

Cross Section Re-Analysis

of Pion Photoproduction on nucleon:

Data from JLAB and MAMI

Boris Tatischeff and Egle Tomasi-Gustafsson

Relativistic Nuclear Physics
and Quantum Chromodynamics”
Dubna, September 29 - October 4, 2008.

Recall of data showing narrow exotic baryonic structures*

* in the mass range $1.0 \leq M \leq 1.45$ GeV



HADRONS

Saturne SPES3 $pp \rightarrow p' \pi^+ X$ M_X $M_{p\pi^+}$ $M_{\pi^+ X}$
 $pp \rightarrow p' p'' X$ M_{pX} ($M_{p\eta}$, $M_{p\pi^0}$, M_{pX})
SPES4 $\alpha p \rightarrow \alpha' X$ M_X
Moscow Meson factory $p d \rightarrow p X$

LEPTONS

Bonn $\gamma p \rightarrow \pi^+ n$ excitation function
MAMI $\gamma n \rightarrow \pi^- \pi^0 p$ $M_{p\pi}$ invariant mass distribution
Compton Scattering from the proton (Saskatchewan, Mainz)

Narrow structures (≈ 20 MeV) weakly excited at the same masses

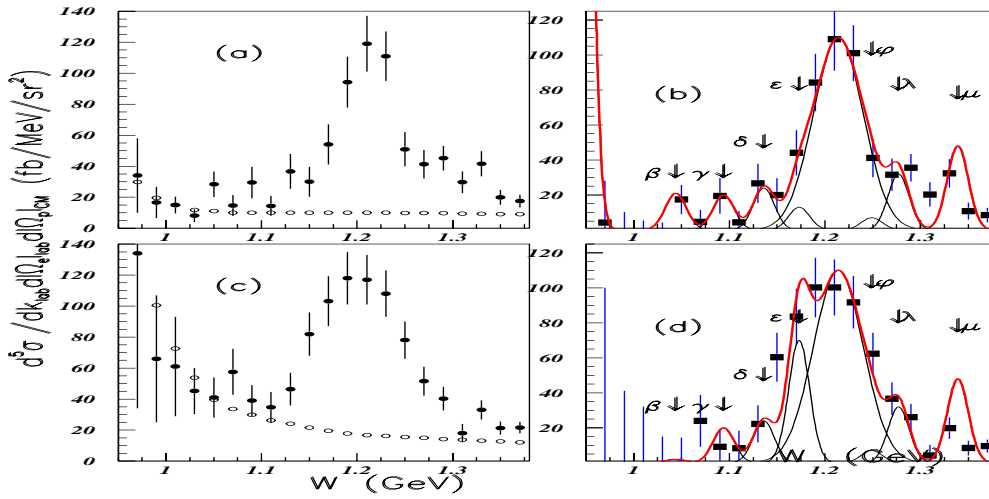
genuine baryonic states.

Reanalysis of some reaction using leptonic probes:

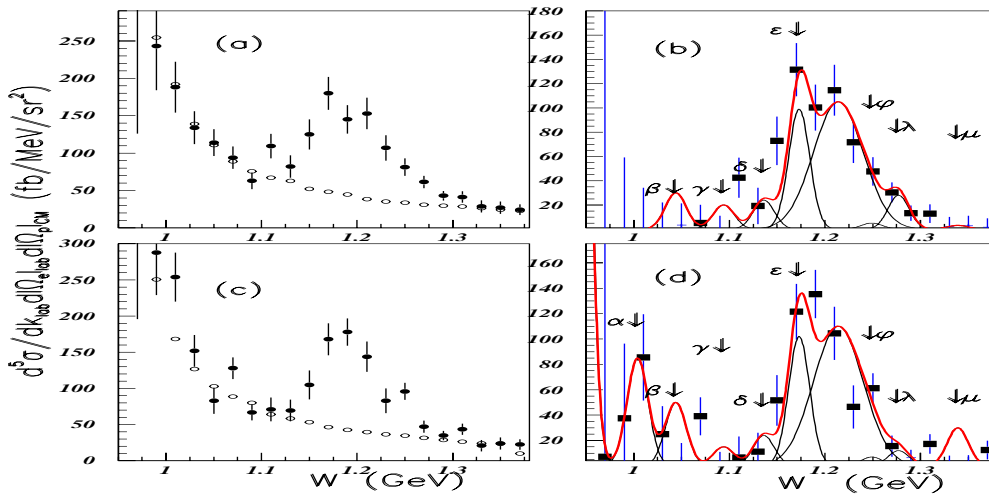
Virtual Compton Scattering from the proton (JLAB) $ep \rightarrow e' p \gamma$
Pion production on protons by Virtual Photons (JLAB) $ep \rightarrow e' N \pi$
($ep \rightarrow e' p \pi^0$ and $ep \rightarrow e' n \pi^+$)

