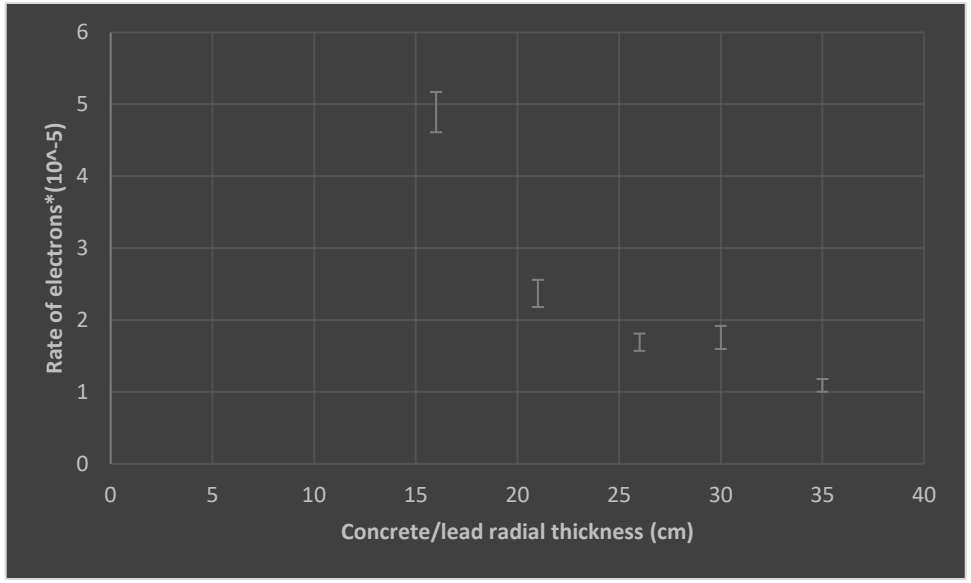


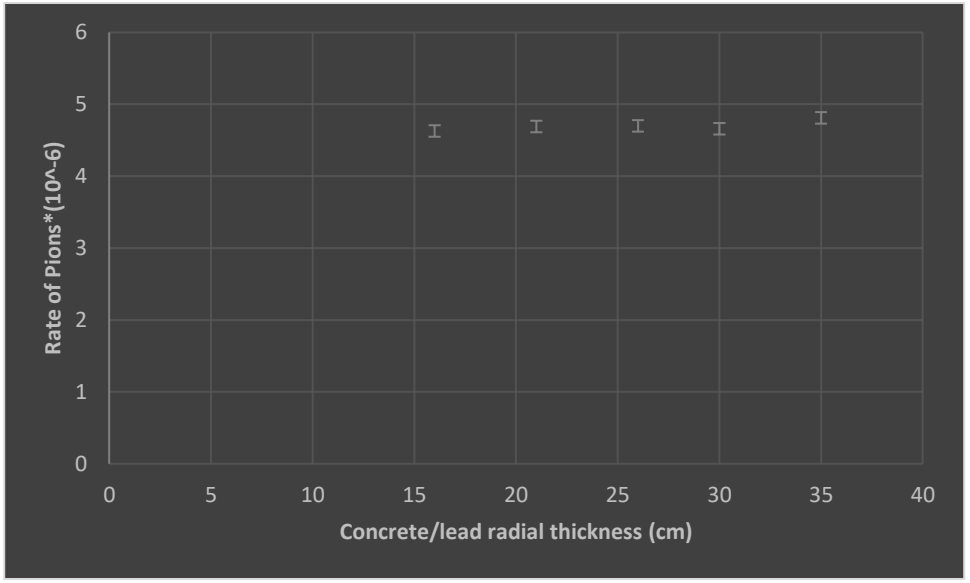


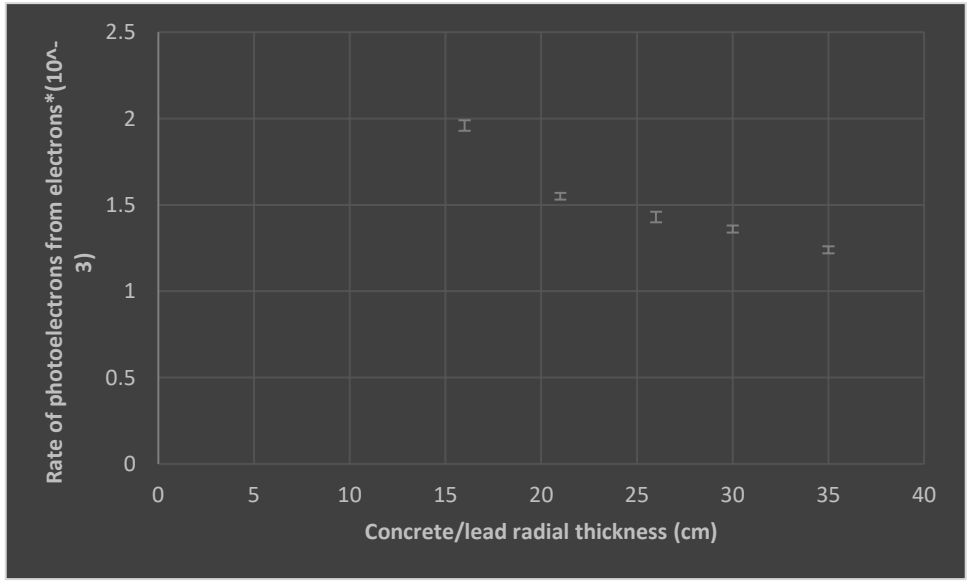
Comparison of rates at the Lucite and PMT for 5,000,000 events (High energy particles, hit.p>2*MeV)

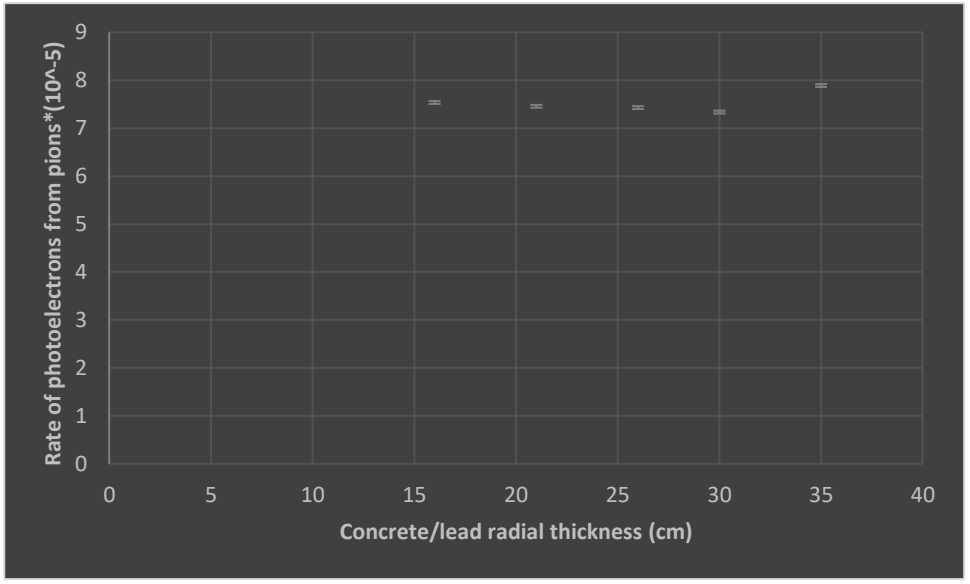
Rates $GHz/\mu A/Detector$	Rate of electrons	Rate of pions	Pi/e	Rate of photoelectrons from electrons	Rate of photoelectrons from pions	Pi/e
Concrete and Lead at 16cm	$(4.89 \pm 0.28) \times 10^{-5}$	$(4.63 \pm 0.08) \times 10^{-6}$	9.47%	$(1.96 \pm 0.03) \times 10^{-3}$	$(7.54 \pm 0.03) \times 10^{-5}$	3.85%
Concrete and Lead at 21cm	$(2.37 \pm 0.19) \times 10^{-5}$	$(4.69 \pm 0.08) \times 10^{-6}$	19.79%	$(1.55 \pm 0.02) \times 10^{-3}$	$(7.46 \pm 0.03) \times 10^{-5}$	4.81%
Concrete and Lead at 26cm	$(1.69 \pm 0.12) \times 10^{-5}$	$(4.70 \pm 0.08) \times 10^{-6}$	27.81%	$(1.43 \pm 0.03) \times 10^{-3}$	$(7.43 \pm 0.03) \times 10^{-5}$	5.20%
Concrete and Lead at 30cm	$(1.76 \pm 0.16) \times 10^{-5}$	$(4.66 \pm 0.08) \times 10^{-6}$	26.48%	$(1.36 \pm 0.02) \times 10^{-3}$	$(7.34 \pm 0.03) \times 10^{-5}$	5.40%
Concrete and Lead at 35cm	$(1.09 \pm 0.09) \times 10^{-5}$	$(4.81 \pm 0.08) \times 10^{-6}$	44.13%	$(1.24 \pm 0.02) \times 10^{-3}$	$(7.89 \pm 0.03) \times 10^{-5}$	6.36%

Comparison of rates at the Lucite and PMT for 5,000,000 events (High energy particles, hit.p>2*MeV)

