Nuclear Physics Group Meeting 6/7

Week 2 Recap / An Introduction to MA-PMTs, MCP-PMTs, and SiPMs

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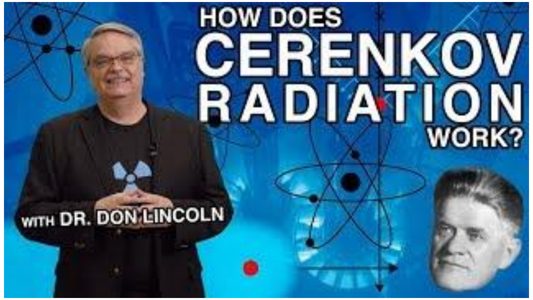
What has been done … (This Week)

- Practiced calculating the Cherenkov Angles for pions, kaons, and protons in quartz and aerogel (6/6)
- Began running simulations with predefined, baseline configurations of the hpDIRC at the EIC (6/6)
- Gained access to the JLab computer farm to run larger simulations in the coming weeks (6/6)
- Independently researched three types of available single-photon detectors (6/3 - 6/5)

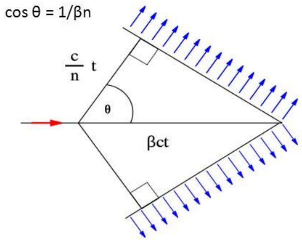
Cherenkov Angle Calculation Practice

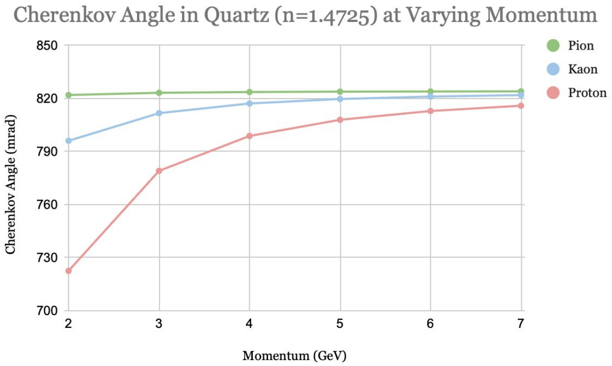
- Derived formula for Cherenkov Angle using provided momentum, particle mass, and refractive index
- Relativistic momentum, natural units, and some algebra

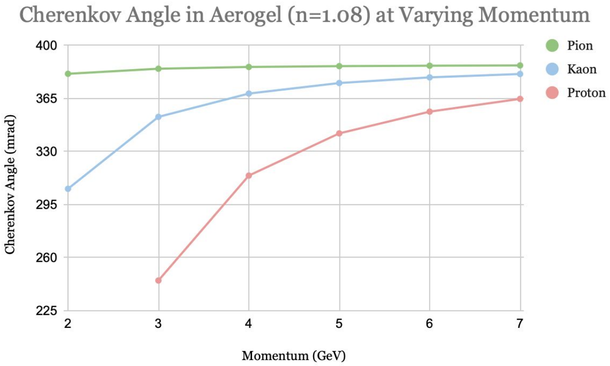


$$\theta = \cos^{-1}\left(\frac{c}{nv_p}\right)$$

$$\theta = \cos^{-1}\left(\frac{\sqrt{p^2 + m^2}}{np}\right)$$







$$p_v = \frac{m_0 v}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

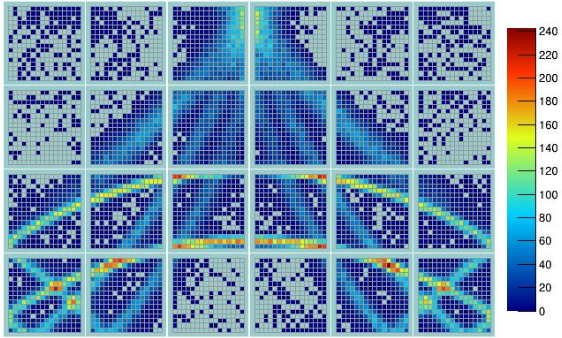
My Experience with the Simulations

- There is a large software package that has been written over numerous years and simulates DIRC Detector Behavior

