be developed in those locations where computer accessible beam sensors are available. Because higher level languages are now supported, interested operators are beginning to write useful programs. DECNET runnning over Ethernet has been installed for communications with the laboratory VAXs, in principle, giving data acquisition programs access to all control functions. In practice, of course, such access will be limited to functions specifically requested by users. Users are welcome to submit any such requests. Remote spin flip control from VAXs will be available early in 1986.

EXPERIMENTAL FACILITIES DEVELOPMENT

Facilities in Operation - C. Foster

1. Existing Beamlines

Considerable effort was expended in 1985 on maintenance and improvement of existing beamlines. Leaking gate valves, slit assemblies and vacuum gauges were replaced or repaired in order to improve beamline vacuum. In addition, vacuum leaks in forelines, magnets and beamline hardware were found and fixed. Electrically operated air valves to actuators used on beam stops and viewers were replaced or repaired. Newly designed single-shaft actuators were installed in many locations on the beamlines. These actuators were designed, constructed and assembled in house. Solenoids were replaced on many beamline actuators to accommodate a change from 110 VAC to 24 VDC operation.

In beamline 7 to the polarized neutron facility, the beamline was reworked to accommodate the installation of a superconducting beam precession solenoid for use in the charge symmetry breaking experiment. Beamline modifications were accomplished on beamline 4 and the beamlines to the 64 inch scattering chamber and QDDM spectrometer to insert high energy beam polarimeters. One of these polarimeters was moved several times during the year to serve experiments in different facilities.

Two of the three Lambertson magnets necessary for beam splitting were installed in beamline 4 and the third was assembled for field studies. A hexapole magnet was moved upstream to a location just before the momentum analyzing magnet to provide space just downstream of that magnet for the RF portion of the splitter and for a superconducting beam precession solenoid. These latter devices were not installed in 1985. An additional beamline quadrupole magnet was installed in beamline 4 as required for proper transport of beam to the swinger, double spectrometer, or Cooler after the modifications described above and the installation of the 30 degree bending magnet, for the double spectrometer, in the beam swinger beamline.

2. New Beamlines

At the end of the year, installation of beamline 8, to the double spectrometer, was about two thirds complete. The old QDDM spectrometer was modified and moved into position as a bending magnet on beamline 8, the upstream bending magnet aligned, all quadrupole magnets, steerers and vacuum hardware had been installed on the beamline upstream of the penetration block but awaited power and controls, and the neutron shutter had been installed in the penetration block and aligned. Downstream of the penetration block, all beamline elements were in place on their supports but not finally aligned. Power and controls were not connected. A standard beamline quadrupole was in place just upstream of the neutron shutter. This quadrupole magnet is to be replaced with a special high gradient quadrupole magnet when received from the vendor early in 1986. Water and air services are installed for beamline 8.

For beamline 9, to the Cooler ring from the present cyclotron, the neutron shutter and its shielding has been installed in the west wall of the present building. Beamline 9 rail support structures are in place and quadrupole and steerer magnets assembled on the supports but not finally aligned.

3. Target Area Improvement

Improvements to the beam swinger experimental area were made to support (n,p) studies, (p,n) experiments and planned spin flip probability measurements in the (p,n) reaction. Also the shielding wall between the swinger magnets and the (n,p) detector area was removed to allow installation of the QDDM magnet in beamline 8 and completely rebuilt. A new shielded entrance maze to the swinger area was constructed in the northwest corner of the Cooler building since the double spectrometer shielding prevents access from the east. The swinger beam dump was moved downstream about 20 feet without decreasing the acceptance solid angle of the faraday cup. This was a large job which required construction of a new faraday cup, fabrication of large beampipe sections, pouring a concrete pad to support dumpshielding, assembly and vacuum testing of the faraday cup and vacuum pipe, and stacking of the dump and pipe shielding. Considerable effort was expended in getting the target drive working reliably from the control computer in the control room.

Much work was done to improve performace of the 64" scattering chamber. A valve was installed to allow controlled slow pumpdown of the chamber to protect fragile targets and detectors from rapid pressure changes during pumpdown. Controls and switches for the megasorb pump used in the pumpdown sequence were extensively reworked to improve reliability and ease of operation. The chamber was carefully cleaned and the main cryopump and in-line cryotrap rebuilt to improve the base vacuum attainable in the chamber. Effort was expended in maintaining this chamber electrically isolated from ground. Controls of the arms and target for this chamber were reworked to improve reliability.

