Recent results on hadron spectroscopy from BES

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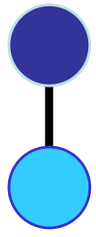
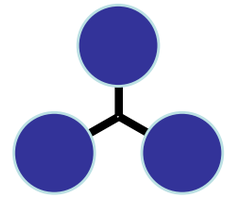
Outline

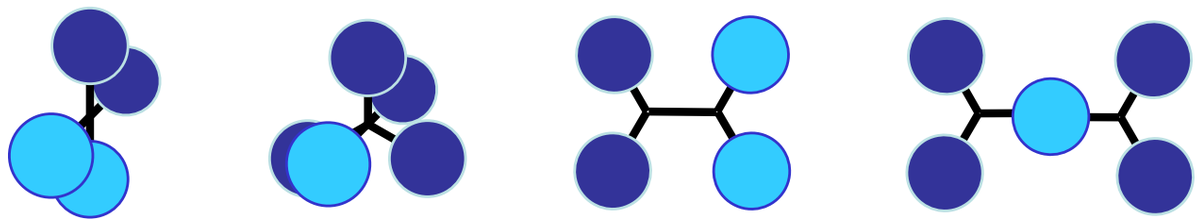
- **Introduction**
- **Facility, Detector and Data**
- **Recent BES Results & Current analyses**
- **Conclusion & Prospects**

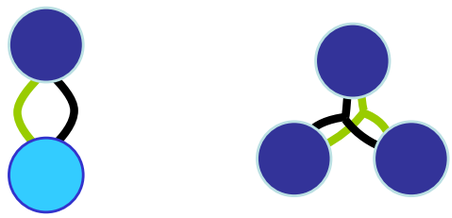
(Exotic) Hadronic Forms of Matter

- Conventionally we know, there are:

  mesons ($q\bar{q}$)  and baryons (qqq) 

- ... but many more forms which are *QCD allowed*, namely

  – Multiquarks 

  – Hybrids 

  – Glueballs 

Exotics in Light Hadron Spectroscopy

- Long years of search for exotic states of matter

  $\Rightarrow$ None unambigously established so far

- Many surprising evidences found experimentally inconsistent the simple meson/baryon model

- Charmonium = Rich source for all kinds of matter; can be studied with hadron spectroscopy

Current + long-lasting Puzzles

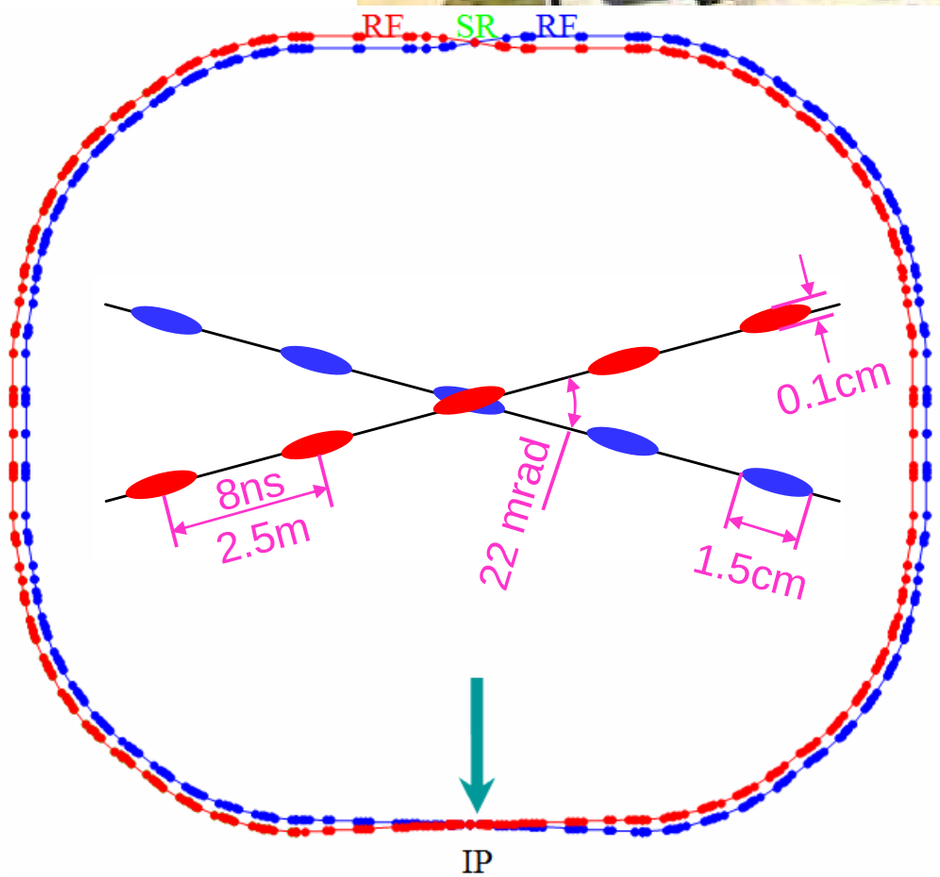
Meson Spectroscopy

- Scalar meson (0^{++}) puzzle: too many out there!
  $f_0(600)/\sigma$, $f_0(980)$, $f_0(1370)$, $f_0(1500)$, $f_0(1710)$ ...
- Same for isoscalar 1^{++} states: 3 instead of 2 observed:
  $f_1(1285)$, $f_1(1420)$, $f_1(1510)$
- Origin of $f_0(980)$ and $a_0(980)$? *Molecules?*

Baryon Spectroscopy

- Understanding of internal baryon structure crucial for nuclear and particle physics
- Experimental data for excited baryons still poor; only 10% observed so far

