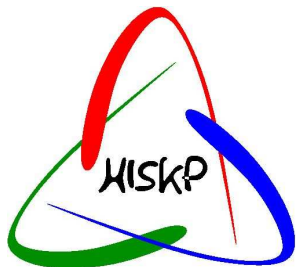


Bonn-Gatchina partial wave analysis: search for high spin baryon states

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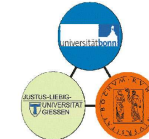
Bonn-Gatchina partial wave analysis group:

A. Anisovich, E. Klempt, V. Nikonov, A. Srantsev, U. Thoma

<http://pwa.hiskp.uni-bonn.de/>



Bonn-Gatchina Partial Wave Analysis



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<u>Data Base</u>	<u>Meson Spectroscopy</u>	<u>Baryon Spectroscopy</u>	<u>NN-interaction</u>	<u>Formalism</u>
<p>Analysis of Other Groups</p> <ul style="list-style-type: none"> • SAID • MAID • Giessen Uni 		<p>BG PWA</p> <ul style="list-style-type: none"> • Publications • Talks • Contacts 		<p>Useful Links</p> <ul style="list-style-type: none"> • SPIRES • PDG Homepage • Durham Data Base • Bonn Homepage
<p>CB-ELSA Homepage</p>				

Responsible: Dr. V. Nikonov, E-mail: nikonov@hiskp.uni-bonn.de
 Last changes: January 26th, 2010.

Search for baryon states

1. Analysis of single meson and double meson photoproduction reactions.

$$\gamma p \rightarrow \pi N, \eta N, K\Lambda, K\Sigma, \pi\pi N, \pi\eta N, \text{CB-ELSA, CLAS, GRAAL.}$$

2. Analysis of single meson and double meson pion-induced reactions.

$$\pi N \rightarrow \pi N, \eta N, K\Lambda, K\Sigma, \pi\pi N.$$

Search for meson states

1. Analysis of the $p\bar{p}$ annihilation at rest and $\pi\pi$ interaction data.
2. Analysis of the $p\bar{p}$ annihilation in flight into two and three meson final state.
3. Analysis of the J/Ψ decays (BES III collaboration).

Analysis of NN interaction

1. Analysis of single and double meson production $NN \rightarrow \pi NN$ and $\pi\pi NN$
2. Analysis of hyperon production $NN \rightarrow K\Lambda p$

A combined analysis of data from different experiments

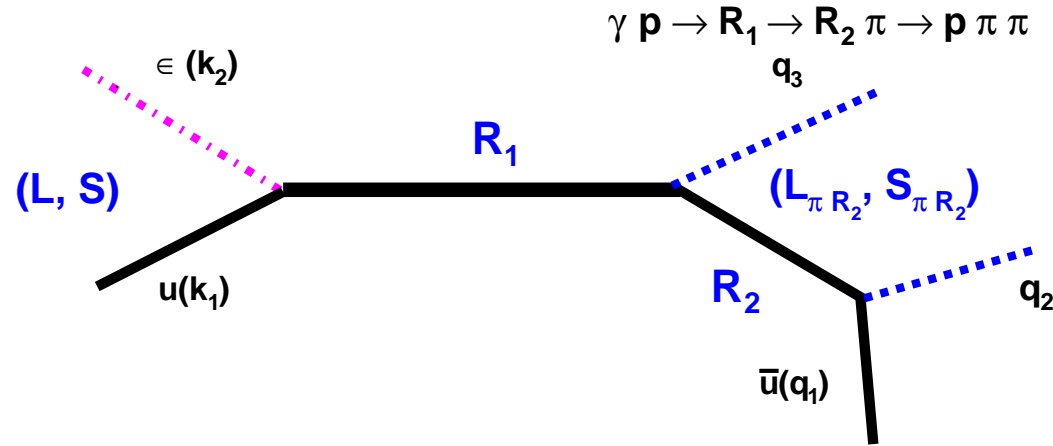
- 1. Fully relativistic approach.**
- 2. Convenient for combined analysis of single and multi-meson photoproduction.**
- 3. Energy dependent, which allow us to impose directly unitarity and analyticity conditions.**
- 4. Convenient for calculation of triangle and box diagrams and for projection of the t and u -channel exchange amplitudes to the partial waves in s -channel.**

A. Anisovich, E. Klempt, A. Sarantsev and U. Thoma, Eur. Phys. J. A 24, 111 (2005)

A. V. Anisovich and A. V. Sarantsev, Eur. Phys. J. A 30 (2006) 427

A. V. Anisovich, V. V. Anisovich, E. Klempt, V. A. Nikonov and A. V. Sarantsev, Eur. Phys. J. A 34 (2007) 129.

Resonance amplitudes for meson photoproduction



General form of the angular dependent part of the amplitude:

$$\bar{u}(q_1) \tilde{N}_{\alpha_1 \dots \alpha_n} (R_2 \rightarrow \mu N) F_{\beta_1 \dots \beta_n}^{\alpha_1 \dots \alpha_n} (q_1 + q_2) \tilde{N}_{\gamma_1 \dots \gamma_m}^{(j) \beta_1 \dots \beta_n} (R_1 \rightarrow \mu R_2)$$

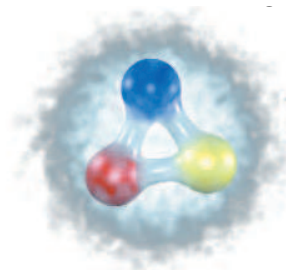
$$F_{\xi_1 \dots \xi_m}^{\gamma_1 \dots \gamma_m} (P) V_{\xi_1 \dots \xi_m}^{(i) \mu} (R_1 \rightarrow \gamma N) u(k_1) \varepsilon_\mu$$

$$F_{\nu_1 \dots \nu_L}^{\mu_1 \dots \mu_L} (p) = (m + \hat{p}) O_{\alpha_1 \dots \alpha_L}^{\mu_1 \dots \mu_L} \frac{L+1}{2L+1} g_{\alpha_1 \beta_1}^\perp - \frac{L}{L+1} \sigma_{\alpha_1 \beta_1} \prod_{i=2}^L g_{\alpha_i \beta_i} O_{\nu_1 \dots \nu_L}^{\beta_1 \dots \beta_L}$$

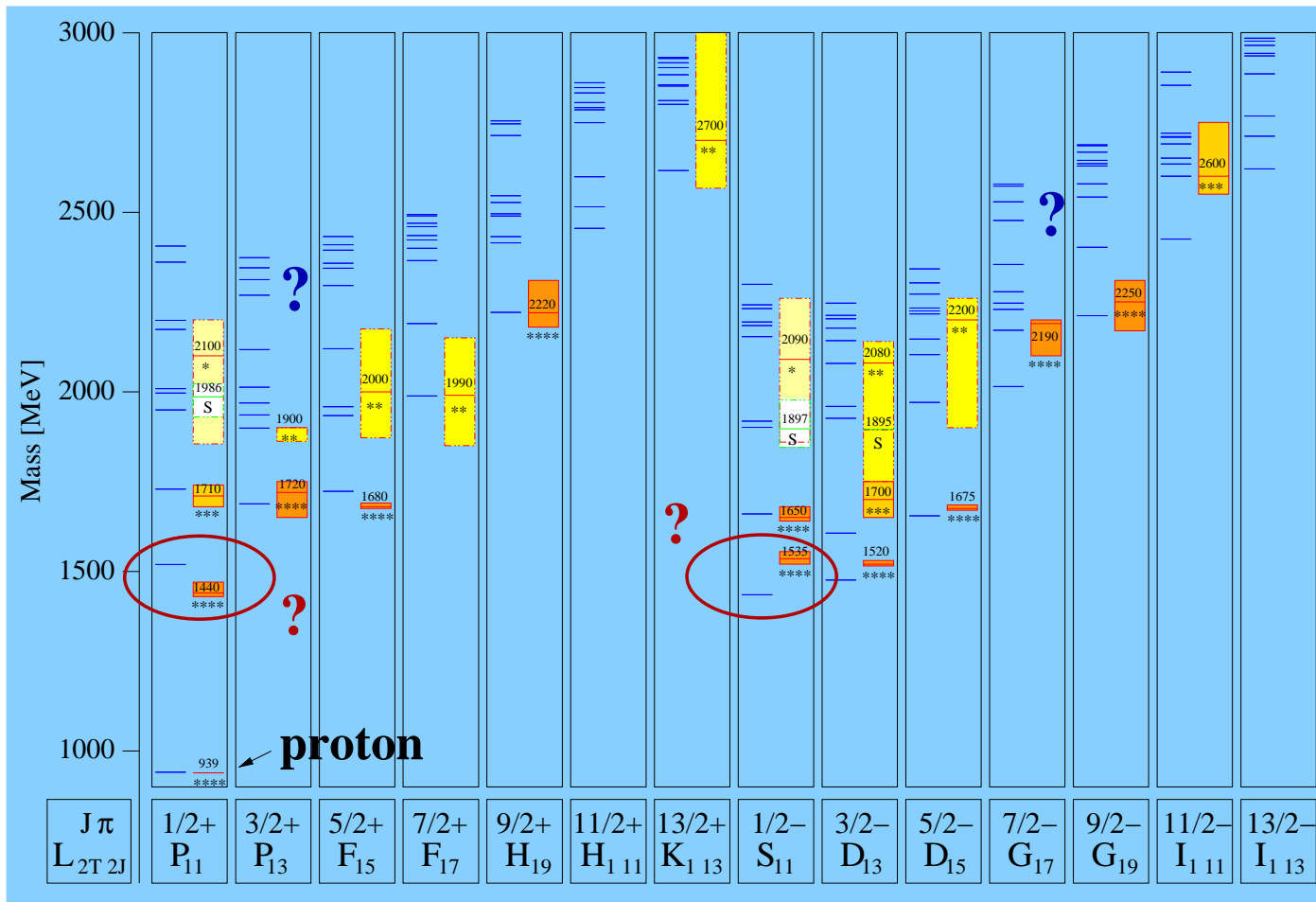
$$\sigma_{\alpha_i \alpha_j} = \frac{1}{2} (\gamma_{\alpha_i} \gamma_{\alpha_j} - \gamma_{\alpha_j} \gamma_{\alpha_i})$$

N^* - resonances in the quark model

Nukleon
 10^{-15} m



U. Loering, B. Metsch, H. Petry et al. (Bonn)



↔

Constituent quarks

Confinement-potential

Residual interaction

Data Base

Pion induced reactions (χ^2 analysis).

