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

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


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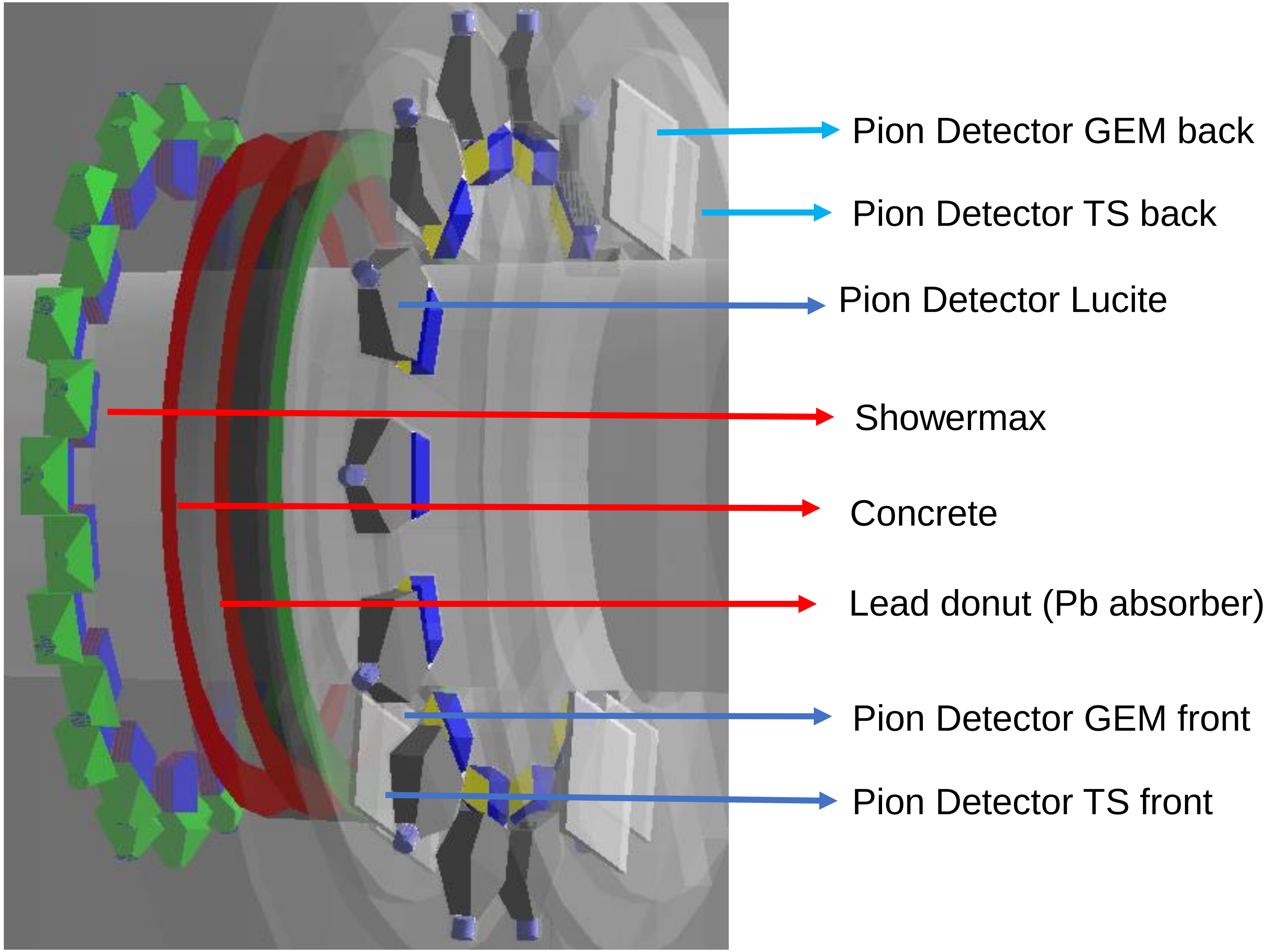
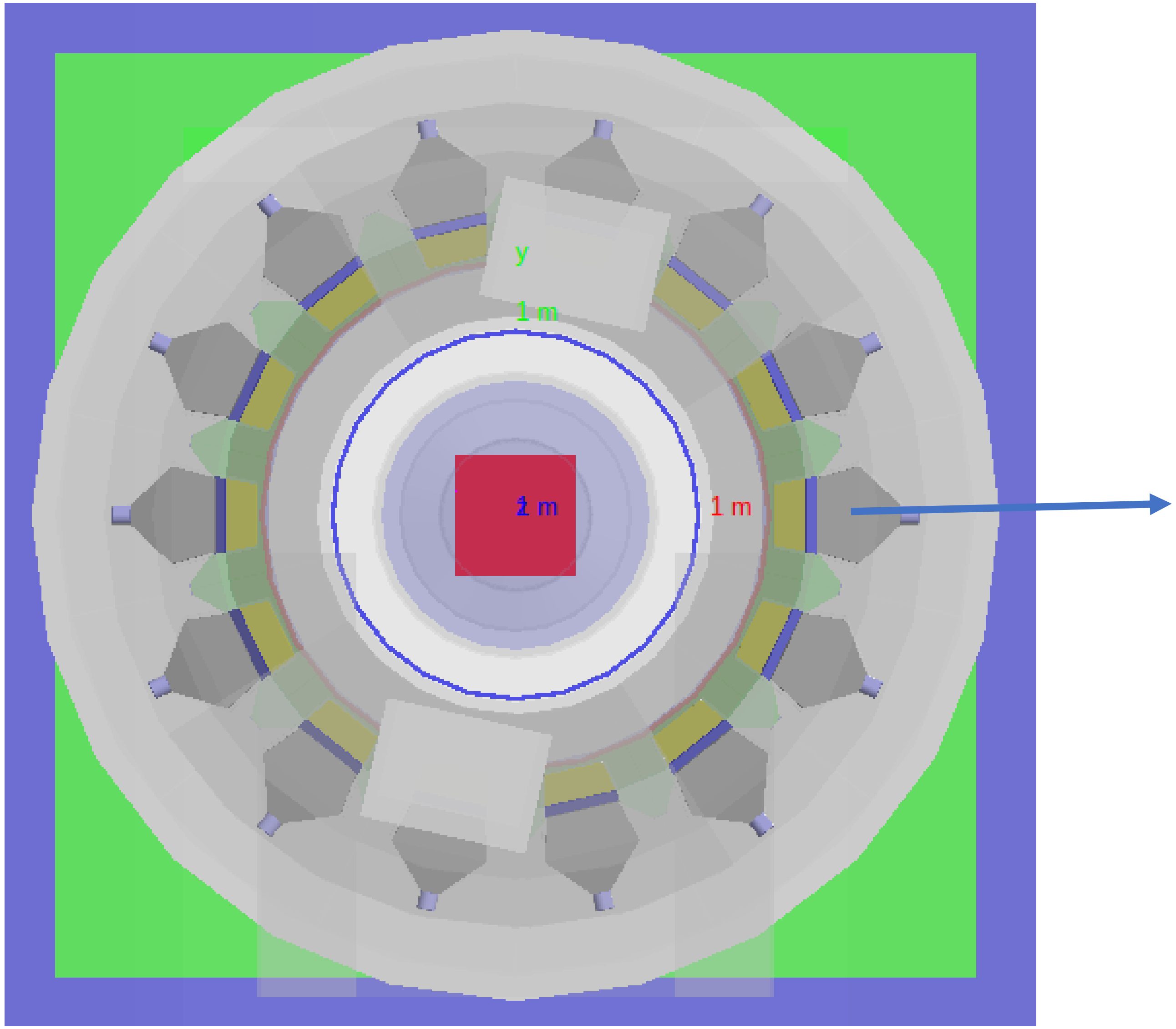
# Presentation Outline

