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CONFIRMATION OF THE L-MESON BY USE OF A HYDROGEN BUBBLE CHAMBER AS A MISSING MASS SPECTROMETER*

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ABSTRACT

We have used the 80-inch BNL liquid hydrogen bubble chamber as a missing mass spectrometer in K^+p interactions at 9 BeV/c, and for those events with stopping-protons, we confirm the existence of the L-meson with observed mass $M = 1740$ MeV and full width at half maximum $\Gamma = 120$ MeV.

In the study of K^+p interactions at several incident momenta we have observed the frequent occurrence of interactions with readily identified slow or stopping protons. This motivated the use of the Hydrogen Bubble Chamber as a missing mass spectrometer, a technique which is particularly useful for those events which do not fit a unique kinematic hypothesis. We present, in this letter, the essential results of using such a technique in an experiment studying K^+p interactions at 9 BeV/c. We find a large strange-meson mass peak at $M = 1740 \pm 20$ MeV and with full width at half maximum of 120 ± 30 MeV. This is presumably the same effect as the L-meson reported earlier.[1]

We have obtained approximately 100,000 triad exposures using the Berkeley camera system[2] with the Brookhaven National Laboratory's 80-inch hydrogen bubble chamber exposed to an rf separated beam[3] of 9 BeV/c K^+ mesons at the AGS. In separate publications, we report results on the production of anti-xi hyperons in this interaction,[4] and we also report on the results of a more conventional analysis of the data using kinematic fitting.[5] This paper is a report on the results of a missing mass analysis of 2-pronged and 4-pronged interactions in approximately 90,000 exposures. The events were digitized on the Lawrence Radiation Laboratory's Flying Spot Digitizer (FSD) and reconstructed in space in the program TVGP on the CDC-6600 computer.[6] A total of 45,000 events have been processed.

The missing mass is defined as:

$$MM = [(E_K + M_P - E_P)^2 - (\vec{P}_K - \vec{P}_P)^2]^{1/2}$$

in which the subscript P refers to the outgoing proton and the subscript K refers to the incident K^+ meson. The principal advantage of this method of analysis is that in addition to knowledge of the beam properties, it requires identification and measurement only of the proton. At high momenta kaons and pions frequently become kinematically equivalent and many ambiguities result from kinematic fitting procedures. The calculation of the missing mass, on the other hand, is dependent on the proper identification of only the proton track. In order to make this identification certain and to obtain the best possible mass resolution we have restricted ourselves to events in which the proton actually stops in the bubble chamber. For these events the proton momentum may be determined with considerable accuracy from its range. Such a selection of stopping proton events implies a momentum transfer cut-off to the proton of about 0.25 $(\text{BeV}/c)^2$. A total of 15% of all events contain protons identified as stopping in the bubble chamber.

To obtain an independent check of our knowledge of the bubble chamber optics and the magnetic field we have studied separately the 2-pronged events with an associated vee. We fit the vees in these events to a special two constraint fit using the measured variables of the two charged decay tracks interpreted as pions and the measured direction of the neutral decaying track, but leaving unspecified both the momentum and mass of the neutral track. Figure 1 shows the fitted mass of the neutral track from this 2 constraint fit for the 2-pronged events with vee. The central value of the mass peak is calculated to be 497.88 ± 0.43 which is to be compared to the known mass of the K^0 meson of 497.87 ± 0.16 as compiled by Rosenfeld, et al.[8] The distribution is Gaussian and has a width of 6 MeV. We have studied the error in the missing mass as a function of the missing mass, and have found that for the elastic interactions (MM = 494 MeV), the error in the missing mass is 40 ± 10 MeV, while as the missing mass increases the error becomes

20 ± 5 MeV.[9] In Fig. 2 we show the error in the missing mass as a function of the missing mass.

In Fig. 3 we show the missing mass distribution for all 2-pronged and 4-pronged interactions with stopping protons. The large peak at the K^+ mass due to the Kp elastic scattering has a full width at half maximum of 120 MeV. The peak corresponding to the $K^*(890)$ resonance has a full width at half maximum of 40 MeV. In addition, there are two peaks over a large background centered at 1320 MeV and 1740 MeV with full widths at half maximum of about 280 MeV and 120 MeV respectively.

