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BXS Re-calibration *

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Early in the commissioning it was noticed by Cecile Limborg that the calibration of the BXS spectrometer magnet seemed to be different from the strength of the BX01/BX02 magnets. First the BX01/BX02 currents were adjusted to 135 MeV and the beam energy was adjusted to make the horizontal orbit flat. Then BX01/BX02 magnets were switched off and BXS was adjusted to make the horizontal orbit in the spectrometer line flat, without changing the energy of the beam. The result was that about 140-141 MeV were required on the BXS magnet. This measurement was repeated several times by others with the same results.

It was not clear what was causing the error: magnet strength or layout. A position error of about 19 mm of the BXS magnet could explain the difference. Because there was a significant misalignment of the vacuum chamber in the BXS line, the alignment of the whole spectrometer line was checked. The vacuum chamber was corrected, but the magnets were found to be in the proper alignment. So we were left with one (or conceivably two) magnet calibration errors.

Because BXS is a wedged shaped magnet, the bend angle depends on the horizontal position of the incoming beam. As mentioned, an offset of the beam position of 19 mm would increase or decrease the bend angle roughly by the ratio of 135/141. The figure of 19 mm is special and caused a considerable confusion during the design and measurement of the BXS magnet. This is best illustrated in Figure 1 which was taken out of the BXS Traveler document. The distance between the horizontal midplanes of the poles and the apex of the beam path was chosen to be 19 mm so the beam is close to the good field region throughout its entire path. Thus it seemed possible that there was an error that resulted in the beam not being on this trajectory, or conversely, that the magnetic measurements were done on the wrong trajectory and the magnet was then mis-calibrated. Mechanical measurements of the vacuum chamber made in the tunnel indicated that the vacuum chamber was in fact in the proper position with respect to the magnet — not 19 mm off to one side — so the former possibility was discounted. Review of the Fiducial Report and an interview with Keith Caban convinced me that there was no error in the coordinate system used for magnet measurements.

I went and interviewed Andrew Fischer who did the magnetic measurements of BXS. He had extensive records, including photographs of the setups and could quickly answer quite detailed questions about how the measurement was done. Before the interview, I had a suspicion there might have been a sign flip in the x coordinate which because of the wedge would result in the wrong path length and a miscalibration. Andrew was able to pin-point how this could have happened and later confirmed it by looking an measurement data from the BXG magnet done just after BXS and comparing photographs. It turned out that the sign of the horizontal stage travel that drives the measurement wire was opposite that of the x coordinate in the Traveler, and the sign difference wasn't applied to the data. The origin $x = 0$ was set up correctly, but the wire moved in the opposite

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Table 1: Results from the integration along the equivalent path to the design path, and the correction implied to the integrated strength of the BXS magnet. BXS is actually 4.01% weaker than the original polynomial predicted.

$\int Bds$ pivot to ∞	-0.04111	Tm
$\int Bds$ pivot-to-pivot	-0.17490	Tm
$\int Bds$ $\pm\infty$	-0.25711	Tm
Current	140.96	A
Polynomial BL@140.96A	0.2679	Tm
Error in BL: Poly - Corrected	0.01075	Tm
Error BL, percent of total	4.01%	

direction to what was expected, just as if the arc had been flipped over about the origin.

To quantitatively confirm that this was the cause of the observed difference in calibration I used the 'grid data', which was taken with a Hall probe on the BXS magnet originally to measure the FINT (focussing effect) term, and combined it with the Hall probe data taken on the flipped trajectory, and performed the field integral on a path that should give the same result as the design path. This is best illustrated in Figure 2. The integration path is coincident with the desired path from the pivot points ($x = 0$) outward. Between the pivot points the integration path is a mirror image of the design path, but because the magnet is fairly uniform, for this portion it gives the same result. Most of the calibration error resulted simply from the different path length between the design path and the measured path.

The results of the integration on the equivalent path are given in Table 1. The corrected calibration has been used to generate a new polynomial for BXS which was implemented in the control system.

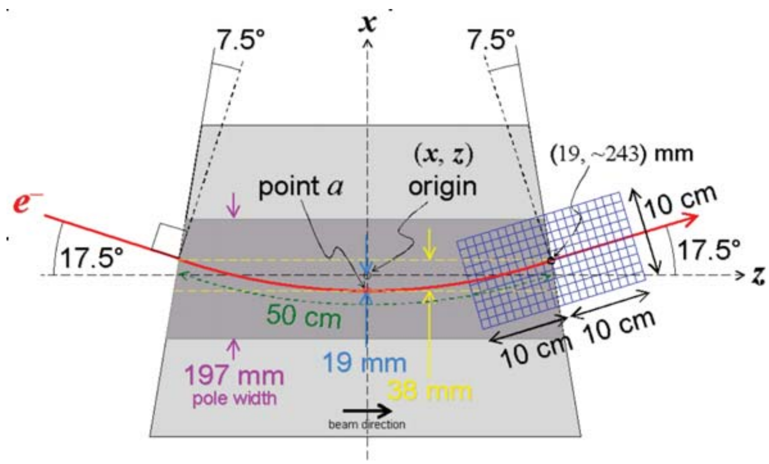

Figure 1: Definition of design beam path to be used for magnetic measurements.

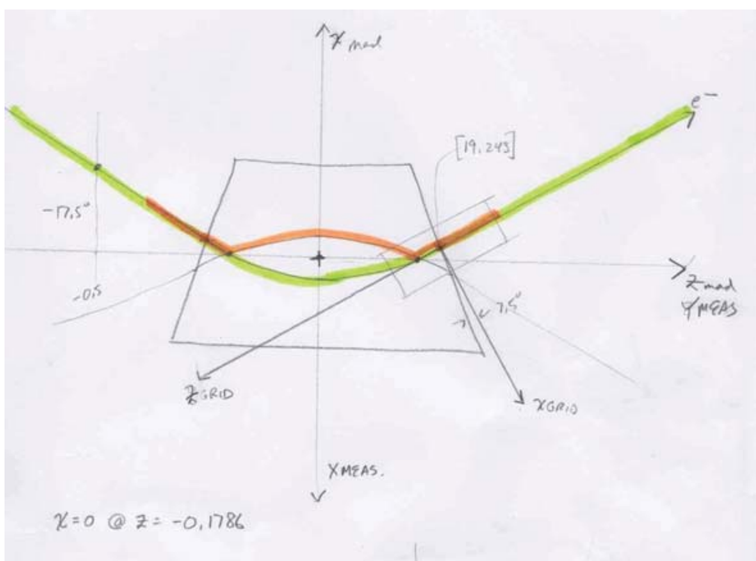

Figure 2: The green path is the design path for the beam. The measured path was equal to the design path but mirrored about $x = 0$. Grid data were obtained over a region centered on one edge in a different measurement setup. The grid data range extended far enough into the magnet that it included the pivot point along the desired path where $x = 0$ which doesn't move when mirrored. The integration path for the correction was the orange path.