CERN/TC/PHYSICS 62-10
20-7-1962

INTERACTIONS OF 1.47 GeV/c NEGATIVE K-MESONS IN HYDROGEN

CERN : W.A. Cooper, H. Courant*, H. Filthuth, A. Minguzzi-Ranzi, H. Schneider+, A.M. Segar**, G.A. Snow++, W. Willis***

Amsterdam : E.S. Gelsema, J.C. Kluyver, A.G. Tenner

Glasgow : K. Browning, I.S. Hughes, R. Turnbull

* FORD Foundation Fellow

\+ On leave from University Hamburg, Germany

** On leave from Rutherford Laboratory, Harwell, England

++ National Science Fundation Senior Postdoctoral Fellow, on leave from Physics Dept., University of Maryland, College Park, Md.

*** FORD Foundation Fellow, on leave from Brookhaven National Laboratory, Upton, N.Y.

PS/3378/jc

I. INTRODUCTION

With the CERN 32 cm hydrogen bubble chamber 190,000 photographs have been taken in a separated K^--meson beam of $1.47 \pm .02$ GeV/c momentum*), corresponding to 2.01 GeV total energy in the $K^- - p$ centre of mass system. In the single stage beam design a 9 m long electrostatic separator was used. One achieved a rejection ratio of π^-- mesons against K^- -mesons of $\sim 10^4$. The purity of the beam was 60 o/o - 70 o/o, the background consisting mainly of μ-mesons[1]. The picture contain in average 7 K^- - mesons, so that there are about 1000 events per mb cross section. We are analysing the pictures for $K^- - p$ interactions producing at least one visible strange particle decay and at least one other charged track. Nearly all the pictures have been scanned and about 1000 events have been measured. We are reporting on a subset of 500 analysed events. All the measurements reported here have been analyzed with the GAP-GRIND geometry and kinematic fitting programmes of CERN. All identifications given by the programme were checked for agreement with estimates of bubble density.

II. CROSS SECTIONS

A preliminary estimate of some of the partial cross sections is summarized in table 1. The numbers were obtained by normalizing the K^- - flux entering the chamber to the number of visible τ^- - meson decays. The dominant cross sections are $\Lambda^o\ 2\pi$, $\Sigma^{\overset{o}{\pm}}\ 2\pi$, $\Lambda^o\ 3\pi$, $\overline{K^o}\ \pi^- p$.

III. SIGMA-PION RESONANCES

a) Reactions $\Sigma^{\pm}\ \pi^{\mp}\ \pi^o$ and $\Sigma^{\pm}\ \pi^{\mp}\ \pi^-\pi^+$ have been studied for the presence of $\Sigma\ \pi$ resonances. In principle resonant states of isotopic spins 0, 1 and 2 could be present in these reactions. From the four body reaction there is no evidence for a doubly-charged $\Sigma\pi$ isobar. However, both reactions seem to show strong charge zero resonant states.

---

*) The uncertainty in the momentum includes a possible systematic error. The actual momentum spread is $\Delta p = \pm 0.01$ GeV/c.

- TABLE I -

$(K^- p)$ PARTIAL CROSS SECTIONS AT 1.47 ± 0.02 GeV/c

$\mu = 2.01$ GeV/c.

$\Lambda^0\pi^+\pi^-$	2.0 ± 0.3
$\Lambda^0\pi^+\pi^-\pi^0$	1.8 ± 0.3
$\Sigma^0\pi^+\pi^-$	1.2 ± 0.3
$\Lambda^0\pi^+\pi^-2\pi^0$, $\Sigma^0\pi^+\pi^-\pi^0$	0.2 ± 0.2
$\Sigma^+\pi^-$	0.9 ± 0.1
$\Sigma^+\pi^-\pi^0$	1.2 ± 0.2
$\Sigma^-\pi^+$	0.4 ± 0.1
$\Sigma^-\pi^+\pi^0$	0.9 ± 0.2
$\Sigma^+\pi^-\pi^+\pi^-$	0.2 ± 0.04
$\Sigma^-\pi^+\pi^+\pi^-$	0.1 ± 0.04

$\bar{K}^0 p\pi^-$	2.0 ± 0.3
$\bar{K}^0\pi^+\pi^- n$, $\bar{K}^0 p\pi^+\pi^-$	0.3 ± 0.1
Σ^0 / Λ^0 $\pi^+\pi^-\pi^+\pi^-$, $\bar{K}^0 p\pi^+\pi^-\pi^+$	0.05 ± 0.02
$\Xi^- K^+$	0.18 ± 0.04

Fig. 1, 1a, 1b show the mass distribution of the zero charge $\Sigma\pi$ states in the three-body reactions. All events consistent with the assignments $\Sigma^{\pm}$ $\pi^{\mp}$ π^{0} have been included in this plot, with the weight appropriate to their detection efficiency. The contamination of $\Sigma^{\pm}$ $\pi^{\mp}$ $2\pi^{0}$ events was estimated to be less than 5 o/o. Since the errors vary from event to event, the plot in the figure is in the form of a constant area ideogram, representing 140 events.

The previously identified I = 0 resonant states [3], at masses of 1.40 and 1.52 GeV, seem to dominate these three-body reactions. The proximity of these two resonant masses, combined with our resolution for this class of event, make it difficult to evaluate the exact relative strengths of the two resonances and of the background, but Y_0^{*} and Y_0^{**} each represents $\sim$25 o/o of these events.

Also indicated is a peaking in the mass spectrum at 1.67 GeV with a width about equal to our resolution, $\pm$ 30 MeV. An indication of a resonance in this region arises in the reaction $\pi^{-} + p \rightarrow Y + K + \pi$ [4]. If this resonance is an I = 1 state, it should appear in the charged $(Y\pi)$ systems. However with our present statistics, it is not possible for us to determine the I spin. We have searched for it in the $\Lambda\pi^{+}\pi^{-}$ reaction, with no conclusive result since, as seen in Fig. 2, that reaction is dominated by the 1.385 GeV Y_1^{*} isobar, which generates a secondary peak in the 1.67 GeV mass region. We also looked at the $\Sigma^{\pm}$ π^{0} mass spectrum and again, in the region of interest around 1.67 GeV, there is a large background of events from the Y_0^{**} production and it is not possible to see any other resonant peak. The $\Sigma^{0}\pi^{+}\pi^{-}$ reaction might contain this resonant state free of contamination from other known hyperon pion resonances but with our statistics to date, only 41 events, it is not possible to say whether any resonance is present or not. One other factor complicating the interpretation of Y^{*} resonances is the possible presence of ρ production which would interfere with all the Y^{*} + π reactions.

