Problems in Baryon Spectroscopy and Baryon Program at BES

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Outline

1. Why baryon spectroscopy ?
2. Problems in baryon spectroscopy
3. Baryon program at BES
4. Prospects

1. Why Baryon Spectroscopy from J/ψ Decays ?

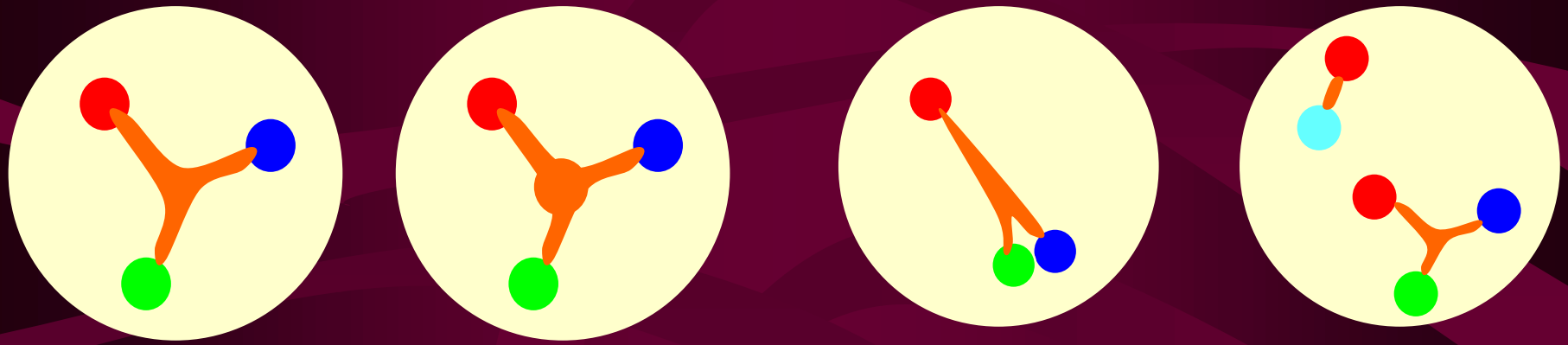
- Baryons = the basic blocks of our world
- Baryons = the simplest system in which three colors of QCD neutralize into colorless objects and the essential confinement character of QCD is manifest.
- Spectroscopy = powerful tool for exploring microscopic structure of matter

Atomic Spectroscopy	$\Rightarrow$	**Atomic Quantum Theory**
Nuclear Spectroscopy	$\Rightarrow$	**Shell Model & Collective motion Model**
Baryon Spectroscopy	$\Rightarrow$	?

- Very poor knowledge on baryon spectroscopy Why ?

2. Problems in baryon spectroscopy

A. Theoretical problem: What are effective degrees of freedom ?



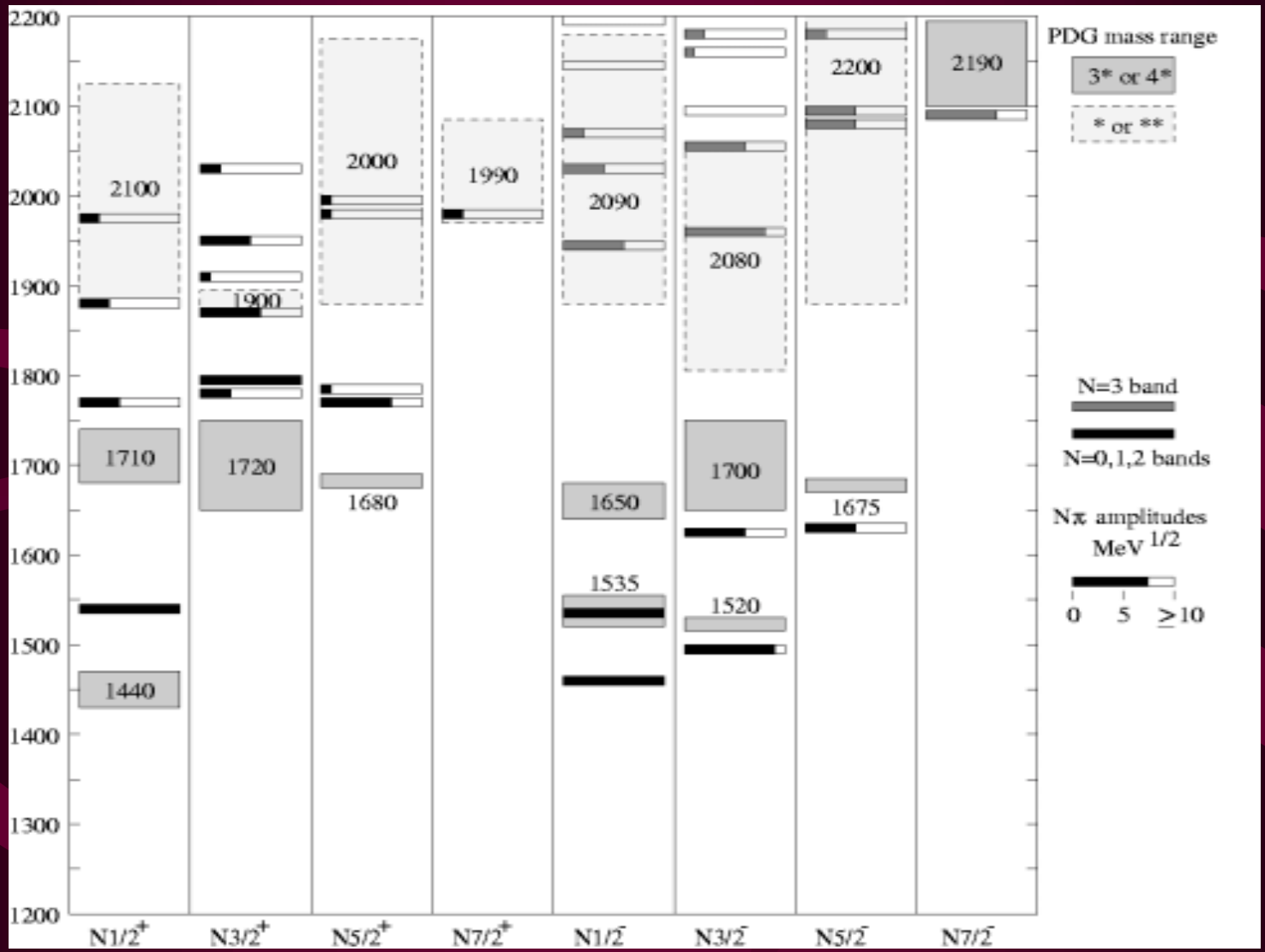
(a) 3q (b) hybrid (c) diquark (d) multi-quark

Predicted states: (d) > (b) > (a) > (c)

"missing" baryon problem: observed states < (a) predicted states

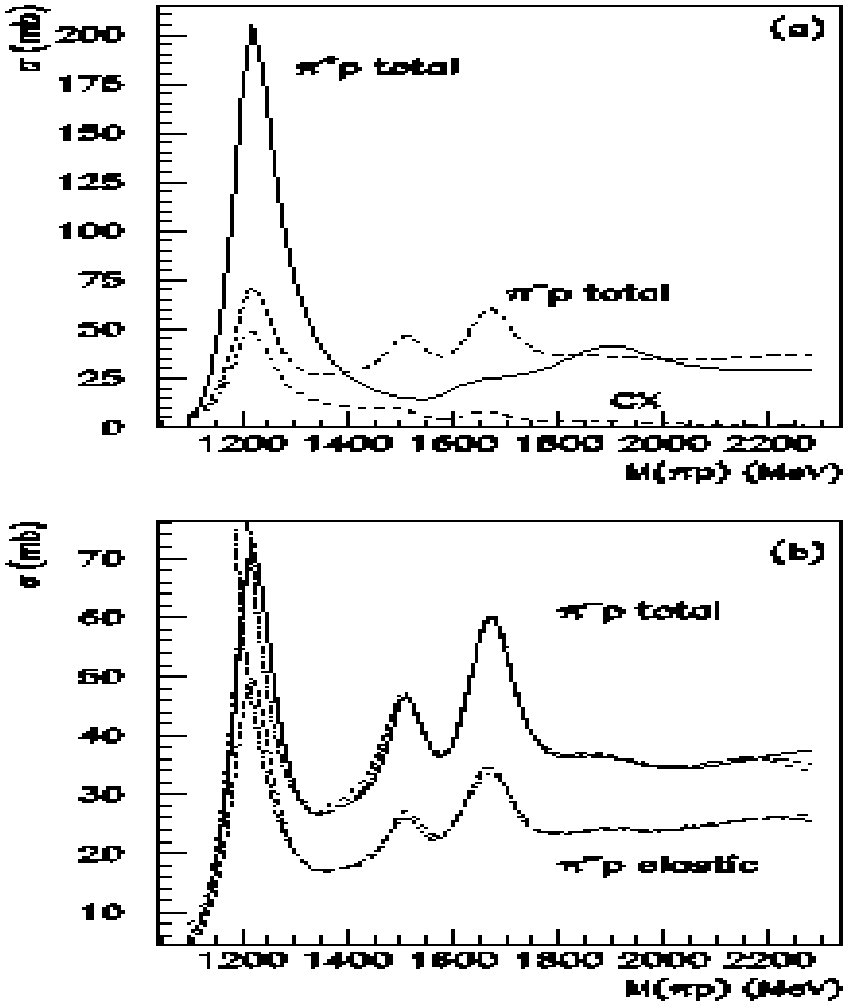
"Missing" N* Problem

Capstick et al.



