Development of a Small High Resolution Position Sensitive Gas Proportional Counter

R. Melin, J.A. Nolen and R.G. Markham

A small proportional counter with extremely good position resolution for lightly ionizing charged particles is desireable in tuning up for high resolution experiments and for resolving closely spaced doublets in cases of special interest. Since solid state position sensitive detectors require special handling, are expensive, and are signal-to-noise limited for protons and deuterons, we are investigating the properties of small charge division proportional counters to fulfill our needs.

The resolution of previous focal plane detectors for charged particles has been somewhat limited by multiple scattering in the windows and gas but primarily by energy loss straggling when used at non-normal incidence. Based on the fact that the resolution of such counters should improve as the thickness is decreased, a thin proportional wire counter was constructed and tested. Normal incidence was used to eliminate the energy loss straggling effects with the attendant disadvantage that only one small region of the counter was near the focal plane.

The counter we tested had a front-to-back thickness of 1 mm with the wire in the center and a length of 10 mm. The wire was carbon coated quartz with a resistance of 8 kΩ/mm and a diameter of 25 μm. The detector had a mylar wafer to support the wire and allow electrical and gas connections, with 8μm Havar windows glued to the wafer.

When biased at 1800 volts and filled with 1 atm of propane gas a total line width of 50 μm, FWHM, was achieved for 35 MeV protons at normal incidence (see Figure). This result was partly limited by the actual line width of the proton group during the test. The 1 mm thick counter was not used routinely because the wires were often destroyed by electrical breakdown.

A counter 10 mm long and having a 2 mm front-to-back thickness has been constructed utilizing the same 8kΩ/mm wire. This counter was milled from aluminum stock and uses G-10 supports for the wire. The front window of 8 μm aluminized mylar is used for reduced straggling and uses an O-ring for the gas seal to simplify the construction.

The 2 mm counter is constructed to be placed in the focal plane of the spectrograph with normal particle incidence. The best overall resolution obtained with this counter is 65 μm FWHM with the detector biased at 2250 volts and filled with 1 atm. of propane. The counter uses a solid state counter in coincidence for particle identification and has been used to tune the dispersion matching of the beam transport system. This counter has proved to be far more reliable than the 1 mm counter although there is still difficulty with the carbon being sputtered from the wire during extended periods with the elastic line at a fixed position on the counter. This effect is enhanced by the magnet feedback system which keeps the elastic line fixed on the center of the counter during the tuning process. This effect is evidenced by a short (≈100 μm) dead spot on the counter.

The present results place a firm experimental upper limit on the resolution attainable with this type of detector.

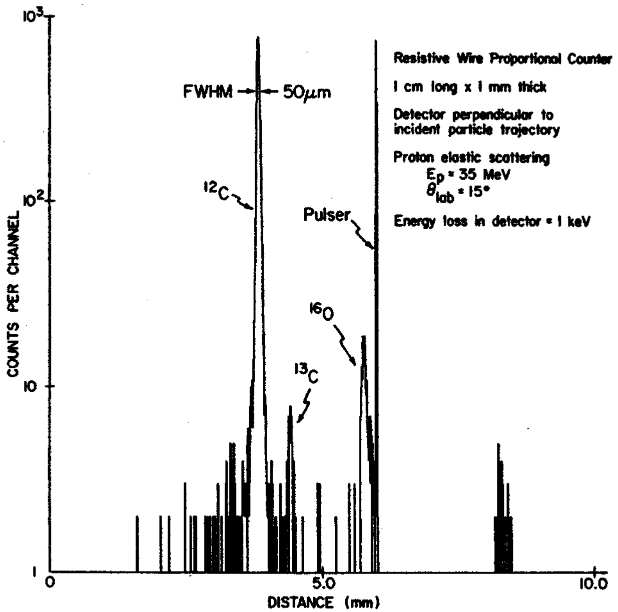

Fig. 1 Spectrum of protons elastically scattered from a carbon target. The detector was oriented perpendicular to the particle trajectories, i.e., at 45° to the focal plane so that only the ^{12}C peak was actually in focus.

A High-Resolution Position-Sensitive Detector for Use in the Focal Plane of the Split-Pole Spectrograph

R.G. Markham and R.G.H. Robertson

It has proven difficult to produce a satisfactory on-line detector for use in the Enge split-pole spectrograph because the line widths obtained are far too narrow for the capabilities of current detector systems. To relieve this problem it was necessary either to go to a much more expensive spectrograph having higher dispersion (such as Q3D types) or to make a dramatic improvement in focal plane detectors. The requirements of the detector are that it be quite long (at least 25 cm), have good spatial resolution (0.25 mm FWHM is adequate for all but certain very high resolution work in which, for example, 50 μm FWHM line widths have been achieved) and have high transparency to allow the use of backing detectors for coincidences and time-of-flight.

For several years single-wire, charge-division proportional counters have been used in the Enge spectrograph and empirically one finds reasonably good resolution (~0.5 mm) for heavily ionizing particles (^{4}He, ^{6}He, etc.) but only 1.5-2.0 mm for high energy protons and deuterons. The reason, as has been confirmed by calculation, is that for lightly ionizing particles energy-loss fluctuations along the particle's path in the gas are very important. Since the particles are incident at 45°, such energy-loss fluctuations convert directly into position fluctuations and poor resolution. We have therefore devised a counter with a geometry that drastically reduces this effect.[1] The counter volume is effectively subdivided into five thinner volumes by replacing the single anode wire with five wires at a 2 mm spacing in the plane of the particle trajectory (Fig. 1). The electric field is desired to be normal to the wire plane everywhere (except close to the wires). The correct field shape in the active region is achieved by adding four more wires, two at the front and two at the back of the plane. These guard wires have a much larger diameter to prevent multiplication from occurring on them--they thus absorb without amplication any electrons produced outside the desired active region. As a result of this geometry, ionization originating anywhere in the active volume produces multiplication only on the wire directly above (or below), and nowhere else. Underneath the anode plane is a cathode plane comprised of metallic stripes oriented parallel to the particle trajectory, i.e. at 45° to the long direction of the counter. The charge induced on the cathode by each avalanche is always in the same location relative to the cathode stripes. Energy loss variations from wire to wire therefore do not lead to position variations.

