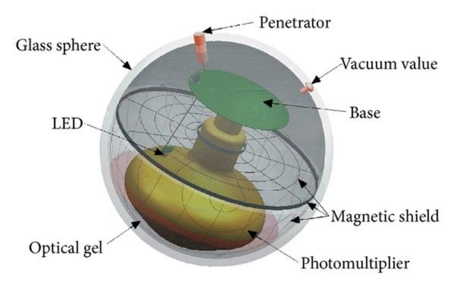
Measuring the angular acceptance of the Digital Optical Module

Outing
Thursday May 23
Thijs van Eeden

Importance of Angular Acceptance

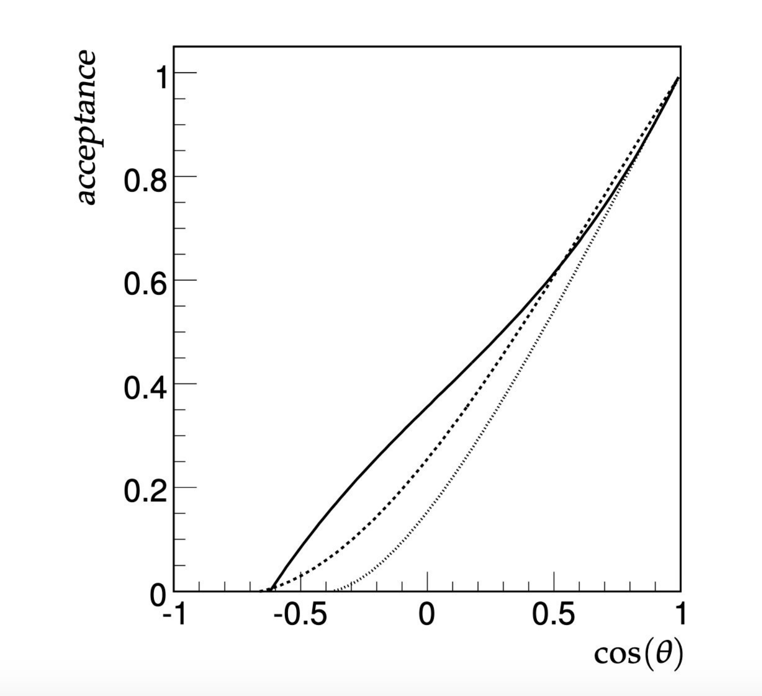


- Important factor in estimating the detection rate

Acceptance with Antares

- Simulations determined acceptance
- While measuring they found a lower atmospheric muon detection rate

Detector acceptance was actually higher than simulated for photons from above!



KM3NeT: What do we know?

Calculate detected photons from flux using effective area

$$N_{det}[s^{-1}] = A_{eff}[m^2] * F[m^{-2}s^{-1}]$$

Effective area has a (theta) dependency

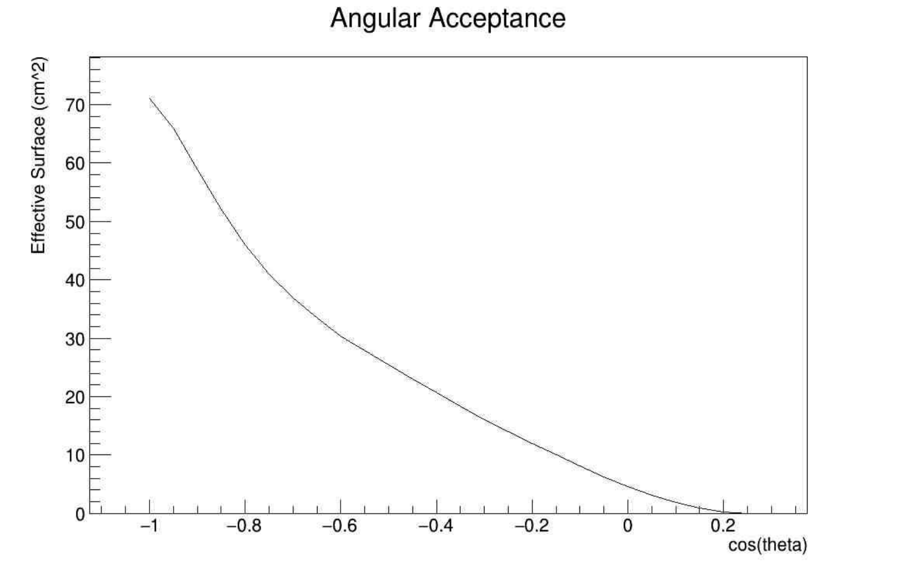
$$A_{eff} = \epsilon_C A_{PMT} qe(\lambda)\epsilon(\theta)e^{-t_{glass}/l_{glass}} e^{-t_{gel}/l_{gel}}$$

This has been simulated!

KM3NeT: What do we know?

Simulations in JSirene (M. de Jong)

$$A_{eff} = A_{cathode} * Acceptance(\theta)$$



Contains geometry PMT and reflector ring

Useful but fails to explain true behaviour PMT, example:

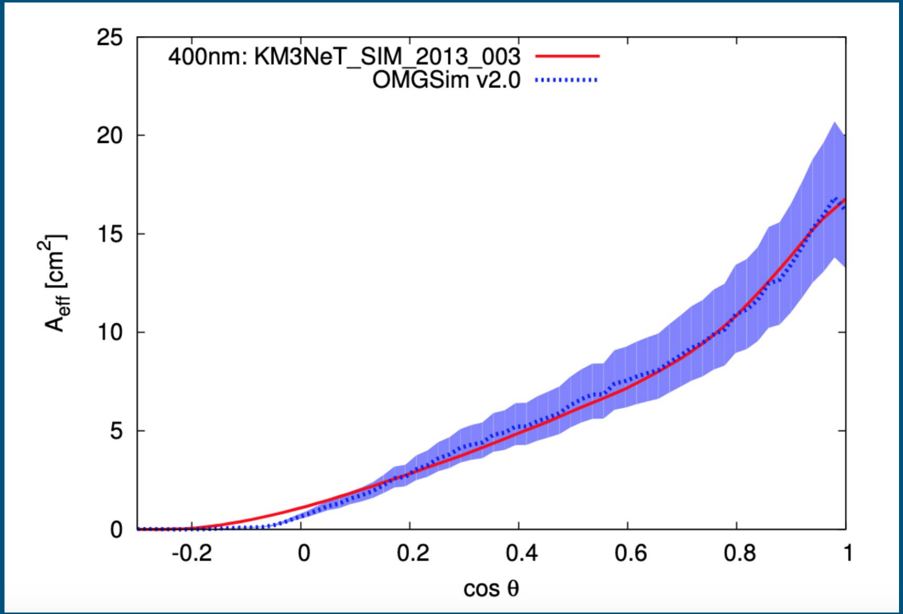
- Photons that hit PMT off optical axis go through different thickness gel/glass

KM3NeT: What do we know?

