EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN/SPSC/76-3/P 58
January 14, 1976

PROPOSAL TO THE SPSC

SEARCH OF MULTIPARTICLE DECAYS OF HIGH MASS STATES PRODUCED IN ASSOCIATION WITH THE ψ (3.1 GeV)

R. BARATE,P. BAREYRE,P. BONAMY,P. BORGEAUD,J.C BRISSON,M. DAVID,J. ERNWEIN,
F.X.GENTIT,G. LAURENS,J. PASCUAL,J. POINSIGNON,A. ROUSSARIE,H. ROUSSARIE,G. VILLET

C.E.N. SACLAY

B.BRABSON,R.CRITTENDEN,R.HEINZ,J.KRIDER ,

INDIANA UNIVERSITY. BLOOMINGTON USA

Contactman: P. Borgeaud

INTRODUCTION

The discovery of the long lived neutral mesons ψ at 3.1 and 3.7 GeV and the rather satisfactory width predictions by the charmonium model suggest a search for charmed mesons and baryons. The small cross section for the associated production of charmed particles, the predicted steep rise of those cross sections with energy, and the predictions about their multiparticle decays require experiments able to handle high incident fluxes, with a large acceptance for many-particle final states.

Eight months ago CERN asked us to study the ability of our apparatus for charm search. Following the seminar given at CERN on April 4th 1975, we wrote a note with our first ideas and calculations. The results of FNAL experiments give us the feeling that the Goliath magnet and its MWPC detectors, in the high energy, high intensity H_3 beam, is well suited for a charm-search experiment.

PHYSICS MOTIVATIONS

We think that the physic motivation for pursuing the discovery of charmed particles does not require a big discussion.

Let us assume the validity of the Zweig rule and let us consider the ψ as a c $\bar{c}$ bound state ; then at sufficiently high energy, reactions with ψ production should be associated with charmed particles. So the ψ production is a gate for charmed hadron experiments. Requiring charmed hadrons to be produced in association with a ψ , reduces the cross section but creates a fantastic increase in signal to noise ratio. Since the charmed particles are presumed [1] to have rather large masses (2 - 2.5 GeV for baryons), the production of these particles in conjunction with the ψ is kinematically depressed at low energies. This depletion could explain the large increase of the inclusive ψ cross section between the SLAC/BNL [2] [3] low energy experiments and the FNAL/ISR [4] [5] high energy experiments. The increase is of two orders of magnitude.

This large increase is also observed in ψ photoproduction experiments [6] . In a recent paper D. SIVERS [7] points out that the interpretation of the ψ particle as a c $\bar{c}$ bound state and the related dynamical rules which suppress their decays into ordinary hadrons imply a mechanism for strong production of charmed hadrons in conjunction with the ψ'. Further calculations [8] with charmed particles suggest that our energy of 150 GeV/c ($\sqrt{s}$ = 18 GeV) is sufficient to ensure that the production of ψ in conjunction with charmed pairs dominates the production of ψ alone (figure 1). Applied to the Υ production the same type of calculation (figure 2) is not in disagreement with the recent experiment of BLOBEL et al[9]. Running at higher energies would give a somewhat better trigger rate but would involve greater experimental difficulties, as the multiplicity increases and the forward particle identification becomes doubtful. Anyway, whether charmed particles exist or not, the hadronic final states produced in association with the ψ seem very interesting, and our apparatus is able to study and measure the distribution of such particles.

BEAM

We intend to use a π^- beam, more favorable than a proton beam for ψ production. The maximum yield of the H_3 beam is 1.3×10^7 π^-/burst with a $\frac{\Delta P}{P} = 0.4$ % at 150 GeV/c maximum momentum, it will remain until 1978 the highest one in Europe.

APPARATUS

The scheme of the proposed lay-out for this experiment is shown on figure 3. It is essentially composed of the same pieces as the one designed for the WA 5 experiment, with the addition of three scintillator hodoscopes, for the detection of two muons and some anticounters.

The apparatus is composed of a wide angle vertex spectrometer (Goliath) for the detection of the recoil particles and of a forward spectrometer composed of two pairs of conjugated arms for the detection of the ψ decay muons.

Goliath has a gap of 1.05 m and the diameter of its poles is 2 m. The field at half power (2MW) is 1.6 T, which gives a bending power of 3.6Tm. We put a 1 m long hydrogen target immediately at the entrance of the magnet. Just downstream of the target we have successively :

-H_3 and PC_1 : 608 x 224 mm^2, 1 mm wire spacing MWPC with 3 wire planes.

The rest of the magnet is filled with seven big modules of MWPC :
CPK 1 to 7 : 750 x 1800 mm^2 , 2 mm wire spacing and 4 wire planes.

The forward spectrometer is equipped with the same large modules, two at the exit of Goliath, and four at a distance of 5 m from the target, defining the two double arms : up right and down left, up left and down right.

The read-out of the MWPC is made according to the CAMAC conventions. For each plane the MWPC can be used as hodoscopes of 3.2 cm strips in the trigger.

Downstream of Goliath, we will put a multicellular Cerenkov counter filled with Nitrogen at atmospheric pressure, for pion identification.

The muon detector has a total thickness of 2.5 m of iron. It is composed of three scintillator hodoscopes. The front and intermediate hodoscopes have horizontal strips, the back hodoscope has crossed strips.

Except for this last part, each piece of the apparatus described in this paragraph exists and is tested.

A PDP 11-45 insures the data acquisition. It has a memory of 32 K, 2 tape units and a direct memory access for the chambers read-out which means that the CAMAC is able to work at its maximum speed.

Assuming 500 words per event, we can store at most 50 events per burst; an increase of the size of the memory buffer would allow more events per burst.

TRIGGER

The basic idea of the trigger is to use the fact that for $x \simeq 0$ and symmetric decay, the mass of the decaying object is proportional to the transverse momentum $P_\perp$. The selection of large $P_\perp$ can be done in two steps:

a) Selection of a large angle between the 2 muons in the vertical plane (not affected by the magnetic field). This is feasible and is due to the large vertical aperture of Goliath (260 mrd). This insures that the ratio $P_\perp / P_L$ is large.

b) Selection of a large longitudinal momentum for the two μ's, which, in conjunction with a), insures that $P_\perp$ is large.

A minimum threshold for these longitudinal momenta is already given by the bending power which sweeps out of the two double arms the low momenta particles.

The trigger on ψ will require simultaneously
- one μ in one of the two double arms,
- a second μ in the conjugate arm which is diagonally opposite (cf. figure 3),

this insures opposite charges for the two muons. Around the median plane the gap in the vertical plane between two arms insures the fulfilment of a), the magnetic field of Goliath, the fulfilment of b). The gap will be adjustable and a compromise will be found experimentally between ψ signal and background ·

All acceptance and background calculations in the next paragraphs are done with a gap of 40 cm and no matrix correlation . It will be shown that this very simple trigger is already selective, cutting low masses and high values of x (cf. Fig. 4a and 5a).

If it appears that time, manpower and money allow it, we will complete our apparatus with simple $e^\pm$ calorimeters, built for identification but not for energy measurement. Triggering also on e^+e^- pairs would double our number of good events and give us access to very interesting final states composed of 3 or more leptons. As observed at SPEAR[16] muons and electrons seems to be produced in association. Named HE on figure 3, those calorimeters are iron-plexipop scintillator sandwiches. Other electron detectors (E_1 E_2 E_3) are disposed in the magnet to veto asymmetric Dalitz pairs and π^o.

