Simulation of a Compton Xenon Telescope

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Motivation

MeV gamma-ray astrophysics provides a little explored window into an energy regime which promises a multitude of new insights. It comprises gamma-ray bursts, MeV blazars, or extragalactic background radiation in the continuum, and it is the energy regime of positron annihilation and nuclear transitions. Gamma-ray lines from isotopes such as ²⁶Al or ⁵⁶Fe can provide unique insights into, e.g., the inner workings of supernova explosions and ongoing nucleosynthesis. Compton scattering is the dominant interaction in this energy range, making a Compton telescope the most promising detector principle. Here we present a Monte Carlo study of a combination of PVT as scatter detector and a liquid xenon TPC as position-sensitive calorimeter.

Backgrounds (Input Spectra)

Proton backgrounds:
For a LEO 500km altitude and inclination of 28°
Models provided by SPENVIS [2]
- Trapped protons: trapped by Earth's magnetic field used model PSB97
- Solar protons: emitted during solar flares
- Galactic cosmic rays: emitted by SNe used model ISO15390
→ used for activation simulation

Gamma ray backgrounds:
- Diffuse gamma-ray background
- Earth albedo
- Activation induced gamma rays

Performance Parameters

The following parameters are used to characterize a Compton telescope:
- Angular resolution measure (ARM):
  \[ ARM = \frac{\phi_{\text{geo}} - \phi}{\text{FWHM}} \]
- Energy resolution
- Field-of-view (FOV)
- Sensitivity describes the minimal detectable flux for:
  - Line
  - Continuum
  - Point source
  - Diffuse
  \[ f = \frac{N^2}{2A_{\text{eff}}t_{\text{obs}}(1 + \sqrt{1 + 4b(n^2)}} \]
  Background rate b;
  Observation time \( t_{\text{obs}} \);
  Effective area \( A_{\text{eff}} \);

Monte Carlo Simulation Framework

Simulations are done with Geant4 [3] and MEGAlib [4]. The geometry used in these simulations consists of 5×5 modules of 22×22 cm² size. Each inherits a D1 detector (12cm Polyvinyltoluene (PVT)), a D2 detector (10cm LXe) and a veto (5cm LXe) with readout. Between D1 and D2 is a gap of 30cm.

**D1:**
- Position resolution 0.29cm
- Energy resolution \( \alpha(E) = 3.49 \% \sqrt{E/\text{MeV}}/\text{MeV} \)

**D2:**
- Position resolution in x-y 0.25mm; in z 0.1mm
- Energy resolution \( \alpha(E) = 1.9 \% \sqrt{E/\text{MeV}}/\text{MeV} \)

Monte Carlo Simulation Results

**Preliminary conclusions:**
Only moderate sensitivity with PVT as D1, due to energy and position resolution.
Ongoing work: Effect of silicon or LXe D1 detectors.