IHEP and BEPC-II Collider



Beam energy:
1.0 - 2.3 GeV

Luminosity:
1×10^{33} $cm^{-2}s^{-1}$

Optimum energy:
1.89 GeV

Energy spread:
5.16×10^{-4}

No. of bunches:
93

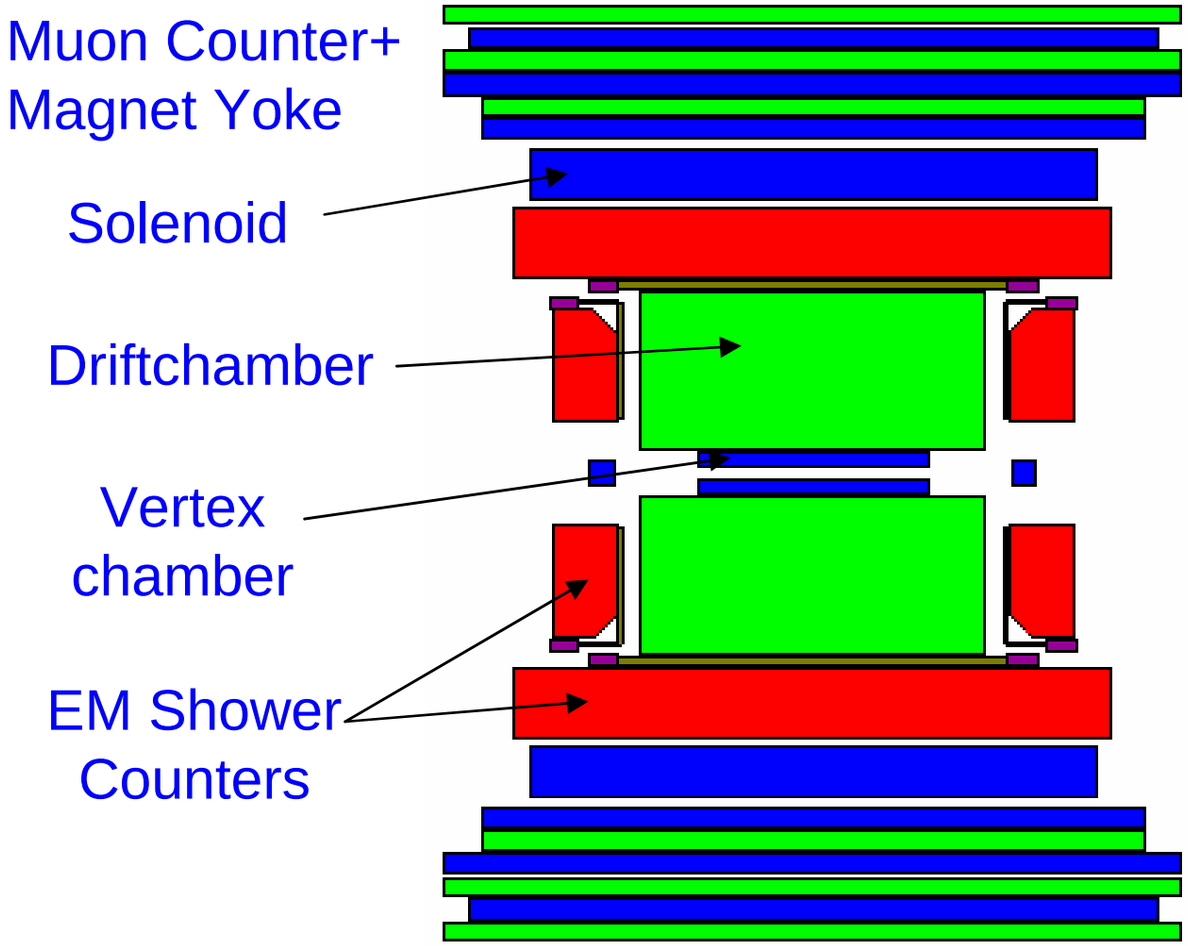
Bunch length:
1.5 cm

Total current:
0.91 A

SR mode:
0.25A @ 2.5 GeV

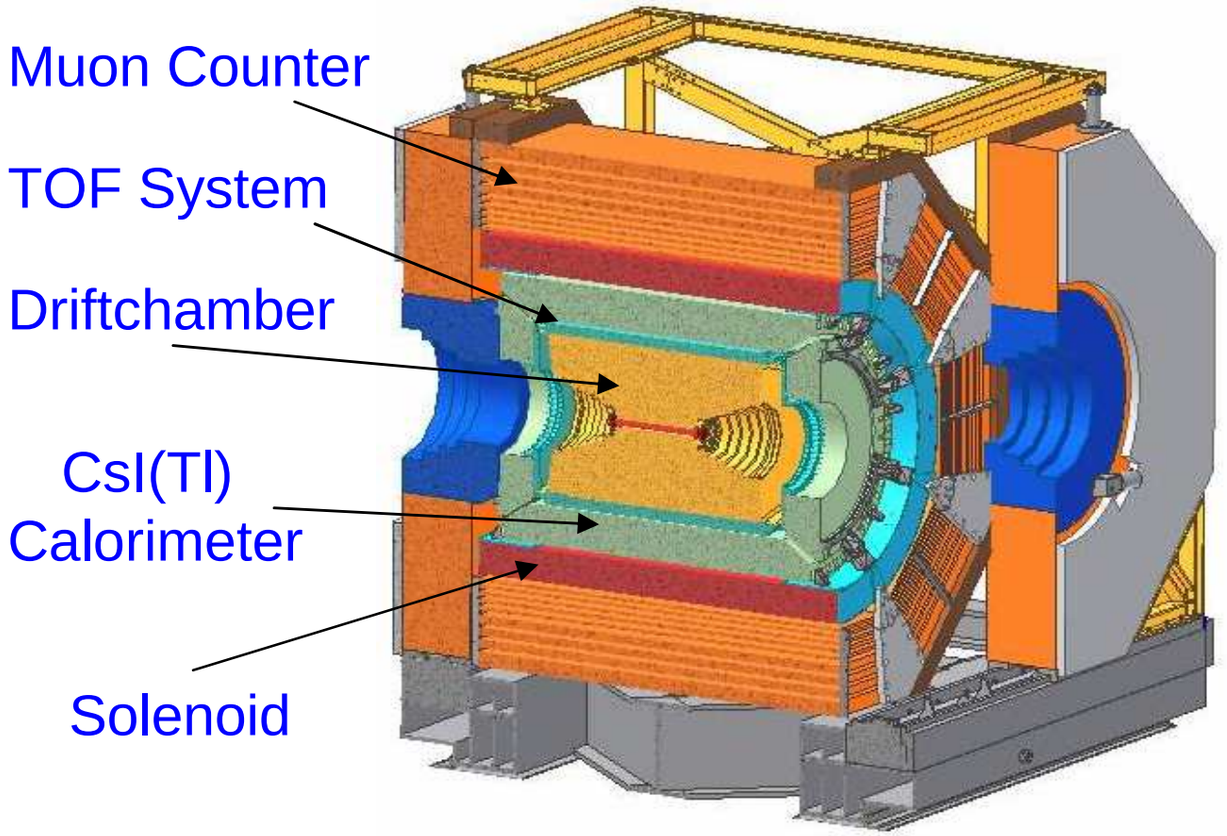
The BES Detectors

BES II @ BEPC



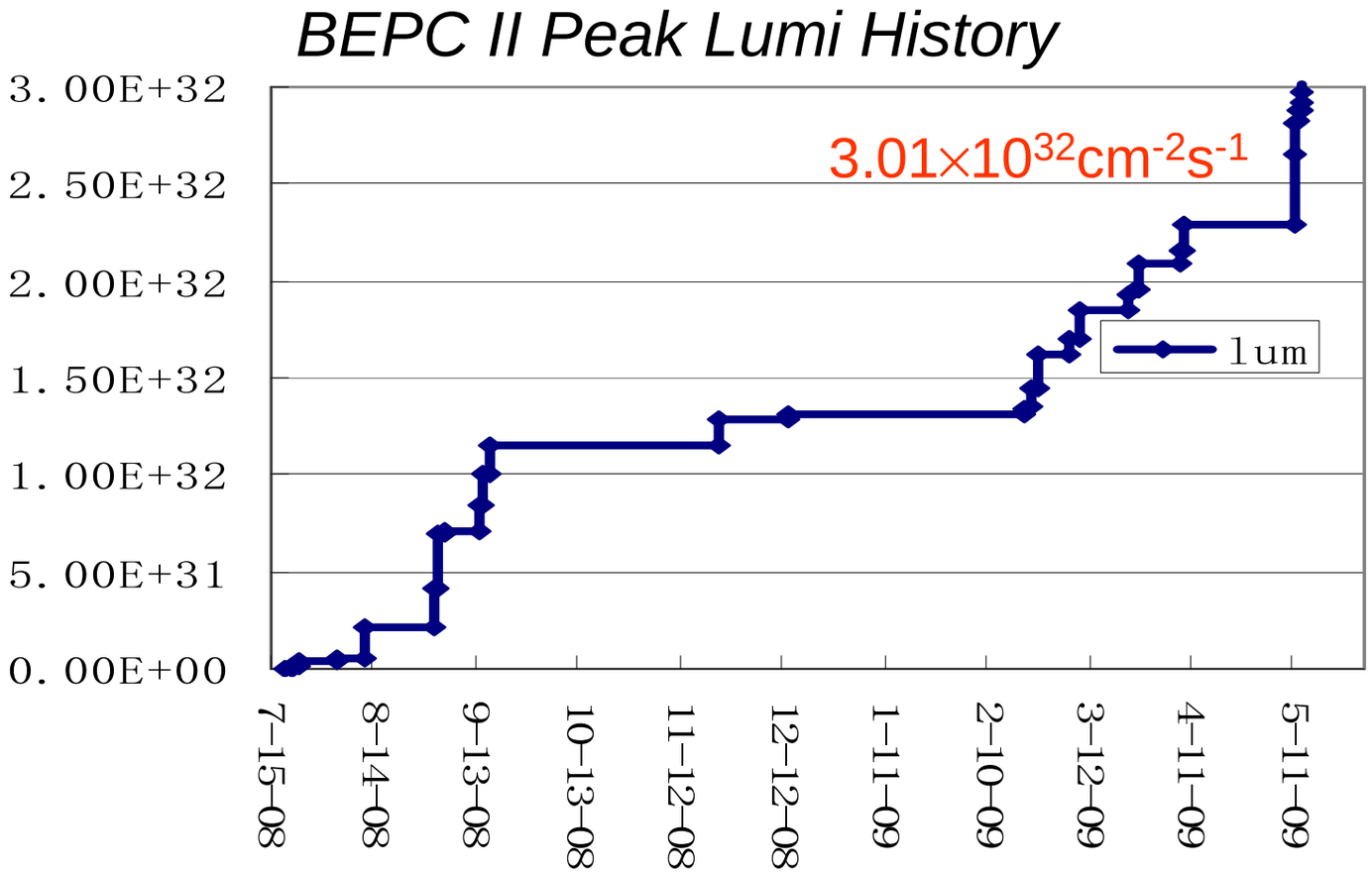
Device	*Performance*
MDC	$\sigma_p/p = 1.7\%\sqrt{1+p^2},\ dE/dx = 8\%$
TOF	180 ps (bhabha)
EMC	$\sigma_E/E < 22\%/\sqrt{E}$
MUC	3 layers
Magnet	0.4 T Solenoidal

BES III @ BEPC II



Device	*Performance*
MDC	$\sigma_{p_t}/p_t = 0.5\%,\ dE/dx < 6\%$
TOF	90 ps (bhabha)
EMC	$\sigma_E/E < 2.3\%/\sqrt{E}$
MUC	9 barrel + 8 endcap layers
Magnet	1 T Solenoidal

Status BEPCII and Data taking

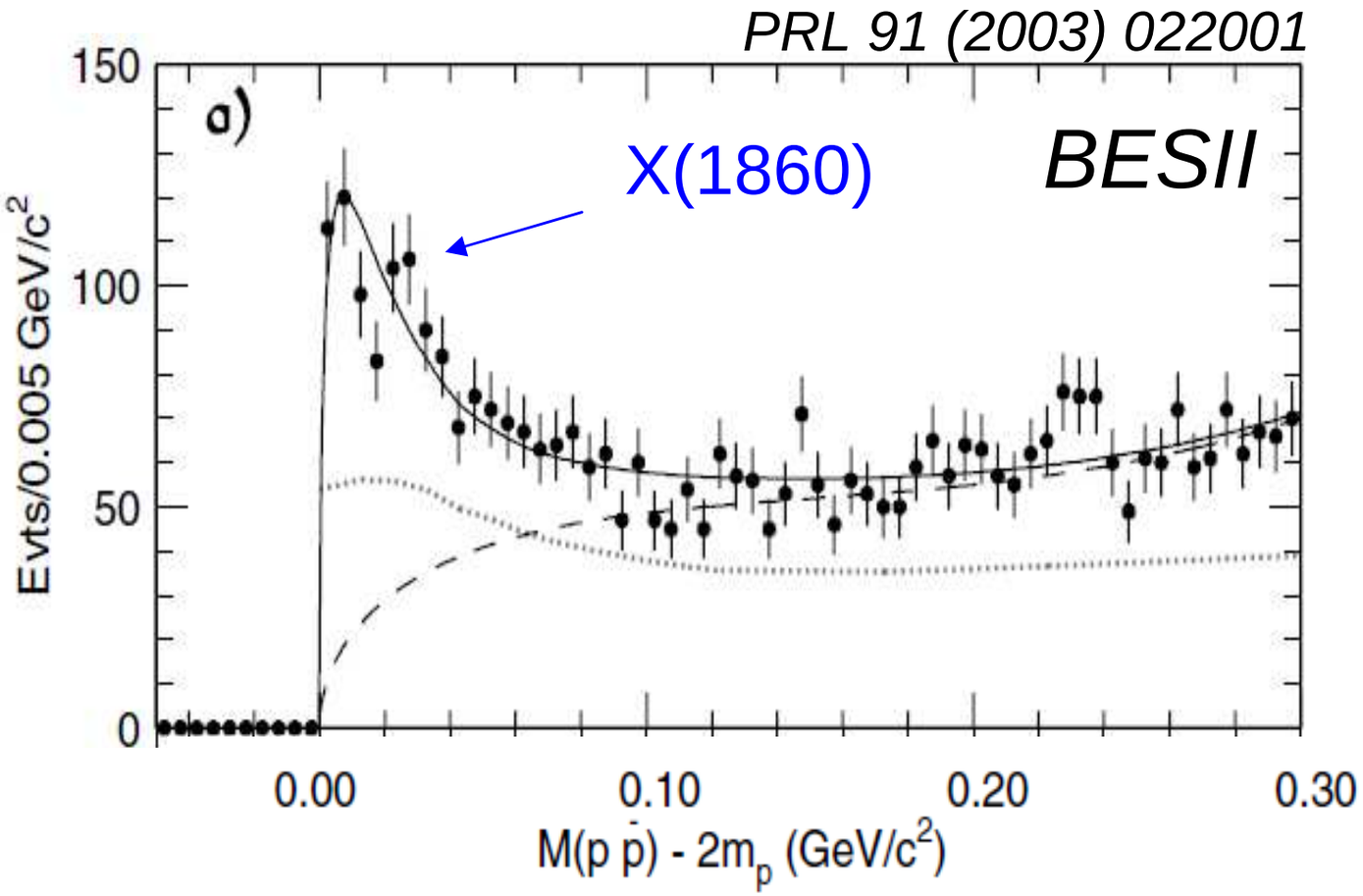


Type	*BES-III* 10^6 ev	*BES-II* 10^6 ev	*CLEO-c* 10^6 ev	*BES-III* 10^6 ev/yr
J/ψ	200	58	-	10000
$\psi(2S)$	100	14	27	3000
$D\bar{D}$	-	0.21	5.2	32
$D_s\bar{D}_s$	-	-	scan	0.8
$D_s\bar{D}_s^*$	-	-	0.55	2.7

