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THE HOLIFIELD HEAVY ION RESEARCH FACILITY[1]

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Development of the Holifield facility has continued with resulting improvements in the number of ion species provided, ion energy for tandem-only operations, and utilization efficiency. In this report, we describe our recent operational experience, development activities, and future development plans.

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1. INTRODUCTION

The Holifield Heavy Ion Research Facility (HHIRF) is located at the Oak Ridge National Laboratory and operated as a national user facility for research in heavy ion science. The facility operates two accelerators: an NEC pelletron tandem accelerator designed to operate at terminal potentials up to 25 MV and the Oak Ridge Isochronous Cyclotron (ORIC) which has been modified to serve as an energy booster for beams from the tandem accelerator. Ion energy performance functions for the facility are shown in Fig. 1.

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The principal experimental devices of the facility include a broad range spectrograph ($ME/q^2 = 225$) equipped with a vertical drift chamber detector system, a 4π spin spectrometer equipped with 72 NaI detectors (Ge detectors and BGO compton-suppression units can be used in place of the NaI detectors), a time-of-flight spectrometer, a 1.6-m scattering chamber, a heavy-ion/light-ion detector (HILI) which will be used for studying inverse reactions, a split-pole spectrograph, and a velocity filter.

The facility, which has been in routine operation since 1982, has been described previously.[1-4] In this report, we will discuss our recent development activities, operational experience, and future development plans.

2. TANDEM ACCELERATOR

2.1 Voltage Performance

Since installation of reconditioned acceleration tubes in 1983, voltage performance of the tandem accelerator has gradually improved. Specifically, the accelerator has been routinely operated at voltages up to 21.0 MV since July 1985 and one scheduled experiment was completed at 22.0 MV in January 1986. The maximum stable voltage demonstrated with beam is 23.5 MV (February 1986). The distribution of operating voltages in a recent one-year period (October 1985 - September 1986) is shown in Fig. 2. During this interval, only 26 full column sparks were experienced.

In an effort to further improve voltage performance of the accelerator, we are now engaged in a program of replacing the present acceleration tubes with tubes of a compressed geometry design.[5,6] Tests on compressed geometry tubes installed in two 61-cm units of the tandem accelerator have been described previously[7] while tests on nine 61-cm units are described in another contribution to this conference.[8] These initial tests suggest that a voltage improvement of the order of 15 percent may be achieved with the compressed geometry tubes.

2.2 Development

Development of other systems of the tandem accelerator has continued over the past several years. The most important improvements include upgrade of the control system hardware, installation of a new chopper/buncher system, charging system modifications, and improvements to both control system and aids-to-operation software. These and other improvements are described in greater detail in other contributions to this conference.[9,10]

2.3 Negative Ion Sources

All operation of the tandem accelerator since our last report[3] has been with the axial geometry cesium sputter source described by Alton.[11] This source, which has been used with both cylindrical and spherical ionizer geometries, has continued to provide excellent reliability, long lifetime, low sample consumption rates, and high beam intensities. In a more recent development, this source has been equipped with an ellipsoidal geometry cesium ionizer[12] which is expected to have a cesium perveance several times larger than the cylindrical and spherical ionizers. Preliminary results indicate that the ellipsoidal ionizer is superior to the spherical and cylindrical cesium ionizers, especially for producing ions from low sputter rate materials such as Nb and from difficult ions such as Li^- and CaH^-.

To facilitate both operational beam development and ion source development, a new ion source test facility, with provisions for both ion beam mass analysis and dc and pulsed beam emittance measurement, has been commissioned. Emittance measurements made with this facility on several axial geometry cesium sputter sources are described in another contribution to this conference.[12]

3. COUPLED OPERATION

Use of the ORIC as an energy booster has proved to be an effective means of producing a wide range of energetic ion beams. To date, 20 ion species have been provided for the facility experimental program at energies up to 1 GeV. Development of the ORIC has continued with emphasis on improved reliability and utilization efficiency. The most important recent activities include installation of a new control system computer, modernization or replacement of all trim coil and harmonic coil power supplies, reduction of the dee aperture (to achieve a full rf tuning range of 6.7 - 20.1 MHz), overhaul and redesign of the rf shorting plane, and continued improvement of beam setup programs. An important consequence of the last activity is that new beams can be accelerated with essentially no extra development time. Details of coupled operation, along with recent improvements to ORIC, have been recently discussed by Martin et al.[4]

4. OPERATIONAL EXPERIENCE

Accelerator utilization statistics for operation of the facility since the beginning of routine operation in 1982 are shown in Table 1. As can be seen, utilization efficiency has improved with a consequent increase in the number of hours of beam provided for research. We have been especially encouraged by the reduction in unscheduled maintenance and the reduced number of interruptions of the experimental program by unscheduled tandem openings which have been experienced in the last eighteen months.

