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Ring Injection Summary

A simulation is used to investigate injection into the E989 muon storage ring. A distribution of muons is propagated from the end of the M5 line, through the injection channel, and into the ring. The injection channel is comprised of the hole through the backleg iron, the fringe field region that extends from the inner edge of the backleg iron between the superconducting coils to the inflector entrance, and the inflector. Propagation through the injection channel is with 3 dimensional field maps. Scattering and energy loss in the coils that overlap the ends of the E821 inflector assume the appropriate mix of aluminum, niobium, etc. The apertures for the E821 inflector are the well know "D" cross section with full width and height of 18mm and 56mm respectively. The "36mm" inflector in the study assumes elliptical aperture with 36mm horizontal and 56mm vertical axis.

The ring guide field consists of uniform vertical B-field and 4 electrostatic quadrupoles equally space around the ring. Each quad subtends 39 degrees of arc. Muons exit the inflector and enter the ring. Each of the electrostatic quads consists of a short and a long section. In the E821 experiment the injected muons necessarily passed through the outer plate of the long section of the first quad to get into the ring. It has been proposed for E989 that the long plate will be displaced outward from 5 to 7cm so that muons will pass inside the plate. We assume that geometry in this study. Some muons will nevertheless hit the plates and muons that hit the plates are scattered. For the purposes of computing scattering angles we assume that the plates are 0.1mm thick aluminum. In all of the scenarious described below we use this same quad plate geometry and scattering parameters.

The muon distribution was generated with the MARS and G4beamline simulations and propagated to the end of the M5 line. There are 10,000 muons in the raw distribution, with energy width $\pm 2\%$ and 95% emittance of about 50 mm-mrad. The dependencies explored include:

1. kicker magnetic field
2. β_x, β_y, η at the inflector exit
3. offset and angle of injected beam just upstream of the hole in the magnet iron

The raw distribution is mapped to the twiss parameters $(\beta, \alpha, \eta, \eta')$ at the entrance to the magnet iron, so that it will emerge at the end of the inflector with the designated exit parameters.

The 10000 muon distribution is propagated through the injection channel and into the ring. Muons that hit the inflector apertures are lost. Collimators at a radial position of

45mm in the ring define the ring aperture. Muons that strike collimators are lost. Some of the injected muons will hit the kicker plates. At present the muons are assumed to simply penetrate the plates without scattering. The magnetic field just outside the kicker plates is in the opposite direction of the field between the plates, and muons in the exterior region will experience the reversed kick. Muons that remain within the ring aperture for 20 turns are declared "stored".

E821 18mm inflector

Dependencies for the E821 inflector are summarized in Figures 1 and 2. The inflector is the e821 magnet with full horizontal aperture of 18mm. Multiple scattering in the inflector end coils is included. The inflector map with gradient ($\sim 2\%$) over the full 18mm width) is superposed on the main magnet fringe field for tracking. The error bars are statistical. Optimum capture occurs with a 210-250G kicker field, 1m $< \beta_x <$ 3m, 6m $< \beta_y <$ 14m, and 0.5m $< \eta <$ 1.5m. Note that there is a sharp minimum for the amplitude of the coherent betatron oscillation of the stored beam at a kicker field of 230G. CBO amplitude otherwise depends weakly on the twiss parameters of the injected beam.

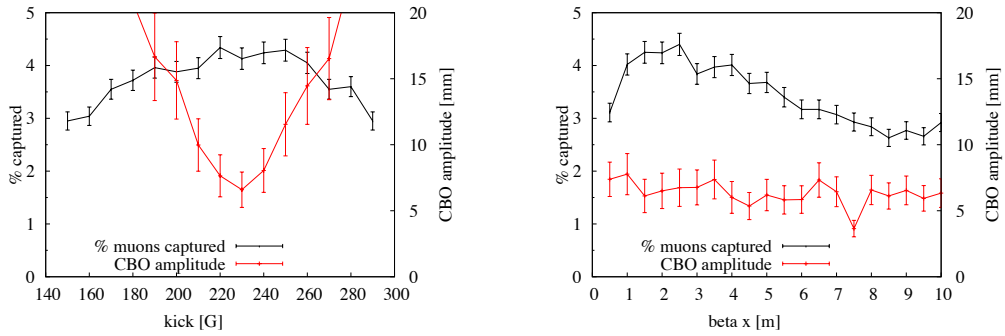

Figure 1: Dependence of muon capture efficiency and amplitude of coherent oscillations of the stored beam on (left)kicker field, and (right)β_x, at the downstream end of the E821 (18mm) inflector.