X(1860) in $p\bar{p}$ close threshold

- BESII observed $p\bar{p}$ enhancement close to threshold

$$J/\psi \to \gamma p\bar{p}$$



Fitted parameters

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

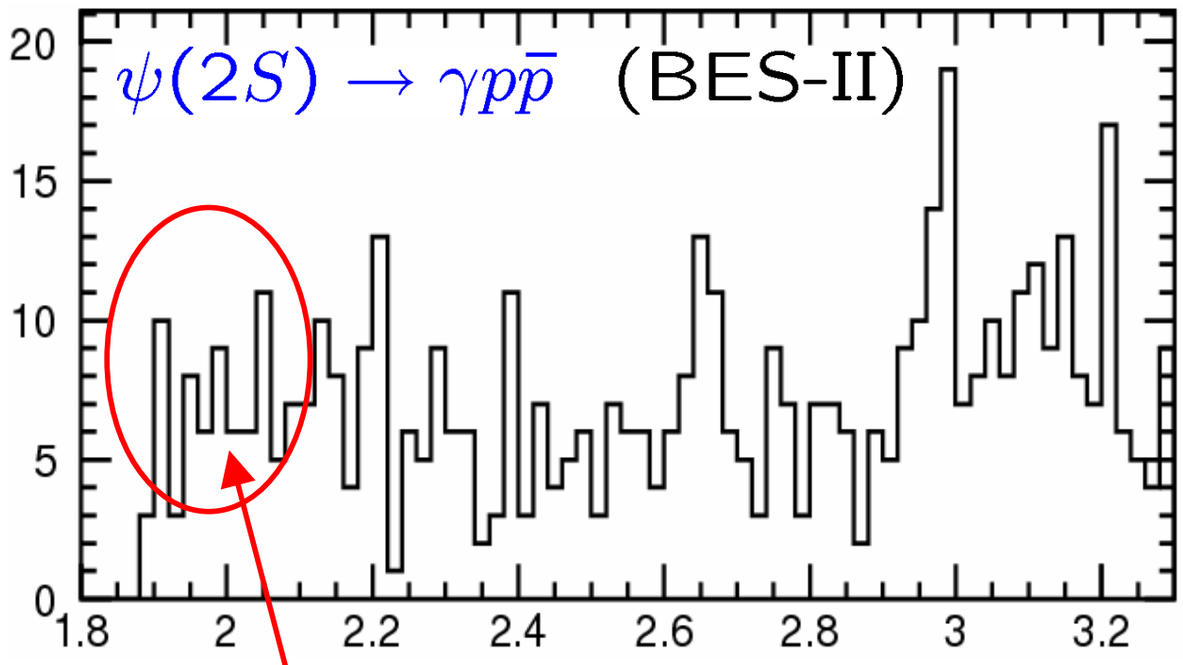
$\sigma < 30\ \mathrm{MeV}/c^2$ (90% CL)

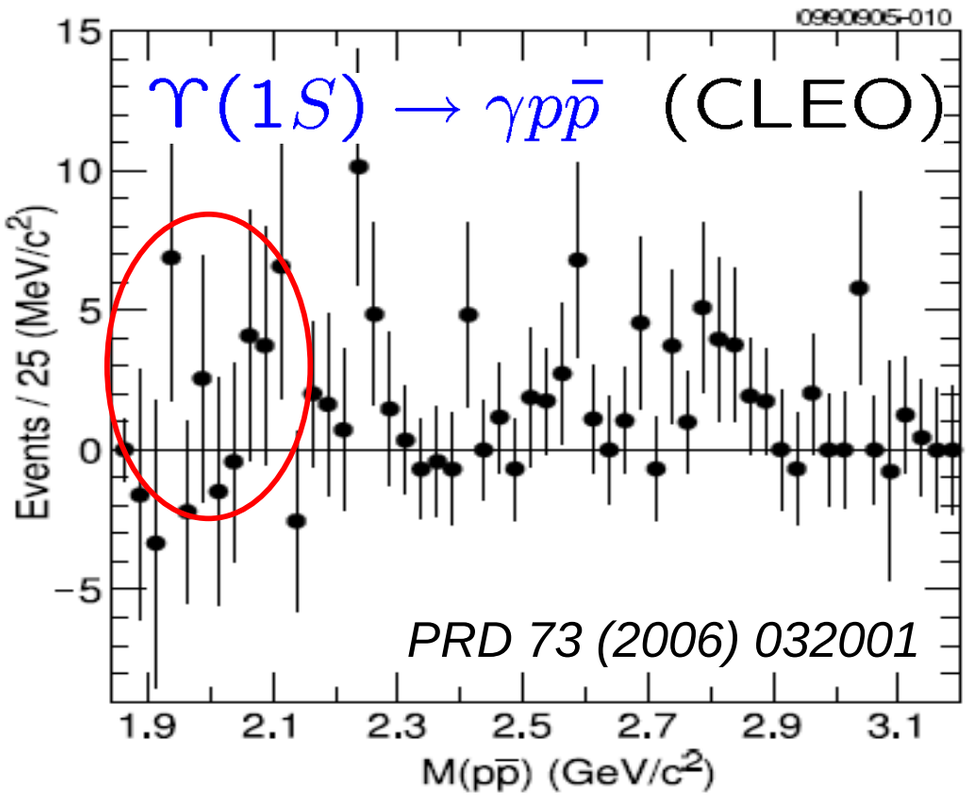
- What it could be theoretically:
  - $p\bar{p}$ bound state
  - FSI effect

X(1860) in $p\bar{p}$ close threshold

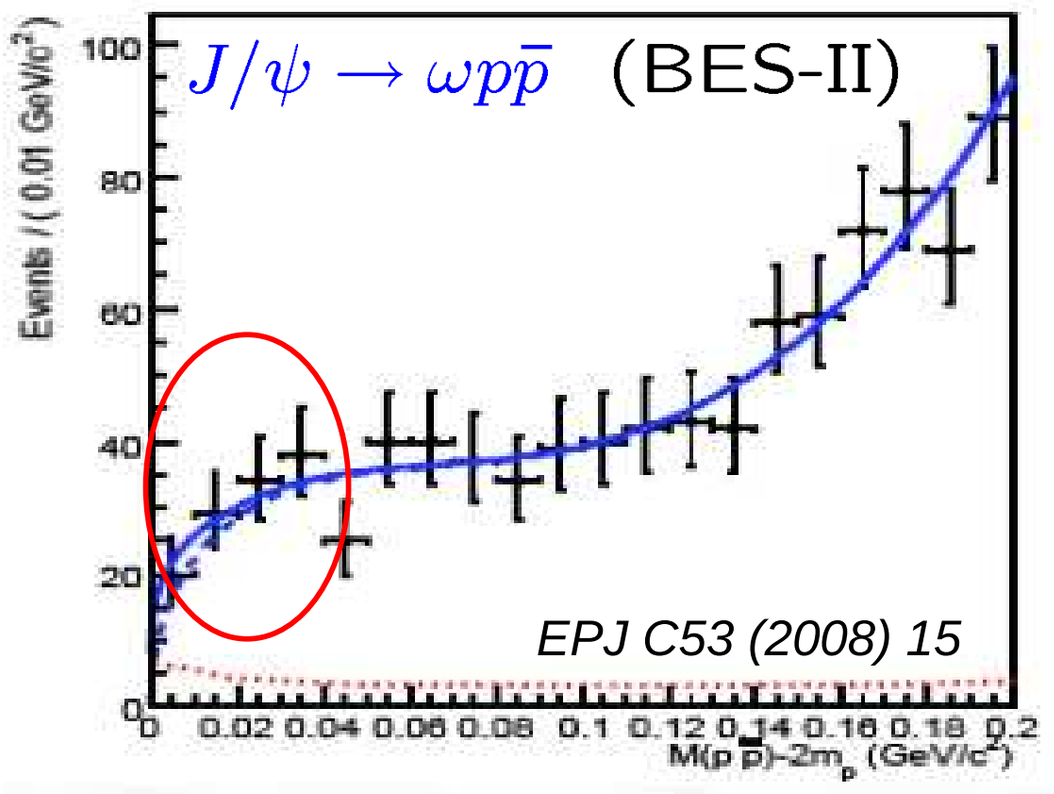
- Several ***none*** observations...

PRL 99 (2007) 011802



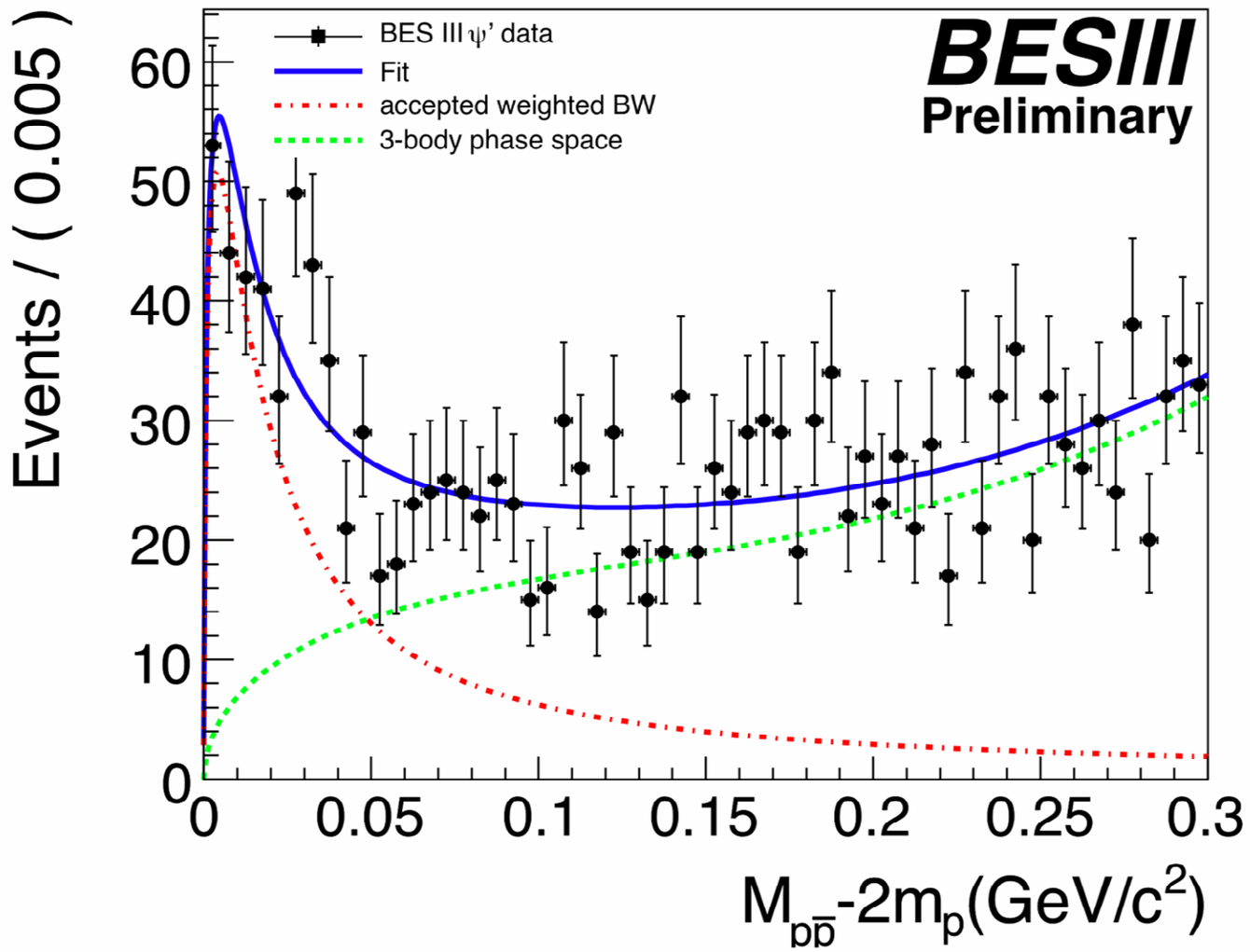


No significant signal of X(1860) found
(only 2σ significance)



X(1860) results of BESIII (prelim.)

$$\psi(2S) \to \pi\pi J/\psi, J/\psi \to \gamma p\bar{p} \text{ (BES-III)}$$



X(1860) fitted parameters

m = 1864.6 ± 5.3 MeV/c^2

σ< 33 MeV/c^2 (90% CL)

(error statistical only)

