Evidence for Some New Hyperon Resonances - to be Checked by K_L Beam

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1) P.Gao, J.Shi, B.S.Zou, PRC86 (2012) 025201
2) J.Shi, B.S.Zou, PRC91(2015) 035202
3) J.J.Xie, J.J.Wu, B.S.Zou, PRC90 (2014) 055204
4) J.J.Wu, B.S.Zou, Few Body System 56 (2015) 165

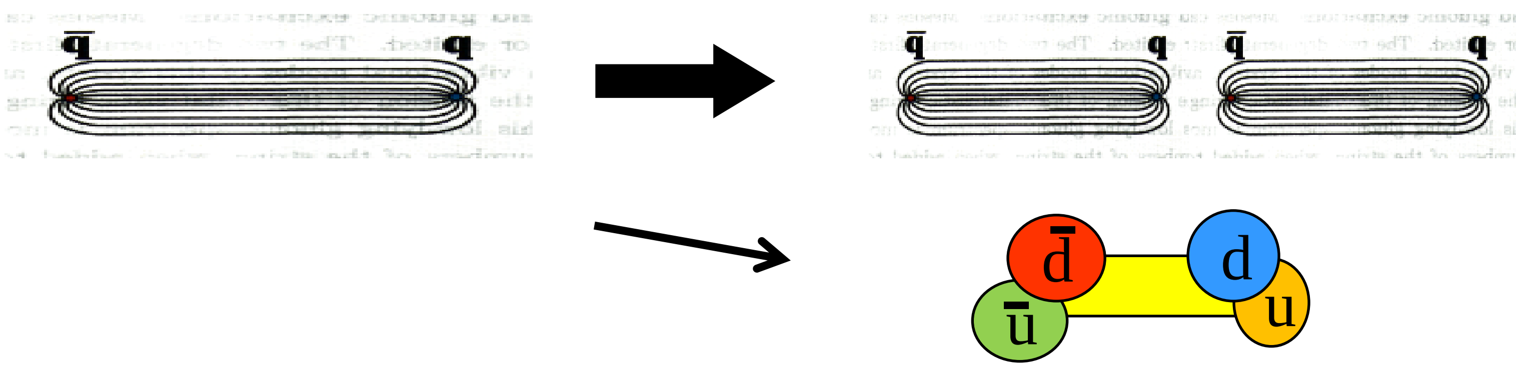
Outline :

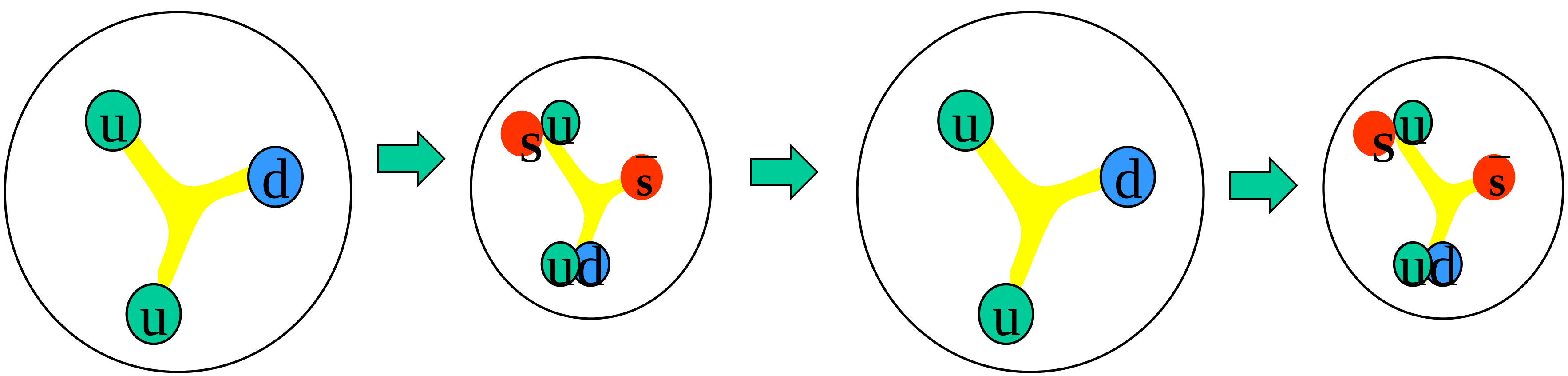
1. **Why hyperon resonances ?**
2. **New results on Σ^* & Λ^* from CB data**
3. **Possible new sources for Σ^* & Λ^***
4. **Conclusions and Prospects**

1. Why hyperon resonances ?

Unquenched dynamics: gluons → $\bar{q}q$

crucial for quark confinement & hadron structure





quenched or unquenched quark models give very different predictions of hyperon spectrum