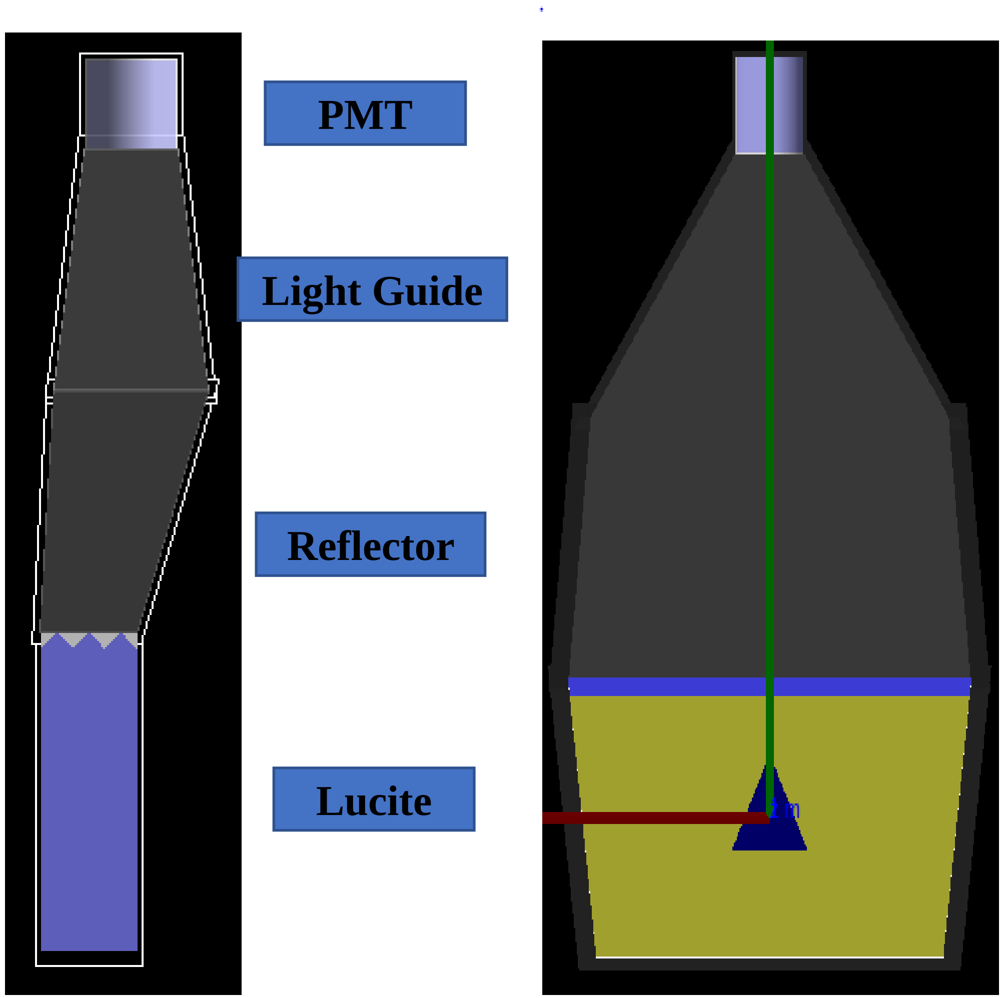
- ✓ **Geometry of Pion Detector system**
- ✓ **Original geometry vs the new geometry**
- ✓ **Problems with the new geometry**
- ✓ **Approaches for resolving the problems**
- ✓ **Results**
- ✓ **Future works**

