G. EQUIPMENT DEVELOPMENT

A strength of the heavy-ion group program is continuing excellence in developing new equipment. During the last year, considerable progress was made in many areas. A new data-acquisition system was developed and was deployed in experiments. The FMA is being upgraded and its focal plane detectors enhanced. The production, separation, capture and transport of ions to the CPT was greatly improved and numerous measurements are now underway. Our development of large area planar detectors for gamma-ray tracking reached sufficient maturity to start a full program of measurements. Involvement in the national gamma ray tracking project GRETA has increased.

g.1. Development of the SCARLET/PICA Data Acquisition System (K. Teh, B. G. Nardi, and A. H. Wuosmaa)

Development on the core SCARLET data-acquisition system is completed. The core system is designed with few assumptions. This makes it easy to adapt the system to different acquisition hardware. However, it also excludes components needed to make it transparently usable. Effort is now being directed to interfacing the system to the ROOT data-analysis software in a user-friendly manner and developing a working setup for ATLAS-based experiments.

At present, the SCARLET software supports the Wiener CC32 CAMAC controller. The PICA CAMAC controller, which is being developed in-house, is nearing completion and support for it will be added to SCARLET system. Other plans are to add VME readout support to SCARLET.

The SCARLET system was used successfully for two on-line experiments. The first on-line experiment at Berkeley revealed various problems that were subsequently corrected for the second experiment at ATLAS where it ran flawlessly. A second SCARLET system is now being assembled for a group in the Chemistry Division for experiments at the APS.

g.2. A Gammasphere Sorting Engine for Use with ROOT (Torben Lauritsen)

To monitor data on-line during experiments with Gammasphere, two principal systems were used so far: DAPHNE and UPAK. The former system only works under the VMS operating system, which is no longer supported and is being phased out. The latter system only works on an old implementation of SunOS, which is out of date and hard to maintain. Thus, there is a need for a new on-line sorting and data display facility for use with Gammasphere.

The 'GSSort' sorting engine and 'GSUtil' utility package for ROOT were created to provide a new on-line sorting environment using the powerful ROOT display/data-analysis package from CERN as the graphical interface to the user. GSSort is able to take input from tape and disk as well as receive UDP data sent to it over the network from the Gammasphere VME data sender. The sorter can sort data into regular root files and shared memory so that the user can dynamically see the data as it is being sorted.

The sorter will completely parse the Gammasphere data as well as external FERA data. Thus, there is no need for the user to know the details of the formats of the Gammasphere data stream. A number of 'standard' Gammasphere spectra are generated in GSSort and the user can control the binning and gating of FERA and Gammasphere data through 1D and 2D conditions via simple sorting commands in a 'chat' script. In this script the user will assign names to the FERA data (by specifying VSN numbers and channels) and manipulate the FERA data. New, so-called, pseudo event vector entries can be generated from the original FERA data named entries via simple arithmetic operations. 1D and 2D plots of the data are also specified in the chatscript and 1D and 2D (banana) conditions can be specified and applied to any of the pseudo event vector entries with simple, often English-like, commands in the sorting chat script.

Most on-line monitoring tasks, that are not too specialized, can be accomplished through sort instructions in this chat script *without any recompilation of the sorting code*. Thus, the user need not know about C++ or FORTRAN programming and compiling in order to look at their data on-line. This should make this new sorting utility significantly more user friendly than DAPHNE and UPAK for the average user.

The GSSort engine is normally controlled from inside root where the sorted spectra are displayed. In addition to utilities for displaying data, setting gates on matrices, fitting peaks, etc. the GSUtil control package also contains utilities for starting and stopping the sorting engine and a utility to look at the interpreted Gammasphere data stream.

GSSort and GSUtil runs on both Solaris (where it is developed and maintained) and Linux machines and can be used for off-line sorting as well. GSSort is well suited to run unattended from script files sorting data from 8 mm tapes in a stacker. See http://www.phy.anl.gov/gs/doc/GSSort for the latest information about the new ROOT based Gammasphere sorting utility.

g.3. **Nuclear Target Development** (J. P. Greene and G. E. Thomas)

The Physics Division operates a target development laboratory that produces targets and foils of various thicknesses and substrates, depending on the requirements, for experiments performed at the ATLAS and Dynamitron accelerators. The targets are prepared from both naturally occurring materials and stable isotopes that are supplied either in pure, elemental form or as stable compounds. In addition to ATLAS experiments, targets and foils are provided for all staff members whether working within the Physics Division or undertaking experiments at other facilities, for instance, the Advance Photon Source (APS). Also, wherever possible, support is provided to other ANL Divisions, and in particular to requests from researchers at the University of Chicago. Numerous collaborations have grown out of efforts between the Physics Division and target laboratory staff with outside groups in order to provide targets. Many of these, unfortunately, cannot be accepted due to the limited resources of, and time constraints placed on the target laboratory staff.

In the past year, numerous targets were fabricated either as self-supporting foils, on various substrates or as "sandwich" targets. Targets produced included ^{107}Ag, Al, Au, ^{136}Ba, Be, ^{13}C, C_{60}, ^{40}Ca, CaO, Cd, Cu, ^{170}Er, ^{54}Fe, Havar, HfO_2, In, ^{7}LiF, ^{24}Mg, ^{24,26}MgO ^{92}Mo, mylar, ^{142}Nd, ^{58,60,62,64}Ni, ^{nat}Ni^{16}O, ^{208}Pb, phosphor, polypropylene, Pt, ^{96}Ru, ^{28}Si, ^{144}Sm, ^{112,116}Sn, ^{130}Te, Th, U, UC_2, V, $^{182,184}WO_3$, Y, and ZrO_2. Many of these target foils were fabricated via mechanical rolling using our small rolling mill. During 2002, approximately 685 targets were prepared for various experiments.

We look forward to the return of Gammasphere to ATLAS and the increase in demands for various targets prepared by the target laboratory. For the past calendar year, 55 targets were prepared for experiments at Gammasphere while at LBNL.

For experiments undertaken to explore and increase the production of the heaviest elements a new, devoted target chamber and larger diameter rotating target wheel were constructed. Intense beams, by necessity, must be employed, requiring new demands upon target performance. Target wheels of isotopic lead on carbon backings were prepared for these initial experimental runs using this chamber coupled to the FMA. The goal of this present work was the production of Rf, element 104 and the study of detection limits and beam rejection employing the split-anode installed as an upgrade to the FMA. Beam intensities up to 250 pnA were put on target. An online target monitoring system was developed to detect target degradation. Calculations were performed in an effort to model the target behavior. This new target chamber system will also allow for gas cooling of the target. A larger wheel of similar design is already in use within a new target chamber at the front end of the CPT experiment using the SPS in Area II. By employing a target wheel station, increased beam currents will be available for the production of low cross section reaction products for precision mass measurements. Sixteen sector, large area target wheels of carbon and nickel were prepared for use in these studies.

Outside of target development, support is being provided for the production of thin plastic films and foils for use in various detector systems developed for experiments at ATLAS as well as energy degraders needed for the CPT and for astrophysics research using radioactive beams at SPS III and the FMA. Several variations of metallized plastic foils were prepared for use in the gas counter detector used at the FMA focal plane.

As part of ATLAS support, the target lab routinely produces carbon stripper foils of 2 $\mu g/cm^2$ for use in the Tandem as well as other thickness for additional stripping throughout the accelerator. Over 285 carbon stripper and gold foils of various types were prepared for ATLAS during this past year. There continues to be an increase in the preparation of various dilutions of isotopic source material into a form and shape suitable for introduction into the ion sources for the production of enriched beams at ATLAS. These included $^{6,7}Li$, ^{64}Ni, $^{33,34}S$, and ^{50}Ti. The continuing procurement of stable and enriched material for ATLAS consumption and maintenance of isotope inventories for enriched beam production is being provided by the target laboratory staff.

The target development laboratory includes state-of-the-art equipment used for thin-film fabrication. The available techniques consist of multiple resistive heating, focused ion beam sputtering, glow-discharge plasma deposition, electron beam and electron bombardment evaporation, electrodeposition and mechanical rolling. The evaporators are maintained under high vacuum and each vessel contains a quartz-crystal film-thickness monitor with deposition rate indicators. Also included are movable shutters, quartz-lamp substrate heaters and thermocouple temperature sensors, allowing for complete process monitoring during target deposition.

Other auxiliary equipment used for target development includes electrodeposition apparatus, a small rolling mill, an alpha particle counting chamber, inert atmosphere glove box, laminar flow clean bench, pellet press, a reduction furnace, and a variety of precision balances. A turbo-pumped target storage facility is in operation for maintaining, under high vacuum, those targets that readily oxidize in air. This system utilizes computer-controlled circuitry to prevent targets from exposure to atmosphere during power interruptions. A second storage system employing a bank of vacuum desiccators and connected to a mechanically pumped manifold is available for use by individual experimenters. An additional set-up, consisting of two large glass desiccators evacuated using a small turbo-pump system, is in operation for long-term material storage. This allows a separation of material storage from target storage, hence eliminating repeated exposure when transferring and retrieving targets.

A low-level radioactive source and target preparation laboratory exists at a separate location within the Division that is dedicated to the production of these sources and targets. Available preparation techniques include multiple resistive heating, employing a diffusion-pumped vacuum evaporator. A second, smaller evaporator system was constructed for close proximity evaporations of higher activity materials, to be used as targets as well as radioactive sources. The small size of this system allows for installation within a hood. Preparation and handling of fission targets (mainly ^{252}Cf) by electrodeposition has been done in this lab for experimental studies at ATLAS as well as routine rolling of natural U and Th foils.

Another area of increased research effort was toward development of radioactive beams for the RIA proposal and involves neutron producing targets which in turn induce fission in uranium or a uranium compound production target. Toward this end, direct measurements of the thermal conductivity of uranium carbide were made using the method of electron beam heating provided by a 10 kV mortar source in vacuum with the temperature measured as a function of beam current using a two-color pyrometer. This work is still in progress.

The 21st World Conference of the International Nuclear Target Development Society (INTDS) was held in the Physics Division at Argonne National Laboratory on November 4-8, 2002. The conference was attended by 60 participants from 14 countries. Thirty-three contributions were presented in 8 sessions coverings a wide variety of target topics. Each session was preceded by an invited talk with the speakers covering general overview of projects, problems, and experimental aspects related to the session topic. Highlights included high power targets and stripper foil applications for the development of the next generation RIB facilities.

g.4. "Relocating" Gammasphere at ATLAS (M. P. Carpenter, C. J. Lister, R.V. F. Janssens, N. Hammond, T. L. Khoo, T. Lauritsen, E. F. Moore, D. Seweryniak, F. G. Kondev,* G. Mukherjee,† S. J. Freeman,‡ and S. F. Zhou§)

During 2002, the Physics Division submitted a proposal to DOE to site Gammasphere back at ATLAS. While this proposal emphasized the use of Gammasphere with the FMA, it also discussed the possibility of utilizing the second beam-line position in Area IV as a standalone position for Gammasphere. This would allow Gammasphere to operate with its full complement of Ge detectors (108) and allow unencumbered operations with several of ancillary devices, namely CHICO, and Hercules. The proposal to move Gammasphere back to ANL was accepted by DOE, and it was agreed that operations at LBNL would cease on October 15, 2002. A group of LBNL and ANL scientists and technicians dismantled Gammasphere in roughly one month and shipped the components to ANL for reassembly.

