Higher difference in rate between Pions and electrons In different geometry of the Lead donut

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

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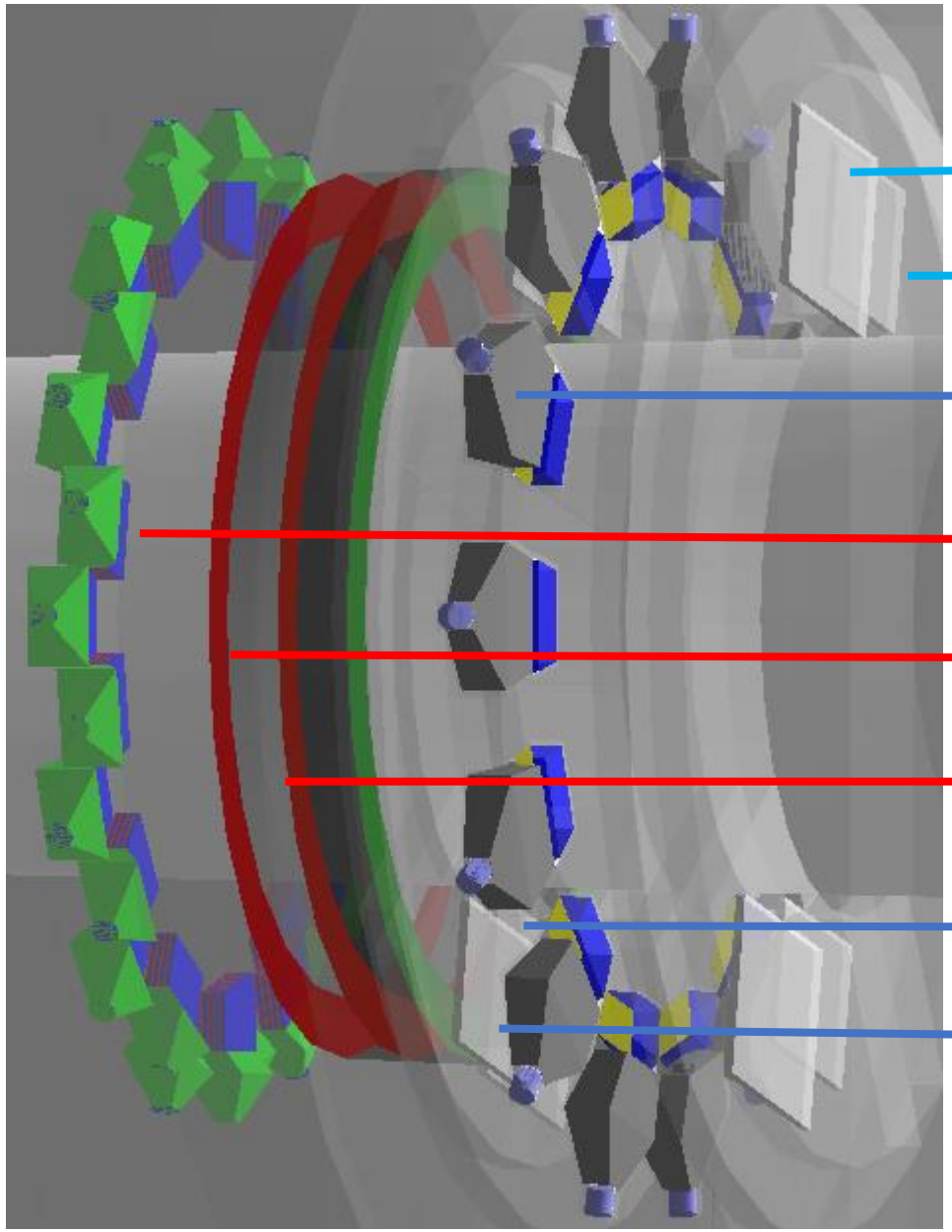
March, 2021

Presentation Outline

- ✓ **Geometry of Pion Detector system**
- ✓ **Original geometry vs the new geometry**
- ✓ **Problems with the new geometry**
- ✓ **Approaches for resolving the problems**
- ✓ **Results**
- ✓ **Future works**

Pion Detector geometry



Pion Detector GEM back

Pion Detector TS back

Pion Detector Lucite

Showermax

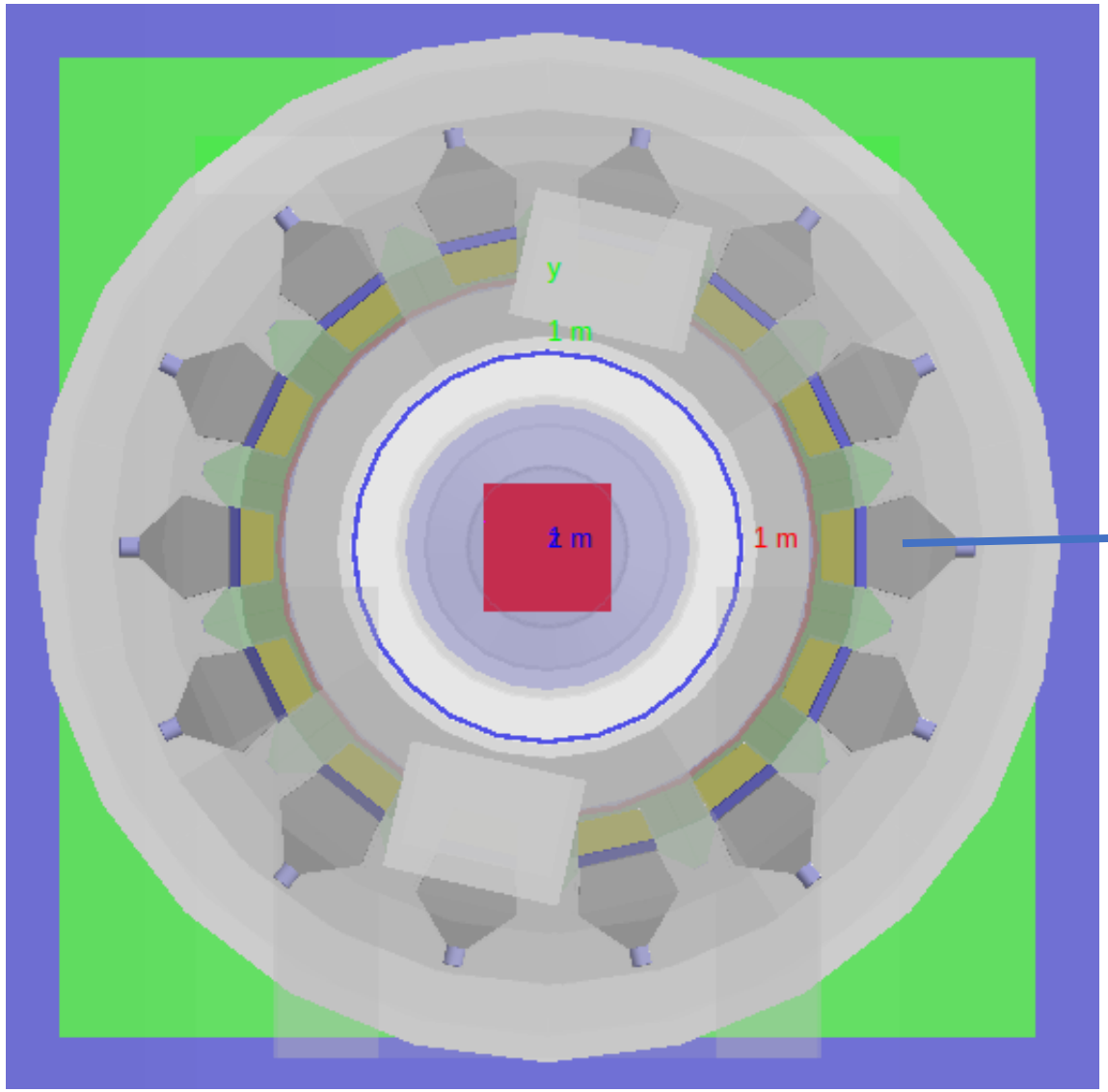
Concrete

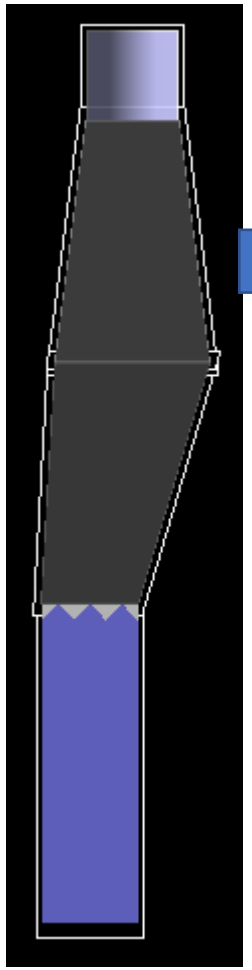
Lead donut (Pb absorber)

