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Magnetic Shielding Inside Toroid Magnets

by

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The toroid magnets surrounding the vacuum decay region of experiment 621 were found to have a field of 52 Gauss at their centers. This Technical Memo describes how we eliminated this field by wrapping the vacuum pipe with high permeability steel foil.

In E-621 we are studying CP violation in the decay $K_S^o \rightarrow \pi^+\pi^-\pi^o$ by measuring the proper time distribution of $\pi^+\pi^-\pi^o$ decays in a short neutral beam. The beam is made with the magnetic channel of the hyperon magnet in the Proton Center beam line. Our spectrometer, in the neutral beam, is bathed in an intense flux of muons that penetrate the hyperon magnet. To reduce the muon flux we have installed seven toroidal magnets just downstream of the hyperon magnet, with the vacuum pipe, containing the neutral beam and decay products, threaded through their centers. The requirement that the magnetic field of the toroids not perturb the K^o decay products, at the level of the resolution of our spectrometer, places an upper limit on this field of about 5 G.

Upon finding that the field was ten times larger, we decided to try shielding the beam pipe with high permeability iron or steel. Upon the suggestion of Aga Visser we contacted the Arnold Engineering Co. of Marengo, IL at (815) 568-2000. After discussion we settled on type M6 grain-oriented silicon steel that has a permeability of about 4000. If formed to the desired shape and annealed, the permeability would double. It comes in rolls 15 in wide and .0136 in thick. In a blizzard, Roger Tokarek and I drove to Marengo and obtained a roll.

I tested the magnetic shielding of the steel foil by wrapping various numbers of layers around a 6 in OD aluminum pipe in the gap of one of the toroids, and then measuring the field at the center of the toroid with a Hall probe. The Hall probe was calibrated with a permanent magnet before and after the field measurements. 0, 2, 4, and 6 layers of steel were used. The effect of adding 2 more layers of steel foil was to reduce the field by a factor of 2 or 3. The test results, shown in Figure 1, are the magnetic field at the toroid's center versus longitudinal position in the toroid. The field happened to be 45° from the vertical. The measurements show the field growing at the end of the toroid, flattening out along the 15 in long steel wrapping, and the edge region, a little less than one pipe diameter in length. The six wrappings were a little less than $\frac{1}{4}$ inch thick and reduced the field to 2 Gauss, well below the required maximum.

I conclude that this is an inexpensive and convenient way of controlling magnetic fields in sensitive locations. I would

like to acknowledge the help of Roger Tokarek and Aga Visser in doing this work.

Fig. 1 Magnetic Field vs. Z