Development of ML Algorithm for Reaction Layer Determination in LISA array

Debajyoti Das

Technische Universität Darmstadt

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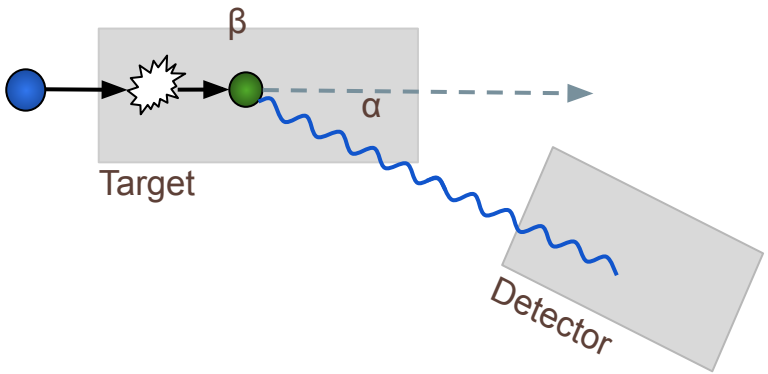
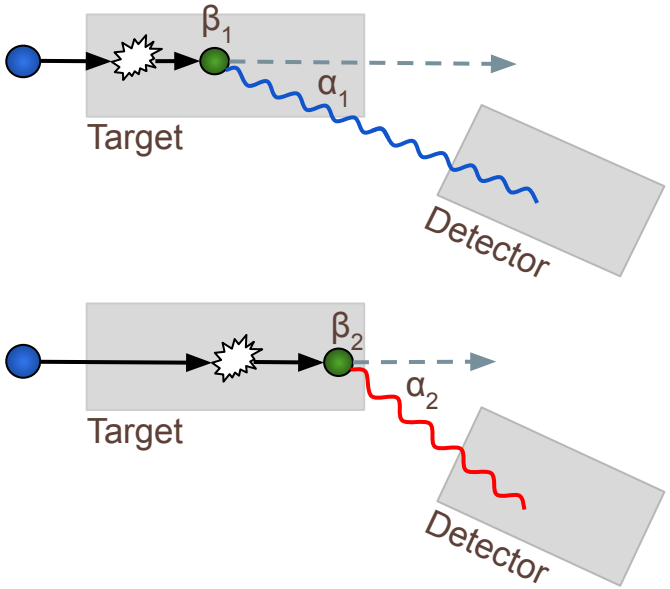
Experimental Method for Lifetime Measurement



$$E_{meas} = \frac{E_0}{\gamma(1 - \beta \cos \alpha)}$$

- In-beam Gamma-ray spectroscopy with intermediate beam energy of v ~ 0.6 c
- The nucleus of interest is produced by reaction in the target
- The reaction product travels through the target and depending on the lifetime of the excited states decays, via emission of Gamma rays, at different position in the Target, which we can measure

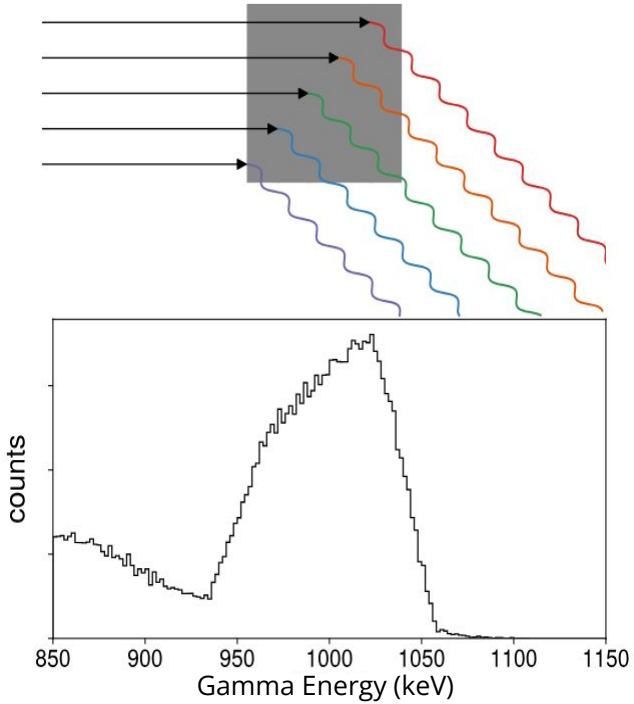
Lifetime measurements with Doppler-shift techniques



