TRIUMF

University of Victoria

Hyper-K

Pion Scattering

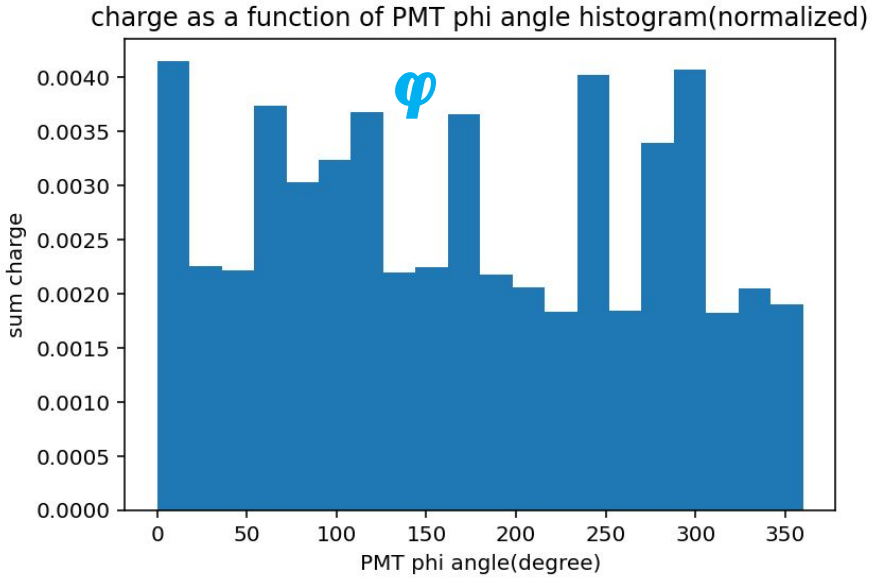
Sahar Taghayor

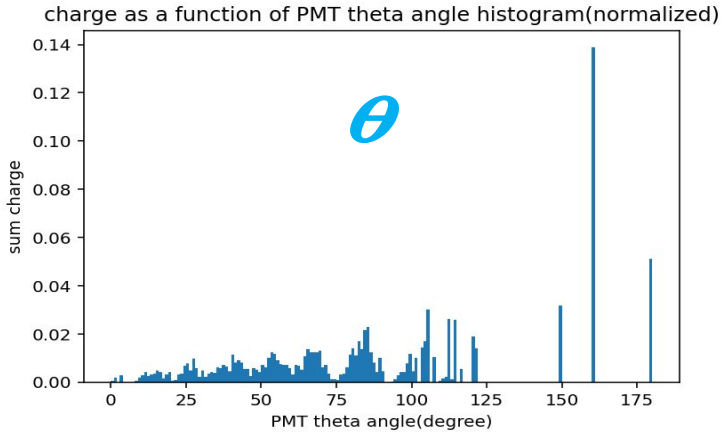
28 Feb 2025

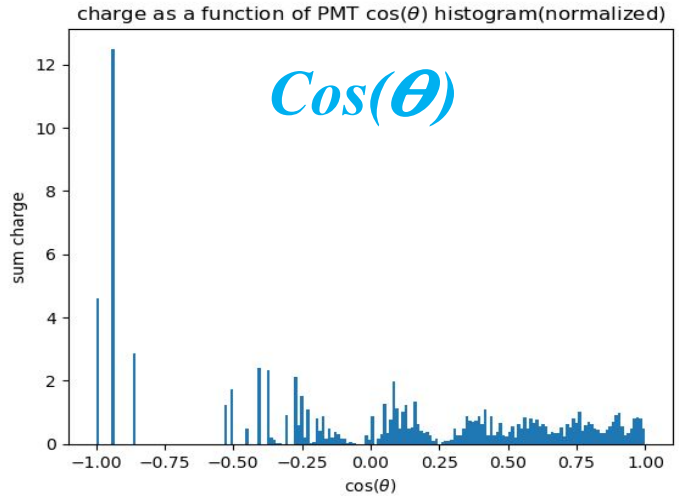
Discovery, accelerated

Uniform Photons to Check Detector Granularity- θ & φ histogram

One million photons simulated ejecting uniformly from the beam starting position in the WCTE tank.



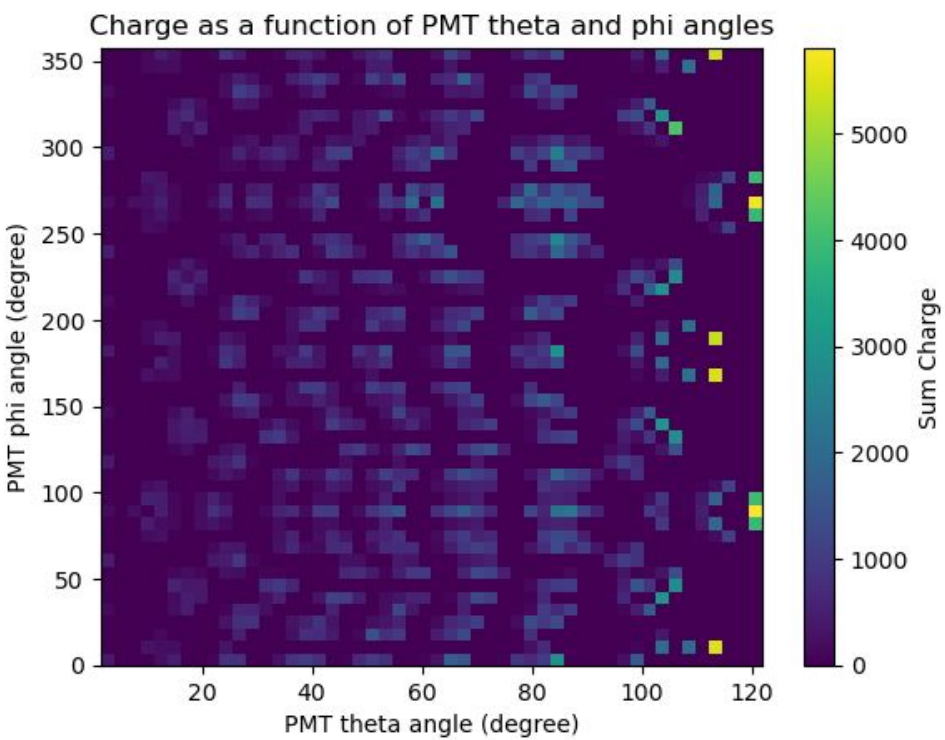


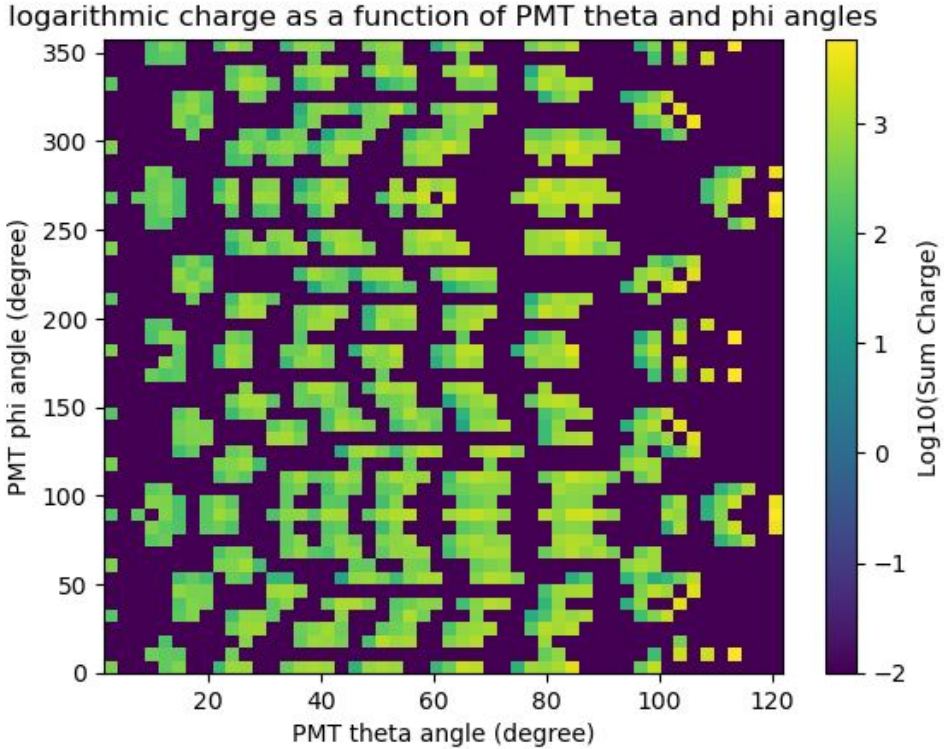


Normalized plots used further in analysis

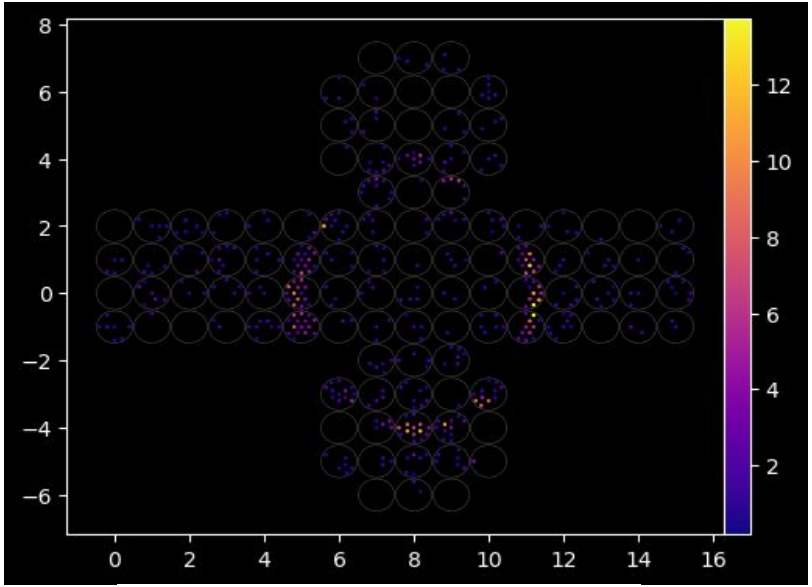
Assigned the zero bins a large number to avoid dividing by zero

