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# NEW ION SOURCES FOR NUCLEAR STRUCTURE STUDIES AT THE TRISTAN FACILITY

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TRISTAN is an on-line isotope separator (ISOL) facility located at Brookhaven National Laboratory's High Flux Beam Reactor. Short-lived neutron-rich nuclei, far from stability, are produced by thermal neutron fission of $^{235}U$. These nuclei can be studied using facilities at the five available beam lines. These facilities include: a 4-detector angular correlation system, a delayed neutron spectroscopy facility, a conversion electron detector, a colinear fast beam dye laser system and a superconducting magnet for g-factor measurements. Ion sources of the surface ionization, negative surface ionization, thermal, FEBIAD, and plasma types are used to provide high yields over a wide range of elements for experiments at the available detector stations.



## 1. THE TRISTAN FACILITY

A schematic layout of the TRISTAN ISOL facility is shown in Fig. 1. A neutron beam of $3 \times 10^{10}$ $n_{th}/cm^2/sec$ is provided by the 60 MW High Flux Beam Reactor at Brookhaven National Laboratory. Ion source development, as well as separator improvements, operation and maintenance is the responsibility of the Brookhaven TRISTAN staff. Experiments are performed by the Brookhaven staff, and an international group of users. Construction of experimental facilities has been done in collaborations of users and in-house staff. Ion sources of the surface ionization [1], negative surface ionization, thermal [2], FEBIAD [3], and high-temperature plasma ionization types are available to be placed in the neutron beam. Each

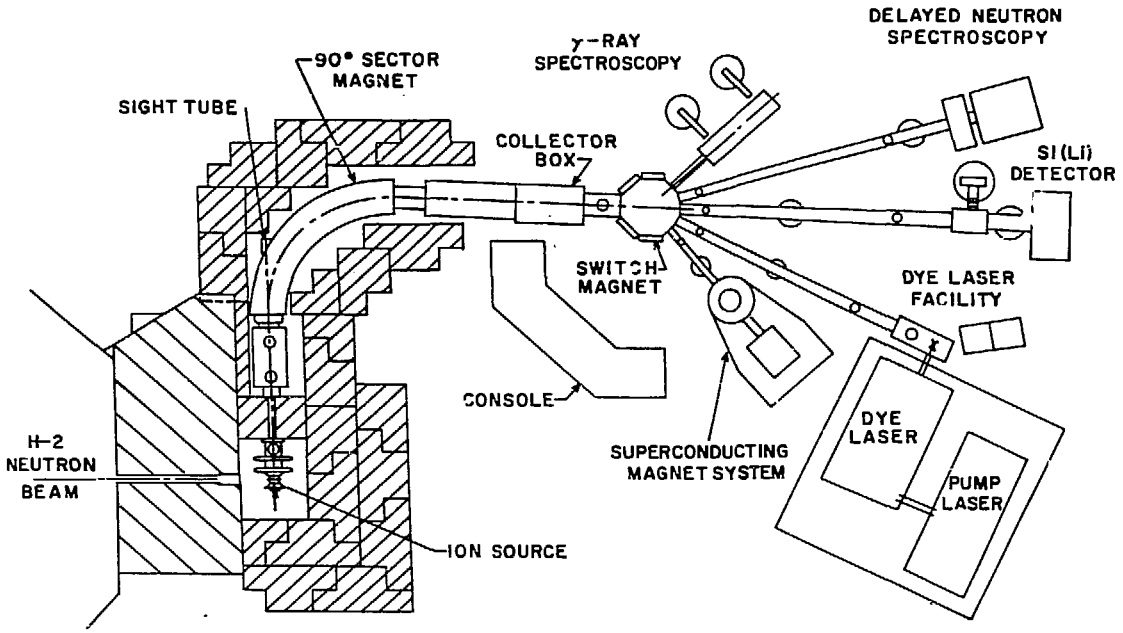


Fig. 1 Schematic layout of the current TRISTAN facility.

source has an internal target. The FEBIAD ion source can contain 2.5g $^{235}U$, whereas the other types can contain up to 10g $^{235}U$. A 90° sector magnet provides the primary mass separation and a ±45° switch magnet gives some additional mass separation for the extreme angles as well as provides beam lines for 5 separate experimental stations.

