PWA of Baryon Resonances at BES

Bing-Song Zou

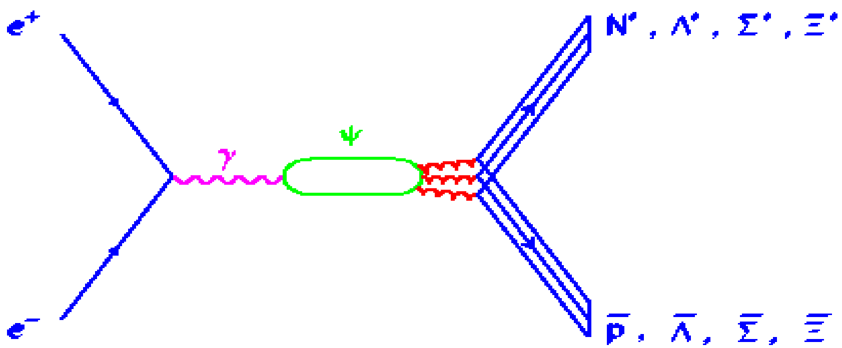
Institute of High Energy Physics, CAS, Beijing

Outline:

- **Introduction**
- **Event-based PWA procedure**
- **N* resonances observed in $\psi \rightarrow \bar{N} \pi N$, $\bar{N} \eta N$**
- **N* and Λ* observed in $J/\psi \rightarrow \bar{\Lambda} K N$**
- **Summary and Prospects**

1. Introduction

$$J/\Psi \rightarrow \overline{B}BM \implies N^*, \Lambda^*, \Sigma^*, \Xi^*$$

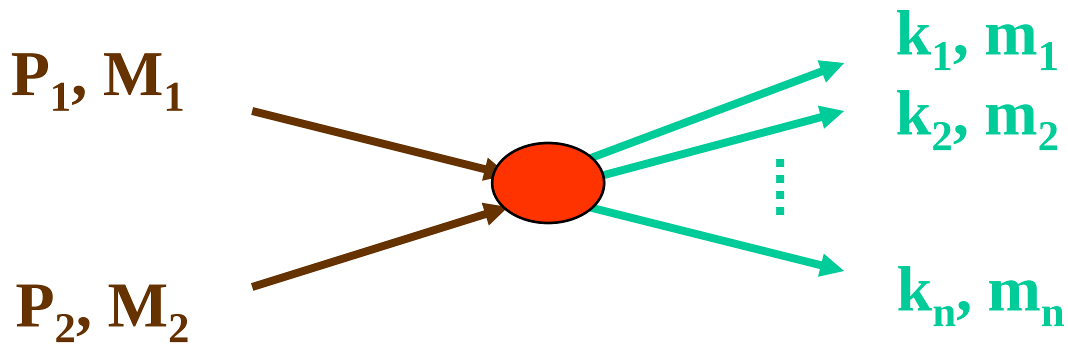


New mechanism for baryon production & an ideal isospin filter

high statistics extension to ψ', χ_{cJ}, η_c

2. Event-based PWA framework

1) Experimental observables – Starting point for PWA



Experimental distribution probability:

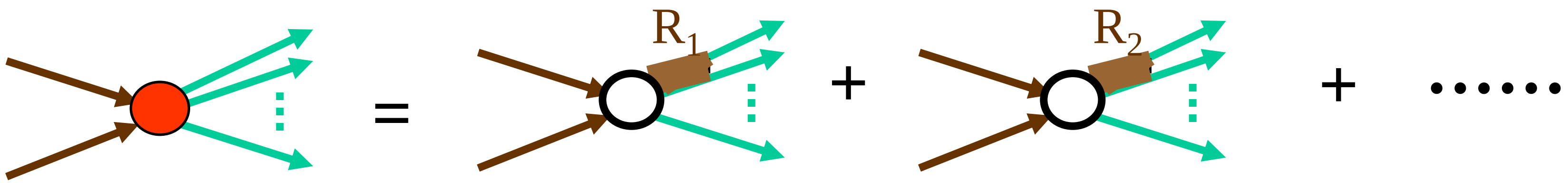
$$W_{exp}(k_1, \ldots, k_n) \sim |\mathcal{M}(k_1, \ldots, k_n)|^2 \, \varepsilon(k_1, \ldots, k_n) \, d\Phi_n(k_1, \ldots, k_n)$$

amplitude efficiency phase space

$$d\Phi_n(P;\, p_1, \ldots, p_n) = \delta^4\left(P - \sum_{i=1}^{n} p_i\right) \prod_{i=1}^{n} \frac{d^3 p_i}{(2\pi)^3 2E_i}$$

various projections

2) Event-based multi-dimensional PWA fit



$$\mathcal{M}(k_1, \ldots, k_n) = C_1 A_{R1}(k_1, \ldots, k_n) + C_2 A_{R2}(k_1, \ldots, k_n) + \ldots$$

$$\Rightarrow \quad W_{th}(k_1, \ldots, k_n; C_1, C_2, \ldots)$$

PWA: fitting experimental data to get $C_1, C_2, \ldots$

Old fashion : χ^2-fit to various projections

Modern technique: multi-dimensional Maximum Likelihood fit to $W_{exp}(k_1, \ldots, k_n)$

CERNLIB programs : FUMILI, MINUIT

3) Construction of PWA covariant tensor amplitudes

R.E.Behrends ,C.Fronsdal, Phys. Rev. 106, 345 (1957)
A.V. Anisovich et al. J. Phys. G 28 15 (2002)

Refs. specific for baryon-antibaryon final states :

W.H.Liang,P.N.Shen,J.X.Wang, B.S.Zou, J.Phys.G28,333 (2002)
B.S.Zou, F.Hussian, PRC67, 015204 (2003)
J.J.Wu, Z.Ouyang, B.S.Zou, PRC80, 045211 (2009)

Basic ingredients :

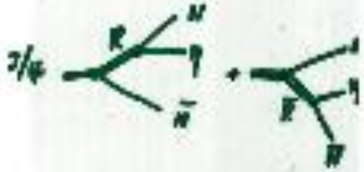
(1) spin wave-function for single particle
(2) orbital wave-function for two-particle system
(3) effective couplings
(4) Breit-Wigner propagator, form factor

For ψ decay to baryons:

- Construction of PWA amplitudes.

Rarita-Schwinger covariant tensor formalism.

(1) $\frac{1}{2}^{\pm}$ N^* .



$$\mathcal{L}_{\eta N R} = -i g_{\eta N R} \bar{N} \Gamma R \eta + h.c.$$

$$\mathcal{L}_{\psi N R} = -g_{\psi_R} \bar{R} \Gamma_\mu N \psi^\mu + \frac{i g_{\psi_R}}{M_R + M_N} \bar{R} \Gamma_{\mu\nu} \xi^\nu_\psi N \psi^\mu + h.c.$$

where

$\Gamma = 1, \quad \Gamma_\mu = \gamma_5 \gamma_\mu, \quad \Gamma_{\mu\nu} = \gamma_5 \sigma_{\mu\nu}$ for $\frac{1}{2}^-$ N^*,

$\Gamma = \gamma_5, \quad \Gamma_\mu = \gamma_\mu, \quad \Gamma_{\mu\nu} = \sigma_{\mu\nu}$ for $\frac{1}{2}^+$ N^*.

$$A_{\frac{1}{2}^-} = G_1 \bar{u} \left[\frac{\not k_1 + \not k_2 + M_{N^*}}{M_{N^*}^2 - s_{12} - i M_{N^*} \Gamma_{N^*}} \gamma_5 \gamma_\mu \varepsilon^\mu + \gamma_5 \not\varepsilon \frac{-\not k_1 - \not k_3 + M_{N^*}}{M_{N^*}^2 - s_{13} - i M_{N^*} \Gamma_{N^*}} \right] v$$

$$+ G_2 \bar{u} \left[\frac{\not k_1 + \not k_2 + M_{N^*}}{M_{N^*}^2 - s_{12} - i M_{N^*} \Gamma_{N^*}} \gamma_5 \sigma_{\mu\nu} \xi^\mu_\psi \varepsilon^\nu + \gamma_5 \sigma_{\mu\nu} \xi^\mu_\psi \varepsilon^\nu \frac{-\not k_1 - \not k_3 + M_{N^*}}{M_{N^*}^2 - s_{13} - i M_{N^*} \Gamma_{N^*}} \right] v$$

$$A_{\frac{1}{2}^+} = \cdots$$

Three basic elements for constructing amplitudes:

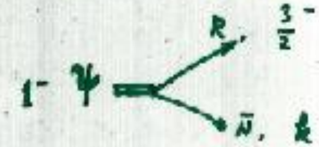
Wave functions, propagators, effective couplings.

(2) $\frac{3}{2}$ N^*

Wave function: $u_\mu(p, s_0) = \sum_{\lambda, s} (1 \lambda \tfrac{1}{2} s | \tfrac{3}{2} s_0) e_\mu(p, \lambda) u(p, s)$

propagators: $P_{\mu\nu} = \frac{\not p + M_0}{p^2 - M_0^2 + i M_0 \Gamma_0} \left[g_{\mu\nu} - \frac{1}{3} \gamma_\mu \gamma_\nu - \frac{2 p_\mu p_\nu}{3 M_0^2} + \frac{p_\mu \gamma_\nu - p_\nu \gamma_\mu}{3 M_0} \right]$

effective couplings:



(1) $\bar{R}^\mu \psi^\nu g_{\mu\nu} N$ $\qquad$ $\bar{R}^\mu \psi^\nu g_{\mu\nu} \gamma_5 N$

(2) $\bar{R}^\mu \psi^\nu \gamma_\nu k_\mu N$ $\qquad$ $\bar{R}^\mu \psi^\nu \gamma_\nu k_\mu \gamma_5 N$

(3) $\bar{R}^\mu \psi^\nu k_\mu k_\nu N$ $\qquad$ $\bar{R}^\mu \psi^\nu k_\mu k_\nu \gamma_5 N$

$i \bar{N} \phi \gamma_5 k_\mu R^\mu$ $\qquad$ $i \bar{N} \phi k_\mu R^\mu$

N* with spin J* = n + ½

wave function : $u_{\mu_1\mu_2\cdots\mu_n}(p, n+\frac{1}{2}, s) = \sum_{s_n, s_{n+1}} (n, s_n; \frac{1}{2}, s_{n+1}|n+\frac{1}{2}, s)\varepsilon_{\mu_1\mu_2\cdots\mu_n}(p, n, s_n)u(p, s_{n+1})$

propagator : $G_{R(q)}^{n+\frac{1}{2}(\pm)} = \frac{P^{n+\frac{1}{2}(\pm)}_{\mu_1\mu_2\ldots\mu_n\nu_1\nu_2\ldots\nu_n}}{q^2 - m_R^2 + i m_R\Gamma_R}, \quad P^{n+\frac{1}{2}(\pm)}_{\mu_1\mu_2\ldots\mu_n\nu_1\nu_2\ldots\nu_n} = \frac{n+1}{2n+3}(\not p \pm m)\gamma^\alpha\gamma^\beta P^{n+1}_{\alpha\mu_1\mu_2\ldots\mu_n\beta\nu_1\nu_2\ldots\nu_n}$

effective couplings : ……

↓

FDC (Automatic Feynman Diagram Calculation) – J. X. Wang

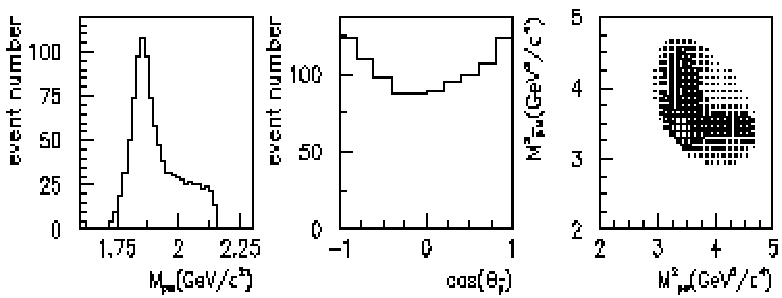
↓

Fortran Programs for amplitudes

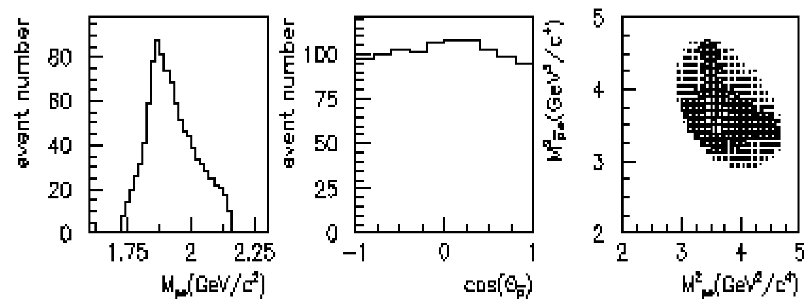
↓

Fit to the data

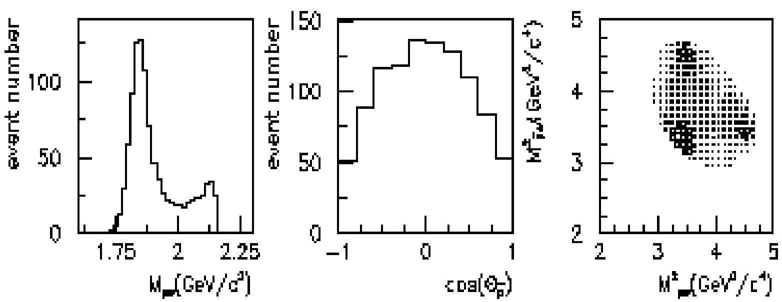
Monte Carlo Simulation for $J/\Psi \rightarrow p + \bar{p} + \omega$



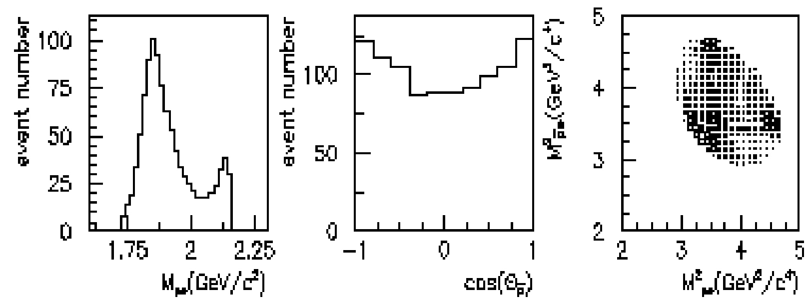
Plots for N^* resonance with $J^P = \frac{1}{2}^-$ and for decay mode 1.



Plots for N^* resonance with $J^P = \frac{3}{2}^+$ and for decay mode 3.