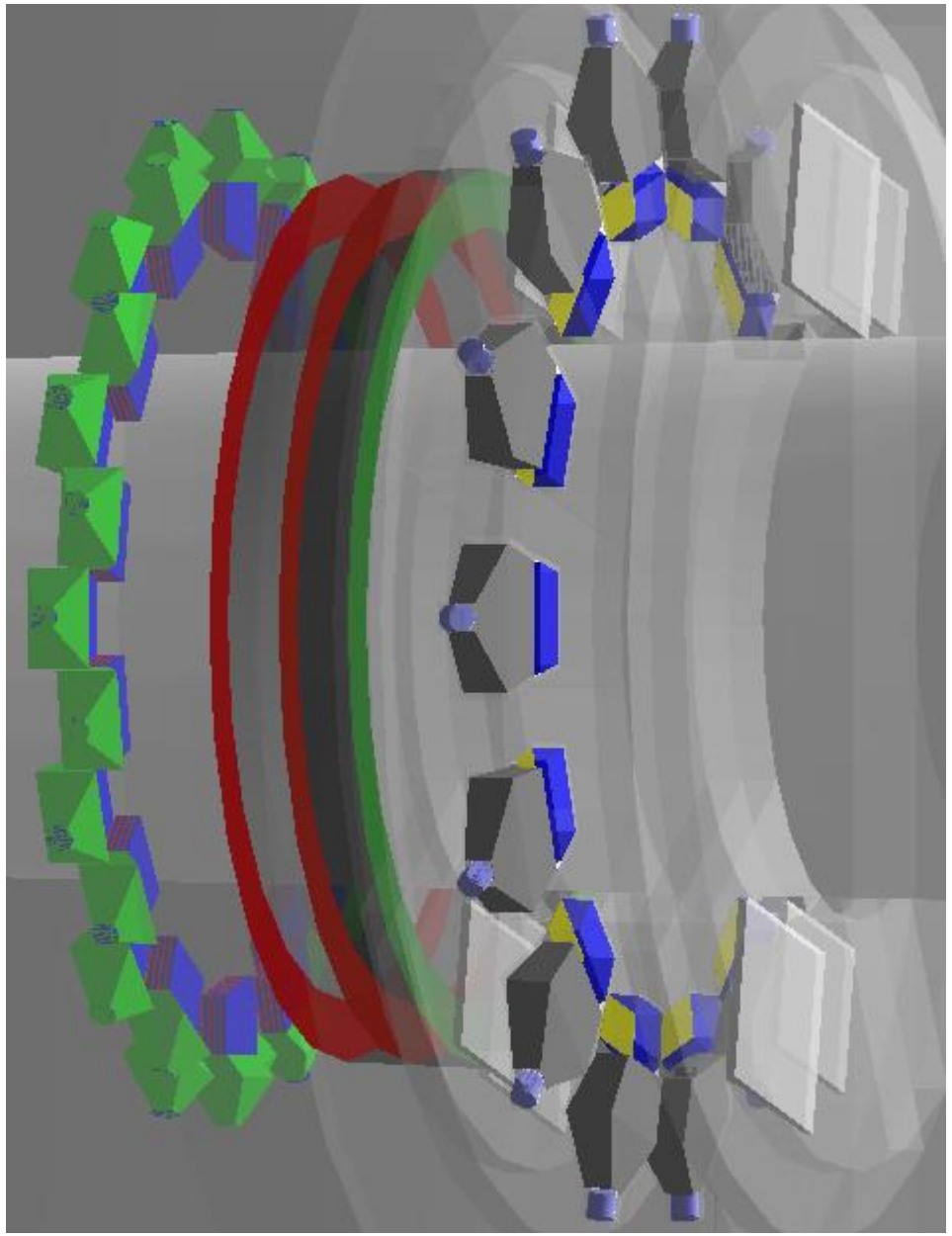


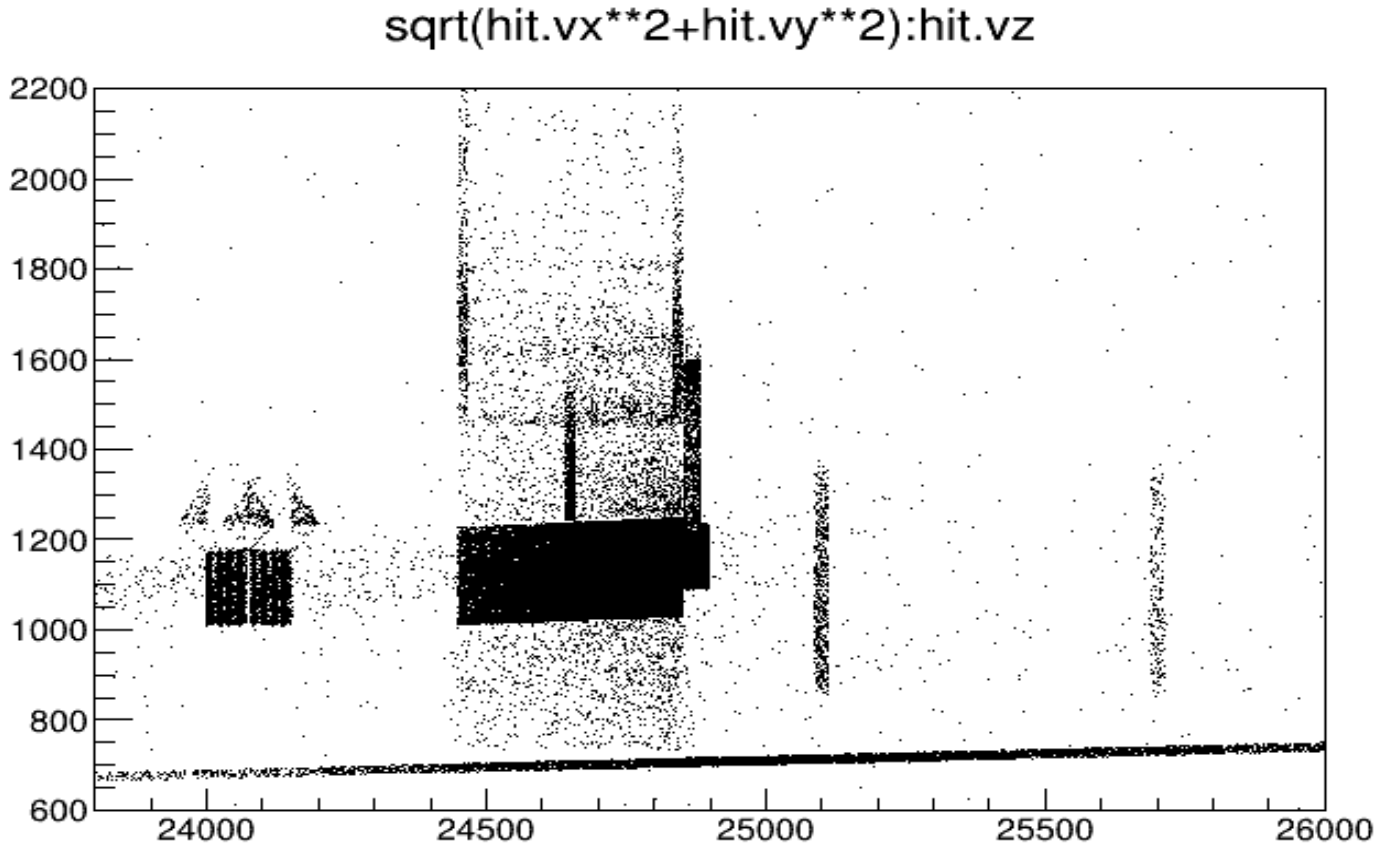






Changing the radial and longitudinal thickness of Concrete and Lead and shifting Lucite inward





- ✓ Concrete/lead radius extend 16, 21, 26, 30, 35 cm
- ✓ Shift Lucite inward and make it shorter (7, 6 and 5 cm)
- ✓ Keep lead at 16 cm, extend concrete only to 26 cm
- ✓ Fix downstream face of donut, then reduce lead thickness

Comparison of rates at the Lucite and PMT for 5,000,000 events (Low energy particles, hit.p<2*MeV)

Rates $GHz/\mu A/Detector$	Rate of electrons	Rate of pions	Pi/e	Rate of photoelectrons from electrons	Rate of photoelectrons from pions	Pi/e
Radial thickness of Concrete and Lead at 16cm -7cm Lucite	$(1.12 \pm 0.04) \times 10^{-4}$	$(7.93 \pm 0.30) \times 10^{-7}$	0.71%	$(1.96 \pm 0.03) \times 10^{-3}$	$(7.54 \pm 0.03) \times 10^{-5}$	3.85%
Radial thickness of Concrete and Lead at 16cm – Shifted 6cm Lucite	$(1.04 \pm 0.04) \times 10^{-4}$	$(6.88 \pm 0.29) \times 10^{-7}$	0.66%	$(1.88 \pm 0.03) \times 10^{-3}$	$(7.63 \pm 0.03) \times 10^{-5}$	4.06%
Radial thickness of Concrete and Lead at 16cm – Shifted 5cm Lucite	$(1.36 \pm 0.20) \times 10^{-4}$	$(6.45 \pm 0.28) \times 10^{-7}$	0.47%	$(1.65 \pm 0.04) \times 10^{-3}$	$(6.75 \pm 0.03) \times 10^{-5}$	4.09%