b) We have analyzed 79 four-body reactions of the type $\Sigma^{\pm}\pi^{\mp}\pi^{+}\pi^{-}$. This class of events is attractive in searching for a $Y\pi$ resonant state with I = 2. But the mass distribution of the doubly charged $\Sigma\pi$ system shows no significant peaking. The Fig. 3 shows the $(\Sigma^{\pm}\pi^{\mp})$ mass distribution, and again the 1.40 and 1.52 GeV resonances seem to be present. The 1.52 GeV resonance has an apparent width comparable to our experimental resolution, while the 1.40 GeV resonance seems to have a larger width. The Y_0 resonances also manifest themselves in the K.E. distribution of the pions. The spectrum of the pions of charge opposite to that of the Σ is enhanced in the low energy region, perhaps due to the contributions of decay pions from the Y_0^* and Y_0^{**}, while the same charge pion spectrum shows an enhancement in the high energy region. These plots, shown in Figs. 4 and 5 can also be interpreted in terms of the mass of the $(\Sigma\,\pi\pi)$. The detailed analysis of this reaction is in principle extremely complicated due to the possible importance of the Peierls mechanism[5] in which two pions are simultaneously in resonance with the Σ.

IV. THE $\Lambda^0\pi^+\pi^-\pi^0$ REACTION

We have completed the analysis of 66 events of this type. This sample could contain a contamination of $\Sigma^0\pi^+\pi^-\pi^0$, and we estimate this effect to be less than 20 o/o.

Fig. 6 shows the mass distribution of the $\pi^+\pi^-\pi^0$ system for this reaction. The ω peak is clearly in evidence, occuring in $\gtrsim$ 50 o/o of all reactions. The peak occurs at 786 $\pm$ 5 MeV and the apparent width is of the order of our experimental resolution, $\pm$ 13 MeV. The $\Lambda^0\omega$ reaction completely overshadows any Y^* production in this channel, and indeed we find no evidence for such production in our events. This strong ω production may also explain the large size of the $\Lambda\pi^+\pi^-\pi^0$ cross section compared with the other four-body cross sections. As yet there is no evidence for $\Lambda\eta$ production in this channel.

V. ANGULAR DISTRIBUTIONS OF "TWO-BODY" REACTIONS

The Figs. 7,8,9 and 10 give the C.M. angular distribution of the pion in the two-body channels $\Sigma^+\pi^-$, $\Sigma^-\pi^+$, and in the pseudo two-body channels $Y_1^{*\pm}\pi^{\mp}$ and $Y_0^*\pi^0$. In all cases the distributions show a forward peaking of the pion, but the peaking is more pronounced when the baryon charge is positive or zero. The angular distributions in the channels $Y_0^{**}\pi^0$ and the 1.67 GeV resonance + π^0 are consistent with isotropy, but in these cases this may simply be due to the lower relative momentum in the $Y^*\pi$ system, which restricts the possible partial waves which can contribute.

VI. THE $\overline{K}^{o}$ p π^- REACTION

This reaction goes almost entirely by the p K^{*-} channel, as is seen in Fig. 8, the mass spectrum of the $\overline{K}^{o}\pi^-$ system. About 80 o/o of the events fall in the peak of the K^* of mass 885 MeV, and we have no events in the 730 MeV mass region where Alexander et al. [6] observe another Kπ resonance. The observed full width of the K^* peak is 60 MeV, but there is a suggestion in our data that the K^* peak is broader in the region of the Dalitz plot where it overlaps the π^-p (3,3) resonance than elsewhere. Although there is no clear evidence for the presence of the (3,3) nucleon-pion resonance, the intrinsic width and mass of the K^* resonance could be less than the values quoted above because of this effect. The angular distribution of the protons in the p K^{*-} reaction slightly favours the backward direction, but our statistics do not yet allow us to make a K^* spin analysis in the manner suggested by A.B. Bég and P.C. De Celles [7].

ACKNOWLEDGEMENTS

We would like to acknowledge the invaluable help of our colleagues G. Amato, R. Böck, B. Czapp, R. Frachet, W. Haldemann, E. Malamud, G. Otter, R. Perret and D. Plane and the cooperation of the Data Handling Groups and the Machine Group at CERN. Finally we wish to thank Prof. Ch. Peyrou for his support of this experiment.

REFERENCES :

1) A One-Stage Separated Beam at the CERN P.S.
Instrumentation Conference, CERN, 1962.

2) GRIND. 709 Kinematics Program.
DD/ExP/62/10 (CERN).

3) M.H. Alston, L.W. Alvarez, P. Eberhard, M.L. Good, W. Graziano, H.K. Ticho and S.G. Wojcicki
Phys. Rev. Letters 6, 698 (1961).

4) G. Alexander, L. Jacobs, G.R. Kalbfleisch, D.H. Miller, G.A. Smith, J. Schwartz
Study of Strange-Particle Resonant States Produced in 1.89 - 2.24 GeV/c π^{-} + p Interactions, Paper submitted to the Eleventh International Conference on High Energy Physics at CERN (1962).

5) R.F. Peierls
Phys. Rev. 118, 325 (1960).

6) G. Alexander, G.R. Kalbfleisch, D.H. Miller and G.A. Smith
Phys. Rev. Letters 8, 447 (1962).

7) Mirza A.B. Bég and Paul C. De Celles
Phys. Rev. Letters 6, 145 (1961).

Figure Captions

Figure 1 - Distribution of the square of the mass for the $\Sigma^{\pm}\pi^{\mp}$ system, for the reactions leading to $\Sigma^{\pm} + \pi^{\mp} + \pi^{o}$.

Figure 2 - Kinetic energy in the C.M.S. for the charged pions from the reaction $K^{-} + p \rightarrow \Lambda^{o} + \pi^{+} + \pi^{-}$.

Figure 3 - Mass of the neutral combinations of Σ and π from $\Sigma^{\pm} + \pi^{\mp} + \pi^{+} + \pi^{-}$ states.

Figure 4 - Kinetic energy in the C.M.S. for the pions with charge opposite to that of the Σ, in the $\Sigma^{\pm} + \pi^{\mp} + \pi^{+} + \pi^{-}$ states.

Figure 5 - Kinetic energy in the C.M.S. for the pions with charge equal to that of the Σ, in the $\Sigma^{\pm} + \pi^{\mp} + \pi^{+} + \pi^{-}$ states.

Figure 6 - Mass distribution of the $\pi^{+}\pi^{-}\pi^{o}$ system from the $\Lambda^{o}+\pi^{+}+\pi^{-}+\pi^{o}$ reactions.

