

Evidence for a new Σ^* Resonance

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Outline:

- **Introduction**
- **A new scheme for the $1/2^-$ baryon nonet**
- **Evidence for the predicted $\Sigma^*(1/2^-)$**
- **Conclusion**

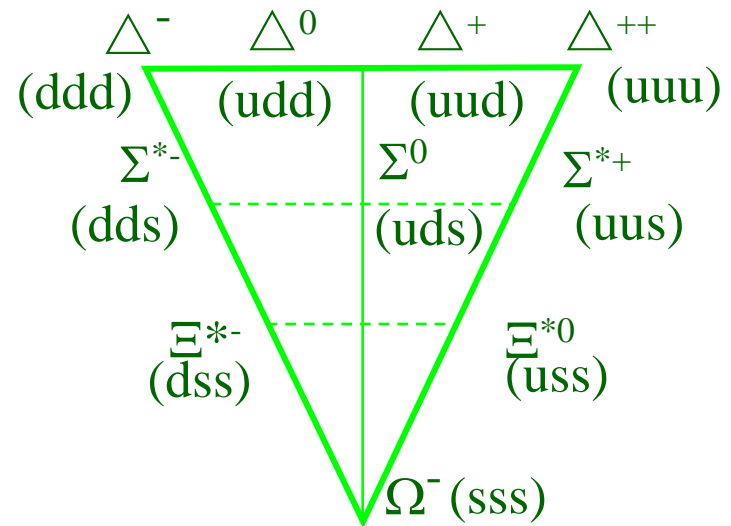
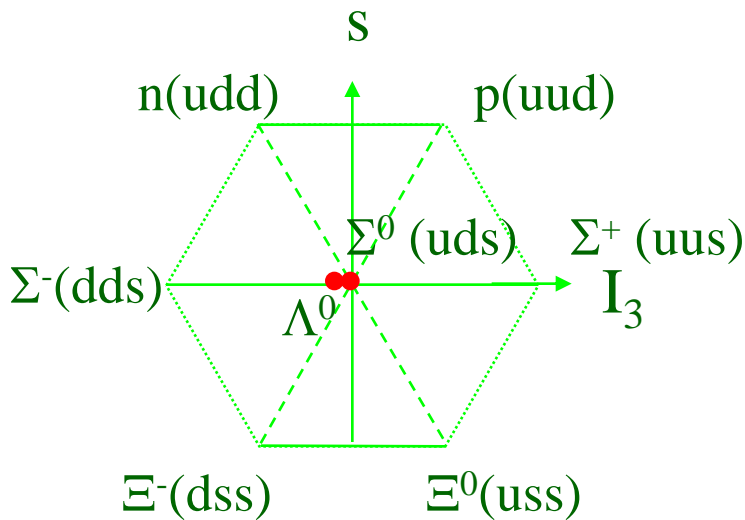
1. Introduction

SU(3) 3q-quark model for baryons

1/2 +

spin-parity

3/2 +



**Successful for spatial
ground states !**

Prediction $m_{\Omega^-} \cong 1670 \text{ MeV}$

experiment $m_{\Omega^-} \cong 1672.45 \pm 0.29 \text{ MeV}$

Evidence for components other than 3q in the proton

Deep Inelastic Scattering (DIS) + Drell-Yan (DY) process

$$\rightarrow \quad \bar{d} - \bar{u} \sim 0.12$$

Garvey&Peng, Prog. Part. Nucl. Phys.47, 203 (2001)

Meson cloud picture: Thomas, Speth, Weise, Oset, Brodsky, Ma, ...

$$|p\rangle \sim |uud\rangle + \varepsilon_1 |n(udd)\pi^+(\bar{d}u)\rangle \\ + \varepsilon_2 |\Delta^{++}(uuu)\pi^-(\bar{u}d)\rangle + \varepsilon' |\Lambda(uds)K^+(\bar{s}u)\rangle + \dots$$

Penta-quark picture : Riska, Zou, Zhu, ...

$$|p\rangle \sim |uud\rangle + \varepsilon_1 |[ud][ud]\bar{d}\rangle + \varepsilon' |[ud][us]\bar{s}\rangle + \dots$$

An outstanding problem for the classical 3q model

- Mass order reverse problem for the lowest excited baryons

uud (L=1) $1/2^- \sim N^*(1535)$ **should be the lowest**

uud (n=1) $1/2^+ \sim N^*(1440)$

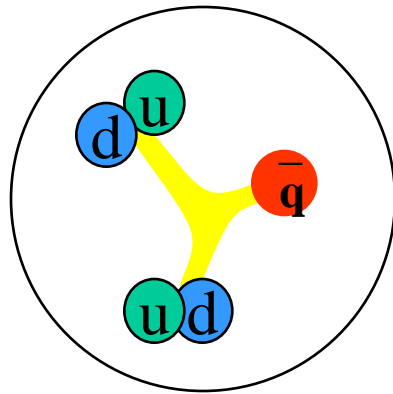
uds (L=1) $1/2^- \sim \Lambda^*(1405)$

harmonic oscillator ($2n + L + 3/2$) $h\omega$

To understand the full baryon spectroscopy, it is crucial to understand the lowest $1/2^-$ baryon nonet first !

