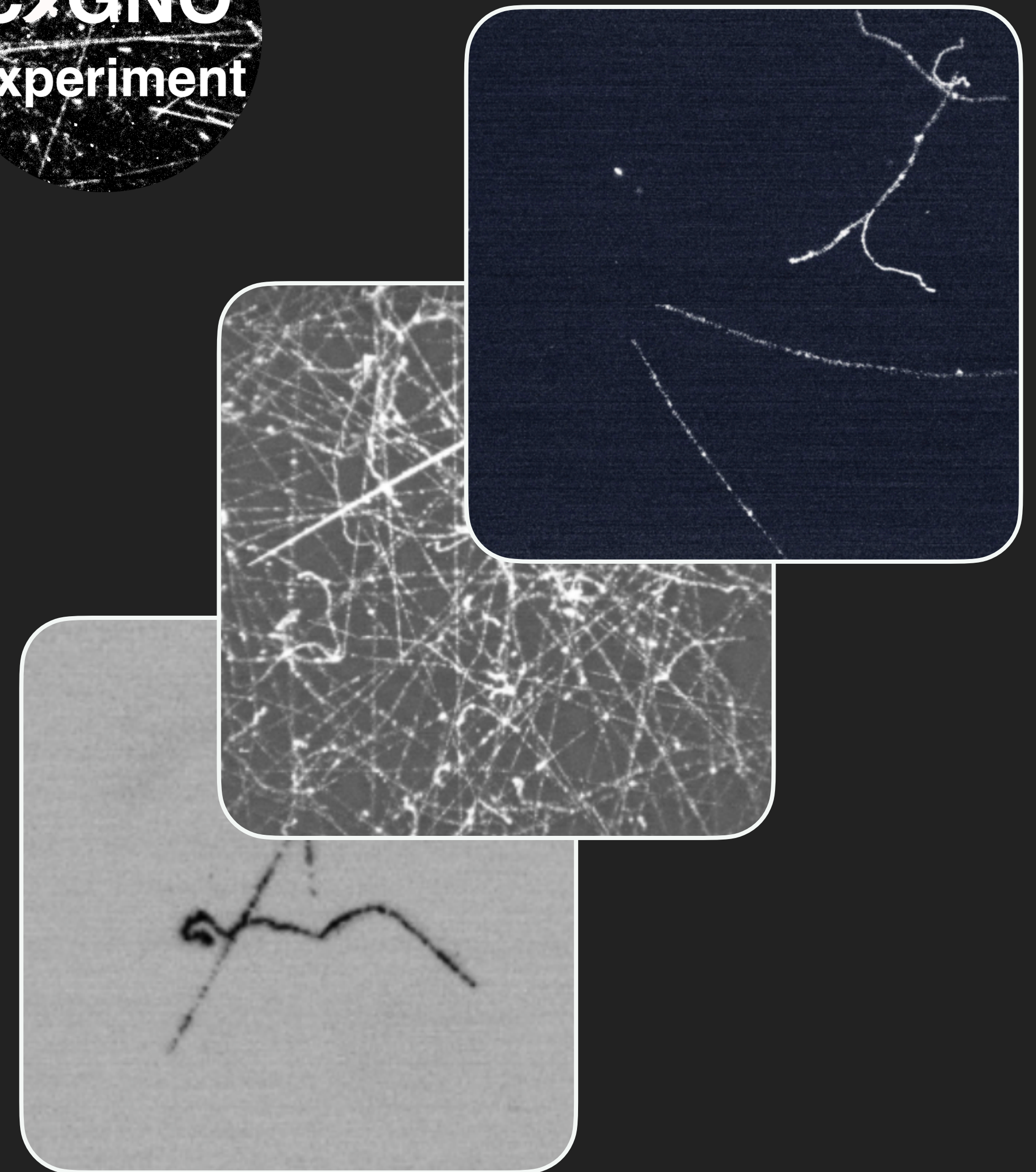


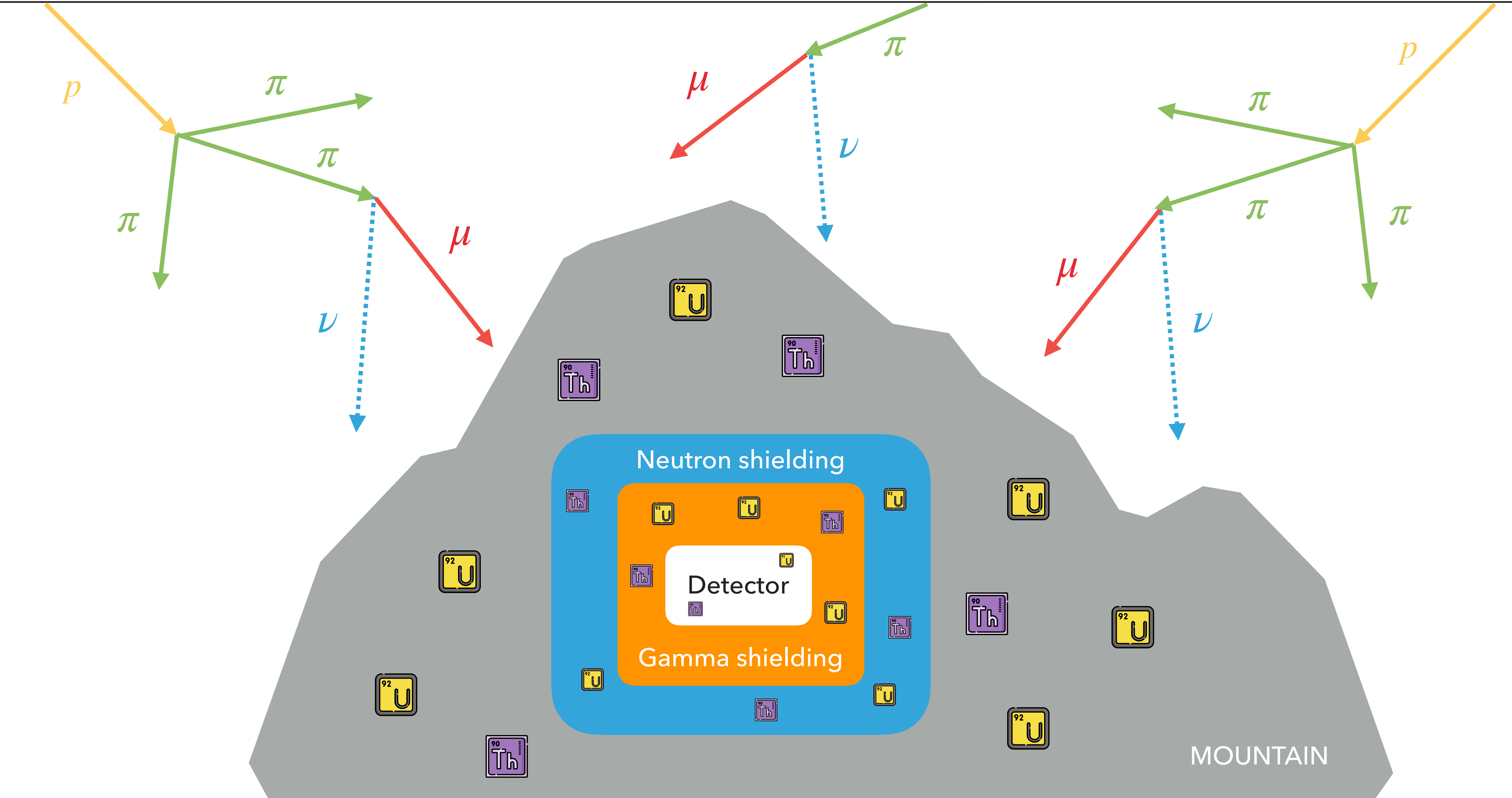
Underground environmental neutron flux measurement with the CYGNO project



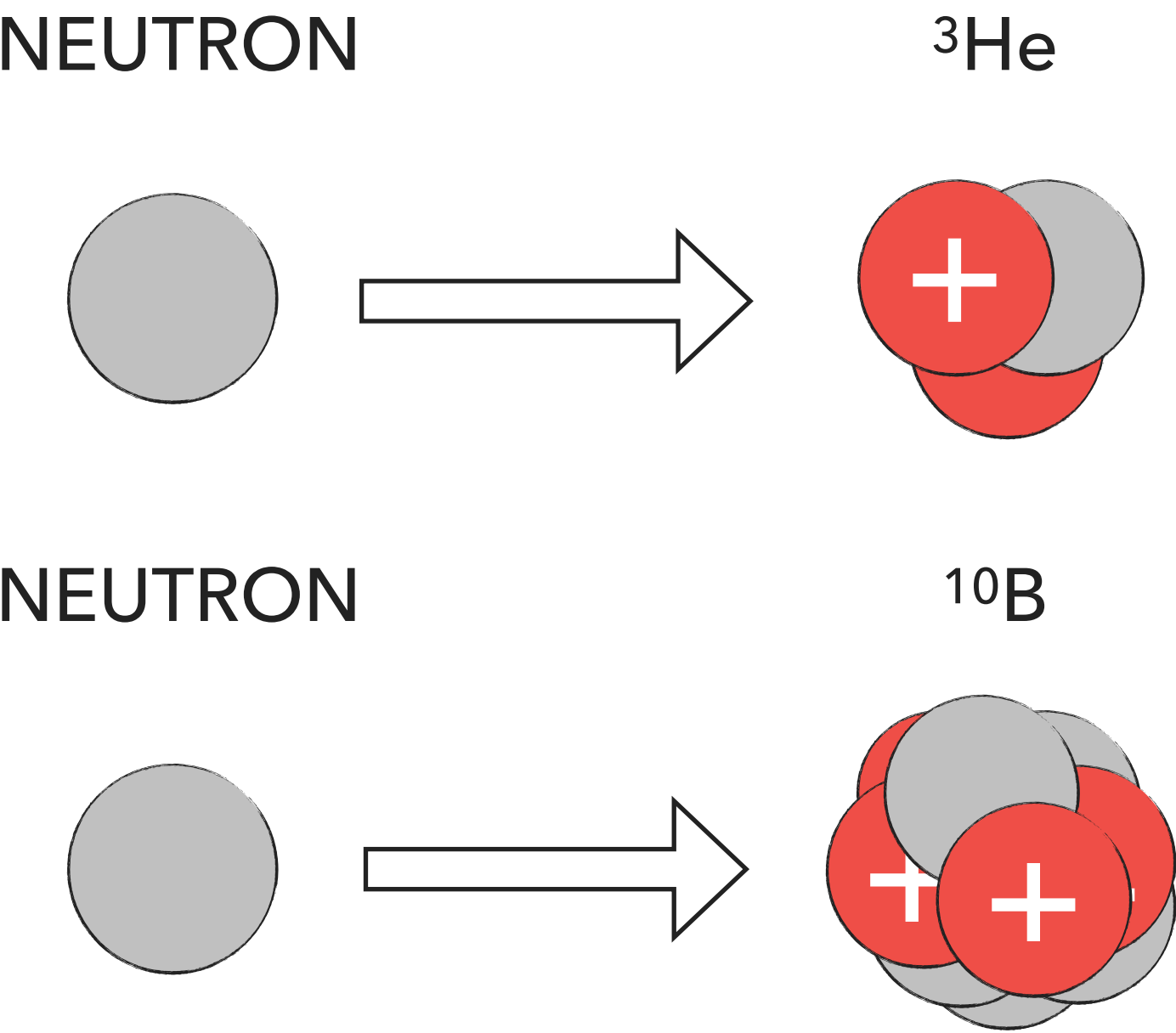
MELBA D'ASTOLFO

melba.dastolfo@gssi.it

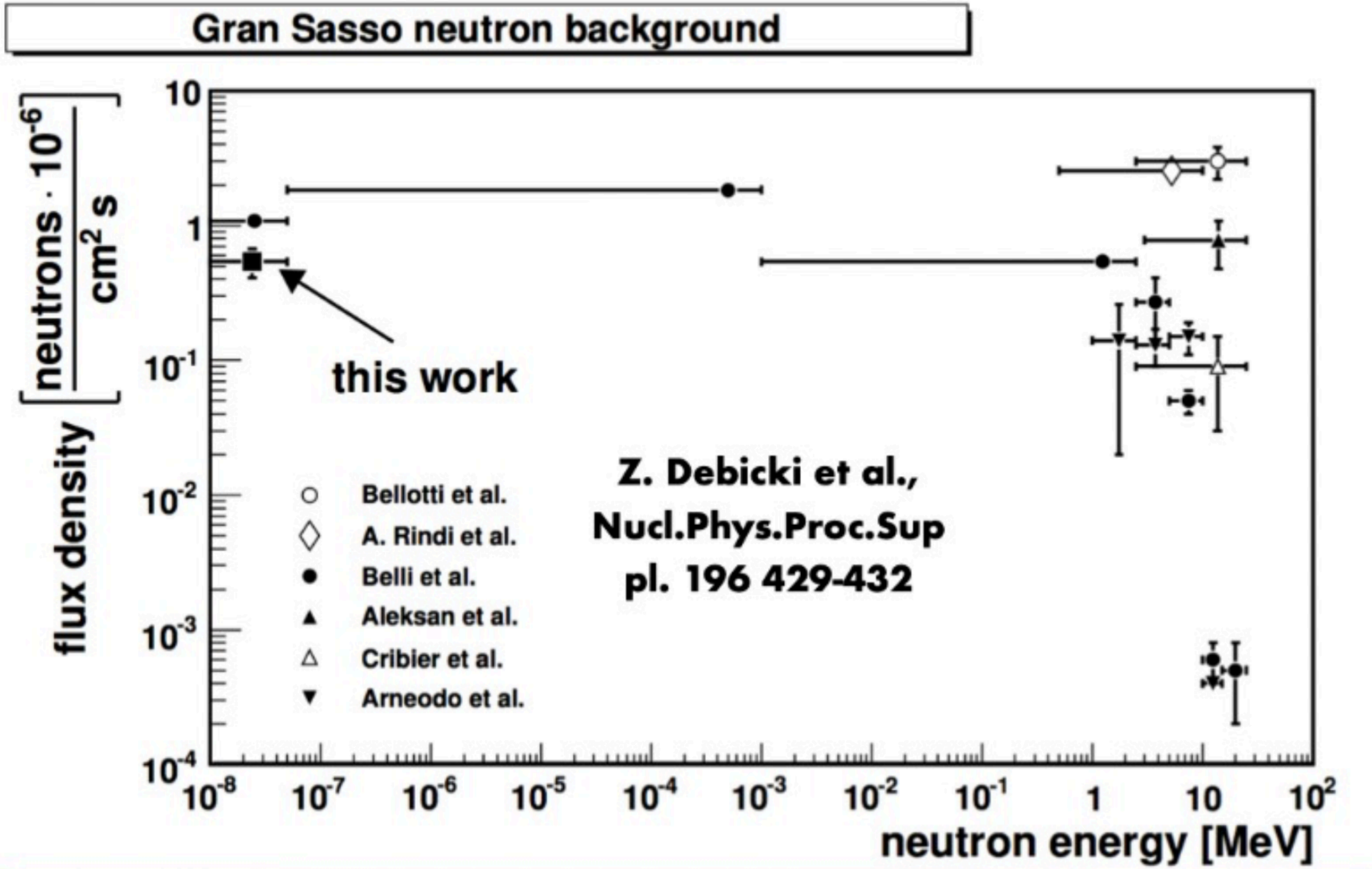
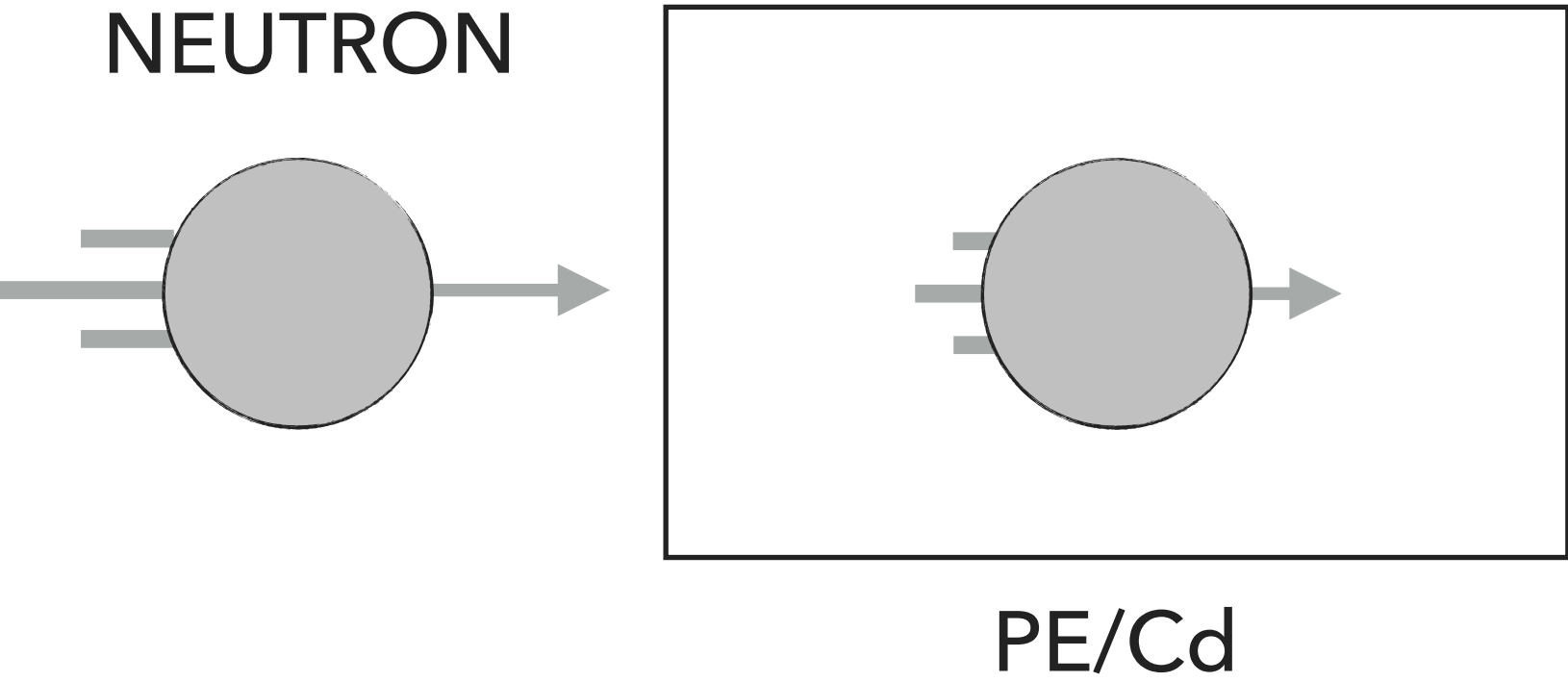




THERMAL NEUTRONS



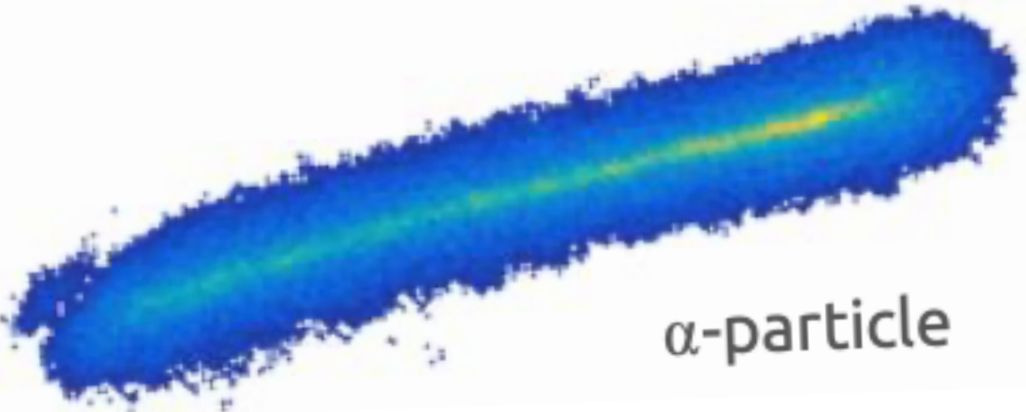
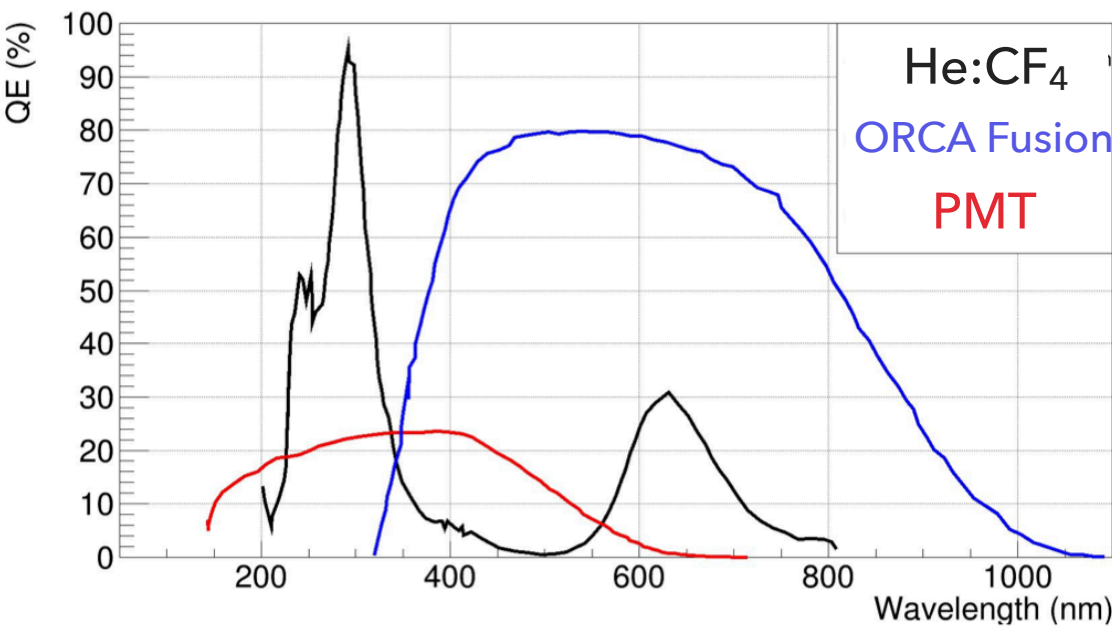
FAST NEUTRONS



