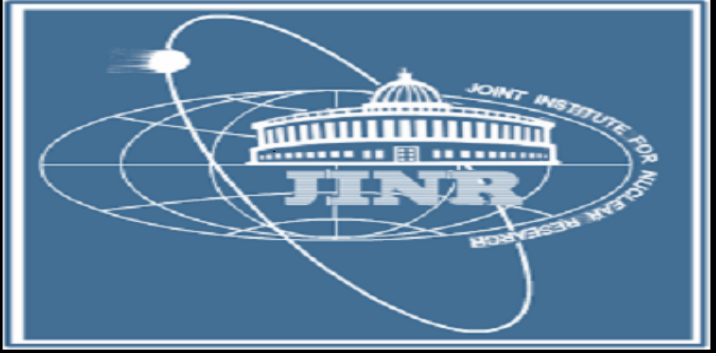


XIX ISHEPP, September 29 – October 4, 2008

Recent results of observations for multi-baryon states with Λ-hyperons and K°_{S} –mesons subsystems at 10 GeV/c

P. Aslanyan, September 30, 2008, JINR

Contents

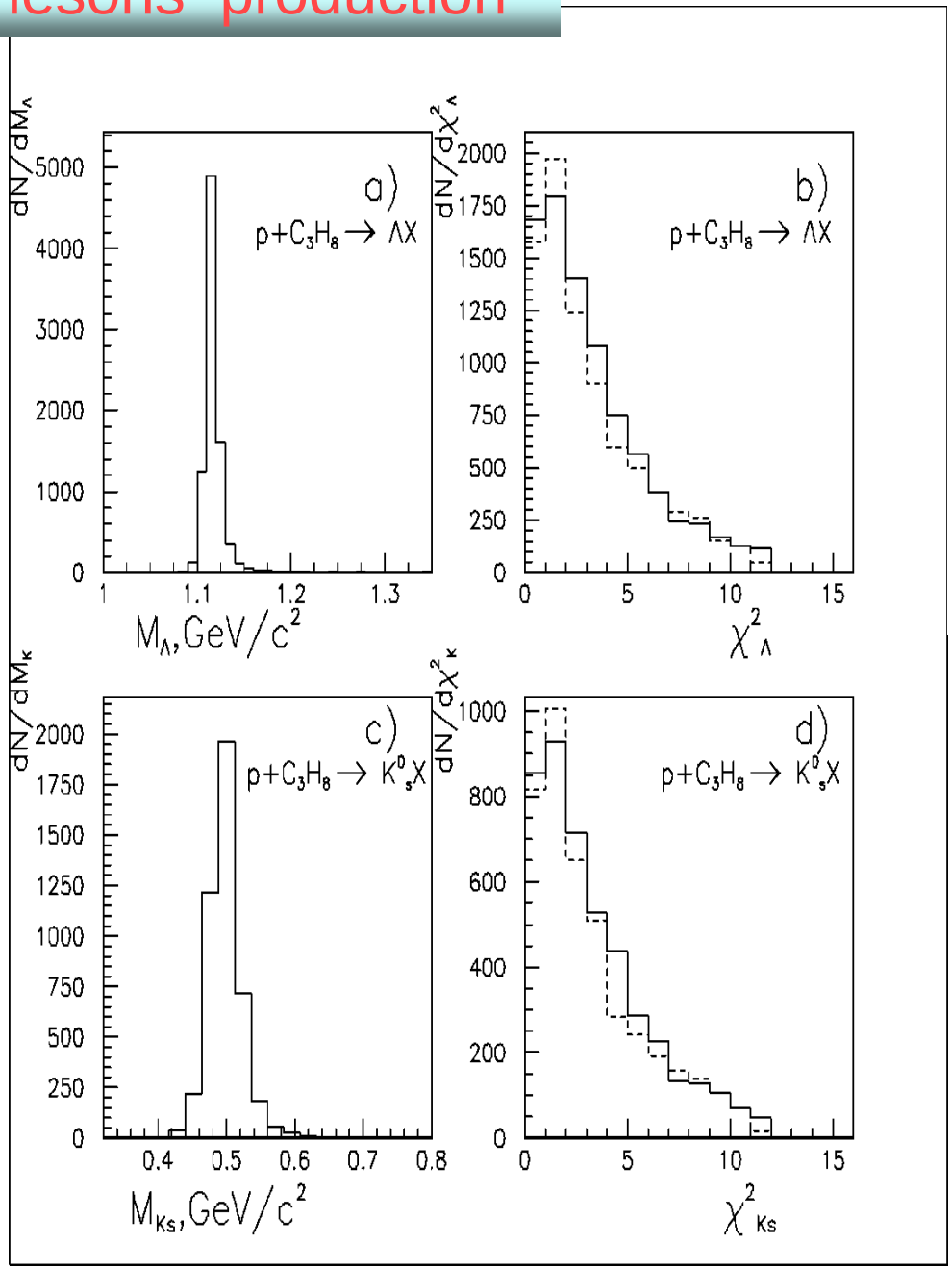
Preview

- There are a few actual problems of nuclear and particle physics which are concerning subject of this study. These are following: in-medium modification of hadrons, the origin of hadron masses, the restoration of chiral symmetry, the confinement of quarks in hadrons, the structure of neutron stars. Strange multi-baryonic clusters are an exiting possibility to explore the properties of cold dense baryonic matter and non-perturbative QCD too. Multi-quark states, glueballs and hybrids have been searched for experimentally for a very long time, but none is established.

- Strange multibaryon states with Λ- hyperon and K_s^0 –meson subsystems has been studied by using data from 700000 stereo photographs or 10^6 inelastic interactions which was obtained from expose proton beams at 10 GeV/c to 2-m propane bubble chamber LHE,JINR. There are not sufficient experimental data concerning for strange-hyperons production in hadron - nucleus and nucleus-nucleus collisions over momentum range of 4-50 GeV/c. A survey for new experiments with much improved statistics compared to those early data would hopefully resolve whether such "exotic“ multi-quark hadron and baryon resonances exist.

Λ- hyperons and K^0_S-mesons production

Figures (a,c) and (b,d) show the effective mass distribution of 8657-events with Λ, 4122-events with K_s^0 particles and their χ2 from kinematic fits, respectively. The expected functional form for χ2 is depicted with the dotted histogram. The measured masses of these events have the following Gaussian distribution parameters M_K= 497.7± 3.6, s.d.= 23.9 MeV/c^2 and M_Λ =1117.0 ± 0.6, s.d.=10.0 MeV/c^2. The masses of the observed Λ, K_s^0 are consistent with their PDG values. The experimental total cross sections are equal to 13.3 and 4.6 mb for Λ and K_s^0 production in the p+C collisions at 10 GeV/c.



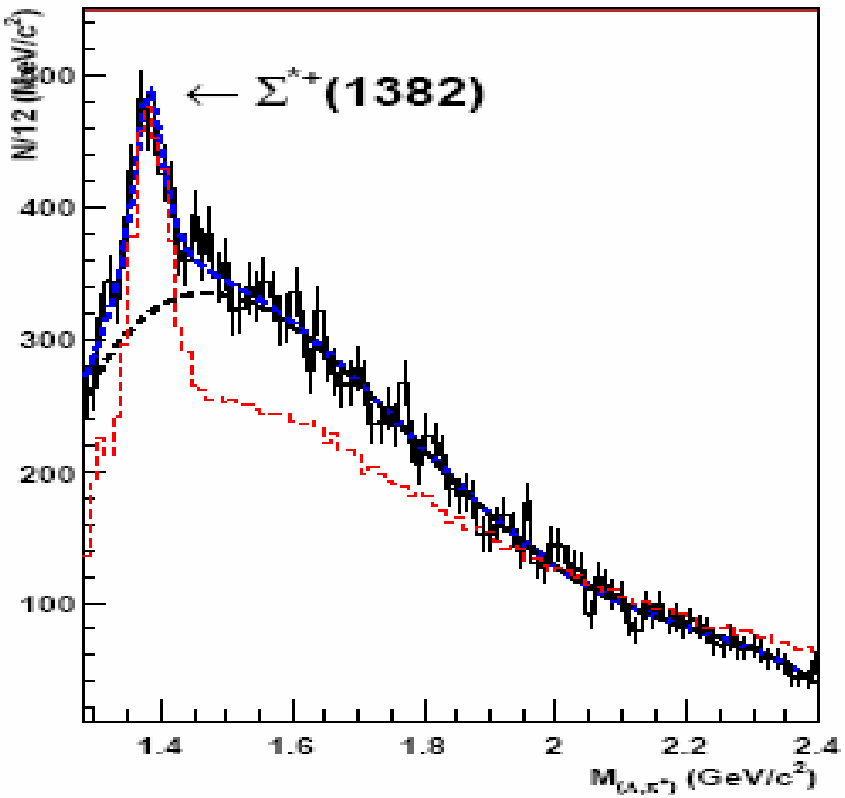
The Background studied three different ways

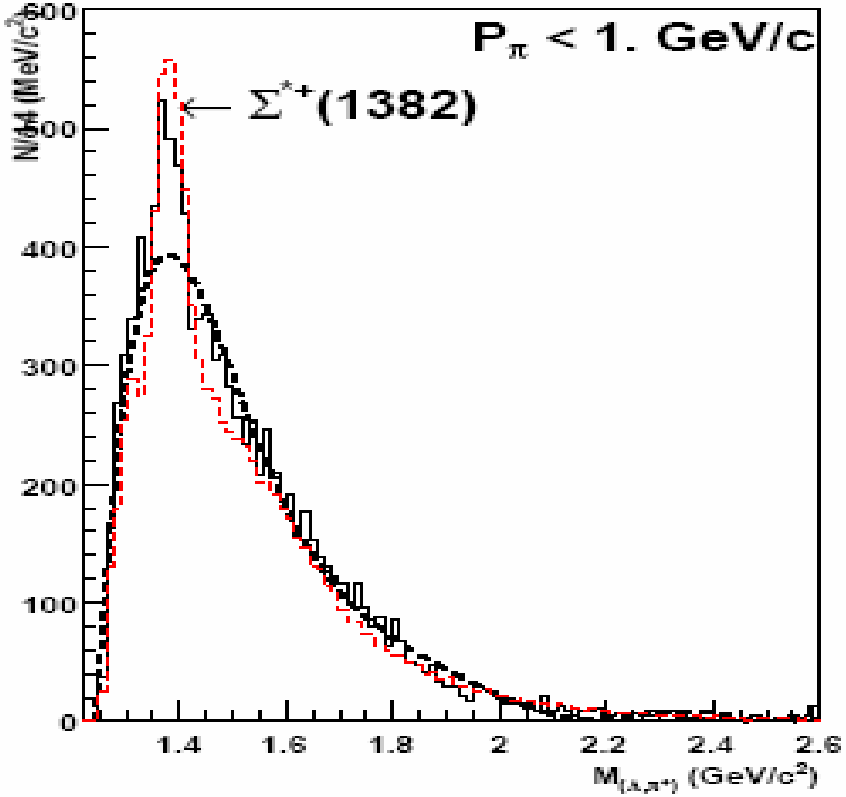
The total experimental background has been obtained by three methods. In the first method, the experimental effective mass distribution was approximated by the polynomial function after cutting out the resonance ranges because this procedure has to provide the fit with χ^2=1 and polynomial coefficient with errors less than 30 %.

The second of the randomly mixing method of the angle between **decaying particles** for experimental events is described in JINR Rapid Comm., N6(74),p209, 1995. Then, these background events were analyzed by using with same experimental condition

The third background method has been obtained by using FRITIOF model with same experimental canditions .

