Complementary studies on N* from e^+e^-, pp and $\bar{p}p$ collisions

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Outline:

- **Introduction**
- **N* from $e^+e^- \to \psi \to \bar{N} N^*$**
- **N* from $pp \to N N^*$**
- **N* from $\bar{p}p \to \bar{N} N^*$**
- **Summary and Prospects**

1. Introduction

Two well-known problems 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)

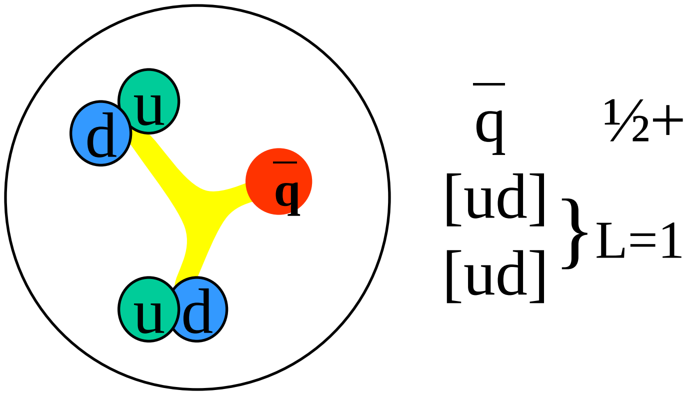
  harmonic oscillator (2n + L + 3/2) hω

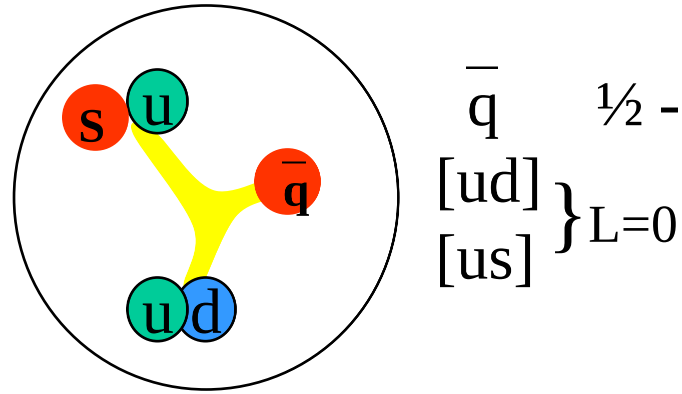
- **The number of predicted states is much less than observed**

  "missing" baryon states : non-existence / to be observed ?

A new scheme to explain the mass reverse problem

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





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$^-$ nonet predicts:

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

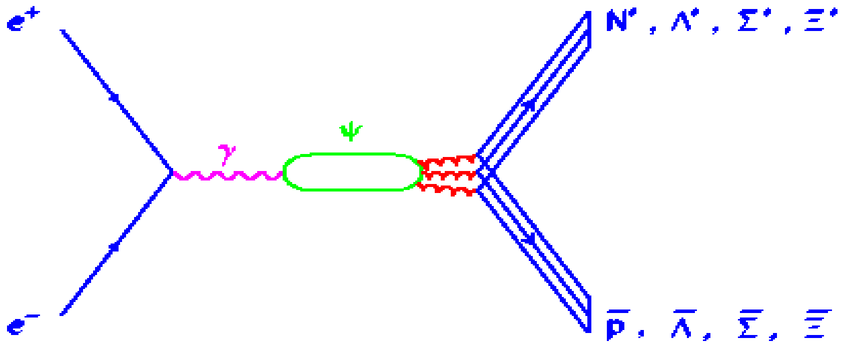
Where to look for "missing" baryon states ?

High statistics γp and Kp experiments

+ e^+e^-, pp & $\bar{p}p$ experiments

2. N* from $e^+e^- \to \psi \to \bar{N}\,N^*$

$$\Psi \to \bar{B}BM \Rightarrow N^*, \Lambda^*, \Sigma^*, \Xi^*$$

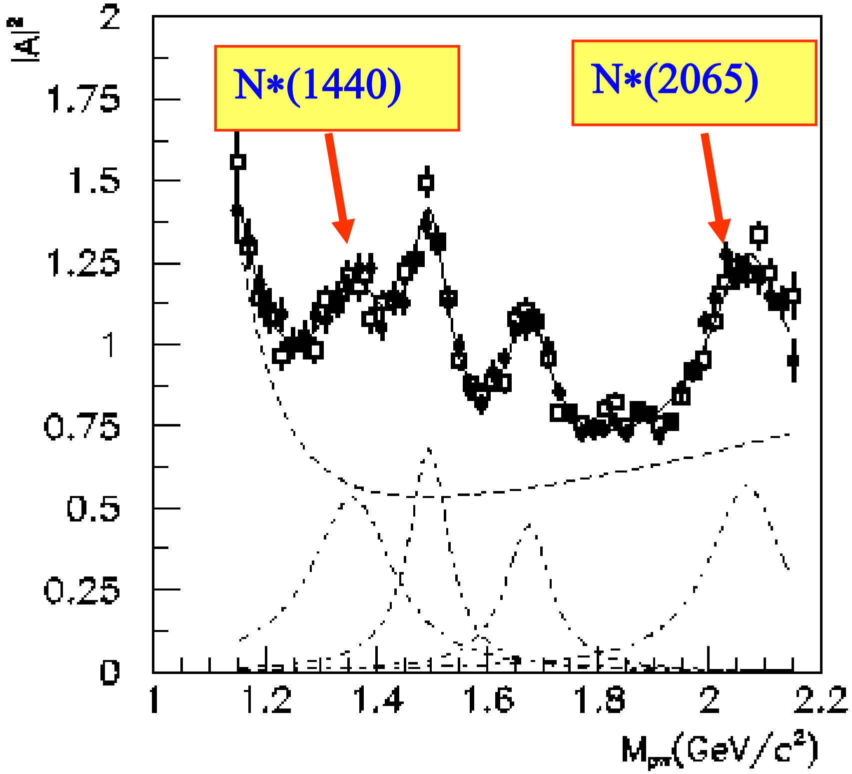


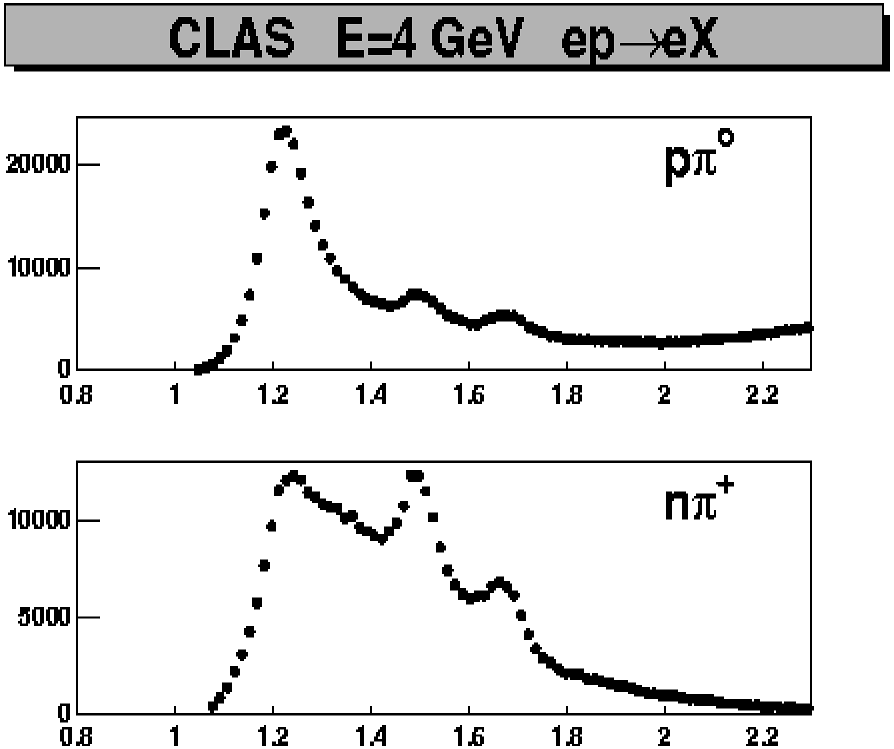
New mechanism for baryon production & an ideal isospin filter

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

J/ψ → $\bar{p}n\pi^+$ & $\bar{n}\pi^-p$

V. Burkert





Observation of two new N* peaks in πN mass spectrum

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

The 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)