OMGSim (C. James)

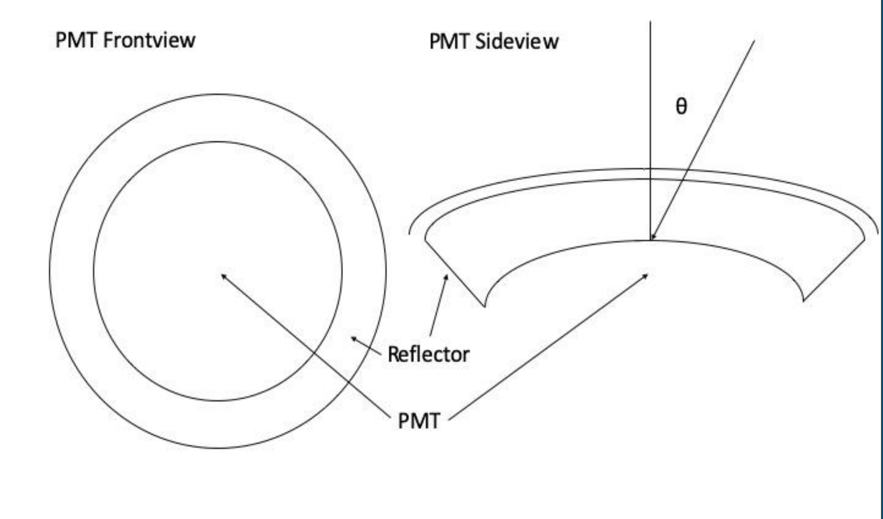
- Fully simulate PMT, glass, gel, qe to get acceptance
- High computational power
- Tabulate the results so we can use them

How can we experimentally check these results?



Research question

What is the angular acceptance of a PMT in an assembled DOM in water?



Sub Questions:

- What is the influence of the position of where a photon hits the PMT on the DOM's signal?
- What is the influence of the angle of incidence on the DOM's signal?
    - Angle of incidence = angle between optical axis PMT and incident light

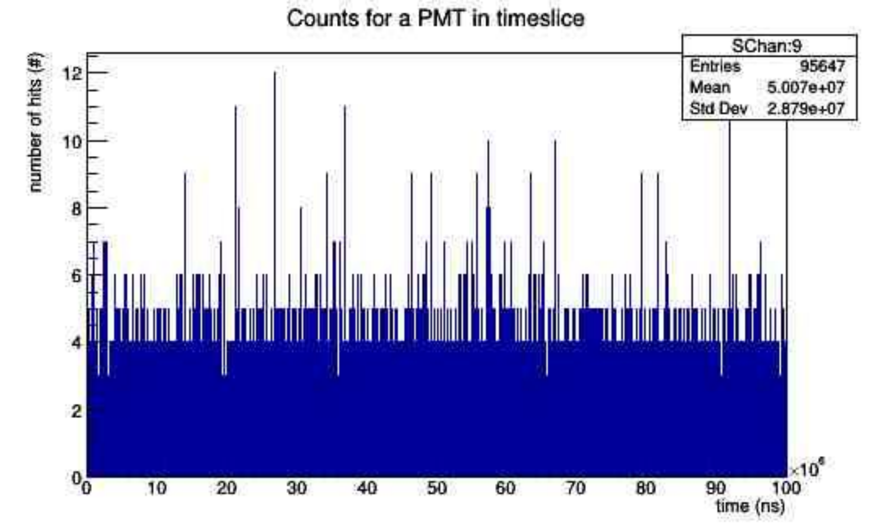
Quantifying the signal

Excite the DOM with a picosecond pulsed laser in single photon regime

DOM registers:

- Time of a hit (t)
- Time-over-threshold (Tot)

How can we find our signal?



Finding the Signal

Picosecond pulsed laser triggered by the nanobeacon of a CLB

CLB and DOM connected to White Rabbit Switch (WRS) for time synchronization

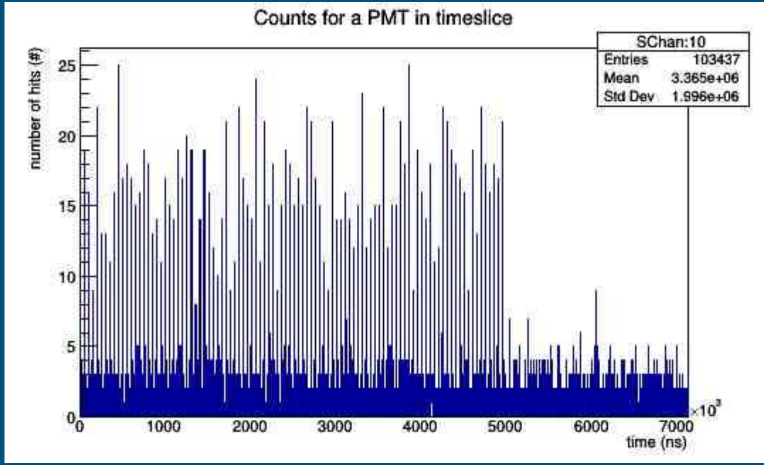
Now we know when to expect our pulse!

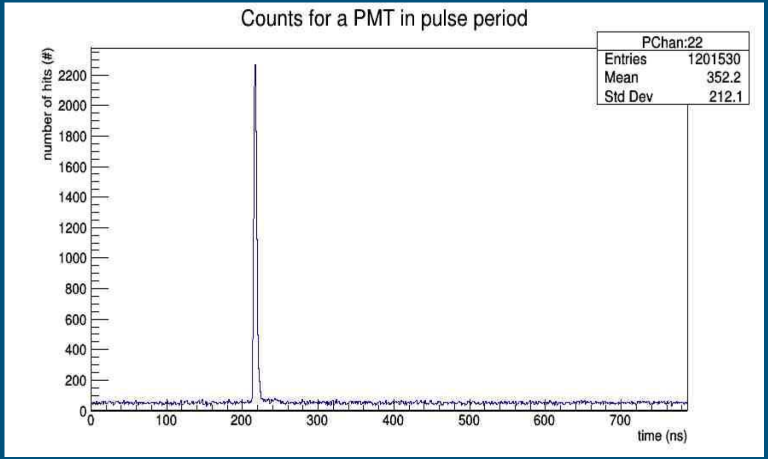
Finding the signal

Send x laser pulses in a timeslice and count the number of hits in a ~20 ns time window

$$\text{Efficiency} = \frac{\text{Counted hits}}{\text{Pulses sent}}$$

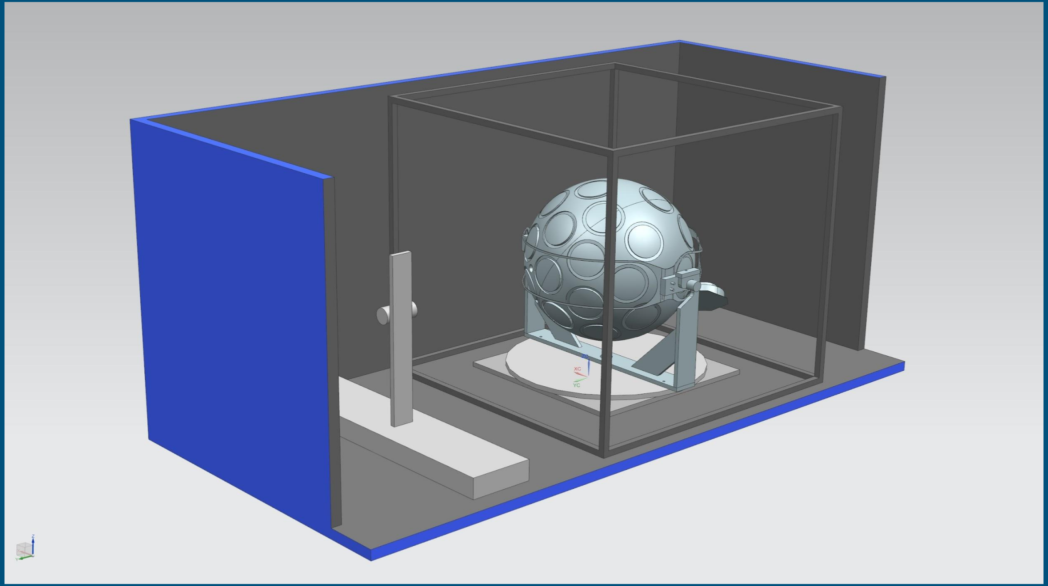
Adjust laser intensity to single photon regime ~0.1 spe per pulse