# Pion Detector geometry

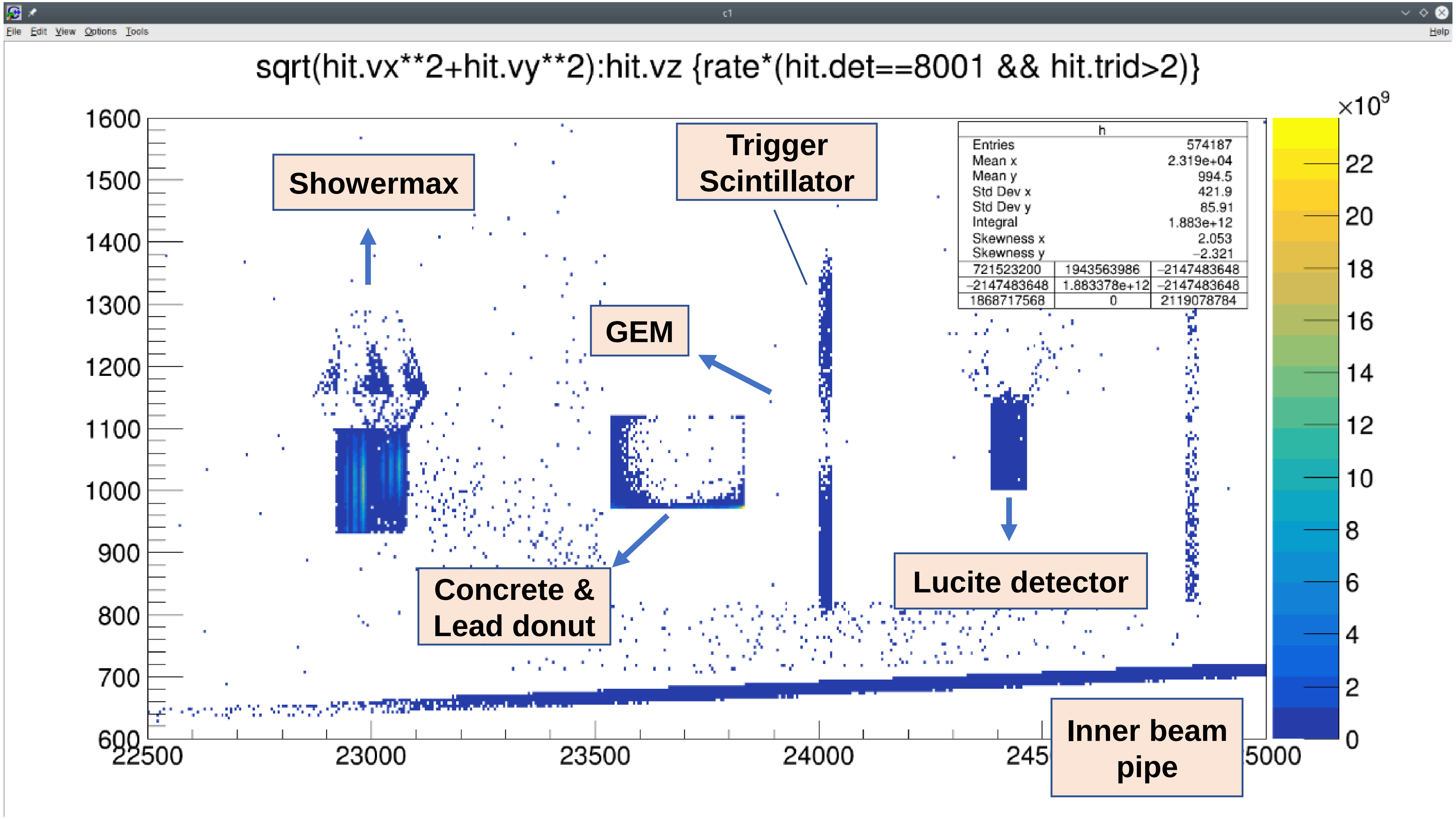


# Pion Detector geometry

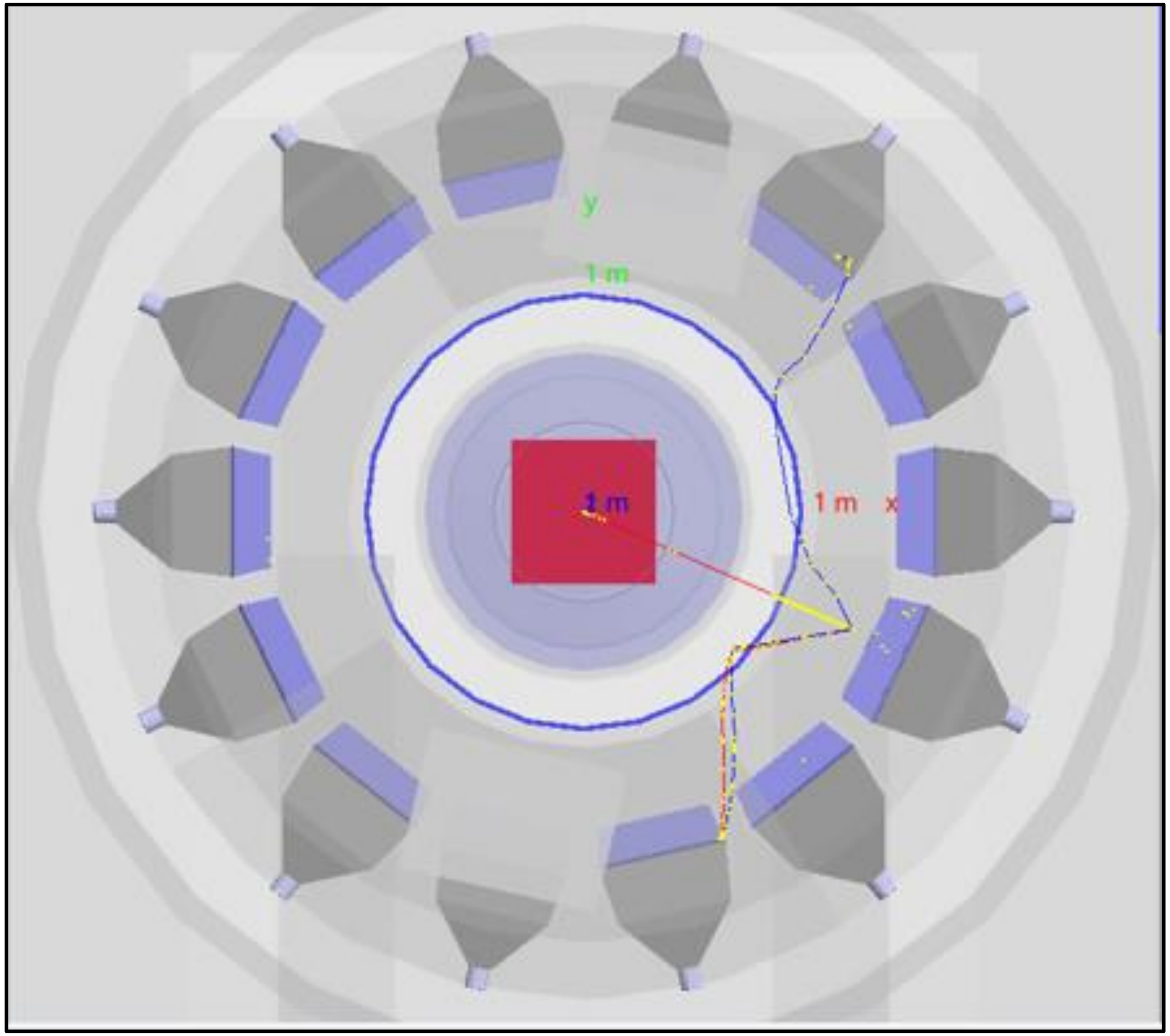


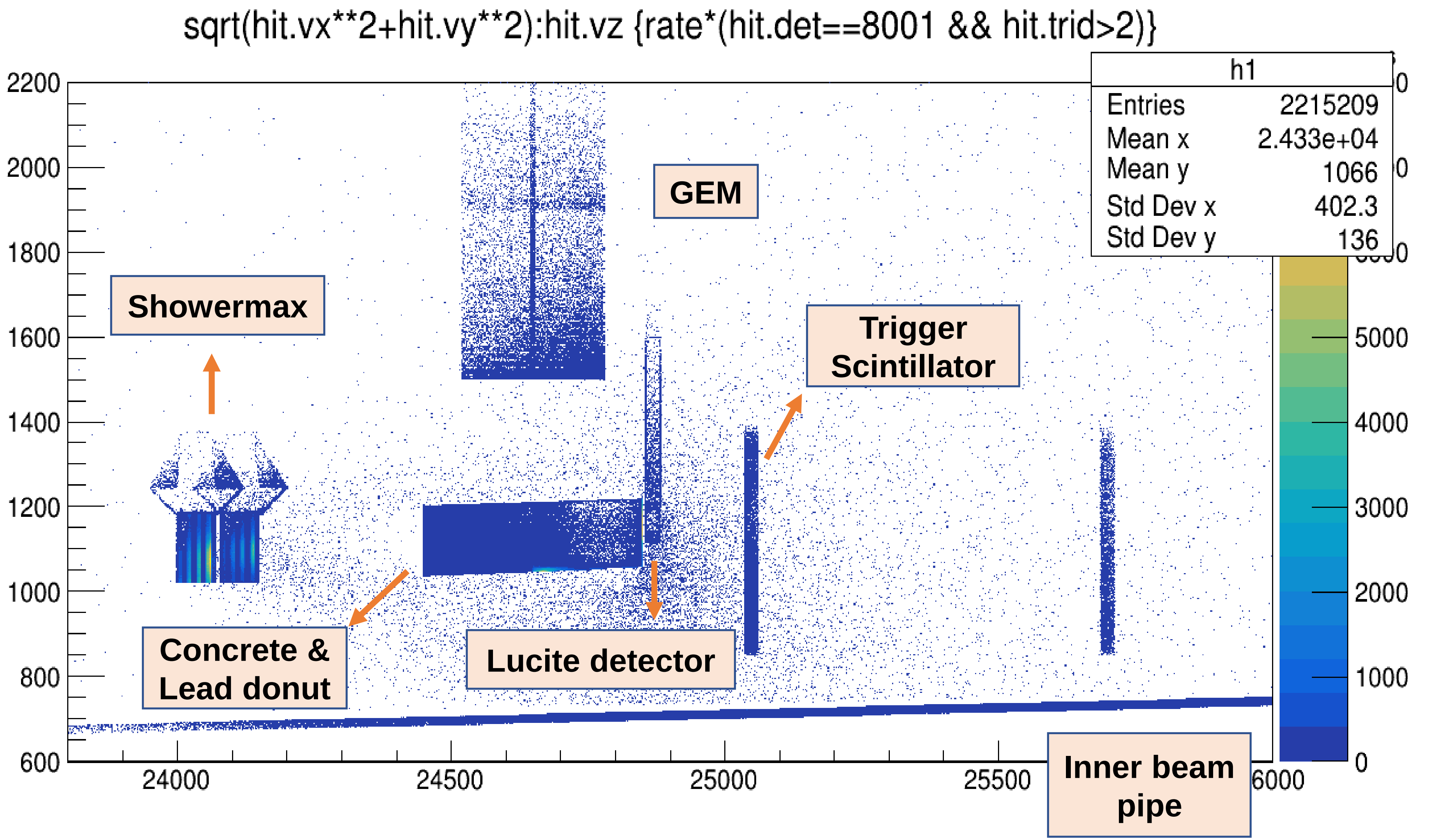
# Original geometry of Pion detector system



# Original geometry of Pion detector system



# New geometry of Pion detector system



## New geometry vs original geometry

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

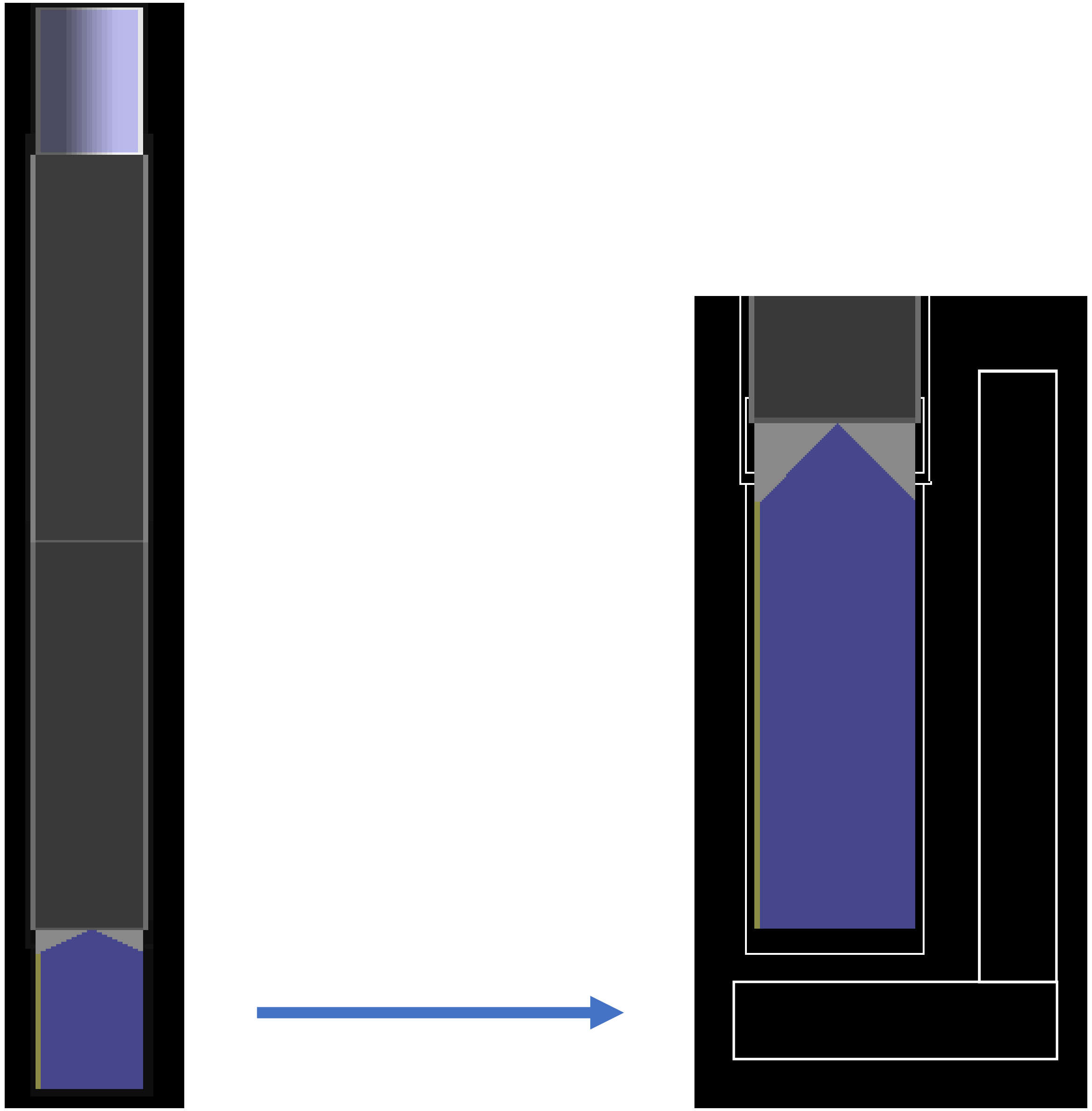
$$\frac{\text{Rate of detected photoelectrons from Pions}}{\text{Rate of detected photoelectrons from electrons}} = 10^{-3} \xrightarrow{\text{New geometry}} 10^{-1}$$

