Study of $\psi' \to p\bar{p}\eta$ at BESIII

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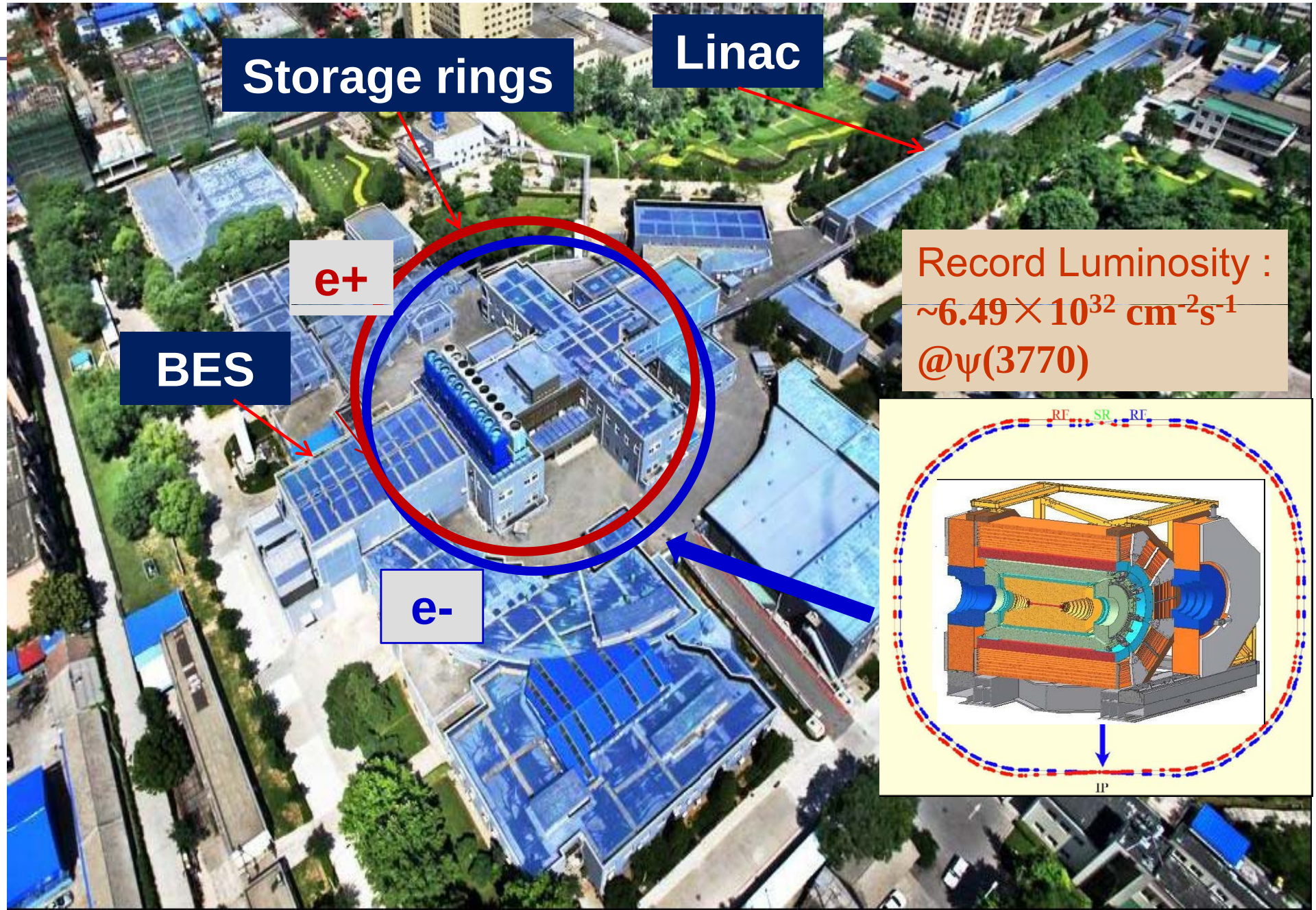
Outline

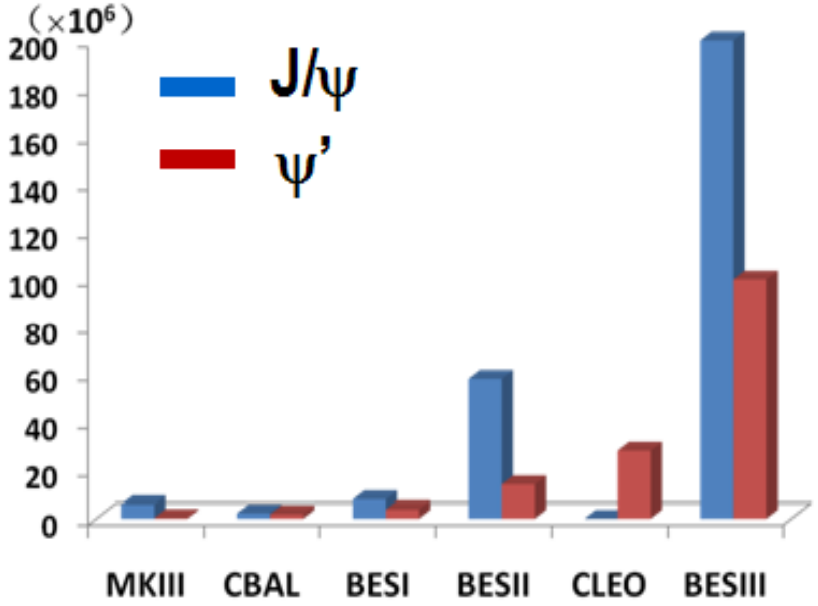
- Introduction to BEPCII/BESIII
- Excited nucleons study at BESIII
- Study of $\psi' \to p\bar{p}\eta$.
- Summary

Introduction to BEPCII/BESIII



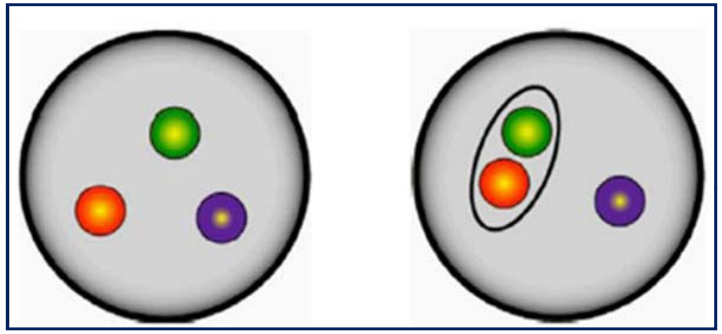
Data samples at BESIII

- 2009
  - ~106 M ψ' events
  - ~225 M J/ψ events
- 2010
  - ~900 pb^{-1} ψ(3770) events
- 2011
  - ~1800 pb^{-1} ψ(3770) events
  - ~470 pb^{-1} ψ(4040) events at 4.01 GeV