Pion Detector GEM front

Pion Detector TS front

Pion Detector geometry



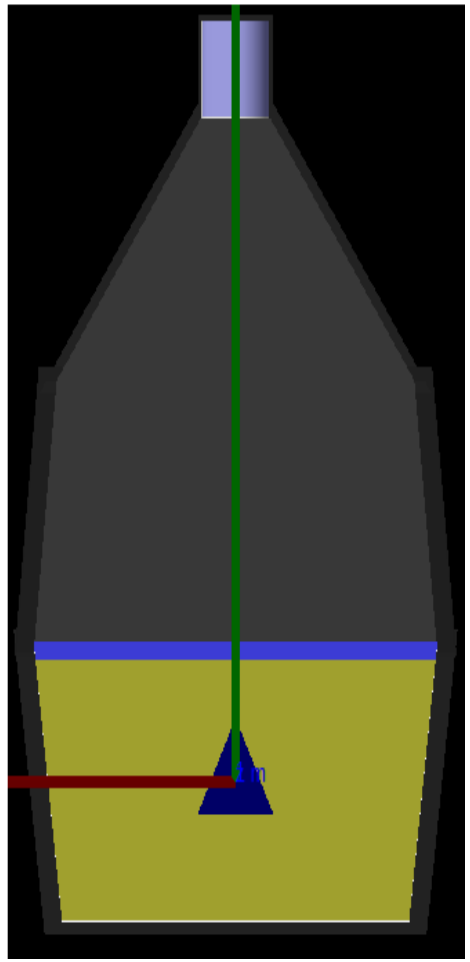


PMT

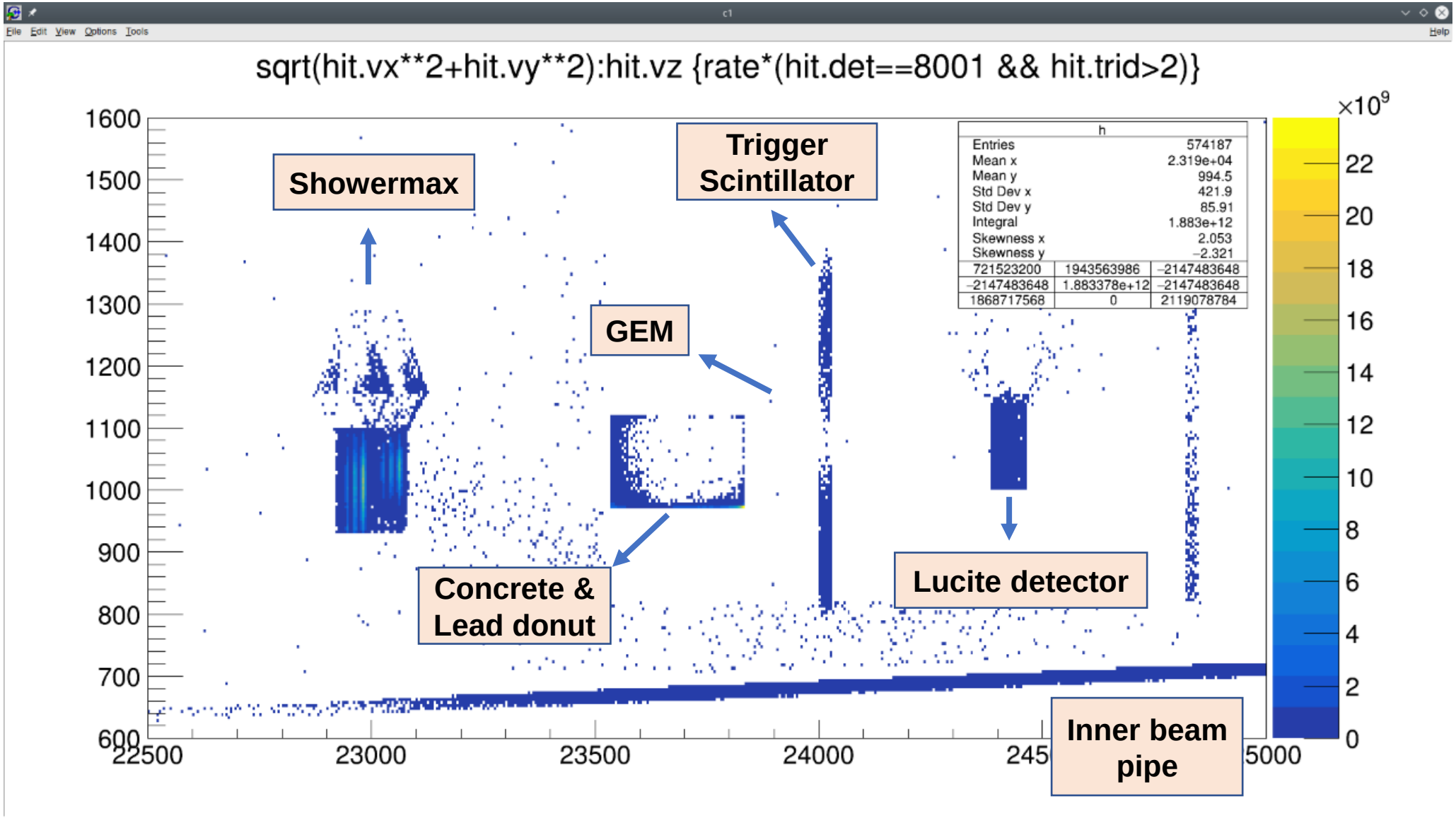
Light Guide

Reflector

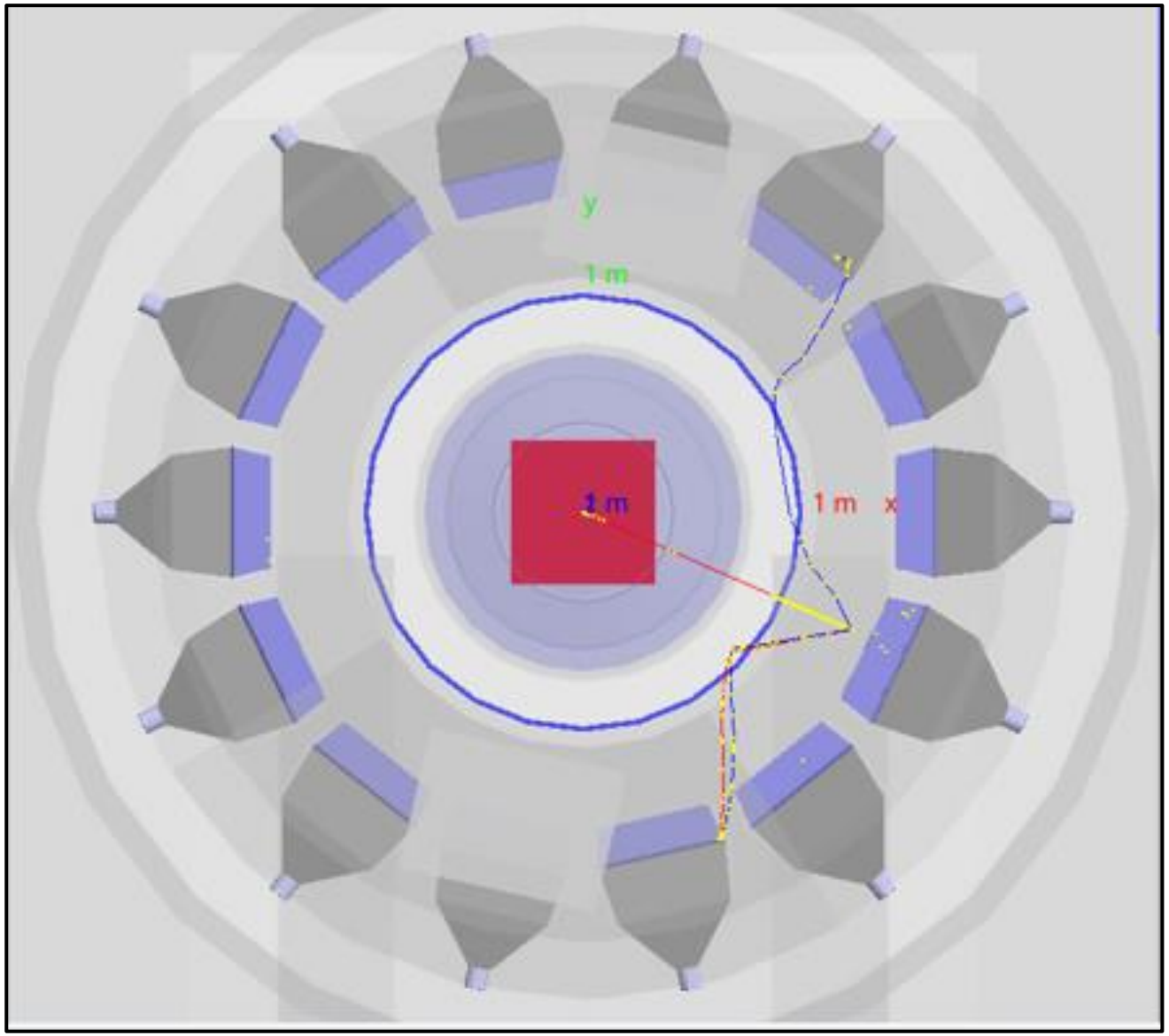
Lucite



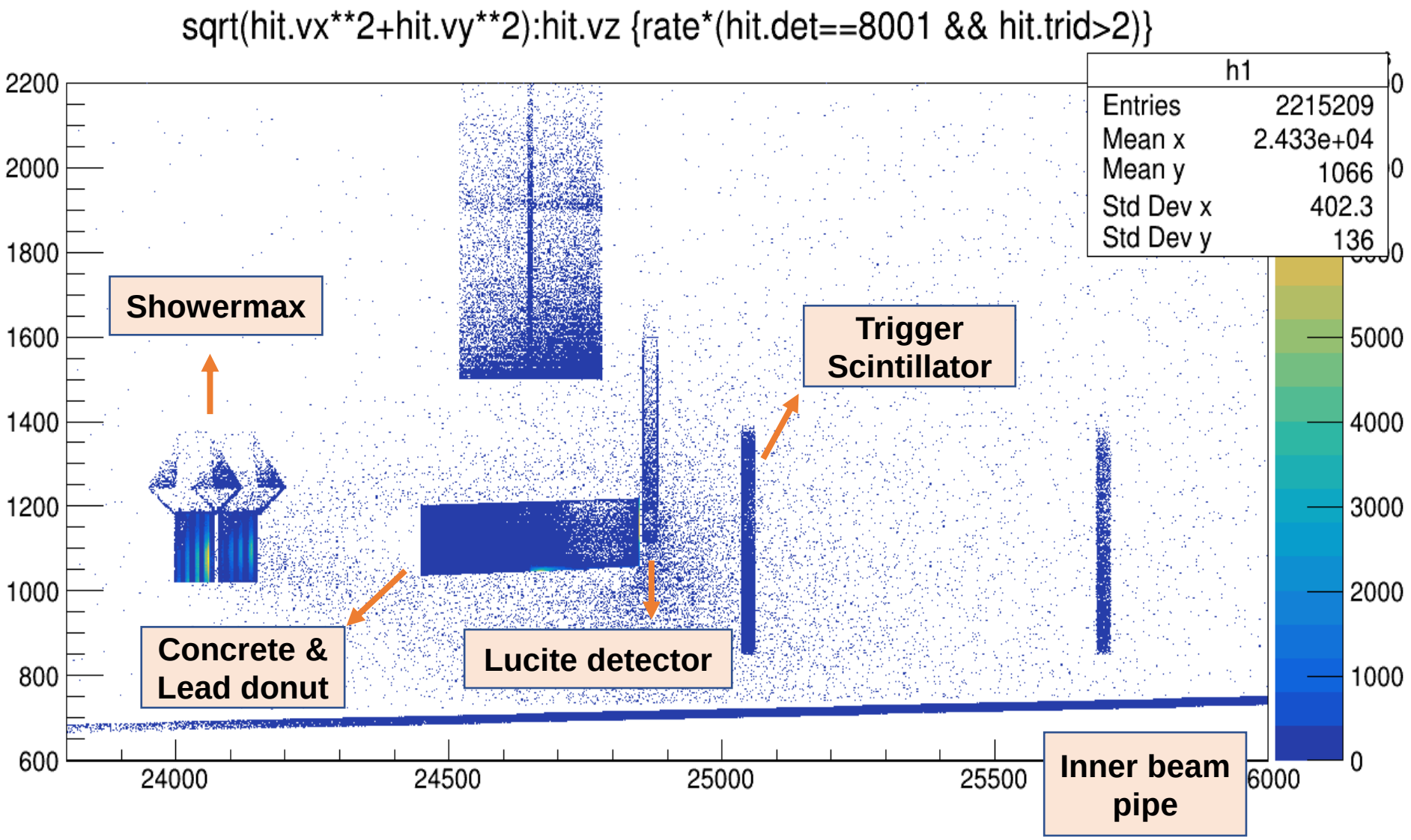
Original geometry of Pion detector system



