Pin-down the nature of the lowest ½- baryons

Evidence for a new Σ* Resonance

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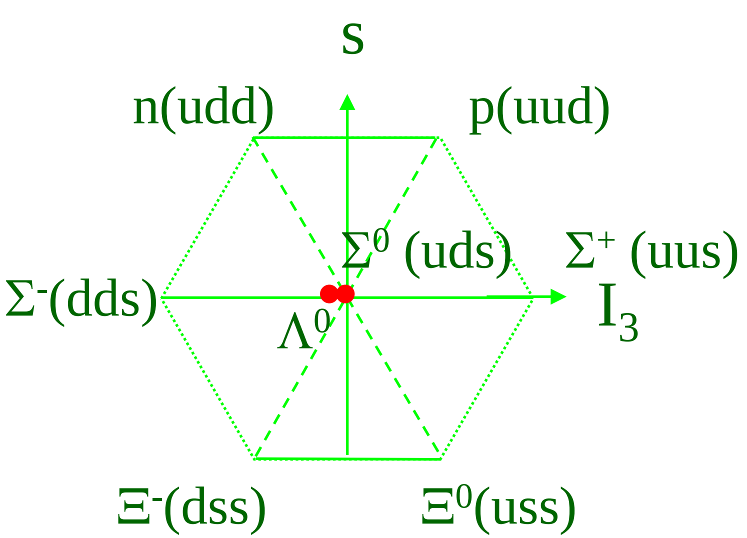
Outline:

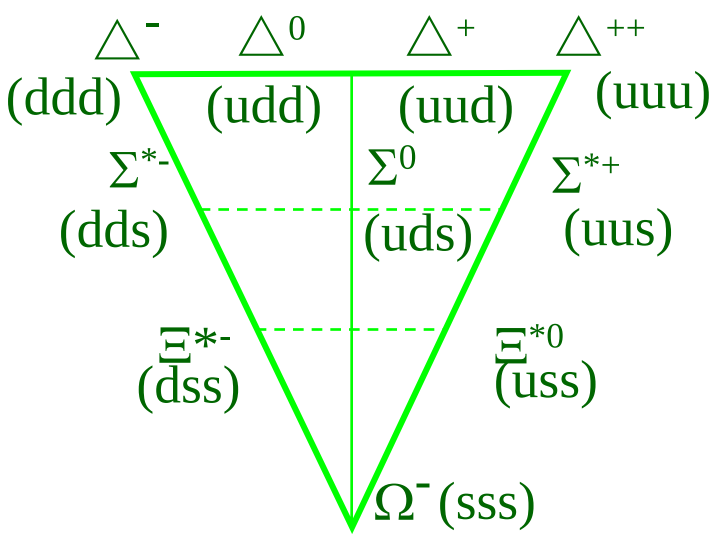
- Introduction
- A new scheme for the $1/2^{-}$ baryon nonet
- Evidence for the predicted $\Sigma^*(1/2^{-})$
- Conclusion

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 MeV**

experiment $m_{\Omega^-} \cong$ **1672.45 ±0.29 MeV**

Evidence for components other than 3q in the proton

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

→ $\bar{d} - \bar{u} \sim 0.12$

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

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

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

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

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

An outstanding problem for the classical 3q model

- **Mass order reverse problem for the lowest excited baryons**

uud (L=1) ½ - ~ N*(1535) should be the lowest

uud (n=1) ½ + ~ N*(1440)

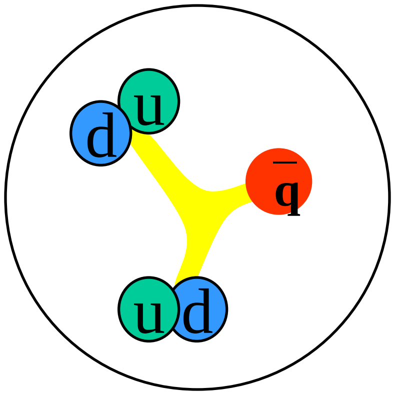
uds (L=1) ½ - ~ Λ*(1405)

harmonic oscillator (2n + L + 3/2) hω

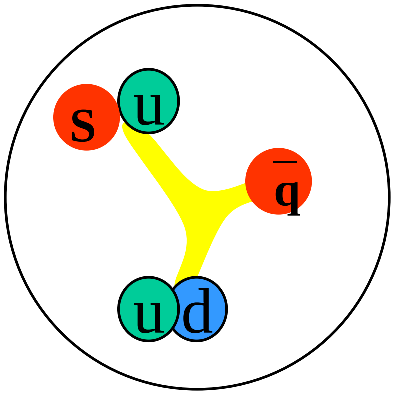
To understand the full baryon spectroscopy, it is crucial to understand the lowest $1/2^-$ baryon nonet first !