## 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 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% |

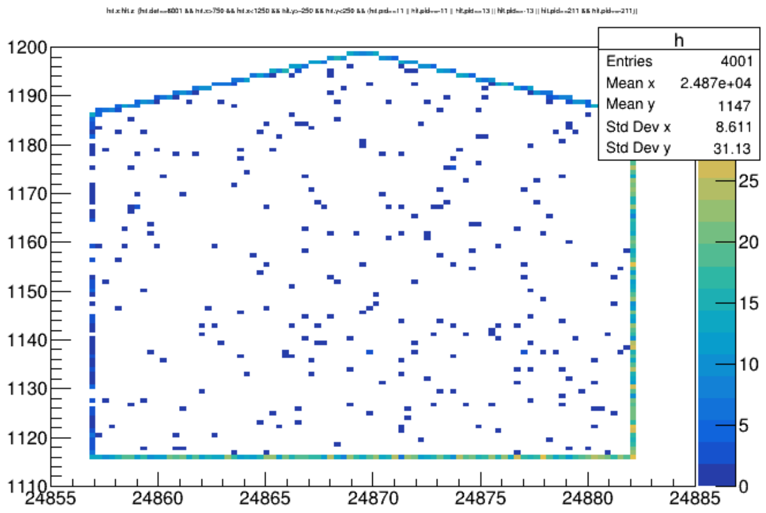
## (High energy particles, hit.p>2*MeV)

| 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% |

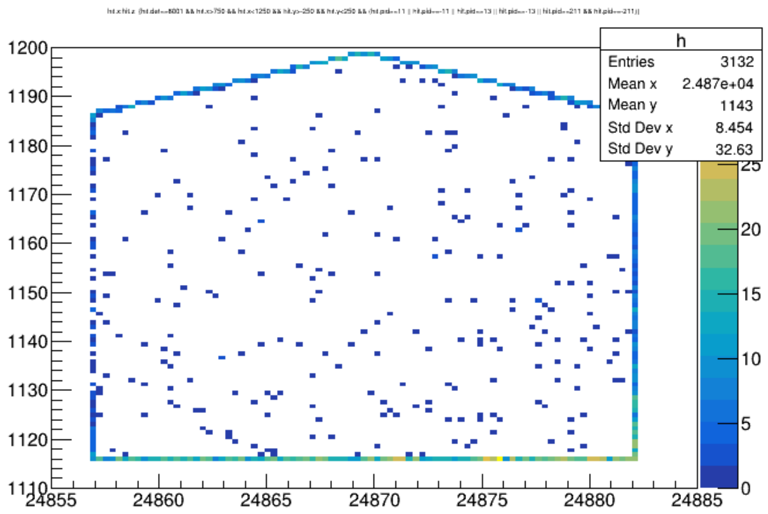
Note: Inclusion of electron, positron, pion, and (anti) Muon (hit.pid==11, -11, 211, -211, 13, -13)

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

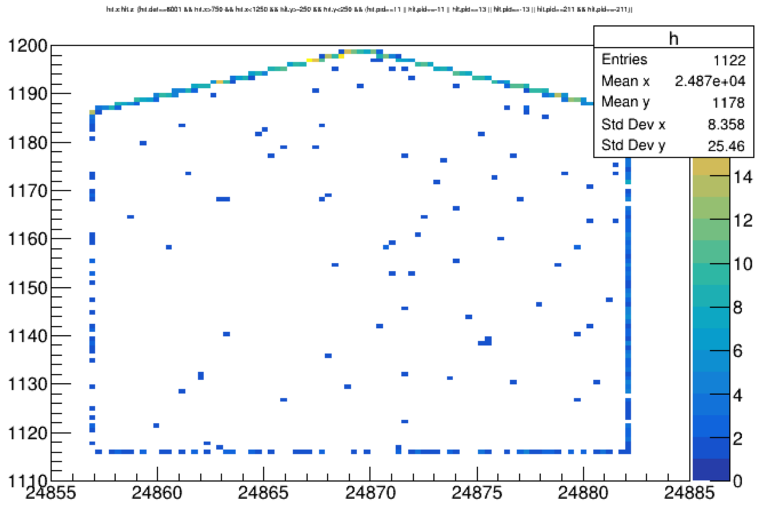
(without shielding)



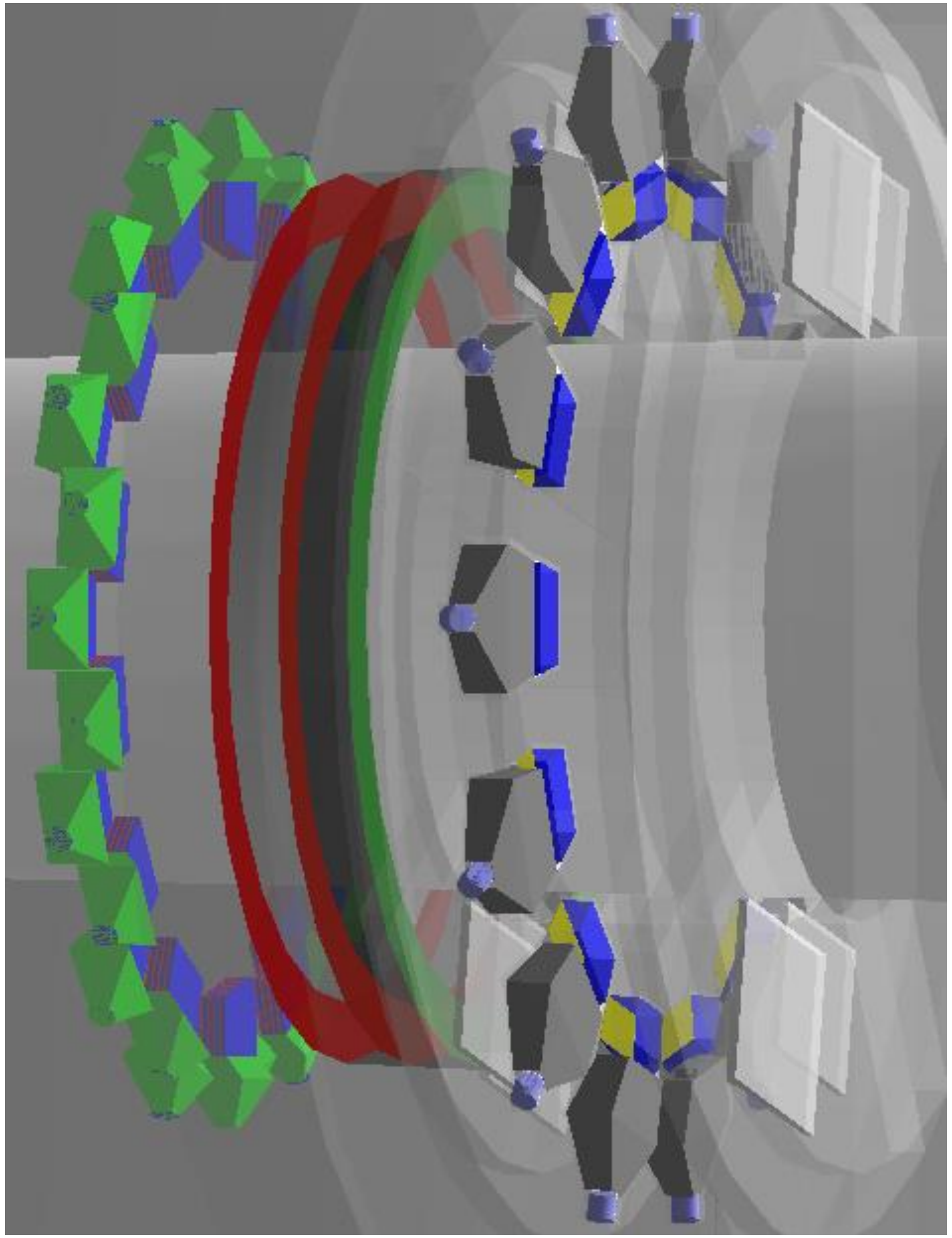

(with downstream shielding)

