Towards partial capture rates of ^{76}Se with ALPACA data

Elizabeth Mondragón | TUM

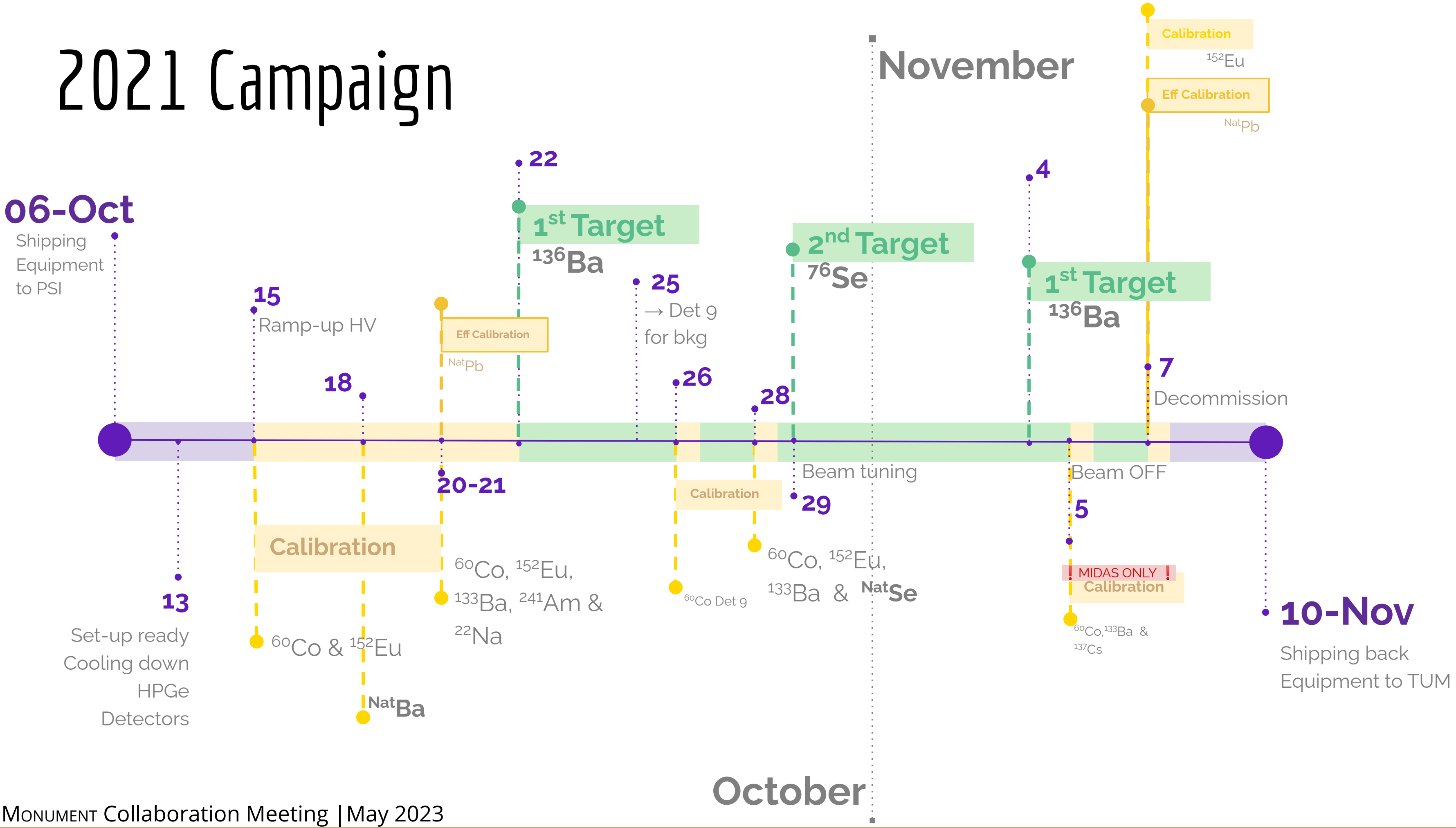
Steps

1. Test analysis chain
    - Select calibration data
    - Select detector
    - Fit calibration peaks
    - Produce relative efficiency curve
    - Select beam data
    - Fit peaks
    - Produce relative intensities
    - Derive partial yields
2. Apply to all 8 detectors
3. Perform multi-detector analysis

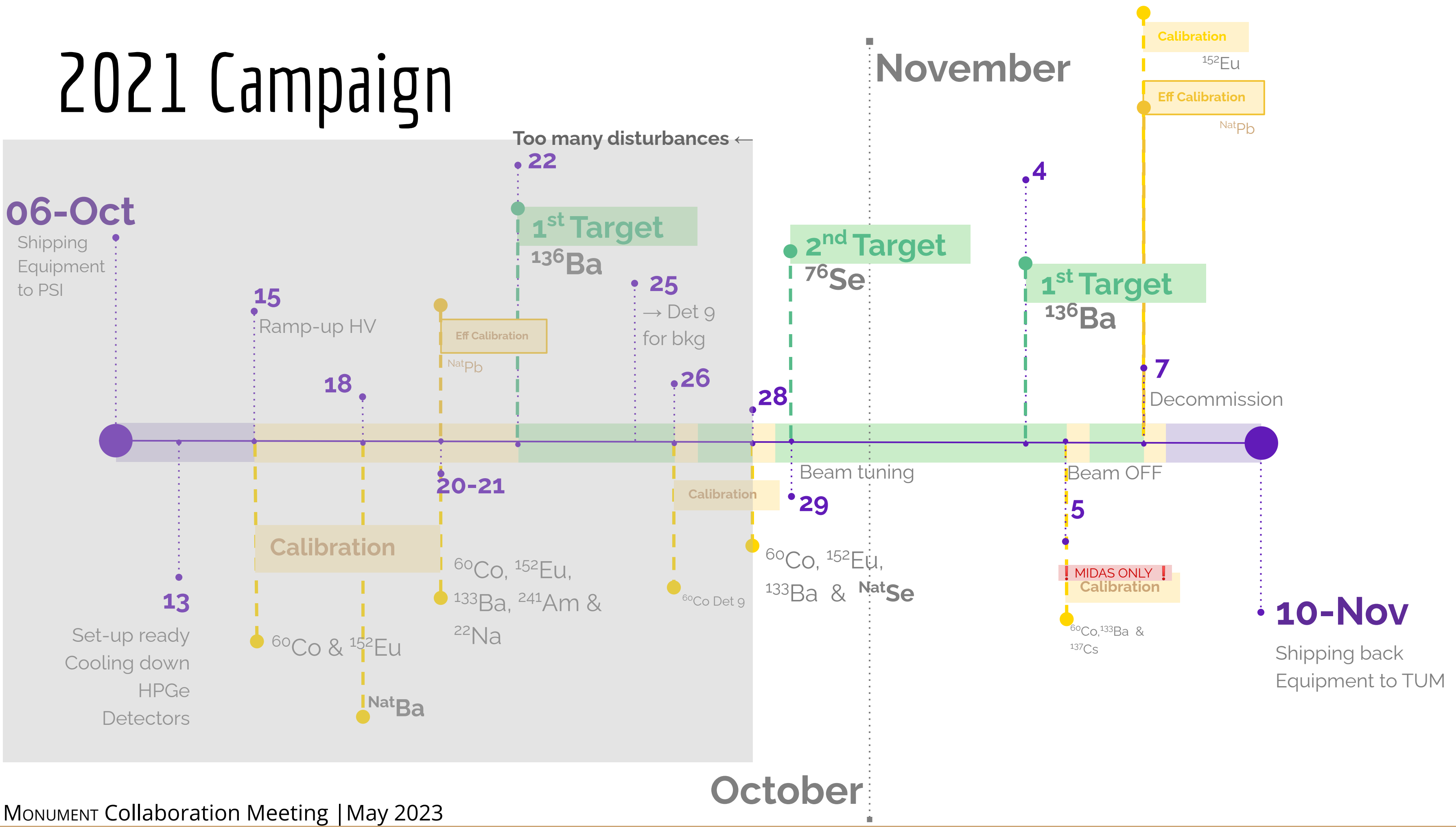
Steps

1. Test analysis chain
    - Select calibration data
    - Select detector
    - Fit calibration peaks
    - Produce relative efficiency curve
    - Select beam data
    - Fit peaks
    - Produce relative intensities
    - Derive partial yields
2. Apply to all 8 detectors
3. Perform multi-detector analysis

