# Comprehensive Data Analysis of High-Energy Events in WCTE

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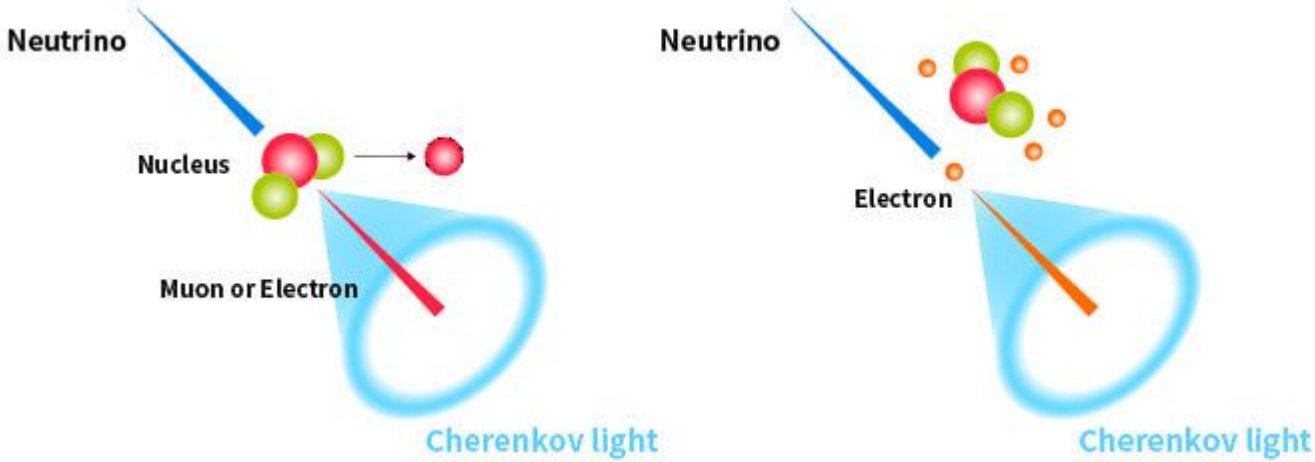
# Summary

- Water Cherenkov Detector Principle
- Cherenkov Profile Measurement
- Event Reconstruction
- Conclusion

