Adam Garnsworthy, TRIUMF

ISAC Science Forum, Oct 2009

SPICE Project Timeline

- Concept – Dec 2008
- Submitted CFI Proposal – April 2009
- Research and Design
- Funding Decision Announced – Nov 2009
- Design Finalization – June 2010
- Construction – Dec 2010
- Installation/Engineering runs – Spring 2011
- Radioactive beam Experiments – Summer 2011

Discrete Energy Electrons in Nuclear Spectroscopy

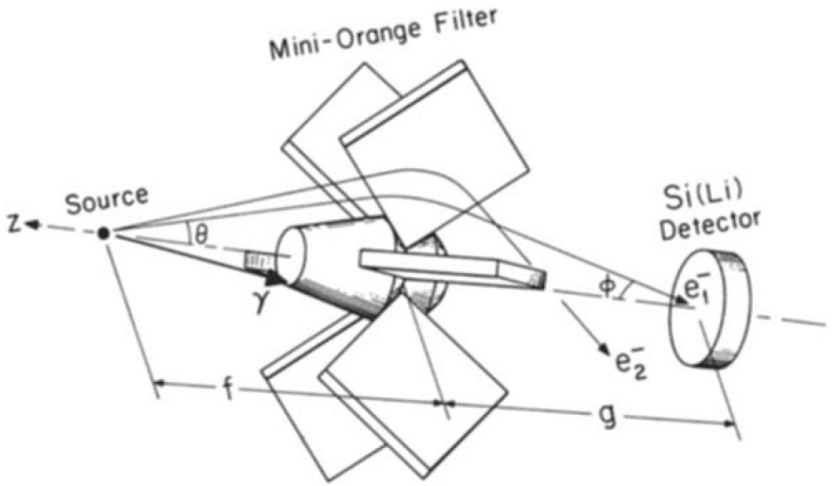
- **Internal Conversion Electrons – Determine transition multipolarities**
- **Electric Monopole Transitions – Decay of 0^+ States - Shape Coexistence, Particle-Hole Excitations**
- **Spectroscopy of Heavy Nuclei – Majority of transitions are low energy and converted**

In-Beam Electron Spectroscopy is Challenging

- **Low Signal-to-Noise ratio**
  - **Sources of Background:**
    - **Delta Electrons (From Heavy Ion hitting target)**
    - **Beta$^-$ decay (Continuum of electron energies)**
    - **Beta$^+$ decay (Continuum of positron energies)**
    - **Photons (X rays and Gamma rays)**
    - **Backscattering of electrons in detector (Angle dependent)**
    - **Secondary electrons (Continuum from scattering of photons and electrons inside the vacuum chamber)**

Existing/Past Devices

Mini-Orange Spectrometer (MOS)

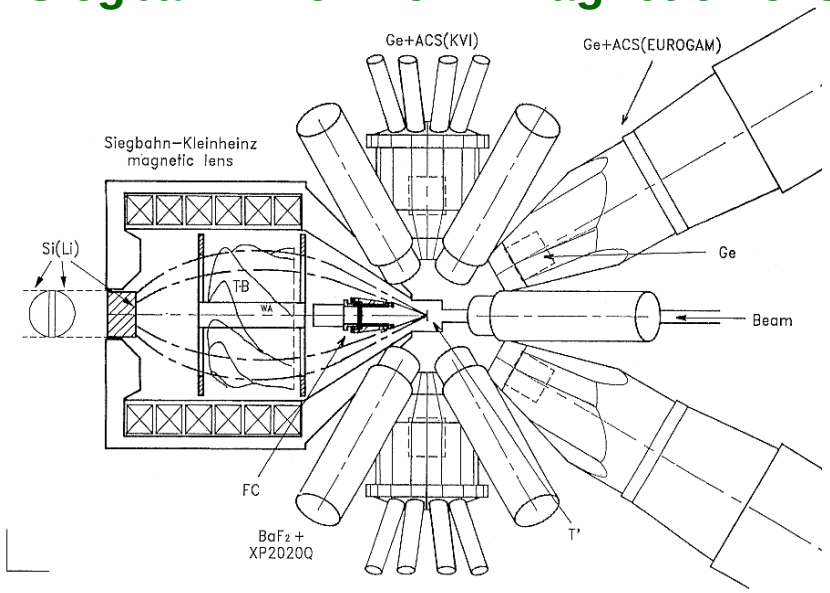


- **Permanent magnets used to bend electrons around a Lead shield**
- **Array of 6 inside target chamber of Ge array**

M.P.Metlay *et al*., NIM A 336, 162 (1993);

B.Aengenvoort et al., EPJA 1, 359 (1998)

Siegbahn-Kleinheinz Magnetic Lens

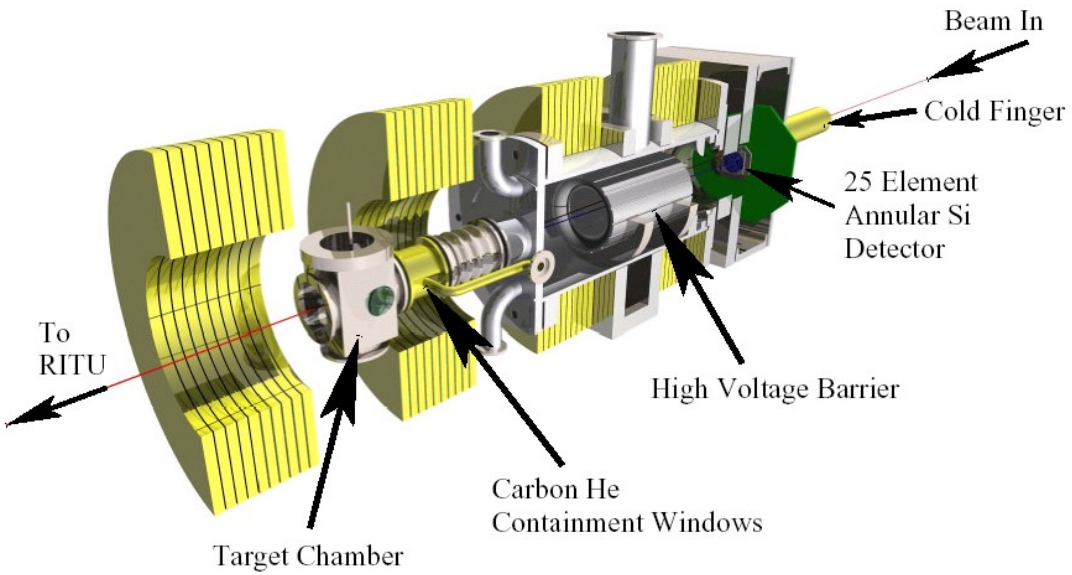


- Adjustable Magnetic field allows high-resolution electron energy/momentum selection
- Used in conjunction with several large Ges

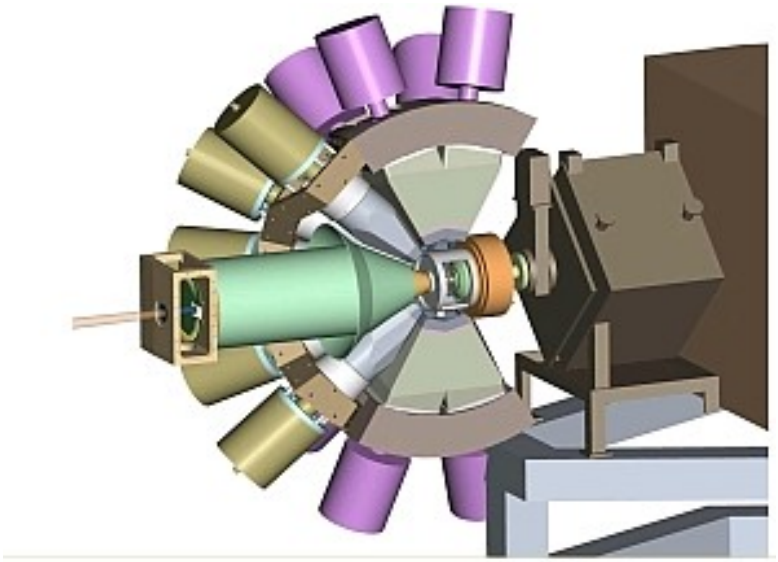
J.S.Dionisio *et al*., NIM A 437, 282 (1999)

