Real-time detection of alpha-particles and gammas using a fast optical camera

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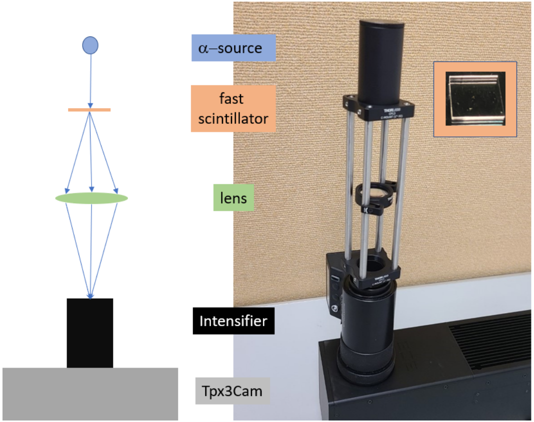
21 March 2021, CPAD 2021 - Stony Brook University (US)

Setup

Optical detection scheme of α-particles

- Real-time detection of alpha-particles essential for nuclear medicine, nonproliferation, security applications, ...
- ^{241}**Am source decay:** 59 keV x-ray emission + 5.49 MeV α-particle emission
- α in LYSO produces **localized flash of light**
- **Light collected** with lens onto intensified optical camera (ASI TpxCam3) with single photon sensitivity
- **TPXCam3:** Timepix3 readout chip + 256×256 pixels (55×55 μm^2 each) optical sensor



[1,2]

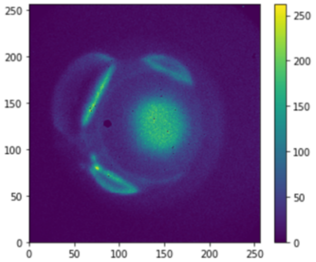
[1] G.D'Amen et al., *Novel imaging technique for α-particles using a fast optical camera*
[2] *TimePix3 project:* https://kt.cern/technologies/timepix3

Reconstruction using **Centroiding Algorithm**

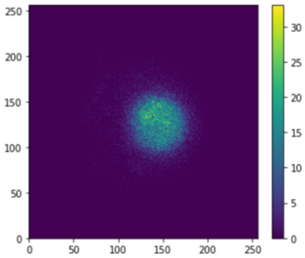
Centroiding Algorithm

Occupancy

Occupancy of reconstructed interactions



Occupancy of high-multiplicity interactions



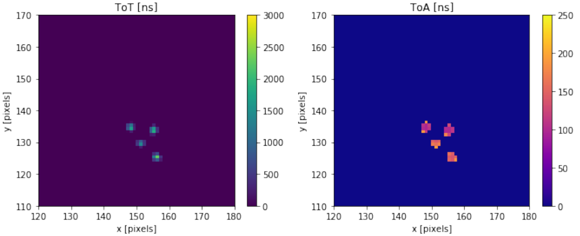
- Each α produces multiple photons in LYSO
- Single photon ID essential for alpha detection
- Reconstructed photons with high ($\geq$20) hit-multiplicity clearly identify **source position**
- LYSO reflections visible from low hit-multiplicity photons

Centroiding Algorithm

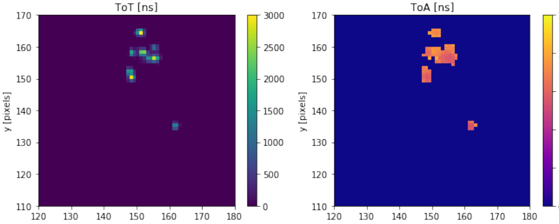
Particle visualization

- Centroiding algorithm relies on **Time of Arrival** (ToA) and **Time over Threshold** (ToT)
- Reconstructed **"photons"** from alpha particle interaction in LYSO can be resolved
- Limits in the approach; does not account for **photon blending**

Resolved α candidate



Blended α candidate



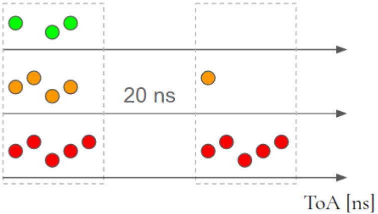
Reconstruction using **Clustering Algorithm**

