BESIII Status and Recent Results

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Outline

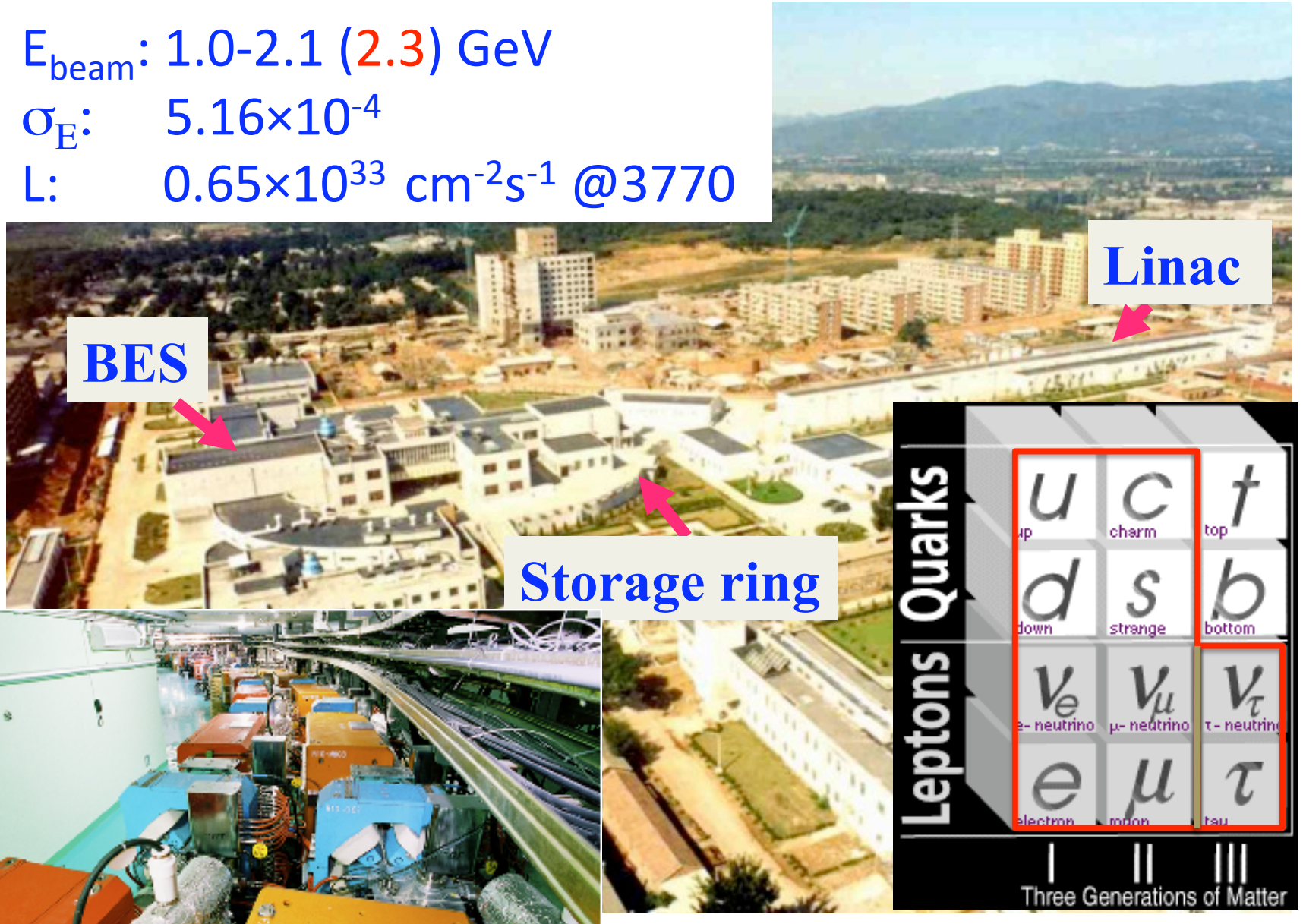
- Introduction
- Status
- Selected recent results
- Excited baryon physics program
- Summary

Beijing Electron Positron Collider (BEPC)

E_{beam}: 1.0-2.1 (2.3) GeV

σ_E: 5.16×10^{-4}

L: 0.65×10^{33} $cm^{-2}s^{-1}$ @3770



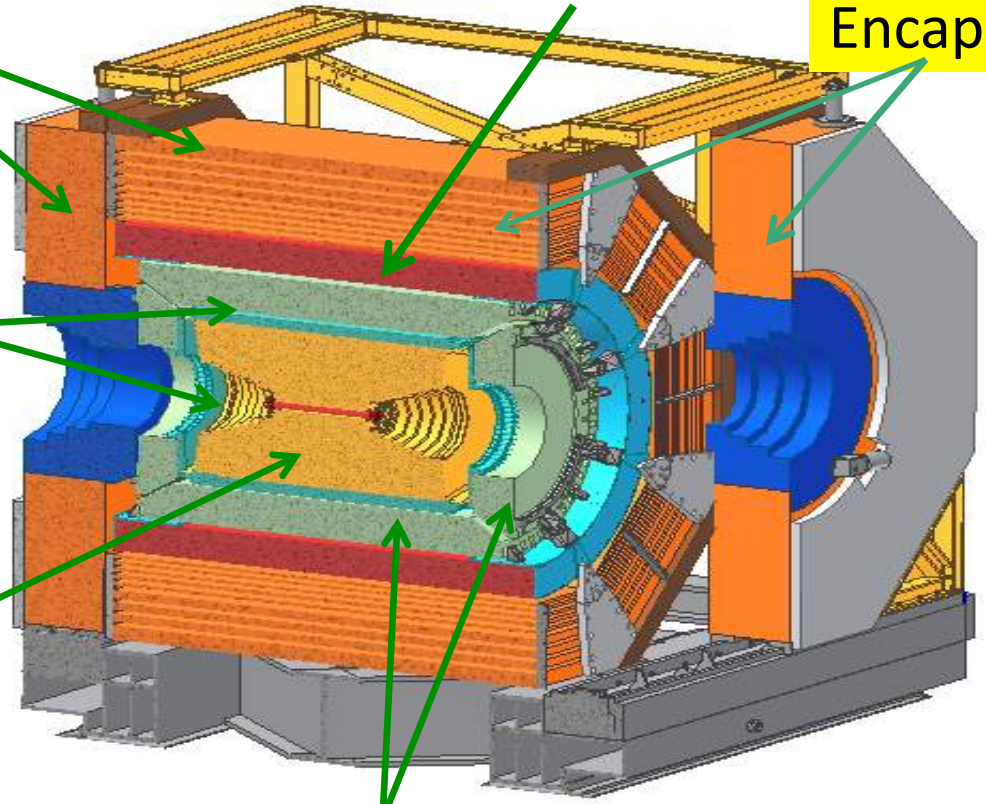
The BESIII Detector

Magnet yoke

SC magnet (1T)

RPC Muon Counter
Barrel: 9 layers
Encaps: 8 layers

Time-of-flight(TOF)
σ_T(barrel): 90 ps
σ_T(endcap): 110 ps



Drift chamber
σ_p/p = 0.5% at 1 GeV
σ(dE/dx)/dE/dx ~ 6%

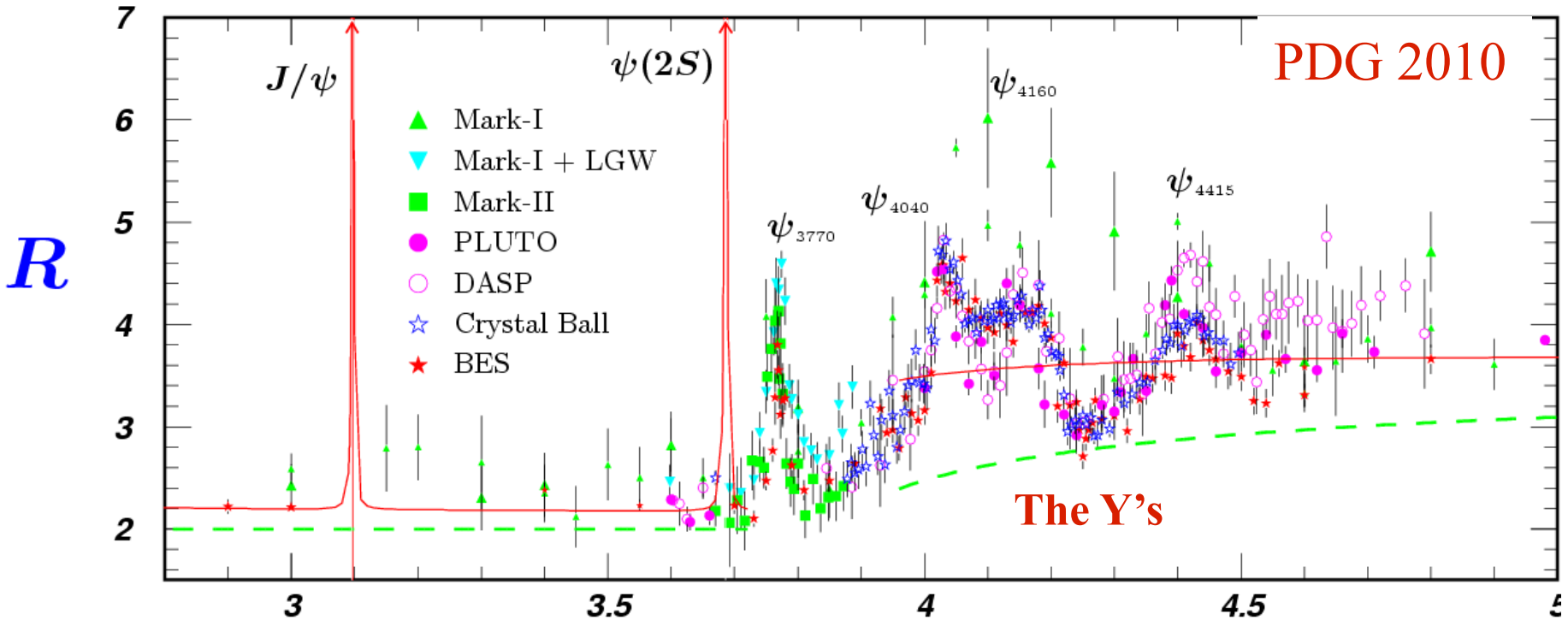
ECAL calorimeter CsI(Tl)
σ_E /E ~2.5% at 1 GeV

BESIII Collaboration

http://bes3.ihep.ac.cn ~300 members from 48 institution of 9 counties

Features of the BEPC Energy Region

- Rich of resonances, charmonium and charmed mesons
- Threshold characteristics (pairs of τ, D, D_s, charmed baryons…)
- Transition between smooth and resonances, perturbative and non-perturbative QCD
- Energy location of the gluonic matter and glueball, exotic states and hybrid



Physics Topics at BES

- **Light hadron spectroscopy**
  - Search for exotic hadrons
  - Spectroscopy of meson and baryons
- **Charmonium**
  - New charmonium states above open charm threshold.
  - Production and decay mechanisms
  - Spectroscopy
- **Open charm**
  - Precision measurement of CKM matrix
  - Decay constants and form factor
  - D_0-D_0bar mixing, CPV
- **Precise measurement of R values, τ mass, …**
- **Search for rare/forbidden decays, LVP, CP violation, etc.**

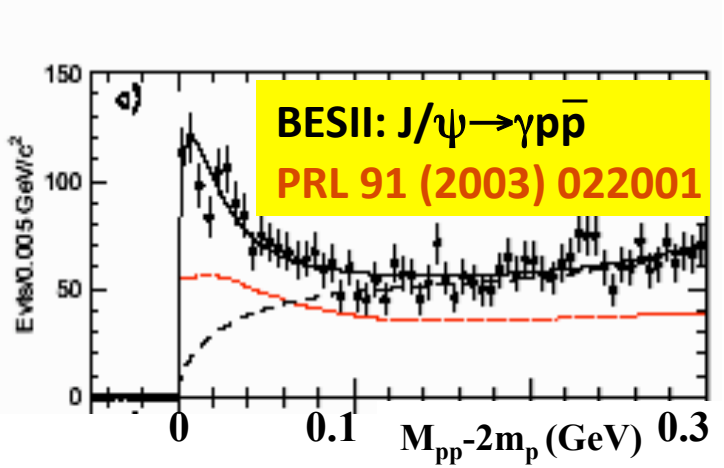
BESIII Data Samples

	Previous	BESIII (2009-2014)	BESIII target
J/ψ	BESII: 58M	2009：225M 2012：1 B (?)	10B
ψ'	BESII: 14M CLEO: 28 M	2009：106M 2012：0.5B (?)	3 B
ψ(3770)	CLEO：0.8 /fb	2010：0.9/fb 2011：2/fb	20 /fb
ψ(4010), ψ(4160),… & scan	CLEO: 0.6 /fb	2011: 0.5/fb (?) 2013：5/fb	
R scan & Tau	BESII	2014	

