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CHARM PHOTOPRODUCTION AND LIFETIMES FROM THE NA14/2 EXPERIMENT

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1. Introduction

This experiment combines a silicon active target, a silicon microstrip telescope allowing precise reconstruction of the charm vertices, and a large-acceptance spectrometer where charged tracks and photons are reconstructed.

Preliminary results are given on the observation of the decay of D^+ and D_s to $\phi\pi$, on the transverse momentum distribution of photoproduced D mesons, and on the measurement of D^0 and Λ_c lifetimes.

2. Apparatus (Figure 1)

This consists mainly of the spectrometer used in the previous NA14/1 photon hard-scattering experiment[1].

The tagged photon beam in the energy range 50–200 GeV/c interacts in a silicon target located in the first magnet (AEG). The momentum of the charged particles is measured in a silicon microstrip telescope and in 70 planes of multiwire proportional chambers (M) situated before and after the second magnet (Goliath); they are identified by two Cherenkov threshold counters C1 in Goliath (K threshold 10 GeV) and C2 after Goliath (K threshold 20 GeV). The photon energies are measured in three electromagnetic calorimeters (E1, E2, E3). The angular coverage for both neutral and charged particles is ± 250 mrad.

The main improvements for NA14/2 were (Figure 2):

i) The construction of a silicon active target[2]: 32 planes perpendicular to the beam, 5×4 cm area, 300 μm thickness, 200 μm spacing, 2 mm strips; each strip has an analog readout allowing the measurement of the evolution of the charged multiplicity in the target (steps due to charm decays, etc.) and the reconstruction of heavily ionizing nuclear fragments localizing the main vertex or a possible reinteraction point precisely.

ii) The design, development and construction of a silicon microstrip telescope[3] (the utility of which appears not to have been restricted to our experiment): 10 planes, 5×5 cm area, 450 μm thickness, 50 μm strips; it is equipped with a digital readout [threshold set at 0.35 minimum ionizing (m.i.)]. Owing to financial constraints (10 000 channels), two strips from different regions are connected to the same readout channel. The performance[4] matches expectation: 9937 channels working, 1 m.i. at 14 σ_{noise}; the transverse accuracy of one track extrapolated to the main vertex is 17 μm.

The trigger is on hadronic interactions of the photon and uses the last planes of the silicon active target and scintillator hodoscopes (H); it is 95% hadronic and provides an enrichment in charm of at least a factor of 2.

After a silicon prototype test in 1984, this experiment registered 17 million hadronic photon interactions in 1985–1986.

3. Analysis

As no microprocessor farm was available during the data taking, filters were necessary to reduce the number of events to be processed through the complete pattern reconstruction program. Three independent fast selections were made:

i) secondary vertices using the microstrips, retaining 16% of the events, most of the charmed events, and used for general charm studies;

ii) 'clean' silicon target, retaining 7% of the events and in particular all the coherent charm production;

iii) K^+K^- (or pK) in the second Cherenkov counter, retaining 7% of the events and giving an unbiased sample of $D_s \rightarrow KK\pi$ or $\Lambda_c \rightarrow pK\pi$.

Thus cross checks of the efficiencies are possible; moreover, 2.8 million raw data have now been directly processed on the 3081E emulators at CERN.

The three filters will be described in the following sections.

4. Secondary vertices' filter[5]

A fast pattern recognition is carried out in some multiwire proportional chambers and the link is made with the microstrips if a non-ambiguous silicon-target vertex is found (70% of the data).

Then:

a) pairs of tracks closer than 200 μm in space having a separation larger than 50 μm in the primary vertex plane are sought

or

b) pairs of tracks closer than 150 μm in space having a distribution $\sigma_x > 500$ μm or $\sigma_{yz} > 50$ μm are accepted.

This retains 16% of the triggers with a charm efficiency of about 70%.

Preliminary results on partial statistics show a large number (500) of D^0's (Figure 3) allowing the measurement of the transverse-momentum distribution of the D (Figure 4). It is seen that the shape is different for charm and for ordinary particles having the same mass (dotted line), and is in good agreement with naïve QCD expectations (given for two different masses of the c-quark).

The D^0 lifetime can be precisely measured using very clean subsamples (see Table 1).

5. Clean silicon-target filter[6]

The aim is to obtain one clean row in the target and to reject nuclear breakup with heavy ionization masking the event.

