STRONG INTERACTIONS OF STRANGE PARTICLES — EXPERIMENTAL

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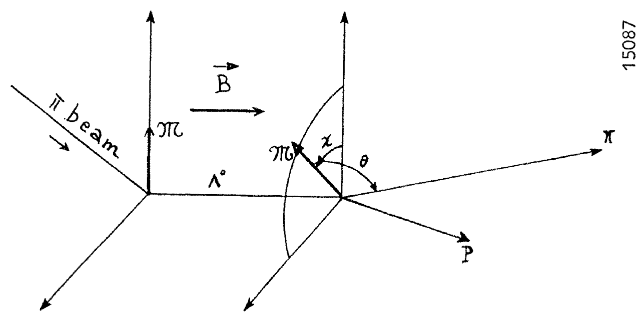
This report attempts to summarize the experimental evidence presented during the parallel sessions S 1-4. The subject matter is shared with Professor Snow (see next report). Even then, it is impossible to discuss all the experimental evidence presented during this session. Ref. [1-5] correspond to the subjects presented during the parallel sessions and not reported here.

I. MISCELLANEOUS TOPICS

a) Magnetic moment of the Λ^0

Two independent measurements were done at the Cosmotron [6-7] of the magnetic moment of the Λ^0. In both experiments a π beam produced polarized Λ's which were allowed to travel in a longitudinal magnetic field. The precession χ of the magnetic moment was measured by analysing the angular distribution in space of the Λ^0 decay taking advantages of the known distribution θ. Fig. 1 summarizes the results of the two experiments. For an average Λ^0 momentum of about 600 MeV/c and a field × length value of $\int Bdl = 10^6$ gauss × cm, the rotation is 30° for one nuclear magneton.

One may conclude that although the two measurements are not completely incompatible statistically, it does not seem reasonable at this early stage of these experiments to attempt any averaging between the two results.



	$\int Bdl$ [G×cm]	Detector	Number of events	Magnetic moment in nuclear magnetons
Ref. [6] π^+ ~1.05 GeV/c	0.5×10^6	spark chamber	300	-1.5 ± 0.5
Ref. [7] π^-	1.4×10^6	diffusion chamber	20	0.0 ± 0.5

Fig. 1 Λ^0 magnetic moment.

b) Parity conservation in strange particle production

At the last Rochester Conference some evidence had been presented on a longitudinal asymmetry of Λ's produced by high energy π^- in a propane chamber which could be interpreted as a non conservation of parity in strong interactions. The same authors [8] reported on a larger sample of events and a re-evaluation of the old data; no asymmetry is now observed. Others authors reported on the same subject with the same result. (See Table I.)

TABLE I

Parity is not violated in strange particule production

		Longitudinal asymmetry of Λ^0: $1+a\cos\theta$	
Ref.			a
8	V.A. Belyakov *et al.* (JINR, Dubna)	π^- 7 GeV/c propane	0.04 ± 0.08
13	F.S. Crawford *et al.* (L.R.L.)	π^- 1.1 GeV/c hydrogen	0.02 ± 0.03
9	M.M. Block *et al.* (Northwestern, Bologna)	K^- stopped helium	0.03 ± 0.04

The same result was also quoted at high energy in a heavy liquid [10].

c) Charge symmetry—charge independence

A great deal of information has been obtained on the production of strange particles by $\pi^{\pm}$ on hydrogen and deuterium in the momentum band of 1 to 1.2 GeV/c [11-14]. Only two results are reported here.

(1) Total cross-sections, angular distributions, polarisations were measured in the two charge symmetric reactions:

$$\pi^+ + d \to p + \Lambda^0 + K^+$$

$$\pi^- + d \to n + \Lambda^0 + K^0$$

Each measurement was done with an accuracy of about 10%. The results were in excellent agreement with the prediction of charge symmetry.

(2) Further measurements were made on the differential cross-sections of the three reactions:

$$\pi^+ + p \to \Sigma^+ + K^+$$

$$\pi^- + p \to \Sigma^0 + K^0$$

$$\pi^- + p \to \Sigma^- + K^+$$

It is well known that according to charge independence the three differential cross-sections obey the inequality

$$2d\sigma(\Sigma^0) \leqq \left(\sqrt{d\sigma(\Sigma^+)} + \sqrt{d\sigma(\Sigma^-)}\right)^2$$

Figs. 2 [13] and 3 [11] show the results of the measurements. In one case (Fig. 2) the measured points shown with their errors correspond to the Σ^+ cross-

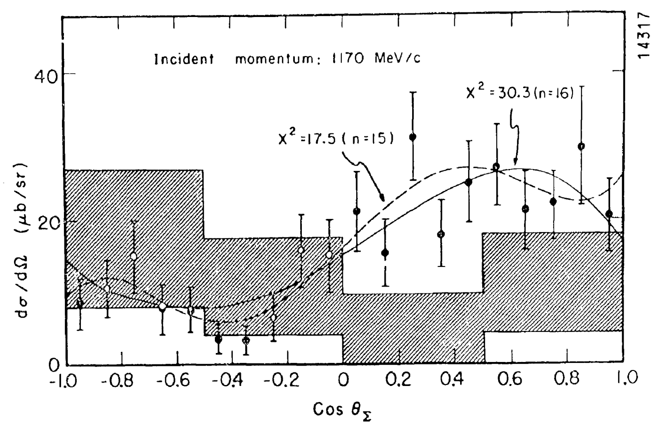


Fig. 2 Differential cross-section for $\pi^+ + p \to \Sigma^+ + K^+$ [13] at 1170 MeV/c. The cross hatched area represents minimum values (with errors) for this cross-section as obtained by other measurements ($\pi^- + p \to \Sigma^0 + \pi^0$ and $\Sigma^- + \pi^+$) of the same authors at 1220 MeV/c.

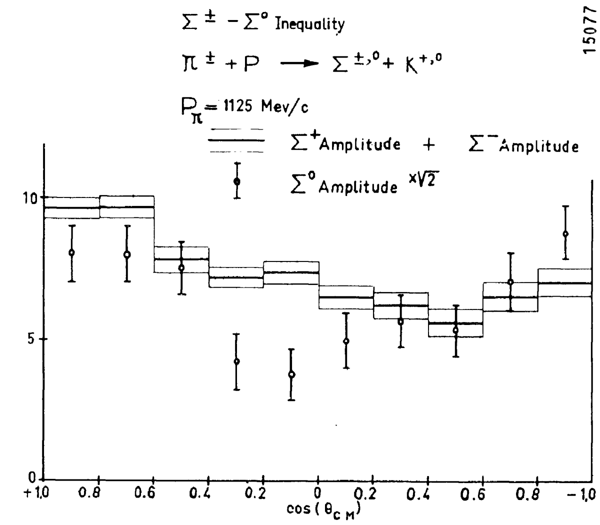


Fig. 3 Amplitudes for $\pi^- + p \to \Sigma^0 + \pi^0$ [11] at 1125 MeV/c. The boxes represent maximum values (with errors) for these amplitudes deduced from the measured cross-sections for $\Sigma^+\pi^+$ and $\Sigma^-\pi^-$ cross-sections at the same momentum.

section and should not fall below the shaded area. In the other case (Fig. 3) the measured points shown with their errors correspond to the Σ^0 cross-section and should not fall above the shaded area.