Results from BESIII

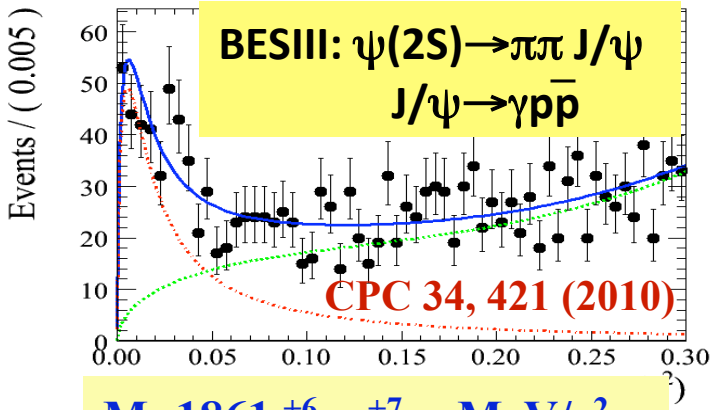
- Confirm BESII results
  - threshold enhancement in $\gamma p\bar{p}$, X(1835), …
- New improved measurements
  - h_c, η_c, χ_{cJ}, , …
- New observations
  - χ_{cJ} decays
  - h_c decays
  - Light hadrons, …

$p\bar{p}$ Threshold Enhancement



$M = 1859\ ^{+3}_{-10}\ ^{+5}_{-25}$ MeV/c^2

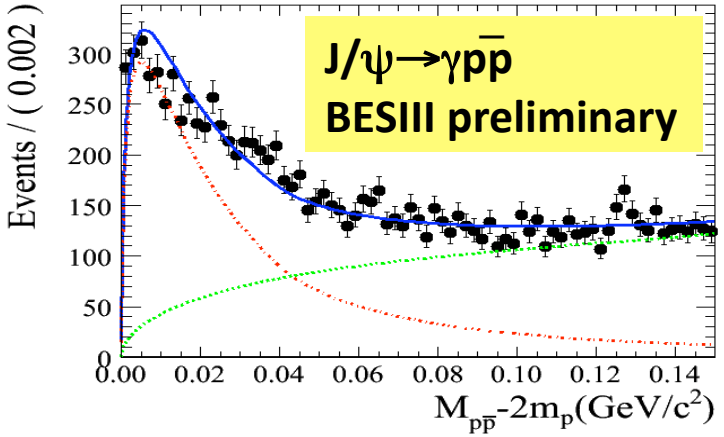
$\Gamma < 30$ MeV/c^2 (90% CL)

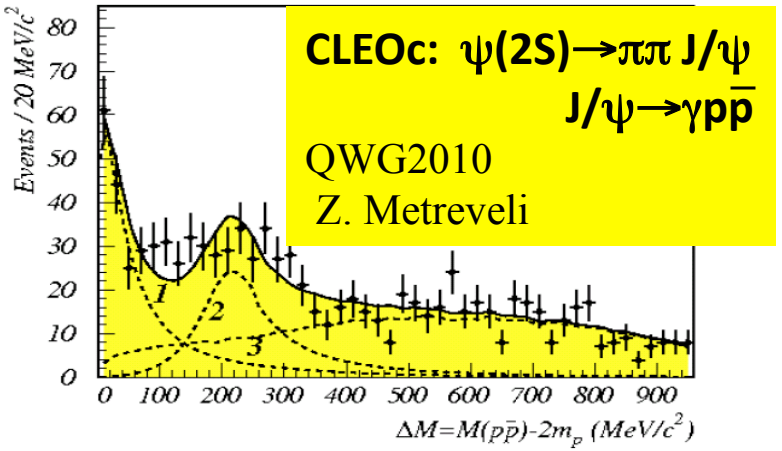


$M = 1861\ ^{+6}_{-13}\ ^{+7}_{-26}$ MeV/c^2

$\Gamma < 38$ MeV/c^2 (90% CL)

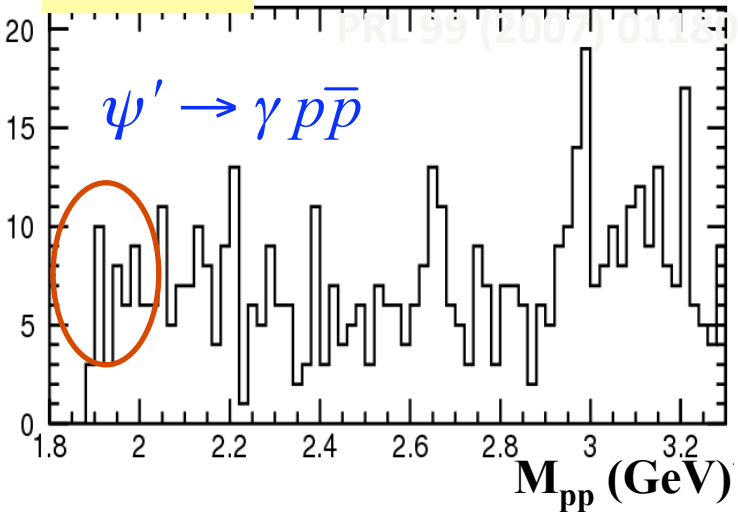
- Observed at BESII in 2003
- Confirmed by CLEOc and BESIII
- Agree with BESII results



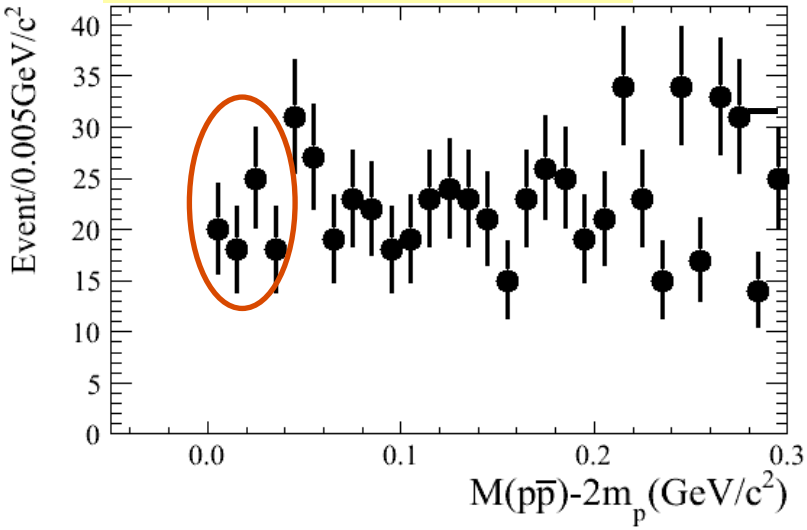


$\psi' \rightarrow \gamma p\bar{p}$

BESII



BESIII preliminary

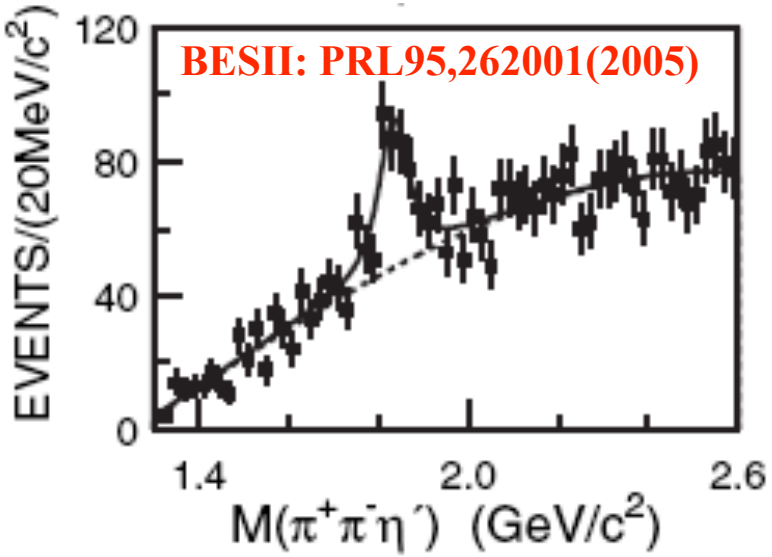


No significant narrow strong enhancement near threshold (~2σ if fitted with X(1860))

No significant narrow threshold enhancement

Pure FSI interpretation of the narrow and strong $p\bar{p}$ threshold enhancement is disfavored. Other possibilities: conventional meson, $p\bar{p}$ bound state or glueball…..?

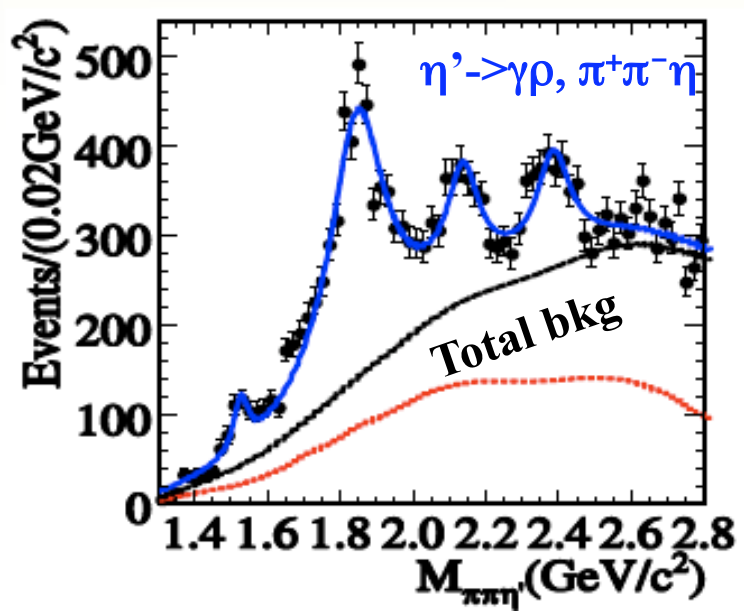
Observation of X(1835) from $J/\psi \to \gamma\pi^+\pi^-\eta'$



M=1833.7±6.1(stat)±2.7(syst)MeV

Γ=67.7±20.3(stst)±7.7(syst)MeV

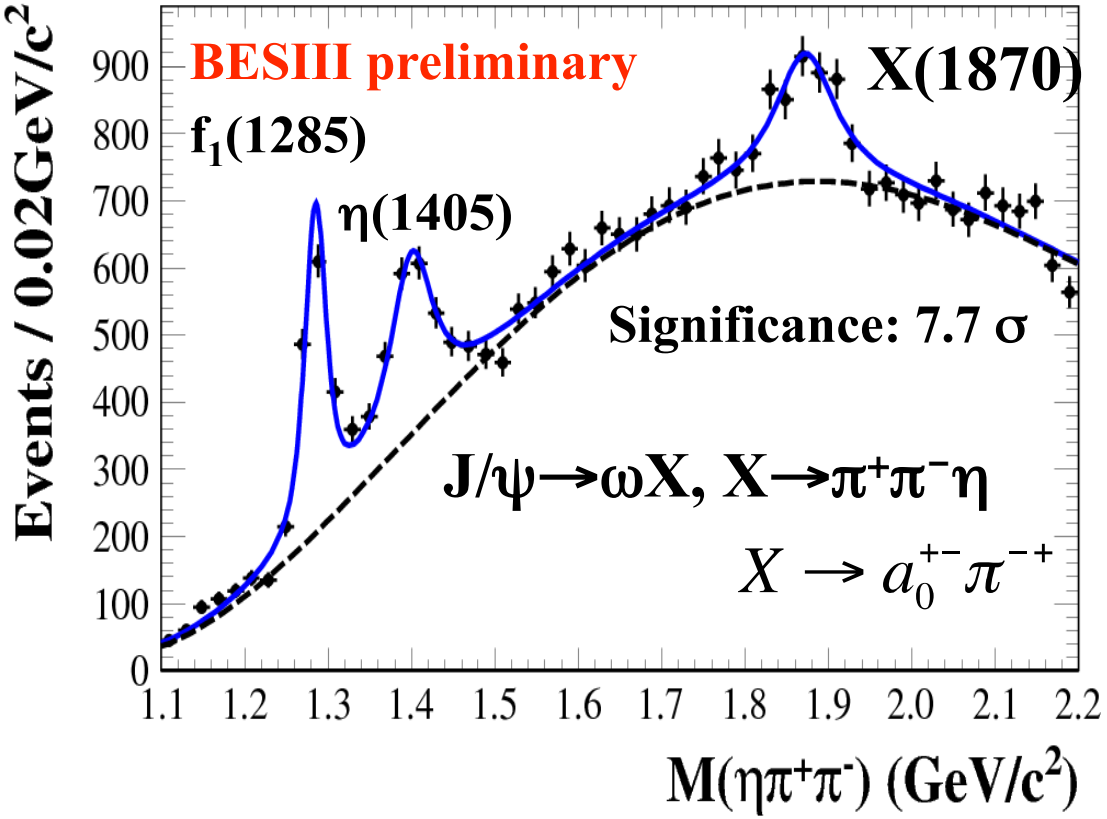
- **X(1835) is confirmed at BESIII**
- **Two new resonances are observed**
- **PWA is needed, inference among the resonances needs to be considered**