$1/2^-$ baryon nonet with strangeness

- **Mass pattern : quenched or unquenched ?**

uds (L=1) $1/2^-$ ~ $\Lambda^*(1670)$ ~ $[us][ds]\bar{s}$

uud (L=1) $1/2^-$ ~ $N^*(1535)$ ~ $[ud][us]\bar{s}$

uds (L=1) $1/2^-$ ~ $\Lambda^*(1405)$ ~ $[ud][su]\bar{u}$

uus (L=1) $1/2^-$ ~ $\Sigma^*(1390)$ ~ $[us][ud]\bar{d}$

Zou et al, NPA835 (2010) 199 ; CLAS, PRC87(2013)035206

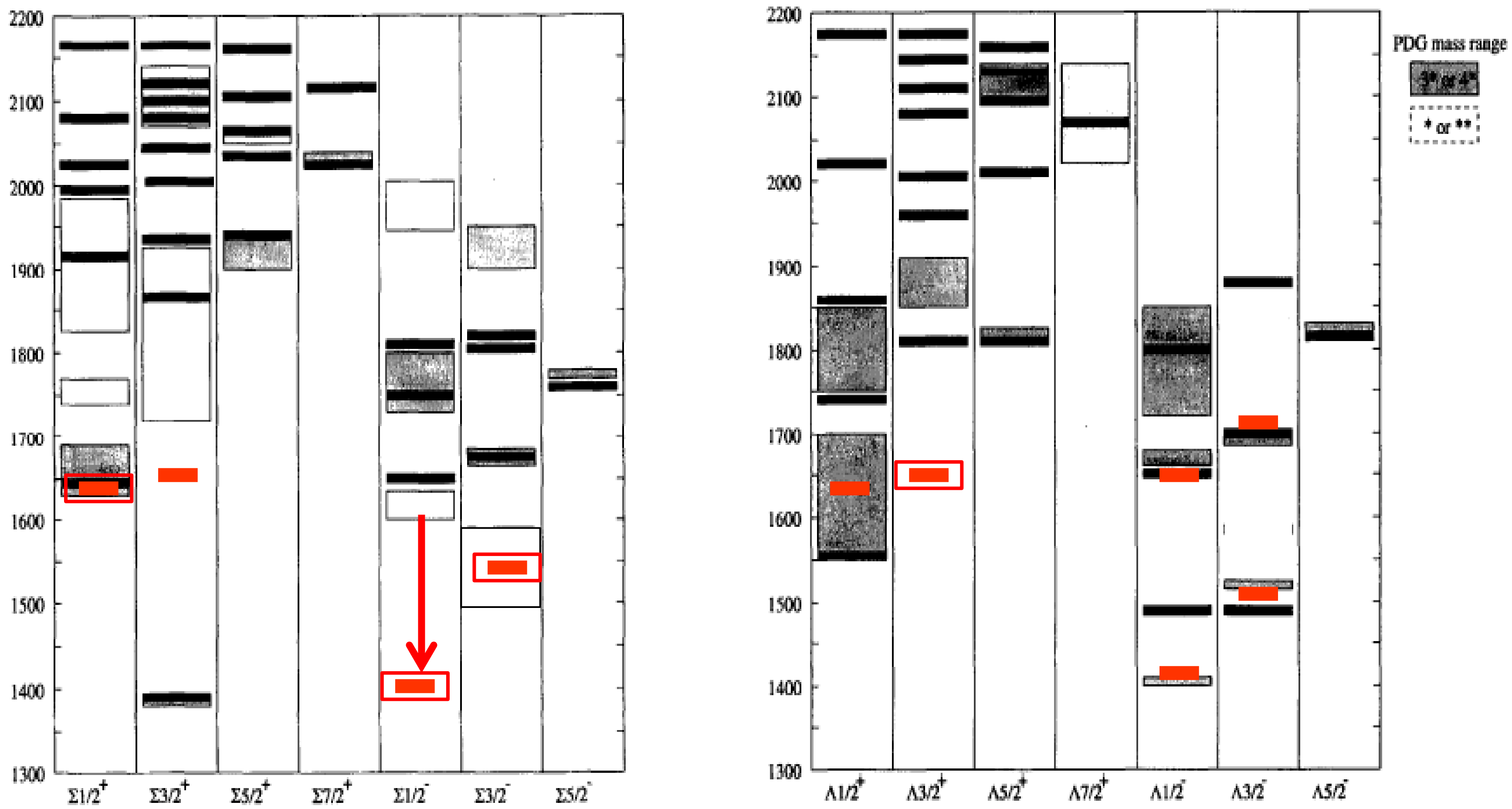
- **Strange decays of N*(1535) and Λ*(1670) :**

N*(1535) large couplings $g_{N^*N\eta}$, $g_{N^*K\Lambda}$, $g_{N^*N\eta'}$, $g_{N^*N\phi}$