B. Experimental Problems :

- Mixture of different isospin states
- Overlap of broad resonances of various spins



$\Rightarrow (7-10)\Delta^*$

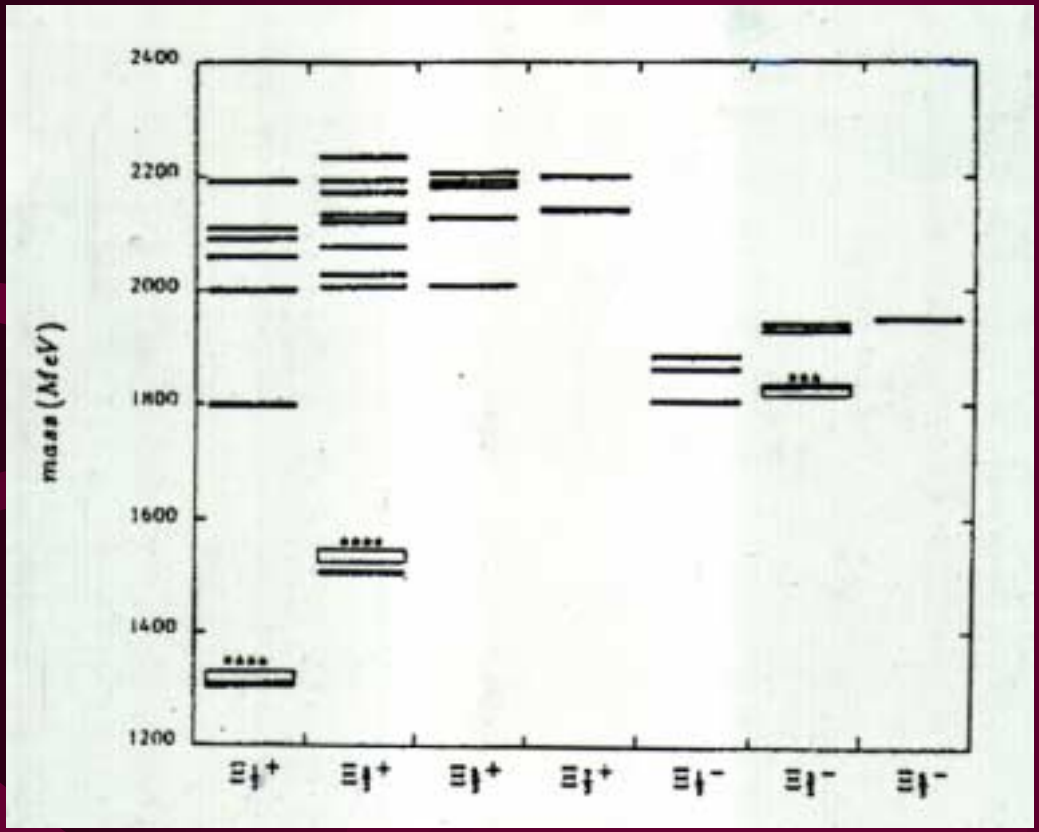
$\Rightarrow (10-13)N^*$

$$K^- p \to \Lambda^*, \Sigma^* \to K^- p$$

$$(7-12)\,\Lambda^* \quad \& \quad (4-8)\,\Sigma^*$$

Problem: Lack of kaon beam

(ssq) - Baryon Spectroscopy Ξ^*



Capstick&Isgur
PRD34(1986)2809

Theory is not challenged due to lack of data !

New Facilities for N*:

- CEBAF@JLAB, USA
- ELSA@Bonn, Germany
- GRAAL@Grenoble, France
- Spring8@JASRI, Japan

Key issues:

- N*(1440) first radial excitation

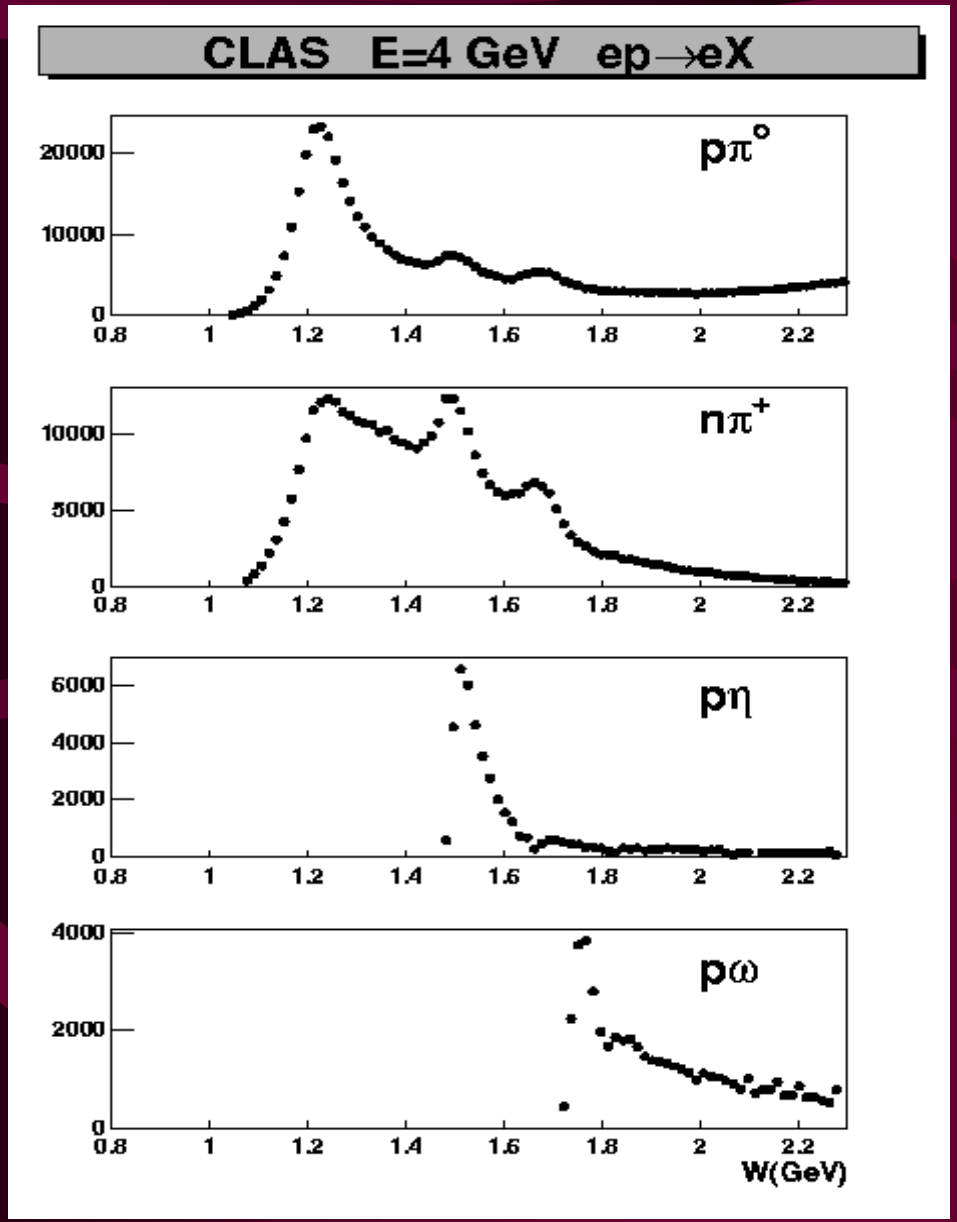
M = 1345-1470, Γ = 160-450 MeV

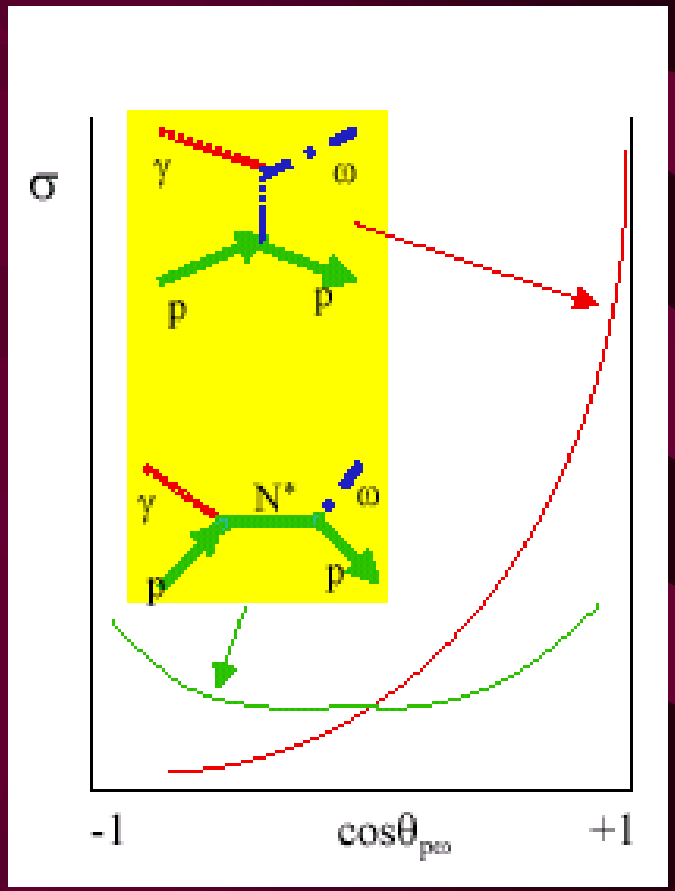
- N*(1535) first L=1 excitation

M = 1495-1555, Γ = 90-250 MeV

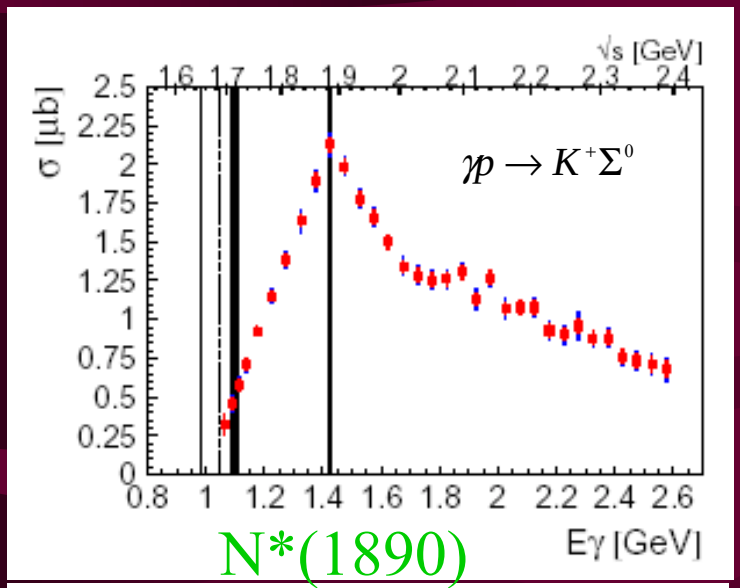
- Missing N* resonances

Hybrid (qqqg), 3-quark, diquark-q

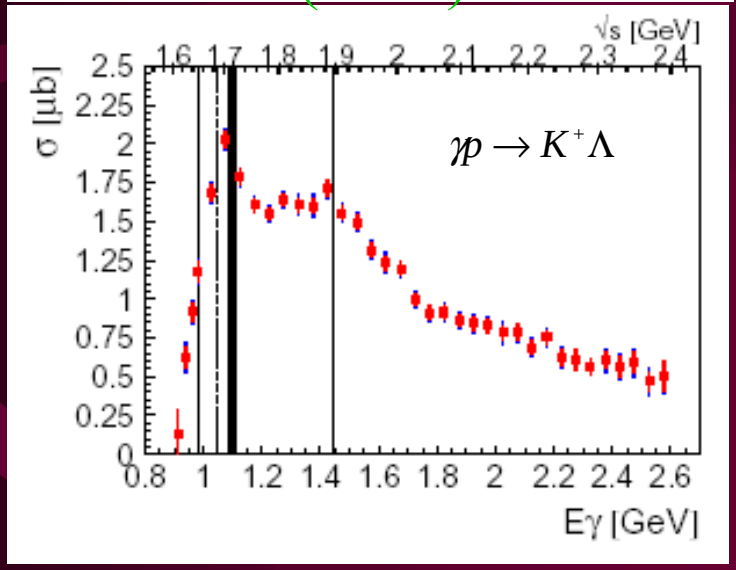

CLAS E=4 GeV ep→eX
pπ°
nπ+
pη
pω
W(GeV)


