Presented at the 5th European Symposium on Nucleon Antinucleon Interactions, Bressanone, Italy, June 23-28, 1980.

BNL-28252

TWO SEARCHES FOR NARROW $\bar{p}p$ STATES IN πp INTERACTIONS

CONF-800688--4

A. S. Carroll

Accelerator Department

Brookhaven National Laboratory, Upton, N.Y. 11973*

Introduction

This report briefly summarizes two recently published searches for narrow pp states in $\pi^{\pm}p$ interactions in the 8 to 10 GeV/c region performed at the AGS. Experiment 716 was a collaboration among Carnegie-Mellon University, Brookhaven National Laboratory, Fermilab and Southeastern Massachusetts University. Members of the collaboration are listed in reference 1, which describes the results based on the first 50% of the data sample. An account of the analysis of the entire data sample is to be found in reference 2.

The second experiment described is Experiment 715 which was performed by a collaboration between Brookhaven National Laboratory and Princeton University. Further details of the experiment and the names of the collaborators are to be found in reference 3.

Both experiments searched for evidence of narrow $\bar{p}p$ states produced predominately by baryon exchange and were sufficiently sensitive to test decisively for the presence of the 2020 and 2204 MeV states reported by the CERN Omega experiment of P. Benkheiri, et al.[4] The techniques employed in the two experiments were sufficiently different such that any systematic biases were extremely unlikely to have occurred in both experiments.

Experiment 716

The Brookhaven National Laboratory multiparticle spectrometer (MPS) was used to detect and reconstruct kinematically events from the reaction

$$\pi^+ p \rightarrow \Delta_f^{++} \; X^o \qquad (1)$$
$$\Delta_f^{++} \hookrightarrow \pi^+ p \qquad X^o \hookrightarrow \bar{p}p$$

Incident 9.8 GeV/c π^+ were chosen to allow the simultaneous study of exotic meson systems with a forward Λ° and $\bar{\Lambda}^\circ$. In addition, the Clebsch-Gordon coefficients for forward Δ^{++} production are more favorable than those for forward Δ° production by π^-. At 9.8 GeV/c with the forward proton trigger set at 5.5 GeV/c, the experiment was sensitive to masses up to $\sim$ 2.5 GeV/c^2.

The apparatus shown in Figure 1 consisted of a set of recoil scintillators and cylindrical spark chambers surrounding the liquid hydrogen target and forward spark chambers interspersed with PWC planes for triggering. Downstream of the magnetic field were further spark chambers for improved resolution, a multicell Cerenkov counter, and a scintillation counter hodoscope.

The trigger selected events with a positive particle forward of momentum $\geq$ 5.5 GeV/c which did not produce light in the Cerenkov counter in coincidence with at least two additional tracks from the target region. A subset of events for checking the normalization and resolution were recorded requiring a forward π^+. As well as numerous Monte Carlo studies, the acceptance and resolution were verified by studying a number of known reactions.[2]

In Figure 2, the energy imbalance for reaction (1) candidates is shown. The shape of the peak and background have been calculated by the Monte Carlo program. The background comes from events with forward kaons and neutral pions. The remaining background for $|\delta E| <$ 100 MeV is estimated to be $\sim$ 30%.

Selecting events with an invariant mass between the trigger proton and the kinematically identified π^+ of less than 1.35 GeV/c^2 leaves a sample of $\sim$ 2000 events. This corresponds to a sensitivity of > 1 event/nb for $\bar{p}p$ masses < 2.3 GeV/c^2. The effective mass resolution of the $\bar{p}p$ pair varies from 10 to 16 MeV/c^2 in this mass interval. We see no narrow resonances at the 95% C.L. with cross sections of $\geq$ 28 nb and masses $\leq$ 2.3 GeV/c^2 as shown in Figure 3.

