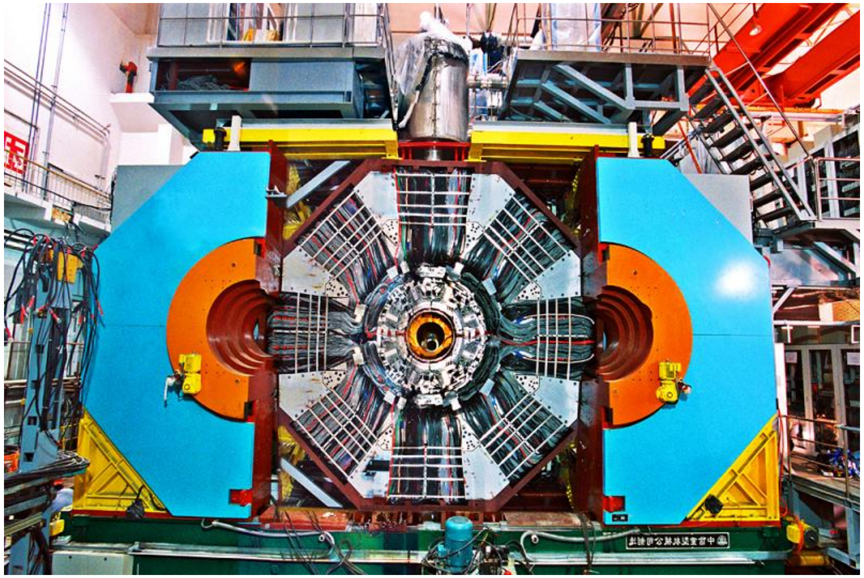
Study of excited Baryons at BESIII



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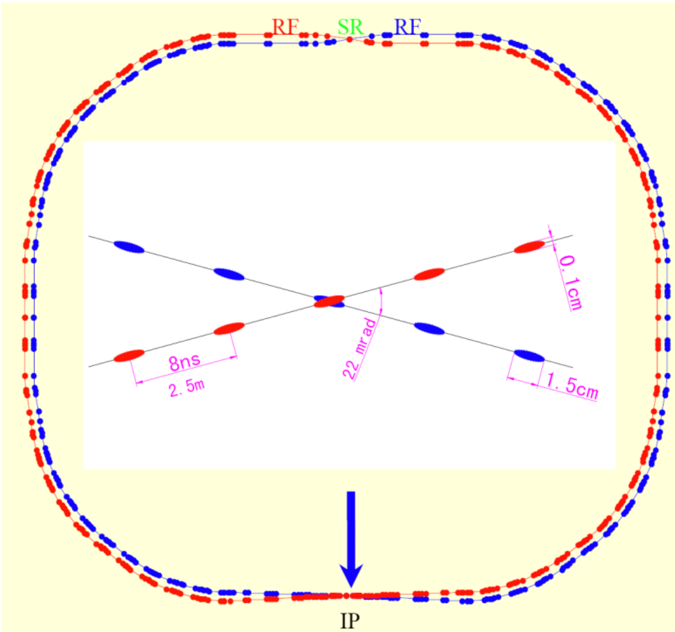
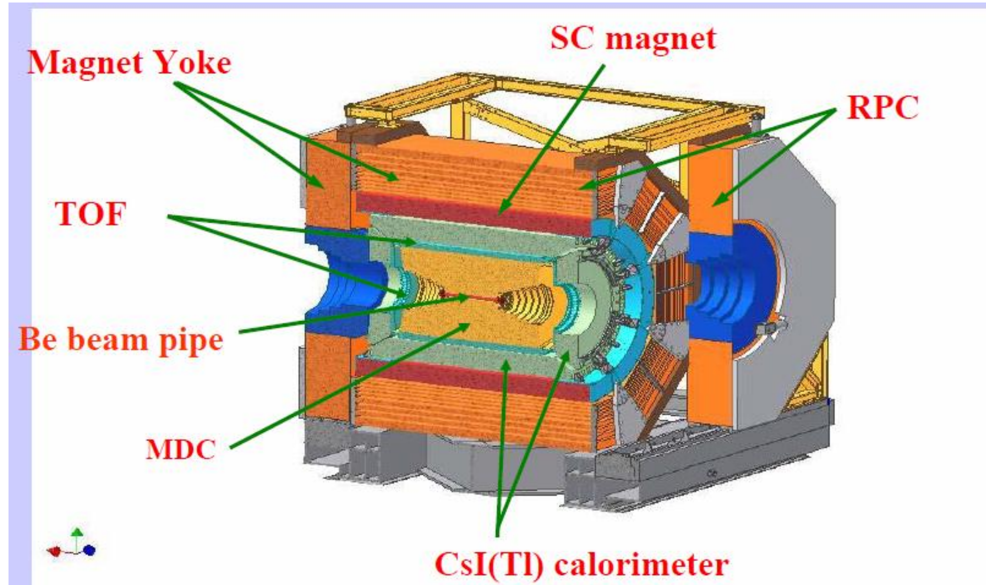
Outline