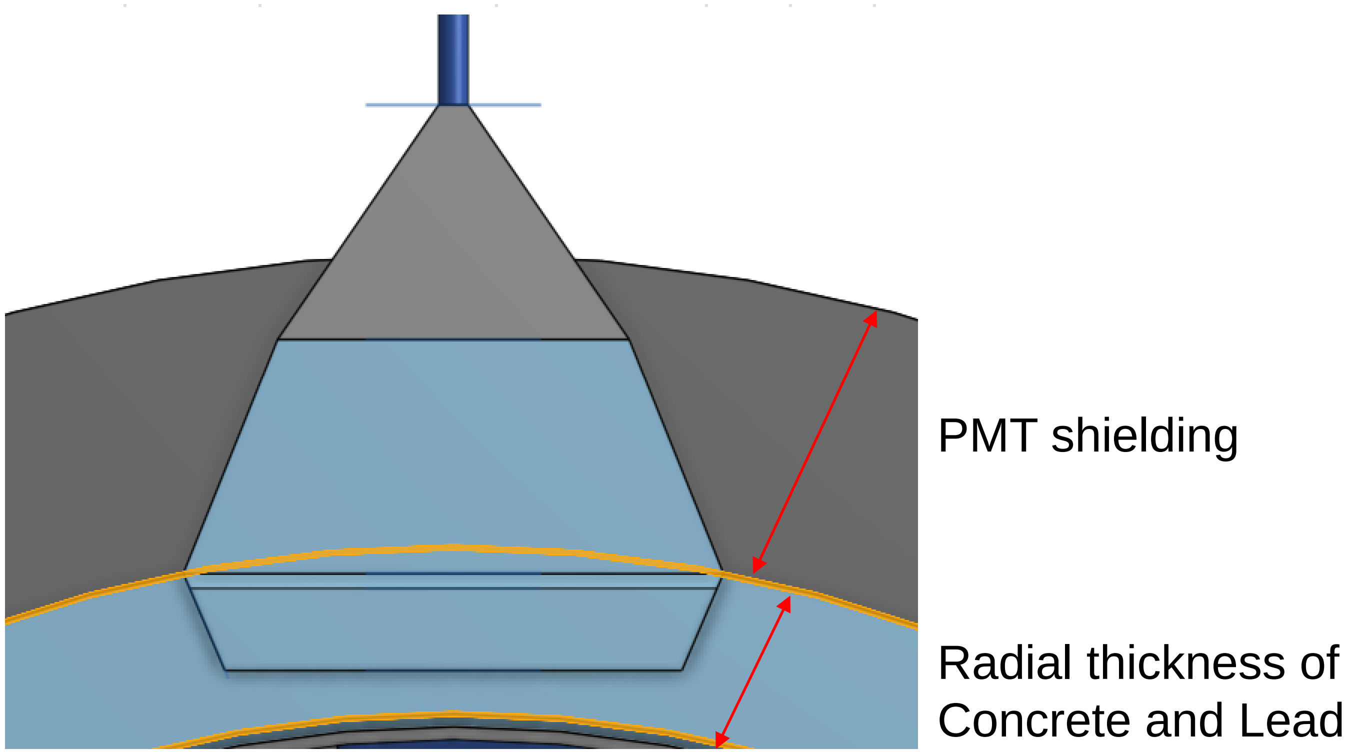



(with inner radial shielding)