Gaseous TPC

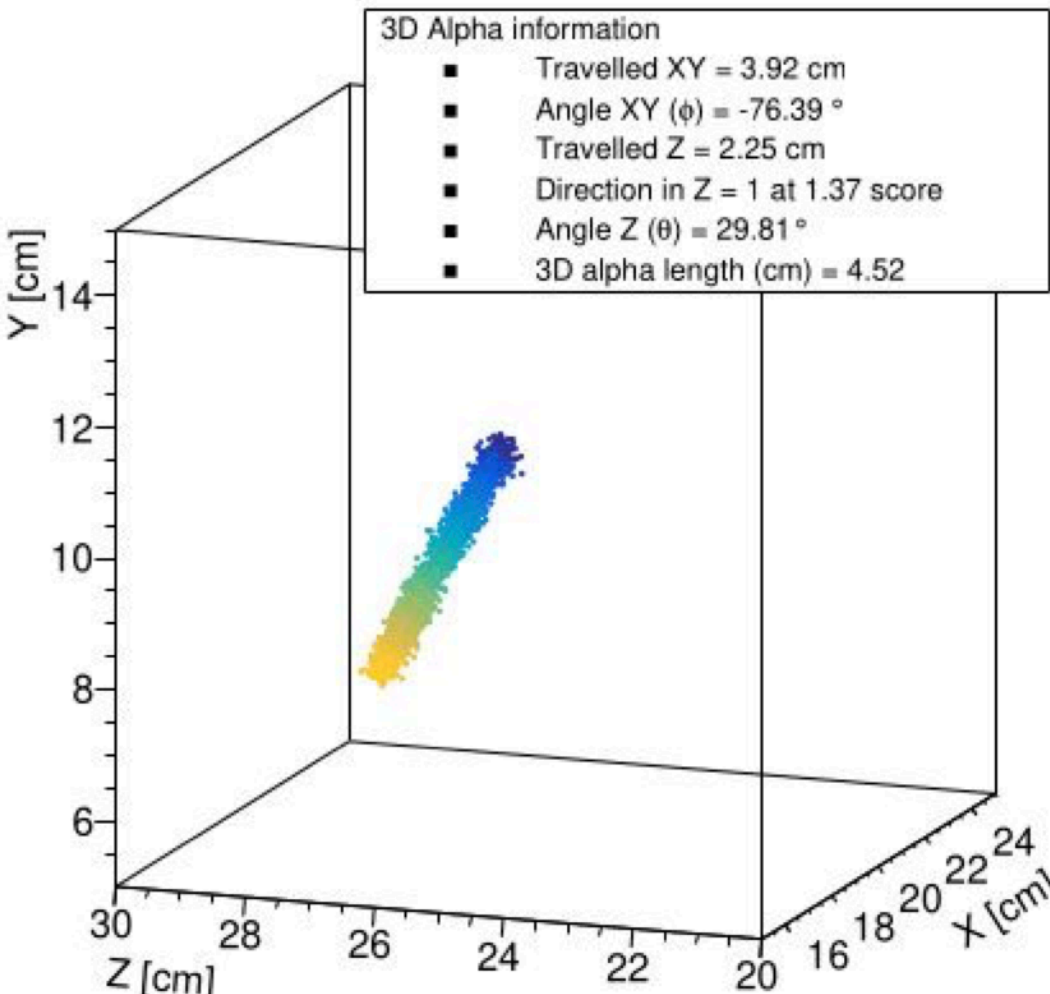
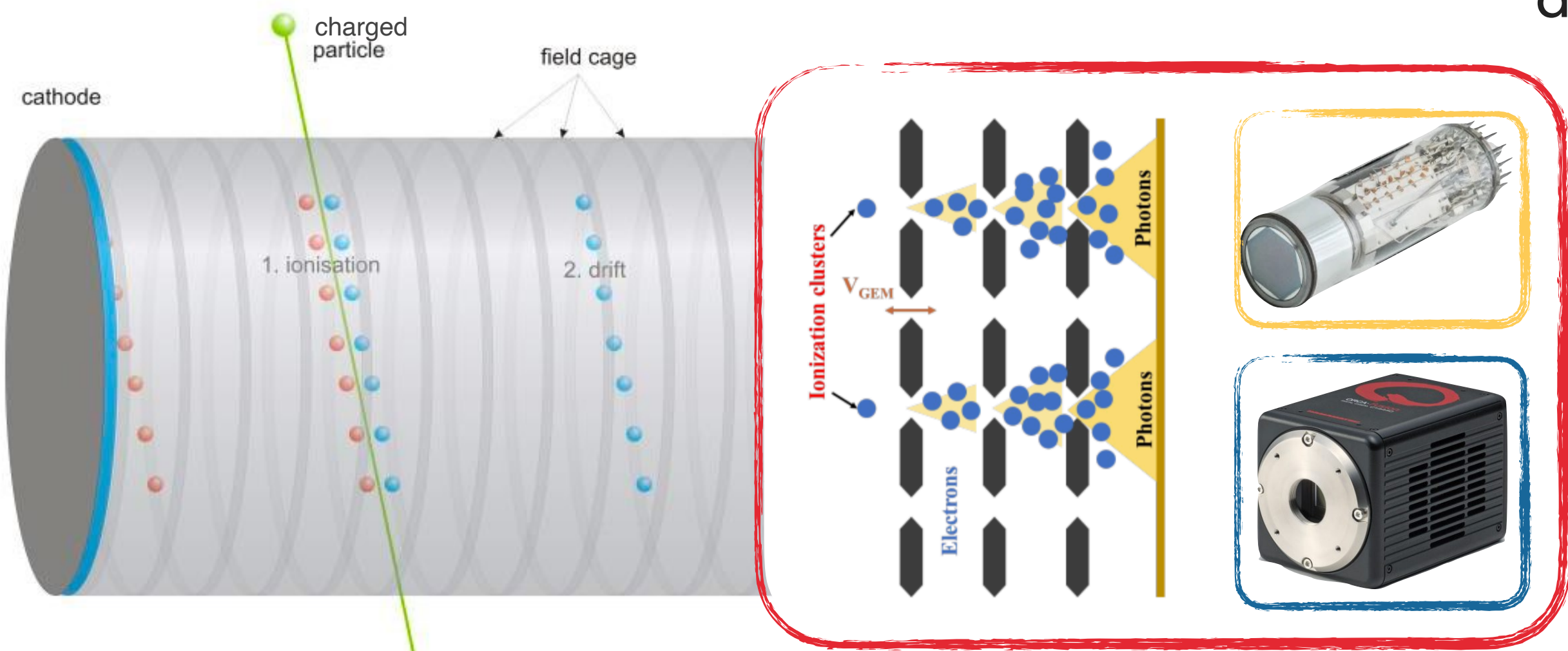
- He:CF₄ (60:40)
- Room temperature
- Atm pressure

Energy
+
X & Y coordinates



Triple GEM

Charge multiplication



1 Jun 2026, 11:30
20m
Aula Magna

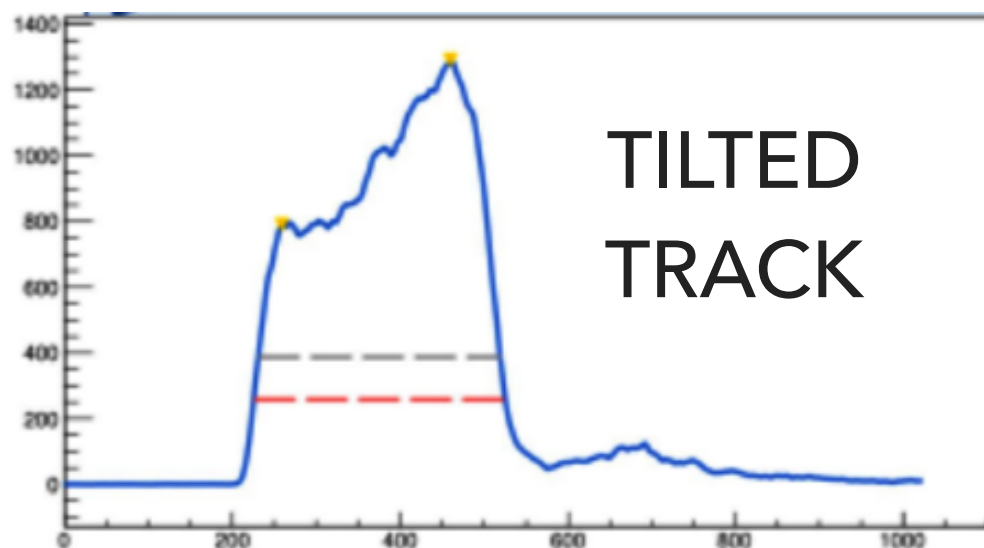
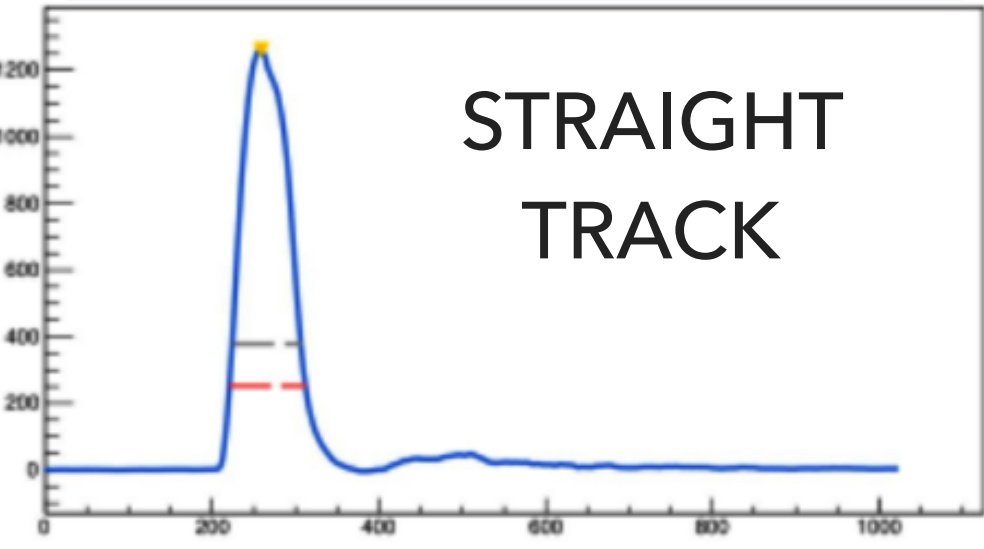
Speaker

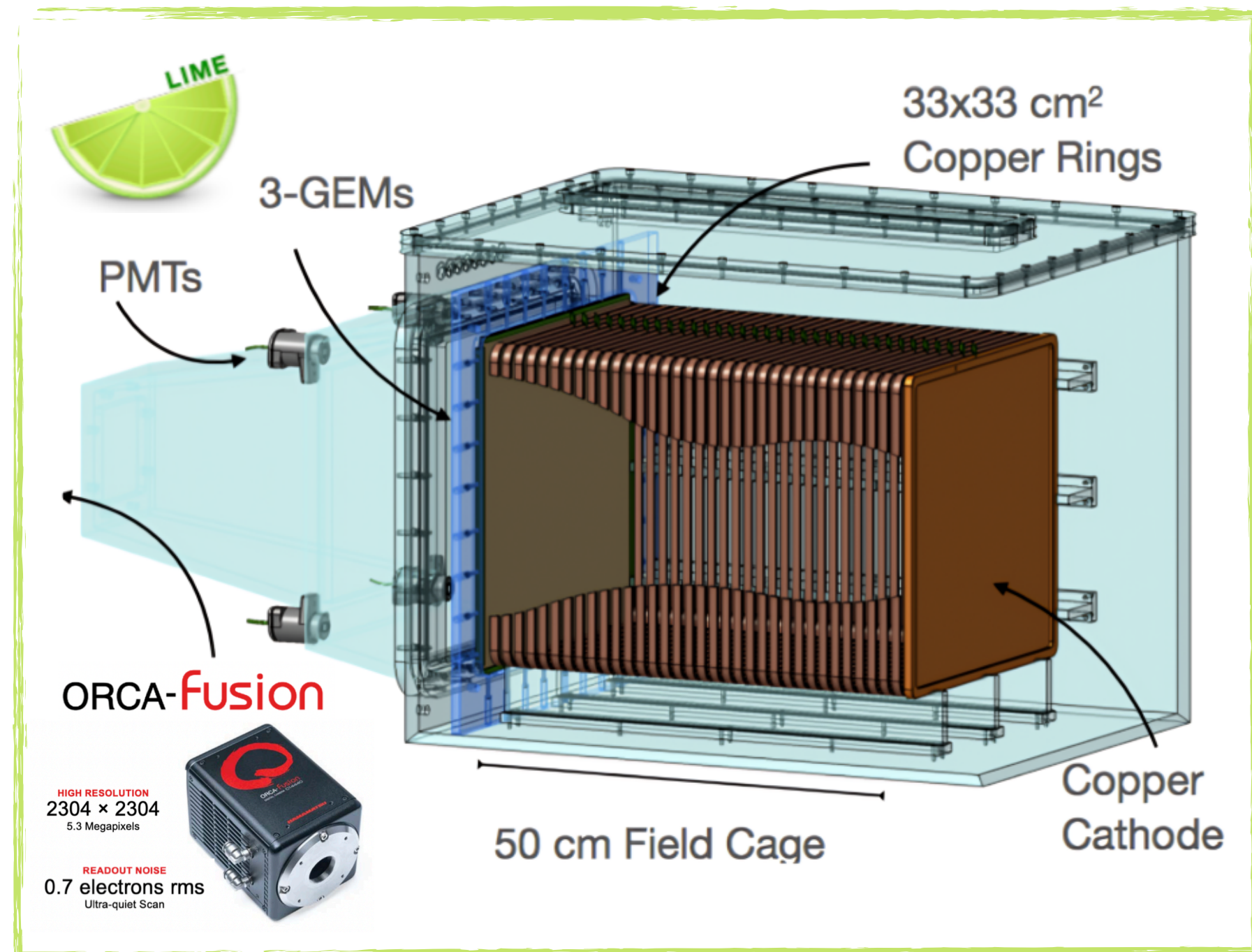
Stefano Piacentini (GSSI & INFN LNGS)

Camera + PMT

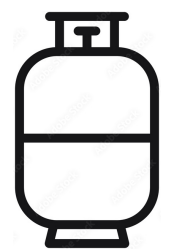
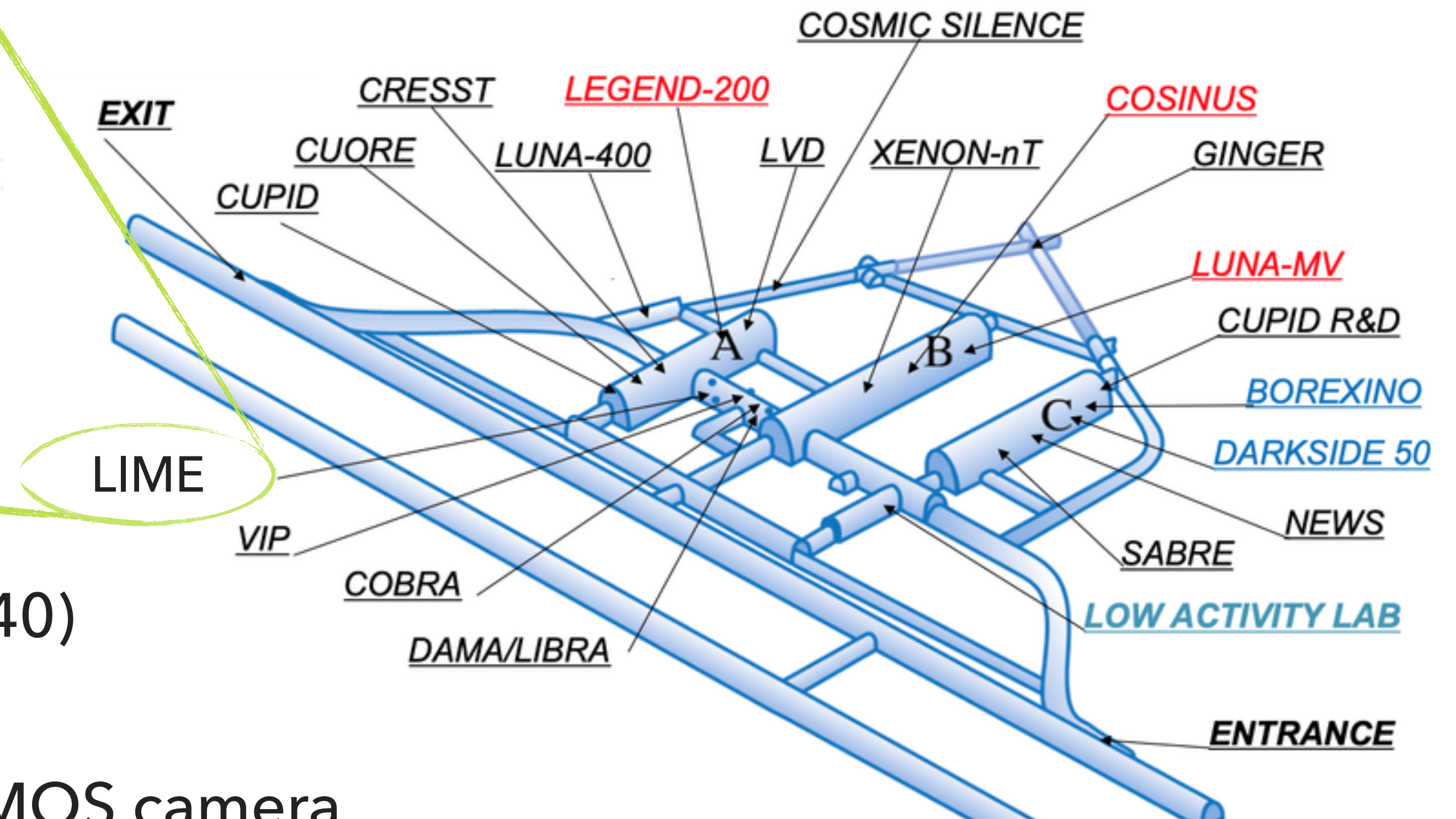
Light from gas scintillation during electron avalanche

Integrated z + Energy





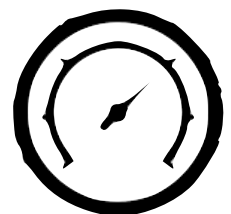
- Running
- Construction/Commissioning
- Decommissioning



50 L active volume of He:CF₄ (60:40)

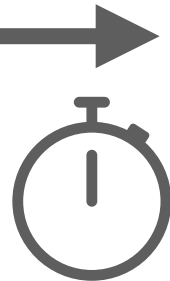


Optical readout → 4 PMTs + 1 sCMOS camera



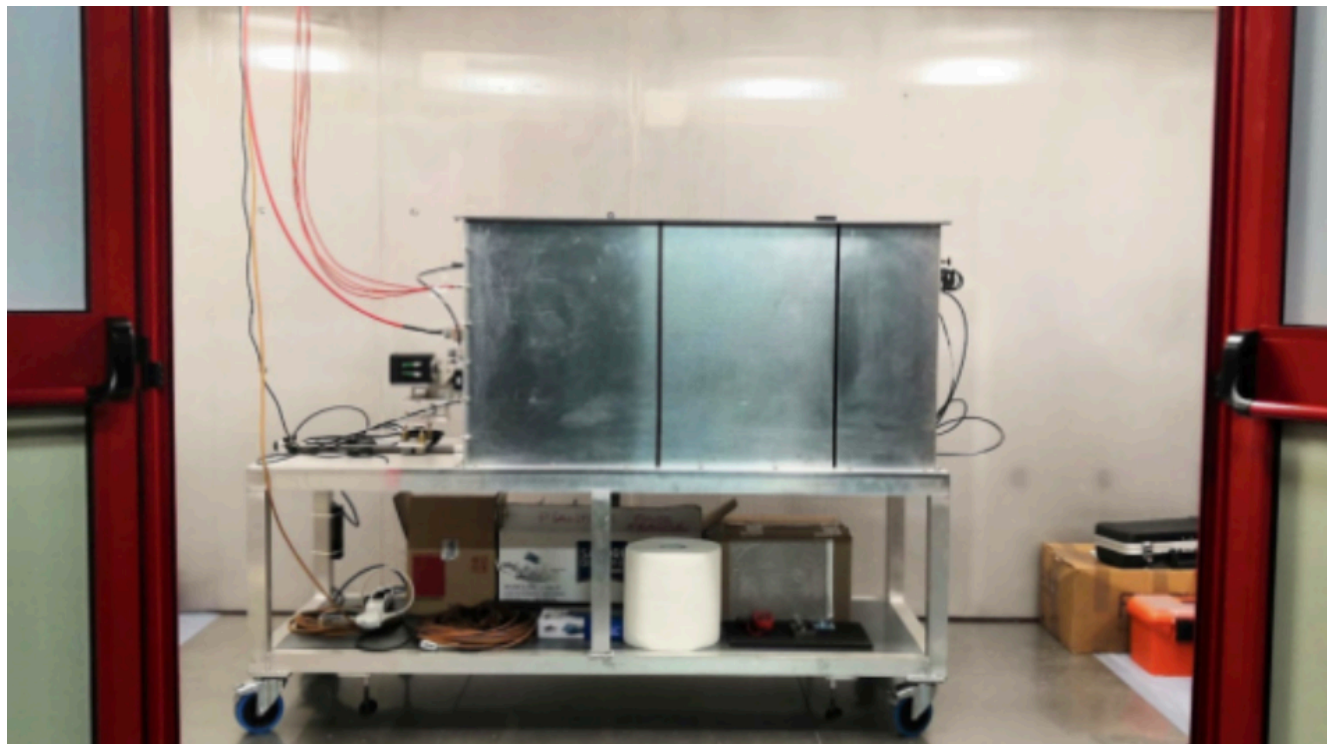
Atmospheric pressure and room temperature

Spr/Sum 2022	Autumn 2022	Winter 2023	Spr/Sum 2023	Win/Spr 2023/4	Sum/Aut 2024
RUN 0 Commissioning	RUN 1 No shielding $R_{\text{PMT}} = 30 \text{ Hz}$ $V_{\text{GEM}} = 420 \text{ V}$	RUN 2 4 cm Cu $R_{\text{PMT}} = 3.5 \text{ Hz}$ $V_{\text{GEM}} = 440 \text{ V}$	RUN 3 10 cm Cu $R_{\text{PMT}} = 1.6 \text{ Hz}$ $V_{\text{GEM}} = 440 \text{ V}$	RUN 4 10 cm Cu + 40 cm H ₂ O $R_{\text{PMT}} = 1.0 \text{ Hz}$ $V_{\text{GEM}} = 420 \text{ V} - 440 \text{ V}$	RUN 5 10 cm Cu $R_{\text{PMT}} = 1.5 \text{ Hz}$ $V_{\text{GEM}} = 420 \text{ V}$
			AmBe ²⁴¹ Am		Neutron flux AmBe



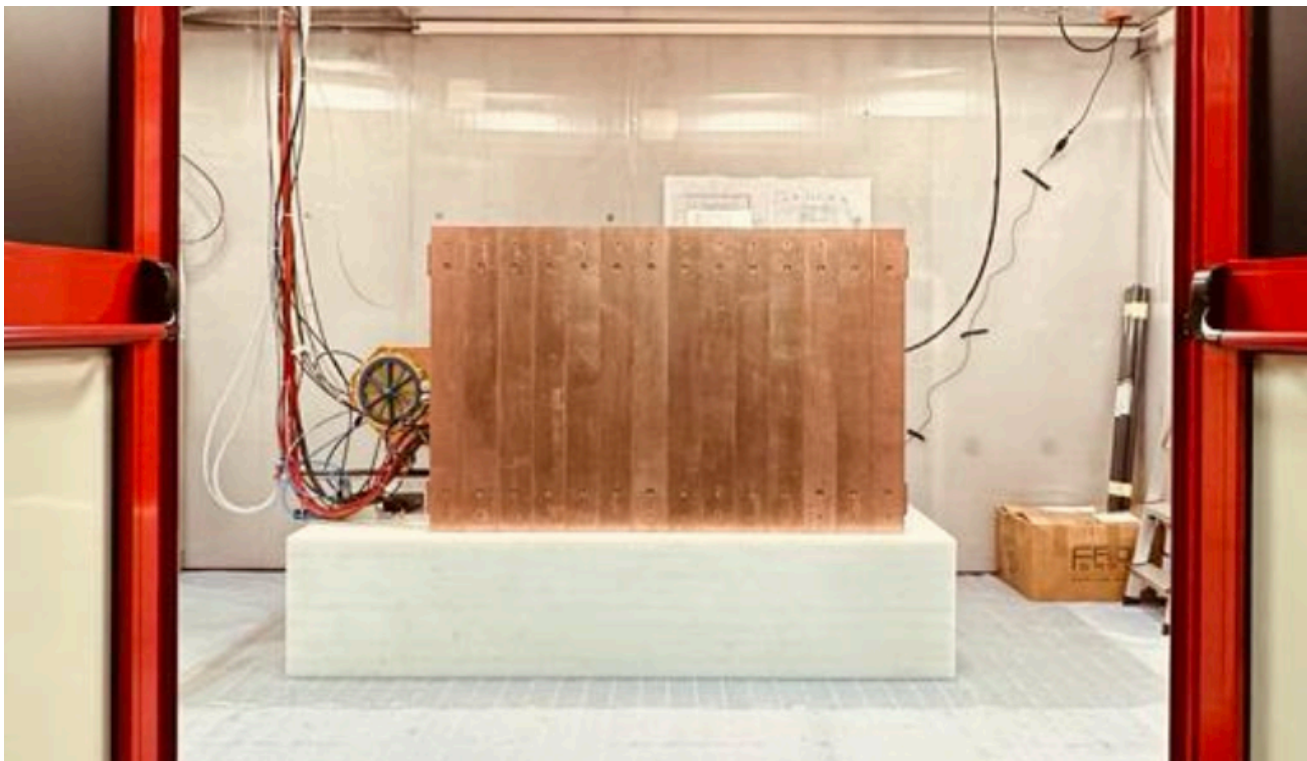
RUN 1

Background dominated by the external sources



RUN 2-3-5

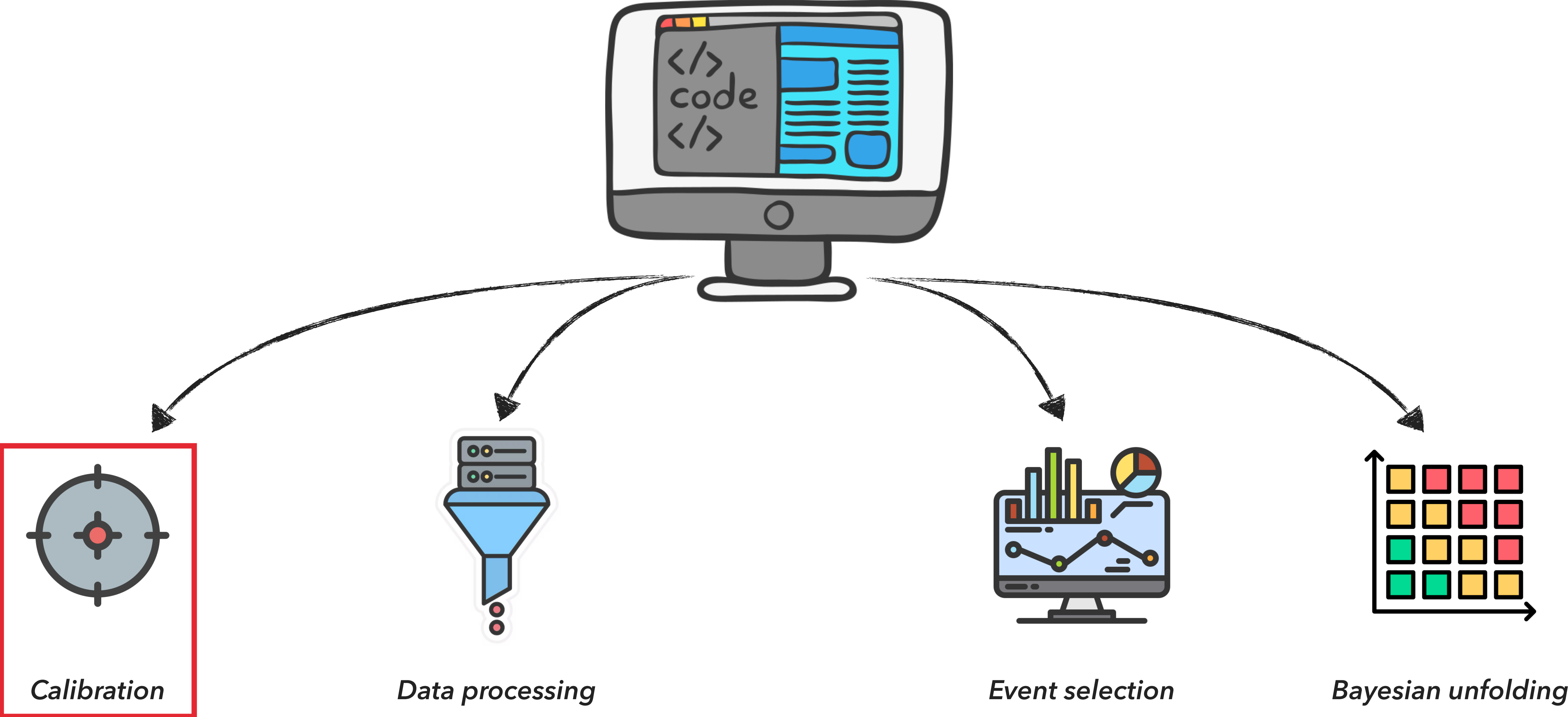
External background suppressed by a factor ~40-600