Beams provided for scheduled experiments since the start of routine operation are shown in Table 2. Of special interest are coupled operation beams provided with separated isotope ion source probes (^{17}O, ^{18}O, ^{110}Cd, ^{116}Sn, and ^{150}Nd) and beams of maximum energy (^{58}Ni and ^{79}Br at 1 GeV).

5. FUTURE DEVELOPMENT

Our principal focus for short-term development of the facility is a proposed synchrotron-cooling-storage ring with the acronym HISTRAP (Heavy Ion Storage Ring for Atomic Physics).[13] HISTRAP is optimized to accelerate, decelerate, and store beams of highly charged very-heavy ions at energies appropriate for advanced atomic physics research. The ring is designed to allow studies of electron-ion, photon-ion, ion-atom, and ion-ion interactions. An electron cooling system will provide ion beams with small angular divergence and energy spread for precision spectroscopic studies and also is necessary to allow the deceleration of heavy ions to low energies. HISTRAP will be injected with ions from either the tandem accelerator or from a dedicated ECR source and 250 keV/nucleon RFQ linac. The ring will have a maximum bending power of 2.0 T·m and have a circumference of 46.8 m. The proposed location of HISTRAP in the facility is shown in Fig. 3.

6. SUMMARY

With almost five years of operational experience, the HHIRF tandem accelerator has proven to be a reliable and flexible accelerator - both in stand-alone mode and as an injector. Steady progress has been made in improving its terminal voltage capability and it is expected that the development efforts now under way will result in achievement of its design voltage in the near future.

Experience with operation of the ORIC as an energy booster has been particularly successful, providing a new range of ion-energy combinations for use in experiments and demonstrating the power and flexibility of a tandem accelerator as an injector for a cyclotron booster.

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Table 1

HHIRF ACCELERATOR UTILIZATION

	FY 83*1	FY 84	FY 85	FY 86	1st Half FY 87
BEAM PROVIDED FOR RESEARCH (HOURS)*2	3249*3	3172	3904	4162	1864
FRACTION OF TANDEM ACCELERATOR "UP TIME"*4 HOURS PROVIDED FOR RESEARCH	57%	64%	67%	70%	65%
FRACTION OF ORIC "UP TIME"*4 HOURS PROVIDED FOR RESEARCH	65%	68%	73%	74%	78%
UNSCHEDULED MAINTENANCE (TANDEM + ORIC) (HOURS)	1470	1882	1013	529	243
NUMBER OF INTERRUPTIONS OF EXPERIMENTAL PROGRAM BY UNSCHEDULED TANK OPENINGS	6	5	7	3	1
COUPLED OPERATION MACHINE RESEARCH (HOURS)	161	130	73	0	1

*1 FY 83 = U.S. GOVERNMENT FISCAL YEAR 1983 = THE INTERVAL, OCTOBER 1982 THROUGH SEPTEMBER 1983 (FOR EXAMPLE).
*2 BEAM PROVIDED FOR RESEARCH WAS REDUCED IN FY 83 AND FY 84 AND WILL BE REDUCED IN FY 87 BY WORK DESIGNED TO IMPROVE TANDEM ACCELERATOR VOLTAGE PERFORMANCE.
*3 INCLUDES 280 H OF ORIC STAND-ALONE OPERATION.
*4 UP TIME = RESEARCH + BEAM TUNING + MACHINE RESEARCH.