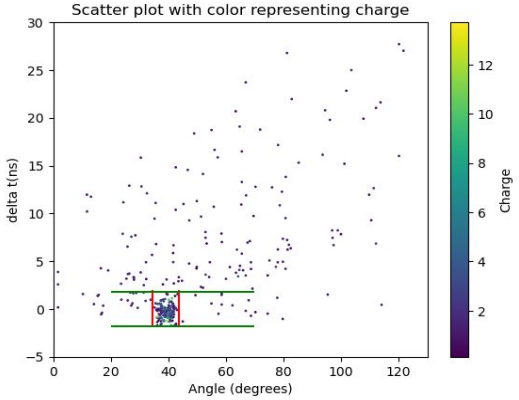
φ -θ 2D histogram from photon bomb

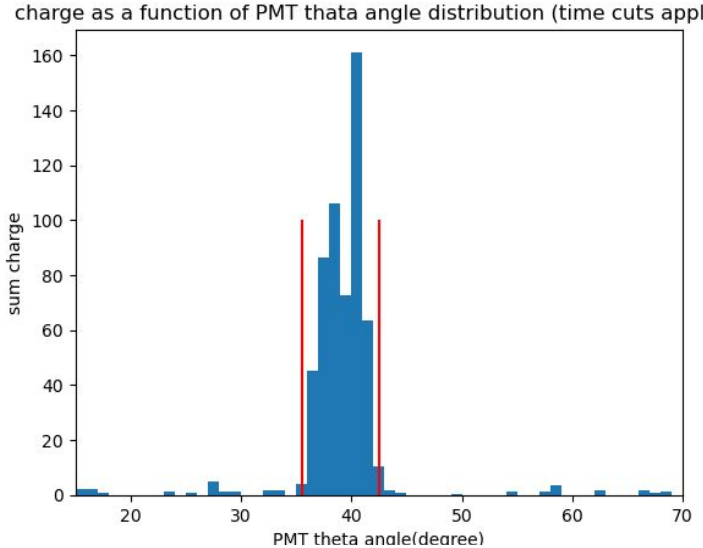


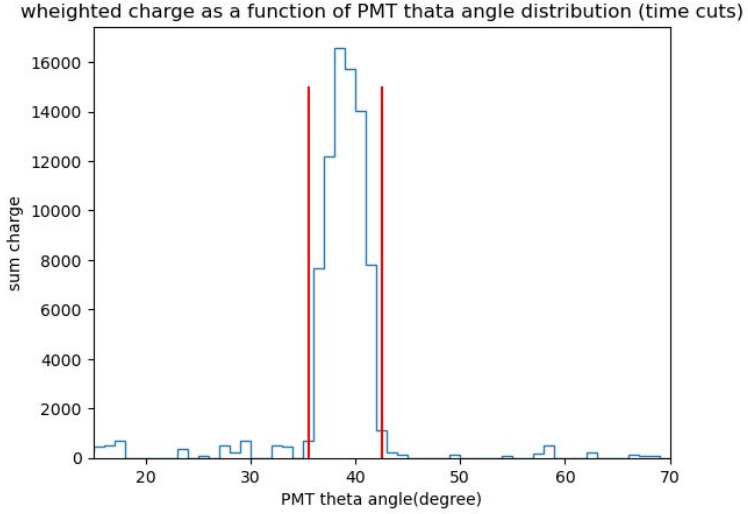


Pion absorption

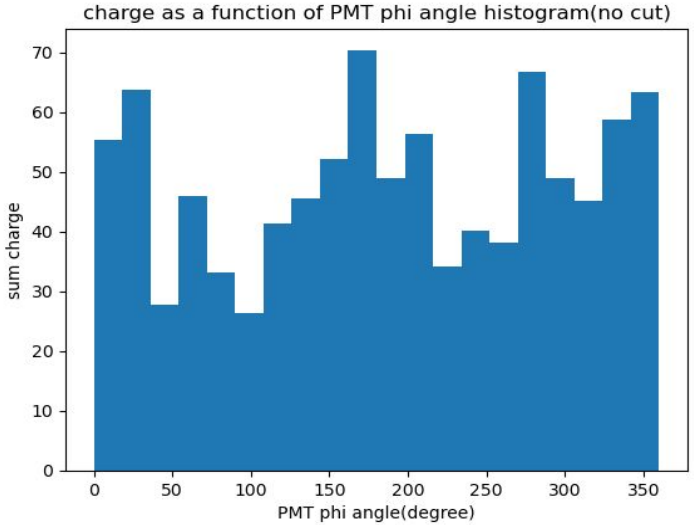


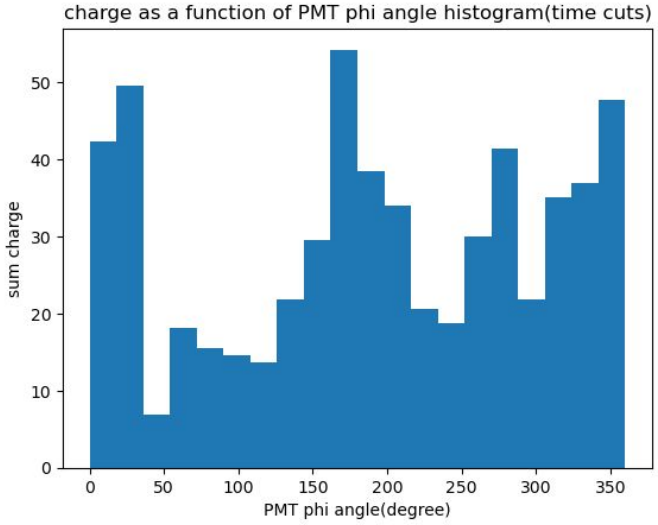


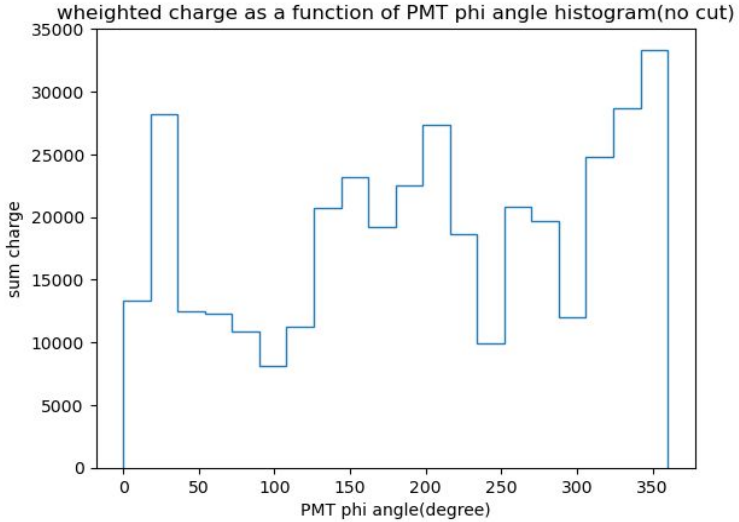


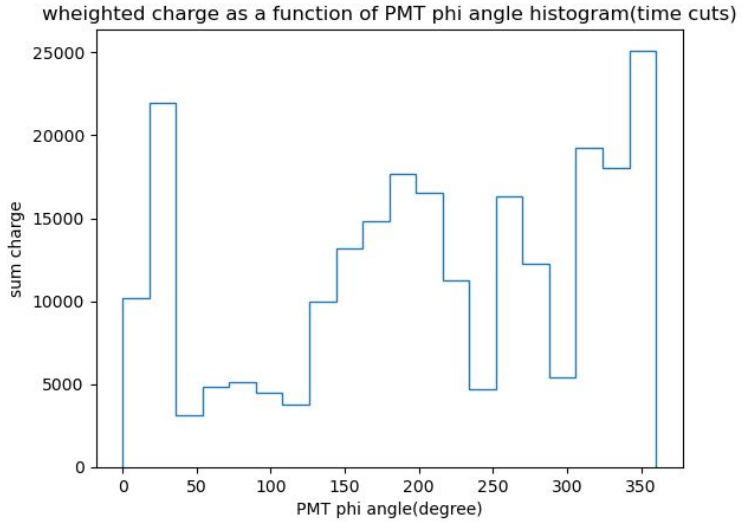


φ histogram


charge as a function of PMT phi angle histogram(no cut)
sum charge
PMT phi angle(degree)
0
10
20
30
40
50
60
70
0
50
100
150
200
250
300
350


charge as a function of PMT phi angle histogram(time cuts)
sum charge
PMT phi angle(degree)
0
10
20
30
40
50
0
50
100
150
200
250
300
350


wheighted charge as a function of PMT phi angle histogram(no cut)
sum charge
PMT phi angle(degree)
0
5000
10000
15000
20000
25000
30000
35000
0
50
100
150
200
250
300
350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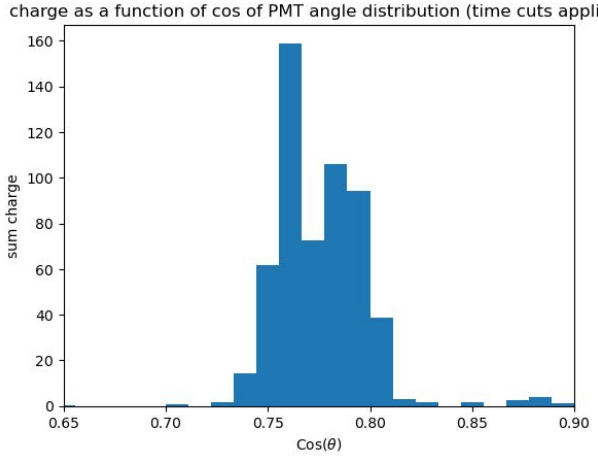
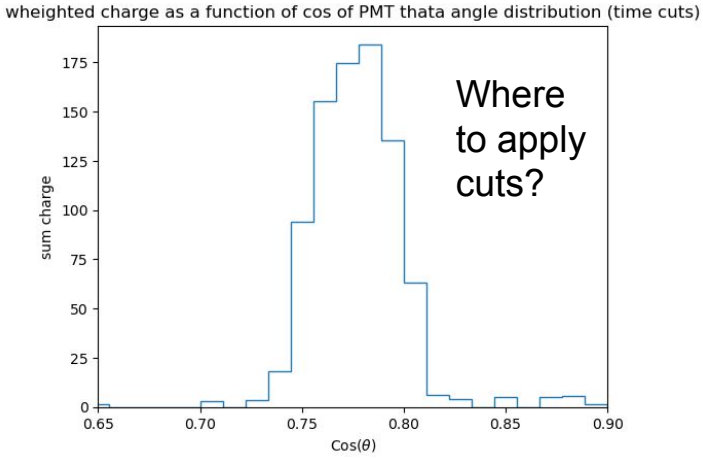
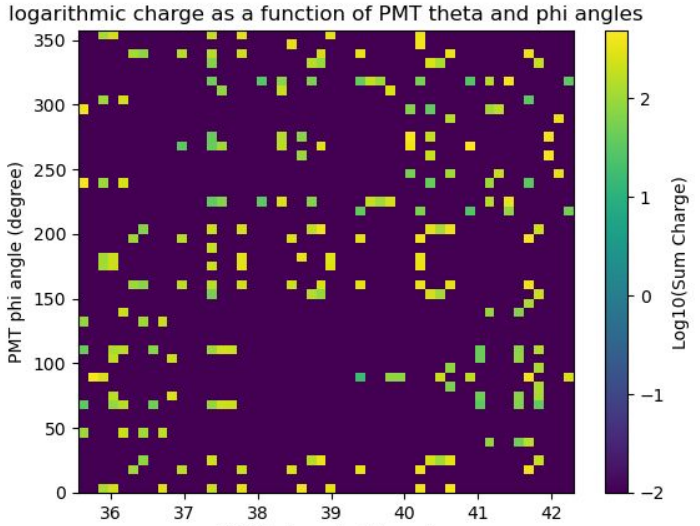
sum charge
PMT phi angle(degree)
0
5000
10000
15000
20000
25000
0
50
100
150
200
250
300
350