Two pion production cross-section measured at MAMI

$\gamma^* p \rightarrow \gamma p$ JLAB (Hall A)

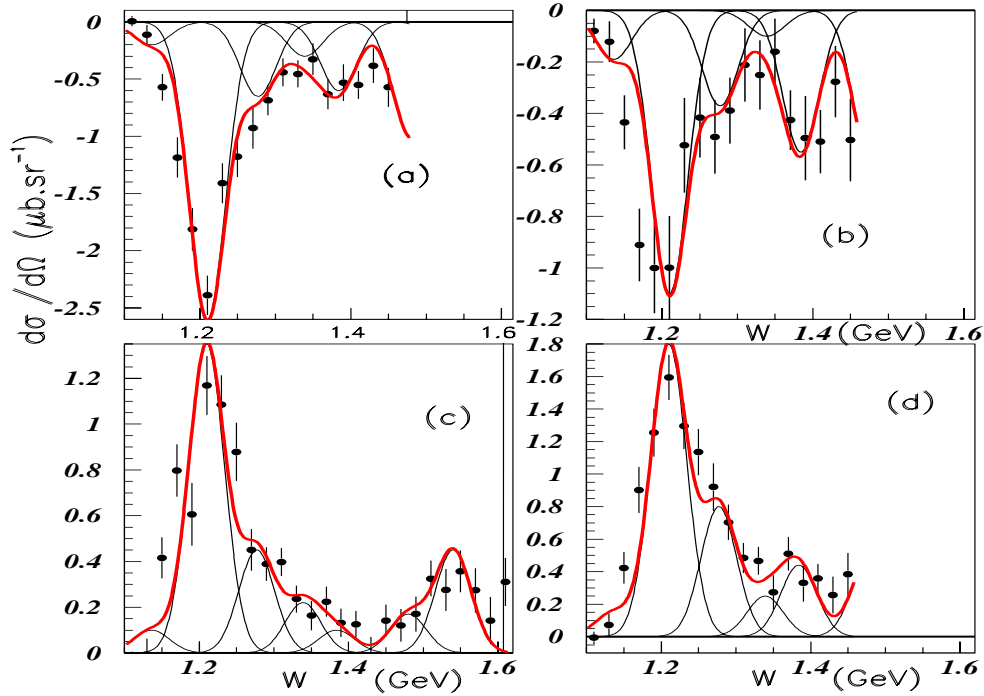


- α : 1004 MeV
- β : 1044 MeV
- γ : 1094 MeV
- δ : 1136 MeV
- ϵ : 1173 MeV
- ϕ : 1249 MeV
- λ : 1277 MeV
- μ : 1339 MeV



G. Laveissière *et al.*, Phys. Rev. C69, 045203 (2004); H. Fonvieille, FIZIKA 13 I, 209 (2004).
 Physical background: BH + Born + π^0 exchange, subtracted. $Q^2=1 \text{ GeV}^2$, $\cos \theta_{\gamma\gamma}^* = -0.975$
 From top to bottom: $\Phi_{\gamma\gamma}=15^\circ, 45^\circ, 135^\circ$, and 165° .

