



# Lab Measurements with a Prototype Module of the *LargE Area burst Polarimeter (LEAP)*

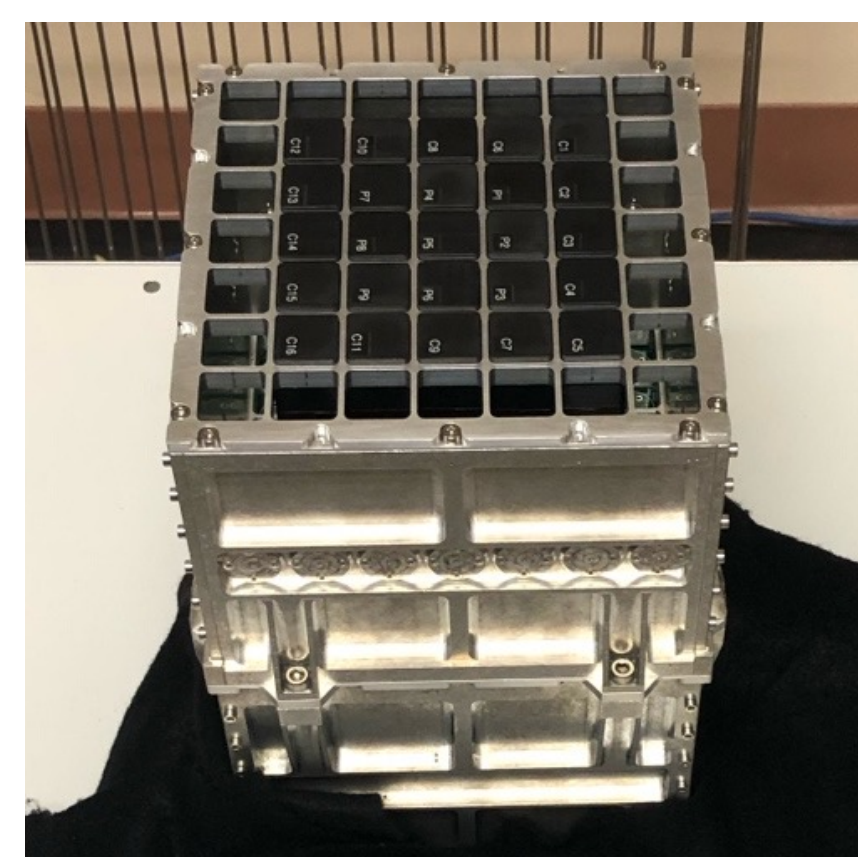
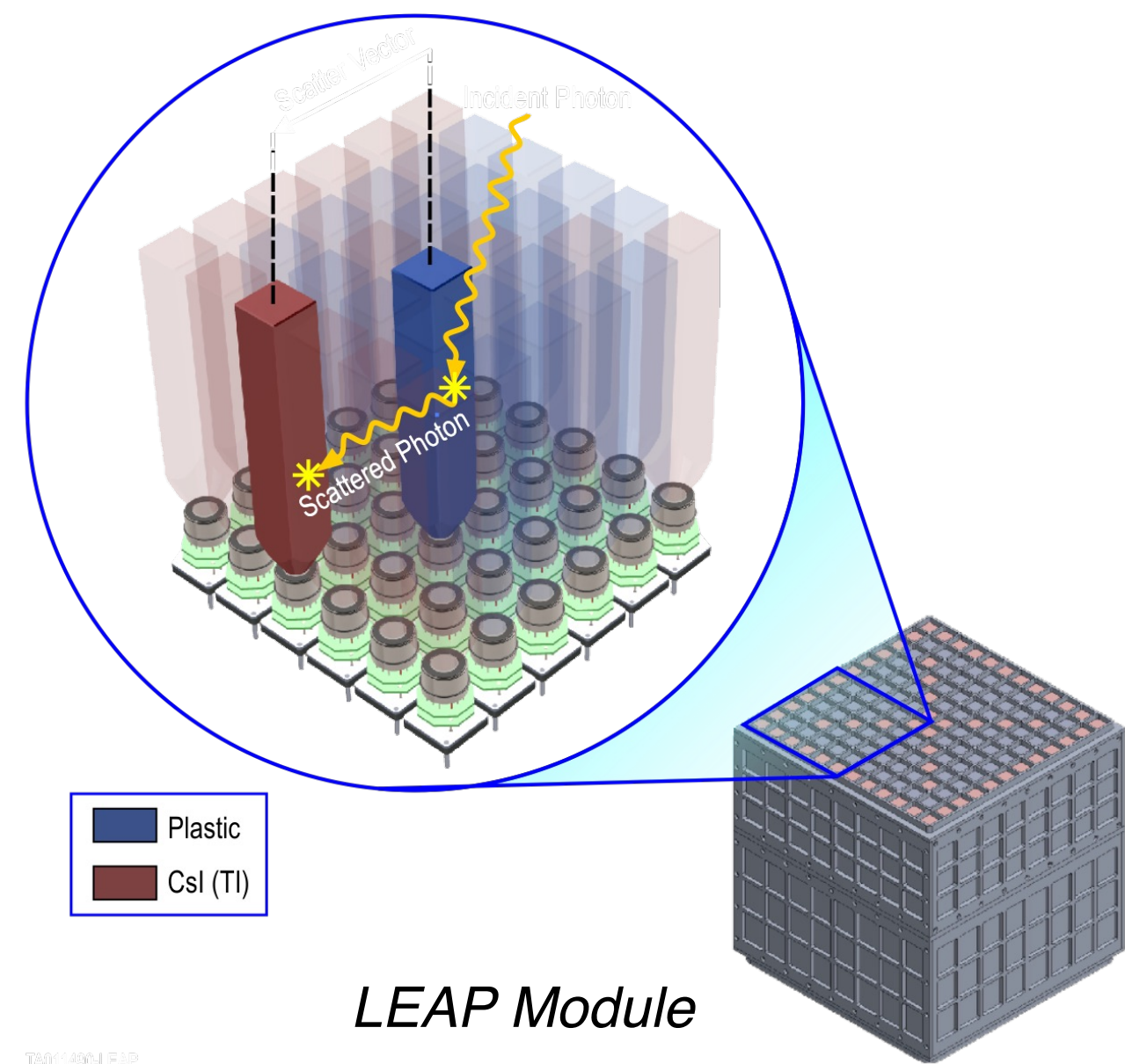
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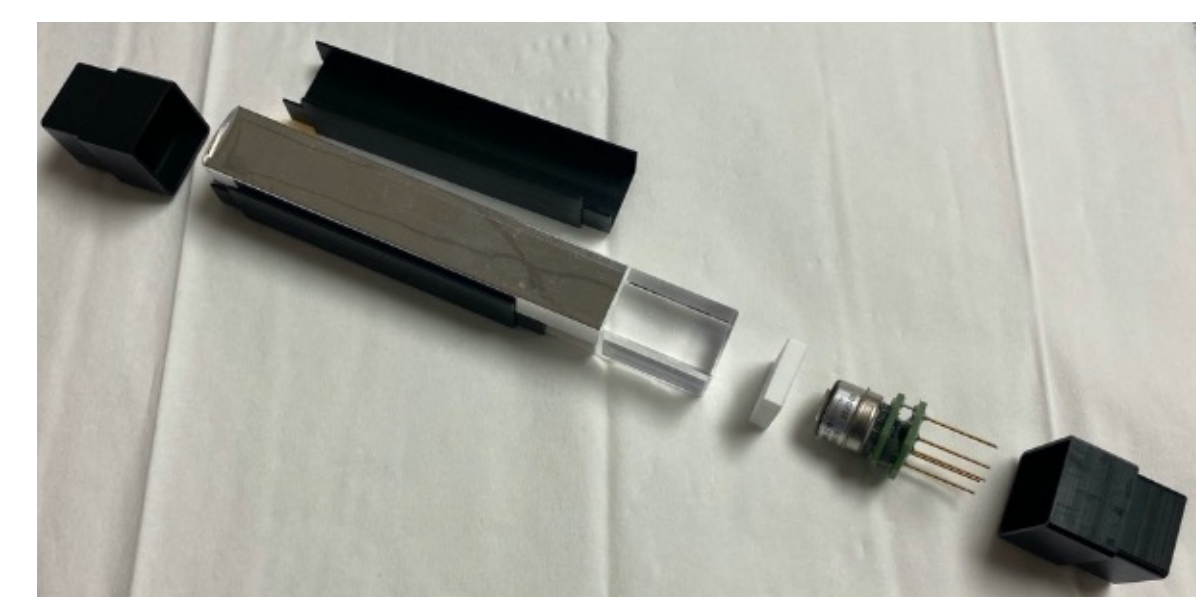
**Abstract:** LEAP is a proposed instrument optimized for measuring polarization and spectra of Gamma-Ray Bursts (GRBs). It is capable of measuring polarization from 50 keV to 1 MeV and spectra from 20 keV to 6 MeV. The instrument consists of seven LEAP Polarimeter Modules (LPMs), each containing a 12x12 array of scintillator-PMT detector elements (PDEs). Two types of scintillators are used within each array. Some elements are made of plastic scintillator (a low-Z material ideal for scattering) and some are made of Cesium Iodide (a high-Z material ideal for photon absorption). A prototype of the instrument has been built to evaluate the design and to characterize the response to polarized photons. The prototype consists of a limited number of detector elements arranged in a 5x5 array and has been used to carry out polarization and spectral measurements for two different partially polarized sources placed at various locations within the FoV. All measurements were compared with GEANT4 simulations to validate the simulations and our understanding of the full instrument design.