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

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



$\bar{q}$ ½+
[ud]
[ud] }L=1



$\bar{q}$ ½ -
[ud]
[us] }L=0

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

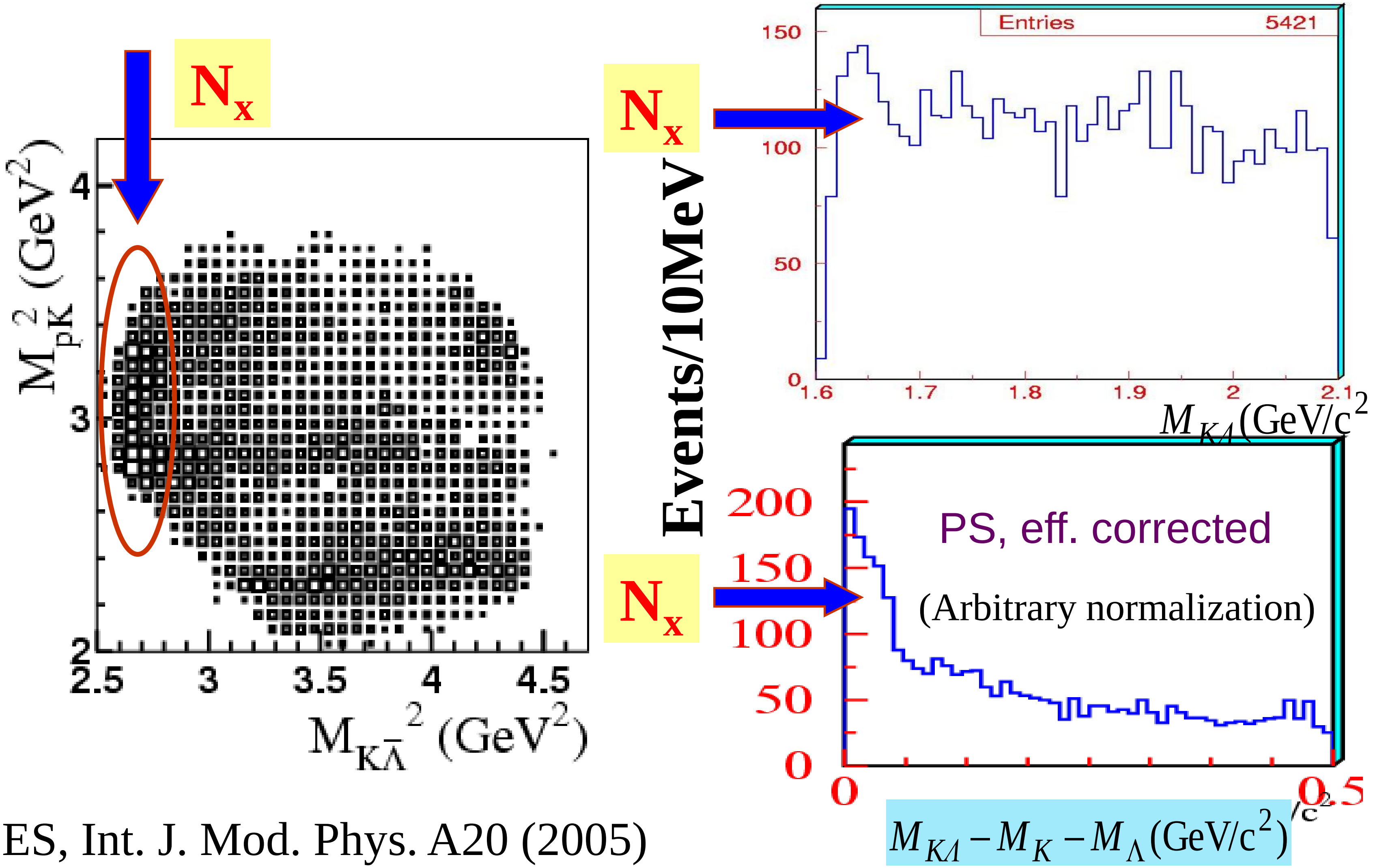
N*(1440) ~ uud (n=1) + ξ [ud][ud] $\bar{d}$ + …

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 !

Strange properties of N*(1535)

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



BES, Int. J. Mod. Phys. A20 (2005)

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

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

$\Downarrow$

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

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

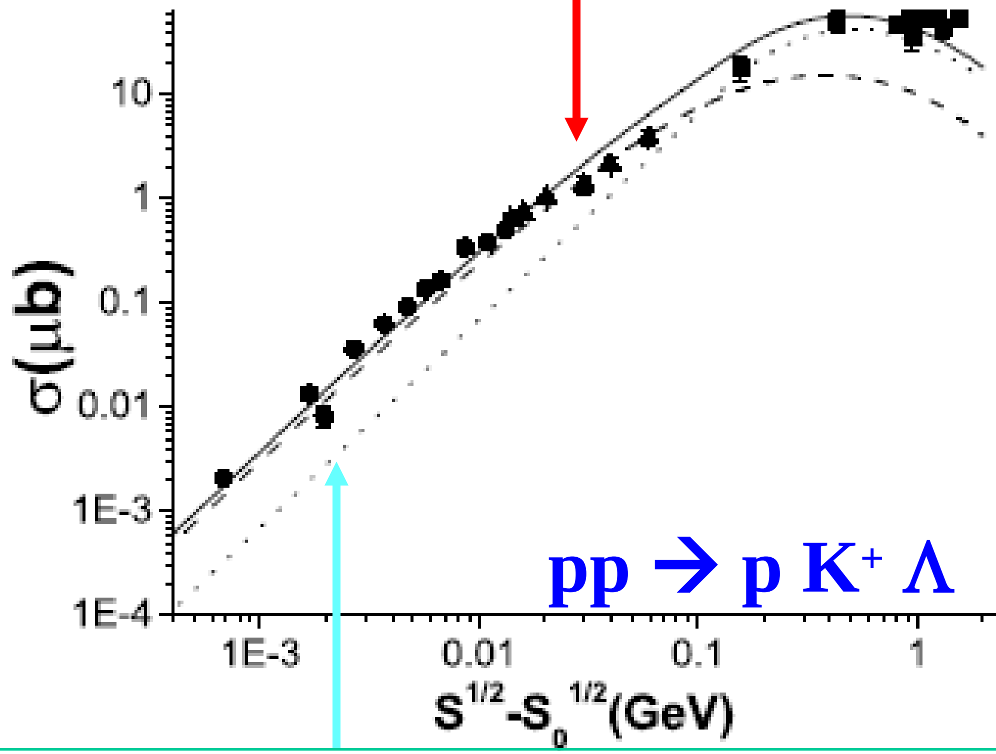
$g_{N^*K\Lambda} / g_{N^*p\eta} / g_{N^*N\pi} \sim 1.2 : 2 : 1$