During the fall of 2002, a scheme for moving Gammasphere between the two beam lines in area IV was devised. Three industrial rollers, each having a 40,000 lb. capacity, were procured. These rollers are routinely used in industrial settings to move heavy equipment. The support structure that the Gammasphere frame rests on when at ANL, was set up at the secondary beam line. Two 10,000 lb. shielding blocks were placed on top of the support structure in order to approximate the weight of Gammasphere. After lifting the support structure with jacks, the rollers were placed underneath. By slowly lowering the jacks, the support structure was positioned on top of the rollers. A team of six was then able to move the 20,000 lb structure over to the FMA and back without incident. After this test, it was concluded that Gammasphere could be moved safely between beam lines in the same manner without removing the detectors.

During the period 12/02 – 1/03, the Ge detectors were annealed and Gammasphere was reassembled in area IV. Initially, Gammasphere will operate in front of the FMA, and we anticipate moving it to the second beam line sometime in 2003. Approximately 10% of the Ge detectors did not operate properly after annealing. At present, we have been able to fix ~½ of these detectors in-house. We anticipate having to send 2 - 5 detectors back to ORTEC for repair. In addition, we discovered that nearly all the BGO detectors had at least one sector not functioning properly. All BGO detectors were repaired. Most of these repairs were to the bias chain of the bases. We anticipate such failures to continue and are considering replacing the bases on all BGO detectors.

Upgrades to the Ge-BGO VXI boards were also made during the shutdown period. All boards were configured to support both single- and split-crystal detectors. The time a Ge detector was available for readout after detecting a γ ray was also extended from 1 to 2 μsecs in order to allow for a better triggering scheme when operating Gammasphere with the FMA.

In February 2003, a beam of ^{58}Ni was tuned into the Gammasphere target chamber. A test experiment using a ^{40}Ar beam on various targets took place 3/11/03 – 3/14/03 with 93 Ge detectors operating in the array. The first PAC approved experiment was performed with Gammasphere during the period 3/17/03 - 3/22/03. Gammasphere is fully operational and the experimental program is in full gear.

*Technology Division, Argonne National Laboratory, †University of Massachusetts-Lowell, ‡University of Manchester, United Kingdom, §University of Notre Dame.

g.5. Electron-Capture Branch of ^{100}Tc and the Efficiency of a Proposed Mo Neutrino Detector (I. Ahmad, F. Naab,* A. Garcia,* S. Triambak,* I. Leikola,† H. Penttilä,† A. Jokinen,† J. Huikari,† S. Rinta-Antila,† J. Aystö,† J. Szerypo,† and P. Dendooven†)

Recently Ejiri *et al.*[1] proposed to use ^{100}Mo as a neutrino detector. Neutrinos would undergo the reaction $\nu + {}^{100}\mathrm{Mo} \rightarrow e^- + {}^{100}\mathrm{Tc}$ and ^{100}Tc would decay with a half-life of 15.8 s emitting another e^-. The signature for a neutrino absorption would be two electrons, providing a way to obtain clean signals. We performed a first run on an experiment to measure the matrix element for the E.C. decay of ^{100}Tc, which determines the neutrino absorption cross section on ^{100}Mo. A previous experiment[2] measured the ^{100}Tc EC branch to be $(1.8 \pm 0.9) \times 10^{-5}$ from which one obtains B(GT; ^{100}Mo $\rightarrow$ ^{100}Tc) = 0.66 ± 0.33, consistent with zero at 95% c.l. The present experiment was undertaken to produce a more significant result by using a separated beam of ^{100}Tc. This would reduce backgrounds that hindered a more accurate measurement in the previous experiment. The present experiment was performed using the IGISOL facility at the University of Jyväskylä.[3] The production of separated ^{100}Tc was very successful. Figure I-71 shows our x-ray spectrum. The Mo x rays are the signature for the EC capture. We are presently analyzing the data and waiting to get more time at Jyväskylä to finish the data taking.

*University of Notre Dame and University of Washington, †University of Jyväskylä, Finland.
[1]Phys. Rev. Lett. **85**, 2917 (2000).
[2]Phys. Rev. C **51**, 439 (1995).
[3]Nucl. Phys. **A693**, 477 (2001).

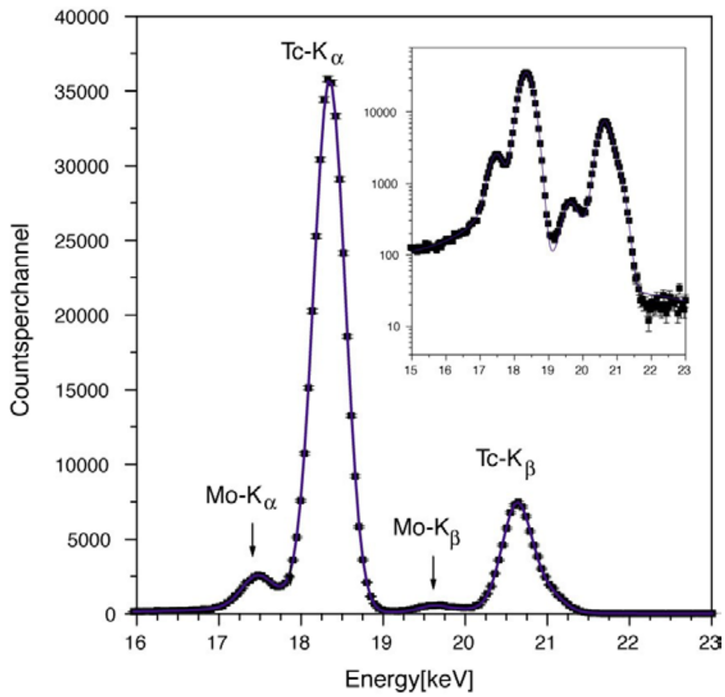

Fig. I-71. X-ray spectrum from ^{96}Tc and ^{96}Tc^m. These data were used to get the relative efficiency between Mo-Ko and 590 keV transitions. The inset is the same, but it is in logarithmic scale for the number of counts per channel.

g.6. Split Anode for the First FMA Electric Dipole (C. N. Davids)

The split anode for the first electric dipole of the FMA was installed and tested using the $^{58}Ni + ^{92}Mo$ reaction. The unused primary beam passes into the anode structure through a 1-cm slit and stops on a tantalum plate inside the anode. It is thus electrically identical to the original anode. In the test the flux of scattered beam detected at the focal plane was reduced by a factor of 8 for the new anode. In experiments conducted with the new anode, lower background rates at the focal plane were reported.

g.7. Delay-Line Shaping Amplifiers for a Double-Sided Silicon Strip Detector (C. N. Davids, P. Wilt, and D. Seweryniak)

A delay-line shaping amplifier system for a double-sided silicon strip detector (DSSD) was constructed, with a total of 200 channels being built. The system was tested using the 80 × 80 DSSD, observing the fast proton emitter $^{113}Cs(T_{1/2} = 17\ \mu s)$ produced via the $^{58}Ni(^{58}Ni,p2n)^{113}Cs$ reaction. The results are shown in Fig. I-72, which shows that decay proton events can be seen down to about 1 μs after the implantation event. The energy resolution of these amplifiers is nearly as good the Gaussian shaping amplifiers that were used up to now with the DSSDs. Normal usage will be to employ both sets of amplifiers in parallel in order to study both long and short half-lives without changing amplifiers.

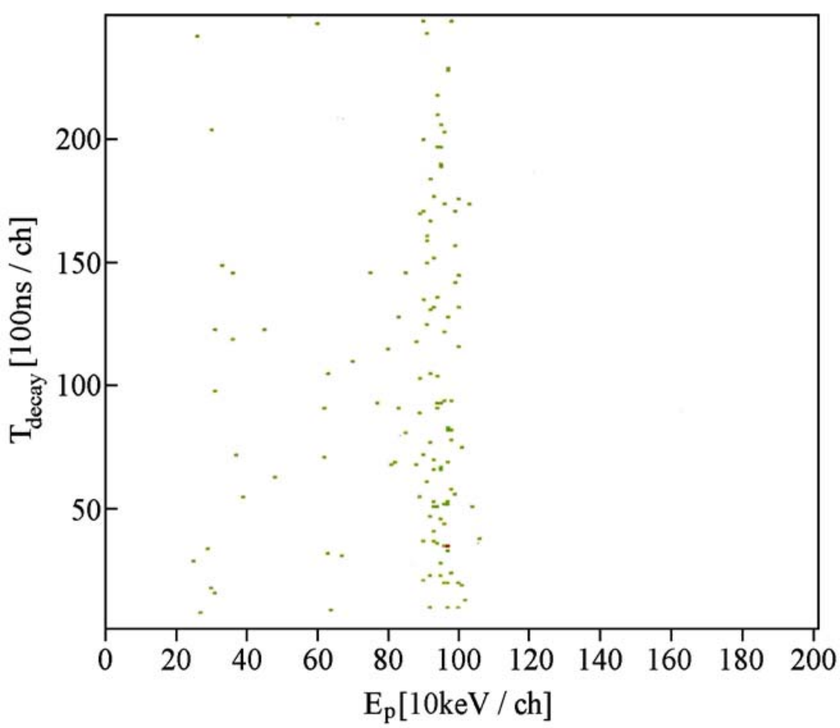

Fig. I-72. Decay time (vertical) vs. energy (horizontal) for protons from ^{113}Cs. The minimum decay time interval is ~1 μs.

g.8. A Bragg Scattering Method to Search for the Neutron Electric Dipole Moment

(M. Peshkin, G. R. Ringo, T. W. Dombeck,* H. Kaiser,† D. Koetke,‡ S. Shirvel,‡ R. K. Smither,§ and S. A. Werner¶)

Polarized neutrons will undergo several thousand Bragg reflections in a slot cut in a perfect silicon crystal and the rotation of their polarization by the crystalline electric fields will be measured to determine the neutron electric dipole moment (EDM). We hope to achieve a sensitivity several times better than that of the best previous measurement (around 1×10^{-25} e-cm, limited by systematic errors) and equally importantly to have very different systematic errors. We developed a suitable slotted crystal. Our experimentally demonstrated reflectivity of 0.99998 was published (Physical Review A **64**, 53607 (2001).

A preliminary experiment to measure the neutron's known magnetic dipole moment (MDM) in the same way, using the interaction of the effective EDM, equal to v/c times the MDM, with the crystalline electric field, should test the principles of the EDM experiment in an easier case. That experiment was approved for running at the Missouri University Research Reactor. The needed solenoid was fabricated and tested, and a beam line is under construction at the reactor.