## Prototype Design

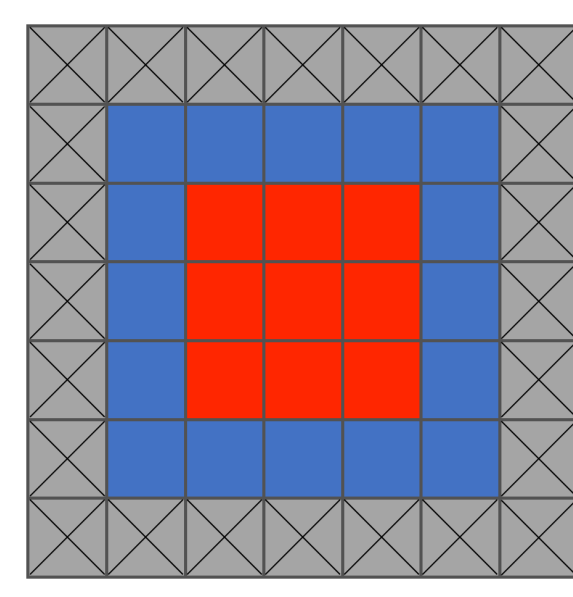
The prototype has been designed as a scaled-down version of one LEAP module. It consists of a 5x5 grid of detectors, some of which are Csl scintillators (C) and some of which are plastic scintillators (P).



LEAP prototype module



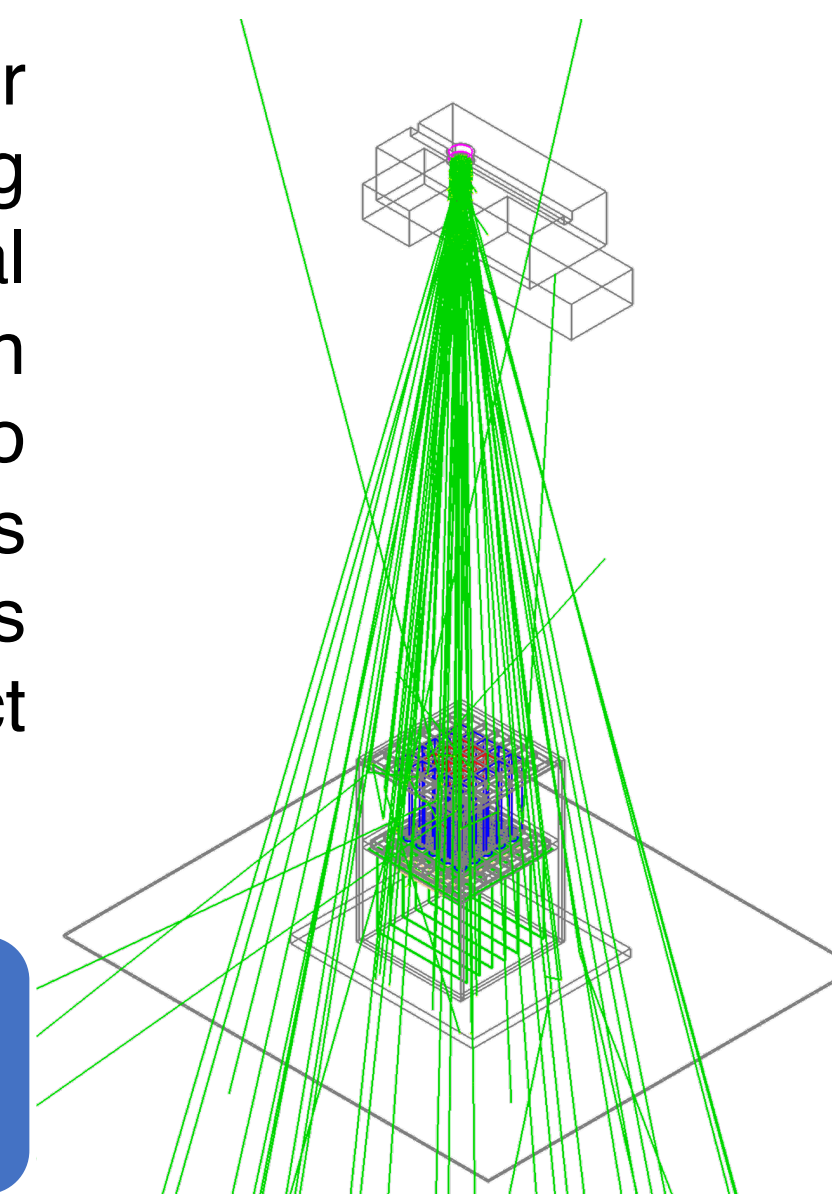
Detector Assembly



Prototype Detector Configuration  
Csl(Tl), Plastic, Empty

## Simulations

Simulations of the prototype, the polarizer/collimator assembly and the support fixtures were built using the GEANT4 toolkit. The simulations are an integral part of the polarization analysis, as they are used in modeling the response of the instrument to unpolarized and fully polarized sources. Simulations that include the polarization of source photons (through  $\sim 90^\circ$  scattering) are also used for direct comparison with lab data.

