Recent Results On Light Hadron Spectroscopy at BESIII

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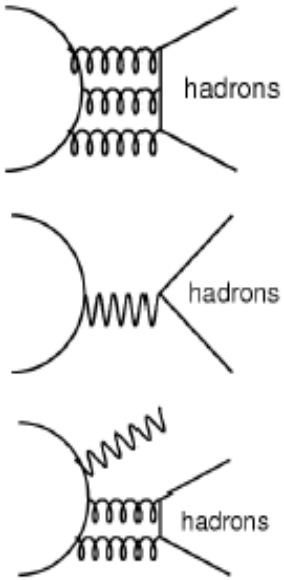
Outline

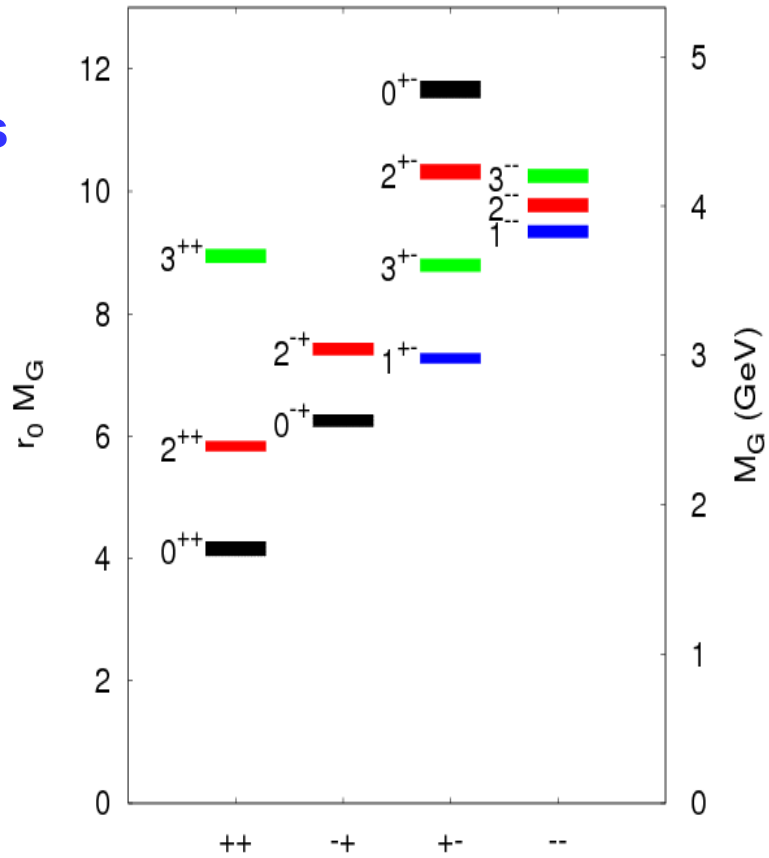
- Introduction
- Recent results on Light Hadron Spectroscopy from BESIII
- Summary

Study of the spectroscopy – a way of understanding the internal structure

glueball spectrum from LQCD

- **Motivation:**
  - Establish spectrum of light hadrons
  - Search for non-conventional hadrons
  - Understand how hadrons are formed
- **Why at a τ-charm collider ?**
  - Gluon rich
  - Clean environment
  - J^{PC} filter , isospin filter