Experimental setup

- Dom submerged in water in an aquarium
- DOM can be rotated over 2 angles (Θ,φ)
- X-Z stage for collimator laser



Vary the angle of incidence and position of laser spot on the DOM

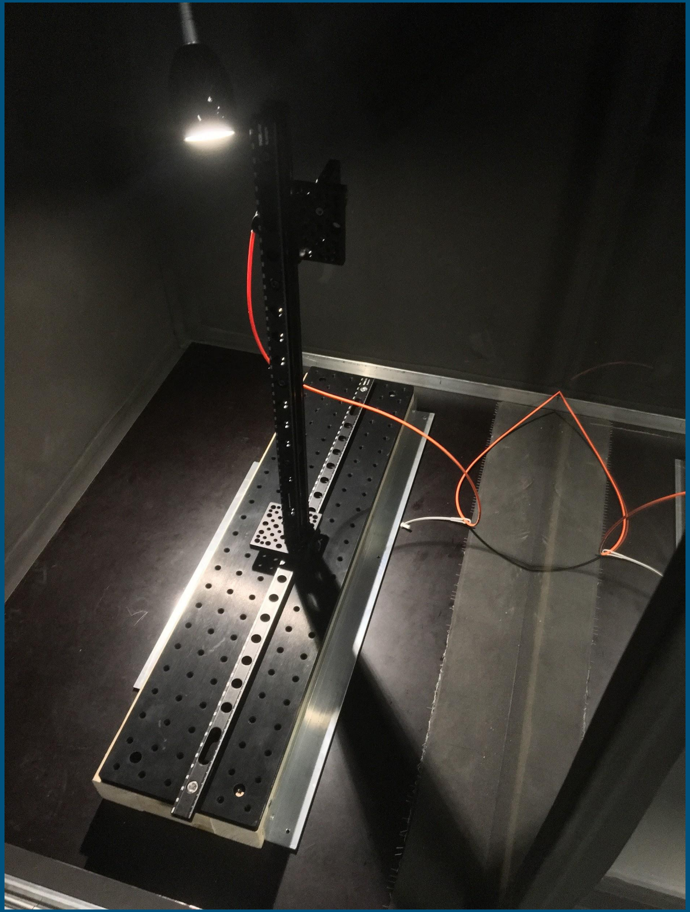
Laser setup

Laser collimator mounted to a X-Z rails

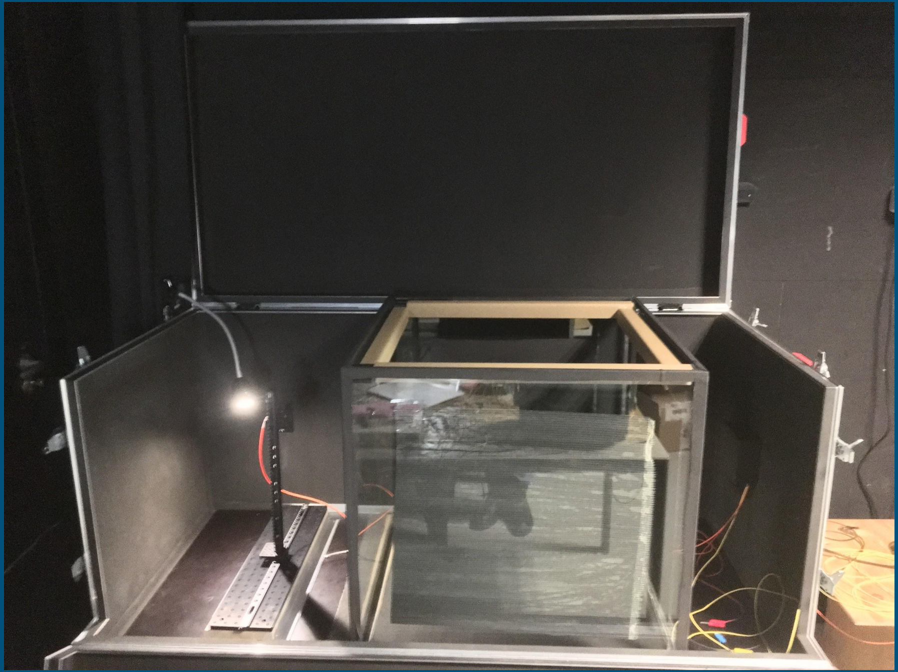
Manually put the laser in various positions

Laser properties:

- Frequency = 25 KHz → ~ 0.1 spe/pulse
- Spot size = ~3 mm



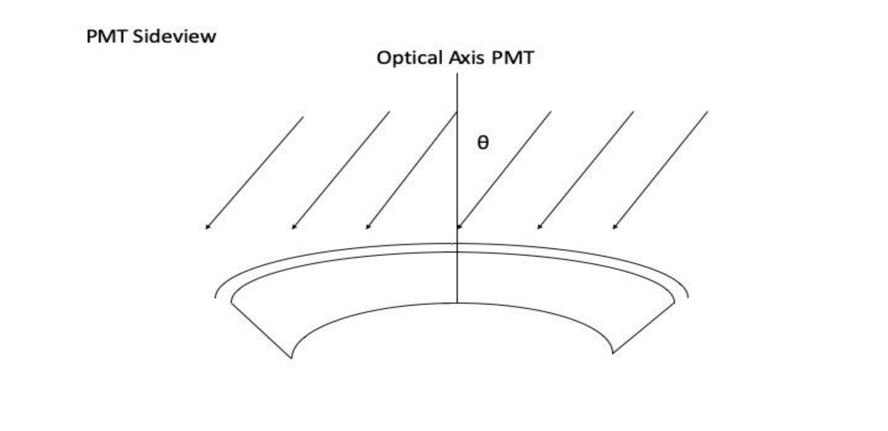
Experimental Setup

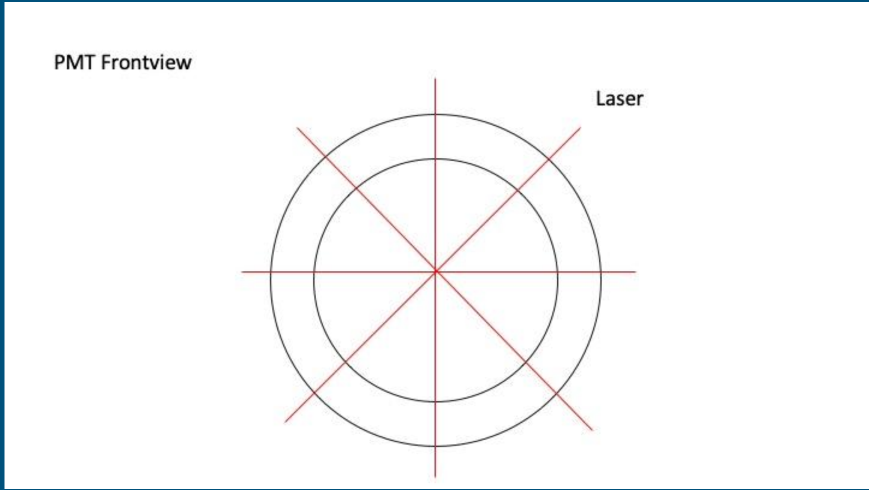


Preliminary Results

Series of grid scans of PMT under several angles of incidence (θ) :