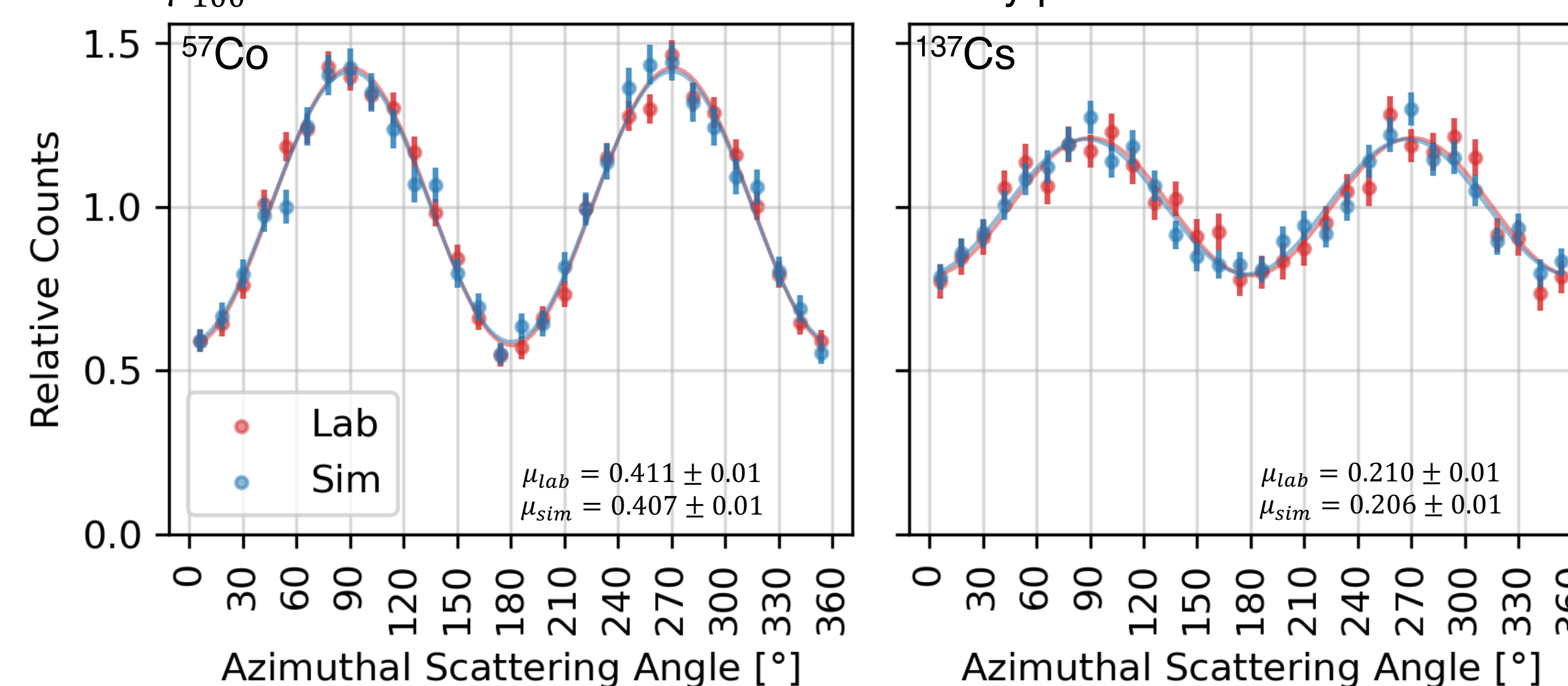


## Analysis

We analyzed the data by measuring the azimuthal scattering angle distribution for PC events, corrected for the nonuniform detection efficiency using an unpolarized source simulation. In determining the scatter angle, it was assumed that events are uniformly distributed within each detector element. Fitting the distribution with a sinusoidal function of the form  $A - B \cos(2(\eta - \eta_0))$ , we obtained the modulation factor  $\mu = B/A$ . The same analysis was used for the lab data and for a corresponding set of simulated data. The measured polarization degree is then determined using the expressions

$$\Pi_{lab} = \frac{\mu_{lab}}{\mu_{100}}, \quad \Pi_{sim} = \frac{\mu_{sim}}{\mu_{100}}$$

where  $\mu_{100}$  is determined from simulations of a fully polarized source.

