

Radioactivities of AMoRE Crystals

Sequential alpha decay signatures of surface-related activity in AMoRE-I



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Why this matters

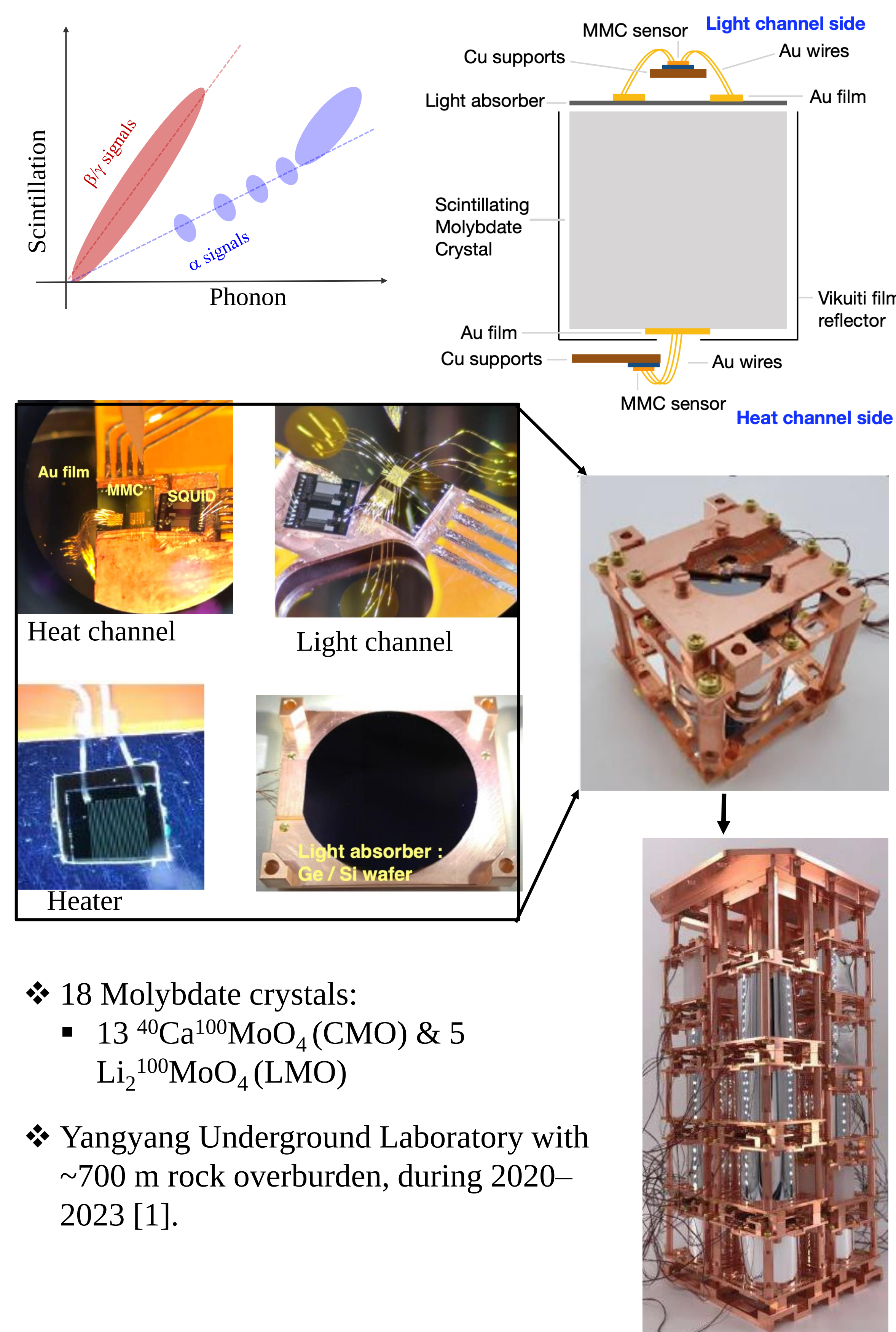
Surface radioactivity is a background-control problem

- AMoRE searches for $0\nu\beta\beta$ of ^{100}Mo with cryogenic molybdate crystals.
- Surface decays can produce degraded α continua and associated β/γ background near the ROI.
- Time correlated α sequences provide information on event topology that is not available from the energy spectrum alone.

