β-decay properties of Co-isotopes

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Motivation

- We want to understand how heavy elements are made vie neutron-capture processes
- In neutron capture processes, it is important to understand β decay
- For exotic nuclei, we rely on models to describe β decay properties
- More experimental data is needed to see how good theoretical models describe neutron rich isotopes
- More experimental data is needed to fully describe neutron capture processes
- One property that is important is the β strength, it tells us how probable it is for an isotope to β decay as a function of excitation energy
- β strength function can also tell us about the shape of the nucleus

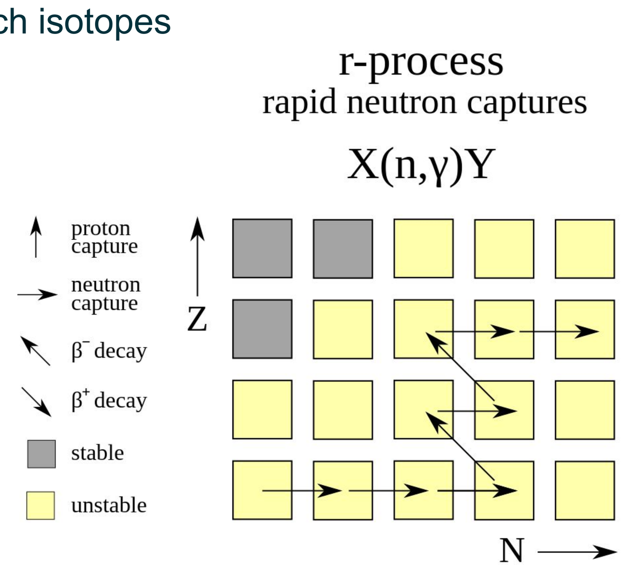

Fig 1: Processes involved in the r process

Total absorption spectroscopy (TAS)

- Experiment at NSCL in 2017 with a cocktail beam
- Used the Summing NaI (SuN) (Fig. 2) detector together with a double sided silicon strip detector
- With the SuN detector, we can detect the individual γ rays and sum them up to find the total excitation energy from the nucleus
- We can then do total absorption spectroscopy (TAS) as seen in Fig. 3

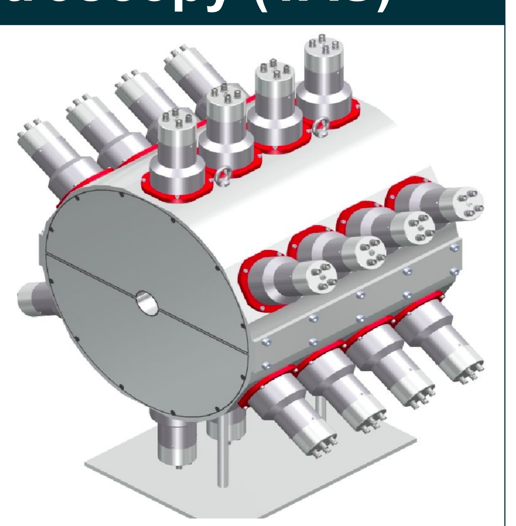

Fig. 2: SuN detector schematic from Ref. [1]