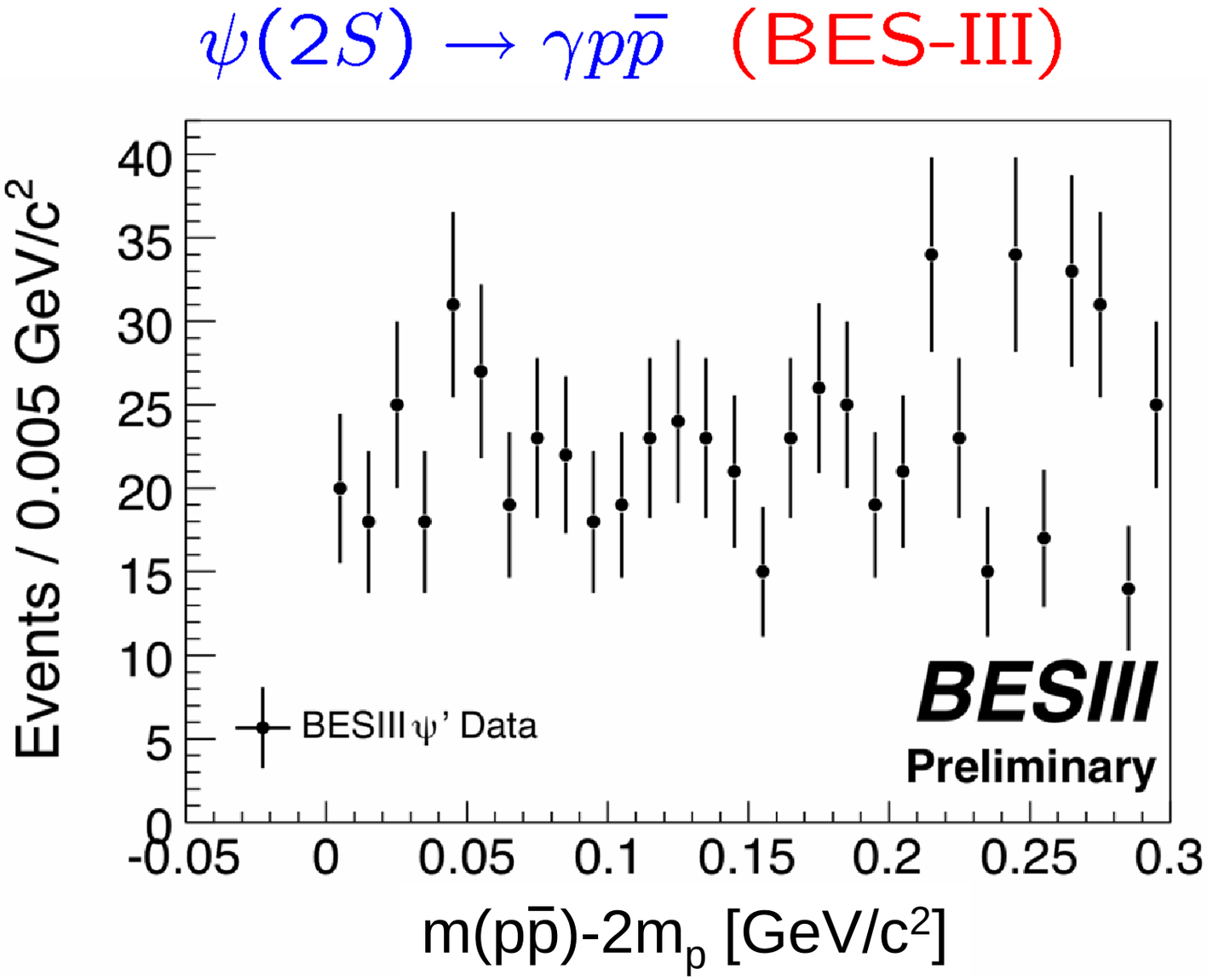
Consistent observation by BES III!

X(1860) results of BESIII (prelim.)

- Checked also for enhancement in ψ‘ decays

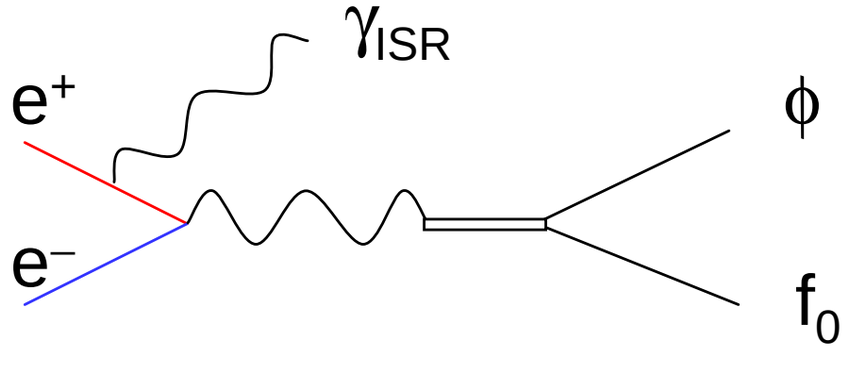
Confirmation of no observation of enhancement in ψ(2S) channel!!

