Cherenkov Detector

Group25

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Cherenkov Effect

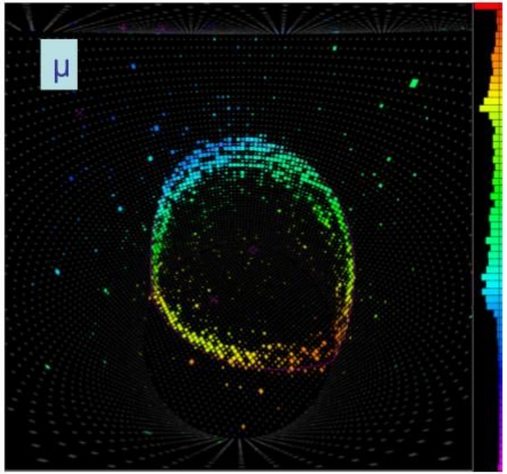
- Named after Russian physicist Cherenkov.
- Light produced by charged particles when they pass through an optically transparent medium at speeds greater than the speed of light in that medium.
- The speed is given by $\beta c = v = c/n$
- Particle emitting cherenkov radiation must satisfy $v_{part} > c/n$

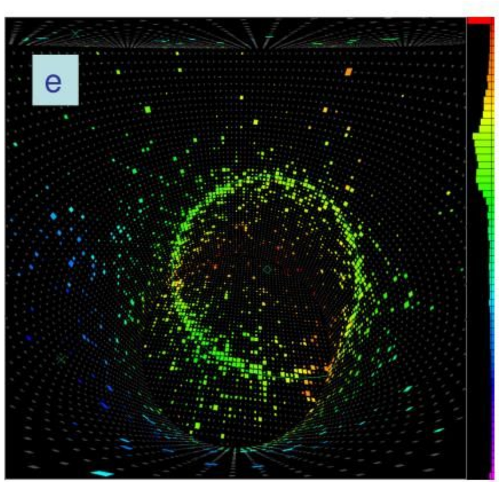
cos(θ) =1/(n□)

- Widely used for particle identification in particle detectors.

Ring Imaging CHerenkov technique (RICH)

- The essence of the ring-imaging method is to devise an optical system with single-photon detectors, that can isolate the Cherenkov photons that each particle emits, to form a single "ring image" from which an accurate θ_c can be dete





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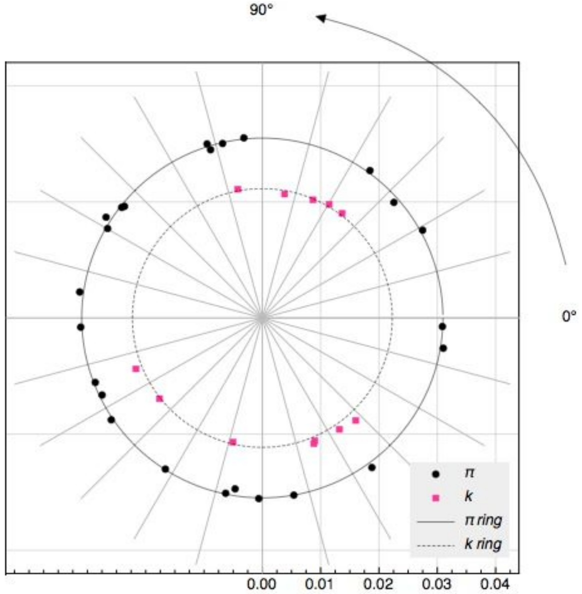


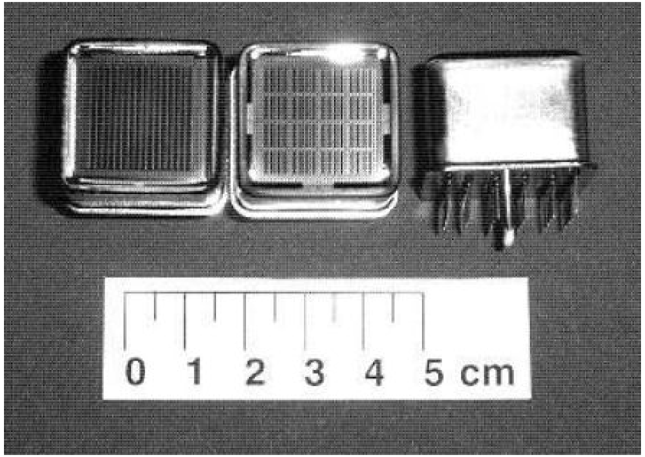
Source - wikipedia

Goals

- Determine the properties of the photomultipliers used in the work
- Measurement of the diffraction pattern by counting individual photons passing through a slit
- Observation of Cherenkov rings produced by cosmic muons in an aerogel radiator

The Experimental setup

We will be working mostly with



Hamamatsu multianode photomultipliers
(L16, M16, M16 from left to right)

