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Compact Space-Borne Telescope for Efficient VHE Gamma-Ray Detection with Oriented Crystals

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Aligning a beam of electrons/photons with the crystallographic axes or planes of a crystal within a some mrad enhances the probability of bremsstrahlung/pair production. This reduces the radiation length, X0, and consequently the electromagnetic shower extent, as recently demonstrated by our team for tungsten [1] and high-Z scintillator (PWO) crystals [2].
We present the possibility of exploiting the X0 reduction for a satellite-based gamma module composed of a converter/tracker and calorimeter system entirely made of oriented crystals.
In case of a pointing strategy, the increased pair production cross-section would improve the detector sensitivity; one might consider reducing the total converter-tracker length. Furthermore, we experimentally demonstrated that the shower enhancement in PWO scintillator crystals is maximal in the direction of gamma rays within about a mrad (0.06°) with the crystallographic axis, thereby increasing the signal-to-background discrimination in such a small angular size. A detector with good angular resolution and enhanced sensitivity in the source direction would be highly advantageous for measuring unidentified gamma-ray sources or investigating the gamma excess in GC for indirect dark matter (DM) searches.
At the same time, the e.m. showers initiated by gamma rays with energies from a few GeV to hundreds of GeV - multi-TeV would be contained in a much smaller volume in a calorimeter composed of oriented crystal scintillators compared to standard detectors [3,4]. Since minimizing the size and weight of onboard detectors is crucial for space missions, a gamma-ray satellite based on the presented technology should lead to a substantial reduction in mission cost. This advantage can be readily adapted in future missions to:
- Increase the detector transverse size to capture more photons.
- Realize lighter detectors, enhancing the space mission feasibility and/or that can rotate fast enough to measure HE/VHE transient/multi-messenger signals.

In general, oriented crystals add new features and sensitivities for measuring particles inside of the crystallographic axis acceptance, while large-angle showers feature equal developments as in not-oriented standard detectors. A compact satellite based on oriented crystals will open unprecedented opportunities in several astrophysics frontiers, currently unexplored due to operational technology limitations. It will provide complementary and unique information to that expected in the next era of VHE gamma-ray sky observation with ground-based IACTs like the CTA observatory.
In this contribution we present the scientific opportunities that will be opened by the use of oriented crystal compact calorimeters in gamma-ray and astroparticle space missions, and the test campaign done at CERN PS&SPS that have been conducted to verify and optimize the approach.

[1] M. Soldani et al., Eur. Phys. J. C 83 (2023) 101
[2] L. Bandiera et al., Phys. Rev. Lett. 121 (2018) 021603
[3] L. Bandiera et al., Frontiers in Physics 11(2023) https://doi.org/10.3389/fphy.2023.1254020
[4] L. Bandiera, V. Haurylavets and V. Tikhomirov Nucl. Instrum. Methods Phys. Res. A 936 (2019) p.124-126
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