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PROPOSAL TO SEARCH FOR CHARMED HADRON PRODUCTION IN $\bar{p}p$ INTERACTIONS IN BEBC

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1. We propose to study $\bar{p}p$ interactions in BEBC at or above 10 GeV/c with as large statistics as possible, in order to search for the possible production, in $\bar{p}p$ annihilations, of narrow-width resonances which could be associated with "charmed quark " mesons. These could be produced either as single particles $(c\bar{c})$ in reactions of the type:

$$\bar{p}p \to \phi_c \; m\pi\text{'s} \quad , \quad \phi'_c \; m\pi\text{'s}$$
$$\bar{p}p \to \eta_c \; m\pi\text{'s} \quad , \quad \eta'_c \; m\pi\text{'s} \qquad (1)$$

or, for the mesons $(c\bar{q})$ in pairs i.e.

$$\bar{p}p \to D_o \bar{D}_o$$
$$\to D^+ \bar{D}^+ \qquad (2\text{ a})$$
$$\to D \; \bar{D} \; m\pi\text{'s} \qquad (2\text{ b})$$

of course the detection of reaction (2) with narrow-widths resonances would represent strong evidence in favour of the charm theory. Tentative estimates of the branching fractions of the decay modes of the D's have been given [1], [2] and are listed below:

$D_o \to K^-\pi^+$	∿ 28%	$D^+ \to \bar{K}^o\pi^+$	∿ 7%
$\to K^o\pi^+\pi^-$	∿ 18%	$\to K^-\pi^+\pi^+$	∿ 28%
$\to \bar{K}^o\pi^o$	∿ 14%	$\to \bar{K}^o\pi^+\pi^o$	∿ 7%
$\to K^-\pi^+\pi^o$	∿ 18%	$\to \bar{K}^o\pi^+\eta$	∿ 28%
$\to K^- 3\pi$	∿ 10%	$\to K^- 3\pi$	∿ 14%

The cross sections for production of ϕ_c, η_c, D's in strong interactions are of course unknown. Our optimism in favour of a $\bar{p}$ experiment is justified by the following points:

- The $\bar{p}p$ annihilation reactions provide the highest CM energy available in "central" (non peripheral) collisions. They represent a large source of high $p_\perp$ events (Fig. 1), the most promising region to look for production of high mass objects.

- In the hypothesis that in production, charm behaves as strangeness one might expect [1] that $\sigma(\text{charmed})/\sigma(K) \simeq \sigma(K)/\sigma(\pi)$. In this respect the $\bar{p}$'s are good candidates for producing charms since a large fraction of $\sigma_{\text{ANNIHILATION}}$ has been measured to go into K_s^0K + anything as shown in Fig. 2. Incident π's also have a sizeable cross section ($\sim$ 2 mb at 10 GeV/c) for production of $K\bar{K}$ pairs; in this case however the $K\bar{K}$ systems are strongly collimated forward and a large fraction of the events ($\sim$ 70%) are concentrated at low Q-value in the $K\bar{K}$ system (Fig. 3) [3].

- Evidence for narrow resonances production in $\bar{p}$ reactions already exists although with statistics somewhat limited i.e.:
  - ϕ_c(?) : $\bar{p}n$ data at 5.5 GeV/c [4] show a sharp enhancement at 3.1 GeV.
  - η_c(?) : $\bar{p}p$ data at 5.7 GeV/c [5] show sharp enhancements, compatible with Γ = 0 MeV at 2.37 GeV and 2.61 GeV (Fig. 5).

EXPERIMENTAL CONDITIONS

We propose to look for reactions (1) and (2) at a $\bar{p}$ momentum of 10 GeV/c (E^* = 4.54 GeV) which corresponds to a threshold mass for the D in reaction (2) of $\sim$ 2.27 GeV. Higher momentum $\bar{p}$ would be desirable provided that this does not endanger the experiment by setting too stringent requirements on the beam.