Observable	N_{data}	$\frac{\chi^2}{N_{\text{data}}}$		Observable	N_{data}	$\frac{\chi^2}{N_{\text{data}}}$	
$N_{1/2-}^* \text{ S}_{11}(\pi\text{N} \rightarrow \pi\text{N})$	104	1.81	SAID	$\Delta_{1/2-} \text{ S}_{31}(\pi\text{N} \rightarrow \pi\text{N})$	112	2.27	SAID
$N_{1/2+}^* \text{ P}_{11}(\pi\text{N} \rightarrow \pi\text{N})$	112	2.49	SAID	$\Delta_{1/2+} \text{ P}_{31}(\pi\text{N} \rightarrow \pi\text{N})$	104	2.01	SAID
$N_{3/2+}^* \text{ P}_{13}(\pi\text{N} \rightarrow \pi\text{N})$	112	1.90	SAID	$\Delta_{3/2+}^* \text{ P}_{33}(\pi\text{N} \rightarrow \pi\text{N})$	120	2.53	SAID
$\Delta_{3/2-}^* \text{ D}_{33}(\pi\text{N} \rightarrow \pi\text{N})$	108	2.56	SAID	$N_{3/2-}^* \text{ D}_{13}(\pi\text{N} \rightarrow \pi\text{N})$	96	2.16	SAID
$N_{5/2-}^* \text{ D}_{15}(\pi\text{N} \rightarrow \pi\text{N})$	96	3.37	SAID	$\Delta_{5/2+} \text{ F}_{35}(\pi\text{N} \rightarrow \pi\text{N})$	62	1.32	SAID
$\Delta_{7/2+} \text{ F}_{37}(\pi\text{N} \rightarrow \pi\text{N})$	72	2.86	SAID	$N_{7/2-}^* \text{ G}_{17}(\pi\text{N} \rightarrow \pi\text{N})$	102	2.69	SAID
$d\sigma/d\Omega(\pi^- p \rightarrow n\eta)$	70	1.96	Richards et al.	$d\sigma/d\Omega(\pi^- p \rightarrow n\eta)$	84	2.67	CBALL
$d\sigma/d\Omega(\pi^- p \rightarrow K\Lambda)$	598	1.68	RAL	$P(\pi^- p \rightarrow K\Lambda)$	355	1.96	RAL+ANL
				$\beta(\pi^- p \rightarrow K\Lambda)$	72	2.45	RAL
$d\sigma/d\Omega(\pi^+ p \rightarrow K^+\Sigma)$	609	1.24	RAL	$P(\pi^+ p \rightarrow K^+\Sigma)$	307	1.49	RAL
				$\beta(\pi^+ p \rightarrow K^+\Sigma)$	7	1.97	RAL
$d\sigma/d\Omega(\pi^- p \rightarrow K^0\Sigma^0)$	259	0.85	RAL	$P(\pi^- p \rightarrow K^0\Sigma^0)$	95	1.25	RAL

Data Base

π and η photoproduction reactions (χ^2 analysis).

Observable	N_{data}	$\frac{\chi^2}{N_{\text{data}}}$		Observable	N_{data}	$\frac{\chi^2}{N_{\text{data}}}$	
$d\sigma/d\Omega(\gamma p \rightarrow p\pi^0)$	1106	1.34	CB-ELSA	$d\sigma/d\Omega(\gamma p \rightarrow p\pi^0)$	861	1.46	GRAAL
$d\sigma/d\Omega(\gamma p \rightarrow p\pi^0)$	592	2.11	CLAS	$d\sigma/d\Omega(\gamma p \rightarrow p\pi^0)$	1692	1.25	TAPS@MAMI
$E(\gamma p \rightarrow p\pi^0)$	140	1.23	A2-GDH	$\Sigma(\gamma p \rightarrow p\pi^0)$	1492	3.26	SAID db
$P(\gamma p \rightarrow p\pi^0)$	607	3.23	SAID db	$\Gamma(\gamma p \rightarrow p\pi^0)$	389	3.71	SAID db
$H(\gamma p \rightarrow p\pi^0)$	71	1.26	SAID db	$G(\gamma p \rightarrow p\pi^0)$	75	1.50	SAID db
$O_x(\gamma p \rightarrow p\pi^0)$	7	1.77	SAID db	$O_z(\gamma p \rightarrow p\pi^0)$	7	0.46	SAID db
$d\sigma/d\Omega(\gamma p \rightarrow n\pi^+)$	1583	1.64	SAID db	$d\sigma/d\Omega(\gamma p \rightarrow n\pi^+)$	408	0.62	A2-GDH
$\Sigma(\gamma p \rightarrow n\pi^+)$	899	3.48	SAID db	$E(\gamma p \rightarrow n\pi^+)$	231	1.55	A2-GDH
$P(\gamma p \rightarrow n\pi^+)$	252	2.90	SAID db	$\Gamma(\gamma p \rightarrow n\pi^+)$	661	3.21	SAID db
$H(\gamma p \rightarrow p\pi^+)$	71	3.90	SAID db	$G(\gamma p \rightarrow p\pi^+)$	86	5.64	SAID db
$d\sigma/d\Omega(\gamma p \rightarrow p\eta)$	680	1.47	CB-ELSA	$d\sigma/d\Omega(\gamma p \rightarrow p\eta)$	100	2.16	TAPS
$\Sigma(\gamma p \rightarrow p\eta)$	51	2.26	GRAAL 98	$\Sigma(\gamma p \rightarrow p\eta)$	100	2.02	GRAAL 07
$T(\gamma p \rightarrow p\eta)$	50	1.48	Phoenix				

Data Base

Kaon photoproduction (χ^2 analysis).

Observable	N_{data}	$\frac{\chi^2}{N_{\text{data}}}$		Observable	N_{data}	$\frac{\chi^2}{N_{\text{data}}}$	
$C_x(\gamma p \rightarrow \Lambda K^+)$	160	1.23	CLAS	$C_x(\gamma p \rightarrow \Sigma^0 K^+)$	94	2.20	CLAS
$C_z(\gamma p \rightarrow \Lambda K^+)$	160	1.41	CLAS	$C_z(\gamma p \rightarrow \Sigma^0 K^+)$	94	2.00	CLAS
$d\sigma/d\Omega(\gamma p \rightarrow \Lambda K^+)$	1320	0.81	CLAS09	$d\sigma/d\Omega(\gamma p \rightarrow \Sigma^0 K^+)$	1280	2.06	CLAS
$P(\gamma p \rightarrow \Lambda K^+)$	1270	2.21	CLAS09	$P(\gamma p \rightarrow \Sigma^0 K^+)$	95	1.45	CLAS
$\Sigma(\gamma p \rightarrow \Lambda K^+)$	66	1.53	GRAAL	$\Sigma(\gamma p \rightarrow \Sigma^0 K^+)$	42	0.90	GRAAL
$\Sigma(\gamma p \rightarrow \Lambda K^+)$	45	1.65	LEP	$\Sigma(\gamma p \rightarrow \Sigma^0 K^+)$	45	1.11	LEP
$T(\gamma p \rightarrow \Lambda K^+)$	66	1.26	GRAAL 09	$d\sigma/d\Omega(\gamma p \rightarrow \Sigma^+ K^0)$	48	3.76	CLAS
$O_x(\gamma p \rightarrow \Lambda K^+)$	66	1.30	GRAAL 09	$O_z(\gamma p \rightarrow \Lambda K^+)$	66	1.54	GRAAL 09
$d\sigma/d\Omega(\gamma p \rightarrow \Sigma^+ K^0)$	72	0.74	CB-ELSA 10	$P(\gamma p \rightarrow \Sigma^+ K^0)$	24	1.06	CB-ELSA 10
$\Sigma(\gamma p \rightarrow \Sigma^+ K^0)$	15	1.13	CB-ELSA 10				

