Measurements of 10 ps lifetime of 10+ state in 128Cs – experiment and analysis

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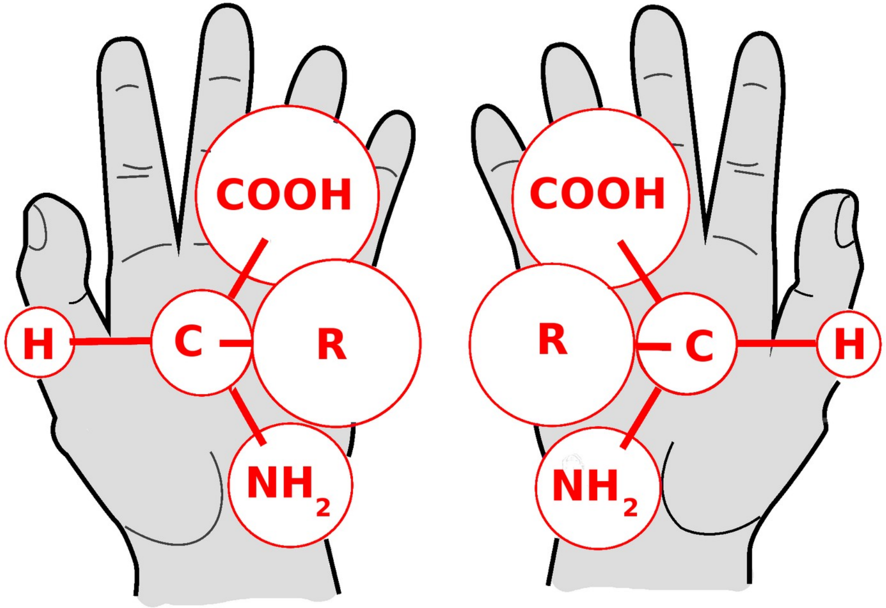
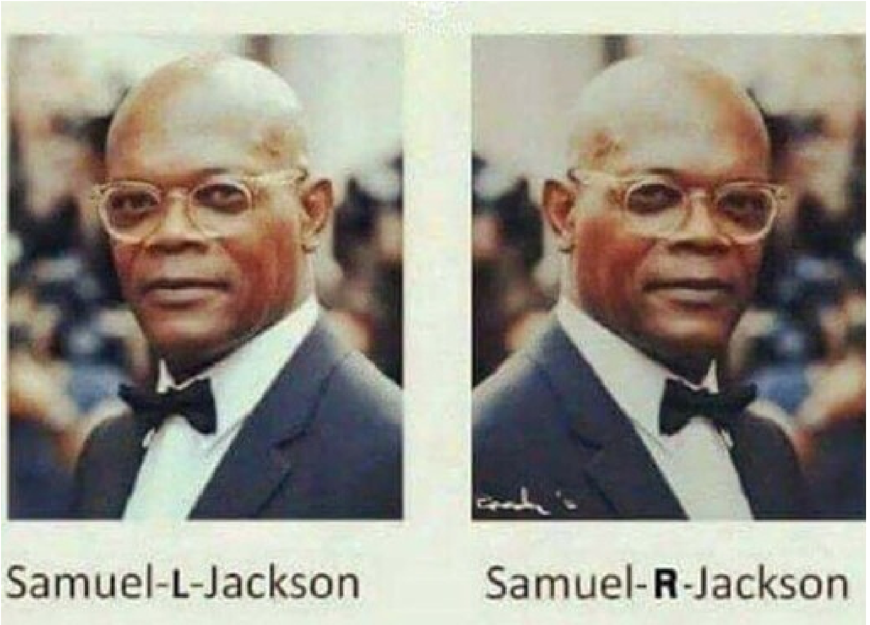
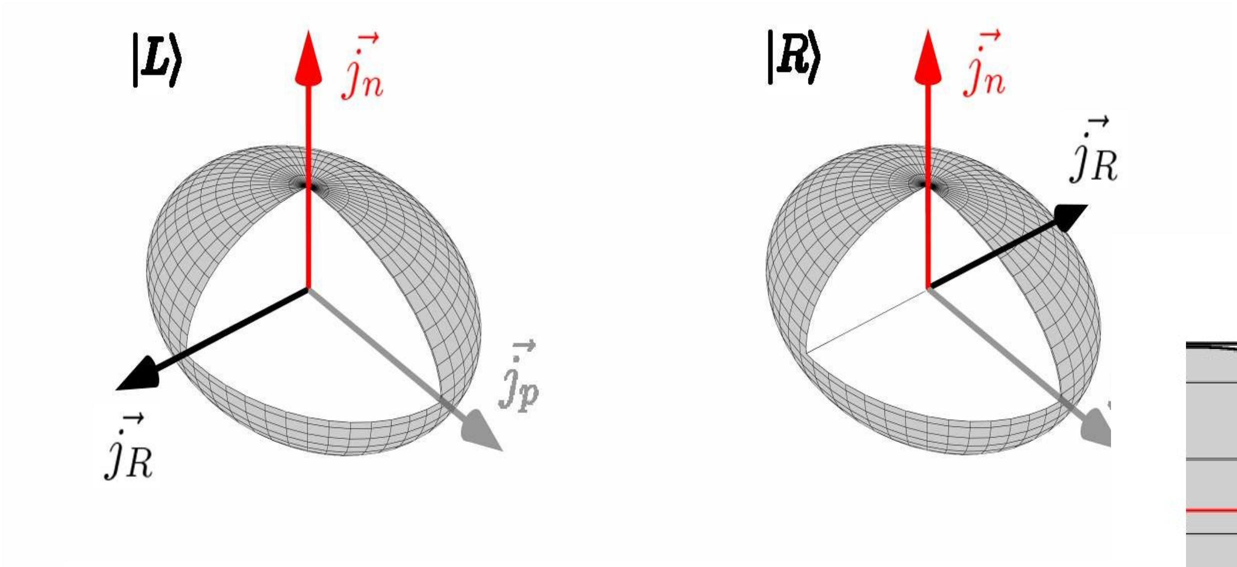
  - Velocity distribution
- Future

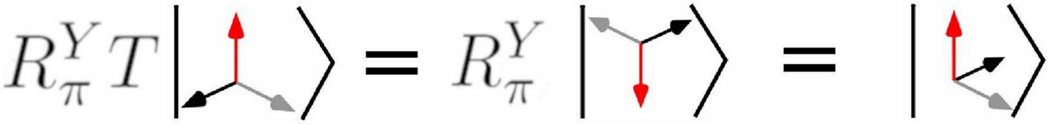
Chirality – 2 states identical, but different