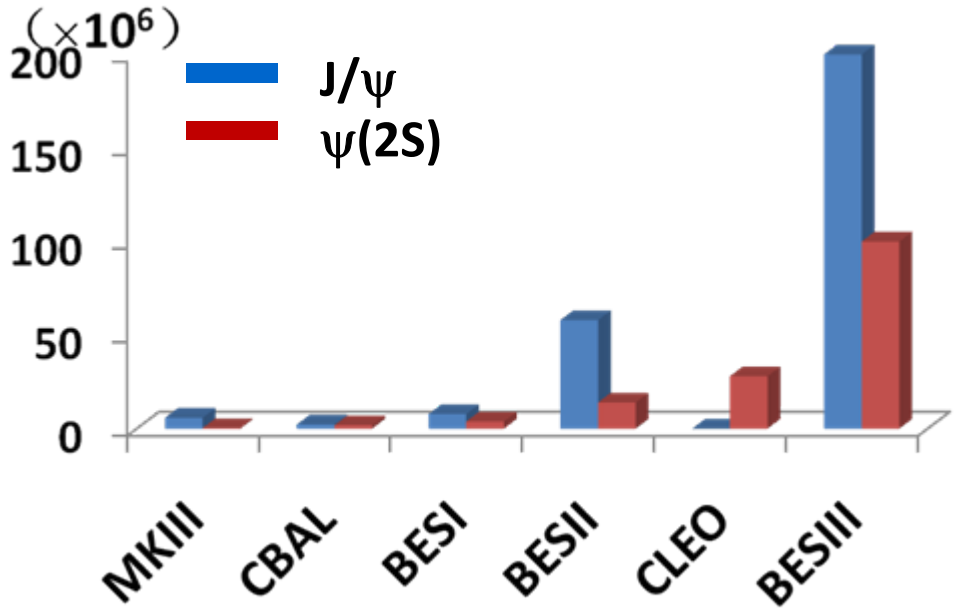




PRD 73 (2006) 014516

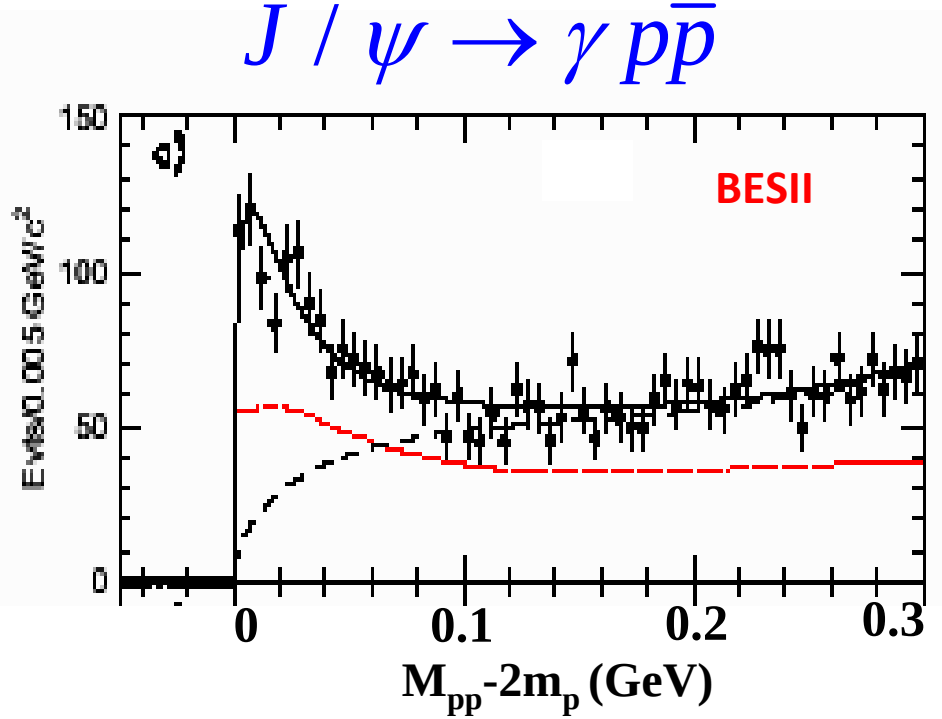
Results from BESIII

- **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, …



$p\bar{p}$ mass threshold study at BES

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



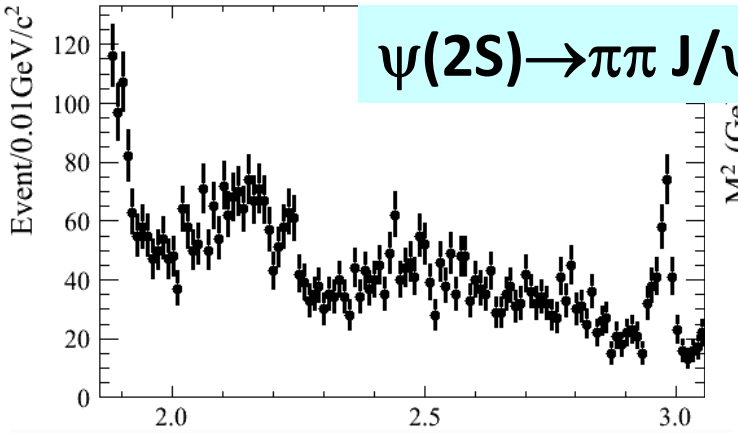
theoretical speculation:

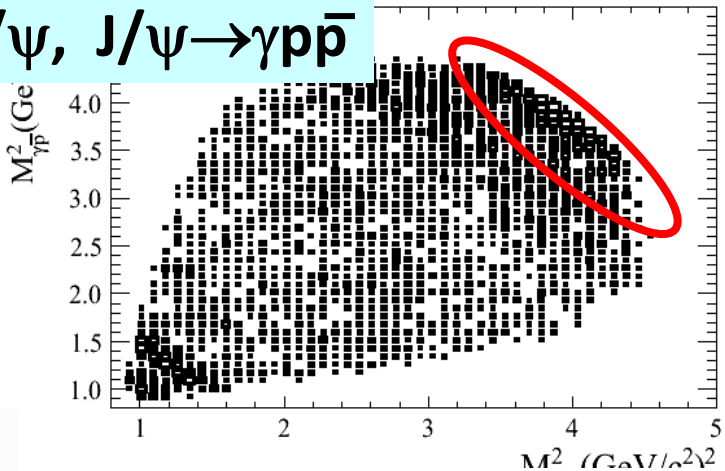
- $p\bar{p}$ **bound state (baryonium)**
- **FSI effect**
- **……**

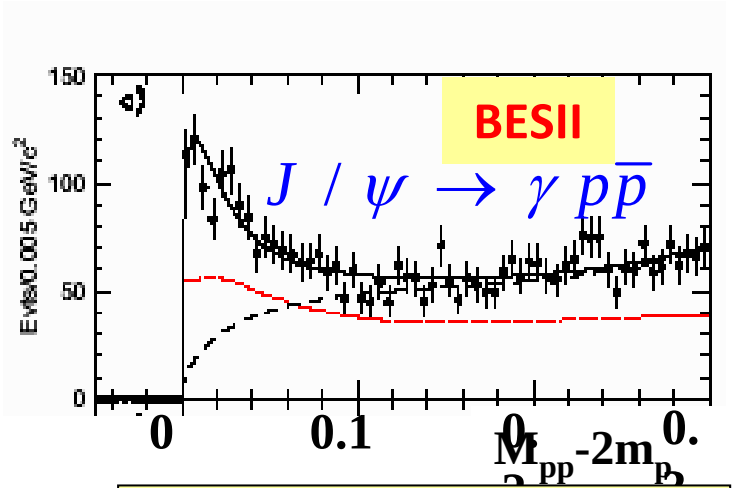
Observation of an anomalous enhancement near the threshold of $p\bar{p}$ mass spectrum