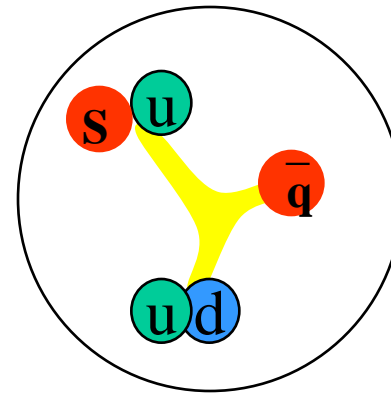
2. A new scheme for the $1/2^-$ baryon nonet

A.Zhang et al, HEPNP29(2005)250 ; B.S.Zou, EPJA35(2008)325



$$\bar{q} \quad 1/2^+$$

$$\left. \begin{array}{l} [ud] \\ [ud] \end{array} \right\} L=1$$



$$\bar{q} \quad 1/2^-$$

$$\left. \begin{array}{l} [ud] \\ [us] \end{array} \right\} L=0$$

$$N^*(1535) \sim uud (L=1) + \varepsilon [ud][us] \bar{s} + \dots$$

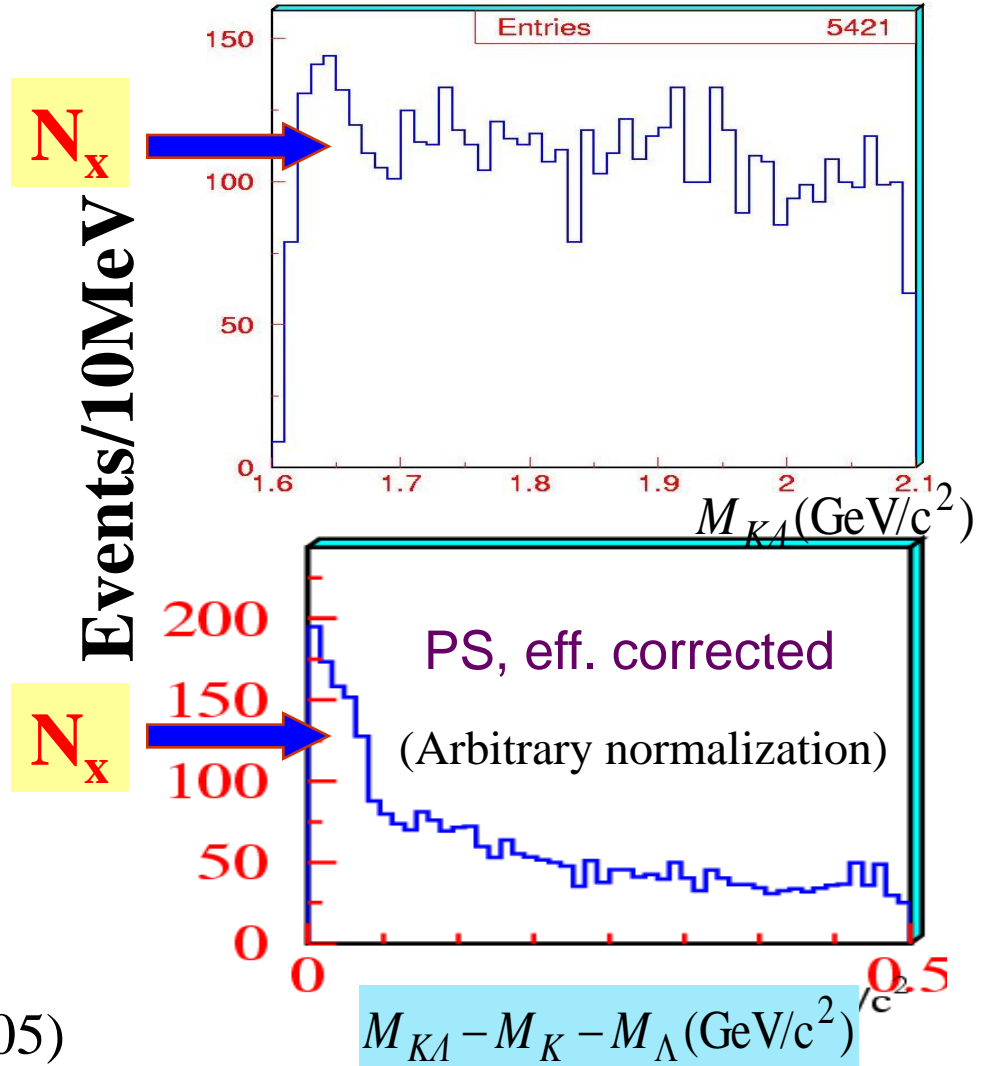
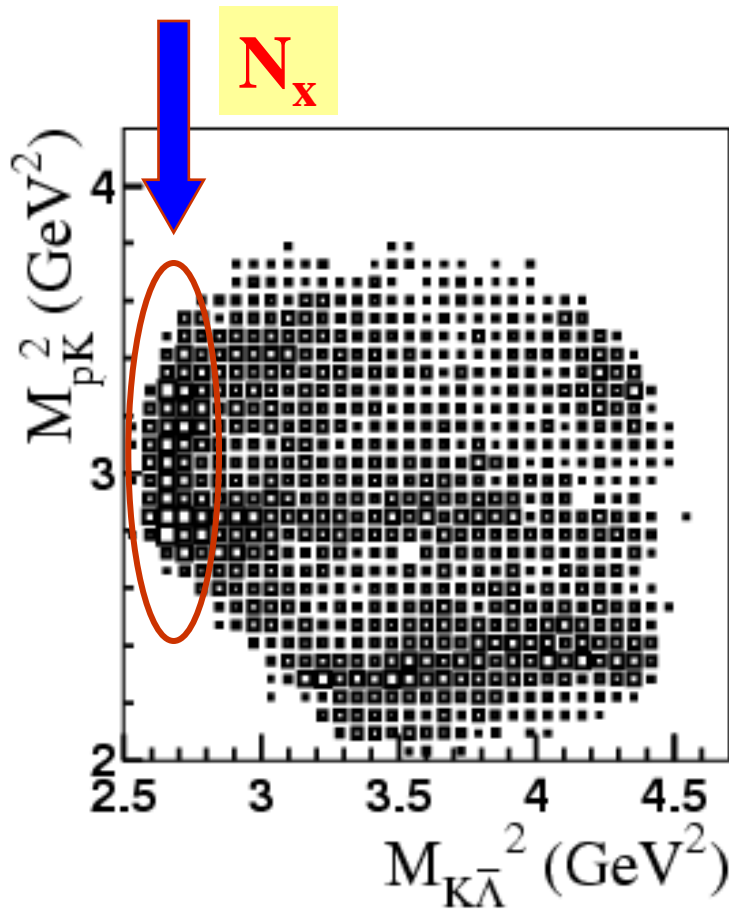
$$N^*(1440) \sim uud (n=1) + \xi [ud][ud] \bar{d} + \dots$$

