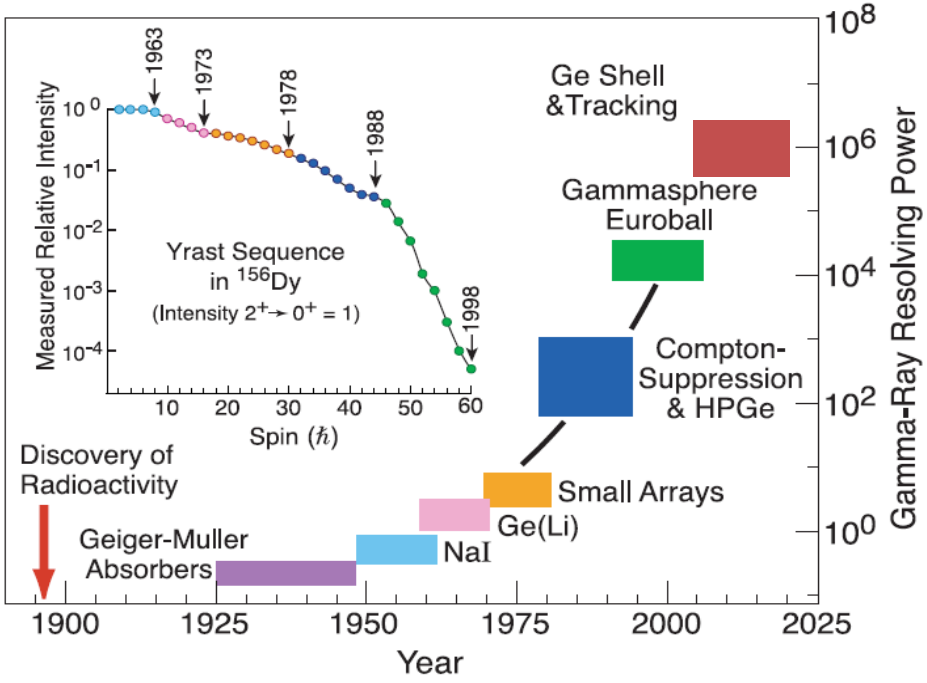
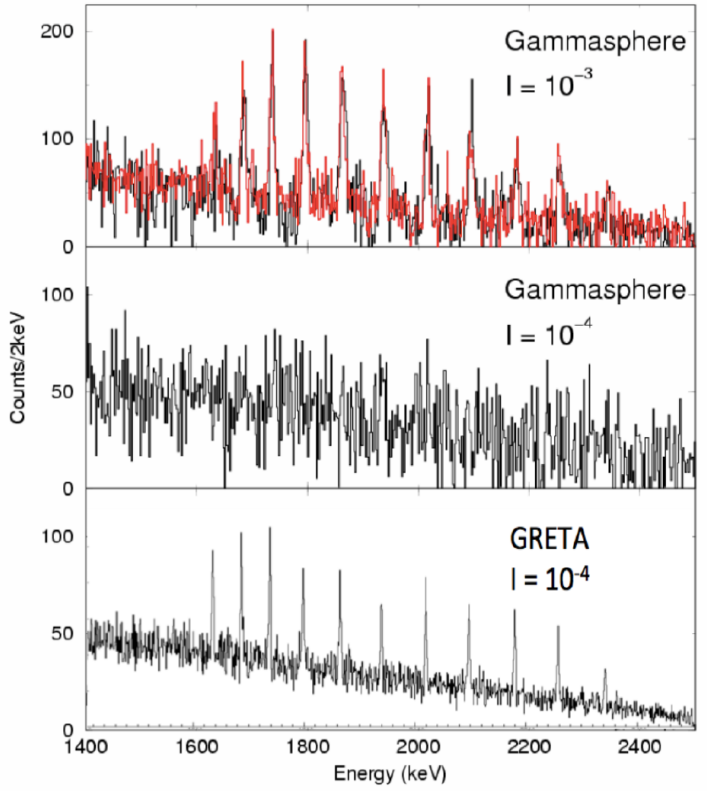
ML - Aim to Improve Resolving Power

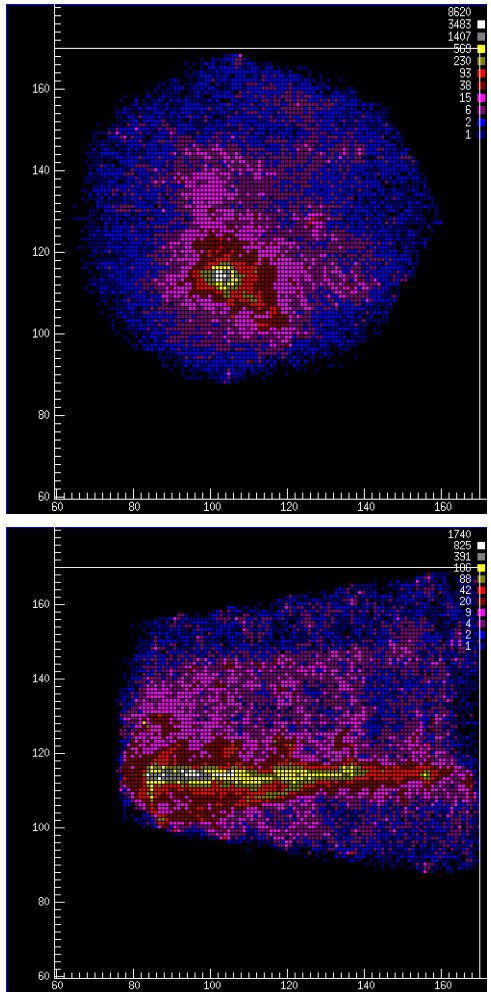
- The science reach of a gamma-ray tracking array can be expressed in terms of resolving power
- Gamma-ray spectroscopy is a statistical measurement - depends on efficiency, peak/total, energy resolution
- ML / algorithmic improvements look to increase this metric





