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ATLAS
EXPERIMENTAL EQUIPMENT

ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

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ATLAS EXPERIMENTAL EQUIPMENT

November 1983 Workshop and Present Status

MASTER

Argonne National Laboratory, Argonne, Illinois

Forewor:

This report is intended to provide users with detailed information about the experimental equipment which will be available for use with ATLAS. It contains summaries from our latest Workshop on ATLAS Experimental Equipment and information on new developments since then. Any additional questions can be directed to the ATLAS User Liaison Physicist or other staff members at Argonne. A list of experimental equipment is given at the end of this report together with names of staff members most familiar with the individual pieces of apparatus.

We gratefully acknowledge financial help from the University of Chicago in supporting the workshop and the printing of this report. Special thanks also go to Sheryl Puro for organizing the workshop and typing this summary.

A limited number of additional copies is available upon request.

Walter Henning
Physics Division
Argonne National Laboratory
December, 1984

Contents

I. Introduction

The ATLAS construction project is nearing completion, with first beams expected in late spring 1985. In addition to approximately doubling the accelerating voltage and mass range of the present prototype superconducting linac booster, the ATLAS project includes as a major component the construction of a new target area with its associated experimental equipment. Design and construction of this equipment has been underway for some time now, and assembly of some of the stations has started in the ATLAS target area.

With ATLAS being a national facility, an effort has been made to include outside-user input in the planning and, if desired, in the construction of the experimental apparatus. Two general workshops and one aimed specifically at the construction of a gamma-ray facility have been held, the first two at the Physics Division at Argonne National Laboratory and the latter at the Physics Department at the University of Notre Dame. The gamma-ray facility is a joint project of Argonne and the University of Notre Dame.

The latest workshop was held in November 1983 with the purpose of presenting an overview of the experimental stations planned for ATLAS, describing the current status of each individual apparatus, soliciting final input on devices of the first phase (i.e. on those that will be ready when beams from ATLAS become available in late spring of 1985), and discussing and collecting new ideas on equipment for the second phase. There were short presentations on the status of the various projects followed by informal discussions. The presentations mainly concentrated on new equipment for target area III, but included some descriptions of current apparatus in target area II that might also be of interest for experiments with the higher-energy beams available in area III. The meeting was well attended with ~50 scientists, approximately half of them from institutions outside Argonne.

The present proceedings summarize the presentations and discussions of this one-day meeting. In addition we take the opportunity to include information about developments since this meeting and an update of the current status of the various experimental stations. We would like to emphasize again that outside-user input is extremely welcome.

II. Agenda of the ATLAS Workshop

Agenda of the ATLAS Workshop
Argonne, Physics Building, R-150, Nov. 8, 1983

9:00 A.M.	Welcome	D. S. Gemmell, ANL
9:05	Introduction to Workshop	W. Henning, ANL
9:15	Status of ATLAS	L. M. Bollinger, ANL
9:45	BGO Spectrometer and Multi-Compton Spectrometer System	R. V. F. Janssens, ANL U. Garg, Notre Dame
10:30	Coffee Break	
11:00	Charged Particle Scattering Facility	D. G. Kovar, ANL
11:30	Superconducting Solenoid for Charged Particles	R. Stern U. of Michigan
11:45	On-Line and Off-Line Data Analysis	L. Welch, ANL
12:00	Gas-detector Development	R. R. Betts, ANL
12:15	LUNCH	
1:00 P.M.	Tour of ATLAS Building	L. M. Bollinger, ANL
1:30	Splitpole Spectrograph	E. Rehm, ANL
1:50	The Recoil-Mass Separator for Heavy Reaction Products at ORNL	S. G. Steadman, MIT
2:10	The Rochester Reaction Product Mass Spectrometer	T. M. Cormier, U. of Rochester
2:30	Discussion on Heavy Fragment Analyzers	
3:00	Coffee Break	
3:30	Cryogenic He-Jet/Laser	D. Lewis, Iowa State Univ.
3:45	Atomic Spectroscopy	G. Berry, ANL
4:10	Superconducting-Solenoid e^- Spectrometer	Z. W. Grabowski, Purdue
4:15	General Purpose Beamlines and Facilities for Users	W. Kutschera, ANL
4:50	Summary and Closing	

III. General Remarks on ATLAS Experimental Areas and User Support

A layout of the complete ATLAS facility is shown in Fig. 1. Three target areas are associated with the accelerator: 1) Area I in the west target room for the FN-Tandem alone; 2) Area II for beams from the present linac booster and later from the first stage of ATLAS; and 3) Area III for beams from the full ATLAS accelerator. As already mentioned, area II has been in use with the linac booster for quite a while. Equipment in that area is completed except for some future modifications and expansions. It is anticipated that an additional beam line and target station will be installed in target room D, presently being used for assembling equipment for the beam lines and apparatus in area III. For completeness we show a layout for area II in Fig. 2, although no major equipment development is planned for those beam lines in the near future.

Discussions at previous workshops have resulted in the planned equipment for area III as indicated in Fig. 3. This equipment was the main subject of the November 1983 workshop, and detailed discussions are presented in this write-up.

Before discussing details of the apparatus, some information on the planned user operation of ATLAS may be useful. At the time of the workshop some of the support indicated below had already been established, some has been instituted in the meantime.

In order to provide a point of contact between users of the Tandem-Linac and the Argonne Physics Division, the position of User Liaison Physicist has been established. As of April 1, 1984, Cary Davids became the User Liaison Physicist. On January 1 , 1985, these duties will be taken over by Bruce Glagola. The major responsibility of the User Liaison Physicist is to provide the necessary support for outside users to successfully carry through

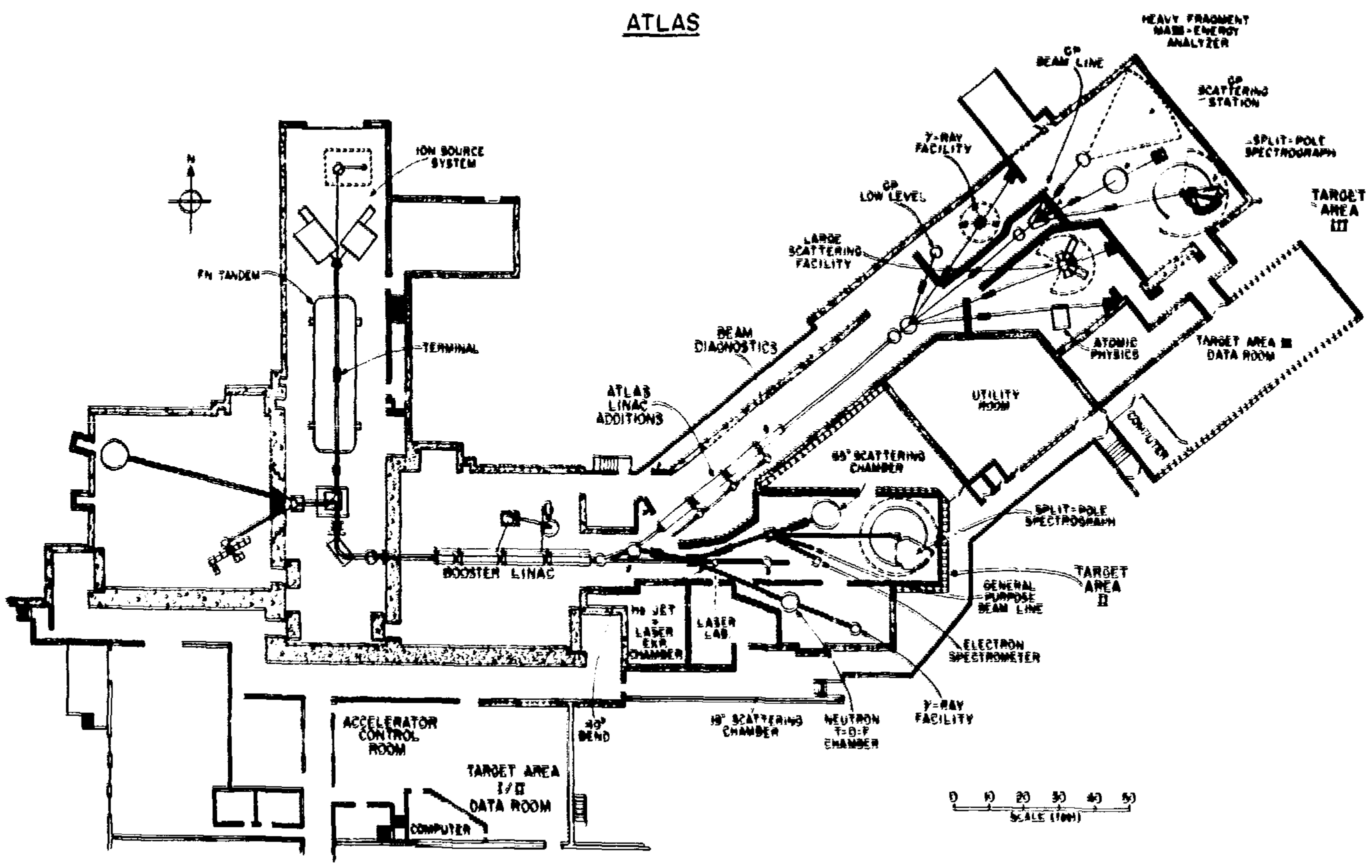

Figure 1.

Layout of the Argonne Tandem-Linac Accelerator System (ATLAS).

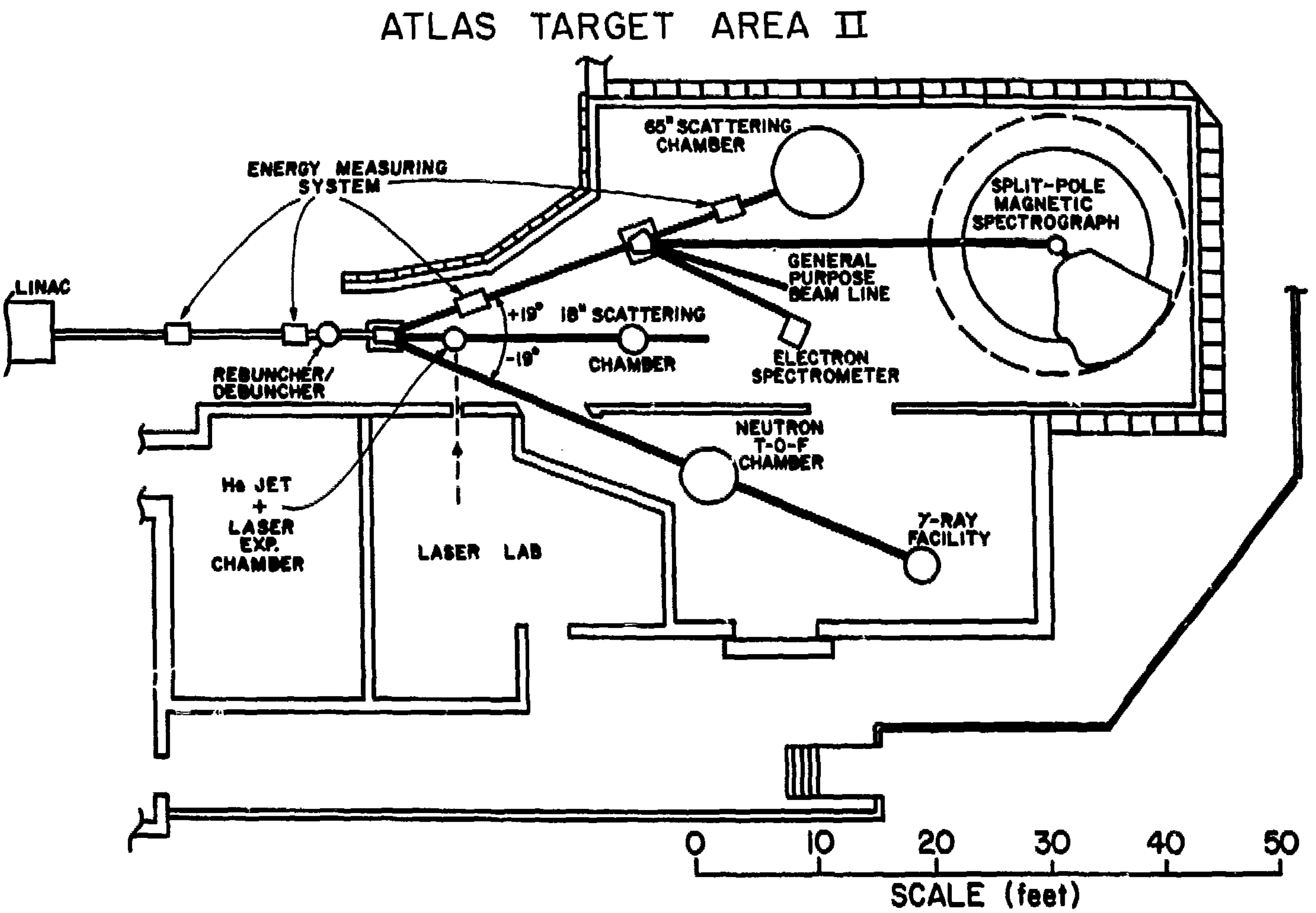

Figure 2.

Layout of beam lines in Target Area II and the locations of various experimental stations that are now operational.

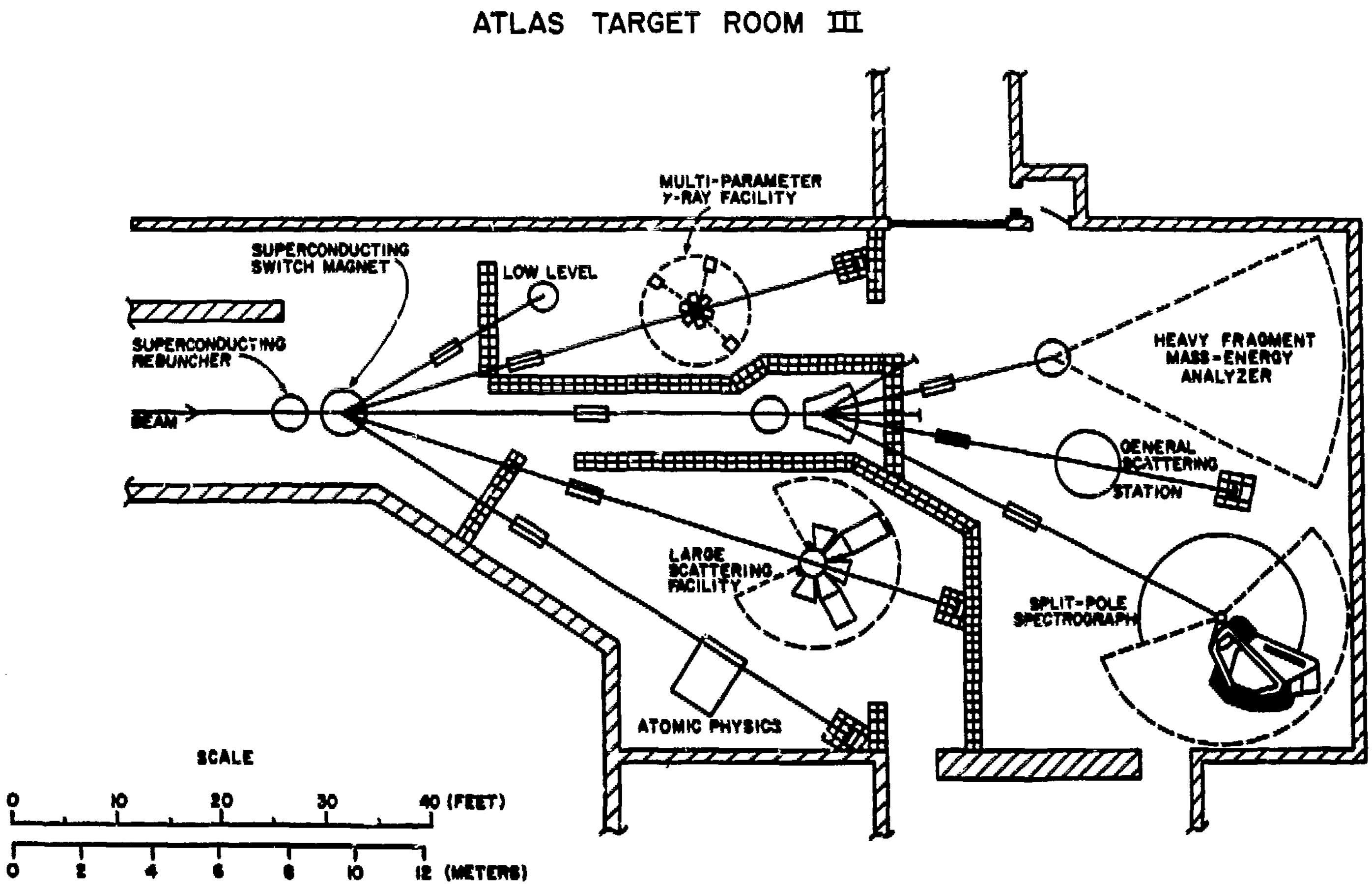

Figure 3.

Planned layout of Target Area III. The beam lines for the γ-ray facility, large scattering facility, the split-pole spectrograph, and the GP beam line are expected to be installed and operational in March, 1985.

their experiment at ATLAS. It also includes being the Secretary of the Program Advisory Committee. He can provide information regarding experimental facilities, availability of technical support for proposed experiments, lodging, travel, and other aspects.

An Experimental Support Group has been established and recently been augmented by an additional technician and a scientific assistant, enabling this group to provide more support for the Tandem-Linac users. To make the most efficient use of these resources, it is important that users requiring assistance inform the User Liaison Physicist of their needs well in advance of their scheduled beam-time.

The University of Chicago, which operates the Argonne National Laboratory, provides support for users of ATLAS. A car is available to users. Also, funds are available for travel support of users, especially students and those users who do not have adaquate travel funds. In this context, housing costs at the Argonne Lodging Facility for all outside ATLAS users are lowered by 50%. Early reservations are adivsed to ensure that room is available.

A Program Advisory Committe (PAC) for the Tandem-Linac has been meeting since 1983 to evaluate proposals. The present PAC members are: W. Benenson (MSU), R. Betts (ANL), E. Cosman (MIT), R. Diamond (LBL), J. Fox (FSU), and W. Henning (ANL). The committee is chaired by J. Schiffer, Scientific Director of the facility.

The first Tandem-Linac User Handbook has been distributed. It has information on the accelerator system, experimental facilities, Argonne procedures, and other points which should be helpful to the ATLAS users.

IV. Topics at the November 1983 Workshop

1. Properties of the ATLAS Accelerator System

(Presented by L. M. Bollinger)

Research with heavy ions at Argonne is performed using beams from the Argonne Tandem-Linac Accelerator System (ATLAS). The final accelerator system is expected to be operational in 1985. An overview of the Accelerator facility is shown in Figure 1 where beams are provided to three experimental areas; Target Area I (Tandem alone), Target Area II (Tandem plus 24 Resonators), and Target Area III (Tandem plus 42 Resonators). The major elements of the system are:

1) an inverted negative-ion sputter source of the FSU Chapman type,
2) an upgraded FN Tandem electrostatic accelerator capable of a maximum terminal voltage of 9 MV,
3) a linar accelerator consisting of independently-phased, superconducting niobium resonators,
4) a bunching system which produces beam pulses of 100 ps FWHM for acceleration by the linac,
5) a rebuncher/debuncher which allows the experimenter to manipulate the longitudinal phase ellipse for optimized timing or energy resolution on target,
6) a beam sweeper for control of the beam duty cycle, and
7) an energy measurement system based on time-of-flight measurements of the beam pulses.