$$\Lambda^*(1405) \sim uds (L=1) + \varepsilon [ud][su] \bar{u} + \dots$$

$N^*(1535)$: $[ud][us] \bar{s} \rightarrow$ larger coupling to $N\eta, N\eta', N\phi$ & $K\Lambda$, weaker to $N\pi$ & $K\Sigma$, and heavier !

Strange properties of $N^*(1535)$

Evidence for large $g_{N^*K\Lambda}$ from $J/\psi \rightarrow p K^- \bar{\Lambda} + c.c.$



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

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

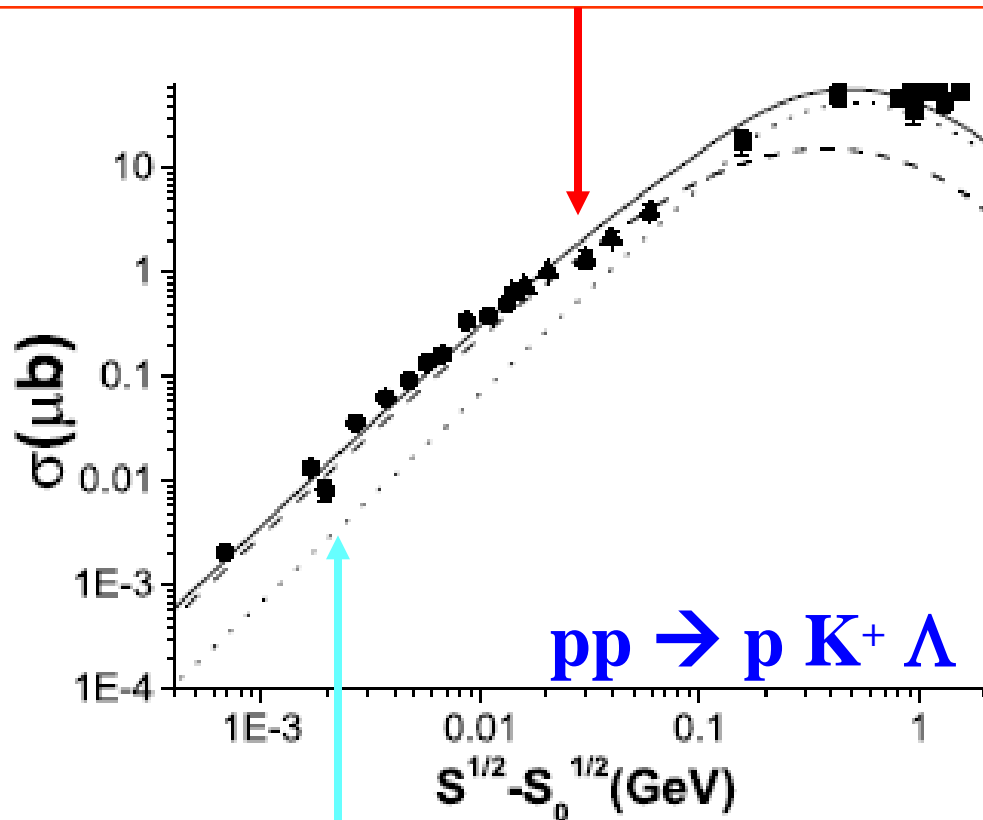
Phenomenology : Large $g_{N^*K\Lambda} \rightarrow$ large $\bar{s}s$ in $N^*(1535)$