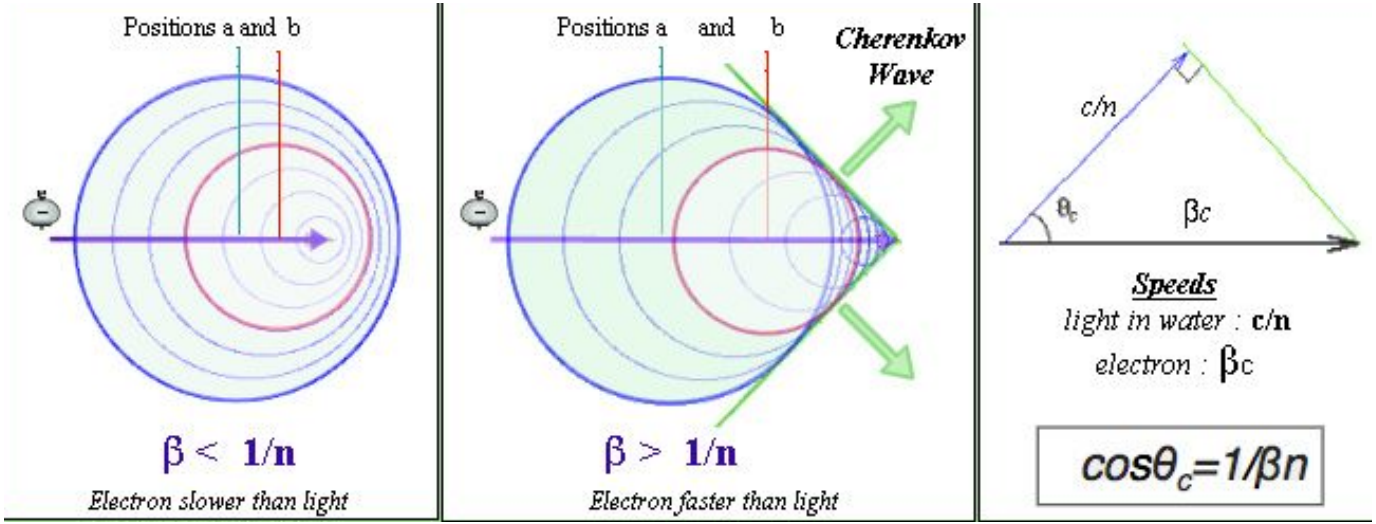
# Water Cherenkov Detector Principle

# How to detect Neutrinos?

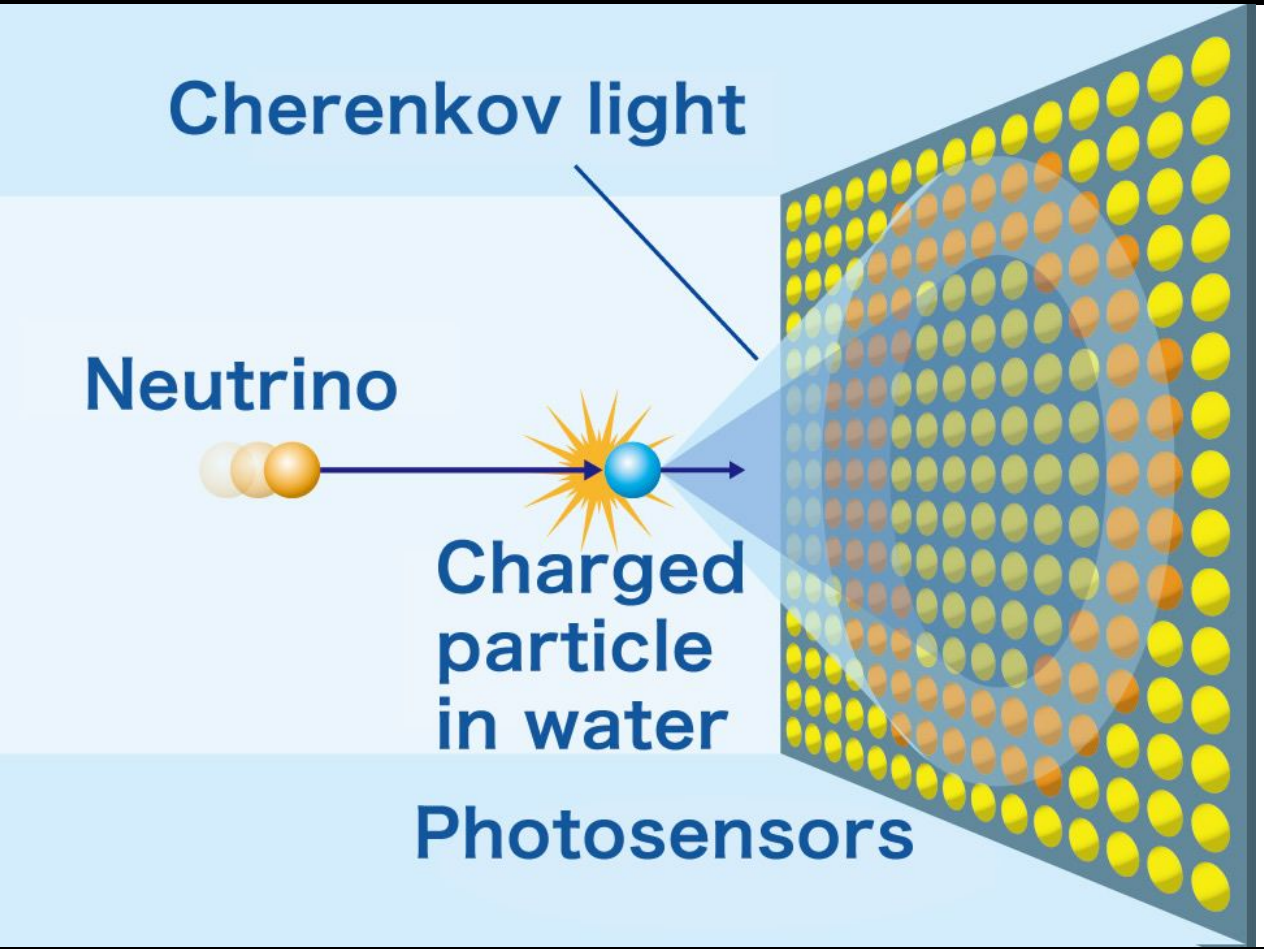


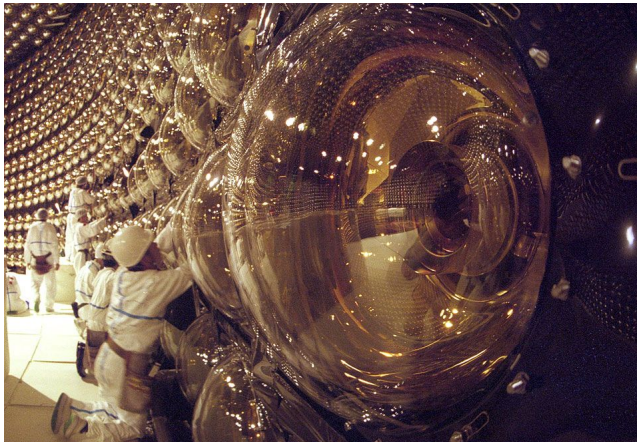
# Cherenkov Radiation

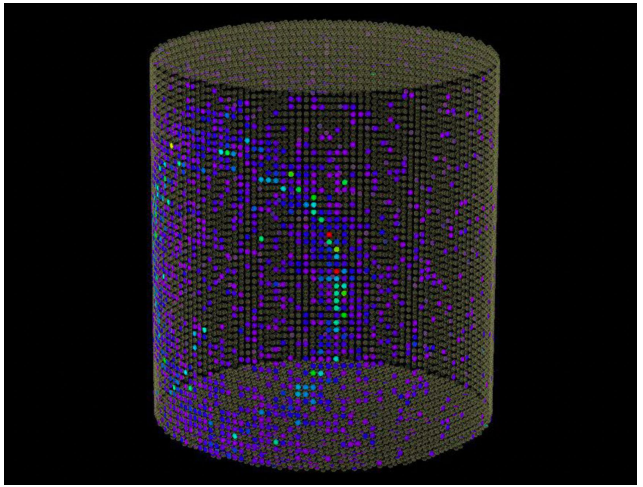
- Charged particle passes through a dielectric medium at a speed greater than the phase velocity of light in that medium = basically moving faster than light
- EM waves form spherical "wavefront" propagating at phase velocity c/n in medium.
- Charged particle polarizes surrounding medium, displacing charges in atoms/molecules.
- Polarized particles absorb energy from charged particle, becoming excited.
- Excited particles release energy as photons when returning to ground state, producing Cherenkov radiation.



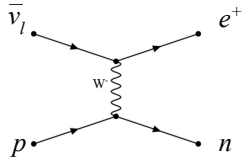
# Water Cherenkov Detector Principle

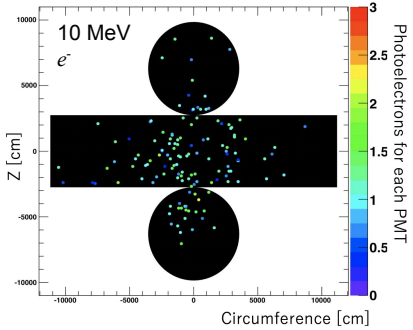


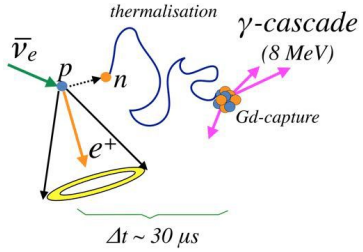





# Event Topologies



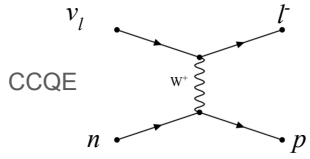



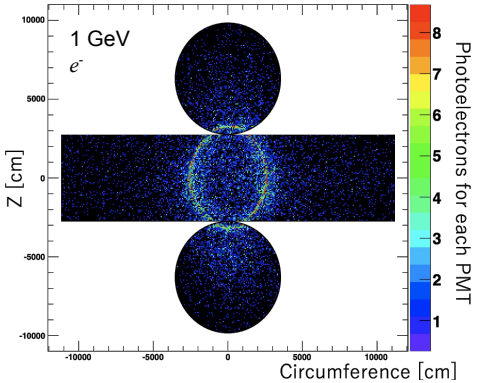

LowE

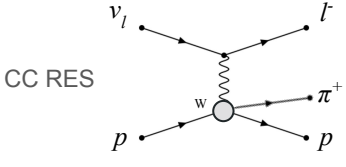
## Event reconstruction

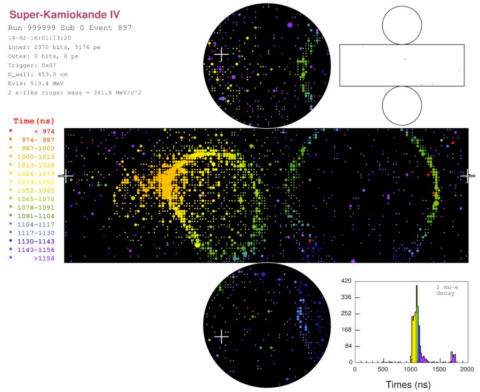
- Particle identification
- Kinematics determination
- Multi-particle separation

