SLAC-PUB-751
December 1970

PHOTOPRODUCTION OF HIGH MASS DIPION PAIRS AT 15 BEV*

F. Bulos, W. Busza,† R. Giese, E. E. Kluge, R. R. Larsen,
D.W.G.S. Leith, B. Richter, and S. H. Williams

Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

B. Kehoe

University of Maryland
College Park, Maryland 20742

M. Beniston

IBM
Palo Alto, California 94304

A. Stetz

Lawrence Radiation Laboratory
Berkeley, California 94720

ABSTRACT

We have measured the cross section for the photoproduction of dipions in the mass range (0.9-2.2) BeV/c^2. The experiment was performed with a 16 BeV bremsstrahlung beam on a Be target. Upper limits on the cross section for photoproduction of high mass vector mesons are determined.

(Submitted to Phys. Rev. Letters.)

*Work supported by the U. S. Atomic Energy Commission.

†Now at Physics Department, MIT, Cambridge, Massachusetts and DESY, Hamburg, Germany.

Most of the previous studies of dipion photoproduction have been confined to the mass range $M_{\pi\pi} \lesssim 1$ BeV/c^2 where rho production dominates. Two studies of high mass production at forward angles and at photon energies less than 9 BeV have been reported in the literature.[1,2] The work reported here covers the range of momentum transfer $|t-t_{min}| \leq 0.3$ (BeV/c)^2 and dipion decay angle $\theta_{\pi\pi}$, $|\cos\theta_{\pi\pi}| \leq 0.6$.

The experimental technique, described in more detail elsewhere,[3] consisted of a 16 BeV bremsstrahlung beam incident on a Be target which was followed by an analyzing magnet and a system of scintillator hodoscopes and wire spark chambers. The geometry of the system was arranged so that the dipion mass acceptance (for energies $\gtrsim 14$ BeV) extended from 0.7 to 2.5 BeV/c^2 and was very insensitive to mass from 1 to 2 BeV/c^2.

As the incident photon and target recoil were not observed, each event was analyzed assuming the reaction was of the form $\gamma + A \rightarrow A + \pi^+ + \pi^-$. A comparison of the energy spectra of the dipions and the incident photon beam reveals that for $E_{\pi\pi} \geq 14$ BeV, the upper limit on the inelastic contamination is 10% for $M_{\pi\pi} \leq 1.0$ BeV/c^2 and 25% for $1.0 \leq M_{\pi\pi} \leq 2.0$ BeV/c^2.

The spectrometer acceptance was unfolded from the observed distributions with the assumption that the cross section was azimuthally uniform in the helicity system.

We observed a total of 620 events in the intervals $E_{\pi\pi} \geq 14$ BeV, $|t-t_{min}| \leq 0.3$ (BeV/c)^2, $0.9 \leq M_{\pi\pi} \leq 2.2$ BeV/c^2, and $|\cos\theta_{\pi\pi}| \leq 0.6$. The distribution of weighted events versus polar decay angle $\theta_{\pi\pi}$ evaluated in the helicity system is shown in Fig. 1. The cutoff at $\cos\theta_{\pi\pi} = 0.6$ is imposed by the acceptance. The data are consistent with p-wave dominated dipions following a $\sin^2\theta_{\pi\pi}$ distribution indicated by the smooth curve.

The momentum transfer distribution is shown for two mass regions in Fig. 2. It is clear from the data that this distribution changes significantly as the dipion mass is varied. This change can not be explained by the nuclear form factor. In Fig. 3 we plot versus $M_{\pi\pi}$ the ratio of the forward $\left(t=t_{min}=-(M_{\pi\pi}^2/2E_{\pi\pi})^2\right)$ cross section to the cross section at $t-t_{min}=-0.12\ (\text{BeV/c})^2$. The curves are calculations of the expected ratio assuming (a) that the effect is due solely to the variation of the nuclear form factor with t_{min}, $\left(e^{45t_{min}}\right)$, and (b) through (d) that, in addition to (a), there is Drell-type dipion production that interferes with the rho production.[4] This model predicts that the t-slope of the elementary process $\gamma + p \rightarrow p + \pi^+ + \pi^-$ depends upon $M_{\pi\pi}$ and is supported, for $M_{\pi\pi} \leq 1.4\ \text{BeV/c}^2$, by experiment.[5] In Figs. 3 and 4, curves (b) - (d) assume different functions for the rho width:

