How low can you go?

Ultra-low background measurements for next gen experiments.

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SNO Day – 2025-06-25

There are many motivations. One is …

LEGEND will put an ASIC chip right on each bare Germanium crystals.

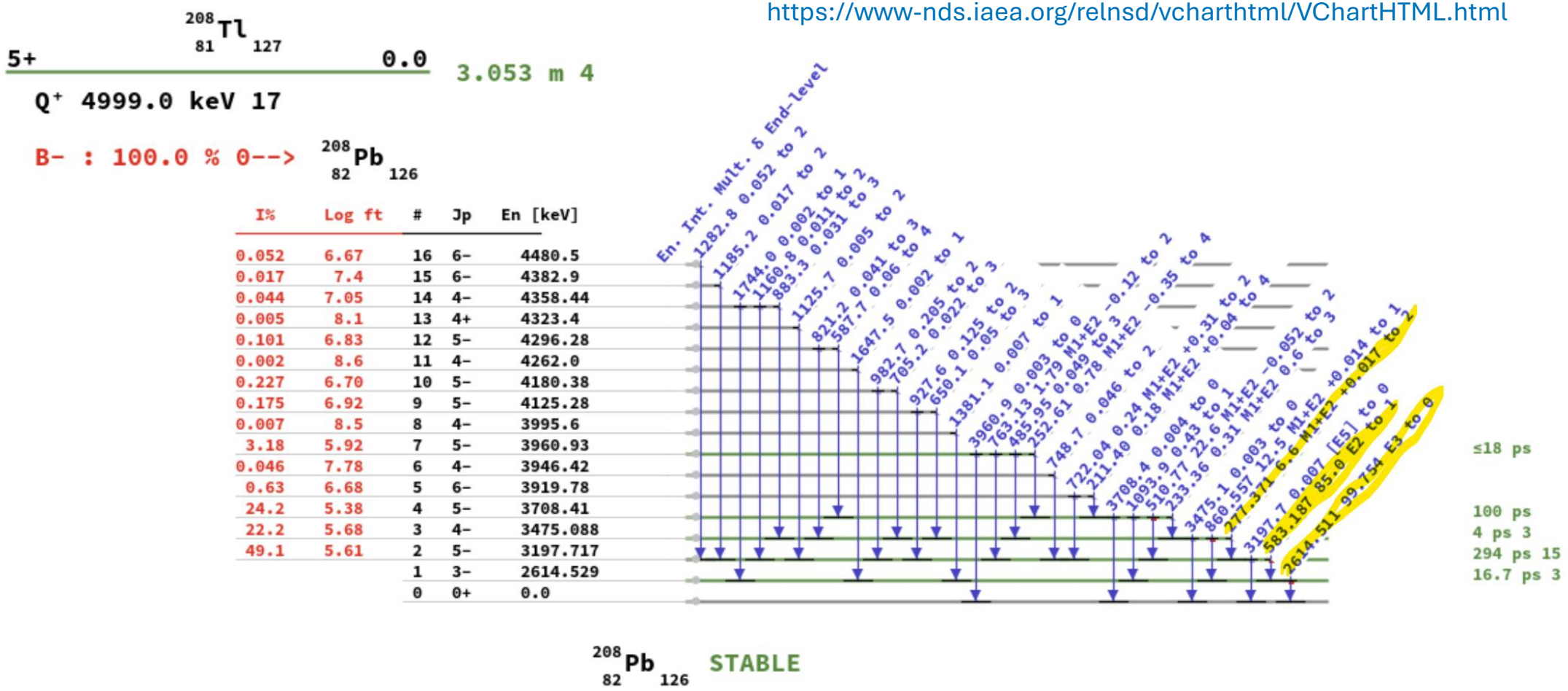
Both Tl-208 and Bi-214 produce gamma rays that overlap the signal energy, 2039 keV.

Radioassay down to 1 mBq/kg for a sample of (at most) tens of grams is hard.

Backgrounds in counting limit sensitivity.