No evidence for a violation of charge independence is observed.

d) Hyperon—antihyperon production in high energy $\bar{p}$—p interactions

Two groups reported on $\bar{p}p$ interactions in the momentum band of 3 to 3.6 GeV/c [15,16].

The $\bar{\Lambda}^0$ mass was found to be equal to the Λ^0 mass within 0.4 MeV [15].

Cross-sections for the various two-body reactions were given (only approximate values are indicated here averaging over three momenta 3, 3.3, 3.6 GeV/c).

$\bar{p}+p\to$	$\Sigma^+\bar{\Sigma}^+$	$\Lambda^0\bar{\Lambda}^0$	$\Sigma^0\bar{\Lambda}^0+\bar{\Sigma}^0\Lambda^0$	$\Sigma^-\bar{\Sigma}^-$	$\Xi^-\bar{\Xi}^-$
$\sigma = \sim$	40 μb	85 μb	85 μb	8 μb	4 μb

The angular distribution was found in all cases (except the last for which statistics are very poor) to be peaked, i.e. the antiparticle was found to be predominantly emitted forward in the centre-of-mass.

Fig. 4 [15] shows the method used for separating the $\Sigma^+\bar{\Sigma}^+$ events from the $\Sigma^-\bar{\Sigma}^-$ events. The top histogram corresponds to $\Sigma^-\bar{\Sigma}^-$ events in which one of the

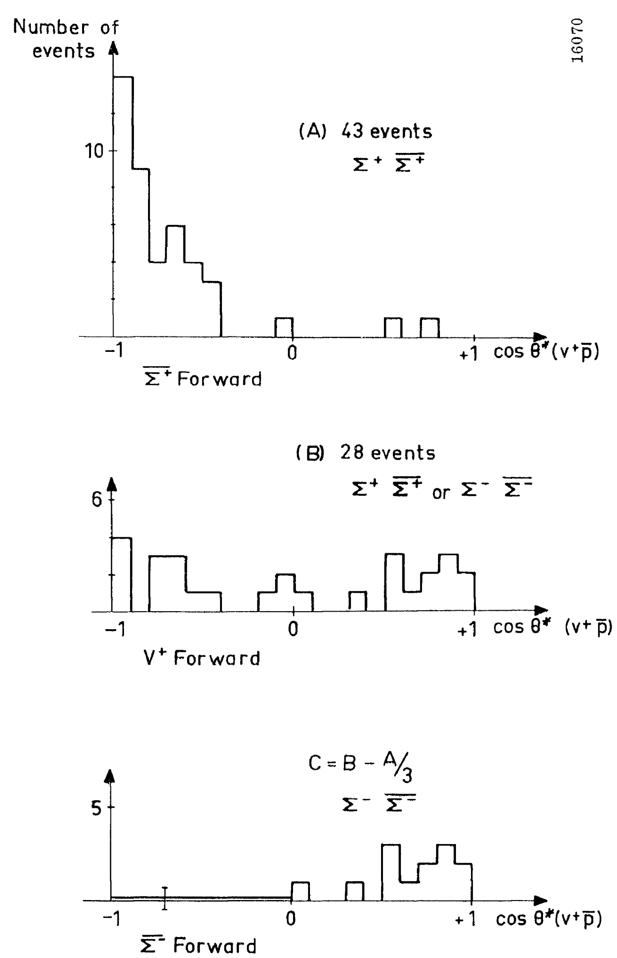


Fig. 4 Identification of $\Sigma^-\overline{\Sigma^-}$ production. Angular distribution of:

$\bar{p}+p\rightarrow\Sigma^+\overline{\Sigma^+}$ (top histogram)

$\bar{p}+p\rightarrow\Sigma^-\overline{\Sigma^-}$ (bottom histogram).

The middle histogram gives the angular distribution of the $V^\pm$ in events in which no individual identification is possible since both hyperon and antihyperon decay via the π mode [15].

hyperons has a nucleonic decay mode thus allowing an unambiguous identification. The second histogram corresponds to events (both $\Sigma^+\overline{\Sigma^+}$ and $\Sigma^-\overline{\Sigma^-}$) in which both hyperons have a pion decay mode. The last histogram gives by difference the $\Sigma^-\overline{\Sigma^-}$ angular distribution.

Note that all histograms give the angular distribution of the positive particle produced.

II. STRANGE ISOBARS

The purpose of the second part of this report is to summarize the new evidence presented at this Conference on the properties of strange isobars.

In Table II an approximate list of the sets of bubble chamber pictures used in the reports (sessions S1—4) is given, together with the explanation of the significance of the various columns.

a) Properties of well-established isobars

We will first study the isobars that can be considered as *well established* and summarize their properties. The purpose will be to fill in Table III for the resonant states of strangeness $S \neq 0$. For the sake of completeness the multipion resonances ($B = S = 0$) were placed in the table following the summary of Professor Puppi. The N^* resonant states ($B = 1$ $S = 0$) were also included, using numbers found in the literature.

1) The K* 888

The properties of the well established K^* were abundantly studied by many authors [17-23, 34]. The K^* resonance was produced with $K^\pm$ or π^- and $\bar{p}$ in hydrogen or propane bubble chamber according to the reactions:

$$K^+ + p \rightarrow K^{*+} + N^+ \qquad (\text{or } K+N^* \text{ or } K^*+N^*)$$
$$K^- + p \rightarrow K^{*\,0}_{\,-} + N^{0}_{+} \qquad (\text{or } K+N^*)$$
$$\pi^- + p \rightarrow K^{*\,+}_{\,0} + Y^{-}_{0} \qquad (\text{or } K+Y^*)$$
$$\bar{p}_{\text{stopped}} + p \rightarrow K^{*\,+}_{\,0} + K + \pi$$

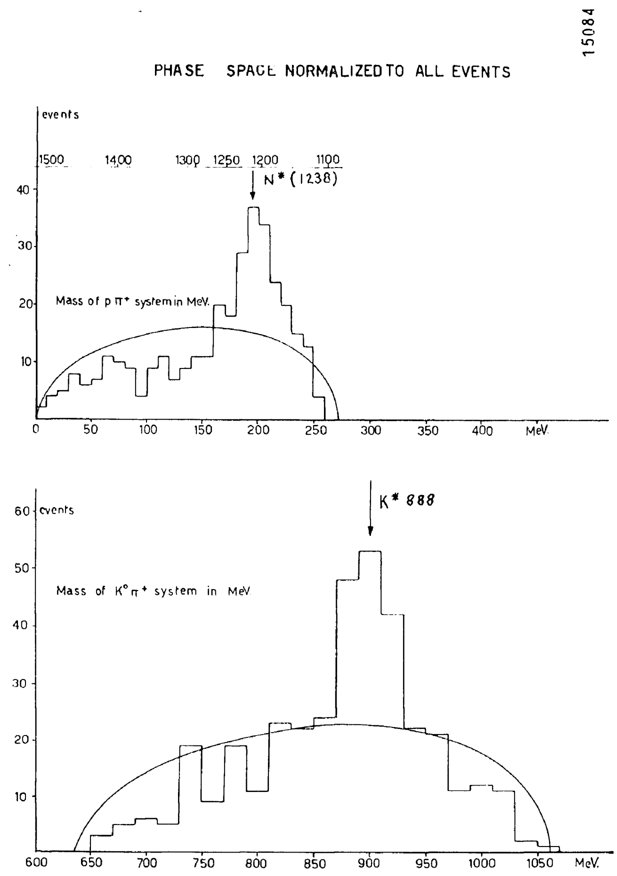


Fig. 5 Example of competition between two productions [22]:

$$K^+ + p \rightarrow \begin{cases} K^* + p \\ K^0 + N^{*++} \end{cases} \qquad (K^-: 1.45\ \text{GeV/c})$$

