RADIOACTIVE ION BEAM PRODUCTION CHALLENGES AT THE HOLIFIELD HEAVY ION RESEARCH FACILITY

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INTRODUCTION

The radioactive ion beam (RIB) project at the Holifield Heavy Ion Research Facility (HHIRF) will provide for reconfiguration of the HHIRF accelerator system to enable provision of low-intensity RIBs for nuclear and astrophysics research. As we have progressed with the design of the reconfiguration, we have encountered several challenges that were not immediately obvious when first contemplating the project. The challenges do not seem insurmountable but should keep life interesting for those of us doing the work.

A brief review of the project will allow a better understanding of the challenges in RIB production. Radioactive ion beams will be produced with the Isotope Separator On-Line (ISOL) postacceleration technique. In particular, radioactive atoms will be produced by reactions in the thick stopping target of an ISOL-type[1] target-ion source assembly using intense beams from the Oak Ridge Isochronous Cyclotron (ORIC) equipped with a light-ion internal source. This ISOL target-ion source assembly will be mounted on a high-voltage platform with a mass separator. The target ion source will operate at potentials up to 50 kV with respect to the high voltage platform. The radioactive atoms produced by nuclear reactions in the target diffuse to the surface of the heated target material, desorb from this surface, and effuse through a heated transfer tube into an ion source where ionization and extraction take place. Two types of ion sources will be initially considered. A Forced Electron Beam Induced Arc Discharge (FEBIAD) source, similar to those used by the ISOLDE facility at CERN and by the UNISOR facility at ORNL, will be built to produce positive ions. These positive ions will be focused through an alkali vapor charge-exchange canal to produce negative ions for tandem injection. In addition, a direct negative surface ionization addition or modification to the above source will be built and investigated. The ions will be separated into a single mass before acceleration to ground potential and subsequent injection into the 25URC tandem accelerator for acceleration to energies of interest for nuclear and astrophysics studies.

The development work for this project is to be done by the Physics Division of Oak Ridge National Laboratory and Oak Ridge Associated Universities UNISOR

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facility. The UNISOR facility has an on-line isotope separator with a FEBIAD thin-target ion source which will be used to develop target-ion source hardware and chemistry. Acceleration of the first radioactive ion beam is scheduled for about April 1995.

UTILIZING EXISTING SHIELDED SPACE

The shielding for the original ORIC facility was designed for 75-MeV, 1-mA proton beams. Figure 1 shows the ORIC vault (room C109) and the original target rooms, C110 and C111, with shielding prescribed by the original standard. Room C111 was chosen to house the target-ion source and its associated high-voltage platform and equipment.[2] Room C110 was eliminated because it would have required some beam line reconfiguration and would have precluded the use of the experimental equipment located there. Work has been proceeding for some months to prepare room C111 for the high-voltage platform. The problem with room C111 is its size. As we continue with the design of the target-ion source and its associated equipment, we find room C111 to be a very tight fit.

TARGET-ION SOURCE

The production of short-lived radioactive species requires careful design of the ISOL source and selection of proper target materials for each species. Fast release of these short-lived species from the target material involves very high-temperature target-ion source operation. The target material must be refractory while also having low vapor pressure (below 10^{-3} Torr) at the operating temperatures (in the range 1300°C to 2000°C) in order to avoid sublimation or vaporization of the target material. The radioactive atoms must be easily diffused from the target and readily volatilized for transport and subsequent ionization. Therefore, the species itself should not be refractory nor should it form refractory compounds within the target material.[2] The stringent requirements between the target materials and beams may actually pose the major challenge to this project. The UNISOR facility will be used for investigating RIB target chemistry and target-ion source design, both during the construction phase and later as more beams are developed.

ISOBAR SEPARATION

Separation of the beam of interest from isobaric contaminants is challenging for any RIB facility. If the (H,n) production reaction is used, there will always be stable isobars available at the target. Table 1 shows that the production of ^{34}Cl by an (H,n) reaction on a $Ce^{34}S$ target would not allow separation of the product from the target material since the $m/\Delta m$ ratio is 192,400. Study of the table shows that one cannot completely avoid the problem by using other production reactions; note particularly the ^{64}Ge and ^{70}Se beams. Even the ^{17}F beam from the AlO_3 target may have ^{17}O as a contaminant. The natural abundance of ^{17}O is 0.038%, which would not be a problem if the ^{17}F beam were large. At best, the expected intensity for this beam is a few particle nanoamperes. Even residual gas atoms in the vacuum may pose a contaminant problem at very low intensities.