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

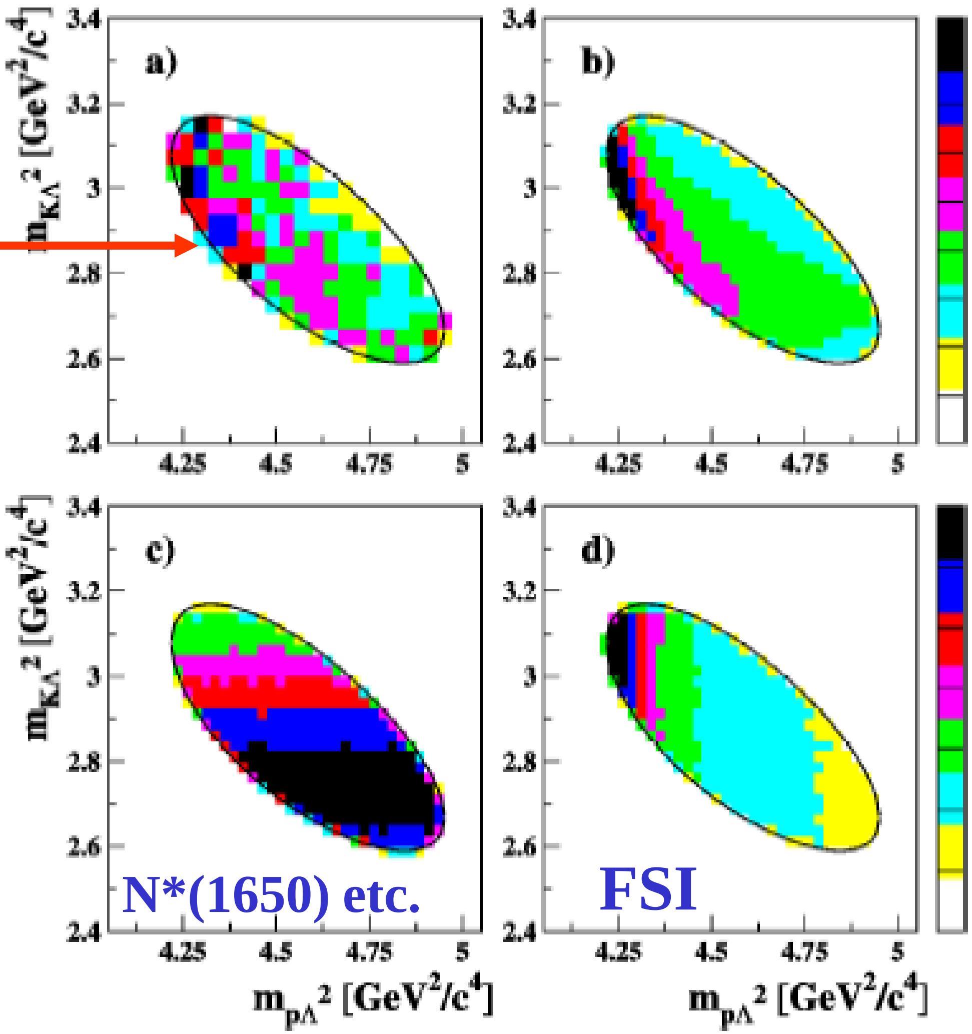


Tsushima,Sibirtsev,Thomas, PRC59 (1999) 369, without including N*(1535)

FSI vs N*(1535) contribution in pp → p K^+ Λ

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 $pp \rightarrow p K^+\Lambda$ / $pp \rightarrow p K^+\Sigma^0$