Data Base

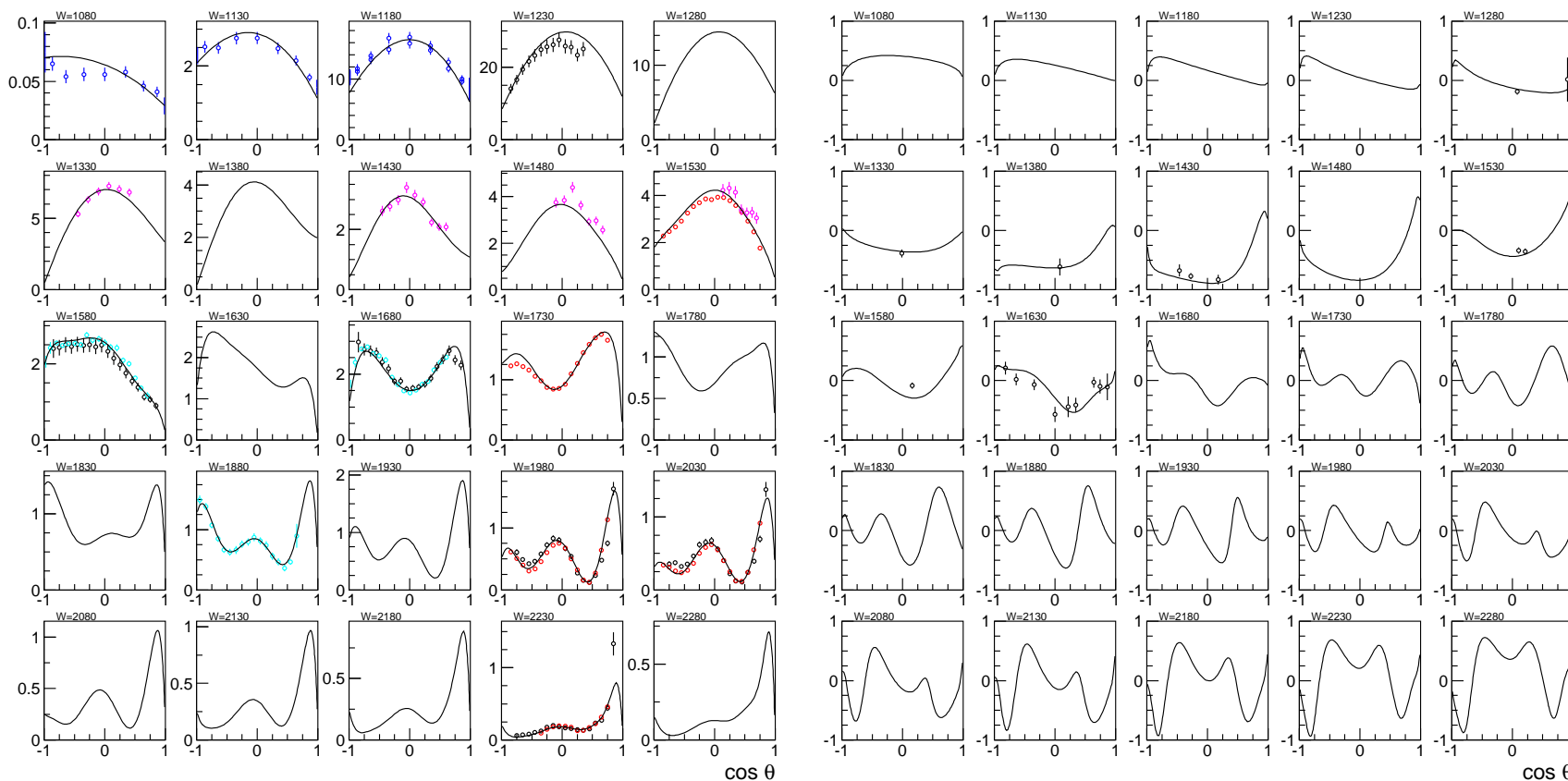
Multi-meson final states (maximum likelihood analysis).

$d\sigma/d\Omega(\pi^- p \rightarrow n\pi^0\pi^0)$	CBALL				
$d\sigma/d\Omega(\gamma p \rightarrow p\pi^0\pi^0)$	CB-ELSA (1.4 GeV)	$E(\gamma p \rightarrow p\pi^0\pi^0)$	16	1.91	MAMI
$d\sigma/d\Omega(\gamma p \rightarrow p\pi^0\eta)$	CB-ELSA (3.2 GeV)	$\Sigma(\gamma p \rightarrow p\pi^0\eta)$	180	2.37	GRAAL
$d\sigma/d\Omega(\gamma p \rightarrow p\pi^0\pi^0)$	CB-ELSA (3.2 GeV)	$\Sigma(\gamma p \rightarrow p\pi^0\pi^0)$	128	0.96	GRAAL
$d\sigma/d\Omega(\gamma p \rightarrow p\pi^0\eta)$	CB-ELSA (3.2 GeV)	$\Sigma(\gamma p \rightarrow p\pi^0\eta)$	180	2.37	GRAAL
$I_c(\gamma p \rightarrow p\pi^0\eta)$	CB-ELSA (3.2 GeV)	$I_s(\gamma p \rightarrow p\pi^0\eta)$			CB-ELSA (3.2 GeV)

In $\pi N \rightarrow meson - baryon$ experiment three observables are needed for a complete experiment: differential cross section, analyzing power and rotation parameter.

For a complete photoproduction experiment 8 observables are needed. But...

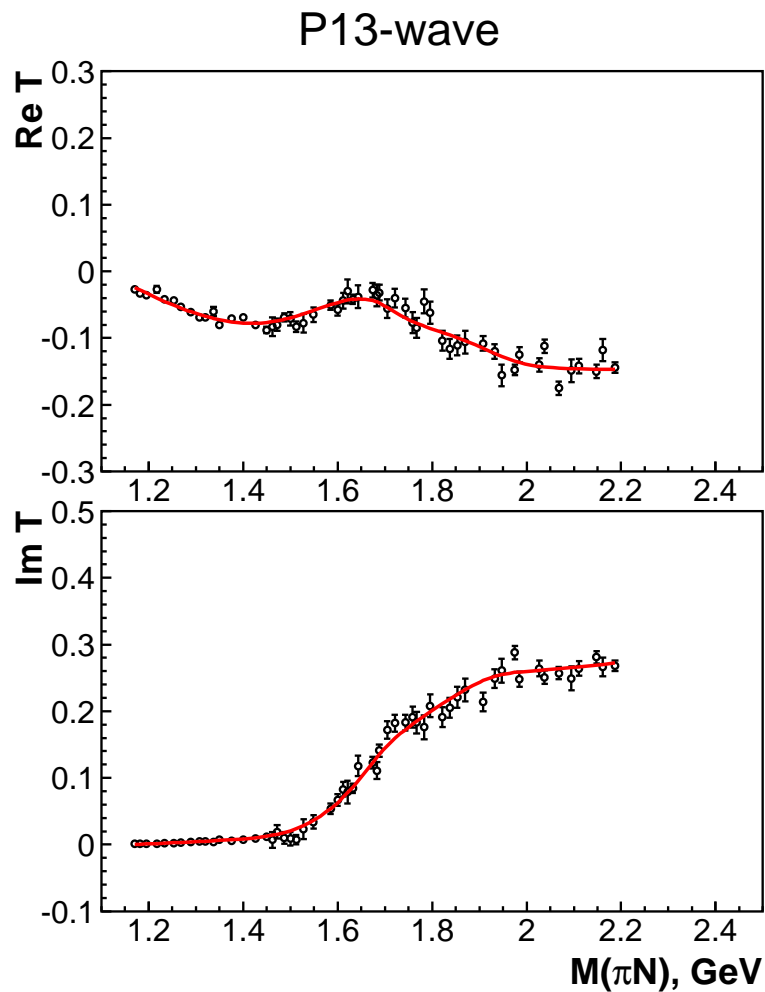
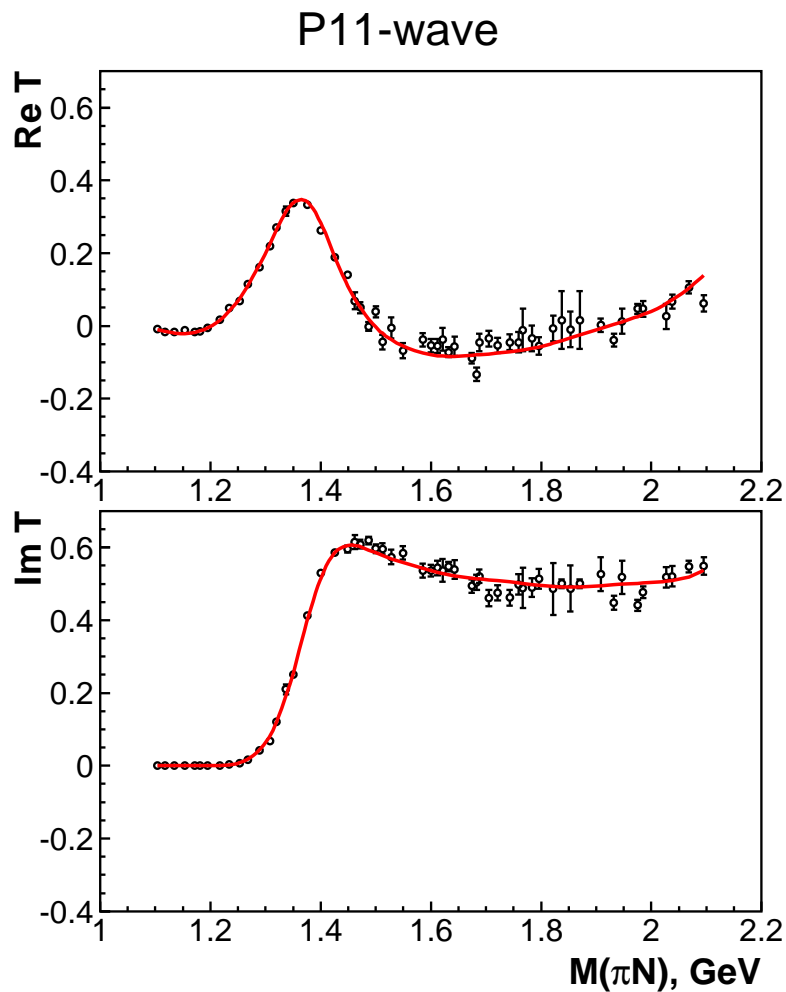
polarization observables are more sensitive to small contributions.