Goal: Identify the ^{232}Th -chain sequence event-by-event and compare the surface-like population across AMoRE-I crystals.

Detector concept

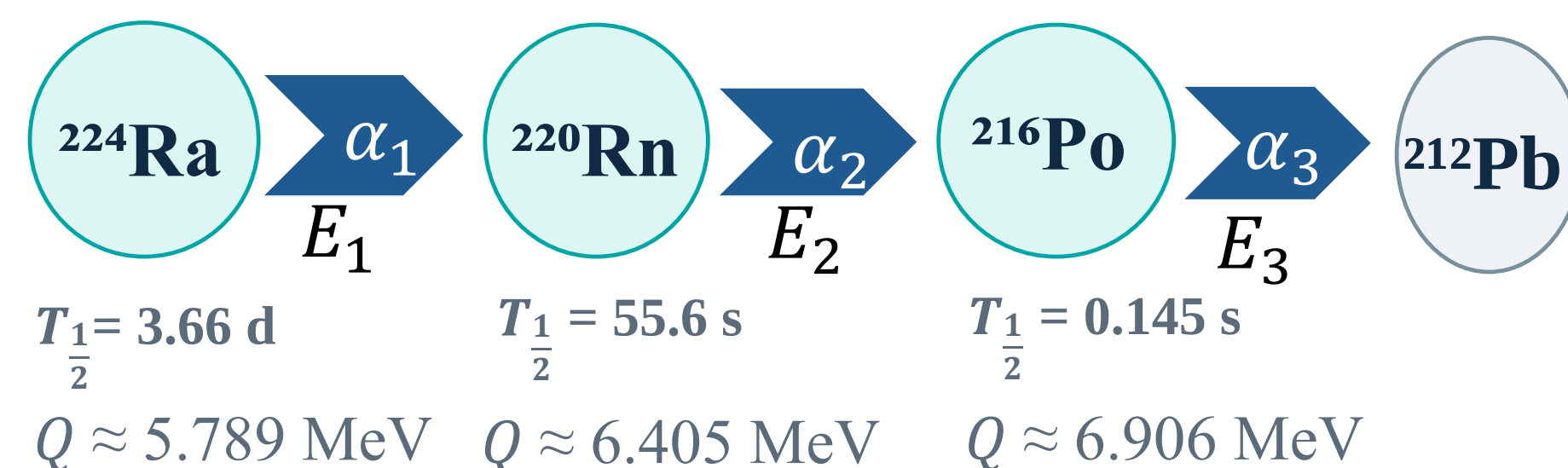
- Simultaneous read-outs of phonon and photon with scintillating calorimeters for α rejection.