TABLE II

Bubble chamber pictures used in the reports made at this conference (Sessions S1—S4 only)

The various columns in this table are self explanatory except the new unit (introduced by A. Rosenfeld): mb equivalent. This number takes into account the length of the chamber, the number of tracks per picture and the number of pictures in such a way that the number of observed events of cross-section σ (mb) for the experiment is number of events = (number of mb equivalent) $\times$ σ

Accelerator	Chamber	Beam momentum in GeV/c	Total energy c.m.	Number of mb equivalent measured and reported	Groups involved in analysis
BERKELEY	72″ H_2	K^- 1.22±3% 1.51±3% 1.80±4%	1900 2030 2150	~1000 ~1000 ~1000	L.R.L. Ref. 17, 25, 27 UCLA
	72″ H_2	π^- 1.89, 1.95, 2.04, 2.16, 2.24 ±0.5%	2140 2240	~1000 ~1000	L.R.L. Ref. 19, 24
	72″ H_2, D_2	π^- 1.03, 1.17, ~1.23 ±0.3%	1700 1780	~5000	L.R.L. Ref. 12, 13 Wisconsin, Purdue Ref. 11 Northwestern, John Hopkins Ref. 12, 14
	15″ H_2	K^- 0.300 to 0.800	1480 to 1700	~ 500	L.R.L. Ref. 28
		K^+ 0.300 to 0.800	1480 to 1700	?	L.R.L.
BROOKHAVEN	20″ H_2	$\bar{p}$ 3.25	2850	500	Brookhaven, Yale Ref. 15
	20″ H_2	K^- 2.24, 2.5 ±1%	2340 2440	700	Brookhaven, Syracuse Ref. 20
	20″ H_2	K^+ 1.94±1%	2200	100	L.R.L. Ref. 34
	14″ H_2	π^- 1.9 2.1	2120 2200	500	Wisconsin Ref. 31
	30″ C_3H_8	π^- 2	2160	~1000	Columbia, Rutgers Ref. 23
DUBNA Synchro-phasotron	55 cm C_3H_8 (24) 50 cm Freon 30 cm Xe	π^- 7-8 π^- 2.8 π^- 2.8	3800 2470 2470	~ 500 (on H_2) ?	Dubna Ref. 8 Institute of theoretical and Experimental Physics, Lebedev Ref. 33
SACLAY	50 cm H_2 35 cm H_2	π^- 1.6 K^+ 1.1	1975 1830	~ 1000 ~ 100	Saclay, Bologna, Bari, Orsay Collège de France, Saclay.
CERN P.S.	81 cm H_2	$\bar{p}$ 3, 3.6 ±0.5%	2770	1500	Imperial College, Birmingham Saclay, Ecole Polytechnique, CERN, Ref. 16
	81 cm H_2	$\bar{p}$ stopped	1876	$2\ 10^5$ stopped	CERN, Collège de France, Ref. 18-36
	81 cm H_2	π^- 10±7%	4500	1200	CERN, Ref. 32
	30 cm H_2 30 cm H_2	K^-, K^+ 1.47±1.5%	2010	200 100	Amsterdam, Glascow, CERN, Ref. 21 Oxford, Padua, Ref. 22
	100 cm Prop. Freon	π^- 6 11 18	~4500	1000 (on hydr.)	Ecole Polytechnique CERN, Torino, Padua, Ref. 10

TABLE III

Table of properties of known resonances

The first four columns give the baryonic number, strangeness, isotopic spin, spin, parity and G parity. In column seven the width in MeV is given for very short lived isobars; the lifetime in seconds is given for the " long lived " particles. The square of the mass is indicated for conveniency. Also in column 9 and 10 the momentum threshold in GeV/c for production by K or π meson of the particle according to the reaction indicated. For example K^- mesons need a momentum larger than 1.52 GeV/c to produce the Ξ^* in the reaction $K^- + p \to \Xi^{*-} + K^+$.

The last column was filled in by A. Rosenfeld. This is linked to a diagram shown in session S2 and gives possible assignments and Regge pole trajectories. The denomination ω, π, K, N, Λ, Σ, corresponds to B, S and I assignments; the code $\alpha\ \beta\ \gamma\ \delta$ corresponds to spin and parity: α: 0^+, 2^+, $1/2^+$, $5/2^+$; β: 0^-, 2^-, $1/2^-$, $5/2^-$; γ: 1^-, 3^-, $3/2^-$, $7/2^-$; δ: 1^+, 3^+, $3/2^+$, $7/2^+$.

