Excited Nucleons at BESIII

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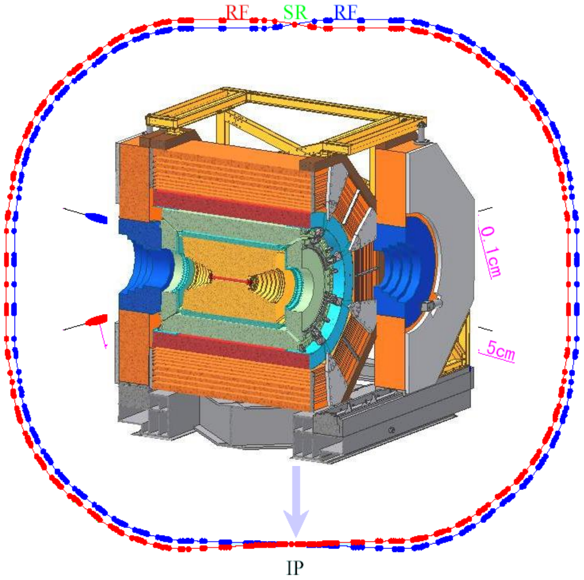
Outline

- Introduction to BESIII/BEPCII
- Advantages of N* studies at e^+e^- colliders
- Partial wave analysis of $\Psi' \rightarrow \eta p\bar{p}$
- Partial wave analysis of $\Psi' \rightarrow \pi^0 p\bar{p}$
- Summary

The BEPCII/BESIII Project



BEPCII: e+e- collider (τ-charm region)

- $\sqrt{s}$: **2.0-4.6 GeV**
- **First collisions: March 2008**
- **Luminosity: ~6.5×10^{32} cm^{-2}s^{-1}@3770**

  (~11×CESRc and ~62×BEPC)

BESIII:

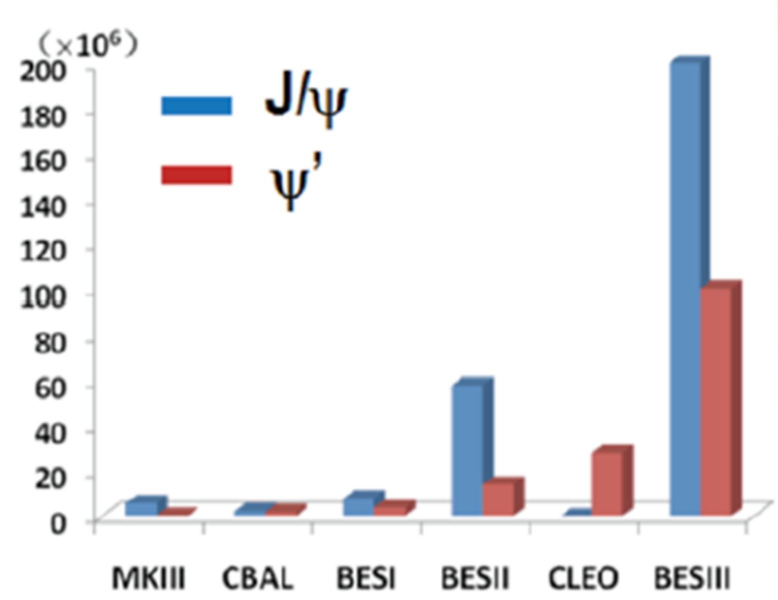
- **Momentum resolution:**

  σ_p/p = 0.58% at 1GeV/c

- **Photons: σ_E/E = 2.5% at 1GeV**
- **TOF: 80ps(barrel), 100ps(endcap)**
- **MUC: 9 layers RPC for barrel, 8 for endcap**

Introduction to the BESIII experiment

BESIII Data



So far BESIII has collected:
~225 Million J/ψ
~106 Million ψ(2S)
~2.8fb^{-1} at the ψ(3770)

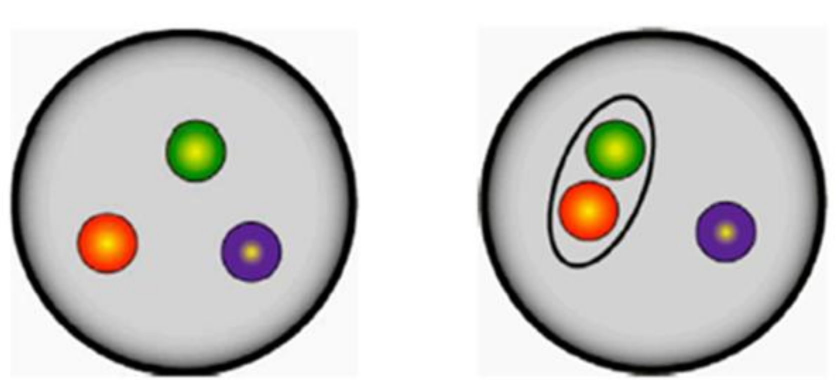
Physics at BESIII

- R_{had} and precision tests of Standard Model
- Light hadron spectroscopy
- Charm and charmonium physics
- τ physics
- Improve the measurement precision

  of CKM matrix elements
- Search for new physics / new particles

“Missing” baryon problem

Quark models predict many more baryon resonances than have been observed

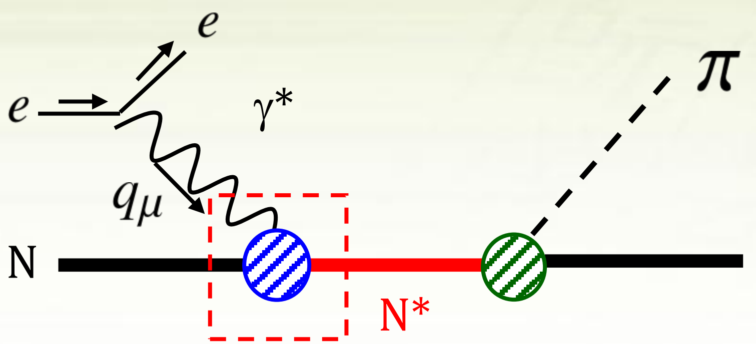


Possible explanations:

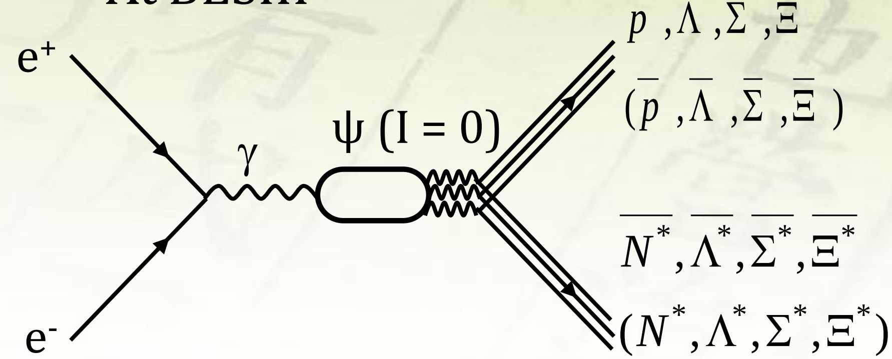
1) Theoretically: Reduce the number of degree of freedom. (Quark-diquark)
2) Experimentally: If the missing N*s have small couplings to πN & γN, they would not have been discovered by experiments using photons or pions.

Comparison of BESIII with πN, γN at N* Study

N* knowledge primarily from πN, γN.