A general purpose gamma-ray spectroscopy facility with a high-speed moving tape collector is available at one of the 45° lines. A 4-detector angular correlation system [4] may be positioned either at the point of ion beam deposit for short-lived activities, or at a downstream position for longer-lived activities. $Q_\beta$ measurements can be made at this station using thin window HPGe (hyperpure Germanium) detectors.

A large, high-efficiency, polyethylene moderated $^3He$ counter is used for $P_n$, $P_{2n}$ and $P_{2n}(\theta)$ measurements. A high resolution time-of-flight neutron spectrometer is also available to measure low energy neutron spectra.

Conversion electron spectra can be studied by using a windowless Si(Li) detector installed at the 0° position. A moving tape collector positions the deposited activity in front of the detector where electron singles, electron γ-ray coincidence and β-gated electron spectra can be simultaneously accumulated.

A colinear-fast beam dye laser facility is available to measure isotope shifts and other hyperfine interactions from nuclides in the ionic state. A quadrupole ion trap is under development for later use with the dye laser system.

A split-pole superconducting magnet with a 6.25 Tesla field strength at 4.2°K is available for g-factor measurements. The magnet is equipped with a λ-point refrigeration unit which allows operation at 2.2°K, resulting in fields of up to 6.75 Tesla. The magnet was specially designed to be used as a solenoid magnet as an alternative configuration. By removing the lower pole piece and installing a HPGe, the solenoid field can be used to focus electrons from β decay onto the face of the detector, resulting in a large effective solid angle for betas, while maintaining a relatively small solid angle for gammas. This system is used for high sensitivity $Q_\beta$ measurements.

An ion implantation facility is currently under development. This facility will include a post accelerator capable of boosting the total ion energy to about 250 kV. The goal of this project is to measure quadrupole moments of excited states by implanting radioactive ions in crystals with known electric field gradients. Implantation into ferromagnetic materials at low temperatures may also be attempted at later stages of the project.

## 2. ION SOURCES AT TRISTAN

### 2.1 Introduction

The primary emphasis on ion source development at TRISTAN has been to produce very long-lived, stable ion sources. The importance of long ion source lifetimes and stable operation is evident by considering that TRISTAN receives 24 days of neutron beam per month. Demands for beam time require that the separator operate continuously during that time period. Such a schedule (24 days on, 6 days off) is exhausting to both equipment and personnel, but makes it possible to perform long-term experiments that could not be attempted under other circumstances. Last year (1983), TRISTAN operated for greater than 90% of the available reactor time. To maintain this sort of performance, an ion source must reliably operate for one full cycle, preferably two. Thus, our goal for an ion source lifetime is 1200 hours, although 600 is acceptable.

All of the sources use highly enriched uranium targets, prepared by impregnating graphite or graphite cloth with uranyl nitrate, which is converted to uranium dioxide or uranium carbide at high temperatures. As noted above, the targets can continue up to 10g $^{235}U$, resulting in very high levels of radioactivity, making frequent ion source changes undesirable.

## 2.2 Surface Ionization Source

The first successful ion source at TRISTAN was the surface ionization source developed by Shmid et al. [1]. The source can be heated to >2000°C using 2500 W of electron bombardment power. Ionizing surfaces of Re and Ta have been used. Ta gives lower yields of Sr and Ba, making it more desirable than a Re ionizer for experiments on Rb and Cs decay. This source is fully developed and has lifetimes of >2500 hours. The surface ionization source produces beams of Rb, Sr, Y, Cs, Ba, Ce, and Pr. Experiments can be performed on these elements and their decay products.