State	M(MeV)	Γ(MeV)	Stat. sig. (σ)
X(1835)	1838.1±2.8	179.5±9.1	25
X(2120)	2124.8±5.6	101±14	7.2
X(2370)	2371.0±6.4	108±15	6.7

PRL 106 (2011) 072002

Observation of X(1870)



The $f_1(1285)$, $\eta(1405)$ and X(1870) primarily decay via $a_0(980)\pi^{\pm}$

M=1873 ± 11 MeV
Γ=82 ± 19 MeV

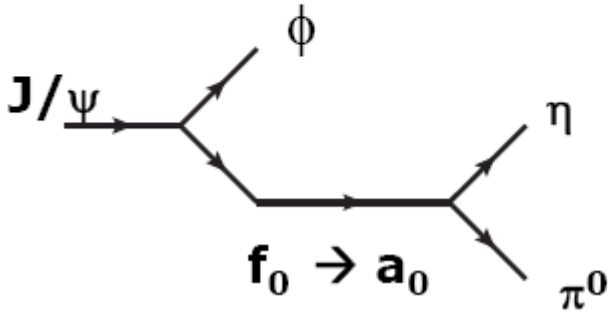
Statistical error only!

Is X(1870) a new resonance, or $\eta_2(1870)$ or X(1835)?

$a_0(980) - f_0(980)$ Mixing

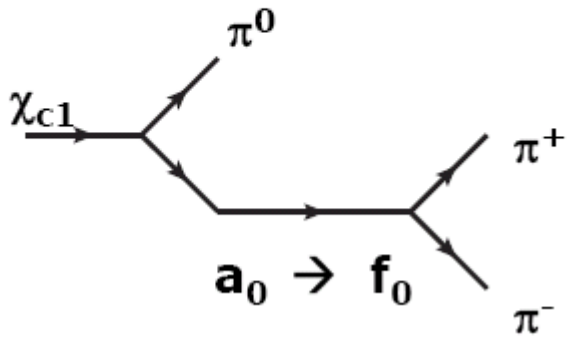
- Mixing intensity provides important information to understand the nature of $a_0(980)$ and $f_0(980)$.
- Narrow peak (8 MeV) at around 980 MeV can be expected in $\eta\pi$ ($J/\psi \rightarrow \phi f_0 \rightarrow \phi a_0 \rightarrow \phi\eta\pi$ case) or $\pi^+\pi^-$ ($\chi_{c1} \rightarrow a_0\pi^0 \rightarrow f_0\pi^0 \rightarrow \pi^+\pi^-\pi^0$ case) invariant mass spectra.

J.Wu, Q.Zhao, B.Zou PRD75 114012,
C. Hanhart etc. PRD76 074028,
etc.



$J/\psi \rightarrow \phi f_0 \rightarrow \phi a_0 \rightarrow \phi\eta\pi$

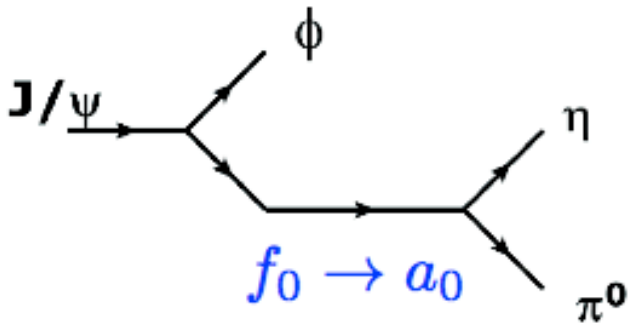
J.Wu, B.Zou PRD78 074017

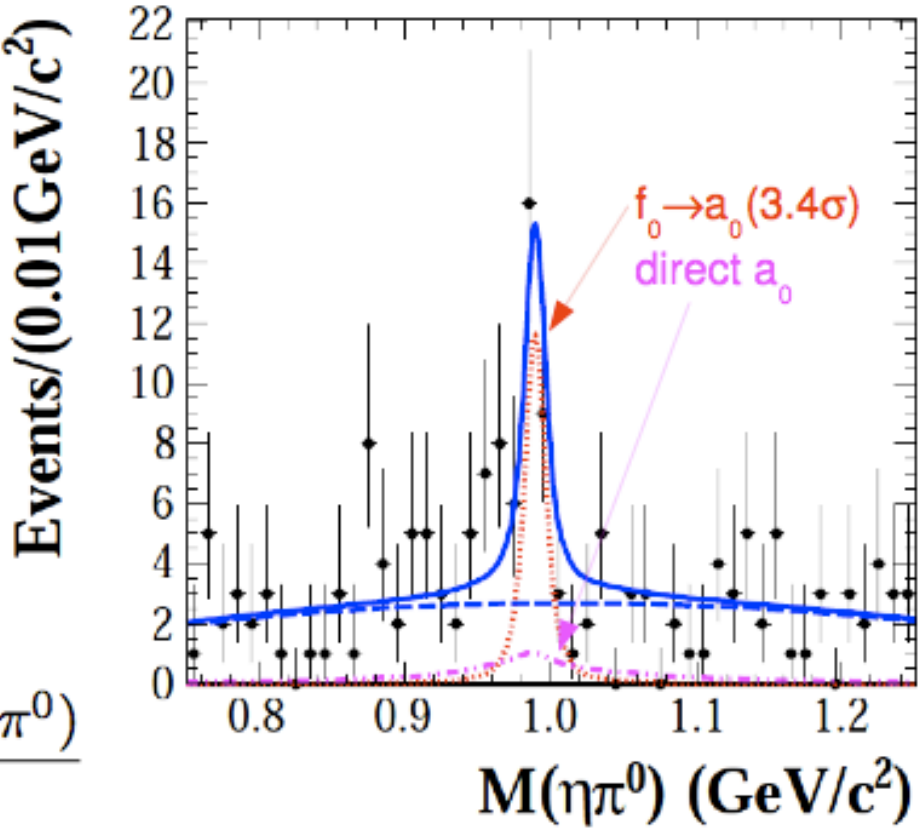


$\chi_{c1} \rightarrow a_0\pi^0 \rightarrow f_0\pi^0 \rightarrow \pi^+\pi^-\pi^0$

a_0-f_0 Mixing

- $f_0 \to a_0$ mixing intensity





$$\xi_{fa} = \frac{\mathcal{B}(J/\psi \to \phi f_0 \to \phi a_0 \to \phi\eta\pi^0)}{\mathcal{B}(J/\psi \to \phi f_0 \to \phi\pi\pi)}$$

$$= (0.6 \pm 0.2_{stat} \pm 0.12_{sys} \pm 0.26_{para})\%$$

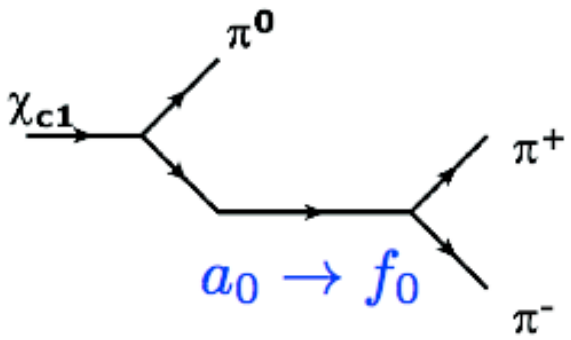
$$< 1.1\% \ (90\%CL)$$

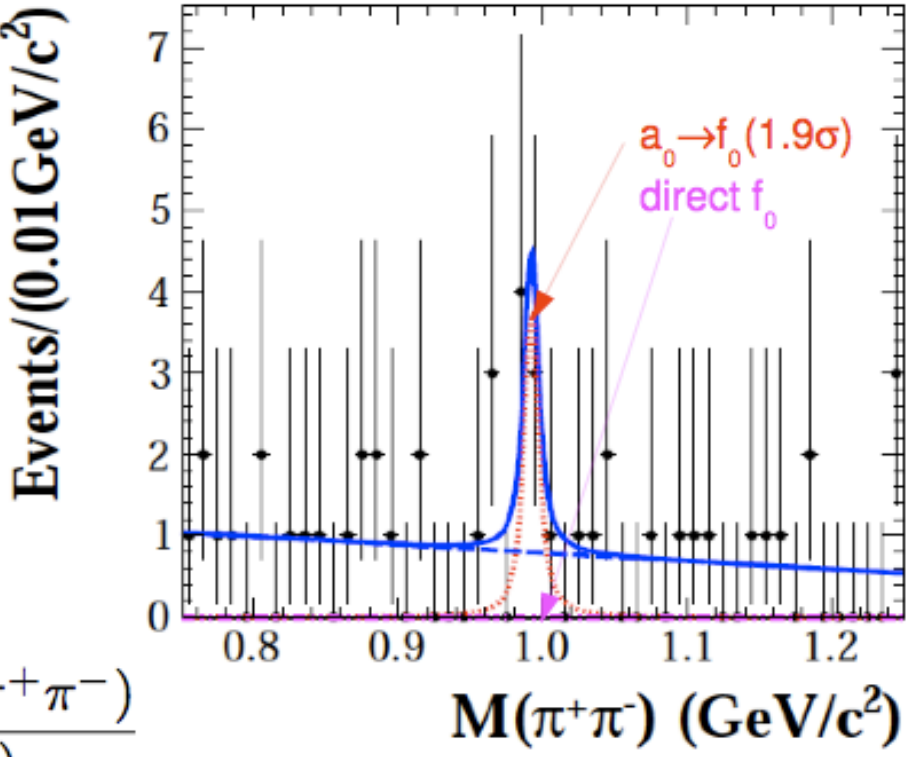
uncertainties from signal parameterization

