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Scintillation-Based Compton Camera via Single Photon Imaging

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Abstract:

A Compton Camera measures the position and energy deposition of gamma-ray interactions in a detector and performs backprojection to determine the direction to the radiation source. Previous scintillation-based methods use silicon photomultipliers (SiPM) to measure the visible light emitted from interactions in a scintillator detector. Those setups consist of SiPM arrays coupled to the sides of either a monolithic or physically pixelated scintillator.

We propose to measure interactions by imaging a monolithic scintillator with a lens and a single photon avalanche diode (SPAD) sensor. SPAD sensors have pixels that are sensitive to individual photons and capture images at very high frame rates. They are becoming increasingly used in consumer markets, driving the emergence of sophisticated high resolution SPAD cameras at low cost. SPAD pixel pitch is on the order of microns with megapixel (1000x1000) resolution arrays recently developed. In contrast, SiPM channel area is on the order of mm^2 with 8x8 channels as a common array resolution.

By imaging with a lens, we introduce a novel paradigm for measuring interactions. The continuous volume in the monolithic scintillator where interactions can be detected is defined by the SPAD camera's field of view, which is controlled by the optics of the imaging system (sensor size, lens focal length and diameter, distance, etc). 3D interaction position is determined using the defocus blur observed in an image and computing perspective projection. Energy deposition is determined by counting photons.

As SPAD sensors continue to increase in size and fill factor, our Compton Camera performance in terms of efficiency and resolution will improve. Also, our method will be cost-effective. Geant4 simulations demonstrate a proof of concept for our prototype. We report the first real images of scintillation events taken with a SPAD camera at 97,000 frames per second.