$$E_{\mathrm{lab}} = E_0 \cdot \frac{\sqrt{1-\beta^2}}{1-\beta\cos\alpha}$$

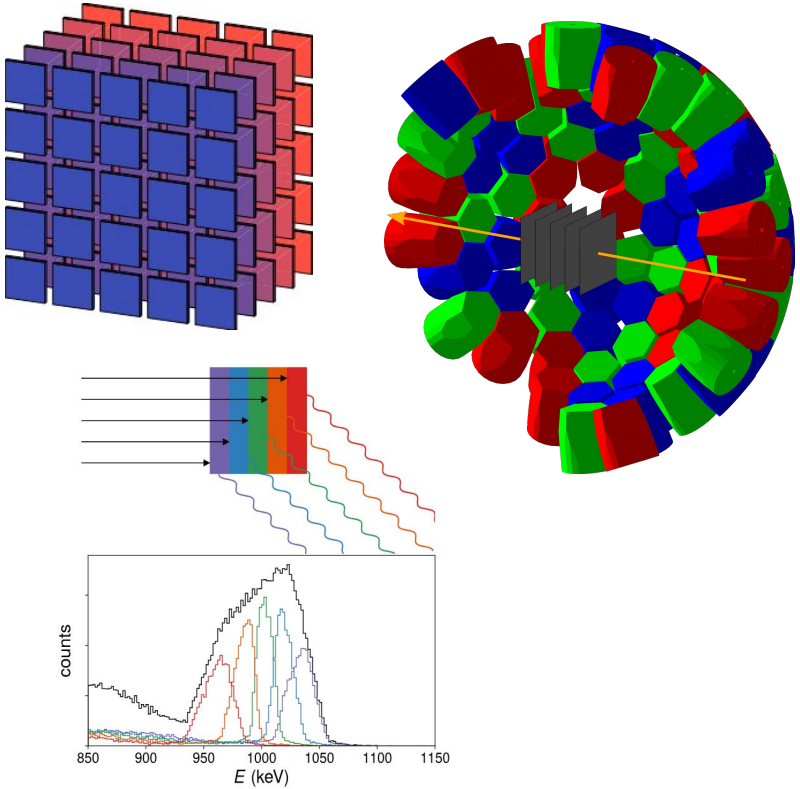
- The Gamma-rays emitted in-flight are subject to doppler effect
- The ejectile losses its energy in the target and can decay at different velocity β and angle α
- Gamma-ray tracking detector like AGATA can measure emission angle α and doppler shifted energy of the gamma-ray.
- We can use these information to reconstruct β
- This gives us information about the lifetime of the excited states