σ
γ
ω
p
p
N*
-1
cosθpω
+1

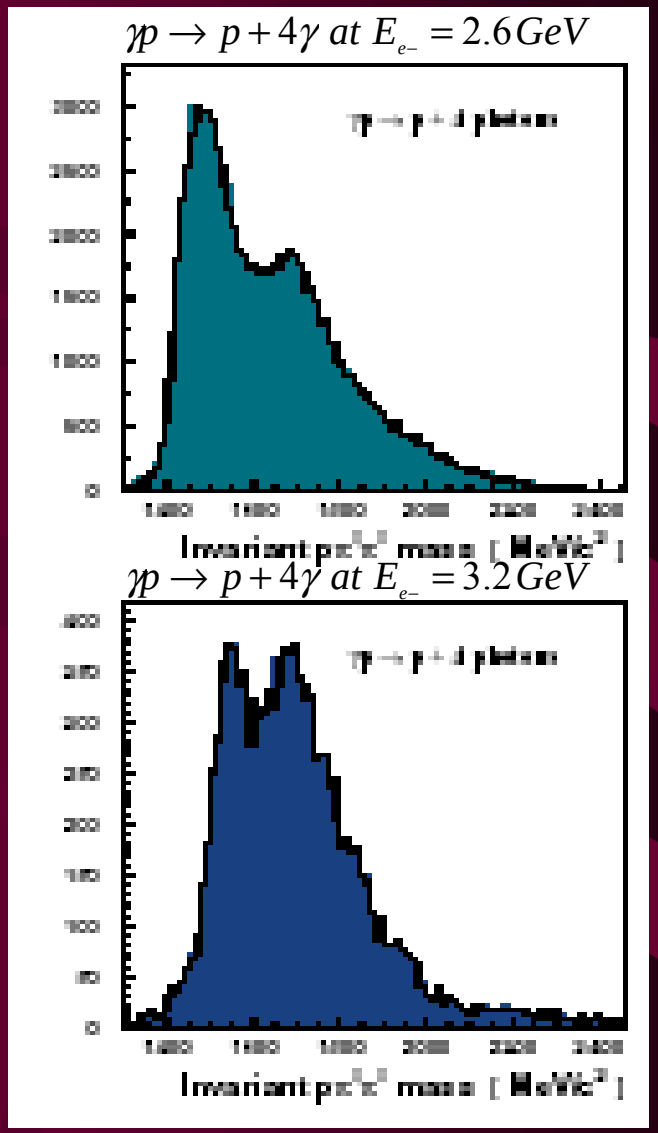
SAPHIR@ELSA (Germany) CBAR@ELSA



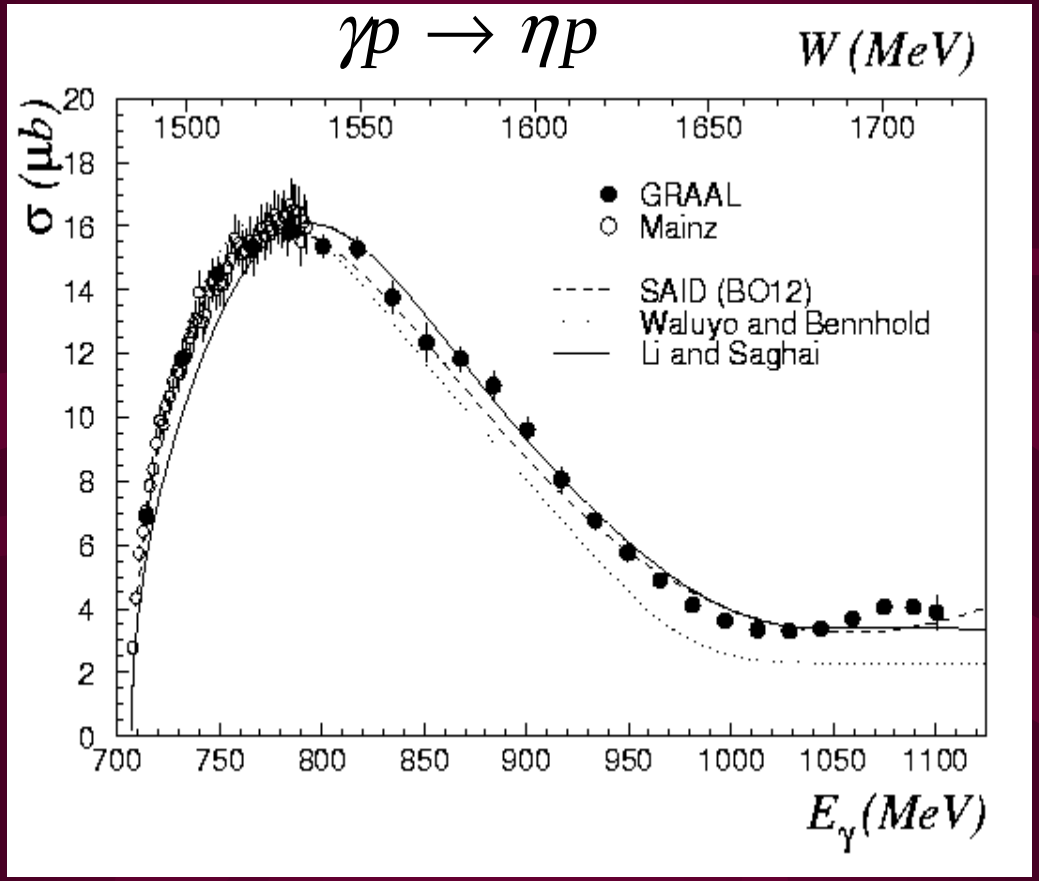
N*(1890)



Phys. Lett. B445 (1998) 20



GRAAL@ESRF in France



Phys. Lett. B528 (2002)

LEPS@Spring-8 in Japan Nakano

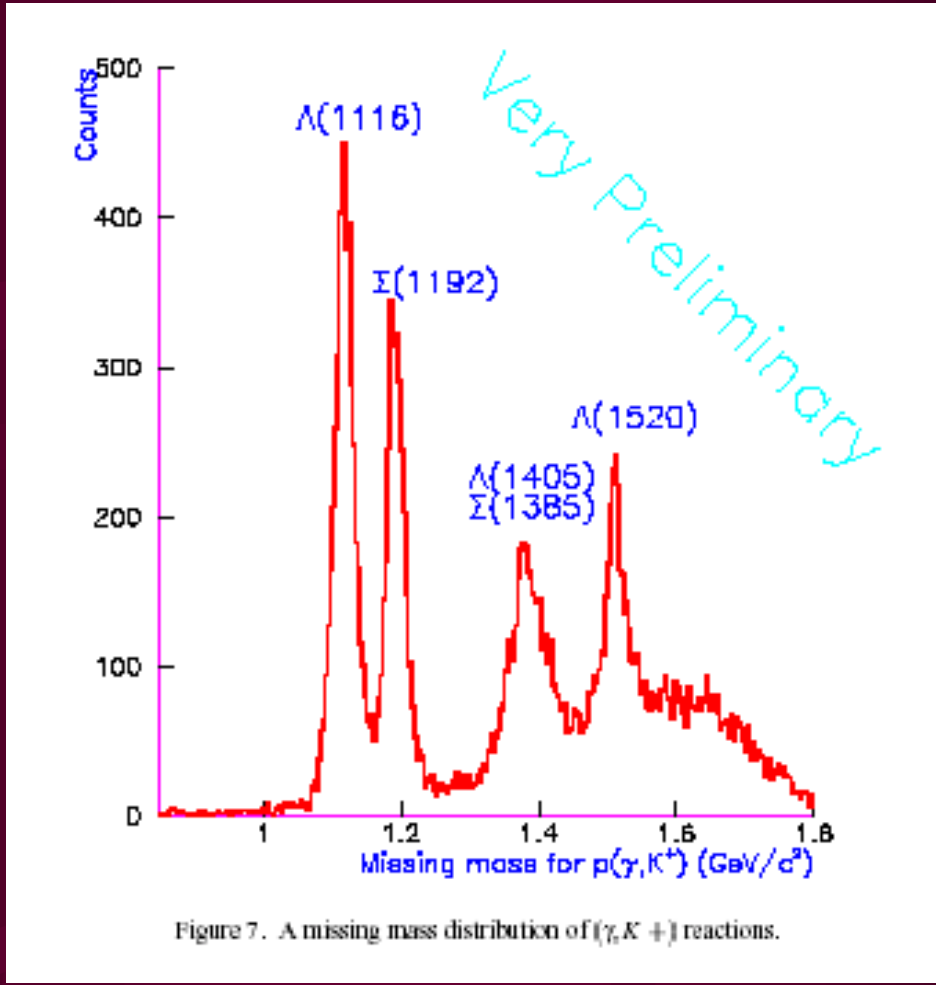
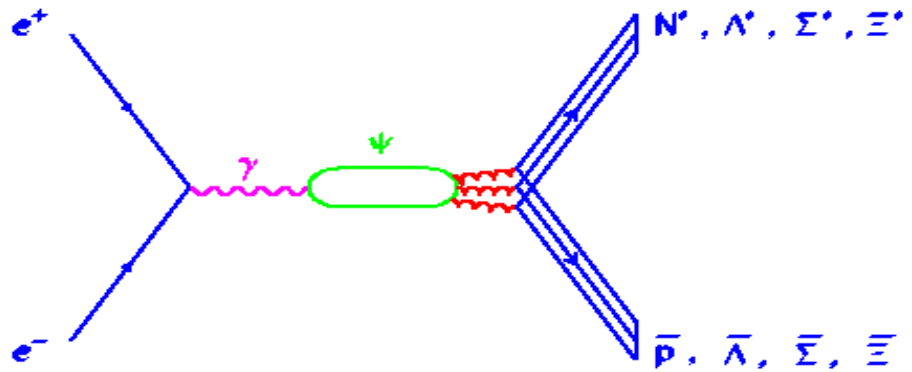


Figure 7. A missing mass distribution of $[\gamma, K^+]$ reactions.

3. Baryon program at BES@BEPC:

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



J/Ψ decay branching ratios (BR$\times 10^3$) for some interested channels

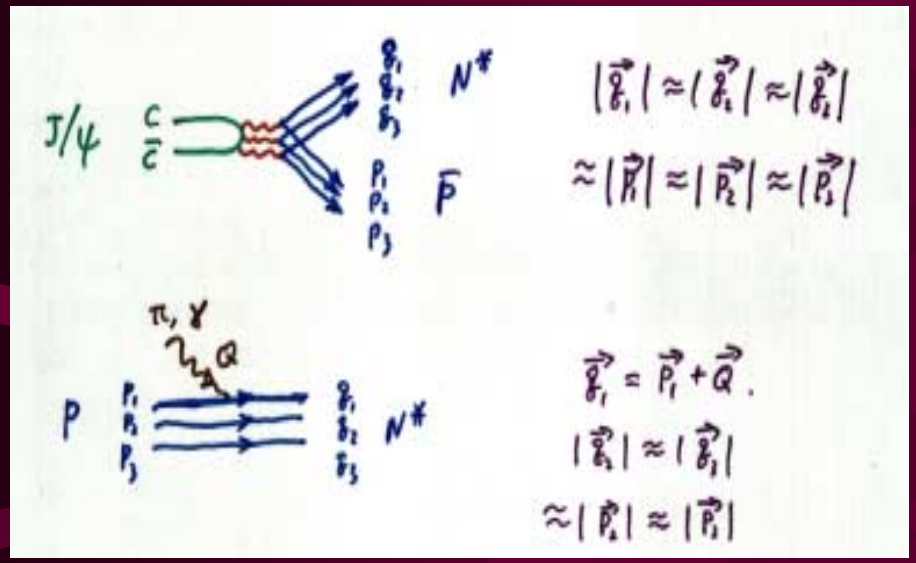
$p\bar{p}$	$\Lambda\bar{\Lambda}$	$\Sigma^0\bar{\Sigma}^0$	$\Xi\bar{\Xi}$	$\Lambda\bar{\Sigma}^-\pi^+$	$pK^-\bar{\Lambda}$	$pK^-\bar{\Sigma}^0$
2.1 ± 0.1	1.4 ± 0.1	1.3 ± 0.2	1.8 ± 0.4	1.1 ± 0.1	0.9 ± 0.2	0.3 ± 0.1
$p\bar{n}\pi^-$	$p\bar{p}\pi^0$	$p\bar{p}\pi^+\pi^-$	$p\bar{p}\eta$	$p\bar{p}\eta'$	$p\bar{p}\omega$	$K^-\Lambda\bar{\Xi}^+$?
2.0 ± 0.1	1.1 ± 0.1	6.0 ± 0.5	2.1 ± 0.2	0.9 ± 0.4	1.3 ± 0.3	$K^+\bar{\Lambda}\Xi^-$?