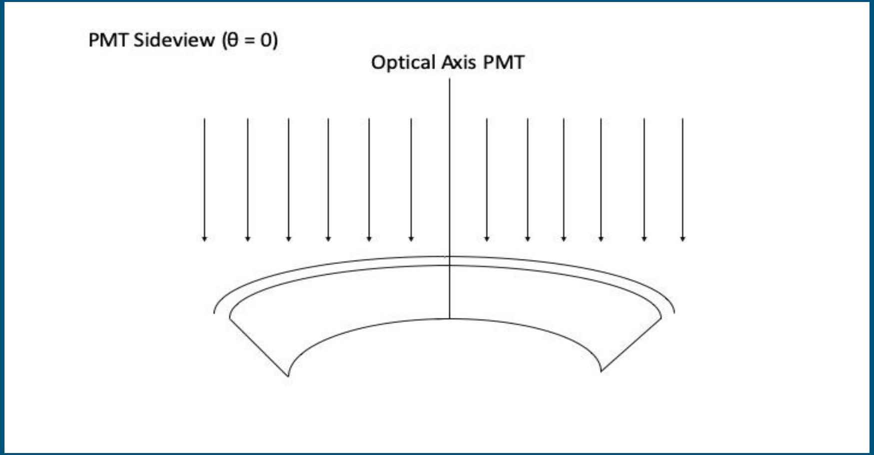
- 4 diagonals of PMT scanned
- Step size ~2-5 mm → ~100 measurements per angle
- Obtain relative efficiency of PMT for different angles





Gridscan (θ = 0)

- Laser parallel with optical axis PMT
- For each measurement obtain efficiency:

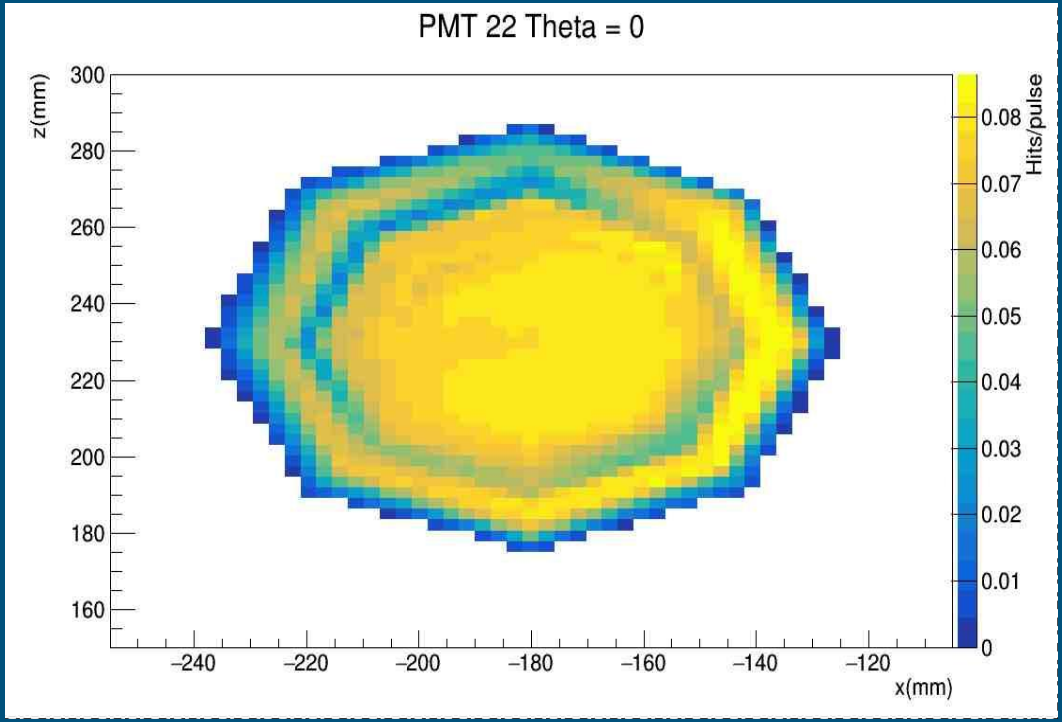


$$\text{Efficiency} = \frac{\text{Counted hits}}{\text{Pulses sent}}$$

- In single photon regime!

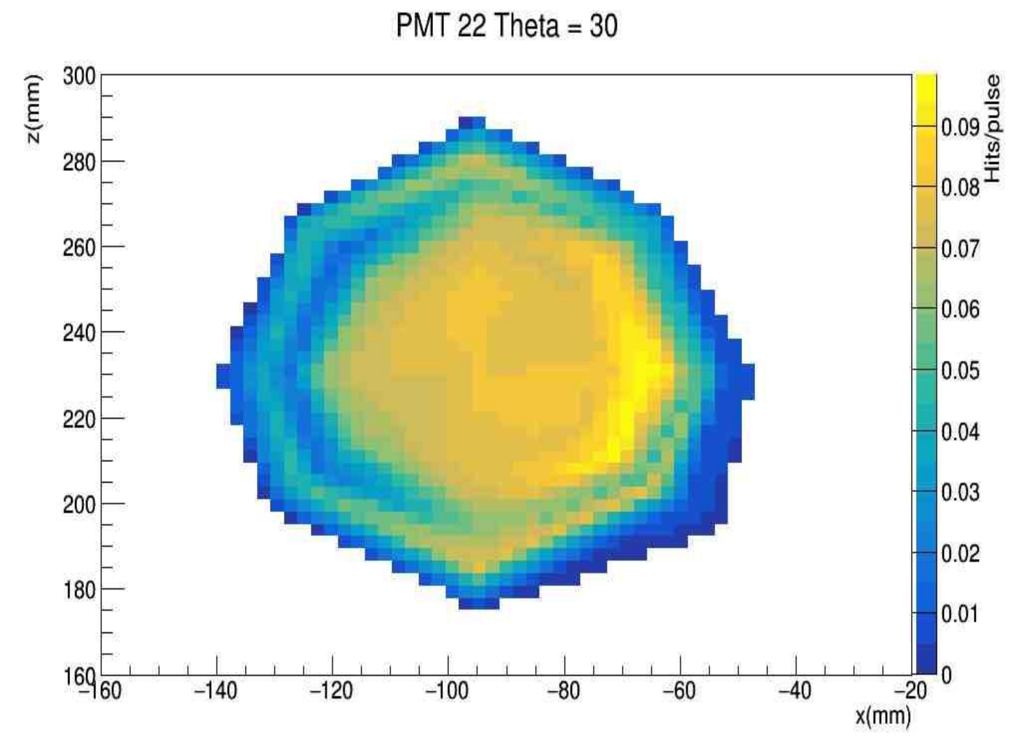
Efficiency $= \frac{\text{Counted hits}}{\text{Pulses sent}}$

Gridscan (θ = 0)