Problem



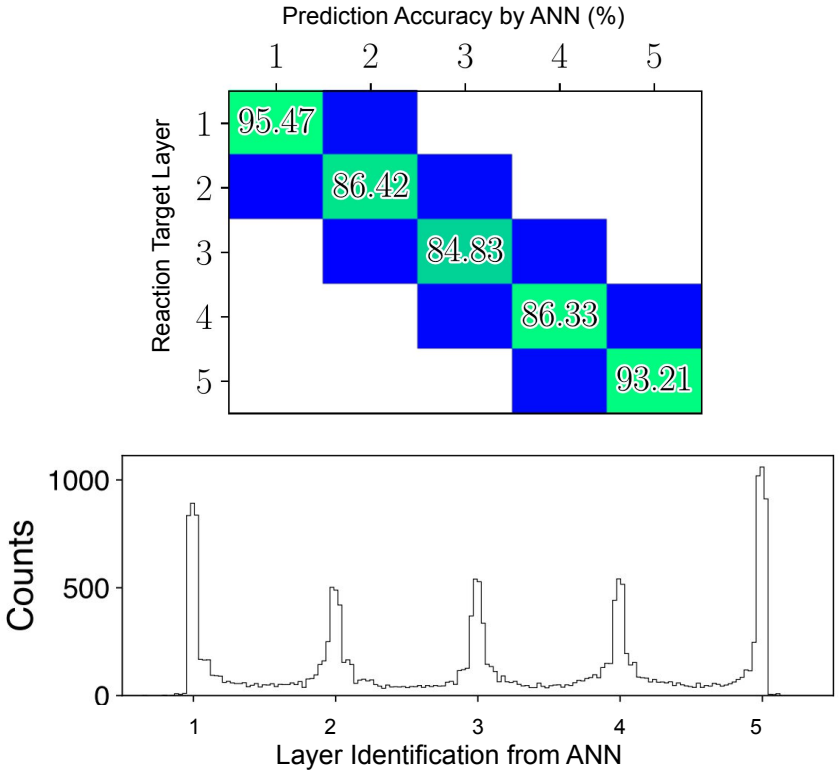
- Highly exotic beams have very low intensities
- To achieve a sufficient luminosity for the measurement we need a thick target
- But the thicker the target is, the larger is the uncertainty in determining the interaction position and velocity
- Thus we get an angle dependent spread in doppler-reconstructed energy spectrum
- Even with AGATA, the resolution is dominated by target effects

Solution: **LI**fetime measurements with **S**olid **A**ctive targets (**LISA**)



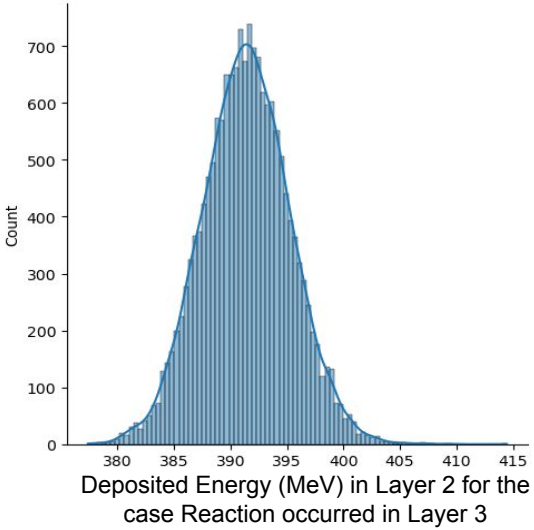
- Replace the passive thick target with a stack of thin active targets
- 5x5x5 array of diamond crystals to be coupled with AGATA
- Measure energy deposition of ions
- This stack of thin layers provides us with better precision in determining the reaction position, without sacrificing the luminosity of a thick target
- Now the goal is to determine the layer where reaction occurs