BESIII, Phys.Rev. D83 032003 (2011)

a_0-f_0 Mixing

- $a_0 \to f_0$ mixing intensity





$$\xi_{af} = \frac{\mathcal{B}(\chi_{c1} \to \phi a_0 \to \phi f_0 \to \phi\pi^+\pi^-)}{\mathcal{B}(J/\psi \to \phi a_0 \to \phi\eta\pi)}$$

$$= (0.31 \pm 0.16_{stat} \pm 0.14_{sys} \pm 0.03_{para})\%$$

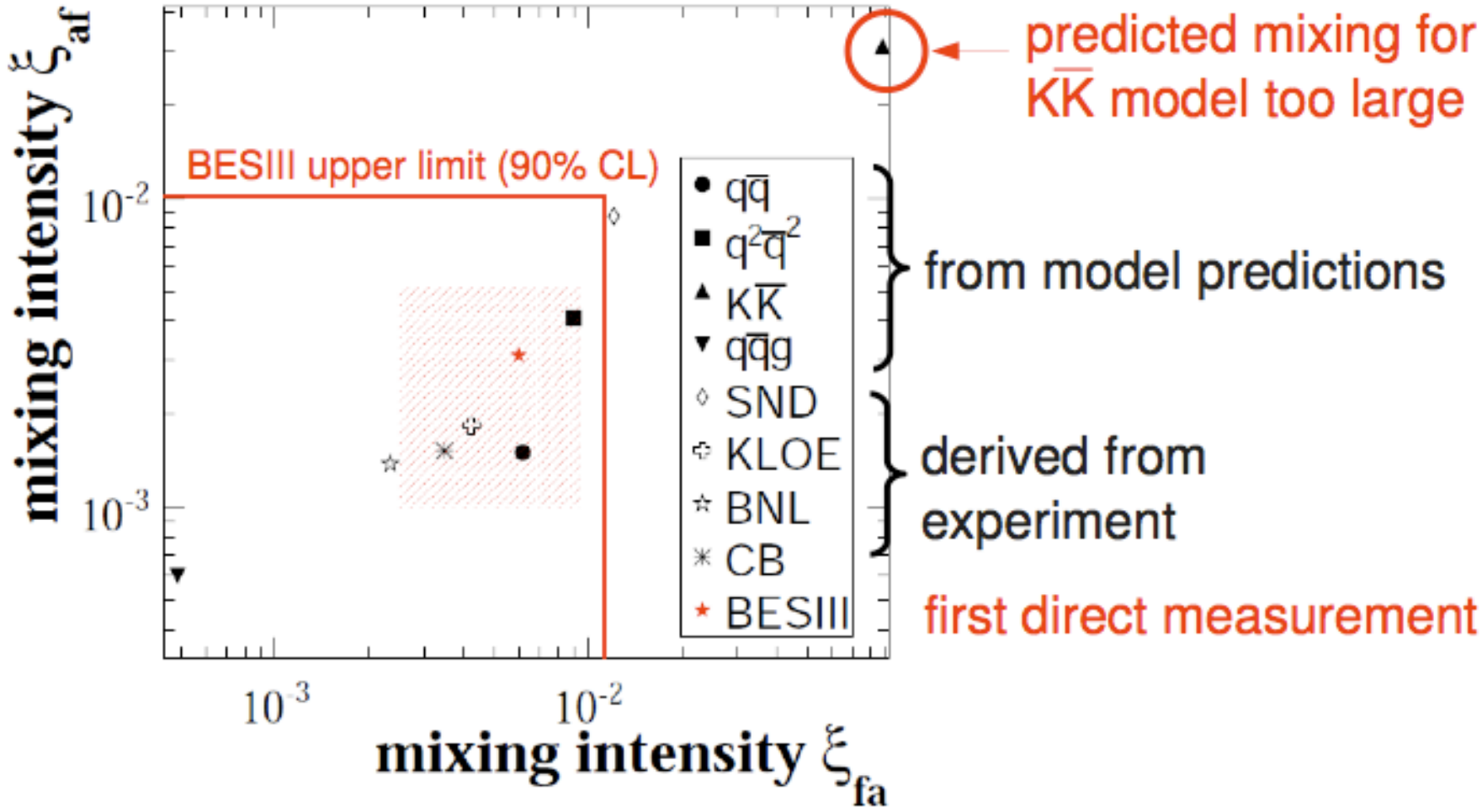
$$< 1\% \ (90\%CL)$$

uncertainties from signal parameterization

BESIII, Phys.Rev. D83 032003 (2011)

a_0-f_0 Mixing

mixing intensities can be derived from measured / predicted
$f_0 \to K^+K^-, a_0 \to K^+K^-, \eta\pi$ coupling constants



Excited Baryon at BES

- The understanding of the internal quark-gluon structure of baryons is one of the most important tasks in both particle and nuclear physics.
- The systematic study of various baryon spectroscopy will provide us with critical insights into the nature of QCD in the confinement domain.
- The available experimental information is still poor, especially for the excited baryon states with two strange quarks, e.g., Ξ^*. Some phenomenological QCD-inspired models predict more than 30 such kinds of baryons, however only two are experimentally well established.

List of Nucleon Resonances (uud, udd)

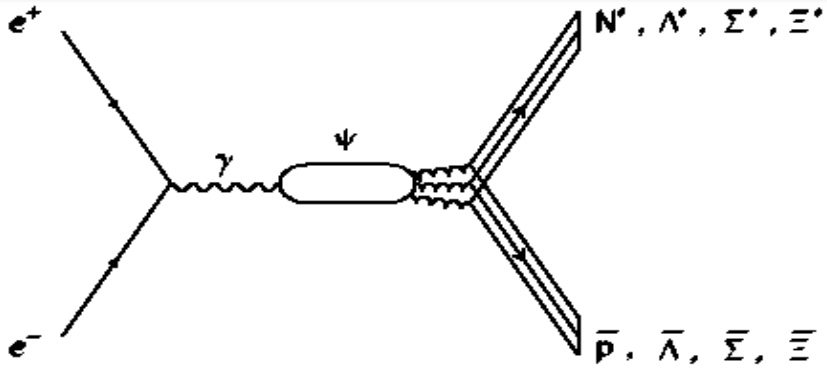
Particle	$L_{2I\cdot 2J}$	Overall status	Status as seen in — $N\pi$	$N\eta$	ΛK	ΣK	$\Delta\pi$	$N\rho$	$N\gamma$
$N(939)$	P_{11}	****							
$N(1440)$	P_{11}	****	****	*			***	*	***
$N(1520)$	D_{13}	****	****	*			****	****	****
$N(1535)$	S_{11}	****	****	****			*	**	***
$N(1650)$	S_{11}	****	****	*	***	**	***	**	***
$N(1675)$	D_{15}	****	****	*	*		****	*	****
$N(1680)$	F_{15}	****	****				****	****	****
$N(1700)$	D_{13}	***	***	*	**	*	**	*	**
$N(1710)$	P_{11}	***	***	**	**	*	**	*	***
$N(1720)$	P_{13}	****	****	*	**	*	*	**	**
$N(1900)$	P_{13}	**	**					*	
$N(1990)$	F_{17}	**	**	*	*	*			*
$N(2000)$	F_{15}	**	**	*	*	*	*	**	
$N(2080)$	D_{13}	**	**	*	*				*
$N(2090)$	S_{11}	*	*						
$N(2100)$	P_{11}	*	*	*					
$N(2190)$	G_{17}	****	****	*	*	*		*	*
$N(2200)$	D_{15}	**	**	*	*				
$N(2220)$	H_{19}	****	****	*					
$N(2250)$	G_{19}	****	****	*					
$N(2600)$	$I_{1\,11}$	***	***						
$N(2700)$	$K_{1\,13}$	**	**						

PDG 2008

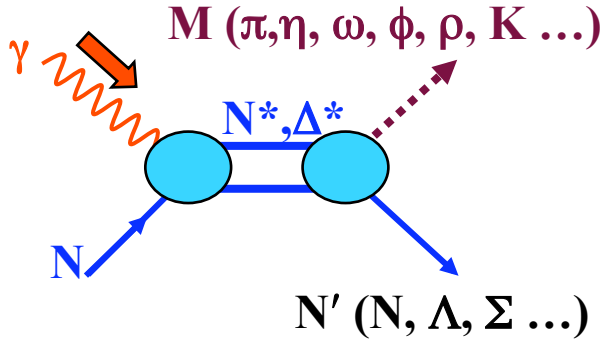
(**)
not well-established

Excited Baryons from Charmonium Decays

$$J/\psi(\psi') \to \bar{B}BM \Rightarrow N^*, \Lambda^*, \Sigma^*, \Xi^*$$

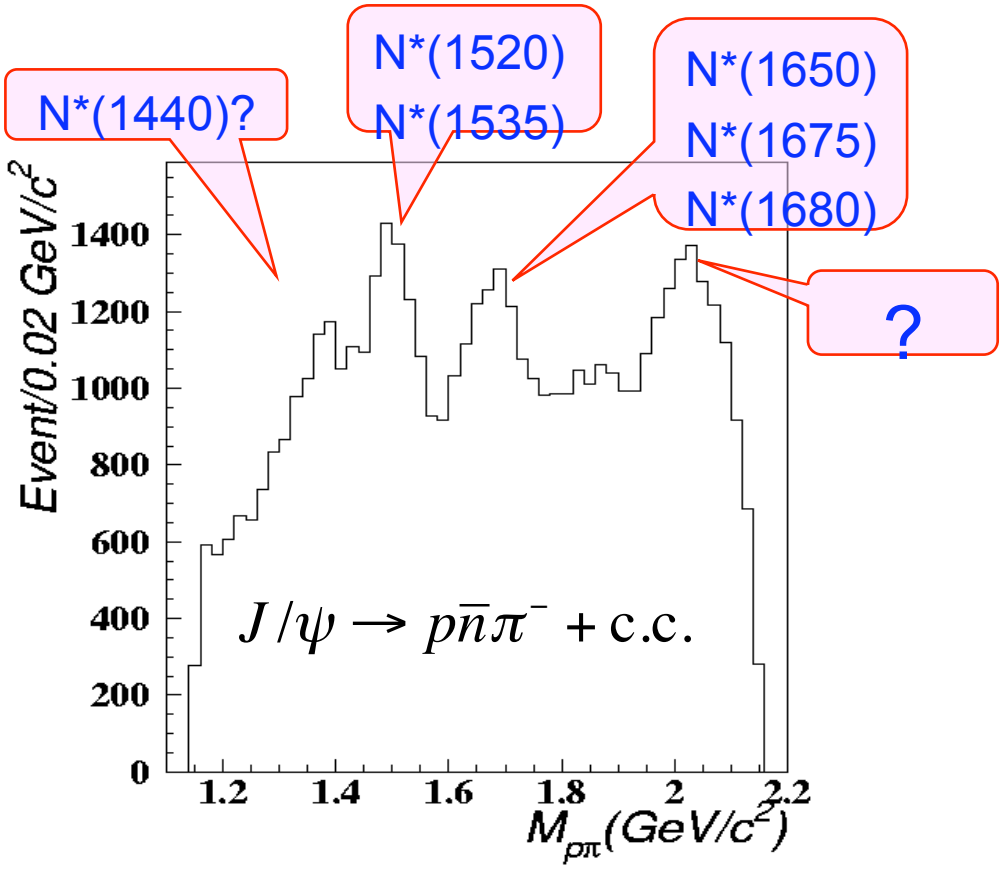


JLab, ELSA, MAMI, ESRF, Spring-8, ….

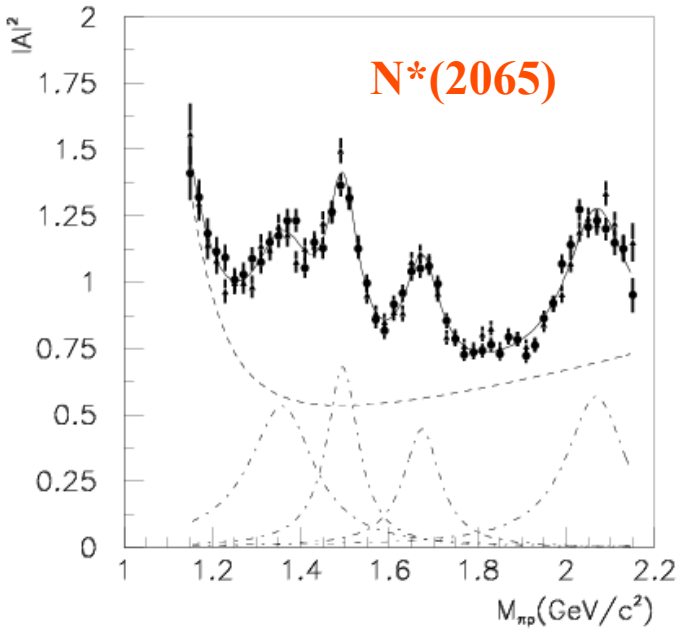


- Excited baryons can be produced through J/ψ decays.
- For J/ψ → πNN̄ and ππNN̄ decays, the Nπ and Nππ are pure isospin ½ system.
- Search for "missing" baryon states and hybrid baryon with large data sample at BESIII/BEPCII.

