01-222N(D) -- FAST BEAM SWITCHER FOR PRIMARY DRIVER

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Funding Profile:

FY 1999	-0-
FY 2000	-0-
FY 2001	$255K
FY 2002	$185K
FY 2003	$185K

Purpose: Since the early 1990s in the field of low energy nuclear science there has been worldwide interest in an advanced facility capable of producing energetic, high-quality beams of radionuclides. The purpose of this LDRD project is to develop design concepts for the major components of the Rare Isotope Accelerator (RIA). to provide the background on which to base a more solid cost estimate. This project aims to develop a fast switcher for the primary beam extracted from the heavy-ion linac to feed simultaneously multiple targets. This element is critical to allow multiple user operation which greatly increases the flexibility and effectiveness of the overall concept.

Approach: It is essential to be able to provide beams to many users simultaneously. This can be done by switching on a fast cycle the primary beams between a number of target stations. This can be done by an RF sweeper in a way similar to what is done at CEBAF but with much stronger fields because of the increased transverse emittance of the heavy ion beams compared to the electron beams for which this approach has been demonstrated. A transverse RF cavity was proposed and studied for this purpose.

Technical Progress and Results: A preliminary design of the Switchyard Beam Transport System (SBTS) has been completed. The main function of the SBTS is a distribution of the high power ion beams to four targets and a beam dump. In order to operate two targets simultaneously the SBTS consists of an RF sweeper. The general layout of the SBTS is shown in Figs. 1 and 2. The thin targets FTA and FTB serve as a source of projectiles for fragment separators. To obtain high resolution in the fragment separator, the beam dimensions are provided within ±0.5 mm in the horizontal bending plane and within ±1.5 mm in the vertical plane. The targets T1 and T2 are thick and assigned for production of radioactive isotopes. Light ion beam dimensions on the targets T1and T2 must be larger than ±2mm in both x and y directions. The RF sweeper splits the beam into two parts of equal intensities. These beams are transported through beamlines A and B correspondingly in order to provide simultaneous operation of the targets FTA and FTB. By changing fields in the dipole magnet B1T1 (B1T2), beams are delivered to target T1 and T2 accordingly. The beamline B is mirror symmetric to the beamline A. The SBTS allows a direct transport of any beam to the beam dump.

The most severe condition for operating of SBTS will be with multi-Q uranium beam. This beam will have the largest transverse and longitudinal emittances compared to

other RIA beams. The beam optics in the beamlines A and B are shown in Fig. 3. Standard beam transport codes were used for the design of the SBTS including the effect of fringing fields of all elements. The SBTS was designed for an average charge state of uranium beam $q_0 = 88.5$, charge spread $\Delta q = \pm 1.5$, and full momentum spread $\pm(\Delta q/q_0 + \delta p/p_0) = \pm 2.1\%$. All envelopes are shown for the transverse beam emittance containing *99.9%* particles.

RF deflection of heavy ions beams in the SBTS is a unique task due to the large beam emittances of the multiple charge state beams. The relatively large momentum spread of the uranium beam will lead to rapid beam debunching. For example, the bunch length will double over a drift distance of 15 m. The use of a high frequency RF sweeper can produce large emittance growth due to the wide phase width of the bunches. A low frequency RF deflector is therefore appropriate for the deflection of heavy ion beams. The RF sweeper design can be based on a H-type RF cavity. Figure 4 shows a general view of such an RF cavity designed with the MAFIA code. Basic parameters of the RF sweeper are listed in Table I. The fundamental frequency of the bunch sequence is determined by the multiharmonic buncher at the Front End of the driver linac and is equal to 57.5 MHz. Therefore the RF sweeper can operate at 115 MHz allowing to split the beam intensity into two halves. The length of the electrode is chosen to provide phase slippage of 180° inside the cavity for uranium beam. This condition eliminates any effect of fringing fields on uranium beam but produces negligible momentum spread for lighter ions because of higher velocity and smaller phase shift. A room temperature RF cavity operating at 115 MHz can provide a maximum electric field on the surface ~20 MV/m in CW mode. We have conservatively designed for a maximum electric field of ~6 MV/m between the electrodes.