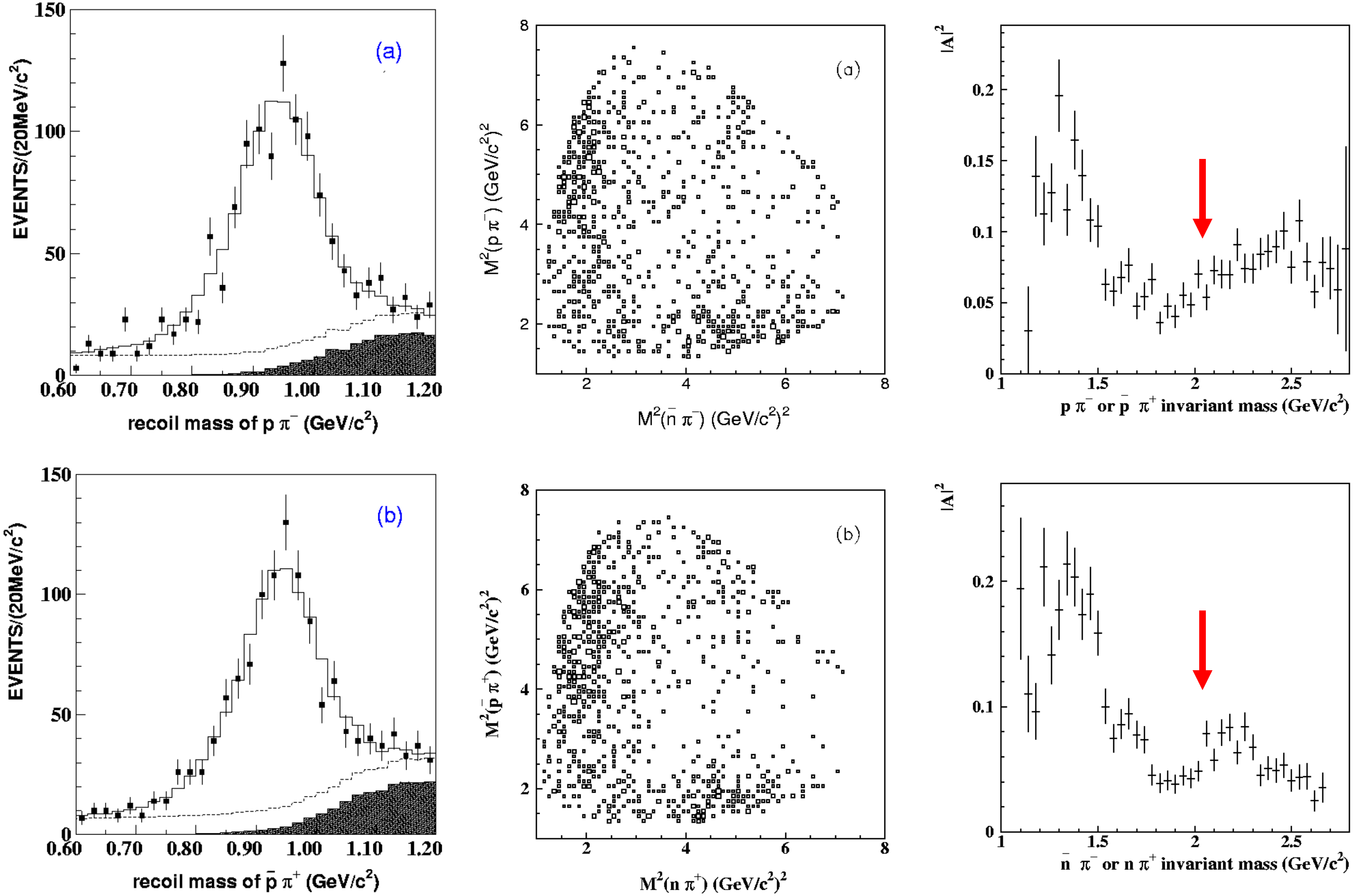
limits its J^P to be $3/2^+$ or $1/2^+$ (spin filter)

PWA with event-based Maximum-Likelihood method

→ Both $3/2^+$ and $1/2^+$ are there.

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

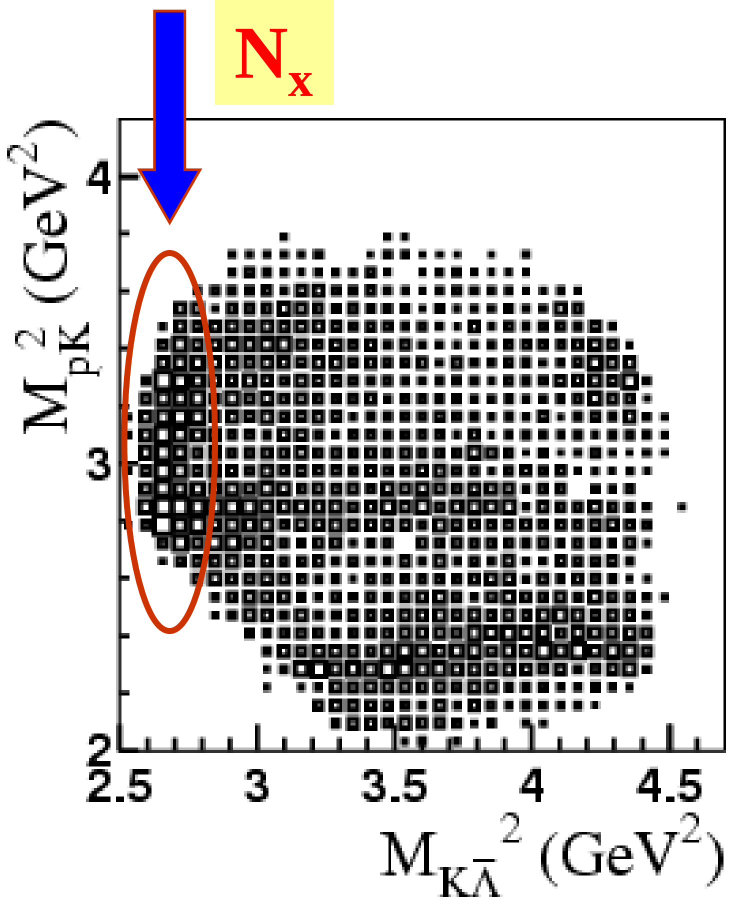
BES, Phys. Rev. D74, 012004 (2006)