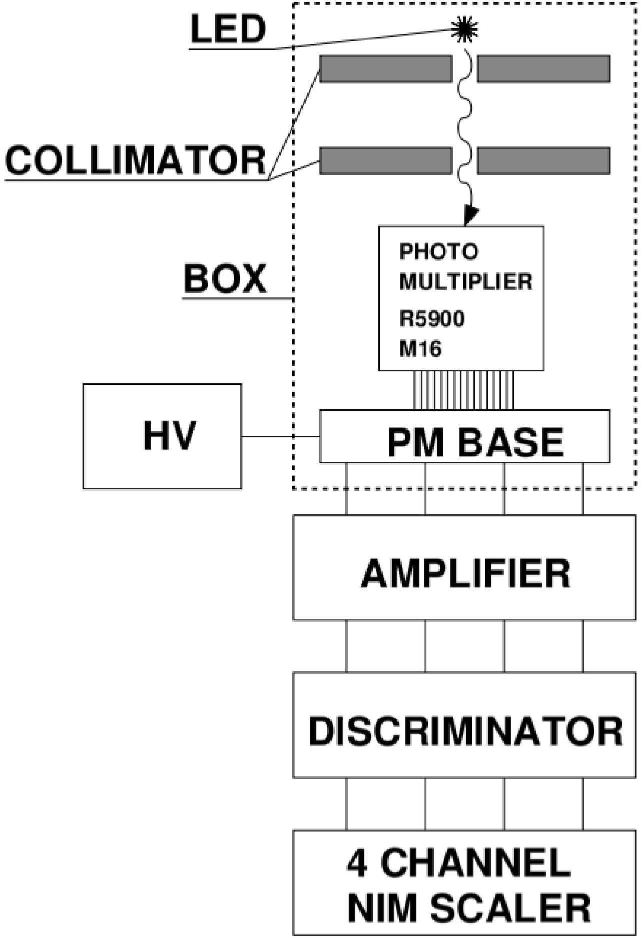
+

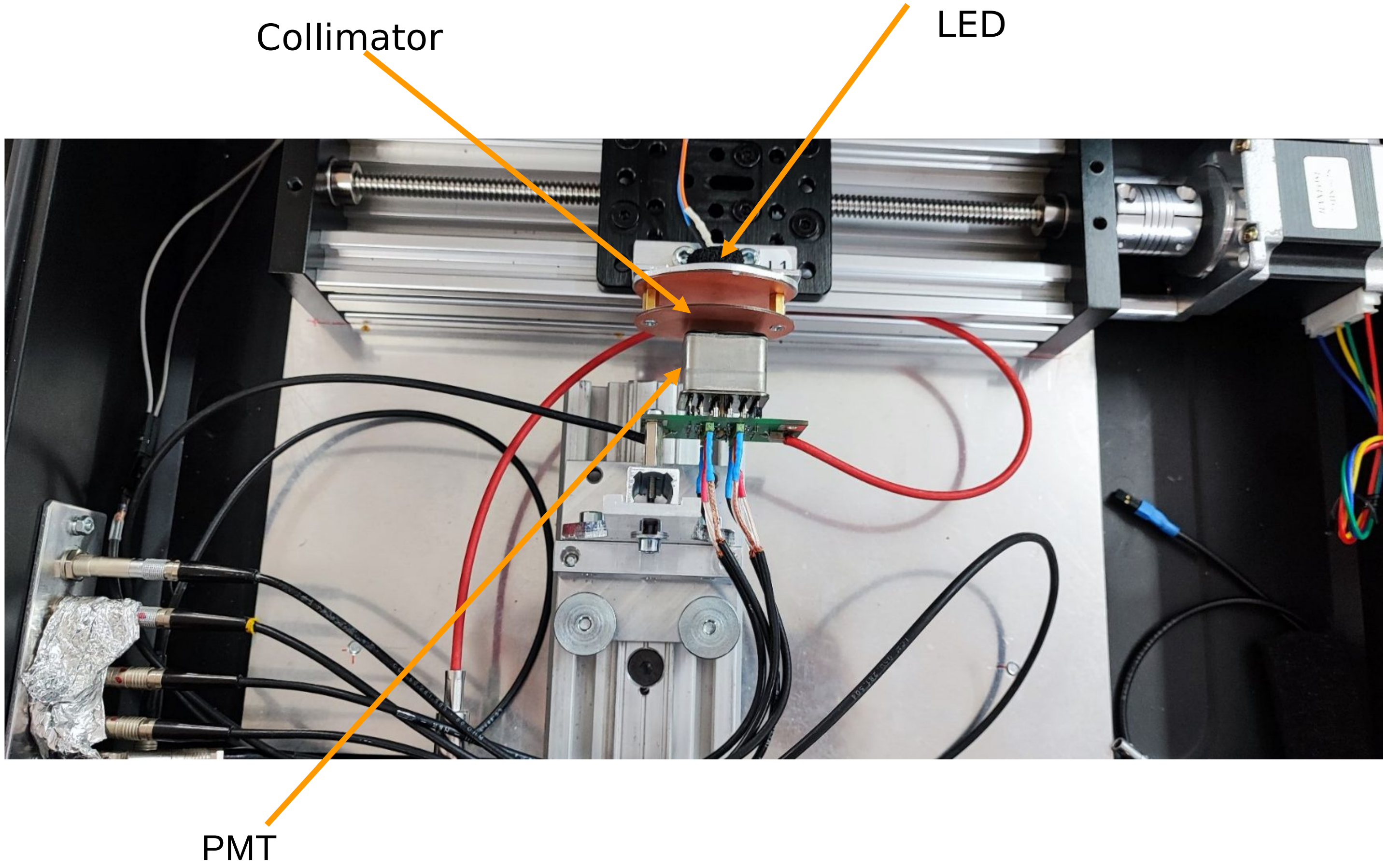
Aerogel (kept inside the box, trust us)

The Experimental setup-1

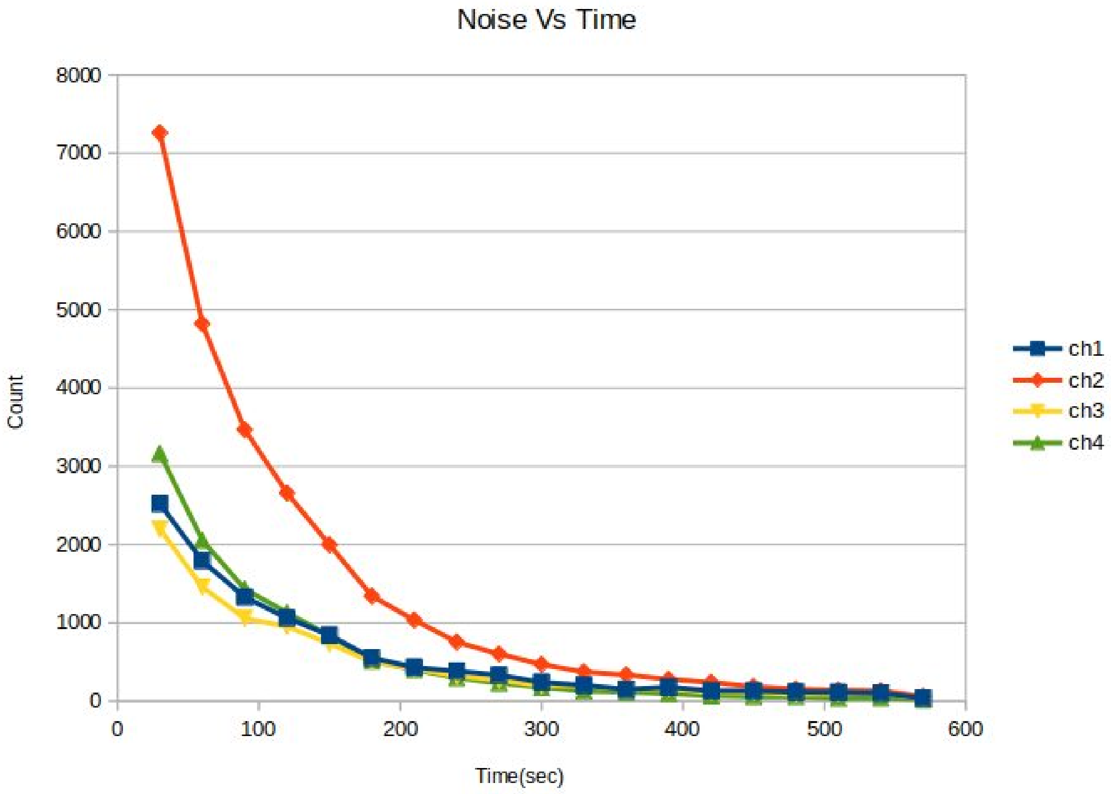
Measurement of the characteristics of the M16 PMT

- The M16 photomultiplier tube (PMT) has four independent anodes or "channels" that allow for position-sensitive detection of photons.
- The four channels are arranged in a 2x2 grid pattern on the end of the PMT and each channel corresponds to a specific region on the detection surface.
- By analyzing the relative signal strengths in each of the four channels, it is possible to determine the position of the incident photon on the surface of the PMT.