Λ*(1670) large coupling $g_{\Lambda^*\Lambda\eta}$

Distinctive

Predictions by quenched - & unquenched - quark models



Quenched quark model: Capstick-Roberts, Prog.Part.Nucl.Phys. 45 (2000) S241-S331
Unquenched model: Helminen-Riska , Nucl. Phys. A 699 (2002) 624
A.Zhang, S.L.Zhu et al., HEPNP 29 (2005) 250

Alternative pictures :

Hadronic molecules	Penta-quark states
N*(1440) ~ Nσ	N*(1440) ~ [ud][ud] $\bar{q}$
N*(1535) ~ KΣ-KΛ	N*(1535) ~ [ud][us] $\bar{s}$
Λ*(1405) ~ KN-Σπ	Λ*(1405) ~ [ud][sq] $\bar{q}$

Kaiser, Weise, Oset, Ramos, Oller,
Meissner, Hyodo, Jido, Hosaka, Oh, …

Distinguishable model predictions for Σ* of $3/2^-$ and $1/2^+$

	qqq	$\bar{q}q^6$ or $\bar{K}\pi N-\pi\pi Y$	
$3/2^-$	Σ*(1650)	Σ*(1570)	Gal 2011
$1/2^+$	Σ*(1720)	Σ*(1630-1656)	Oset 2008

Experiment knowledge on hyperon states still very poor !

Ω* in PDG:

**** Ω(1672) $3/2^+$,

*** Ω (2250)

** Ω (2380), Ω (2470)

Ξ* in PDG:

**** Ξ(1320) $1/2^+$, Ξ(1530) $3/2^+$

*** Ξ(1690) , Ξ(1820) $3/2^-$, Ξ(1950) , Ξ(2030)

** Ξ(2250) , Ξ(2370)

* Ξ(1620) , Ξ(2120) , Ξ(2500)

Σ^* in PDG2012

****	$\Sigma(1189)1/2^+$ $\Sigma^*(1385)3/2^+$ $\Sigma^*(1670)3/2^-$ $\Sigma^*(1775)5/2^-$ $\Sigma^*(1915)5/2^+$ $\Sigma^*(2030)7/2^+$
***	$\Sigma^*(1660)1/2^+$ $\Sigma^*(1750)1/2^-$ $\Sigma^*(1940)3/2^-$ $\Sigma^*(2250)??$
**	$\Sigma^*(1620)1/2^-$ $\Sigma^*(1690)??$ $\Sigma^*(1880)1/2^+$ $\Sigma^*(2080)3/2^+$ $\Sigma^*(2455)??$ $\Sigma^*(2620)??$
*	$\Sigma^*(1480)??$ $\Sigma^*(1560)??$ $\Sigma^*(1580)3/2^-$ $\Sigma^*(1770)1/2^+$ $\Sigma^*(1840)3/2^+$ $\Sigma^*(2000)3/2^-$ $\Sigma^*(2070)5/2^+$ $\Sigma^*(2100)7/2^-$ $\Sigma^*(3000)??$ $\Sigma^*(3170)??$

All from old experiments of 1970-1985 !!

No established $1/2^-$ Σ^* , Ξ^*, Ω^* !

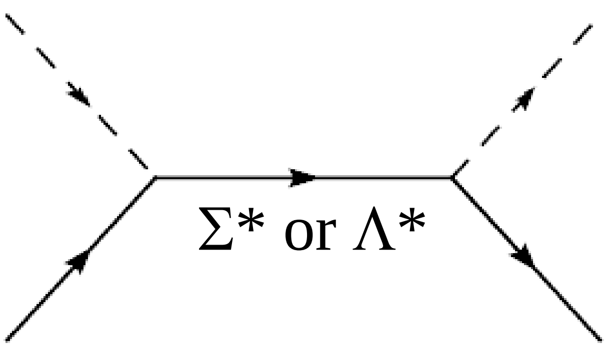
2. New results on Σ* & Λ* from CB data

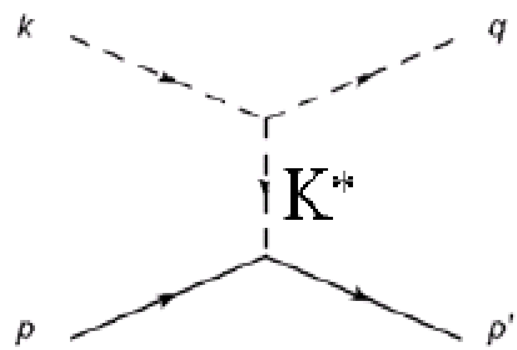
Crystal Ball： Prakhov et al., **PRC 80**(2009) 025204

