



# Gamma-ray Spectroscopy and Imaging Using Pixelated CdZnTe

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## Overview

High resolution gamma-ray spectroscopy and imaging are valuable capabilities for nuclear non-proliferation and international safeguards. Other applications include fundamental nuclear physics, nuclear medicine, and industrial safety. Pixelated CdZnTe systems can provide 3D position sensing of gamma rays with high energy resolution all during room temperature operation. With additional developments in the readout electronics, noise has been significantly reduced leading to the latest OrionUM system demonstrating 0.51% FWHM for all events and 0.34% for single-pixel events. This high-performing system has allowed for real-time Compton imaging and high-resolution imaging when using a time-encoded coded aperture system.

## OrionUM Digital system

Current OrionUM systems use 9 CdZnTe semiconductor detectors with dimensions  $2 \times 2 \times 1.5$  cm<sup>3</sup>. Each crystal is pixelated with an  $11 \times 11$  array of electrodes with 1.72 mm pixel pitch. Electrode geometry is leveraged to reconstruct 3D positions of individual gamma-ray interactions.



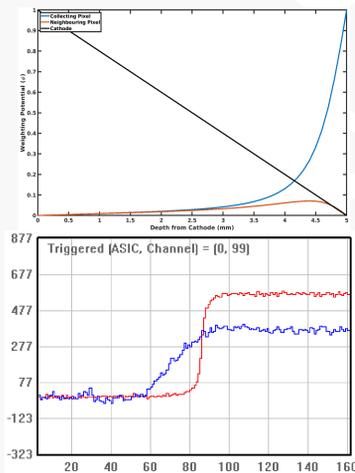
## Shockley-Ramo Theorem

The Shockley-Ramo theorem is used to predict the induced charge on an electrode by a moving charged particle. Gamma-ray interaction depth can be reconstructed from the signals induced on the pixelated anodes and planar cathode by freed electrons.

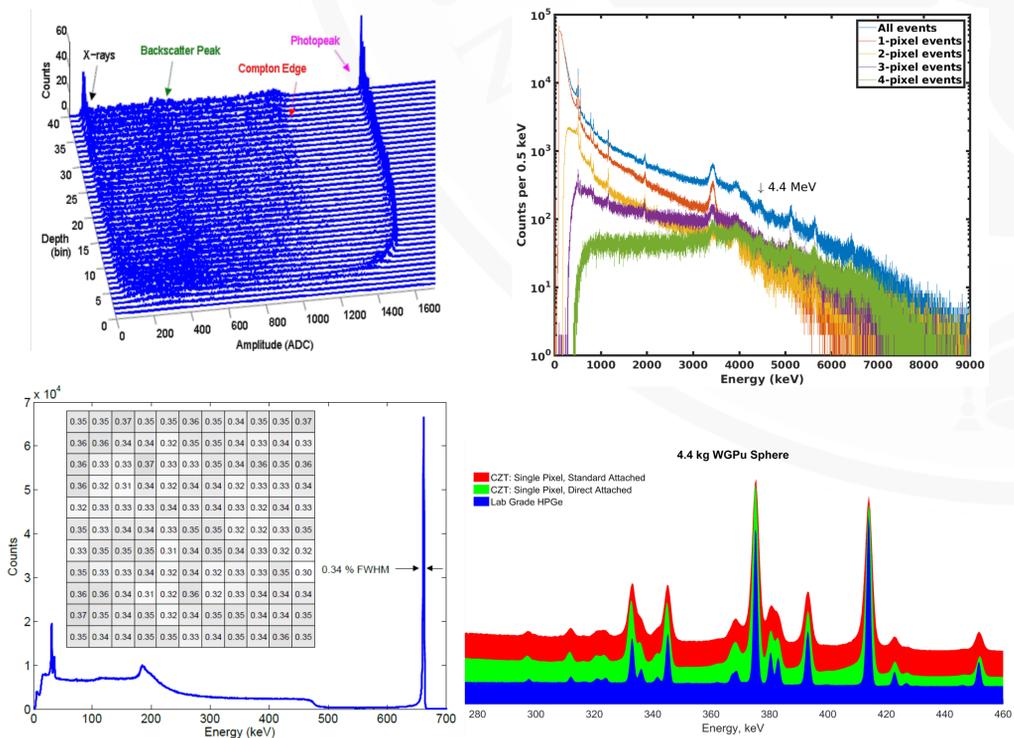
$$\Delta Q = -q[\phi_0(\vec{x}_f) - \phi_0(\vec{x}_i)],$$

Where,

$\Delta Q$  is the total induced charge  
 $\vec{x}_i, \vec{x}_f$  is the initial and final position  
 $\phi_0$  is the weighting potential



