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EVIDENCE FOR A NEW PARTICLE WITH NAKED "BEAUTY" AND FOR ITS ASSOCIATED PRODUCTION IN HIGH-ENERGY (pp) INTERACTIONS.

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SUMMARY

Evidence is reported for the existence, with six standard deviations significance, of a new particle: the heaviest baryon observed so far, whose mass is measured to be $m = (5{,}425\ ^{+175}_{-\ 75})$ MeV/c^2. Its width is compatible with zero. It is electrically neutral and it decays into a proton, a D^0, and a π^-. This particle is produced in association with a hadronic state whose semileptonic decay contains a positive electron. The partial cross-section for the observed effect is $\Delta\sigma = (3.8 \pm 1.2) \times 10^{-35}$ cm^2. The interpretation of these results is in terms of the associated production of naked "beauty" states in (pp) interactions at $\sqrt{s} = 62$ GeV c.m. energy. The new particle is identified as the first "beauty"-flavoured baryon with quark composition (udb), i.e. the Λ_b^0. The discrimination power of the experiment against "known" physics, is of the order of 10^{-10}.

Dedicated to Andrei Sakharov on his sixtieth birthday.

(Submitted to Nuovo Cimento Letters)

1. INTRODUCTION

The relevance of the "leading" baryon effects in hadronic phenomena[1]) has prompted a thorough study of its applications in many fields of particle production[2-8]). We have recently reported[9]) proof that even the heavy-flavoured baryon Λ_c^+ is produced following the "leading" effect.

The application of the same "leading" technique to search for heavier flavoured states brings us to the observation of a new particle. It is the highest-mass baryonic state observed so far. It is electrically neutral and decays into a proton, a D^0, and a negative pion. This new baryonic state is produced in association with another hadronic state which decays semileptonically into an e^+. The new particle is identified as the first "beauty"-flavoured baryon, the Λ_b^0, whose quark composition is $\left[(ud)b\right]$, with the (ud) pair in an isosinglet state. The purpose of the present paper is to report on this work.

Let us remark that even if the higher-flavour symmetries such as SU_5 cannot exist, because of being badly broken, the "beauty" quark flavour (b), when coupled to ordinary quarks (u,d), is expected to reproduce a sequence analogous to the well-known "strange" baryons and mesons. In fact the "strange" and "beauty" quarks are both "down"-like.

The lowest-mass state of baryons with a b-quark is therefore expected to be electrically neutral, as is the "strange" Λ^0, unlike the case of the lowest charmed baryon state Λ_c^+, which is electrically charged.

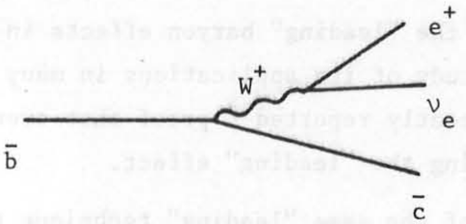
The first point in the search for the lowest-mass baryon, with "beauty" flavour Λ_b^0, is therefore to look for a proton plus other mesons to make up a system which is electrically neutral. Because of obvious observational reasons, we require that this electrically neutral state be made with secondary particles, all electrically charged.

The "beauty" flavour (b) is Cabibbo-favoured to decay into a "charm" flavour. This means that a signature for the Λ_b^0 decay is the presence of a charmed state, such as the D^0, which can be detected in our set-up as a $(K^-\pi^+)$ pair.

Notice that the quark decay sequence is $b \to c \to s$, which means that the K^+ is forbidden to be at the end of the decay chain.

Thus the baryonic final state to be searched for should have a proton, a negative K meson, a π^+, and a π^-. These are the basic ingredients that are needed in order to search, with our experimental set-up, for the first member of a neutral baryon family with open "beauty" flavour.

We now turn to the associated "antibeauty" state. This could be a meson or a baryon. However, the key point is that the Cabibbo-favoured semileptonic decay of the "antibeauty"-flavoured state is expected to follow the pattern illustrated in the diagram below:



(1)

This means that the presence of a positive electron, e^+, is the expected signature for an "antibeauty" decay. If an anticharm state would be involved in the process, the decay chain would be $\bar{c} \to \bar{s} + e^- + \bar{\nu}_e$. The presence of a negative electron could be due either to the decay of a directly produced anticharm particle or to the second step in the "antibeauty" decay chain: $\bar{b} \to \bar{c} \to \bar{s} + e^- + \bar{\nu}_e$.

The main purpose of the present experiment was to search for a reaction which could only come from the associated production of a "beauty"-flavoured baryon plus an "antibeauty"-flavoured state. For this reason the e^+ trigger was chosen.

The reaction investigated was, therefore,

$$pp \to (p\underset{\hookrightarrow K^-\pi^+}{D^0}\pi^-) + e^+ + \text{anything}\,, \tag{2}$$

with the "leading" conditions[9] imposed on the baryonic state $(pK^-\pi^+\pi^-)$ (see Section 4). The initial (pp) state was the ISR colliding proton beams at $\sqrt{s} = 62$ GeV total c.m. energy.

2. EXPERIMENTAL SET-UP

The experimental set-up is shown in Fig. 1. It consists of a large-volume magnetic field, the so-called Split Field Magnet (SFM), equipped with a powerful multiwire proportional chamber (MWPC) complex for track detection. A system of gas threshold Čerenkov counters and electromagnetic shower detectors (EMSD)[10] was used for electron detection. The e^+ trigger was given by the coincidence of two Čerenkov counters (C_0C_3 or C_0C_4) and by the condition of a minimum energy release, $E^e_{\min} \geq 500$ MeV, in the corresponding EMSD.

A "dE/dx" chamber[11] (i.e. a MWPC with analog read-out, placed very near to the intersection region) was used, at the software level, to reject events due to Dalitz π^0 and η decays, and to external γ conversions.

The momentum measurement, provided by the SFM and the MWPCs, coupled to the time information obtained via a large time-of-flight system (TOF), allowed particle identification[12] (π, K, p) up to $\sim$ 2 GeV/c.

