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THE PARTICLE SEPARATOR AT LOS ALAMOS*

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There is only one beam separator presently being developed at Los Alamos and this is for the EPICS channel at LAMPF. EPICS (Energetic Pion Channel and Spectrometer) operates from 20 to 300 MeV pion energy. Excessive electron and positron contamination exists in this channel from 20 to 50 MeV and heavy proton contamination persists over the rest of the range. Energy degraders will not work in EPICS due to the high energy resolution required, 1 part in 10^4. All the contaminating particles generate background, but the protons are particularly undesirable due to their strong ionization signal in detectors which otherwise compounds their ten to one predominance and reduces the signal-to-noise ratio to about 0.01 in experiments involving Π^+. Experiments comparing cross-sections with Π^+ and Π^- reactions require that proton contamination be reduced by at least 100:1 over most of the energy range and electron and positron contaminations be reduced by at least 10:1 at the lowest energies. To accomplish these goals without loss of energy resolution, an active beam separator is being developed which operates on the electrostatic crossed-field principal. Despite this standard operational approach, the EPICS separator has several unusual features.

The first out-of-the-ordinary characteristic of the EPICS separator is its low average energy and the wide dynamic range over which it must perform. This is shown in Fig. 1 for proton separation, where it is seen that to maintain a relatively uniform separation angle $\Delta\theta$ of 18 mr, the electric field in the gap must vary from 2.6 kV/cm at 50 MeV to 36 kV/cm at 300 MeV.

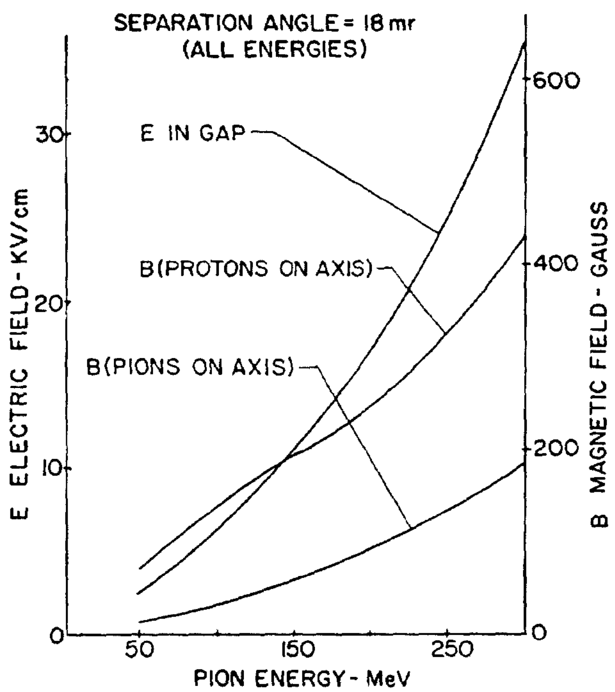

Fig. 1. EPICS Separator Parameter Range

Since the separator can operate in two modes, either pions-on-axis or protons-on-axis, the dynamic range of the magnetic field is even greater, 30 to 1. At 50 MeV with pions-on-axis, the minimum magnetic field required for 18 mr separation of protons is only 20 gauss. The control of the separator fields over these wide ranges, as well as the long-term stability of regulation are questions to be answered during the course of the testing program which is now under way.

The other unusual features of the EPICS separator lie in its mechanical design aspects. Perhaps the most dramatic departure from convention is the enclosure of the entire assembly, including the magnet, within the vacuum line of the channel itself. This is done by building a 6.2 cubic meter flux box as a permanent part of the line and rolling the separator unit into it on tracks to be sealed by a heavy steel door. This assembly is shown in Fig. 2. The flux box serves to

