EXPERIMENTAL FACILITIES DEVELOPMENT

A. Facilities in Operation

1. Target Area Improvement

As a result of the Cooler and Dual Spectrometer projects, efforts were made to reduce the amount of man power devoted to target area development and improvement throughout 1984. These efforts are reflected in both the scope and number of experimental facility developments accomplished. An active research program was supported in the normal way by the research support personnel of the laboratory and some significant improvements made.

The target drive of the beam swinger facility was reworked in order to restore the capability for target changes from the cyclotron control room. A 20-foot wide path was cleared by removing brush and small trees on the 45-degree flight line to allow placement of a neutron detector hut at 160 meters. A number of temporary modifications were made in a zero degree hut setup in order to accommodate an engineering model of the COMPTEL telescope for study of neutron backgrounds and for calibration as a neutron detection device. In order to reduce backgrounds for (n,p) experiments, the exit of the swinger vacuum chamber was modified. The exit opening (and the next downstream section of beamline) were enlarged so that beam could not scrape the thick aluminum wall. This required unstacking most of the shielding around the beamline just upstream of the beam dump. When restacking this shielding boron was added and care was taken to reduce background from fast neutrons as much as possible.

To do $(p,p'\gamma)$ experiments the QDDM spectrometer was modified twice by removing the sliding band scattering chamber and replacing it with a special low-mass scattering chamber. For the second of these runs, a table was fabricated to support two heavily lead-shielded bismuth germanate γ-ray detectors. A lifting device was designed and fabricated to allow safe handling of liquid helium dewars for the CSB experiment. This device is suspended from the overhead I-beam supports for QDDM services and has proven useful for lifting various objects from the inside to the outside of the 2-foot high concrete spectrometer support ring and vice versa. Development of the focal plane polarimeter has continued. This work has been done primarily by experimenters with modest laboratory support.

Some effort went into facilitating the CSB experiment. In particular; hardware to support, position, and allow removal of the liquid hydrogen target was fabricated and installed. A large chilled-water cooled air handler was installed to provide cooling for the CSB experiment.

The QQSP was used routinely throughout this year with no significant mechanical modifications.

For an experiment to measure tensor-polarized deuteron capture by hydrogen isotopes, a new double-sided scattering chamber was designed, fabricated and installed in the low-intensity experimental area (γ-cave). A special setup was installed for the measurement of bit-flip rates in microprocessor chips. The out-of-the-plane table was installed and removed several times during the year. The now standard thin-wall-chamber (p,γ) setup was routinely used several times as well.

As usual the 64" scattering chamber has been used for a variety of experiments this year. A major effort has gone into providing good vacuum for those experiments which use channel plate detectors. The encoders for digital readout of target angle and table position have been replaced. In addition, the mechanism for the target angle readout has been modified to move critical components out of the vacuum. The in-line cryo-trap for catching oil coming down the beamline before it enters the scattering chamber has been rebuilt. Discussions continue about modifications of the chamber to allow out-of-the-reaction-plane measurements with this chamber.

2. Spin Rotation and Polarization Transfer Facility

During 1983, the development of the horizontally polarized beam was completed with the demonstration that high polarization from separated turns could be achieved up to 200 MeV, and that the polarization direction could be adjusted through changing the turn number of the beam in the main stage cyclotron. The next phase of the development was the calibration of the two high-energy beam line polarimeters, which was completed by March, 1984. Since that time, operation of the horizontally polarized proton beam has been devoted to calibration of the polarimeter for the focal plane of the QDDM spectrometer, and the measurement of spin rotation and polarization transfer in proton elastic and inelastic scattering.

The major components of the system are shown in Fig. 13. The spin precession solenoid is located downstream from the polarized ion source terminal. Roughly 200 A are required to precess the spin axis of the 600 keV beam into the horizontal plane. Because the spin does not precess in a perfectly horizontal plane during acceleration, some adjustment of this solenoid current is needed whenever the spin direction out of the main stage cyclotron is changed. The spin precession solenoid has a small focussing effect on the beam, and its operation at full current requires the readjustment of the steering and focussing in the low energy beam line.

Customarily, the low energy polarimeter is used exclusively for measurements of the vertical beam polarization. With the spin precessed beam, this function is served during data acquisition by the two high energy polarimeters. However, neither of these polarimeters contains equipment to maintain the location and direction of the beam on the polarimeter target. It is therefore possible to obtain information

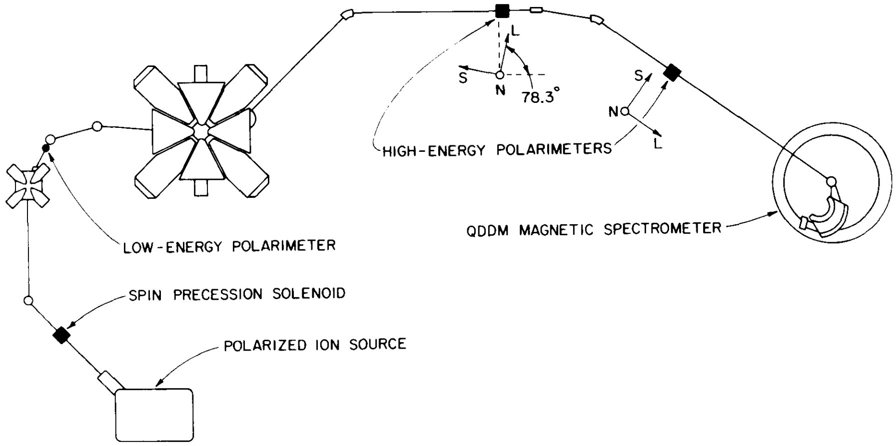

Figure 13. Map to scale of the beam line from the ion source to the QDDM magnetic spectrometer. The components described in the text are used to prepare and monitor the horizontally polarized proton beam.

only on the average magnitude of the spin "up" and "down" polarizations from the ion source. In our application, we make use of the automatic centering on the low energy polarimeter target to obtain a measure of the magnitude of the spin "up" and spin "down" polarizations separately without interference from large systematic errors. For this measurement, the spin precession solenoid must be off.