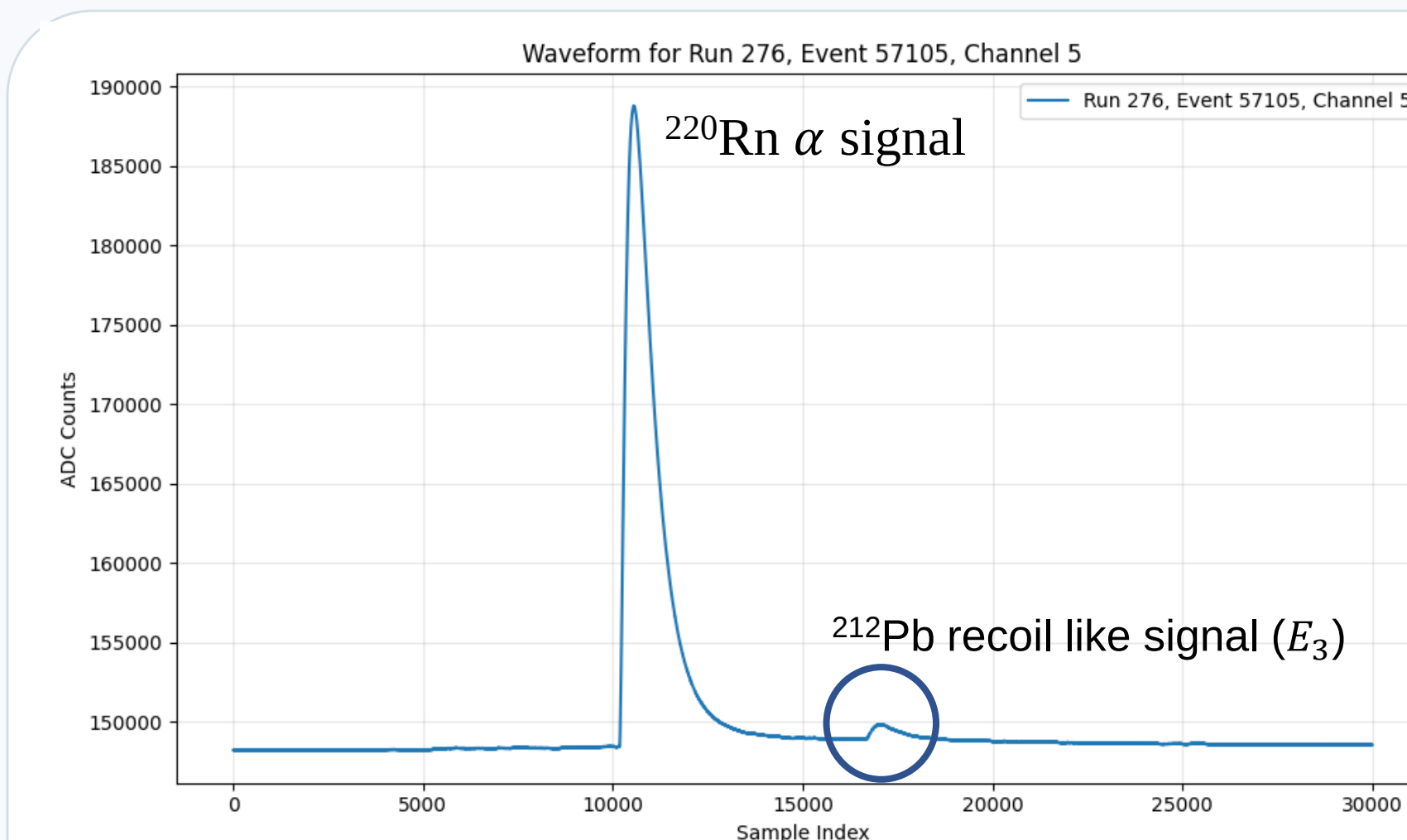
- 18 Molybdate crystals:
 - 13 $^{40}\text{Ca}^{100}\text{MoO}_4$ (CMO) & 5 $\text{Li}_2^{100}\text{MoO}_4$ (LMO)
- Yangyang Underground Laboratory with ~ 700 m rock overburden, during 2020–2023 [1].

Sequential alpha signals

Characteristics ^{232}Th -chain sequence



- E_1, E_2 and E_3 are the reconstructed energies of the 1st, 2nd and 3rd signals in the decay
- The calorimeter records the total deposited decay energy when α + daughter recoil are both contained.
- Near a surface, one particle can escape, producing a degraded or recoil-like third pulse.