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

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

**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 $pp \rightarrow p K^+ \Lambda$

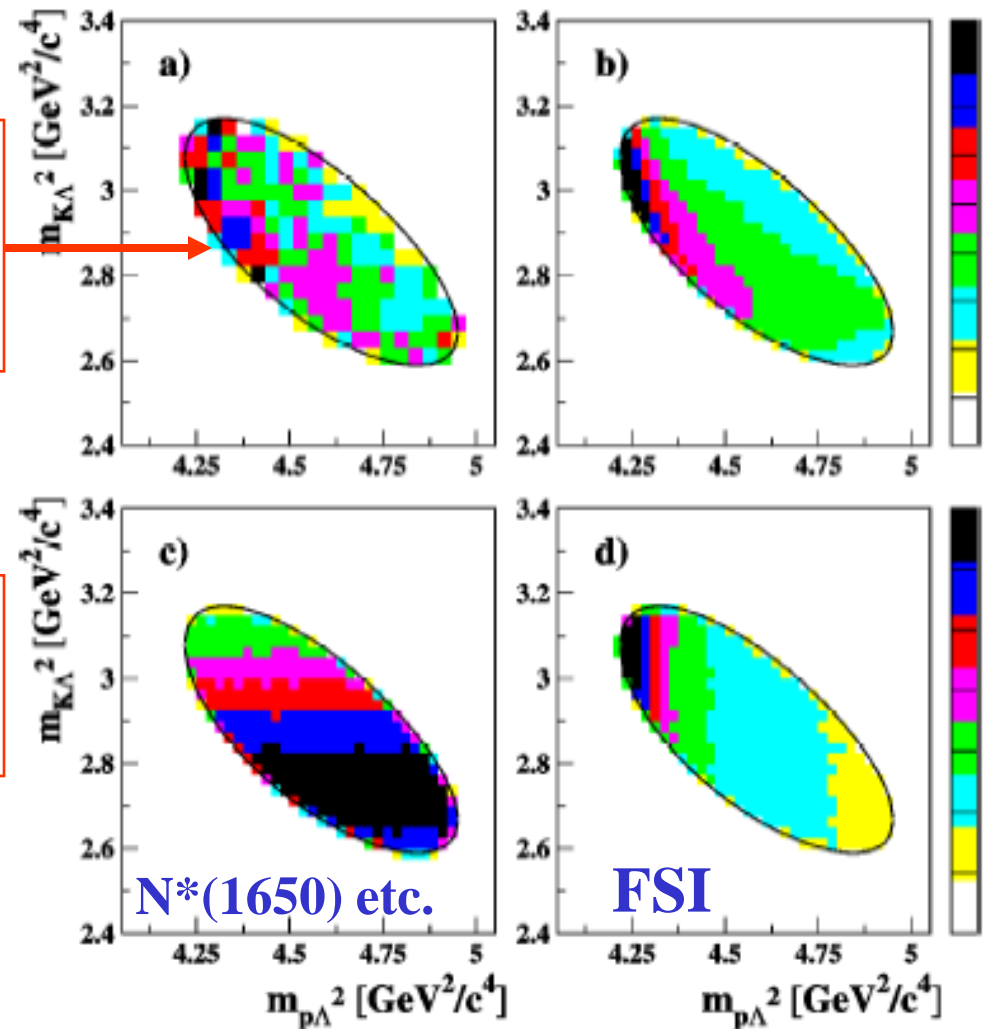
B.C.Liu & B.S.Zou, Phys. Rev. Lett. 98 (2007) 039102 (reply)

A.Sibirtsev et al., Phys. Rev. Lett. 98 (2007) 039101 (comment)