3. DATA ANALYSIS

A sample of about 1.5×10^6 trigger events corresponding to a total integrated luminosity of 4.39×10^{36} cm^{-2} was reduced to $\sim 3 \times 10^4$ events by a software filter, where conditions more stringent than those at the fast trigger level were required:

i) Uncorrelated background from γ's and charged hadrons was rejected by asking for a reconstructed track through the positron detector (MWPCs, Čerenkov counters, EMSDs), and for the matching of the impact point of this track with the energy cluster released in the EMSDs.

ii) External γ conversions and π^0,η Dalitz decays were rejected using the "dE/dx" chamber information, either by a pulse-height cut (unresolved e^+e^- pairs) or by the detection of two close, but resolved, tracks. After the full reconstruction of the $\sim 3 \times 10^4$ events, a final check was carried out to verify that the positron track fitted the interaction vertex.

Monte Carlo simulation studies and data taken during calibration runs allowed us to choose a transverse momentum cut for the positron [$p_T(e^+) \geq 800$ MeV/c], which maximizes acceptance with optimum background rejection. The residual contamination from neutral hadrons [point (ii) above] is estimated to be less than about 50%, while the background level from charged hadrons [point (i) above] is below 2%. The over-all efficiency for genuine "single" positron detection is about 45%.

The particles entering in the ($pK^-\pi^+\pi^-$) invariant mass spectrum had to satisfy the following conditions:

i) to be part of an event where there is a positive electron, with $p_T(e^+) \geq 800$ MeV/c;

ii) to fit the vertex of the event within ±5 cm;

iii) to have a momentum uncertainty $\Delta p/p \leq 30\%$.

The particle identification, in terms of p, K^-, π^+, π^-, was obtained using the following criteria: i) the proton is any positive track, not identified as a K^+ or a π^+ by TOF; ii) the K^- is any negative track, not identified as an $\bar{p}$ or a π^- by TOF; iii) the π^+ is any positive track, not identified as a K^+ or a proton by TOF; iv) the π^- is any negative track, not identified as a K^- or an $\bar{p}$ by TOF. These are quite loose conditions, because the TOF system, in spite of being large, covers only about 10% of the total solid angle. Nevertheless, these conditions are helpful in reducing the number of particle combinations per event.

4. RESULTS

4.1 The mass spectrum

In our previous Λ_c^+ study we have already shown that the "leading" proton technique allows a clear Λ_c^+ signal to be seen$^{13)}$. Moreover, the Λ_c^+ itself shows a "leading" effect$^{9)}$. This study has prompted the suggestion that, also for the heavier flavour production such as "beauty", the "leading" baryon conditions could be important for selecting a signal from the large physical background due to multiparticle production processes which dominate high-energy (pp) interactions.

For this reason, in the event sample selection we have adopted the "leading" baryon conditions:

$$x_F = \frac{\vec{p}_{\text{proton}} \cdot \vec{p}_{\text{incident}}}{|\vec{p}_{\text{incident}}|^2} \geq 0.32 \ ,$$

and

$$|y|_{pK^-\pi^+\pi^-} \geq 1.4 \ .$$

If the heavy-flavoured baryon Λ_b^0 follows the same "leading" effect as does the $\Lambda_c^{+\ 9)}$, the above conditions are expected to produce the best possible sample of $(pK^-\pi^+\pi^-)$ candidates for Λ_b^0.

The choice $x_F \geq 0.32$ was suggested from the knowledge that the proton-to-pion ratio, in inclusive measurements$^{14)}$, was measured to be greater than 2 and increases with x_F. This is obviously an important condition for having a sample enriched with protons. It could be argued that the inclusive measurements$^{14)}$ do not necessarily imply its validity in the exclusive channel we are searching for. However, the results show that this criterion for proton selection is a good one.

In order to clean the event sample, we have studied the charged particle multiplicity associated with the class of events searched for. The main principle was to be guided by physics intuition, and then to check if this was introducing bias in the class of events searched for. The production of heavy states is expected to be an interaction with high inelasticity; so the multiplicity associated with the event should not be too low. Moreover, in the direction opposite to the (e^+), at least one particle should be present if the decay is really due to a heavy-mass object. We therefore chose for the associated charged multiplicity, i.e. the "anything" in reaction (2), the condition $(n_{ch}) \geq 4$. Of these four particles, at least one had to be opposite to the positron direction. These are quite efficient conditions for background suppression, while leaving the sample to be searched for almost unbiased, as shown by Monte Carlo simulation programs and by a detailed analysis of the experimental data.

To recapitulate, the event selection is based on the following conditions:

i) $p_T(e^+) \geq 800$ MeV/c;

ii) $|x_F| \geq 0.32$;

iii) $|y|_{pK^-\pi^+\pi^-} \geq 1.4$;

iv) $(n_{ch}) \geq 4$, with at least one opposite to the (e^+).

We will call this set of conditions: set α.

Figure 2 shows the $(pK^-\pi^+\pi^-)$ invariant mass spectrum with set α conditions applied to the data.

The next step is to apply the D^0 trigger to these events. In order to do this, the $(K^-\pi^+)$ mass spectrum has been worked out, as shown in Fig. 3. To obtain the sample with the D^0 trigger, a cut symmetric with respect to the nominal D^0 mass[15)] and twice as large as our mass resolution in the $(K^-\pi^+)$ mass range,

$$\left[1.7 \leq m(K^-\pi^+) \leq 2.0\right] \text{ GeV}/c^2 ,$$

has been applied.

Figure 4 shows the $(pK^-\pi^+\pi^-)$ mass spectrum with the D^0 trigger. Here evidence is found for an enhancement with (29.4 ± 7.4) combinations above the background, in the mass range

$$\left[5.35 \leq m(pK^-\pi^+\pi^-) \leq 5.50\right] \text{ GeV}/c^2 .$$

The statistical significance is ∿ four standard deviations. The ratio of signal-to-background is one to two.

In order to check the "flatness" of our system of detection-plus-analysis chain, we have studied the $(pK^-\pi^+\pi^-)$ mass spectra using event mixing in three ways: i) take a D^0 and combine it with a proton and a π^- from another event; ii) take a D^0 plus a proton and combine them with a π^- from another event; iii) take a proton and combine it with a D^0 plus a π^- from another event. The observed χ^2 distributions for the invariant masses corresponding to these various types of background random-mixing events have been compared with the theoretically expected χ^2 distribution. The same study has been done for the mass spectrum where we observe the $(pK^-\pi^+\pi^-)$ enhancement. The experimentally observed χ^2 distributions have been compared with the theoretical χ^2 expectations. A good agreement has been found between the expected and the observed fluctuations. This study shows that the "flatness" of our detector-plus-analysis chain is very satisfactory.