ADVANTAGES OF USING BEBC

BEBC is ideal for the type of physics we propose to study here in that in combines, at the same time, the following characteristics:

a) Good resolution ($\varepsilon \sim 250\mu$, H = 35 Kgauss). Events simulation studies of reaction (2) at 10 and 12 GeV/c in BEBC and the 200 HBC gave the results shown in Table I (Appendix 1). It appears that for H = 35 Kgauss the resolution on effective or missing masses is $\sim$3-times better in BEBC than in the 200 HBC. If it turned out that running with H = 35 Kgauss (with the metal piston in BEBC) worsened the ε, a field as low as 20 Kgauss would still be acceptable as it gives ΔM's of the order of a factor 2 better than in the 200 HBC.

b) Reasonable particle identification (ionization density, high probability for δ-rays on secondary tracks, dE/dX over a long length trapping, secondary interactions,...). This property may turn out to be extremely useful in detecting "anomalous" events: strangeness non conservation (as expected in charmed mesons decay), anomalous V^o decays, etc.?

c) Good strange particle (V^O) detection efficiency.

d) Good γ-ray detection efficiency ($\sim$ 15%).

METHOD OF ANALYSIS

Reactions (1) will be hopefully detected as sharp peaks in the various mass spectra in the usual way. The drawbacks which afflict the high multiplicity events, i.e., the large number of (wrong) combinations, are partly overcome here by the good ΔM resolution, which enhances the separation between the sharp peak and the background.

In the case of pair production (reaction 2a) we propose to get all decay modes of one of the D-mesons : $D_{K\pi}\cdot\bar{D}_{all}$ or $D_{K\pi\pi}\cdot\bar{D}_{all}$ ... by studying the events on the 45° line in the scatter diagram of $M_{K\pi(K\pi\pi)}$... vs. the missing mass to the system $K\pi$ or $K\pi\pi$ ... (Fig. 6).

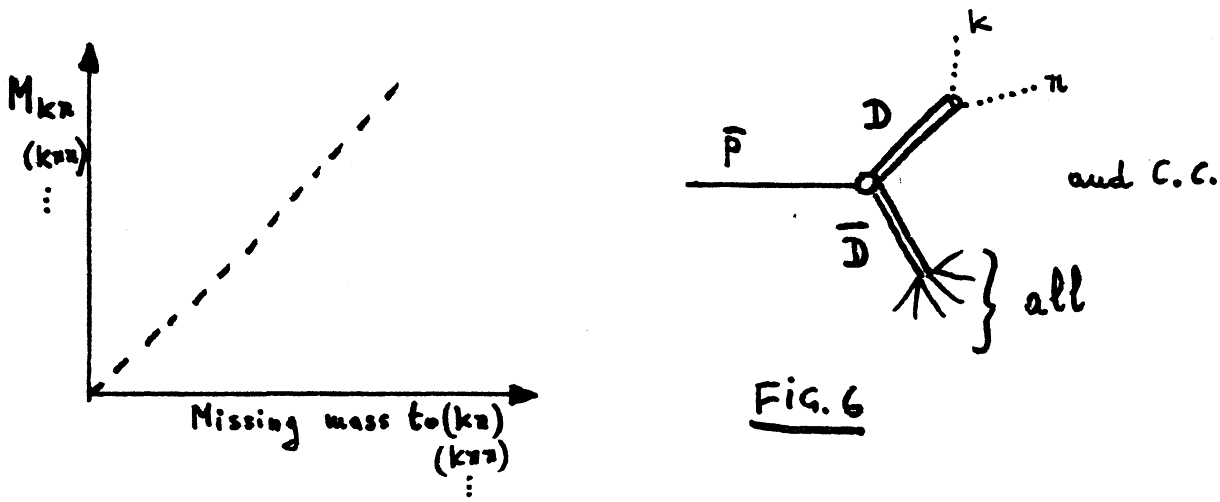

FIG. 6

Similarly, for reaction (2b) one could plot $M_{K\pi}$etc. vs. the missing mass to the $(K\pi)+ m\pi$'s (charged) system.

In this way all events can be used independently of their constraint type, with (at least) the measured resolutions on effective and missing masses given in Table 1. In particular these small errors will open up the possibility to use all 0-C events which at 5.7 GeV/c, represent some 70% of all K^o_S annihilations. This method presents also the advantage of decreasing the number of combinations to be considered since in the scatter diagram of Fig. 6, no specific mass assignment is necessary inside the system treated globally as "missing mass".

If an effect is detected, BEBC characteristics mentioned above will allow a clean sample separation - with background proportional to ΔM - ; this together with the good particle identification and V^o and γ-detection will contribute to a clear determination of its different properties e.g. angular distributions, decay modes, cross sections etc.