No significant improvements were made in experimental facilities in the Gamma cave or to the Pion Spectrometer.

Many miscellaneous tasks were performed to support the CSB experiment as well as experiments in the swinger, gamma cave, pion spectrometer, 64" scattering chamber and QDDM (before it was dismantled). These efforts constitute the normal operational support of experiments at IUCF. They have suffered somewhat this year as a result of competition for manpower from spectrometer and Cooler construction. This situation is likely to continue for the next several years. Therefore, it is well for users to plan to put more effort into the performance of experiments at IUCF until construction projects are completed.

Germanium Detector Development - D.L. Friesel

The use of high-purity germanium detectors continued at about the same pace as for the last few years. Five experiments requiring germanium detector telescopes were run in 1985 with proton, deuteron, ^{3}He, ^{4}He and ^{7}Li beams. A total of 43 shifts of scheduled operation were used for these experiments. One detector, #514-8.6, a 15 mm thick stopping detector, was returned to LBL in February for repair because it would no longer hold sufficient bias for full depletion. This detector was originally placed into service here in 1979 and has since been exposed to over 255 shifts of beam in 40 different experimental runs. It has also undergone 92 anneal cycles for a total annealing time of about 2000 hours. The detector was returned to IUCF in May and has been operating well since. The boron ion implanted entrance window, which serves as the P^{+} contact, had deteriorated and was replaced. This particular failure mode, which is relatively easy to repair, is the most common difficulty observed in the 10 years these detectors have been used at IUCF. As noted above, however, even these failures are rare. The new 20 mm thick stopping detector (#601-6.3), which is fabricated from n-type germanium and has the lithium N^{+} contact, has also been used satisfactorily in one experiment this year. This is the thickest planar detector yet received here, and will be used in many future telescopes to reduce the number of detectors required to achieve a desired energy range. The list of the currently available germanium detectors and their physical properties is provided in Table IV. The operating history of these detectors is also given in this table.

One of the five experimental runs with these detectors this year was used to make additional measurements of their radiation damage properties. As previously reported,[1] a difference in the behavior of n- and p-type germanium detectors when irradiated with neutrons and with protons had been observed during their routine use. The radiation damage anneal rate also appears to be dependent on whether the detector was fabricated from n- or p-type germanium and on the damaging particle type. A preliminary measurement of these effects was made in February by placing two detector telescopes in the path of a proton flux produced by small angle scattering from a 30 mg/cm^2 gold target. Although this was not an ideal experimental configuration, it did serve to verify that the major cause of the observed differences in the behavior of the detectors when irradiated with protons or with neutrons is the volume of the detector that is actually damaged. Charged particle damage is generally restricted to the central 12% of the total volume of the crystal by the collimating aperture which defines the solid angle. Neutron damage, however, is not restricted by the aperture, and is generally distributed uniformly over the entire volume of the detector. Hence, a deterioration of the detector resolution, as measured with a ^{60}Co source, is observed well before depletion bias changes are evident when the detectors are damaged by neutrons. Conversely, since only a fraction of the detector volume is damaged by charged particles, the ^{60}Co resolution appears to remain good even though a large depletion bias change is observed because much of the crystal volume is undamaged. While the damaging radiation during these measurements was primarily protons, the effects of neutron damage were simulated by removing the collimating aperture from one of the telescopes to permit uniform irradiation of the whole cyrstal. A

Table IV. 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	352	11	744	NA
501- 9.6	n	~ 2.0	4.4	100	400	488	15	857	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	616	15	505	NA
501- 6.7	n	10.77	2.7	1800	200	1714	97	2380	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	898	25	1153	NA
517- 9.7	n	~15.0	1.2	1500	200	1772	88	2128	NA
				STOPPING DETECTORS					
172- 3.1	p	10.6	0.98	350	2000	721	23	538	1.23
514- 7.0	p	~15.21	1.86	1600	2000	2109	118	23656	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	56	7	84	0.93
602- 6.1	n	~20.0	0.75	1700	1500	69	8	1551	0.63

more detailed description of these effects and the collective experiences of using germanium detectors for intermediate energy charged particles was recently published.[2]