Gamma coincidence can be exploited to reduce backgrounds.

https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html

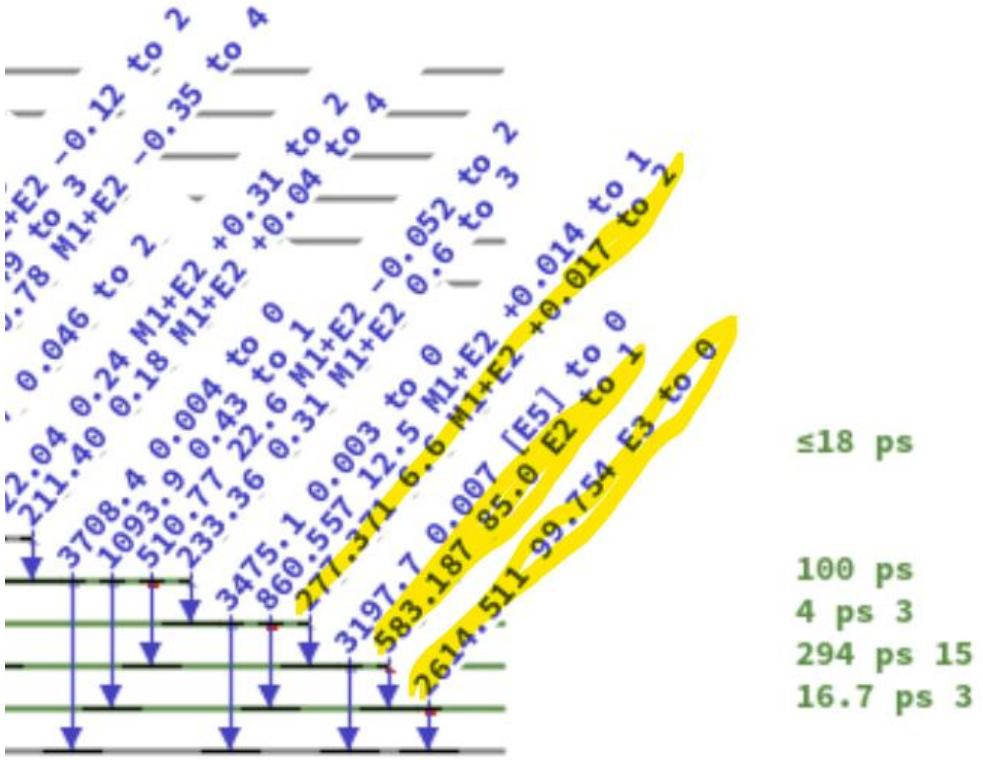


Gamma coincidence can be exploited to reduce backgrounds

For today – consider two pairs

