MOLLER Pion Detector Design: Progress Update

Different concrete/lead radius for the new geometry with shielding in the electron and pion generator

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

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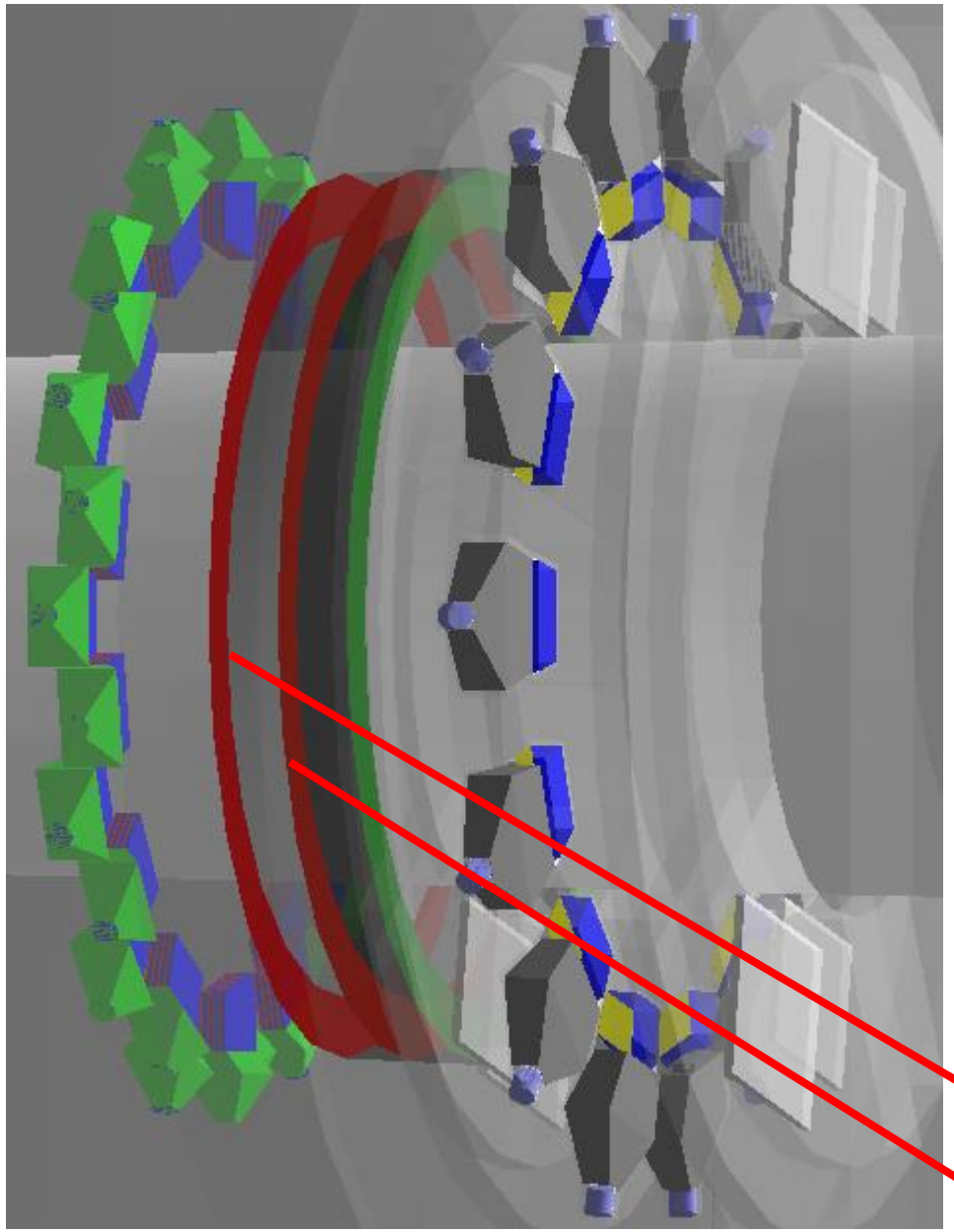
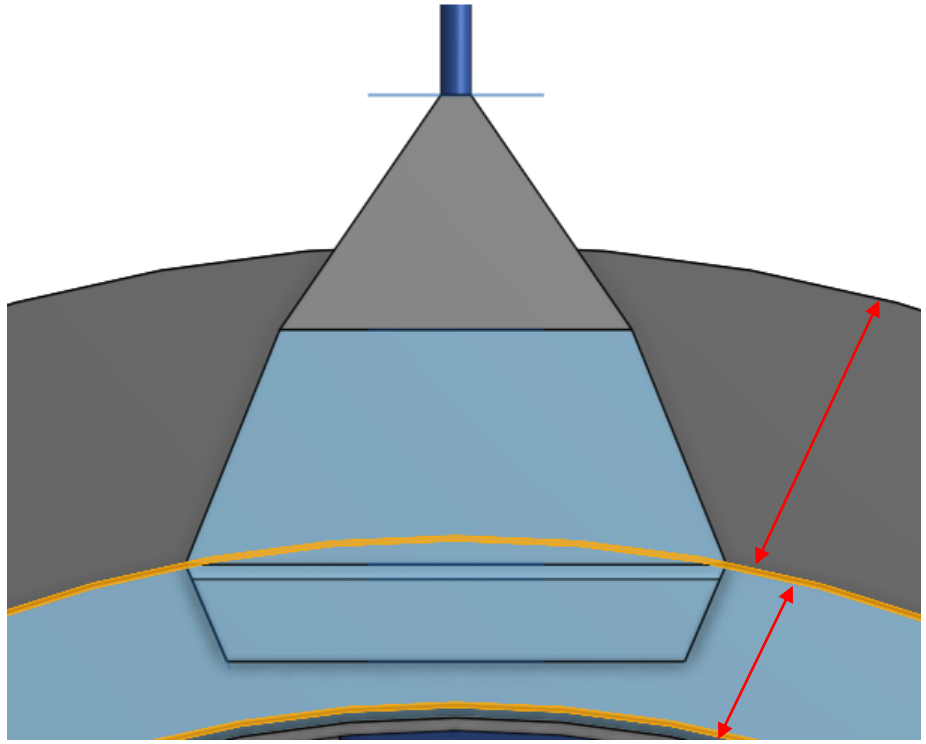
University of Manitoba

Geometry of Pion detector



Concrete
Lead donut (Pb absorber)