Clustering Algorithm

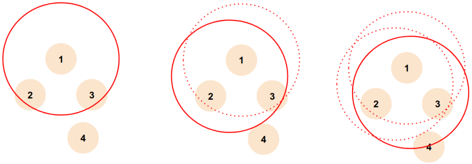
Hits, Clusters, Events

- **Hit:** x, y, ToA, ToT information of photon on pixel
- **Event:** "*temporal slice*" of hits, no two registered more than $\Delta T = 20$ ns apart
- **Cluster**: subset of an Event; hits within $R = 3$ pixels from cluster center and temporally close
- Cluster center iteratively re-computed via non-weighted center-of-mass method to minimize exclusion of outliers

Events definition



Cluster center iterative reconstruction

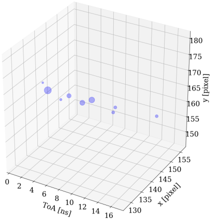


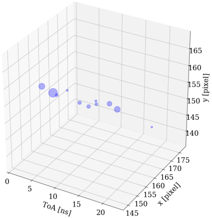
Clustering Algorithm

Cluster reconstruction

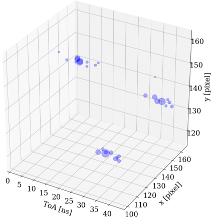
- 3D visualization of events (x, y, ToA) shows separate clusters (+ ToT for dot size)
- Some events have ≥2 clusters (**multi-clusters event**), others a **single cluster**
- ToA information corrected to minimize time-walk effect
- Are "*clusters*" good approximation of "*single photons*"?

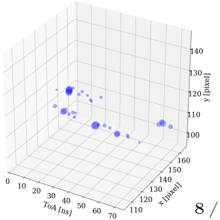
Single-Cluster event





Multi-Clusters event

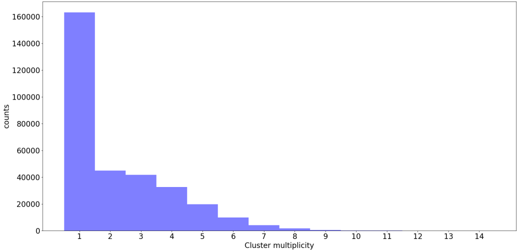




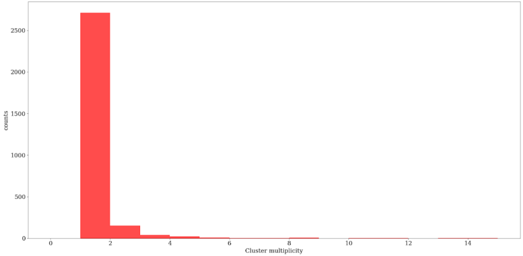
Clustering Algorithm

Cluster Multiplicity

^{241}**Am dataset** (alpha + photons)



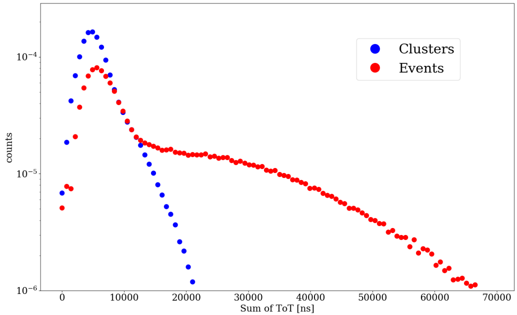
Photons dataset



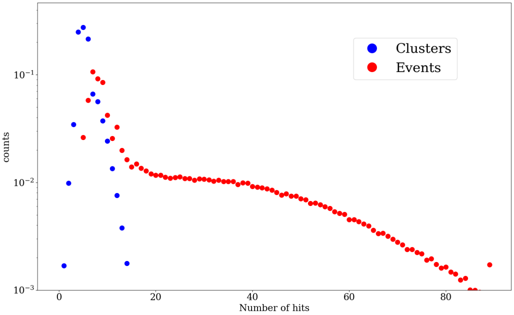
- Results compared to **single-cluster test dataset**: *thermal photo-electrons* from photocathode with blinded intensifier, indistinguishable from single photons.
- Populations correspond to the ^{241}**Am productions of x-ray (Single-cluster events) and α-particles (Multi-cluster events)**, once reconstruction efficiencies of the algorithm are taken into account