A system mass resolution of 10,000 or greater is planned as a part of this project. Careful selection of nuclear reactions and targets must also be done to try to avoid the worst isobar problems. High system mass resolution requires very close attention to the details in all specifications. Voltage ripple on the platform power supplies cannot be tolerated, nor can mechanical vibration. All magnets in the system must be manufactured to exact tolerances and correction elements must be provided.

ACCELERATOR CHANGES

Changes to the two accelerators do not present as many challenges as does the ion source or its platform, but they are not trivial. The ORIC must return to high-beam current, light-ion operation with an internal ion source. This change involves some modification to the ion source and the addition of shielding to internal components of the cyclotron. Long-term, day-to-day operation of the cyclotron with 55 MeV protons at an intensity above 30 microamperes brings activation and radiation problems. The radiation safety system for the ORIC area and procedures for entering this area are being changed to address some of these problems.

Low intensity diagnostics will be required for tuning the tandem accelerator and may be useful for terminal potential stabilization. Mass separators typically use low intensity diagnostics but many of these diagnostics are not suited for the environment within the accelerator tank. Tentative plans are to have a possible combination of a sensitive Faraday cup with a secondary electron multiplying device. Terminal stabilization may be done with the generating voltmeter (GVM) only, or a new type of beam current feedback may be devised. Changes to the tandem accelerator will also help address the isobar separation problem. Plans to improve the mass resolving power of the tandem accelerator include reducing the terminal voltage ripple and reconfiguring the high-energy beam line to better use the existing energy analyzing magnet.

RADIATION

A worst case estimate of radiation on the high-voltage platform for one year operation yields a total ionizing dose of the order 10^7 rads and a neutron flux of 9 x 10^{14} n/cm^2 at one meter from the target. This estimate assumes 50 μA of 50 MeV protons hitting a Ge target for a total of 2000 hours. Electronics are not able to survive at this level of radiation, as is shown in Figure 2.[3] The electronics must be moved to a second high-voltage platform and shielded by a wall between the two platforms as shown on Figure 1. There will also be some form of local shielding for the source. Two platforms require more space in an area that is already small and they must be connected with high-voltage conduits that penetrate the wall. In addition to microcircuit damage, there can be deterioration of some dielectrics. The materials used for insulation in wires and in the conduit must be chosen carefully. Figure 3 compares the radiation effects on some common polymer dielectrics.[4] Teflon, which is a common dielectric in cables, will not be practical in the source area. Even PVC, which seems suitable from the figure, has been found to be totally unsatisfactory at the

CERN ISOLDE source since it breaks down and forms hydrochloric acid with any moisture in the air. Careful selection of materials will, of course, be necessary for all components on the source platform, not just the electrical ones. Ionization of the air, at this level of radiation, may contribute to instability of the platform voltage. Therefore, the source platform will be fully enclosed with an electrostatic equipotential shield to reduce possible power supply loading due to ionization currents.

Radiation will contribute to problems inside the vacuum system as well as in the room. Perhaps the greatest problem is activation of the source and the beam line components near it. When high primary-beam currents and heavy target materials are used, remote handling of these components will probably be necessary for removal and maintenance. This capability must be planned for from the start of the project. Remote handling capability affects almost every aspect of the design. All equipment must be designed in such a way as to allow remote manipulators to dismantle and move it. A method of placing the sources into lead casks and removing them to a clean-up or permanent storage area will be required. Although details of the remote handling system have not been finalized, the design of other components is being done to allow inclusion of such systems.

CONCLUSION

The RIB project at HHIRF is a challenging project in many respects. Once finished, however, it will give the HHIRF the capability to provide the research community with an opportunity to extend our knowledge of physics. Those of us on the project team are enjoying the challenges and look forward to the first accelerated radioactive beam in our tandem.