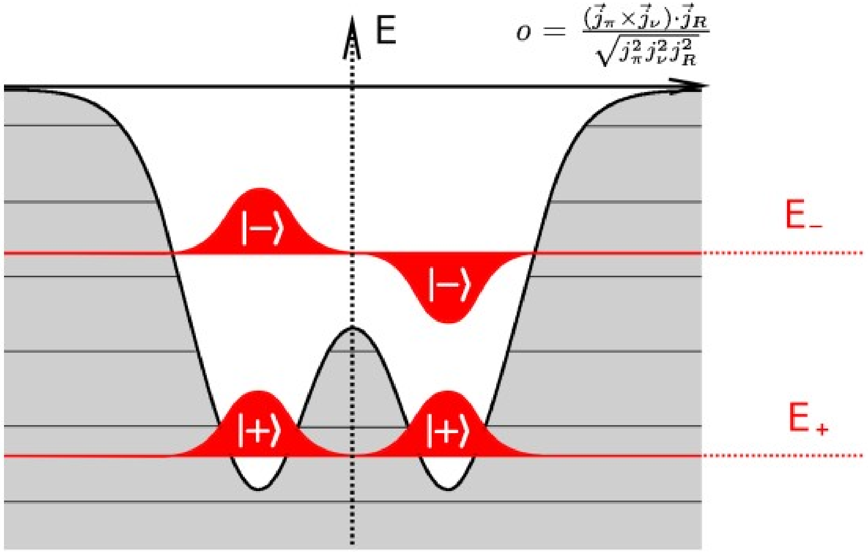




Nuclear chirality – time reflection



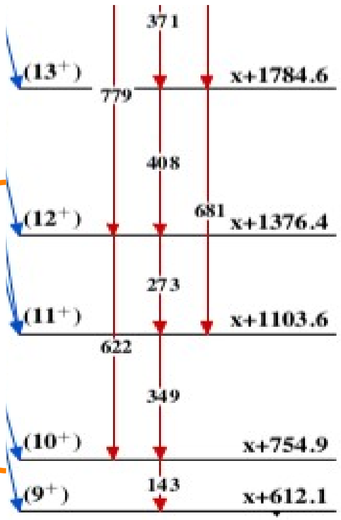




^{128}Cs – chiral nuclei

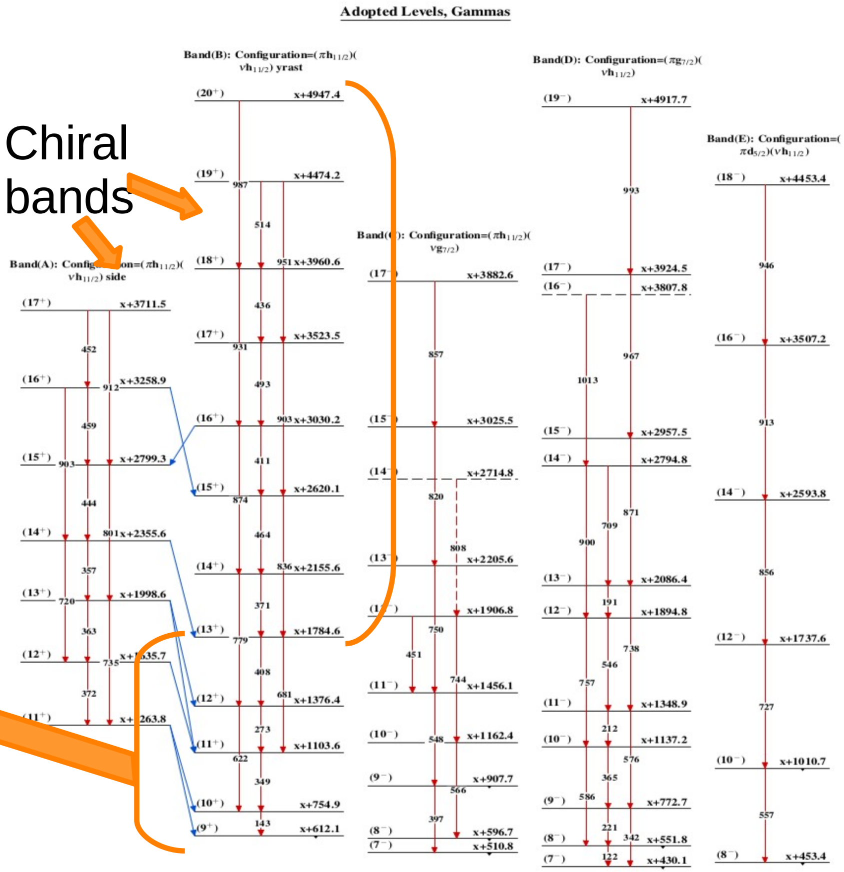
Unknown chirality

Not chiral!



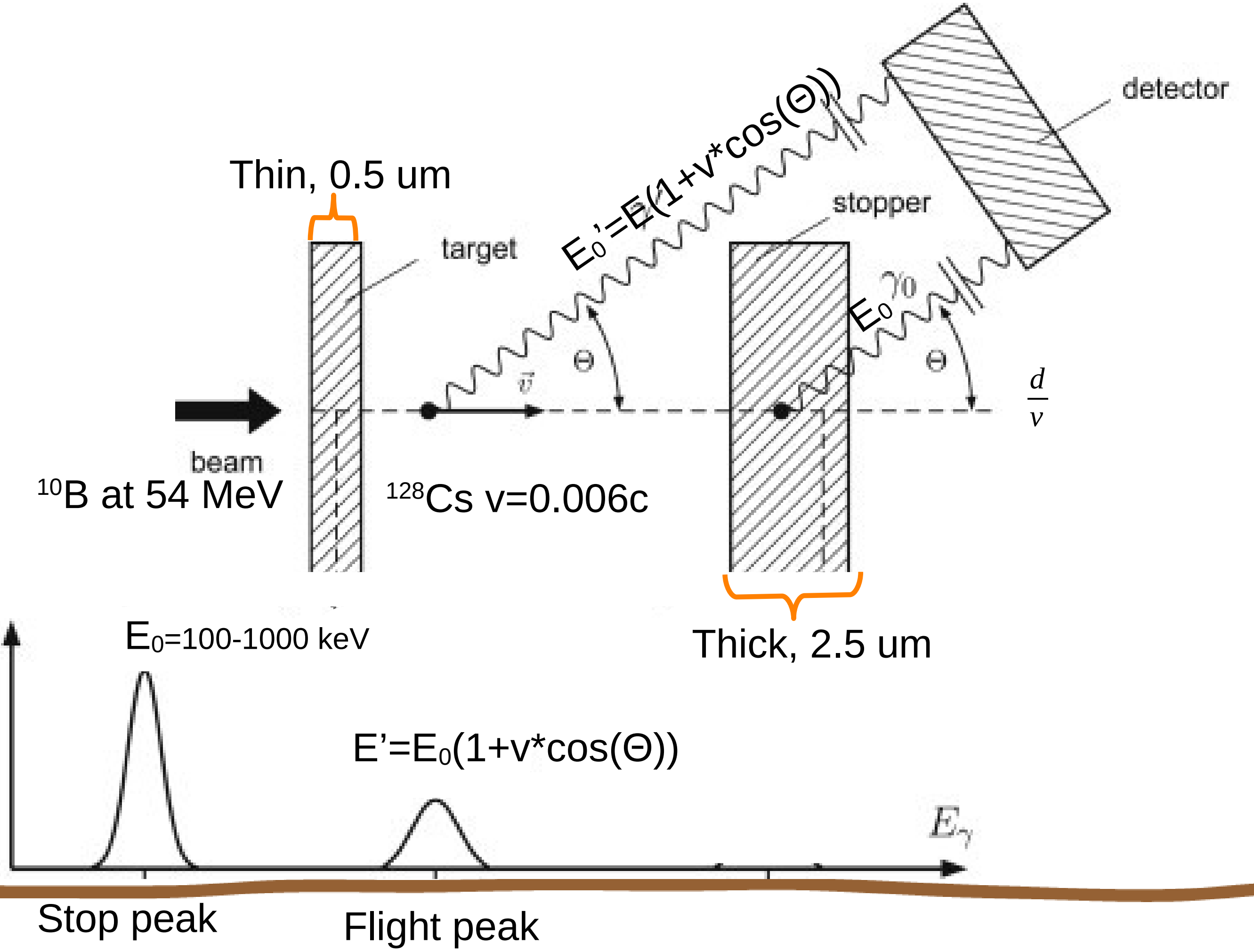
Chiral states

Chiral bands



NNDC.bnl.gov, adopted levels in ^{128}Cs

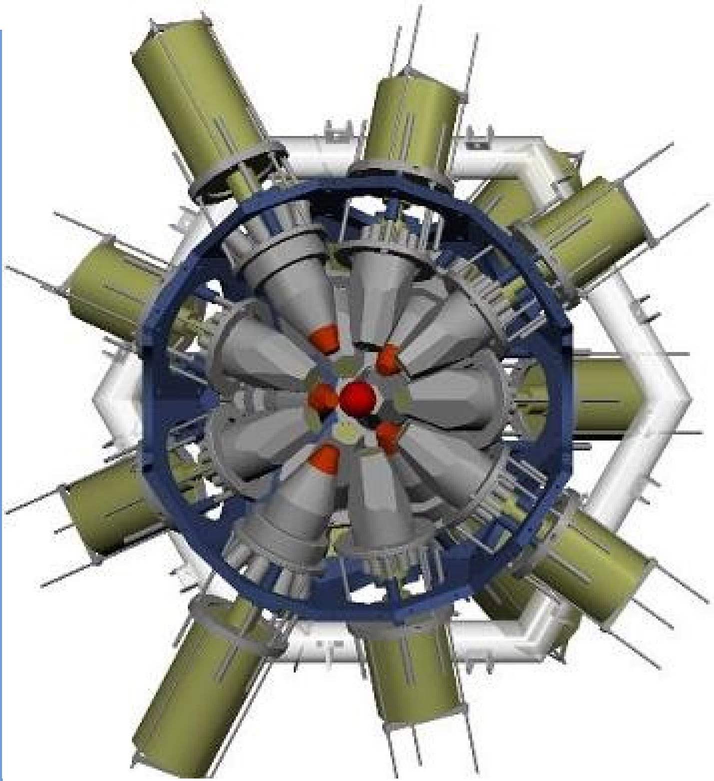
Recoil Distance Doppler Shift – lifetime measurement



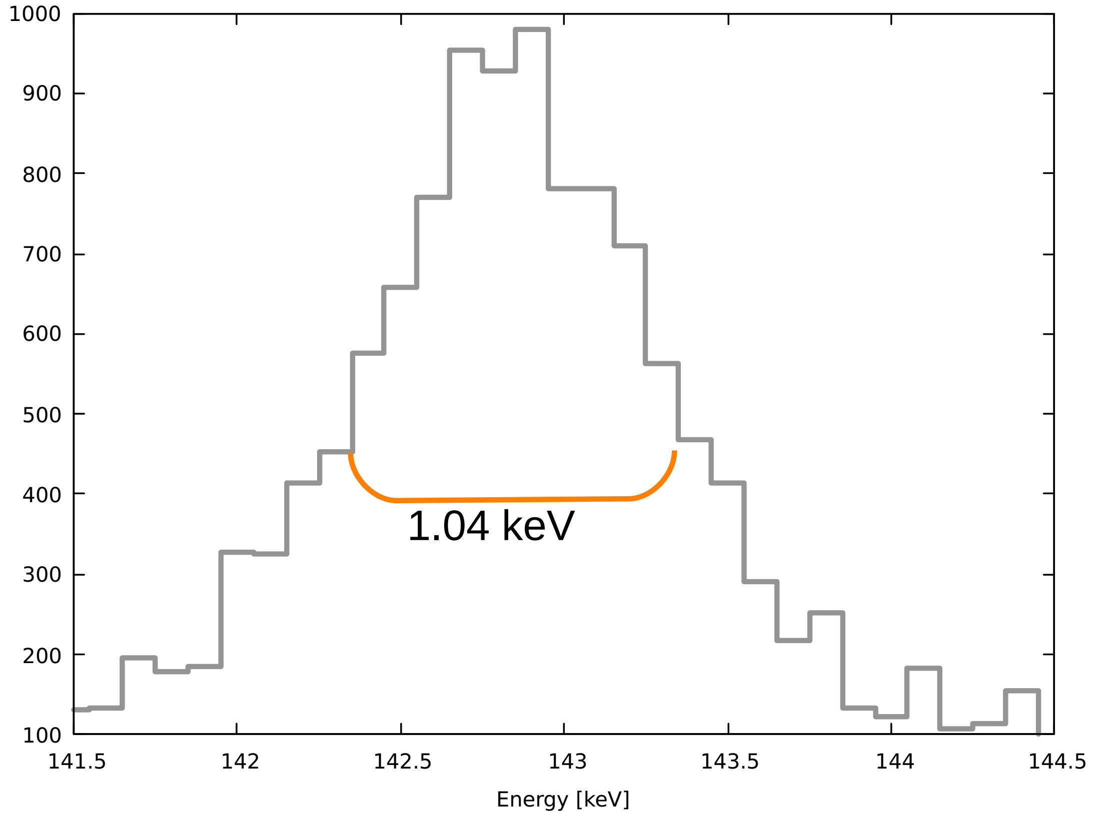
- Flight time t= $\frac{d}{v}$
- Probability of de-excitation during flight $e^{\frac{-t}{\tau}}$
- Minimal distance 15 um
- v=0.006c=1.8*10^{6}m/s
- Minimal time 8 ps

