THE INSTITUTE OF MATHEMATICAL SCIENCES
MADRAS - 4 (India)

Report on Recent Experimental Data,

1963

by

K. Venkatesan*

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PREFACE

The present report is a collection of the reports on recent experimental data issued monthly during the year 1963, commencing from the month of April. In the initial stages it was thought useful to compile the data such that, e.g., cross-sections for various processes over large ranges of energies and angles were assembled in a single place. This involved inclusion of the not-so-recent experimental data also. Thus in the case of pion-nucleon scattering cross-sections, the "ancient" and famous experimental values of Fermi, Ashkin and others are included as well as the most recent experimentals which try to decide whether there is or not a shrinking in the diffraction peack. The data cover strong, electromagnetic and weak interactions.

The section on many body problems, constitutedby Dr. R. Vasudevan gives an account oftwo important experiments, -one which refers to the direct measurement of the energy gap in super conductors and the other to the third sound in liquid heliun films.

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APRIL 1963

TOTAL AND PARTIAL CROSS-SECTIONS FOR PION NUCLEON SCATTERING UPTO 1.5 BEV INCIDENT ENERGY

(Data collected by K.Venkatesan)

The present report summarises in the form of tables the data on the total, elastic and inelastic cross-sections for pion-nucleon scattering for energies of the incident pion ranging upto 1.5 Bev, the region in which the most striking feature of the pion-nucleon interaction, namely, the resonances happen to lie. The data for energy regions below the first pion-nucleon resonance have been taken from Bethe-de Hoffmann's "Mesons and Fields", Vol.II, which is reliable at least regarding the cross-sections and large phase-shifts in this region. For higher energies recent data have been used of which those of Brisson et al for $\pi^+ - p$ and $\pi^- - p$ total cross-sections see to be the most extensive ones. Single experiments covering large energy ranges if reliable have been preferred to others.

EXPERIMENTAL DATA (REPORT FOR APRIL)

(K.Venkatesan)

Total Cross-Sections

π^{+}-p Scattering

Pion kinetic Energy (Lab) in Mev	σtot in mb	Authors
135	128 ± 4	Ashkin1)
152	175 ± 6	..
165	188 ± 5	Glicksman1)
185	188 ± 8	Ashkin1)
196	200 ± 14	,,
210	148 ± 20	Yuan1)
280	88 ± 11	,,
340	48 ± 9	Lindenbanm1)
382	40.78 ± 1.62	Brisson et al2)
476	23.67 ± 1.08	,,
574	17.37 ± 0.82	,,
633	15.16 ± 0.72	,,
673	14.77 ± 0.67	,,
778	19.44 ± 0.80	,,
827	21.36 ± 0.81	,,
847	22.42 ± 0.83	,,
872	21.85 ± 0.86	,,
910	24.5 ± 1.3	D.Stonehill et al3)
990	27.9	Kopp et al4)
1090	30.1 ± 1.6	D.S4onehill et al3)
1260	40.3 ± 2.2	,,

π^-p Scattering

Pion kinetic energy (Lab) in Mev	σtot in mb	Authors
133	46.9 ± 2.4	Ashkin[1]
165	67.5 ± 1.5	Glicksman[1]
169	64 ± 6	Fermi[1]
187	63.5 ± 1.6	Glicksman[1]
195	63.1 ± 2.5	Ashkin[1]
209	57.2 ± 2.9	Glicksman[1]
265	43.5 ± .6	Yuan[1]
340	28 ± 11	Lindenbanm[1]
370	28.9 ± 1.4	Brisson et al[2]
426	29.5 ± 1.4	,,
468	30.00 ± 1.2	,,
518	34.9 ± 1.3	,,
567	44.6 ± 1.9	,,
591	45.8 ± 1.7	,,
604	45.5 ± 1.8	,,
616	45.1 ± 1.7	,,
643	44.4 ± 2.2	,,
665	39.2 ± 1.4	,,
719	35.1 ± 1.5	,,
749	37.6 ± 1.6	,,
769	37.4 ± 2.0	,,
819	47.9 ± 1.9	,,
840	54.6 ± 2.1	,,
868	58.6 ± 2.4	,,
890	57.8 ± 2.2	,,
918	54.5 ± 2.4	,,
943	50.4 ± 2.6	Brisson et al[2]
972	44.7 ± 2.2	,,

Pion kinetic energy (Lab) in Mev	σ_{tot} in mb	Authors
1014	39.6 ± 2.0	Brisson et al[2)]
1076	35.9 ± 2.0	,,
1150	35.5 ± 2.0	,,
1450	32.5 ± 0.6	SOBB Collaboration[5)]

PION-PRODUCTION IN PION-NUCLEON SCATTERING

$$\pi^- + p \rightarrow \pi^- + \pi^+ + n \tag{1}$$

$$\rightarrow \pi^- + \pi^0 + p \tag{2}$$

$$\pi^+ + p \rightarrow 2\pi + N \tag{3}$$

$$\rightarrow 3\pi + N$$

$$\rightarrow \Sigma^+ K^+$$

Pion kinetic energy Mev	Total cross-sections (mb)			Authors
	σ_1	σ_2	σ_3	
290	0.4 ± 0.2	2.0 ± 0.9		Goodwin et al[6)]
370	1.93 ± 0.37	1.2 ± 1.0		
427	3.36 ± 0.74	0.4 ± 1.6		
500			2.85 ± 0.5	Wiilis[7)]
600			~ 4	Kopp et al[4)]
800			9	,,
1000			12.5	,,
1200			20	,,
1400			26	,,
910			14.33 ± 1.6	Stonehill

Pion kinetic energy Mev	Total cross-sections (mb)			Authors
	σ_1	σ_2	σ_3	
1090			17.45 ± 2.12	Stonehill et al3)
1260			23.82 ± 2.87	

$\pi^{+}p$ Elastic cross-sections

Kinetic energy in Mev	$\sigma(\pi^{+}p)$ in mb.	$\sigma(\pi^{-}p)$ in mb.	in	Authors
533	15.32 ± 0.47	16.20 ± 0.50		J.A.Helland et al9)
581	12.17 ± 0.57	19.96 ± 0.54		
698	8.02 ± 0.22	15.75 ± 0.28		
873	12.05 ± 0.45	26.58 ± 0.61		"
990	14.54 ± 0.71	19.82 ± 0.24		"
1311	19.34 ± 0.61			"

Kinetic energy in Mev	$\sigma(\pi^+ p)$ in mb.	$\sigma(\pi^- p)$ in mb.	Authors
1555	13.04 ± 0.78		J.A.Felland et al9)
910	10.3 ± 0.9		Stonehill et al3)
1090	12.6 ± 1.1		"
1260	16.5 ± 1.4		"
1450		9.65 ± .30	SOBB Collaboration5)

$\pi^- p$ Phase Shifts in Degrees

E_π in Mev	$\delta 1$	$\delta 3$	$\delta 11$	$\delta 13$	$\delta 31$	$\delta 33$	Authors
120	8	-12	-4	2	6	30	
144	14	-13	-5	3	5	46	de Hoffman et al
169	7	-4	-7	-1	3	64	
194	-14	-13	5	0	-16	90	
217	-4	-20	-7	7	-14	107	
220	14.0 ± 4.3	-15.8 ± 1.5	6.2 ± 3.3	-5.2 ± 0.8	-2.0 ± 2.9	111 ± 1.8	Pontecorvo 8)

in Mev	δ_1	δ_3	δ_{11}	δ_{13}	δ_{31}	δ_{33}	Author
240	11.2 ± 4.4	18.1 ± 1.3	10.0 ± 5.4	-2.4 ± 1.4	-3.1 ± 2.5	115± 1.1	
270	25.7 ± 2.5	-20.1 ± 1.3	5.3 ± 3 3	-1.2 ± 1.2	-7.1 ± 1.8	129.0 ± 0.9	
307	17.1 ± 5.2	-23.9 ± 1.2	11.4 ± 3.3	-5.0 ± 1.2	-10± 2	132.4 ± 0.9	
333	29.2 ± 1.8	-26.5 ± 1.4	8.1 ± 2.9	-2.0 ± 1.3	-10.5 ± 2.1	137.2 ± 1.1	

REFERENCES

1) Bethe - de Hoffmann, Mesons and fields Vol.II, Row,Peterson and Company, New York (1955)

2) J.C.Brisson et al, Phys. Rev. Letters 3, 561 (1959)

3) D.Stonehill et al, Phys. Rev. Letters 6, 624

4) J.K.Kopp et al, Phys. Rev. 123, 301 (1961)

5) Saclay-Orsay-Bari-Bologna collaborations (to be published in Nuovo Cimento)

6) L.K.Goodwin et al, Phys. Rev. 122, 655 (1961)

7) W.J.Willis, Phys. Rev. 116, 753 (1959)

8) B.Pontecorvo (Rapporteur), 9th international conference on High Energy Physics, Kiev (1959)

(9) J.A.Helland et al, International conference on High Energy Nuclear Physics, CERN (1962)

RECENT EXPERIMENTAL DATA (Report for May)

In the earlier part of this report, we present some recent experimental data on weak interaction processes including some which may be crucial to the theory of weak interactions, viz., the evidence for the existence of $\Delta Q/\Delta S = -1$ currents in leptonic hyperon decays. The data is mainly taken from Crawford's excellent report at the 1962 CERN conference with inclusion of some later experimental results.

In the latter half of the report, we continue the table of cross-sections for pion-nucleon scattering which was given for the region .1 - 1.5 Bev in the last report with recent data on scattering in the region 1.5 -6 Bev. The main feature of these results is the presence of two new resonances in the pion-nucleon resonances which at such relatively high energies is of considerable significance for theories of the pion-nucleon interaction. We present a table of the parameters for the earlier resonances also for completeness.

Total cross-sections for the photoproduction of single, double and triple pions from nucleons in the sub Bev region are given in the form of curves.

Lifetimes

Particle	τ in secs	Authors.
π^+	$2.4 \pm 1.0 \times 10^{-8}$	Bacastow et al 1)
π^0	$2.3 \pm 0.8 \times 10^{-16}$	Glasser et al 2)
~~K_2^0~~ Ξ^-	$1.16^{+0.26}_{-0.17} \times 10^{-10}$	Bertanza et al 3) (Brookhaven)
	$1.28^{+0.41}_{-0.25} \times 10^{-10}$	(Syracuse) 4)
K_2^0	$6.8^{+2.6}_{-1.5} \times 10^{-8}$	F.S.Crawford 4)

Particle	τ in secs	Authors.
	$8.1^{+3.3}_{-2.4} \times 10^{-8}$	Bardon et al[4)]
	$5.1^{+2.4}_{-1.3} \times 10^{-8}$	Darmon et al[4)]
K_1^0	$0.835 \pm 0.025 \times 10^{-10}$	Golden et al[4)]
	0.90 ± 0.05 ″	Garfinkel[4)]
	$1.06 \ {}^{+0.08}_{-0.06}$ ″	Eisler et al[4)]
	$1.15 \ {}^{+0.40}_{-0.25}$ ″	Blumenfeld et al[4)]
	$0.84 \ {}^{+0.35}_{-0.19}$ ″	Cooper et al[4)]
	$0.81 \ {}^{+0.23}_{-0.19}$ ″	Brown et al[4)]
	1.07 ± 0.13 ″	Boldt et al[4)]
	0.94 ± 0.05 ″	Crawford et al[4)]
H^3	$1.23^{+0.31}_{-0.20} \times 10^{-10}$	Block et al[4)]
H^4	$1.2^{+0.7}_{-0.3} \times 10^{-10}$	Crayton et al[4)]

Asymmetry parameters for the Λ and Ξ decays, $\Lambda \rightarrow p + \pi^-$ and $\Xi^- \rightarrow \Lambda + \pi^-$

$$\alpha = \frac{2 \text{ Re } Sp^*}{|S|^2 + |p|^2} \ ; \qquad \beta = \frac{2 \text{ Im } S^*p}{|S|^2 + |p|^2}$$

$$\equiv \frac{(|S|^2 - |p|^2)}{(|S|^2 + |p|^2)}$$

where S and p refer to the S and p wave amplitudes for decay

No. of events	$\alpha_{\Xi^-}\alpha_{\Lambda}$	α_{Ξ^-}	β_{Ξ^-}	γ_{Ξ^-}	Authors
75	-0.63 ± 0.20	$+1^{+0}_{-0.35}$	-0.63 ± 0.31	$+0.63 \pm 0.31$	Eastern 4)
450	-0.30 ± 0.08	$+0.49 \pm 0.14$	-0.63 ± 0.31	$+0.63 \pm 0.31$	Berkeley 4)
100	-0.52 ± 0.13	$+0.85 \pm 0.23$	-0.68 ± 0.22	--	U.C.L.A. 4)
550	-0.38 ± 0.06	$+0.62 \pm 0.11$	--	--	California (aug)4
18	-0.65 ± 0.35	$+1.00^{+0}_{-0.55}$	--	--	Fowler et al 4)

The table clearly indicates that α_{Ξ^-} and α_{Λ} are of opposite signs and the sign of α_{Ξ^-} is positive

Λ decay

Λ -source	α	β	γ	Authors
$\pi^- + p$	-0.62 ± 0.05	$+0.19 \pm 0.19$	$+0.78 \pm 0.04$	Cronin and Overseth 4)
$K^- + He$	-0.66 ± 0.25	--	--	Gray et al 4)
$\pi^- + p$	$-0.6^{+0.13}_{-0.17}$	Assume = 0	$+0.74^{+0.09}_{-0.23}$	Beall et al 4)
π^- + Propane	-0.45 ± 0.04	--	--	Birge and Fowler 4)
π^- + iron	$0.85^{+0.15}_{-0.21}$	--	---	Boldt et al 4)

Asymmetry parameters for $\Sigma^+ \rightarrow p + \pi^0$ (α^0),

$\Sigma^+ \rightarrow n + \pi^+ (\alpha+)$ and $\Sigma^- \rightarrow n + \pi^- (\alpha -)$

$\alpha_0 = + 0.78 {}^{+0.08}_{-0.09}$ (Beall et al 4)
(of the same sign as)

$\alpha_+ = 0.03 \pm 0.08$ (Cork et al 4)

$\alpha_- = +0.16 \pm 0.21$ (Tripp et al 4)

$= + 0.04 \pm 0.23$ (Nursbanm et al 4)

<u>Δ I = 1/2 rule</u> in nonleptomic hyperon decays.

$$B_\Lambda = \frac{(\Lambda \rightarrow p\pi^-)}{(\Lambda \rightarrow p\pi^-) + (\Lambda \rightarrow n\pi^0)}$$

B_Λ	Authors
0.685 ± 0.017	Crawford et al 4)
0. 72 ± 0.08	Baglin et al 5)
0. 65 ± 0.05	Columbia group 5)
0. 63 ± 0.03	Crawford et al 4)
0. 65 ± 0.05	Braon et al 4)
0.660	I = 1/2 rule.

$$\frac{\alpha_\Lambda (n\pi^0)}{\alpha_\Lambda (p\pi^-)} = + 1.10 \pm 0.27 \quad \text{(Cork et al 4)}$$

Δ I = 1/2 rule gives 1.00

For the decay $\Lambda \rightarrow n + \pi^0$, $\gamma_0 = + 0.78 {}^{+0.22}_{-0.42}$ (Block et al 4)

This indicates a predominant S-wave decay.

<u>Leptomic decay models of strange particles:</u>

Evidence for $\Delta Q = -\Delta S$ currents:- Galtieri et al 4) have observed an event of the type $\Sigma^+ \rightarrow n + \mu^+ + \nu$ which involves a $\Delta Q = -\Delta S$ baryon current.

From a study of the decay $K_2^0 \rightarrow \pi^{\pm} + L^{\mp} + \nu(\bar{\nu})$ where $L = e$ or μ, Alexander et al find for the rate of decay averaged over all four decay modes (into $e^{\pm}, \mu^{\pm}$) the value

$$\Gamma_2(L^{\pm}) = (9.31 \pm 2.49) \times 10^6 \, \mathrm{sec}^{-1}$$

From the $|\Delta I| = 1/2$ rule for the baryon current,

$$\Gamma_2(L^{\pm}) = 2\Gamma_{K^+}(\pi^0 L^+ \nu) = (16.5 \pm 1.18) \times 10^6 \, \mathrm{sec}^{-1}$$

Thus there is a 50 to 1 odds against $\Delta I = 1/2$ rule which implies the presence of either or both of the currents (3/2, 1/2) and (3/2, 3/2). The latter implies $\Delta Q = -\Delta S$ If this current is absent, we have the prediction $\Gamma_2(L^{\pm}) = \Gamma_1(L^{\pm})$ for $L = e$ or μ where $\Gamma_1 = \Gamma(K_1^0 \rightarrow \pi^{\pm} + L^{\mp} + \nu(\bar{\nu}))$. Experimentally,

$$\Gamma_1(L^{\pm})/\Gamma_2(L^{\pm}) = 6.6^{+6.0}_{-4.0}$$ (Alexander et al ^{4})

$$\Gamma_1(L^{\pm})/\Gamma_2(L^{\pm}) = 3.5^{+3.9}_{-2.7}$$ (Crawford et al ^{4})

$$\Gamma_1(e^{\pm})/\Gamma_2(e^{\pm}) = 11.9^{+7.5}_{-5.6}$$ (Ely et al)

Thus the $\Delta S = \Delta Q$ rule is probably wrong.

<u>Pionic decay modes of K_1^0 and K_2^0.</u>

$\Delta I = \frac{1}{2}$ rule predicts $B(K_1^0) = \dfrac{\Gamma(K_1^0 \rightarrow 2\pi^0)}{\Gamma(K_1^0)} = \dfrac{1}{3}$

If enough ($\Delta I = 3/2$) part is added to account for the existence of $K^+ \rightarrow \pi^+ + \pi^0$ mode, then $B(K_1^0)$ should lie between 0.29 and 0.38. The following table of experimental values shows no discrepancy with the $\Delta I = 1/2$ prediction except the value of

$B\ (K_1^0)$	Authors
0.294 ± 0.021	Chretien et al 4)
0.329 ± 0.013	Brown et al 4)
0.260 ± 0.024	Anderson et al 4)
0. 32 ± 0.04	Crawford et al 4)

$K_2^0 \_ \pi^0 + \pi^0 + \pi^0.$

Δ I = 1/2 rule predicts $\Gamma_2(000) - (5.55 \pm 0.97) \times 10^6\ \mathrm{sec}^{-1}$

$\Gamma_2(000) = (4.07 \pm 1.38) \times 10^6\ \mathrm{sec}^{-1}$ (Alexander et al 4)

which shows a 1.3 standard deviation discrepancy with the Δ I = 1/2 rule.

$$\frac{\Gamma(K_2^0 \to 3\pi^0)}{\Gamma(K_2^0 \to \text{charged decay})} = 0.38 \pm 0.07$$

(M.H. Anikina et al 4)

$$\frac{\Gamma(K_2^0 \to \pi^+ + \pi^- + \pi^0)}{\Gamma(K_2^0 \to \text{charged decay})} = 0.134 \pm 0.018$$

(D. Lucers et al 4))

$$\frac{\Gamma(K_2^0 \to 3\pi)}{\Gamma(K^+ \to 3\pi)} = 1.0 \pm 0.3$$

= 1.311 (From ΔI = 1/2 rule)

Total cross sections.