$d\sigma/d\Omega$

T

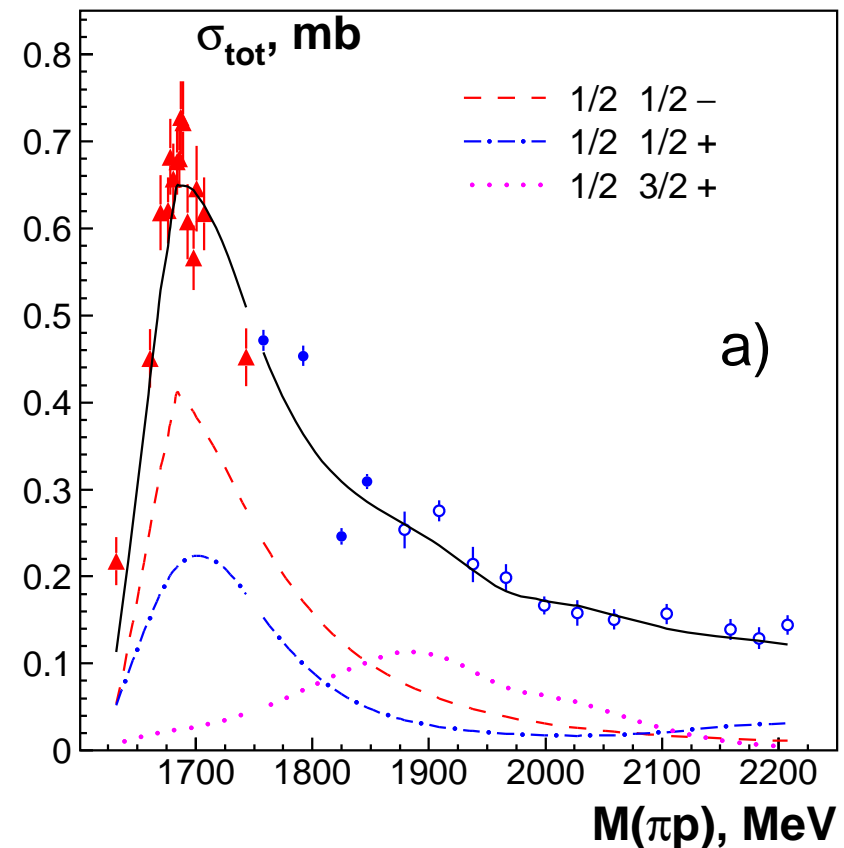
The SAID energy independent solution for P_{11} and P_{13} partial waves



The fit of the the $\pi^- p \rightarrow K \Lambda$ reaction

Full experiment for $\pi N \rightarrow K \Lambda$:
differential cross section, analyzing
power, rotation parameter.

**A clear evidence for resonances which
are hardly seen (or not seen) in
the elastic reactions:** $N(1710)P_{11}$,
 $N(1900)P_{13}$,



The total cross section for the reaction
 $\pi^- p \rightarrow K^0 \Lambda$ and contributions from
leading partial waves.

Amplitude for the πN transition into channels πN , ηN , $K\Lambda$ and $K\Sigma$:

$$A_{\pi N} = \omega^* [G(s, t) + H(s, t)i(\vec{\sigma}\vec{n})] \omega' \quad \vec{n}_j = \varepsilon_{\mu\nu j} \frac{q_\mu k_\nu}{|\vec{k}||\vec{q}|} .$$

$$G(s, t) = \sum_L [(L+1)F_L^+(s) + LF_L^-(s)] P_L(z) ,$$

$$H(s, t) = \sum_L [F_L^+(s) - F_L^-(s)] P_L'(z) .$$

$z = \cos \Theta$, the angle of the final meson in c.m.s.

$$|A|^2 = \frac{1}{2} \text{Tr} [A_{\pi N}^* A_{\pi N}] = |G(s, t)|^2 + |H(s, t)|^2 (1 - z^2)$$

and the recoil asymmetry can be calculated as:

$$P = \frac{\text{Tr} [A_{\pi N}^* \sigma_2 A_{\pi N}]}{2|A|^2 \cos \phi} = \sin \Theta \frac{2 \text{Im} (H^*(s, t) G(s, t))}{|A|^2} .$$

Near threshold, only contributions from S and P -waves are expected. For the $S_{2I,2J}$ and $P_{2I,2J}$ amplitudes we have

$$\underline{S_{2I,1}}; \quad G = F_0^+; \quad H = 0; \quad |A|^2 = |F_0^+|^2 \quad (1)$$

$$\underline{P_{2I,1}}; \quad G = F_1^- z; \quad H = -F_1^-; \quad |A|^2 = |F_1^-|^2 \quad (2)$$

$$\underline{P_{2I,3}}; \quad G = 2F_1^+ z; \quad H = F_1^+; \quad |A|^2 = |F_1^+|^2(3z^2+1)$$

where the indices $(2I, 2J)$ remind of the isospin I and the spin J of the partial waves.

The recoil asymmetry vanishes unless different amplitudes interfere.

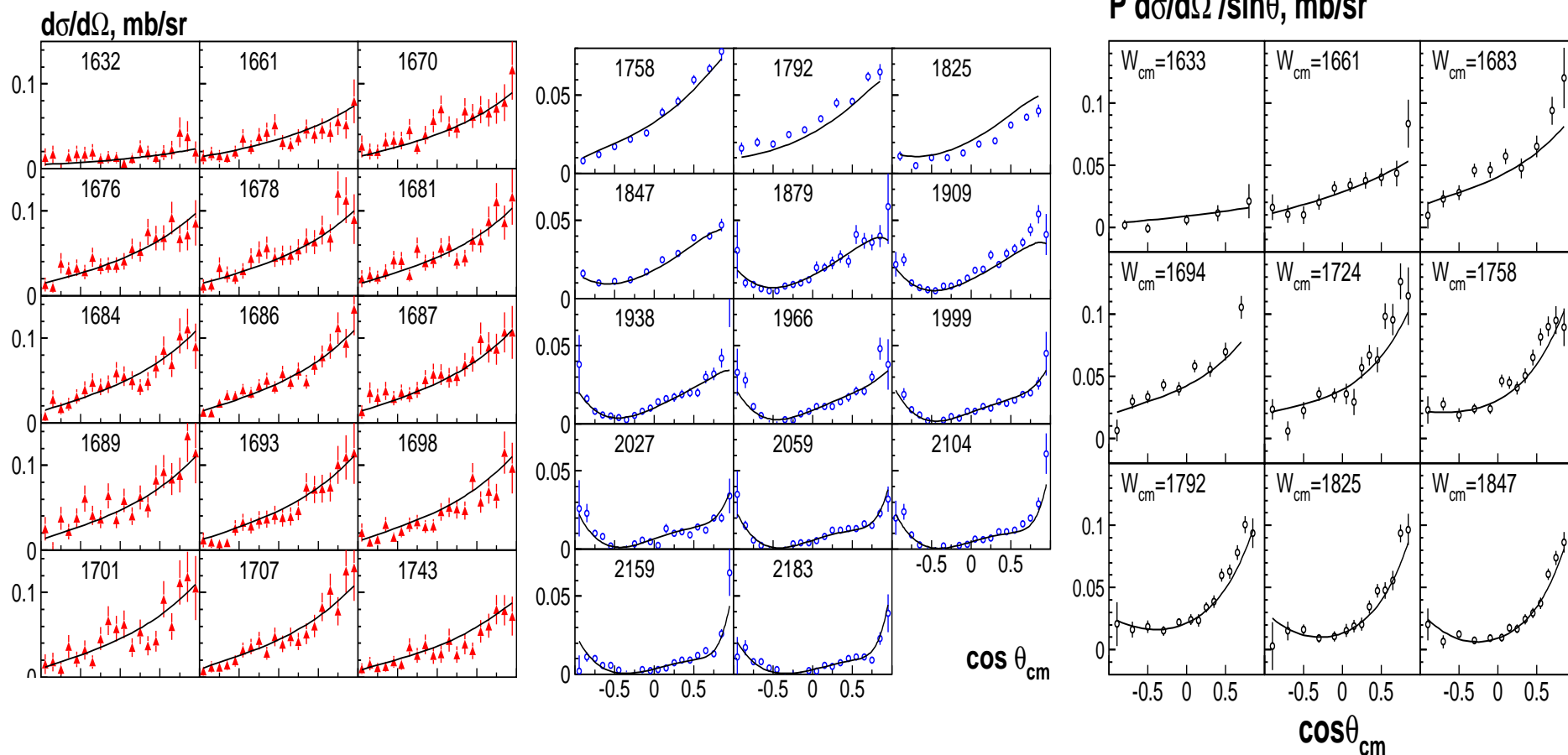
$$\underline{S_{2I,1} + P_{2I,1}} : \quad P \frac{|A|^2}{\sin \Theta} = -2\text{Im}(F_0^+ F_1^{-*}) \quad |A|^2 = |F_0^+|^2 + |F_1^-|^2 + 2z\text{Re}(F_0^{+*} F_1^-)$$

$$\underline{S_{2I,1} + P_{2I,3}} : \quad P \frac{|A|^2}{\sin \Theta} = 2\text{Im}(F_0^+ F_1^{+*}) \quad |A|^2 = |F_0^+|^2 + |F_1^+|^2(3z^2+1) + 4z\text{Re}(F_0^{+*} F_1^+)$$