Cos(θ) and φ -θ 2D histogram

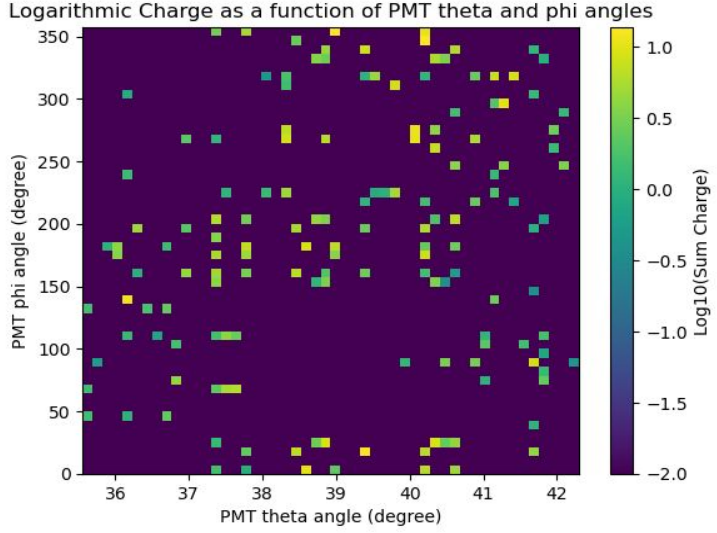




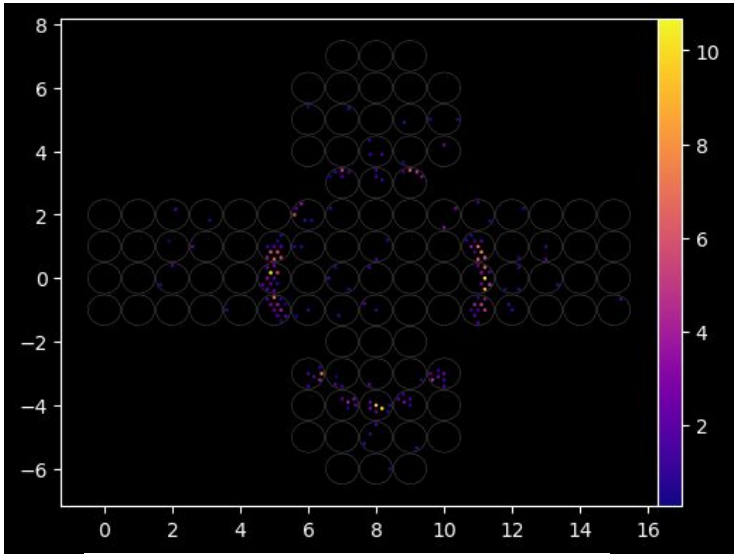
Photon bomb

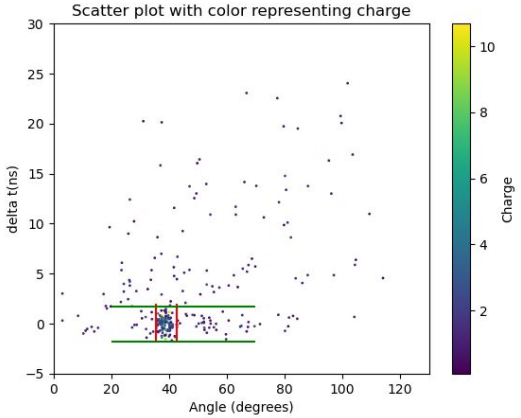


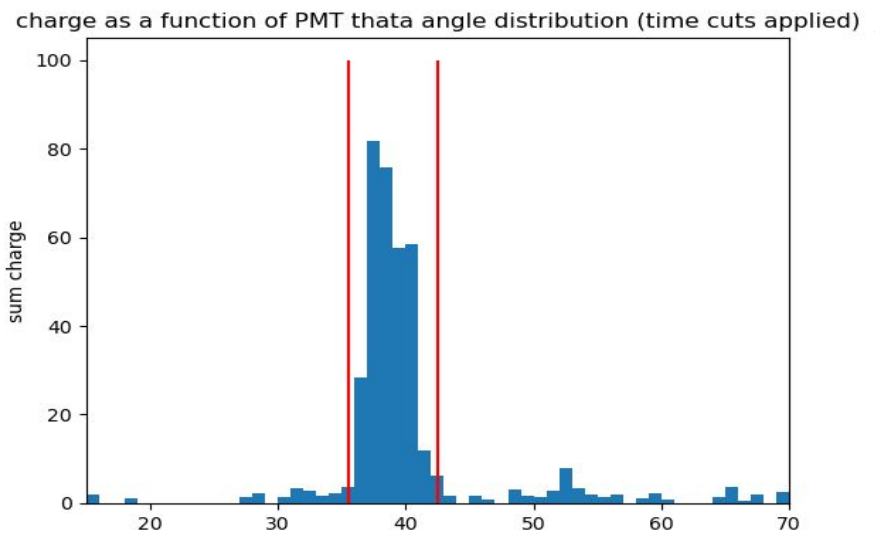
Pion event

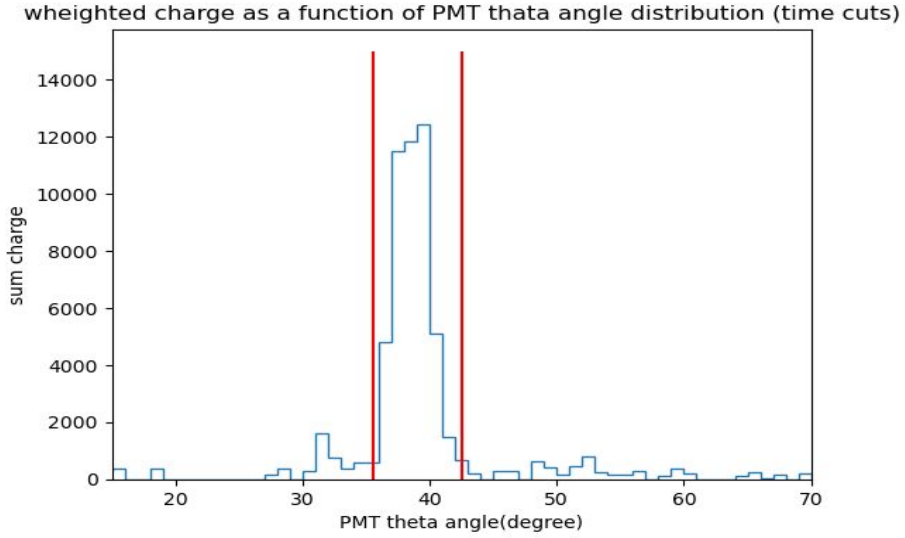


Another Pion absorption!