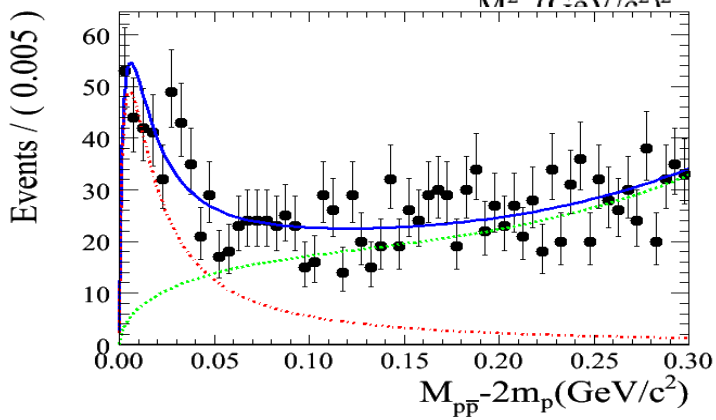
PRL 91 (2003) 022001

$p\bar{p}$ mass spectrum and Dalitz plot at BESIII









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

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

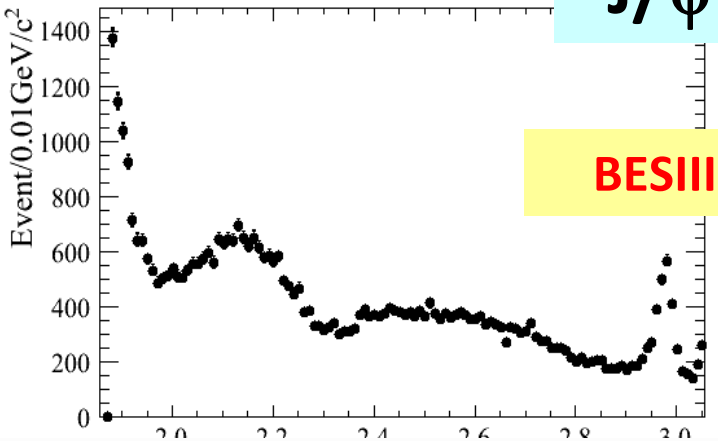
PRL 91 (2003) 022001

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

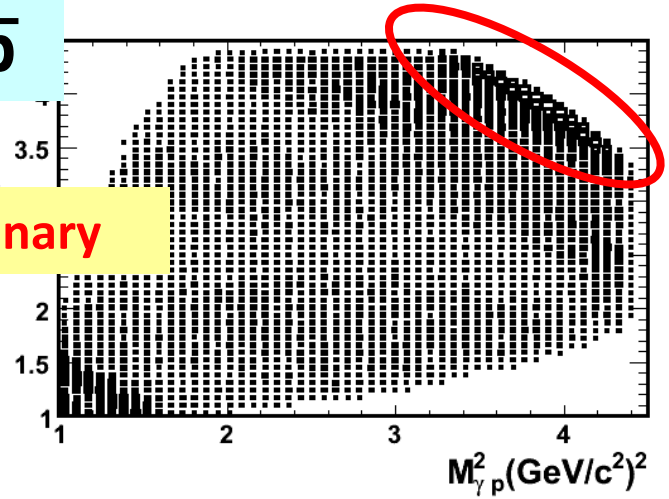
$\Gamma < 38$ MeV/c^2 (90% CL)

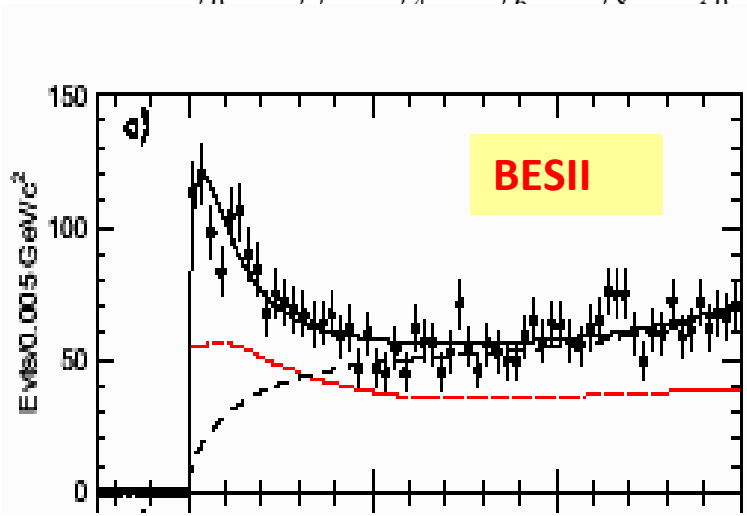
Chinese Physics C 34, 421 (2010)

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

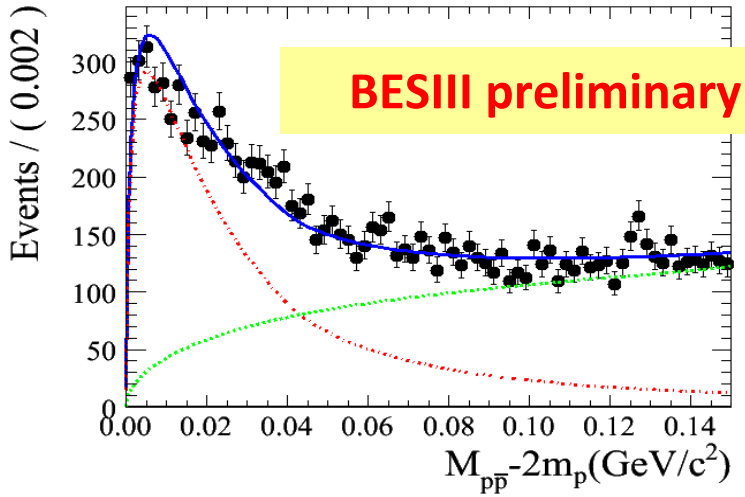


BESIII preliminary





BESII



BESIII preliminary

M=1859 $^{+3}_{-10}$ $^{+5}_{-25}$ MeV/c²

Γ < 30 MeV/c² (90% CL)

Fit result:

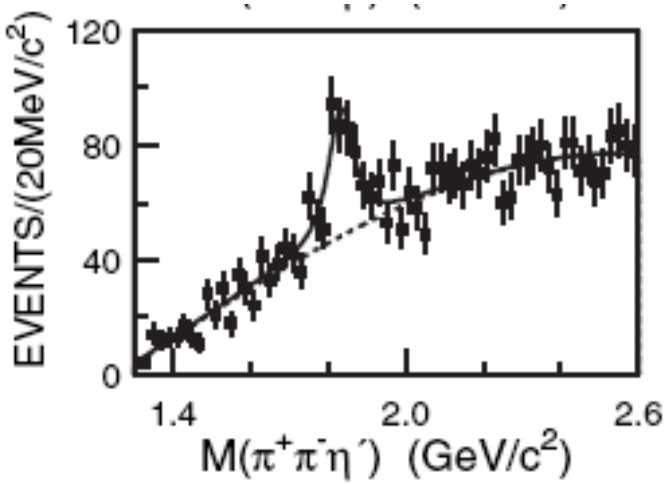
$\mathrm{Mass} = 1861.6 \pm 0.8 MeV/c^2$