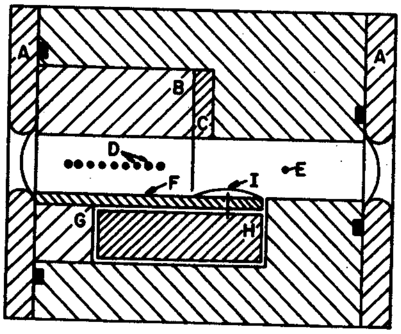

Fig. 1.--Schematic cross section of the counter. The various parts are: (A) window frames, (B) anode support, (C) separator foil frame, (D) anode wires--five active and four guards, (E) anode wire for ΔE counter, (F) pickup stripe board, (G) frame for delay line and board, and (H) delay line.

Translation of the induced cathode charge to a position signal is accomplished by connecting each cathode stripe to successive taps on a commercial delay line (following the method of Iwata, et al.) and measuring the propagation time to the ends of the delay line. This design leads to a relatively simple, compact structure which is both inexpensive and easy to use. Further, it lends itself very naturally to the addition of backing counters--only the anode plane obstructs the passage of ions.

A 25 cm long version has seen extensive use for one and a half years; more recently one 50 cm long has come into use (Fig. 2). So far only the shorter one has been carefully tested for resolution. Table 1 summarizes the calculated contributions to the line width for 35 MeV protons and 32 and 160 MeV ^{16}O ions. The multiple scattering estimates for oxygen are quite uncertain being based on the formula

$$\langle\theta^2\rangle^{1/2} = 0.9\left[\frac{z(z+1)}{A}\right]^{1/2}\frac{Z_p}{E_p}\sqrt{t}\ \text{mrad}$$

where Ep is in MeV and t in μg/cm^2 and the coefficient chosen to conform to the data of Cline, et al.[3] For protons an actual line width of 0.24 mm FWHM has been observed including a contribution of 0.1 mm from the beam. The table shows that most of the calculated line width is due to energy loss straggling which is not totally compensated (only five active wires). The calculated contributions do not account for the observed line width; the residual (assuming statistical independence) is of the same magnitude as the calculated width. There are many effects not included in the above such as: electron diffusion, fluctuations in the avalance, and timing inaccuracies. Probably only the multiple scattering effects are worse for heavy ions. As Table 1 indicates this is not too severe for energetic heavy ions.

This detector was designed expressly for the Enge split-pole spectrograph; hence, it is tailored to optimize resolution for particles incident at 45° and it has a small vertical acceptance. The optimum angle can readily be varied by changing the stripe angle. It is a little more difficult to increase the vertical acceptance. The best way to do this probably is to maintain the separation between the anode plane and pickup stripes while increasing the vertical opening. At some point this would necessitate the inclusion of field shaping wires to maintain a uniform field above the anode plane. This is presently being tried at Indiana.[4]

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TABLE 1.--Calculated line widths mm FWHM.

Source	p 35 MeV	^{16}O 32 MeV	^{16}O 160 MeV
Window Scattering,[a]	0.05	0.43	0.08
Gas Scattering,[b]	0.04	0.30	0.06
Ionization Fluctuations	0.13	0	0.13
Noise	0.05	-	-
Total	0.15	0.52	0.16
Best observed Minus Beam	0.22	-	-
Residual	0.16	-	-

[a] 6 μm thick mylar

[b] propane at 1/3 atmosphere

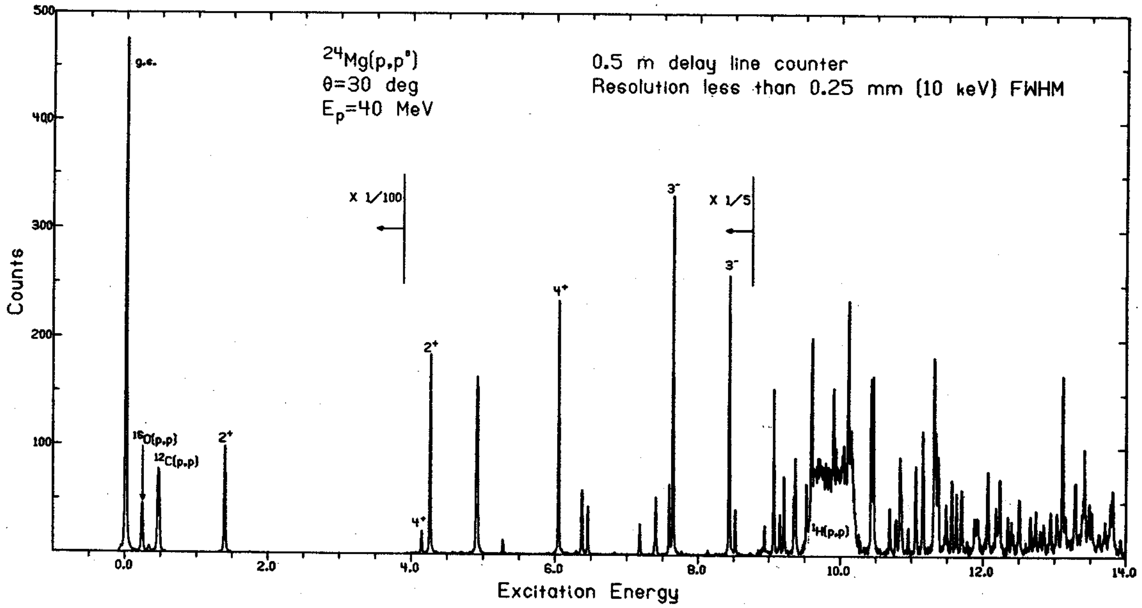

Fig. 2 Position spectrum of ^{24}Mg(p,p') using the 50 cm long detector.