Baryon number B	Strangeness S	Isotopic Spin I	Parity G Spin J^{PG}	Name	Mass (MeV)	Γ (MeV) or τ (sec)	(Mass)^2 (GeV)^2	Thresholds for Production (GeV/c) $\pi - N$	$K - N$	Dominant Decay Modes	Possible Assignments Regge Pole Trajectory
0	0	0	0^{-+}	η	548	$\leqslant 10$	0.30	$\eta - N$ 0.69	$\eta - \Lambda$ 0.73	$\frac{\text{neutrals}}{\pi^+ + \pi^- + \pi^0} = \frac{75}{25 \pm 4}$	0^{-+} $^+\omega_\beta$
			1^{--}	ω	782	$\leqslant 15$	0.61	ωN 1.09	$\omega \Lambda$ 1.24	$\frac{\text{neutrals}}{\pi^+ + \pi^- + \pi^0} = \frac{14 \pm 4}{86}$	1^{--} $^-\omega_\gamma$
											2^{++} $^+\omega_\alpha$
		1	0^{--}	π	$\pm$ 139,6 0 135,0	2.5 10^{-8} 2 10^{-16}	0.02	$\pi N \pi$ 0.28	$K N \pi$ 0.53	$\mu + \nu_\mu$ $\gamma + \gamma$	0^{--} $^-\pi_\beta$
			1^{-+}	ϱ	750	~ 100	0.56	ϱN 1.03	$\varrho \Lambda$ 1.16	$\pi + \pi$	1^{-+} $^+\pi_\gamma$
											0^{+-} $^-\pi_\alpha$
0	1	$1/2$	$0^-_?$	K	$\pm$ 493,9 0 497,8	1,22 10^{-8} 10^{-10};6 10^{-8}	0.244	$K\Lambda$ 0.9	$K\Lambda K$ 1.69	$\mu + \nu$ $\pi + \pi$	0^- K_β
			??	K^*	888	50	0.79	$K^*\Lambda$ 1.65	$K^* N$ 1.09	$K + \pi$ 100%	1^- K_γ
1	0	$1/2$	$1/2^+$	N	+ 938.2 0 939.5	0 10^3sec	0.88	$\bar{N}NN$ 3.78	$\Lambda \bar{N} N$ 4.16	$p + e^- + \nu_e$	$1/2^+$ N_α
			$3/2^-$	2nd Res.	1512	130	2.24	N^* 0.73	KN^* 1.48	D wave $\to N\pi$	$3/2^-$ N_γ
			$5/2^+$	3rd Res.	1688	140	2.85	N^* 1.04	KN^* 1.87	F wave $\to N\pi$	$5/2^+$ N_α
		$3/2$	$3/2^+$	1st Res.	1238	145	1.53	N^* 0.32	KN^* 0.88	P wave $\to N\pi$	$3/2^+$ 1_δ
			$>3/2$?	4th Res.	1922	185	3.7	N^* 1.49	KN^* 2.45	? $\to N\pi$	$7/2^+$ 1_δ
1	−1	0	$1/2^+$	Λ^0	1115,4	2.5 10^{-10}	1.24	$K\Lambda$ 0.9	Λ <0	$N + \pi$	$1/2^+$ Λ_α
			??	Y_0^*	1405	50 or <2	1.97	KY_0^* 1.44	Y_0^* <0		$1/2^-$ Λ_β
			$3/2^-_?$	Y_0^*	1520	15	2.31	KY_0^* 1.68	Y_0^* 0.4	D wave ? $\Sigma\pi$ 60 D wave KN 30 $\Lambda 2\pi$ 10	$3/2^-$ Λ_γ
			$>3/2$?	Y_0^*	1815		3.3	KY^* 2.38	Y_0^* 1.06	?	$5/2^+$ Λ_α
		1	$1/2^+_?$	Σ	+ 1189.4 − 1196.0 0 1191.5	0.81 1.61 } 10^{-10} $<.1$	~ 1.42	$K\Sigma$ 1.03	Σ <0		$1/2^+$ Σ_α
			??	Y_1^*	1385	50	1.92	KY^* 1.4	Y_1^* <0	$\Lambda\pi$ 98 $\Sigma\pi$ 2±2	$3/2^+$ Σ_δ
1	−2	$1/2$	??	Ξ	− 1321 0 ?	1.2 10^{-10}	1.75	ΞKK 2.38	$K\Xi$ 1.06	$\Lambda\pi$	
			??	Ξ^*	1532	?	2.35	$\Xi^* KK$ 2.93	$K\Xi^*$ 1.52	$\Xi\pi$	

In parenthesis are given some of the competitive reactions observed in these productions. Since, due to interference effects, these may play an important role in the final interpretation, it is worthwhile to mention that the N_{33} resonance appears abundantly in the K^+p reactions, either as interference in the 3 body reaction, see Fig. 5 [22], or as a two body production $K^*+N^*_{33}$, see Fig. 6 [34]. The first resonance does not show up significantly in $K^- p$ production. The K^-p reactions produces also Y^*.

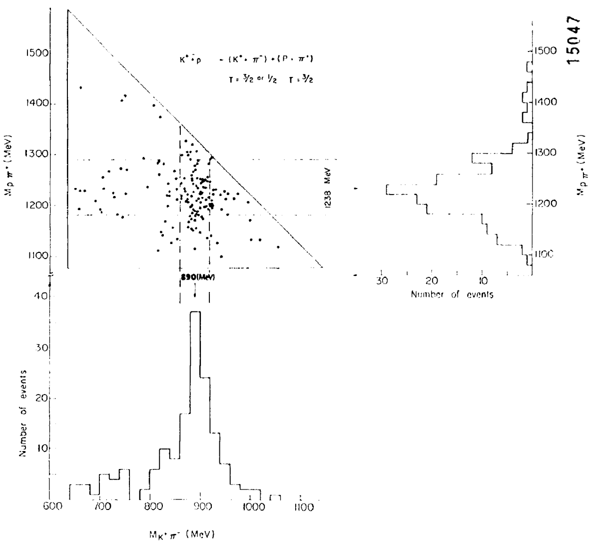


Fig. 6 Example of two body reaction produced by 2 GeV/c K^+ mesons in the 20″ chamber [34]:

$$K^+ + p \rightarrow N^* + K^*.$$

Table IV summarizes the results on mass and width as presented at this Conference. The convenient number of 888 can be given for the mass. Note that a finite width of about 50 MeV is now an established fact in contra-distinction with the value of 16 MeV reported previously (*).

Fig. 7 shows the results of Alexander *et al.* on the K^* production at two energies of π^-: the upper histogram is for $p \sim 1.95$ GeV/c and the lower histogram for $p \sim 2.2$ GeV/c. For both of these energies the K^*888 shows clearly. One notices a sharp bump at 730 for the lower energy. This point will be discussed later.

The conflicting evidence presented on the spin of the K^* are discussed in the following report (Snow).

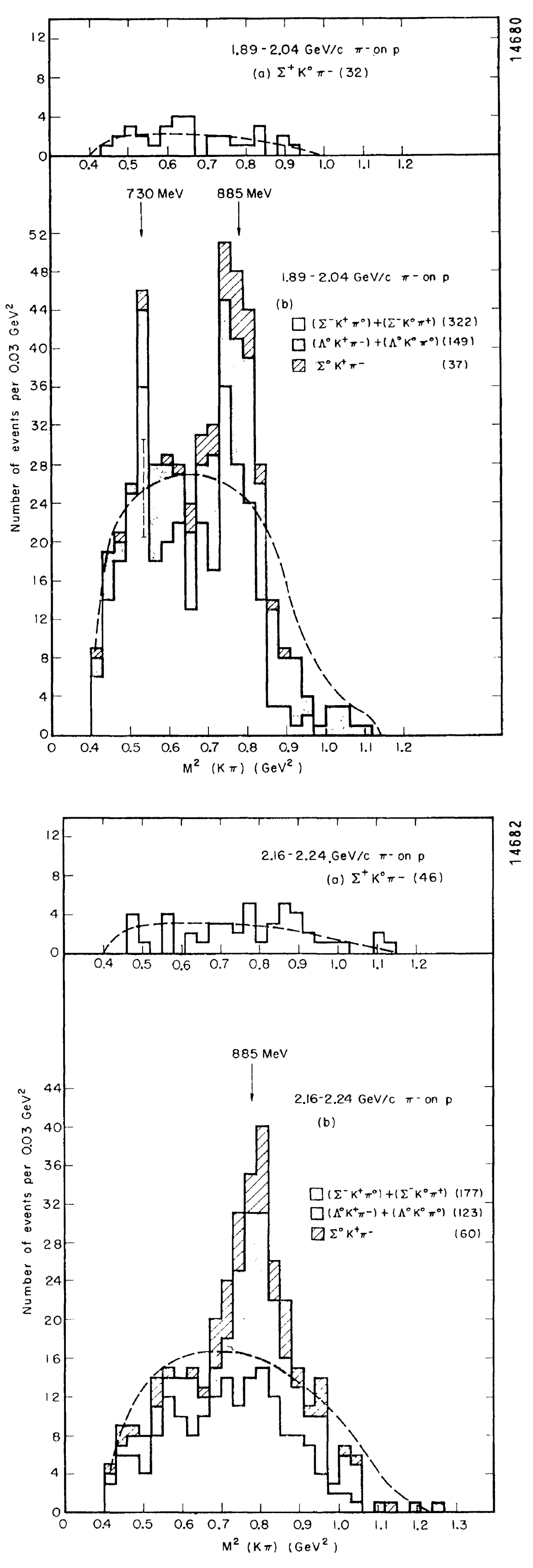


Fig. 7 K production with π^- mesons of $\sim$1.96 GeV/c (above) showing both K^*888 and K^*730 and at 2.2 GeV/c (below) in which K^*888 remains but K^*730 does not show up [24].