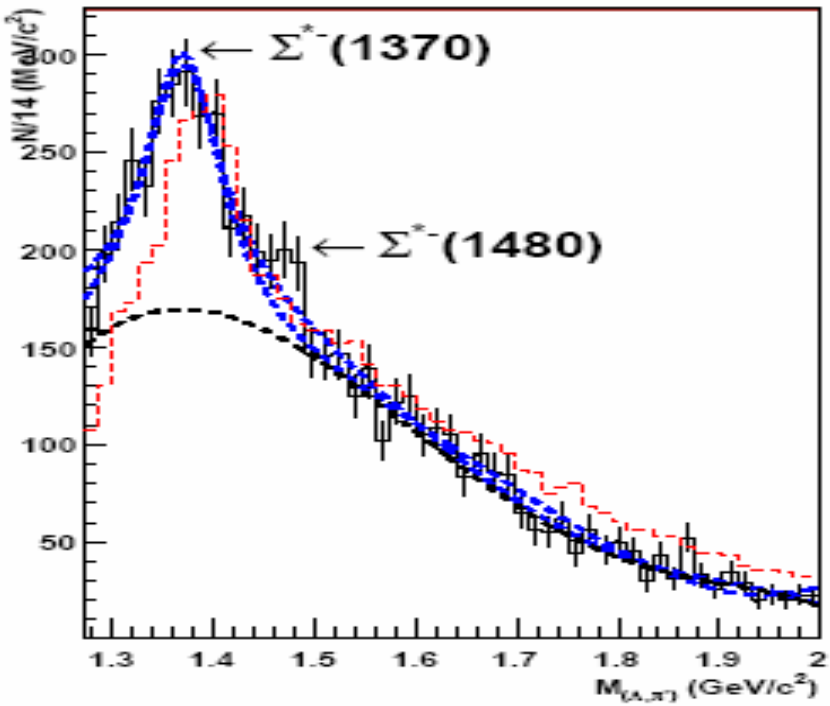
$(\Lambda\pi^+)$ spectra

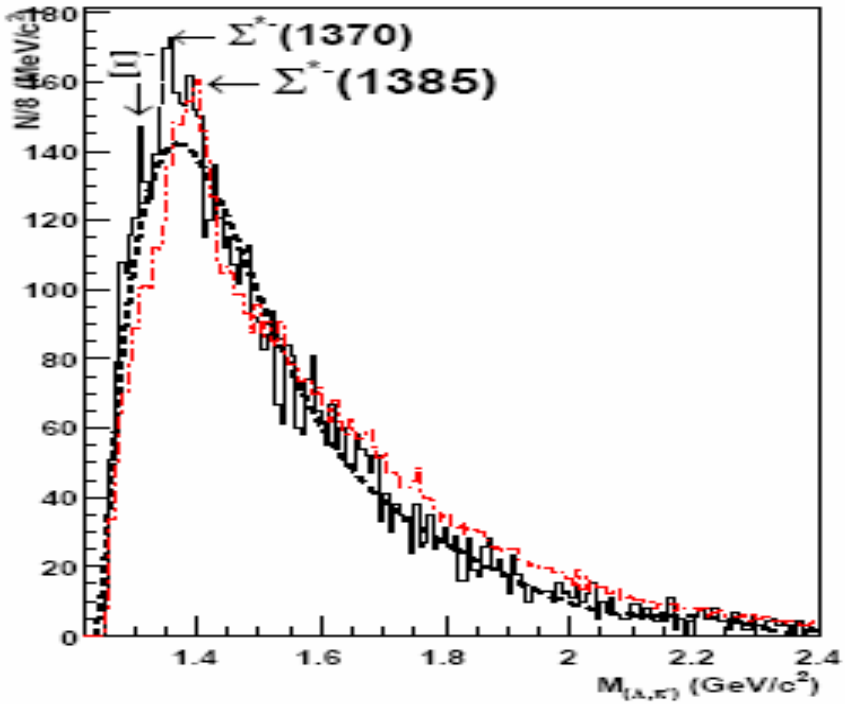




Test method is with known resonance. The resonance (19534 comb.)with similar decay properties as $\Sigma^*(1382)$ is registered with more than 13 S.D.. The decay width is equal to $\Gamma \approx 40$ MeV/c^2 ($\Delta M/M \approx 0.7$ %). A masses and width are consistent with PDG values for $\Sigma^*(1382)$. After cut of over momentum $P_\pi < 1$ GeV/c there is shift for maximum In mass range of 1370 MeV/c^2(9095 comb.). The cross section of $\Sigma^*(1382)$ production (≈540 exp. events) is equal to 1 mb at 10 GeV/c for p+C interaction. The cross section for reaction $pp \rightarrow \Sigma^{*+}(1382)X$ is equal to ≈ 0.06mb. The cross section for the same reaction $pp \rightarrow \Sigma^*(1382)X$ from PDG at momentum 6.6 GeV/c is equal to 0.03 mb.

$(\Lambda\pi^-)$ spectra

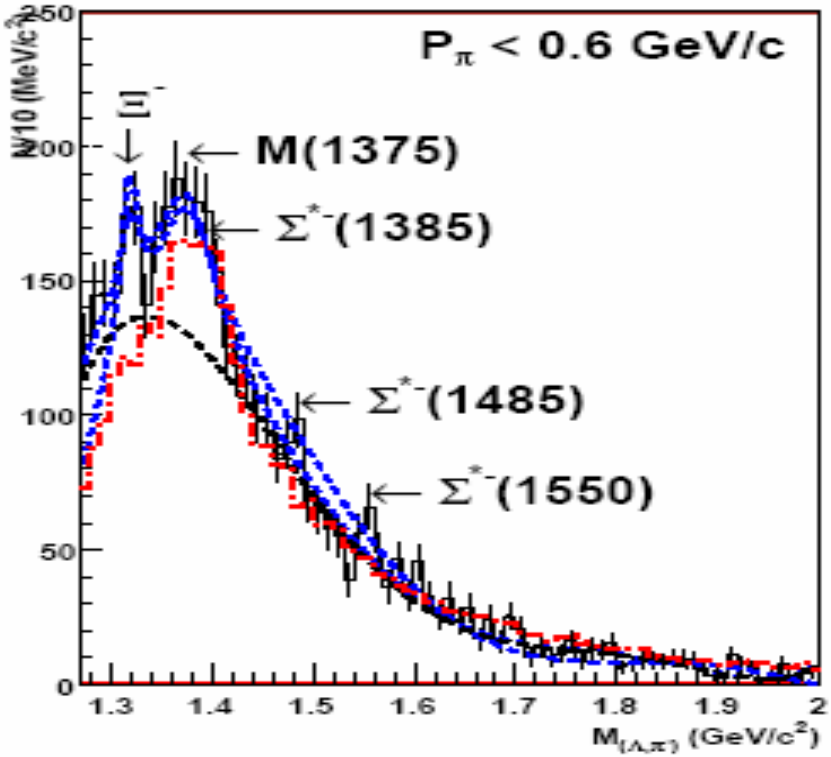


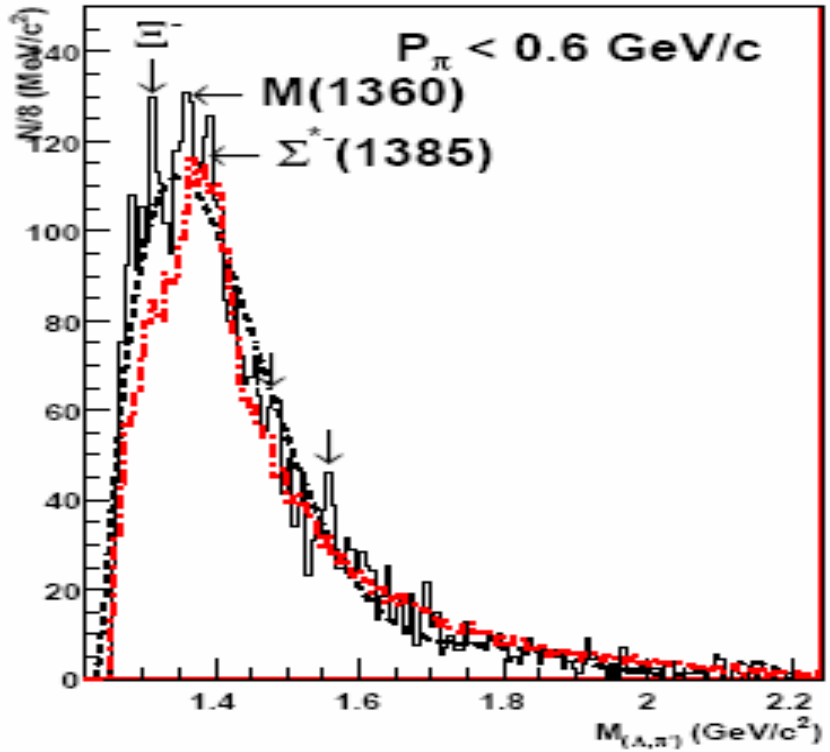


The $\Lambda\pi^{--}$ effective mass distribution for all 6465 combinations with bin sizes of 14 and 8 MeV/c^2**.** The solid curve(Fig.a) is the sum of the background (by the first method) and 1 Breit-Wigner resonance. There is significant enhancement In the mass range of 1370 MeV/c^2, with Γ = 103 MeV/c^2. The cross section of Σ^{*-}(1385) production (≈680 events) is equal to ≈ 1.2 mb at 10 GeV/c for p+C interaction.**The width of Σ^-(1385) have observed ≈ 2 times larger than PDG value.** Figure (b) shows effective mass distribution with bin size of 8 MeV/c^2, where there are also significant enhancements in mass regions of 1317(3.0 S.D.) and 1480(3.2 S.D.).

There are negligible enhancements in mass regions of 1520 and 1550 MeV/c^2.

($\Lambda\pi^-$) spectra





The cross-section of stopping Ξ^- production ($\geq$65 events from 3829 comb.) in nuclear medium is equal to $\geq$ 120 μb) at 10 GeV/c for p+propane interaction. The sum ofl experimental cross section for stopping Ξ^- (65 ev.) and identified by weak decay channel (75 ev.) is more than 4 times larger than the cross section of Ξ^- which is obtained by fritiof model with same experimental conditions. There is observed peak in mass range of Σ^{*-}(1480) resonance too which is agreed with SVD2 report on ICHEP06 and COSY. Further studies are required to confirm the existence of the Σ^{*0} (1480) hyperon and to determine its quantum numbers.

Ξ^- events by weak decay channels $\Lambda\pi^-$

These 5 Ξ^- events have identified on 30 % experimental data. The calculated cross section and number of events with Ξ^- by FRITIOF are equal to 41 μb (or 11.3 μb) and 42 events(or 34 ev.) for p+propane (or p+C) collision. Then experimental cross section was estimated by weak decay channel for $\Xi^-\rightarrow\Lambda\pi^-$ (w=1/e_Λ =5.3) which is equal to ≈80 μb in p+propane collision.

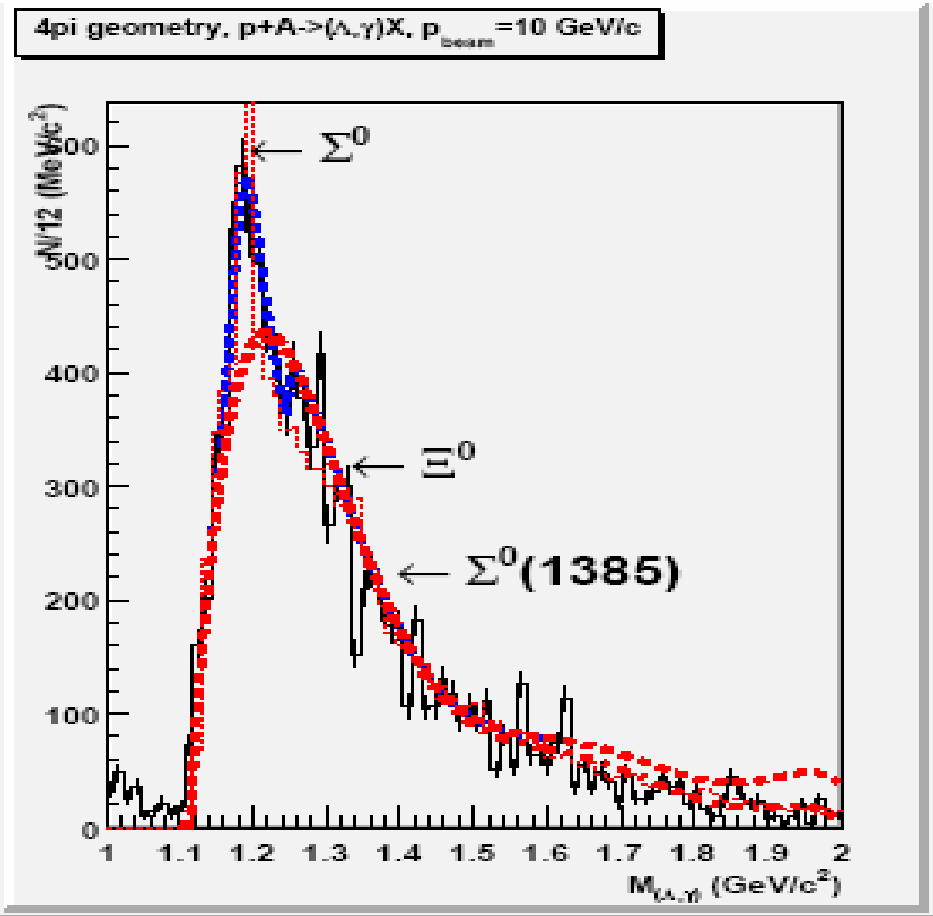
Table 3:Mass and a momentum Ξ hyperon is determined by weak decay channels of $\rightarrow \pi^-\Lambda$.