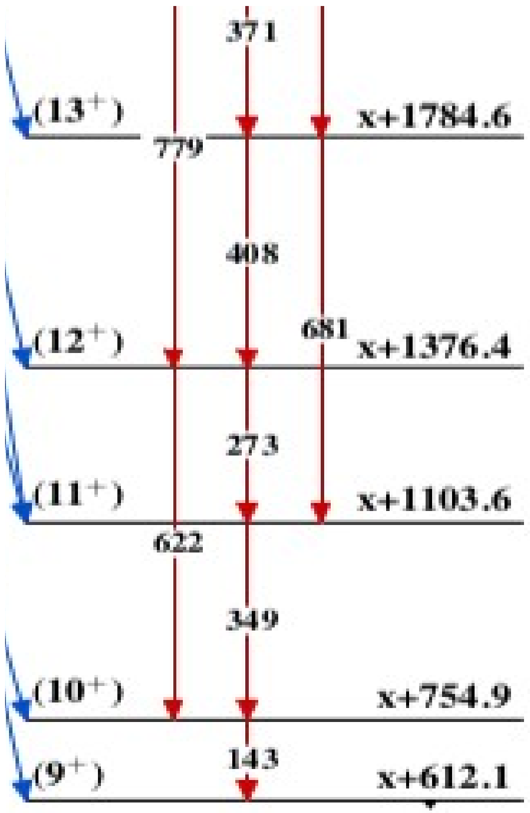
Experiment setup

- Heavy Ion Laboratory, Warsaw
- 13 days of beam
- $6*10^9$ particles per second
- Crossection 350 mbar, probability $\sim5*10^{-7}$
- 3000 ^{128}Cs produced per second
- Eagle – 14 detectors 10-20 cm from target, 2 cm diameter
- ~0.06% chance photon collected by single detector
- 1.8 single detection per second



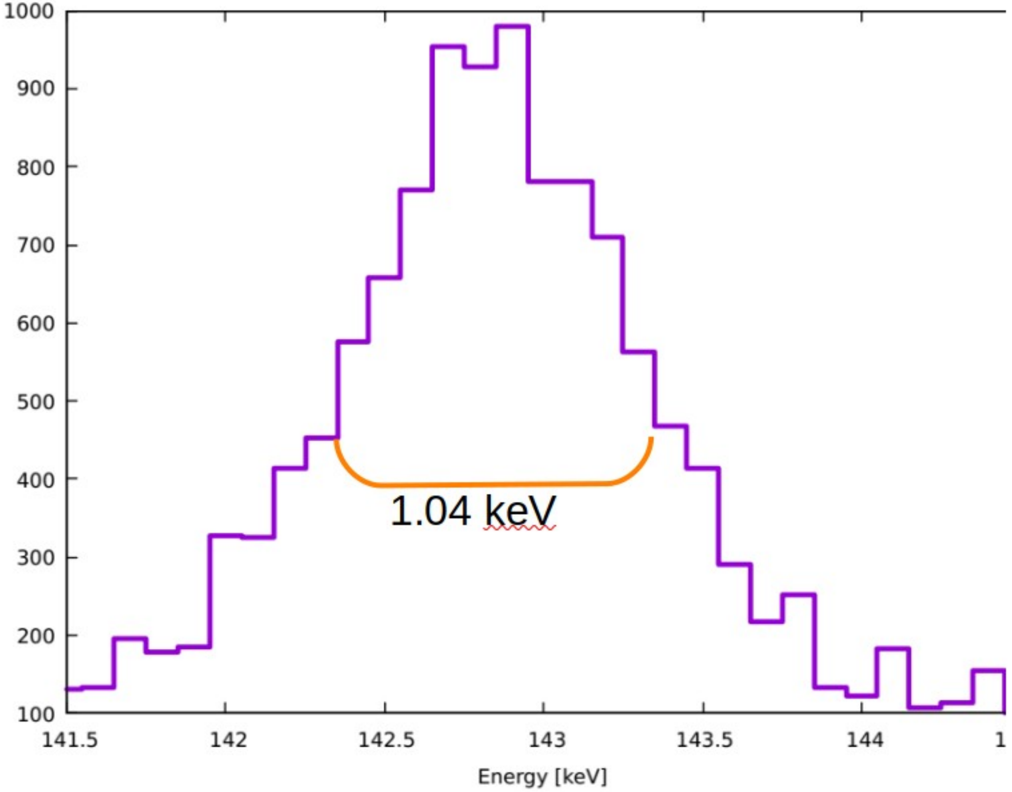
Resolution vs Doppler shift

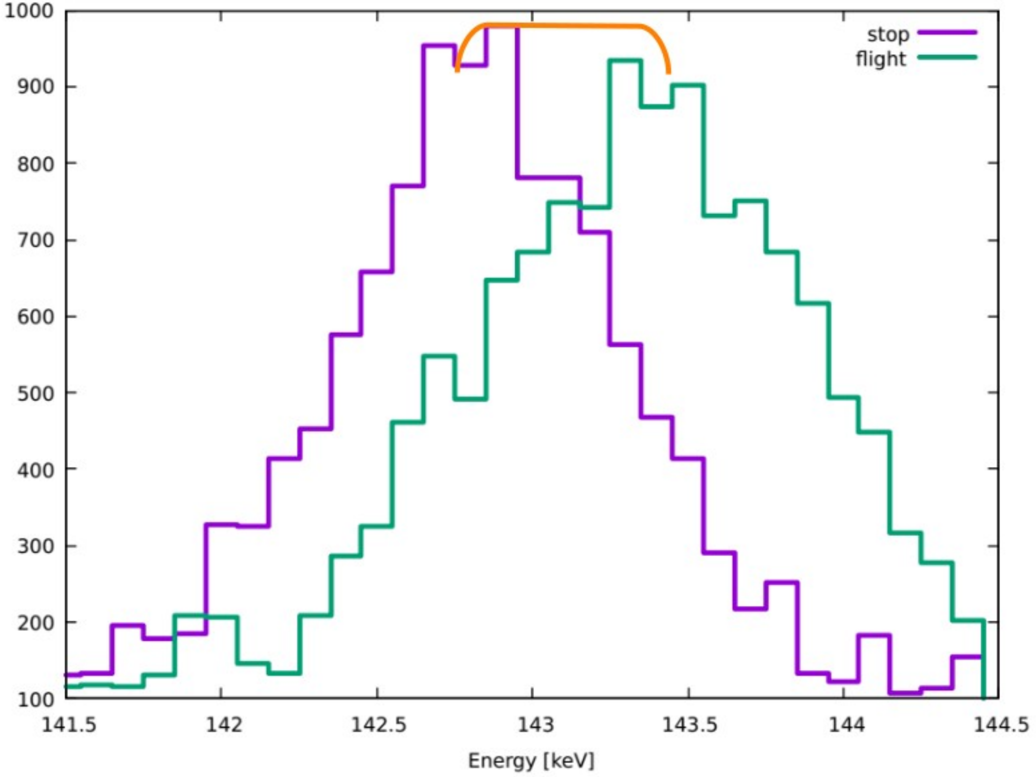




Resolution vs Doppler shift

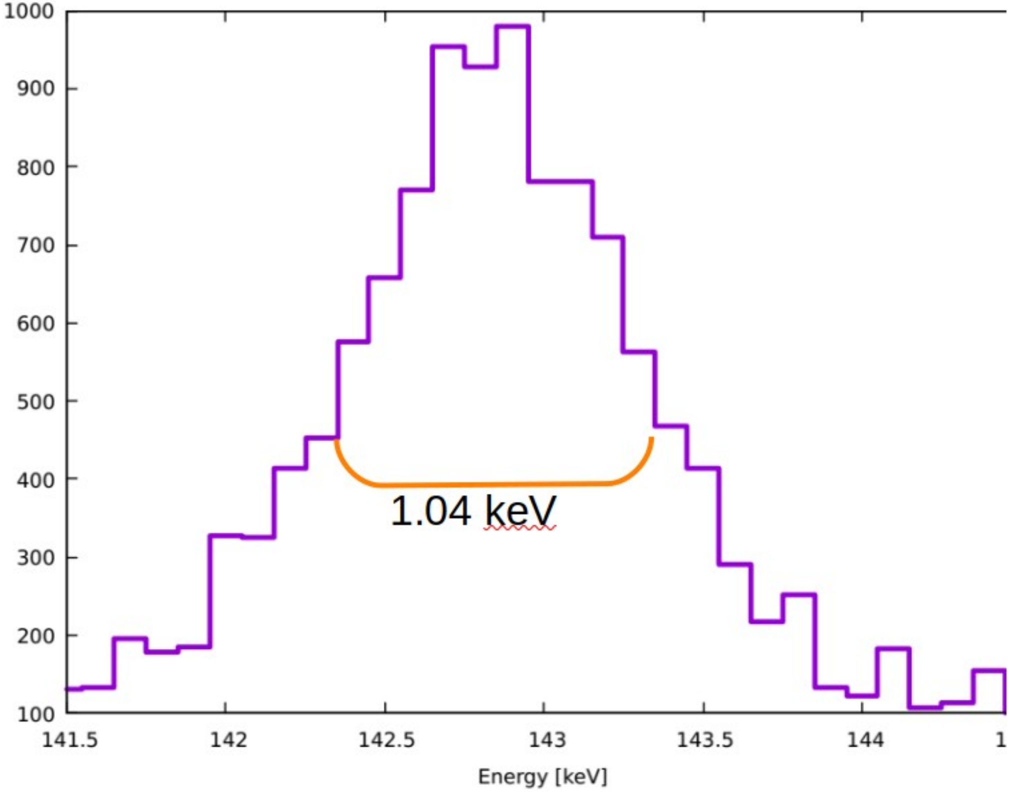
$143 \cdot 0.006 \cdot \cos(\Theta) = \mathbf{0.76\ keV} < \mathrm{FWHM}$