The conditions are:

i) a charged multiplicity measured in the target between 3.5 and 10 m.i. in only one row for the last 4 planes,

ii) at least 9 planes hit,

iii) a multiplicity bigger than 13 m.i. in not more than 3 planes.

This filter retains 7% of the triggers; only one half are hadronic and they are mainly low-multiplicity events; but it saves events even without spectrometer tracks at the main vertex (coherent, etc.). One such example is shown in Figure 5: D^+D^- production with only four tracks in the spectrometer and one grey track giving the main vertex.

The cleanliness of this filter allows the reconstruction of many decay modes with big combinatorial possibilities (cf. $D^0 \rightarrow K\pi\pi\pi$ in Figure 6) above a low background.

6. K^+K^- (or Kp) filter[7]

This filter requires two kaons or protons below threshold in the second Cherenkov counter ($6 < p_K < 20$ GeV, $p_p < 38$ GeV). It selects 7% of the triggers, and allows the study, for instance, of the full sample of ϕ's in the experiment. The $\phi\pi$ spectrum obtained with a cut on the proper time at 3.5×10^{-13} s is shown in Figure 7 and displays clean signals of the D^+ in this Cabibbo disfavoured mode as well as the charmed strange meson D_s.

Asking for a non-ambiguous proton ($21 < p_p < 38$ GeV), a clean Λ_c signal in the $pK\pi$ mode (Figure 8) is also obtained despite a very small flight-distance cut ($\Delta x > 1.5$ mm) and with only 1/3 of the statistics. The very preliminary lifetime obtained is: $1.6^{+0.6}_{-0.4}\, 10^{-13}$ s.

7. Conclusion

The microstrip telescope developed by the NA14/2 Collaboration has worked well and allows precise vertex reconstruction.

The silicon target gives an independent measurement of the two vertices for clean events; when nuclear breakup occurs, grey tracks still permit a good primary-vertex reconstruction and a better rejection of reinteractions.

Preliminary results (with 500 D^0) allow the measurement of the lifetime $\tau(D^0) = 4.43 \pm 0.37 \times 10^{-13}$ s. They show that D mesons are not produced as ordinary particles with the same mass, and give a p_T distribution of the D in good agreement with naïve QCD. Clean signals of D^+ and D_s^+ in $\phi\pi$ and $KK\pi$ decays, and Λ_c in $pK\pi$ decays have been observed, giving a preliminary lifetime measurement for the Λ_c of 1.6×10^{-13} s with $1/3$ of the statistics.

On the full sample, we expect more than 1000 reconstructed D^0's, 50 Λ_c, etc.

It seems difficult to compete with the statistics of Experiment E691 for lifetime measurements, but we shall have other systematics (silicon target added) and we are working in a complementary photon energy range (40–120 GeV/c), where the proportion of the various charmed particles is expected to be different.

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References

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Table 1

Channel	Flight/σ	Minimum decay time (s)	N_{signal}	$N_{backgr.}$	τ (10^{-13} s)
$D^0 \rightarrow K\pi$ (no D*) (K identified)	4	4×10^{-13}	85	40	4.42 ± 0.52
$D^0 \rightarrow K\pi$ (from D*)	1	2×10^{-13}	88	20	4.44 ± 0.53