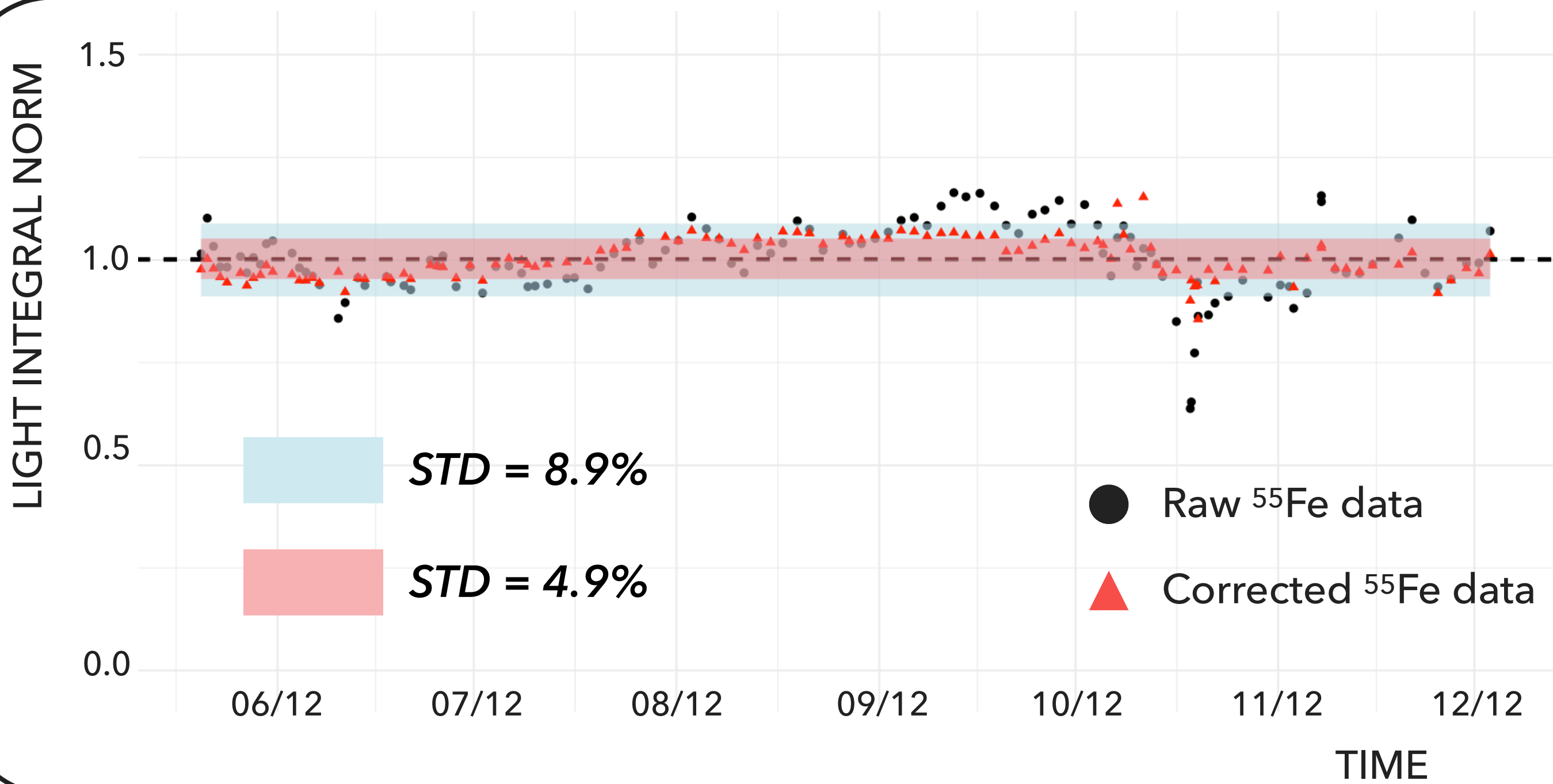
RUN 4

Residual external neutron background suppression



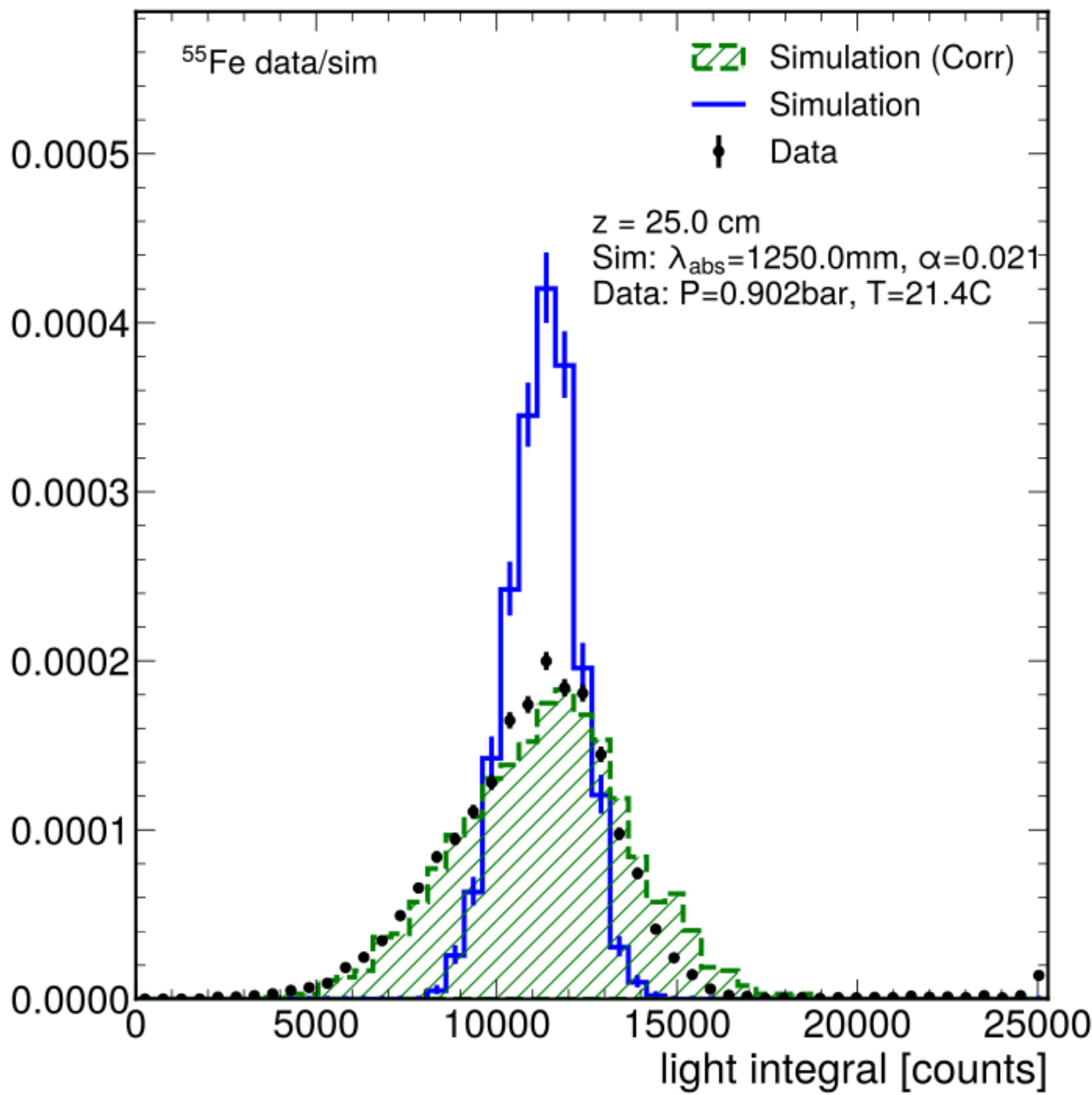


DATA



SIMULATION

Simulation must reproduce the *same variability of the data*



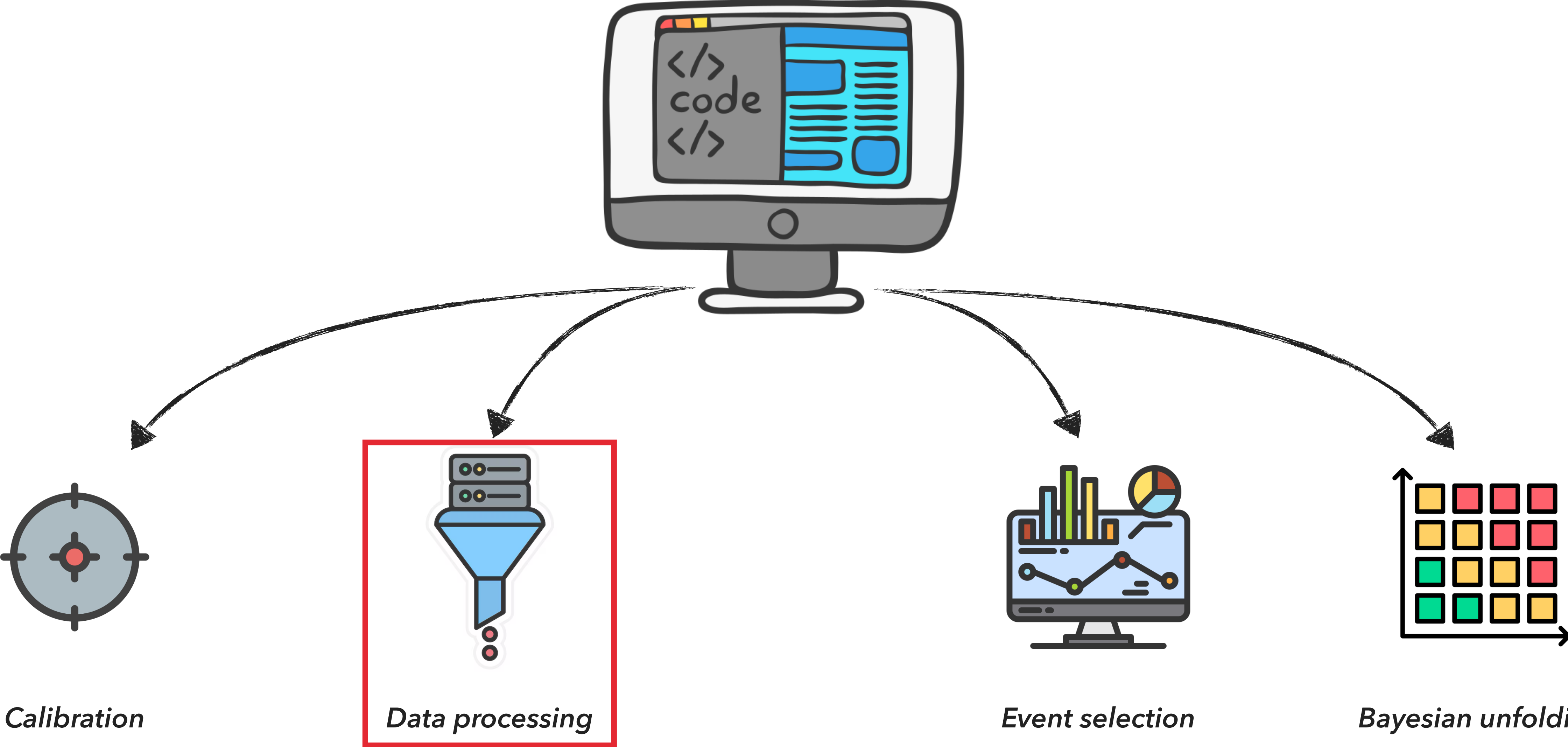
ENVIRONMENTAL MODEL

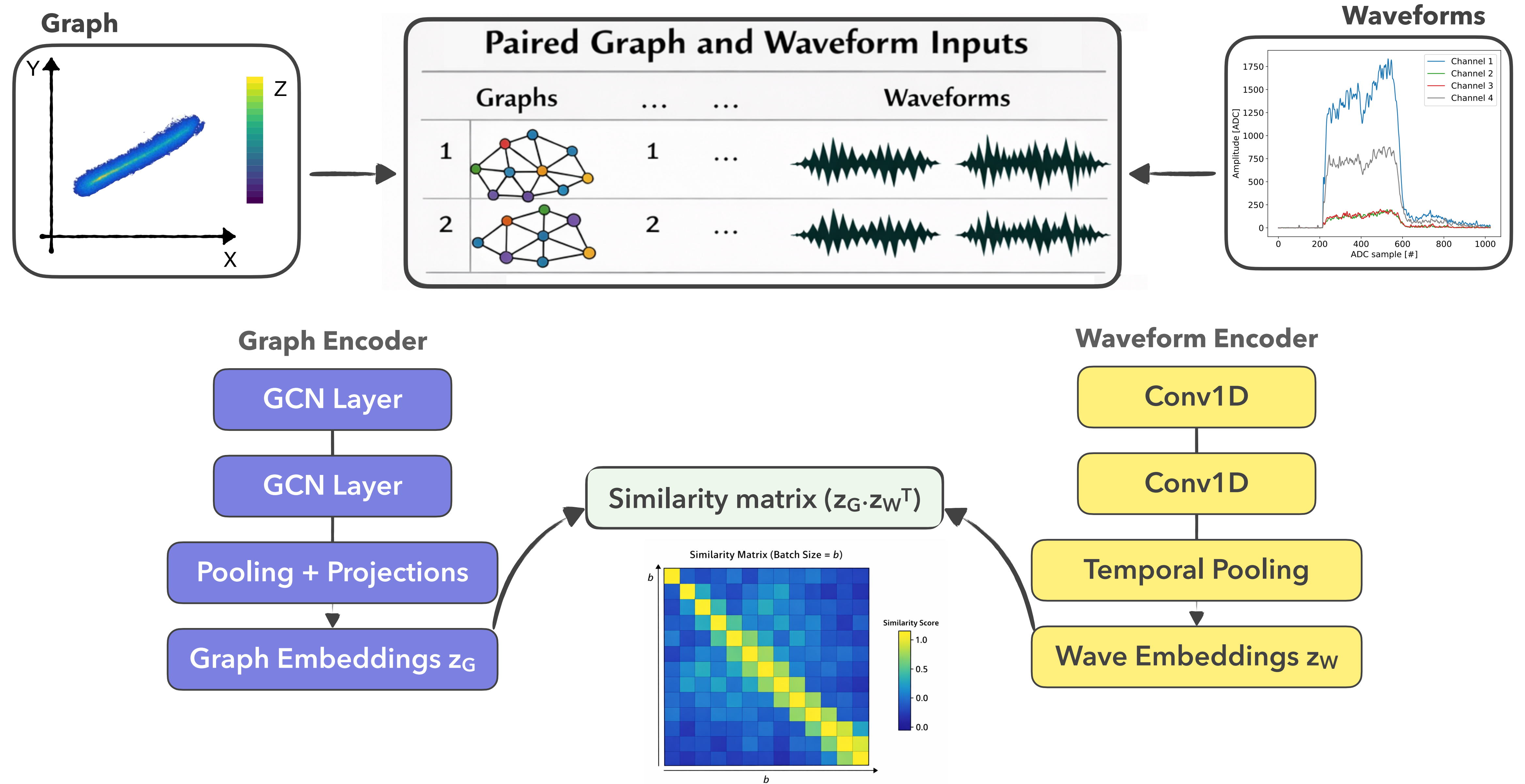
Fit provides
continuous LY
estimates
between
calibration runs

$$LY \propto K \frac{T^A}{P^B O^C H^D}$$

Pressure (P)
Temperature (T)
Oxygen (O)
Humidity (H)