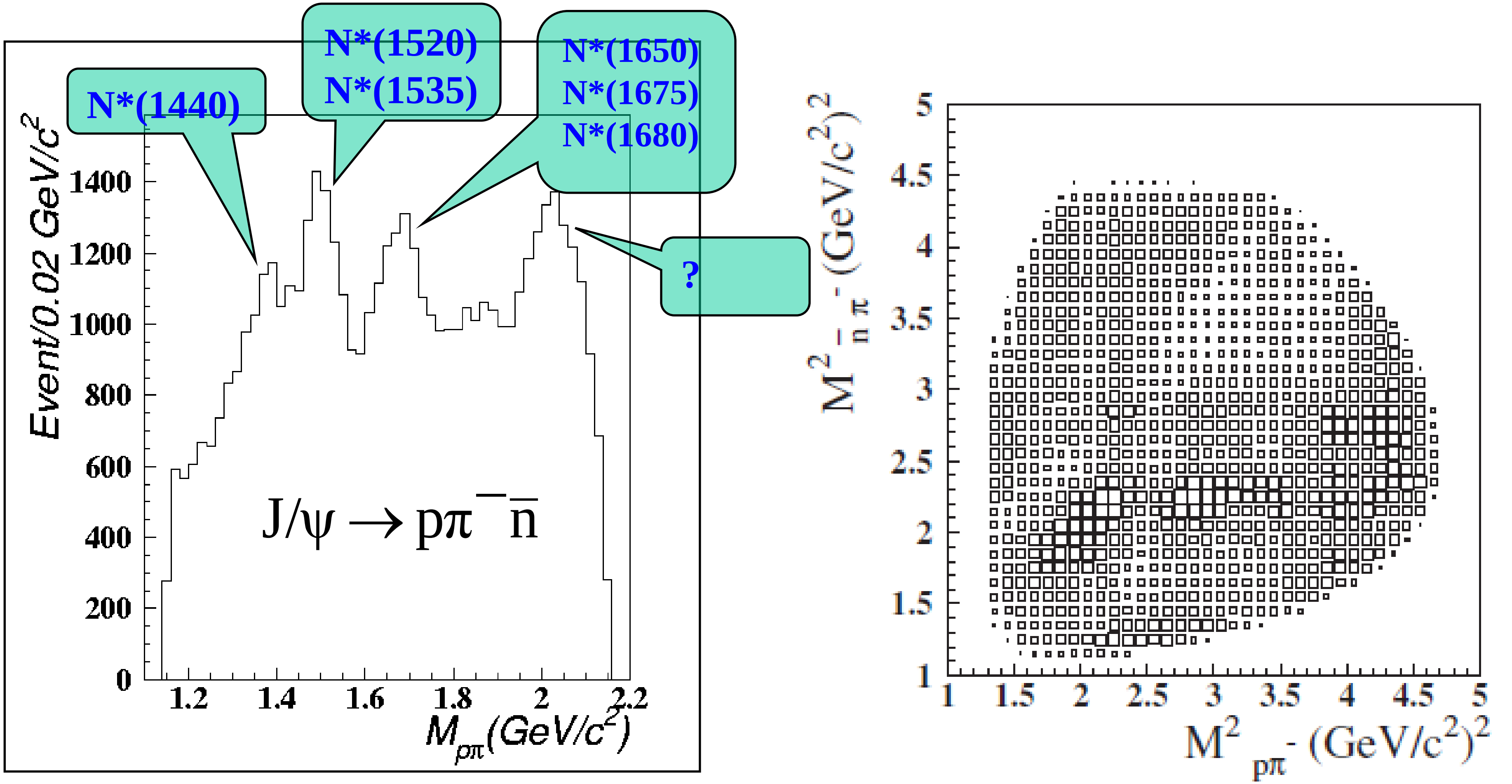
Plots for N^* resonance with $J^P = \frac{3}{2}^+$ and for decay mode 2.



Plots for N^* resonance with $J^P = \frac{5}{2}^-$ and for decay mode 4.

W.H.Liang, P.N.Shen, J.X.Wang, B.S.Zou, J. Phys. G28 (2002) 333

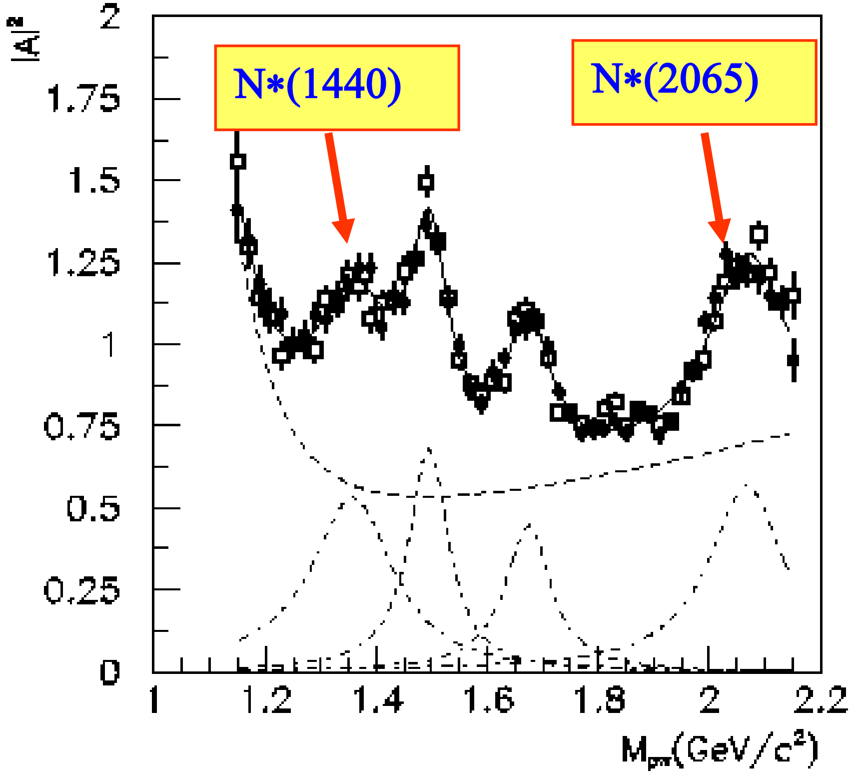
3. N* resonances observed in $\psi \rightarrow \bar{N} \pi N$

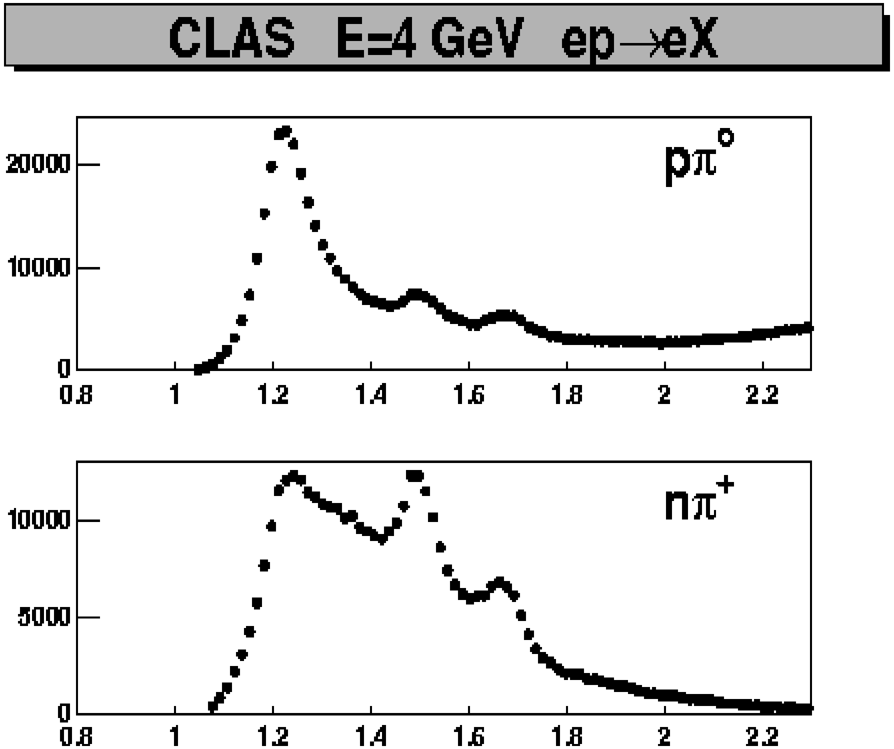


N* in ψ → $\bar{p}n\pi^+$ & $\bar{n}\pi^-p$

$J/\psi \to \bar{p}n\pi^+$ & $\bar{n}\pi^-p$

V. Burkert





Observation of two new N* peaks in πN mass spectrum

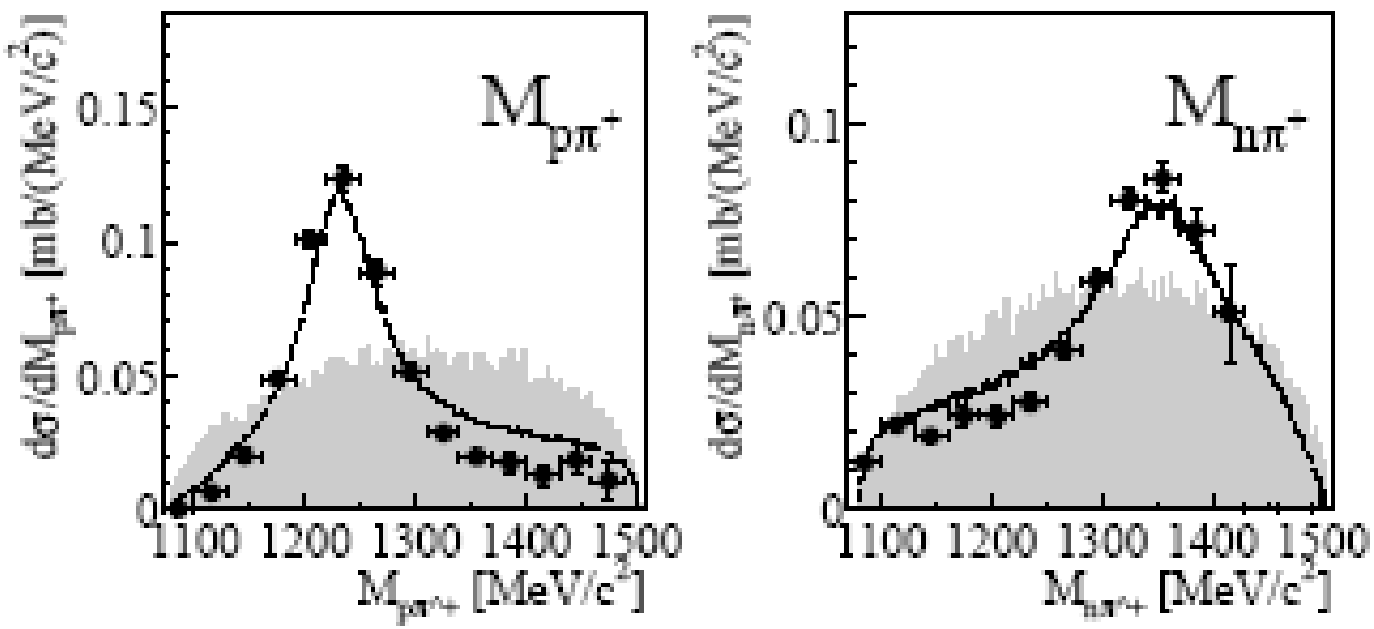
BES, Phys.Rev.Lett.97(2006)062001

The first experiment "seeing" N*(1440) in πN mass spectrum

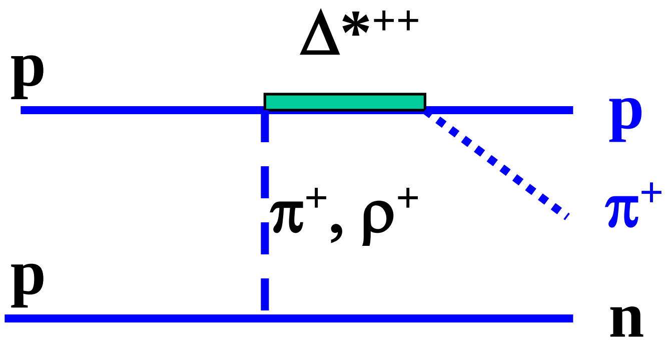
BESII	$M = 1358 \pm 17$,	$\Gamma = 179 \pm 56$	MeV
PDG08	$M = 1365 \pm 15$,	$\Gamma = 190 \pm 30$	MeV

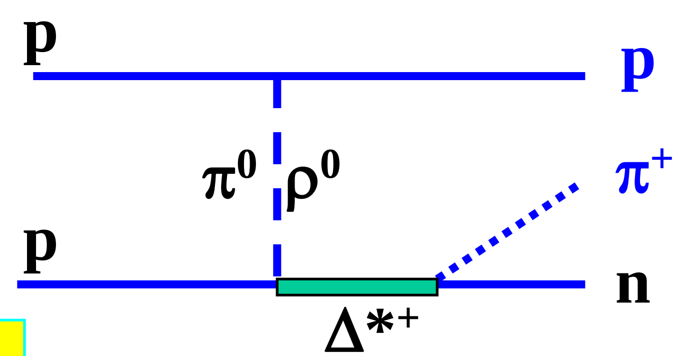
Another experiment "seeing" N*(1440) in πN mass spectrum

CELSIUS-WASA Collaboration, nucl-ex/0612015

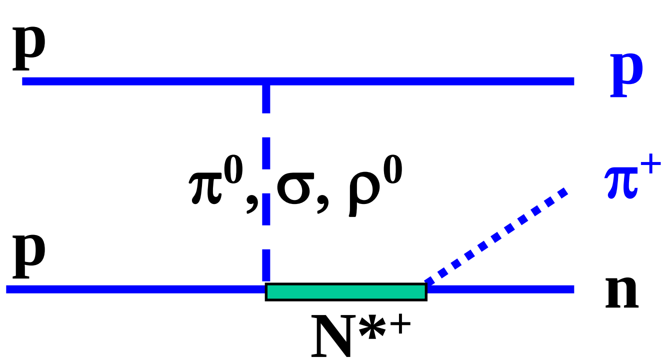


Higher energies and Dalitz plots are needed at COSY&CSR !





9:1

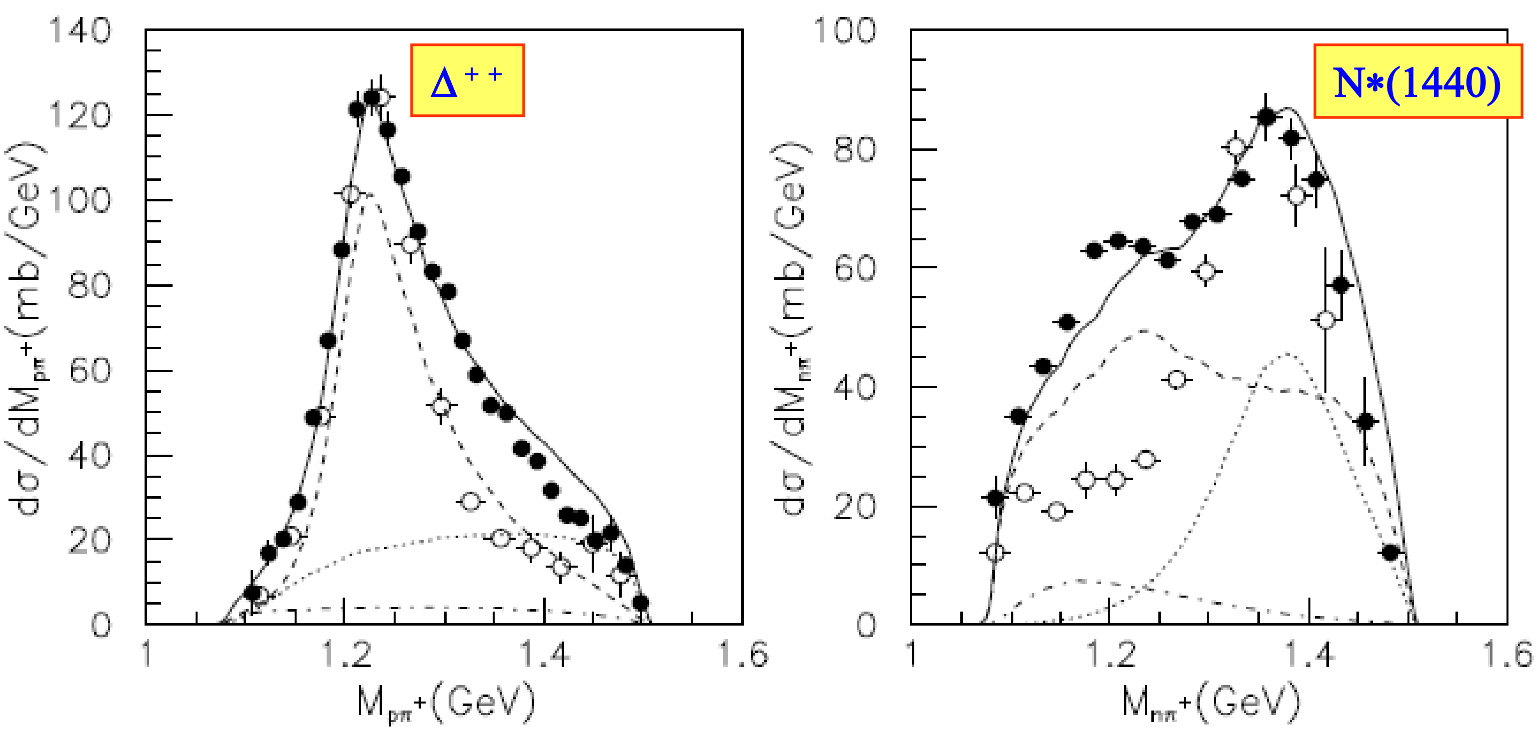


A quite good isospin filter !