Existing/Past Devices

SACRED



SAGE



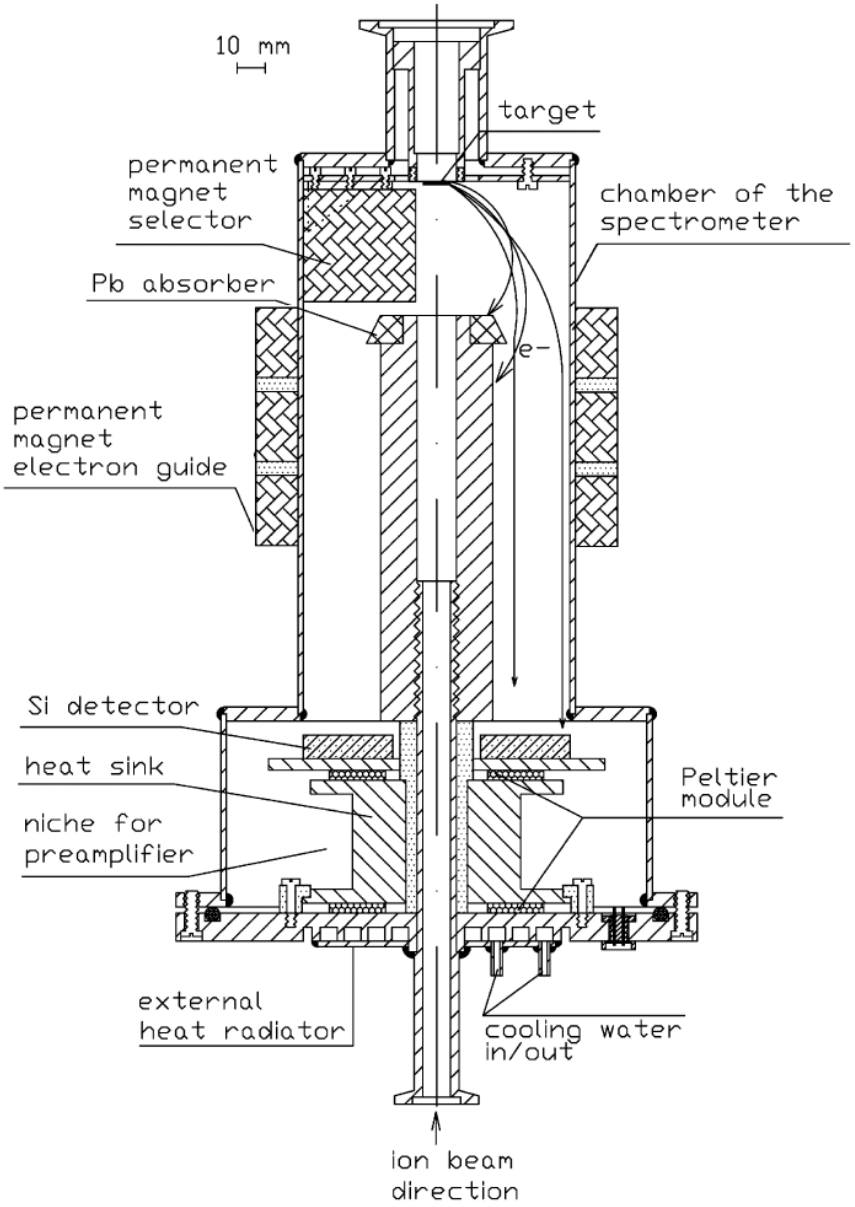
- **Co-linear normal-conducting coils (solenoid)**
- **Excellent devices for studying super-heavy nuclei (ie. Electrons between 200 – 1000keV)**

P.A.Butler *et al*., NIM A 381, 433 (1996);

H.Kankaanpää *et al*., NIM A 534, 503 (2004)

http://ns.ph.liv.ac.uk/~rdh/sage2.htm

Existing/Past Devices

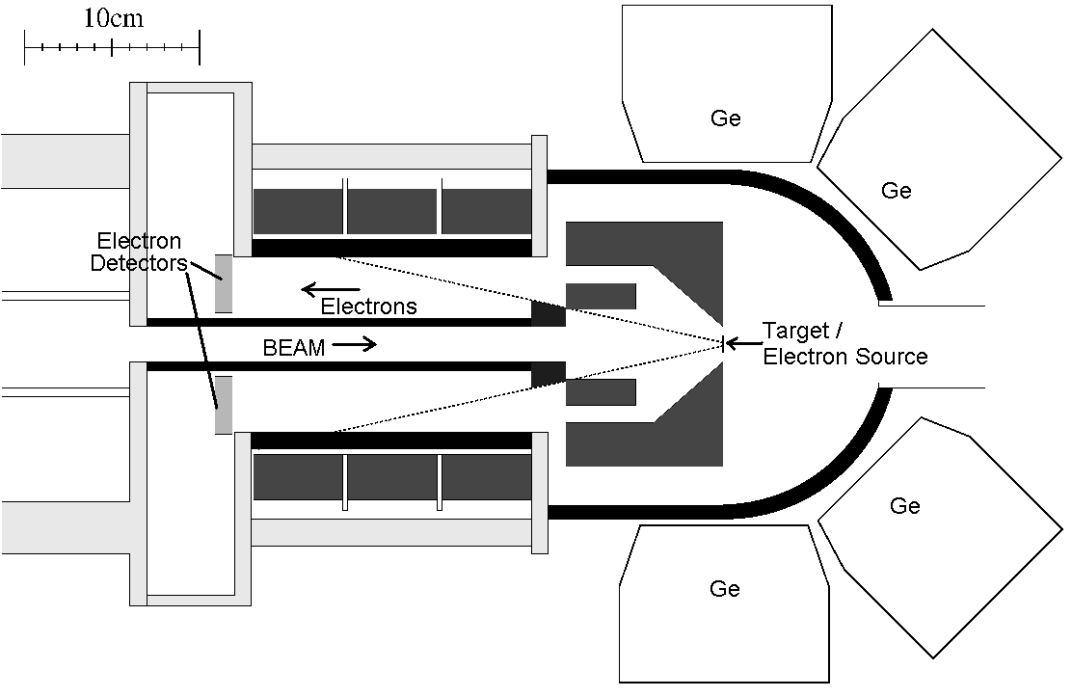


ICE Spectrometer (Lodz/Warsaw)

- **Combination of inhomogeneous and homogeneous magnetic lenses**
- **Lots of Potential**
  - **Compact, backward-angle geometry**
  - **Small amount of material in target chamber**
  - **Sensitivity to higher-energy electrons**
- **Inspiration for SPICE**

J.Andrzejewski *et al.*, NIM A 585, 155 (2008)

SPICE
SPectrometer for Internal Conversion Electrons



- **Couples to 12 TIGRESS Clovers for gamma-electron coincidences (Plus other ancillaries)**
- **Backward angle geometry and Delrin vacuum chamber for background suppression**
- **High efficiency for electrons 100keV to 4MeV**
- **High granularity for electron-electron coincidences**