NUMBER OF EVENTS

In the beam time available for BEBC one could get several hundred thousands of pictures with up to 50 events/μb (500 kilopictures with 10 $\bar{p}$ per pulse in 250 cm INVOL).

σ_{TOT}	$\sim$ 50 mb	50 events/μb	$\rightarrow$	$2.5\ 10^6$ events
$\sigma_{ANNIHIL.}$	$\sim$ 12 mb	" " "	$\rightarrow$	0.6 "
$\sigma_{K^o_{seen}}$	$\sim$ 1 mb$\div$2 mb	" " "	$\rightarrow$	50'000 $\div$ 100'000 events

SCANNING AND MEASURING CAPACITY

The two groups with their ERASME capacity (in CERN) and an HPD (at I.C.) could scan and measure the load of this experiment with up to 100'000 V^o events in approximately 1 year.

We propose to measure in the first place all events with associated V^o's. These are mainly K^o annihilations although Λ's and $\bar{\Lambda}$'s will also be present and will be measured at the same time. Subsequently the other annihilations will be scanned for and measured (with some selection criteria to eliminate small p secondary protons or antiprotons).

Independently of the outcome of the charmed mesons search, a $\bar{p}$ run in BEBC in the 10 GeV/c region would represent a good complement to the $\bar{p}$ experiments now in progress in the 200 HBC at 12 GeV/c at 12 GeV/c (CERN TCC 72-39) or proposed in the same chamber by the "Working party on $\bar{p}$ interactions" (CERN TCC 74-25).

ACKNOWLEDGEMENTS

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APPENDIX

Results of a study of event simulation comparing resolutions in the 200 HBC and BEBC are shown in Table I.

The reaction generated is

$$\bar{p}p \rightarrow D_o \bar{D}_o \quad ; \quad D_o \rightarrow k^{\pm}\pi^{\mp} \quad ; \quad \bar{D}_o \rightarrow \text{all}$$

The D_o is detected by the effective mass of the (kπ) system, the $\bar{D}_o$ by the missing mass to the Kπ system.

The widths of the D's were $\Gamma_D = 0$; the angular distributions were assumed isotropic both for the production and decay of the D's.

The parameters $^1/p$, λ,ϕ were given spreads within their errors (Coulomb + distortions) in the usual way. The incident $\bar{p}$ momentum was assumed to be known from the beam optics to $\pm$ 0.2%, the λ and ϕ are measured in the chamber (10 cm track length in the case of the 200 HBC, 15 cm in BEBC). No secondary interactions nor decays were introduced and the tracks were taken as straight. The errors on the masses given in Table 1 correspond to ΔM <u>measured</u> of the type one could use for <u>all</u> events Oc, 1c, 4c.

References:

[1] M.K. Gaillard, B.W. Lee, J.L. Rosner, "Search for Charm" Fermi Lab. Pub. 74/34 THY and G. Altarelli, N. Cabibbo, L. Maiani, " enhancement of Non leptonic decays of Charmed particles" PTENS 74/5

[2] R. Hubbard - private communication

[3] A. Bigi et al. Nuovo Cimento 33 (1964) 1249

[4] H. Braun et al. Report to the 1971 Amsterdam Conference CBH 71-3 STRASBOURG

[5] H.W. Atherton et al. CERN/D.Ph.II/Phys. 71-18 (1971)

TABLE I : $pp \to D_o \bar{D}_o$; $D_o \to K^{\pm}\pi^{\mp}$; $\bar{D}_o \to$ all ; M_D = 2,15 GeV ; $\Gamma_D = 0$

Pinc.	200 HBC H=17.5 kgauss ε=70μ	BEBC H=35 kgauss ε=250μ	H=25 kgauss ε=250μ	H=20 kgauss ε=250μ
10 GeV/c	$\Delta M_{k\pi}$ = ±22 Mev ΔMM = ±30 Mev	±8 Mev ±10 "	±9 Mev ±13 "	±11 Mev ±15 "
12 GeV/c	ΔM ±24 Mev ΔMM ±43 "	±9 Mev ±16 "	±10 Mev ±20 "	±12 Mev ±22 "

ΔMM = error on missing mass to the (kπ) system

INVOL 200 HBC : ΔX = 100 cm ; Δy = 15 cm ; ΔZ = 2 cm

INVOL BEBC : ΔX = 250 cm ; Δy = 80 cm ; ΔZ = 4 cm

$\langle P_T \rangle$ versus $\langle |P_L| \rangle$
CORRELATIONS IN
ANNIHILATION AND
NON-ANNIHILATION
PROCESSES