⇒ FSI unlikely



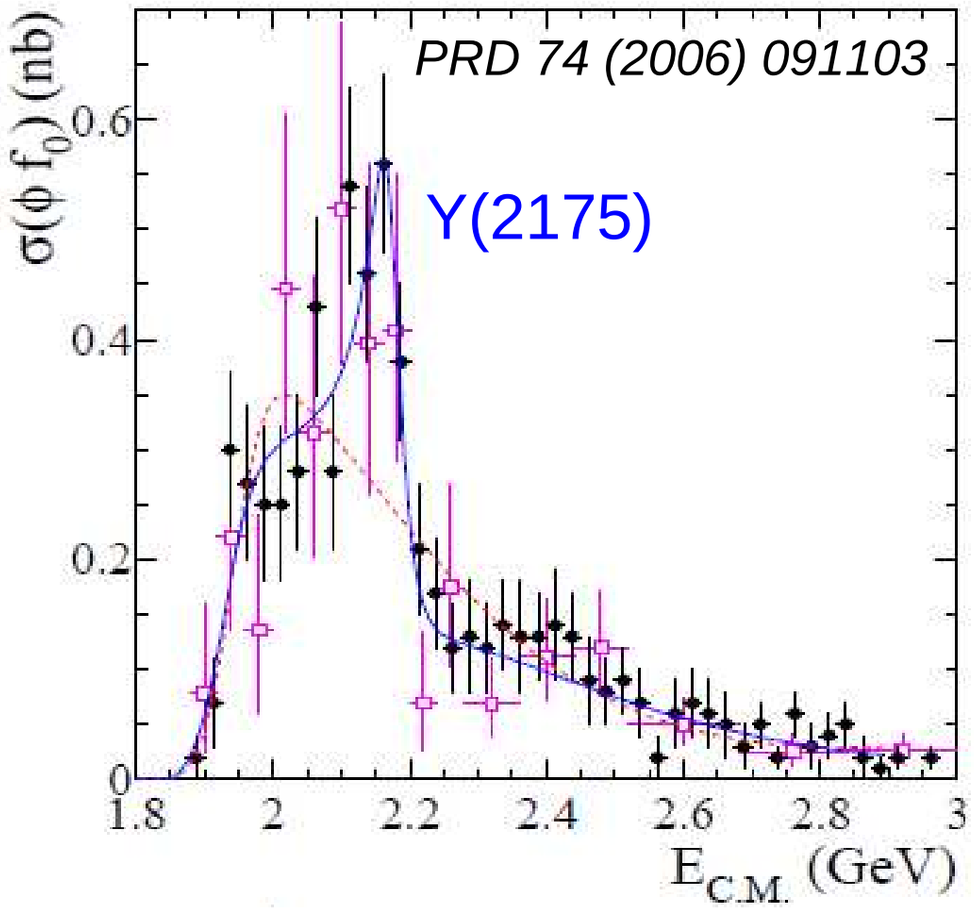
Y(2175) in BaBar ISR data

- Observation by BaBar in ISR events

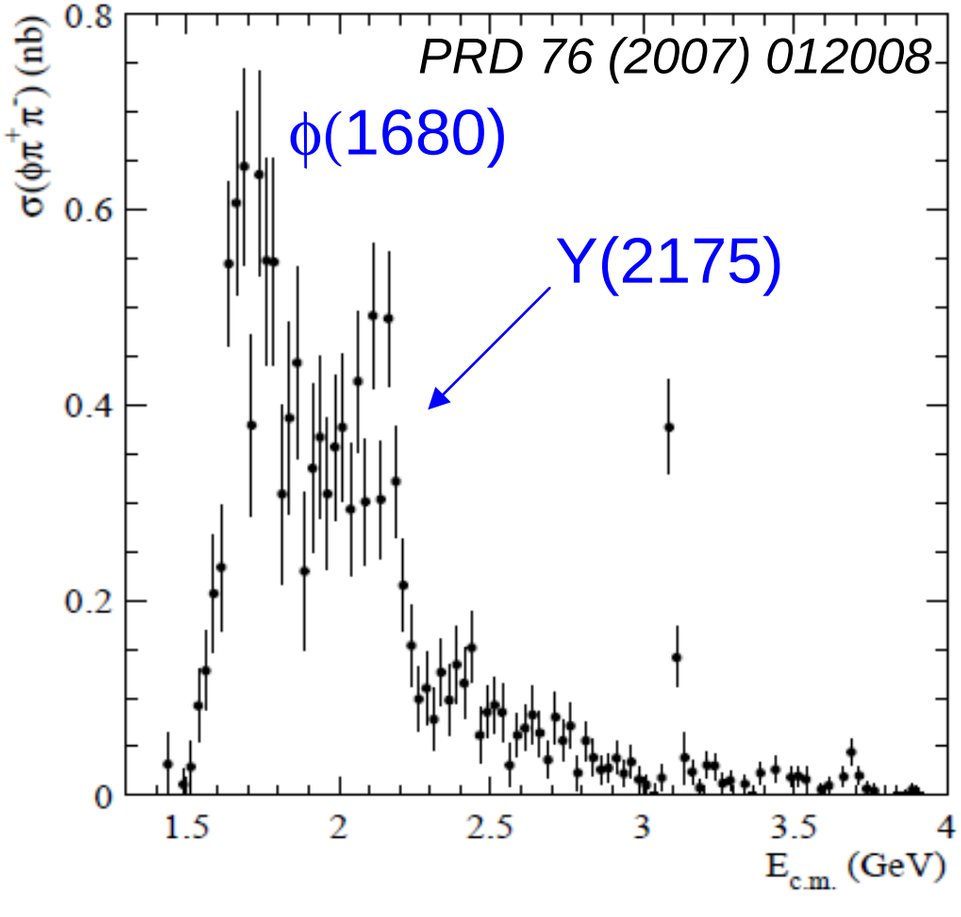


m = 2175 ± 10 ± 15 MeV/c²
Γ = 58 ± 16 ± 20 MeV/c²

$e^+e^- \to \gamma_{isr}\,\phi f_0(980)$

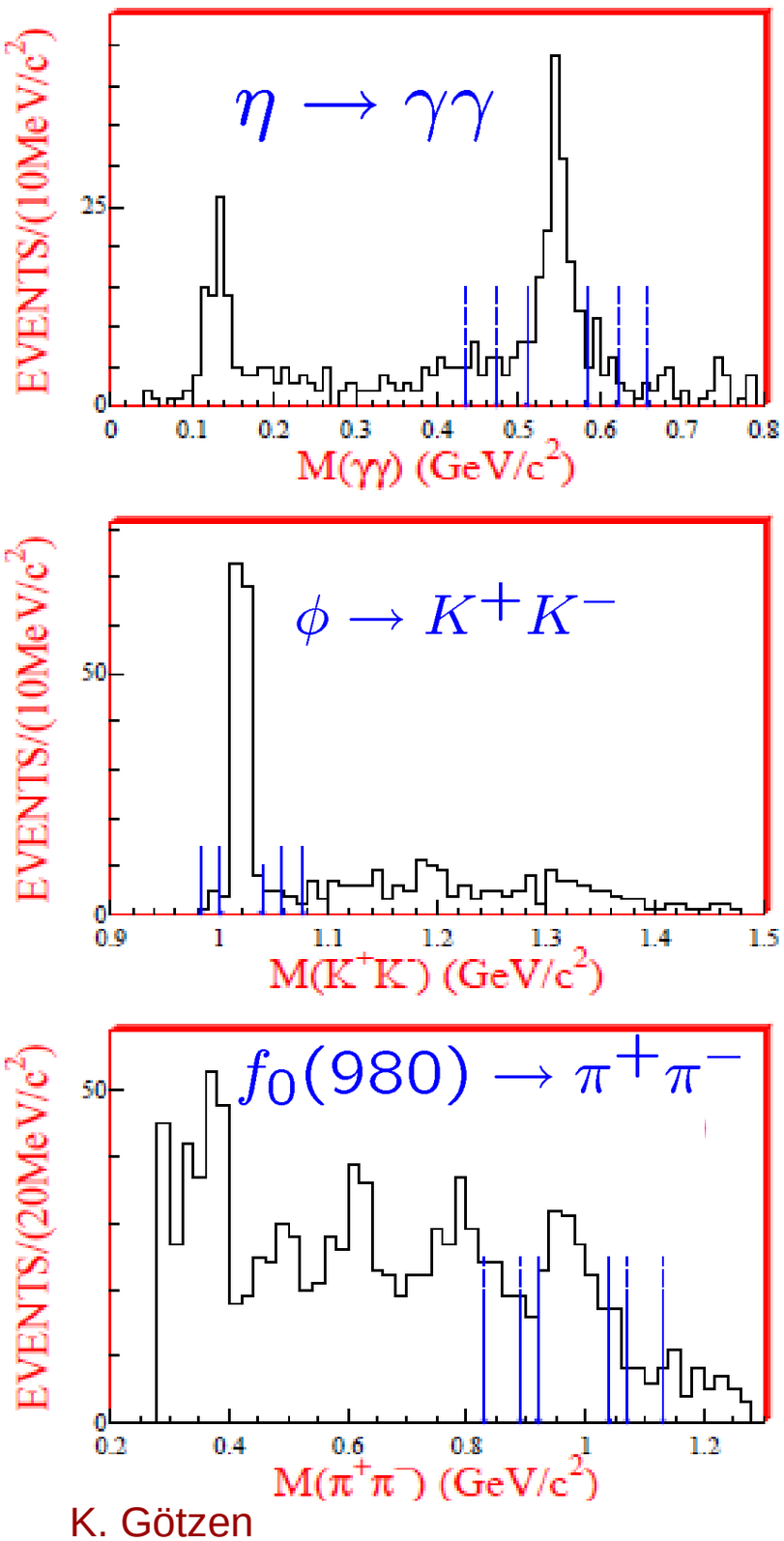


$e^+e^- \to \gamma_{isr}\,\phi\pi^+\pi^-$

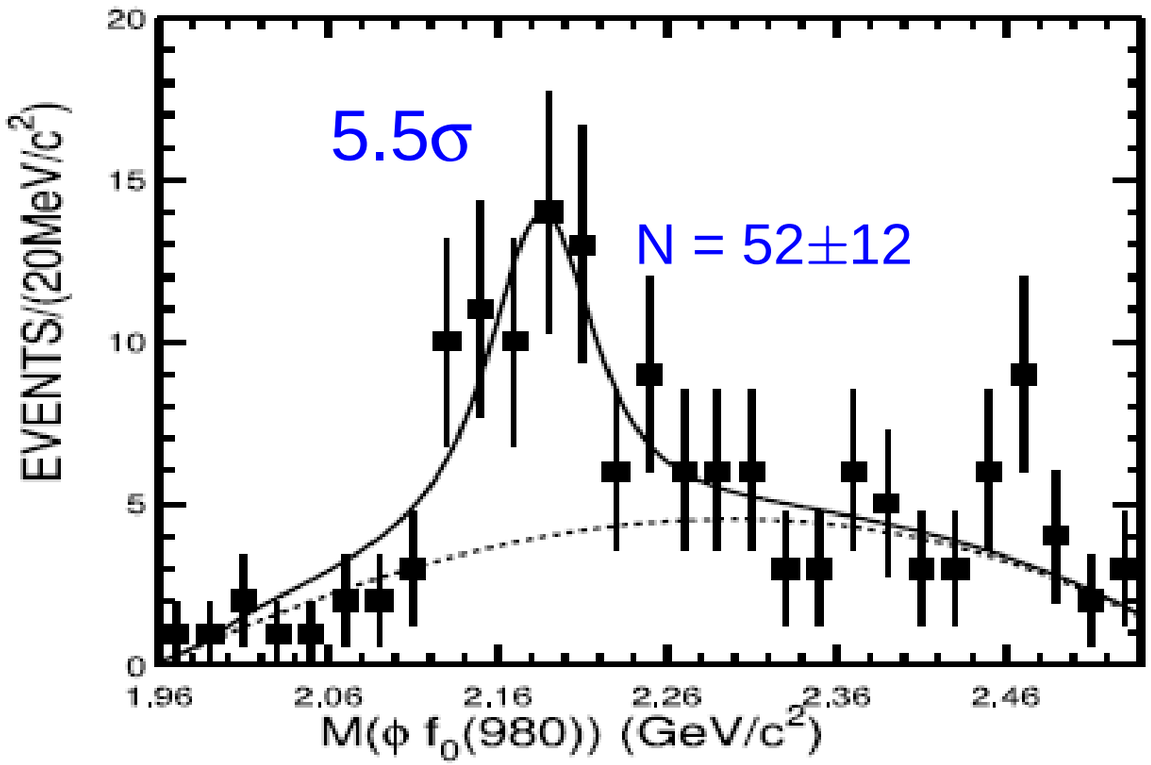


Y(2175) in BES-II: $J/\psi \to \eta\phi f_0(980)$

Signal/SB regions



PRL 100 (2008) 102003

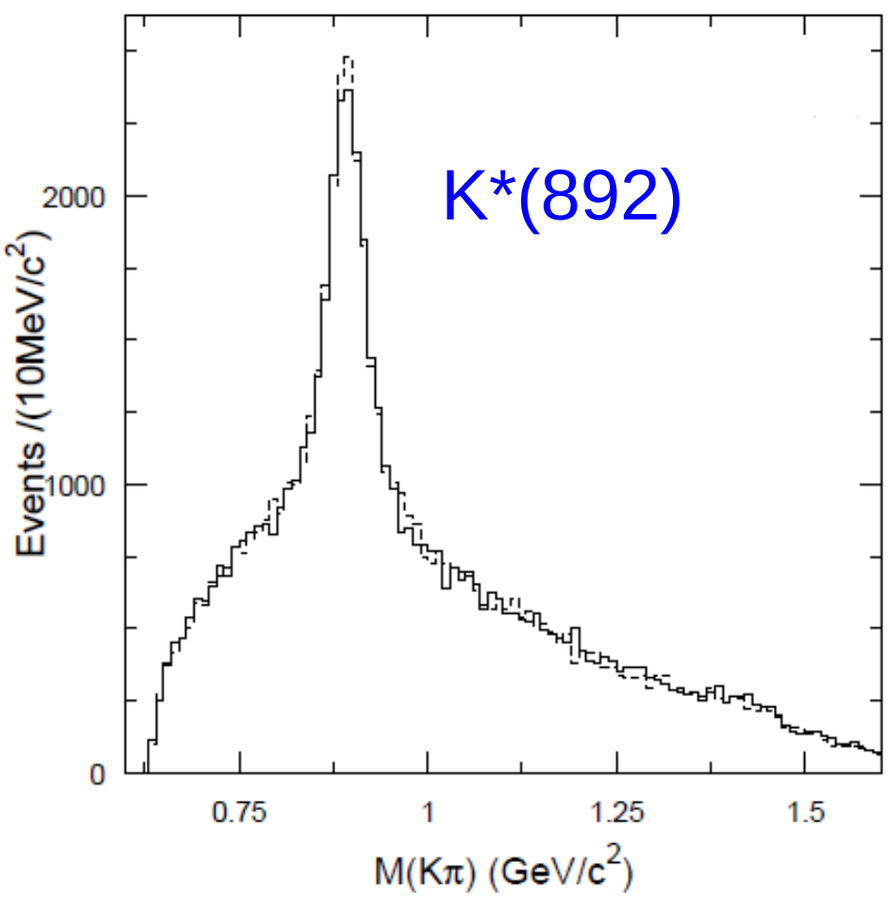


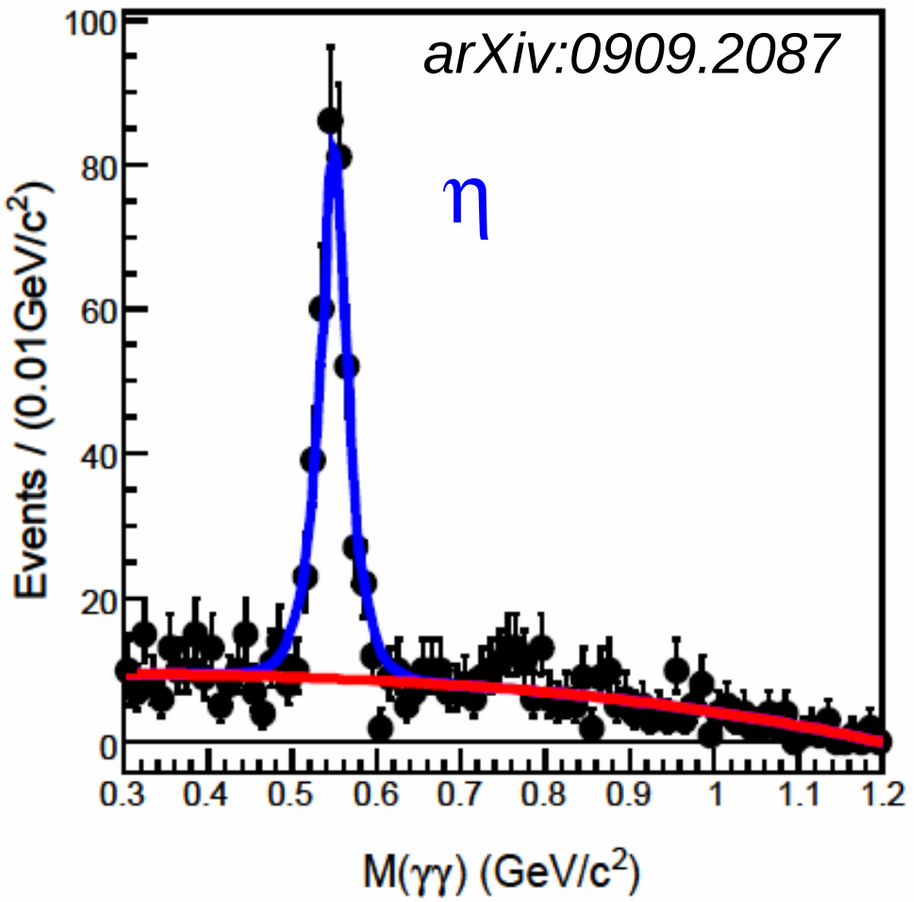
$$m = 2186 \pm 10 \text{ MeV/c}^2$$
$$\Gamma = 65 \pm 23 \text{ MeV/c}^2$$

$$BR(J/\psi \to \eta Y) \cdot BR(Y \to \phi f_0) \cdot BR(f_0 \to \pi^+\pi^-) = (3.23 \pm 0.75_{stat} \pm 0.73_{syst}) \times 10^{-4}$$