$\Gamma < 8\ \mathrm{MeV}(90\%\ \mathrm{CL})$

Confirmation of X(1835) and observation of two new structures in

$$J/\psi \to \gamma\, \pi^+ \pi^- \eta'$$

X(1835) observed at BESII in $J/\psi \to \gamma \pi^+ \pi^- \eta'$



$BESII\ result(\text{Stat. sig.} \sim 7.7\sigma):$

$M = 1833.7 \pm 6.1(stat) \pm 2.7(syst)MeV$

$\Gamma = 67.7 \pm 20.3(\text{stat}) \pm 7.7(\text{syst})\text{MeV}$

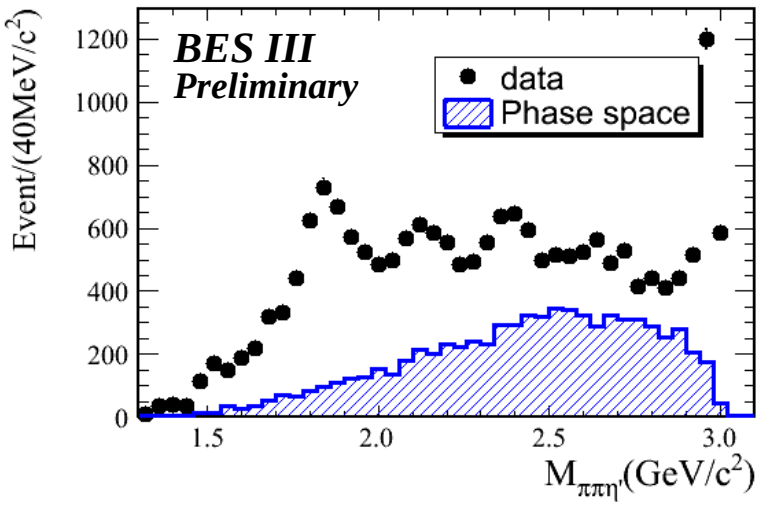
PRL 95,262001(2005)

- **Confirmation of X(1835) is necessary at BESIII.**
- **LQCD predicts the 0^{-+} glueball mass is ~2.3GeV.**

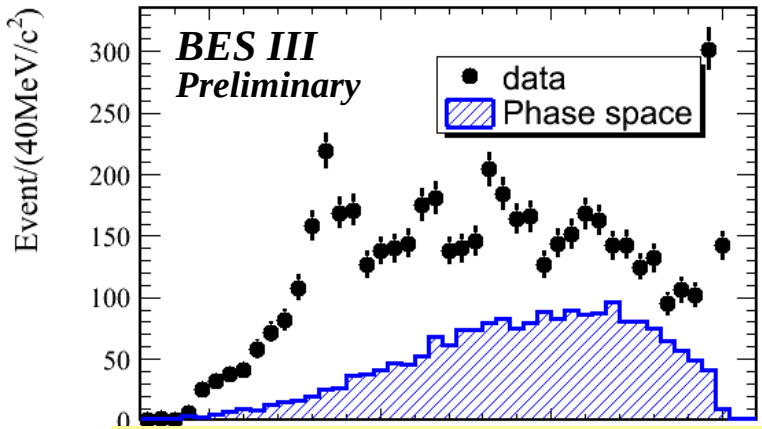
Important and interesting to study $J/\psi \to \gamma\pi^+\pi^-\eta'$

$J/\psi \to \gamma \pi^+ \pi^- \eta'$ @BESIII

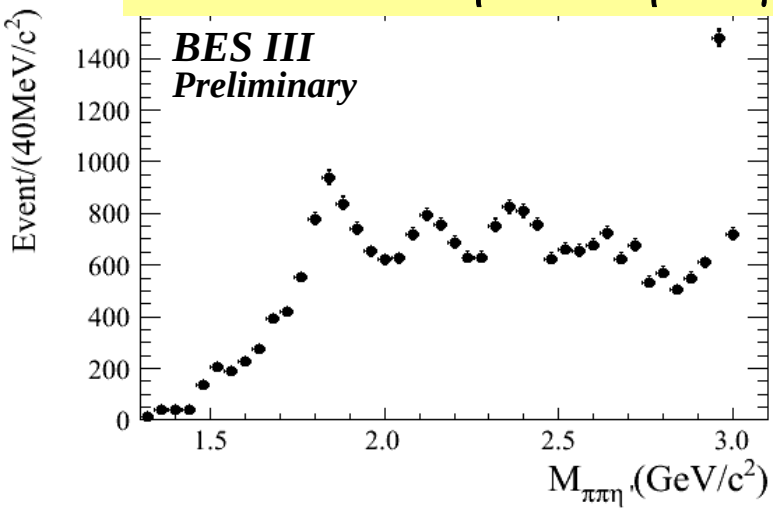
$\eta' \to \gamma\rho$



$\eta' \to \pi\pi\eta$



Combination of η' to $\pi^+\pi^-\eta$ and $\gamma\rho$



- **X(1835) and η_c are observed.**
- **Two additional structures at M~2.1GeV and 2.3GeV observed**
- **$f_1(1510)$.**

Combined mass spectrum fitting

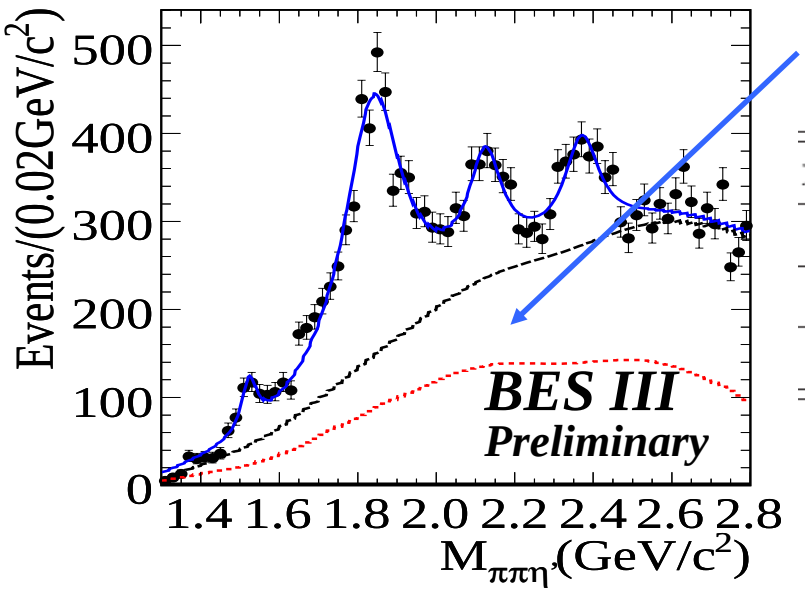
- **Fitting with four resonances (acceptance weighted BW ⊗gauss)**
- **Three background components:**

- Contribution from non-η' events estimated by η' mass sideband

- Contribution from $J/\psi \to \pi^0\pi^+\pi^-\eta'(\eta' \to \gamma\rho)$

- Contribution from "PS background"

$$f_{bkg}(x) = (x-m_0)^{1/2} + a_0(x-m_0)^{3/2} + a_1(x-m_0)^{5/2},\ m_0 = 2m_\pi + m_{\eta'}$$