In addition to these effects, there have been hints both at IUCF and elsewhere that the rate of irradiation may be far more important than previously thought. The detector resolution degradation and depletion bias changes are not just linearly proportional to the number of intercepted particles, but are also dependent on the rate at which they are intercepted. Hence, a significant amount of self annealing must occur even when these detectors are maintained at LN_2 temperatures. These effects have been observed in practice, but have not been measured precisely. IUCF and LBL are collaborating on a recently approved experiment (#267) to carefully measure these effects. A grant has been received from NASA, which has an interest in this because of the planned use of germanium detectors in satellite borne experiments, to construct two multi-detector cryostats to perform the proposed experiment. The neutron damage rate effect studies will be carried out with a neutron source at LBL and proton damage rate effects will be studied with the beam from the IUCF cyclotrons. The difference in anneal rate reported earlier will be measured during these experiments as well. In addition to having a significant impact on the way germanium detectors are used here, these measurements could possibly provide information on "short term annealing" in Germanium. The experiments with the proton beam are expected to be carried out in June.

1) 1982 IUCF Scientific and Technical Report (Germanium Detector Development), p. 215.

2) R.H. Pehl, D.L. Friesel, and P.N. Luke, Nucl. Instr. & Methods A242, 103 (1985).

Computer Hardware - D. DuPlantis

The laboratory took delivery of its fourth VAX class computer, a VAX 8600, in 1985. This concludes a series of purchases outlined in an October 1981 report "Plan for Data Acquisition and Scientific Computers at the Indiana University Cyclotron Facility". The computers were purchased at the rate of one a year, three VAX 11-750's and finally a VAX 8600. It is interesting to note that we planned the purchase of the 8600 three years before it was released. It was called a VAX 7X0 in our report, and its purchase had to be delayed one year due to its late availability. Because of the stretched out purchasing plan, users have had to be flexible. VAX 750's have been used to run analysis codes until the arrival of the 8600, clearly a less than optimum situation. Available disk space has been rationed to allow for on-line acquisition to compete with off-line and analysis work in the same environment.

The arrival and installation of the VAX 8600 in late November 1985, was relatively uneventful. The computer, configured in the so-called clustered package, consisted of an 8600 SPU, 12 Megabytes of memory, 104 communication lines, floating point accelerator, cluster controller, two RA-81, 456 Megabyte disk drives, and two TA-78, 6250 BPI tape drives. We added a third RA-81 disk drive from an existing VAX 11-750. Though we were interested in attaching at least one of the VAX 11-750's to the cluster, the necessary hardware was not purchased due to budgetary constraints. After a short breaking-in period with the usual minor problems, the computer was available to users on January 14, 1986. Though the computer "benchmarks" at something like 5 to 6 VAX 11-750's, some of the analysis codes, which heavily use G Floating point expressions, ran 20 times faster than on the 11-750. Needless to say, for the short term, users are delighted and the queues flow smoothly.

The arrival of the VAX 8600, meant that the computer systems underwent a major reconfiguration for hopefully the last time. The following table is a summary of the current situation.

The VAX node "Hera" is now installed in the Cooler computer area. The computer is coupled into the laboratory Ethernet over an 150 meter optical link. The installation of its air-conditioning system and the MBD for the front-end will proceed during 1986. The operation of the focal-plane detection system for the new spectrometer will be performed from the Cooler building adjacent to the spectrometer location.

The first of the Harris Computers was decommissioned during 1985. System "A" was removed from the downstairs control room, along with its data station, CAMAC crate, and other support equipment. This is the first step toward the total phasing out of the Harris computers. All new experiments are strongly encouraged to be VAX based. It is anticipated that, as the CSB experiment comes to a close, there will be no additional on-line Harris computer support furnished. A single Harris computer will be maintained for replay as long as it is possible to do so without an unreasonable level of support.

TABLE V

Summary of IUCF Acquisition and Analysis Computers

Nodename:	Location:	CPU:	Memory:	Disks:	Tapes:	Comments:
VENUS	Main computer room	8600	12 MB	3 RA-81	2 TA-78	Analysis computer
APOLLO	Main computer room	11-750	5 MB	1 RA-81	2 TU-78 2 TU-77	On-line acqusition MBD in control room
ZEUS	Main computer room	11-750	3 MB	1 RM-80	1 TU-77	On-line acquisition MBD in control room
HERA	Cooler computer room	11-750	4 MB	1 RA-81	1 TU-77	On-line acqusition Spectrometer, TOF
"SYSTEM B"	Control room	Harris	192 KB	1 28 MB	2 Lo den	Last generally available Harris computer
"SYSTEM C"	CSB Hut	Harris	288 KB	1 28 MB	2 Lo den	PNF experiment use

Data-Acquisition Software - N.R. Yoder

The VAX data-acquisition programs have continued to be developed, with more feedback from experimental users. Several experiments have used the VAX-11/750 computers for acquisition. Data-acquisition software development has been concentrated on the XSYS program (originally written at TUNL).

