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Novel type of compact satellite borne gamma-ray telescope based on oriented crystals

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It has been known since the ‘50s that the lattice structure may strongly influence the electromagnetic processes in oriented crystals. In particular, if a beam of electrons or photons is aligned with the crystalline axes or planes, the probability of bremsstrahlung or pair production, respectively, are strongly enhanced. This results in a shortening of the radiation length, X0, and thereby of the electromagnetic shower exten. In the ‘90s, the CERN NA43 and NA48 experiments measured the X0 reduction in high-Z crystals of single element, such as tungsten, with a reduction factor of 3-4 times in case of perfect crystal-to-beam alignment. This factor decreases gradually as the angle between the photon/electron and crystal axes increases. Despite this, a measurable effect is maintained up to about 1°. Recently, our group extended these studies to high-Z scintillators commonly used in electromagnetic calorimeter. In particular, we measured a huge X0 reduction for 120 GeV electrons interacting with a lead tungstate crystals (PWO), from 8.9 to 1.6 mm in the case of beam alignment w.r.t crystal axes.
With the birth of multimessenger astrophysics, one may think of pointing a telescope towards a source. In a satellite with a gamma module made of oriented crystals, the shower of gamma rays with energy larger than 100 GeV can be completely contained in a quite restrained volume, thus reducing the necessary weight (and therefore the cost) compared to those currently used.
If we take as an example the FERMI LAT, each of its “tower”is composed by a Tracker and a Calorimeter module. The first one consists of layers of silicon detectors interleaved with thin W converter foils, while the Calorimeter is made of CsI scintillator crystals. An incoming gamma ray interacts with the W foil, thus converting in pairs that deposit their energy into the Calorimeter.
In case of pointing, an oriented crystals based hodoscopic calorimeter would strongly enhance the sensitivity of the telescope above few GeV, thus containing the electron/positron showers at energies up to TeV and more in a smaller volume as compared to standard detectors. Furthermore, if the W conversion foil is substitute by a crystalline W or high-Z crystal scintillator, the tracker length can be reduced and consequently the multiple scattering, with an improvement of the resolution in the localization of the gamma-ray, thus helping its identification.
The required 1° alignment precision needed for X0 reduction can be easily satisfied with “usual” satellites. Moreover, such an apparatus would continue to operate in a standard way in the absence of pointing.
Several fields of the astrophysics could be explored using the pointing strategy, for example:
1) observation of unidentified Fermi gamma-ray sources;
2) follow-up of flaring/transient and multimessenger sources;
3) pointing of the galactic center for the dark matter decay lines detection.
The connection with the TeV astrophysics from the ground is also fundamental and a detector in space able to see photons with increased efficiency in the range 10-100 GeV or more is what is needed for joint science with IACT observatories as CTA.
The idea of an oriented crystals based satellite may be useful in future missions, e.g., GAMMA-400.

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