Red line: estimated contribution of ①+ ②

Black line: total background

resonance	$M(\ \mathrm{MeV}/c^2)$	$\Gamma(\ \mathrm{MeV}/c^2)$	Stat. sig.
X(1835)	1838.1 ± 2.8	179.5 ± 9.1	$> 25\sigma$
X(2120)	2124.8 ± 5.6	101 ± 14	$> 7.2\sigma$
X(2370)	2371.0 ± 6.4	108 ± 15	$> 6.7\sigma$

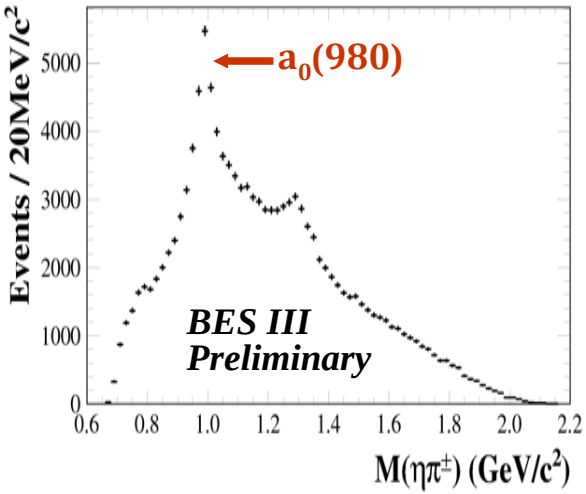
- **X(1835) resonance is confirmed at BESIII, but the width is significantly larger than that measured at BESII with one resonance in the fit.**
- **Two new resonances, X(2120) and X(2370), are observed with significances larger than 7.2σ and 6.7σ, respectively.**
- **PWA is needed not only to determine the spin-parities of above three resonances, but also to make more precise measurements on masses, widths and BRs by considering possible interferences among them.**

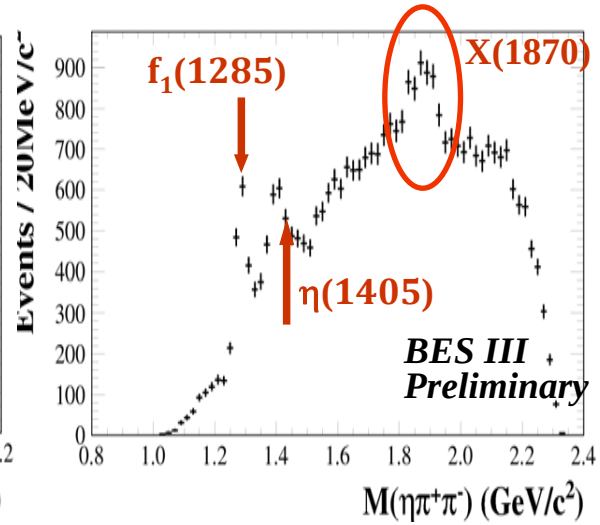
Observation of $X(1870) \to a_0(980)\pi$

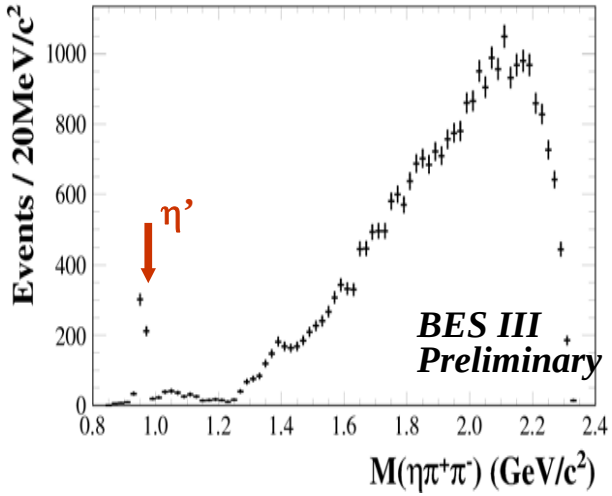
in $J/\psi \to \omega\pi^+\pi^-\eta$ at BESIII

$J/\psi \to \omega\pi^+\pi^-\eta$ @BESIII

- With $a_0(980)$:
- Veto $a_0(980)$:



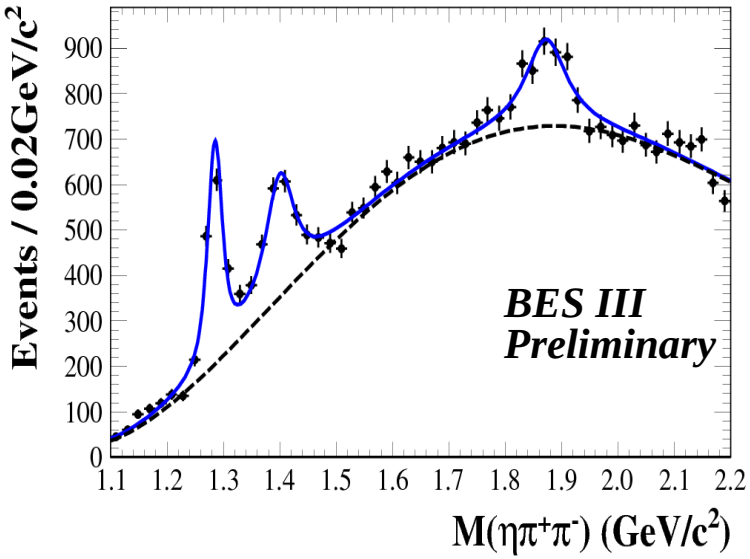




The $f_1(1285)$, $\eta(1410)$ and X(1870) primarily decay via $a_0(980)\pi^{\pm}$

Mass spectrum fitting

- Fitting with three resonances (acceptance weighted BW⊗Gauss)
- Background component described by Polynomial function



$$Fit\ result\ (stat.\ sig.\sim 7.7\sigma)$$
$$M = 1873 \pm 11 MeV$$
$$\Gamma = 82 \pm 19 MeV$$

Whether the X(1870) is the X(1835) or $\eta_2(1870)$, or a new resonance, further study is needed.