Figure 7 - Angular distributions of the pions in the reactions leading to

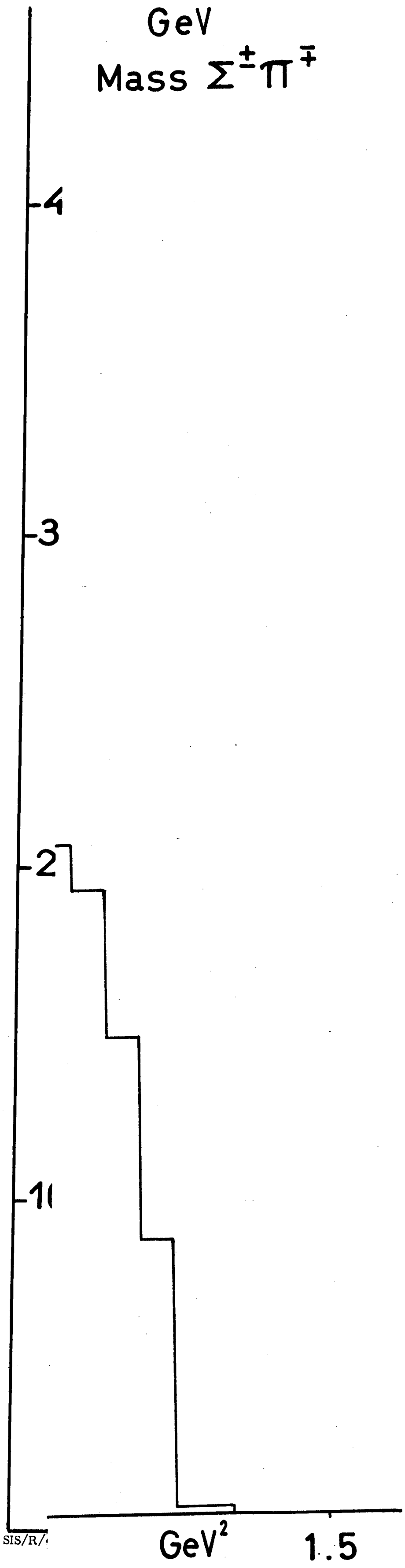
a) $\Sigma^{+} + \pi^{-}$

b) $\Sigma^{-} + \pi^{+}$

c) $Y_{o}^{*} + \pi^{o} \rightarrow \Sigma^{\pm} + \pi^{\mp} + \pi^{o}$

d) $Y_{1}^{*} + \pi^{\pm} \rightarrow \Sigma^{o} + \pi^{+} + \pi^{-}$.

Figure 8 - Kinetic energy distribution, in the C.M.S., for the protons from the reaction $K^{-} + p \rightarrow \overline{K^{o}} + \pi^{-} + p$.


GeV
Mass Σ±π∓
4
3
2
1(
SIS/R/
GeV²
1.5

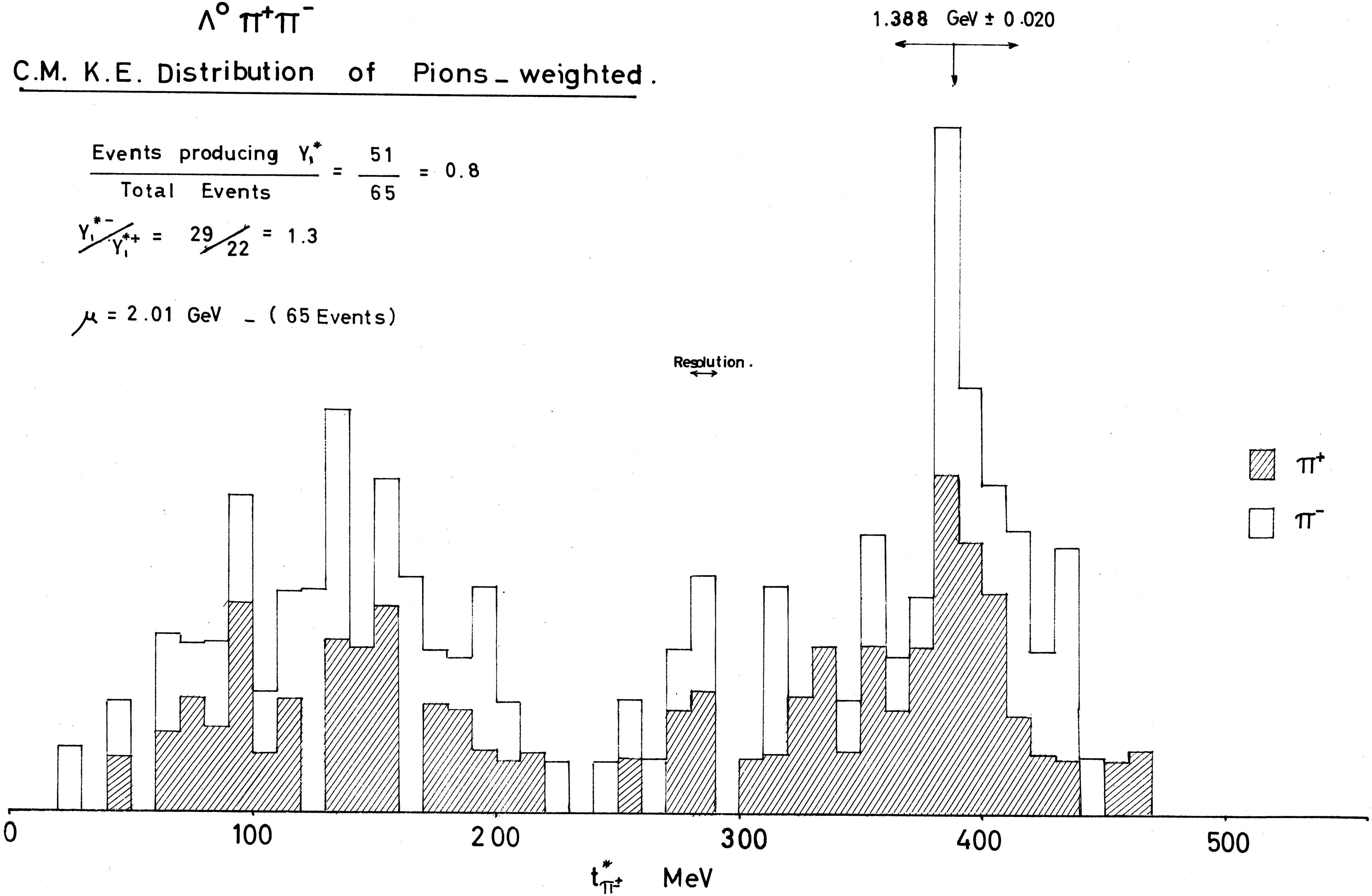
$\Lambda^0 \pi^+ \pi^-$

C.M. K.E. Distribution of Pions – weighted.