- Beijing Spectroscopy III @ BEPCII
- Excited baryon program at BESIII
- Tool for the baryon partial wave analysis
- Study of N* at BESIII

BEPCII and BESIII Detector





BEPCII:

- $\sqrt{s}$: **2.0-4.6 GeV**
- **Luminosity:**

  ~6.9×10^{32} cm^{-2}s^{-1} @3.773

  (Design: 1×10^{33} cm^{-2}s^{-1})

BESIII:

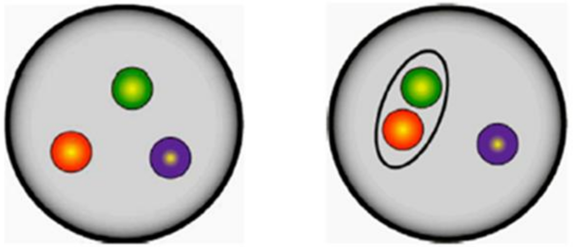
- **MDC: σ_p/p = 0.5% @ 1GeV/c**
- **EMC: σ_E/E = 2.5% at 1GeV**
- **TOF: 80ps(barrel), 110ps(endcap)**
- **MUC: 9 layers RPC for barrel, 8 for endcap**

Study of Excited Baryon States

- ➢ Probe the internal structure of light quark baryons
- ➢ Search for missing baryons predicted by quark model

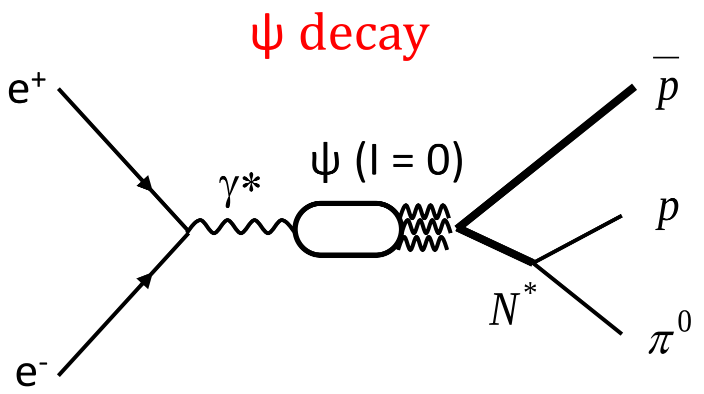
Quark models predict more baryon resonances than observed.

- *Theoretically: Reduce the number of d.o.f (di-quark?)*
- *Experimentally: The missing N*s have small couplings to πN and γN*



- ➢ Obtain a better understanding of the strong interaction force in the non-perturbative regime

Experimental Advantages of Ψ decaya



- Pure isospin 1/2 .

  ψ (I = 0)→ p (I=1/2) $\bar{p}\,\pi^0$ (I=1/2)   N* --yes, Δ* -- no

- Relatively large branching ratio.

  Br(J/ ψ → p $\bar{p}$ π^0) ~ 2.0e-3

- ψ decay to baryon anti-baryon pair through *3 or more gluons*. It's favorable place for looking for N* resonances which have small couple to πN and γN, but stronger coupling to g^3N.