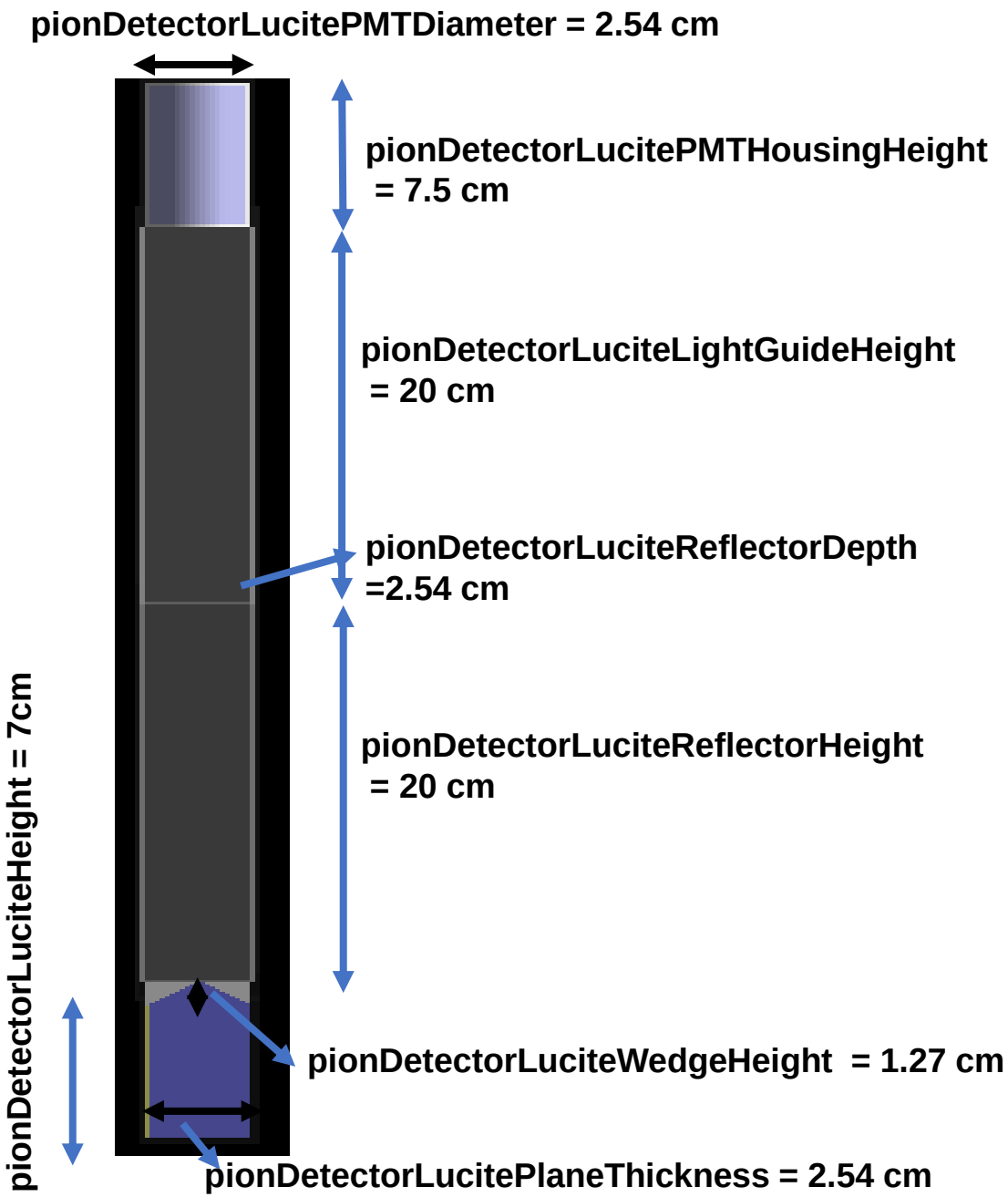


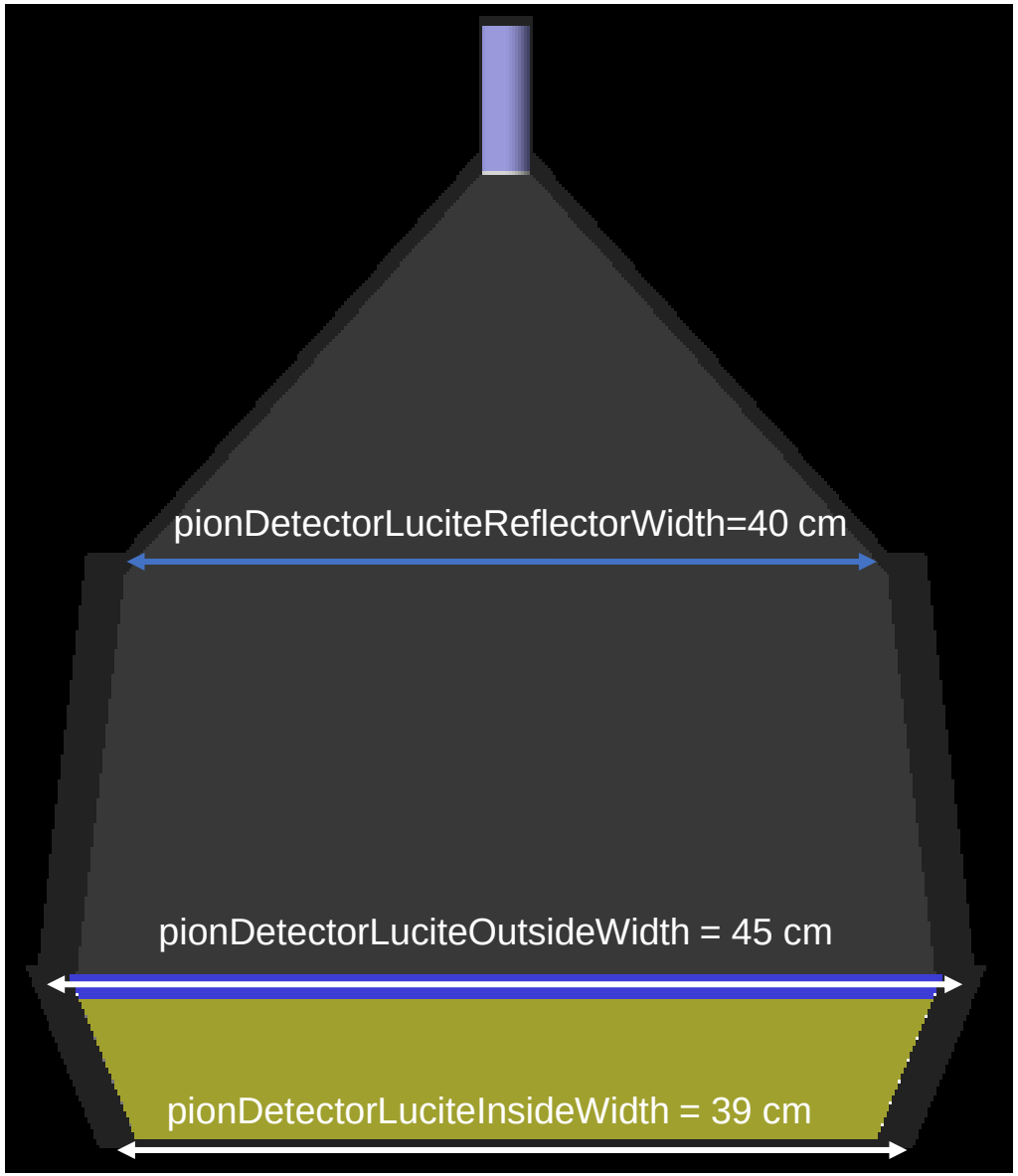
PMT shielding

radial 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

Geometry of Lucite detector

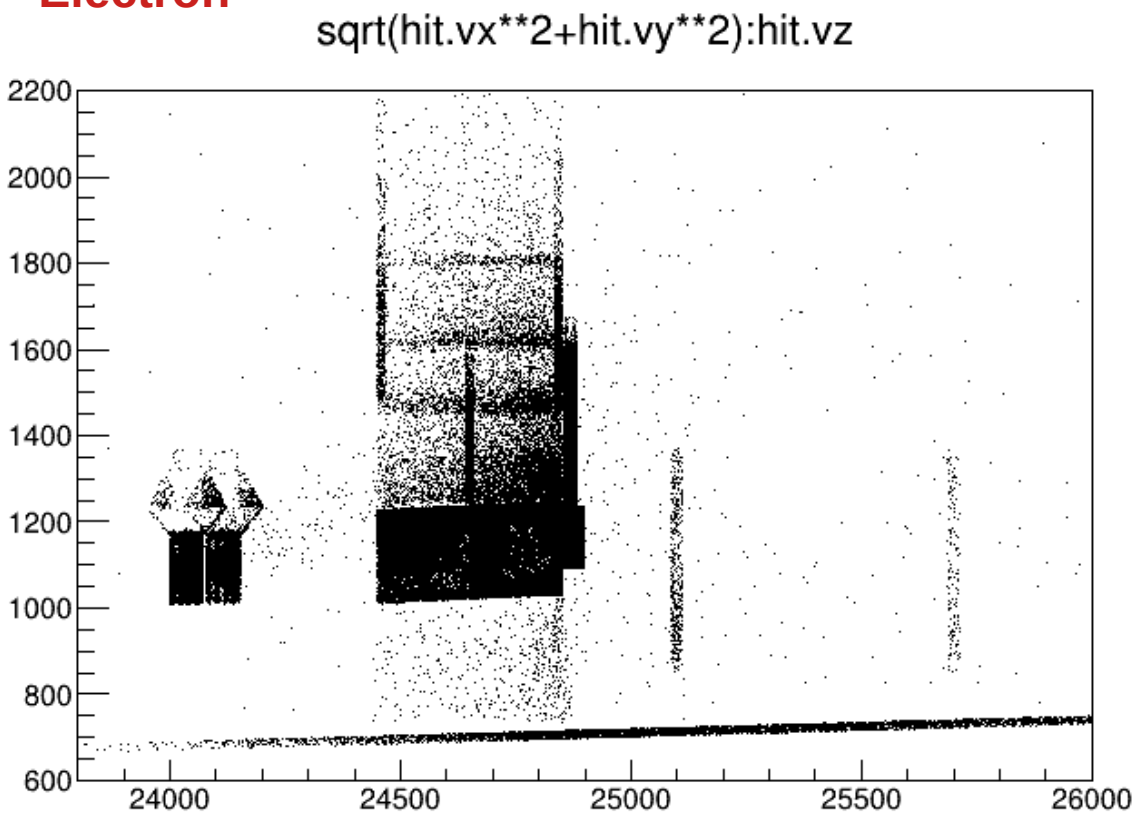




The origin location of all the secondaries anywhere for 5,000,000 events

(16 cm concrete and upstream Lead)

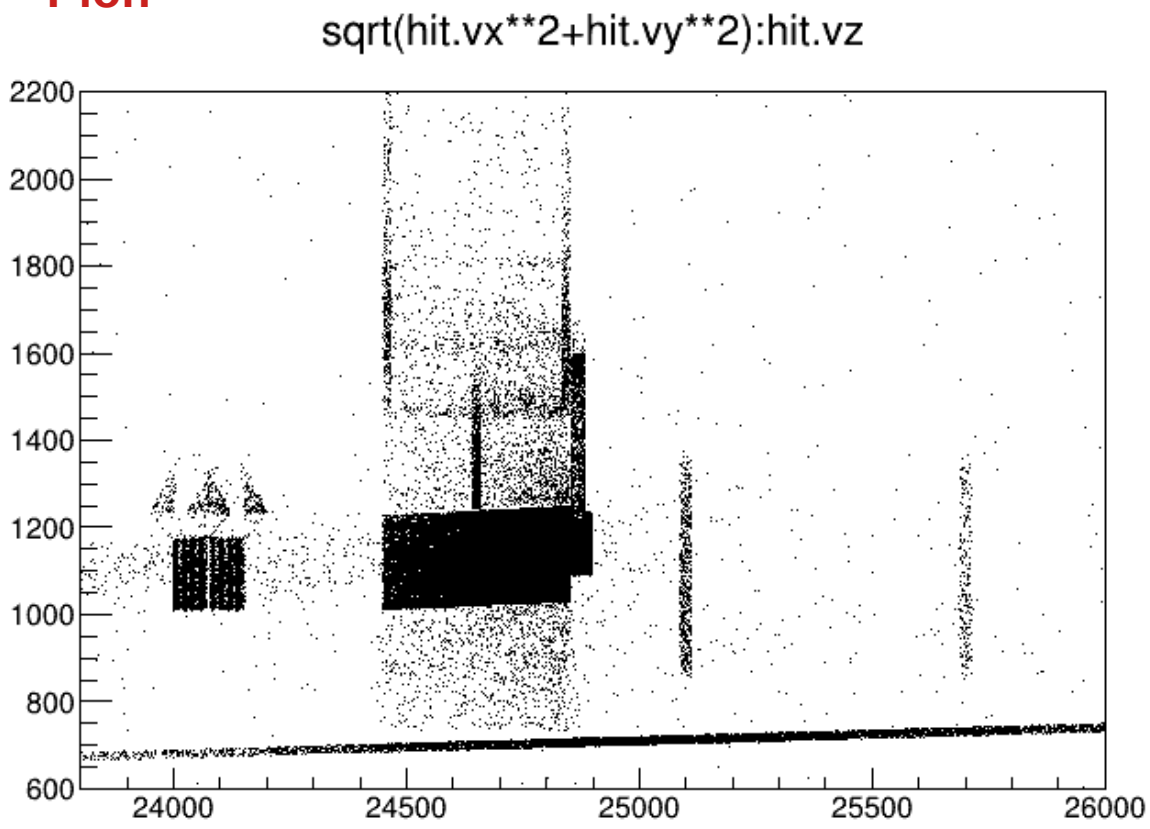
Electron



hit.trid==1 12

hit.trid==2 10

Pion



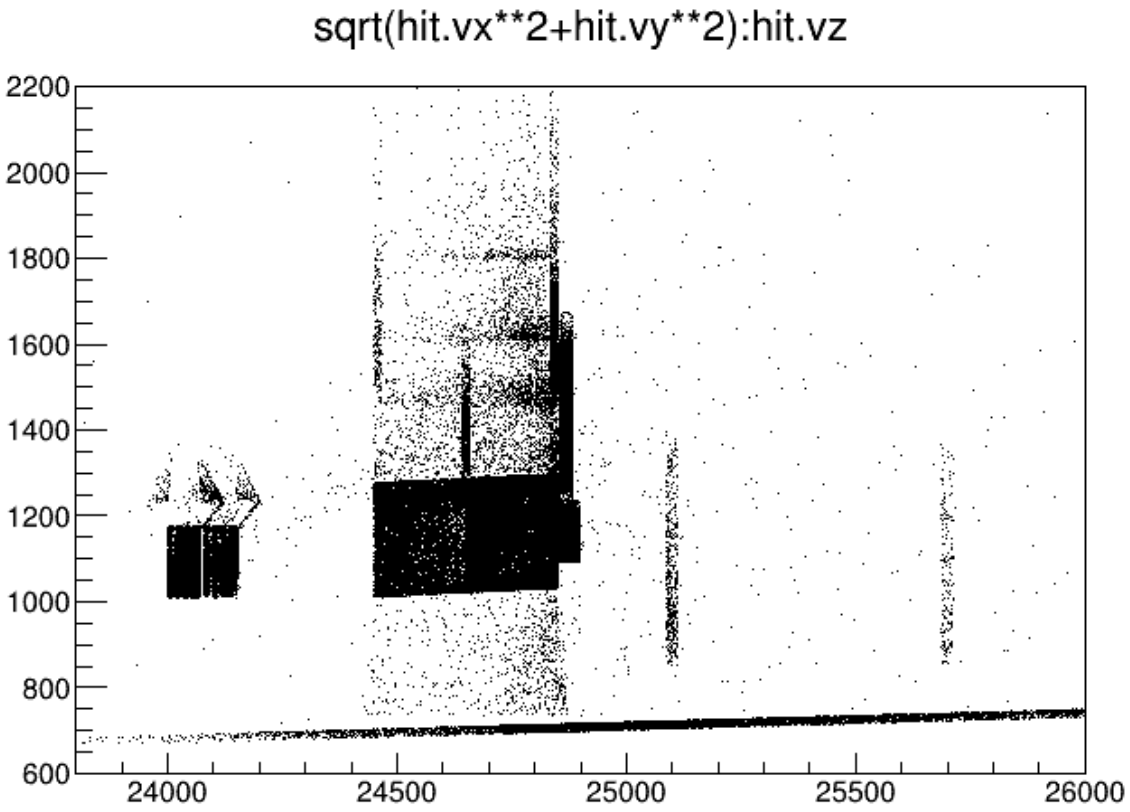
hit.trid==1 142857

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

(21 cm concrete and upstream Lead)

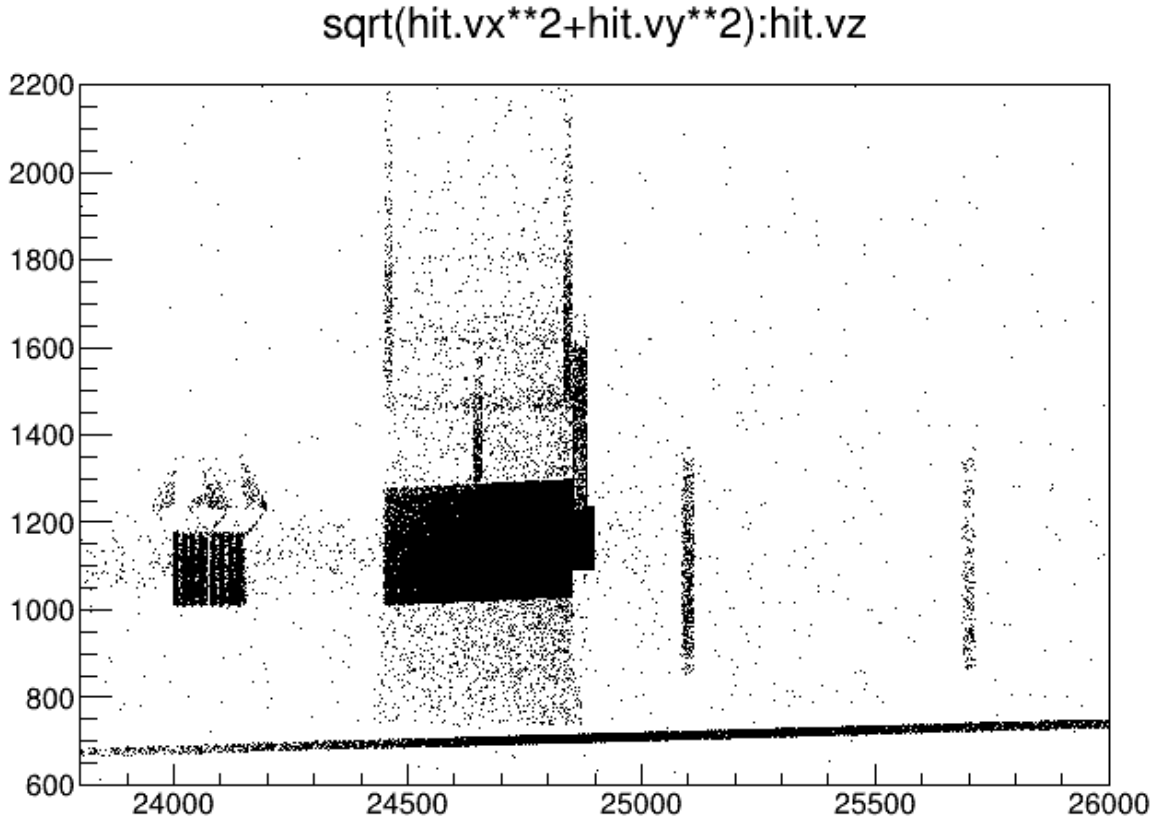
Electron



hit.trid==1 78

hit.trid==2 82

Pion



hit.trid==1 146168

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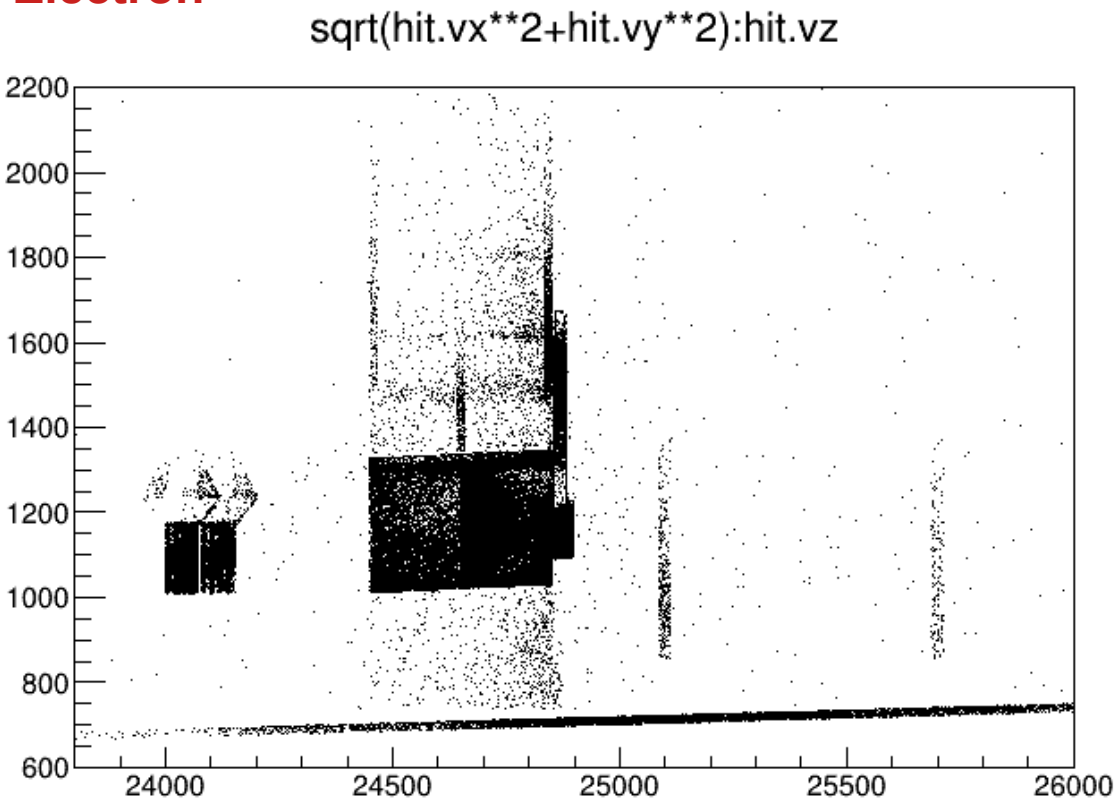
T->Draw("sqrt(hit.vx**2+hit.vy**2):hit.vz>>h1(100,23800,26000,100,600,2200)")