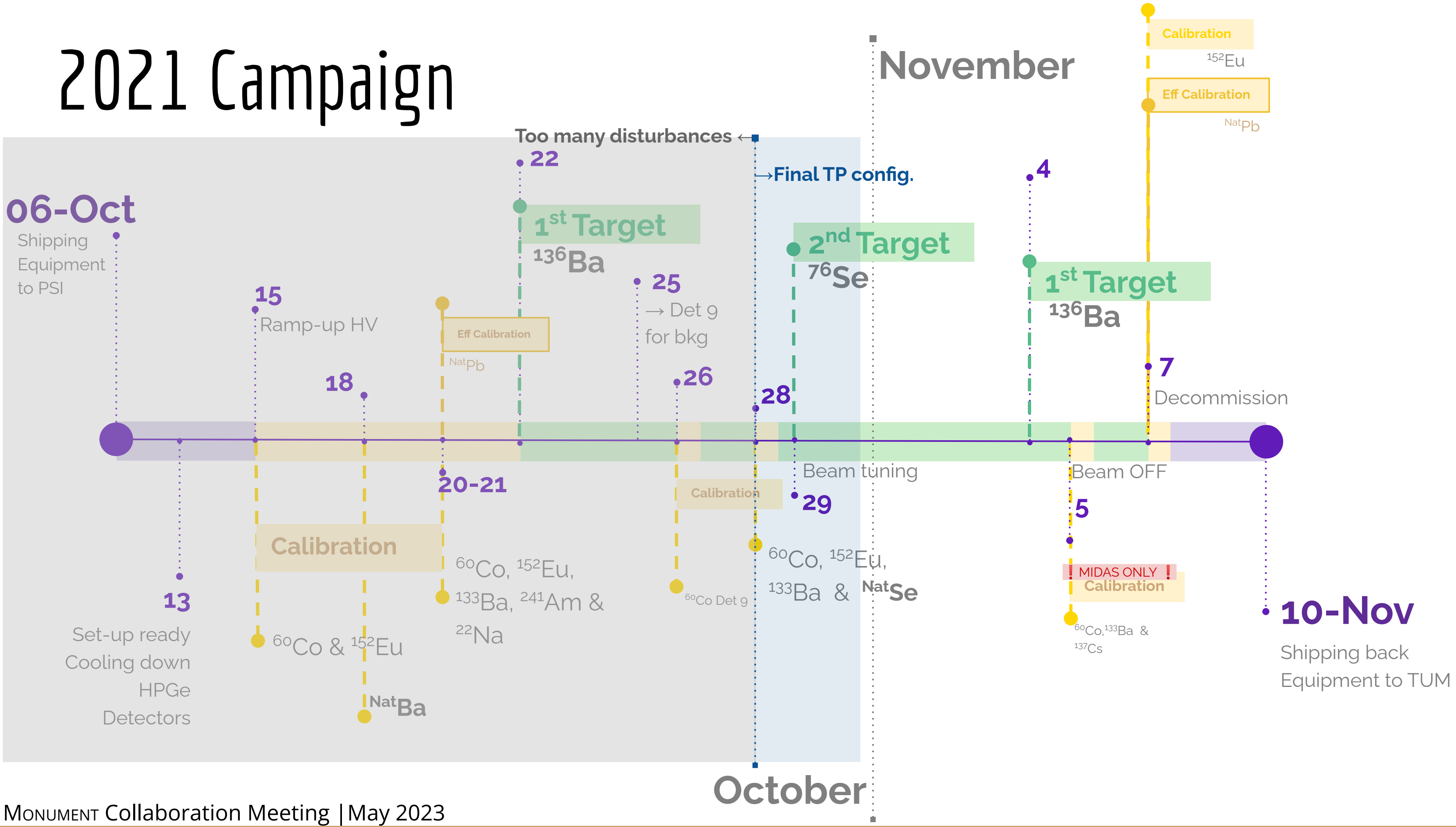
2021 Campaign



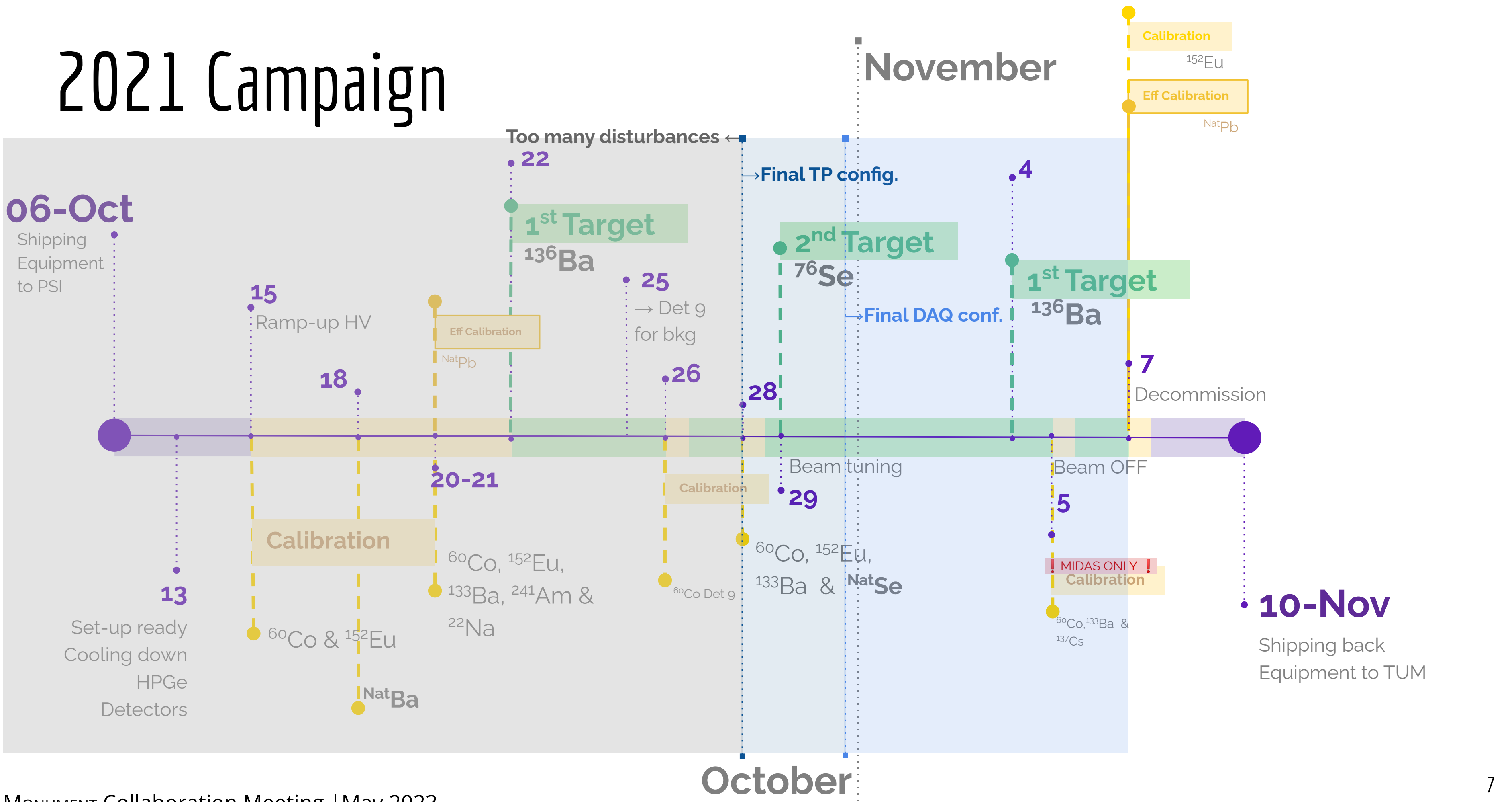
2021 Campaign



2021 Campaign



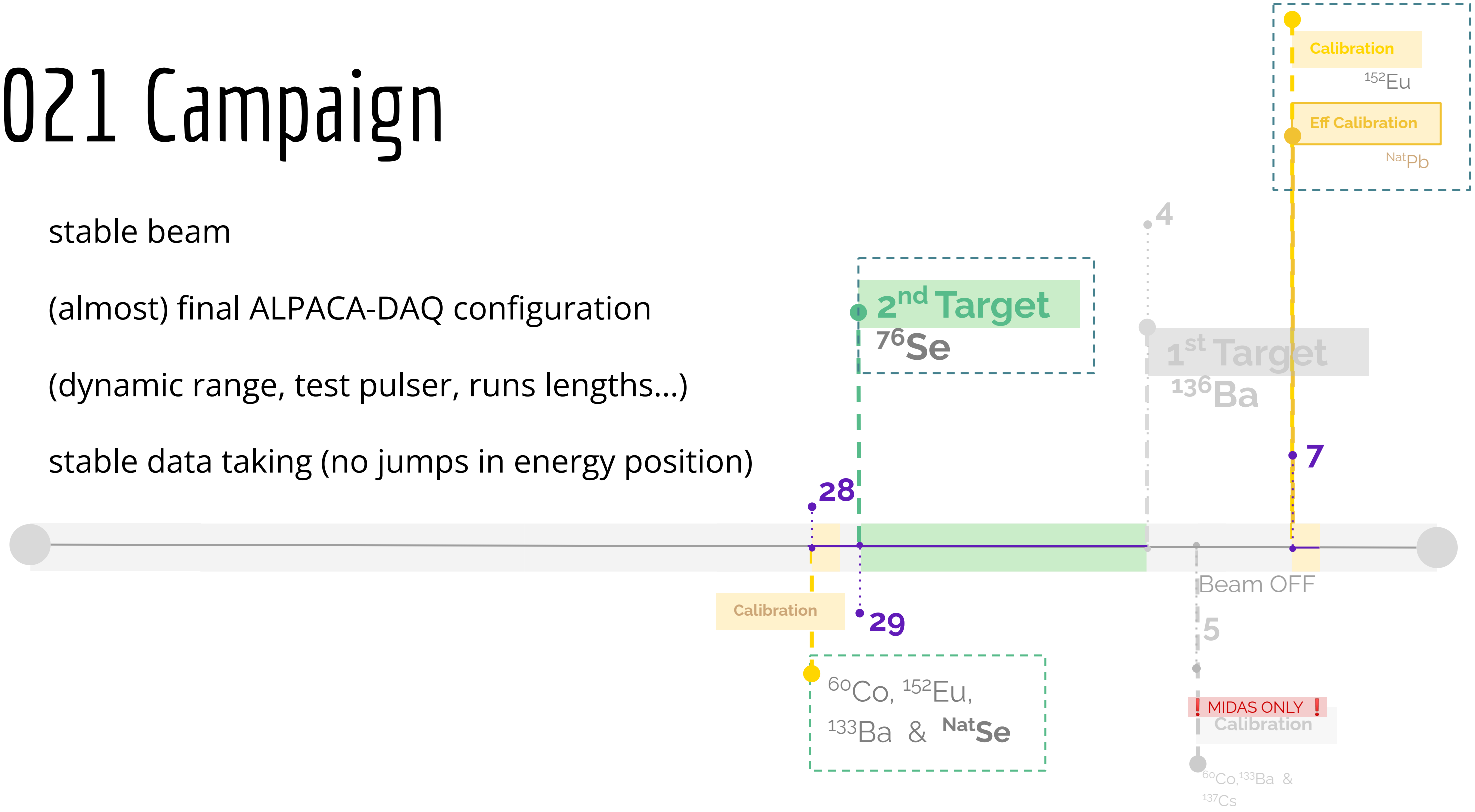
2021 Campaign



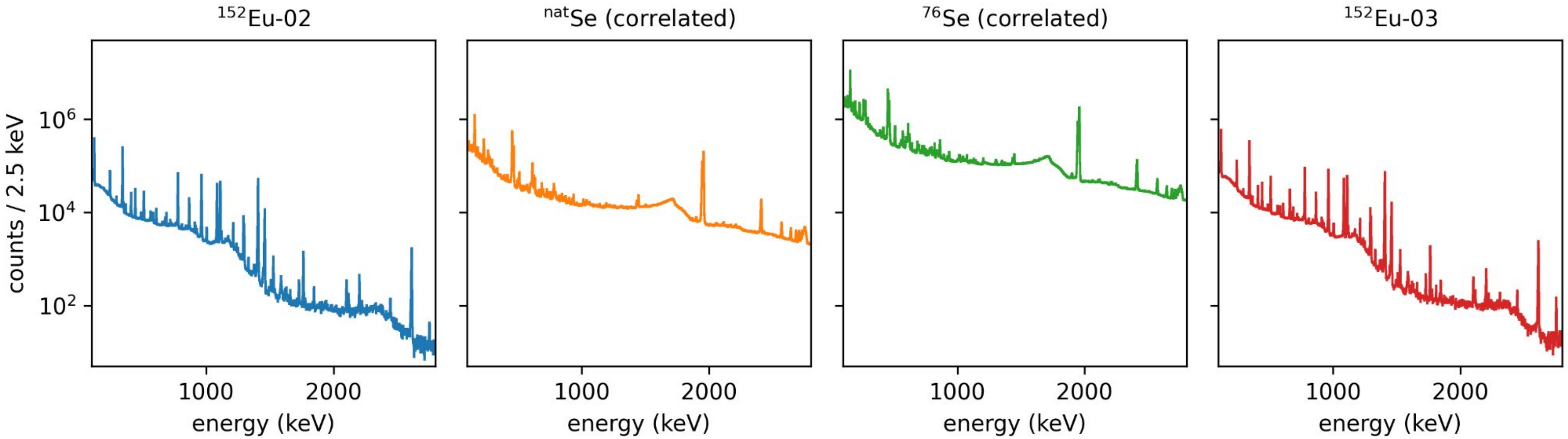
2021 Campaign

- stable beam
- (almost) final ALPACA-DAQ configuration

  (dynamic range, test pulser, runs lengths…)
- stable data taking (no jumps in energy position)

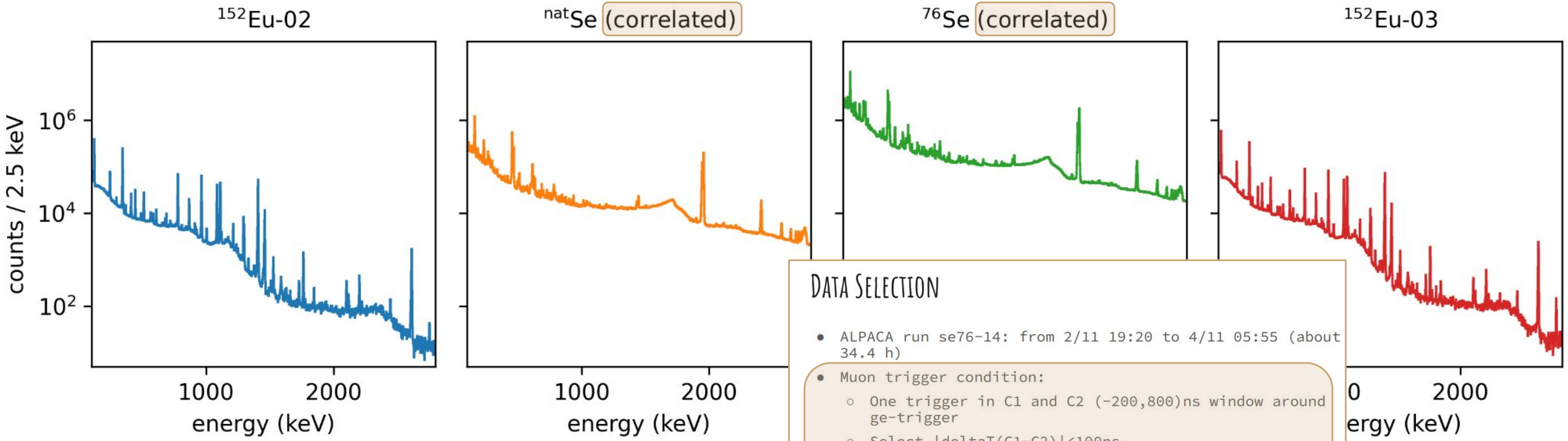


Data sets



- summed data for all detectors, different statistics

Data sets



- summed data for all detectors, diffe

Data Selection

- ALPACA run se76-14: from 2/11 19:20 to 4/11 05:55 (about 34.4 h)
- Muon trigger condition:
  - One trigger in C1 and C2 (-200,800)ns window around ge-trigger
  - Select |deltaT(C1-C2)|<100ns
  - Muon-stop trigger time: $t_{\mu\text{-stop}}=(t_{C1}+t_{C2})/2$
  - Anticoincidence trigger with C0: |deltaT(μ-stop-C0)|<100 ns

