ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

11/VII-72

E1 - 6598

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ЛАБОРАТОРИЯ ВЫСОКИХ ЭНЕРГИЙ

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Submitted to XVI International Conference
on High Energy Physics, Batavia.

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This report represents coherent-production studies /1–8/ done in nuclear emulsion. The experimental procedures used here are the following:

i) in a multiplicity distribution of the "clean" stars (no slow charged particle, no recoil nucleus, no accompanying electron) there are distinct peaks at multiplicity $n=3$ and much less distinct at $n=1$ apart from the maximum expected to appear at $n=5-6$ in the Serpukhov energy region. They are attributed to coherent three- and one-prong interactions in which neither destruction nor excitation of the target nucleus is seen. An example of such distribution is shown in fig. 1 for 60 Gev/c pions and 67 Gev/c protons

ii) $\sum_{i=1}^{n} \sin\theta_i$ - parameter (roughly proportional to the longitudinal - momentum transfer to the target nucleus) has been applied in order to estimate the number of the coherent interactions N_n. For that we compare the $\sum_{i=1}^{n} \sin\theta_i$ distribution between "clean" and "dirty" events of a given multiplicity n. The latter are interactions with single nucleons and cannot be coherent. An example of such procedure is shown in fig. 2 for 67 Gev/c protons. The dependence of the estimated N on the value of $(\sum_{i=1}^{n} \sin\theta_i)_{max}$ actually assumed as an upper limit for the coherent events is also shown. For emulsion nuclei we expect $(\sum_{i=1}^{n} \sin\theta_i)_{max}$=0.25-0.45. It is seen that in the large region of $\sum_{i=1}^{n} \sin\theta_i$ the estimated number N of coherent interactions does not depend on the actual choice of $(\sum_{i=1}^{n} \sin\theta_i)_{max}$. The error of this value of N_n is the smallest at the beginning of the plateau. It should be pointed out that this estimate of N_3 agrees with estimate made in procedure. i) assuming a smooth multiplicity distribution of the incoherent background. Hereafter we use only $\sum_{i=1}^{n} \sin\theta_i$ method which can be applied to all multiplicities.

Table 1 shows the summary of the experimental results obtained in a homogeneous way. L is a total length traced in a given experiment. $\lambda = L/N$ is a coherent-interaction length in nuclear emulsion and $\sigma \sim 1/\lambda$ is the coherent cross section for the average emulsion nucleus.

Now let us comment on the individual coherent-production channels.

i) one-prong events. We see an effect for protons at the Serpukhov energies. The N_1-values given here are probably strongly underestimated due to the fact that we had to remove all small-deflection-angle in order to get rid of elastic scattering. In fact this channel can be as high as the three-prong one. This is probably connected with coherent reactions $p \to p\pi^0$ and $p \to n\pi^+$ which are likely to be most favoured by the coherent phase space.

For pions it is hardly possible to give any estimate with the help of the procedures described above. The only reaction which can give a sizable contribution here is $\pi^- \to \pi^- \pi^0 \pi^0$ since $\pi^- \to \pi^- \pi^0$ is forbidden for diffractive processes. The former coherent reaction was studied in emulsion for 60 Gev/c pions in Ref. /14/.

ii) five-prong events. This channel is very weak at our energies and in majority of cases the results should be treated as an indication. This is certainly due to the coherent phase space which damps the high masses of the system produced coherently especially for low energies. An increase of the coherent cross section with energy is seen at any case for pions.

iii) the three-prong events represent our best sample. For pions we could even estimate the cross section for the channel without neutral pions. This was done either by direct momentum measurements performed in a part of our sample or with the help of the formula

$$N_3 - 2.2\,N_5 \text{ since } \frac{\pi^- \to \pi^+\pi^-\pi^-\pi^0\pi^0}{\pi^- \to \pi^+\pi^+\pi^-\pi^-\pi^-} = 2.2 \text{ for isospin } T = 1.$$

The results obtained with the help of both methods agree within the limits of errors and the average values are shown in Table 1.

The proton results are for the mixture of three-particle, four-particle, etc., reactions. Nevertheless the relevant cross sections are lower than those for the reaction without neutral pions at the same energy - cf fig. 3. This can be explained in terms of the optical model. Namely the incident pions are absorbed less than protons in a nuclear matter. The same is probably true for a $\pi^+\pi^-\pi^-$ system /9/ as compared with a $p\,\pi^+\pi^-$ /10/ or similar one.

The energy dependence of both cross sections is shown in fig. 3. This is compared with some theoretical predictions.