Clustering Algorithm

Flux ($\sum$ ToT)



Hit multiplicity



- Distribution of **total ToT** and **number of hits** in each event or cluster
- Event distributions peak at low value; shape compatible to cluster distributions (single-photon events)
- Hypothesis: **peak regions populated by single-cluster events** (x-ray photons); tails populated by multi-cluster events (α)

Summary & Future Prospects

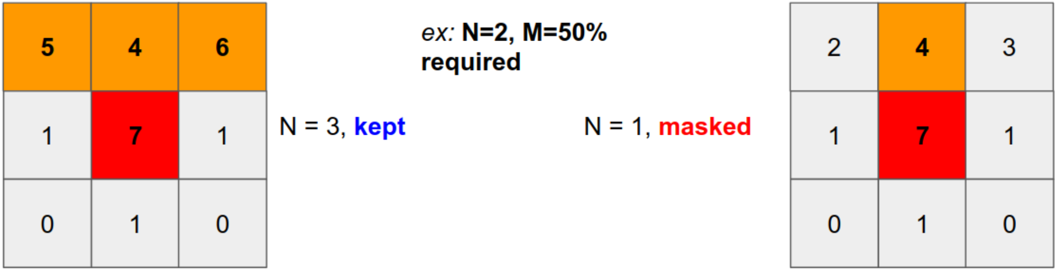
- **Imaging of α-particles using fast optical camera** by collecting photons produced by α in thin layer of LYSO is a viable approach
- Developed a **clusterization algorithm** to exploit spatial and temporal information
- Optical technique suitable for **x-rays or other ionizing radiation** with $\sigma_t \sim 10$ ns
- Sensitivity to **x-rays in energy range 10 - 100 keV**, where conventional solid-state x-ray detectors have limited sensitivity
- **Main detection techniques for neutrons** (^{10}B or ^{6}Li), **result in emission of α-particles**; the proposed approach may be exploited[3]
- Allows for **free-space light collection** from large distances/large field using appropriate lens (for sufficiently strong α emitters)

[3] J.Yang et al., *A novel energy resolved neutron imaging detector based on TPX3Cam for the CSNS*

Backup

Hotspot Masking

- Compute Average number of entries per pixel
- Check for pixels with height $>$ average
- if less than N additional neighbouring bins are $>$ (pixel height * M%), pixel gets masked



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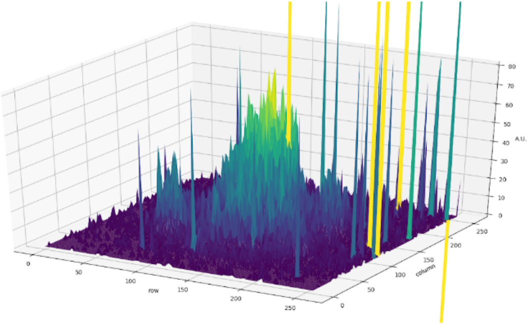
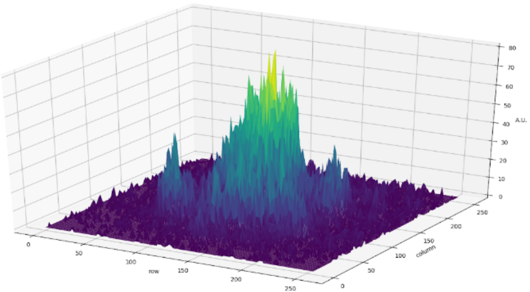
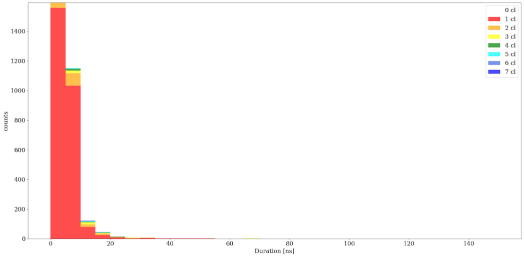




Clustering Algorithm

Stacked duration

Single photons



Americium