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E-613 Memo UM-74
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Proposal for Further Beam Dump Neutrino Running

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Summary

We propose that we run the E613 detector during the probable 1983 running period. We request an extension of 1000 hours of beam time. If the proton energy at that time is 400 GeV (e.g. prior to Doubler operation) we may request some time at a lower energy (perhaps 300 GeV) as indicated below. If the standard energy is greater than 400 GeV (e.g. the doubler is operating) we request all of our running at that standard energy.

The original approval for E613 was for 1000 hours; we received about 500 hours in our 1981 run, and expect to run for about 500 hours in the 1982 run, scheduled to begin in March.

On December 4, 1981 we wrote the PAC to request that the E613 detector be included in the Tevatron plans. Table I, taken from that document, indicated further running plans. It is abundantly clear that the spring 1982 run of a little over 6 weeks will only begin to explore that physics. The program summarized in Table I requires a total of about 2.0×10^{18} protons. At an average of 10^{13} protons/minute and 100 hours running per week this corresponds to about 30 weeks. In 1982 we will do some A dependence studies and some normal tungsten running but not enough to get our desired statistics on ν_e/ν_μ fluxes as a function of energy and angle.

I. ν_e/ν_μ Ratio

The preliminary results from our Spring 1981 run are tantalizing. We obtain

$$R = \nu_e \text{ flux}/\nu_\mu \text{ flux} = .64 \pm .16.$$

If this ratio is in fact less than one it is a very important result, an apparent violation of μ-e universality.

This measurement is based on subtracting the expected neutral current (nc) events from our 0μ sample and does not depend on our ability to separate ν_e charged current events (cc) from nc events. From our analysis to date we believe we can separate out a sample which is 83% pure ν_e and $\overline{\nu}_e$ cc events and which includes 81% of all such cc events. We are pursuing a measure of R using this separation which is then independent of the nc/cc ratio for electron neutrinos. Comparison of the two methods will allow us to measure the nc/cc ratio for ν_e.

Figure 1 shows results of the various beam dump experiments which have reported values for R. It is beginning to be disturbing that all of these results are less than one. Our Spring 1982 run should provide us with sufficient data to be statistically more certain and to provide some crucial checks of our procedure.

However, if this effect is real, the dependence on neutrino energy and angle will be quite important. If, for example, the effect is due to neutrino oscillations then examining the energy dependence of R will be critical. If the excess of ν_μ is due to some unanticipated production mechanism for ν_μ, the dependence of R on p_T may well be critical. Because of our broad angular acceptance we are a unique facility for examining this question. We will need further running to be able to subdivide the data into energy and transverse momentum bins in each of which we can examine this ratio.

II. Energy Excitation Curve for Prompt Neutrino Production

We propose measuring the dependence of the prompt neutrino cross section on incident proton energy. This dependence is a matter of considerable interest. For central $D\overline{D}$ charm production this dependence is expected to be[1] as shown in Figure 2. (The absolute prediction is low by about a fact of 3.5 at 400 GeV). Given that our measured $D\overline{D}$ cross section is about 25 μb at 400 GeV this would predict a cross-section of 110 μb at the ISR energy of $\sqrt{s}$ = 62 (GeV). However, several ISR groups obtain cross-sections between one fourth to several millibarns at this energy. Figure 3 (from F. Muller[2]) summarizes the experimental situation at high energy.

It has been proposed by Brodsky et al[3], Barger et al[4], Margolis[5] and others that diffractive production ($\Lambda_c\overline{D}$) might play a role in prompt neutrino production. At present energies our experiment and the Caltech-Rochester

experiment (Fig. 3) find no evidence for diffractive production. Based on the observed neutrino energy spectrum we can only set upper limits on it which are far smaller than the central production at 400 GeV.

Thus the mechanism for the strong increase of charm production with energy, if real at all, is uncertain. It could correspond to a threshold effect for production of some new states, a very exciting possibility. Note also that higher energies allows us to examine even higher p_T values.

When examining the energy dependence in the E613 apparatus, our rate increases with energy both because of the assumed increase in cross section and because of the increase in apparatus acceptance. This is illustrated in Figure 4. We have examined the question of whether the change of acceptance depends strongly on the form of the cross section. We have parameterized the D-pair production as:

$$E \frac{d^3\sigma}{dp^3}\Big|_{D\bar{D}} = (1-|x|)^n \, e^{-ap_\perp}$$

with standard values of n=3, a=2. We find that changing n to 4 or a to 3 cause a change in the ratio of acceptance at 600 GeV to that at 400 GeV of less than 5%.