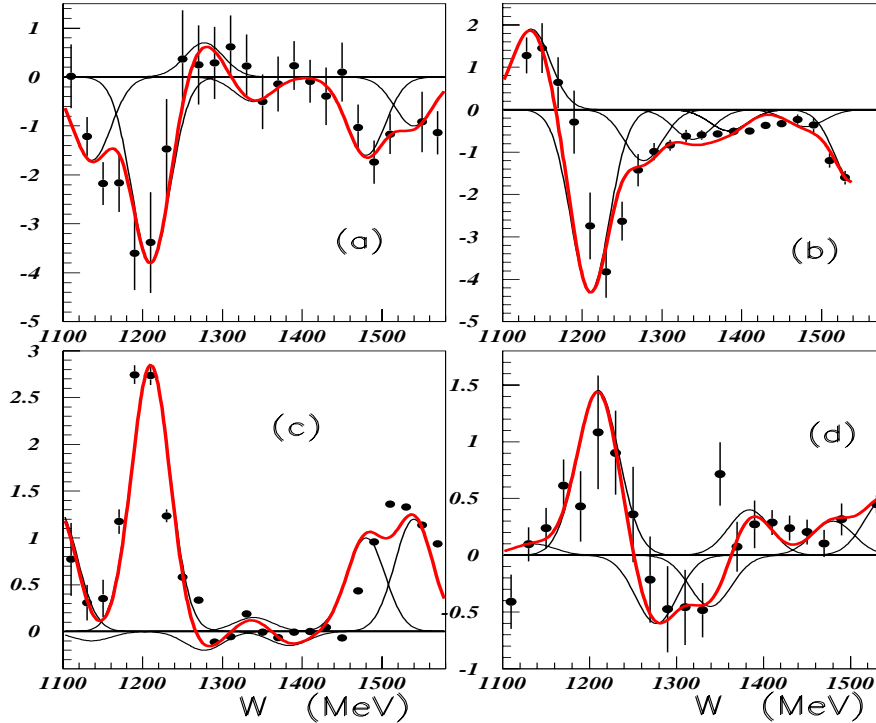
Cross-sections at four backward angles. $Q^2 = 1 \text{ GeV}^2$
 $\sigma_T + \epsilon\sigma_L$, σ_{TT} , and σ_{TL} structure functions measured.
Reanalysis of the differences between data and MAID2003 model.
With same narrow structure masses and an unique width.



G. Laveissière *et al.*, The Hall A Collaboration, Phys. Rev. C69, 045203 (2004)

Insert	structure function	θ
(a)	$d\sigma_T/d\Omega + \epsilon d\sigma_L/d\Omega$	145.59°
(b)	$d\sigma_{TT}/d\Omega$	145.59°
(c)	$d\sigma_{TL}/d\Omega$	151.05°
(d)	$d\sigma_{TL}/d\Omega$	145.59°

Cross-sections at ten angles and four momentum transfers $Q^2 = 0.3, 0.4, 0.5,$ and 0.6 GeV^2
 $\sigma_T + \epsilon\sigma_L, \sigma_{TT},$ and σ_{TL} structure functions measured.
 Reanalysis of the differences between data and MAID2003 model.
 With same narrow structure masses and an unique width.



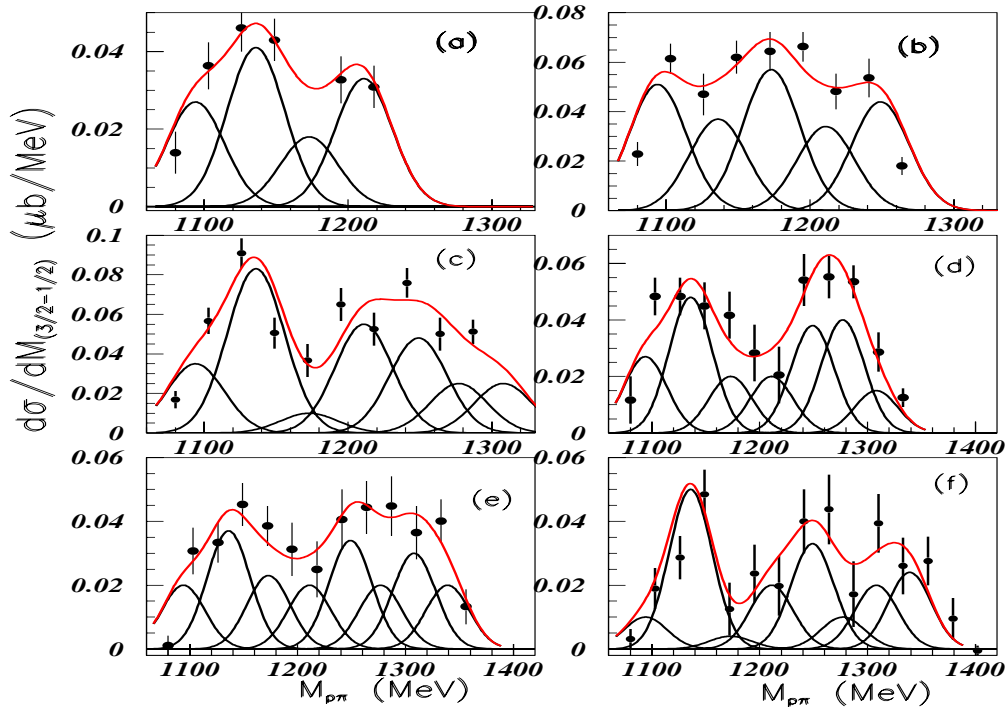
H. Egiyan *et al.*, Phys. Rev. C73, 025204 (2006).