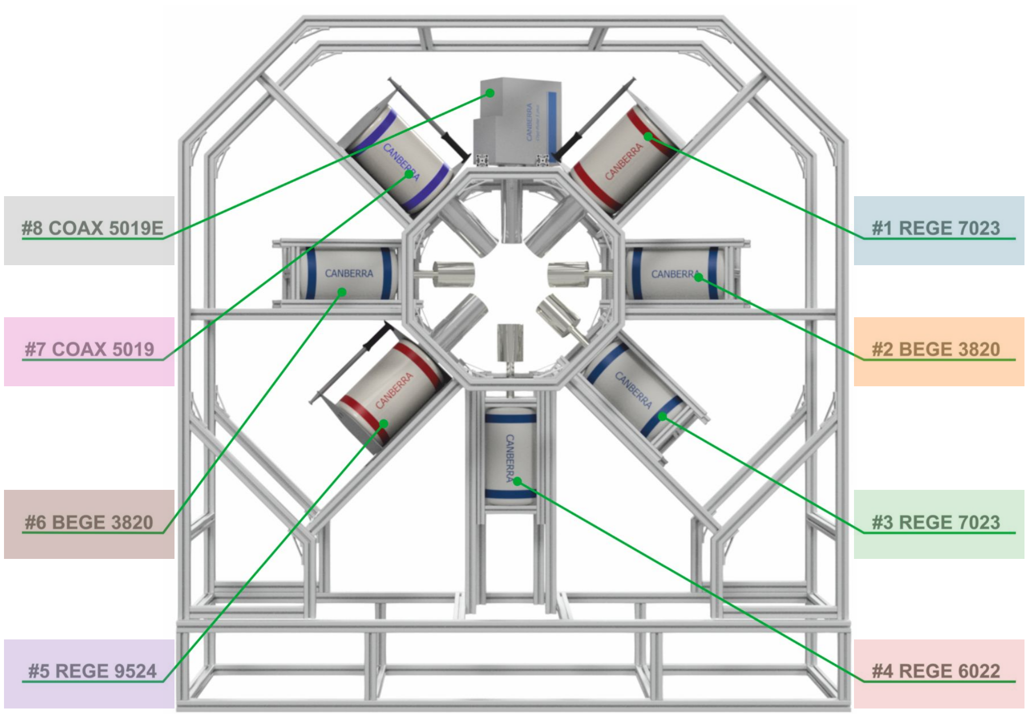
See slides from last meeting for details

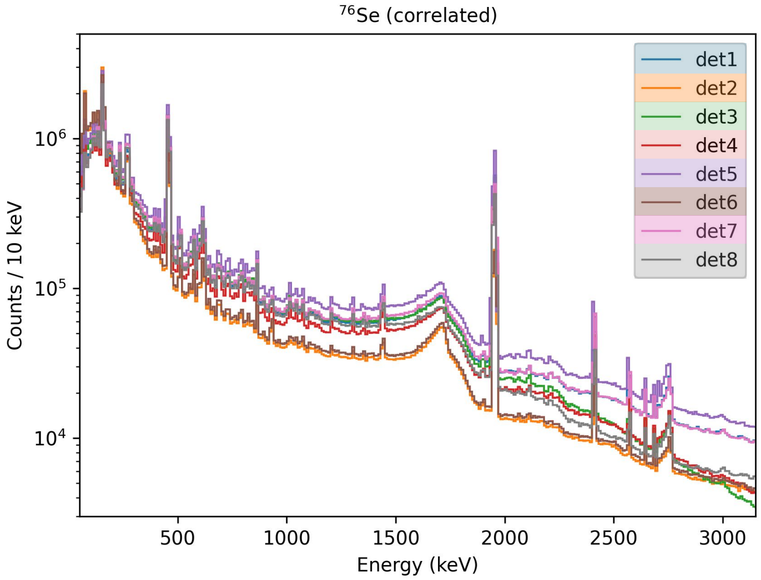
From Elisabetta's slides

Steps

1. Test analysis chain
   - Select calibration data
   - Select detector
   - Fit calibration peaks
   - Produce relative efficiency curve
   - Select beam data
   - Fit peaks
   - Produce relative intensities
   - Derive partial yields
2. Apply to all 8 detectors
3. Perform multi-detector analysis