In order to compare directly this experiment with that of reference 4, one needs to understand the production mechanism. Most baryon exchange processes proceed via nucleon rather than Δ exchange. In particular, the authors of reference 4 have searched for the two states in

$$\pi^- p \rightarrow p\,(\bar{p}n) \qquad (2)$$

The absence of signals in reaction (2) may be interpreted as due to nucleon exchange dominance.[5]

The mass spectrum of reference 4 is very similar to that shown in Figure 3 outside of the regions of the reported peaks. If we assume nucleon exchange dominance, then we should see $\sim$ 140 events above backgrounds of $\sim$ 160 events in single 40 MeV/c^2 bins. This is illustrated by the smooth curves in Figure 3. Under these assumptions, the two states would appear as 11 s.d. Alternative possibilities are to scale as the ratio of the cross sections (6.5) in the two experiments which results in 8 s.d. Finally, against all evidence, if one assumed Δ exchange dominance, the states would still appear as 3 s.d. effects.

Experiment 715

This experiment utilized a double-arm spectrometer which was originally built by Princeton University for a series of charmed particle searches,[6] and which was subsequently augmented with precise time of flight counters and three sets of threshold Cerenkov counters for use in a search for six-quark states by a Brookhaven and Princeton collaboration. For the $\bar{p}p$ study, the spectrometer was used to identify protons and anti-protons in the reaction

$$\pi^- + \text{target} \rightarrow \bar{p}p + \text{anything.} \qquad (3)$$

Data were taken both with a 23 cm liquid hydrogen target at a beam momentum of 8.1 GeV/c and with a 15 cm graphite target at 8.8 GeV/c. The beam intensities were approximately 2×10^7 particles/sec, which allowed for high sensitivity despite the small acceptance. The heavily instrumented spectrometer arms provided very good effective mass resolution and excellent particle identification for relatively slow $\bar{p}p$ pairs. The forward going particles were not detected.

Events were selected with a simple trigger. In each spectrometer arm, a coincidence was required among signals from the three planes of scintillation hodoscopes (labeled S,F, and B, in Figure 4) in conjunction with no corresponding signal in the outer section of the water Cerenkov counter. The particle type associated with each trajectory was determined from the threshold Cerenkov counters and the measured time-of-flight between the S- and B- counter hodoscopes. Figure 5 shows the $\tau-\tau_{expected}$ for particles identified as protons and antiprotons by the Cerenkov counters. A time-of-flight resolution of $\sigma = 0.3$ nsec permitted a cut at $\pm$ 1 nsec. Contamination of the protons was $\leq$ 1% for all momenta, while that of the antiprotons varied from $\leq$ 1% at 0.6 GeV/c to $\leq$ 10% at 2.8 GeV/c.

The mass resolution varied approximately linearly from 6 MeV/c^2 at 2.0 GeV/c^2 to 20 MeV/c^2 at 2.5 GeV/c^2. To be included in the mass distributions of Figure 6, the event had to fall in the region of phase space where the total detection efficiency (the product of geometric acceptance, reconstruction efficiency, particle identification and transmission probabilities) was greater than 10^{-5}. The 95% confidence level limits for the production of narrow (with respect to the resolution) resonances varied between 19 nb and 41 nb for the combined data of Figure 6c. The total detection efficiency was calculated assuming an angular distribution associated with a typical baryon exchange processor, $d\sigma/du \propto e^{3u}$.

This experiment covers a similar kinematic region to that of P. Benkheiri, et al.[4] They claimed to find narrow resonances in the exclusive channel $\pi^- p \rightarrow p_f \pi^- \bar{p}p$ at $M_{\bar{p}p}$ = 2020 and 2200 MeV/c^2 recoiling off the $\Delta(1238)$ and the N*(1520). Since our experiment does not rely upon detecting a specific decay mode of the $\Delta(1238)$ or the $N^*(1520)$, we would expect inclusive cross sections of 136 ± 36 nb for the 2020 MeV/c^2 state and 51 ± 15 nb for the 2200 MeV/c^2 state. For the 2020 MeV/c^2 state, their measurement is inconsistent with our upper limit of 46 nb for a state with width $\Gamma = 24$ MeV/c^2.[13] The 2200 MeV/c^2 state was only observed recoiling against the $\Delta(1238)$ which falls outside our efficiency cut-off for the carbon running. Our upper limit of 71 nb from the hydrogen data is not inconsistent with their measurement. It should be noted that while there is an overlap between the kinematic regions explored by the two experiments, ours has a smaller geometric acceptance and covers a narrower range in u.

