Simulation of Multi Electrode Lens Stack of MRCO: A Path Towards Digital Twin

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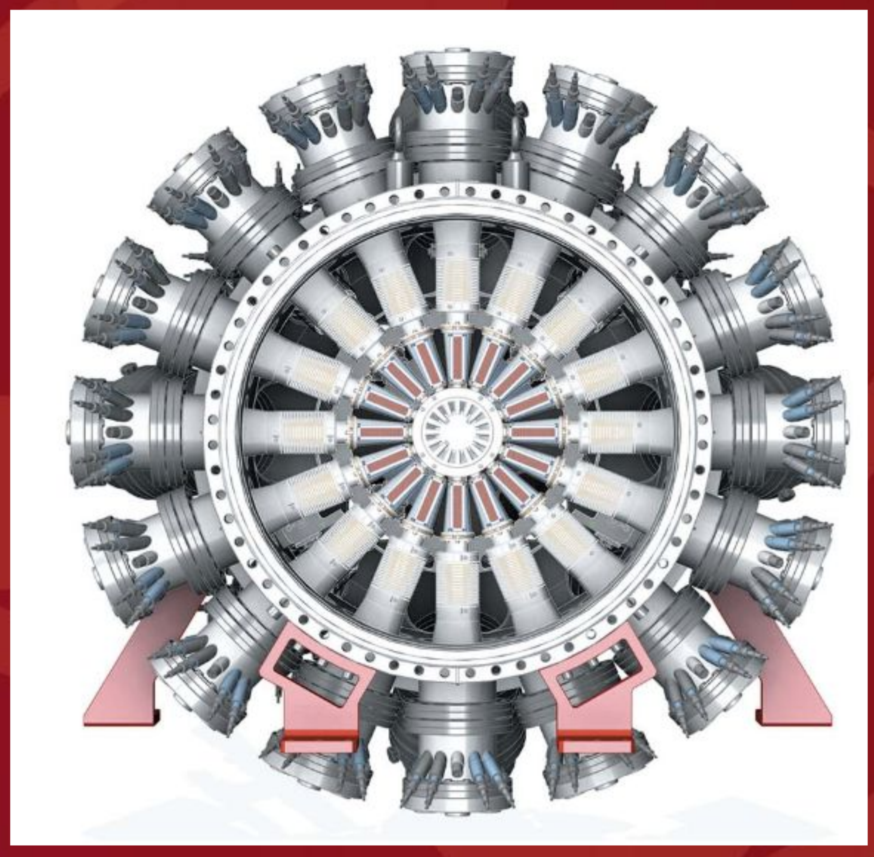


The axial view of a detector array with 16 electron time of flight (TOF) spectrometers placed perpendicular to the direction of X-rays[1]

1. Goals

Multi-resolution 'Cookiebox' (MRCO) spectrometer consists of an angular array of 16 electron time-of-flight (eTOF) spectrometers in a circle, with 4 additional eTOF in 'Magic angle'. Each eTOF consists of 25 electrodes forming a lens stack for electron optics. The goal of this project is to build the infrastructure for a ML model to optimize the lens stack parameters to:

- Measure electrons distribution across a wide range of kinetic energies.
- Maximize collection efficiency of the spectrometer.
- Enhance focusing without saturating the detector.