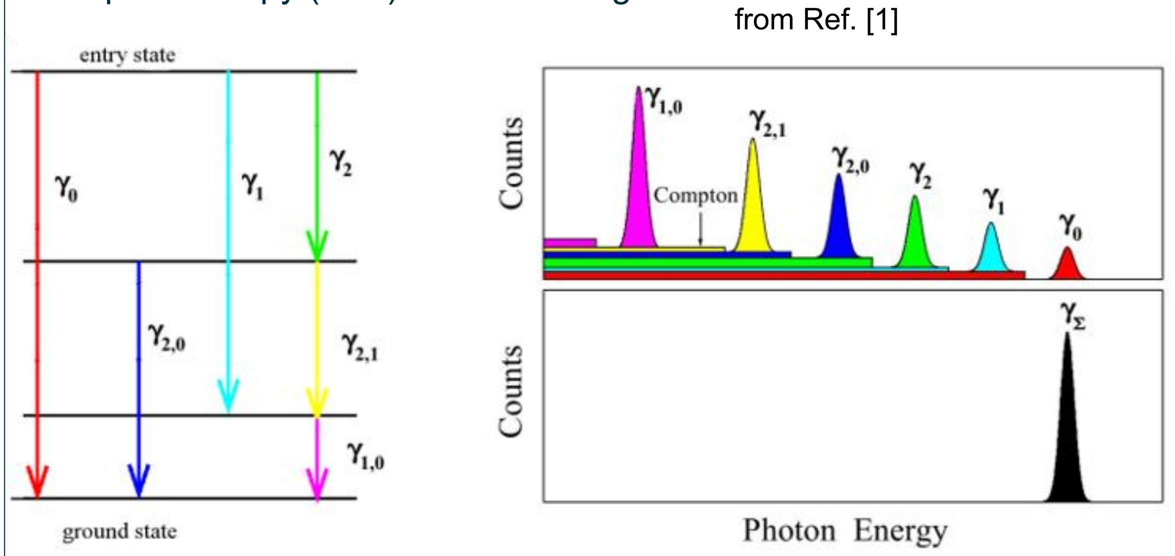

Fig 3. Cartoon decay scheme. Left is cascade from excited nuclei. Right is in SuN.

- TAS works with the SuN detector, since we can sum up all the individual γ rays from the segments to find the excitation energy of the nucleus after it has undergone β decay.
- With this information, we can try to simulate the same decay for the range of available excitation energies
- Then we can fit the simulated spectra as a function of:
  - the multiplicity (number of γs seen in the detector)
  - initial excitation energy
  - individual γ rays
- The weights from this χ2 minimization is the β decay intensity and will then be used to find the β strength function as a function of energy

Results

- For expanding this analysis, it is important to be able to benchmark the new analysis method with existing data.
- Already, there has been an experiment on ^{71}Co where the β strength, I_β has been found.
- To be sure that the analysis is correct when expanding it to look at 2D histograms instead of just projections, I can compare my expanded analysis with the existing data, as shown in Fig. 3 from Ref. [2].

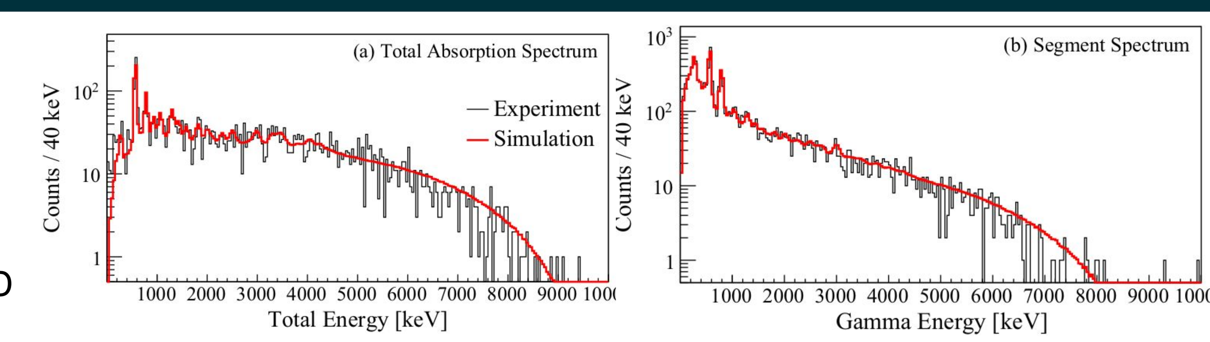

Fig. 4: Fit of simulation to extract I_β from the segments and total absorption spectrum. From Ref. [2]