ACCEPTANCE

To get our acceptance on the ψ, we have generated dimuon events according to the following distribution :

... / 5.

$x_L(\psi)_{CM}$ flat between -0.6 and +0.6 (1) $x_L = \frac{2 P_L^*(\psi)}{\sqrt{s}}$

according to e^{-5x_L} outside

$P_\perp^2(\psi)$ according to $e^{-P_\perp^2}$ (2)

The choices are a good approximation of the recent results of PILCHER et al [10] (see Fig. 5b and 6b).

To get an idea on our selectivity on the dimuon mass, we have also generated events with a flat distribution in the dimuon mass, other parameters of the distribution being identical with (1), (2). The result is shown on figure 4a. We see the strong rejection of the low lepton-lepto masses, specially in the ρ vicinity. The necessity of such a rejection is clearly shown in the $\mu\mu$ mass spectrum of ANTIPOV et al (figure 4b).

The result is a global acceptance for the ψ of 9.0 %, with a gap of 40 cm. The acceptance as a function of $x_L(\psi)$ is shown on figure 5a. On figures 4a, 5a, 6a, the three curves correspond to different values of the gap (30, 40, 60 cm).

Comparing our acceptance curves (Fig. 5a and 6a) with the corresponding experiment distributions (Fig. 5b and 6b) we see that maximum acceptance is provided in the range of $P_\perp^2$ and x_L where ψ production is also maximum.

SENSITIVITY

In a beam dump experiment PILCHER et al have measured the cross section for ψ production in the range :

$$0.05 \leqslant x_L \leqslant 1$$

$$0. \leqslant P_\perp^2 \leqslant 4 \text{ GeV}^2$$

In this range of phase space and for π^+'s of 150 GeV/c, they got a cross-section (including the branching ratio into 2 μ) of 3.2 ± 0.7 nb per nucleon. Assuming a linear A dependence to convert from cross section per nucleus to cross section per nucleon. Assuming the classical $A^{2/3}$ dependence would lead to 6.7nb. In the following calculations we shall use the pessimistic one (3.2nb).

There is a large incertainty in getting the total cross section from these measurements made in a limited phase space but it is a priori reasonable to assume, in the central x_L region, symmetry between positive and negative x values. For this reason we assume a total cross-section of 6.4 nbarn. With a target of 100 cm H_2, 10^7 incident π^-, the luminosity is :

$$100 \times 10^7 \times 0.071 \times 6 \times 10^{23} = 4.10^{31}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$$

Combining this luminosity with acceptance and taking 450 burst/hour we get :

$$4 \times 10^{31} \times 0.09 \times 450 \times 10^{-33} = 1.6\ \mathrm{ev/nb/\ hour.}$$

With a cross section of 6.4 nb/nucleon this yields to 0.023 ψ events per burst. Taking into account a security factor of 0.5 we end with :

1.6x6.4x0.5x24 = 123 Ψ events each day.

RESOLUTION ON THE Ψ MASS

Using a high energy approximation the dimuon mass near $x = 0$ is given as a function of the decay particles momenta and angle by

$$M^2_{\mu\mu} \simeq 2\ p_+\ p_-\ (1 - \cos\theta)$$

for a symmetric disintegration $p_+ = p_- = p$,

$$M^2_{\mu\mu} = p^2\ \theta^2$$

This case corresponds to the maximum acceptance of our set-up.

The mass resolution is given by :

$$\frac{\Delta M}{M} = \sqrt{\left(\frac{\Delta p}{p}\right)^2 + \left(\frac{\Delta\theta}{\theta}\right)^2}$$

Using the error calculation given by KEY et al [12] corresponding to our MWPC arrangement, we get the following resolution **formula** :

$$\frac{\Delta p}{p} = \pm 1.17\ 10^{-3} \times p \qquad \text{with p in GeV/c}$$

$\Delta\theta$

This leads at 150 GeV incident momentum, in a symmetric decay of the dimuon at $x = 0$, to

$$p = 13.7 \text{ GeV/c}$$
$$\theta = 225 \text{ mr}$$

the resolutions are :

$$\frac{\Delta p}{p} = \pm 1.6 \%$$
$$\frac{\Delta \theta}{\theta} = \pm 0.5 \%$$
$$\frac{\Delta M}{M} = \pm 1.7 \%$$

BACKGROUND

In order to estimate the background, we have generated by Monte-Carlo the following distributions for inclusive pions :

(a) $P_\perp$, the transverse momentum, according to

$$e^{-6 P_\perp} \quad \text{for} \quad 0 < P_\perp < 1 \text{ GeV/c}$$
$$e^{-2.4 P_\perp} \quad \text{for} \quad P_\perp > 1 \text{ GeV/c}$$

(b) Y, the rapidity in the CM system, according to a constant distribution between Y min and Y max.

For a justification of (a), see for instance [13].

For (b), a 3 peaks distribution (one broad peak around Y = 0 and two others around Y min and Y max) would perhaps have been better, but because of the fact that the 3 regions in rapidity are not so well separated at 150 GeV/c, a flat distribution is not so bad an approximation, and is anyway pessimistic.

This Monte-Carlo gives a probability for a pion going through one of our lever arms and decaying into a μ of $2.4\ 10^{-3}$. If we assume a mean number of 6 pions per interaction, 3 positive and 3 negative, the probability that one positive (negative) pion is seen is $7.2\ 10^{-3}$. The probability that another negative (positive) pion is seen at the same time in the diagonally opposed lever arms is $(7.2\ 10^{-3}) / 2$.(*) With 6. 10^5 interactions (excluding elastic and all neutral interactions) for a burst of 10^7 π, we get :

$$6 \times 10^5 \times 7.2 \times 10^{-3} \times \frac{7.2}{2} \times 10^{-3} = 16$$

background events per burst.

We have computed the dimuon mass spectrum of those events. Figure 8 shows that the contamination is negligible above 2.5 GeV mass.

The muon filter is designed to have a low probability to confuse muons and hadrons. With 2.5 meter thickness the probability of a hadron of 10 GeV to punch through is 0 .1 %. With the previous Monte Carlo, we get a probability of 8.7 % for one pion to enter one of our lever arm. Making the same type of calculation as above, this **leads to** :

$$6 \times 10^5 \times (3 \times 0.087) \times 3 \times \frac{0.087}{2} \times 0.001 \times 0.001 = 0.025 \text{ event per burst}$$

Further discrimination is achieved by pulse height measurements in the intermediate hodoscope ; at this level, the hadronic cascade has a probability of 30 % to give more than 3 particles in which case it can be rejected. This reduces the above number to 0.01 event per burst.

Another type of background is given by the coincidence of a μ belonging to the beam halo (and not seen by the big halo veto counter which we intend to put in front of Goliath) and another μ from a π produced in the target. The probability of detecting one positive or negative pion in one of the four lever arms with the assumed multiplicity is :

$$6 \times 2.4\ 10^{-3} = 14.4 \times 10^{-3}$$

The probability of having one halo muon in one lever arm during a 20 ns coincidence time, assuming a 1 % leakage of the halo veto, is

$10^6 \times 2 \times 10^{-8} \times 0.01 = 2 \times 10^{-4}$ assuming $10^{-6}\ \mu / 2\ m^2$ sec [14]

For the 6. 10^5 interactions we get :

$$6 \times 10^5 \times 2 \times 10^{-4} \times 14.4 \times 10^{-3} = 1.8 \text{ event/burst}$$

This calculation does not take into account the fact that we will require correlations between horizontal strips, eliminating muons manifestly not coming from the target.