Original geometry of Pion detector system



New geometry of Pion detector system



New geometry vs original geometry

$$\frac{\text{Rate of detected Pions}}{\text{Rate of detected electrons}} = 0.1 \xrightarrow{\text{New geometry}} 100$$

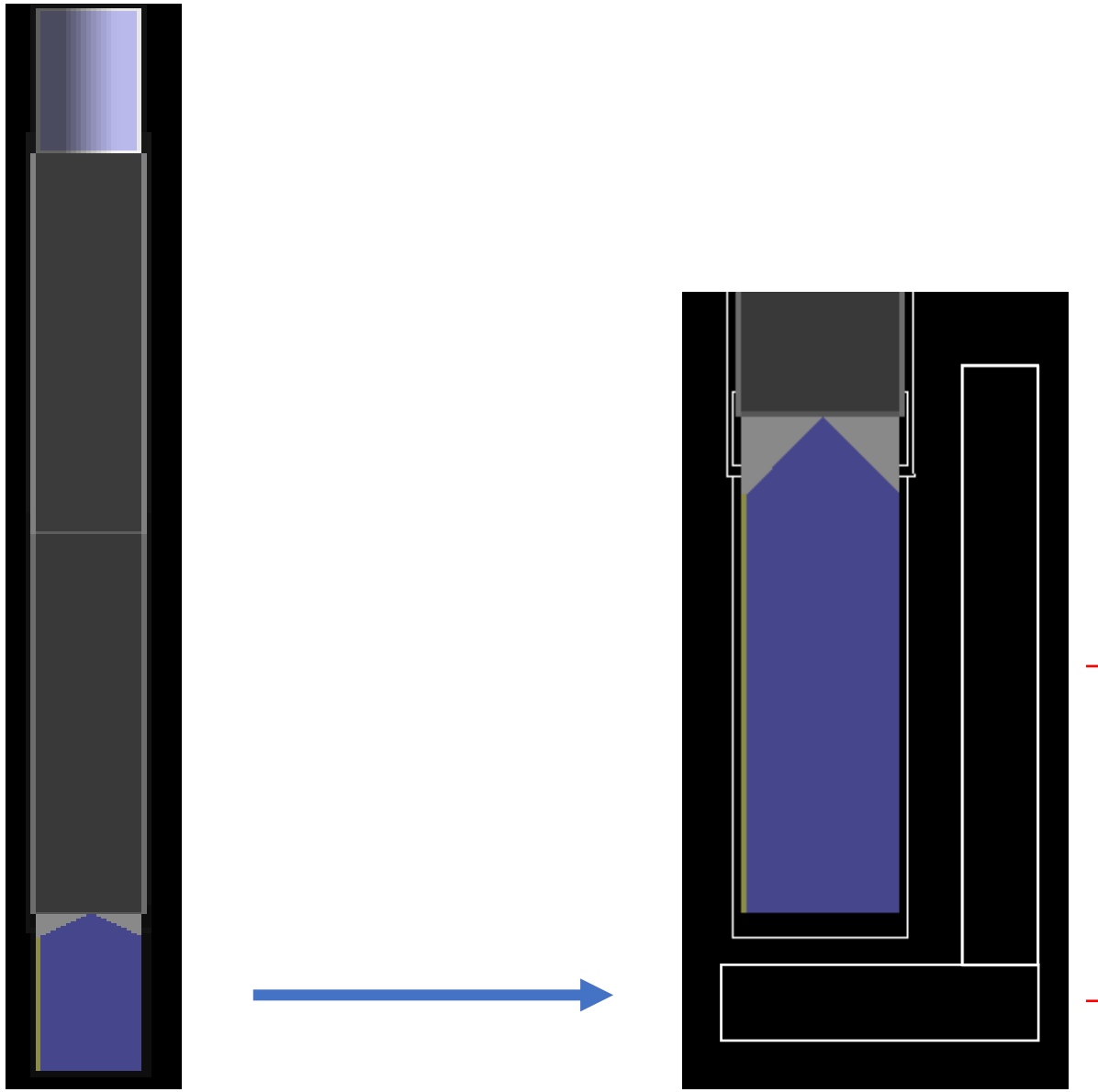
$$\frac{\text{Rate of detected photoelectrons from Pions}}{\text{Rate of detected photoelectrons from electrons}} = 10^{-3} \xrightarrow{\text{New geometry}} 10^{-1}$$

Problem with the new geometry

$$\frac{\text{Rate of detected Pions}}{\text{Rate of detected electrons}} \sim 10$$

$$\frac{\text{Rate of detected photoelectrons from Pions}}{\text{Rate of detected photoelectrons from electrons}} \sim 0.1$$

New geometry with shielding (downstream shielding and inner radial shielding)



Downstream shielding
(0.5 inch Lead)

Inner radial shielding
(0.5 inch Lead)

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
Without shielding	$(2.73 \pm 0.01) \times 10^{-3}$	$(2.89 \pm 0.06) \times 10^{-6}$	0.11%	$(2.200 \pm 0.003) \times 10^{-2}$	$(5.424 \pm 0.008) \times 10^{-4}$	2.47%
With downstream(DS) shielding	$(2.08 \pm 0.01) \times 10^{-3}$	$(4.74 \pm 0.07) \times 10^{-6}$	0.23%	$(2.087 \pm 0.004) \times 10^{-2}$	$(5.800 \pm 0.008) \times 10^{-4}$	2.78%
With DS and inner radial shielding	$(8.21 \pm 0.09) \times 10^{-4}$	$(5.10 \pm 0.08) \times 10^{-6}$	0.62%	$(1.235 \pm 0.003) \times 10^{-2}$	$(5.743 \pm 0.008) \times 10^{-4}$	4.62%

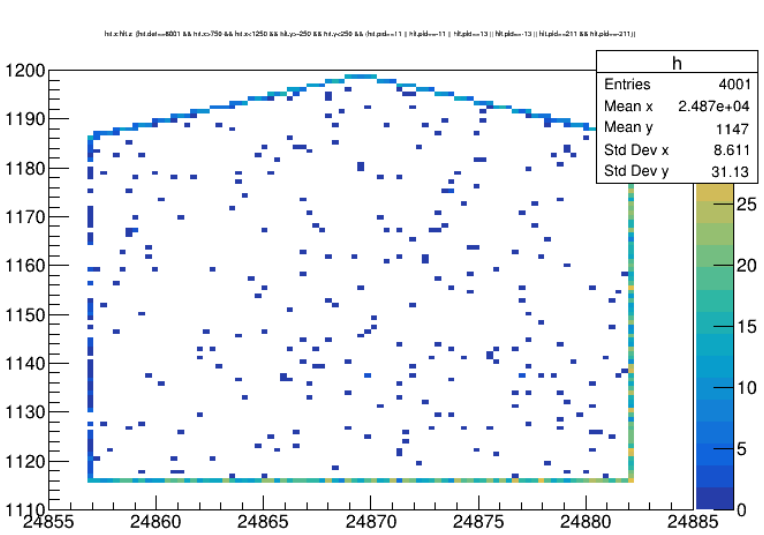
(High energy particles, hit.p>2*MeV)

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
Without shielding	$(5.52 \pm 0.06) \times 10^{-4}$	$(2.69 \pm 0.02) \times 10^{-5}$	4.87%	$(2.200 \pm 0.003) \times 10^{-2}$	$(5.424 \pm 0.008) \times 10^{-4}$	2.46%
With downstream(DS) shielding	$(5.14 \pm 0.06) \times 10^{-4}$	$(2.80 \pm 0.02) \times 10^{-5}$	5.45%	$(2.087 \pm 0.004) \times 10^{-2}$	$(5.800 \pm 0.008) \times 10^{-4}$	2.78%
With DS and inner radial shielding	$(1.66 \pm 0.04) \times 10^{-4}$	$(2.79 \pm 0.02) \times 10^{-5}$	16.80%	$(1.235 \pm 0.003) \times 10^{-2}$	$(5.743 \pm 0.008) \times 10^{-4}$	4.65%

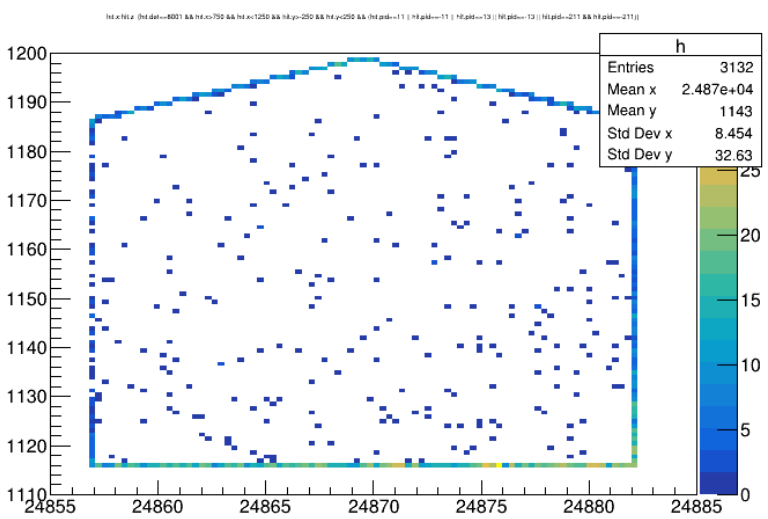
Note: Inclusion of electron, positron, pion, and (anti) Muon (hit.pid==11, -11, 211, -211, 13, -13)

