

DETECTING LIGHT IONS AND ELECTRONS WITH TRIMS SILICON DETECTORS

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TRIMS (Tritium Recoil-Ion Mass Spectrometer)

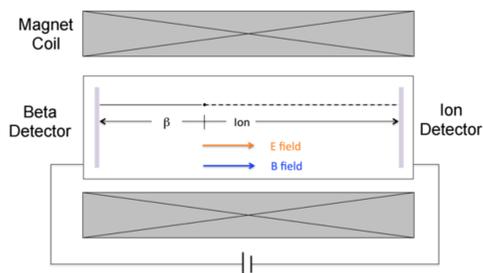


Fig. 1. Sketch of the TRIMS experiment. [1]

- 60 kV electric field
- 0.2 T magnetic field

The goal of the TRIMS experiment is to measure the molecular tritium (T_2) β decay branching ratio to the bound state ${}^3\text{HeT}^+$. The setup consists of a decay volume filled with T_2 gas, with one silicon detector on each end. Mass-3 (dissociated) and mass-6 (molecular) ions can be distinguished using ion energy and time of flight relative to the beta electron.

The main decay branches of T_2 are:

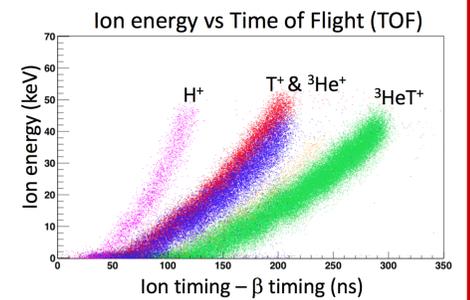
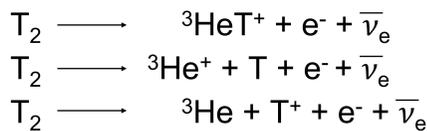


Fig. 2. Geant4 simulation of ion energy vs time of flight for H^+ , T^+ , ${}^3\text{He}^+$ and ${}^3\text{HeT}^+$ [1].

Interactions of ions and β electrons with silicon detectors

To understand the TRIMS energy reconstruction and compute correct branching ratios as a function of beta energy, we modeled scattering interactions inside the dead layer with SRIM [2] and KESS [3].

- Total detector thickness of 500 μm .
- Dead layer of 100 nm in which the energy deposited is not completely recovered in the voltage signal.



Figure 3. PIPS Canberra detector.

β electrons in the silicon detector

Applying the package KESS [3] of the Kassiopeia software, simulations of electrons in silicon were carried out.

- Initial energy from 5 keV to 80 keV
- 2 keV steps
- 10^3 electrons in each energy range.

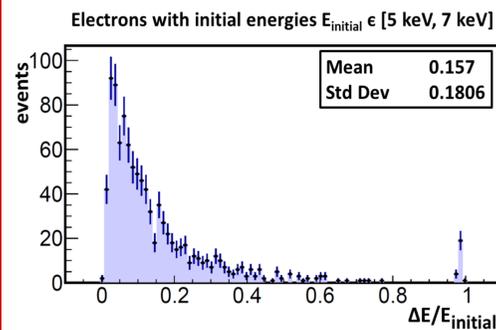


Figure 7. Relative energy loss of electrons with initial energies between 5 keV and 7 keV.

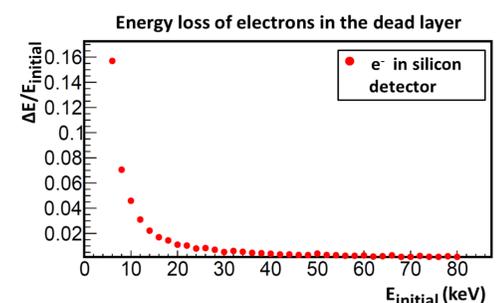


Figure 8. Mean values for the relative energy loss of electrons with different initial energies.

Ions in the silicon detector

- A silicon detector with TRIMS characteristics was simulated using the software SRIM.
- 99,999 ions were simulated per initial energy (E_{initial}).
- Interactions whose response depends on the ion type are especially important to obtain an accurate branching ratio.

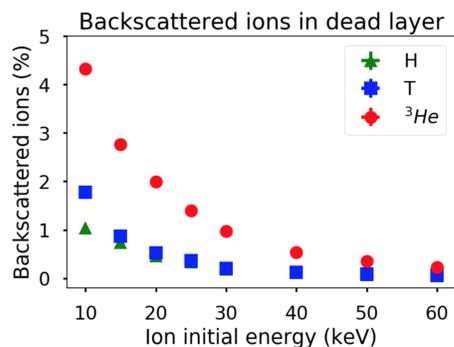


Figure 3. Percentage of backscattered ions.

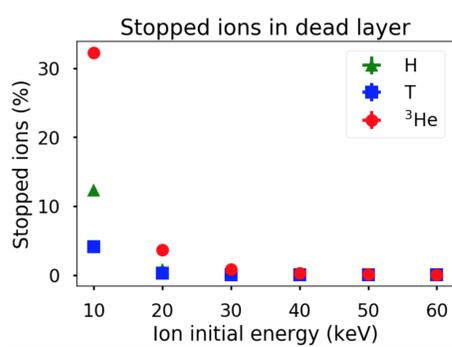


Figure 4. Percentage of stopped ions.

- The energy loss in the dead layer (E_l) is used to calculate the detected energy (E_d) [4]:

$$E_d \approx E_{\text{initial}} - E_l/2$$

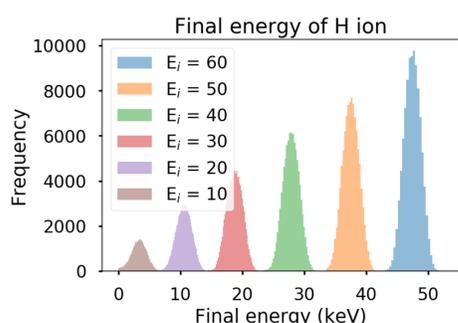


Figure 5. Histograms of the energy of an H ion after crossing a 100 nm silicon dead layer.

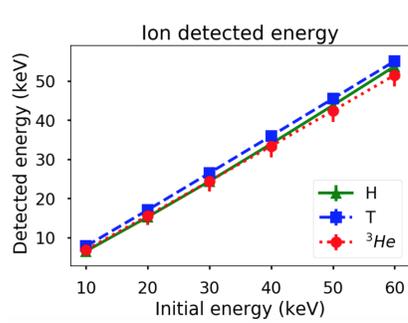


Figure 6. Energy detected for H, T and ${}^3\text{He}$ ions vs its initial energy.

Conclusions

- High-energy ions are less likely to be backscattered and more likely to pass through the dead layer. ${}^3\text{He}$ ions lose more energy in the dead layer than T ions due to their nuclear charge.
- The relative energy loss of electrons in the dead layer decreases rapidly with the increasing initial energy.
- By including these results in the TRIMS simulation, we can obtain a more accurate understanding of the data.

Acknowledgments and References

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