Conclusions

Two very different experiments have searched for narrow $\bar{p}p$ states in kinematic region corresponding to baryon exchange. At the 95% confidence level of ∼ 30 nb, neither experiment observes any statistically significant enhancements from threshold to 2.3 GeV/c^2. Restricting the Jackson angle of the $\bar{p}p$ decay or the mass of the forward N^* system does not change this conclusion. In particular, Experiment 715 is inconsistent with the reported production of the 2020 MeV/c^2 state and Experiment 716 is inconsistent with both the 2020 and 2204 MeV/c^2 states.

Figure Captions

Fig. 1. Plan view of the Brookhaven Multiparticle Spectrometer as utilized for Experiment 716.

Fig. 2. Energy imbalance for reaction (1) candidates. The curve is the sum of a smooth background and Monte Carlo shape for reaction (1).

Fig. 3. $\bar{p}p$ mass spectrum for reaction (1) from Experiment 716. The smooth curve is a polynomial, χ^2/DOF = 47/49, plus the signals expected for nucleon exchange production of the 2020 and 2204 MeV/c^2 states of Ref. 4.

Fig. 4. Elevation view of one arm of the double-arm spectrometer used in Experiment 715. Each arm is located at 18° with respect to the incident beam direction.

Fig. 5. Time-of-flight differences: (a) protons and (b) antiprotons.

Fig. 6. $\bar{p}p$ mass spectra for Experiment 715: (a) hydrogen target data, (b) carbon target data, and (c) combined sample.

References

*Work supported in part by the U.S. Department of Energy and the U.S. National Science Foundation.

1. R. M. Bionta, A. S. Carroll, R. M. Edelstein, D. R. Green, E. J. Makuchowski, S. P. Morrissey, J. S. Russ, J. J. Russell, N. Sharfman and R. B. Sutton, Phys. Rev. Lett. 44, 909, 1980.
2. D. R. Green, Search for Narrow $\bar{p}p$ States in 10 GeV/c Interactions, Proceedings of the VI International Conference on Experimental Meson Spectroscopy, Editors, S. U. Chung and S. J. Lindenbaum (to be published)
3 A. S. Carroll, I-H. Chiang, R. A. Johnson, T. F. Kycia, K. K. Li, L. S. Littenberg, M. D. Marx, R. Cester, R. C. Webb and M. S. Witherell, Phys. Rev. Lett. 44, 1572 (1980).
4. P. Benkheiri, et al., Phys. Lett. 68B, 483 (1977).
5. P. Benkheiri, et al., Phys. Lett. 81B, 380 (1979).
6. R. Cester, et al., Phys. Rev. Lett. 37, 1178 (1976) and 40, 139 (1978).
7. A. S. Carroll, et al., Phys. Rev. Lett. 41, 777 (1978).