Comparison of rates at the Lucite and PMT for 5,000,000 events (High energy particles, hit.p>2*MeV)

Rates $GHz/\mu A/Detector$	Rate of electrons	Rate of pions	Pi/e	Rate of photoelectrons from electrons	Rate of photoelectrons from pions	Pi/e
Radial thickness of Concrete and Lead at 16cm -7cm Lucite	$(4.89 \pm 0.28) \times 10^{-5}$	$(4.63 \pm 0.08) \times 10^{-6}$	9.47%	$(1.96 \pm 0.03) \times 10^{-3}$	$(7.54 \pm 0.03) \times 10^{-5}$	3.85%
Radial thickness of Concrete and Lead at 16cm –Shifted 6cm Lucite	$(3.79 \pm 0.20) \times 10^{-5}$	$(4.20 \pm 0.08) \times 10^{-6}$	11.08%	$(1.88 \pm 0.03) \times 10^{-3}$	$(7.63 \pm 0.03) \times 10^{-5}$	4.06%
Radial thickness of Concrete and Lead at 16cm –Shifted 5cm Lucite	$(3.60 \pm 0.63) \times 10^{-5}$	$(3.56 \pm 0.07) \times 10^{-6}$	9.89%	$(1.65 \pm 0.04) \times 10^{-3}$	$(6.75 \pm 0.03) \times 10^{-5}$	4.09%

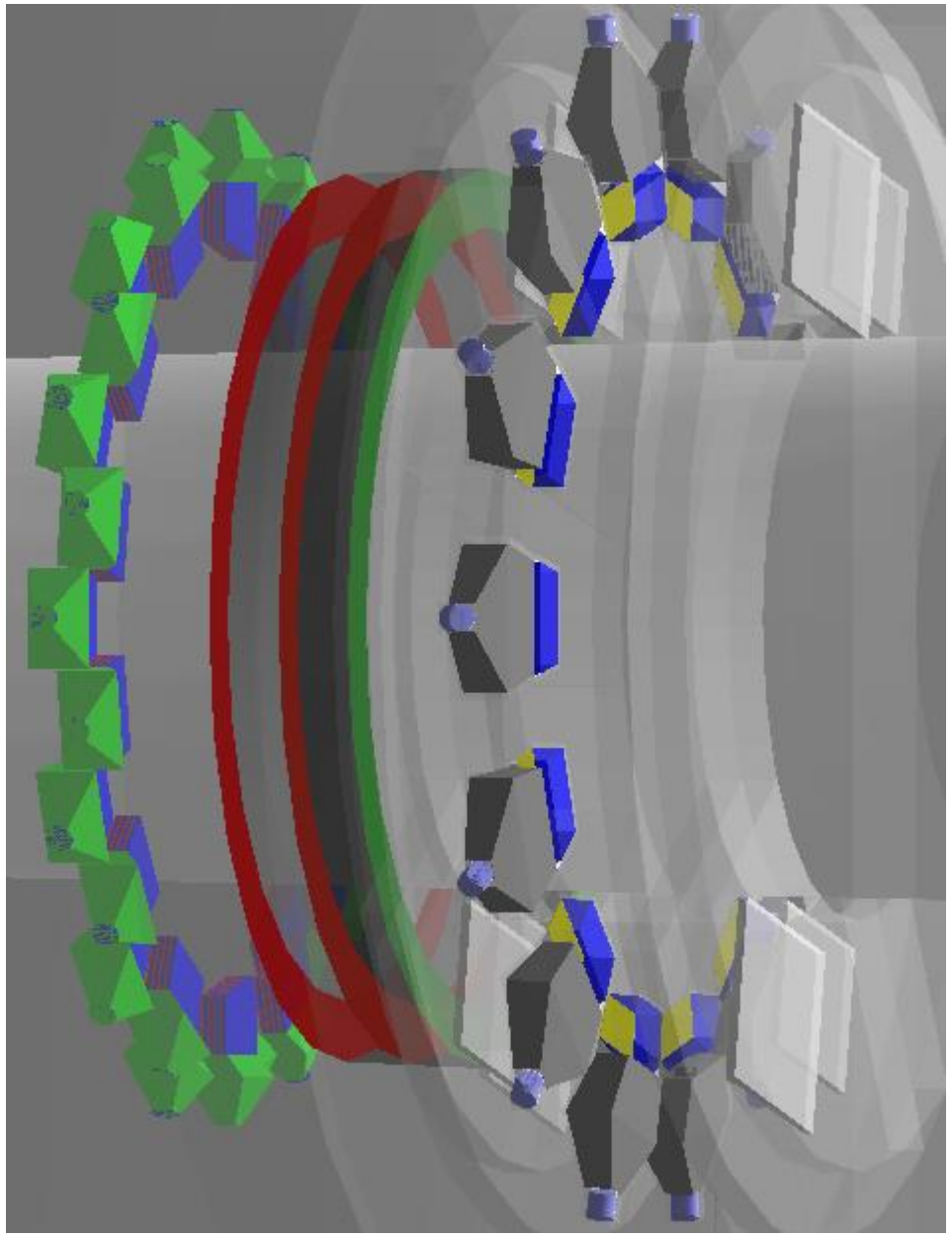
Comparison of rates at the Lucite and PMT for 5,000,000 events (Low energy particles, hit.p<2*MeV)

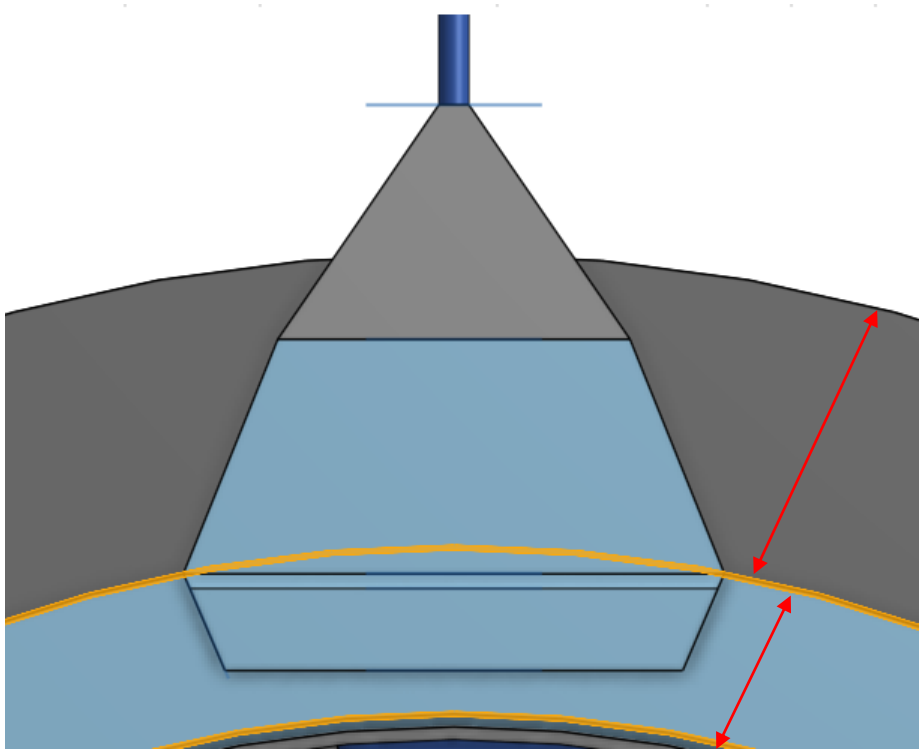
Rates $GHz/\mu A/Detector$	Rate of electrons	Rate of pions	Pi/e	Rate of photoelectrons from electrons	Rate of photoelectrons from pions	Pi/e
Radial thickness of Concrete and Lead at 16cm -7cm Lucite	$(1.12 \pm 0.04) \times 10^{-4}$	$(7.93 \pm 0.30) \times 10^{-7}$	0.71%	$(1.96 \pm 0.03) \times 10^{-3}$	$(7.54 \pm 0.03) \times 10^{-5}$	3.85%
Radial thickness of Concrete and Lead at 16cm – Shifted 6cm Lucite	$(1.04 \pm 0.04) \times 10^{-4}$	$(6.88 \pm 0.29) \times 10^{-7}$	0.66%	$(1.88 \pm 0.03) \times 10^{-3}$	$(7.63 \pm 0.03) \times 10^{-5}$	4.06%
Radial thickness of Concrete and Lead at 26cm – 7cm Lucite	$(6.10 \pm 0.38) \times 10^{-5}$	$(7.30 \pm 0.29) \times 10^{-7}$	1.20%	$(1.43 \pm 0.03) \times 10^{-3}$	$(7.43 \pm 0.03) \times 10^{-5}$	5.20%
Radial thickness of Concrete and Lead at 26cm – Shifted 6cm Lucite	$(6.02 \pm 0.35) \times 10^{-5}$	$(7.09 \pm 0.29) \times 10^{-7}$	1.18%	$(1.31 \pm 0.02) \times 10^{-3}$	$(7.72 \pm 0.03) \times 10^{-5}$	5.89%