Experimental advantages:

- Pure isospin 1/2 πN and $\pi\pi N$: $\Psi \to \bar{n}p\pi^-, \bar{p}p\pi^0, \bar{p}n\pi^+, \bar{p}p\pi^+\pi^-$
- Missing N* with small couplings to πN & γN , but large coupling to gggN : $\Psi \to \bar{p}p\eta,\ \bar{p}p\omega,\ \bar{p}p\eta',\ \bar{p}p\phi,\ \bar{p}\Lambda K,\ \bar{p}\Sigma K, \ldots$
- Not only N*, but also $\Lambda^*, \Sigma^*, \Xi^*$: $\Psi \to \Xi\Lambda K, \Xi\Sigma K, \ldots$
- Less allowed spins due to threshold effect, hence less overlap effects.

Theoretical advantages:

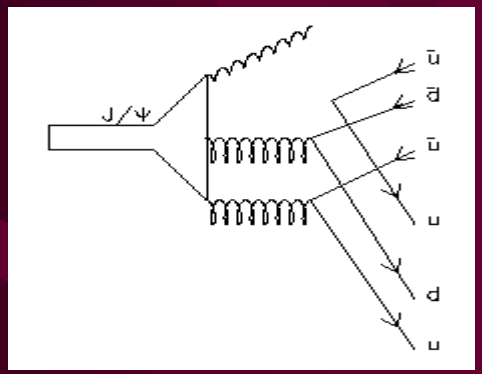
- **A new way to probe the quark structure of N***

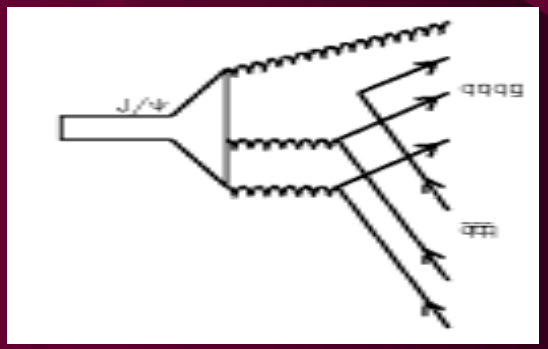


Probe different aspects of the quark distributions inside N*.

B.S.Zou et al, EPJA11 (2001) 341

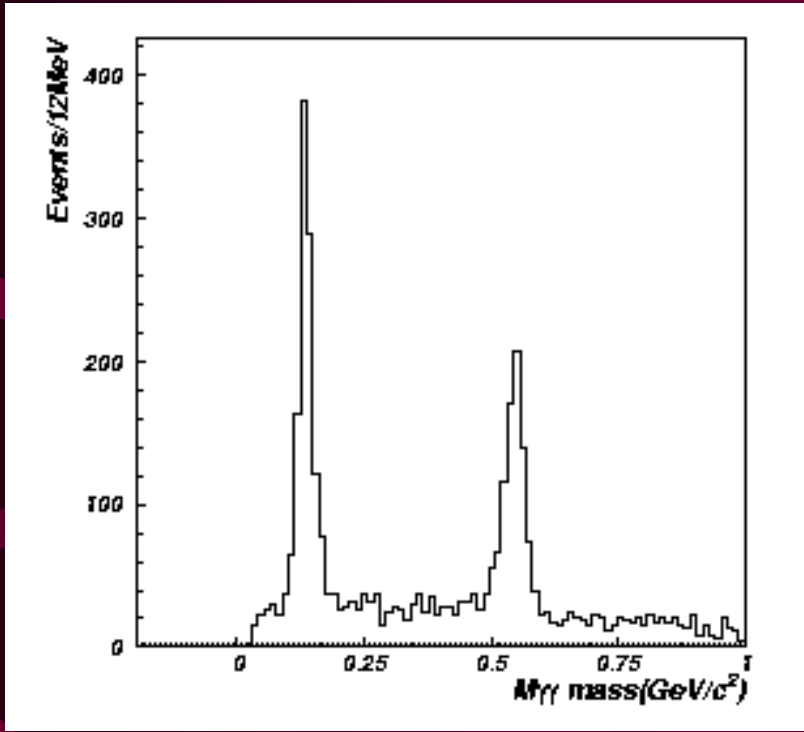
- **Study hybrid baryon**



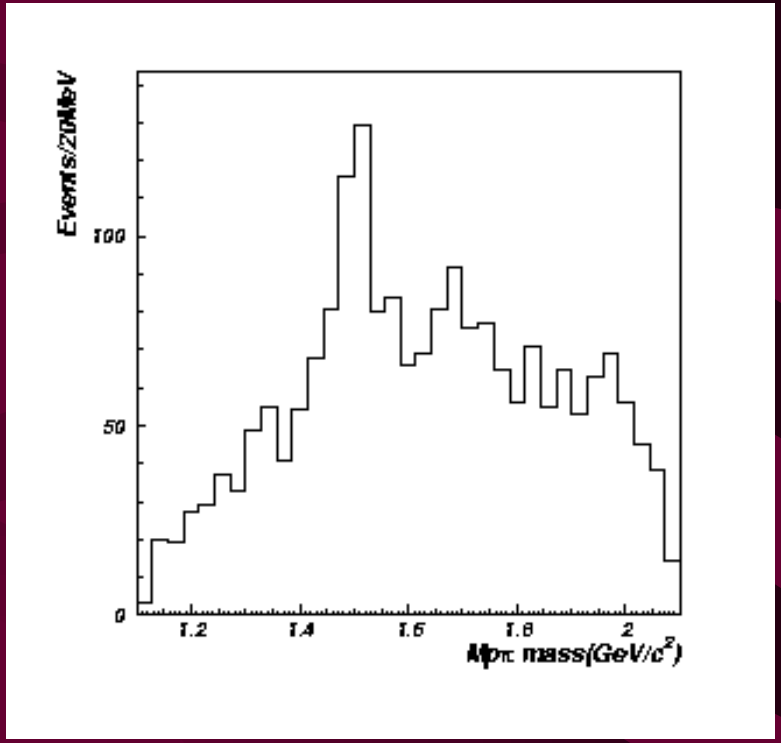


Some results from BES

$M_{\gamma\gamma}$ in $J/\Psi \to \bar{p}p\gamma\gamma$



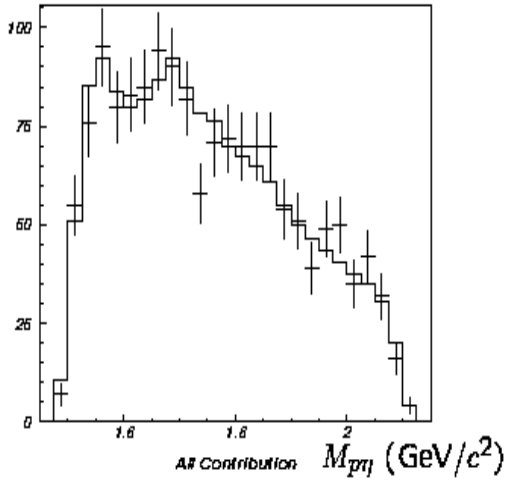
$M_{N\pi}$ in $J/\Psi \to \bar{p}p\pi^0$

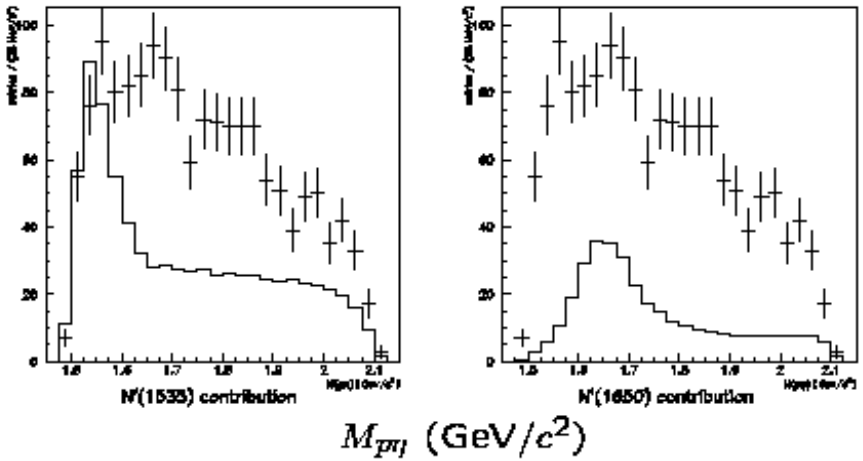


BESI 7.8M J/ψ

H.B.Li, BES, H.C.Chiang, G.X.Peng, B.S.Zou, Nucl. Phys. A675 (2000) 189c

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





$N^*(1535)$ parameters	BES	PDG2000
Mass (MeV)	1530 ± 10	$1520 - 1555$
Γ (MeV)	95 ± 25	$100 - 250$
$N^*(1650)$ parameters	BES	PDG2000
Mass (MeV)	1647 ± 20	$1640 - 1680$
Γ (MeV)	145^{+80}_{-45}	$145 - 190$