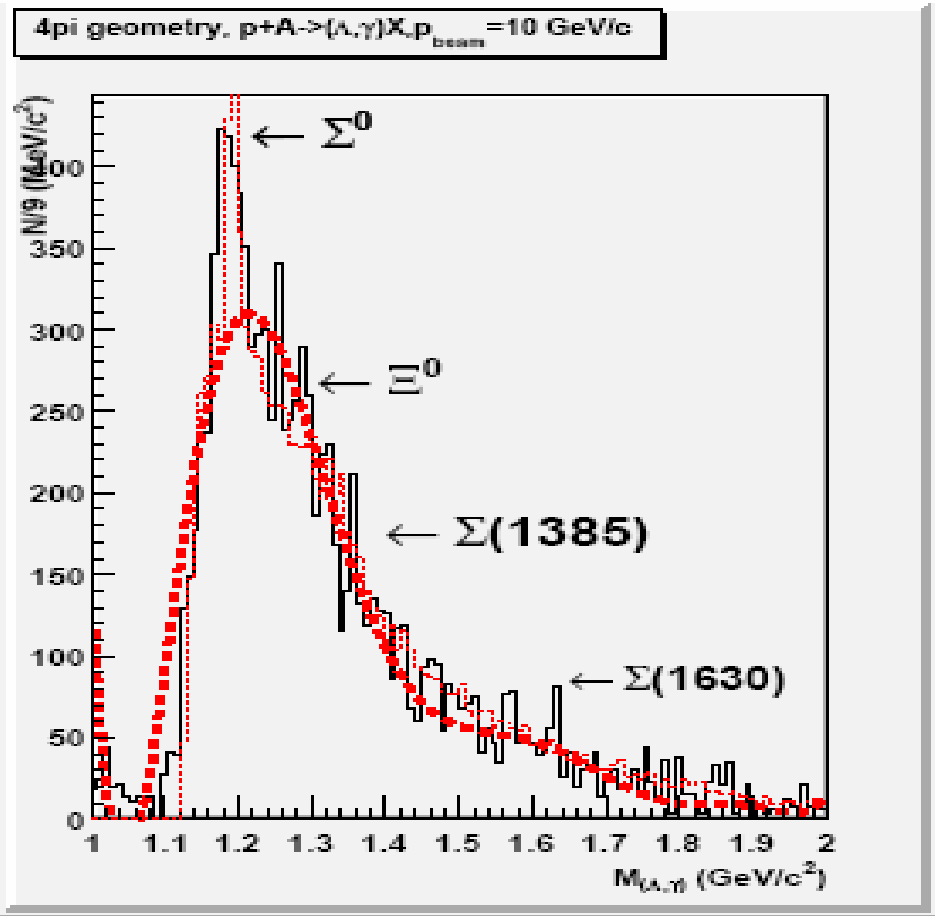
N	Momentum of Ξ^- GeV/c	M_{π^-p} invariant mass of Ξ^- (GeV/c^2)	Mass of Ξ^- with fits (GeV/c^2)	C.L. One vertex fit%
1	0.902±0.037	1.312±0.009	1.313±0.008	89.2(1V-2C)
2	0.973±0.038	1.316±0.008	1.315±0.007	96.0(1V-2C)
3	1.320±0.055	1.315±0.006	1.321±0.009	75.3(1V-2C)
4	1.298±0.038	1.313±0.007	1.323±0.008	29.8(1V-2C)
5	2.777±0.335	1.315±0.006	1.398±0.023	6.9(1V-2C)

P.Z. Aslanyan, JINR Commun.,E-2001-265,2002.

Figure 4: Two body weak decay Ξ^- hyperon $\rightarrow \pi^- + \Lambda$: a)first event;b) second event.

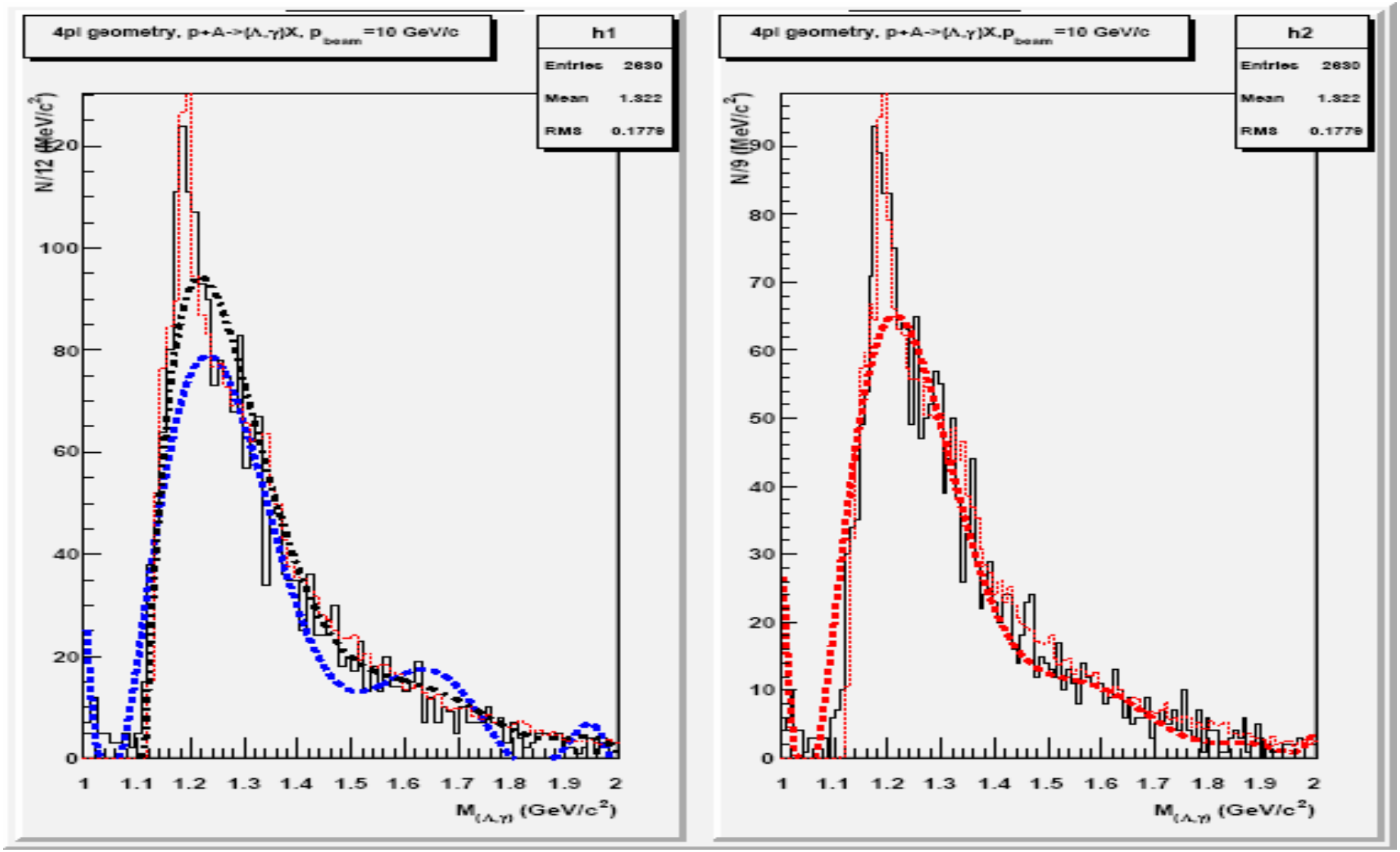
Preleminary spectrum for ($\Lambda\gamma$)





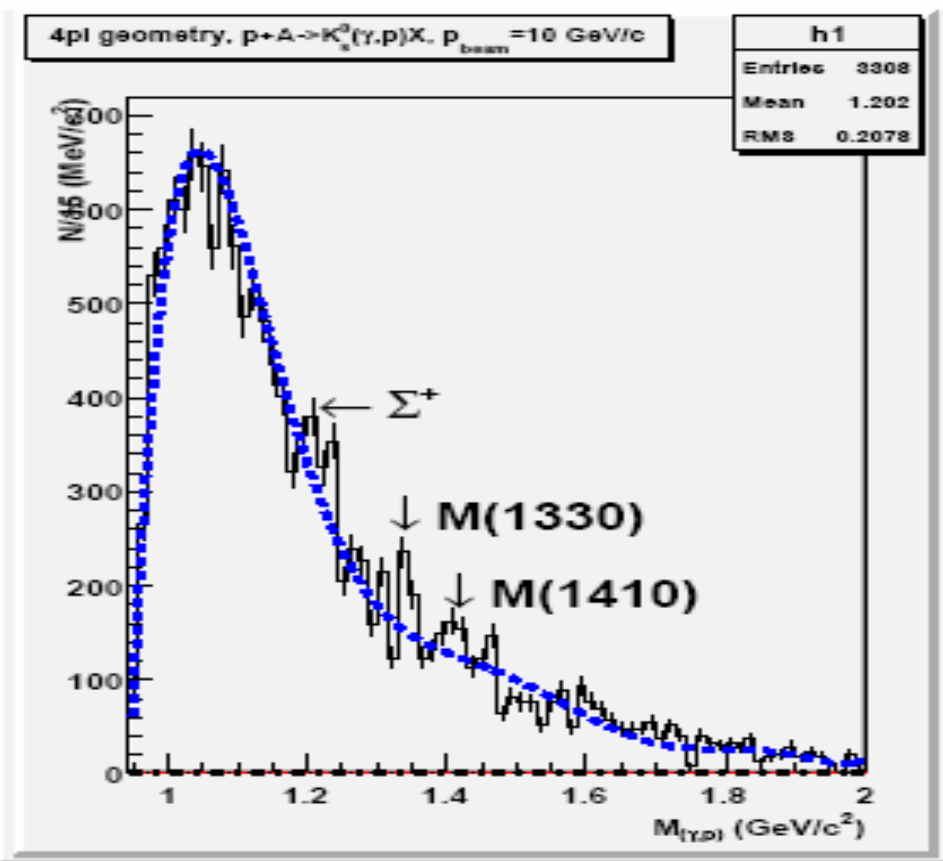
The cross section of production for $\Sigma^0(1189)$ ($\approx$700 events, with geometrical weights of $\langle w_\gamma \rangle$=4.1) is equal to $\approx$ 1.3 mb at 10 GeV/c for p+C interaction at 10 GeV/c which is $\approx$ more 1.5 **times** larger than simulated cross section by FRITIOF. **The observed width of Σ^0 is $\approx$2 times larger than value of experimental errors.** There are also enhancements in mass ranges of 1290,1320 ,1360, 1410, 1560 and 1630 at bin sizes 12 and 9 MeV/c^2 which are can be reflection for enhanement productions from well known hyperons in effective mass spectrum from decay channel $\Lambda\pi^0$.

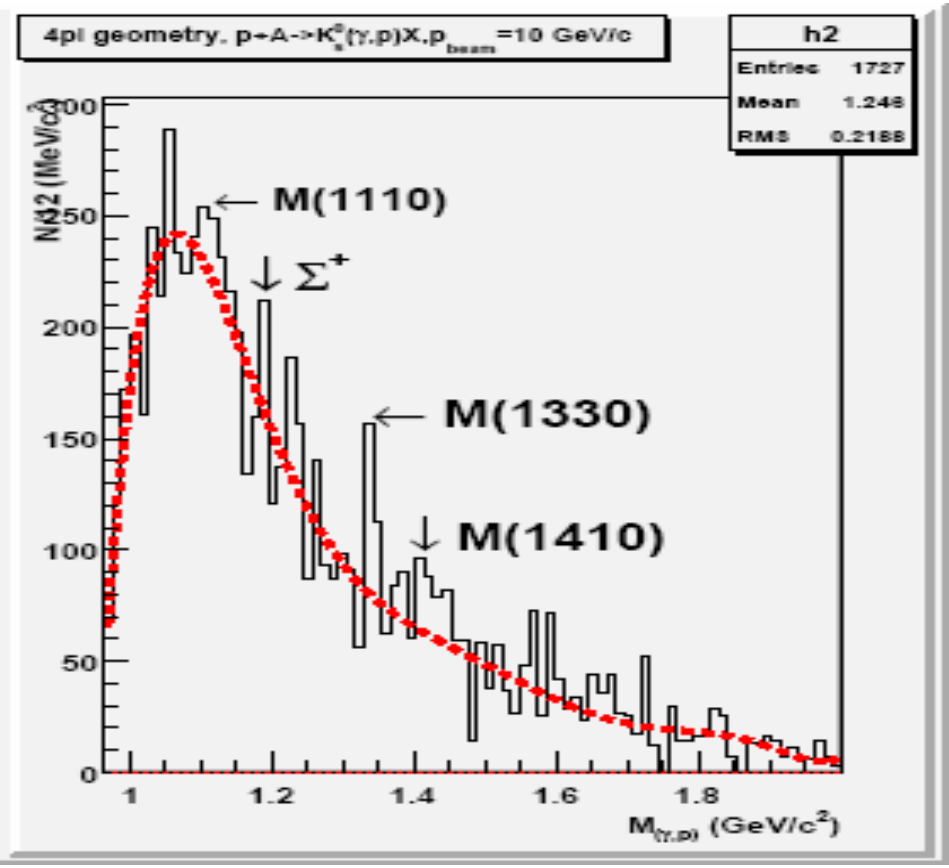
Preleminary spectrum for ($\Lambda\gamma$)



The $\Lambda\gamma$ effective mass distribution without geometrical efficiency for Λ and γ. There are same enhancements in mass range of 1190,1290,1320,1380 and 1480 Mev/c^2.