Comparison of rates at the Lucite and PMT for 5,000,000 events (High energy particles, hit.p>2*MeV)

Rates $GHz/\mu A/Detector$	Rate of electrons	Rate of pions	Pi/e	Rate of photoelectrons from electrons	Rate of photoelectrons from pions	Pi/e
Radial thickness of Concrete and Lead at 16cm -7cm Lucite	$(4.89 \pm 0.28) \times 10^{-5}$	$(4.63 \pm 0.08) \times 10^{-6}$	9.47%	$(1.96 \pm 0.03) \times 10^{-3}$	$(7.54 \pm 0.03) \times 10^{-5}$	3.85%
Radial thickness of Concrete and Lead at 16cm –Shifted 6cm Lucite	$(3.79 \pm 0.20) \times 10^{-5}$	$(4.20 \pm 0.08) \times 10^{-6}$	11.08%	$(1.88 \pm 0.03) \times 10^{-3}$	$(7.63 \pm 0.03) \times 10^{-5}$	4.06%
Radial thickness of Concrete and Lead at 26cm –7cm Lucite	$(1.69 \pm 0.12) \times 10^{-5}$	$(4.70 \pm 0.08) \times 10^{-6}$	27.81%	$(1.43 \pm 0.03) \times 10^{-3}$	$(7.43 \pm 0.03) \times 10^{-5}$	5.20%
Radial thickness of Concrete and Lead at 26cm –Shifted 6cm Lucite	$(1.58 \pm 0.11) \times 10^{-5}$	$(4.28 \pm 0.08) \times 10^{-6}$	27.08%	$(1.31 \pm 0.02) \times 10^{-3}$	$(7.72 \pm 0.03) \times 10^{-5}$	5.89%

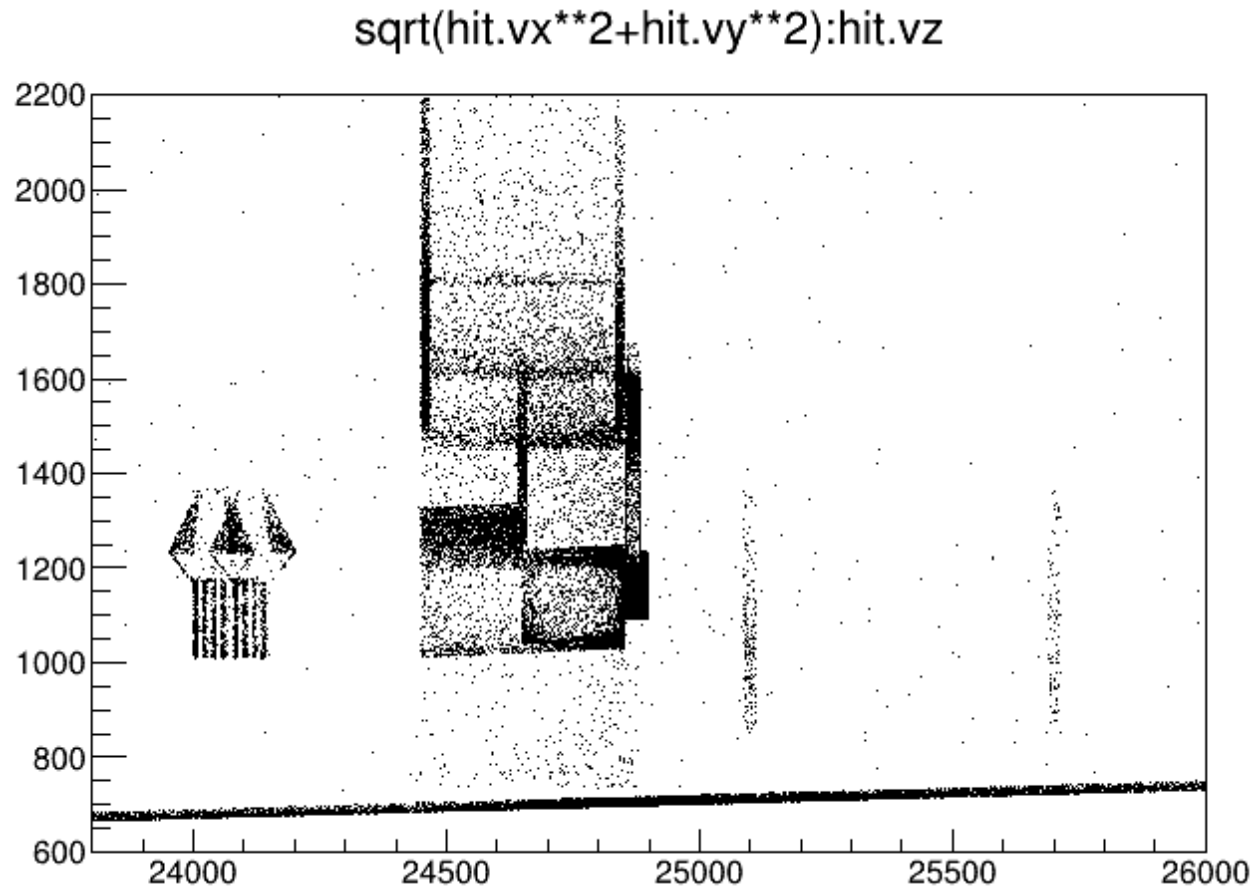
Changing the radial and longitudinal thickness of Concrete and Lead and shifting Lucite inward



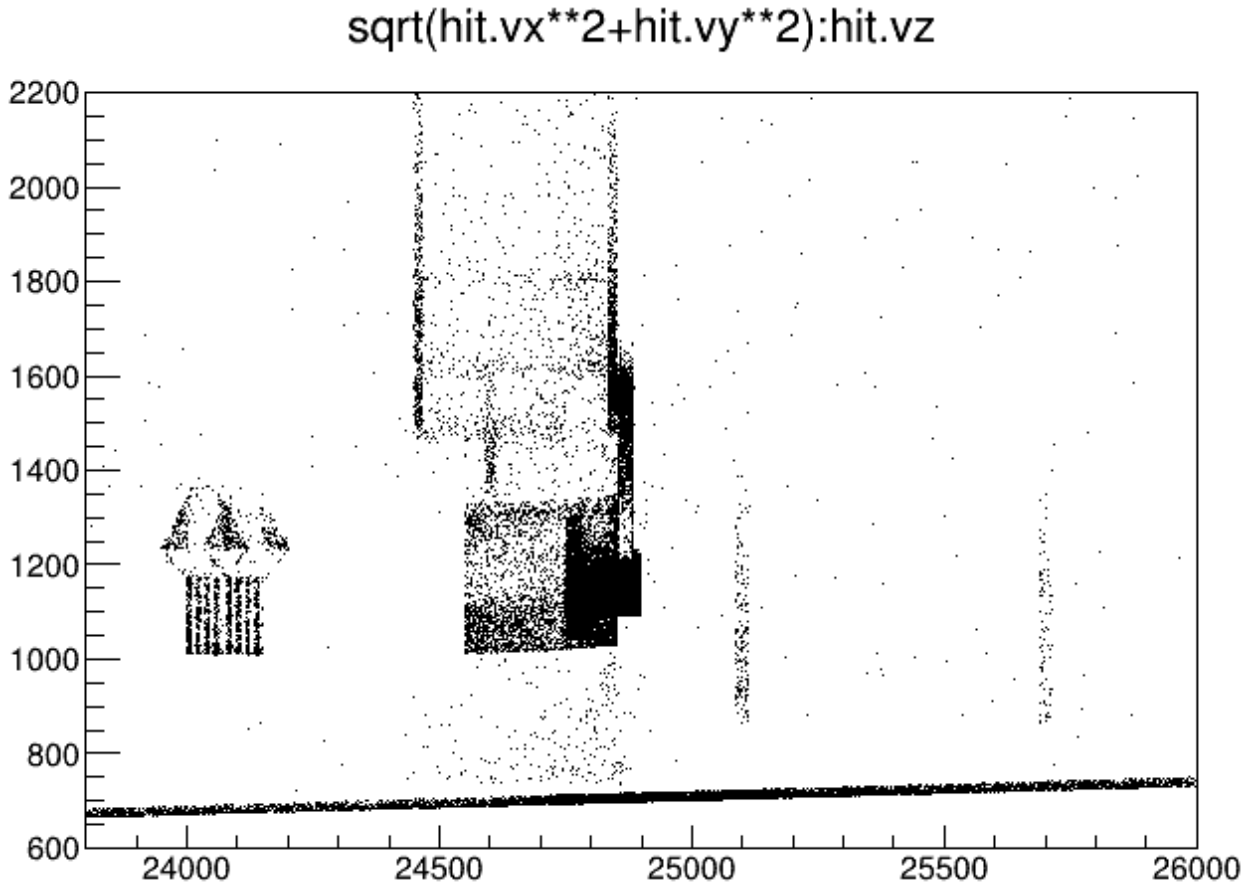


- ✓ Concrete/lead radius extend 16, 21, 26, 30, 35 cm
- ✓ Shift Lucite inward and make it shorter (7, 6 and 5 cm)
- ✓ Keep lead at 16 cm, extend concrete only to 26 cm
- ✓ Fix downstream face of donut, then reduce lead thickness