(*) And not $(7.2 \times 10^{-3}) / 4$ because, due to the magnetic field deviation positive (negative) pions go predominantly on right (left) part of the detector.

A third type of background is given by prompt dimuons coming from low mass vector mesons. We have done a Monte-Carlo using the mass distribution and the $P_\perp$ and P_L distribution for the $\mu\ \mu$ system as measured by KNAPP et al[4]. Estimating the cross section for ρ production at 150 GeV to be 5 mb[15], we end with a trigger rate of 0.07 events/burst.

The total expected background is roughly 18 events per burst.

FINDING CHARMED HADRONS

Having shown the relative abundance of our trigger, the acceptable rate of background, one important point remains. It is our capability of handling the very complex events associated with the ψ.

To get an idea about this question, we have generated final states of the type :

$\bar{D}\ \psi\ C$	$\bar{D}$ charmed meson,
	C charmed baryon.

The Monte-Carlo assigns to the ψ a flat and narrow x_L distribution, centered around $x = 0$. The $P_\perp$ distribution is chosen identical with the one measured by KNAPP et al[4].

The $\bar{D}$ has a $e^{-6P_\perp}$ distribution in $P_\perp$. Azimuthal angles are chosen equi-probable between 0 and 2 π for $\bar{D}$ and ψ. The value of the longitudinal momentum for the $\bar{D}$ is determined using energy conservation, choosing among the two solutions the one which sends the $\bar{D}$ forward in the center of mass.

All parameters for the C are then given by momentum conservation.

Among plenty of possibilities, some of them having simpler configurations, we then choose for the $\bar{D}$ and the C the following quite complicated cascades allowing four C fits :

$$\begin{array}{l} \bar{D} \to K^{*}\ \rho \\ \qquad\qquad \hookrightarrow \pi^+\pi^- \\ \qquad \hookrightarrow K^+\pi^- \end{array} \qquad\qquad \begin{array}{l} C \to N^{*}\ K^{*} \\ \qquad\qquad \hookrightarrow K^-\pi^+ \\ \qquad \hookrightarrow p\ \pi^- \end{array}$$

With the two μ's from the ψ, this gives 10 particles in the final state. In order that one particle may be considered as seen, we have required it to cross at least four MWPC modules. On the total number of events where ψ's are seen, we find that in 100 % of these events the four particles coming from the $\bar{D}$ are seen, while in 8 % of the events the $\bar{D}$ and C (i.e. all particles) are seen (i.e. where a four constraint fit is possible).

We have also used this Monte Carlo to reconstruct the mass of the $\bar{D}$ assuming no identification of the four particles (i.e. assuming that the four particles are pions). A broadening of the peak to 200 MeV FWHM has been seen, which indicates the usefulness of a multicellular Cerenkov. More specific triggers (for instance with Λ) are under study.

PATTERN RECOGNITION

The pattern recognition is the bottleneck of all the multiparticle detection experiments.

One must first notice that the number of events to be analyzed is highly reduced by the fact that one can reconstruct the dimuon mass using the informations of the lever arm only.

The resolution thus obtained ($\Delta M/M \simeq \pm$ 8 %) yields a background accouting for half of the observed ψ's as one can see on the measured dimuon spectrum of figure 4b. The total amount of multiparticle events to be reconstructed is under 20.000.

Presently we are performing simulations of the multiparticle events configuration, taking into account the characteristics of our set-up :

- 34 proportional wire planes in the magnetic field, tilted at 4 different angles allowing to reconstruct without ambiguity 9 points in space.
- the efficiency of the proportional chambers is independent of the multiplicity.
- very low noise level on the wires, we have measured in a test using 8 of the large chambers 1 hit per 10^3 wires per 10^4 strobes of 150 ns width.
- the good spatial resolution, for the chambers just after the vertex it is 0.3 mm.

If we compare our situation, on the pattern recognition point of view, with Ω type detectors we have the following advantages :

- efficiency nearly equal to 100 % due to the use of four planes per module : no missing point.

- We don't have to match views : the modules give points in space.
- Having few events to analyze (<20000) we can use more sophisticated (and time consuming) methods for pattern recognition (using helix and not parabola for instance). In particular we intend to do a scanning of all the events in order to
  - save the tracks not seen by the program
  - find all V_o candidates

we have, on the contrary, the following disadvantage:

- much less points per track

RUN PLANS

We require a total of 1400 hours of data taking, this would yield ~ 7000 ψ's, with a safety factor of 0.5 included. This number is computed with 40 cm gap. If the trigger rate is not prohibitive we will run with 30 cm gap or less. With 30 cm gap the ψ's number will be 10000. This data taking should be preceded by 2 test periods in order to set-up the apparatus and to adjust the trigger on the ψ with some beam dump events.

We require from CERN the 2.5 m iron filter, the power for the magnet (1.6 MW) and 60 hours of 7600 computer.

We would also like to have access to the electronic pool in case of emergency. Besides this, we would appreciate very much if a person of DD could collaborate with us for some time.

CONCLUSION

We have shown that the use of the main parts of the modular apparatus built for WA 5 experiment is very competitive in the charm search. Summarizing the main arguments in favour of this experiment are :

- a high energy beam of 150 GeV/c
- fast MWPC detectors inside and outside the magnetic field
- a flexible geometry and a selective trigger on the ψ' (we are out of the diffraction cone, and we require two leptons of opposite sign at high

REFERENCES

1 CERN BOSON WORKSHOP, CERN.TH 1964 (1974).
H. HARARI, SLAC-PUB. 1514 (1974).
N.A. TÖRNQUVIST, CERN.TH 2002 (1974).

2 J.E. AUGUSTIN et al, Phys. Rev. Letters 33, 1406 (1974).
J.E. AUGUSTIN et al, SLAC-PUB. 1520 (1975).

3 J.J. AUBERT et al, Phys. Rev. Letters 33, 1604 (1974).

4 B. KNAPP et al, Phys. Rev. Letters 34, 1044 (1975).

5 F.W. BUSSER el al, Phys. Letters, 56B, 482 (1975).

6 B. KNAPP et al, Photoproduction of narrow resonances, Fermilab preprint(1975).
D.E. ANDREWS et al, Phys. Rev. Letters, 34, 233 (1975).
J.F. MARTIN et al, Phys. Rev. Letters, 34, 288 (1975).