$\bar{p}p \to$ pions ○

$pp \to NN +$ pions ⎫ ▫ pions
$\bar{p}p \to \bar{N}N +$ pions ⎭ ◻ nucleons

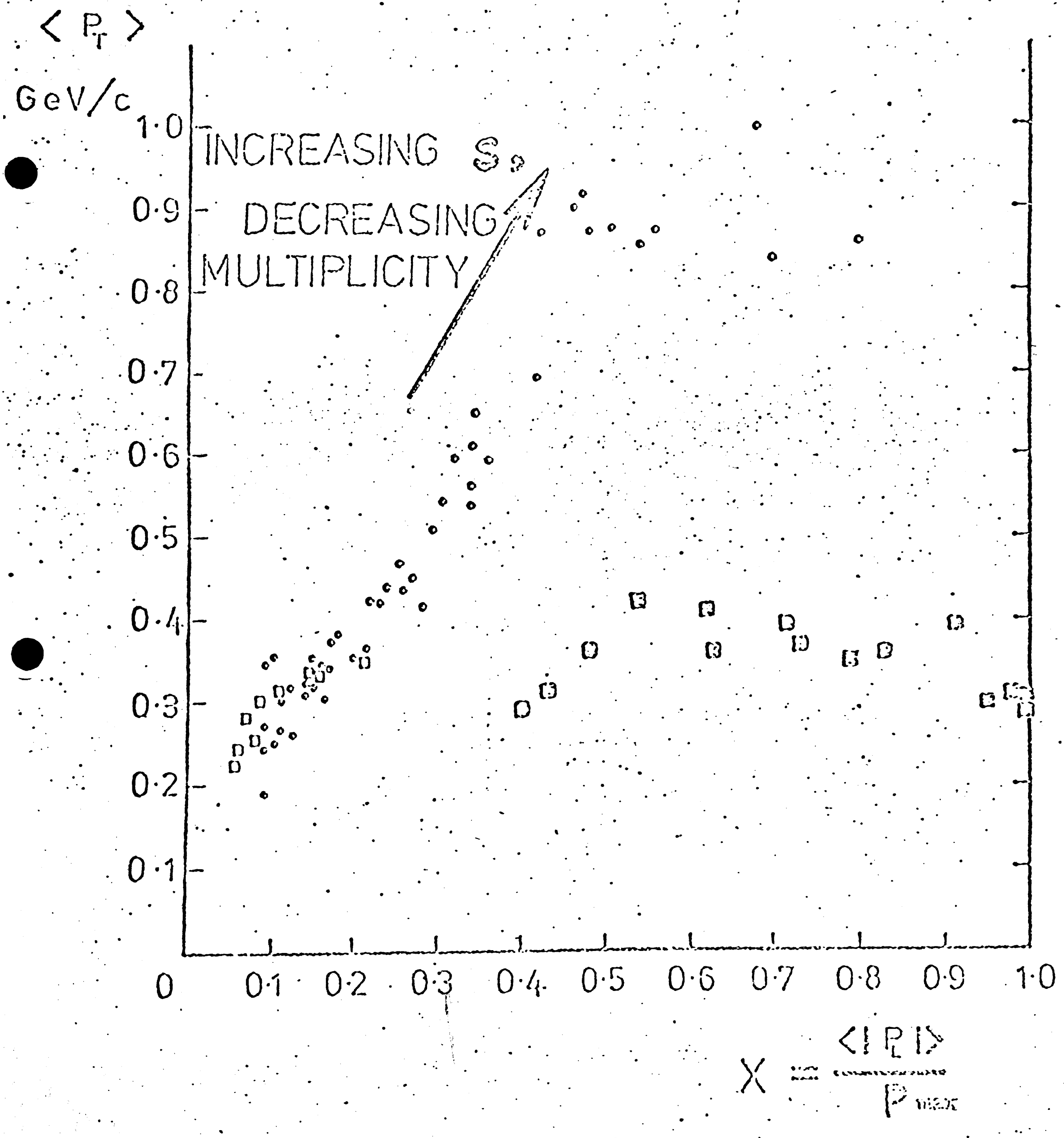

FIGURE 1 from Ref. CERN-TCC/74-

(a) 3.6 GeV/c $\bar{p}p$ Nucl. Phys. B (1970) 416.
(b) 5.7 " "
(c) 14.75 " " NAL Pub 73/81 EXP (1974)