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

(26 cm concrete and upstream Lead)

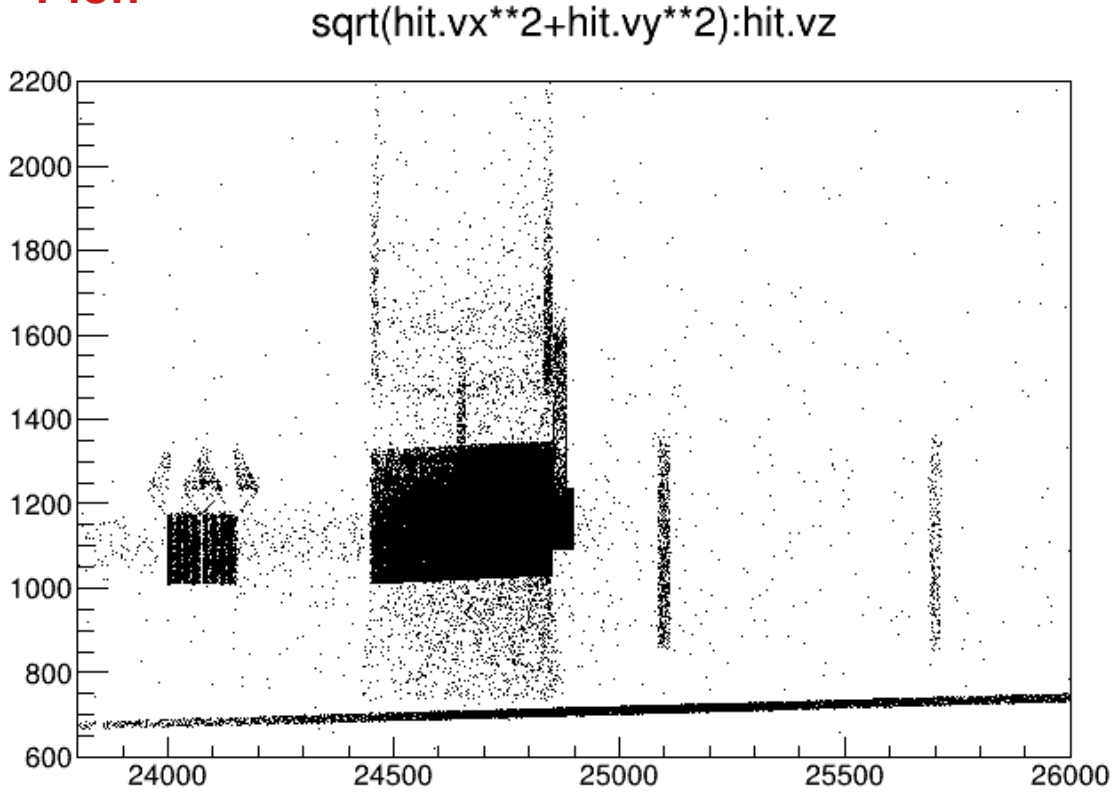
Electron



hit.trid==1 1

hit.trid==2 0

Pion



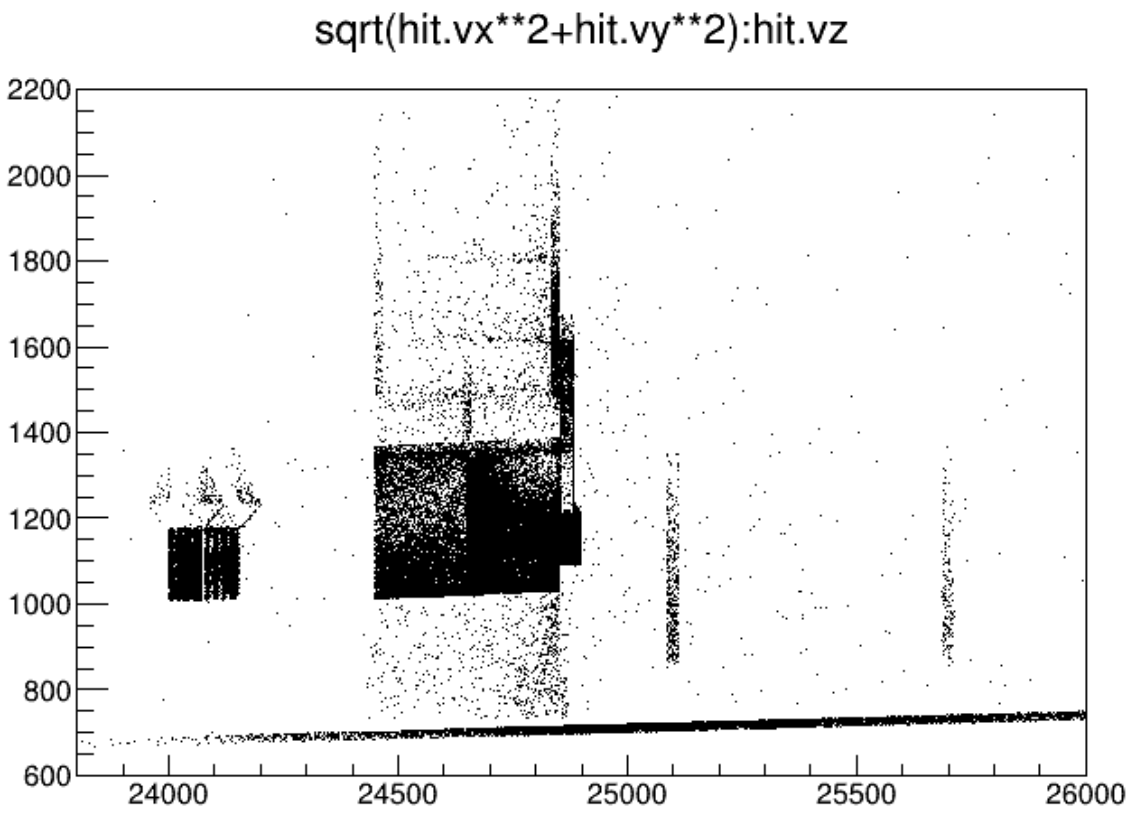
hit.trid==1 150426

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

(30 cm concrete and upstream Lead)

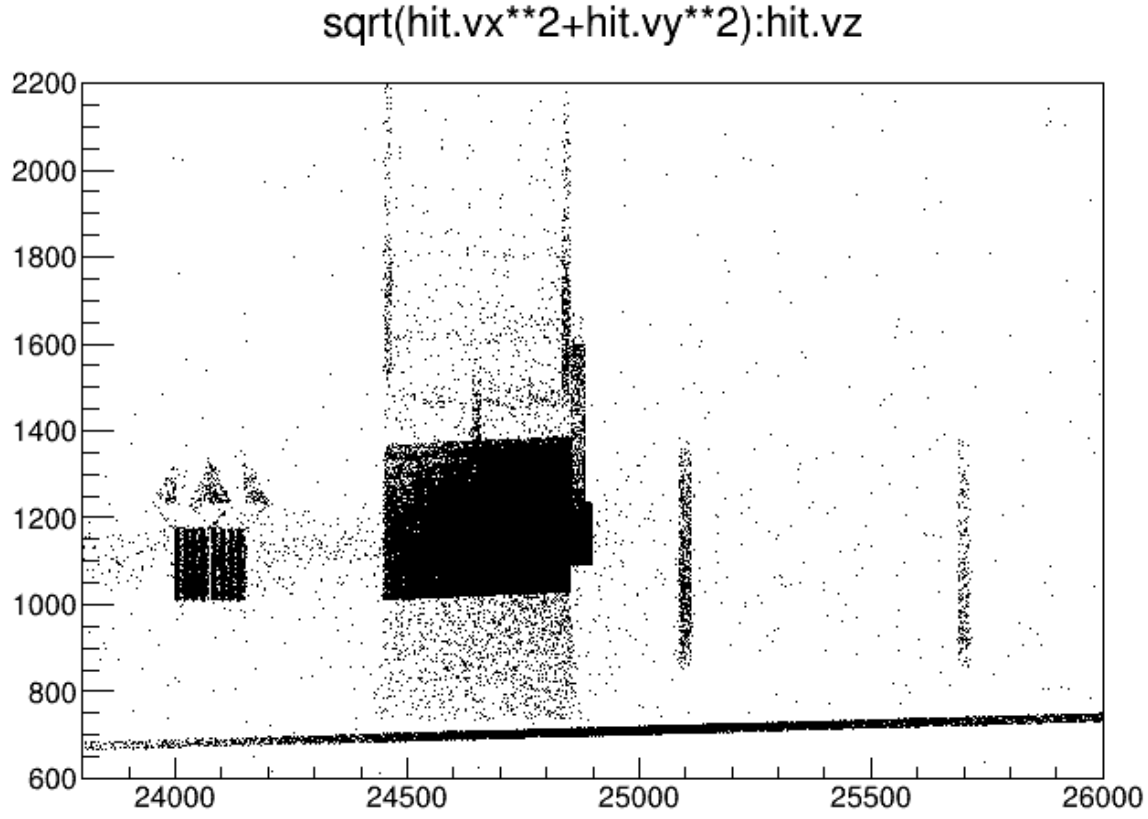
Electron



hit.trid==1 1

hit.trid==2 1

Pion



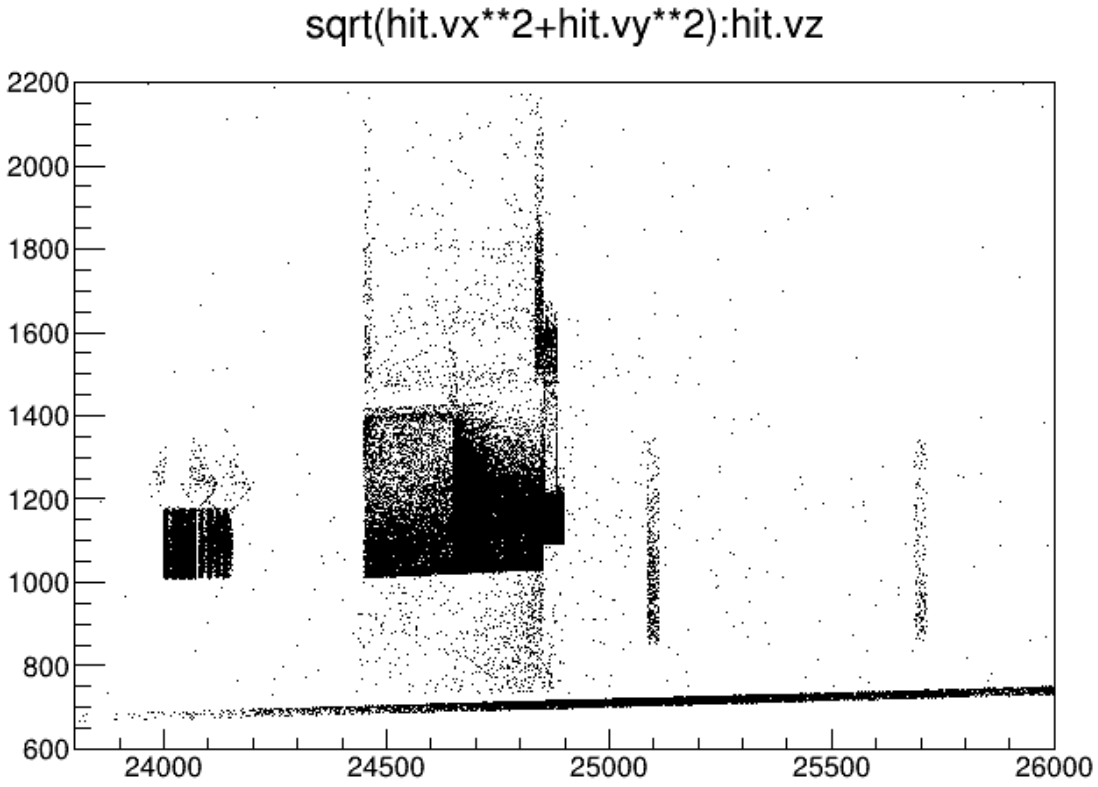
hit.trid==1 145238

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

(35 cm concrete and upstream Lead)

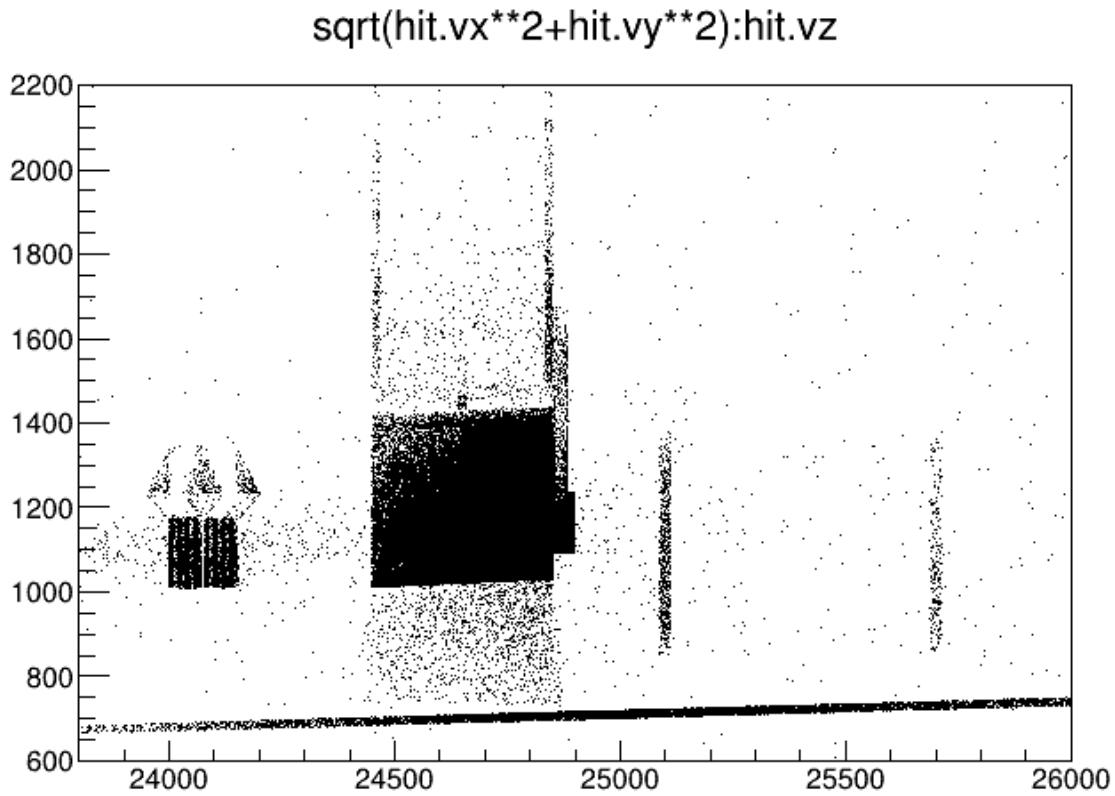
Electron



hit.trid==1 0

hit.trid==2 0

Pion



hit.trid==1 147195

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)