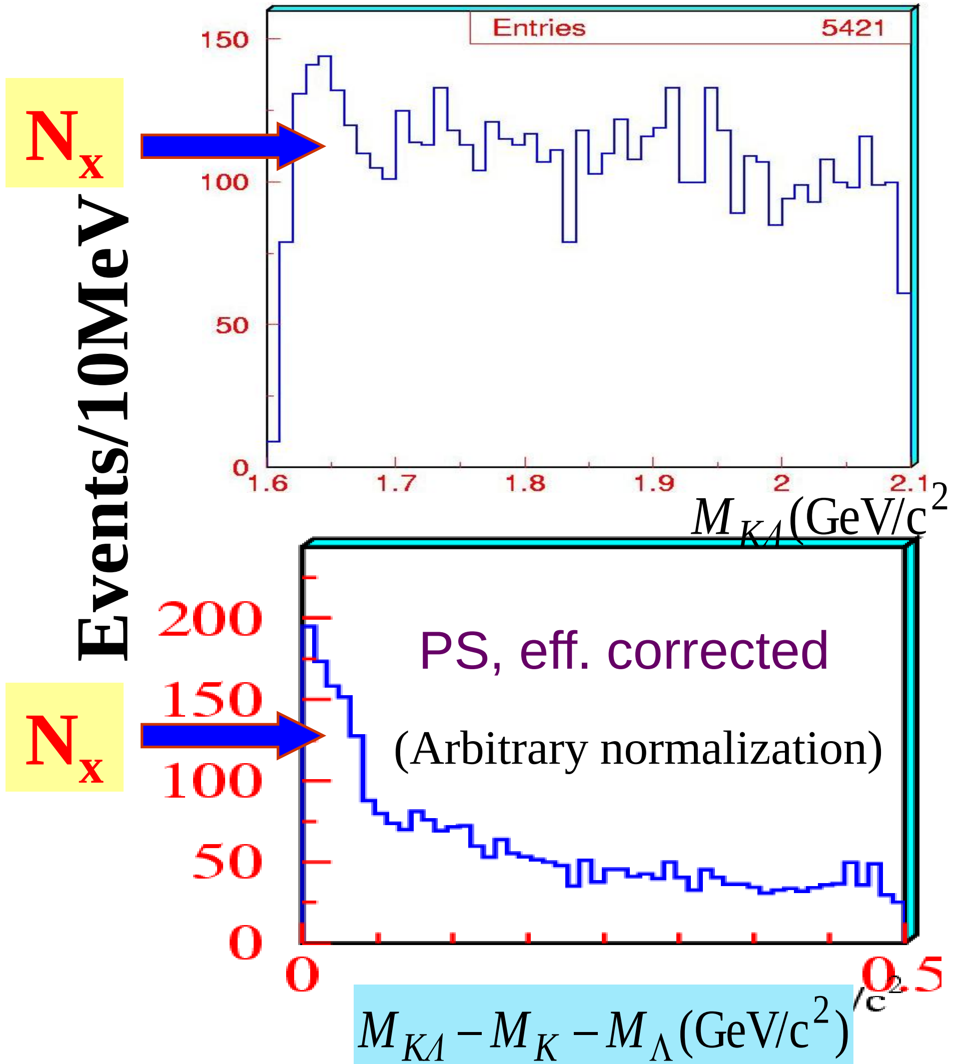


Clear N*(1440) peak and evidence for N* above 2 GeV

2) N^* in $\psi \rightarrow \bar{\Lambda} K N$

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





Mass 1500~1650MeV

Width 70~110MeV

J^P favors 1/2-

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

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 $\bar{s}s$ in N*(1535)

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

Many more channels:

$J/\psi \rightarrow \bar{p}p\eta$: **Phys. Lett. B510 (2001) 75**

$J/\psi \rightarrow \bar{\Lambda} K_S n$: **Phys. Lett. B659 (2008) 789**

$J/\psi \rightarrow \bar{p}p\omega$: **Eur. Phys. J. C53 (2008) 15**

$J/\psi \rightarrow p\bar{p}\pi^0$: **Hongxun Yang's talk**

$\psi(2S) \rightarrow \bar{p}p\pi^0$, $\bar{p}p\eta$: **Phys. Rev. D71 (2005) 072006**

J/ψ decay branching ratios ($BR*10^3$)

$p\bar{n}\pi^-$	$p\bar{p}\pi^0$	$p\bar{p}\pi^+\pi^-$	$p\bar{p}\eta$	$p\bar{p}\eta'$	$p\bar{p}\omega$
2.4 ± 0.2	1.1 ± 0.1	6.0 ± 0.5	2.1 ± 0.2	0.9 ± 0.4	1.3 ± 0.3
$\Lambda\bar{\Sigma}^-\pi^+$	$pK^-\bar{\Lambda}$	$pK^-\bar{\Sigma}^0$	$\bar{p}p\phi$	$\Delta(1232)^{++}\bar{p}\pi^-$	$pK^-\bar{\Sigma}(1385)^0$
1.1 ± 0.1	0.9 ± 0.2	0.3 ± 0.1	0.045 ± 0.015	1.6 ± 0.5	0.51 ± 0.32

BES3 : $10^8 \sim 10^9$ $\psi(3686)$ & $10^9 \sim 10^{10}$ $J/\psi(3097)$

$N^* \sim 2740$ MeV, $\Lambda^* \sim 2570$MeV,

$\Sigma^* \sim 2490$ MeV, $\Xi^* \sim 2360$ MeV

3. N* from pp → N N*

complimentary e^+e^- and pp experiments

$\psi \to P K^- \bar{\Lambda}$ vs $P P \to P K^+ \Lambda$

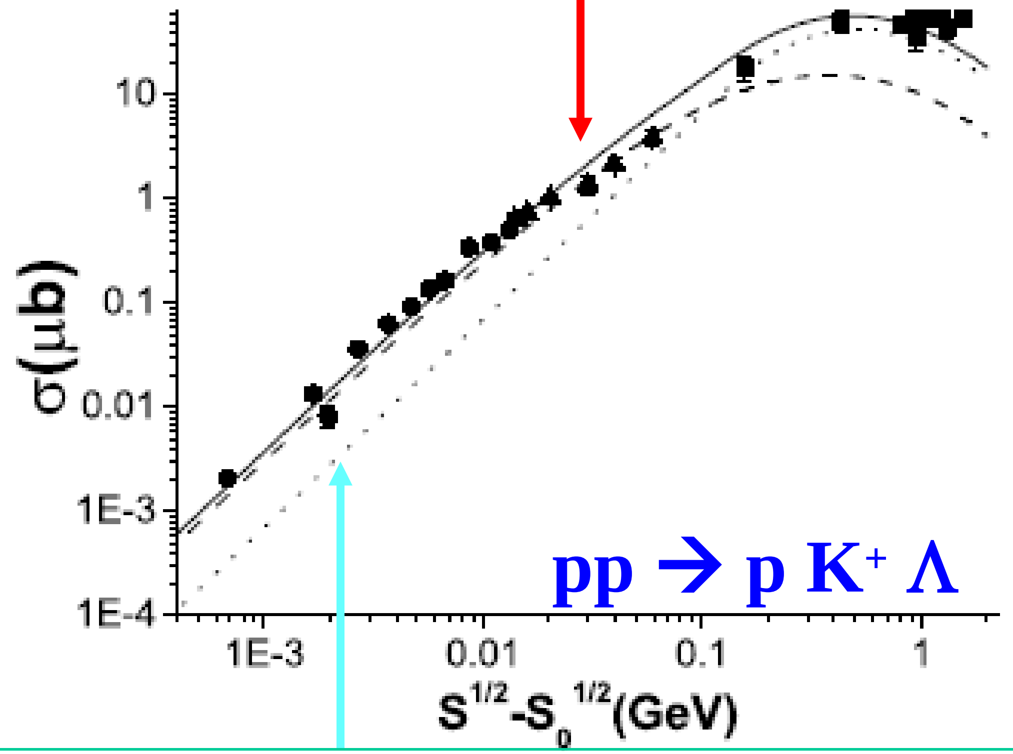
$P \bar{\Lambda}$ & $P \Lambda$ the same t-channel interaction

$K^- \bar{\Lambda}$ & $K^+ \Lambda$ the same interaction

$P K^-$ for Λ^* $P K^+$ for pentaquarks

Evidence for large $g_{N^*(1535)K\Lambda}$ 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