The locations of the high energy polarimeters in Fig. 13 were chosen to provide information on all three polarization components. In a single scattering experiment, parity conservation does not permit a polarimeter to be sensitive to the component of the polarization along the beam direction. However, the anomalous magnetic moment of the proton is large enough that the longitudinal component at the QDDM target is nearly sideways in the switchyard ahead of the 36° bend into the QDDM beam line. For 200 MeV, the precession angle relative to the proton momentum is $\phi = 78.3°$. The polarimeter mounted in that location contains only one pair of detectors for measuring the sideways polarization at that point. The longitudinal component P_L at the QDDM target is then given by

$$P_L = \frac{P_R - P_S \cos\phi}{\sin\phi} = \frac{P_R - 0.1018\ P_S}{0.9792}$$

where P_R is the sideways component measured by the upstream polarimeter, and P_S is the sideways component at the QDDM target.

The high energy polarimeters observe elastic scattering at 20° from natural carbon targets. The targets are in place during data acquisition at the QDDM. The thickness is varied from 100 to 800 $\mu g/cm^2$ to match the computer dead time between singles events from the six polarimeter detectors and the coincidences from the focal plane detector array.

Calibration of the analyzing power of the three detector pairs was made by placing each polarimeter into the QDDM beam line so that each detector pair in turn assumed a horizontal orientation. Then the analyzing power of that pair was compared with the analyzing power from elastic scattering from ^{12}C at 12.5° as measured in the QDDM. That analyzing power is well known as a function of energy from double scattering experiments performed at Harwell and Orsay. (We found that proton-proton analyzing powers were too poorly known to provide a calibration standard.) The calibration was made in steps of 10 MeV between 170 and 200 MeV. Analyzing powers for the three detector pairs agreed well with each other. A band showing the precision of the calibration is given in Fig. 14. In addition to the polarization transfer experiments, these polarimeters have been used for two experiments involving vertically polarized beam, since they provide information on the beam polarization during each run.

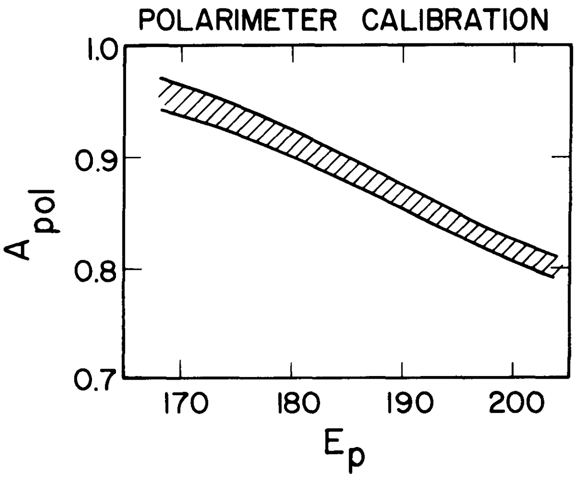

Figure 14. Analyzing power calibration for the high-energy beam line polarimeters as a function of proton beam energy. The band follows the mean of the calibrations for each pair of detectors, and has a width given by the statistical errors in the calibrations.

The detectors in the high energy polarimeters are 2"×6" NaI(Tl) crystals, each preceded by a brass collimator containing a 1/4" tapered aperture. No additional shielding is used. These detectors are sensitive to beam halo, and careful beam line tuning is required in order to maintain resolution (usually less than 1% for the elastic peak). During calibration, it was found that the downstream polarimeter was less sensitive to background from the beam stop if it was moved upstream. That polarimeter is now located close to stop 4 in beam line 5. In this configuration, beam currents up to 50 nA have been run with satisfactory results.

All of the polarization transfer experiments have run with 200 MeV beam energy. Careful tuning is required at that energy to minimize the vertical steering effects of the $\nu_z = 1$ resonance in the main stage cyclotron. Stable operation is obtained during cool weather and after the magnets have been at full current for about two days. Adjustments to the tune are required at least once every day to maintain good turn separation, and therefore high horizonatal polarization, at extraction from both machines.

3. Wire Chambers

(i) Helical detectors

This fall, during a long run on the QDDM, the helix developed a "dead spot". This helix had been in use for over a year. The "dead spot" is an area on the helix where the efficiency is reduced. In conjunction with this reduced efficiency the dead spot is characterized by a sudden increase in the current drawn from the high voltage supply while the detector is exposed to large background radiation. When the large background radiation is removed the current will stay high for awhile and, after a brief period of time, return to a near zero value.

The spare helix was exchanged for the helix with a dead spot. The spare helix immediately formed a dead spot in the same location that the spot had appeared on the previous helix. We now had no spare and two helices with dead spots. Similar "dead spots" have been reported in the literature.[1,2,3] In order to keep the experiment running a cure suggested by M. Atac[3] was attempted.

To cure the "dead spot" approximately 0.12 liters/Minute of CO_2 was bubbled through ethyl alcohol (CH_3CH_2OH) and mixed with the usual gas mixture of 1.25 liters/Minute of Argon mixed with 0.29 liters/Minute of CO_2. Since this increased the amount of CO_2 in the system the operating voltage was raised from 2600 to 2800 volts. With this new gas mixture the "dead spot" disappeared. Atac observed[3] "... even a damaged chamber can be successfully used when complete UV quenching is achieved". From this observation it appears that enough ethyl alcohol was added for a chamber of these dimensions (anode to cathode spacing 7.9 mm, cathode wire thickness .05 mm, cathode wire spacing 0.5 mm) to keep a significant number of UV photons from reaching the cathode. This conclusion is further supported by observations at SLAC[4] "...the literature was searched for the absorption properties of CO_2. A window was found at 1200 Angstroms. This corresponded to the emission lines of doubly ionized Argon".