Different radial and longitudinal thickness of Concrete and Lead



Radial thickness of Concrete = 26cm
Radial thickness of Lead = 16cm
longitudinal thickness of Concrete and Lead = 20cm



Radial thickness of Concrete and Lead = 26cm
longitudinal thickness of Concrete = 20cm
longitudinal thickness of Lead = 10cm

Comparison of rates at the Lucite and PMT for 5,000,000 events (Low energy particles, hit.p<2*MeV)

Rates $GHz/\mu A$ /Detector	Rate of electrons	Rate of pions	Pi/e	Rate of photoelectrons from electrons	Rate of photoelectrons from pions	Pi/e
R-T of Concrete and Lead at 26cm	$(6.10 \pm 0.38) \times 10^{-5}$	$(7.30 \pm 0.29) \times 10^{-7}$	1.20%	$(1.43 \pm 0.03) \times 10^{-3}$	$(7.43 \pm 0.03) \times 10^{-5}$	5.20%
R-T of concrete at 26 cm and Lead at 16 cm	$(1.49 \pm 0.24) \times 10^{-4}$	$(7.72 \pm 0.30) \times 10^{-7}$	0.52%	$(2.08 \pm 0.04) \times 10^{-3}$	$(7.82 \pm 0.03) \times 10^{-5}$	3.76%
L-T of Concrete at 20cm and Lead at 10cm (R-T at 26)	$(9.64 \pm 1.06) \times 10^{-5}$	$(1.04 \pm 0.04) \times 10^{-6}$	1.08%	$(1.92 \pm 0.04) \times 10^{-3}$	$(1.003 \pm 0.004) \times 10^{-4}$	5.20%

Comparison of rates at the Lucite and PMT for 5,000,000 events (High energy particles, hit.p>2*MeV)

Rates $GHz/\mu A$ /Detector	Rate of electrons	Rate of pions	Pi/e	Rate of photoelectrons from electrons	Rate of photoelectrons from pions	Pi/e
R-T of Concrete and Lead at 26cm	$(1.69 \pm 0.12) \times 10^{-5}$	$(4.70 \pm 0.08) \times 10^{-6}$	27.81%	$(1.43 \pm 0.03) \times 10^{-3}$	$(7.43 \pm 0.03) \times 10^{-5}$	5.20%
R-T of concrete at 26 cm and Lead at 16 cm	$(5.73 \pm 0.56) \times 10^{-5}$	$(4.78 \pm 0.08) \times 10^{-6}$	8.34%	$(2.08 \pm 0.04) \times 10^{-3}$	$(7.82 \pm 0.03) \times 10^{-5}$	3.76%
L-T of Concrete at 20cm and Lead at 10cm (R-T at 26)	$(2.61 \pm 0.18) \times 10^{-5}$	$(6.33 \pm 0.09) \times 10^{-6}$	24.25%	$(1.92 \pm 0.04) \times 10^{-3}$	$(1.003 \pm 0.004) \times 10^{-4}$	5.20%

R-T : Radial thickness **L-T : Longitudinal thickness**

Changing the aluminum thickness in the Showermax wall

Aluminum thickness should be 20 mil thick, or 0.5 mm

```
### wall parameter

#thick_wall_mirror_box_tungstenquartz= 3.302
thick_wall_mirror_box_tungstenquartz= 0.5
```

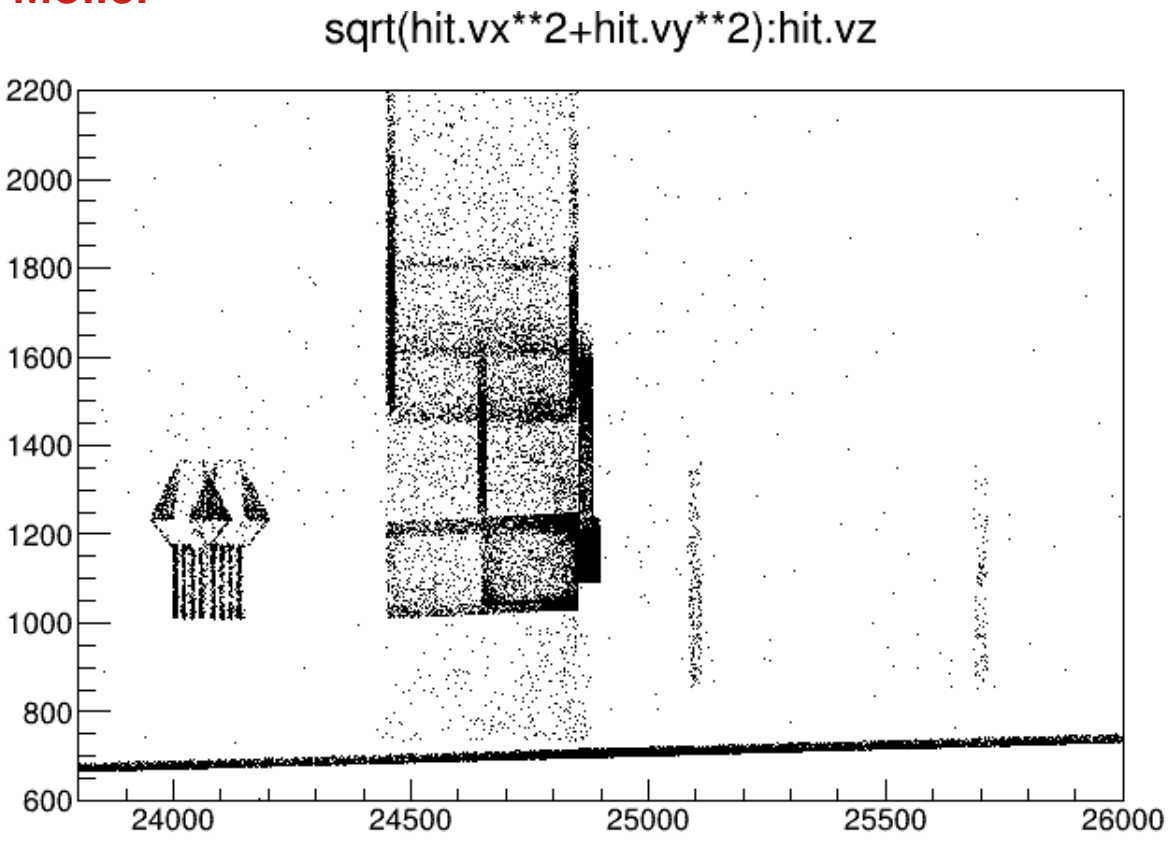
Line 129 in showermaxgen.py should have x1 set to thick_mirror_box_bot instead of ..._tungstenquartz

```
out+="\t<trd name=\"solid_mirror_box_top_1\" lunit=\"mm\" x1=\""+str(thick_mirror_box_bot+2*thick_wall_mirror_box_tungstenquartz)+"\"  x2=\""+str(thick_mirror_box_top+>
out+="\t<trd name=\"solid_mirror_box_top_2\" lunit=\"mm\" x1=\""+str(thick_mirror_box_bot)+"\"  x2=\""+str(thick_mirror_box_top)+"\" y1=\""+str(width_mirror_box_tungst>
```

The origin location of all the secondaries anywhere for 5,000,000 events

(16 cm concrete and upstream Lead - 7cmLucite)