To provide the necessary beam center deflection of ±4 mrad, two RF sweepers are required. The RF sweepers are followed by DC septum magnets of special design shown in Fig. 5. Basically this is two septum magnets without magnetic field between them. The latter allows the transport of the beam to a beam dump located on a straight line with the linac.

Specific Accomplishments: The results of this work have been presented at an international conference: G. Savard, “The U.S. Rare Isotope Accelerator Project,” 2001 Particle Accelerator Conference (PAC2001), Chicago, IL (June 18-22, 2001).

Table 1: Basic parameters of the rf deflector for the RIA switchyard

Maximum electric field	6 MV/m
Effective length	1.0 m
Deflecting angle	± 2 mrad
Characteristic resistance according the MAFIA simulations	3 MOhm
Required rf power (twice of MAFIA prediction)	11 kW

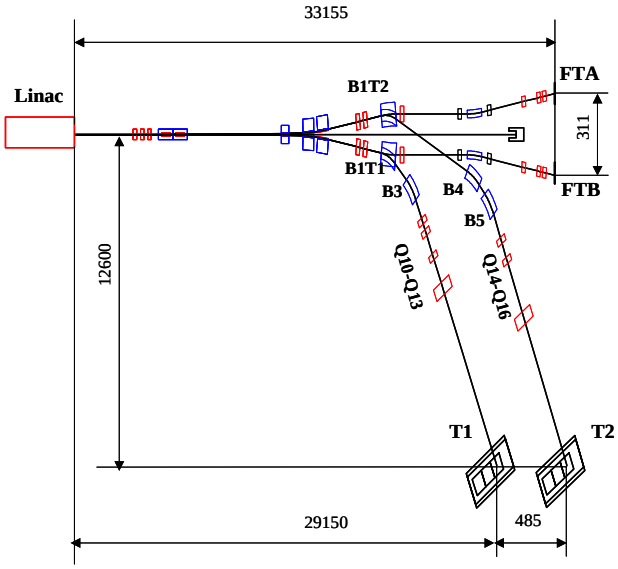

Figure 1. General layout of the switchyard. The dimensions are in millimeters.

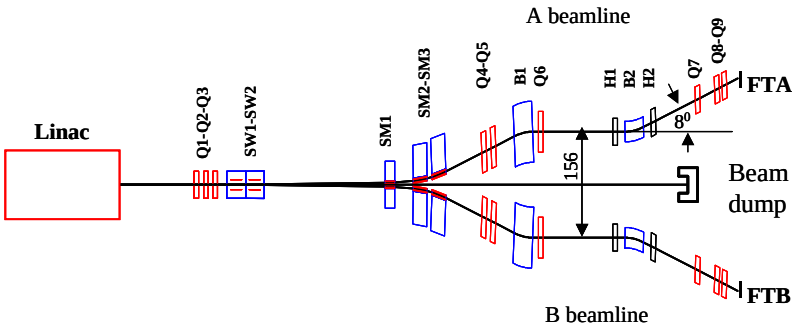

Figure 2. Schematic layout of the A and B beamline.

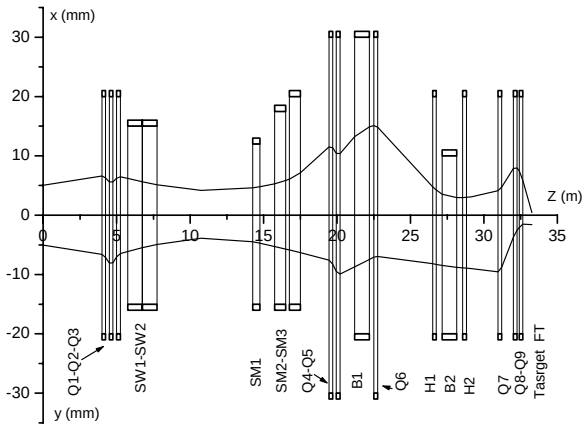

Figure 3. Beam envelopes along the beamline from the linac to fragment separator targets FTA and FTB.