“missing” baryons problem

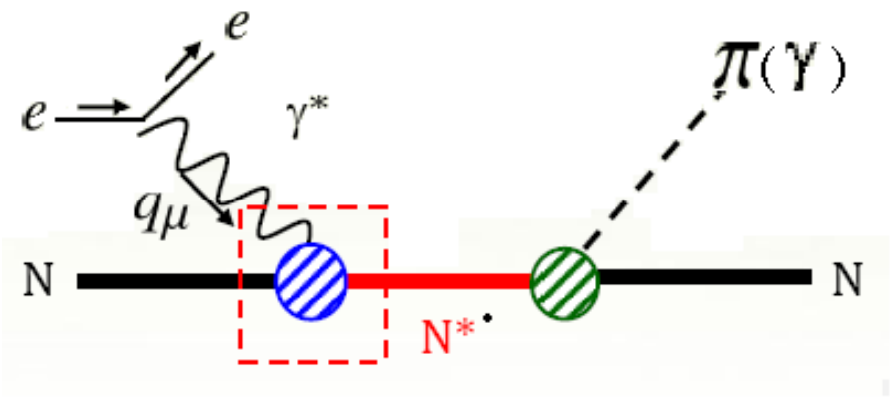
- Quark models predict many more baryon resonances than have been observed



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

Advantages of N* study at BESIII

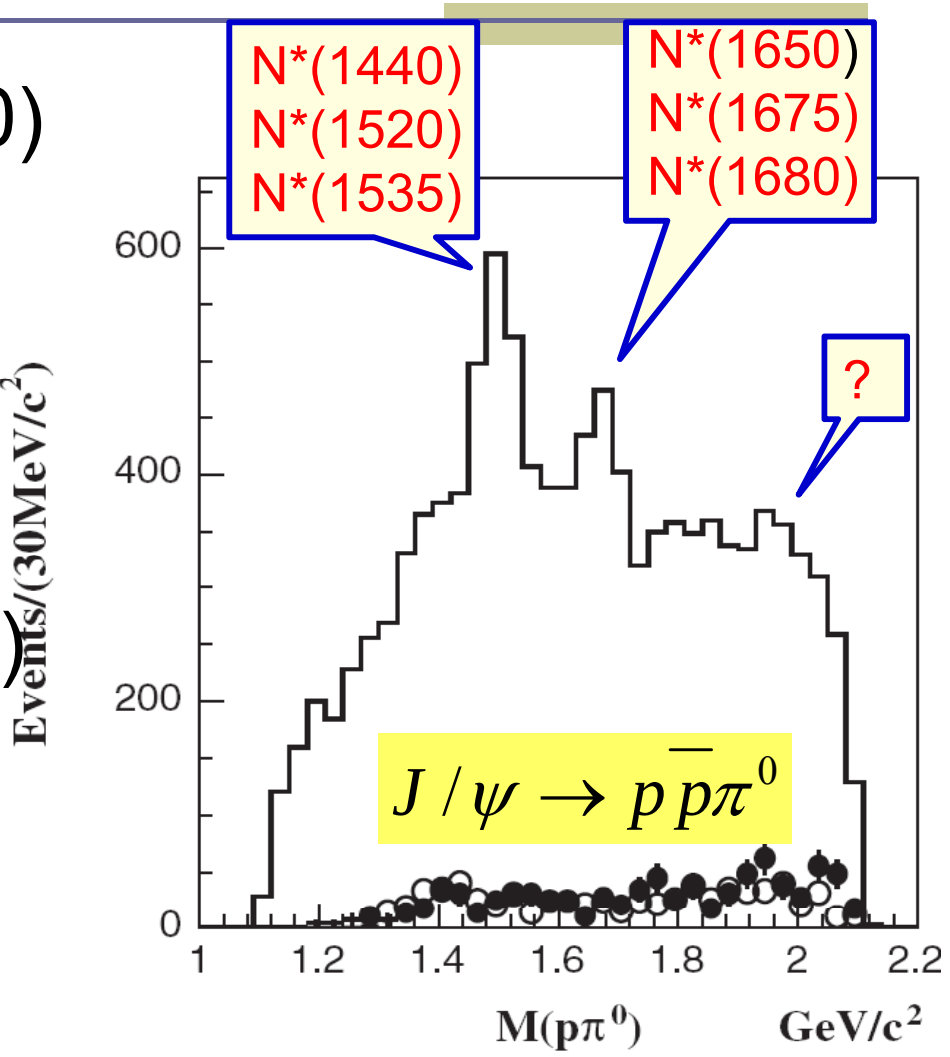
- N* knowledge primarily from πN, γN



- At BESIII,
  - Pure isospin ½
  - Study by many decay channels, such as $\pi N, \eta N, \omega N \ldots$
  - N* and $\bar{N}$*, twice of the statistics
  - Large statistics for charmonium states

Previous results of BESII on N*

- Observation of N*(2050)