Detector Development--Spectrograph Aberration Correction

R.G. Markham

Most focal plane detectors do not provide simply for aberration corrections. This is important since the line widths obtained with the split-pole are completely aberration limited for solid angles over 2 ms. If only the theta aberrations are corrected by the detection system, the solid angle could be increased to about 4 ms without further loss of resolution. Additionally one could compensate the time-of-flight and energy-loss signals for variations with theta to improve the mass identification. Thus, it is with real interest that we explore new detector schemes.

A detector which shows considerable promise is the hybrid chamber developed and in use at the M.I.T. Bates Laboratory.[1] In this application the counter is used to detect high energy electrons and perform aberration corrections, just as we propose. Transforming the Bates detector for use with heavy charged particles is a major project. But the principle is sound; hence, success at some level is assured.

The primary changes required are to remove the dependence of the detector on an external timing signal and to modify construction to allow operation in vacuum. Additionally one would like to streamline the construction to reduce costs and increase reliability (although this is not known to be a problem).

A schematic of the proposed design is shown in Fig. 1. The basic idea is to measure the drift times of the ionization electrons to the active wires. With a knowledge of these drift times one can then reconstruct the particle trajectory--its angle and intersection point with the wire plane. If an accurate external start time is available, only drift times to two wires are needed. We may not want to rely on an external time signal since it might not be possible to obtain one with some short ranged particles. Thus, at least three signals--producting two relative drift times and which signal was first--are required to reconstruct the event. In practice one might like an additional one or two signals to improve the precision by averaging out fluctuations and by not relying heavily on the time information from the wire closest to the particle track. This avoids problems due to the non-uniform fields near the wires.

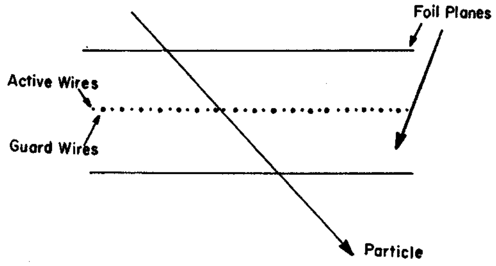

Fig. 1 Schematic plan view of proposed detector. Active-to-guard wire spacing 2 mm and total depth 25 mm.

If it were necessary to readout each active wire separately, this would not be such an attractive design. Instead one can connect every third (fourth or fifth) wire together so that one only gets three (four or five) signals, see Fig. 2.

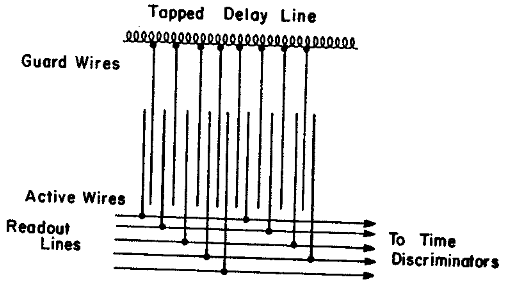

Fig. 2 Schematic of readout encoding. Guard signals used for coarse location with active wires giving fine interpolation.

In this way one has a repeating sequence of wires and can accurately determine the position within the sequence. To fully determine the position of the event one then needs to locate the event to a given sequence of wires. This is accomplished by connecting each guard wire to successive taps on a delay line. The relative time difference of the induced signals at the two ends of the line gives a coarse location of the event. This readout scheme becomes especially simple when combined with a Camac multistop time-digitizer. The entire readout electronics consists of a delay line and several amplifier-discriminator chips. Additional electronics would be used with backing detectors to perform mass identification and time derivation.

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Development of an Area Scanning Device for use in ^{13}N Tracer Analysis

R.G. Markham, M. Stya*, N.J. Taber* and S.M. Austin

In the study of the metabolism of blue-green algae (described elsewhere in this report) ^{13}N labeling is used to trace the biochemical processes taking place. The labeled compounds are separated spatially on a cellulose coated glass plate via electroporesis or chromatography. To improve the separation it would be very useful to perform two successive drifts in different solutions and in orthogonal directions. The problem then is to determine the two dimensional spatial distribution of the β^+ emitting ^{13}N. To do this with good detection efficiency and spatial resolution on a time scale consistent with the 10 minute half life of ^{13}N we are developing a proportional counter system which determines one coordinate of the emitting nucleus. Location in the orthogonal direction is determined by restricting the detector aperture and mechanically scanning across the plate.

The detector consists of two single-wire, proportional counters placed back-to-back. The counters are 20 cm long, 1 cm wide and 0.5 cm deep. The longitudinal position of the positron is determined in each counter by resistive-anode, charge-division readout. From these determinations and the known geometry of the source and counters, the on-line computer (described elsewhere in this report) reconstructs the longitudinal coordinate of the emitting nucleus on the glass plate. The spatial uncertainty depends greatly on the angle of incidence of the positron on the detector. Near normal incidence to the counter the resolution is dominated by a combination of multiple scattering in the counter foils and gas and by the electrical noise of the anode wires. At oblique angles the effect of ionization fluctuations rapidly spoils the resolution. Final testing of the system is not complete. Preliminary results indicate that for normal incidence the resolution should be about 1mm FWHM and for 45° incidence about 3 mm FWHM. The 45° acceptance corresponds to a solid angle of about 1 sr.

The glass plate rests on a table which oscillates in the transverse direction to the detector. The length of scan is 10 cm and the transverse detector opening is 0.25 cm. The detector opening and source to detector distance determines the transverse spatial resolution. Unfortunately restricting these parameters to small values also diminishes the detection efficiency, hence, the above respresents a compromise favoring detection efficiency.

The counter operates on a gas filling of one atmosphere of propane. The anode wires are 127 μm diameter silica fibers with a pyrolytic carbon coating. The total resistance is about 70 kilohms and the counter operates with a potential of 3200 volts on the wires. The maximum counting rate is about 1000 counts-per-second, limited by the on-line data processing speed. We anticipate some improvement in rate with improved software.