Normalizing flow maps MC
observables to arbitrary gas
conditions





SELECTION CUTS



1 track - 1 wfs set per event



Wfs set within sCMOS global exposure window



Track light integral > 850 ADU

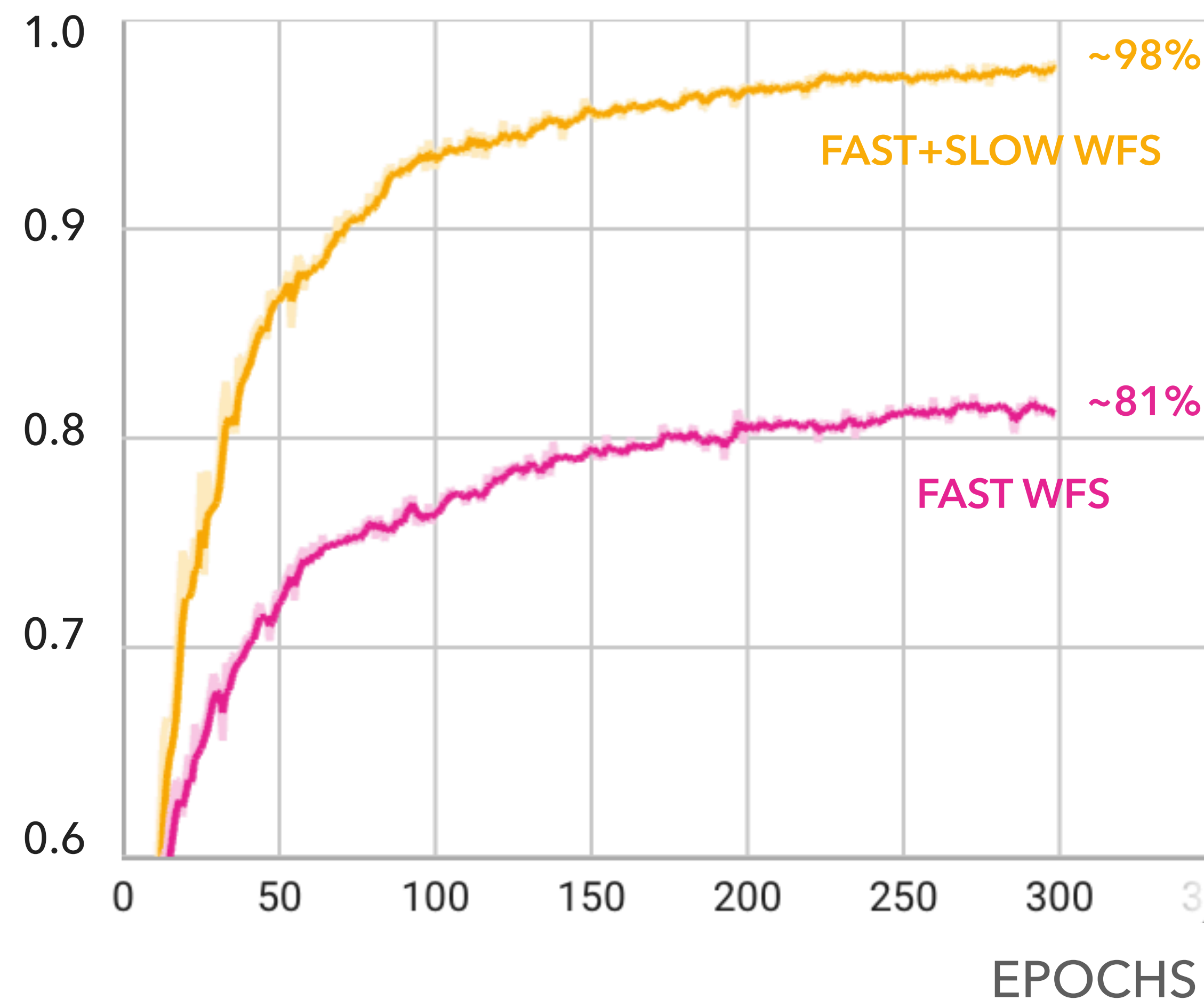


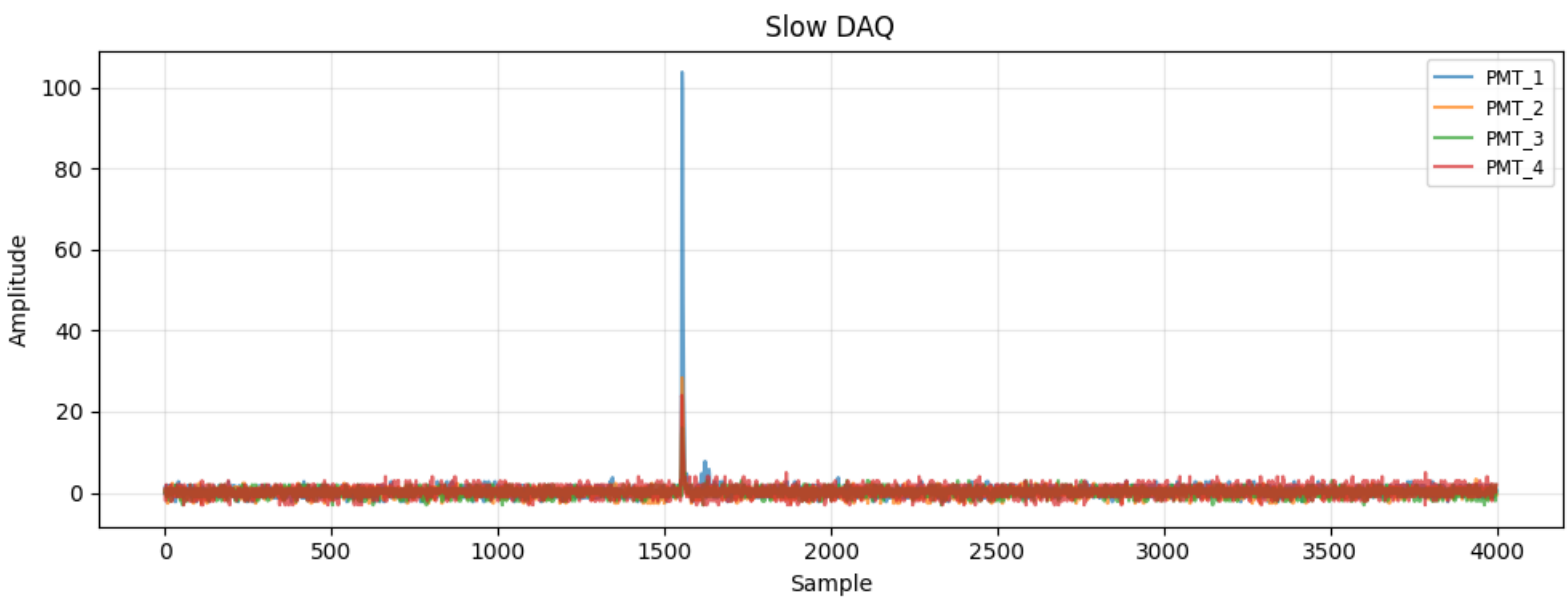
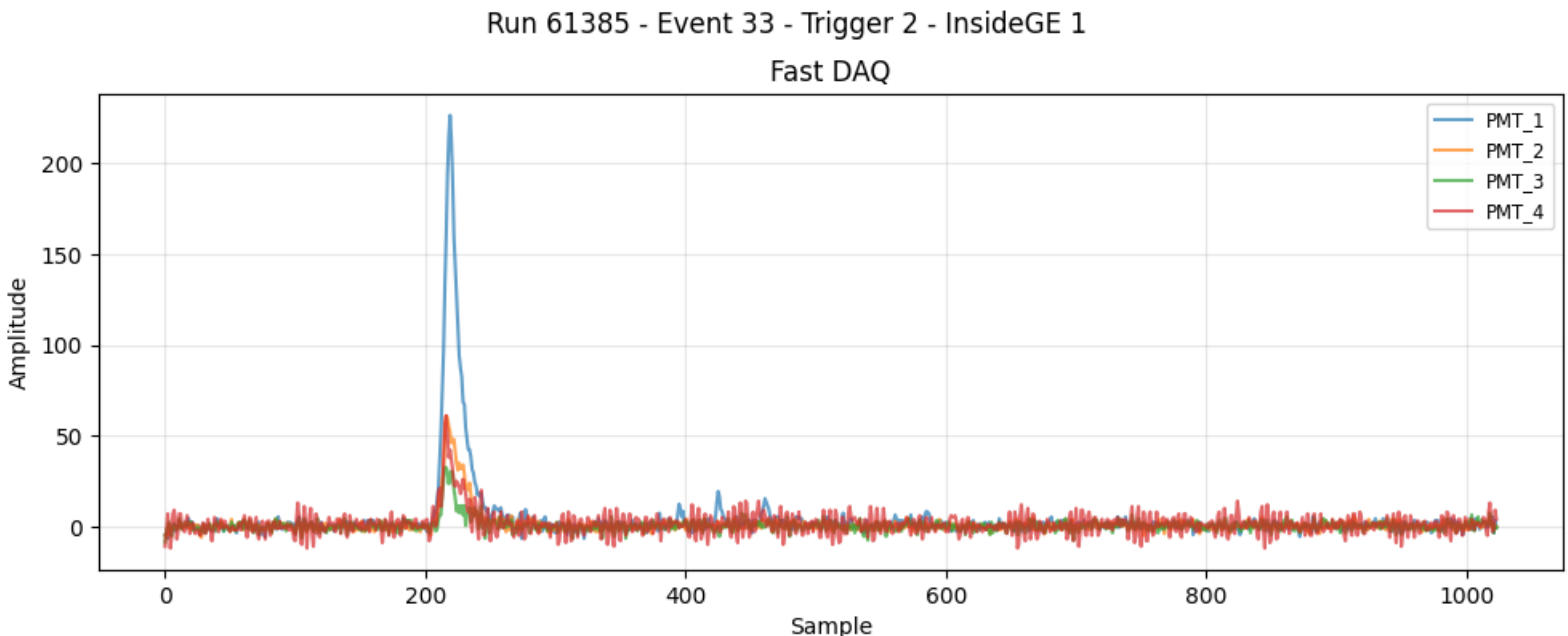
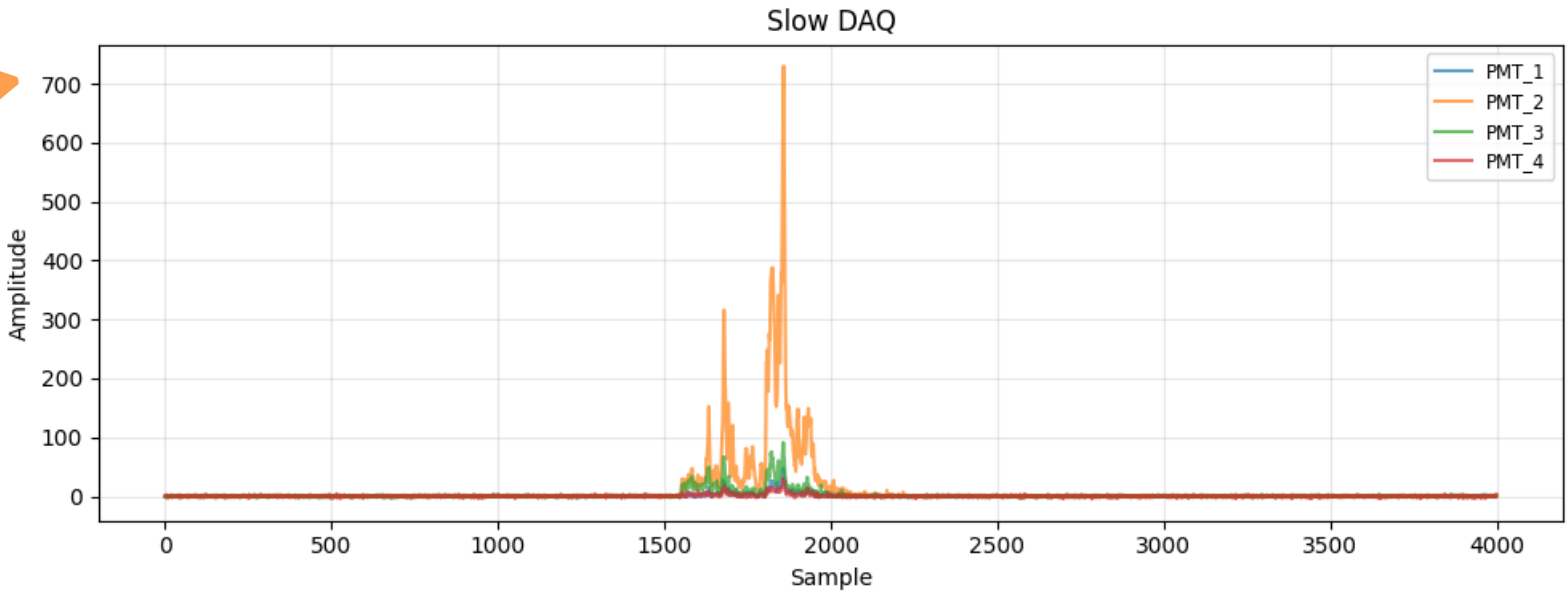
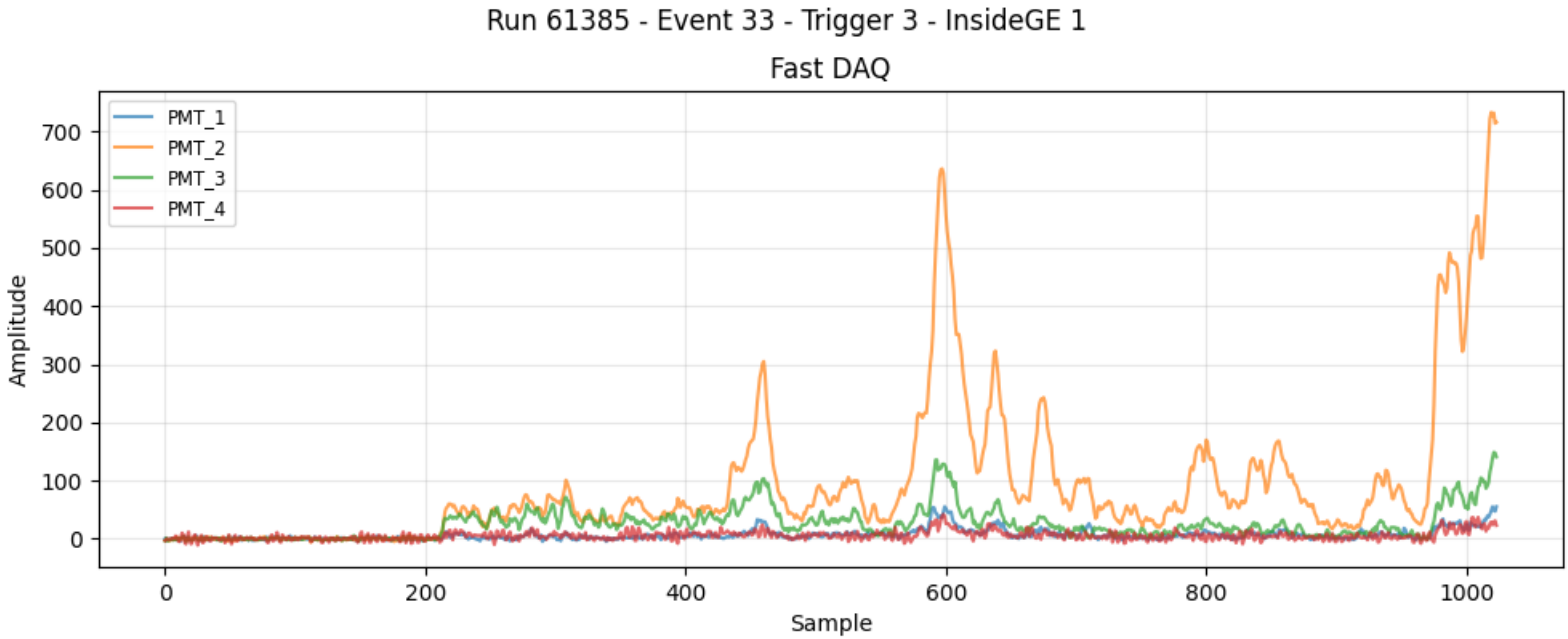
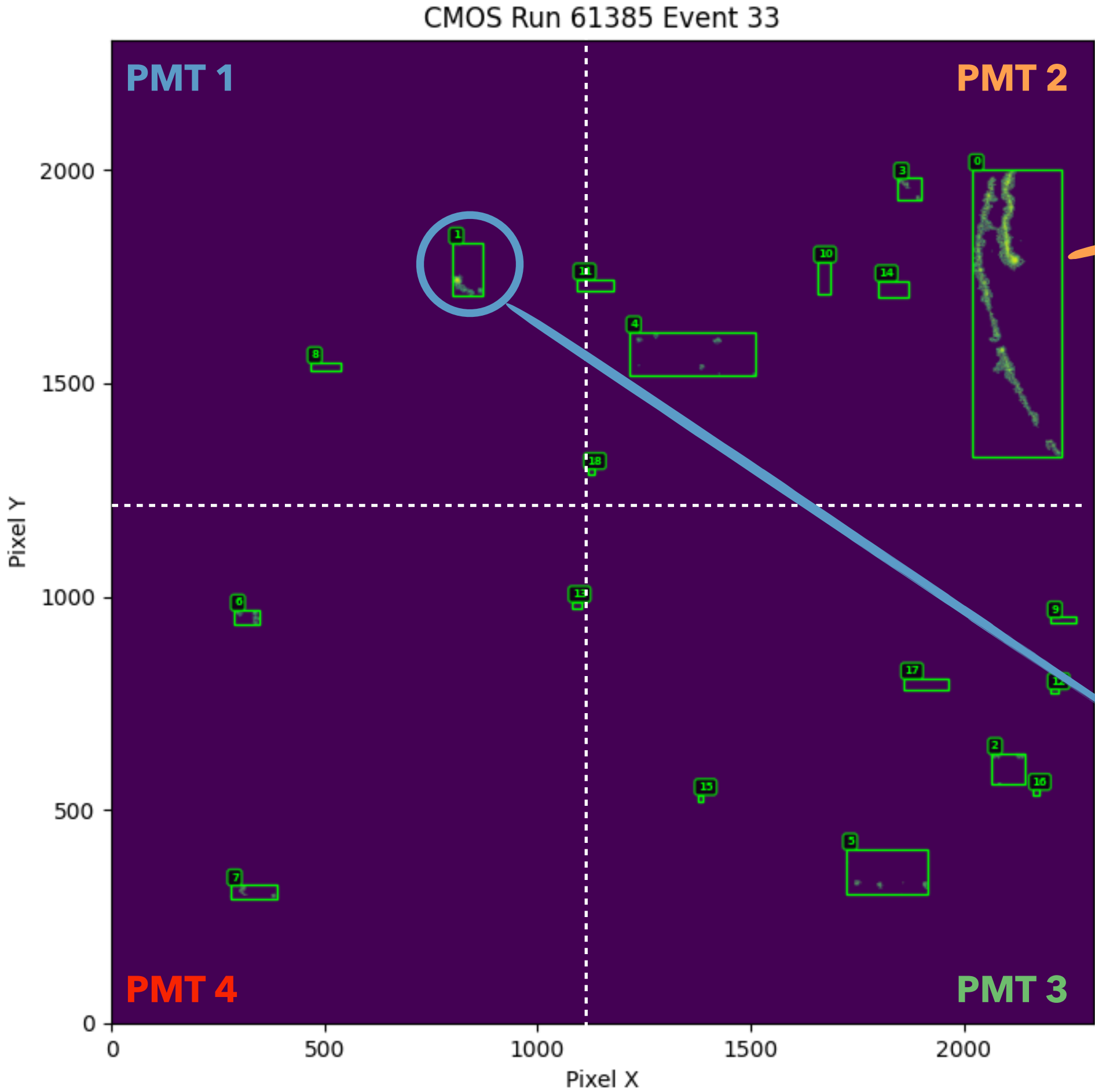
Track centroid radius ≤ 800 px

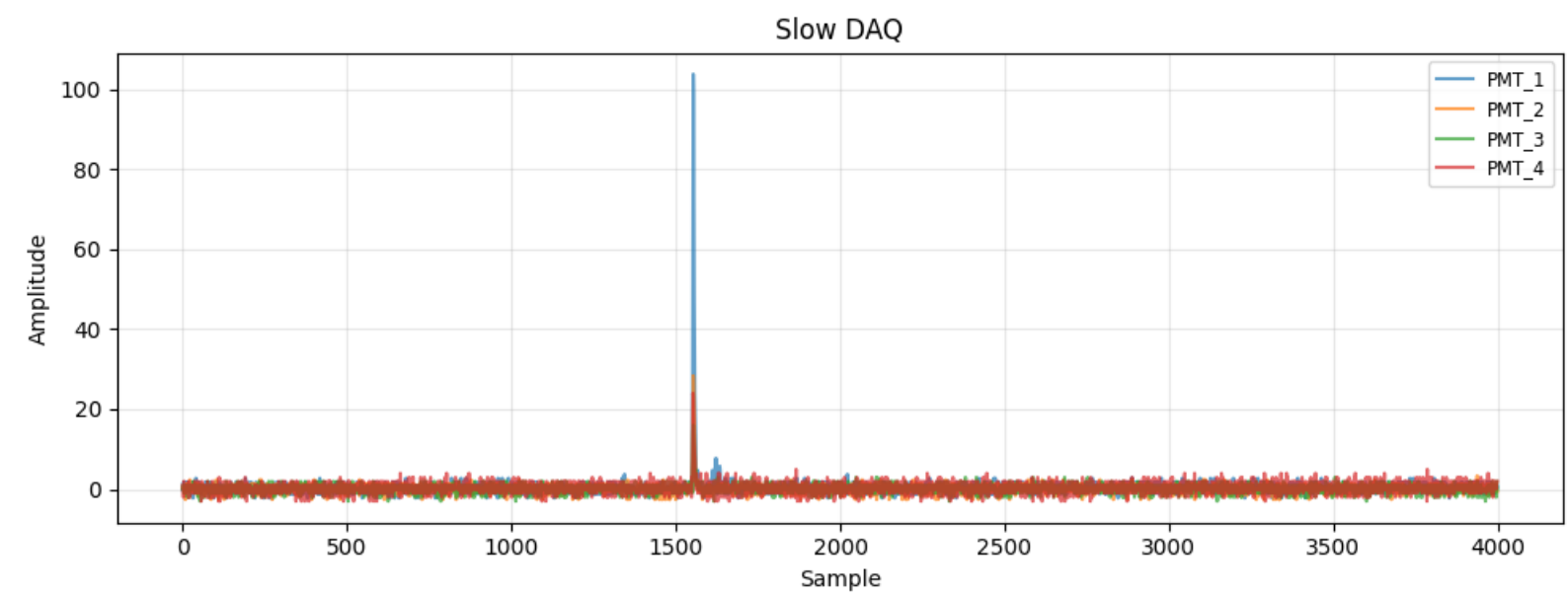
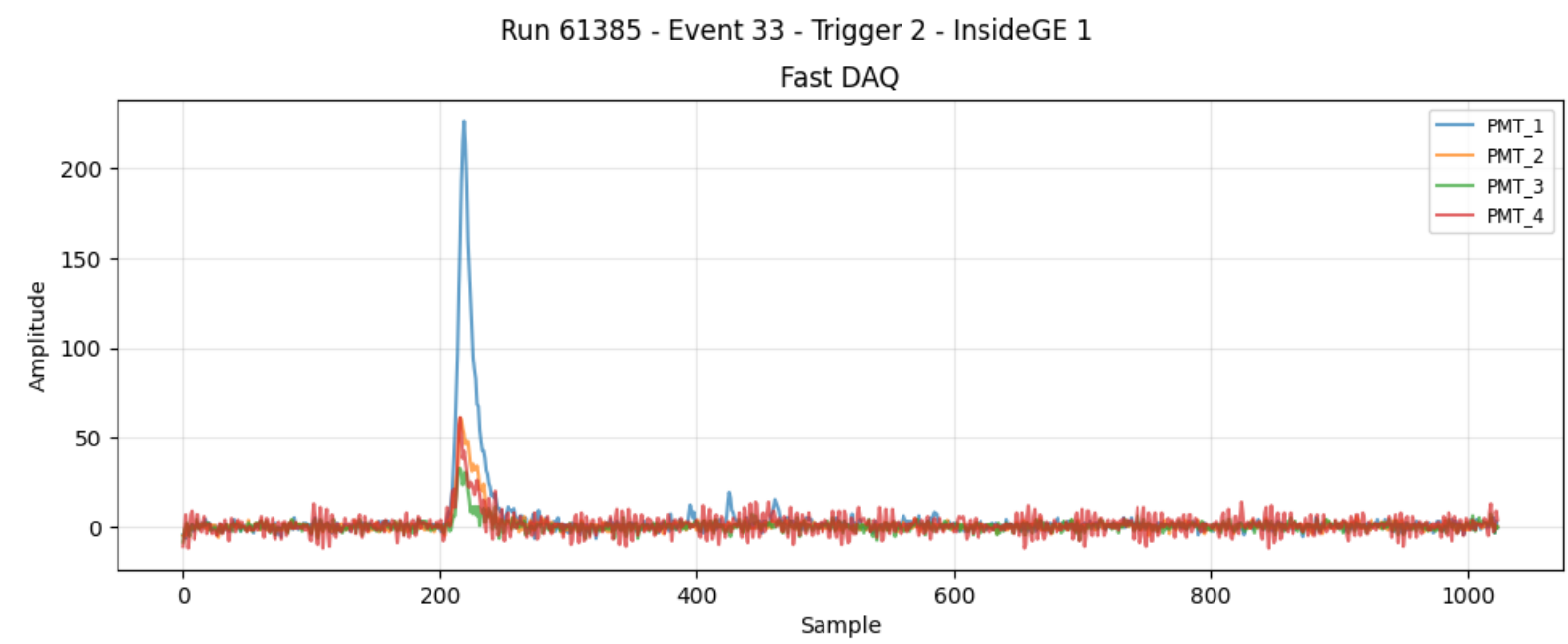
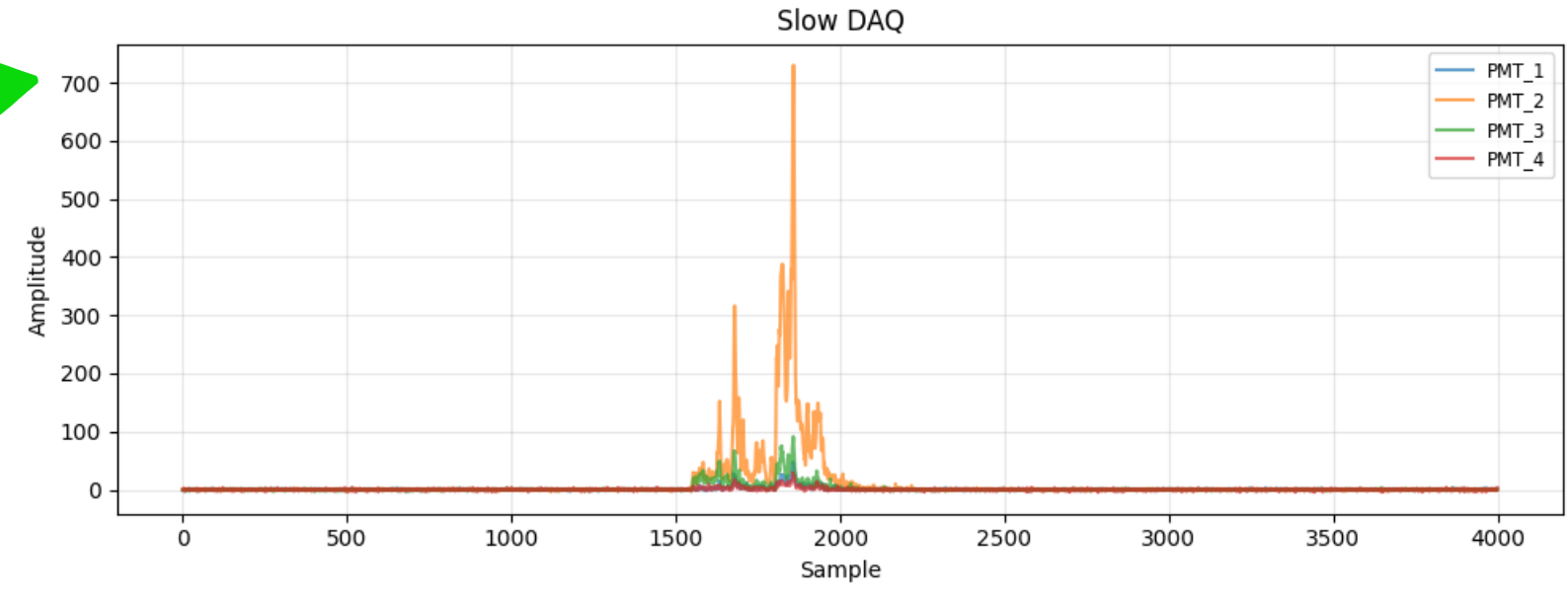
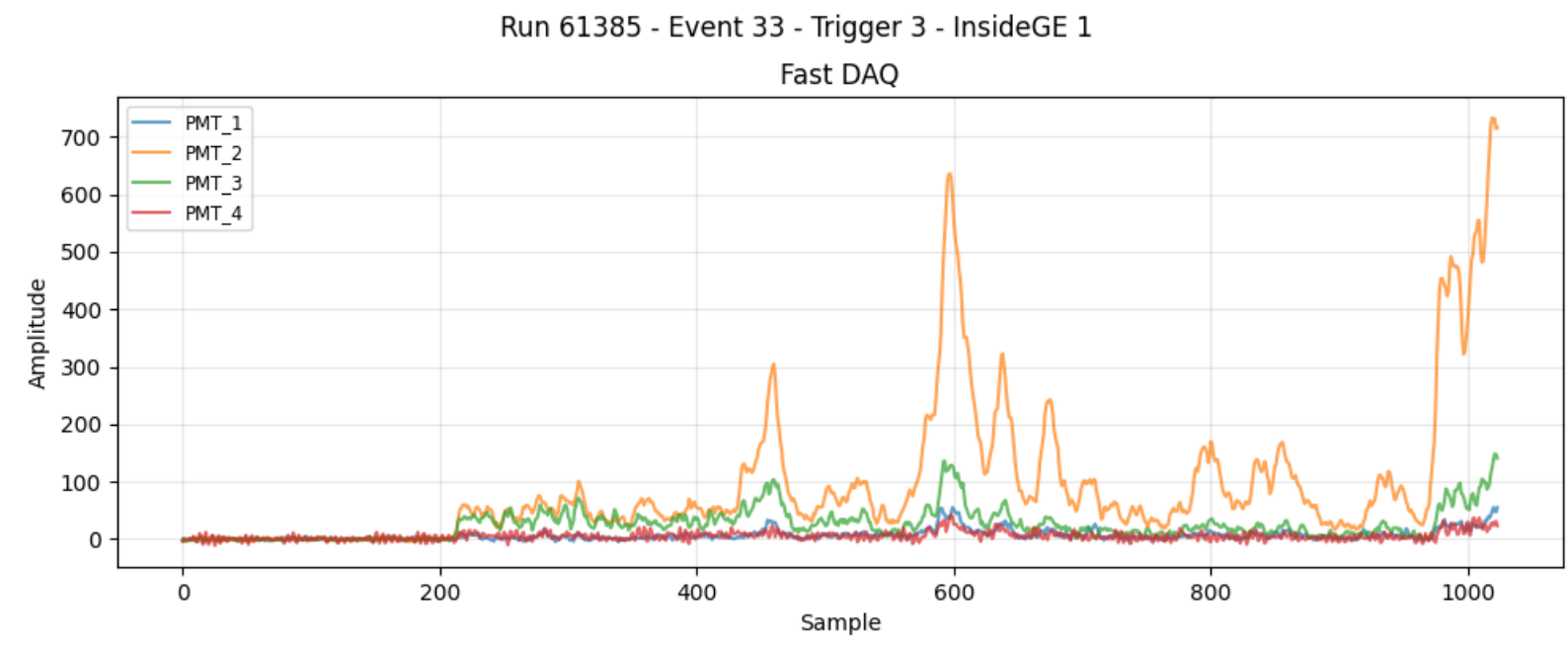
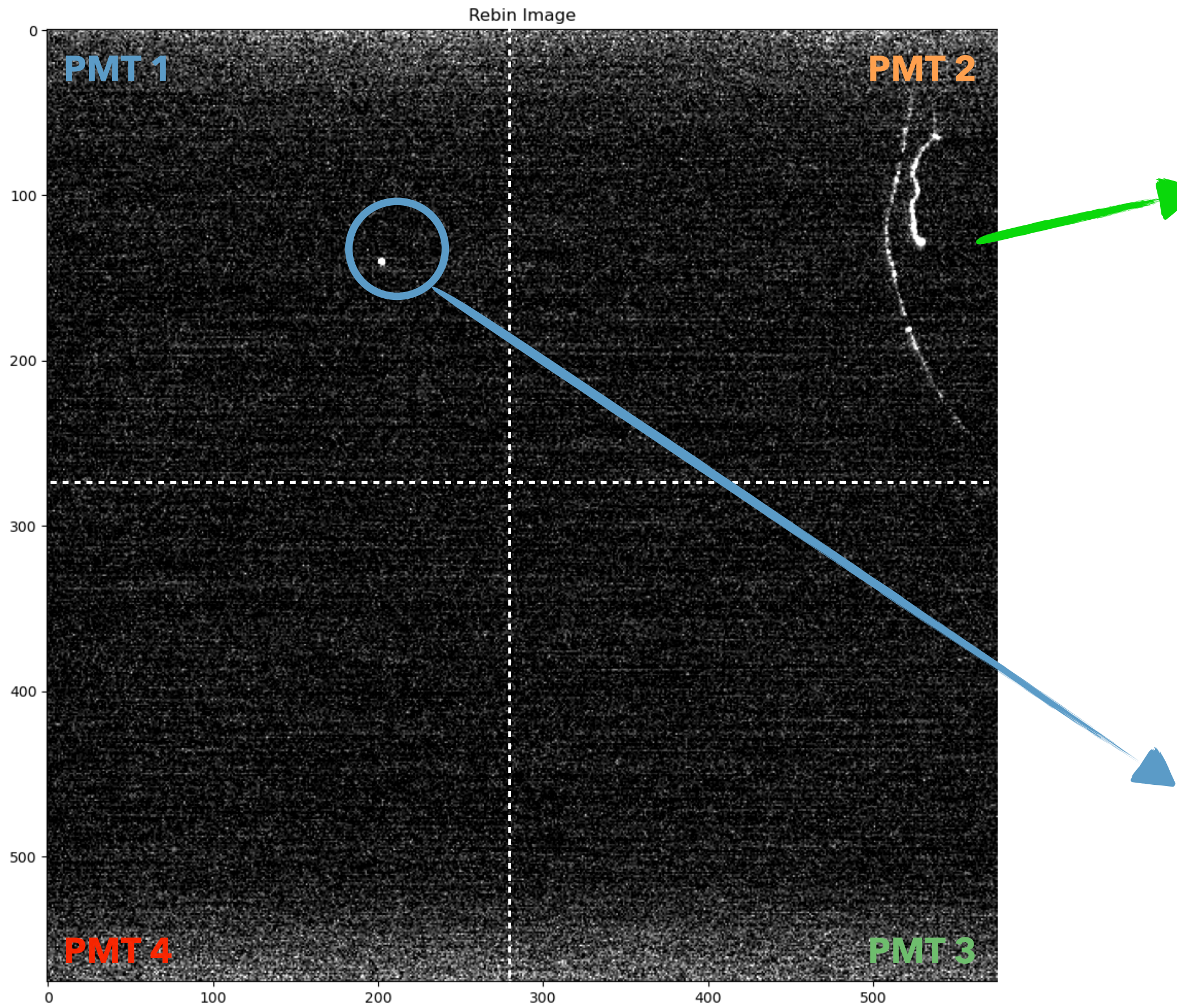