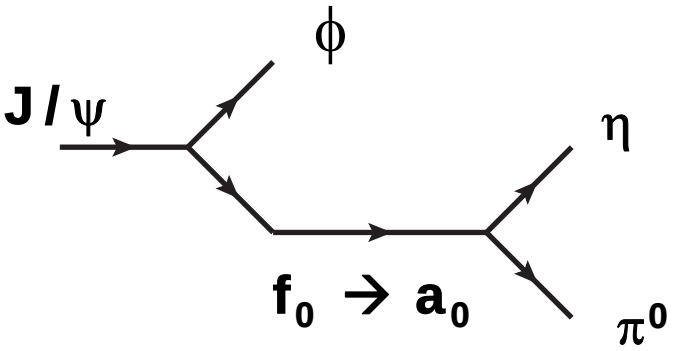
$a_0(980)$ – $f_0(980)$ mixing

- a_0 / f_0 : $q\bar{q}$, four quarks, $K\bar{K}$ molecule, hybrids,…
- Study of the mixing of a_0 and f_0 will shed new light on the enigmatic light scalars. No firm experimental determination.
- A narrow peak (8MeV) between the charged and neutral kaon thresholds (987~995 MeV).

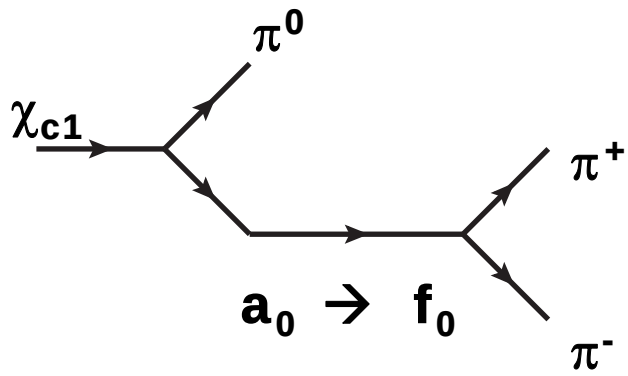
J.Wu, Q.Zhao, B.Zou PRD75 114012,

C. Hanhart etc. PRD76 074028,

etc.



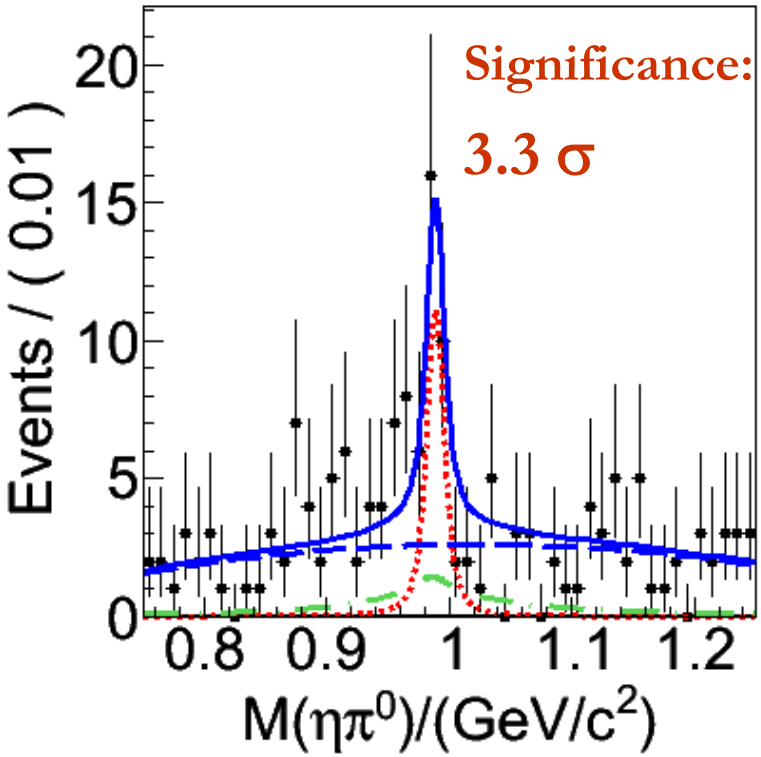
J.Wu, B.Zou PRD78 074017



$a_0(980)$–$f_0(980)$ mixing: $f_0 \to a_0$ transition

$J/\psi \to \phi f_0 \to \phi a_0 \to \phi\eta\pi^0$

BESIII Preliminary



.... **Mixing signal**

--- **$a_0(980)$ contribution from $J/\psi \to \gamma^*/K^*K \to \phi a_0(980)$**

--- **Background polynomial**

$N(\text{mixing}) = 24.7 \pm 8.6$

(<36.7 @90% C.L)

$$\text{Br}(J/\psi \to \phi f_0 \to \phi a_0 \to \phi\eta\pi^0)$$

$$= (3.1 \pm 1.1 \pm 0.8) \times 10^{-6}$$

($<5.5 \times 10^{-6}$ @ 90% C.L.)

Mixing intensity:

$$\xi_{fa} = \frac{\text{Br}(J/\psi \to \phi f_0 \to \phi a_0 \to \phi\eta\pi^0)}{\text{Br}(J/\psi \to \phi f_0 \to \phi\pi\pi)^{[\text{BESII}]}}$$