Insert	structure function	θ	Q^2 (GeV^2)
(a)	$d\sigma_T/d\Omega + \epsilon d\sigma_L/d\Omega$	52.5°	0.3
(b)	$d\sigma_T/d\Omega + \epsilon d\sigma_L/d\Omega$	127.5°	0.4
(c)	$d\sigma_{TT}/d\Omega$	97.5°	0.3
(d)	$d\sigma_{TL}/d\Omega$	67.5°	0.4

Experimental helicity-dependent invariant-mass cross-sections for the $p\pi^\pm$ system. Difference

between spin 3/2 and spin 1/2 states: $\sigma_{3/2} - \sigma_{1/2}$

Longitudinally polarized photons and longitudinally polarized proton target.



J. Ahrends *et al.*, Eur. Phys. J. A 34,11 (2007)

Fix-Arenhövel model renormalized (0.5) and subtracted from data

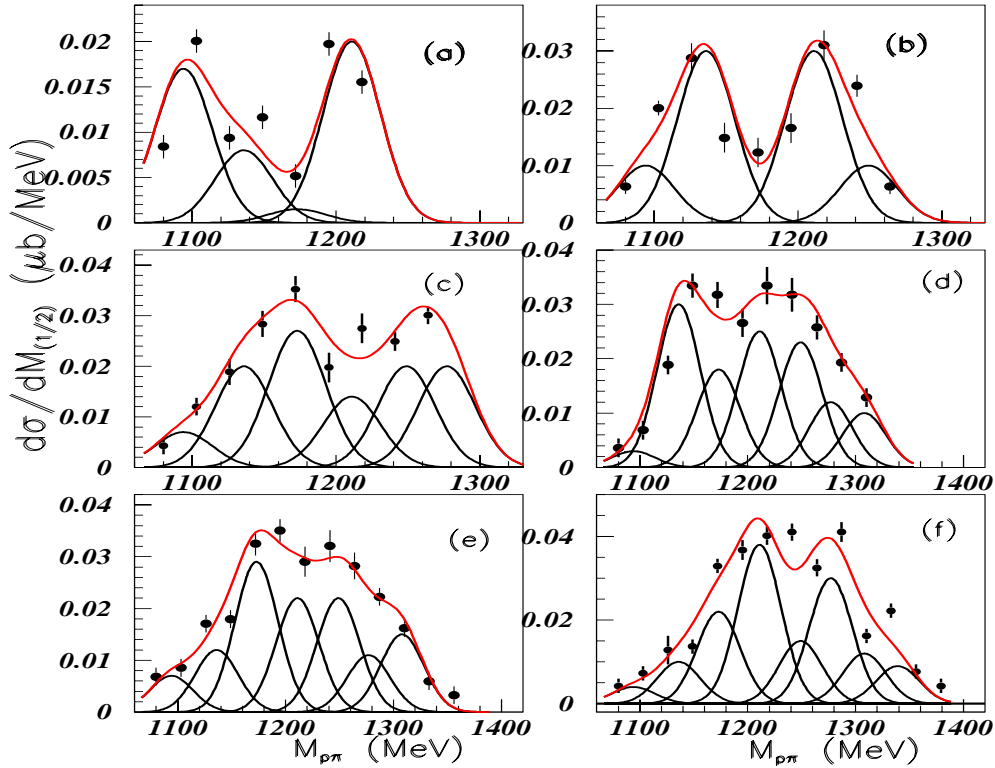
- (a) $500 \leq T_\gamma \leq 550$ MeV
- (b) $550 \leq T_\gamma \leq 600$ MeV
- (c) $600 \leq T_\gamma \leq 650$ MeV
- (d) $650 \leq T_\gamma \leq 700$ MeV
- (e) $700 \leq T_\gamma \leq 750$ MeV
- (f) $750 \leq T_\gamma \leq 800$ MeV