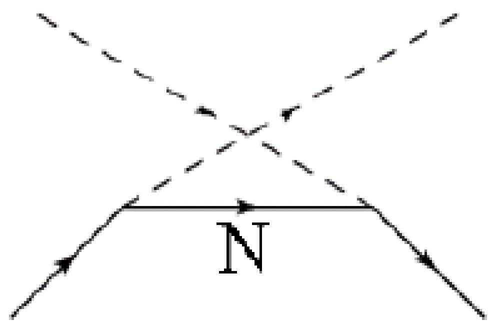
$$K^- + p \to \pi^0 + \Lambda \qquad \& \qquad K^- + p \to \pi^0 + \Sigma^0$$

p_K=514-750 MeV, $\sqrt{s} = 1569 - 1676$ MeV

The high precision new data can give valuable information on Σ* & Λ*







$\Sigma^*(1620)1/2^-$ → supporting evidence for quenched qqq models ?

Problem : evidence for its existence is very shaky !

Among 4 references listed in PDG for it:

One without PWA for J^P

Two based on multi-channel analysis gave contradicted BRs

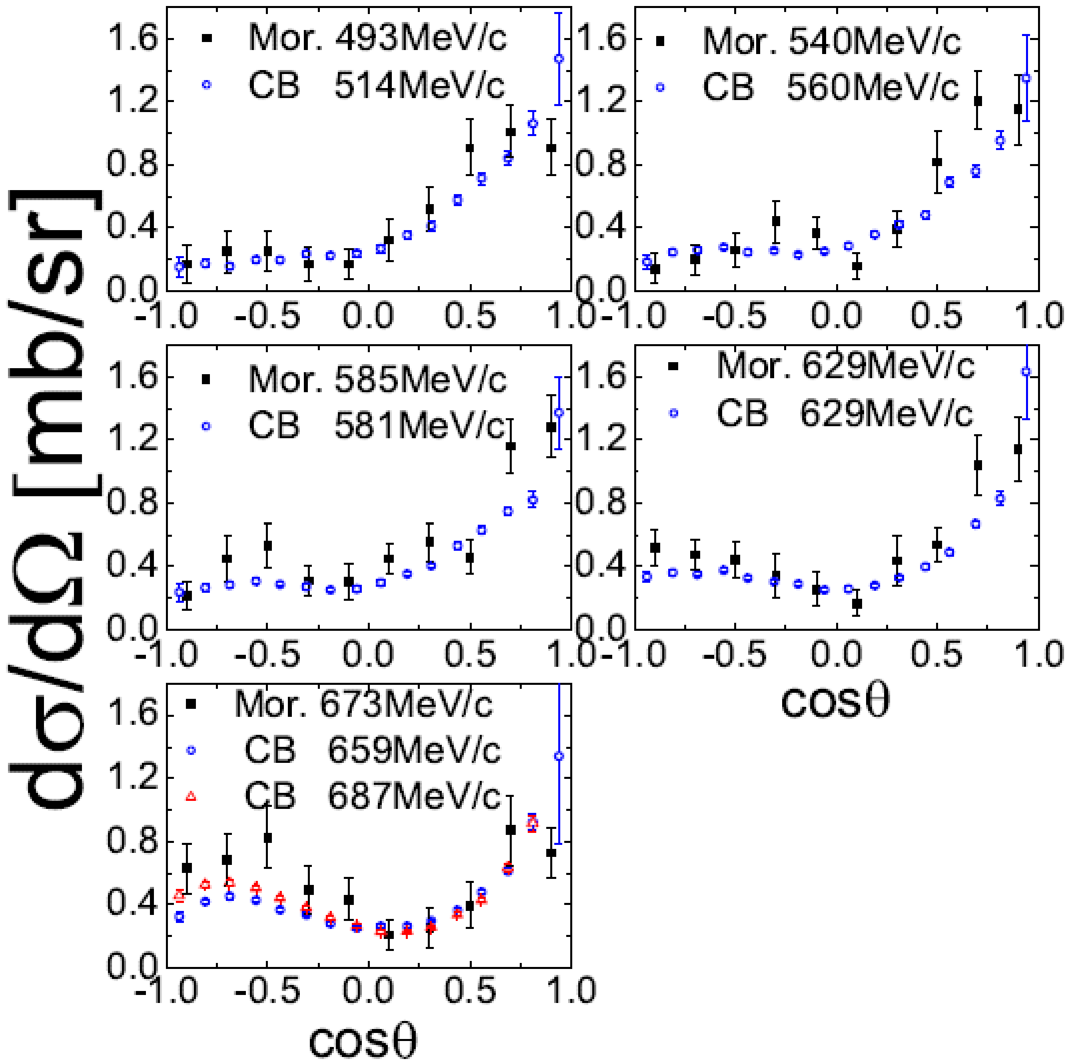
Other later multi-channel analyses claim to $\Sigma^*(1660)1/2^+$

The 4-th gave two comparable solutions with and without it by fitting $K^- n \to \pi^- \Lambda$ data