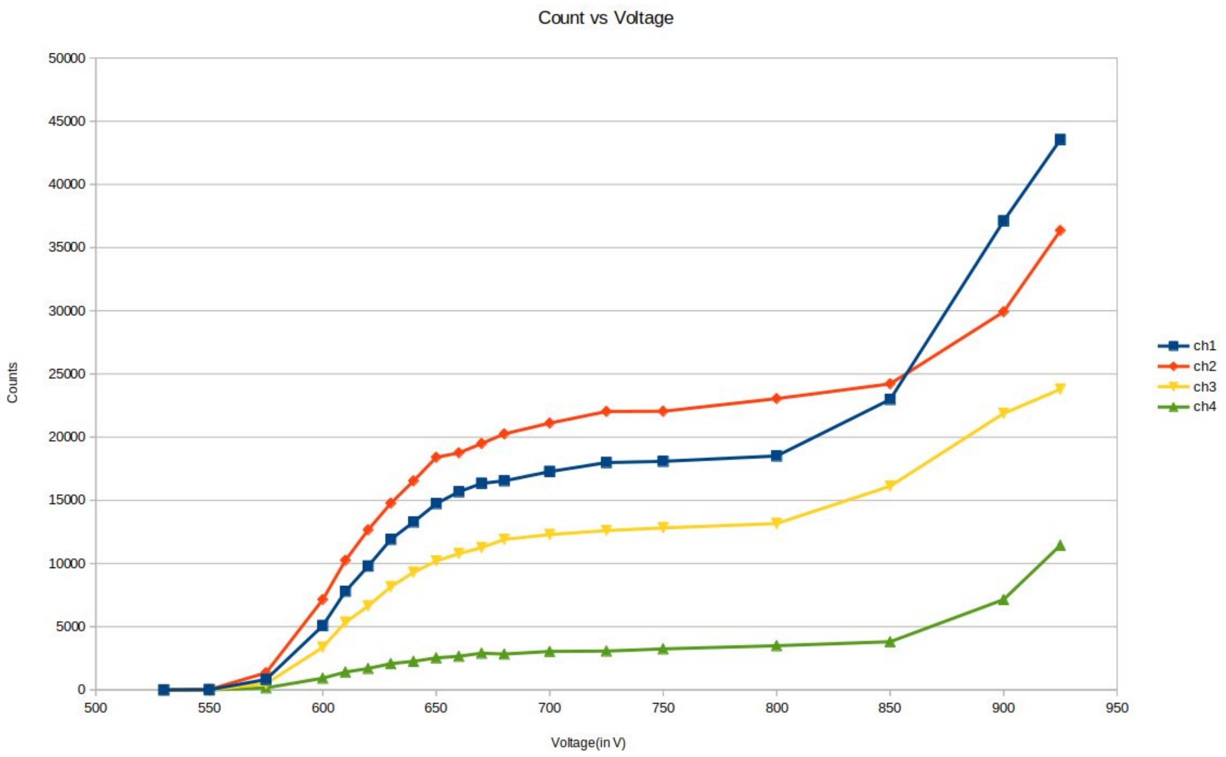

Collimator
LED
PMT

Results



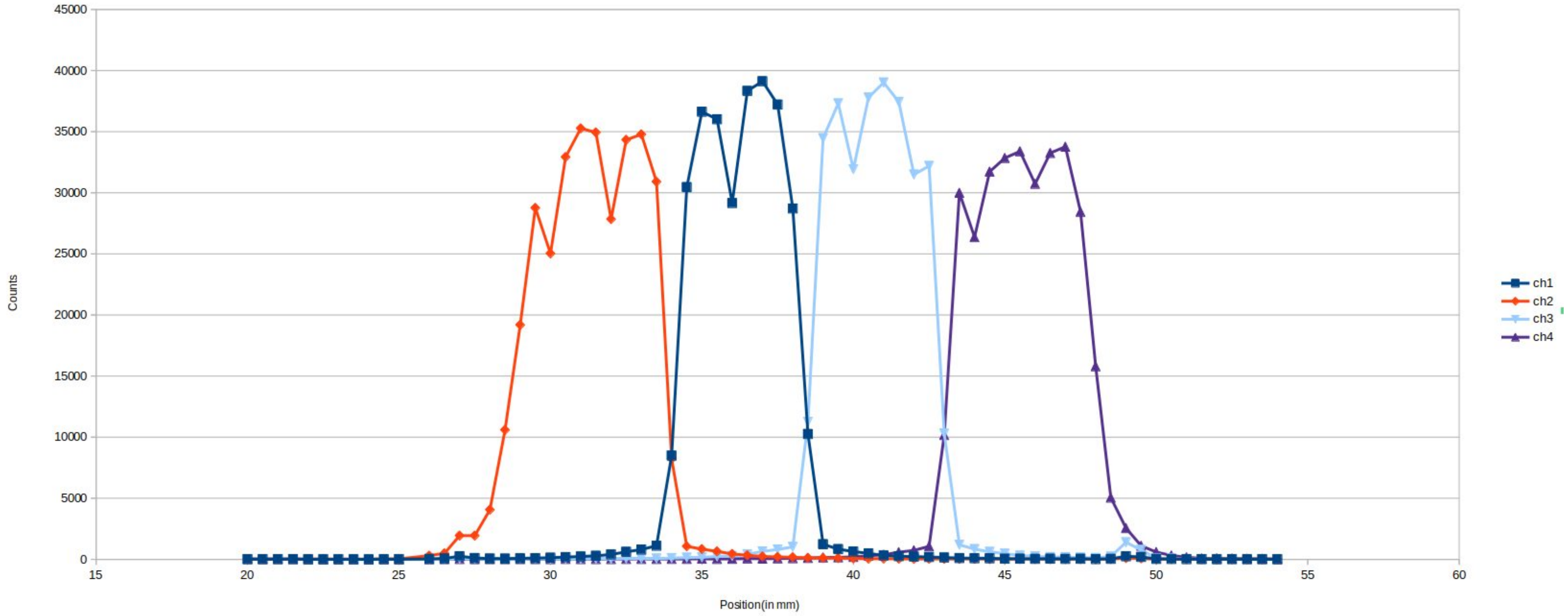
The noise counts over time for 4 channels of the PMT