7 D. SIVERS, Phys. Rev. D., Vol.11 n° 11, p.3253 (1975).

8 D. SIVERS, Preprint Rutherford Lab. RL.75-171 T.142.

9 V. BLOBEL et al, Phys. Rev. Lett. 34,1118 (1975).

10 K.J. ANDERSON et al, preprint : Enrico Fermi Institute, Univ. Chicago.

11 Yu. M. ANTIPOV et al, preprint IPHE, Serpukhov.

12 KEY et al, NAL. Summer Study, Vol.3, p.177 (1969).

13 BANNER et al, Phys. Letters, 44B, 537 (1975).

14 D. PLANE, CERN Internal report, LAB.II/EA note 74-7 (1974).

15 J. DERRE et al, Internal report DPhPE 75-08 (1975).

16 M. PERL, SLAC. Lepton and Photon Conference. August 1974.

FIGURE CAPTIONS

1a) From Ref. 8 : Drell-Yan calculations of π p $\rightarrow \psi$ and π p $\rightarrow \psi D \bar{D}$

1b) From Ref. 8 : Drell-Yan calculations of $\bar{p}$ $\bar{p} \rightarrow \psi$ and p p $\rightarrow \psi D \bar{D}$

2) From Ref. 8 : Drell-Yan calculations of p p $\rightarrow \emptyset$ and p p $\longrightarrow$ K

3) Scheme of the set up.

4) a) Our acceptance vs dimuon mass for different values of the gap between the chambers at 8 m from the target.

   b) Dimuon mass spectrum measured by Yu.M. ANTIPOV et al, ref. 11.

5) a) Our acceptance vs $x_L = \dfrac{2 P_L^* (\psi)}{\sqrt{s}}$ for different values of the gap.

   b) x_L distribution measured in a beam dump experiment by ANDERSON et al, ref. 10.

6) a) Our acceptance vs $P_\perp^2$ for different values of the gap.

   b) $P_\perp^2$ distribution measured by ANDERSON et al, ref. 10.

7) Our acceptance vs the cosine of the angle of the incident π and one muon coming from ψ decay in the ψ rest frame.

8) Dimuon mass spectrum computed with muons coming from pion decays.

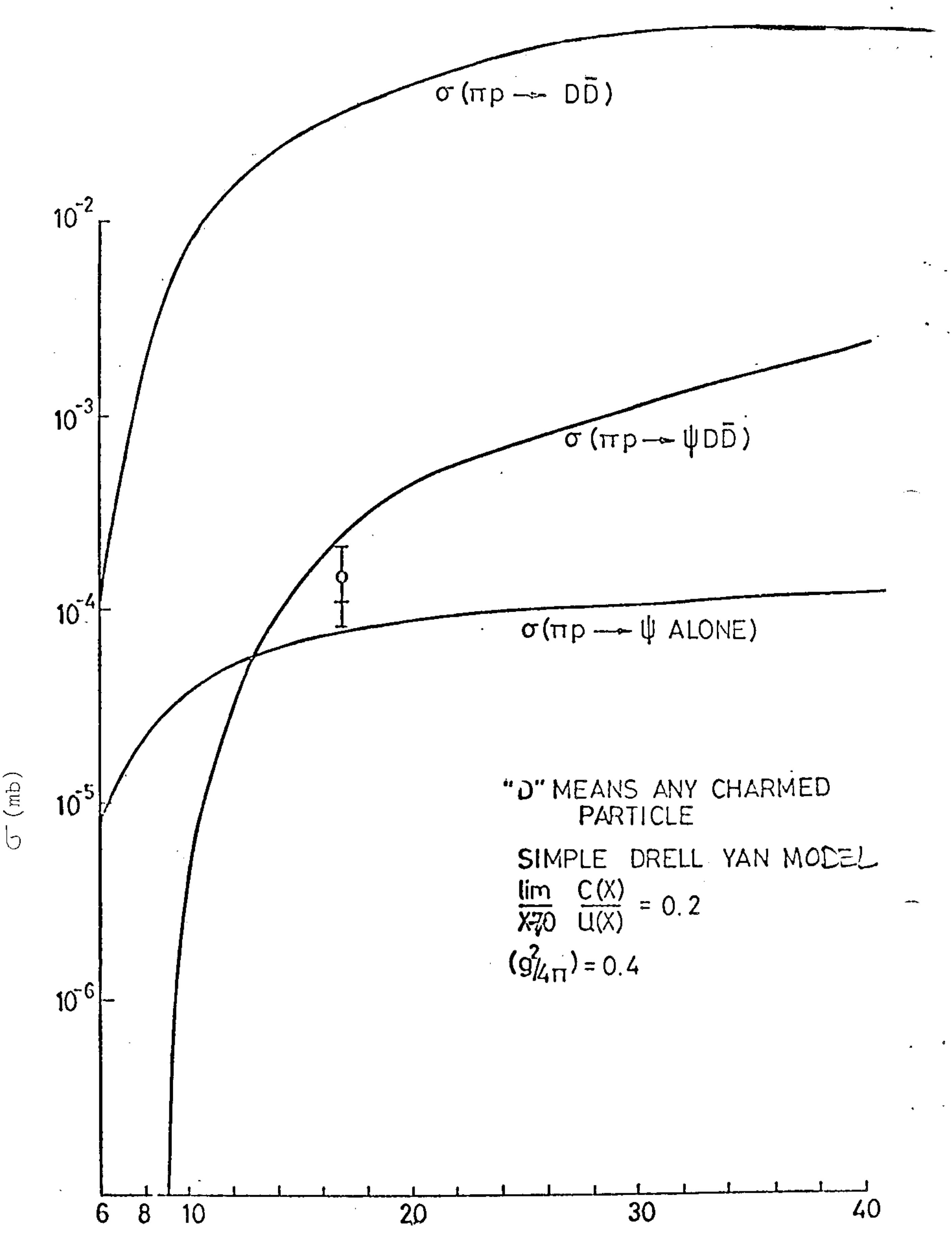
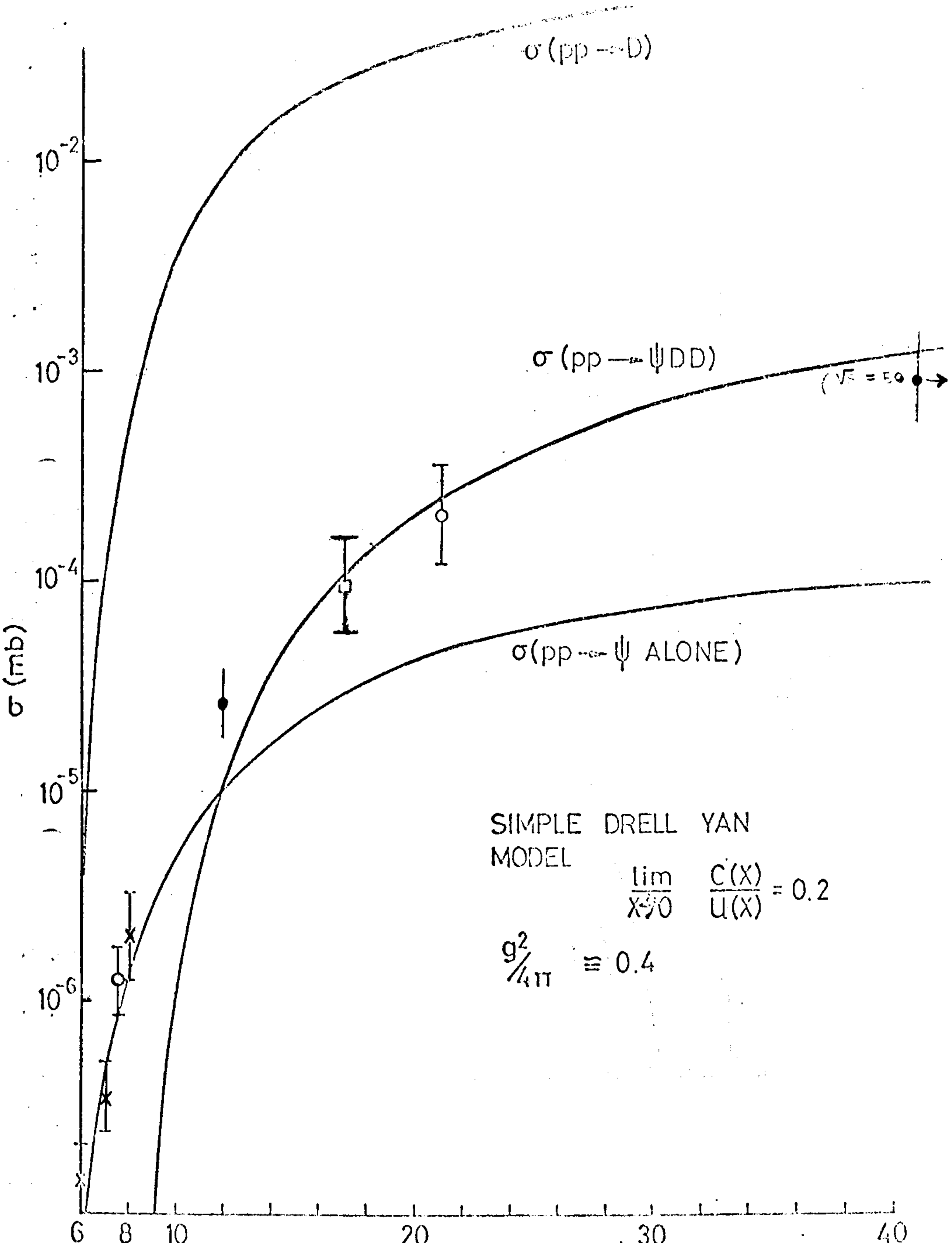