Issues involving the penetration of the neutrons into the silicon, which may impact aspects of the design of the experiment. Those issues are currently under investigation in theoretical models. They are also expected to be clarified in the MDM experiment.

*Fermi National Accelerator Laboratory, †University of Missouri, ‡Valparaiso University, §APS User Program Division, Argonne National Laboratory, ¶National Institute of Standards and Technology.

g.9. Transmission Ion Chamber

(T. Pennington, D. J. Henderson, D. Seweryniak, K. E. Rehm, C. L. Jiang, C. N. Davids, C. J. Lister, B. J. Zabransky, and B. Blank*)

A Transmission Ionization Chamber (TIC) was constructed for the use at the focal plane of the Fragment Mass Analyzer (FMA). The motivation for the construction of the TIC was twofold. First, an astrophysics experiment studying ^{69}Br via the β decay of ^{69}Kr[1] would benefit greatly by adding a TIC to the existing implantation station. Second, in the study of extreme sub-barrier heavy-ion fusion evaporation reaction, the background due to the scattering of the beam particles can be reduced by developing a hybrid detector system such as PPAC-TIC-PPAC-TIC-PPAC.

The TIC is basically a copy of the normal ion chamber used with the FMA, based on a Daresbury design with some construction improvements. The transmission chamber has an active length of 8.82 inches (~22.4 cm). It is equipped with a segmented anode ΔE_1 located 2.00 inches (~5 cm) from the front face of the detector, followed by ΔE_2 2.00 inches further back (~5 cm), and ΔE_3 is located 4.88 inches (~12.4 cm) behind ΔE2. All three of the ΔE signals can be combined internally by the use of jumpers between each of the ΔE areas. One design improvement of the TIC is the removal of all polymers containing materials (except for the anode and Frisch grid which were constructed on PC Board material) and their replacement with ceramic. This improvement will allow easier pump down and shorter outgassing of the detector. A new detector mounting system allows for the modular use of the vacuum chamber for other types of detectors, e.g. the Microchannel Plate (MCP) detector. Also, during the design discussions for the TIC it was decided that the focal plane PPAC exit window would be reinforced to take reverse pressure up to 50 torr using a 302 stainless steel mesh that was photo-etched by FOTOFAB. The mesh is 0.003 inches (76.2 μ) thick with 0.003 inch wide approximately square cross section wires to support the window. In Fig. I-73 a photograph of the window support mesh is shown. The exit window of the TIC has a modified version of the 302 stainless steel window support structure, shown in Fig. I-74.

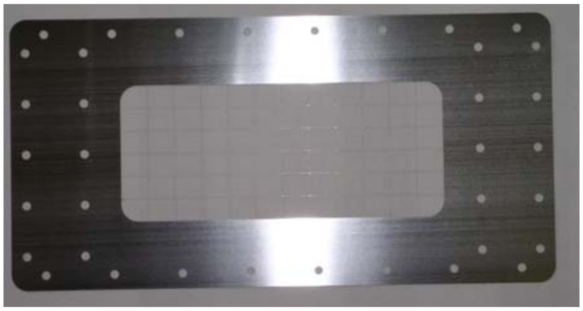

Figure I-73

Figure I-74

The TIC exit window consists of 120 μg/cm^2 Mylar film mounted on a Lexan support, shown in Fig. I-75.

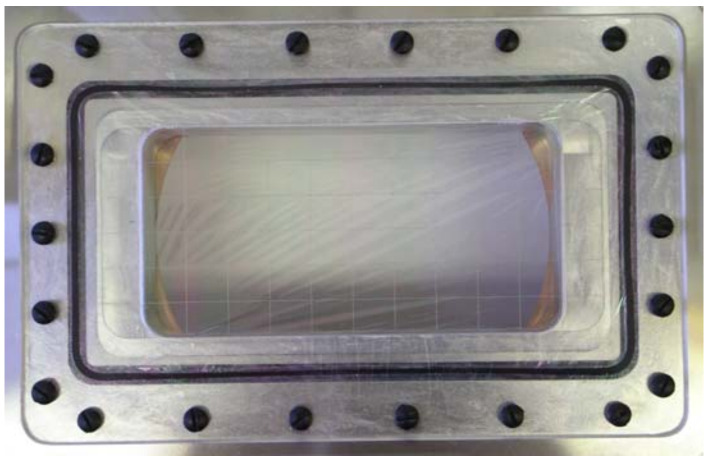

Figure I-75

A calculation shows that the shielding efficiency of the Frisch grid is 99.17 percent,[4] which is approximately the same for the DIC. In Figs. I-76, I-77, and I-78, pictures of the completed TIC are shown in the detector support structure with the vacuum chamber removed.

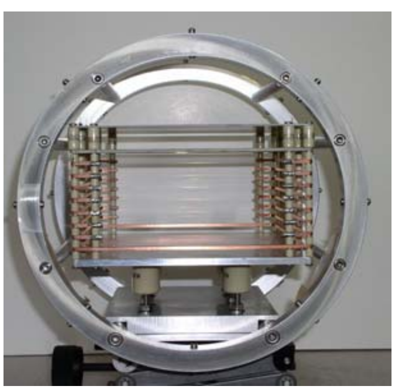

Figure I-76

Figure I-77

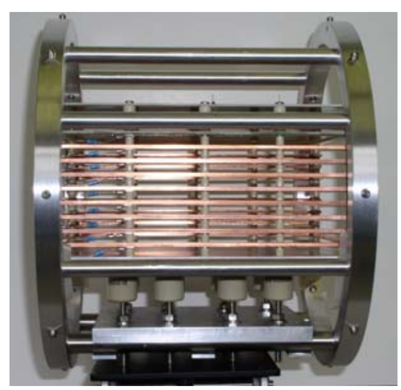

Figure I-78

Currently the Frisch grid is grounded but this can be easily changed with a small modification of the detector wiring to allow a potential to be applied. On April 25-27, 2003, the TIC was used in an experiment with good results.

*Argonne National Laboratory and Centre d'études Nucléaires de Bordeaux-Gradignan, France.
[1]B. Blank *et al*., ATLAS PAC Proposal Experiment Number 994, Submitted Feb. 07, 2003.
[2]C. L. Jiang, K. E. Rehm, and T. Pennington, private communication.
[3]T. Pennington and B. J. Zabransky, private communication.
[4]O. Buneman, T. E. Cranshaw and J. A. Harvey, Canadian Journal of Research **27A**, 191-206 (1949).

g.10. Isobar Separator for the Canadian Penning Trap (G. Savard, A. R. Levand, W. Trimble, Z. Zhou, J. Clark,* J. Vaz,* J. C. Wang,* and K. S. Sharma†)

During this year, a one Tesla Penning trap was designed, built and operated as an isobar separator for the Canadian Penning Trap (CPT) mass spectrometer system. Both stable and unstable isotopes can be precisely measured in the CPT mass spectrometer. In practice, the Penning trap requires ion beam at low kinetic energy (~ few eV) and accepts only few ions in one injection to obtain precise mass measurement.[1] However, radioactive ions produced either on-line (the nuclear reactions between the heavy-ion beams from ATLAS and the targets) or off-line (fission fragments of ^{252}Cf source) are of high kinetic energy (~100 MeV) and cover a large mass range. This means the ions have to be de-accelerated and the contaminants removed before sending them to the Penning trap (Fig. I-79).

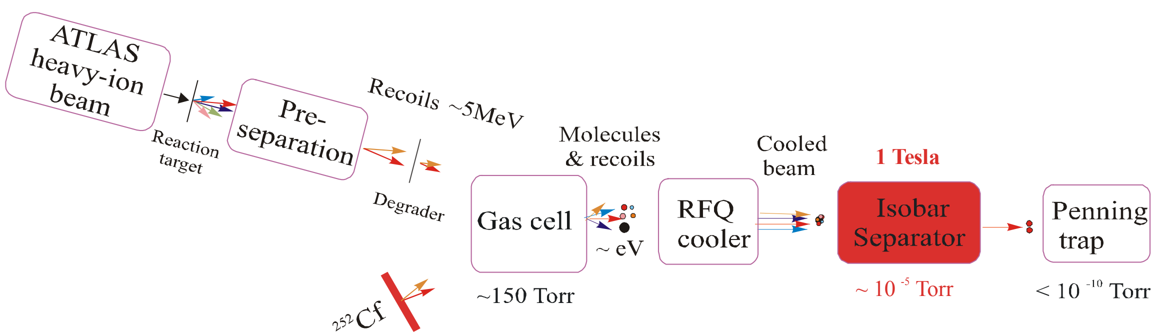

Fig. I-79. Schematic view of the Canadian Penning Trap system with isobar separator.

For the first issue, the gas cell is an ideal solution.[2] High-energy beams can be stopped in ~150 Torr helium and extracted by the combination of a DC axial field, gas flow, and RF voltage at the cone. However, while ions are thermalized in the gas cell, all the components of the gas can be ionized, including helium and hydrocarbons. Essentially, the hydrocarbon ions become the main contaminant ions in the Penning trap. For the cleaning of the contaminants, we need an isobar separator. For example, Table I-5 shows the main contaminants during a measurement of the ^{68}Se, which is an important waiting-point along the rp-process. The resolving powers required to remove the various contaminants are listed as well.

The isobar separator is a Penning trap, operated with 10^{-5} Torr helium pressure.[3] Ions in a constant magnetic field B and an axial quadrupolar electric field (Fig. I-80a) have three eigen frequencies of motions: magnetron ω_-, modified cyclotron ω_+, and axial ω_z (Fig. I-80b). If buffer gas is present in the trap, the kinetic energy of the ions will be lost due to collisions, resulting in the increase of the orbital radius of the unstable ω_- motion for all ions, called ω_- cooling (Fig. I-80c). If an RF excitation voltage at frequency ω_c is applied on the ring electrode of the trap (Fig. I-80d), only the ions with $m/q = B/\omega_c$ will receive and lose kinetic energy periodically from $m(\omega_- r)^2/2$ to $m(\omega_+ r)^2/2$ (Fig. I-80e). The ions will be led to the center of the trap due to energy loss of ω_+ motion (reverse Fig. I-80c, called ω_+ cooling) and since the ω_+ cooling is faster than the ω_- cooling, the selected ions (red in Fig. I-80f) will be separated from the other ions. Typical parameters of this isobar separator for $m/q = 71$ are shown in Table I-6.