The oscillating shape becomes visible with $\nearrow T_\gamma$

$M=1136$ MeV, 1249 MeV, 1277 MeV,

Experimental cross-sections of the invariant $p\pi^\pm$ mass for the spin-1/2 state

Longitudinally polarized photons and longitudinally polarized proton target.



J. Ahrends *et al.*, Eur. Phys. J. A 34,11 (2007)

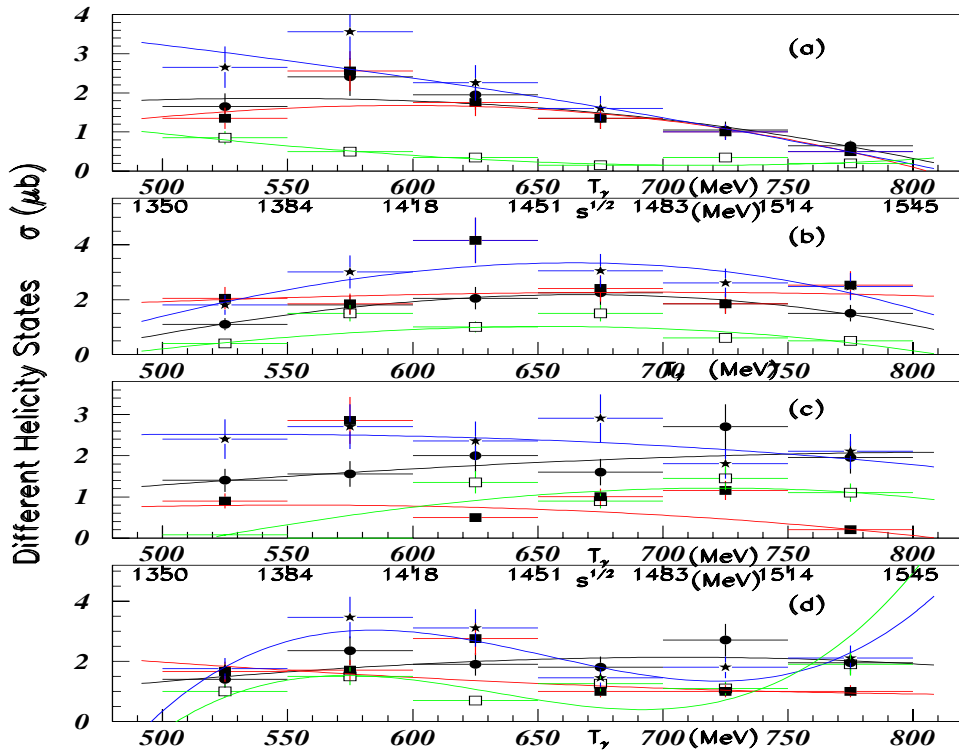
Fix-Arenhövel model renormalized (0.5) and subtracted from data

- (a) $500 \leq T_\gamma \leq 550$ MeV
- (b) $550 \leq T_\gamma \leq 600$ MeV
- (c) $600 \leq T_\gamma \leq 650$ MeV
- (d) $650 \leq T_\gamma \leq 700$ MeV
- (e) $700 \leq T_\gamma \leq 750$ MeV
- (f) $750 \leq T_\gamma \leq 800$ MeV

The oscillating shape becomes visible with decreasing T_γ

$M=1094$ MeV, 1136 MeV, 1210 MeV, 1277 MeV.