Table 2

HHIRF BEAMS PROVIDED FOR SCHEDULED EXPERIMENTS

BEAM	MAXIMUM ENERGY (MeV)	MODE†
^{1}H	25	T
^{7}Li	128	T,C
^{9}Be	158	C
^{10}B	168	C
^{11}B	169	T,C
^{12}C	300	T,C
^{13}C*	67	T
^{16}O	405	T,C
^{17}O*	381	C
^{18}O*	352	T,C
^{19}F	190	T
^{24}Mg	178	T,C
^{25}Mg	132	T
^{26}Mg*	160	T
^{27}Al	196	T
^{28}Si	333	T,C
^{29}Si	150	T
^{30}Si	264	T
^{32}S	725	T,C
^{34}S*	155	T
^{36}S*	123	T
^{35}Cl	703	T,C
^{37}Cl	187	T
^{40}Ca	227	T
^{44}Ca*	201	T
^{45}Sc	200	T
^{46}Ti*	280	T
^{48}Ti	581	T,C
^{49}Ti*	235	T
^{50}Ti*	250	T
^{51}V	220	T
^{52}Cr	230	T
^{56}Fe	842	T,C
^{58}Ni	1010	T,C
^{60}Ni	228	T
^{63}Cu	189	T
^{65}Cu	290	T
^{64}Ni*	290	T
^{74}Ge	306	T
^{76}Ge	305	T
^{79}Br	1000	C
^{81}Br	604	C
^{82}Se	295	T
^{90}Zr	395	T
^{93}Nb	276	T
^{107}Ag	374	T
^{109}Ag	733	C
^{116}Cd*	499	C
^{116}Sn*	684	T,C
^{120}Sn	240	T
^{150}Nd*	760	C
^{197}Au	591	T
^{238}U	119	T.

† T = Tandem alone; C = Coupled mode.

* Beam provided with separated isotope probe sample.

Figure Captions:

1. Ion energy performance functions for the ORIC, the HHIRF tandem accelerator (gas-foil stripper mode), and coupled operation of the tandem accelerator and the ORIC. The functions shown were calculated with the assumption of a final intensity of about 10^{11} particles/s.

2. The number of runs in 1-MV-wide intervals is shown as a function of tandem accelerator terminal potential for the period October 1, 1985, through September 30, 1986.

3. Plan View of the proposed HISTRAP facility as an addition to the HHIRF. The storage ring in the lower left will be injected with ions from either the existing 25-MV tandem accelerator or from a dedicated ECR source and RFQ preaccelerator.

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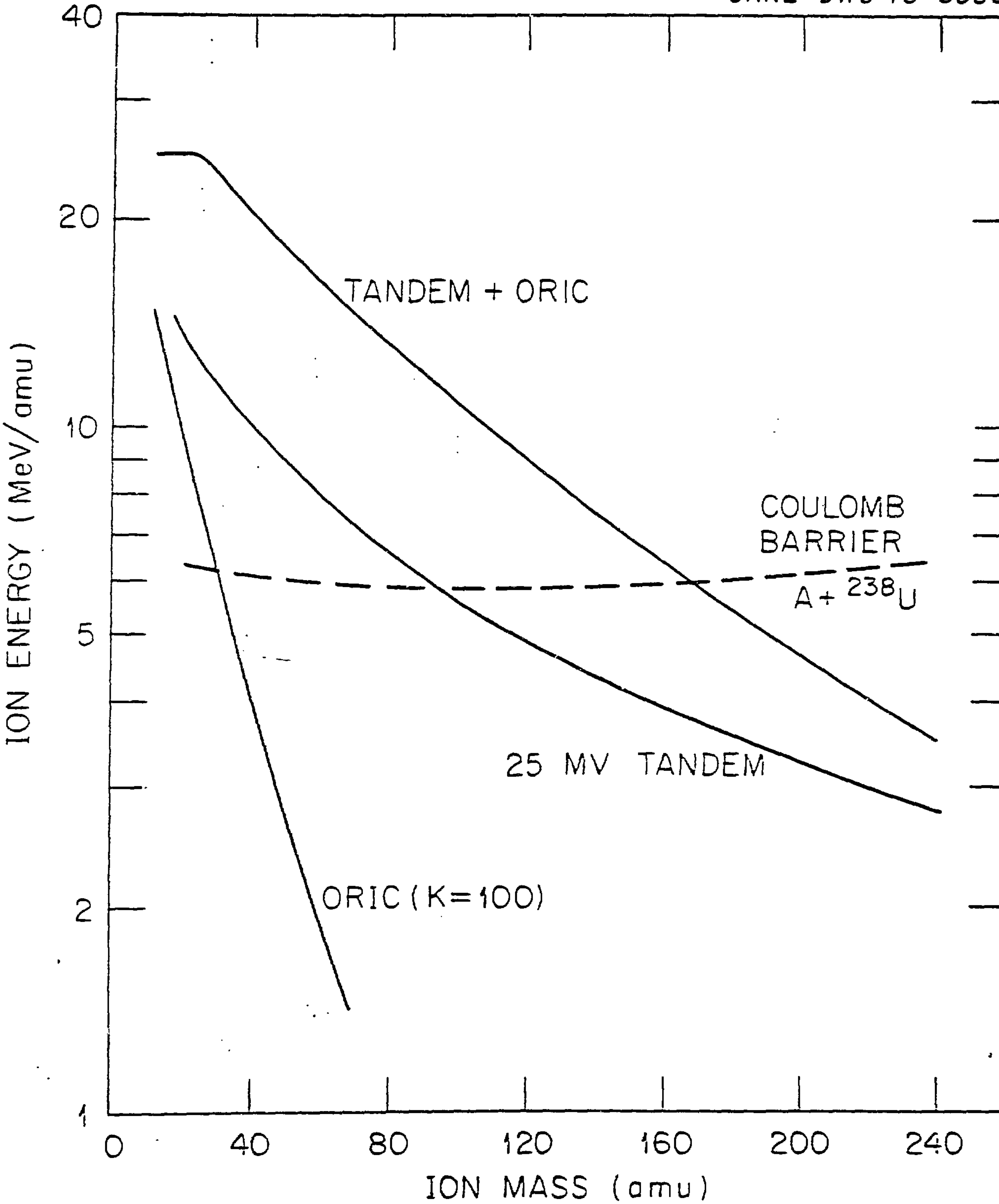

