POLARIZATION and SPIN TRANSFER at 800 GEV

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ABSTRACT

Fermilab experiment E756 has measured the polarization of Ω^- hyperons produced by 800 GeV protons to be small compared to that of Ξ^- hyperons. When produced by a neutral beam containing polarized Λ and Ξ^0 hyperons, both the Ω^- and the Ξ^- have a significant polarization indicating a large spin transfer at high energies. Using this polarization, a very preliminary measurement of the Ω^- magnetic moment gives 2.0 ± 0.2 nm.

Judging from the attendance at this workshop, the unfashionable technique of using spin measurements to explore the strong interaction still has its partisans. I suspect that many of us believe that the regular behavior of the large spin effects in high energy production[1] and scattering experiments[2] suggests that spin does play an important role in the strong interaction.

Today I am here to report the very preliminary results of Fermilab experiment E756 from the just completed fixed target run. The primary goal of E756 is to make the first measurement of the Ω^- magnetic moment. The Ω is the simplest of the "stable" baryons having 3 strange valence quarks with parallel spins. We hope this measurement will clarify the origin of the apparent inconsistency among the magnetic moments of the octet baryons.[3]

In order to measure the Ω magnetic moment using the precession technique, one needs to produce a polarized sample of Ωs. The standard technique is to produce the polarized sample at a p_T of about 1 GeV/c using a proton beam. This is the technique we have used for Λ, Ξ^0, Ξ^-, Σ^+, and Σ^- hyperons (see Figures 1,2,3)[4]. If the proton produced Ωs were not polarized, we were prepared to attempt to produce the polarized sample by first producing polarized Λs and Ξ^0s using protons and then producing polarized Ωs by spin transfer from the polarized neutral beam. If the spin transfer were zero, we had yet a third scheme in mind.

In order to produce a polarized Ω from a proton, the Ω must "remember" that it is a fragment of the incident proton to give the necessary correlation between production angle and polarization. If baryon number were conserved by constructing the Ω from the proton, one could imagine the Ω being produced by sequentially substituting one valence s quark at a time for the light valence quarks in a proton. We know (Figure 1) that the Ξs produced by protons (2 new valence s quarks) have approximately the same polarization as Λs produced by protons (1 new valence s quark) . On the other hand, one could argue that, since the Ω has no valence quarks in common with the incident proton, it carries no information about the proton direction and hence cannot be polarized. As Figure 4 shows, antiΛs (3 new valence quarks) produced by protons are not polarized.[5]

Because it was easiest, we began by measuring the polarization of Ωs produced at 2.5 mrad by 800 GeV protons. We used the same basic spectrometer that has served us well since E8.[6] This apparatus, shown in Figure 5, also accepted Ξ^- events. The spectrometer was supplemented by 8 planes of 100μm pitch silicon strip detectors for tracking the Ω (Ξ^-) before it decayed into a ΛK^- ($\Lambda\pi^-$). At this time we have analyzed roughly half of our Ω data using a crude version of our reconstruction program. The 40,000 events in that sample are shown in Figure 6 (ΛK mass) and Figure 7 (Ω momentum). The signal is very clean with little background under the mass peak. The sample peaks at a value of x_F greater that 0.5 and p_T greater than 1.0 GeV/c. This is the kinematic region where the polarizations of other hyperons were on the order of 20%.

From our 1987 run we expect to obtain 100,000 Ωs and 8 million Ξ^- events with an average momentum of 400 GeV/c , x_F of 0.5, and p_T of 1 GeV/c. Our detected Ξ^-/Ω ratio was about 80, giving us a yield of 5 Ωs and 400 Ξ^-s per 20 second spill of 2.5×10^{10} protons on a 1/4 interaction length Be target. Figure 8 shows our measured polarization for about 1% of the Ξ^- data from 800 GeV protons agrees well with our previously measured polarization from 400 GeV protons. The same Figure also shows that the polarization of Ωs is small if not zero.

When our results indicated that Ωs produced by protons were not polarized, we reconfigured the targeting area to try the spin transfer technique by adding a 6m sweeping magnet (B2) with a field of 1.8T just upstream of our target. Inside the sweeping magnet was a collimator with a 3mm x 3mm limiting aperture to define a neutral beam. A 1 interaction length Cu target was just upstream of this sweeping magnet. The 800 GeV protons interacted in the copper target producing a neutral beam at 2 mrad. The neutral beam then interacted in a second copper target, also 1 interaction length, at 0 mrad to produce Ωs and Ξ^-s as shown in Figure 9. By scaling from our previous 400 GeV data, with 5×10^{11} protons on the upstream target, we expected a neutral beam consisting of 3×10^8 γs, 2×10^8 ns, 5×10^7 polarized Λs, 2×10^7 K^0s, and 1×10^6 polarized Ξ^0s to be incident on the downstream target.[7] After interacting in the downstream target we estimated that the numbers of Ωs produced by n, Λ, and Ξ^0, would be in the ratio of 1:3:5 with those produced by γ and K^0 much smaller. In other words, we expected about 90% of the Ωs to be produced by polarized Λs and Ξs in the neutral beam.

Figures 10 and 11 show the ΛK^- mass and the detected Ω momentum spectrum for this sample. Again the Ω sample has very little background. We obtained 20,000 Ωs and 1.5 million Ξ^-s with an average momentum of about 300

GeV/c from this part of E756. The ratio of Ξ^-/Ω detected was roughly the same as for proton production giving a yield of 0.8 Ω and 50 Ξ^- per 20 second spill of 6×10^{11} protons. The polarization of the resulting sample is shown in Figure 12. Less than 10% of the Ξ data has been analyzed for this figure. It is clear that we have produced a neutral beam of polarized s quarks, and that there has been a large spin transfer to both the Ωs and the Ξs.