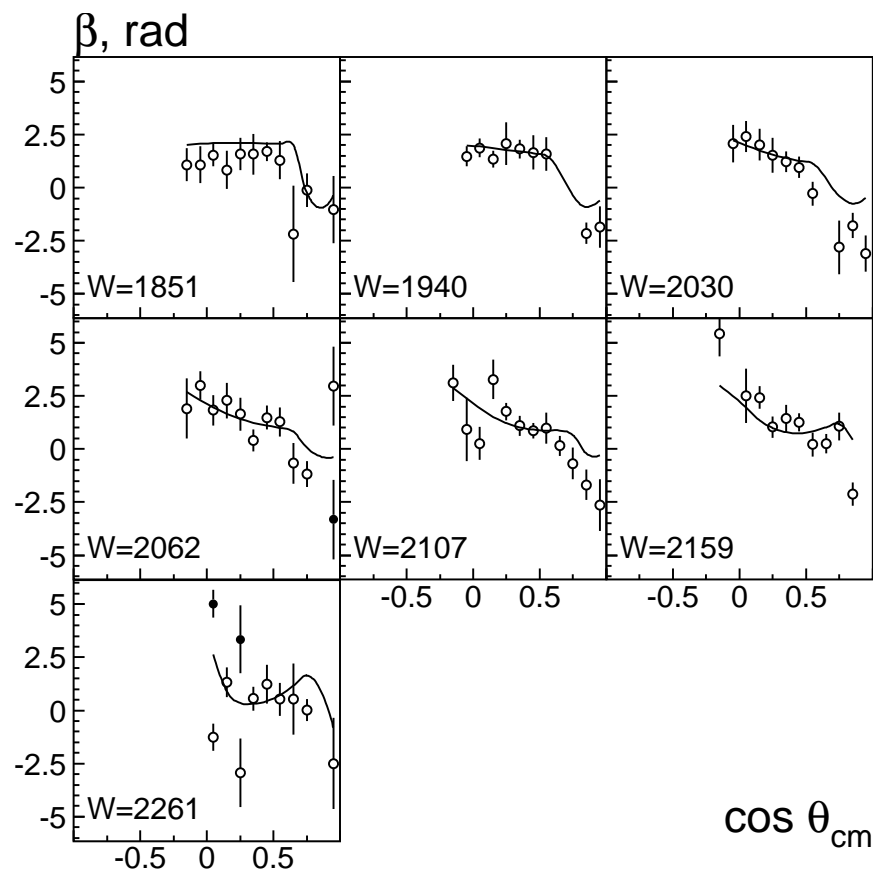
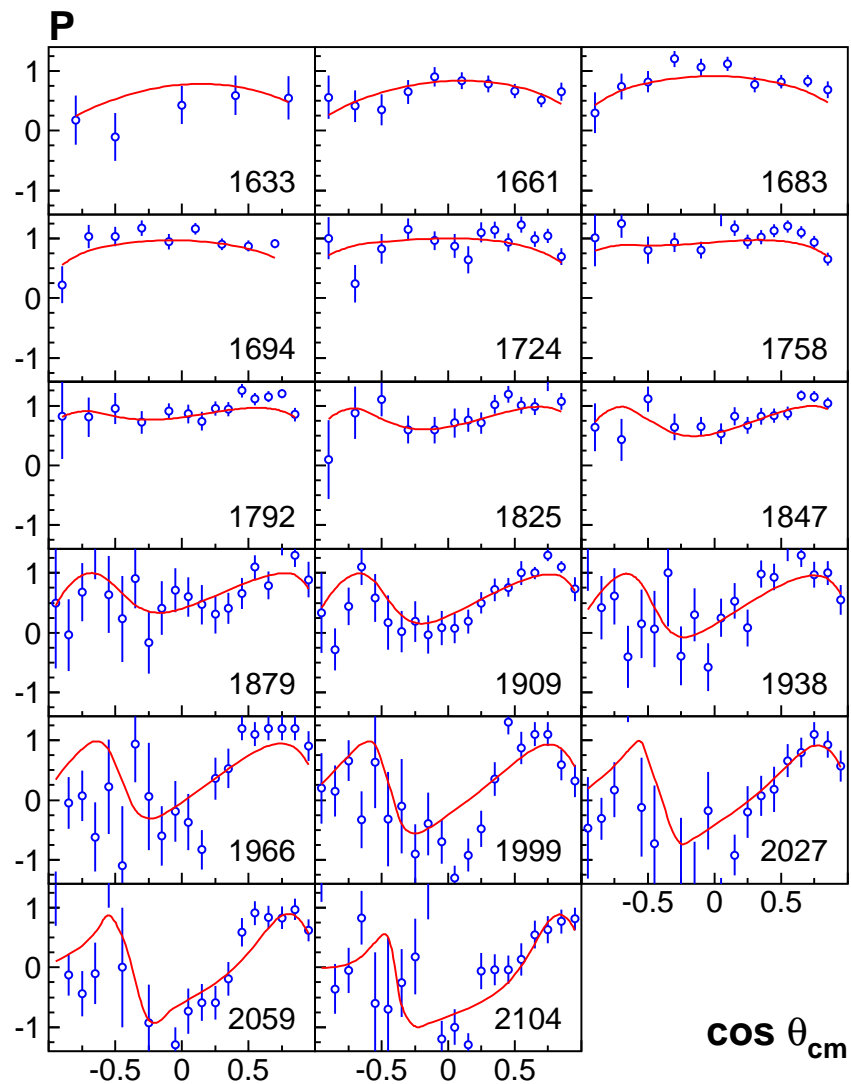
$$\underline{P_{2I,1} + P_{2I,3}} : \quad P \frac{|A|^2}{\sin \Theta} = 6z\text{Im}(F_1^{+*} F_1^-) \quad |A|^2 = |F_1^+ - F_1^-|^2 + z^2 \quad 3|F_1^+|^2 - 2\text{Re}(F_1^{+*} F_1^-) \quad .$$

where $|A|^2$ represents the angular distribution and $P |A|^2 / \sin \Theta$ an observable proportional to the recoil polarization parameter P .

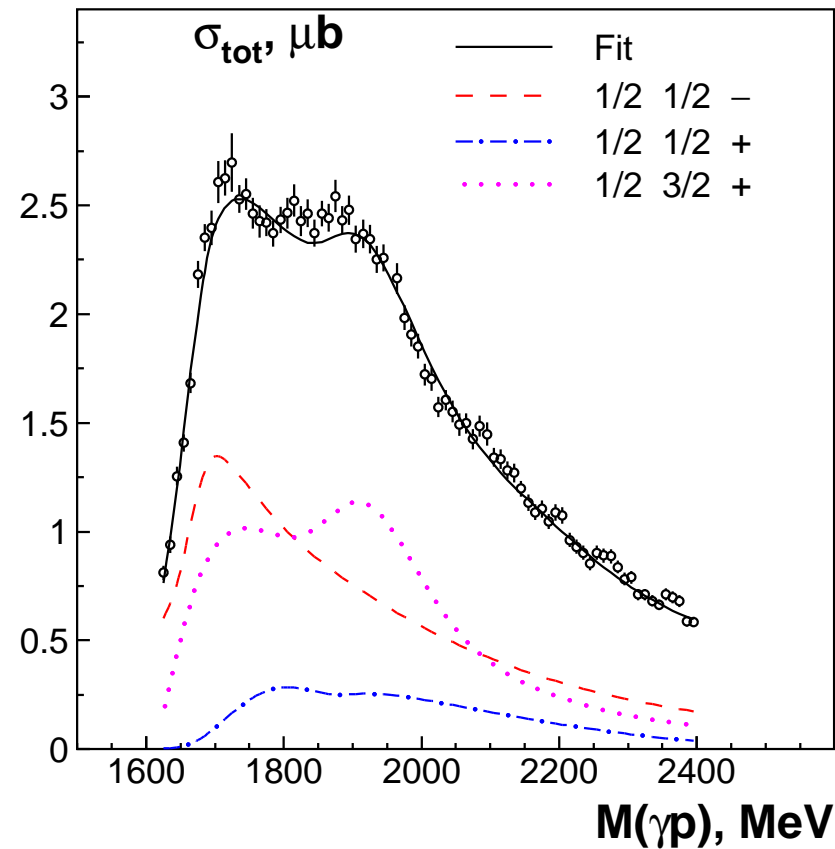
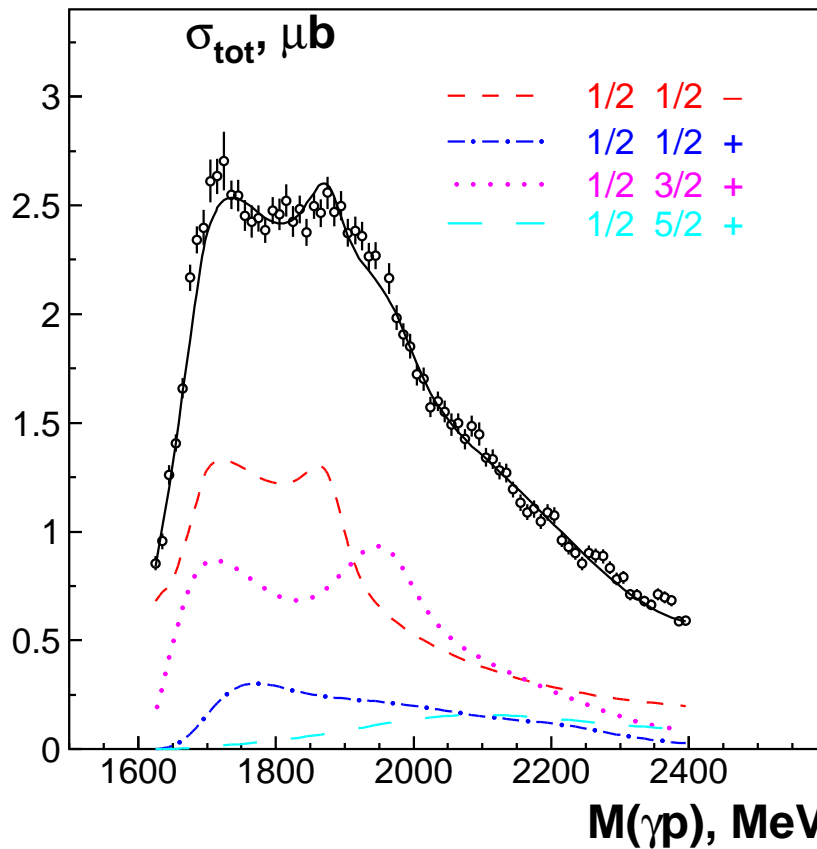
The fit of the the $\pi^- p \rightarrow K \Lambda$ reaction (differential cross section)