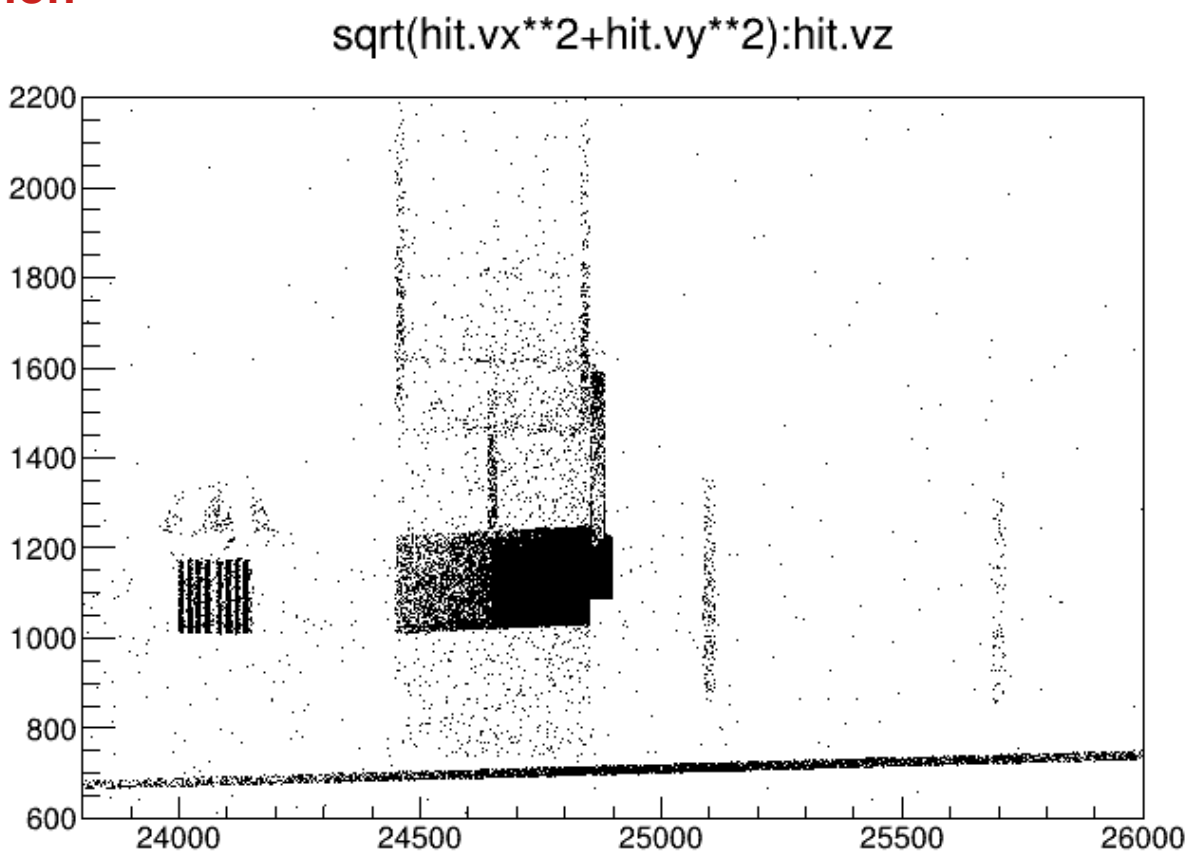
Moller



hit.trid==1 25

hit.trid==2 20

Pion



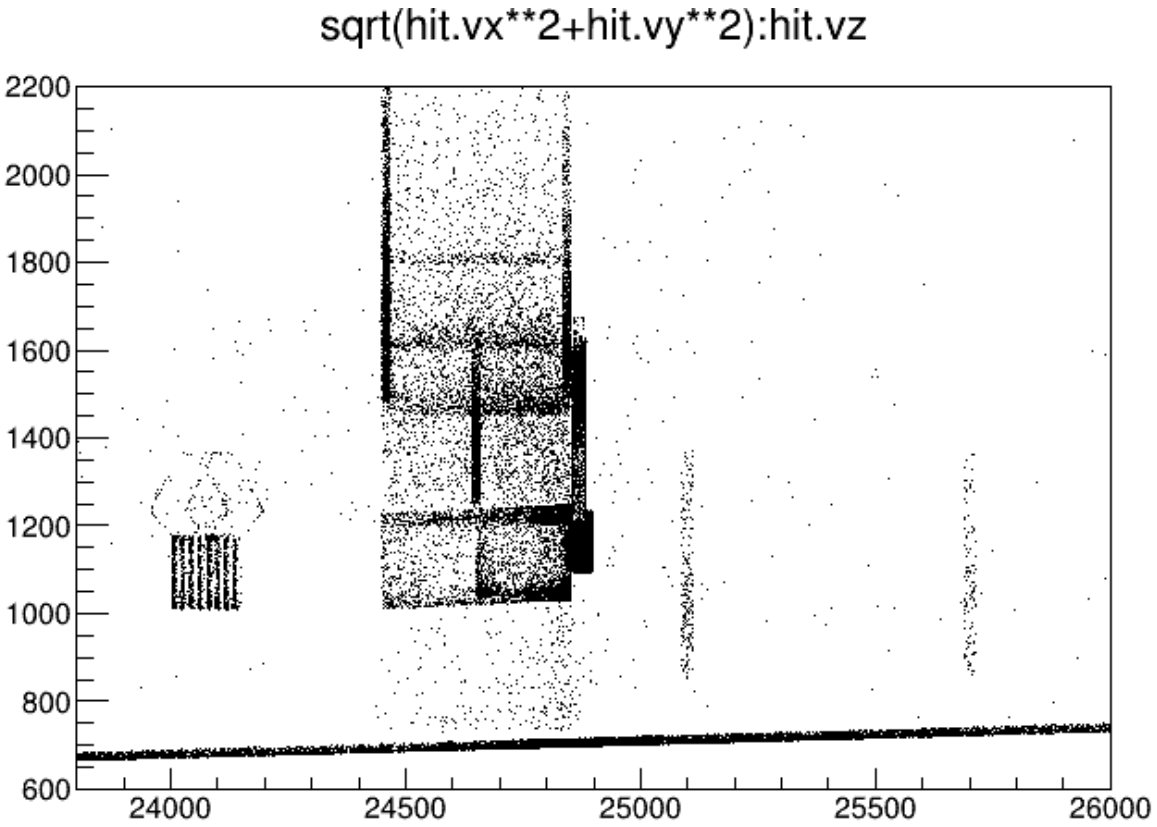
hit.trid==1 488

T->Draw("sqrt(hit.vx**2+hit.vy**2):hit.vz>>h1(100,23800,26000,100,600,2200)")

The origin location of all the secondaries anywhere for 5,000,000 events

(16 cm concrete and upstream Lead - 7cmLucite)

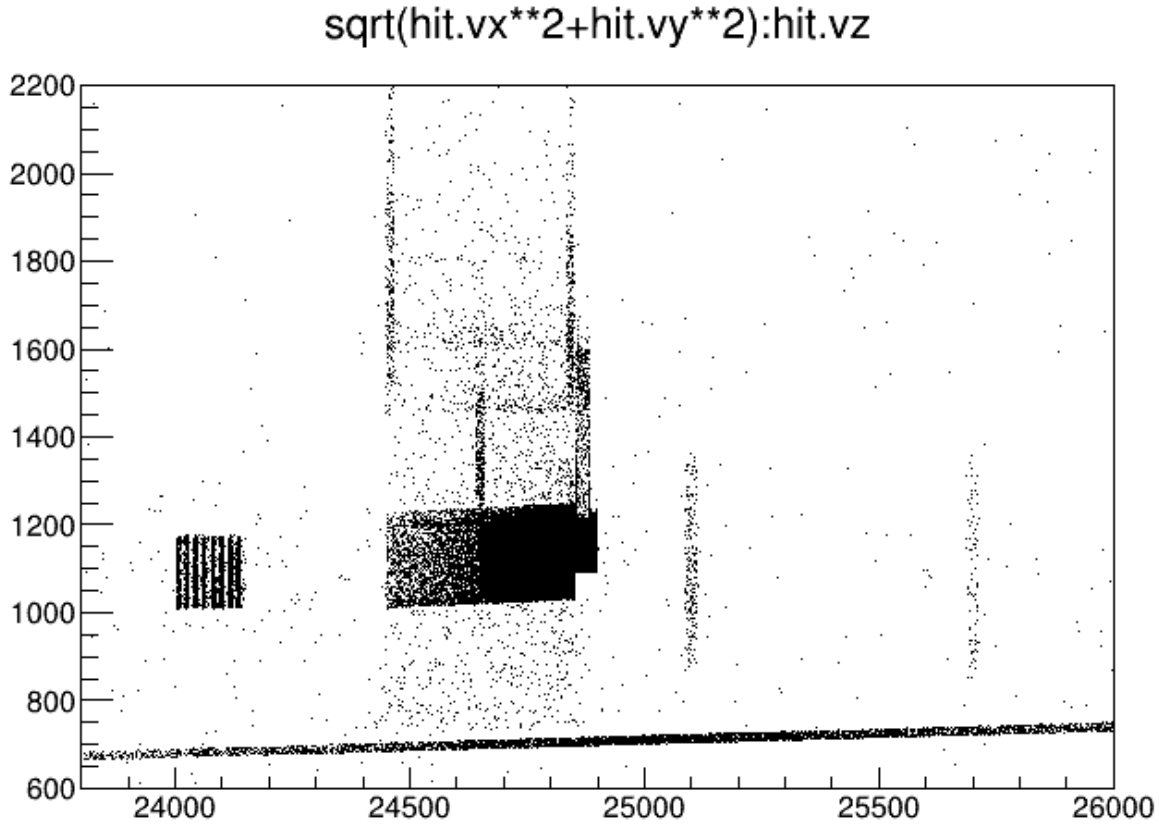
Moller



hit.trid==1 6

hit.trid==2 9

Pion



hit.trid==1 492

T->Draw("sqrt(hit.vx**2+hit.vy**2):hit.vz>>h1(100,23800,26000,100,600,2200)")

Comparison of rates at the Lucite for 5,000,000 events (Low energy particles, hit.p<2*MeV)

Rates $GHz/\mu A/Detector$	Rate of electrons	Rate of pions	Pi/e	Rate of photons from electrons	Rate of photons from pions	Pi/e
Showermax with aluminum thickness=3.302 mm	$(1.12 \pm 0.04) \times 10^{-4}$	$(7.93 \pm 0.30) \times 10^{-7}$	0.71%	$(1.96 \pm 0.03) \times 10^{-3}$	$(7.54 \pm 0.03) \times 10^{-5}$	3.85%
Showermax with aluminum thickness=0.5 mm	$(1.26 \pm 0.07) \times 10^{-4}$	$(7.69 \pm 0.30) \times 10^{-7}$	0.61%	$(2.07 \pm 0.03) \times 10^{-3}$	$(7.10 \pm 0.03) \times 10^{-5}$	3.42%

Comparison of rates at the Lucite for 5,000,000 events (High energy particles, hit.p>2*MeV)