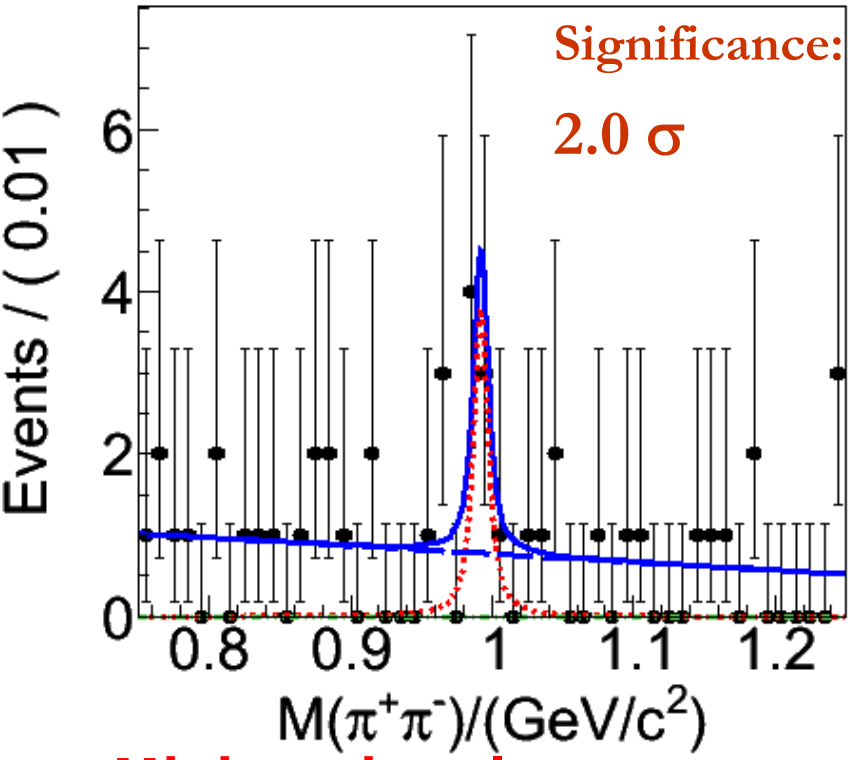
$$= (0.6 \pm 0.2 \pm 0.2)\%$$

($<1.1\%$ @ 90% C.L.)

$a_0(980)$ – $f_0(980)$ mixing: $a_0 \to f_0$ transition

$\psi' \to \gamma\chi_{c1}$, $\chi_{c1} \to a_0\pi^0 \to f_0\pi^0 \to \pi^+\pi^-\pi^0$

BESIII Preliminary



.... Mixing signal

--- $f_0(980)$ contribution from other processes

--- Background polynomial

$N(\text{mixing}) = 6.5 \pm 3.2$

(<12.1 @90% C.L)

$$\text{Br}(\psi' \to \gamma\chi_{c1})\text{Br}(\chi_{c1} \to a_0\pi^0 \to f_0\pi^0 \to \pi^+\pi^-\pi^0)$$

$$= (2.8 \pm 1.4 \pm 0.5) \times 10^{-7}$$

($<5.5 \times 10^{-7}$ @ 90% C.L.)

Mixing intensity:

$$\xi_{af} = \frac{\text{Br}(\chi_{c1} \to a_0\pi^0 \to f_0\pi^0 \to \pi^+\pi^-\pi^0)}{\text{Br}(\chi_{c1} \to \pi^0 a_0 \to \eta\pi^0\pi^0)}$$ [PDG]

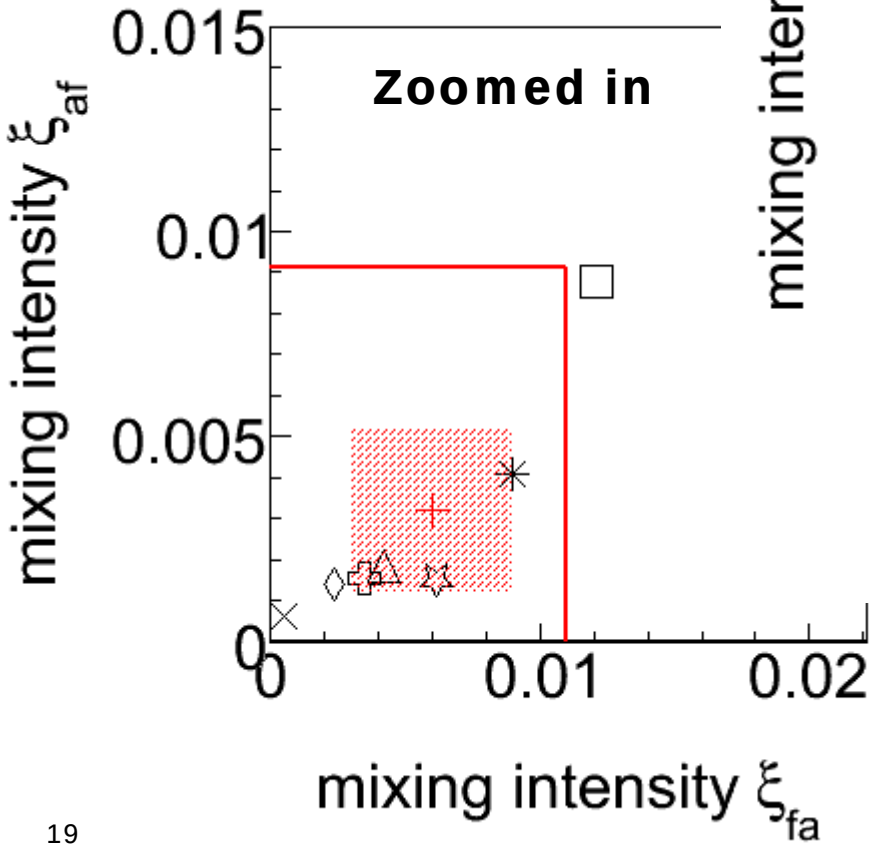
$$= (0.3 \pm 0.2 \pm 0.1)\%$$

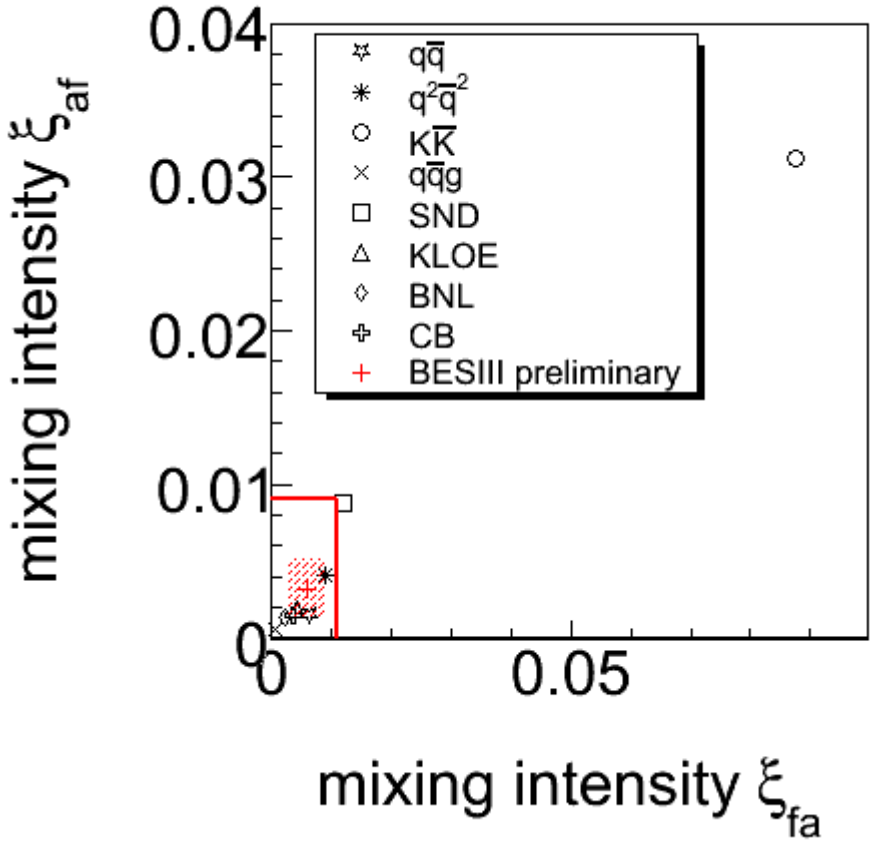
(<0.9% @ 90% C.L.)