In Fig. 4 the expected maximum projectile energies for heavy-ion beams from ATLAS for the various target areas are plotted.

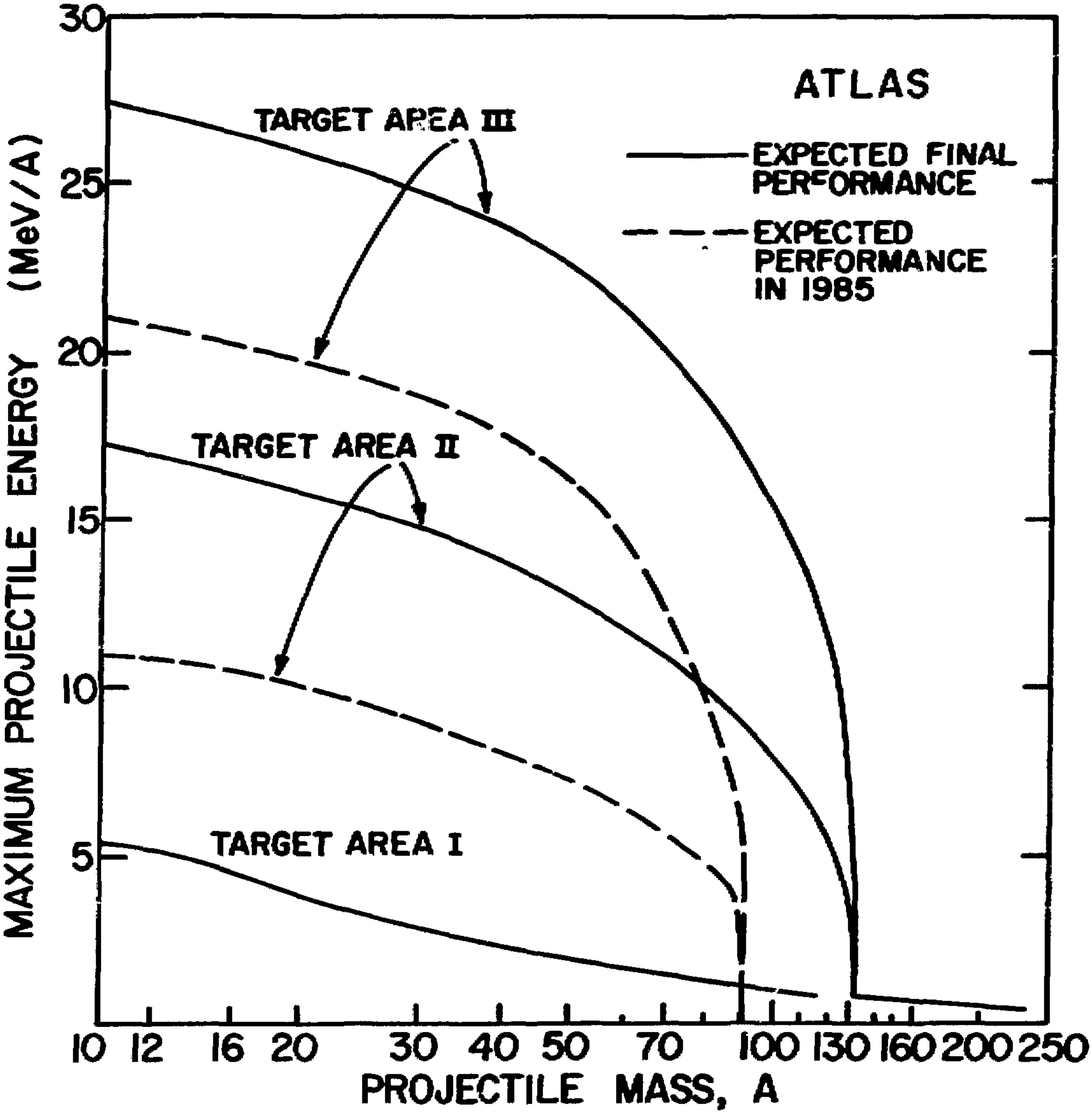

Figure 4.

Maximum projectile energies available from ATLAS. The dashed curves indicate the energies expected to be available in 1985 in the various target areas. The solid lines indicate what energies should eventually be possible.

2. Gamma-Ray Facility for ATLAS

(Presented by R. F. V. Janssens and U. Garg)

A proposal for a γ-ray facility for ATLAS to be constructed by a collaboration between the University of Notre Dame and ANL was submitted to DOE in summer 83 and has been funded for its initial phase. This facility will ultimately consist of a BGO array with 56 elements and 10 Compton-suppressed Germanium spectrometers (CSS) arranged in two rings around the array (see Figs. 5 and 6). The internal BGO array serves as a γ-ray calorimeter and also provides a measure of the γ-ray multiplicity distribution characterizing each event. Each CSS (Fig. 7) is expected to have excellent suppression over the whole energy range; for an incident photon of 1.2 MeV the expected peak/total ratio is $\gtrsim 0.64$, a figure which is comparable to the best that has been achieved for any Compton-suppression system. With 10 CSS's of this type, double- and triple-coincidence spectra of excellent quality can be obtained in a resonable time. The ability to select events within a specific range of sum-energy and multiplicity, together with the extreme sensitivity of the Compton-suppressed spectrometers, constitute a new tool for heavy-ion physics. Gamma-spectroscopic studies of very high quality and detail will be possible, promising significant advances in understanding nuclear structure as a function of spin and temperature. The instrument can also be used with ease in conjunction with charged-particle detectors located outside the BGO array. This will provide information toward a complete characterization of heavy-ion collision dynamics and reaction mechanisms. The instrument is ideally matched to the physics which can best be studied with ATLAS.

Due to the substantial amount of funding required, it has been decided to organize the construction in two phases. In the first phase, we plan to build a system comprising a small central BGO "ball" surrounded by an

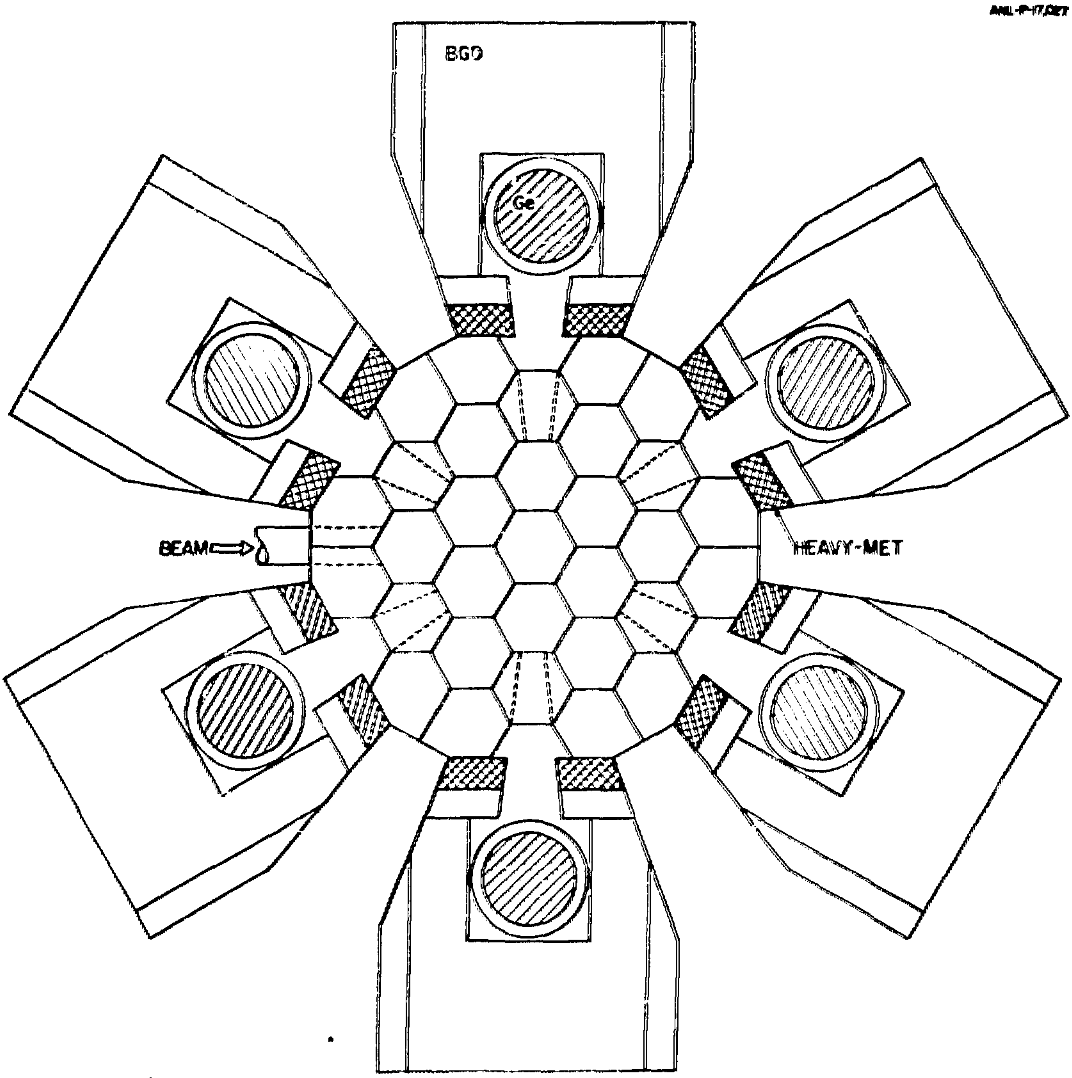

Figure 5.

Horizontal section of detector assembly. A central BGO array of 50 detectors is surrounded by two rings, each accommodating up to 6 Compton suppressed Ge detectors, located 20° above and below the equatorial plane. The array can also be used on a stand-alone basis, with additional elements on the outermost ring, for a full complement of 56. The diameter of the BGO array is $\lesssim$ 25 cm.

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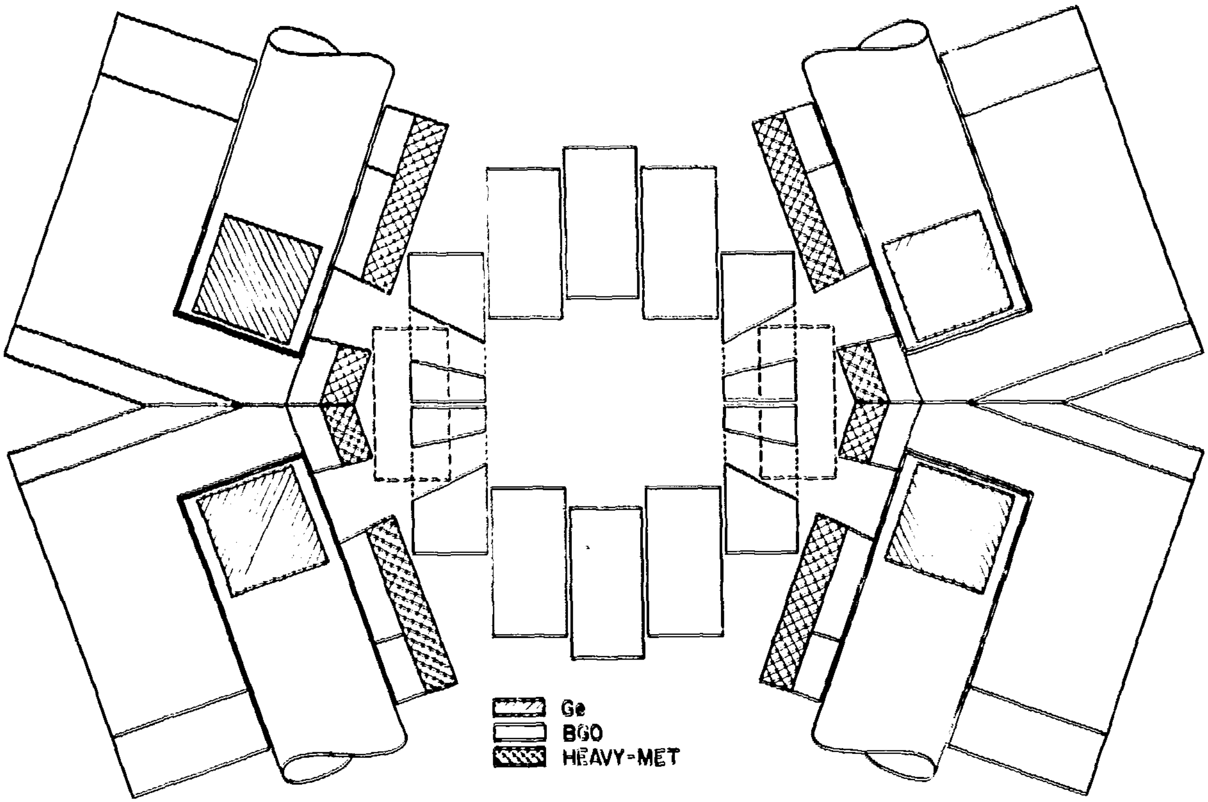


Figure 6.

Vertical section of detector assembly in a plane defined by the target and the center of a Ge crystal. 4 Compton-suppression spectrometers are shown around the BGO array. The internal space within the array could accomodate a chamber (or other apparatus) of 11.5 cm diameter and 8 cm height. The array can be pulled apart vertically into two halves if more space is required. The Ge crystals can be rotated around the target in the vertical plane to a maximum angle of 90° between crystals.

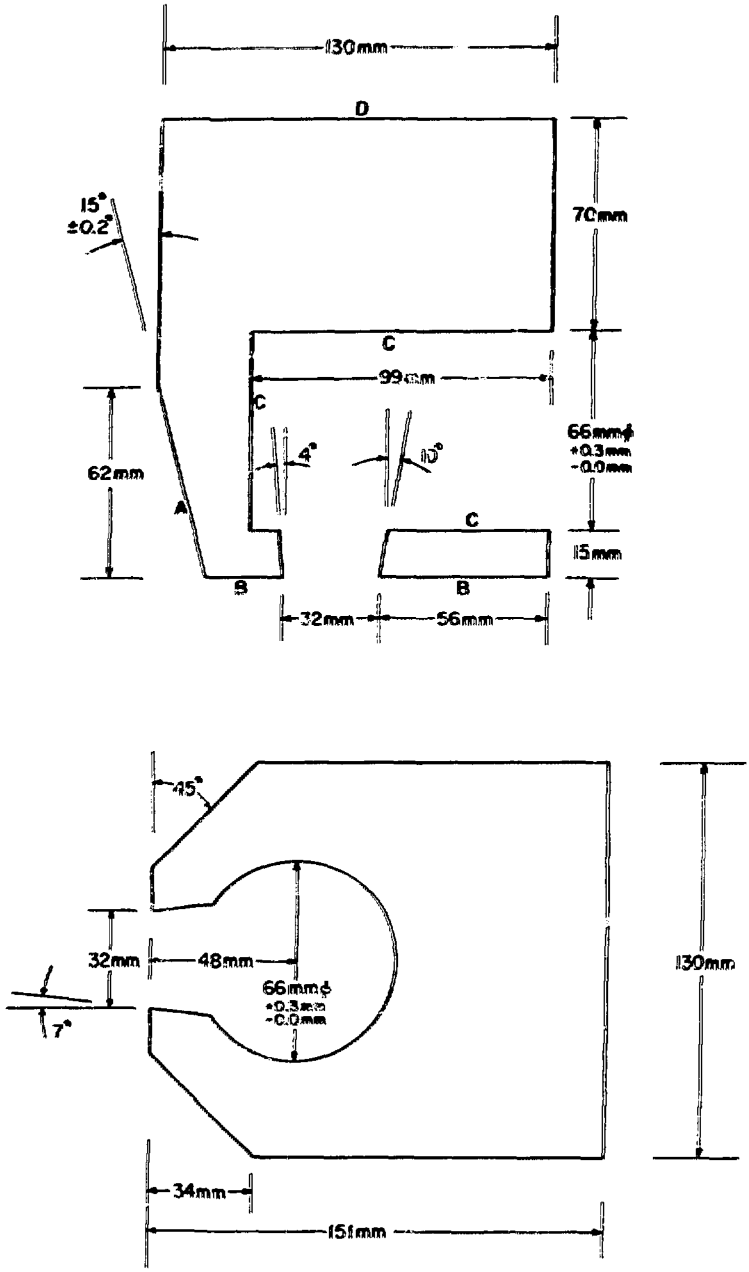


Figure 7.

BGO-Compton Suppression Spectrometer.
Upper part: View from the side;
Bottom part: View along the Ge crystal axis.

array of six Compton-suppressed Ge detectors. The mechanical support structure will, however, be constructed in such a way that it will accommodate the complete system without modifications. In the same spirit, the design of the electronics for the apparatus will also take into account the need for expansion towards the full system. The performance of the apparatus in the two phases is summarized in Table I.

Recently, prototype BGO elements have been acquired and the evaluation of a prototype BGO Compton Suppression Shield has been completed. Fig. 8 is a photograph of the shield along with a Ge detector and Fig. 9 shows the γ-ray spectra of a ^{60}Co source measured with this instrument and the suppression factor as a function of the detected photon energy. The overall performance of the shield is very satisfactory, being quite close to that expected. The peak/total ratios are 0.16 and 0.54 for the unsuppressed and suppressed spectra, using an n-type Ge detector with 16% efficiency. In the eventual facility, Ge detectors with efficiencies of > 23% will be employed for which peak/total ratios of > 0.64 are expected. In a gamma-gamma matrix >41% of the events will then be in photopeak-photopeak coincidences to be compared with a typical value of < 3% obtained with unsuppressed detectors.

Design studies are underway for the mechanical support of the entire device as well as for some electronics modules. Figure 10 shows a schematic diagram for the front end electronics of the BGO "ball". It is expected that the first phase of the gamma-ray facility will be ready by Fall 1985, although experiments using components will begin well before that.