Rates $GHz/\mu A/Detector$	Rate of electrons	Rate of pions	Pi/e	Rate of photons from electrons	Rate of photons from pions	Pi/e
Showermax with aluminum thickness=3.302 mm	$(4.89 \pm 0.28) \times 10^{-5}$	$(4.63 \pm 0.08) \times 10^{-6}$	9.47%	$(1.96 \pm 0.03) \times 10^{-3}$	$(7.54 \pm 0.03) \times 10^{-5}$	3.85%
Showermax with aluminum thickness=0.5 mm	$(5.17 \pm 0.40) \times 10^{-5}$	$(4.41 \pm 0.08) \times 10^{-6}$	8.53%	$(2.07 \pm 0.03) \times 10^{-3}$	$(7.09 \pm 0.03) \times 10^{-5}$	3.42%

T->Draw("1","(rate/5.95e13)*(hit.det==8001 && hit.p<2*MeV && (hit.pid==11 || hit.pid==-11 || hit.pid==211 || hit.pid==-211 || hit.pid==13 || hit.pid==-13))")

T->Draw("1","(rate/5.95e13)*(hit.det==8000)")

Note: 5.95e13 comes from 85*14*10^9*50 to be in the unit of $GHz/\mu A/Detector$/simulation

Changing the Lead donut support thickness

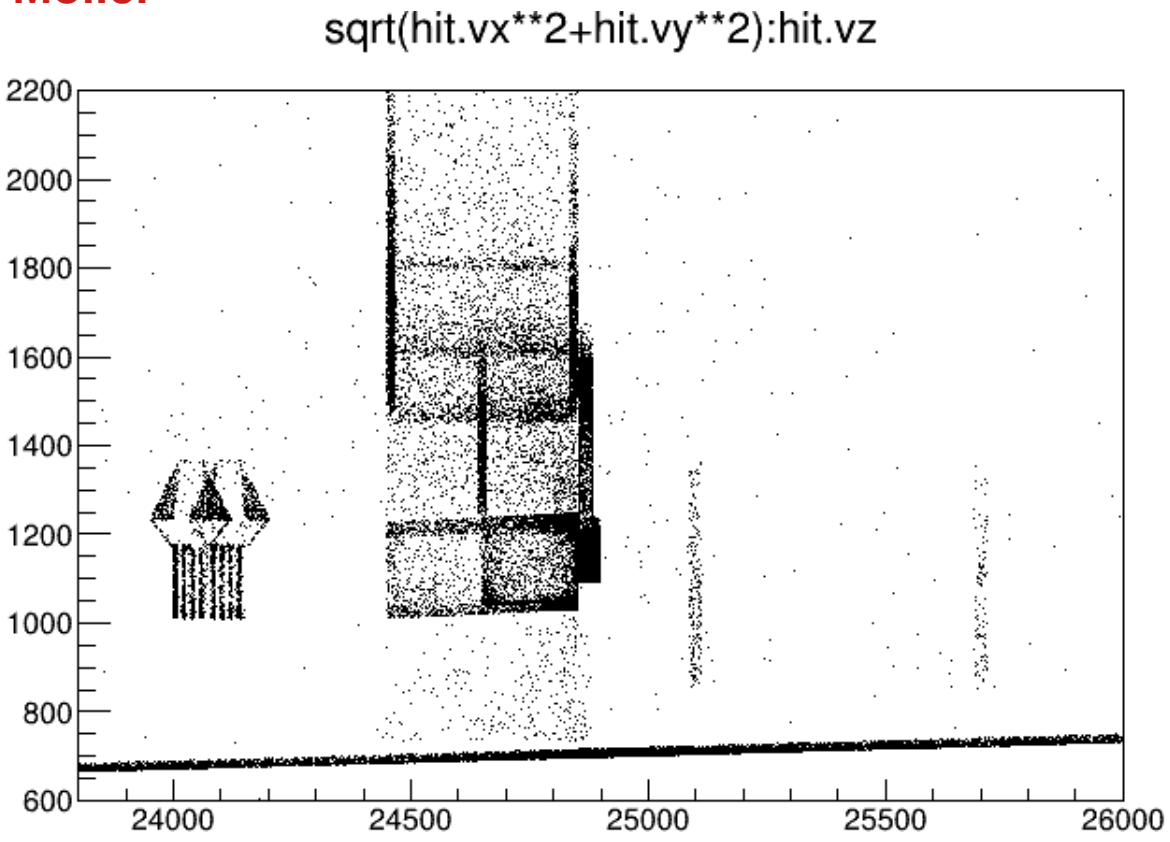
```
 <!-- Donut top support -->
-  <quantity name="donutTopSupportThickness"       type="length" value="0.75" unit="in"/>
+   <quantity name="donutTopSupportThickness"       type="length" value="0.01" unit="in"/>
    <quantity name="donutTopSupportWidth"          type="length" value="1524.000" unit="mm"/>
    <quantity name="donutTopSupportOuterRibDistance" type="length" value="1397.000" unit="mm"/>
    <quantity name="donutTopSupportInnerRibDistance" type="length" value="705.033" unit="mm"/>

    <!-- Donut bottom support -->
-  <quantity name="donutBotSupportThickness"       type="length" value="0.75" unit="in"/>
+   <quantity name="donutBotSupportThickness"       type="length" value="0.01" unit="in"/>
    <quantity name="donutBotSupportWidth"          type="length" value="1828.800" unit="mm"/>
    <quantity name="donutBotSupportOuterRibDistance" type="length" value="1701.800" unit="mm"/>
    <quantity name="donutBotSupportInnerRibDistance" type="length" value="841.685" unit="mm"/>
```

The origin location of all the secondaries anywhere for 5,000,000 events

(16 cm concrete and upstream Lead - 7cmLucite)