In Fig. 4 we show separately the missing mass distributions for the 2-pronged and 4-pronged interactions with stopping protons. The K^+ and $K^*(890)$ peaks, are, of course, associated solely with the 2-pronged interactions. The peaks at 1320 MeV and 1740 MeV however are associated with both 2-pronged and 4-pronged interactions. This indicates that these may be resonances decaying ultimately into two or more particles. In fact, resonance phenomena in the $K\pi\pi$ system have been reported in the regions of both the 1320 MeV peak and the 1740 MeV peak.[1,10-16] Evidence for internal structure for the broad peak centered at 1320 MeV has been reported,[10] however the experimental resolution available with this missing mass spectrometer technique does not permit us to observe this effect reliably here. The contribution to the broad peak at 1320 MeV from the 4-pronged events is primarily in a narrower (~ 120 MeV wide) band centered at 1300 MeV, while the contribution from the 2-pronged events also includes an enhancement about 120 MeV wide centered at 1420 MeV, which is presumably due to the $K\pi$ decay of the $K^*(1420)$ resonance. We interpret this difference as evidence against the $K\pi$ decay mode of the $K^*(1250)$ - $K^*(1320)$ resonance system, which is not resolved in this data.

Bartsch et al.[1] have reported the existence of an L-meson of mass $M = 1789 \pm 10$ MeV and width $\Gamma = 80 {+20 \atop -40}$ MeV in the final state $(K\pi\pi)^-$ in the reactions

$$K^-p \rightarrow K^-p\pi^+\pi^- \quad \text{and} \quad K^-p \rightarrow K^0p\pi^0\pi^-$$

at 10 BeV/c. We interpret our experiment as a confirmation of the existence of a large enhancement in the region of the L-meson, however in these preliminary results we have not as yet been able to determine if there is any significant internal structure for the L-meson enhancement. To ascertain the effect of the resolution on the overall width of this peak, we have studied the ideogram of the missing mass for events with stopping protons, and have observed the full width at half maximum of this peak to be no wider than 120 MeV.

In order to investigate the missing mass for events with larger four-momentum transfer to the proton than $0.25\ (\text{BeV/c})^2$, we have studied events in which the proton momentum is sufficiently low ($<$ 1 BeV/c) to allow the proton to be identified by ionization. Although these events have poorer resolution than the stopping protons, they display essentially the same structure as the events with stopping protons except that the missing mass may here be as large as 3.2 BeV. A study of the mass distributions and the Chew-Low plots gives no indication that the peak at 1740 MeV is part of a larger structure which extends to higher masses and four-momentum transfers to the proton; an effect which would not appear in the stopping protons alone.

We thank R. Shutt and the staff of the 80-inch bubble chamber and H. Foelsche and the AGS staff for helping with the exposure. We thank H. White and the FSD staff for their assistance in processing the film, and acknowledge the valuable support given by our scanning and programming staff, in particular E. R. Burns.

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

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FIGURE CAPTIONS

Fig. 1. The fitted mass of the neutral track from the 2-constraint fit for the 2-pronged events with vee.

Fig. 2. Missing mass distribution for all 2-pronged and 4-pronged interactions with stopping protons vs the error in the missing mass.

Fig. 3. Missing mass distribution for all 2-pronged and 4-pronged interactions with stopping protons. The insert shows the detailed structure for inelastic interactions.

Fig. 4. Missing mass distribution for (a) all 2-pronged, and (b) 4-pronged interactions with stopping protons.