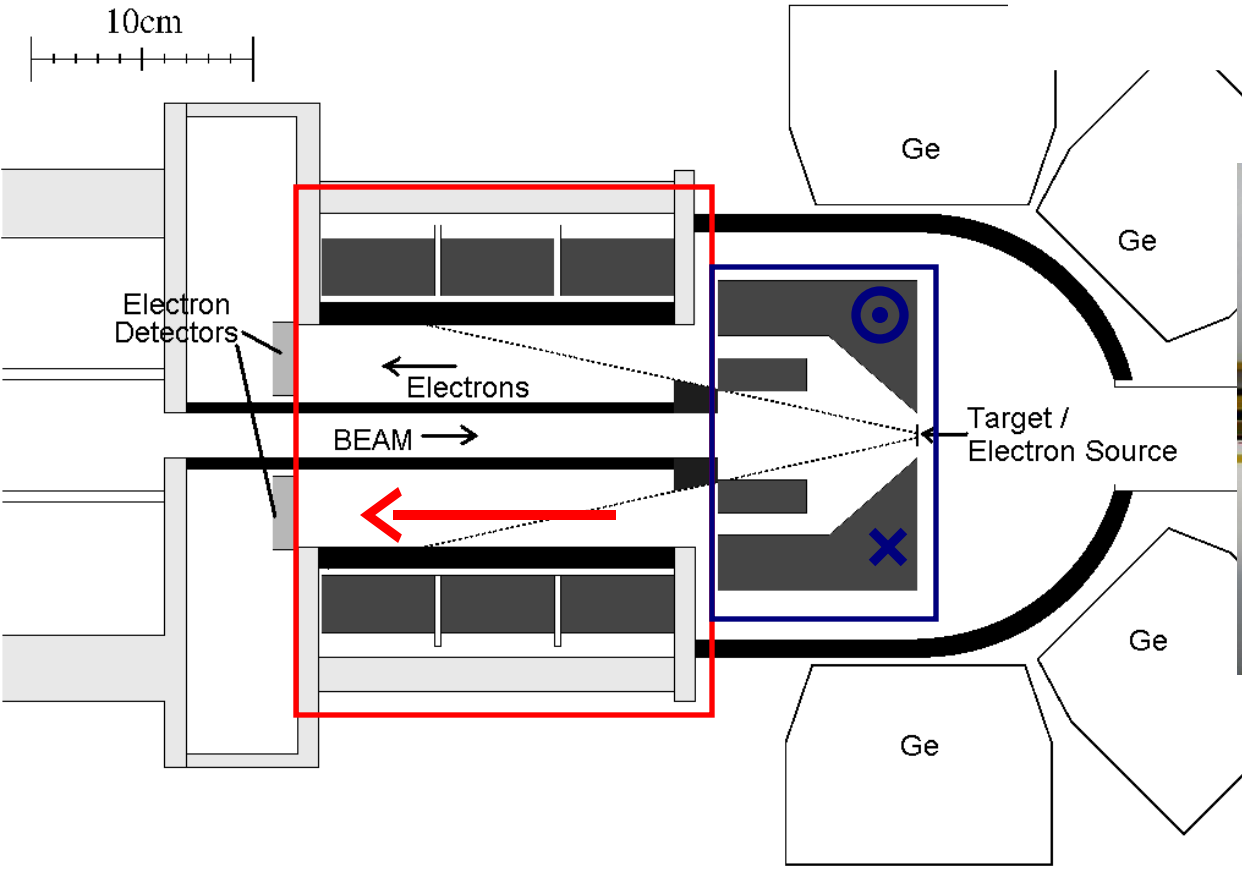
2-Stage Permanent Magnetic Lens Design

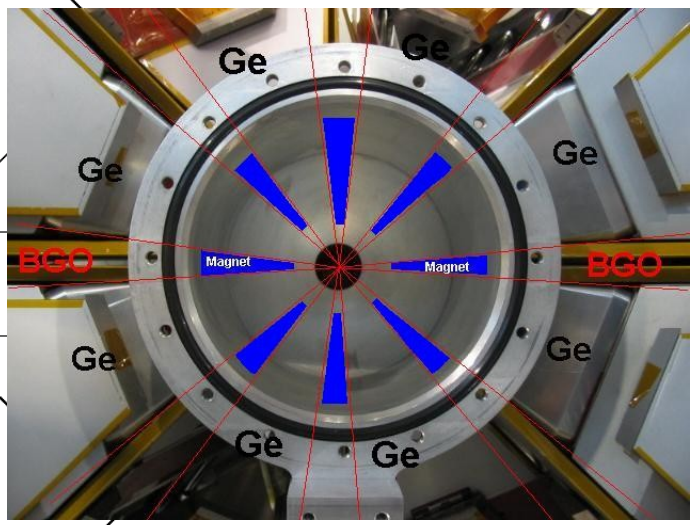
Transport Magnets

- *B* parallel with beam axis
- Electrons experience helical motion

Collector Magnets

- *B* perpendicular to beam axis
- Electrons with a large range of emission angles are redirected along beam axis





Research and Development

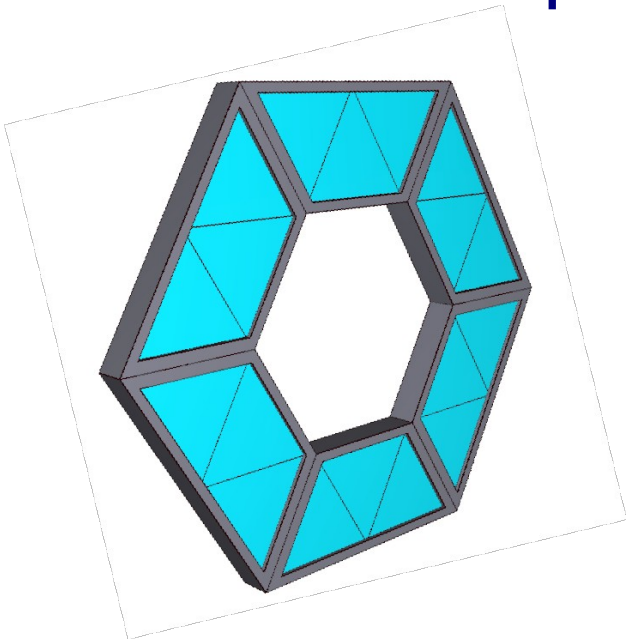
- **GEANT Simulations**
- **Investigation of novel detector solutions (CZT)**
- **Permanent Magnetic Lens Design and Optimization**
- **Mechanical Support Structure**
- **Advanced Cooling system**