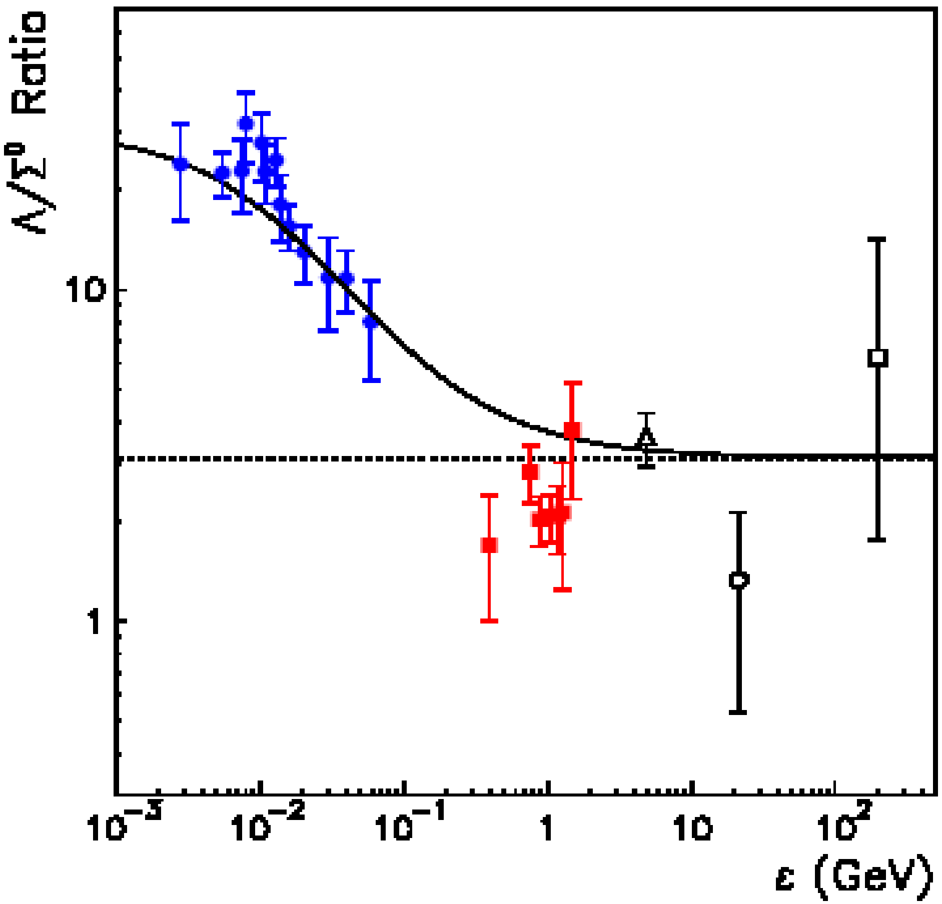


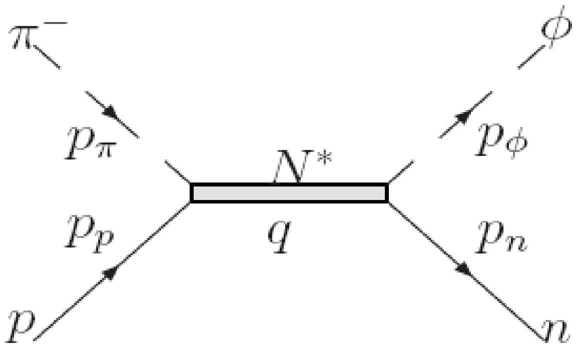
Fig. 3. The Λ/Σ^0 cross-section ratio as a function of the excess energy ϵ. The solid circles show the ratio obtained for the $pp \to K^+\Lambda p$ and $pp \to K^+\Sigma^0 p$ reactions at COSY [2]. Solid

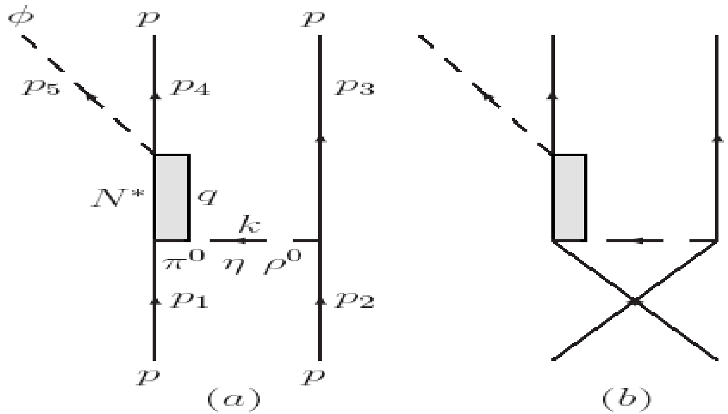
A.Sibirtsev et al., EPJA29 (2006) 363

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

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:

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

Prediction of other unquenched models:

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

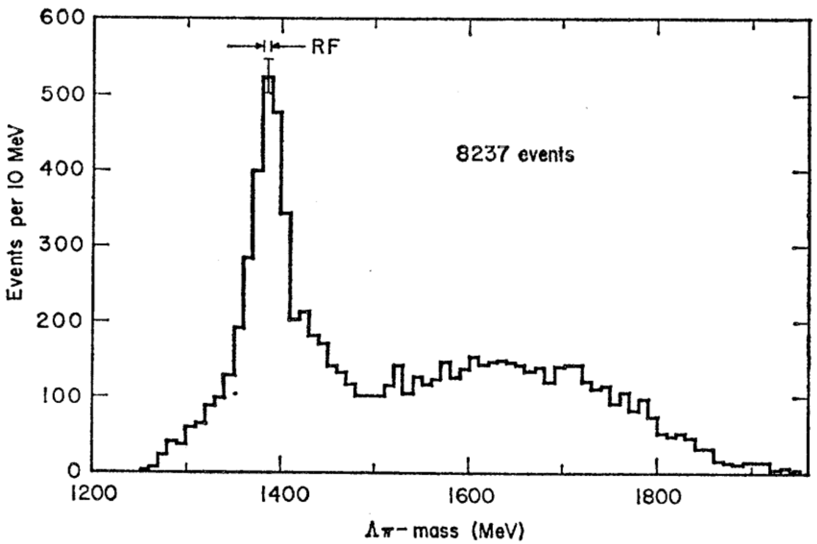
$\Sigma^*(1/2^-) \sim \Lambda^*(1/2^-)$

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

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

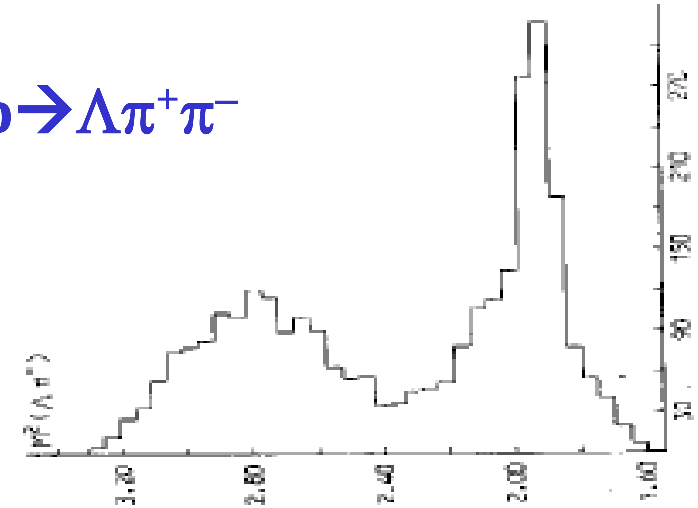
Important to look for the $\Sigma^*(1/2^-)$ around 1380 MeV !

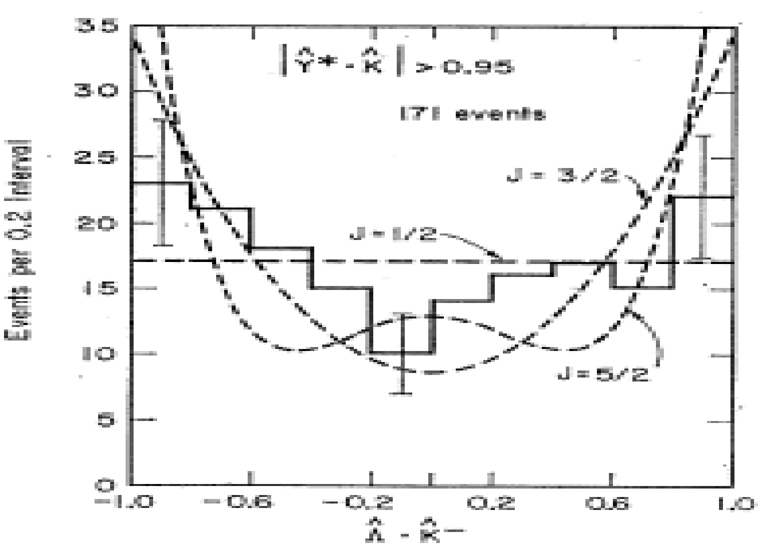
3. Evidence for the predicted $\Sigma^*(1/2^-)$