Kinetic Energy (Bev)	$\sigma(\pi^+ + p)$ (mb)	$\sigma(\pi^- + p)$ (mb)	Authors.
1.51	34.90 ± 0.47	34.06 ± 0.36	Diddens et al[6)]
1.59	..	34.67 ± 0.47	
1.69	30.62 ± 0.47	34.38 ± 0.40	
1.80	..	35.38 ± 0.42	
1.85	29.23 ± 0.41	..	
1.90	29.31 ± 0.43	35.94 ± 0.51	
2.00	29.07 ± 0.30	35.73 ± 0.25	
2.11	30.01 ± 0.29	35.63 ± 0.23	
2.21	30.39 ± 0.27	34.63 ± 0.29	
2.32	31.10 ± 0.26	34.01 ± 0.37	
2.42	30.55 ± 0.27	..	
2.52	30.89 ± 0.27	33.87 ± 0.32	
2.63	29.99 ± 0.27	..	
2.73	29.87 ± 0.26	32.85 ± 0.32	
2.83	29.49 ± 0.23	..	
2.93	28.96 ± 0.35	32.29 ± 0.28	
3.03	28.84 ± 0.22	..	
3.14	28.38 ± 0.27	31.90 ± 0.19	
3.34	28.43 ± 0.22	..	
3.55	27.99 ± 0.16	31.35 ± 0.22	
3.76	27.70 ± 0.23	..	
3.97	27.37 ± 0.26	30.27 ± 0.22	
4.18	27.84 ± 0.23	..	
4.39	27.22 ± 0.23	29.92 ± 0.22	
5.79	..	28.16 ± 0.21	
1.86	..	35.7 ± 0.08	Longo and Moyer[7)]
2.946	..	30.9 ± 0.9	
4.102	..	30.8 ± 1.0	
4.9	..	28.7 ± 1.0	

Paramets of the resonances of the pion - nucleon system upto 1.5 Bev. pion Kinetic energy 8)

Particle.	Lab. Kinetic Energy of pion (Mev).	Mass (Mev)	Γ (Mev)	J	I	P
N { n p	--	940 938		1/2	1/2	+
N *	190	1238	90	3/2	3/2	+
N **	600	1510	60	3/2	1/2	-
N ***	900	1680	100	5/2	1/2	+
N ****	1300	1900	200	?	3/2	?

Some parameters of the two new resonances 6)

I	Kinetic Energy (Bev) lab.	Momentum (Bev/C) lab.	Momentum (F^{-1} 1) Centre of Mass	$4\pi\lambda^2$ (Mb) Centre of Mass	Total energy (Bev) Centre of Mass.	Full width (Bev) Centre of Mass.
1/2	1.95	2.08	4.52	6.14	2.19	0.2
3/2	2.37	2.51	5.04	4.95	2.36	0.2

TOTAL CROSS SECTIONS FOR PHOTOPRODUCTION OF SINGLE,DOUBLE AND TRIPLE PIONS FROM NUCLEONS

Cross-sections for single pion photoproduction9)

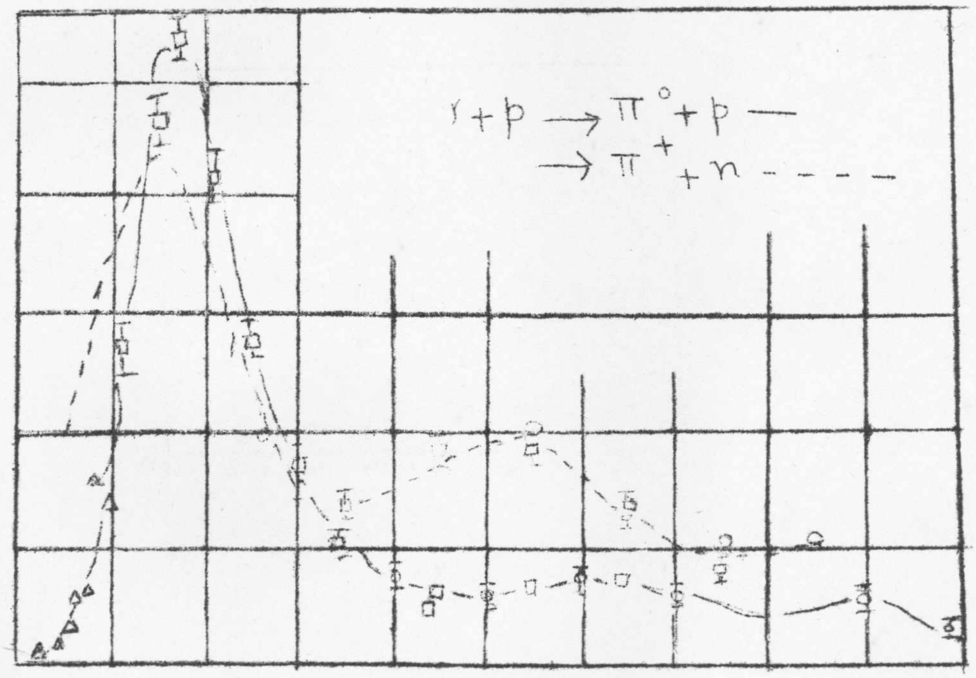


Fig.1

Illinois

Caltech

Cornell

CROSS-SECTIONS FOR MULTIPLE MESON PRODUCTION

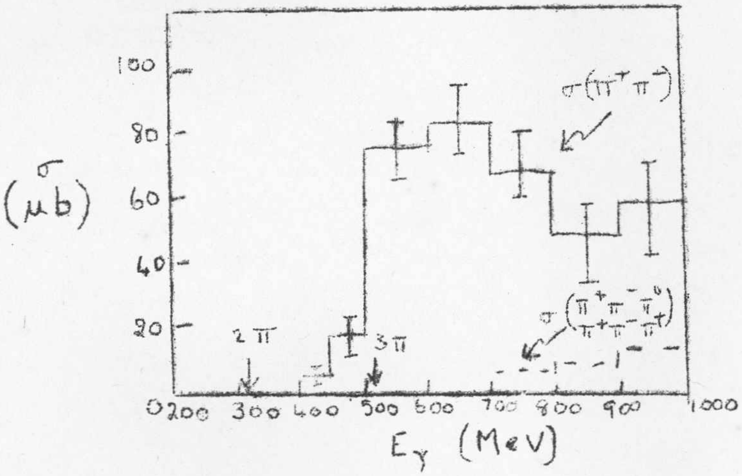


Fig.2

The solid line histogram represents the total cross-section for $\gamma + p \longrightarrow p + \pi^+ + \pi^-$. The dashed histogram refers to the combined cross-sections for the processes $\gamma + p \longrightarrow p + \pi^+ + \pi + \pi^0$ and $\gamma + p \longrightarrow n + \pi^+ + \pi^- + \pi^+$

REFERENCES

1) R.Bacastow et al, Phys. Rev. Letters, 9, 400 (1962)

2) R.G.Glasser, 1960, International Conference on High Energy Physics, Rochester.

3) L.Bertanza et al, Phys. Rev. Letters. 9, 229 (1962)

4) F.S.Crawford: 1962 International Conference on High Energy Physics, CERN

5) 1960 International Conference on High Energy Physics, Rochester.

6) A.N.Diddens et al, Phys. Rev.Letters 10, 262 (1963)

7) M.J.Longo and B.J.Moyer, Phys. Rev. Letters. 9, 466 (1962)

8) Some Remarks on Recent Experiment data, Notes of informal talk by Prof.E.Segre at the Institute of Mathematical Sciences, Madras, by Miss T.K.Radha & K.Raman

9) G.Bernardini (Rapporteur) 9th International Conference on High Energy Physics, Kiev (1959)

10) B.H.Chasan et al, Phys. Rev. 119, 811 (1960)

JUNE 1963

RECENT EXPERIMENTAL DATA

The present report is mainly concerned with the differential cross-sections at various energies for pion-nucleon scattering. Holland et al5) have studied the angular distributions in $\pi^{\pm}$-p elastic scattering over a wide range of energies. (530 to 1550 Mev) results which we reproduce in the form of curves (Figs. 1, 2 and 3) are quite significant in determining the J values of the higher resonances which lie in this region. They fitted their values with an equation of the form

$$\frac{d\sigma}{d\Omega^*}(\theta^*) = \sum_{n=0}^{N} a_n \cos^n \theta^*$$

where θ^* is the angle in the centre of mass at which the pion is scattered. Noticeable features of the curves 1 and 2 are the backward peak and subsequent sharp drop-off of the cross-section at 18° degrees in the π^-- p dscattering near the 900 Mev. peak and the sharp rise of cross-sections near 180° in the π^+-p scattering include data from many other experiment also. At 900 Mev (π-p) the small value of a_6 suggests that there is little scattering from partial-wave states with total angular momentum J = 7/2 or higher. The large value of a_5 may indicate that a superposition of $F_{5/2}$ and $D_{5/2}$ partial waves is prominent in the scattering. At 600 Mev (π^--p) the value of the coefficients do not seem to indicate the prominence of any single partial wave state. The similarity of the differential cross-section curves at 350 and 580 Mev. except for the larger value of the forward diffraction peak at the higher energy, may indicate that the 600 Mev peak is due to inelastic scattering rather than an elastic resonance.

At 1350 Mev (π^+-p) the small value of a_7 suggests that there is little scattering from partial-wave states with J = 9/2 or larger. The large value of a_6 may indicate that F7/2 scattering is prominent (therein G7/2 scattering could give the same results). The assignment F7/2 is consistent with the Regge trajectory.

We also give the differential cross-sections at higher energies. The important conclusion of these experiments (those Ting et al and and Brand et al that there is practically no shrinking in the diffraction peaks in π-p scattering in the energy range 3-10 Gev/C. This is in the contrast to the case of nucleon-nucleon scattering where a definite shrinkage has been observed (The results for this case will be given in a subsequent report). Further the results at 10 Gev/C at small momentum transfers deviates from the exponential shape usually assume. The absence of shrinkage of the diffraction peak goes against the Regge squared pole hypothesis for the problem. (In the tables t = of momentum transfer and s = square of total energy in centre of mass)

Other results quoted are the mass and decay parameters for t the Ξ-particle, and an experiment which gives the $\Sigma-\Lambda$ parity to be even.

Differential cross-sections for pion-nucleon scattering

$\pi^- + p \rightarrow \pi^- + p$ 1)

$T\pi^- = 128$ Mev.

$$\frac{d\sigma}{d\Omega} = \left[(0.55 \pm 0.07) + (0.34 \pm 0.12)\cos\theta + (1.30 \pm 0.24) \cos^2\theta \right] 10^{-27}\ \mathrm{cm}^2/\mathrm{sterad.}$$

$T\pi^- = 162$ Mev.

$$\frac{d\sigma}{d\Omega} = \left[(0.93 \pm 0.07) + (0.51 \pm 0.12)\cos\theta + (2.28 \pm 0.22) \cos\theta^2\theta \right] 10^{-27}\mathrm{cm}^2/\mathrm{sterad}$$

$\pi^- + p \rightarrow \pi^0 + n$

$T\pi- = 31$ Mev 2)

$$\frac{d\sigma}{d\Omega} = (1.00 \pm 0.02 \left[(0.51 \pm 0.04) - (0.61 \pm 0.11) P_1(\cos\theta) + (0.12 \pm 0.36) P_2(\cos\theta) \right]$$

$T\pi^- = 128$ Mev 1)

$$\frac{d}{d} = \left[(1.33 \pm 0.12) - 1.61 \pm 0.13)\cos\theta + (2.15 \pm 0.36)\cos^2\theta \right] \quad \mathrm{mb/sterad}$$

$\pi^+ + p \rightarrow \pi^+ + p$ 1)

$T\pi+ = 390$ Mev.

$$\frac{d\sigma}{d\Omega} = \left[1.12 + 4.27\cos\theta + 4.68\cos^2\theta \right]\ \mathrm{mb/sterad}$$

π-p scattering differential cross-sections[3] ([illegible])

(A(s) = scattering amplitude)

System	p Gev/c	A(s)	Range of |t| (Gev/c)^2	s (Gev)^2	log s
π^- + p	3.15	7.5 ± 0.4	0 - 0.4	6.68	1.90
π^+ + p	3.15	7.[illegible] ± 0.2	0 - 0.6	6.68	1.90
π^- + p	4.13	8.0 ± 0.5	0 - 0.4	8.48	2.14
π^- + p	4.13	7.2 ± 0.2	0 - 0.9	8.48	2.14
π^- + p	4.95	7.8 ± 0.4	0 - 0.4	9.99	2.30
π^- + p	4.95	6.9 ± 0.2	0.- 0.9	9.99	2.30
π^+ + p	2.92	7.0 ± 0.4	0 - 0.4	6.26	1.83
π^+ + p	2.92	6.2 ± 0.3	0 - 0.7		1.[illegible]
π^+ + p	1.33	7.3 ± 0.4	0 - 0.4	3.36	1.21
π^- + p	1.47	7.3 ± 0.6	0 - 0.4	3.62	1.29
π^- + p	1.85	9.3 ± 1.7	0 - 0.4	4.30	1.46
π^- + p	2.00	8.7 ± 0.5	0 - 0.4	4.[illegible]7	1.52
π^- + p	5.17	8.4 ± 0.7	0.04	10.4	2.34
π^- + p	6.80	7.8 ± 1.1	0.- 0.4	13.4	2.60
π^- + p	15.90	8.6 ± 1.5	0 - 0.4	30.10	3.40

The differential cross-sedtion shows an exponential behaviour

$$\frac{d\sigma}{dt} = \left(\frac{d\sigma}{dt}\right)_{t=0} \exp\left[A(s)\, t\right]$$

But there is no noticeable shrinkage of the peak.

π^--p differential elastic cross-section at 10 Gev/c 4)

t interval [Gev/C]^2	$d\sigma/dt$ [mb (Gev/c)$^{-2}$]
0)T.P a) - t = 0	35.0 ± 0.75
0.009 - 0.02	not used
0.02 - 0.04	30.68 ± 2.81
0.04 - 0.06	28.14 ± 2.08
0.06 - 0.08	18.62 ± 1.45
0.08 - 0.10	16.72 ± 1.35
0.10 - 0.12	11.62 ± 1.12
0.12 - 0.14	10.30 ± 1.05
0.14 - 0.16	9.16 ± 1.00
0.16 - 0.18	7.52 ± 0.89
0.18 - 0.20	7.63 ± 0.91
0.20 - 0.22	6.59 ± 0.84
0.22 - 0.24	5.05 ± 0.74
0.24 - 0.28	3.87 ± 0.45
0.28 - 0.32	3.45 ± 0.43
0.32 - 0.36	2.41 ± 0.36
0.36 - 0.42	1.65 ± 0.24
0.42 - 0.50	1.22 ± 0.181
0.50 - 0.60	0.534 ± 0.106
0.60 - 1.80	0.162 ± 0.042
0.80 - 1.00	0.0755 ± 0.028
1.00 - 1.20	0.068 ± 0.029
1.20 - 1.60	0.020 ± 0.011

a) O.T.P. = Optical theorem limit

σ_{tot} = (26.5 ± 0.35) mb

elastic = (4.59 ± 0.16) mb

The results for the differential cross-section were fitted by the formula

$$\frac{d\sigma}{dt} = k\, e^{at + bt^2}$$

where

$$a(0.02,\ 0.4) = (11.4 \pm 1.07)\ (\mathrm{Gev/C})^{-2}$$

$$b(0.02,\ 0.4) = (8.9 \pm 2.8)\ (\mathrm{Gev/C})^{-2}$$

$$k(0.02,\ 0.4) = (43.0^{+2}_{-3.5})\ \mathrm{mb}\ (\mathrm{Gev/C})^{-2}$$

Comparison of the result of Ref. ~~11~~ 4 for the slope, $A(t, t_2)$ of the diffraction peak with other results.

Pion momentum (Gev/c)	t_1 $[\mathrm{Gev/c}]^2$	t_2 $[(\mathrm{Gev/c})^2]$	logs	$A(t_1, t_2)$ $[\mathrm{Gev/c}]^{-2}$	Authors
3.15	0.05	0.4	1.90	7.5 ± 0.4	Ting et al 3)
4.13	0.07	0.4	2.14	8.0 ± 0.5	,,
4.95	0.69	0.4	2.30	7.8 ± 0.4	,,
4.65	0.65	0.4	2.26	7.7 ± 0.4	Munir and Zorn 4)
5.17	0.03	0.4	2.34	8.4 ± 0.7	Thomas 4)
6.8	0.03	0.4	2.60	7.8 ± 1.1	W.Kang-chang et al 4)
7.0	0.03	0.4	2.65	7.3 ± 0.7	Hofmokl et al 4)
10.0	0.06	0.4	3.01	7.5 ± 0.34	Brandt et al 4)
16.0	0.01	0.4	3.45	8.6 ± 1.5	(Zapek et al 4)

$\Sigma - \Lambda$ Relative parity$^{6)}$

Courant et al have studied the reaction

$\Sigma^0 \rightarrow \Lambda^0 + e^+ + e^-$ to determine the relative parity of $\Sigma\Lambda$. The problem is to establish the decay as an electric (odd $\Sigma - \Lambda$ parity) or a magnetic (even parity) dipole transition. For even parity the radiative matrix element is proportional to the momentum of the Dalitz pair. For odd parity the matrix element is independent of the pair momentum. ~~so~~ Thus for odd parity more Dalitz pairs exhibiting large invariant mass would be expected to occur than for even parity. The data of Courant et al favour an even $\Sigma - \Lambda$ relative parity.

$\Sigma^+ \rightarrow p + \gamma$ 7)

Burnstein et al report an event of this type from a Σ^+ produced by K^- in a hydrogen bubble chamber. The branching ratio is $\sim$ 0.4

Life-time $\tau({}_{\Lambda}He^{4,5}) = 1.4^{+1.8}_{-0.5} \times 10^{-10}$ secn 8) 3)

Mass and decay parameters of Ξ particles$^{9)}$

m_{Ξ^-} = 1321.1 ± 0.65 Mev/C^2

τ_{Ξ^-} = (1.55 ± 0.31) x 10^{-10} sec

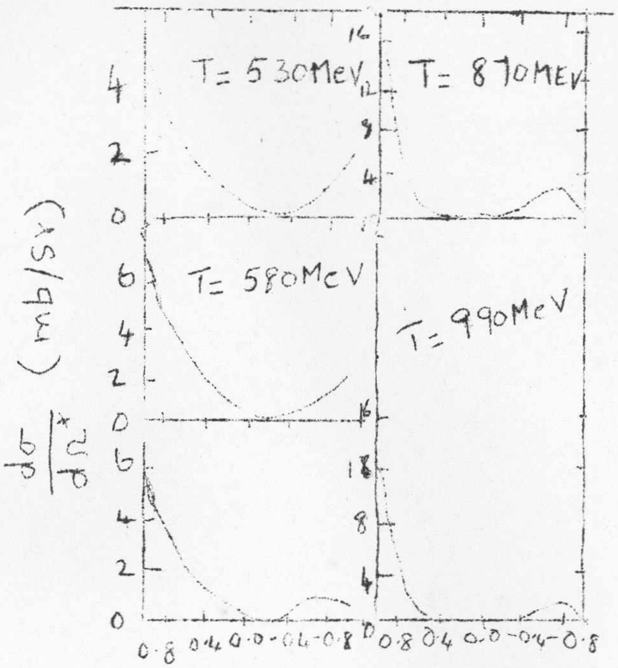
α_{Ξ^-} = 0.73 ± 0.21

β_{Ξ^-} =-0.44 ± 0.36

γ_{Ξ^-} = 0.52 ± 0.44

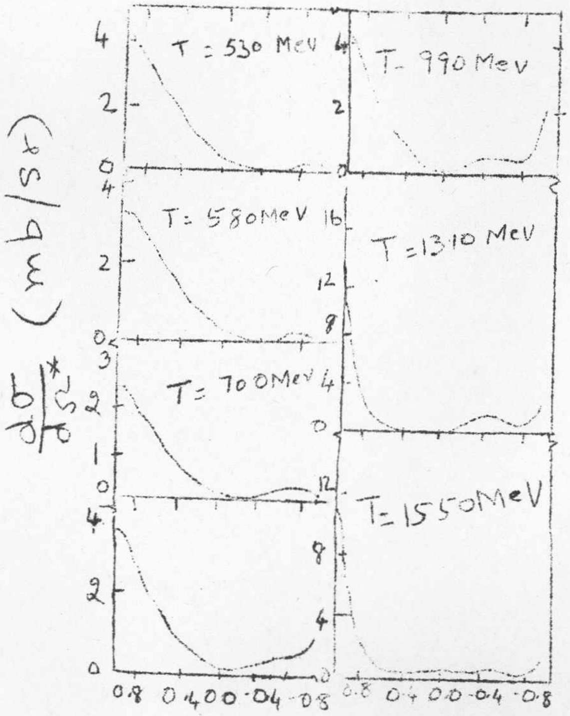
m_{Ξ^0} = 1325 ± 5 Mev/C^2

Fig 1.