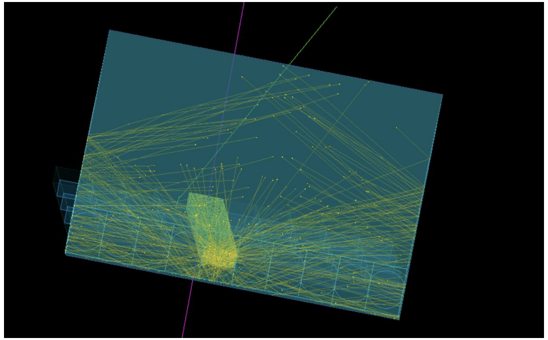
- The software includes material properties, different particle types, and physical processes such as Cherenkov radiation, electromagnetic interactions, and photon behavior

- Currently only altering parameters such as momentum, polar angle, particle type, and previously investigated sensors

- Much room to explore and change the code



1000 events, 30 degree polar angle, 6 GeV/c



1 event, 30 degree polar angle, 6 GeV/c, 3 mm pixel size

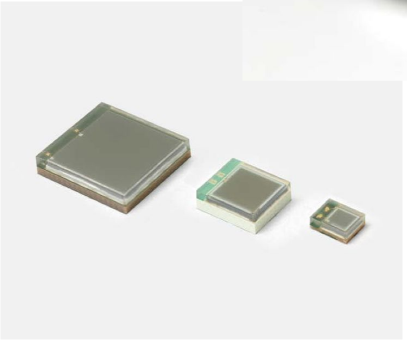
A Bowl of Alphabet Soup

MA-PMT : Multi-Anode Photomultiplier Tube

Hamamatsu 8x8 Multianode PMT (H12700A)

MCP-PMT : Microchannel Plate Photomultiplier Tube

Hamamatsu 16 Matrix Multianode MCP-PMT (R10754-07-M16)



SiPM : Silicon Photomultiplier

Hamamatsu Multi-Pixel Photon Multiplier (S14160)

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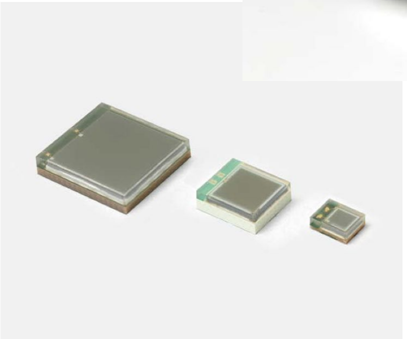


What is a Photomultiplier?

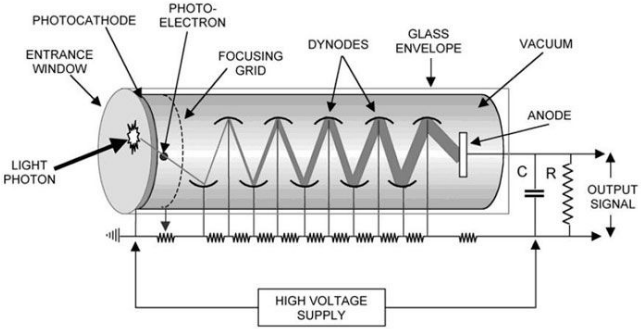
- A device used to detect and measure low levels of light by amplifying the light signal to produce a measurable output
- Converts photons into electrical signals through the photoelectric effect followed by electron multiplication
- End goal for each of the sensors is the same: produce an efficient, reliable, and measurable signal. Method of production varies