In conclusion, we have measured that the polarization of Ωs produced by protons at high energy is much smaller than that of other hyperons. We have produced a secondary polarized neutral beam which we have then used to produce a tertiary polarized charged hyperon beam. The spin transfer is large both to Ωs and to Ξ^-s from a polarized neutral beam. This technique of "quark splicing" gives an inexpensive way to make polarized baryons at high energies. A very preliminary analysis of our data gives the Ω magnetic moment to be -2.0 ± 0.2 n.m. Our goal for the next run is to improve the precision to 0.03 n.m.

A high energy experiment is a team effort and there are many people who contributed to the success of this one. We would especially like to thank the many people at Fermilab, both management and staff, who helped us change from a polarization to a spin transfer experiment with a minimal loss of data taking time.

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REFERENCES

1. For a review see K. Heller, Proceedings of the VII International Symposium on High Energy Spin Physics, Protvino (USSR), 81 (1987) and the references quoted therein.
2. For a review see Y. Makdisi, Proceedings of the VII International Symposium on High Energy Spin Physics, Protvino (USSR), 81 (1987) and the references quoted therein.
3. For a review see L. Pondrom, Proceedings of the VII International Symposium on High Energy Spin Physics, Protvino (USSR), 81 (1987) and the references quoted therein.
H. Lipkin, Proceedings of the VII International Symposium on High Energy Spin Physics, Protvino (USSR), 81 (1987) and the references quoted therein.
4. G. Bunce et al, PRL 36 , 1113 (1976).
K. Heller et al, PRL 51 , 2025 (1983).
C. Wilkinson et al, PRL 58, 855 (1986).
R. Rameika et al, PR D33 , 3172 (1987).
5. K. Heller et al, PRL 41 , 607 (1978).
6. P. Skubic et al, PR D18 , 3115 (1978).
7. A. Beretvas et al, PR D35 , 53 (1986).

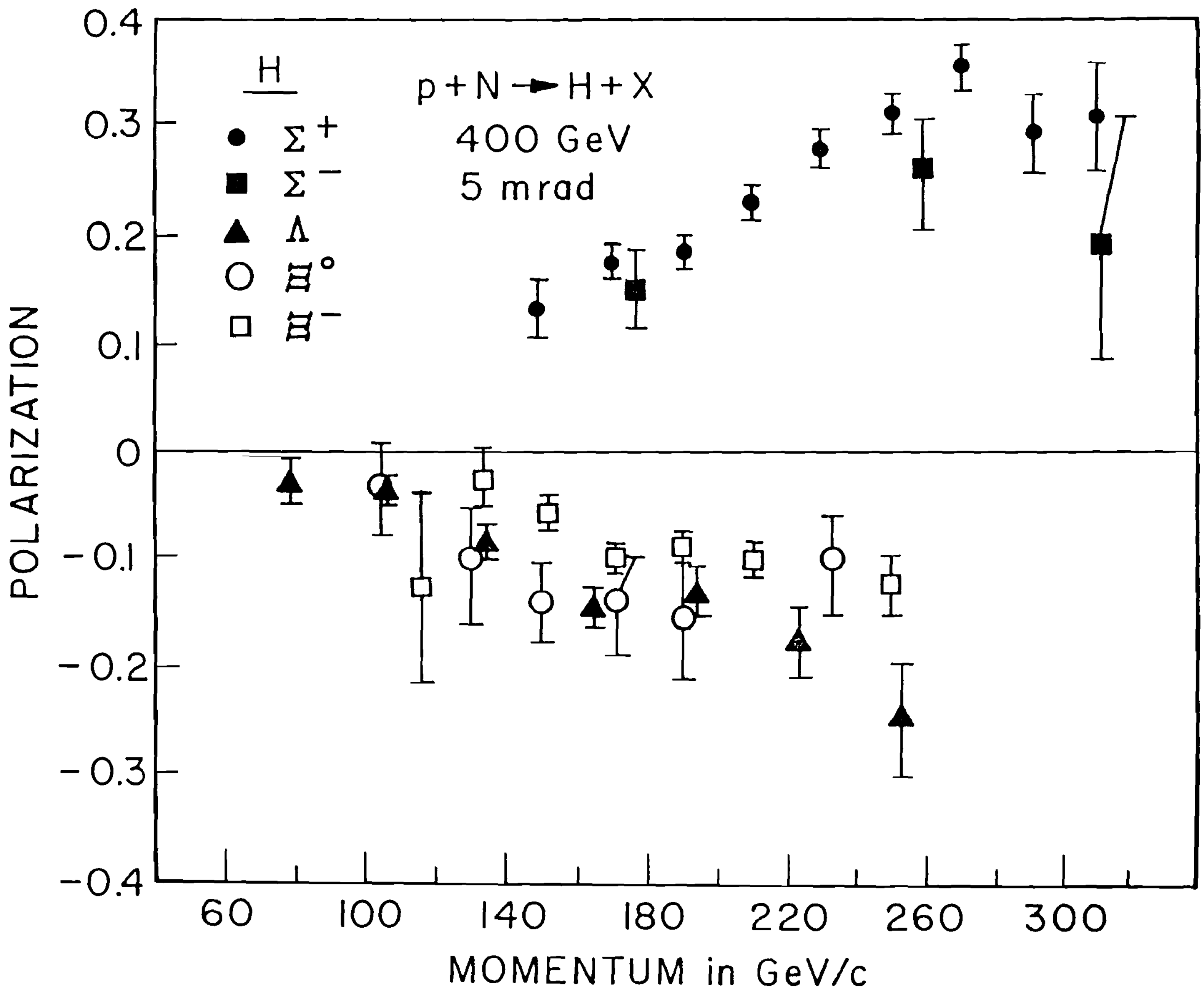


FIGURE 1. Polarization of hyperons produced at 5 mrad by 400 GeV protons.