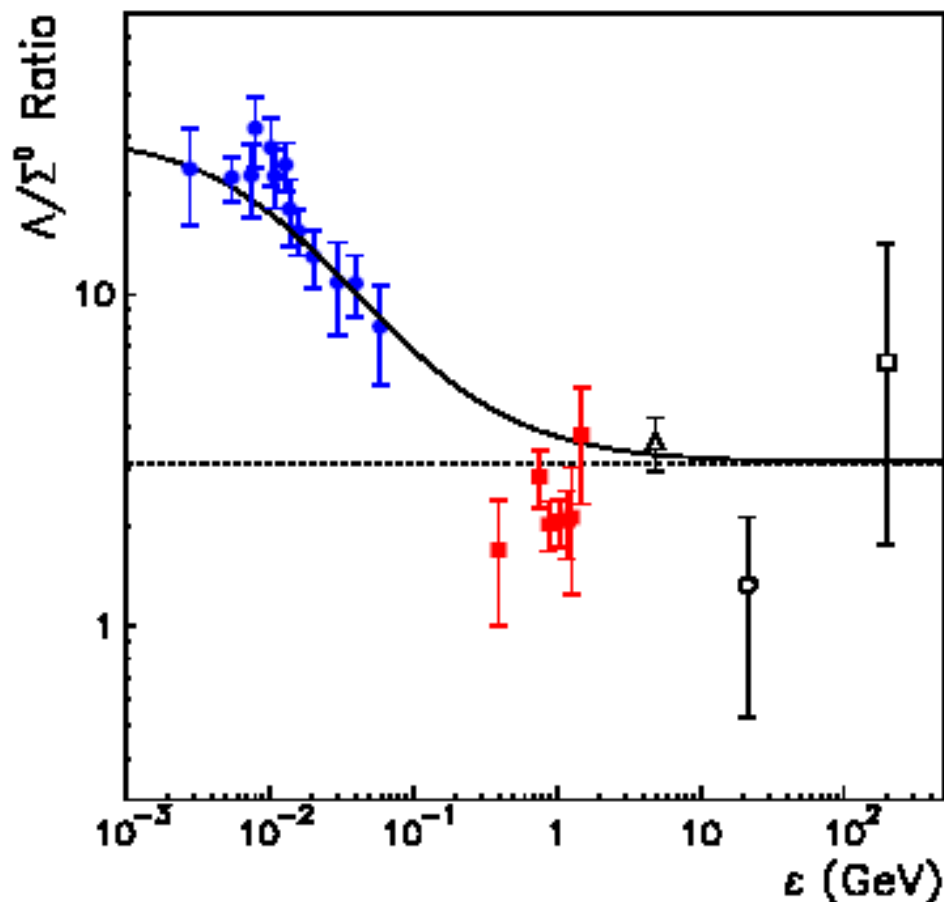
COSY-TOF data
S. Abdel-Samad *et al.*,
Phys.Lett.B632:27(2006)



**Both FSI & $N^*(1535)$
are needed !**



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



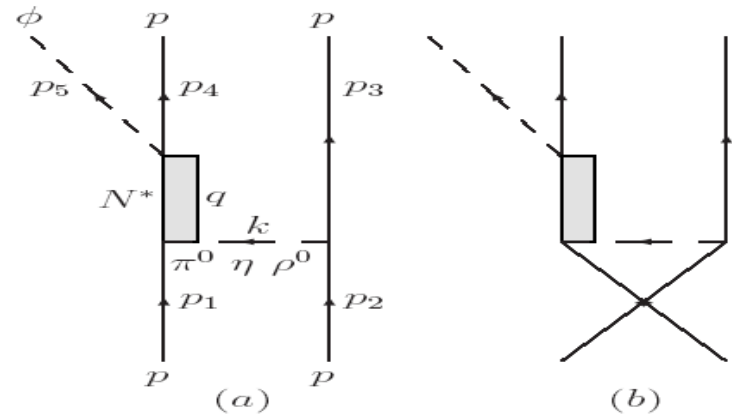
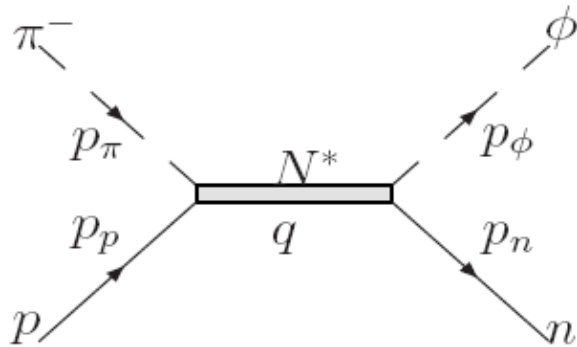
**A.Sibirtsev et al.,
EPJA29 (2006) 363**

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 $pp \rightarrow K^+ \Lambda p$ and $pp \rightarrow K^+ \Sigma^0 p$ reactions at COSY [2]. Solid

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

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

Xie, Zou & Chiang, PRC77(2008)015206; Cao, Xie, Zou & Xu, nucl-th/09050260



Evasion of OZI rule by $N^*(1535)$!