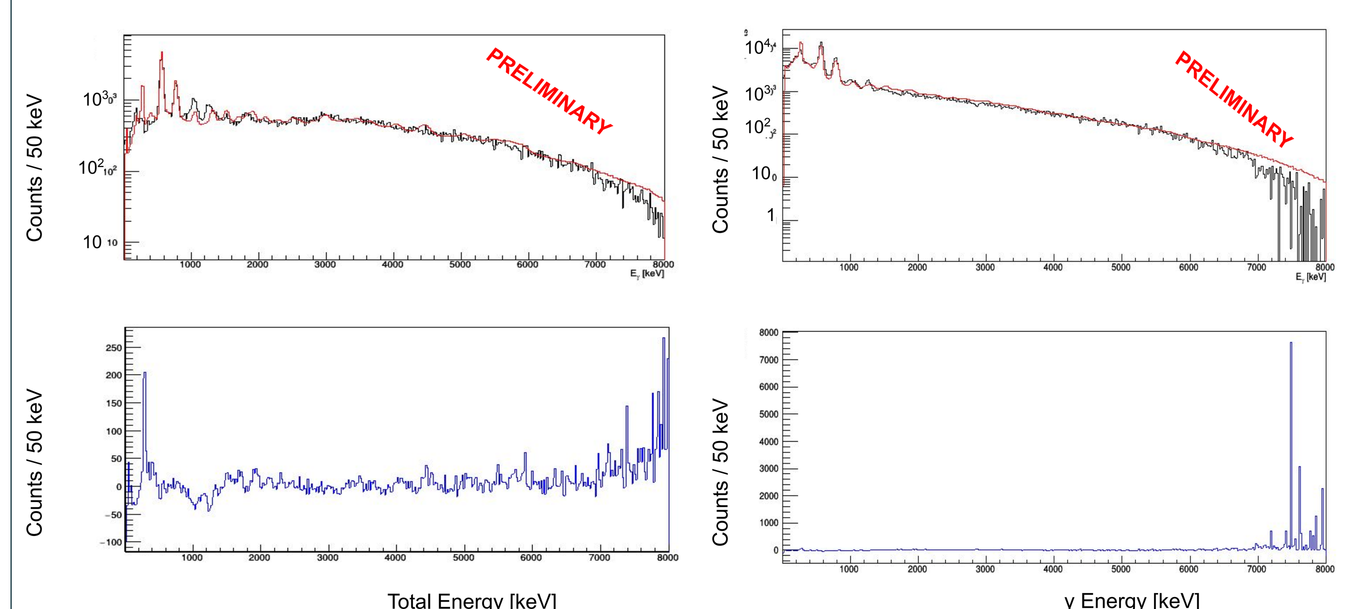

Fig. 5: Fit of simulation to extract I_β from the segments and total absorption spectrum for ^{71}Co.

- As seen in Fig. 5, you can see that the preliminary fits of ^{71}Co looks good in 1D, this is done simultaneously with fitting the 2D spectra.
- In Fig. 6, you can see that the diagonal stripes from the experimental spectra is well recreated in the fitted simulations, which will not be possible to do in only the 1D projections.
- See Fig. 7 for illustration of how one entry state will show up in the 2D matrix.