Look for "missing" N* by σp production !

Theoretical study on pp→pnπ^+

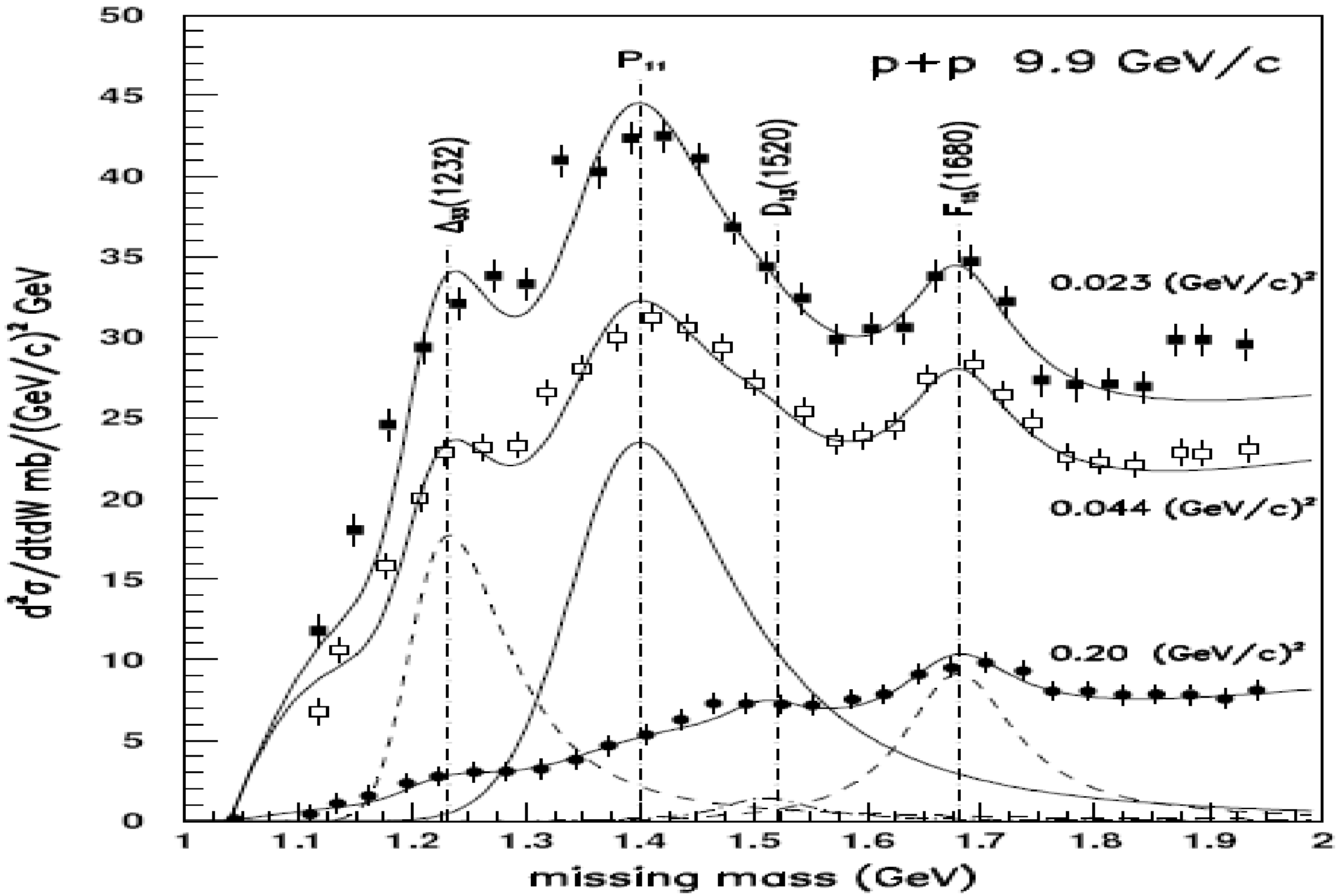
Z.Ouyang,J.J.Xie,B.S.Zou &H.S.Xu, Nucl.Phys.A 821(2009)220; IJMPE(2009)



Including N*(1440) by σ exchange is crucial to reproduce data

H.P.Morsch, Int.J.Mod.Phys.A20(2005)1699

N*(1440) in missing mass of α + p → α + X & p + p → p + X



p + p → p + X

$\gamma p \rightarrow p\ \pi^0\ \pi^0$

A.V. Sarantsev et al., Phys. Lett. B659, 94 (2008).

$pN \rightarrow \pi\pi NN$

X.Cao, B.S.Zou, H.S.Xu, Phys. Rev. C 81(2010) 06***

Both analyses demand larger σN/πΔ ratio for N*(1440)

The new N*(2065) peak in πN mass spectrum

$$M = 2068 \pm 3\,^{+15}_{-40}\ \mathrm{MeV/c^2},\ \Gamma = 165 \pm 14 \pm 40\ \mathrm{MeV/c^2}$$

$J/\psi \rightarrow \bar{n}$ N*(2065) with L=0 (small excess energy)

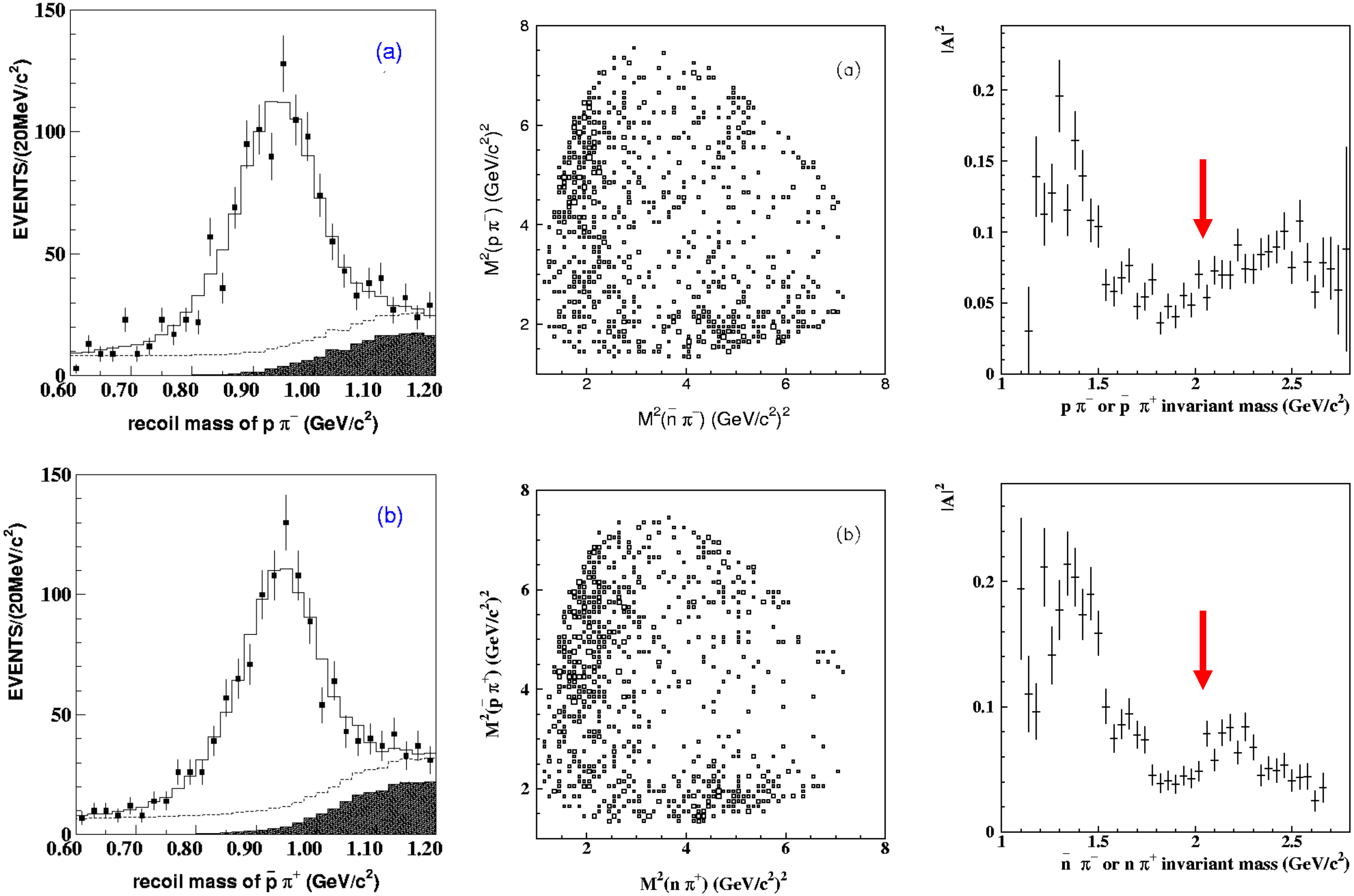
limits its J^P to be $3/2^+$ or $1/2^+$ (spin filter)

PWA with event-based Maximum-Likelihood method

→ Both $3/2^+$ and $1/2^+$ are there.

1/2+ or 3/2+ (improve log likelihood by 400)
1/2+ + 3/2+ (improve log likelihood further by 60)

$\psi(2S) \to p\pi^- \bar{n} + c.c.$



Phys. Rev. D74, 012004 (2006)

$\gamma p \rightarrow \pi^+ n$ & $\gamma n \rightarrow \pi^- p$

Jlab Hall A Collaboration,
L.Y.Zhu et al., PRL91 (2003) 022003

Clear broad resonance cluster around 2.2 GeV

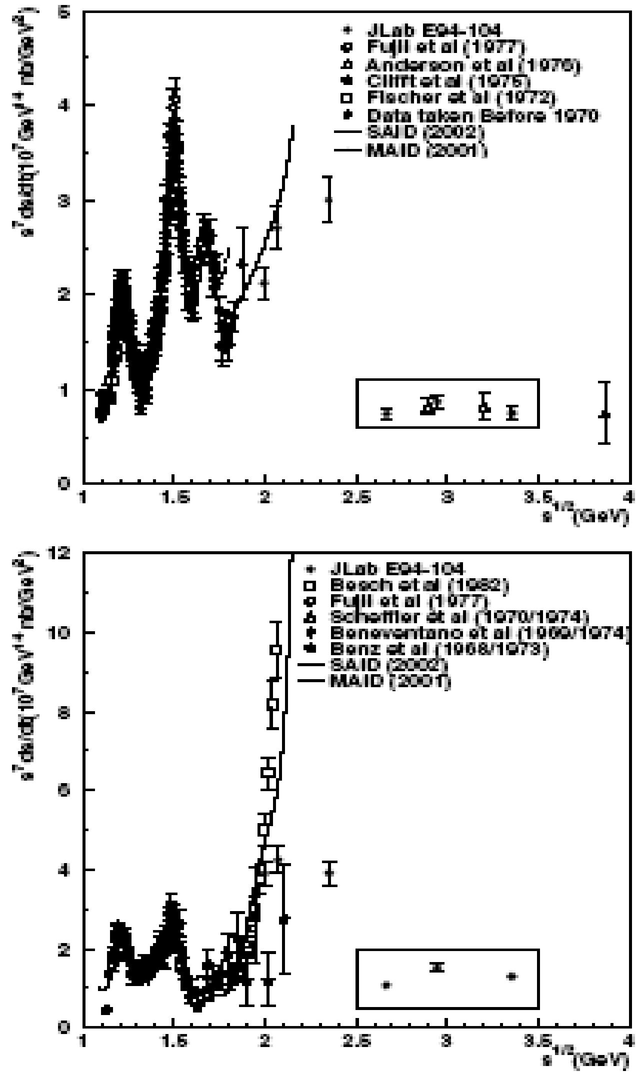
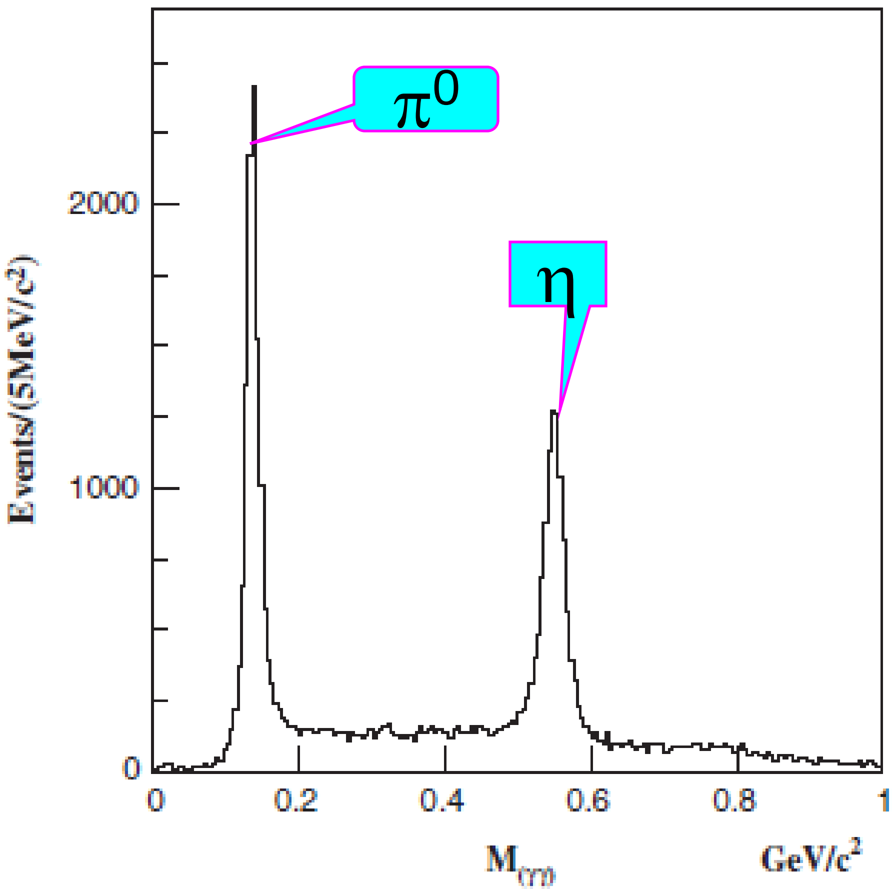
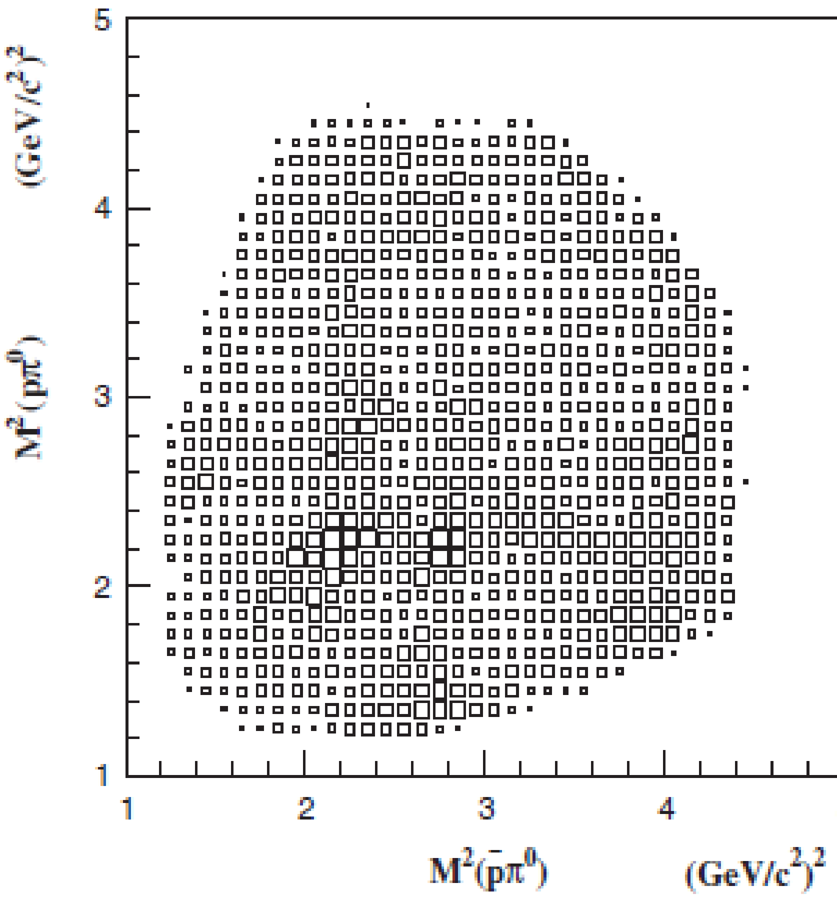