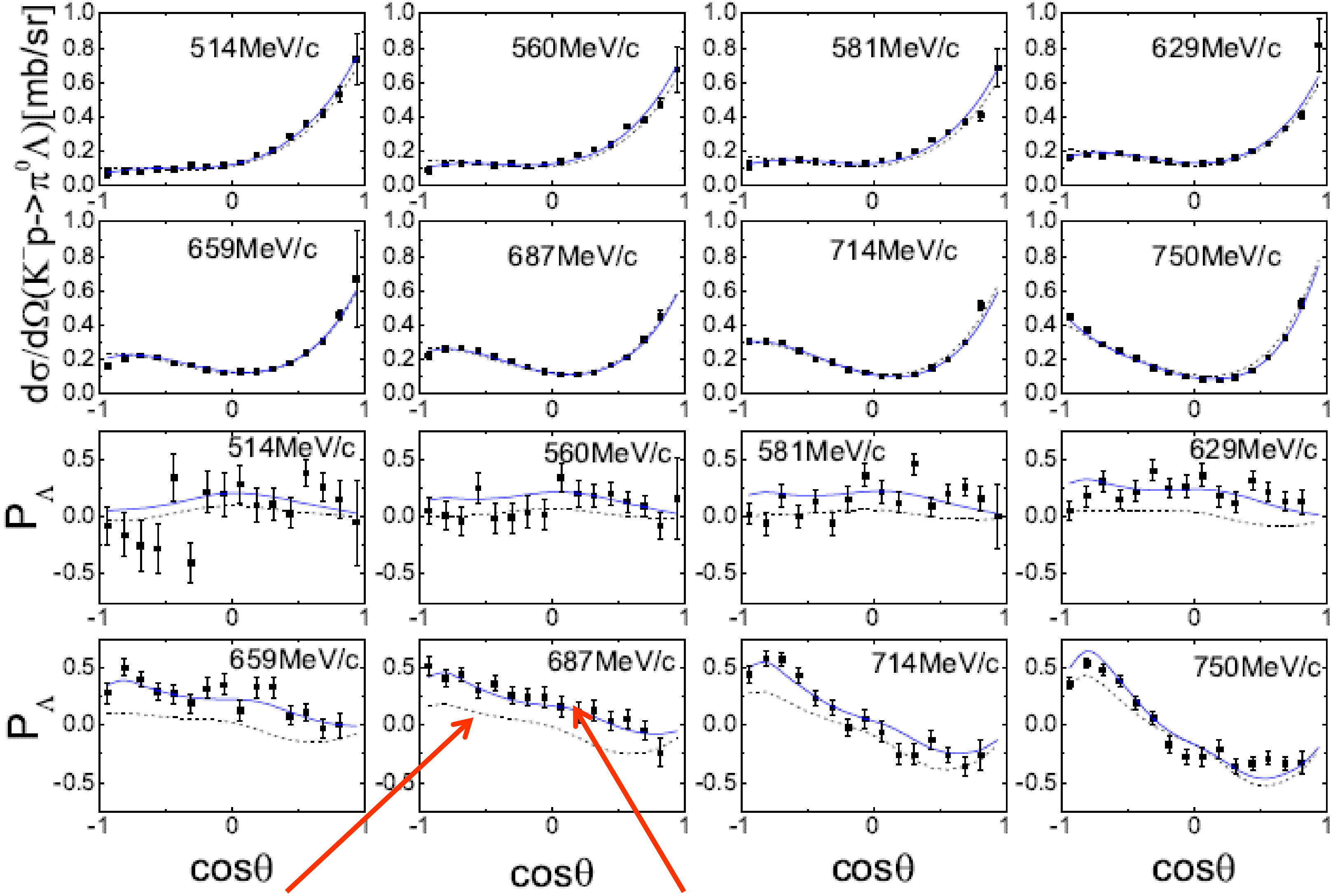
W.A. Morris et al., PRD17, 55 (1978)

Is the new CB data compatible with the old $K^- n \to \pi^- \Lambda$ data analyzed by W.A. Morris et al., claiming possible $\Sigma^*(1620)1/2^-$?

new CB data on $K^-p \rightarrow \pi^0\Lambda$ vs old $K^-n \rightarrow \pi^-\Lambda$ data



new CB data on $K^-p \rightarrow \pi^0\Lambda$: No $\Sigma(1620)\ 1/2^-$ needed !!