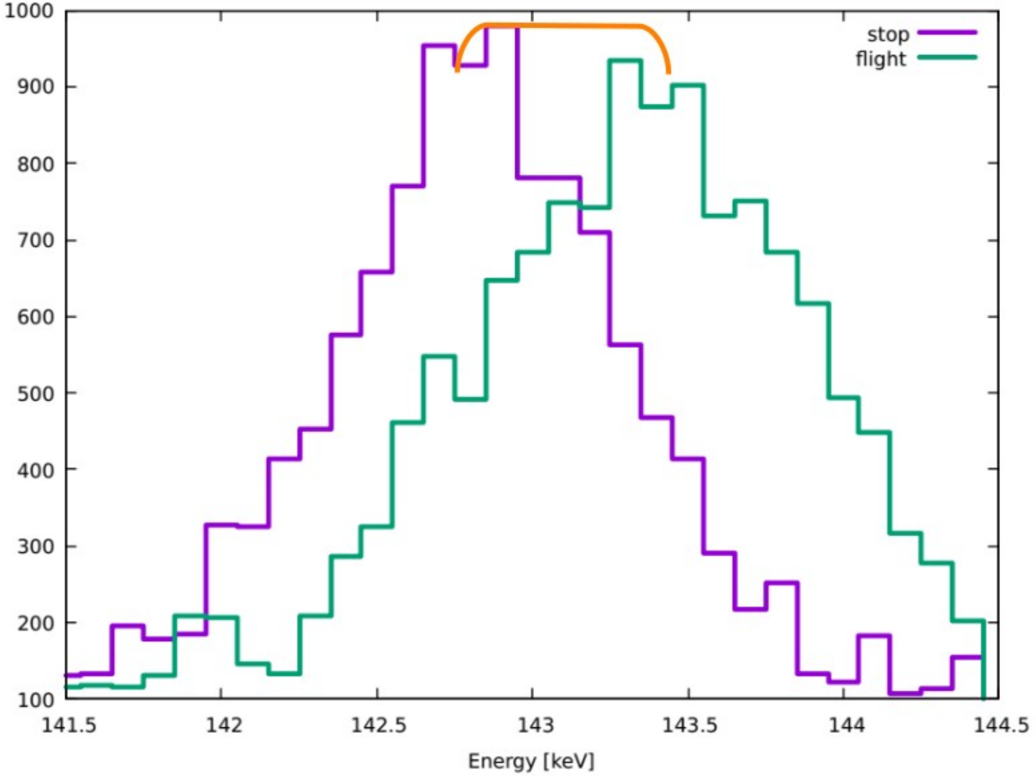




Resolution vs Doppler shift

$143*0.006*\cos(\Theta)=$**0.76 keV**$<$FWHM





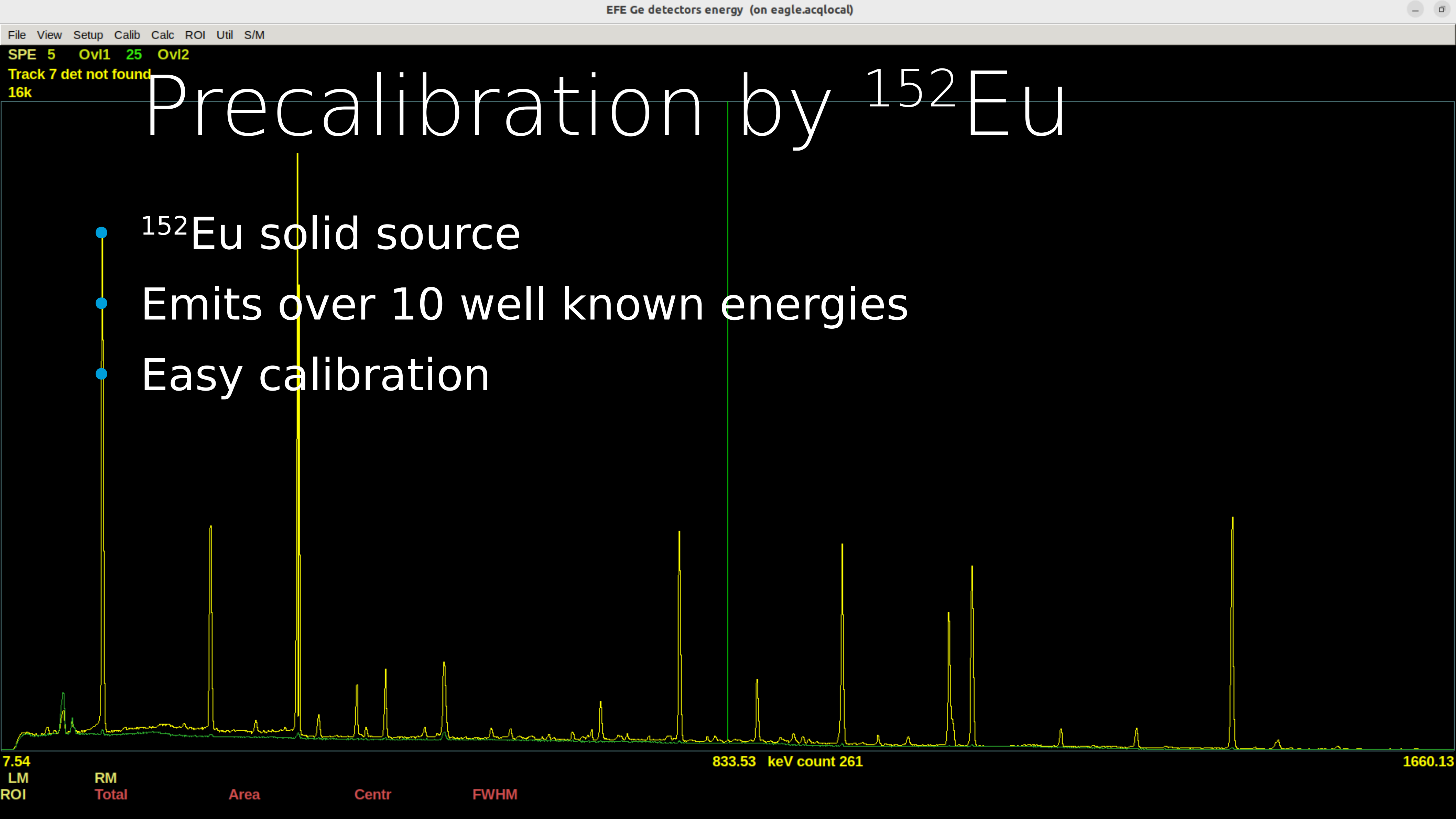
Very precise calibration needed!

Calibration

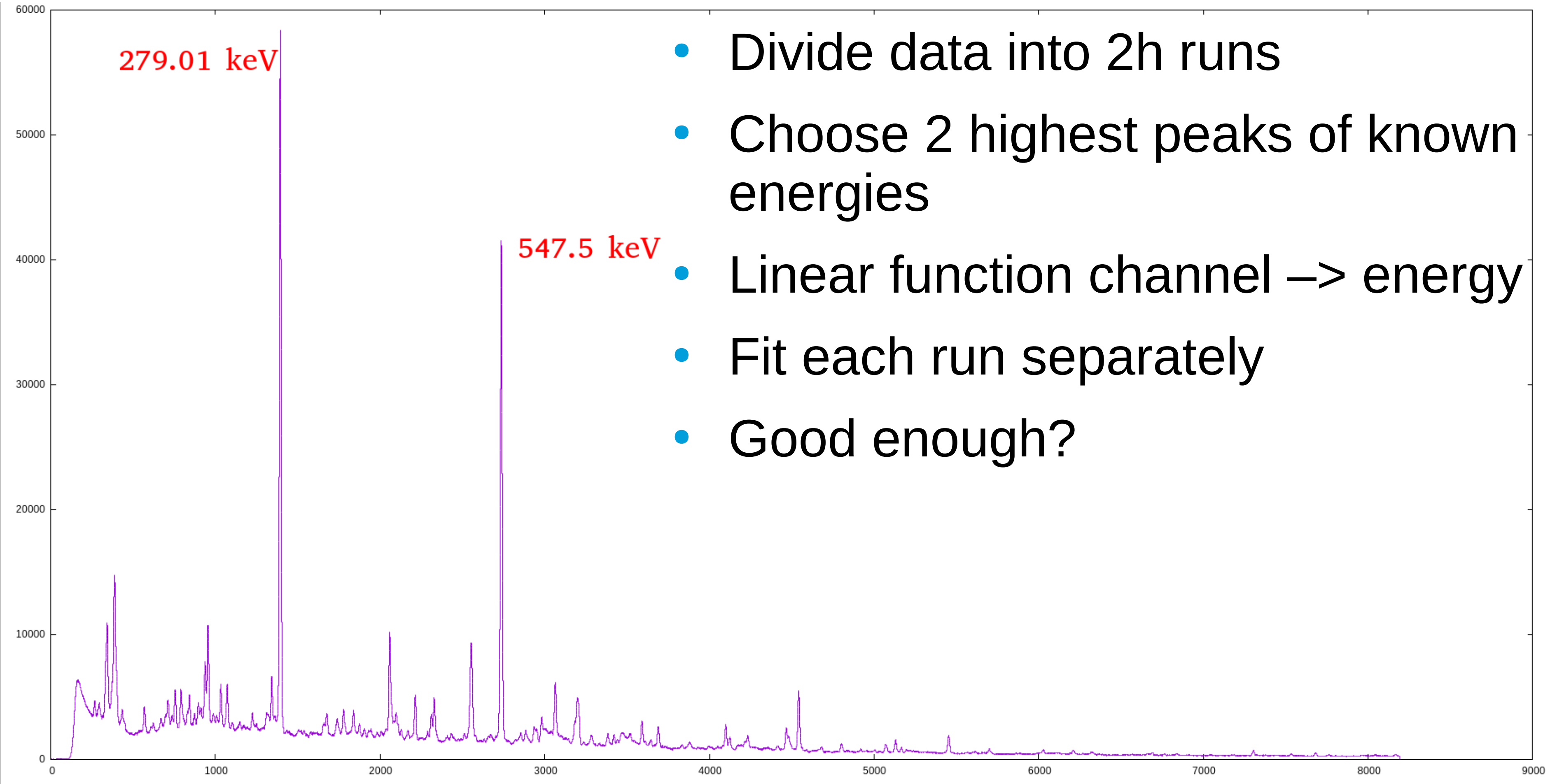
- Detector is a crystal
- We measure voltage
- Voltage is proportional to energy deployed
- Voltage depends also on temperature, beam intensity etc.
- Calibration is linear function from voltage to photons energy
- Calibration changes at ~1% with time