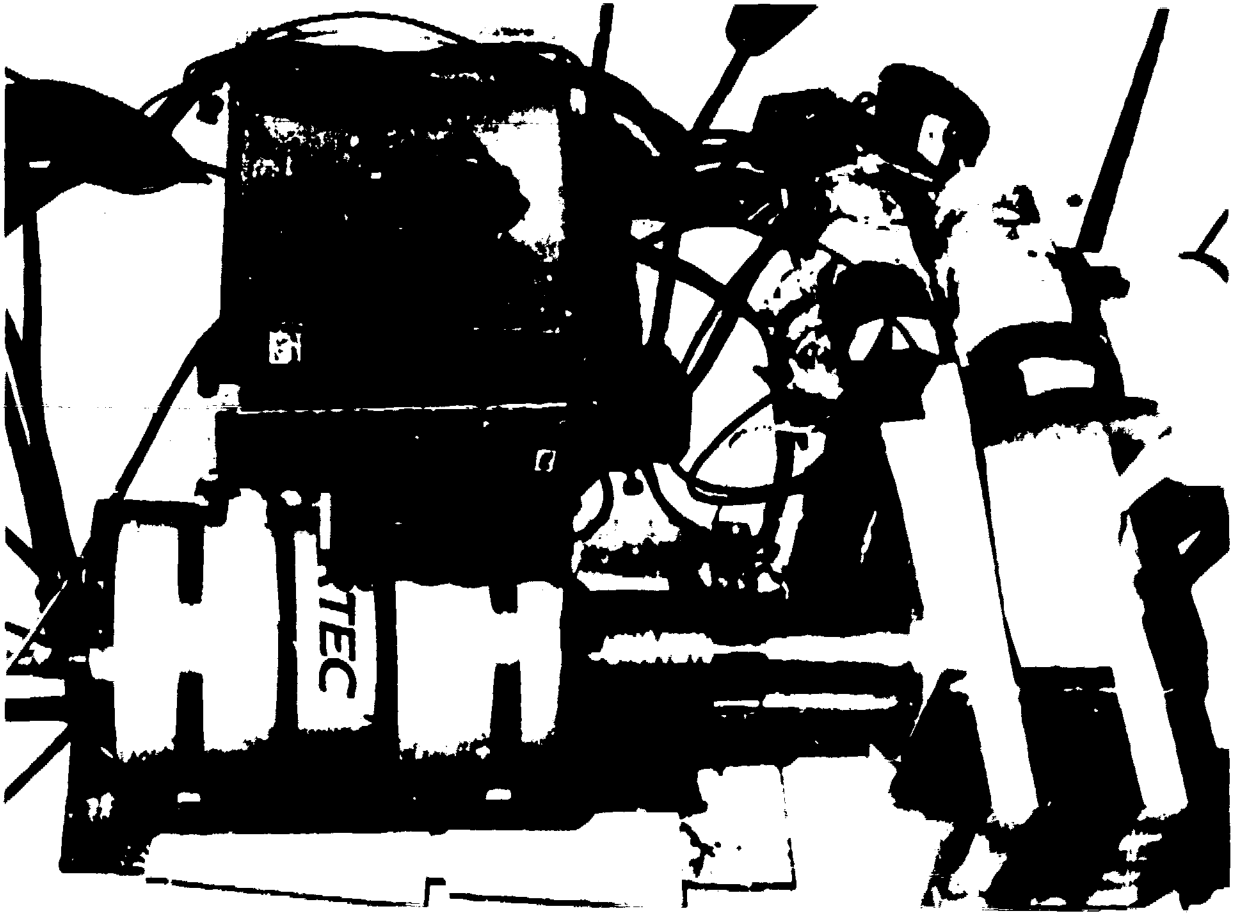


Figure 8.

A photograph of the Compton-suppressed spectrometer showing a Ge detector inside the BGO shield.

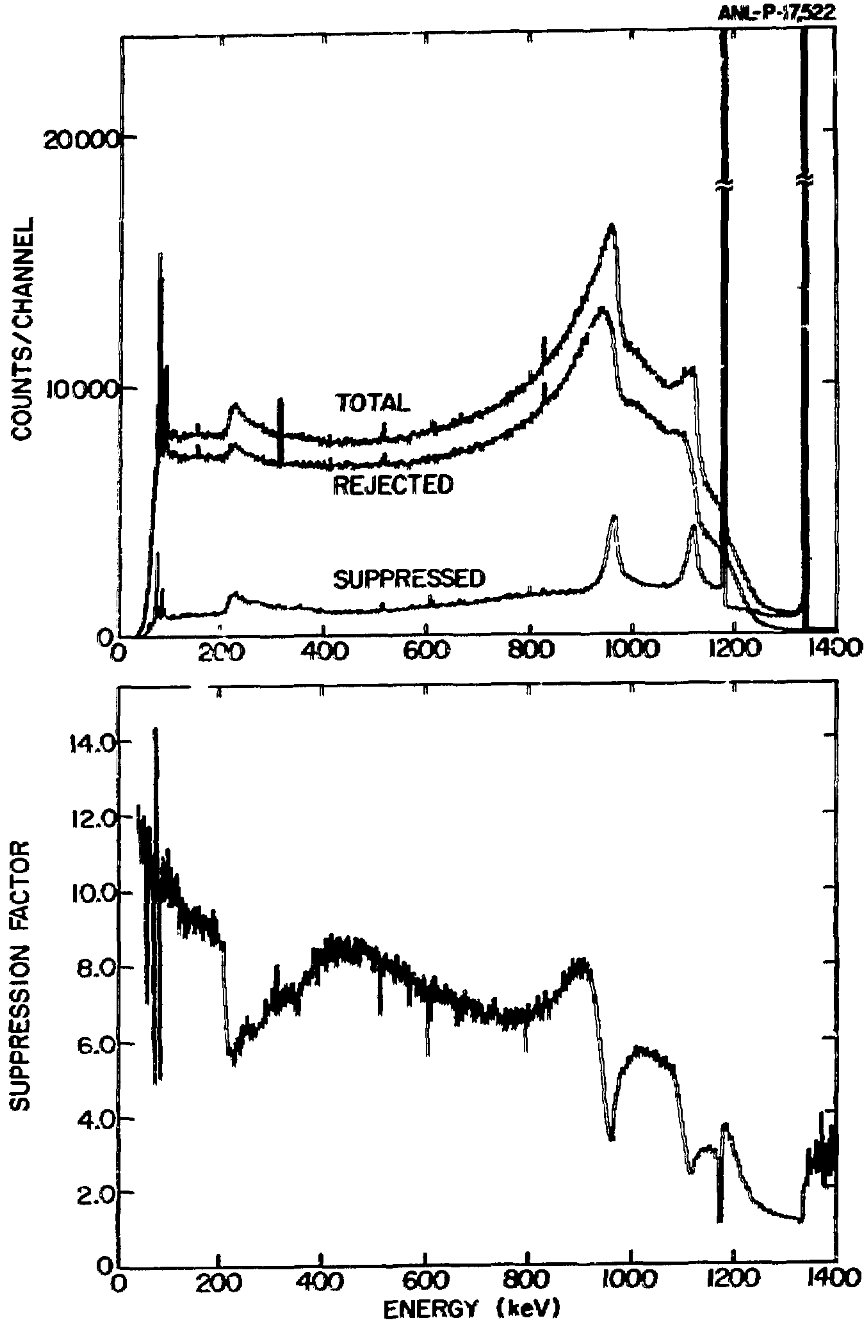


Figure 9.

Gamma-ray spectra of a ^{60}Co source (top) and the suppression factor obtained by dividing the total spectrum by the suppressed spectrum.

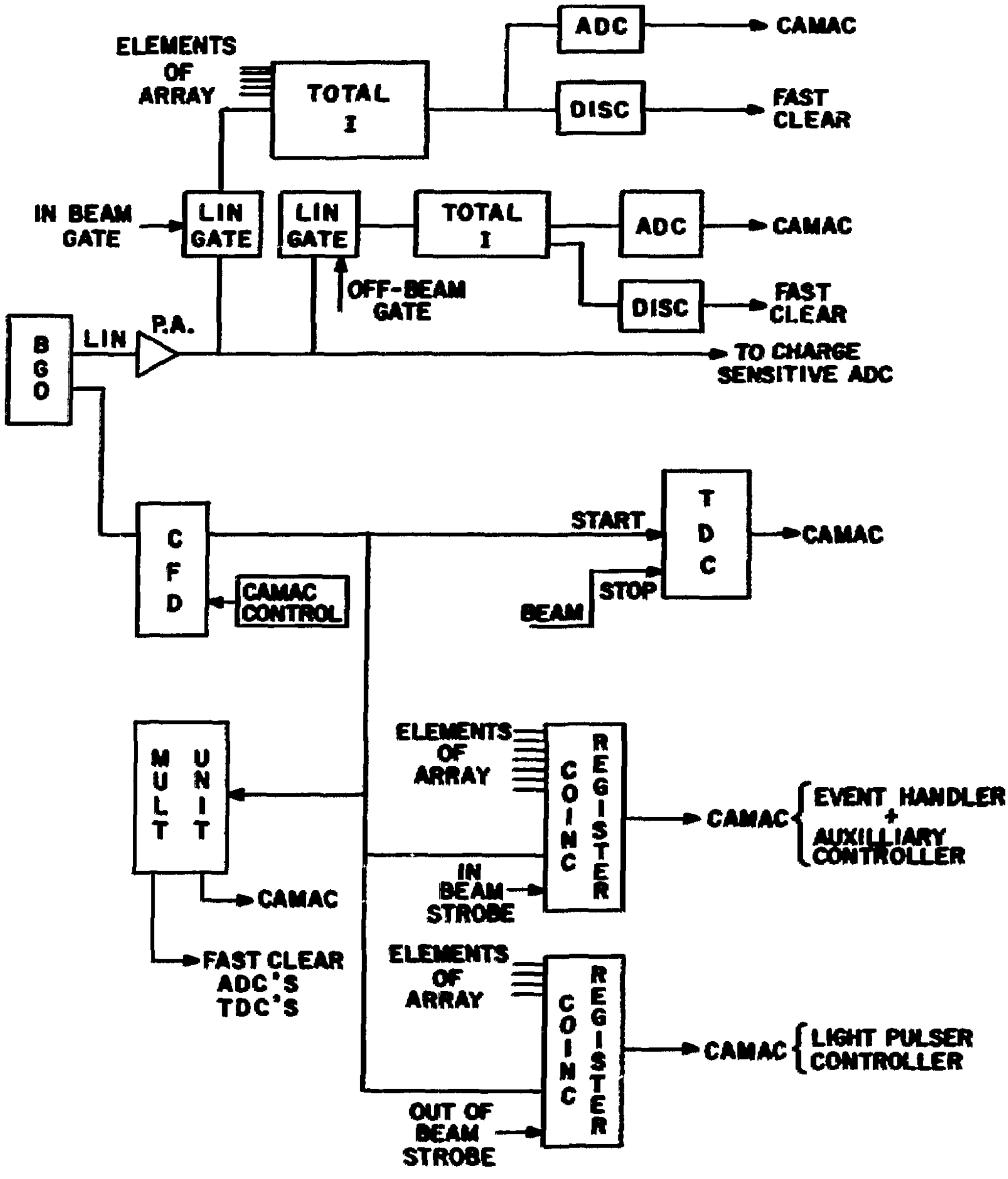


Figure 10.

Schematic diagram of Front End Electronics for the BGO 'ball'.

Table I. Characteristics of the proposed γ-ray facility.

	Phase 1	Phase 2
ARRAY		
Number of elements	14	50/56
Total efficiency		.85
Multiplicity Resolution	~65%	~35%
Sum Energy Resolution		~24%
CSS		
Number of elements	6	10
Peak/Total		.64
Target-Ge distance	<18 cm	18
Count rates for		
10^5/sec reaction rate (M=30)		
1 fold	1.6×10^4	2.1×10^4
2 fold	1.05×10^3	2.5×10^3
3 fold	35	170

3. Large Scattering Facility

(Presented by D. G. Kovar)

To accomodate a wide range of charged-particle experiments involving for example large area detectors and long time-of-flight distances two facilities seem possible: either a) a large vacuum vessel or b) a smaller vessel with movable extender arms. Extensive discussion before and during the workshop led to the design outlined below.

A schematic layout of the scattering chamber is given in Figs. 11 and 12. It is expected to be in a rudimentary operational mode in early spring of 1985. The central vacuum vessel is relatively small (36" diameter) where the upper half is rotatable by ±45° and the lower half is fixed. The upper chamber has five large (12" x 12") ports (in-plane and spaced by 45°) on which large area detectors or vacuum extensions can be mounted, and a sliding vacuum seal for the entrance beam pipe to allow for the rotation of the upper chamber under vacuum. The upper chamber is attached to a large rotatable platform which provides the torque for rotation and serves as the platform for supporting the detector systems attached to the ports. The lower fixed chamber houses three independently movable gear rings on which detectors can be mounted (similar to the 65" scattering chamber in Target Area II), the target assembly, and the various feedthroughs for cables and controls. It will be of stainless steel construction and teflon seals will be employed in the rototating seal between the upper and lower chambers, and the sliding seal at the entrance. Figure 13 shows a test setting for a sliding-seal arrangement based on teflon seals.

The various motions and readouts will be accomplished using a PDP-11/23 computer which will also have the capability for controlling the voltages and pressures for the more complex experimental configurations

SCHEMATIC LAYOUT OF CHAMBER CONFIGURATION

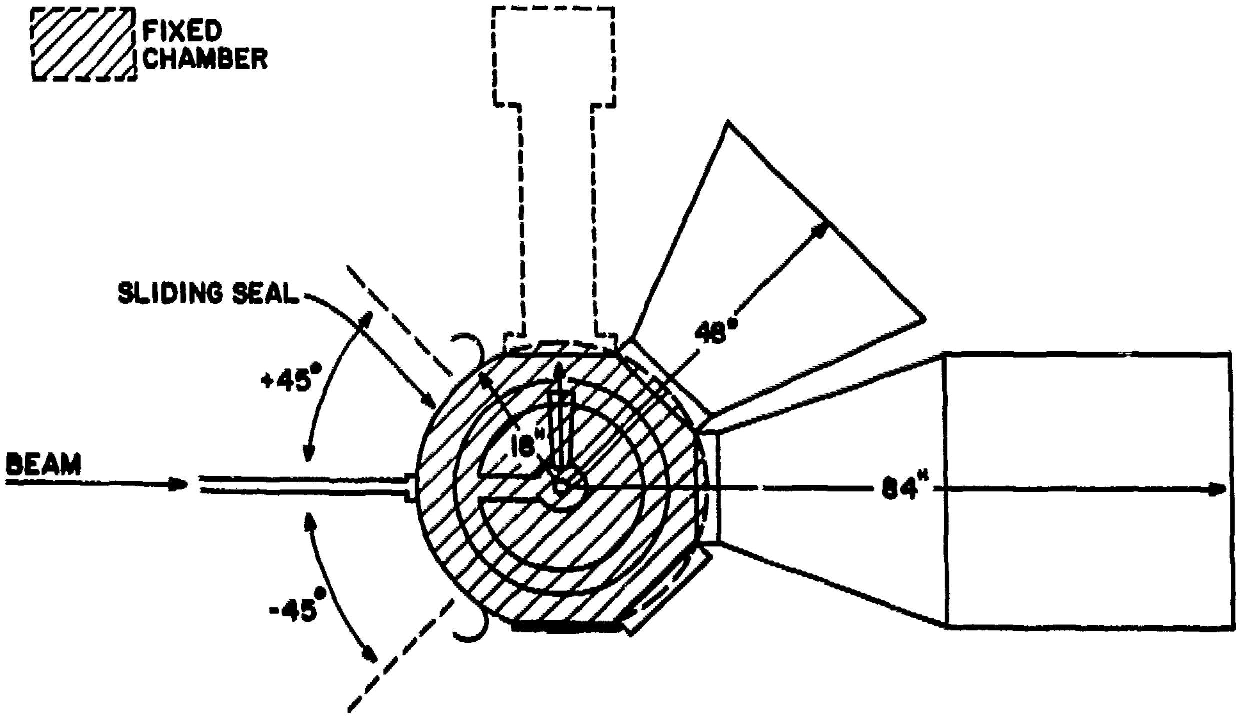


Figure 11.

Schematic layout of the scattering chamber configuration. The lower chamber (hatched) is fixed. The upper chamber which has five large ports (on which three possible detector configurations are indicated) has a sliding seal for the entrance beam pipe and can be rotated by ±45°. Three independently movable rings in the lower chamber will be used for mounting detectors inside the chamber.

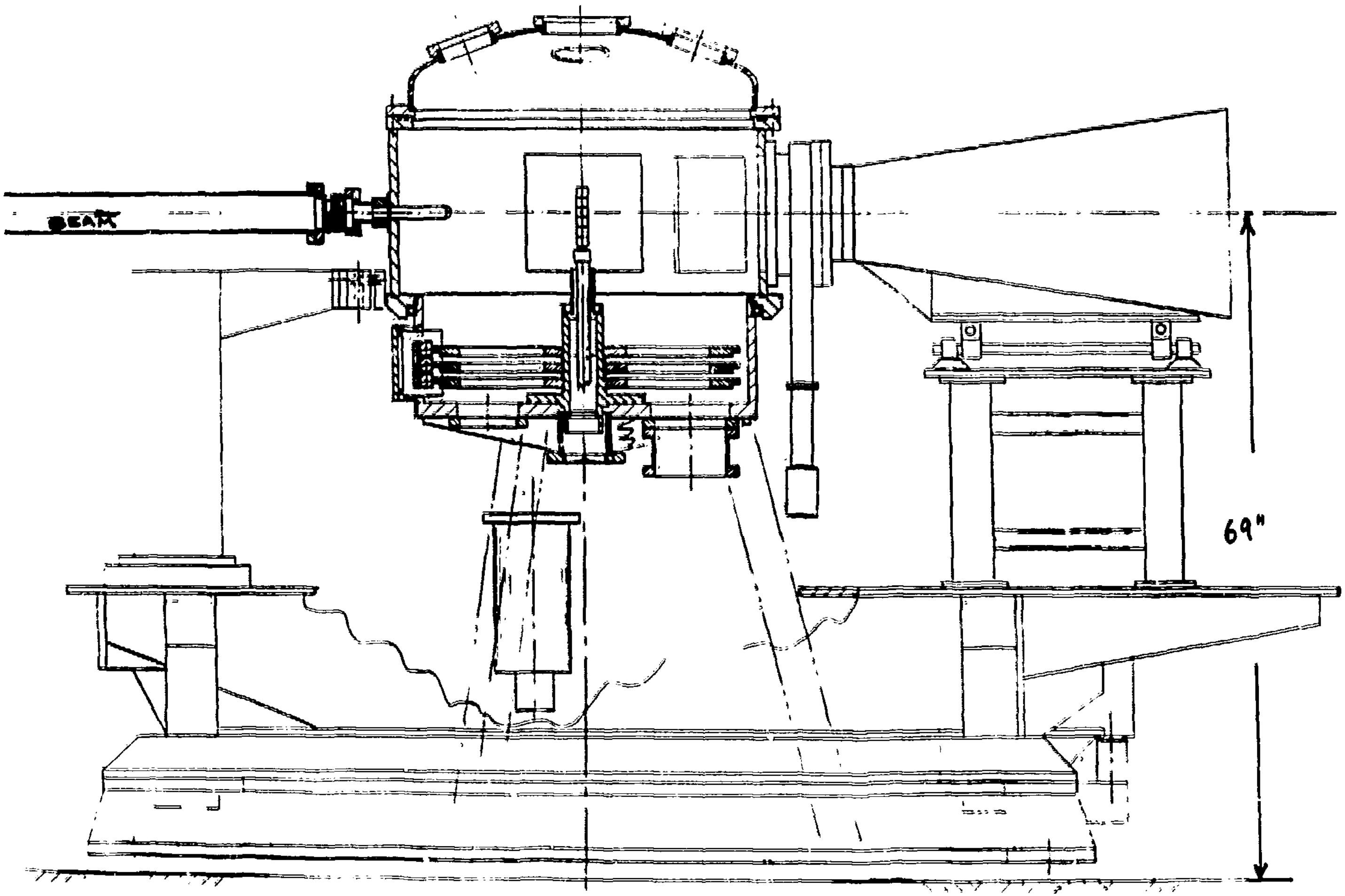


Figure 12. Schematic sideview of the Scattering Facility showing the central vacuum vessel with sliding seal at the entrance port, one extender for a large area detector and the rotating base (gun mount) that moves with the rotating upper half of the central scattering chamber.