Differential cross-section for $\pi^- - p$

Fig 2



Differential cross section for $\pi^+ - p$

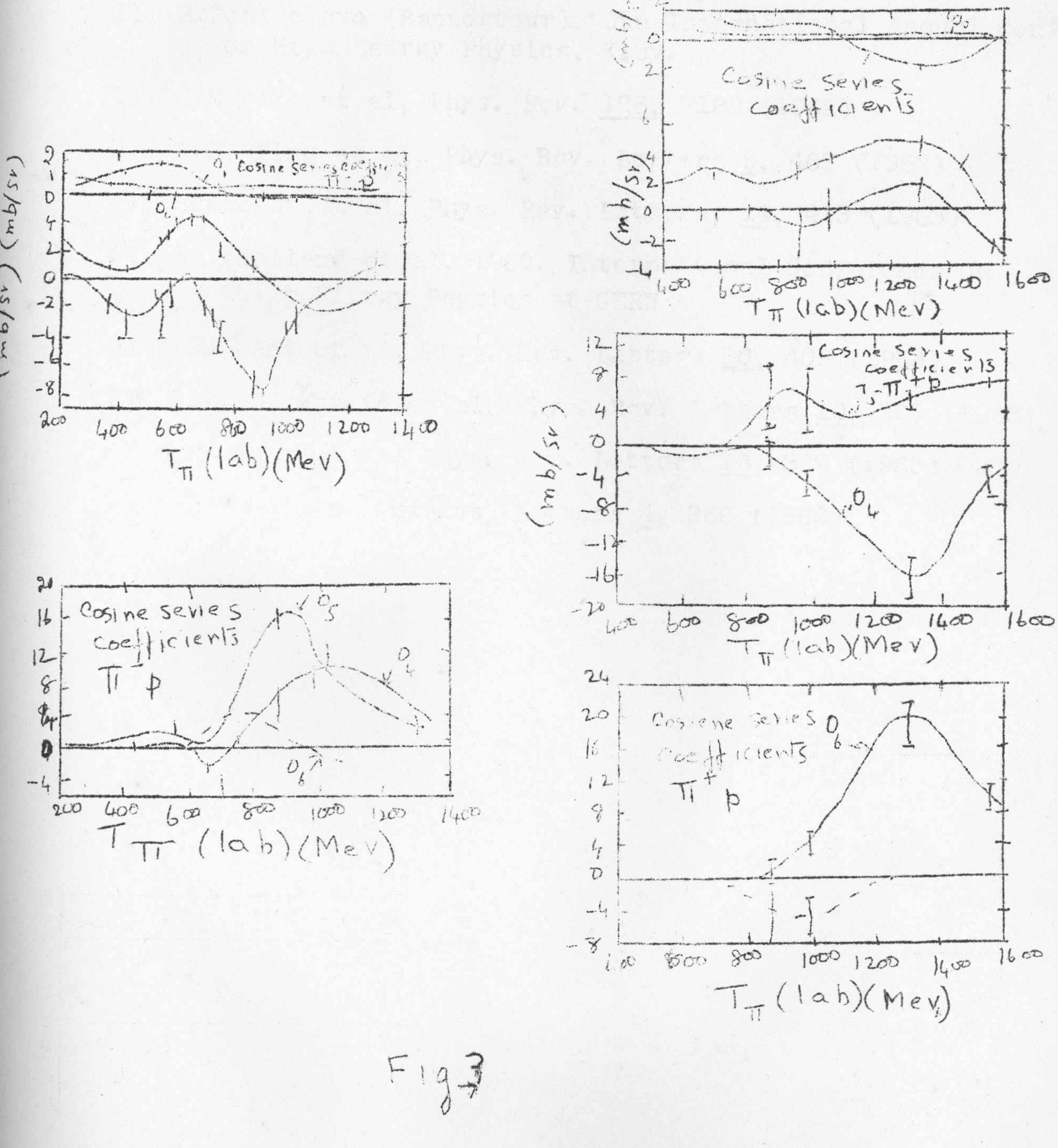

(mb/sr) (mb/sr)
2
1
0
4
2
0
-2
-4
-6
-8
a_1
Cosine series coefficients
$\pi^- p$
a_2
200
400
600
800
1000
1200
1400
T_π (lab)(MeV)
(mb/sr)
2
0
2
6
4
2
0
-2
-4
a_3
Cosine series coefficients
400
600
800
1000
1200
1400
1600
T_π (lab)(MeV)
(mb/sr)
12
8
4
0
-4
-8
-12
-16
-20
Cosine series coefficients
T_3 $\pi^+ p$
a_4
400
600
800
1000
1200
1400
1600
T_π (lab)(MeV)
20
16
12
8
4
0
-4
Cosine series coefficients
$\pi^- p$
a_5
a_4
a_6
200
400
600
800
1000
1200
1400
T_π (lab)(MeV)
24
20
16
12
8
4
0
-4
-8
Cosine series coefficients
a_6
$\pi^+ p$
400
600
800
1000
1200
1400
1600
T_π (lab)(MeV)

Fig 3

REFERENCES

1) B.Pontecorvo (Rapporteur), 9th International Annual Conference on High Energy Physics, Kiev.

2) K.Miyake et al, Phys. Rev. 126, 2188 (1962)

3) C.C. Ting et al, Phys. Rev. Letters 9, 468 (1962)

4) S.Brandt et al, Phys. Rev. Letters, 10, 413 (1963)

5) J.A.Helland et al, 1962. International Conference on High Energy Physics at CERN

6) H.Courant et al, Phys. Rev. Letters 10, 409 (1963)

7) R.A. Burnstein et al, Phys. Rev. Letters 10, 307 (1963)

8) Y.W.Kang et al, Phys. Rev. Letters 10, 302 (1963)

9) H.Schneider, Physics, Letters 4, 360 (1963)

JULY 1963

I

In the first half of the present report, we give the parameters for all the observed resonances in the $\pi\pi$, πK $K\bar{K}$ and pion-hyperon systems. Production cross-sections for some of them are also given. Evidence for the G-violating two pion decay mode of the ω-meson is quoted.

The latest values for the lifetimes of the elementary particles are given.

In the second part of the report, kindly prepared by Dr. R. Vasudevan, the third sound in liquid helium films is discussed. The first and second sounds are also defined and the numerical values of their velocities are given. The nature of the third sound, its velocity and experimental details in detecting this phenomenon are given at some length.

THE PION-PION RESONANCES

Parameters for the pion-pion resonances[1)]

Resonance	Established Quantum Number	Possible Assignment $I(J^{PG})$	Possible Assignment Regge Trajectory	Mass (Mev)	(Mev)
f = Vacuum?	$0(\gtrless 2^{++})$	$0(2^{++})$	$+\omega_\alpha$	1250	75
η	$0(0^{-+})$	$0(0^{-+})$	$+\omega_\beta$	548	<10
ω	$0(1^{--})$	$0(1^{--})$	$-\omega_\gamma$	782	<15
ρ^+	$1(1^{-+})$	$1(1^{-+})$	$+\pi_\gamma$	770 ± 10	130±10[2)]
ρ^0	"	"	"	750 ± 10	100±10[2)]

Production cross-sections (in mb) for ρ, η and ω in pion nucleon collisions[2)]

Process	Momentum in Bev/c 2.34	Momentum in Bev/c 2.62	Momentum in Bev/c 2.90
$\pi^+ + p \longrightarrow \pi^+ + p + \pi^0$	4.7 ± 0.3		3.6 ± 0.3
$\longrightarrow \pi^+ + \pi^+ + n$	2.2 ± 0.25		2.1 ± 0.3
$\longrightarrow \pi^+ + p + \pi^+ + \pi^-$	3.2 ± 0.2	3.5±0.3	3.1 ± 0.2
$\longrightarrow \pi^+ + p + \pi^+ + \pi^- + \pi^0$	3.1 ± 0.2	3.6±0.3	4.1 ± 0.2
$\longrightarrow \pi^+ + \pi^+ + \pi^+ + \pi^- + n$	0.27 ± 0.06	0.37±0.08	0.56 ± 0.06
$\longrightarrow p + \rho^+$	2.1 ± 0.3		1.4 ± 0.2
$\longrightarrow \pi^+ + p + \rho^0$	1.4 ± 0.25	1.4± 0.25	0.95 ± 0.2
$\longrightarrow \pi^+ + p + \eta^0$	0.75± 0.15	0.75±0.18	0.80 ± 0.15
$\longrightarrow \pi^+ + p + \omega^0$	1.3 ± 0.2	1.6±0.2	1.6 ± 0.2

Fickinger et al4) report evidence for a twopion ($\omega \rightarrow \pi^+ + \pi^-$) decay mode of the ω-meson which they infer from the effective mass distribution of the two pions produced in $\pi^- + p \rightarrow n + \pi^- + \pi^+$ at an incident pion momentum of 1.7 Bev/c This may be due to the fact that since the $\omega - \rho$ mass difference is small electromagnetic interference between the two states may greatly enhance the $\overset{G}{\cancel{P}}$-forbidden decay $\omega \rightarrow 2\pi$ (Glashow)

The K-π resonances1)

Particle or Resonance	Established Quantum Number	Possible Assignment I(J^{PG})	Possible Assignment Regge Trajectory	Mass (Mev)	Mev
K K^0 $K^\pm$	1/2(0^-)	1/2(0^-)	K_β	498 494	0
$K^*_{1/2}$ (888)	1/2(1^-)	1/2(1^-)	K_γ	888	50
$K^*_{1/2}$ (725)	1/2(?)	?	?	725	<15

Resonance in the $K\bar{K}$ system

Resonance	Established Quantum Number	Possible Assignement I(J^{PG})	Possible Assignement Regge Trajectory	Mass (Mev)	(Mev)
φ	0(1^{--})	0 (1^{--})	— ω_γ	1020	<5

Parameters for the pion-hyperon Resonances[1)]

Particle or Resonance	Established Quantum Number	Possible Assignment I(JPG)	 Regge Trajectory	Mass (Mev)	(Mev)
Λ	$0(1/2^+)$	$0(1/2^+)$	Λ_α	1115	0
Y_0^* (1815)	$0(J \geq 5/2)$	$0(5/2^+)$	Λ_α	1815	120
Y_0^* (1520)	$0(3/2-)$	$0(3/2-)$	Λ_γ	1520	16
Y_0^* (1405)	0(?)	$0(1/2^-)$	Λ_β	1405	50
$\Sigma \begin{cases} \Sigma^+ \\ \Sigma^0 \\ \Sigma^- \end{cases}$	$1(1/2^+)$	$1(1/2^+)$	Σ_α	1189 1193 1197.4	0
Y_1^* (1385)	$1(J \geq 3/2)$	$1(3/2^+)$	Σ_δ	1385	50
Y_1^* (1660)	1(3/2)	$1(3/2^-)$	Σ_γ	1660	40
$\Xi \begin{cases} \Xi^0 \\ \Xi^- \end{cases}$	1/2(1/2?)	$1/2(1/2^+)$	Ξ_α	? 1321	0
Ξ^* (1530)	1/2(>1/2)	$1/2(3/2^+)$	Ξ_δ	1530	<7

Lifetimes of the Elementary Particles[3)]

Particle	Mean life (Sec)
$\mu^\mp$	$(2.212) \pm 0.001) \times 10^{-6}$
$\pi^\pm$	$(2.55 \pm 0.0.35) \times 10^{-8}$
π^0	$(2.2 \pm 0.8) \times 10^{-16}$
K^+	$(1.224 \pm 0.013) \times 10^{-8}$
K_1	$(1.00 \pm 0.038) \times 10^{-10}$

Particle	Mean Life (Sec)
K_2	$6.1(+1.6/-1.1) \times 10^{-8}$
n	$(1.013 \pm 0.029) \times 10^{3}$
Λ	$(2.51 \pm 0.09) \times 10^{-10}$
Σ^+	$0.81(+0.06/-0.05) \times 10^{-10}$
Σ^0	$<0.1 \times 10^{-10}$
Ξ^-	$1.28(+0.38)/ -0.30) \times 10^{-10}$
Ξ^0	1.5×10^{-10} (1 event)

REFERENCES

1. A.H. Rosenfeld, Tentative Data on Strongly Interacting Particles, Table VI UCRL - 8030, January 1963.

2. C.Alff et al, Phys. Rev. Letters 9, 322 (1962)

3. A.H.Rosenfeld, Table I UCRL - 8030

4. W.J.Pickinger et al: Phys. Rev. Letters, 10, 457 (1963)

THIRD SOUND IN LIQUID HELIUM FILMS. 5), 6), 7)

INTRODUCTION:

As is well known in bulk liquid helium, an ordinary sound wave can be propagated with a definite velocity. This is called the first sound. The normal and superfluid components oscillate in phase during this process giving rise to the ordinary pressure wave. The approximate velocity of the first sound is ~~almost~~ about 200 m/sec.

Landau in 1941, deduced that small fluctuations in entropy or temperature are propagated as undamped dispersionless waves, in He II. In this case, the two components oscillate out of phase, and if a standing temperature wave is built up, the superfluid component collects at the nodes where there is very little temparature oscillations. This second sound travels with a velocity given by $u_2 = \frac{\rho_s}{\rho_n}\frac{T_0 S_0^2}{C_0}$; where ρ_s and ρ_n are the superfluid and normal component densities respectively and T_0, S_0 and C_0, the steady temparature, entropy and specific heat respectively. At 1.5°K, this leads to a value of 20 m/sec. Peshkov using a resonance method, found a velocity of 20.36 m/sec. at 1.63°K. There may be a weak coupling between the first and second sound.

It has been suggested by Atkins in 1959, that, in liquid helium film there might be yet another type of wave notion termed third sound in which the superfluid component oscillates but the normal component remains, locked to the wall. This should appear as an oscillation in the thickness of the film. The liquid has to be a superfluid for these oscillations since otherwise, these will be quickly damped if there is friction or visocity in the fluid. The velocity of this sound is only 50 cm/sec i.e., much lower than either the second or first sound.

Surface waves on bulk liquid helium were discovered by Atkins, in 1953. However for a thin film, the restoring force is not gravity but the forces which are responsible for the formation of the film including the van der waals forces of attraction between the helium atoms and the wall on which the film is formed. We are interested in the case of wave lengths long compared to ~~with~~ the thickness of the film. This is analogous to the classical case of a long wave on water in a shallow channel and it is well known that the oscillatory motion of a fluid is mainly in a direction parallel to the bottom of the channel. Let us suppose that the superfluid component oscillates in this fasion, with its velocity V_s almost parallel to the wall on which the film is formed. The velocity V_n of the normal component parallel to the wall is negligible because of viscosity. It is impossible to make the normal component oscillate parallel to the wall if

$$d << (2\eta_n/\omega\rho_n)^{1/2}$$

(η_n is the viscosity), d = thickness of film, ω = frequency)

For the superfluid component we do not have to worry about the viscosity and the tangential velocity at the wall can be finite. To a first approximation the normal component is at rest and there is a surface wave of the superfluid component. At the peak of a wave the superfluid component is collected and the temperature at this point is lowered, while at a trough the temperature is raised so that in addition to the pressure gradient there is an additional restoring force due to thermomechanical effect. At the trough the film will evaporate while at the crest it will condense. Writing the hydrodynamic equations for the superfluid component taking all this into account, a travelling wave solution for ~~the~~ ξ, the variation in the level of the liquid can be found and it is found to have a velocity given by

$$u_3^2 \sim \frac{\rho_s}{\rho}\, df \left[1 + \frac{TS}{L} \right]$$

where T, S and L are temperature, entropy and heat of varpourisation per gram. If evaporation effects are neglected we have

$$u_3^2 \sim \frac{\rho_s}{\rho} \left[df + \frac{S\,T\,(S - \beta/\rho)}{C} \right]$$

where $\beta = \left(\frac{dp}{dT}\right)_{v.p.c}$ is the slope of the vapour pressure curve and C the specific heat. f ~~is~~ represents the restoring forces, due to van der walls forces of attraction between the walls of the vessel and the liquid. It can also be shown that except at very near λ-point a large fractional change in film thickness is possible, without the velocity of the superfluid component approaching its critical value.

• • •

Probably third sound may provide a new weapon to attack the problem of liquid helium film. The helium film is formed on a horizontal stainless steel mirror approximately 2 inch long and 3/8 inches wide contained in an experimental chamber. Third sound is excited by evaporating a narrow strip of the film periodically with pulses of infra red radiation (with chopping frequency from 2 to 200 cycles/sec. Since the detection of temparature variation in the film is difficult a modification of the method of Jackson et al for measuring thickness of the static film is used. A narrow beam of plane polarised mercury green light is incident on the stainless steel mirror at an angle of $67.1/2^{\circ}$. Upon reflection the beam becomes elliptically polarised and is then converted back into plane polarised light by a quarter wave plate with the effect that the plane of polarisation becomes tilted through a small angle proportional to the thickness of the film. Therefore when the film thickness oscillates there is an oscillation in space of the plane of polarisation, which is converted by passage through an analysing prism to an oscillation in intensity. This is measured by a photo multiplier, a phase sensitive detector and a pen recorder. In actual experiments the detector was kept a fixed distance four on end of the mirror and the variation in output was measured as the emitting source was displaced step by step along the mirror. In this way the wavelength of the third sound was obtained. Detailed analysis showed that they had excited a travelling wave of third sound, with amplitude equal to ± 15 per cent of the mean film thickness and the attenuation coefficient was not greater than $.3cm^{-1}$.

The mean wave length was .97 c.m. In a typical measurement, the film height was 8.0 c.m. and the temperature 1.1°K; the frequency being 72.4 cycles/sec. Therefore the wave velocity was 71 cm/sec.

To convince ourself that it was third sound that was propagated, it was found that (1) the signal disappeared when (a) the detector was switched off (b) when emitter was switched off and (c) when the whole film was evaporated by auxilliary heater. It may be argued that the film may be undergoing evaporation from behind by thermal waves propagating in the mirror. But this does not seem to be the case because (i) the observed attenuation was small, whereas thermal waves are attenuated strongly. (2) The velocity for a given film was independent of frequency whereas velocity of thermal waves is proportional to the square root of frequency. (3) The velocity depended strongly on film thickness whereas thermal waves would depend solely on the nature of the mirror.