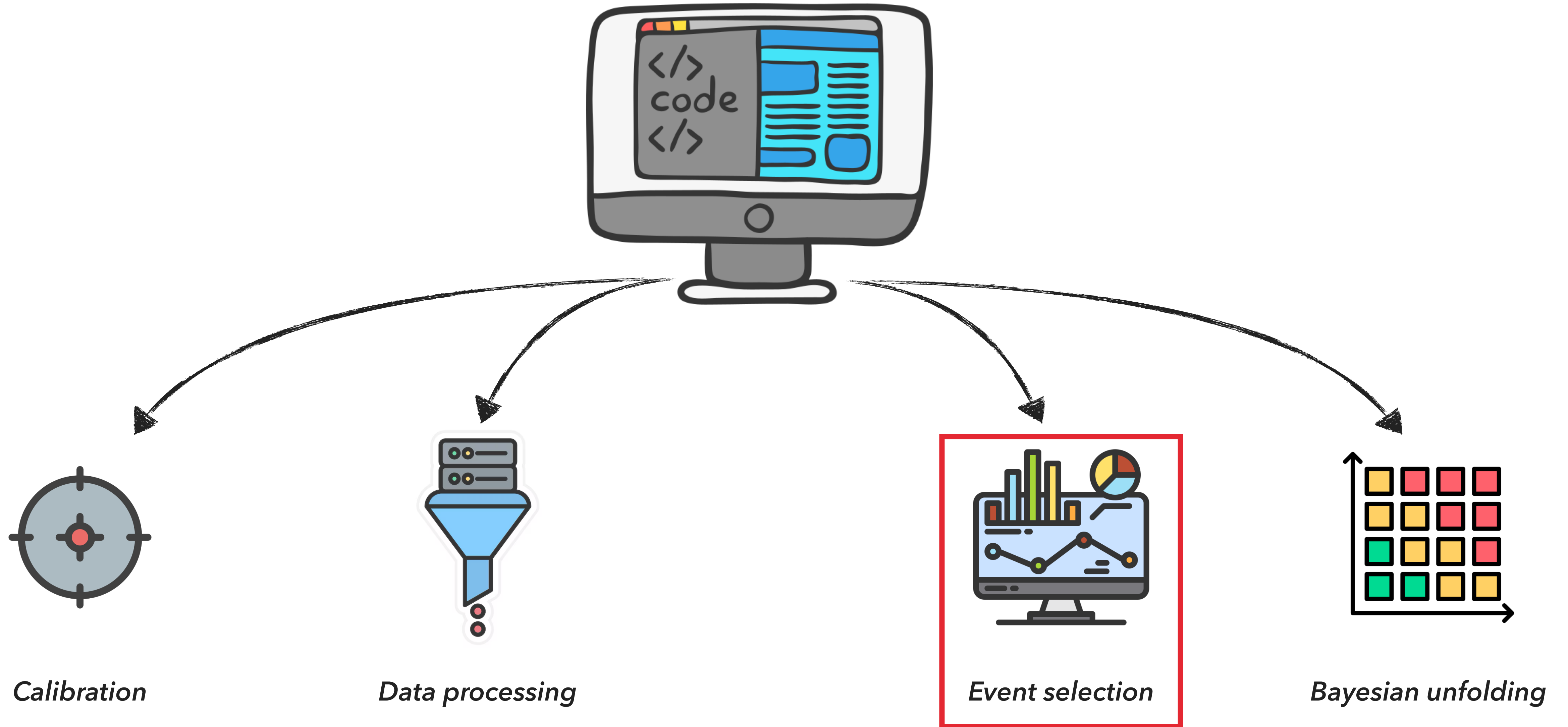
Track RMS > 6

Accuracy/validation_hungarian

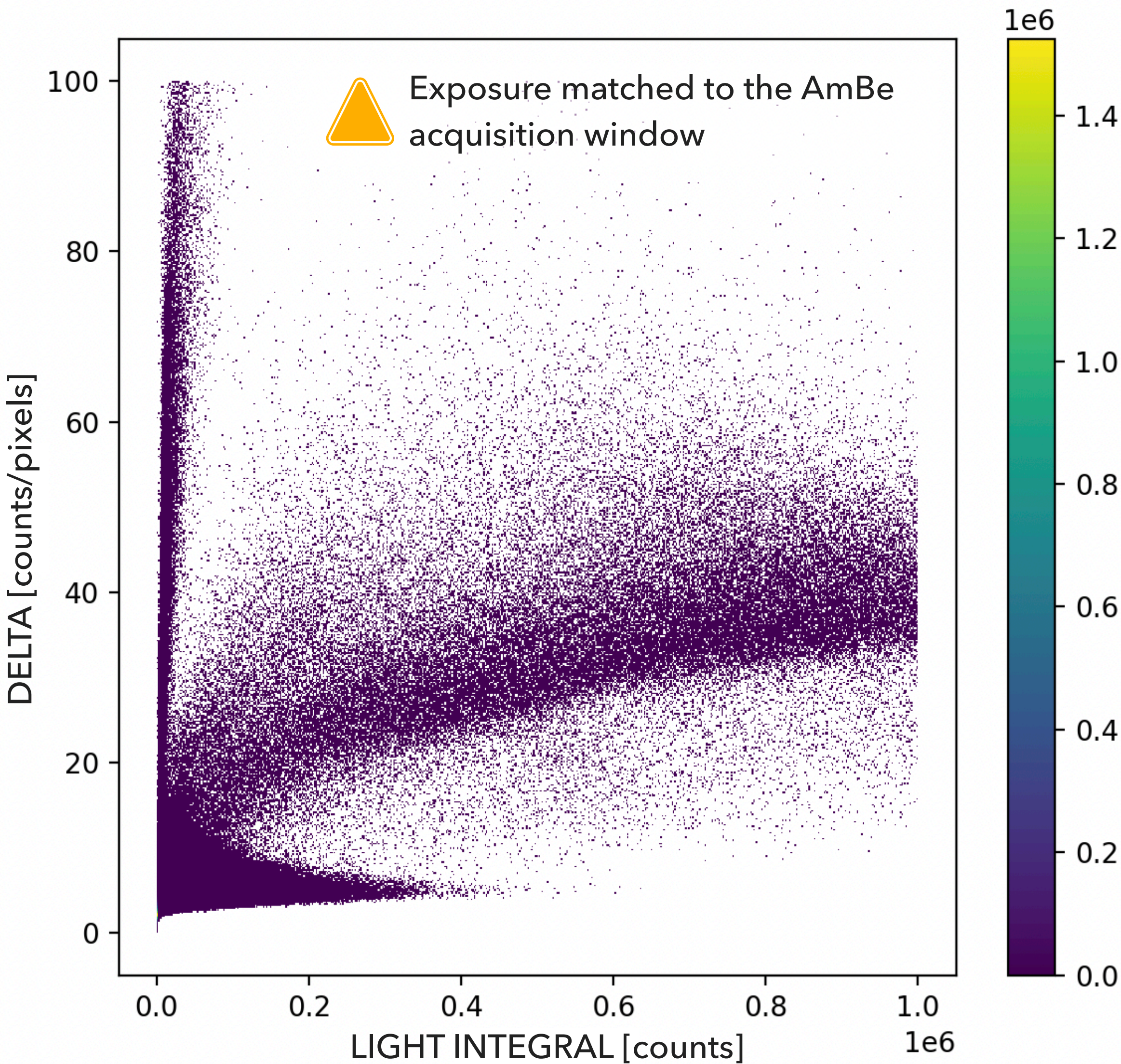




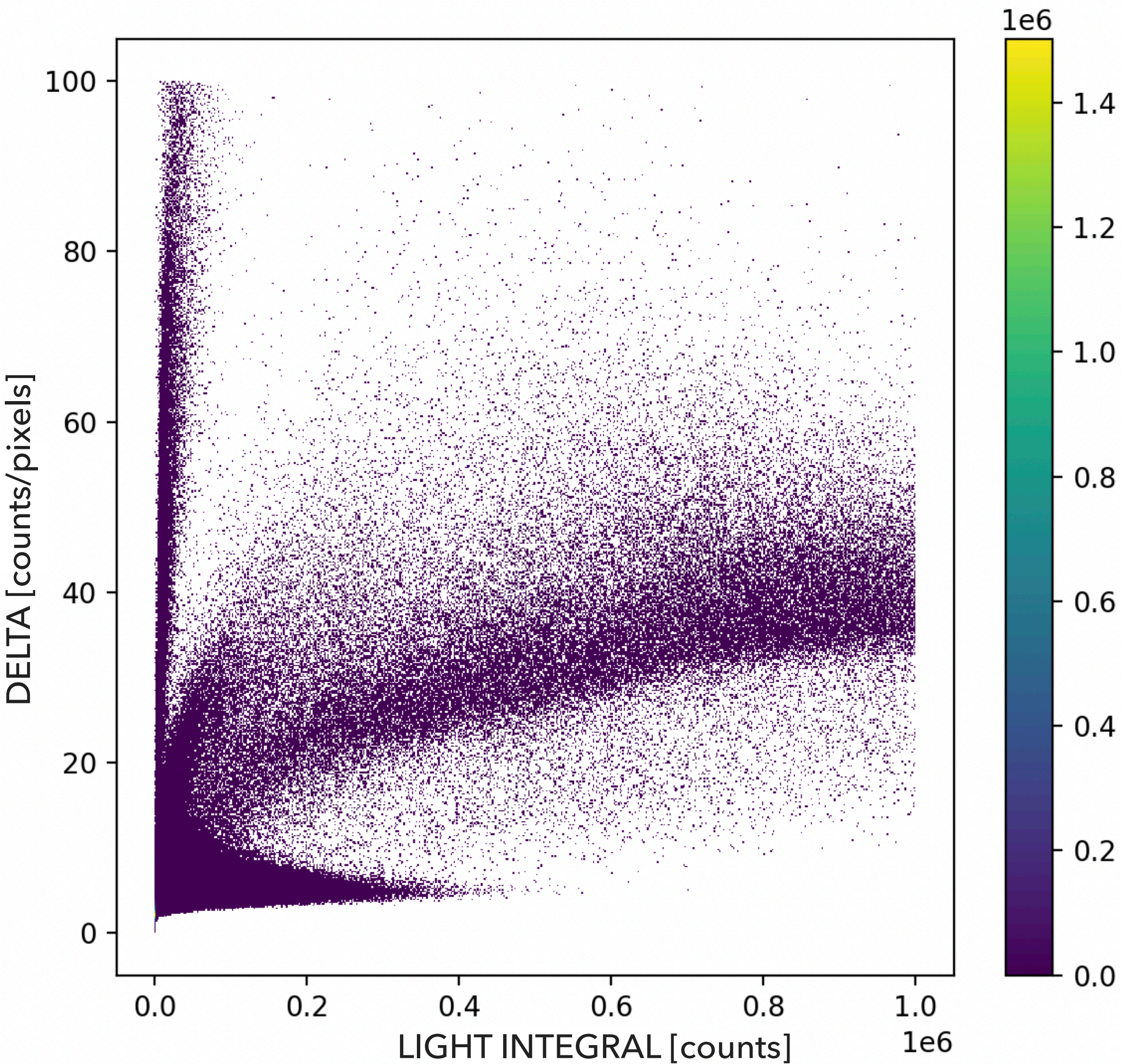




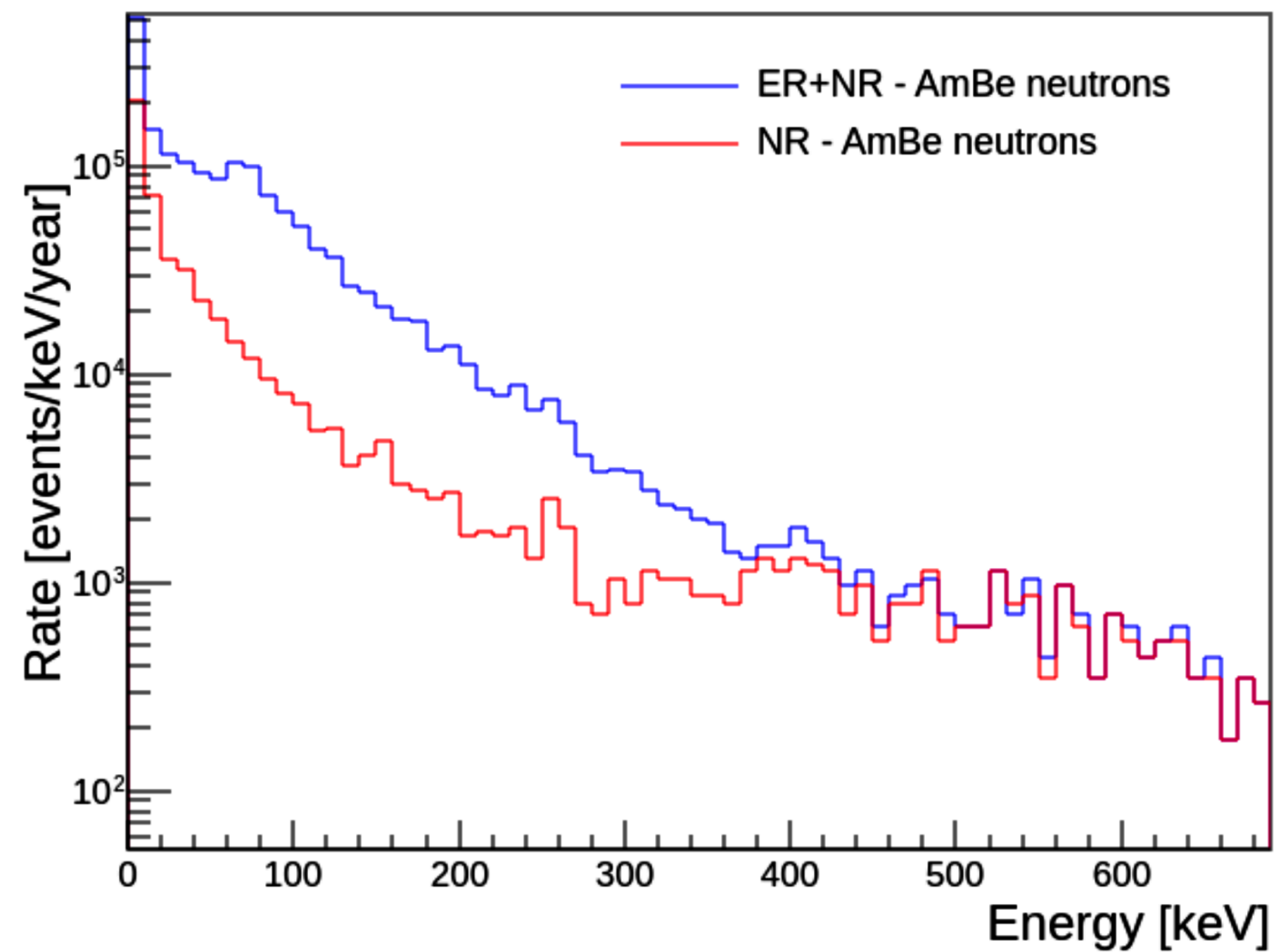
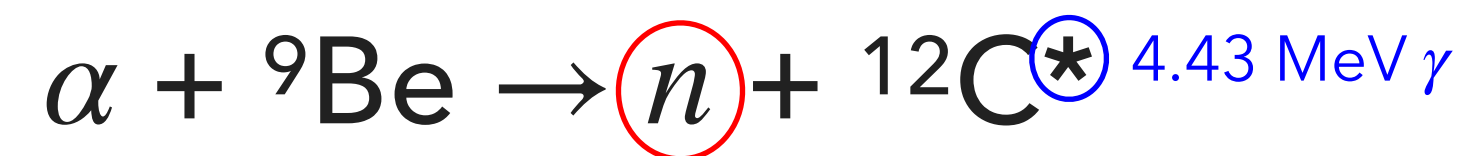
RUN5 - EXTERNAL n_s CAMPAIGN



RUN5 - AMBE CAMPAIGN

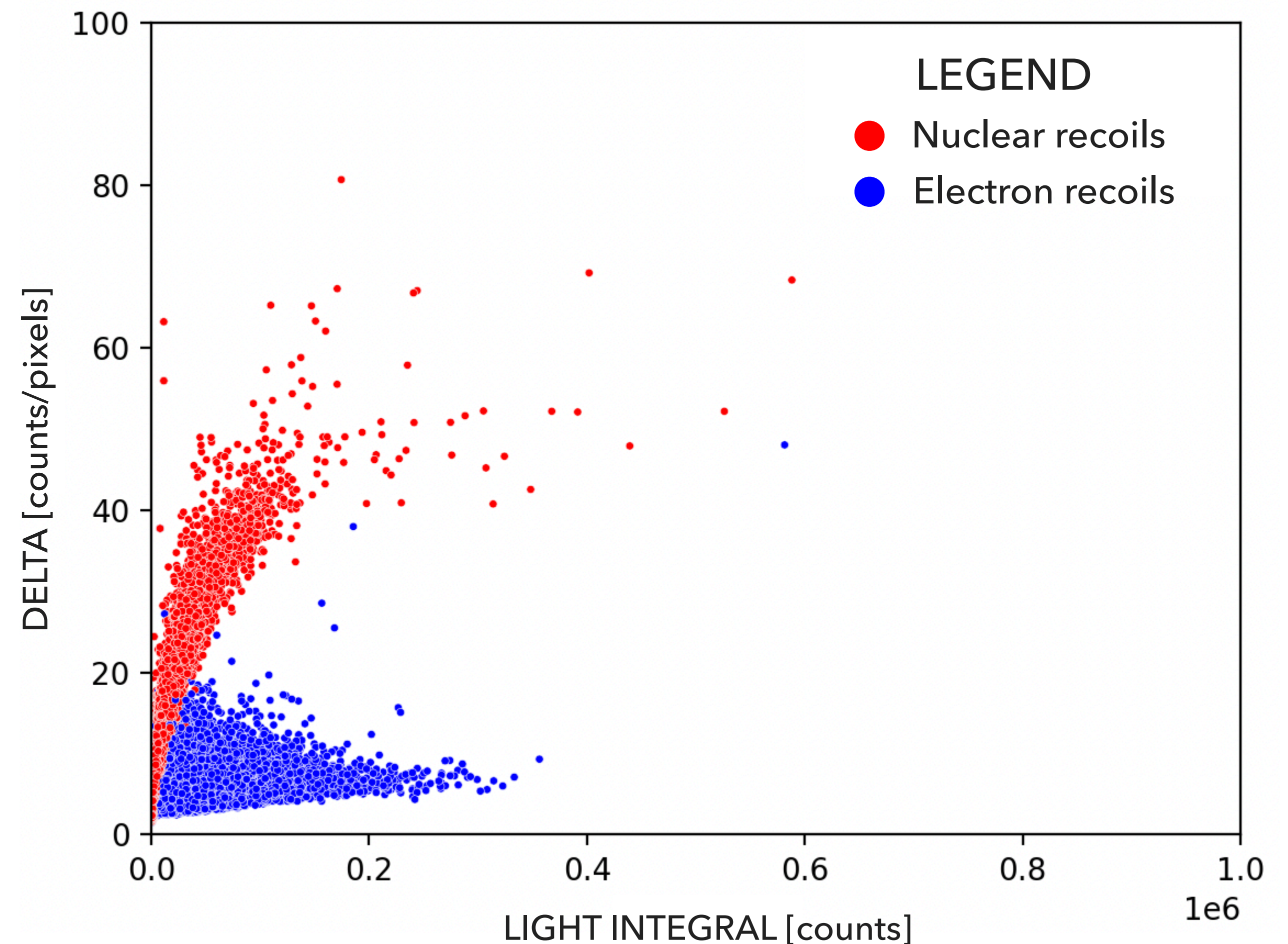


What does the AmBe source produce?