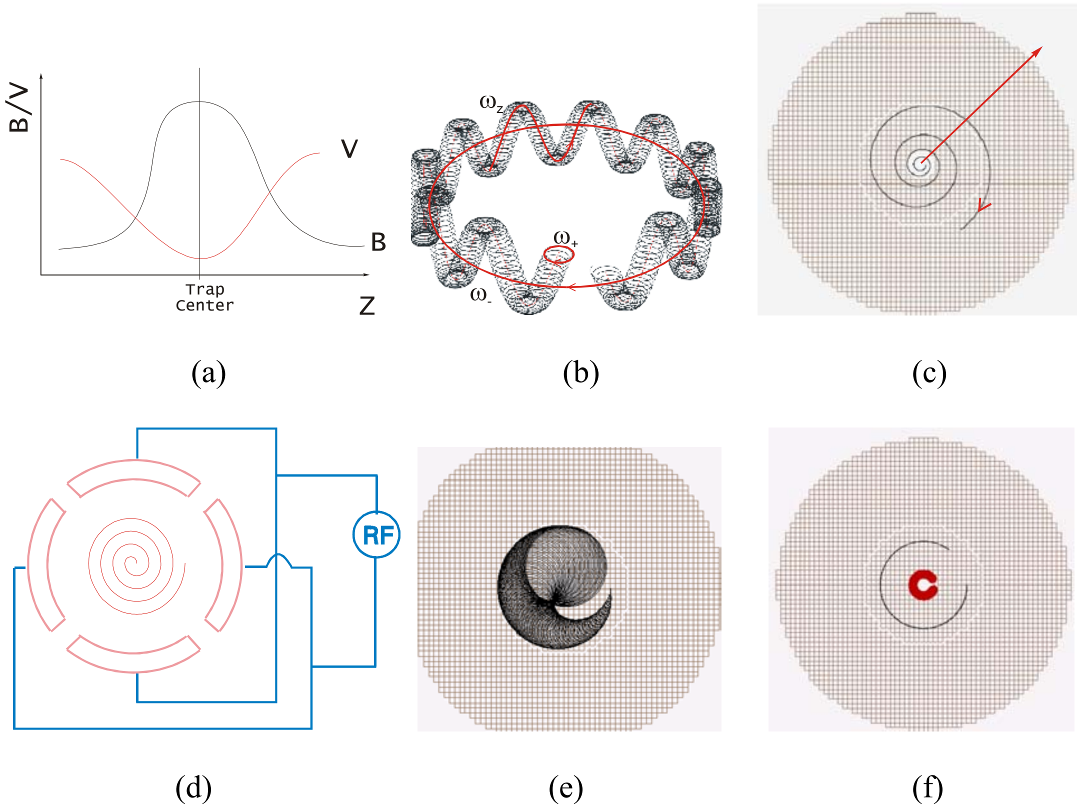

Fig. I-80. Principle of the isobar separator.

Table I-5. Main contaminants associated with ^{68}Se.

isotope	mass	abundance	R (resolution)
^{68}Se	67.9419	1	
^{68}Ge	67.9281	98	5000
^{68}As	67.9368	54	13000
C_5H_8	68.0626	400	600
C_4H_4O	68.0262	100	800

Table I-6. Working parameters of the isobar separator for m/q = 100.

parameter	symbol	value
magnetic field	B	1 Tesla
cyclotron frequency	ω_c	211.40 kHz
RF voltage	V_{RF}	10 mV
cooling time	t	200 ~ 430 ms
He pressure	P	<0.1 mTorr

At present, the mass resolving power of the isobar separator is about 1000. At this resolving power, with the suppression of 95% of the molecular contaminants, many isotopes, like ^{64}Ge, ^{64}Ga, ^{65}Ge, ^{68}Se, ^{68}As, ^{107}Sb, ^{107}Sn, ^{108}Sb, ^{108}Sn, which were previously very difficult to deal with, can now be measured. Efforts to further improve the resolving power are being undertaken.

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*Argonne National Laboratory and University of Manitoba, Winnipeg, Manitoba, †University of Manitoba, Winnipeg, Manitoba.

[1]G. Bollen, S. Becker, H.-J. Kluge, M. König, R. B. Moore, T. Otto, H. Raimbault-Hartmann, G. Savard, L. Schweikhard, H. Stolzenberg (the ISOLDE Collaboration), Nucl. Instrum. Methods **A368**, 675, (1996).

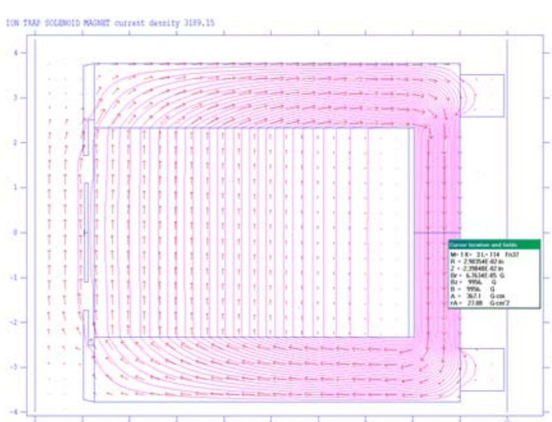
[2]G. Savard, J. Clark, C. Boudreau, F. Buchinger, J. E. Crawford, H. Geissel, J. P. Greene, S. Gulick, A. Heinz, J. K. P. Lee, A. Levand, M. Maier, G. Münzenberg, C. Scheidenberger, D. Seweryniak, K. S. Sharma, G. Sprouse, J. Vaz, J. C. Wang, B. J. Zabransky, Z. Zhou and the S258 collaboration, Nucl. Instum. Methods B, in press.

[3]G. Savard, St. Becker, G. Bollen, H.-J. Kluge, R. B. Moore, T. Otto, L. Schweikhard, H. Stolzenberg, U. Wiess, Phys. Lett. **A158**, 247, (1991).

g.11. A Compact High-Homogeneity Solenoid Magnet for the CPT Isobar Separator

(G. Savard, A. Levand, J. Clark, J. Nolen, J. Wang, W. Trimble, and Z. Zhou)

A Penning-trap-based isobar separator was constructed for the CPT mass spectrometer system. The space available for the device was limited which put severe constraints on the size of the magnet for the isobar separator. A very compact design for the high-field solenoidal magnet that provides the uniform axial field for the isobar separator was required. The resolution and thus the usefulness of the trap depend on the strength and quality of the field. The strength of the field for this type of magnet is limited by resistive heating from the amount of current passing though the windings. The requirements are a resistive solenoid magnet with a 2-inch clear bore, a one Tesla field uniform to on part in 10,000 in a cylindrical volume of 1 cm radius by 2 cm long. To design the magnet, the Poisson electromagnetic simulation program from Los Alamos was used to analyze and optimize possible configurations. A long solenoid is usually needed to achieve field uniformity. A shorter solenoid can be used but to compensate for the fringing effects we must remove some of the center windings. This can allow one to meet the field requirements but the magnet power is then too high at about 25 kW. Tailoring the flux return steel near the bore produces a flatter field from a shorter solenoid, but the dimensions are critical, mainly due to nonlinear effects of saturation. A steel ring was found to effectively flatten the field in the shorter solenoid and also provide a tunable element. In the end, two concentric rings were used, the smaller inner ring being easily accessed through the bore to tweak the field. The magnet power is 10 kW and meets the field requirements (see Fig. I-81).



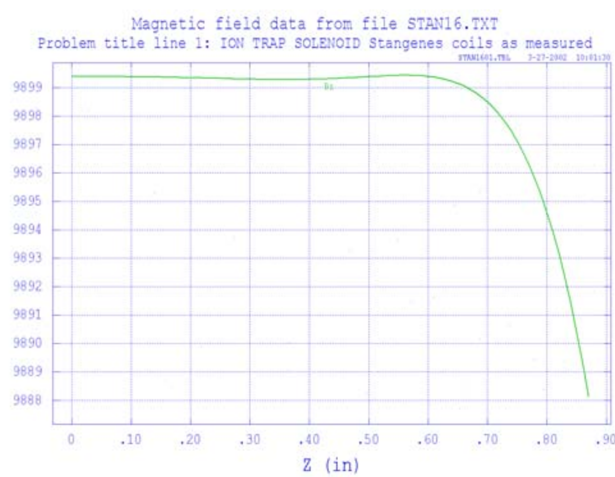


Fig. I-81. Magnetic field predictions.

The physical construction of the magnet is designed for easy assembly without introducing asymmetries in the field (see Fig. I-82). The magnet consists of steel circular end plates, a tubular outer shell, eight pancake windings (Fig. I-83), an inner brass tube to support the windings and packing gland nuts to locate and center the brass tube to the end plates. The whole assembly (Fig. I-84) is clamped together with tie rods around the periphery. Pancake coil windings are simpler to assemble and to connect to power and cooling water. The coils are staggered so the connections exit through the split outer tube at four quadrants. Standard 18 inch by 1.15-inch steel pipe was used for the outer tube. Some magnetic flux is leaving the outer tube, since the magnetic properties of the pipe are not as good as assumed and a thicker wall would have been better but the field properties still meet specifications.

For field mapping, a GMW teslameter with a Hall effect probe was used with the analog output to a high-resolution voltmeter. The trap vacuum chamber material is slightly magnetic, due to cold working of the 304 stainless steel bar. This causes a slight axial asymmetry of the field, but it is still within specifications (Fig. I-85). A slight off-axis field component cannot be excluded by these measurements but is calculated to have a negligible effect on the trap precision.

Various aspects of the magnet stability were investigated. Current ripples are damped heavily by the inductance of the magnet and are at a level where they are of no concern. Heating of the power supply shunt causes a long term drift. Additional circuitry to correct this using a current transformer sensor was installed but later found to produce a fluctuation with a period of approximately one second. It was removed. An existing more stable power supply was found that will eliminate the current stability issues. It was also found that the bore of the magnet reached temperatures in excess of 40 C after many hours of operation. At a field of 1 Tesla, the magnet is operated at 40 volts and 250 amps for a total of 10 kW for a magnet bore of less than 20 cm length. This causes outgassing of the vacuum chamber hosting the Penning trap which then limits the lifetime of the ions in the trap. Reversing water flow through the magnet put cool inlet water next to the end plates, reducing trap temperatures somewhat. A booster pump to increase water flow will be installed to lower temperature further and totally eliminate this problem.

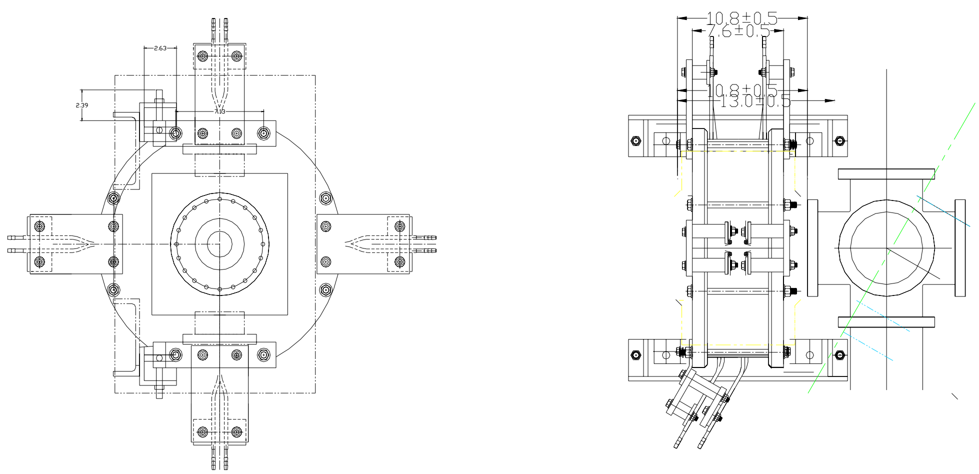


Fig. I-82. Magnet assembly drawing.