The velocity and amplitude of the third sound decrease with increasing temperatures in qualitative agreement with the theory.

5. L.D. Landan J. Phys. U.S.S.R. 5, 77 (1941).
6. K.R. Atkins Phys. Rev. 113 962 (1954).
7. E.J. Bonje and L.C.Jackson Proc. Roy. Soc. Lond. A.205 270 (1951) and Proc. Roy. Soc. Lond. A.240 243 (1957)

AUGUST 1963

INTRODUCTION

The scattering cross-sections, differential and total for nucleon-nucleon scattering form the first part of the data presented in this report. The results on elastic proton-proton scattering in 10-20 Bev region by Diddens et al which demonstrate the shrinking of the diffraction pattern for the process with increasing energy as required by the Regge behaviour of the amplitudes are given at length.

Data on pion-production in nucleon-nucleon collisions and cross-sections for neutron scattering from nuclei are also included.

An experiment on the isotopic spin assignment for the K* resonance with mass $\sim$ 726 is quoted and cross-sections for the production of this resonance as well as the 885 Mev K* resonance are given.

The latest data on the parameters of the Ξ^- particle regarding the mass of the particle and of the $\Xi - \pi$ resonance and the lifetime of the Ξ^- are quoted.

Nucleon-Nucleon total scattering cross-sections[1)]

Momentum (Gev/c)	Total cross-section $\sigma_{tot}(p\text{-}p)$ (mb)	 $\sigma_{tot}(\text{"}p\text{-}n\text{"})^*$ (mb)	Difference $\sigma_{tot}(p\text{-}p) - \sigma_{tot}(\text{"}p\text{-}n\text{"})^*$ (mb) *
3.27	47.1 ± 0.9	3.7 ± 1.3	10.0 ± 1.6
4.51	42.1 ± 0.7	3658 ± 0.9	5.3 ± 1.1
5.83	41.6 ± 0.6	37.0 ± 0.8	4.6 ± 1.0
7.75	41.6 ± 1.1	37.6 ± 1.6	4.0 ± 1.9

* $\text{"}p-n\text{"} = (p-d) - (p-p)$

Elastic scattering of protons-from protons[2)]

Momentum (Gev/c)	12.1	1515.	1816.	21.4	26.2
Elastic	10.4 ± 1.7	9.2 ± 1.4	9.0 ± 1.8	8.0 ± 1.6	9.8 ± 2.2

Differential elastic p-p scattering cross-sections[2)]

P_0 = Momentum of the incoming proton

θ = Scattering angle

$-t$ = Four-momentum transfer.

$(P_0)_{lab}$ (Gev/c)	θ_{lab} (m rad)	$\theta_{c.m}$ (deg)	$-t$ $(GeV/c)^2$	$\left(\frac{d\sigma}{d\Omega}\right)_{lab}$ (mb/sr)	$\left(\frac{d\sigma}{d\Omega}\right)_{c.m}$ (mb/sr)	$\left[\left(\frac{4\pi}{\sigma_T p}\right)^2 \times \frac{d\sigma}{d\Omega}\right]_{c.m.}$
12.1	8.8	2.66	0.011	4.03	146	1.10
	19.1	5.73	0.052	2.60	96	0.70
	29.1	8.72	0.121	1.20	45	0.33
	39.1	11.75	0.219	0.58	21.3	0.16
	49.1	14.7	0.342	0.20	5.9	0.057
15.5	8.9	3.02	0.019	5.79	165	0.96
	18.9	6.40	0.086	2.63	76	0.44
	28.9	9.71	0.195	0.92	27	0.16
	38.9	13.25	0.364	0.22	6.4	0.038
	48.9	16.50	0.563	0.036	1.1	0.0059
18.6	10.8	3.82	0.036	7.93	209	0.87
	20.8	7.30	0.134	2.46	66	0.28

$(P_0)_{lab}$ (GeV/c)	θ lab (mrad)	$\theta_{c.m}$ (deg)	$-t$ $(GeV/c)^2$	$\left(\frac{d\sigma}{d\Omega}\right)_{lab}$ (mb/sr)	$\left(\frac{d\sigma}{d\Omega}\right)_{c.m}$ (mb/sr)	$\left[\left(\frac{4\pi}{\sigma_{T\pi}}\right)^2 \times \frac{d\sigma}{d\Omega}\right]_{c.m}$
	30.8	10.7	0.290	0.46	12.6	0.051
	40.8	14.4	0.520	0.059	1.6	0.0068
	50.8	17.8	0.794	0.009	0.25	0.0011
21.4	8.3	3.29	0.032	8.65	1820	0.75
	18.6	7.30	0.155	1.95	43	0.175
	28.6	11.18	0.0364	0.29	6.4	0.025
	38.6	15.30	0.680	0.024	0.52	0.0022
	48.6	19.0	1.055	0.002	0.045	0.00018
26.2	9.5	4.21	0.064	11.3	189	0.65
	19.5	8.60	0.268	1.31	22.4	0.078
	29.5	12.88	0.596	0.072	1.24	0.0043
	39.5	17.03	1.042	0.0041	0.075	0.00025

Elastic $p-p$ cross-sections[3)]

s = square of total ~~ener~~ C.M. energy

M = the nucleon mass.

θ_{lab} (mrad)	$(P_0)_{lab}$ (GeV/c)	$\frac{s}{2M^2}$	$-t$ $(\text{GeV}/c)^2$	$\left(\frac{d\sigma}{d\Omega}\right)_{lab}$ (mb/sr)	$\theta_{c.m}$ (deg.)	$\left(\frac{d\sigma}{d\Omega}\right)_{c.m}$ (mb/sr)	$\left[\left(\frac{4\pi}{\sigma_T k}\right)^2 \frac{d\sigma}{d\Omega}\right]_{c.m}$
56.5	12.29.99	14.8	10.524	4524	17.55	1765	1.61.1 x 10^{-2}
56.5	15.89	17.9	0.783	10	19.2	0.30	1.6 x 10^{-3}
,,	17.30	19.4	0.925	4.5	20.0	0.13	6.4 x 10^{-4}
,,	17.75	19.9	0.973	5.3	20.2	0.15	7.0 x 10^{-4}
,,	18.69	20.9	1.084	1.5	20.7	0.039	1.7 x 10^{-4}
,,	19.56	21.9	1.184	0.53	21.2	0.013	5.7 x 10^{-5}
,,	19.75	22.1	1.206	0.90	21.3	0.022	9.5 x 10^{-5}
,,	19.91	22.2	1.221	0.54	21.4	0.013	5.6 x 10^{-5}
,,	21.88	24.3	1.474	0.23	22.3	0.0062	2.5 x 10^{-5}
,,	22.74	25.2	1.590	0.24	22.6	0.005	1.9 x 10^{-5}
,,	26.02	28.7	2.071	0.10	24.2	0.019	6.3 x 10^{-5}
60.5	13.29	20.5	1.184	0.56	21.9	0.015	7.0 x 10^{-5}
,,	27.83	30.6	2.68	0.026	26.6	0.00047	1.5 x 10^{-6}

110	8.94	10.5	0.91	2.75	28.4	0.14	1.45×10^{-3}
,,	11.28	13.0	1.43	0.31	31.5	0.013	1.08×10^{-4}
,,	13.98	15.9	2.17	0.12	34.6	0.0044	2.88×10^{-5}
,,	15.96	18.0	2.80	0.04	36.7	0.0013	7.68×10^{-6}
,,	18.97	21.1	3.86	0.0055	39.5	0.0016	7.55×10^{-7}
,,	21.46	23.9	4.91	0.0011	41.8	0.00003	1.2×10^{-7}
,,	22.92	25.4	5.55	<0.0007	43.0	<0.00002	$<7 \times 10^{-8}$

The curve of $s/2M^2$ against $\left[\left(\frac{4\pi}{\sigma_T k}\right)^2 \left(\frac{d\sigma}{d\Omega}\right)\right]_{c.m}$ demonstrates conclusively a shrinking of the proton-proton diffraction pattern with increasing energy which is in conformity with the Regge hypothesis.

Pion Production in Nucleon-Nucleon Collision

Smith et al[4)] studied the reactions

$$p + p \rightarrow p + p, \quad p + n + \pi^+, \quad p + p + \pi^0, \quad d + \pi^+$$

at 2.85 Bev incident energy. The centre of mass angular distribution in the elastic case showed a strong diffraction peaking at 0°. Cross-section for angles $< 2.5^{\circ}$ is 2.45 ± 0.31 mb and for angles

$> 2.5^\circ$ if it 12.87 ± 0.69 mb Thus

$$\sigma_{el} \simeq 15 \text{ mb}$$

$$\sigma_{pn\pi^+} = 11.44 \pm 0.65 \text{ mb}$$

$$\sigma_{pp\pi^0} = 2.90 \pm 0.31 \text{ mb}$$

$$\sigma_{d\pi^+} = 0.11 \pm 006 \text{ mb}$$

$$\sigma_{\text{multiple pions}} = 7.37 \pm 0.51 \text{ mb}$$

$$\frac{\sigma_{pn\pi^+}}{\sigma_{pp\pi^0}} = 3.94 \pm 0.48$$

$$\frac{\sigma_{\text{multiple pions}}}{\sigma_{pn\pi^+} + \sigma_{pp\pi^0}} = 0.514 \pm 0.043.$$

The nucleon in the $pn\pi^+$ and $pp\pi^0$ reactions is strongly peaked at 0° and 180° in c.m.s. suggesting dominant high-angular momentum states. The $\pi^+ - p$ comes out in a I = 3/2 isobar at least in 50% of the collisions. But there was no evidence for a J = 3/2 scattering.

Neutron- cross-sections at 5 Bev5)

	Pb	Sn	Cu	Al
σ_{tot} in mb	2534 ± 105	1986 ± 88	1158 ± 34	614 ± 33
σ_{reaction} in mb	1670 ± 79		586 ± 25	381 ± 27

	C	H
σ_{tot}	319 ± 20	33.6 ± 1.6
$\sigma_{reaction}$	235 ± 16	

These values are about 200% below the corresponding valuesat 1.4 Bev.

The K*-Resonances:- The experiment of Miller et al6) establishes the existence of an unstable meson with strangness S = +1 mass 726 ± 3 Mev and full-width $\Gamma \lesssim$ 20 Mev from a study of the Kπ effective mass distributions observed in $\pi^{+}-p$ interactions. The simplest interpretation of these data suggests the isotopic spin assignment I = 1/2. The production cross-sections are summarized in the following table, χ denoting the new resonance.

Estimated cross-sections for $\pi^- + p \longrightarrow \Sigma^- + \chi^+$ and

$$\longrightarrow \Sigma^- + K^*(865)$$

Pion momentum (Gev/c)	X^+		K* (885)	
	observed events	cross-section	observed events	cross-section
1.51, 1.69	0	0	Below	threshold
1.90, 2.05	29	6 ± 2	105	20 ± 2
2.17, 2.25 & 2.36	26	3 ± 1	274	30 ± 2

Parameters for Ξ^{-} 7)

The Ξ^{-} was produced in the reaction

$$K^{-} + p \rightarrow \Xi^{-} + K^{+} + \pi^{0}$$

$$\text{or} \quad \Xi^{-} + K^{0} + \pi^{+}$$

$$\text{or} \quad K^{-} + n \rightarrow \Xi^{-} + K^{0} + \pi^{0}$$

$$\text{or} \quad \Xi^{-} + K^{+} + \pi^{-}$$

$$m_{\Xi^{-}} = 1321.0 \pm 0.5 \text{ Mev}$$

$$\tau_{\Xi^{-}} = 1.91^{+0.17}_{-0.15} \times 10^{-10} \text{ sec.}$$

An event of the type $\Xi^{0} + n \rightarrow \Xi^{-} + p$ was observed as well as two of the type $\Xi^{-} + Z \rightarrow \Xi^{0}_{\delta} + Z'$ followed by $\Xi^{0}_{\delta} \rightarrow \Xi^{-} + \pi^{+}$

Mass of the $\Xi\,\pi$ resonance $M_{\Xi^{-}\pi^{+}} = 1553 \pm 7$ Mev.

For the asymmetry parameters, the values are

$$\alpha_{\Lambda}\,\alpha_{\Xi^{-}} = -0.33 \pm 0.09$$

Taking $\alpha_{\Lambda} = -0.62 \pm 0.07$, we have

$$\alpha_{\Xi^{-}} = +0.53 \pm 0.16.$$

REFERENCES

1) A.N.Diddens et al, Phys. Rev. Letters 9, 32 (1962)

2) A.N.Diddens et al , Phys. Rev. Letters 9, 108 (1962)

3) A.N.Diddens et al,,Phys. Rev. Letters 9, 112 (1962)

4) G.A.Smith et al, Phys. Rev. 123, 2160 (1961).

5) J.A.Atkinson et al , Phys. Rev. 123, 1850 (1961)

6) D.H.Miller et al ; Physics Letters 5, 279 (1963)

7) L.Jaunea~~x~~u et al, Physics, Letters 5, 261 (1963).

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SEPTEMBER 1963

INTRODUCTION

In an earlier issue (May 1963) we gave an account of weak interaction data based on the report of Crawford at the 1962 Cern Conference. In the present report we give the latest figures on the subject presented at the Conference in Brookhaven on weak interactions held from 7th to 11th September, 1963. The Institute of Mathematical Sciences was represented by Dr.T.K.Radha who kindly made these data available to us The topics covered include evidence for and against $\frac{\Delta Q}{\Delta S} = -1$ decays, evidence for the conserved vector current (CVC) hypothesis, leptonic and nonleptonic decays of hyperons, the three-pion-decay modes of the K-particle, parameters for the Ξ particle, asymmetry parameters in nonleptonic hyperon decays and capture rates of muons in complex nuclei.

In the second part of the report on many particle systems Dr.R.Vasudevan has given an account of the first experiment which directly measured the energy gap in superconductors. The experiment due to Ivar Giaver uses the quantum mechanical tunneling effect in superconducting films.

ELEMENTARY PARTICLES

Evidence for

$\frac{\Delta Q}{\Delta S} = -1$ decays2)

(i) From the experimental ratio of K_1^0 to K_2^0 decay rates,

$\Gamma_{K_1^0} / \Gamma_{K_2^0} \simeq 12^{+8}_{-6}$, we get the ratio

$$\frac{\left(\frac{\Delta Q}{\Delta S}\right) = -1}{\left(\frac{\Delta Q}{\Delta S}\right) = +1} \approx 0.55$$

(ii) Observation of an event of the decay $\Sigma^+ \to n + \mu^+ + \nu$ by Galtieri et al1)

(iii) Berkeley hydrogen bubble chamber experiment on K_1^0 and K_2^0 leptonic decays shows that

$$\frac{K_1^0 \to \text{leptons}}{K_2^0 \to \text{leptons}} = 6^{+6}_{-4}$$

(iv) Cern experiments ~~for~~ on leptonic decays of Σ give

$$\frac{\Sigma^-(\mu)}{\Sigma^+(\mu)} = \frac{7}{1(?)} \quad \text{and} \quad \frac{\Sigma^-(e)}{\Sigma^+(e)} = \frac{8}{0}$$

(v) Concerning ~~For~~ the purely axial vector Ke_4 decay, the decay $K^+ \longrightarrow \pi^+ + \pi^+ + e^- + \bar{\nu}$ which corresponds to $\Delta S = -\Delta Q$ has been observed only once as compared to the $K^+ \to \pi^+ + \pi^- + e^+ + \nu$ of which 49 events have been observed.

Thus for the axial vector case $\frac{\Delta Q}{\Delta S}$ *= 1 looks valid*

For the pure vector interaction as in the case of the K^0 leptonic decays, this is not so conclusive.

($K_1^0 - K_2^0$) mass difference2)

Group	Method of production	$\Delta m \times 10^5$
~~Piccioni et al~~	~~By Regeneration~~	~~0.84^+~~
Piccioni et al	By Regeneration	$0.84^{+0.29}_{-0.22}$
Fifca et al	Production of K° by absorption	1.9 ± 0.3
Camerini et al	Production of K° by absorption	1.5 ± 0.2
Berkeley	From K⁻ decay	2.3 ± 0.7
Crawford	—	$1.6^{+0.65}_{-0.35}$

CONCLUSIONS FROM HIGH-ENERGY NEUTRINO EXPERIMENTS2)

The events reported are 55 elastic events, 59 inelastic, 19 capture and 12 events of backward leptonic scattering. The data agree with the theoretical cross-sections of Lee and Yang3). No heavy boson was observed below 10 Bev. Magnetic moment of $\nu_\mu <$ 2 x 10^{-8} Bohr magnetons.

Magnetic moment of $\nu_e \lesssim$ 1.4 x 10^{-9} Bohr magnetons.

σ total for $\nu + Z = \nu + \mu^+ + \mu^- + Z$ is $< 2 \times 10^{-39}\,\text{cm}^2$

μ^- Capture experiments in complex nuclei

Negative muon capture in complex nuclei is a phenomenon which can be viewed as a method for studying either (a) the ~~muon~~ muon capture interaction or (b) nuclear physics as probed by a ~~weekly~~ weakly interacting charged particle. Data on this subject provide a test for the hypothesis of Universal Fermi Interaction (UFI)

Capture in liquid hydrogen2)

Group	No. of Events	No. according to UFI
CERN	450 ± 50	?
Chicago	428 ± 85	
Argonne	445 ± 43	585
Columbia	464 ± 42	570

Reaction	No. of events	No. according to UFI
$\mu^- + He^3 \rightarrow H^3 + \nu$	1520 ± 50	1530 ± 150
	1440 ± 90	
$\mu^- + C^{12} \rightarrow B^{12} + \nu$	6750 ± 300 - 750	6900 ± 150

$$\frac{\mu^- + Ca \rightarrow \gamma + all}{\mu^- + Ca \rightarrow all} = (3.05 \pm .35) \times 10^{-4} \quad \text{(Experiment)}$$

$$= 2.3 \times 10^{-4} \quad \text{(UFI)}$$

The conclusions are that there is agreement up to 20% with UFI, with an anomaly in the case of $\mu^- + Ca$ experiments.

μ^- Capture from complex nuclei[4)]

Element	(A - Z)/2A	Lifetime (μ sec)	Capture Rate (10^6 Sec^{-1})
Ca	0.27203	164.02 ± 2.25	5.66 ± 0.09
As	0.28000	153.89 ± 2.43	6.06 ± 0.12
Y	0.28090	120.16 ± 1.35	7.89 ± 0.11
Nb	0.27957	92.32 ± 1.07	10.40 ± 0.14
Ag	0.28232	88.69 ± 0.91	10.86 ± 0.13
Cd	0.28667	90.48 ± 0.81	10.63 ± 0.11
In	0.28679	84.81 ± 0.83	11.37 ± 0.13
Sn	0.28955	89.89 ± 1.03	10.70 ± 0.14

Element	(A - Z)/2A	Lifetime (μ sec)	Capture rate (10^6 Sec^{-1})
Sb	0.29072	91.66 ± 1.09	10.49 ± 0.14
I	0.29134	86.10 ± 0.67	11.20 ± 0.11
Cs	0.29323	87.81 ± 1.89	10.98 ± 0.245
Ba	0.29623	94.45 ± 0.72	10.18 ± 0.10
La	0.29496	89.90 ± 0.69	10.71 ± 0.10
Ce	0.29314	84.37 ± 0.69	11.44 ± 0.11
Pr	0.29078	72.14 ± 0.59	13.45 ± 0.13
~~Nd~~ Nd	0.29210	78.54 ± 0.75	12.32 ± 0.14
Sm	0.29388	79.17 ± 1.01	12.22 ± 0.17
Gd	0.29658	80.08 ± 0.95	12.09 ± 0.16
Tb	0.29560	76.19 ± 0.66	12.73 ± 0.13
Ho	0.29697	74.91 ± 0.61	12.95 ± 0.13
Ta	0.29834	75.48 ± 0.64	12.86 ± 0.13
~~An~~ Au	0.29949	72.57 ± 0.45	13.39 ± 0.11
Tl	0.30186	70.33 ± 0.92	13.83 ± 0.20
Pb	0.30210	74.87 ± 0.41	12.98 ± 0.10
Bi	0.30143	73.30 ± 0.36	13.26 ± 0.10
RPb	0.30082	71.50 ± 0.37	13.61 ± 0.10

(Radiogenic lead)

The data are consistent with the formula of Primakoff5) and the UFI.