277 and 583 keV

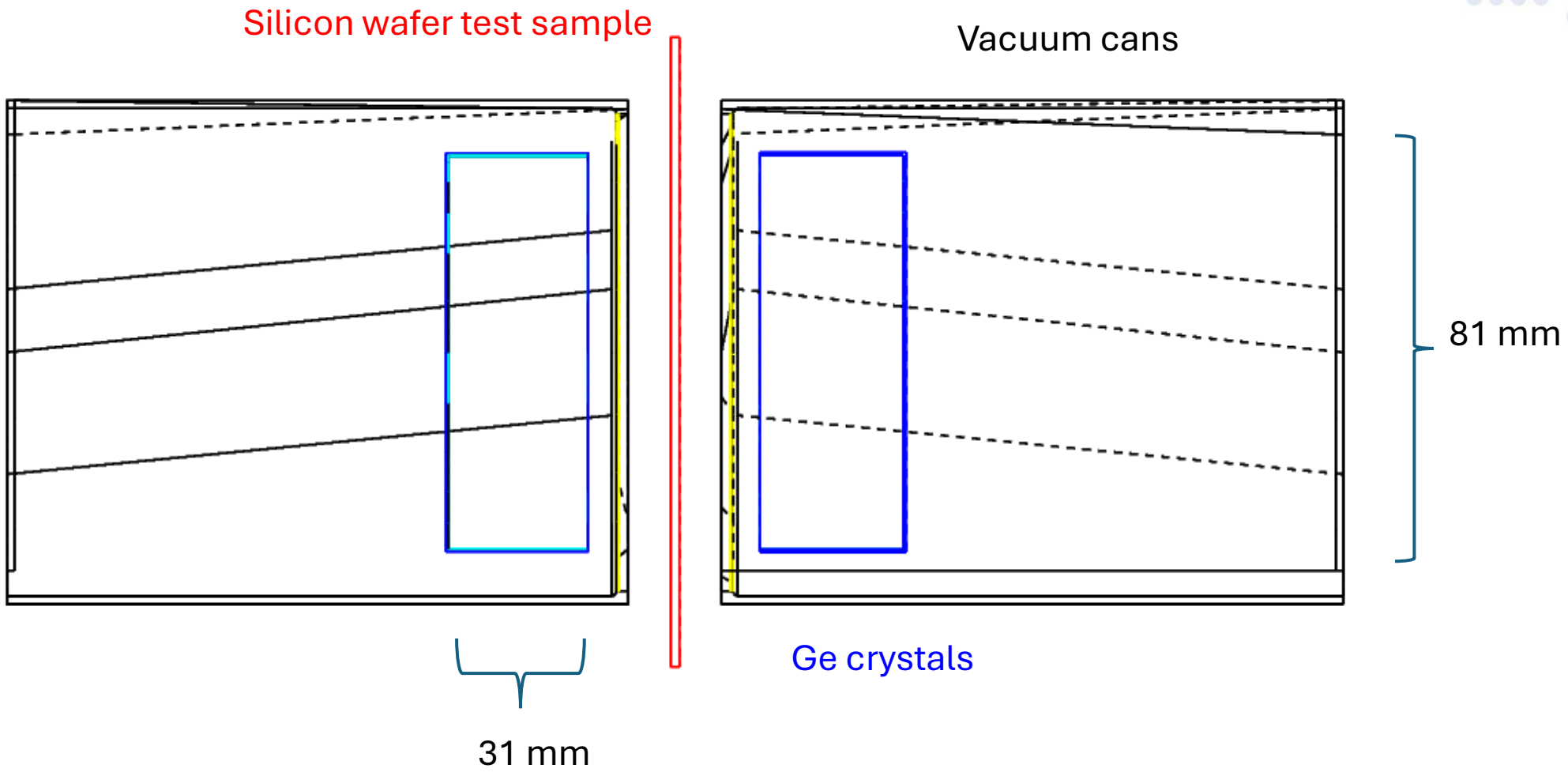
583 and 2614 keV



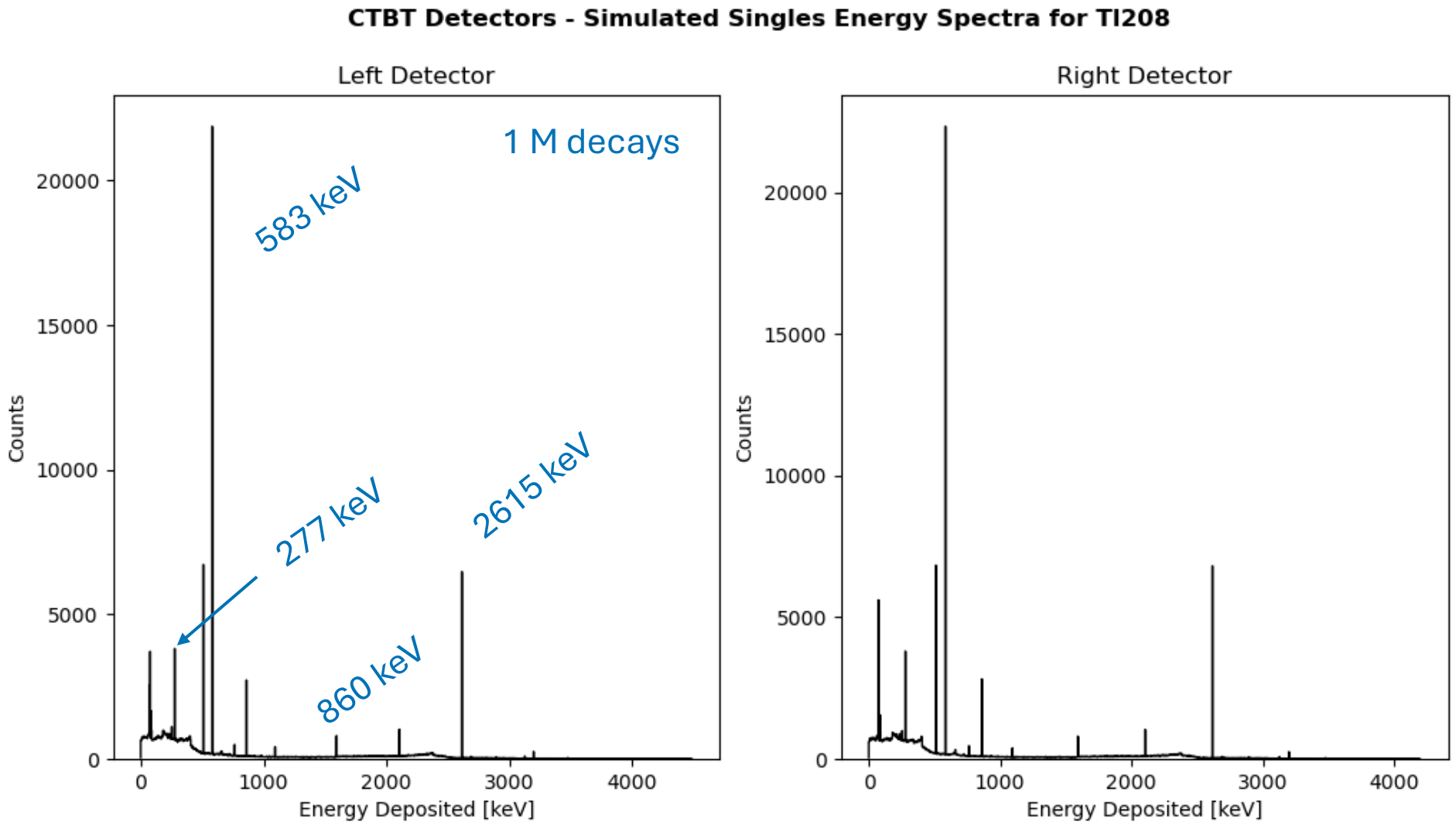
Long term plan: 2 to 3 years

1. Do some MC investigations and use calibration data to correct MC efficiencies.
2. Develop a couple of geometries to optimize signal extraction and background rejection.
3. Write out a detailed background model and budget.
    1. Shielding design
    2. Intrinsic backgrounds in the Ge crystals
4. Write a proposal.

