# HIGH RESOLUTION CHERENKOV DETECTORS FOR COSMIC RAY ISOTOPE EXPERIMENT

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ABSTRACT

Cherenkov detectors can be used to measure the velocity of particles in a variety of configurations designed to study the isotopic composition of galactic cosmic rays. In order to achieve the highest possible resolution it is necessary to understand the geometrical properties of the detector in detail. We have carried out Monte-Carlo simulations of propagation of photons in a diffusive detector to help to achieve that understanding. We have also measured the scattering properties of diffusively reflecting white paint and of surface treatments for the radiator material. We find that the absorption of light in the radiator is an important light loss mechanism. We also use these simulations to find optimal mapping techniques and data reduction strategies. The application of these techniques will be discussed with respect to the ALICE Cherenkov detector[1].

1. Introduction. The use of the Cherenkov detector in balloon-borne cosmic ray experiments was first introduced by Webber and McDonald[2]. Ever since, these detectors have become an indispensable tool in experiments where the velocity of an incident particle of known charge is measured. However, the resolution of these detectors often causes a severe limitation in the resolution of ultimate physical parameters measured in an experiment. For example, in experiments designed for isotopic mass measurement using the Cherenkov versus range technique, the resolution in mass number depends critically on the resolution of Cherenkov detectors.

The resolution of a Cherenkov detector depends upon the total light collection efficiency as well as spatial uniformity. The highly directional nature of Cherenkov emission leads to further complications of dependency of light collection efficiency on the energy and incident angle of the projectile. Besides, background signals from $\delta$-electrons above Cherenkov threshold, residual scintillation in the radiator, Cherenkov emission from white paint (usually used in the integration chamber) etc., limit the ultimate resolution of the detector. Though the resolution is limited primarily by photo electron statistics, other effects may become significant either at large pulse heights or in detectors with high detection efficiency as the resolution scales with the number of photo electrons as $n_{pe}^{-1/2}$. Requirements on a large area of these detectors further increases the importance of spatial uniformity.

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High resolution is usually achieved by processes such as selecting a radiator of high photon yield per cm., by placing the radiator material in a white diffusion box with a high photo cathode to total area ratio, by frosting the surfaces of the radiator to eliminate specular reflections, by resolution quality control of the selected Photomultiplier (PM) tubes, etc.

In this paper we shall discuss the Monte-Carlo simulations carried out to study the nonuniformity in the Cherenkov response due to the geometry of the set up. Also discussed are the results of laboratory tests on the various surface treatments for the radiator. All the results refer in general to a detector of square geometry and in particular to a Cherenkov detector to be employed in the large area isotopic composition experiment ALICE[1].

2. Properties of the Cherenkov Detector. The response of a Cherenkov detector is determined by Monte-Carlo simulations. The actual geometry of a Cherenkov detector to be used in ALICE is adopted in the simulations. Briefly, the Cherenkov radiator consists of 113.7 x 113.7 x 2.25 $cm^3$ Pilot 425, a plastic with an index of refraction of 1.5. The radiator is housed in a chamber having dimensions 114.3 x 114.3 x 20 $cm^3$. The chamber interiors are coated with a diffusely reflecting $BaSO_4$ paint[3] which has a reflectivity of 95 percent in the visible light region. The detector configuration utilizes 24 RCA S83006 photomultiplier tubes of 5" diameter, forming an effective detection area of 3354 $cm^2$. The PM tube has a maximum quantum efficiency of ~ 30 percent at a wavelength of ~ 400 nm.

The required percentage spatial uniformity in the response of this Cherenkov detector is shown against resolution in mass number for the ALICE detector assembly in Figure (1). It is seen that less than a percent nonuniformity is required to achieve a mass resolution of ~ 0.3 A.M.U. Usually, Cherenkov detector responses are mapped[4,5] using accelerator beams.

However, it is unwieldly to map large area detectors using accelerators. Alternatively, one can simulate the Cherenkov chamber response map and map the detector using cosmic ray muons or flight data.

Two extreme cases of surfacing of the radiator, namely, 'perfectly polished' and 'ideal frosted' are considered in our simulation. In the case of 'polished' surface, light is required to follow Snell's law at the boundary while an isotropic angular distribution is assumed for the 'frosted' surface whenever photons pass the boundary of the radiator. Each photon is followed until it is either absorbed by the radiator or the white paint coated wall or detected by PM tubes. A photon is considered to be absorbed if it is surviving even after 50 reflections either in the walls or in the radiator. A five percent probability for absorption of photons is assumed for the white paint coated wall and a uniform angular distribution for the scattered photon off the wall. The individual PM tube responses are assumed to differ only in parameters describing the relative positions of impact point and center of the photo cathode.

The simulated response of the detector for a particle passing through with different incident angles is shown in Figure (2) for 'polished' surface, 'polished' and 'frosted' surfaces of a radiator doped with waveshifter. Frosting of the surface reduces the nonuniformity as expected.

Laboratory tests were carried out to study the angular distribution of outgoing light for different surface treatments. Four samples of lucite of thickness 5 mm are chosen. One side of each sample is polished while the other side is either polished, machined with a fly-cut technique, sandblasted or sandpaper treated using 80 grit sandpaper. A He-Ne laser beam ($\lambda$ = 6320 Å) is made to impinge on the polished surface of the samples at right angles and the angular distribution of the forward component of light is measured at the other side. The angular distributions are shown in Figure (3) for all samples along with an angular distribution obtained for a surface coated with a white paint of $BaSO_4$ base. It is seen that for all test samples, the transmitted light is far from isotropic.