Smooth and continuous cross-section variations versus T_γ

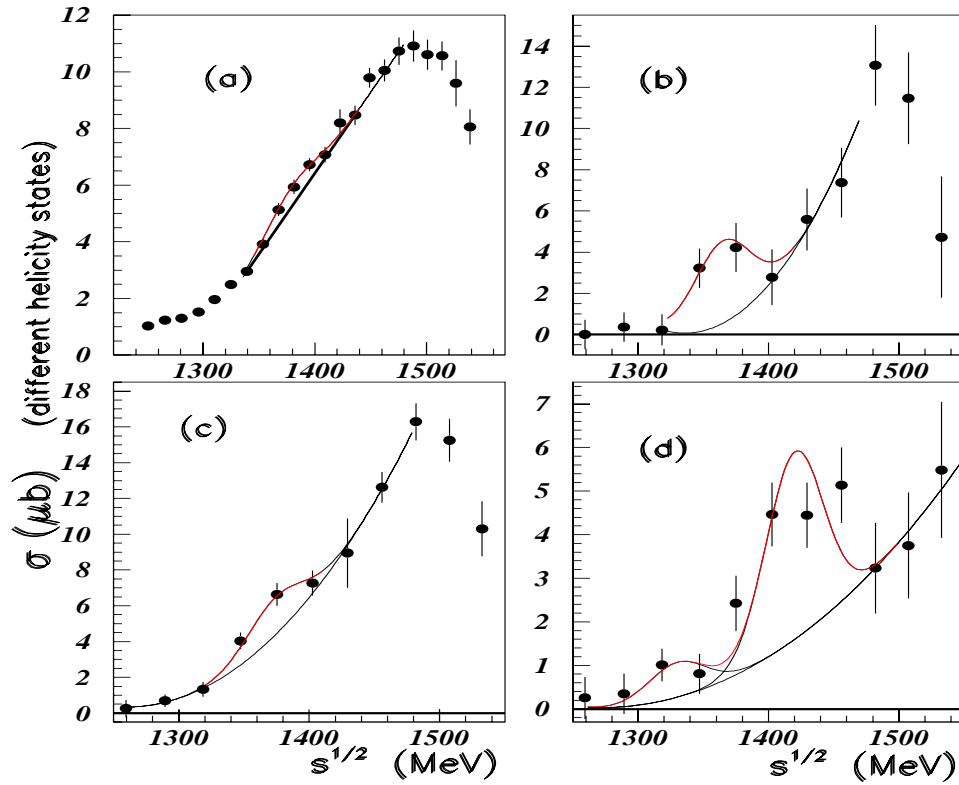


J. Ahrends *et al.*, Eur. Phys. J. A 34,11 (2007)

- (a) $M_X=1094$ MeV
- (b) $M_X=1136$ MeV
- (c) $M_X=1173$ MeV
- (d) $M_X=1211$ MeV

- full circles: unpolarized cross-sections (*0.2)
- full squares: helicity dependent cross-sections (spin 3/2 - spin 1/2).
- stars: spin 3/2 state cross-sections
- empty squares: spin 1/2 state cross-sections

Experimental helicity-dependent invariant-mass cross-sections.
Longitudinally polarized photons and longitudinally polarized proton target.