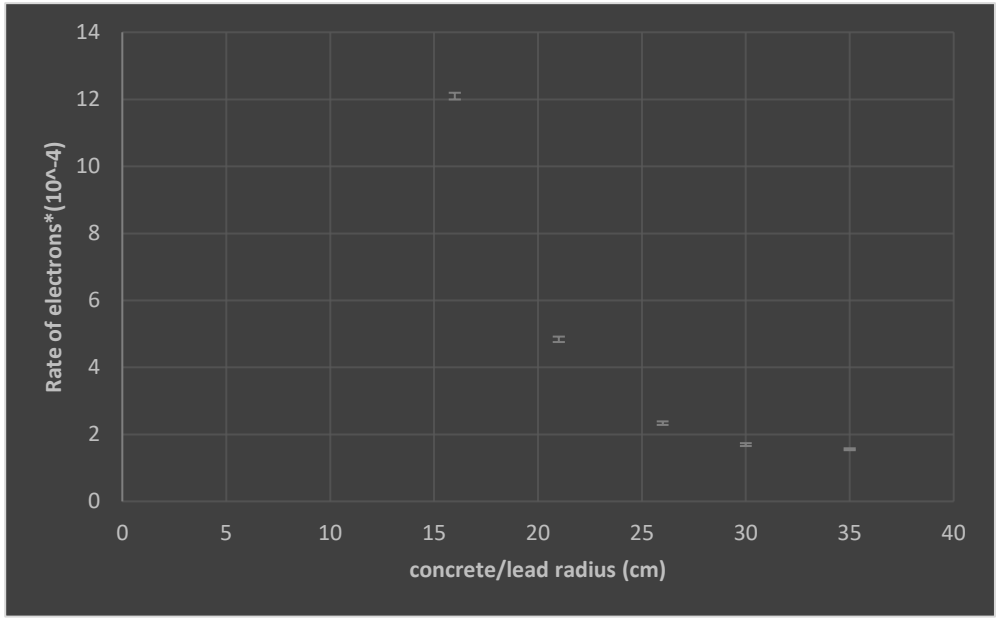
Rates $GHz/\mu A/Detector$	Rate of electrons	Rate of pions	Pi/e	Rate of photons from electrons	Rate of photons from pions	Pi/e
Concrete and Lead at 16cm	$(1.21 \pm 0.01) \times 10^{-3}$	$(5.76 \pm 0.08) \times 10^{-6}$	0.48%	$(2.134 \pm 0.006) \times 10^{-2}$	$(5.087 \pm 0.008) \times 10^{-4}$	2.38%
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%

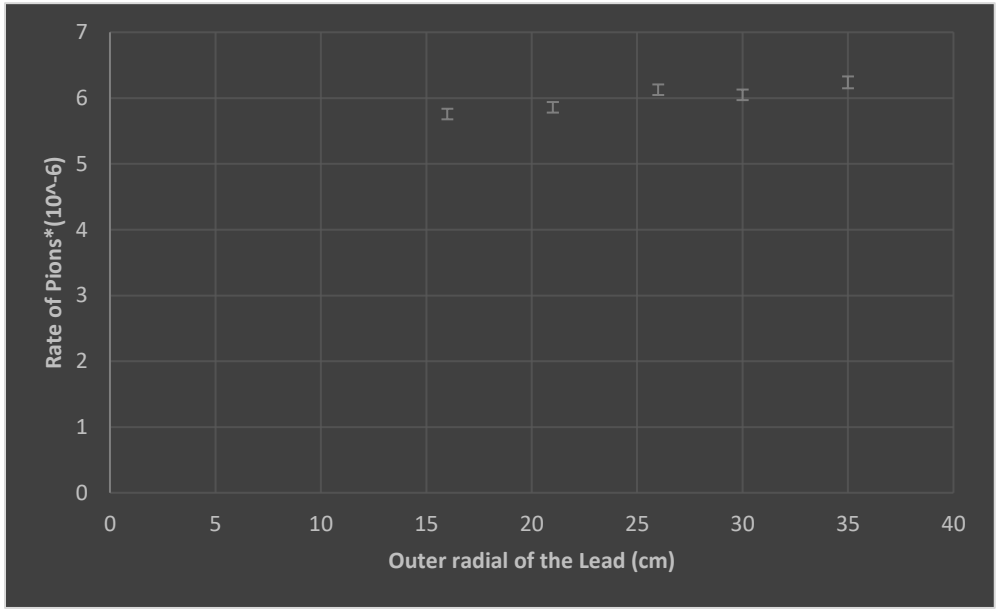
T->Draw("1","(rate/5.95e13)*(hit.det==8001 && hit.p<2*MeV && (hit.pid==11 || hit.pid==-11 || hit.pid==211 || hit.pid==-211 || hit.pid==13 || hit.pid==-13))")

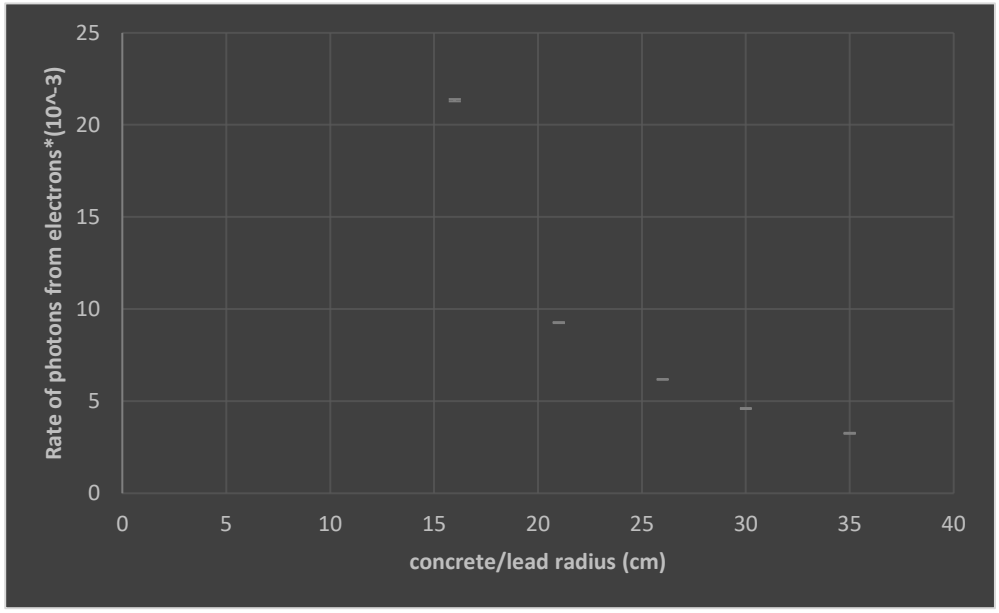
T->Draw("1","(rate/5.95e13)*(hit.det==8000)")

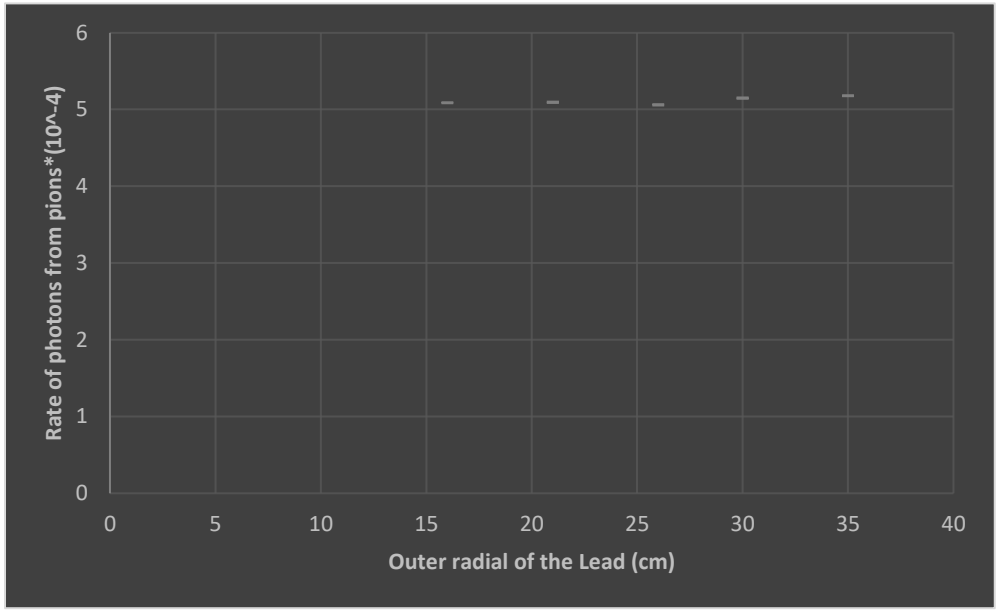
Note: 5.95e13 comes from 85*14*10^9*50 to be in the unit of $GHz/\mu A/Detector$/simulation

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)

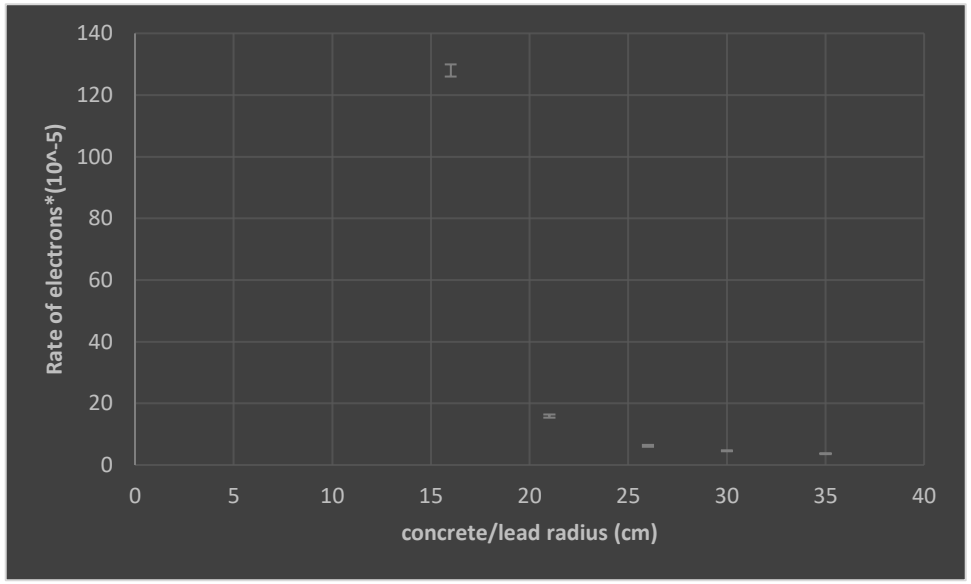
Rates $GHz/\mu A/Detector$	Rate of electrons	Rate of pions	Pi/e	Rate of photons from electrons	Rate of photons from pions	Pi/e
Concrete and Lead at 16cm	$(1.28 \pm 0.02) \times 10^{-3}$	$(1.543 \pm 0.005) \times 10^{-4}$	12.05%	$(2.134 \pm 0.006) \times 10^{-2}$	$(5.087 \pm 0.008) \times 10^{-4}$	2.38%
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%

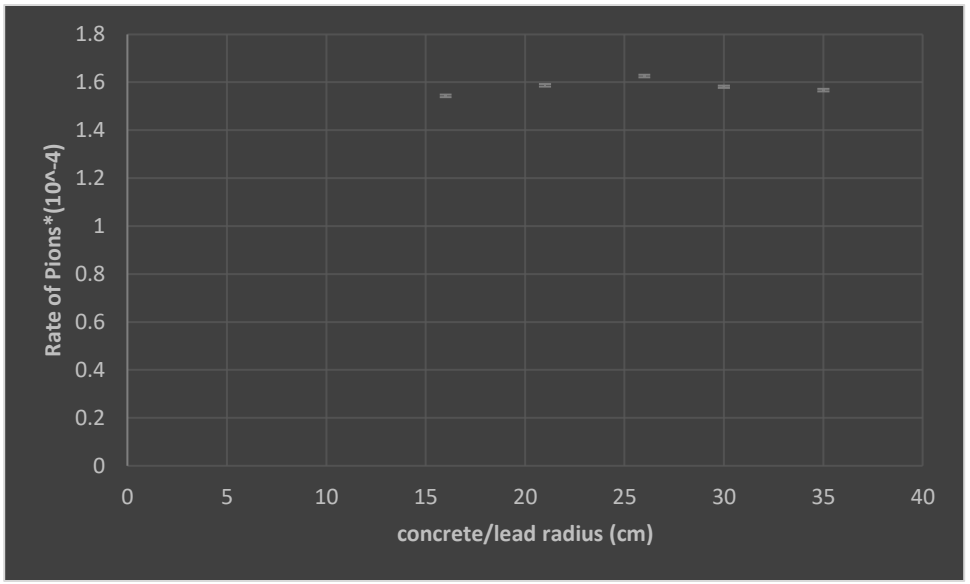
T->Draw("1","(rate/5.95e13)*(hit.det==8001 && hit.p>2*MeV && (hit.pid==11 || hit.pid==-11 || hit.pid==211 || hit.pid==-211 || hit.pid==13 || hit.pid==-13))")