$$\Gamma_b = \Gamma_\rho \frac{M_\rho}{M_{\pi\pi}} \frac{q^3}{q_\rho^3}$$

$$\Gamma_c = \Gamma_b \frac{1 + R^2 q_\rho^2}{1 + R^2 q^2}$$

$$\Gamma_d = \Gamma_\rho \quad \text{for} \quad M_{\pi\pi} \geq M_\rho$$

with q the pion momentum in the π-π c.m., $M_\rho = 0.765\ \text{BeV/c}^2$, $\Gamma_\rho = 0.140$ BeV, and $R^2 = 2.3\ (\text{BeV/c})^{-2}$.

In Fig. 4 we show the weighted yield $\left(\text{for } |t-t_{min}| \leq 0.046\ (\text{BeV/c})^2\right)$ versus $M_{\pi\pi}$ and the expectations (normalized to the rho peak) based on the model of rho production plus interfering Drell-type dipions.[4] This small t region, where coherence dominates, would most sensitively reveal the presence of any vector mesons.

There is no consistency between the data and the model dependent calculations as displayed in Figs. 3 and 4. Although the precise manner in which the rho tail disappears is unknown we believe that the widths Γ_b and Γ_d represent the extremes and that the truth is intermediate to these. An upper limit for any dipion production $d\sigma_V/dM_{\pi\pi}$ in excess of rho and Drell-type production can be deduced from the difference of the data and curve d, Fig. 4. Assuming that all dipions have a $\sin^2 \theta_{\pi\pi}$ distribution we deduce at $M_{\pi\pi} = 1.4\text{-}1.6$ BeV/c^2 the upper limit $d\sigma_V/dM_{\pi\pi} \leq 10^{-2} \left(d\sigma/dM_{\pi\pi} (M_{\pi\pi} = M_\rho)\right)$. If we attribute this possible excess to the production of a vector meson which couples directly to the photon and further assume $\Gamma_V = \Gamma_\rho$ and unity branching ratio to two pions, then we conclude that $g^2_{V\gamma}/g^2_{\rho\gamma} \leq 10^{-2}$, $g^2_{V\gamma}$ being the direct meson-photon coupling strength. We can also deduce an upper limit for f(1260) production of $2 \times 10^{-2} \sigma_\rho$, the factor of 2 arising from the difference in the acceptance of a 1^- and 2^+ dipion system. Coherent photoproduction of a 2^+ state violates C conservation and the ratio of forbidden to allowed cross section of 2×10^{-2} enables one to delimit the violation.

REFERENCES

1. N. Hicks et al., Phys. Letters 29B, 602 (1969).
2. G. McClellan et al., Phys. Rev. Letters 23, 718 (1969).
3. F. Bulos et al., Phys. Rev. Letters 22, 490 (1969).
4. P. Soding, Phys. Letters 19, 702 (1966).
5. H. H. Bingham et al., Phys. Rev. Letters 24, 955 (1970).

FIGURE CAPTIONS

1. Weighted events versus $|\cos\theta_{\pi\pi}|$ in the helicity system. $1.0 \le M_{\pi\pi} \le 2.0$ BeV/c^2, $|t-t_{min}| \le 0.3$ (BeV/c)^2 and $E_{\pi\pi} \ge 14.0$ BeV.

2. Momentum transfer distributions for $E_{\pi\pi} \ge 14.0$ BeV, $|\cos\theta_{\pi\pi}| \le 0.6$ and (a) $0.8 \le M_{\pi\pi} \le 1.0$ BeV/c^2 and (b) $1.0 \le M_{\pi\pi} \le 2.0$ BeV/c^2. Smooth curves are drawn only as a viewing aid.

3. Variation with $M_{\pi\pi}$ of ratio of cross sections at $t=t_{min}$ to that at $t-t_{min} = -0.12$ (BeV/c)^2. $E_{\pi\pi} \ge 14.0$ BeV, $|\cos\theta_{\pi\pi}| \le 0.6$. Curves explained in text.