Y(2175) in BES-II: $J/\psi \to \eta K^{*0}\bar{K}^{*0}$

- More experimental data needed to understand the nature of Y(2175)
- Now working on $J/\psi \to \eta K^{*}\bar{K}^{*}$, $\eta\Lambda\bar{\Lambda}$, $\eta K\bar{K}$





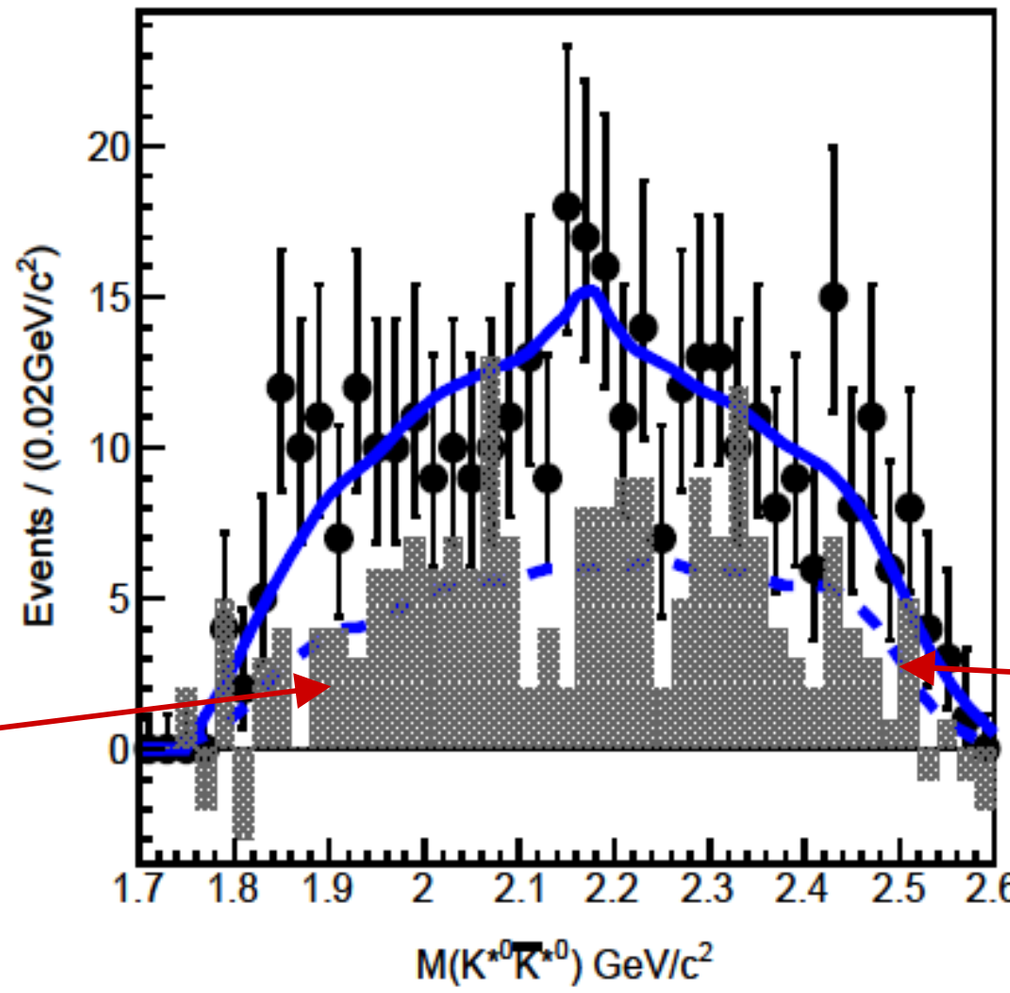
- First measurement of

$$BR(J/\psi \to \eta\, K^{*0}\bar{K}^{*0}) = (1.15 \pm 0.13 \pm 0.22) \times 10^{-3}$$

Y(2175) in BES-II: $J/\psi \to \eta K^{*0}\bar{K}^{*0}$

- Study invariant $K^{*0}\bar{K}^{*0}$ mass

arXiv:0909.2087



Background

3 body phasespace

- No obvious enhancement found near 2175 MeV/c^2

$$UL\ (90\%\ C.L.) : BR(J/\psi \to \eta Y) \cdot BR(Y \to K^*\bar{K}^*) < 2.52\times10^{-4}$$

Observation of neutral κ

- κ first seen in $K\pi$ scattering
- Existence of κ still under controversial discussion

- Recent measurements
  - ***E791***: observed neutral κ in $D^+ \rightarrow K^-\pi^+\pi^+$

$m = 797 \pm 19 \pm 43$ MeV/c^2, $\Gamma = 410 \pm 43 \pm 87$ MeV/c^2

  - ***FOCUS***: $D^+ \rightarrow K^-\pi^+\mu^+\nu$ data requires broad 0^+ component in $K\pi$
  - ***CLEO***: $D^0 \rightarrow K^-\pi^+\pi^0$ data find no evidence of κ

  - ***BES-II***: observes neutral κ in $J/\psi \rightarrow K^{*0}K\pi \rightarrow K\pi K\pi$

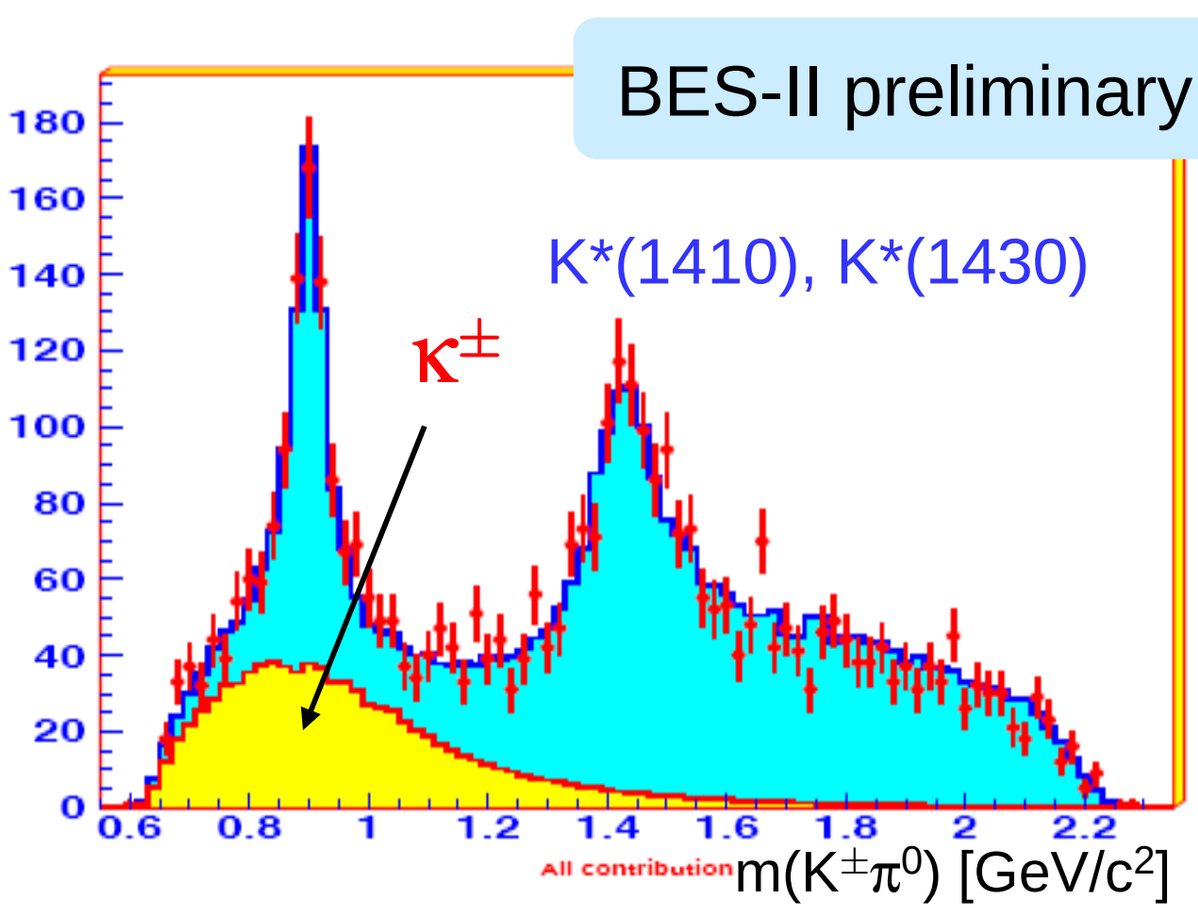
Pole at $(841 \pm 30\,^{+81}_{-73}) - i\,(309 \pm 45\,^{+48}_{-72})$ MeV/c^2

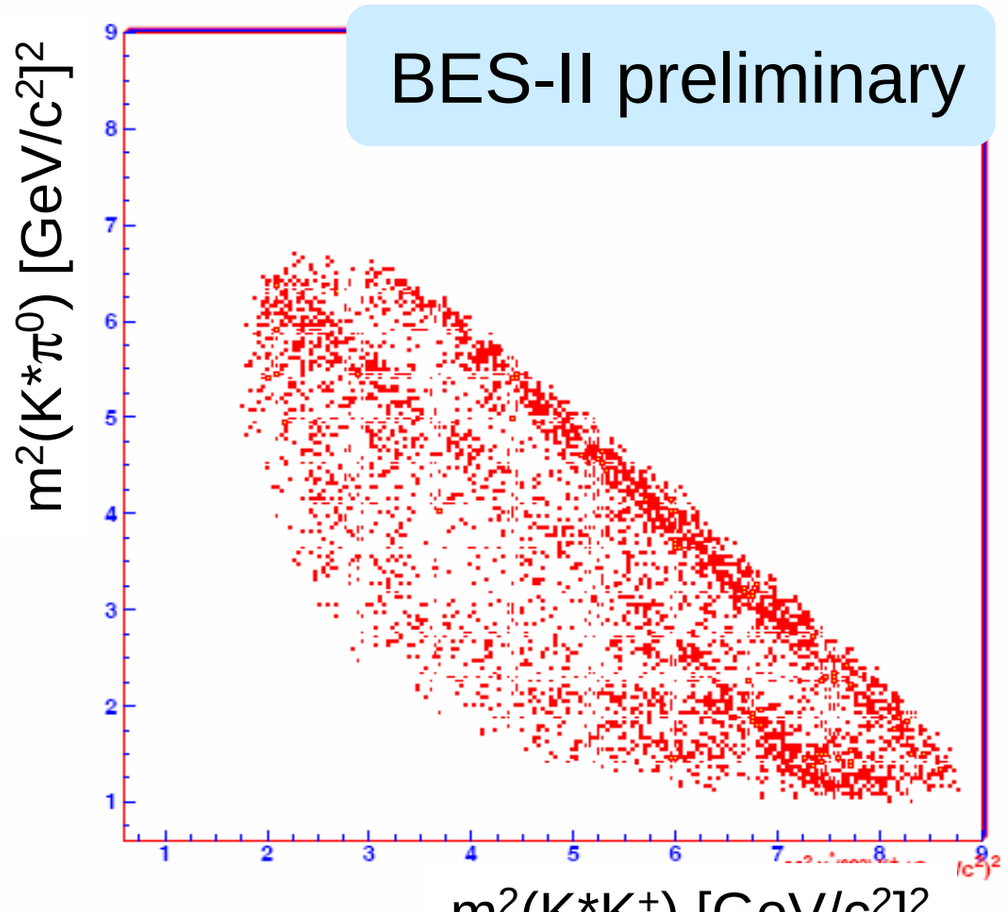
Observation of charged κ

- ***CLEO***: necessity for charged $\kappa^{\pm}$ in $D^0 \to K^+K^-\pi^0$
- ***BaBar***: no charged κ needed to describe data