## 2.3 The FEBIAD Source

A FEBIAD source, modeled after that of Kirchner [5] is also in use. The source is modified to provide longer lifetimes and a larger target area to make use of the full size of the neutron beam. Details of the source will be given in a forthcoming publication. Lifetimes of up to 1500 hours have been achieved. The lifetime and wide array of elements available from this source have made it the source most used at TRISTAN. The ion source is shown in Fig. 2. The FEBIAD ion source produces beams of Cu, Zn, Ga, Ge, Se, Br, Kr, Rb, Ag, Cd, In, Sn, Sb, Te, I, Xe, and Cs, making it possible to study the decays of isotopes of those elements and their decay products.

## 2.4 Thermal Ion Source

The TRISTAN thermal ion source is described in detail by Piotrowski et al. [2]. This source was based on the TRISTAN surface ionization source and was the first of a "family" of ion sources which share a common design for the target, heater, base plate, and heat shields. This family

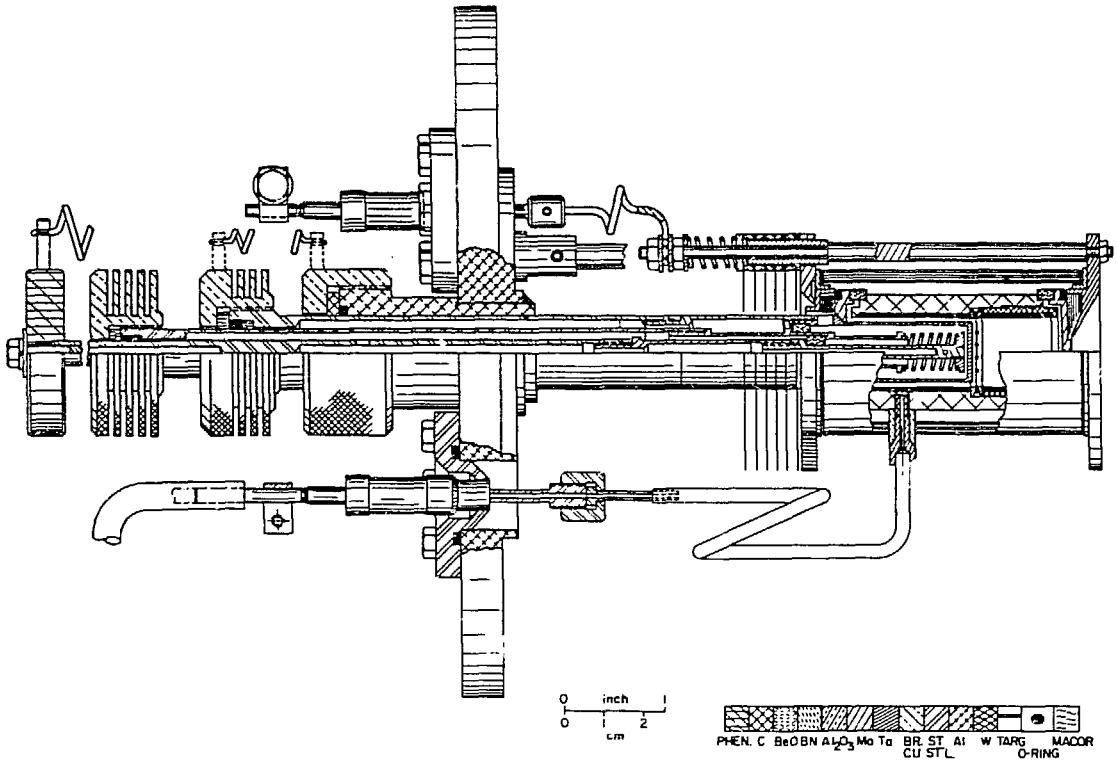


Fig. 2 The TRISTAN FEBIAD ion source.