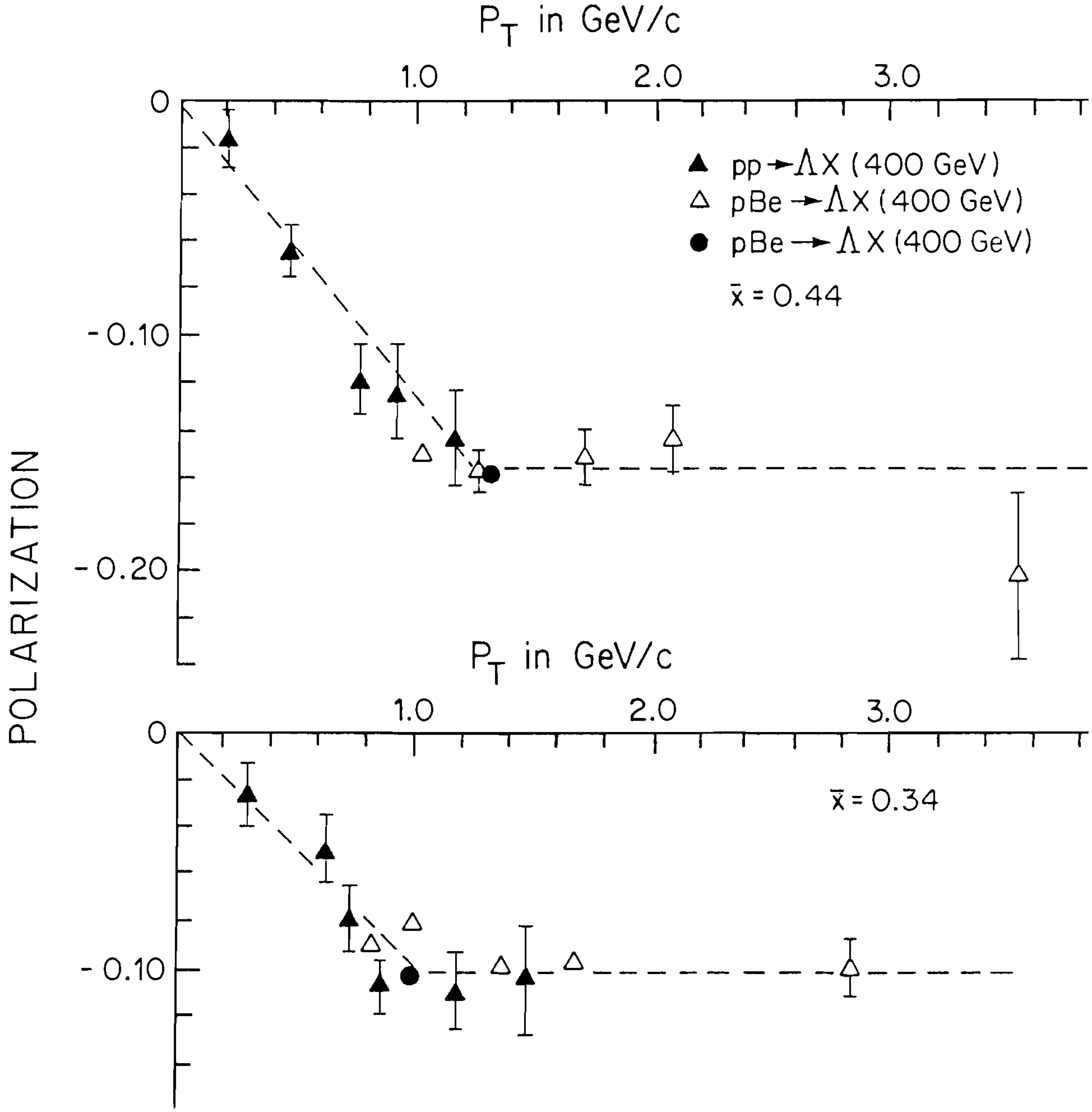


FIGURE 2. Λ polarization as a function of p_T for fixed x_F.