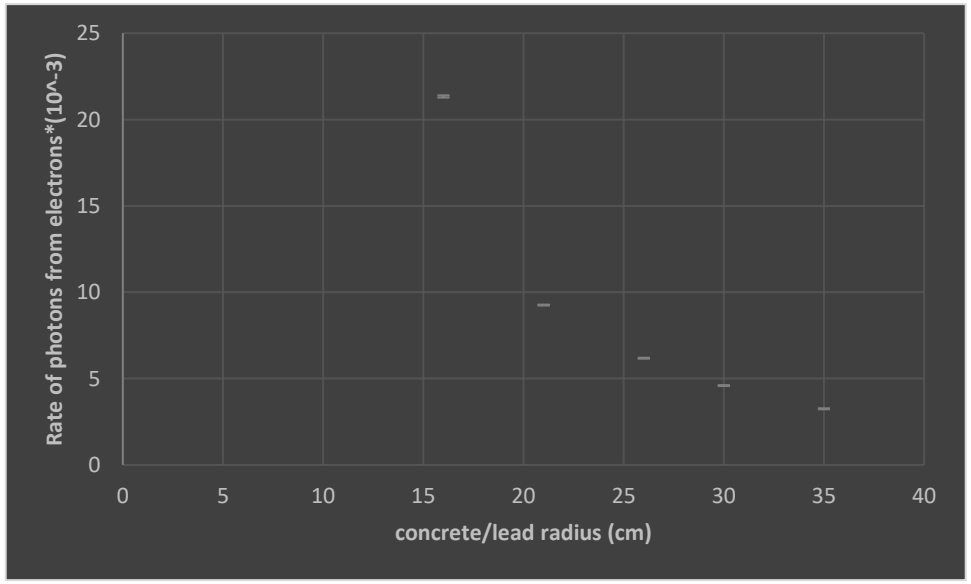
T->Draw("1","(rate/5.95e13)*(hit.det==8000)")

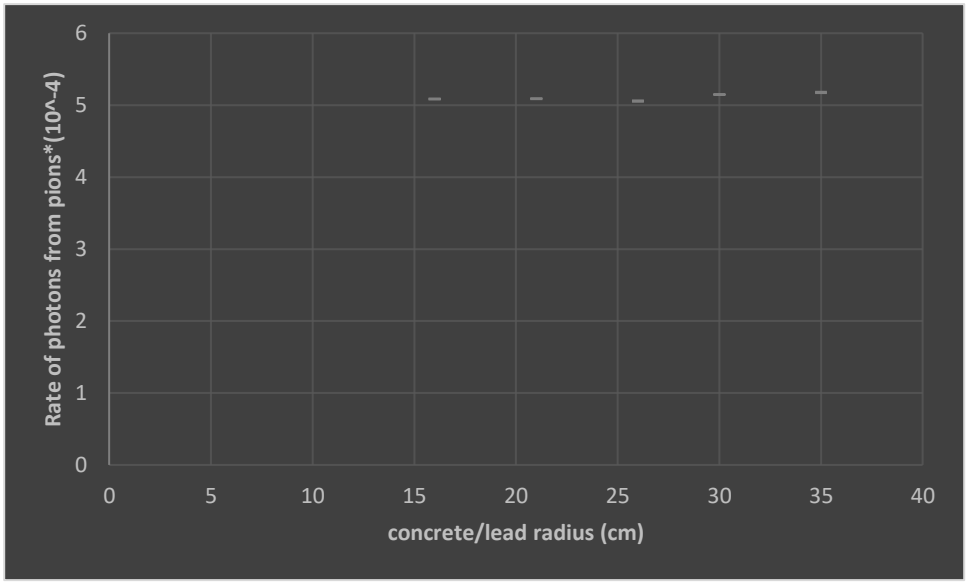
Note: 5.95e13 comes from 85*14*10^9*50 to be in the unit of $GHz/\mu A/Detector$/simulation

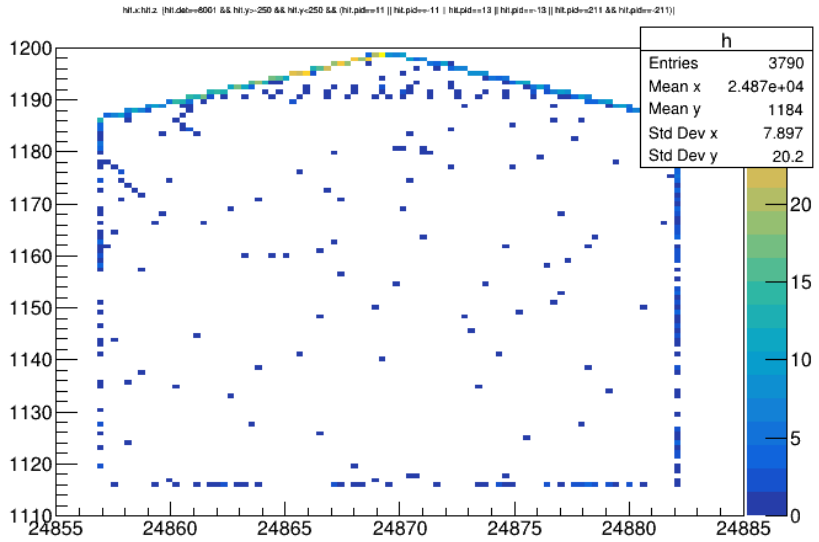
Comparison of rates at the Lucite for 5,000,000 events (High energy particles, hit.p>2*MeV)



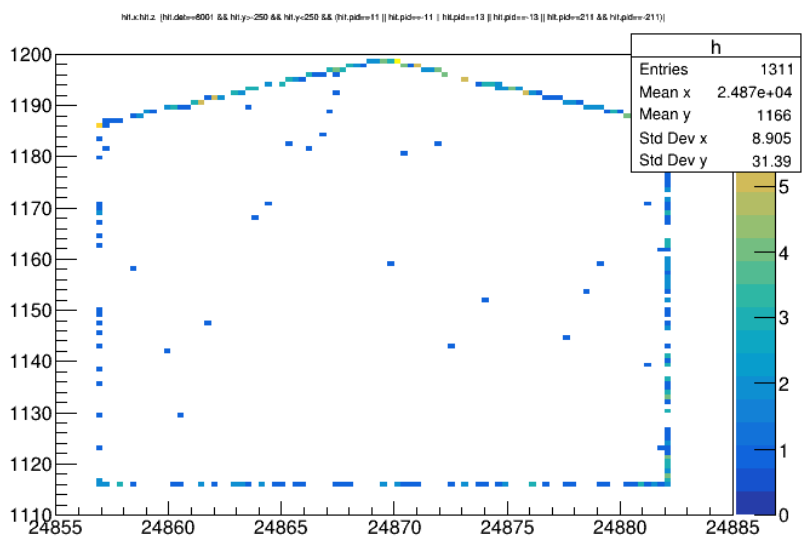




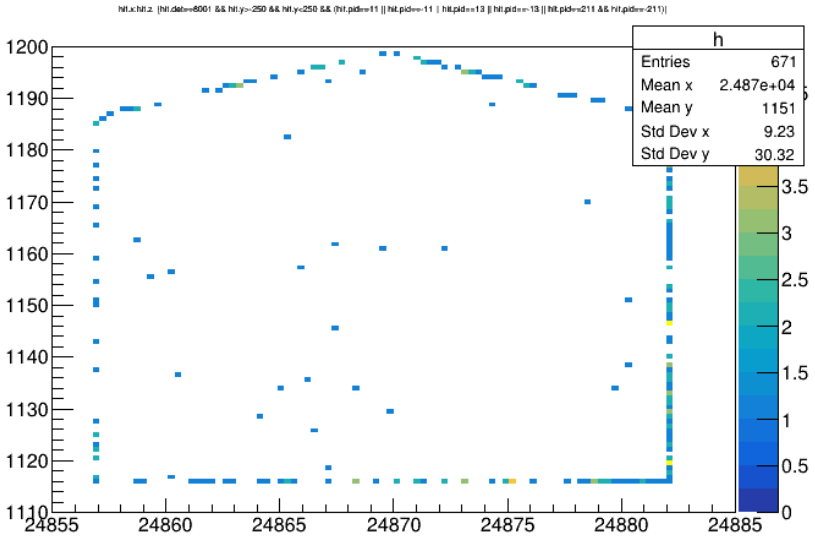




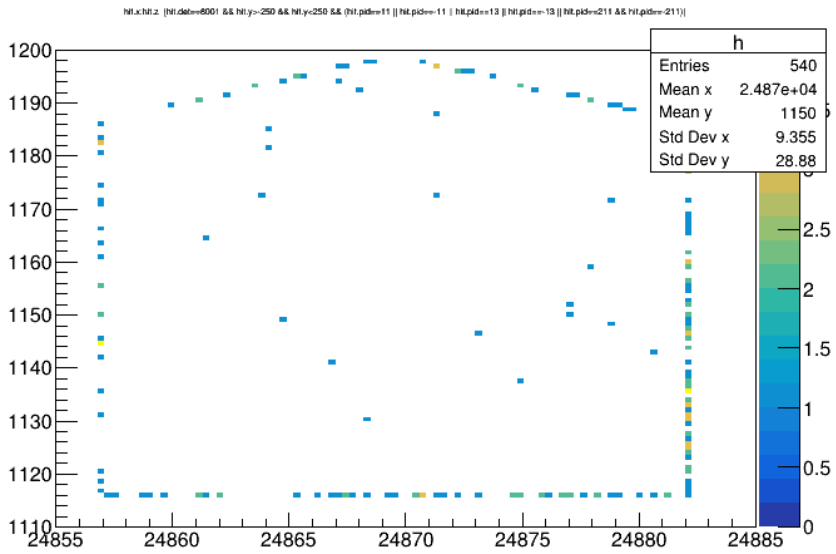
Concrete and Lead at 16cm



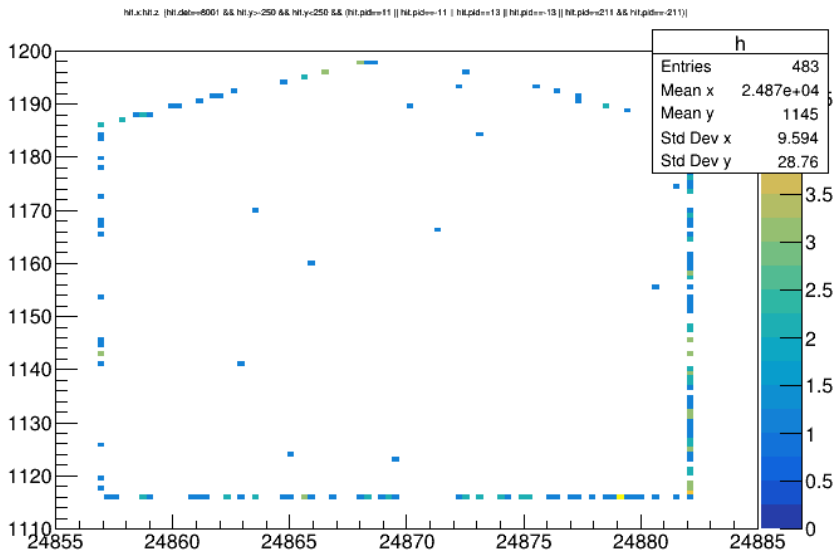
Concrete and Lead at 21cm



Concrete and Lead at 26cm

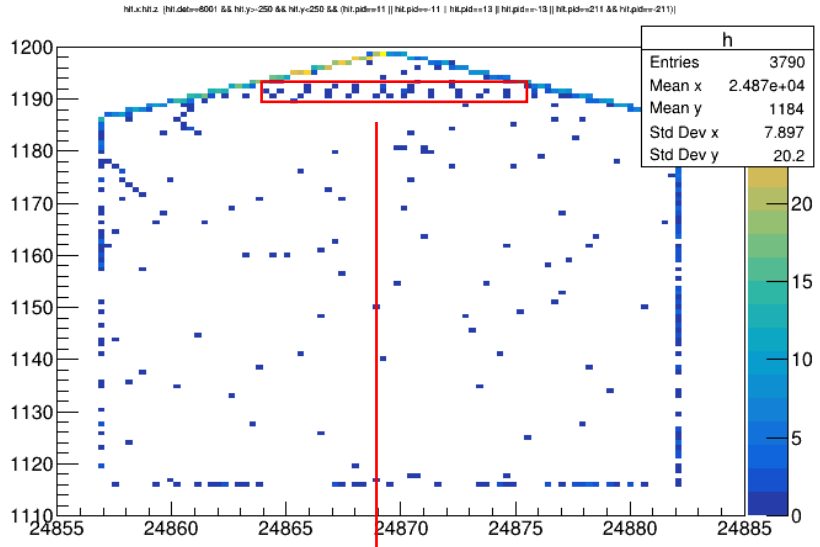


Concrete and Lead at 30 cm

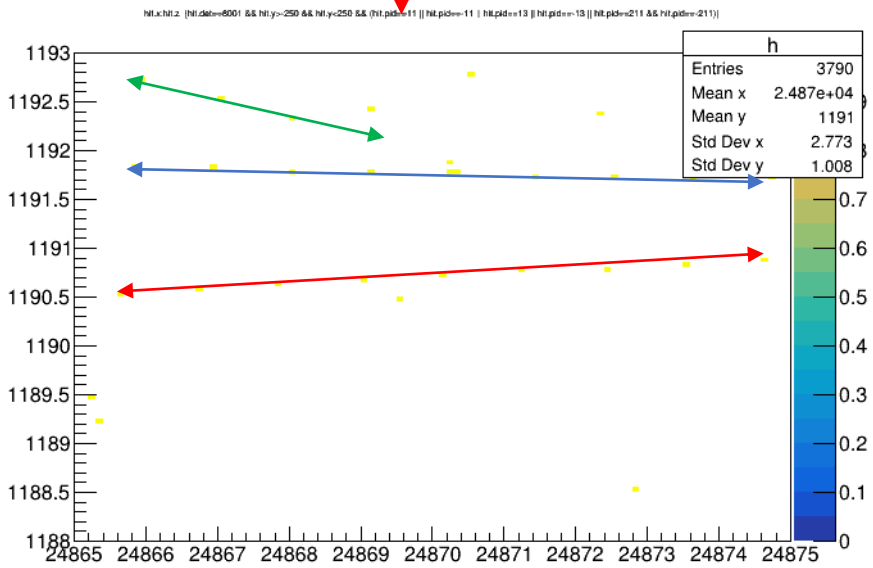


Concrete and Lead at 35cm

T->Draw("hit.x:hit.z >>h(100,24855,24885,100,1110,1200)","hit.det==8001 && hit.y>-250 && hit.y<250 && (hit.pid==11 || hit.pid==-11 || hit.pid==13 || hit.pid==-13 || hit.pid==211 && hit.pid==-211)","colz")