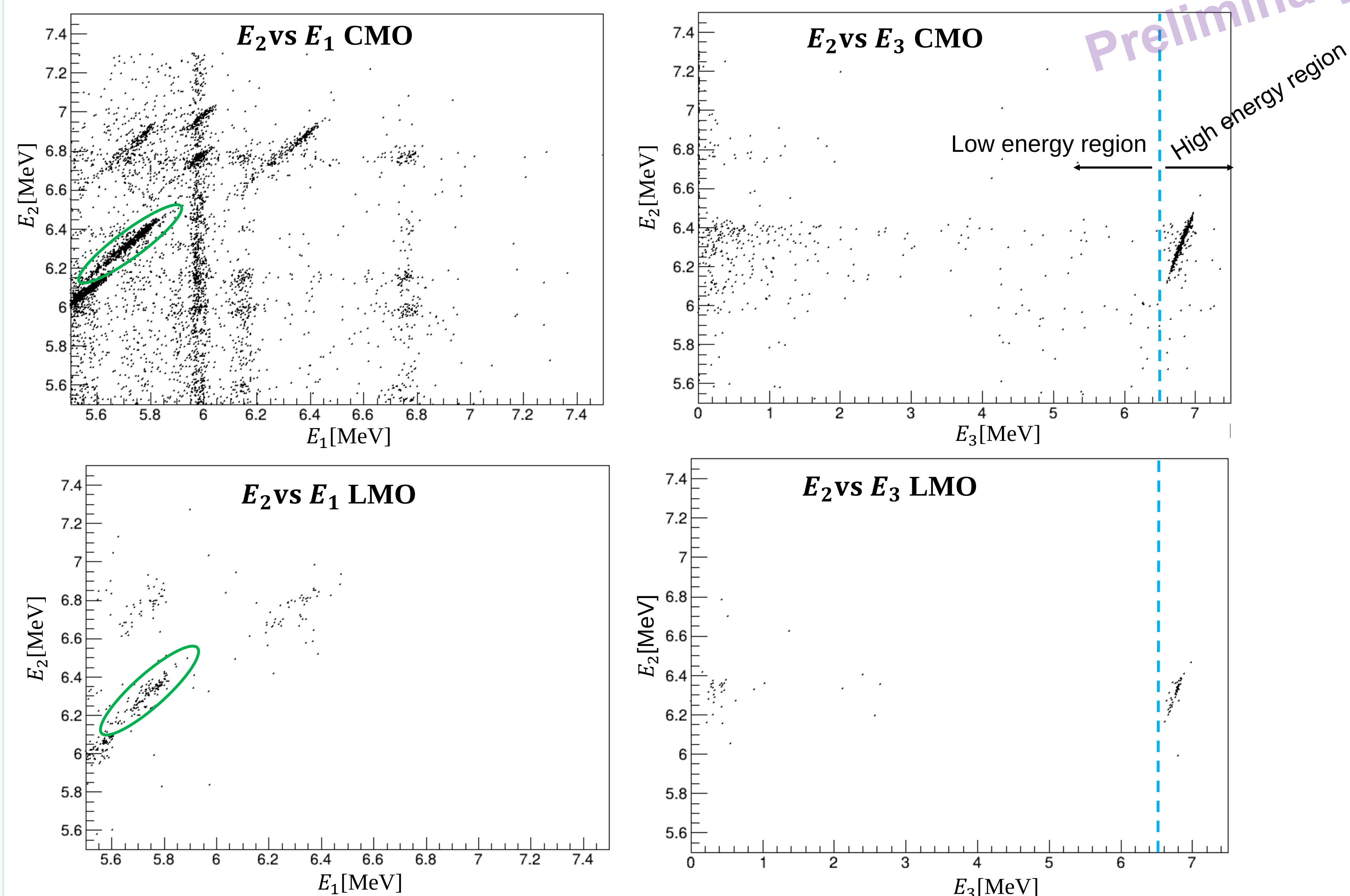
Use “third pulse (E_3)” for the full selected population: low-energy events are not necessarily full-energy α deposition

❖ Tag windows

- α_1 to α_2
 - $5.5 \text{ MeV} < E_2 < 7.5 \text{ MeV}$
 - $\Delta t_{12} < 10 \times T_{1/2}$ of ^{220}Rn (556 s)
- α_2 to α_3
 - $\Delta t_{23} < 10 \times T_{1/2}$ of ^{216}Po (1.45 s)

