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The AMS Program at LLNL *

I. D. Proctor

Lawrence Livermore National Laboratory, Livermore, CA 94550

ABSTRACT

Livermore will have an operational Accelerator Mass Spectrometer (AMS) by mid-1989 as part of its new Multi-user Tandem Laboratory. The spectrometer was designed primarily for applications in archaeology and the geosciences and was co-funded by the University of California Regents. Radiological control for personnel protection, ion sources and injection systems, the tandem and all beam handling hardware are operated with a distributed processor computer control system. The Tandem is the former University of Washington injector FN which has been upgraded with Dowlish tubes, pelletron charging and SF_6 gas. Design goals for the AMS system, computer aided operation, automated measurement capability, initial results and some of our intended applications will be presented.

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1. Introduction

Lawrence Livermore National Laboratory (LLNL) is building an AMS facility as part of a new Multi-user Tandem Laboratory (MTL) [1] which incorporates a distributed computer for control of the complete laboratory. The spectrometer was co-funded by the University of California Regents and the Nuclear Physics and Chemistry Divisions of LLNL primarily with archaeological and geochronology applications in mind. The goal for the AMS facility is to develop a measurement capability with a completely automated system for routine applications. Several groups at LLNL are exploring new AMS applications in biomedical research, environmental studies and clinical procedures yet to be fully exploited by the technique.

2. Description of the Equipment

A schematic diagram of the major components in the Multi-user Tandem Laboratory (MTL) is shown in Fig. 1. Jay Davis will discuss details of the complete laboratory in another paper at this conference. Most of the large hardware has been reused from the old cyclograaff facility, purchased used, or obtained from excess and reworked to meet the needs of the new laboratory. Areas that are crucial for reliable and precise operation of a laboratory of this type have not been compromised. Critical elements such as power supplies, hardware control interfacing and the computer control system were selected with emphasis on ease of implementation and proven reliability in applications similar to this laboratory. The AMS portion of the MTL was designed without compromise of its functional performance by locating the injection and high energy analysis systems at the optimum positions for their intended use.

Ion-optical design for the MTL was done by John Southon of Simon Fraser University using the code Optryk [2]. Large apertures in optical elements permit nearly aberration and loss-free transport. The AMS portion of the laboratory is designed to accept an ion source divergence of up to 15 mRad. No transmission loss is expected through all defining apertures and optical elements to the detector location. Some ions will be lost at the gridded lens forming the ion source image for the pulsed inflector and at the gridded lens located at the entrance to the low energy tube. All isotopes are expected to undergo nearly identical attenuation at these grids resulting in small fractionation.

2.1 Ion Sources and Injection System

Goals for the AMS system include the ability to handle large sample throughput with modest precision, in many cases, and high precision capability in selected applications. The present hardware configuration will permit measurements for a wide range of isotopes ranging from beryllium to iodine. Hydrogen and heavier isotopes will be added at a later date. The dual 90-degree pulsed injector shown near the base of the tandem in Fig. 1 provides at least two independent source positions for AMS use. The upper 90-degree port is intended for low background or high precision applications, and the lower port for routine use including tagged samples. We plan eventual expansion to two or three selectable sources at the lower location.

Initial operation will use a Genus Model 846 ion source which is based on a design by Roy Middleton [3]. The Model 846 source is a modification of an older Middleton design (the Model 860). The new design incorporates a spherical ionizer for brighter Cs beams, a robust cathode insulator, a provision to move the sample in small controlled transverse steps to prevent deep cratering under Cs bombardment, and a cylindrical extraction geometry to improve the emittance. Each source holds up to 60 computer addressable samples which are transferred through an unload/load cycle in no more than 30 seconds. Extensive testing of the performance for this source will be necessary before an AMS measurement capability can be established.

A pulsed injector magnet and vacuum tank was designed and built by Danfysik to our requirements. The magnet is a 50 cm radius dipole with a rotatable exit pole face allowing double focusing operation from both source locations. The vacuum tank has a 3 cm clear aperture with the tank insulated to 10 kV DC from the magnet pole pieces. The entire vacuum tank from object to image point will operate as an electric accel/decel (or the inverse) double gap lens providing velocity selection of the sequential isotope selected for injected into the tandem. A bipolar power supply (the bouncer) will switch the vacuum chamber by up to 5 kV. Switching time is 2 ms with 12 bit resolution [4]. Control of the bouncer power supply and data gating is by a data acquisition computer that communicates to the operational control system via a LAN line.