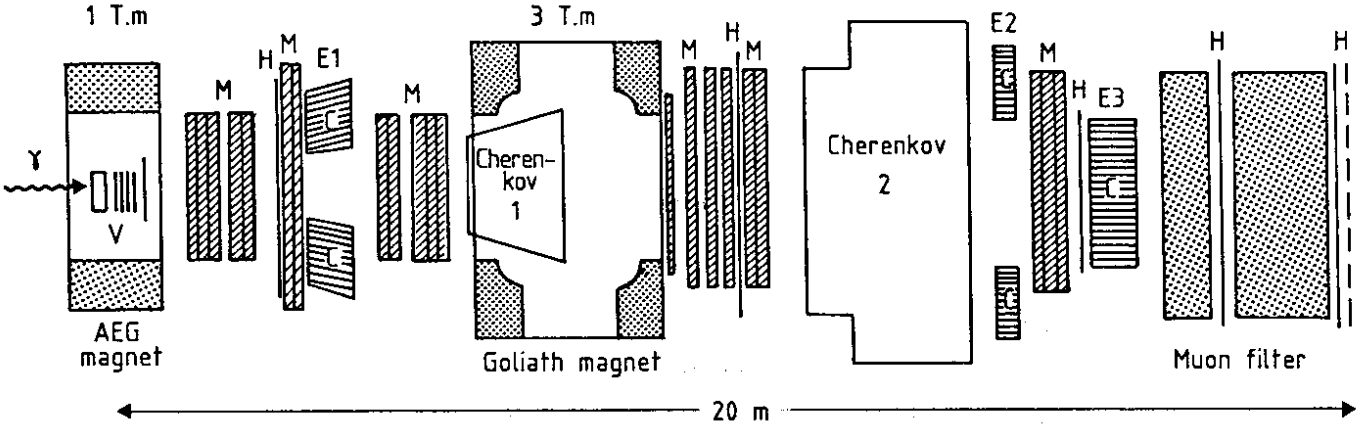

Figure 1 The NA14/2 spectrometer.