J. Ahrends *et al.*, Phys. Lett. B624, 173 (2005)

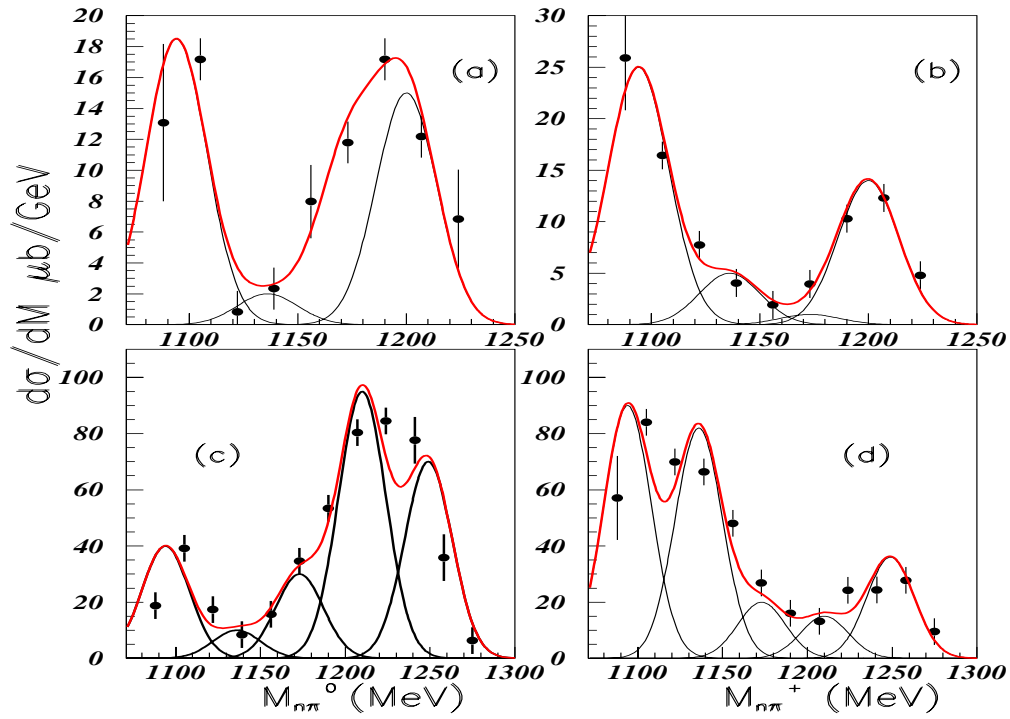
$500 \leq T_\gamma \leq 800$ MeV

- (a) cross-section
- (b) helicity dependent cross-sect.: $\Delta\sigma = \sigma_{3/2} - \sigma_{1/2}$
- (c) the spin state $\sigma_{3/2}$ cross-section
- (d) the spin state $\sigma_{1/2}$ cross-section

M=1380 [1384] MeV, $\sigma=22$ MeV
M=1365 [1384] MeV, $\sigma=22$ MeV
M=1374 [1384] MeV, $\sigma=22$ MeV
M=1330 [1339] MeV, $\sigma=22$ MeV
M=1420 MeV, $\sigma=22$ MeV
[SPES3 mass]

Seven different incident photon energy ranges. Two lowest shown.

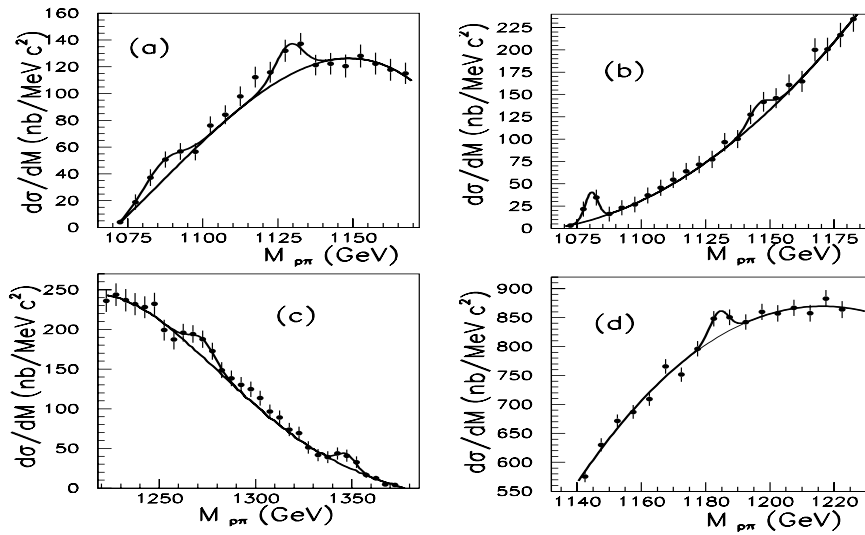
Subtraction of a (renormalized) calculated phase space acting as a physical background.