2.2 Acceleration and High Energy Analysis

Fig. 2 is a photograph of the high energy extension of the AMS system showing most of the large analysis hardware. This picture was taken during initial alignment checkout of the AMS leg. The stable isotope chamber, the Wien filter and the detector system are not installed. The tandem is the former University of Washington injector FN. It has been upgraded with Dowlish titanium tubes, a pelletron charging system and SF_6 gas for high voltage insulation. The tandem presently operates with the terminal stripper box from the LLNL EN. A new stripper assembly incorporating a gas recirculator, an insulated stripping tube for fast terminal stabilization, and a larger capacity foil changer will be installed in 1989. Terminal stabilization for AMS use will include GVM, CPU and a sectored Faraday cup for error signal generation. The feedback signal is applied via corona and terminal modulation [4]. Feedback loops are hard-wired with computer selectable control values.

High energy definition is performed by a symmetric 3Q-2D-3Q structure for momentum analysis, followed by a Wien filter for velocity selection. The magnetic quadrupole triplets have 10 cm apertures and the dipoles and Wien filter 5 cm apertures. The dipoles have square entrance and exit pole faces and are operated in a 1R-1R configuration with a slightly asymmetric image of the stripper formed at the point of symmetry. The Y acceptance of the dipoles is nearly twice the calculated full beam envelope. The X acceptance of the first dipole is marginal for measurement of the complete mass $^{12:13:14}C$ triplet without adjustment of the magnetic field. These isotopes will be measured as two independent pairs when delta ^{13}C is required.

2.3 Detection and Data Acquisition

Initial operation of the detector system will be with a multicathode gas ionization counter similar to the Rochester design [5]. This counter is an integral part of the lid of a multipurpose detector chamber, so changing detector types is performed by changing lids. The analysis magnet from the LLNL EN tandem will be converted to a gas filled magnet to be located behind the counter chamber. Time-of-flight analysis will be available using the straight through port of this magnet.

Standard NIM nuclear electronics are used to process signals from these detectors. Digitization and final data gating is done in CAMAC under control of the data acquisition and handling computer system. The separate data handling computers are identical to the computers used for laboratory control. The supervisor data handling computer performs preliminary data reduction and controls all archival and retrieval functions through a commercial database program. Data is archived on removable 300 Mbyte hard disc platters with a total disc capacity of 900 Mbytes. Data sets, including all parameters of the AMS system, can be converted to ASCII files on 5-inch floppy discs for analysis at a remote location.

2.4 Computer Control System

Control of all laboratory hardware and data acquisition functions is accomplished through two distributed systems of Hewlett-Packard 9000 computers. This system is described in a paper by Thomas Moore at this conference. The local state vector for a CAMAC hardware interface is maintained by a HP 9000/319 computer which receives instructions and reports results via a LAN line to a supervisor HP 9000/350 computer. The AMS supervisor data handling computer controls the detector state vector, can read laboratory hardware vectors and can request new hardware vectors through the laboratory supervisor computer. The distributed nature of these systems allows near real time viewing and preliminary reduction of data without any compromise in acquisition speed.

3. Discussion and Prospectus

The AMS beamline at Livermore's MTL was originally designed for use in archaeological, geochemical and nuclear test diagnostics development. Exploration of new applications using this technology, particularly in biomedical and environmental research, has established several areas of interest to LLNL programs beyond the design goal. Some 20 possible new applications using AMS have been identified in a series of multidisciplinary workshops. Two new applications identified are briefly outlined below.

A small arginine-rich protein, protamine, packages DNA inside the nucleus of all mammalian sperm. The protamines inactivate all the sperm's genes and packs its DNA in a highly condensed, virtually inert state. The AMS technique using ^{14}C tagged protein has enough sensitivity to validate the presence of protamine gene mutations where one of the two human protamine genes lose their ability for expression. In a separate experiment using selective modification of the DNA molecule and protein sequencing, AMS analysis will uniquely identify the protamine-DNA binding site.