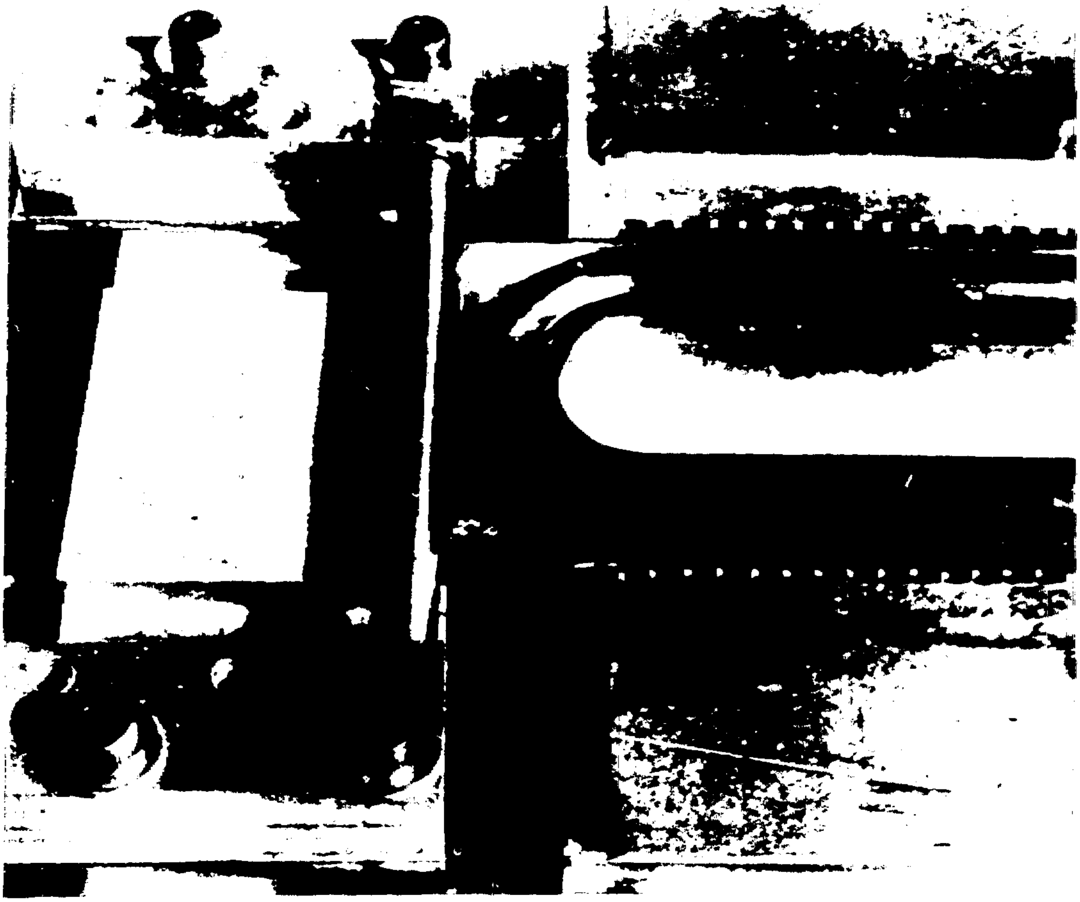


Figure 13.

Test setup for the teflon sliding seals for the scattering chamber. The tests showed that two dry spring-loaded teflon seals with pump-out in between provided an excellent configuration; namely, low friction with sealing properties adequate to obtain the 2×10^{-6} - 5×10^{-7} torr vacuum planned.

involving multiple gas detector systems. The basic specifications for the scattering chamber are listed in the table below.

Atlas Scattering Facility Specifications

MATERIAL:	- Stainless steel, polished - Seals: metal, teflon and dry viton
SIZE OF CENTRAL CHAMBER:	- 36" diameter by 33" high - "Tophat" lid - Upper 20": rotatable (±45 degrees) - Lower 13": fixed
PORTING:	- Upper Section 5 - 12" x 12" square ports at beam center height (±18.2 degrees with 8.6 degrees blind between) 1 - 1" x 90 degree slot (for sliding seal) - Lower Section Side 2 - 6" x 8" metal seal 12 - 2" conflat - Lower Section Bottom 3 - 8" ID conflat 3 - 6" ID conflat
DETECTOR MOUNTING:	INSIDE - Movable 3 rings accuracy <.01 degree independent of chamber rotation - Stationary monitor mounting off baseplate collimation mounting off baseplate Faraday cup mounting off baseplate OUTSIDE - 13' diameter gun mount turntable - Accuracy <.03 degrees - Support in excess of 2000 lbs. - 2 to 3 meter flight paths practical
TARGET ASSEMBLY:	- 5 to 8 - 1" square target ladder - Vacuum interlock capability
VACUUM SYSTEM:	- 1 cryopump (1500 l/s) on chamber - 1 turbo pump (1500 ℓ/s) on chamber - Sorption system for roughing
VACUUM PERFORMANCE:	- $<1 \times 10^{-6}$ in <1 hour - $<3 \times 10^{-7}$ ultimate

Computer Control of the Scattering Facility (S. J. Sanders)

Motions

There are six motions possible with the ATLAS scattering chamber: three ring rotations, rotation of the entire upper chamber, vertical positioning of the target ladder, and the rotations of the target ladder. It will be possible to control each of these motions under remote computer control, although local control bypassing the computer will also be available. The electronics needed for the motion controls are schematically drawn in Figure 14. The computer communicates through a CAMAC crate with an electronics module that sets the preset indexers for the stepping motors. A remote control box connected to this module allows for changing positions, etc., without using the computer. Absolute encoders attached to the motor shafts give position readouts which are available locally as well as at the computer (via the CAMAC crate).

Chamber Status

The computer will also be responsible for monitoring various status conditions of the scattering chamber. At a minimum the pressure in the chamber, the pressure in the beam line leading to the chamber, the status of the entrance gate valve, and the status of the gate valves leading to vacuum pumps will be monitored. It will be possible to change the status of the gate valves from the computer. Since certain sequences of operations can be quite damaging, the computer program will have to check user commands for possible condition conflicts. For instance, if the pressure difference across a gate valve is not within a pre-specified range, it should not be possible to open that valve. (This particular condition will be checked by a hardwired

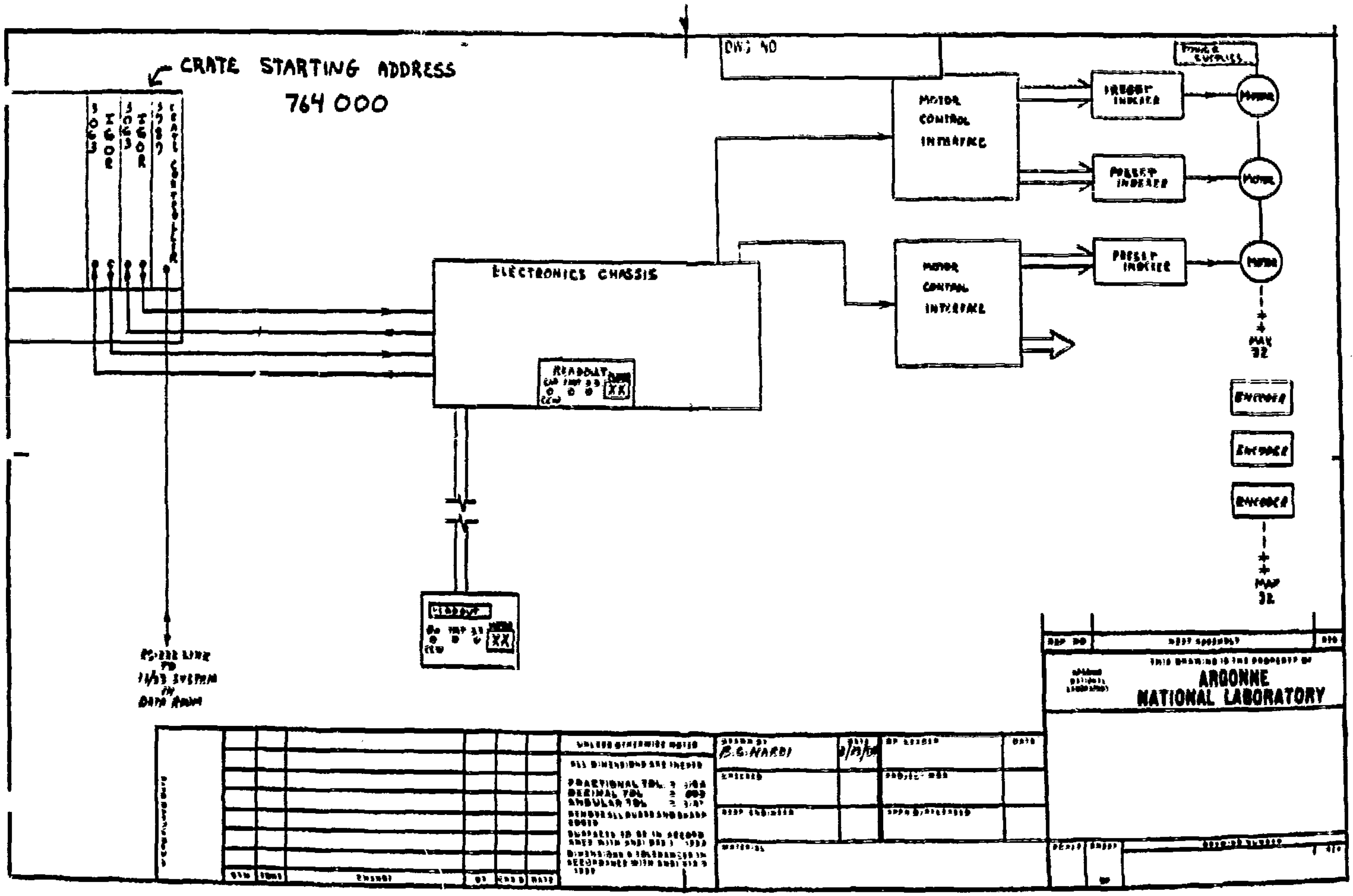


Figure 14.

Computer control of the various motions of the Scattering Facility.

interlock system, so in fact the program will be responsible primarily for informing the experimenter why the command was ignored.) As another example, there should be a way to inform the program of the locations of detectors in the chamber. Once the locations are defined, it should not be possible to run detectors mounted on different rings into each other. A color monitor in the data room and a black and white graphics monitor out by the chamber will be used for visual representation of the chamber status.

Gas Counters

Many of the experiments envisioned for the scattering chamber use gas counters for particle detection. At the very least it is expected that the counter pressures will be monitored by the computer. An unexpected pressure change in a counter can signify a serious situation requiring user intervention and probably such changes should result in the entrance gate valve and the gate valves leading to the vacuum pumps being closed. It is also hoped that the computer can be used for changing counter gas pressures, although this will a be considerably more difficult task (manual control of gas handling systems can be tricky). If the computer is allowed to change gas pressures, it will also be necessary to have the computer control, or at least monitor, the counter voltages. Changing the gas pressure in certain counters without first removing the applied high voltage can result in serious damage to the counter.

Hardware

The computer system, to be located in the new data room shown in Figure 1, will be based on an PDP 11/23 PLUS processor module with an RSX-11M operating system. Communications with a CAMAC crate located by the scattering chamber will be though an RS-232 crate controller. Although the data rate for this crate controller is modest (19,200 Baud), it does allow for the computer and CAMAC crate to be separated by the large distance between the data room and the scattering chamber. The preset indexers controlling the stepping motors will be addressed through Argonne built electronics by way of CAMAC Input Gate/Output Register (IGOR) modules. The Argonne modules also permit local control of the stepping motors. Most of the commercially available hardware needed to run the three rings in the chamber has been ordered. The design of the Argonne built modules is well advanced, although not yet completed. The remaining modules -- needed for rotation of the chamber, control of the target ladder, monitoring the chamber status, etc. -- have, in general, not yet been specified.

Software

Only a general outline has been developed so far for the computer control software. A commercial software package has been purchased for the CAMAC crate controller. The "user-friendly" requirement suggests a menu-driven program for user interactions. As much as possible, each menu also displays the pertinent chamber status information.

A data link is planned between the control computer and the VAX 750 computer being used for data acquisition. It may also be possible to link the scattering chamber control computer and the ATLAS accelerator computer. The form of these data links has not been determined although, at a minimum, it is hoped that various status information can be shared among the different systems.

One requirement of the control program is that users be able to add functions at a later date. As new experiments are developed it is quite probable that there will be a demand to use the computer to control specific, as yet undefined, parts of the apparatus. It should be possible for users to add to the menu and easily access the CAMAC crate. User access also implies that there should be extensive program notes within the computer code and that those parts of the code which may need to be modified or added to should be written in FORTRAN.

Schedule

The stage 1 hardware items need to be ready by mid-January, 1985. These items are needed for the initial allignment of the chamber, rings, and target assembly. The software needed to control the various chamber motions should be ready by late January, 1985. The graphical display of the chamber status, and the other chamber status and control functions handled by the computer, should be available sometime before September, 1985.

4. A Gas Detector Development Laboratory

(Presented by R. R. Betts)

The effort in gas detector development for equipment at ATLAS has been rather fragmented up to the end of 83. The following types of counters were available with several of them still in the development stage: a) The spectrograph focal-plane counters; b) a derivative of the spectrograph counter for use in scattering chamber experiments, consisting of a large acceptance ΔE-E ionization chamber with a resistive wire position read out; c) two parallel plate avalanche counters with position read out with active areas of 10 x 10 cm; d) a MPI Heidelberg type $\Delta E/E$ ionization chamber with x and y position readout; e) two channel plate timing devices which are now routinely operating with ~150 ps time resolution. f) Various small ionization chambers and avalanche counters.

In an attempt to bring some coherence to this effort we are currently setting up a detector development and testing laboratory. A large room in building 200 (Chemistry Building) is being refurbished and will contain a 30" vacuum test chamber, a dedicated gas handling system, electronics and a PDP11/23 computer with CAMAC interface for initial testing of detectors. A smaller "clean room" is also available for foil stretching, wire winding and more limited detector testing near the linac. It is also hoped that through close association with the Electronics Division we will be able to test and develop state-of-the-art electronics for these detectors.

Longer term development ideas include detectors for the new large scattering chamber being constructed and possible development of a multiwire proportional counter with individual wire readouts. Presently, a system consisting of a low-pressure Breshkin-type large-area detector followed by ionization-chambers is being built for the scattering facility.

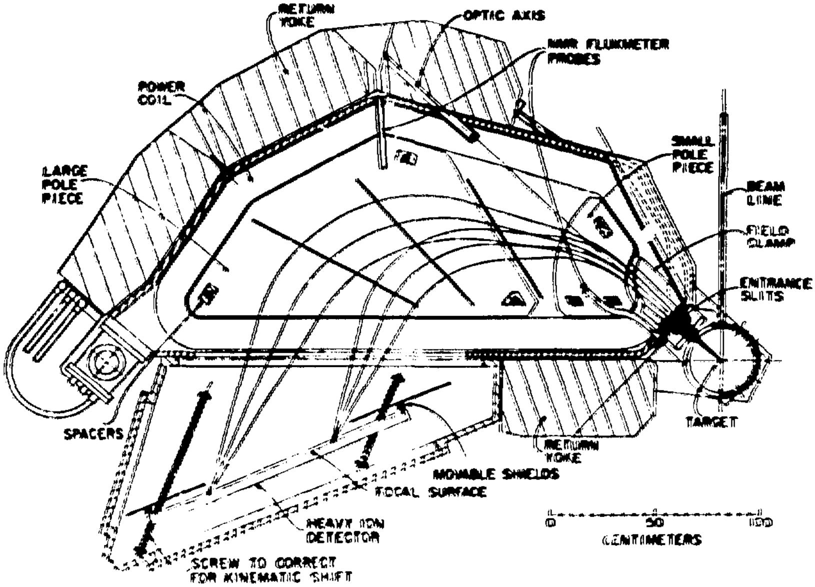
5. Enge Splitpole Magnetic Spectrographs

(Presented by K. E. Rehm)

As indicated in the layout of the ATLAS facility (Figure 1) there are two magnetic spectrographs available, one in Target Area II and the second in Target Area III. They are both of the Enge split-pole type and are virtually identical in all major components, such as target chamber, magnetic field, ion optics and detection systems. Both will be equipped with a cryogenic pumping system. Particles are usually detected with an ionization-chamber type focal-plane detector developed at Argonne. Recently a parallel plate avalanche counter has been added providing for time-of-flight using the pulsed beam, and resulting in excellent mass resolution from the measurements of time and Bρ. In addition, in both spectrographs nuclear emulsion plates can still be used. The split-pole spectrograph located in Target Area II is operational. The one in Target Area III is expected to be operational in 1985.

The general properties of the split-pole spectrograph are described in a number of papers by H. Enge. A schematic layout of the split-poles used at Argonne is shown in Fig. 15. The upper part shows the split-pole in area II where lower rigidity beams are avaiable. In order to extend the rigidity range to the higher-energy beams expected in area III an extender box will be mounted between magnet and camera box as indicated in the figure, to allow movement of the deep ionization-chamber counter to the high-rigidity region of the focal plane. Since the actual spectrograph performance is largely determined by the focal-plane detector properties, the most important ones are listed for the respective spectrograph-detector systems in the table below.

Figure 16 shows a cross section through the present focal-plane ionization-chamber detector. Since the particles enter the detector at 45° the effective length of the particle path inside the dector are a factor $\sqrt{2}$ larger than the dimensions shown in the figure. Clear mylar foils of 1.5μm thickness (or 2.5μm and 6.4μm at higher pressures) are used for the entrance window. Counter gas is Freon (CF_4) with a maximum pressure of 500 Torr. An electronically controlled gas-supply system keeps the pressure constant to ±0.1%. Two remotely controlled Ta sheets in front of the detector allows one to shield unwanted regions of the focal plane. Signals from the detectors are processed in a dedicated electronics setup and fed into the PDP 11/45 on-line computer via CAMAC interface. Computer programs are available to calculate magnetic field settings and kinematic corrections, and to perform multiple filtering of on-line data. Examples of typical data are given in Fig. 17.



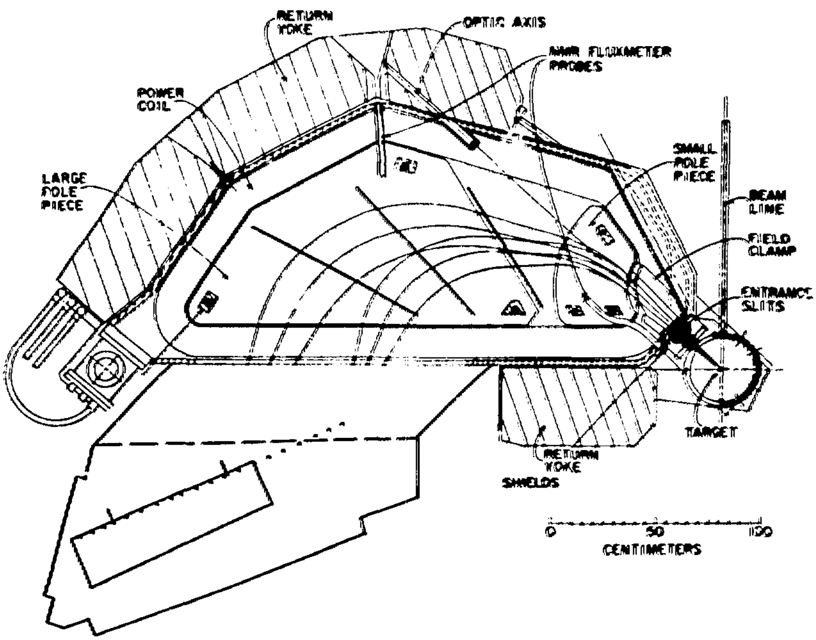


Figure 15. Schematic layout of the split-pole magnetic spectrographs used at ATLAS. The upper part shows the spectrograph in area II where lower rigidity beams are available. For area III, in order to extend the rigidity range to the higher-energy beams expected, an extender box will be mounted between magnet and camera box as indicated in the lower figure.

