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A 100 EVTS/μb K^+p EXPERIMENT AT 7 GeV/c IN BEBC.

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Summary:

The two most interesting subjects to be investigated are:

a) $K\pi$ phase shift analysis,

b) S = +1 meson spectrum in the missing-mass spectrometer mode.

We are proposing an experiment consisting of 600.000 pictures to be taken in the BEBC filled with hydrogen exposed to a R.F. separated K^+ beam at 7 GeV/c.

The present "world sample" of K^+ interactions in hydrogen bubble chambers, taking into account all existing exposures between 3 and 16 GeV/c, corresponds to a sensitivity of about 150 evts/μb. Only two experiments (Berkeley - Group A - at 12 GeV/c and CERN - Bruxelles - Birmingham - Paris - Saclay at 16 GeV/c) reach the 35 evts/μb level. Another (English collaboration at 10 GeV/c) reaches 15 evts/μb, whereas all the others are below the 10 evts/μb level.

The proposed experiment, using a primary intensity of 20 K^+ per picture and a fiducial region of 2.5 meter length, would yield 100 evts/μb, nearly doubling the world sample.

With a total amount of 1.8×10^6 interactions (3 interactions/ picture) concentrated in a single experiment a large amount of physical information can be extracted. Only two of the most interesting subjects will be mentioned here.

a) <u>Kπ interaction.</u>

The largest effort made so far in the Kπ phase-shift analysis is that of the Bruxelles - CERN - UCLA collaboration, that used data from the "International K^+p Bubble Chamber data collaboration".[1]

The events used for the analysis are of the type

$$K^+p \rightarrow K^+\pi^-\Delta^{++} \qquad (1)$$

and

$$K^+p \rightarrow K^0\pi^0\Delta^{++} \qquad (2)$$

coming from the channels

$$K^+p \rightarrow K^+\pi^- p\,\pi^+ \qquad (1a)$$

and

$$K^+p \rightarrow K^0\pi^0 p\,\pi^+ \qquad (2a)$$

In Table 1 we give the number of events for reactions (1) and (2) used by the Bruxelles - CERN - UCLA collaboration. We also estimate the contributions that will come from the Berkeley - Group A - and the CERN - Bruxelles - Birmingham - Paris - Saclay experiments, not included in the aforementioned analysis. Finally, we give the expected yields for the proposed experiment.

As can be seen from the table, due to the fall-off of the cross-sections for reactions (1) and (2) with increasing energy, the contributions of the two larger experiments at 12 and 16 GeV/c will be relatively modest, so that our proposed experiment will more than double the world sample of $K\pi\Delta^{++}$ usable for the Kπ phase-shift analysis.

It is worthwhile to point out that to have the whole sample concentrated in a single experiment will avoid problems of different mass resolutions and poor knowledge of absolute cross-section normalization factors which arise always in a collection of different experiments.

The mass resolution both for the 4C reaction (1a) and the 1C reaction (2a) will be an important parameter of the experiment, particurlarly in connection with the existence of a narrow ($\Gamma \lesssim 30$ MeV) resonance in the δ_0^1 phase found as a possible solution by the authors of ref. 1. It is not possible to know in advance what the "pointing error" in BEBC will be, so we cannot give a value for the mass resolution we hope to achieve. However, for a pointing error of 500 μ, the resolution will not be worse than that of a "conventional" hydrogen bubble chamber.

b) S = +1 mesons in the "Missing Mass Spectrometer" mode.

The Missing Mass Spectrometer (MMS)(2) and the CERN Boson Spectrometer (CBS)(3) have investigated the non strange boson spectrum from 0.5 to 3.0 GeV, with the missing mass method, with a typical mass resolution of 7.5 MeV (half-width) by measuring the proton recoiling from an incident π^-, under conditions such that the measurement of one parameter only (the angle or momentum respectively) allowed a good determination of the missing mass. The experiments were performed at various π^- energies, that gave access to different boson masses.

The unique possibility offered by BEBC of stopping particles of momenta up to about 800 MeV/c, by "trapping" them in the magnetic field, together with the accurate measurements of range and angles that are common features of all hydrogen bubble chambers, make BEBC a very good competitor for the missing mass spectrometer.

In our case, i.e. with K^+ of $\simeq$7 GeV/c, the measurement of all the protons stopping in the chamber with momenta between 200 and 800 MeV/c, would allow the study of the strange boson spectrum between

0.8 and 2.5 GeV.

In the combined spectrum of the MMS and CBS, resonances with a 5 μb production cross section were shown with fairly good statistical accuracy. For the same cross section our experiment, having a sensitivity of 100 evts/μ b, would give about 400 events <u>in the peak</u>, (assuming 20% loss at small momentum transfer), to be compared with 200-300 detected by MMS and CBS.