Concrete and Lead at 16cm



Row	Instance	hit.x	hit.z	hit.trid	hit.mtrid	hit.pid
668637	7	1192.7689	24870.542	68493	68245	11
949598	40	1192.7309	24865.917	2	0	11
949598	41	1192.5327	24867.01	2	0	11
949598	42	1192.3179	24868.092	2	0	11
949598	43	1192.1012	24869.180	2	0	11
949598	44	1191.8980	24870.263	2	0	11
1705931	0	1190.4918	24869.548	80612	80573	11
2159735	0	1189.4669	24865.220	13382	13329	11
2625303	12	1192.3739	24872.396	40314	40245	-11
2706881	1	1188.5432	24872.896	66182	61859	-11
2894161	1	1189.2108	24865.350	85885	85850	11
3308393	1	1192.4117	24869.101	7724	7616	11
3313249	98	1191.8370	24865.86	2	0	11
3313249	99	1191.8081	24866.951	2	0	11
3313249	100	1191.7770	24868.043	2	0	11
3313249	101	1191.7618	24869.141	2	0	11
3313249	102	1191.7555	24870.238	2	0	11
3313249	103	1191.7550	24870.324	2	0	11
3313249	104	1191.7487	24871.420	2	0	11
3313249	105	1191.7399	24872.515	2	0	11
3313249	106	1191.7291	24873.609	2	0	11
3313249	107	1191.7198	24874.702	2	0	11
3540940	29	1190.5431	24865.608	2	0	11
3540940	30	1190.5790	24866.743	2	0	11
3540940	31	1190.6179	24867.877	2	0	11

Type <CR> to continue or q to quit ==>

3540940	32	1190.6607	24869.011	2	0	11
3540940	33	1190.7061	24870.144	2	0	11
3540940	34	1190.7528	24871.278	2	0	11
3540940	35	1190.7999	24872.411	2	0	11
3540940	36	1190.8487	24873.544	2	0	11
3540940	37	1190.8954	24874.678	2	0	11

==> 31 selected entries

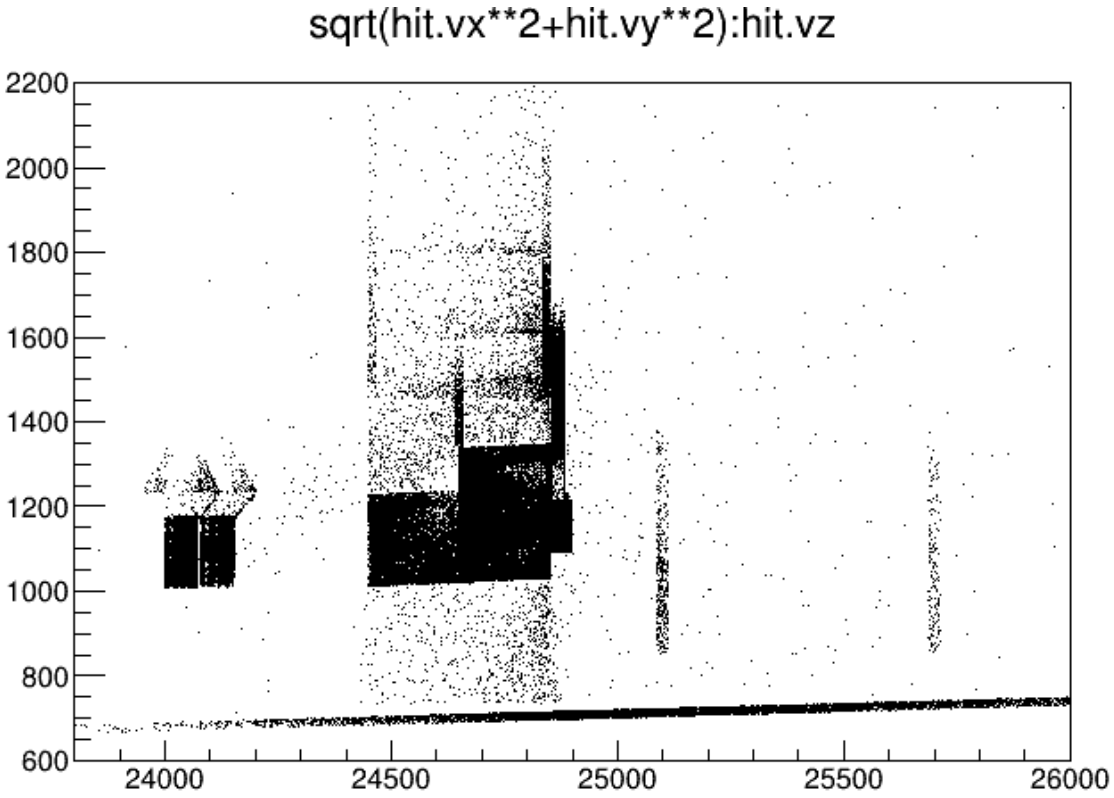
T->Draw("hit.x:hit.z >>h(100,24865,24875,100,1188,1193)","hit.det==8001 && hit.y>-250 && hit.y<250 && (hit.pid==11 || hit.pid==-11 || hit.pid==13 || hit.pid==-13 || hit.pid==211 && hit.pid==-211)","colz")

T->Scan("hit.x:hit.z","hit.det==8001 && hit.x>1188 && hit.x<1193 && hit.z>24865 && hit.z<24875 && hit.y>-250 && hit.y<250 && (hit.pid==11 || hit.pid==-11 || hit.pid==-211)")

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

(16 cm concrete and 26 cm upstream Lead)

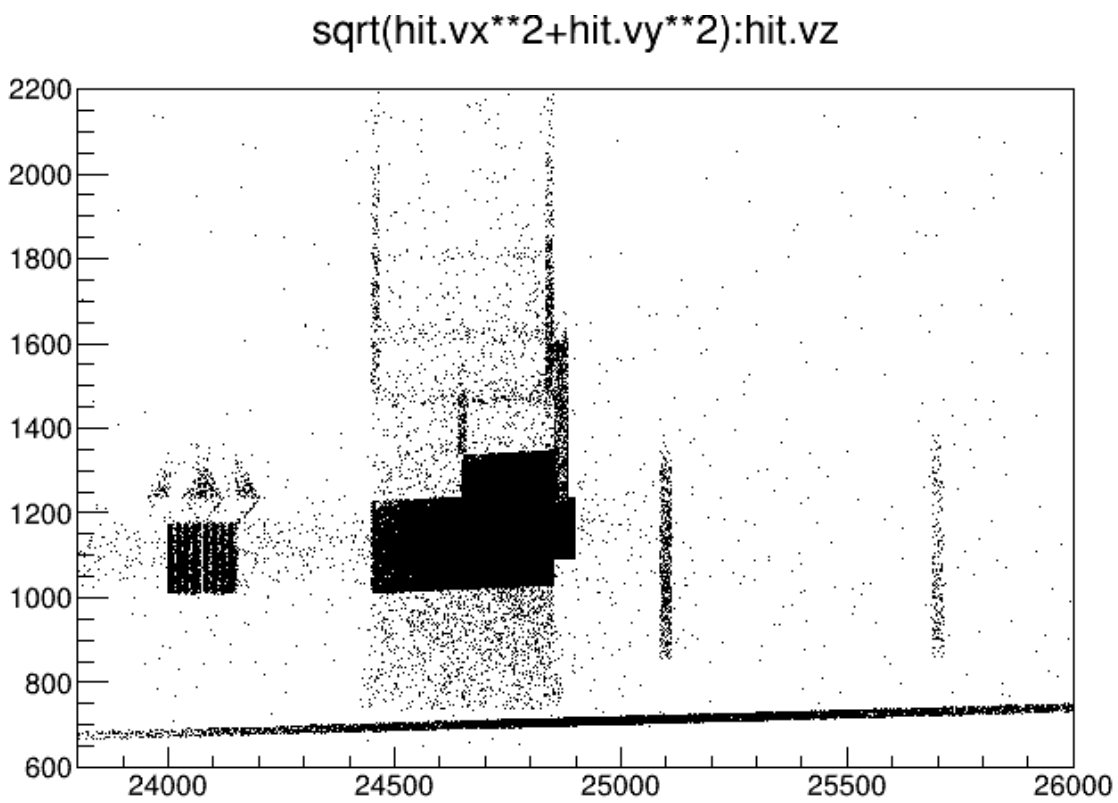
Electron



hit.trid==1 24

hit.trid==2 120

Pion



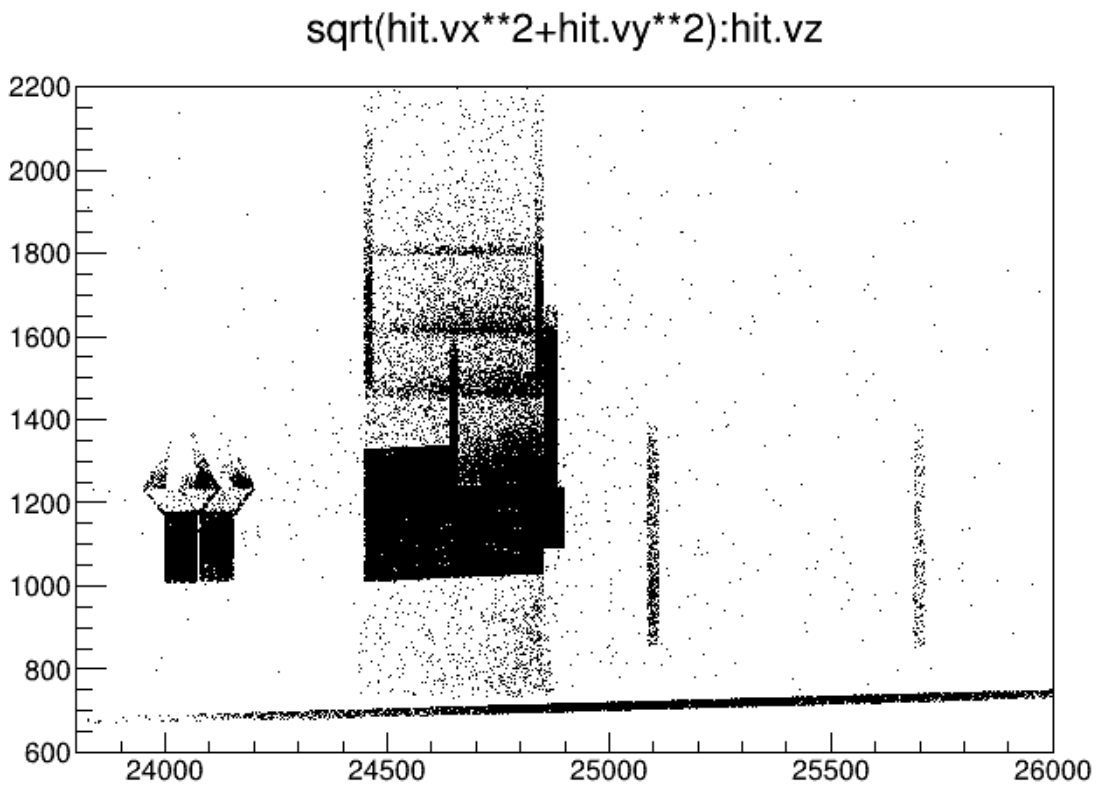
hit.trid==1 147730

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

(26 cm concrete and 16 cm upstream Lead)