Fig. 2

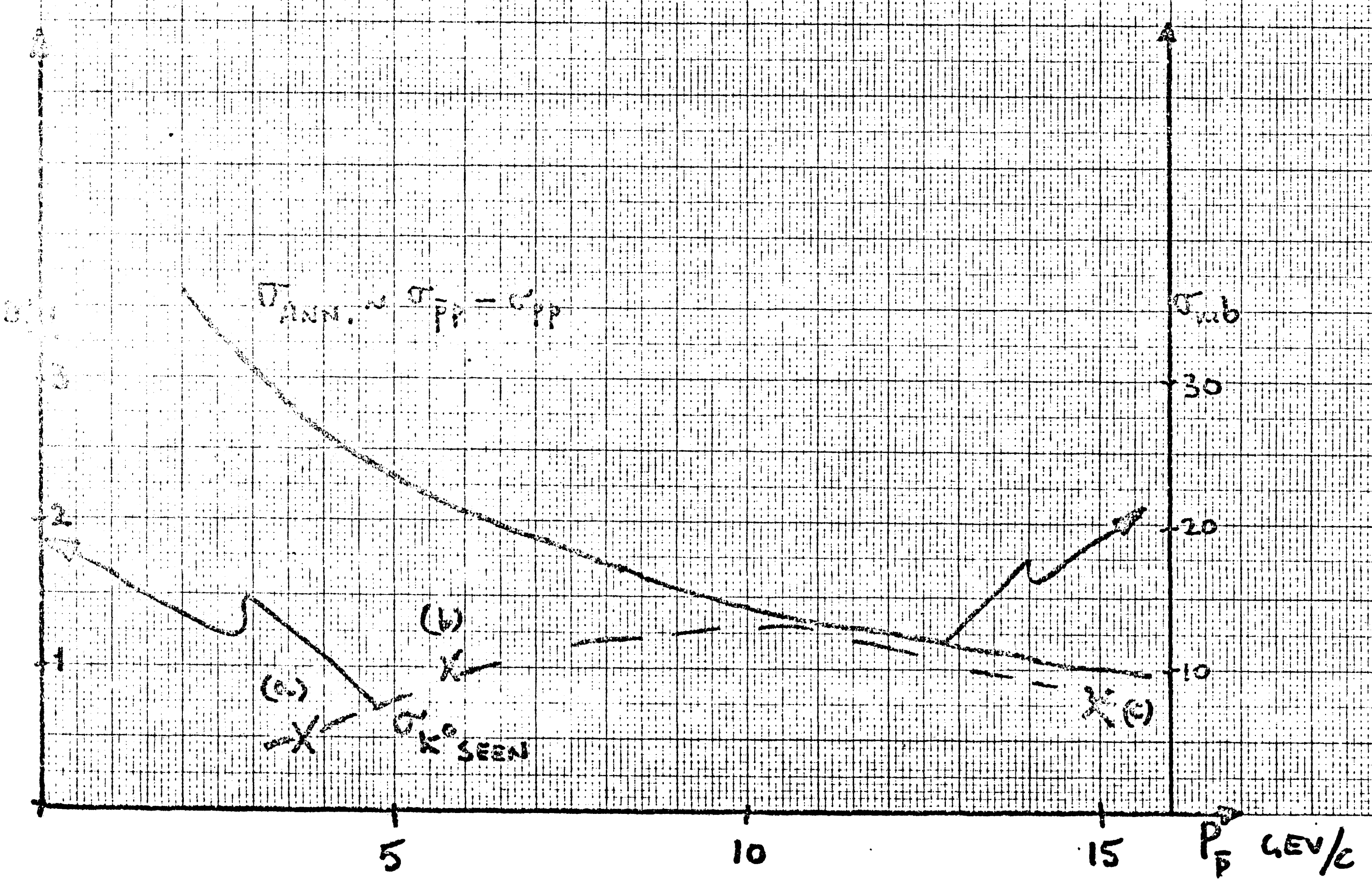

Fig. 3

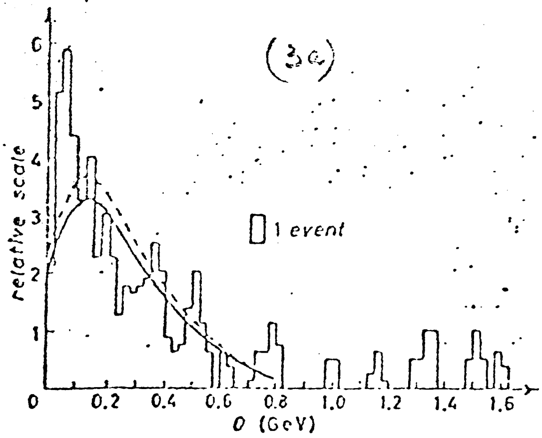

Fig. 8. – Ideogram (in intervals of 25 MeV) for the Q-value of the $K_1^0K_1^0$ system. For each event a constant error of ± 50 MeV was assumed. The lines represent the background as calculated by a Monte-Carlo