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Neutron Time-of-Flight Facility

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I. Introduction

A neutron time-of-flight (TOF) facility incorporating a beam swinger has been constructed at the Michigan State University Cyclotron Laboratory. In the beam-swinger arrangement, the neutron detector is held fixed, and the charged-particle beam that produces neutrons is rotated with respect to the detector by using a movable magnet. To get a reasonable count rate for long flight paths (∿30 meter), a large-volume (1.7 liter) neutron counter with good time resolution has been constructed. The analog signals from the detector are digitized and processed in a PDP11/45 computer connected to a CAMAC crate. A data-acquisition program has been written to process the multiparameter information from the detector.

II. Beam Swinger

The physical layout of the beam swinger is shown in Fig. 1. The proton beam from the Cyclotron is bent 90° by the fixed magnet and enters the swinger along its horizontal axis of rotation. The C-shaped magnets bend the beam by -44° and 134°, respectively, so that the beam, after emerging from the swinger, is perpendicular to its original direction. For studying (p,n) reactions, the target is placed along the axis of rotation of the swinger. Neutrons from the target emerge in a horizontal plane through an opening in the 1.8-meter-thick concrete shielding wall into a 32 meter long hall way. The flight path may be changed from 4 to 32 meters by moving the detector. By rotating the swinger magnet, the scattering angle may be changed from 0° to 160°, beyond which point the magnet yoke blocks the flight path; there is a cutaway section so that a scattering angle of 180° can be used.

The swinger magnets have a bending radius of 30". The pole tips are 3" wide and have a 1 1/4" gap with a taper on each pole tip to make them double focusing (n=1/2). The maximum field is approximately 14.4 KG, sufficient to bend the most rigid particles produced by the Cyclotron (76 MeV ^{3}He).

III. Detector

The present neutron detector is made of a rectangular box of UVT lucite of 1m x 13cm x 1.3cm internal dimensions (see Fig. 2). The box is filled with the liquid scintillator NE 224. A small lucite chamber is attached to the box to allow for thermal expansion of the liquid. The light pipes are also of UVT lucite, viewed by two RCA 8850 photomultipliers. The anode signal and the linear signal from the ninth dynode are extracted with an ORTEC 265 photomultiplier base.

IV. Electronics

The block diagram of the electronics is shown in Fig. 3. The times of arrival, T_1 and T_2, of the light flashes from a neutron event reaching the photomultipliers are measured with respect to the cyclotron RF using constant-fraction discriminators. The light pulses at the two ends and their 50%-rise times are measured in the conventional way using double-delay-line shaping amplifiers. The linear signal from the summing amplifier and the time information from the time to amplitude converters are fed to a PDP11/45 computer for further processing. The rise time information is used for pulse shape discrimination (PSD) to separate neutrons from gamma induced events.

V. Computer Program

The hardware available is a PDP11/45 computer interfaced with a CAMAC crate. The crate contains an ORTEC octal ADC, scope drivers for live display, scalers, and realtime clocks (see computer section). The multiparameter signals from the neutron detector are digitized and stored in a data buffer. A FORTRAN program has been written for processing the data and storing as one-dimensional spectra. From the time information T_1 and T_2-T_1, the neutron time of flight $(T_1+T_2)/2$ is computed in the program. The TOF spectrum can be gated by the total light output in the scintillator and/or the pulse-shape-discrimination signal to separate neutron events from gamma events. The program is quite flexible and can do simple tasks like computing area under a peak and calibrating the TOF spectrum to an energy spectrum.

VI. Detector Performance

The time resolution of the long detector is found to be exceptionally good. For end-to-end timing with a collimated source, time resolutions of 1 ns and 0.4 ns are obtained for light pulses corresponding to 2.4 and 16 MeV of electron energy respectively. The detector resolution is approximately proportional to $E^{-1/2}$ and contributes 0.2 ns to the TOF resolution for light pulses equivalent to 16-MeV electrons. This, combined with the narrow pulse width (∿300ps) of the proton beam and small thickness of the detectors, allows an excellent resolution for timing with respect to the RF. A typical spectrum for the ^{7}Li(p,n)^{7}Be reaction at E_n=43 MeV with a 31.7-meter flight path is shown in Fig. 4. The time resolution is 550 ps (FWHM), corresponding to an energy resolution of approximately 150 keV at 43 MeV, of which 83 keV is due to target thickness.

Experiments done with the beam swinger are described in other sections of this report.

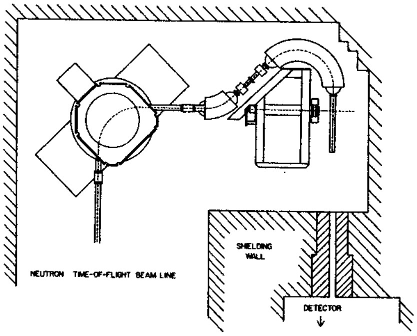

FIG. 1.--Neutron time of flight beam line.

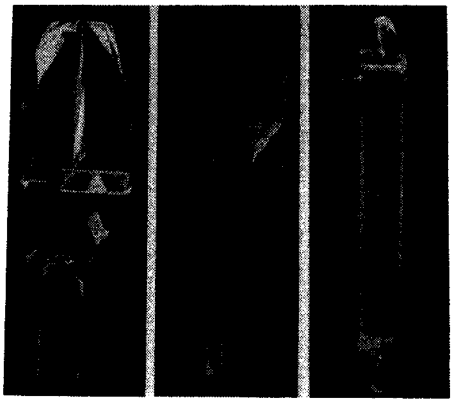

FIG. 2.--Neutron detector.

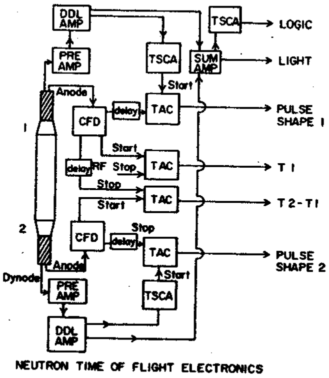

FIG. 3.--Block diagram of electronics.