Preliminary spectrum for (γ p) subsystem





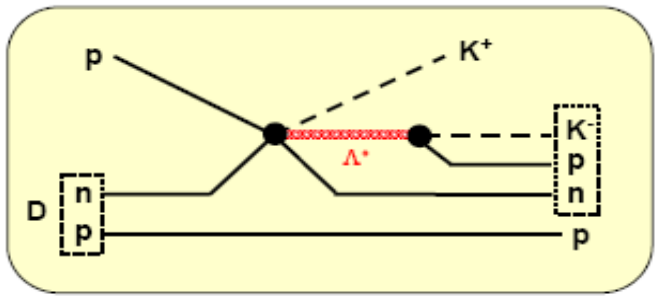
The observed peaks in mass range of Σ^+(1189)(6 S.D.) and 1230 MeV/c^2 is reflection from decay pπ^0 (51.57 %). The peak in mass range of 1230 MeV/c^2 can interpreted as shift mass of Σ^+ in versus of different γ-s registered from decay of π^0 . The significant signals have observed in mass range of 1330 MeV/c^2 (7 S.D.) This can interpreted as Λ state at 1330 MeV/c^2 that have been suggested in Ya.I. Azimov et al., Phys. Rev. C 68, 045204 (2003). There are small enhancements in mass range of 1050, 1110 and 1410 MeV/c^2.

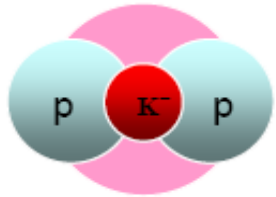
(Λ,p) spectra

•Recently, the existence of discrete nuclear bound states of $K^{0bar}p$ has been predicted with phenomenological Kaonic Nuclear Cluster (KNC) model which is based on the experimental information on the $K^{0bar}N$ scattering lengths, kaonic hydrogen atom and the Λ*(1405) resonance.

Λ(1405)-Doorway Process

T. Yamazaki & Y. Akaishi, Phys. Lett. B535 (2002) 70.





Iso-doublet

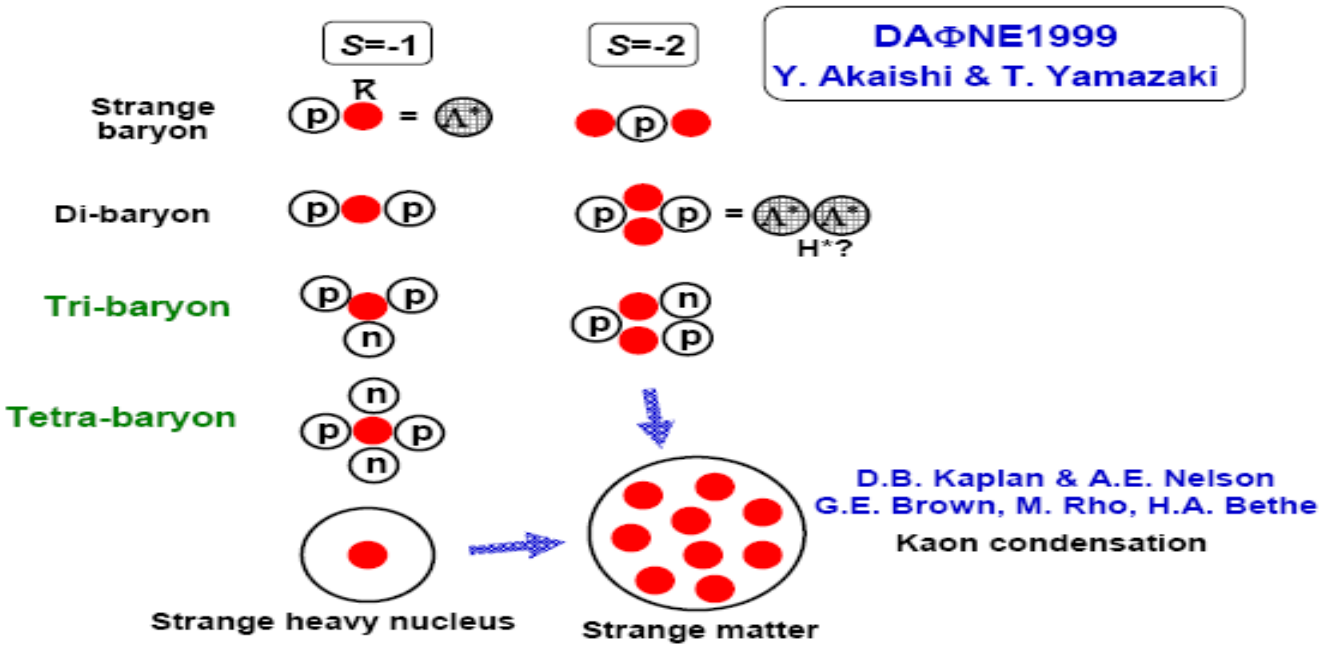
T=1

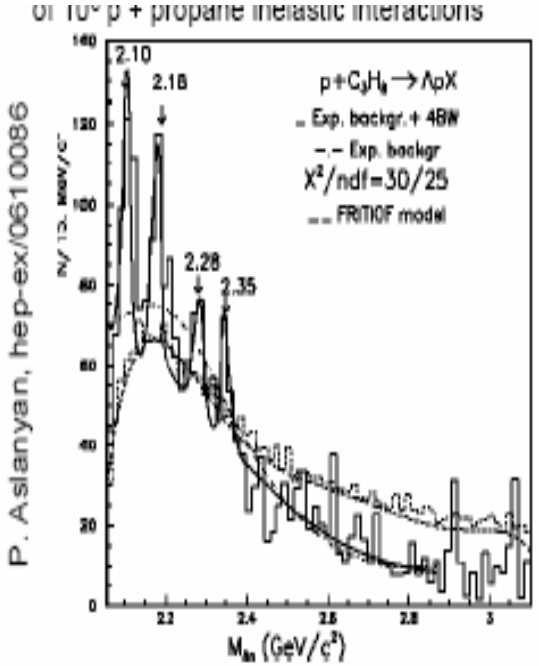
D(p,p'K⁺)pnK⁻

(p,K⁺) S⁺(3140)

Missing mass spectroscopy

Few-Body $\bar{K}N$ Systems





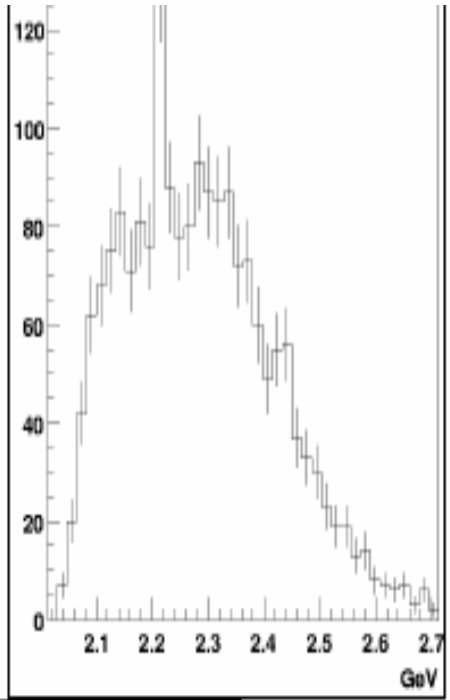
10^4 events

Cuts:

IM(Λ) in [1085 – 1145] MeV and cosΘ < -0.4

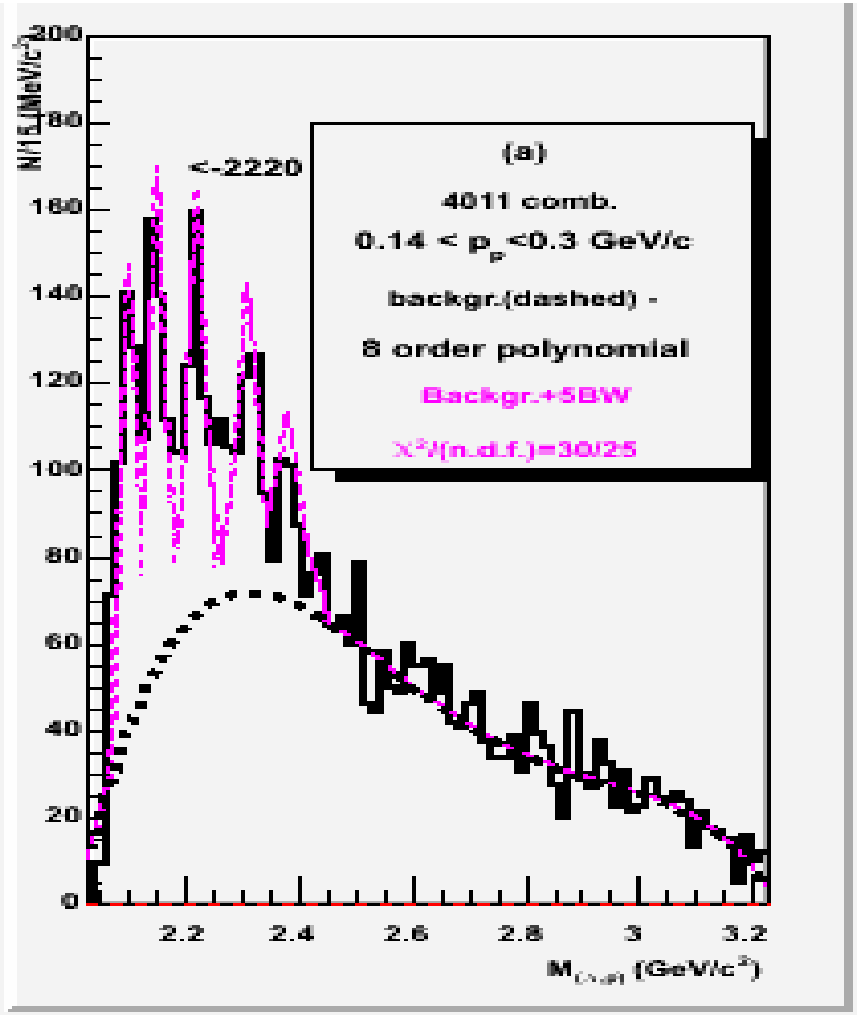
Θ – angle between Λ and K^0_S

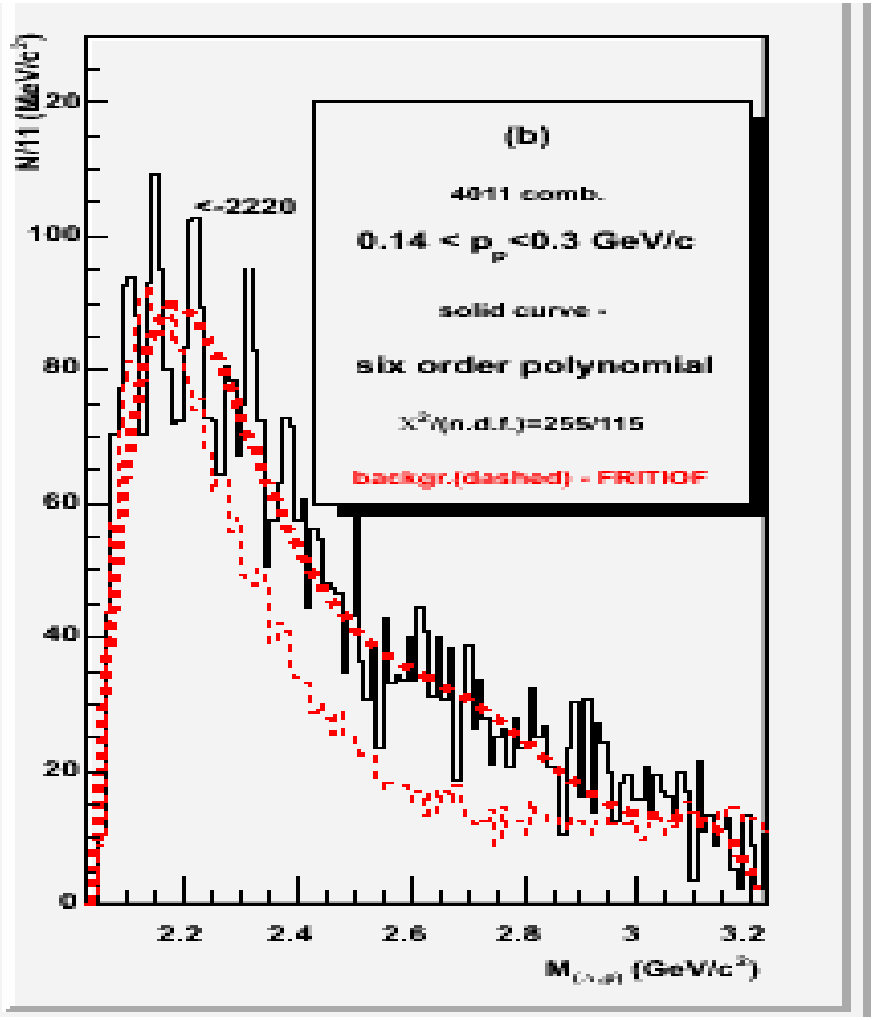
→ talk by P. Aslanyan



		M (MeV)	Γ (MeV)	P/Λ	P/(IN)	Sign (σ)
FOPI	HI: Al+Al	2120 ± 10	59 ± 12	$1.7 \cdot 10^{-2}$		5.0
	HI: Ni+Ni	2140 ± 10	59 ± 19	$2.2 \cdot 10^{-2}$		5.4
FINUDA PRL 94(2005)212303	K^- stopped on ^{12}C, $^{6,7}Li$	2255 ± 9	67 ± 14	$3\text{-}4 \cdot 10^{-2}$	$1. \cdot 10^{-3}$	? (10)
Obelix	$\bar{p}$ stopped in ^4He	2209 ± 5	< 24.4		$>1.4 \cdot 10^{-4}$	3.7
Dubna	p + A	2100, 2180, ...	<10		?	?

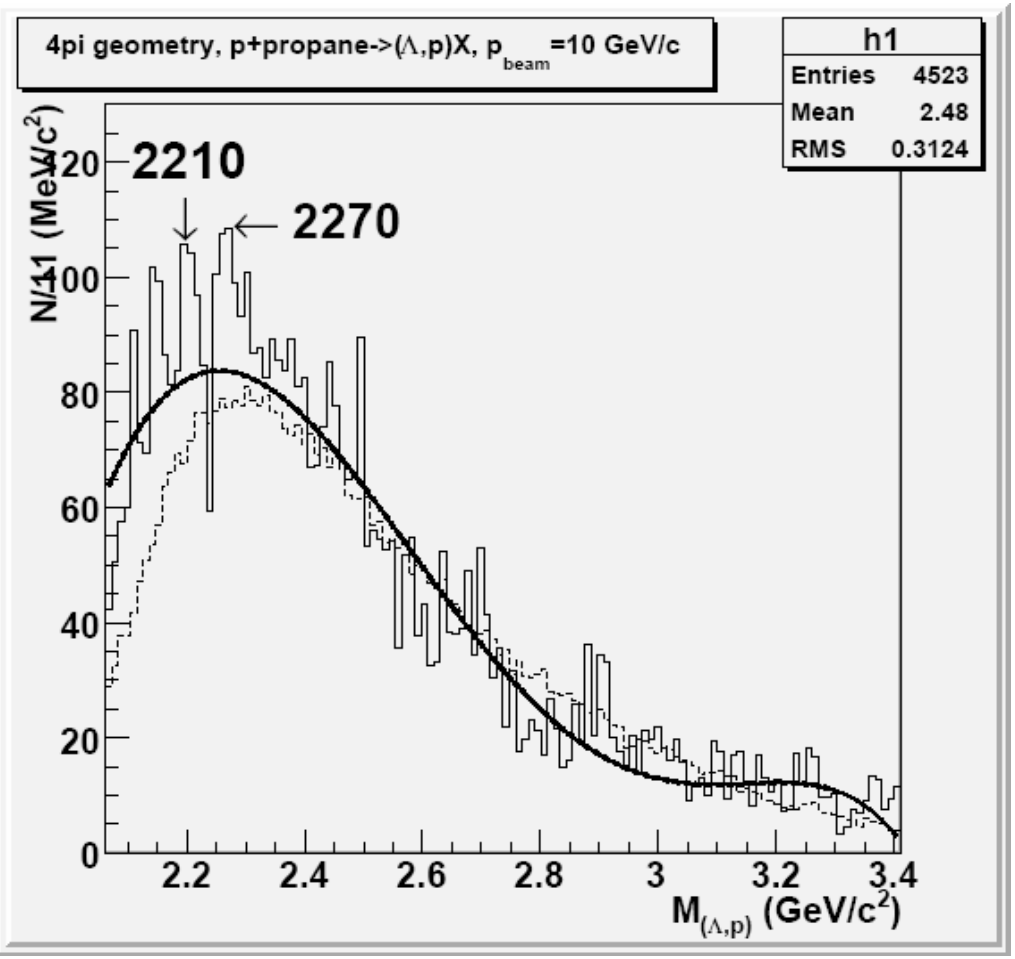
(Λ,p) spectrum with stopped protons

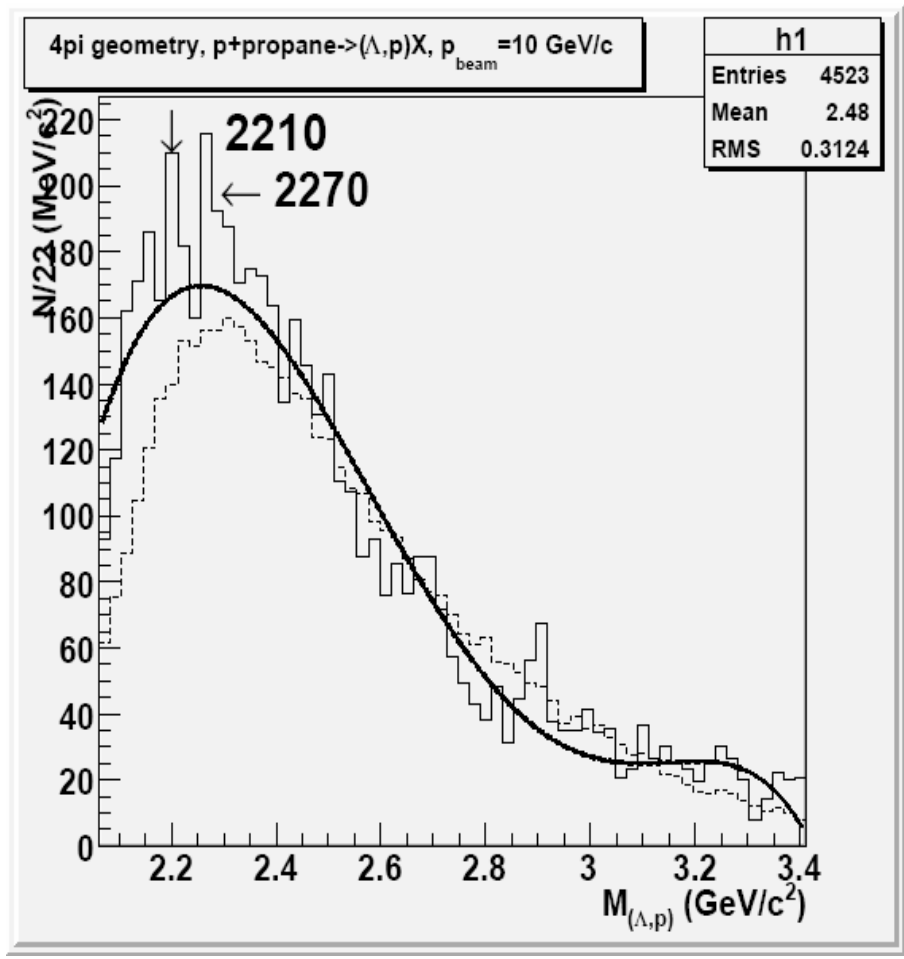




The Λp effective mass distribution for 4011 combinations **for stopped protons with a momentum of 0.14≤ P ≤ 0.30 GeV/c.** The momentum resolution for stopped protons is equal to Δp/p=1% . In this case we have good statistic and effective mass resolution ΔM/M≈0.6%.

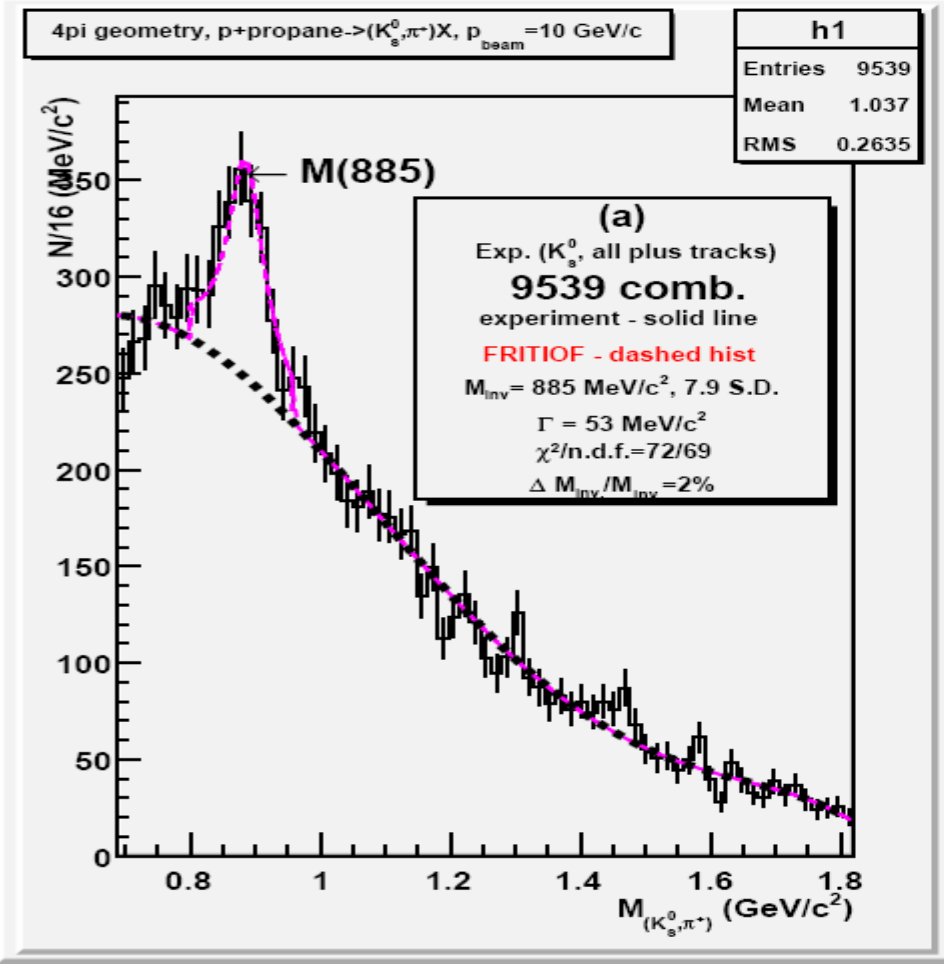
(Λ,p) spectrum with relativistic protons