PWA method at BESIII

- Unbinned maximum likelihood fit

- The amplitudes are constructed using the relativistic covariant tensor amplitude formalism

BES Coll., Phys. Rev. D80, 052004 (2009)
W.H. Liang, P.N. Shen, J.X. Wang, B.S. Zou, J. Phys. G 28, 333 (2002)

The general form for covariant tensor amplitude is:

$$A = A^{j}_{prod-X} (BW)_X \, A_{decay-X}$$

Probability to observe the event characterized by the measurement ξ

$$P(\xi) = \omega(\xi)\varepsilon(\xi) \Big/ \int d\xi \, \omega(\xi)\varepsilon(\xi)$$

Where $\varepsilon(\xi)$ is the detection efficiency.

differential cross section is:

$$\omega(\xi) = \frac{d\sigma}{d\Phi} = \left| \sum_j A_j \right|^2$$

The joint probability density for observing the N events is:

$$L = \prod_i^N P(\xi_i) = \prod_i^N \frac{(\frac{d\sigma}{d\Phi})_i \varepsilon(\xi_i)}{\sigma'}$$

We try to minimize

$$S = -\sum_i^N \ln[(\frac{d\sigma}{d\Phi})_i / \sigma']$$

The total cross section σ' is evaluated using MC:

$$\int d\xi \omega(\xi)\varepsilon(\xi) = \sigma' \rightarrow \frac{1}{N_{acc}} \sum_k^{N_{acc}} (\frac{d\sigma}{d\Phi})_k$$