4. Variation of yield versus $M_{\pi\pi}$ for $|t-t_{min}| \le 0.046$ (BeV/c)^2, $|\cos\theta_{\pi\pi}| \le 0.6$ and $E_{\pi\pi} \ge 14.0$ BeV. (Data for $M_{\pi\pi} \le 0.9$ BeV/c^2 acquired from our study of rho photoproduction at 16 BeV.) Dashed curve is the calculated acceptance and the solid curves are explained in text.

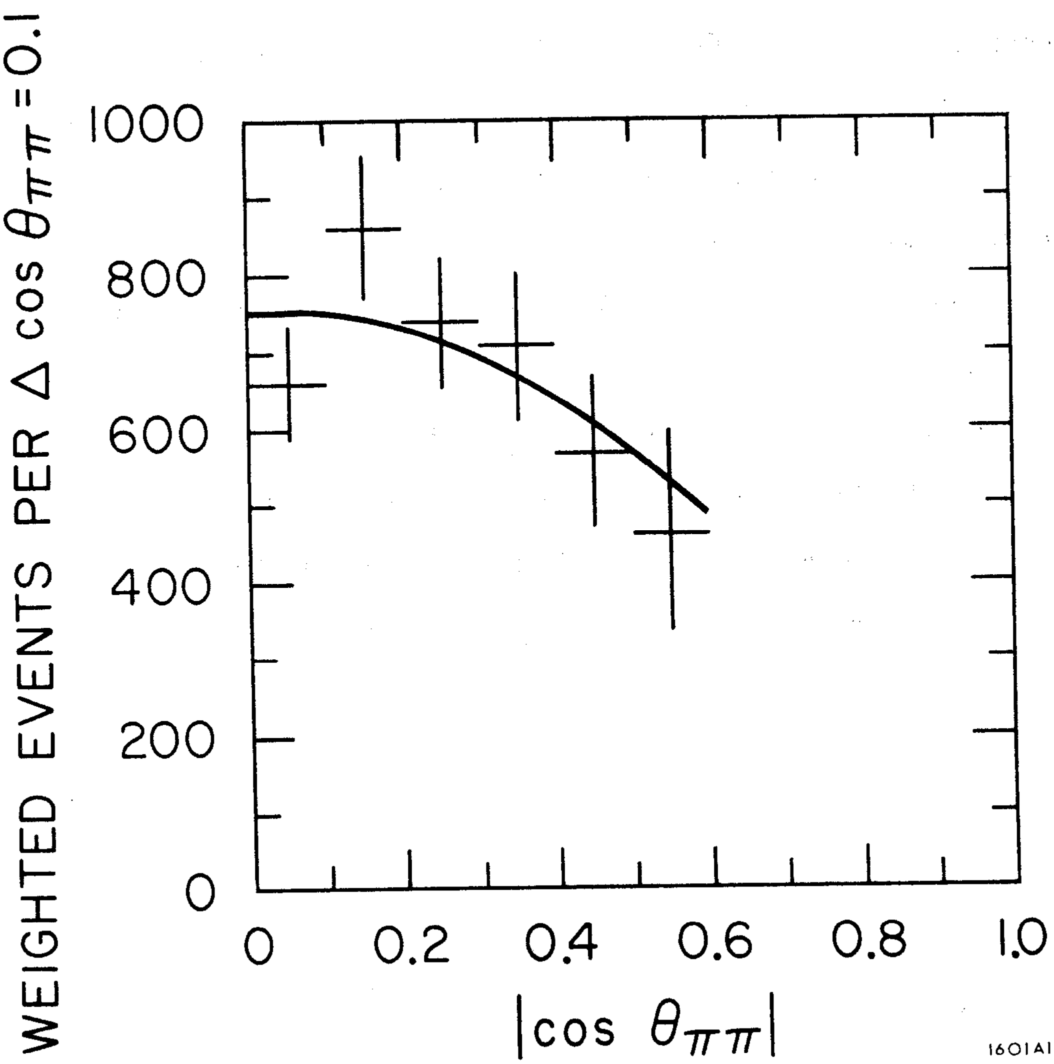
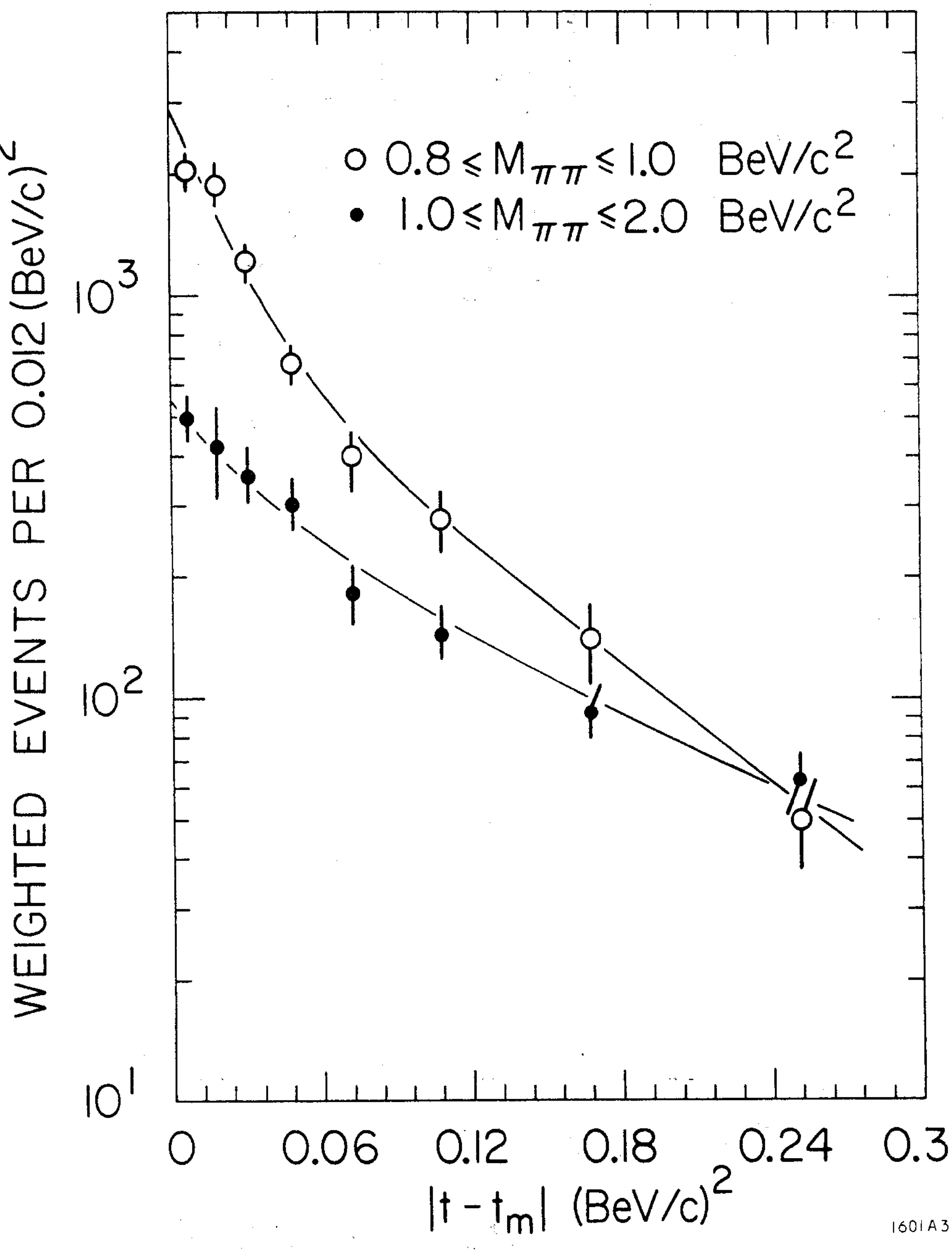
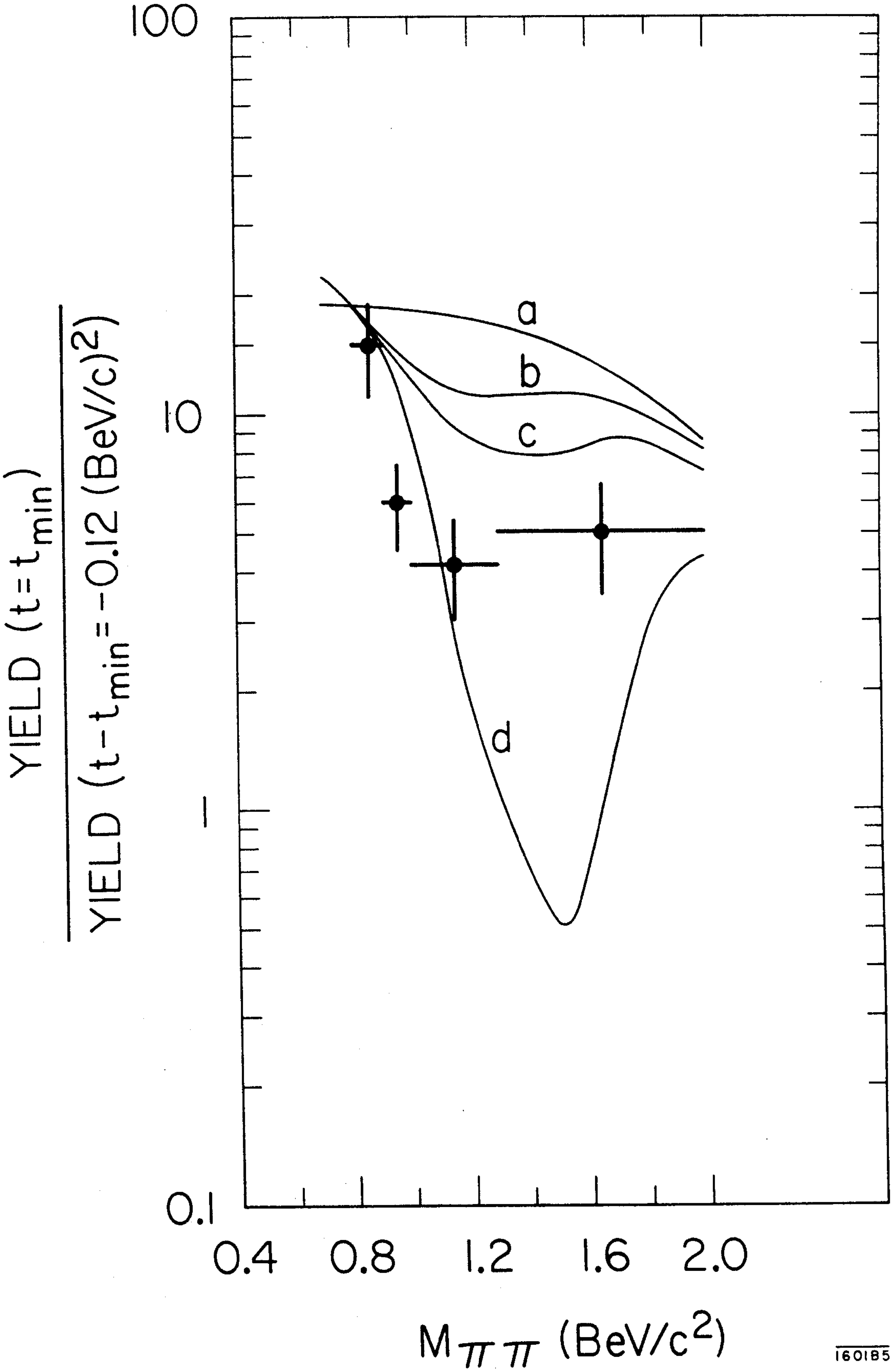