FIG. 1. The scaled differential cross section $s^7 \frac{d\sigma}{dt}$ versus center-of-mass energy for the $\gamma p \rightarrow \pi^+ n$ (upper plot) and $\gamma n \rightarrow \pi^- p$ (lower plot) at $\theta_{c.m.} = 90°$. The data from JLab E94-104 are shown as solid circles. The error bars for the new

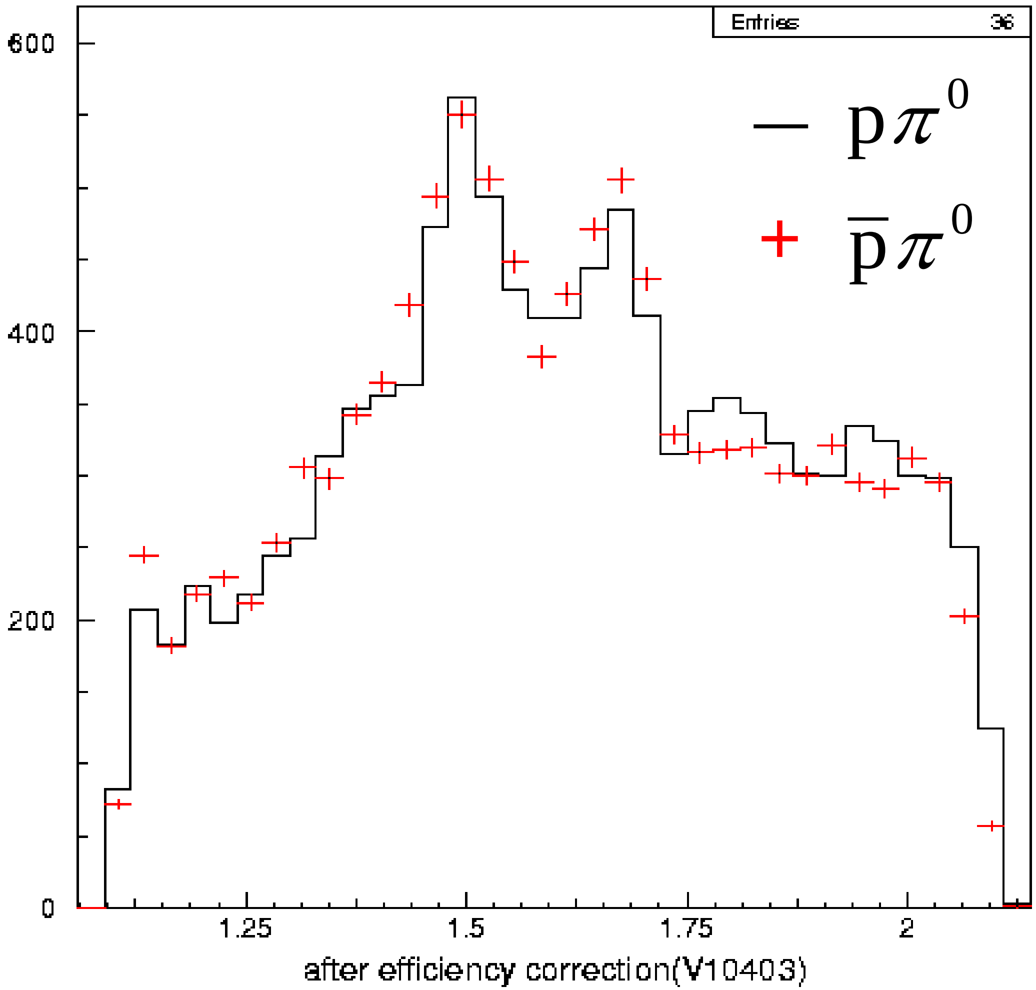
N* in $J/\psi \to p\bar{p}\pi^0$





Phys.Rev.D80:052004,2009

N* in $J/\psi \to p\bar{p}\pi^0$



N* in $J/\psi \to p\bar{p}\pi^0$

- **More than 10 K events were selected, and detailed PWA was performed**

- **N(1440), N(1520), N(1535), N(1650), N(1675), N(1680), N(1710) are needed.**

- **N(2065) is needed in the fit, and J^{PC} favor 3/2+**

$$M = 2040\,^{+3}_{-4} \pm 25\ \mathrm{MeV/c^2},\ \Gamma = 230 \pm 8 \pm 56\ \mathrm{MeV/c^2}$$

Resonance	Mass (MeV/c^2)	(Width MeV/c^2)	J^P	Fraction (%)
$N(1440)$	1455^{+2}_{-7}	316^{+5}_{-6}	$\frac{1}{2}^+$	16.37
$N(1520)$	1513^{+3}_{-4}	127^{+7}_{-8}	$\frac{3}{2}^-$	7.96
$N(1535)$	1537^{+2}_{-6}	135^{+8}_{-8}	$\frac{1}{2}^-$	7.58
$N(1650)$	1650^{+3}_{-6}	145^{+5}_{-10}	$\frac{1}{2}^-$	9.06
$N(1710)$	1715^{+2}_{-2}	95^{+2}_{-1}	$\frac{1}{2}^+$	25.33
$N_x(2065)$	2040^{+3}_{-4}	230^{+8}_{-8}	$\frac{3}{2}^+$	23.39

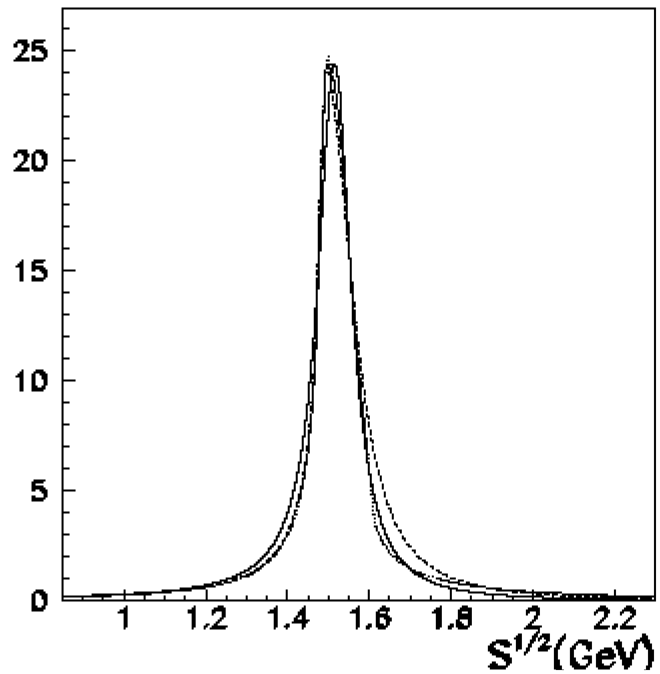
$$\Gamma_{N(1440)(s)} = \Gamma_{N(1440)}\left(0.7\frac{B_1(q_{\pi N})\rho_{\pi N}(s)}{B_1(q_{\pi N}^{N^*})\rho_{\pi N}(M_{N^*}^2)} + 0.3\frac{B_1(q_{\pi\Delta})\rho_{\pi\Delta}(s)}{B_1(q_{\pi\Delta}^{N^*})\rho_{\pi\Delta}(M_{N^*}^2)}\right)$$

T.P. Vrana, S.A. Dytman, T.-S. H. Lee, Phys.Rept.328 (2000)181

B.C. Liu, B.S. Zou, PRL96 (2006) 042002; PRL98 (2007) 039102

Mass of N*(1535)

$$BW(p_{N^*}) = \frac{1}{M_{N^*}^2 - s - iM_{N^*}\Gamma_{N^*}(s)}$$



(1) $\Gamma_{N^*}(s) = 98MeV$

$M_{N^*} = 1515MeV$

(2) $$\Gamma_{N^*}(s) = \Gamma^0_{N^*}\left(0.5\frac{\rho_{\pi N}(s)}{\rho_{\pi N}(M^2_{N^*})} + 0.5\frac{\rho_{\eta N}(s)}{\rho_{\eta N}(M^2_{N^*})}\right) = \Gamma^0_{N^*}\left[0.8\rho_{\pi N}(s) + 2.1\rho_{\eta N}(s)\right]$$

$$M_{N^*} = 1535 \text{ MeV and } \Gamma^0_{N^*} = 150 \text{ MeV}$$

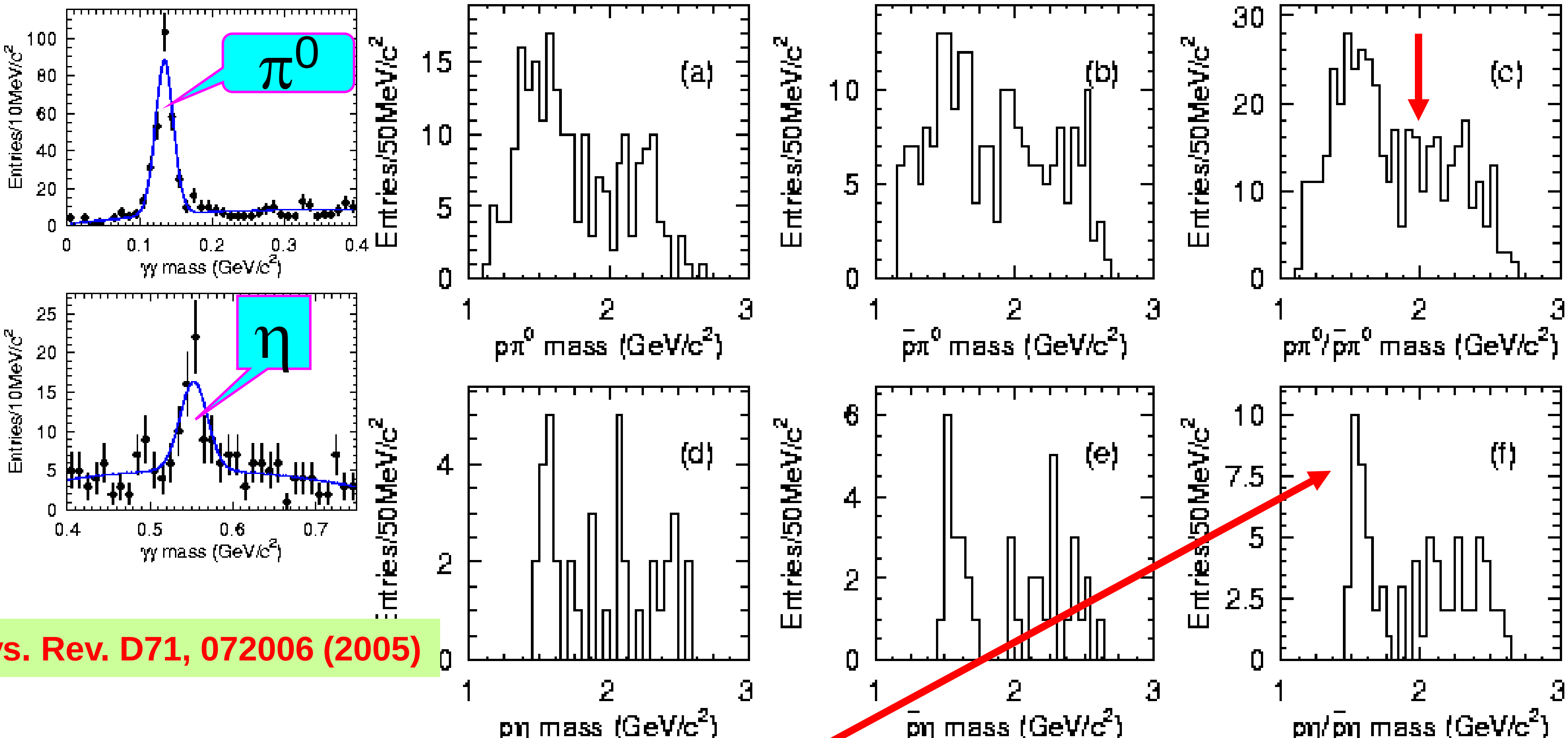
(3) $$\Gamma_{N^*}(s) = \Gamma^0_{N^*}\left[0.8\rho_{\pi N}(s) + 2.1\rho_{\eta N}(s) + 3.5\rho_{\Lambda K}(s)\right]$$

$M_{N^*} \approx 1400MeV$

$\Gamma^0_{N^*} = 270MeV$

S. Ceci, A. Svarc, B. Zauner, Phys.Rev.Lett.102 (2009) 209101

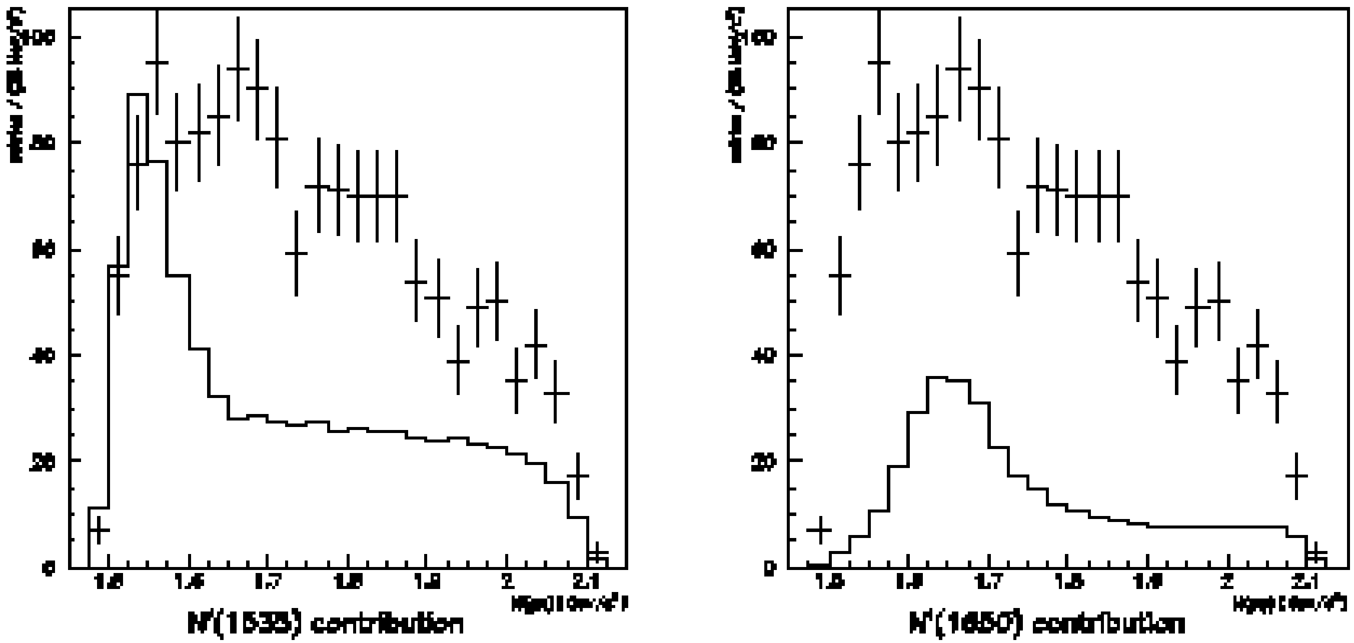
$$\psi(2S) \rightarrow p\bar{p}\pi^0(\eta)$$