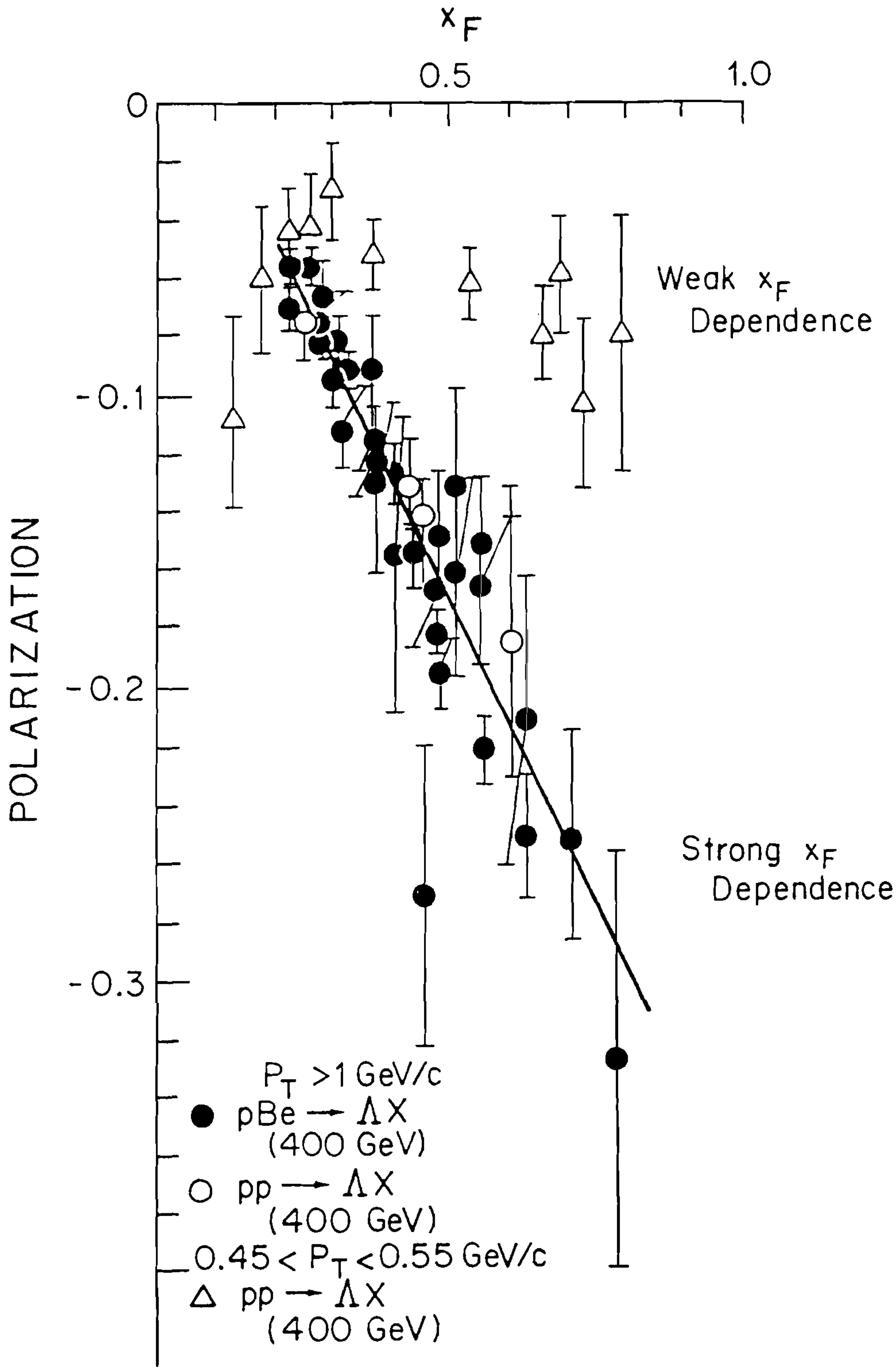


FIGURE 3. Λ polarization as a function of x_F.

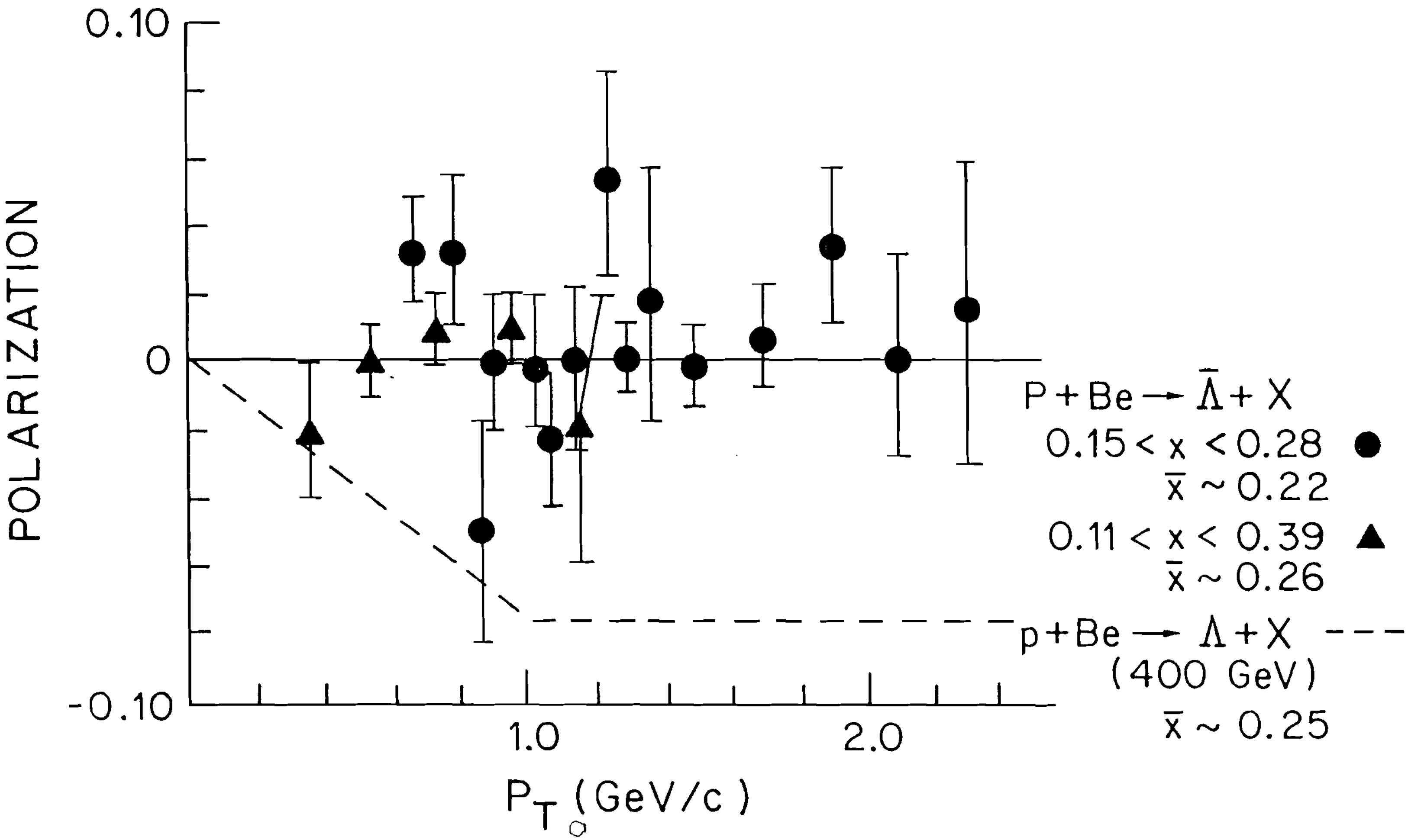
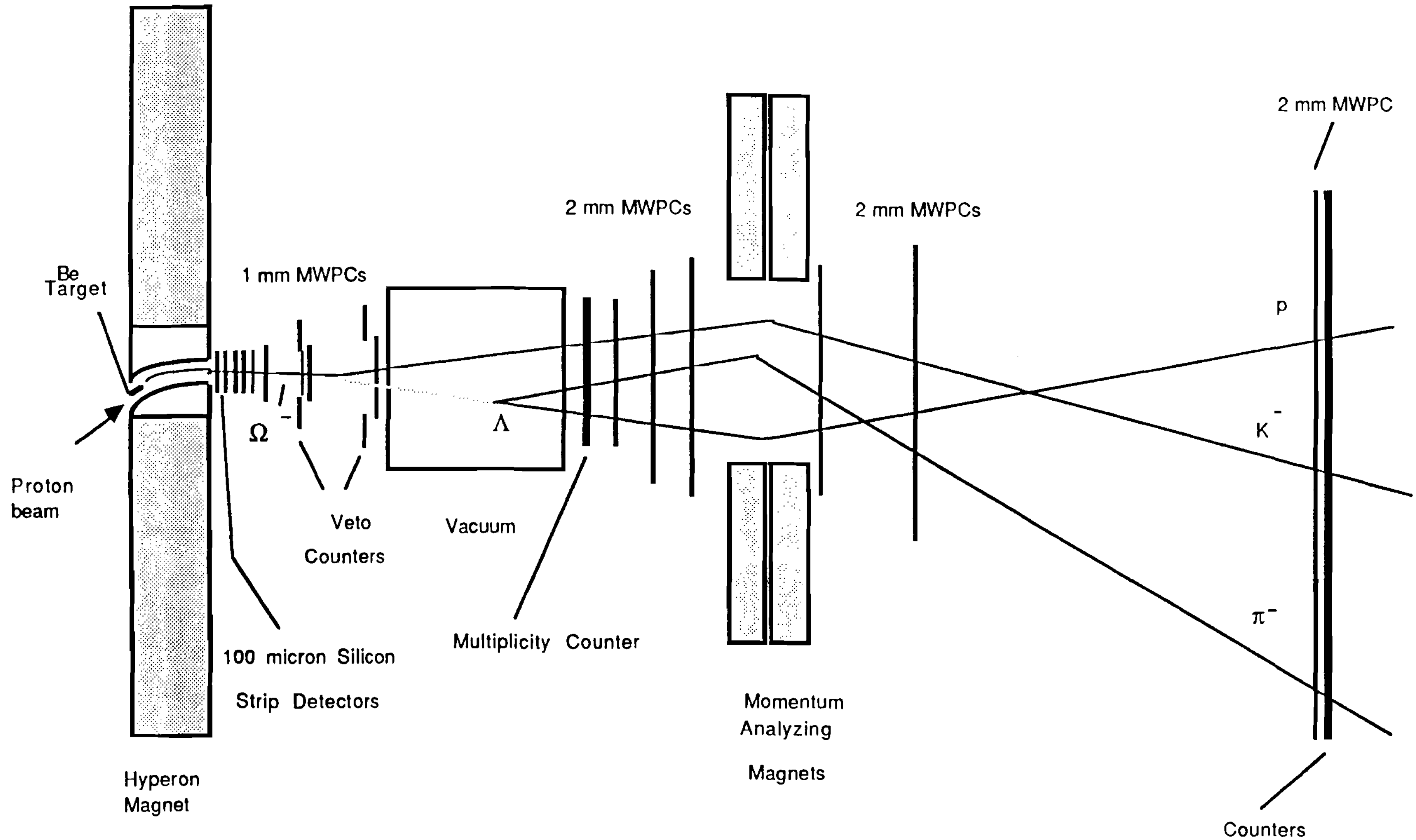