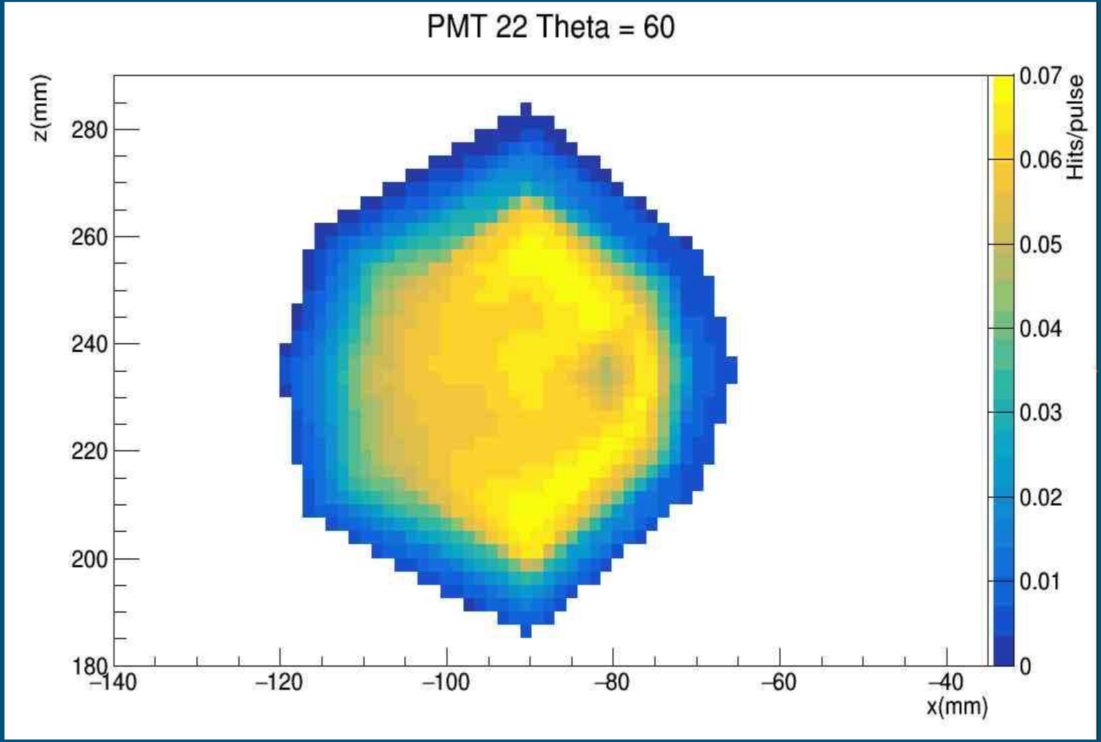
Gridscan (θ = 30)

$$\text{Efficiency} = \frac{\text{Counted hits}}{\text{Pulses sent}}$$



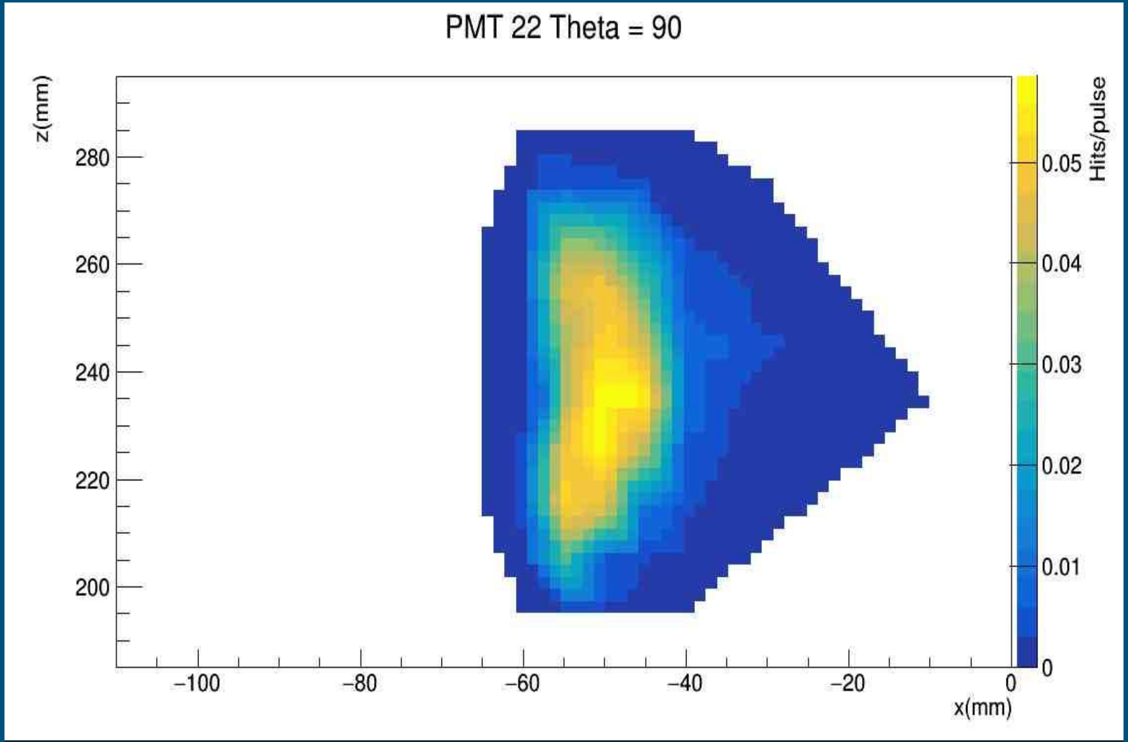
$$\text{Efficiency} = \frac{\text{Counted hits}}{\text{Pulses sent}}$$

Gridscan (θ = 60)



$$\text{Efficiency} = \frac{\text{Counted hits}}{\text{Pulses sent}}$$

Gridscan (θ = 90)



Angular Acceptance

Next:

- Integrate efficiency for every DOM orientation
- Normalize and plot vs cos θ
- Compare with simulations (JSirene)

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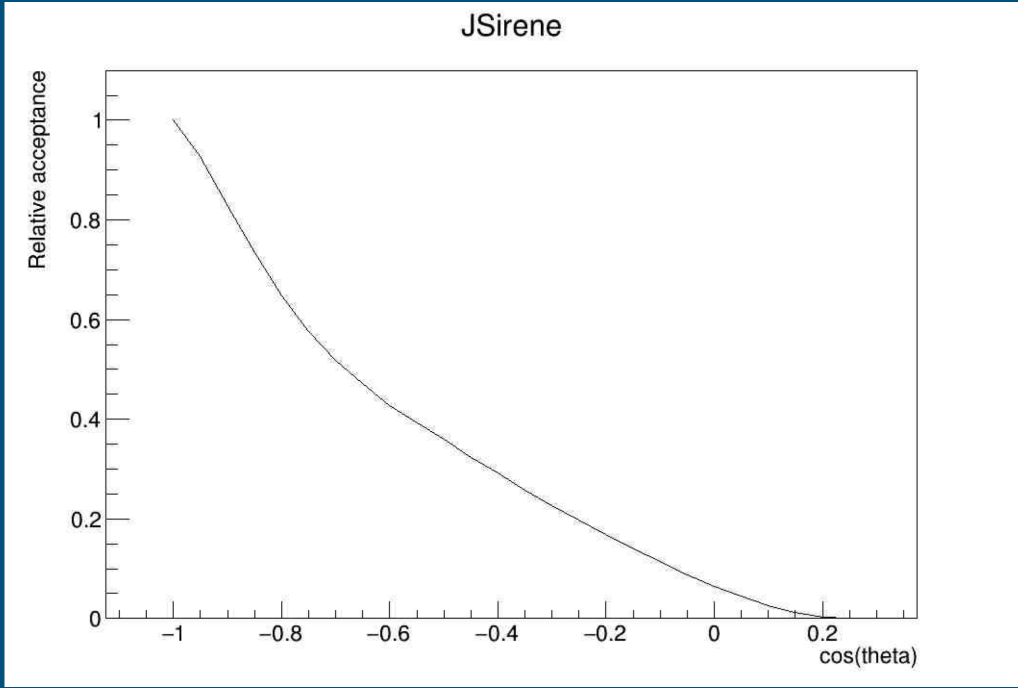