N*(2050) from BESII



BESII:
Phys. Rev. Lett. 97 (2006) 062001



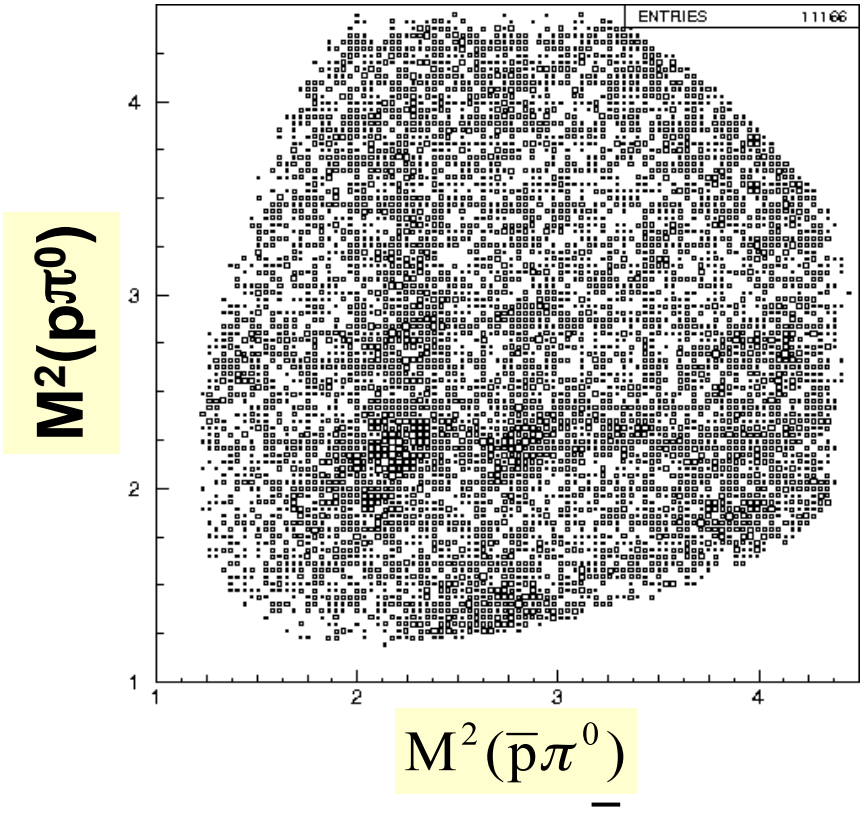
PWA not yet done

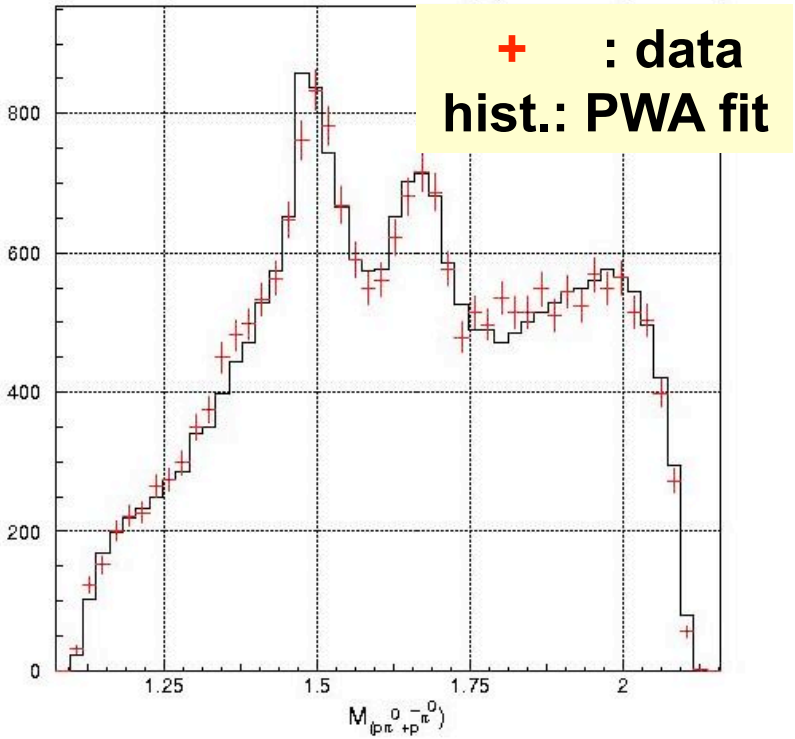
J^P of N(2050): $1/2^+$ or $3/2^+$

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

N*(2050) from $J/\psi \to p\bar{p}\pi^0$

BESII: Phys. Rev. D 80, 052004 (2009)





N*(2050) stat. sig. >>5σ, the spin-parity favors $3/2^+$

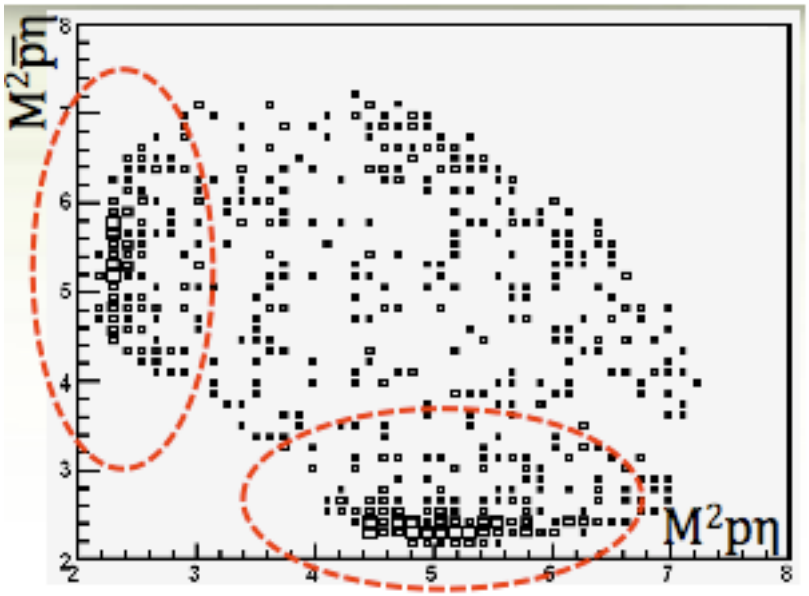
$$M = 2040^{+3}_{-4} \pm 25\ \text{MeV},\ \Gamma = 230 \pm 8 \pm 52\ \text{MeV}$$

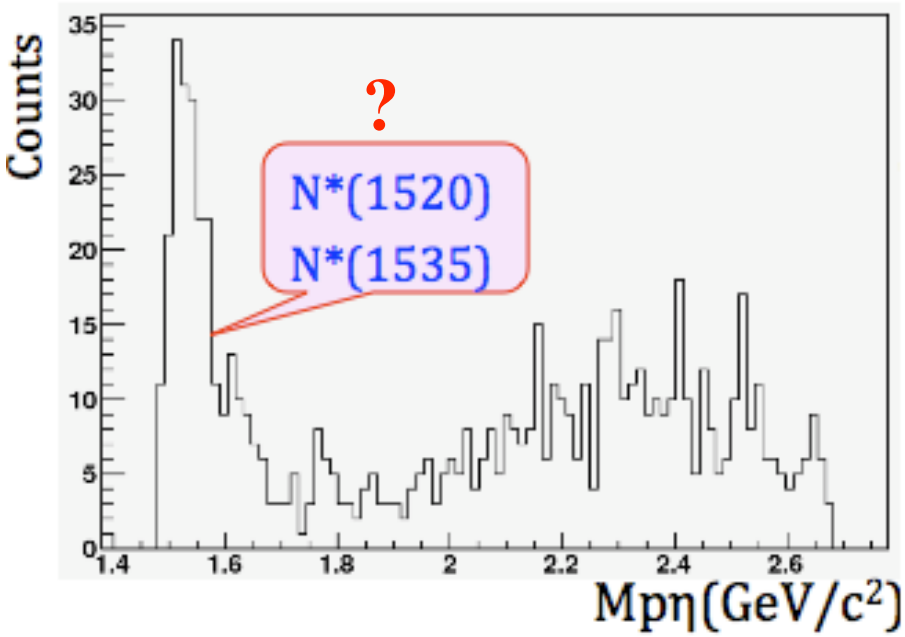
N*	M(MeV/c^2)	Γ(MeV/c^2)	J^P	fraction(%)	Br (×10^{-4})
N(1440)	$1455^{+2}_{-7} \pm 43$	$316^{+5}_{-6} \pm 67$	1/2+	9.74~25.93	1.33~3.54
N(1520)	$1513^{+3}_{-4} \pm 13$	$127^{+7}_{-8} \pm 37$	3/2-	2.38~10.92	0.34~1.54
N(1535)	$1537^{+2}_{-6} \pm 12$	$135^{+8}_{-8} \pm 39$	1/2-	6.83~15.58	0.92~2.10
N(1650)	$1650^{+3}_{-6} \pm 26$	$145^{+5}_{-10} \pm 31$	1/2-	6.89~27.94	0.91~3.71
N(1710)	$1715^{+2}_{-2} \pm 29$	$95^{+2}_{-1} \pm 44$	1/2+	4.17~30.10	0.54~3.86
N(2050)	$2040^{+3}_{-4} \pm 25$	$230^{+8}_{-8} \pm 52$	3/2+	23.0~41.8	0.91~3.11

BESIII will provide better opportunity to study of baryon spectroscopy!

$N^*(1535)$ from $\psi' \rightarrow p\bar{p}\eta$ at BESIII

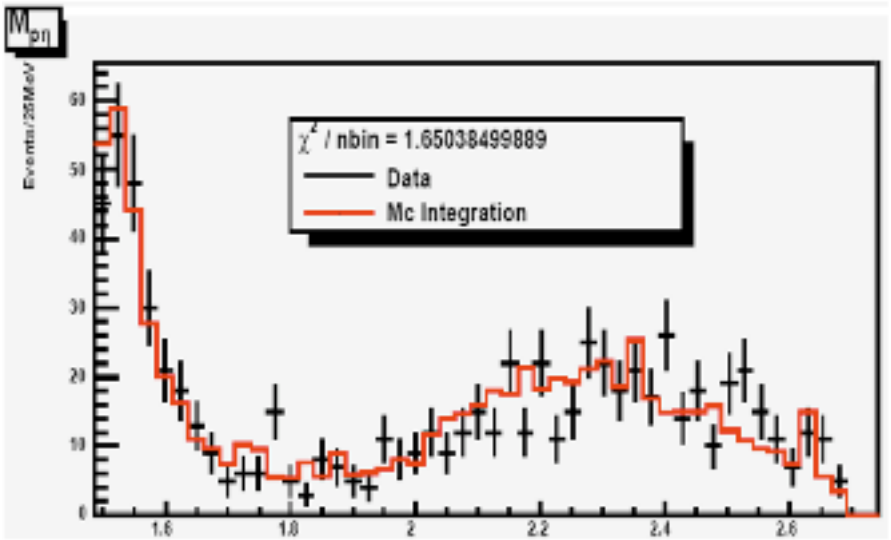
Yutie Liang's talk for details

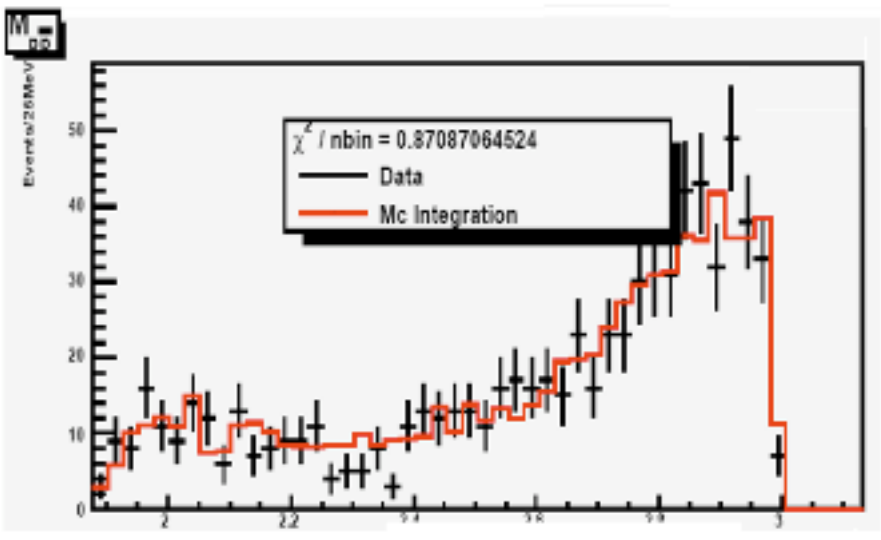




Preliminary

Preliminary Results from PWA





½⁻ N(1535) is significant in the PWA

BESIII preliminary

$$M = 1.524^{+0.005+0.016}_{-0.005-0.004}\ \mathrm{GeV/c^2}$$

$$\Gamma = 0.130^{+0.027+0.028}_{-0.027-0.014}\ \mathrm{GeV/c^2}$$

$$B(\psi' \to \eta p\bar{p}) = (6.6 \pm 0.2 \pm 0.6) \times 10^{-5}$$

PDG :