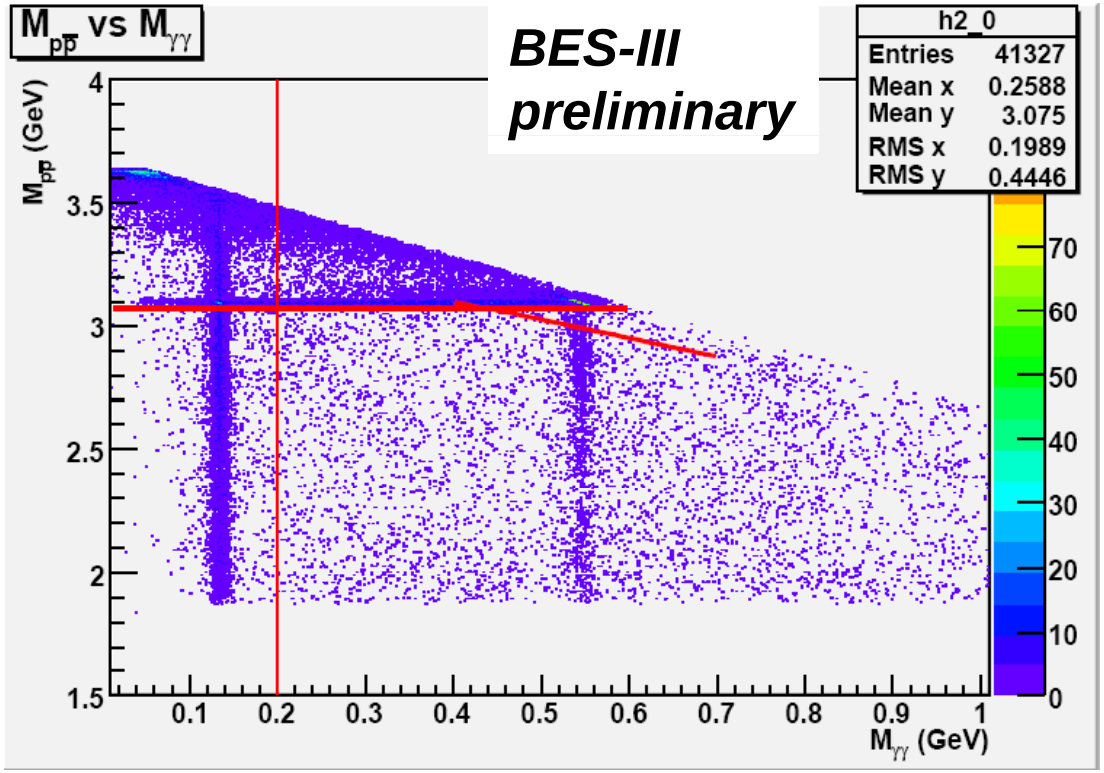


Phys.Rev.D80:052004,2009

- Parameters of N*(2050)
  - $M = 2040^{+3}_{-4} \pm 25 MeV$

    $\Gamma = 230 \pm 8 \pm 52 MeV$
  - $J^P : \left(\frac{3}{2}\right)^+$

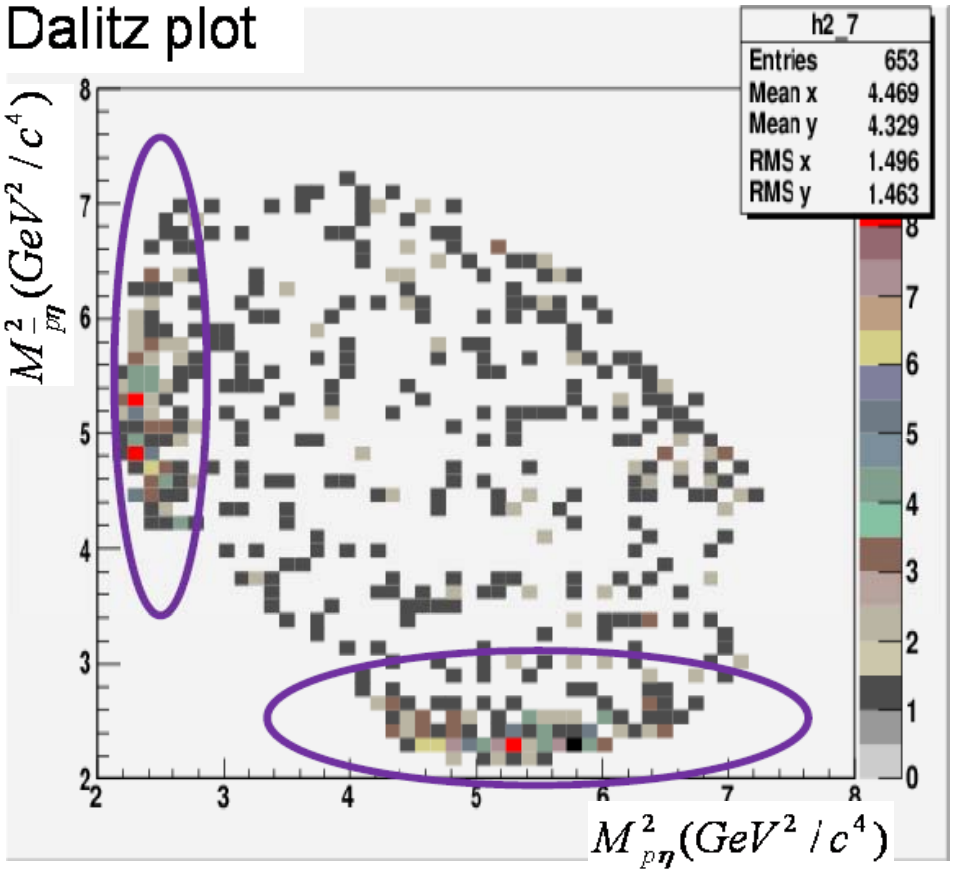
Analysis of $\psi' \to p\bar{p}\eta(1)$

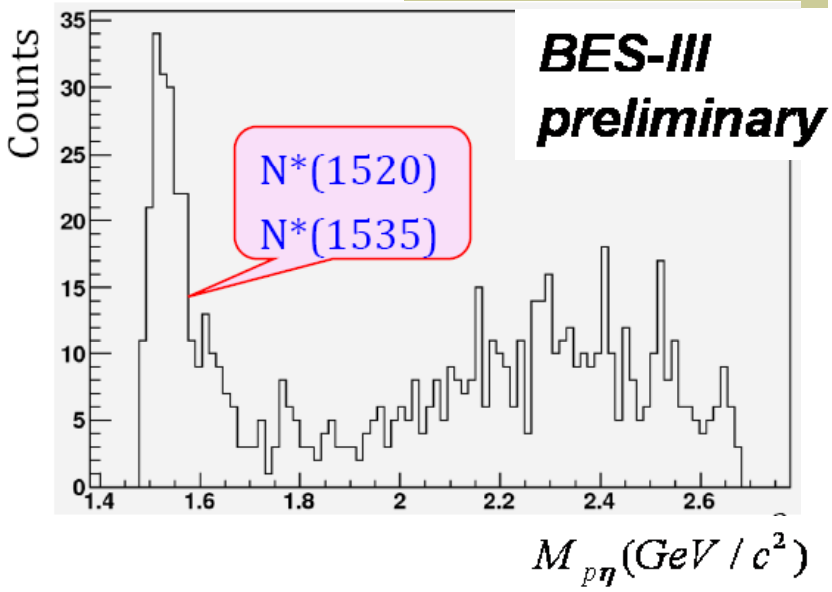


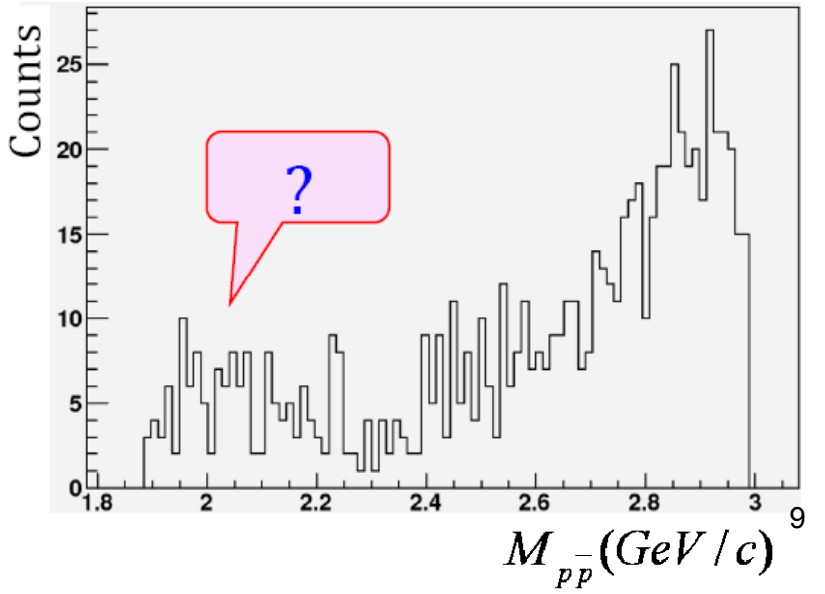
In this analysis, only $\eta \to \gamma\gamma$ are used.