A key question now arises. The enhancement (Fig. 4) has (29.4 ± 7.4) combinations in the mass range

$$[5.35 \leq m(pK^-\pi^+\pi^-) \leq 5.50]\ \mathrm{GeV}/c^2\ .$$

If this enhancement is really a Λ_b^0, then going back to the $(pK^-\pi^+\pi^-)$ mass spectrum without the D^0 trigger (Fig. 2) and applying a cut in the mass range

$$[5.35 \leq m(pK^-\pi^+\pi^-) \leq 5.50]\ \mathrm{GeV}/c^2\ ,$$

we should find in the $(K^-\pi^+)$ mass spectrum a D^0 signal with a number of events compatible with the $(pK^-\pi^+\pi^-)$ enhancement observed in Fig. 4.

The result is shown in Fig. 5a, where the dotted-line and full-line histograms show the $(K^-\pi^+)$ mass spectra OUT and IN, respectively, with reference to the $(pK^-\pi^+\pi^-)$ mass range where we observe the enhancement (IN), and to the adjacent mass bins (OUT). Notice that in the dotted histogram there is no enhancement in the D^0 mass range, as expected. The D^0 enhancement is present in the full-line histogram. Figure 5b shows the IN minus OUT distribution. In the D^0 mass range there are (28.5 ± 5.5) combinations above the background level. This is in excellent agreement with our expectations, based on the hypothesis that the $(pK^-\pi^+\pi^-)$ enhancement is a Λ_b^0 decaying via a charmed meson. The statistical significance for the presence of the D^0 is ∿ 5.5 standard deviations.

We are now in a position to go further: i.e. to apply a more precise mass-range cut, where the D^0 really shows up in the $(K^-\pi^+)$ mass spectrum. Notice that the barycentre of the D^0 enhancement in Figs. 5 is about 60 MeV/c^2 below the "nominal" D^0 mass value. We attribute this mass shift to instrumental effects already observed when using the SFM as a mass spectrometer[16]). This shift suggests, for the D^0 cut, the values

$$[1.725 \leq m(D^0) \leq 1.875]\ \mathrm{GeV}/c^2\ ,$$

since it is in this mass interval that the $(K^-\pi^+)$ enhancement is observed. This procedure is justified because the primary purpose of the present experiment is certainly not to measure the D^0 mass. The knowledge of the D^0 is merely used to apply a (D^0, e^+) software trigger in (pp) interactions, in order to study possible candidates for "beauty"-flavoured baryons.

The results of the sharp D^0-cut in the $(pK^-\pi^+\pi^-)$ mass spectrum are shown in Fig. 6. There is a clear enhancement in the same mass range,

$$[5.35 \leq m(pK^-\pi^+\pi^-) \leq 5.50]\ \mathrm{GeV}/c^2\ ,$$

with a signal-to-background ratio that is twice as good: now it is one to one.

There are two ways of estimating the statistical significance of the observed effect:

i) to fit the whole spectrum with a polynomial function and to evaluate the background level in the two bins where we observe the "enhancement"; this procedure gives (31.5 ± 4.9) for the enhancement above the background level, i.e. 6.4 standard deviations;

ii) to evaluate the background level simply by using three mass bins on each side of the two bins where we observe the "enhancement"; this procedure gives (29 ± 5.2) for the enhancement above the background level, i.e. 5.6 standard deviations.

An estimate of the consequences of the $(K^-\pi^+)$ mass shift in the $(pK^-\pi^+\pi^-)$ system again gives ∿ 60 MeV/c^2 if the effect is coming from a systematic error in the momentum measurements, and ∿ 100 MeV/c^2 if the effect is attributed to a systematic error in the angular measurements. We conclude that the absolute mass value of Fig. 6 should be shifted upwards either by 60 MeV/c^2 or by 100 MeV/c^2. It follows that for our $(pK^-\pi^+\pi^-)$ mass range we have to take into account the observed D^0 mass shift in order to get the correct Λ_b^0 mass range. This turns out to be

$$[5.35 \leq m(pK^-\pi^+\pi^-) \leq 5.60] \text{ GeV/c}^2 .$$

The most likely interpretation of our results is in terms of the following reaction:

$pp \to \Lambda_b^0 + [$"antibeauty" flavoured state$] +$ anything

$\hookrightarrow e^+ +$ anything (3)

$\hookrightarrow p\pi^- D^0$

$\hookrightarrow K^-\pi^+$

with the Λ_b^0 mass measured to be

$$m(\Lambda_b^0) = (5{,}425\ {}^{+\,175}_{-\,75})\ \text{MeV/c}^2 . \qquad (4)$$

This mass value is in agreement with a theoretical estimate[17)] which fits the known charmed baryon masses quite well, and with the more exact bounds calculated by Martin[18)], using flavour independence of quark forces. We emphasize that the absolute mass determination in our set-up cannot be established more accurately because there is no absolute calibration which is possible in the 5 GeV/c^2 mass range with a well-known resonance.

We have not studied whether, in the same mass range, there is a positive and/or a negative state. The identification of the enhancement in terms of the isosinglet Λ_b^0 is based on the fact that the mass appears to be the lowest possible one for a $[(ud)b]$ state.

4.2 The partial cross-section estimate

A detailed study of the whole mass spectrum in Fig. 6 shows that the number of combinations exceeds the number of events, on the average by a small percentage (25%), in each mass bin. In order to work out the cross-section for the enhancement reported in Fig. 6, the number of combinations has to be divided by 1.25.

As already reported in Section 3, the total (pp) luminosity is $L(pp) = 4.39 \times 10^{36}\ \text{cm}^{-2}$.

Let us call $\Delta\sigma_5$ the partial cross-section for the reaction

$$pp \rightarrow \underbrace{(p\underbrace{K^-\pi^+}_{D^0}\pi^-)}_{\substack{\text{with leading}\\ \text{baryon conditions}}} + \underbrace{e^+}_{p_T \geq 800\ \text{MeV}/c} + \underbrace{\text{anything}}_{n_{ch} \geq 4} \qquad (5)$$

measured under the experimental conditions already specified and synthetically indicated in formula (5). In order to evaluate $\Delta\sigma_5$, it is necessary to know the global acceptance efficiency ε_5 for detecting the final state (5). In fact,

$$\Delta\sigma_5 = \frac{\text{Number of events}}{\varepsilon_5 \cdot L(pp)} .$$

The efficiency ε_5 has been calculated via Monte Carlo simulation programs and taking into account the electronic efficiencies and other details of all instruments which make up our detector: MWPCs, EMSDs, (dE/dx) chamber, Č counters, TOF, etc. The value for ε_5 turns out to be

$$\varepsilon_5 = (11.9 \pm 1.2)\% .$$

The result is

$$\Delta\sigma_5 = (3.8 \pm 1.2) \times 10^{-35}\ \text{cm}^2 .$$

The value of $\Delta\sigma_5$ does not need any model for the production and decay of Λ_b^0 and $M_{\bar{b}}^-$, the associated "antibeauty"-flavoured state. It represents the sensitivity of our experimental set-up, when illuminated by a final state such as (5).