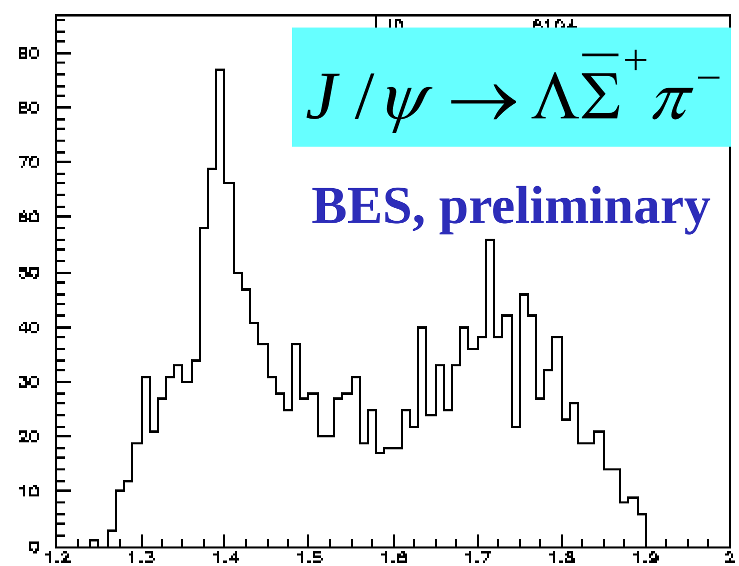
Cameron et al., NPB143(1978)189

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





Huwe, PR181(1969)1824

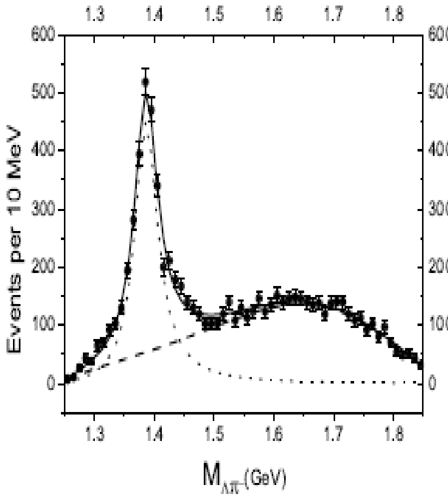


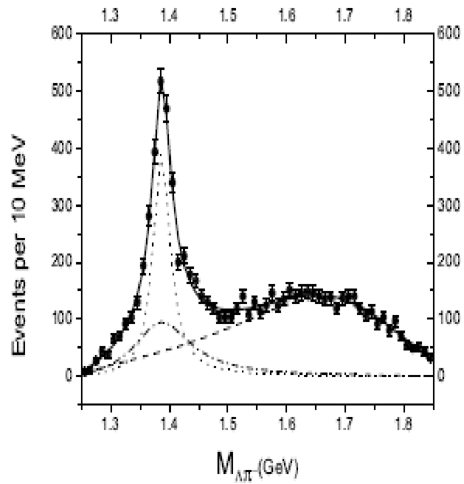
$J/\psi \rightarrow \Lambda \bar{\Sigma}^+ \pi^-$