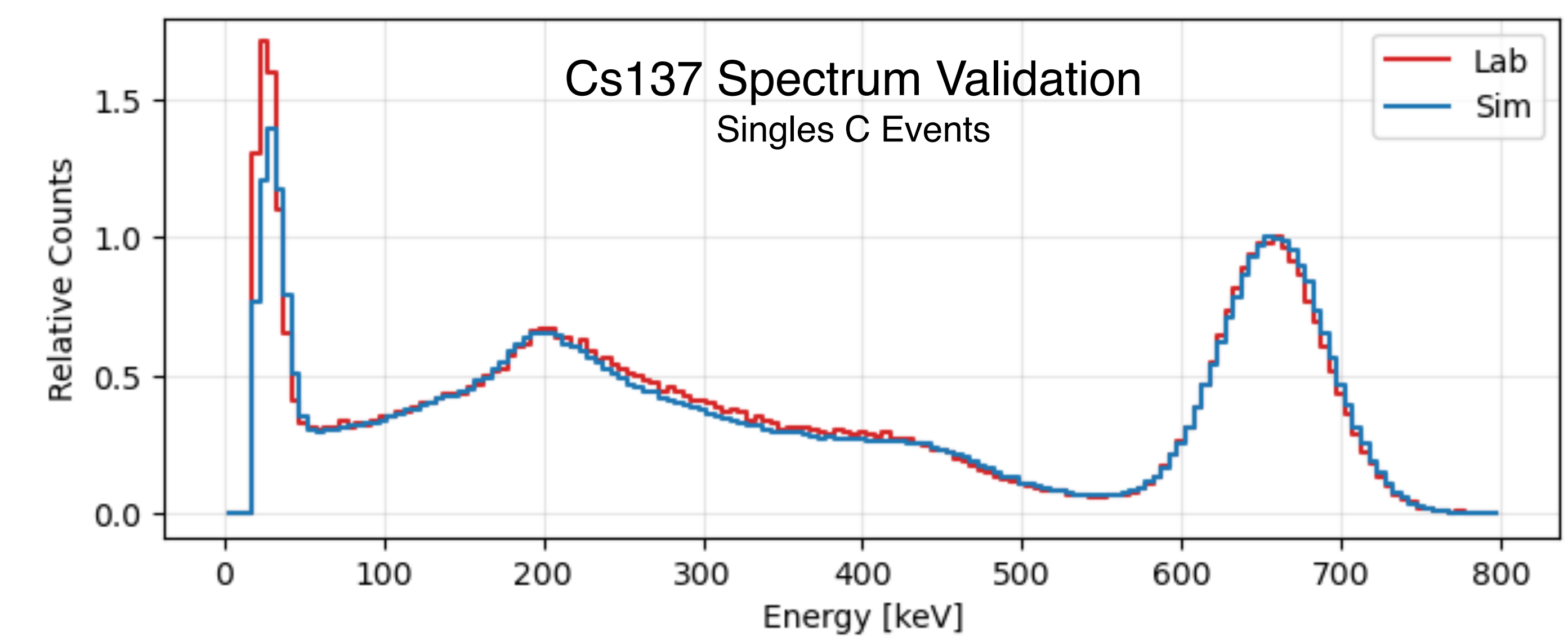


## Future Work

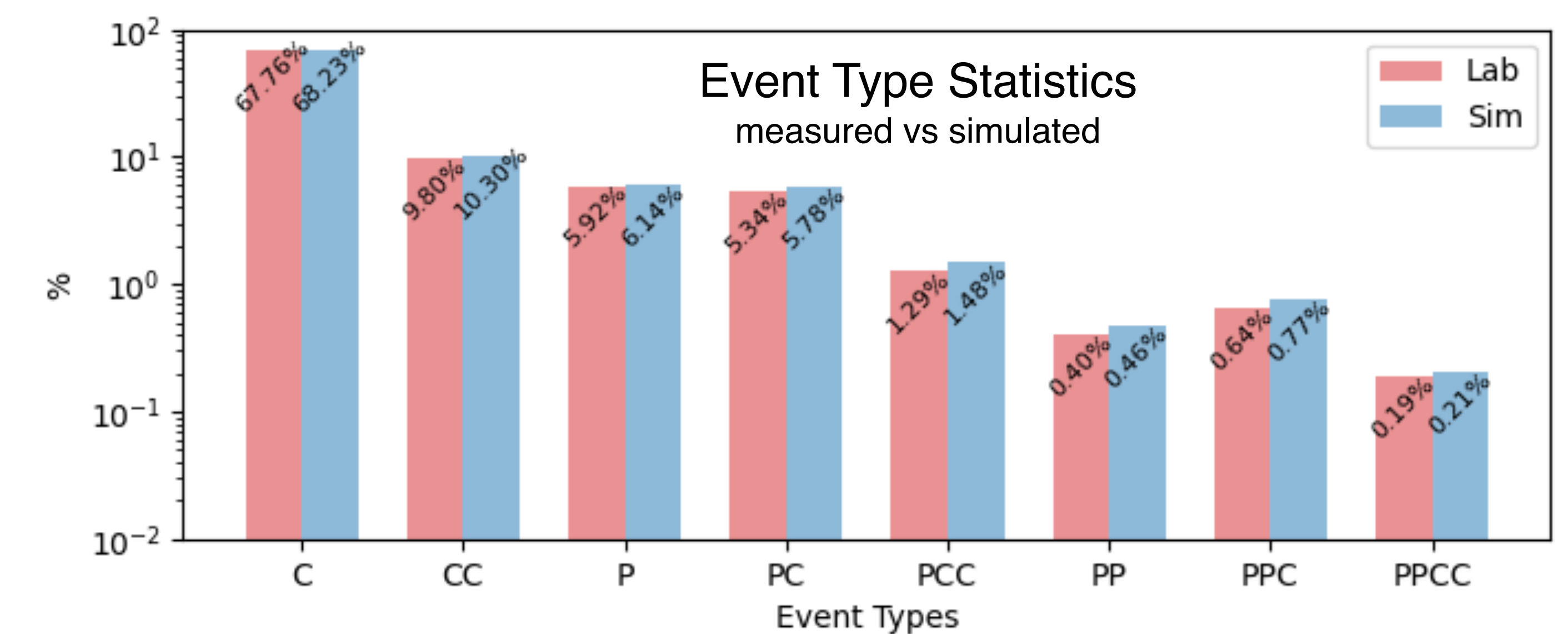
Given the large set of data that has been collected for different source geometries, we will utilize this data to further optimize polarization measurement algorithms.

- We will incorporate a more realistic distribution of event interaction sites to the analysis, rather than the uniform distributions used here. A more realistic distribution would include the effects of photon penetration depth within the Csl(Tl) scintillator.
- We will use a Maximum Likelihood Analysis, which adds the measured total energy and Compton scattering angle for each photon to the polarization analysis.

