SPICE - A NEW IN-BEAM CONVERSION-ELECTRON SPECTROMETER AT TRIUMF

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CHANGING LIVES IMPROVING LIFE

INTRODUCTION

SPectrometer for Internal Conversion Electrons (SPICE) will be an ancillary detector system to be coupled to the TIGRESS germanium detector array at TRIUMF. It is optimised to measure internal conversion electrons (ICE) produced in nuclear reactions. Its main features will be:

- An annular segmented Si(Li) detector of 50 mm radius and 5 mm thickness, positioned 115 mm upstream from the target, to be cooled with liquid nitrogen.
- A magnetic lens made from permanent magnets to guide the electrons from the target to the detector.
- A photon shield made from a Hevimet alloy to stop background from gamma rays.
- Coupling to TIGRESS to allow for simultaneous electron and gamma-ray detection.

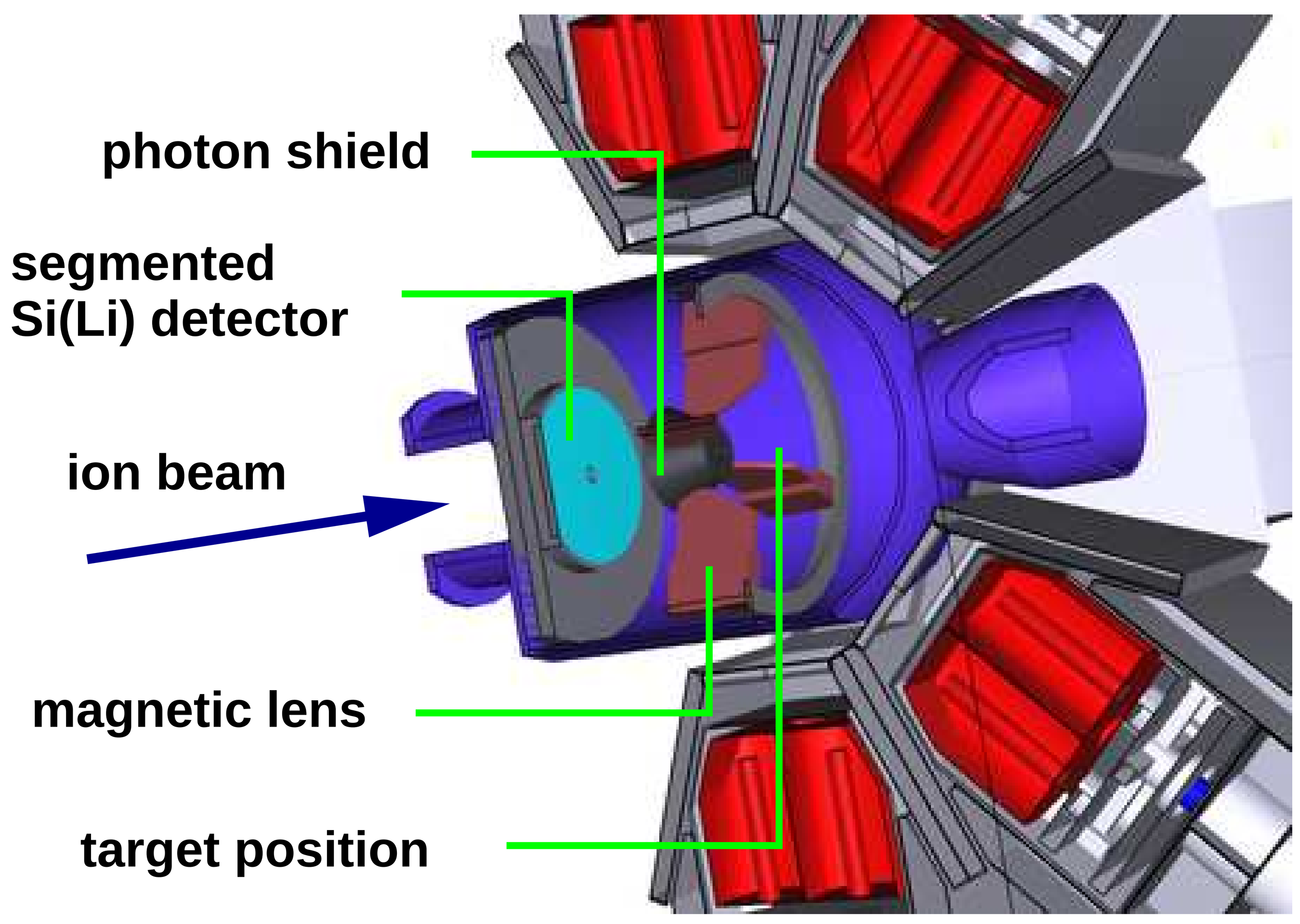

FIGURE 1: Drawing of the SPICE spectrometer, positioned inside the forward TIGRESS detectors.