Because the observed rate increases very steeply with energy we would clearly prefer to examine energy dependence at higher rather than lower energies. We note that at 900 GeV the rate in our apparatus per proton is a factor of 7.5 greater than at 400 GeV for central $D\bar{D}^\circ$ production if the Leveille energy dependence given in Figure 1 is correct. Note that the operation above 400 GeV requires an upgrading of M2 beam line bending magnets, as detailed below. The lowest practical energy for us is probably 300 GeV for which the observed rate would be 40% of the rates at 400 GeV. To minimize

systematic effects, we believe it is important to run at two or more energies with the same setup.

III. B Decay Neutrinos

As a note for the future if we can obtain 10000 prompt ν events at 1000 GeV ($\sim 2\times10^{17}$ protons on target) then we expect about 100 neutrinos from B decay. These would have a much broader $p_\perp$ distribution than we have now and should be distinguishable.

Consequences to the Program

If the Tevatron is delayed and a running period is scheduled for 1983 using the existing 400 GeV accelerator, we request that the first portion of our extended run should be during this period. In this case we may request that a fraction of the run be at 300 GeV.

If the first running following the current 1982 winter-spring period is with the Tevatron then we request that our run be at the Tevatron energy: 500 to 1000 GeV. If the Tevatron runs for a period at each of several energies as it slowly works up toward 1000 GeV, it would be ideal for us.

In order to run at energies significantly above 400 GeV the M2 beam would require upgrading at least the second bend with superconducting dipoles and possibly with either additional conventional quadrupoles or superconducting quads. (There are two 25 mr bends in the M2 beam line.)

The operation of E613 would require either alternating running with E605 or implementing an M1-M2 split.

The alternative to this proposal is an early completion of the prompt neutrino beam dump and experimental facilities in the Neutrino Area. As this dump is still being designed and must be perfected to accommodate the stringent demands of the bubble chambers we are not optimistic that it will be completed in time for a 1983-84 Tevatron running period. As the M2 beam must

be upgraded to Tevatron energies for any future use we look upon this upgrade as only a matter of Laboratory priorities, and not as an incremental cost.

We believe that our beam dump will be satisfactory for the higher proton energies of the Tevatron. The muon flux at our detector is dominated by lower energy muons, of less than 50 GeV. Our dump and shield may be improved through addition of a third 8 ft. dump magnet (already fabricated) and the addition of more passive shielding.

REFERENCES

1. J. Leveille, private communication, 1981.
C. Michel, Rencontre de Moriond, p. 461, 1979.

2. F. Muller, Hadroproduction of Charmed Particles, Proceedings of the IV Warsaw Symposium on Elementary Particle Physics, Kazimierz, Poland 24-31 May, 1981, p. 141-186.

3. S.J. Brodsky et al., Phys. Rev. D23, 2745 (1981), see also S.J. Brodsky paper in Proceedings of the 1981 EPS Study Conference on Truth, Beauty, and Charm, Erice.

3. V. Barger et al., Phys. Rev. D25, 112 (1982).

4. B. Margolis paper in Proceedings 1981 EPS Study Conference on Truth, Beauty and Charm, Erice.

TABLE I

	Protons on target/10^{17}	
I. Dependence of σ on A		
Cu full density target	1.5	$\Delta\sigma/\sigma$ ~13%
1/3 density target	.75	Based on a tungsten cross the difference between $A^{2/3}$ and A^1 is 40%
Be full density target	1.5	$\Delta\sigma/\sigma$ ~ 65%
1/3 density target	.75	$A^{2/3}$ vs A^1 is a 270% difference
II. Further W running at one energy		
W full density target	10	
1/3 density target	4	

a) Neutrino oscillations - This suffices to get a $\sin^2 2\alpha$ limit to about .20 (for $\Delta > 600\ (eV)^2$). This accuracy is needed if the mixing is at about the same level as the Cabibbo angle. (We are aware of a result reported by one CERN group in which a limit approaching this accuracy is quoted. In our opinion the errors quoted there are very optimistic.) We well may wish to do better than .20. The accuracy is just proportional to the square root of the exposure. Note that our region of sensitivity includes the mass range favored by the Tretyakov tritium experiment.

b) μ^-/μ^+ ratio - Important for charmed baryon production estimates. We wish to look at this as a function of neutrino angle and energy.