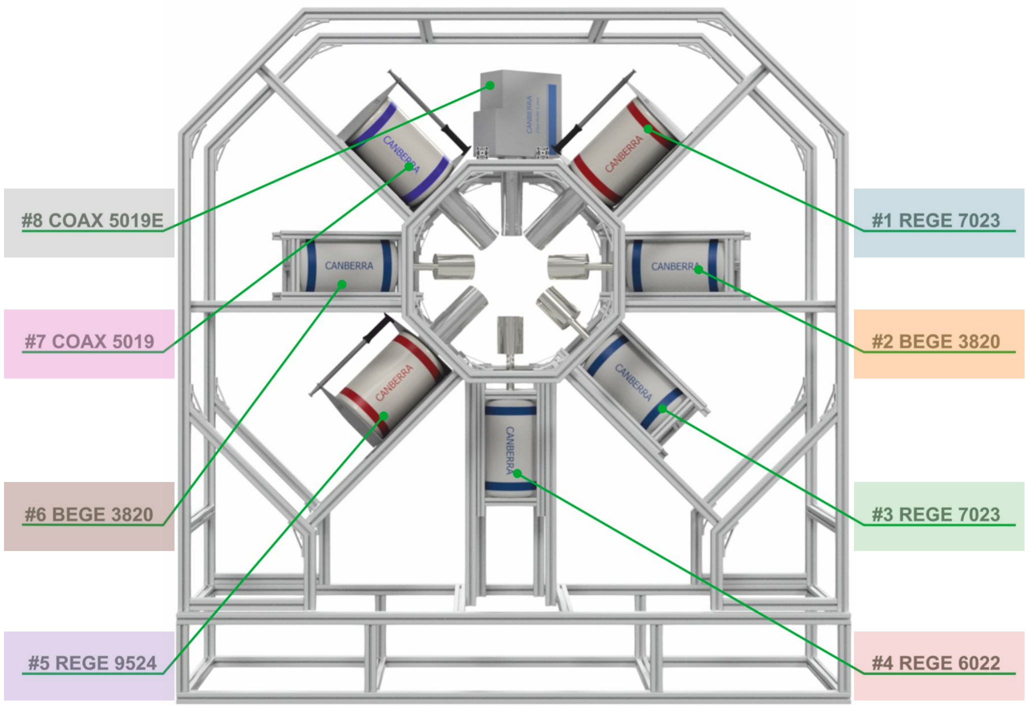
Detector characteristics

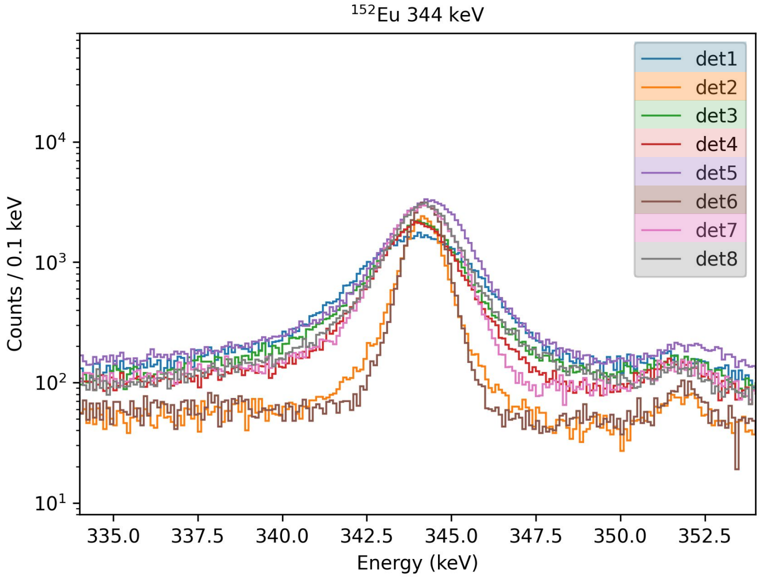




- Different efficiencies

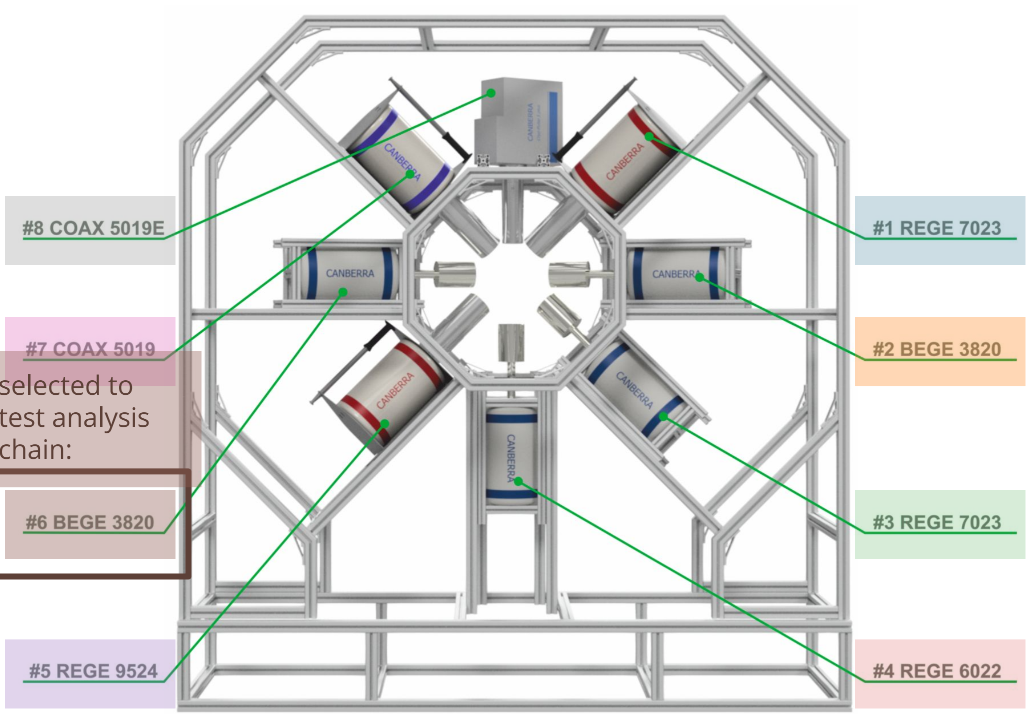
Detector characteristics



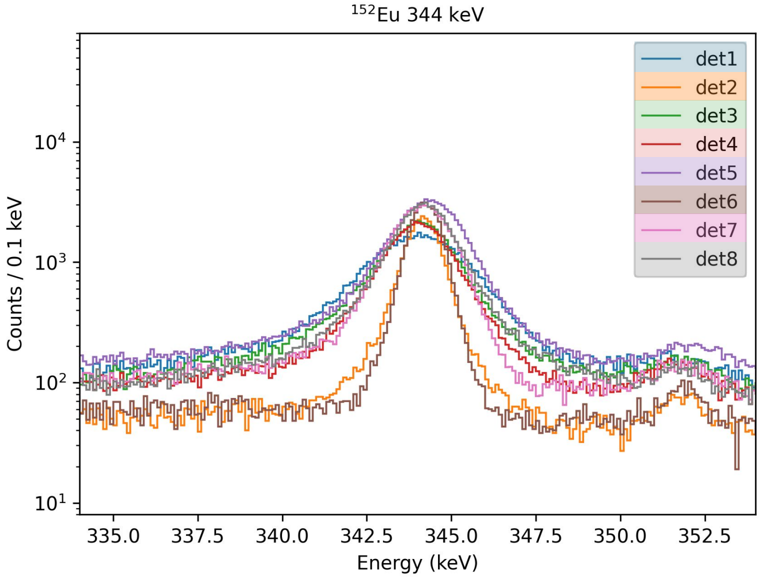


- Different resolutions

Detector characteristics



selected to test analysis chain:



- Different resolutions

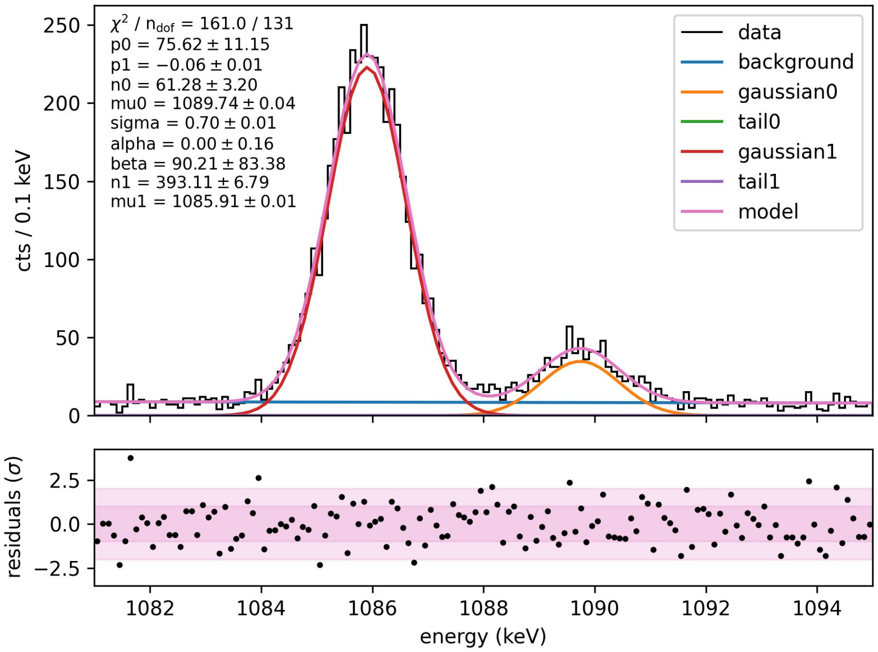
Steps

1. Test analysis chain
    - Select calibration data
    - Select detector
    - Fit calibration peaks
    - Produce relative efficiency curve
    - Select beam data
    - Fit peaks
    - Produce relative intensities
    - Derive partial yields
2. Apply to all 8 detectors
3. Perform multi-detector analysis

Peak fits

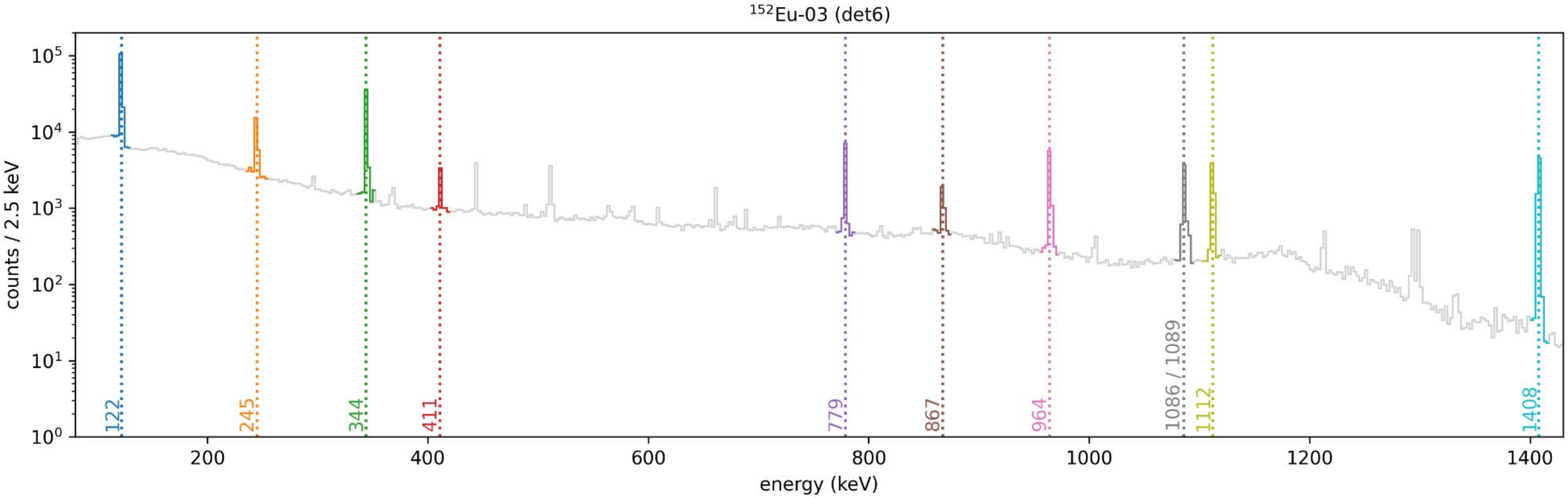
$$f(E,..) = \sum_i \overbrace{n_i}^{\text{Amplitude}} \cdot \left(\underbrace{(1-\alpha)}_{\text{Fraction Gauss}} \cdot \overbrace{\frac{1}{\sqrt{2\pi}\sigma} \cdot \exp\left(\frac{-(E-\mu_i)^2}{2\sigma^2}\right)}^{\text{Gauss}} + \underbrace{\alpha}_{\text{Fraction tail}} \cdot \overbrace{\frac{1}{2\beta} \cdot exp\left(\frac{E-\mu_i}{\beta} + \frac{\sigma^2}{2\beta^2}\right) \cdot erfc\left(\frac{E-\mu_i}{\sqrt{2}\sigma} + \frac{\sigma}{\sqrt{2}\beta}\right)}^{\text{Tail}} \right) + \overbrace{\sum_i p_i \cdot E^i + \sum_i \underbrace{\frac{s_i}{2} \cdot erfc\left(\frac{E-\mu_i}{\sigma\sqrt{2}}\right)}_{\text{Step function}}}^{\text{Background}}$$