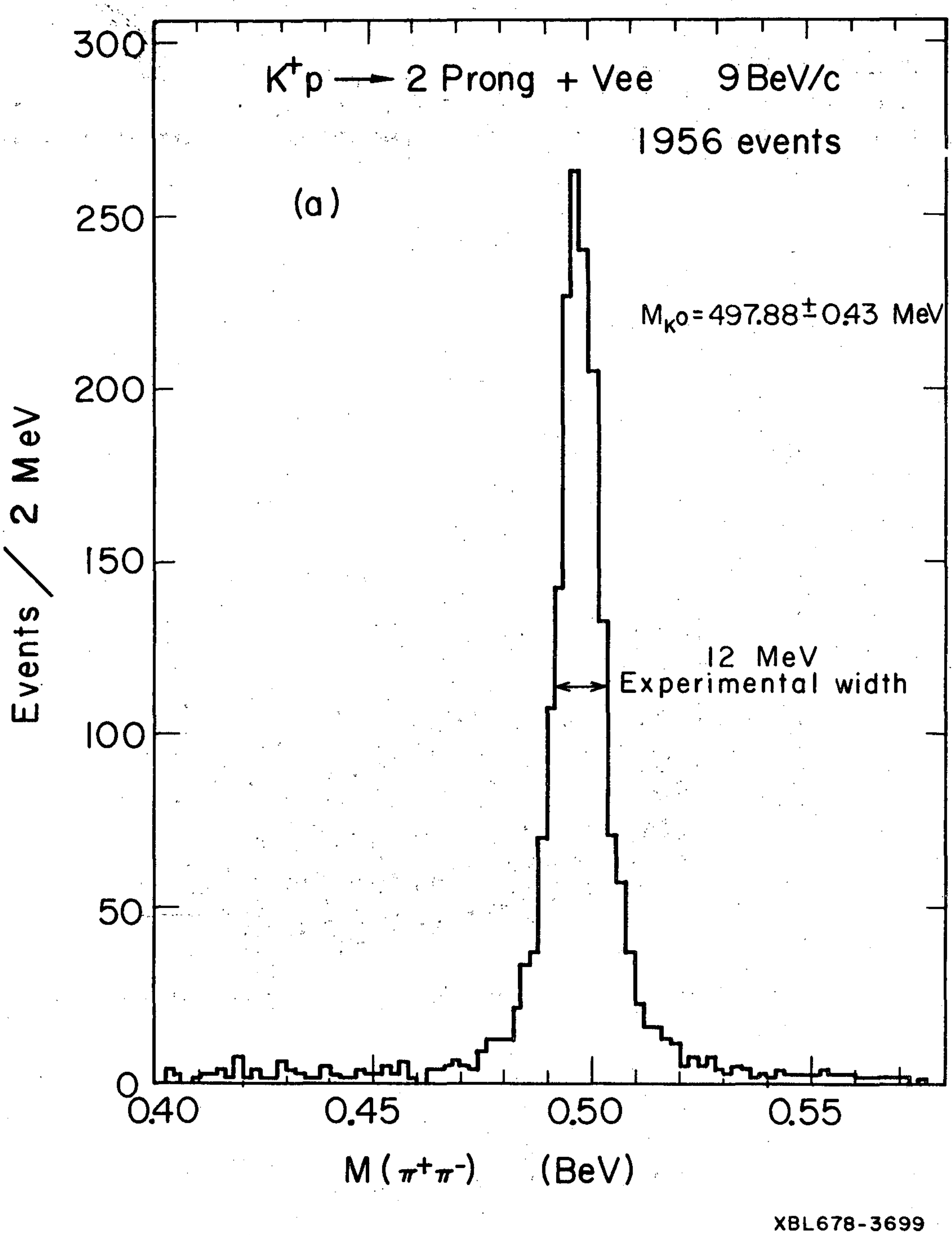
K⁺p ⟶ 2 Prong + Vee 9 BeV/c
1956 events
(a)
M$_{K^0}$ = 497.88 ± 0.43 MeV
12 MeV
Experimental width
Events / 2 MeV
300
250
200
150
100
50
0
0.40
0.45
0.50
0.55
M ($\pi^+\pi^-$) (BeV)
XBL678-3699