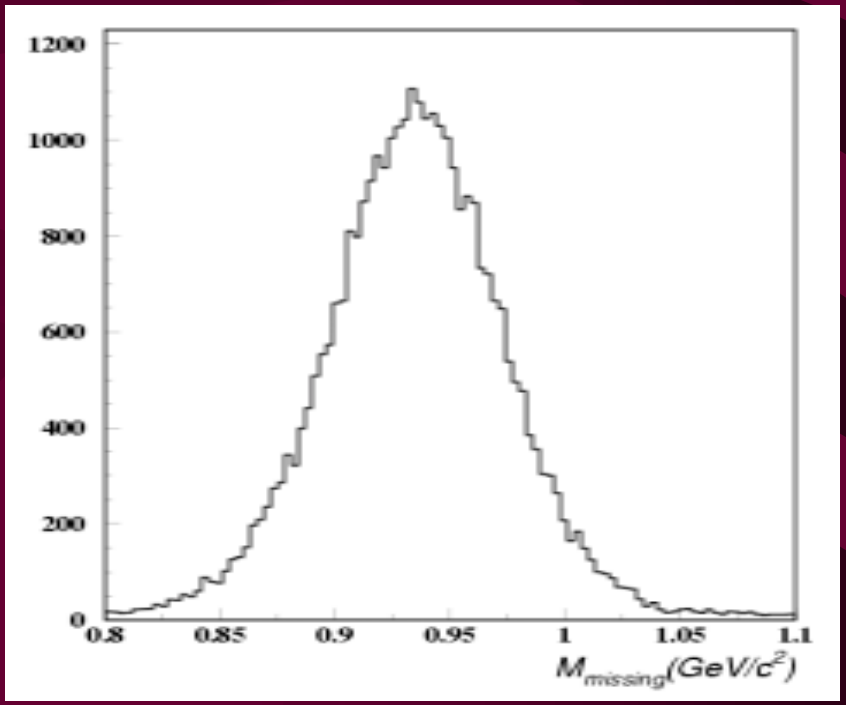
BES Collaboration, Phys. Lett. B510 (2001) 75

$J/\psi \to p\bar{n}\pi^-$ from BESII data

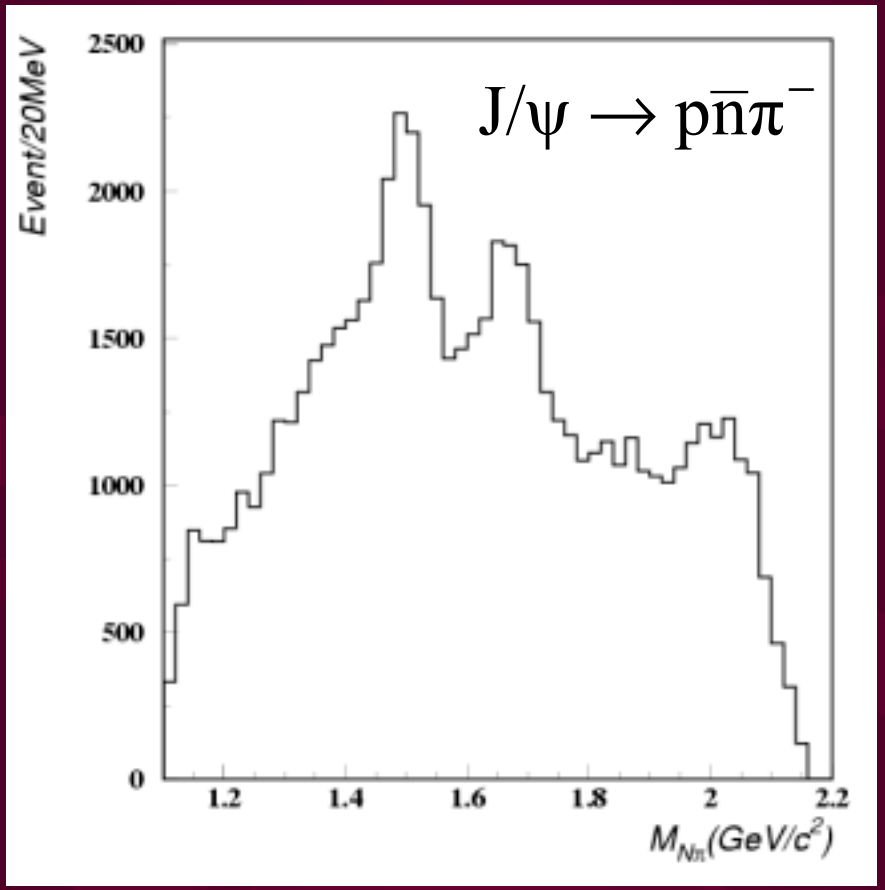
- Events selection

- 2 good charged tracks
- Q1+Q2 = 0
- $|\cos\theta| < 0.85$
- PID: TOF and dE/dx
- *Prob*(χ^2, 1C) > 0.055
- 0.78 GeV < $M_{missing}$ < 1.13 GeV
- $M_{p\pi} > 1.13$ GeV

BESII 27M (preliminary)



BESII 27M (preliminary)



Why N*(2020) peak? L=0 limits it to be 3/2+ or 1/2+

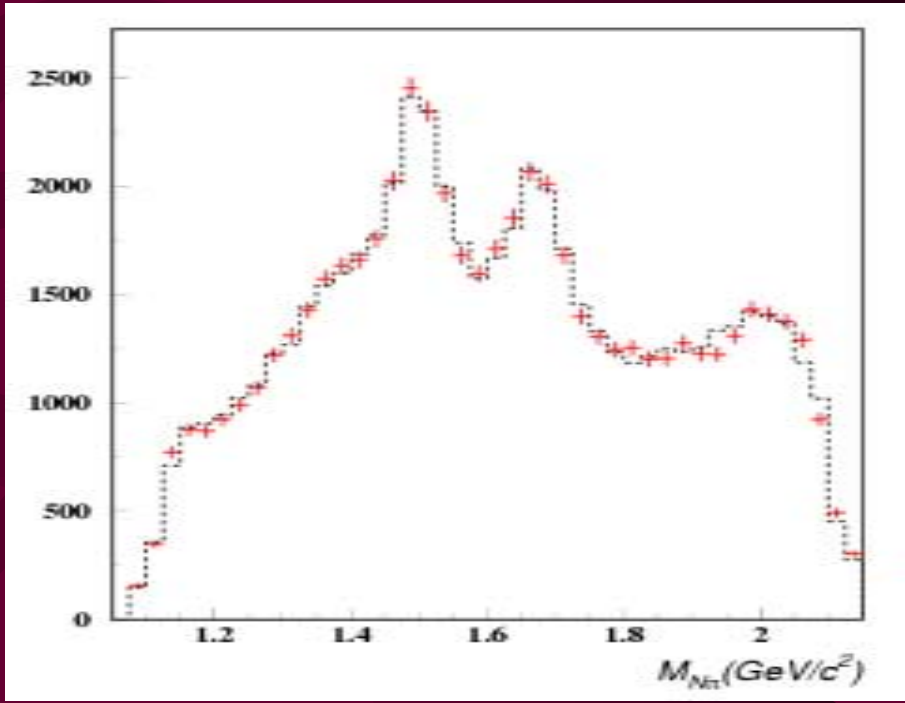
A new “missing” N* ?

- partial wave analysis is performed
- partial waves used in the fit:

N*(1440) (1/2+)
N*(1520) (3/2-)
N*(1535) (1/2-)
N*(1650) (1/2-)
N*(1675) (5/2-)
N*(1680) (5/2+)
N*(2020) (3/2+)
……

Where, N*(1440), N*(1520), N*(1535) and N*(1680) are most significant.