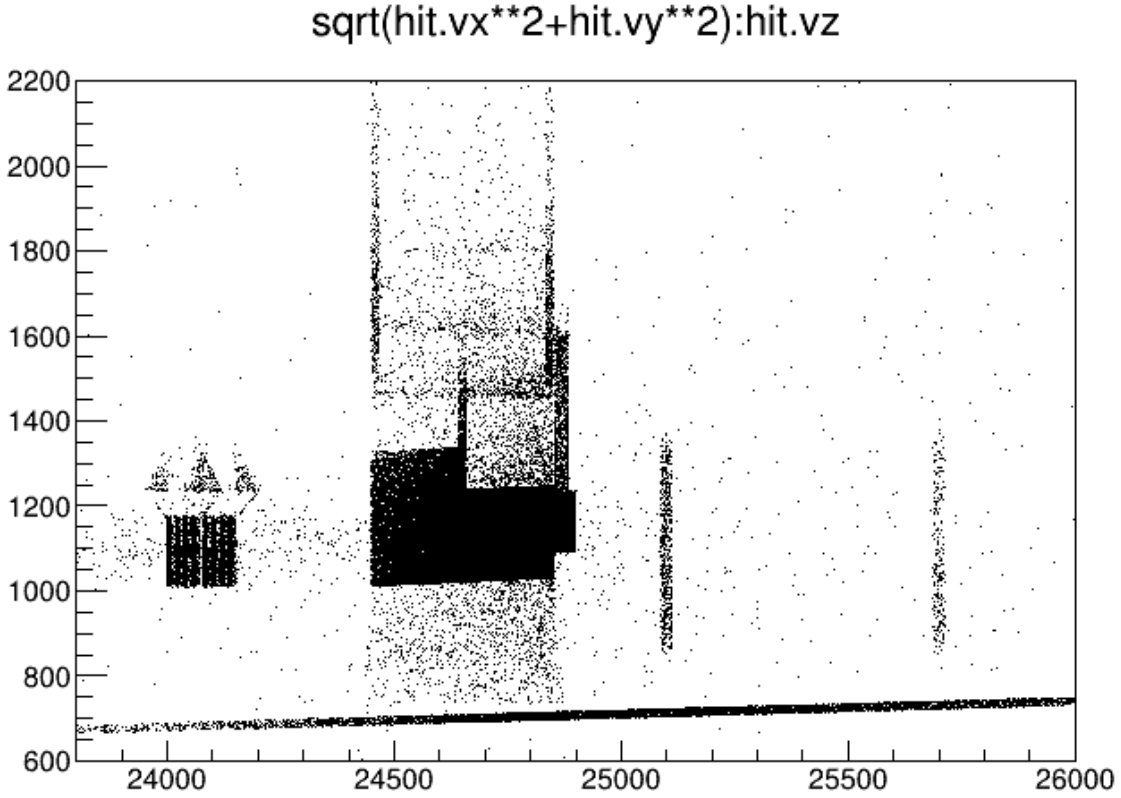
Electron



hit.trid==1 3531

hit.trid==2 2864

Pion



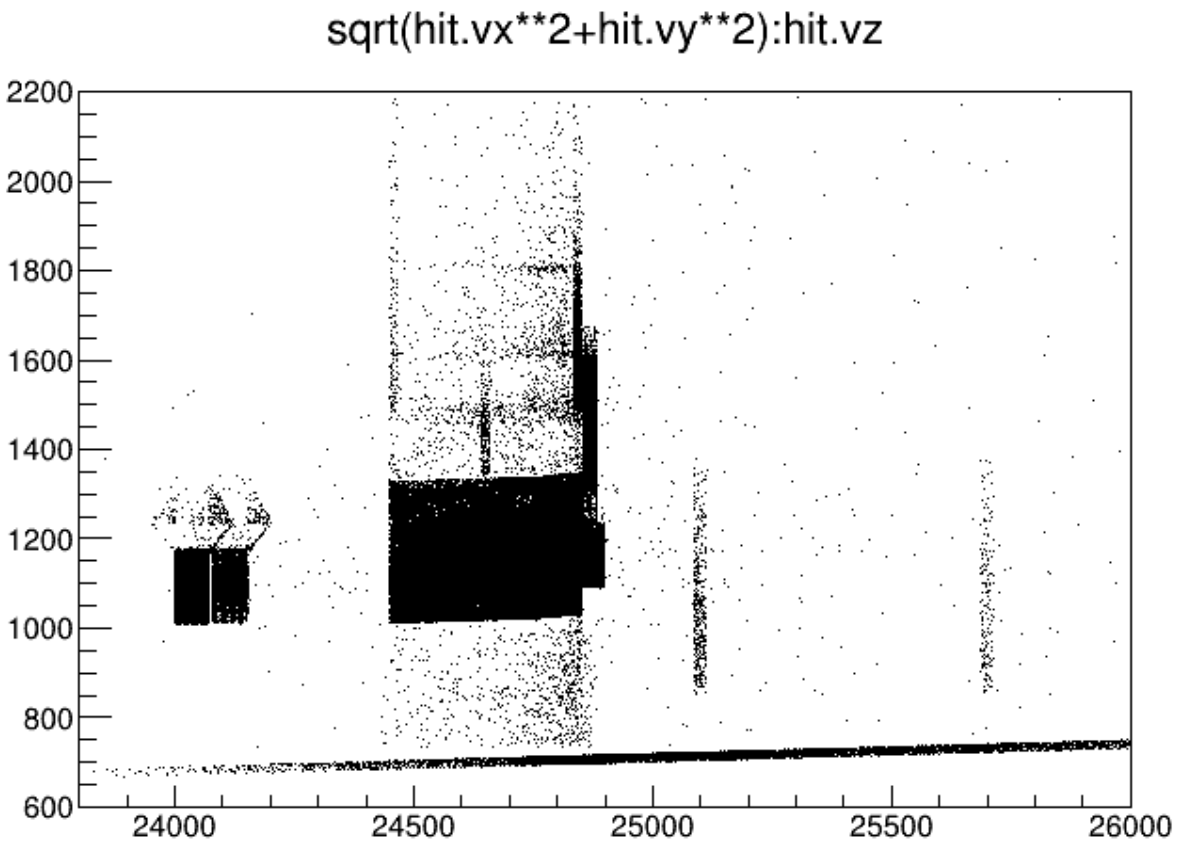
hit.trid==1 149559

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

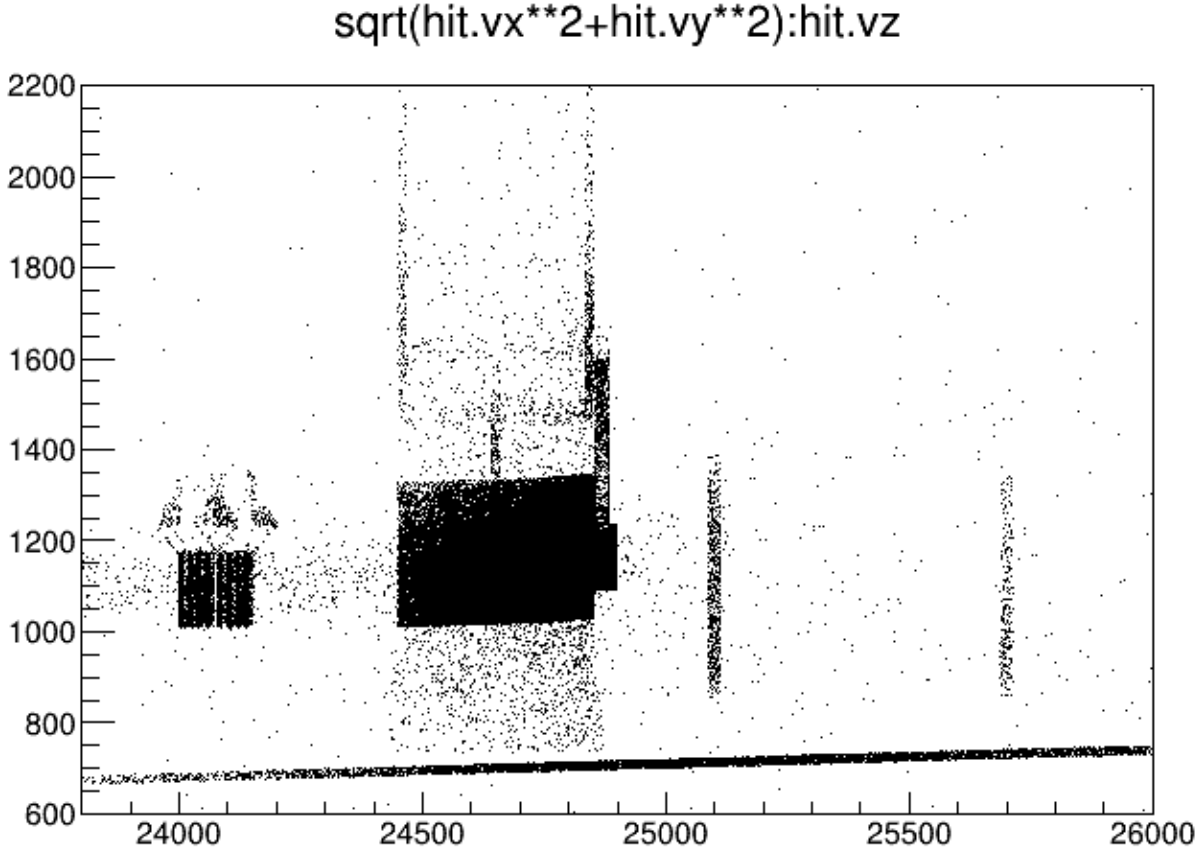
The origin location of all the secondaries anywhere for 5,000,000 events

Fix downstream face of donut, then reduce lead thickness, (10 cm lead thickness and 30cm Concrete thickness)

Electron



Pion

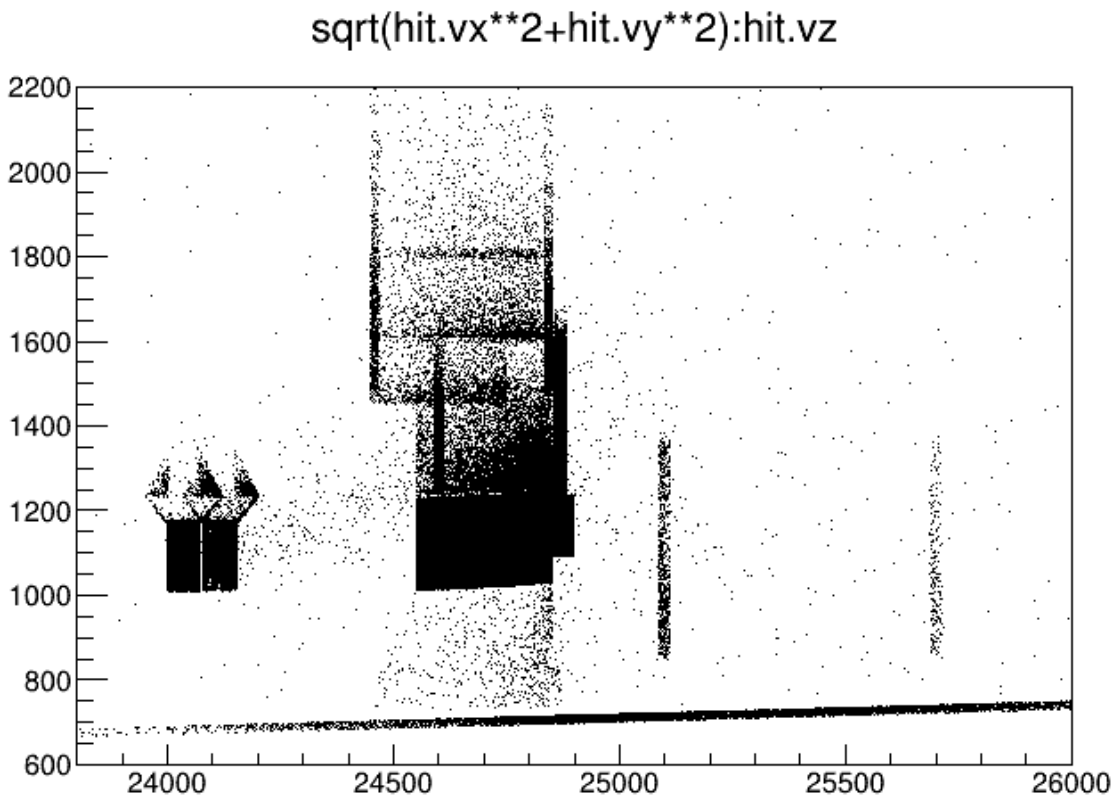


T->Draw("sqrt(hit.vx**2+hit.vy**2):hit.vz>>h1(100,23800,26000,100,600,2200)")

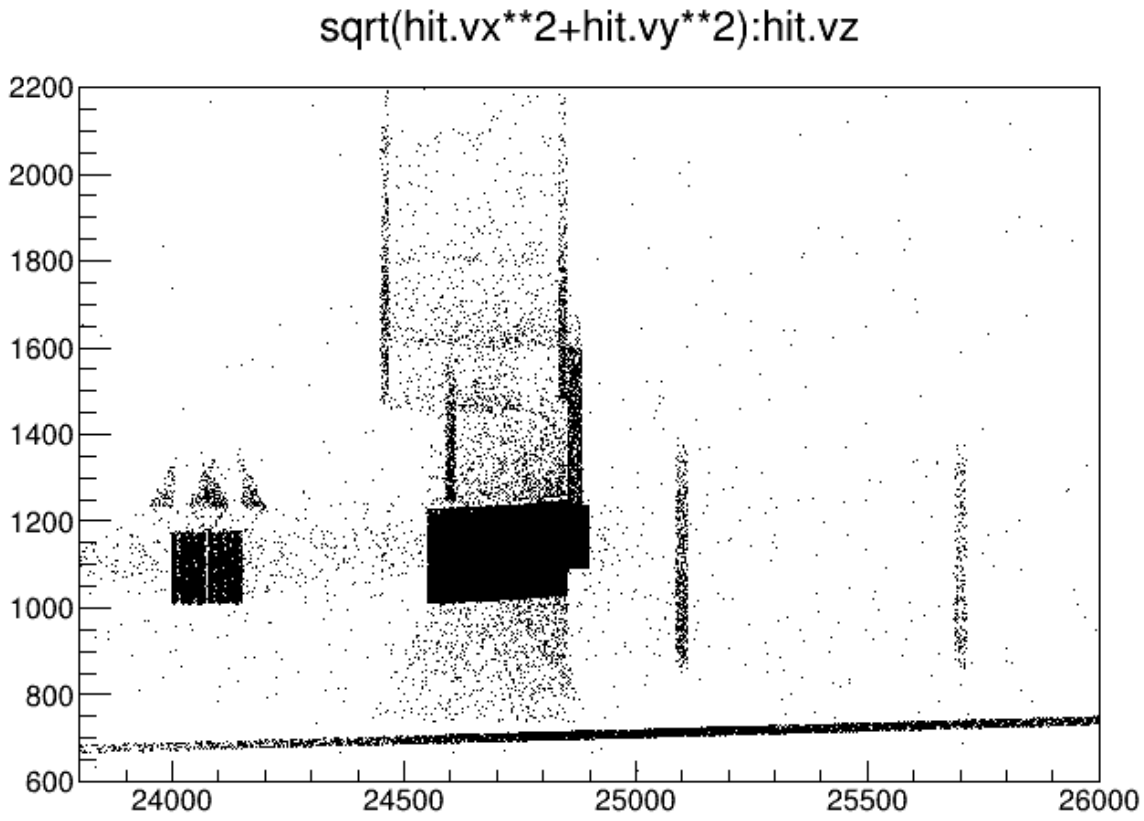
The origin location of all the secondaries anywhere for 5,000,000 events

Fix downstream face of donut, then reduce lead thickness, (10 cm lead thickness and 20cm Concrete thickness)

Electron



Pion



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

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
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%
16 cm concrete and 26 cm upstream Lead	$(2.90 \pm 0.05) \times 10^{-4}$	$(6.01 \pm 0.08) \times 10^{-6}$	2.07%	$(7.74 \pm 0.02) \times 10^{-3}$	$(5.135 \pm 0.008) \times 10^{-4}$	6.63%
26 cm concrete and 16 cm upstream Lead	$(1.90 \pm 0.01) \times 10^{-3}$	$(5.98 \pm 0.08) \times 10^{-6}$	0.31%	$(3.120 \pm 0.006) \times 10^{-2}$	$(5.111 \pm 0.008) \times 10^{-4}$	1.64%
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%
20cm Concrete and 10cm Lead thickness	$(3.22 \pm 0.02) \times 10^{-3}$	$(8.83 \pm 0.10) \times 10^{-6}$	0.27%	$(5.720 \pm 0.708) \times 10^{-2}$	$(7.336 \pm 0.009) \times 10^{-4}$	1.28%
30cm Concrete and 10cm Lead thickness	$(1.36 \pm 0.01) \times 10^{-3}$	$(8.29 \pm 0.10) \times 10^{-6}$	0.61%	$(2.785 \pm 0.005) \times 10^{-2}$	$(6.919 \pm 0.009) \times 10^{-4}$	2.48%