SCIENTIFIC MOTIVATION

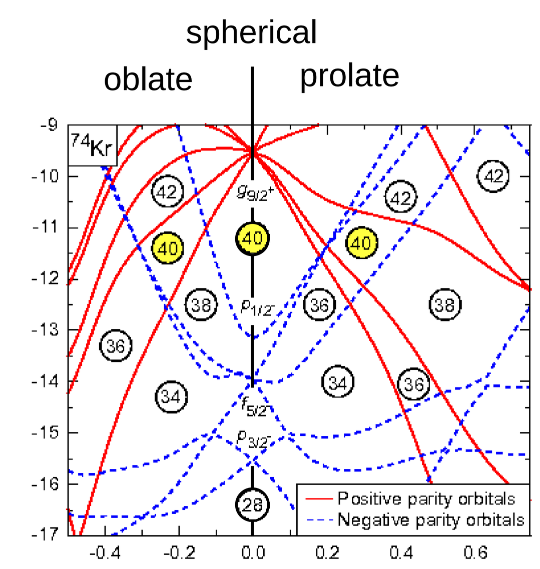

FIGURE 2: Nilsson diagram calculated for ^{74}Kr. Adopted from NSC ISF White paper, Nov 2006.

One of the experimental focuses of SPICE will be the investigation of **shape coexistence**. Different shapes, which lie very close in energy, can either originate from close-lying single-particle configuration with different shapes, or from excitation over shell gaps with large residual interaction.

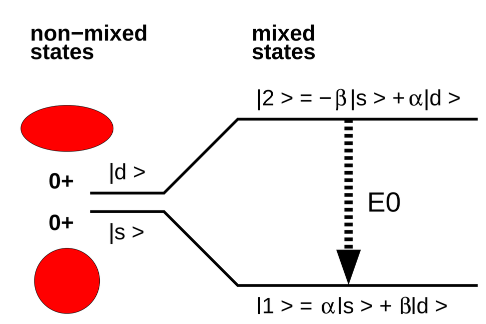

FIGURE 3: Schematic of two-state mixing.

Two close-lying states with the same spin and parity will be subject to **mixing**, which modifies the wave functions, energies, and transition rates. The degree of mixing needs to be identified to study the underlying structures. **Electric monopole transitions** ($E0$) are ideal tools to study mixed states. They occur between states of the same spin and parity, and their transition amplitude is directly proportional to the difference in the mean square radii $\Delta\langle r^2\rangle$ and the mixing amplitudes α and β:

$$\rho_{if}(E0) \propto \langle \Phi_i | m(E0) | \Phi_f \rangle = \alpha\beta\Delta\langle r^2\rangle \,. \quad (1)$$

As γ ray emission is a forbidden process for $E0$ transitions, they can only proceed by either internal conversion or internal pair formation.

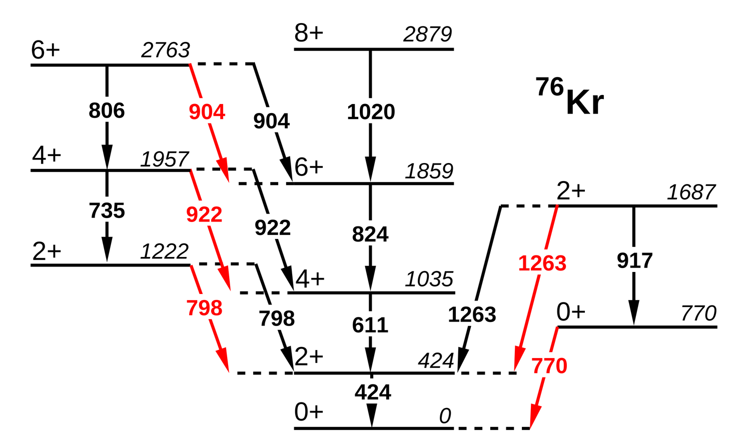

FIGURE 4: Partial level scheme of ^{76}Kr. The transitions expected to be seen in experiment are indicated. Possible $E0$ transitions are given in red, M1 and E2 transitions in black. The similar transition energies of the $E0$ transitions point towards highly-mixed bands.