BESII 27M (preliminary)

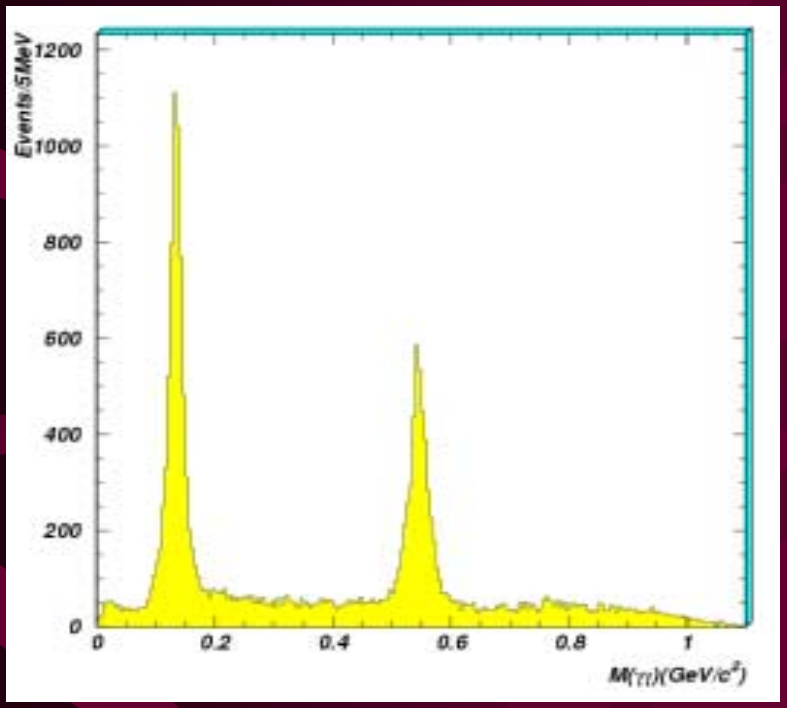


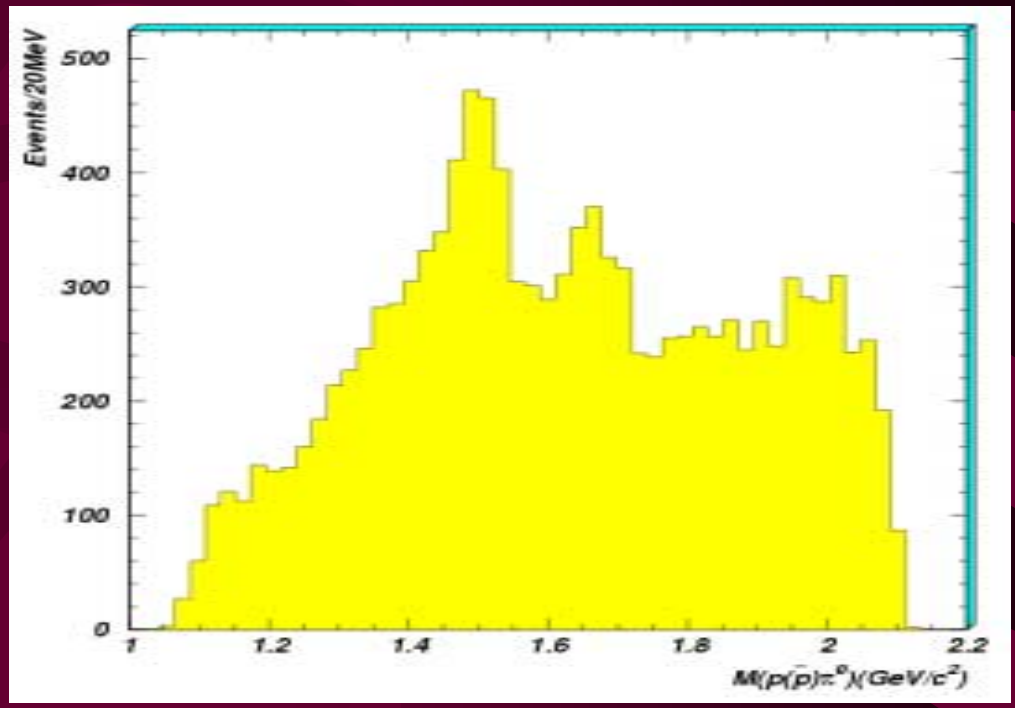
N*(2020) (3/2+) : $M = 2020 \pm 10\ MeV, \quad \Gamma = 220 \pm 10\ MeV$

Errors are under further investigation

$J/\psi \to p\bar{p}\pi^0$ from BESII data

BESII 58M (preliminary)





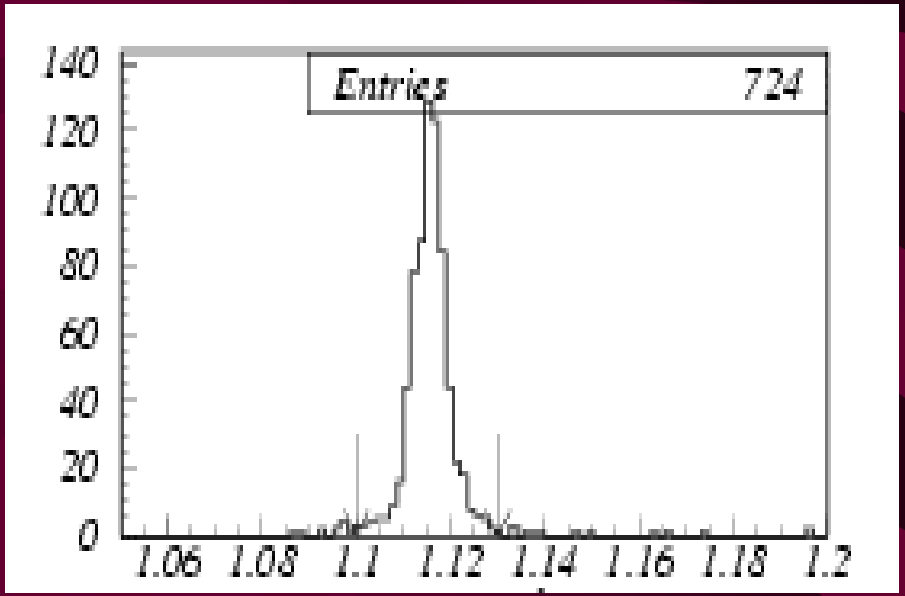
PWA will be performed

$J/\psi \to p\bar{p}K\pi$ from BESII data

Events selection

- 4 good charged tracks
- At least one $p(\bar{p})$
- $\chi^2<20$
- 0.35 GeV$<M_K<$0.65 GeV

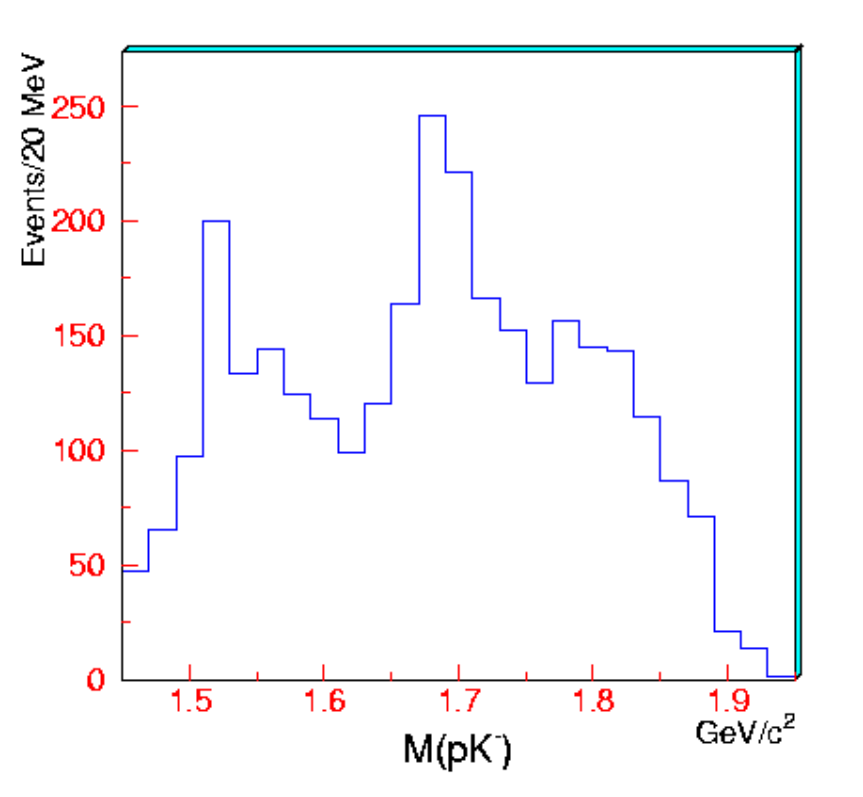
BESII 58M (preliminary)