FIGURE 4. Anti-Λ polarization as a function of p_T.



Plan View of E756 Spectrometer (not to scale)

FIGURE 5. E756 apparatus.

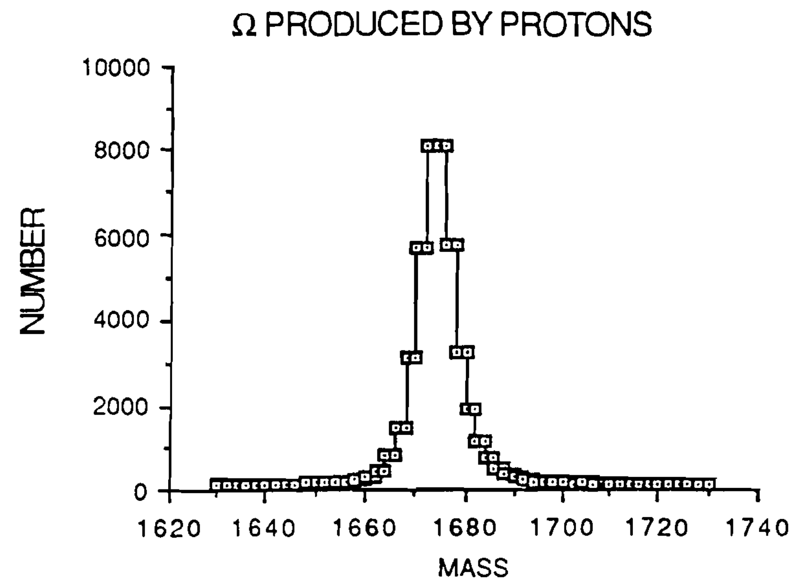


FIGURE 6. Reconstructed mass of detected ΛK^- showing the Ωs produced by protons.