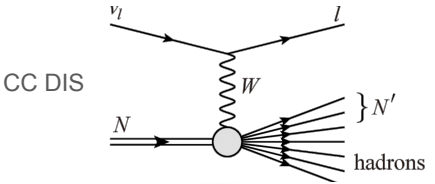
HighE

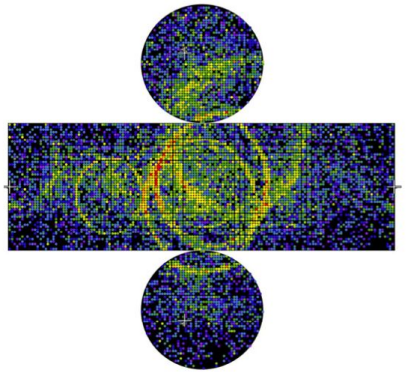


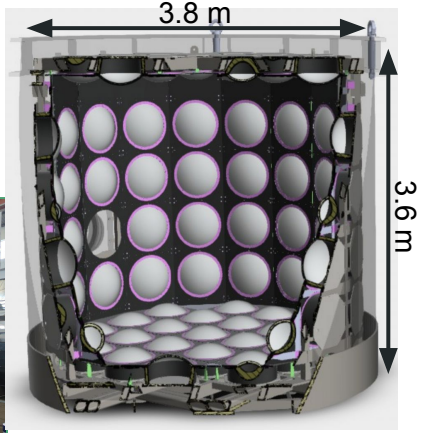



# WCTE

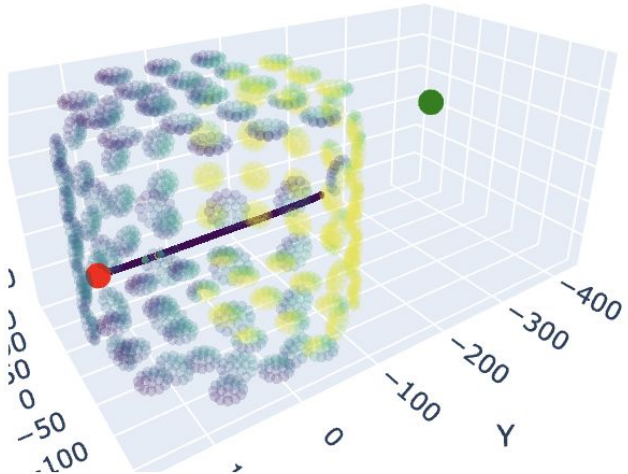
- The Water-Cherenkov Test Experiment (WCTE) is a prototype water Cherenkov detector at CERN.
- Operated with a low momentum (200-1200 MeV/c) flux of $\pi^{\pm}$ , $\mu^{\pm}$ , $e^{\pm}$ .
- Data taking period with WCTE is scheduled for fall 2024.
- The main purpose of this experiment :
  - Prove the new technologies that are being developed for the next-generation water-Cherenkov experiments, Hyper-K and Intermediate Water Cherenkov Detector (IWCD) ;
  - Properly modeling the detector response;
  - Studying physical processes such as Cherenkov light profile produced by secondary particles;
  - Energy scale calibration.