Phys. Rev. D71, 072006 (2005)

- A faint accumulation of events around 2065 MeV/c^2
- The enhancement between 1.4 and 1.7 GeV/c^2
- Possible N*(1535) in the pη invariant mass

PWA Results from $J/\psi \to p\bar{p}\eta$ (BESI 7.8M)

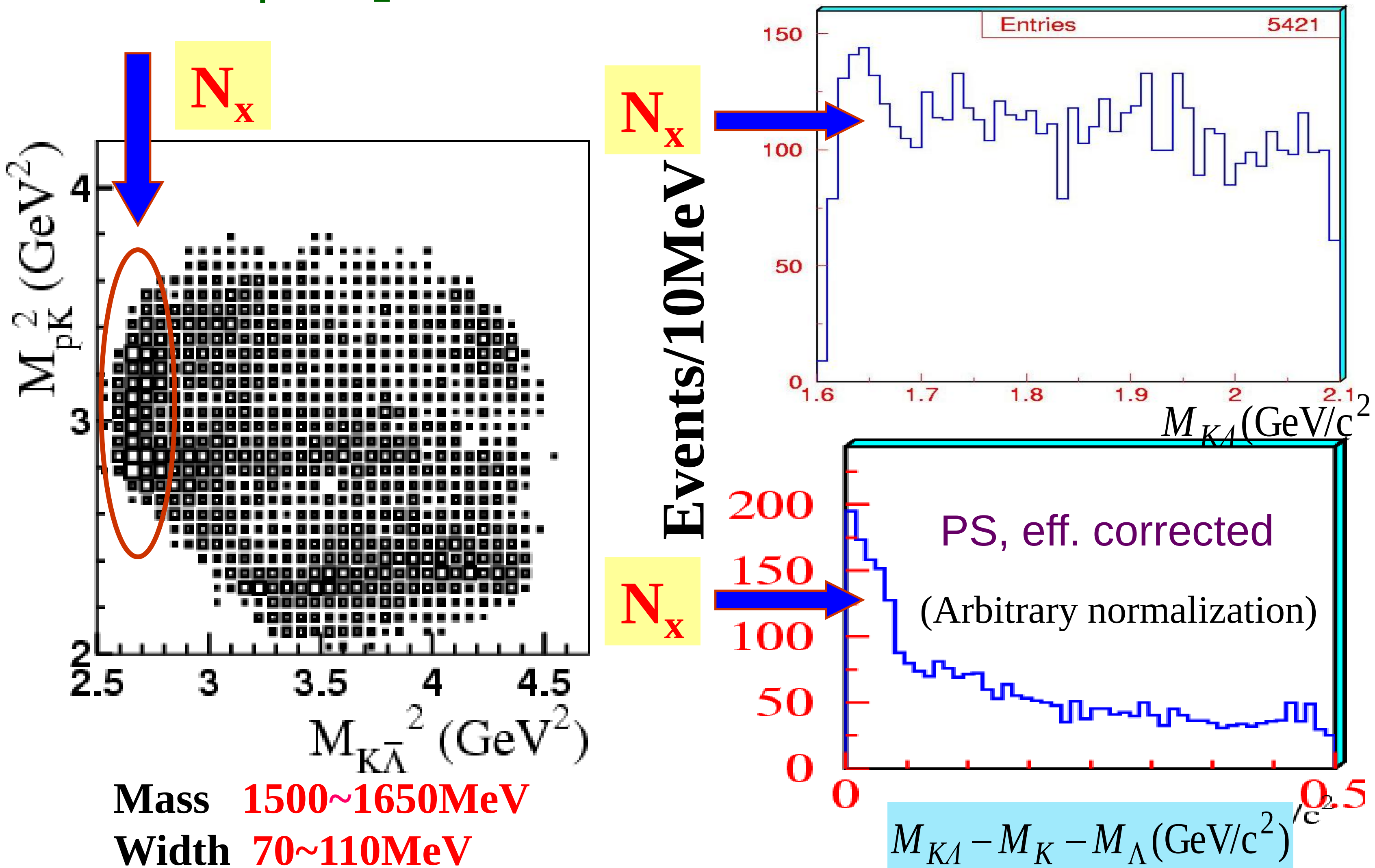


$M_{p\eta}$ (GeV/c^2)

Phys. Lett. B510 (2001) 75

4. N* and Λ* observed in J/ψ → $\bar{\Lambda}$ K N

N* in J/ψ → p K^- $\bar{\Lambda}$ + c.c.



Mass **1500~1650MeV**

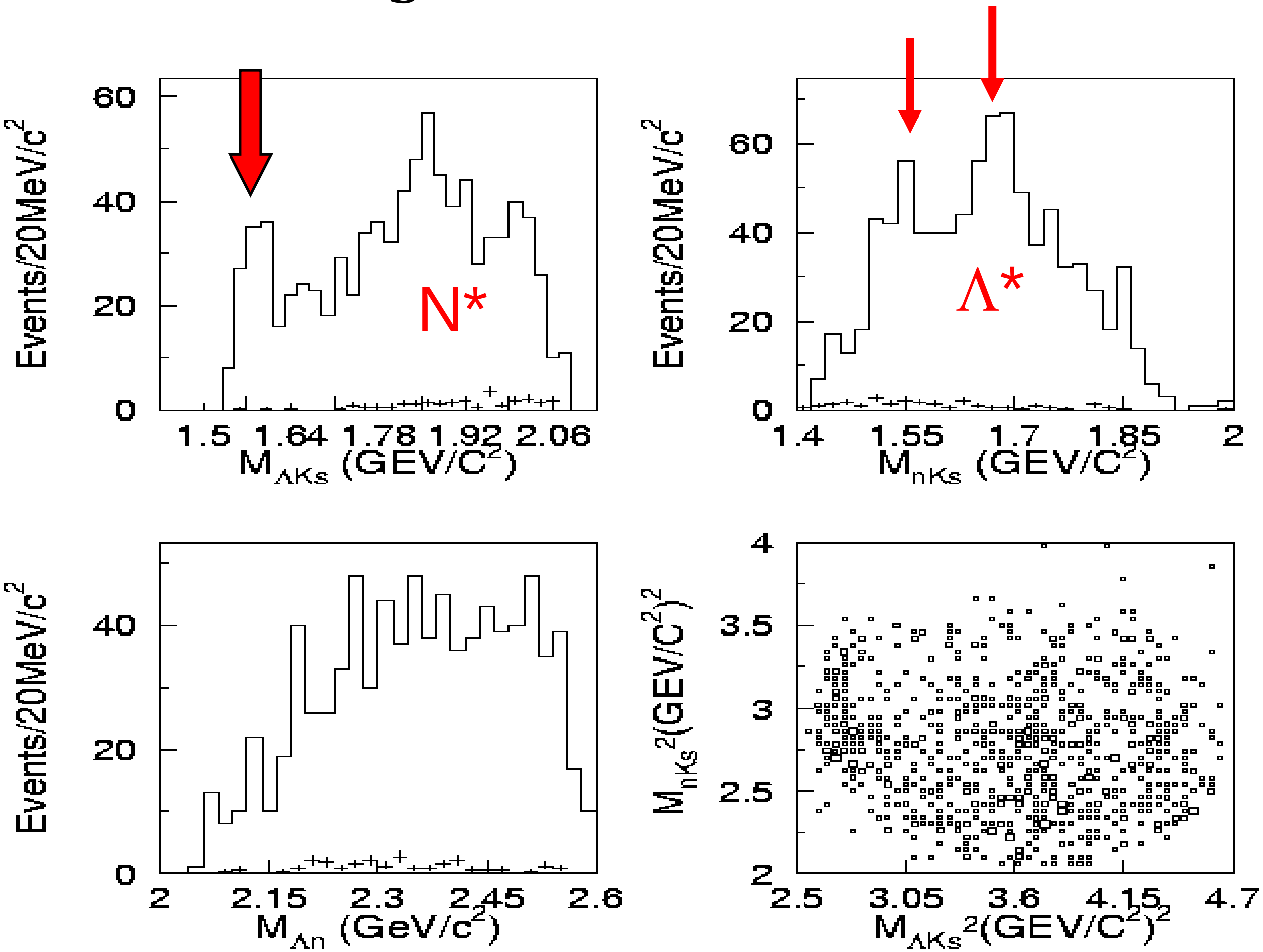
Width **70~110MeV**

J^P **favors 1/2-**

H.X.Yang, BES, IJMPA20 (2005) 1985

$J/\psi \to nK_S^0\overline{\Lambda}$

Phys. Lett. B659 (2008) 789



- **An enhancement near ΛK_S threshold is evident**
- **N* and Λ* found in the ΛK_S and nK_S spectrum**

a) Assuming N_x to be purely N*(1535) :

B.C. Liu, B.S. Zou, PRL96 (2006) 042002; PRL98 (2007) 039102

From relative branching ratios of

$$J/\psi \rightarrow p\,\bar{N}^* \rightarrow p\,(K^-\bar{\Lambda})\,/\,p\,(\bar{p}\eta)$$

$$g_{N^*K\Lambda}/g_{N^*p\eta}/g_{N^*N\pi} \sim 2:2:1$$

b) N_x as dynamical generated with unitary chiral theory:

N*(1535) + non-resonant part

L.S.Geng, E.Oset, B.S. Zou, M.Doring, PRC79 (2009) 025203

$$g_{N^*K\Lambda}/g_{N^*p\eta}/g_{N^*N\pi} \sim 1.2:2:1$$

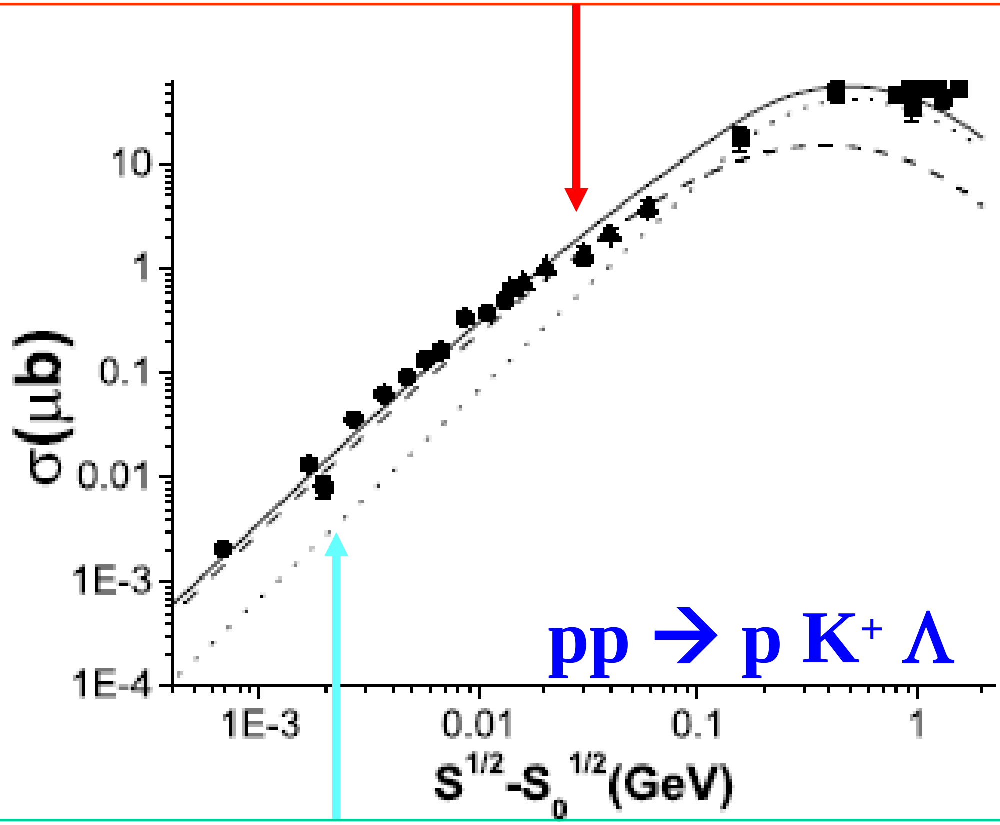
Phenomenology : Large $g_{N^*K\Lambda}$ → large $\bar{s}s$ in N*(1535)

$\bar{s}$[su][ud] or $K\Lambda$-$K\Sigma$ state

Evidence for large $g_{N^*K\Lambda}$ from pp → p K^+ Λ

Total cross section and theoretical results with N*(1535), N*(1650), N*(1710), N*(1720)

B.C.Liu, B.S.Zou, Phys. Rev. Lett. 96 (2006) 042002



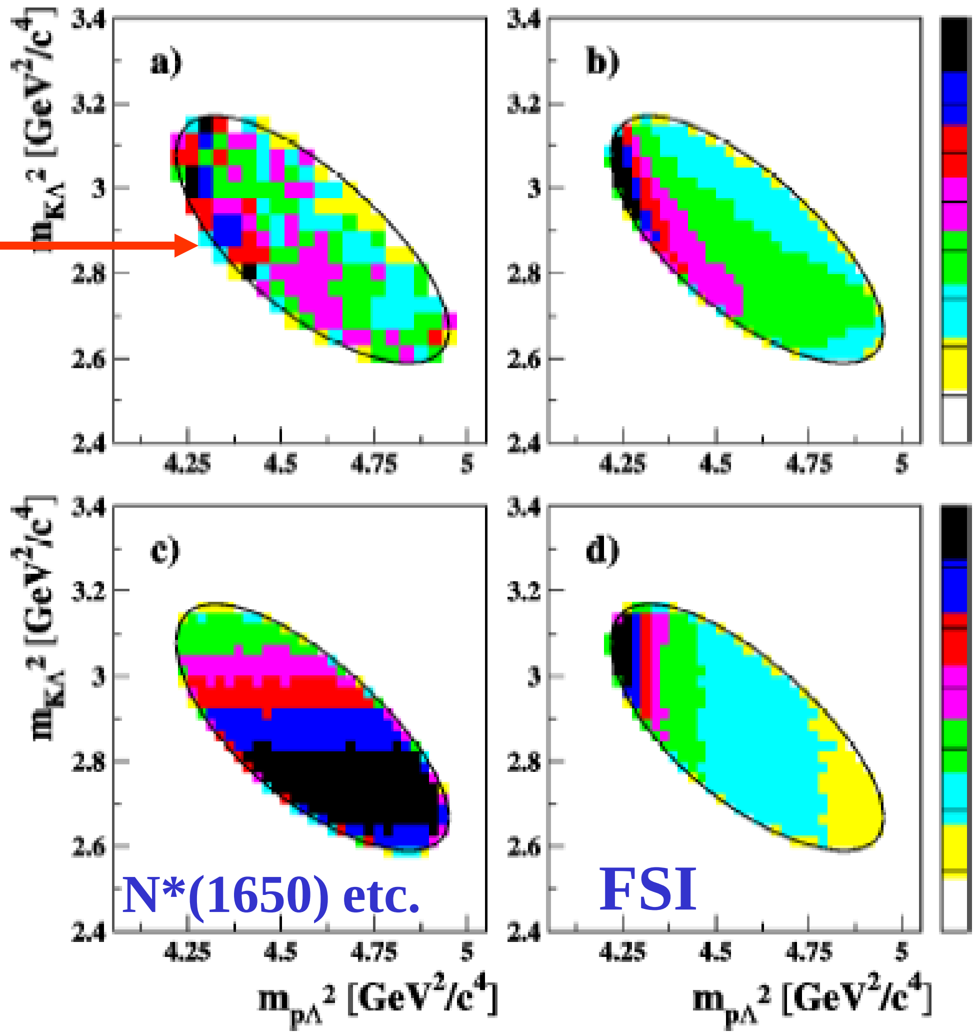
Tsushima,Sibirtsev,Thomas, PRC59 (1999) 369, without including N*(1535)