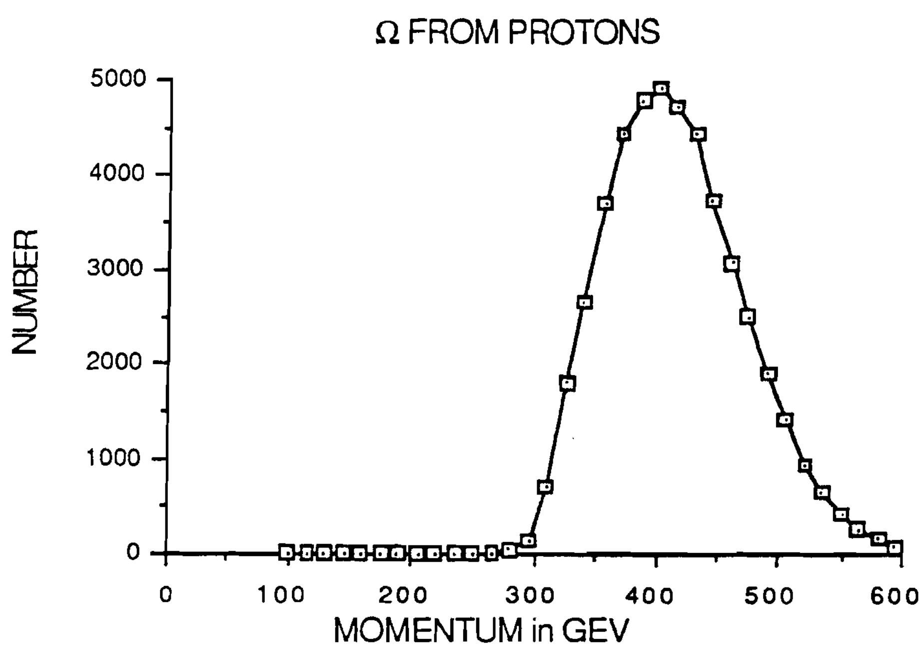


FIGURE 7. Momentum spectrum of Ωs produced by protons and detected by the apparatus.

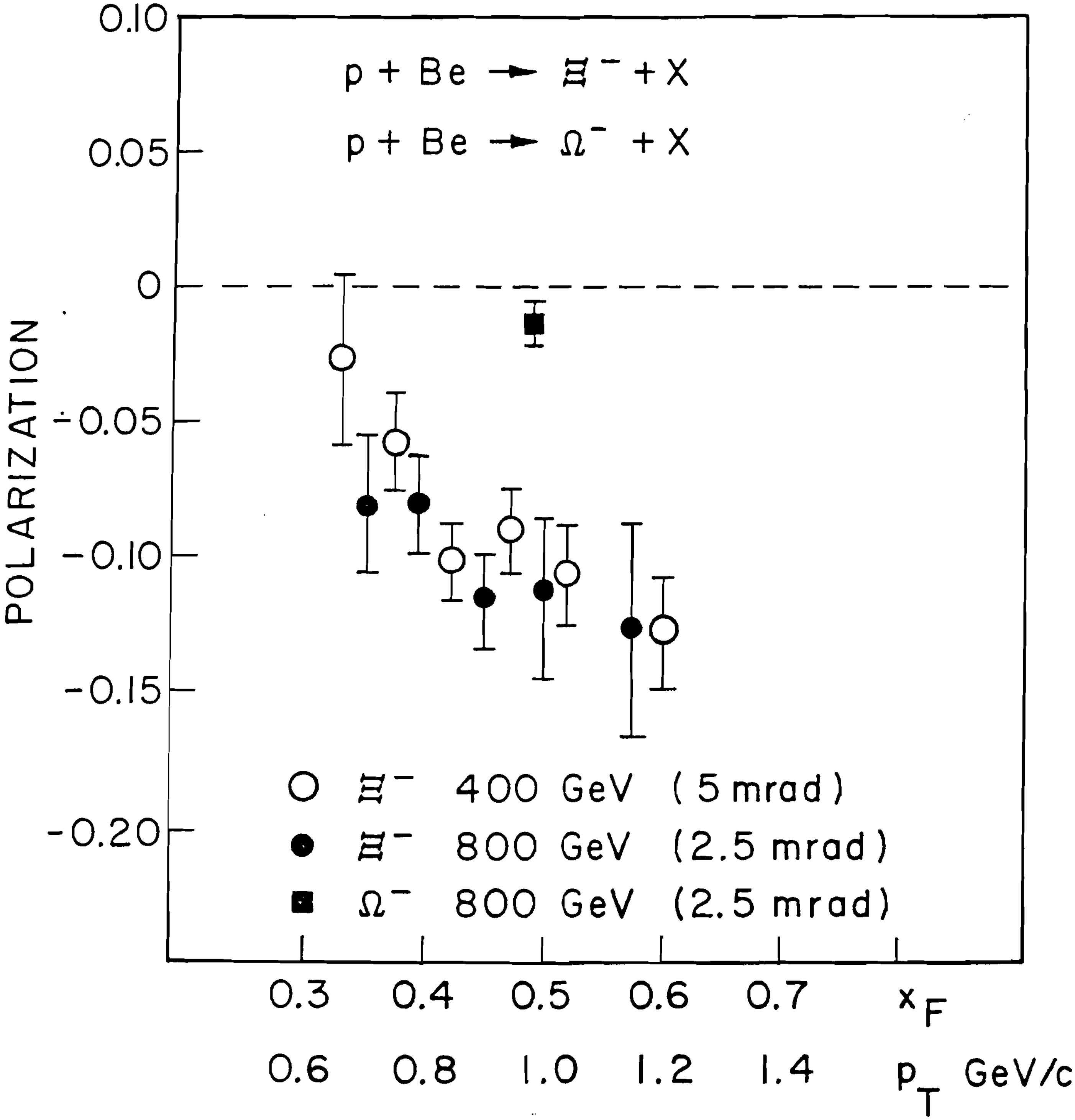


FIGURE 8. Polarization of Ξ^- and Ω produced by protons in E756 compared with previous 400 GeV results.