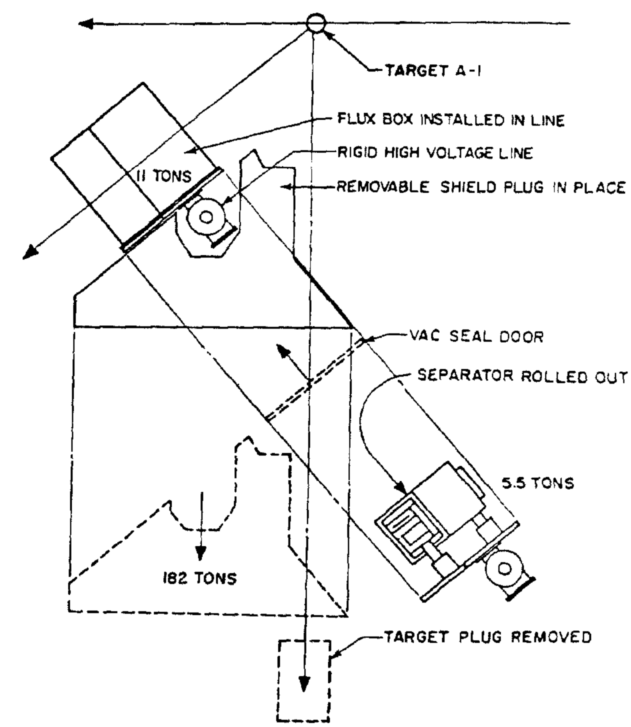

Fig. 2. Separator Removal and Shield Door

clamp the field of the separator magnet at a uniform boundary, unaffected by the presence of stacked steel shielding which would otherwise distort the field. This is especially important since the magnet gap is 80 cm, large compared to its 93 cm length, resulting in an extensive fringing field. The separator assembly is attached to the 10 cm thick steel door which is sealed by a 7 meter long aluminum o-ring. The box is then evacuated to channel vacuum which can be pressure controlled from 10^{-3} torr to 10^{-6} torr by a 500 liter per second turbo-molecular pump. The entire assembly of flux box and separator weighs 11 tons (metric). Rolling the intact separator out of the flux box facilitates rapid removal of the radioactive unit from the line with no disassembly of the line itself. The flux box is situated between the first and second bending magnets of the EPICS line. It is elevated at an angle of 52.6° and the separator electrodes are oriented vertically. Since no access to the rear of the flux box is possible, a single high voltage electrode is used to solve the problem of voltage delivery to a pair of vertically oriented electrodes accessible from only one side. However, this places unusually high stress on the insulator of the powered electrode which applies up to 320 kV across a 9-cm gap. Even though this total gap voltage is low compared to other crossed-field units of this type, it represents an equivalent 640 kV balanced two-electrode system and this implies special precautions in designing the voltage delivery and distribution system.

Since the separator is situated only 4.3 m from target A-1, it is exposed to an extremely high neutron and gamma flux, up to 10^8 rad/yr. This requires that the unit be designed to be rad-hard where possible and that it be deeply enclosed within the massive shielding of the EPICS line. The centroid of the unit will lie 4.2 m beneath the top level of the shield. To allow access for removal, a rollaway shield plug, weighing 182 tons (metric) is provided as shown in Fig. 2. The estimated time required to roll open the shield block, remove the separator, reseal the flux box, and roll close the shield plug is 8 hours. During this period, the entire Area A, containing six experimental channels including Biomedical, must be shut down, so expeditious handling of extremely heavy components is required. It is expected that removal for maintenance may be required on a monthly basis.

Another unconventional design feature which has yet to fully prove itself is the nested equipotential shield electrode structure shown in Fig. 3. The main electrode is 43 cm x 142 cm and is guard-ringed by four dished equipotential shields, all fabricated of 304 stainless steel. The shields are attached to every second kovar spacer of the high voltage insulators. The intermediate insulator spacers are connected together by the extendable rods seen in Fig. 4. The vacuum-brazed insulators themselves are shown in Fig. 5 with the shield supports laser spot-welded onto the spacers. The intermediate spacers, not supporting equipotential shields, are protected by corona rings. Each stage of the 10-stage insulators carries as much as 32 kV; the outer surface is of course in vacuum, while the interior is protected by high pressure sulfur-hexaflouride.

