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Development of ultra-compact detectors based on oriented crystals for the observation of high energy e+/e- and gamma rays in space

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High-density and high-Z crystals are a key element of most detectors used to observe High Energy (HE) $\gamma-$rays and cosmic rays from space, such as Fermi-LAT and DAMPE. The lattice structure of these materials is usually ignored for all practical purposes, such as instrument calibration or simulation. However, recent studies have shown that this is a rough approximation, since $e^{\pm}$ and photons with an energiy above few GeV impinging along the axis of an oriented crystals interact differently from the ordinary. Specifically, if the angle between the $e^{\pm}$ (photon) trajectory and the crystal axis is smaller than $\sim 0.1^{\circ}$, a large enhancement of the bremsstrahlung (pair production) cross-section is observed. A weaker enhancement effect can be observed even for incidence angles as large as 1°. These enhancements grow for energies as large as few TeV and then saturates.

These effects could be exploited to develop novel ultra-compact space-borne telescopes for the detection of HE photons and $e^{\pm}$. For instance, a calorimeter composed of oriented scintillating crystals could contain the e.m. showers as efficiently as a much thicker (and thus heavier and more expensive) non-oriented one. This allows to either dramatically extend its energy range, or to reduce its thickness and significantly improve its effective area, without increasing the overall volume and weight. The acceleration of the e.m. shower allows also a better discrimination of hadrons from $\gamma-$rays and $e^{\pm}$. Another possibility is the design of a silicon-tungsten tracker for $\gamma-$ray astronomy using oriented crystalline converters: the detector could be made much thinner, thus improving the low-energy angular resolution, without losing in high-energy photon conversion efficiency.

This detector concept is highly interesting for both cosmic ray astrophysics and $\gamma-$ray astronomy. In the latter, oriented crystals could allow the development of larger effective area or lighter-weight detectors sensitive to multi-GeV photons. Coupled with a high spatial resolution, such a detector could be operated to monitor the γ-ray sky, resolve unknown sources in the galactic plane and investigate the nature of the gamma excess in the galactic center, while also providing a high sensitivity to fast e.m. transients, taking advantage of the enhanced compactness of the oriented calorimeter for swift satellite repointing.

In this contribution we discuss the scientific opportunities that will be opened by the use of oriented crystal in compact detectors for cosmic-ray and $\gamma-$ray astronomy, along with the techniques used to simulate and assemble such instruments. We will also present some results obtained by the OREO collaboration, which at present time is the first and only group that was ever able to fully develop and test an oriented calorimeter composed of $PbWO_4$ crystals.

Eligibility for ”Best presentation for young researcher” or ”Best poster for young researcher” prize

Yes

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