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

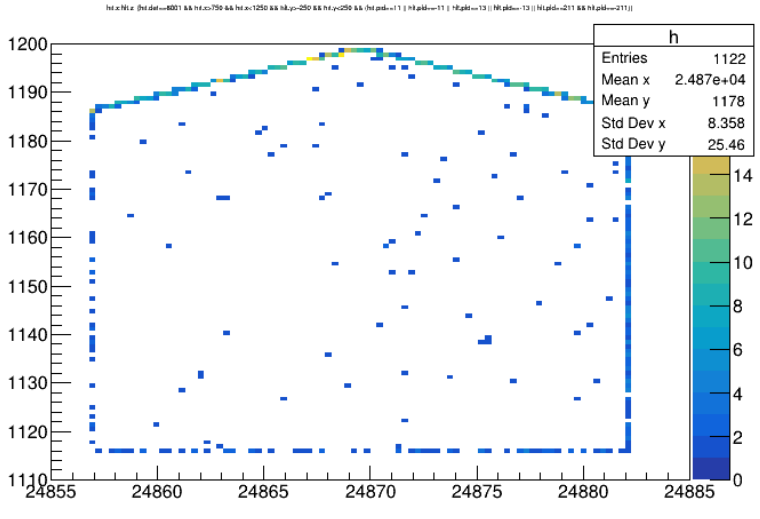
(without shielding)



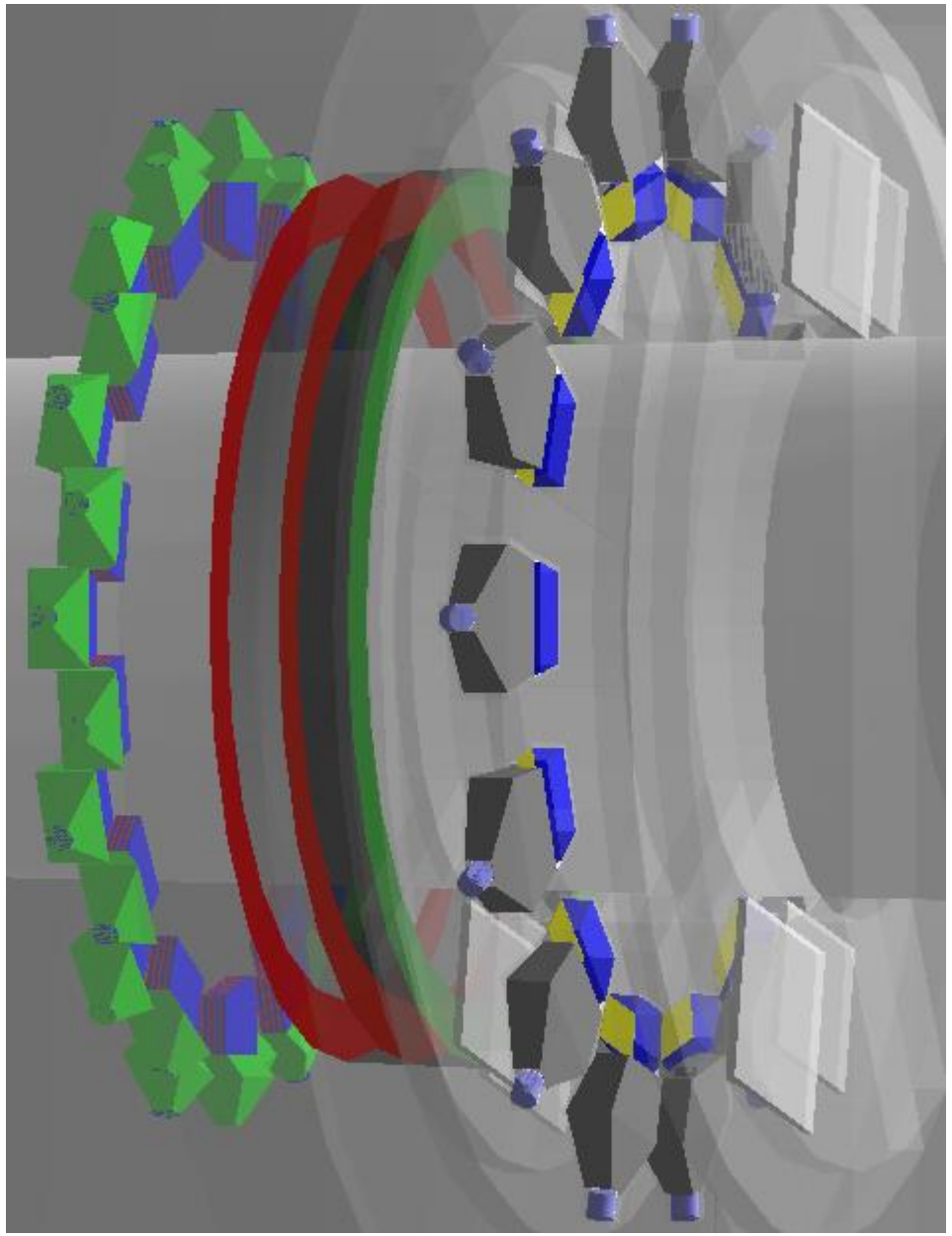
(with downstream shielding)

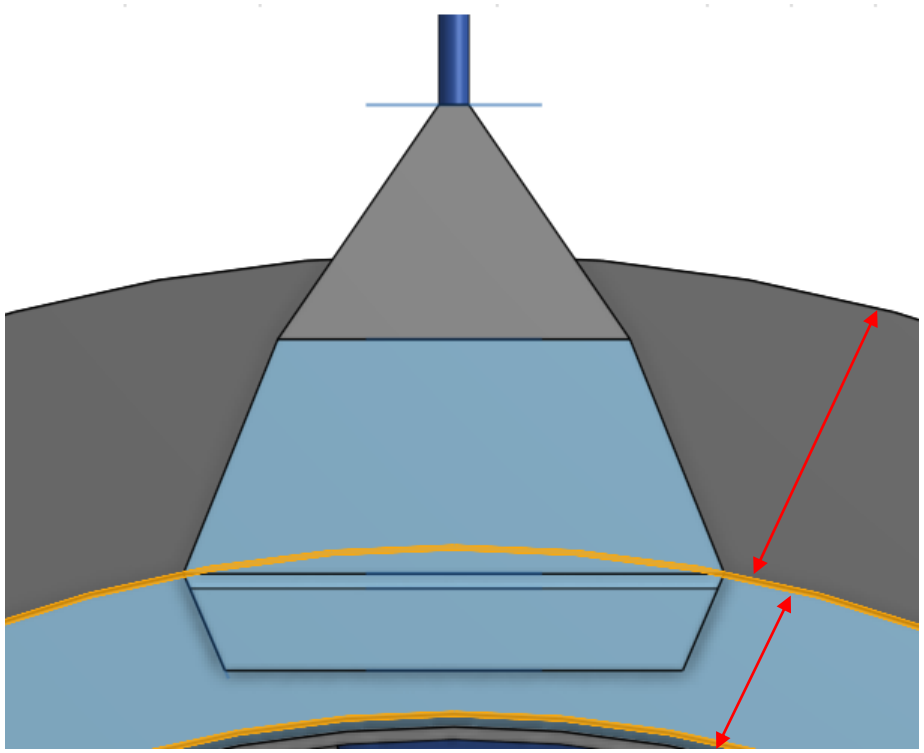


(with inner radial shielding)



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



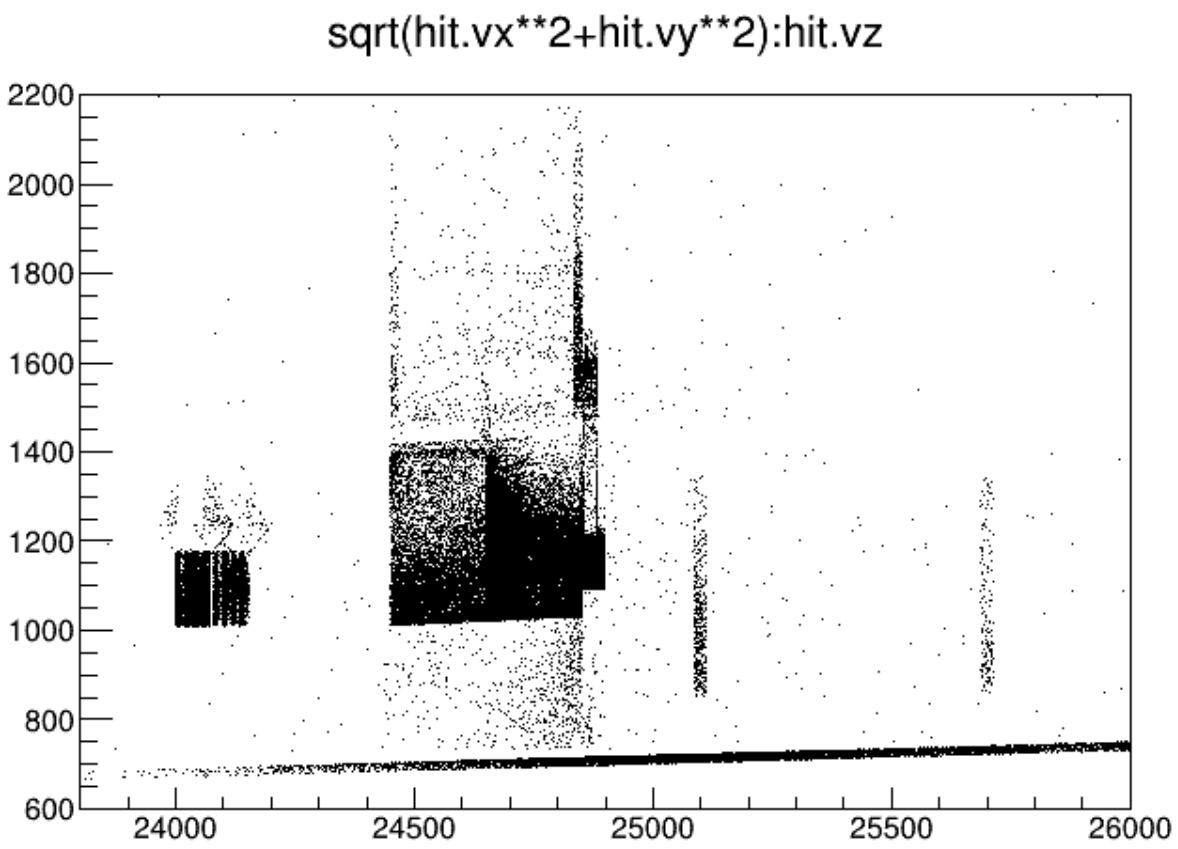


- ✓ Concrete/lead radius extend 16, 21, 26, 30, 35 cm
- ✓ Shift Lucite inward and make it shorter (7, 6 and 5 cm)
- ✓ Keep lead at 16 cm, extend concrete only to 26 cm
- ✓ Fix downstream face of donut, then reduce lead thickness