At BESIII

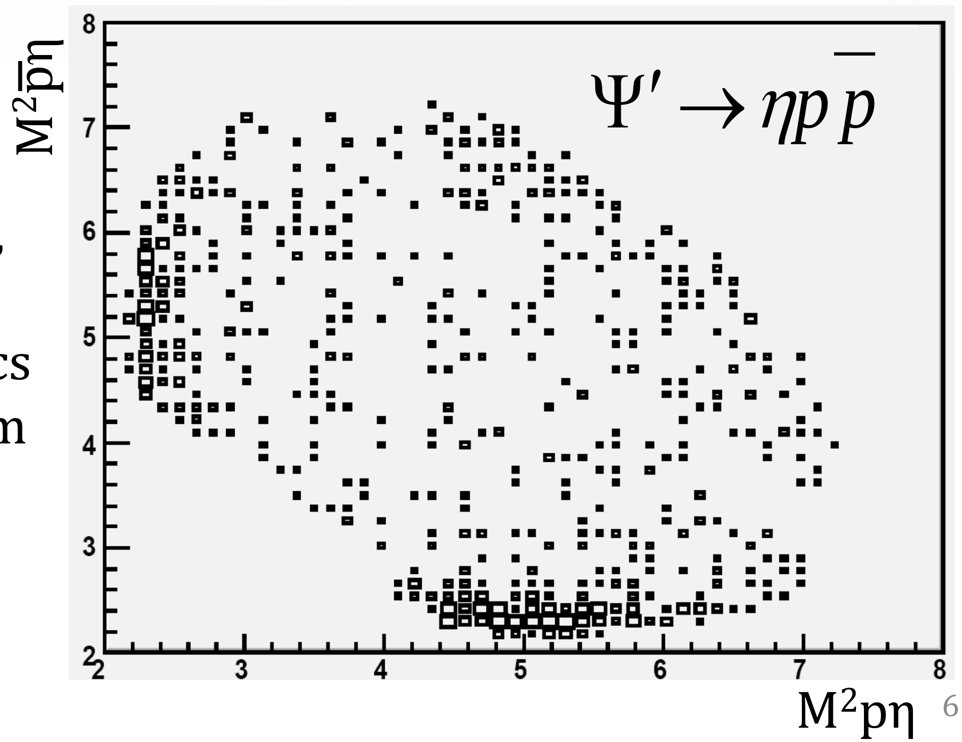


1: Pure Isospin 1/2

2: Study by many decay channels, such as π^0N, ηN, η'N, ωN…

3: N* and $\overline{\text{N}}$*, twice of the statistics

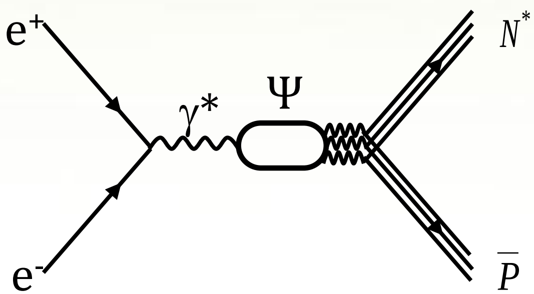
4: Large statistics for charmonium states

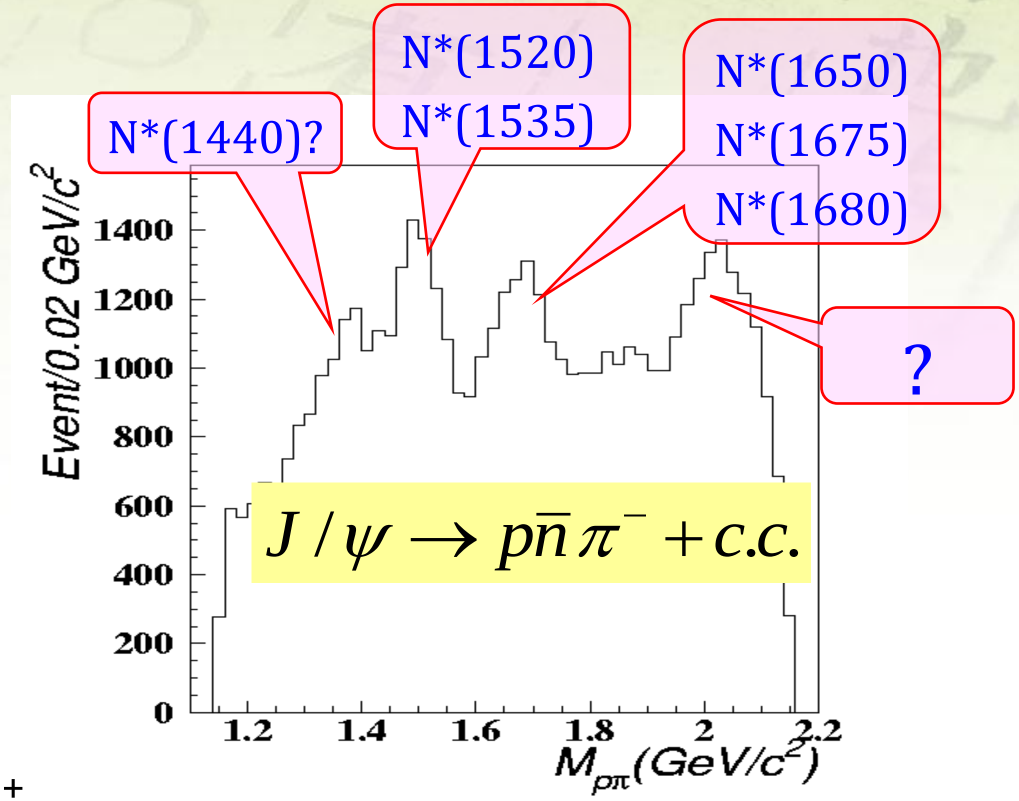


Previous result of BESII on N* Physics

Observation of N(2050)

Pure Isospin 1/2





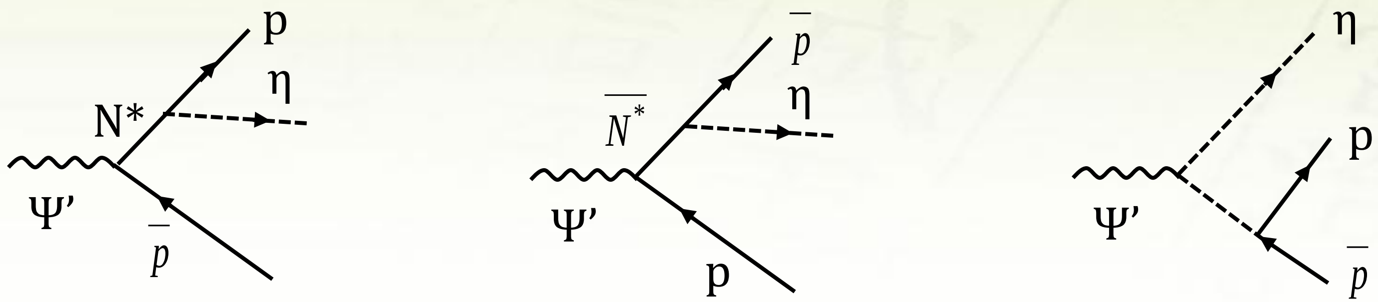
J^P of N(2050): $1/2^+$ or $3/2^+$

$$M = 2065 \pm 3^{+15}_{-30} \text{MeV}/c^2 \quad \Gamma = 175 \pm 12 \pm 40 \text{MeV}/c^2$$

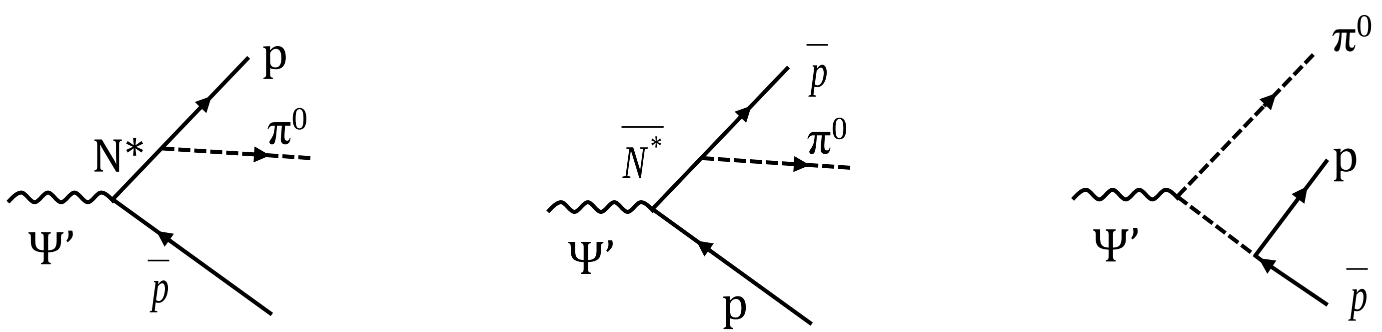
PRL 97, 062001 (2006)