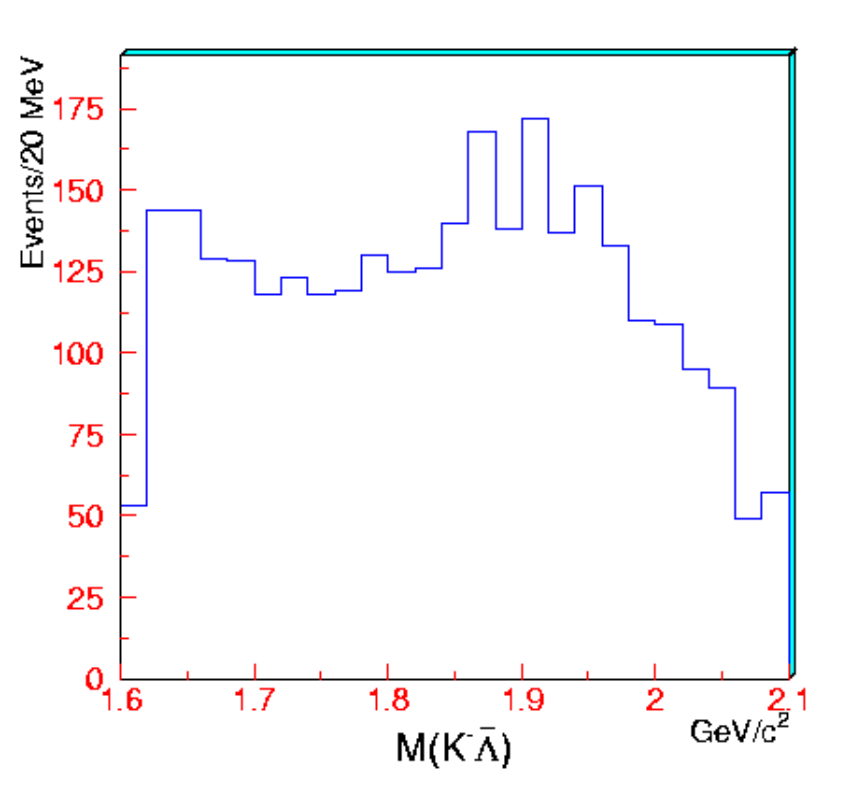
$M_{\bar{p}\pi}$ (GeV/c^2)

J/ψ → pKΛ from BESII preliminary

Λ*



N*



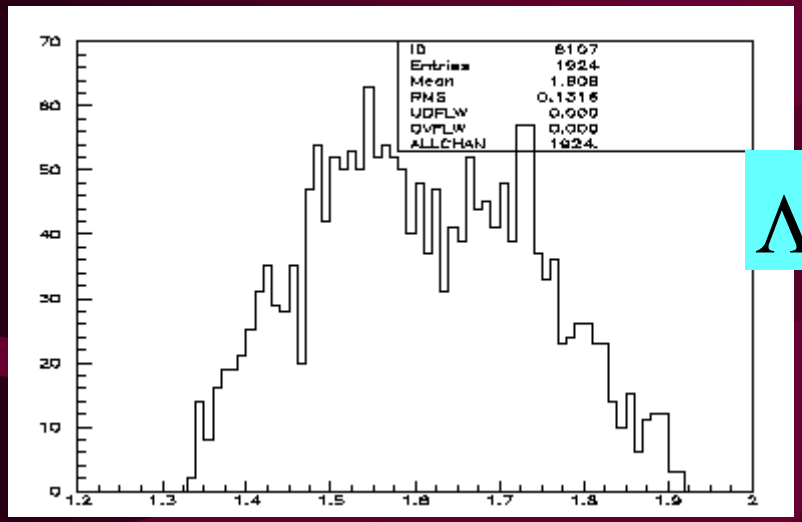
Λ(1520), Λ(1690) and Λ(1810)

N*(1900) ?

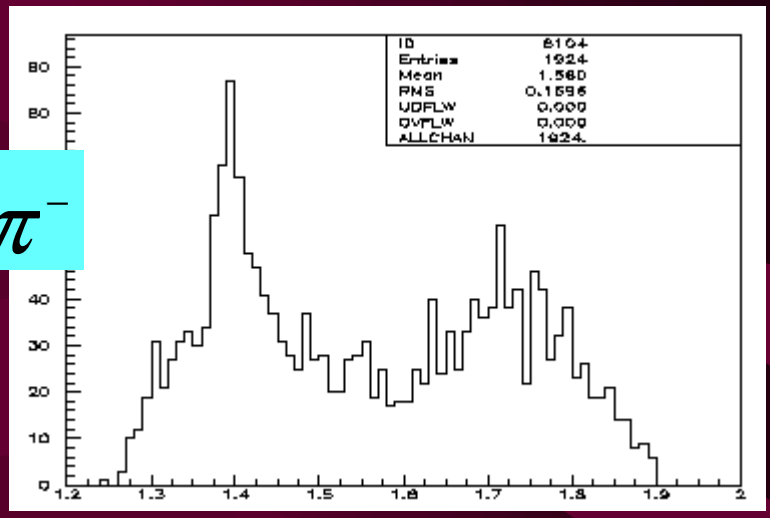
$J/\psi \rightarrow \Sigma\Lambda\pi$ for Λ^* and Σ^* (BESII very preliminary)

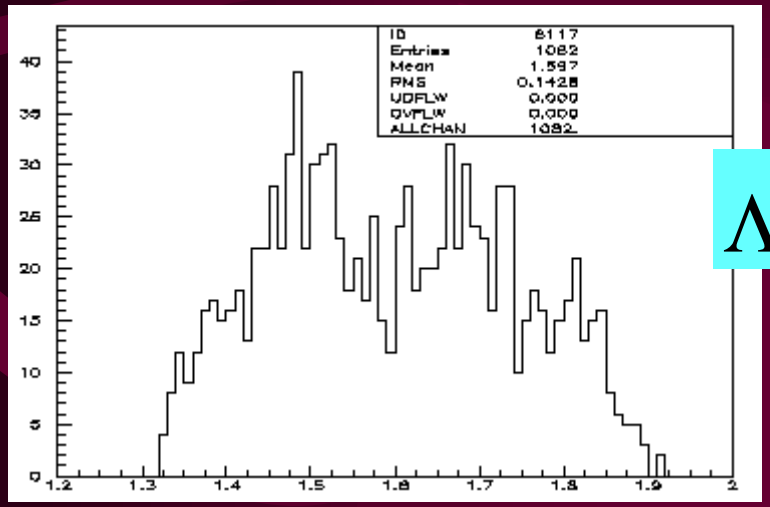
Λ^*

Σ^*

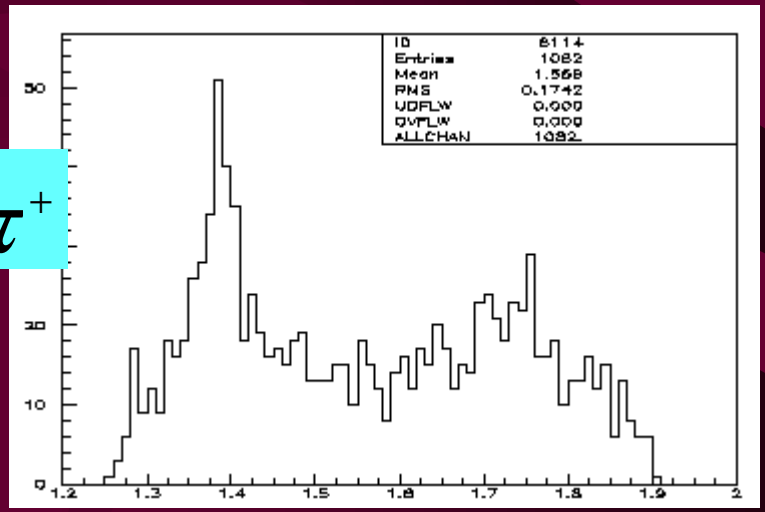


$\Lambda\bar{\Sigma}^{+}\pi^{-}$





$\Lambda\bar{\Sigma}^{-}\pi^{+}$



$M_{\pi\Sigma}$

$M_{\pi\Lambda}$

4. Prospects

BESII 58M J/ψ Many interesting baryonic channels with a lot of PWA hard works to do

BESIII@BEPC2 (2007) 10^{10} J/ψ & 10^{9} ψ'

CEBAF, ELSA, GRAAL, Spring-8,CLEO-c,JHF(kaon beam)

competition & complementary

Complete N*,Λ*,Σ*,Ξ* baryon spectroscopy

Internal quark gluon structure of baryons !