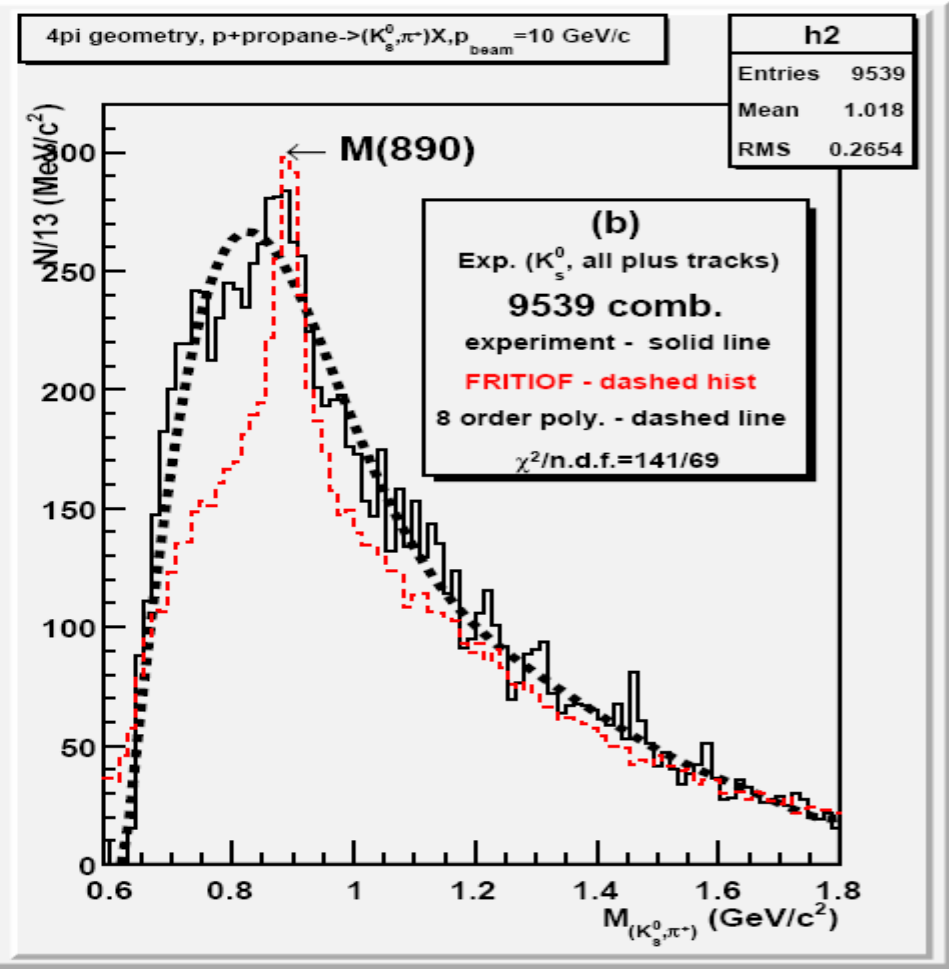




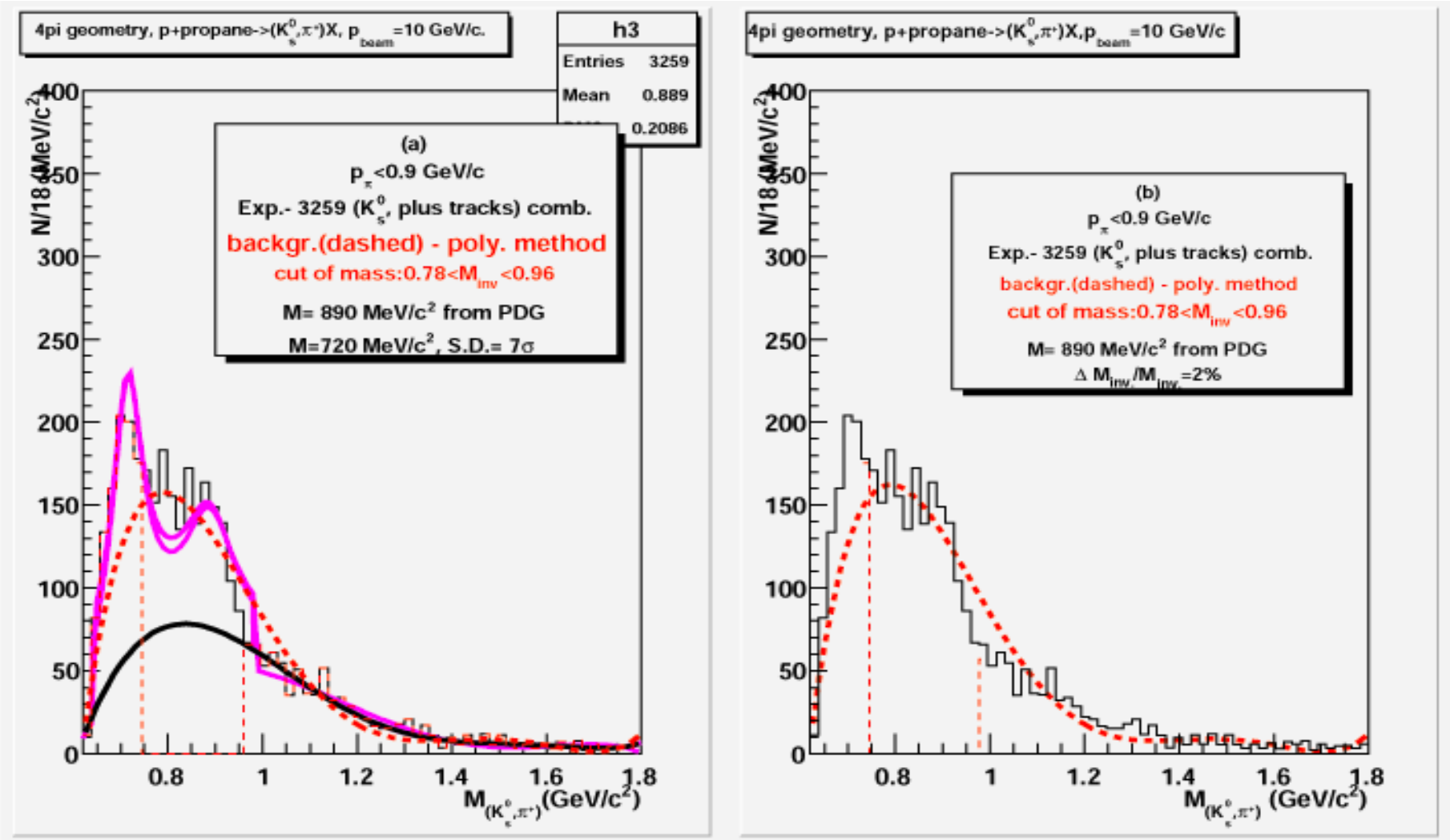
Recent Λp effective mass distribution for 4523 comb. **with relativistic protons at momentum of P >1.5 GeV/c** is shown in Figure. The solid curve is the 6-order polynomial function (χ^2/n.d.f=270/126). Backgrounds for analysis of the experimental data are based on FRITIOF and the polynomial methods. There are significant enhancements in mass ranges of 2145(4.4 S.D.), 2210(4.7 S.D.), 2270(4.0 S.D.) and small enhancements in mass ranges of 2105,2440, 2670 and 2900 MEv/c^2.

$K^0_s\pi^+$ - spectra





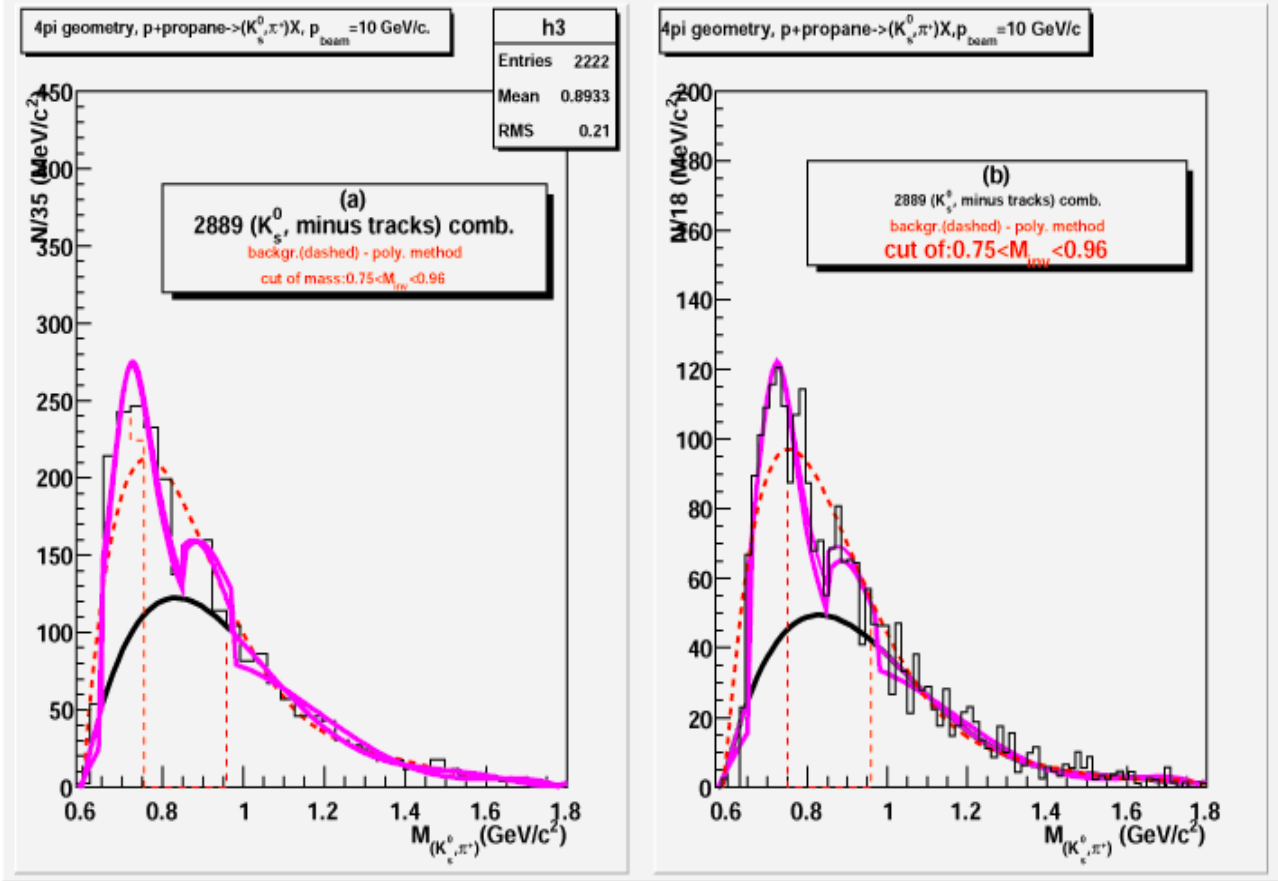
The effective mass distribution for all $K^0_s\pi^+$ -combinations from reaction *pA* .The solid curve is the background taken in the form of 8-th degree polynomial plus 1BW. The dashed histogram is the background by FRITIOF. The invariant mass has significant enhancement in range of 885 Mev/c^2 ,7.9 S.D.(from PDG). The cross section of K*(892) production (430 exp.events) is equal to 0.46 mb at 10 GeV/c for p+C interaction.



The solid curve is the sum of 2BW and background (black) taken in the form of a superposition of polynomial up to the 6-th degree. The dashed curve(red) is the background by polynomial without mass range of $0.75 < M_{K\pi} < 0.98$ MeV/c^2 when a 1BW function was used.

$K^0_s\pi^-$ - spectrum

The solid curveis the sum of 2BW and background (black) taken in the form of a superposition polynomial up to the 6-th degree. The dashed curve (red) is the background by polynomial without mass range of $0.75< M_{K\pi} <0.96$ MeV/c^2 when was used 1BW function.



Resonance decay mode	$M_{K\pi}$ MeV/c^2	Experimental Width (Γ_e) MeV/c^2	Γ MeV/c^2	The statistical significance
$K^0_s\pi^\pm$	885	70	52	6.0-8.2
$K^0_s\pi^\pm$	780	30	12	2.5- 4.2
$K^0_s\pi^\pm$	720-730	55-145	35-125	4.1-15.2

PDG 2005

$\Theta(1540)^+$ $I(J^P) = 0(?^?)$ Status: **

A REVIEW GOES HERE – Check our WWW List of Reviews

$\Theta(1540)^+$ MASS

As is done through the *Review*, papers are listed by year, with the latest year first, and within each year they are listed alphabetically. NAKANO 03 was the earliest paper.