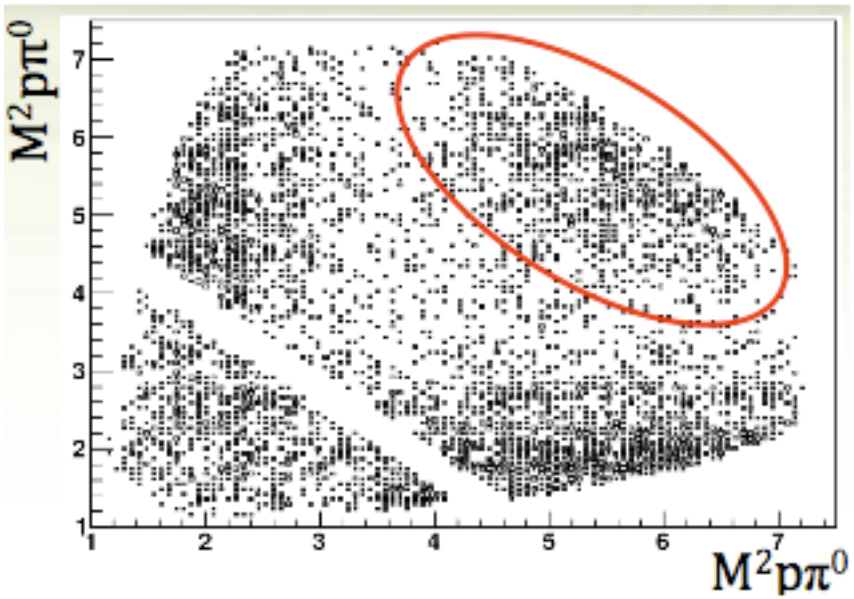
$1.525 - 1.545\ \mathrm{GeV/c^2}$

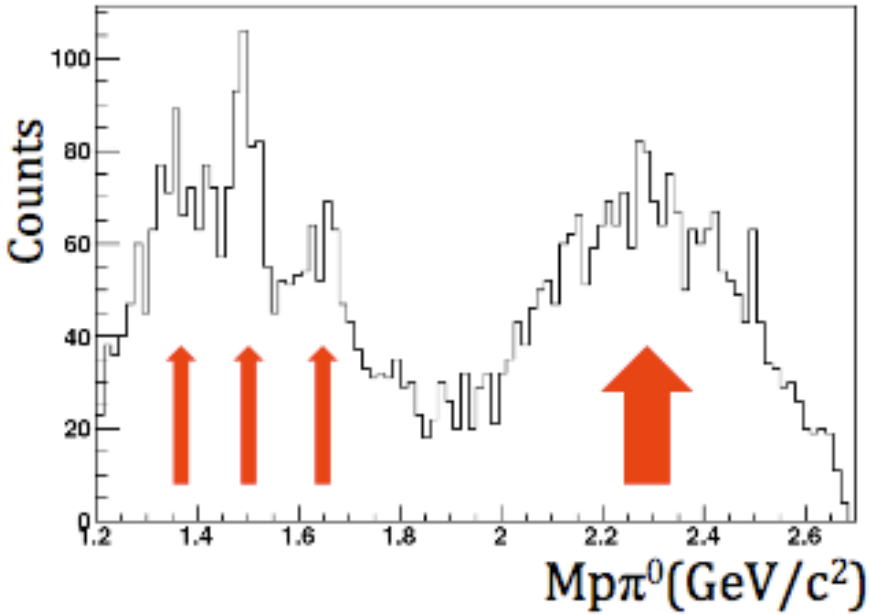
$0.125 - 0.175\ \mathrm{GeV/c^2}$

$(6.0 \pm 1.2) \times 10^{-5}$

Analysis of $\psi' \rightarrow p\bar{p}\pi^0$ at BESIII

Preliminary

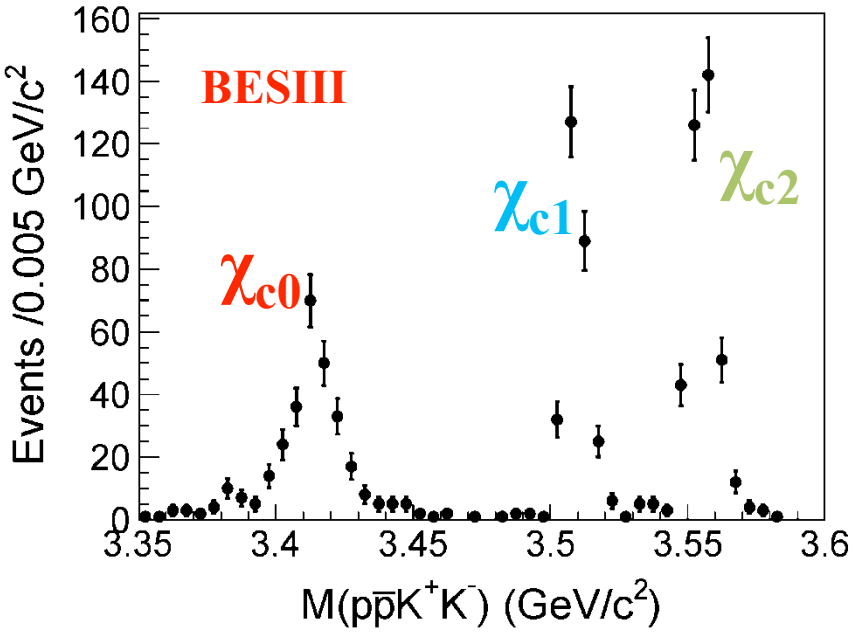


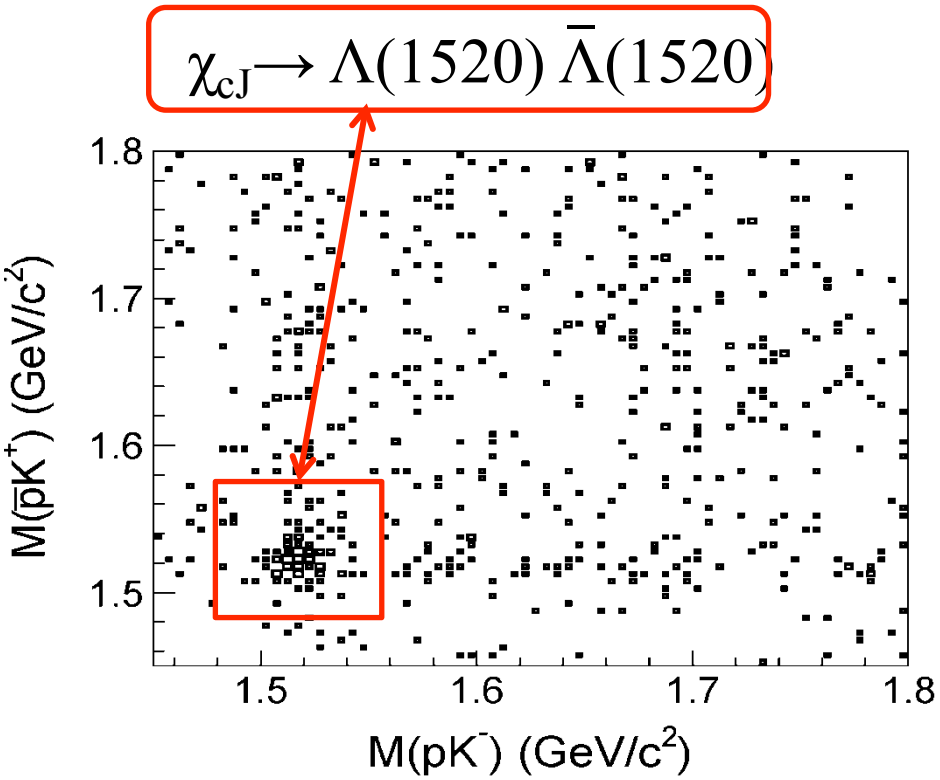


PWA is underway

Observation of χ_{cJ} decaying into $p\bar{p}K^+K^-$

- COM can describe most of χ_{cJ} decays except $\chi_{cJ}\to\Lambda\bar{\Lambda}$
- So far, only ground states of baryon (p, Λ) pairs has been reported in χ_{cJ} decays.
- Excited baryon state ($\Lambda(1520)\to pK$) is observed for the first time in the χ_{cJ} decays at BESIII





Observation of χ_{cJ} decaying into $p\bar{p}K^+K^-$

Besides two-body component, three-body components $\chi_{cJ} \to \bar{p}K^+\Lambda(1520)$+c.c. and $\chi_{cJ} \to p\bar{p}\varphi$ are also observed.

	χ_{c0}	χ_{c1}	χ_{c2}
$B(\chi_{cJ} \to p\bar{p}K^+K^-)$ (10^{-4})	1.24±0.20±0.18	1.35±0.15±0.19	2.08±0.19±0.30
$B(\chi_{cJ} \to \bar{p}K^+\Lambda(1520)+c.c.)$ (10^{-4})	3.00±0.58±0.50	1.81±0.38±0.28	3.06±0.50±0.54
$B(\chi_{cJ} \to \Lambda(1520)\bar{\Lambda}(1520))$ (10^{-4})	3.18±1.11±0.53	< 1.00	5.05±1.29±0.93
$B(\chi_{cJ} \to p\bar{p}\phi)$ (10^{-5})	6.12±1.18±0.86	< 1.82	3.04±0.85±0.43

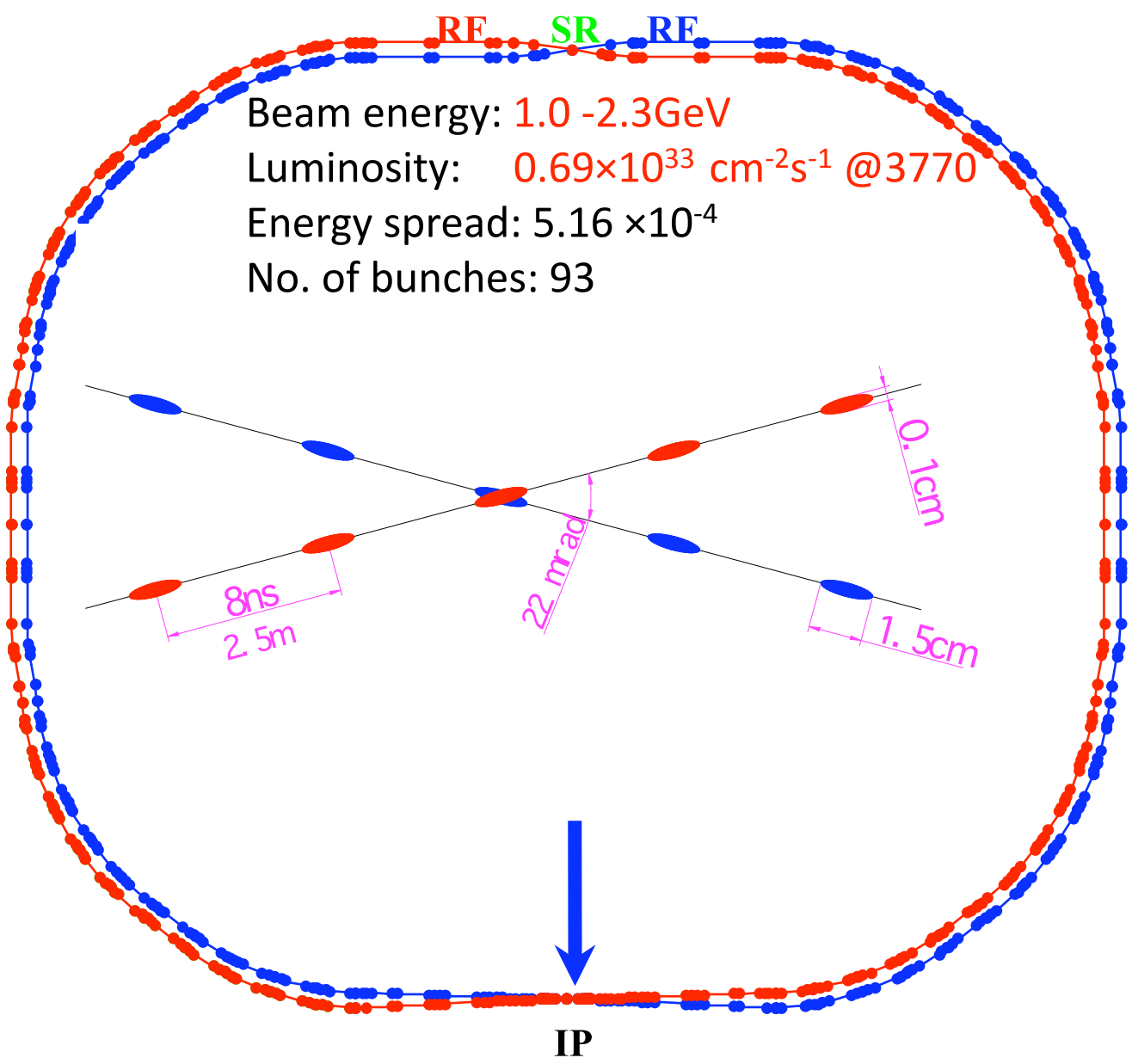
All are the first measurements from BESIII