The fit of the $\pi^- p \rightarrow K \Lambda$ reaction



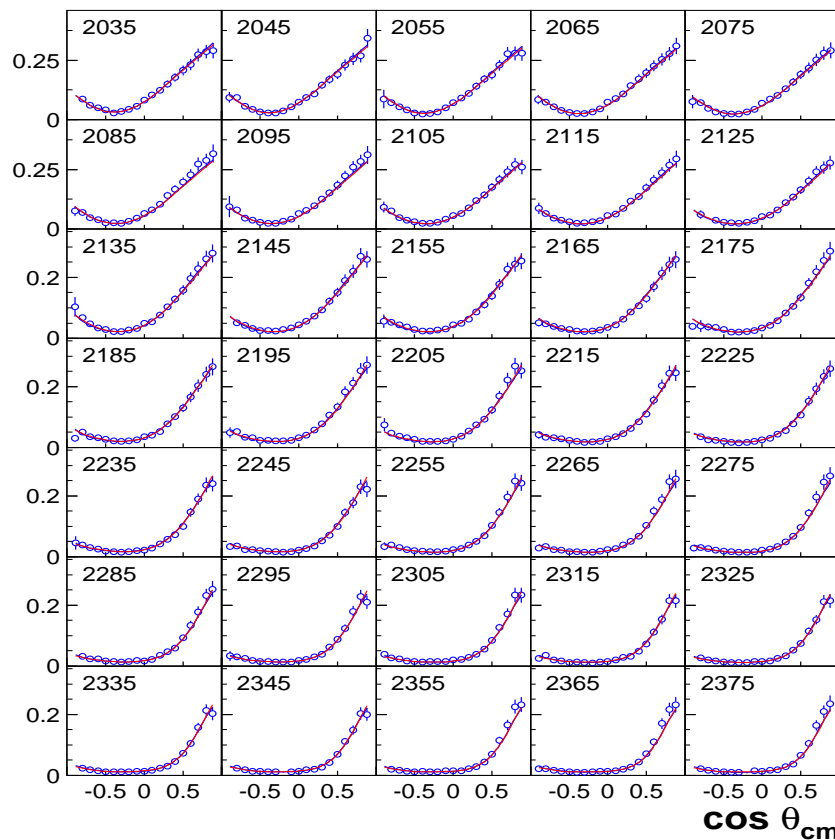
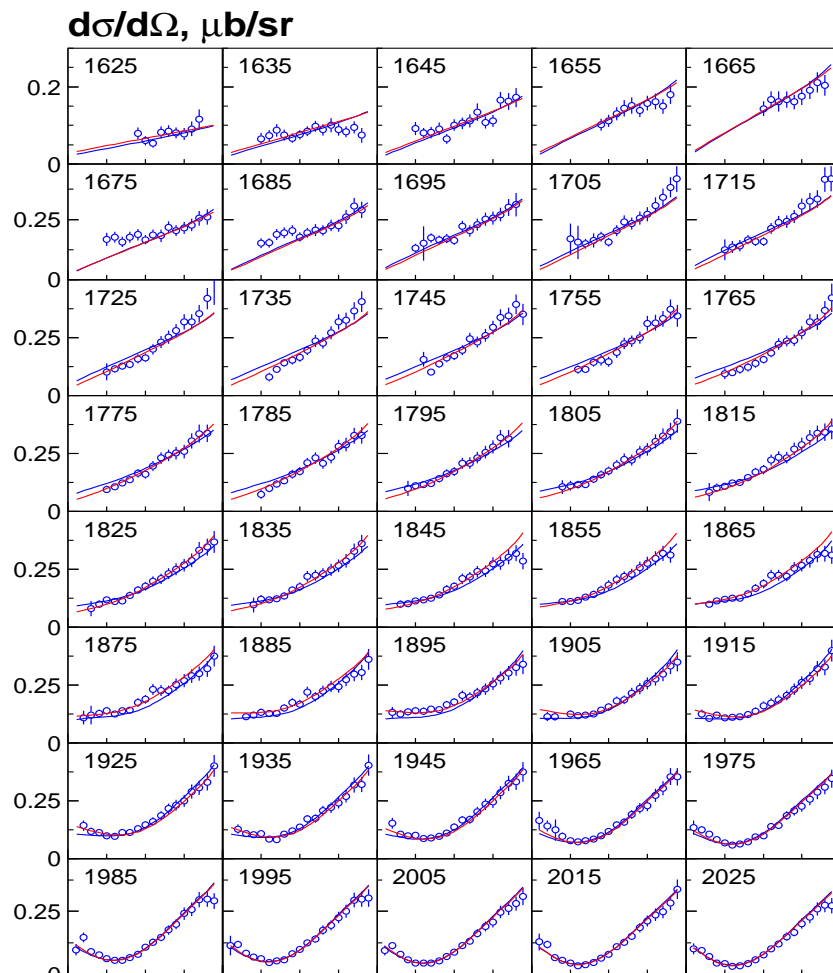
The $\gamma p \rightarrow K \Lambda$ reaction (CLAS 2009)



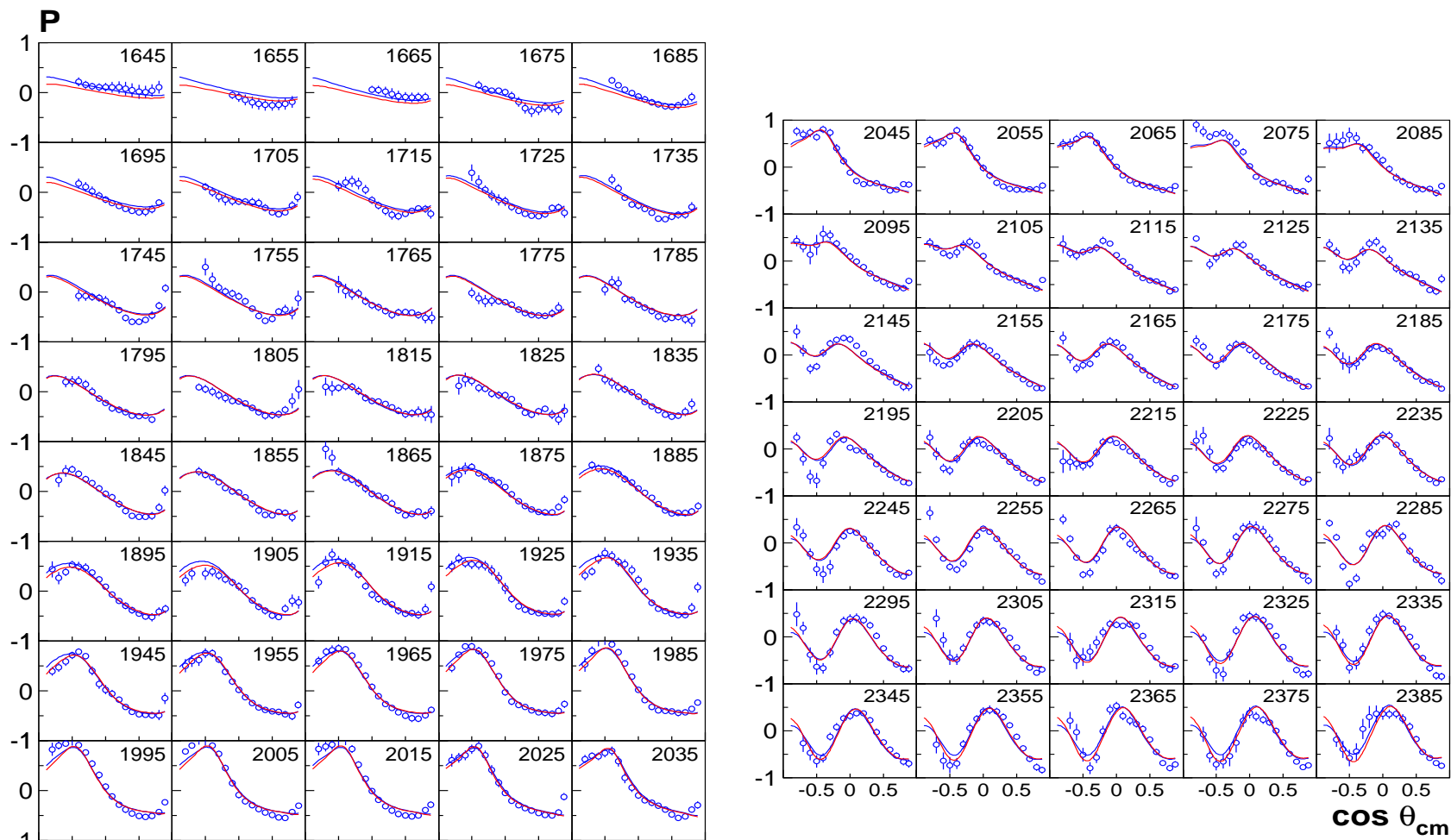
In the first solution the new S_{11} state with mass $1890 \pm 10 \text{ MeV}$ and width $90 \pm 10 \text{ MeV}$ is introduced in the fit.