method (upper line is normalized to total area of histogram, lower line to the part $Q > 200$ MeV).

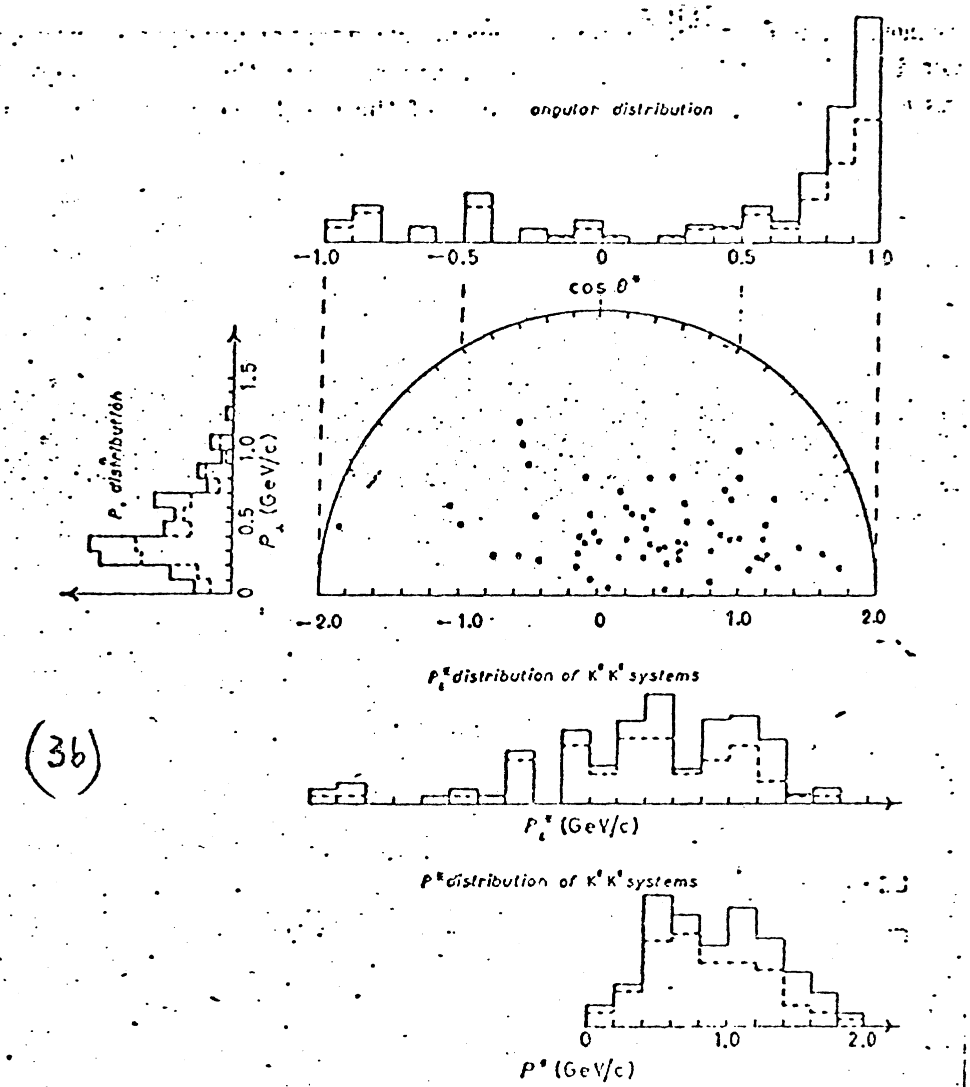

Fig. 4. – $P_\perp$-$P_\parallel^*$ plot and histograms for system formed by both K_1^0 produced in the reaction $\pi^- + p \rightarrow K_1^0 + K_1^0 + \mathcal{N} + n\pi$.