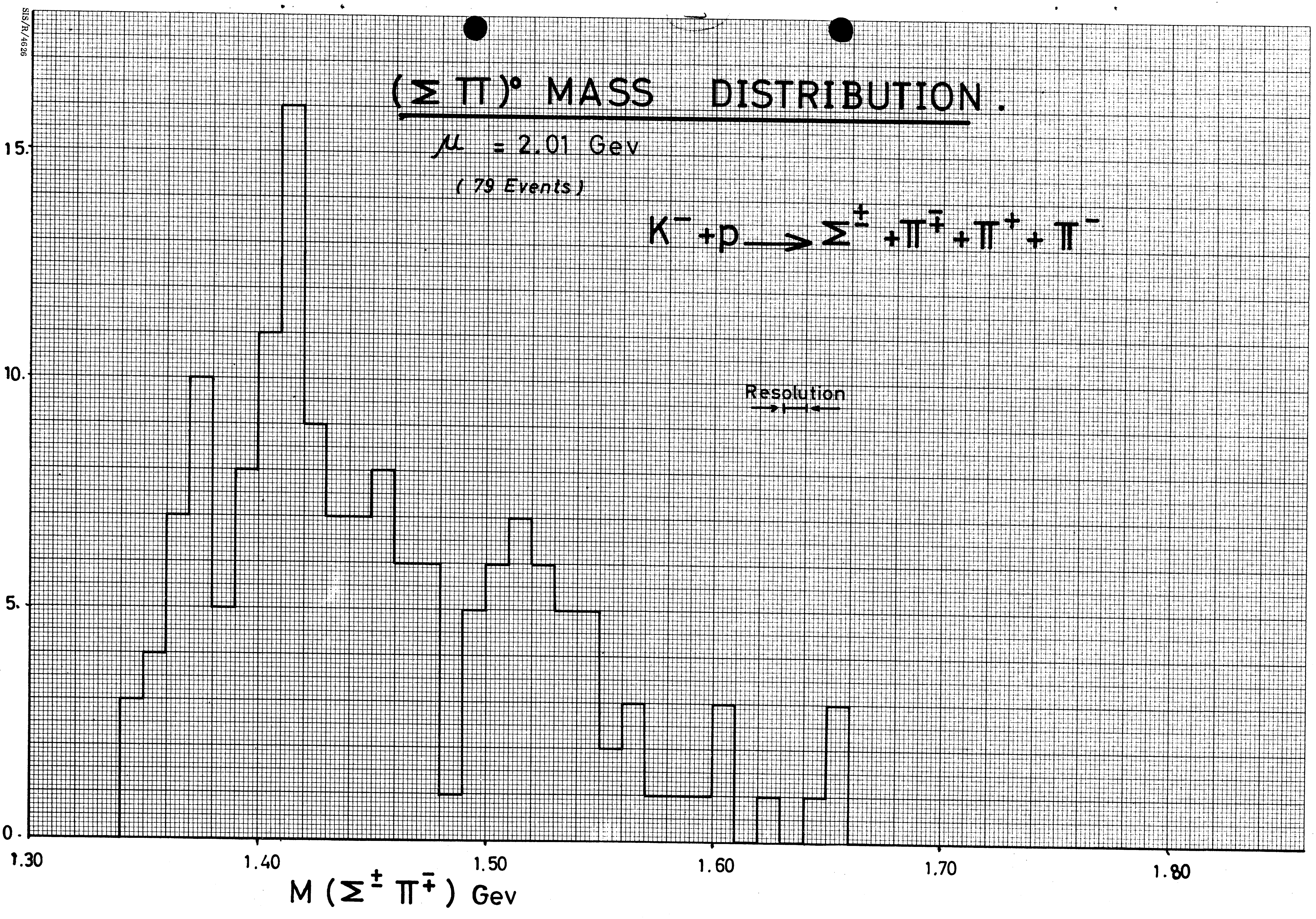
$\frac{\text{Events producing } Y_1^*}{\text{Total Events}} = \frac{51}{65} = 0.8$

$Y_1^{*-} / Y_1^{*+} = 29/22 = 1.3$

$\mu = 2.01$ GeV – (65 Events)