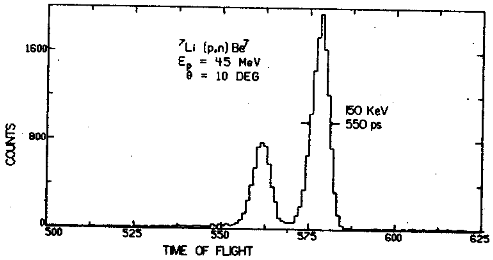

FIG. 4.--Time of flight spectrum for 43 MeV neutrons.

Activation and Angular Distribution Measurements of the ^{7}Li(p,n)^{7}Be(0 + 0.429) Reaction as an Efficiency Calibration Standard for Neutron Detectors

S. Schery, L. Young, R. Doering, R. Bhowmik, and S. Austin

The ^{7}Li(p,n)^{7}Be (0 + 0.429) reaction provides a potentially convenient neutron source which could be used to calibrate neutron detectors for neutron time-of-flight measurements. The cross section is large and the emitted neutron energy is well separated in spectra from lower energy neutrons. The presence of a significant kinematic shift with angle can be used to advantage to provide a range of neutron energies for a given proton energy. This reaction has been measured fairly extensively below 7 MeV proton energy[1], but higher energy measurements[2] are limited in both completeness and accuracy.

Since the 0.429 MeV state of ^{7}Be is the only particle emission stable excited state in ^{7}Be, the measured activation cross section for production of ^{7}Be is exclusively due to the ground state and first excited state reactions. The 53.4 day half life of ^{7}Be is long enough that targets can be counted at a convenient time after activation. The production cross section is measured by observing the 0.478 MeV (10.4% branch) gamma emission in ^{7}Li that accompanies the decay of ^{7}Be. The total cross section obtained by this technique is independent of neutron measurements.

We have been carrying out activation measurements of the ^{7}Li(p,n)^{7}Be (0 + 0.429) reaction in the energy range 25 to 45 MeV. Complementary angular distributions have been obtained with scintillation detectors using the beam swinger time-of-flight system. The activation results provide a check on the absolute normalization for these angular distributions.

Lithium targets, separated by energy degrading shims, have been placed in series in "stacks" for simultaneous irradiation for precise relative measurement of the total cross sections. This procedure insures precise knowledge of relative beam fluxes. The stacks are placed in the bottom of a Faraday cup immediately after a beam collimator. The charge collection of this arrangement has been checked with a second Faraday cup which could be inserted before the collimator by a pneumatic plunger.

The Li targets were made by pressing 99.99% enriched ^{7}Li metal with a precisely machined stamp and mold. Thicknesses were measured by weighing and were in the range 20 to 45 mg/cm^2. A secondary measurement was done directly with a micrometer. Uniformity of thickness was checked by weighing small sections of targets removed with a small diameter tubular cutter as well as by repeatability of activation measurements of separate targets done under similar conditions.

Aluminum foils 8 mg/cm^2 thick were placed after each Li target to collect recoiling ^{7}Be nuclei. Beam currents varied depending upon target thickness and energy and could be as low as 25 nAmp to minimize heating. Activated targets and catcher foils were counted with Ge(Li) detectors using National Bureau of Standards and IAEC sources as references.

Figure 1 shows preliminary results for the total cross section for the proton energy range 25 to 45 MeV. It is expected that these total cross sections can be measured with an accuracy of $\pm$5% or better. The results at 25, 35, and 45 MeV will be used to normalize the angular distributions taken with the scintillation detectors. The resulting angular distributions can be used to calibrate neutron detectors by predicting neutron fluxes at a given angle either using a target of known thickness or alternatively, using a measurement of ^{7}Be activity induced in the target.

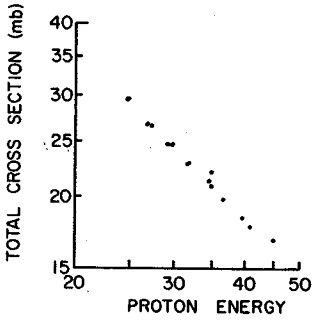

Fig. 1 Log-Log plot of the total cross section for the reaction ^{7}Li(p,n)^{7}Be (0 + 0.429) versus proton energy.

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A Magnet for Measuring g-Factors

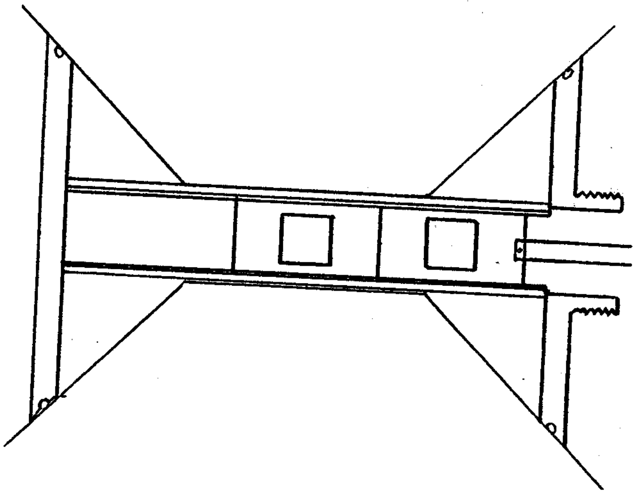
S.R. Faber, L.E. Young, and F.M. Bernthal

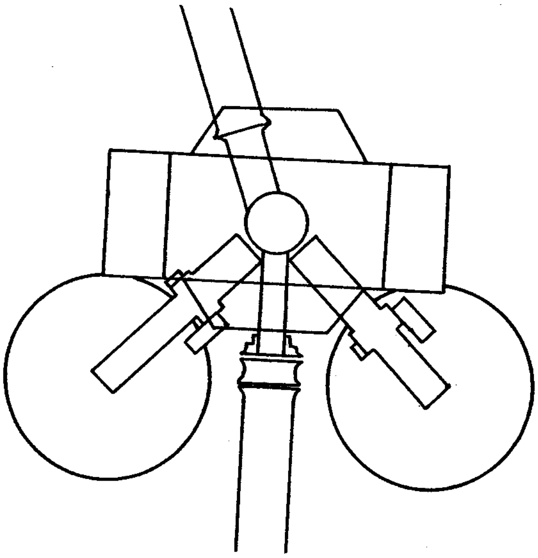
A magnet is currently under construction that is to be used for measuring g-factors by the perturbed angular distribution technique, i.e. measuring the rate of precession of the gamma ray angular distribution from a target in-beam under the influence of a magnetic field. The magnet should attain a field of 23 kilogauss at 300 amps, which will allow g-factor measurements of isomers with half lives from around 10 nsec. to the maximum possible with this technique.