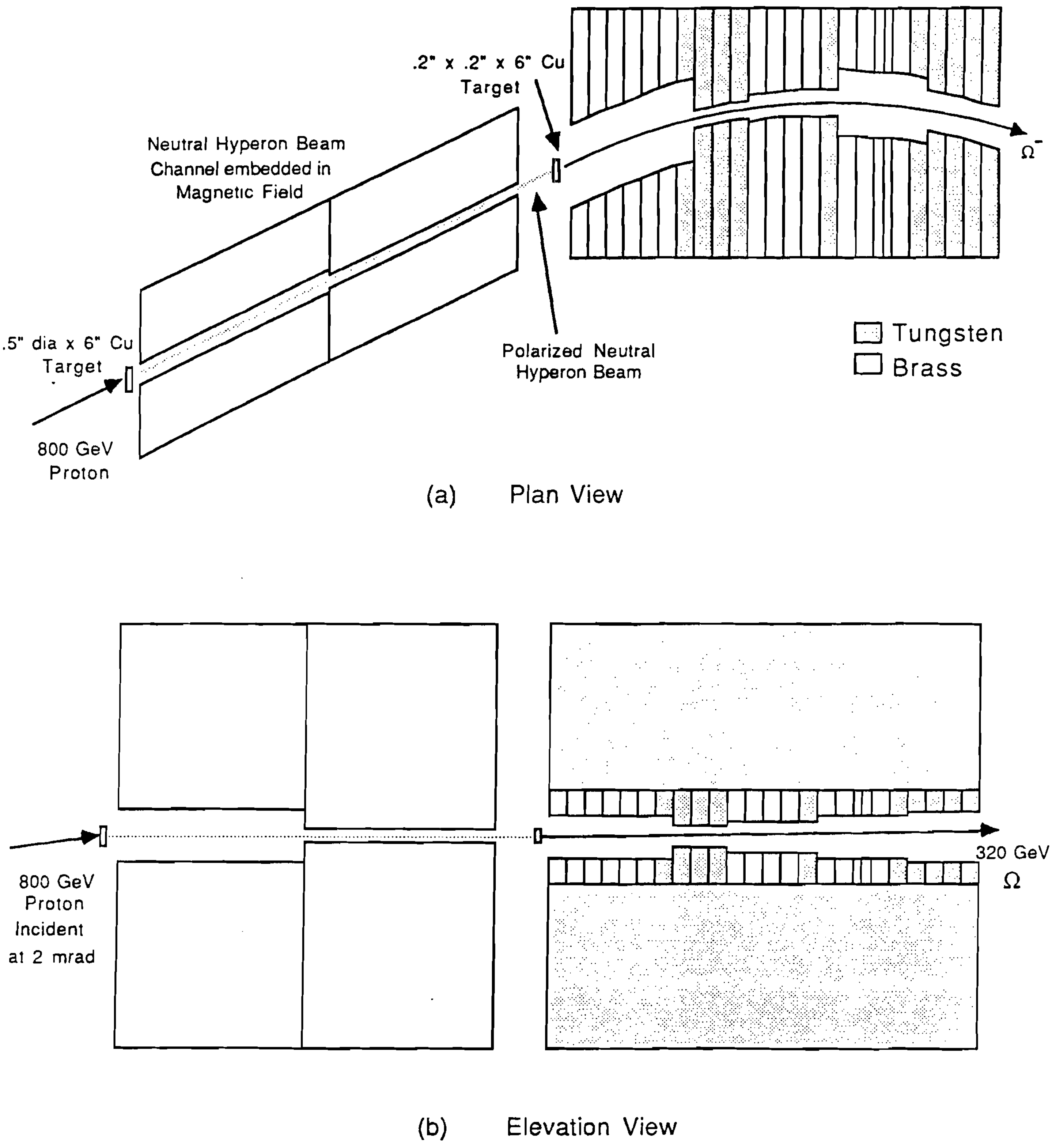


FIGURE 9. Upstream target area of E756 for producing a tertiary negative beam from a secondary neutral beam. The two targets and the neutral and charged collimators are shown.

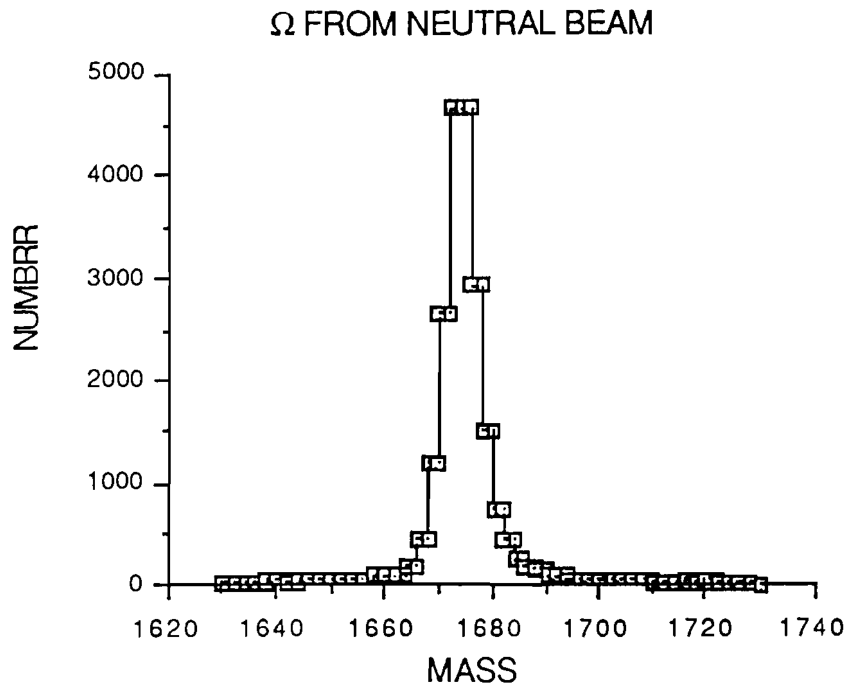


FIGURE 10. Reconstructed mass of detected ΛK^- showing the Ωs produced by the neutral beam.