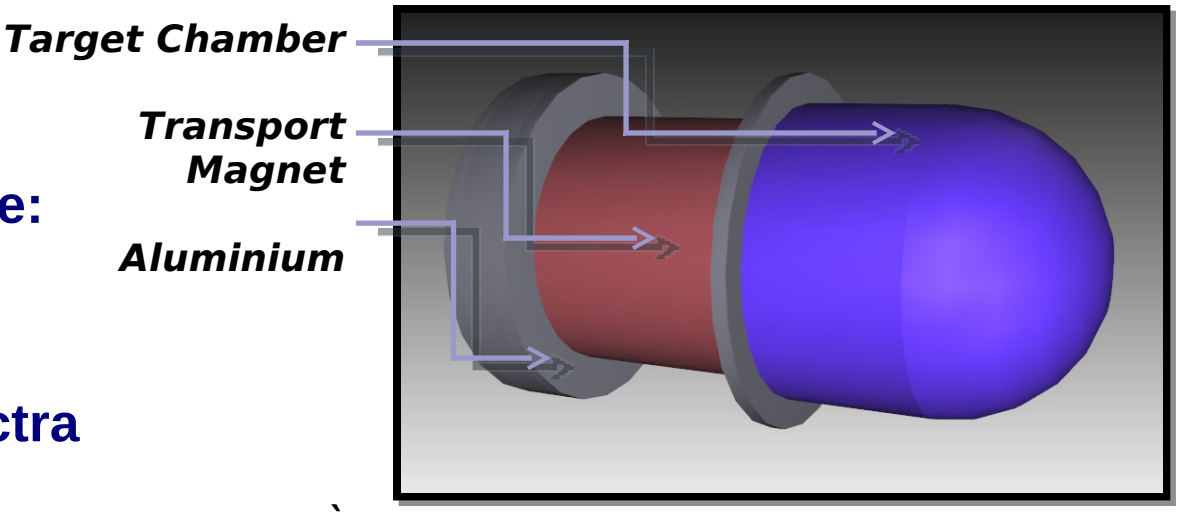
SPICE Geant4 Simulation

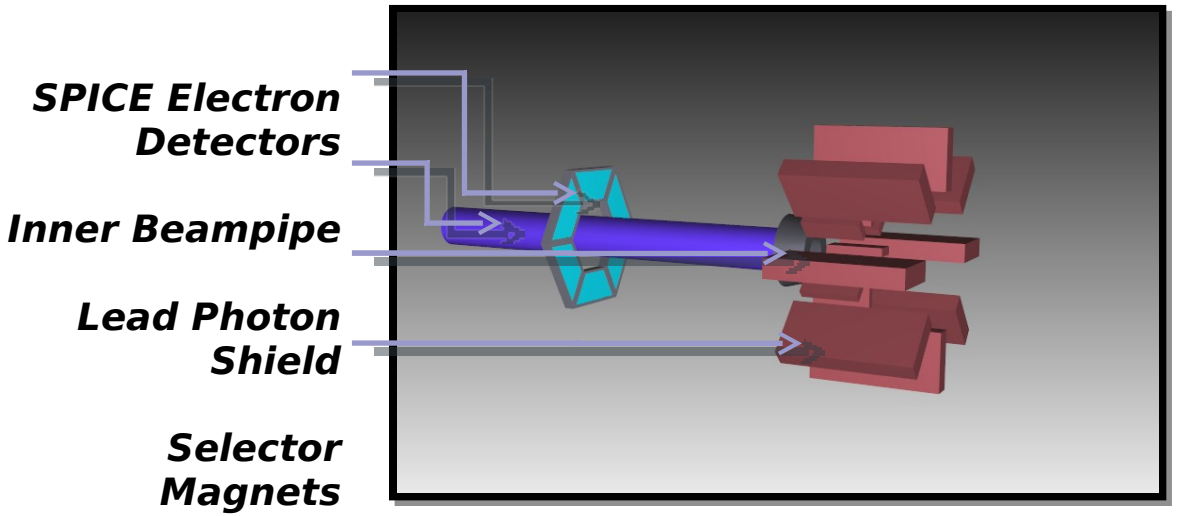
***SP**ectrometer for **I**nternal **C**onversion **E**lectrons*

GEANT used to investigate:

- **Choice of Detectors**
- **Sources of Background**
- **Effect on TIGRESS Spectra**

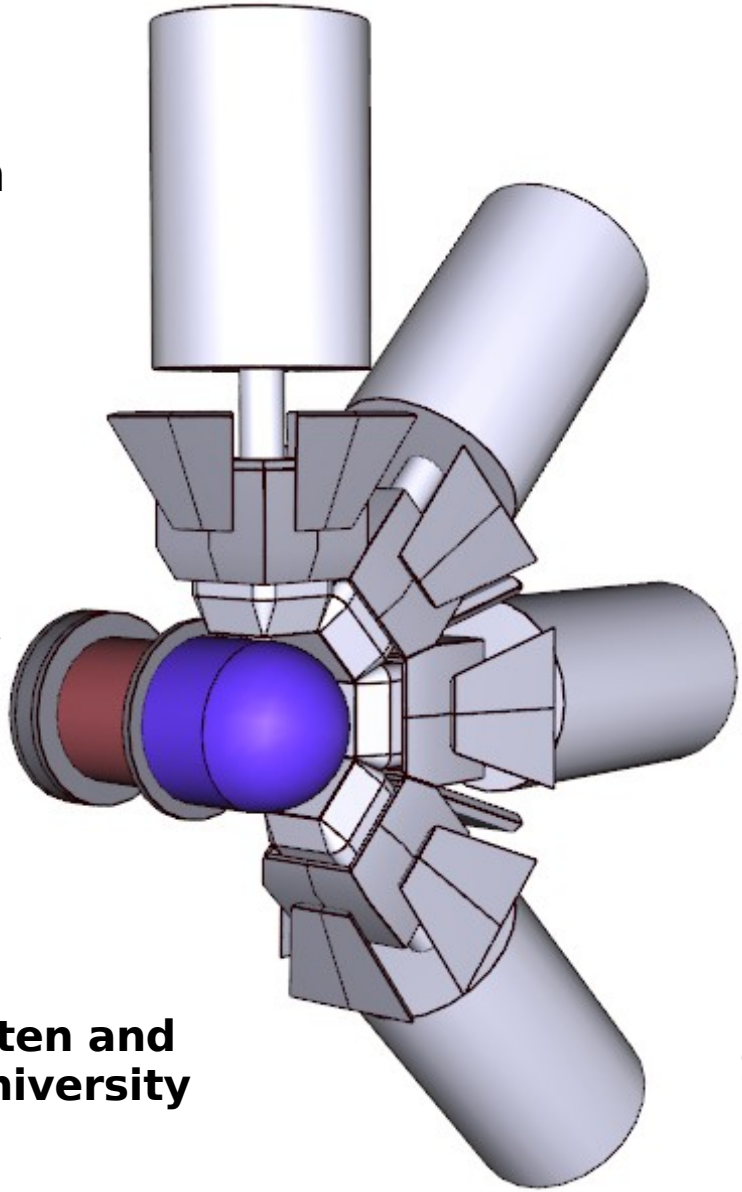


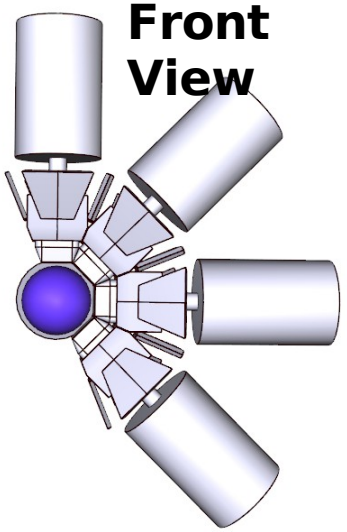


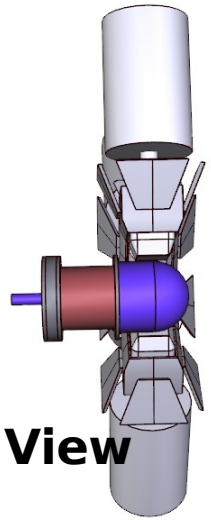


TIGRESS+SPICE Simulations

- SPICE can couple to TIGRESS with up to twelve clover detectors to perform high-efficiency gamma-electron coincidence spectroscopy of exotic nuclei.
- The TIGRESS+SPICE configuration can also support additional ancillary detectors such as the EMMA recoil mass spectrometer.







SPICE GEANT Simulations written and performed by Ryan Dunlop, University of Guelph.