In order to derive the production cross-section for the reaction

$$pp \rightarrow \Lambda_b^0 + M_{\bar{b}}^- + \text{anything} , \qquad (6)$$

it would be necessary to assume the validity of six distribution functions: two for the production and one for the decay of Λ_b^0, and three more for the $M_{\bar{b}}^-$, together with three branching ratios:

$$B_1(D^0 \to K^-\pi^+) = \frac{D^0 \to K^-\pi^+}{D^0 \to \mathrm{all}} \; ,$$

$$B_2(M^-_{\bar{b}} \to e^+) = \frac{M^-_{\bar{b}} \to e^+ + \mathrm{anything}}{M^-_{\bar{b}} \to \mathrm{all}} \; ,$$

$$B_3(\Lambda^0_b \to pD^0\pi^-) = \frac{\Lambda^0_b \to pD^0\pi^-}{\Lambda^0_b \to \mathrm{all}} \; ,$$

one of which, B_3, is unknown; B_2 needs a further assumption about the nature of the "antibeauty"-flavoured state, $M^-_{\bar{b}}$, in terms of a baryon or of a meson; and B_1 is measured with large uncertainties. The cross-section σ_6 has been estimated[19] using three models, and turns out to be about five orders of magnitude above the value $\Delta\sigma_5$. A comparison has also been made[19] with the Λ^+_c associated production cross-section, measured in the same experimental conditions. For this comparison it is necessary to choose six other distribution functions, for the production and decay of the Λ^+_c and $\bar{D}$, plus two branching ratios:

$$B_4(\bar{D} \to e^-) = \frac{\bar{D} \to e^- + \mathrm{anything}}{\bar{D} \to \mathrm{all}} \; ,$$

$$B_5(\Lambda^+_c \to pK^-\pi^+) = \frac{\Lambda^+_c \to pK^-\pi^+}{\Lambda^+_c \to \mathrm{all}} \, .$$

In fact the reaction to be compared with reaction (6) is:

$$pp \to \Lambda^+_c + \bar{D} + \mathrm{anything} \; , \tag{7}$$

with the final-state decays: $\Lambda^+_c \to pK^-\pi^+$ and $\bar{D} \to e^- + \mathrm{anything}$.

The most interesting result of these very wide extrapolations is that the associated "beauty" production cross-section σ_6 is compatible with being an order of magnitude below the associated "charm" production cross-section σ_7. This study is reported elsewhere[19].

4.3 A remark

The data reported here have an interesting meaning in terms of "forbidden" charm physics. In fact, in so far as we remain in the domain of the "charm" flavour quantum number, the observation of a positive electron is the signature for the semileptonic decay of a "charmed" state. Therefore the associated hadronic state must be an "anticharmed" particle.

An anticharm quantum number means that we should observe an antibaryon. But we do observe a baryon with more than five standard deviations significance. The signature for the "baryonic state" is the presence of the proton. This is forbidden by charm physics.

Moreover, this baryonic state contains a D^0 meson. The D^0 is observed with more than five standard deviations significance. The signature that we are dealing with a D^0 and not with an $\bar{D}^0$ is the $(K^-\pi^+)$ decay. An antibaryonic state with a D^0 would have been forbidden by charm physics; a baryonic state with an $\bar{D}^0$ also. These states would have been "anomalous" for charm physics, but forbidden only once. The state we are observing is doubly forbidden by charm physics: it is a baryonic state and it contains a charmed meson. These are independent features. One is based on the knowledge of a baryon being there; the other, on the knowledge that a D^0 is there. We are therefore observing an effect which is doubly forbidden in the field of charm physics, but wanted by "beauty".

5. CONCLUSIONS

The data reported show evidence for the existence of an enhancement in the $\left[p(K^-\pi^+)_{D^0}\pi^-\right]$ mass spectrum in the range

$$\left[5.35 < m(p\underset{\hookrightarrow K^-\pi^+}{D^0}\pi^-) \leq 5.60\right] \mathrm{GeV}/c^2 .$$

The estimate of the partial cross-section for this enhancement, produced in association with a positive electron and observed in our experimental set-up with all conditions specified, is $(3.8 \pm 1.2) \times 10^{-35}$ cm^2.

The statistical significance of the enhancement is either 5.6 or 6.4 standard deviations, according to two different methods of calculating the background. The width of the enhancement is perfectly consistent with the mass resolution of the apparatus. The interpretation of the effect is in terms of a baryon whose quark composition is $\left[(ud)b\right]$ with the (ud) pair in an isosinglet state, i.e. the Λ_b^0 with mass

$$m(\Lambda_b^0) = (5{,}425 \; {}^{+\,175}_{-\;\;75}) \; \mathrm{MeV}/c^2 .$$

The evidence for the "beauty"-flavoured quantum number in this $(pK^-\pi^+\pi^-)$ enhancement is based on two facts:

i) the e^+ signature, which is coming from the semileptonic decay of the "anti-beauty"-flavoured state produced in association with the Λ_b^0.

ii) the presence of the D^0 state in the sample where the $(pK^-\pi^+\pi^-)$ enhancement is observed.

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Figure captions

Fig. 1 : Top view of the experimental set-up, showing the SFM with its associated MWPC system, the Čerenkov counters (C0, C1, C2, C3, C4, C5), the electromagnetic shower detectors (EMSDs) (lead/scintillator sandwiches, SW2, SW3, SW4, SW5 and lead-glass, LG3, LG4), and the time-of-flight system (TOF). The "dE/dx" chamber is indicated by the number 209.

Fig. 2 : ($pK^-\pi^+\pi^-$) invariant mass spectrum in events selected with the set-α conditions.

Fig. 3 : ($K^-\pi^+$) invariant mass spectrum in events selected with the set-α conditions.

