Title

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DISCLAIMER

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INTRODUCTION

Since the initial acceleration of heavy ions at the Bevatron[1] there has been an increasing number of short runs with heavy ions to calibrate cosmic ray instruments. Many of these experiments have used the magnetic spectrometer system set up by the Heckman group for measuring fragmentation cross sections (Bevatron experiment 162-H). The purpose of this short paper is to gather together the properties of this spectrometer system and some facts about heavy ion beams at the Bevatron in order to make this information more readily available to physicists who wish to calibrate an instrument or have some other short experiment in mind. The information presented here should make it possible to write proposals for this class of experiments without reference to the complete Bevatron Experiments' Handbook (UCRL 17333). However, the Handbook is a necessity for proposing major experiments.

CURRENTLY AVAILABLE BEAMS

Particle	^{2}H, ^{4}He, ^{12}C, ^{14}N, ^{16}O.
Energy	0.2 - 2.1 GeV/N. Typical extraction energies are 0.28, 1.0, and 2.1 GeV/N. Intermediate energies can be achieved with degrading.
Energy Spread	300 keV/N FWHM.
Flux	Variable 10^{1} - 10^{6} particles per pulse. Particles per pulse can generally be held within a factor of 2 between successive pulses.
Spill	0.2 - 1.0 sec (shorter spill at the lower energy extraction).
Spill Structure	Generally no worse than 20 to 1 range of instantaneous rate within a spill.
Pulse Frequency	10 - 17 pulses per minute, the higher rate available at low extraction energy.
Emittance	$\epsilon_{vert} \leq 26$ cm mrad, $\epsilon_{horiz} \leq 5$ cm mrad (90% of beam).

SPECTROMETER PROPERTIES

The spectrometer arrangement is shown in Fig. 1. This apparatus is located in Channel II of the external beam area of the Bevatron. The basic design requirement was to be able to bring fragments from the target area to a focus at the guide rail, over a large rigidity range, while keeping the primary beam in vacuum to reduce background.

The Bevatron's extracted beam (labled ^{16}O beam in Fig. 1) enters at target area, which presently is an air gap to allow placement of degraders, scintillators, and targets. The quadrupoles Q1-4 focus any rigidity up to 9 GV/c on the guide rail while M1 + M2 produce at the guide rail a deflection D which is inversely proportional to the rigidity. The rail coordinates range from 0.0 cm for an undeflected beam to 400.0 cm at maximum deflection.

The great utility of this arrangement for experiments requiring selected isotopes can be seen as follows: If a primary beam of rigidity R is deflected to appear at D $\simeq$ 200 cm with a target in place, then fragments of rigidity 0.5R to 2R can be focused at the guide rail. Because fragments of the projectile move with velocities very close to the initial beam velocity[2] their rigidity and hence their deflection is determined only by their mass-charge ratio through the relationship.

$$D(Z, A) = 400(\frac{Z}{A}), \tag{1}$$

where Z and A are, respectively, the charge and mass (amu) of the fragment. In Fig. 2, the rail coordinates are shown for all isotopes observed for a primary beam of ^{16}O. The flux of the heavier isotopes is generally confined to a few centimeters on either side of the central value given by Eq. 1. This can be seen for the carbon isotopes produced by a ^{16}O beam on a ^{9}Be target at 2.1 GeV/N in Fig. 3. The ordinate in Fig. 3 is the number of particles in an area of approximately 1.25 cm^2 at the guide rail per beam particle incident on the ~4 g target. Thus with 10^6 beam particles per pulse available, appreciable fluxes of almost any isotope can be produced. The only restriction is that the isotope have a lifetime of the order of the transit time t from the target to the rail. At beam energies of 2.1 GeV/N, the transit time (80 nsec) corresponds to a proper time $t = 80/\gamma = 25$ nsec.

All of the magnets in the spectrometer are computer controlled and deflections may be read from a scale on the guide rail. A program exists which requires as input the rigidity of the beam, A and Z of the desired isotope, and a rail position, D. The computer will then focus the spectrometer magnets so that the isotope appears at D.

In summary, this system, with suitable degraders at the target area or at the guide rail, can deliver almost any isotope up to ^{16}O at any energy up to 2.1 GeV/N.

EXPERIMENTAL FACILITIES

Experiment Space	There is a space of 12 ft. beyond the guide rail with a 12 ft. ceiling in the cave. The beam line is 4 ft. above the floor and smaller experiments can be placed on the guide rail support which is 16 inches below beam line.
Assistance	The Bevatron assigns a staff member to each experiment to assist and communicate.
Signals	Timing signals are available to allow predictions of beam spill, etc.
People Space	There is an experimental house for visitors located outside the cave (50 ft. cable distance). The floor area is 200 sq. ft.