The major part of the graphics display development was completed. The display program features include multiple spectra in windows of variable sizes and ability to use all of the laboratory graphics terminals and plotting devices. Device independence is achieved by using the Unified Graphics System; device driver modules have been developed to support all laboratory graphics terminals and plotters, including the Seiko GR-2414-50 high-resolution color terminals.

The VAX data-acquisition systems have performed generally as expected during experiments. As previously reported, we can achieve about 13000 data words per second with 10% front-end dead time. Most experiments use multiple independent event streams.

The XSYS program is also available for data replay; options were added to permit writing event-output tapes containing processed event data, and also to directly replay event tapes produced by the RAQUEL program on the HARRIS computers. It is possible to replay RAQUEL event data at a faster rate on the VAX computers. Currently, work is being done to automate the process of specifying the experimental configuration. Another development to be done soon is support for an automatic fast-spin flip mode of operation. This will use the already established DECNET connection which links the VAX computers with the PDP-11/44 control computer, enabling the acquisition computer to more easily synchronize its actions with the polarized ion source.

The Los Alamos Q data-acquisition program has been tested in data-acquisition mode successfully at IUCF. This program is now installed on all the VAX computers. Q will not be quite as fast in terms of raw acquisition or basic event processing, but it offers certain advantages. The Q histogram display programs, which originally required terminals emulating 4010 protocol, have been converted to use the Unified Graphics System. Q will be used for the focal-plane detector system development, as well as for some experiments in the near future.

High-Energy Polarimeters E.J. Stephenson

We have recently reviewed the calibration of the high-energy beam line polarimeters used in the measurement of polarization transfer. Several corrections, which will be described below, have now been applied to the calibration.

The high-energy polarimeters consist of three pairs of NaI(Tl) detectors mounted in the switchyard and beam line 5. When operated with the QDDM, they provided a continuous monitor of all components of the proton beam polarization for beam energies near 200 MeV. Each pair of detectors observes protons elastically scattered from a thin carbon target at a laboratory angle of 20°. The calibration compared the analyzing power of these detector pairs with that for proton elastic scattering from ^{12}C at a laboratory angle of 12.5°. This reference reaction and scattering angle were chosen because of the availability of double scattering measurements at a number of bombarding energies near 200 MeV. The reference reaction was observed by the QDDM with normal (vertical) polarization, and each polarimeter detector pair was mounted in turn in a horizontal configuration upstream to make the comparison.

The calibration data set consisted of cross section and vector analyzing power angular distributions measured between 11.5° and about 20° with the QDDM, and asymmetries taken from the polarimeter detector pairs. Since the same beam passes through both targets, a direct comparison of the polarimeter asymmetry with the 12.5° measurements should provide the needed calibration. Online, polarimeter analyzing powers between 0.96 at 170 MeV and 0.81 at 200 MeV were recorded. We have now applied several corrections to these measurements. Cross section measurements on both sides of the beam were used to determine the angular offset of the beam on the QDDM target. In addition, a scale factor difference, which can arise from unequal spin up and spin down polarizations, was removed from the analyzing power measurements made on both sides of the beam. This difference was checked in most cases against measurements of the polarization magnitude difference made in beam line 2. The agreement was good. Since there is no stabilization of the beam position on the polarimeter, the analysis gives a value of only the average polarization of the two spin states. This average was also corrected to second order for the difference in spin-up and -down magnitudes.

Figure 12 shows the 12.5° analyzing power reference curve as a function of momentum transfer (or beam energy). The solid point measurements come from double scattering experiments at Uppsala and Rochester. In principle, these points provide a primary standard for the analyzing power scale. To clarify the energy dependence in the neighborhood of 200 MeV, we also considered elastic scattering measurements at 160, 200,