In addition to solving the problem of the "dead spot" the new gas mixture allowed the chamber to operate at higher background rates without drawing excessive dark current.

This running mode was so successful that all future runs with the helix will use this new gas mixture.

(ii) Multiwire Proportional Chambers (MWPC)

While investigating the breakdown of a MWPC used in the CSB experiment it was noticed that the epoxy holding the sense wires was mixed incorrectly allowing the wires to slip. Consequently all of the large wire chambers for CSB were examined and several were found to have incorrect epoxy mixtures. For some of the detectors the wires that had slipped were replaced and all the wires had more epoxy added to hold them in place.

The general purpose x-y pair of MWPC's for general lab use has not been designed. If time permits they will be designed and built next year.

An x-y-U chamber has been designed for use in the n-p experiment. The chamber has a single anode plane with a delay line connecting the anode wires. Each cathode is connected to a separate delay line. One cathode has wires perpendicular to the anode wires. The other cathode has wires at a 45° angle to the anode wires. With this arrangement multiple hits can be sorted out. If time permits they will be built next year.

(iii) Wire winding machine

The wire feed device has been built for the wire winding machine. Interface of the IBM PC was completed by the data acquisition group. The table will be built later. If wire chambers need to be built before the table is finished the Indiana high energy physics group will let us use their table.

(iv) Polypropylene stretcher

The polypropylene stretcher was completed early in 1984. We were able to make films suitable for vacuum windows in parallel plate avalanche counters. However, the thickness was not uniform enough for high voltage planes. We feel that the problem is with the polypropylene and will try polypropylene from different sources in the future.

(v) Gas handling system

This year we will construct a gas handling system capable of operation from a few Torr to 10,000 Torr of pressure.

(vi) Low-Pressure Multi Wire Chamber for Heavy-Ion Detection

Following the completion of a prototype[5] and its successful operation in several experiments[6] two devices of the same type were recently designed, built and tested with a 95 MeV ^{6}Li Beam at IUCF.[7] They are x-y position sensitive with active area of 17×17 cm^2, position resolution better than 2 mm, timing resolution ~700 ps. There are no basic changes in the apparatus construction with respect to the prototype. The wire spacing is 2 mm, gap between cathode and anodes 3 mm, operating voltage ~570 V at 8 torr of isobutane.

1) G. Charpak, H.G. Fisher, C.R. Gruhn, A. Minten, F. Sauli, and G. Ploh, Nucl. Inst. and Meth. <u>99</u>, 279 (1972).

2) R. Thun, C.W. Akerlof, P. Alley, D. Koltick, R.L. Loveless, D.I. Meyer, M. Zumberge, D. Bintinger, R.A. Lundy, D.D. Yonanovich, W.R. Ditzler, D.A. Finley, F.J. Loeffler, E.I. Shibata, and K.C. Stanfield, Nucl. Inst. and Meth. <u>138</u>, 437 (1976).

3) M. Atac, IEEE Trans. Nucl. Sci. <u>NS-31</u>, 99 (1984).

4) D. Koltick, SLAC-HRS-197.

5) 1982 IUCF Scientific and Technical Report, p. 214.

6) 1983 IUCF Scientific and Technical Report, p. 143.

7) This report, p. 109.

4. Scintillation Detector Lab

During the past year, 75 scintillation detectors have been constructed or repaired. Included in this total are two hodoscope arrays for the radiative capture experiment, E234. Two nine-element liquid scintillator hodoscopes were constructed and tested for the cold high-spin nuclei experiment, E232. These liquid scintillators were the first to be constructed at IUCF which optimize the pulse shape discrimination (PSD) properties of NE213. After a long investigative process we now feel that detectors which are operated in the PSD mode, can be built routinely.

An in-beam experiment was performed during the past summer to maximize the energy resolution of plastic scintillators. Two detectors of different geometries were used. One scintillator was a cylinder of NE102 7.6 cm dia. × 12.7 cm. The second scintillator was a truncated cone, 7.1 cm dia. at the base × 12.7 cm. These two detectors were mounted on RCA 4524 photomultipliers. Various reflective wrapping methods were tested. The scheme which gave the best resolution with a ^{60}Co source (~17.5%) was painting the front surface and top half of both the cylinder and cone. The two detectors were then placed at 20° with respect to the beam incident on a ^{12}C target, behind brass collimators, 4 cm thick with 0.8 cm apertures. The target was bombarded by protons with an energy of 80 MeV. A spectrum of the scattered particles was then measured (Fig. 15). The resolutions for the cone and cylinder were found to be 1.93 ± 0.1% and 1.77 ± 0.1%, respectively. Within the given error, both geometries are equally good. These resolutions are approaching the value which is useful in (n,p) measurements (1.0% of resolution at E_p = 100 MeV).

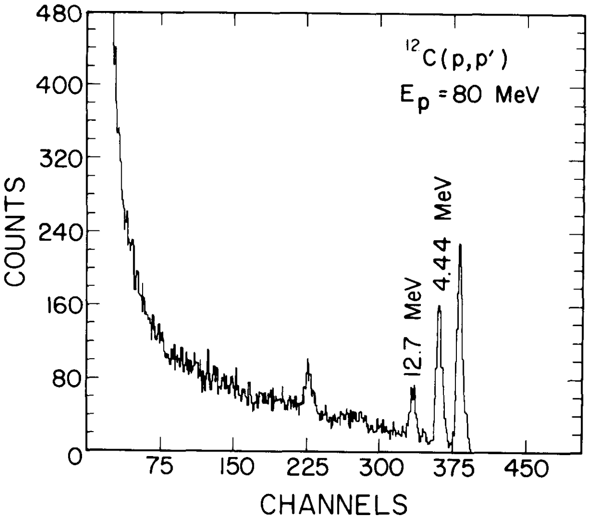

Figure 15. Pulse height spectrum from a plastic scintillator cylinder mounted on a RCA 4524 photomultiplier.