And
$Br(\eta \to \gamma\gamma)=39.31\%$

Analysis of ψ'→pp̄η(2)







Introduction to **P**artial **W**ave **A**nalysis(PWA)

- Construct amplitude A_i for each possible partial wave

$$A_i = A_{prod} A_{Breit-Wigner} A_{decay}$$

- Construct differential cross section

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

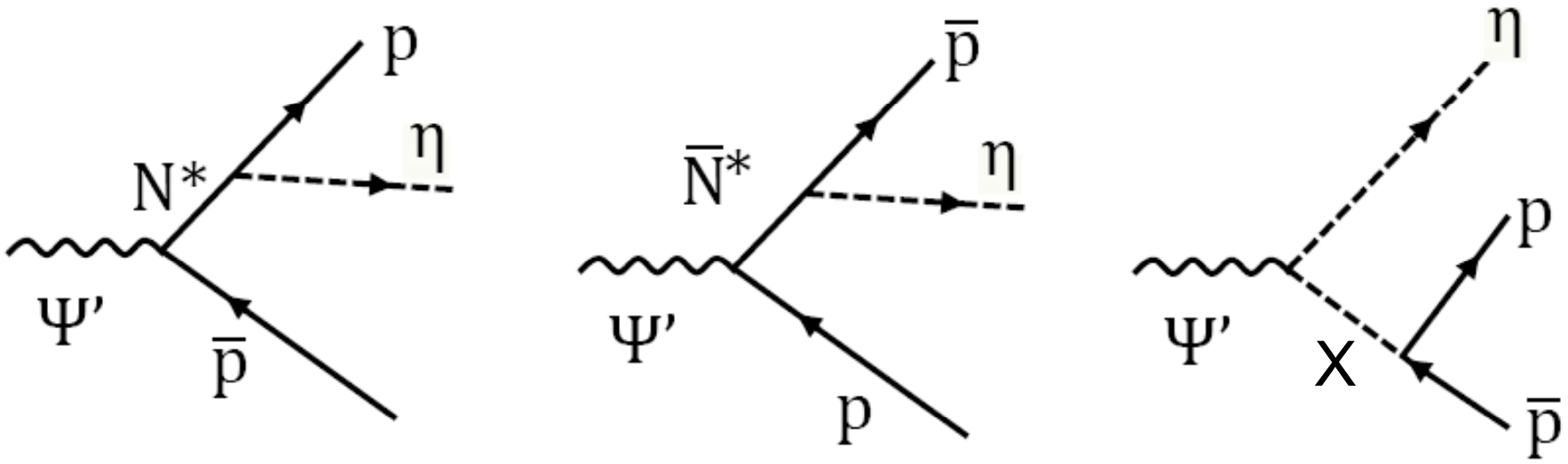
- Construct log likelihood function

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

- Maximize log likelihood function

PWA of $\psi' \to p\bar{p}\eta$

- Feynman diagrams related to $\psi' \to p\bar{p}\eta$

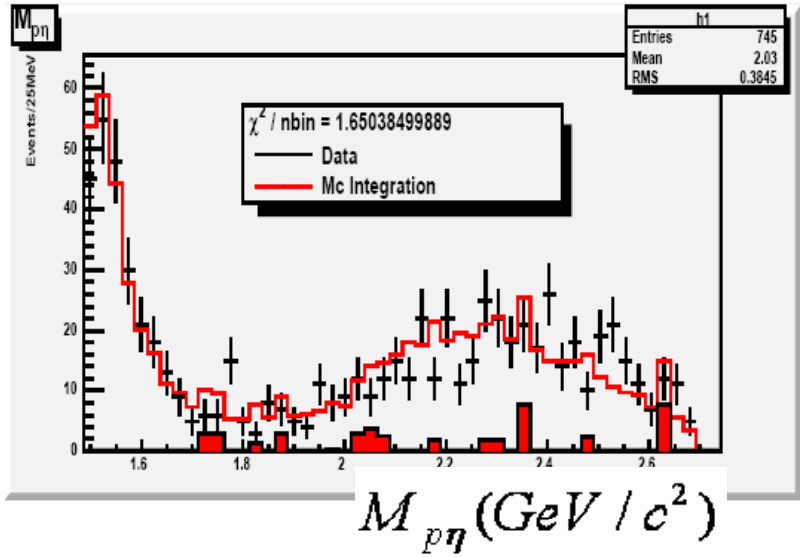


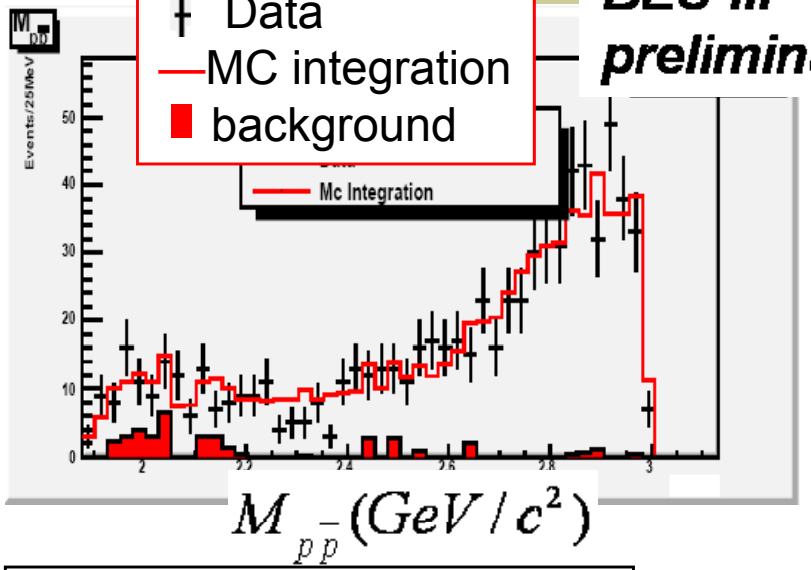
Best solution of PWA

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

Resonance	$I(J^P)$	-Δs	Δn.d.f	Significance (σ)
$N(1535)$	$\frac{1}{2}(\frac{1}{2}^-)$	184	4	$>> 5\sigma$
phase-space	$\frac{1}{2}(\frac{1}{2}^+)$	74	4	$>> 5\sigma$