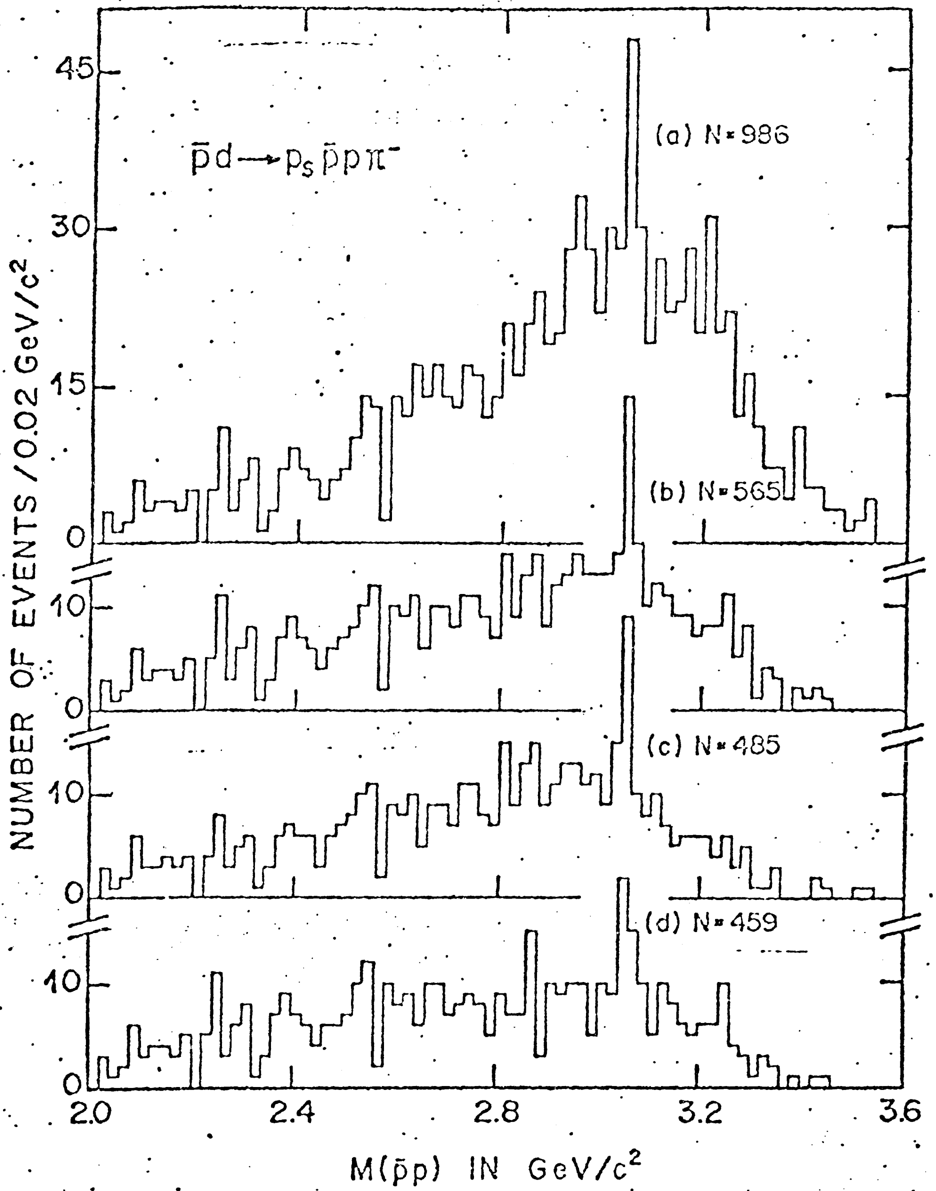

Figure 4 from H. BRAUN et al {Strasbourg CBH-71-3 Report to Amsterdam Conference

The $M_{\bar{p}p}$ distributions

a) All the $\bar{p}d \rightarrow p_s \bar{p} p \pi^-$ events.

b) Excluding the events in the $\bar{\Delta}^{--}$ band defined by $1.16 < M_{\bar{p}\pi^-} < 1.32$ GeV/c^2.

c) Excluding the events in the $\bar{\Delta}^{--}$ band and also those for which the faster proton has a laboratory momentum less than 0.28 GeV/c.

d) Excluding the events in the $\bar{\Delta}^{--}$ and Δ^0 bands i.e. : $1.16 < M_{\bar{p}\pi^-}$, $M_{p\pi^-} < 1.32$ GeV/c^2.