Precalibration by ^{152}Eu

- ^{152}Eu solid source
- Emits over 10 well known energies
- Easy calibration

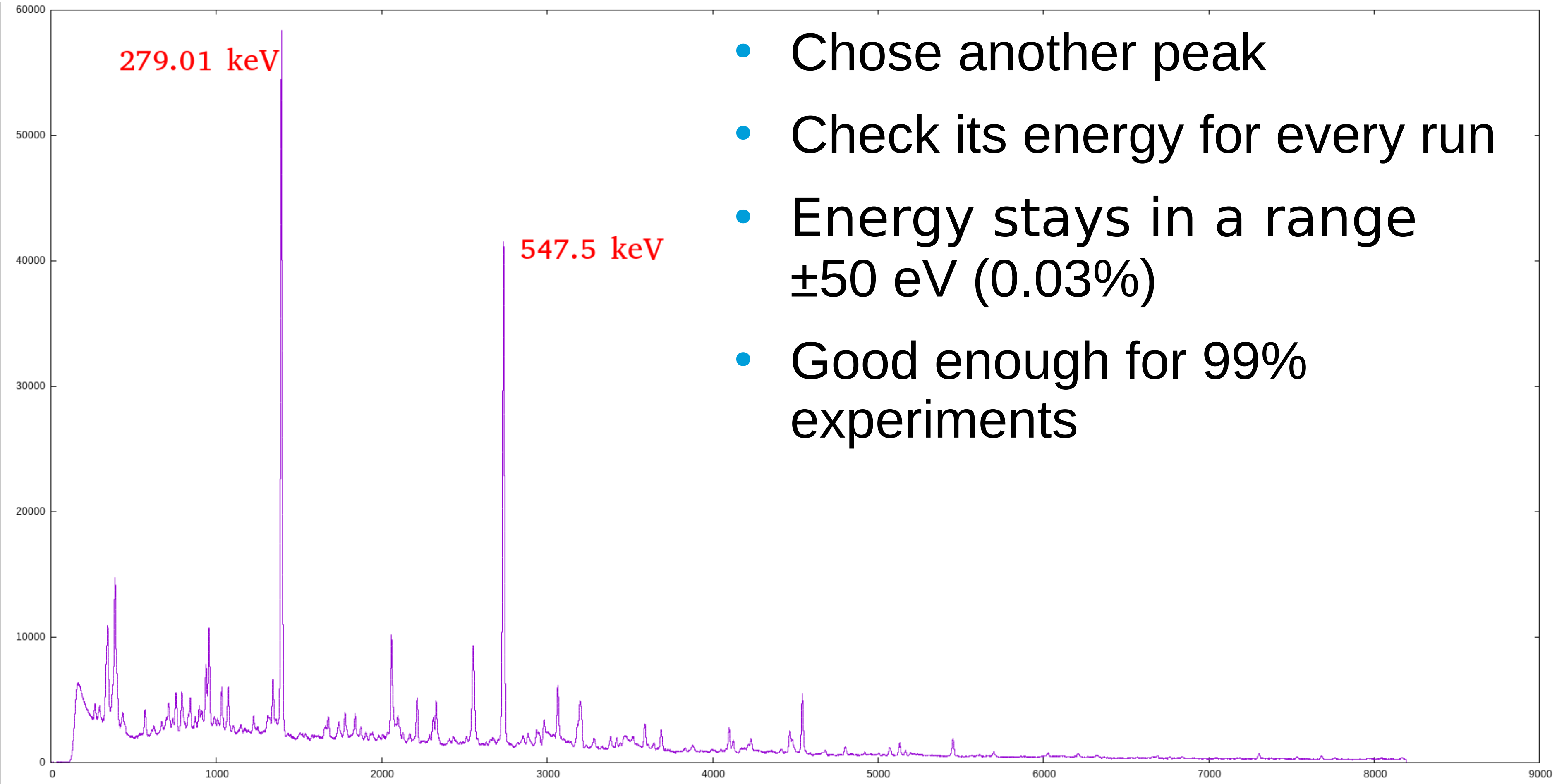


Calibration on 2 peaks



- Divide data into 2h runs
- Choose 2 highest peaks of known energies
- Linear function channel –> energy
- Fit each run separately
- Good enough?

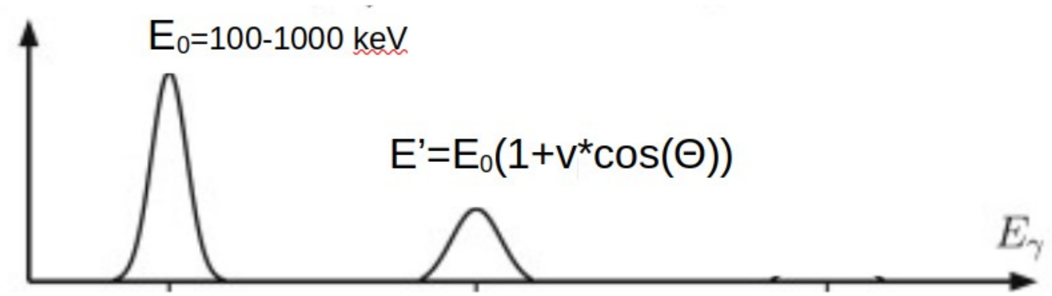
Calibration on 2 peaks

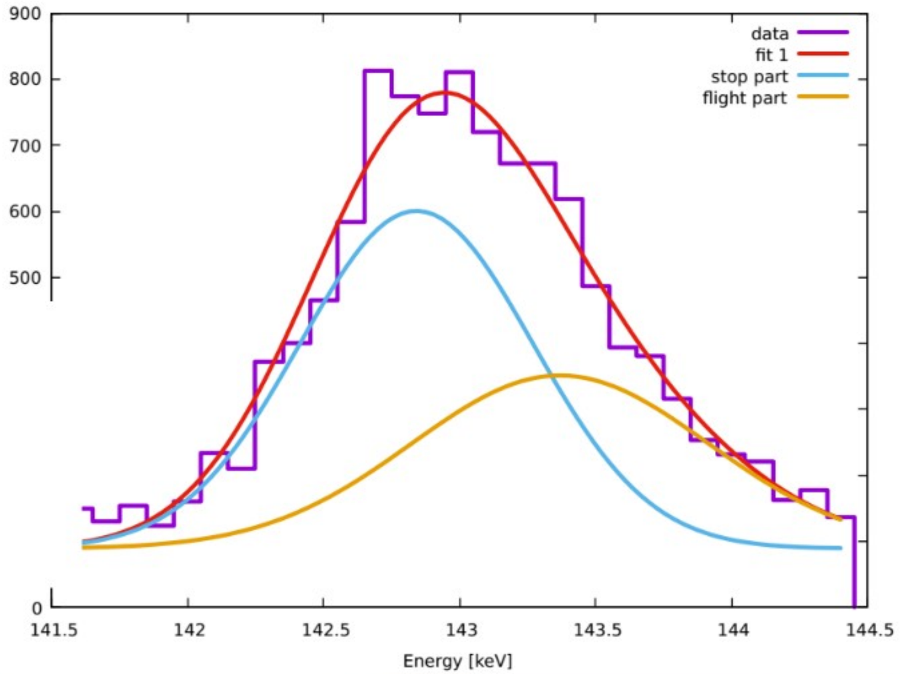


- Chose another peak
- Check its energy for every run
- Energy stays in a range ±50 eV (0.03%)
- Good enough for 99% experiments

Enough calibration?