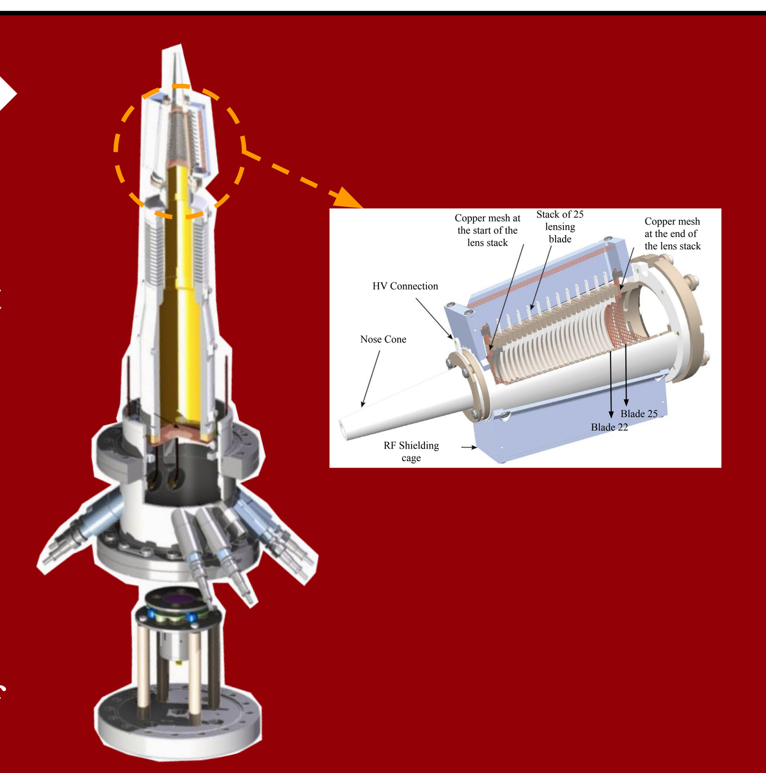
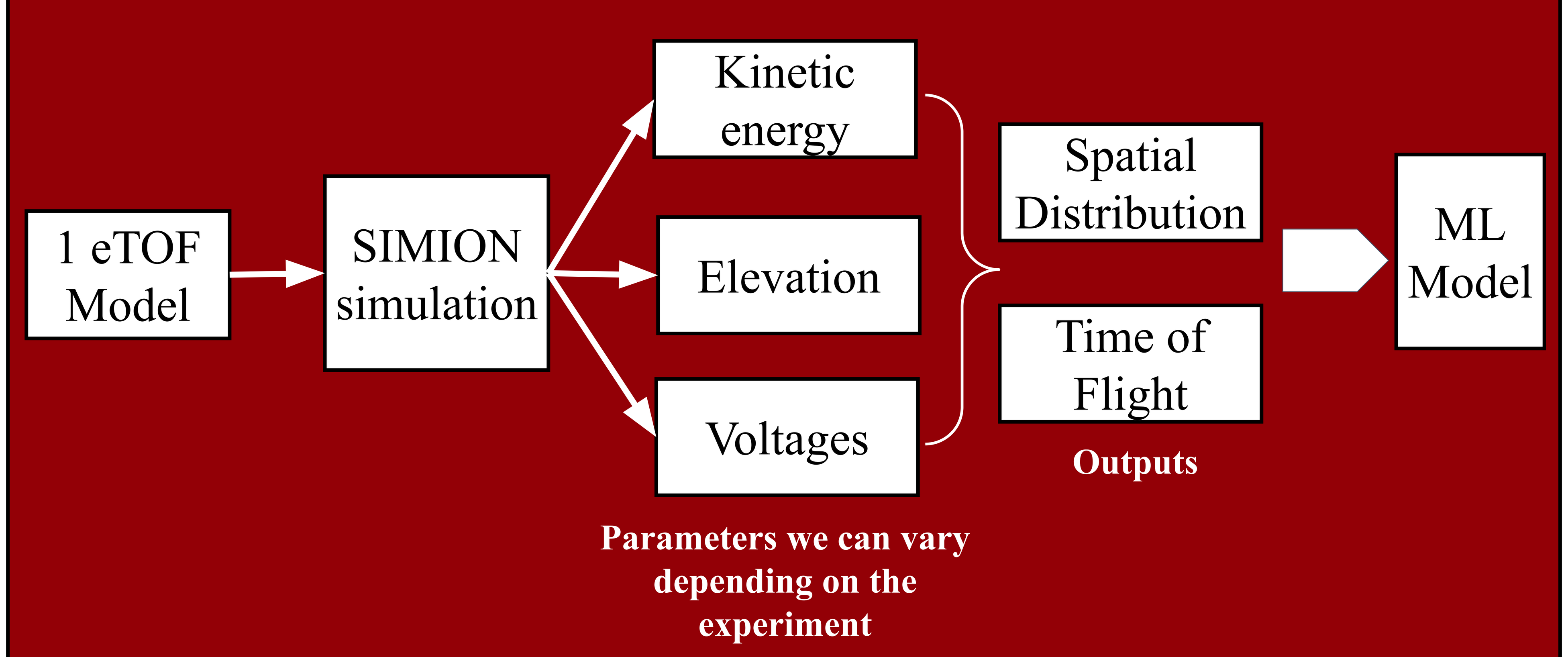