Fig. I-83. The Stangenes pancake coil winding.

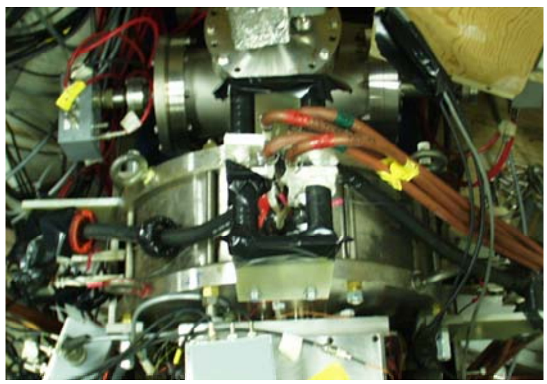


Fig. I-84. The installed magnet in Area 2.

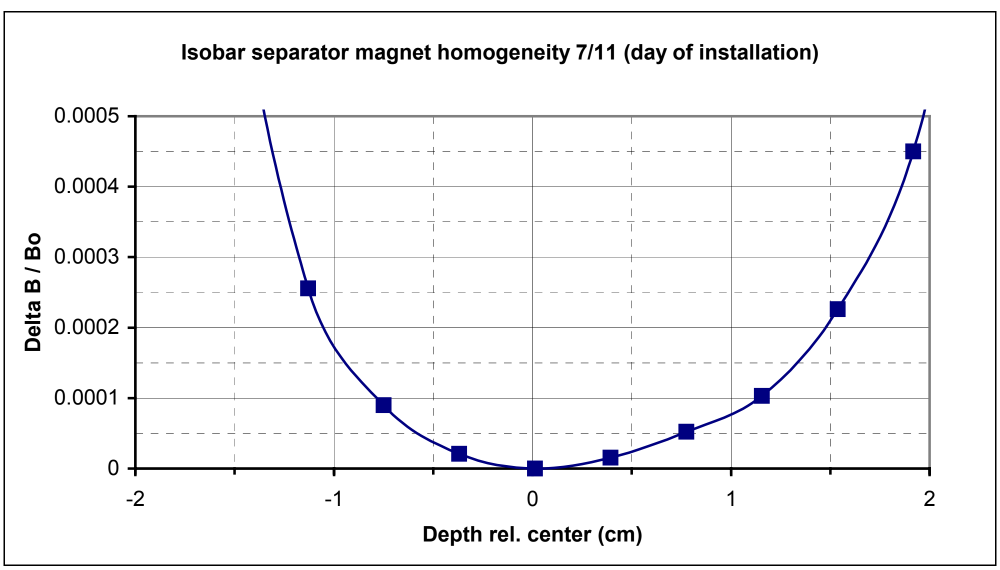


Fig. I-85. An early magnet axial field measurement.

g.12. Technical Progress in Hyper Pure Germanium Double-Sided Strip Detector Development (S. J. Freeman,* C. J. Lister, S. Fischer, N. Hammond, and K. Teh)

Tests were made of a hyper pure germanium doubled-sided strip detector. This detector is the third in a series of models which form part of a development program in collaboration with Pat Sangsingkoew, AMETEK Industries. The germanium wafer is approximately 92 × 92 mm and 2-cm thick. The nominal front face has a sixteen vertical strip electrodes of 5-mm width formed by ion implantation of boron to a depth of <1 μm. The bias voltage of 1300 V is applied to this face and the strips are AC-coupled to warm preamplifiers. The nominal back face has sixteen horizontal strips with 5-mm wide electrodes formed by lithium diffusion to a depth of approximately 600 μm. In order to prevent the subsequent migration of lithium in the crystal destroying the strip integrity, 1-mm deep saw cuts of width 0.5 mm are made between the horizontal strips. The back electrodes are also DC-coupled to warm preamplifiers. In order to mount the crystal in the cryostat, the germanium is sandwiched between two 1-mm thick sheets of boron nitride and the edges surrounded by an aluminum ring. Condensed sixteen-channel electronics were used to amplify and digitize signals from the front and back of the detector and events involving the coincidence between at least one pair of strips on the front and back were recorded. Data was taken with a variety of sources spanning γ-ray energies from 88 to 1836 keV.

The lithium and boron strips show distinct differences in the variation of resolution with energy as shown in Fig. I-86. The variation on the boron strips is similar to that expected for a regular unsegmented planar detector. The absolute magnitude of the resolution is higher than expected in this case, due to noise issues in the condensed electronics which

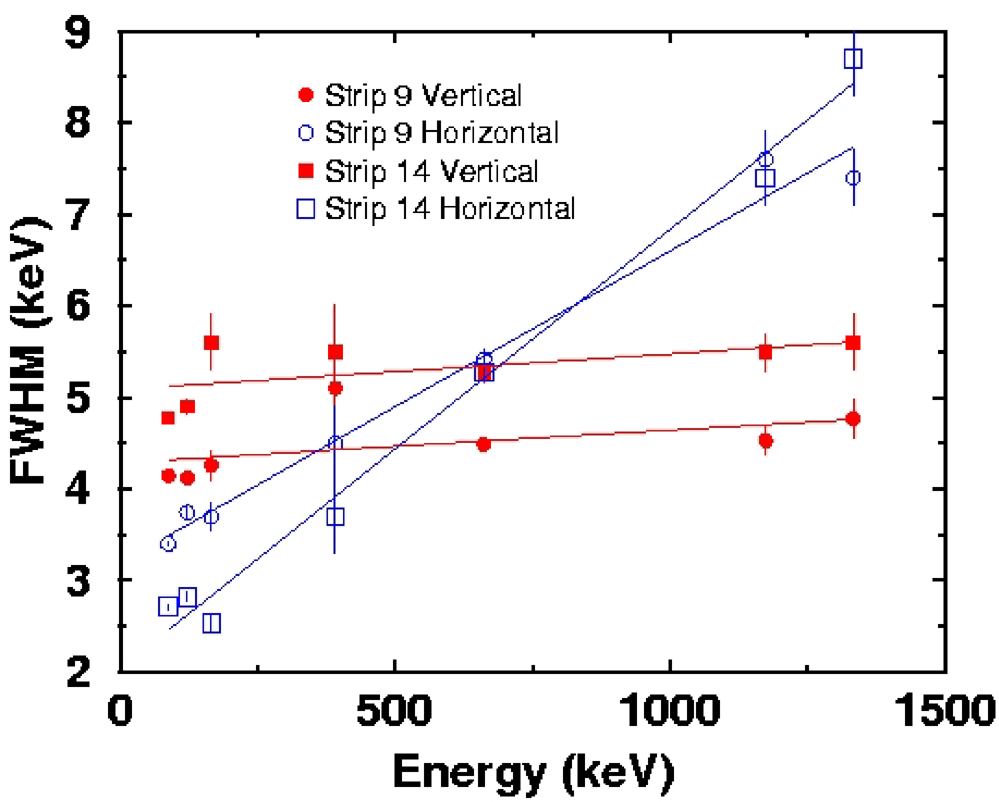


Fig. I-86. Variation of resolution with energy for some example strips on the lithium (horizontal) and boron (vertical) sides of the crystal.

are under investigation. The resolution of the boron strips measured using a simple single channel MCA was typically 2.3-keV FWHM at 122 keV. The behavior of the lithium strips is very different and exhibits a very strong variation with γ-ray energy, typical of that expected in a detector with strong fluctuations in the charge collection efficiency. In the case of strip detectors, it is not surprising to see an asymmetry in the properties of the two electrodes which is possible due to the small physical size of the electrodes. The induced signal in any particular electrode is small unless charge is very close to it; the signal generated in an electrode on one side of the detector is, therefore, dominated by the charges drifting towards that electrode. The variation of resolution with energy suggests that the electron collection by the lithium side suffers poorer efficiency than the collection of the holes by the boron electrodes. A comparison of spectra taken with illumination from the front and from the back appears to rule out bulk trapping, and the effect may be associated with the saw cuts on the lithium side.

Investigations were made of multiple strip events in the detector. A cross-talk effect was observed when reconstructing the full energy from the sum of energies in events involving two adjacent strips, which is not present in the case of two non-adjacent electrodes (see Fig. I-87). There is a noticeable shift in gain in the case of adjacent double-strip events when compared to single-strip or non-adjacent double-strip events of the order of a few percent of the photopeak energy. This effect appears to arise from a capacitive coupling between adjacent strips.

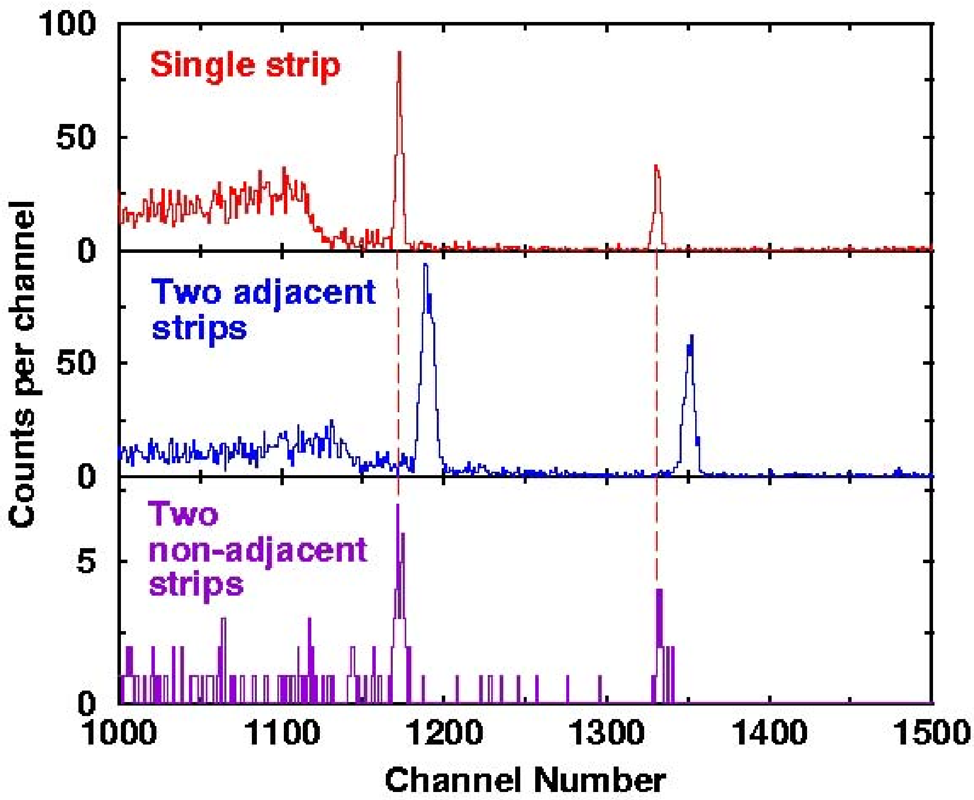


Fig. I-87. Illustration of the gain shifts between single-pixel events (top), two-pixel events with neighboring strips (middle) and two-pixel events with non-adjacent strips (bottom).