Figure 1

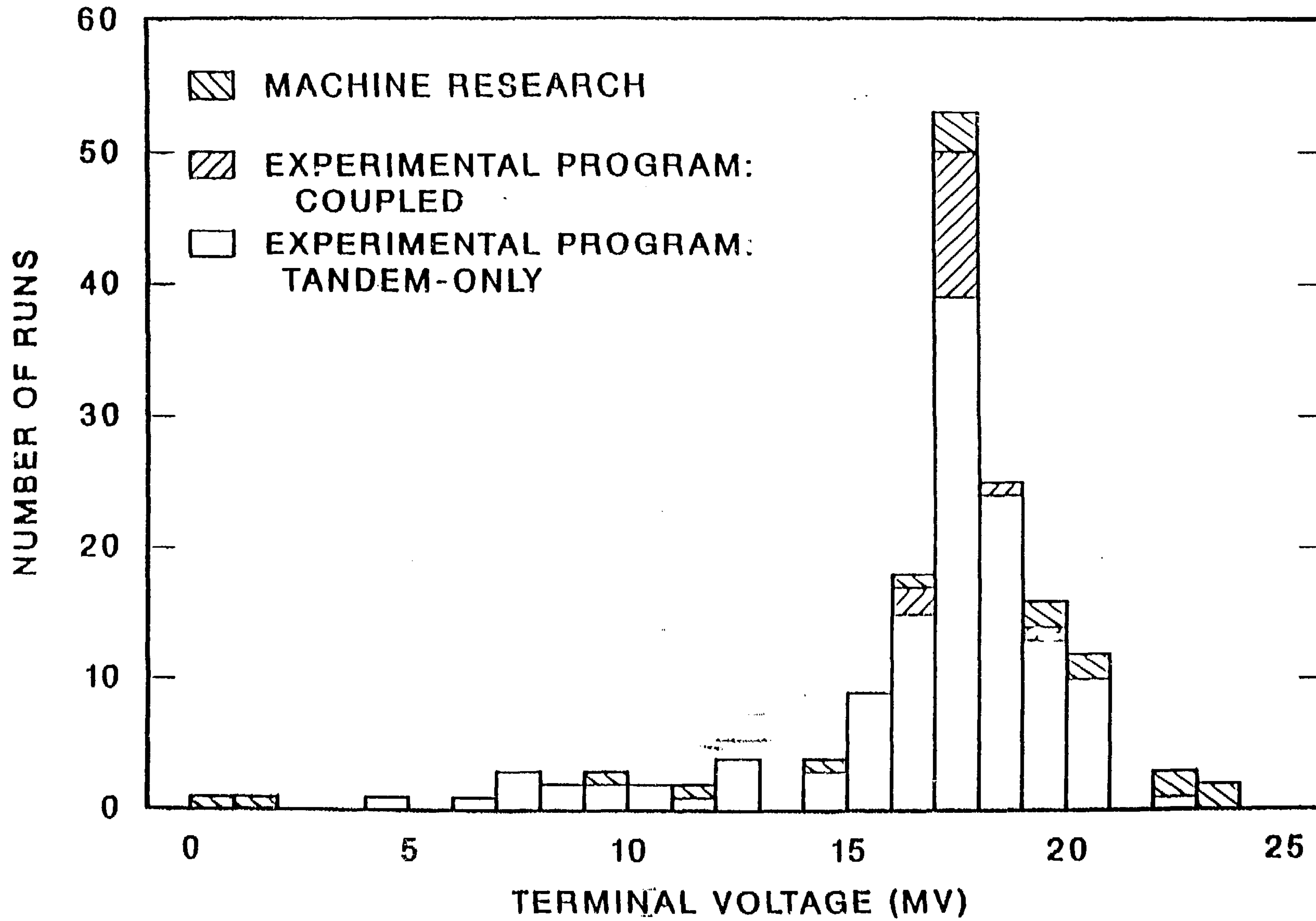
MACHINE RESEARCH
EXPERIMENTAL PROGRAM: COUPLED
EXPERIMENTAL PROGRAM: TANDEM-ONLY
NUMBER OF RUNS
TERMINAL VOLTAGE (MV)
0
10
20
30
40
50
60
0
5
10
15
20
25