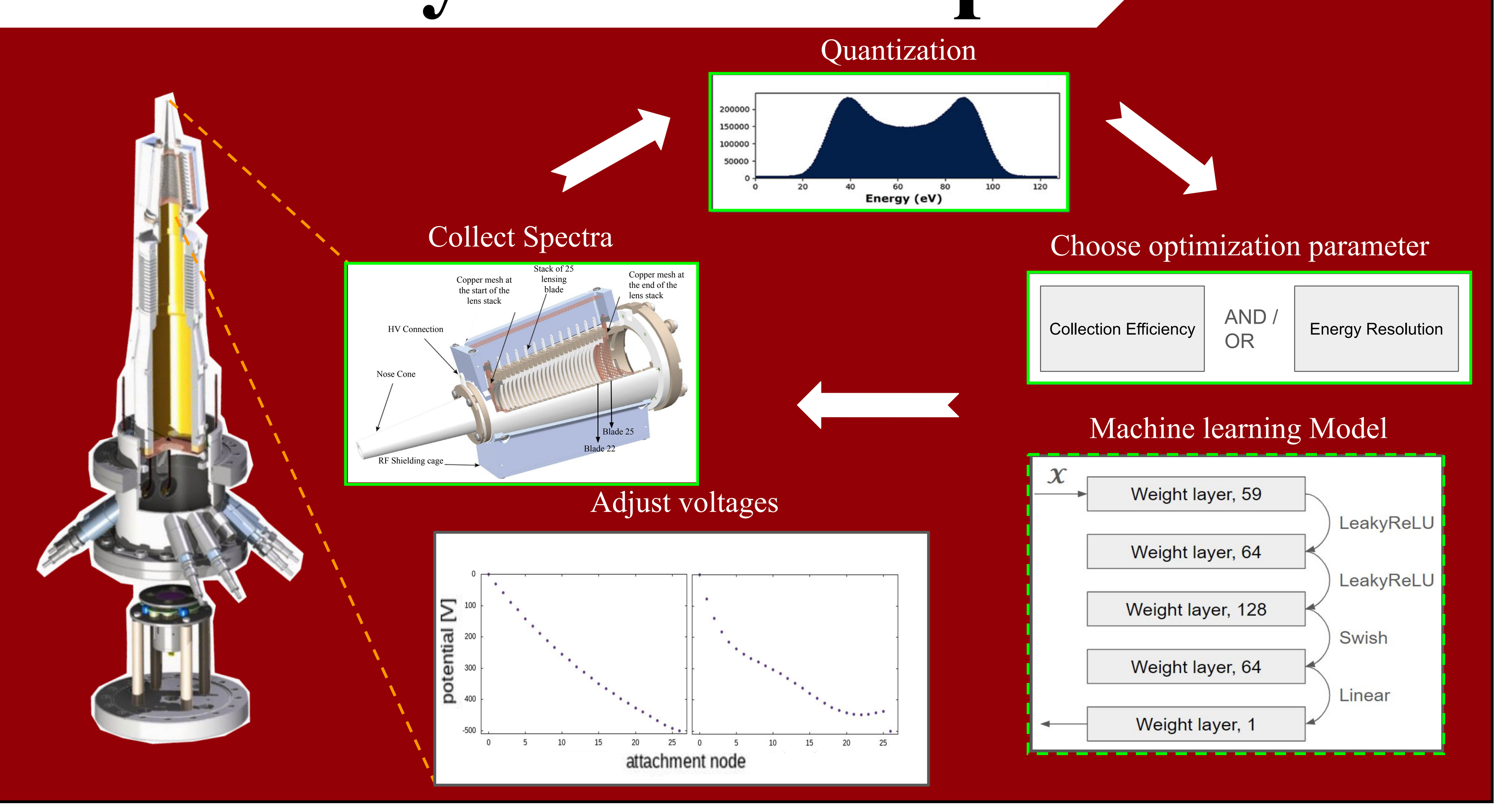