Illumination of the detector using calibrated sources from a distance of 10.35 cm from the center of the crystal results in an absolute efficiency of 2.19(4)% at 121 keV, which compares well with that expected from a Monte Carlo simulation of the detector.

A fourth generation planar strip detector was recently delivered which was designed to incorporate good resolution features onto one side of the detector which uses cold FETs. The properties of this detector are currently being evaluated.

*On sabbatical leave from University of Manchester, United Kingdom.

g.13. Position Interpolation in a Germanium Planar Detector Using Digital Pulse Processing (C. J. Lister, J. Ammann,* and S. M. Fischer*)

We have begun to investigate gamma ray “tracking” by using digital pulse processing. It is clear that both depth and lateral information can be easily obtained for planer germanium detectors. Using a bank of LeCroy digital storage oscilloscopes, triggered by events of interest selected by external electronics, we were able to capture images of charge deposition, and the induced charges produced as the charge migrates across the crystal. Analysis of the relative intensity of image charges offers a rather straightforward way of obtaining sub-strip lateral position. Figure I-88 shows a typical image. Figure I-89 shows an analysis of several hundred images to obtain the lateral position sensitivity. The overall resolution is ~2 mm FWHM, though the resolution is depth-dependent, being better for very shallow or very deep interactions.

*DePaul University.

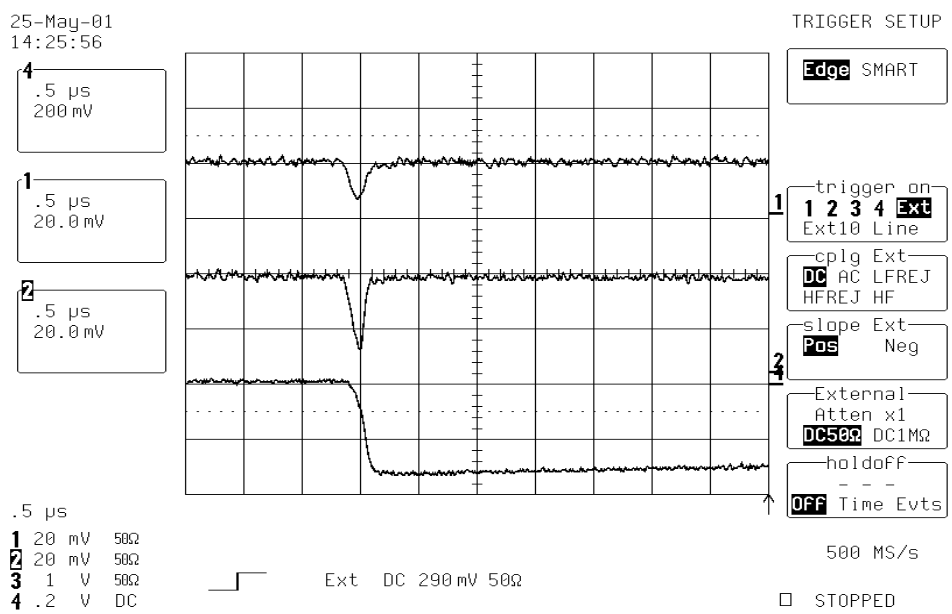


Fig. I-88. Digital recording of preamplifier pulses collected when all the charge from a 1.33 MeV gamma-ray is deposited under a single strip of the HpGeDSSD (bottom trace). The induced image charges can clearly be seen on the neighboring strips (top traces). The image shows an interaction with was slightly offset to one side of the strip, so the image charges have different intensity.

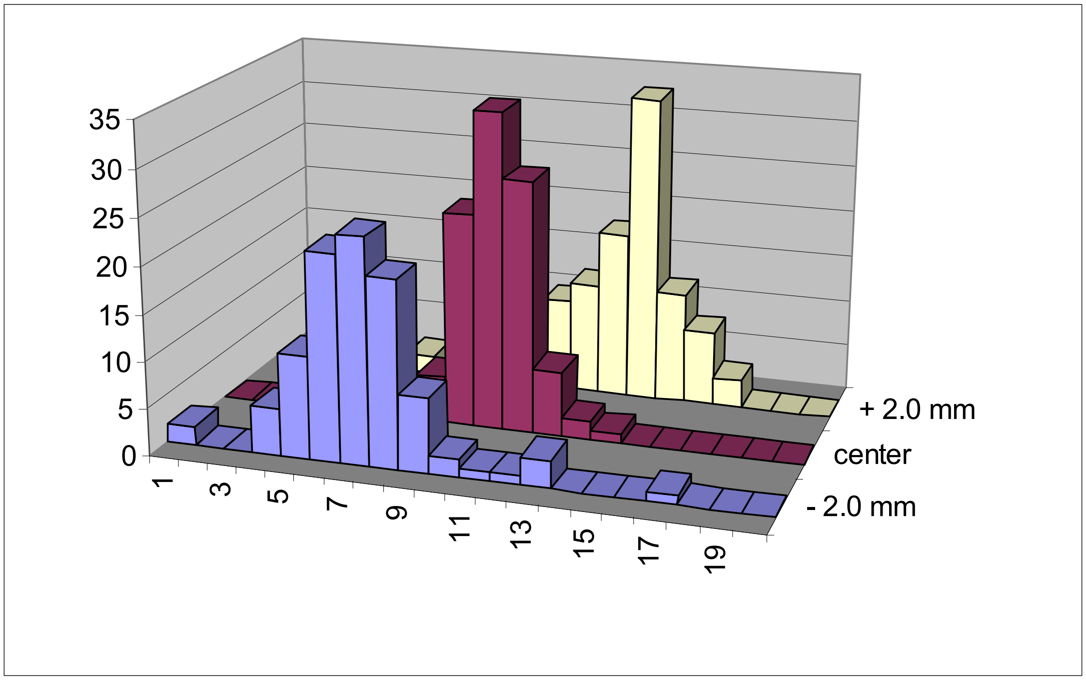


Fig. I-89. A distribution of calculated interaction positions measured for gamma-rays injected under a single strip, and inferred from the charge induced on the neighboring strips. The source was a ^{54}Mn line source, collimated to <0.25 mm, which emits 835 keV photons. It was positioned with a computer controlled motor drive in the center of a 5 mm strip and then offset by 2 mm towards either edge of the strip.

g.14. Accuracy of Gamma Ray Tracking as a Function of Detector Noise (T. L. Khoo, C. J. Lister, E. F. Moore, and S. Grullon*)

A useful application of gamma-ray tracking is to determine the direction of a photon incident on a detector and, thereby, to enhance gamma rays from a source at a specific location and suppress those from random directions. This feature can make it possible to investigate gamma radiation from a very weak source (common if the activity is very far from stability), which might otherwise be swarmed by background from, say, the room. As a start of a project to quantitatively ascertain the enhancement in sensitivity through gamma ray tracking, we used a Monte Carlo method to construct events from the source and from random directions. The Compton interactions in a Ge detector were then analyzed, assuming that the photons originated from the source, to construct the energy spectrum. Gamma rays from the direction of the "source" were correctly identified, whereas those from random directions could be rejected. In the limit of zero noise, tracking can be correctly accomplished with close to unit efficiency. However, the success rate decreases as the detector noise increases, e.g. with a noise equivalent to 2.3 keV FWHM the correctly identified fraction dropped to ~80%.

*Summer student, Florida International University.

g.15. Use of HpGeDSSDs for Imaging and Material Analysis (C. J. Lister, D. Nisius,* and S. M. Fischer†)

As part of a NASA SBIR project, we are involved in exploiting our position sensitive planar detectors (HpGeDSSDs) to image small objects and deduce their material composition through differential x-ray absorption. The NASA solicitation is to develop techniques to eventually search for fossils on Mars. In the short term it is to develop technologies that can produce real-time x-ray images.

For the Phase 1 test, a strong (50 mCi) ^{109}Cd source was used to produce a pencil beam of x-rays (22,24 keV) and 88 keV nuclear gamma rays. The divergent beam was focused on our 92 mm × 92 mm position sensitive LEPS detector placed ~2 m away. The system had spatial resolution of ~700 µm. Small objects could be mounted on a goniometer and raised into the beam. The attenuation of radiation could then be determined, which depends on the thickness and elemental composition of the object. The object could then be rotated in the beam, allowing data to be acquired which could produce a 3-D image.

Figure I-90(a,b) shows a photograph of the experimental arrangement to produce an absorption image of a NASA sample consisting of a 7 mm × 3 mm quartz disk with two 1 mm holes, one filled with paraffin and one with graphite. The image is shown in Fig. I-91, where the overall absorption of x-rays by the disk is clear, as are the two holes which exhibit different degrees of absorption.

This project successfully completed Phase 1 and was funded for a Phase 2 SBIR. To improve the spatial resolution, a CdZnTe strip detector system is being built, which should have similar characteristics, but finer pitch strips that should give an order of magnitude position resolution improvement at the cost of about a factor four in energy resolution. CdZnTe detectors operate at room temperature, so are more practical for the eventual Mars mission.

*BioImaging Research Inc., †DePaul University.

(a) (b)

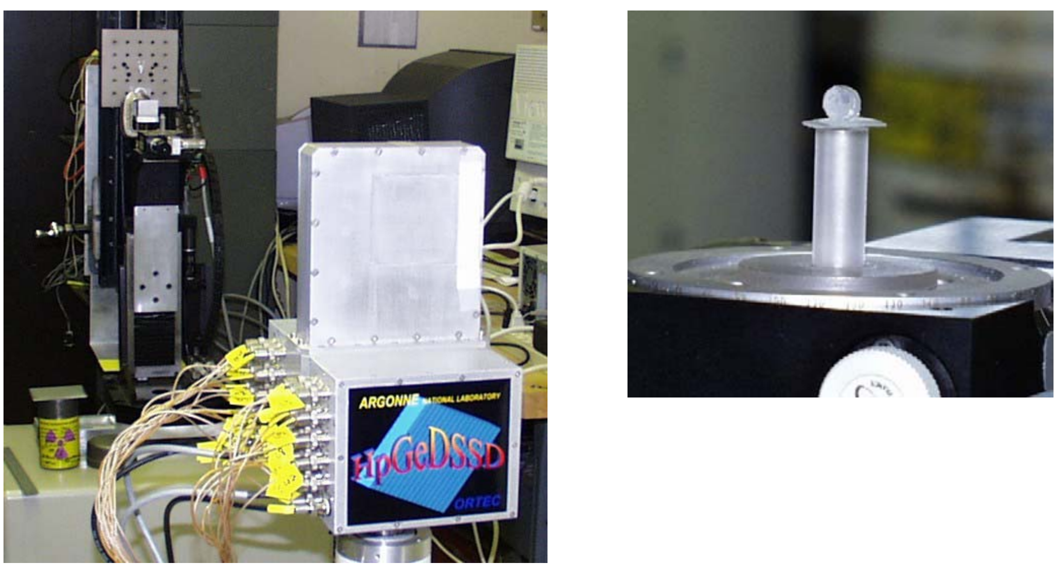


Fig. I-90. (a) left. A photograph of the experimental setup showing the source block and detector. (b) An enlargement of the quartz sample under study.