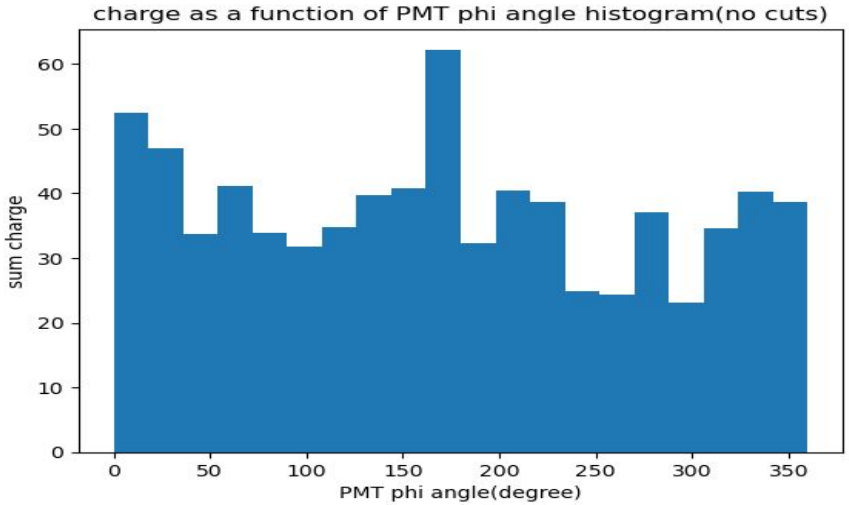


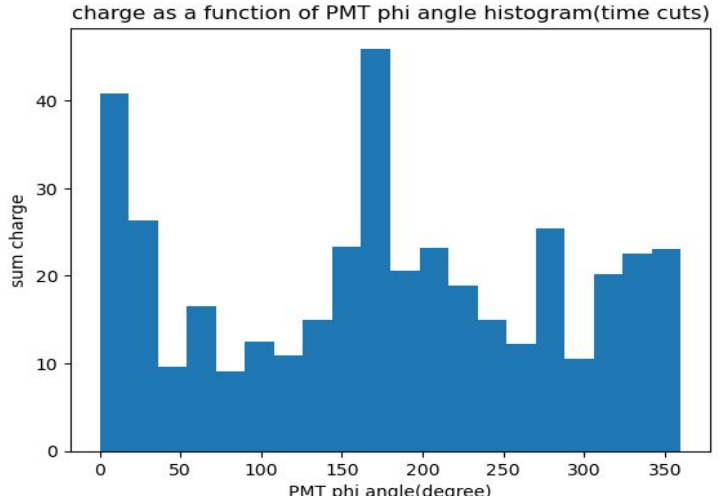






φ histogram


charge as a function of PMT phi angle histogram(no cuts)
sum charge
PMT phi angle(degree)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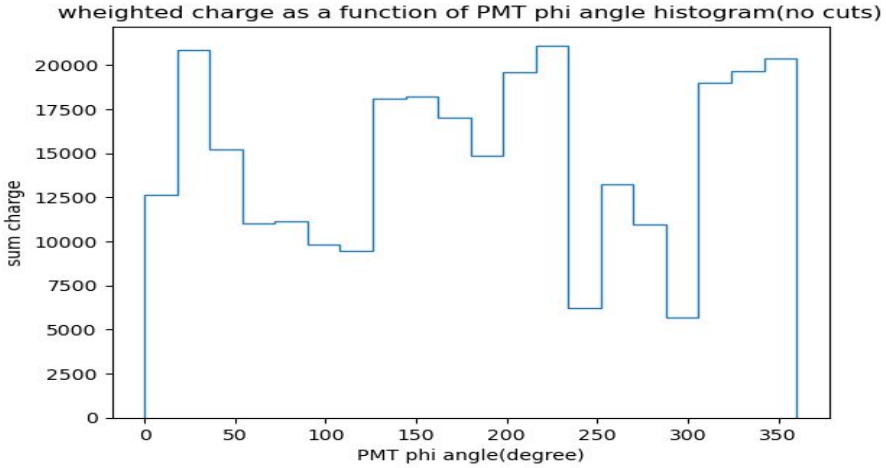
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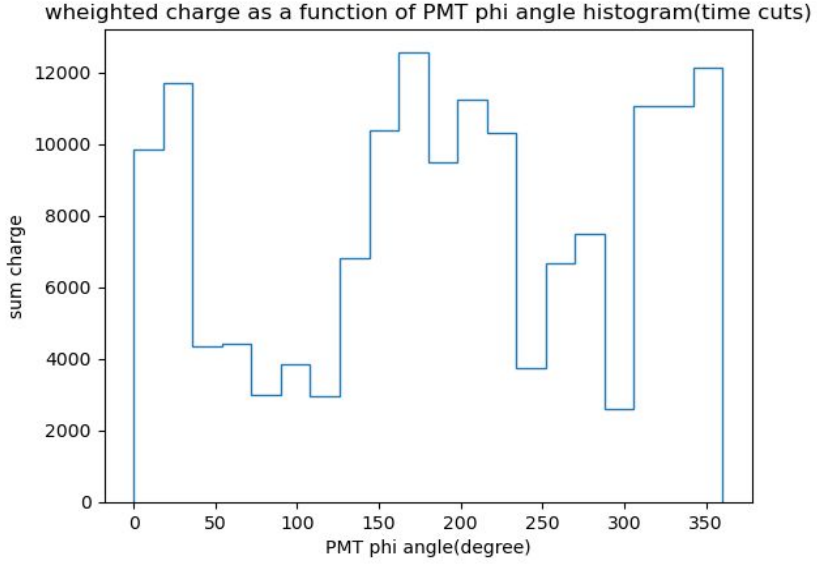
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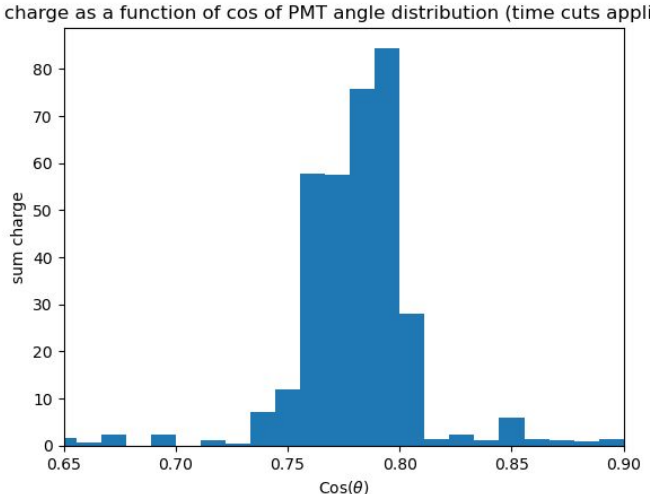
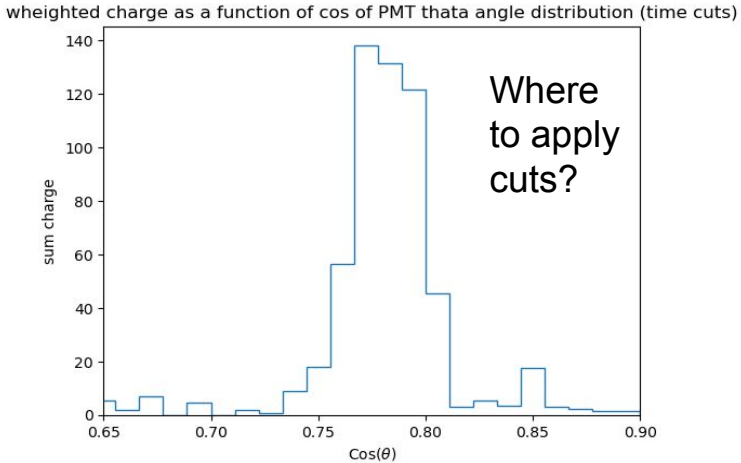
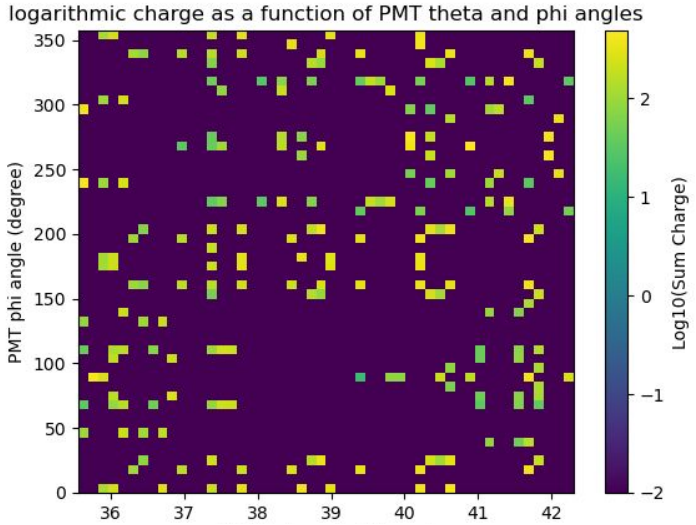
sum charge
PMT phi angle(degree)

Cos(θ) and φ -θ 2D histogram

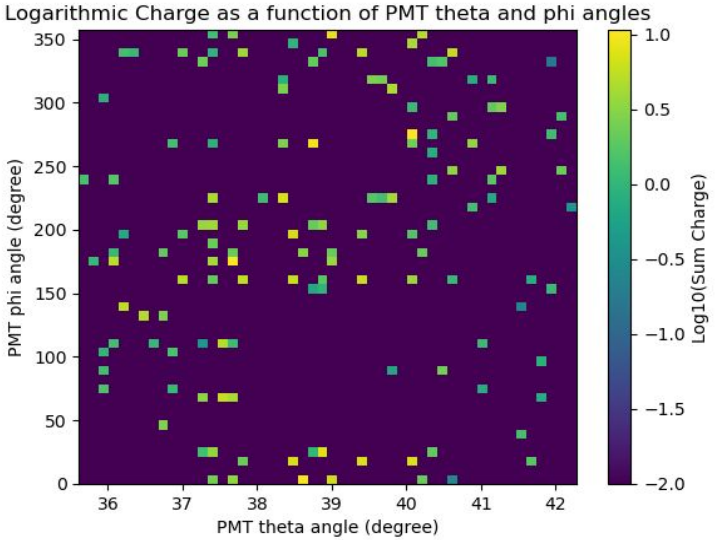




Photon bomb



Pion event



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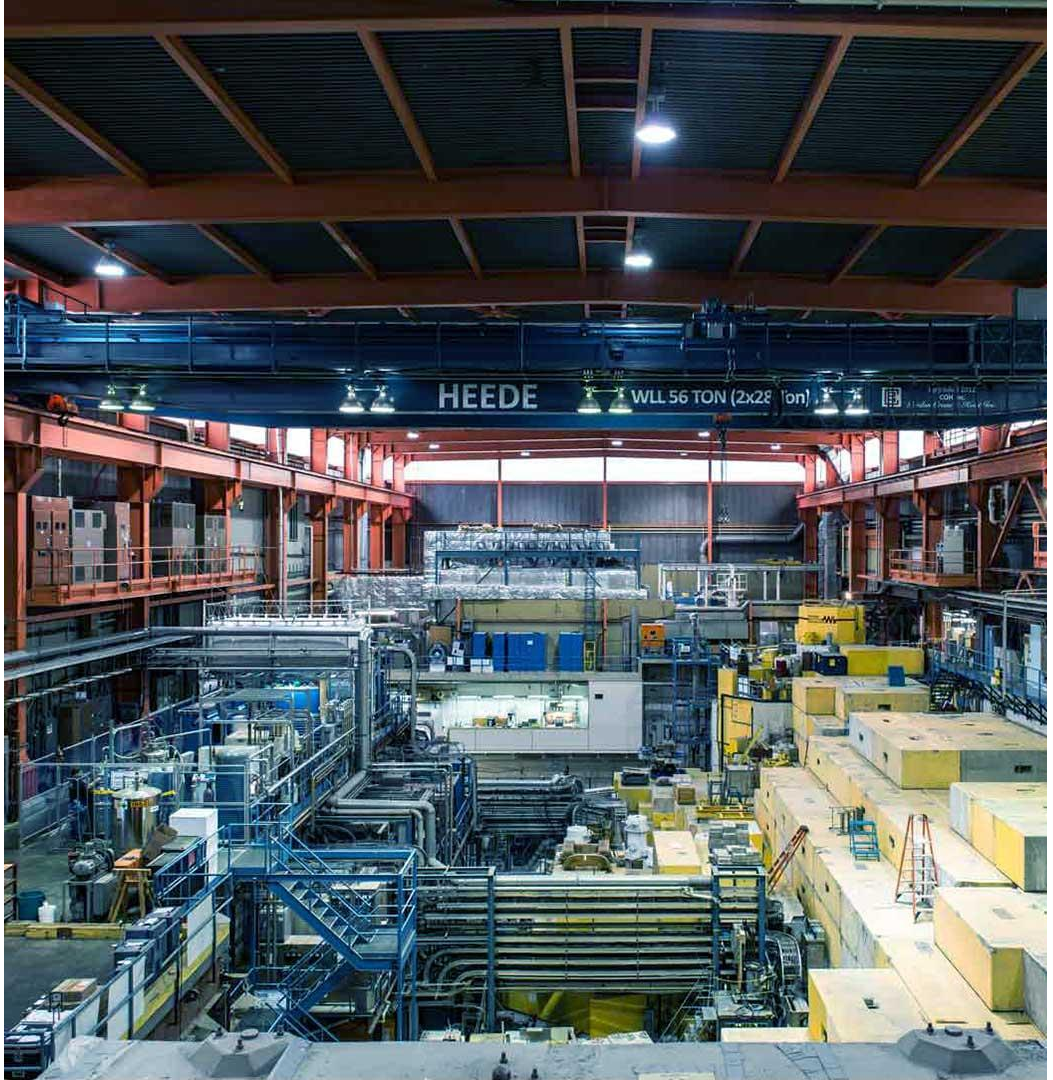
Thank you.