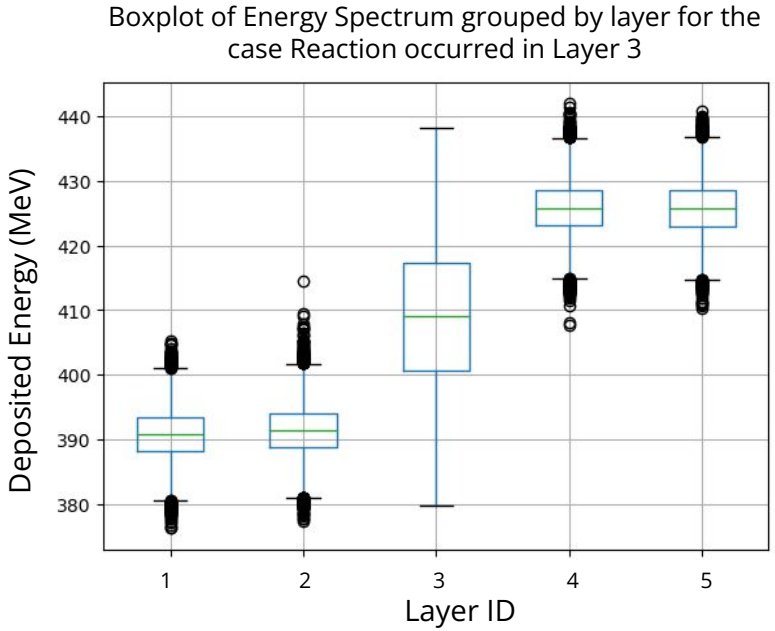
Artificial Neural Network for Reaction Layer Determination



- We are using Geant4 to simulate energy spectrum to train the algorithm
- Multi-class classification problem
- We have used Artificial Neural Network to train the model
- ANN shows good performance but position identification for middle layers (2,3,4) is relatively low

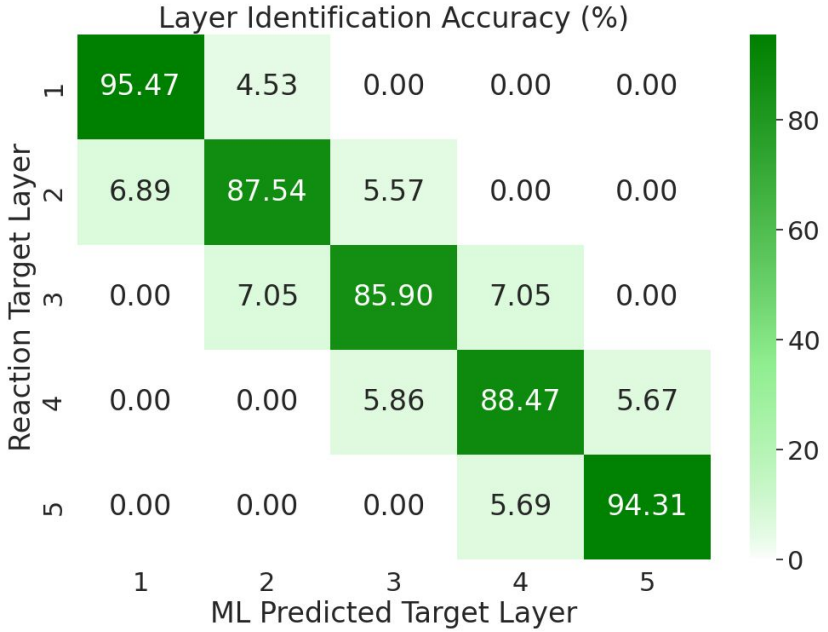
Improve Accuracy of ML Algorithm





- Spread in deposited Energy Spectrum
- This spread causes for the poor identification of the middle layers
- Clip the outliers to improve accuracy

Random Forest Algorithm



- Used Random Forest Algorithm
- Prediction accuracy improved for the middle layers when outliers outside 99.5th percentile are clipped

Future Plans:

- More realistic simulation in Geant4
- To improve accuracy of the algorithm, we plan to work on better feature selection
- Implement FWHM of the energy spectrums as a feature in the algorithm
- We are also planning to use Deep Learning algorithms on the filtered data
- Final goal is to implement the best performing algorithm on the experimental Energy Spectrum for Reaction Layer Identification

Thank you for your attention

K. Wimmer, J. Bardak, B. Bles, Z. Chen, D. Das, F. Drent, E. M. Gandolfo, W. Poklepa, M. Reece,
Herrmann, N. Imai, N. Jovancevic, M. Kis, N. Kitamura, H. Kleis, K. Koch, D. Maletic, S. Michimasa, C. Nociforo, G. Andreetta, S.
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