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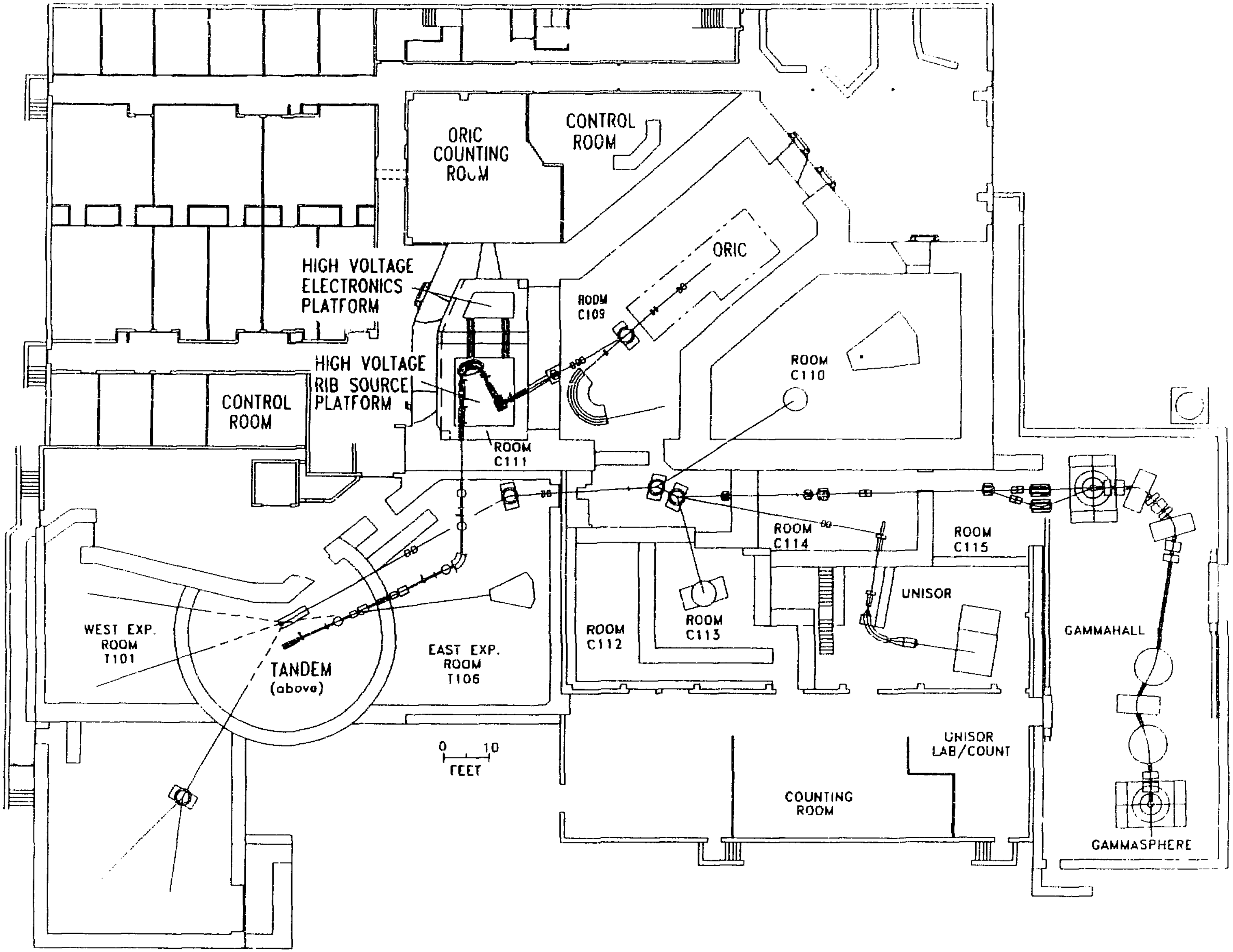

Figure 1. FLOOR PLAN OF THE HHIRF SHOWING THE NEW RIB PLATFORM AND ASSOCIATED BEAM LINES. ALSO SHOWN IS THE PLANNED GAMMAHALL ADDITION.

