OPERATING CHARACTERISTICS OF ARGONNE'S 50 μs RF PARTICLE SEPARATOR BEAM*

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Summary

An RF separated beam line, Beam 10, for the 12-ft bubble chamber has been constructed at Argonne's ZGS Complex. It utilizes two copper S-band RF deflecting structures, currently separated by a drift length of 31.25 m. The structures are excited from a central high-power RF modulator station, which can provide up to 10 MW of 50 μs pulsed RF power to each structure. The beam is instrumented with proportional wire chambers and scintillation counters. The first use of this beam was in taking 100,000 pictures in the 12-ft bubble chamber of 7.14 GeV/c protons where the rejected π^+ contamination was 7%. Currently, tuning studies to provide a separated K^- beam at 6.52 GeV/c are taking place. Some pictures of interesting K^- interactions in the 12-ft chamber are included. A unique feature of this beam is the use of a fast RF diode switch to turn off the low power RF drive and, consequently, stop the beam when a maximum number of tracks (typically about 10) have entered the chamber. This feature has resulted in an improvement of the picture taking rate of the chamber by 30% for the 7.14 GeV/c proton run.

Introduction

Short pulse (a few μs) RF separated beam lines, employing two and three RF separator structures have been in use at SLAC,[1] Brookhaven,[2] CERN,[3] and Serpukhov[4] for several years. Because the ZGS's "short" beam extraction time is about 30 μs, Argonne's RF separators are required to operate with a long RF pulse length of 50 μs. In order to keep the relative phase constant (to within a few degrees), it was decided to power the separators from a central modulator with a common pulse transformer. This ensures that the phase modulation due to klystron high voltage ripple stays within the required limits over the full pulse length. An additional feature is to allow a change in the distance between separators so as to accommodate different desired momentum beams. The beam optics was designed to facilitate this possibility by incorporating a parallel beam section.

RF Separator Systems and Separators

Figure 1 presents a block diagram of the RF system for the long pulse RF separators. The modulator is of the line type. It has two 25 μs, 25 section, m-derived pulse forming networks of characteristic impedance 11.18 Ω. The networks are resonantly charged through the 5 H charging inductors and series diodes to twice the power supply voltage. The lines are discharged in parallel into a 1 to 10 quadrifilar pulse step-up transformer by the CH1191 hydrogen thyratrons, and are designed to give less than 1% flattop voltage ripple. The klystron loads as seen through the transformer, are designed to present a slight mismatch to the networks to turn off the thyratrons at completion of the pulse.

The RF power for the separators is provided by two RCA 8568 high-power klystron amplifiers. This tube has been operated at power levels as high as 10 MW for 50 μs into a dummy load.[5] The safe operating power level for the separators is 6 MW max.[6] Typical operating levels have been 4 MW. The drive lines to each of the klystrons contains a remotely controllable phase shifter and attenuator for individual phase and power level control. The main drive is provided by a hard-tube modulator driven Eimac 4K3SN klystron amplifier. The signal source is provided by a low power frequency stabilized (phase locked to a crystal) signal generator. This signal is amplified by a 1 W, TWT amplifier to drive the 4K3SN.

The diode switch turns off the drive to the 4K3SN when a predetermined number of tracks have entered the chamber. The trigger for turnoff is provided by a scintillation counter coincidence pair, which are situated immediately after the final momentum analysis slit. Turnoff of the RF requires about 2 μs including signal transit time. Turning the RF drive off causes all particles to hit the beam stopper and, consequently, none enter the chamber. Ordinarily the bubble chamber flash would be vetoed with occurrence of too many tracks. The RF diode switch has resulted in an improvement of about 30% in the chamber picture taking rate in the 7.14 GeV/c proton experiment.

Argonne's RF separators are copper, iris-loaded, circular waveguide structures operating in the HEM_{11}, $2\pi/3$ deflecting mode,[3] and were modeled after the SLAC LOLA IV separator design. They have a beam aperture of 1.767 in., an electrical length of 140.55 in., and an operating frequency of 2856.2 MHz in vacuum at 98°F. They give a synchronous deflection of 5.9 MeV/c at 1 MW (the deflection scales as $P^{1/2}$). The separators are spaced 31.25 m apart so that K^- separated beams at 4.6, 5.0, 6.52, and 8.0 GeV/c can be obtained. The beam will be operated first at 6.52 GeV/c.