PWA projection

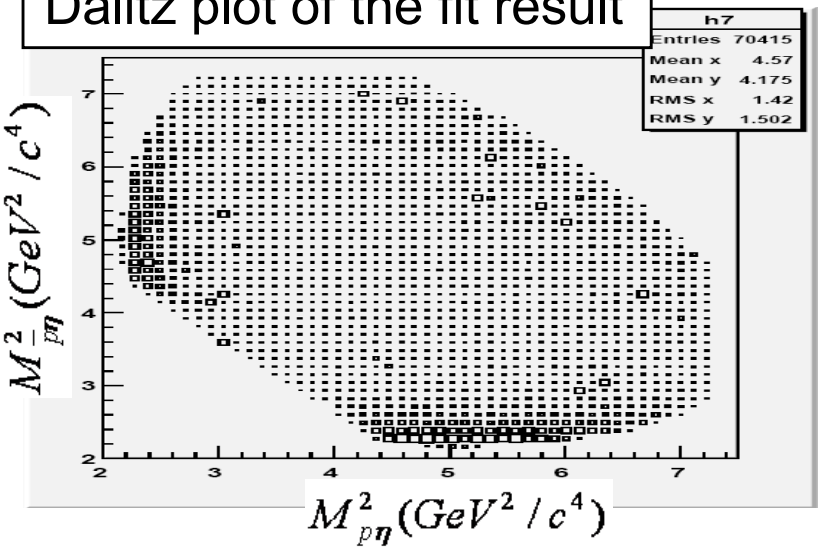




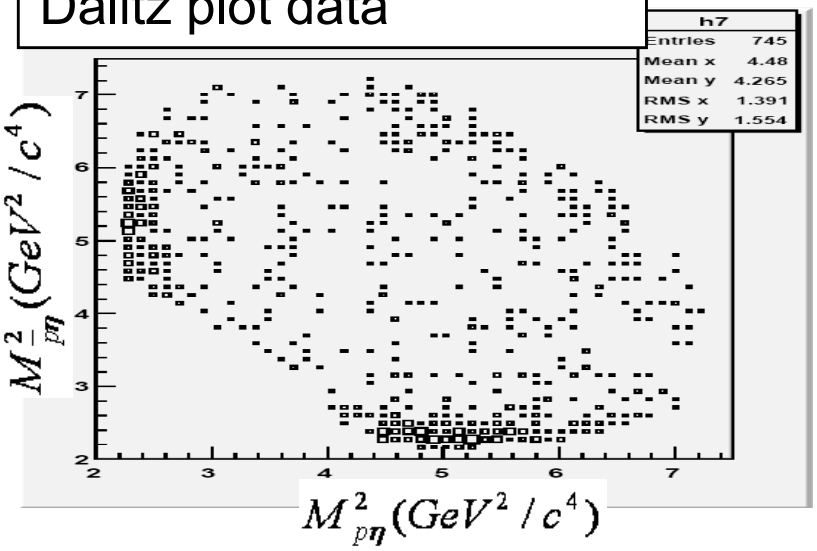
Data
MC integration
background

BES-III preliminary

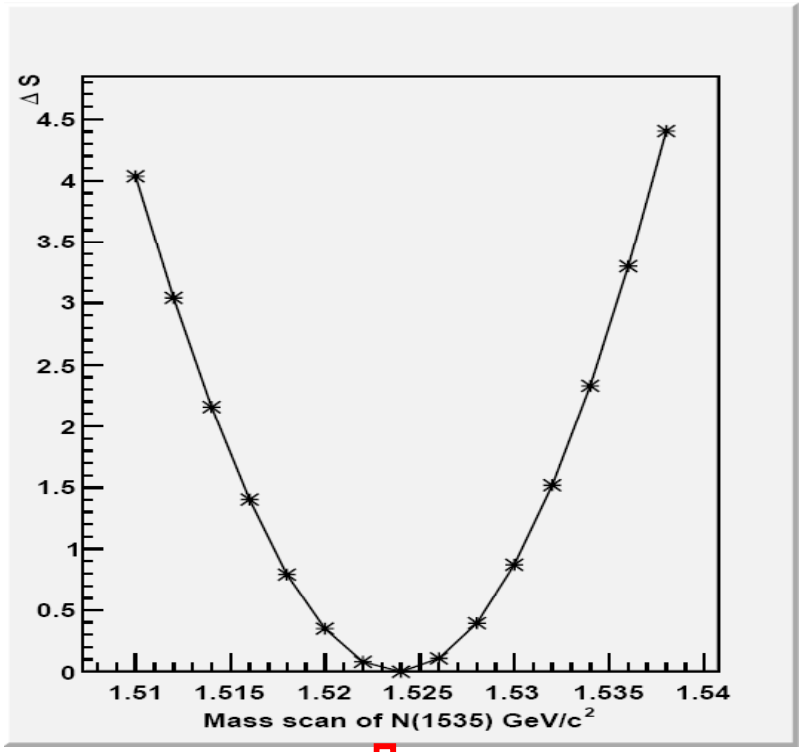
Dalitz plot of the fit result

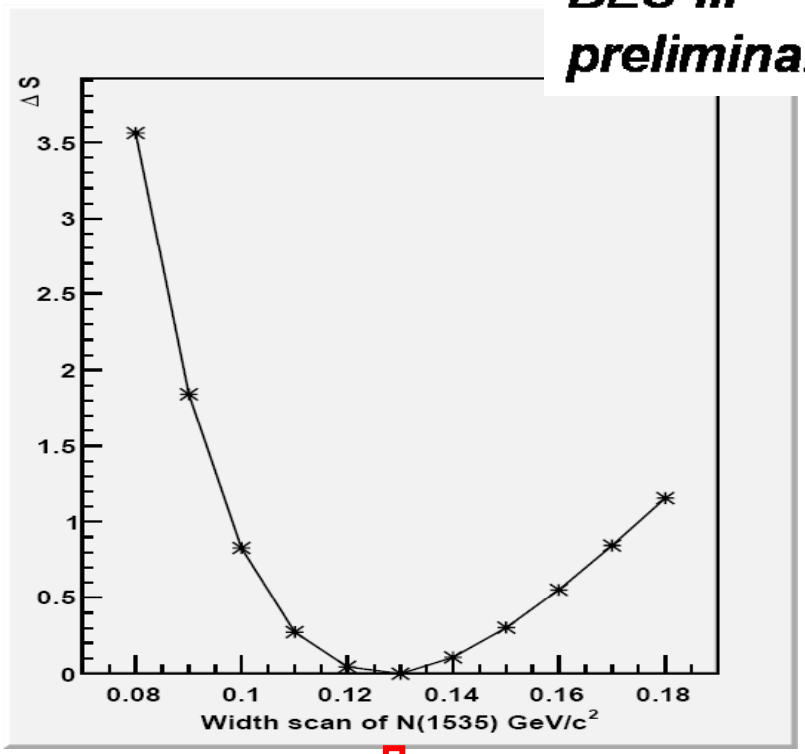


Dalitz plot data



Mass and width scan of N(1535)





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$$M_{N(1535)} = 1.524\,GeV/c^2$$

$$\Gamma_{N(1535)} = 0.130\,GeV/c^2$$

Spin-parity(J^p) determination

Resonance	$I(J^P)$	$-\Delta S$	Significance(σ)
N(1535)	$\frac{1}{2}(\frac{1}{2}^-)$	16.5	—
	$\frac{1}{2}(\frac{3}{2}^+)$	45.1	$>> 5\sigma$
	$\frac{1}{2}(\frac{3}{2}^-)$	186.2	$>> 5\sigma$

- J^P of N(1535) is $\frac{1}{2}^-$, which is consistent with the PDG value.

