CERENKOV COUNTERS FOR HIGH ENERGY NUCLEI: SOME NEW DEVELOPMENTS*

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In this report we discuss a method to determine with gas Cerenkov counters the Lorentz factor, $\gamma = E/mc^2$, of cosmic ray nuclei with high accuracy ($\sim$1% for iron) over the range $\gamma \sim 20$-100.

Conventional integrating gas Cerenkov counters in cosmic ray instruments measure the total flux of light produced by an incoming particle. The accuracy of such a measurement is statistically limited to $1/\sqrt{N}$, (where N is the number of collected photoelectrons), but has a fixed minimum value due to systematic contributions from residual gas scintillation, Cerenkov light from paint, light from delta-rays, etc. For gases with high Cerenkov thresholds, ($\gamma > 20$), the Cerenkov light levels of such integrating counters become extremely low, comparable to these sources of background. Thus, the energy resolution is quite poor, even for counters with large pathlengths and with a very large number of photomultipliers.

As an alternative, we consider the measurement of the Cerenkov emission angle θ, by use of a suitable imaging system. The resolution of such a system is $\Delta\theta/\theta \times 1/\sqrt{N}$, where $\Delta\theta$ is the accuracy of determination of the Cerenkov angle from imaging one collected photoelectron. If it is possible to construct a device with $\Delta\theta/\theta \ll 1$, one would achieve far better resolution than with an integrating counter for the same N. In addition, the sources of background mentioned above are greatly suppressed by an imaging system.

Imaging counters, known as ring imaging Cerenkov counters (RICH), have been recently developed for use on accelerators. In these devices a spherical mirror is used to focus the Cerenkov light, from a particle travelling along the optical axis, into a circular ring on a gas filled, position sensitive, detector for UV photons.

The application of a RICH to cosmic ray studies is not straightforward, because the isotropic nature of the particles precludes aligning the optical axis of the system with a "beam" of particles. Clearly, we must examine the image of off-axis particles to determine the amount of image distortion as a function of the direction of the incoming nucleus. We may then define an acceptance solid angle, relative to the optical axis, within which the nucleus produces an image with an acceptable level of distortion. By computer simulations, we have studied the properties of the image, which becomes elliptical, for off-axis particles. The dominant problem in the reconstruction is associated with

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the thickness of the detecting device, which must be $\gtrsim$ 10cm to provide a reasonable quantum efficiency. Ring images for on-axis particles may be reconstructed by measuring the coordinates, x and y, of photoelectrons in a plane perpendicular to the optical axis. However, for off-axis particles, the third coordinate z, corresponding to the depth in the detector, must also be measured. We show that with this information an accurate reconstruction of the elliptical ring image is possible for a rather large acceptance solid angle.

For example, a 3m cylindrical RICH, having a 1.4m diameter detector, would be capable of measuring the energy of an iron nucleus to $\sim$1% at γ=50, with an acceptance aperture of $\sim 0.24m^2$str. Such an energy measurement could be combined with the proposed superconducting magnet spectrometer facility on the Space Station to determine isotopic abundances at energies far beyond those covered in present experiments.