Gell-Mann's review of validity of the CVC hypothesis2)

Experiment gives $G_V \simeq G_\mu$ (5% error)

Caltech experiments give

$$G_V = (0.985 \pm 0.003) \quad (G_\mu \text{ uncorrected})$$
$$= 0.975 \quad (\text{if corrected})$$

Experiments on Al^{20} : G_V = (0.995 ± 0.003) (G_μ uncorrected)

= 0.985 (if corrected)

Experiments on $\pi^+ \rightarrow \pi^0 + e^+ + \nu$

$$G_V = (1.14 \pm 0.16) \, G_\mu \quad (\text{Dubna group})$$
$$= (1.06 \pm 0.10) \, G_\mu \quad (\text{CERN})$$

indicating real agreement with the CVC hypothesis. The discrepancies in the other cases may be due to Coulomb effects, radiative corrections or vector bosons corrections. If the discrepancies are not real, then $G_\mu \neq G_V$

Polarisation of electron in μ -decay2)

The CERN group reported that the electron in $\mu^+ \rightarrow e^+ + \nu + \bar{\nu}$ is not polarized.

Leptonic decays of hyperons2)

Decay	U.F.I.	Calculations (on the basis of unitary symmetry)	Experiment	U.F.I. / Experiment
$\Lambda^0 \rightarrow p e^- \nu$	1.5×10^{-2}	1.1×10^{-3}	$(.82 \pm .13) \times 10^{-3}$	18
$\rightarrow p \mu^- \nu$	2×10^{-2}			
$\Xi^- \rightarrow \Lambda e^- \nu$	2×10^{-2}	0.56×10^{-3}	$(2\text{-}3) \times 10^{-3}$	7
$\Sigma^- \rightarrow n e^- \nu$	5.8×10^{-2}	0.8×10^{-3}	$(1^{+.5}_{-.3}) \times 10^{-3}$	60
$\Sigma^- \rightarrow n \mu^- \nu$	2.6×10^{-2}		$(.8 \pm .3) \times 10^{-3}$	30
$\Sigma \rightarrow \Lambda e^- \nu$	1.0×10^{-4}		$(.6 \pm .3) \times 10^{-4}$	1.7
$\Sigma^+ \rightarrow \Lambda^0 + e^+ + \nu$	0.6×10^{-4}			

$\Sigma^+ \rightarrow e^+ + \Lambda + \nu \longrightarrow$ (no event)

(35 events)

$\Sigma^- \rightarrow e^- + \Lambda + \nu$

$$\frac{R(\Sigma^+ \rightarrow e^+ + \text{(invisible)})}{R(\Sigma^+ \rightarrow \mu^+ + \text{(invisible)})} = \frac{3}{1?}$$

$$R(\Sigma^- \rightarrow n \mu^- \nu) = (.8 \pm 0.3) \times 10^{-3}$$

$$R(\Sigma^- \rightarrow \Lambda e^- \nu) = (0.6 \pm 0.3) \times 10^{-4}$$

$R(\Sigma^- \rightarrow n + e^- + \nu)$ $(4 \pm 1.5) \times 10^{-3}$

$R(\Sigma^- \rightarrow n + \mu^- + \nu)$ 1.3×10^{-3} (90%) accuracy)

There is no evidence for $\Delta s = 2$ decays. An upper limit is given by·

$$\frac{R(\Xi^- \rightarrow n\pi^-)}{R(\Xi \rightarrow \Lambda\pi^-)} \approx 0.5\%^{6)}$$

ΔI = 1/2 rule and nonleptonic decays (Dalitz's review)$^{2)}$

$$R = \left[\frac{K_1{}^0 \rightarrow 2\pi^0}{K_1{}^0 \rightarrow \text{all } 2\pi}\right] \approx 1/3 \text{ theoretically}$$

= 0.264 ± 0.024 ⁑
0.288 ± 0.021 ⁑ Experimentally
0.335 ± 0.14 ⁑

From the ΔI = 1/2 rule the matrix elements for the decays $\Sigma^+ \rightarrow p + \pi^0 (M_0)$, $\Sigma^+ \rightarrow n + \pi^+ (M_+)$ and $\Sigma^- \rightarrow n + \pi^- (M_-)$ are connected by the relation $(\sqrt{2}\, M_0 + M_+) = M_-$. Experimentally these decay rates are, respectively, (0.666 ± 0.47) ~~$\text{x}10^{-10}$~~ $\times 10^{+10}$ (0.641 ± 0.046) 10^{10} and (0.634 ± 0.25) x 10^{10}.

The ~~assymetry~~ asymmetry parameters for these decays are

$\alpha_0 = -.78 \begin{smallmatrix} + .09 \\ - .08 \end{smallmatrix}$

$\alpha_+ = - 0.03 \pm .08$

$\alpha_- = -.16 \pm 0.21$

$-.04 \pm .23$

For strict ΔI = 1/2 rule→ $\alpha_+ \simeq \alpha_- = 0$ and $\alpha_0 \simeq 1$

The best fit gives $\alpha_0 = -0.95$

<u>Non-leptonic decays of Ξ particle</u>

Mode	Amplitude	Lifetime
$\Xi^- \to \Lambda + \pi^-$	$M_1 + \frac{1}{2} M_3$	1.75×10^{-10} sec
$\Xi^0 \to \Lambda + \pi^0$	$\frac{1}{\sqrt{2}} M_1 - \frac{1}{\sqrt{2}} M_3$	$\sim 3.5 \times 10^{-10}$ sec

A lifetime 2.8×10^{-10} gives $M3/M1 = 0.07$

<u>Three pion decay modes of the K-particle</u>

The ΔI = 1/2 rule predicts $\Gamma_2(\pi^+\pi^-\pi^0)$

$= 2\Gamma(\pi^+ + \pi^0 + \pi^0) \approx (2.87 \pm 0.20) \times 10^6 \sec^{-1}$

$$\Gamma_2(000) = 1.565\ \Gamma(++-)$$
$$-1.255\ \ (+000)$$

(phase factors included)

$\Gamma_2 = (17.2 \pm 2.5) \times 10^6 \sec^{-1}$. The old experimental values

a $(12.3^{+5.2}_{-3.6}) \times 10^{6} \sec^{-1}$ $(19.00 \pm 6.7) \times 10^{6}\ \overset{\text{sec}^{-1}}{\cancel{\text{sec}}}{}^{-1}$

$$X = \frac{\Gamma_2(000)}{\Gamma_2(\text{charged})} = 0.24 \pm 0.08$$

$$Y = \frac{\Gamma_2(+-0)}{\Gamma_2(\text{charged})} = \begin{matrix} 0.151 \pm 0.03 \\ 0.12 \pm 0.02 \\ 0.185 \pm 0.035 \end{matrix} \Bigg\} \text{ Different Experiments}$$

$= 0.14 \pm 0.045$ (Dubna)

Theoretically $\dfrac{\Gamma_2(000)}{\Gamma_2(+-0)} = 1.94 \pm 0.02$ whereas

experiment gives a value 1.62 ± 0.6.

The conclusion ~~give~~ is all the experimental esults are compatible with ΔI = 1/2 rule, the biggest discrepancy being in the decay $K^+ \to \pi^+ + \pi^-$)

Parameters for the Ξ - particle$^{2)}$

$$m_{\Xi^-} = 1321.2 \pm 0.35 \text{ Mev}$$

$$m_{\Xi^-} - m_{\Xi^0} = \left.\begin{array}{l} 4.2 \pm 2.6 \\ 6.1 \pm 1.6 \end{array}\right\} \text{(2 xperiments)}$$

Average Δm = 5 Mev while SU_3 predicts 6.7 ± .4 Mev.

Lifetime of Ξ^-

Group	τ_{Ξ^-}
CERN	$(1.55 \pm 0.31) \times 10^{-10}$ sec
LRL	$(1.75 \pm 0.07) \times 10^{-10}$ sec
UCLA	$(1.77 \pm 0.12) \times 10^{-10}$ sec
EPT	$(1\ 91 \pm 0.16) \times 10^{-10}$ sec
BNL	$(1.74 \pm 0.18) \times 10^{-10}$ sec

Average value = $(1.77 \pm 0.5) \times 10^{-10}$ sec

Assymetry parameters

$$\left.\begin{array}{ll} \alpha_{\Xi^-} & = -0.49 \pm 0.16 \\ \beta_{\Xi^-} & = -0.51 \pm 0.08 \\ & = \pm 0.02 \pm 0.22 \\ \gamma_{\Xi^-} & = 0.87 \pm 0.10 \end{array}\right\} \text{(BNL)}$$

$$\alpha_\Lambda \alpha_\Xi = -0.22 \pm 0.18 \quad \text{(LRL)}$$

$$= -0.40 \pm 0.34 \quad \text{(BNL)}$$

$$= 0.\ 7 \pm 0.26 \quad \text{(UCLA)}$$

Best values

$$\alpha_{\Xi^-} = -0.50 \pm 0.065$$

$$\beta_{\Xi^-} = 0.32 \pm 0.17$$

$$\gamma_{\Xi^-} = 0.80 \pm 0.08$$

REFERENCES

1. Report on Recent Experimental Data, Matscience Report (May 1963)

2. Dr.T.K.Radha (Private communication)

3. T.D.Lee and C.N.Yang, Phys. Rev. Letters 4, 307 (1960)

4. T.A.Filippas et al, Phys. Letters 6, 118 (1963)

5. H.Primakoff, Rev. Mod. Phys. 31, 802 (1959), R.Klein and L.Wolfenstein, Phys. Rev. Letters 9, 408 (1962)

6. M.Ferro-Luzzi et al, Phys. Rev. 130, 1568 (1963).

MANY PARTICLE SYSTEMS

TUNNELING EFFECT IN SUPERCONDUCTORS

As is well-known; the microscopic explanation of superconductivity is based on the possible formation of Cooper pairs and the consequent appearance of energy gap in the excitation spectrum of the superconductors. Though the magnitude of this gap is only 10^{-3} electron volts, the enormous changes produced in the electrodynamic properties of the superconductor as compared with the normal metal is very striking. Till recently there has not been a direct method of measuring the energy gap, though indirect methods like ultrasonic attenuation and infra-red scattering methods have been used.

A strikingly simple and direct method was deviced by Ivar Giaver(1) in the General Electric Research Laboratories, New York to determine this gap by what is known as the tunnelling experiment in superconducting films;

When two metals are separated by a thin insulating film electrons can flow between the two conductors due to quantum mechanical tunnel effect. If a small potential difference is applied between the two metals, the current through the film will vary linearly with applied voltage as long as the density of states in the two metals is constant over the applied range. as it is formost normal metals. In a superconductor however the density of states changes, rapidly in a narrow energy range centred at the Fermi level. So the voltage current characteristics become nonlinear.

Aluminum/aluminum oxide/lead sandwiches were prepared by vapour depositing aluminum on glass slides in vacuum, oxidizing the aluminum in air for a few minutes at room temperature and then vapour depositing lead over the aluminumoxide. The oxide layer separating aluminum and lead is about 15-20 Å thick.

At liquid helium temperature, in the presence of a magnetic field applied parallel to the film and sufficiently strong to keep the lead in the normal state the tunnel current is linear in the voltage. However, when the magnetic field is removed and lead became superconducting, the tunnel current is very much reduced at low voltages, as shown in Fig.1. Identical results were obtained with both directions of flow.

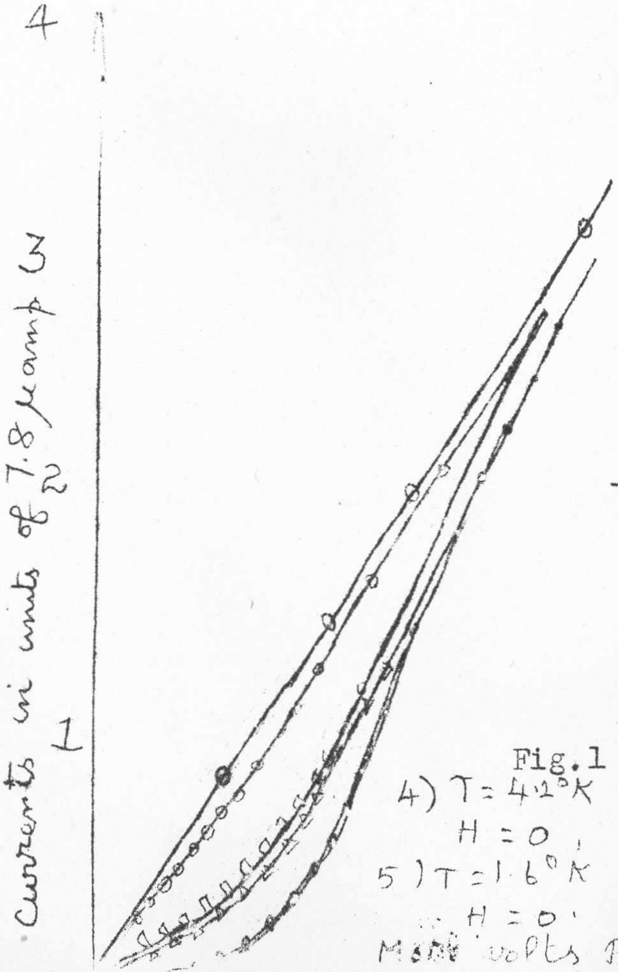


Fig.1

Tunnel current between Al and Pb through Al_2O_3 film as a function of voltage

(1) T = 4.2°K
H = 2.7 Koe

2) T = 4.2°K H = .8 koe

3) T = 1.6°K, H = 0.8 Koe

4) T = 4.2°K
H = 0

5) T = 1.6°K
H = 0

The slope $\frac{dI}{dV}$ of the curve when H = 0, T = 1.6°K divided by $\frac{dI}{dV}$, for normal lead can be plotted and on the naive picture that the tunnelling current is proportional to the density of states; this curve expresses the density of states in the superconducting state relative to the density of states in the normal state as a function of energy measured from the Fermi energy. The curve reservables, the Bardeen Cooper Schrieffer(2) density of states for quasiparticles excitations. (Fig 2)

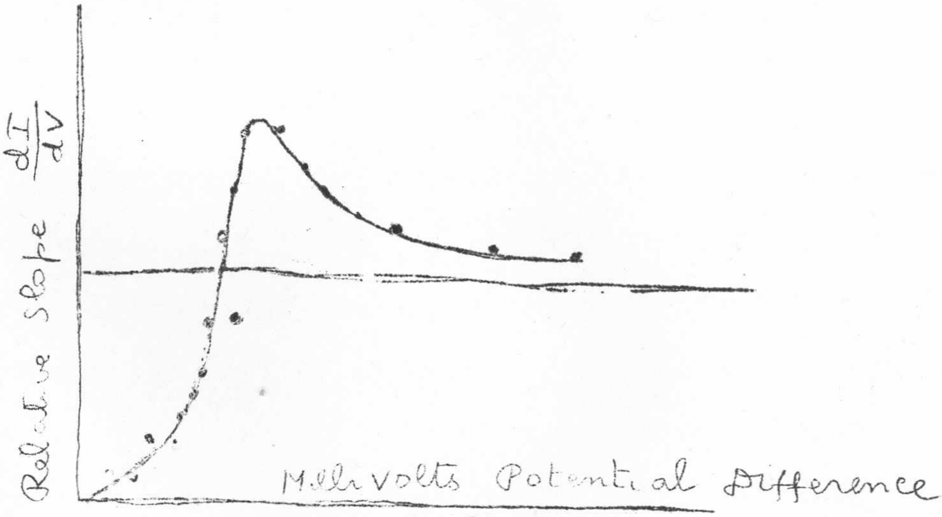
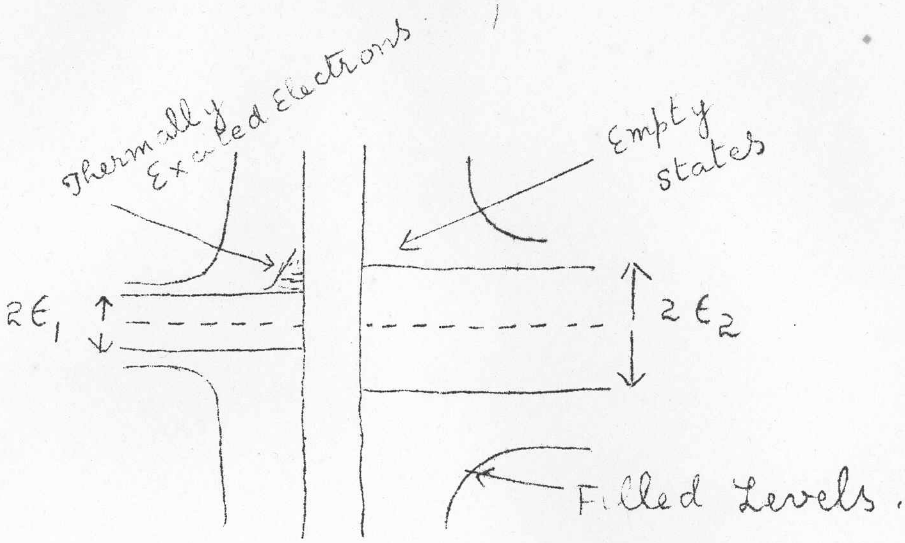


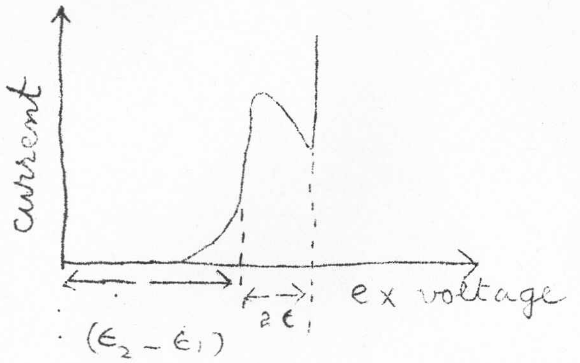
Fig. 2.

An approximate measure of half the energy gap is given by the point at which the relative slope $\frac{dI}{dV} = 1$. On this basis the gap width for lead is $(4.2 \pm .01)\, kT_c$

A more direct measurement of the gap is possible when electrons tunnel between two superconductors and if we accept the one particle model of the superconductor. A metal oxide sandwich can always be formed and if we look at the following picture of the filled and unfilled levels, we can get an idea of the nature of the variation in current with applied voltage.