Evidence for large $g_{N^*N\eta'}$ from $\gamma p \rightarrow p \eta'$, $pp \rightarrow pp\eta'$

M.Dugger et al., PRL96 (2006) 062001; X.Cao & X.Lee, PRC78(2008)035207

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

$$\Lambda^* \quad [us][ds] \bar{s} \quad \sim \quad 1575 \text{ MeV}$$

$$\Sigma^* \quad [us][du] \bar{d} \quad \sim \quad 1360 \text{ MeV}$$

$$\Xi^* \quad [us][ds] \bar{u} \quad \sim \quad 1520 \text{ MeV}$$

Prediction of other unquenched models:

(1) 5-quark model Helminen & Riska, NPA699(2002)624

$$\Sigma^*(1/2^-) \sim \Lambda^*(1/2^-)$$

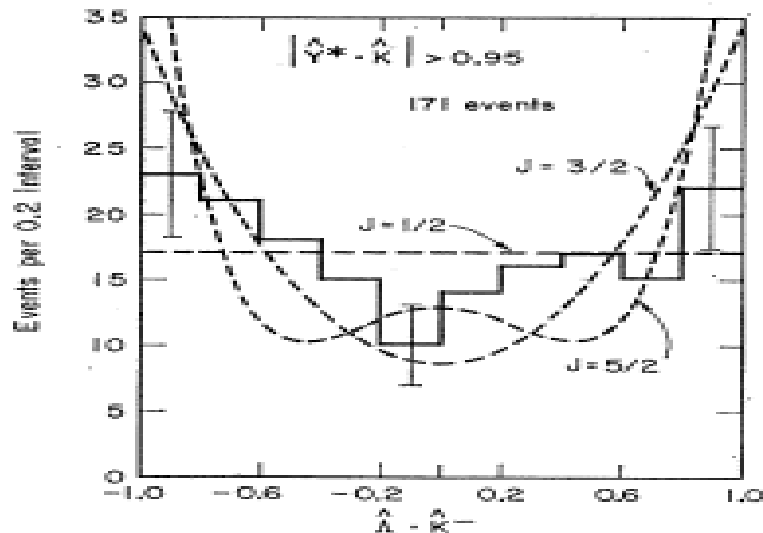
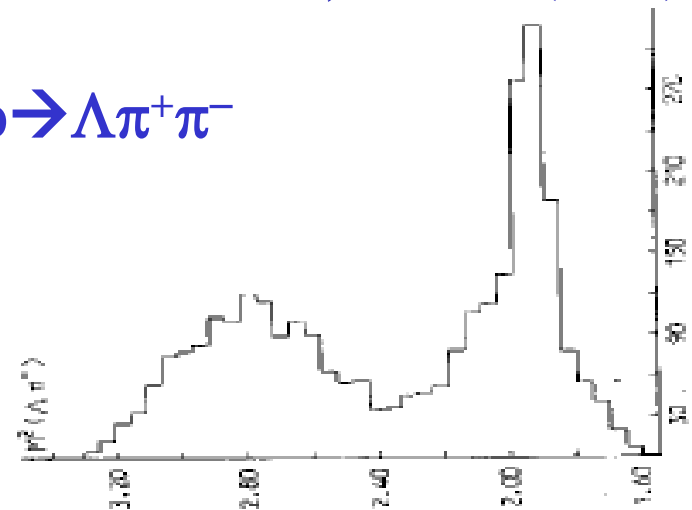
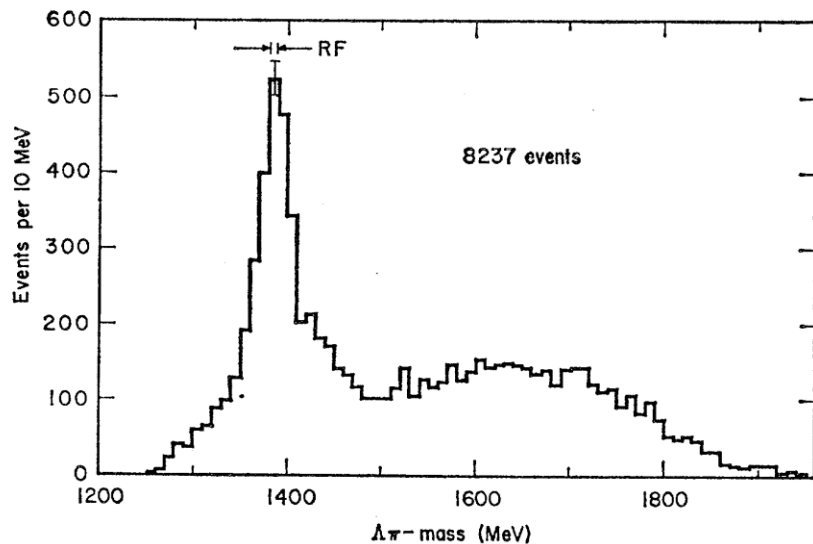
(2) meson-baryon dynamics Jido-Oset et al. , NPA725(2003)181