***Fig 1**: The image on the top left displays one of the MRCO spectrometers, and the image on the top right shows the cross-section of the lens stack (25 blades)[1].*

2. Methodology



3. Summary/Future Steps



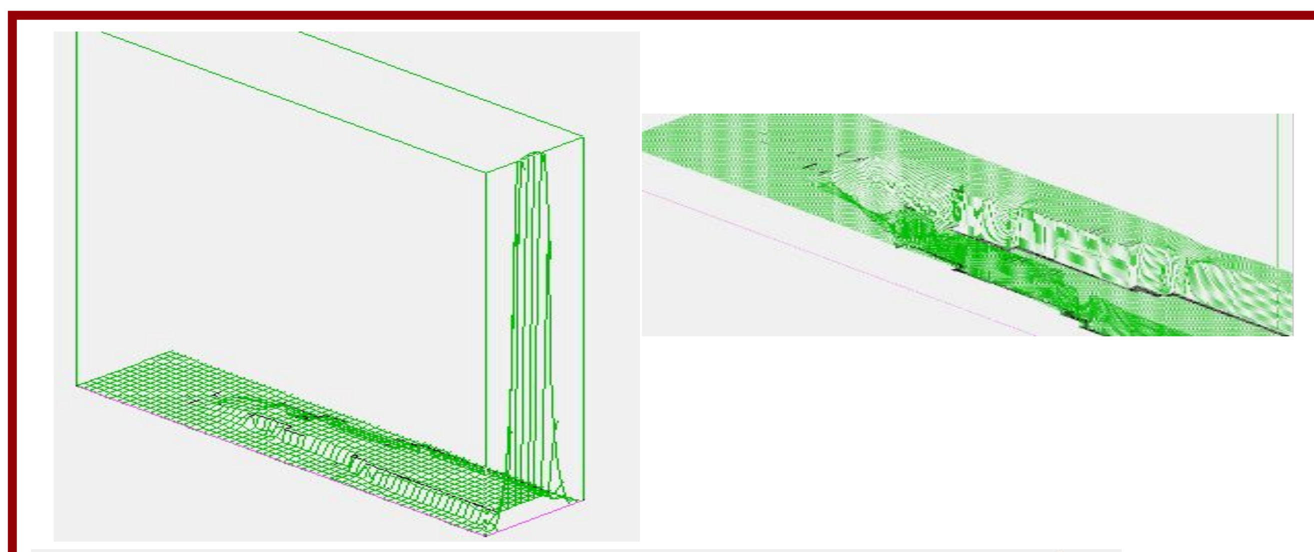


***Fig 2**: A potential energy view of the potential array (electrostatic) using the XY PE view in Simion.*

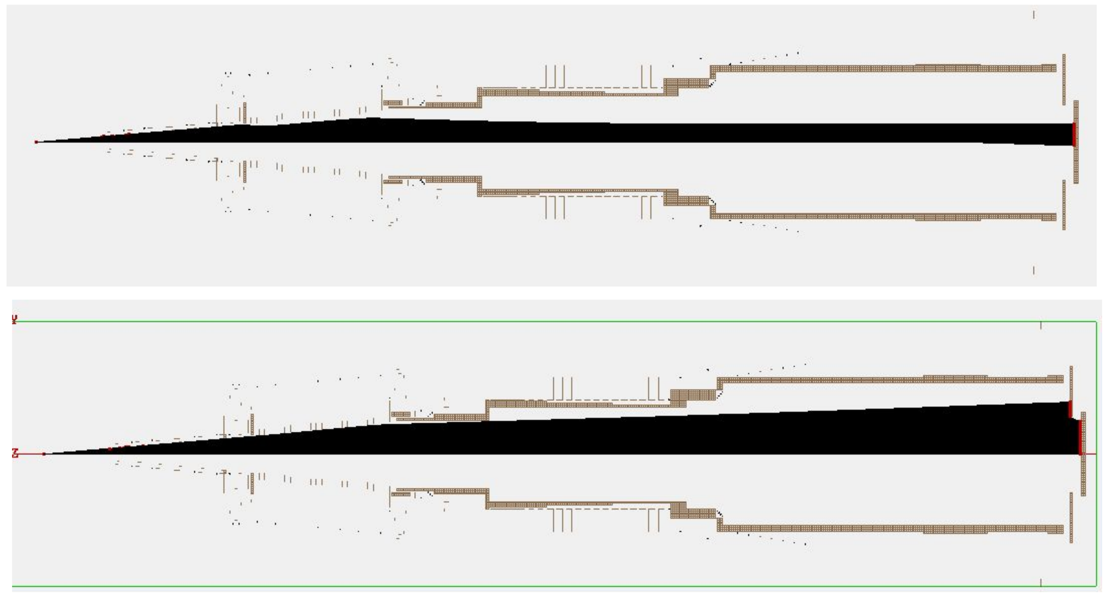


***Fig 3**: Impact of retarding/accelerating voltages and focusing on simulated electron trajectories in an eTOF spectrometer.*