Submitted to PRD. arXiv:1103.2661

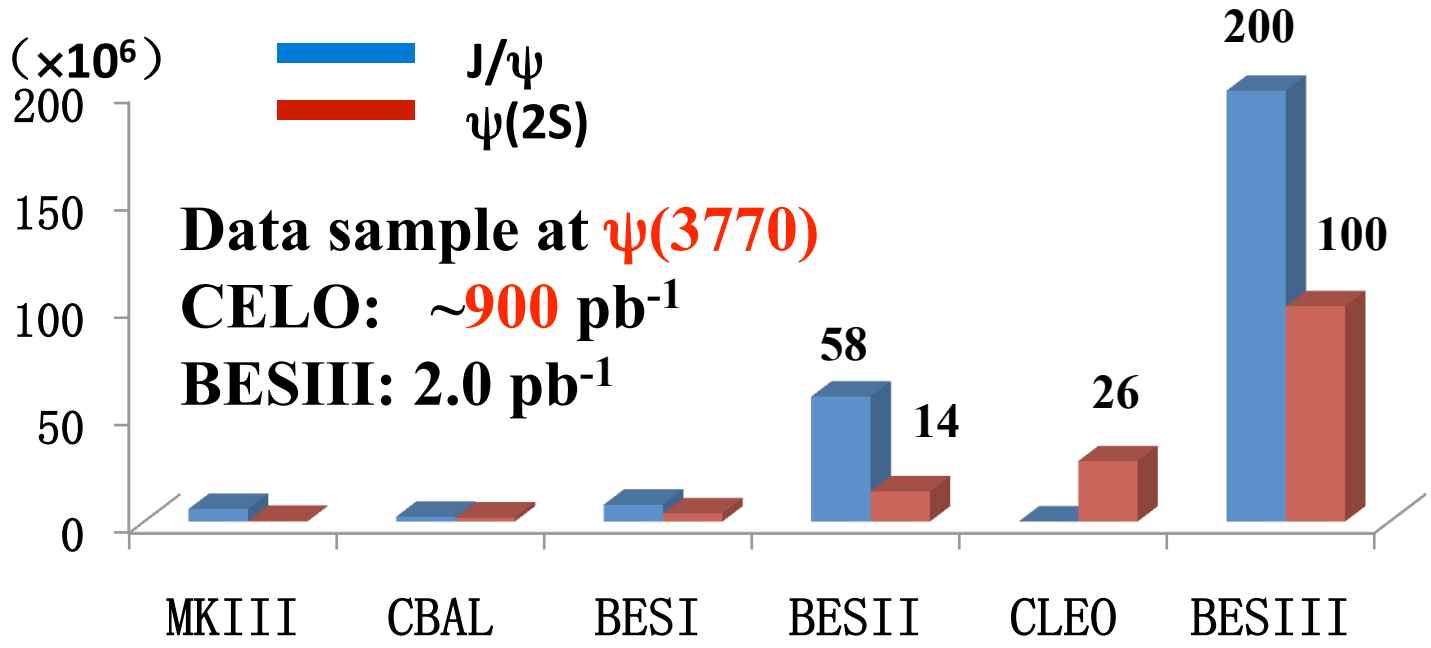
Summary

- BEPCII/BESIII is performing well
  - Peak luminosity reached at 3770 MeV: 6.5×10^{32}.
  - Data collected: 106 M $\psi(2S)$, 225 M J/ψ , 2.8 fb^{-1} at $\psi(3770)$.
  - ~500 pb^{-1} data sample will be collected at 4.01 GeV by the end of May.
  - Higher statistics data will be accumulated in the near future for J/ψ, ψ' data sample.
- Results are obtained from data sample of J/ψ, ψ'.
- Baryon physics program is underway, stay tuned.

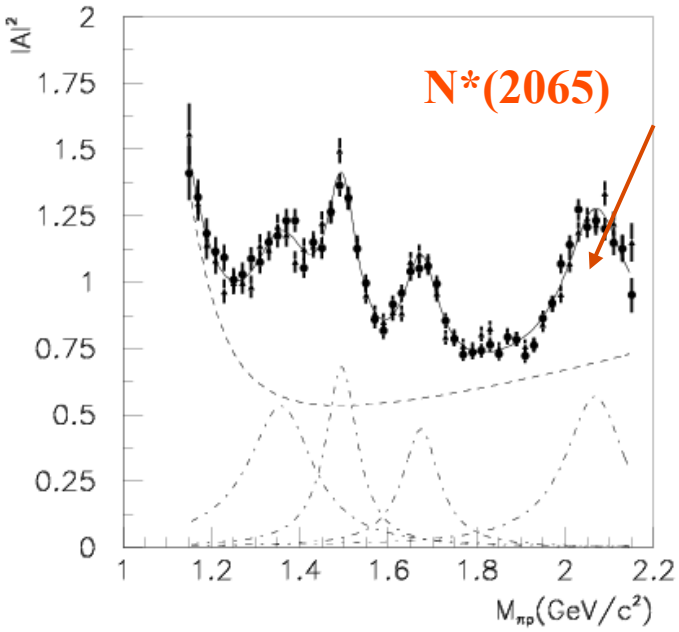
Upgraded BEPC-BEPCII



BES Data Samples



$$J/\psi \to p\bar{n}\pi^- + c.c.$$



Phys. Rev. Lett. 97 (2006) 062001

BW fit yields:

$$M = 2065 \pm 3^{+15}_{-30}\ \mathrm{MeV/c^2}$$

$$\Gamma = 175 \pm 12 \pm 40\ \mathrm{MeV/c^2}$$

PWA is performed.

- **well-established N*'s are fixed to PDG values.**
- **for N*(2065), L=1 is much worse than L=0 in the fit.**

→ $1/2^+$ or $3/2^+$ (improve log likelihood by 400)

$1/2^+$ + $3/2^+$ (improve log likelihood further by 60)

Study of h_c

- **Inclusive** analysis of $\psi(2S) \rightarrow \pi^0 h_c$

  identify h_c in the inclusive recoiling mass spectrum of π^0.

- **E1-tagged** analysis of $\psi(2S) \rightarrow \pi^0 h_c$, $h_c \rightarrow \gamma\eta_c$

  tag E1 photon (~503 MeV) in $h_c \rightarrow \gamma\eta_c$

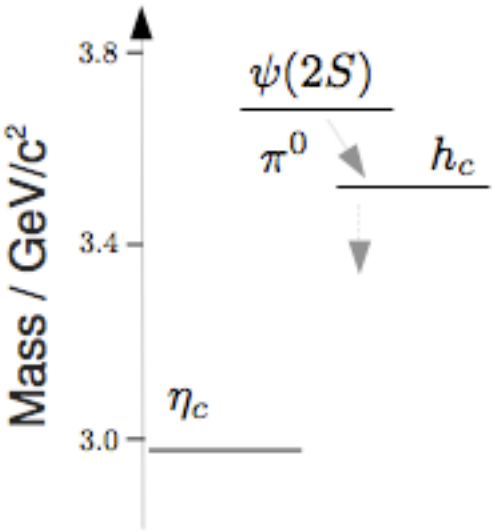
  h_c significance improved in inclusive π^0 spectrum

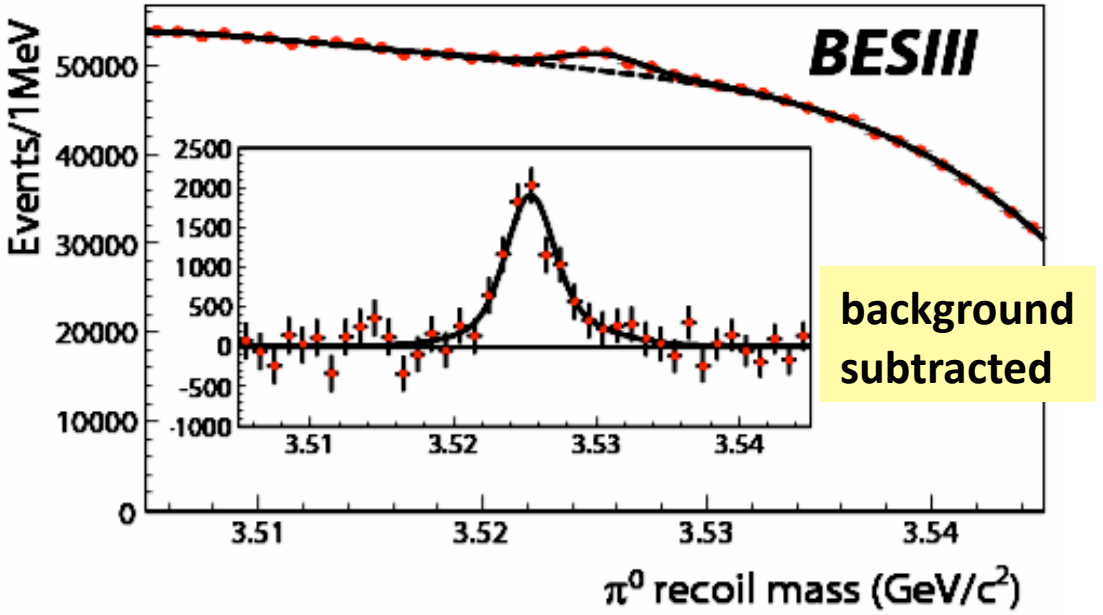
- **Exclusive** analysis of $\psi(2S) \rightarrow \pi^0 h_c$, $h_c \rightarrow \gamma\eta_c$

- h_c hadronic decays

Observation of h_c: Inclusive $\psi(2S) \rightarrow \pi^0 h_c$

- Reconstruct h_c from the recoil of inclusively identified π^0
- Fit: D-Gaussian signal + 4th Poly. bkg





background subtracted

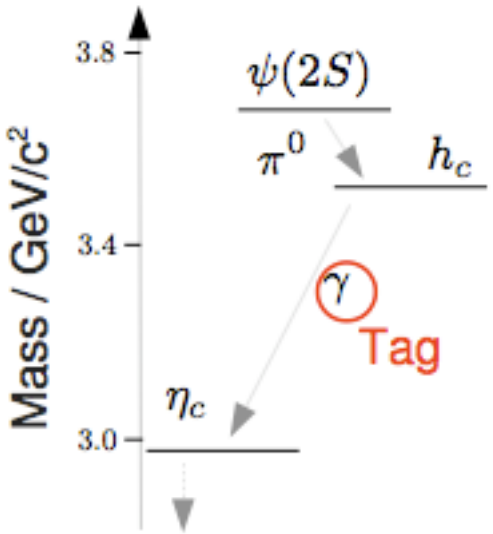
	BESIII	Prediction
$\mathcal{B}(\psi(2S) \rightarrow h_c\pi^0)$ $[10^{-4}]$	$8.4 \pm 1.3 \pm 1.0$	4...13 (1)
$\mathcal{B}(h_c \rightarrow \eta_c\gamma)$ [%]	$54.3 \pm 6.7 \pm 5.2$	48 (NRQCD) (1)
		88 (PQCD) (1)
		38 (2)