III. Energy Dependence of Cross-Section

Energies:	Protons on target/10^{17}	
Highest	~ .7-1.5 per energy	1.5 gives about 10% accuracy at 400 GeV
480		
300		

Note that CERN claims $\sigma(D\bar{D}) \gtrsim .25$ mb at ISR energies compared to our 25 μb at 400 GeV.

These proton estimates are based on our present rates with half of our hoped for improvement in dead time and efficiencies. They should be considered as having at least a ± 40% error.

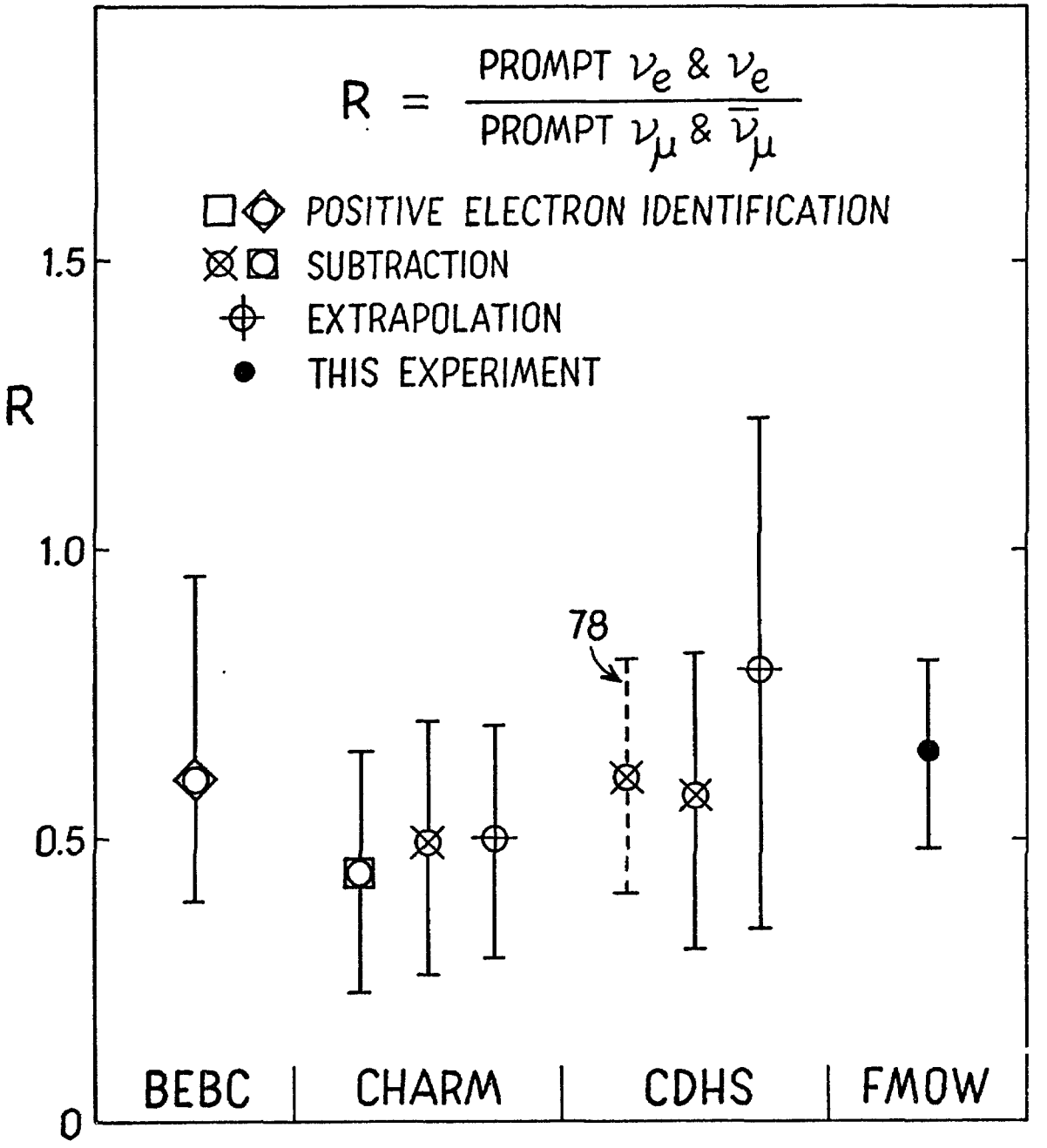

R = PROMPT ν_e & ν_e / PROMPT ν_μ & $\bar{\nu}_\mu$
POSITIVE ELECTRON IDENTIFICATION
SUBTRACTION
EXTRAPOLATION
THIS EXPERIMENT
R
1.5
1.0
0.5
0
78
BEBC
CHARM
CDHS
FMOW