Several highly mutagenic amino-imidazole-heterocyclic amine (IQ-type) compounds have been isolated from or detected in fried meat. Identification of these IQ compounds requires cooking and processing several hundred kg of meat, therefore, no reasonable experiment has been proposed to identify the precursor amino acid, sugar or sugar derivatives responsible for the IQ production. Using AMS, a single hamburger can be tagged with sufficient ^{14}C incorporated into a potential IQ type precursor to uniquely identify its incorporation into the mutagenic compound.

LLNL will soon have operational a new AMS facility that incorporates several novel features. LLNL is committed to develop the capability of this facility to state of the art performance in both automated operation and measurement precision. New applications using AMS are identified to broaden multidisciplinary use of the remarkable sensitivity available with the technique.

References

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Figure Captions

Figure 1:
Artist's plan view of the laboratory with some of the major components identified.

Figure 2:
Photograph of the high energy AMS extension. Magnets and vacuum system are complete, but the stable isotope chamber, Wien filter and detector components remain to be installed.

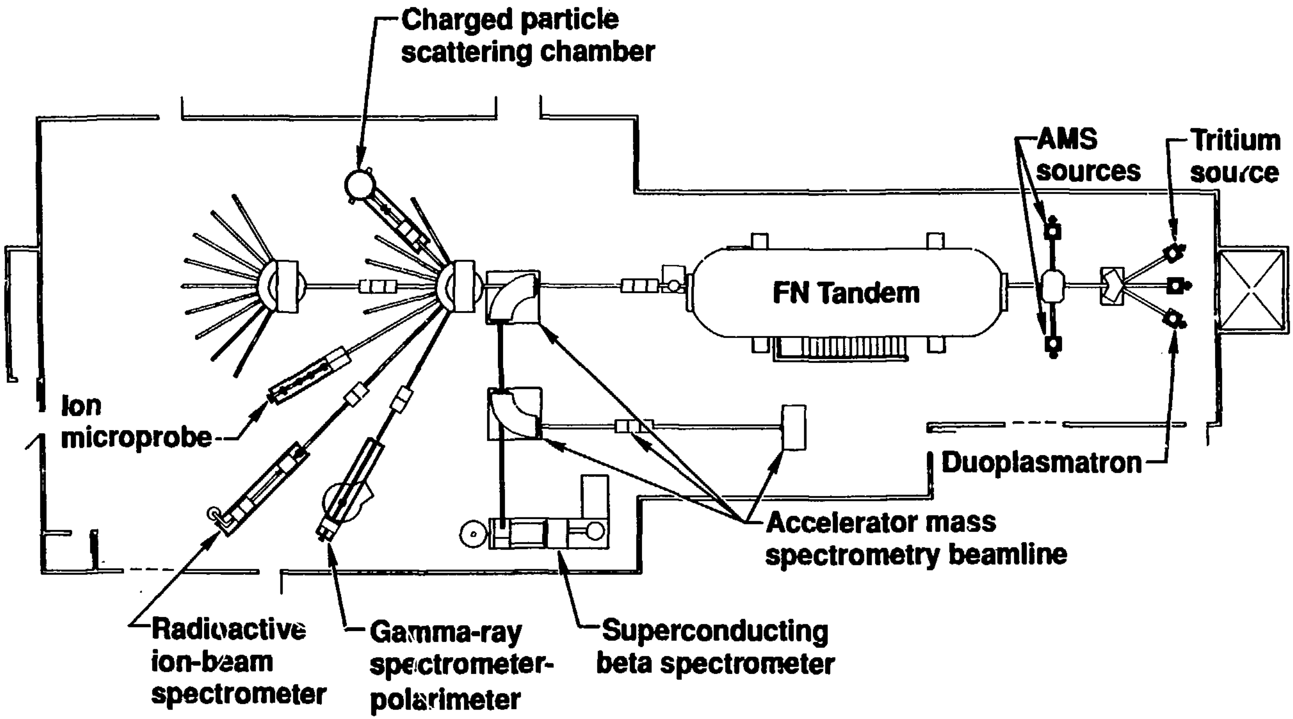

Figure 1

AH-[illegible]-U-1247-1

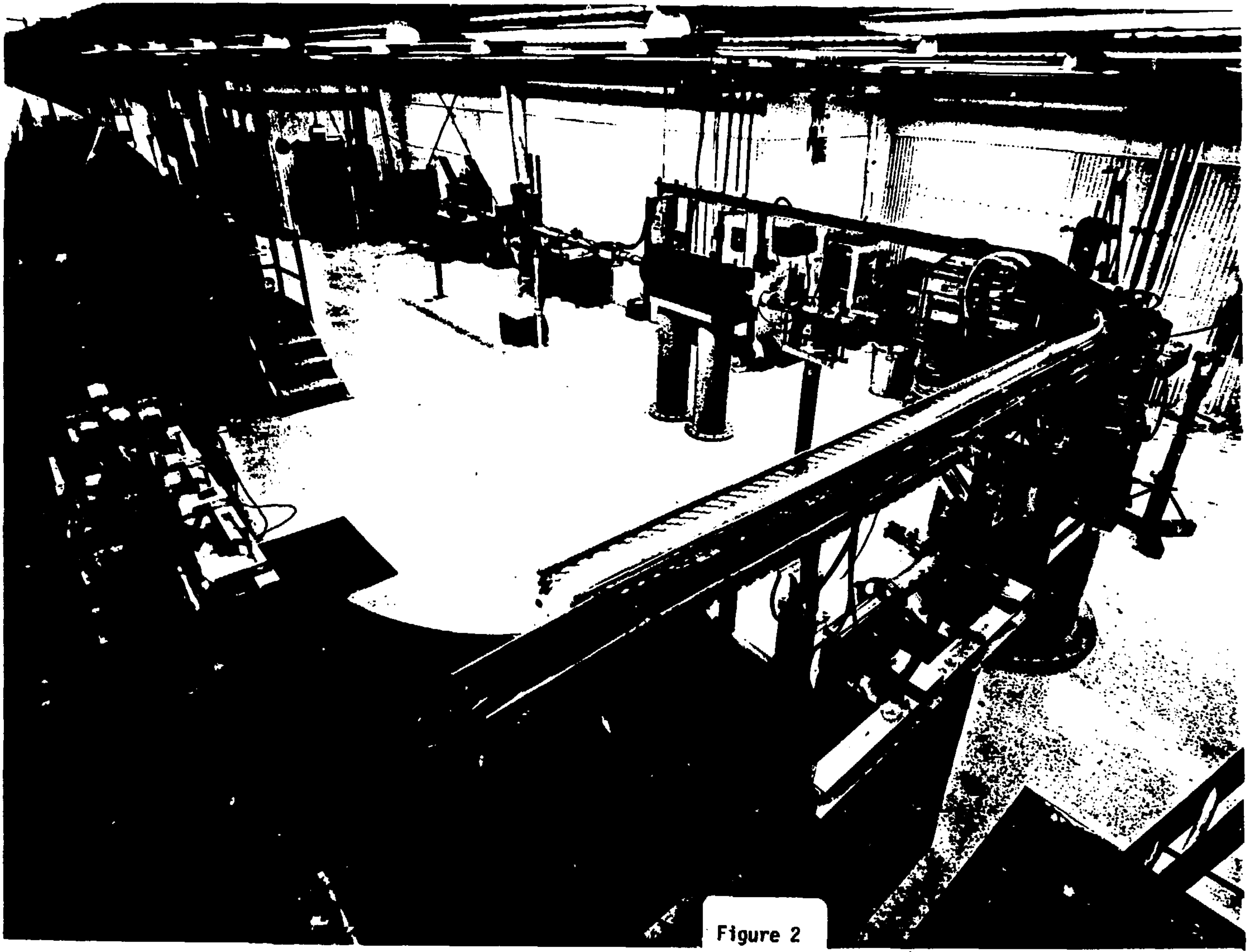

Figure 2