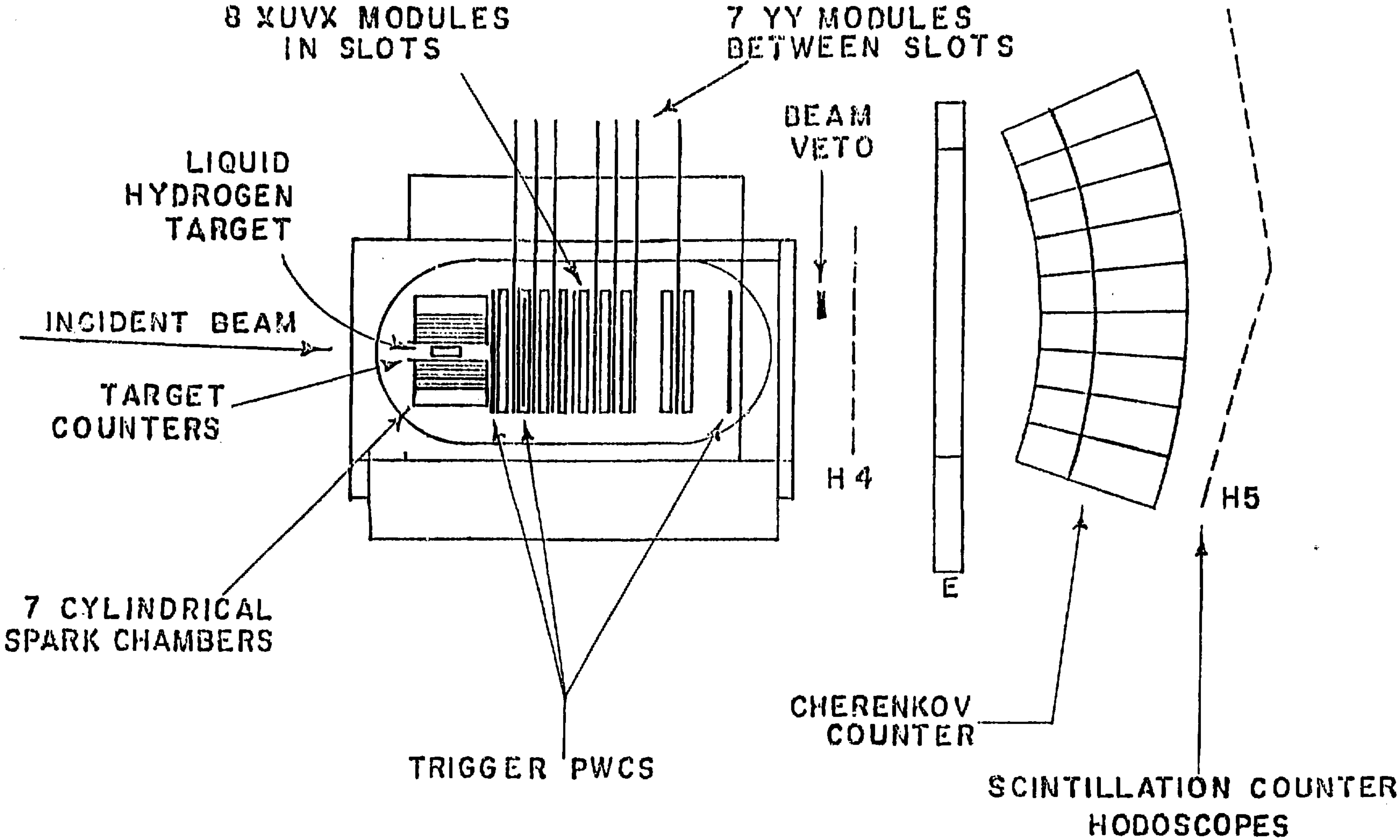
8 XUVX MODULES
IN SLOTS
7 YY MODULES
BETWEEN SLOTS
BEAM
VETO
LIQUID
HYDROGEN
TARGET
INCIDENT BEAM
TARGET
COUNTERS
H 4
E
H5
7 CYLINDRICAL
SPARK CHAMBERS
CHERENKOV
COUNTER
TRIGGER PWCS
SCINTILLATION COUNTER
HODOSCOPES