broad non-resonant $\Sigma^*(1/2^-)$ structure

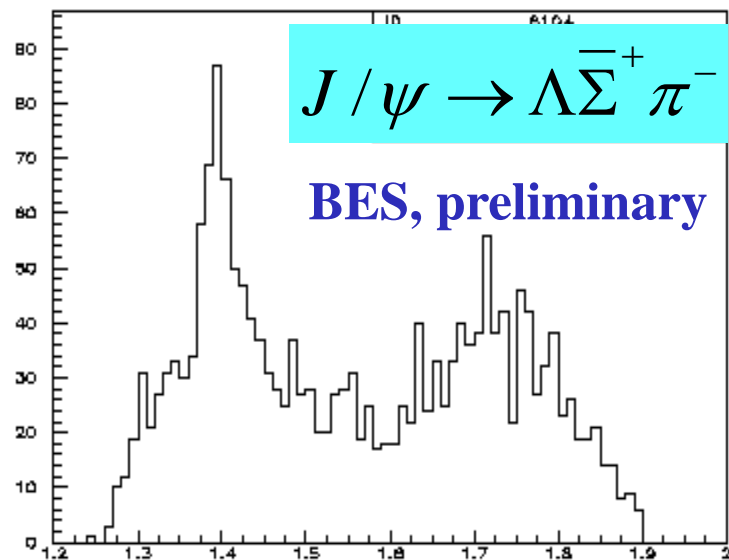
Important to look for the $\Sigma^*(1/2^-)$ around 1380 MeV !

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

Cameron et al., NPB143(1978)189

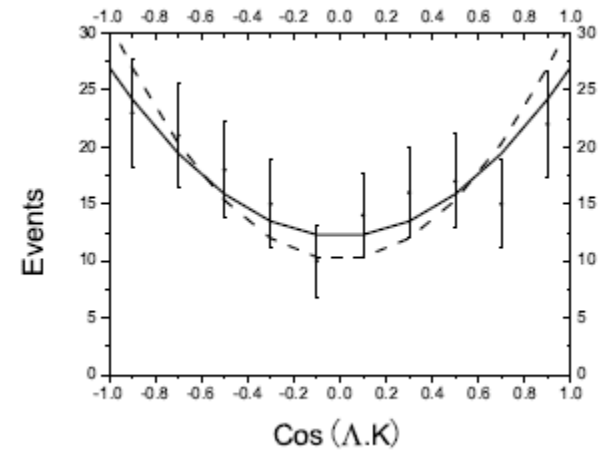
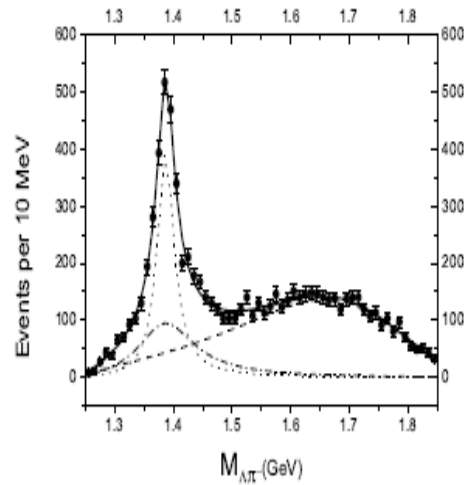
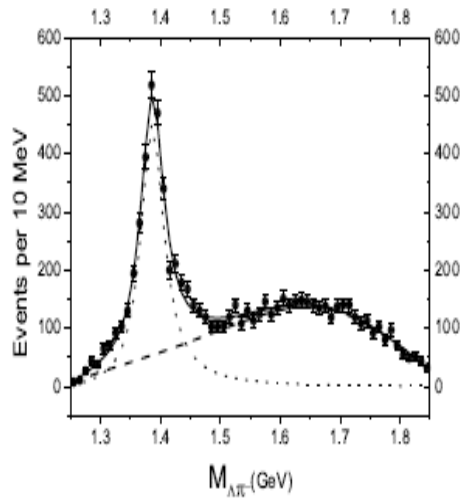


Huwe, PR181(1969)1824



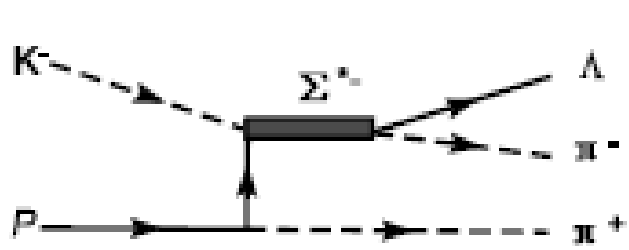
BES, NSTAR04

$M_{\pi\Lambda}$

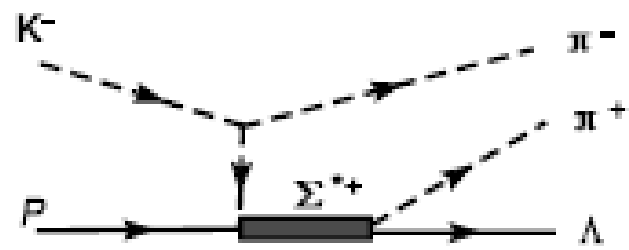


	$M_{\Sigma^*(3/2)}$	$\Gamma_{\Sigma^*(3/2)}$	$M_{\Sigma^*(1/2)}$	$\Gamma_{\Sigma^*(1/2)}$	χ^2/ndf (Fig.1)	χ^2/ndf (Fig.2)
Fit1	1385.3	46.9			68.5/54	6.9/9
Fit2	1386.1	34.9	1381.3	118.6	58.0/51	3.2/9