The two superconductors one on the left and the other on the right have energy gaps $2t_1$ and 2t2 have an insulator in between and for the smaller gap superconductor there will be a few thermally excited electrons. As voltage is applied, an increasing current will flow because more and more of the thermally excited electrons in the left hand superconductor will flow to the right. When the applied voltage is more than $\epsilon_2 - \epsilon_1$, half the difference of the two energy gaps, it has become energetically possible for all thermally excited electrons to tunnel though ~~when~~ When the voltage is increased further, only the same number of electrons are available for tunnelling and so the current decreases. Finally when a voltage greater than half the sum of the two energy gaps $\epsilon_2 + \epsilon_1$ is applied the current will increase rapidly because the electrons below the gap can begin to flow. As is seen in the curves of Jones Nicol et al$^{(3)}$ for the $Al - Al_2O_3 - Pb$ sandwiches there was a region in which the current decreased with the voltage i.e. the I-characteristics exhibited a negative resistance region. When the Al was brought to the normal state by applying the magnetic field, this disappeared



As a simple arguments we can say that the one way tunneling current is proportional to an integral over all energies of the product of the number of electrons in one metal by the number of unoccupied states (holes) in the other metal at the corresponding energy. The net current is given by the difference in the opposed one way currents. With the energy zero at the Fermi level for metal 1 and with metal 1 at a positive potential.

$$I \propto \int \{ \rho_2(E-V) f(E-V) \rho_1(E) [1-f(E)] - \rho_2(E-V) [1-f(E-V)] \rho_1(E) f(E) \} dE$$

With all the energies measured in units of kT, V is the energy equivalent of the applied voltage, ρ_1 is the density of states function formmetal 1, ρ_2 that for metal 2, and f(E) is the Fermi function ;

$$f(E) = \frac{1}{1+e^{E}}$$

The density of states ρ (E) near the Fermi surface = $N(0)\left|\frac{E}{[E^2-\epsilon(T)^2]^{1/2}}\right|$ for $|E| \geqslant \epsilon(T)$ and $\rho = 0$ for $|E| < \epsilon(T)$

This can be seen from the work of BCS(2).

These experiments therefore give adirect measurement of the energy gaps which according to the results of Giaver are given at $T \sim 1^{\circ}K$ as :-

$$2\epsilon_{Pb} = (2.68 \pm \cdot 06) \times 10^{-3}\,\text{ev} = (4\cdot 33 \pm \cdot 10)kT_c$$

$$2\epsilon_{In} = (1\cdot 05 \pm \cdot 03) \times 10^{-3}\,\text{ev} = (3\cdot 63 + \cdot 10)kT_c$$

$$2\epsilon_{Al} = (0\cdot 32 \pm \cdot 03) \times 10^{-7}\,\text{ev} = (2\cdot 3 + \cdot 03)kT_c$$

The arguments used in the above rests on the idea that the only relevant factor incalculating the tunnelling current is the density of states in energy of the quasiparticles on both sides of the insulator. A more detailed analysis from a many particle view point is advanced by Bardeen(4) to explain the observed results.

REFERENCES

1. Ivor Giaver, Phys. Rev. letters 5, 147, 464, (1960)
2. J.Bardeen L.N.Cooper and J.R.Schrieffer, Phys. Rev. 108, 1175 (1957)
3. J.Nicol S.Shapiro and P.H. Smith, Phys. Rev. letters 5, 461 (1960)
4. J.Bardeen, Phys. Rev. letters vol.6, 57, (1961).

OCTOBER 1963.

INTRODUCTION

The elementary particles section of the present report begins with the reported discovery at CERN of a positively charge vector boson, one of a family of such bosons the existence of which may prove decisive for the theories of weak interactions. An account of these bosons is given.

The total cross-sections for the interactions of K^+ and K^- mesons with the proton, neutron and the deuterons resulting in scattering or production of particles are presented for a wide range of energies of the incident particles. The most striking feature (which has been well recognized) of these data is the fact that the K^+ total scattering cross-sections show no significant variation with momentum from 3.25 to 19.0 Bev/c, the constan value being 18.4 mb over the entire range. The K^- total elastic scattering cross-sections show on the other hand, a slowly decreasing trend from a value of about 45 Mb at 0.3 Bev/c to a value of about 21 mb at 19 Bev/c. The difference in the $K^- - K^+$ cross-section decreases from about 8 mb at 6 Bev/c to approximatel 3 mb at 19 Bev/c. Hence these data cannot confirm the Pomeranchul limit theorem.

A recent experiment at Saclay concerning neutral decay modes of the η meson the results of which are in good agreement with the unitary symmetry model is quoted.

ELEMENTARY PARTICLES

Weak Vector Bosons1)

Preliminary results of high energy neutrino experiments at the CERN presented at the International Conference on Elementary Particles held in Siena, Italy, earlier this month seem to indicate the production of a positively charged weak vector boson in these reactions. The confirmation of this result and possible discovery of similar bosons of different quantum numbers may prove quite decisive for the various theories of weak interactions that have been proposed.

The description of the weak interaction in the form of the direct interaction of two currents (and the tacit assumption that the interaction is local) violates unitarily at high energies and the theory is not renormalizable in more than the lowest order. Hence the necessity of a boson with spin one mediating the weak interactions has been envisaged in the theory. Such a boson should have mass greater than that of the K-meson mass and would be short-lived (Lifetime = 10^{-12} or 10^{-13} secs) The mediation of weak interactions by the vector boson would require in order to forbid the unobserved decay $\mu \longrightarrow e + \gamma$ the existence of two neutrinos ~~as~~ which has been confirmed experimentally Various theories of weak interactions have predicted different numbers of these bosons depending on the number of independent currents involved in the interaction. Lee and Yang postulated, assuming the validity of the $|\Delta \vec{I}| = \frac{1}{2}$ rule for the strangeness changing weak interactions that there should be a quartet of vector bosons W^+, W^- N^0 and $\overline{N^0}$ which have the dual-isotopic spin property that sometimes they behave like an isotopic spin triplet and a singlet and in other contexts like two isotop spin doublets (and hence called schizzons). In a later theory Lee required a single set of six bosons (cosisting of two positive, two neutral and two negative particles) inorder to include the $\Delta Q = -\Delta S$ interactions. A similar number was postulated by Takeda. The model of Behrend and Sirlin admits of an octet of vector bosons. Recently Marshak et al have postulated two sets of charged vector bosons $W_0^{(\pm)}$, $W_1^{(\pm)}$ the first coupled to the strangeness conserving and the second to the strangeness-changing currents which in their scheme of baryon-lepton symmetry can have both leptonic and baryonic parts. The masses of the two bosons are different $(m(W_1) \simeq \sqrt[4]{20}\, m(W_0))$ to account for the low transition probabilities for the strangeness-violating leptonic decays of the hyperons.

Thus further experimental work on these bosons is important for the theory of weak interactions.

K-meson Nucleon Interactions

Total Cross-sections for K⁺ on Protons 2)

Momentum (Bev/c)	σ_{Total} (mb)
3.25	17.5 ± 1.2
4.0	17.6 ± 1.2
5.5	17.9 ± 0.8
7.0	18.4 ± 0.6
8.5	18.7 ± 0.6
10.0	18.8 ± 0.7
10.9	18.1 ± 0.7
11.5	19.0 ± 0.6
12.5	18.3 ± 0.8
13.4	17.5 ± 0.6
15.0	18.5 ± 0.7
16.9	18.8 ± 0.6
19.0	17.3 ± 0.9

Total cross-sections for K⁻ on protons

Momentum (Bev/c)	σ Total (mb)
0.3	44.5 ± 6.4 (48^{3})
0.4	38.9 ± 4.7(69^{4})
0.98	$47.1^{-2.2}_{+1.8}$ 4)
1.23	$33.8^{-0.8}_{+0.6}$ 4)
1.35	$31.2^{-0.4}_{+0.9}$ 4)
1.48	$32.5^{-0.4}_{+0.8}$ 4)
1.60	$32.5^{-0.1}_{+0.8}$ 4)
1.73	$32.5^{-0.1}_{+0.6}$ 4)
1.95	30.5 ± 0.4 4)
2.48	$26.9^{+0.3}_{-0.5}$ 4)
2.97	25.3 ± 0.4 4)
3.98	$25.4^{-0.5}_{+0.7}$ 4)
4.0	23.2 ± 1.9 2)
5.5	24.3 ± 0.8 2) 1)

Momentum (Bev/c)	σ_{Total} (mb)
7.0	25.0 ± 0.5 2) 1)
8.5	24.6 ± 0.8 1)
10.0	23.2 ± 0.7 2) 1)
11.5	23.3 ± 0.8 1)
12.0	22.9 ± 0.7 1)
13.4	21.5 ± 0.7 1)
14.5	21.6 ± 0.8 1)
15.8	21.9 ± 0.8 1)
19.1	21.6 ± 1.7 1)

Total cross-section for K^- on neutrons 4)

Momentum (Bev/c)	σ_{Total} (4)
0.98	$31.2^{+4}_{-1.6}$
1.23	$29.4^{+2.5}_{-1.1}$
1.48	$26.4^{+2.3}_{-1.0}$

Momentum (Bev/c)	σ_{Total} (mb)
1.73	$24.3^{+1.9}_{-0.8}$
1.95	$22.7^{+1.9}_{-0.9}$
2.48	$22.6^{+1.7}_{-0,9}$
2.97	$22.4^{+1.5}_{-0.3}$
3.98	$20.5^{+1.2}_{-0.9}$

Total cross-sections for K^- on deuterons[4)]

Momentum (Bev/c)	σ_{Total} (mb)
0.98	$74.3^{-1}_{+0.8}$
1.23	$60.7^{-0.1}_{+0.5}$
1.48	$56.6^{+0.4}_{-0.5}$
1.73	$54.9^{+0.9}_{-0.5}$

Momentum (Bev/c)	σ_{Total} (mb)
1.95	$51.3^{+1.1}_{-0.7}$
2.48	$47.8^{+1.9}_{-0.1}$
2.97	$46.2^{+1.9}_{-0.1}$
3.98	$44.7^{+1.9}_{-0.5}$

Total cross-sections for the elastic charge exchange process $K^- + p \rightarrow \bar{K}_0 + n$

Momentum (Bev/c)	σ_{Total} (mb)
0.3	2.7 ± 2.7 (1) 3)
0.4	3.1 ± 3.7 (5) 3)
1.0	10.4 ± 1.7 3)
1.15	5.3 ± 0.5 (107) 5)
1.5	3.8 ± 0.7 4)
2.5	1.9 ± 0.3 4)
4.0	2.5 ± 0.5 4)

Productions cross-sections for K^+ on protons6)

In the four-particle final states of the $K^+ - p$ interaction at 1.96 Bev/c, these states are predominantly produced via 'double resonance' production, i.e. $K^+ + p \rightarrow K^*(890) + N^*_{33}(1238)$. The experimental data support a spin-zero meson exchange, presumably a pion, for small four momentum transfers $(\Delta^2 \leq 25\ m_\pi^2)$

The cross-sections for the various charge-state combination in the reaction $K^+ + p \rightarrow K\pi p\pi$ at 1.96 Bev/c are given in the following table.

Charge combination	K^*	N^*_{33}	σ_{exp} (mb)	No. of events observed
$K^+\pi^- p\pi^+$	$K^+\pi^-$	$p\pi^+$	1.7 ± 0.2	435
$K^0\pi^0 p\pi^+$	$K^0\pi^0$	$p\pi^+$	1.3 ± 0.2	110
$K^0\pi^+ n\pi^+$	$K^0\pi^+$	$n\pi^+$	0.33 ± 0.1	-
$K^+\pi^0 n\pi^+$	$K^+\pi^0$	$n\pi^+$	unmeasurable	-
$K^+\pi^0 p\pi^0$	$K^+\pi^0$	$p\pi^0$	,,	-

Production cross-sections for K⁻ on protons 3), 5)

Reaction	σ_{Total} (mb)		
	0.3(Bev/c)	0.4(Bev/c)	1.15 (Bev/c)
$K^- + p \rightarrow \Sigma^- + \pi^+$	8.3 ± 2.8 (9)	6.0 ± 1.8(11)	1.4 ± 0.2(37)
$\rightarrow \Sigma^+ + \pi^-$	9.2 ± 2.9(10)	9.9 ± 2.2(13)	1.3 ± 0.2(84)
$\rightarrow \left.\begin{matrix}\Sigma^0 + \pi^0 \\ \Lambda^0 + \pi^0\end{matrix}\right\}$	7.5 ± 3.4(5)	11.7 ± 3.3(13)	1.68 ± 0.2(70)
$\rightarrow \Lambda^0 + \pi^+ + \pi^-$	0.9 ± 0.9(1)	1.1 ± 0.8(2)	3.1 ± 0.4(14)
$\rightarrow \Sigma^0 + \pi^+ + \pi^-$		0.5 ± 0.5(1)	1.0 ± 0.2(27)
$\rightarrow \Sigma^- + \pi^+ + \pi^0$			0.8 ± 0.2(54)
$\rightarrow \Sigma^+ + \pi^- + \pi^0$			1.0 ± 0.2 (57)
$\rightarrow \Sigma^+ + \pi^- + \pi^0 + \pi^0$			0.18 ± 0.06(13
$\rightarrow \Sigma^- + \pi^+ + \pi^0 + \pi^0$			0.12 ± 0.05(9)
$\rightarrow K^{*-} + p$			1.35 ± 0.3(21)
$\rightarrow K^{*0} + n$			0.9 ± 0.15(23)
$\rightarrow K^- + p + \pi^0$			1.0 ± 0.3(30)
$\rightarrow K^- + \pi^+ + n$			2.1 ± 0.4(26)
$\rightarrow \overline{K^0} + p + \pi^-$			2.0 ± 0.3(48)
$\rightarrow \overline{K^0} + n + \pi^0$			1.3 ± 0.3(26)

(The figures in brackets denote the number of events observed)

As already mentioned in the introduction, the data on elastic scattering of a K-meson on protons show that the Pomerauanchuk limit is not attained even at 19 Bev/c. Further if we assume the functional form $A + \frac{B}{E^{1-\alpha(0)}}$ ($E =$ total laboratory energy) of incident particle) suggested by the Regge pole theory; since $\sigma_{total}(K^+p)$ is constant over a wide range of energies, the contributions of the several trajectories other than the vacuum must be small or must cancel out so that we can write $\sigma_{total}(K^+p) = A$ For $\sigma_{total}(K^-p)$ we have both terms surviving. The best fit to the data between 4 and 19 Bev/c gives.

$$A = 18.4 \pm 0.2 \text{ mb} , \quad B = 21.7 \pm 6.2$$

and $\alpha(0) = 0.36 \pm 0.13$

$\alpha(0)$ is a second pole which has the same quantum numbers as the vacuum and may correspond to the second vacuum trajectory proposed by Igi

Branching Ratio of Neutral decay modes of η meson

Recent deuterium bubble chamber experiments at Saclay[7)] give the following values for the various neutral decay modes of the $\eta\ (0^{-+})$ meson.

$$\frac{\eta \to 3\pi^0}{\eta \to \text{all neutrals}} = 0.48 \pm 0.13$$

$$\frac{\eta \to 2\gamma}{\eta \to \text{all neutrals}} = 0.52 \pm 0.13$$

Hence
$$\frac{\eta \to 2\gamma}{\eta + 3\pi^0} = 1.01 \pm 0.18$$

This values fits well with the theoretical predictions of the unitary symmetry model.

REFERENCES

1) Press Report on the discovery of the vector boson (New York Times, Western Edition, October 14, 1963)

) T.D. Lee and C.N.Yang, Phys. Rev. 119, 1410 (1960)

T.D.Lee, Phys. Rev. Letters 9, 319 (1962)

G.Takeda, Ann. Phys. 18, 310 (1962); 'Lectures on Weak Interactions' (Lectures delivered at the Summer School at Kodaikanal, India in June 1963.

R.E.Behrends and A.Sirlin : Phys. Rev. 121, 324 (1961)

R.E.Marshak, C.Ryna,
T.K.Radha and K.Raman Proprint.

2) W.F.Baker et al, Phys. Rev. 129, 2285 (1963)

3) P.Nordin, J.A. Phys. Rev. 123, 2168 (1961)

4) V.Cook et al, Phys. Rev. 123, 320 (1961)

5) W.Graziano and S.G.Wojcicki; Phys. Rev. 128, 1868 (1962)

6) G.Goldhaber et al, Physics Letters, 6, 62 (1963)

7) A.Muller et al : Saclay Proprint.

NOVEMBER, 1963.

INTRODUCTION

We begin the present report with a review of some experimental results presented at the International Conference on Elementary Particles held at Sienna in October. The review is based on an informal talk given by Dr. M. Jacob of Saclay at the Institute in which he summarised the main theoretical and experimental results presented at the conference.

Continuing the cross-section data on K-meson-nucleon interactions we give some further numbers, mainly in the low energy region. The possibility of new resonances in the $\Xi - \pi$ system at masses 1660 and 1740 Mev is indicated in one of these experiments. Evidence for a negative $KN\Sigma$ parity is quoted as well as the production of Y_0^* and Y_1^* along with their anti-particles in $p - \bar{p}$ collisions.

In the section on high-energy scattering cross-sections we mention the theoretical predictions of Taylor on the high energy behaviour of π-p, K-π & $\bar{p} - p$ cross-sections. The prediction of near constancy of the total K - p cross-sections above 8 Bev/c at least does not seem to be borne out experimentally.

The results of an experiment done at Saclay on total and differential cross-sections for $\pi - p$ scattering and total cross-sections for pion production in $\pi - p$ collisions at 800 and 900 Mev. are given as well the work of Smith on strange particle production in pion-nucleon collisions.

Finally we give an account of some theoretical considerations by Yang on high energy neutrino experiments in which he makes out that the CERN experiment may not yield much more information on the vector boson than its possible existence and also indicates how the weak form factors can be determined from the experiment.

ELEMENTARY PARTICLES

A review of some experimental results presented at the Sienna Conference (October, 1963. 1)

Strong Interactions;- (i) K^--p scattering at 3 Bev;- The most interesting feature of the experiments done by the Saclay-Ecole Polytechnique-Amsterdam collaboration on processes like

$$K^- + p \to Y^* + \pi$$

is that the K^* exchange appears to play a dominant role in these processes. Processes where such exchanges are not allowed seem to have negligible cross-sections (about 1/10th less than for the K^* - exchange processes)

E.g. $K^- + p \to Y_1^{*+} + \pi^-$ for which a K^* - exchange is possible is observed while

$K^- + p \to Y_1^{*-} + \pi^+$ is not observed.

Similarly, the reaction

$\bar{p}\, p \to \bar{\Sigma}^{+}\ \Sigma^{+}$ in which K^* can be exchanged is observed while $\bar{p}\, p \to \bar{\Sigma} - \Sigma^{+}$ which cannot proceed through such an exchange has a small cross-section compared to the former reaction.

Further light on the dominance of such an exchange mechanism can be thrown by observing the polarisation and spin correlations.

(ii) New meson resonances:- A $(\omega\,\pi)$ resonance at 1250 Mev and in the $I = 1$ state was observed as a peak in the 4-pion spectrum in the reaction $\pi + N \to N + 4\,\pi$. The spin-parity (which is not known) of the resonance can be ascertained from studying the polarisation of the ω as revealed through measurements on its decay products.

A ($\bar{K}$ K π) resonance at 1450 Mev which seems to decay predominantly into $K^* + K^-$ ($\bar{K}^* + K$) was also reported, as also was the $K\pi$ resonance at 730 Mev (which has been observed earlier).