Fig. 1

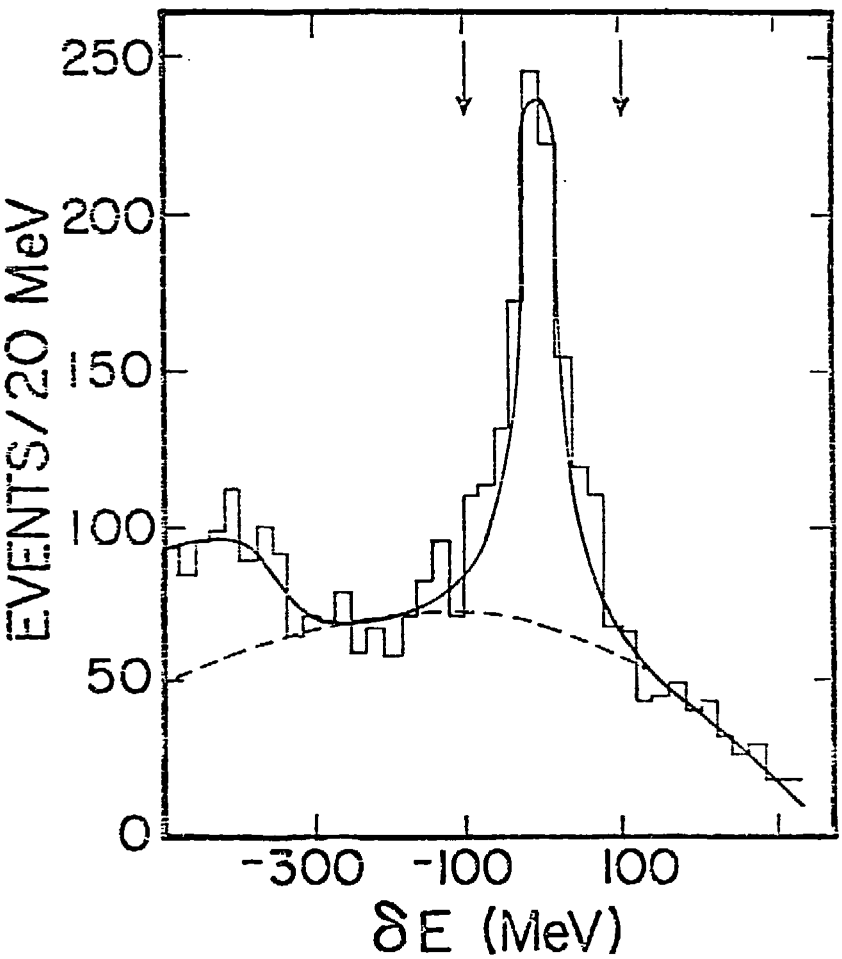

Fig. 2

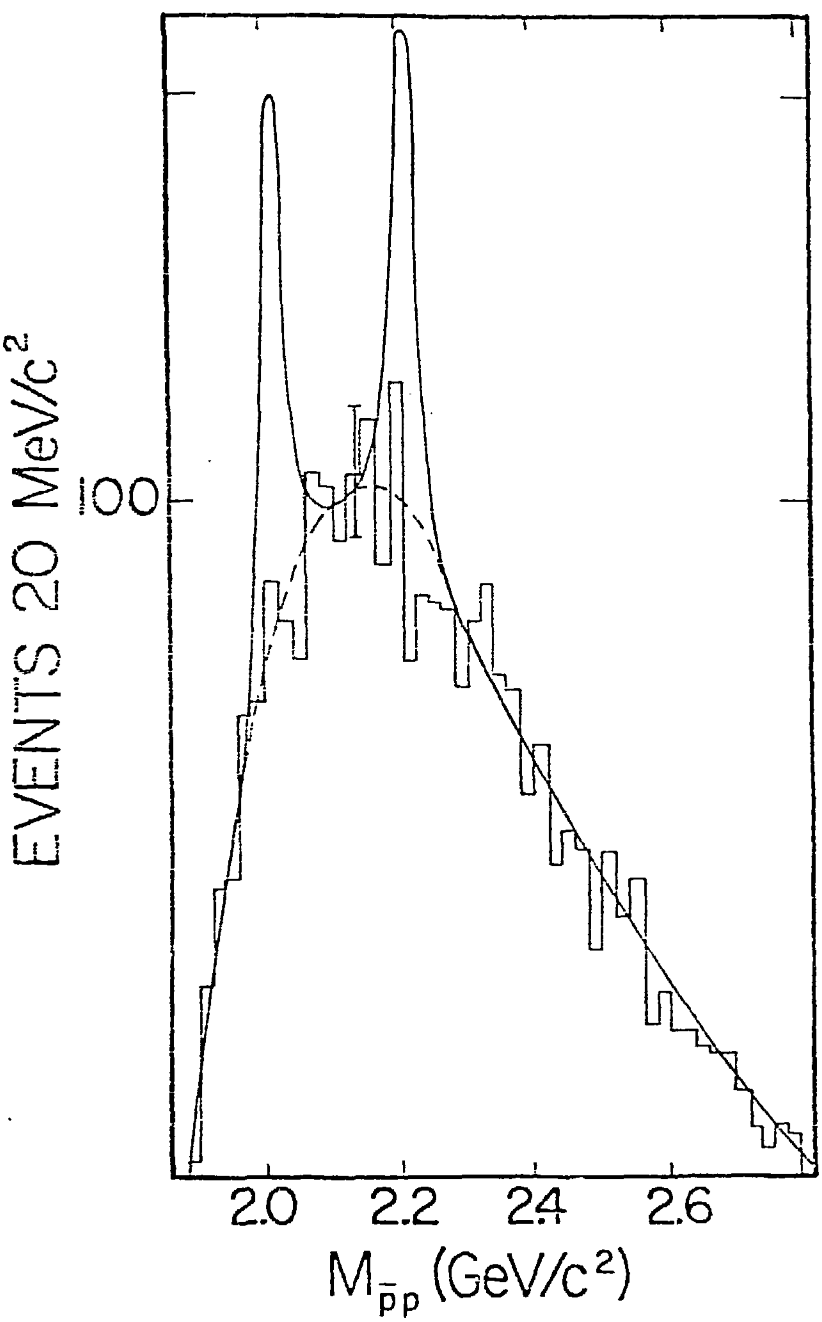

Fig. 3

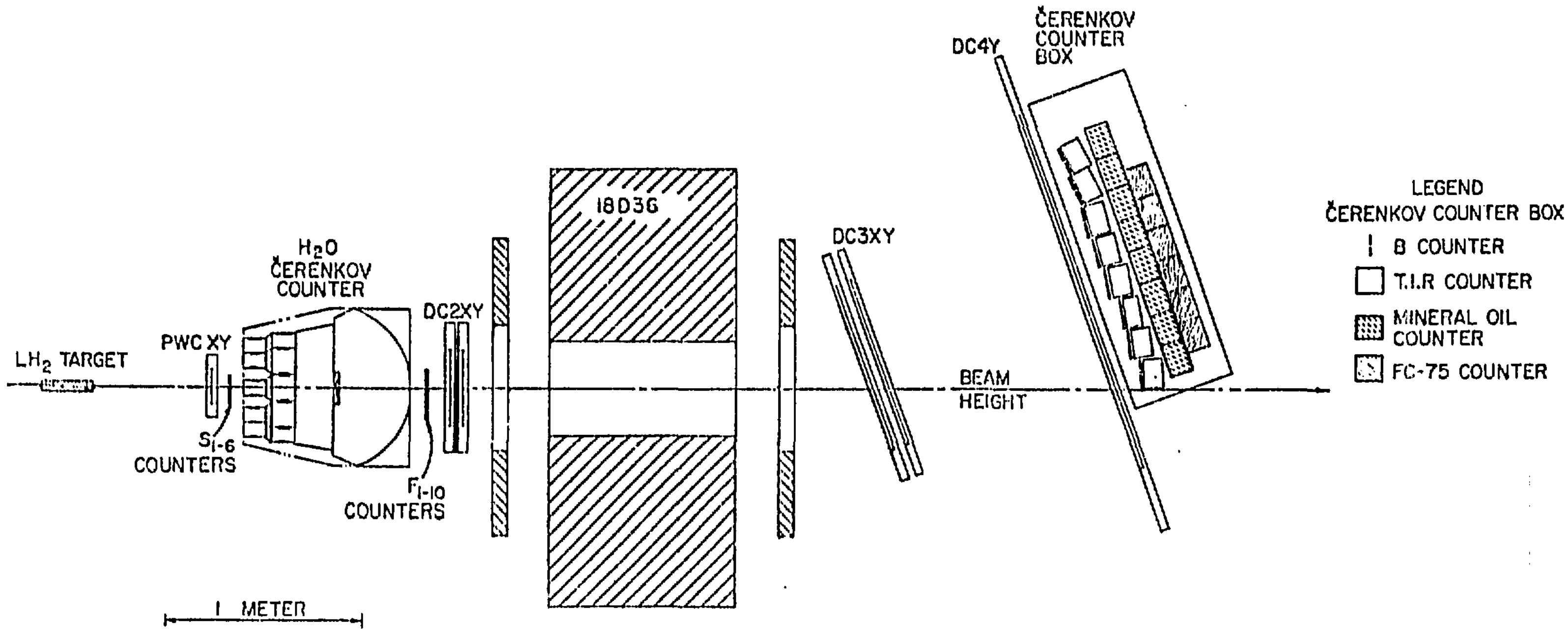
ČERENKOV
COUNTER
BOX
DC4Y
18D36
H₂O
ČERENKOV
COUNTER
DC3XY
DC2XY
PWC XY
LH₂ TARGET
BEAM
HEIGHT
S₁₋₆
COUNTERS
F₁₋₁₀
COUNTERS
1 METER
LEGEND
ČERENKOV COUNTER BOX
B COUNTER
T.I.R COUNTER
MINERAL OIL
COUNTER
FC-75 COUNTER