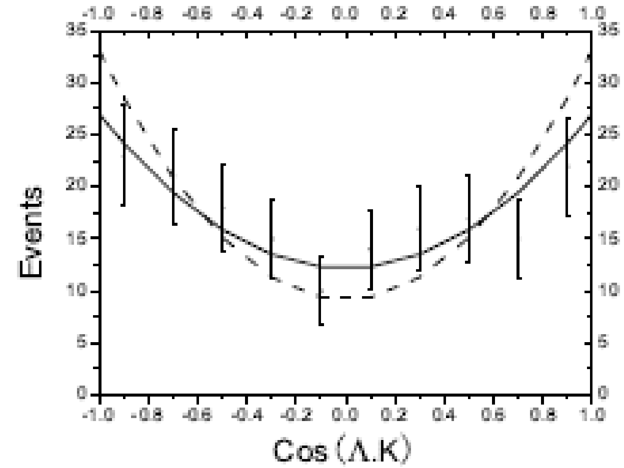
BES, preliminary

BES, NSTAR04

$M_{\pi\Lambda}$

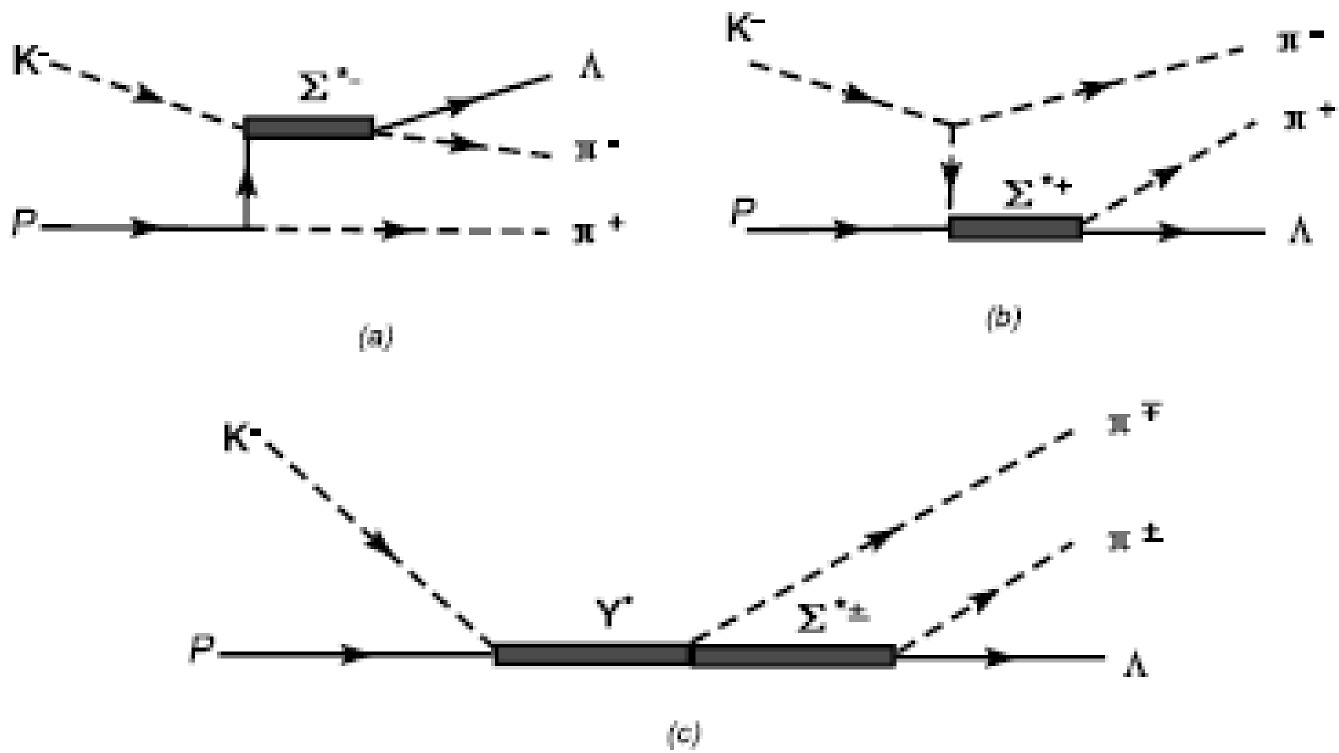






	$M_{\Sigma^*(3/2)}$	$\Gamma_{\Sigma^*(3/2)}$	$M_{\Sigma^*(1/2)}$	$\Gamma_{\Sigma^*(1/2)}$	χ^2/ndf(Fig.1)	χ^2/ndf(Fig.2)
Fit1	1385.3 ± 0.7	46.9 ± 2.5			$68.5/54$	$10.1/9$
Fit2	$1386.1^{+1.1}_{-0.9}$	$34.9^{+5.1}_{-4.9}$	$1381.3^{+4.9}_{-8.3}$	$118.6^{+55.2}_{-35.1}$	$58.0/51$	$3.2/9$

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



K⁻
Σ*⁻
Λ
π⁻
P
π⁺
(a)
K⁻
π⁻
π⁺
Σ*⁺
P
Λ
(b)
K⁻
π∓
π±
Y*
Σ*±
P
Λ
(c)

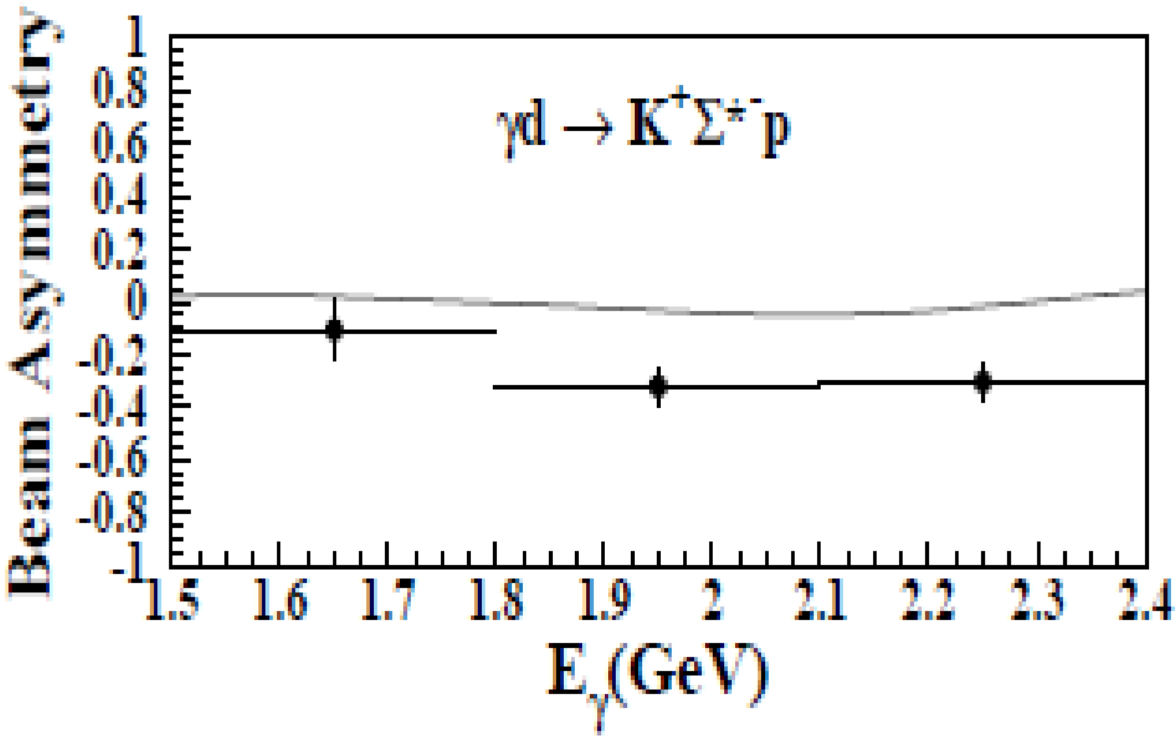
J/ψ decay   branching ratio * 10^4

$\bar{p}\,\Delta(1232)^+$	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 Σ(1385) and Ξ(1520) peaks there are $1/2^-$ components ?

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

LEPS, PRL102(2009)012501



Something new ?

