HIGH SENSITIVITY SEARCH FOR MULTI-MUON EVENTS PRODUCED BY 225 GEV HADRONS*

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As a part of a program undertaken at Fermilab to study the detailed production of dimuons by hadron beams incident on nuclear targets, we have performed a sensitive search for additional muons accompanying the dimuon. Such additional muons are predicted to accompany J production in models incorporating associated charmed particle production. The apparatus and data analysis have been described previously[1]. In this paper we discuss the additional requirements imposed on the data to ensure a clean multi-muon sample. The results were obtained with a 225 GeV positive beam, and carbon and tin targets. A more detailed description of the experiment is given in another contribution to the conference[2].

In a total sample of 670,000 dimuon events we start with 4877 multi-muon candidates. These are events having three or more tracks downstream of the cyclotron magnet, all of which point to struck scintillation counters in a large hodoscope placed behind 2.5 meters of steel. An additional 2.2 meters of iron close to the target absorbs hadrons before a significant fraction can decay. However, some hadrons do penetrate it, and if their tracks point to the same scintillator as does a genuine muon in a dimuon event, they fake a multi-muon event. To reject such background, we demand that each track point to a separate struck scintillator. This requirement, which rejects only 3% of real multi-muons, removes 635 of the candidates.

Another source of trigger background, dimuon events accompanied by a muon in the halo of the beam, are eliminated by requiring that all muons reconstruct to vertices within 12.5 cm transverse to the beam. Figure 1a shows the vertex distributions, of the dimuon events, to indicate that this cut removes a negligible number of good events. We also require that all three muons have a satisfactory vertex -- figure 1b shows the distribution of χ^2 for the trimuon events. Finally, we further suppress possible halo contamination by rejecting all events having any muon with a momentum greater than 100 GeV/c. In summary, all these cuts remove less than 5% of multi-muon events originating in the target, but reduce the sample of candidates to 1312 events. It is important to note that the effects of the cuts on the multi-muon signal are determined from the observed properties of the dimuon data, not from computer simulations.

The remaining events are summarized in Table 1. There are no events with more than 4 muons. The charge ratio of the trimuons, $\frac{N_{+-+}}{N_{+--}}$, is 1.5, slightly larger than the 1.4 expected if the third muon is always the product of a pi decay.

Figure 2 is a plot of the invariant mass of all opposite sign pairs. Except for two J events there are none with masses greater than 2.2 GeV. In the corresponding dimuon sample there are 1666 J events. Both $2/1666 \approx 1 \times 10^{-3}$ and $1312/670{,}000 \approx 2 \times 10^{-3}$ are consistent with the expected pi decay contamination of 2×10^{-3}. We thus conclude that we see no evidence at this level for the production of extra muons in conjunction with either low mass or high mass pairs.

The computation of cross section limits is made simple by the fact that the only losses of single muons in the forward hemisphere are due to the 8 GeV range requirement imposed by the iron muon identifiers and the 100 GeV cut imposed in the analysis (see Fig. 3). The former eliminates an elliptical segment in the $x_f - p_T$ plane with intercepts at Feynman $x_F = .035$ and $p_T = 740$ Mev/c. The latter eliminates muons with $x_F > .43$. Within these boundaries our acceptance is unity and the cross section limit for J events accompanied by an extra muon is

$$\frac{\sigma(J + \mu)}{\sigma(J)} < 2.5 \times 10^{-3}$$

with 90% confidence. This result rules out, for example, pair production of J's to a limit of 3.5%, within the virtually complete acceptance for detecting at least one of the 2 muons from the second J. Associated production of charmed mesons with muonic decays is similarly at a level of less than

$$\frac{2.5 \times 10^{-3}}{BR(\text{Meson} \to \mu)}.$$

Absolute cross-section limits are obtained by using the J-production cross-sections of Ref. 2. We have, for the J in the forward hemisphere ($x_F > 0$)

$$B\sigma\left[(J \to \mu\mu) + \text{extra } \mu\right] < 2 \times 10^{-35}\ \text{cm}^2/\text{nucleon}\ (\pi^+\ \text{induced})$$
$$< 1 \times 10^{-35}\ \text{cm}^2/\text{nucleon}\ (p\ \text{induced})$$

Finally, for μ's accompanying all lower mass dimuons, the limit is 2×10^{-3} of the total dimuon production cross-section.

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Table I

Charge Distribution of Multi-Muon Events.

		Total Charge			
		-1	0	1	2
Proton Induced:					
	3 muons:	310		508	
	4 muons:		4		1
Pion Induced:					
	3 muons:	157		209	
	4 muons:		1		0

Figure Captions

Figure 1 a) Distribution of radius of event vertex from beam axis of all dimuon events from the sample of reference 2.

b) Distribution of χ^2 for trimuon vertices.