# Changing the radial and longitudinal thickness of Concrete and Lead

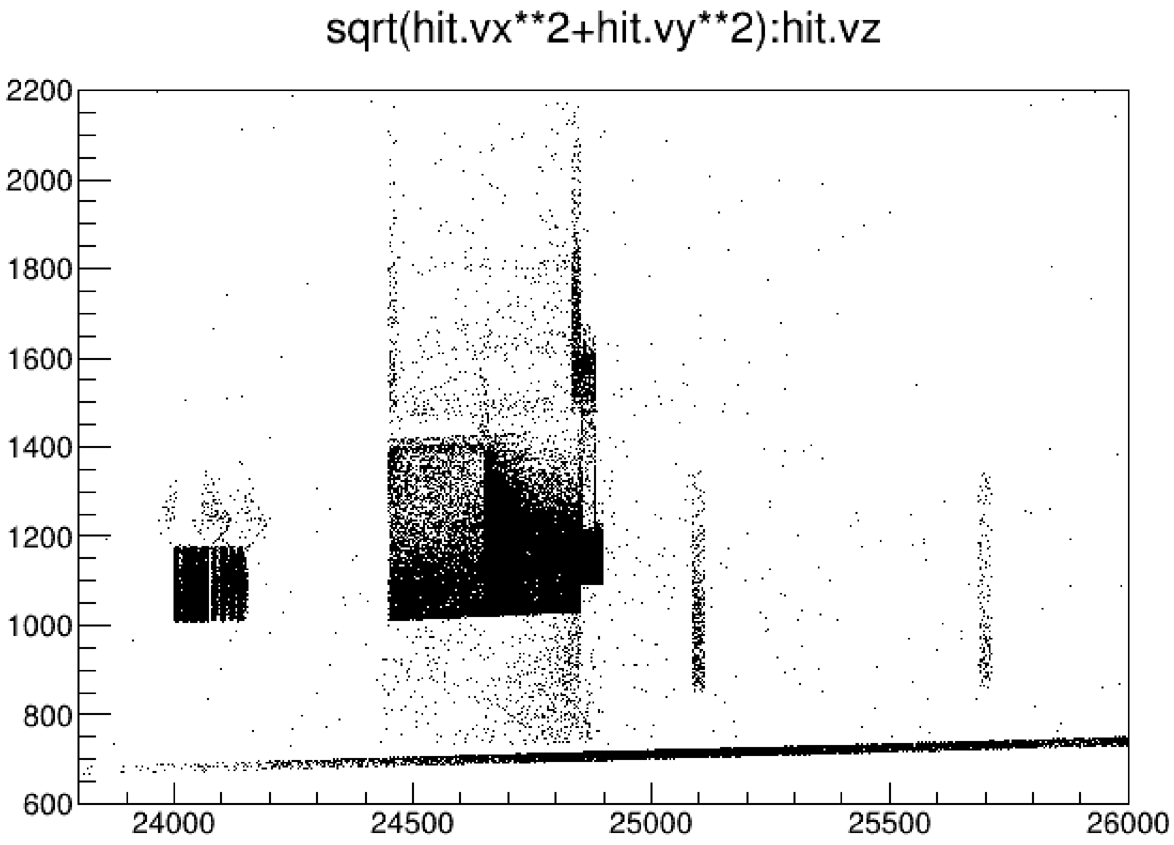




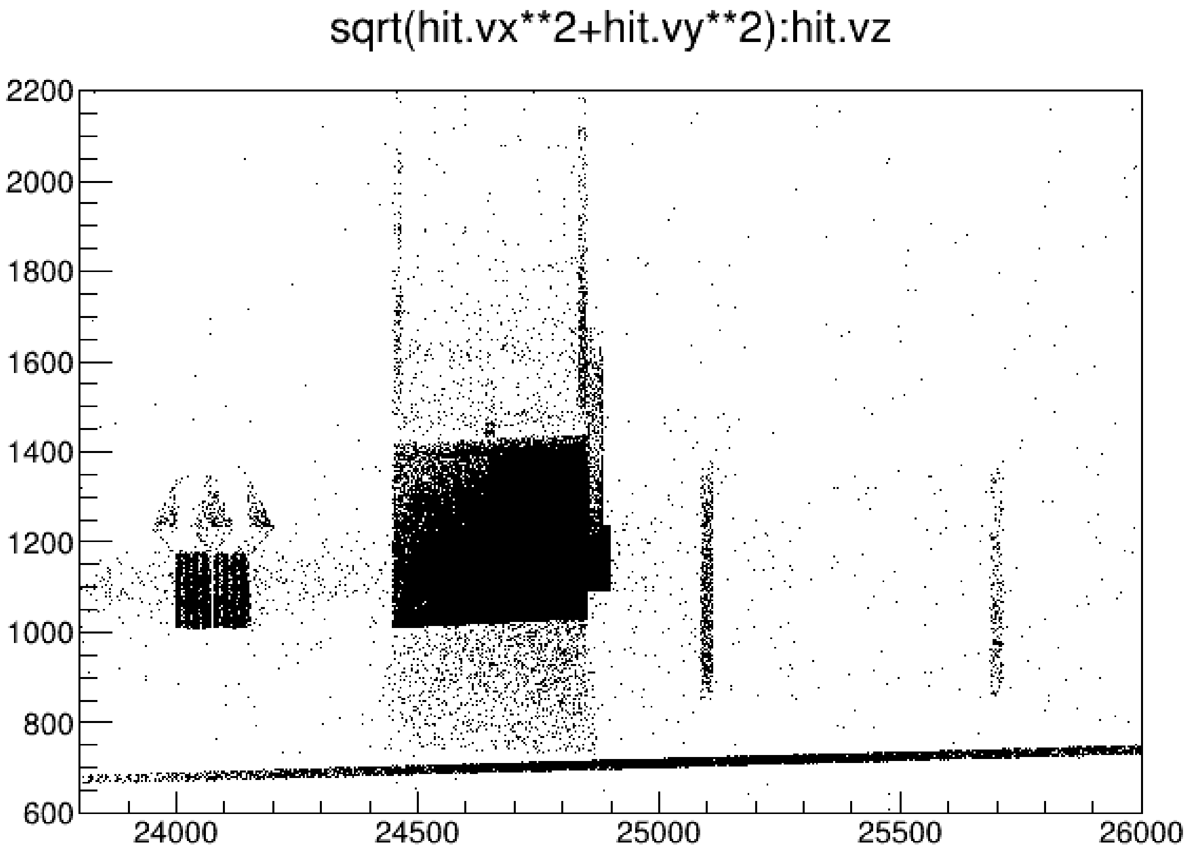

- ✓ Concrete/lead radius extend 16, 21, 26, 30, 35 cm
- ✓ Keep concrete at 16 cm, extend lead only to 26 cm
- ✓ Keep lead at 16 cm, extend concrete only to 26 cm
- ✓ Fix downstream face of donut, then reduce lead thickness

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

## Moller



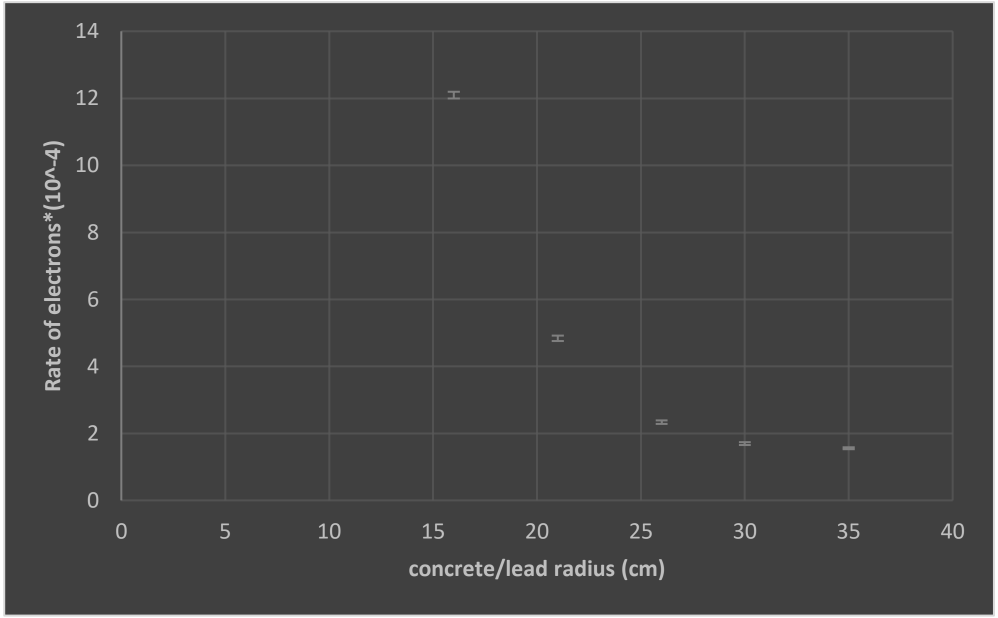

## Pion

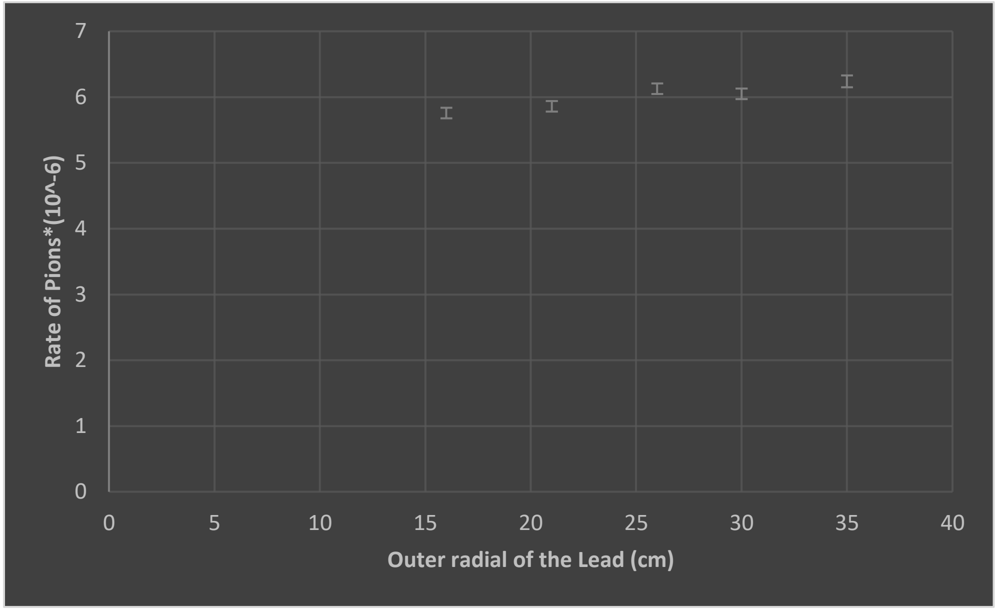


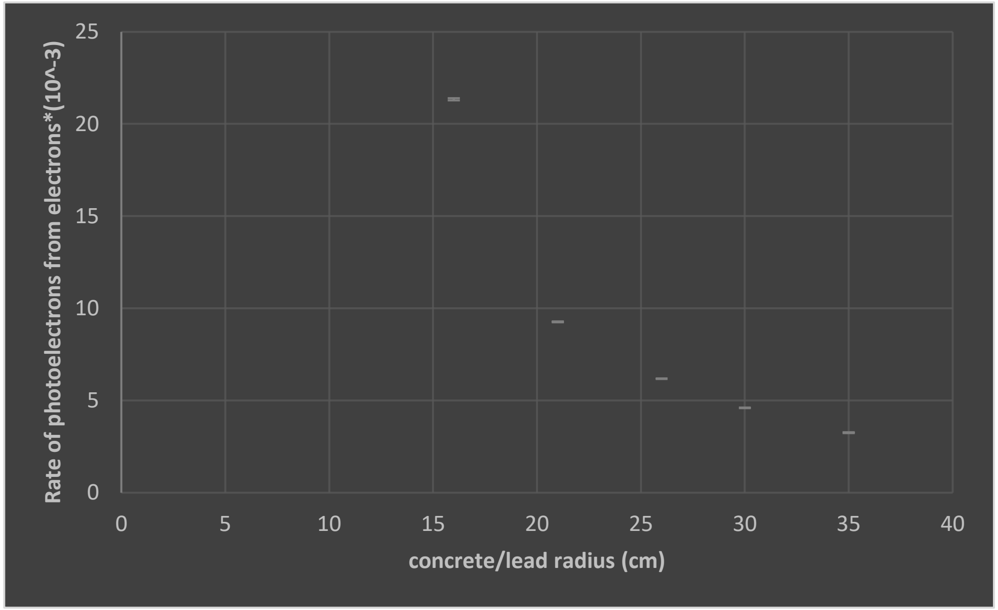
# Comparison of rates at the Lucite for 5,000,000 events (Low energy particles, hit.p<2*MeV)