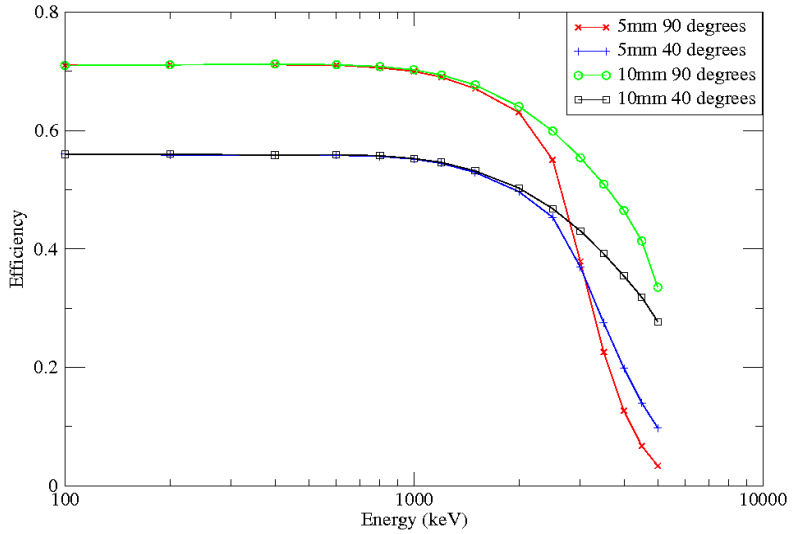
Detectors for Electron Spectroscopy

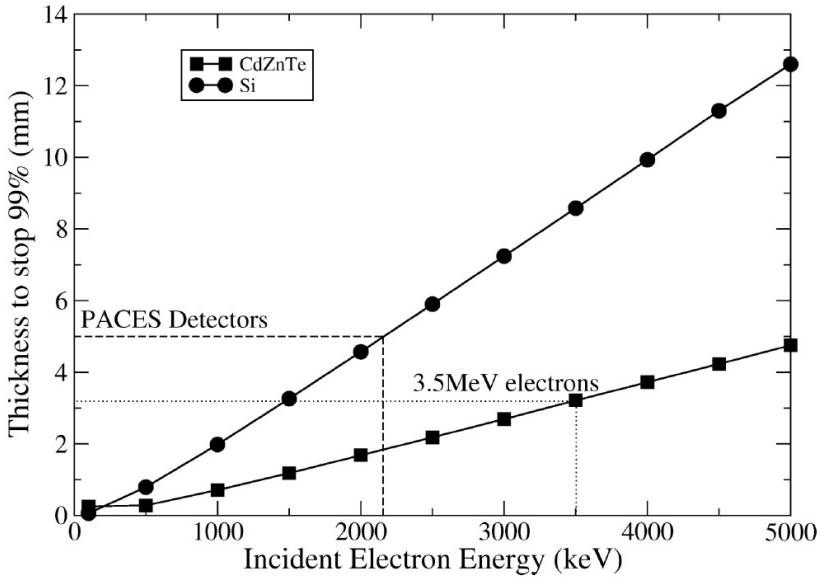
10mm Thick Lithium-Drifted Silicon

- Has always been the detector of choice
- Superior energy resolution
- LN2 operating temperature
- Rather thick detector needed for high-energy electrons

Cadmium Zinc Telluride (CZT)

- Room-temperature Semiconductor
- Higher-Z means only very thin detector required (Low sensitivity to photons)
- Backscattering reduces efficiency

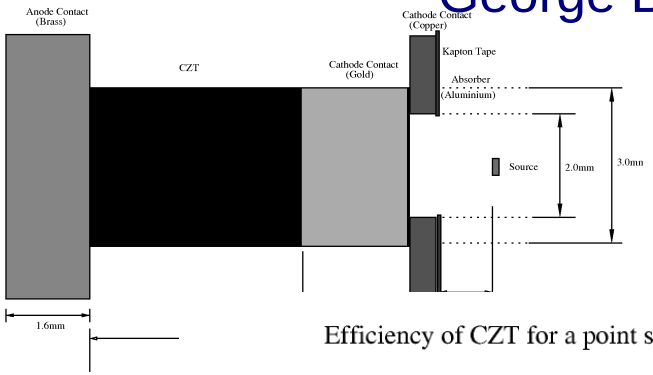


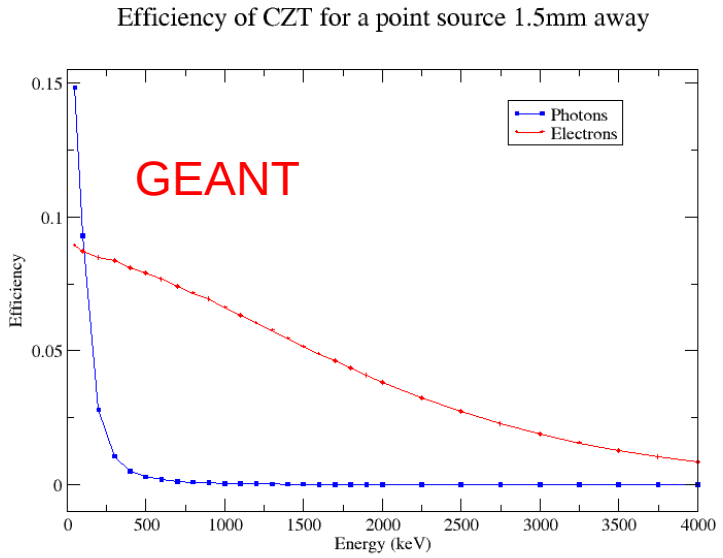


Characterizing CZT Detectors

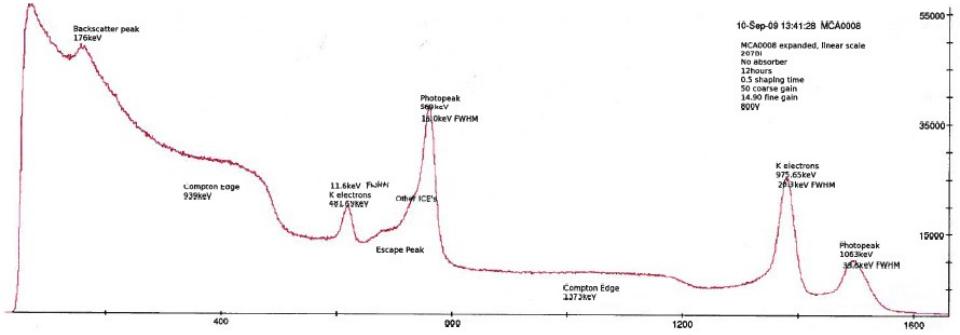
Rachel Ashley, TRIUMF

George Beer, UVIC

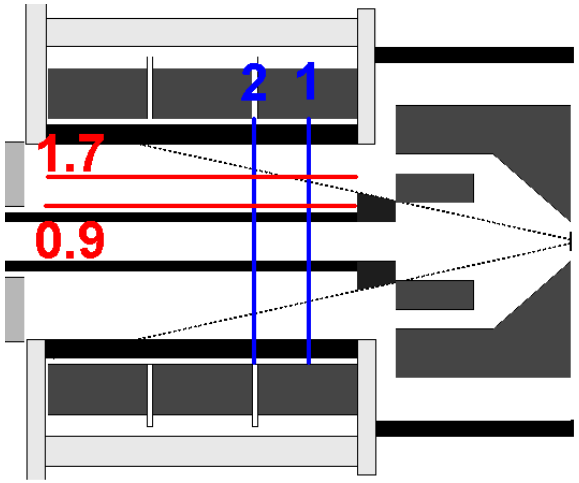




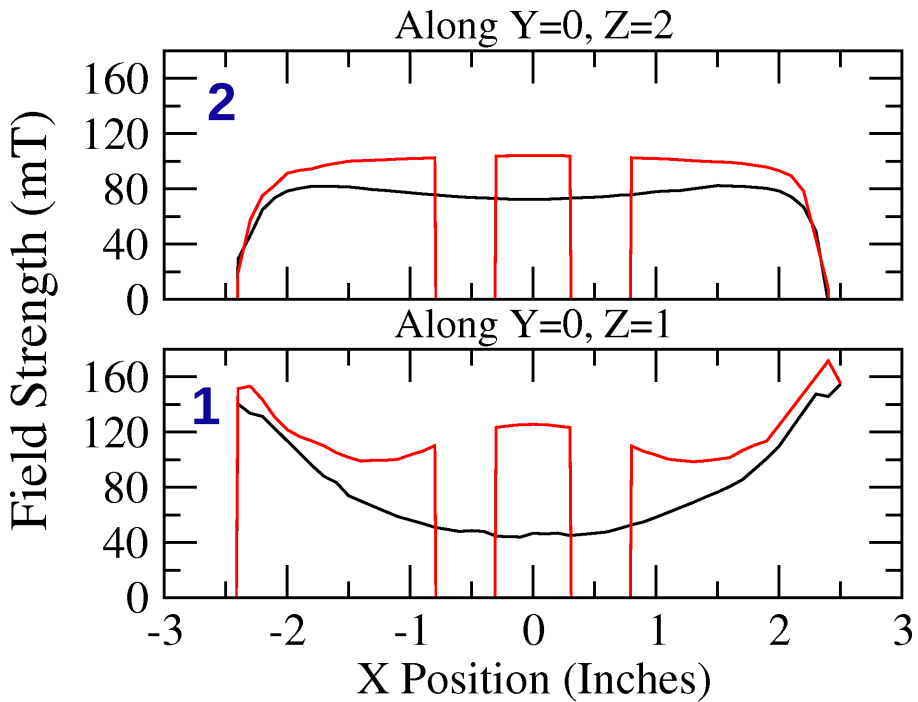
- Resolution for electrons vs gamma rays
- Efficiency for electrons vs gamma rays
- Resolution as a function of temperature (30 to -20 degrees C)
- Findings will be published soon