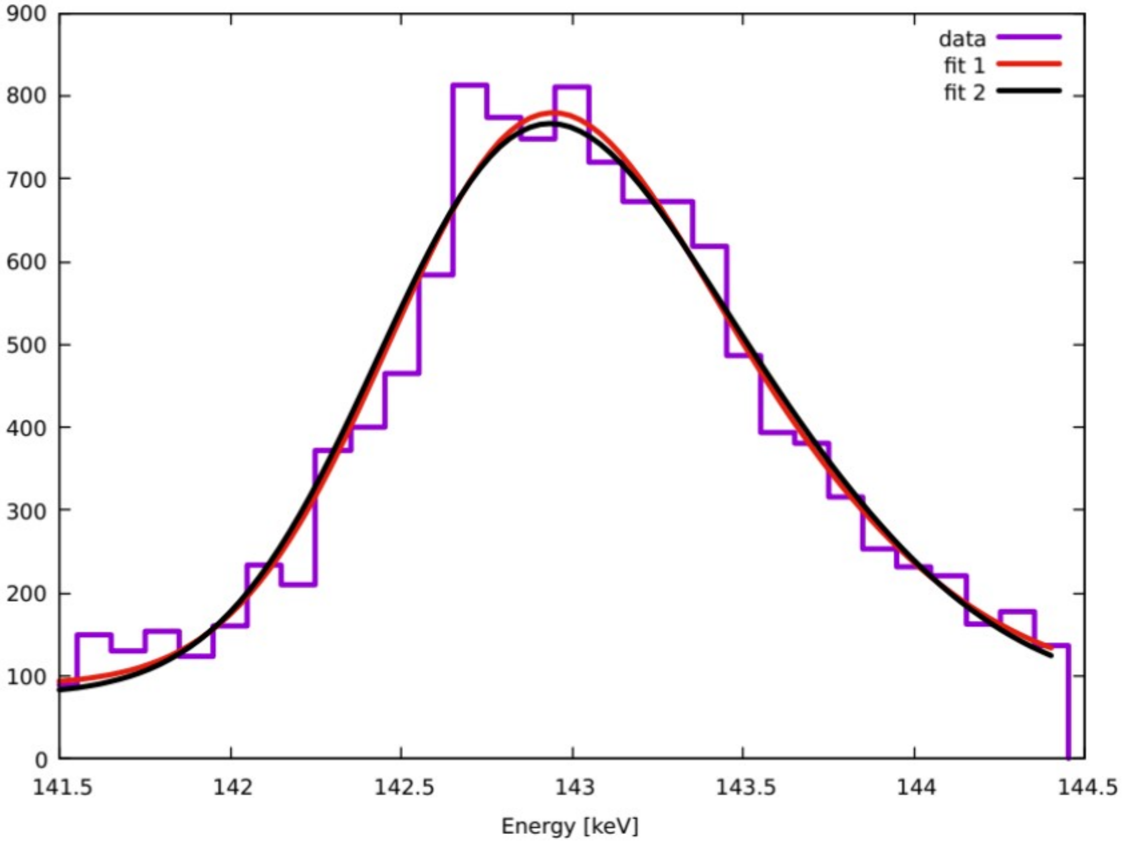
- Flight and stop peaks
- Normally separated, now not
- Can't see 2 peaks, must fit



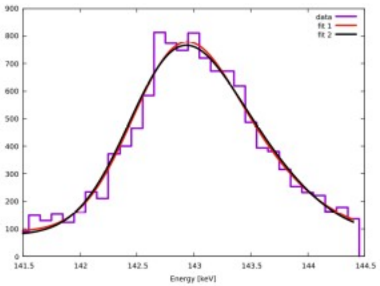


Enough calibration?

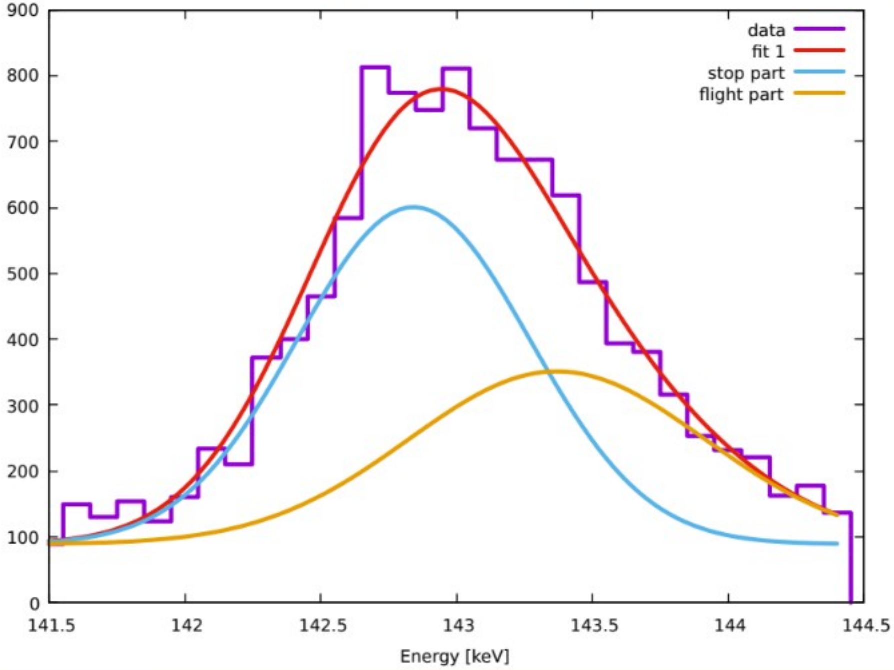
- 50 eV difference
- Similar fit, BUT

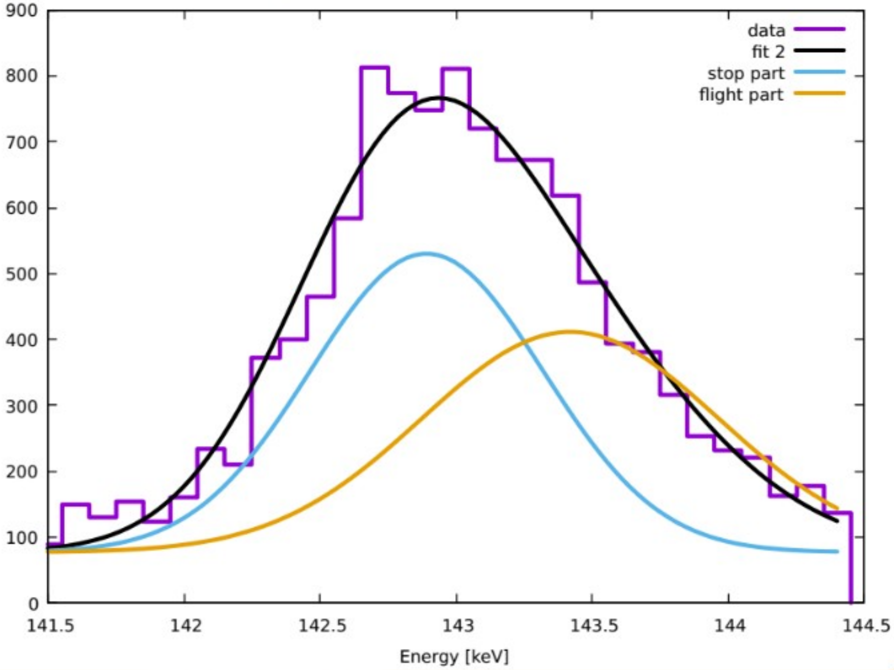


Enough calibration?



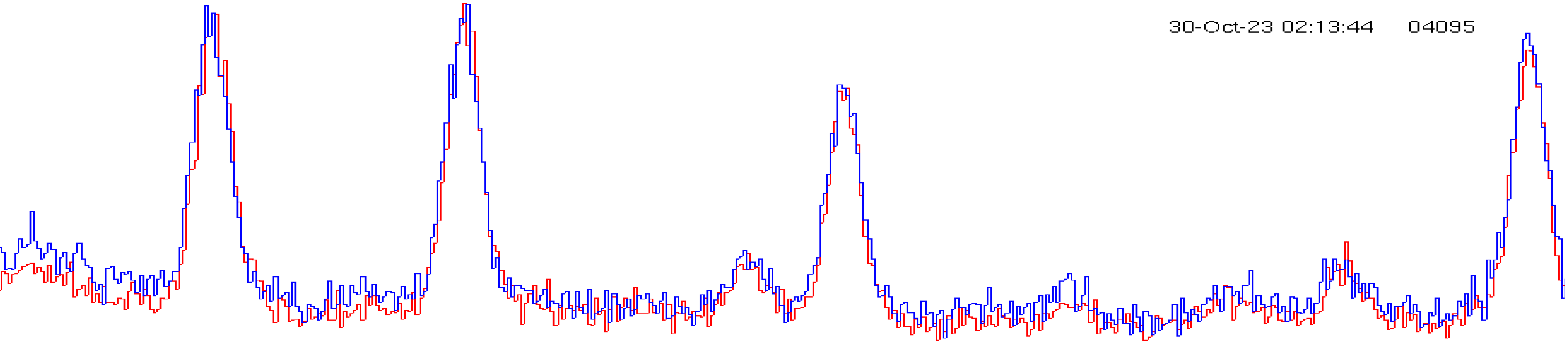
- 50 eV difference
- Similar fit, BUT flight and stop parts very different!