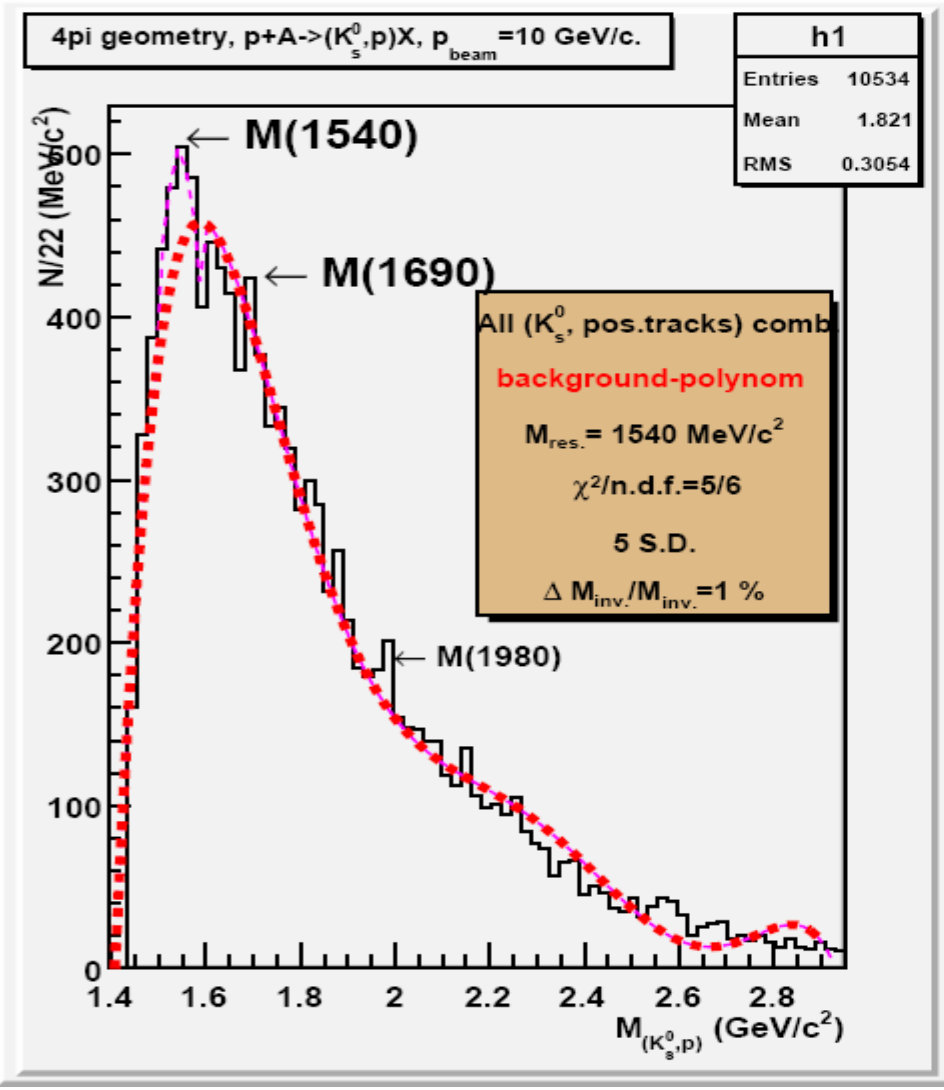
Since our 2004 edition, there have been several new claimed sightings of the $\Theta(1540)^+$ (see entries below marked with bars to the right), but there have also been several searches with negative results:

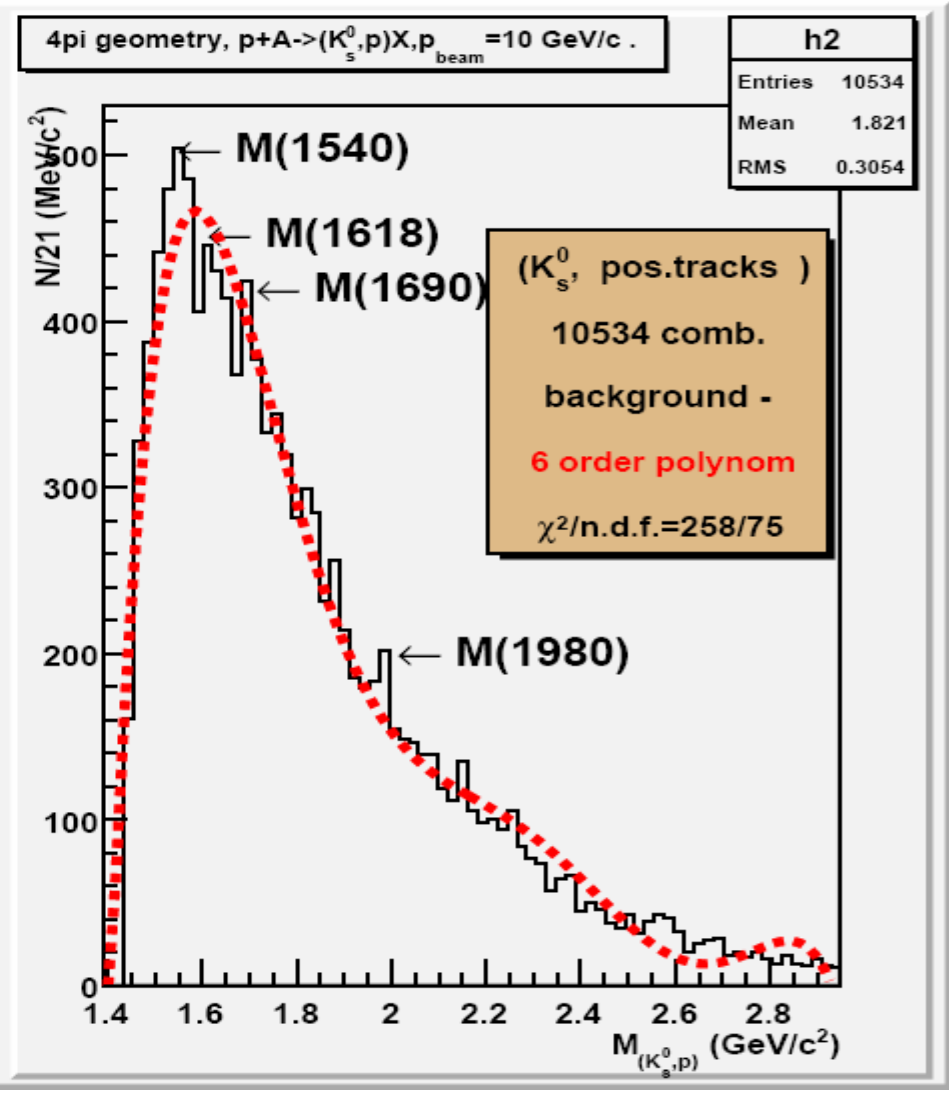
- ANTIPOV 04 (SPHINX Collab.) in $pN \to (nK^+, pK^0_S,$ or $pK^0_L)\ \overline{K}^0 N$ in proton–carbon reactions at 70 GeV/c;
- BAI 04G (BES Collab.) in J/ψ and $\psi(2S)$ decays;
- SCHAEL 04 (ALEPH Collab.) in Z decays;
- ABT 04A (HERA-B Collab.) in p nucleus reactions at midrapidity and $\sqrt{s}$=41.6 GeV;
- LONGO 04 (HyperCP Collab.) in interactions of a high-energy beam of π^+, K^+, p, and charged hyperons with tungsten.

In general, these experiments with negative results have many more events than do the experiments with positive results. (Against this, however, it may be argued that the recent negative results are often from experiments with different reactions or at different energies from the experiments with positive results.)

Furthermore, the $\Theta(1540)^+$ finds almost no support from the claimed observations of other pentaquarks, the $\Phi(1860)$ and the $\Theta_c(3100)$, for which the evidence is very weak. (See the Listings following the $\Theta(1540)^+$.) Thus we have reduced the status of the $\Theta(1540)^+$ to two stars.

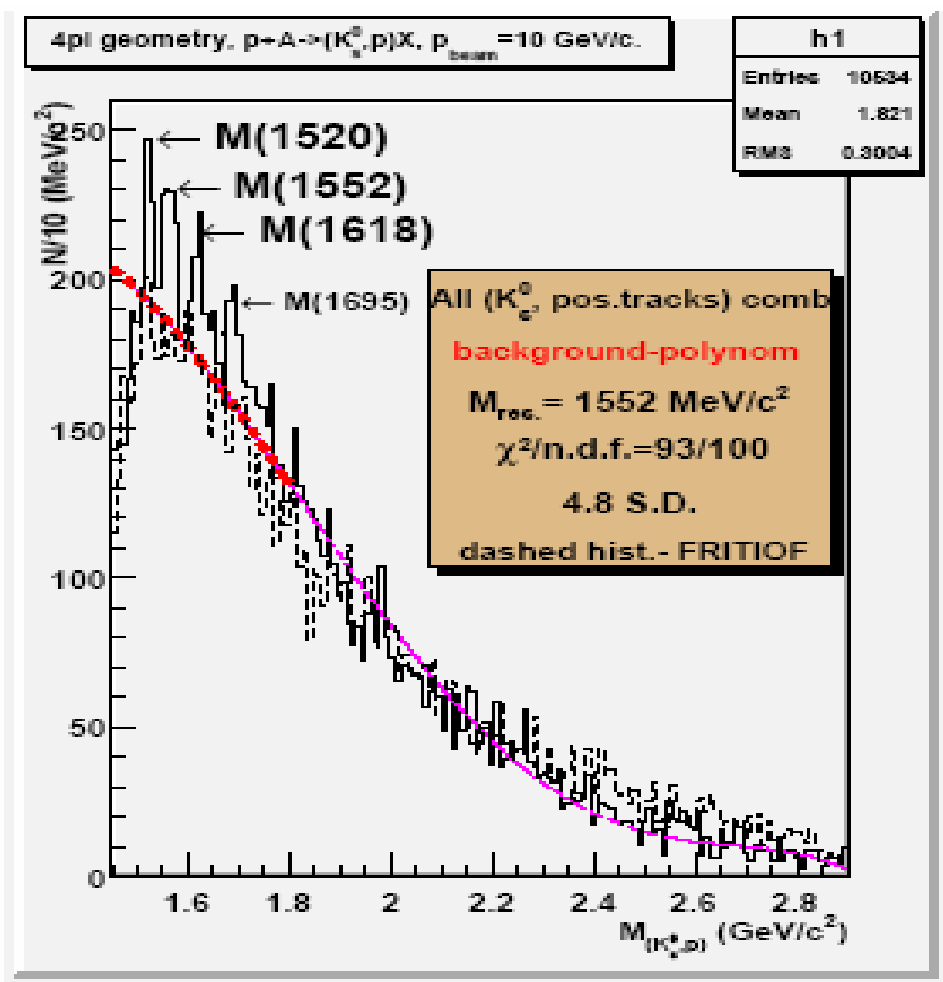
($K^0_s p$) – spectrum for all combination

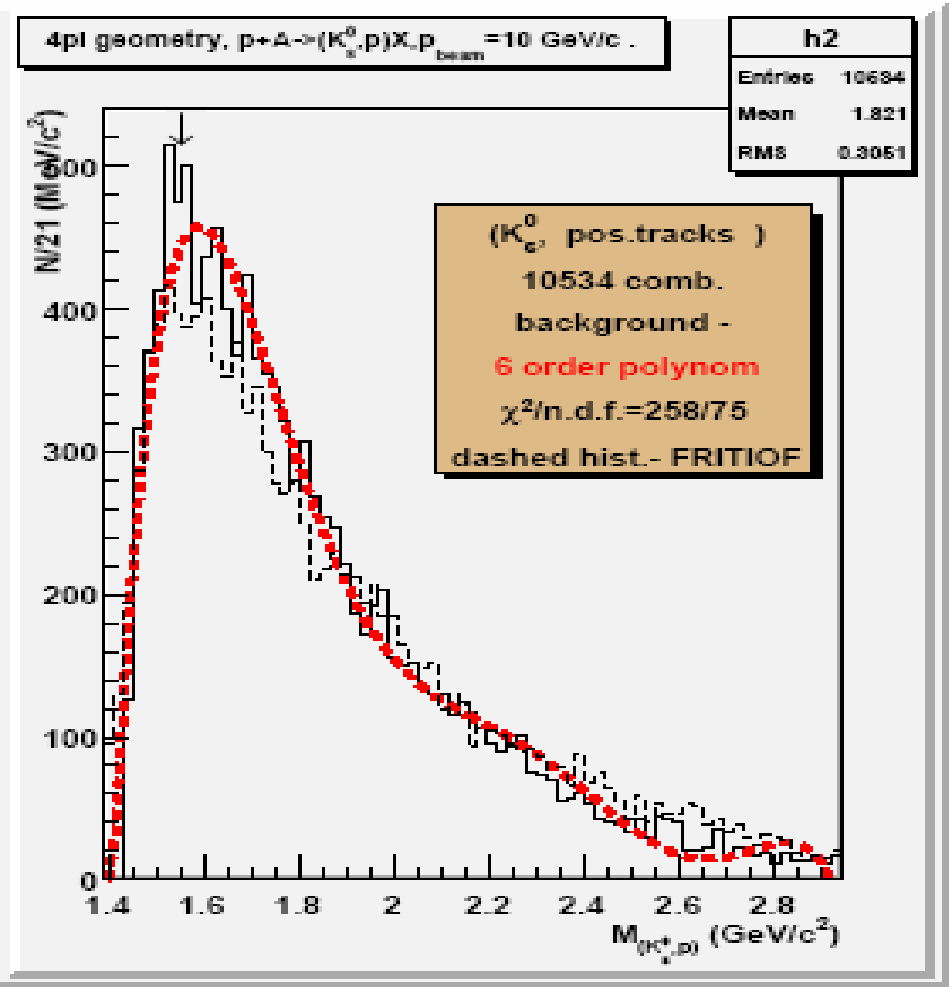




The ($K^0_s p$) effective mass distribution for all 10534 combinations with bin size 22 MeV/c^2. The dashed curves(Fig.) are the background by the polynomial method.There is significant enhancement in mass region M(1540)(5 S.D., Γ_e=45 MeV/c^2) with width $\leq$ 30 MeV/c^2. There are small enhancements in mass regions of 1618(3.5 S.D.),1690(3.8 S.D.) and 1980(2.8 S.D.) MeV/c^2 , because is χ2/n.d.f.=229/75