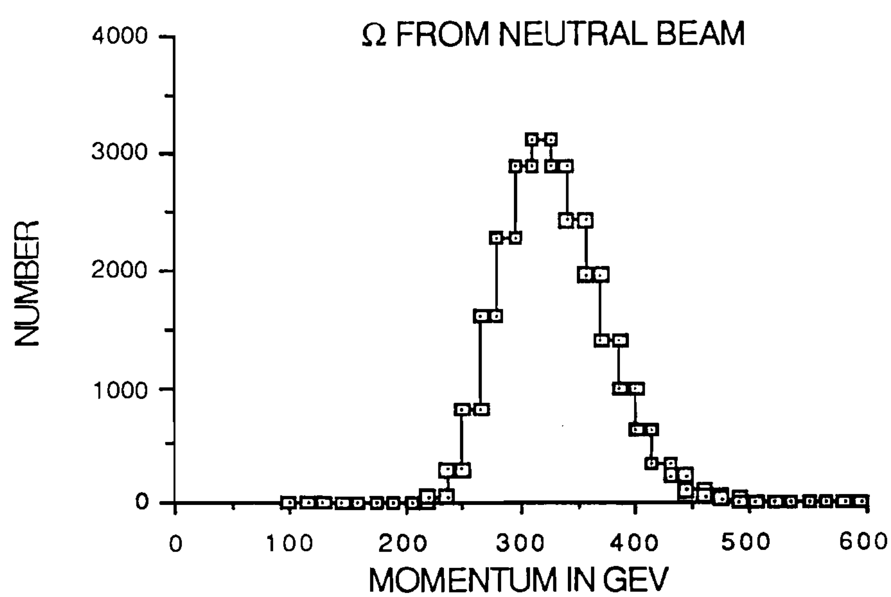


FIGURE 11. Momentum spectrum of Ωs produced by the neutral beam and detected by the apparatus.

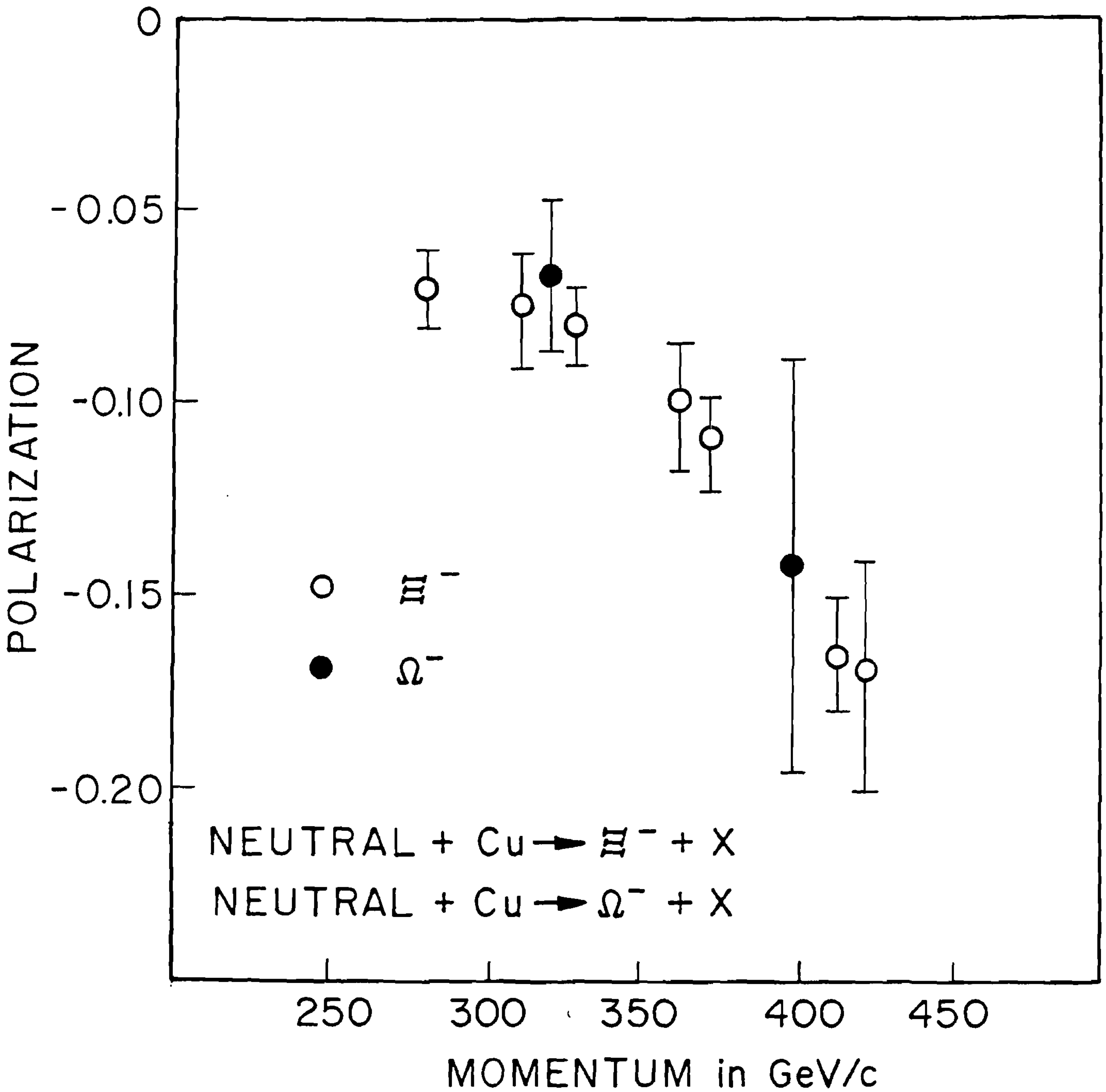


FIGURE 12. Polarization due to spin transfer of the Ξ^-s and Ωs produced by the neutral beam at 0 mrad.