Analysis related to N* Physics at BESIII

- Partial wave analysis of Ψ’→ $\eta p\bar{p}$



- Partial wave analysis of Ψ’→ $\pi^0 p\bar{p}$



Introduction to PWA

- Construct amplitude A_i for each possible partial wave

$$A_i = A_{prod} A(Breit-Wigner) A_{decay}$$

- Construct differential cross section

$$\frac{d\sigma}{d\Omega} = \left| \sum_i A_i + A_{background} \right|^2$$

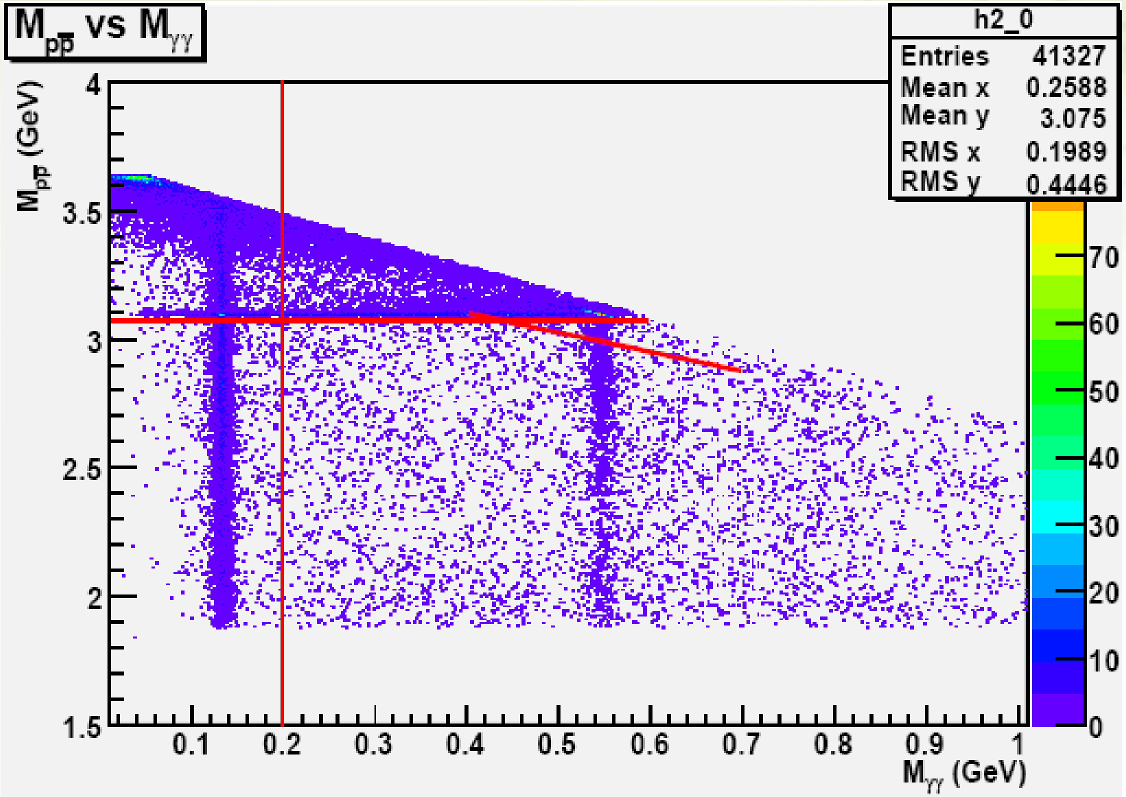
- Construct log likelihood function

$$\ln L = \sum_{i=1}^{N} \ln\left(\frac{d\sigma}{d\Omega} / \sigma\right)$$

- Maximize log likelihood function

Analysis of Ψ'→ η$p\bar{p}$

Preliminary

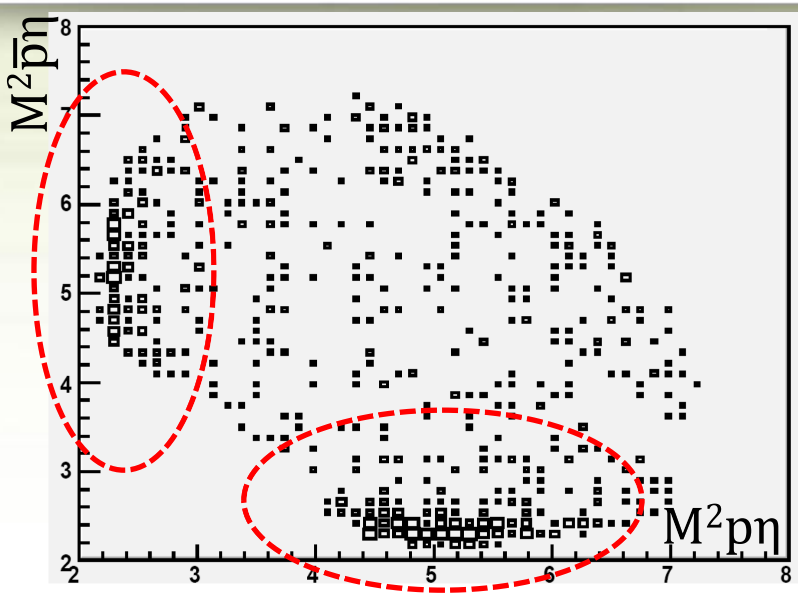


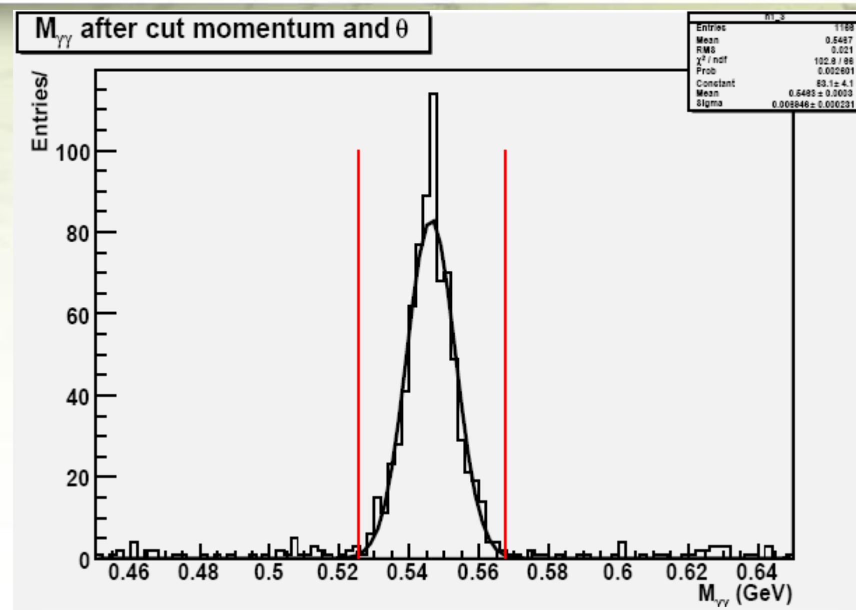
In this analysis, only η→γγ are used.

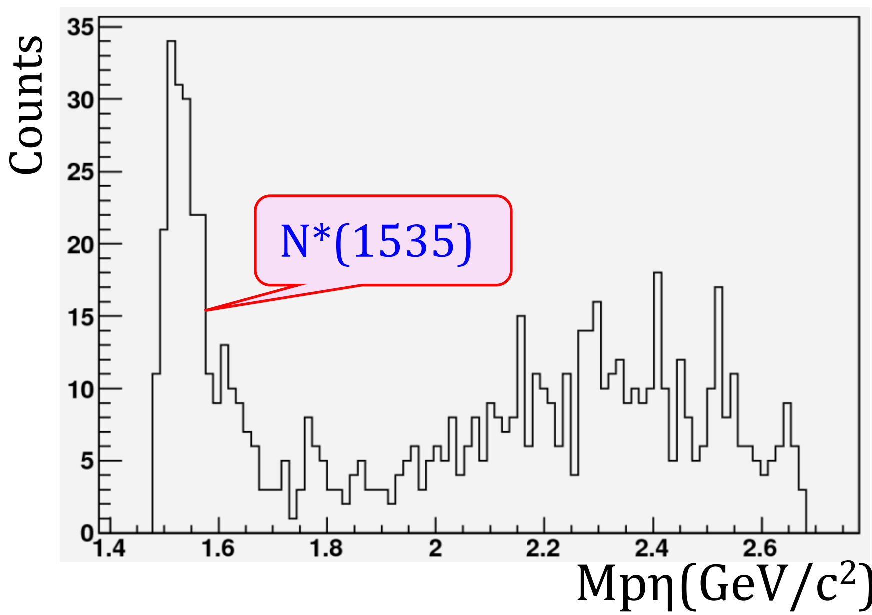
B(η→γγ) = 39.31%

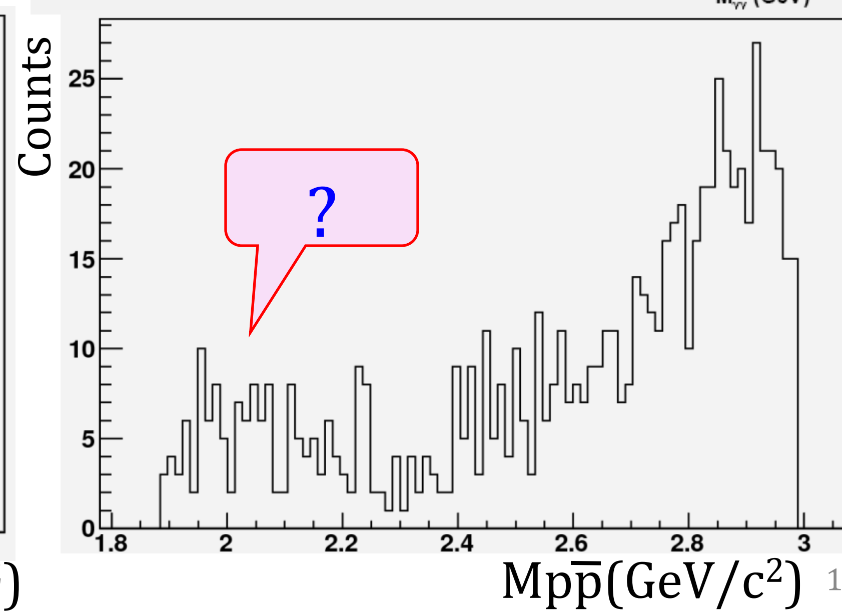
Analysis of $\Psi' \rightarrow \eta p\bar{p}$