Results



The noise counts over time for 4 channels of the PMT

Results

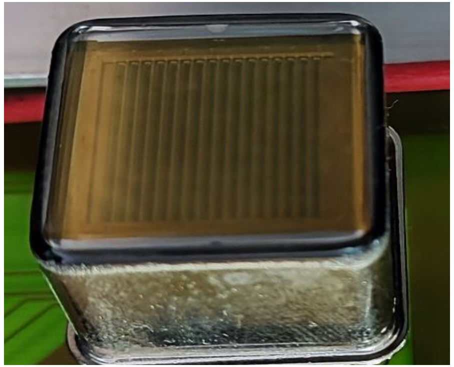


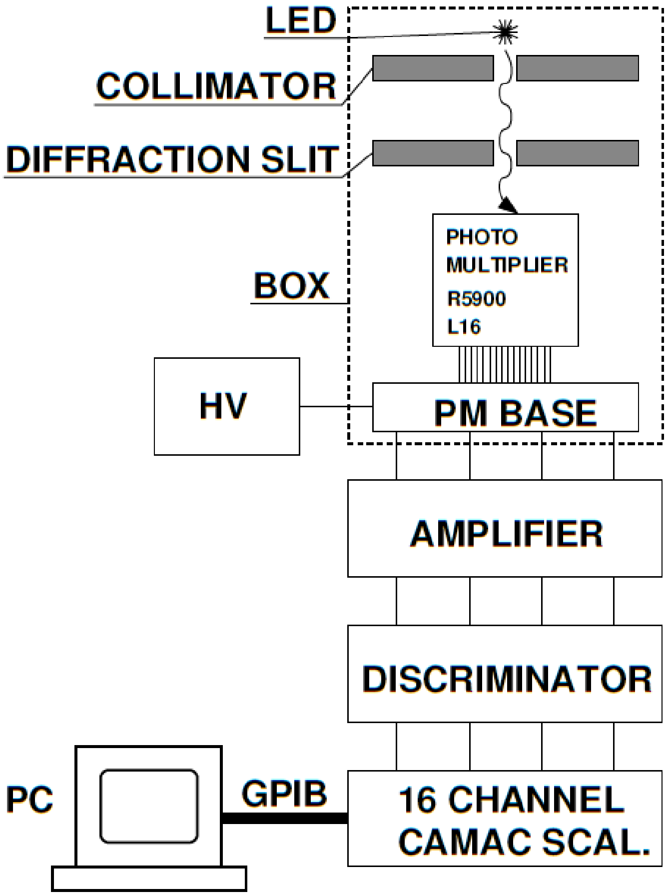
Count rate on 4 channels of the M16 PMT depending on the light spot position.