FUTURE DEVELOPMENTS

In 1974, the transfer line between the Bevatron and the Super Hilac injector (Bevalac) will be operational. The Bevalac will produce more intense heavy ion fluxes with beams of ions as heavy as ^{56}Fe. Also in 1974 a 50 MeV linac will be introduced as the primary proton source for the Bevatron. This will allow the present source to be devoted exclusively to heavy ions, thus reducing to a few hours the time required to convert to heavy ion operation.

PROPOSALS

Experiment proposals should include:

1. A short summary of the experiment.

2. Energies and particles desired.
3. Space and power requirements.
4. Estimates of set-up and data-taking times.
5. Dates when your group can be ready to proceed with the experiment.

All proposals are reviewed by theBevatron Scheduling Committee which meets formally about every three months. However, short experiments of the type we are discussing here generally fall into a class of experiments which can be treated less formally. We quote from the Bevatron Experimenters' Handbook:

> "Another class of experiments is called 'Parasitic'. The general definition of a parasitic experiment is one that requires a negligible amount of Bevatron beam, equipment, and manpower. In addition it must not interfere with the formal Bevatron schedule. If an experiment fits these rather stringent criteria, it can be approved by the ex-officio members of the Committee together with the Bevatron Operations Group without a formal session of the Scheduling Committee."

Proposals should be sent to

W. D. Hartsough
Building 50, Room 150
Lawrence Berkeley Laboratory
Berkeley, Calif. 94720
Telephone: 415-843-2740, x5501

Questions involving scheduling or fees should also be addressed to Mr. Hartsough.

Any questions of a technical nature involving the heavy ion Bevatron beams and the spectrometer described above can be referred to either

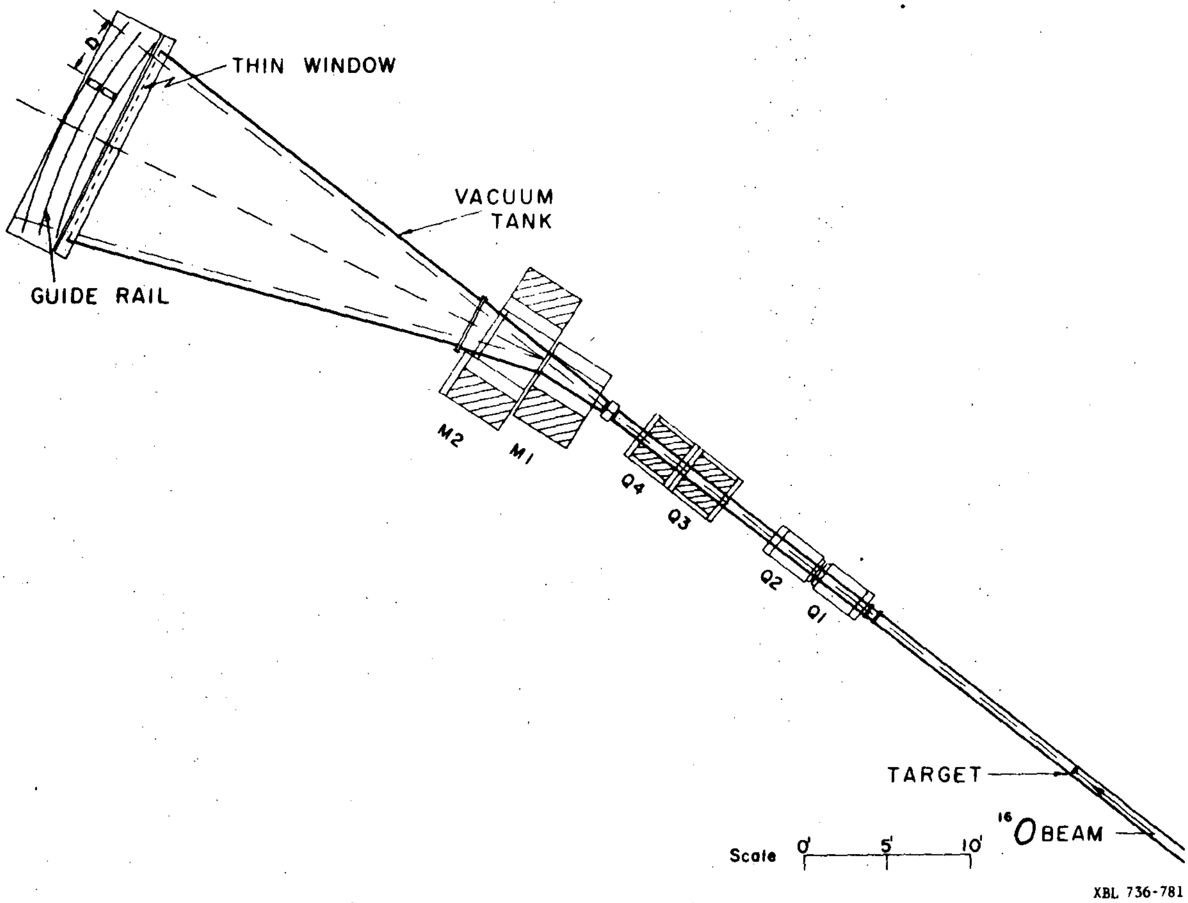
Douglas Greiner or Peter Lindstrom
Building 50, Room 245
Lawrence Berkeley Laboratory
Berkeley, Calif. 94720
Telephone: 415-843-2740, x5685