Fig. 4 : ($pK^-\pi^+\pi^-$) invariant mass spectrum in events selected with the set-α conditions plus the "nominal" D^0 trigger.

Fig. 5 : a) Invariant mass distributions of the ($K^-\pi^+$) pairs in the ($pK^-\pi^+\pi^-$) mass ranges:

i) 5.35-5.5 GeV/c^2 (IN, solid line);

ii) 5.2-5.35 GeV/c^2 and 5.5-5.65 GeV/c^2 (OUT, dotted line).

The events are selected with the set-α conditions. The OUT distribution has been normalized to the total area of the IN distribution.

b) The IN-OUT difference.

Fig. 6 : ($pK^-\pi^+\pi^-$) invariant mass spectrum in events selected with the set-α conditions plus a "sharp" D^0 trigger.

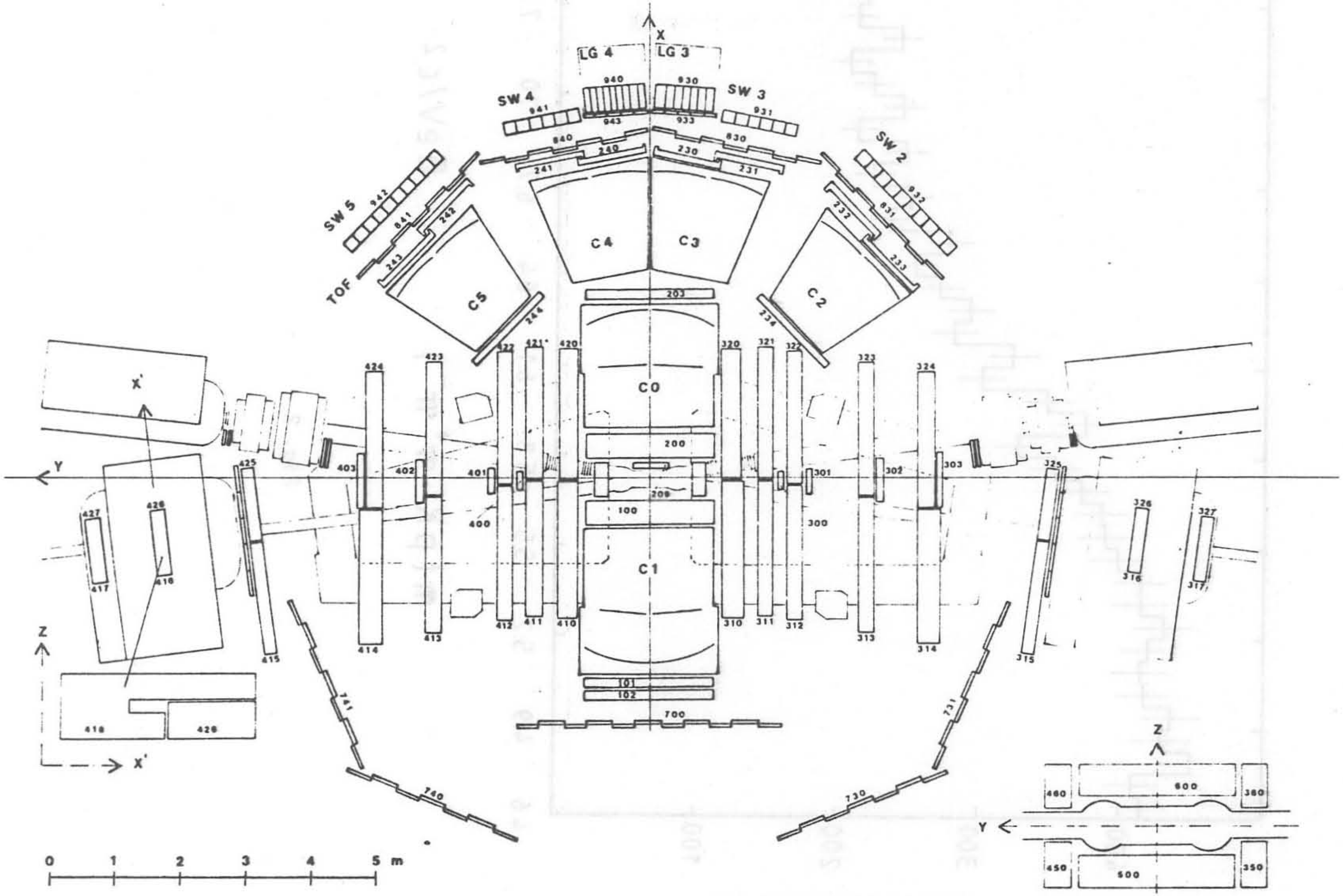
X
LG 4
LG 3
940
930
SW 4
SW 3
941
931
943
933
840
830
240
230
241
231
SW 5
942
SW 2
932
841
831
242
232
243
233
TOF
C4
C3
C5
C2
244
234
203
424
423
422
421'
420
320
321
322
323
324
C0
X'
200
Y
403
402
401
301
302
303
325
426
427
209
100
400
300
326
327
416
417
C1
316
317
412
411
410
310
311
312
313
314
414
413
415
315
Z
101
102
700
741
731
418
428
X'
740
730
Z
600
460
360
Y
450
500
350
0
1
2
3
4
5 m

