A Fast Switching E-Field Kicker, For The Temporal and Spatial Division of a 26.6 MeV/c Surface Muon Beam.

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Abstract

A description is given of the design and commissioning of a fast switching E-field kicker system, for the temporal and spatial division of a 26.6 MeV/c muon beam. The system is an important component in a recent CEC funded upgrade of the surface muon experimental facility at ISIS, the high intensity neutron source, at the Rutherford Appleton Laboratory, Chilton, Oxfordshire, United Kingdom.

1 INTRODUCTION

The ISIS pulsed muon facility as built in 1987 [1], delivered a pair of 82 ns (fwhm) pulses, with a peak to peak separation of 340 ns, to a single experiment area, at a prf of 50 Hz. This double pulse time structure limited the available frequency range for μSR (muon spin resonance) to discrete frequencies up to a maximum of approximately 10 MHz. This disadvantage was removed in 1989 by the addition of a fast E-field kicker [2] that removed the second muon pulse. The successful operation of this kicker increased the scientific utilisation of the facility at a cost of a factor of two in intensity. This was a tolerable loss, as the majority of experiments typically used only 30% of the available double pulsed muons, being limited by high data acquisition rates at early times with the consequent severe distortions induced in the measured spectra.

With a single experiment area, there was a three-fold over-subscription for beam time. To solve this problem, a proposal was made in 1989, to the CEC large facilities program, to extend the facility, and provide three experiment areas with the capability of simultaneous operation with single pulses at a prf of 50 Hz. This was to be achieved with a temporal and spatial division of the muon pulse pair by a fast switching E-field septum kicker.

2 MODE OF OPERATION

A plan view of the CEC funded muon beam line is shown in Fig. 1, with the position of the kicker indicated by the letter K. Operation of the CEC kicker is illustrated in Fig. 2. A simplified plan view shows the 700mm long central anode, equidistant from the two outer grounded cathodes. At the start of the cycle, the central anode is at a potential of 32.5 kV, producing an electric field of about 0.6 MV/m in the gaps. The first muon bunch is bisected and subsequently deflected through angles of 66.5 mr by