Preliminary









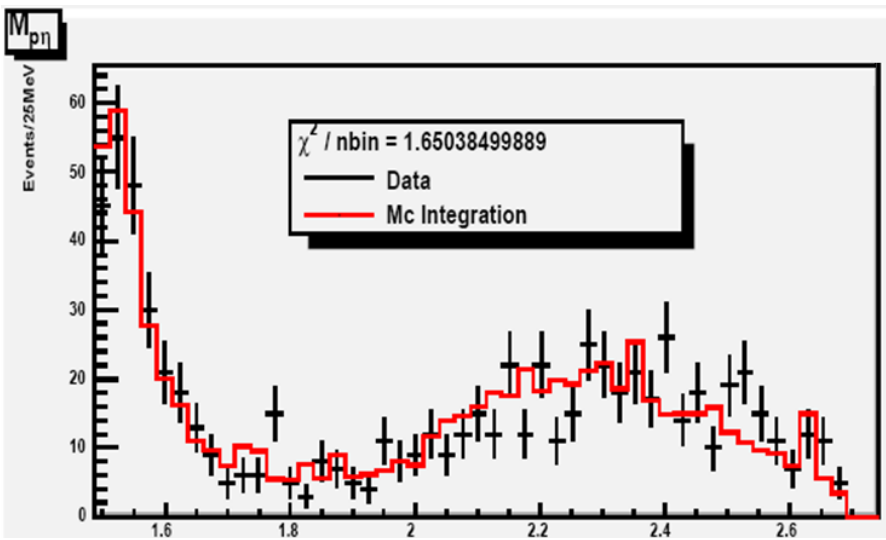
Results from PWA

Preliminary

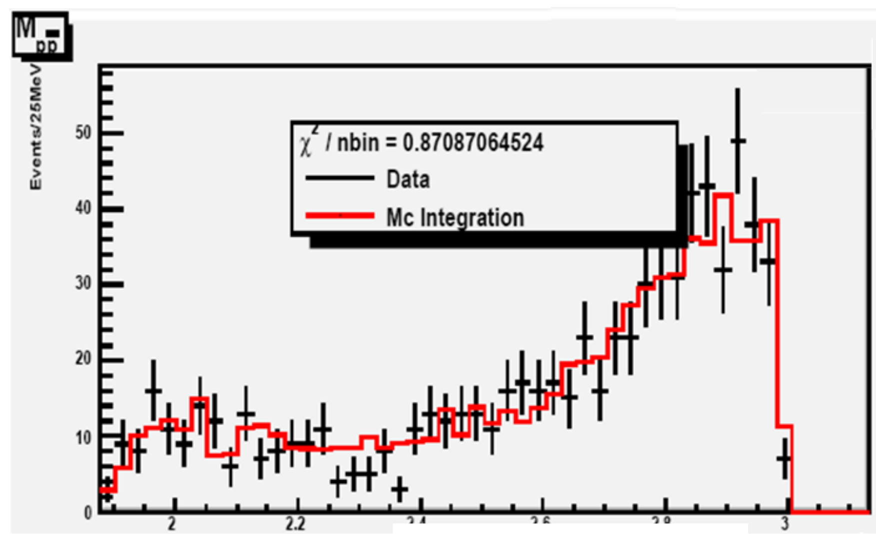
1) N(1535) and PHSP(1/2-) are significant in this analysis

N(1440)	N(1520)	N(1535)	N(1650)	N(1700)
N(1710)	N(1720)	N(1900)	N(2080)	PHSP(1/2-)

2) MC projection is consistent with data (MC = N(1535)+PHSP)



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



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

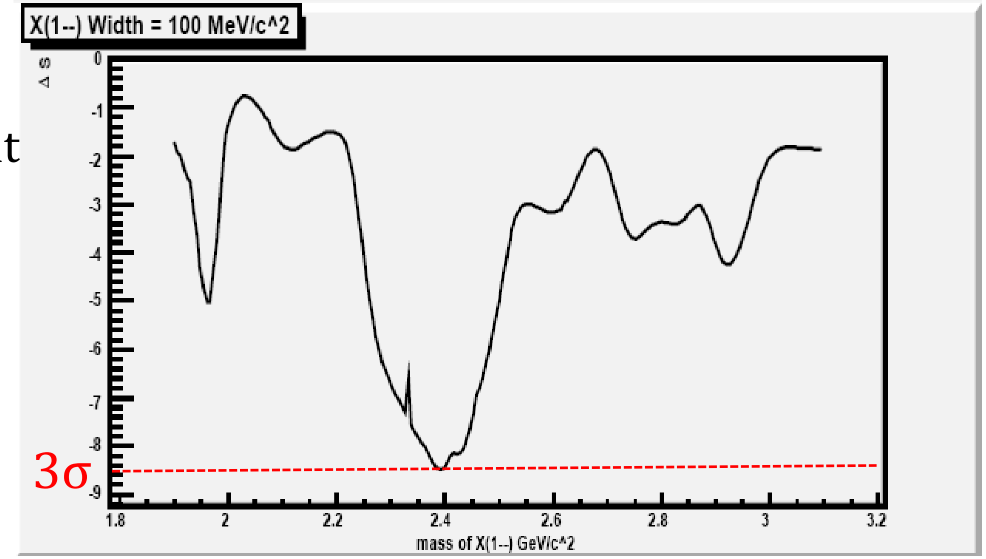
Results from PWA

Preliminary

3) J^P of N(1535) favors ½-, consistent with the PDG value.

Resonance	$I(J^P)$	$-\Delta S$
N(1535)	$\frac{1}{2}(\frac{1}{2}^+)$	16.5
	$\frac{1}{2}(\frac{3}{2}^+)$	45.1
	$\frac{1}{2}(\frac{3}{2}^-)$	186.2
PHASE-SPACE	$\frac{1}{2}(\frac{1}{2}^+)$	0.4
	$\frac{1}{2}(\frac{3}{2}^+)$	37.9
	$\frac{1}{2}(\frac{3}{2}^-)$	33.4

4) No $p\bar{p}$ structure significant



Results from PWA

Preliminary

Mass and width of N(1535):