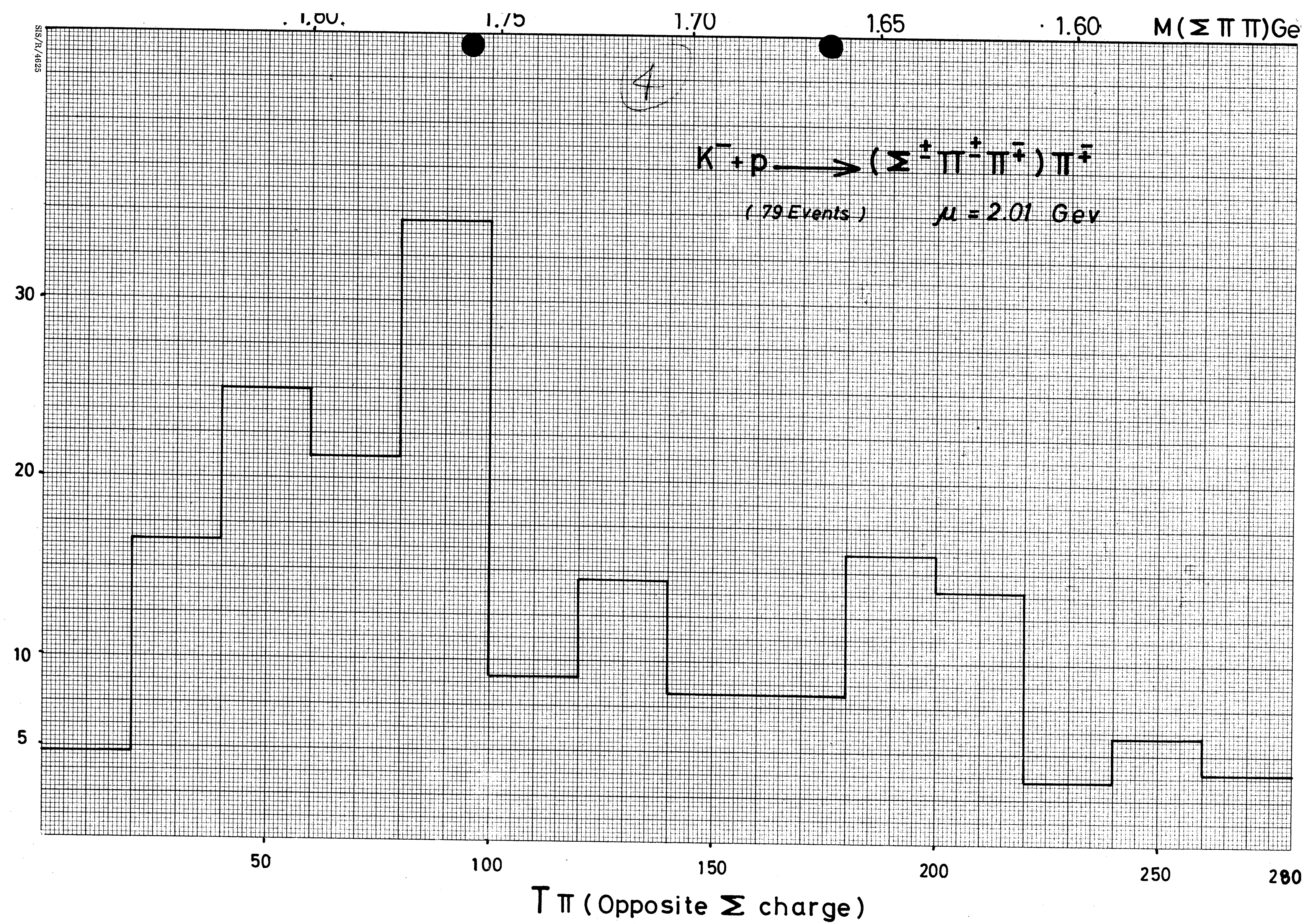


SIS/R/4621



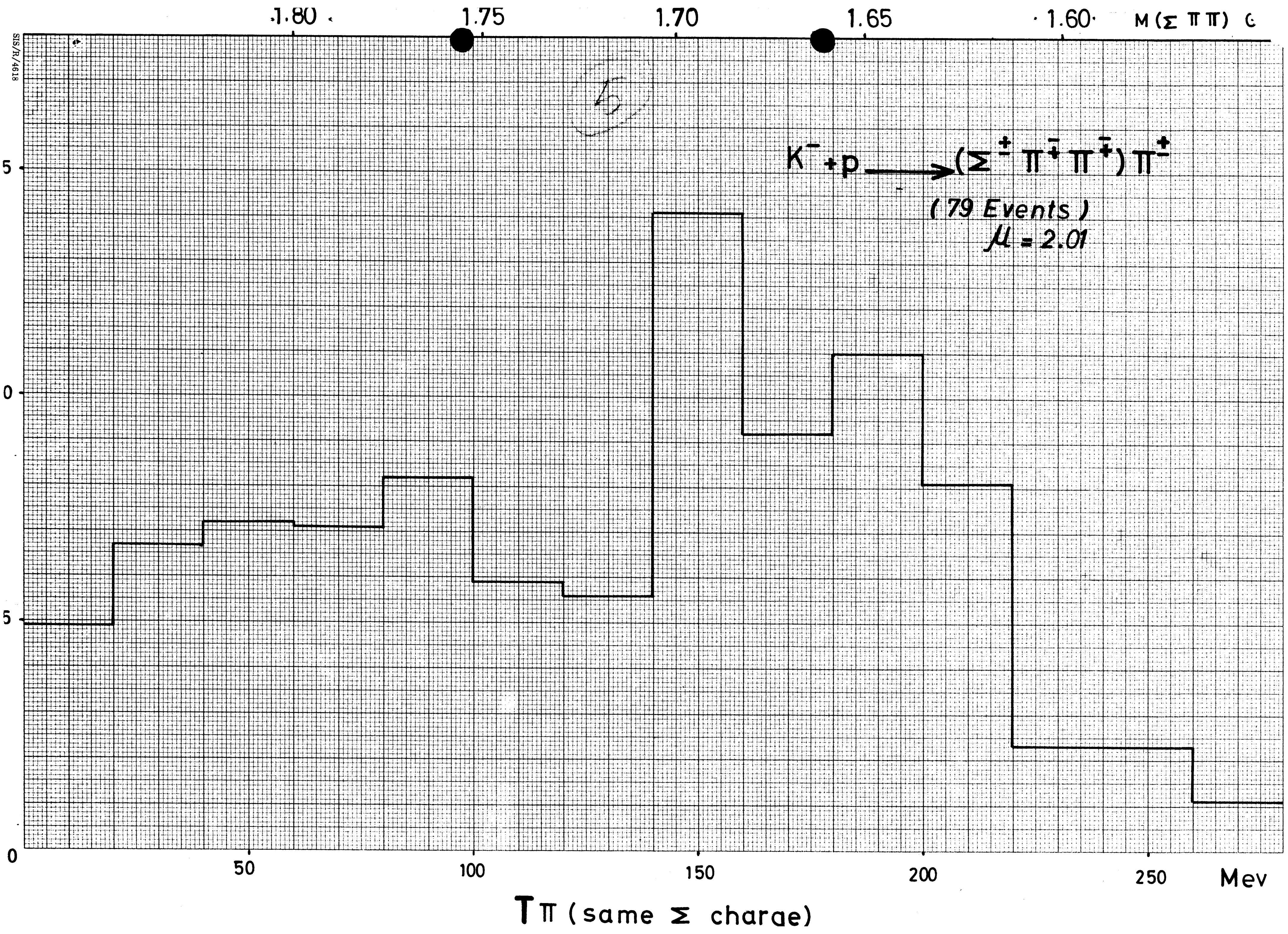
(Σ π)° MASS DISTRIBUTION.
μ = 2.01 Gev
(79 Events)
$K^- + p \longrightarrow \Sigma^\pm + \pi^\mp + \pi^+ + \pi^-$
Resolution
15.
10.
5.
0.
1.30
1.40
1.50
1.60
1.70
1.80
M ($\Sigma^\pm$ $\pi^\mp$) Gev

SIS/R/4626



. 1.80.
1.75
1.70
1.65
. 1.60
M(Σ π π)Ge
4
$K^- + p \longrightarrow (\Sigma^{\pm} \pi^{\pm} \pi^{\mp}) \pi^{\mp}$
(79 Events)
$\mu = 2.01$ Gev
30
20
10
5
50
100
150
200
250
280
Tπ (Opposite Σ charge)