(*) M. H. Alston *et al.* Phys. Rev. Letters *6*, 300 (1961).

TABLE IV

K^* mass and width

	GeV/c	Mass	Width	#events	Authors	Ref.
K^-	1.22 1.51	890	47	~500	M. H. Alston *et al.* (Berkeley)	17
	1.47	890	60	42	A. Cooper *et al.* (CERN, Amsterdam, Glasgow)	21
	2.3	900	$\leqslant$40	42	L. Bertanza *et al.* (Brookhaven, Syracuse)	20
π^-	~2.0 ~2.2	885	60	400	G. Alexander *et al.* (L.R.L. Berkeley)	19
π^-	2.0	898	60	270	D. Colley *et al.* (Columbia, Rutgers)	23
$\bar{p}$	stopped	885	55	650	R. Armenteros *et al.* (CERN, Paris)	18
K^+	1.5	900	60	50	G. B. Chadwick *et al.* (Oxford, Padua)	22

2) Y_0^* 1405

The evidence on this isobar was not very convincing before this Conference (*).

Definite confirmation was presented by many authors [20, 21, 24, 25].

The interactions studied were:

$$K^- + p \to [Y_0^* \to \Sigma^\pm + \pi^\mp] + \pi^0$$
$$\pi^- + p \to [Y_0^* \to \Sigma^\pm + \pi^\mp] + K^0$$

Interferences with other Y^* states and also in the second case with the K^* were observed.

Fig. 8 shows the results of Ref.[25] in which one observes clearly the Y_0^* (1405) and Y_0^* (1520). It is interesting to note how these resonances reflect in the $\Sigma^\pm\pi^0$ distribution.

The absence of charged states strongly suggested isotopic spin zero. This was confirmed by a study of the rate of production of $(Y_{1405}^* \to \Sigma^0\pi^0)\pi^+\pi^-$.

The best numbers on mass and width are:

$$M = 1405 \text{ MeV} \qquad \Gamma = 50 \text{ MeV}.$$

No information exists on the spin of this isobar.

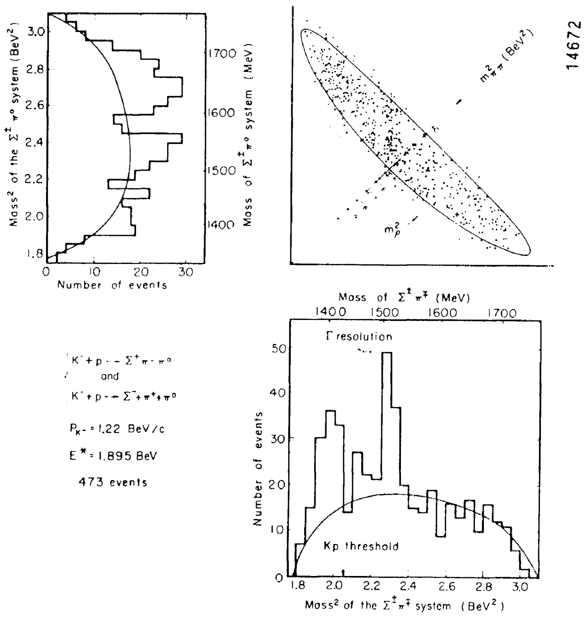


Fig. 8

This width of 50 MeV is given by all bubble chamber experiments. On the other hand an emulsion experiment [26] gives strong evidence for a much smaller width <2 MeV. For the complete reasoning I shall refer to the original paper. This result is based on the observation of a narrow and significant peak between 160 and 180 MeV/c of the resultant momentum of

(*) M. H. Alston *et al.* Phys. Rev. Letters *6*, 698 (1961).

the Σ^+ and π^- in the reaction in emulsion: (A and B are two nuclei of the emulsion)

$$\underset{\text{(at rest)}}{K^-} + A \rightarrow \Sigma^+ + \pi^- + B$$

This narrow line of $(\Sigma^+ + \pi^-)$ momentum proves the existence of a two body $Y^* + B$ reaction and the width of the peak gives a maximum width for the Y^* of 2 MeV.

The author also measured the effective mass of the $\Sigma^+ + \pi^-$ system in the peak and found a value of 1405. Finally this observation is compatible with a carbon capture

$$K^- + C^{12} \rightarrow Y^*_{1405} + B^{11}$$

We will have to accept for the time being two possible values for Γ:

$$\Gamma = 50 \text{ MeV (bubble chambers)}$$

$$\Gamma < 2 \text{ MeV (emulsion).}$$

3) Y_0^* 1520

This isobar was also observed in the reactions given above. Since the K+nucleon mass is 1432 any resonant state for which the mass is larger than this value will show up in bumps in the KN cross-section.

Indeed the 1520 resonance was thoroughly studied in a 400 MeV/c K^- beam. The results are discussed by Snow in relation with the Σ-Λ parity.

4) Y_0^* 1815

The present status of this resonance observed in K^-N interactions at 1100 MeV/c is presented by Snow.

5) Y_1^* 1385

This was the only isobar presented at the Rochester Conference. The observation was made in a K^- beam of 1.15 GeV/c.

$$K^- + p \rightarrow (Y_1^* \rightarrow \Lambda^0 + \pi^\pm) + \pi^\mp$$

Many authors reported on the properties of this resonant state [20, 21, 23, 24, 27, 29, 30].

The production reactions were

$$K^- + p \rightarrow (Y_1^* \rightarrow \Lambda^0 + \pi^\pm) + \pi^\mp$$

$$\pi^- + p \rightarrow (Y_1^* \rightarrow \Lambda^0 + \pi^{\bar{0}}) + K^{+}_{0}$$

Interference with the K^* was observed in the second case. At 1.22 GeV/c K^- momentum the first reaction showed about 100% production as presented in Fig. 9 [27] where 1300 events are plotted.

The best values for the mass and width are

$$M = 1385 \text{ MeV} \qquad \Gamma = 50 \text{ MeV}$$

Interesting results were also obtained in a spark chamber [29] on the Y_1^* properties as observed in the reaction $\pi^- p \rightarrow K^0 (Y_1^{*0} \rightarrow \Lambda^0 + \pi^0)$. The measured mass is the same but the width was smaller i.e. 25 MeV.

The spin of Y_1^*

Before this Conference Ely *et al.* (*) observing about 400 Y_1^* produced by 1.1 GeV/c K^- in a propane chamber gave strong evidence for a spin $J \geqq 3/2$.

At this Conference no conclusive new evidence was brought.