- binned maximum likelihood fit (Poisson) using iminuit (python)
- Gaussian peak(s) with left tail (pile-up, incomplete charge collection) on polynomial background with step*
- to do: implement pull terms (e.g. position, width), right tail handling (test pulser shape issue, others?)

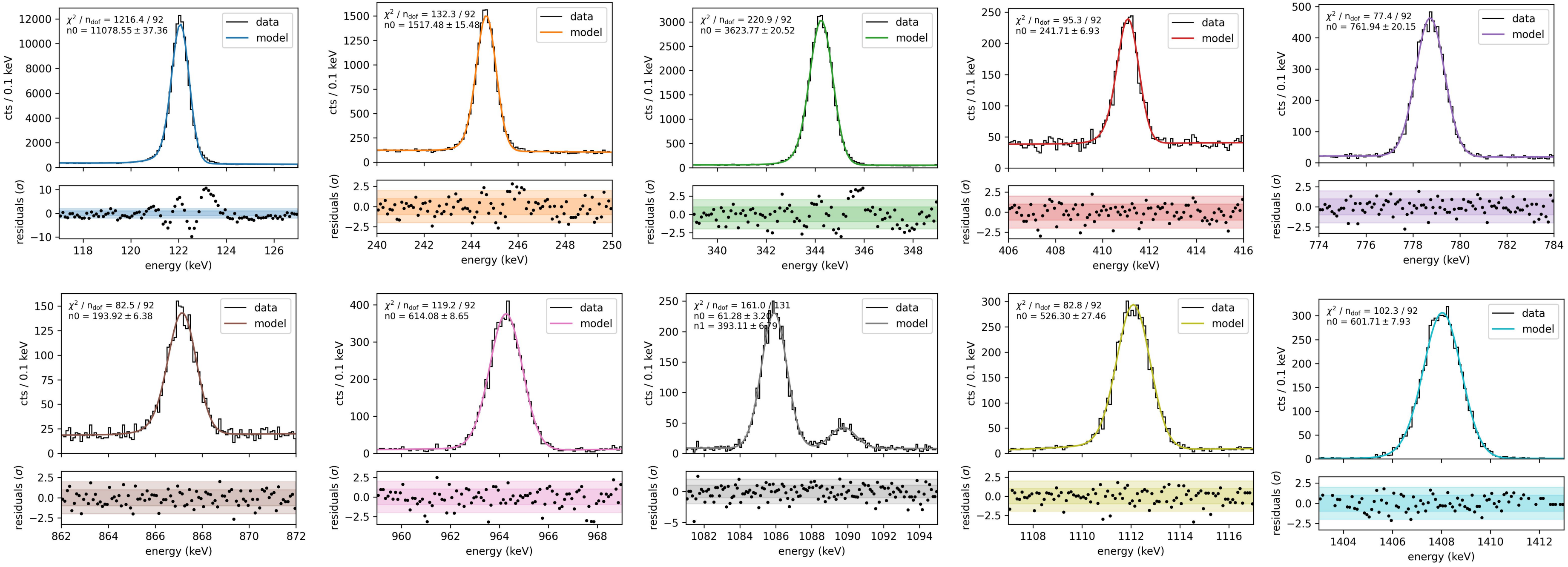


*[GERDA, EPJC 81 682 (2021)]