($K^0_s p$) – spectra for all combination with bin sizes 10 and 21MeV/c^2

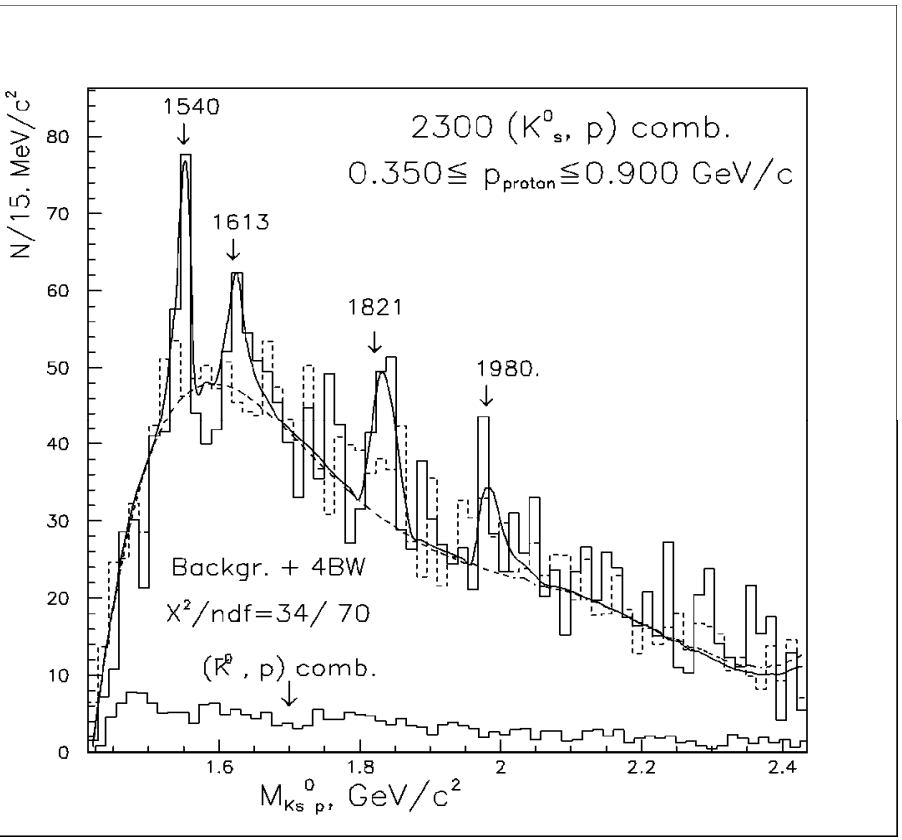


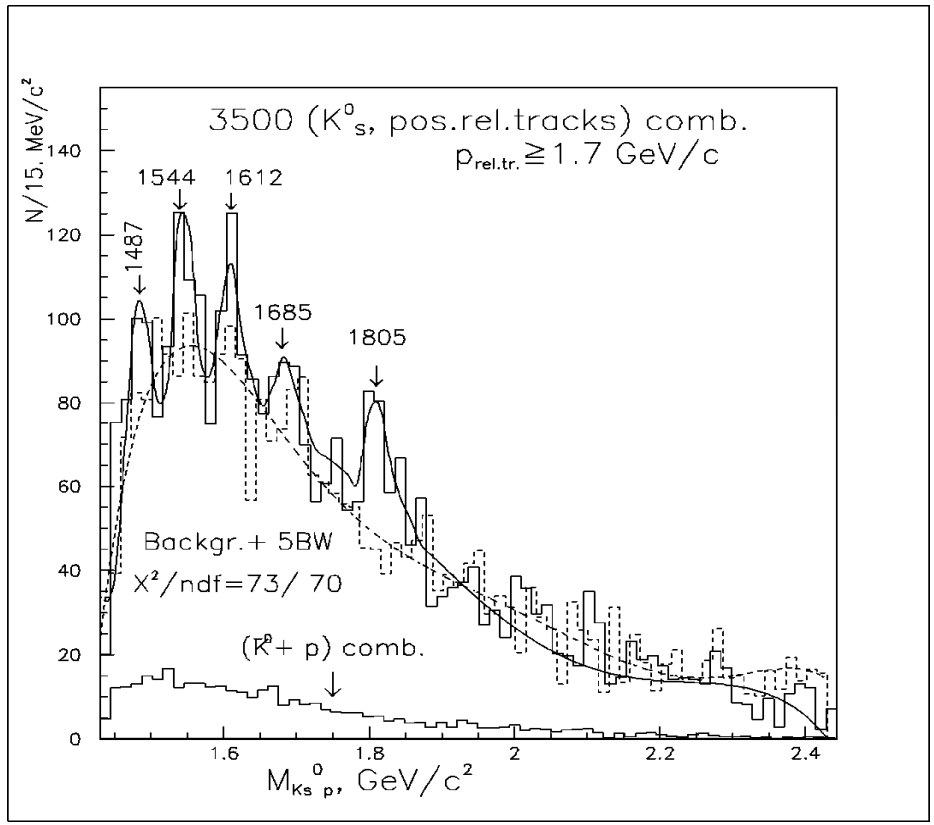


The ($K_s{}^0 p$) effective mass spectra shows significant resonant structures with M = 1520 (≥4.5 S.D., Γ≤13 MeV/c2),1552(≥ 5.9 S.D., Γ≤ 15 MeV/c^2), 1618(3.8 S.D., Γ ≈36 MeV/c^2), and 1695 (3.8 S.D., Γ≈40 MeV/c^2). There are small enhancement in mass ranges of 1750, 1820 and 1980 MeV/c^2 (Figure).

$K_s^0 p$ - spectra

P.Aslanyan et al., JINR, E1-2004-137,2004; Nucl. Physics A 755, 375, (2005)(cited105).





The $K_s^0 p$ effective mass distribution for identified protons with a momentum of 0.350≤ P ≤ 0.900 GeV/c is shown in Figure. The solid curve is the sum of the background and 4 Breit-Wigner resonance curves.The cross section is equal to 90 μb for p+propane reaction.

The $K_s^0 p$ invariant mass distribution at momentum P$p \geq$ *1.7 GeV/c* (3500 combinations) is shown in Figure. The histogram is approximated by a polynomial background curve and by 5 resonance curves taken in the Breit-Wigner form. The dashed curve is the background taken in the form of a superposition of Legendre polynomials up to the 6 -th degree.

Summary

- **The invariant mass** spectra **for** (Λ, π), (K^0_s, π) **and** (Λ, γ) **has observed well known strange baryons** $\Sigma^{*+}(1385)$, K*(890) and Σ^0 (from PDG). Test method.
- **The experimental** Λ/π+ **ratio in the pC reaction is approximately 1.5 times larger than ratio from pp reactions or from simulated pC reaction by FRITIOF model at momentum 10 GeV/c.**
- **A number of important peculiarities were observed in pA** $\rightarrow \Lambda(K^0_S)$ **X reactions in the effective mass spectrum for exotic states with decay modes (TABLE 1) : 1) (Λ, π), (Λ,γ), (p , γ), (Λ, π ,π), (Λ,p), (Λ, p, p), (Λ, Λ), (ΛK^0_s);**
- **Peaks for (Λ,p) and (Λ, p, p) spectra are agreed with experimental data from the recently reports of FOPI, E471(KEK), OBELIX, FINUDA collaborations, but there are some conflicting with peak positions or widths.**
- **The mass and width of exited** $\Sigma^{*-}(1385)$ **are observed with mass of M(1370) and two time larger** width **in medium of carbon** than data from PDG. **In particularly, such of behavior can explain as a sum of contributions from enhancement productions of stopping** Ξ^-.
- **There are signals in maas range of** $\Sigma^{*\pm}(1480)$, $\Sigma^{*0}(1480)$ **by channels of** (Λ, π), (Λ,γ) which conformed from reports of **SVD2 and COSY collaborations.**
- **There is peak in maas range of M (1330) (as** Λ**) by channel of (p , γ)(preliminary).**
- **There are enhancement productions from all observed hyperons than calculated geometrical cross sections.**
- These peaks (1750±18) and (1795±20) MeV/c^2 observed in mass spectrum of (ΛK^0_s) are possible candidates for two pentaquark states: the N^0 with quark content udsds decaying into ΛK^0 and the Ξ^{*0} with quark content udssd decaying into ΛK^0(bar).

P. Aslanyan, JINR, September 30, 2008

Table 1. The observed signals from mass spectra with Λ subsystems

Decay mode	M (MeV/c^2)	Γ(MeV/c^2)	S.D.
$\Lambda\gamma$	Σ^0	55(PDG)	12.0
$\Lambda\pi^+$	Σ^{*+}(1382)	40(PDG)	12.9
$\Lambda\pi^+\pi^-$	Λ*(1600)	55(PDG)	5.5
	Λ*(1750)	54(PDG)	4.2
	Λ*(1830)	51(PDG)	5.6
$\Lambda\pi^-$	Σ^{*-}(1370)	93 (PDG)	11.3
	Ξ^- (1320)	-	3.0
	Σ^{*-} (1480)	-	3.2
Λp	2100	24	5.7
	2150	19	5.7
	2220	28	6.1
	2310(2270)	30	3.7
	2380	32	3.5
ΛΛ	2370	-	4.5
Λpp	3140	40	6.1
	3320	-	4.8
ΛK^0_s	1750	14	5.6
	1795	26	3.3

• **The observed peak in mass range of 1540 (width 30 MeV/c^2) for primary (K^0_S,p) spectrum can interpreted as a sum of reflection from two peaks in mass ranges of 1520 and 1552 MeV/c^2 with widths $\leq$ 15 MeV/c^2.**

•Table 2 shows the effective mass and width for resonances which are obtained from the data for identified protons at momentum range of 0.350$\leq$ $P_{proton} \leq$ 0.900 GeV/c.

•The analysis of simulated data for effect/background ratios at momentum of 4.5, 10 and 30 GeV/c are shown that necessary for identification of the exotic narrow states are apply kinematical restrictions for separation of protons from π^+ and K^+ combinations at momentum 10 and 30 GeV/c .

Table 2. The observed signals for (K_s^0p) *mass* spectrum

Resonance system	M MeV/c^2	Γ_e MeV/c^2 Experiment	Γ MeV/c^2	The statistical significance N_{sd}
K^0_sp	1540±8	18.2±2.1	9.2±1.8	5.5±0.5
K^0_sp	1613±10	23.6±6.0	16.1±4.1	4.8±0.5
K^0_sp	1821±11	35.9±12.0	28.0±9.4	5.0±0.6

• Peaks in $K^0_s\pi^\pm$ spectrum (below Table 3) are observed candidates for κ scalar meson with mass of 720 S.D. (4.1-15.2 S.D) , 780 MeV/c^2 (2.5 - 4.2 S.D.) and width $\Gamma\approx$(35-125) MeV/c^2 , $\Gamma\approx$12 MeV/c^2 respectively.

•The search and study of decay channels for exotic strange multi-baryon states with Λ and K_s^0 subsystems at FAIR(GSI), JPARC(KEK), Frascati (INFN) and MPD(NICA,JINR) **can get a valuable information about their nature, properties and it will be as a test for observed data on PBC. Higher statistics for new experiments with mass resolution ≈1% and interactions with different nucleus are needed.**

Table 3. The observed signals for mass spectrum

Resonance decay mode	$M_{K\pi}$ MeV/c^2	Experimental Width (Γ_e) MeV/c^2	Γ MeV/c^2	The statistical significance
$K^0_s\pi^\pm$	885(PDG)	70	52	6.0-8.2
$K^0_s\pi^\pm$	780	30	12	2.5- 4.2
$K^0_s\pi^\pm$	720-730	55-145	35-125	4.1-15.2

Present Status of Experimental Investigation of Deeply Bound Kaonic States

T. Yamazaki and Y. Akaishi

ECT*, Trento, June 22, 2006

Present stage

Experiments: premature

KEK $S^0(3115)$ --> Iwasaki's talk

FINUDA: very interesting, but need more studies

GSI p+p, p+d, HI reactions --> Herrmann

Dubna C_3H_8 + p ---> Aslanyan

AGS+KEK (K^-,N) ---> Kishimoto

Coming experiments

GSI --> Buehler

FINUDA

KLOE (AMADEUS) --> Kienle, Zmeskal

J-PARC --> Onishi