A position sensitive scintillation detector, which was first developed in 1982[1] has been refined and was shown to work very successfully this past December. The detector consisted of 10 scintillator-optical fiber elements which are all mounted to a single RCA 8575 photomultiplier. The optical fibers differed in length by 76.2 cm from one to the next, resulting in total lengths of 30.5 cm to 716.3 cm. The scintillators were mounted in ascending order of length on a frame. This detector was then placed in the 64" Scattering Chamber at the target position. The detector was bombarded by a 0.5 nA beam of 95 MeV deuterons. The anode signal of the detector and the RF signal of the cyclotron were fed into a TAC and the output was pulse-height analyzed (Fig. 16). Each peak corresponds to an individual element. Elements 8, 9, and 10 (563.9 cm, 640.1 cm, 716.3 cm) do not show up. This may be due to the fact that the optical fibers of these elements are too long and the light produced by the scintillator is absorbed before reaching the photomultiplier. Calculations show

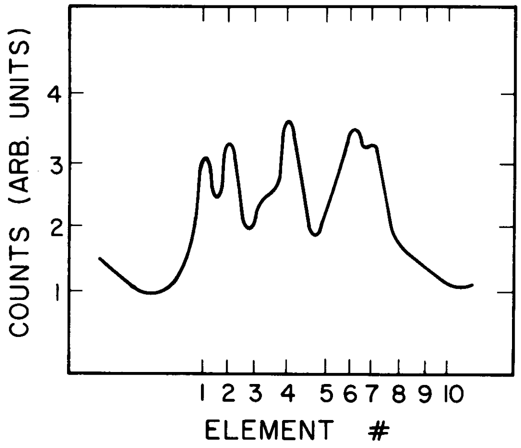

Figure 16. Pulse height spectrum from a position sensitive scintillation detector.

that the longest length of optical fiber which will still transmit enough light to fire the phototube is 580 cm. This agrees well with the observed values.

Construction is underway to produce an x,y detector. Such a detector would be useful in measuring the beam profile provided the beam current is less than 1nA.

1) IUCF Scientific and Technical Report 1982, p. 212.

5) High-Purity Germanium Detector Development

During 1984, high-purity germanium detectors were successfully used in 6 experimental runs consuming over 30 shifts of beam time. Only one of these runs was used to develop their use in our application at IUCF. In this experiment, two germanium telescopes were used to detect coincidences from p+d elastic scattering produced by a 160 MeV proton beam incident on a CD_2 target to measure deuteron and proton detection efficiencies in germanium at IUCF particle energies. The deuteron loss ratio was found to vary from about 3% at 35 MeV to over 20% at 105 MeV. Details of these measurements are discussed in Part 1 of this report[1] and compared with previous measurements at other energies.

With the exception of the above run, little specific development work on the behavior of these detectors in our radiation environment has been done for the last two years. Hovever, a three week visit to IUCF by Dr. Richard Pehl of LBL in late 1984 has prompted an extensive review of the status of our use of high-purity germanium for the detection of intermediate energy charged particles. The ongoing accumulation of data on the changes of the physical properties of the Indiana-LBL detectors during the radiation damage and anneal cycles experienced over the last 4 years is beginning to show some interesting patterns. Chief among these is an apparent difference in the radiation damage anneal rate for detectors made from n-type and p-type germanium. Radiation damage anneal rate differences of about a factor of four were reported for severely neutron damaged detectors in the 1982 annual report. However, after reviewing the anneal history of the most used n- and p-type germanium detectors for the last several years, it appears that detectors made from n-type germanium anneal significantly faster than a similarly damaged detector made from p-type germanium, whether the damaging particles are neutrons or charged particles. A precise quantification of this observation needs to be made, and plans for doing this in the near future are being discussed.

Another property of these detectors which has clearly emerged from their use here at Indiana is that the impurity concentration of the transmission detectors fabricated from n-type germanium can have a significant impact on their useful lifetime in a high radiation environment. Because of the depletion bias reduction caused by the creation of p-type defects when being damaged by intermediate energy particles, transmission detectors made from very pure n-type germanium will experience a proportionately larger change in their impurity concentration (and therefore their physical properties) than would one made from relatively impure germanium. In one extreme case reported in 1982, a very pure n-type germanium detector had at least part of its matter changed to p-type material during the course of an experiment. Since that time, this effect has been observed on at least one other occasion. Hence, when a detector telescope is being assembled for use in a high neutron or charged particle background, we now choose n-type detectors which have a high impurity concentration to insure their survival for the duration of the run. Details of these and other phenomena observed during the course of our use of these detectors since our last published report[2] are presently being prepared for publication. In addition, several development runs at Indiana and possibly elsewhere are being planned to make a more careful measurement of these effects.

The high-purity germanium detectors are available for use by experimental users upon request. Four detector cryostats are available for use inside the 64" scattering chamber or externally in the Gamma cave using the 3-D scattering table. A current list of the available detectors and their physical properties is provided in Table I. Users may set up their own

Table I.