Extra 1^{--} resonance scan

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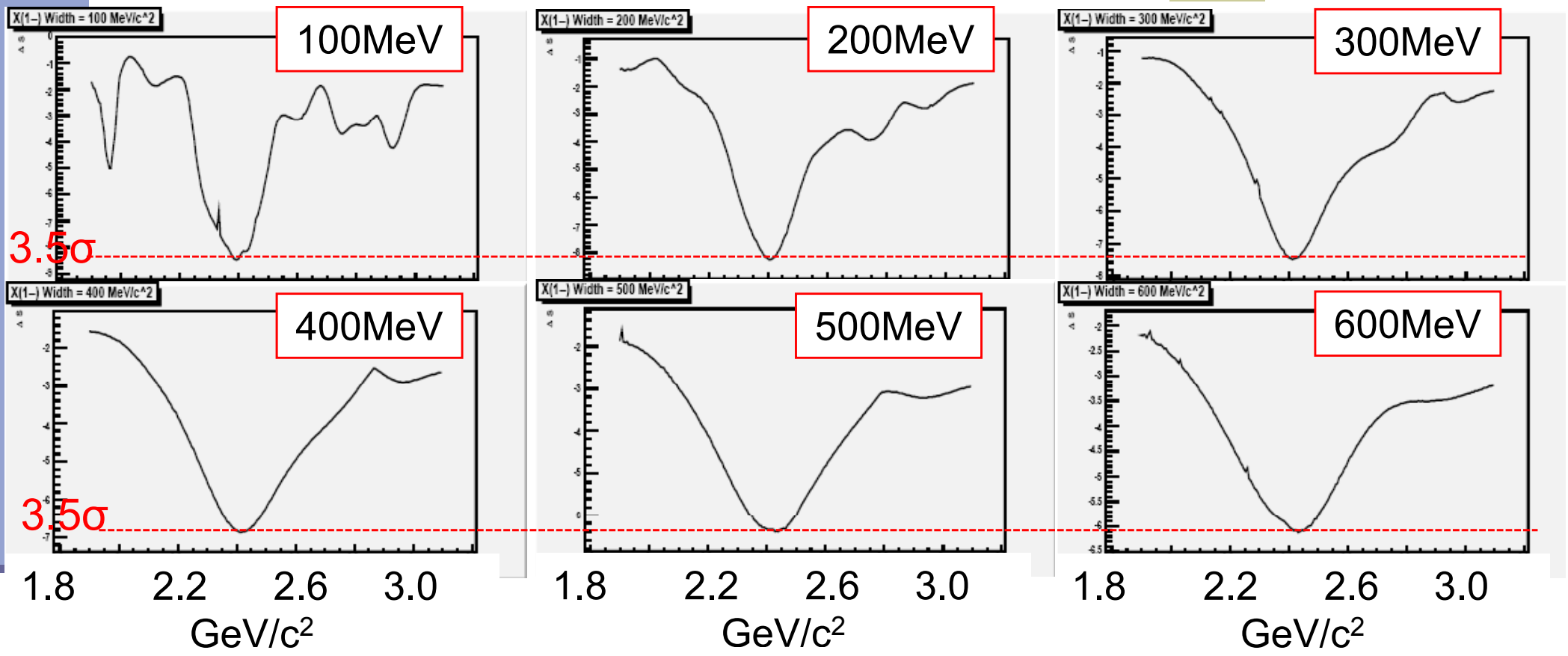


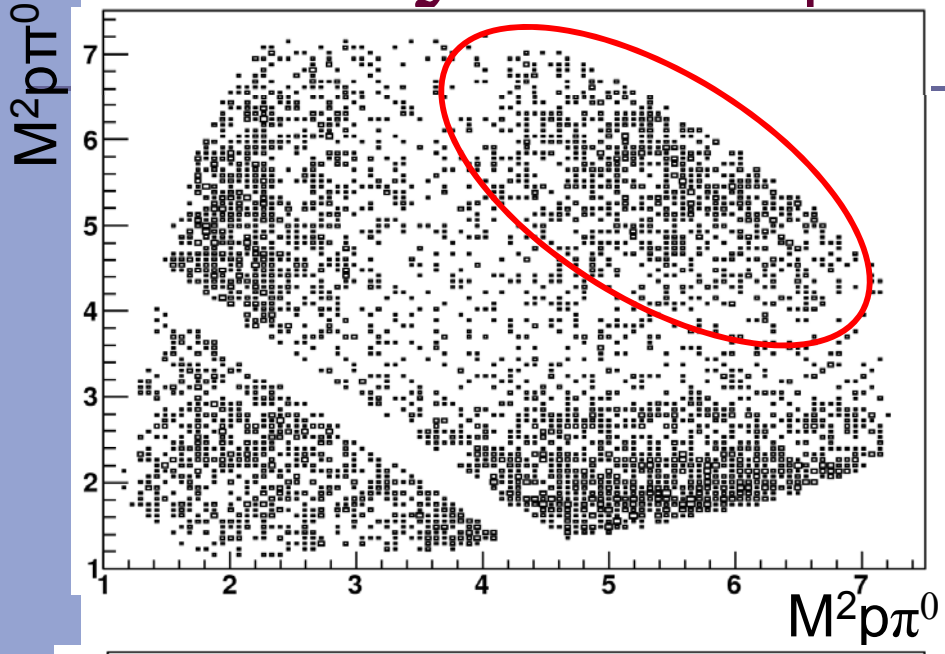
All the significances are less than 3.5σ,
and there is not likely to be a $p\bar{p}$ structure in $\psi' \to p\bar{p}\eta$.

Systematic error

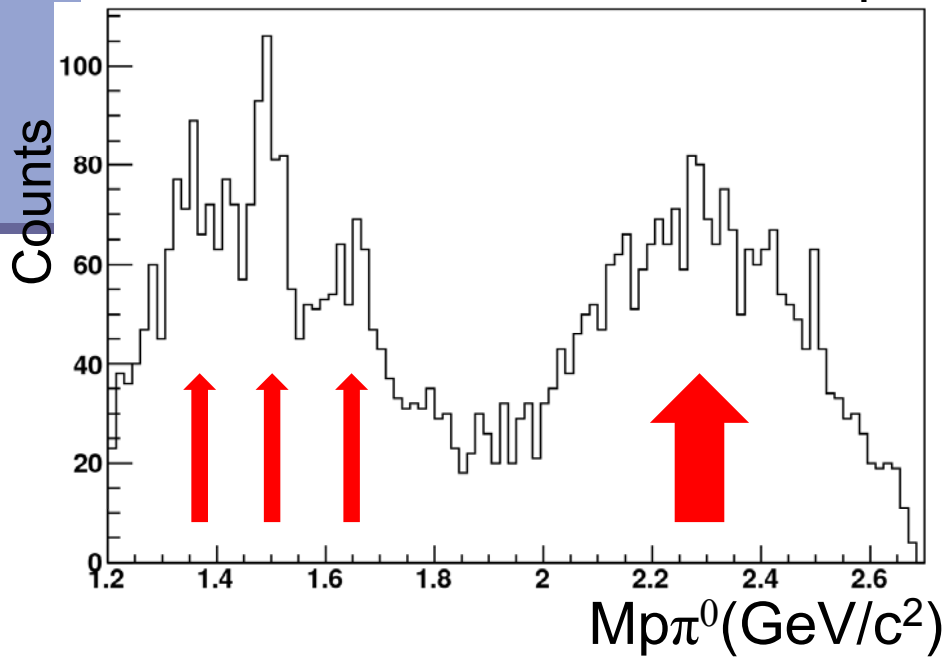
Source	$\Delta_{Mass}(\mathrm{MeV}/c^2)$	$\Delta_{Width}(\mathrm{MeV}/c^2)$	$\Delta(B.R.)/B.R.(\%)$
Charged Track Detection Efficiency	—	—	$\pm 4\%$
Photon Detection Efficiency	—	—	$\pm 2\%$
PID	—	—	$\pm 2\%$
Kinematic Fit	—	—	$\pm 7\%$
ψ' Total Number	—	—	$\pm 4\%$
$\psi' \to p\bar{p}\eta$ Total Systematic Error	—	—	$\pm 9\%$
Contribution of Additional Resonance	$+2$	$+60$	$+143\%$
(with PWA)	-4	-10	-4%
Different BW Formula	—	—	$^{+17\%}_{-21\%}$
Different Background Level	$+10$	$^{+10}_{-10}$	$+8\%$
N(1535) Total Systematic Error	$^{+10}_{-4}$	$^{+61}_{-14}$	$^{+144\%}_{-21\%}$