$$M = 1.524^{+0.005+0.010}_{-0.005-0.004} GeV/c^2$$

$$\Gamma = 0.130^{+0.027+0.061}_{-0.024-0.014} GeV/c^2$$

PDG:
1.525~1.545GeV/c^2

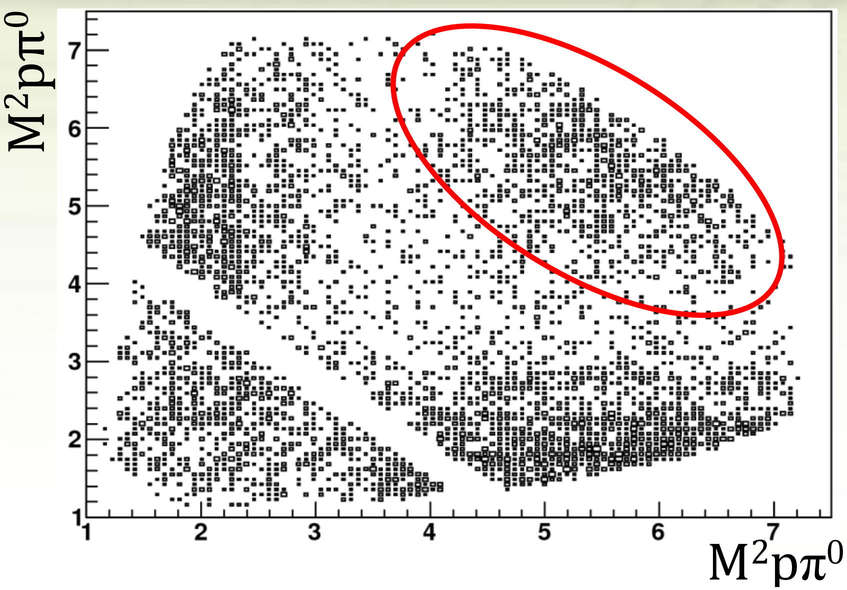
0.125~0.175GeV/c^2

$$B(\psi' \to \eta p \bar{p}) = (6.6 \pm 0.3 \pm 0.6) \times 10^{-5}$$

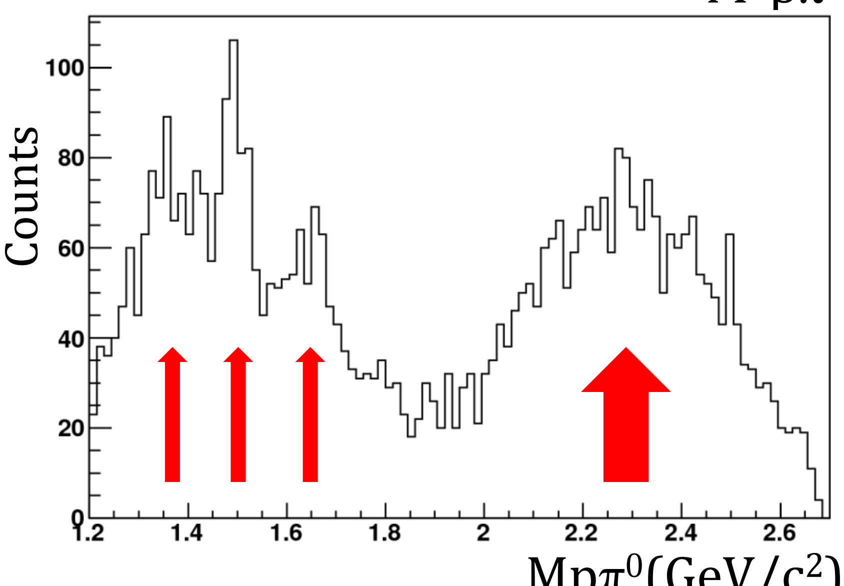
PDG: $(6 \pm 1.2)*10^{-5}$

Analysis of $\Psi' \to \pi^0 p\bar{p}$

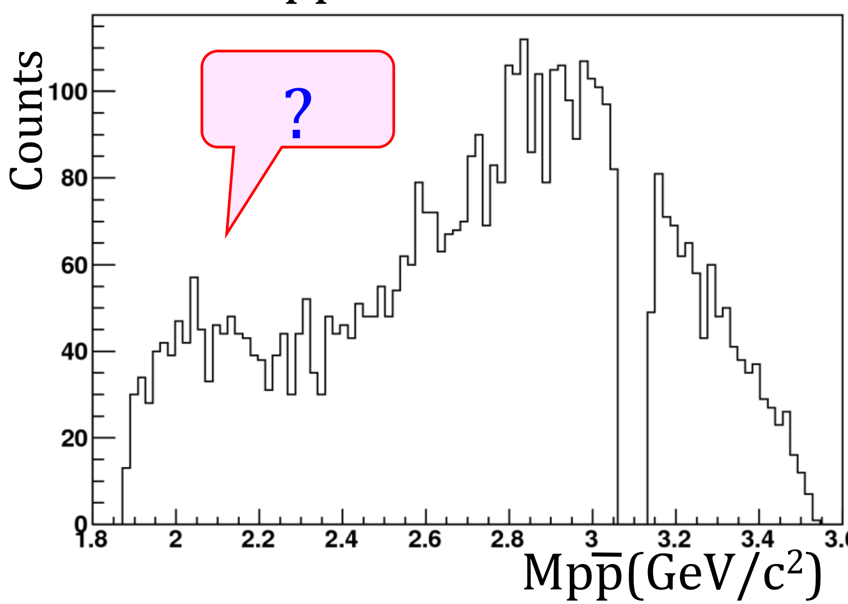
Preliminary



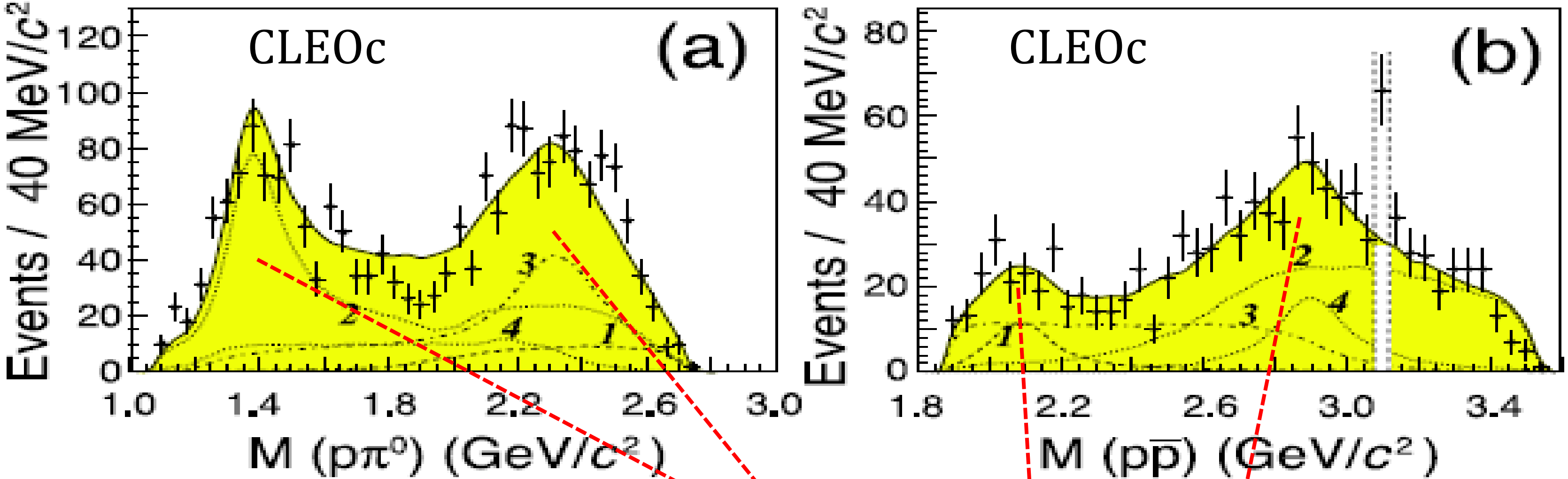
PWA of this channel is ongoing.

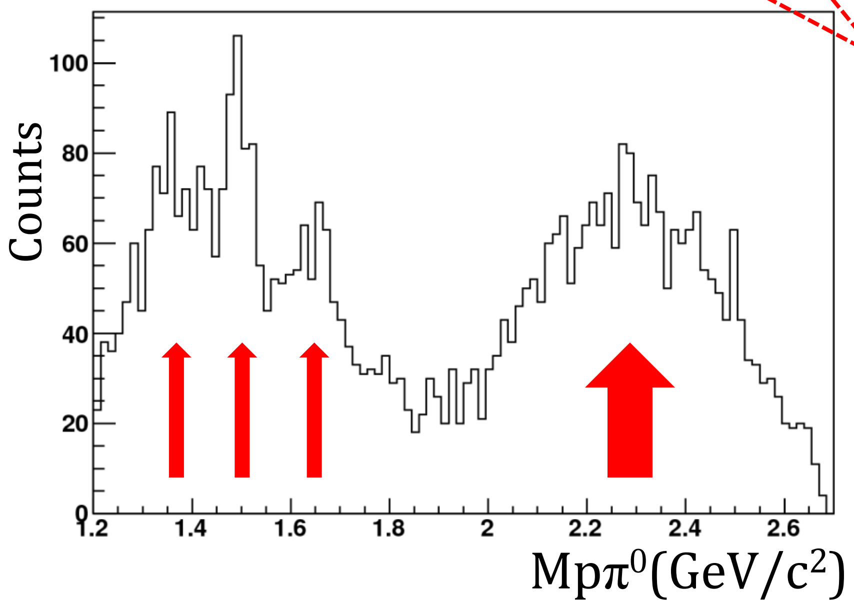


Mass of $p\bar{p}$



Compare with CLEOc





Resonance	M (MeV/c^2)
$N_1^*(1440)$	1400±25
$N_2^*(2300)$	2300±25
$R_1(2100)$	2103±8
$R_2(2900)$	2900±20