Where do neutron- and gamma-induced events appear in detector observables?

ER → low- δ band NR → high- δ band

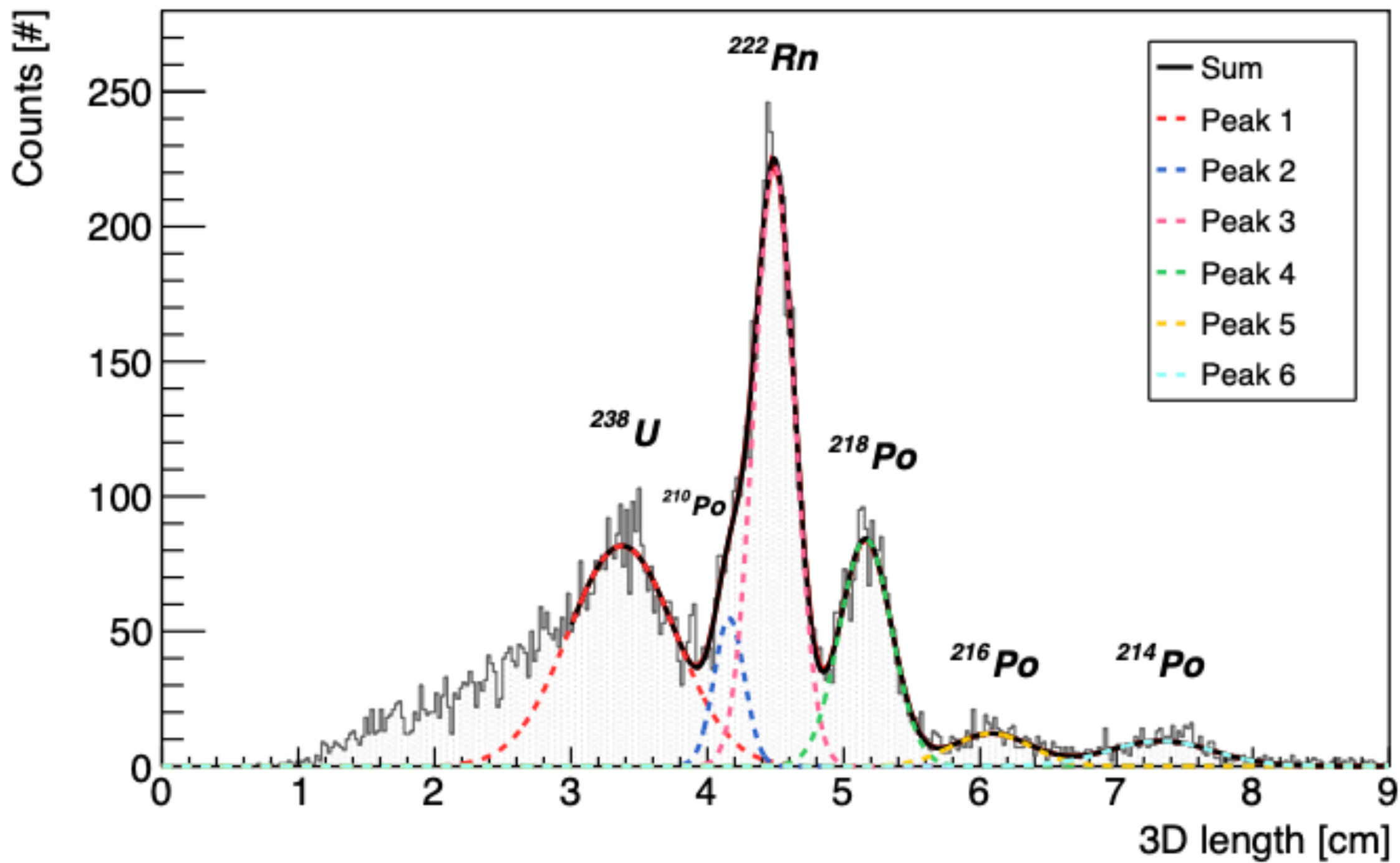


*What alpha-emitting contaminants
are present in LIME?*

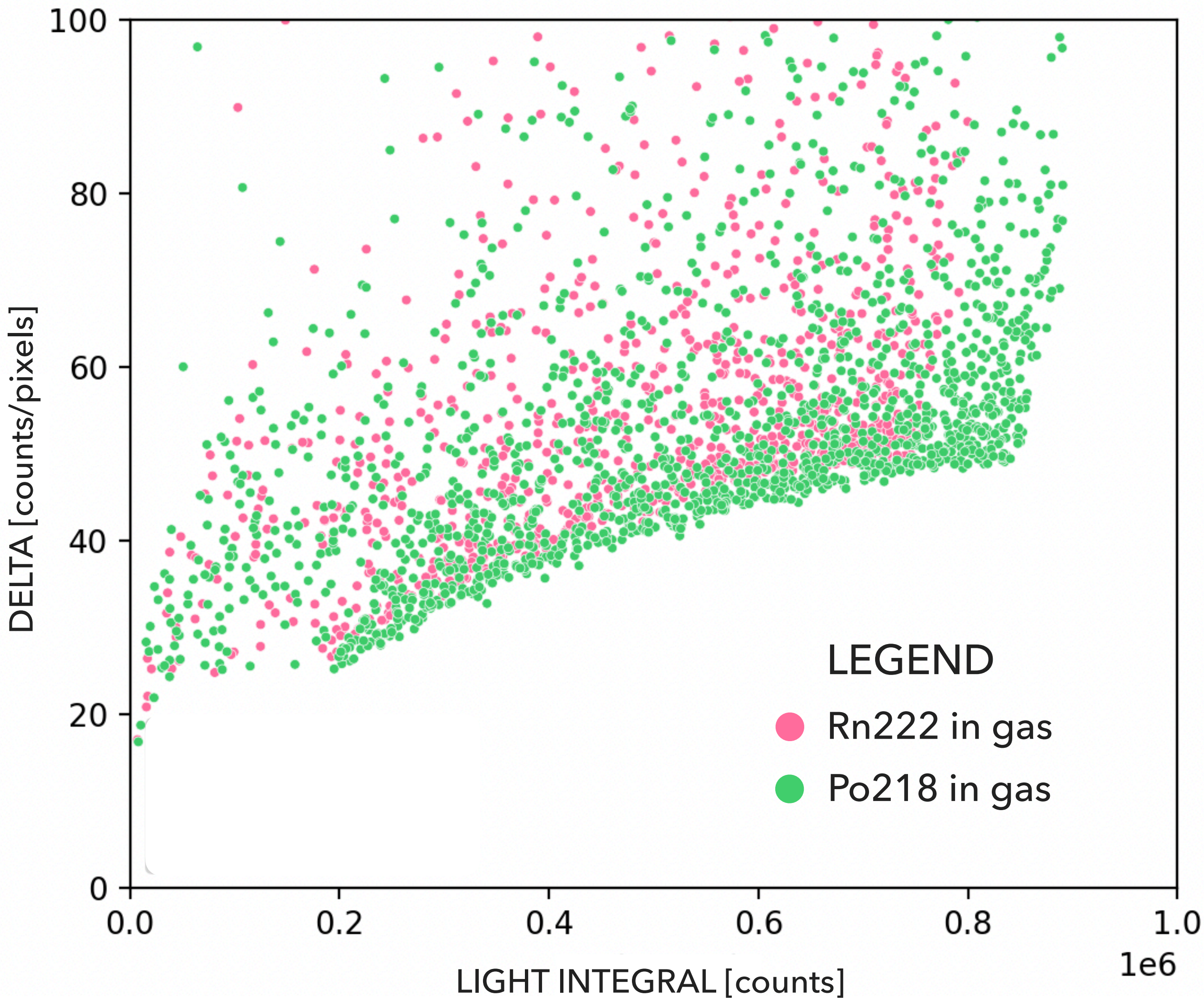
Radon in the gas

Radon daughters

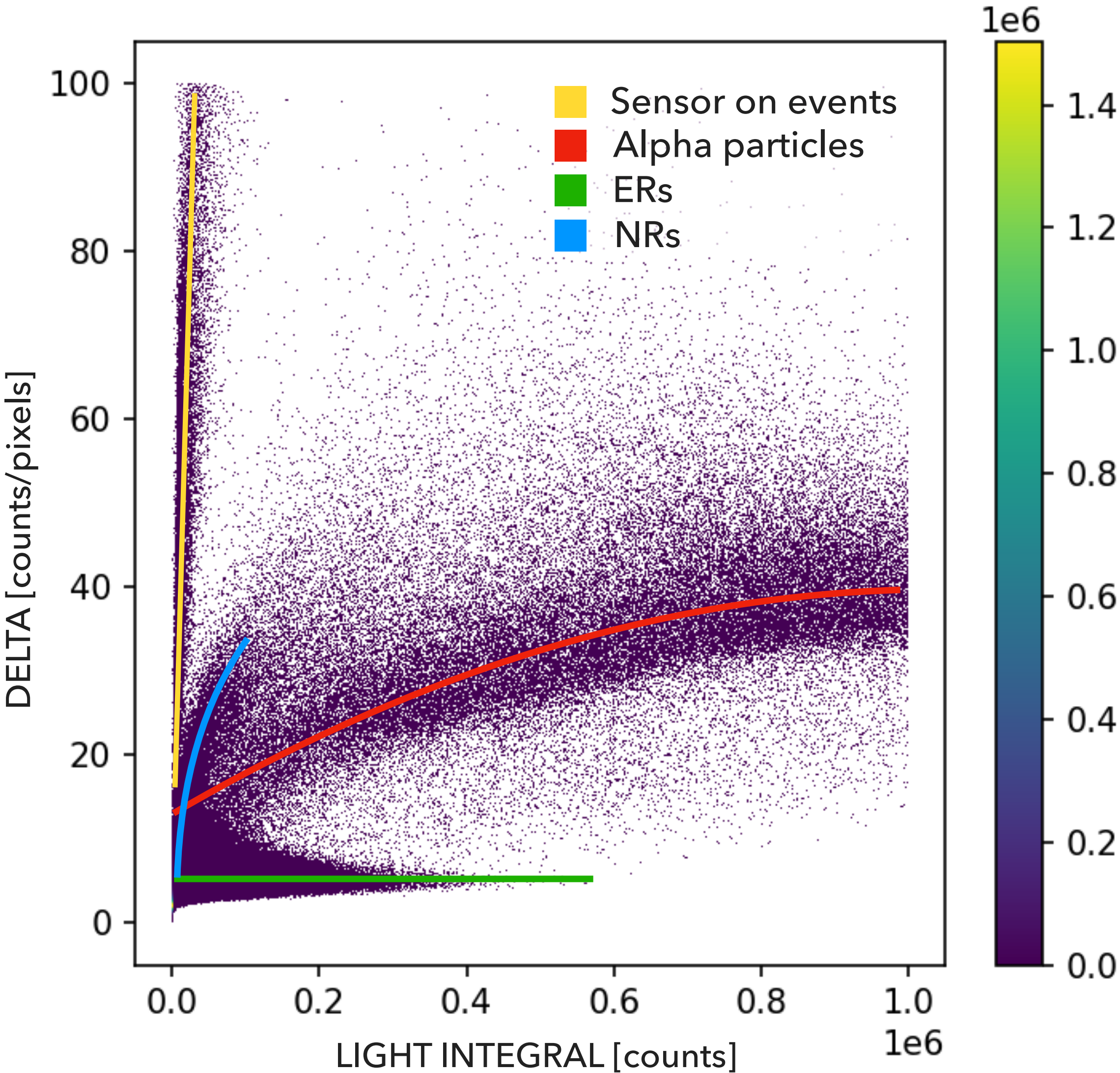
Surface/bulk U-chain contamination



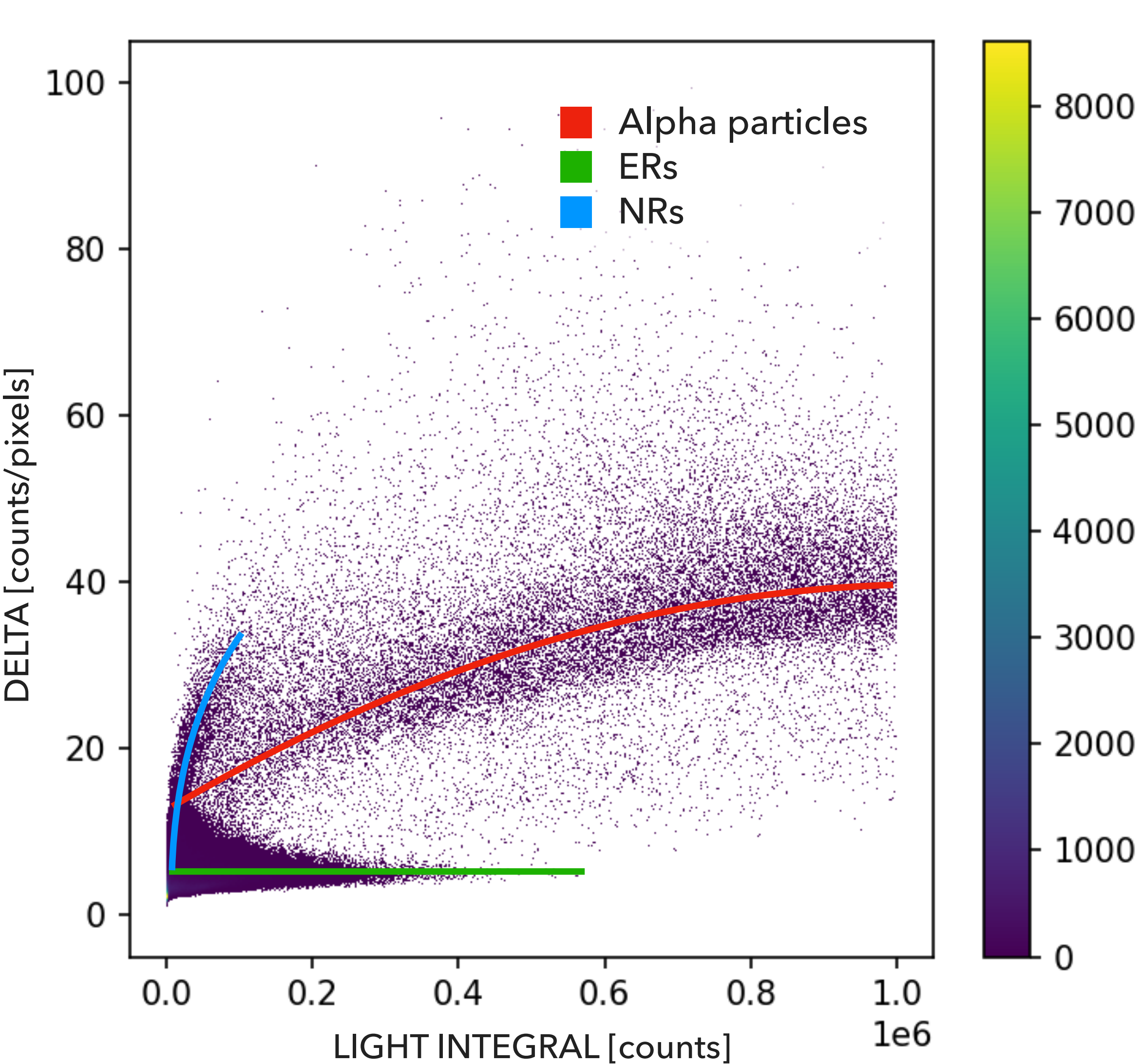
*How do alpha events appear in detector
observables?*