SIS/R/4625

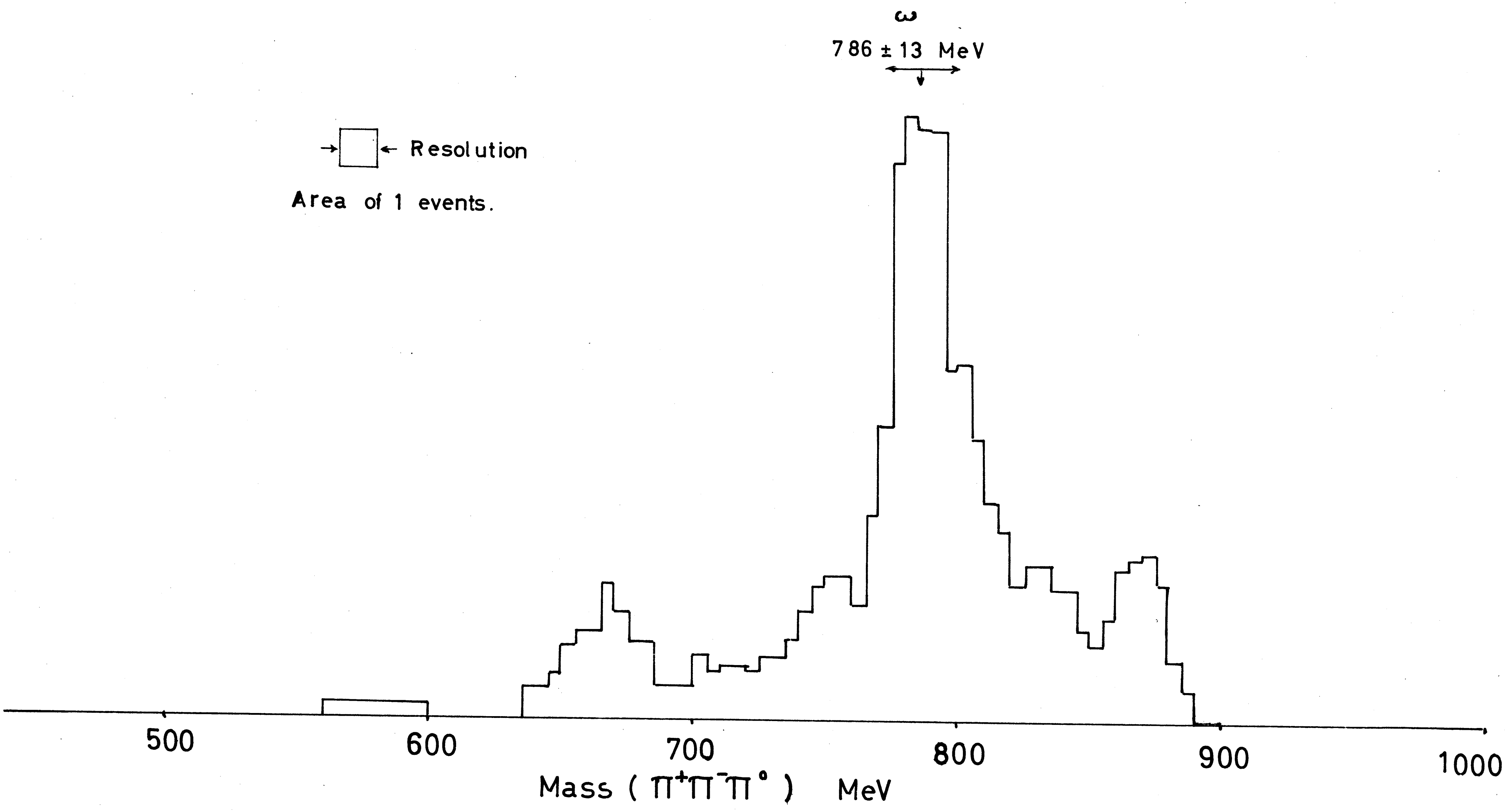


1.80
1.75
1.70
1.65
1.60
M(Σ π π)
K⁻ + p → (Σ± π∓ π∓) π±
(79 Events)
μ = 2.01
5
0
5
0
50
100
150
200
250
Mev
Tπ (same Σ charge)
SIS/R/4618

$\Lambda^0 \pi^+ \pi^- \pi^0$

Mass Distribution ($\pi^+ \pi^- \pi^0$)

$\mu = 2.01$ GeV (66 Events)