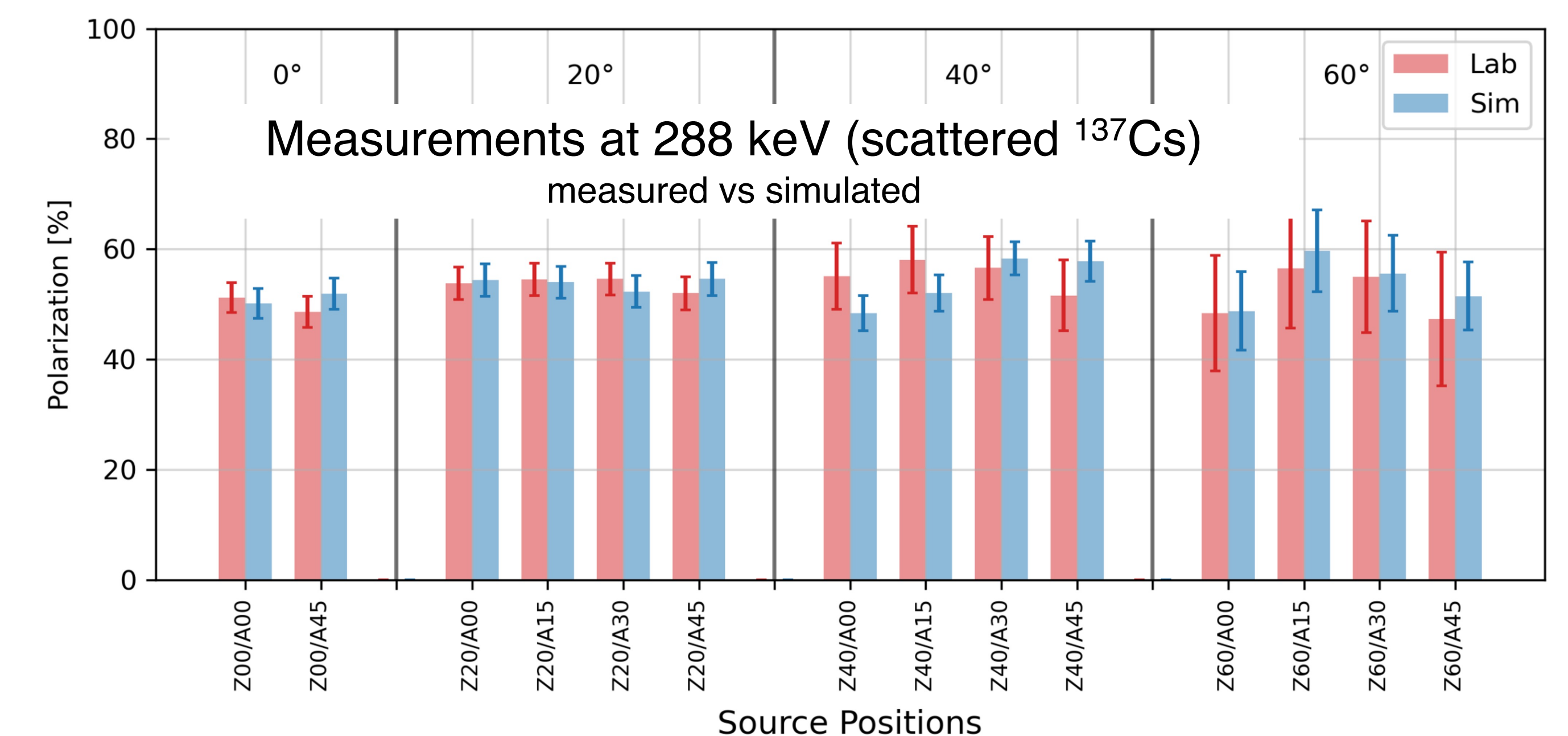
## Results



The spectrum from single C events from an energy calibration run at 662 keV matches that from the corresponding simulation.

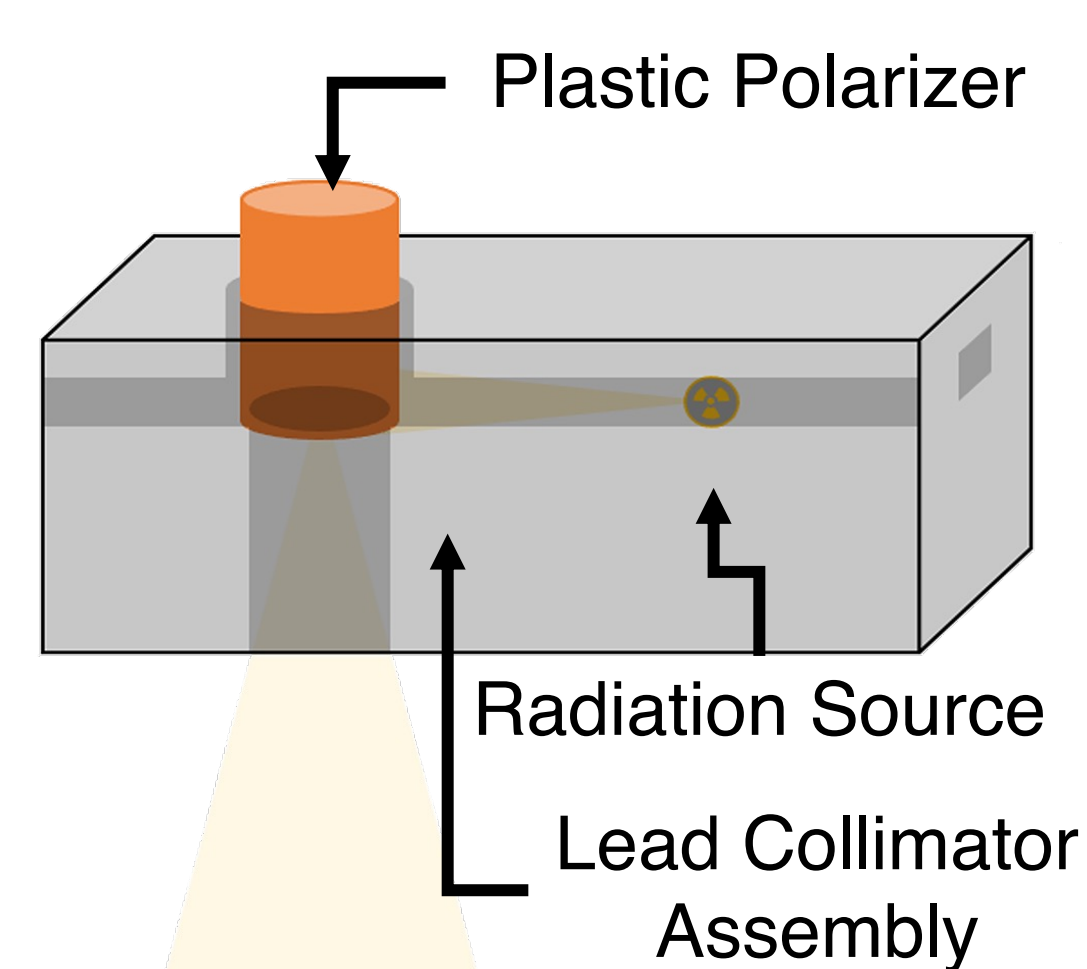


Each event is assigned an "event type", which identifies the number of triggered elements and the detector element type for each trigger. Measured statistics match those from simulations.