Table 1. Possible First Holifield Facility Radioactive Ion Beams

BEAM	^{17}F	^{17}F	^{18}F	^{18}F	^{33}Cl	^{34}Cl	^{64}Ge	^{68}As	^{70}Se
Lifetime	64s	64s	1.8h	1.8h	2.5s	32m	64s	2.6m	41m
Production Reaction	(4He,n)	(D,n)	(4He,n)	(H,n)	(D,n)	(H,n)	(3He,3n)	(H,3n)	(3He,3n)
Target Material	BN	AlO_3	$B^{15}N$	$Al_2{}^{18}O_3$	CeS	$Ce^{34}S$	^{64}ZnO	Zr_5-$^{70}Ge_3$	Zr_5-$^{70}Ge_3$
MASS CONTAMINANTS									
$m/\Delta m$ WRT RIB	C +1000	C +1000	C +700	C +700	Mg +1200	Si +2300	Co -11100	Cu -9500	Cu -47000
	N +2600	N +2600	N +1400	N +1400	Al +2600	P +8000	Ni -4700	Zn -5700	Zn -8200
	O -5700	*O -5700	O -10100	*O -10100	Si +70800	*S +192400	Cu -5400	Ga -7700	Ga -8900
					P -5800		*Zn -5200	Ge -7800	*Ge -7300
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									Br +6300

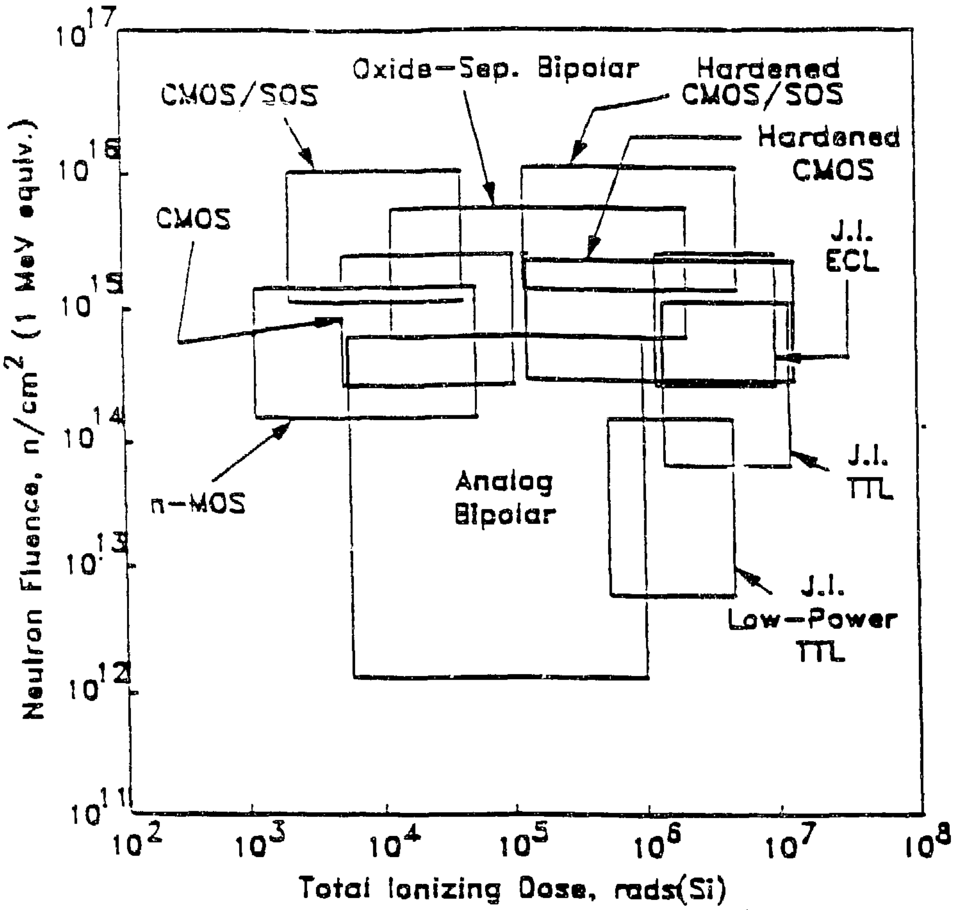

Fig. 2. Schematic representation of microcircuit susceptibility.[3]