Figure 2 Invariant-Mass Distribution of all $\mu^+ \mu^-$ pairs accompanied by a third muon (all cuts have been applied).

Figure 3 Range of acceptance for a third muon accompanying a dimuon. Inside the cuts, the acceptance is virtually complete. The muons accompanying the two J events are shown by circles.

REFERENCES

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† Enrico Fermi post-doctoral fellow.

‡ A. P. Sloan fellow.

1. K. J. Anderson, et al., PRL 36, 237 (1976).
2. K. J. Anderson, et al., Production of the J(3.1) and $\Psi'(3.7)$ in 225 GeV Collisions of π^+, π^-, and protons with nuclei, paper submitted to this conference.

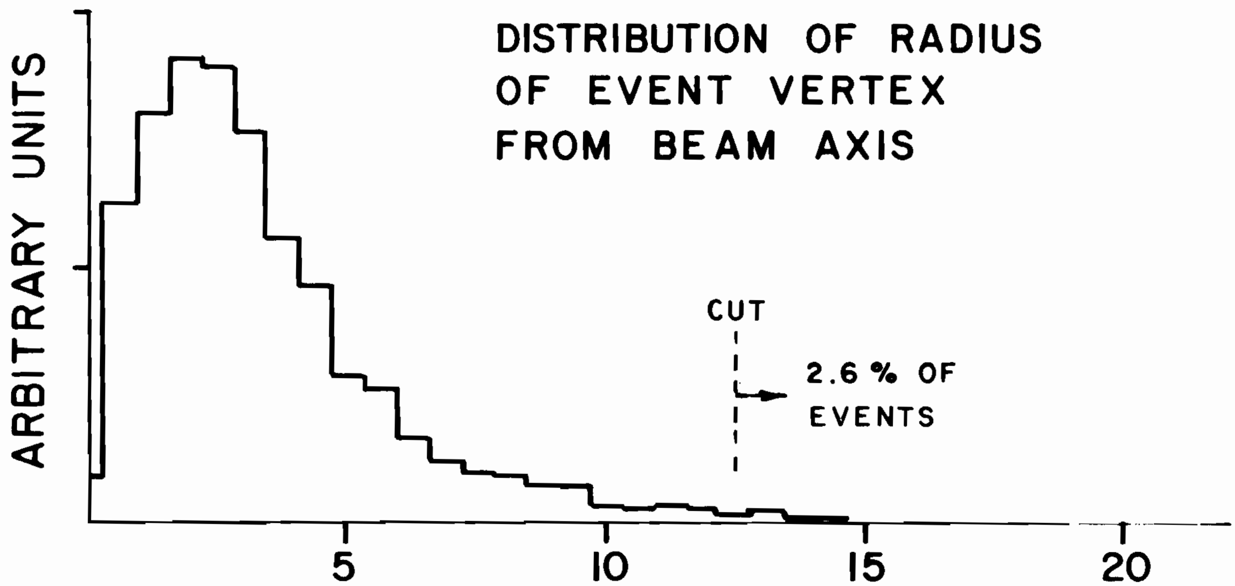


FIGURE 1 a

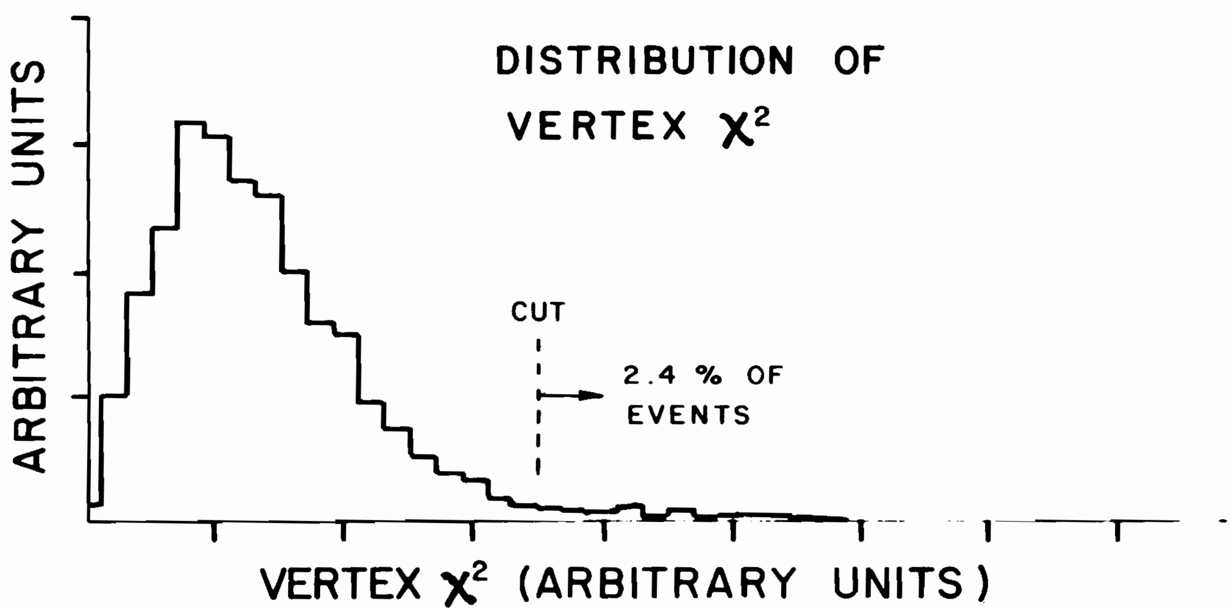
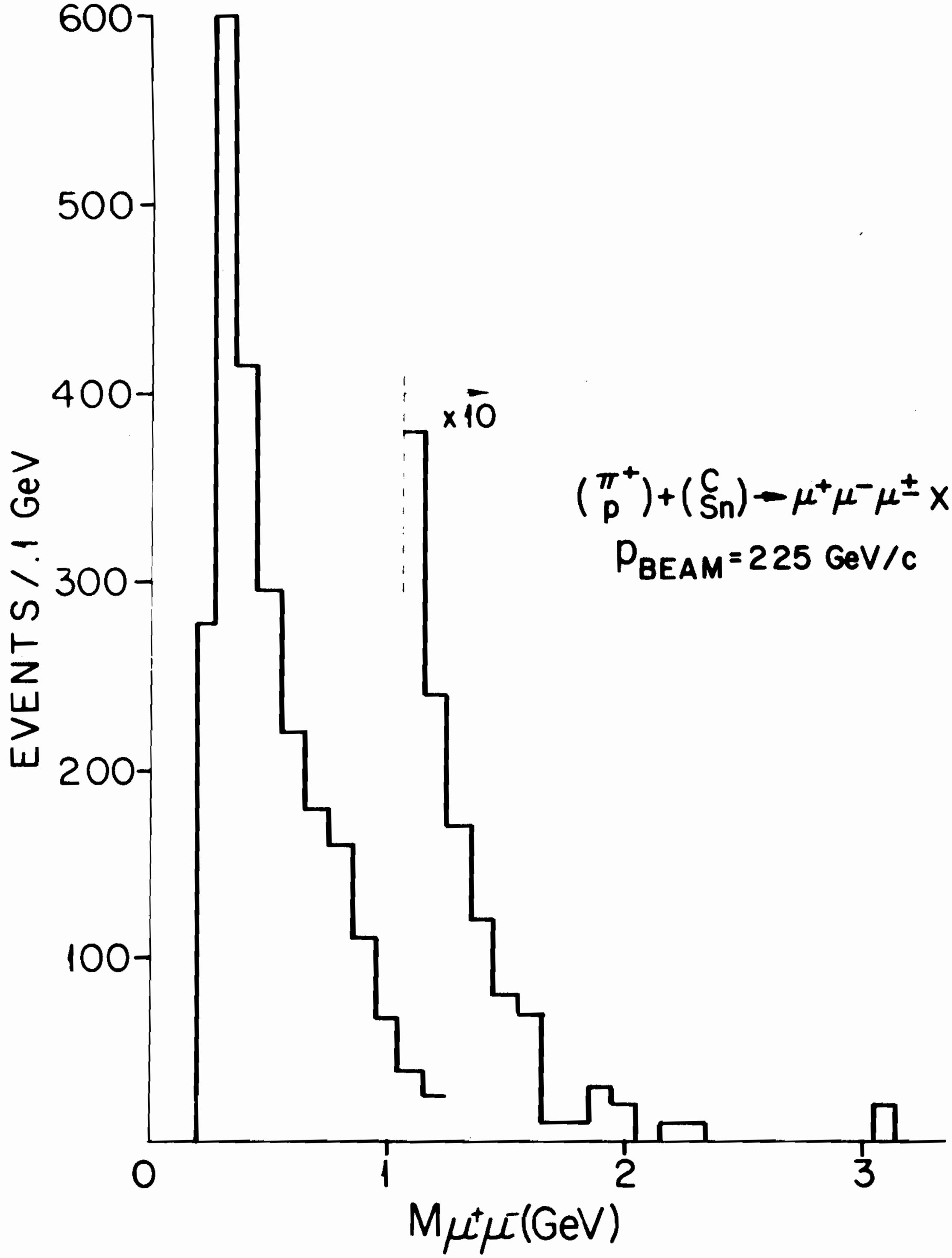