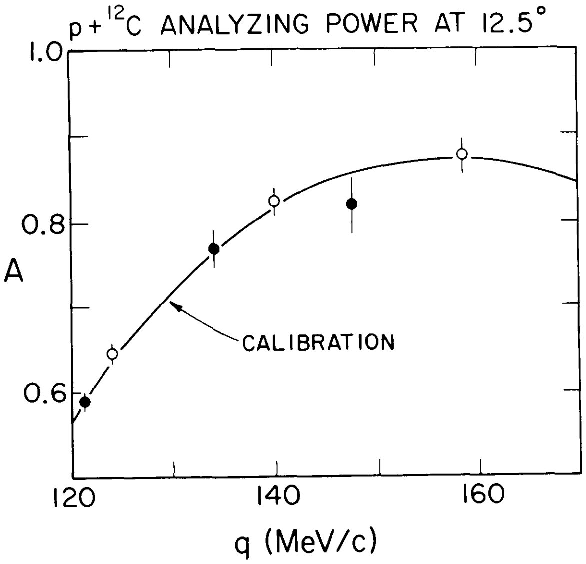

Figure 12. The reference curve used in the high-energy polarimeter calibration showing analyzing power at Θ_{lab} = 12.5° as a function of momentum transfer (or bombarding energy). The solid points are taken from double scattering experiments at Uppsala and Rochester, and the open points are taken from elastic scattering angular distributions measured at IUCF and TRIUMF.

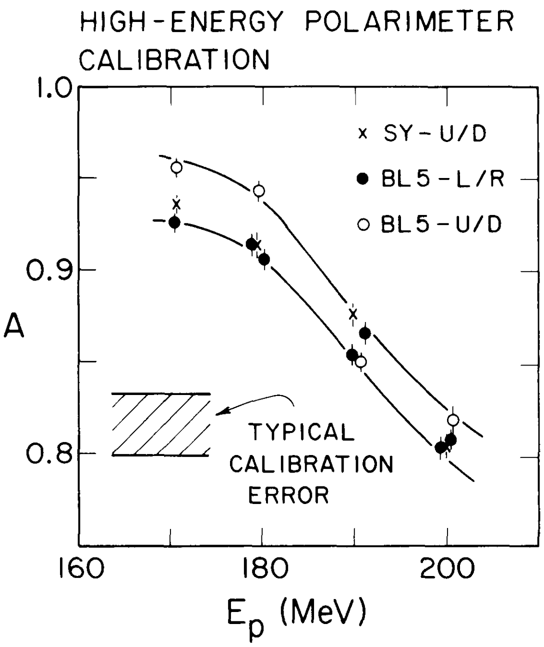

Figure 13. The calibrated analyzing power of the three high-energy polarimeter detector pairs as a function of bombarding energy. The errors are statistical only; the typical scale error in the Fig. 13 reference curve is also shown. The smooth curves which bracket the data are a guide to the eye.

and 250 MeV, as shown by the open circles. The reference curve is a stiff spline fit to all of the available measurements and is consistent with all of the available input.

The analyzing power calibration for each detector pair is shown in Fig. 13. Two detector pairs (left/right and up/down) were located on the beam line 5 polarimeter, and one (up/down) on the switchyard polarimeter. The errors shown in the figure are statistical only. There is more variation among these measurements than is indicated by the statistical errors. Since these variations are not systematic with detector pair, they are unlikely to be associated with opening angle differences (and thus real analyzing power differences). The solid lines are guides to the eye outlining the range of variation in the calibration. Also indicated is the size of the scale error associated with the reference curve of Fig. ?X.

These polarimeters are now available for general laboratory use, and have the desirable feature of providing information on all spin components concurrent with data acquisition.

Wire Chambers - K. Solberg

(i) Multiwire Proportional Chambers

During a CSB run a near disaster occurred when the gas was accidentally shut off while the chambers were running. A gas pressure monitor was added to the system in order to prevent this from happening again. If the gas pressure drops below the set point on the gas monitor, an audible signal is emitted and a logic signal is sent to the computer.

(ii) Wire Winding Machine

The table for the wire winding machine was fabricated during 1985 and the entire machine was assembled. The prototype x-chamber for the K-600 was wound on the new machine. The machine performed adequately for construction of the prototype but a few flaws, which must be cleared up, remain.

Some development time was spent trying to use the wire winding machine as a scanner for measuring the position of the wires in an assembled chamber. The system appears to be feasible, but the flaws in the wire winding machine must be cured before we can implement the system.

(iii) Gas Handling System

Parts were ordered for the gas handling system for controlling pressure in a chamber from a few torr to 10,000 torr. After the parts arrive, the gas handling system will be assembled.