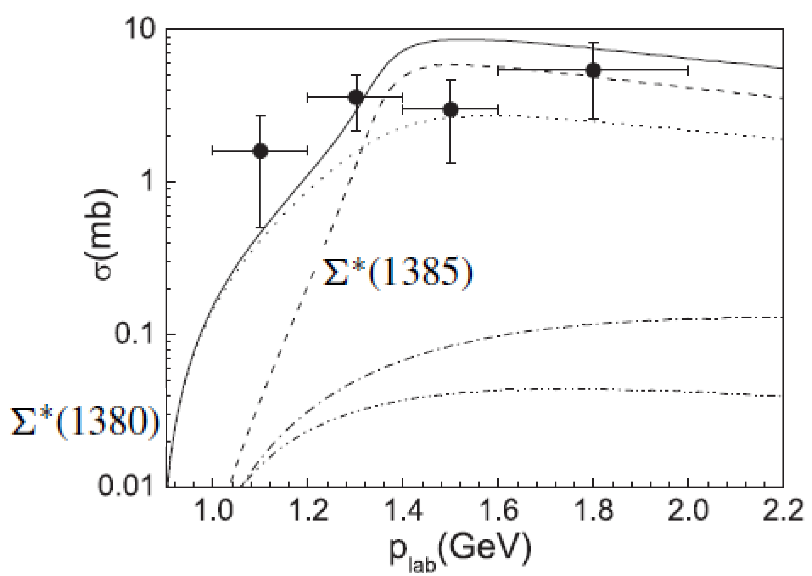
with basic ingredients

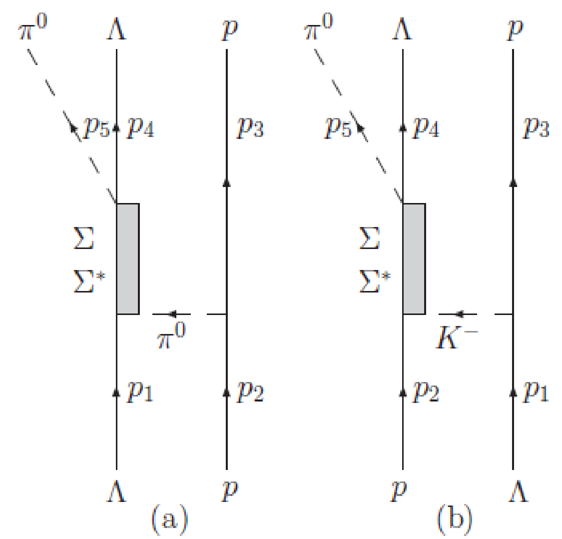
adding $\Sigma(1635)\ 1/2^+$

CB Λ Polarization data is crucial for discriminating Σ(1620)1/2⁻ from Σ(1635) 1/2⁺ .

PDG2014 downgrades Σ(1620)1/2⁻ from ** to *

New evidence for Σ(1380)1/2⁻ from $\Lambda p \to \Lambda p \pi^0$





J.J.Xie, J.J.Wu, B.S.Zou, PRC90 (2014) 055204

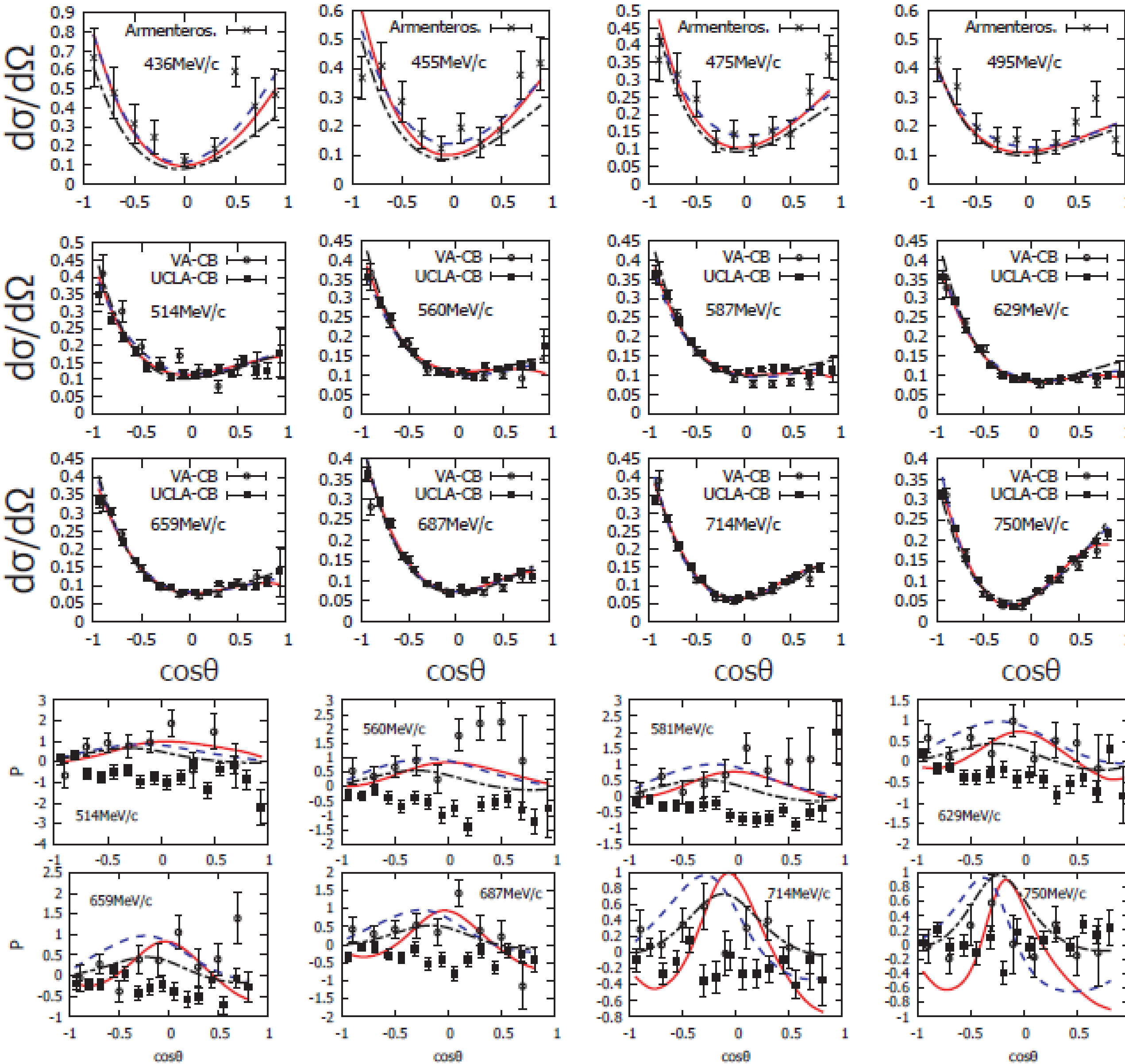
The combined fit of new CB data on $K^{-}p \to \pi^{0}\Lambda$ and old $K^{-}n \to \pi^{-}\Lambda$ data of $\sqrt{s} = 1569 - 1676$ MeV shows:

1) **$\Sigma(1660)1/2^{+}$ is definitely needed, while $\Sigma(1620)\ 1/2^{-}$ is not needed at all !**

2) **Additional $\Sigma(1542)3/2^{-}$, $\Sigma(1840)3/2^{+}$, $\Sigma(1610)1/2^{+}$ may exist.**

Fits to new CB data on $K^-p \rightarrow \pi^0\Sigma^0$ J.Shi, B.S.Zou, PRC91(2015) 035202

$\Lambda^*(1670)1/2^-$ **** + $\Sigma^*(1600)1/2^+$ *** → $\chi^2 = 763$ for 236 data points



$\Lambda^*(1670)1/2^-$ & $\Lambda^*(1600)1/2^+$
+ $\Lambda^*(1690)3/2^-$ ****
→ $\chi^2 = 540$

$\Lambda^*(1670)1/2^-$ & $\Lambda^*(1600)1/2^+$
+ $\Lambda^*(1680)3/2^+$ (new)
→ $\chi^2 = 419$

$\Lambda^*(1680)3/2^+$ replaces
$\Lambda^*(1690)3/2^-$ ****

Strong support for unquenched quark model!

Shi&Zou, PRC91(2015) 035202 :

new $\Lambda^*(1680)3/2^+$ M=1682±1 MeV, Γ=132±1 MeV

Further supports for a new $\Lambda^*(1680)3/2^+$ from coupled channel analysis of KN reactions

Kamano, Nakamura, Lee, Sato, PRC92 (2015) 025205 :

M=1681+2 −8 MeV, Γ=10+22 −8 MeV

Fernandez-Ramirez, Danilkin, Manley, Mathieu, Szczepaniak arXiv:1510.07065 [hep-ph] :