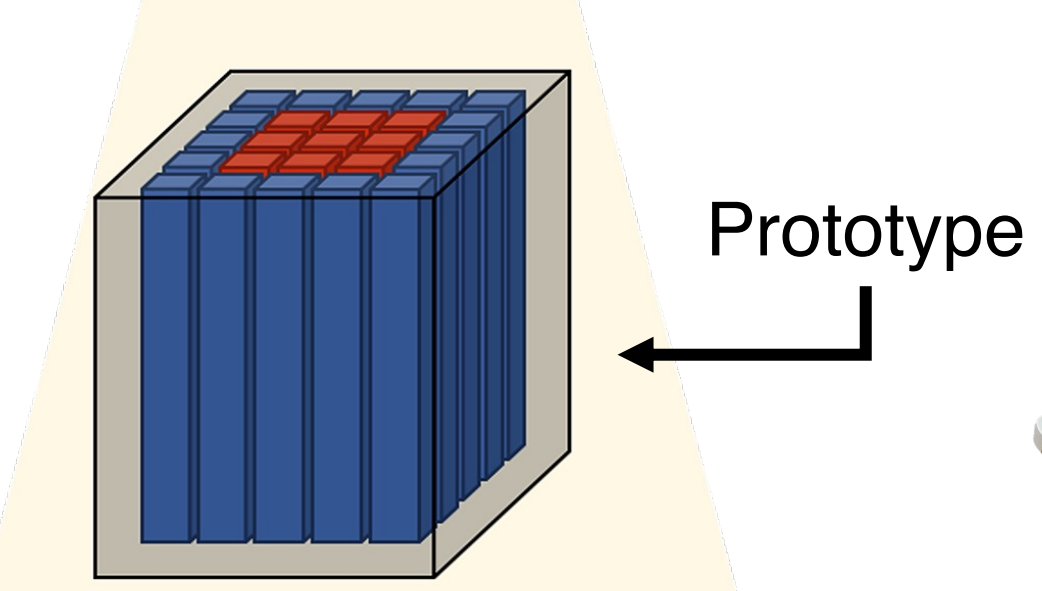
Measurements at 288 keV over a range of zenith and azimuth show excellent agreement with simulations. An unpolarized beam of 662 keV photons scattered at  $\sim 90^\circ$  results in a 288 keV photon beam with a polarization of  $\sim 58\%$ .

## Measurements

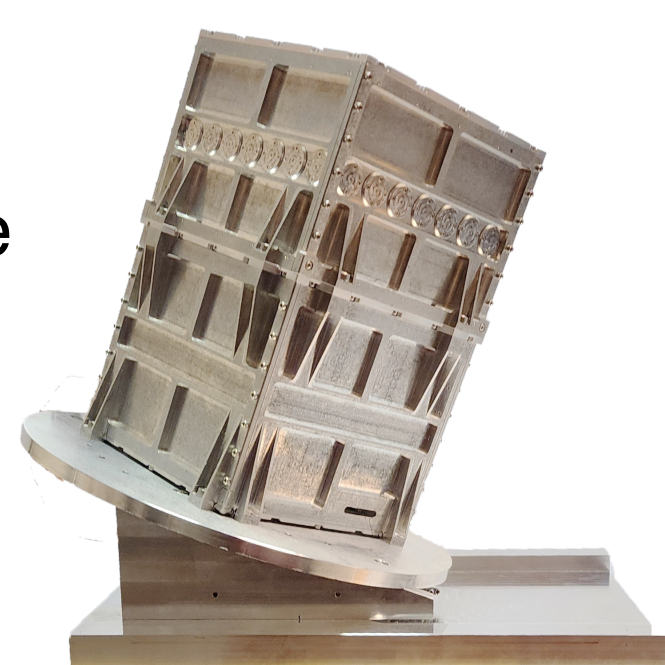


A polarized beam is created by scattering photons from a radioactive source off a plastic polarizing element. Pb collimation is used to select  $90^\circ$  scatters. The table below shows the resulting photon energies and polarization degree.

Source	<sup>137</sup> Cs	<sup>57</sup> Co
Energy (keV)	662	122
Scattered Energy (keV)	288	99.5
Polarization Degree (%)	57.8	95.6



Prototype



A support fixture allowed for various orientations. Source measurements covered a full quadrant within the FOV, with zenith angles of  $0^\circ$ ,  $15^\circ$ ,  $30^\circ$ , and  $45^\circ$ , and azimuth angles of  $0^\circ$ ,  $15^\circ$ ,  $30^\circ$ , and  $45^\circ$ .