The background contribution are removed from data

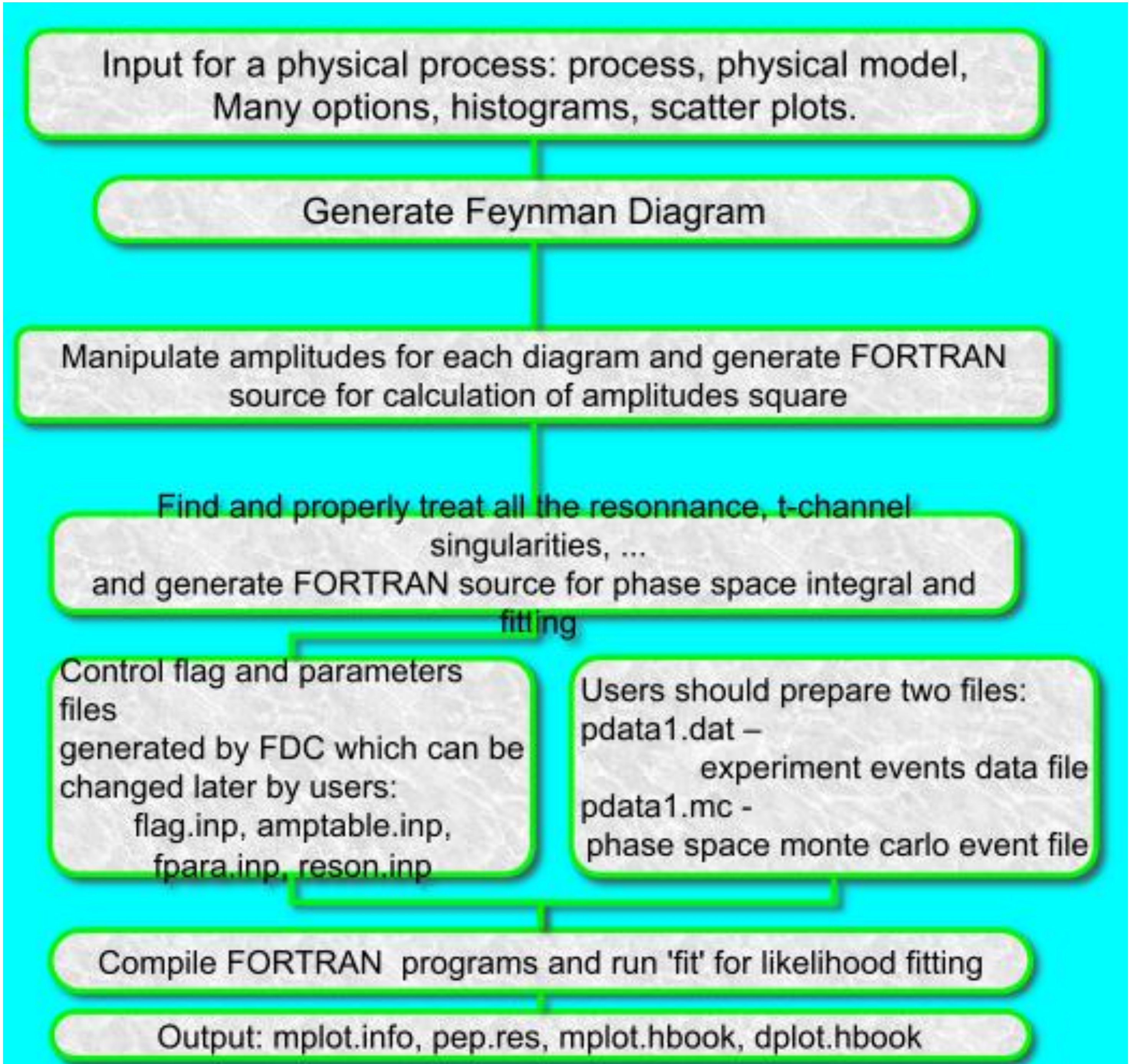
$$S = -(\ln L_{data} - \ln L_{BG})$$

FDC-PWA

J.X. Wang, Nucl. Instrum. Meth., A534, 241 (2004)

- The expression of the effective interaction vertices and the propagators for the high spin states are quite complicated. *FDC* will help us.
- *Feynman Diagram Calculation (FDC)*, was developed by Jianxiong Wang from 1993, and FDC-PWA was started from 1998.
- To work with high spin states (*0, 1/2, …, 4, 9/2*) and construct effective Lagrangians
- The rule to construct effective Lagrangian for PWA: Lorentz invariance, C-parity, P-parity and CP conservation, $H=H^+$, … …
- A complete of the Fortran sources was generated to do the PWA on experiment data
- Event generator for a given physical process

FDC-PWA (II)



Input for a physical process: process, physical model, Many options, histograms, scatter plots.
Generate Feynman Diagram
Manipulate amplitudes for each diagram and generate FORTRAN source for calculation of amplitudes square
Find and properly treat all the resonnance, t-channel singularities, ... and generate FORTRAN source for phase space integral and fitting
Control flag and parameters files generated by FDC which can be changed later by users: flag.inp, amptable.inp, fpara.inp, reson.inp
Users should prepare two files: pdata1.dat – experiment events data file pdata1.mc - phase space monte carlo event file
Compile FORTRAN programs and run 'fit' for likelihood fitting
Output: mplot.info, pep.res, mplot.hbook, dplot.hbook

Study of N* resonances at BESIII

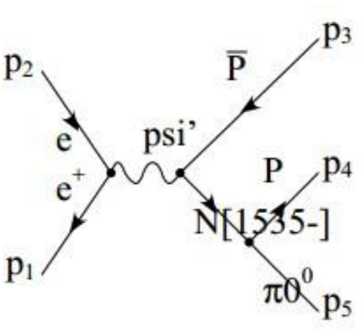
$\Psi(3686) \rightarrow p\,\bar{p}\,\pi^0$

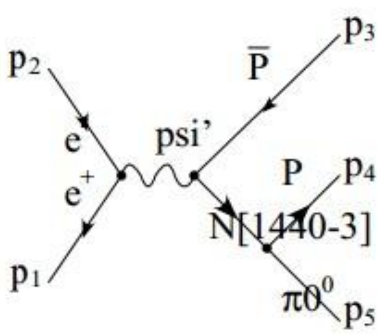
Phys. Rev. Lett. 110, 022001 (2013)

- Searching for N* resonances.
- Ψ(3686) decay provide larger phase-space than J/Ψ decay.