The dependence on the offset and angle of the injected beam with respect to the reference trajectory indicate beam steering tolerances. The reference is the trajectory that emerges from the inflector at the midpoint of the inflector aperture and on a tangent line displaced 7.7cm from the closed orbit of the ring. Figures 3 show that the offset and angle are sensitive at the $\sim$ 1mm and $\sim$ 0.5mrad level respectively.

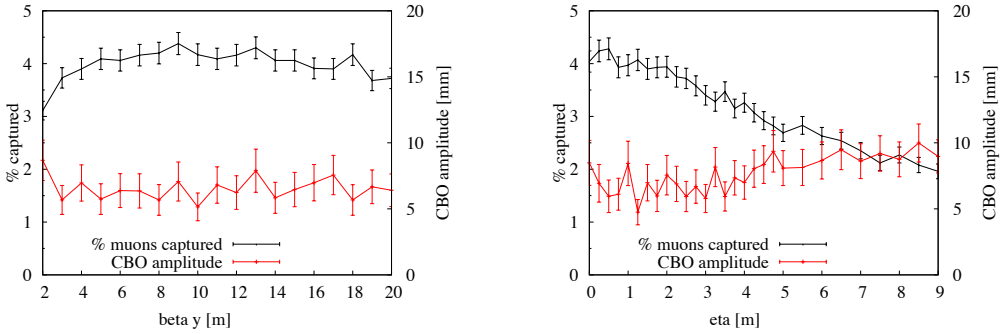

Figure 2: Dependence of muon capture efficiency and amplitude of coherent oscillations of the stored beam on (left)β_y and (right)η at the downstream end of the inflector.

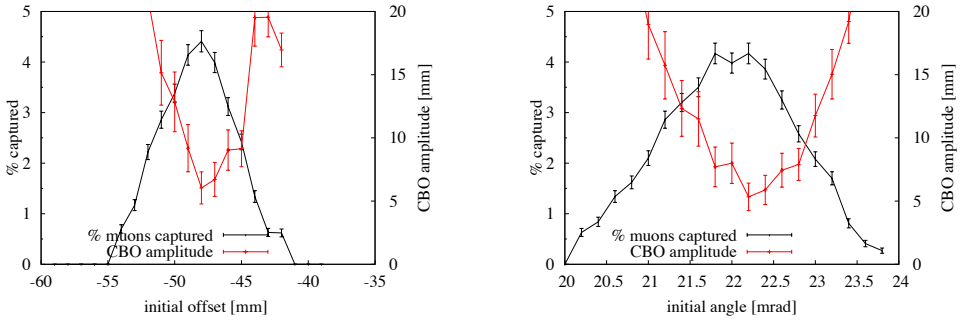

Figure 3: Dependence of muon capture efficiency and amplitude of coherent oscillations of the stored beam on; (left)offset and (angle)angle of the trajectory just upstream of the hole in the backleg iron, using the E821 inflector.