A 5 in. diameter target chamber is to be placed between two semi-conical pole tips as shown in the diagram. The magnet is the former 0° horizontal beam correcting magnet from the spectrograph line. It will be modified by the addition of new pole tips and by extending the yoke sides. A 1 in. gap between the 2.5 in. diameter tips accommodates the target. A rack capable of handling two targets will stretch horizontally across the chamber as shown. An observation window will exist toward the rear of the chamber to allow positioning of the beam on the scintillator. Sliding seals will be welded to the chamber to accept the 2 in. diam. entrance beam pipe and the 3 in. exit tube. The beam will be bent considerably after passing through the magnet so the exit port must be at an angle. To incorporate beams of all possible rigidities, bent exit pipes must be used if the beam is to be stopped a significant distance away from the detectors.

The magnet will be installed in vault 5, the neutron time-of-flight room, on the spare beam line there. It will be powered by the TOF 90° bending magnet power supply.

Many suitable high-spin isomers in the right half-life range have been discovered by our group and by others in the Z=70-84 region that are particularly well suited for study using the MSU cyclotron for inducing (α,xn) reactions. First measurements with the new system are planned for the fall of 1976.





On-Line Conversion-Electron Spectrometer

L.L. Kneisel,* W.H. Bentley, W.H. Kelly, and R.A. Warner

A simple and relatively inexpensive internal conversion spectrometer has been used for the last several months in experiments on-line with the MSU cyclotron. Spectra taken with this device are displayed with the discussions of ^{48}V and ^{93}Tc elsewhere in this report. It has also been used in a recent study[1] of high-spin states in ^{176}Hf.

The electron energy spectrum is obtained from a liq. N_2 cooled, 80 mm^2 x 3 mm Si(Li) diode. Electrons are transported from the target chamber, around a Pb γ-ray shield and through a set of helical anti-positron vanes, by the field of a double-focussing solenoidal momentum filter. In operation, the system is much like the device at U.C. Davis,[2] although the two instruments are of quite different construction.

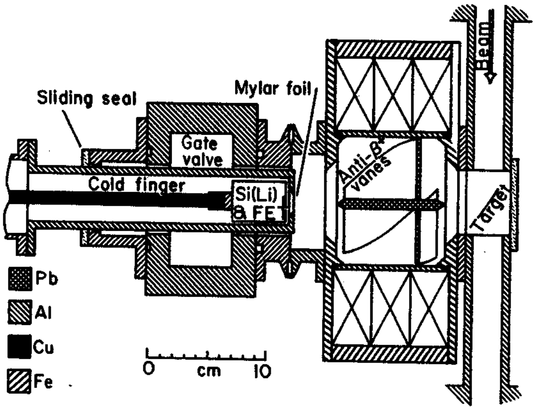


Figure 1.--Horizontal cross section through the axis of the spectrometer showing the detector in counting position. The magnet coils are outside the vacuum.

The MSU spectrometer, depicted in Fig. 1, consists of four distinct assemblies to facilitate modifications. The target chamber, the solenoid and Pb insert, the gate valve and sliding seal, and the detector cryostat are routinely separated from one another between runs, as the beam line and target chamber are often used for other types of experiments. The cryostat vacuum is isolated by a 1.8 mg/cm^2 aluminized Mylar foil, strong enough to allow the cryostat to be stored in air. The gate valve and sliding seal assembly allow operation without the Mylar window should an experiment require better resolution for low energy transitions.

Transmission for momenta matching the field settings is about 1%, while the momentum bite at any given field setting is about 20% FWHM. Fig. 2 contains the results of fixed field efficiency measurements for full-energy peaks of a ^{207}Bi source.

For most experiments, the magnet current is swept with a triangular waveform of period about 1 min., Si(Li) pulse height and magnet current are digitized for each pulse counted, and only those events are saved which have a pulse height appropriate to the magnet current they accompany; thus discriminating effectively against scattered electrons. This technique has been used by others,[2-4] and reduces the background considerably.

The measurement of an α_k as small as 4 x 10^{-5} (for the 1099-keV transition in ^{48}V) attests to the sensitivity of this simple spectrometer.

This description is condensed from a more complete report.[5]

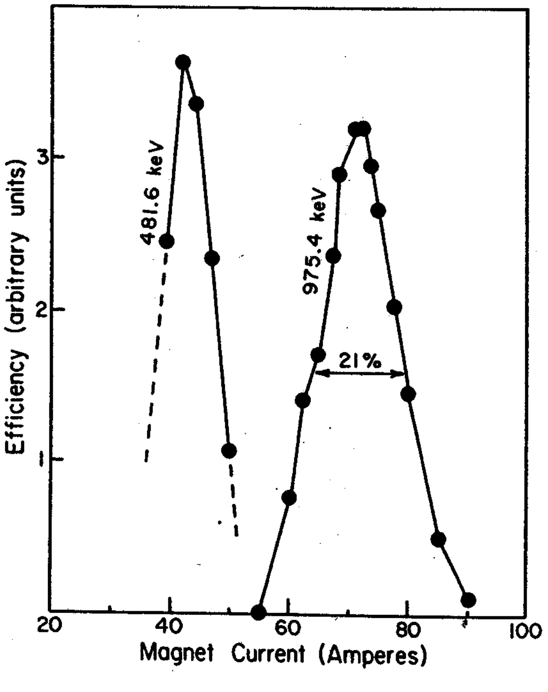


Figure 2.--Relative efficiency of the spectrometer for detection of full energy from ^{207}Bi electrons.