FSI vs N*(1535) contribution in $pp \rightarrow p K^+ \Lambda$

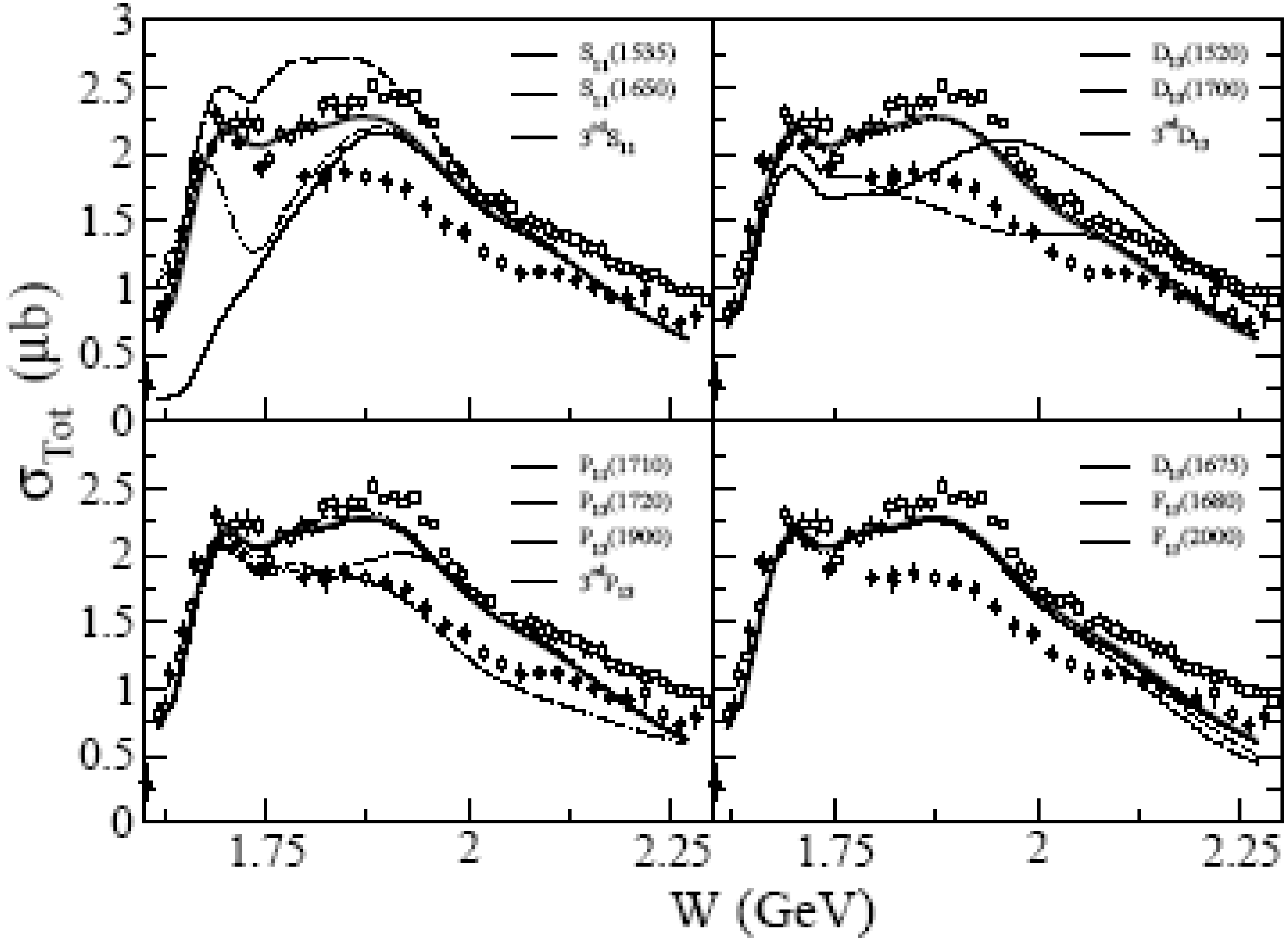
B.C.Liu & B.S.Zou, Phys. Rev. Lett. 98 (2007) 039102 (reply)
A.Sibirtsev et al., Phys. Rev. Lett. 98 (2007) 039101 (comment)

COSY-TOF data
S. Abdel-Samad *et al.*,
Phys.Lett.B632:27(2006)

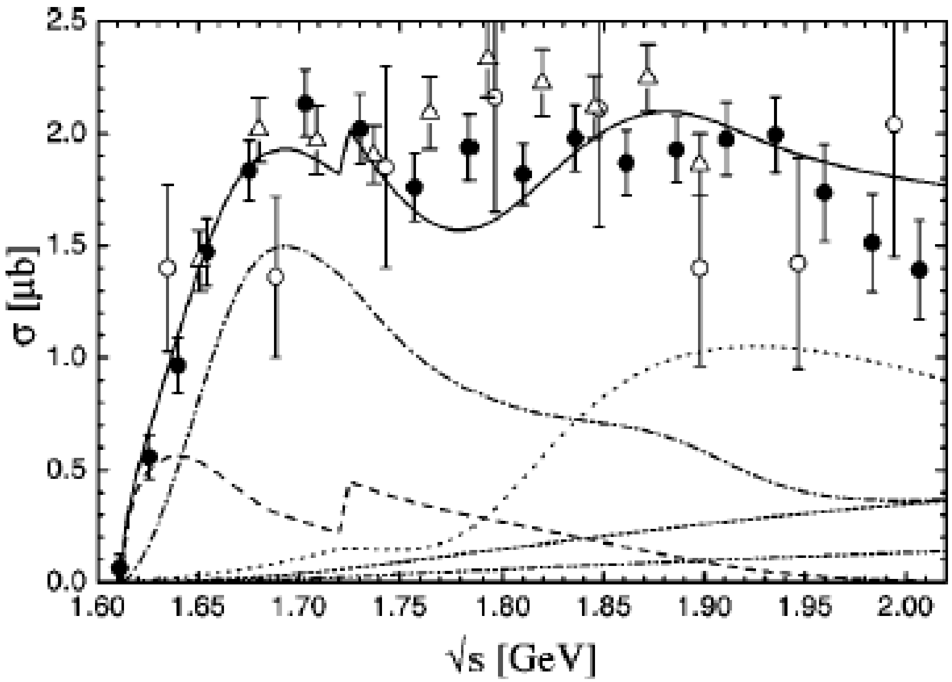
Both FSI & N*(1535) are needed !



Evidence for large $g_{N^*K\Lambda}$ from $\gamma p \rightarrow K^+ \Lambda$



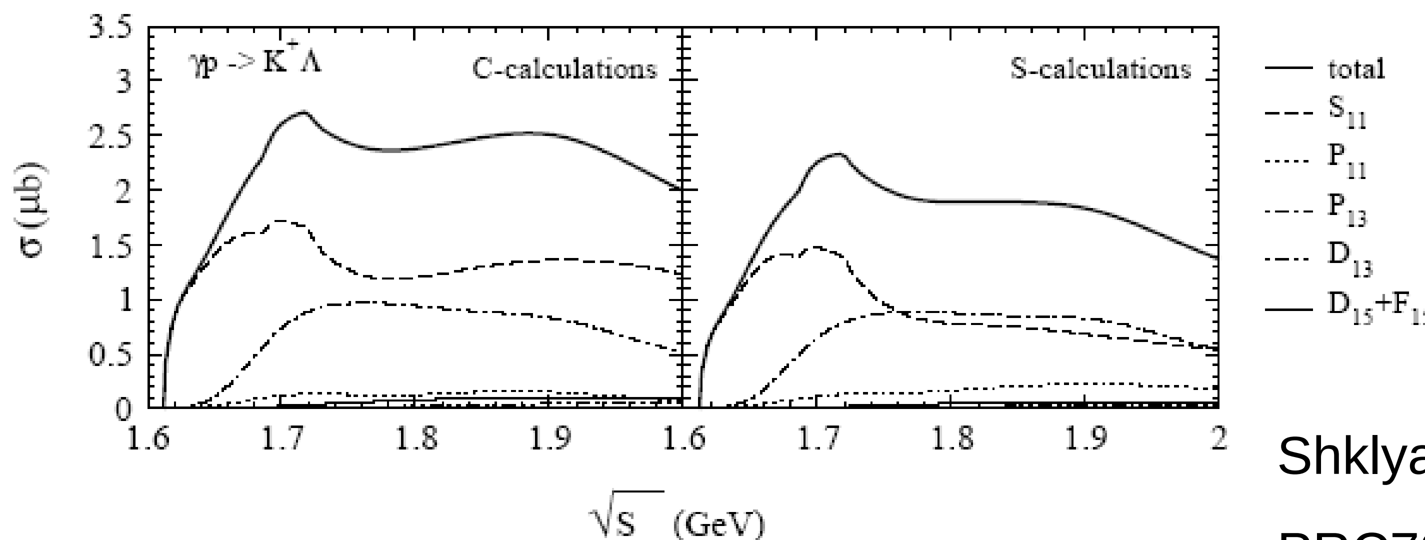
B. Julia-Diaz, B. Saghai, T.-S.H. Lee, F. Tabakin, Phys. Rev. C **73**, 055204 (2006)



G.Penner&U.Mosel,
PRC66 (2002) 055212

Partial wave decomposition
For the fit to SAPHIR92-94
Data

Dashed line : 1/2 -
Dot-dashed line : 3/2+

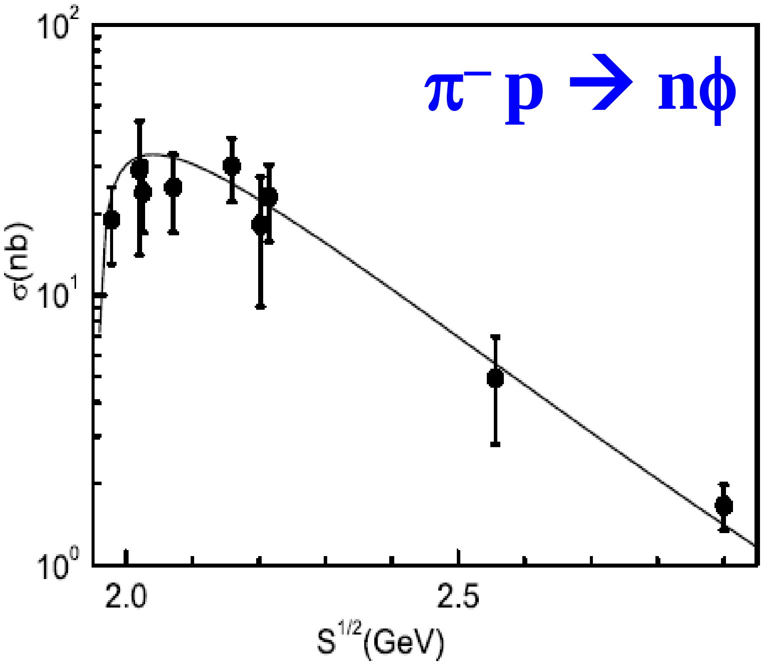


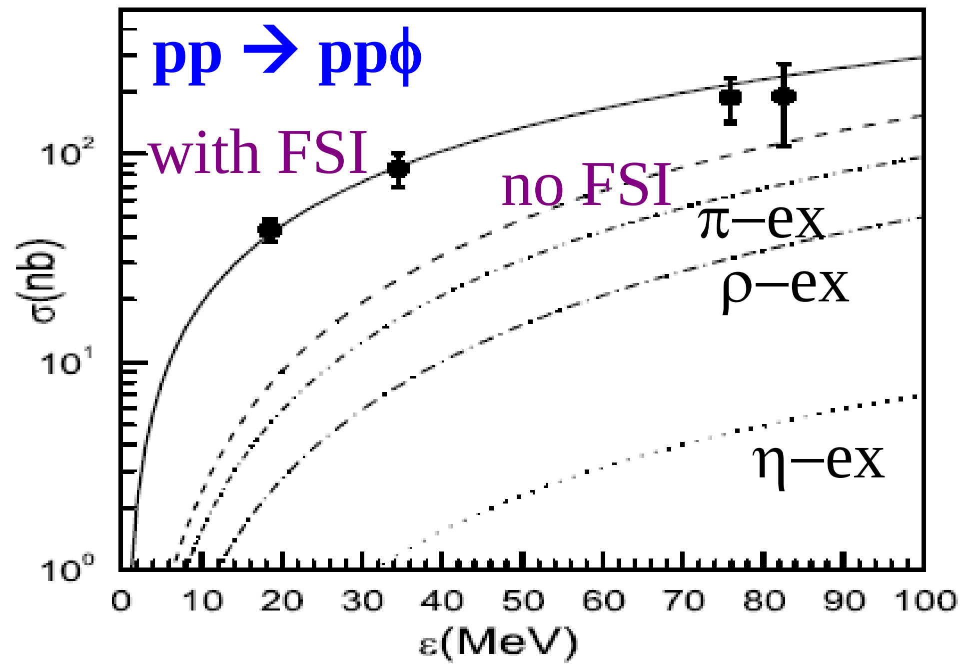
Shklyar,Lenske&Mosel,

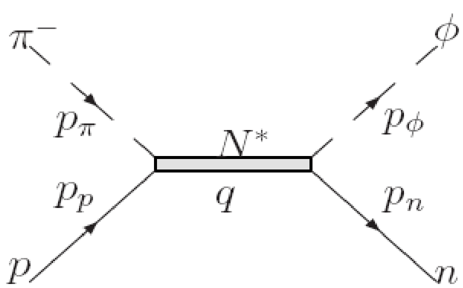
PRC72 (2005) 015210

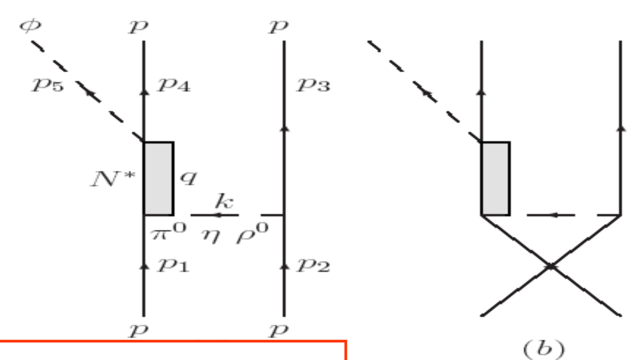
Evidence for large $g_{N^*N\phi}$ from $\pi^- p \rightarrow n\phi$ & $pp \rightarrow pp\phi$

Xie, Zou & Chiang, arXiv:0705.3950









Evasion of OZI rule by N*(1535) !

