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PERFORMANCE OF THE LAMPF PARTICLE SEPARATOR*

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Summary

The electrostatic beam separator in the EPICS channel at LAMPF is now nearly fully operational. Improvements to the high voltage transmission system and the electronic controls as well as a higher quality channel vacuum have allowed the unit to be operated at its design field strengths. The bias electrode has proven to be useful in reducing ion-exchange currents and associated electrode heating. The detachable shielding and other apparatus for removing the separator from the activated channel has been perfected and its application is described.

Introduction

The EPICS beam separator is a "plug-in" design which must operate in an extremely high radiation environment only 4.3 m from target A-1. Its rad-hard design features have been described in detail in ref. 1. The design fields for the separator are 3.4 MV/m (300 kV) and 400 G which provides 18 mr separation for 416 MeV/c pions and protons. Basically, the unit operates with a single powered electrode, the other electrode being a series of close-set bars at ground potential. Behind the bars is a third electrode which can be voltage-controlled to minimize ion exchange currents by absorbing secondary electrons. The entire separator assembly is attached to a two-ton steel door which bolts to a 6.2 cubic meter evacuated fluxbox. The box forms an integral part of the EPICS channel and is cocked at 52.6° between 1P-BM01 and 1P-BM02 (see Fig. 1). The flux box provides a uniform field clamp for the separator magnet as well as a convenient access to the interior of the channel; however, this feature requires that the separator operate at channel vacuum which, until recently, was of poor quality. The separator magnet is enclosed within the vacuum and cooled by rad-hard, water-cooled MI conductors. The electrodes are mounted in the vertical plane and the powered electrode is an assembly consisting of a 43 cm x 142 cm stainless steel plate guard-ringed by four nested equipotential shields all cantilevered off a pair of segmented, vacuum brazed feedthroughs. The shields provide excellent protection for the feedthroughs by assuring a uniform gradient of no more than 16 kV/cm across the insulating segments. The interior of the feedthroughs carries SF_6 at 700 KPa which provides insulation for a plug-in voltage divider connected to the shields through the insulator segments. The high-voltage transmission line is a rigid assembly also pressurized with SF_6 and the cable termination is a quick-release plug immersed in oil. The 600 kV cable passes through the primary shield wall to the spectrometer area where the separator power supply, control and interlock electronics, and pressurizing gas bottles are located. Remote control of the electronic system is possible from the counting house, situated outside a second shield wall.

Final Installation in the EPICS Line

A major fabrication problem in the final installation of the separator was the flux box. The rim face of the box had to be machined for a choice of either aluminum or viton O-rings 1.75 m on a side. The box was then welded to the channel framing to provide final alignment for the separator as it slips inside by means of hardened alignment pins. To remove the separator for maintenance, a portion of the primary shield wall is disassembled to form a pair of massive rails along which the 180-ton shield plug is retracted, as shown in Fig. 2. A second set of rails is then put in place perpendicular to the line of the channel to allow the separator itself to be removed on a wheeled carriage. The flux box can then be sealed by a spare blank-off door.

The vacuum line connecting the flux box to the top of the shielding passes through the 3 m of concrete and steel in an offset manner. It is one of two vacuum lines on the channel but the two together could not improve the vacuum to much better than 3×10^{-5} torr and did little to eliminate the heavy organics that rapidly deconditioned the separator electrodes during the early days of operation. This became clear during early high voltage tests of the unit where several hours of painstaking conditioning were required while the voltage was inched above 250 kV. Then, when the unit was shut down for a few hours, the entire process had to be repeated. Upon removal of the separator from the line, the blemished main electrode showed characteristics of organic contamination, principally oil and grease residues. To improve these matters, a high capacity 30 cm LN_2 trap and 25 cm gate valve were installed within 1 m of the flux box. Vacuum quality has improved ever since and separator conditioning has become much easier and more permanent. Before the trap was installed, degassing in the channel at proton currents over 50 μA resulted in a factor of 3 increase in pressure and frequent arcing of the separator. After installation of the trap, with beam currents up to 100 μA, no observable increase in pressure occurs and the separator performance is similar to the beam-off condition.

To extend the range of operation, a slo-leak system for bleeding N_2 into the flux box was also installed. Since most of the separator use has been below 300 kV, this feature is rarely used although with it, electrode voltages of 340 kV have been achieved and glow discharges have been ignited in the flux box in a predictable manner.

Electronic Improvements

Numerous improvements have been made to the high voltage engineering aspects of the separator. One of these is a high-powered 33 MΩ resistor in series with the main electrode. This resistor reduces regulation at the electrode, but it also protects the main HV cable from VSWR arc-over damage. Since the separator is essentially "permanently" locked in the line and removal a difficult operation, poorer regulation is a small price to pay for reliability. To compensate for the current limiting resistor, a feedback control loop is used to hold voltage at the Cockcroft-Walton power supply to ±0.05% with automatic current crossover to allow automatic conditioning. Success with this circuit however, has been questionable to present and a commercial power supply is under order to replace the old Cockcroft-Walton and driver electronics. Other design improvements deal with the oil filled termination for the HV cable. The terminating insulator has been equipped with corona rings and concentric acrylic cylinders were installed to break up the oil path around the insulator. Also, a circulating pump was installed to keep the oil moving. Finally, a large access cover was fashioned for the termination to make cleaning, inspection, and oil replacement easier since this termination is in a high radiation area and will require periodic servicing when the linac beam current comes up to 1 mA.