It was also observed that the contamination of the surface due to the sandblasting process is higher than the rest. Samples are kept inside a light diffusion box mounted with a green Light Emitting Diode (LED), ($\lambda$ = 5700 Å) and a photomultiplier. A significant absorption of light due to contamination of the surface is observed in the case of sandblasted samples. However, this absorption may be reduced if one uses $AlO_2$ for blasting the surface instead of sand.

The nonuniformity due to a geometric dependent variation in the response of the Cherenkov detector is studied through Monte-Carlo simulations. Particles are made to impact at different positions in the detector, and the Cherenkov response is mapped. The percentage of detected photons is plotted in Figure (4) against the distance along the diagonal for two attenuation mean free paths of 1 m and 10 m.

3. Conclusions. A sandpaper treated surface looks good for our purpose. Radiators doped with waveshifting materials and having a long attenuation length tend to make the detector response uniform over the area besides yielding higher light output. Further simulations are being carried out and the results will be compared with the mapped response of the Cherenkov detector, obtained using cosmic ray muons. Also simulations are currently being extended for a detector of circular geometry[6].

4. Acknowledgement. We thank Dr. Walter Viehmann for results on scattering experiments.

References

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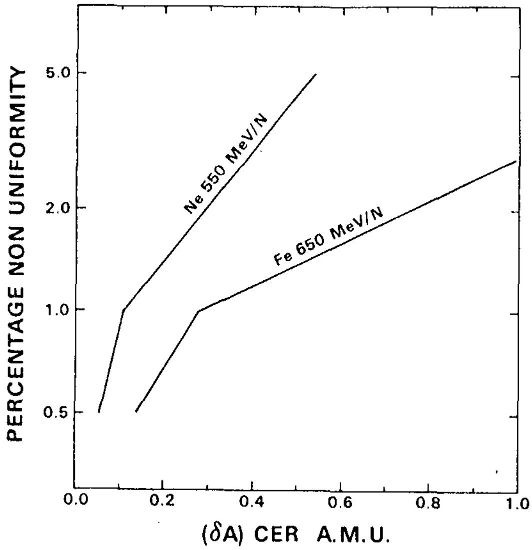


Figure 1.

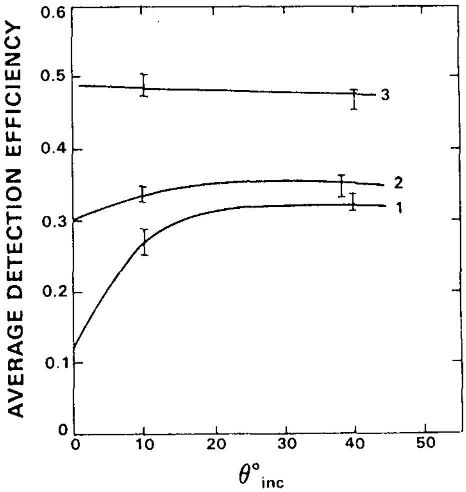


Figure 2.
1. Polished surface
2. Polished surface of a radiator doped with wave-shifter.
3. Frosted surface of a radiator doped with wave-shifter

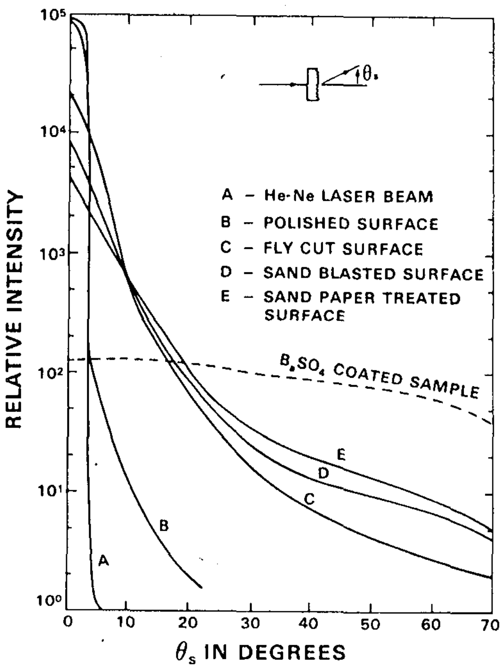


Figure 3.

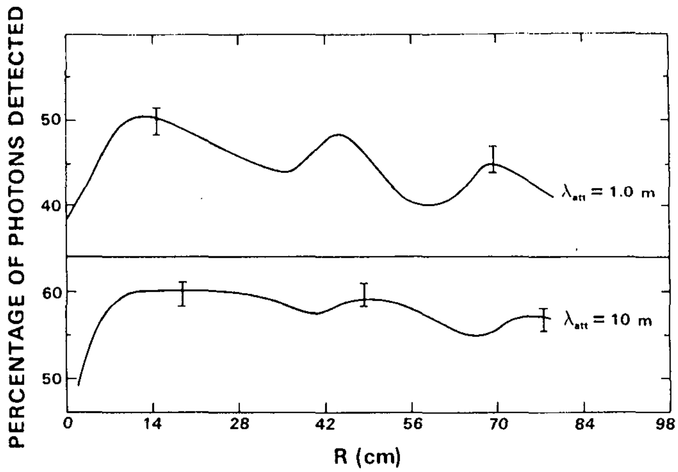


Figure 4.