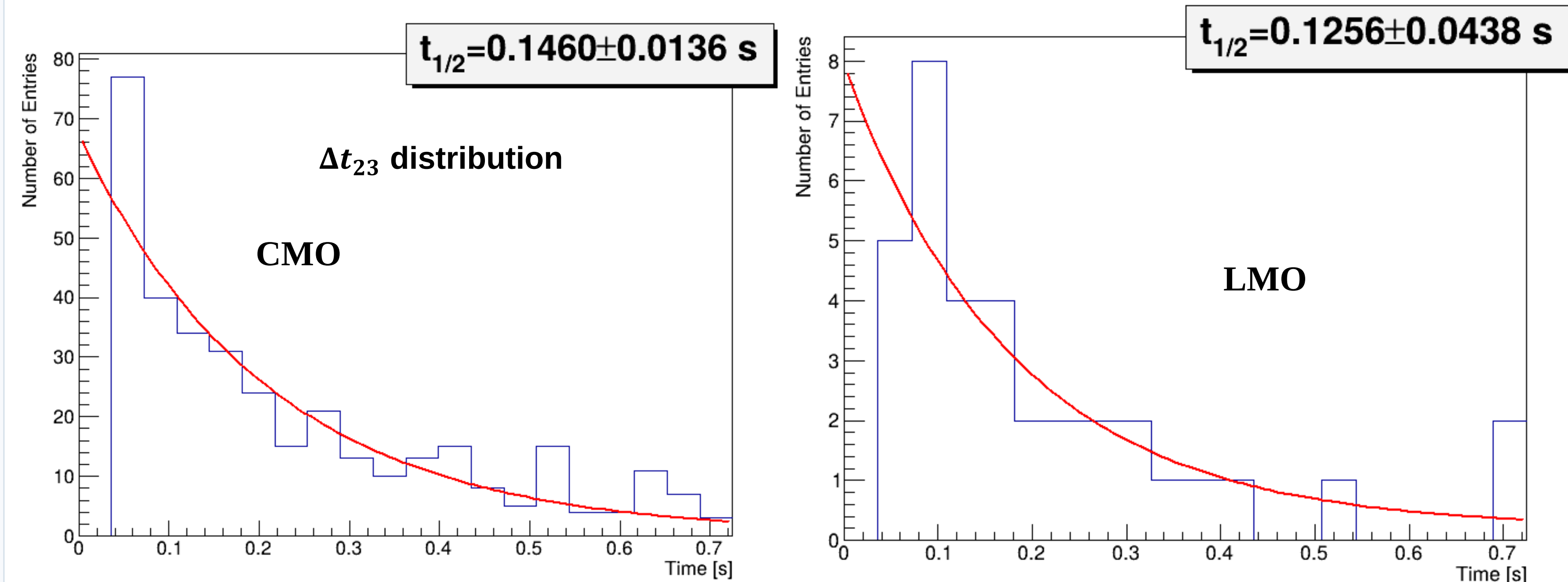
Sequential-alpha validation: Energy topology and timing

E_2 vs E_3 shows two populations



Why the third-pulse timing is decisive?

- For a genuine ^{216}Po daughter, the delay from E_2 to E_3 should follow an exponential with $T_{1/2} \approx 0.145 \text{ s}$.