FIGURE 1 b



600
500
400
300
200
100
0
1
2
3
EVENTS/.1 GeV
x10
(π^+, p) + (C, Sn) → $\mu^+\mu^-\mu^\pm$ X
p_{BEAM} = 225 GeV/c
$M_{\mu^+\mu^-}$ (GeV)

FIGURE 2

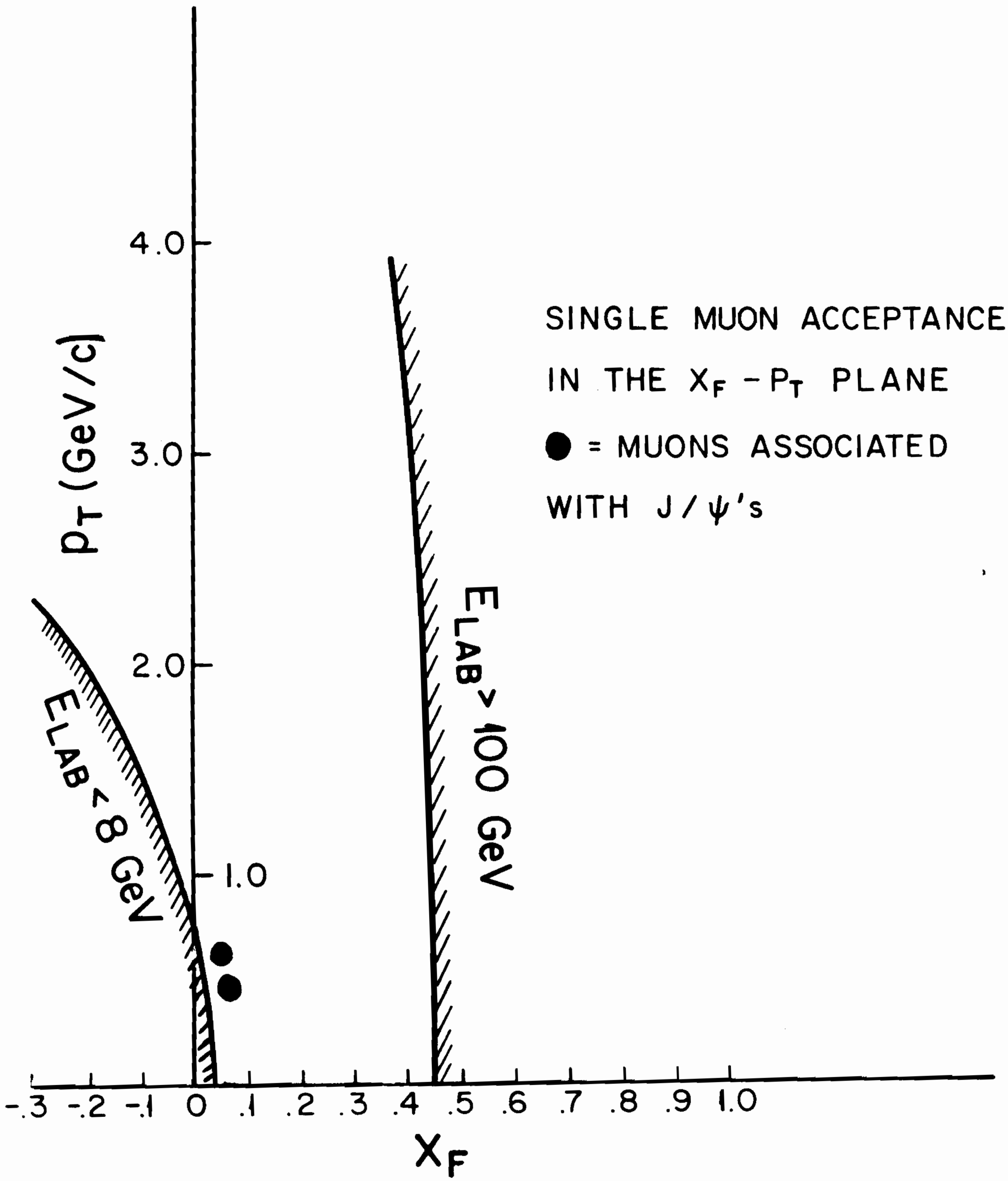

SINGLE MUON ACCEPTANCE
IN THE XF - PT PLANE
● = MUONS ASSOCIATED
WITH J/ψ's
pT (GeV/c)
4.0
3.0
2.0
1.0
ELAB < 8 GeV
ELAB > 100 GeV
-.3 -.2 -.1 0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0
XF

FIGURE 3