REFERENCES

1. Grunder, H. A. Hartsough, W. D., Lofgren, E. J., Science, 174, 1128 (1971).
2. Heckman, H. H., Greiner, D. E., Lindstrom, P. J., and Bieser, F. S., Phys. Rev. Lett., 28, 926 (1971).

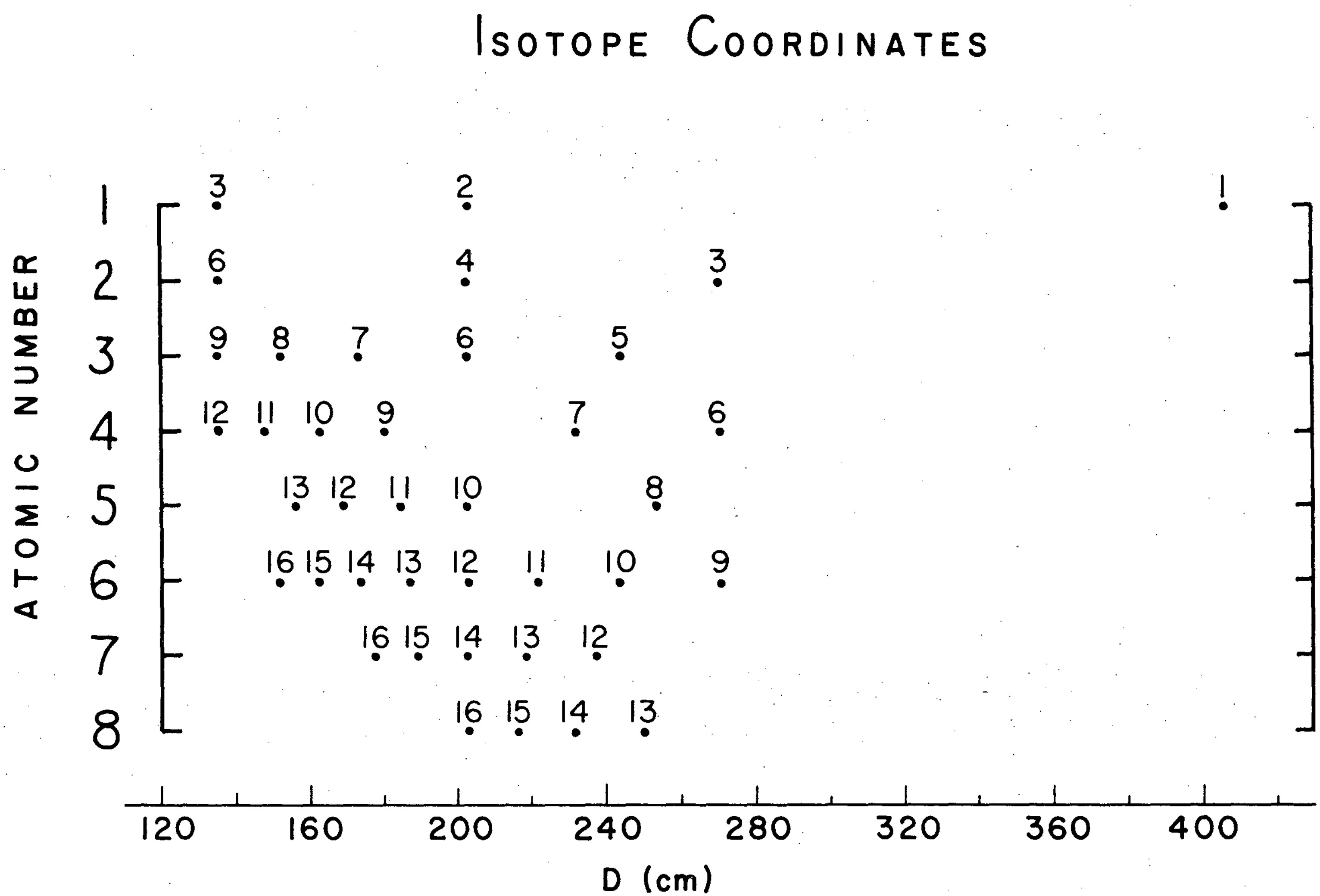
FIGURE CAPTIONS

1. Focusing magnetic spectrometer arrangement. Fragments from the target area within 10 mm of 0° are focused at the guide rail. The system can focus rigidities up to 9 GV.
2. Plot of isotope deflections for fragmentation on a ^{16}O beam centered at D = 200. The numbers plotted refer to the mass in amu of the isotope.
3. Plot of carbon isotopes observed from the fragmentation of a ^{16}O beam in a Be target. N(D) is the flux integrated over a 1.25 cm^2 area at the guide rail per incident beam particle.