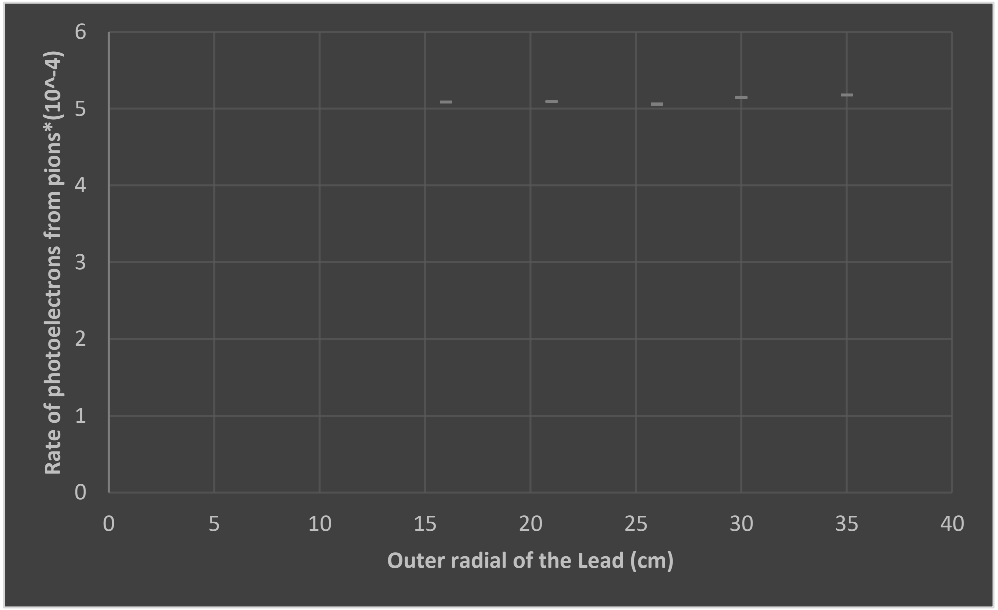
| Rates $GHz/\mu A$ $/Detector$ | Rate of electrons | Rate of pions | Pi/e | Rate of photoelectrons from electrons | Rate of photoelectrons from pions | Pi/e |
|---|---|---|---|---|---|---|
| Concrete and Lead at 16cm | $(1.21 \pm 0.01) \times 10^{-3}$ | $(5.76 \pm 0.08) \times 10^{-6}$ | 0.48% | $(2.134 \pm 0.006) \times 10^{-2}$ | $(5.087 \pm 0.008) \times 10^{-4}$ | 2.38% |
| Concrete and Lead at 21cm | $(4.84 \pm 0.08) \times 10^{-4}$ | $(5.86 \pm 0.08) \times 10^{-6}$ | 1.21% | $(9.26 \pm 0.03) \times 10^{-3}$ | $(5.092 \pm 0.008) \times 10^{-4}$ | 5.50% |
| Concrete and Lead at 26cm | $(2.34 \pm 0.05) \times 10^{-4}$ | $(6.13 \pm 0.08) \times 10^{-6}$ | 2.62% | $(6.18 \pm 0.02) \times 10^{-3}$ | $(5.059 \pm 0.008) \times 10^{-4}$ | 8.18% |
| Concrete and Lead at 30cm | $(1.70 \pm 0.04) \times 10^{-4}$ | $(6.05 \pm 0.08) \times 10^{-6}$ | 3.56% | $(4.60 \pm 0.02) \times 10^{-3}$ | $(5.149 \pm 0.008) \times 10^{-4}$ | 11.19% |
| Concrete and Lead at 35cm | $(1.56 \pm 0.03) \times 10^{-4}$ | $(6.24 \pm 0.09) \times 10^{-6}$ | 4% | $(3.25 \pm 0.02) \times 10^{-3}$ | $(5.179 \pm 0.008) \times 10^{-4}$ | 15.93% |

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



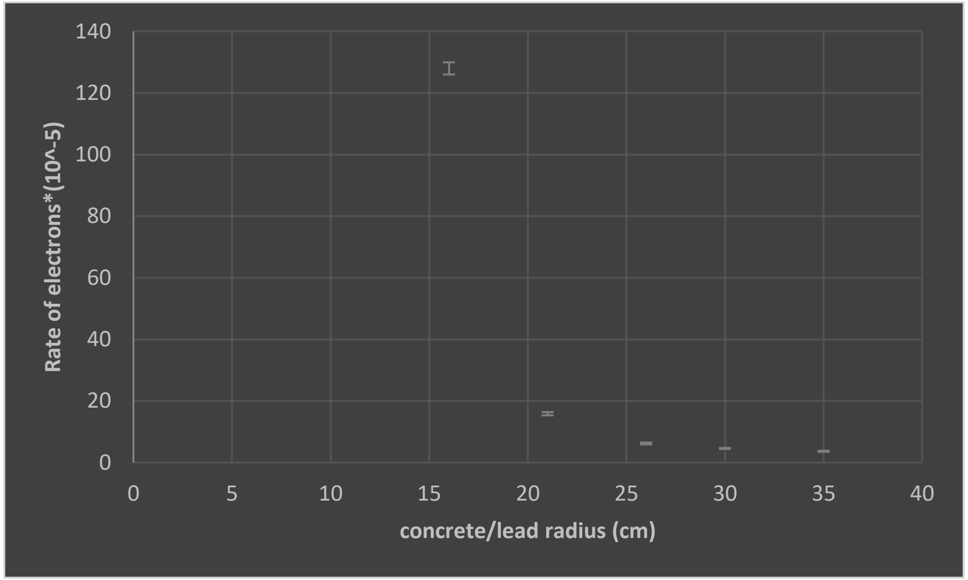



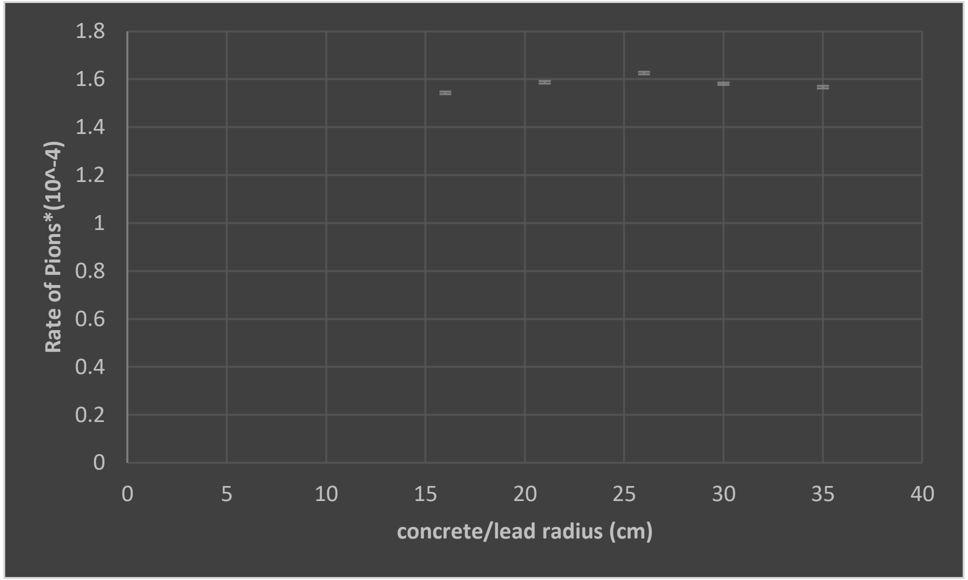



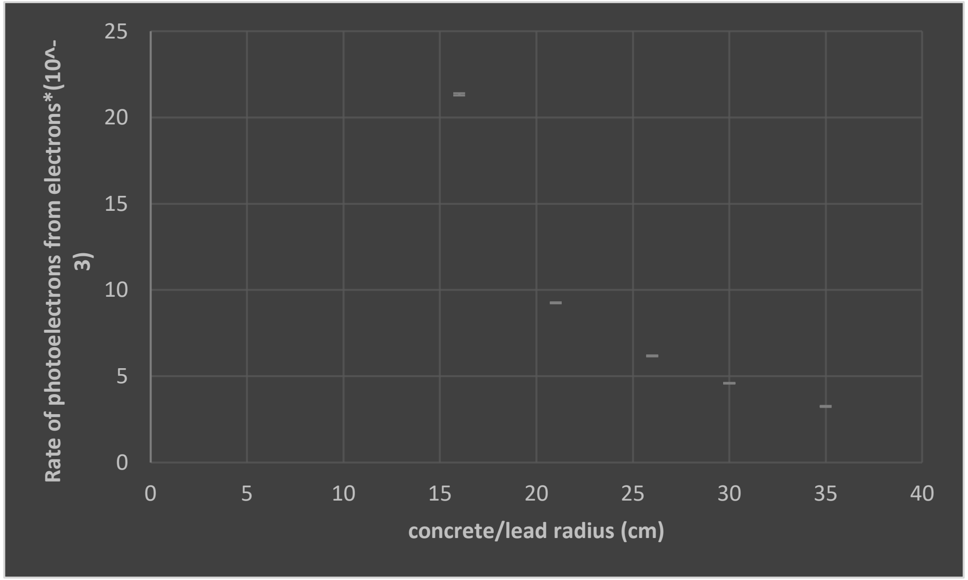
# Comparison of rates at the Lucite for 5,000,000 events (High energy particles, hit.p>2*MeV)