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Cryogenic Helium Jet System[+]

R.G.H. Robertson[*], T. Bowles[**], and S.J. Freedman[***]

We have initiated at Princeton a program (described in more detail elsewhere in this report) to produce and observe $T_z=-2$ isotopes as radioactivies. Identification of these isotopes relies on coincident observation of β-delayed protons and the recoiling daughter nuclei ejected by the protons.

The activities, produced typically by ^{3}He bombardment, are thermalized in He and transported to a low-background area by a He-jet system. Initially a fairly conventional system, consisting of a target, capillary, skimmer, and catcher foil in front of a Si detector, was used, but to obtain good transport efficiency over the distance of 3.75 m from target to detector required the addition of impurities to the He. Unfortunately it is necessary in the recoil TOF apparatus to observe β-delayed protons or α particles passing through the catcher foil ($\sim$20 μg cm^{-2} Formvar). Consequently the buildup on the foils caused by the impurities quickly degraded the particle spectra. Running with "pure" helium greatly reduced (but did not entirely eliminate) the buildup. However, the transport efficiency was then quite poor, 6×10^{-4}.

Encouraged by the discovery by Aysto et al.[1] that high efficiencies could be obtained using pure He if the entire source volume were cooled to liquid air temperatures, we constructed a cryogenic He jet system.

Commerical "pure" He (99.98%) was passed through a liquid nitrogen (LN) trap, a section of room temperature pipe, and then was cooled again by LN before it entered the target cell through a porous bronze diffuser. The cell, 8" x 6" x 6" of welded Al plate, was in contact with LN, and isolated in a larger vacuum chamber. Beam passed through the cell via .002" Al windows. The target itself projected into the beam inside the cell and activities were extracted via a flared polyethylene capillary of 0.070" I.D. located just behind the target. The cell temperature was measured to be 92° K.

The efficiency was measured (by observing ^{25}Si β-delayed protons) over a range of capillary-skimmer distances and a limited range of cell pressures. The ^{24}Mg(^{3}He,2n)^{25}Si total cross-section has not been measured at 58 MeV but was estimated to be 50 μb, based on an extrapolation from data at lower energies. It was found that the efficiency increased monotonically as the capillary-skimmer distance was reduced (Fig. 1). The efficiency was essentially independent of cell pressure in the range 14-20 psia. At 15 psia and 5 mm, where most of the data were taken, the He flow rate was 150 atm cm^{3} sec^{-1}, post-skimmer pressure 30 μT, and the efficiency 0.2%.

A substantial increase in transport efficiency, to 1%, was achieved by adding O_2 gas, about 0.1-1.0% by volume. A plausible explanation is the formation of simple molecules with recoil atoms, thereby decreasing their thermal diffusion to the walls of the capillary. It was quite clear that no large clusters were being transported (at least not the type formed at room temperature even with "pure" helium) because the 2.15 MeV α line from the decay of ^{20}Na is an extremely sensitive indicator of buildup of material on the catcher foils, and its position and linewidth remained unchanged after days of continuous operation.

The cryogenic system, in addition to its superlative cleanliness, showed none of the capricious behaviour common in impurity-doped room-temperature systems. The efficiency was reproducible to about 10%, and highly stable.

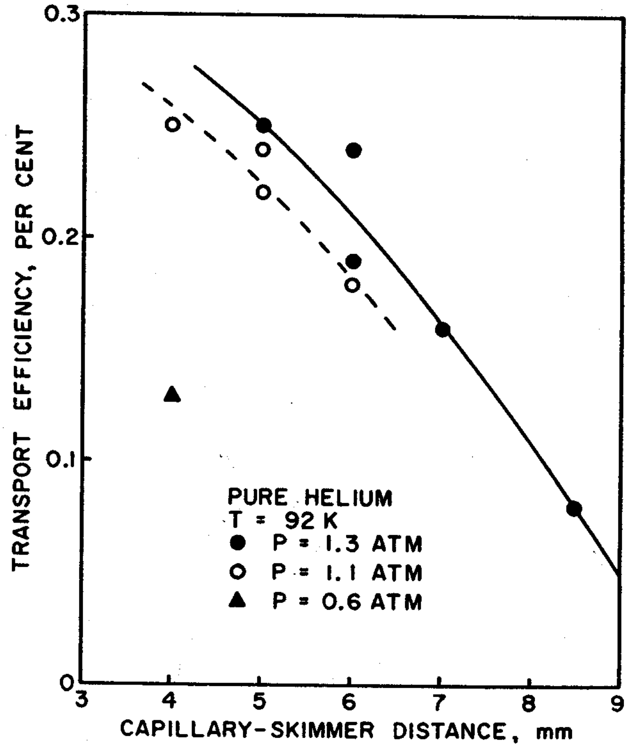

Figure 1. Efficiency of transport as a function of skimmer-capillary distance and target cell pressure.

[+] Research performed at Princeton University

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Target Preparation via Argon Beam Sputtering

J.A. Nolen and M.S. Curtin

Development has continued in the use of a compact inexpensive glow discharge ion source in the preparation of thin film targets for high resolution experiments. The goal has been to make thin targets of separated isotopes (in the range of 30 μgm/cm^2 to 2 mgm/cm^2) that have proven difficult for standard evaporation and e-beam techniques.

The sputtering method consists of directing a beam of accelerated argon ions onto a small compressed disc of isotope (∿50 mgm) which is "sputtered" and collected on a substrate of formvar, carbon or a glass slide coated with a release agent. The major problems associated with the sputtering apparatus are:

i) arcing from the high potential region to ground along the low density argon feed line.

ii) hydrocarbon build up during sputtering of low yield elements.

The design of a faraday cage which will house the needle valve and eliminate the voltage drop across the low density argon feed line is underway, hopefully solving the first problem. The problem of hydrocarbon build up may also be eliminated by this change because it may be due to slow discharge erosion of the Poly-flo tubing leading to the needle valve.