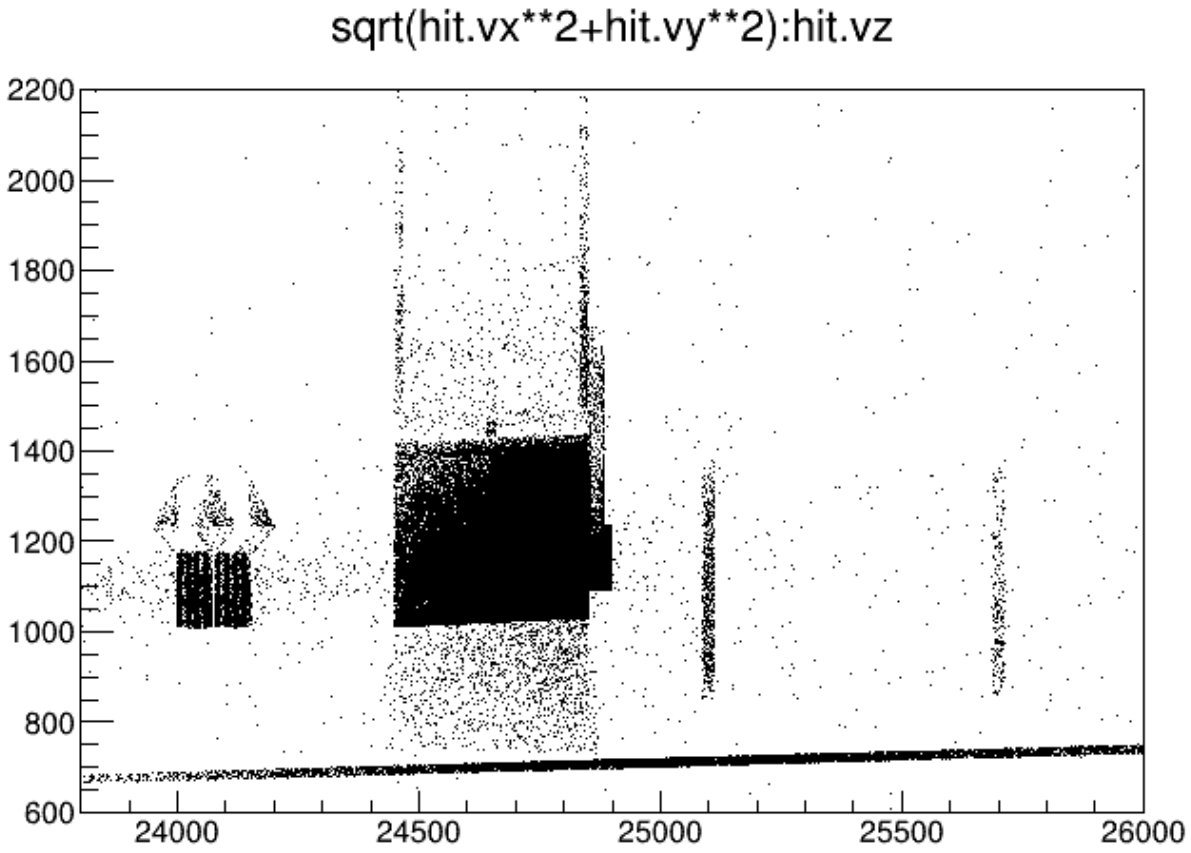
Changing the radial and longitudinal thickness of Concrete and Lead

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

Moller



Pion

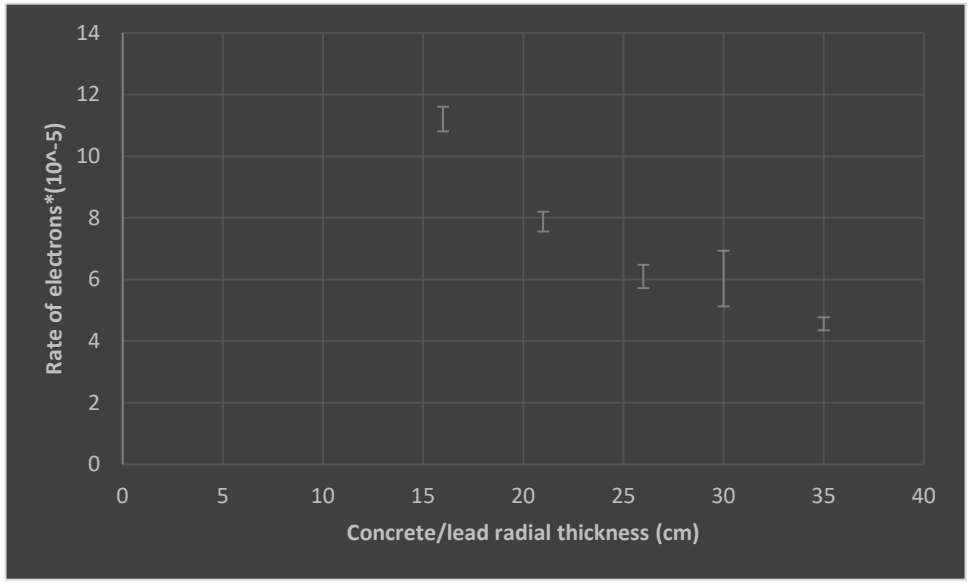


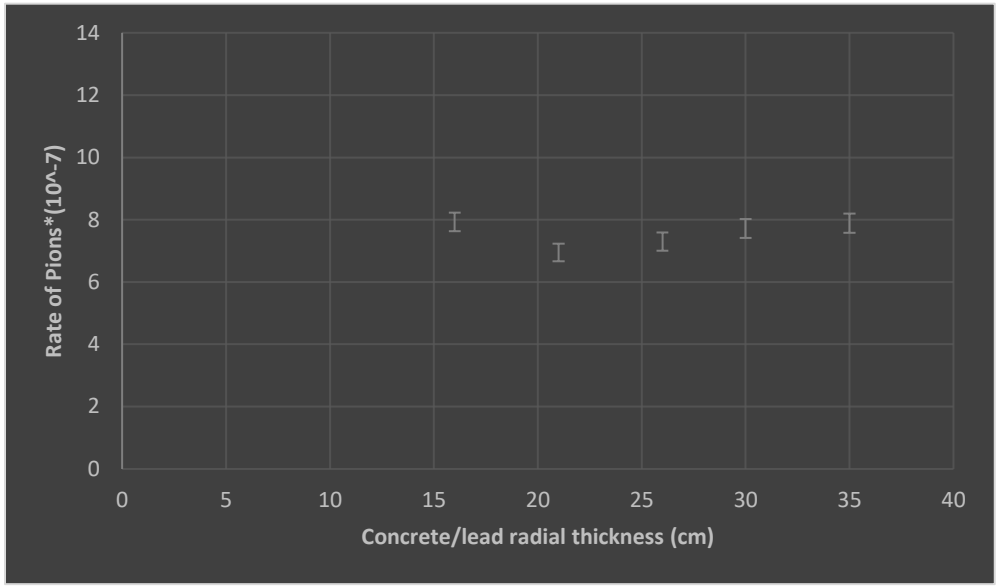
Comparison of rates at the Lucite and PMT for 5,000,000 events (Low energy particles, hit.p<2*MeV)

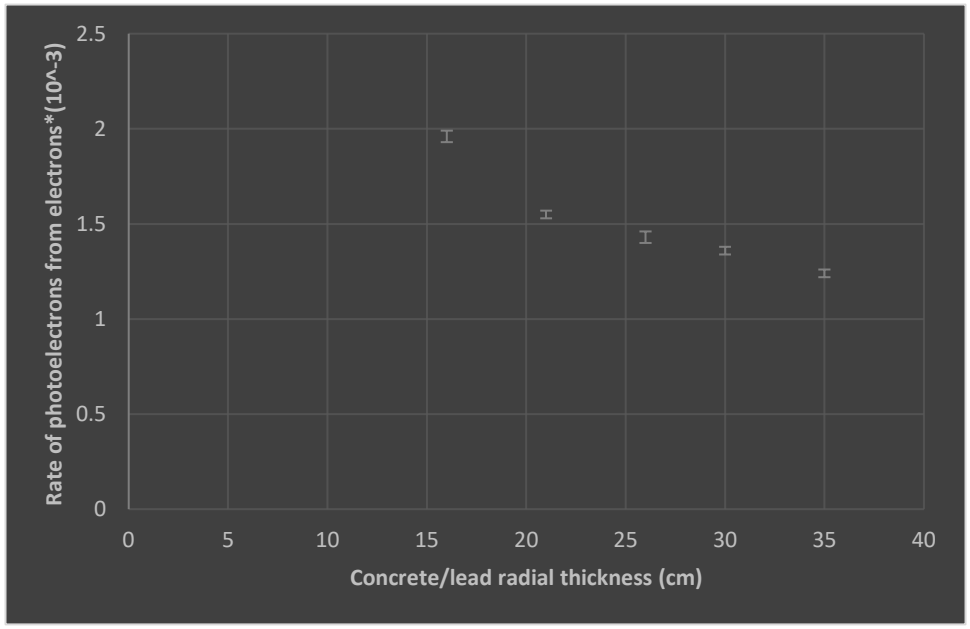
Rates $GHz/\mu A$ $/Detector$	Rate of electrons	Rate of pions	Pi/e	Rate of photoelectrons from electrons	Rate of photoelectrons from pions	Pi/e
Concrete and Lead at 16cm	$(1.12 \pm 0.04) \times 10^{-4}$	$(7.93 \pm 0.30) \times 10^{-7}$	0.71%	$(1.96 \pm 0.03) \times 10^{-3}$	$(7.54 \pm 0.03) \times 10^{-5}$	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%