The first is an optical model calculation performed by Lesniak and Lesniak who obtained the absolute values of the coherent cross section for $\pi^- \to \pi^+\pi^-\pi^-$ and for the $p\,\pi^+\pi^-$ reaction /12/. It is seen that the theoretical curves agree qualitatively with the experimental data if one takes into account that the experimental points for the three-prong proton coherent interaction contain an admixture of four- and more particle reactions.

The second is a Deck-type calculation performed by the Tashkent group /13/. Curve 3 is a calculation in the framework of the Trefil formalism performed in Alma-Ata /15/. The σ vs E plot obtained in this way is fitted to the experimental results on the $\pi^- \to \pi^+\pi^-\pi^-$ reaction and is seen also to reproduce the increase of the cross section.

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Received by Publishing Department
on July 13, 1972.

Table 1.

Momentum Gev/c	Primary particle	Final state	Additional neutrals	L(m)	N_n	(m)	(mb)	Ref
17	π^-	$\pi^+\pi^-\pi^-$	possible	7656	171±20	45^{+6}_{-5}	4,8±0,6	/3/
17	π^-	$\pi^+\pi^-\pi^-$	excluded	7656	156±18	49^{+7}_{-5}	4,4±0,6	/3/
17	π^-	$2\pi^+3\pi^-$	unlikely	7656	2	-	-	/3/
45	π^-	$\pi^+\pi^-\pi^-$	possible	2725	131±15	21^{+3}_{-2}	9,9±1,1	/3/
45	π^-	$\pi^+\pi^-\pi^-$	excluded	2725	87±16	31^{+5}_{-4}	6,7±1,0	/3/
45	π^-	$2\pi^+3\pi^-$	unlikely	2725	17±6	161^{+87}_{-42}	1,3±0,5	/3/
60	π^-	$\pi^+\pi^-\pi^-$	possible	3147	197±16	16±1	12,9±1,1	/1/
60	π^-	$\pi^+\pi^-\pi^-$	excluded	3147	139±21	23^{+4}_{-4}	9,0±1,3	/1/
60	π^-	$2\pi^+3\pi^-$	unlikely	3147	21±8	150^{+92}_{-41}	1.4±0.5	/1/
22	p	$p\pi^+\pi^-$ $n\pi^+\pi^+\pi^-$	possible	10109	190±26	53^{+8}_{-6}	4.0±0.6	/4,5,6,7/
22	p	$p\pi^+\pi^+\pi^-\pi^-$ $n3\pi^+2\pi^-$	unlikely	2330	3	-	-	/8/
50	p	$p\pi^0$ $n\pi^+$	possible	2568	>41±10	$<63^{+20}_{-13}$	>3.3±0.8	results of
50	p	$p\pi^+\pi^-$ $n2\pi^+\pi^-$	possible	2568	65±11	40^{+8}_{-6}	5.2±0.9	the Tashkent
50	p	$p2\pi^+2\pi^-$ $n3\pi^+2\pi^-$	unlikely	2568	10±4	260^{+170}_{-80}	0.8±0.3	group
67	p	$p\pi^0$ $n\pi^+$	possible	3057	> 70±20	$<44^{+17}_{-9}$	>4.8±1.4	/2/
67	p	$p\pi^+\pi^-$ $n2\pi^+\pi^-$	possible	3057	106±14	29^{+4}_{-3}	7.2±0.9	/2/
67	p	$p2\pi^+2\pi^-$ $n3\pi^+2\pi^-$	unlikely	3057	11± 5	280^{+230}_{-90}	0.7±0.3	/2/

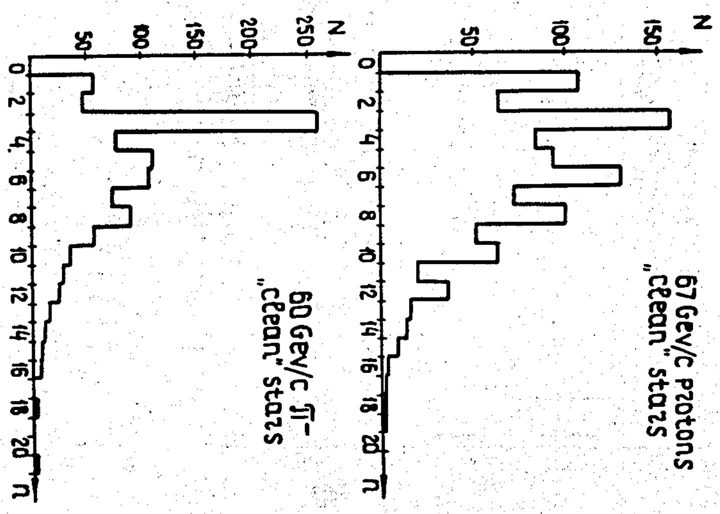

Fig. 1.