Figure 1

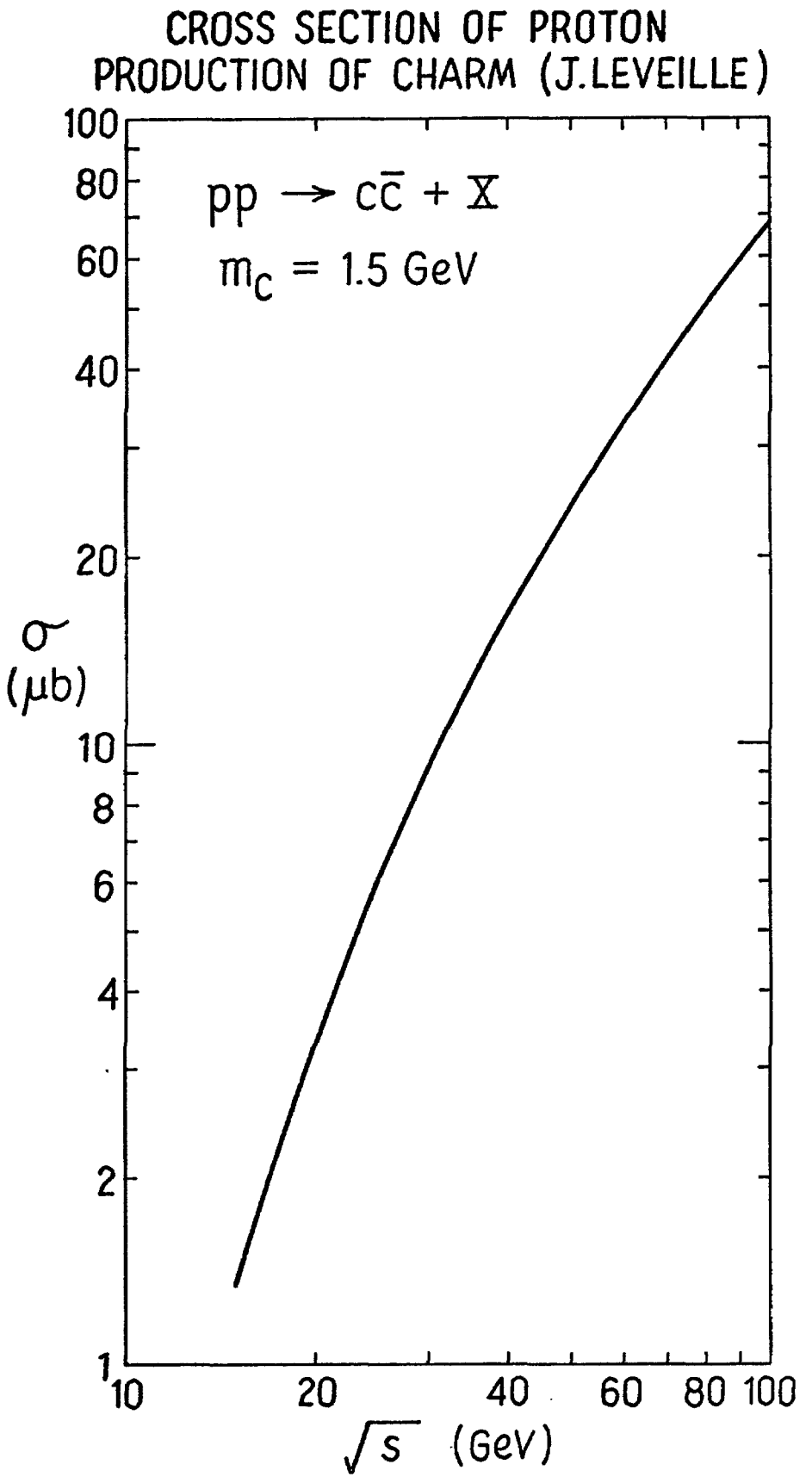
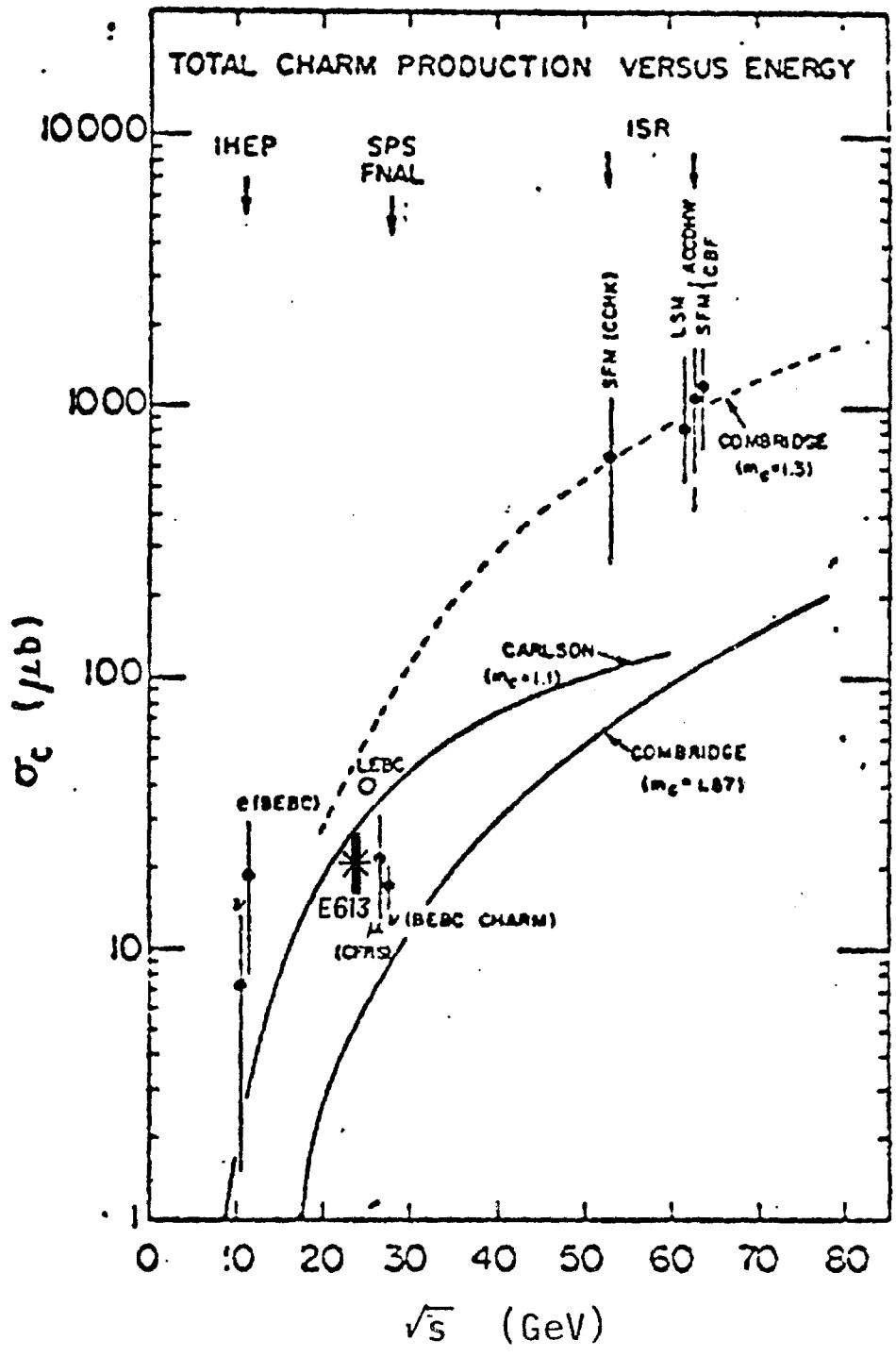

CROSS SECTION OF PROTON
PRODUCTION OF CHARM (J.LEVEILLE)
pp → cc̄ + X
m_c = 1.5 GeV
σ
(μb)
100
80
60
40
20
10
8
6
4
2
1
10
20
40
60
80
100
√s (GeV)