The RF power is supplied to the separators by

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high-power, copper, vacuum waveguide. Each separator and its associated waveguide is pumped with 3-200 ℓ/s Vac Ion pumps, and has an operating vacuum of 1×10^{-8} torr with the RF power on. Waveguide directional couplers are used to monitor the forward and reflected power. In the event of high reflected power or high vacuum pressure, the system is interlocked to turn off the RF for protection of the separators.

The temperature of the separators and waveguide is maintained constant by circulating closed-cycle, temperature-controlled water, at 10 gal/min, through water channels on the separators and waveguide. In order to keep heat loss and temperature fluctuations to a minimum, the waveguide was completely wrapped with a foam-rubber type insulation. The RF phase cable is also wrapped inside the insulation to keep its temperature and, therefore, phase length constant. The system has maintained the temperature at 98°F $\pm 0.5^{\circ}$F with large variations of ambient temperature.

The Beam Optics

The beam design utilizes 0° production of secondaries in the extracted proton beam at the ZGS. The pre-separation momentum analysis with $\Delta p/p \sim \pm 1\%$ is followed by a further bend to restore the beam parallel to the initial extracted proton beam direction. The separation stage uses the conventional CERN two cavity design,[7] and it extends functionally from the vertical angle collimator following the second magnetic bend, to the beam stopper. The target is focussed, both horizontally and vertically, at the center of each deflector with unity angular magnification between them. The angular separation achieved at the second deflector is converted to a vertical position separation at the beam stopper, which is immediately followed by a horizontal collimator to redefine the image for the post-separation momentum selection. This final momentum analysis is done with a momentum bite $\Delta p/p \sim \pm 1\%$ in order to achieve a good rejection of μ, particularly important in the case of a separated K^- beam. The momentum slit for this stage is constructed from iron with the low momentum jaw magnetized to 15 kG in order to further reduce the number of μ reaching the chamber. This final stage of the beam focusses vertically at the chamber entry window and spreads the beam over 3 - 4 ft horizontally to facilitate picture scanning. The total length of the beam is 142.7 m. As previously mentioned, the beam design incorporates a parallel beam, both horizontally and vertically for the post-separation dispersing magnets which then allows the intercavity spacing to be varied. This is done by moving the second deflector and the following four quadrupoles relative to the first deflector. In addition, the four intercavity quadrupoles must be repositioned.

Beam Instrumentation

All collimator settings and also the beam stopper height can be controlled remotely. The beam optics is tuned using a slow resonant extraction mode giving a beam spill of about 250 μs. The beam profiles at the various horizontal and vertical foci, and also at the beam stopper are observed using proportional wire chambers with either integrating or digital readouts, according to the counting rates involved. A tuning matrix[8] is used to move the various foci relative to the detectors in order to determine optimum quadrupole gradients for the required beam momentum. Provision is also made for using scintillation counters at several places in the beam, such as the beam stopper and after the final momentum slit where, additionally, a threshold gas C-counter is located. This latter is particularly useful in studying the π (μ) and K components in the beam.

We include, Fig. 2, two typical 12-ft chamber pictures of interactions of 6.52 GeV/c K^- mesons obtained in the tuning schedule.