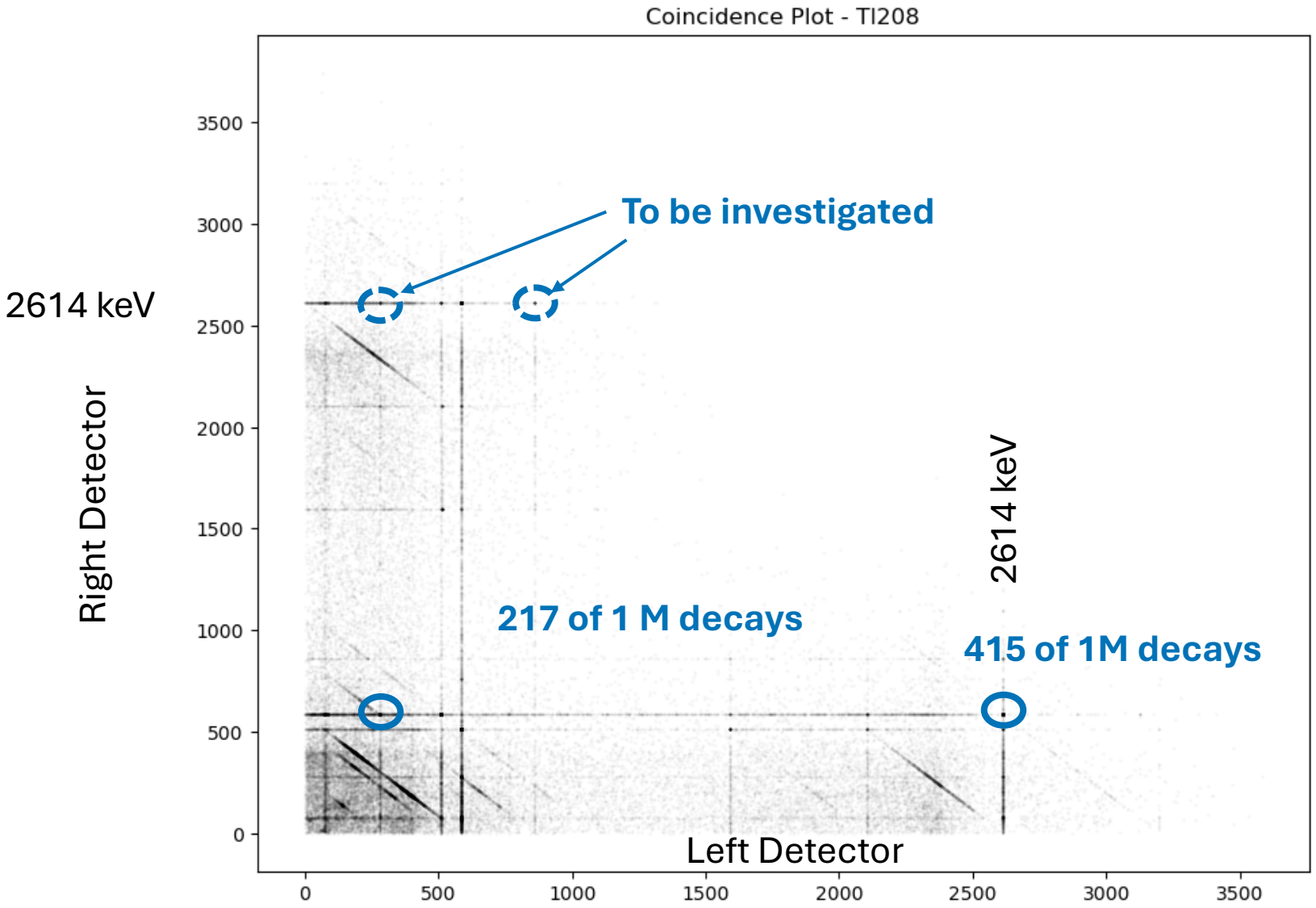
Example Tl-208 Simulation using the CTBT crystals



Singles spectra



Plotting the Energies of coincidence events allows us to isolate coincidences that can reduce backgrounds



Detection Rates are low

Singles:

Assume 1 mBq/kg

25 g sample → 2.5e-5 Bq

Assume 10% singles efficiency

→ 0.2 detections/day

→ 10 days to 2.3 events (90% sensitivity if background free)