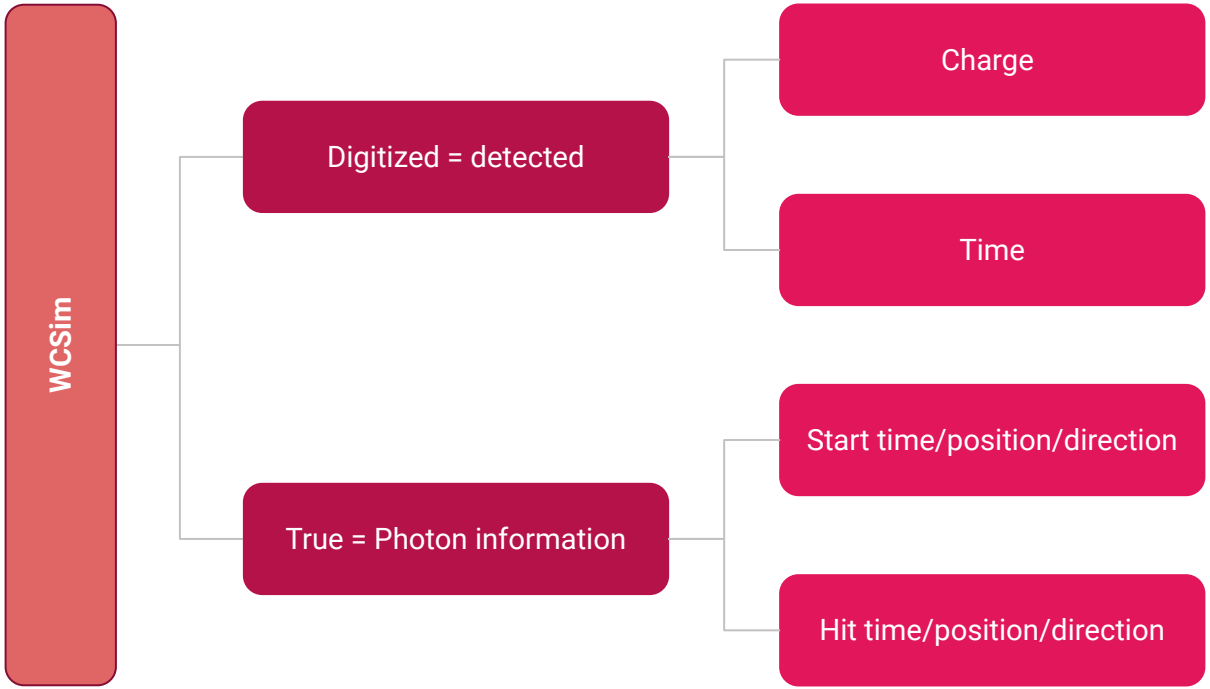
# Cherenkov Profile Measurement

# WCSim - Water Cherenkov Simulation

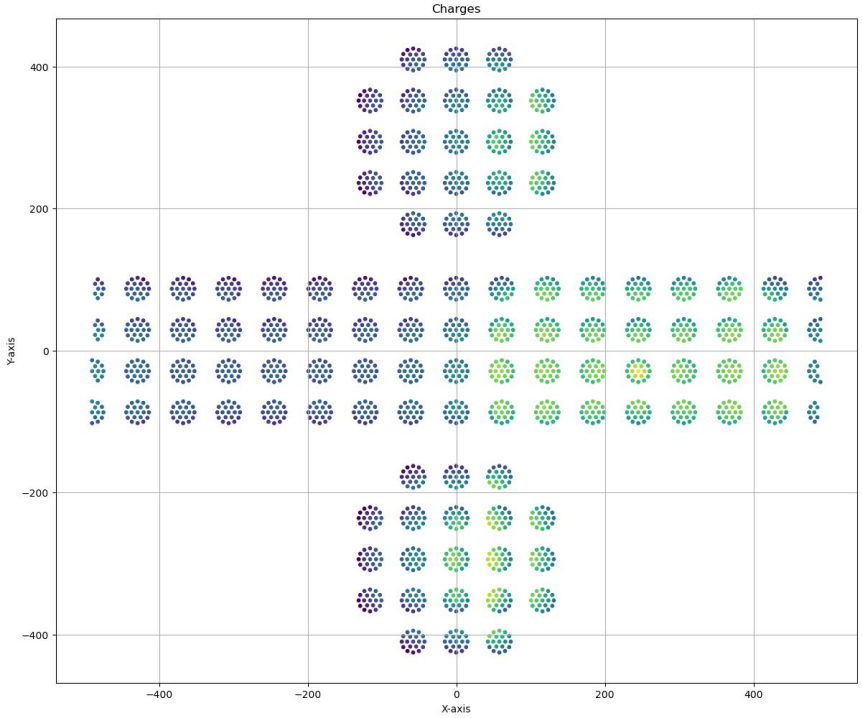
- 3m diameter *3m tank;
- Beams :
  - Electron beams from 260MeV to 1000MeV
  - Muon beams from 175Mev to 900MeV;
- Distance from tank wall : 20-40cm
- Time window : ~10ns
- Number of events per simulation : 1000
- Group velocity in water vg ~ 22 cm/ns



