

How low can you go?

Ultra-low background measurements for next gen experiments.

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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.

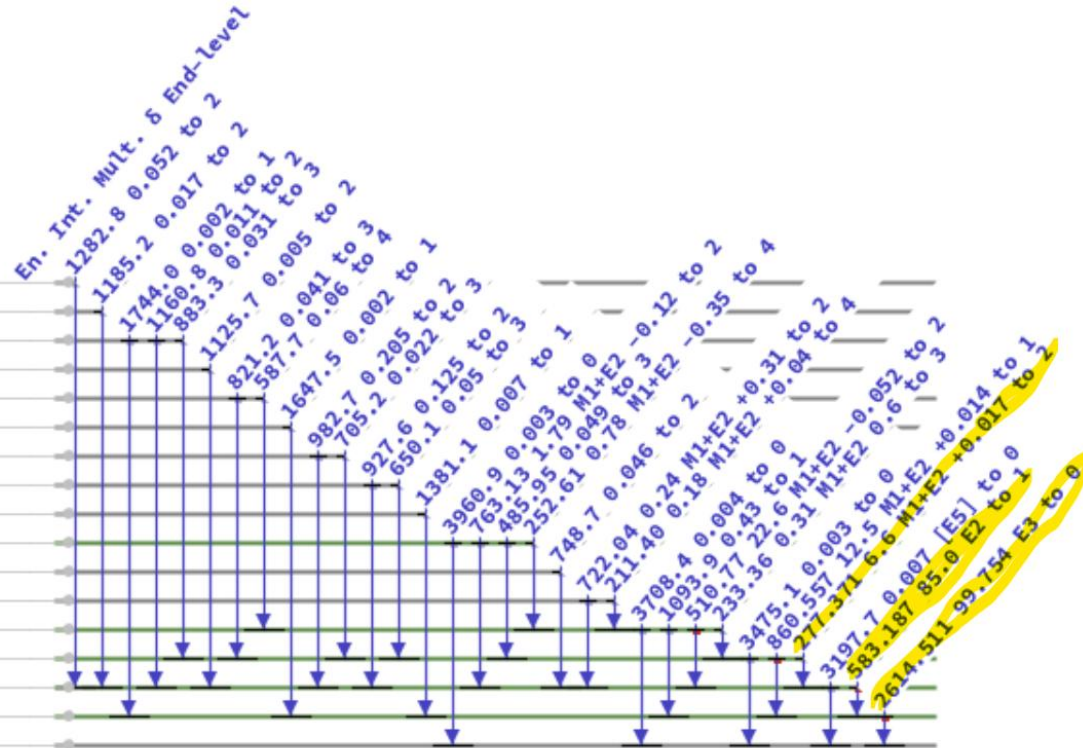
<https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html>

$^{208}\text{Tl}_{81}^{127}$ 0.0 3.053 m 4

Q^+ 4999.0 keV 17

B- : 100.0 % 0--> $^{208}\text{Pb}_{82}^{126}$

I%	Log ft	#	Jp	En [keV]
0.052	6.67	16	6-	4480.5
0.017	7.4	15	6-	4382.9
0.044	7.05	14	4-	4358.44
0.005	8.1	13	4+	4323.4
0.101	6.83	12	5-	4296.28
0.002	8.6	11	4-	4262.0
0.227	6.70	10	5-	4180.38
0.175	6.92	9	5-	4125.28
0.007	8.5	8	4-	3995.6
3.18	5.92	7	5-	3960.93
0.046	7.78	6	4-	3946.42
0.63	6.68	5	6-	3919.78
24.2	5.38	4	5-	3708.41
22.2	5.68	3	4-	3475.088
49.1	5.61	2	5-	3197.717
		1	3-	2614.529
		0	0+	0.0