Various targets have been made throughout this past year. Among these have been platinum, gold, silver, molybdenum and copper. All the targets mentioned above revealed very small amounts of contamination, while targets of chromium, hafnium, thorium and uranium all appear to have been unsuccessful. In fig. 1, the results from a sputtered natural platinum target are compared to those from a rolled foil of ^{194}Pt. The preparation of this sputtered target took about 3 hours, yielding a thickness of approximately 150 μgm/cm^2. As noted earlier "a" 50 mgm disc was used but the actual amount of isotope sputtered from this disc was only ∿800 μgm for a typical 150 μgm/cm^2 target. Isotopic platinum targets of 194,196, 198 platinum have also been prepared and used in (p,t) reaction studies (see separate contribution by Deason <u>et al</u> in this annual report).

The sputtering of gold may be useful in the technique of sandwiching various elements between two very thin layers of gold. The previous method employed flash evaporation of gold onto already existing targets the drawback being that the heat generated in this process is not desireable. Since the sputtering process is essentially a "cold" process this difficulty does not arise.

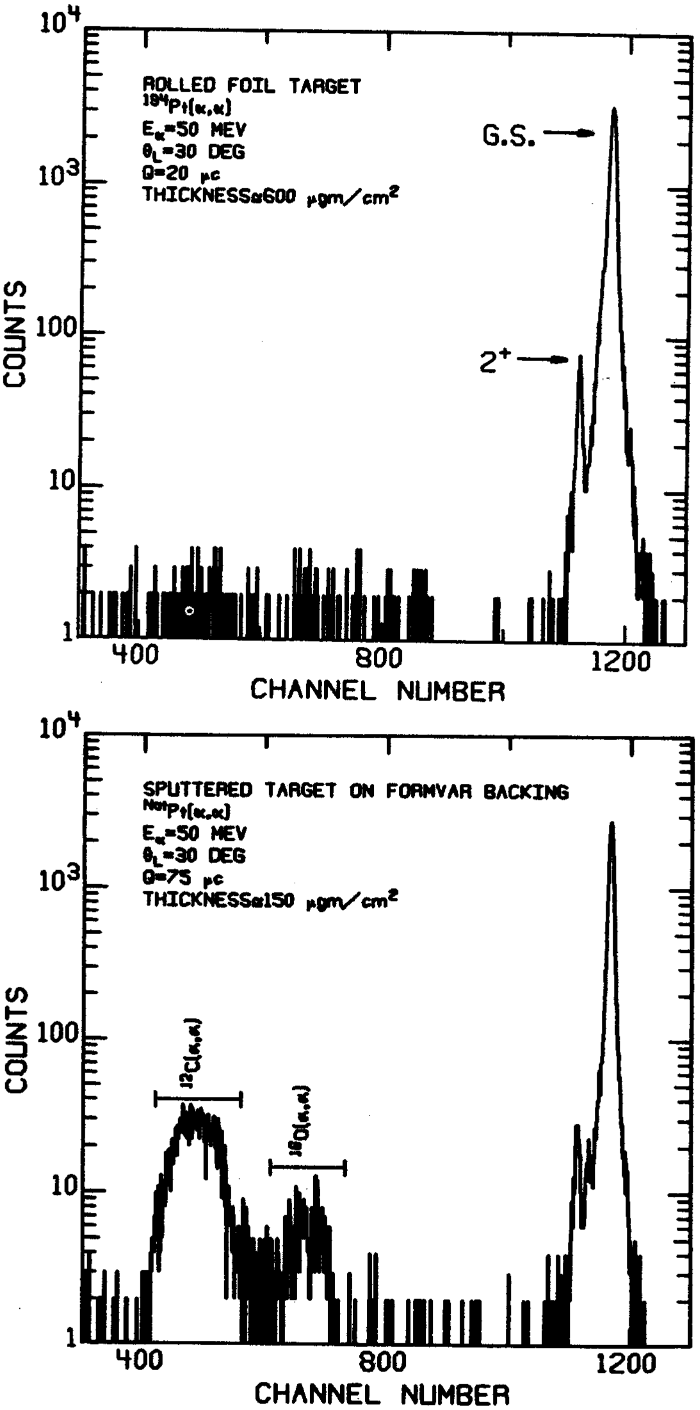

Figure 1. upper: Spectrum of alpha particles scattered from a rolled foil plantinum target. Lower: Spectrum of alpha particles scattered from a platinum target prepared by the sputtering method.

A Camac-PDP 11 Data Acquisition System

C. Morgan, R. Au, R. Markham

Last year we bought a camac system to be used with our PDP 11/45 computer. This system consists of a crate, crate controller, point plotter and character generator for our CRT display, two input registers, an output register, a dual DAC, 2 Quad scalers, 2 real time clocks, 2 coincidence boxes, an octal ADC, and a dataway display. At this time all the modules are functional and in use except for the coincidence registers which lack documation. A large library of routines (EXTLIB) has been written to allow FORTRAN programmers to write data acquisition programs. These programs can acquire one through eight parameter data through the octal ADC, and up to eight scalers and or real time clock inputs. The input registers allow real time control of the program by use of 48 switches and 12 thumbwheels.

Our initial effort was to enable the FORTRAN programmer access to all the camac boxes. This allows a program to be quickly written and debugged so that new ideas for data acquisition for new types of experiments may be implimented with very little delay.

The camac system has been very successful for the rapid building of programs for the FORTRAN programmers, however, this system has two drawbacks. First the operating system we have lacks proper documentation for ease of incorporating our modules into the system. Secondly the PDP 11/45 is a rather small machine with no internal protection which is not suited to time sharing. Thus our normal one-person-at-a-time procedure can make for relatively long delays in developement.

As this time a dozen data acquisition programs have been written. These range from simple single parameter programs to very complicated multiparameter programs. Those programs which are written entirely in FORTRAN can acquire data at rates up to approximately 500 events per second. Several programs have machine language processing routines which allow rates up to the maximum allowed by the ADC (approximately 10,000 per second). These machine language routines are planned as the final stage of development for most programs.