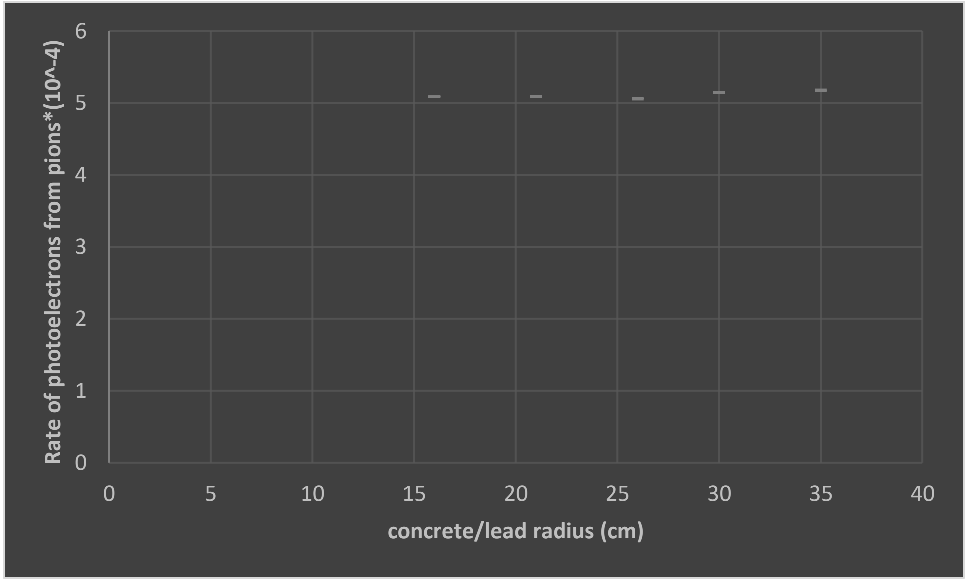
| Rates $GHz/\mu A$ $/Detector$ | Rate of electrons | Rate of pions | Pi/e | Rate of photoelectrons from electrons | Rate of photoelectrons from pions | Pi/e |
|---|---|---|---|---|---|---|
| Concrete and Lead at 16cm | $(1.28 \pm 0.02) \times 10^{-3}$ | $(1.543 \pm 0.005) \times 10^{-4}$ | 12.05% | $(2.134 \pm 0.006) \times 10^{-2}$ | $(5.087 \pm 0.008) \times 10^{-4}$ | 2.38% |
| Concrete and Lead at 21cm | $(1.59 \pm 0.05) \times 10^{-4}$ | $(1.587 \pm 0.005) \times 10^{-4}$ | 99.8% | $(9.26 \pm 0.03) \times 10^{-3}$ | $(5.092 \pm 0.008) \times 10^{-4}$ | 5.50% |
| Concrete and Lead at 26cm | $(6.22 \pm 0.28) \times 10^{-5}$ | $(1.626 \pm 0.005) \times 10^{-4}$ | 261% | $(6.18 \pm 0.02) \times 10^{-3}$ | $(5.059 \pm 0.008) \times 10^{-4}$ | 8.1% |
| Concrete and Lead at 30cm | $(4.59 \pm 0.19) \times 10^{-5}$ | $(1.581 \pm 0.005) \times 10^{-4}$ | 344% | $(4.60 \pm 0.02) \times 10^{-3}$ | $(5.149 \pm 0.008) \times 10^{-4}$ | 11.19% |
| Concrete and Lead at 35cm | $(3.69 \pm 0.15) \times 10^{-5}$ | $(1.567 \pm 0.005) \times 10^{-4}$ | 424% | $(3.25 \pm 0.02) \times 10^{-3}$ | $(5.179 \pm 0.008) \times 10^{-4}$ | 15.93% |

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



# 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 photoelectrons from electrons | Rate of photoelectrons from pions | Pi/e |
|---|---|---|---|---|---|---|
| R-T of Concrete and Lead at 26cm | $(2.34 \pm 0.05) \times 10^{-4}$ | $(6.13 \pm 0.08) \times 10^{-6}$ | 2.62% | $(6.18 \pm 0.02) \times 10^{-3}$ | $(5.059 \pm 0.008) \times 10^{-4}$ | 8.18% |
| R-T of concrete at 16 cm and Lead at 26 cm | $(2.90 \pm 0.05) \times 10^{-4}$ | $(6.01 \pm 0.08) \times 10^{-6}$ | 2.07% | $(7.74 \pm 0.02) \times 10^{-3}$ | $(5.135 \pm 0.008) \times 10^{-4}$ | 6.63% |
| R-T of concrete at 26 cm and Lead at 16 cm | $(1.90 \pm 0.01) \times 10^{-3}$ | $(5.98 \pm 0.08) \times 10^{-6}$ | 0.31% | $(3.120 \pm 0.006) \times 10^{-2}$ | $(5.111 \pm 0.008) \times 10^{-4}$ | 1.64% |
| L-T of Concrete at 30cm and Lead at 10cm (R-T at 26) | $(1.36 \pm 0.01) \times 10^{-3}$ | $(8.29 \pm 0.10) \times 10^{-6}$ | 0.61% | $(2.785 \pm 0.005) \times 10^{-2}$ | $(6.919 \pm 0.009) \times 10^{-4}$ | 2.48% |
| R-T of Concrete and Lead at 16cm | $(1.21 \pm 0.01) \times 10^{-3}$ | $(5.76 \pm 0.08) \times 10^{-6}$ | 0.48% | $(2.134 \pm 0.006) \times 10^{-2}$ | $(5.087 \pm 0.008) \times 10^{-4}$ | 2.38% |
| L-T of Concrete at 20cm and Lead at 10cm (R-T at 16) | $(3.22 \pm 0.02) \times 10^{-3}$ | $(8.83 \pm 0.10) \times 10^{-6}$ | 0.27% | $(5.720 \pm 0.708) \times 10^{-2}$ | $(7.336 \pm 0.009) \times 10^{-4}$ | 1.28% |

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

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

| Rates<br>$GHz/\mu A/Detector$ | 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 | $(6.22 \pm 0.28) \times 10^{-5}$ | $(1.626 \pm 0.005) \times 10^{-4}$ | 261% | $(6.18 \pm 0.02) \times 10^{-3}$ | $(5.059 \pm 0.008) \times 10^{-4}$ | 8.18% |
| R-T of concrete at 16 cm and Lead at 26 cm | $(8.07 \pm 0.30) \times 10^{-5}$ | $(1.572 \pm 0.005) \times 10^{-4}$ | 195% | $(7.74 \pm 0.02) \times 10^{-3}$ | $(5.078 \pm 0.008) \times 10^{-4}$ | 6.56% |
| R-T of concrete at 26 cm and Lead at 16 cm | $(2.10 \pm 0.02) \times 10^{-3}$ | $(1.620 \pm 0.005) \times 10^{-4}$ | 7.71% | $(3.120 \pm 0.006) \times 10^{-2}$ | $(5.212 \pm 0.008) \times 10^{-4}$ | 1.67% |
| L-T of Concrete at 30cm and Lead at 10cm (R-T at 26) | $(2.83 \pm 0.02) \times 10^{-3}$ | $(2.678 \pm 0.006) \times 10^{-4}$ | 9.46% | $(5.720 \pm 0.708) \times 10^{-2}$ | $(7.336 \pm 0.009) \times 10^{-4}$ | 1.28% |
| R-T of Concrete and Lead at 16cm | $(1.28 \pm 0.02) \times 10^{-3}$ | $(1.543 \pm 0.005) \times 10^{-4}$ | 12.05% | $(2.134 \pm 0.006) \times 10^{-2}$ | $(5.087 \pm 0.008) \times 10^{-4}$ | 2.38% |
| L-T of Concrete at 20cm and Lead at 10cm (R-T at 16) | $(6.16 \pm 0.07) \times 10^{-3}$ | $(2.189 \pm 0.005) \times 10^{-4}$ | 3.55% | $(2.785 \pm 0.005) \times 10^{-2}$ | $(6.919 \pm 0.009) \times 10^{-4}$ | 2.48% |

**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, the lead has a larger impact

1- Shifting Lucite inward to avoid hitting at the edges

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

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

4- Increasing the dimensions of the shielding

5- 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

University of Manitoba