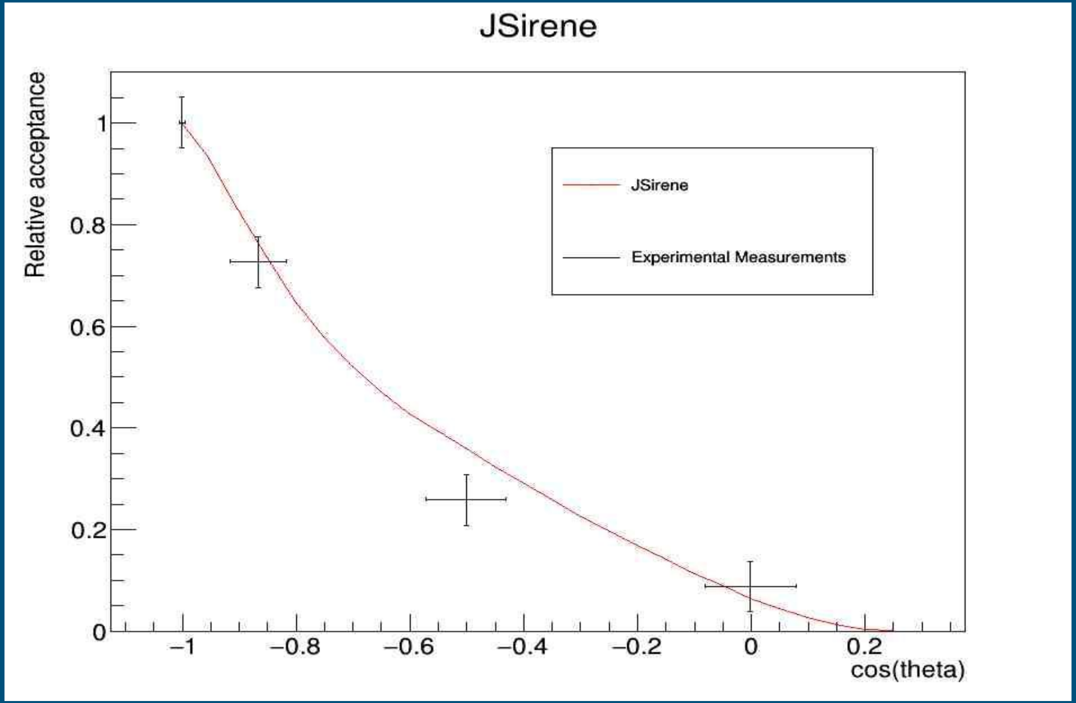
Angular Acceptance

Compare simulation with data

- Normalized JSirene plot
- Relative acceptance of a PMT

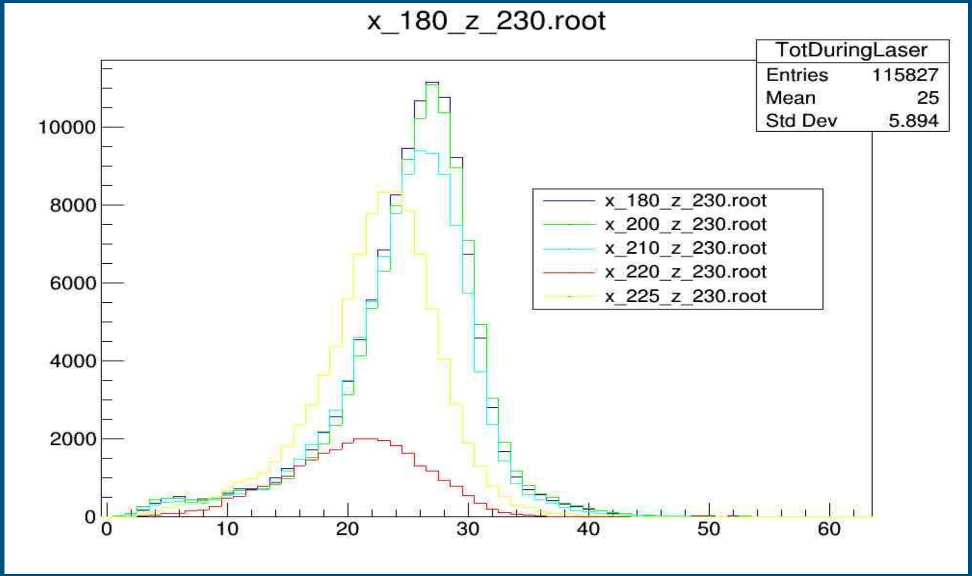
Deviates at θ = 60

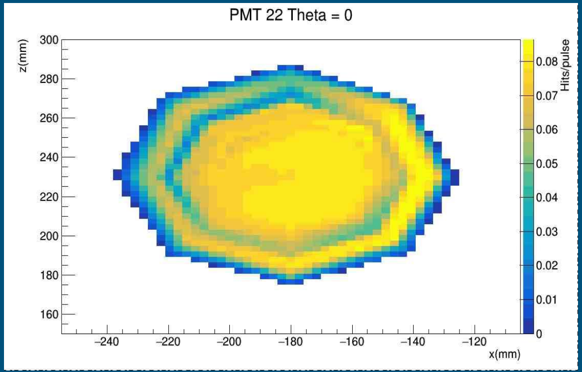
More measurements needed
Especially for θ > 90



Gridscan - ToT (θ = 0)

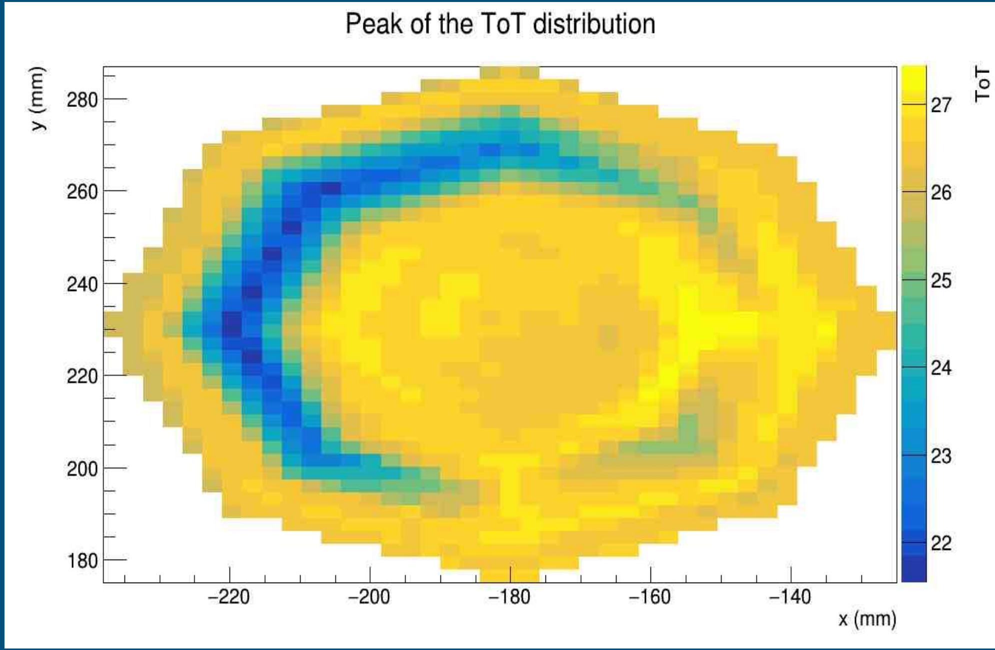
- ToT peak shift
- Small ToT peak around 5 ns
  - Integrate area 0<ToT<10 and divide by total