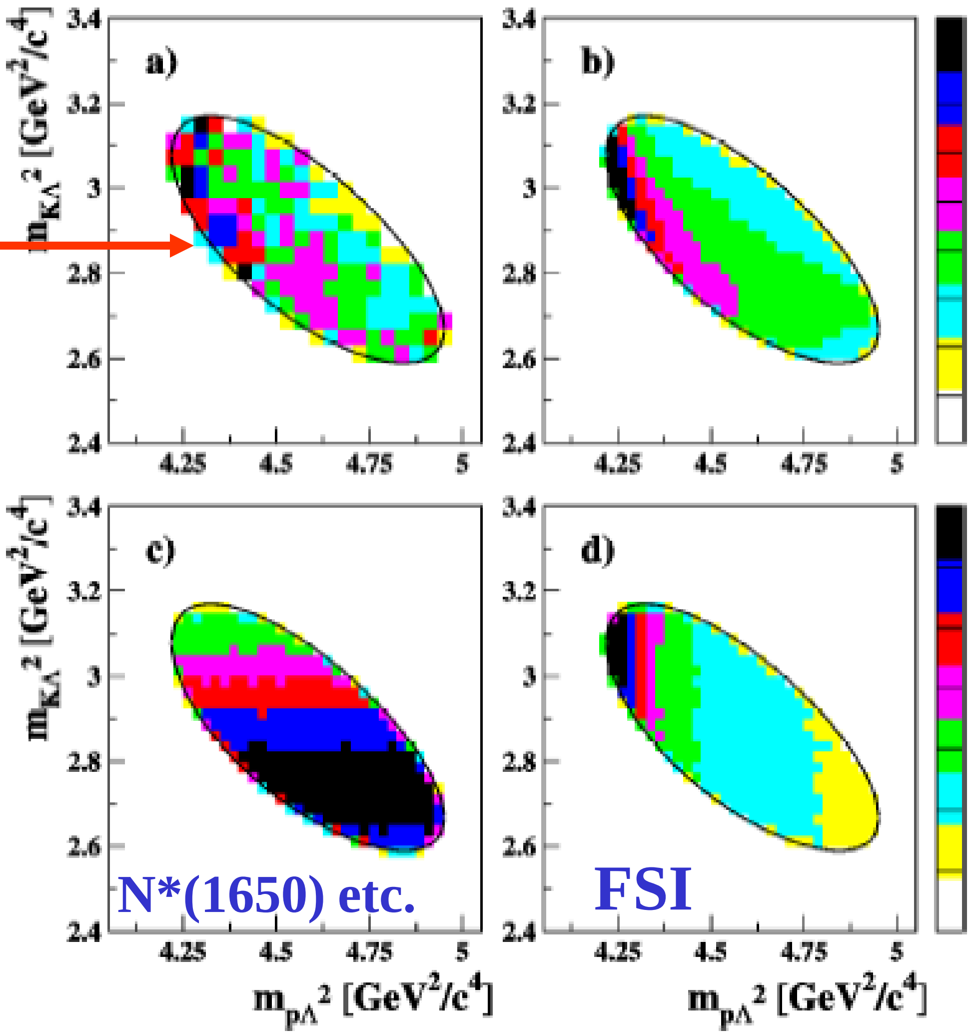


Tsushima,Sibirtsev,Thomas, PRC59 (1999) 369, without including N*(1535)

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 !

N*(1440) in pp → pnπ $^{+}$, consistent with J/ψ → $\bar{p}$nπ^{+}

CELSIUS-WASA Collaboration, nucl-ex/0612015

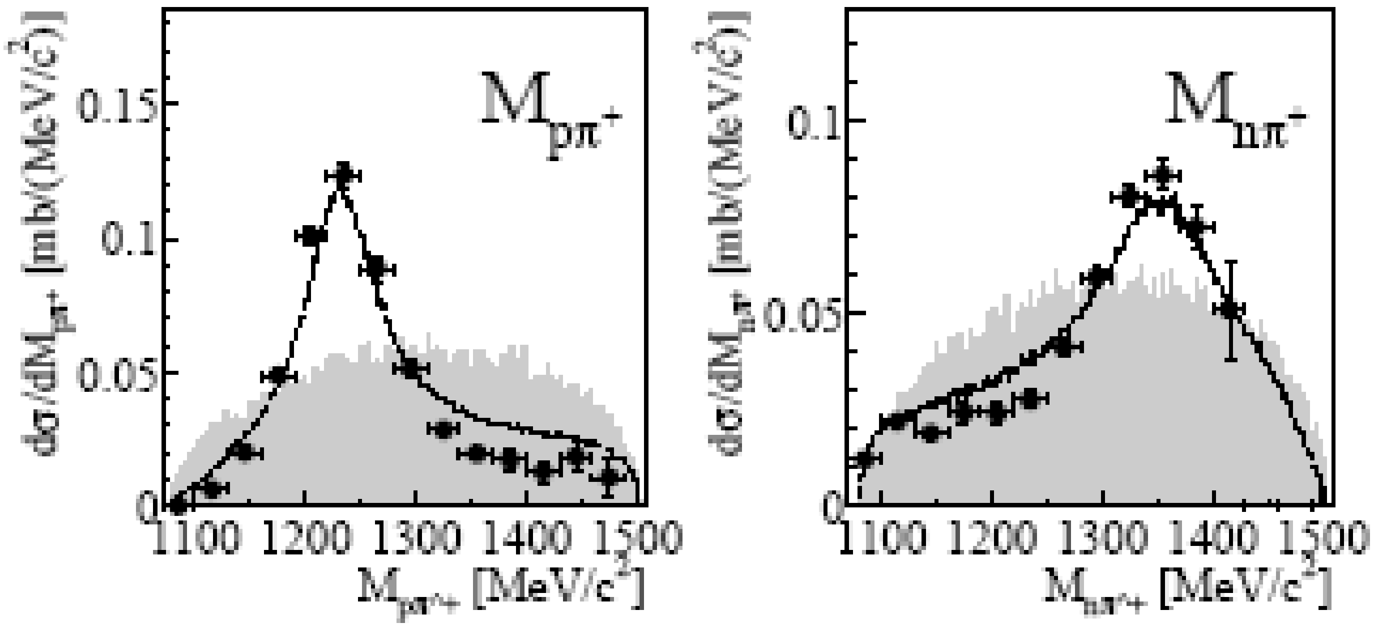
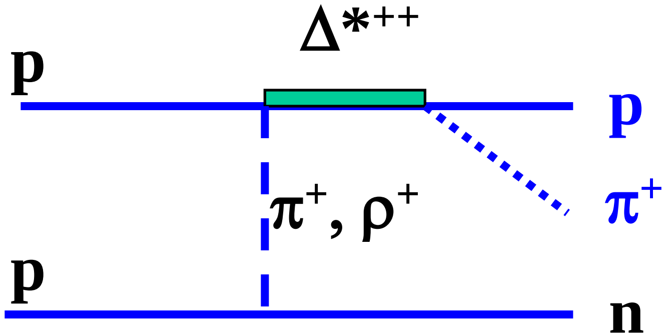
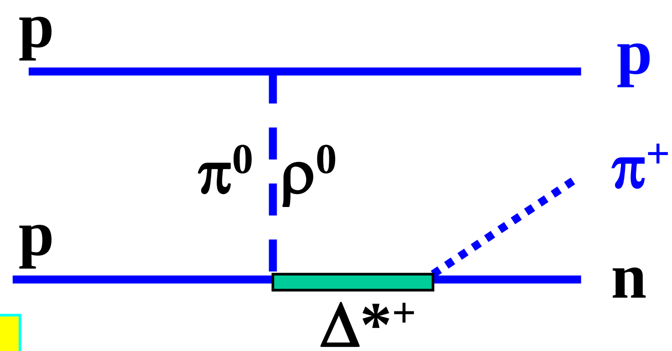


Figure 2: Invariant mass spectra $M_{p\pi^+}$ and $M_{n\pi^+}$ obtained from the measurement of the $pp \to np\pi^+$ reaction at T_p = 1300 MeV. The shaded areas show the pure phase space distributions, whereas the dashed lines show calculations assuming BW shapes for both the Δ^{++} and the Roper excitation [19].