THIN WINDOW
VACUUM TANK
GUIDE RAIL
M2
M1
Q4
Q3
Q2
Q1
TARGET
Scale 0' 5' 10'
16O BEAM
XBL 736-781

Fig. 1



XBL 736-778

Fig. 2

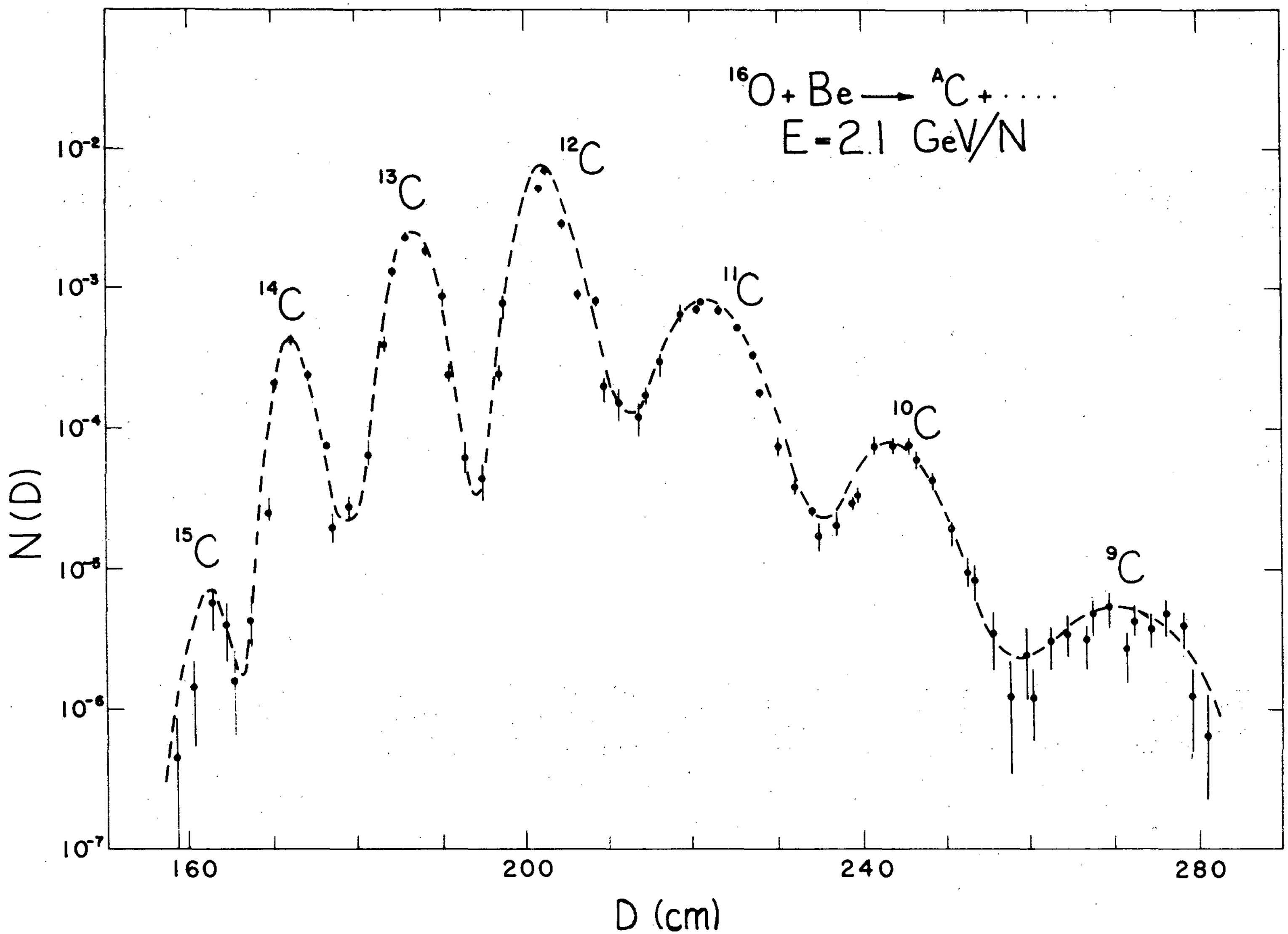


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Fig. 3

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