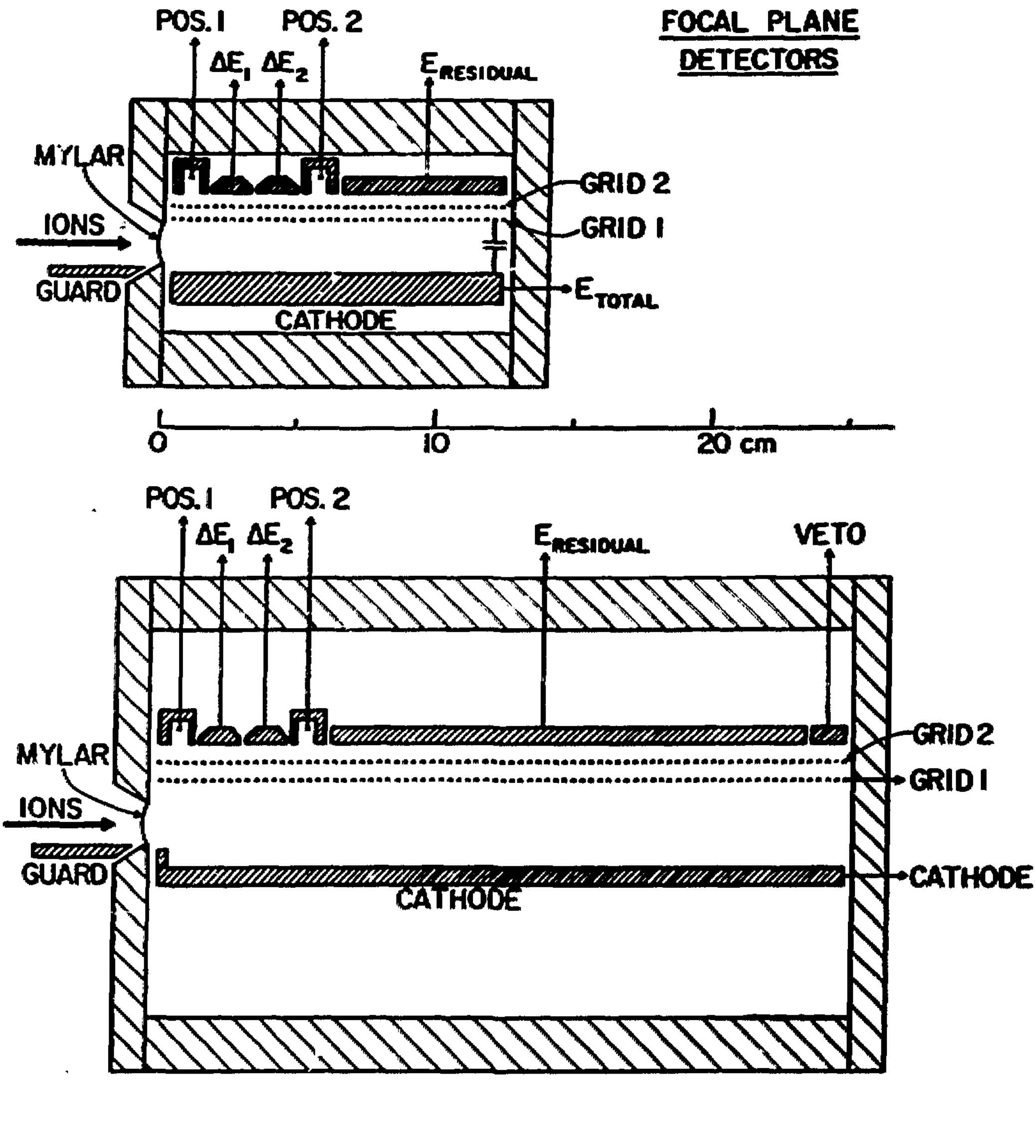


Figure 16.

Cross sections and dimensions of the two position-sensitive gas ionization chambers presently in use at the Argonne split-pole spectrographs.

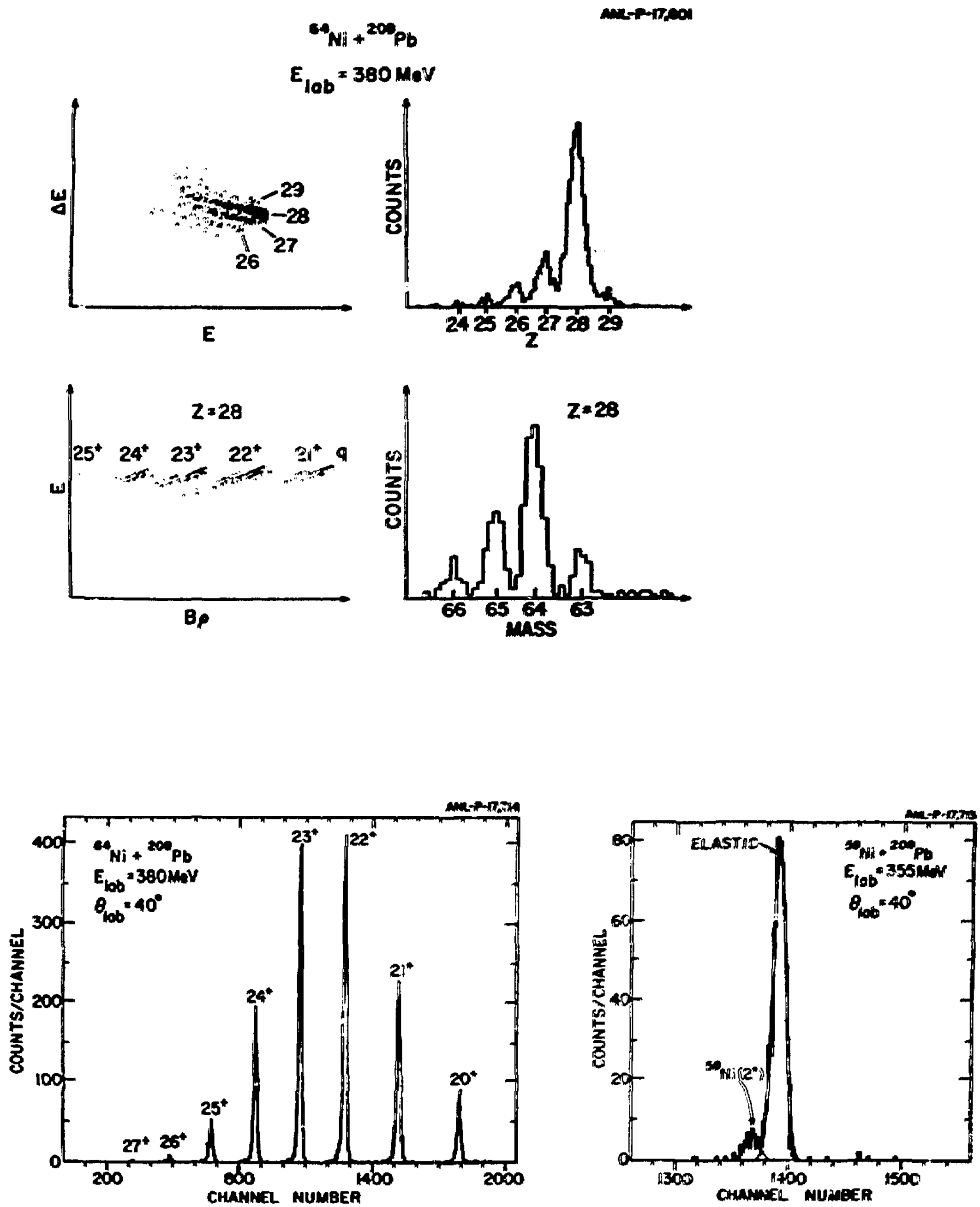


Figure 17.

Examples of typical data obtained with the split-pole focal plane gas detector for heavy ions.

An important parameter determining limits in optimum resolution is the beam spot size x_o. With total magnification M_H, dispersion D, kinematic constant $K = \frac{1}{p}\frac{dp}{d\theta}$, and emittance $\varepsilon = x_o\theta_o$ the energy resolution is given by:

$$\frac{dE}{E} = \sqrt{\left(\frac{2M_H x_o}{D}\right)^2 + \left(\frac{2K\varepsilon}{x_o}\right)^2}.$$

The quantity E/dE is plotted in Fig. 18 as a function of x_o.

The expected total energy resolution for heavy particles and its various contributions:

	LINAC	ATLAS
Beam spot size and emittance	1500-2000	1500-2000
Small angle scattering ($50 \mu g/cm^2$)	4000	6000
Magnet inhomogenity	5000	5000
Target effects ($50 \mu g/cm^2$)	1000	1000
$\delta p/p$	3000	3000
Detector resolution	1250	1250
$\frac{E}{\Delta E}$ (total)	660 (780)	820 (1170)

The numbers in parentheses give the resolution without the detector contribution.

The spectrograph target chamber is made of stainless steel, 31.75 cm in diameter and 15 cm high. A sliding seal allows the rotation of the spectrograph around the fixed chamber. The whole chamber is insulated from ground potential and can be used as a Faraday cup. There are four sideports

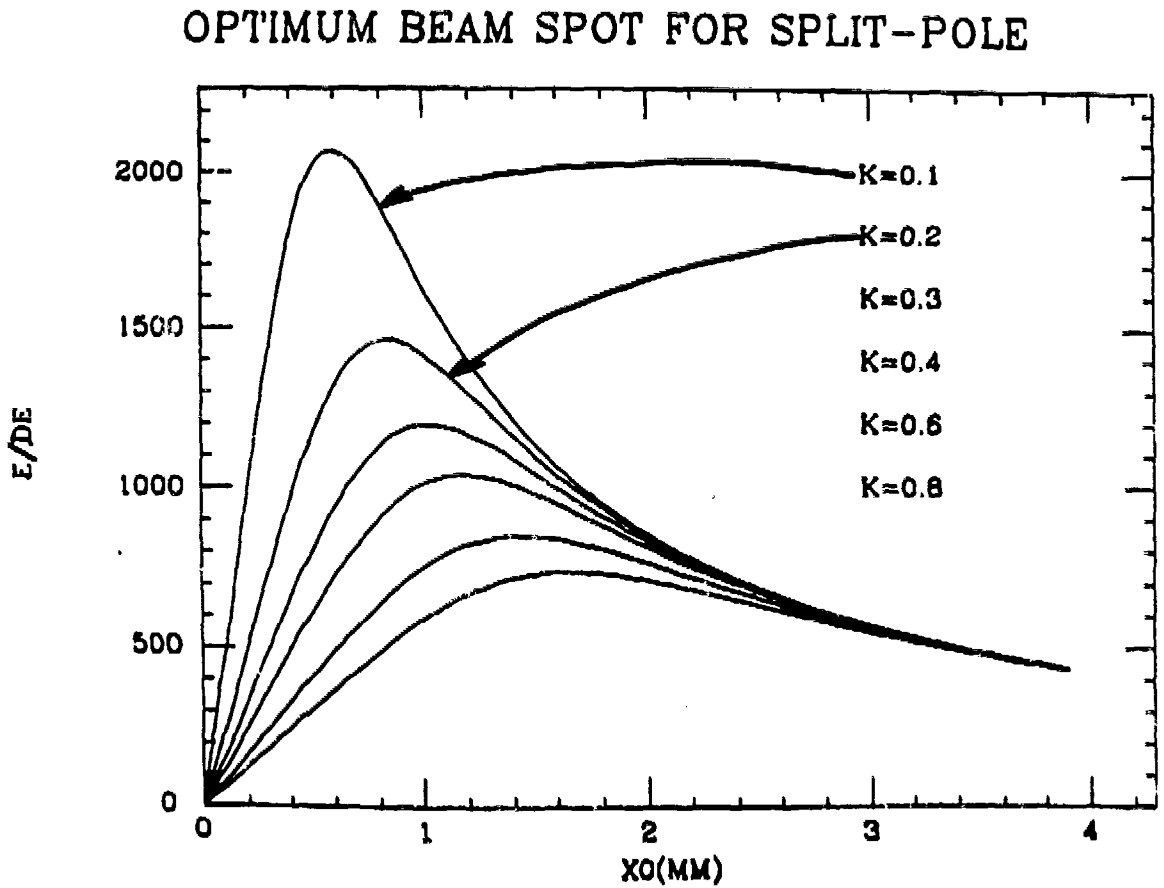


Figure 18.

Energy resolution of the split-pole spectrograph as a function of beam spot size x_0 for different values of the kinematic constant K.

available between -60° and -120° which can be used for various purposes (target transfer under vacuum, viewing window, insert for Ge detector, etc.). Two monitor detectors are located ~13° below the target-spectrograph plane and symmetric with respect to the beam axis. They can both be remotely rotated behind a fixed aperture to avoid effects of detector deterioration with heavy-ion beams. The target holder is inserted through the top of the chamber and holds four targets of the ANL standard 1" x 1" size. During experiments vacuum in the 10^{-7} and 10^{-6} Torr range has been obtained in the linac spectrograph target chamber and detector box, respectively.

Table III.1
Properties of the Split-Pole Spectrographs and Focal Plane Detection Systems

	Small Gas Detector	Large Gas Detector	Nuclear Emulsion
Maximum mass-energy product $\frac{ME}{q^2}$ (amu · MeV)	70	60	90
Range of bending radius, ρ_{min} - ρ_{max} (cm)	60-80	55-75	40-90
Range of energy, E_{max}/E_{min}	1.7	1.7	4.8
Solid angle*	<5.4 msr	<5.4 msr	<5.4 msr
Angular range	-15°/+120°	-15°/+120°	-15°/+120°
Useful focal length (cm)	50		50 120
Horizontal Magnification, $\Delta x_{target}/\Delta x_{focal\ plane}$	0.34	0.34	0.34
Vertical magnification, $\Delta y_{target}/\Delta y_{focal\ plane}$	2.7-3.1	2.5-3.0	1.7-3.3
Energy dispersion $\frac{\Delta x(\text{focal plane})}{\Delta E}$ $(\frac{mm}{\%})$	1	1	1
Focal plane orientation	45°	45°	45°
Position resolution	1.1 mm (^{16}O) 1.6 mm (^{37}Cl) 2.2 mm (^{58}Ni)		
ΔE/E from position measurement (100 MeV ^{12}C)	0.1%	0.1%	
ΔE/E from E_{total} measurement	1%	1%	
δ(ΔE)/ΔE from ΔE measurement (with ray-tracing correction)	3%	3%	
Maximum detector thickness (mg/cm^2)	23	44	>30
Counting rate limit (counts/sec)	~10^3	~10^3	none

*Presently available are spectrograph entrance apertures with 0.038, 0.252, 1.00, 5.43 and 5 x 0.20 msr (5-slit aperture).

6. Cryogenic He-Jet/Laser Spectroscopy Project

(Presented by D. A. Lewis, Iowa State University)

A collaboration between Argonne National Laboratory, Iowa State University and the University of Minnesota has been formed with the goal to determine nuclear moments of short-lived nuclei (to ~ 0.1s) through their atomic hperfine structure. In the proposed experiments nuclei produced with heavy-ion reactions must be formed into neutral atoms and carried into a low light and nuclear radiation background where laser spectroscopy is possible. It is attempted to accomplish this using a scattering chamber with He-jet consisting of a target cell attached to a 50 cm long capillary which empties through a skimmer into a high vacuum region (Fig. 19). Recoiling nuclei produced in an array of targets are stopped in the spacings between targets in 1 atm. of 78° He gas which transports them through the capillary and skimmer into the high vacuum region. The chamber is presently located on the 0° beamline of target area II.

Since the nuclei of interest can only be produced in limited numbers, it is necessary to use a high sensitivity detection technique. We are using the photon burst method which uses the fact that a single atom can resonantly scatter hundreds of photons during its transit through laser light. By using the time correlation of detected photons, background can be reduced or eliminated. An example of this technique is given in Fig. 20. The high vacuum region of the He-jet chamber houses an efficient light collector (Fig. 21, bottom) which directs resonantly scattered photons to photomultiplier tubes. A laser spectroscopy system (Fig. 21, top) which produces narrow band light reproducibly tunable over appropriate frequency ranges is housed in a radiation-shielded room adjacent to the He-jet. With this sytem we have shown that it is possible to make high precision

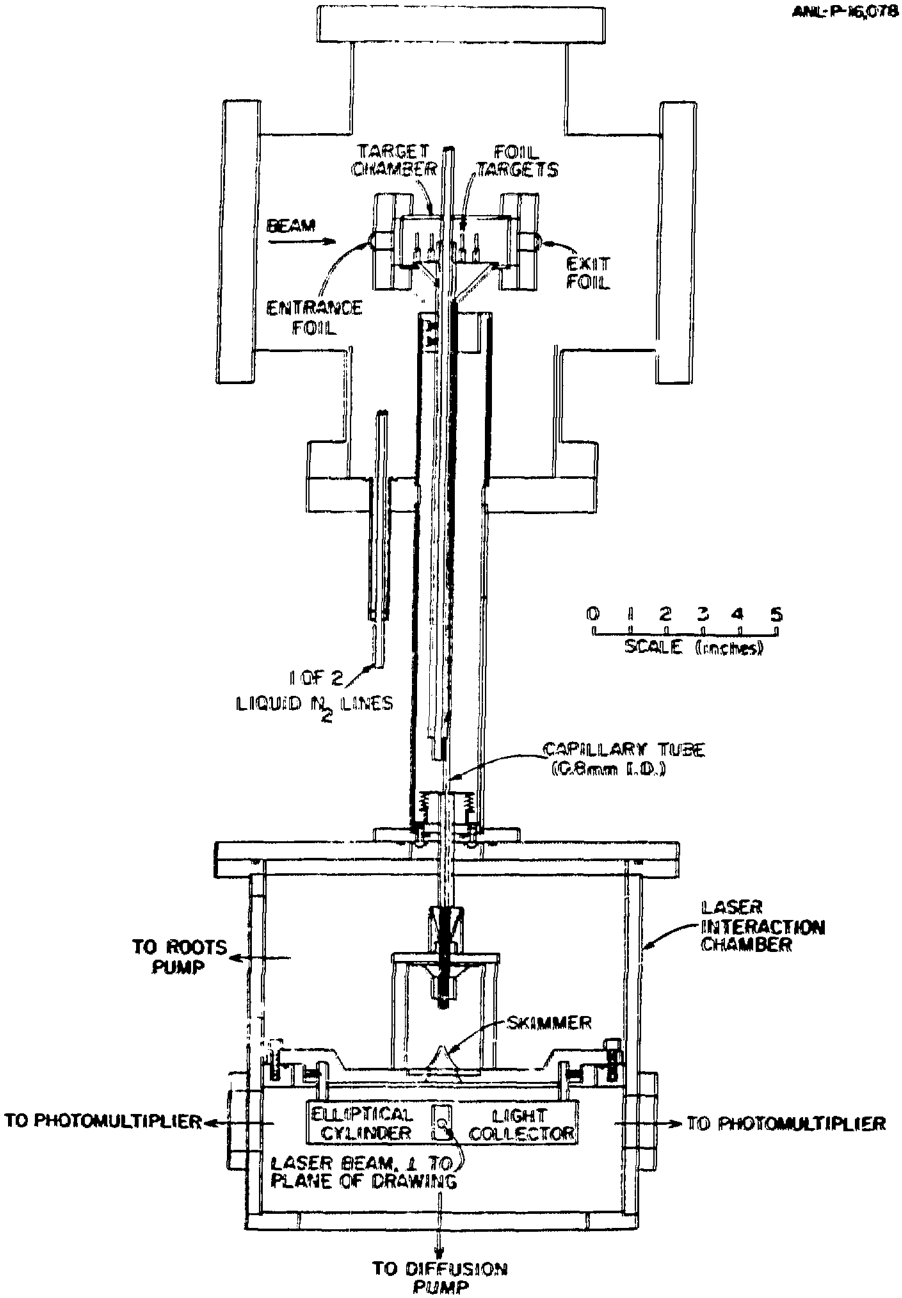


Figure 19.