Fig. 1

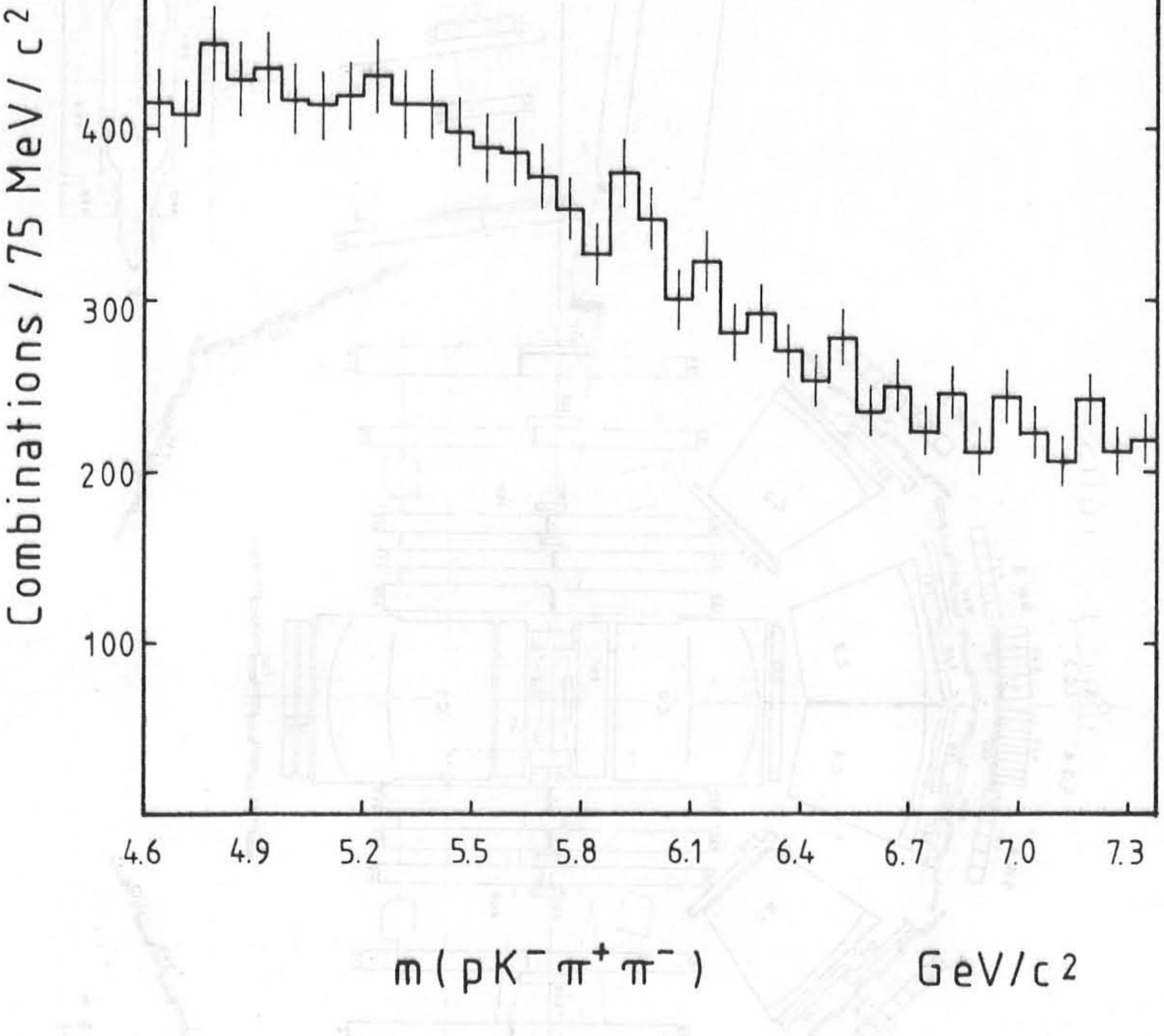
Combinations / 75 MeV/ c^2
400
300
200
100
4.6
4.9
5.2
5.5
5.8
6.1
6.4
6.7
7.0
7.3
$m(pK^-\pi^+\pi^-)$
GeV/c^2