$$\Gamma_{N(1440)} \rightarrow \Gamma_{N(1440)}(0.7\frac{B_1(q_{\pi N})\rho_{\pi N}(s)}{B_1(q_{\pi N}^{N*})\rho_{\pi N}(M_{N*}^2)} + 0.3\frac{B_1(q_{\pi\Delta})\rho_{\pi\Delta}(s)}{B_1(q_{\pi\Delta}^{N*})\rho_{\pi\Delta}(M_{N*}^2)})$$

$$\Gamma_{N(1535)} \rightarrow \Gamma_{N(1535)}(0.5\frac{\rho_{\pi N}(s)}{\rho_{\pi N}(M_{N*}^2)} + 0.5\frac{\rho_{\eta N}(s)}{\rho_{\eta N}(M_{N*}^2)})$$





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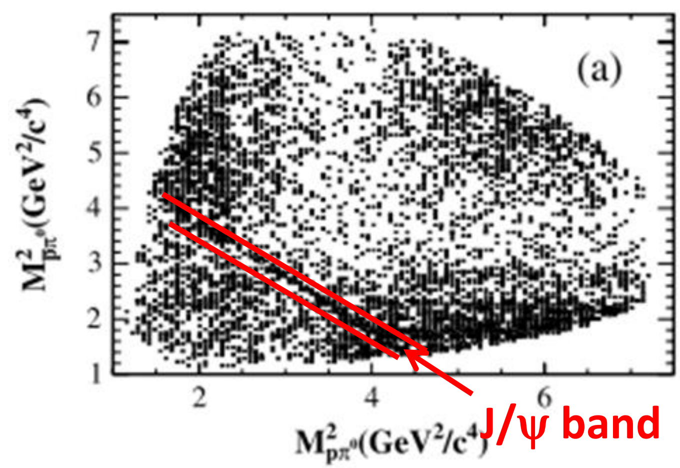
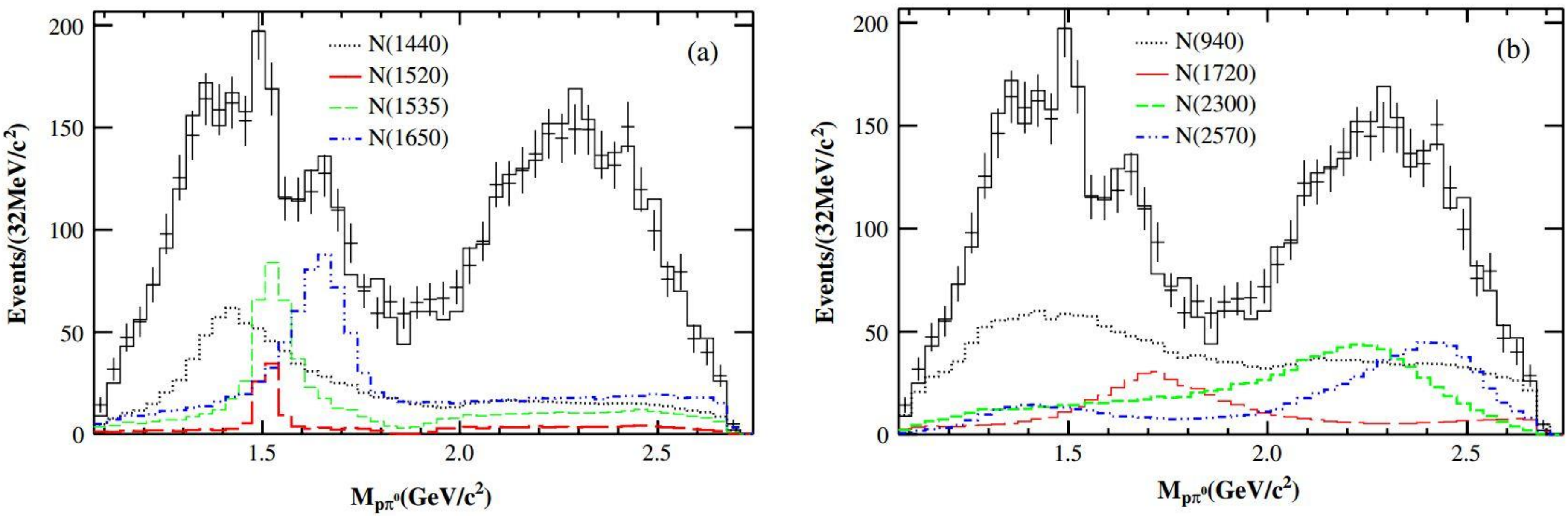