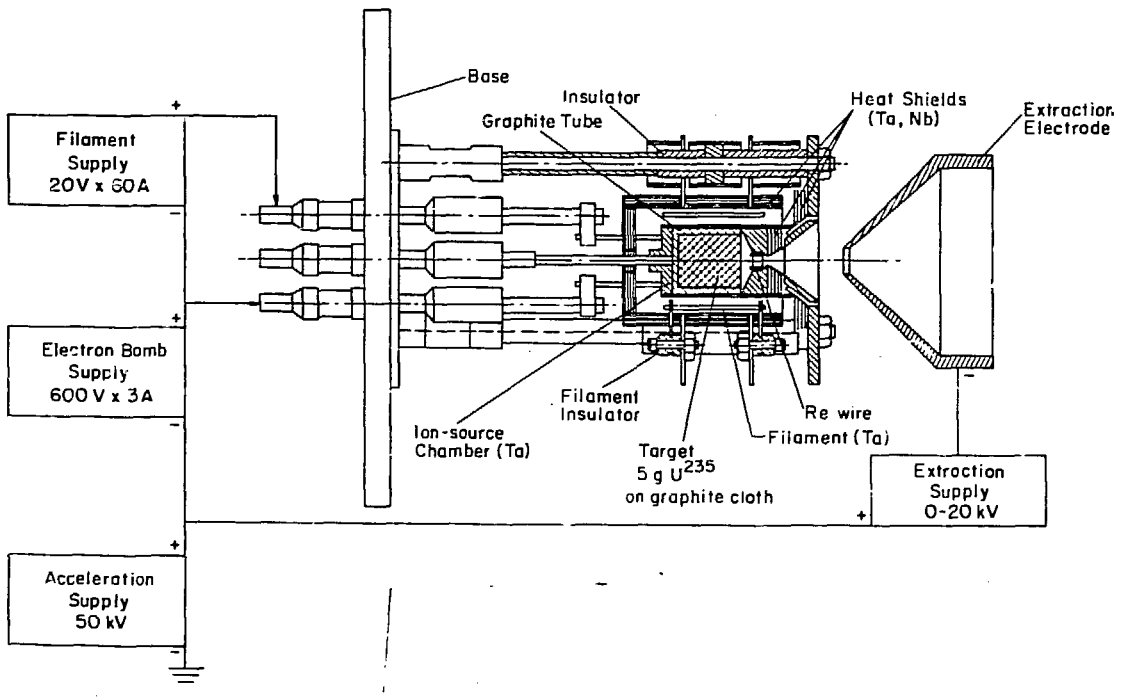


Fig. 3 The TRISTAN thermal ion source, showing the construction common to the family of sources.

of TRISTAN ion sources includes the thermal, negative and high-temperature plasma sources (to be described below). The targets use graphite or graphite cloth to contain the uranium in a tube which is heated by electron bombardment by a filament. The filament is supported by Ta wires which protrude through the heat shields and attach to insulators on the support rods. This construction is indicated in Fig. 3 which shows the thermal ion source. With this arrangement, the target can be heated to 2500°C with 1800 W of electron bombardment power. Although all the ion sources in this family have been tested on line, none are yet in routine use since the lifetime of each source is presently only about 2 weeks. The problem with these sources is now believed to be understood, and extended lifetimes should be possible. The thermal ion source produces beams of Ga, Ge, As, Rb, Sr, Y, In, Sn, Cs, Ba, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd. Tb, Dy, and Ho, making it possible to study the decays of isotopes of those elements and their decay products.

## 2.5 Negative Ion Source

The TRISTAN negative ion source produces beams of halogens (Br and I from neutron fission of $^{235}U$). An important feature of this type of source is that it produces only $Br^-$ and $I^-$, so that experiments on low yield masses of Br and I can be studied without the intense interferences from Kr, Rb, Xe, and Cs. The source is constructed in the same fashion as the thermal ion source, except that the Ta/Re ionizer is replaced by a Ta tube with a $LaB_6$ ionizer. Electrons from the source are deflected by a permanent magnet and a plate with a 1000 V potential.