Questions or comments?



Discovery, accelerated

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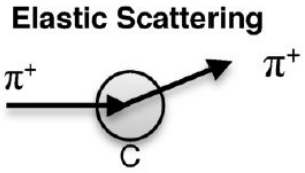
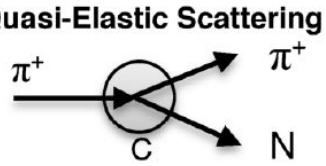
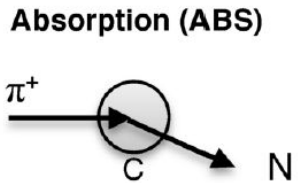
Backup

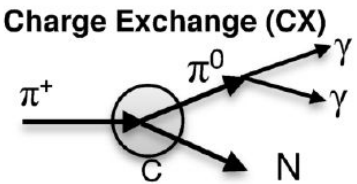
Pion Interactions on Nuclei

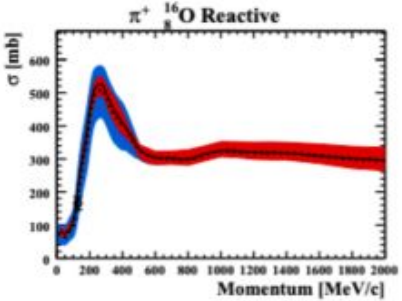
Dominant π± and A interactions in the sub-GeV region. “N” represents any number of nucleons leaving the nucleus

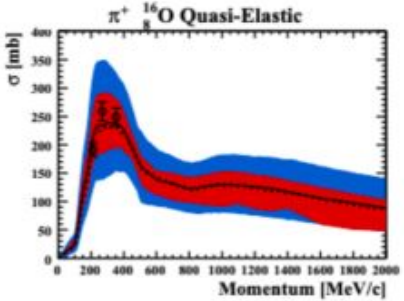


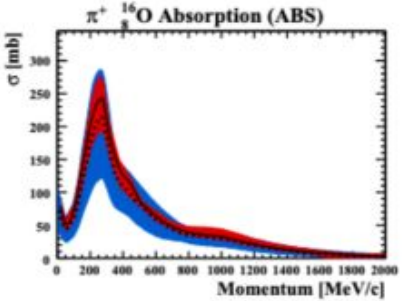


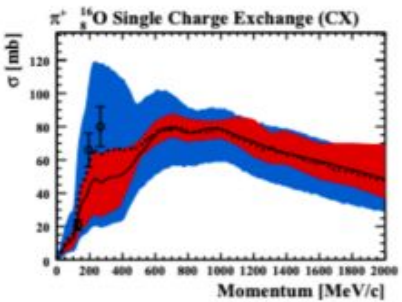


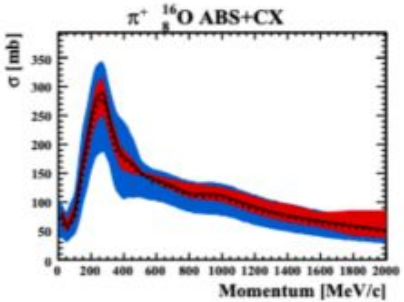












FSIFitter best fit

FSIFitter ±1σ band

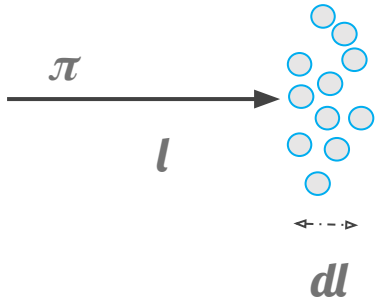
TN-032 best fit (dashed)

TN-032 ±1σ band

- Not enough data on pion-water cross section

Pion Cross Section

Pion and water molecule cross-section can be found by having the distribution of the length it travels in water before each type of interaction

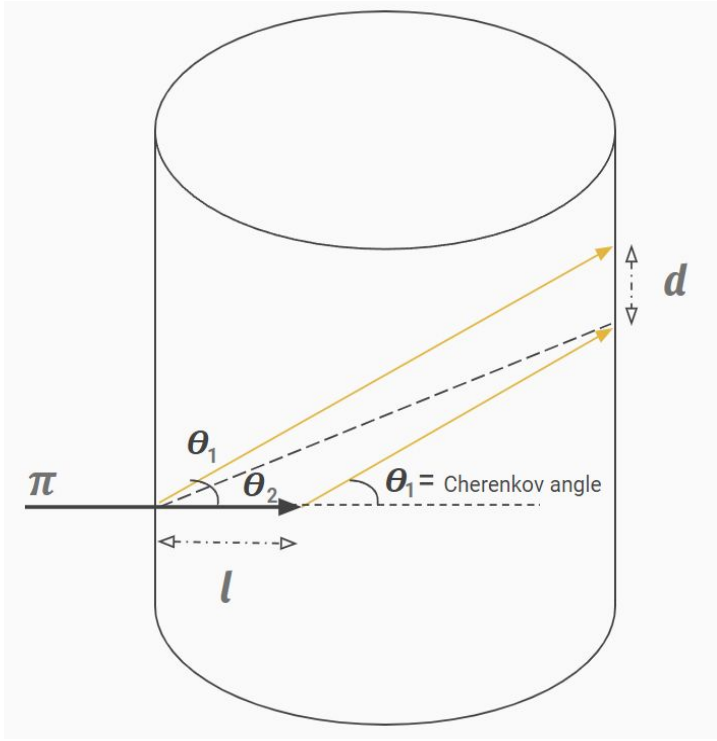


$$P_{(\text{pion-water molecule interaction})} = \sigma \times n$$

number density of water molecules: $n = \dfrac{\rho N_A}{M}$

$$P_{(\text{pion-water molecule interaction at } L)} = \frac{\phi_{(\ell)} d\ell}{1 - \int_0^L \phi_{(\ell)}\, d\ell} = \frac{\phi_{(\ell)} d\ell}{\int_L^\infty \phi_{(\ell)}\, d\ell}$$

$$\sigma_{(E_{\pi(\ell)})} = \frac{M}{N_A \rho} \times \frac{1}{\int_L^\infty \phi_{(\ell)}\, d\ell} \times \phi_{(\ell)}$$

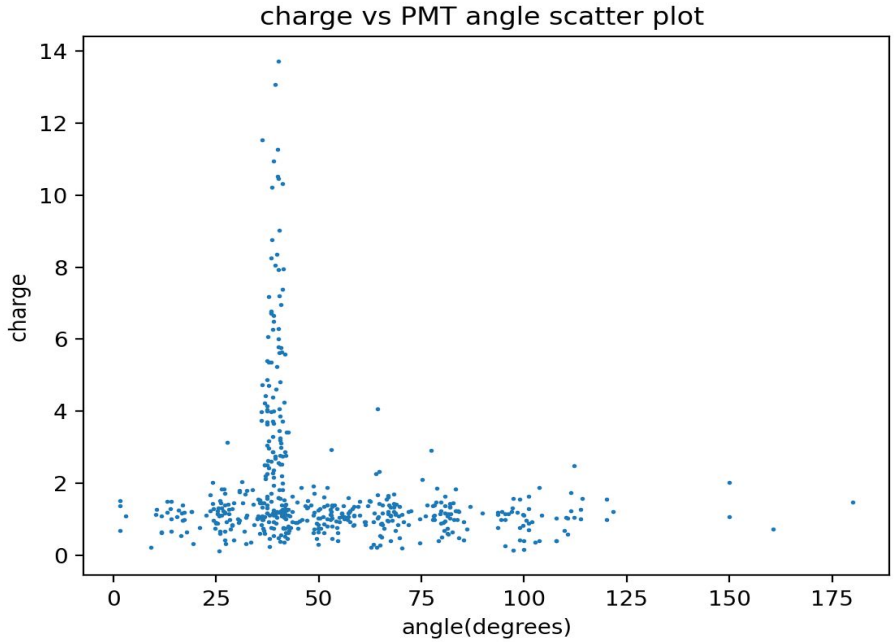


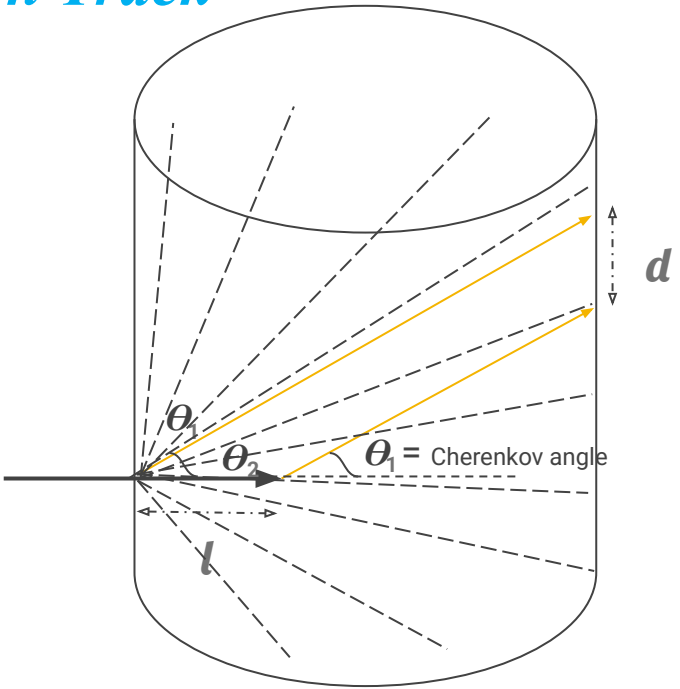
$$\ell = \frac{d}{\tan\theta_1} = 2R\left(1 - \frac{\tan\theta_2}{\tan\theta_1}\right)$$

where θ_1 is the Cherenkov angle

Distribution of Angle between PMT and Pion Track

- Find the angle each PMT makes with the pion track from the start of the track
- Plot the PMT hits as a function of angle