FIG. 1a (From D. SIVERS et al.)


σ (pp → D)
σ (pp → ψ D D)
(√s = 50
σ(pp → ψ ALONE)
σ (mb)
10^-2
10^-3
10^-4
10^-5
10^-6
SIMPLE DRELL YAN
MODEL
lim X→0 C(X)/U(X) = 0.2
g²/4π ≅ 0.4
6
8
10
20
30
40

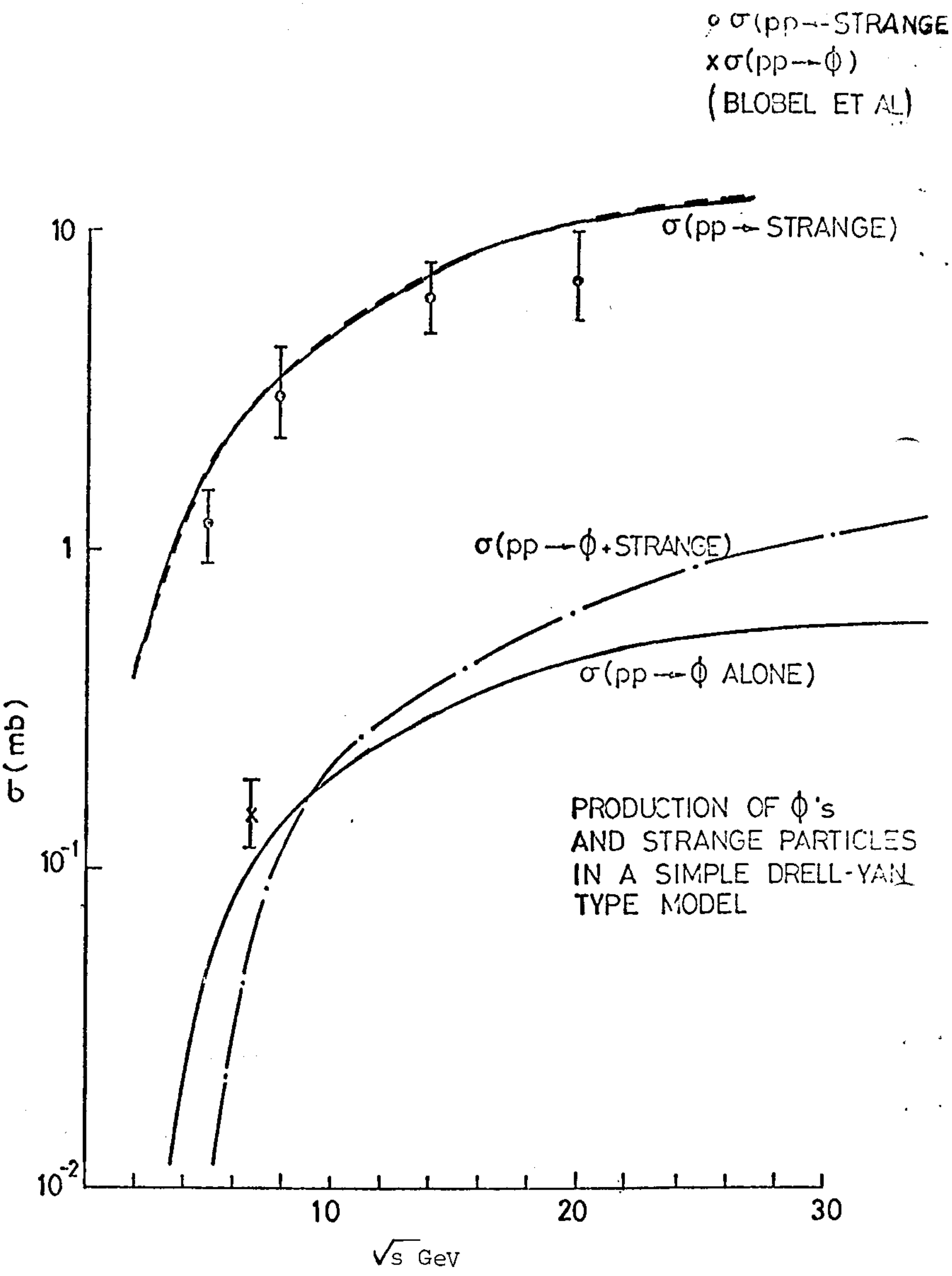


FIG. 2 (From D. SIVERS et al.)