IUCF Germanium Detector List

Detector No.	Ge Type	Thickness (mm)	Impurity Concent. ($X10^{10}$ cm^{-3})	Depl. Bias (-V)	Delta (V)	Total hrs Beam Time	No. Thermal Cycles	Total hrs Anneal	Li Layer Depth mm
				TRANSMISSION DETECTORS					
501- 9.3	n	~ 2.0	4.4	100	150	200	5	158	NA
501- 9.6	n	~ 2.0	4.4	100	400	336	9	271	NA
551-11.8	n	5.18	7.5	1100	200	200	12	300	NA
475-10.7	n	9.07	3.3	1700	100	1276	66	1617	NA
477- 6.1	n	9.52	2.0	1000	350	504	14	469	NA
501- 6.7	n	10.77	2.7	1800	200	1490	93	2022	NA
474- 5.8	n	~12.0	1.6	1600	200	249	10	406	NA
555-10.0	n	~13.0	2.4	2200	500	610	20	700	NA
517- 9.7	n	~15.0	1.2	1500	200	1580	87	2032	NA
				STOPPING DETECTORS					
172- 3.1	p	10.6	0.98	350	2000	585	22	318	1.23
514- 7.0	p	~15.21	1.86	1600	2000	1875	108	2702	3.30
514- 8.6	p	14.94	1.10	1200	2000	2067	92	2002	1.17
525- 8.6	p	~12.0	1.10	1000	2000	0	1	84	0.93
603- 6.1	n	~20.0	0.75	1700	1500	0	3	61	0.63

telescopes from the detectors listed or request a particle energy range and let us select the detectors required.

1) D.L. Friesel et al., this report, p. 119.

2) A Variable Geometry High-Purity Germanium Telescope for Use with Intermediate Energy charged Particles, D.L. Friesel, R.H. Pehl, and B.S. Flanders, Nucl. Instrum. and Meth. 207, 403 (1983).

6. Target Lab Technical Status

Target preparations for 1984 included: CD_2, ^{6,7}Li, ^{10}B, $H_3{}^{10}BO_3$, ^{12,13,14}C ^{15}N-melamine, CF_2, LiF, ^{24}MgO, ^{24}Mg, Al, $^{29,30}SiO_2$, Si, ^{34}S, K, ^{40,42,44,48}Ca, ^{51}V, ^{56,58}Fe, ^{59}Co, ^{71}Ga, $Ca^{81}Br_2$, ^{87}Sr, ^{93}Nb, Ag, Au, $^{133}CsNO_3$, $^{140}CeF_3$, ^{144}Sm, DyF_3, ^{165}Ho, ^{183}W, WO_3, ^{199}HgO, ^{205}Pb, Bi, ^{232}Th, $^{238}UF_4$.

Brief descriptions of several techniques which were developed or extended during the year follow:

1. An extensive development effort produced a carbon-14 powder target of 12 mg/cm^2 with only 274 μg/cm^2 of binder. To begin, a non-radioactive analog of the ^{14}C powder was produced from CO_2. This allowed, for the first time, investigation into its intractable physical properties. Subsequently, it was discovered that grinding the powder under xylene removed the resistance of the fluffy power to form a pellet upon compaction.

The entire process of handling, preparation, compacting and packaging was done in the safety of the the absolute-filter hood. This was possible because of the use of a new four-column, 5-ton indicating press and a special compacting die, both of which were designed and built in-house (at a very low cost) for use in the hood.

2. A method for the reduction of isotopically enriched $^{71}Ga_2O_3$ to the metal was developed. Pure metal and an efficiency of 94.3% were achieved in a small teflon electroplating cell of precise geometry. Argon was bubbled through the solution to inhibit unwanted reactions at the electrodes and to cause the Ga metal droplets to coalesce (thereby minimizing chemical attack by the solution). Also, the method of forming ~25 mg/cm^2 targets of Ga (developed last year) was improved by using 1" wide teflon tape between glass plates as the substrate for the molten metal.

3. Continuing work on binding pressed powder targets (with the smallest amount of material possible) produced a method which is quite simple and has proven to be highly useful. A solution of the adhesive from common adhesive tape in petroleum ether is either mixed with the target powder or sprayed onto a substrate such as thin carbon foil (before air-settling a powder). Because the adhesive remains slightly sticky, the amount of it required is small in comparison to the amount of CH or CH_2 required for the same binding strength.

In most applications, the fact that the adhesive contains oxygen as well as carbon and hydrogen is offset by the small amount required. Sufficiently uniform layers as thin as 6 μg/cm^2 can be applied. As yet, the adhesive has not "let go" or otherwise failed in the cyclotron beam.

An old Orb-Ion^{TM} and Ti getter pumped stainless steel vacuum station has been brought into operation as a result of the need to store several freshly made 500 μg/cm^2 ^{40,42,44}Ca targets for a run which was postponed. Although a Varian spokesman told us that replacement parts are no longer available and that we must have the only Orb-Ion^{TM} pump still running in the country, the system is operating satisfactorily and will undoubtedly be of further use.

Due to the work load and the necessity to train a new target lab assistant, the only development work on fiber and whisker targets was the successful demonstration that 7μ carbon fibers can be thinned with our electron beam gun.

At present, the lab capabilities include: general vacuum evaporation, pack rolling in air and inert gas, air and liquid settling, electroplating, die pressing, arc melting, and reduction of most enriched oxides to the elemental form.

7. Data Acquisition

(i) Computer Systems-Hardware

The third VAX data acquisition system was ordered and installed this year. The computer, a VAX 11/750, was configured in much the same manner as the previous two. Dual RA81 456-Mbyte disk drives, dual TU78 6250 BPI tape drives, and 4 megabytes of memory was ordered. The higher density drives will provide for more efficient data storage for some of the larger experiments.

Because of a Digital Equipment Corporation 45% grant through the National Science Foundation, it was possible to provide an Ethernet communication system for all of the VAX's and the PDP 11/44 control computer. Running under DECNet, it is now possible to communicate among all the systems. As soon as the new control computer comes on-line, spin-flip will be controlled through this link. When the third VAX 11/750 is moved into the cooler building, the Ethernet link will be extended over an optical fiber cable using DEC model DEREP remote repeaters that have already been purchased.

The BI-RA MBD front-end has been moved into the downstairs control room. Because of the upstairs location of the cpu's, it is necessary to run a Unibus over 150 feet. Using two Able Unibus repeaters, the system performs with no noticeable degradation. The tape drives will soon be moved downstairs also. A single massbus cable run of 120 feet will not require any repeaters.