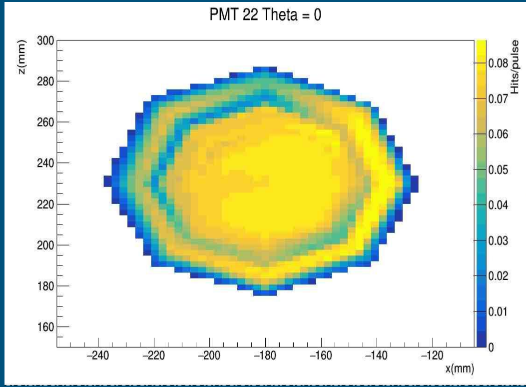




Gridscan - ToT Peak (θ = 0)

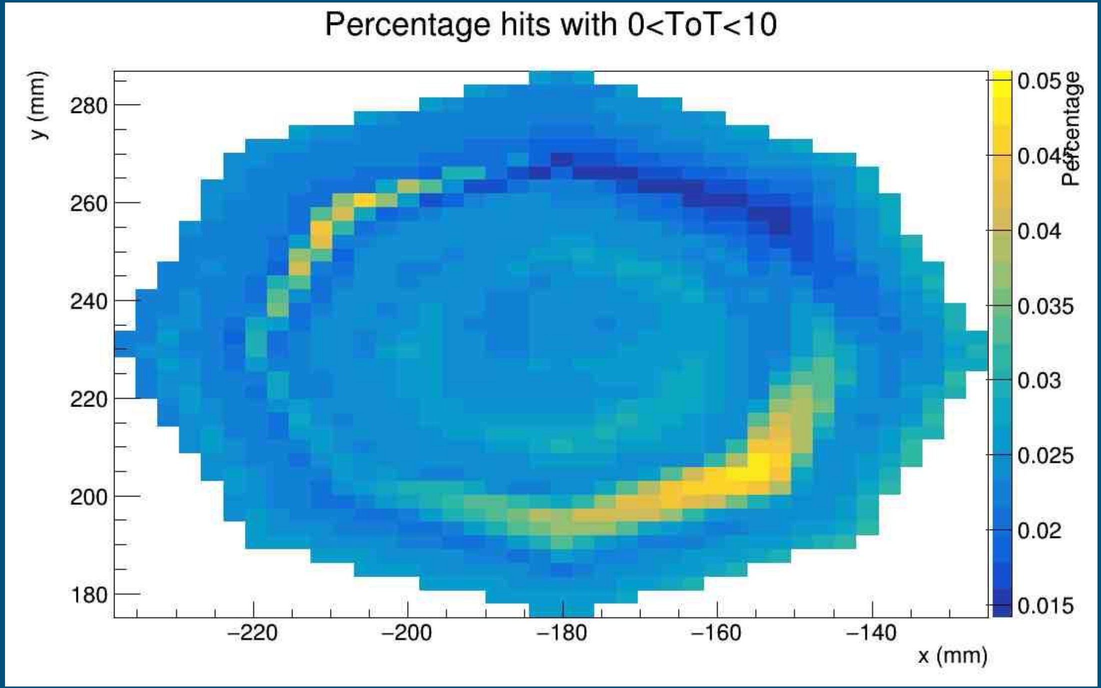
- Compare ToT peak position

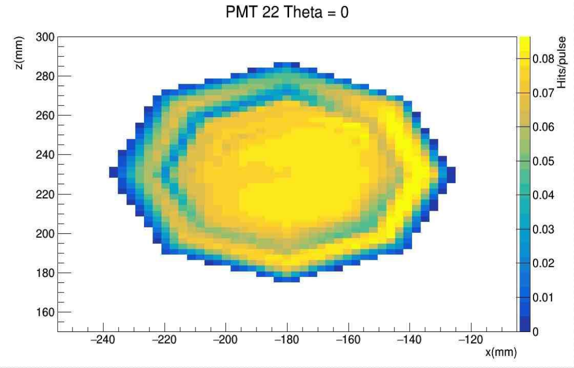




Gridscan - 0 < ToT < 10

- Integrate area 0<ToT<10 and divide by total



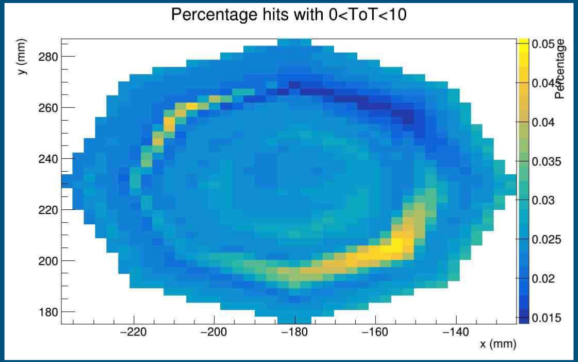


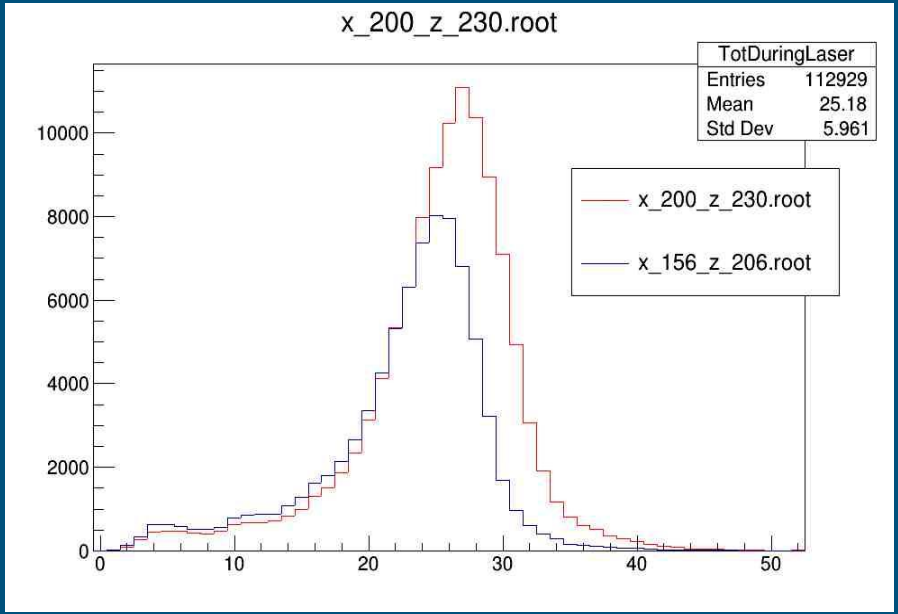
Gridscan - 0 < ToT < 10

Compare two spots!

- One in the middle
- And one on the edges with relatively more hits with 0 < ToT < 10

Looks like peak around 5 ns stays the same, but total integral is lower!