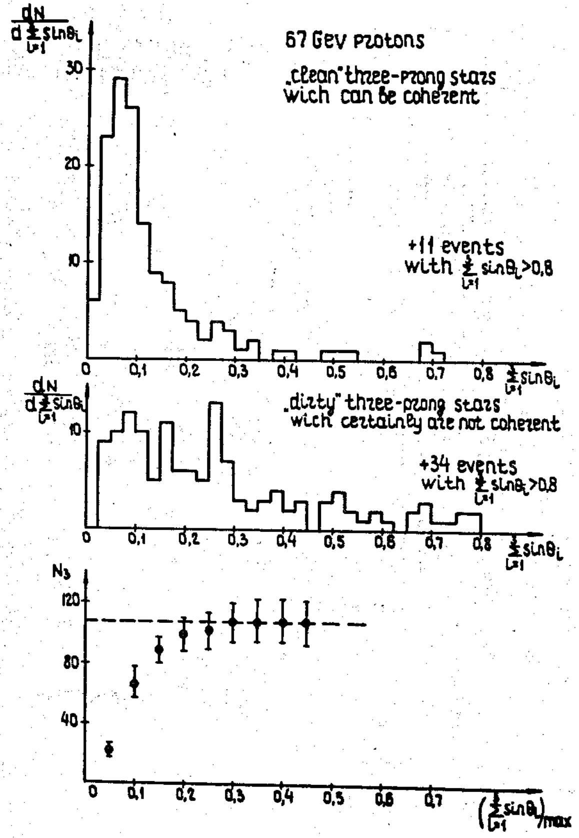
$\frac{dN}{d\sum_{i=1}\sin\theta_i}$
30
20
10
67 GeV protons
„clean" three-prong stars wich can be coherent
+11 events with $\sum_{i=1}\sin\theta_i > 0,8$
0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
$\sum_{i=1}\sin\theta_i$
$\frac{dN}{d\sum_{i=1}\sin\theta_i}$
10
„dirty" three-prong stars wich certainly are not coherent
+34 events with $\sum_{i=1}\sin\theta_i > 0,8$
$\sum_{i=1}\sin\theta_i$
N_3
120
80
40
$\left(\sum_{i=1}\sin\theta_i\right)_{max}$

Fig. 2.

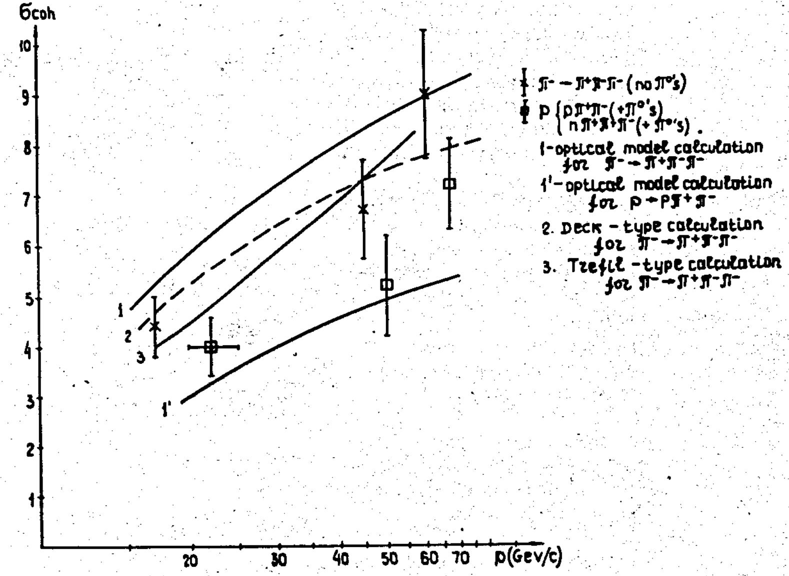
σ_{coh}
10
9
8
7
6
5
4
3
2
1
1
2
3
1'
20
30
40
50
60
70
p(GeV/c)
$\pi^- \to \pi^+\pi^-\pi^-$ (no π^0's)
p $\begin{cases} p\pi^+\pi^- (+\pi^0\text{'s}) \\ n\pi^+\pi^+\pi^- (+\pi^0\text{'s}) \end{cases}$.
1-optical model calculation for $\pi^- \to \pi^+\pi^-\pi^-$
1'-optical model calculation for $p \to p\pi^+\pi^-$
2. Deck - type calculation for $\pi^- \to \pi^+\pi^-\pi^-$
3. Trefil -type calculation for $\pi^- \to \pi^+\pi^-\pi^-$

Fig. 3.