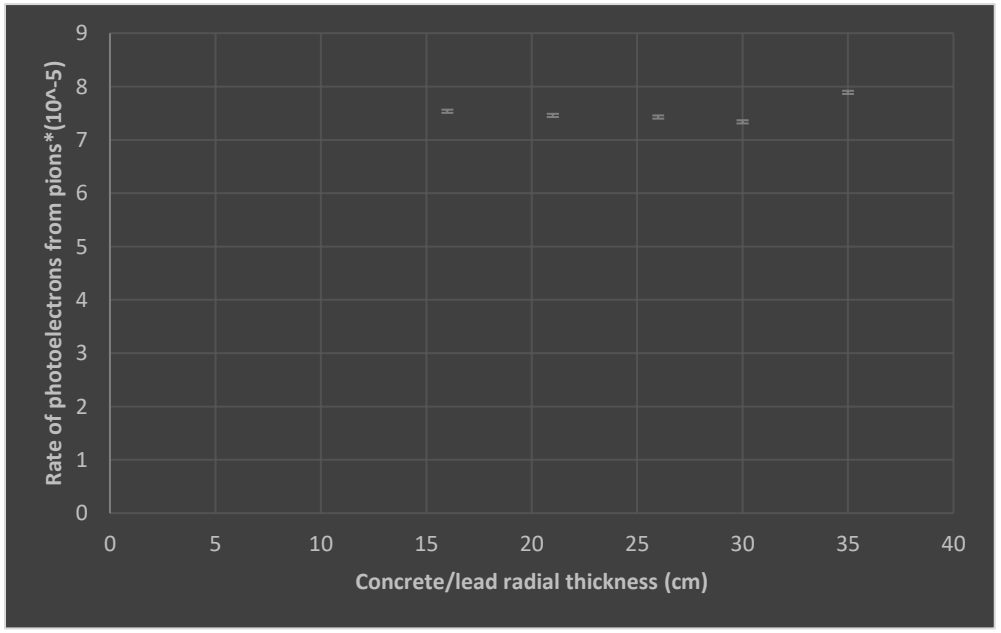
Note: Inclusion of electron, positron, pion, and (anti) Muon (hit.pid==11, -11, 211, -211, 13, -13)

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





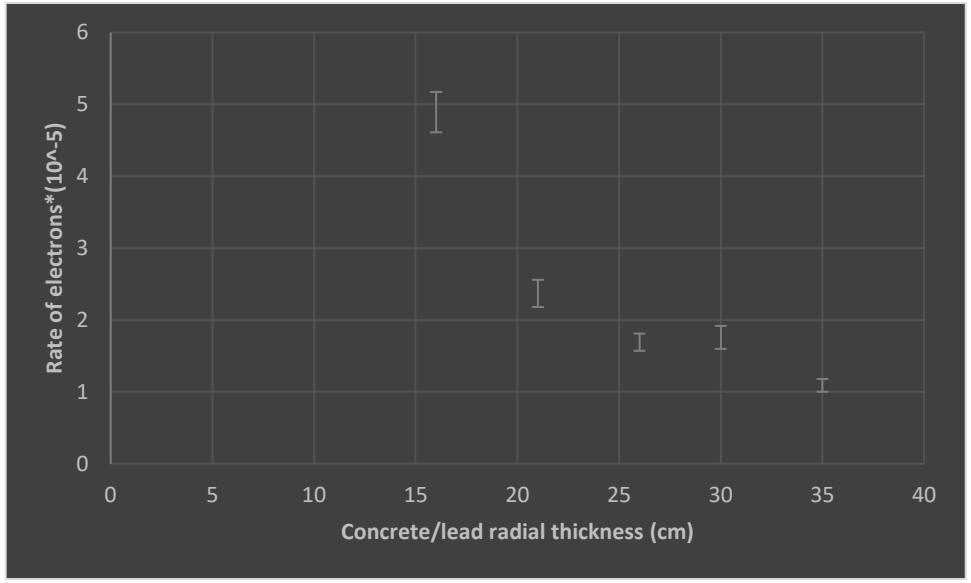


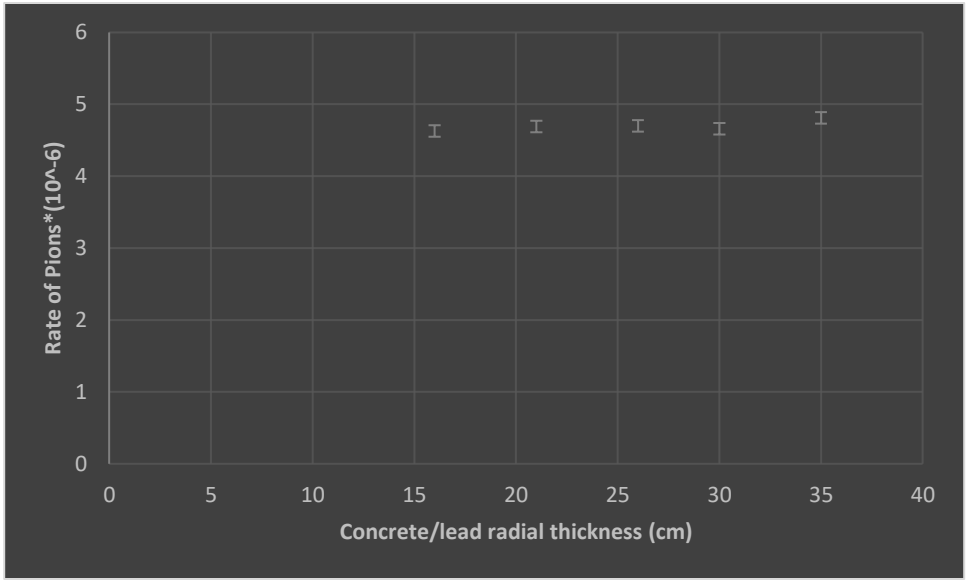


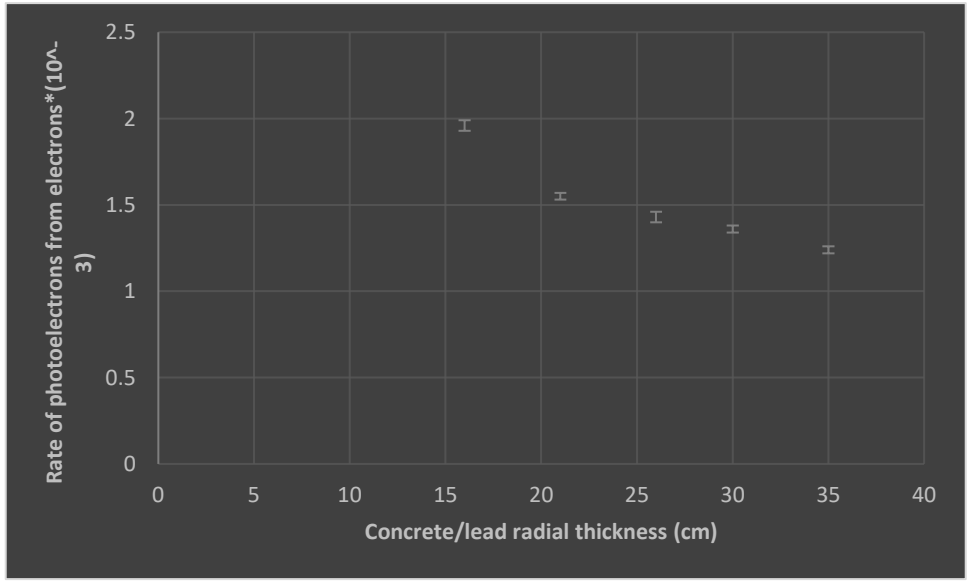
Comparison of rates at the Lucite and PMT for 5,000,000 events (High energy particles, hit.p>2*MeV)

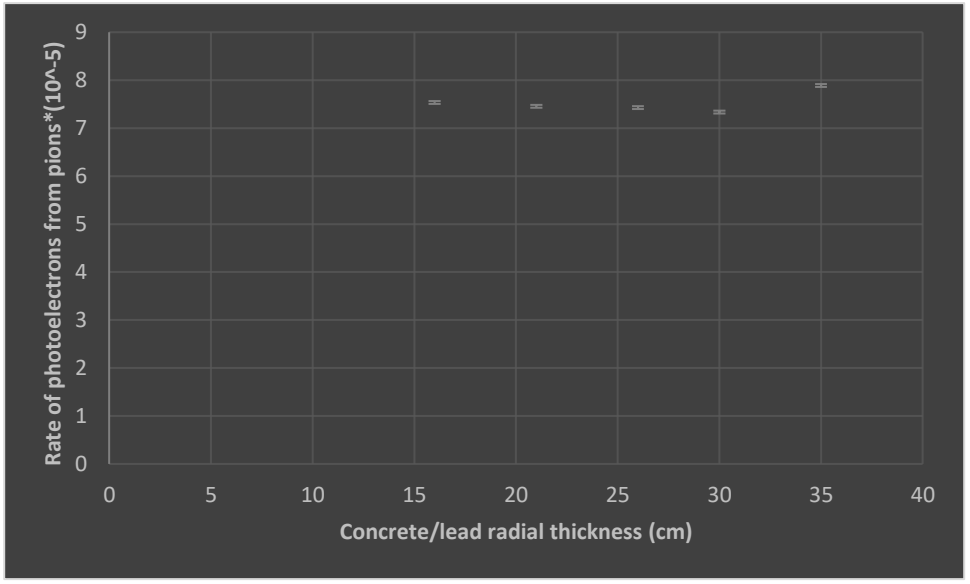
Rates $GHz/\mu A/Detector$	Rate of electrons	Rate of pions	Pi/e	Rate of photoelectrons from electrons	Rate of photoelectrons from pions	Pi/e
Concrete and Lead at 16cm	$(4.89 \pm 0.28) \times 10^{-5}$	$(4.63 \pm 0.08) \times 10^{-6}$	9.47%	$(1.96 \pm 0.03) \times 10^{-3}$	$(7.54 \pm 0.03) \times 10^{-5}$	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)