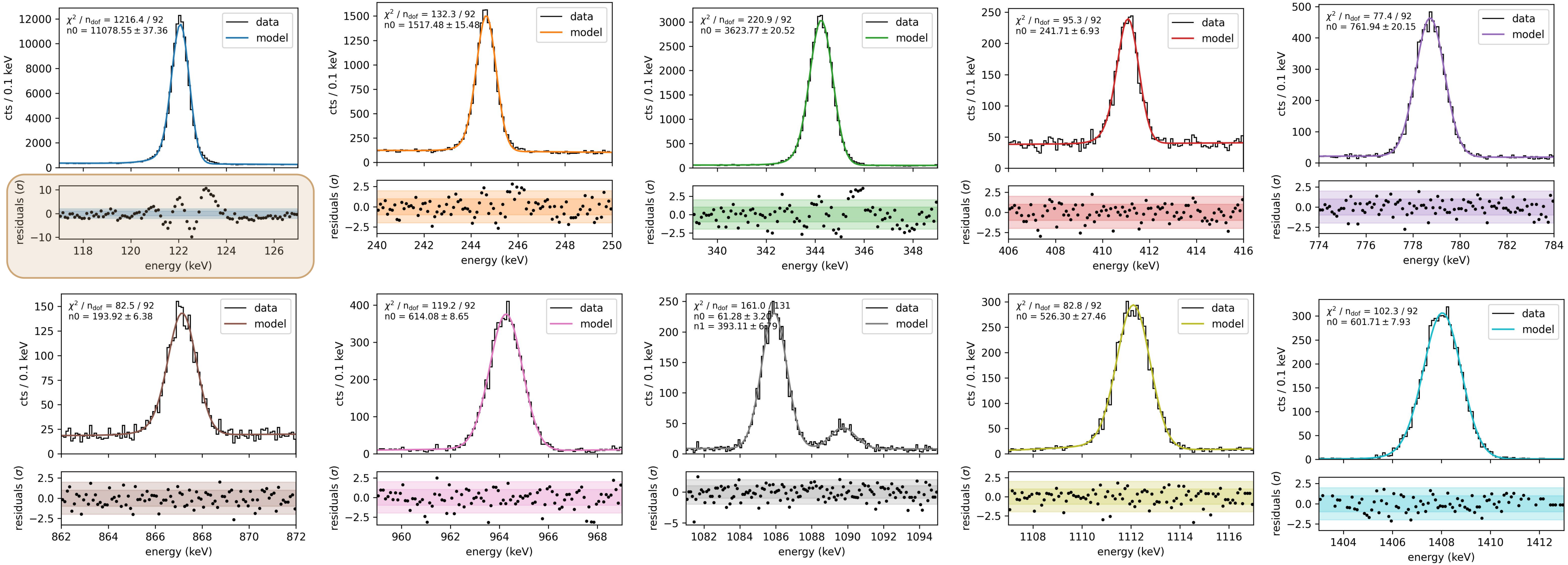
Calibration spectrum



Calibration peak fits



Calibration peak fits



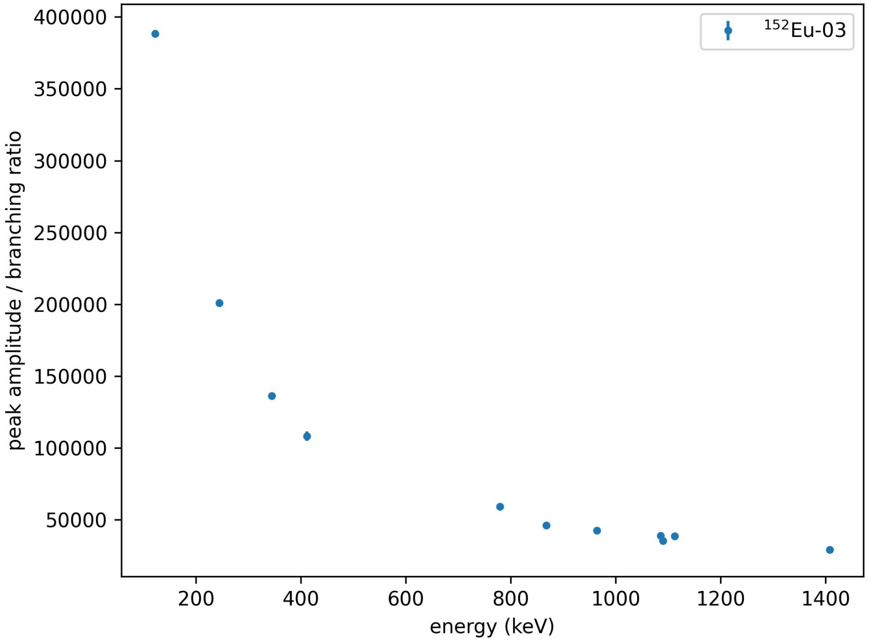
Steps

1. Test analysis chain
   - Select calibration data
   - Select detector
   - Fit calibration peaks
   - Produce relative efficiency curve
   - Select beam data
   - Fit peaks
   - Produce relative intensities
   - Derive partial yields
2. Apply to all 8 detectors
3. Perform multi-detector analysis

Relative efficiency

Peak (keV)	Branching Ratio (%)	Peak (keV)	Branching Ratio (%)
121.8	28.53 ± 0.16	867.4	4.23 ± 0.03
244.7	7.55 ± 0.04	964.1	14.51 ± 0.07
344.3	26.59 ± 0.20	1085.8	10.11 ± 0.05
411.1	2.24 ± 0.01	1089.7	1.73 ± 0.01
778.9	12.93 ± 0.08	1112.1	13.67 ± 0.08
		1408.0	20.87 ± 0.09

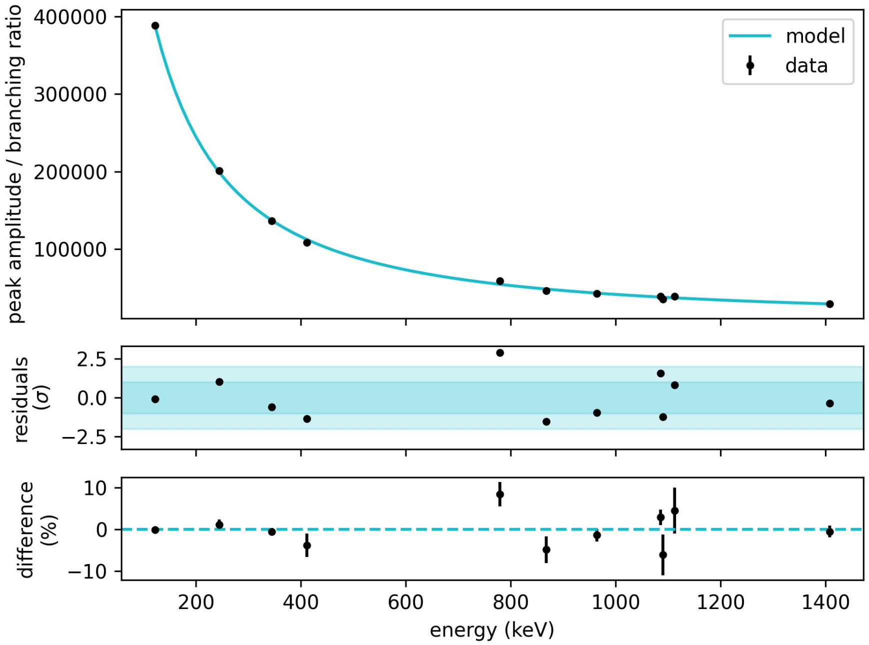
From nudat3



Efficiency fit

$$p(E) = \frac{1}{E} \cdot \sum_i C_i \ln(E)^i \,*$$

- χ^2 fit (Neyman) using iminuit
- model under study

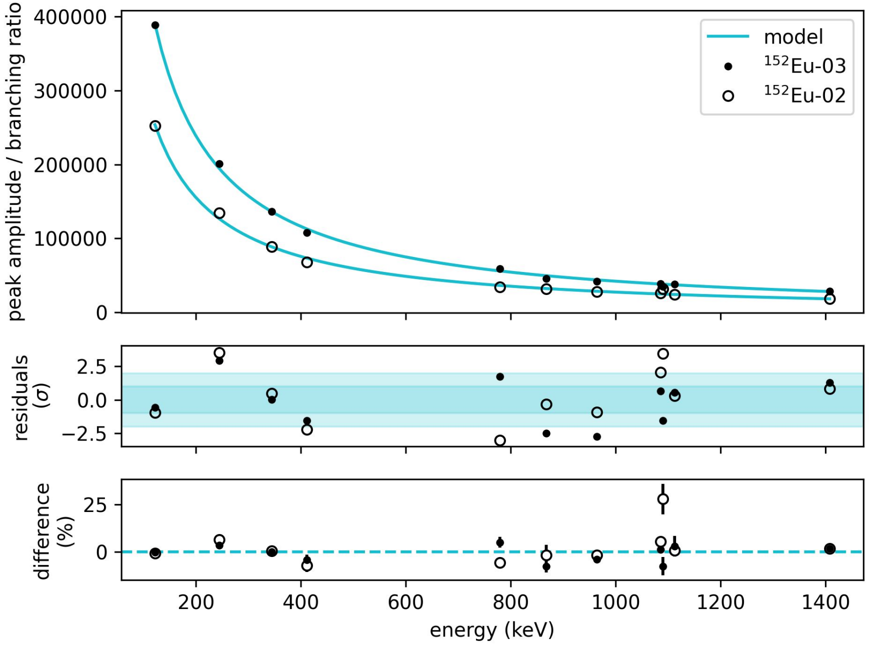


*AIP Conference Proceedings 1584, 38–44 (2014)

Combined efficiency fit

$$p(E) = \frac{1}{E} \cdot \sum_i C_i \ln(E)^i$$

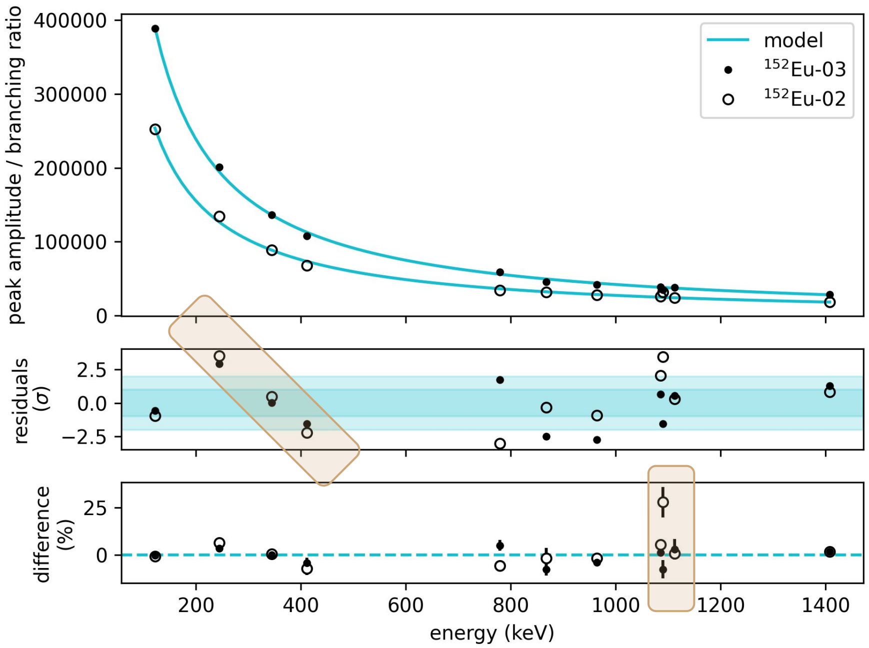
- χ^2 fit (Neyman) using iminuit
- model under study
- shared shape parameters for different calibration runs
- to do: estimate uncertainty (bootstraping, systematics?)