≤18 ps

100 ps

4 ps 3

294 ps 15

16.7 ps 3

$^{208}\text{Pb}_{82}^{126}$ STABLE

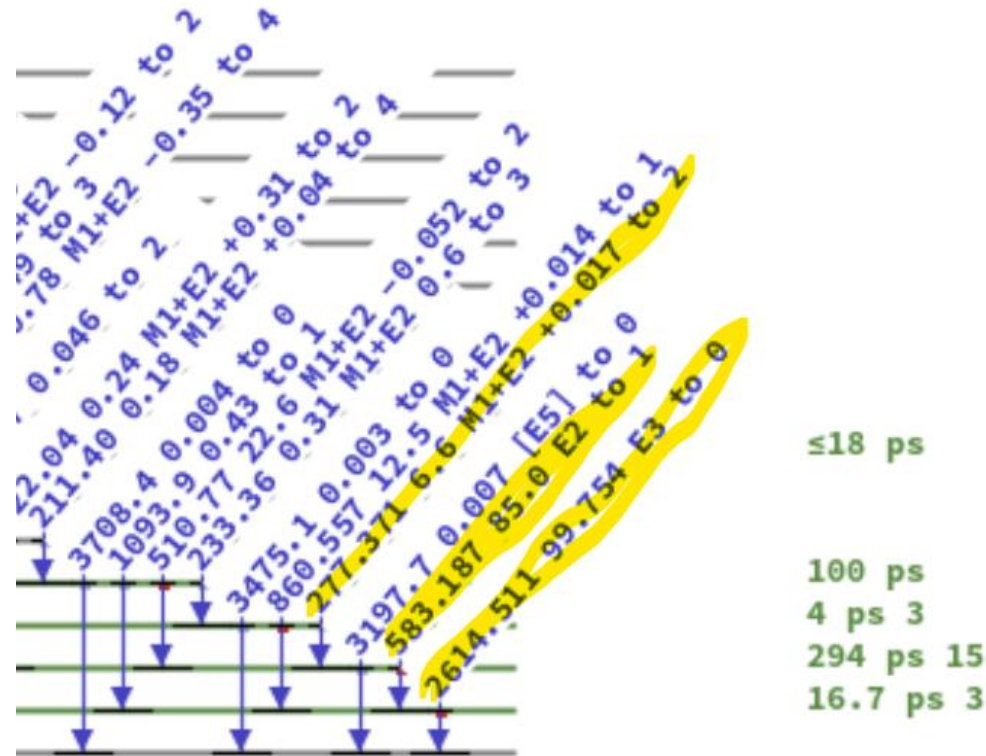


Gamma coincidence can be exploited to reduce backgrounds

For today – consider two pairs

277 and 583 keV