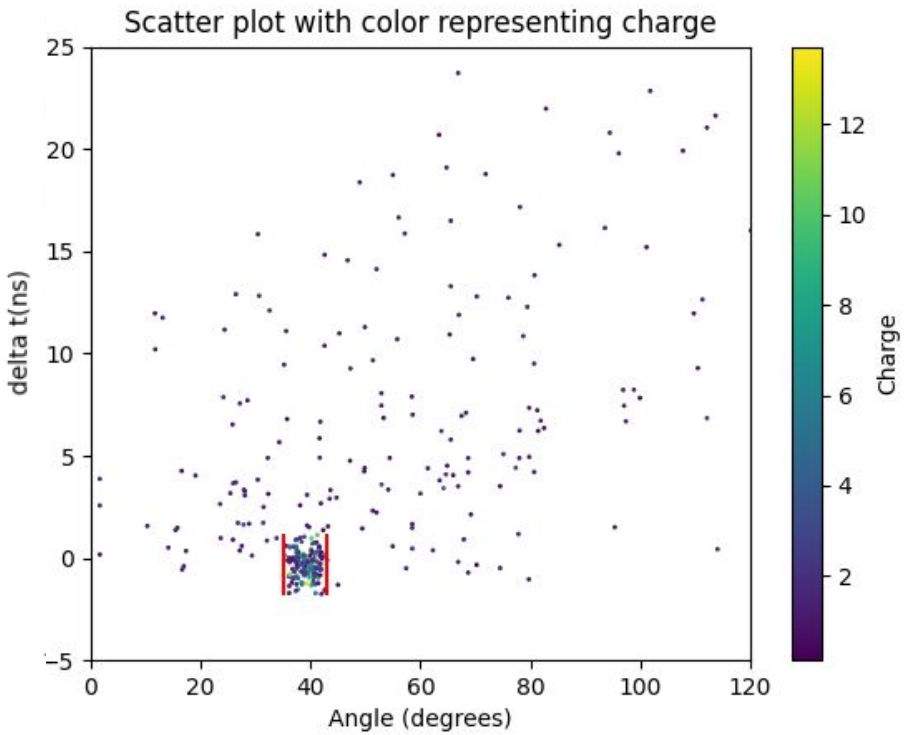




$$\ell = \frac{d}{\tan\theta_1} = 2R\,(1 - \frac{\tan\theta_2}{\tan\theta_1})$$

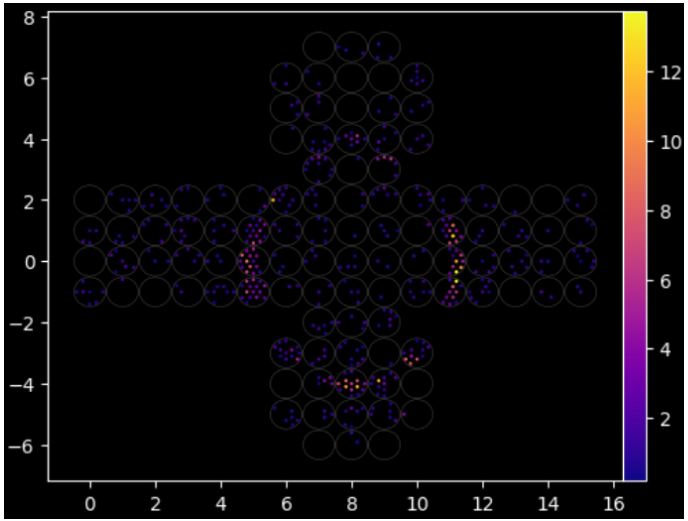
where θ_1 is the Cherenkov angle

Hit Time, PMT Angle, Hit Charge Plot and Event Display



A pion with 700 MeV/c momentum gets absorbed in the detector.

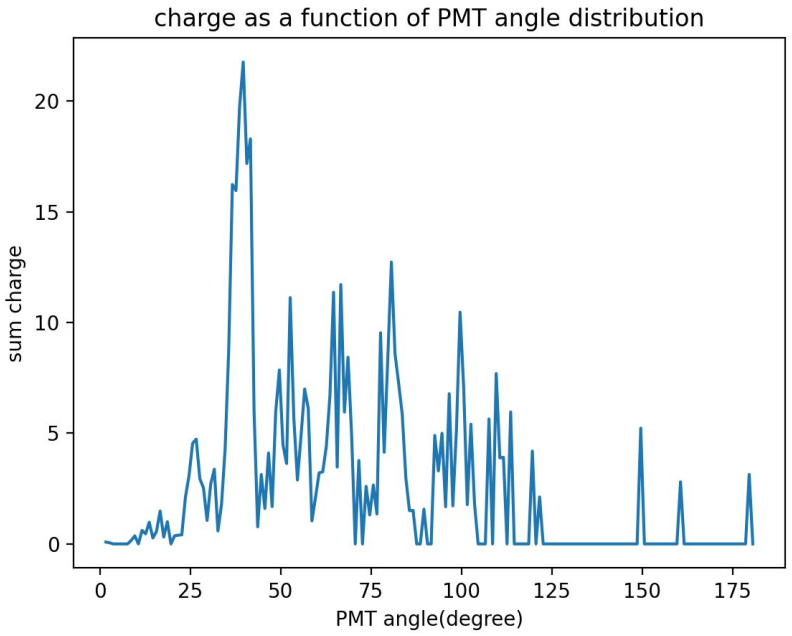
- Find the time of flight of a photon from the track start position to each PMT

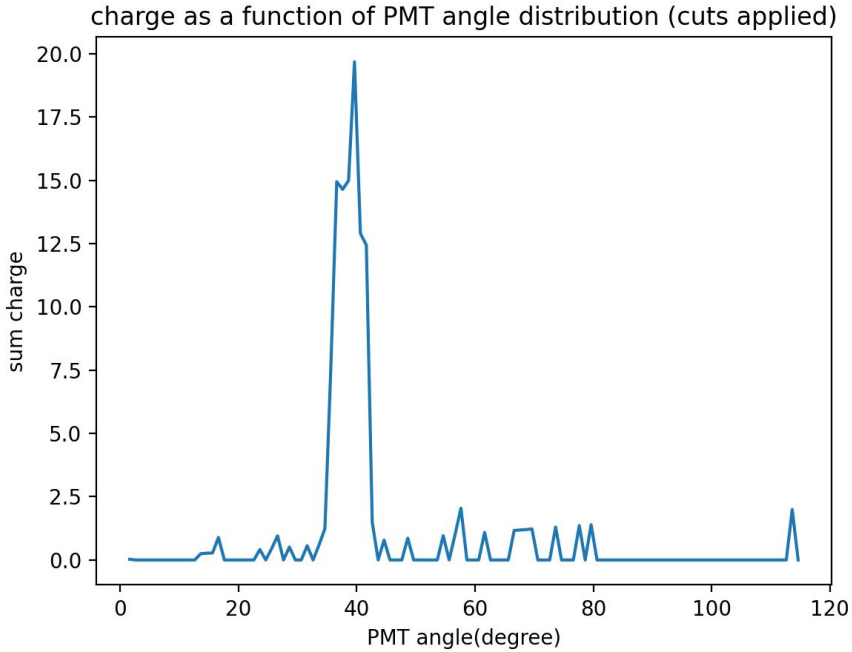


Distribution of Angle between PMT and Pion Track

- Sum all the PMT hits at each angle
- Plot this histogram from the charge vs PMT angle scatter plot

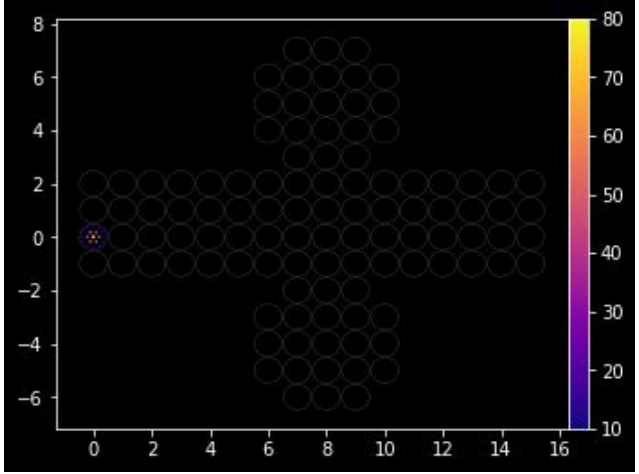
- Apply the time cuts
  - Pion's path length can be found from the width of this peak

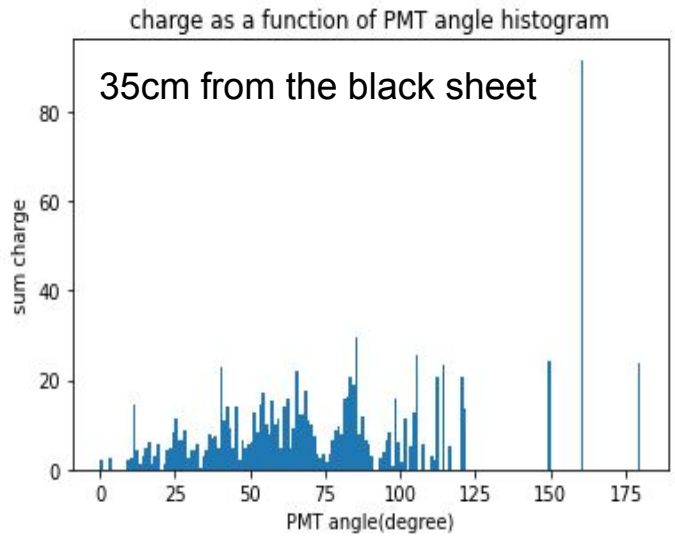


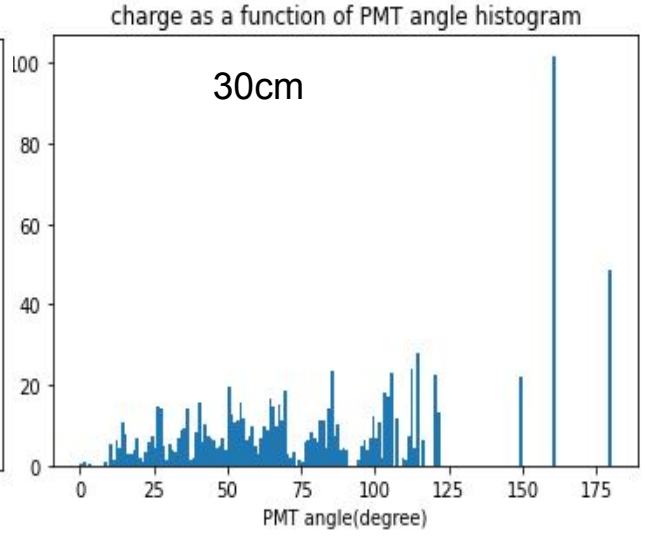


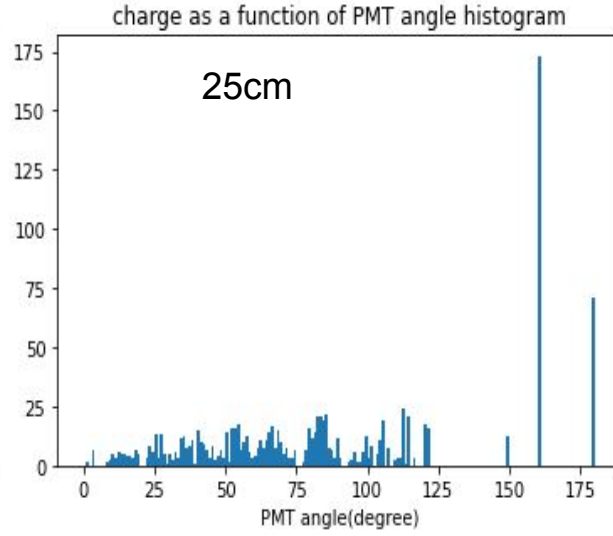
10000 photons simulated ejected uniformly in the WCTE tank