Combined efficiency fit

$$p(E) = \frac{1}{E} \cdot \sum_i C_i \ln(E)^i$$

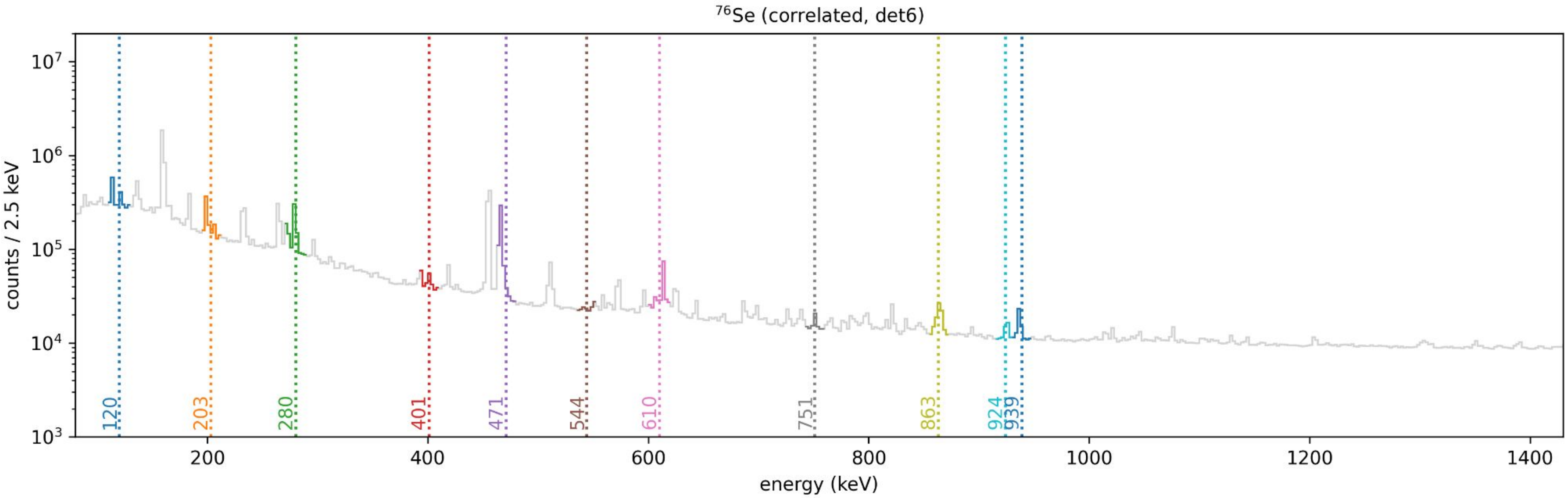
- χ^2 fit (Neyman) using iminuit
- model under study
- shared shape parameters for different calibration runs
- to do: estimate uncertainty (bootstraping, systematics?)



Steps

1. Test analysis chain
    - Select calibration data
    - Select detector
    - Fit calibration peaks
    - Produce relative efficiency curve
    - Select beam data
    - Fit peaks
    - Produce relative intensities
    - Derive partial yields
2. Apply to all 8 detectors
3. Perform multi-detector analysis

Physics spectrum



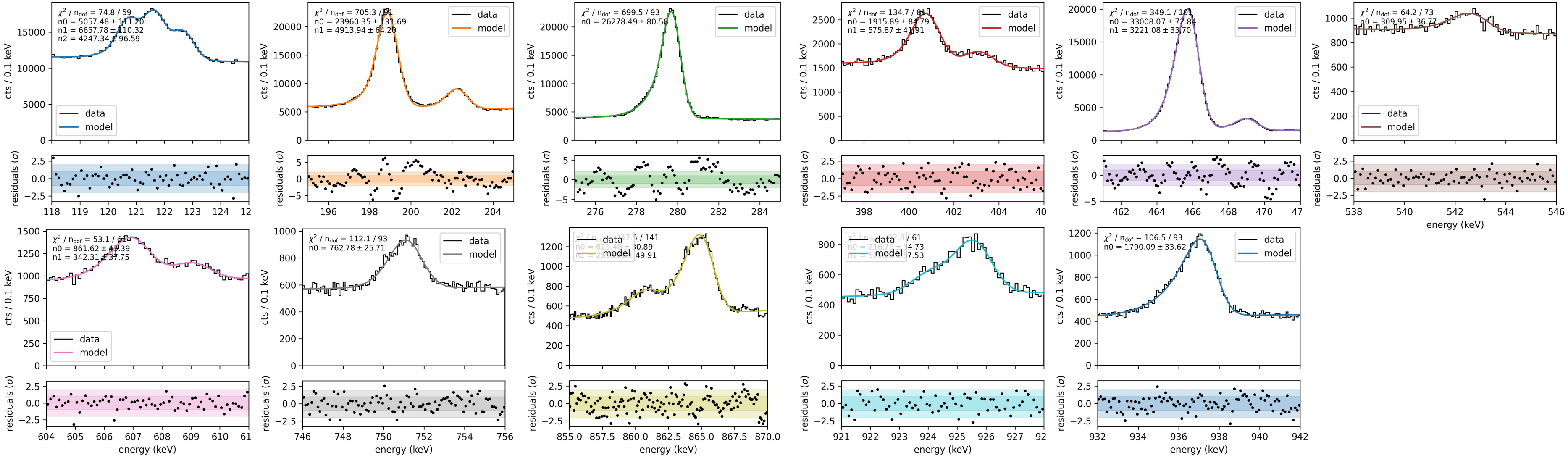
- selected lines from OMC4DBD paper*

*[Zinatulina et al. PRC 99(2) (2019)]

Steps

1. Test analysis chain
    - Select calibration data
    - Select detector
    - Fit calibration peaks
    - Produce relative efficiency curve
    - Select beam data
    - Fit peaks
    - Produce relative intensities
    - Derive partial yields
2. Apply to all 8 detectors
3. Perform multi-detector analysis

Physics Peak fits



Steps

1. Test analysis chain
   - Select calibration data
   - Select detector
   - Fit calibration peaks
   - Produce relative efficiency curve
   - Select beam data
   - Fit peaks
   - Produce relative intensities
   - Derive partial yields
2. Apply to all 8 detectors
3. Perform multi-detector analysis

Relative intensities (preliminary)

Relative Intensity = Counts / Efficiency

*from nudat

Peak position (keV)		Counts			Efficiency (%)			Relative Intensity (%)		
From literature*	From fit									
120.3	120.7	50574.8	±	1112.0	233.6	±	8.1	**8.2**	**±**	**0.3**
122.2	122.7	42473.4	±	965.9	230.0	±	7.9	**7.0**	**±**	**0.3**
203.5	202.3	49139.4	±	642.0	138.8	±	4.8	**13.5**	**±**	**0.5**
280.3	279.8	262784.9	±	805.8		100			**100**	
401.8	400.8	19158.9	±	847.9	68.5	±	2.4	**10.6**	**±**	**0.6**
471.0	469.3	32210.8	±	337.0	57.8	±	2.4	**21.2**	**±**	**0.8**
544.0	543.0	3099.5	±	367.7	49.4	±	1.8	**2.4**	**±**	**0.3**
610.0	609.4	3423.1	±	377.5	43.6	±	1.6	**3.0**	**±**	**0.3**
751.8	751.5	7627.8	±	257.1	34.6	±	1.2	**8.4**	**±**	**0.4**
863.3	861.4	6254.8	±	308.9	29.6	±	1.1	**8.0**	**±**	**0.5**
924.7	924.3	2167.5	±	347.3	27.4	±	1.0	**3.0**	**±**	**0.5**
939.7	937.7	17900.9	±	336.2	26.9	±	1.0	**25.4**	**±**	**1.0**

Steps

1. Test analysis chain
    - Select calibration data
    - Select detector
    - Fit calibration peaks
    - Produce relative efficiency curve
    - Select beam data
    - Fit peaks
    - Produce relative intensities
    - Derive partial yields
2. Apply to all 8 detectors (weighted average)
3. Perform multi-detector analysis

Multi-detector fit

- make use of array by combined fit of each line using
  - individual peak shape
  - common peak position (flexible within calibration uncertainty)
  - common intensity (regulated efficiency ratio, deadtimes)

Conclusion

- set up analysis chain for partial capture rates, tested for one detector
- to do:
  - understand problematic peak shapes (e.g. right tail)
  - improve fitting (e.g. pull terms on resolution/position)
  - find best efficiency model (detector dependence?)
  - investigate potential systematics
  - set up multi-detector analysis

What precision do the theorists need?