arXiv:1007.2886v2 [hep-ex] 12 Oct 2010

Summary

1. PWA of $\psi' \rightarrow \eta p\bar{p}$ are done. The measured mass and width of N(1535) agree with PDG values.

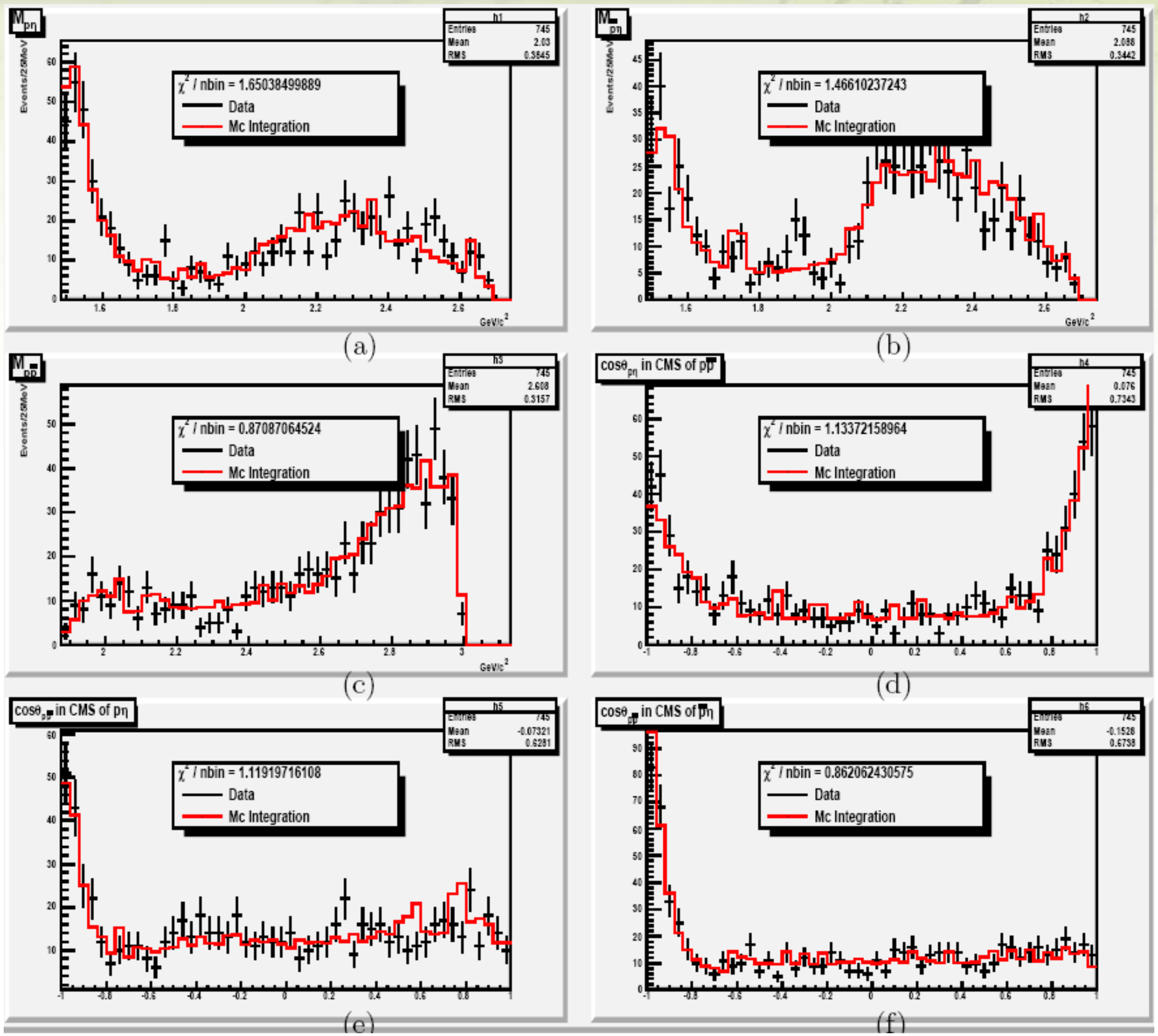
2. PWA of $\psi' \rightarrow \pi^0 p\bar{p}$ is ongoing.

3. This general method could be extended to many decay channels, $p\bar{p}\eta', p\bar{p}\omega, p\bar{p}\varphi, p\bar{p}\rho, p\bar{p}\pi^0\pi^0, p\bar{p}\pi^+\pi^-$, (or Λ^*, Ξ^*) ...

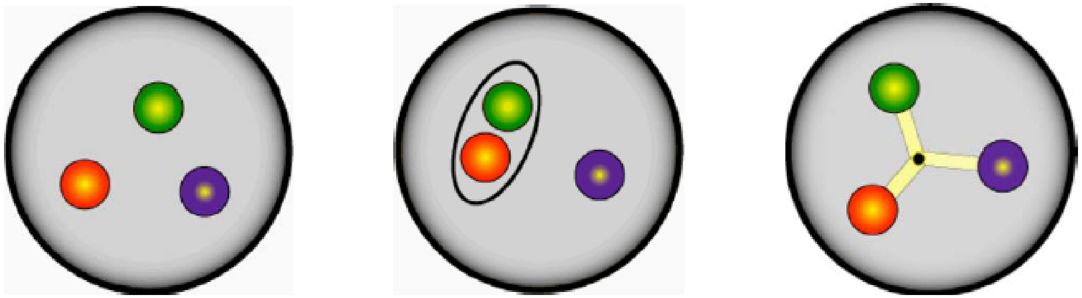
3. BESIII is a great tool to study baryon resonances.

Thank you!

Backup


χ^2 / nbin = 1.65038499889
Data
Mc Integration
(a)
χ^2 / nbin = 1.46610237243
Data
Mc Integration
(b)
χ^2 / nbin = 0.87087064524
Data
Mc Integration
(c)
χ^2 / nbin = 1.13372158964
Data
Mc Integration
(d)
χ^2 / nbin = 1.11919716108
Data
Mc Integration
(e)
χ^2 / nbin = 0.862062430575
Data
Mc Integration
(f)

Effective Degrees Of Freedom



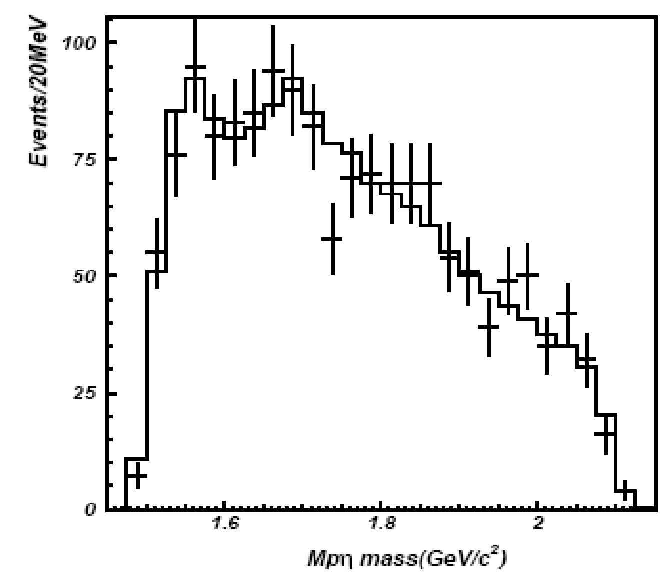
Quark Models

- Symmetric Constituent Quark Models predict overabundance of excited states (“missing” resonance problem)
- Quark-Diquark Models predict fewer states
- Quark and Flux-Tube Models predict increased number of states

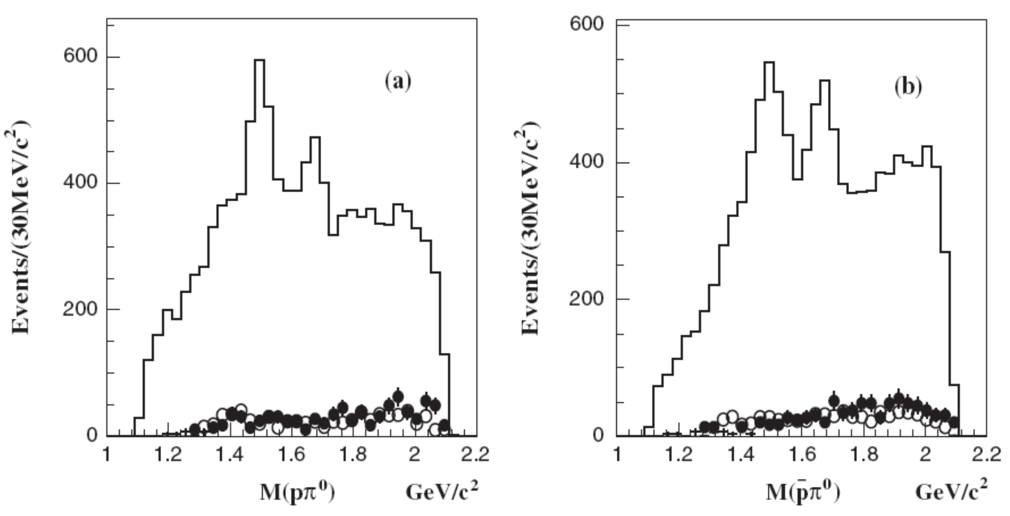
Remarks of BESI, BESII on N* Physics

BESI:

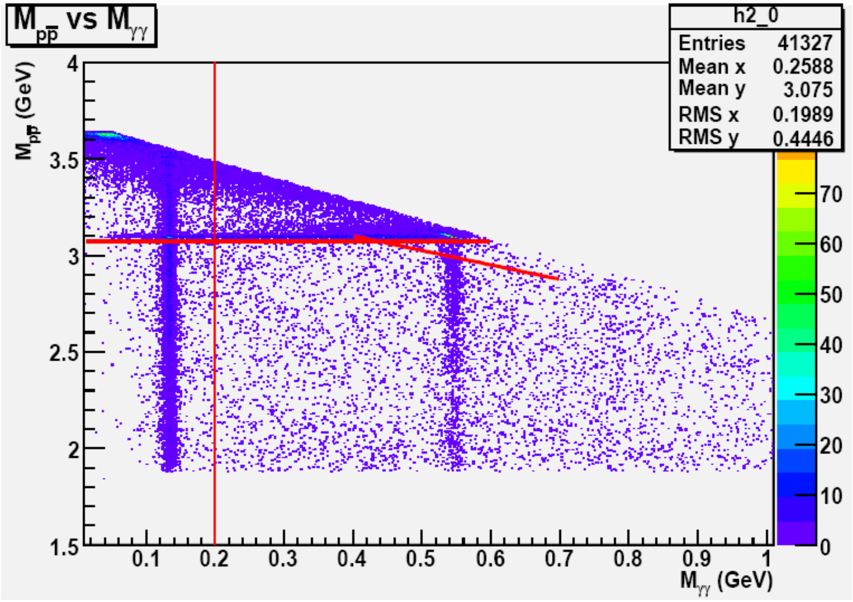
Recent N* Results From J/ψ Decays
arXiv: hep-ex/9910032 (1999)

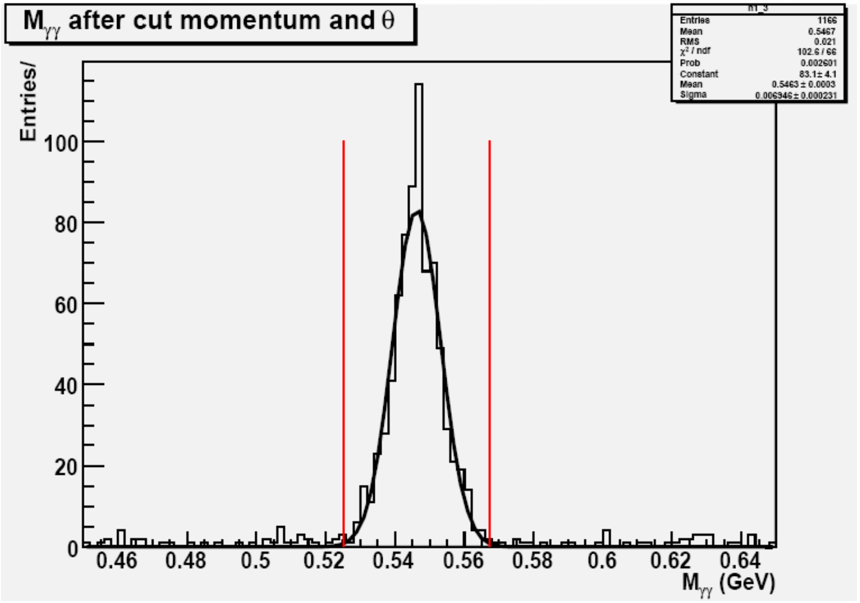


PWA of J/Psi → ppbar π^0.
PRD 80, 052004 (2009)

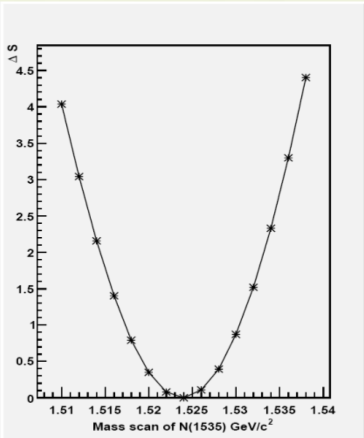


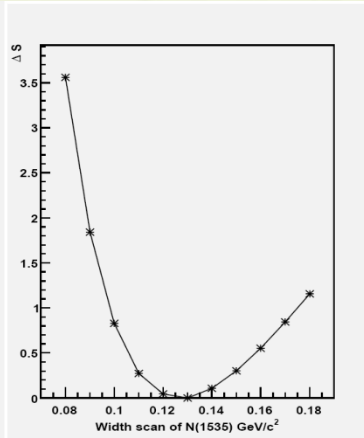
Event Selection

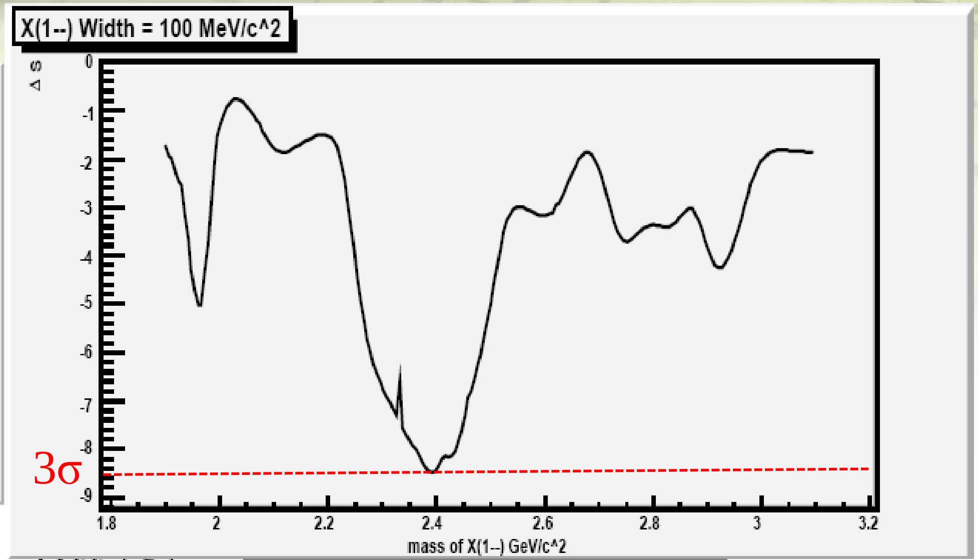




Remarks of BESII on N* Physics







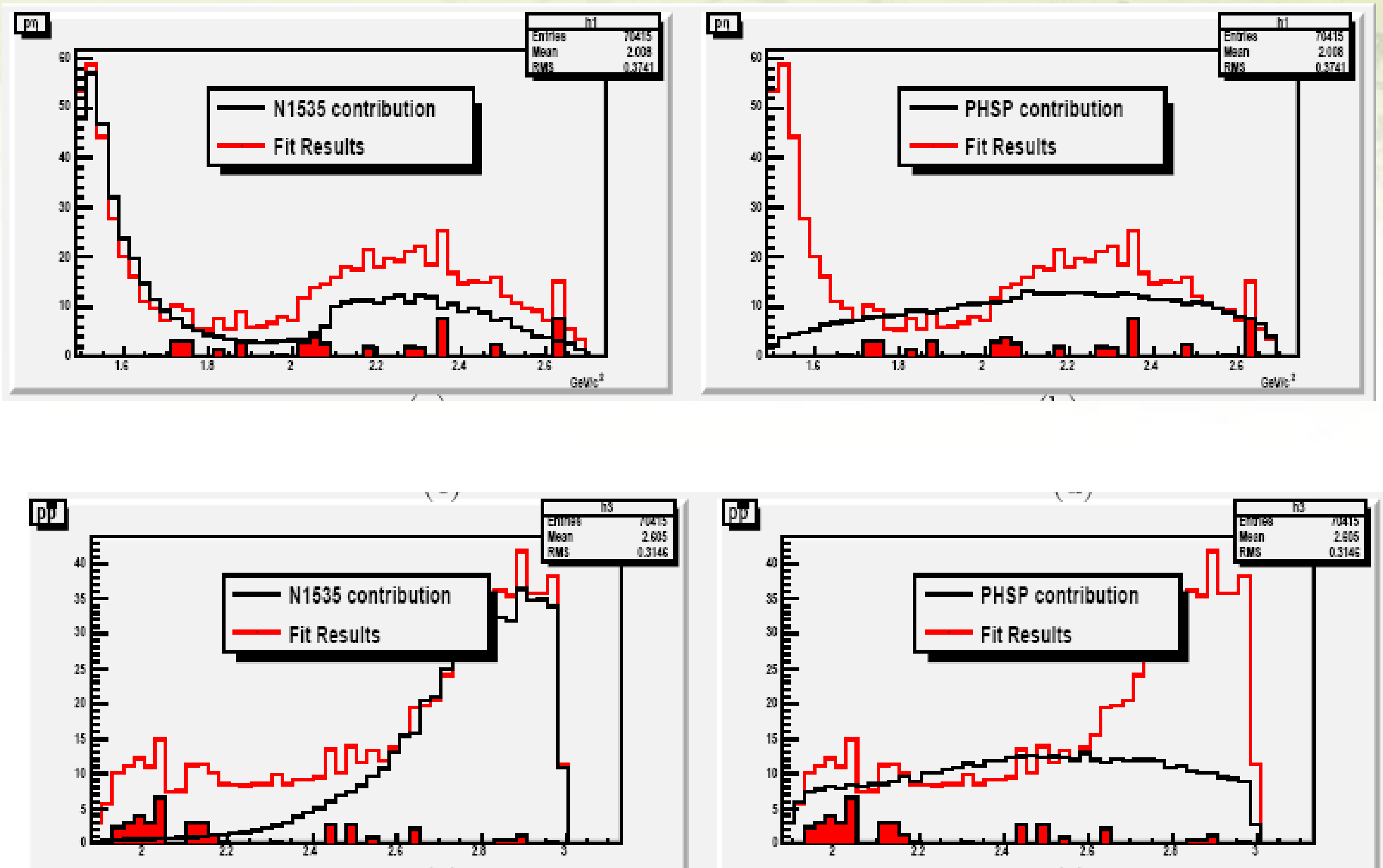
$$BW(s) = \frac{\cdots}{M_{N^*}^2 - s - iM_{N^*}\Gamma_{N^*}(s)}$$