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

Comparison of rates at the Lucite for 5,000,000 events

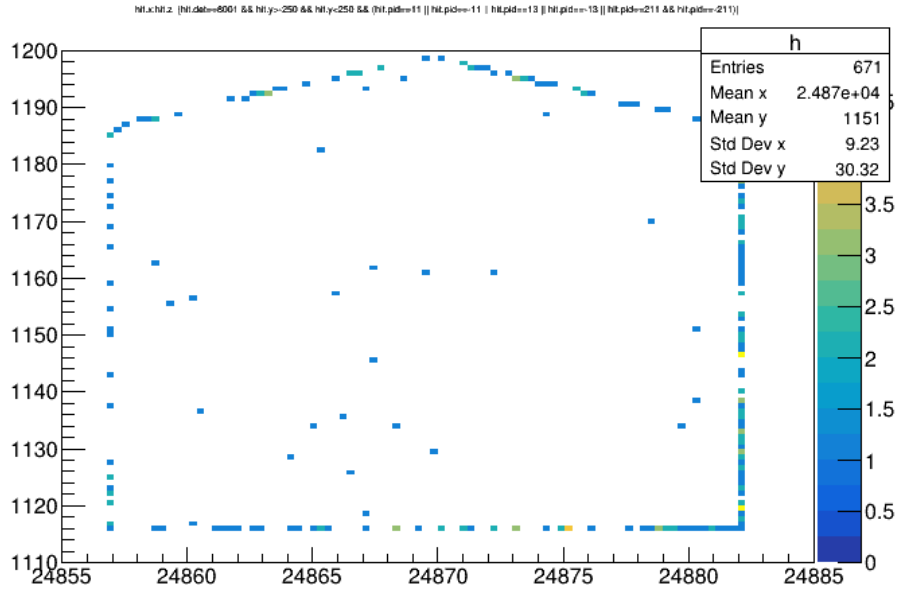
Rates $GHz/\mu A/Detector$	Rate of electrons	Rate of pions	Pi/e	Rate of photons from electrons	Rate of photons from pions	Pi/e
Concrete and Lead at 26cm	$(6.22 \pm 0.28) \times 10^{-5}$	$(1.626 \pm 0.005) \times 10^{-4}$	261%	$(6.18 \pm 0.02) \times 10^{-3}$	$(5.059 \pm 0.008) \times 10^{-4}$	8.18%
16 cm concrete and 26 cm upstream Lead	$(8.07 \pm 0.30) \times 10^{-5}$	$(1.572 \pm 0.005) \times 10^{-4}$	195%	$(7.74 \pm 0.02) \times 10^{-3}$	$(5.078 \pm 0.008) \times 10^{-4}$	6.56%
26 cm concrete and 16 cm upstream Lead	$(2.10 \pm 0.02) \times 10^{-3}$	$(1.620 \pm 0.005) \times 10^{-4}$	7.71%	$(3.120 \pm 0.006) \times 10^{-2}$	$(5.212 \pm 0.008) \times 10^{-4}$	1.67%
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%
20cm Concrete and 10cm Lead thickness	$(2.83 \pm 0.02) \times 10^{-3}$	$(2.678 \pm 0.006) \times 10^{-4}$	9.46%	$(5.720 \pm 0.708) \times 10^{-2}$	$(7.336 \pm 0.009) \times 10^{-4}$	1.28%
30cm Concrete and 10cm Lead thickness	$(6.16 \pm 0.07) \times 10^{-3}$	$(2.189 \pm 0.005) \times 10^{-4}$	3.55%	$(2.785 \pm 0.005) \times 10^{-2}$	$(6.919 \pm 0.009) \times 10^{-4}$	2.48%

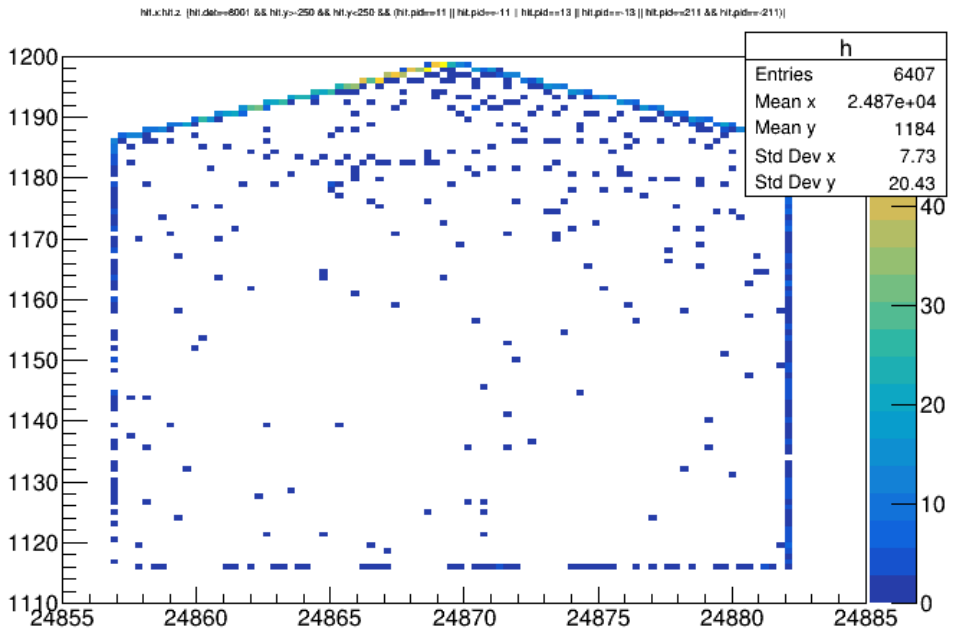
T->Draw("1","(rate/5.95e13)*(hit.det==8001 && hit.p>2*MeV && (hit.pid==11 || hit.pid==-11 || hit.pid==211 || hit.pid==-211 || hit.pid==13 || hit.pid==-13))")

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

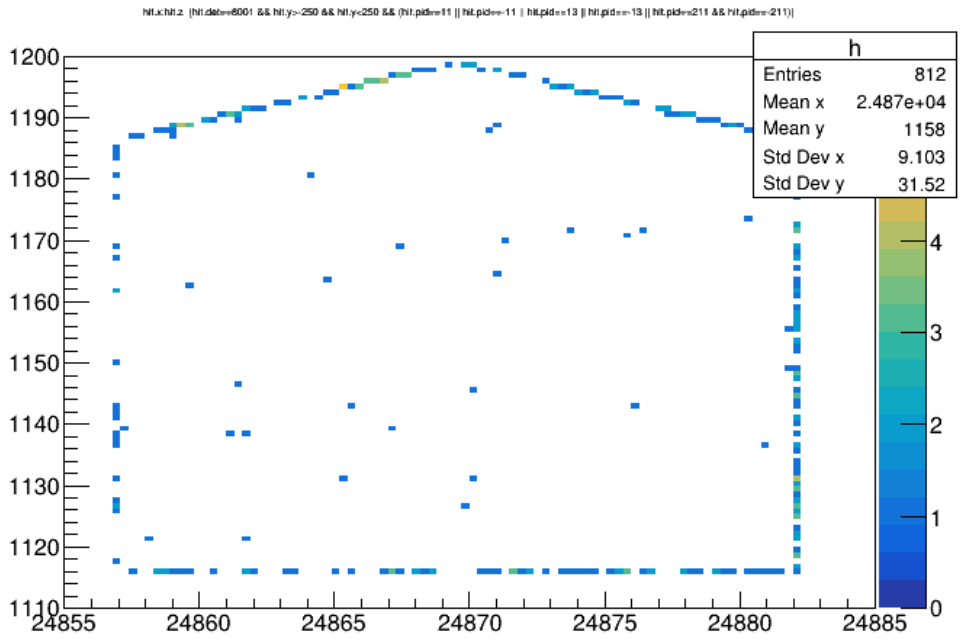
Note: 5.95e13 comes from 85*14*10^9*50 to be in the unit of $GHz/\mu A/Detector$/simulation

26 cm concrete and lead



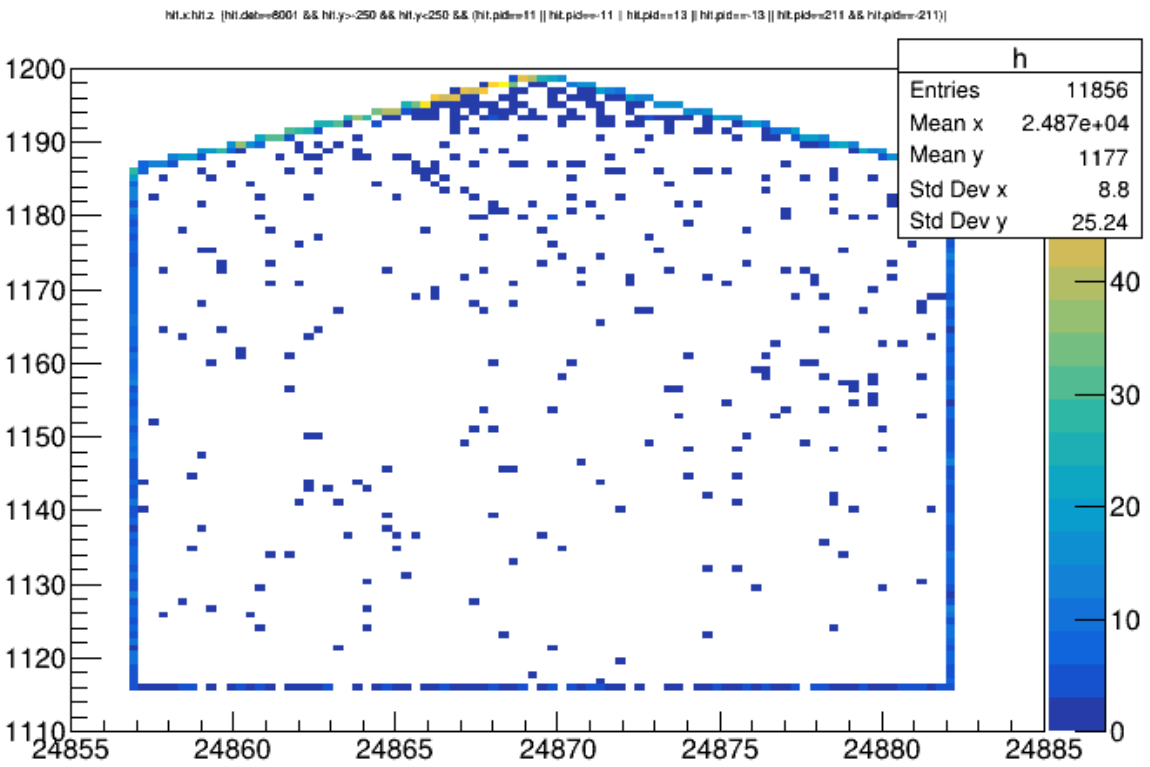


26 cm concrete and 16 cm Lead

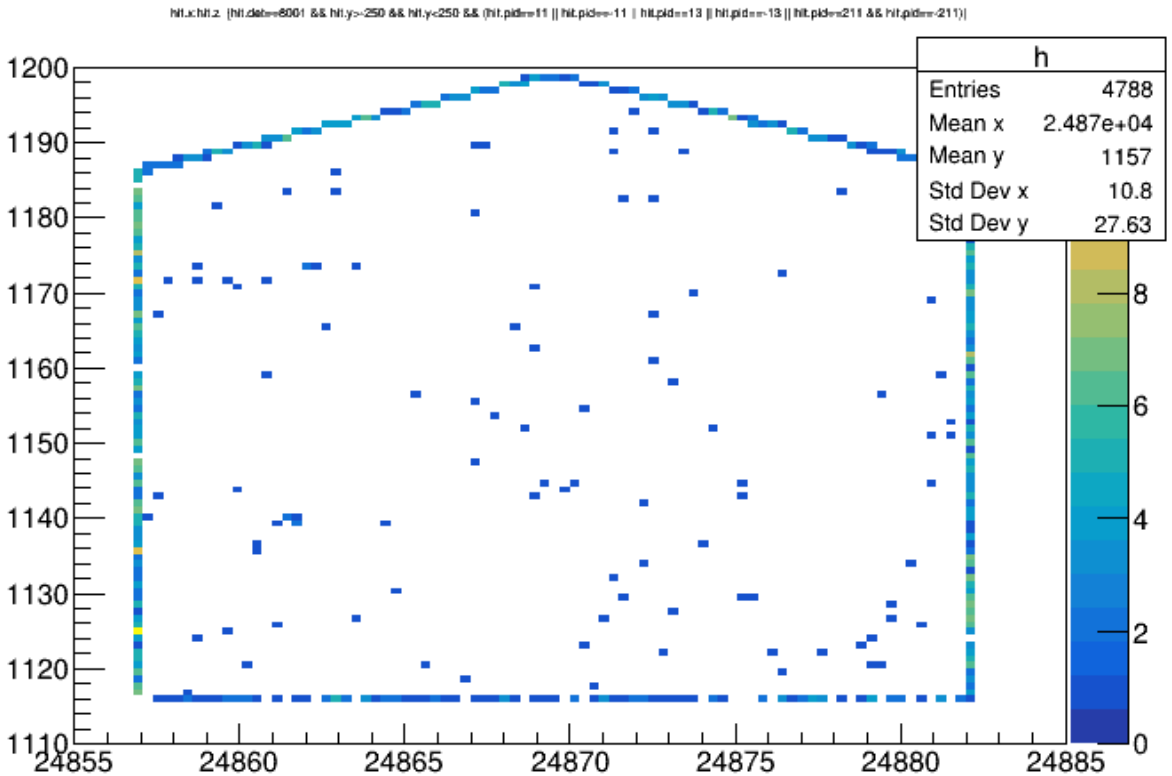


16 cm concrete and 26 cm Lead

T->Draw("hit.x:hit.z >>h(100,24855,24885,100,1110,1200)","hit.det==8001 && hit.y>-250 && hit.y<250 && (hit.pid==11 || hit.pid==-11 || hit.pid==13|| hit.pid==-13 || hit.pid==211 && hit.pid==-211)","colz")



20cm Concrete and 10cm Lead thickness



30cm Concrete and 10cm Lead thickness

Thank you

University of Manitoba