SPECTROMETER PERFORMANCE

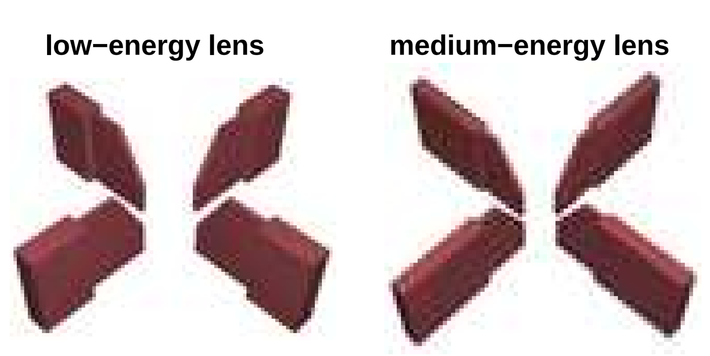

FIGURE 5: The two easily interchangeable NdBFe magnetic lens designs.

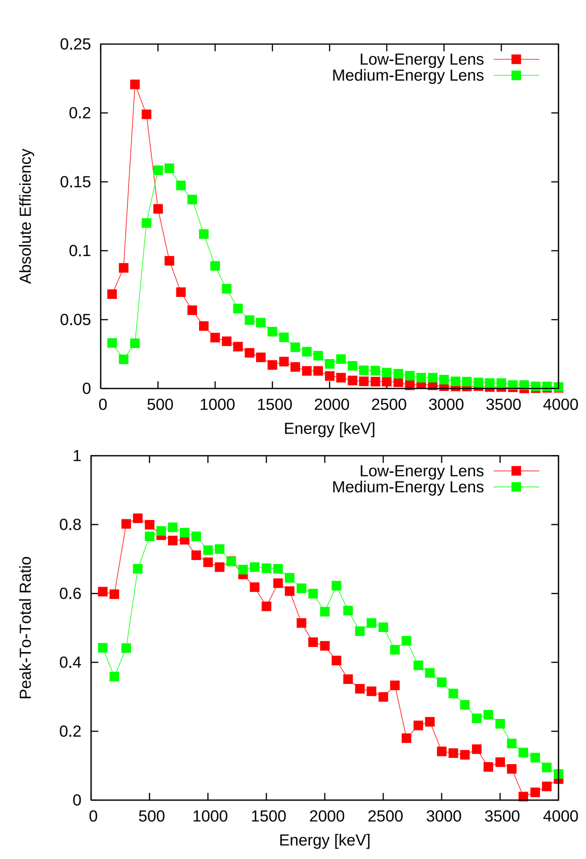

FIGURE 6: Simulated full-energy electron efficiency and Peak-to-Total ratio for the two lens designs.

Expected sources of background and how they are minimized:

- **Delta Electrons**
  - backward geometry, target bias, transmission drop at low E
- **β^- decay**
  - coincidence with ISAC-II RF
- **β^+ decay**
  - directed away from detector by magnetic field
- **Photons**
  - photon shield attenuates photons
- **Backscattering of e$^-$ from Detector**
  - angle of incidence
- **Secondary Electrons**
  - delrin target chamber and plastic coating reduce production

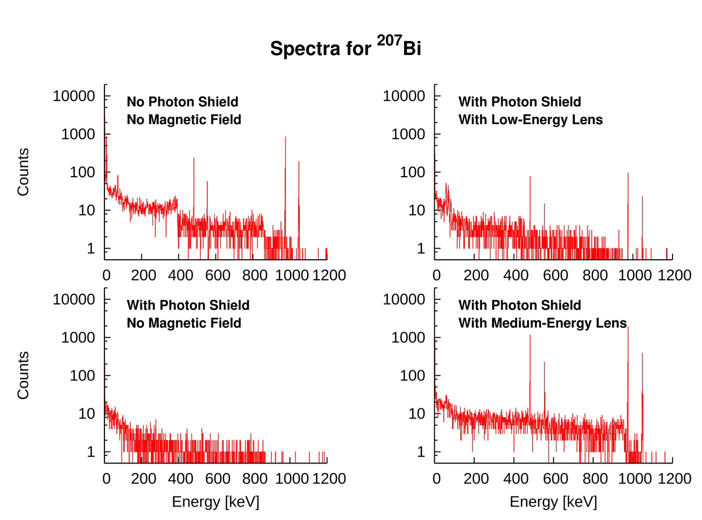

FIGURE 7: Simulated ^{207}Bi spectrum with and without photon shield and magnetic field.