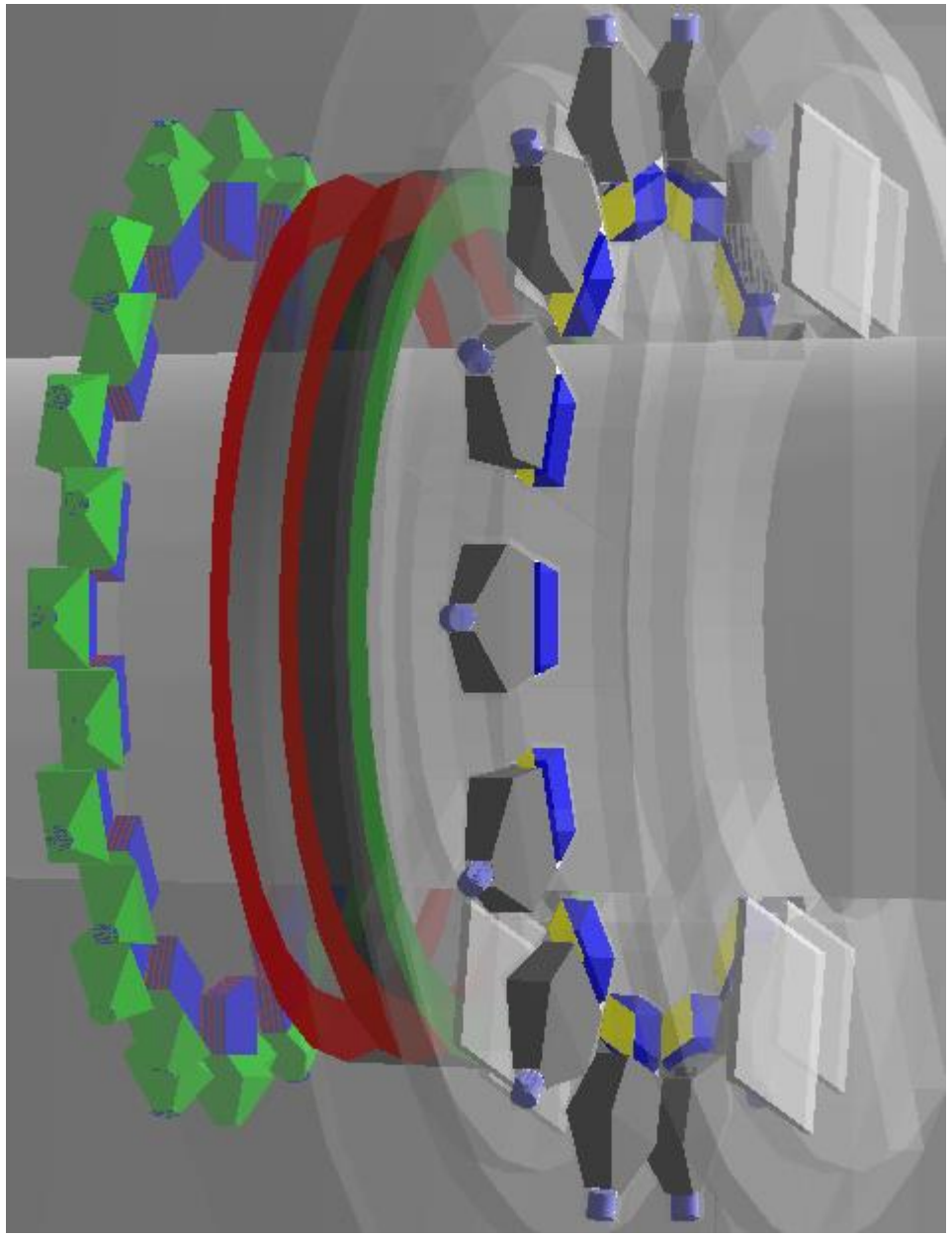


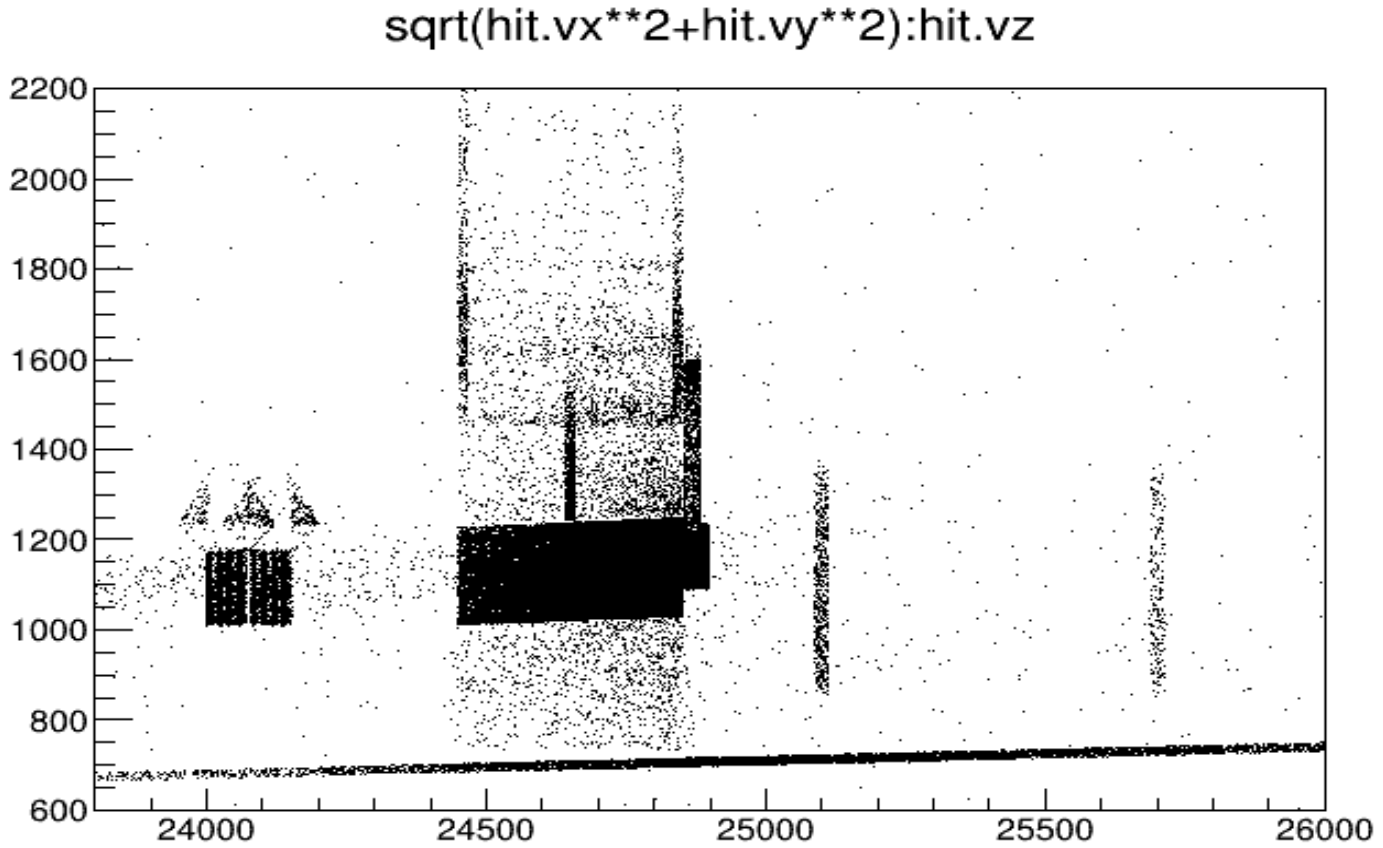






Changing the radial and longitudinal thickness of Concrete and Lead and shifting Lucite inward





- ✓ 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%

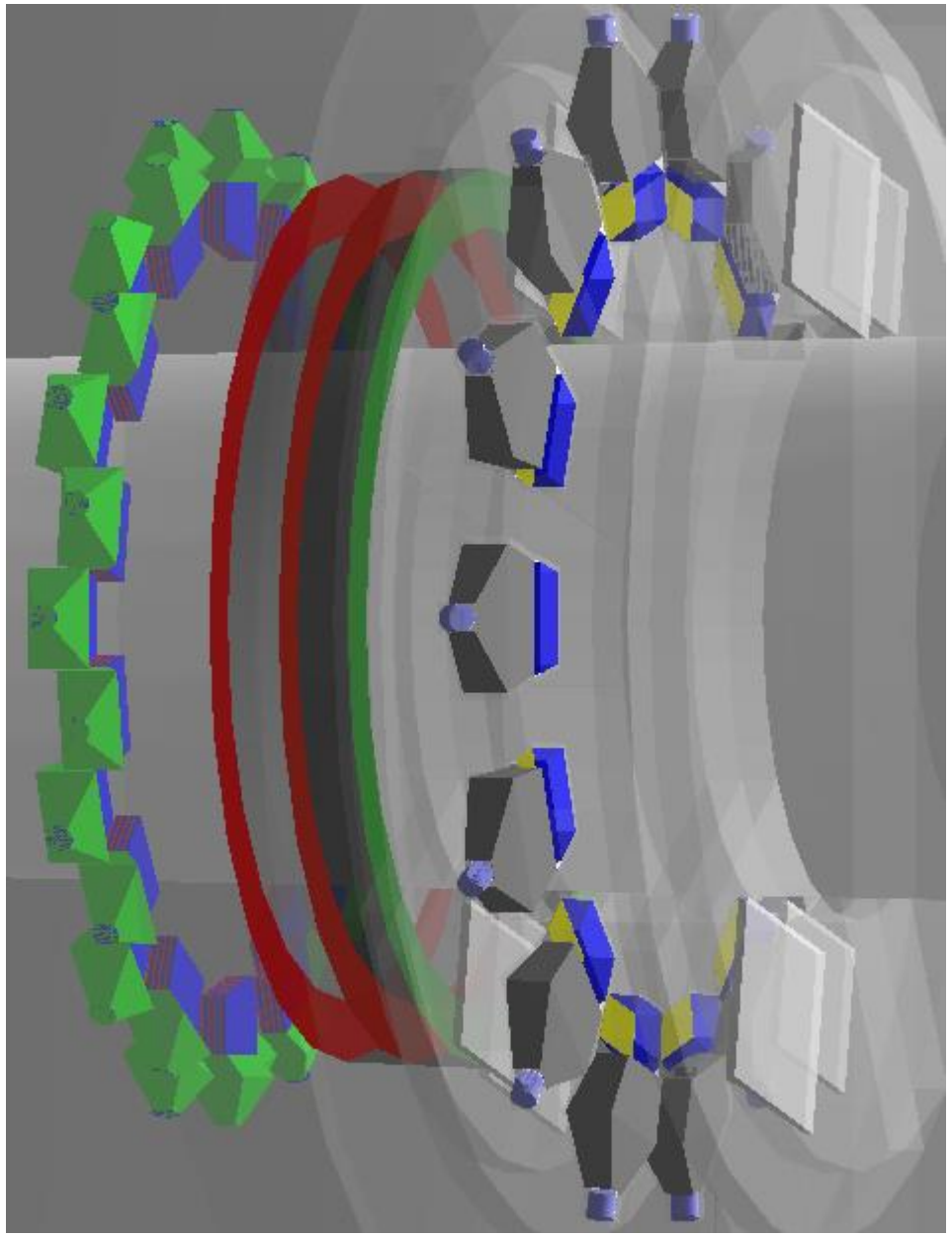
Comparison of rates at the Lucite and PMT for 5,000,000 events (Low energy particles, hit.p<2*MeV)