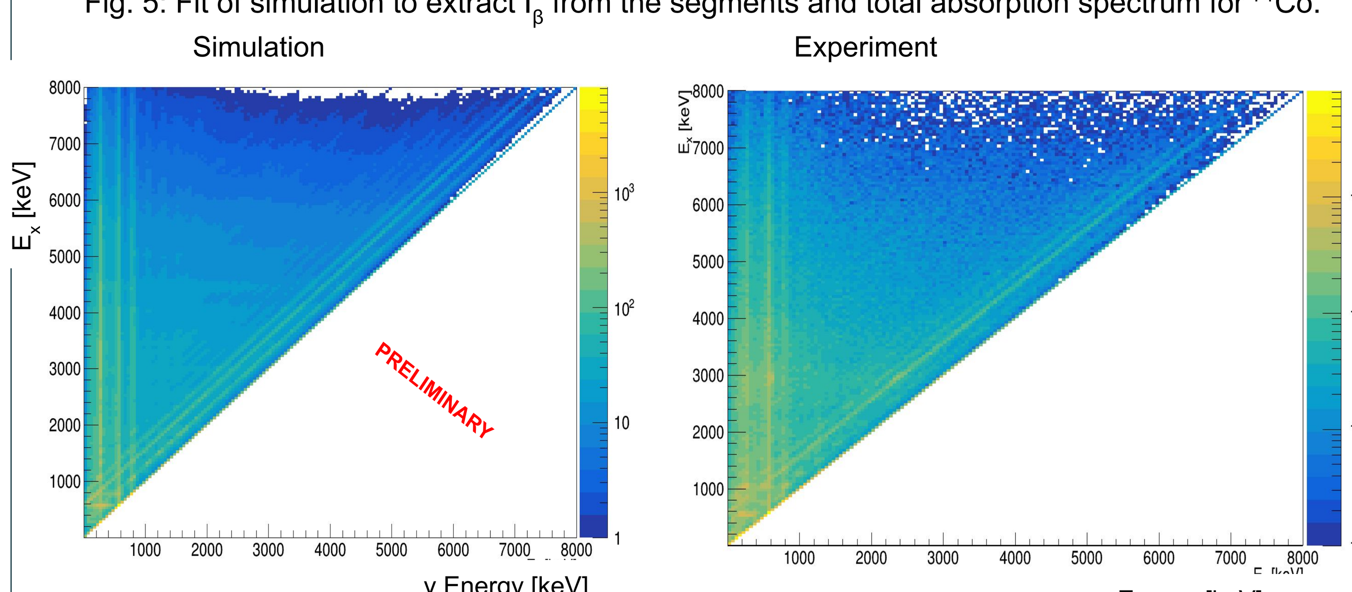

Fig. 6: Fit of simulation to extract I_β the 2D matrix which shows γ energy versus excitation energy for ^{71}Co. Note the diagonal streaks in the experimental spectra.

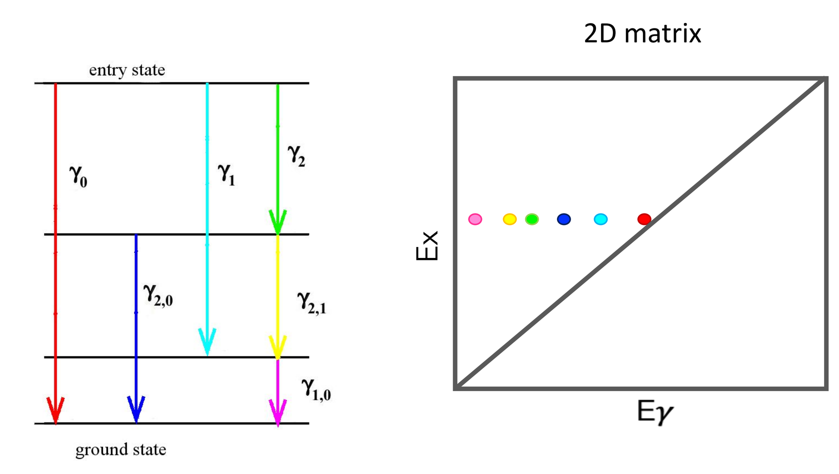

Fig 7. Cartoon decay scheme. Left is cascade from excited nuclei. Right is the correlation of the excitation energy with the individual γs showing up in the segments on the x-axis, versus the sum of segments on the y-axis

Fitting neutrons

- One thing that has to be taken into account when we move on to ^{72}Co is the β-delayed neutrons. See Fig. 8 and 10.
- This is evident because we can observe characteristic γs coming from the β-delayed daughter. See Fig. 9.

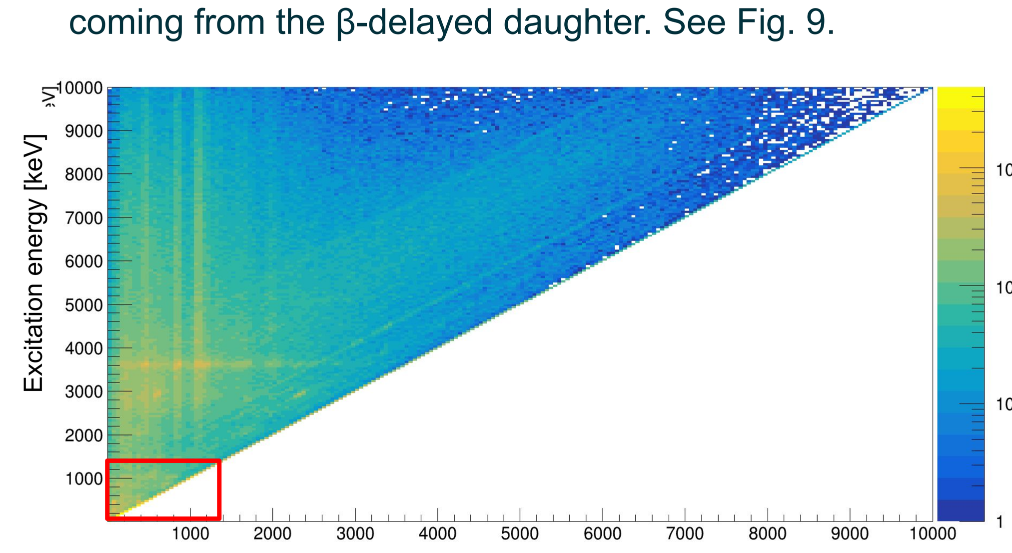

Fig. 8: Experimental results to fit to extract I_β the 2D matrix which shows γ energy versus excitation energy. Note the area marked in red for β delayed neutron emission.