A second BI-RA MBD was ordered toward the end of the year to bring the second VAX on-line. The MBD is only a temporary solution for the VAX front-end. It certainly does not provide the numerical capabilities that are desired for some of the more complex experiments. It is anticipated that the LeCroy CAB processor will provide the long term solution.

A pair of high speed data acquisition graphic displays was purchased this year. The specifications called for a parallel interface to the VAX, color display, and at least 1024 × 1024 resolution. The Tektronix 4115B terminal was certainly a possibility, but it was too expensive. Instead, after several rounds of quotations, a Seiko model GR-2414-50 was selected. Though somewhat slower, 78 mega-pixels per second, versus 125 MPX, the Seiko costs $10K less than the Tektronix. It supports 1280 × 1024 resolution with a 60 Hz refresh rate for a flicker free display. The terminal connects to the VAX through a DR11-W interface, and uses the standard VAX software driver. A software support package is provided since the parallel transmission mode does not match any standard protocol.

The specifications for the IUCF analysis computer were established during the year. A VAX 8600 (code named "Venus"), was the computer chosen as the best compromise between the computing capabilities required and the ability of our limited staff to support another computer manufacturer. The 8600 is equivalent to approximately 3-4.5 VAX 11/780's.

The 8600 was ordered in a cluster configuration as it is not yet available in any other way. The standard package comes with 12 Mbytes of memory, floating point accelerator, Ethernet support, star coupler, storage controller, and four communications interfaces. We added two RA81 disk drives and two TU78 tapes drives. When the system arrives, we will move an additional RA81 drive over from an existing VAX. This will provide nearly 1.4 Gigabytes of on-line disk storage.

It is anticipated that two of the other 750's may be added to the cluster later if it is operationally desirable.

During 1984 we have added a small number of IBM "personal computers" to the laboratory. They are being used for word processing, spreadsheets, VT100 terminal emulation, CAMAC equipment checkout, and a crude automated printed circuit board layout system. Normally these functions would either be too expensive to bring into a VAX environment or they would represent a significant manpower investment. Using mainly undergraduate student support, we are providing these services with little impact on the main development programs.

(ii) VAX Data-Acquisition Software Development

Data acquisition development for the VAX-11/750 computers has continued as described in the last report.[1] The program for on-line acquisition is XSYS/IUCF, a modified version of XSYS developed at TUNL.

Most of the development efforts on this program were concentrated on the MBD code, the VAX data-acquisition I/O and event-sorting code, and graphic display modules. The code for the Bi-Ra Micro-programmable Branch Driver (MBD) controls both the CAMAC operations, and the direct-memory access (DMA) to the VAX. In addition, the MBD code can now perform limited user-programmed arithmetic operations and tests which use a simple set of user commands developed for filtering event data before transmission to the VAX buffers. The VAX and MBD DMA codes use a circular list of buffers which are filled and processed with front-end delays between buffers of less than 50 microseconds.

New graphic display modules have been written to use a device-independent graphic subroutine package (Unified Graphic System from Stanford), which presently supports our Tektronix 4112, DEC VT 102/131 retrographics, DEC GIGI terminals, and the TRILOG dot-matrix printer. Device modules for the ZETA pen plotter, and the new high-resolution Seiko GR-2414-50 D-Scan display terminal will be developed in 1985. Each data-acquisition VAX will have one of the Seiko terminals as the principal on-line graphics display device; the resolution is 1280 × 1024 with up to 15 colors.

As planned a short data-acquisition run with beam was done in January 1984. The test demonstrated that the new program could acquire data properly, and helped make some adjustments in operating-system parameters to optimize virtual-memory paging, which otherwise tends to interfere at high data rates. Another test with the fast-spin-flip beam was also done, to demonstrate a method of identifying spin without a direct link between the control and data-acquisition computers; this link will be established sometime in 1985.

The VAX with XSYS/IUCF was used for a physics experiment on intermediate mass fragments (E260) in November. This experiment had 3 independent events, each with 5 data words, and ran without problems in the data-acquisition system, although still using older verisons of the display programs.

Performance tests of continuous-mode data-acquisition indicate the following statistics (time in microseconds):

1. Time from event LAM (generated after ADC conversion) to busy reset = 10 + 4*(no. of data words)
2. Time to transfer event data to VAX buffer (after busy reset) = 10 + 4*(no. of data words)

This results in about 10% dead time for 3000 events/second with 4 data words.

We have continued to support LISA for VAX data replay, and have installed the Los Alamos Q-system software for data replay. Q will be available as an alternative data-acquisition system after software updates and a hardware module are obtained in 1985. The MBD and CAMAC for the VAX will be moved to the control-room area in the beginning of 1985, and it is expected that the VAX computers will increasingly be used for data acquisition in experiments during 1985. In addition to supporting needs of current experiments, there will be software development effort and planning and new experimental facilities, including the focal-plane detector system and future storage-ring experiments.

1) IUCF Scientific and Technical Report 1983, p. 214.

B. Future Facilities

1. The IUCF-Maryland Dual Spectrometer System

Fabrication of the large dipole magnets for the K=300 and K=600 spectrometers, along with their main and trim coils, was completed in the summer of 1984. Inspection of the assembled magnets at the fabricator (Demmer Corporation of Lansing, MI) had shown all pole-tip assemblies to be well within the specified limits of dimensional tolerances, flatness, surface finish, and median-plane symmetry. The K=300 magnet was reassembled at IUCF in June and powered up for preliminary magnetic field measurements. The magnetic properties of the iron were found to be very good; the desired maximum field of 17 kG was indeed achieved at the design current and appears to be well below the saturation limit. Through a series of edge field scans we determined the optimum dimensions and location of the "Rose shims" which are mounted along the side edges of the pole tips in order to increase the usable width of the uniform field region by nearly 10 cm (except at the highest fields) and thereby achieve the full design solid angles for the spectrometers.