Target Lab Technical Status - W. Lozowski

Target preparations for 1985 included: CD_2, $^{6,7}Li$, ^{10}B, $H_3{}^{10}BO_3$, ^{11}B, $^{12,13}C$, ^{15}N-melamine, ^{15}N gas cell charging system, $Al_2\,{}^{16}O_3$ of 80-687 $\mu g/cm^2$ self-supporting foil, ^{27}Al, ^{30}Si, ^{34}S, $^{40,42,44,48}Ca$, ^{59}Co on Be, $^{66,67}Zn$, ^{72}Ge, $^{86,88}Sr$, ^{93}Nb, Ag, Au, ^{183}W, WO_3, ^{208}Pb, ^{209}Bi, $^{238}UF_4$.

In February, the target lab assistant began working on a full time basis. This was done to allow more effort to be directed toward development of cooler targets.

At long last, the modifications and hookup of the double-work-station glovebox were completed, compliments of an extended accelerator shutdown at the end of the year. The glovebox is a wonderful addition to the fabricating, loading, transfer and long-term storage of air sensitive materials in the lab. Briefly: both the swinger target assembly and the vacuum transfer for the ORTEC scattering chamber mate to the glovebox; the pion production target chamber will pass through the ante chamber; target storage jars may be evacuated inside the box; a small rolling mill is inside; an electrobalance is inside; there is ample room for storage on shelves in the rear of the box; one may use a motorized drive chain to retrieve an otherwise hard-to-reach target jar; and moisture and oxygen levels should be 1-5 ppm.

Some target development highlights of 1985 were:

1. A foil handling device was developed which significantly reduces the risk involved in handling and mounting very thin foils: especially those which tend to curl when free. The foil is simply sucked onto the flat end of a tube on which a 325 mesh stainless steel screen has been glued. In this variation of a vacuum probe, the screen is somewhat larger than the foil to be held and the suction force is controlled by throttling the vacuum connection. Using the device, tightly curled 250 $\mu g/cm^2$ x 25 mm square $^{24,26}Mg$ foils were coaxed flat and released successfully on a target frame which had been lightly coated with uncured epoxy mix.

2. Pressed powder targets/samples of 375 mg/cm^2 were prepared which have specific levels of desired elements

in the range of 5 to 1000 ppm. This experience was gained as a result of an IUCF experiment concerned with the quantification of Ir in clay soil samples. Forty clay pellets were prepared and doped with 0.5-2μl of standard solutions of Ir, Mn, Fe, Mg, Co and Ba cations. Several preparation difficulties were encountered and surmounted.

3. Special targets of ^{183}W powder on Be foil were developed and fabricated for unique Mossbauer experiments conducted jointly by Purdue and Missouri Universities. The work presented an opportunity to push air-settling and adhesion techniques at IUCF (which it did). The targets were 0.5 - 1.5mg/cm^2 ^{183}W powder uniformly distributed over an area of 1cm x 2.7cm. Pressure sensitive adhesive of 16 - 40μg/cm^2 held the powder in place on the 5 - 10mg/cm^2 Be support foils. The targets were double-sided in that the ^{183}W powder was distributed on both sides of the Be.

4. For the first time (at IUCF) $^{66,67}ZnO$ was reduced to the metal, consolidated, and rolled to make targets of ~14mg/cm^2. Overall efficiencies of 82 - 87% were achieved for the expensive isotopes and the fabricated targets were reported to have been "very clean".

NEW FACILITIES

The IUCF-Maryland Dual Spectrometer System - P. Schwandt

After nearly three years of design, fabrication and acquisition of all major components for the K600 and K300 dual spectrometer system, installation of the system in the north high-bay area of the original accelerator building (see IUCF floorplan, Fig. 4) finally began in late spring of 1985, as detailed below. Early in the year the decision had been made to concentrate efforts on bringing the K600 spectrometer into operation first and delay installation of the K300 magnet and its support carriage until some time after completion of K600 tests with beam because of limited manpower resources and the press of competing development projects. We managed to complete the major portion of the K600 installation by the end of 1985. We were unable, however, to realize our original goal of first tests with beam of the K600 system by the beginning of 1986, partly because we underestimated the magnitude of the workload represented by the multitude and complexity of all the subsystems involved, and partly because of unavoidable (and in some cases unforeseen) diversion of critical technical personnel to other high-priority projects such as readying the CSB experiment for production running and rebuilding the swinger area shielding and exterior beam dump during October, extensive cyclotron repair and development work during a prolonged, unscheduled shutdown in December caused by a major component failure, and the beginning of necessary electrical installation work in the Cooler building.

The first phase of the K600 installation process began in May 1985 with the removal of the roof beams and wall blocks comprising the beam swinger area shielding. This allowed installation of magnets for the new beam transport line (BL8) to the spectrometer