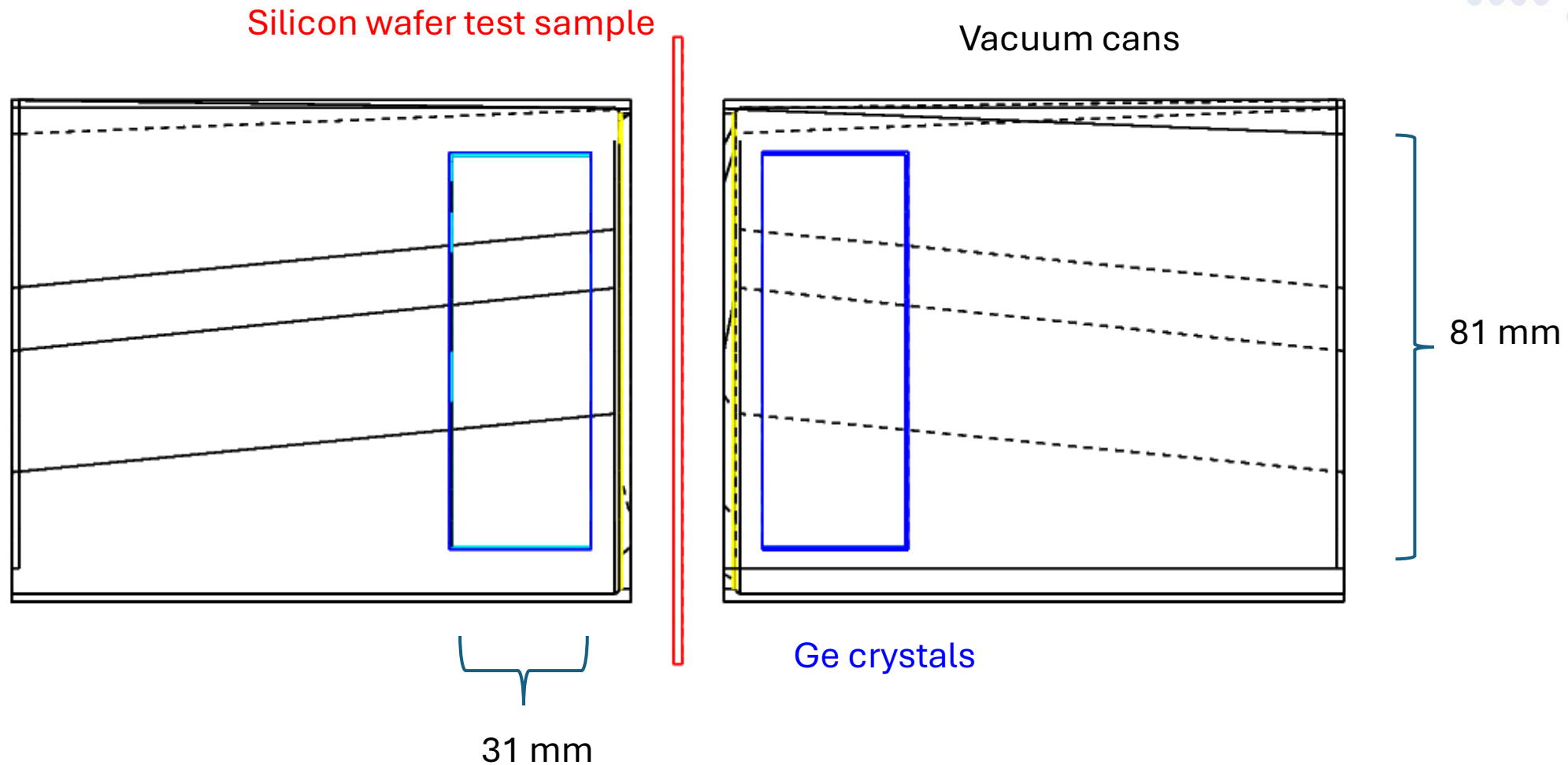
583 and 2614 keV



Long term plan: 2 to 3 years

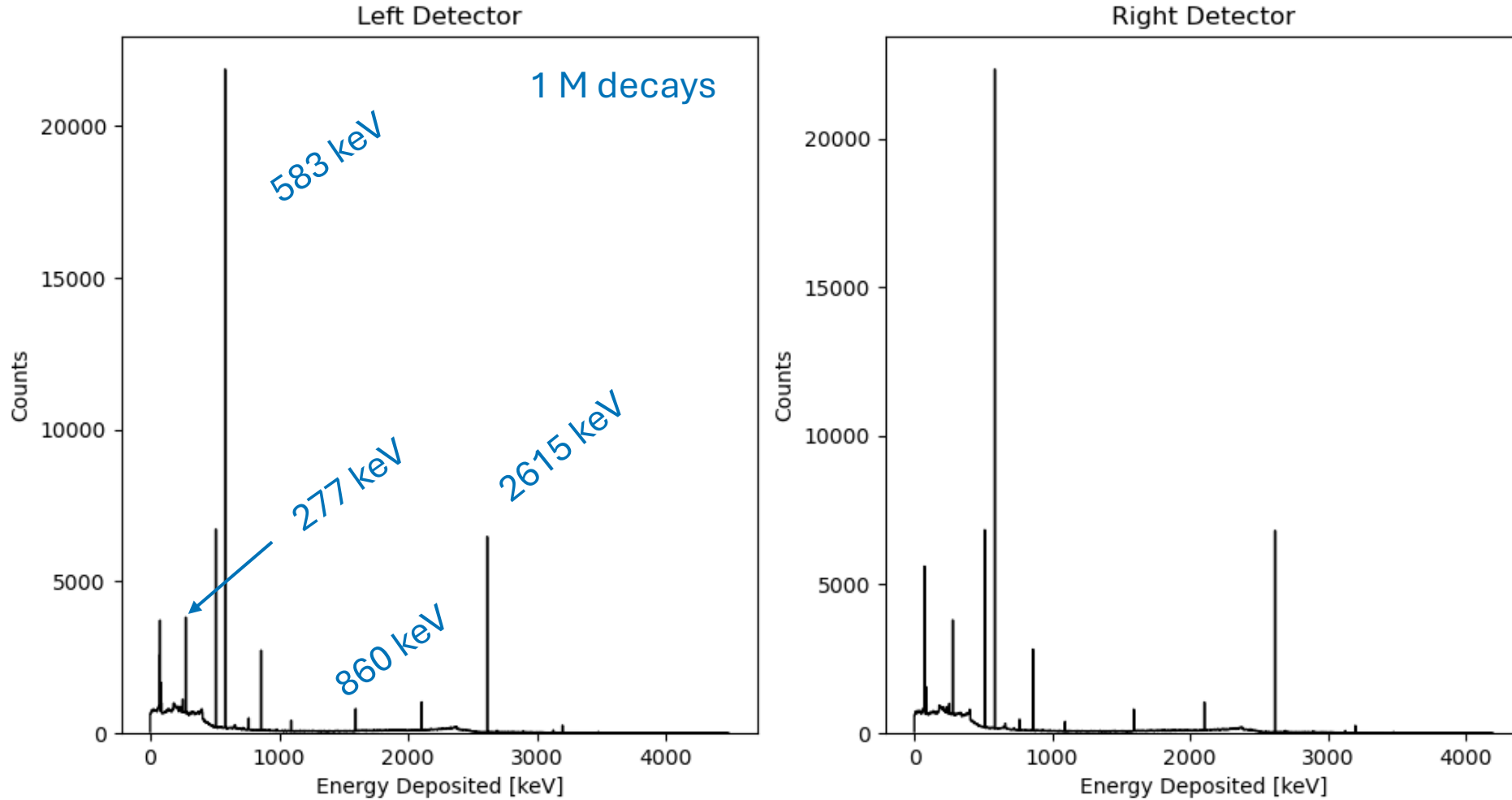
1. Do some MC investigations and use calibration data to correct MC efficiencies.
2. Develop a couple of geometries to optimize signal extraction and background rejection.
3. Write out a detailed background model and budget.
 1. Shielding design
 2. Intrinsic backgrounds in the Ge crystals
4. Write a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