Figure 2

ORNL-DWG 86-12000

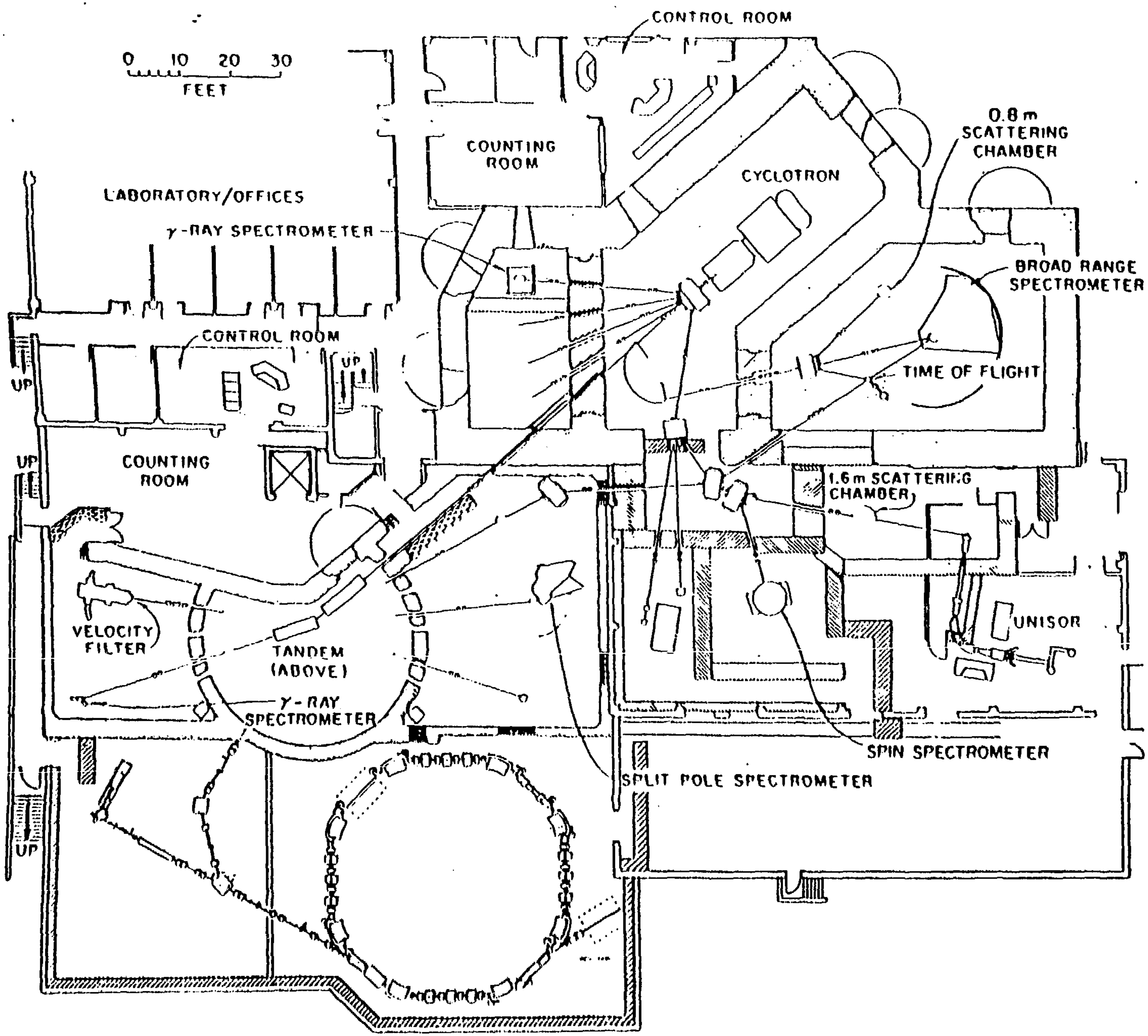

Figure 3