A surprising fact was that with much larger statistics [27] (1300 events at K^- momentum 1.22) the indication for a spin $\geqq 3/2$ had less statistical weight than in the previous result of Ely *et al.*

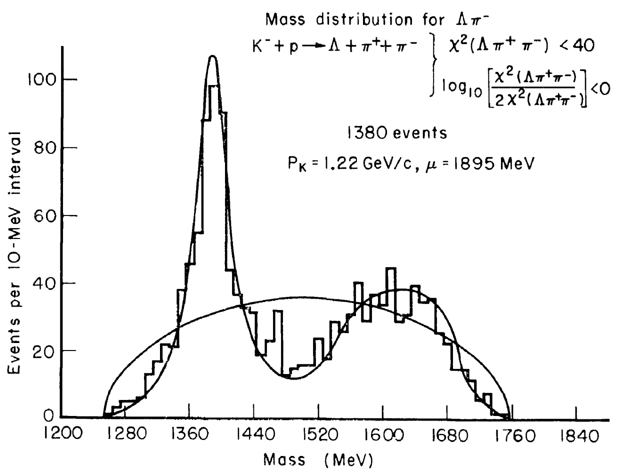


Fig. 9 The solid line fitting the data was computed assuming 100% reaction $K^- + p \rightarrow Y_1^* + \pi$ with a mass 1385 and a width $\Gamma = 50$ for Y_1^* [27].

(*) R. P. Ely *et al.* Phys. Rev. Letters 7, 461 (1961).

Y_1^*'s produced in a helium chamber [30] according to the reaction: $K^- + He^4 \rightarrow Y_1^* + He^3$ were analysed in order to measure the Y_1 spin. The result was inconclusive.

The same inconclusive result was presented in Ref.[23] although in that case an indication was given on the parity if the spin was known (S wave if $J = 1/2$; P wave if $J = 3/2$).

The analysis of the spark chamber data [29] in which the reaction ($\pi^- p \rightarrow Y_1^* + K$) is below the threshold of K^* production favours spin 1/2.

Finally the problem is still open although the original result of Ely *et al.* still strongly favours $J \geqq 3/2$.

The branching ratio of Y_1^* in $\Sigma + \pi$ was still found compatible with zero.

6) Ξ^* 1532

Good evidence on this new Ξ^* resonance was presented by two groups [20, 35]. This new Ξ^* was produced by K^- at 2.3 and 1.8 GeV/c in hydrogen bubble chambers.

Fig. 10 [20] and Fig. 11 [35] show their results. It seems clear from these that a new isobar at 1532 MeV exists.

The width is not yet clearly known since the two laboratories disagree (~30 MeV [20]; $\leqq$ 7 MeV [35]).

Isotopic spin 1/2 seems well established by both laboratories.

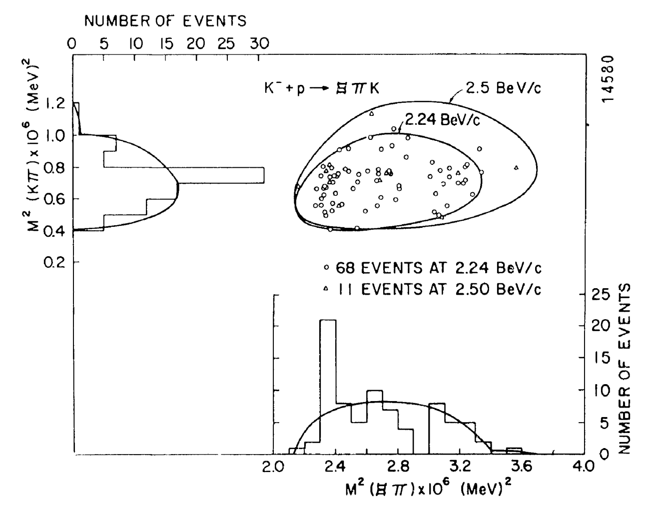


Fig. 10 This shows the Brookhaven-Syracuse results [20] on the events: $K^- + p \rightarrow \Xi + \pi + K$. Both the known K^*888 and the new Ξ^* show up clearly.

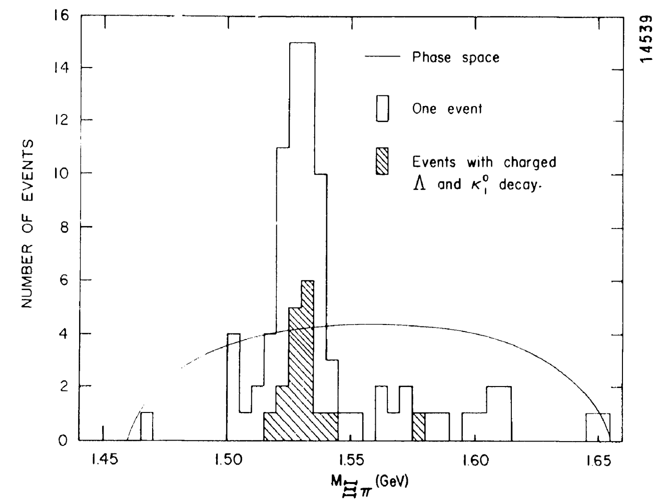


Fig. 11 This shows the UCLA [35] results on the events $K^- + p \rightarrow \Sigma^- + \pi^{\overset{+}{0}} + K^0$. The Ξ^* is clearly visible. Note that for this value of momentum the K^*888 is not produced.

There is an indication of spin $\geqq 3/2$ [20] but this cannot be considered as firmly established.

b) Possible new resonant states

We will now review the evidence on other isobars choosing for a b) criterion either one strong evidence with no supporting evidence or many independent evidences of small statistical weight. As we will go down the list the degree of confidence in the data will decrease. It is nevertheless of interest to list the observations reported.

1) K* 730

The only existing evidence is quite strong [24] (see Fig. 7): " the statistical significance of this peak above the background is estimated to nearly three standard deviations " according to the authors.

Although many authors who studied the K^*888 searched for this 730 resonance, no evidence was presented at this Conference.

2) $K\overline{K}$ interaction(*)

Erwin *et al.* presented at the Washington meeting evidence on the production of $K\overline{K}$ in $\pi^- p$ collision at about 2 GeV/c

$$\pi^- + p \rightarrow K_1^0 + K_1^0 + n\,; \qquad \pi^- + p \rightarrow K^0 + K^- + p\,.$$

(*) Sakurai insisted on the importance of distinguishing a bump in the $K^0{}_1K^0{}_1$ distribution from a bump in the $K^0{}_1K^0{}_2$ distribution. He also mentioned: it is quite possible that there is an s-wave scattering length effect for $K^0{}_1K^0{}_2$ and at the same time a sharp $K^0{}_1K^0{}_2$ bump which can be regarded as the decay of an ω like vector meson.

An enhancement in the number of events for small masses of the $(K_1^0 K_1^0)$ system was reported. This evidence was also presented at this conference [31].

For π^- of much higher energies (and for $K_1^0 K_1^0$ modes of decay) similar evidence was presented [8, 10, 32]. The first and the last authors compared the effective mass distribution to a curve computed by a Monte Carlo method combining kaons from differents events. A significant increase in the number of $K_1^0 K_1^0$ events of small effective mass (below 1200 MeV) is observed although the existence of a peak cannot be definitely proved. May I remark that a considerable amount of interesting results were obtained by these authors on high energy production of strange particles.