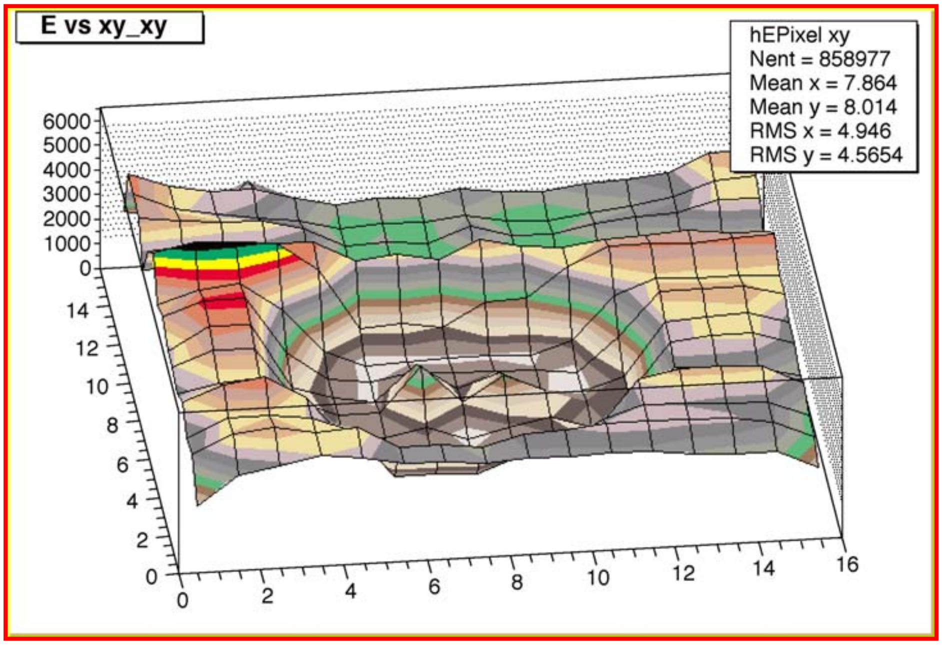


Fig. I-91. A two-dimensional absorption image of a 7 mm quartz disk with recessed paraffin and graphite inclusions. The position resolution is better than 700 μm.

g.16. Compton Polarization Measurements with a Double-Sided Germanium Strip Detector (N. J. Hammond, C. J. Lister, S. J. Freeman, S. M. Fischer, G. Mukherjee, R. V. F. Janssens, E. F. Moore, K. Teh, D. G. Jenkins, and G. D. Jones*)

We employed a double-sided germanium strip detector (GeDSSD) to measure the Compton polarization of low-energy gamma rays. Conventional gamma-ray polarimeters, using coaxial germanium detectors, are ineffective at such energies due to the increased probability of photoelectric absorption and the subsequent decrease in the photon mean free path. The strip detector used for this study possesses an effective pixel size of 25 mm^2 with a total active surface area of 640 cm^2 and therefore allows the identification of Compton-scattered events with much smaller path lengths. A novel technique for measuring the polarization sensitivity at low energy was proposed by Jones,[1] whereby alpha decay is used to fully align excited states in their m = 0 substates which then decay via pure dipole or quadrupole transitions of high, or even full (|P| = 1), linear polarization. We conducted a test to measure the efficacy of this technique and also to commission a new data acquisition system, Scarlet, which was used to stream data to the ROOT front-end analysis package. Using a ^{228}Th source and a single Si detector positioned as shown in Fig. I-92, we were able to identify both "vertically" and "horizontally" scattered E2 gamma rays following second generation alpha decays to the first excited state in ^{220}Rn. An example gamma-ray spectrum gated by such alphas is shown in Fig. I-93.

To make a definitive measurement we propose to use an additional Si detector in a position perpendicular to the first as displayed in Fig. I-92. This arrangement not only allows a doubling of the count rate but also facilitates the rotation of the target-Si detector system through pi radians which will be crucial to reduce systematic errors arising from differences in the efficiency of measuring horizontal and vertically scattered photons. A new target chamber, which houses both Si detectors and the source material was built to this effect. We are in the process of procuring a ^{227}Th source for the measurement which should additionally allow us to resolve spin ambiguities in the level structure of ^{219}Rn. We expect to begin collecting data in spring 2003.

*University of Liverpool, United Kingdom.
[1]G. D. Jones, Nucl. Instrum. Methods **A491**, 452 (2002).

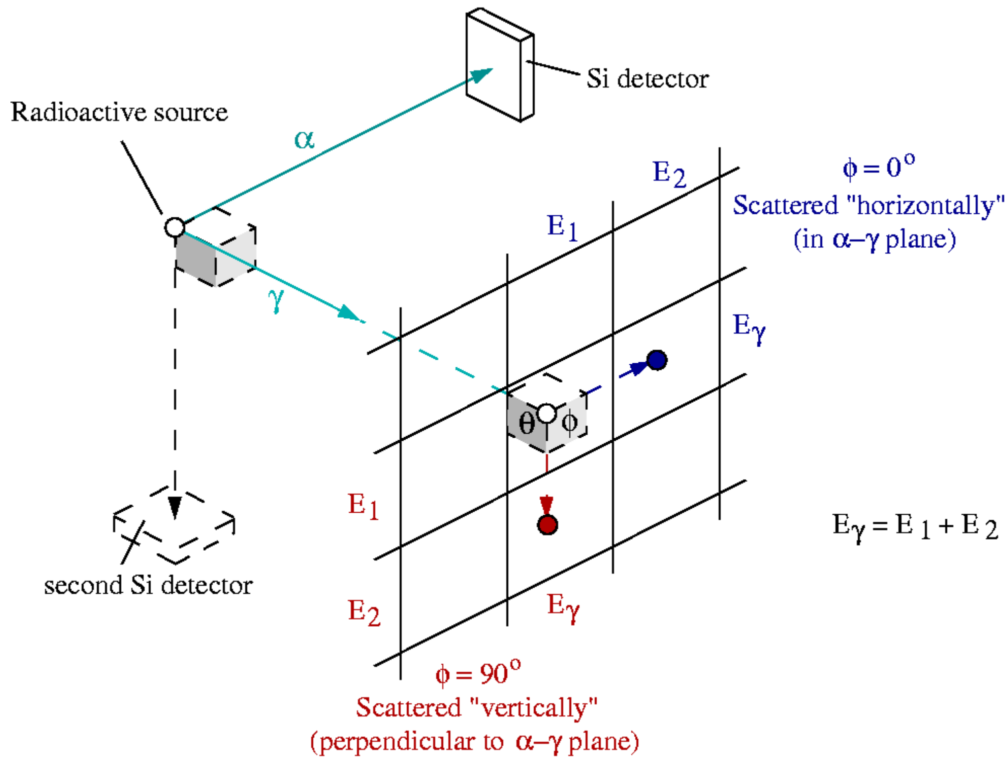


Fig. I-92. Schematic representation of set-up, with silicon detectors mounted at 90° to allow two simultaneous measurements of γ-ray polarization and remove many systematic uncertainties.

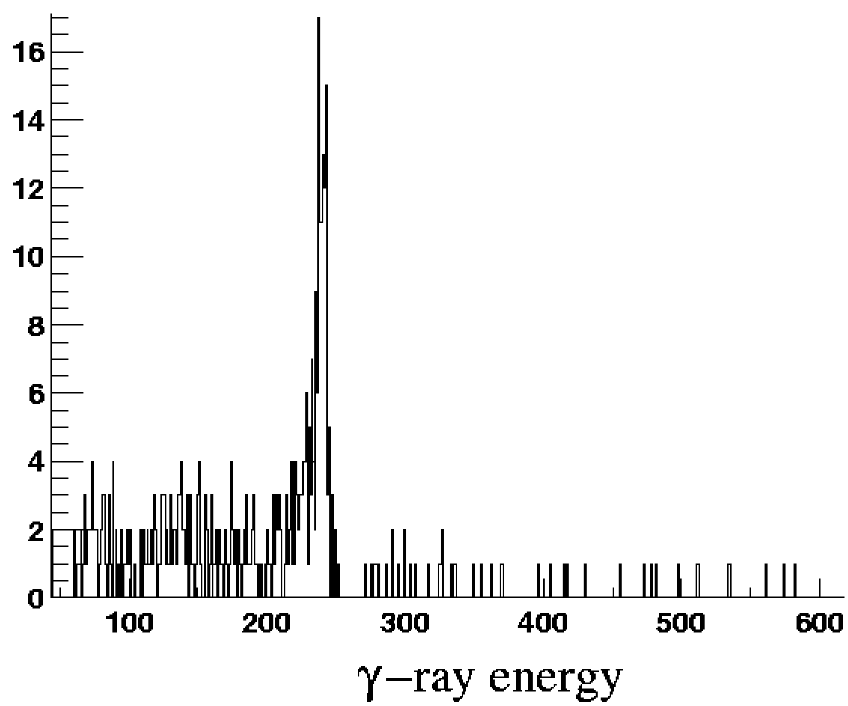


Fig. I-93. A typical γ-ray spectrum showing the 241 keV γ-ray following the 5449 keV α-decay of ^{224}Ra. The asymmetry of scattering of these γ-rays yields the polarization of the radiation.

g.17. Doppler Reconstruction of Gamma-Rays from Fast Moving Sources Using the "Mark 3" HpGeDSSD (C. J. Lister, N. Hammond, R. V. F. Janssens, M. P. Carpenter, K. Teh, S. J. Freeman,* and S. M. Fischer†)

Considerable progress is being made in making high purity germanium detectors that are position sensitive. One approach is to use large area planar wafers of germanium and fabricate orthogonal strip electrodes in order to achieve position sensitivity. The technical developments in these detectors are discussed in section g.12.

One application of detectors of this type is to achieve superior Doppler reconstruction from fast moving sources. We are looking at a useful "benchmark" test with which to evaluate position sensitive counters. The $^{12}C(^{136}Xe,4n)^{144}Sm$ reaction at 595 MeV seems to be ideal. It involves simple and robust beam and target, the targets can be fabricated very thin, the recoil velocity is high, $\beta = 8.7\%$, the reaction is dominated by a single channel which has a high production cross section of ~400 mb, and gamma rays covering a wide range of energies are produced.