During the summer we completed the assembly of the large, high-precision X-Y field mapping table and interfaced it to the computer-controlled probe drive and data-acquisition system. A linear array of 16 Hall probes mounted at the end of a 3m long lightweight but very stiff arm (a composite structure of carbon fibers and aluminum honeycomb) permits us to map efficiently an area of nearly 2m × 3m extent. The dedicated mapping computer system precisely controls the probe positioning with a minimum of oscillation through carefully programmed acceleration/deceleration sequences during the motion. At each mapping point the computer reads and processes all Hall voltages via a multichannel, high-precision digital voltmeter and records the data on magnetic tape for off-line analysis on a VAX 11/750. The interfacing and debugging of the mapper control and read-out system hardware and software took considerably longer than anticipated (in part as a result of defects in the commercial, microprocessor-based motor controller) and delayed the start of the K=300 field mapping by nearly two months. A complete set of field maps at various magnet excitations was obtained by mid-December and is awaiting computer analysis in preparation for magnetic shimming of the dipole entrance and exit boundaries to produce the desired field boundary contours. Installation of the first of the two K=600 dipole magnets in the mapping area also commenced before the end of the year. During the spring of 1985, mapping and remapping (after shimming) of all three spectrometer dipole assemblies set up in this area should proceed efficiently on a rotating basis by simply relocating the mapper table as needed.

Fabrication bids for the large-aperture, open-sided entrance quadrupole magnets were received in October, but since even the lowest bid came in considerably over budget, we decided on in-house machining of the massive steel yokes, with only the specially contoured pole pieces and coils fabricated outside. Other small magnets (septum and hexapole magnets for the K=600 spectrometer) have been designed and in part fabricated. The main dipole vacuum chambers are being fabricated by an outside vendor and are expected to be delivered early in 1985. Turbomolecular pumps to evacuate these chambers have been ordered.

The detailed engineering design of the dual spectrometer carriages, along with the conventional wheel-and-track drive systems and a common, low-profile central hub, was completed only recently and fabrication bids are being solicited. The design of these spectrometer support systems and associated tracks had undergone considerable reevaluation and modification during the past several months, culminating in a much simpler yet stronger design.

Prototype dipole leveling and alignment fixtures underwent evaluation and load testing in preparation for final design and fabrication in quantity early next year. A massive turnover fixture (for safely rotating the 34-ton K=300 dipole assembly from its horizontal assembly orientation to its final, vertical operating position on its carriage) was fabricated in the IUCF machine shop.

Detailed planning of the hardware configuration for the new beam line leading to the dual-spectrometer target location has commenced; all bending and focussing magnets, along with their support stands and power supplies, are in house. Development of beam line and spectrometer utilities are reasonably far advanced: AC power installation on the service balcony is complete; the University of Maryland DC power supplies for the spectrometer dipole magnets have been renovated; procurement and installation of the extensive new cooling water system serving both the cooler-storage ring and the dual spectrometers began in the fall. Acquisition or fabrication of controls components and circuits for beam line and spectrometers is 80% complete. The concrete roof beams and wall blocks for shielding the dual-spectrometer area have been acquired, and riser blocks to support the roofbeams at the 17' level (up from the normal 12' level of the high bay) over the whole dual-spectrometer area are being designed.

The present schedule for completion of the dual spectrometer project is predicated on the decision to bring the K=600 spectrometer into operation first and as soon as feasible, with the K=300 installation delayed until some appropriate time (2-3 months) after the start of K=600 spectrometer tests with the beam. This latter milestone is scheduled for August 1985. This K=600 schedule is consistent with our expectation that mapping and shimming of the dipole fields will be completed in May 1985, track and carriage installation can occur during the May-June period, followed by magnet installation and alignment in the period July-August. Fabrication and testing of entrance quadrupole and vacuum chambers should be completed well ahead of their installation. Installation of the new beam transport line to the dual spectrometer area (including QDDM relocation), the shielding wall separating the spectrometer and beam swinger, and the services (AC, DC power; cooling water) hopefully can proceed in parallel during late spring-early summer, dictated primarily by the experimental schedule for the swinger system in the spring of 1985; little progress can be made until the swinger area shielding can be dismantled for a period of about 3 months.

Wire Chambers for the Dual Spectrometer System

Due to a spate of unforseen problems with other multi-wire chambers and helical detectors in use throughout the laboratory, the design and construction of the prototype detectors for the K=600 spectrometer have been delayed. Progress has been made, however, on the construction of a high-precison, microcomputer-controlled wire winding machine, and we now anticipate that prototype focal plane wire chambers will be constructed and ready for testing in early summer of 1985.

However, since the K600 spectrometer is expected to be on line and ready for initial tests before the planned fast-readout electronics for the chambers will be available (see the following section of this report), the plans for detector construction have been altered so that the K600 may be tested and used with its full resolution capabilities but at a reduced counting rate. The detectors used in this initial mode will be identical to the final set of detectors except that instead of the individual wire readout to be used in the final set, the initial set of chambers will have anode wires connected to delay lines. Hence the accuracy will be adequate for ray tracing but the counting rate capabilities will be inferior to the final amplifier-per-wire design.

Focal Plane Electronics for the Dual Spectrometer System

Some progress towards the sophisticated focal-plane detector and fast read-out electronics system described in the 1983 IUCF Annual Report[1] has been made. The funding proposal to the NSF received generally favorable reviews and was in principle approved in full. A first installment of $150K was received in late September which will allow us to proceed with acquisition and fabrication of enough components to provide a complete slice (wire chamber to data acquisition computer) through the system for proof-of-principle demonstration of the proposed concept and hardware (now anticipated to occur in the fall of 1985).

Design work, prototyping and purchasing of electronics is proceeding somewhat behind schedule. Most of the delay has been due to problems in selecting a proper chamber preamplifier.