The width of the ω-meson $\overset{\omega}{\text{has}}$ found to be 9-10 Mev which is much larger than the one originally expected (1 Mev or less).

(iii) The Ω^- with Baryon number 1 and strangeness S = -3 which according to the prediction of the SU_3 symmetry should form together with the $N^*_{3/2}$, Y* and Ξ^* resonances a decuplet (10 representation) was looked for in a reaction of the type,

$$K^- + p \rightarrow \Omega^- + K^+ + K^0 + n$$

but was not found. But the energy used was only 200 Mev above threshold, where the production cross-section could only be of the order of a microbarn. Hence we cannot conclude that Ω does not exist as a bound state.

(iv) An anomaly in pion-nucleon scattering at 420 Mev (which lies between the first and second resonances at 200 and 600 Mev respectively) was reported. The evidence comes both from pion-nucleon scattering and the observation of a fourth quasi-elastic peak in nucleon-nucleon diffraction scattering.

(v) Further evidence for an even $\Sigma\Lambda$ parity was obtained from an analysis of the Dalitz pairs in the decay

$$\Sigma^0 \rightarrow \Lambda^0 + e^+ + e^-$$

(For an earlier experiment of the same kind, see, e.g. the June 1963 issue of these reports).

ELECTROMAGNETIC INTERACTIONS:-

Nothing very new was reported. Measurements of the form factors confirm the validity of conventional quantum electrodynamics. No evidence for a core which would mean that one of the form factors should go to a constant (not zero) at ~~length~~ large t was found. The form factors cannot be fitted by a Clementel-Villi formula if we use the ρ, ω and φ masses observed.

Hofstadter reported experiments for determining the neutron form factors from electron scattering of H^3 and He^3. The theoretical calculations were done by Schiff. (Values for the form factors at various values of momentum transfer will be presented in the next report.)

Dispersion relations (e.g. the work of Ball) and phenomenological analysis of photo-production data indicate that ρ - exchange gives negligible contribution to the process and low energies and the CGLN formula gives good agreement in this region.

Measurements on the branching ratics of the neutral decay modes of the η ~~ρ~~ -meson, made at Saclay were reported (see the report for October 1963).

WEAK INTERACTIONS:-

(i) The violation of the $\frac{\Delta S}{\Delta Q} = +1$ rule was looked for in the mixing effects in K^0 decay.

$$\begin{aligned}\frac{\Delta S}{\Delta Q} = +1 \Longrightarrow K^0 &\to \pi^- + e^+ + \nu ; \not\to \pi^+ + e^- + \bar{\nu} \\ &\to \pi^- + \mu^+ + \nu ; \not\to \pi^+ + \mu^- + \bar{\nu}\end{aligned}$$

$K^0 \longleftrightarrow \bar{K}^0$, Conversion sets in as the K^0 beam progresses;

This would result in the production of e^- from the decay $K^0 \rightarrow \pi^+ + e^- + \bar{\nu}$ ($\frac{\Delta S}{\Delta Q} = -1$). With only $\frac{\Delta S}{\Delta Q} = +1$ the e^- distribution along the K^0 path would be zero at the beginning. This distribution was measured and the violation of $\frac{\Delta S}{\Delta Q} = +1$, if any, was found to be very small. (For earlier results of the same kind see, e.g. the report for September 1963.)

(ii) Neutrino experiments at CERN and preliminary indication of the production of the vector boson (see report for October 1963). – The incident neutrinos are μ- neutrinos obtained from π - decay. Processes in which lepton pairs were produced were ~~wo~~looked for. Both μe and $\mu\mu$ pairs were found.

Cross-sections for K^+ on protons at 1.96 Bev/C.2)

Reaction product	Cross-section in m b .
$K^+ p$ (elastic)	7.6 ± 1.0
$K^0 \pi^+ p$	4.6 ± 0.6
$K^+ \pi^0 p$	2.0 ± 0.3
$K^+ \pi^+ n$	1.6 ± 0.3
$K^+ \pi^- p \pi^+$	$\sim$ 0.2
$K^+ \pi^- \pi^0 \pi^+ p$	0.05 + 0.02
$K^0 \pi^+ \pi^- \pi^+ p$	0.02 + 0.01
$K^+ \pi^- \pi^+ \pi^+ n$	0.01 + 0.006
$K^+ K^+ \Lambda^0$	< 0.01.

$$\sigma\ (K^- + p \rightarrow \Lambda + \omega) \qquad 1\ \text{m b at 1500 Mev/c}$$

$$(K^- + p \rightarrow \Lambda + \varphi \text{ and } \Lambda + \rho) \Big\} \sim 100\ \mu\text{b at 2000 Mev/c} \quad 3)$$

$K^- - p$ interactions at 2.3 Bev/c 4) leading to final states:

$$\Xi^- + \pi^+ + K^0, \quad \Xi^- + K^+ + \pi^0 . \quad \Xi^0 + K^+ + \pi^-$$

were studied4). In addition to the well established Ξ^*(1530) and K* (880) resonances, the K* (730) resonance as also the possibility of smaller peaks at M^2 ($\Xi\ \pi$) $\sim$ 2.75 Bev^2 and ~~at~~ $\sim$ 3.025 Bev^2 which correspond to $\Xi\ \pi$ masses of 1660 and 1740 Mev respectively were observed. There was no indication of a peak at 1600 Mev as predicted by the mass formula within the framework of the Octet assignment of Alvarez et al (who suggested that N* (1512), Y^*_0 (1520) and Y^*_1 (1660) could be accommodated in a new octet provided a second Y^*_1 exists (with mass 1600) and spin-parity $3/2^-$.

Cross-sections for K^- - p reactions for various momenta (in Mev/c).$^{5)}$

Reaction products	Cross sections (mb)						
	p_K = 293 ± 42	350 ± 31	397 ± 30.	392 ± 30	390 ± 30	436 ± 26	513 ± 20
$K^- + p$	48.2 ± 4.2	34.0 ± 3.2	31.9 ± 2.5	34.0 ± 3.0	32.7 ± 1.8	30.6 ± 3.2	26.5 ± 3.2
$\overline{K_o} + n$	8.0 ± 1.2	5.1 ± 1.1	8.1 ± 1.0	10.0 ± 1.0	8.8 ± 0.7	6.0 ± 1.2	3.6 ± 0.6
$\Sigma^+ + \pi^-$	13.6 ± 1.4	10.6 ± 1.4	11.4 ± 1.0	14.0 ± 1.4	12.5 ± 0.8	8.2 ± 0.9	7.5 ± 1.1
$\Sigma^- + \pi^+$	10.0 ± 1.1	6.9 ± 1.0	6.0 ± 0.6	8.3 ± 0.9	6.9 ± 0.5	6.1 ± 0.7	4.9 ± 0.8
$\Sigma^o + \pi^o$ $\Lambda^o + \pi^o$	5.2 ± 0.9	6.3 ± 1.4	6.9 ± 0.9	6.4 ± 1.0	6.7 ± 0.6	4.9 ± 1.3	1.7 ± 0.3
$\Lambda^0 + \pi^o + \pi^o$	5.2 ± 0.9	4.5 ± 1.0	2.9 ± 0.5	3.3 ± 0.6	3.1 ± 0.3	3.2 ± 0.7	1.6 ± 0.4
$\Lambda^0 + \pi^+ + \pi^-$	0.3 ± 0.2	1.9 ±0.6	1.2 ±0.4	1.8 ± 0.3	1.5 ± 0.2	0.8 ± 0.4	1.1 ± 0.3
$\Sigma^o + \pi^+ + \pi^-$	0.15 ± 0.10	0.9 ± 0.3	1.2 ± 0.3	2.4 ± 0.4	1.6 ± 0.2	1.5 ± 0.4	2.0 ± 0.4
$\Sigma^+ + \pi^- + \pi^o$	0. ±0.08	0.0 ±0.09	0.02 ±0.05	0.21 ±0.10	0.11 ± 0.04	0.18 ±0.11	0.20 ± 0.12
$\Sigma^- + \pi^+ + \pi^o$	0.005 ± 0.05	0 ±0.06	0.03 ±0.03	0.17 ±0.009	0.12 ± 0.05	0 ±0.06	0.14 ± 0.10
Total	90.7 ± 4.9	70.2 ± 4.2	69.6 ± 3.2	80.6 ± 4.0	73.8 ± 2.3	61.5 ± 4.1	49.5 ± 3.7
$(\Sigma\pi)_{I=0}$	15.6 ± 2.7	18.9 ± 4.2	20.7 ± 2.7	19.2 ± 3.0	20.1 ± 1.8	14.7 ± 3.9	5.1 ± 0.9
$(\Sigma\pi)_{I=1}$	13.2 ± 2.5	4.9 ± 3.3	3.6 ±2.2	9.5 ± 2.6	6.0 ± 1.4	4.5 ± 2.8	9.0 ± 1.5
$\pi \bar{\lambda}^2$	35.7	25.6	21.4	20.8	20.9	17.3	13.0

The data on differential cross sections strongly favoured an incident $K^- p$ resonant D-state with the most likely angular momentum being $J = 3/2$. (Below 300 Mev/c, the $K^- - p$ interaction is strongly dominated by S-waves.) With the parity of the incoming angular momentum state identified, the determination of the $K \Sigma N$ parity becomes a matter of measuring the angular momentum of the ΣN state, $D_{3/2}$ for negative $K N \Sigma$ parity, $P_{3/2}$ for positive $K N \Sigma$ parity. After eliminating all ambiguities, the conclusion is that the $K N \Sigma$ parity is negative.

$K^- - p$ interactions at 3 Gev/c[6)]

We give in the following table the partial production cross-sections for various final states given by Gelsema et al (Saclay. - Ecole Polytechnique (Paris) - Amsterdam collaboration)*

Final state	Partial cross-section in mb
$\Lambda^0 \pi^+ \pi^-$	0.58
$\Lambda^0 \pi^+ \pi^- \pi^0$	1.85
$(\Sigma^0) \pi^+ \pi^-$ + neutrals	1.65
$\Sigma^0 \pi^+ \pi^-$	0.48
$\overline{K^0} p \pi^-$	1.71
$\overline{K^0} p \pi^- \pi^0$	1.94
$\overline{K^0} p^+ \pi^-$ + neutrals	0.34
$\overline{K^0} \pi^+ \pi^- + n$	1.24
$\overline{K^0} \pi^+ \pi^-$ + neutrals	0.69
$\Sigma^+ \pi^-$	0.28

(contd.)

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* We are thankful to Dr. M. Jacob for making a preprint of this work available to us.

contd..

Final state	Partial cross-section in m b	
$\Sigma^+ \pi^- \pi^0$	0.04	
$\Sigma^- \pi^+ \pi^0$	0.24	
$\Sigma^- \pi^+$ + neutrals	0.27	
$\Sigma^+ \pi^+ \pi^- \pi^-$	0.24	
$\Sigma^+ \pi^+ \bar{\pi}^= \pi^- \pi^0$	0.18	
$\Sigma^+ \pi^+ \pi^- \pi^-$ + neutrals	0.03	
$\Sigma^- \pi^- \pi^+ \pi^+$	0.21	
$\Sigma^- \pi^- \pi^+ \pi^+ \pi^0$	0.18	
$\Sigma^- \pi^- \pi^+ \pi^+$ + neutrals	0.03	
$\Xi^- K^+$	23 ± 8	μb
$\Xi^- K^+ \pi^0$	29 ± 8	μb
$\Xi^- K^0 \pi^+$	52 ± 10	"
$\Xi^- K^+$ ~~+0+~~ $>\pi$'s	37 ± 9	"
$\Lambda^0 K^0 \bar{K}^0$	38 ± 10	"
$\Sigma^0 K^0 \bar{K}^0$		
(Λ^0 or Σ^0) $K^0 \bar{K}^0$ + neutrals	57 ± 12	"
$\Sigma^\pm K^\mp K^0$	35 ± 15	"
$\Sigma^\pm K^\mp K^0$		
$\Sigma^\pm \pi^\mp K^0 \bar{K}^0$	23 ± 12	
$\Sigma^\pm \pi^\mp K^0 \bar{K}^0 + \pi^0$		

The production $\Xi^* K$/ $K^* \Xi$ / $K \pi \Xi$ is in the ratio 2/3/5

Y* production in p - $\bar{p}$ collisions 7)

Thorndike used a liquid hydrogen bubble chamber and antiprotons with momenta upto 3.7 Bev/c . To search for anti-Y_1^* (1335), channels that have Λ^0's and additional pions were considered. The anti-isobar $\bar{N}^{*}_{3/2}$ (1238) shows up most clearly in the 4-prong events that are identified as $p + \bar{p} + \pi^- + \pi^+$. Hence it seemed reasonable to investigate the $\Lambda^0 + \bar{\Lambda}^0 + \pi^+ + \pi^-$ channel for evidence of Y_1^* and $\bar{Y}_1^*$ states. The histo-gram showed peaks corresponding to a mass of 1385. As regards the angular distributions, the baryon (Y_1^*) goes backwards in the c. m. s. and the antibaryon ($\bar{Y}_1^*$) goes forward but the distribution is much less peaked than that of Λ^0 and $\bar{\Lambda}^0$. This would be consistent with a one-particle (with isospin Y_2) exchange mechanism for $\Lambda^0 + \bar{\Lambda}^0$ production and some different mechanism, less peripheral in character, for the Y^* and $\bar{Y}^*$ cases.

Culwick et al also report the observation of Y_0^* (1405), Y_0^* (1520) and Y_1^* (1385) as well as their antiparticles in $p - \bar{p}$ collisions.

HIGH ENERGY SCATTERING CROSS-SECTIONS[3)]

In the report for June 1963 we referred to the experiments of Ting et al and Brand et al on pion-nucleon scattering in the energy range 3-10 Bev/c which showed that there is practically no shrinking in the diffraction peak in this energy range. This seems to be true even upto 20 Bev/c[9)]. The peak can be fitted by the exponential shape $\frac{d\sigma}{d\Omega} \propto e^{At}$ where t t is the momentum transfer and $A = (8\ \text{Bev}/c)^2$. [Brand et al however noticed deviation from the exponential form at 10 Bev/c). Taylor tries to explain these features as well to predict the high energy behaviour of $\pi - \pi$, $K^{\pm} - p$, $p - p$ and $p - \bar{p}$ scattering by considering a field-theoretic model in which coupled sets of non-linear equations relating the off-mass shell S-matrix elements are set up. Using what is essentially the strip-approximation (neglect of higher mass systems apart from the 2 pion state in the ''potential'') and under various other assumptions he argues that the shape of the diffraction peaks for $\pi^{\pm} - p$, $K^{\pm} - p$, $p - p$ and $p - \bar{p}$ will be the same. He also predicts the near constancy of total $\pi - p$ cross-sections above 3 Bev/c, of $K - p$ above 8 Bev/c and of $p - p$ and $p - \bar{p}$ cross-sections above 17 Bev/c. The experimental results for $K - p$ scattering at least (see report for October 1963) seem to contradict the latter prediction.

$\pi^{\pm} - p$ collisions at 800 and 900 Mev[10]

Total cross sections in m b

	T_π (Mev)	Total number of events	Elastic	$\pi^{\pm}\pi^{0}p$	$\pi^{\pm}\pi^{+}n$	Four prongs	$\geqslant 2$ neutral
π^+	900	2800	11.6 ±0.8	7.5±0.5	1.7±0.2	0.6	0.8
π^-	900	5200	24.5 ±0.2	5.7±0.6	10.1±0.9	0.6	1.7
π^-	800	1900	14.4 ±1.5	3.9±0.5	8.2±0.8	0.4	1.1

ELASTIC DIFFERENTIAL CROSS-SECTIONS

$$\frac{d\sigma}{d\Omega} = \sum_{0}^{n} a_{\ell} \cos^{\ell}\theta_{c.m.} ; \quad 0.95 > \cos\theta \text{ c.m.} \geq -1.0$$

	T_π (Mev	a_0 mb/ster	a_1 mb/ster	a_2 mb/ster	a_3 mb/ster	a_4 mb/ster.	a_5 mb/ster.
$\pi^+ p$	900	0.29 ± 0.02	0.73 ± 0.09	1.87 ± 0.10	0.79 ± 0.18		
$\pi^- p$	900	0.35 ± 0.03	−0.45 ± 0.16	−0.62 ± 0.35	−6.76 ± 0.91	9.60 ± 0.62	16.4 ± 1.1
$\pi^- p$	800	0.22 ± 0.04	0.03 ± 0.20	−1,4 ± 0.4	− 2.4 ± 1	2.4 ± 0.5	6.0 ± 1

STRANGE PARTICLE EVENTS IN π^- -p COLLISIONS[11)]

Final state.	Total No. of events	cross-sections (μb)		
		1.69 Bev/c	2.05 Bev/c	2.36 Bev/c
$\Lambda^0 K^0$	2110	170 ± 30	150 ± 30	110 ± 20
$\Sigma^0 K^0$	555	96 ± 12	90 ± 12	90 ± 12
$\Sigma^- K^+$	1376	130 ± 20	63 ± 8	37 ± 5
$\Lambda^0 K^+ \pi^-$	1009	69 ± 9	140 ± 20	100 ± 10
$\Lambda^0 K^0 \pi^0$	403	77 ± 18	120 ± 20	120 ± 20
$\Sigma^0 K^+ \pi^-$	530	10 ± 3	43 ± 9	56 ± 8
$\Sigma^- K^+ \pi^-$	575	17 ± 4	45 ± 8	37 ± 5
$\Sigma^- K^0 \pi^+$	1257	36 ± 5	85 ± 10	95 ± 14
$\Sigma^+ K^0 \pi^-$	425	15 ± 4	25 ± 5	37 ± 5
$K^0 \bar{K}^0 n$	101	29 ± 11	65 ± 18	99 ± 18
$K^0 K^- p$	137	3 ± 1	30 ± 9	30 ± 3

Neutrino experiments:-

We mentioned earlier the experiments with high energy neutrinos being conducted at the CERN. We present here some theoretical considerations regarding these experiments made by Yang[12)].

Neutrino experiments can throw light on the following:

1) The question of two neutrinos (which has been settled already).
2) The neutrino flip hypothesis.
3) The conservation of leptons.
4) The possible existence of a neutral lepton current.
5) The point structure of the lepton current.
6) Universality of weak interactions involving $e^{\pm}$ and $\mu^{\pm}$
7) The $| \Delta I | = 1$ rule.
8) Strange particle production in neutrino reactions.
9) Interaction with extremely large momentum transfers.
10) Possible production of $W^{\pm}$
11) Matrix elements of weak interaction (form factors).

We shall consider only (10) and (11) above. The vector boson W can be produced through the process.

$$\left.\begin{array}{l} \nu + Z \longrightarrow Z' + \mu^- + W^+ \\ \bar{\nu} + Z \longrightarrow Z' + \mu^+ + W^- \end{array}\right\} \qquad (I)$$

which have the same total cross sections. The process goes through one $\nu_\mu W$ vertex. Excess momentum is taken through the electromagnetic field by the nucleus and its constituent nucleons. The process can be divided into a coherent part in which the nucleus recoils unexcited as a whole and a coherent part in which the nucleus is excited or breaks up. For the first process $q_{min} = \frac{(m_W + m_\mu)^2}{2E_\nu}$ where E_ν = lab. energy of the incoming ν. For a nucleus of radius R, if $q_{min}R >> 1$, the production of a W would require penetration of the nucleus. Thus the coherent process becomes unimportant. Therefore for low energies one expects the incoherent process to dominate while for high energies the coherent process dominates. The value of the total cross-section is extremely sensitive to the mass m_W and the energy E_ν and to the extra magnetic moment of W. At energies of a few hundred Mev above threshold the processes (I) will in general dominate over all other neutrino processes (which are of the order of magnitude of $\sim 10^{-38}$ cm^2). To identify these processes in the CERN experiment one looks for $\mu^- e^+$ and $\mu^- \mu^+$ pairs in which the e^+ and μ^+ originate from the decay of W^+ (lifetime of W is less than 10^{-17} secs. and not $10^{-12} - 10^{-13}$ as mentioned in the previous report).