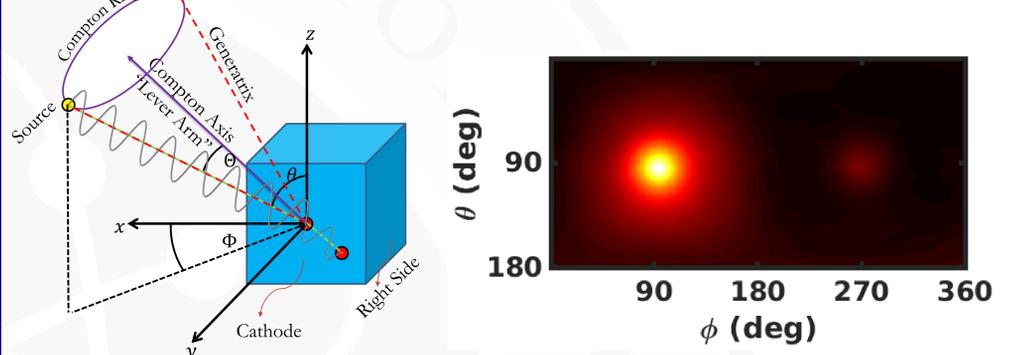
## Gamma-ray Spectroscopy



## Compton Imaging

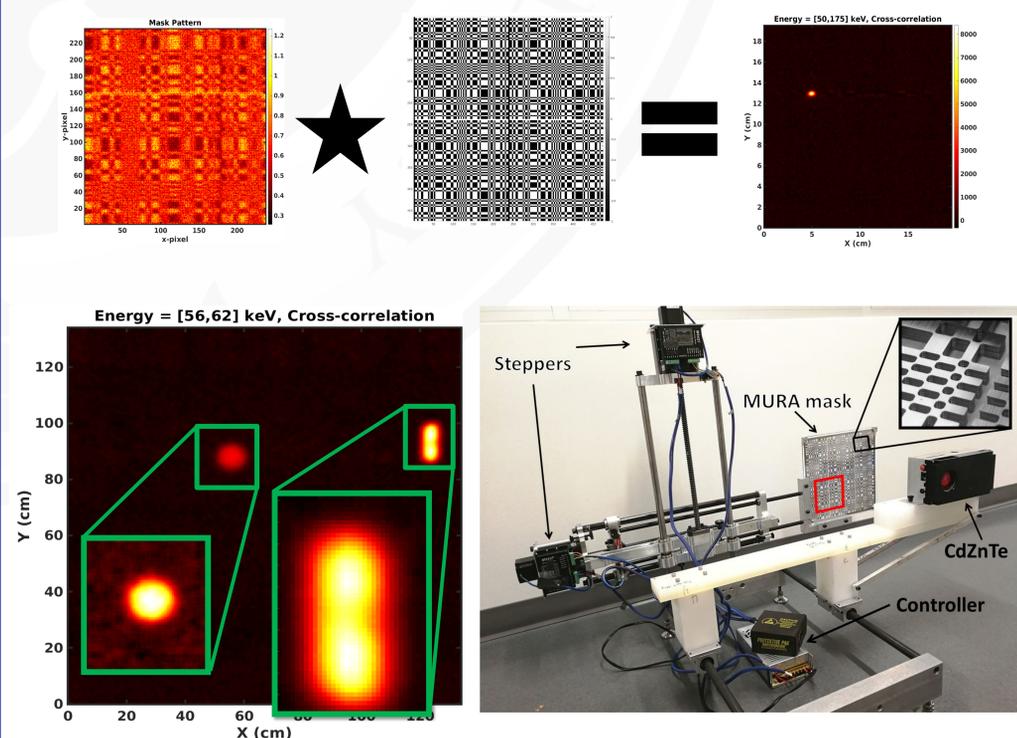
Compton imaging relies on the Compton scattering of photons to reconstruct events and determine incident photon direction. This technique requires knowledge of energy and interaction location of each event. The incident gamma ray can be reconstructed onto a cone with opening angle:

$$\cos(\theta) = 1 - \frac{m_e c^2 E_1}{E_0(E_0 - E_1)}$$



## Time Encoded Imaging

Coded aperture relies on an array of open and closed elements that attenuate the radiation to be imaged. This mask encodes the radiation's origin in a 2D shadow which is recorded with our position-sensitive detector. The shadow can then be decoded to reveal an image of the radiation's source. If the mask is set on a moving stage, the signal can then be encoded temporally, resulting in high-resolution time-encoded imaging (TEI). The current TEI system (MIRA) makes use of a rank 79, 1 mm pitch Tungsten MURA mask.



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