The opposing electrode is at ground potential and is composed of 13 mm diam. rods spaced on 25 mm centers after the wire electrode concept of the Rutherford Labs.[1] The rods are assembled into the electric flux box shown in Fig. 6. Behind the ground-plane electrode is a biasing electrode. The combination of "wire-electrode" and biasing electrode may prove effective in reducing ion-exchange currents although this has yet to be demonstrated in practice.

The use of an electric field not symmetrical about

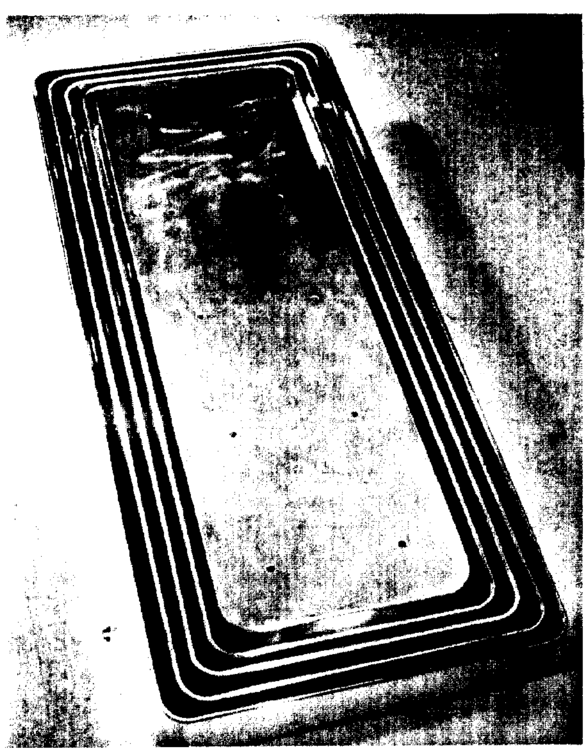

Fig. 3. Nested Electrode Structure

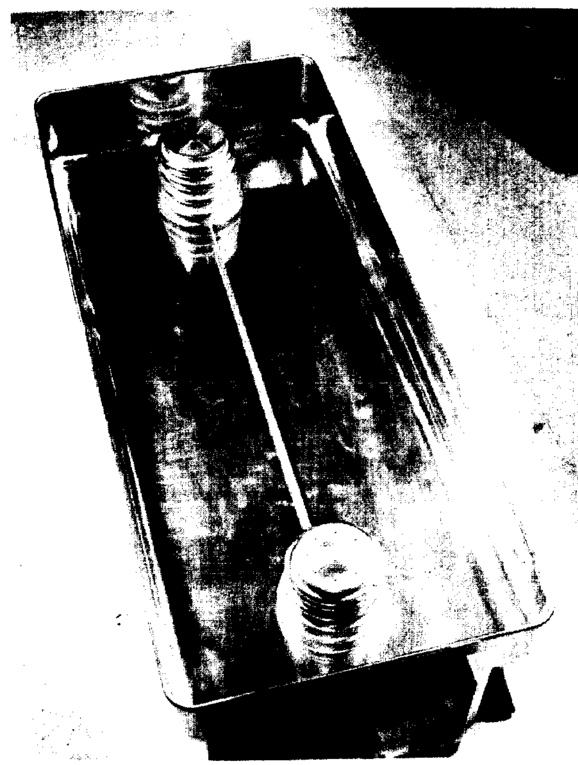

Fig. 4. Interelectrode connections

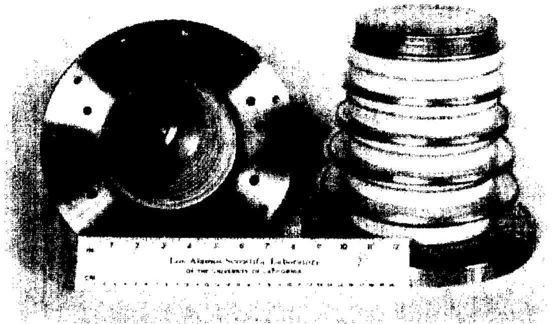

Fig. 5. Segmented Insulators

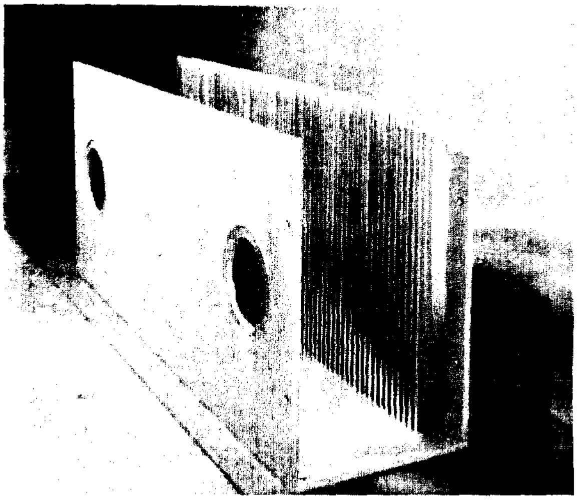

Fig. 6. Electric Flux Box with Bar Electrode

Fig. 7. Assembly of Separator in Flux Box

the beam center line has defocusing effects but calculations indicate the transverse electric impulse integral varies only 0.5% across the beam width which is tolerable within the energy resolution specifications of the EPICS channel.

The electric flux box and electrodes are cantilevered on two steel feedthroughs as shown in Fig. 7. The magnet is supported by a heavy carriage attached directly to the door. The lower feedthrough - closest to the target - contains the voltage delivery system including the externally mounted rigid high-voltage line and cable termination seen in Fig. 8. A gas-feed pipe allows pressurization of the line and both feedthroughs to 6 atm SF_6. Only the lower cannister and central portion of the rigid HV line are so pressurized. The upper cannister contains transformer oil in which the plug-in HV cable terminates. The upper feedthrough farthest from the target, holds the most delicate part of the entire separator assembly, the voltage divider shown in Fig. 9. This unit, besides being exposed to high radiation fields, is tightly confined within the 13 cm inner diameter of the insulator. A total resistance of 2000 MΩ with 100 watts dissipation capacity distributes the 320 kV along the ten insulator spacers by means of thirty-three spring loaded buttons on eleven corona rings.