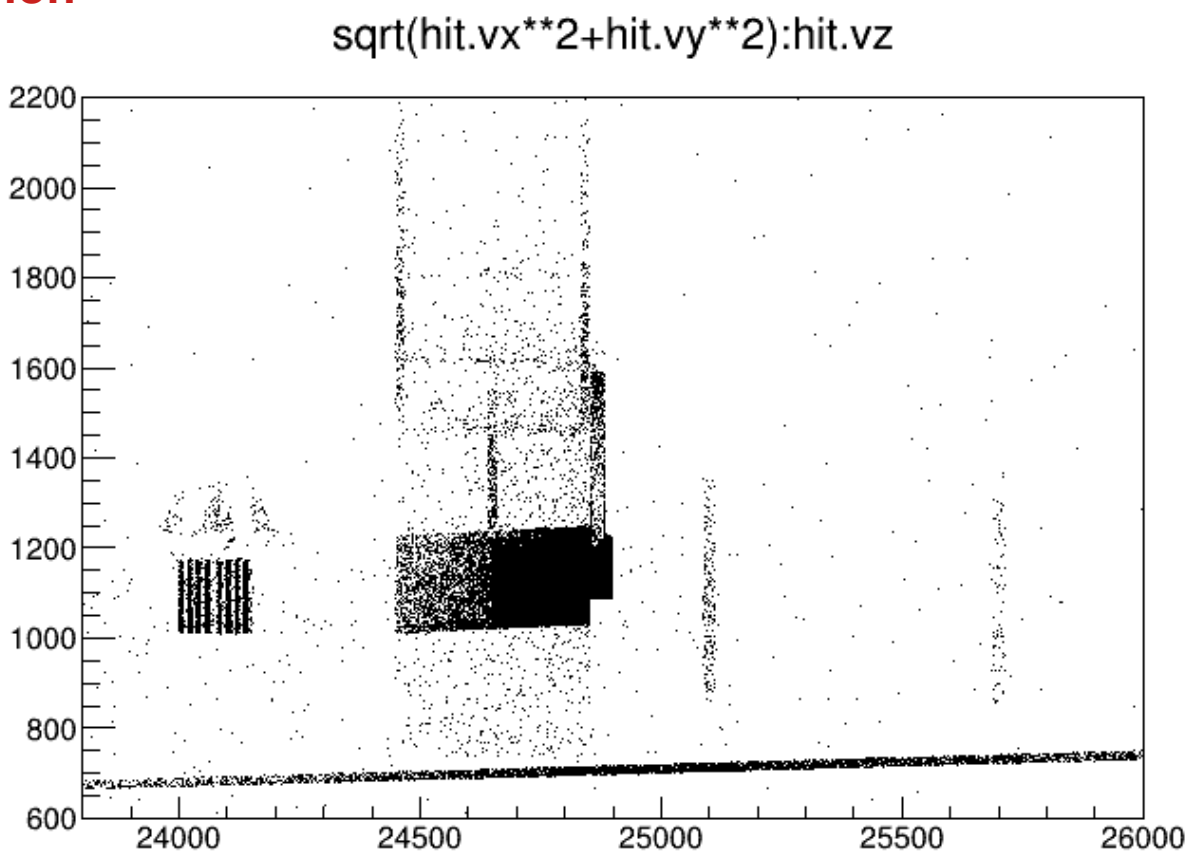
Moller



hit.trid==1 25

hit.trid==2 20

Pion



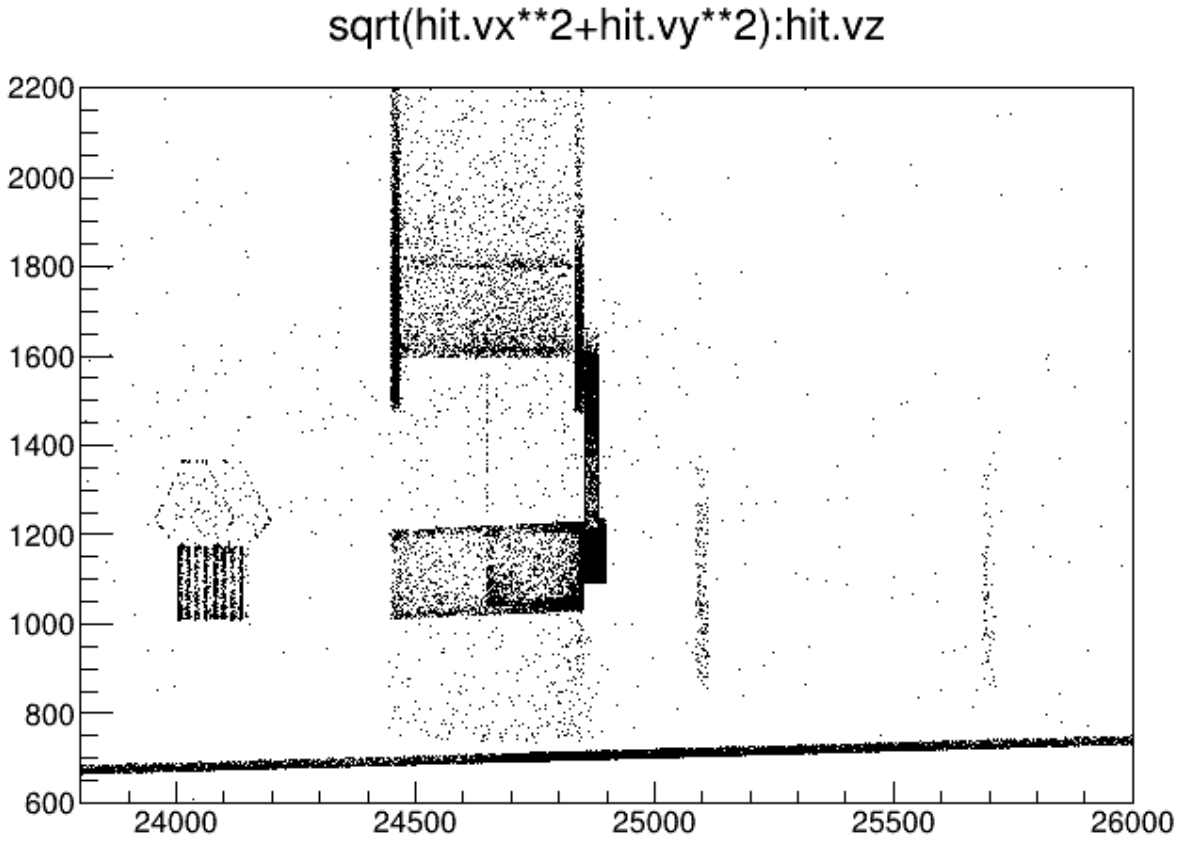
hit.trid==1 488

T->Draw("sqrt(hit.vx**2+hit.vy**2):hit.vz>>h1(100,23800,26000,100,600,2200)")

The origin location of all the secondaries anywhere for 5,000,000 events

(16 cm concrete and upstream Lead - 7cmLucite)

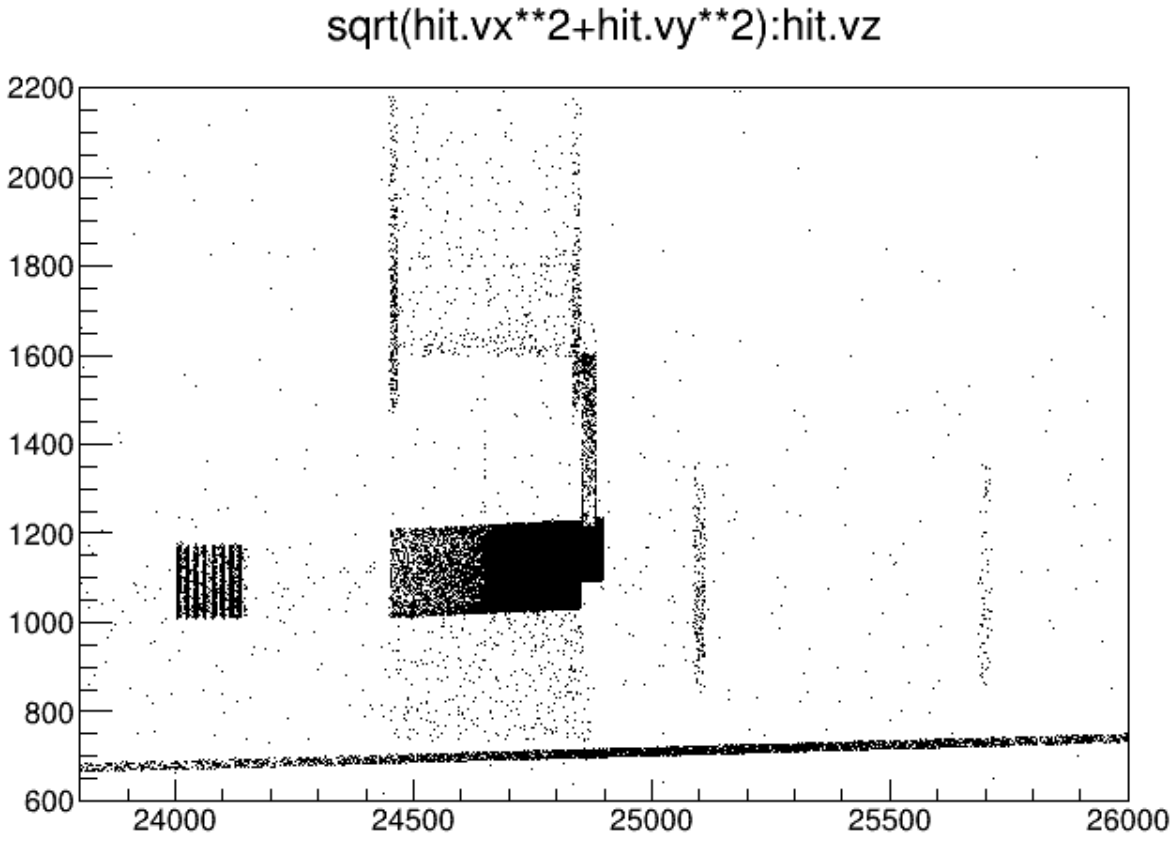
Moller



hit.trid==1 24

hit.trid==2 58

Pion



hit.trid==1 459

T->Draw("sqrt(hit.vx**2+hit.vy**2):hit.vz>>h1(100,23800,26000,100,600,2200)")

Comparison of rates at the Lucite for 5,000,000 events (Low energy particles, hit.p<2*MeV)

Rates $GHz/\mu A/Detector$	Rate of electrons	Rate of pions	Pi/e	Rate of photons from electrons	Rate of photons from pions	Pi/e
Donut Top/Bot SupportThickness = 0.75 in	$(1.12 \pm 0.04) \times 10^{-4}$	$(7.93 \pm 0.30) \times 10^{-7}$	0.71%	$(1.96 \pm 0.03) \times 10^{-3}$	$(7.54 \pm 0.03) \times 10^{-5}$	3.85%
Donut Top/Bot SupportThickness = 0.01 in	$(1.22 \pm 0.03) \times 10^{-4}$	$(7.24 \pm 0.30) \times 10^{-7}$	0.59%	$(2.03 \pm 0.03) \times 10^{-3}$	$(7.52 \pm 0.03) \times 10^{-5}$	3.70%s

Comparison of rates at the Lucite for 5,000,000 events (High energy particles, hit.p>2*MeV)

Rates $GHz/\mu A/Detector$	Rate of electrons	Rate of pions	Pi/e	Rate of photons from electrons	Rate of photons from pions	Pi/e
Showermax with aluminum thickness=3.302 mm	$(4.89 \pm 0.28) \times 10^{-5}$	$(4.63 \pm 0.08) \times 10^{-6}$	9.47%	$(1.96 \pm 0.03) \times 10^{-3}$	$(7.54 \pm 0.03) \times 10^{-5}$	3.85%
Showermax with aluminum thickness=0.5 mm	$(5.21 \pm 0.67) \times 10^{-5}$	$(4.65 \pm 0.08) \times 10^{-6}$	8.93%	$(2.03 \pm 0.03) \times 10^{-3}$	$(7.52 \pm 0.03) \times 10^{-5}$	3.70%

T->Draw("1","(rate/5.95e13)*(hit.det==8001 && hit.p<2*MeV && (hit.pid==11 || hit.pid==-11 || hit.pid==211 || hit.pid==-211 || hit.pid==13 || hit.pid==-13))")

T->Draw("1","(rate/5.95e13)*(hit.det==8000)")

Note: 5.95e13 comes from 85*14*10^9*50 to be in the unit of $GHz/\mu A/Detector$/simulation

Thank you

University of Manitoba