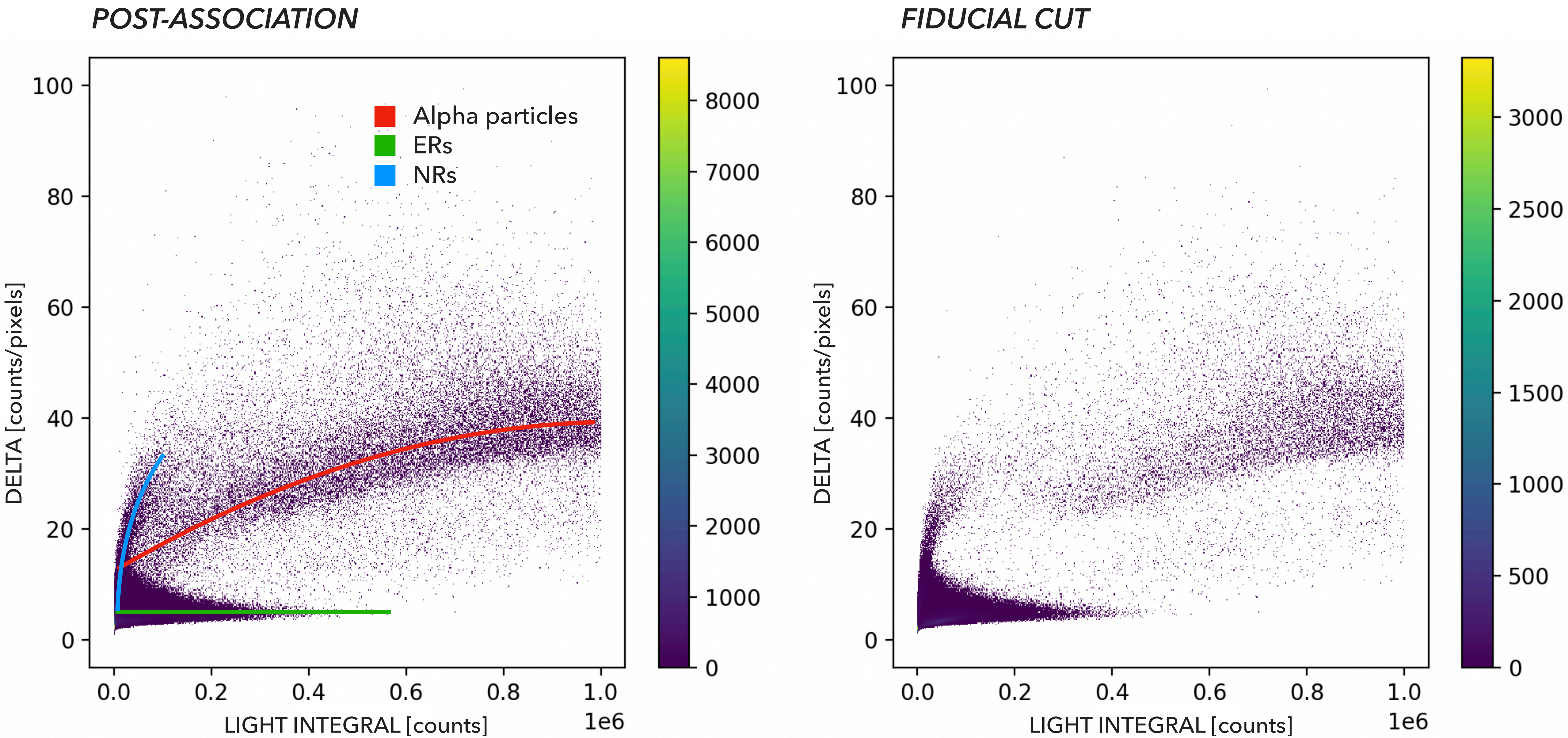


PRE-ASSOCIATION

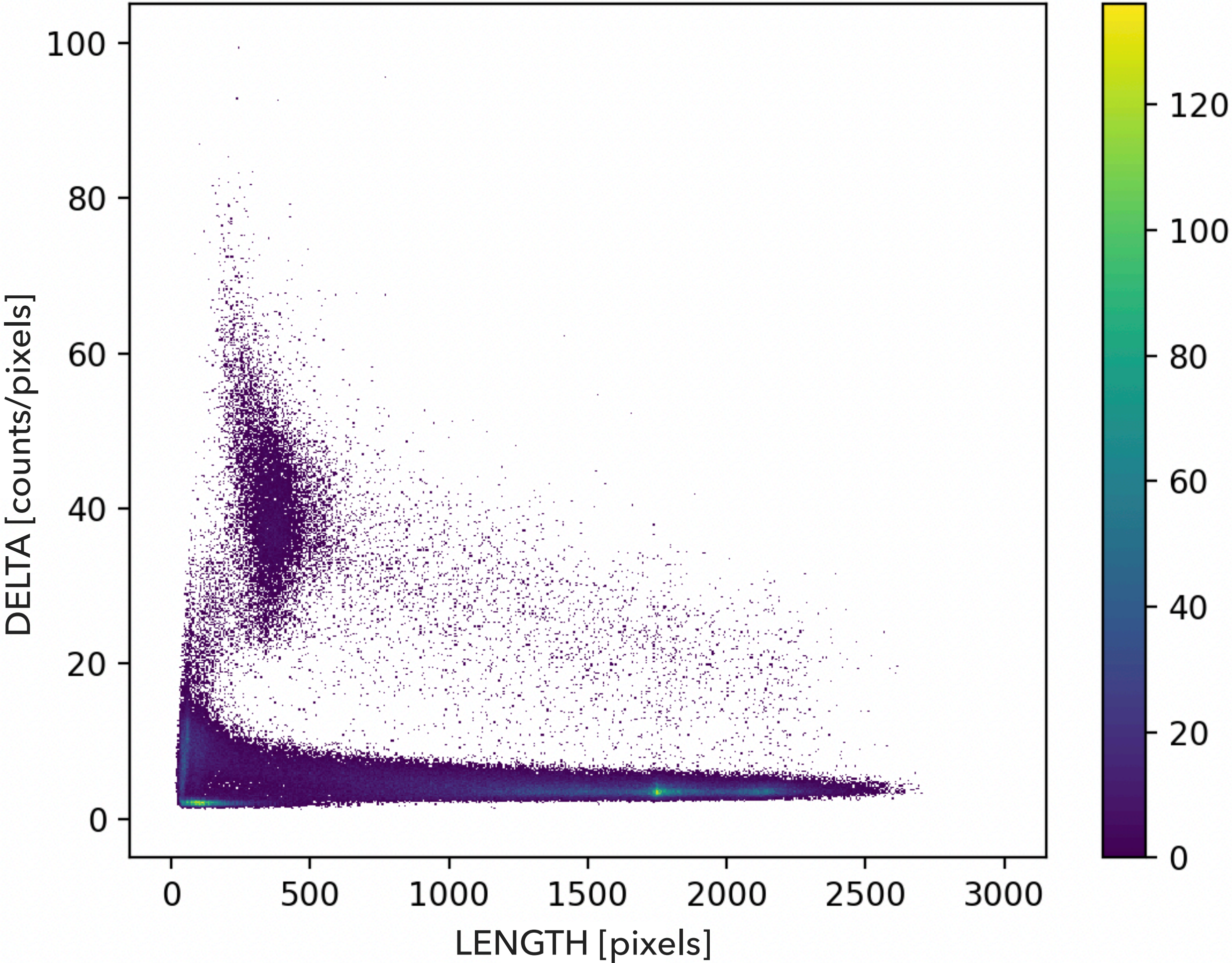


POST-ASSOCIATION

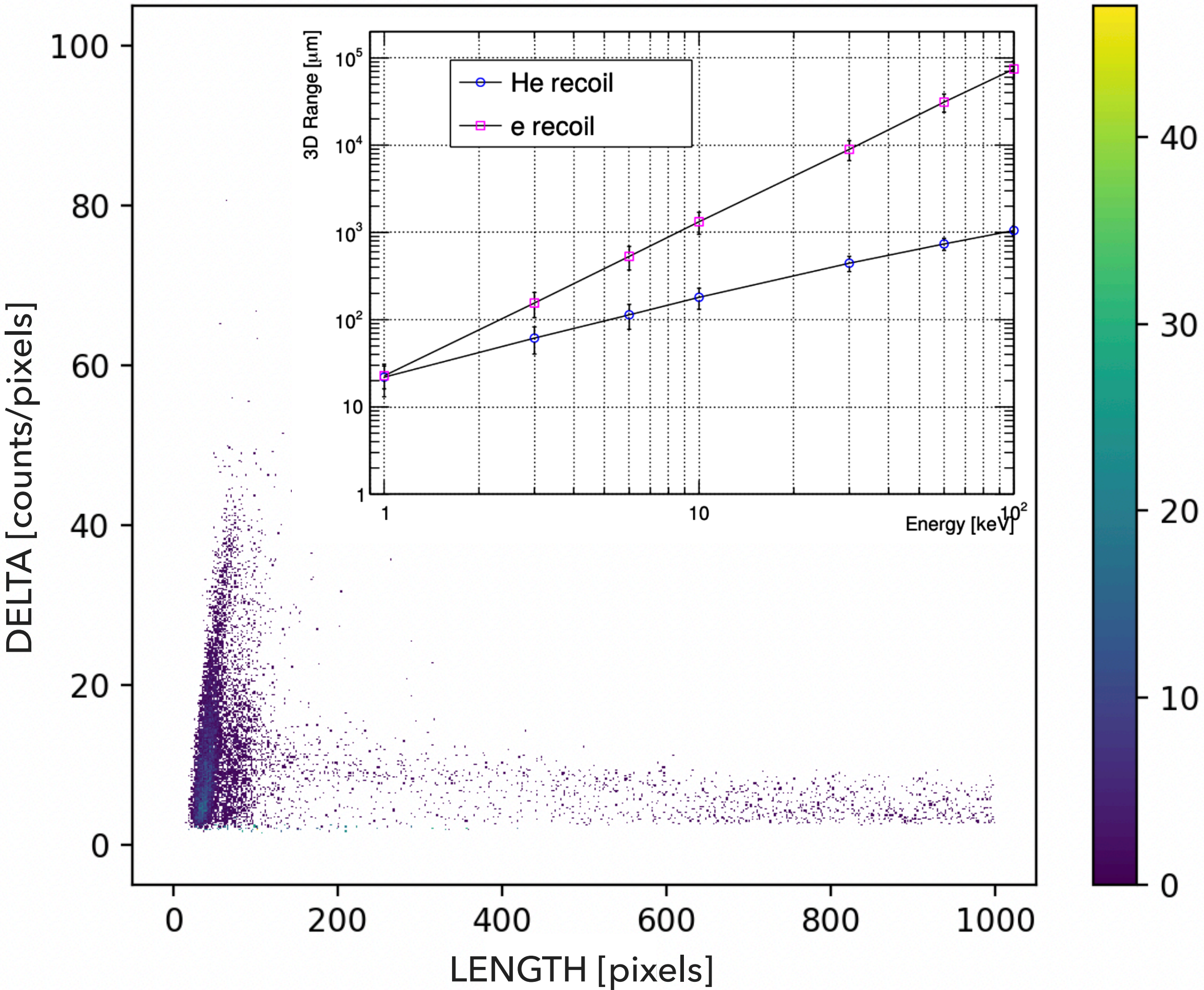




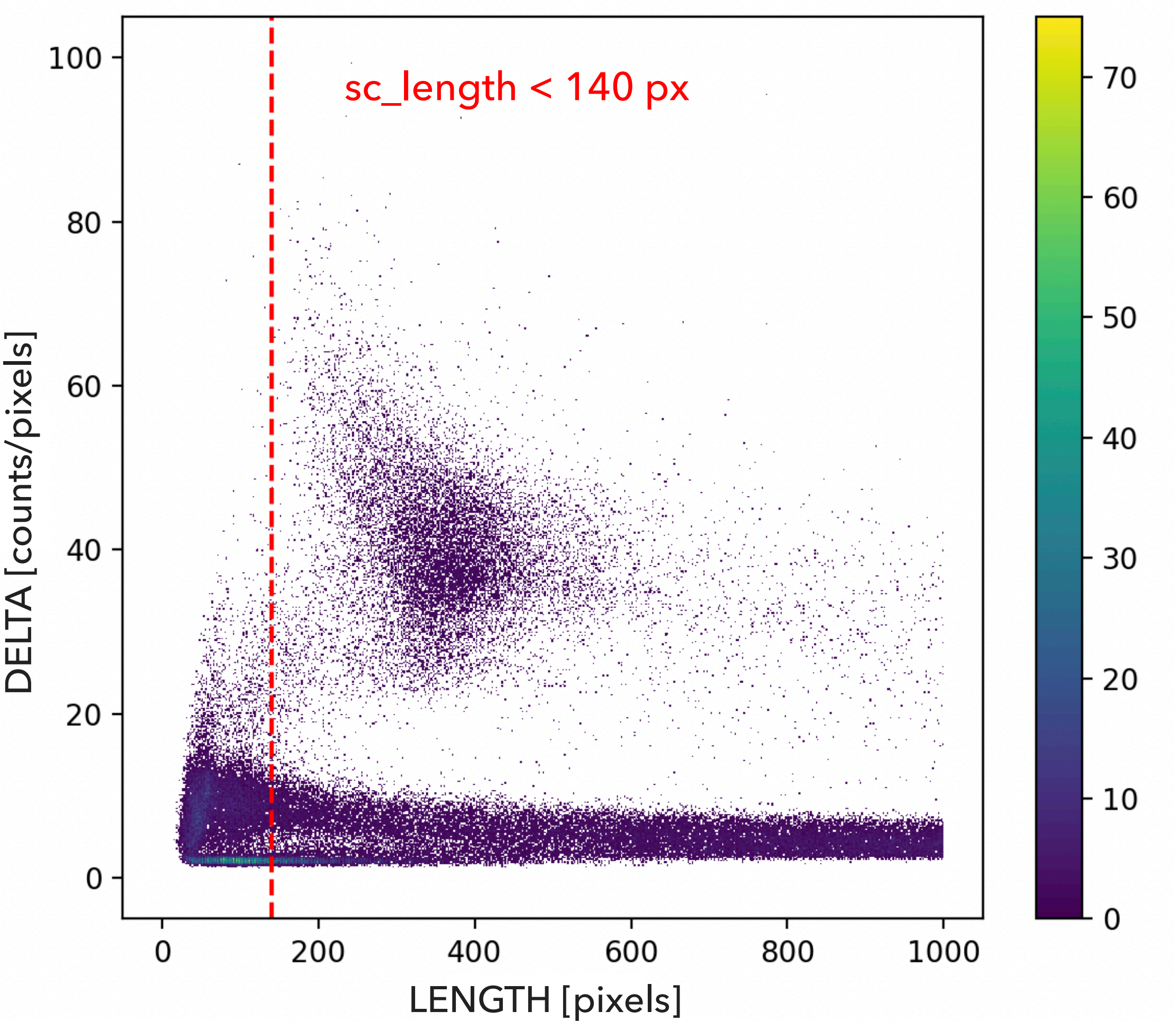
AMBE DATA



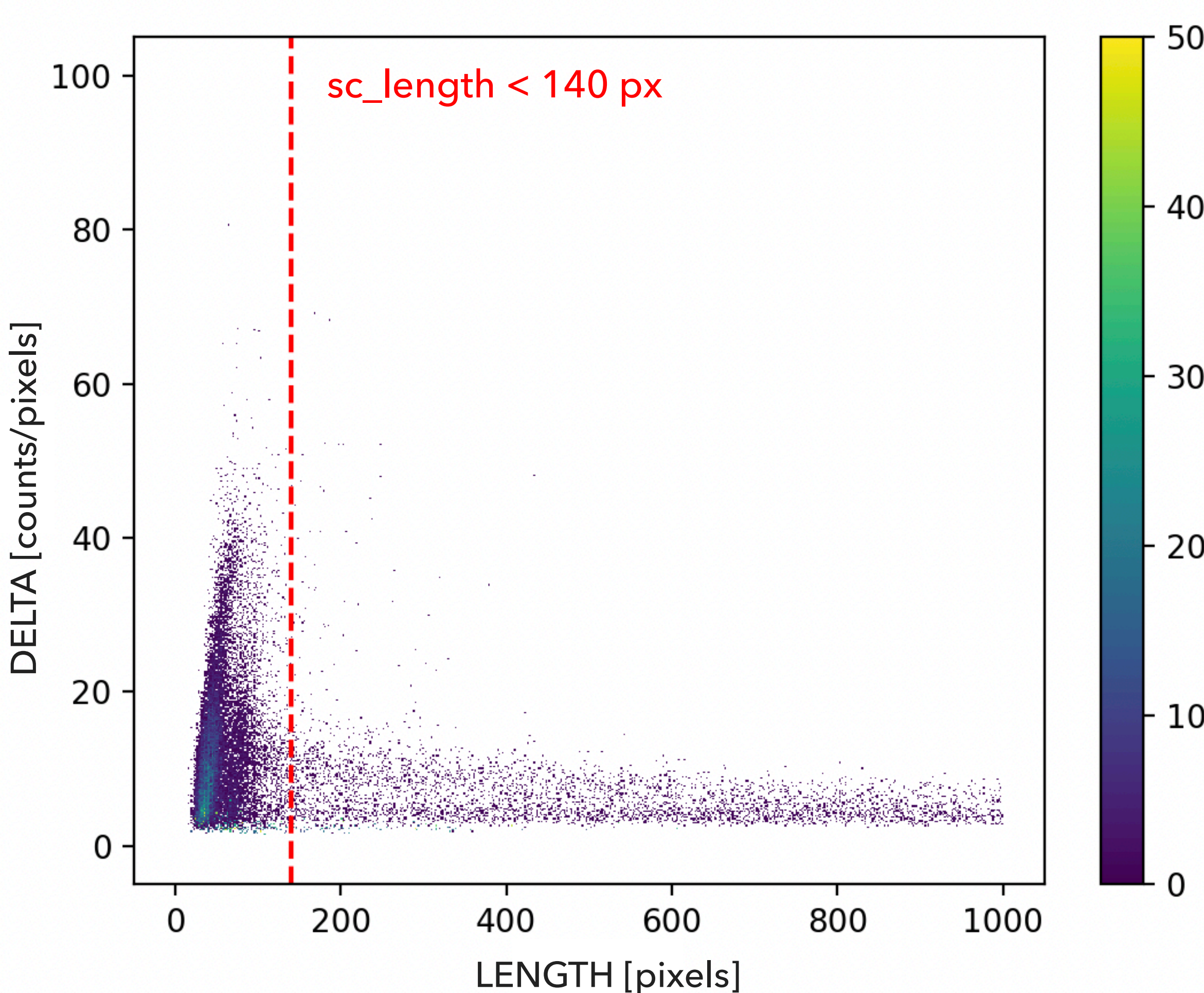
AMBE NEUTRONS SIMULATION



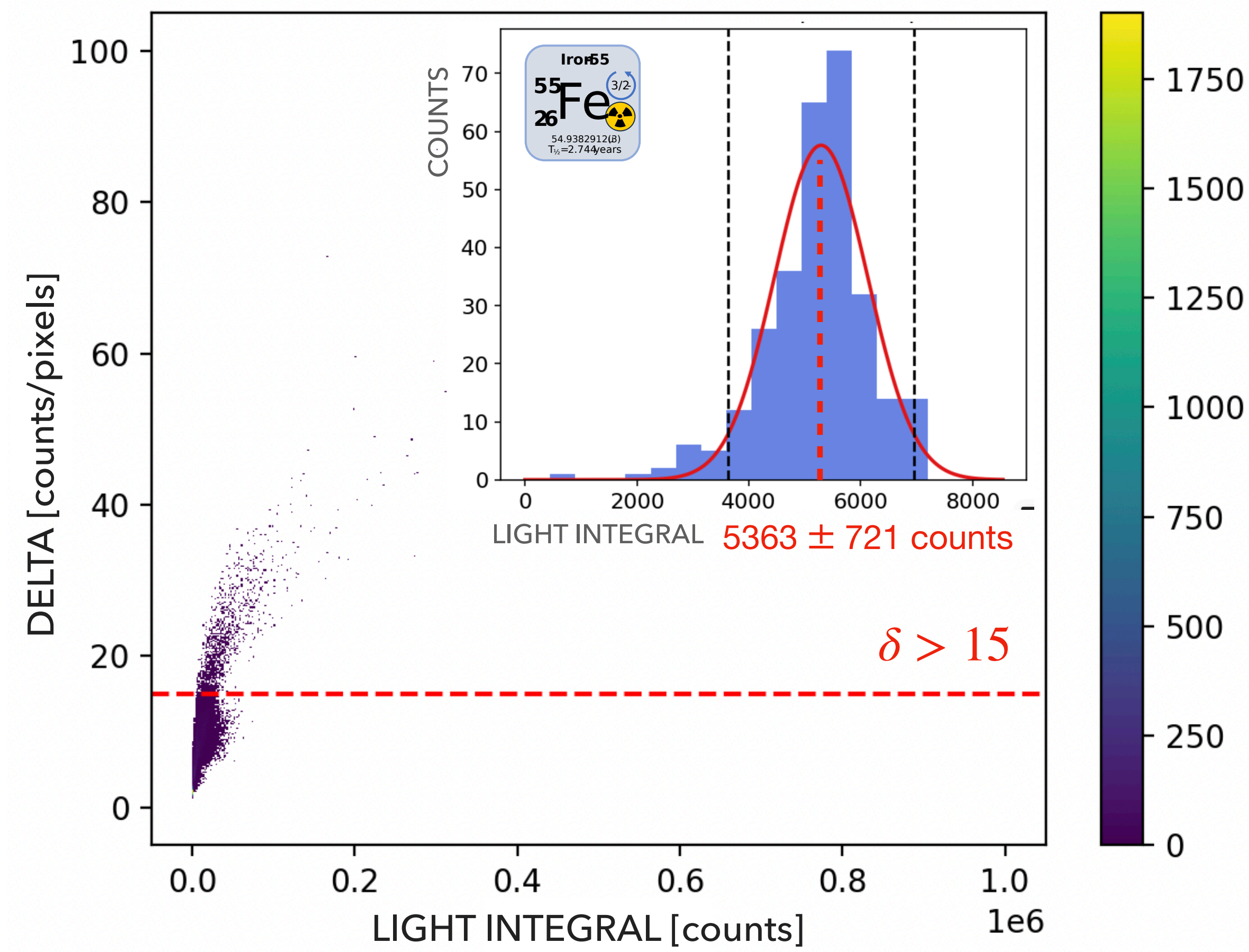
AMBE DATA - ZOOM



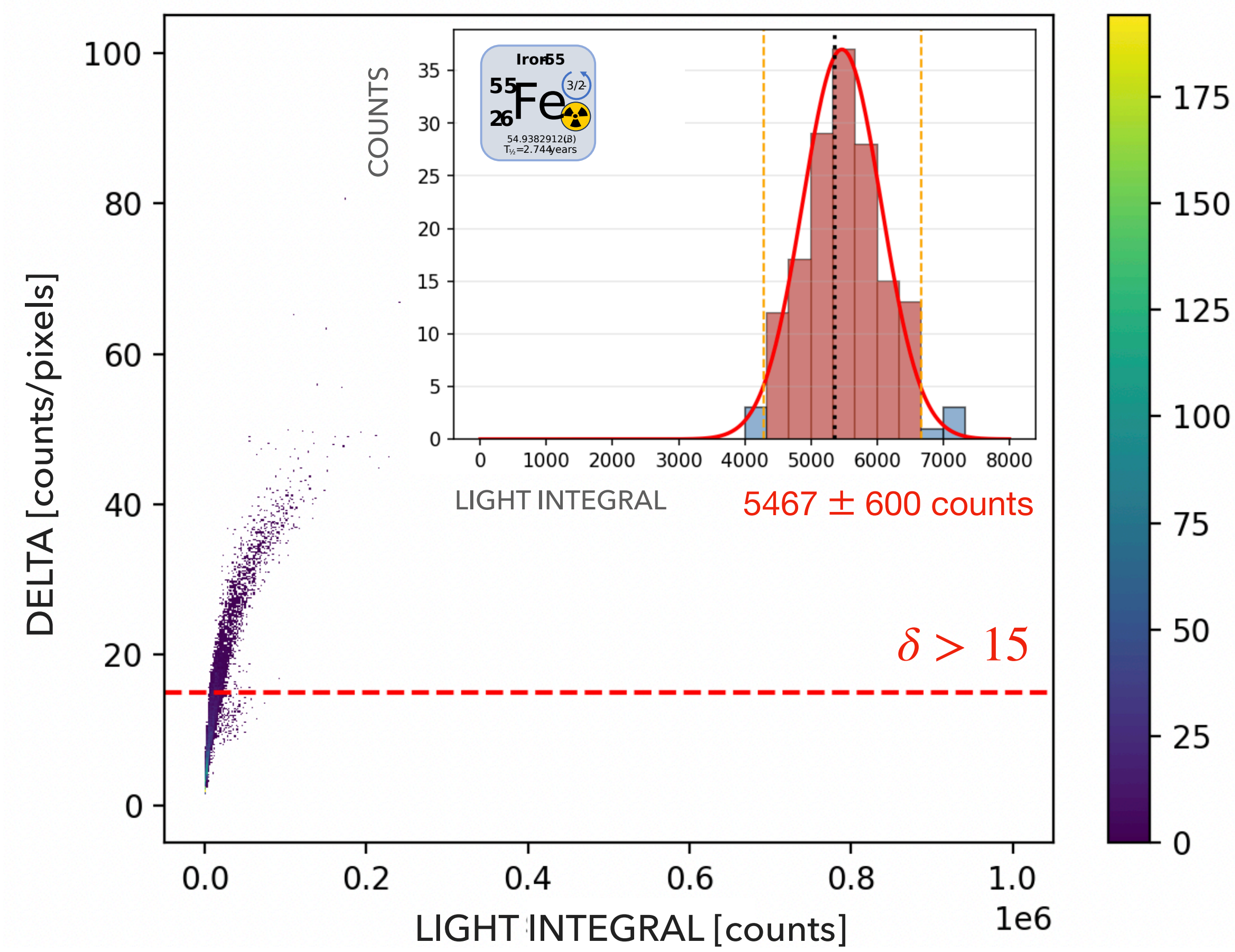
AMBE NEUTRONS SIMULATION - ZOOM



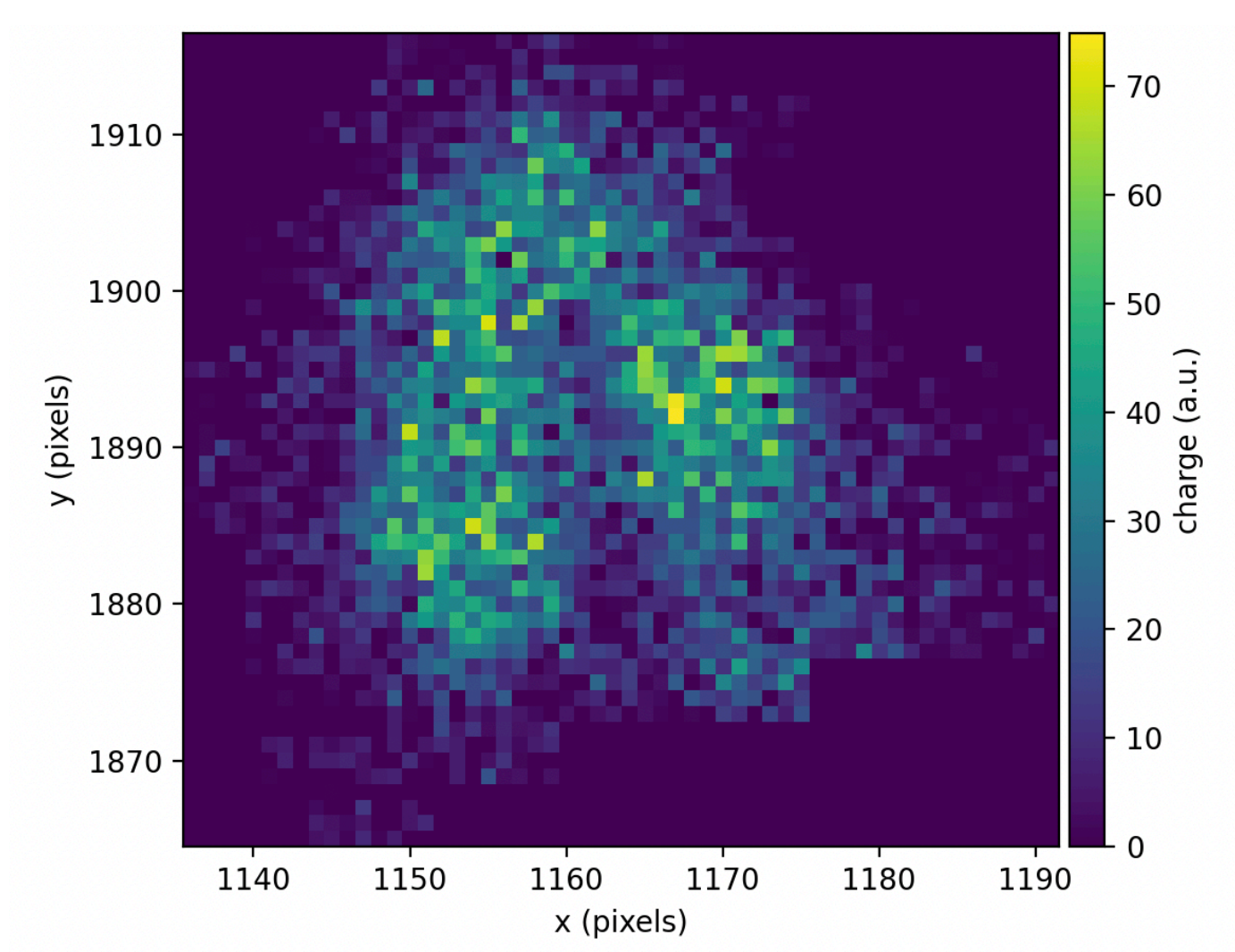
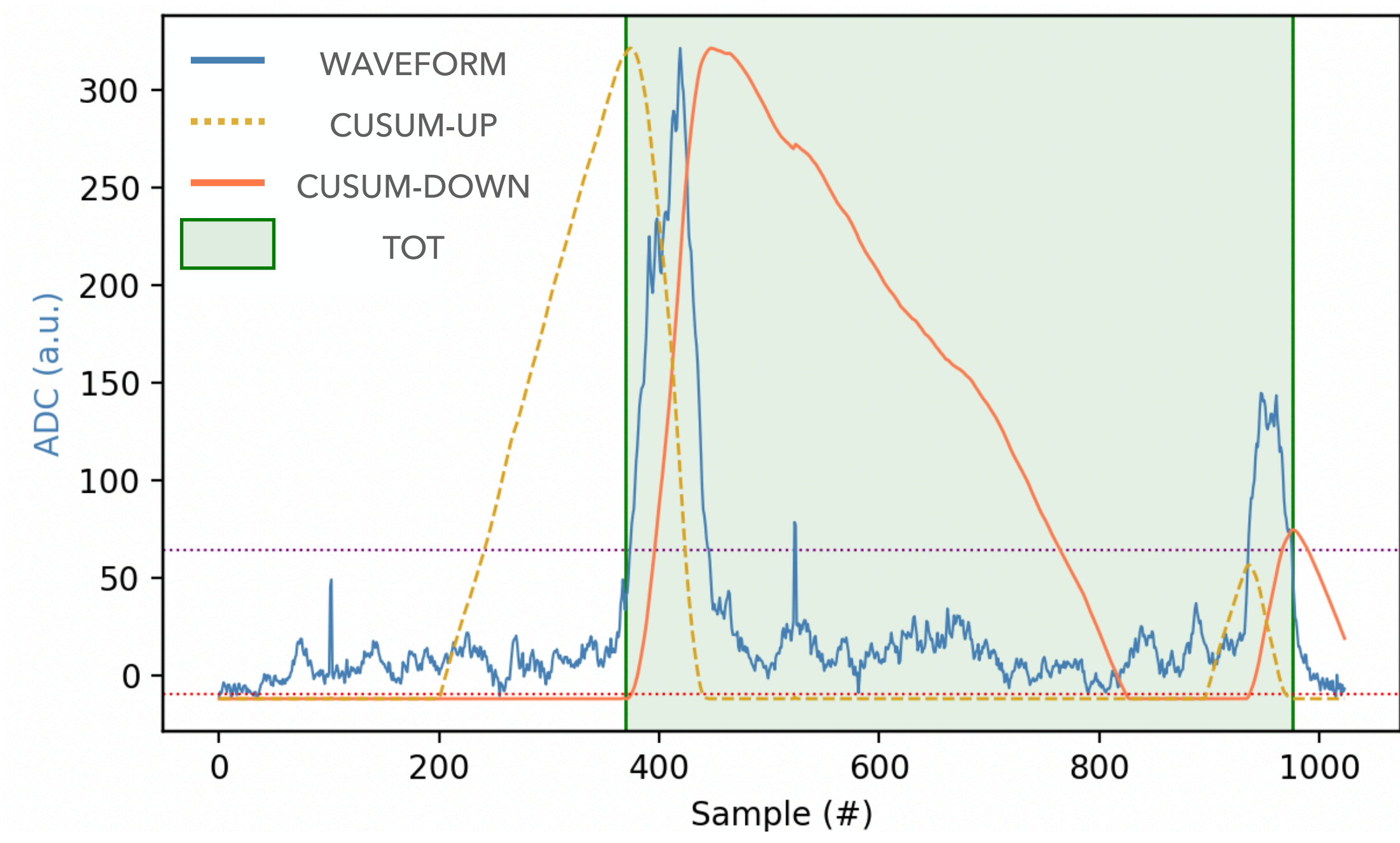
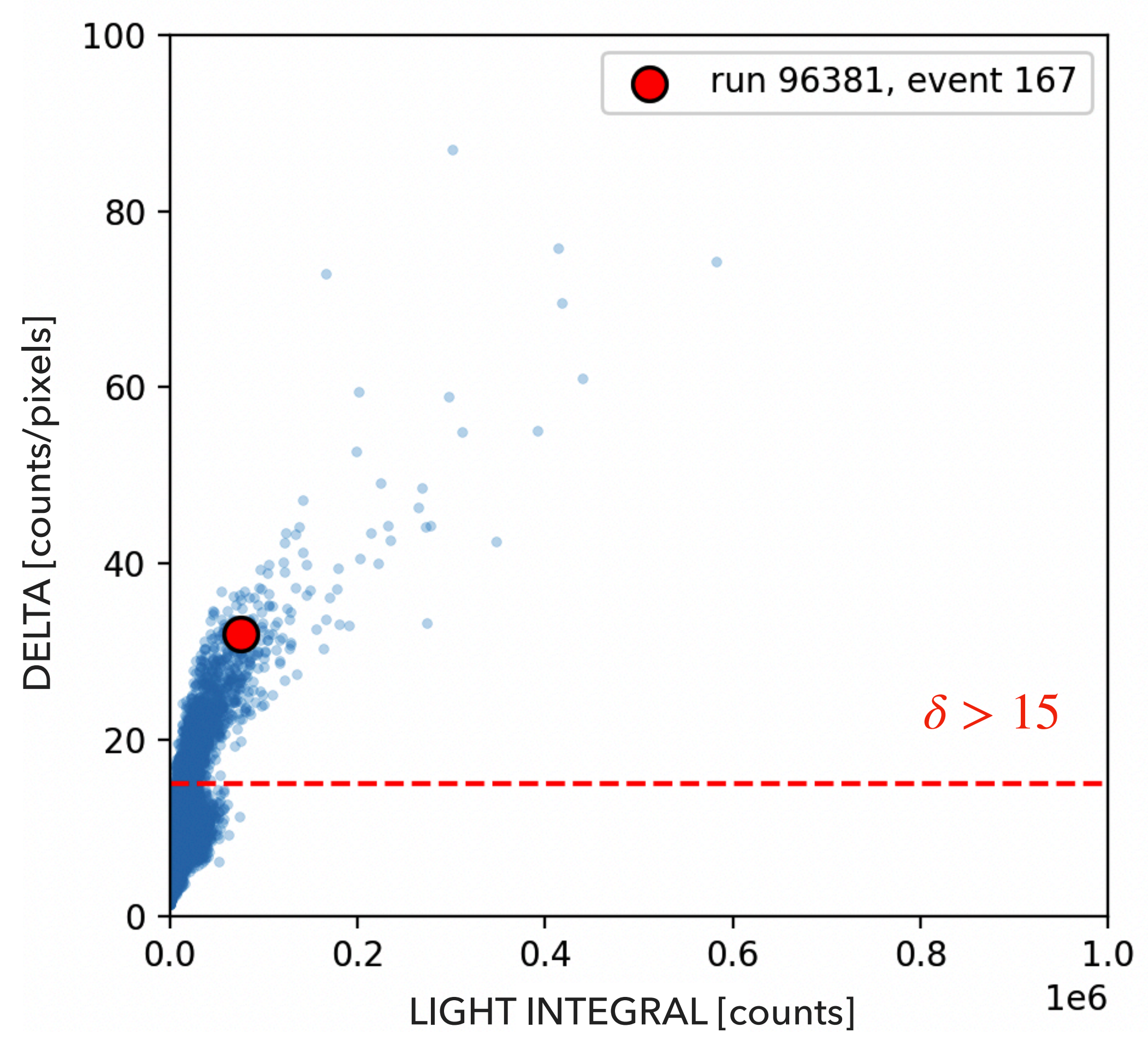
AMBE DATA
(*sc_length* < 140 px)