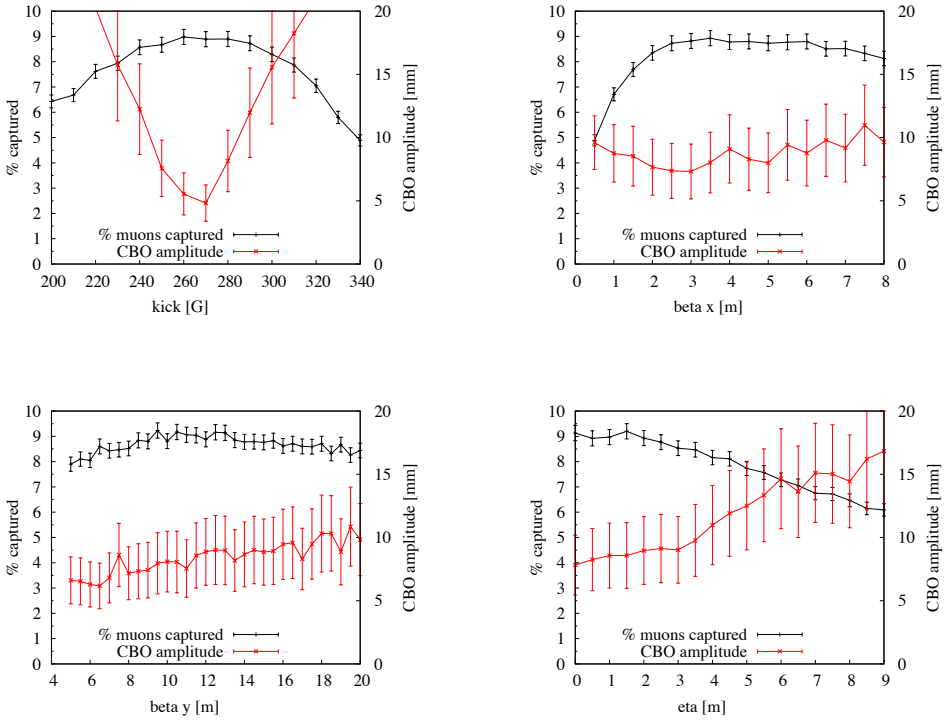

Figure 4: Dependence of muon capture and ampltude of coherent betatron oscillations of the stored beam on; (top left) kicker field and (top right)β_x (bottom left)β_y and (bottom right) η. The inflector is assumed to have full horizontal aperture of 36mm with uniform field (no gradient) and without overlapping end coils.

36mm inflector

A similar calculation is performed assuming the larger aperture (36mm) inflector. Dependencies are somewhat different for a larger aperture inflector as shown in Figure 4. The simulations with the 36mm inflector assume no scattering in end coils, and no field gradient in the inflector. The inflector field is assumed uniformly superposed on the fringe field of the main magnet. The optimum kick is increased to 270G, 2.5m $< \beta_x <$ 6m, 9m $< \beta_y <$ 14m, and $0 < \eta <$ 2.5m.

Inflector end coil scattering

Scattering in the coils that overlap the ends of the E821 inflector effect capture efficiency. The efficiency for eight different scenarios are summarized in Figure 5. Configuration 1

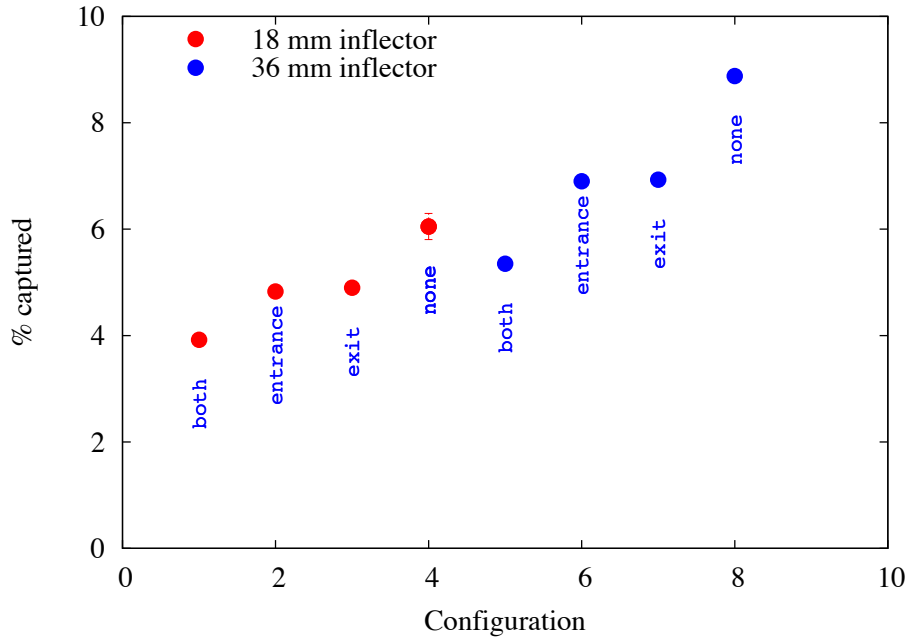

Figure 5: Summary of dependence on the effect of the scattering in inflector end coils. Red points correspond to the 18mm inflector with field gradient, and blue points for the 36mm inflector with no gradient. A representative statistical error bar is included. “both” - scattering in both ends of inflector, “entrance” - scattering in entrance only, ”exit”- scattering in exit only, ”none” - no scattering.

corresponds to the E821 inflector with coils overlapping both ends. Configuration 8 is for a 36mm aperture inflector with no overlapping coils.