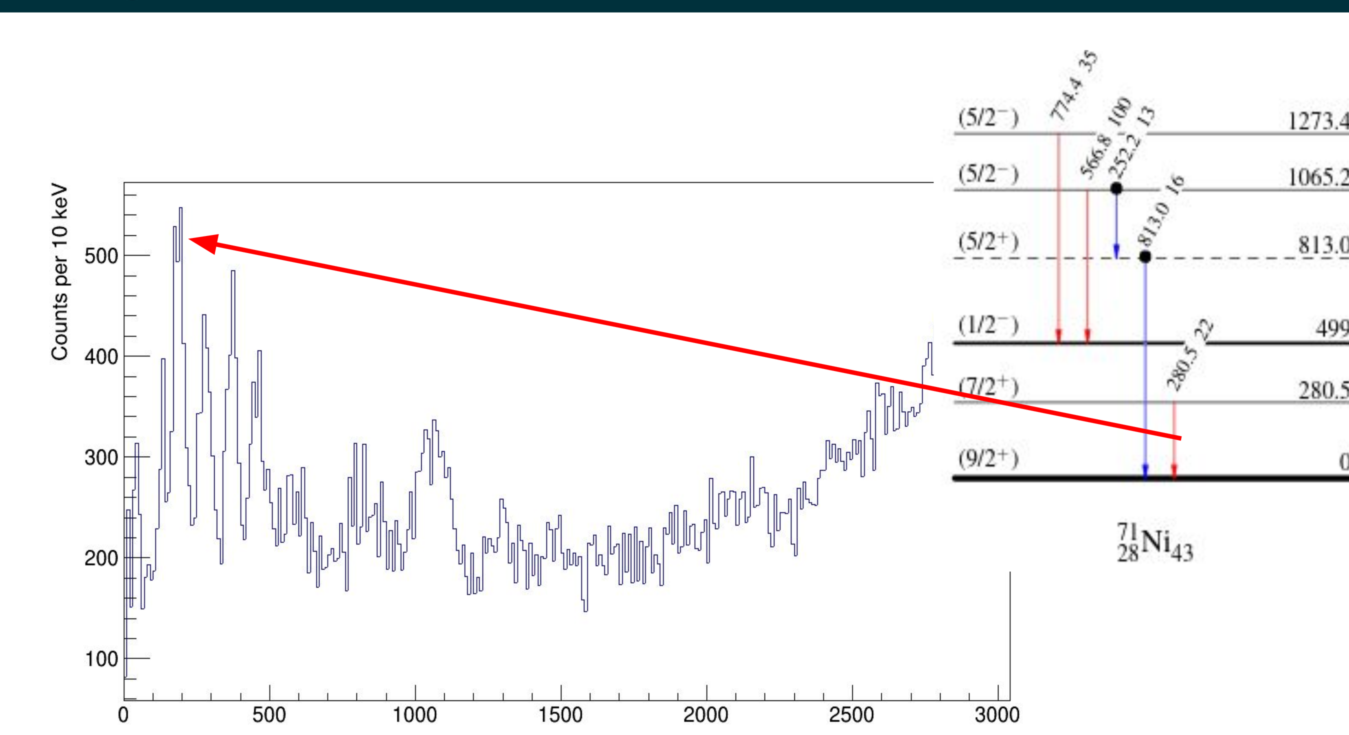

Fig. 9: γs seen in the ^{72}Co decay spectrum that is from ^{71}Ni de-excitation. Decay scheme is from Ref. [3]

Discussion

- When adding in neutrons, it should possible to to recreate the experimental data with the β delayed neutron emission
- This will be important to find the combinations of simulations that fit best to the experimental data.
- See Fig. 10 for preliminary simulation results for ^{72}Co