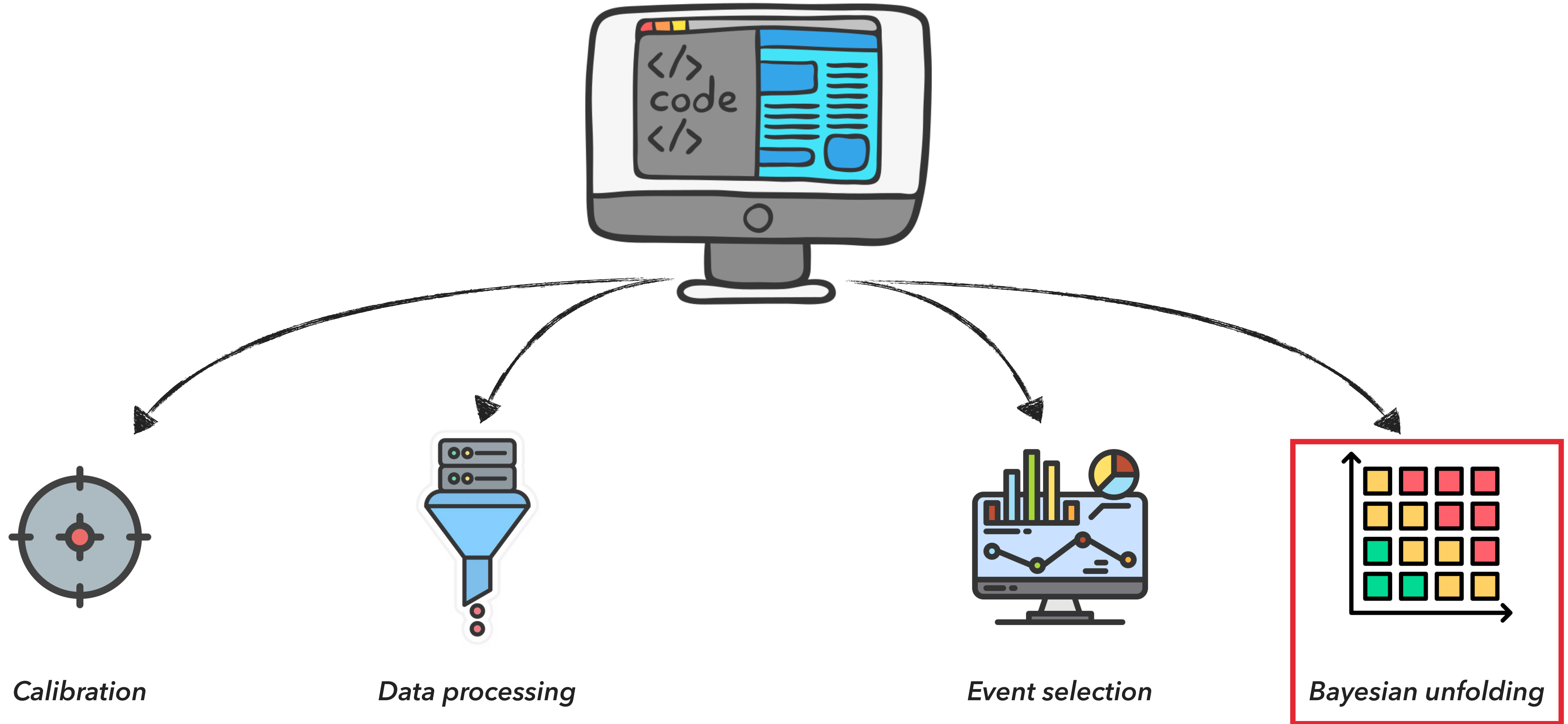


AMBE NEUTRONS SIMULATION
(*sc_length* < 140 px)



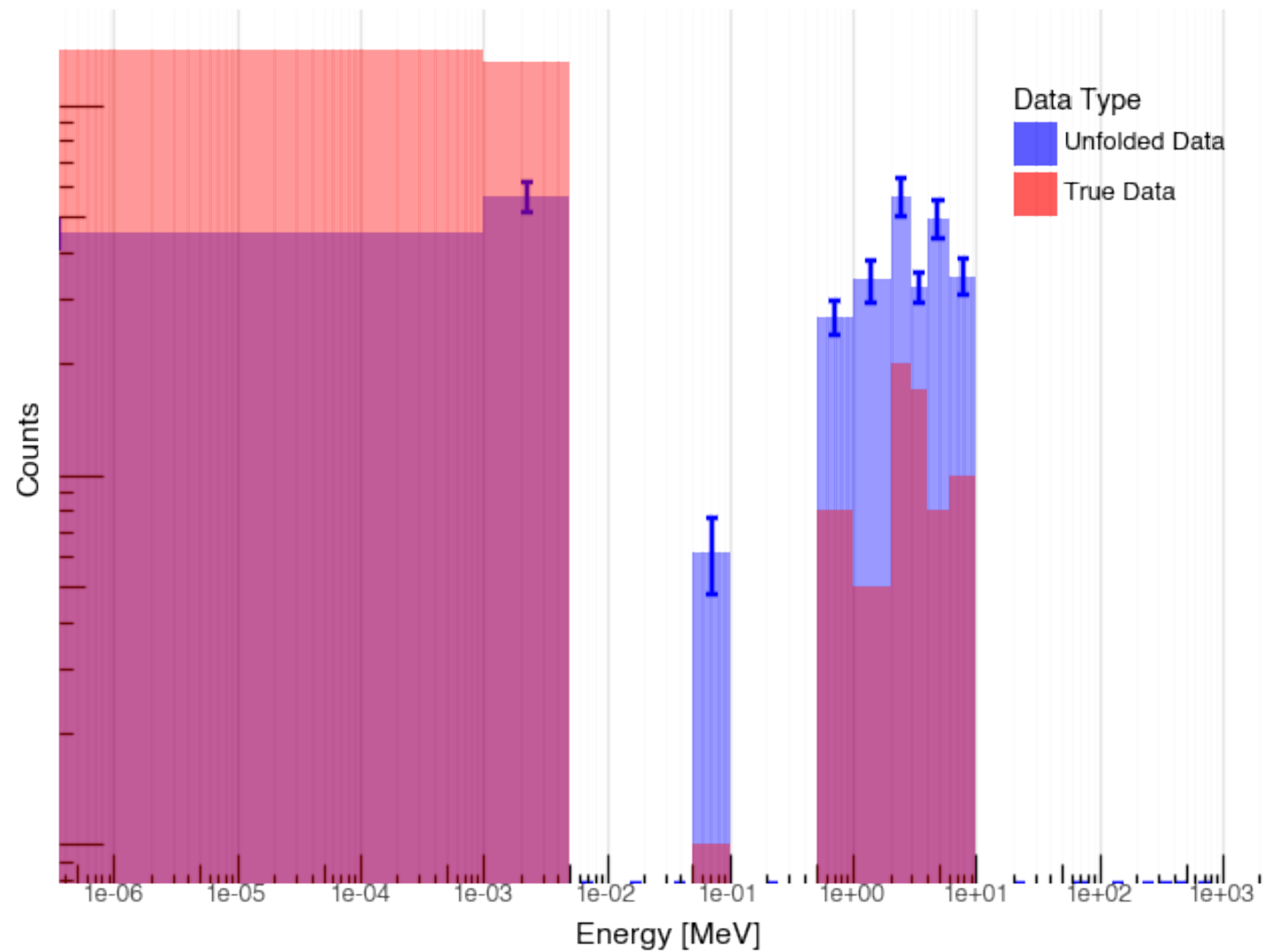
Associated PMT waveforms provide additional observables (e.g. TOT) that may further improve the purity of the selected NR sample





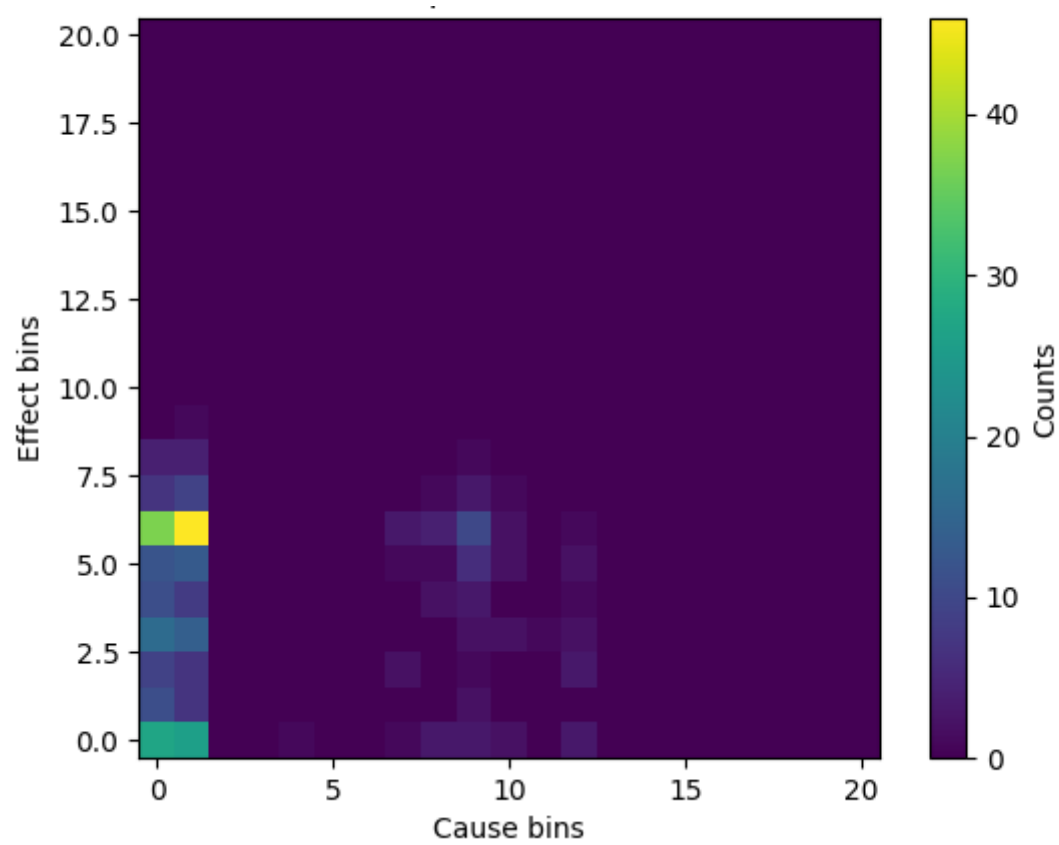
$$\phi(C_\mu) = \sum_{i=1}^{n_E} \frac{P(E_j | C_\mu) P(C_\mu)}{\epsilon_\mu \left[\sum_{\nu}^{n_C} P(E_j | C_\nu) P(C_\nu) \right]} n(E_i)$$

Diagram illustrating the Bayesian iterative unfolding equation. The equation relates the unfolded spectrum $\phi(C_\mu)$ to the true data $n(E_i)$, the response matrix $P(E_j | C_\nu)$, and the efficiency ϵ_μ . The terms $P(E_j | C_\mu)$ and $P(C_\mu)$ are circled in blue and red respectively, with arrows pointing to the 'RESPONSE MATRIX' and 'EFFICIENCY' labels. The term $n(E_i)$ is circled in blue with an arrow pointing to the 'DATA' label.

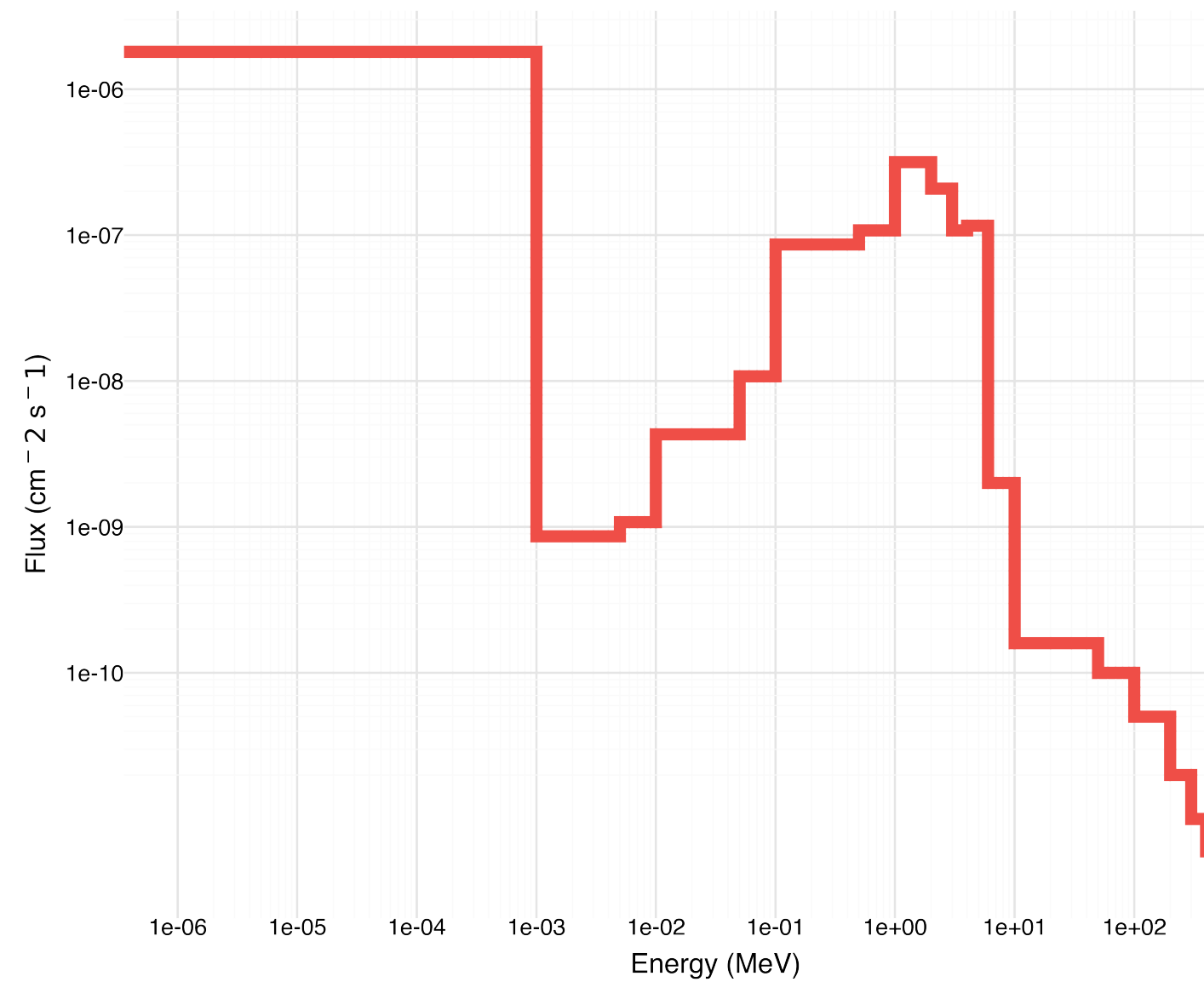


UNFOLDED SPECTRUM

RESPONSE MATRIX



DATA



PRIOR



G. D'Agostini [https://doi.org/10.1016/0168-9002\(95\)00274-X](https://doi.org/10.1016/0168-9002(95)00274-X)



P. Belli et al. / F. Arneodo et al.

NEXT STEPS

- ◎ **Determine detector response matrix**

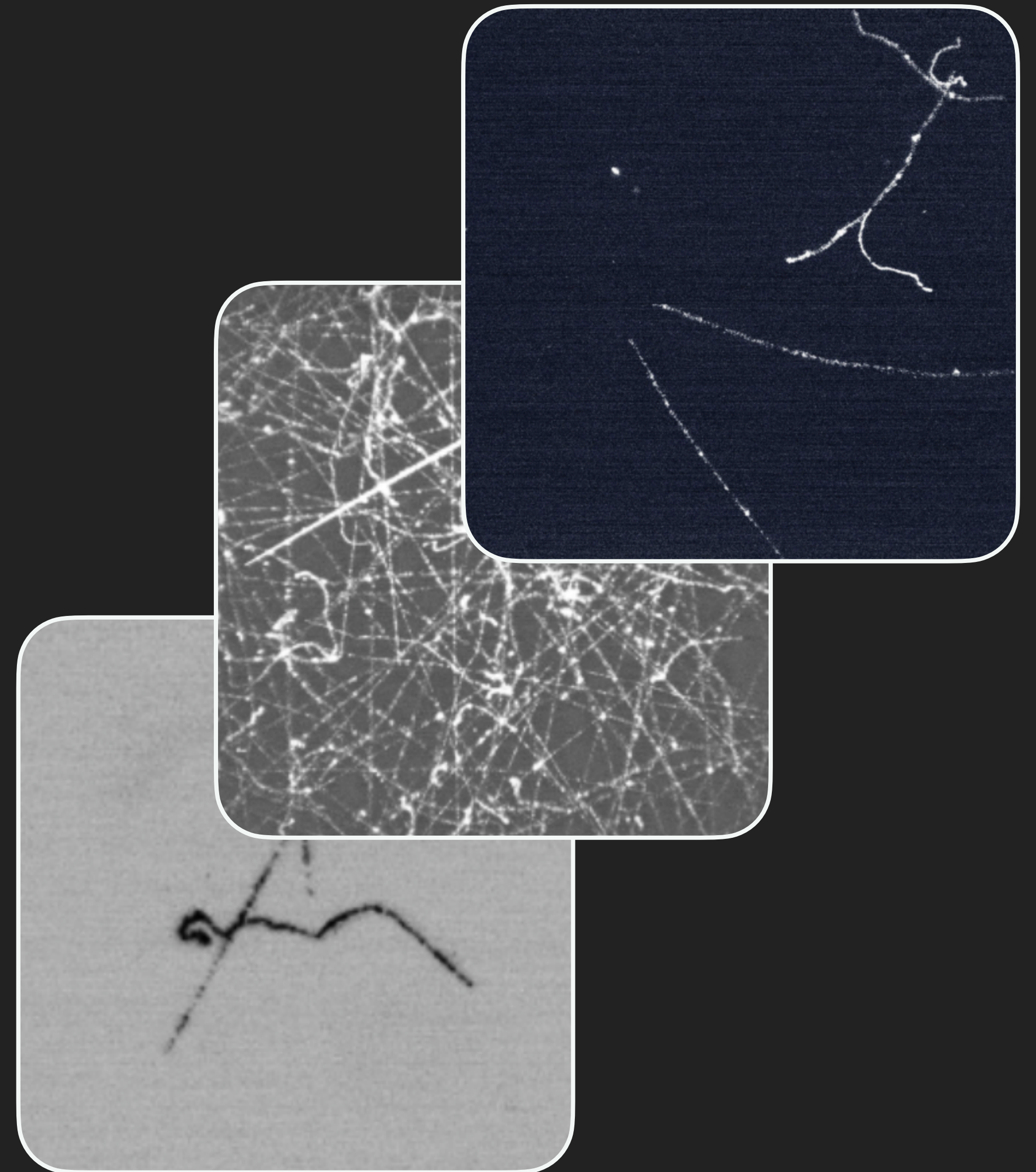
- Test it with different fluxes and priors

- ◎ **Finalize cuts on ambe run**

- Valide the whole pipeline on ambe data
- Determine uncertainties on unfolding procedure

- ◎ **Apply the analysis pipeline on the external neutrons induced recoils**

- ◎ **Estimate underground neutron flux**



BACK-UP