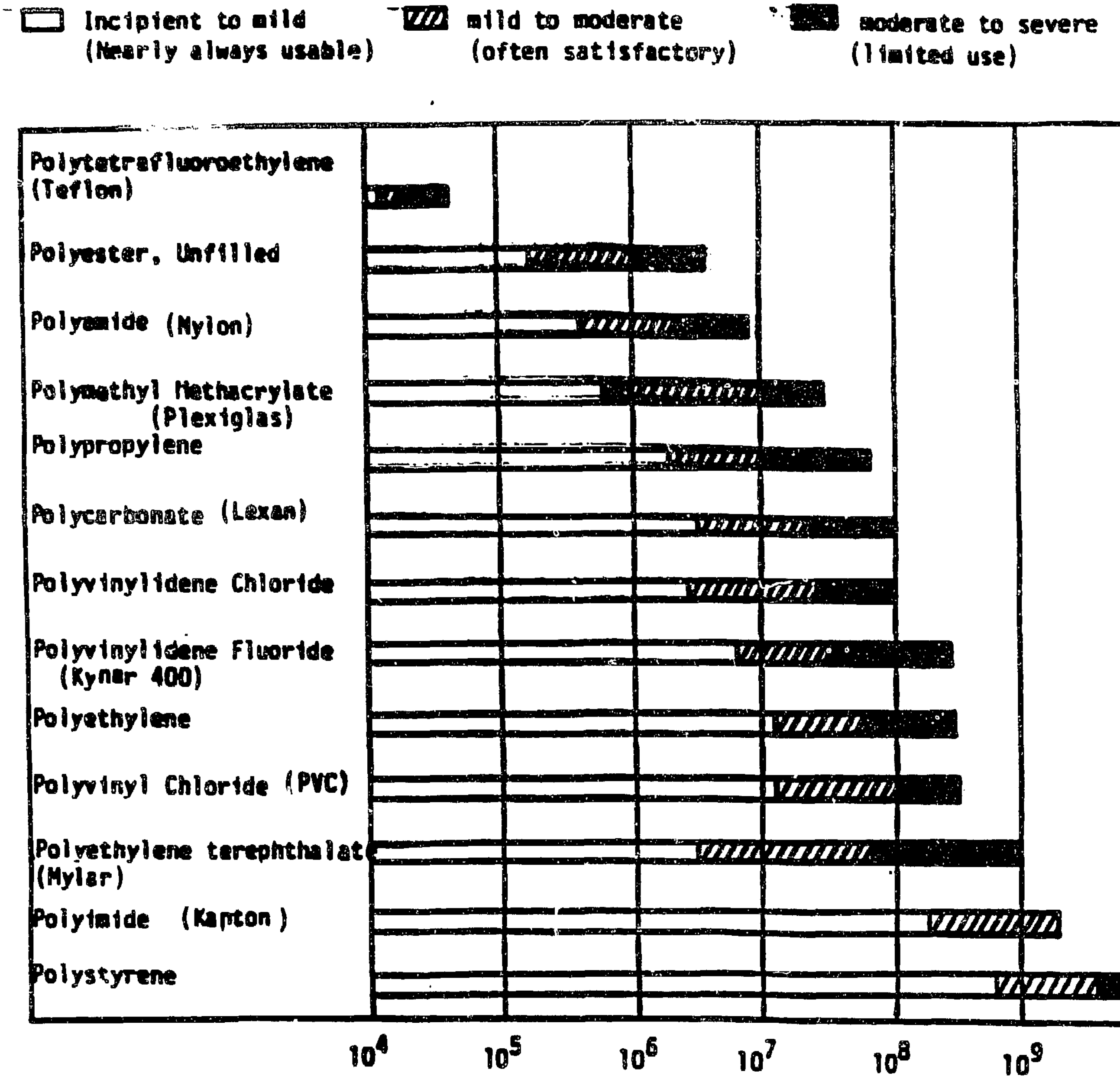

Fig. 3. Radiation effects on polymer diclectrics.[4]