Figure 2



From F. Muller, Hadroproduction of Charmed Particles, p.141, Proceedings of the IV Warsaw Symposium on Elementary Particle Physics (1981)

Figure 3

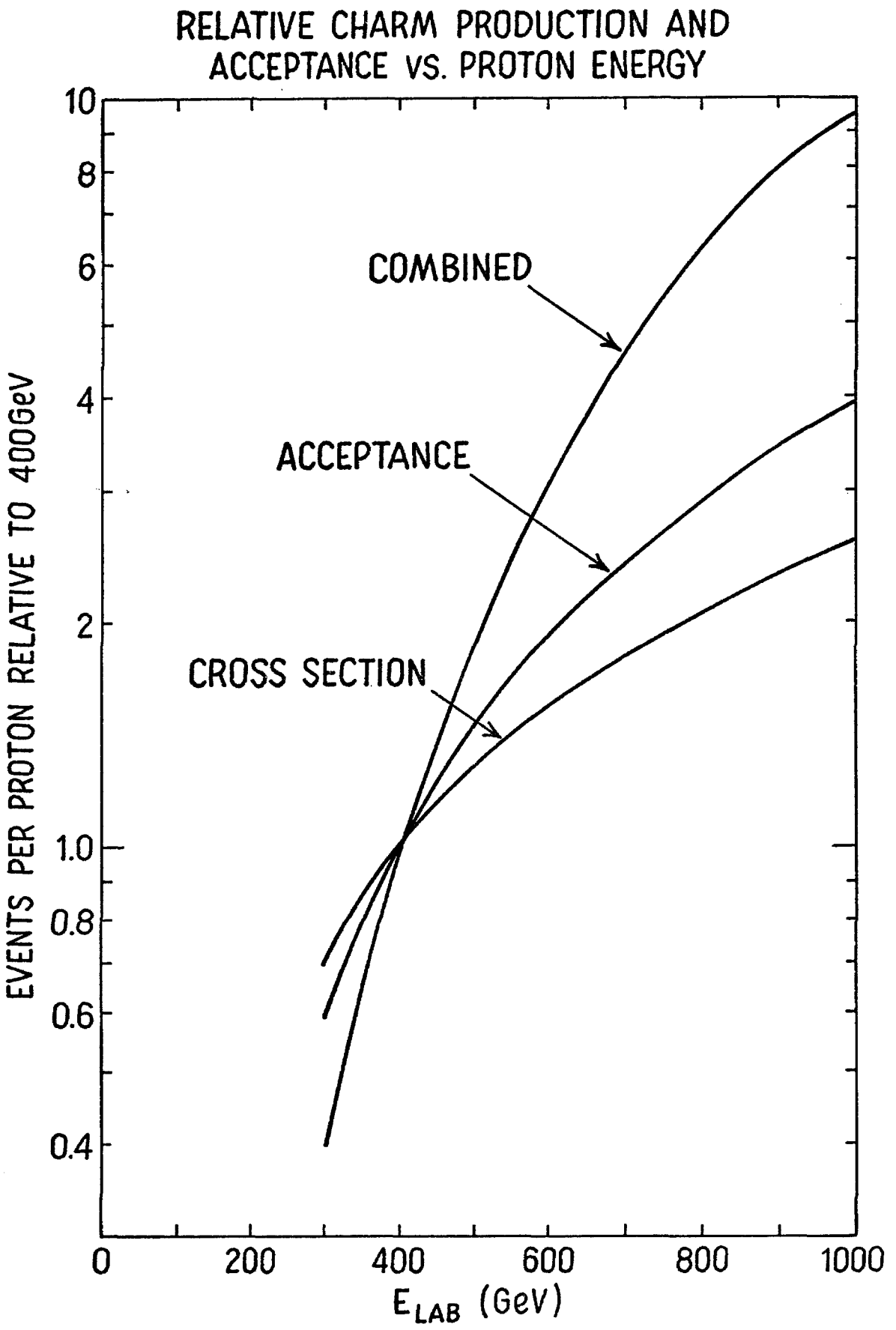

RELATIVE CHARM PRODUCTION AND
ACCEPTANCE VS. PROTON ENERGY
EVENTS PER PROTON RELATIVE TO 400GeV
10
8
6
4
2
1.0
0.8
0.6
0.4
COMBINED
ACCEPTANCE
CROSS SECTION
0
200
400
600
800
1000
E_LAB (GeV)

Figure 4