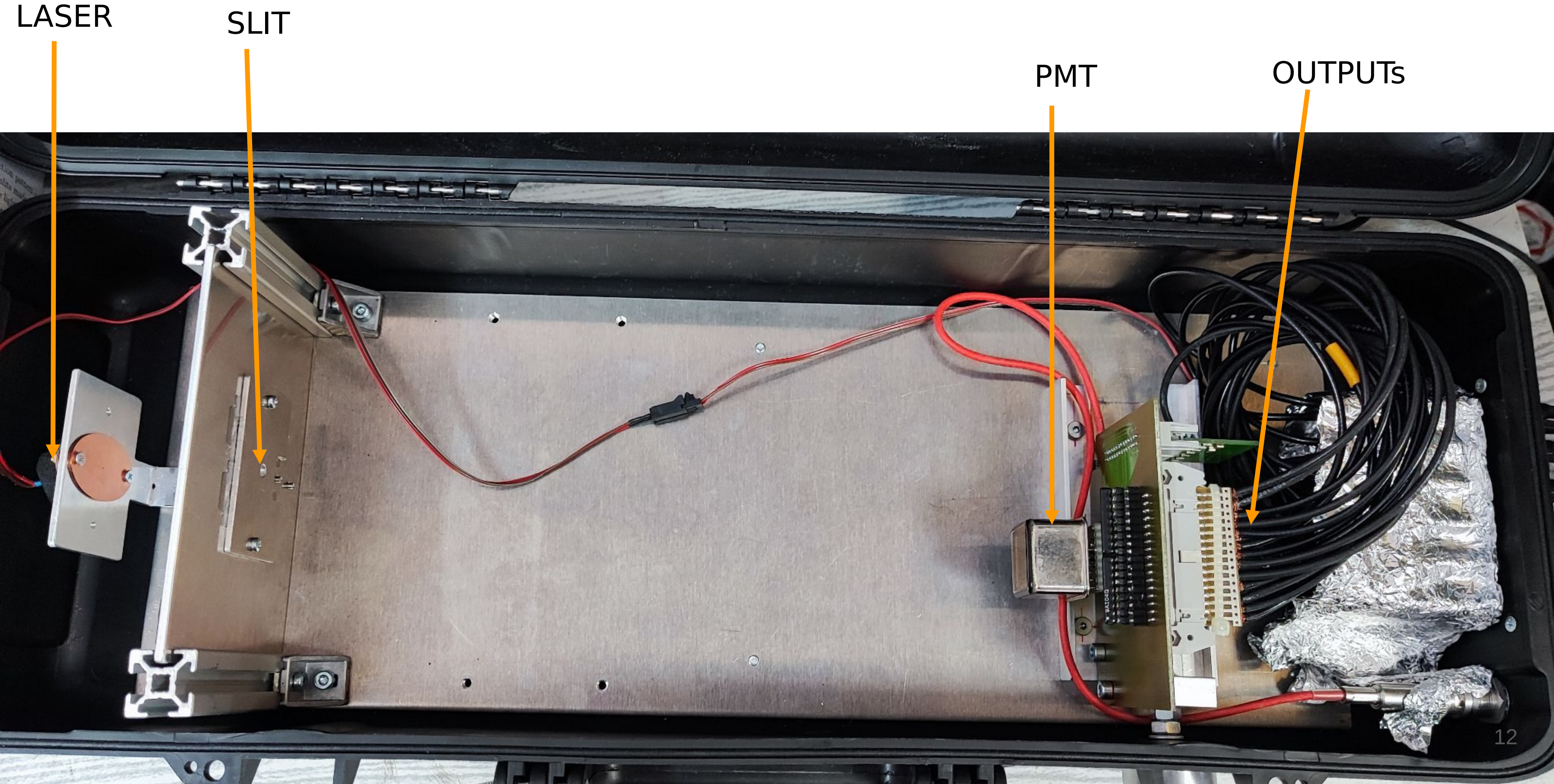
The Experimental setup-2

Measuring the diffraction with the L16 PMT

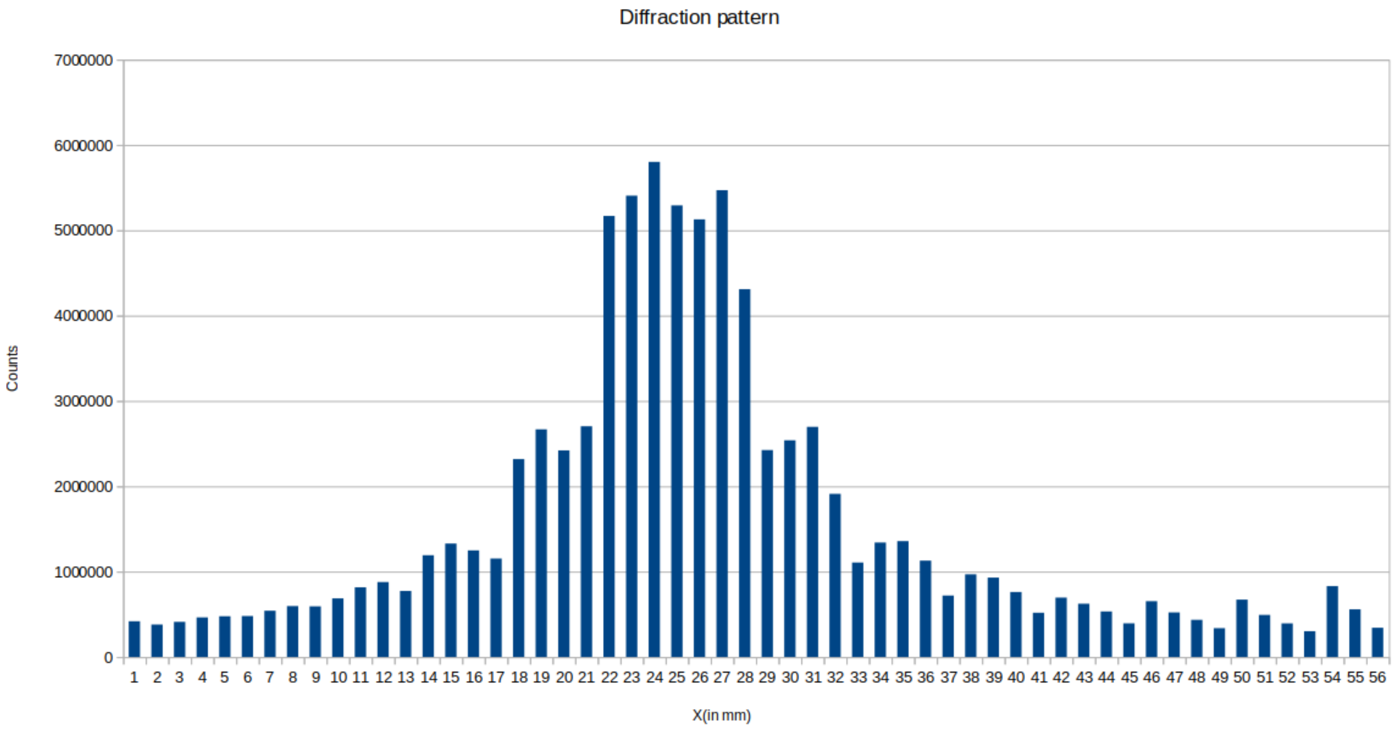
- The L16 anode, is divided into 16 strips of 16mm length and 1 mm pitch.
- A diffraction pattern is demonstrated by using a light beam from a laser pointer and slits.
- The diffraction pattern is measured in at various positions of the PMT relative to the light beam and the results are appropriately connected.