Example Tl-208 Simulation using the CTBT crystals

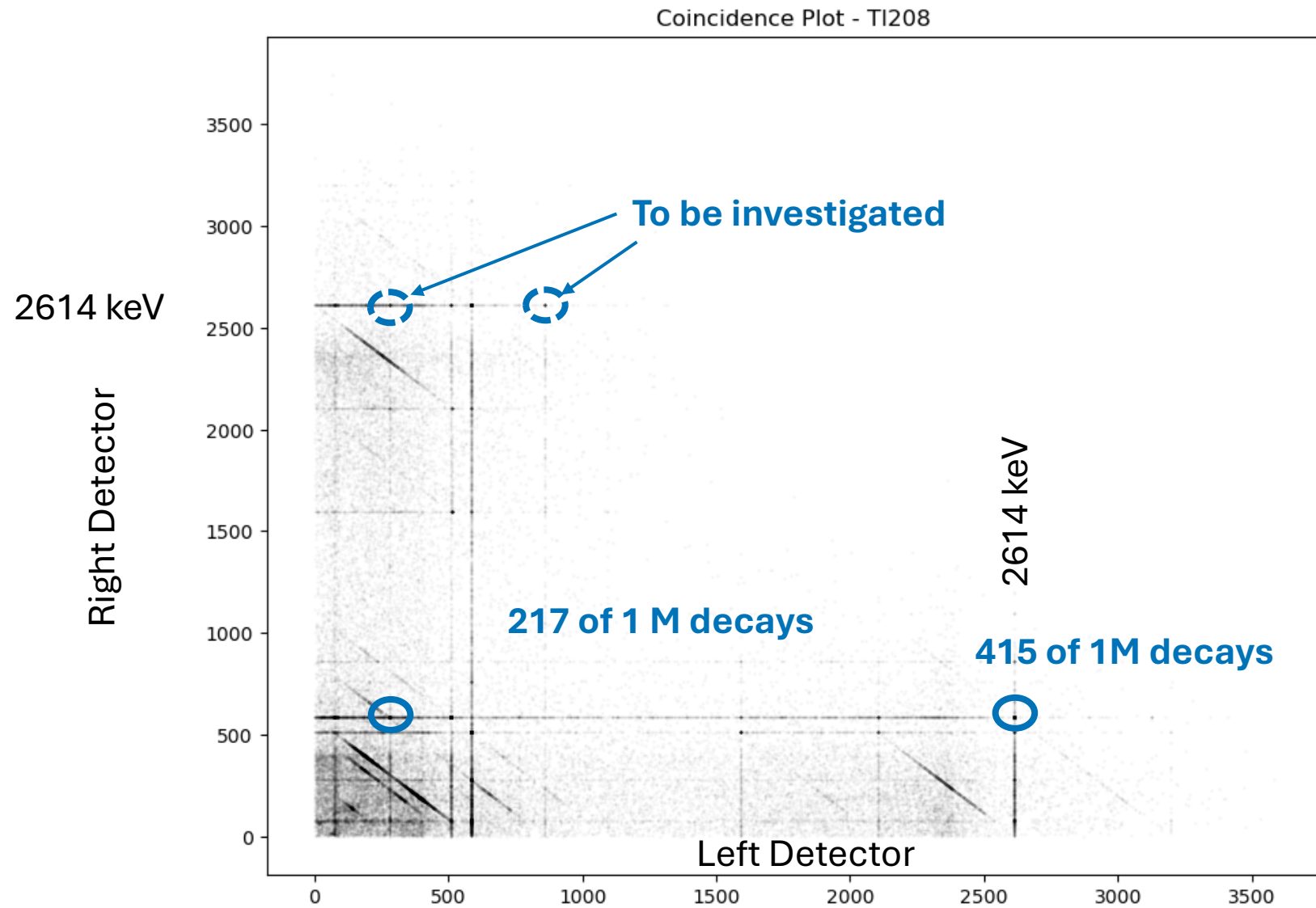


Singles spectra

CTBT Detectors - Simulated Singles Energy Spectra for TI208



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 $\rightarrow 2.5\text{e-}5$ Bq

Assume 10% singles efficiency

$\rightarrow 0.2$ detections/day

$\rightarrow 10$ days to 2.3 events (90% sensitivity if background free)

Coincidence:

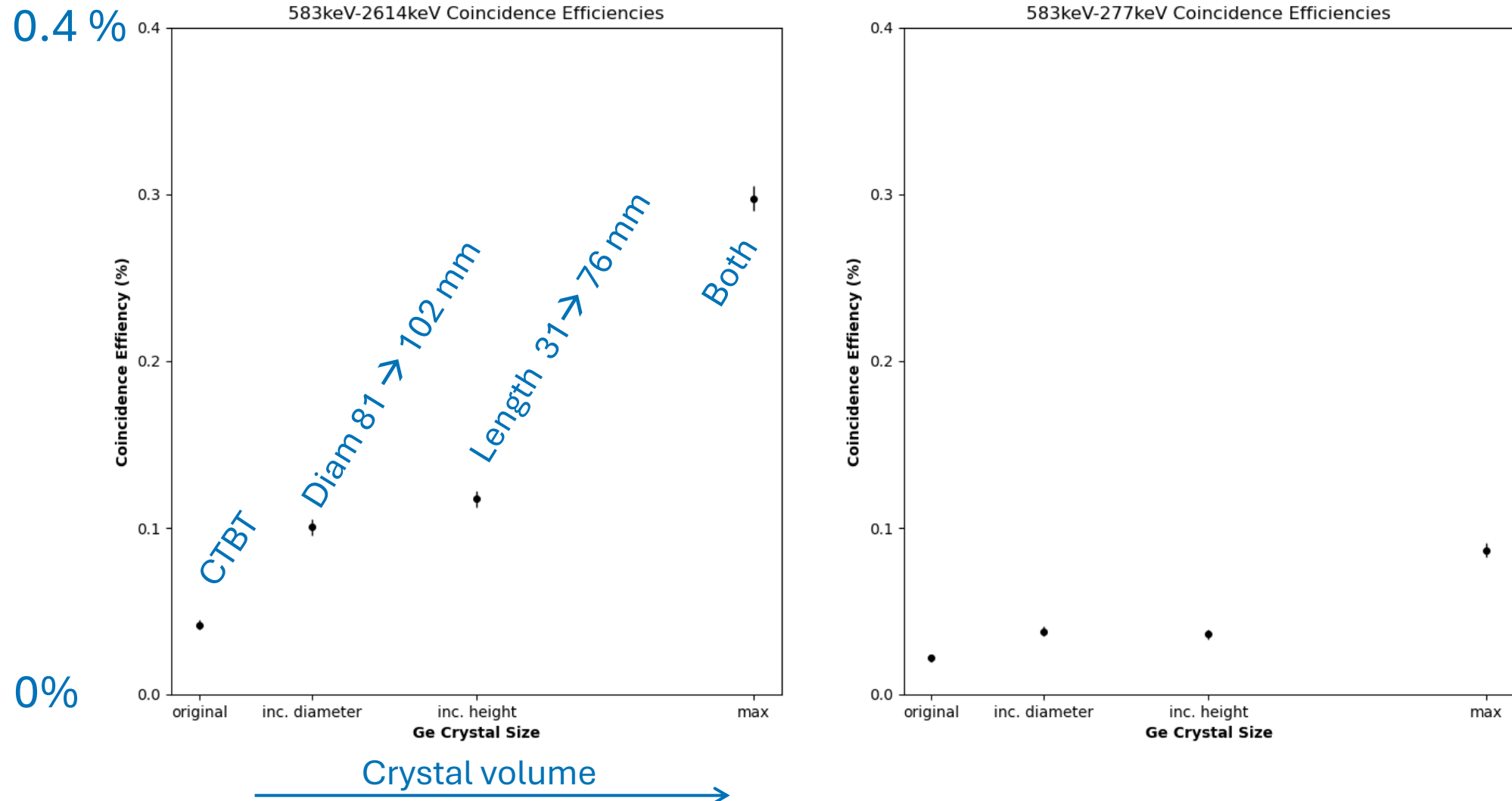
Assume 0.3% coinc efficiency

$\rightarrow 0.006$ detections/day

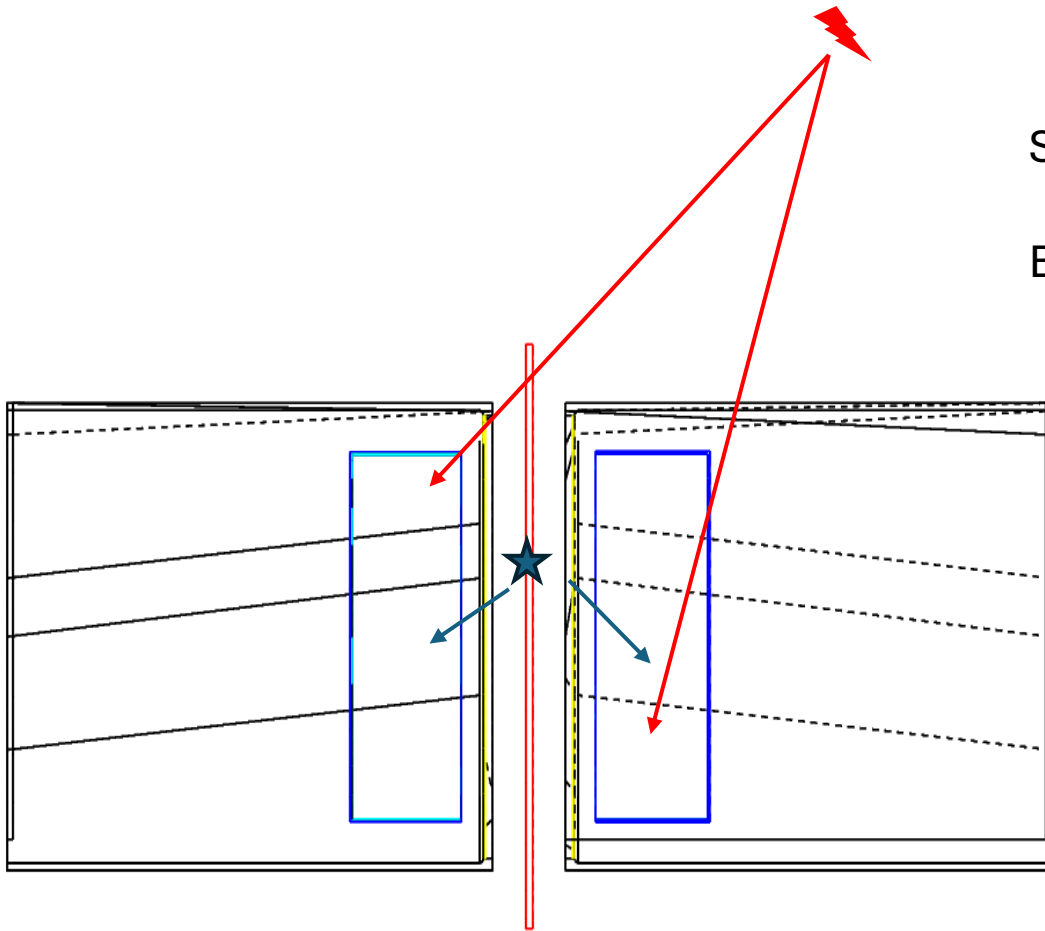
$\rightarrow 350$ days to 2.3 events (90% sensitivity of background free)

Larger diameter and thicker crystals help