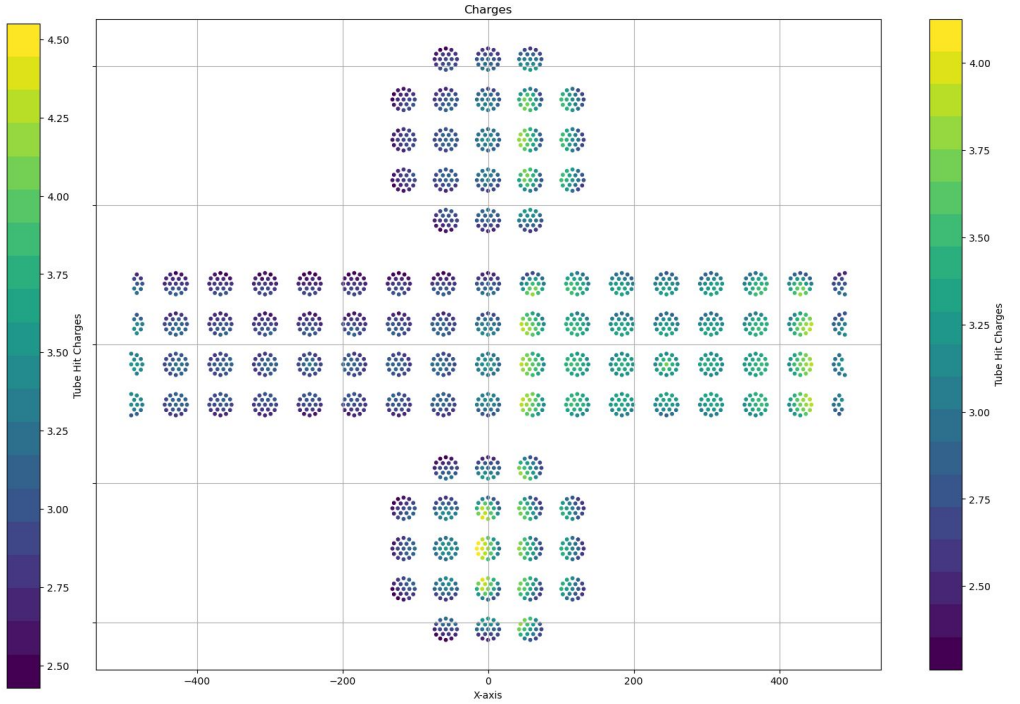
# WCSim Features



# Event Display of the Charge - Unfolded

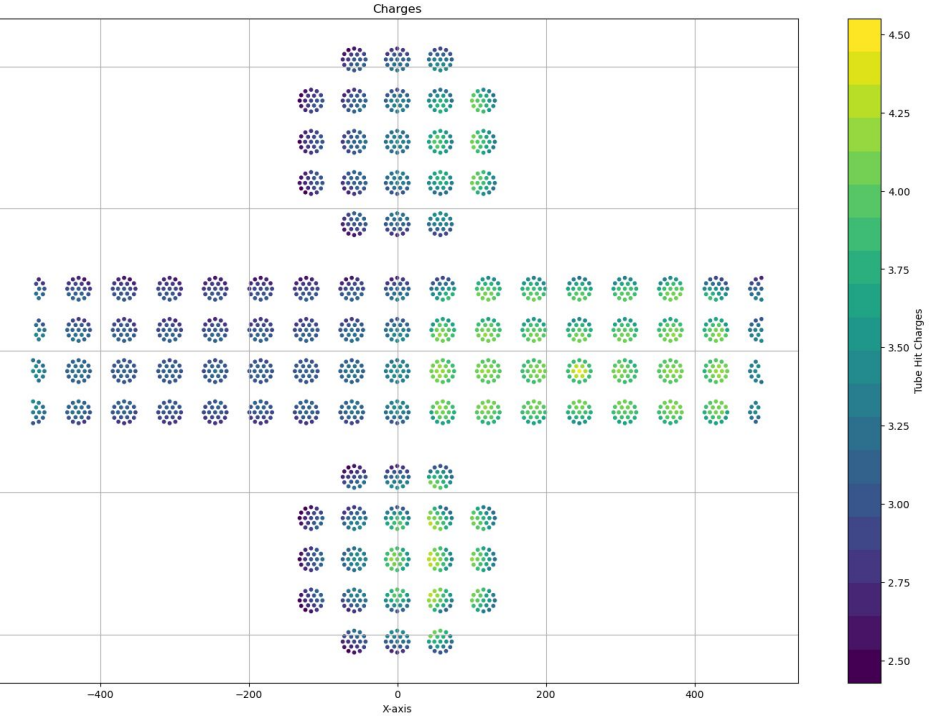



e- Beam at 800MeV

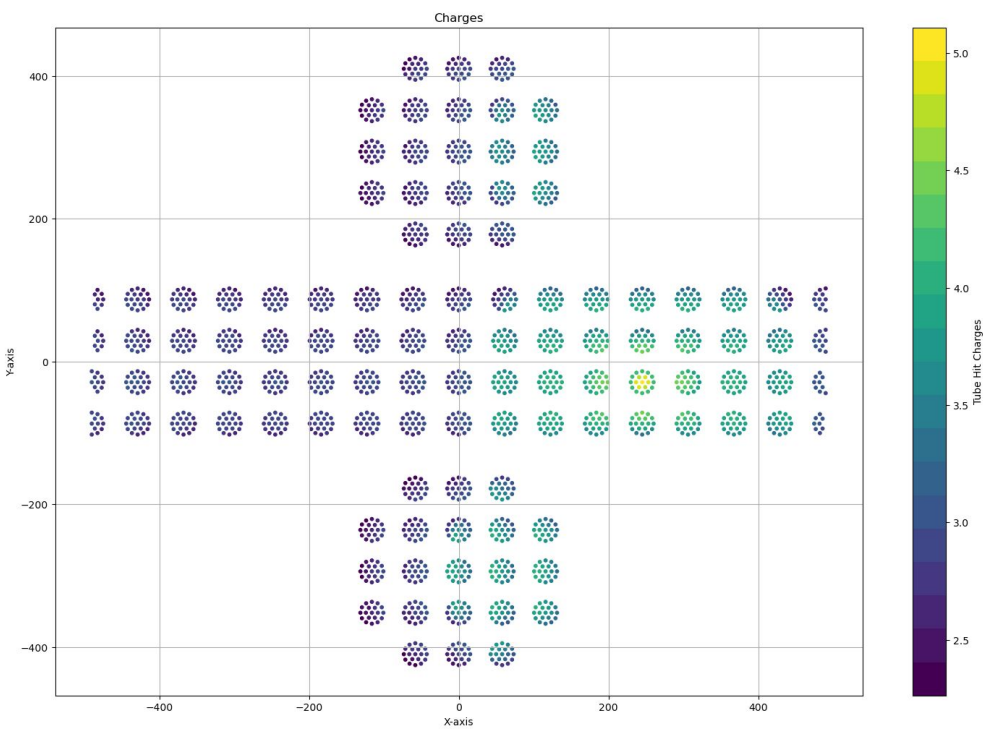



e- Beam at 260MeV

# Event Display of the Charge - Unfolded

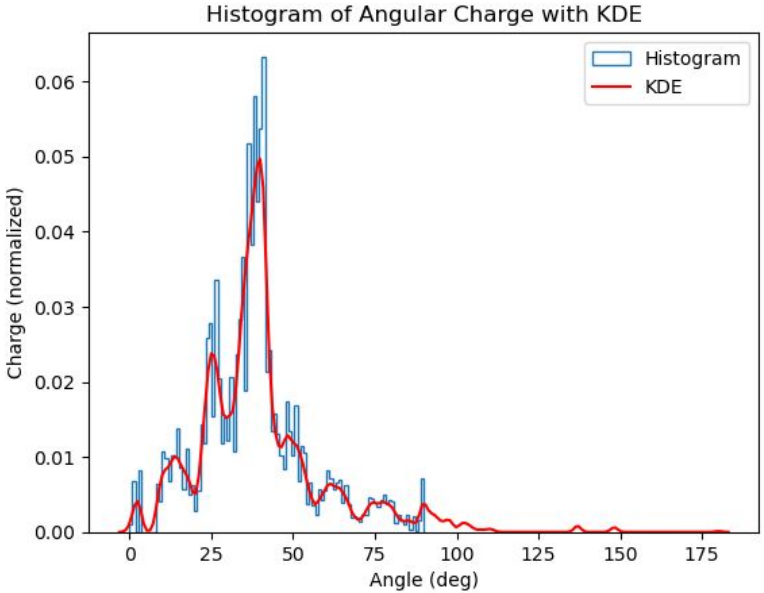



e- Beam at 800MeV

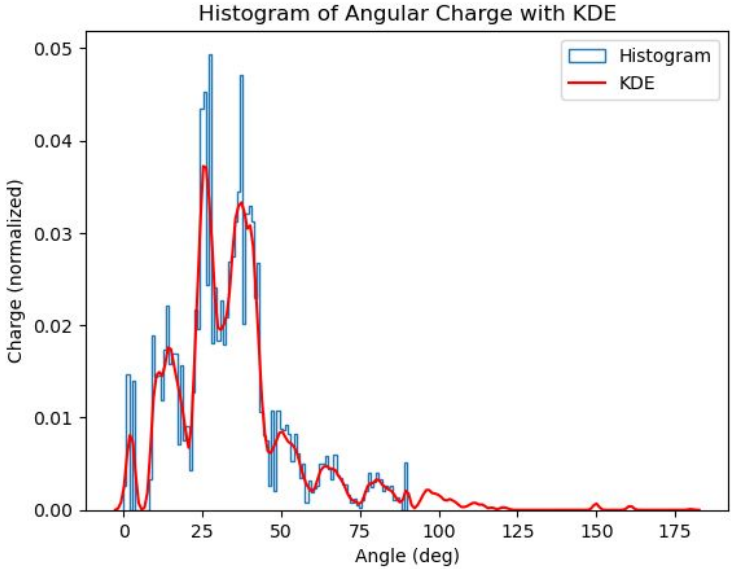



muon Beam at 900MeV

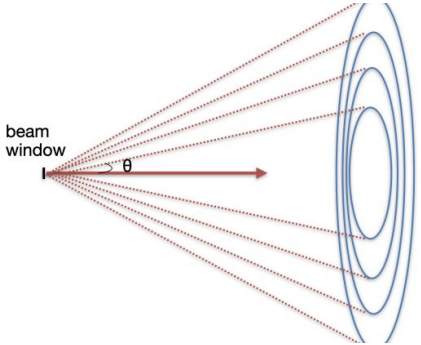
# Angular Charge Distribution - Opening Angle