Evidence for weaker $g_{N^*K\Sigma}$ from $pp \rightarrow p K^+\Lambda$ / $pp \rightarrow p K^+\Sigma^0$

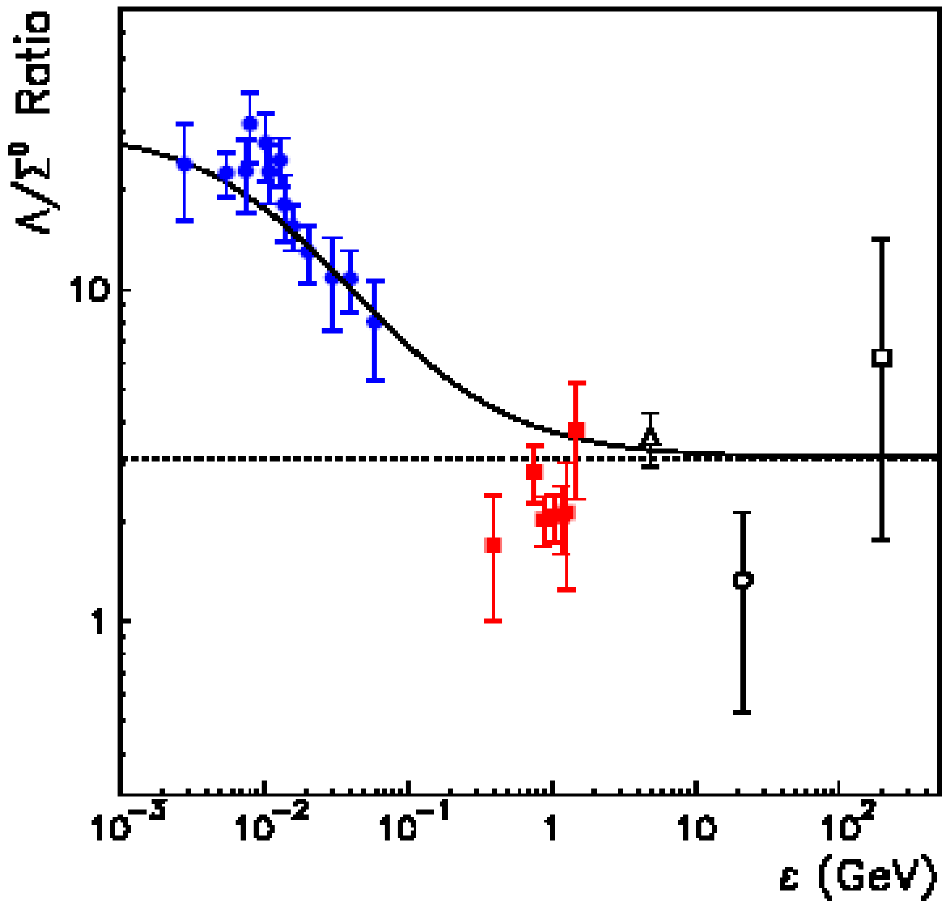
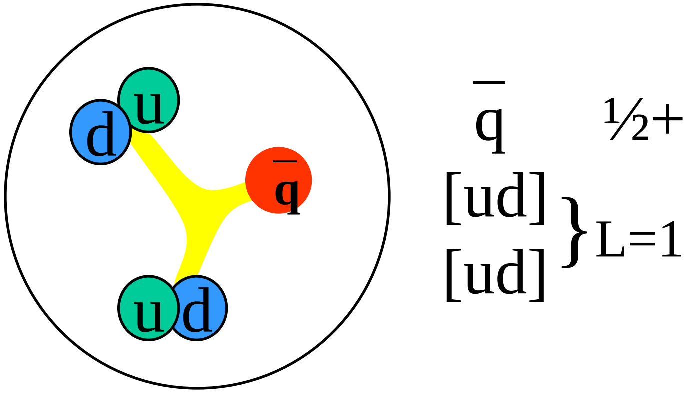


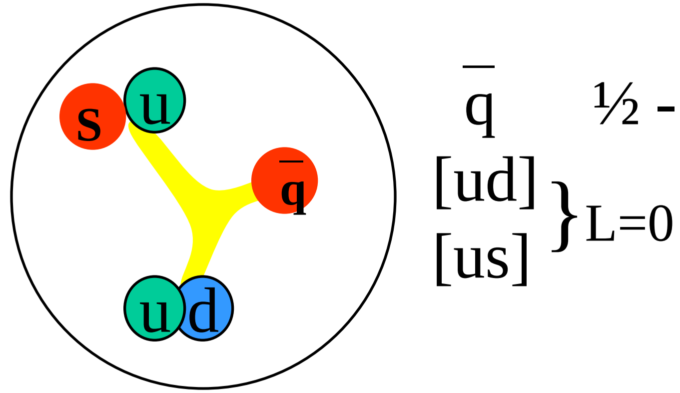
Fig. 3. The Λ/Σ^0 cross-section ratio as a function of the excess energy ϵ. The solid circles show the ratio obtained for the $pp \to K^+\Lambda p$ and $pp \to K^+\Sigma^0 p$ reactions at COSY [2]. Solid

A.Sibirtsev et al., EPJA29 (2006) 363

[2] P.Kowina et al., EPJA22 (2004) 293

Nature of N*(1535) and its $1/2^{-}$ octet partner





Zhang et al, hep-ph/0403210

N*(1535) ~ uud (L=1) + ε [ud][us] $\bar{s}$ + …

N*(1440) ~ uud (n=1) + ξ [ud][ud] $\bar{d}$ + …

Λ*(1405) ~ uds (L=1) + ε [ud][su] $\bar{u}$ + …

N*(1535): [ud][us] $\bar{s}$ → larger coupling to Nη, Nη', Nϕ & KΛ, weaker to Nπ & KΣ, and heavier !

The new picture for the $1/2^-$ octet predicts:

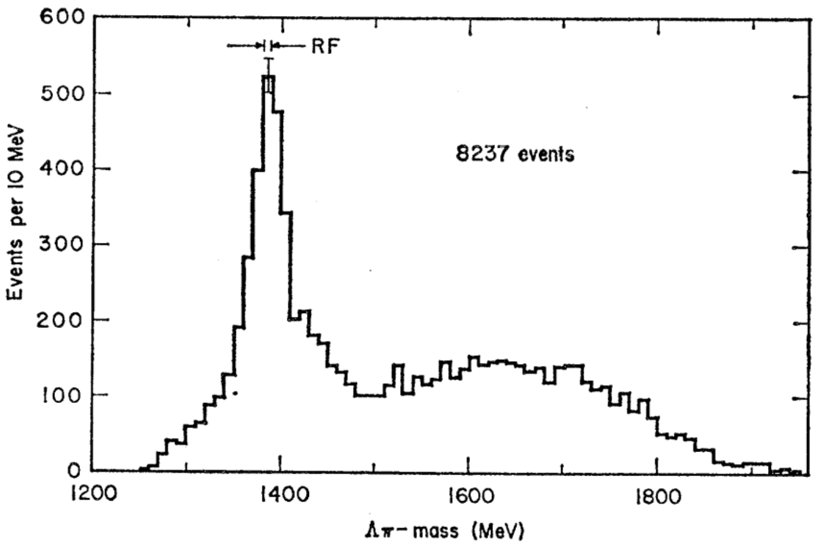
Λ^*	$[us][ds]\,\bar{s}$	~	1575 MeV
Σ^*	$[us][du]\,\bar{d}$	~	1360 MeV
Ξ^*	$[us][ds]\,\bar{u}$	~	1520 MeV

J/ψ decay		branching ratio * 10^4	
$\bar{p}\,\Delta(1232)^+$	3/2+	< 1	} SU(3) breaking
$\bar{\Sigma}^-\,\Sigma(1385)^+$		3.1 ± 0.5	
$\bar{\Xi}^+\,\Xi(1520)^-$		5.9 ± 1.5	
$\bar{p}\,N^*(1535)^+$	1/2-	10 ± 3	} SU(3) allowed
$\bar{\Sigma}^-\,\Sigma(1360)^+$		?	
$\bar{\Xi}^+\,\Xi(1530)^-$		?	

It is very important to check whether under the $\Sigma(1385)$ and $\Xi(1520)$ peaks there are $1/2^-$ components ?

Evidence for the predicted $\Sigma^*(1/2^-)$

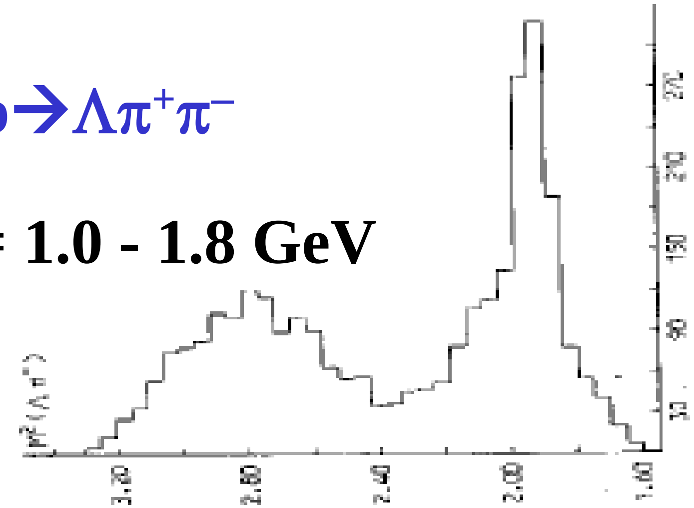
Huwe, PR181(1969)1824

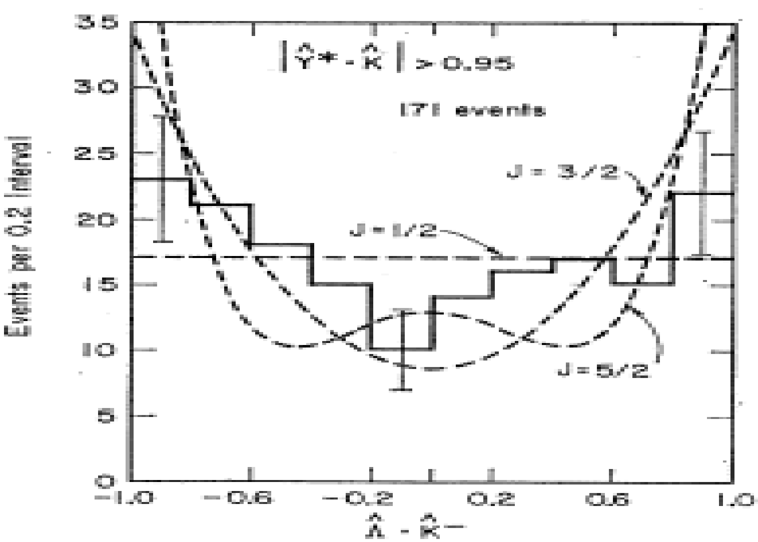


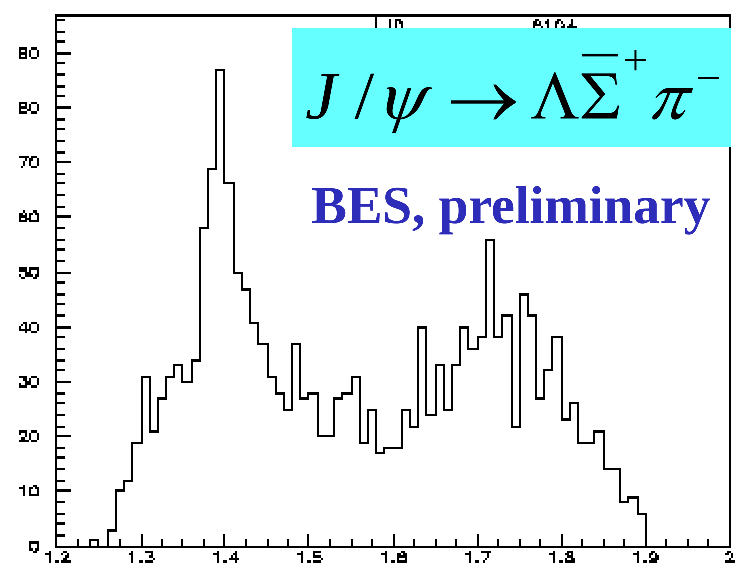
Cameron et al., NPB143(1978)189

$K^- p \rightarrow \Lambda\pi^+\pi^-$

P_K = 1.0 - 1.8 GeV





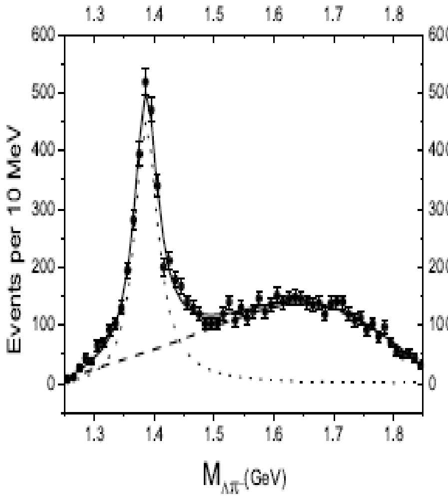


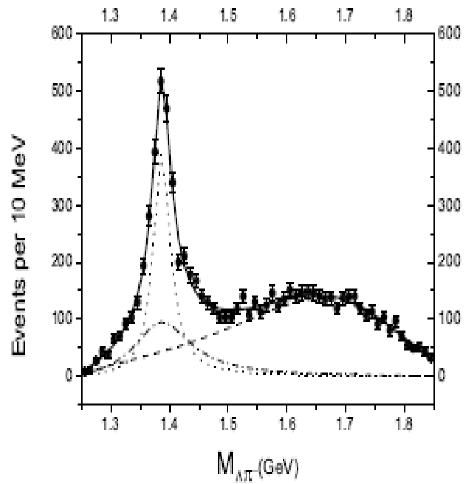
$J/\psi \rightarrow \Lambda\bar{\Sigma}^+\pi^-$

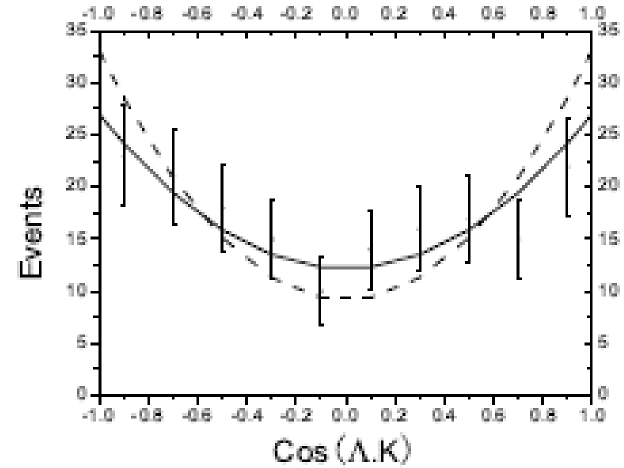
BES, preliminary

BES, NSTAR04

$M_{\pi\Lambda}$







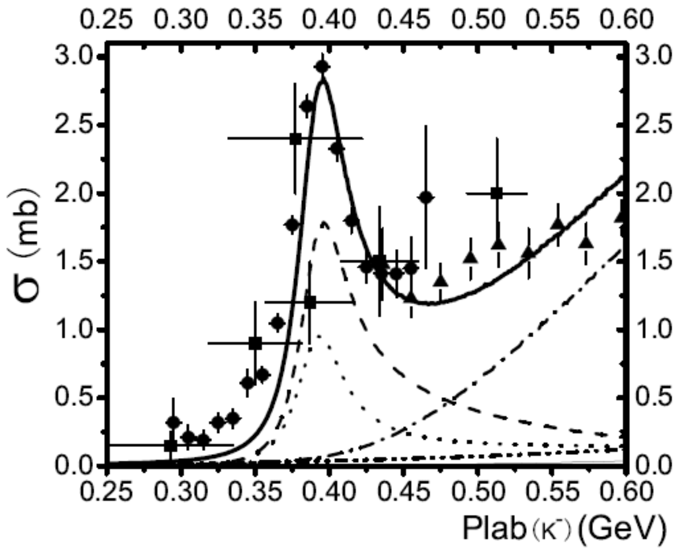
	$M_{\Sigma^*(3/2)}$	$\Gamma_{\Sigma^*(3/2)}$	$M_{\Sigma^*(1/2)}$	$\Gamma_{\Sigma^*(1/2)}$	χ^2/ndf(Fig.1)	χ^2/ndf(Fig.2)
Fit1	1385.3 ± 0.7	46.9 ± 2.5			$68.5/54$	$10.1/9$
Fit2	$1386.1^{+1.1}_{-0.9}$	$34.9^{+5.1}_{-4.9}$	$1381.3^{+4.9}_{-8.3}$	$118.6^{+55.2}_{-35.1}$	$58.0/51$	$3.2/9$