Dependence of Germanium Crystal Size on Efficiencies of TI208 Coincidences in CTBT Detectors



Coincidence counting can reduce backgrounds more than signal



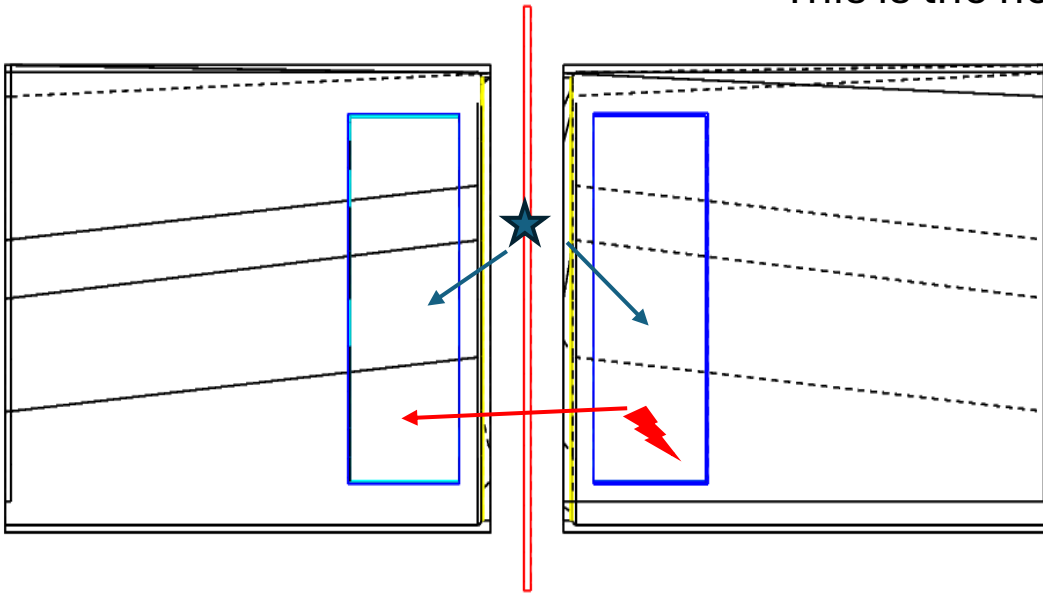
Signals have an optimized geometrical efficiency.

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