Source of photons moved along the beam axis









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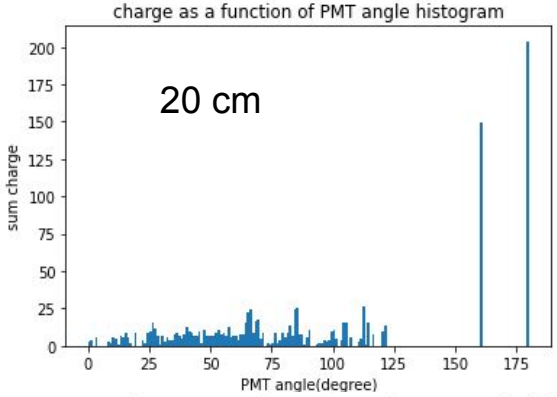
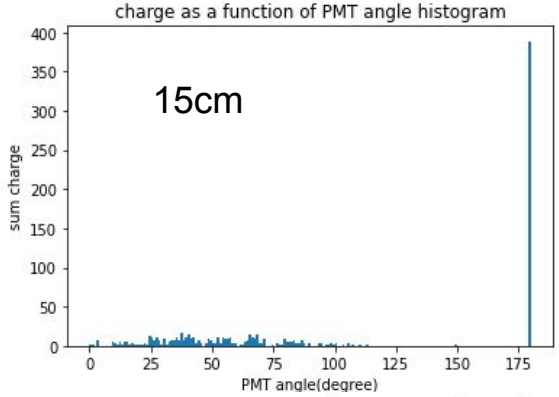
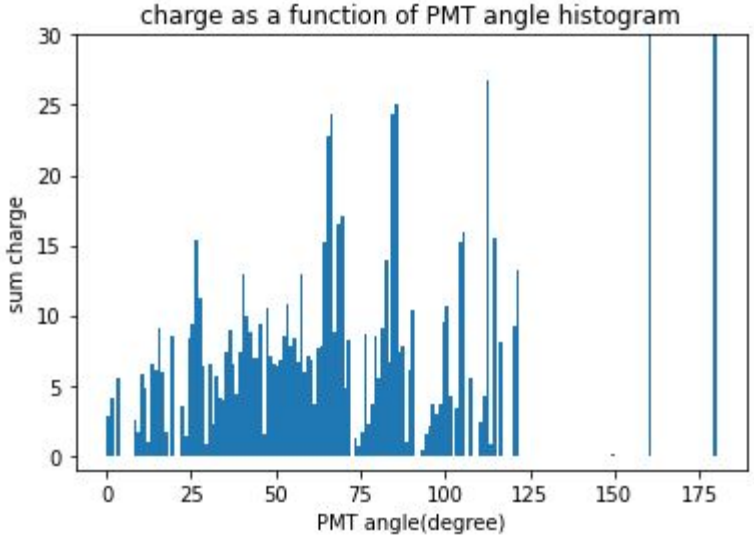
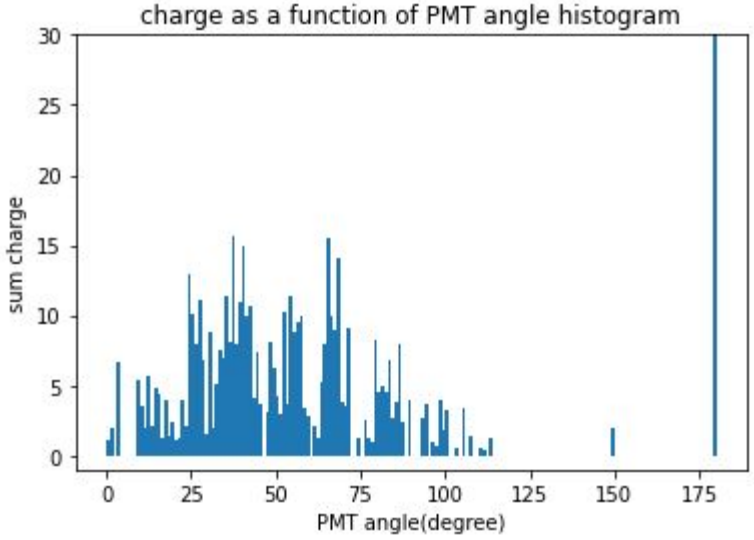
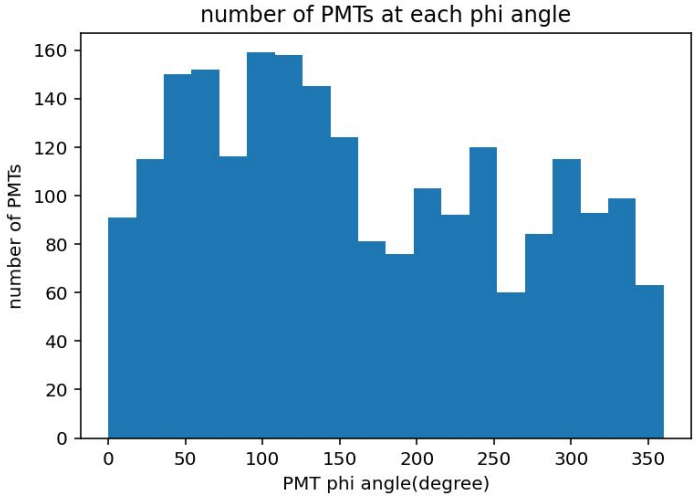