The plug-in voltage divider[1] has functioned flaw-

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lessly for several hundred hours of operation. It is a compact unit that distributes the voltage across the 10 segments of the main feedthrough insulators and the four equipotential shields. It is 13 cm in diameter and 20 cm long and rated at 350 kV in 700 kPa SF_6. The present design is shown in Fig. 3. Despite its satisfactory performance, the unit is structurally weak, so it has been redesigned with more strongly brazed insulators and the Kovar spacers have been dumbbell-shaped to provide arc down protection between segments.

Separator Performance

The present power supply and load form a sharply resonant system. The plate supply current of the C-W driver tubes is the best indication available of the power being dissipated in the main electrode gap. Since the driver stage runs at 4 kV, an incremental change in driver current, holding other parameters constant, represents a proportional change in ion exchange current or power in the main gap, with a proportionality constant at 320 kV of about 0.0125. Using this feature, the driver currents recorded in the 300 kV region are shown in Fig. 4 with N_2 bleed and then again with the bias electrode turned on to 1 kV. The bias electrode reduces the drive current by 20 mA at 225 kV which represents a reduction of over 50 watts in electrode heating. Use of the bias electrode is now a routine part of the operation of the separator.

Another interesting test done in late 1975 utilized α-particles from a ^{242}Cm source to check channel aberrations. As part of these tests, the separator voltage was set to 50 kV and the magnet adjusted to bring the α-beam on center. The electric and magnetic impulses delivered to the α's under these conditions are about 10 times that seen by 300 MeV Π's. Aberrations due to the separator magnetic field and the nonsymmetrical electric field caused by the single powered electrode construction were thereby greatly magnified. However, no adverse effects were seen in the α count rate or momentum resolution, which was measured at 2×10^{-4} $\Delta p/p$ (FWHM).

Proton separation is the main task of the EPICS separator. Proton rejection ratios of >100:1 have been measured for pion energies of 67.5, 151, 225, and 265 MeV (see Fig. 5). Beam components are chiefly pions, protons, muons, and electrons and no unexpected beam impurities have been found. The channel tuneup has shown that the beam line operates at its design specifications, i.e., the output phase space is as planned in all dimensions and the beam intensity is as predicted.

The high voltage performance of the separator has also been encouraging but is very dependent on channel vacuum and subject to operational problems with the present power supply. Long duration runs at 275 kV have been made with acceptably low spark rates, qualification runs of the system at its design levels of 300 kV and 400 G were successfully completed, and shorter runs have tested the unit to 340 kV. It should be pointed out that while these voltages may appear low by separator standards, they are more difficult to achieve with the single electrode design of the EPICS separator. The final test of possible aberrations caused to the channel by the separator fields will come later this spring when momentum resolution of full energy pion beams will be checked with the spectrometer system now being completed.

Reference

[1]"The Particle Separator at Los Alamos," D. Liska, IEEE Transactions onNuclear Science, Vol. NS-22, No.3, 1975.