e- Beam at 260MeV




e- Beam at 800MeV



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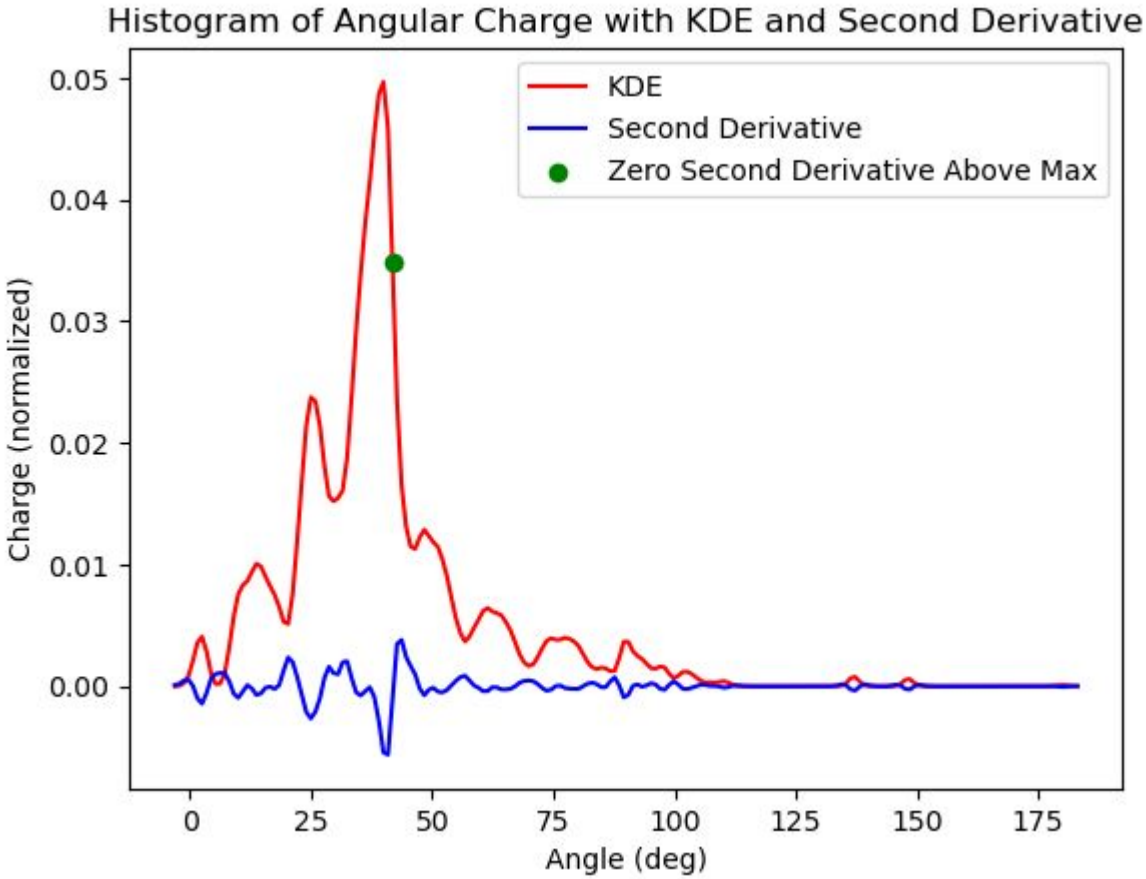
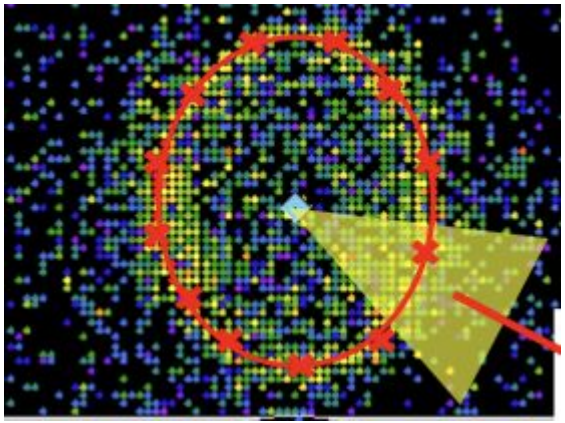



First maximum value of the KDE function at x = 39.96°

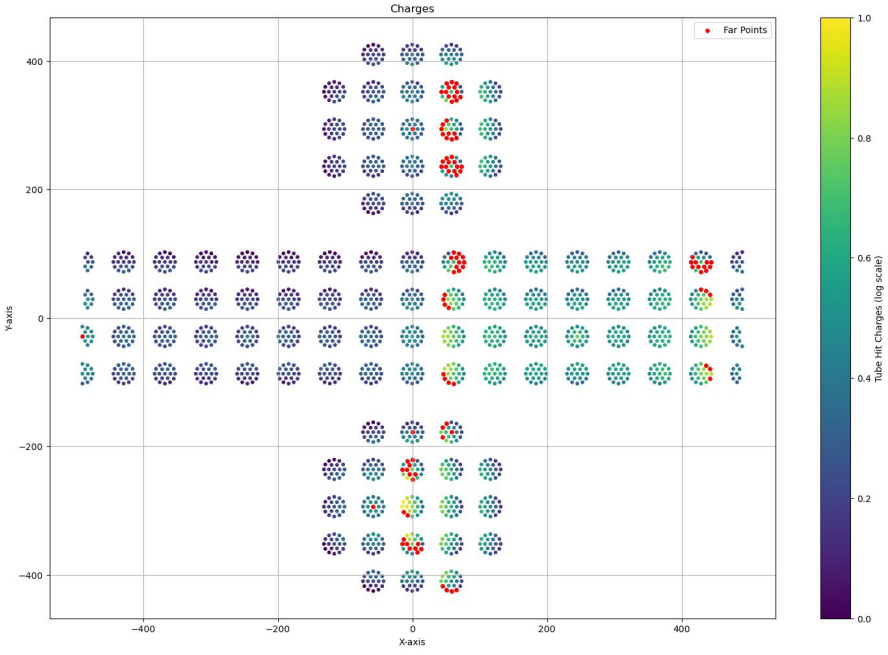
Second maximum value at x = 25°

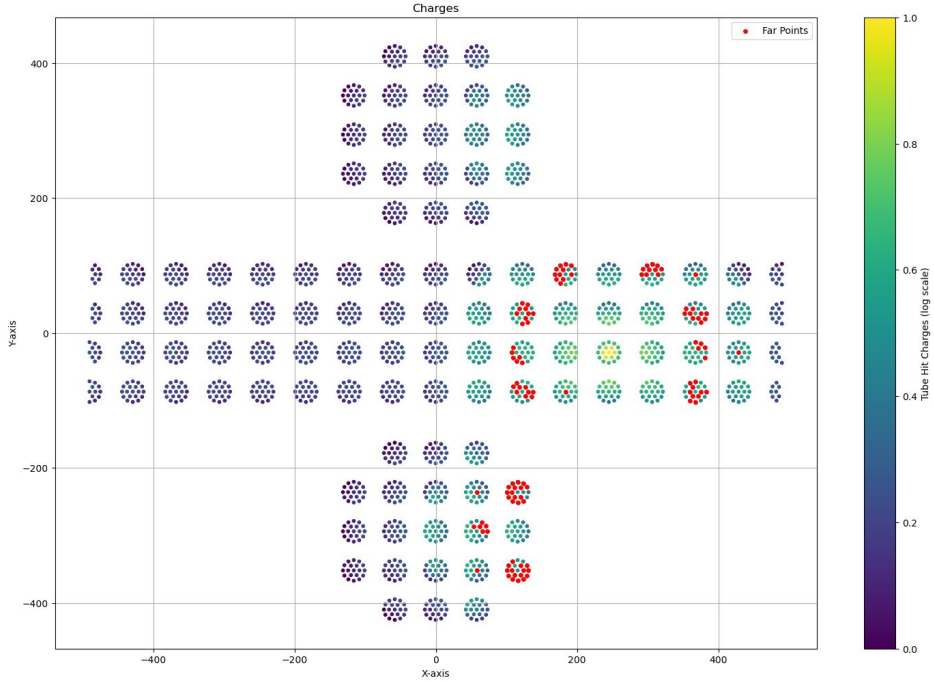
Points where second derivative is zero and above max value:
Angle: 41.83 -> Edge of the ring