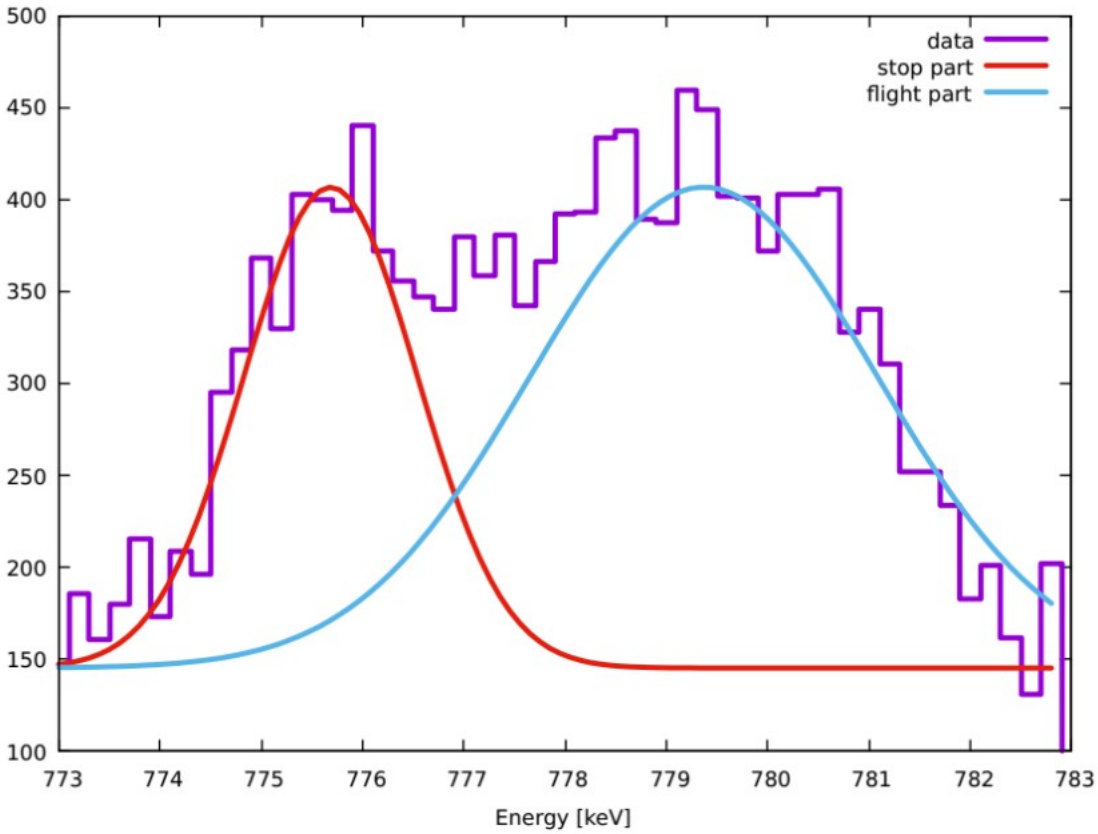
Final calibration

- Much longer procedure
- Peak stay within ±5-10 eV limit
- Theoretical (statistical) limit – 2-3 eV
- Should be enough



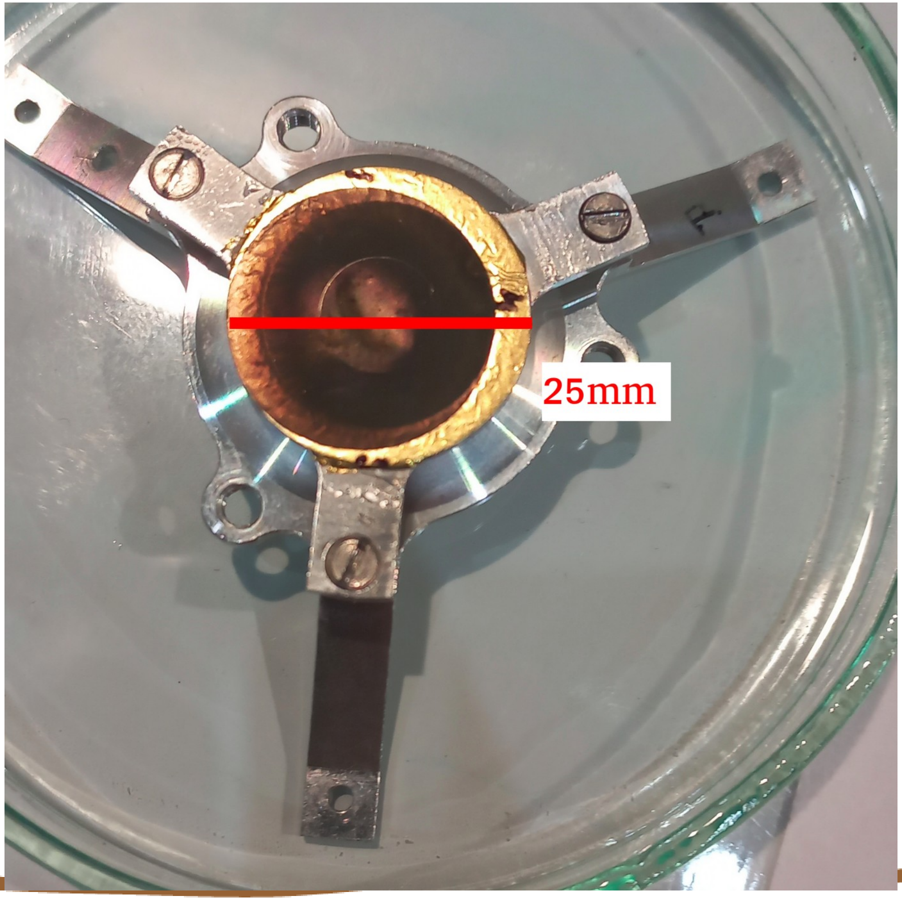
Unexpected problem

- Higher energy, more separated
- Known lifetime <1 ps
- 600 um distance, 330 ps flight
- Why there is stop (unshifted) part?

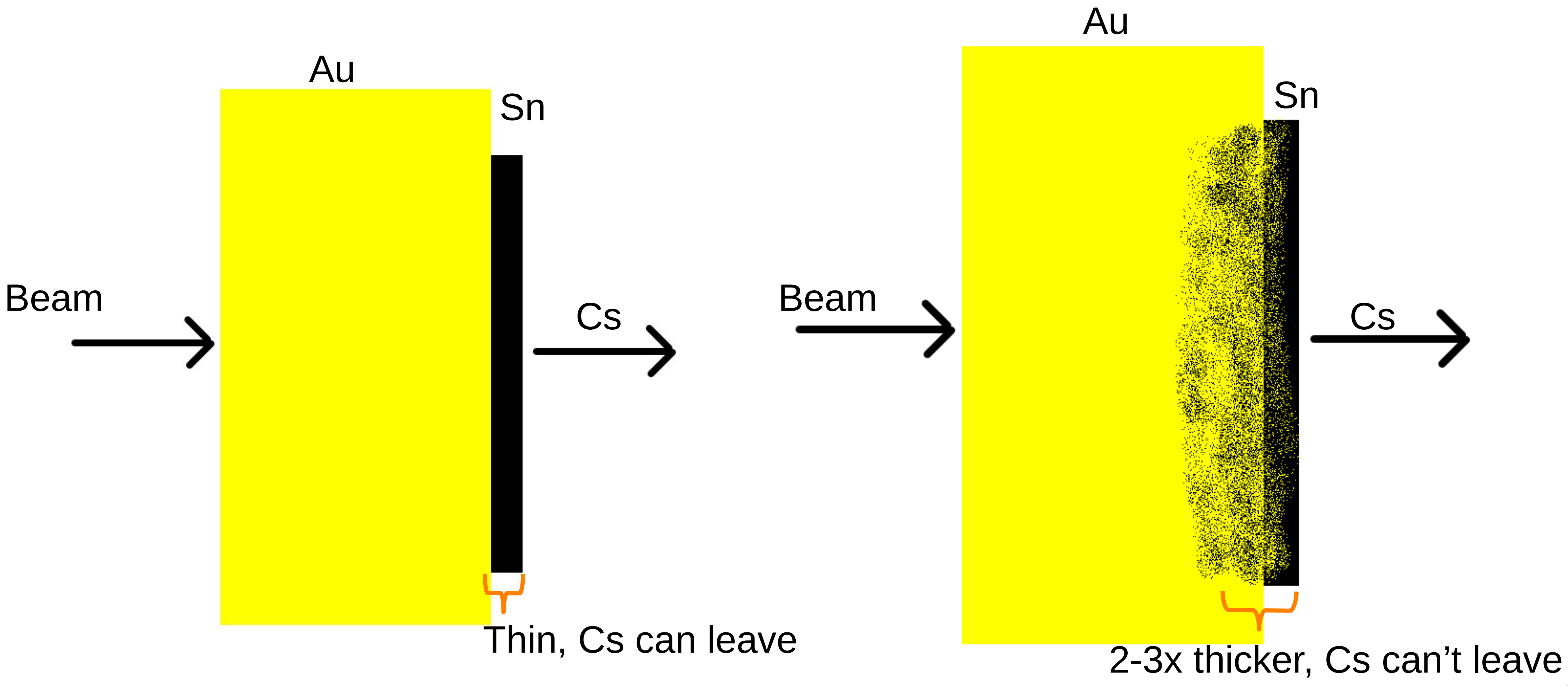


Target details

- 0.5 um tin (Sn)
- Too thin – needs a support
- 2.5 um gold
- Gold is heavy – no reaction
- Beam first hit gold, then tin
- Reaction in tin, product Cs leaves target
- Stops after some time