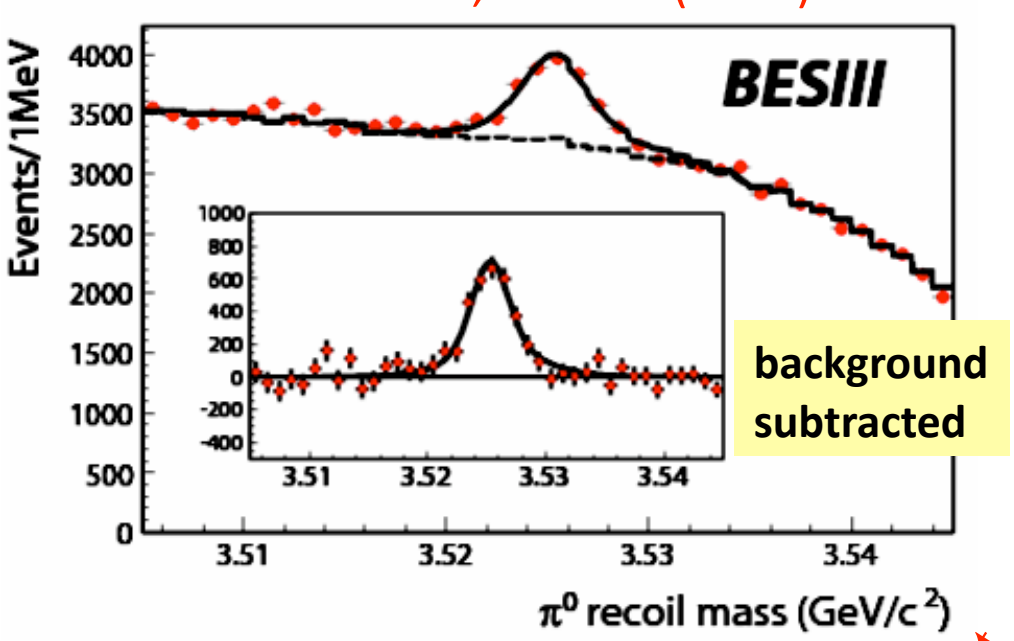
first measurement

(1) Kuang, PRD65, 094042 (2002)
(2) Godfrey, Rosner, PRD66, 014012 (2002)

Observation of h_c: E1-tagged $\psi(2S)\to\pi^0 h_c, h_c\to\gamma\eta_c$

BESIII PRL 104, 132002 (2010)





- Recoil mass spectrum of identified
- Tag photon from h_c->$\gamma\eta_c$

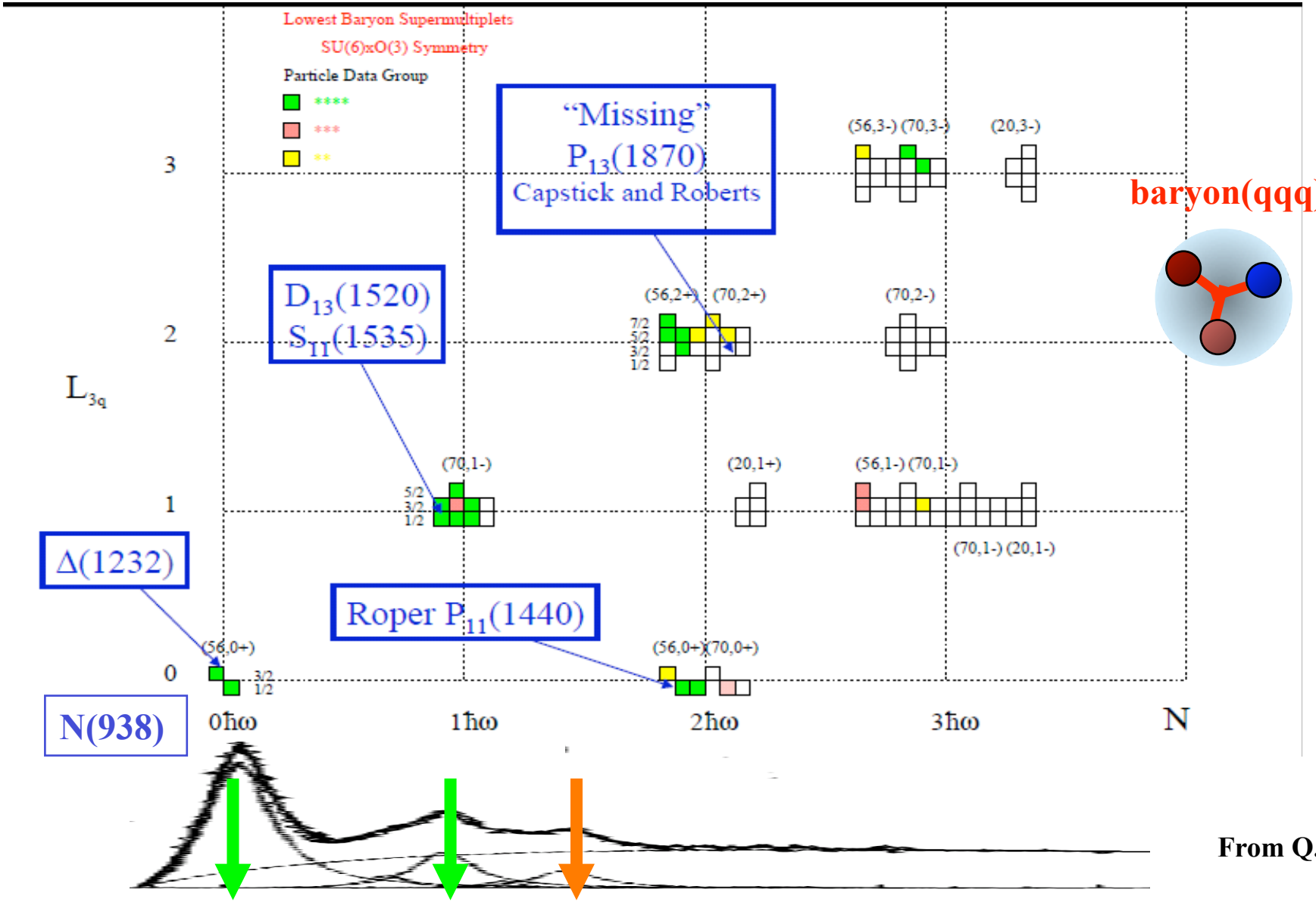
First measurement

$M(h_c) = 3525.40 \pm 0.13 \pm 0.18$ MeV/c^2

$\Gamma(h_c) = 0.73 \pm 0.45 \pm 0.28$ MeV/c^2 (< 1.44 MeV/c^2 @ 90% CL)

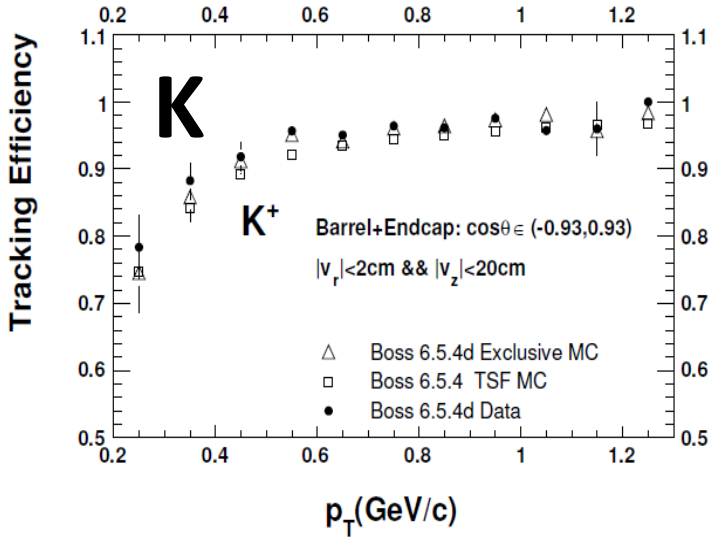
$Br(\psi(2S)\to\pi^0 h_c)\times Br(h_c\to\gamma\eta_c) = (4.58 \pm 0.40 \pm 0.50)\times10^{-4}$

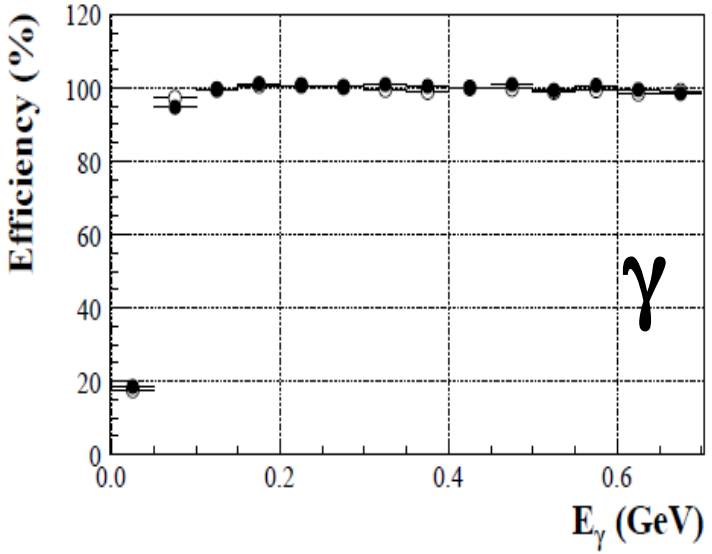
Theory predicts much more baryons than what observed → missing baryons

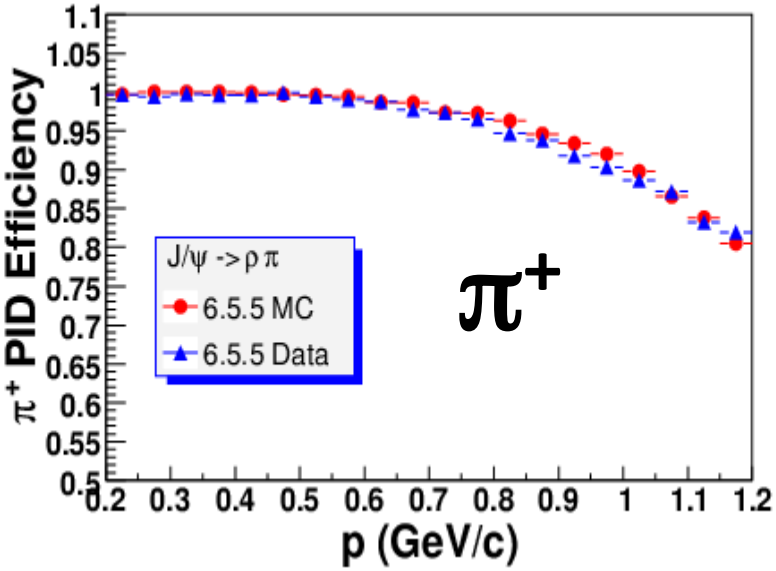


From Q. Zhao

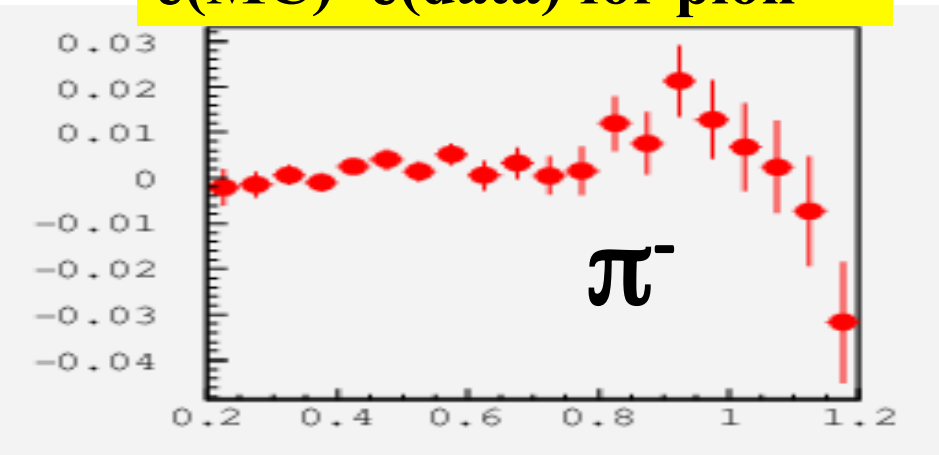
Agreement Between Data and MC







ε(MC)- ε(data) for pion-



Study of χ_{cJ}

The χ_{cJ} decays provide important information for

- **study gluonium: $\chi_c \rightarrow gg \rightarrow (qq)(qq)$**
  C. Amsler and F. E. Close,Phys. Rev. D 53, 295 (1996).
- **test of Color Octet Mechanism (COM)**
  G. T. Bodwin *et al*., Phys Rev. Lett. D51, 1125 (1995).
  H.-W. Huang and K.-T. Chao, Phys. Rev. D54, 6850 (1996).
  J. Bolz *et al*., Eur. Phys. J. C 2, 705 (1998).

- **First measurement of $\chi_{cJ} \rightarrow \omega\phi$, $\chi_{c1} \rightarrow \omega\omega, \phi\phi$**
- **First measurement of $\chi_{cJ} \rightarrow \gamma\phi$**
- **……**

(arXiv:1103.2661, arXiv:1103.5564, …)