Several preamps are being evaluated for the system: LRS 2735A, LRS 2735B, Nanometric N-277C, and a CERN card. Time slewing and noise tests indicate that the LRS 2735A will probably be the card used in the final drift chamber system.

The system for the K600 and K300 spectrometers will involve about 750 channels of TDC information. LRS 4201 TDC's will be used in conjunction with a lab built 32-way multiplexer and hit-register module (MUX). This TDC will provide the required 1/2 nsec time resolution for the vertical drift chambers with a digitization time of about one microsecond. Six prototypes of the MUX have been constructed and the artwork for the production unit is underway.

To achieve the goal of ten percent dead-time at 10 kHz event rates, we are designing a simple high-speed, read-only CAMAC crate controller for the system. An inexpensive, general purpose commercial CAMAC controller will provide for self-testing and control, while the lab-built unit will empty the crate in an abbreviated CAMAC cycle in about 5 microseconds. The design of this unit is underway. It is worth noting that FASTBUS cannot supply the necessary time resolution nor the required duty cycle for the readout.

After being compacted into a high-speed FIFO buffer, the data stream (of about 50 words) will be sent to a preprocessor. Present plans call for the use of an array of 11-73's to handle the expected data rates. We are evaluating the use of an MDB Systems model MLSI-JFEP11 for the front-end processor. This device will operate in a standard Q-bus backplane in a multi-processor configuration. Each unit has dual-ported memory and status registers for communications with a host processor. Depending on the actual throughput attained, approximately 10 units will be used in the final array.

Preprint plans also provide for a pulse injection and voltage monitoring system, so that all the electronics may be tested under closed-loop control. All thresholds will also be under computer control.

1) 1983 IUCF Scientific & Technical Report, p. 216; see also "A Focal Plane Detector and Fast Electronics System for the IUCF Dual Magnetic Spectrometers", H. Nann, December 1983.

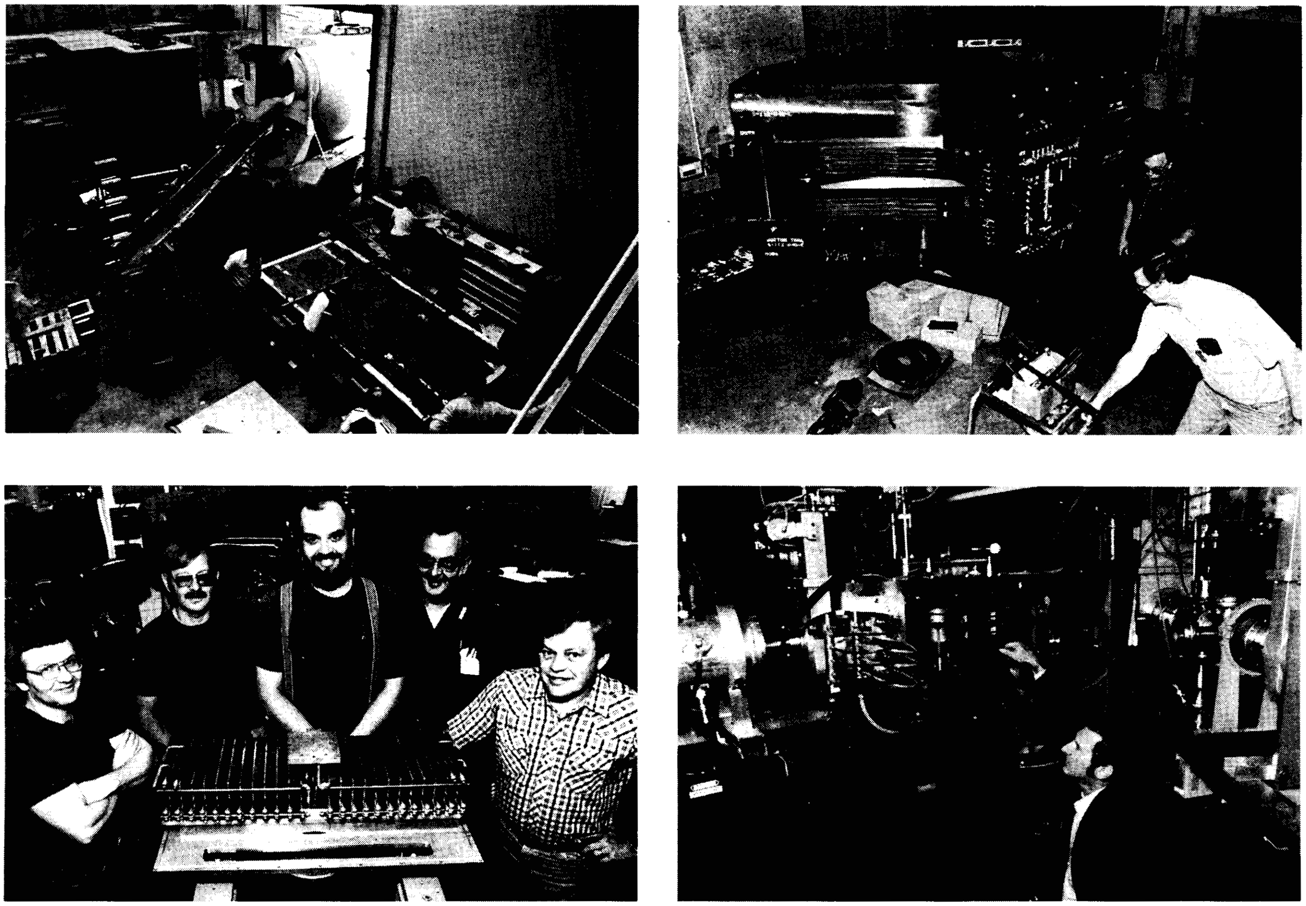

Figure 17. Clockwise from upper left: a) Base for magnet mapping system, b) K300 dipole during assembly, c) Ferrite kicker magnet for the beam splitter, d) Stripper loop mounted in beam line one.