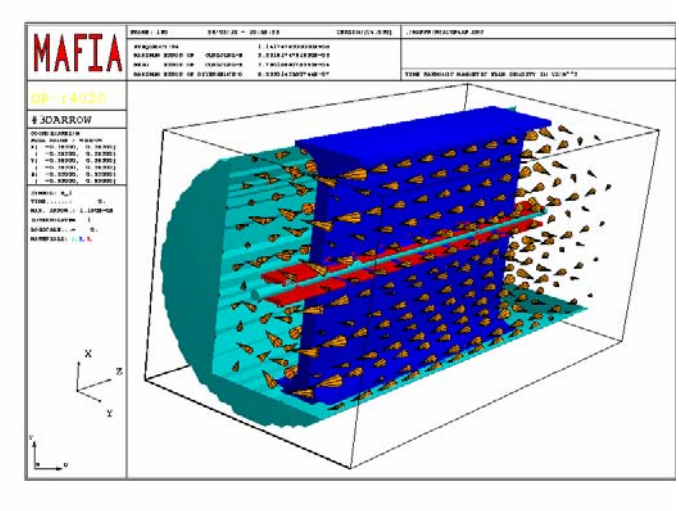

Figure 4. MAFIA simulations of the H-type cavity for formation of 115 MHz transverse deflecting electric field between the electrodes (red plates on the figure). The arrows represent magnetic field flow. The cylindrical envelope of the cavity is cut away to open an internal view.

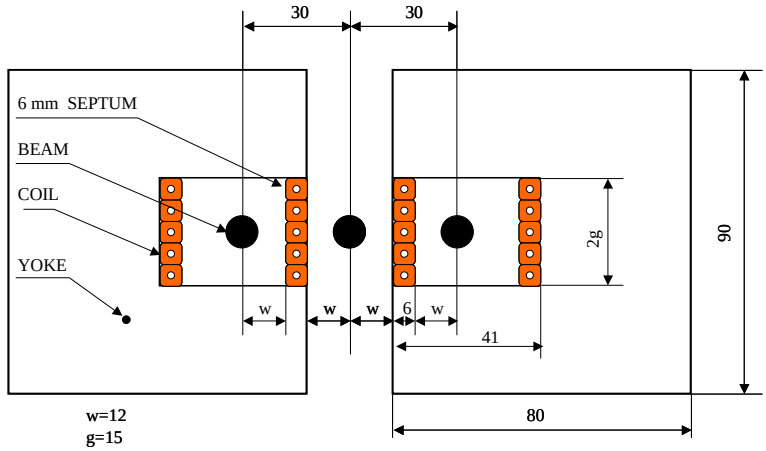

Figure 5. Three way water cooled DC current septum magnet SM1.

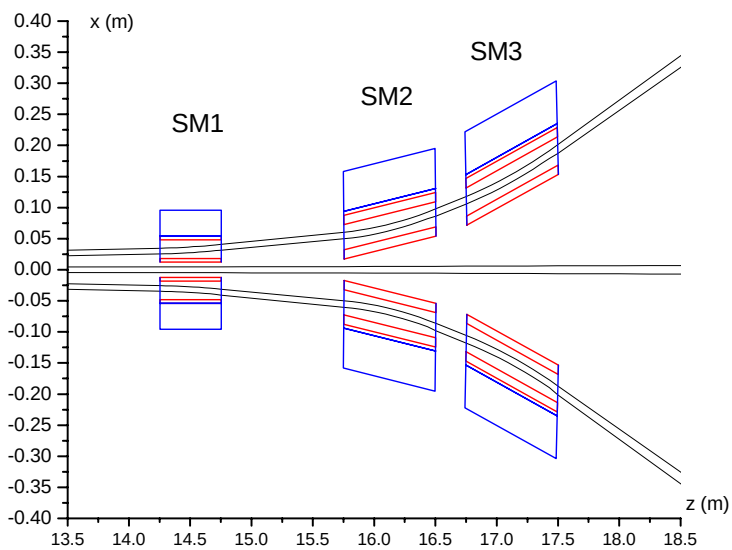

Figure 6. Beam envelopes in horizontal plane in the septum magnets SM1, SM2 and SM3 (see Fig. 2).