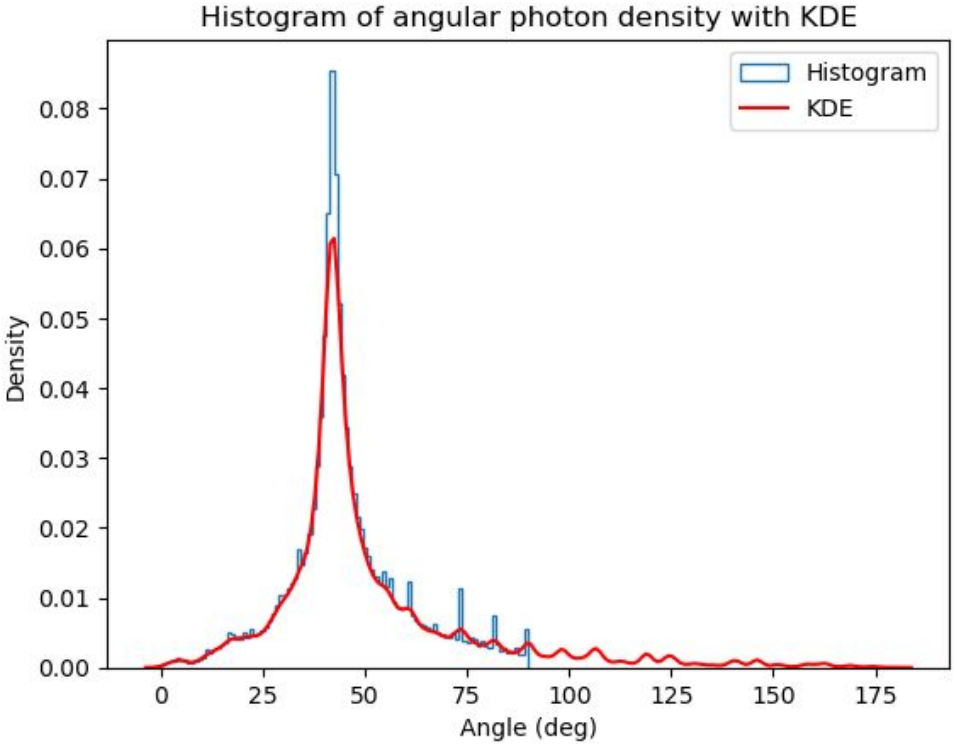
# Angular Charge Distribution - Opening Angle

Charge profile => Ring patterns

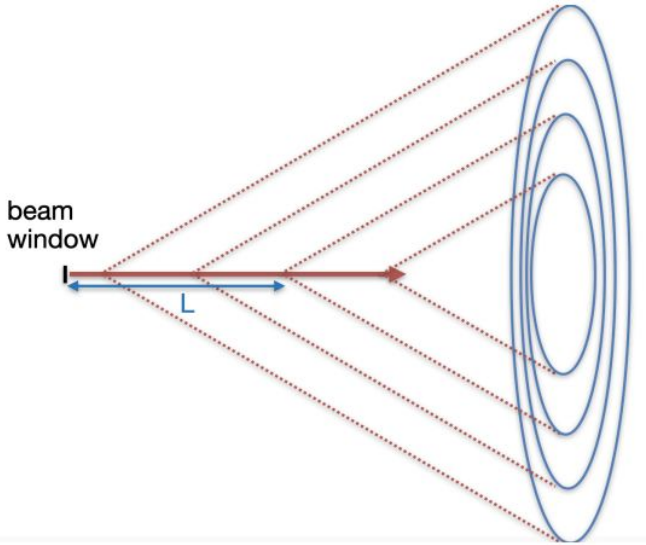


# Angular Charge Distribution - Emission angle



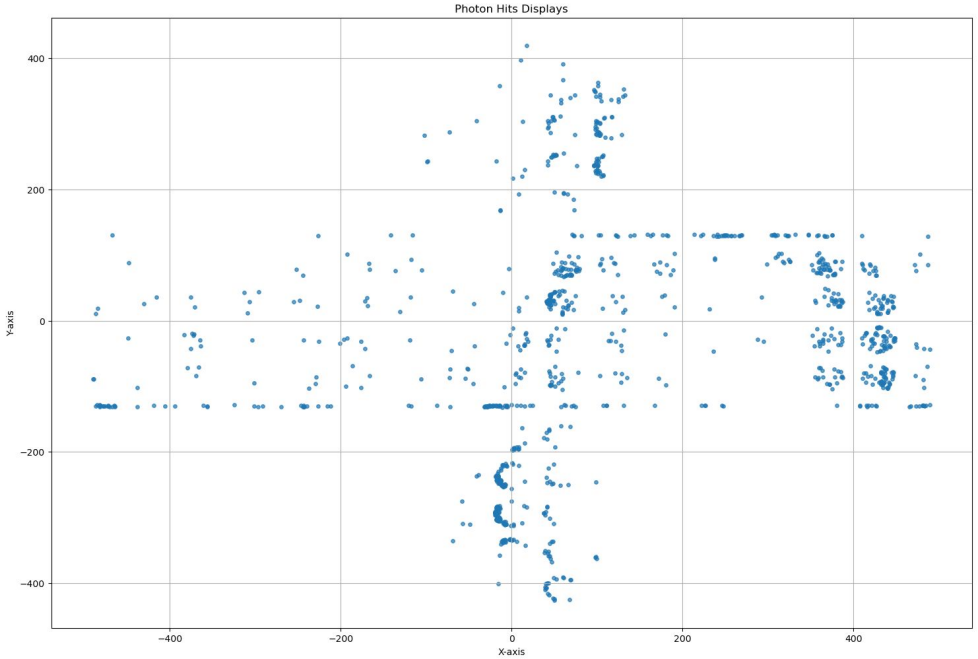

Maximum value at x= 42°
=> Cherenkov angle

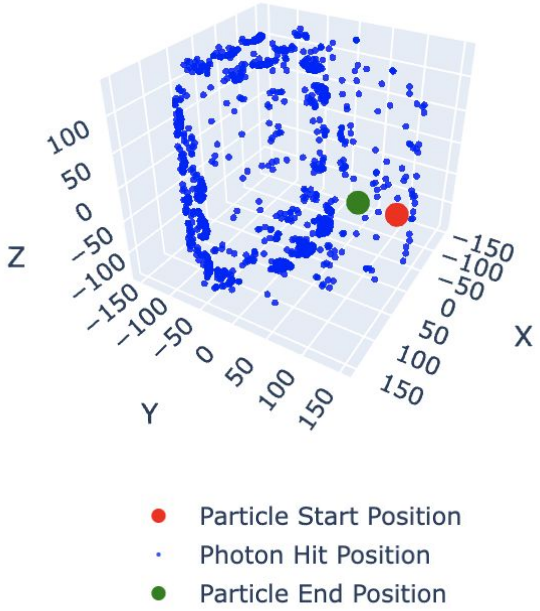


# Event Reconstruction

# Emitted Photons - End Positions

We can retrieve the emitted photons from the true photon information of the simulation