- ***BES-II***: study of $J/\psi \to K^{*\pm}\,\kappa^{\mp} \to K_S\,\pi^{\pm}\,K^{\mp}\pi^0$

  Pole at $(849 \pm 51\,^{+14}_{-28}) - i\,(288 \pm 101\,^{+64}_{-30})$ MeV/c^2





Compare fit results for κ^0 and $\kappa^\pm$

Resonance parameters for charged κ

	Constant BW	BW with ρ	Zheng
Mass [MeV]	$810 \pm 68^{+15}_{-24}$	$884 \pm 40^{+11}_{-22}$	$1165 \pm 58^{+120}_{-41}$
Width [MeV]	$536 \pm 87^{+106}_{-47}$	$478 \pm 77^{+71}_{-41}$	$1349 \pm 500^{+472}_{-176}$
Pole [MeV]	$(849 \pm 77^{+18}_{-14})$ $-i(256 \pm 40^{+46}_{-22})$	$(849 \pm 51^{+14}_{-28})$ $-i(288 \pm 101^{+64}_{-30})$	$(839 \pm 145^{+24}_{-7})$ $-i(297 \pm 51^{+50}_{-18})$

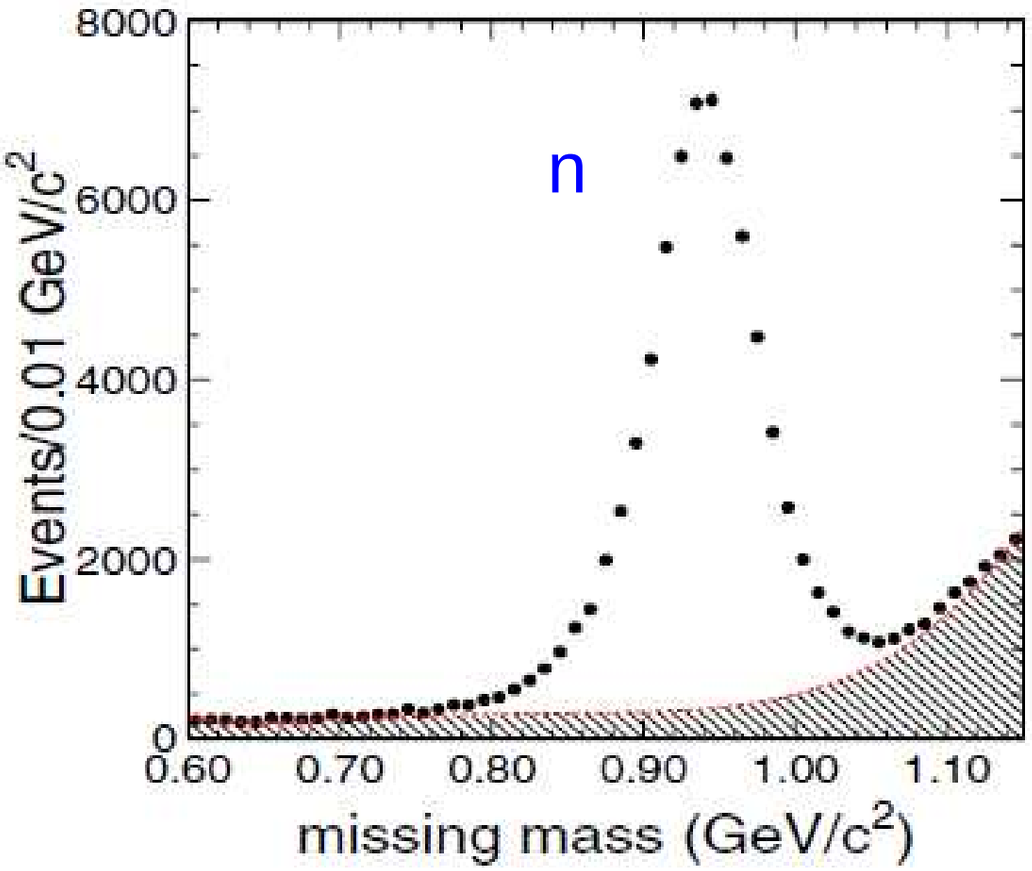
Reference: Resonance parameters for neutral κ

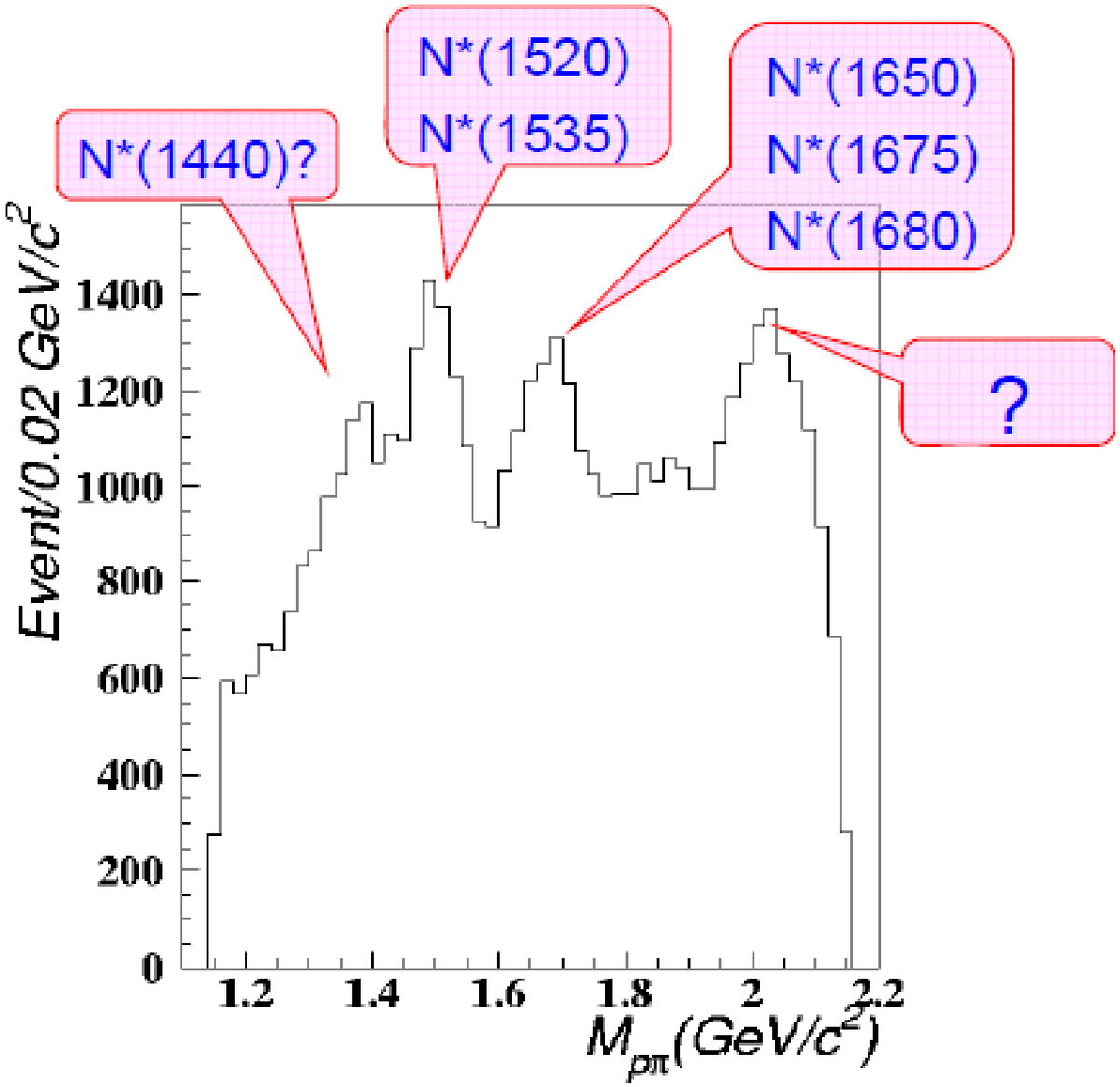
	Constant BW	BW with ρ	Zheng
Mass [MeV]	$745 \pm 26^{+14}_{-91}$	$874 \pm 25^{+12}_{-55}$	$1140 \pm 39^{+47}_{-80}$
Width [MeV]	$622 \pm 77^{+61}_{-78}$	$518 \pm 65^{+27}_{-87}$	$1370 \pm 156^{+406}_{-148}$
Pole [MeV]	$(799 \pm 37^{+16}_{-90})$ $-i(290 \pm 33^{+25}_{-38})$	$(836 \pm 38^{+18}_{-87})$ $-i(329 \pm 66^{+28}_{-46})$	$(811 \pm 74^{+17}_{-83})$ $-i(285 \pm 20^{+18}_{-42})$

Consistent fit results for pole positions and for neutral and charged κ!