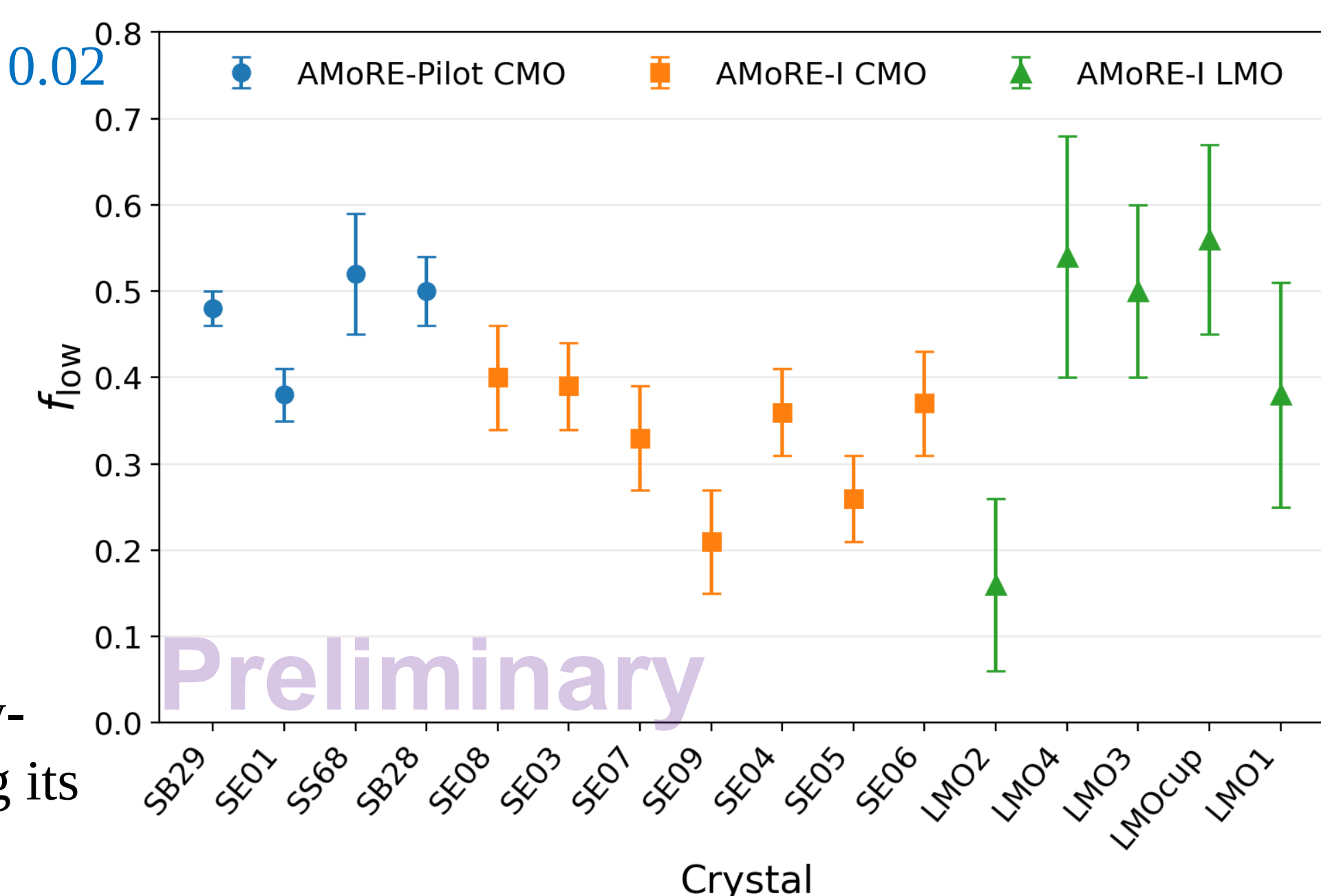


Low-energy third-pulse fraction

Average fraction:

- CMO reused from AMoRE-Pilot [2, 3]: 0.47 ± 0.02
- AMoRE-I CMO: 0.33 ± 0.03
- AMoRE-I LMO: 0.43 ± 0.05

$$f_{\text{low}} = \frac{N(E_3 < 6.5 \text{ MeV})}{N(\text{selected third pulses})}$$



Summary and Outlook

- Sequential $^{224}\text{Ra} \rightarrow ^{220}\text{Rn} \rightarrow ^{216}\text{Po}$ α events are identified using energy and time correlation.
- The $E_3 < 6.5 \text{ MeV}$ population has E_2 -to- E_3 delay-time distribution consistent with ^{216}Po , supporting its interpretation as surface-like population.
- The low energy fraction shows clear crystal/group dependence, whose physical origin is not yet understood.
- Investigate the origin of the crystal-group dependence, especially Pilot CMO vs AMoRE-I CMO.
- Evaluate detection/selection efficiencies and systematic uncertainty
- Test the robustness of the low-/high-energy classification and the 6.5 MeV boundary.
- Perform a quantitative surface/volume decomposition only after these effects are constrained.