A histogram of 37 events [20] was presented comprising a small number of observed $K_1^0 K_1^0$ events (3) and about the same number of $K_1^0 + (K_2^0 \text{ or } K_1^0)$ and $K^+ + K^-$ events. The production reaction was:

$$K^- + p \rightarrow (K + \overline{K} + \Lambda^0) \qquad \text{at 2.4 GeV/c}$$

A strong enhancement is seen in the $K\overline{K}Q$ value region between 0 and 100 MeV.

Finally in the reaction [18]

$$\underset{\text{at rest}}{\overline{p}} + p \rightarrow K_1^0 + K_1^0 + \omega^0 \quad \text{47 events}$$
$$\rightarrow K^+ + K^- + \omega^0 \quad \text{79 events}$$

the $K\overline{K}$ mass spectrum was presented.

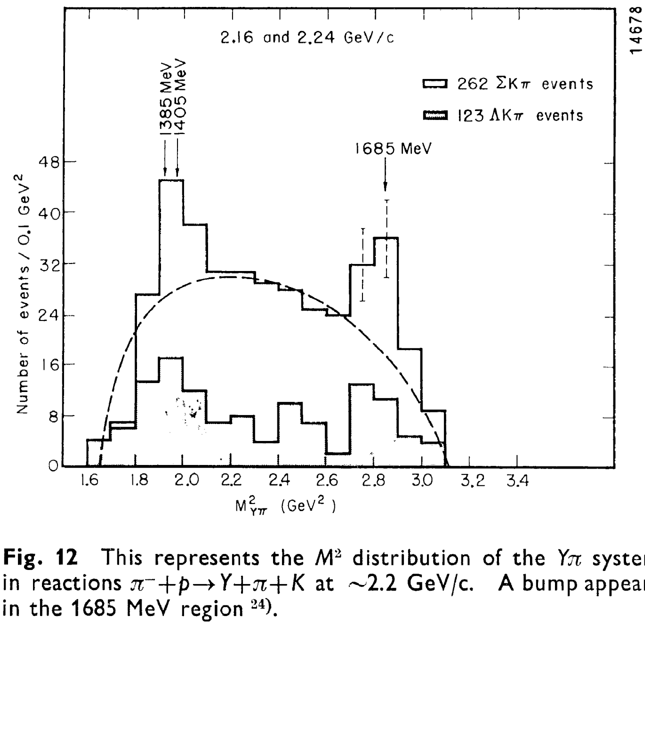


Fig. 12 This represents the M^2 distribution of the $Y\pi$ system in reactions $\pi^- + p \rightarrow Y + \pi + K$ at $\sim$2.2 GeV/c. A bump appears in the 1685 MeV region [24].

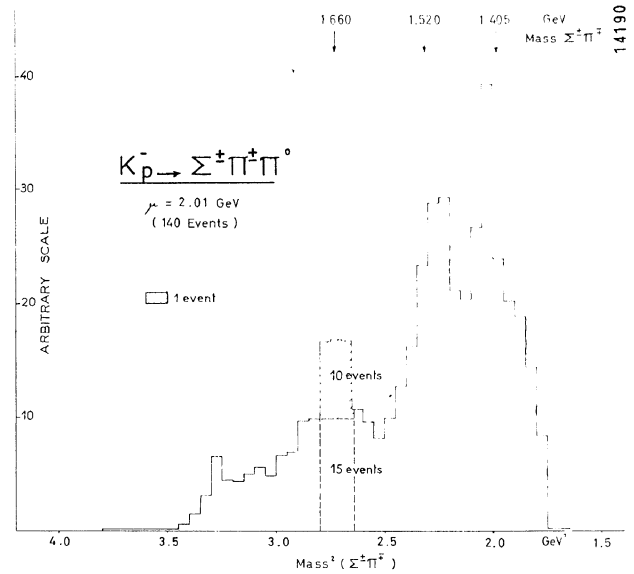


Fig. 13 The $\Sigma\pi$ distribution [21] observed in K^-p interactions shows a slight enhancement around 1660. The statistical weight might be estimated as slightly more than one standard deviation.

Phase space for the two K's is limited to the mass band 1000-1100 MeV. No peaking was observed for either of the $K_1^0 K_1^0$ or $K^+ K^-$ combinations.

To summarize, the result of Erwin *et al.*, i.e. enhancement of low Q values $K_1^0 K_1^0$ events, is confirmed at higher energies although the data is not sufficient to indicate whether there is or not a resonant $K_1^0 K_1^0$ system in the physical region.

The data of Ref. [20] (mixture of $K_1^0 K_1^0$, $K_1^0 K_2^0$ and $K^+ K^-$) show the same effect.

This peaking is not observed for either $K_1^0 K_1^0$ or $K^+ K^-$ events produced by stopped antiprotons in the reaction $\overline{p} + p \rightarrow K + \overline{K} + \omega^0$.

3) Y* 1685

The three not very convincing evidences on a possible $I = 1$ isobar are:

An enhancement in the $K^- p \rightarrow \Sigma^- \pi^+$ cross-section at $p_K = 760$ MeV/c with a change in angular distribution [28].

Two slight bumps observed in the $\Sigma\pi$ and $\Lambda\pi$ effective mass distributions at the values of 1660 and 1685 in the interactions $\pi^- + p \rightarrow Y + K + \pi$ at $\sim$2.2 GeV/c and $K^- + p \rightarrow Y + \pi$ at 1.5 GeV/c (see Figs. 12 and 13 [24-21]).

Further evidence is certainly needed on this subject.

(4) Indications on a possible **Y* 1550** resonance of isotopic spin $\geqq 1$ has been reported (*) previously. A search was made [21, 25] for $I = 2$ resonant states in this region of mass in interactions of the type:

$$K^- + p \rightarrow \Sigma^{\pm}\pi^{\pm}\pi^{\mp}\pi^{\mp}$$

No significant peak in the region 1550 was observed.

5) ΛK and ΣK resonant states

The first observation of these $B = 1$, $S = 0$ resonant states was made by Erwin *et al.* (see discussion after this paper). The effective mass was $\Sigma - K = 1920$ which is exactly the mass of the fourth resonance in the $N\pi$ system—but the observed width was different!

No supporting evidence was presented at this Conference on this possible state.

Evidence was also presented by Kutznetov *et al.*[33] on a reaction in heavy nuclei by π^- at 2.8 GeV/c:

$$\pi^- + \text{Nucleus} \rightarrow \Lambda^0 + K^0 + \pi^+\pi^-$$

A peaking was observed at ~1650 MeV in the ΛK system. A similar search made at higher energies (~10 GeV) [10, 32] did not show any similar bump.