The lepton pairs can also arise from the processes

$$\nu_\mu + Z \rightarrow Z' + \nu_\mu + \left\{ \begin{array}{c} e^+ + e^- \\ \mu^+ + \mu^- \end{array} \right\}$$

$$\nu_\mu + Z \rightarrow Z' + \nu_e + e^+ + \mu^-$$

The order of magnitude of such processes is theoretically $\sim 2 \times 10^{-42}$ per nucleon which is less than 1/20 th of one percent of the dominant process $\nu + n \rightarrow p + \mu^-$ (II)

Thus if one percent of the neutrino induced reactions are identified as giving rise to lepton pairs, most probably they are due to W production in processes (I).

The CERN experiment can also ~~yie~~ yield interesting quantitative results concerning the form factors for the process (II) and for

$$\bar{\nu} + p \rightarrow n + \mu^{+} \qquad \text{(II')}$$

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REFERENCES

1. Informal talk on ''The Sienna Conference'', October 1963, by Dr. Maurice Jacob, Visiting Scientist at the Institute of Mathematical Sciences.

2. S. Goldhaber: Proceedings of the Athens Topical Conference on recently discovered resonant particles (Ohio University.)

3. R.H. Dalitz: -do- -do-

4. P.L. Connaley et al: -do- -do-

5. M.B. Watson, M.Ferro-Luzzi and R.D.Tripp: Phys. Rev. 131, 2248 (1963).

6. E.S.Gelsema et al: Preprint.

7. A.M.Thornelike: Proceedings of the Athens Topical Conference on recently discovered resonant particles (Ohio University).

   B.B.Culwick et al: Phys. Rev. Letters 11, 346 (1963).

8. J.G.Taylor: Cambridge Preprint.

9. Foley et al: Phys. Rev. Letters 10, 376 (1963).

10. C.Gensollen et al: Saclay Preprint.

11. G.A.Smith: Proceedings of the Athens Topical Conference on recently discovered resonant particles (Ohio University).

12. C.N. Yang: Report at the weak interactions conference, Brookhaven National Laboratories, Sept. 9-11, 1963.

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KV/GB

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Introduction

The major part of the section on elementary particles of the present report is devoted to the electromagnetic form factors of the proton and the neutron for a large range of values for the momentum transfer. The proton form factors are given in terms of G_E and G_M which are linear combinations of the Dirac and Pauli form factors. The advantages of using such form factors are mentioned. The electric form factor goes to zero for a value of the square of the momentum transfer of $45\ F^{-2}$

As regards the neutron form factors, we present the theoretical considerations of Schiff et al who show how the experiments on high energy electron scattering from H^3 and He^3 can be used to obtain the electromagnetic form factors for the neutron. The values calculated are in good agreement with the data obtained from electron scattering from deuterons.

Differential cross-sections for the photoproduction of the lambda and sigma hyperons at various energies are given. There seems to be a resonance at an incident energy of 1050 Mev.

Finally we quote an experiment on pion-nucleon scattering which shows a second maximum in the $\pi^- - p$ differential cross-section at $\cos\theta_{c.m.} = 0.2$ at a momentum 2 Gev/c. The width of the $\pi^+ - p$ diffraction peak changes considerably in the 1 to 3 Gev/c momentum interval whereas there is no significant charge in the width of the $\pi^- - p$ diffraction peak in this interval.

ELEMENTARY PARTICLES

Electric and Magnetic form factors of the Nucleon

For a discussion of experiments on the electromagnetic form factors of the nucleon, certain simplification is afforded in the quantitative treatment of the errors and error correlations by using instead of the conventional Dirac and Pauli form factors $F_1(q^2)$ and $F_2(q^2)$ linear combinations of them defined by

$$G_E(q^2) = F_1(q^2) - \frac{q^2 K}{4M^2} F_2(q^2)$$

$$G_M(q^2) = F_1(q^2) + K F_2(q^2)$$

where K is the anomalous magnetic moment in nuclear magnetons and M is the mass of the nucleon. $G_M(q^2)$ does not tend to 1 (as $F_2(q^2)$ does) as q^2 tends to zero. As pointed out by Yennie et al, these linear combinations correspond~~s~~ to zero and one unit of angular momentum transferred along the direction of the virtual photon exchanged in the scattering process. Also Sachs et al showed that

$$\left[6 \frac{dG_E}{dq^2}\right]^{\frac{1}{2}}_{q^2=0} = \text{r.m.s. radius of charge}$$

$$\left[6 \frac{dG_M}{dq^2}\right]^{\frac{1}{2}}_{q^2=0} = \text{r.m.s. radius of magnetic moment.}$$

Hand has shown that the terms in G_E and G_M do not interfere in the Rosenbluth formula for elastic scattering.

The following table gives the values of G_E and G_M for the proton over a wide range values of the square of the momentum transfer .

Proton for factors$^{1)}$

q^2 (F^{-2})	q^2 $(\mathrm{Bev}/c)^2$	$\frac{\hbar^2 q^2}{4M^2c^2}$	$t = \frac{\hbar^2 q^2}{M_\pi^2 c^2}$	G_{E_p}	dG_{E_p}	G_{M_p}	dG_{M_p}	Authors
.28	0.0101	0.0031	0.56	0.973	0.014			Yount and Pine
.30	0.0116	0.0033	0.60	0.959	0.010			Lehmann et
.30	0.0116	0.0033	0.60	0.974	0.006			Drickey and Hand
.36	0.0140	0.0040	0.70	0.967	0.040			Bumiller et
.49	0.0190	0.0054	0.98	0.933	0.009			Lehmann et
.57	0.0221	0,0063	1.14	0.915	0.037			Bumiller et
.60	0.0233	0.0066	1.20	0.940	0.007			Drickey & H
.62	0.0241	0.0069	1.24	0.922	0.010			Yount & Pin
.79	0.0307	0.0087	1.58	0.920	0.037			Bumiller et
.93	0.0361	0.0103	1.86	0.848	0.034			Bumiller et
.00	0.0388	0.0111	2.00	0.881	0.009	2.508	0.036	Lehmann

q^2 (F^{-2})	q^2 (BeV/c)	$\frac{\hbar^2 q^2}{4 M^2 c^2}$	$t = \frac{\hbar^2 q^2}{m_\pi^2 c^2}$	G_{E_p}	dG_{E_p}	G_{M_p}	dG_{M_p}	Authors
1.05	0.0408	0.0116	2.10	0.884	0.009			Lehmann et al
1.30	0.0505	0.0144	2.60	0.867	0.025			Yount and Pine
1.38	0.0536	0.0153	2.75	0.873	0.036	2.437	0.100	Bumiller et al
.60	0.0621	0.0177	3.19	0.849	0.004			Drickey & Hand
2.00	0.0776	0.0211	3.99	0.810	0.024			Bumiller et al
.00	0.0776	0.0221	3.99	0.875	0.022	1.703	0.302	Littaner et al
.00	0.776	0.0221	3.99	0.784	0.013	2.234	0.306	Lehman et al
2.20	0.0854	0.0243	4.38	0.790	0.006			Drickey & Hand
2.98	0.116	0.0329	5.95	0.725	0.021	2.034	0.016	Lehmann et al
.00	0.155	0.0442	7.99	0.650	0.034	1.776	0.119	Bumiller et al
.00	0.155	0.0442	7.99	0.749	0.173	1.366	1.567	Littauer et al
.20	0.202	0.0575	10.38			1.794	0.049	Yount and Pine
.64	).219	0.0624	11.26			1.493	0.017	Gram and Dally
.00	0.233	0.0663	11.98	0.557	0.557	1.551	0.400	Bumiller et al
6.00	0.233	0.0663	11.98	0.654	0.654	1.284	0.056	Littauer et al
8.00	0.310	0.0885	15.97	0.400	0.400	1.375	0.251	Bumiller et al
8.00	0.318	0.0885	15.97	0.473	0.473	1.217	0.031	Littauer et al
8.87	0.344	0.0981	17.71			1.202	0.023	Gram and Dally
0.0	0.388	0.111	20.0	0.419	0.033	0.989	0.030	Bumiller et al
10.0	0.388	0.111	20.0	0.558	0.021	0.821	0.034	Littauer et al
0.0	0.383	0.11	20.0	0.417	0.02	1.119	0.045	Janssen
12.0	0.466	0.133	24.0	0.30	0.044	1.07	0.051	Bumiller et al
12,0	0.466	0.133	24.0	0.466	0.032	0.957	0.050	Littauer et al

q^2 (F^{-2})	q^2 (Bev/c)^2	$\frac{\hbar^2 q^2}{4M^2c^2}$	$t = \frac{\hbar^2 q^2}{m_\pi^2 c^2}$	G_{Ep}	dG_{Ep}	G_{Mp}	dG_{Mp}	Authors
12.43	0.482	0.148	24.81			0.937	0.014	Gram and Dally
14.0	0.053	0.155	27.9	0.256	0.054	0.916	0.048	Bumiller et al
15.0	0.582	0.166	29.9	0.416	0.022	0.717	0.019	Littaner et al
16.0	0.621	0.177	31.9	0.281	0.050	0.782	0.038	Bumiller et al
16.23	0.630	0.179	32.4	0.350		0.726	0.011	Gram and Dalle
18.0	0.699	0.199	35.9	0.350	0.024	0.662	0.016	Bumiller et al
20.0	0.776	0.221	39.9	0.316	0.045	0.524	0.025	Littaner et al
20.2	0784	0.223	40.3					
22.0	0.854	0.243	43.9	0.295	0.046	0.563	0.015	Bumiller et al
4.0	0.931	0.265	47.9	0.249	0.109	0.416	0.041	Littaner et al
24.0	0.931	0.265	47.9	0.204	0.545	0.521	0.037	Bumiller et al
5.0	0.970	0.276	49.9	0.396	0.037	0.447	0.016	Berkelman
0.0	1.164	0.332	59.9			0.430	0;026	Littaner et al
0.0	1.164	0.332	59.9	0.359	0.037	0.382	0.014	Berkelman
5.0	1.358	0.387	69.9	0.258	0.044	0.314	0.012	,,
0.0	1.552	0.442	79.9	0.436	0.073	0.232	0.018	,,
5.0	1.746	0.498	89.9	0.00	0.250	0.238	0.022	,,

Neutron Form Factors 2)

High energy electron scattering from H^3 and He^3 at Stanford can provide distribution of charge densitites magnetic moment densities and sizes of the two mirror nuclei. The charge form factor of the neutrons, F_{ch}^{n} found till now by studying the deuteron can be determined by the present method. Assume that the total charge density and total magnetic moment density c can be expressed without mutual interference as the sum of contributions from each of the three nucleons together with an exchange magnetic moment density. The contribution from each nucleon is the resultant of the distribution of its center in space which is determined by the nuclear wave function and its own strength which is assumed to be the same as for the free proton or for the neutron in deuterium. With some assumptions regarding the dominant wave functions, the value of F_{ch}^{n} found was in substantial agreement with other determinations.

q^2 (F^{-2})	F_{ch}^{n}
1.0	-0.024 ± 0.162
1.5	+0.091 ± 0.095
2.0	+0.050 ± 0.062
2.5	-0.028 ± 0.069
3.0	-0.006 ± 0.086
3.5	-0.039 ± 0.053
4.0	-0.093 ± 0.083
4.5	±0.015 ± 0.107
5.0	+0.007 ± 0.084

E

Differential cross-section for $\gamma + p \rightarrow K^+ + \Lambda^0$ and $\gamma + p \rightarrow K^+ + \Sigma^0$ 3)

k_γ nominal (MeV)	k_γ (MeV)	θ (degr)	$d\sigma/d\Omega$ (10^{-31} cm²/sr)
934	934	90.0	0.55 ± 0.04
975	976	31.1	1.34 ± 0.8
1003	974	64.0	1.33 ± 0.8
1003	1002	30.0	2.04 ± 0.07
	1003	60.3	1.69 ± 0.09
	1004	88.6	1.54 ± 0.09
	1004	132.0	1.21 ± 0.10
1018	1013	30.3	2.28 ± 0.11
	1020	43.6	1.96 ± 0.11
	1018	55.6	2.00 ± 0.10
	1022	69.8	1.55 ± 0.08
	1024	94.2	1.45 ± 0.11
	1018	97.0	1.33 ± 0.16
1038	1036	45.0	2.30 ± 0.00
	1040	27.5	2.81 ± 0.14
1054	1054	30.0	2.76 ± 0.15
	1055	42.5	2.71 ± 0.13
	1054	53.5	2.44 ± 0.14
	1051	80.2	1.96 ± 0.12
	1054	89.7	1.57 ± 0.99
	1060	132.3	1.23 ± 0.11

k_γ nominal (Mev)	k_γ	θ (degr.)	$d\sigma/d\Omega$ (10^{-31} cm^2/sr)
10.80	1080	46.5	2.44 ± 0.12
	1080	90.0	1.58 ± 0.08
	1080	119.7	1.25 ± 0.08
11.30	1130	90.0	1.42 ± 0.13
1157	1157	30.0	0.83 ± 0.20
	1157	49.5	1.17 ± 0.18
	1152	76,0	1.12 ± 0.17
	1157	104.0	0.51 ± 0.10
	1157	134.5	0.38 ± 0.15
	1174	47.7	1.50 ± 0.17
	1142	46,0	1.19 ± 0.11
	1158	46.8	1.35 ± 0.14

Diffraction peaks of pion-nucleon scattering[4)]

There is a second max in the $\pi^- - p$ differential cross-section at $\cos\theta = 0.2$ (barycentric system) at 2 Gev/c. This maximum is less pronounced in the $\pi^+ - p$ system. It is also shown that while the width if the $\pi^+ - p$ diffraction peak changes considerably in the 1.0 to 3.0 Gev/c momentum interval no significent change in the width of the $\pi^- - p$ diffraction peak is observed in this interval. The total elastic cross-sections are 7.94 ± 0.9 mb for $\pi^- p$ and $9.1^{+2}_{-1.3}$ for $\pi^+ p$. The second maximum is not seen at 3.0 Gev/c or above or at 1.6 Gev/c or below. It is not clear whether this can be considered as a second diffraction peak at 2.0 Gev/c. The $\pi^+ - p$ differential cross-section confirms the previous measurements that the $\pi^+ - p$ differential cross-section is larger than the $\pi^- - p$ for all regions outside the diffraction peak at 2.0 Gev/c.

$$\frac{d\sigma(\theta)}{d\Omega} = \underbrace{\left[\frac{d\sigma(\theta)}{d\Omega}\right]_0}_{\leftarrow \text{peak value}} e^{At}$$

The following table shows that for the $\pi^- - p$ system, the A values rise rather smoothly from 7.0 (Gev/c) at 1.34 Gev/c to 7.9 (Gev/c) at 3.15 Gev/c. i.e. the $\pi^- - p$ diffraction peak simply narrows slightly over this momentum range. On the other hand the A values of the $\pi^+ - p$ system increases from 4.0 (Gev/c) at 1.12 Gev/c to a peak of about 8.2 (Gev/c) at 1.5 Gev/c; then decrease to 5.0 (Gev/c) and finally rise again at 2.92 Gev/c to 7.6 (Gev/c) which is close to the $\pi^- - p$ value at that momentum. This behaviour can be thought of as a considerable narrowing of the diffraction peak over the 1-to 3 Gev/c interval combined with a sudden and temporary narrowing at 1,5 Gev/c, possibly associated with the resonance at that momentum.

Exponential fits to diffraction peaks.

Incident pion laboratory momentum (Gev/c)	A (GeV/c^2
1.34	7.5 ± 0.4
1.48	7.5 ± 0.4
1.59	7.1 ± 0.2
1.85	9.3 ± 1.7
2.01	7.8 ± 0.2
2.5	8.5 ± 0.8
3.15	7.9 ± 0.3
π^+-p elastic scattering	
1.12	4.1 ± 0.2
1.45	7.4 ± 0.6
1.50	8.2 ± 0.3
1.69	6.4 ± 0.2
2.00	5.0 +± 0.4
2.02	5.7 ± 0.4
2.50	6.9 ± 0.5
2.92	7.6 ± 0.3

REFERENCES

1) I.N. Hand et al, Rev. Mod. Phys. 35, 335 (1963)

2) L.I.Schiff, H.Collard R.Hofstadter, A.Johansson and M.R.Yearian Phys. Rev. Letters, 11, 387 (1963)

3) R.L.Anderson et al, Phys. Rev. Letters 9 131,(1962)

4) D.E.Damouth, L.W.Johnes and M.L.Perl Phys. Rev. Letters 11, 287 (1963).

INDEX

STRONG INTERACTIONS

Pion-nuclear interactions	Month	Page
π^+p scattering		
Total cross sections	April	1
	May	7
Elastic cross sections	April	4
	November	11
Differential cross-sections	June	3,7,8
	November	12
	December	7
π^--p scattering		
Total cross-sections	April	2
	May	7
Elastic cross-sections	April	4
	November	11
Differential cross-sections	June	3-8,6
	November	12
	December	7
	April	4a
π-p phase shiffs		
Pion production cross-sections	April	3
	November	11
Production of strange particles	April	9,10
	August	8
	November	12
Nucleon-Nucleon-scattering		
Total cross-sections	August	2
Elastic cross-sections	"	2
Differential cross-sections	"	3-6
Pion production in	"	6
Neutron cross-sections	"	7
p-$\bar{p}$ collissions, production in	November	9

ctd).

	Month	Page
K-meson-nucleon interactions		
K^+-p total cross sections	October	3
	November	6
Production cross sections for K^+ on protons	November	8
K^-p total cross-sections	October	4
K^--n " "	"	5
K^--d " "	"	6
K^--p charge exchange cross-sections	"	7
Production cross-sectionsfor	October	9
K- on protons	November	6-9
The parametersof the resonances		
The pion-nucleon resonances	May	8
The pion-pion resonances	June	1
The K-π resonances	"	2
	August	8
Resonance in the KK system	June	2
The Pion-hyperon resonances	"	3
The ω-π resonance	November	2
ELECTROMAGNETIC INTERACTIONS		
Photoproduction of single, double and triple pions from nucleons.	April	9,10
Photo production of lambda and sigma hyperons.	December	6
Electromagnetic form factors of the neutron.	"	5
Electromagnetic form factors of the proton.	"	2
Neutral decay modes of Eta-meson	October	10
Sigma-lambda relative parify	June	9
Weak Interactions		
Report on weak interactions at the 1962 CERN conference by F.S.Crawford.	May	1-6
The Brookhaven International Conference on weak interactions; September, 1963.	September	1-10
Review of experimental results presented at the Siena conference, October, 1963.	November	4-5
Lifetimes of the elementary particles	July	3
Mass and decay parameters of the cascade particle.	June	9
	August	9
Weak vector bosons	October	1
High energy nentrino experiments	November	13
Many Particle Systems		
Third sound in liquid helium films	July	5-9
Tunneling effect in super conductors	September	12-18