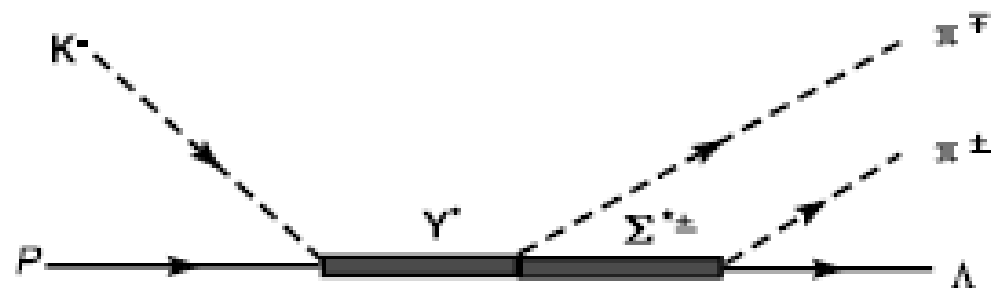
J.J.Wu, S.Dulat, B.S.Zou



(a)



(b)



(c)

J/ψ decay

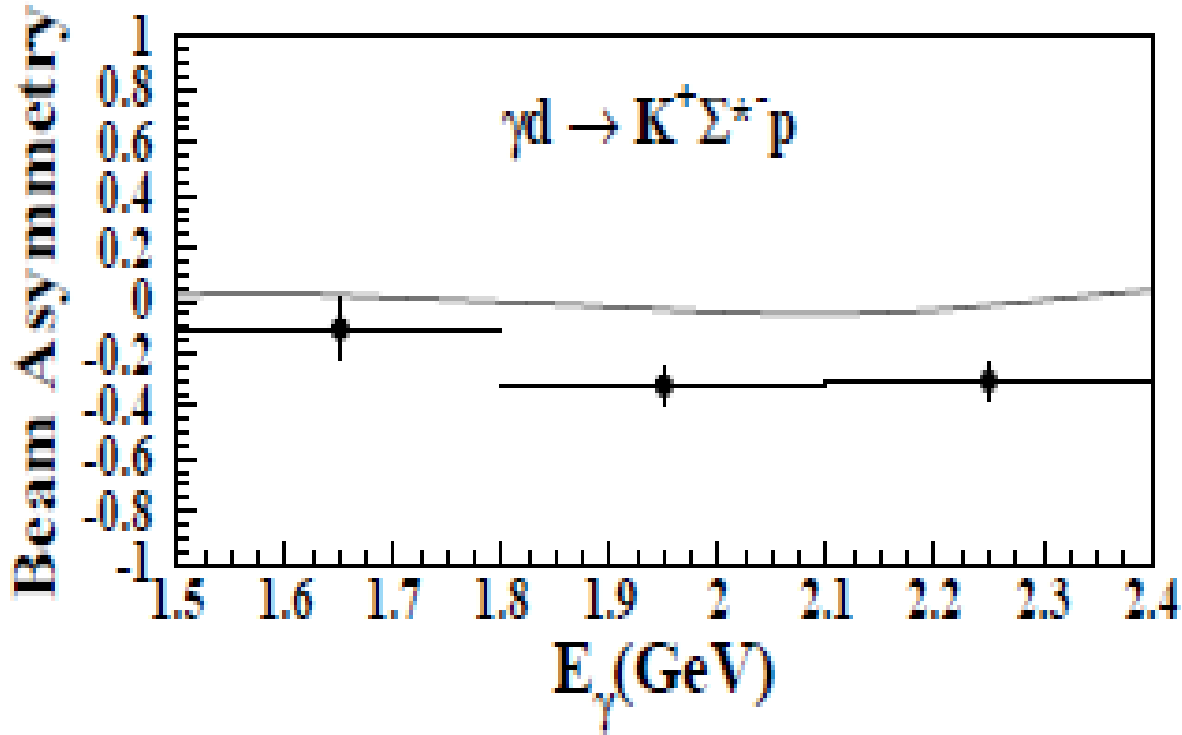
branching ratio * 10⁴

$\bar{p} \Delta(1232)^+$	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 ?

Other evidence: failed to reproduce data with $\Sigma^*(1385)$

LEPS, PRL102(2009)012501



Something new ?

4. Conclusion

- 1) Quenched quark models and unquenched models gives very distinctive predictions for $\Sigma^*(1/2^-)$;
- 2) Possible existence of a $\Sigma^*(1/2^-)$ around 1380 MeV cannot be excluded although its evidence is not strong ;
- 3) It should be checked by forthcoming experiments :
 $K^- p \rightarrow \pi \Sigma^*(1360), \Sigma^*(1360) \rightarrow \Lambda \pi$
 $\gamma N \rightarrow K^+ \Sigma^*(1360), \Sigma^*(1360) \rightarrow \Lambda \pi$
 $J/\psi \rightarrow \bar{\Sigma} \Sigma^*(1360), \Sigma^*(1360) \rightarrow \Lambda \pi$