In order to give an estimate of the expected mass resolution the following assumptions have been made.

The error on the missing mass M being given by:

$$M = \frac{1}{2M}\left[\left(\frac{\delta M^2}{\delta P_k}\right)^2 (\Delta P_k)^2 + \left(\frac{\delta M^2}{\delta P_p}\right)^2 (\Delta P_p)^2 + \left(\frac{\delta M^2}{\delta \cos\vartheta}\right)^2 (\Delta \cos\vartheta)^2\right]^{1/2} \qquad (3)$$

we have assumed:

$$\frac{\Delta P_k}{P_k} = \pm 0.5\%$$

The errors on the proton momentum and angle are computed, assuming measurement by range up to 500 MeV/c with the formulae:

$$\frac{\Delta P_p}{P_p} = \frac{1}{3.52}\,\frac{\Delta L}{L},$$

$$\Delta\vartheta = \left[1.2\times 10^{-8}\frac{\varepsilon^2}{L^2} + \left(\frac{L}{2\rho}\,\frac{\Delta P_p}{P_p}\right)^2 + \frac{2\times 10^{-3} L\alpha}{P_p^2\beta^2}\right]^{1/2}$$

and measurement by curvature for $p_p > 500$ MeV/c with the formulae:

$$\frac{\Delta P_p}{P_p} = \left[\frac{0.133\,\alpha}{H^2 L \beta^2} + \frac{3.55\times 10^{-6}\, p^2 \varepsilon^2}{H^2 L^4}\right]^{1/2}$$

$$\Delta\vartheta = \left[\frac{2\times 10^{-3} L\alpha}{p^2\beta^2} + \frac{1.44\times 10^{-7}\varepsilon^2}{L^2}\right]^{1/2}$$

In the above formulae:

$$\alpha = \log(4.8p) + \log(145\frac{p}{M}).$$

L = track length in cm.

ΔL = $2 \times \varepsilon$

ρ = radius of curvature in cm.

p = momentum in MeV/c

ε = pointing error in μ , assumed 300 μ

H = magnetic field in Kgauss = 37 Kgauss

ϑ = angle in radians.

The dip angle has been assumed to be zero, and the contribution of its error forgotten. A beam defining length of 50 cm. has been assumed (this gives a contribution to the error on the angle: $\Delta\vartheta = \pm 2$mrad). A floor on the proton momentum error $\Delta p_p/p_p \geqslant 0.7\%$ has been imposed.

For a discussion of the formulae used see for example ref.4.

Fig. 1 shows the ϑ-p plot with curves of fixed M and of fixed ΔM. As can be seen a mass resolution of 7-8 MeV can be obtained for masses higher than 1.5 GeV, at proton angles smaller than about 30°. In the full angular and momentum range masses between 0.8 and 2.5 GeV can be explored with a relolution not worse than 25 MeV.

We mention last what is probably the biggest and the most obvious advantage of this experiment, that is the fact that for any anomaly detected in the missing mass spectrum all the information about the particles "on the other side" is available for measurement and is unbiased.

At a scanning rate of 20 evts/hour per scanning table, 10 tables working two shifts per day would complete the scanning in 2.5 years.

The total number of events to be measured for a) and b) is $1.0-1.2 \times 10^6$, if one neglects elastic events, very short protons, etc.. Since half of them would consist of one track events (the proton) they could be measured very fast, even taking into account that secondary interactions of the protons would have to be measured, for a precise momentum determination.

For two automatic measuring machines, this would imply 2.5 years of work. The proposing groups of Padova, Roma and Trieste, can supply 11 tables and 1 of the measuring machines(+) needed to complete the measurements in 2.5 years. Collaboration with a group equipped with an automatic measurement machine is therefore desirable.

The proposal has been approved by the Italian Istituto Nazionale di Fisica Nucleare.

Spokesman for the experiment is Prof. A. Bettini.

TABLE 1

	World DST	Berkeley - Group A - 12 GeV/c	CERN-Brux. etc.. 16 GeV/c	Proposed Experiment(*) 7 GeV/c
$K^+p\pi^+\pi^-$	77267	30163		135000
$K^+\pi^-\Delta^{++}$	31122	11000	9000	58000
$K^0p\pi^+\pi^0$	18806	6430		39000
$K^0\pi^0\Delta^{++}$	4845	1860	1500	11000

(*)Assuming 85% processing efficiency.

(+)The measuring machine, a PEPR, could be made available to this experiment for 50% of the time, yielding about 250.000 events per year.