Analysis of $\psi' \to p\bar{p}\pi^0(1)$

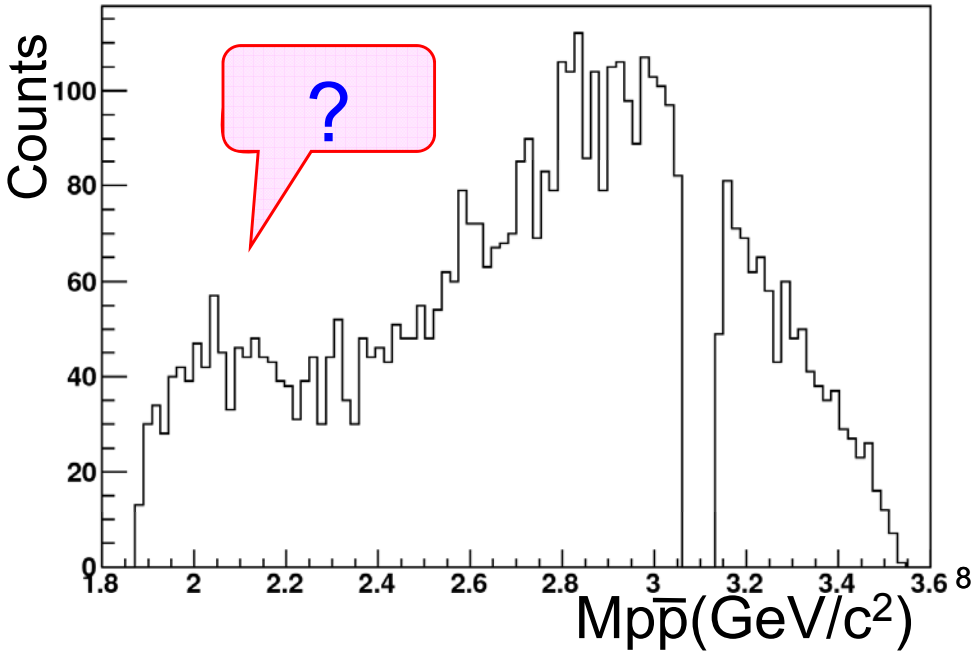
BES-III preliminary



PWA of this channel is ongoing.