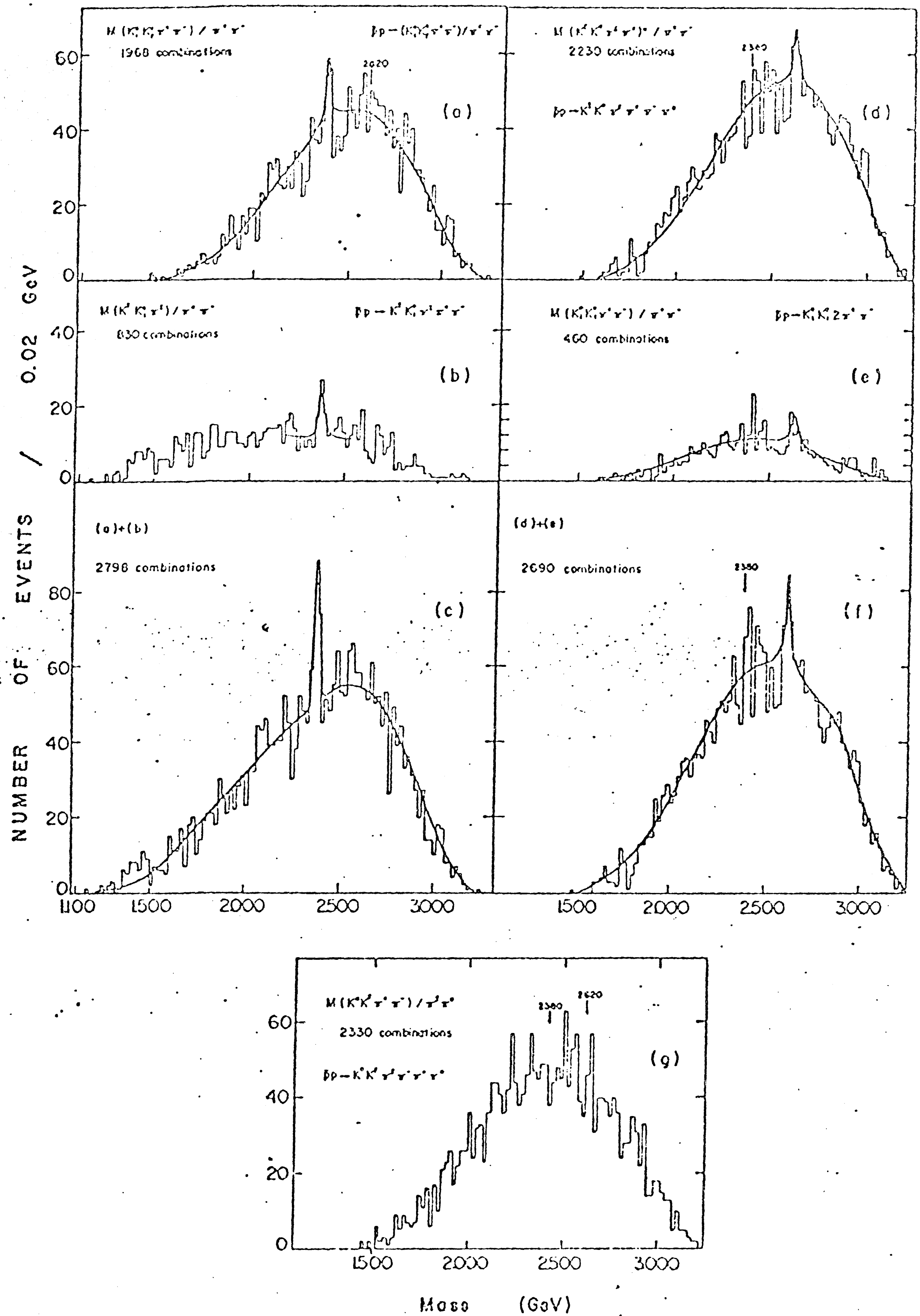

Fig 5 Reference H.W. Atherton et al CERN/D-Ph II/Phys. 71-18