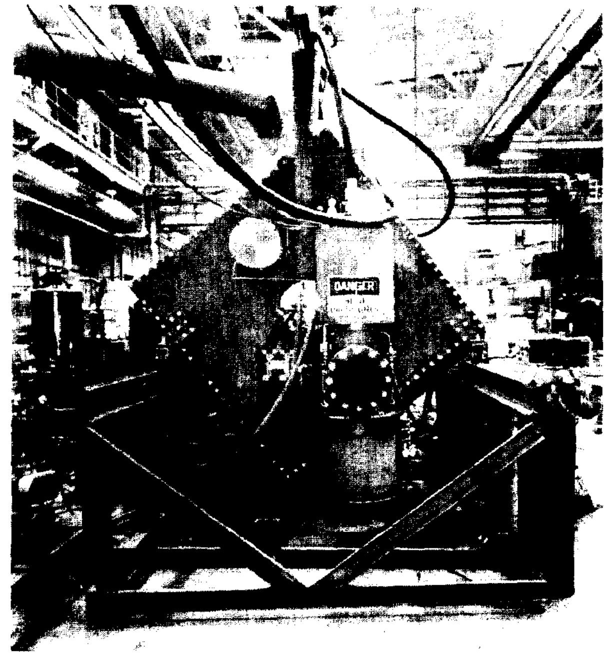

Fig. 8. Pressurized HV Transmission Line

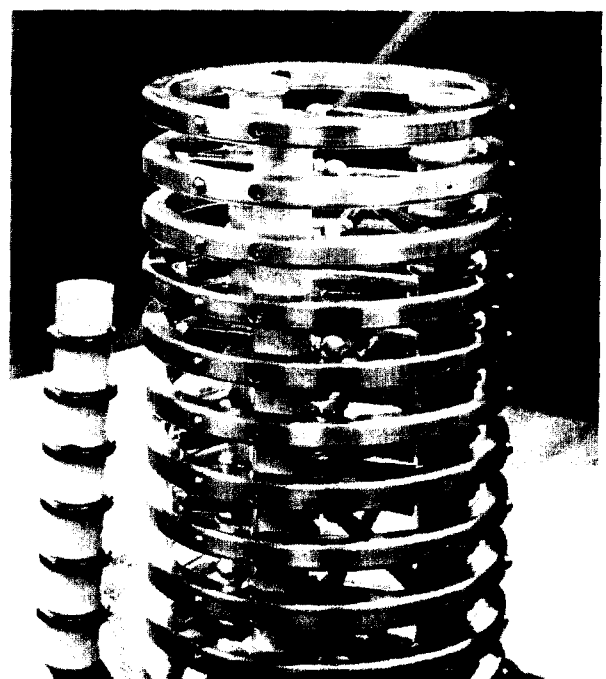

Fig. 9. 320 kV, 50 watt Voltage Divider

The voltage divider is also protected by 6 atm SF_6. It can easily be removed for servicing from the outside.

The rest of the separator system is conventional in design. The power supply, shown in Fig. 10, is a

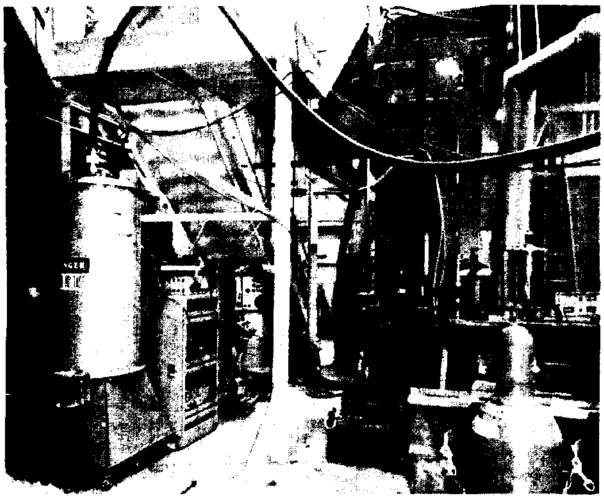

Fig. 10. 400 kV Cockcroft-Walton

surplus PPA Cockcroft-Walton capable of +400 kV at 1 ma. A positive anode voltage was chosen because of an advantage in controlling anode-cathode ion currents. The driver electronics is patterned after PPA designs using a frequency servo to drive the 33 kHz CW/separator combination at resonance. At present only open-loop voltage control and only overcurrent and load-spark protection is available, but this is enough to carry on the testing program while the rest of the electronics is being developed.

The Cockcroft-Walton power supply has been tested at 435 kV for extended periods following repair and adjustment of this surplus unit and construction of the driver electronics. The entire high voltage transmission line has been tested to 350 kV and the entire system to 170 kV with full magnetic field. Without magnetic field, the electrodes have been operated to 240 kV in vacuum before deconditioning began to set in. Testing is continuing concurrently with electronics development. Bias electrode has still to be tried.

Acknowledgment

L. B. Dauelsberg and D. C. Slater deserve high credit for their assistance in building and testing the separator system under difficult conditions of beam channel construction and lack of personnel.

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References

1. "Wire Electrodes in Electrostatic Separators," W. A. Smith, The Rutherford High Energy Laboratory.