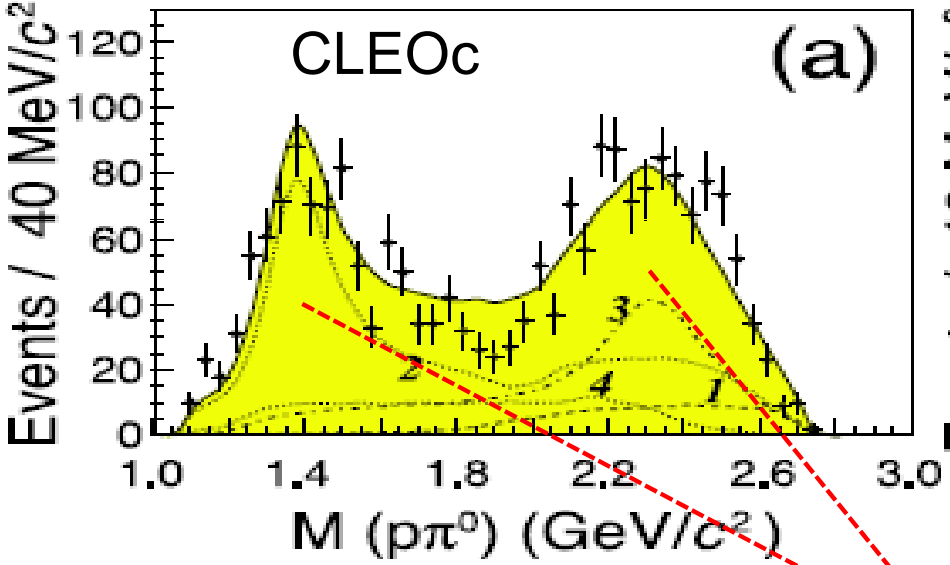


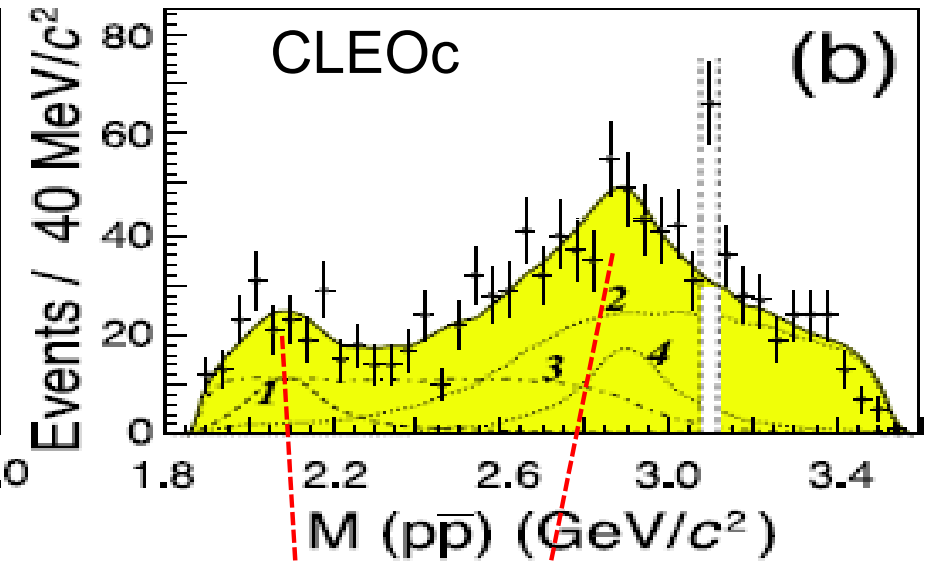
Mass of $\bar{p}p$

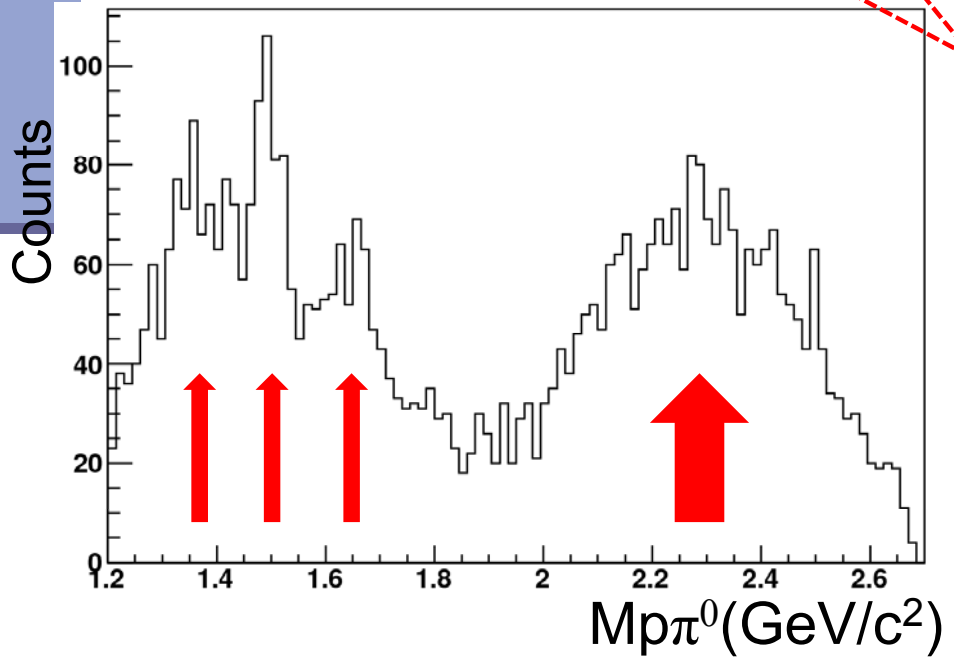


Analysis of $\psi' \to p\bar{p}\pi^0(2)$

BES-III preliminary







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

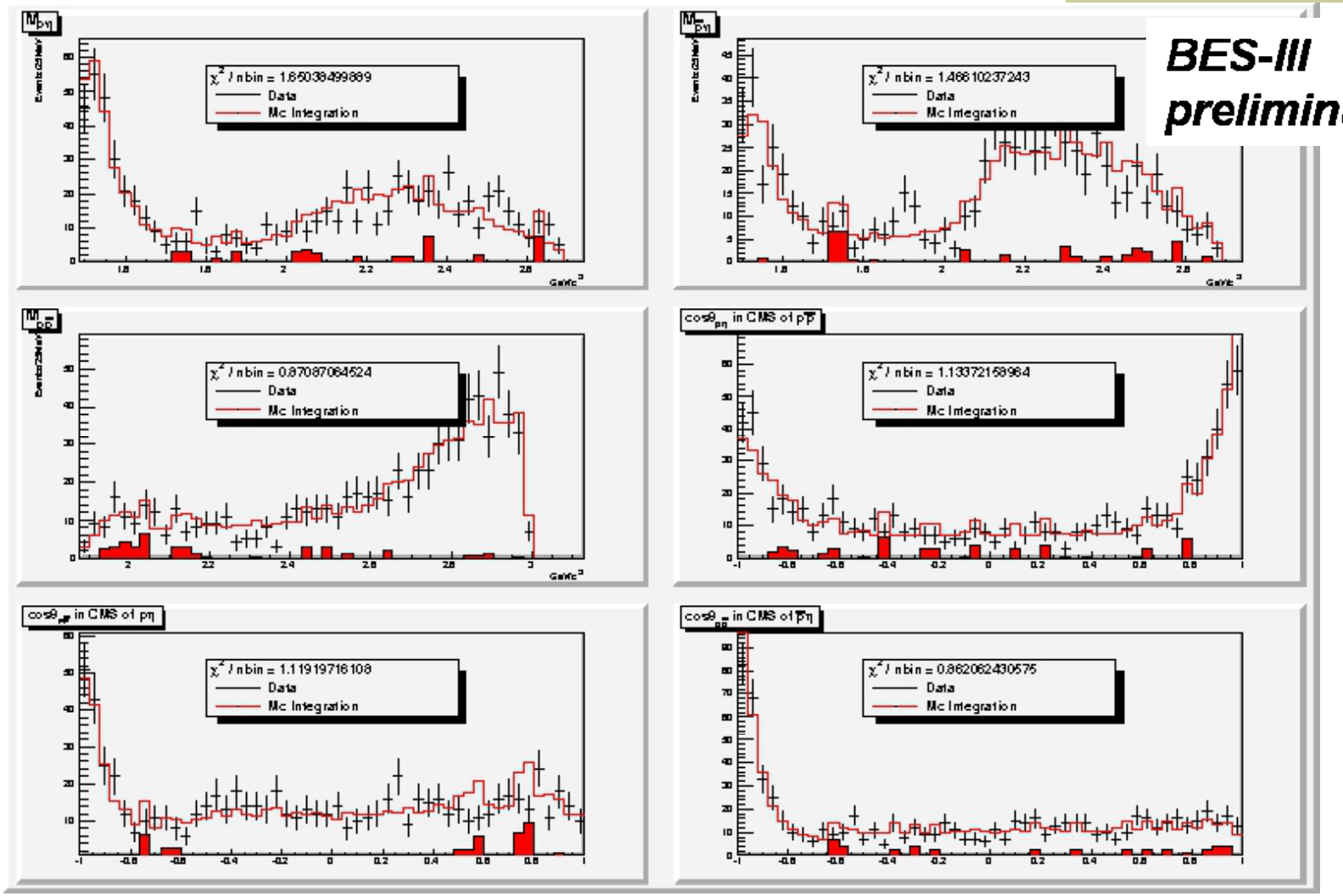
- In the PWA of $\psi' \to p\bar{p}\eta$, very significant N(1535) component has been found.

	BES-III preliminary	PDG
Mass(GeV/c^2)	$1.524^{+0.005+0.010}_{-0.005-0.004}$	1.525~1.545
width(GeV/c^2)	$0.130^{+0.027+0.061}_{-0.027-0.014}$	0.125~0.175
Br($\psi' \to p\bar{p}\eta$)	$(6.6\pm0.2\pm0.6)\times10^{-5}$	$(6\pm1.2)\times10^{-5}$
Br($\psi' \to N(1535)\bar{p}$)× Br($N(1535) \to p\eta$+c.c.)	$5.5^{+0.3+7.4}_{-0.3-1.1} \times10^{-5}$	—

- BESIII is a good place to study baryon resonances!

Thank you!

Backup



BES-III preliminary

Breit-wigner formula used in PWA

$$BW(s) = \frac{1}{M_{N^*}^2 - s - iM_{N^*}\Gamma_{N^*}(s)}$$

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

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