## 2.6 High Temperature Plasma Ion Source

Figure 4 shows the high temperature plasma ion source, where the heat shields are not shown to make the diagram more simple. This source represents a novel concept in ISOL ion sources in that the target is located (and is actually part of) the cathode. At operating temperatures (near 2500°C) electrons are emitted from the Ta chamber walls, from the target material and from an emitter disk over the target. The emitter disk also keeps graphite cloth in the target chamber from touching, and thereby

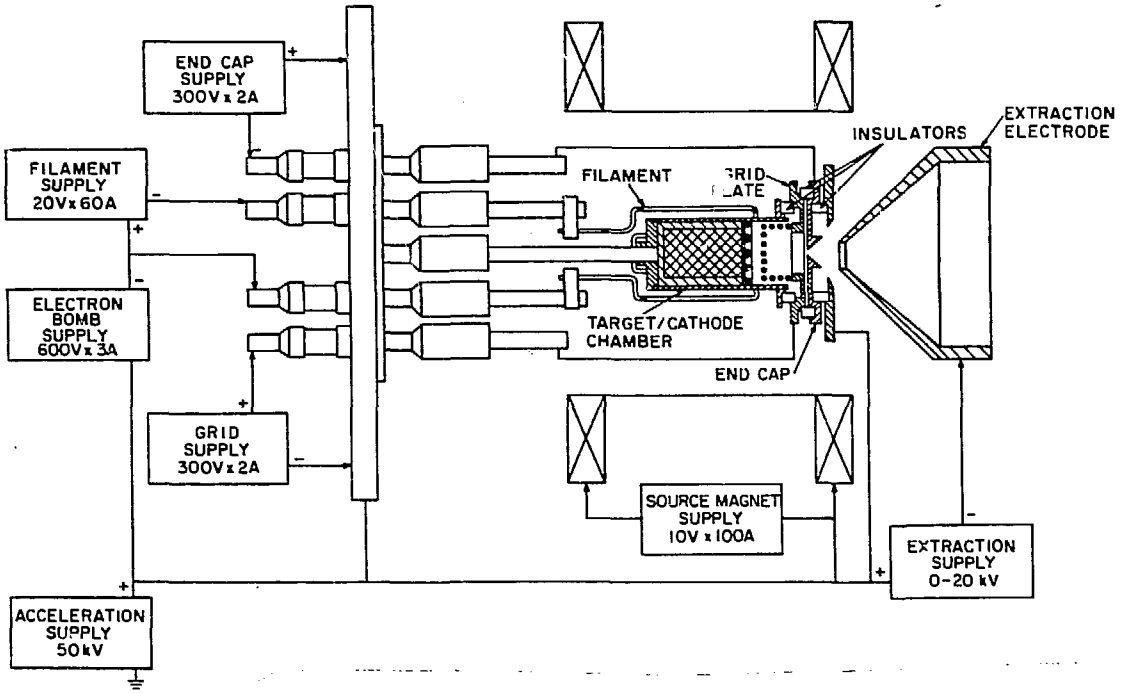


Fig. 4 The TRISTAN high temperature plasma ion source.

short circuiting, the anode. The anode consists of W-wire grid which protrudes into the target/cathode chamber.

The high temperature at which this source operates gives much faster diffusion than the lower temperature FEBIAD source, and overall gives higher yields by a factor of 10. Although the lifetime of this source is short (2 weeks) the problem is common with the other sources in this "family" and is not associated with the grid (anode) construction. The anode in the high temperature plasma source has operated for a total of about 2000 hours without failure. All failures were associated with the filament and heat shield configuration. The high temperature plasma ion source produces beams of Cu, Zn, Ga, Ge, As, Se, Br, Kr, Rb, Sr, Y, Ag, Cd, In, Sn, Sb, Te, I, Xe, Cs, Ba, Ce, and Pr, making it possible to study the decay of isotopes of these elements and their decay products.

## 3. CONCLUSION

The use of these ion sources at TRISTAN makes it possible to study all but a few of the elements accessible via thermal neutron fission of $^{235}U$. The combination of ion source productivity, high beam time, and a

large array of experimental techniques and apparati makes TRISTAN a versatile and important instrument for nuclear structure studies of neutron-rich nuclei that are far from stability.

## 4. ACKNOWLEDGEMENT

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