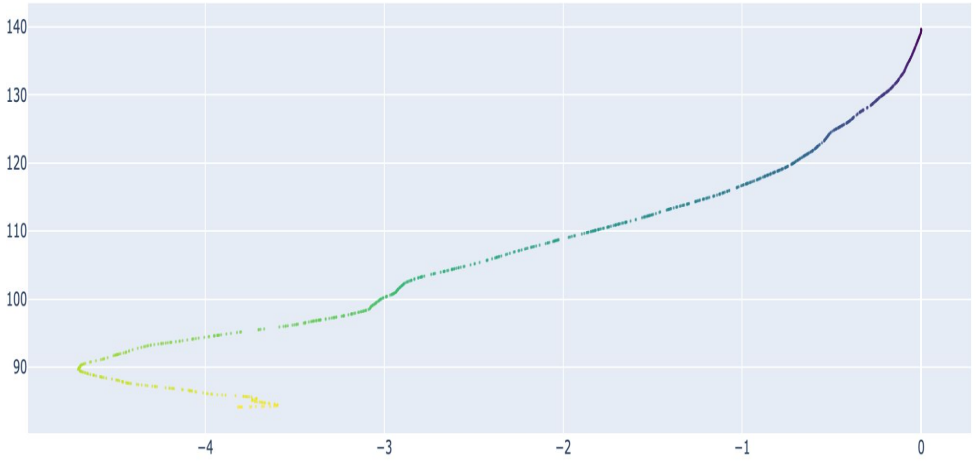


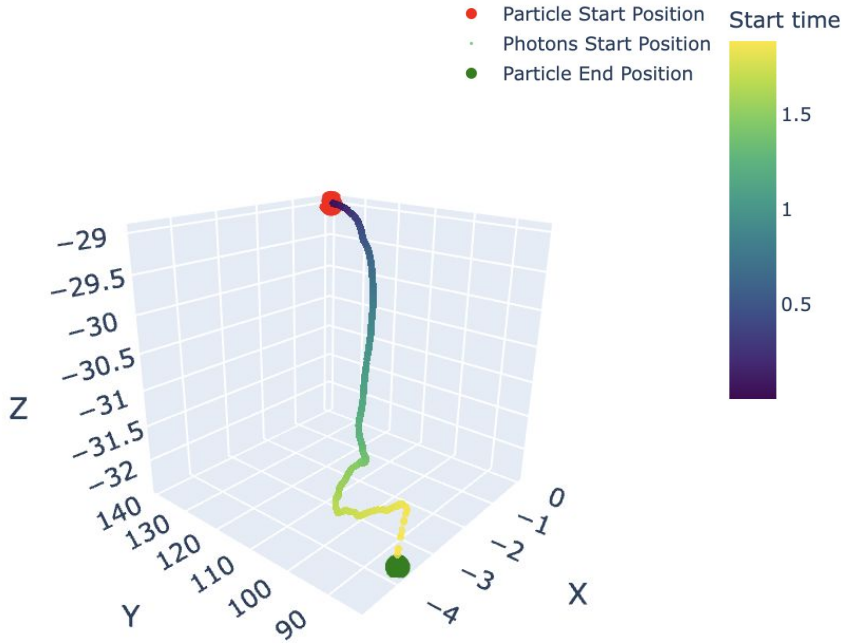



# Emitted Photons - Start Positions

“True start positions” of the photons emitted by the particle = particle path

XY - Plane

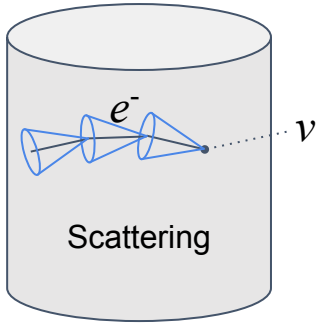


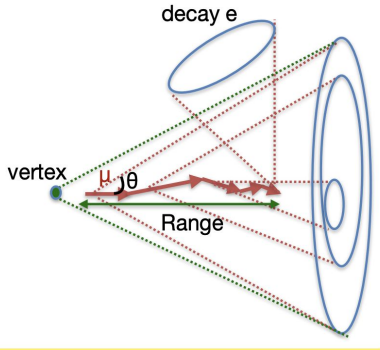

e- Beam at 260MeV

# Reconstruction

- The particle can experience scattering -> Change in its trajectory




- Reconstructing the photon positions can help us evaluate the particle's path
- Azimuthal asymmetry is a good tool for identifying scatterings



# Conclusion

What's to come?

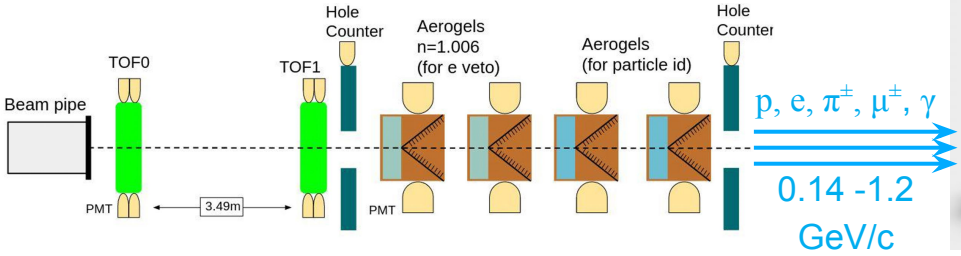
- Path reconstruction;
- Comparison of sub-GeV muon and electron Cherenkov profiles for energy scale calibrations;
- Unrelated : Testing Depth and Level Sensor performances for Water level monitoring (WCTE).

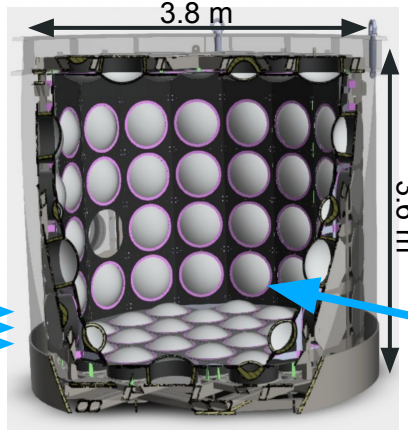
# Thank you!

Appendices

# The Water Cherenkov Test Experiment (WCTE)

- Prototype of IWCD to demonstrate new photosensor, calibration, and ML event reconstruction and simulation technologies
  - Verification and optimization towards Hyper-K
- Operational this fall at CERN East Area, T9 beamline with well-understood particle beam
  - Control samples to constrain neutrino experiment modeling, which can make immediate impact to T2K and Super-K
    - ILANCE student: *Oumaima El Jaafari*


- Kavli IPMU leadership:
  - Ultra-pure and Gd-loaded water systems (*P. de Perio*)
  - Analysis coordinator (*K.M. Tsui*)