Photomultiplier Tubes

Avalanche Photodiodes

The Sensors

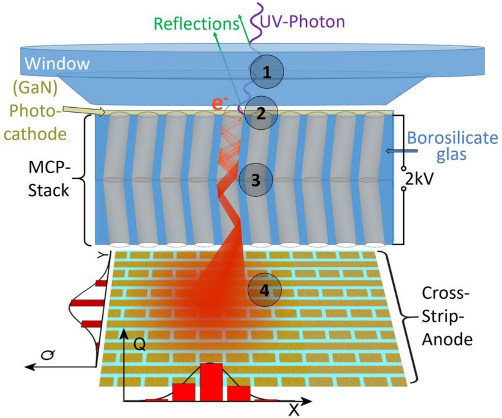
MA-PMTs



- Use external photoelectric effect

- Secondary electrons produced through interactions with dynodes

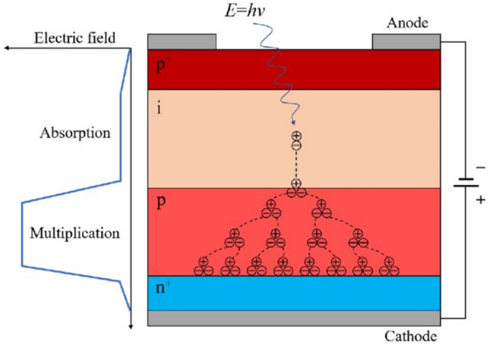
MCP-PMTs



- Use external photoelectric effect

- Secondary electrons produced through interactions with microchannels

SiPMs



- Use internal photoelectric effect

- Secondary electrons produced in electron-hole pairs by impact ionization of atoms in the semiconductor lattice

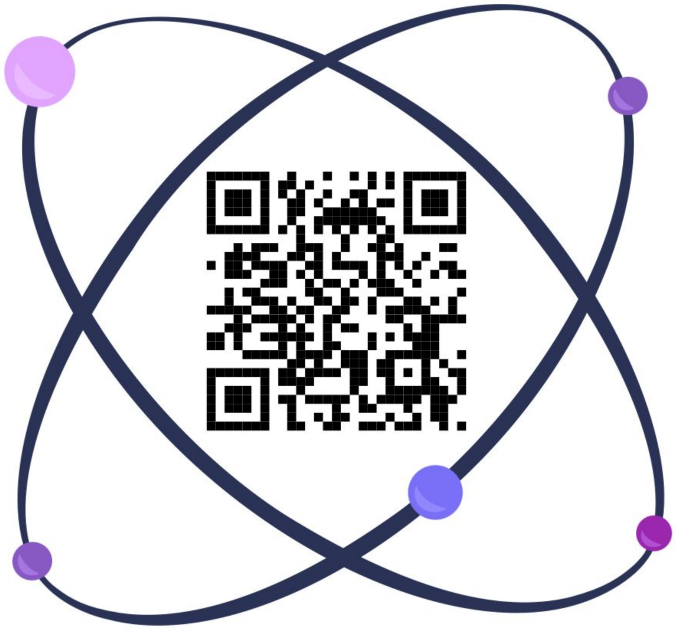
Comparison of PMTs and SiPMs Performance

	PMTs	SiPMs
Gain	10^5 - 10^7	10^5 - 10^7
Spectral Range	190 nm - 1700 nm	320 nm - 900 nm
Bias Voltage	≈ 1000 V	≈ 60 V
B-Field Sensitivity	Needs Protection	Immune
Dark Output	500 CPS	1000 kCPS
Light Exposure Sensitivity	Possible Damage	No Damage
Temperature Sensitivity	Low	Medium
Warm-Up Time	Few Minutes	Instant
Typical Time Resolution	≈ 130 ps	≈ 100 ps

What needs to be done … (Next Week)

- Begin using simulations as a tool to investigate the behavior of photon sensors and the impact of the sensors on the measurable results

- Continue learning about DIRC technology as a whole and better understand the role of sensor technology in the big picture



Link to Hamamatsu Webinar Comparing PMTs and SiPMs