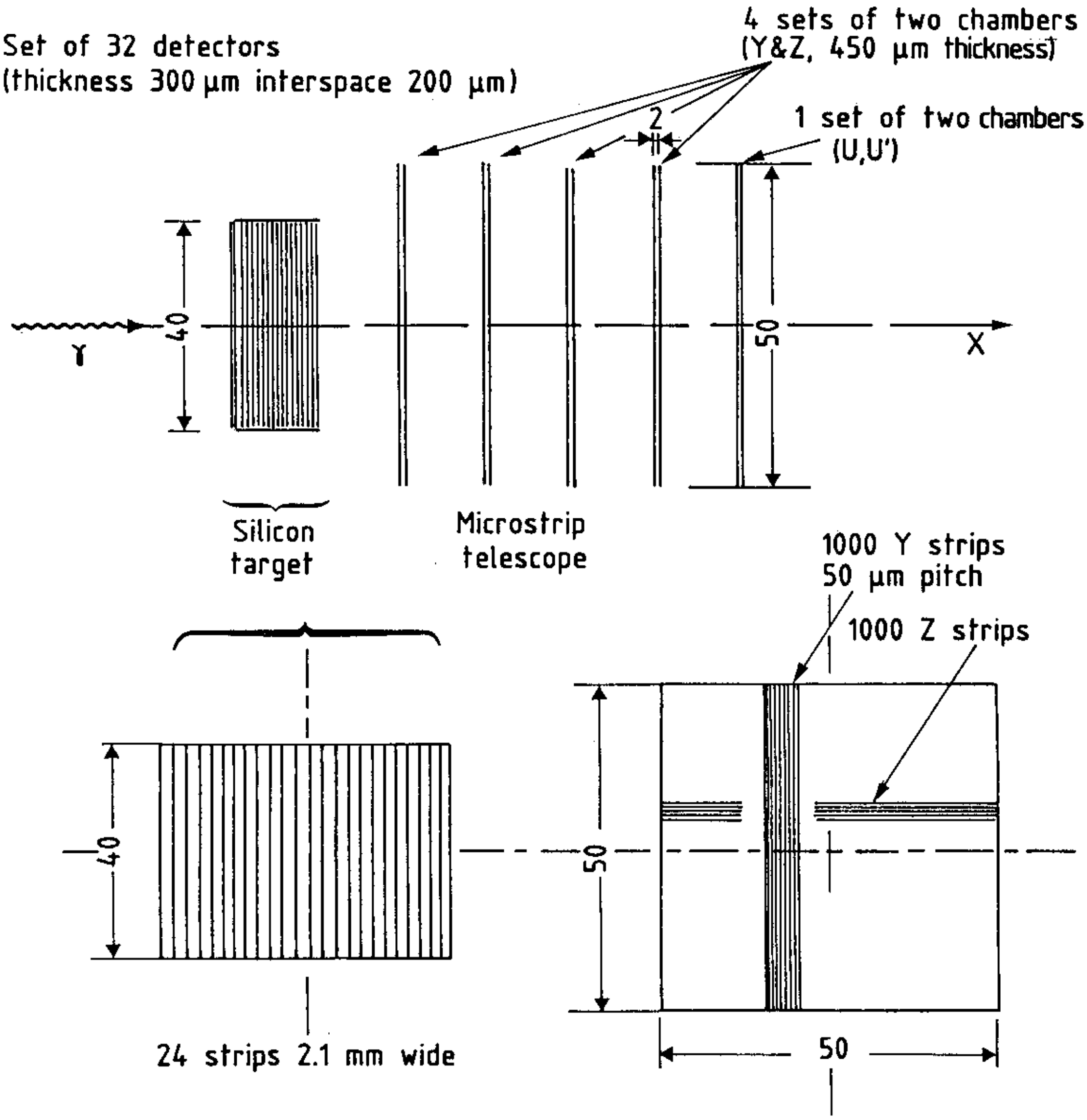

Figure 2 The vertex detector.

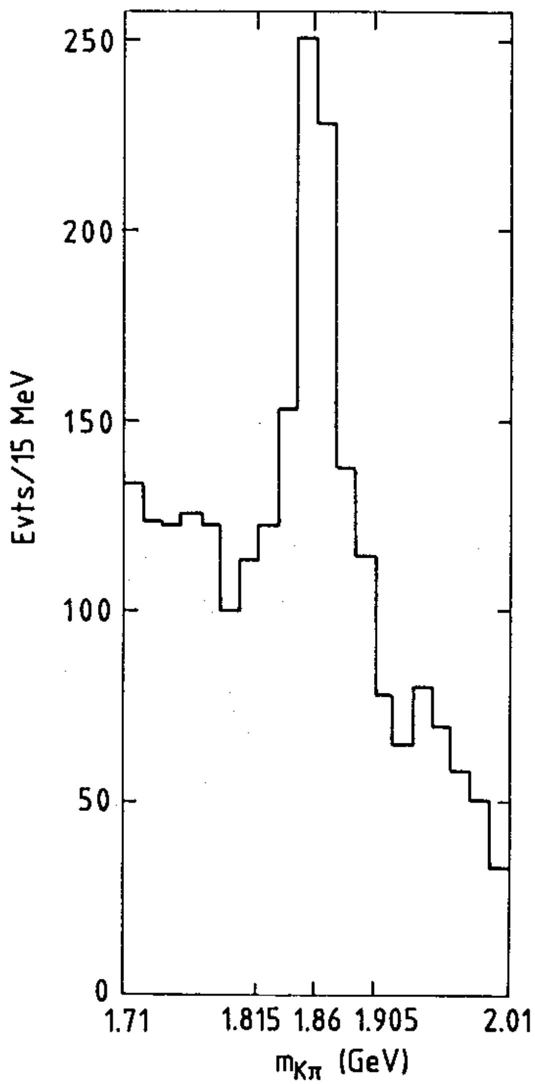

Figure 3 Kπ mass spectrum (secondary vertices' filter).