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





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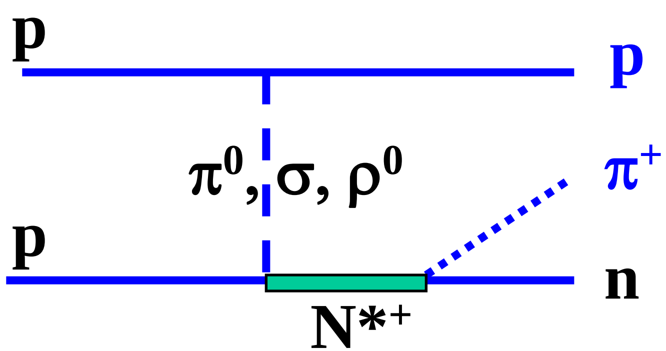
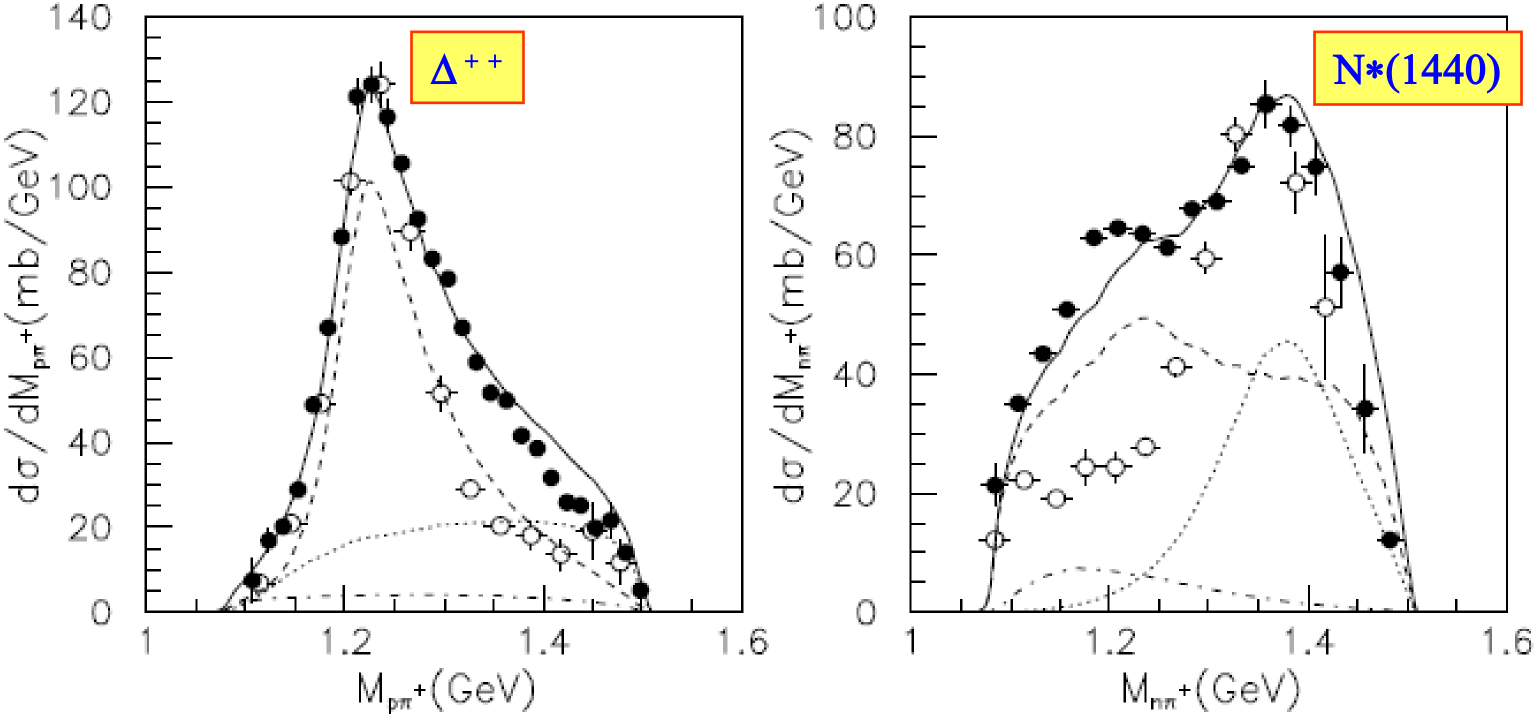


A quite good isospin filter !

Look for "missing" N* by σp production !

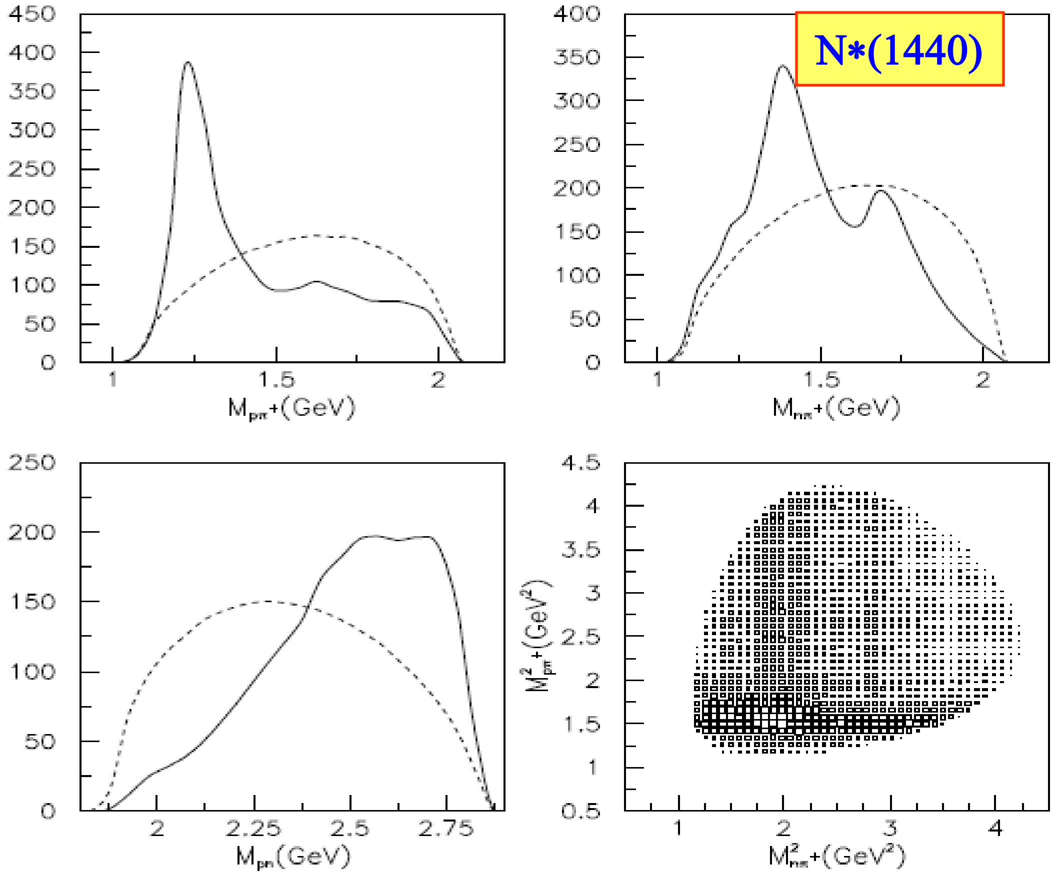
Theoretical study on pp→pnπ^+

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



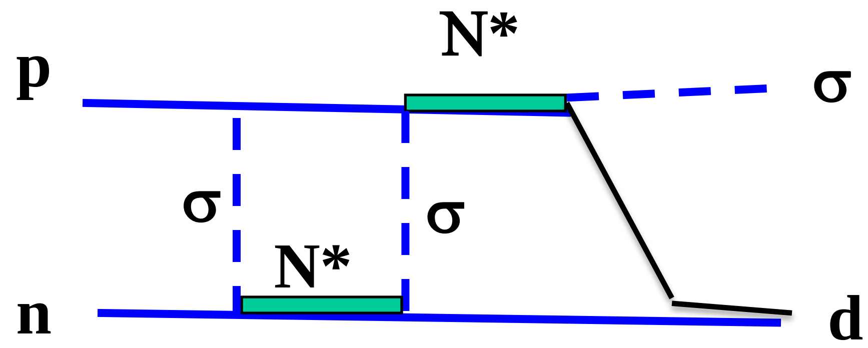
Including N*(1440) by σ exchange is crucial to reproduce data

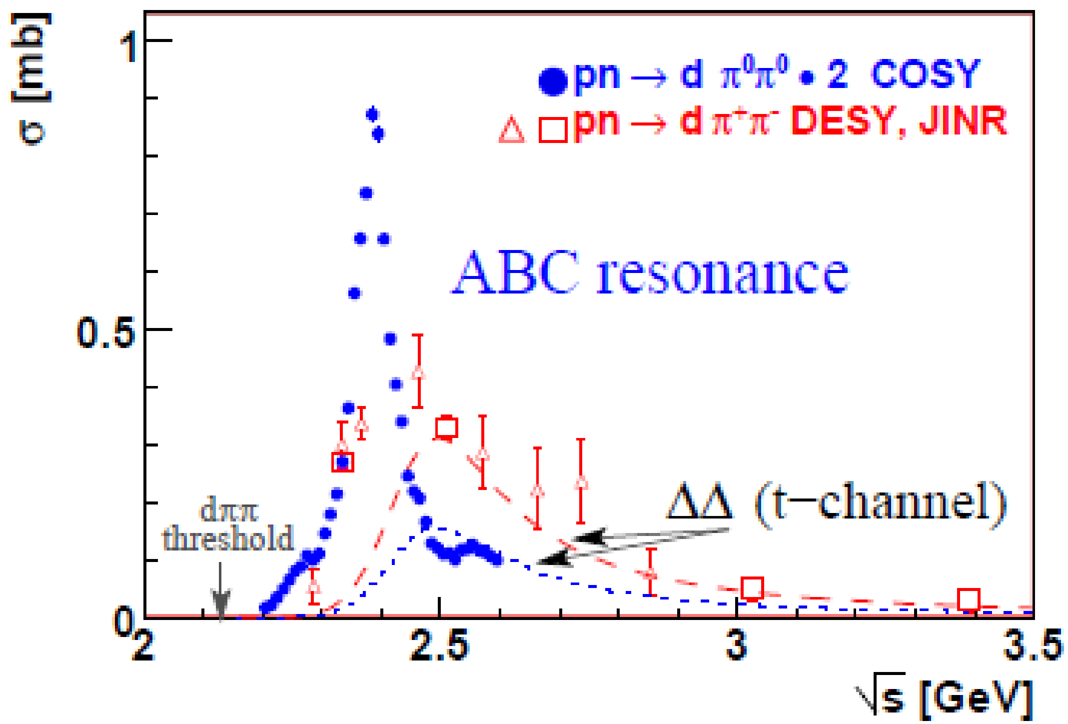
Prediction for pp→pnπ^+ at T_p=2.88 GeV



to be checked by COSY&CSR

a NN*(1440) → dσ state ?