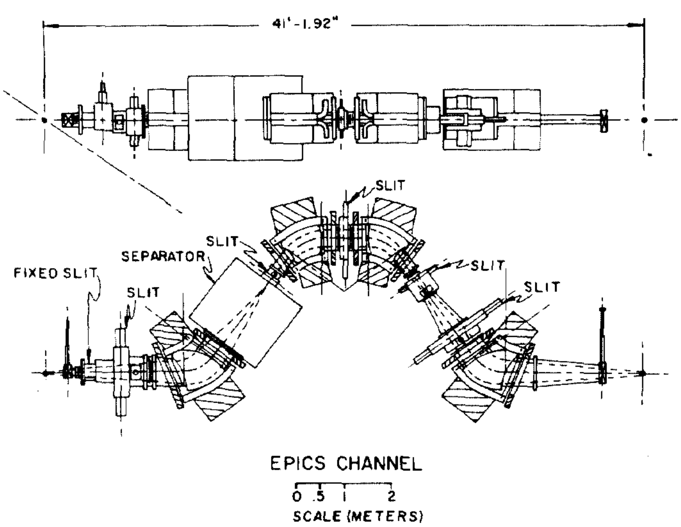

Fig. 1 Physical Layout of the EPICS Beam Channel

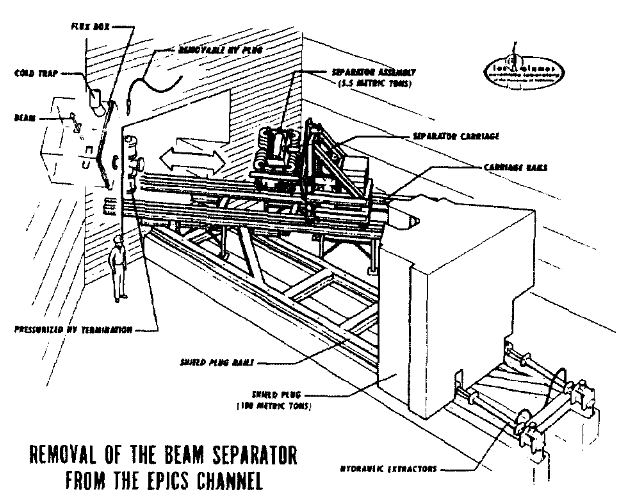

Fig. 2 Removal of the Beam Separator from the EPICS Channel

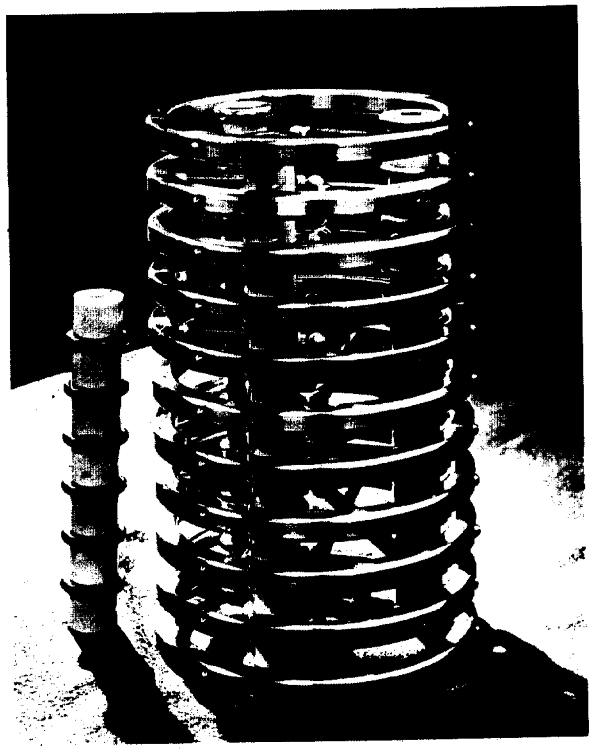

Fig. 3 350 kV, 100 Watt Plug-In Voltage Divider

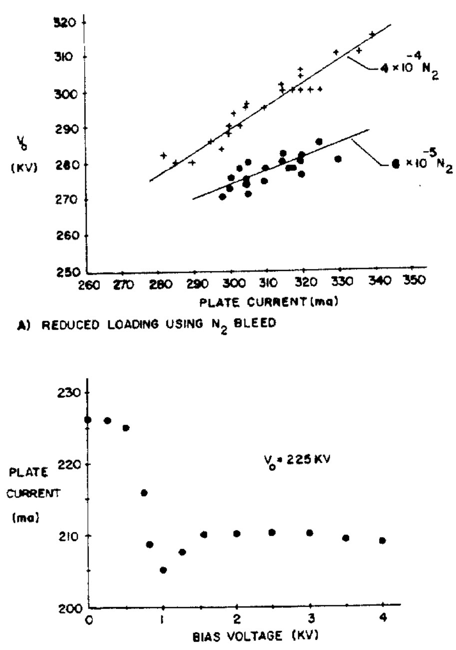

Fig. 4 Separator Performance as Function of N_2 Bleed and Bias Electrode Voltage

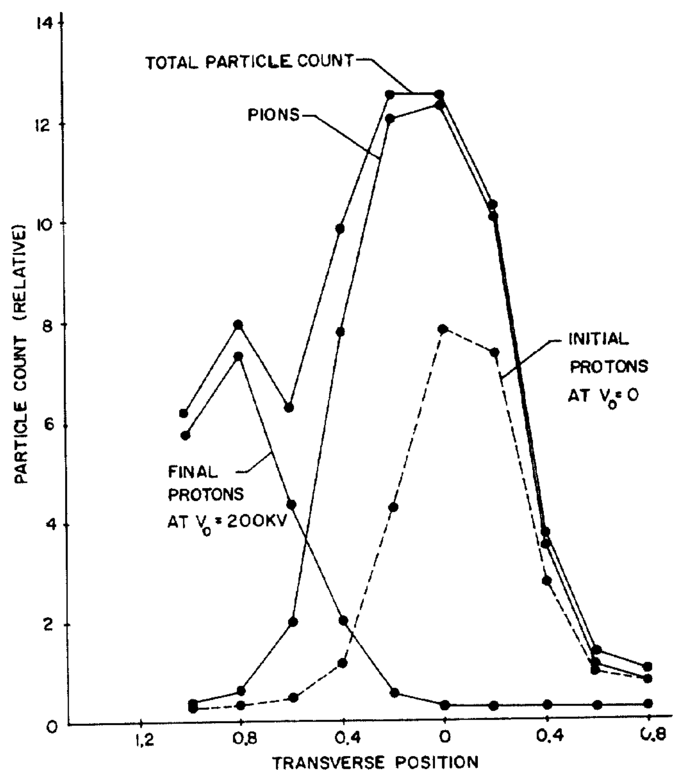

Fig. 5 Proton Separation from 256 MeV Pions