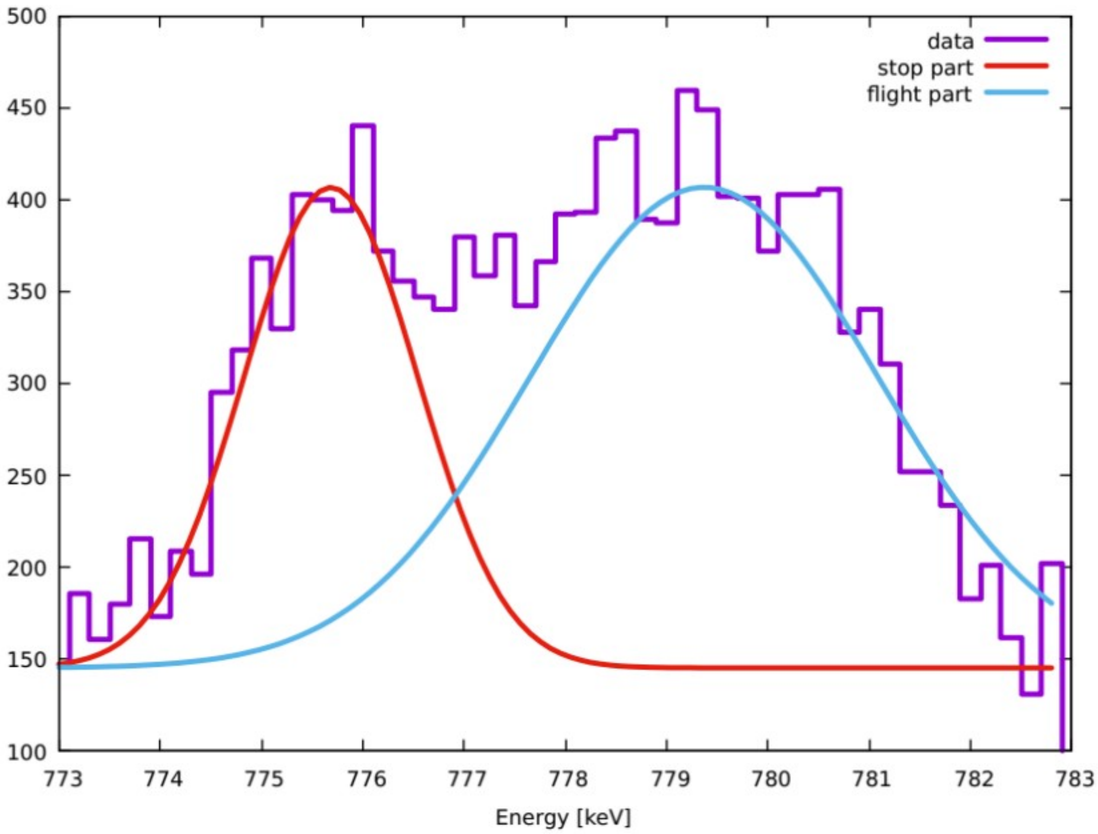


Diffusion


Au
Sn
Beam
Cs
Thin, Cs can leave
Au
Sn
Beam
Cs
2-3x thicker, Cs can’t leave

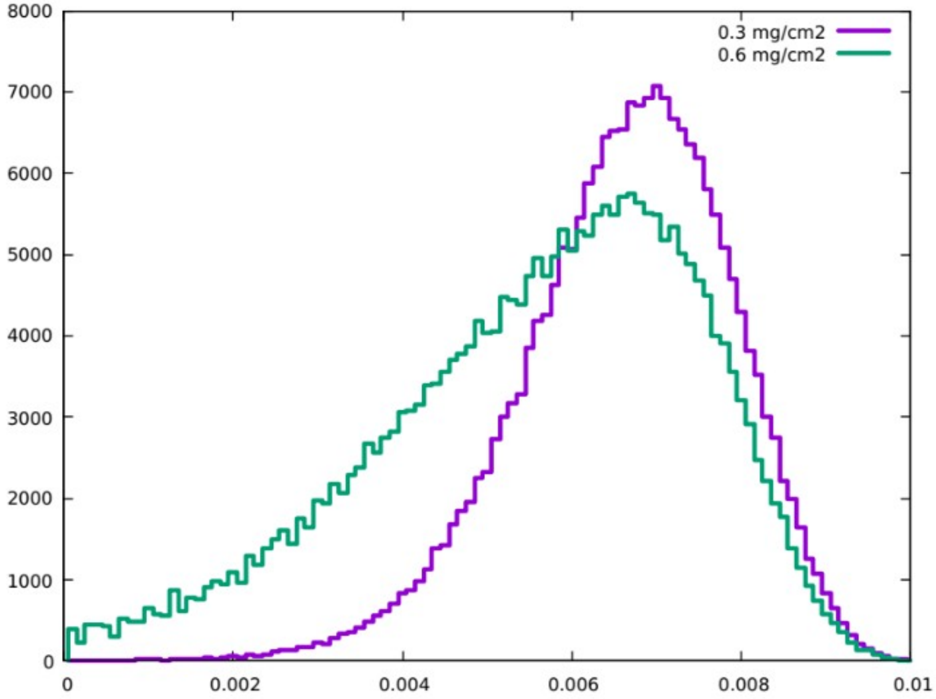
Unexpected problem

- Higher energy, more separated
- Known lifetime <1 ps
- 600 um distance, 330 ps flight
- Why there is stop (unshifted) part? Diffusion!



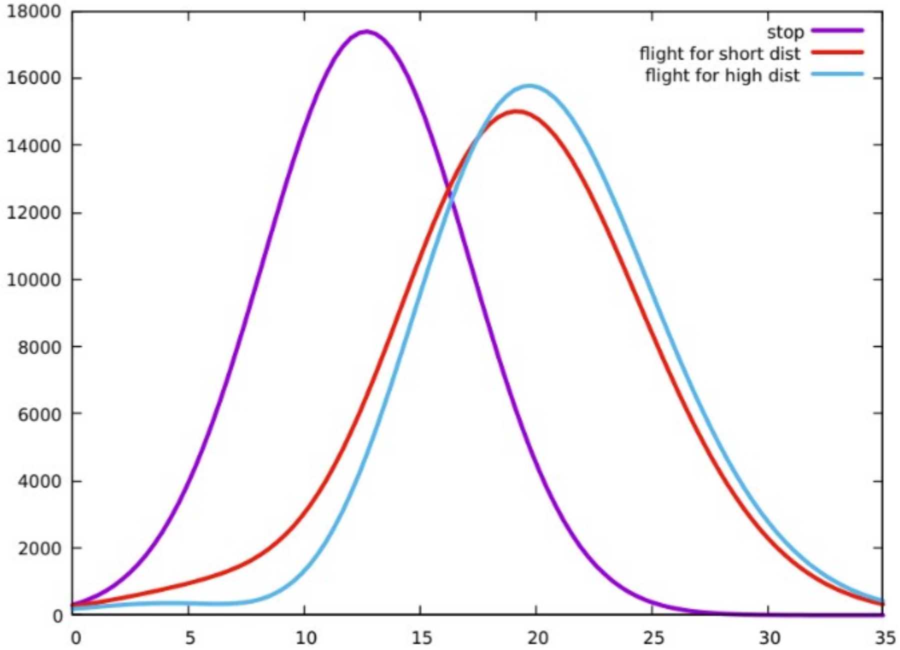
Velocity distribution

- Thin target – velocities 0.007(2)c
- Thick target – velocities at all the range from 0 to maximum
- Diffused target – unknown velocity distribution



Flight peak shape

- Flight time $t = \frac{d}{v}$
- Probability of de-excitation during flight $e^{\frac{-t}{\tau}}$
- Lower v – higher de-excitation probability
- Lower v – lower Doppler shift
- Higher energies less probable for short distance

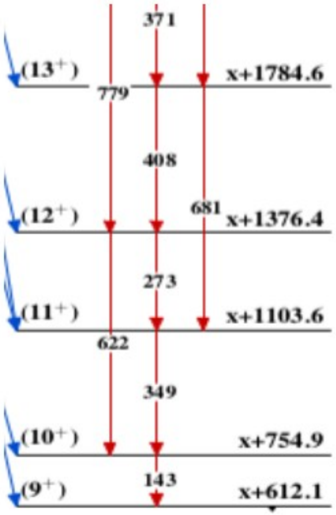


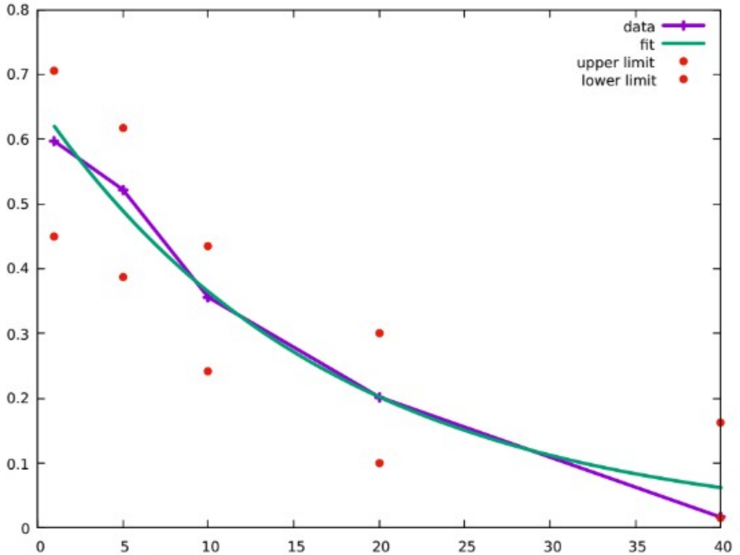
Velocity distribution – reverse engineering

- Assume different velocity distributions
- Simulate peak shaper
- Compare to data
- Fit best by least squares
- χ^2=9.5, should be 5±3 (5 dof)
- Still working on it

Best results for today

- 12+ lifetime 5±4 ps
- 11+ lifetime <4 ps
- 10+ lifetime 12±6 ps
- Might change, but <20 ps
- 10+ non-chiral!





Future

- PAC commission at HIL in mid January 2024
- Decide now, then 3 or more months of preparation
- 2 ideas for next experiment:
  - ^{128}Cs again, different reaction, higher velocities
  - ^{126}Cs – similar reaction, different isotope, less examined

Questions&Ideas

^{128}Cs experiment on Palladium

- $^{110}Pd(^{22}Ne,p3n)^{128}Cs$
- Beam nuclei over 2x heavier
- Beam energy over 1.5x larger
- Recoil velocities over 3x larger
- So 11^+ and 12^+ states lifetimes measured much more precisely
- BUT proton emission – 5-10x less statistics
- Solution: DIAMANT – proton detector soon istalled

^{126}Cs experiment

- $^{120}Sn(^{10}B,4n)^{126}Cs$
- Another chiral nuclei
- Not known the lifetime of 9^{+} state – we could measure
- Similar energies, but lifetimes could be much different
- BUT how to prevent tin from diffusing?

Decision before PAC!