Cryogenic He-jet chamber consisting of a target cell attached to a 50 cm long capillary which empties through a skimmer into a high vacuum region.

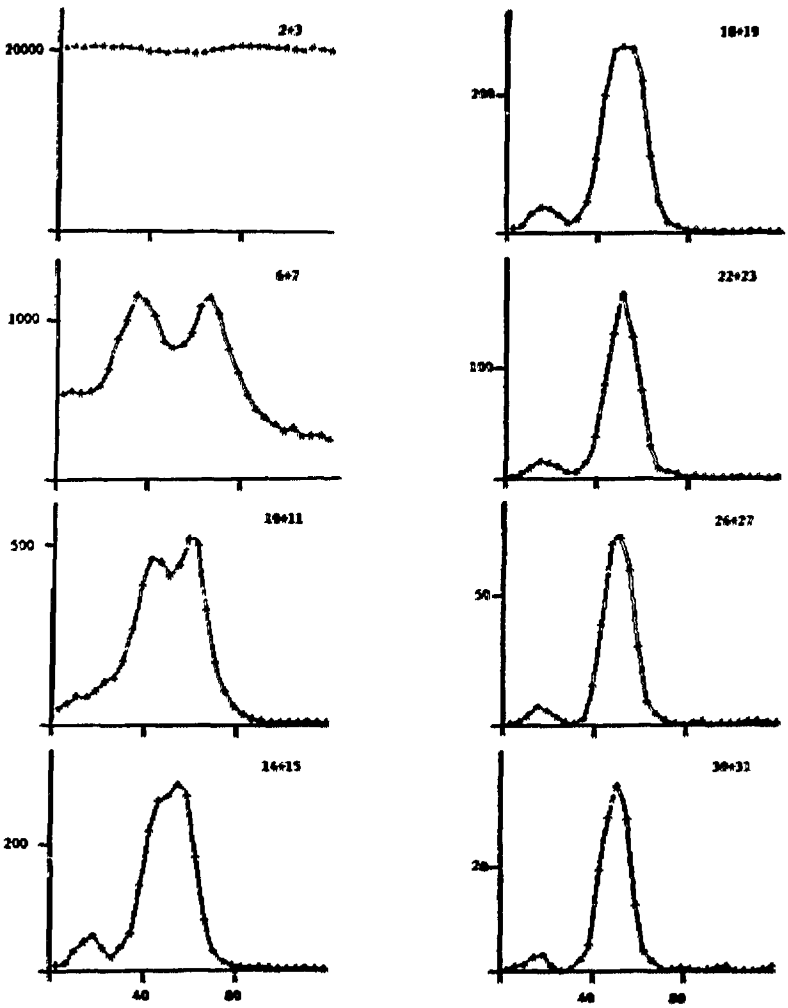


Figure 20.

Selected burst spectra for the 5535Å resonance line in natural Ba illustrating the photon burst method for resonance laser spectroscopy. These were taken using a 1 cm long interaction region with an average power density at roughly 5 mW/cm^2. The atomic beam flux was about 100 atom/s. The mode 2 coincidence time was 24 μs and a minimum of one photon from each PMT was required for a valid event. The horizontal scale for the figure is laser frequency in channel number where a one channel difference corresponds to 1.829 MHz. The multiplicities are grouped together by 2's, e.g. the events corresponding to multiplicities 2 and 3 are included in the same spectrum. Only alternate spectra (i.e. 2+3, 6+7, 10+11,...) are shown. The large peak near channel 54 is due to ^{138}Ba (72% abundant) and the small peak near channel 18 is due to ^{137}Ba, F=5/2 (11% abundant).

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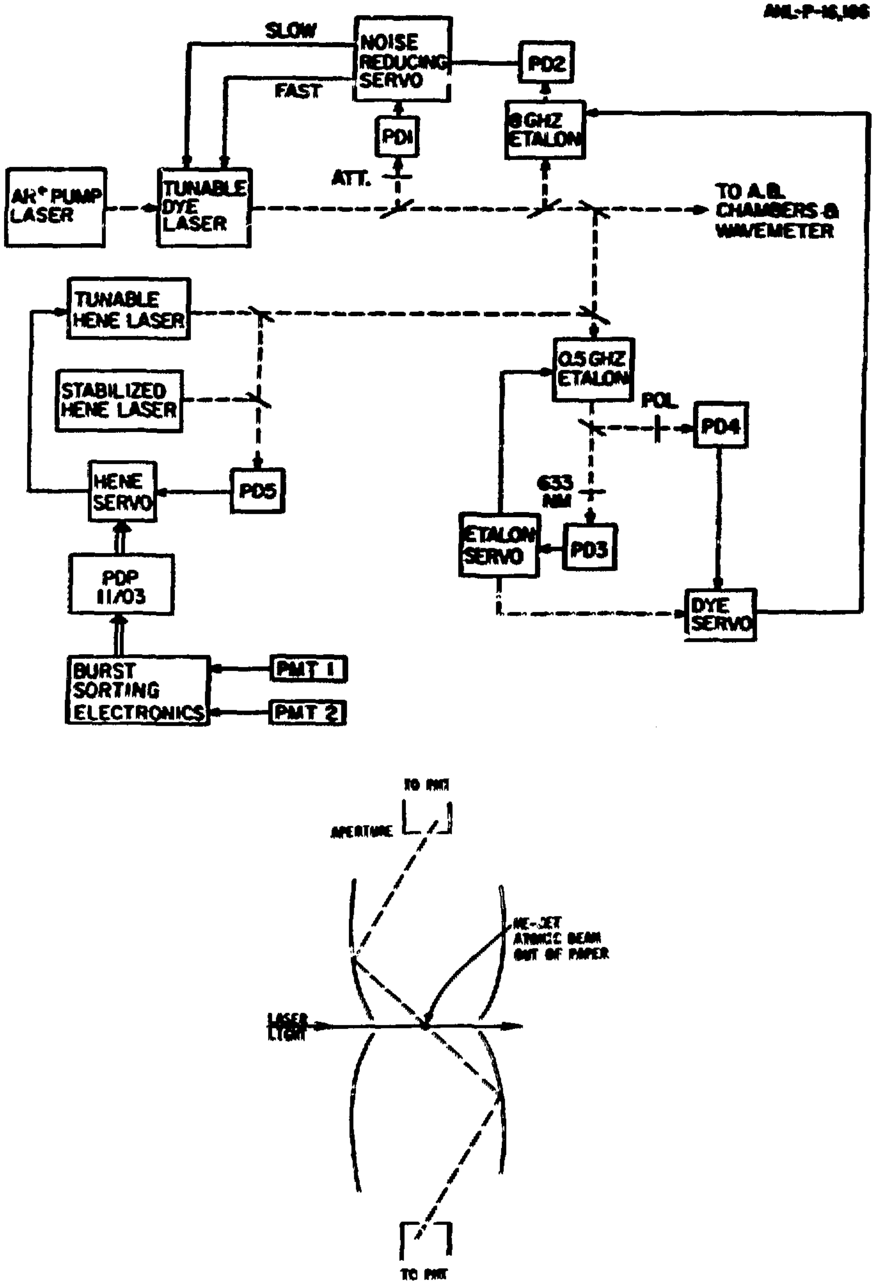

Figure 21.

Some details of the laser setup. Top: The laser spectroscopy system producing narrow band light, reproducibly tunable over the necessary frequency ranges. Bottom: Light collector to direct randomly scattered photons into photomultiplier tubes.

measurements in an off-line atomic beam chamber with fluxes of only a few atoms/s.

We have studied the properties of the He-jet system by collecting transported activity produced on-line on catcher foils, removing these through vacuum interlocks, and measuring the decay. The purity of the He gas is of critical importance and boiloff from liquid He is now used as the source. At present the yield of nuclei produced on-line and delivered into phase space useful for laser spectroscopy is a few/s. We are working to improve this yield and to establish whether or not it is in the form of free atoms.

7. Recoil-Mass Separator/Mass Spectrometer

(Presentations by T. M. Cormier, University of Rochester, and S. Steadman, MIT)

For the second phase of equipment development at ATLAS we are considering the combination of some form of heavy-recoil mass separator or possibly high-resolution mass spectrometer. One obvious application is the measurement of fusion cross sections and detecting fusion evaporation residues with very low yields. However, one can envision a large number of additional applications where the mass spectrometer acts as a filter in concidence with other spectroscopic detection devices, very much like the crystal or BGO balls used in compound nucleus spectroscopy. Examples, by no means complete, are given in Fig. 22. If possible, we would also like to make use of the pulsed beam properties of ATLAS, and possibly of superconducting elements used with the accelerator (rf cavities, solenoids, magnets).

As a basis for our discussion, two existing devices with different characteristics were presented: The Rochester Recoil Mass Spectrometer by T. M. Cormier and the MIT Recoil Mass Separator located at Oak Ridge by S. Steadman. Layouts of the two devices are shown in Figs. 23 and 24.

The Rochester device (Fig. 23) is a high-resolution mass spectrometer providing direct detection and identification of nuclear reaction products according to mass with a resolving power of $m/\Delta m > 400$ and an energy resolution of ~1%. The device is a velocity dispersionless mass spectrometer in which a single measurement of the position of a particle along the focal plane determines the particle's mass. The first order optics is shown in Fig. 25. The geometric solid angle of the spectrometer can be as large as 5 msr (limited by quadrupole diameters) and the velocity acceptance is $\sim \pm 6\%$. Mass points on the focal plane are >3mm in diameter (depending on solid angle

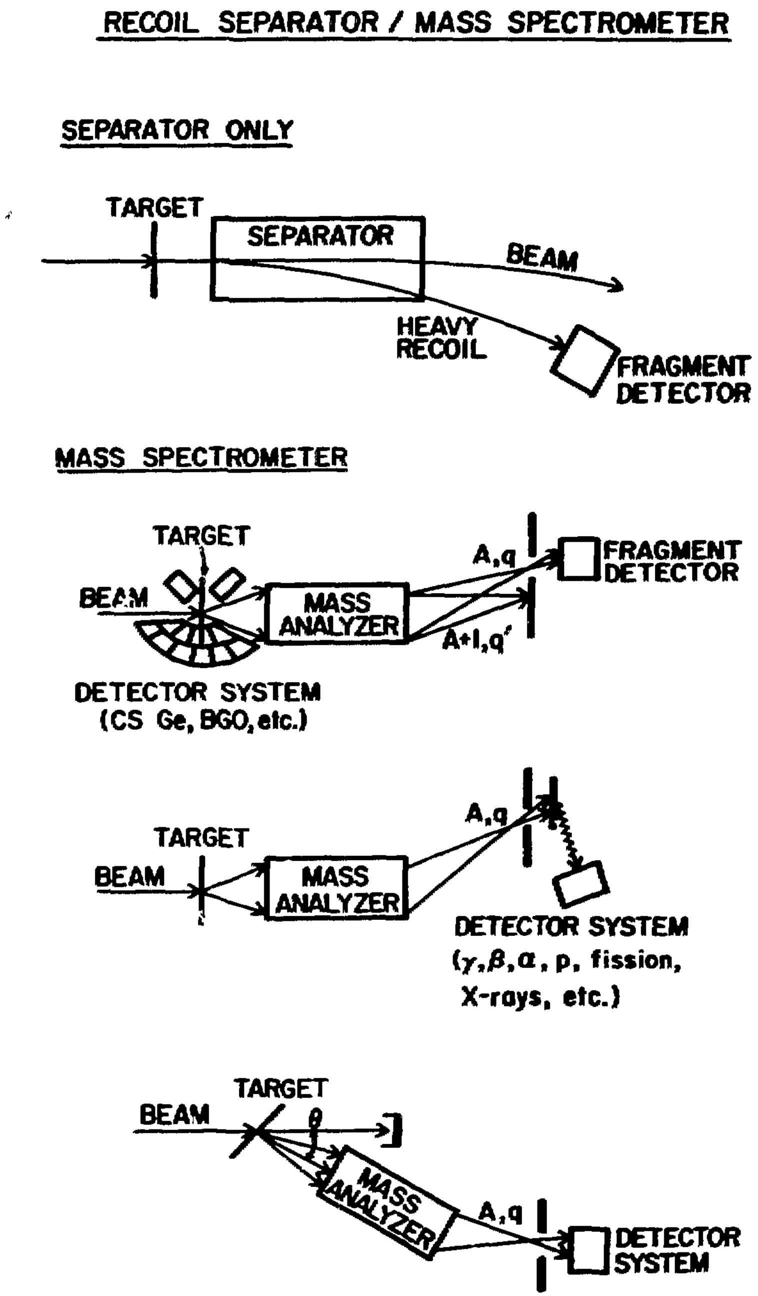

Figure 22.

Some examples of applications of a recoil-mass seperator/mass spectrometer.

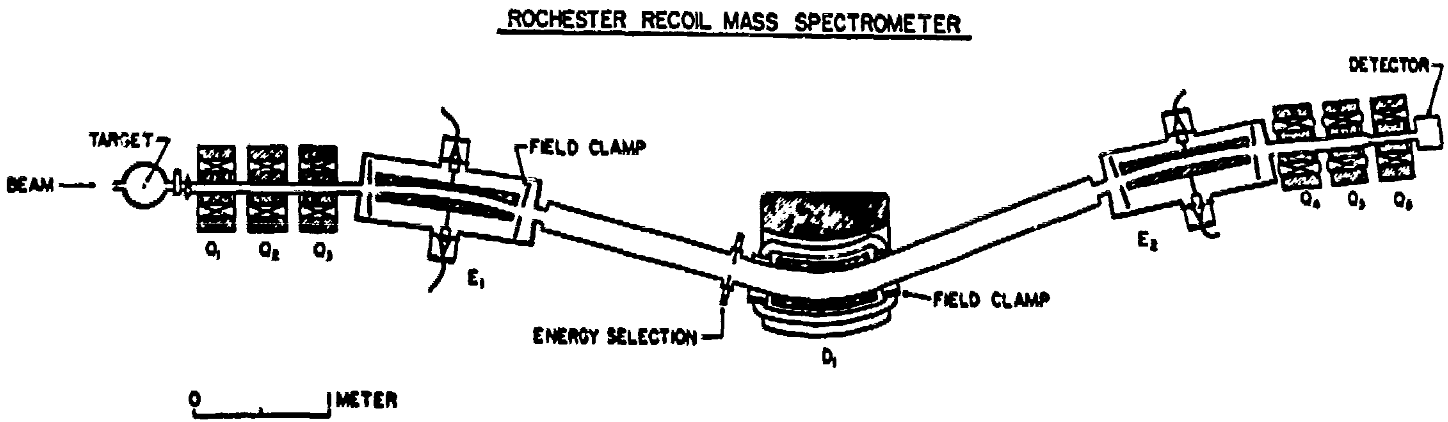

Figure 23.

Schematic layout of the Rochester Recoil Mass Spectrometer.

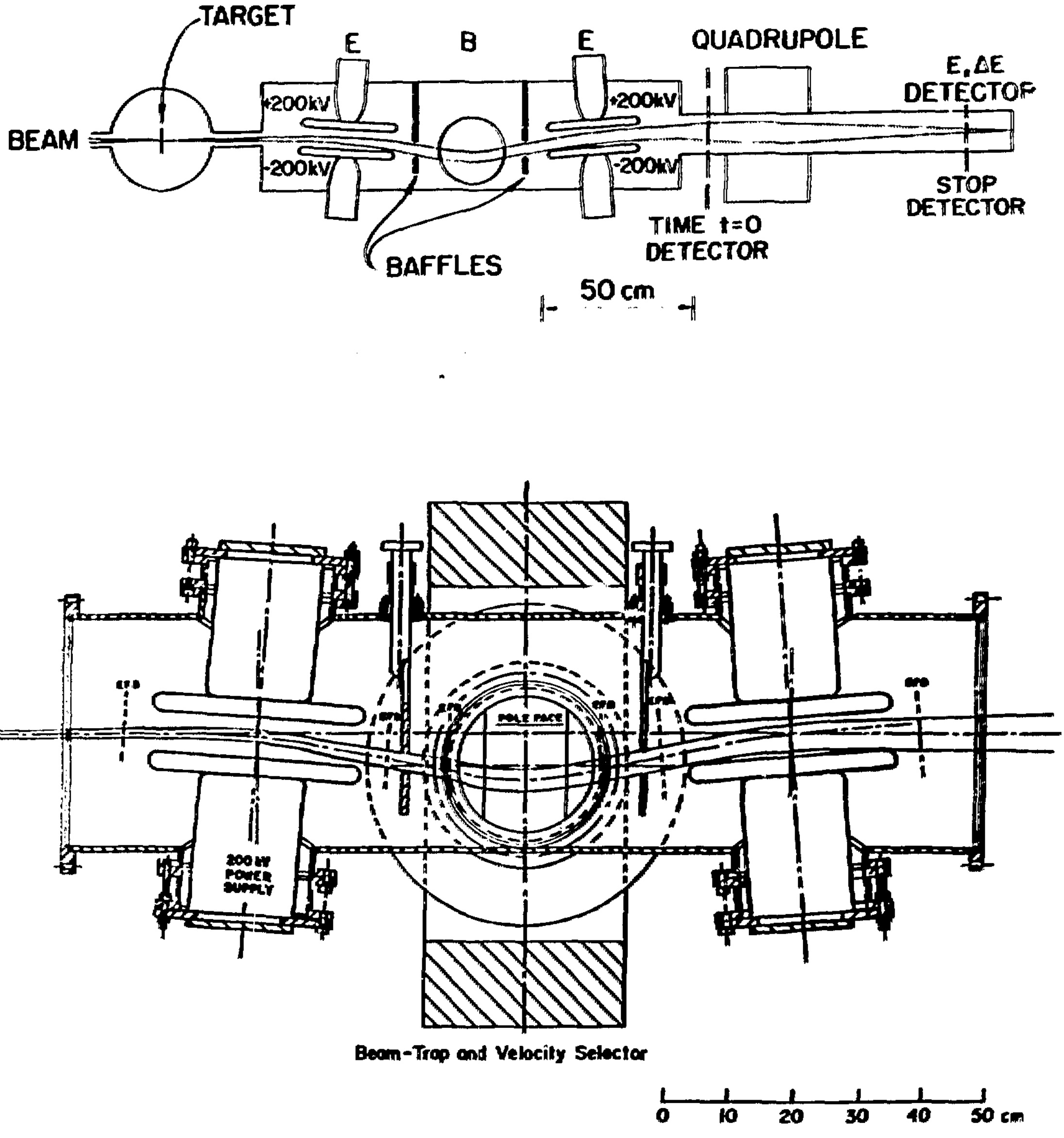

Figure 24.