(6) A number of possible resonant states of kaons or hyperons with many pions were presented [8]. These were observed in the interactions in propane by energetic π^- mesons. The authors compared the observed distribution to phase space and indicated the existence of

K^{***}	decaying into $K^0\pi^+\pi^-\pi^+$	mass 1630
K^{**}	decaying into $K^0\pi^{\pm}\pi^{\pm}$	mass 1150
Y^{**}	decaying into $\Lambda^0\pi^+\pi^-$	mass 1760

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DISCUSSION

Capps: Concerning the π-cascade resonance, if this is really isotopic spin ½ and of the same family as the (3, 3) $\pi-N$ resonance and the Y_1^*, then the pion-cascade interactions must not be the most important ones, since these would give repulsion in the $I = ½$ states. The important interaction could be a K interaction, or maybe an η interaction, if the η is the isotopic spin zero brother of the pion. A strong η-cascade might lead to a $P_{3/2}$ $I = ½$ $\pi^-\Xi$ resonance, and that model would also be consistent with the observed narrow width; since the resonance occurs below η-cascade threshold, it might be weakly coupled to the π-cascade channel, into which it is forced to decay. There are many other possible mechanisms for this resonance; the reason I mention this is that if the η interacts strongly with the cascade it might also with the Σ and Λ. There may be $\eta\Lambda$ or $\eta\Sigma$ resonances perhaps above the thresholds. I would like to urge people to look hard for η-baryon resonances as well as for π-baryon and K-baryon resonances.

Lundby: Could the narrow width observed in emulsion by Frisk for the 1405 resonance be due to the lack of phase space available for high mass values? This would be particularly serious if you had much capture to excited states in B^{11}.

Ekspong: The available energy is 12 MeV for the K^--carbon reaction, which aside from phase space makes it possible for the Y^* mass to go up to 1405+12 = 1417 MeV. However, this part is suppressed by phase space. On the other side the Y^* mass may go down without limit and this part should be enhanced by phase space. I can see no reason based on phase space for the observed line to be so narrow (phase space does not vary much within the observed line). The one reason I can think of is that the width of Frisk object is indeed very small. I agree that one should look for other interpretations, either of the emulsion result or of the bubble chamber result.

Yamaguchi: I think you have taken the ground state B^{11} in the reaction $K^- + C^{12} \rightarrow B^{11} + Y^*$. Is it right?
If you take into account the possibility of $K^- + C^{12} \rightarrow Y^* + B^{11*}$ (with many possible excited B^{11}), what kind of effects do you find in your mass and width analysis of Y^*?

Ekspong: We have looked for that. The first excited state in this is 2 MeV, next 4.5 MeV. The momentum should shift 7 times more, that is 14 MeV/c, which is more than our resolution. There might be excited states, we do not know. It should shift the position of the line, not the width. The width is independent of the assumption that capture takes place only from carbon. We agree this is an assumption. It would be interesting to see if the bubble chamber people could have seen anything like that.

Gottstein: Is there any explanation for the fact that this reaction is only seen in carbon, and not in, say, nitrogen or oxygen? Oxygen is fairly frequent in nuclear emulsion.

Ekspong: Yes, this has worried us. If you look at our data and blame the large spike on carbon, oxygen should appear at 200 MeV/c. Nitrogen is not very frequent in emulsions.

Burhop: I think it is a fact for these clean $\Sigma\pi$ events. A study based on the absence of Auger electrons indicates that they come mainly from light nuclei.

Ekspong: Auger electrons are present but fewer than in a random sample. We think that ⅔ of our captures are in light nuclei and the rest from Ag and Br.

Burhop: Could I ask some of the bubble chamber people what their errors are in the width determinations of the Y_0^*?

Rosenfeld: The errors in the 72″ bubble chamber are about 7 MeV for Y_0^* events which is much smaller than the experimental widths we quote. If you just calculate the mass of this system by our technique, does the peak remain so sharp?

EKSPONG: The total width is in this case 20 MeV.

EISENBERG: After hearing about the Stockholm results on the narrow width of Y_0^* (produced in K^- captures at rest in nuclear emulsions, giving rise to $\Sigma+\pi$), we have also made the $|\mathbf{P}_\Sigma+\mathbf{P}_\pi|$ plot using our original events which were published over a year ago in our Y_0^*-paper. We also obtain a sharp peak, very similar to the Stockholm peak, between 160-180 MeV/c. We cannot offer an explanation for this phenomenon at the present time.

MIHUL: I want to mention a fact that was not included in the report namely experimental data about $\Lambda - p$ elastic scattering. In Dubna on the basis of 27 events we have found an elastic cross-section of 36 ± 14 mb. Also we presented the angular and momentum distribution of the scattered particles.

LUNDBY: A remark on the 1550 MeV $T=1$ or 2, $T_z=-1$ resonance. Other evidence neither agrees nor contradicts the counter experiment at CERN. In general if the width of a resonance is 100 MeV or more, one needs considerably more pictures in order to see it in bubble chamber data.

GREGORY: It was my job to report that nothing was seen. There might, of course, be reasons for not seeing it, in spite of its existence.

LUNDBY: The experimenters should quote an upper limit for the cross-section.

GREGORY: I quite agree with you. It would make the job of the rapporteur easier if in all the observations, it had been clearly stated what was the fraction of the cross-section that gave a certain type of common resonance or combination of resonances.

LINDENBAUM: I notice from your table and talk that you show many pion-baryon resonance states and several pion-kaon resonance states but do not show kaon-baryon resonance states. Could you comment on the situation especially with respect to K^+-baryon resonant states and in particular as to whether one has searched sufficiently for them. Also can one conclude that the positive kaon-baryon coupling, especially for positive kaons, is smaller than pion-baryon or pion-kaon couplings.

ROSENFELD: It may be misleading to talk about " pion-hyperon " versus " kaon-baryon " resonances. If you look at the branching ratio of the well-established Y_0^* (1520), it decays 60% of the time into $\Sigma+\pi$, 30% of the time into nucleon$+\bar{K}$ and 10% of the time into $\Lambda\pi\pi$. Moreover, the KN to $\Sigma\pi$ ratio is slightly *greater* than suggested by phase space.

WALKER: I would like to note that we have observed peaks in the $\Sigma - K$ mass spectrum at 1920 MeV in runs at 1.89 and 2.1 GeV/c π^-. This peak is narrow ($\sim$15 MeV) and probably well above background. In all we have about 50 counts in this peak if we combine our two runs.

PEYROU: I would like to point out again that when you are looking for bumps and peaks it is always an extremely dangerous procedure to mix the data of different instruments with different precision. If you have one which gives a peak more or less sharp, not absolutely statistically significant maybe, and you have confirmatory evidence from something which has a broader resolution, if you add both together it looks even less convincing than both separately.

NGUYEN DINH-TU: I would like to point out the cascade decay properties of the resonances obtained at Dubna. These resonances decay into well-known resonances, for example

$$(\Lambda\pi\pi) \rightarrow Y_1^* + \pi \;;$$

$$(K\pi\pi\pi) \begin{matrix} \rightarrow K^* + \pi + \pi \\ \rightarrow K \;\; + \pi + \rho \end{matrix}$$

ROSENFELD: As long as we are all jumping on you, I should point out that you are technically incorrect in your rather reasonable statement that the two experiments to determine the magnetic moment of the Λ^0 cannot be combined. It is true that they do not look exactly the same, but even if you take Warshaw's errors at face value, then the two experiments are only 2.1 standard deviations from being consistent, and the average is about $(0.75 \pm 0.4)\,\mu_N$. If you increase Warshaw's errors, it is even more tempting to average them.