Fig. 4

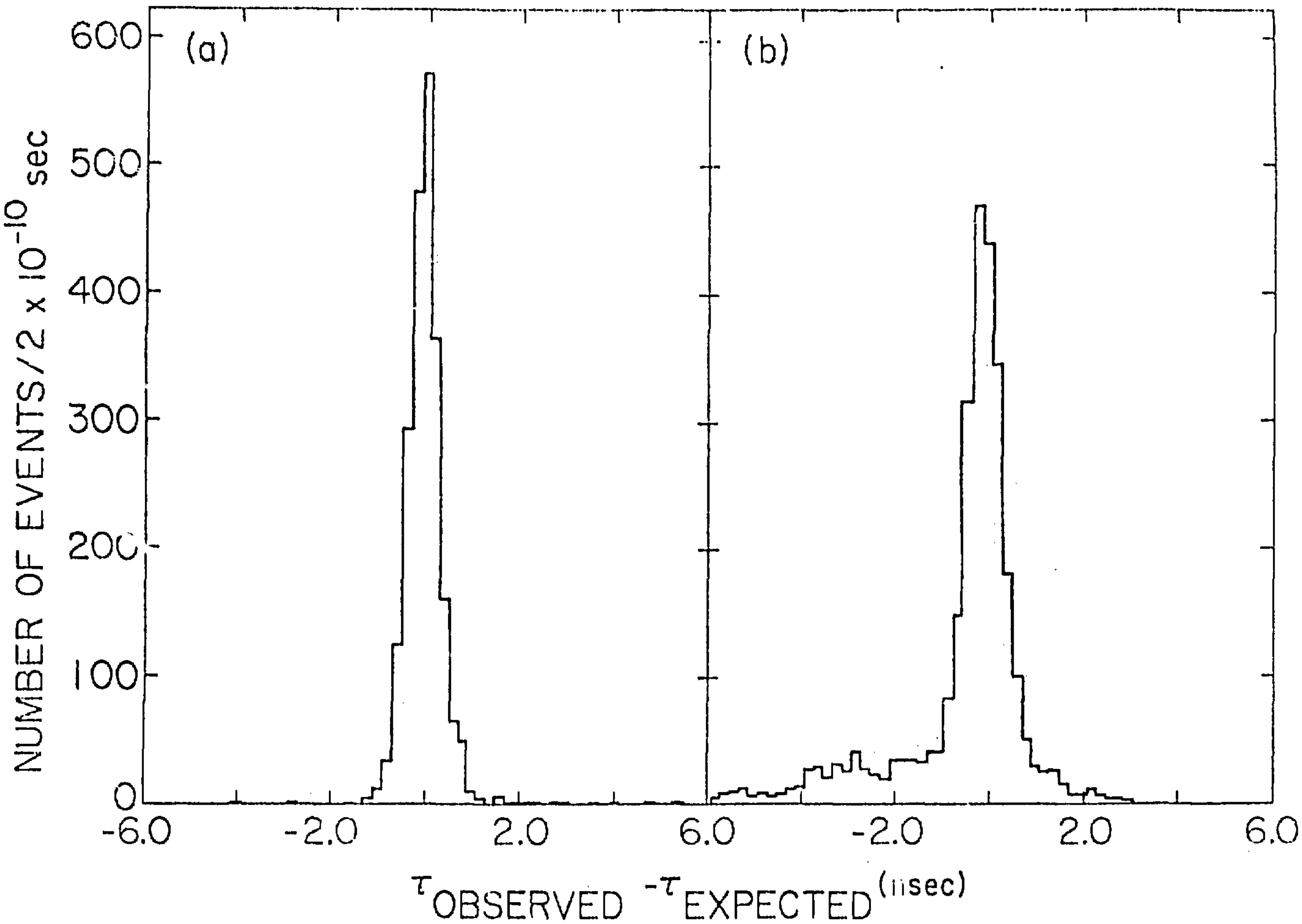
(a)
(b)
NUMBER OF EVENTS/2 x 10^-10 sec
τOBSERVED -τEXPECTED (nsec)
0
100
200
300
400
500
600
-6.0
-2.0
2.0
6.0