$$\Gamma_{N^*}(s) = \Gamma_{N^*}^0 \left(0.5\frac{\rho_{\pi N}(s)}{\rho_{\pi N}(M_{N^*}^2)} + 0.5\frac{\rho_{\eta N}(s)}{\rho_{\eta N}(M_{N^*}^2)}\right)$$

$$\rho_{XN}(s) = \frac{2q_{XN}(s)}{\sqrt{s}} = \frac{\sqrt{(s-(M_N+M_X)^2)(s-(M_N-M_X)^2)}}{s}$$

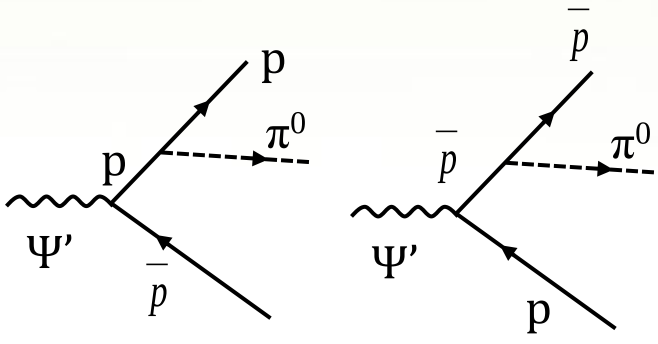
$$B(\psi' \to \eta p \bar{p}) = (6.7 \pm 0.2 \pm 0.6) \times 10^{-5}$$

$$B(\psi' \to N(1535)\bar{p}) \times B(N(1535) \to \eta p) = (6.0^{+0.3+8.7}_{-0.3-1.3}) \times 10^{-5}$$


pη
h1
Entries 70415
Mean 2.008
RMS 0.3741
N1535 contribution
Fit Results
PHSP contribution
GeV/c²
pp̄
h3
Mean 2.605
RMS 0.3146

(e) (f)

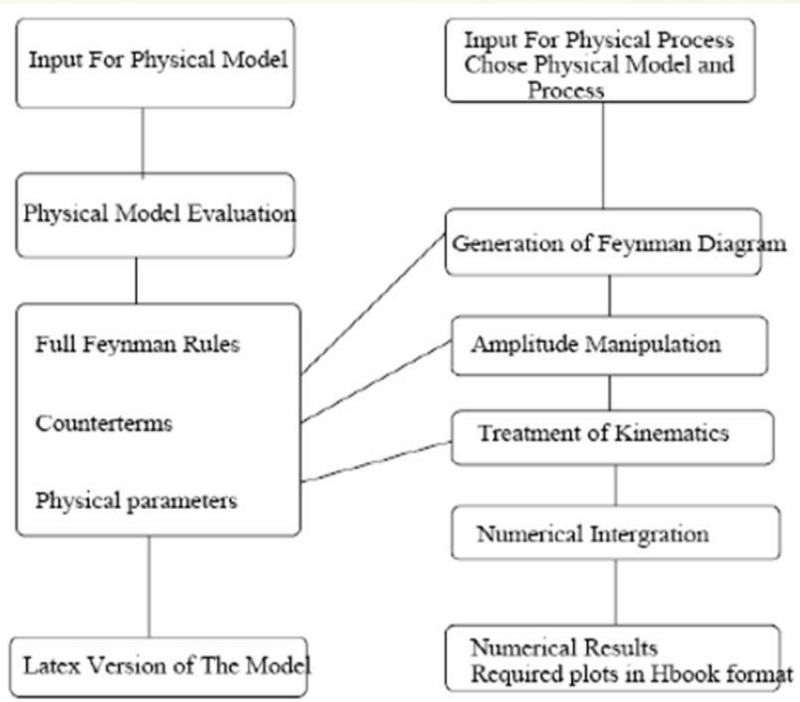
Results from PWA

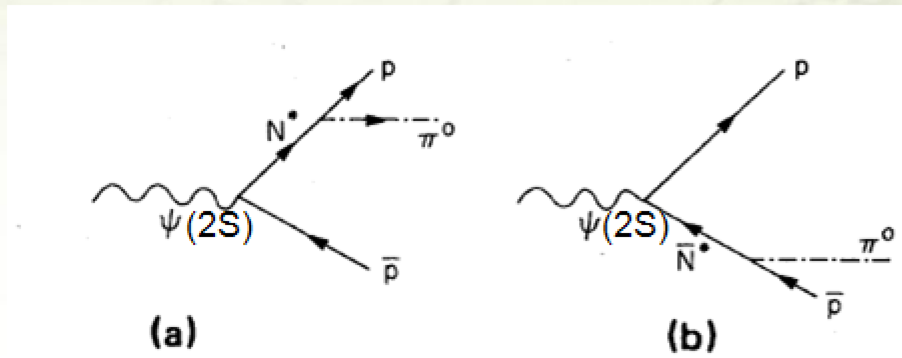


Mass and width of N(1535) are measured and consistent with the PDG values. The branching ratio of Ψ(2S)→ η pp is in agreement with the PDG value, and has a factor two smaller error.

Introduction to Feynman Diagram Calculation(FDC)

This is a tool to calculate Feynman Diagrams and generate the amplitude of partial wave automatically.





Eg. For Spin = 3/2

$$A_{\frac{3}{2}+} = \bar{u}(\kappa_2, s_2)\kappa_{2\mu}P^{\mu\nu}_{3/2}(c_1 g_{\nu\lambda} + c_2\kappa_{1\nu}\gamma_\lambda + c_3\kappa_{1\nu}\kappa_{1\lambda})\gamma_5 v(\kappa_1, s_1)\psi^\lambda$$

$$P^{\mu\nu}_{3/2+} = \frac{\gamma\cdot p + M_{N*}}{M^2_{N*} - p^2 + iM_{N*}\Gamma_{N*}}[g^{\mu\nu} - \frac{1}{3}\gamma^\mu\gamma^\nu - \frac{2p^\mu p^\nu}{3M^2_{N*}} + \frac{p^\mu\gamma^\nu - p^\nu\gamma^\mu}{3M_{N*}}]$$

Progress in FDC Project, Wang, JX hep-ph/0407058

statistical significance

For a resonance X,

$\mathcal{L}_0$ is the likelihood when X is **NOT** included in the fit;

$\mathcal{L}_1$ is the likelihood when X is included in the fit;

Δndf is the number of changed degree of freedom which equals the free parameters of X;

u equals the twice difference of the log-likelihood.

$$u = -2\ln\mathcal{L}_0 - (-2\ln\mathcal{L}_1) \quad obeying \quad \chi^2(u, \Delta ndf)$$

Using functions provided by CERNLIB(G100, G105), the statistical significance of X will be given by:

$$prob(u, \Delta ndf)$$

$$S = dgausn(1 - 0.5 * prob(u, \Delta ndf))$$

Input : u, Δndf, **Output** : S