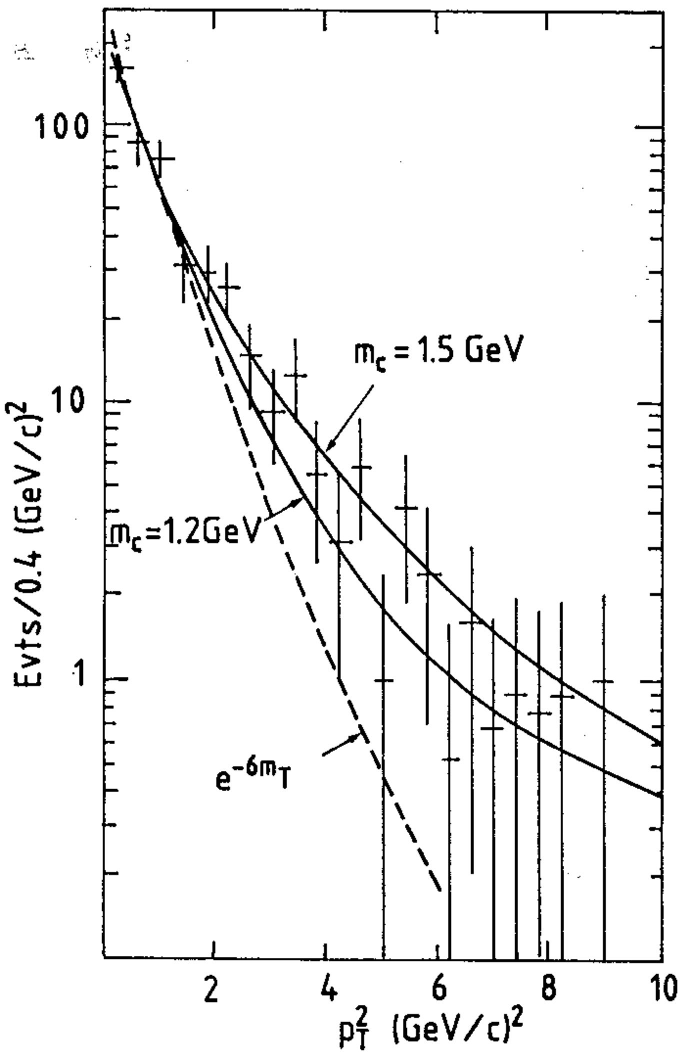

Figure 4 D-meson transverse-momentum distribution.

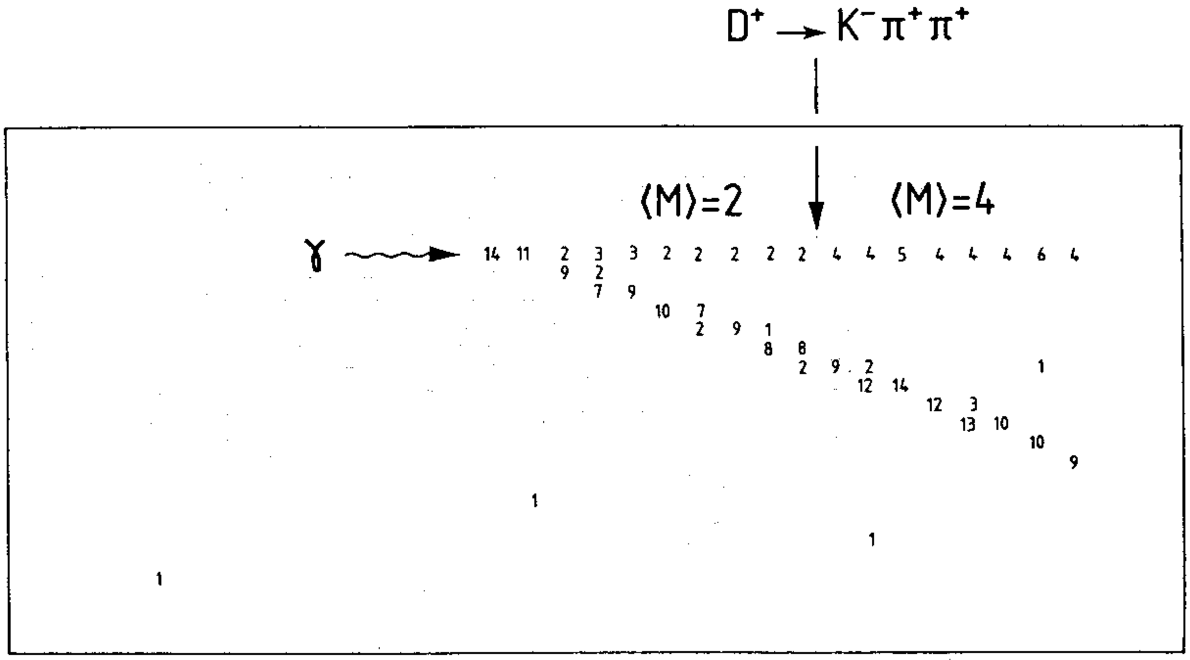

Figure 5 Display of a D^+D^- event in the active target.

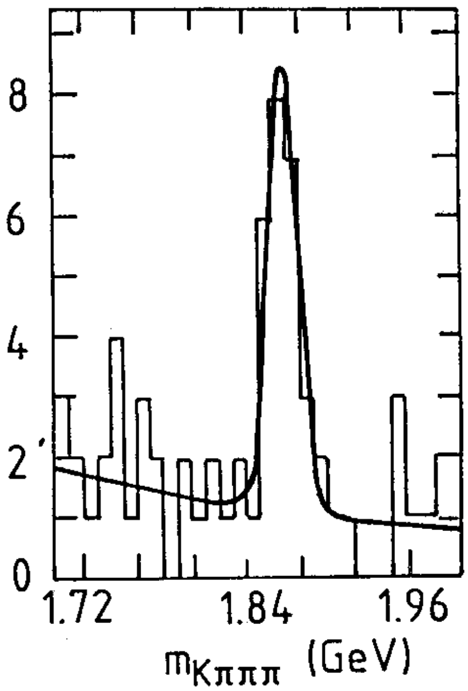

Figure 6 $K\pi\pi\pi$ mass spectrum with $\Delta x > 1.5$ mm (active target filter).