W. Langgärtner *et al.*, Phys. Rev. Lett. 87, 052001 (2001)

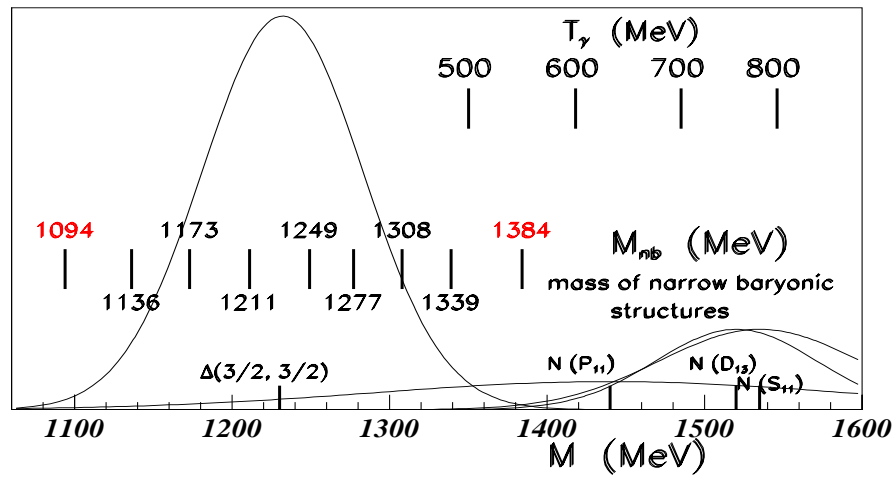
(a) and (b) $322 \leq T_\gamma \leq 540$ MeV
 (c) and (d) $540 \leq T_\gamma \leq 611$ MeV

$M = 1094, 1211, 1249$ MeV.

Comparison between γd and γp reactions.

A. Zabrodin *et al.*, Phys. Rev. C60, 055201 (1999) $500 \leq T_\gamma \leq 800$ MeV.

Insert	Mass (MeV)	width (MeV)	S.D.	Energy range (MeV)	SPES3 mass (MeV)
(a)	1086.5	6	3.1	$500 \leq T_\gamma \leq 600$	1094
(a)	1128.8	4.5	3.	$500 \leq T_\gamma \leq 600$	1136
(b)	1080.6	2.5	2.5	$700 \leq T_\gamma \leq 750$	1094
(b)	1145.9	4.0	1.6	$700 \leq T_\gamma \leq 750$	1136
(c)	1272.3	6.6	2.9	$700 \leq T_\gamma \leq 750$	1277
(c)	1346.4	4.7	1.9	$700 \leq T_\gamma \leq 750$	1339
(d)	1184	2.7	2.9	$500 \leq T_\gamma \leq 800$	1173

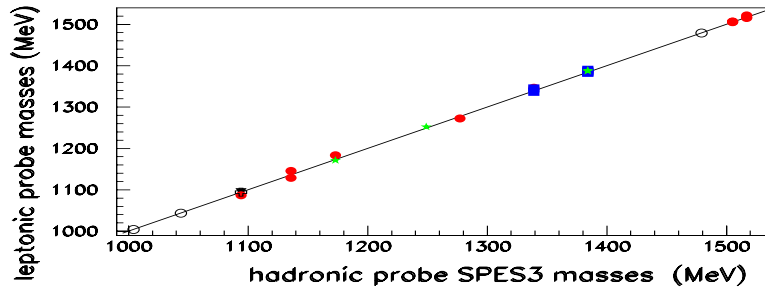


Arbitrary amplitudes

$M=1094$ MeV free from interferences between N , $\Delta(1232)$, and physical background since the one pion production is nearby (1078 MeV).

Excitation of lower mass structures, below pion production threshold.

- Narrow baryonic structures **observed** in spectra from leptonic probe reactions.
- **Same masses** as those where they were observed with hadronic probes.



- Regge-like trajectories show they can be splitted into five different mass-range "regimes" (five different slopes).
- Eventually connected with different number of $(q - \bar{q})$ additional configurations ?
- Connection of exotic baryon mass spectrum, between experimental and calculated from exotic meson mass spectrum