Top: Schematic layout of the MIT/ORNL Recoil Separator.
Bottom: Technical layout of beam trap and velocity selector.

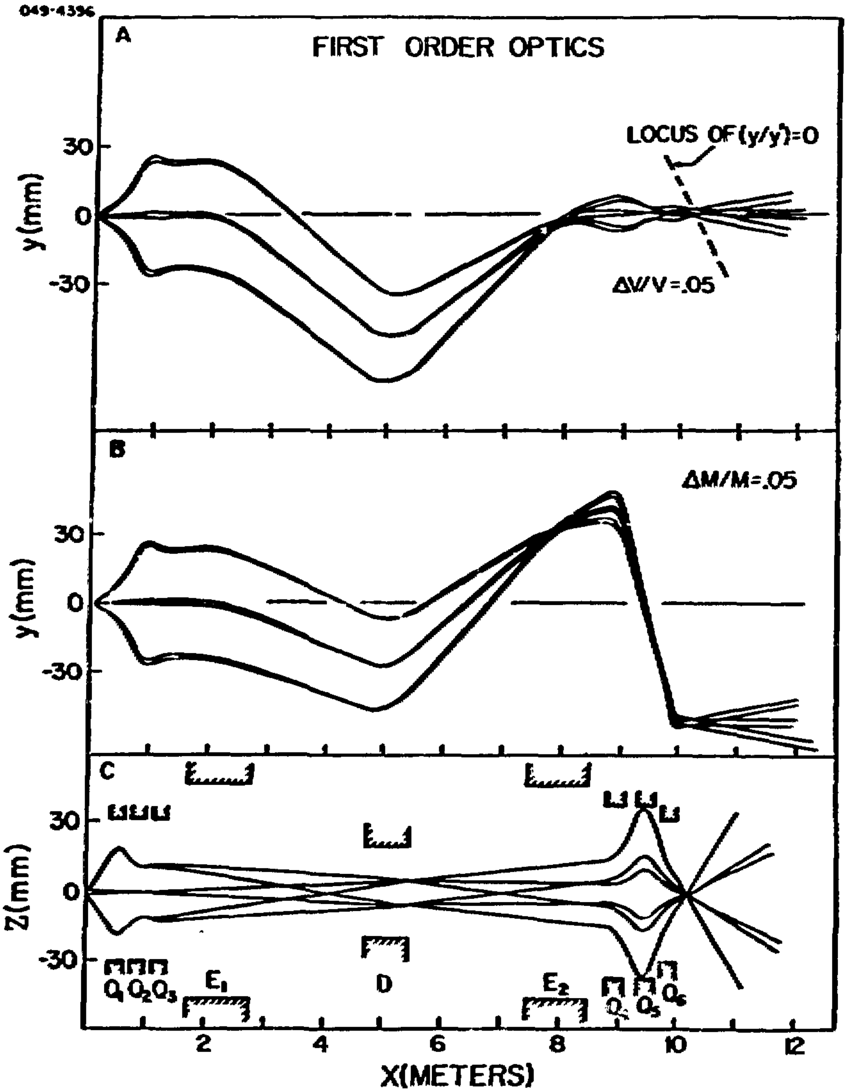

Figure 25.

First order optics calculations for the Rochester Recoil Mass Spectrometer.

(A) Median Plane, six rays: $Y_o = \pm 0.5$ mm, $Y'_o = 0, \pm 0.02$, $\delta_v = 0.05$, $\delta_m = 0$.

(B) Median Plane, six rays: $Y_o = \pm 0.5$ mm, $Y'_o = 0, \pm 0.02$, $\delta_m = 0.05$.

(c) Transverse Plane, six rays: $Z_o = 0.5$ mm, $Z_o = 0, \pm 0.05$, $\delta_v = \delta_m = 0$.

and beam spot size) and thus even very crude one-dimensional position sensitive detectors can be used. In Fig. 26 results are shown for compound nucleus masses after particle evaporation for the $^{35}Cl + ^{58}Ni$ fusion reaction, verifying the predicted good mass resolving power.

Disadvantages of this device are the fact (no principle limitation) that it is fixed in angle at $\theta_{lab} = 0°$, partly as a consequence of its large size, and that it is somewhat limited in acceptance (only 1-2 charge states at a time for all practical purposes and ±6% velocity acceptance).

A recoil separator such as the one presented by S. Steadman generally allows for a larger acceptance, is more compact and thus more easily allows movement away from a fixed angle. The MIT version can swing out to $\theta_{lab} = 15°$. Below are the specifications of the MIT/ORNL Recoil Mass Separator:

A) General:

System: EDEQQ

Acceptance Angle: Horizontal ±23 mrad Vertical ±15 mrad

Solid Angle: 1.2 msR

Reaction Angles: 0-15 degrees

B) Electrostatic Deflectors:

Effective Lenght: 45 cm; Airgap: 6 cm

Max. Voltage (design): ±180 kV

Max. E_k/q at 10 Degree Deflection: 8.4 MV

C) Magnetic Dipole:

Angle of Deflection: 0-20 degrees

Orbit Radius at 20 Degrees: 77.6 cm

Airgap: 8.22 cm, max. field (design): 12 kG

Max. $B\rho$ at 20 Degree Deflection: 931 kG-cm

D. Optics:

Magnification: M_x=0.205 (at 70 cm) M_y=0.989

Dispersion: D = .079 cm/percent velocity

Chromatic Aberration: 5.4 x 10^3 cm/mr-percent (P/Q)

In Fig. 24 a schematic layout is shown and in Fig. 27 a velocity and charge state scan.

A comparison that summarizes some characteristic features of the two devices discussed here is given below:

Velocity Selector	Recoil Mass Spectrometer
1. No mass resolution except via TOF	1. Excellent mass resolution: $\frac{M}{\Delta M} \gtrsim 400$.
2. Solid angle 1.2 msr, but all charge states	2. Solid angle 5-6 msr, 1 or 2 charge states
3. Solid angle = geometric; can obtain σ	3. Solid angle more difficult to calibrate
4. Can vary deflection angle if E field limited	4. Deflection angle fixed
5. Beam does not hit plates	5. Beam hits plates in present design; seems no problem though.
6. Can swing in θ, measure dσ/dθ.	6. Fixed at 0°, but could be modified to swing in θ.
7. Compact, inexpensive.	7. More elements needed, thus less compact and more expensive.

The discussions about an Argonne Recoil Mass Spectrometer centered on the characteristics given above and the physics limitations connected with them: absolute vs. relative cross-section measurements; mass resolution; advantage of a high-resolution mass filter for coincidence measurements with other decay

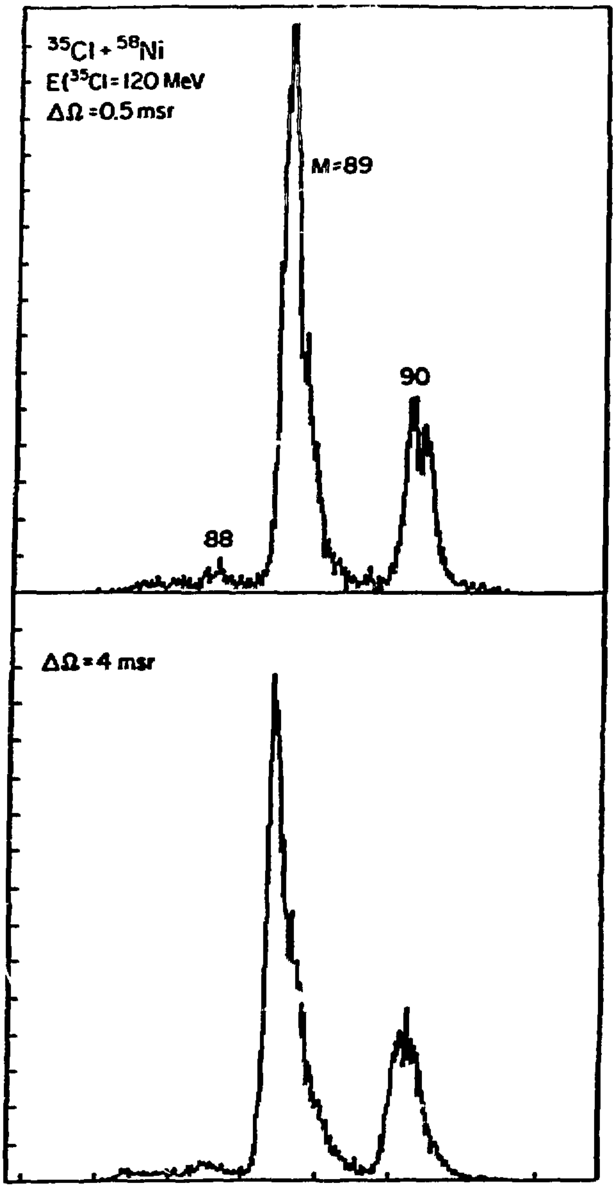

Figure 26.

Compound nucleus masses after particle evaporation detected and identified in the focal plane of the Rochester Recoil-Mass Spectrometer.

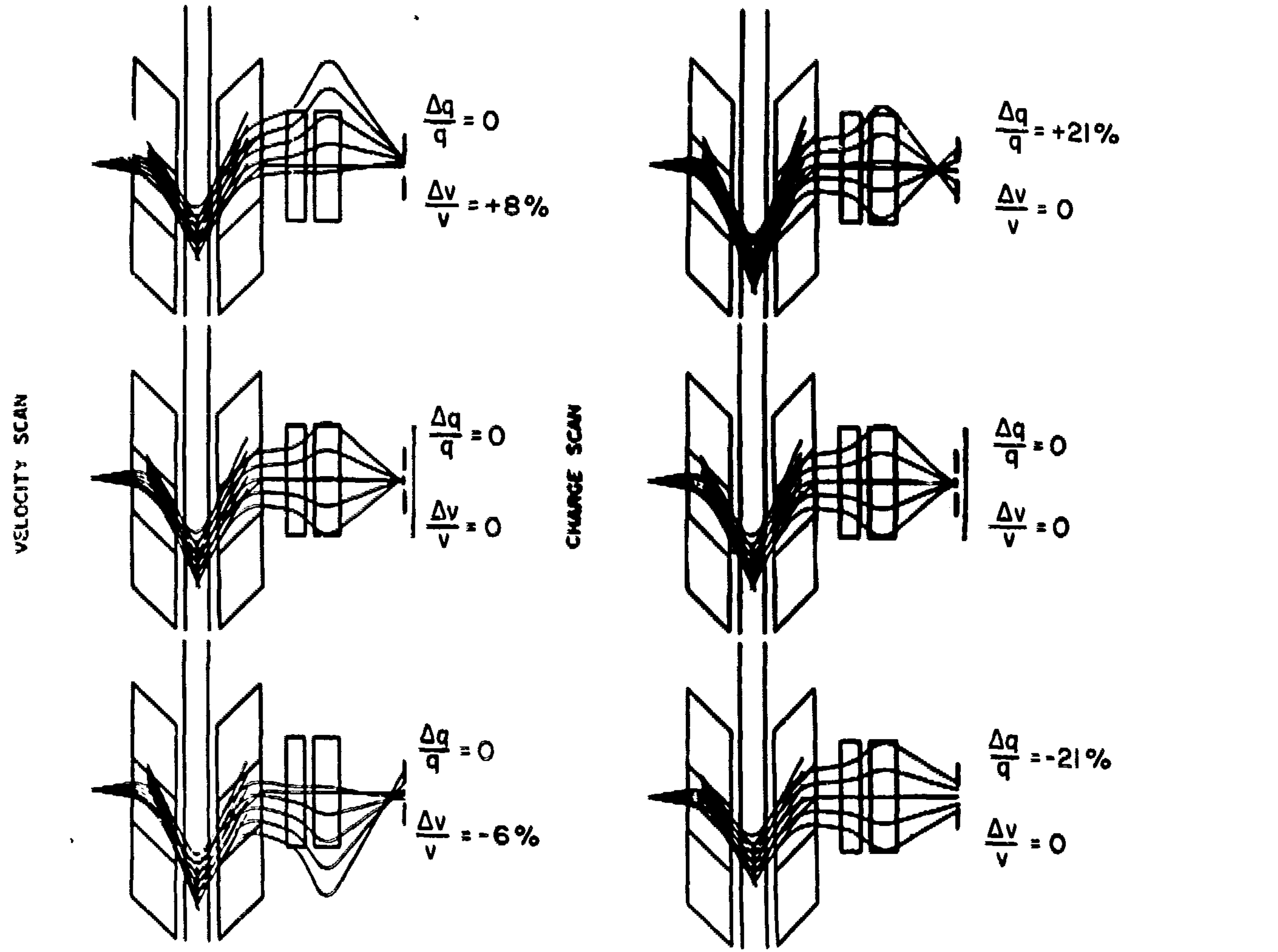

Figure 27.

Velocity and charge state scan for the MIT/ORNL Recoil Mass Separator.

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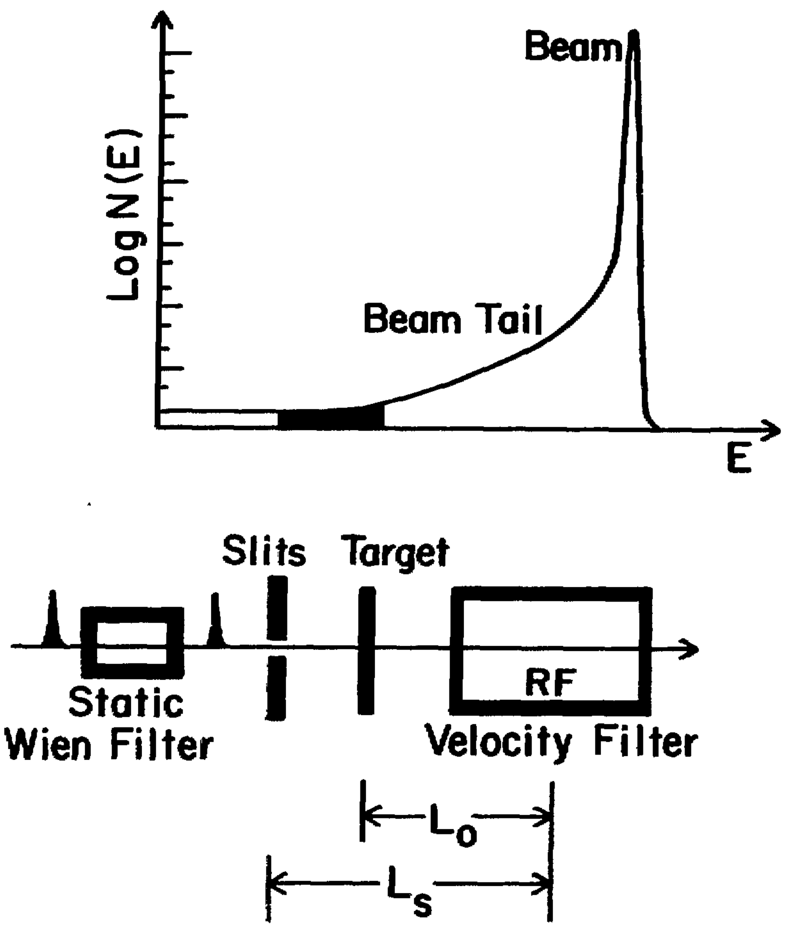


Figure 28.

Possible use of the pulsed beam structure at ATLAS in an rf-based velocity filter. In addition to the rf-operation of the filter (see also Figure 29) an additional "beam-cleaning" static filter with poor resolution (≈10%) can be used. It would be operated in such a way that beam particles from the (unavoidable) beam tail, with velocities identical to those of the reaction products of interest, are generated at a selected location and consequently arrive at the rf-filter with the same velocity but out-of-phase timing or vice versa.

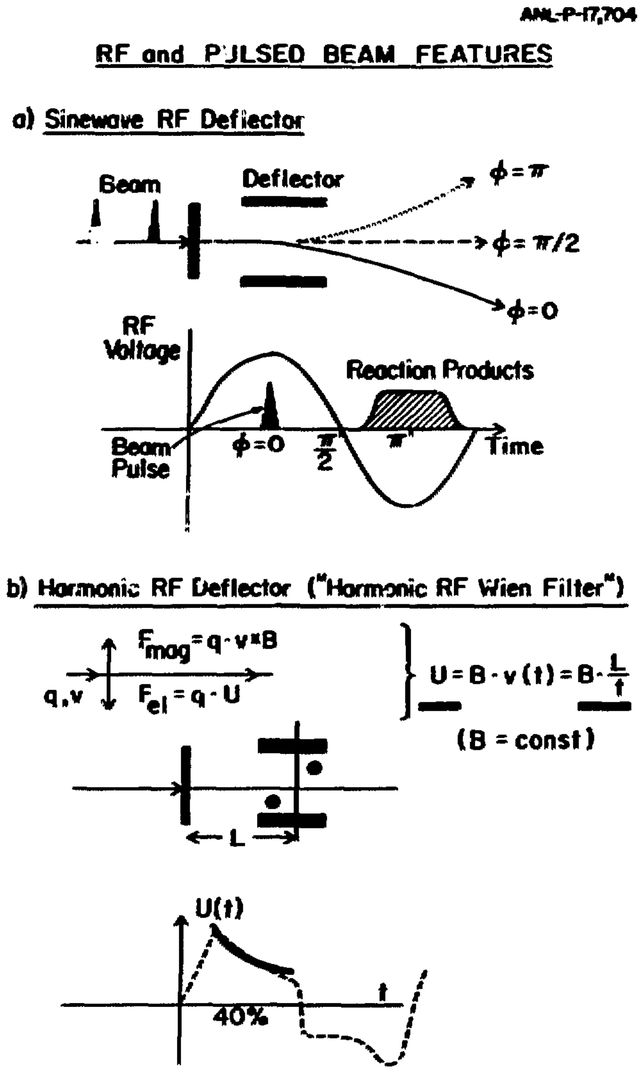


Figure 29.

Velocity acceptance for an rf-type "harmonic" Wien filter. The 1/t dependence of the electric rf-field could probably be achieved by a superposition of the first few harmonics of the rf-frequency.

products; angular range; inverse kinematics applications; general flexibility and ease of operation etc. In addition aspects related to the rf properties of the beams from ATLAS were touched upon. They have recently been further studied. Some of these ideas are sketched in Fig. 28 and Fig. 29. It has become clear that we are yet far away from a final design and therefore any input into the discussion at this time from the user community is particularly welcome.