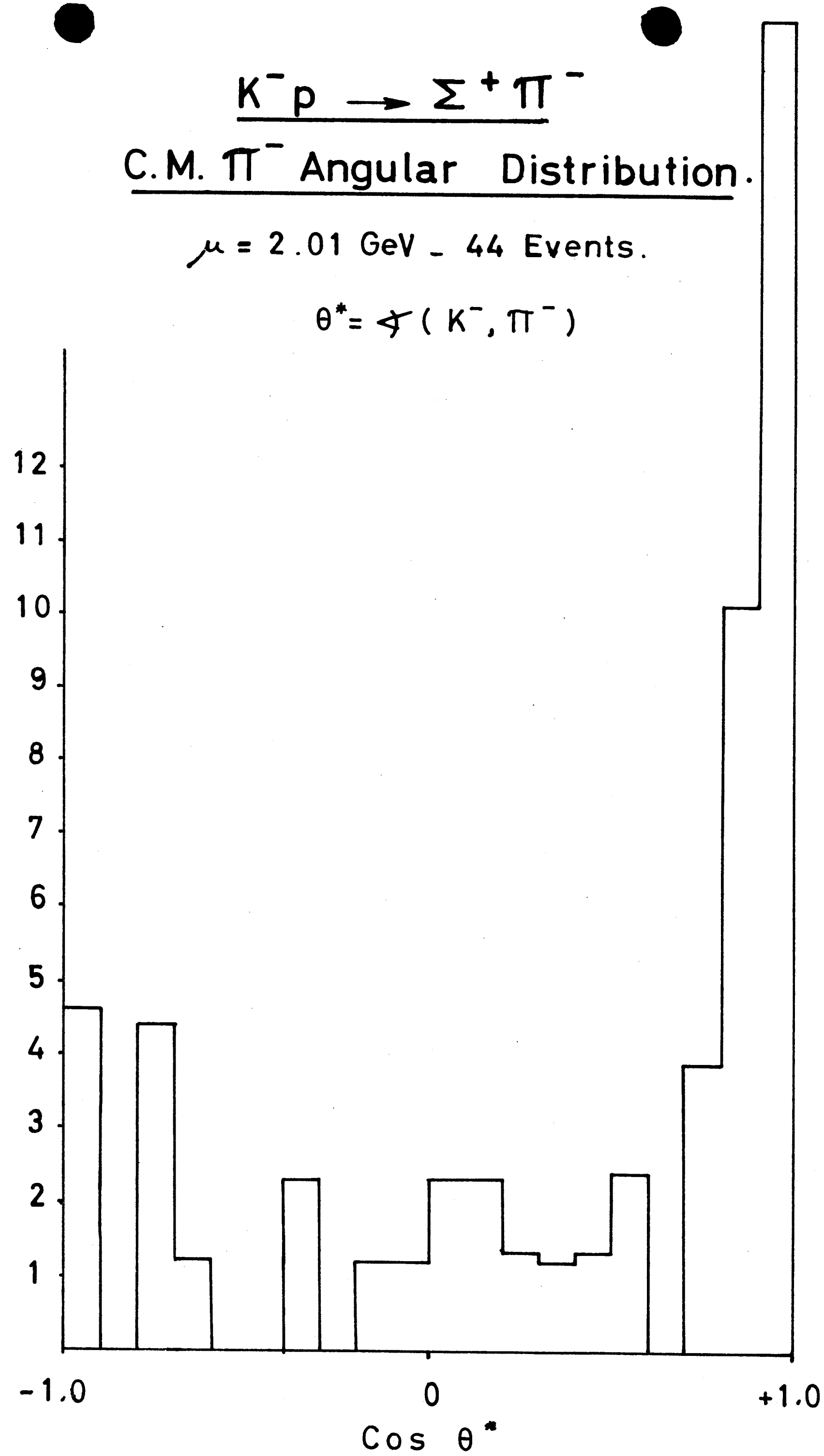


$K^- p \rightarrow \Sigma^+ \pi^-$

C.M. π^- Angular Distribution.

μ = 2.01 GeV _ 44 Events.

$\theta^* = \sphericalangle(K^-, \pi^-)$



SIS/R/4616

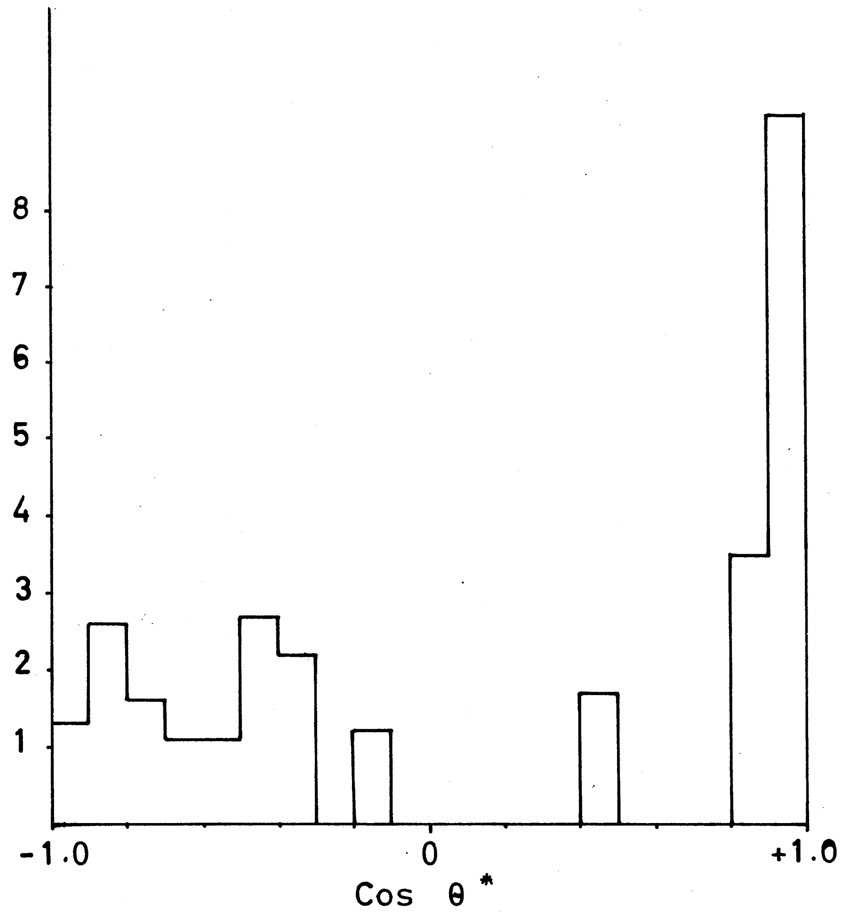
SIS/R/4621

$K^- p \longrightarrow \Sigma^- \pi^+$

C.M. π^+ Angular Distribution.

$\mu = 2.01$ GeV - 25 Events.