LASER
SLIT
PMT
OUTPUTs

Results: diffraction pattern

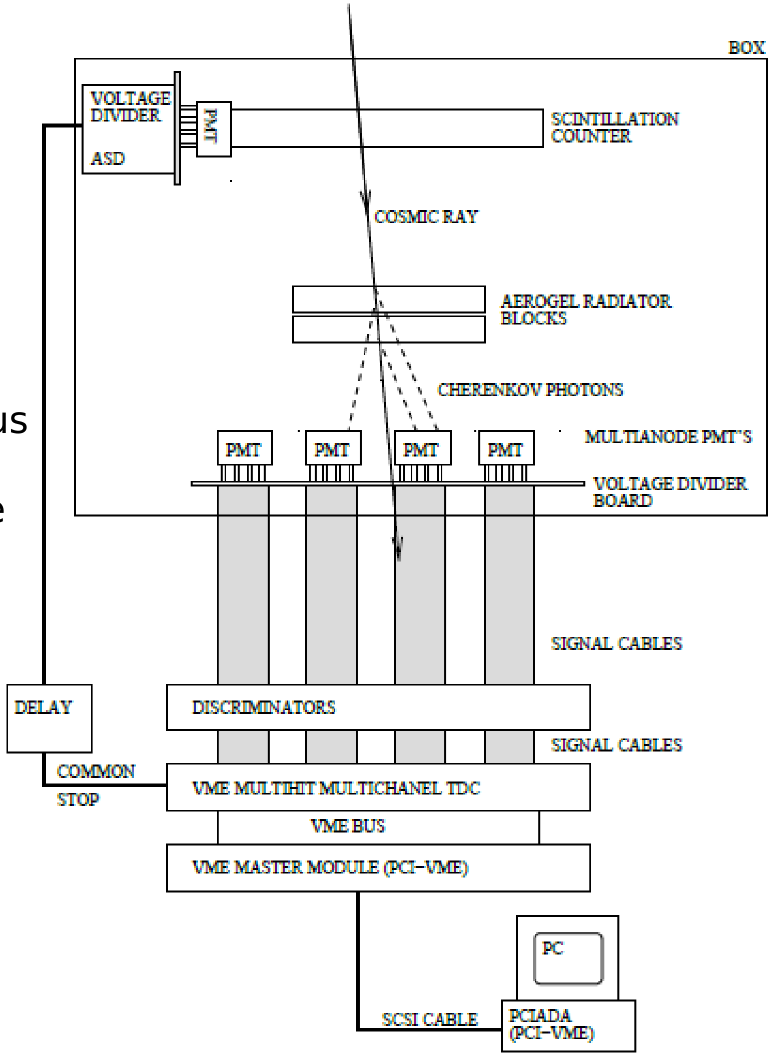


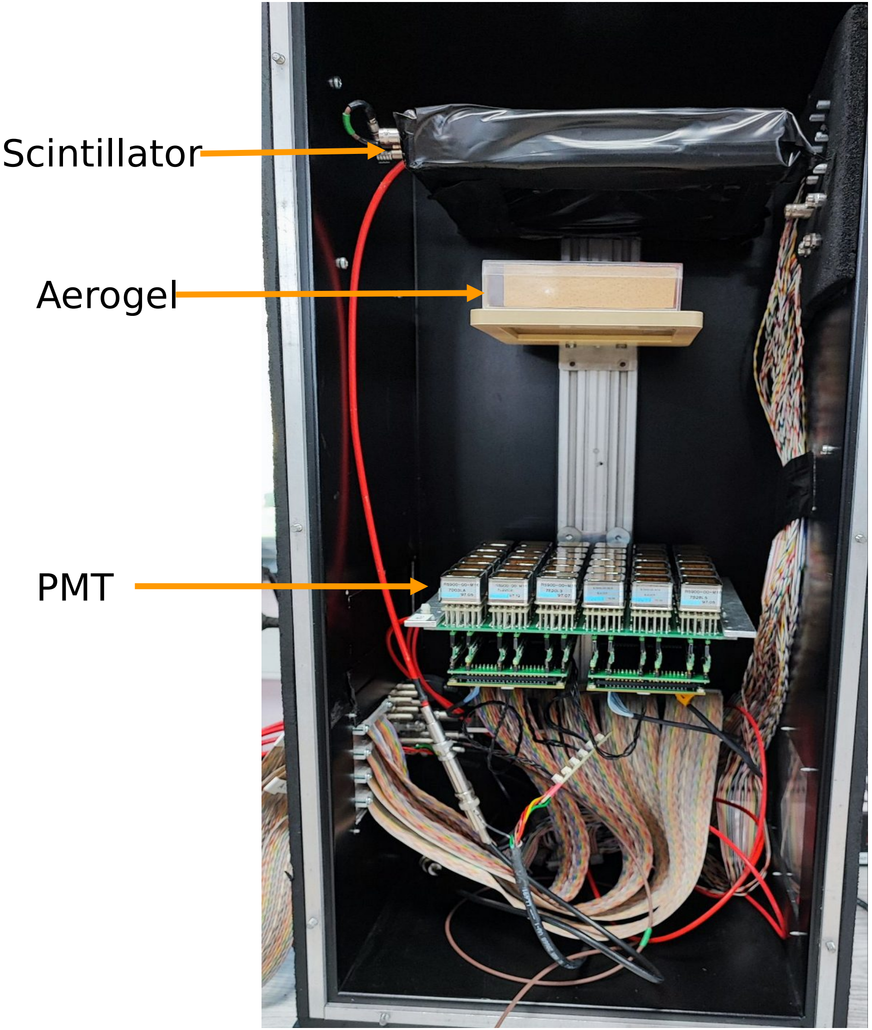
Diffraction pattern seen with the L16 PMT

The Experimental setup·

RICH counter for the cosmic muons

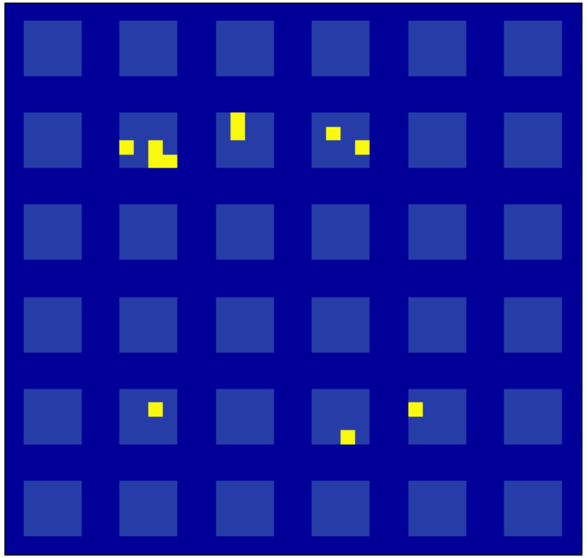
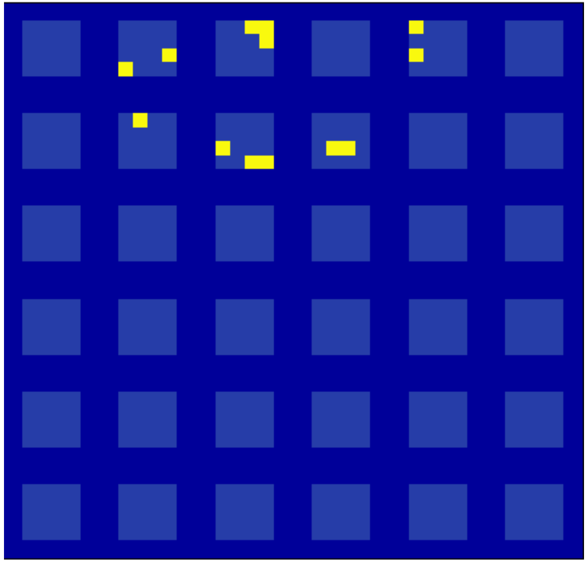
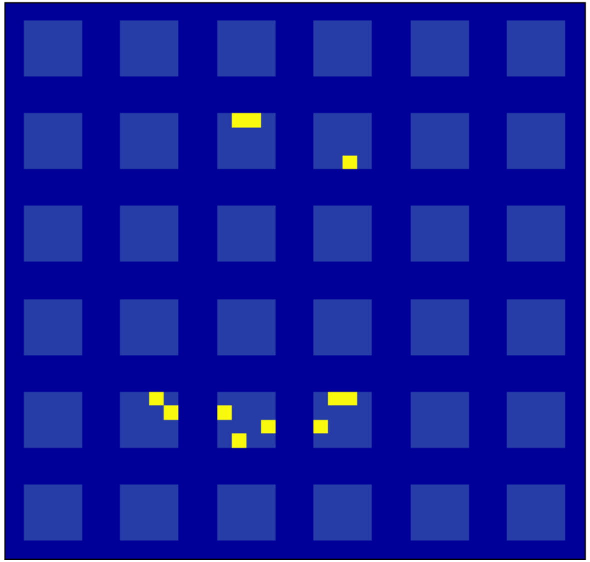
- With a position sensitive detector of single photons, one may detect a Cherenkov ring image from which the Cherenkov angle and thus the particle velocity may be determined.
- This information can be used further to find the mass of Most large detector systems operating at the high energy accelerators and colliders, include such a Ring Imaging Cherenkov detector.
- The same approach of using aerogel for PID is adapted in ARICH (Belle II experiment).