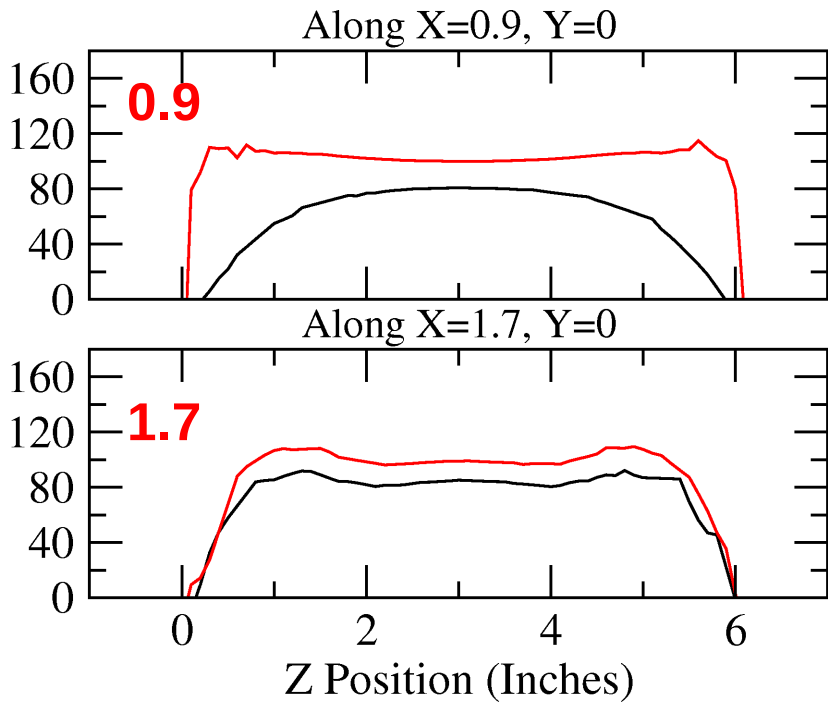


2-Stage Magnetic Lens Design (COMSOL)



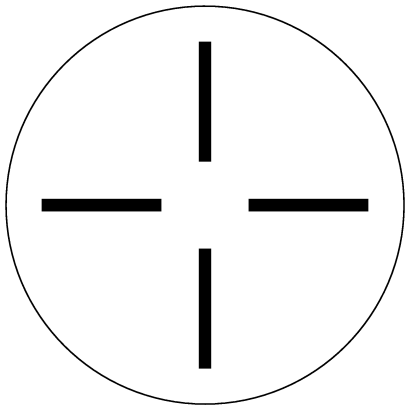
Adding a central magnet cylinder increases field strength and uniformity within the transport region

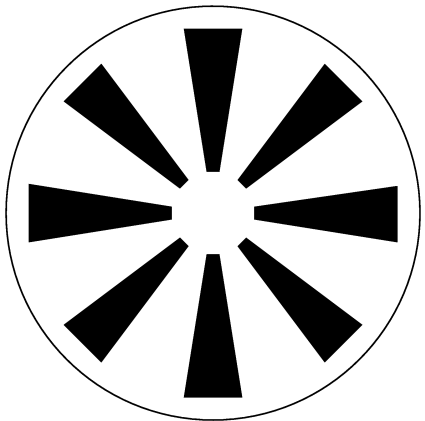


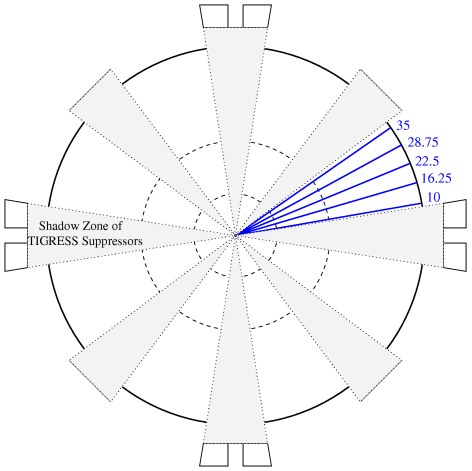


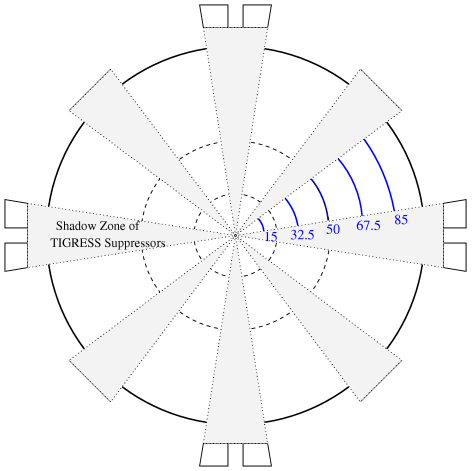
2-Stage Magnetic Lens Design (COMSOL)

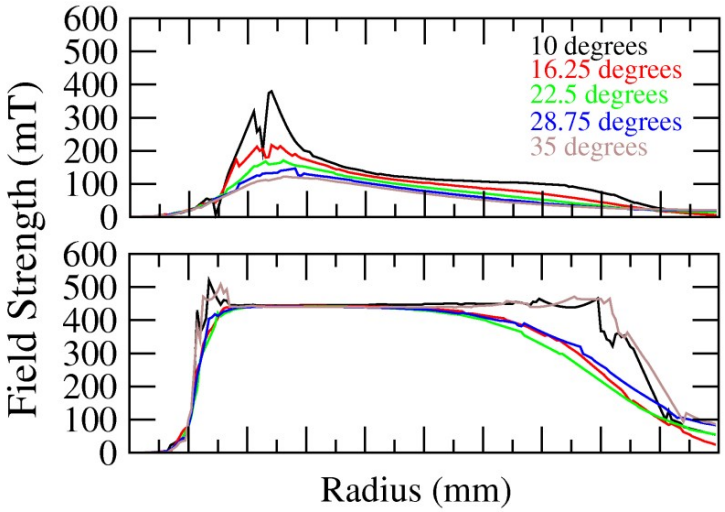
NdFeB magnets can produce fields well in excess of what is required. Appropriate shapes can produce uniform fields.