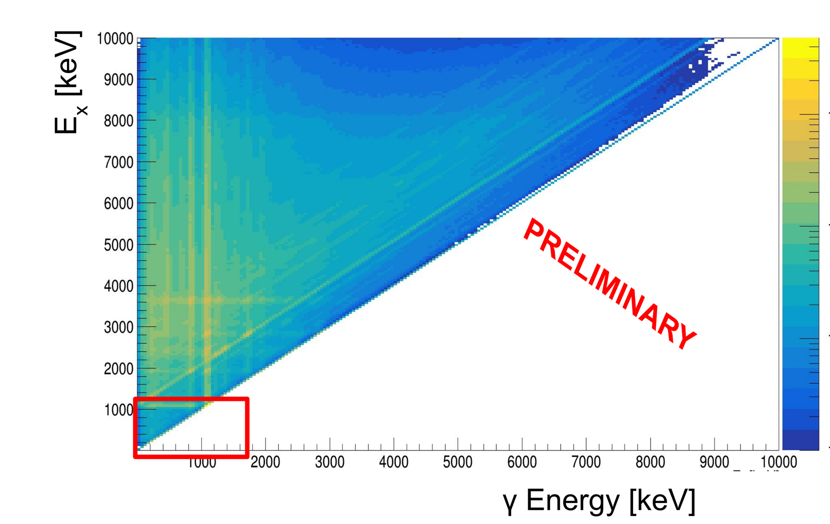

Fig. 10: Fit of simulation to extract I_β the 2D matrix which shows γ energy versus excitation energy. Note the area marked in red for β delayed neutron emission.

Summary and future outlook

- Expansion of TAS analysis to fitting 2D spectra
- Agrees with previous results done by S. Lyons et. al [2] for ^{71}Co
- Have to fit neutrons to account for β-delayed neutrons in odd-odd Co isotopes, which are ^{72}Co and ^{74}Co
- These Co-isotopes are marked in Fig. 11.

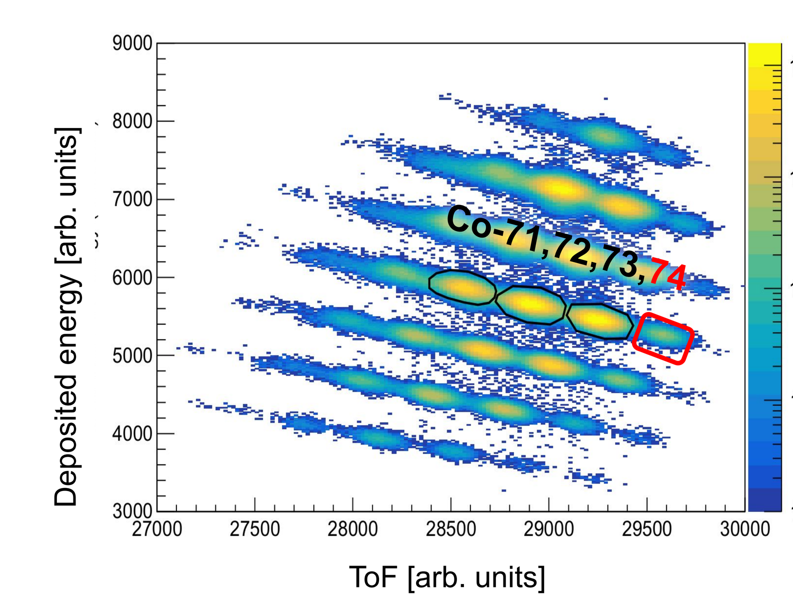

Fig. 11: Time of Flight spectra from the cocktail beam, where Co-isotopes has been circled in black or red. From Ref. [4]

Sources

[1] A.Simon et. al. NIMA **703**, 0168-9002 (2013)

[2] S. Lyons et al. Phys. Rev. C **100**, 025806 (2019)

[3] C.L. Dunford and T.W. Burrows, Online Nuclear Data Service, Report IAEA-NDS-150 (NNDC Informal Report NNDC/ONL-95/10), Rev. 95/10 (1995)9, International Atomic Energy Agency, Vienna, Austria

[4] R. Lewis. PhD thesis (2019)

This material is based upon work supported in part by the Department of Energy National Nuclear Security Administration through the Nuclear Science and Security Consortium under Award Number DE-NA0003996.