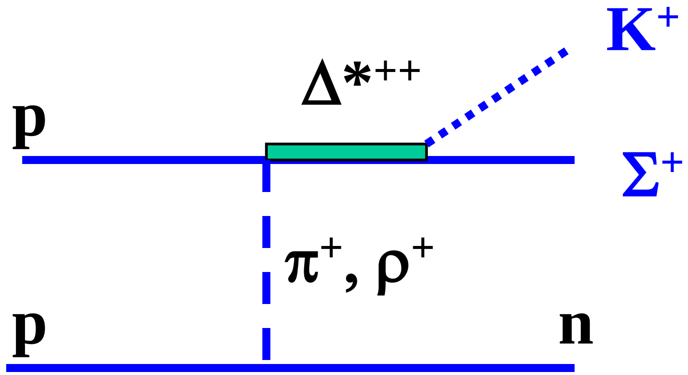




Juelich 2008 annal report

pp→nK$^+$Σ$^+$: the best place for ρ$^+$p → Δ*$^{++}$ (uuu)

J.J.Xie & B.S.Zou, Phys. Lett. B649 (2007) 405



Δ*$^{++}$ (uuu) -- the most accessible system with 3 identical valence quarks

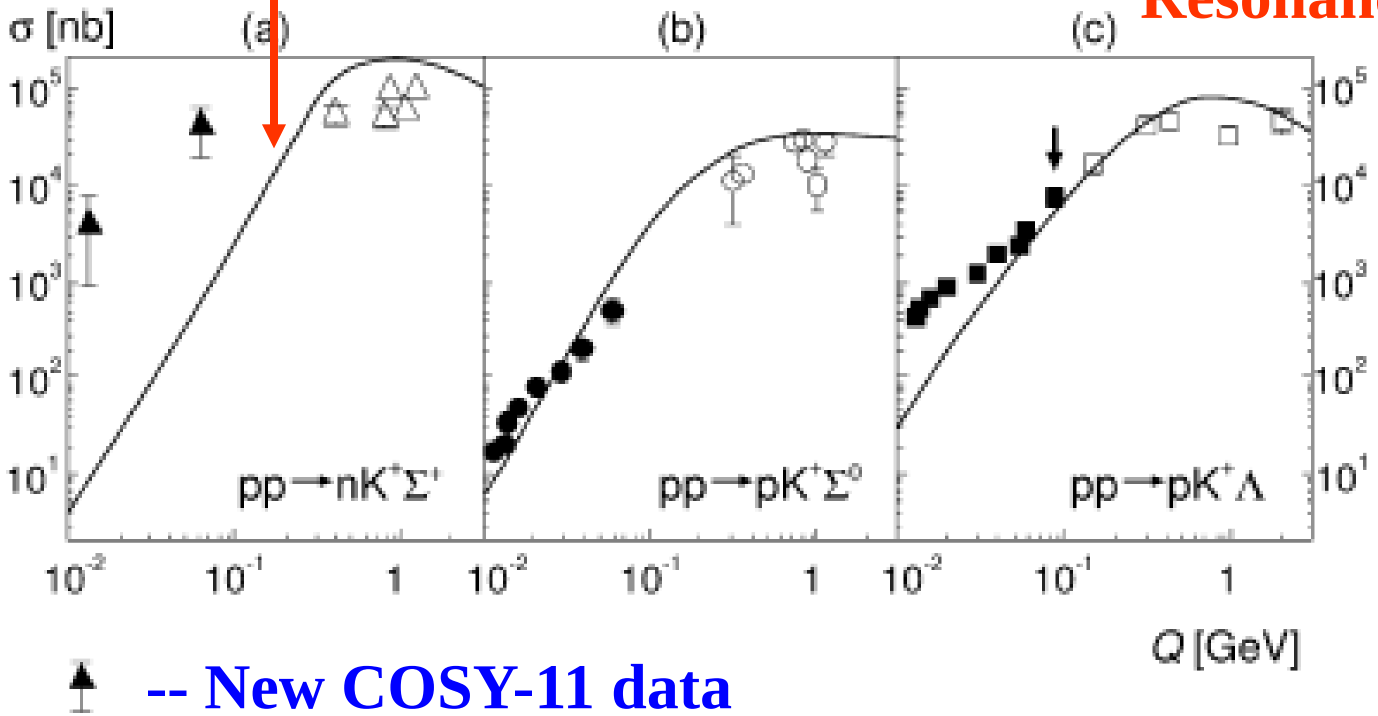
-- our present knowledge from π$^+$p data is still very poor

-- accessible at COSY and CSR

Status on the study of $pp \rightarrow nK^+\Sigma^+$

N. Tsushima, et al., Phys. Rev. C 59 (1999) 369.

Resonance model



-- New COSY-11 data

T. Rożek et al. / Physics Letters B 643 (2006) 251–256

Incohenrent π/K exchange model also fails to reproduce these data

A. Sibirtsev, et al., Nucl. Phys. A 646 (1999) 427.

Our calculation for pp→nK⁺Σ⁺

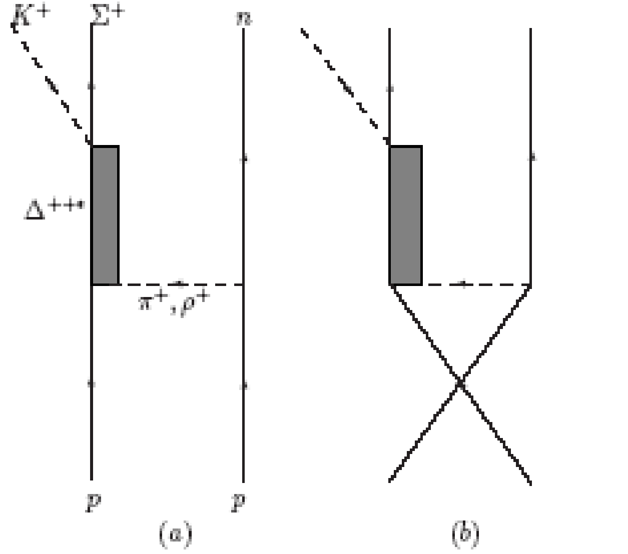
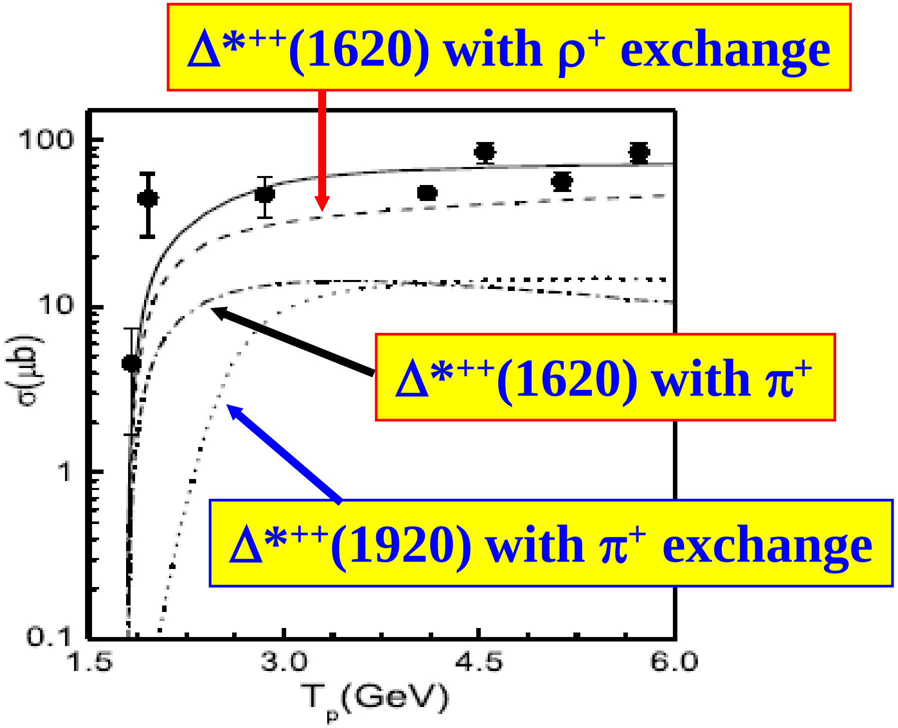


Figure 1: Feynman diagrams for $pp \to nK^+\Sigma^+$ reaction.



t-channel ρ-exchange plays important role !