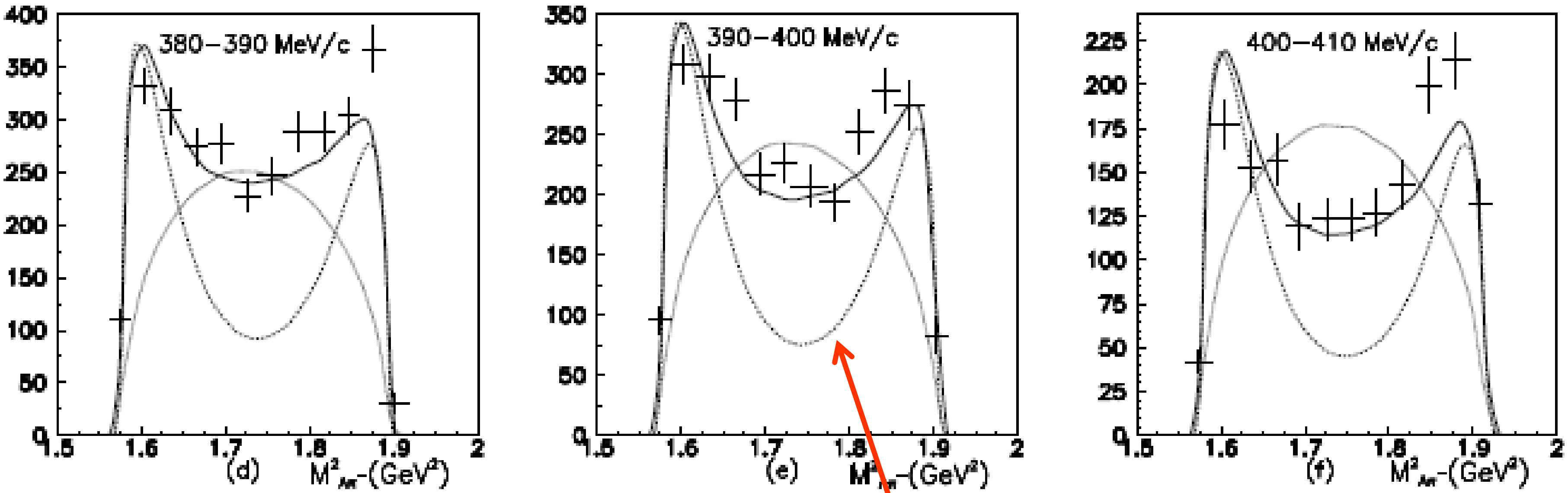
J.J.Wu, S.Dulat, B.S.Zou, PRD80 (2009) 017503

$$K^- p \to \Lambda^* \to \Sigma^{*-}_{3/2}\pi^+ \to \Lambda\pi^+\pi^-$$

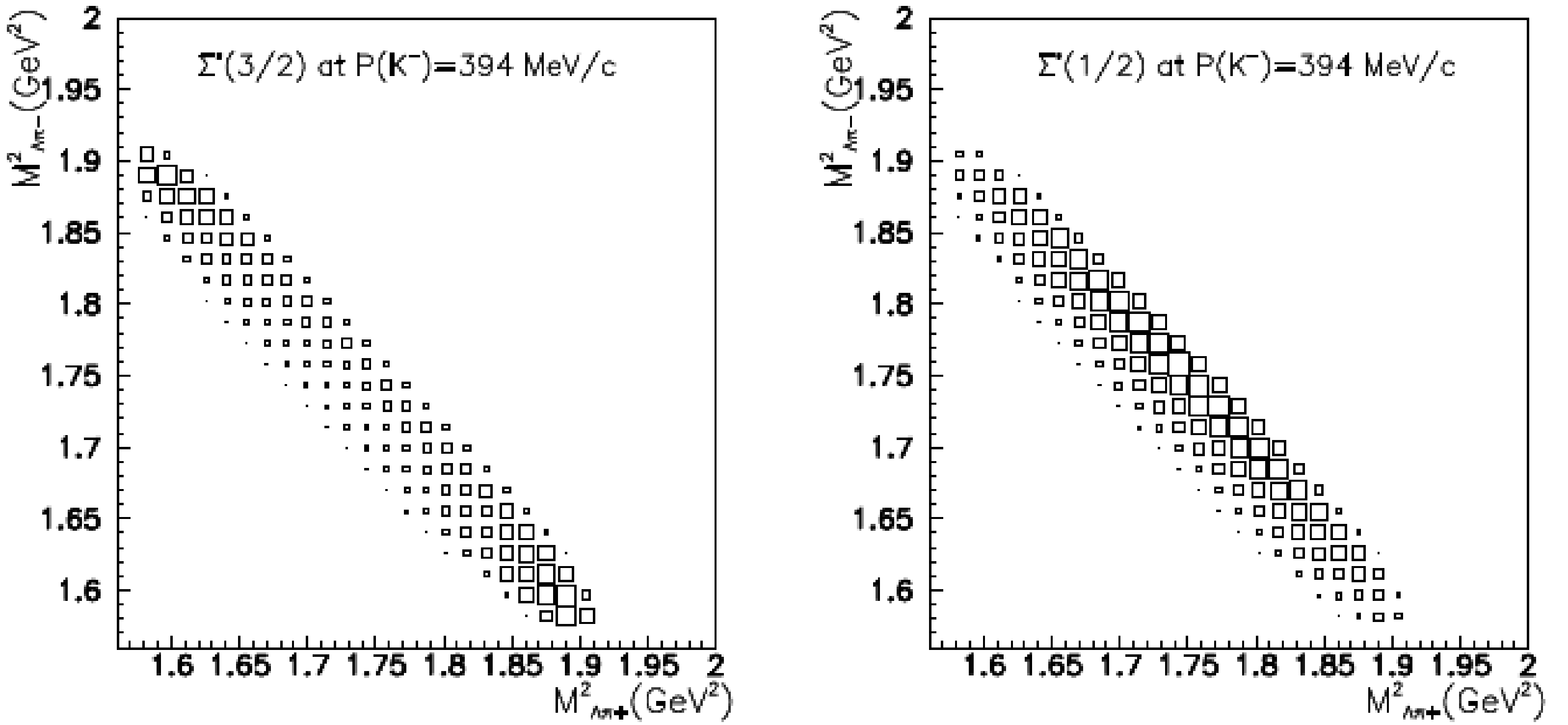
$$K^- p \to \Lambda^* \to \Sigma^{*-}_{1/2}\pi^+ \to \Lambda\pi^+\pi^-$$

$P_K \approx 0.4$ GeV





J.J.Wu, S.Dulat, B.S.Zou, Phys. Rev. C81 (2010) 045210



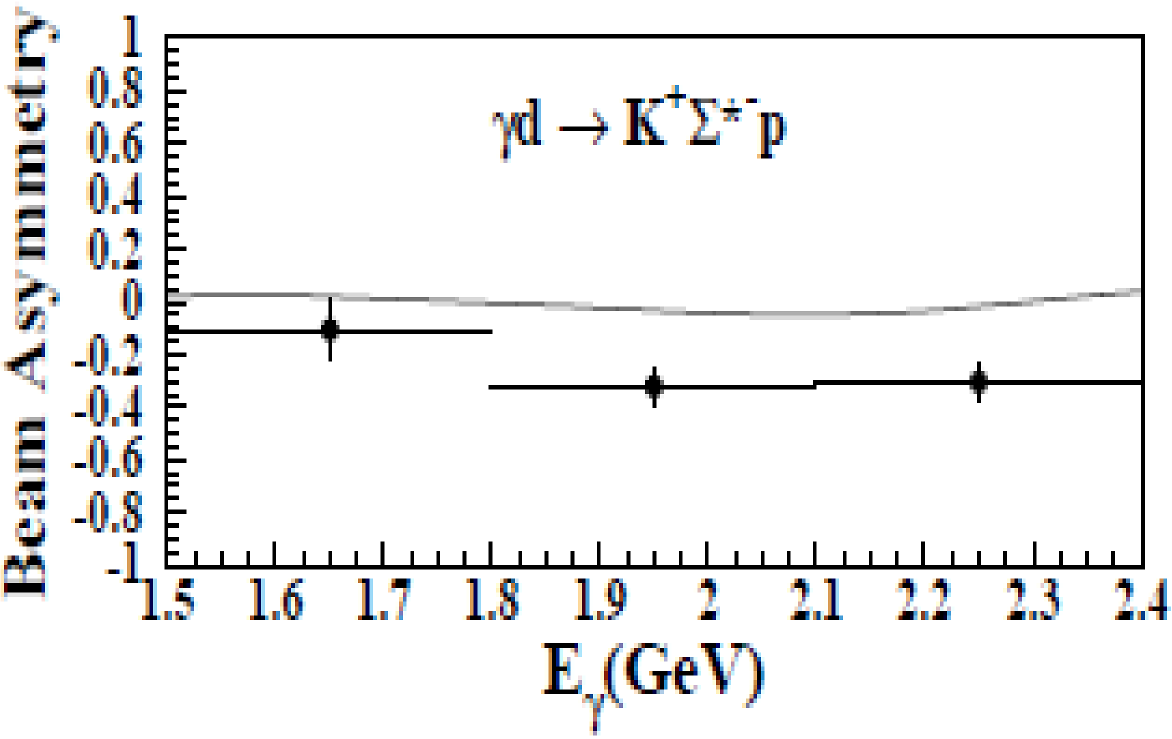
$\Sigma^*(3/2^+)$ & $\Sigma^*(1/2^-)$ → different Dalitz plots & mass spectra

Both are needed to reproduce the data !

Other evidence: failed to reproduce data with Σ*(1385)

LEPS, PRL102(2009)012501

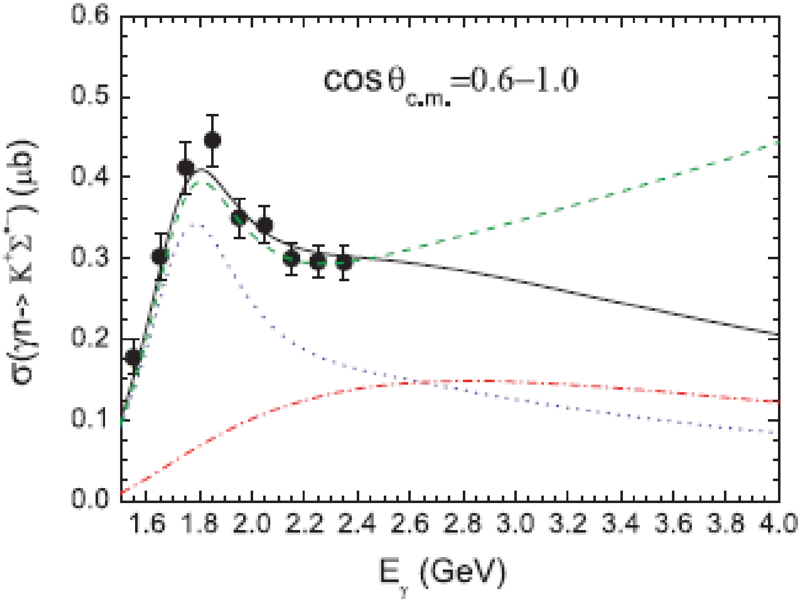
Y. Oh, C. M. Ko, and K. Nakayama, PRC77(2008) 045204

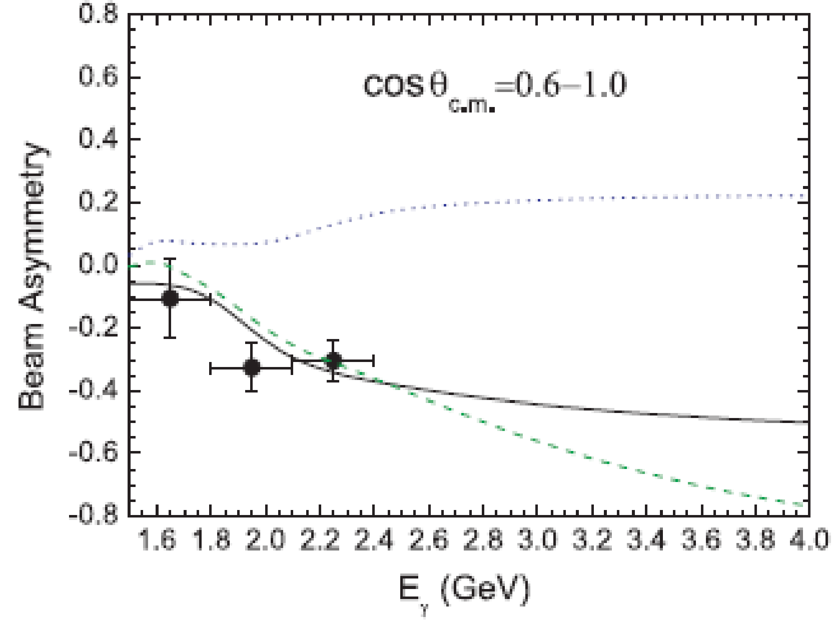


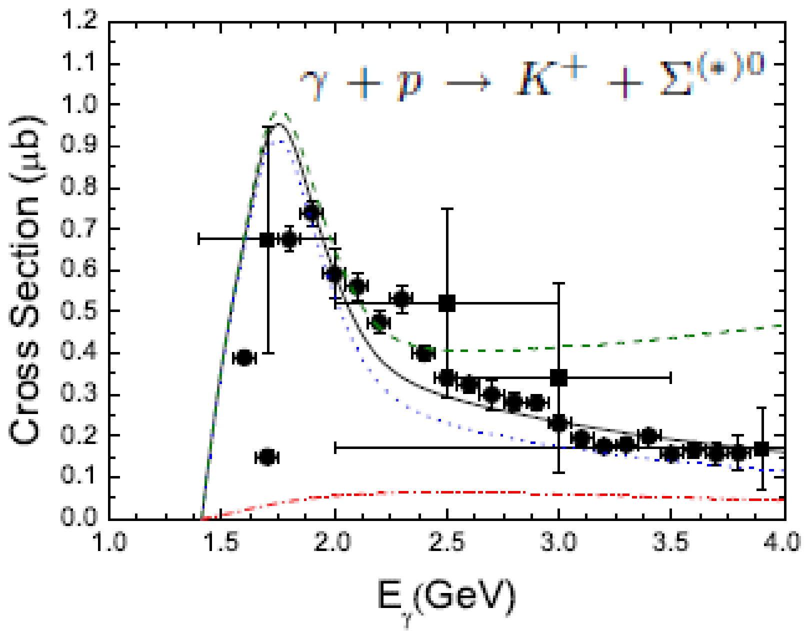
Something new ? **Σ*(1/2⁻) ?**

P.Gao, J.J.Wu, B.S.Zou, Phys. Rev. C 81 (2010) 055203

$$\gamma + n \rightarrow K^+ + \Sigma^{(*)-}$$







dot lines: $\Sigma^*(3/2^+)$ with h=1.00

dashed : $\Sigma^*(3/2^+)$ with h=1.11

solid: including $\Sigma^*(1/2^-)$

P.Gao, J.J.Wu, B.S.Zou,
Phys. Rev. C 81 (2010) 055203

5. Summary and Prospects

$J/\psi \to \bar{N} \pi N$: N*(1440) peak at 1360 MeV

N*(2065) 1/2+ & 3/2+

$J/\psi \to \bar{N} \eta N$: N*(1535)

$J/\psi \to \bar{\Lambda} K N$: Nx or N*(1535) ?

Large [ud][us] $\bar{s}$?

High statistics and PWA are needed !

Prospects :

2001 58M J/ Ψ 2003 14M Ψ′

2009 BEPCII double ring upgrade 200M J/Ψ & 100M Ψ’

⇩

Completing N*, Λ*, Σ*, Ξ* spectra, deducing ΨBB* couplings which provide a new way for exploring baryon structure.

CEBAF, CLEO-c, JPARC(kaon beam), COSY, CSR, PANDA, …

competition & complementary

⇩

? Important Discoveries

Thanks !