Fig. 2

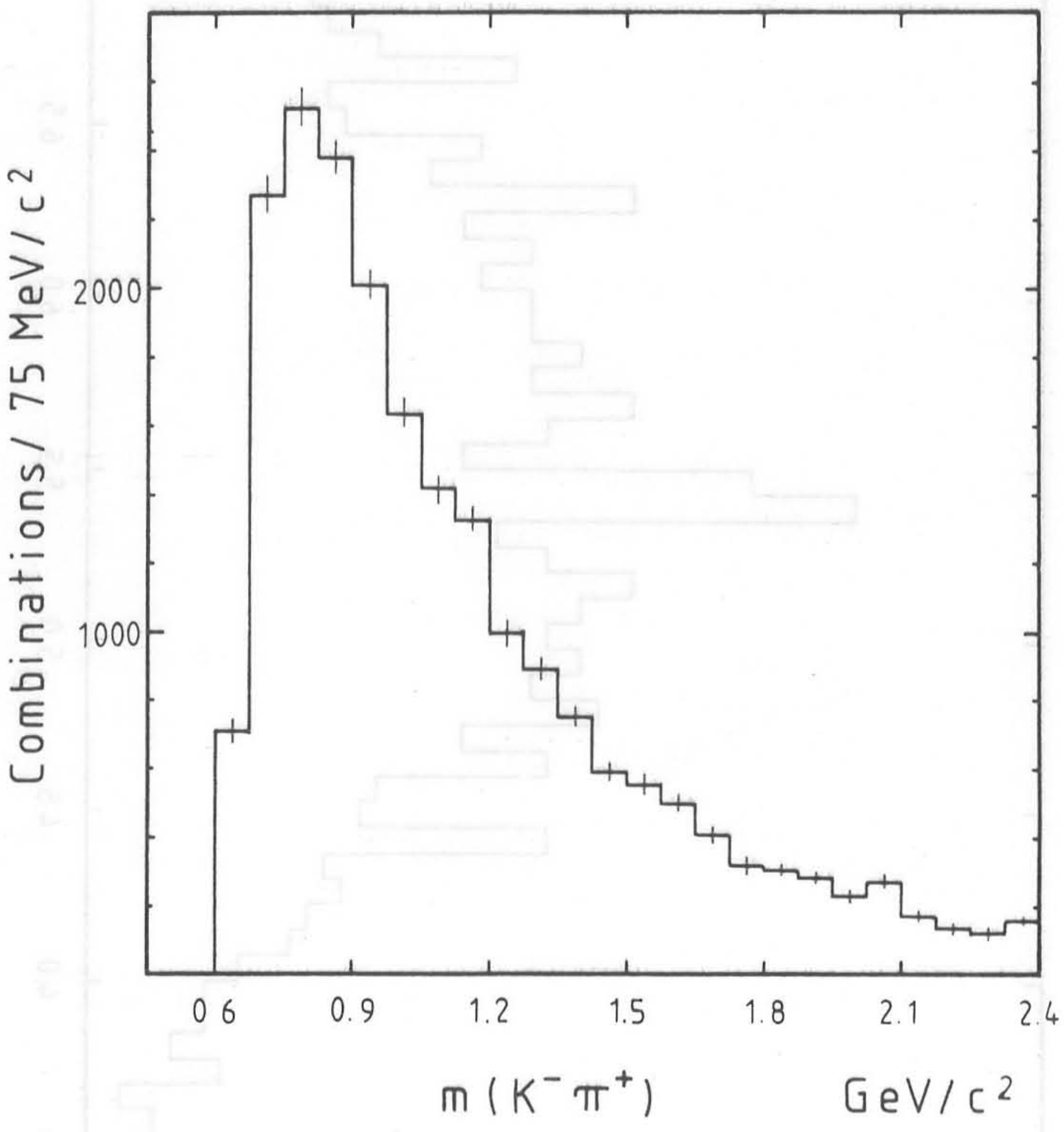

Fig. 3

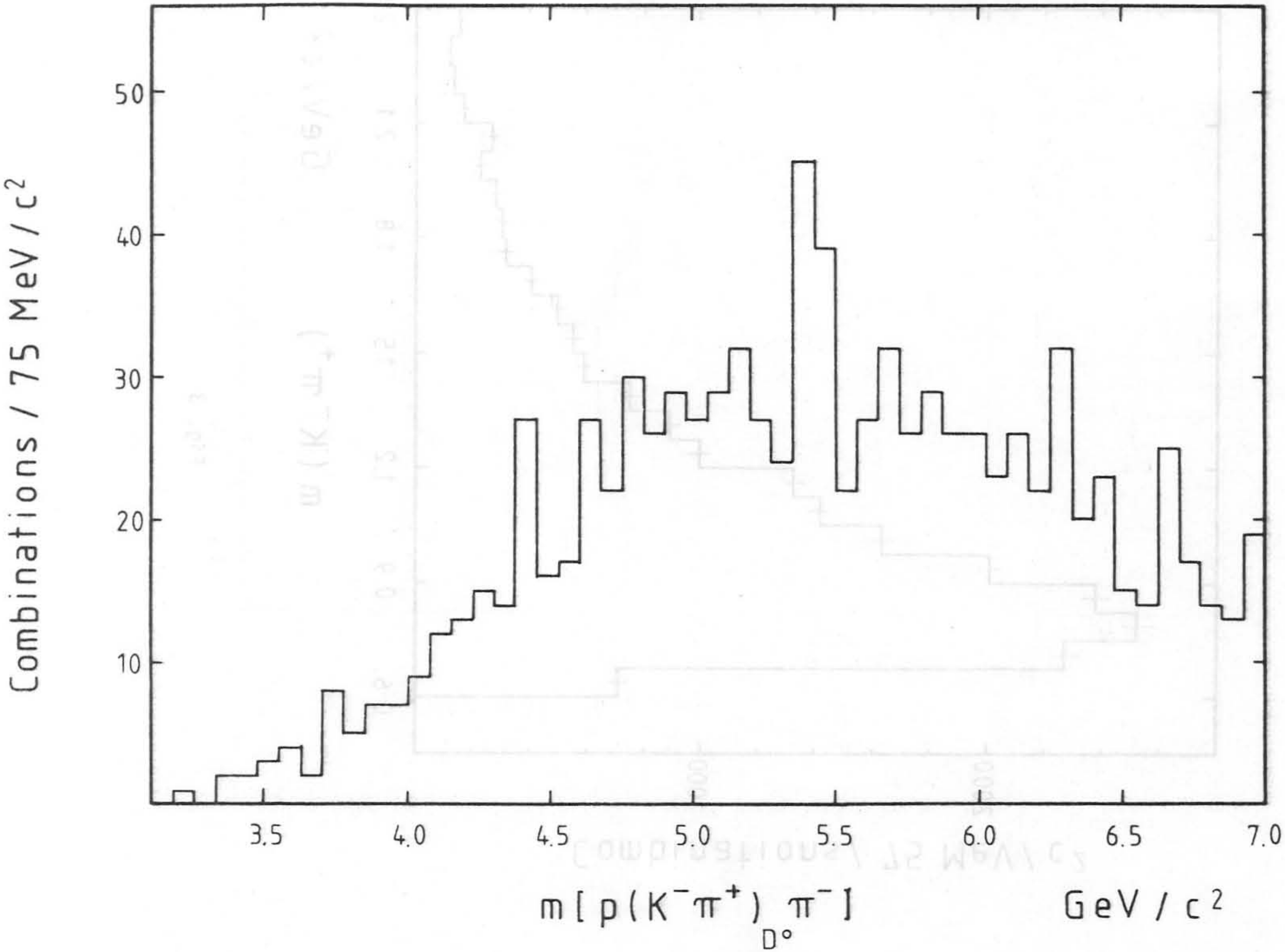
50
40
30
20
10
Combinations / 75 MeV / c^2
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
$m[p(K^-\pi^+)_{D^\circ}\pi^-]$
GeV / c^2