Dalitz plot and projections: predictions to be checked by COSY&CSR

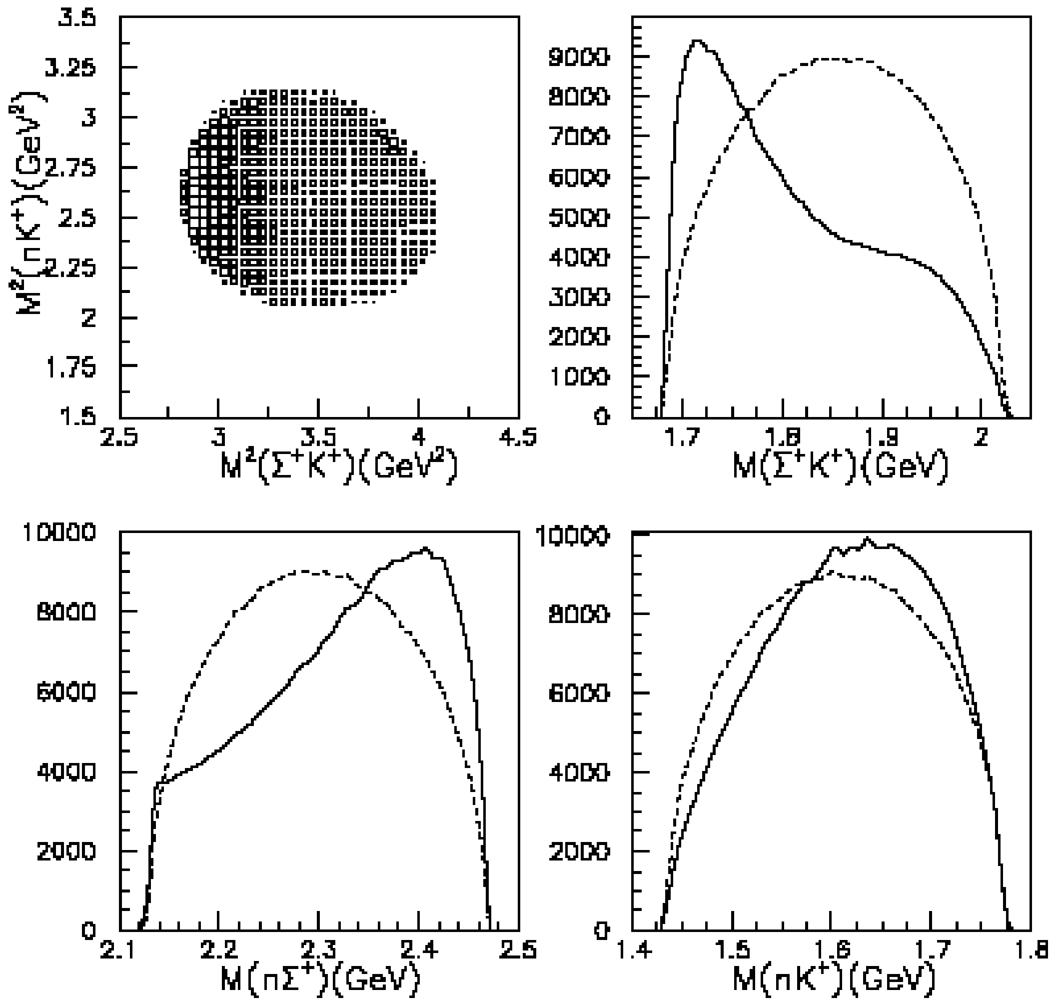


Figure 3: The Dalitz Plot and invariant mass spectra for the $pp \to nK^+\Sigma^+$ at T_P=2.8GeV, compared with pure phase space distributions (dashed curves)

4. N* from $\bar{p}p \rightarrow \bar{N} N^*$

$T_b \sim 2GeV$	p p	vs	$\bar{p}$ p
σ_{tot} (mb)	50		90
σ_{el} (mb)	25		35
$\sigma_{pn\pi+}$ (mb)	15		10

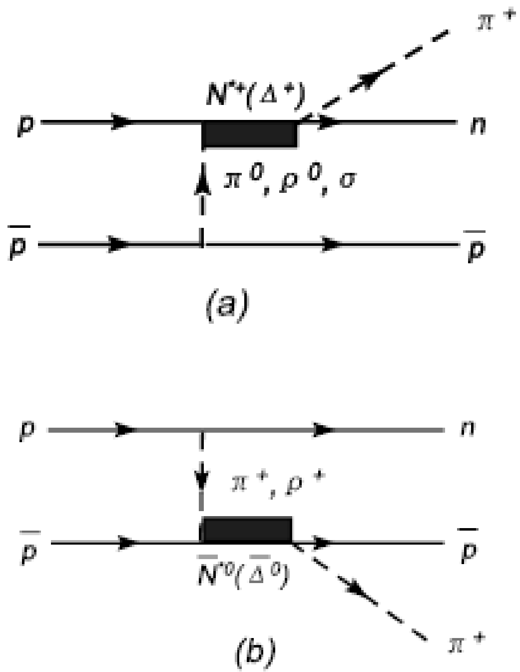
All final states of e^+e^- are accessible by $\bar{p}p$

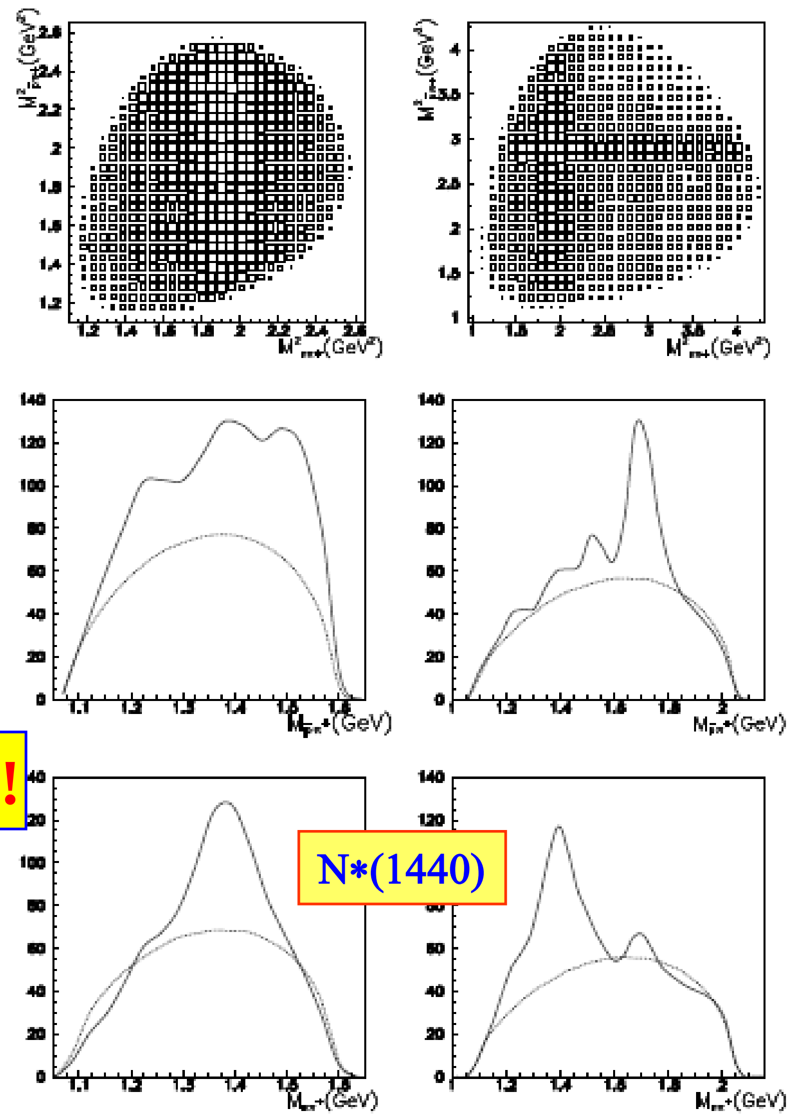
A large portion of $\bar{p}p$ final states contain baryons

& should not be wasted at PANDA/FAIR

$\bar{p}p \rightarrow \bar{p}n\pi^+$: the best place for studying N*(1440) and other N* - Nσ

J.J.Wu, Z.Ouyang, B.S.Zou, ArXiv: 0902.2295 [hep-ph]





t-channel σ-exchange dominates !