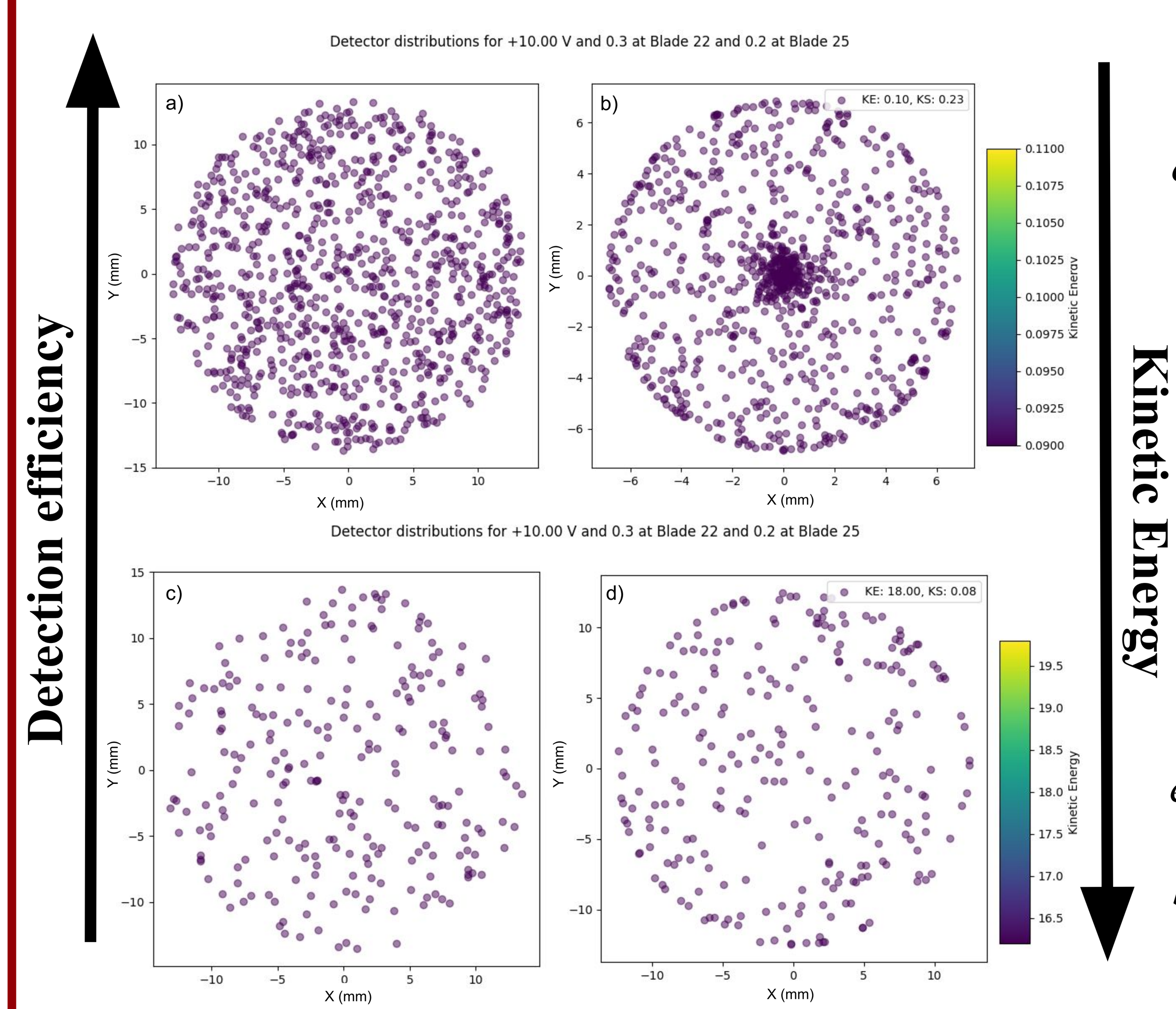


***Fig 4**: The spectrometer detector geometry, with each purple point indicating an electron hit, for 0.1 eV to 18 eV kinetic energy.*