4. Conclusion

1) **Quenched quark models and unquenched models gives very distinctive predictions for $\Sigma^*(1/2^-)$;**

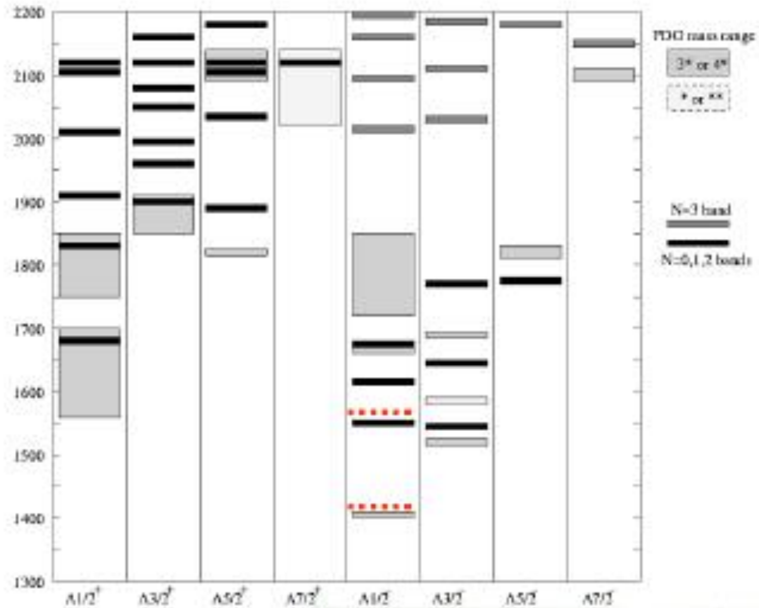
2) **Possible existence of a $\Sigma^*(1/2^-)$ around 1380 MeV cannot be excluded although its evidence is not strong ;**

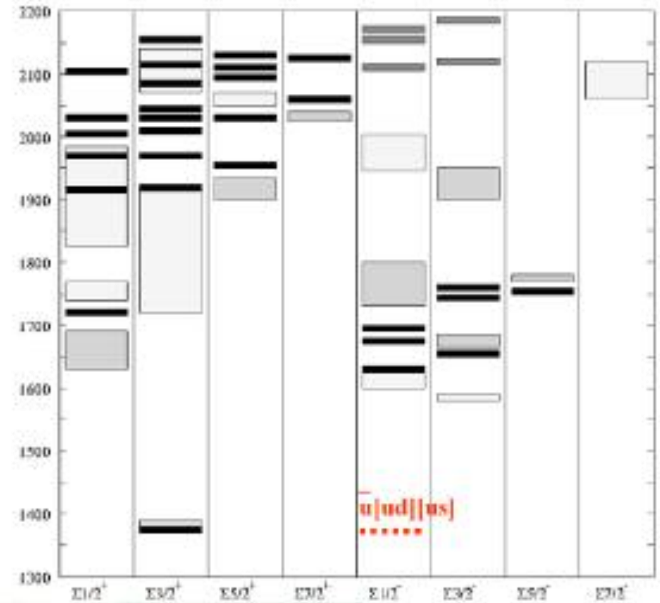
3) **It should be checked by forthcoming experiments :**

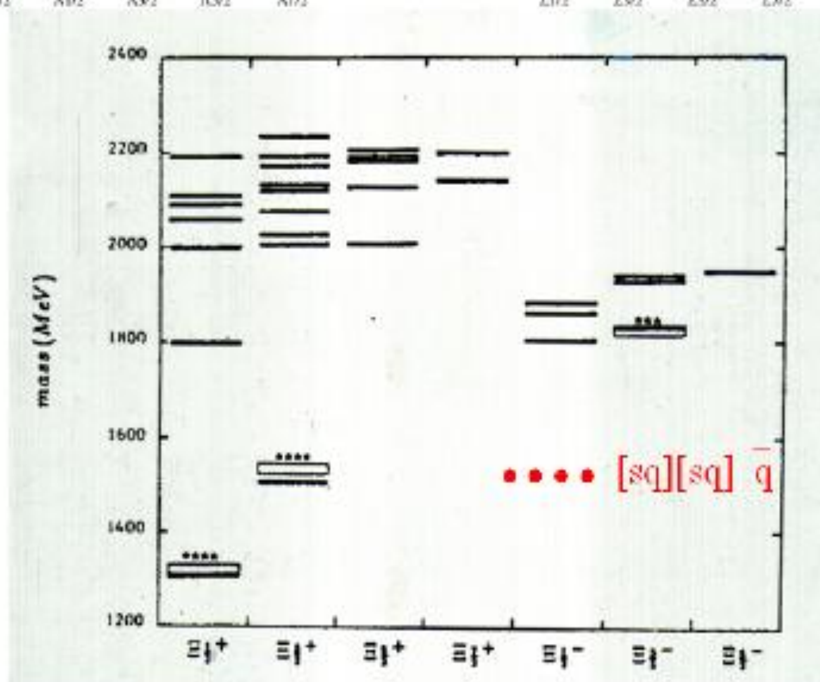
$K^- p \rightarrow \pi\, \Sigma^*(1360),\ \Sigma^*(1360) \rightarrow \Lambda\, \pi$

$\gamma N \rightarrow K^+\, \Sigma^*(1360),\ \Sigma^*(1360) \rightarrow \Lambda\, \pi$

$J/\psi \rightarrow \bar{\Sigma}\, \Sigma^*(1360),\ \Sigma^*(1360) \rightarrow \Lambda\, \pi$


PDG mass range
3* or 4*
* or **
N=3 band
N=0,1,2 bands


ū[ud][us]


mass (MeV)
****
***
[sq][sq] q̄