A closer look to the PMTs

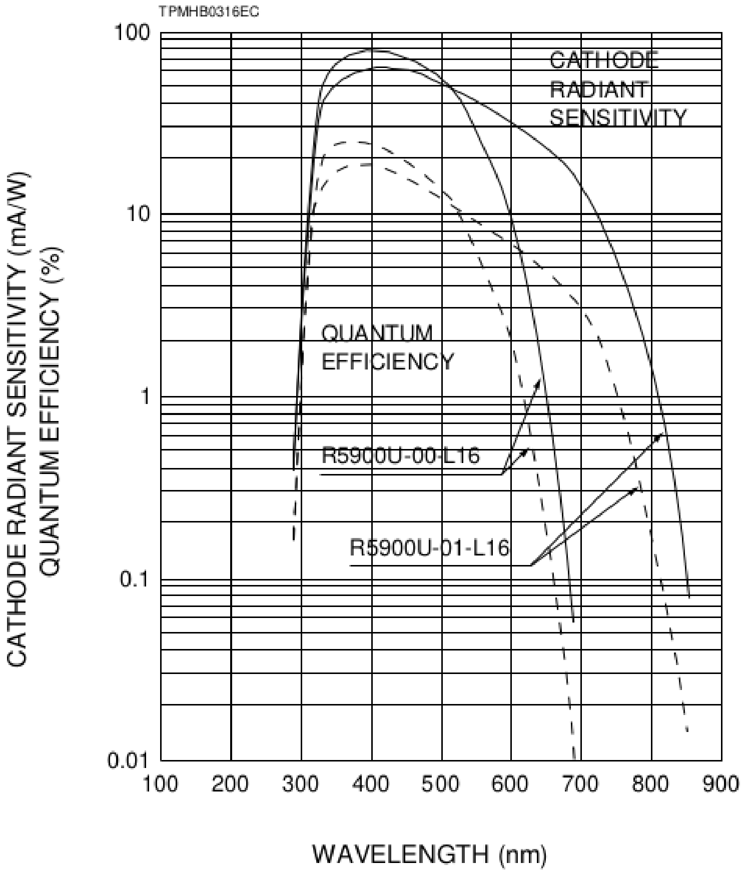
Results: ring image formation

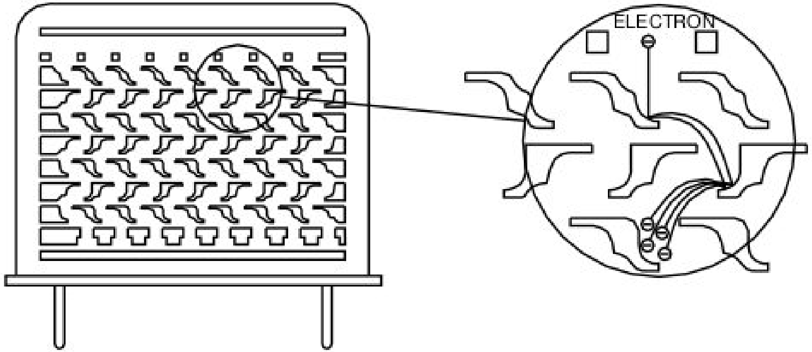




Conclusions

- The M16 and L16 PMTs are position sensitive single photon detectors, which is an important characteristic.
- The position sensitivity for the M16 photomultiplier is observed.
- The diffraction pattern was seen with the L16 photomultiplier.
- The Cherenkov rings coming from the cosmic muons is observed.
- The experiment gives an idea of how cherenkov radiators are used in particle detectors.

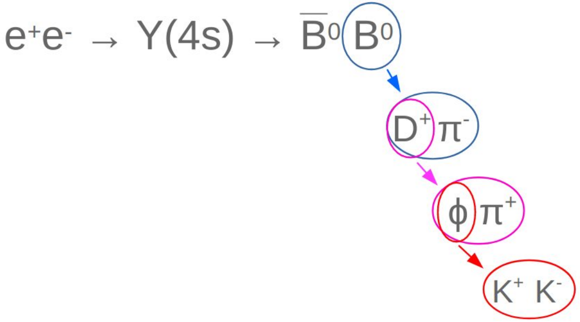
Thank You


TPMHB0316EC
CATHODE RADIANT SENSITIVITY (mA/W)
QUANTUM EFFICIENCY (%)
100
10
1
0.1
0.01
CATHODE
RADIANT
SENSITIVITY
QUANTUM
EFFICIENCY
R5900U-00-L16
R5900U-01-L16
100
200
300
400
500
600
700
800
900
WAVELENGTH (nm)

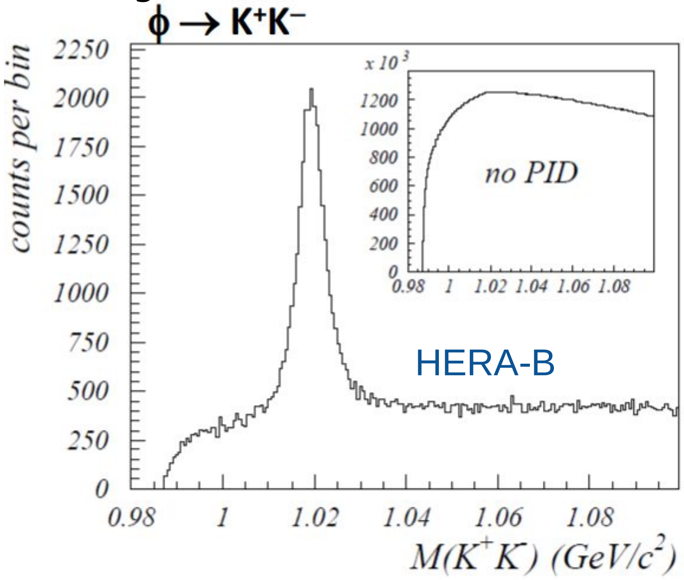

ELECTRON

Particle Identification(PID)