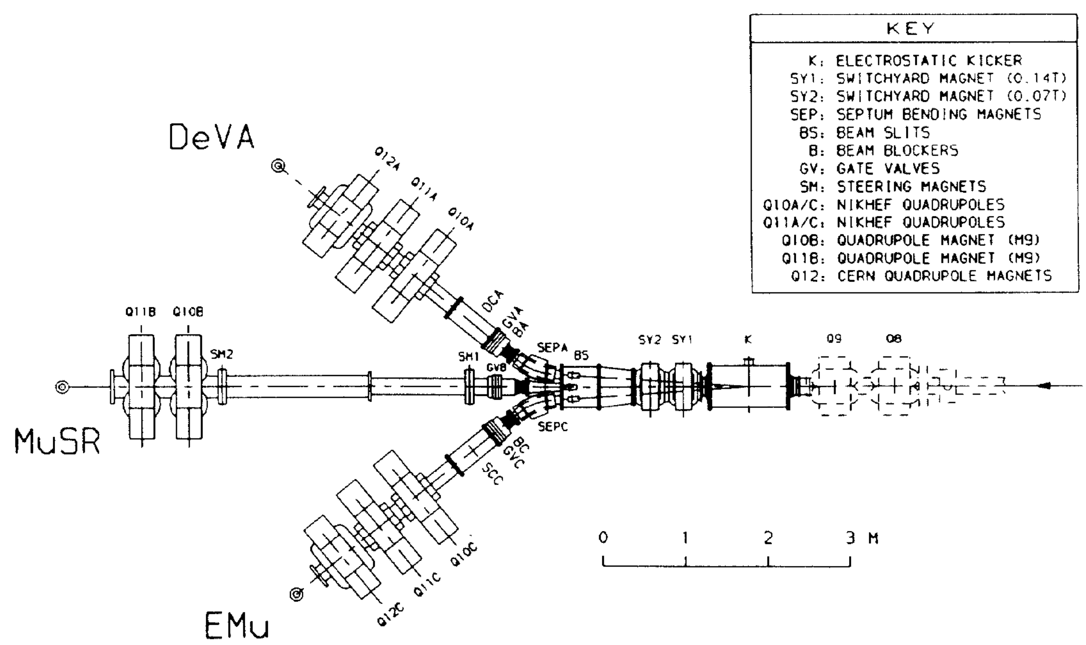

Figure 1: Plan view of the CEC muon beam lines

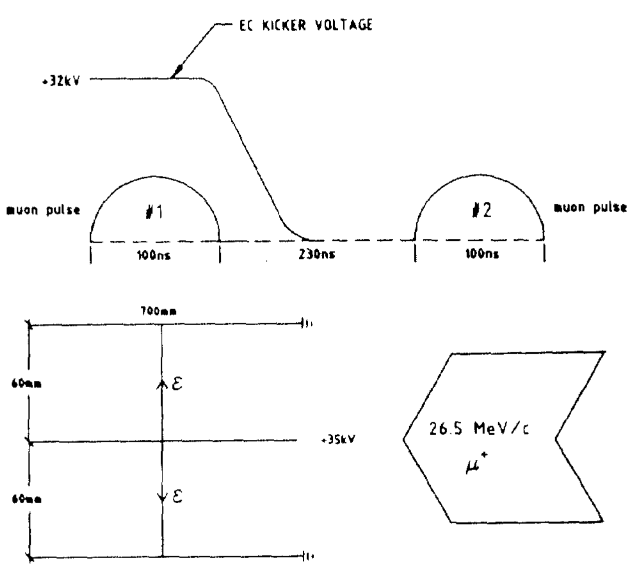

Figure 2: Mode of operation

the electric field, to provide two simultaneous muon pulses to the outer (EMu and DeVA) areas. Just after the passage of the first muon pulse the kicker field is rapidly reduced to zero. The second muon pulse is consequently undeflected, and travels on to the MuSR area.

3 MECHANICAL CONSTRUCTION OF THE CEC KICKER

The mechanical construction of the E field kicker is shown in Fig. 3. This design produces the required 66.5 milliradian deflection, for 26.61 MeV/c positive muons, with an electrical length of 0.7 metres, and an applied voltage of 32.5 kV.

Maximum deflection for a given electrical length, and applied voltage, has been achieved by matching the curvature of the outer electrodes to the path of the deflected muons. The finite element code PE2D [3] was used to model and optimise the electric field design.

Components subject to high electric fields are manufactured from 304 grade stainless steel, and have been electropolished to achieve a suitable surface finish [4]. The selection of a 2.0 mm thick central electrode was dictated by the need to maintain adequate stiffness and flatness, a field level of not more than 50 kV/cm at the fully radiused electrode edge, and minimum muon loss (~5%).

Other features of the design are the commercial high voltage feedthrough, the use of canted beryllium/copper spring rings, and fingerstrip to provide low impedance electrical connections between the 'in vacuum' components. The high voltage electrode support insulators are made from 'PEEK' [5], a strong, high temperature, advanced polymer, and have been designed using specialised techniques [6].

4 THE CEC KICKER DRIVE SYSTEM.

A block diagram of the kicker system is shown in Fig. 4. This low power configuration is capable of charging the kicker electrode to 32.5 kV (±0.25%) in less than 15 ms, and discharging to 0 V (±0.25% of 32.5 kV) in less than 200 ns.

The CX1528 medium power, single gap thyratron [7], was selected for its good high voltage holdoff, convenient air cooling, and the promise of a long operational life in this application.

Other features of the design are the commercial high voltage capacitor charging supply with internal gating function, stabilised DC heater and reservoir supplies (for reduced thyratron trigger jitter), and a commercial high voltage power mosfet thyratron trigger unit.

A timing waveform schematic is shown in Fig. 5. At t=0, V2 has settled to 32.5 kV (±0.25%), and the thyratron grid driver has just received a trigger pulse. At t=150 ns the first muon pulse enters the kicker, and is horizontally divided and deflected through equal and opposite angles of 66.6 mrad, by the electric field. These muons are subsequently transported through a septum magnet to the