Next steps

- Compare acceptance with OMGSim results
- Measure cos θ > 0 (and more angles)
- Locate errors and perform error analysis
- Analyze Transit times
    - Prepulses and afterpulses
- Analyze ToT
    - Peak at 5 ns

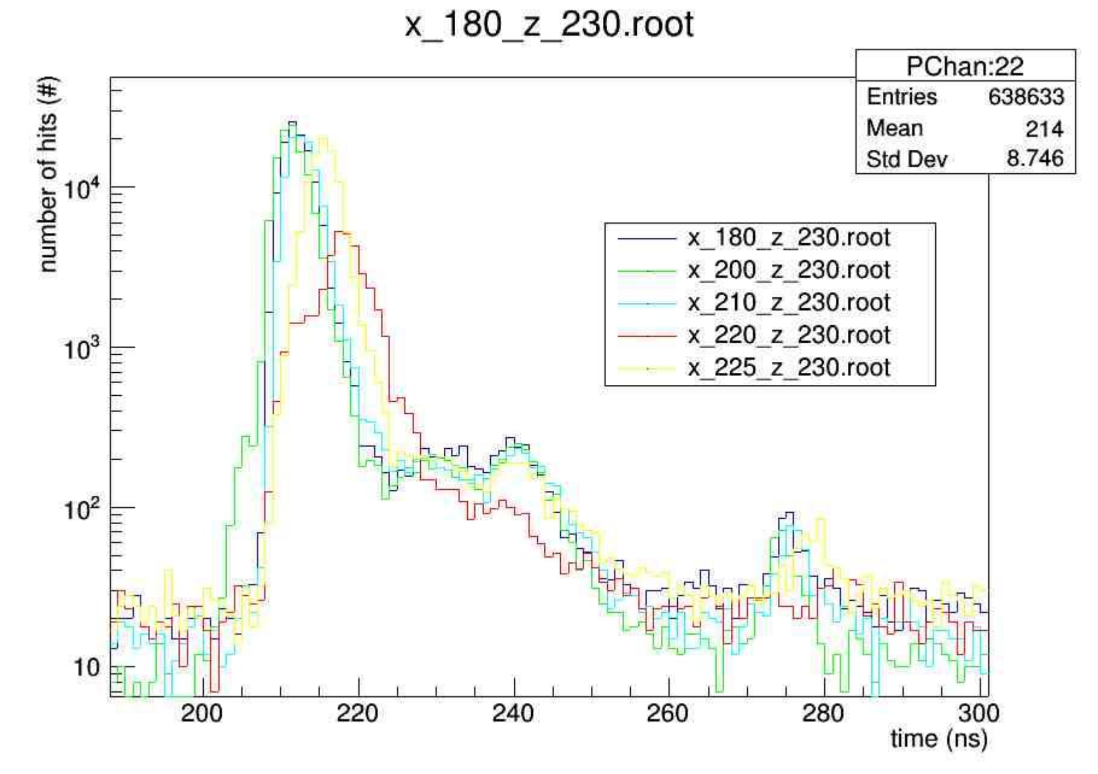
Write thesis!

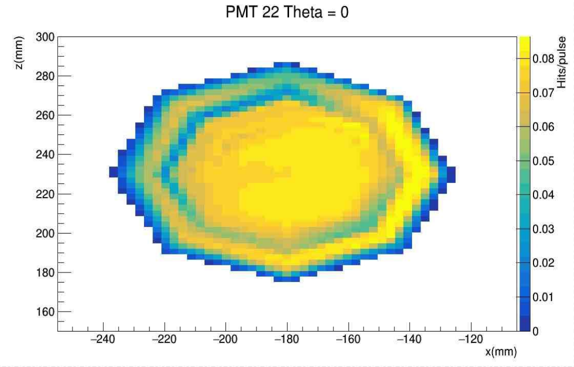
Thank you for listening!

Questions?

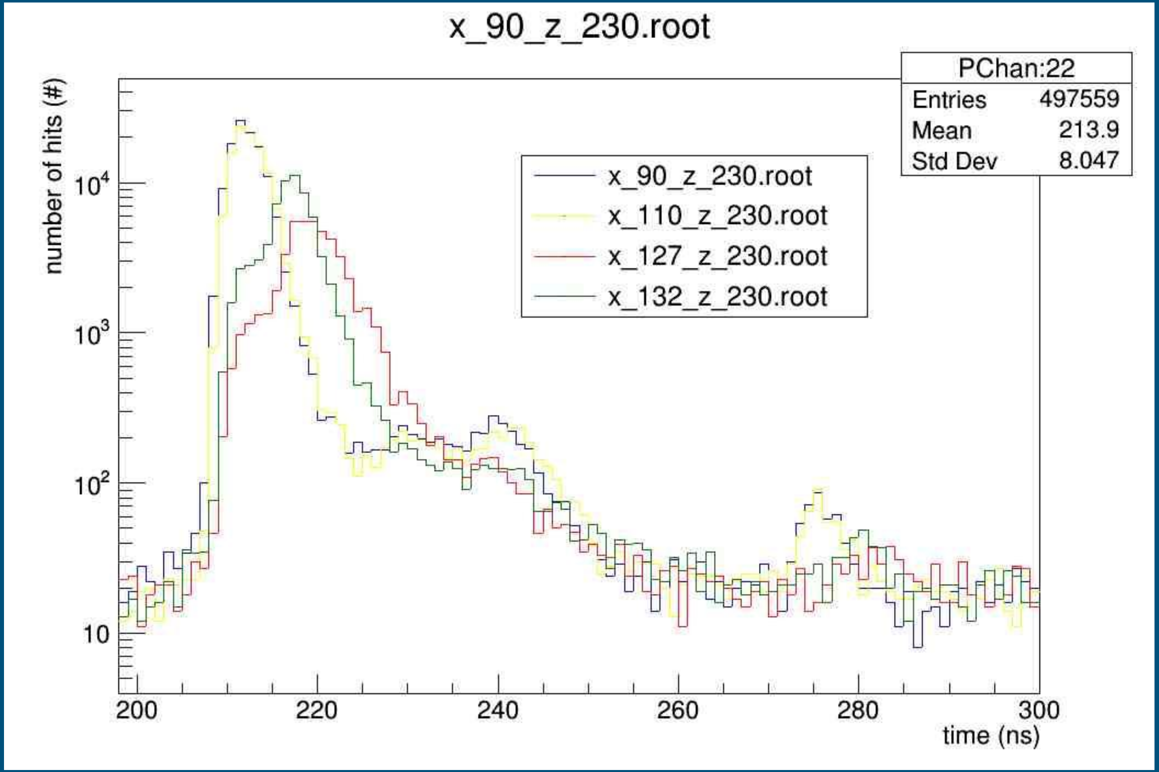
Backup

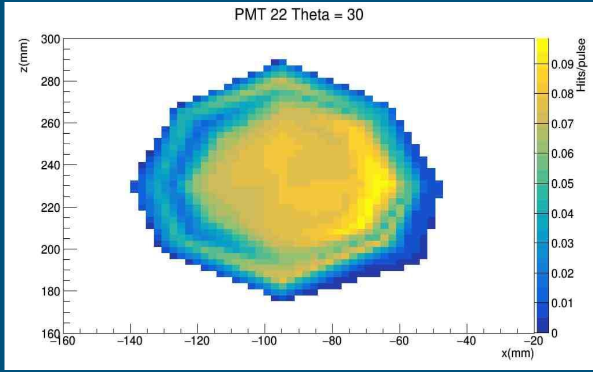
Gridscan - Arrival Times (θ = 0)





Gridscan - Arrival Times (θ = 30)





Gridscan - ToT (θ = 30)