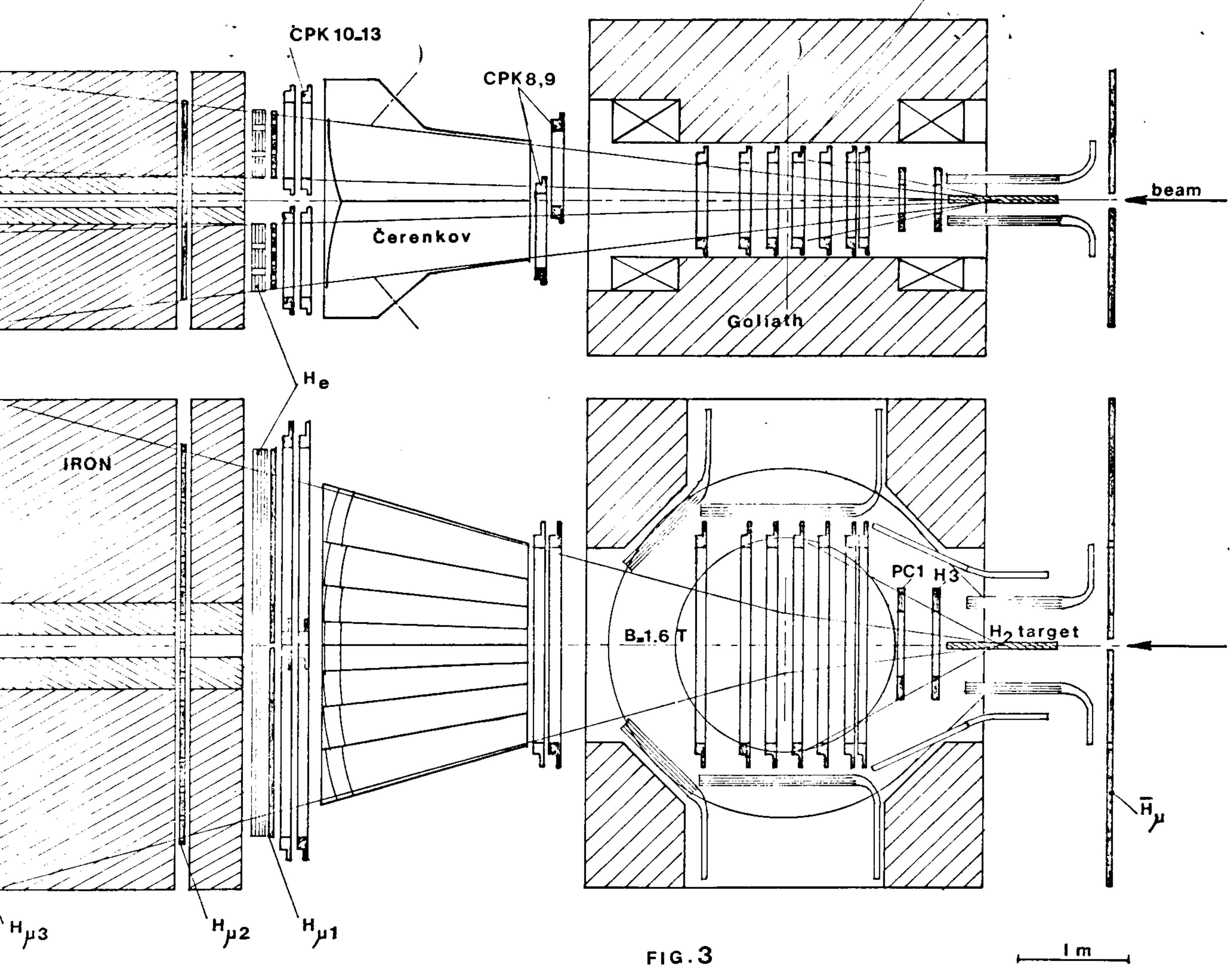

ČPK 10-13
CPK 8,9
beam
Čerenkov
Goliath
H_e
IRON
PC1
H_3
H_2 target
B=1.6 T
$\overline{H}_\mu$
$H_{\mu3}$
$H_{\mu2}$
$H_{\mu1}$
1 m

FIG. 3

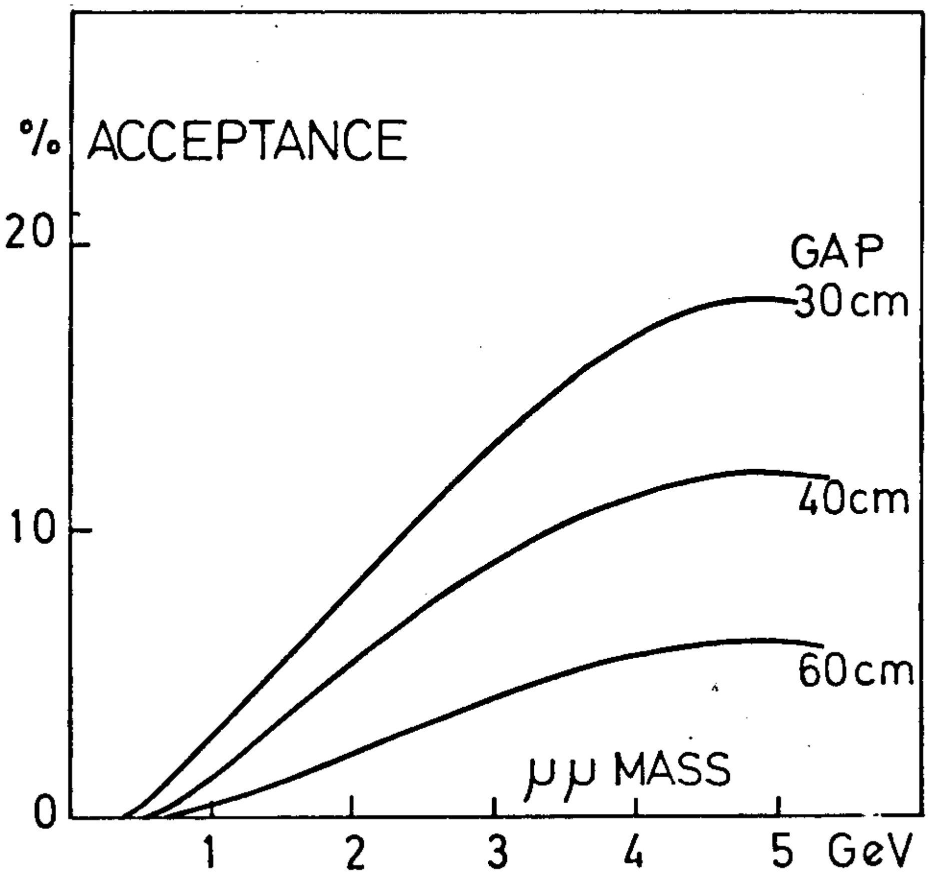


FIG. 4a

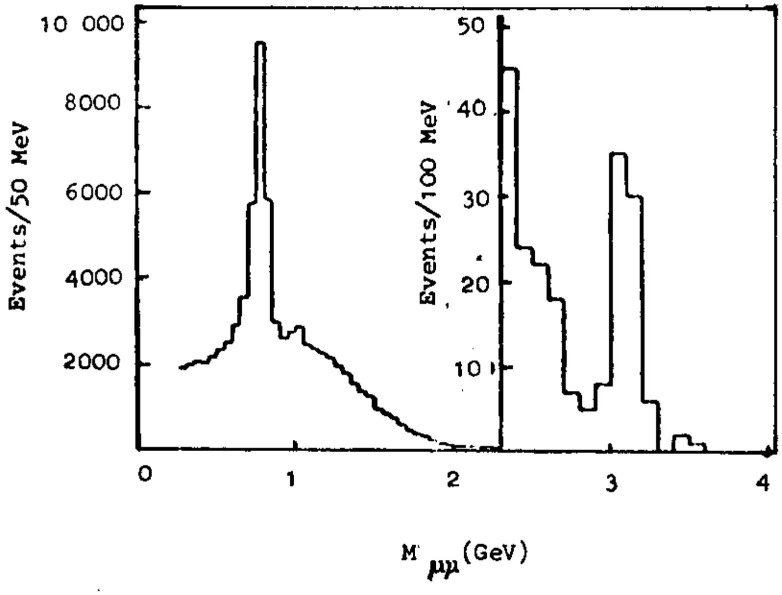


Fig. 4b

Dimuon mass spectrum measured without carbon absorber

(From ANTIPOV et al.)