The fit of the $\gamma p \rightarrow K \Lambda$ differential cross section

(CLAS 2009)



The fit of the $\gamma p \rightarrow K \Lambda$ recoil asymmetry (CLAS 2009)

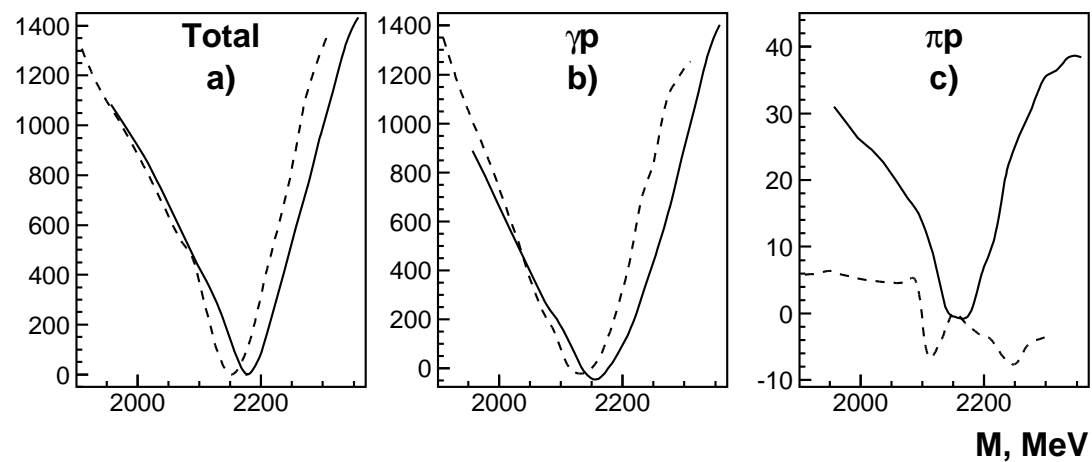
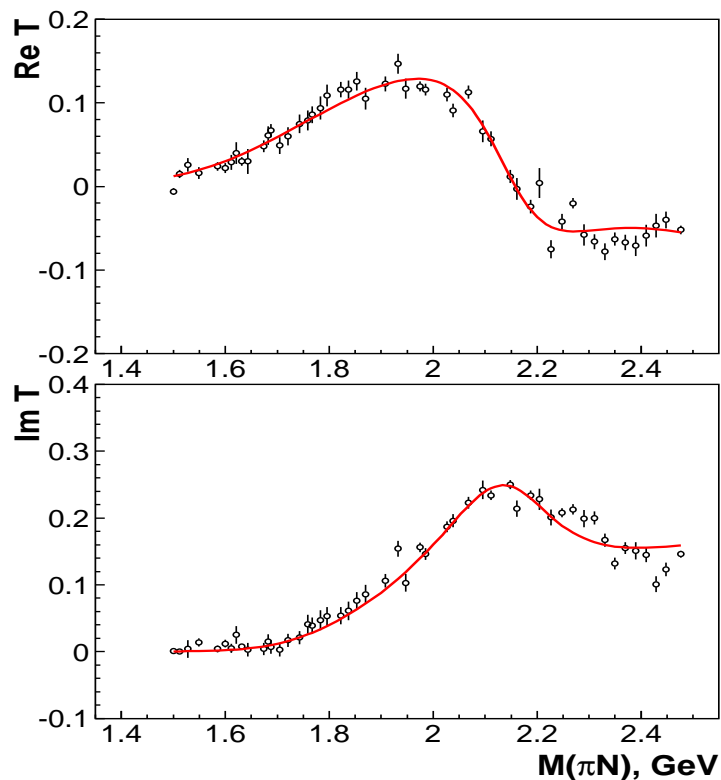


Pole position of baryon states (Re and -2Im) in the mass region 1900-2300 MeV

State		Solution 1	Solution 2	Arndt	Hoehler	Cutcosky
$N(1875) \frac{1}{2}^+$ *	Re	1860 ± 20	1840 ± 30		1885 ± 30 (Manley)	
	-2Im	160 ± 20	320 ± 50		113 ± 44 (Manley)	
$N(1890) \frac{1}{2}^-$ *	Re	1890 ± 15	1890 ± 15	—	1880 ± 20	—
	-2Im	90 ± 15	90 ± 15	—	95 ± 30	—
$N(1880) \frac{3}{2}^-$ **	Re	1885 ± 10	1870 ± 15	—	—	1880 ± 100
	-2Im	190 ± 20	180 ± 20	—	—	180 ± 60
$N(2130) \frac{3}{2}^-$ **	Re	2135 ± 25	2130 ± 25	—	2081 ± 20	2050 ± 70
	-2Im	310 ± 30	300 ± 30	—	265 ± 40	200 ± 60
$N(1900) \frac{3}{2}^+$ **	Re	1915 ± 20	1900 ± 25	—	—	—
	-2Im	240 ± 30	260 ± 40	—	—	—
$N(2000) \frac{5}{2}^+$ **	Re	$1800 - 1950$	$1800 - 1950$	1807	1882 ± 10	—
	-2Im	$100 - 300$	$100 - 300$	109	95 ± 20	—
$N(2100) \frac{5}{2}^+$	Re	2090^{+20}_{-40}	2110^{+20}_{-80}	—	—	—
	-2Im	560 ± 100	540 ± 100	—	—	—
$N(2070) \frac{5}{2}^-$	Re	2050 ± 30	2065 ± 20	—	—	—
	-2Im	370 ± 30	360 ± 30	—	—	—
$N(1990) \frac{7}{2}^+$ **	Re	1980 ± 25	2100 ± 30	—	~ 1935	1900 ± 30
	-2Im	180 ± 30	300 ± 60	—	~ 260	260 ± 60
$N(2190) \frac{7}{2}^-$ * * *	Re	2160 ± 15	2150 ± 20	2070	2042	2100 ± 50
	-2Im	320 ± 30	290 ± 30	520	480	400 ± 160

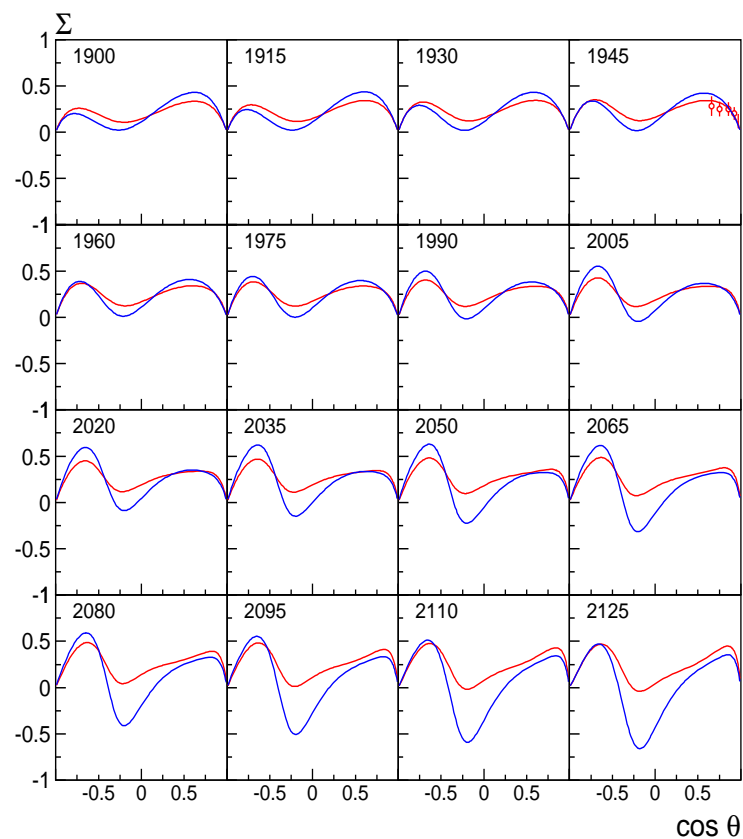
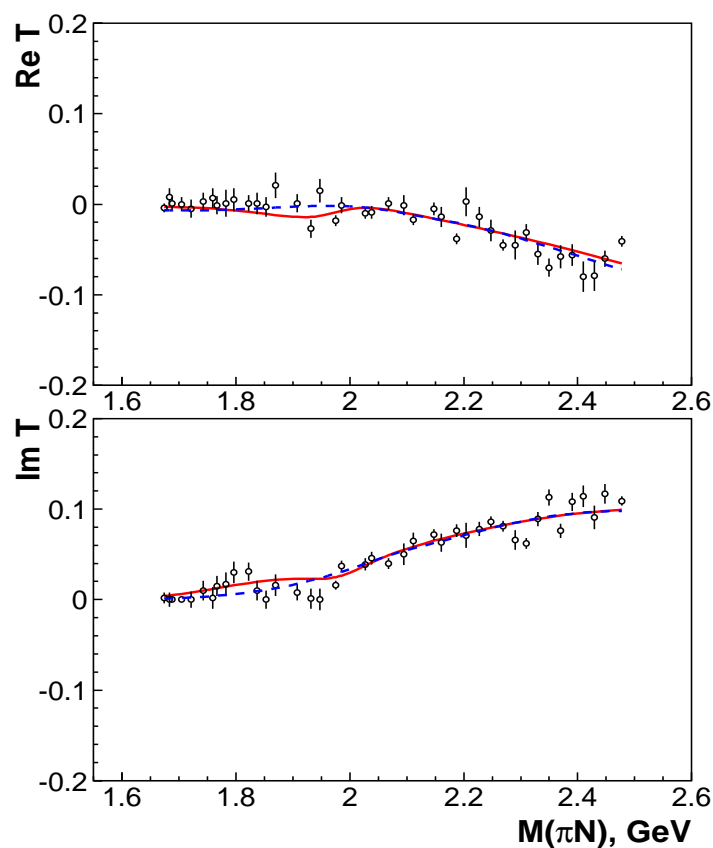
G_{17} : pole position and Breit-Wigner parameters

State		Solution 1	Solution 2	Arndt	Hoehler	Cutcosky
$N(2190) \frac{7}{2}^-$	Re	2160 ± 15	2150 ± 20	2070	2042	2100 ± 50
***	-2Im	320 ± 30	290 ± 30	520	480	400 ± 160
BW	M	2180	2165	2152.4 ± 1.4	2140 ± 12	2200 ± 70
parameters	Γ	330	300	484 ± 13	390 ± 30	500 ± 150