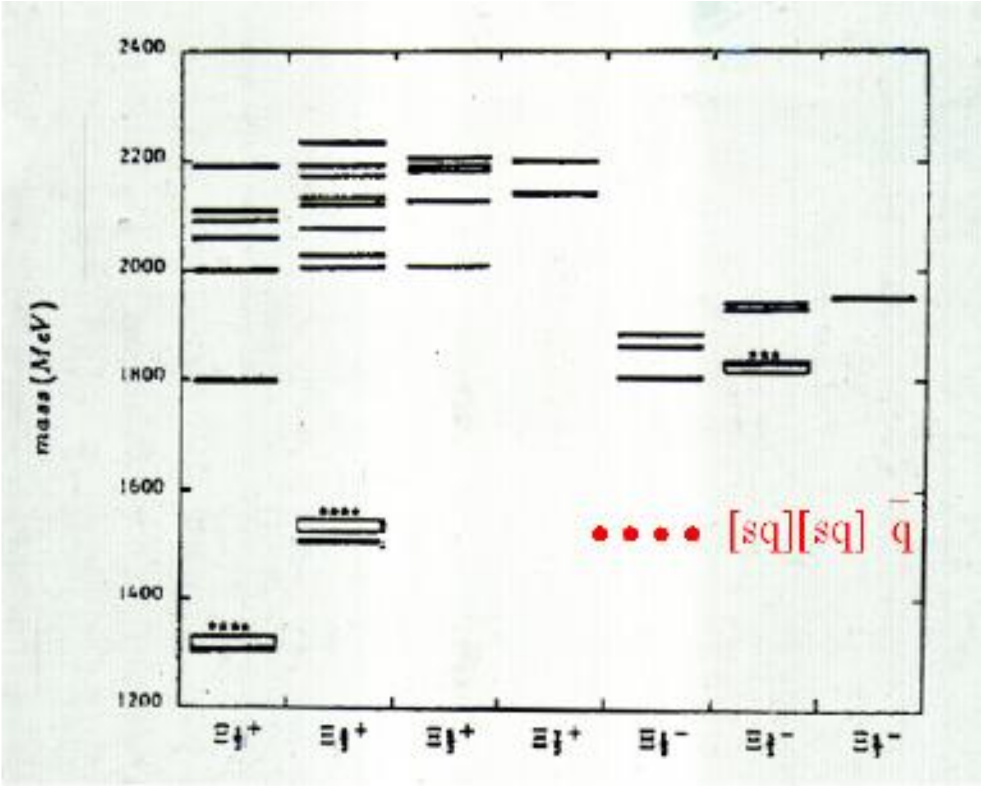
Δ-production suppressed !

π,ρ-exchange → $\bar{N}$* ~ 4N*

T_b ~ 1.55GeV T_b ~ 2.88GeV

5. Summary and Prospects

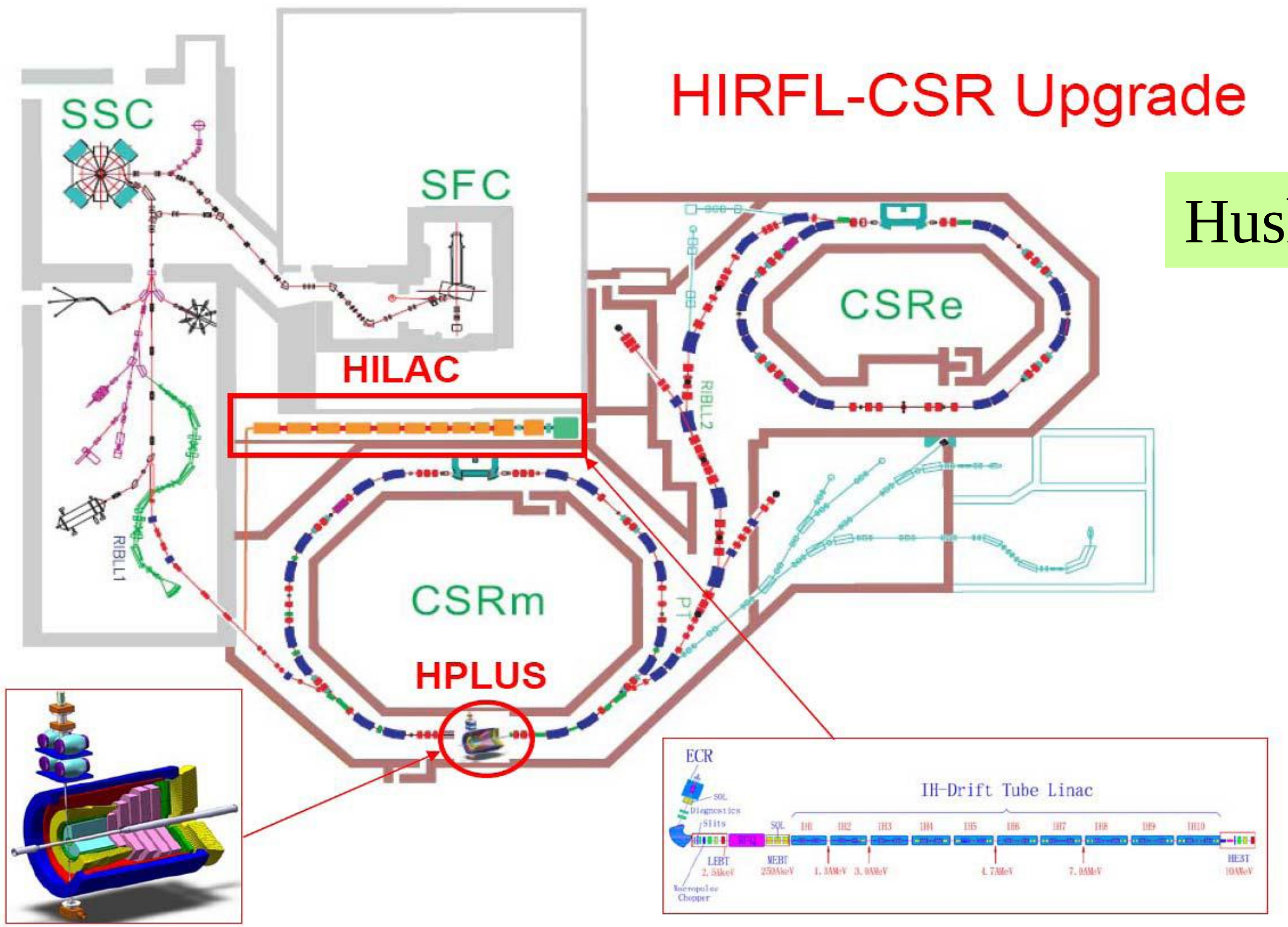
1) ψ decays : a nice filter for N*, Δ*, Λ*, Σ*, Ξ*



BES3 : $10^8 \sim 10^9$ **ψ(3686) & $10^9 \sim 10^{10}$ J/ψ(3097)**

Many new baryon resonances should be observed !

2) pp : nice place for $\rho^+ p \rightarrow \Delta^{*++}$ & $\sigma p \rightarrow N^*$



Hushan Xu

Important for HPLUS/CSR to continue the effort at COSY

3) $\bar{p}p$: best place for $\sigma p \rightarrow N^*$ & maybe Ω^*

PANDA should also play important role on baryon spectroscopy.

+ γp at CEBAF, ELSA, Spring-8 + Kp at JPARC + …

⇩

new era of baryon spectroscopy

Atomic Spectroscopy ⇒ Atomic Quantum Theory

Nuclear Spectroscopy ⇒ Shell Model & Collective motion Model

Baryon Spectroscopy ⇒ ? Important discoveries

Thanks !