Fig. 4

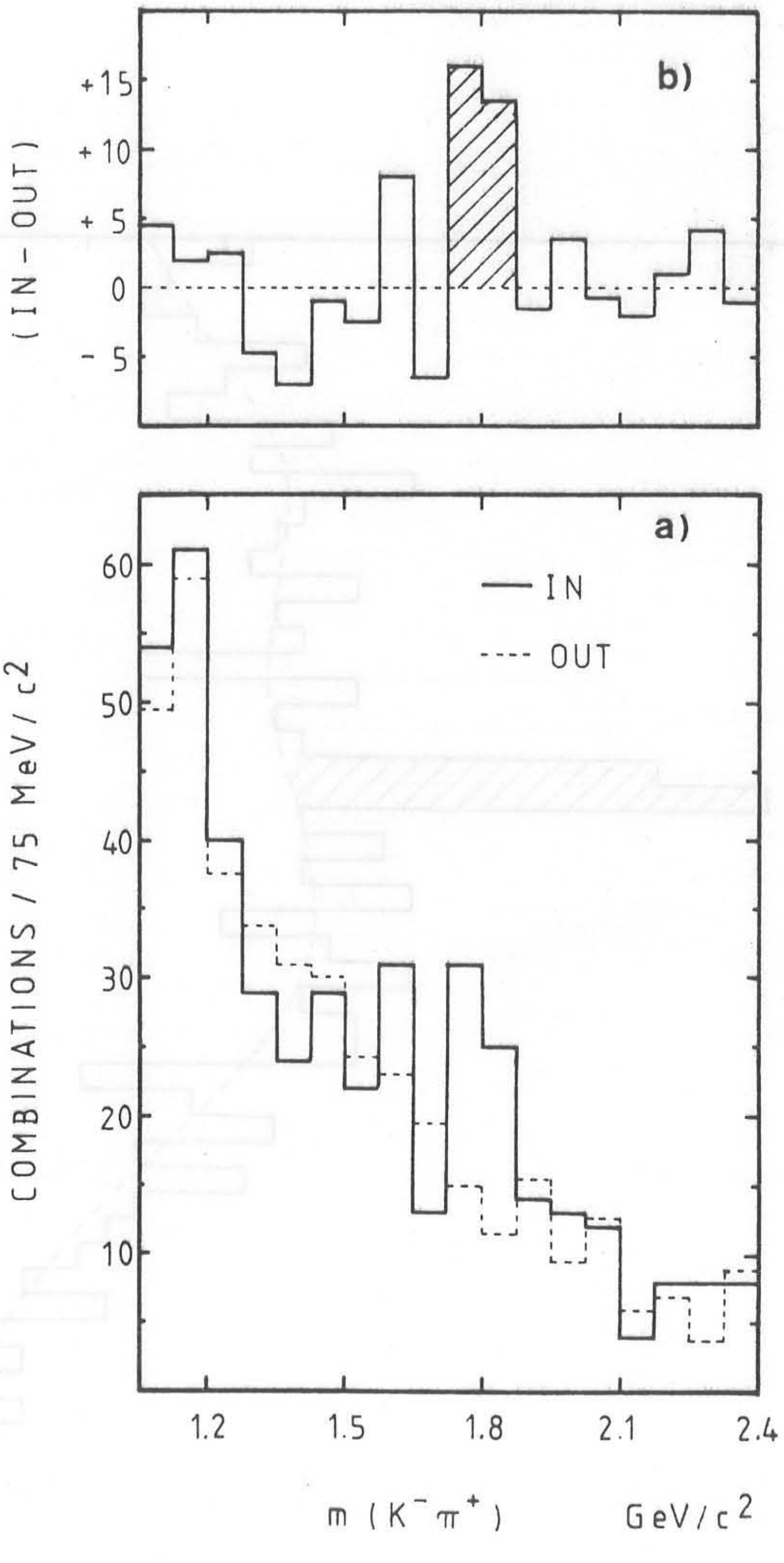
b)
(IN - OUT)
+15
+10
+5
0
-5
a)
IN
OUT
COMBINATIONS / 75 MeV / c²
60
50
40
30
20
10
1.2
1.5
1.8
2.1
2.4
m (K⁻π⁺) GeV/c²

Fig. 5

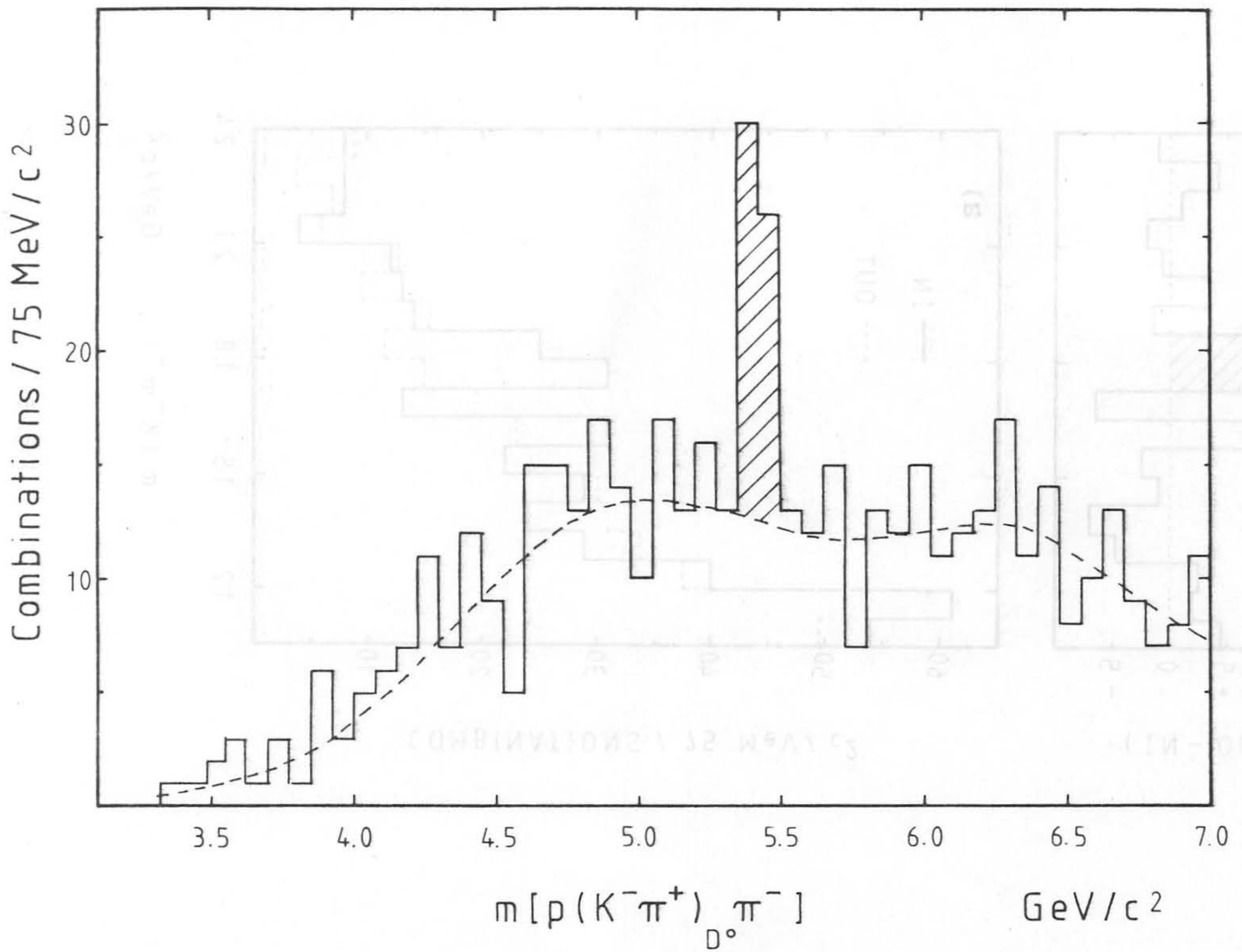
30
20
10
Combinations / 75 MeV/c²
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
$m[p(K^-\pi^+)_{D^\circ}\pi^-]$
GeV/c²

Fig. 6