M=1690±4 MeV, Γ=46±11 MeV

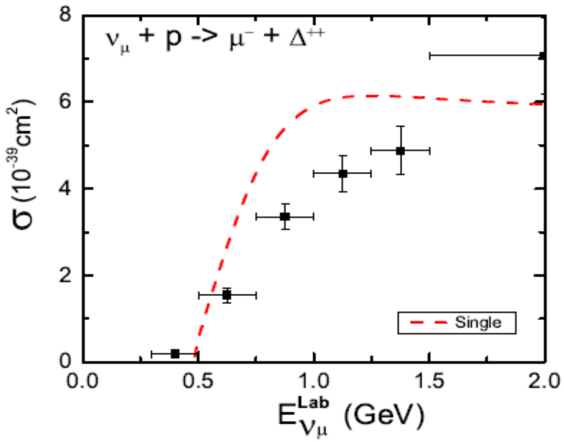
Liu&Xie, PRC86(2012)055202

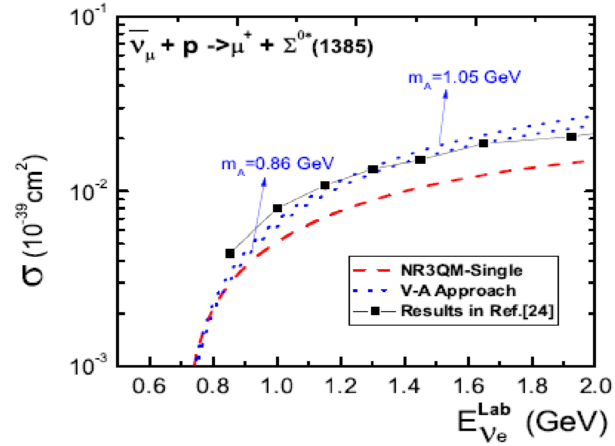
new $\Lambda^*(1670)3/2^-$ → $\Lambda\eta$ with width of 1.5 MeV

[us]{ds} $\bar{s}$

3. Possible new sources for Σ* & Λ*

1) $\bar{\nu}_{e/\mu} + p \rightarrow e^+/\mu^+ + \pi + \Lambda/\Sigma$, **Wu, Zou, FBS 56 (2015) 165**

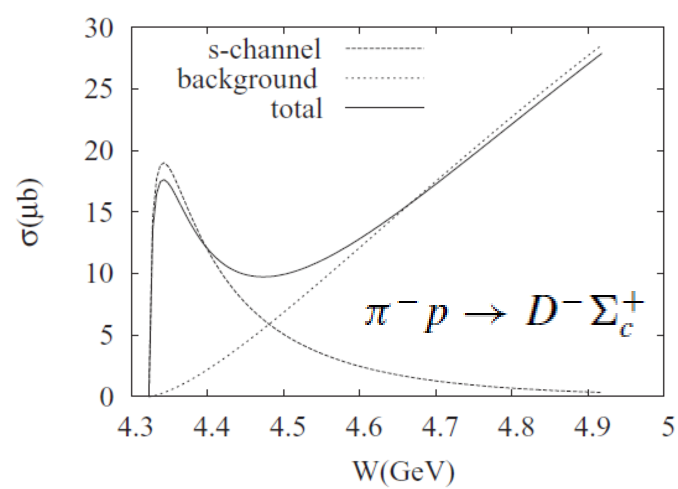




MiniBooNE → an ideal place for studying Σ* & Λ* below Kp threshold

2) $\Lambda_c^+ \longrightarrow \Lambda\pi^+\pi^0$ **BR=3.6%**

Λ_c production from πp, γp, e+e– at BESIII, JPARC, JLAB, BelleII



Garcon, Xie, PRC **92** (2015)035201

3) K^-, K_L beam experiments at JPARC&Jlab

Elegant new source for Λ^*, Σ^* & Ξ^* hyperon spectroscopy

→ talks by H.Ohnishi, M.Manley, K.Nakayama, Y.Oh

$K_L p \rightarrow \Lambda\pi^+, \Sigma^0\pi^+, \Sigma^+\pi^0, \Sigma^{*0}\pi^+, \Sigma^{*+}\pi^0$: $\Sigma^*(1540)\ 3/2^-$

$K_L p \rightarrow \Sigma^0\pi^0\pi^+, \Lambda\pi^0\pi^+$: $\Sigma^*(1380)1/2^-, \Sigma^*(1540)\ 3/2^-, \Lambda^*(1680)3/2^+$

$K_L p \rightarrow \Sigma^0\eta\pi^+, \Lambda\eta\pi^+$: $\Sigma^*(1380)1/2^-, \Sigma^*(1540)\ 3/2^-, \Lambda^*(1670)3/2^-$

4. Conclusions and Prospects

- **New hyperons support unquenched quark picture**

new $\Sigma^*(1380)1/2^-$ replaces $\Sigma^*(1620)1/2^-$ **

new $\Lambda^*(1680)3/2^+$ replaces $\Lambda^*(1690)3/2^-$ ****

new $\Lambda^*(1670)3/2^-$ with width of 1.5 MeV $[ud]\{ss\}\bar{s}$

$\rightarrow \Lambda\eta$ Liu&Xie, PRC86(2012)055202

new $\Sigma^*(1540)\ 3/2^-$

$3/2^-$ baryon nonet with strangeness

$\Lambda^*(1670) \sim [ud]\{ss\}\bar{s}$

$N^*(1520) \sim [ud]\{uq\}\bar{q}$

$\Lambda^*(1520) \sim [ud]\{su\}\bar{u}$

$\Sigma^*(1540) \sim [ud]\{sd\}\bar{d}$

pentaquark prediction: $\Xi(1630)1/2^-$ & $\Xi(1690)3/2^-$

- **All these and more new hyperons can be studied by forthcoming K beam experiments !**

Thanks !