The left plots (a and c) represent an ideal uniform distribution for that radius, while the right plots (b and d) show simulated detector distribution. 0.1 eV kinetic energy exhibits more focusing on a few points (undesirable) but have higher collection efficiency. 18 eV kinetic energy results in better distribution but lower collection efficiency.

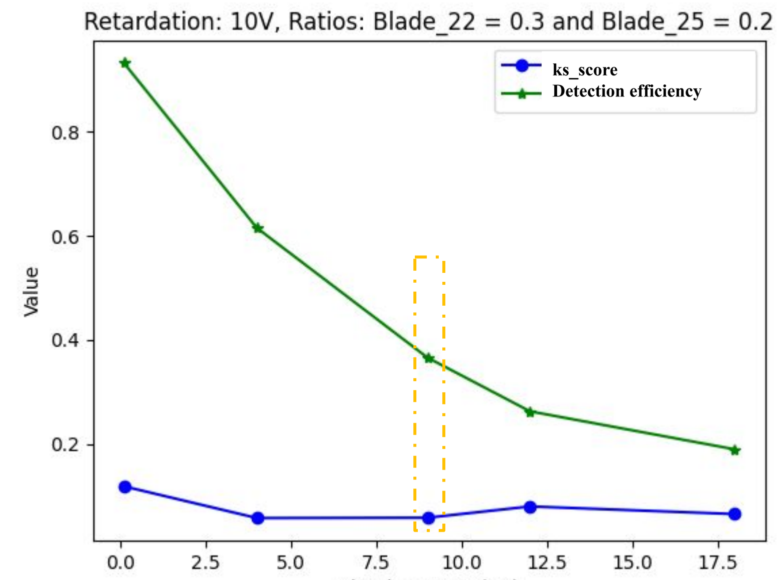


***Fig 5:** Detection efficiency and KS score for ratios 0.3 (70% retardation at blade 22) and 0.2 (80% retardation at blade 25) as kinetic energy increases. Lower energies show higher efficiency at the detector but also higher focusing (higher KS score, undesirable). As kinetic energy increases, detection efficiency decreases while the KS score improves (uniform distribution). For this distribution, the values at 4 eV (highlighted by the box) are optimum.*

* **KS (Kolmogorov–Smirnov) Test** in our case, measures the deviation of the simulated detector distribution (right) from a uniform distribution (left), quantifying how different the simulated distribution is from the expected uniform distribution.

$KS\_statistic,\ D_{n,m} = sup|F_{1,n}(x) - F_{2,m}(x)|$

References and Acknowledgement

1. Walter, P., et al. *J. Sync. Rad.*, vol. 28, no. 5, pp. 1364–76 (2021).
2. Fanis, AD, et al. *J. Sync. Rad.*, vol. 29, no. 3, pp. 755–64 (2022).

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Scan Me!

Adventures in Simulation

During the initial days of learning and working with Simion, I encountered a bit of a false start with the scale factor while running Simion GUI. Initially, I accidentally used a scale factor of 1, which set the spectrometer to a centimeter scale (100 times larger than the intended millimeter scale of 0.05). This required me to re-run a few simulations and adjust my approach.

In addition to my main project on Simion, I also had the opportunity to explore Geant4 software. I managed to create some interesting animations by considering a few physics processes

Acknowledgements

First and foremost, I would like to express my gratitude to my mentor, Razib for his expertise, guidance, encouragement, and honest feedback throughout the course of my project. It has also been a wonderful experience working with Amanda and gaining both theoretical and practical knowledge in this exciting field, which I was exploring for the first time. I would also like to thank Ryan, Jack, Kurtis, and Benji for their support and guidance. Additionally, I want to extend my thanks to my intern mate Joanne, who stood by me through thick and thin, as well as to my friends for always being there. Words are not enough to express my gratitude for the support I received from Alan Fry, Arturo, and Nina, who constantly kept us on track and made my time here special and memorable.