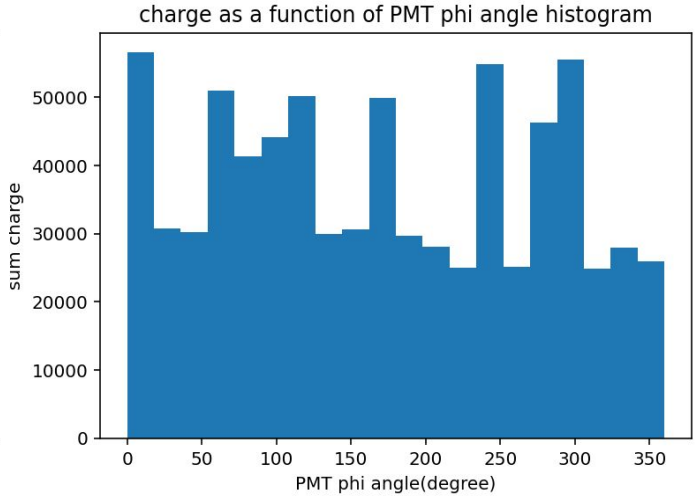




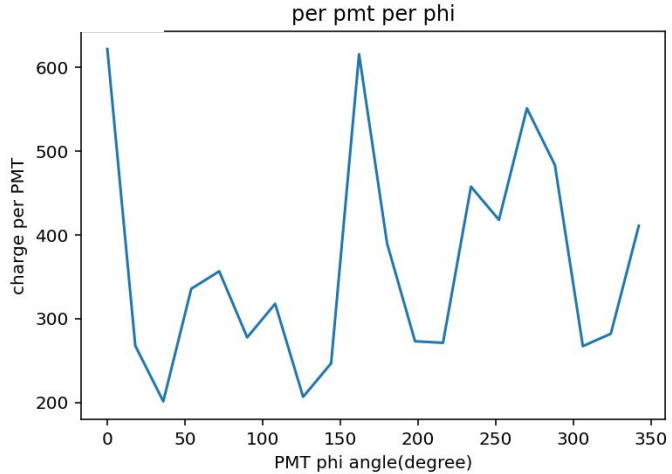


Uniform Photons to Check Detector Granularity - φ histogram

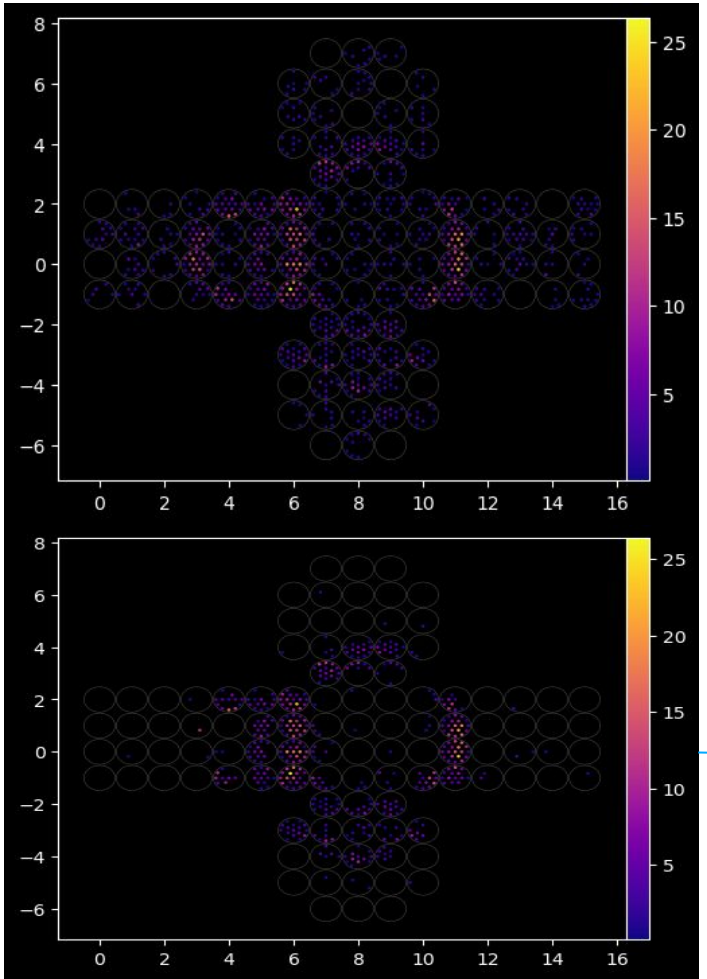




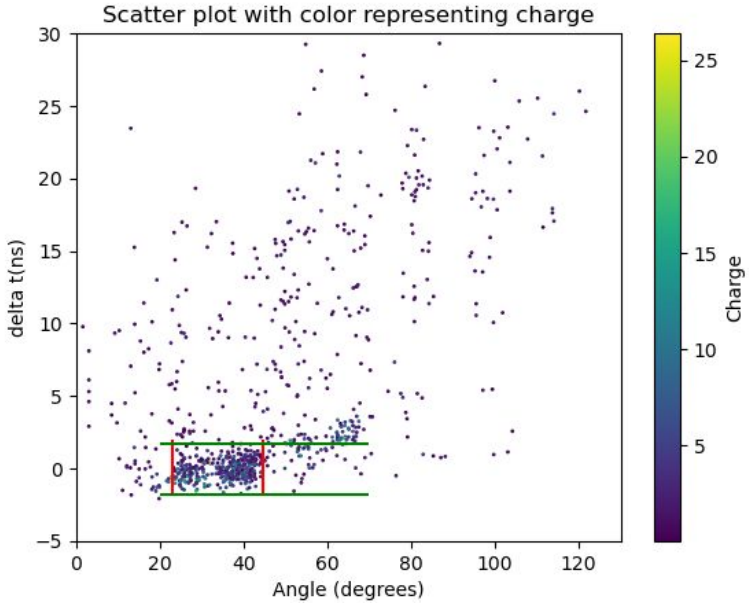
Expected this to be uniform,
Needs further check and debugs



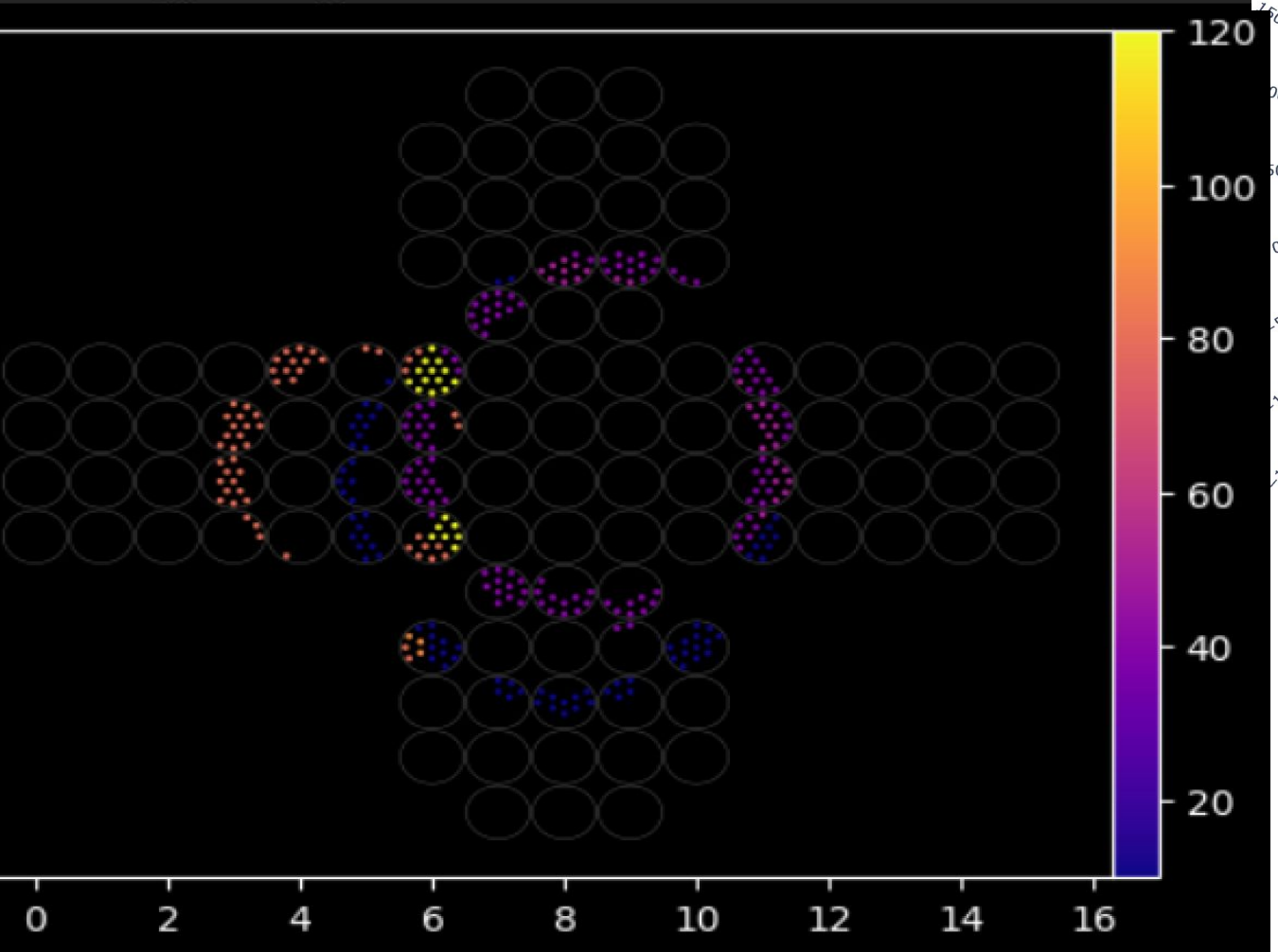
A more complicated pion event with three scatterings and rings

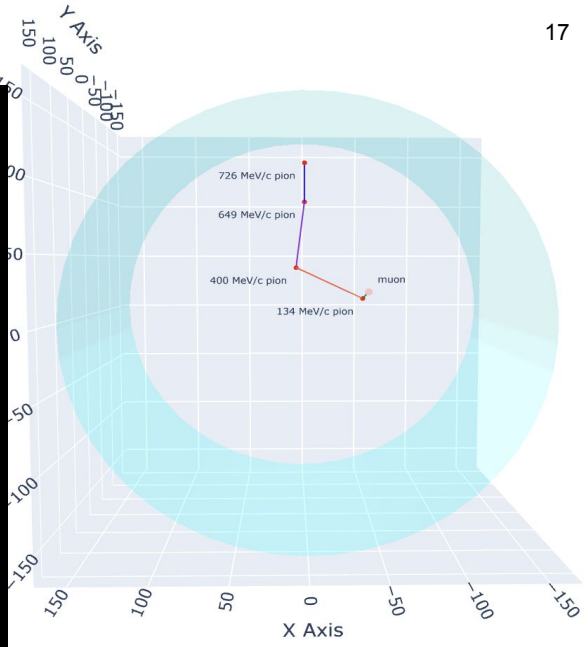


Event display with green time cuts

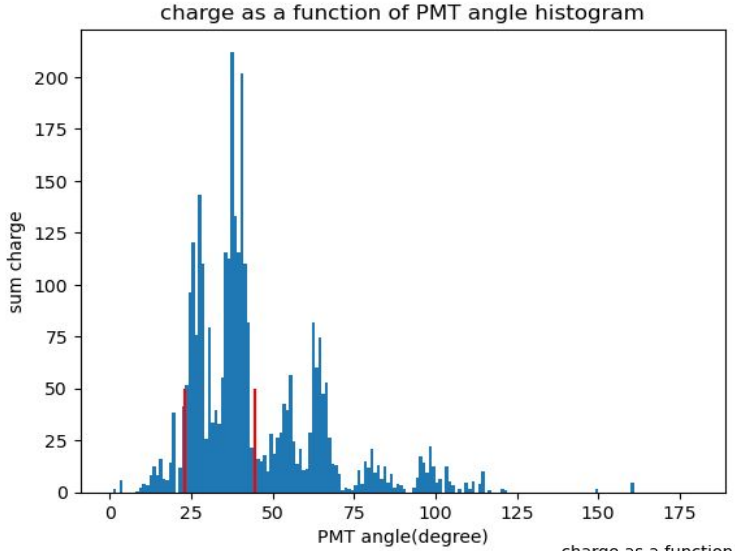


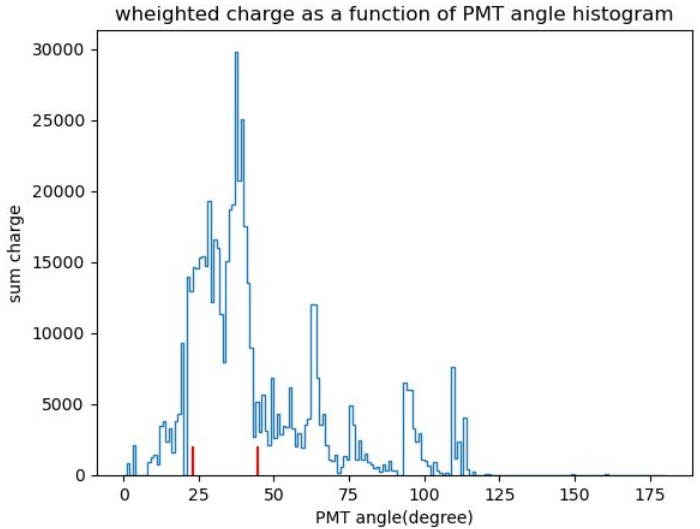
ated rings using the true information:

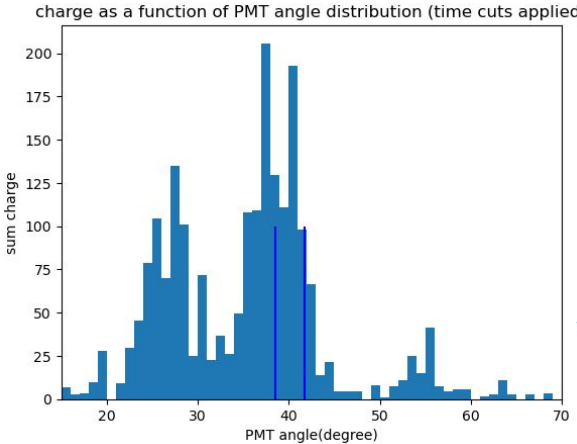




A more complicated pion event with three scatterings and rings







green time cuts applied