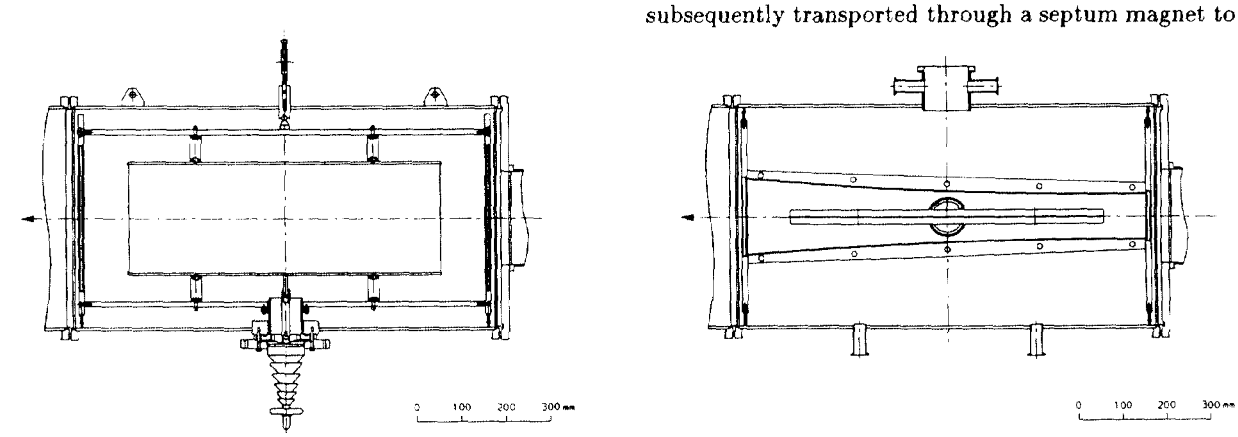

Figure 3: CEC kicker showing side and plan views

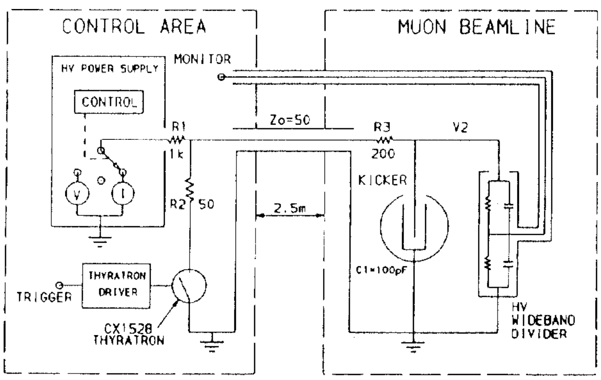

Figure 4: Block diagram of the CEC kicker system

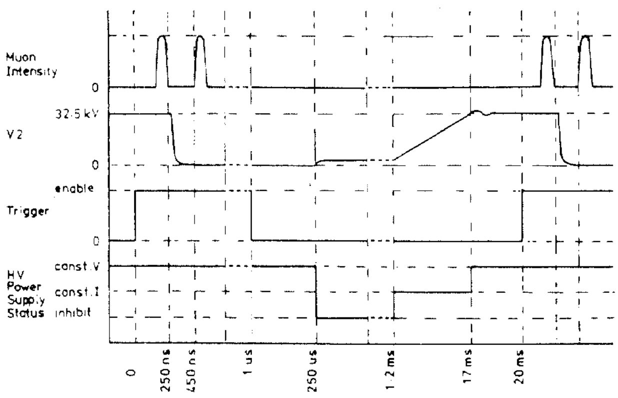

Figure 5: Timing and waveform schematic

left and right experimental areas. At t=250 ns, the thyratron fires, and V2 decays with a time constant of C1*(R2+R3) (25 ns). The timing is set so that at t=250 ns the first muon pulse has (just) passed through the kicker. At t=450 ns the second muon pulse enters the kicker and passes through, undeflected, to the central experimental area. At t=250 μs the high voltage power supply responds to the low impedance load at its output, and switches from constant voltage to inhibited mode. After an internally generated delay of about 1 ms, the supply switches to constant current enabled mode (t=1.2 ms). At t=17 ms, the system capacitance (500 pF) is charged to 32.5 kV, and settles to 0.25% of 32.5 kV by t=19.5 ms, ready for the next cycle.

5 OPERATIONAL MEASUREMENTS

At the time of writing, the kicker system has run with beam for more than 4500 hours, with few problems. The operating voltage, predicted by electrostatic field computation [3] of 32.0 kV compares favourably with that obtained by the optimisation of muon intensity in the DeVA and EMu beam lines (35.5 kV). The voltage waveform, measured with a wide-band high voltage probe (Tek P6015A), shows the voltage settling to < 0.25% of 32.5 kV in 180 ns.

Fig. 6 shows the action of the CEC kicker on the muon

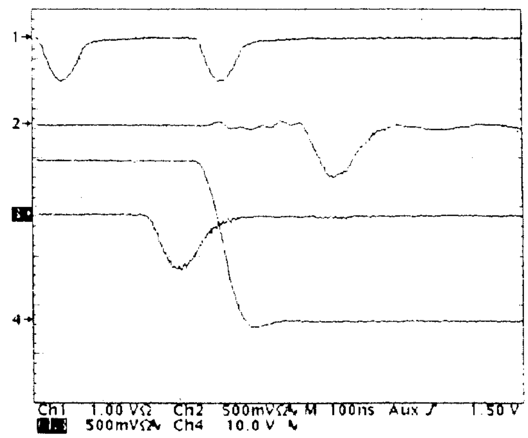

Figure 6: Action of CEC kicker on muon pulses

pulses. The top trace shows the Cerenkov pulses revealing the time structure of the protons at the production target. The second and fourth traces are derived from the muon detectors in the MuSR and EMu beam lines respectively, and show the relationship with the kicker voltage waveform (third trace) in distributing the two muon pulses to the EMu/DEVA and MuSR beam lines.

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