WEIGHTED EVENTS PER Δ cos θ_ππ = 0.1
1000
800
600
400
200
0
0
0.2
0.4
0.6
0.8
1.0
|cos θ_ππ|
1601A1

Fig. 1



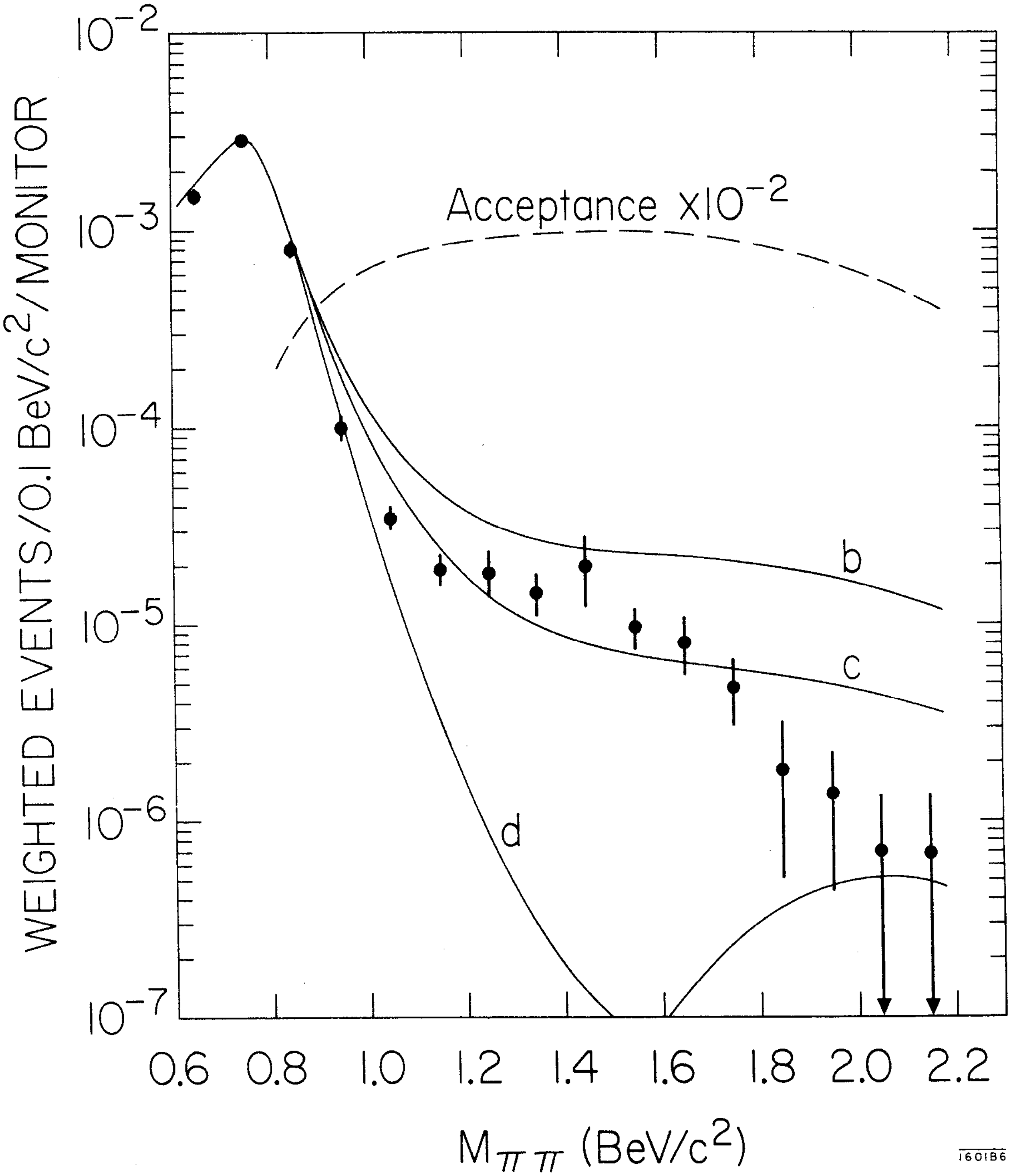
○ 0.8 ≤ $M_{\pi\pi}$ ≤ 1.0 BeV/c^2
● 1.0 ≤ $M_{\pi\pi}$ ≤ 2.0 BeV/c^2
WEIGHTED EVENTS PER 0.012 (BeV/c)^2
10^3
10^2
10^1
0
0.06
0.12
0.18
0.24
0.3
$|t - t_m|$ (BeV/c)^2
1601A3

Fig. 2



100
10
1
0.1
0.4
0.8
1.2
1.6
2.0
a
b
c
d
YIELD (t=t_min)
YIELD (t-t_min=-0.12 (BeV/c)^2)
M ππ (BeV/c^2)
160185

Fig. 3



WEIGHTED EVENTS/0.1 BeV/c²/MONITOR
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
Acceptance X10⁻²
b
c
d
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
Mππ (BeV/c²)
1601B6

Fig. 4