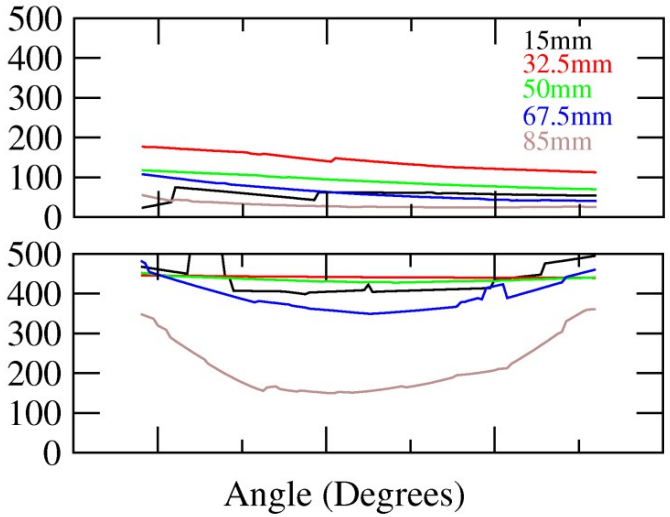










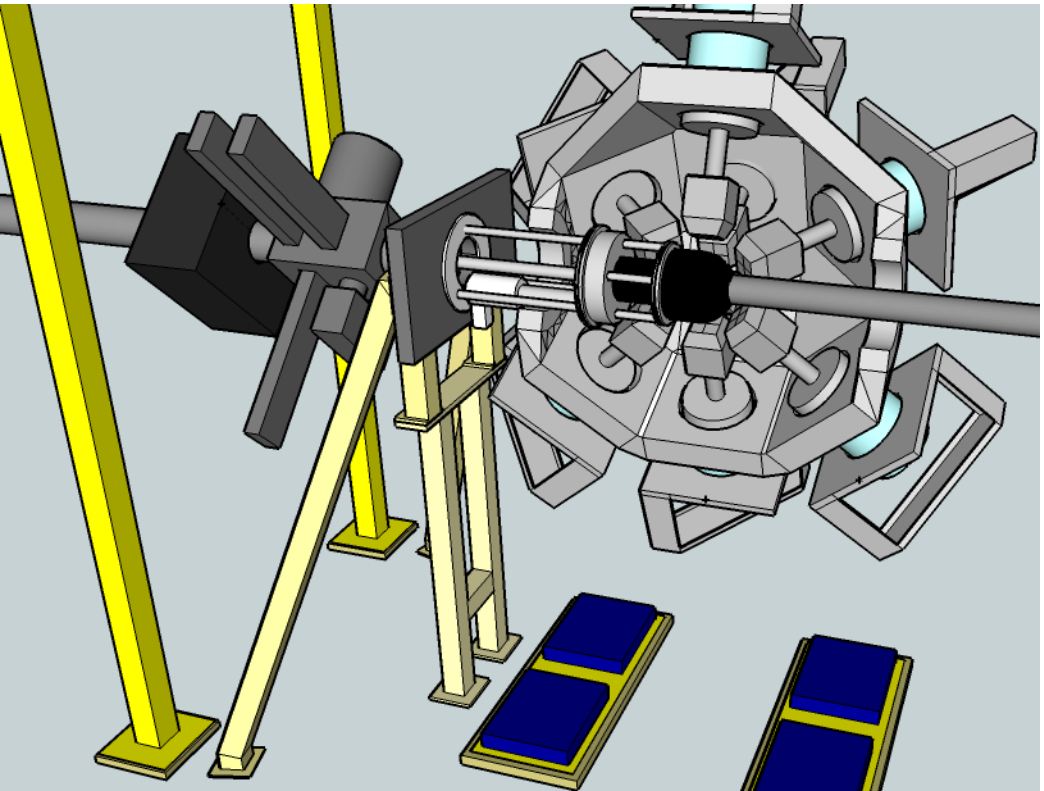


Development is still at an early stage but looks very promising

Engineering

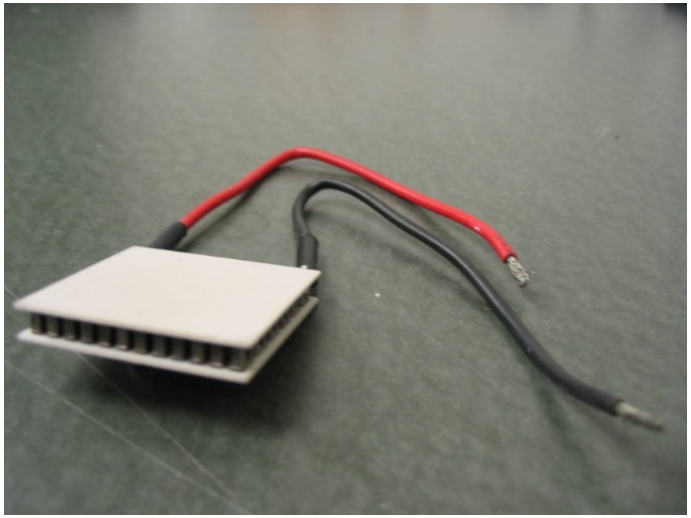
Mechanical Support Structure

Magnets will weight close to 50kg and located at centre of TIGRESS



Cooling System

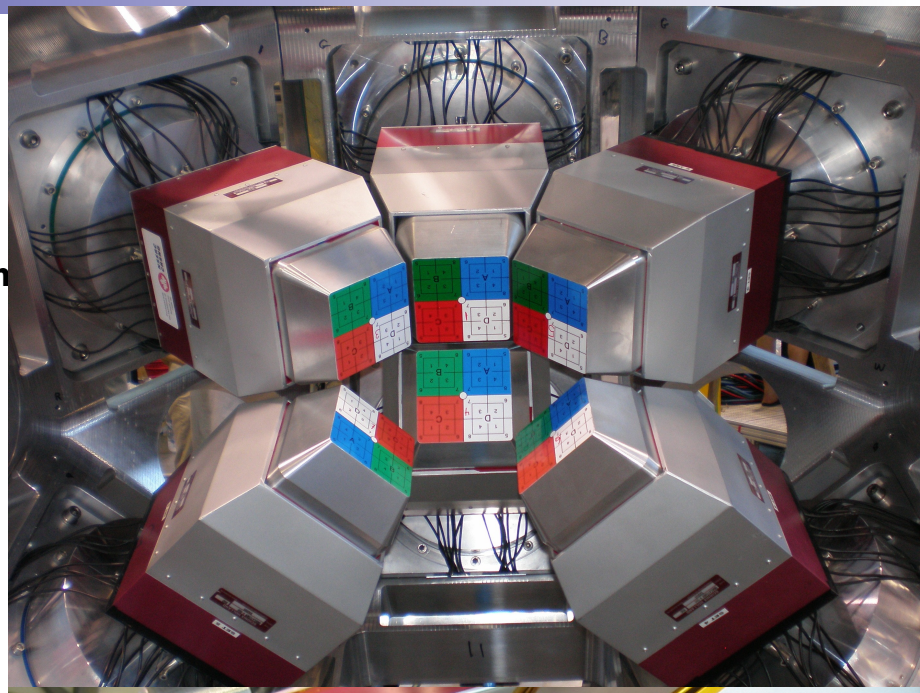
It takes ~2hrs to cool and ~12hrs to warm PACES. Combining a LN_2 reservoir with solid-state Peltier coolers can produce a system with greater temperature stability and faster cooling/warming periods