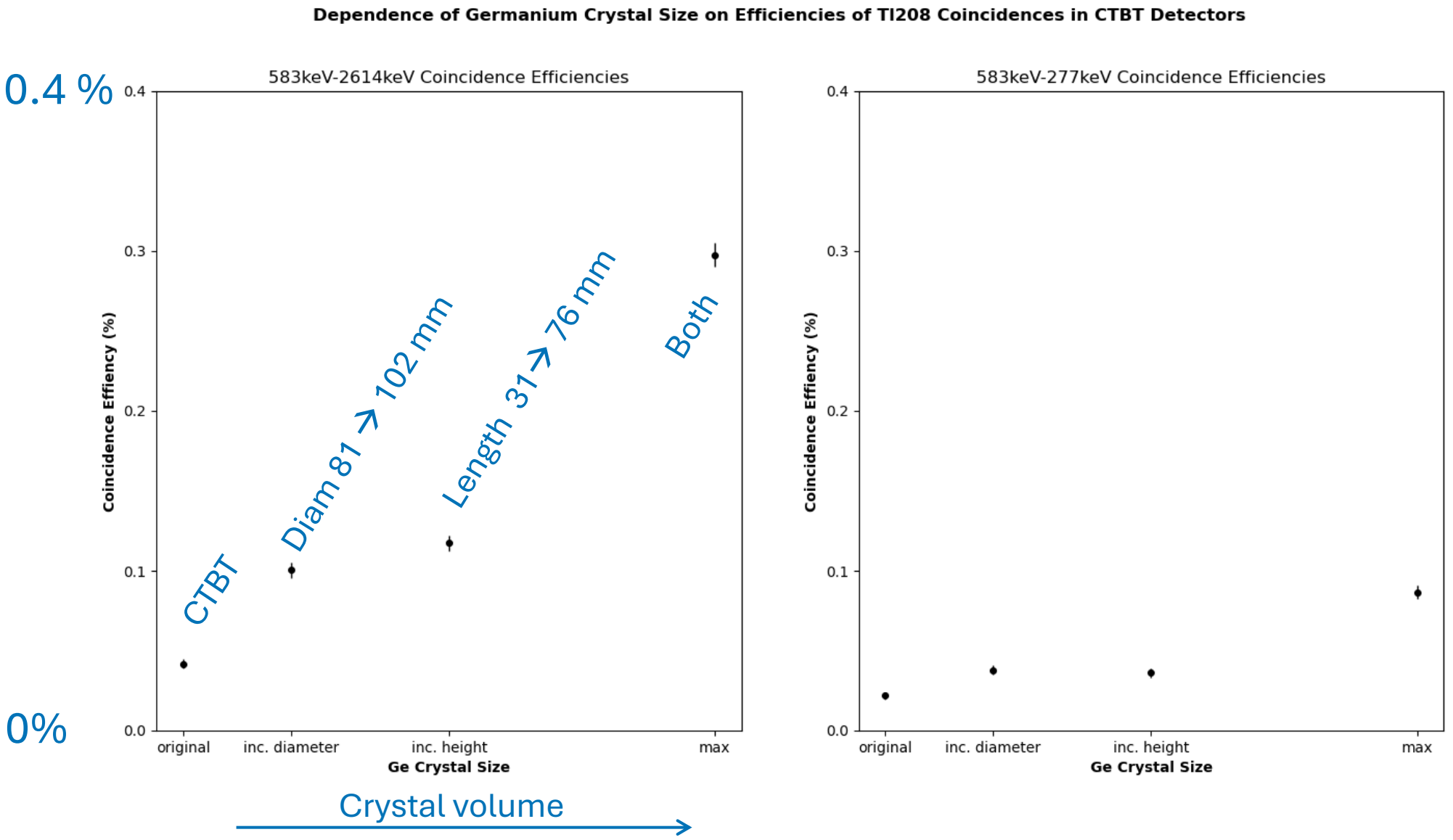
Coincidence:

Assume 0.3% coinc efficiency

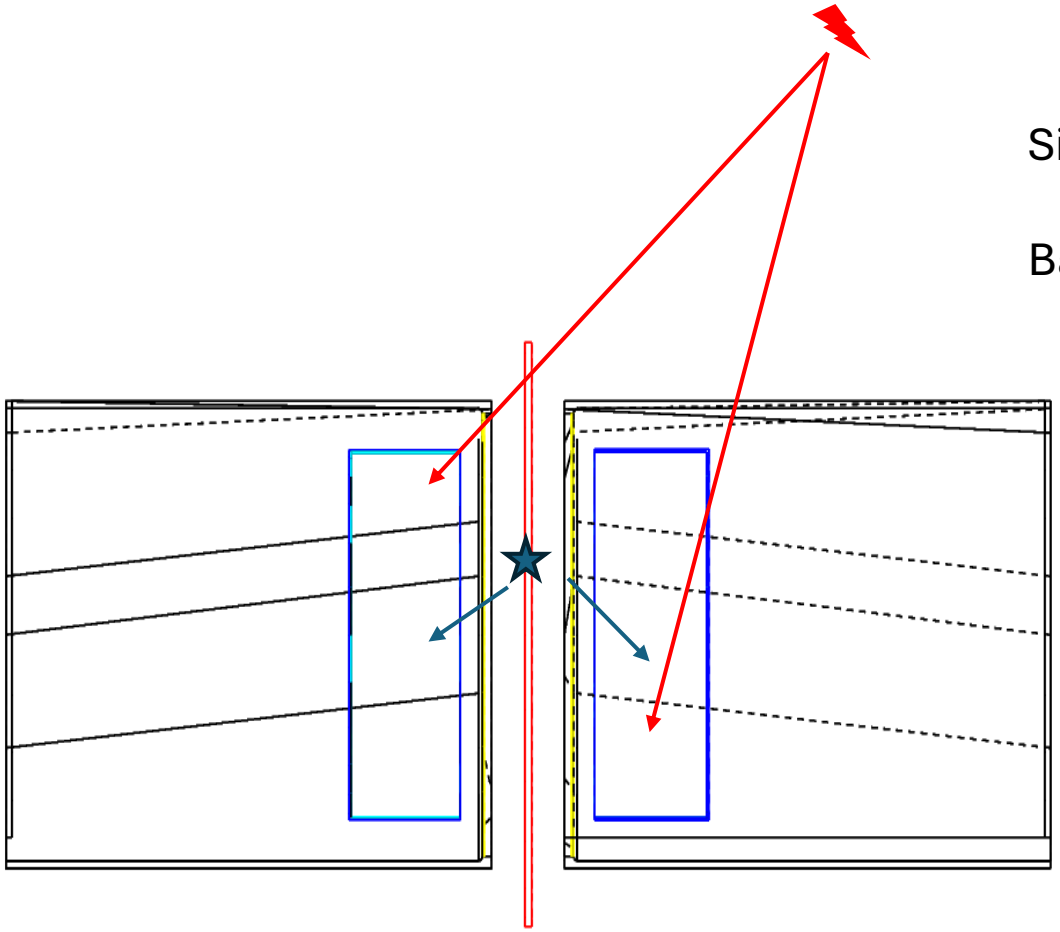
→ 0.006 detections/day

→350 days to 2.3 events (90% sensitivity of background free)

Larger diameter and thicker crystals help



Coincidence counting can reduce backgrounds more than signal



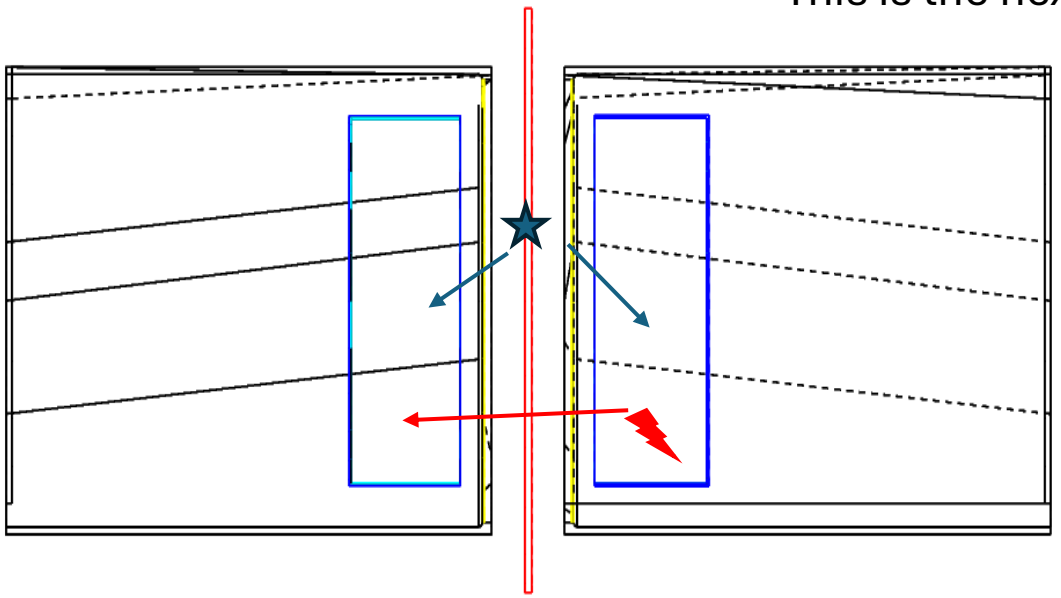
Signals have an optimized geometrical efficiency.

Background efficiencies go as **$1/r^4$**

Coincidence counting can reduce backgrounds more than signal

Internal backgrounds are trickier, but detector with internal background must give exactly the right energy.

This is the next task.



Stay tuned

- We are 6 weeks into this study
- Internal backgrounds next
- Check against reality using calibrated sources in CTBT