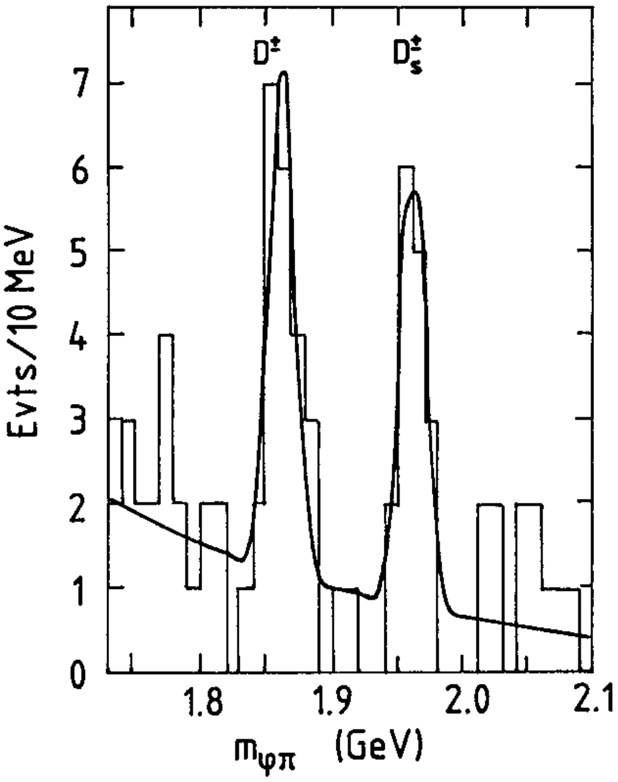

Figure 7 $\phi\pi$ mass spectrum with $\tau > 3.5 \times 10^{-13}$ s ('KK' filter).

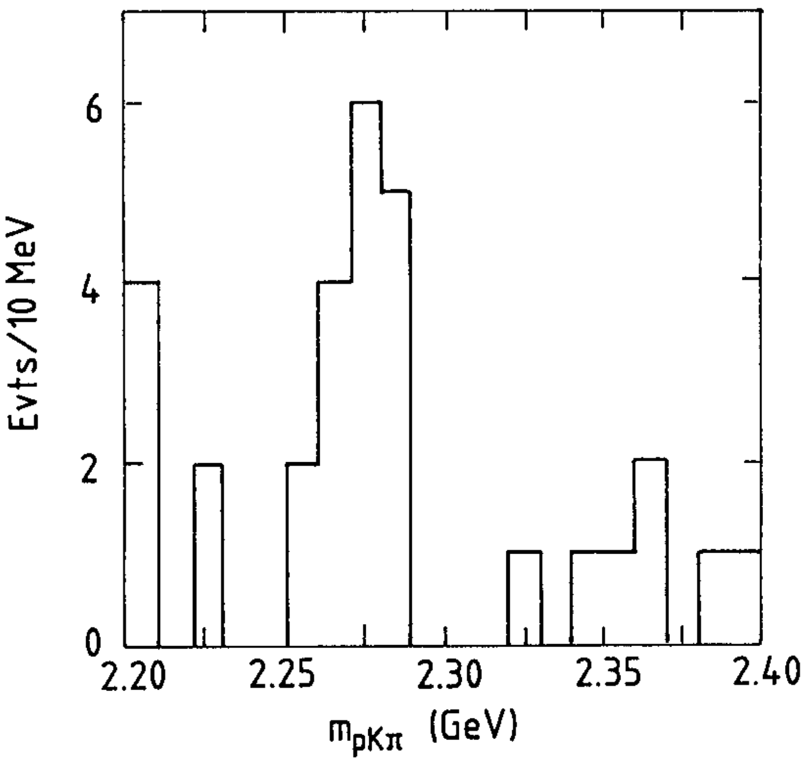

Figure 8 pKπ mass spectrum with $\Delta x > 1.5$ mm ('pK' filter).