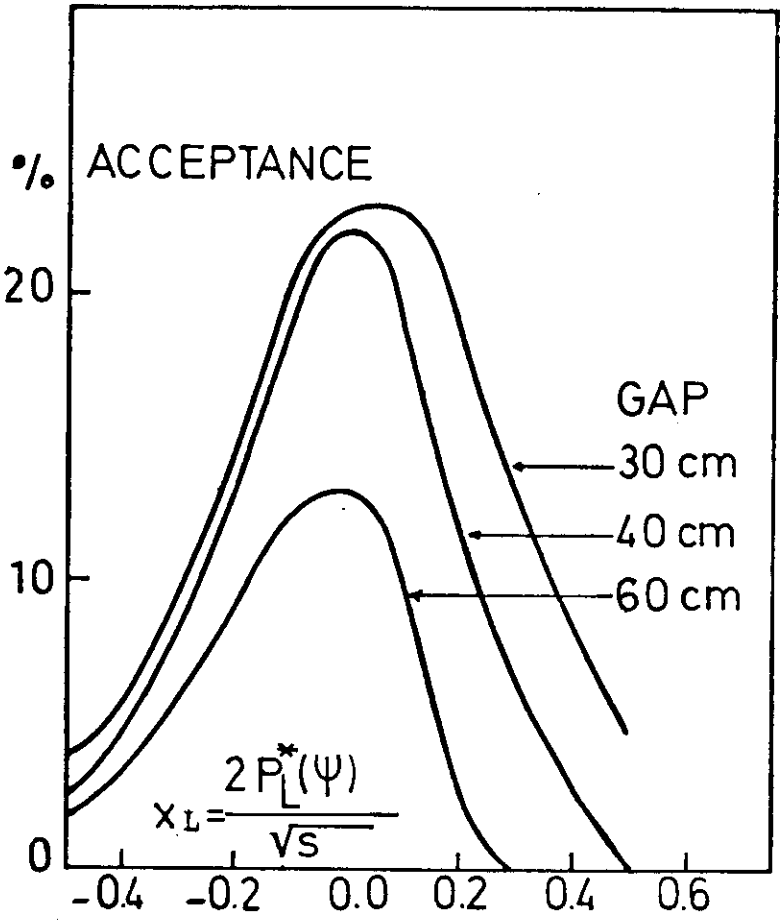
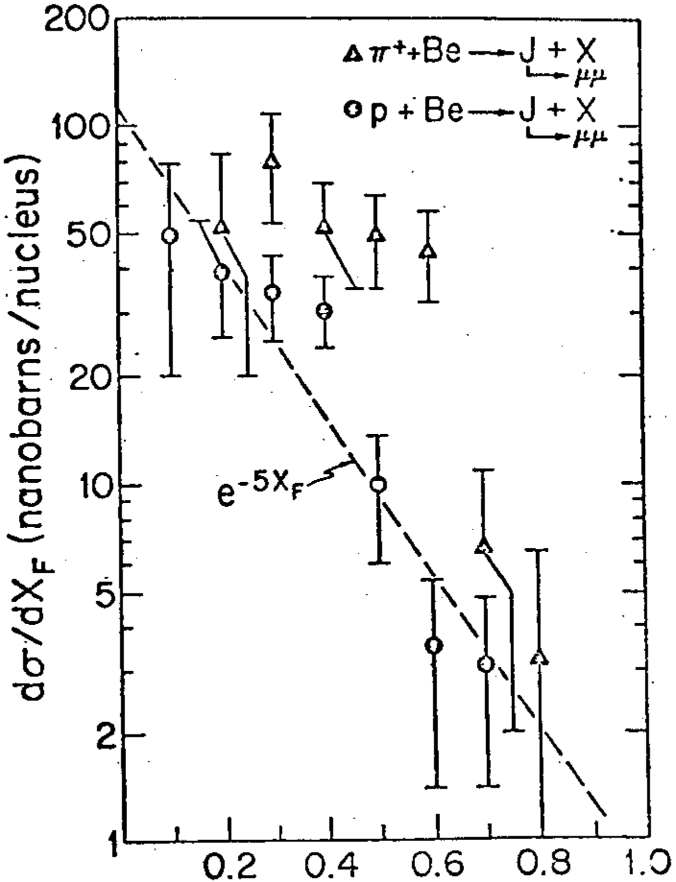

%
ACCEPTANCE
20
10
0
GAP
30 cm
40 cm
60 cm
$X_L = \frac{2P_L^*(\psi)}{\sqrt{s}}$
-0.4
-0.2
0.0
0.2
0.4
0.6

FIG. 5a


200
100
50
20
10
5
2
1
$d\sigma/dX_F$ (nanobarns/nucleus)
$\Delta\ \pi^+ + Be \rightarrow J + X$
$\hookrightarrow \mu\mu$
$\circ\ p + Be \rightarrow J + X$
$\hookrightarrow \mu\mu$
e^{-5X_F}
0.2
0.4
0.6
0.8
1.0