Observation of new N* baryons

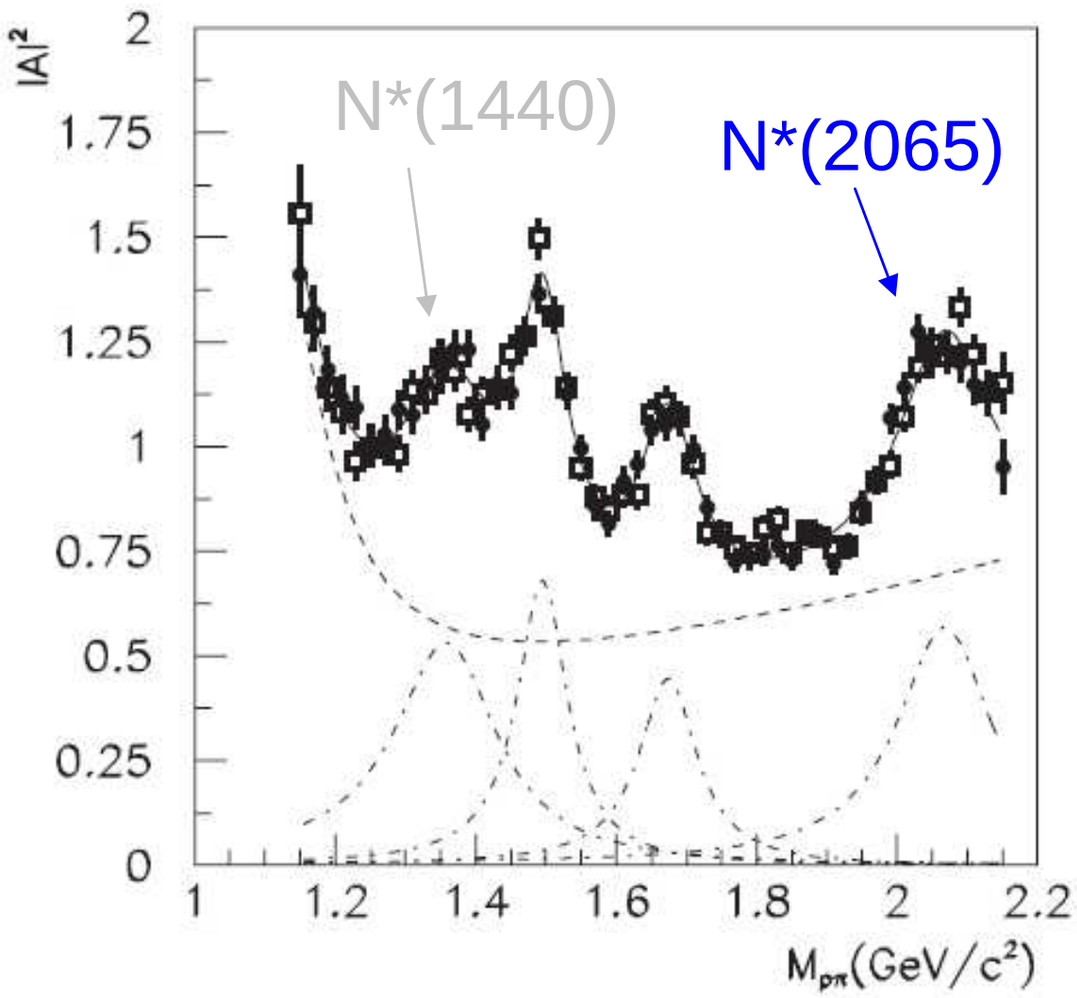
$$J/\psi \to p\bar{n}\pi^- + \text{c.c.}$$





PRL 97 (2006) 062001

Observation of new N* baryons



Breit Wigner Fit Result

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

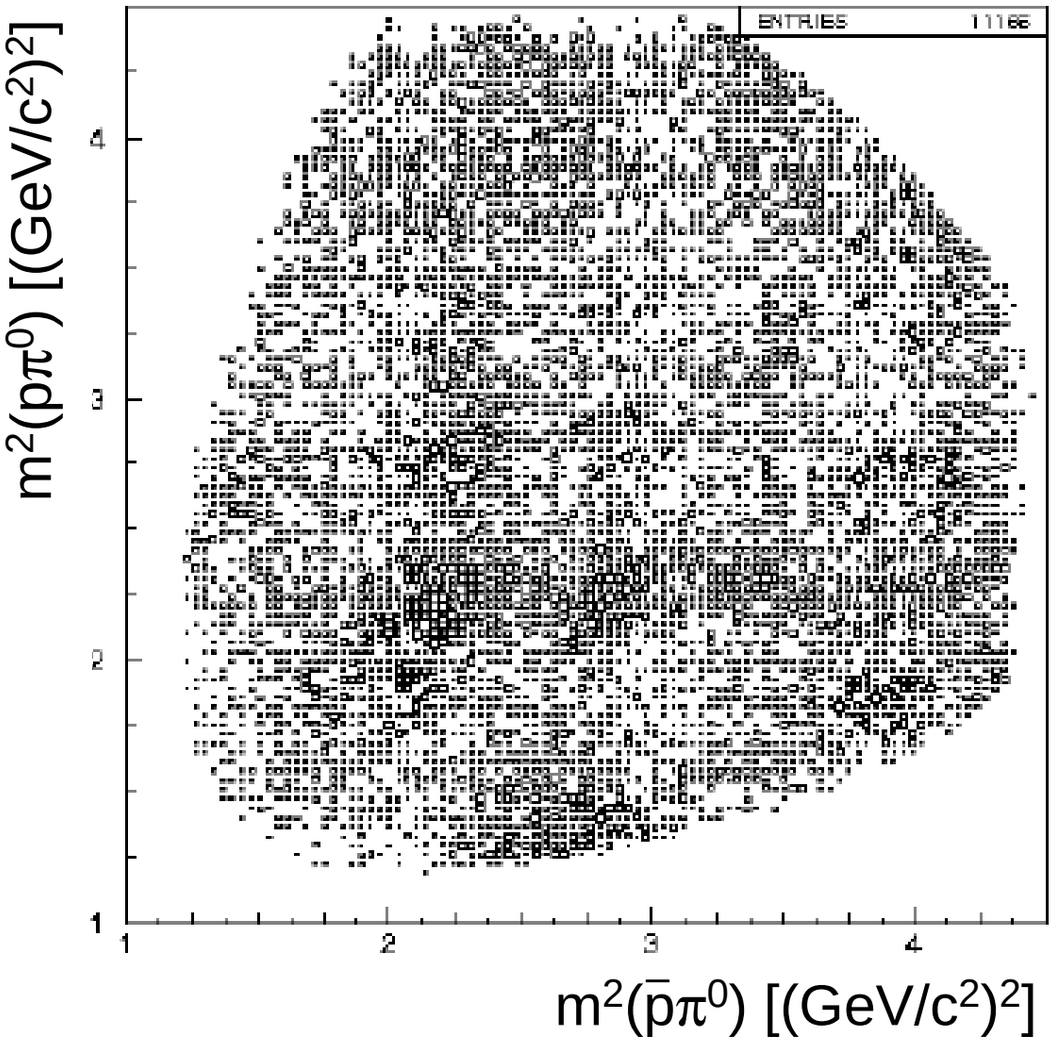
$\Gamma = 175 \pm 12 \pm 45$ MeV/c^2

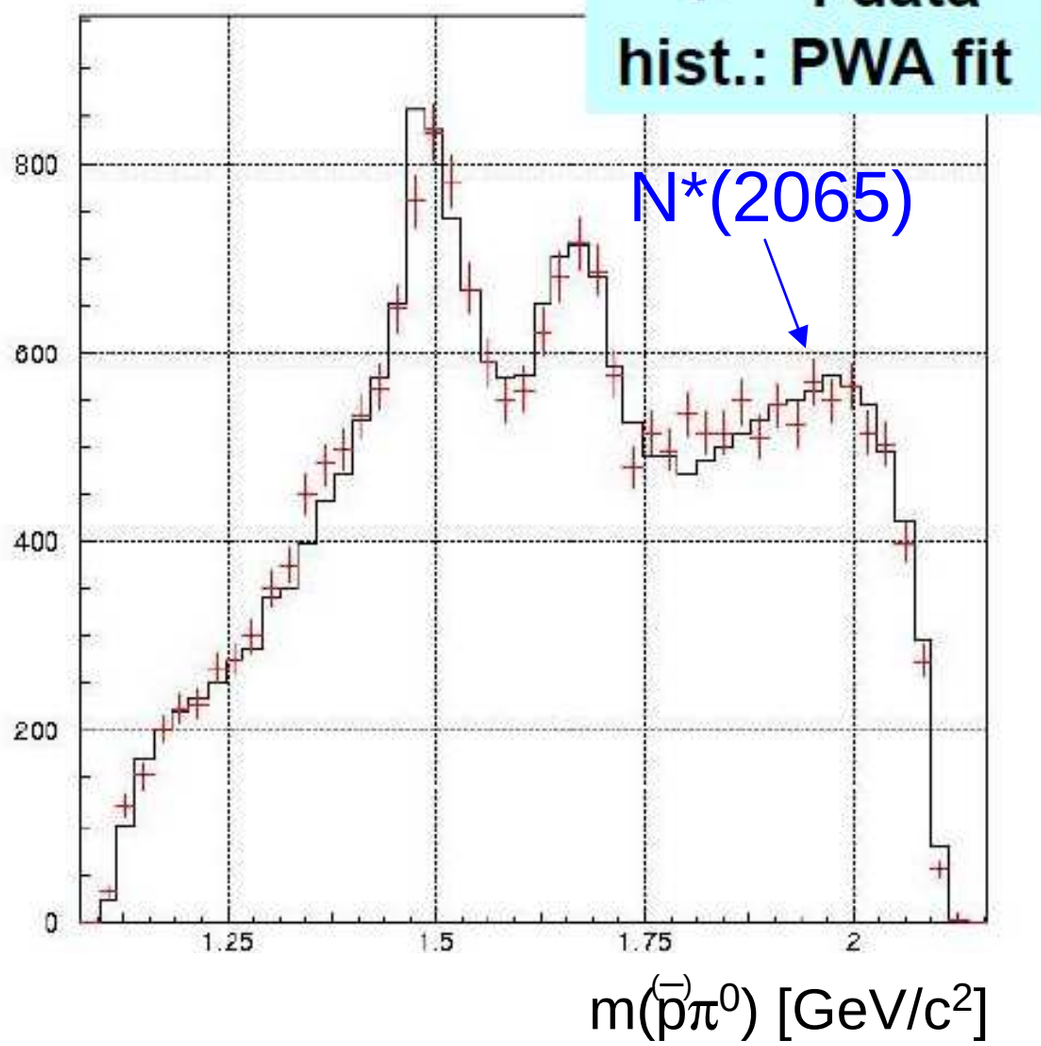
- Partial Wave Analysis performed
- Fixed parameters of well established N*s
- L = 0 preferred against L = 1 in fit
- $J^P = 1/2^+, 3/2^+$

Observation of new N* baryons

N*(2065) also observed in $J/\psi \to p\bar{p}\pi^0$

arXiv:0905.1562 - Accepted by PRD





Statistical significance >> 5σ

PWA favours $J^P = 3/2^+$

$m = 2040 \pm 25\ ^{+3}_{-4}$ MeV/c^2

$\Gamma = 230 \pm 8 \pm 52$ MeV/c^2

Conclusion & Prospects

- Many interesting analyses being worked on

- BESIII will resume data taking for $\approx$ 5 months until next summer

- Possible plans (to be decided in Nov.):
  - J/ψ : 500 - 1000 M (2 - 4 months)
  - $\psi(2S)$: 500 - 1000 M (2 - 4 months)
  - $\psi(3770)$: 0.7fb^{-1} (2 months) + lineshape scan

- **Exiting times with a lot of new measurements ahead**

The BES-III Collaboration

About 300 physicists - 42 Institutions - 9 Countries

Bochum University
Budker Institute of Nuclear Physics
Carnegie Mellon University
China Center of Adv. Science and Tech.
GSI Darmstadt
Graduate University of Chinese Acad. of Sc.
Guangxi Normal University
Guangxi University
Henan Normal University
Huangshan College
Huazhong Normal University
Hunan University
INFN, Laboratori Nazionali di Frascati
Indiana University
Institute of High Energy Physics
Joint Institute for Nuclear Research
KVI/University of Groningen
Liaoning University
Nanjing Normal University
Nanjing University
Nankai University
Peking University
Seoul National University
Shandong University
Shanxi University
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University of Rochester
University of Science and Tech. of China
University of Turin
University of Washington
University of the Punjab
Wuhan University
Zhejiang University
Zhengzhou University