8. Equipment from User Groups:

a) Superconducting-Solenoid Charged-Particle Spectrometer

(Presented by R. Stern, U. of Michigan)

Several outside-user groups are planning to set up major experimental apparatus for their programs at ATLAS or already now at the booster linac. A project that is particularly advanced is the superconducting solenoid for charged-particle measurements by the group from the University of Michigan. This device was first presented at the workshop, but in the meantime has already been installed and successfully tested with beams from the linac booster. Fig. 30 shows a layout of the spectrometer.

Superconducting solenoids can serve as large solid angle (20-200 msr) reaction-product separator/spectrometers for detection of low-rigidity ions at small angles ($\theta < 15^0$). Thus, these devices could be quite useful in many types of high-energy heavy-ion reactions where one wishes to detect either fusion products (high mass) or projectile-like fragments at small angles, without interference from the intense elastic group. As an example, the production and efficient detection of very neutron-rich reaction products are of interest, particularly if one is using a secondary-ion beam to initiate the reaction and thus requires high efficiency. These devices can also be used

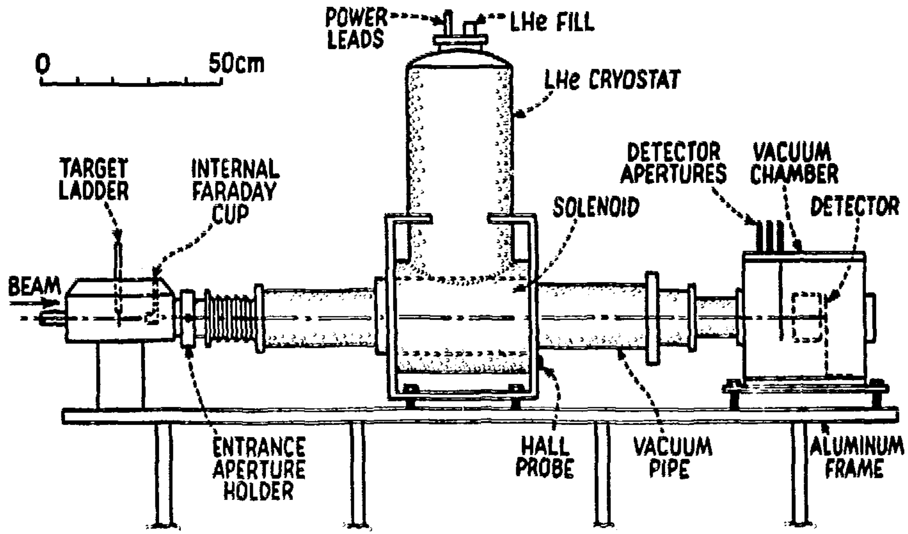


Figure 30.

Layout of the University of Michigan Superconducting-Solenoid Charged Particle Spectrometer.

to detect $\pi^{\pm}$ and other particles, so their development is of general interest. A particularly attractive feature is the ability to do time-of-flight measurements over a large path length (> 1 m) yet retain a good solid angle.

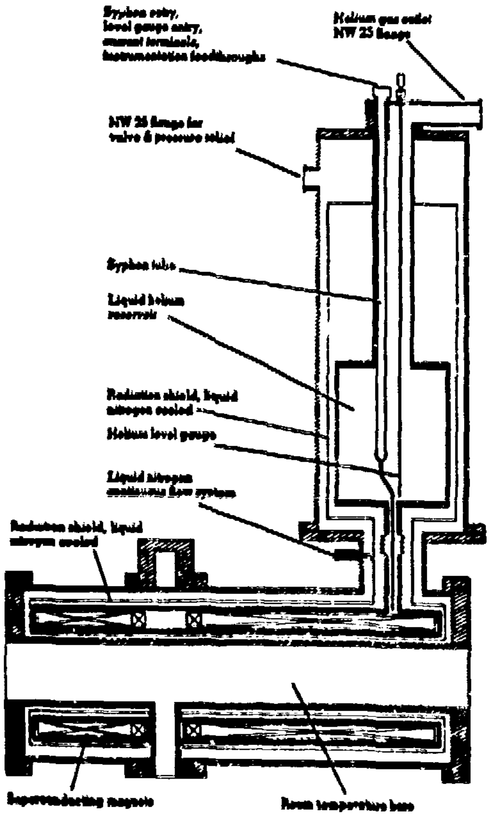
b) Superconducting-Solenoid e^- Spectrometer

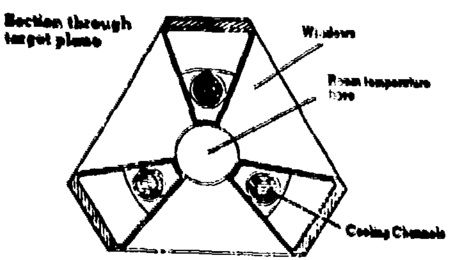
The Superconducting-Solenoid e^- Spectrometer to be installed by the Purdue Group at ATLAS is shown in Fig. 31. The magnet system is a set of NbTi solenoids on a horizontal axis, consisting of a split pair to provide a target field, and long solenoids extending this axial field in both directions. A flat field along 500 mm length, variable up to 2 Tesla will be obtained with the same current in all coils. Alternative field profiles are possible using various current combinations. The power supplies will allow the field to be swept rapidly. The spectrometer is similar to those existing at H.M.I. Berlin, K.F.A. Jülich and Lawrence Livermore Laboratory (installed at Los Alamos Laboratory). The magnets have been delivered, scattering chamber and beam stop have been constructed, installed, and the whole system has been vacuum tested. The detector system is presently being prepared for installation. It is hoped to have the spectrometer available for experiments in 1985. The device will be initially installed at the booster linac in area II for testing and first measurements.

9. General Purpose Beam Lines

(Presented by W. Kutschera)

As indicated in Figure 2, several beam lines (or ports on the switch magnets for potential beam lines) are reserved for general purpose applications. It is planned that they be available for experimental equipment to





SPECIFICATION

Superconductor: Multi-filamentary NbTi

Coil construction: Windings vacuum impregnated with epoxy resin, aluminium former.

Operating field at 4.2K: 0-2 Tesla

Operating current at 2 Tesla: 62 amps

Field profiles obtainable ([illegible]): a) 0-2 Tesla flat field; b) Minimum at target, e.g. 0.5 Tesla at target, 2 Tesla along solenoids c) Maximum at target, e.g. 1.5 Tesla at target, 1 Tesla along solenoids

Field uniformity of flat field: 3% over 500mm, extending horizontally 150mm and 350mm either side of the target.

Field modulation: 0-2 Tesla in 200 secs. (0.01 (0.01 Tesla/sec)

Room temperature horizontal bore: 85mm dia x 650mm long

Room temperature radial access: 3 channels, 30mm x 240° (total angle)

Flanges: Two 150 CF flanges at ends. 3 rectangular flanges for full access to the radial channels

Overall height: 980mm

Overall length: 650mm

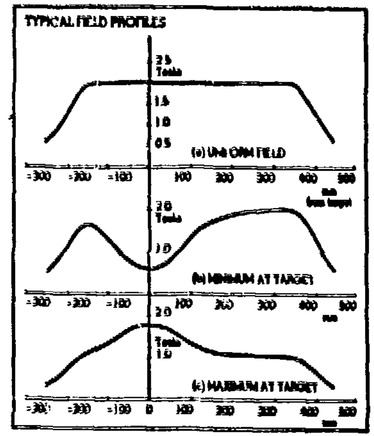
Rotatability: The cryostat may be rotated up to 30° from vertical

Cryostat: Aluminium and stainless steel

Radiation shields: Aluminium with piped liquid nitrogen system. Superinsulated.

Liquid helium capacity: 4-6 litres

Liquid helium consumption: 200cc/hour, rising to 600cc/hour during rapid field modulation at high fields.



Ancillary Equipment

Power supplies: Two PS120R superconducting magnet power supplies, featuring integral electronic ramp or external program, high stability and full protection of both the magnet and power supply in the event of a quench.

Level gauge: Removable superconducting wire sensor with standard C.C.L. control unit.

Liquid nitrogen transfer system: Constant displacement pump providing controlled continuous cooling of the radiation shields.

Figure 31.

Layout and specifications for the Purdue University Superconducting Solenoid e⁻-Spectrometer.

to be set up for specific experiments or short-term programs. They will be equipped, as will the dedicated beam lines, with a beam diagnostic station near the experimental setup that serves two functions: i) to allow beam tuning up to the experimental station and ii) to provide a reference point which together with a second reference point on an alignment post behind the experimental setup allows alignment of the experimental equipment.

There will also be auxiliary pumping available on the general purpose beam lines to support to a limited extent the vacuum in the experimental equipment.

10. Atomic Physics Beam Line

One of the beam-lines now under design and construction is to be dedicated to atomic physics users. Figure 32 indicates the layout of the proposed beam-line. It is hoped that this line will be ready for operation in the early summer of 1985. We are at present in the process of gathering requests and suggestions for the type of equipment and support which external users will need for efficient use of this beam-line for atomic physics experiments. Indicated in Fig. 32 is an atomic spectroscopy target chamber equipped with a 2.2 m grazing-incidence spectrometer. A recent development of potential interest to users might be the fact that the accelerator system has been used successfully in an Accel-Decel mode. That is, acceleration through the 8.5 MV Tandem, followed by foil stripping and deceleration through the Linac. Final energies reached were 350 keV/amu for fully stripped sulfur and oxygen, but we estimate that final energies can be reduced below 200 keV/amu.

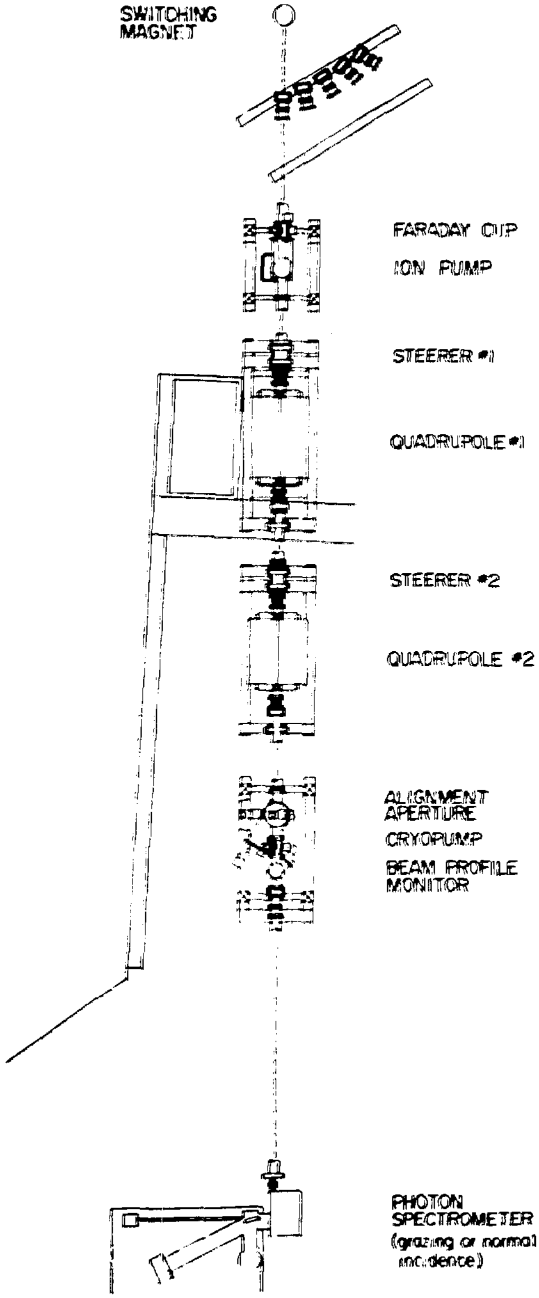


Figure 32.

Atomic physics beam line which can accomodate various experimental equipment. Here shown with a photon spectrometer mounted in the target position.

11. On-line and Off-line Data Collection and Analysis

(Presented by L. Welch)

A project to satisfy the data-acquisition requirements of ATLAS has been implemented. The system called DAPHNE (Data Acquisition by Parallel Histogramming and Networking) will consist of three major hardware components (Fig. 33) and considerable software support. The hardware will consist of a CAMAC system, a multibus-based front-end processor utilizing several single-board computers (SBC's) in a loosely-coupled parallel mode, and a super-mini computer. The super-mini computer is a VAX 750 to maintain compatibility within the Division and has already been purchased. The CAMAC crate will be governed by the VAX via an RS232 crate controller through which a programmable auxiliary crate controller (AUX) can be downloaded. The VAX-CAMAC communications link has been tested and the cross-compiler for the AUX also has been written. The AUX will be the Event Handler as designed by David Hensley of ORNL and more thorough testing of the downloading process will be done upon receipt of an Event Handler.

The CAMAC-MULTIBUS data link will be from a CAMAC FIFO module (which is being filled by the Event Handler) over parallel twisted pairs differentially driven to a parallel input port of one of the Multibus single-board computers. This part of the system is currently being designed and built by the Electronics Division.

The MULTIBUS-VAX communications will be via a DMA board on the UNIBUS of the VAX. The hardware board for the Multibus has been built and the UNIBUS board was commercially available. The software drivers, to function under the VAX operating system VMS, are presently being written. The MULTIBUS-VAX communications link will also be used to download the SBC's (most probably based on the 80286/80287 Intel microprocessor chips) from cross

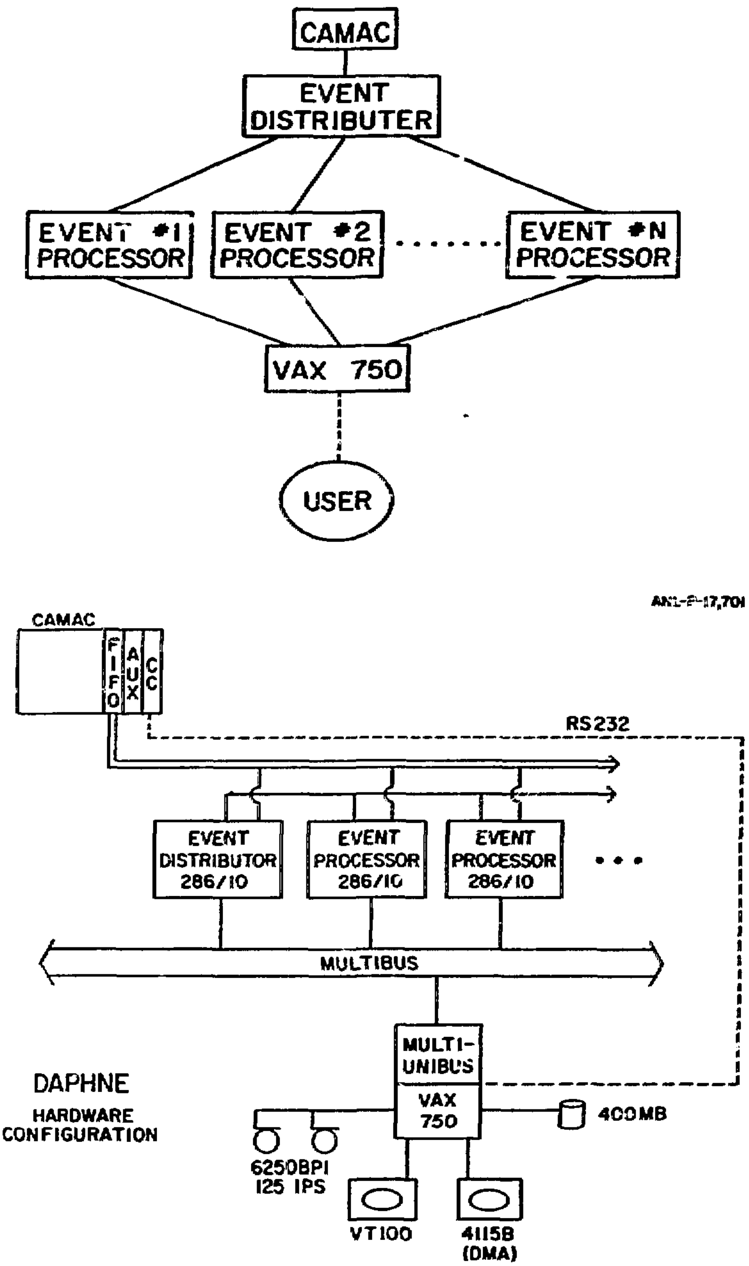


Figure 33.

The concept of DAPHNE depicting the parallel nature of event processing (top), and the hardware front end configuration of DAPHNE (bottom).

software on the VAX.

Since the time of the workshop considerable support software on the VAX has been written. Histograms can be created, displayed, plotted, printed, saved and recalled. Interactive definition of CAMAC structure is implemented. Many of the utility routines which allow changing or deleting data-acquisition parameters have been implemented.

Extensive use has been made of the programming tools available in VMS. The Command Language Interpreter (CLI) has considerably eased the user-software interface. Global Sections has greatly eased the process-process communication and has greatly aided modularity.

It is anticipated that DAPHNE will be available for replay analysis in the near future so that considerable testing and user reaction can be obtained before on-line usage.

For the off-line data analysis the Physics Division's VAX 780 has been upgraded to provide better performance by (1) adding 2MB of memory to bring the total to 4MB, (2) adding a 125 ips 6250 bpi tape drive, (3) adding a floating-point accelerator, and (4) adding an additional communications board to provide 16 more terminal lines. In addition, the VAX was tied into the site-wide NJE network which in turn is tied into the national BITNET. This will in principle allow outside users of ATLAS to establish a communication link between their local computers and those at ATLAS and the Physics Division.

V. User Liaison for ATLAS Experimental Program

User Liaison Physicist

Presently: C. N. Davids (312)972-4062 (4044)

After Jan. 1, 1985: B. Glagola (312)972-3890 (4044)

Target Area II

		Telephone Number
65" Scattering Chamber	W. F. Henning	(312)972-4058 (3663)
Split-Pole Spectrograph	K.-E. Rehm	(312)972-4073 (4020)
Gamma-Ray Facility	T.-L. Khoo	(312)972-4034 (4020)
18" Scattering Chamber	B. B. Back	(312)972-3619 (3655)
Neutron TOF Chamber	B. B. Back	(312)972-3618 (3655)
Electron Spectrometer	R. V. F. Janssens	(312)972-8426 (4020)
General Purpose Beam Line	W. Kutschera	(312)972-4026 (4020)
Laser Spectroscopy Lab.	C. N. Davids	(312)972-4062 (4044)

Target Area III

		Telephone Number
Beam Line System	W. Kutschera	(312)972-4026 (4020)
BGO-Compton Suppressed Ge(Li) Detector	R. V. F. Janssens/ T.-L. Khoo	(312)972-8426 (4020) (312)972-4034 (4020)
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Split-Pole Spectrograph	K.-E. Rehm	(312)972-4073 (4020)
Mass Spectrometer	W. F. Henning	(312)972-4058 (3663)

		Telephone Number
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Detector Laboratory	B. D. Wilkins	(312)972-3632 (3655)
Electronics	R. V. F. Janssens	(312)972-8426 (4020)
Linac Operations	R. C. Pardo	(312)972-4029 (4020)

VI. Technical Support for ATLAS Experimental Equipment

Design, construction, assembly and testing of the experimental equipment at ATLAS are proceeding on schedule and are producing devices of high technical quality. This would not be possible without the dedication and skill of the technical support staff at Argonne. The various individuals contributing to this broad effort are recognized in the list below.

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Data Handling	D. Cyborski	
Assembly and Operation:	R. Nielsen	
		C. Bolduc A. Drabik D. Little J. Ray
	R. Kickert	
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