KINEMATIC CORRECTION

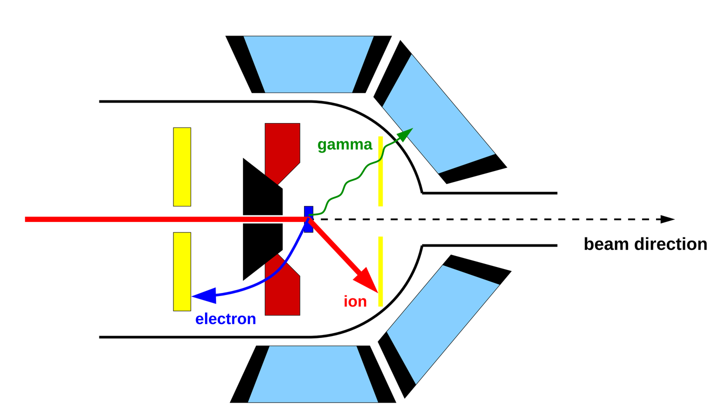

FIGURE 8: Schematic of typical Coulomb-excitation experiment.

One way to study shape coexistence is by exciting nuclear states in Coulomb excitation. In this case, the electrons will be emitted from a source moving at relativistic velocity. The kinematically broadened peaks have to be energy corrected from the position information in the Si(Li) detector.

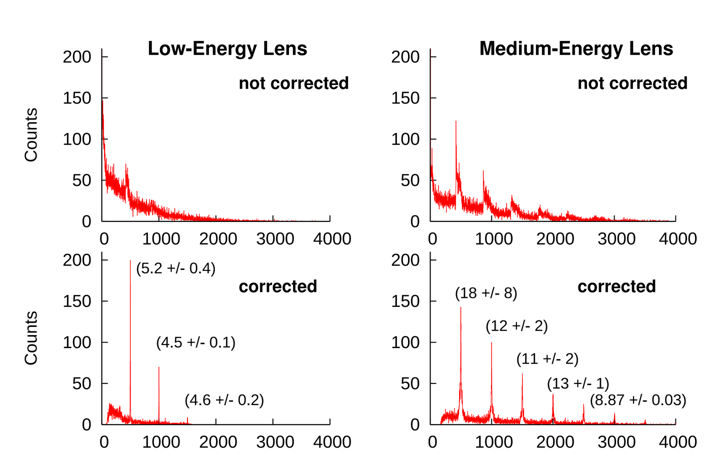

FIGURE 9: Simulated electron spectra for electrons emitted from a recoil moving with β=0.1, without and with kinematic correction applied.

TIGRESS

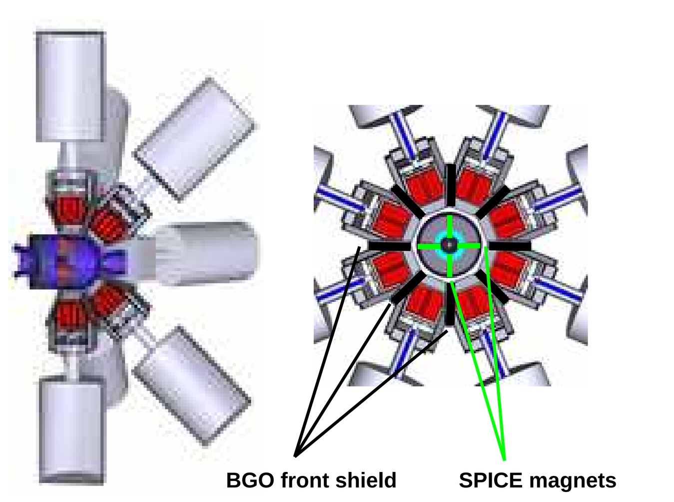

FIGURE 10: TIGRESS in conjunction with SPICE. The magnetic lens lines up with the BGO shields.

TIGRESS is a setup of up to 16 BGO-Compton suppressed HPGe detectors in close geometry around the target position. With SPICE, the 12 forward detectors will be used, which have a photopeak efficiency of approximately 12% at 1332.5 keV. In order to minimize the effect of SPICE on the efficiency and P/T ratio of TIGRESS, the magnetic lens is designed to align with the BGO shields.

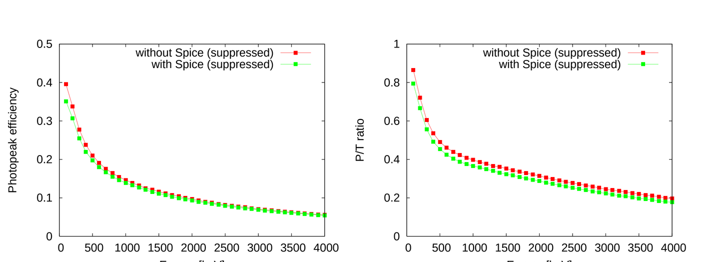

FIGURE 11: Simulated TIGRESS γ-ray efficiency and Peak-to-Total ratio with and without SPICE.

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