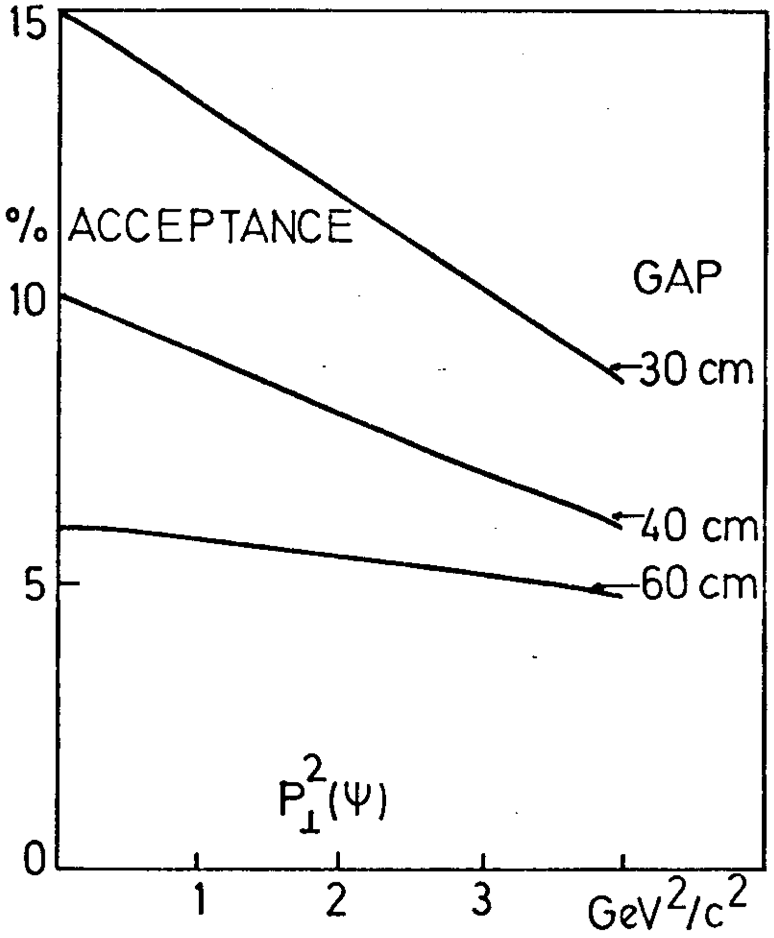


FIG. 6a

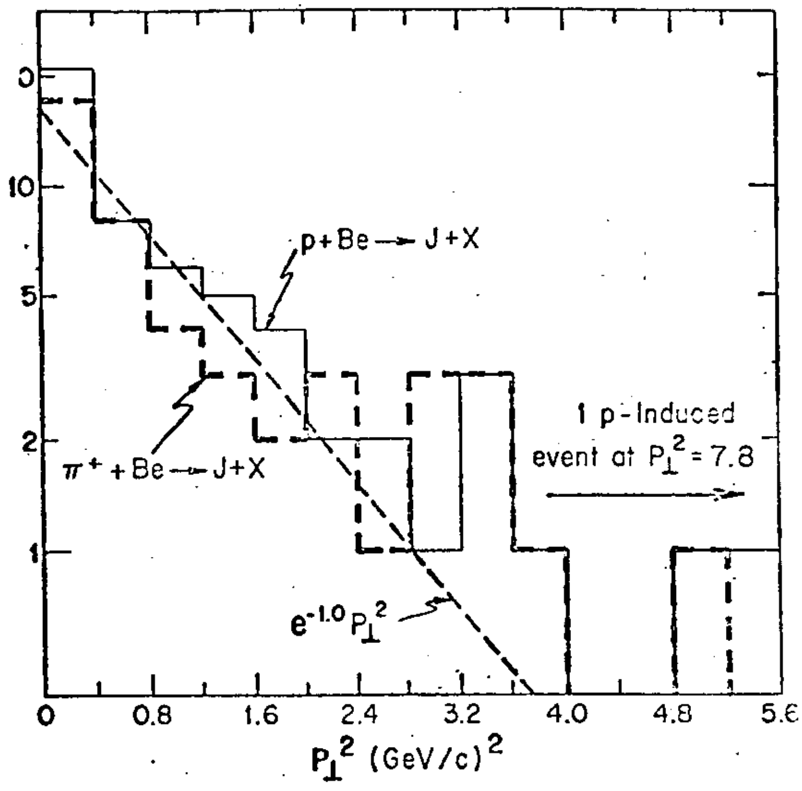


FIG. 6b (From PILCHER et al.)

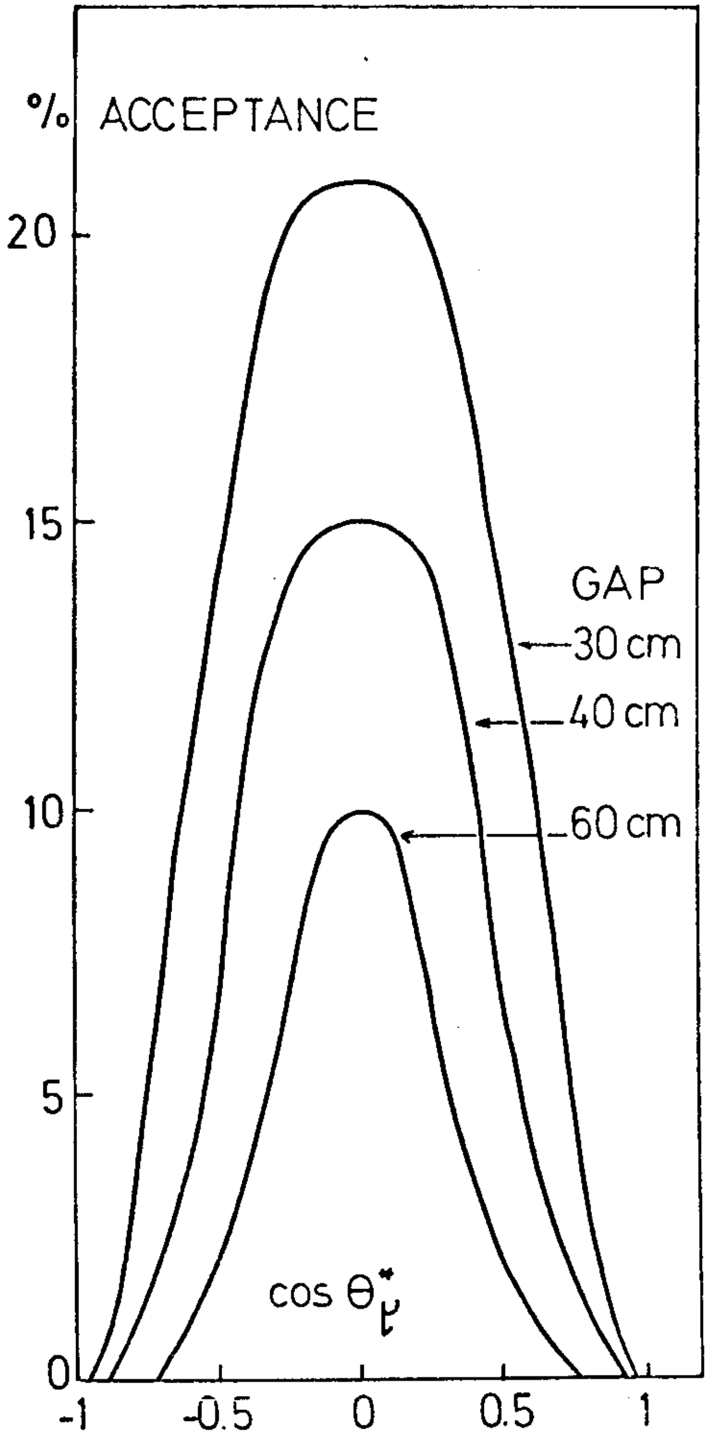

% ACCEPTANCE
20
15
10
5
0
-1
-0.5
0
0.5
1
GAP
30 cm
40 cm
60 cm
$\cos\theta^*_\mu$

FIG.7

```
BL5 HGR   2          i+2       (         HASSE DU PSEUDO MU MU
                     --------------------------------------------------------
XLOC   602
WLOC   603
TEST     5
                          NX      DELX      XLOW         XMEAN     XRMS   CONTENT   EXC
                         100       .05        0.        .43764   .26972   88.677



   16          5
   15          X
   14          X47
   13          XXX
   12          XXX
   11          XXX
   10          XXX6
    9          XXXX
    8          XXXXX
    7          XXXXX
    6          XXXXX1
    5          XXXXXX75 0
    4          XXXXXXXX X
    3          XXXXXXXX5X
    2          XXXXXXXXXX5  9
    1          XXXXXXXXXXX64X31132121211200 21311 1  0   000 0     0       0

CON-           111
TENT           53397544241  1
       0                  1                   2                    3 Mμμ(GeV)
       0000436591645045483102212111111000112010000000000000000000000000000
       0000869880862376360477512390247550625740600400021202000004000000020
       0000402867942643133165403167479200168770203705047704000009000000030

BIN             1         2         3         4         5         6
NOS    1234567890123456789012345678901234567890123456789012345678901234567

LOW                        11111111111111111111222222222222222222223333333
BIN
EDGE   0011223344556677889900112233445566778899001122334455667788990011223
       0505050505050505050505050505050505050505050505050505050505050505050
```

Fig. 8