N* in ψ′ → p $\bar{p}$ π^0

Phys. Rev. Lett. 110, 022001 (2013)



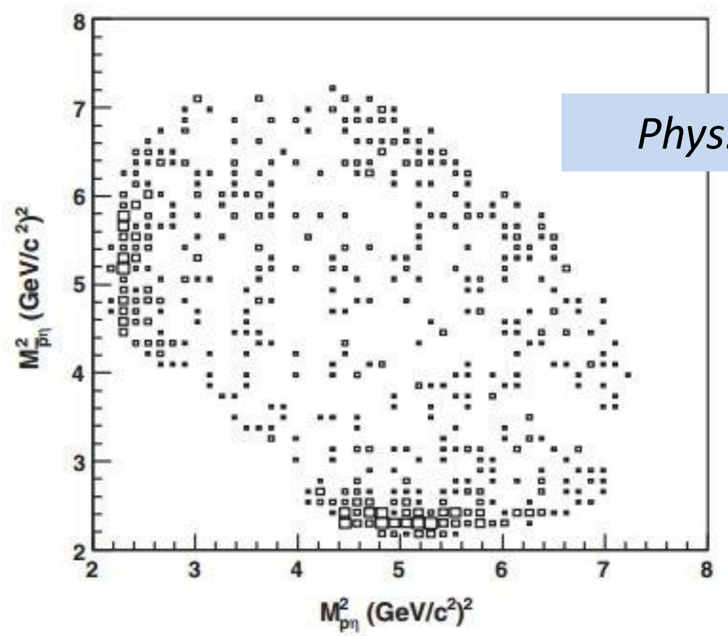
Resonance	$M(\mathrm{MeV}/c^2)$	$\Gamma(\mathrm{MeV}/c^2)$	Sig.	J^P
$N(1440)$	1390^{+11+21}_{-21-30}	$340^{+46+70}_{-40-156}$	11.5σ	1/2+
$N(1520)$	1510^{+3+11}_{-7-9}	115^{+20+0}_{-15-40}	5.0σ	3/2-
$N(1535)$	1535^{+9+15}_{-8-22}	120^{+20+0}_{-20-42}	9.3σ	1/2-
$N(1650)$	1650^{+5+11}_{-5-30}	150^{+21+14}_{-22-50}	12.2σ	1/2-
$N(1720)$	1700^{+30+32}_{-28-35}	$450^{+109+149}_{-94\ -44}$	9.6σ	3/2+
N(2300)	$\mathbf{2300^{+40+109}_{-30-0}}$	$\mathbf{340^{+30+110}_{-30-58}}$	$\mathbf{15.0\sigma}$	1/2+
N(2570)	$\mathbf{2570^{+19+34}_{-10-10}}$	$\mathbf{250^{+14+69}_{-24-21}}$	$\mathbf{11.7\sigma}$	5/2-

Study of N(1535)
$\Psi(3686) \rightarrow p\ \bar{p}\ \eta$

➢ Threequark resonance or ΣK-Nη coupled-channel effect?