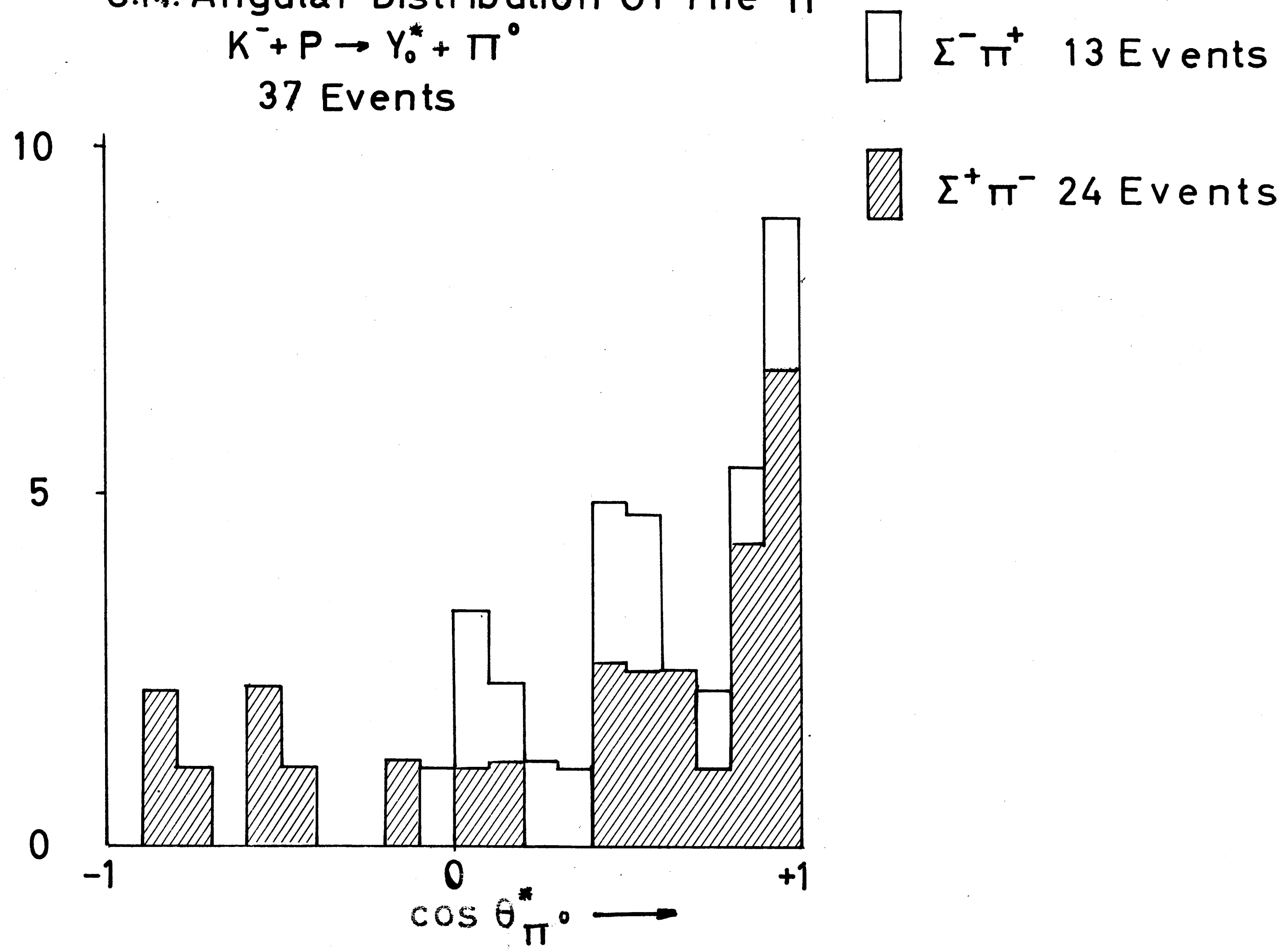
$\theta^* = \measuredangle (K^-, \pi^+)$



C.M. Angular Distribution Of The π^{o}

$K^{-} + P \rightarrow Y_{0}^{*} + \pi^{o}$

37 Events

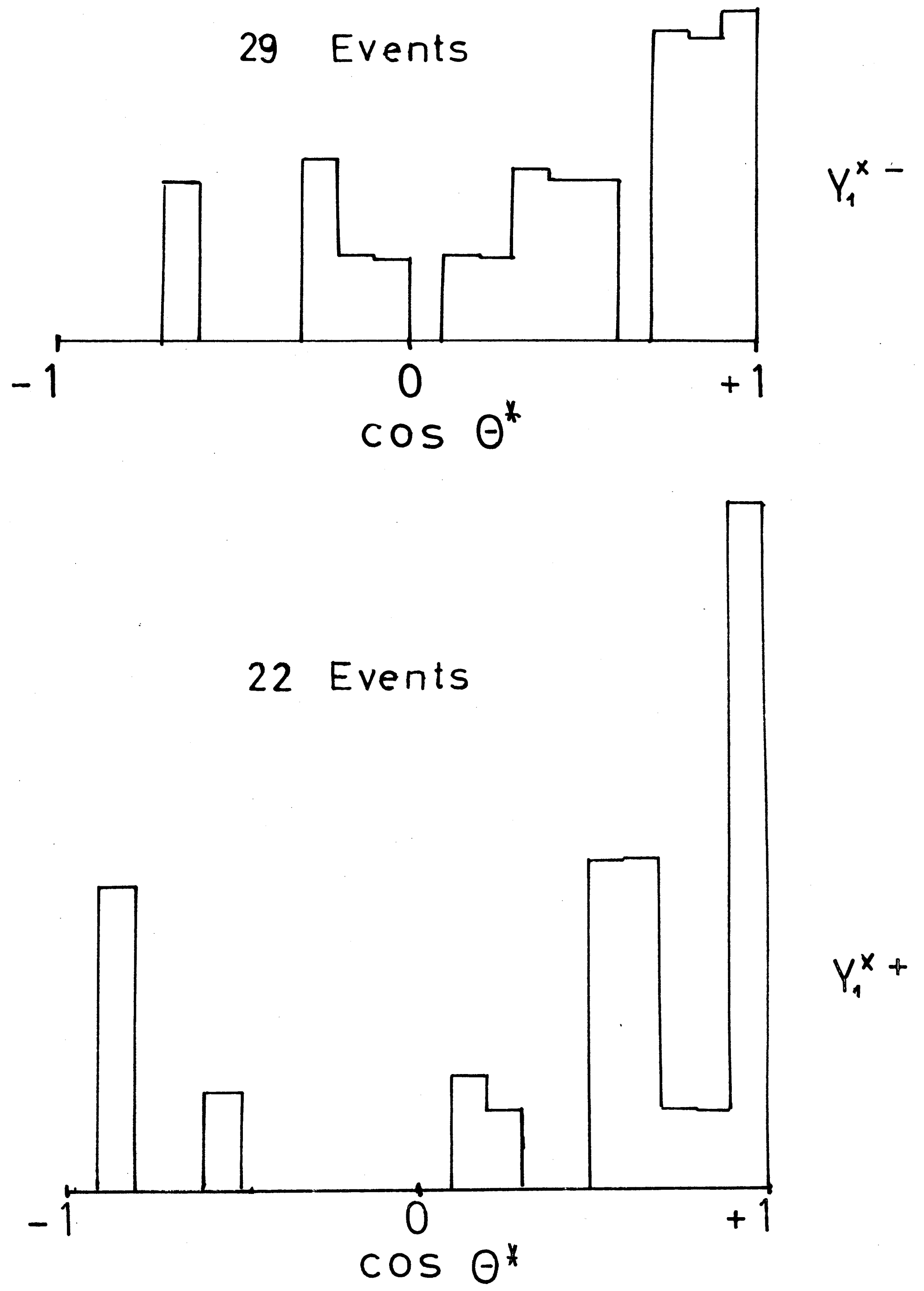


SIS/R/4623

Y_1^* C.M. ANGULAR DISTRIBUTION

$\Lambda^0 \pi^+ \pi^-$

$350 < t_{\pi} < 440$ MeV



Proton Kinetic Energy Distribution

$K^{-}p \longrightarrow p\bar{K}^{0}\pi^{-}$ (42 events)

μ = 2.01 GeV.

$K^{*}p$