Fig. 1

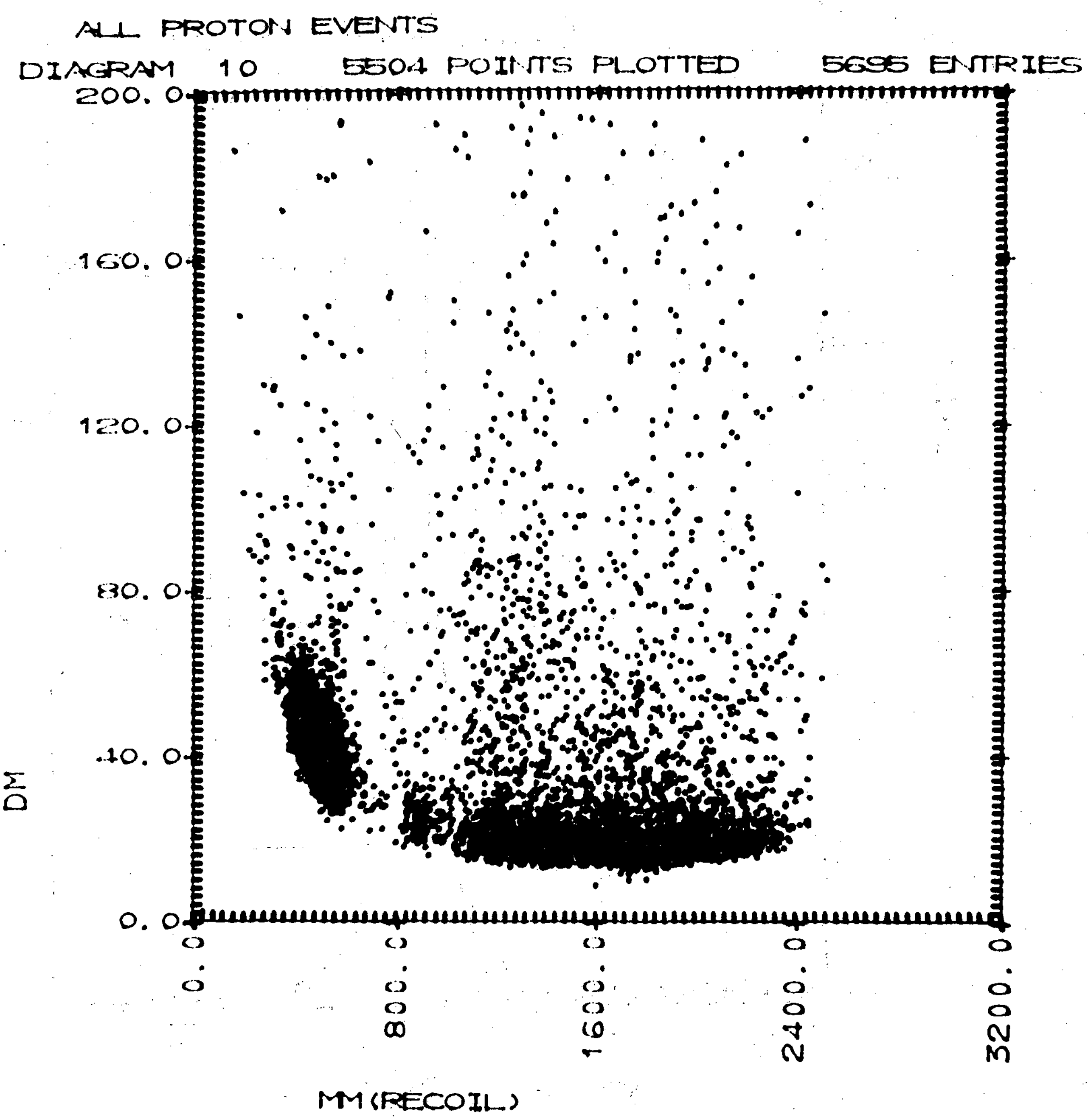
ALL PROTON EVENTS
DIAGRAM 10 5504 POINTS PLOTTED 5696 ENTRIES
200.0
160.0
120.0
80.0
40.0
0.0
DM
0.0
800.0
1600.0
2400.0
3200.0
MM(RECOIL)