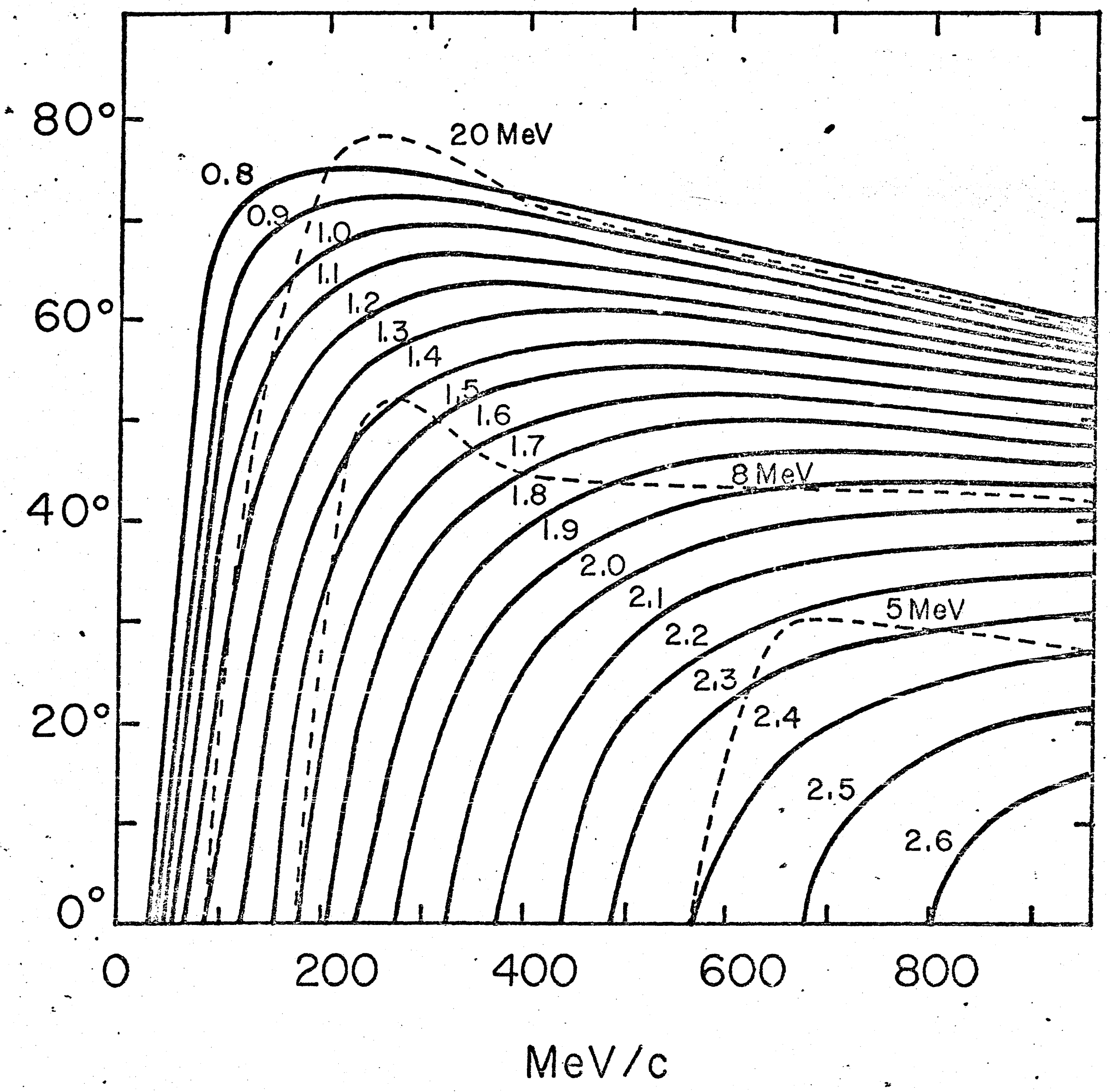
REFERENCES

(1)- H.H. Bingham et al.:"A new Analysis of $K\pi$ scattering as observed in $K^+p \to K^0\pi^0\Delta^{++}$ from 3 to 13 GeV/c". CERN/D.Ph.II/PHYS. 71-22 Rev, 25 Oct. 1971.

(2)- G. Chikovani et al. Phys. Lett, B 25 44 (1967).

(3)- H. Benz et al. Phys. Lett, B 28 233 (1968).

(4)- "Design study for a High Magnetic Field Hydrogen Bubble Chamber for use on Nimrod". RHEL/S/101 (1967).


80°
60°
40°
20°
0°
0
200
400
600
800
MeV/c
20 MeV
8 MeV
5 MeV
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6