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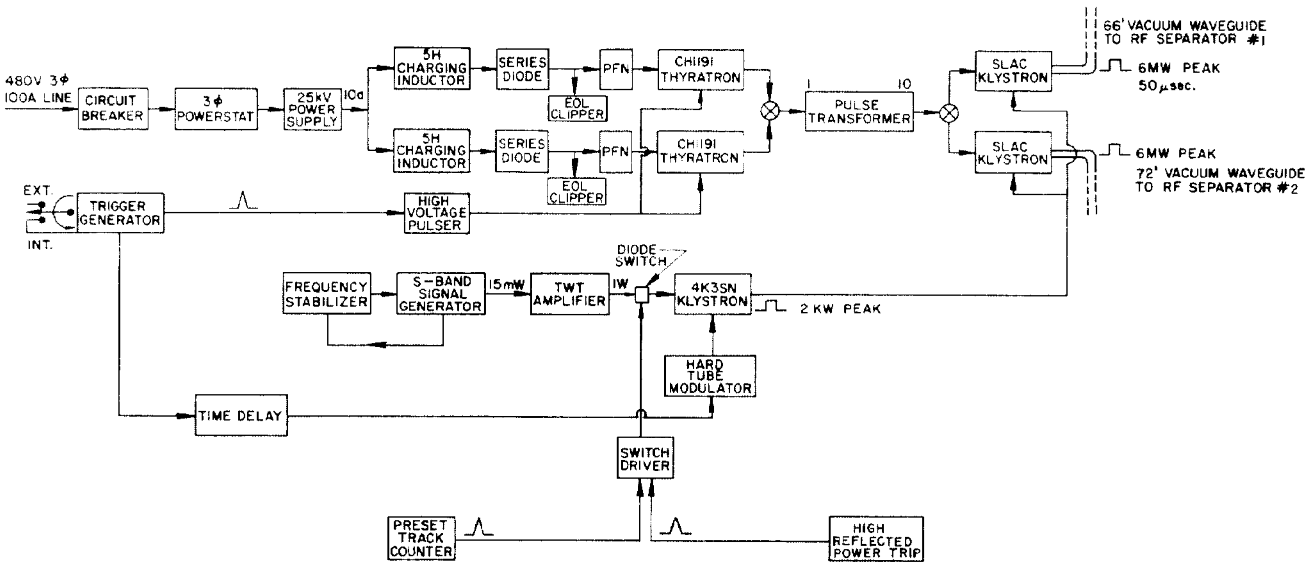

Fig. 1. Block diagram of the RF system for the long pulse particle separators.

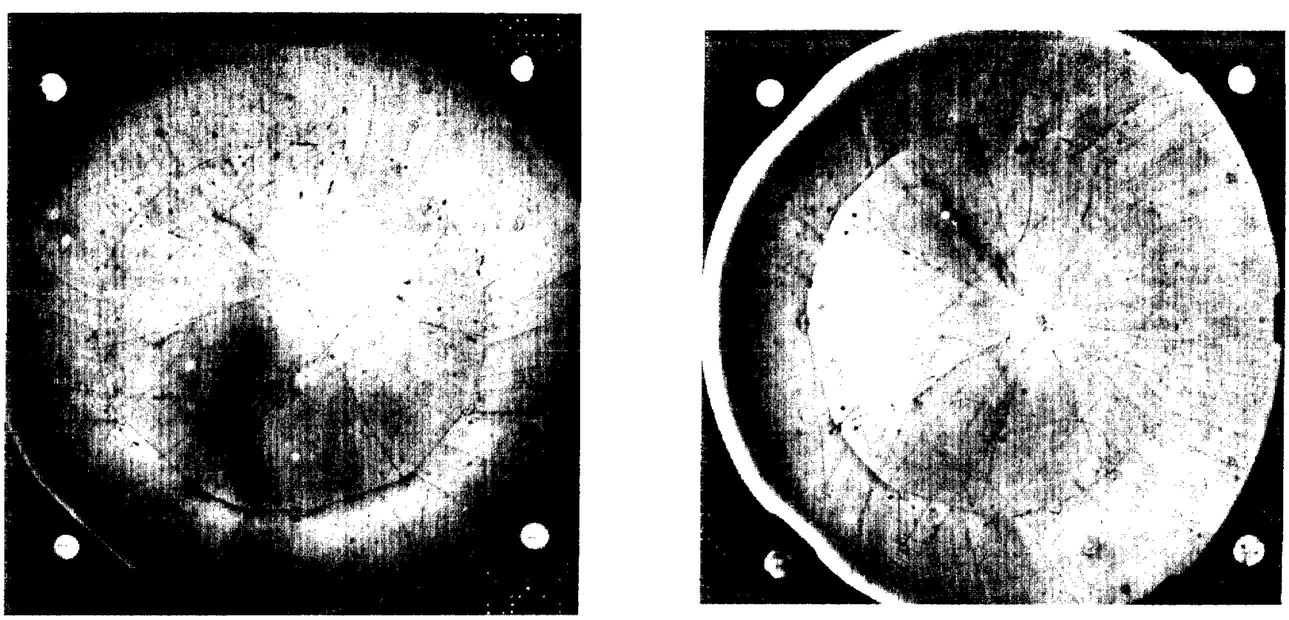

Fig. 2. K^- meson proton interactions in the 12-ft bubble chamber at 6.52 GeV/c.