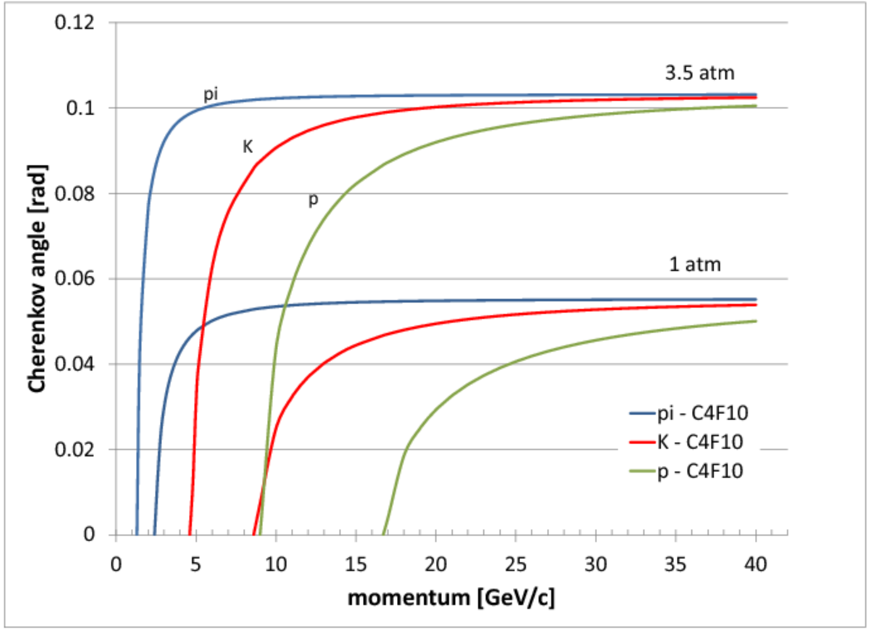
- We are often interested in reconstructing the whole decay chain and hence to reconstruct all final state particles.



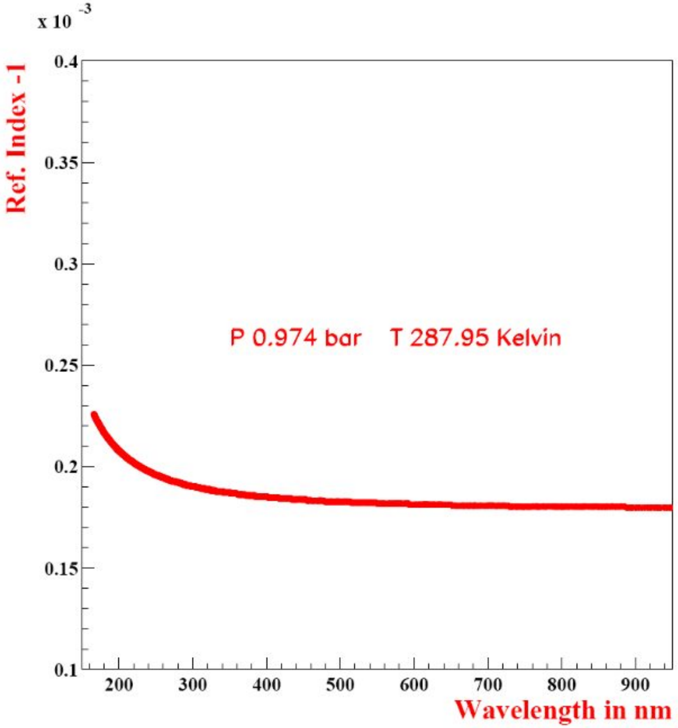
- A clear peak in the invariant mass distribution after PID information is taken into account.
- PID necessary to reduce background.



How Cherenkov Radiation helps in PID?



Dependence of the Cherenkov angle from the particle momentum helps discriminate type of the particle n= n(λ) : Different photons from the same charged track can have different Cherenkov Angles.(cos(θ) =1/(n)). This spread in angles gives rise to 'Chromatic Error' when measuring the average θ.



- Filter out the low wavelength photons before they reach the photodetector.
- Appropriate choice of the radiator material
- Recent development: Measure the Time-Of-Propagation of photons
  to estimate their wavelengths and correct for the
  chromatic error. (Time= (PathLength in the detector) / Velocity)

Cherenkov Detector:

A Cherenkov detector is a particle detector, which is based on detection of Cherenkov radiation. Cherenkov radiation is nearly instantaneous and with fast pulse processing equipment can be measured in picoseconds.

Cherenkov counters contain two main elements:

- A radiator through which the charged particle passes,
- a photodetector (e.g. a photomultiplier tube – PMT).

Cherenkov counters may be classified as either a Imaging or a Threshold type, depending on
whether they do or do not make use of “Cherenkov angle (θ)” information.

In the simple case of a threshold detector the mass-dependent threshold energy allows the discrimination between a lighter particle (which does radiate) and a heavier particle (which does
not radiate) of the same energy or momentum. Imaging counters may be used to track particles
as well as identify them. Cherenkov detectors are widely used over:

- fast particle counters
- hadronic particle identification
- tracking detectors performing complete event reconstruction

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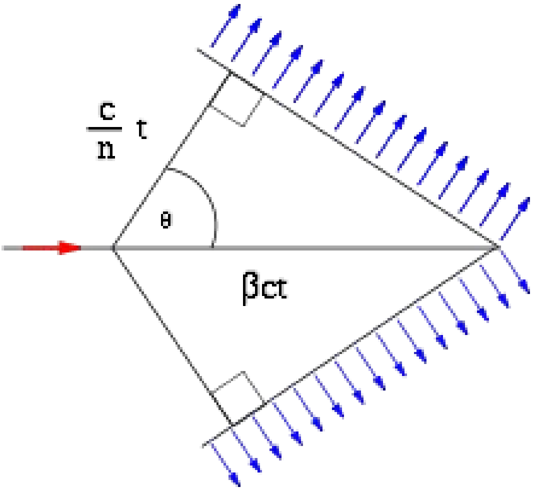
Cherenkov Effect

where n = Refractive Index

$$\beta = \frac{v}{c} = \frac{p}{E} = \frac{p}{\sqrt{p^2 + m^2}} = \frac{1}{\sqrt{1 + (m/p)^2}}$$

β= velocity of the charged particle in units of speed of light (c) vacuum
p, E ,m = momentum, Energy, mass of the charged particle.



Results: noise

- When a PMT is turned on or initially connected, its internal components can experience some transient behavior as the high voltage power supply stabilizes and the PMT reaches its equilibrium state. During this transient period, the PMT may exhibit a higher noise level than its steady-state operation.
- It is also possible that some photons are present in the setup, for example, from background radiation or cosmic rays, and these could contribute to the observed noise level.

Results: High Voltage Plateau Measurement

- The plateau region is the optimal high voltage range for the PMT, where it's most sensitive to photons and has the best signal-to-noise ratio.
- Operating PMT at this voltage ensure that the PMT is operating at its maximum sensitivity and stability, which is important for accurate and reliable measurements.

Results: position dependence of the count rate

- M16 PMT is being used as the detector to measure the spatial distribution of the photons scattered by the slit. The diffraction pattern in the photon count rate reflects the pattern of the scattered photons.
- By analyzing the diffraction pattern, one can determine the resolution of the PMT in detecting photons at different positions on the detector surface.