Fig. 5

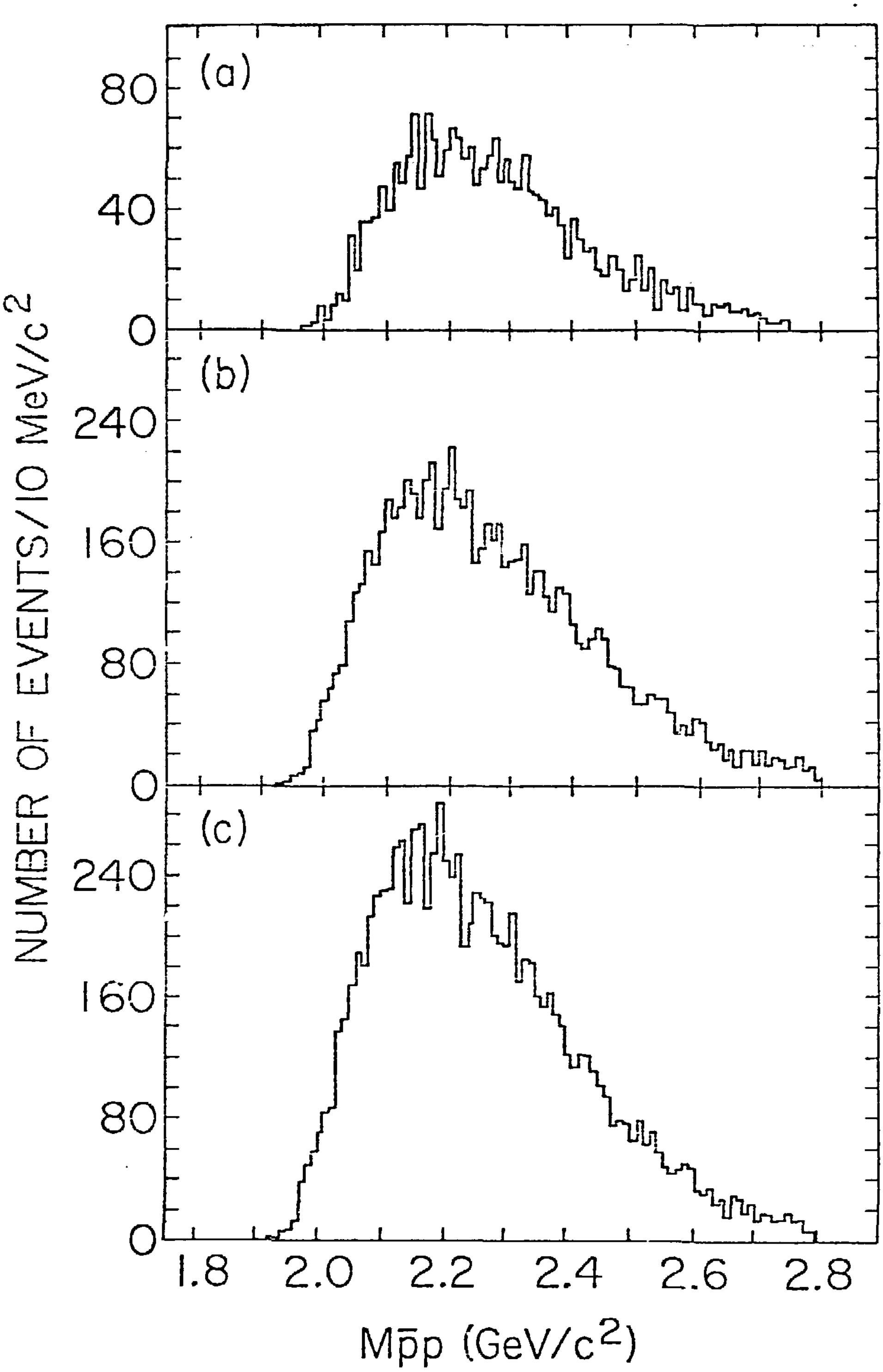
(a)
(b)
(c)
NUMBER OF EVENTS/10 MeV/c2
0
40
80
0
80
160
240
0
80
160
240
1.8
2.0
2.2
2.4
2.6
2.8
Mp̄p (GeV/c2)

Fig. 6