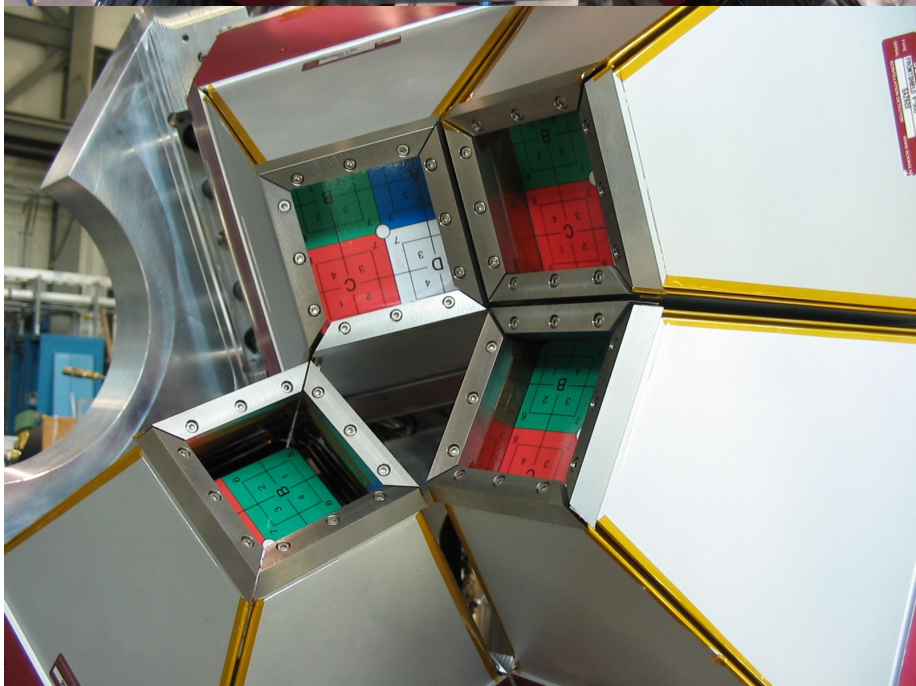


TIGRESS

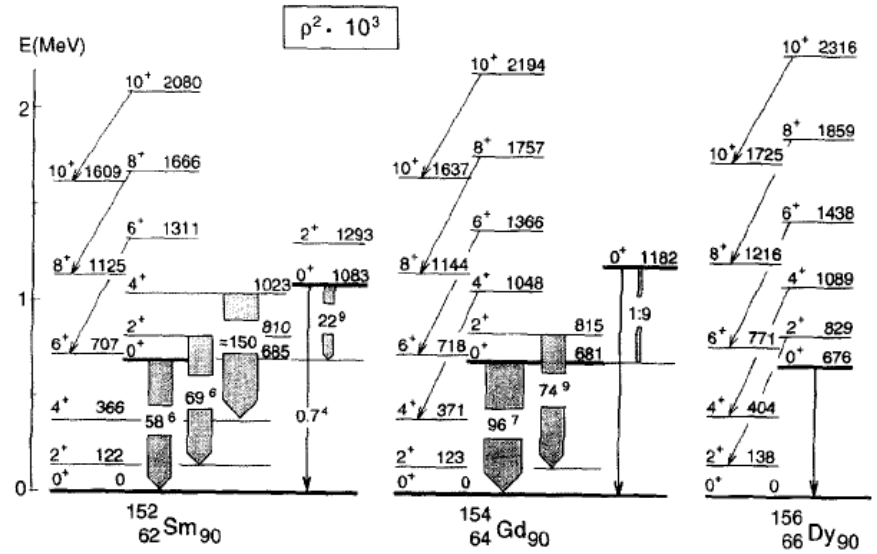
TRIUMF ISAC Gamma-Ray Escape-Suppressed Spectrom

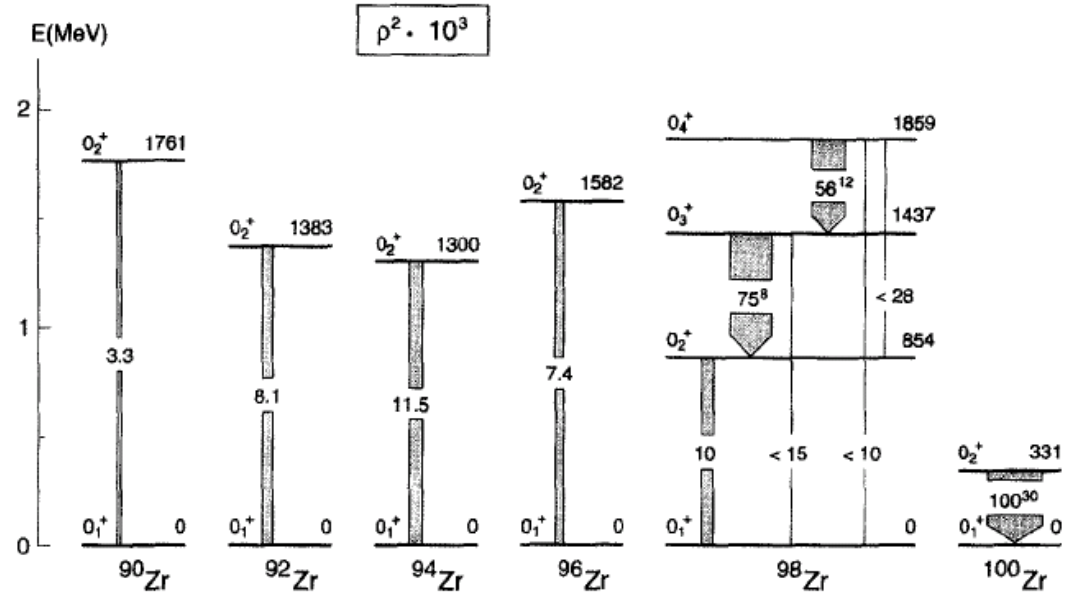
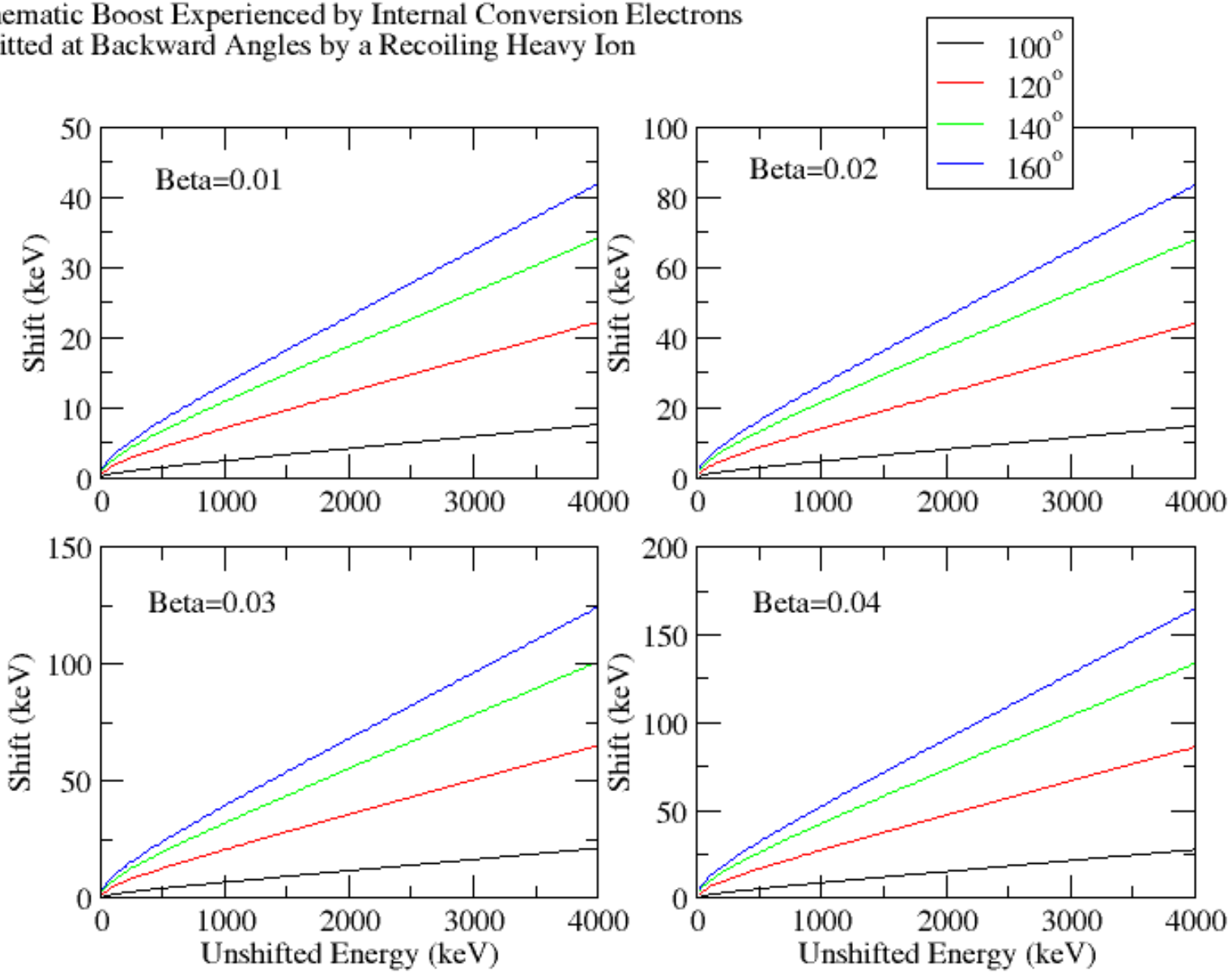
- **An array of up to 16 highly-segmented HpGe clover detectors**
- **High detection efficiency**
- **High spectral quality (Segmentation and BGO Suppression)**
- **Optimised for sensitive gamma-ray spectroscopy with accelerated radioactive beams**





Nuclear Structure from *E0* Transitions





Kinematic Boost Experienced by Internal Conversion Electrons
Emitted at Backward Angles by a Recoiling Heavy Ion