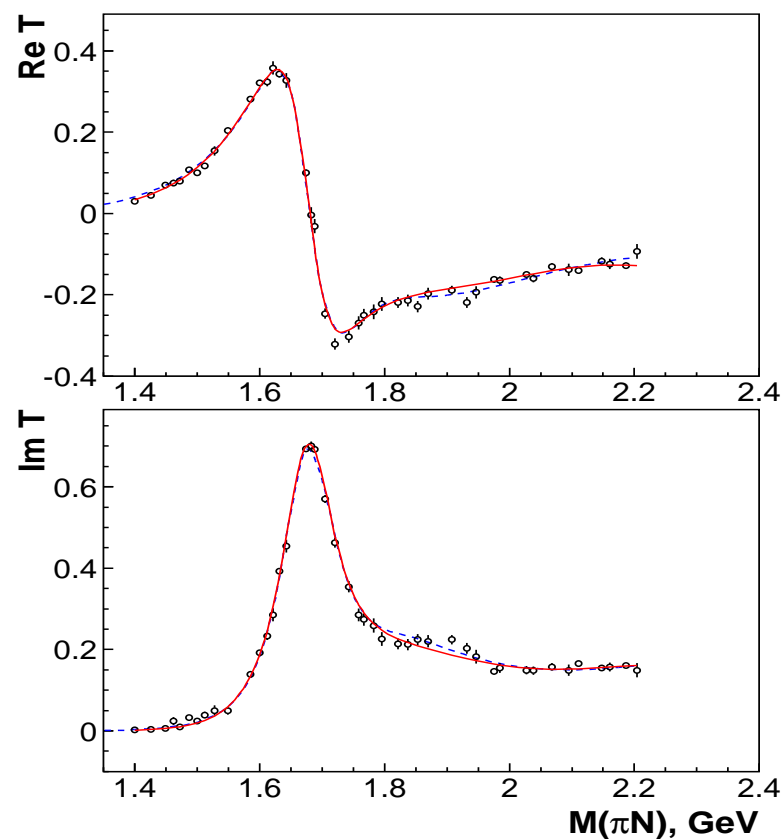
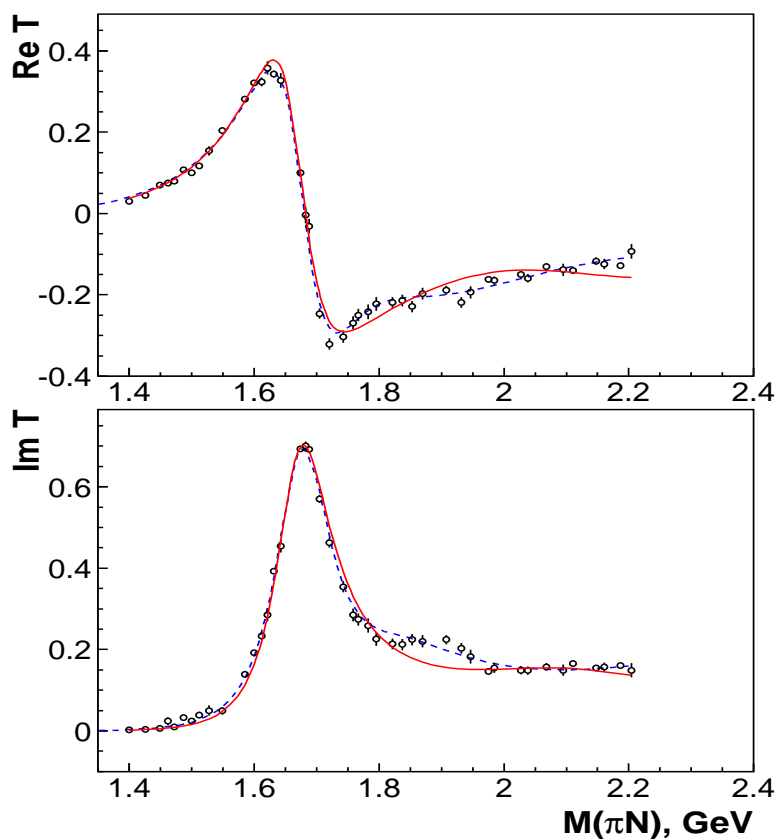
Pole position of F_{17} and helicity couplings (absolute value ($10^{-3} \text{ GeV}^{\frac{1}{2}}$)/phase (degrees))

State		Solution 1	$A(\frac{1}{2})/A(\frac{3}{2})$	Solution 2	$A(\frac{1}{2})/A(\frac{3}{2})$
$N(1990) \frac{7}{2}^+$	Re	1980 ± 25	$15/14^\circ$	2100 ± 30	$76/50^\circ$
**	-2Im	180 ± 30	$28/3^\circ$	300 ± 60	$78/45^\circ$



Pole position of F_{15} : two and three pole solution

State		Solution 1	Solution 2	Arndt	Hoehler	Cutcosky
$N(2000) \frac{5}{2}^+$	Re	1800 – 1950	1800 – 1950	1807	1882 ± 10	—
	-2Im	100 – 300	100 – 300	109	95 ± 20	—
$N(2100) \frac{5}{2}^+$	Re	2090^{+20}_{-40}	2110^{+20}_{-80}	—	—	—
	-2Im	560 ± 100	540 ± 100	—	—	—



Holographic QCD (AdS/QCD)

L, S, N	κ_{gd}	Resonance					Pred.
$0, \frac{1}{2}, 0$	$\frac{1}{2}$	$N(940)$					input: 0.94
$0, \frac{3}{2}, 0$	0	$\Delta(1232)$					1.27
$0, \frac{1}{2}, 1$	$\frac{1}{2}$	$N(1440)$					1.40
$1, \frac{1}{2}, 0$	$\frac{1}{4}$	$N(1535)$	$N(1520)$				1.53
$1, \frac{3}{2}, 0$	0	$N(1650)$	$N(1700)$	$N(1675)$			1.64
$1, \frac{1}{2}, 0$	0	$\Delta(1620)$	$\Delta(1700)$		$L, S, N=0, \frac{3}{2}, 1:$	$\Delta(1600)$	1.64
$2, \frac{1}{2}, 0$	$\frac{1}{2}$	$N(1720)$	$N(1680)$		$L, S, N=0, \frac{1}{2}, 2:$	$N(1710)$	1.72
$1, \frac{1}{2}, 1$	$\frac{1}{4}$	$N(1890)$	$N(1875)$				1.82
$1, \frac{3}{2}, 1$	0	$\Delta(1900)$	$\Delta(1940)$	$\Delta(1930)$			1.92
$2, \frac{3}{2}, 0$	0	$\Delta(1910)$	$\Delta(1920)$	$\Delta(1905)$	$\Delta(1950)$		1.92
$2, \frac{3}{2}, 0$	0	$N(1880)$	$N(1900)$	$N(1880)$	$N(1980)$		1.92
$0, \frac{1}{2}, 3$	$\frac{1}{2}$	$N(????)$					2.03
$3, \frac{1}{2}, 0$	$\frac{1}{4}$	$N(2070)$	$N(2170)$	$L, S, N=1, \frac{1}{2}, 2:$	$N(????)$	$N(????)$	2.12
$3, \frac{3}{2}, 0$	0	$N(2200)$	$N(2250)$	$L, S, N=1, \frac{1}{2}, 2:$	$\Delta(2223)$	$\Delta(2200)$	2.20
$4, \frac{1}{2}, 0$	$\frac{1}{2}$	$N(2220)$					2.27
$4, \frac{3}{2}, 0$	0	$\Delta(2390)$	$\Delta(2300)$	$\Delta(2420)$	$ L, N=3, 1:$	$\Delta(2400)$	2.43
$5, \frac{1}{2}, 0$	$\frac{1}{4}$	$N(2600)$			$ $	$\Delta(2350)$	2.57

Parity doublets of N and Δ resonances at high mass region

Parity doublets must not interact by pion emission
and could have a small coupling to πN .

$J=\frac{1}{2}$	$\mathbf{N}_{1/2+}$ (1880) *	$\mathbf{N}_{1/2-}$ (1890) *	$\Delta_{1/2+}$ (1910) ****	$\Delta_{1/2-}$ (1900) ^a **
$J=\frac{3}{2}$	$\mathbf{N}_{3/2+}$ (1900) **	$\mathbf{N}_{3/2-}$ (1875) **	$\Delta_{3/2+}$ (1940) ^a ***	$\Delta_{3/2-}$ (1990) ^a *
$J=\frac{5}{2}$	$\mathbf{N}_{5/2+}$ (1880) **	$\mathbf{N}_{5/2-}$ (2070)	$\Delta_{5/2+}$ (1940) ****	$\Delta_{5/2-}$ (1930) ^a ***
$J=\frac{7}{2}$	$\mathbf{N}_{7/2+}$ (1980) **	$\mathbf{N}_{7/2-}$ (2170) ****	$\Delta_{7/2+}$ (1920) ****	$\Delta_{7/2-}$ (2200) *
$J=\frac{9}{2}$	$\mathbf{N}_{9/2+}$ (2220) ****	$\mathbf{N}_{9/2-}$ (2250) ****	$\Delta_{9/2+}$ (2300) **	$\Delta_{9/2-}$ (2400) ^a **
$J=\frac{5}{2}$	$\mathbf{N}_{5/2+}$ (2100) **	$\mathbf{N}_{5/2-}$ (2070)	$\Delta_{5/2+}$ (1940) ****	$\Delta_{5/2-}$ (1930) ^a ***
$J=\frac{7}{2}$	$\mathbf{N}_{7/2+}$ (2100) **	$\mathbf{N}_{7/2-}$ (2170) ****	$\Delta_{7/2+}$ (1920) ****	$\Delta_{7/2-}$ (2200) *
$J=\frac{9}{2}$	$\mathbf{N}_{9/2+}$ (2220) ****	$\mathbf{N}_{9/2-}$ (2250) ****	$\Delta_{9/2+}$ (2300) **	$\Delta_{9/2-}$ (2400) ^a **

Summary

- The analysis of (almost) all available data for production of baryons in the pion and photo induced reaction is completed.
- We have observed a set of new states in the region 1800-2150 MeV, however, this number is much less than that predicted by the classical quark model.
- The low spin states fit very well the AdS/QCD prediction as well as the idea about chiral restoration at high energies.
- There are two solutions for the $N_{\frac{7}{2}^+}$ lowest state which should be distinguished from analysis of beam asymmetry data on photoproduction of hyperon-kaon final states which have to be released in 3-4 months.
- The situation for $N(\frac{5}{2}^+)$ can be resolved with reanalysis of πN elastic data and an analysis of new data on double pion photoproduction.
- The search for the chiral partner of $\Delta_{7/2^+}(1920)$ state is the main subject in our current analysis of double pion and $\pi^0\eta$ photoproduction data