Fig. 2

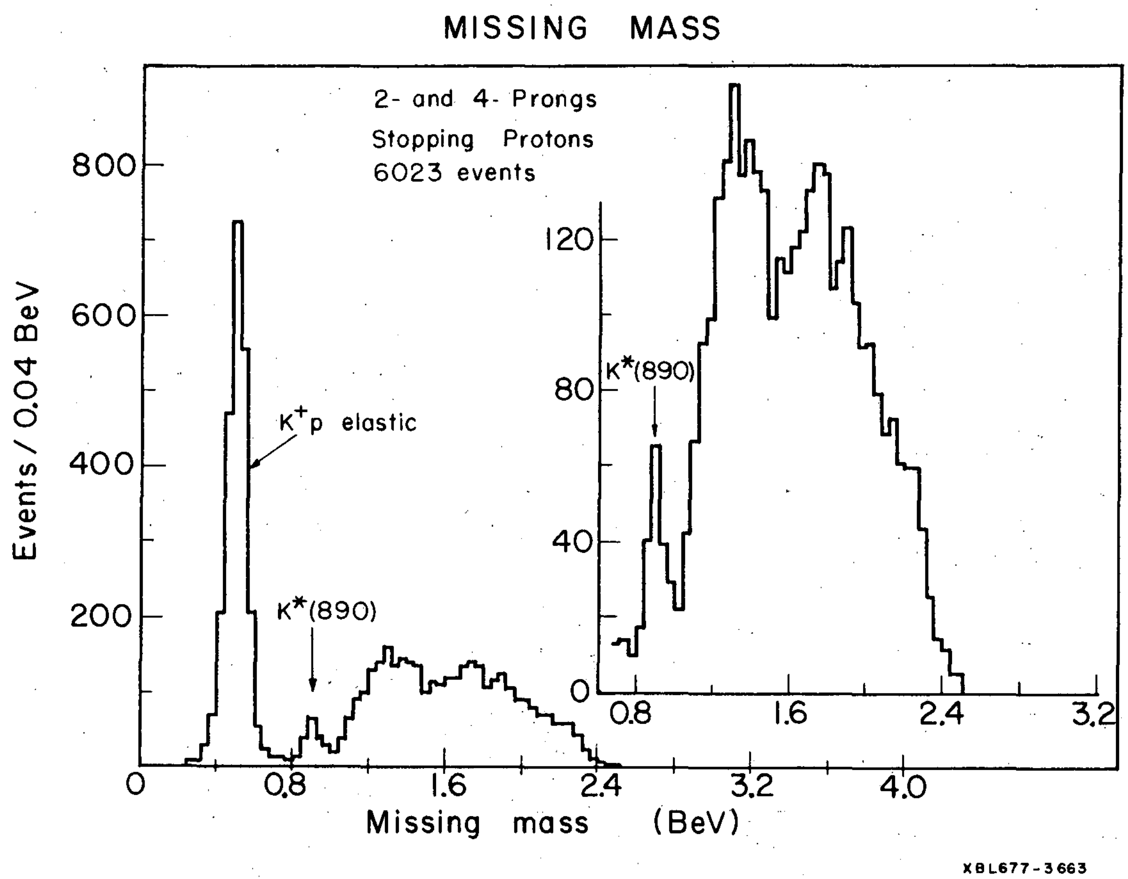
MISSING MASS
2- and 4- Prongs
Stopping Protons
6023 events
Events / 0.04 BeV
800
600
400
200
0
K+p elastic
K*(890)
120
80
40
0
K*(890)
0.8
1.6
2.4
3.2
0.8
1.6
2.4
3.2
4.0
Missing mass (BeV)
XBL677-3663