Basic computational aspects

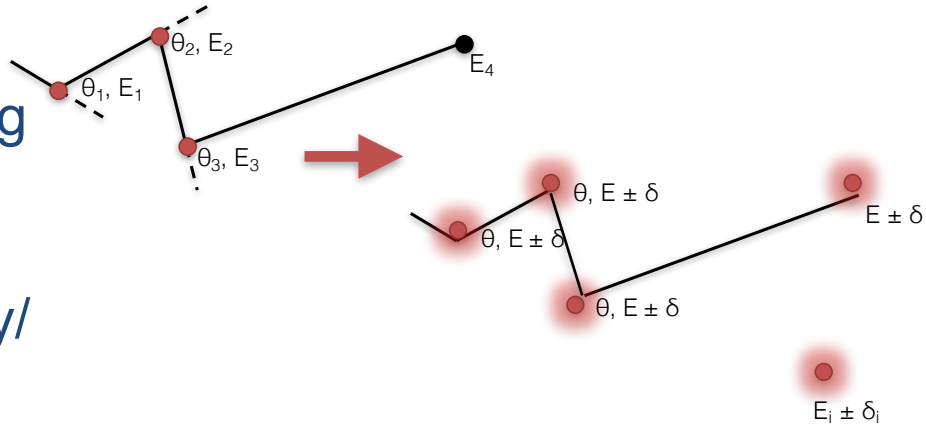
- Data Rate: (streaming):
  - 4k evt/s/crystal, 120 crystals, 8k /evt
  - 3.8 GB/s aggregate rate
- Bases (simulation) size: 1.5 GB x 120 crystals
- File Formats: custom binary
- Problem type:
  - Regression (decomp)
  - Clustering / classification (tracking)
- Current Algorithm: (decomp):
  - Adaptive grid search
  - Nonlinear least-square
- Current limitations / opportunities:
  - Detector simulation fidelity (hyper-parameters), improved Compton tracking, modeling of signal/noise, overfitting



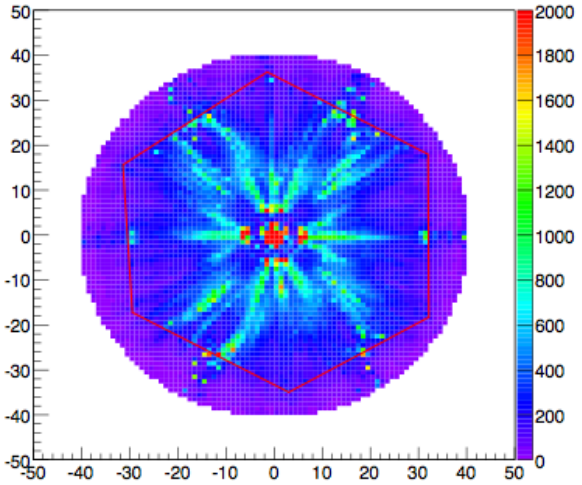
Projection of decomposed interaction point positions from collimated Cs source

Machine Learning Opportunities [1]

- Improve Compton tracking
  - Use simulations to train tracking algorithms
  - Can capture aspects beyond Compton scattering .. geometry/ material effects



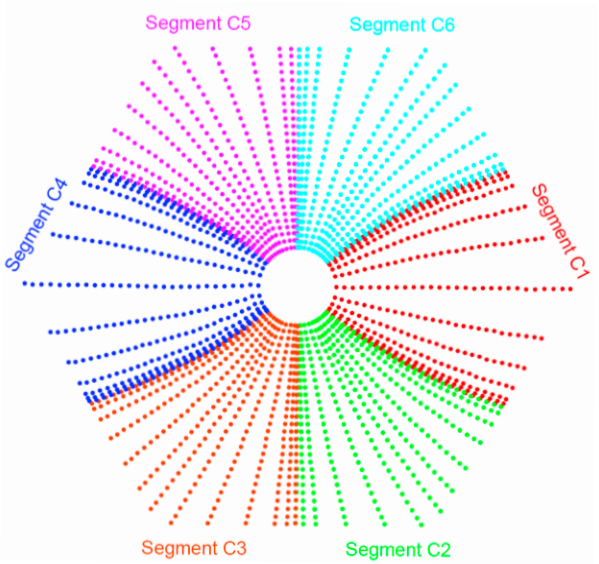
- Improved cost functions for signal decomposition algorithm:
  - Currently use least square error
  - Number of interactions is not known a-priori, detector simulation imperfect
  - Overfitting is a problem - better methods to prevent this in cost function



(problematic) x-y projection for ^{60}Co flood field

Machine Learning Opportunities [2]

- Detector simulation - parameter estimation:
  - Simulation of detector involves several parameters - impurity concentrations, charge carrier mobilities in the semiconductor, electronics response
  - Parameters not well determined
  - Fit simulation hyper-parameters with data subject to known constraints (pencil, flood field) .. optimize .. **[computationally intensive!]**



Quasi-cylindrical grid,1 mm avg spacing
(D. Radford, K. Lagergren)

- Employ machine learning frameworks:
  - Move algorithms to ML frameworks (TensorFlow) to take advantage of effort directed towards massive multithreading, new processor types, easy access to alternate/new algorithms

CPU

GPU

TPU