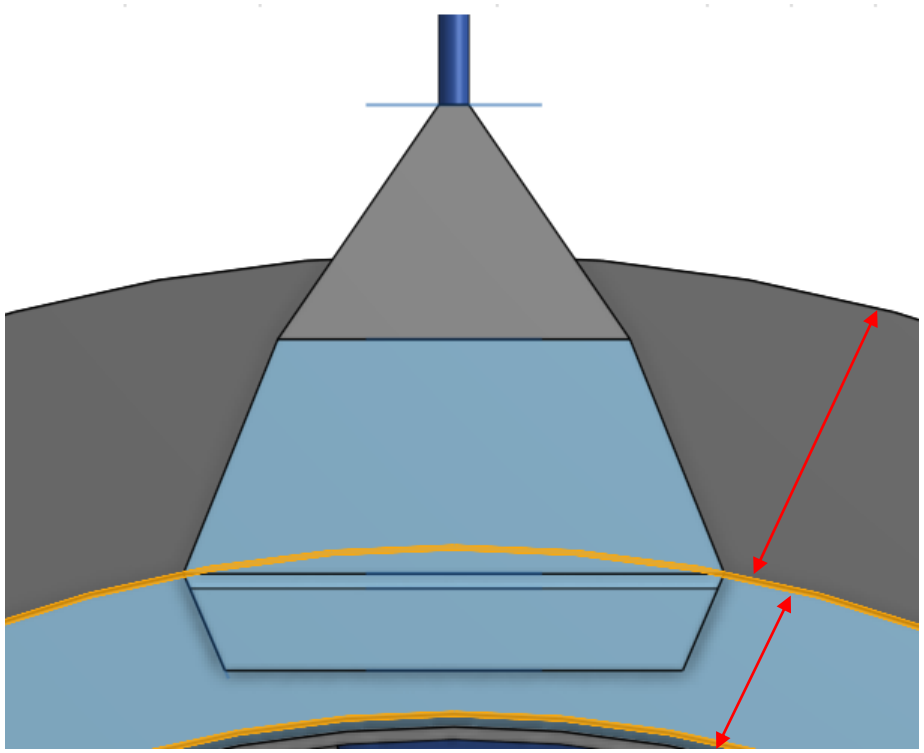
Rates $GHz/\mu A/Detector$	Rate of electrons	Rate of pions	Pi/e	Rate of photoelectrons from electrons	Rate of photoelectrons from pions	Pi/e
Radial thickness of Concrete and Lead at 16cm -7cm Lucite	$(1.12 \pm 0.04) \times 10^{-4}$	$(7.93 \pm 0.30) \times 10^{-7}$	0.71%	$(1.96 \pm 0.03) \times 10^{-3}$	$(7.54 \pm 0.03) \times 10^{-5}$	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



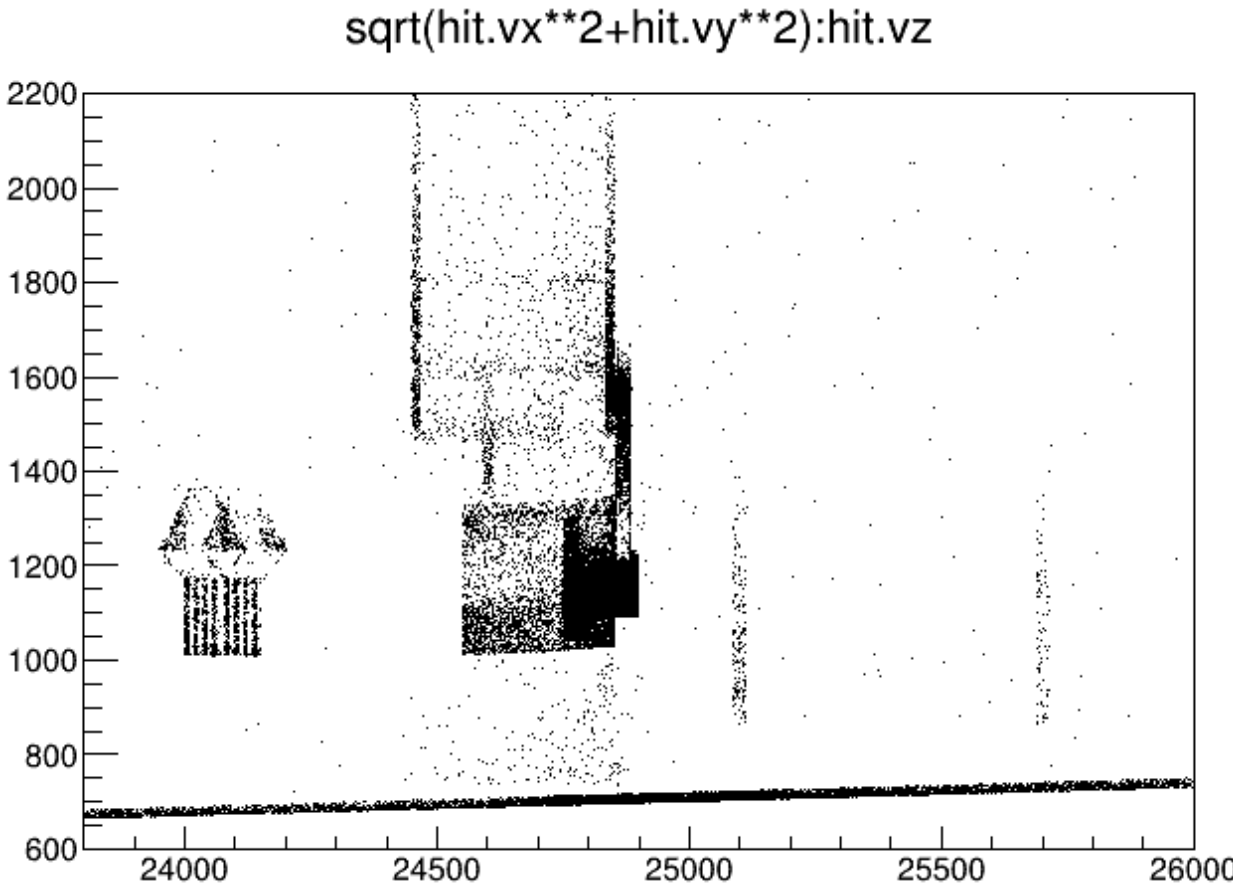


PMT shielding

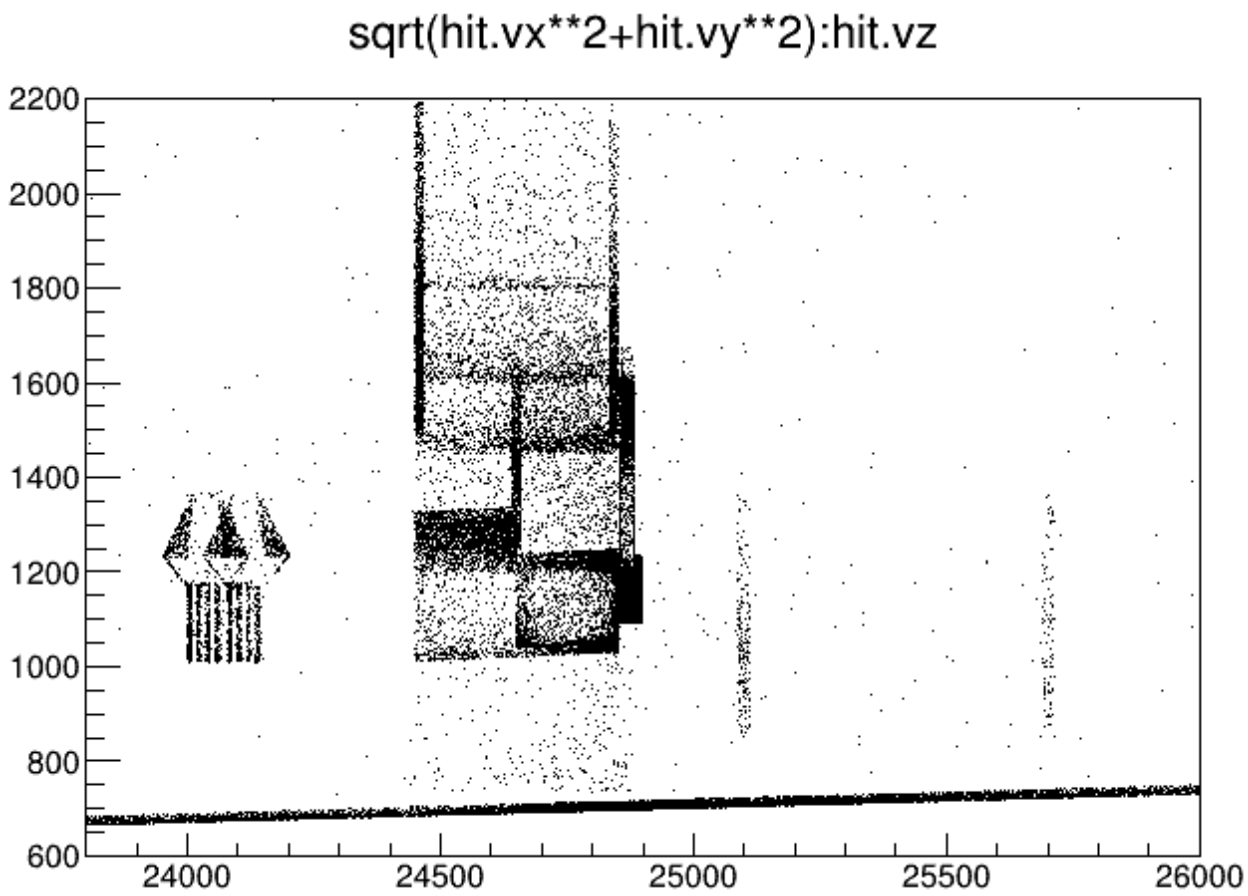
Radial thickness of Concrete and Lead

- ✓ 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 and Lead = 26cm
longitudinal thickness of Concrete = 20cm
longitudinal thickness of Lead = 10cm



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

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**

Results

- ✓ New geometry avoids showermax secondaries into lucite in other sectors
- ✓ Shielding removes low energy particles that are hitting the Lucite when moving backwards
- ✓ Rate of electrons goes down as radial size of the donut is increased
- ✓ When changing the radial thickness of concrete and lead independently, the lead has a much larger impact
- ✓ When changing the longitudinal thickness of concrete and lead independently, thinner Lead has the same results for ration of photoelectron’s rates.

1- Replace the donut by a wall with a hole in simulation

2- Run visualization for Moller generator events that cause light to reach the pion detector PMT

3- Increasing the dimensions of the shielding

4- Change the air to vacuum and see how much scattering of air direct secondaries from the showermax back into the top of Lucite detector

Thank you

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