N(1535) may deserve an interpretation beyond the quark model

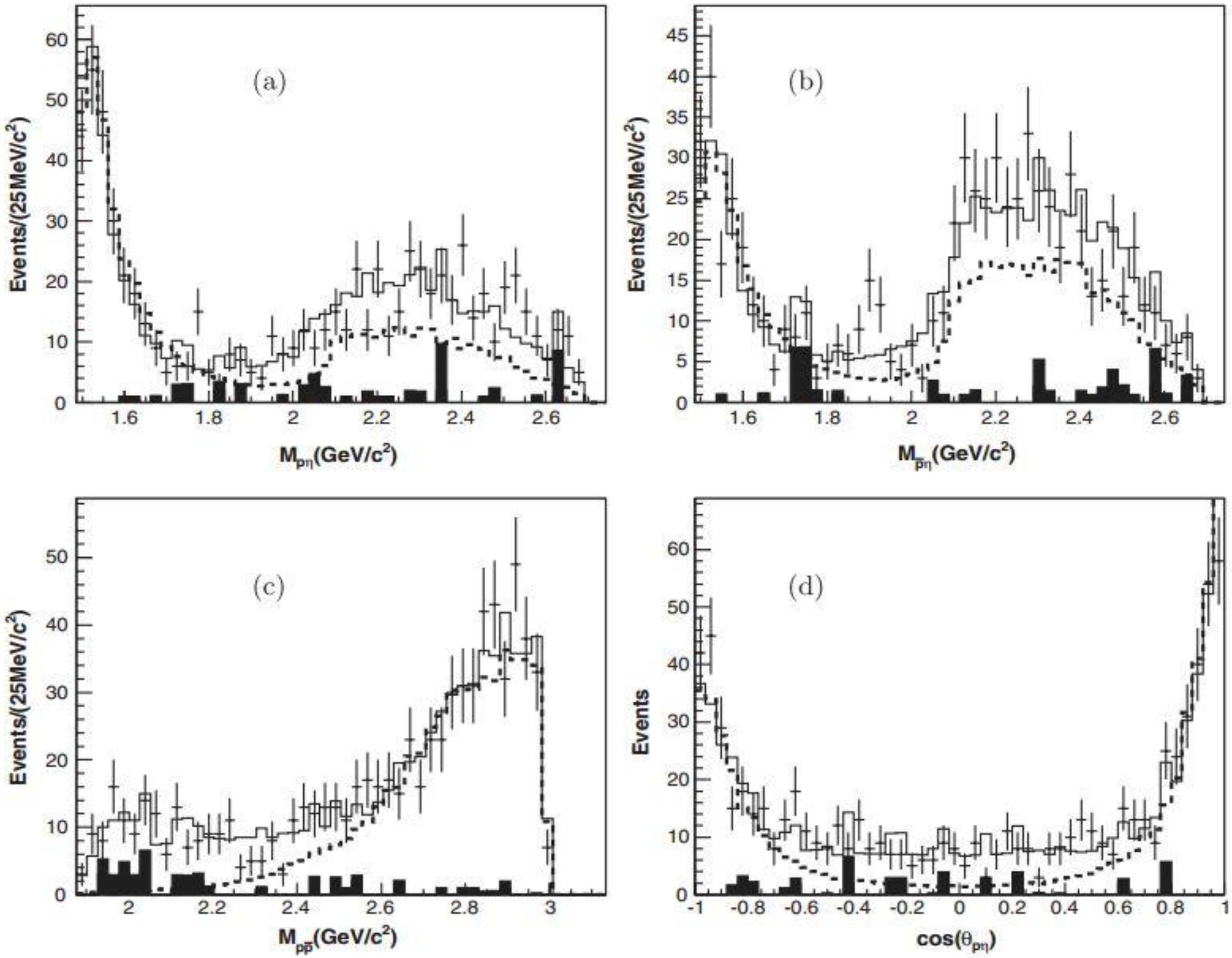
➢The large decay branching ratio to Nη.



Phys. Rev. D. 88, 032010 (2013)

N* in ψ' → p $\bar{p}$ η

Phys. Rev. D. 88, 032010 (2013)



Two components:

1. N(1535) ½-
2. PHSP

Mass:

$1.524^{+0.005+0.010}_{-0.005-0.004}$ GeV/C²

Width:

$0.130^{+0.027+0.061}_{-0.027-0.014}$ GeV

PDG:

M=1.535±0.01GeV/c²

Γ = 125~175MeV/c²

Thank you for your attention!