Figure I-94 shows our latest spectrum. It consists of events firing a single strip on the front and a single strip on the back of the detector, so reflects the simplest data where only one interaction point is involved. The 5-mm strip pitch allows good angle determination and thus reasonable Doppler reconstruction, about 8-keV fwhm at 600 keV. At present, we are examining the "multi-hit events" to find how many can be reliably reconstructed. We are also studying the pulse risetimes in order to extract depth information, which can, in principle, further refine the hit-angle estimate.

Several areas of development emerge as important factors for further improvements. The intrinsic detector resolution can be improved. In April 2003 the "Mark 4" detector will be delivered with cold-FET preamps. Factory tests show the new counter has 1.1 keV resolution at 122 keV, a factor 2 better that the "Mark 3".

The electronic noise of the shaping amplifiers and ADC's needs improvement in order to preserve the detectors intrinsic energy resolution characteristics. At present, the high density 16-channel amplifiers appear to cause significant degradation of energy resolution, >0.5 keV, when compared to data collected with a single amplifier and MCA.

The mechanical alignment of detector and target become critical. Also, it becomes more important to align both the direction of the beam and the exact beamspot size and position.

The longitudinal velocity of residues needs to be determined on an event-by-event basis. This can best be achieved using the Fragment Mass Analyzer (FMA) to detect residues and measure their time-of-flight in the 8.2 m isochronous spectrometer. The intrinsic recoil cone due to evaporation is small, but the residue direction can also be established using two position-sensitive counters at the focal plane.

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*Sabbatical Visitor from the University of Manchester, United Kingdom, †DePaul University.

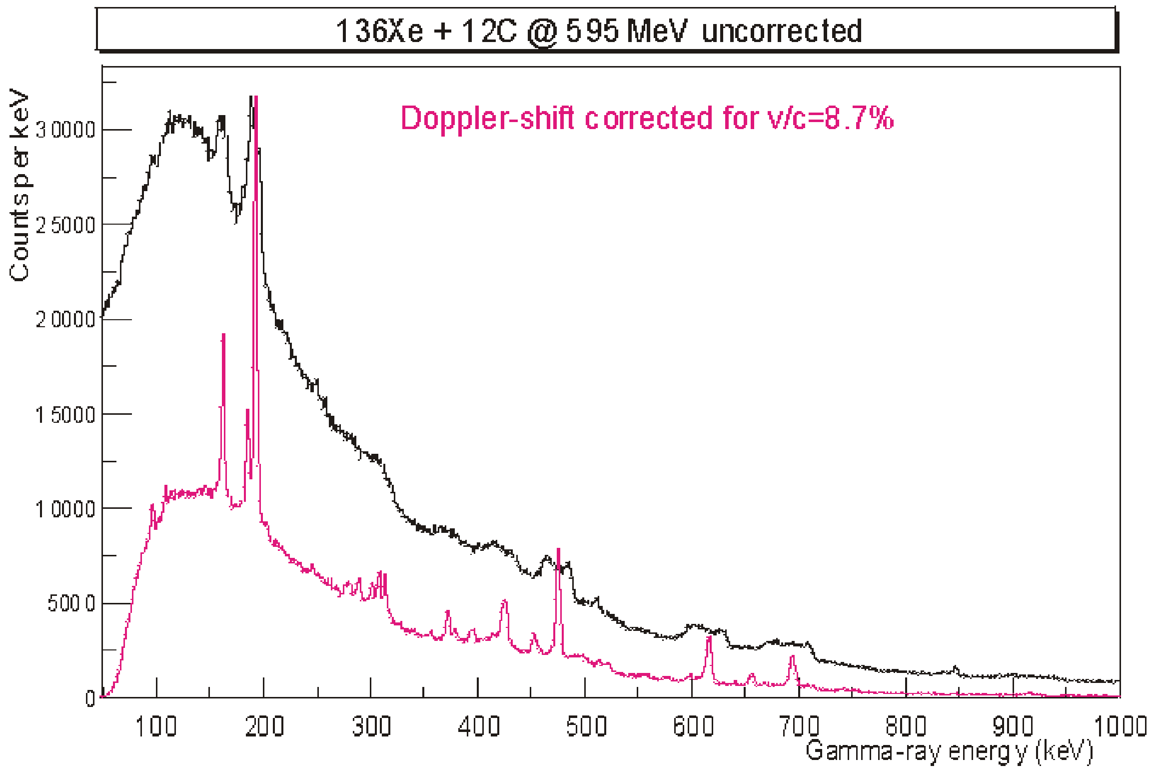

Fig. I-94. The effect of pixel-by-pixel Doppler correction. The raw data (black) reflects the energies of gamma-rays observed hitting the 92 × 92 mm detector that is mounted 100 mm from the target. The red curve is the subset of "single pixel" events (~20%) that have been corrected for the known kinematics of the reaction and using the measured hit position.

g.18. Development of the X-Array, an Efficient Focal Plane Gamma Ray Spectrometer (C. J. Lister, M. P. Carpenter, R. V. F. Janssens, T. L. Khoo, T. Lauritsen, and E. F. Moore)

The X-Array spectrometer is a detector optimized for efficiently measuring electromagnetic radiation following proton, alpha, beta or isomeric decays. The array is designed for "offline" use, at the FMA focal plane, or at a remote tape station. For this application the design criteria are quite different from "in-beam" spectrometers like Gammasphere. Above all it needs very high efficiency for a broad range of gamma ray energies, from 10's keV to 10 MeV. It can be much more physically compact than "in-beam" systems, as multiplicities are low and there are no Doppler corrections to be made.

We made many MCNP Monte Carlo simulations of various designs, and selected a five-sided, double layer box which will surround the FMA focal plane. The first layer of detectors are made of large area position sensitive LEPS detectors, which are being developed by our group in collaboration with Ortec (see section g.12.). The second layer of counters will be large volume germanium "clover" detectors, for enhancing the high energy efficiency and for suppressing backgrounds.

We started the procurement for the five large "clover" gamma-ray counters. After lengthy discussion with manufacturers concerning costs and performance, a non-segmented clover built from germanium crystals >60 mm in diameter was chosen. The specification was written and we are awaiting bids for the first two detectors. We hope to be able to instrument a "two-sided" box during this year to start exploring the many physics opportunities.

g.19. Gamma-Ray Tracking Coordinating Committee (T. L. Khoo, C. Baktash,* D. Cline (chair),† R. Kroeger,‡ A. Macchiavelli,§ M. Riley,¶ M. Thoennessen,|| and K. Vetter**)

The Gamma-Ray Tracking Coordinating Committee [GRTCC] was appointed, on January 21, 2002, by the Directors of the Nuclear Science Divisions at the Argonne National Laboratory, Lawrence Berkeley National Laboratory, and Oak Ridge National Laboratory, at the request of the DOE Division of Nuclear Physics, to promote the development of γ-ray tracking detector technology in nuclear structure research. The goal was to help organize the γ-ray tracking community to provide widespread support and to provide an effective plan for the future. The initial charge, made to this Committee was to take a broad role in the development of γ-ray tracking detectors in this country. In particular there are three elements of the charge that should be addressed in a timely manner.

- Develop the various physics justifications for γ-ray tracking and establish the performance goals that are required in each area.
- Formulate a national R&D plan for γ-ray tracking detectors.
- Examine the currents efforts in γ-ray tracking that are underway in the United States and provide the Department of Energy with advice about how they should proceed.

The recommendations of the Committee were based on requested written answers to questions that were posed to the major γ-ray tracking detector projects, GRETA, GARBO, and MSU, the Gamma-Ray Tracking Fact Finding Meeting held at Argonne March 29-30, 2002 and extensive discussions by the Committee. The attendees to the fact-finding meeting included active participants developing the projects mentioned above, the European AGATA project, the NRL Astrophysics Tracking Group, the GRETA Steering Committee, and representatives of the Gammasphere User Group. The current and planned efforts in γ-ray tracking were discussed frankly and openly leading to unanimous support for a set of important and unambiguous conclusions. Based on the conclusions derived at the Argonne meeting, the other information provided, and discussion, the Coordinating Committee made the following recommendations (excerpted from the full report of the Committee):

1. A 4π Gamma-Ray tracking facility is an important new initiative within the 2002 NSAC Long Range Plan. This committee unanimously recommends a shell of closely packed coaxial Ge-detectors as outlined in the GRETA conceptual design for this 4π γ-ray tracking facility. We strongly recommend that DOE support this effort.

2. R&D necessary to demonstrate the full functionality of this detector was identified and has to be addressed at the highest priority. We note that a substantial fraction of this R&D effort is manpower that must be supported.

3. The R&D phase, the subsequent final design, and the construction of GRETA should continue to be a community effort; in particular, it should involve significant participation by the low energy nuclear physics national laboratories and universities.

4. Tracking with planar detectors is of interest to the nuclear science community and has a wide range of applications outside of nuclear physics. R&D efforts in this direction should be supported as part of the drive to develop tracking, as most of the electronics and software challenges are common to all tracking detectors.

5. Gammasphere continues to be the premier national γ-ray facility until GRETA becomes operational. This research facility must be supported to sustain the vitality of the field.

The Committee also made the following two observations regarding implementation of R&D for γ-ray tracking detectors:

(a) The current situation of a sole vendor for GRETA detector modules could have a significant impact on both the cost and delivery schedule for construction of GRETA. Development of a second vendor should have a high priority.

(b) Gamma-ray tracking, for all practical purposes, is an entirely new technique in γ ray detection, which has applications for homeland security in the detection of nuclear materials, with an emphasis on imaging and sensitivity, e.g. to image radioactivity in dirty bombs. It also has applications in diverse areas of science such as astrophysics, and diagnostic medical uses.

The full report of the committee may be found at: www.pas.rochester.edu/~cline/full-report-19July.pdf.

*Oak Ridge National Laboratory, †University of Rochester, ‡Naval Research Laboratory, §Lawrence Berkeley National Laboratory, ¶Florida State University, ||Michigan State University, **Lawrence Livermore National Laboratory.

g.20. Participation in GRETA and GRETINA Gamma Ray Tracking Projects
(C. J. Lister, M. P. Carpenter, R. V. F. Janssens, and T. L. Khoo)

The Heavy Ion group continued to be involved in the development of GRETA, a 4-π gamma-ray tracking detector. This concept is being developed at Lawrence Berkeley National Laboratory as a possible replacement for Gammasphere and a key device for exploiting radioactive beams at the Rare Isotope Accelerator, RIA. C. J. Lister is on the steering committee, and the other staff members in working groups. In the short-term, plans are being put into place to construct GRETINA, a ¼ of the full shell. We are interested in various physics and technical aspects of this project. One area of interest is signal digitization and deconvolution, an area that is important both for GRETA and for gamma ray tracking in HpGeDSSD planar wafers. We expect to formalize our long-term involvement in this project during the early part of 2003.