Fig. 3

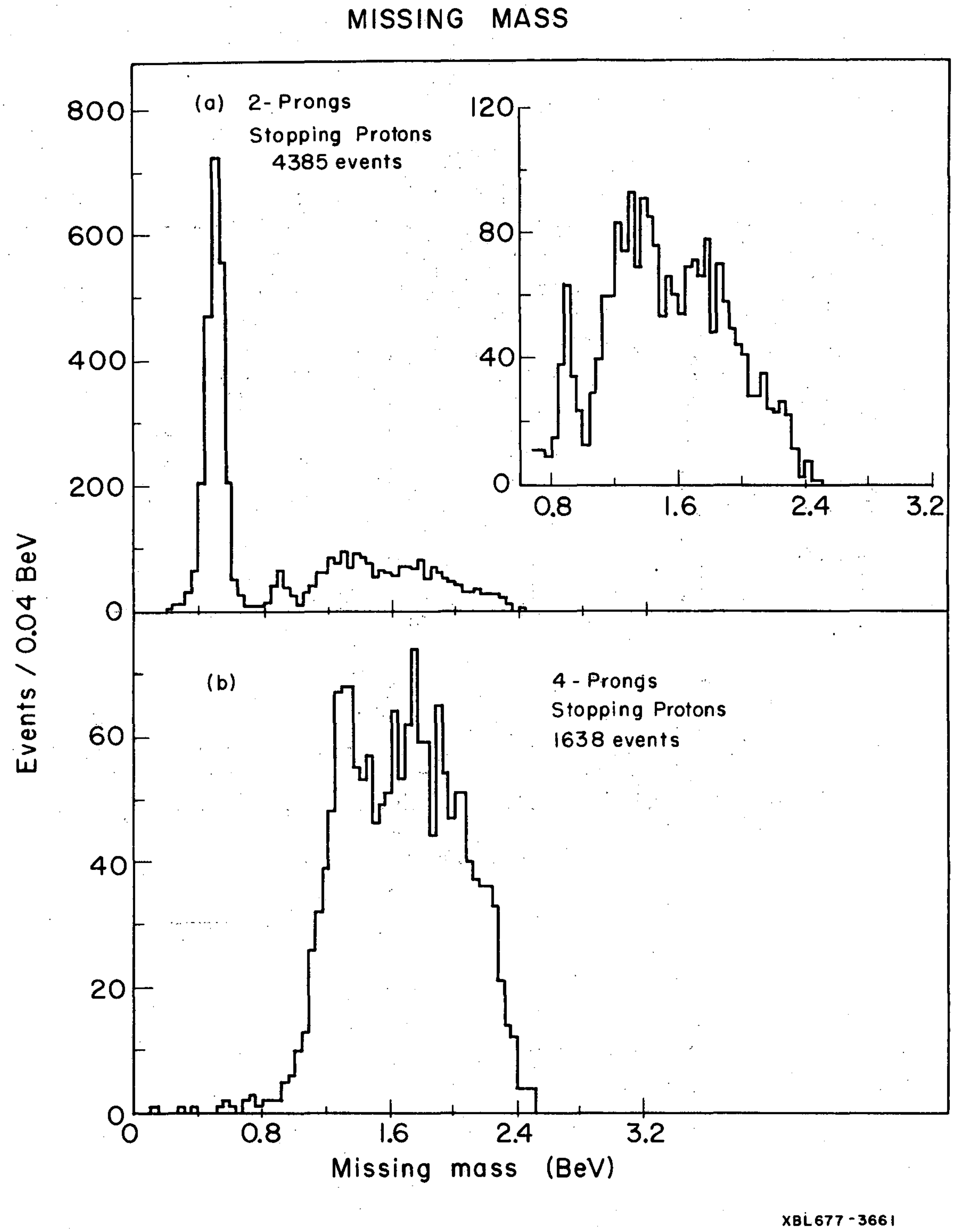
MISSING MASS
(a) 2-Prongs
Stopping Protons
4385 events
(b)
4 - Prongs
Stopping Protons
1638 events
Events / 0.04 BeV
Missing mass (BeV)
0
0.8
1.6
2.4
3.2
800
600
400
200
120
80
40
60
20
XBL677-3661

Fig. 4