Models of a_0/f_0 give different resonance parameters
Comparison with ξ_{fa}/ξ_{af} from those parameters

a_0–f_0 mixing:

a sensitive probe





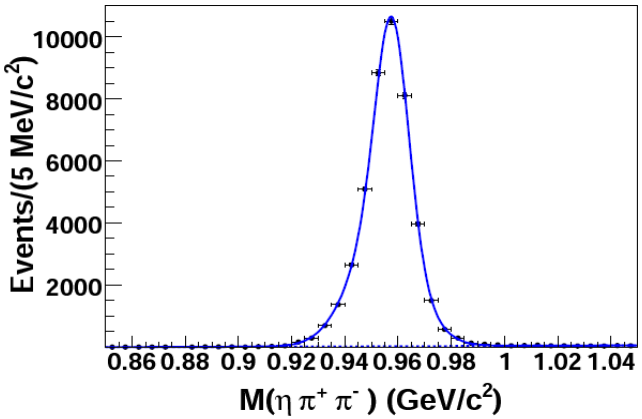
BESIII Preliminary

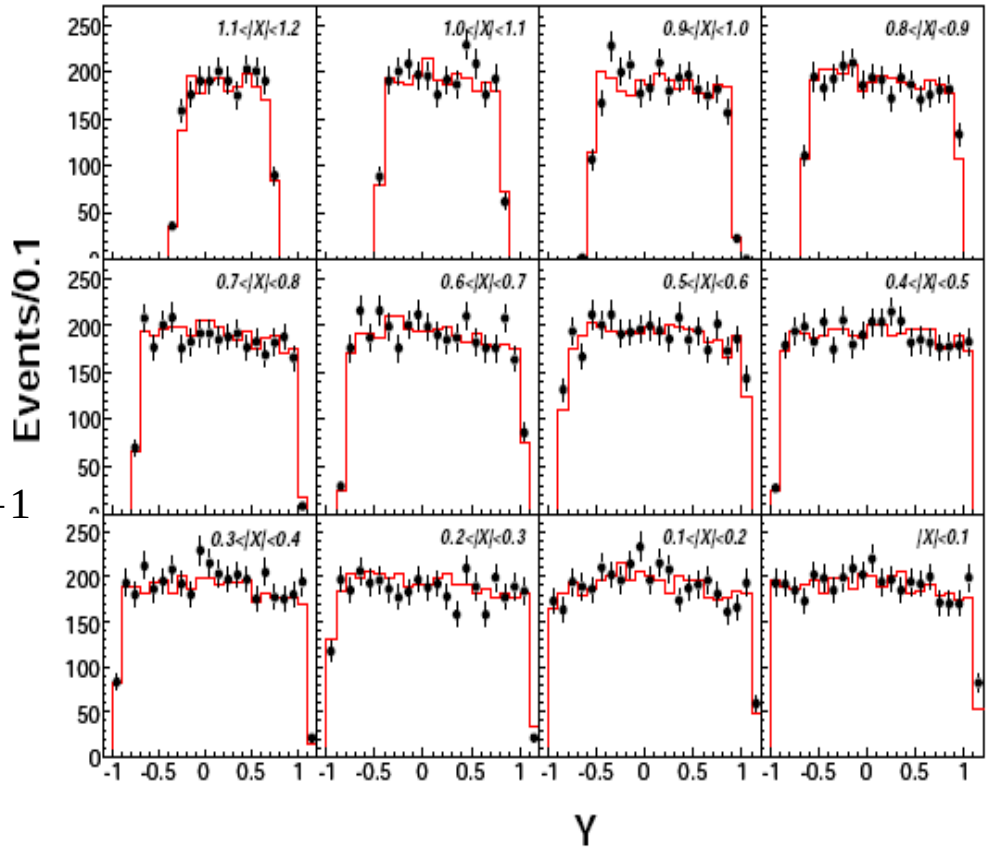
shaded region: BES3 measurements

red line: BES3 upper limit

dots: various predictions

Matrix Element Measurement of the decay $\eta' \to \eta\pi\pi$





$$X = \frac{\sqrt{3}}{Q}(T_{\pi^+} + T_{\pi^-}) \text{ and } Y = \frac{m_\eta + 2m_\pi}{m_\pi}\frac{T_\eta}{Q} - 1$$

General parametrization :

$$\mathrm{M}^2 = A(1 + aY + bY^2 + cX + dX^2)$$

Linear parametrization :

$$\mathrm{M}^2 = A(|1 + \alpha Y|^2 + cX + dX^2)$$

Table: The left four columns are for a,b,c and d. The right for $Re(\alpha)$, $Im(\alpha)$, c and d.

VES[1]	Theory	This work	CLEO	VES[2]	This work
-0.127 ± 0.018	-0.116 ± 0.011	-0.047 ± 0.012	-0.021 ± 0.025	-0.072 ± 0.014	-0.033 ± 0.006
-0.106 ± 0.032	-0.042 ± 0.034	-0.068 ± 0.021	0.000 (fixed)	0.000 ± 0.100	0.000 ± 0.050
$+0.015 \pm 0.018$	–	$+0.020 \pm 0.012$	0.000 (fixed)	$+0.020 \pm 0.019$	$+0.018 \pm 0.010$
-0.082 ± 0.019	$+0.010 \pm 0.019$	-0.073 ± 0.013	0.000 (fixed)	-0.066 ± 0.034	-0.058 ± 0.013

VES[1]: Phys. Lett. B 651, 22 (2007) Theory: Eur. Phys. J A 26, 383 (2005)
CLEO: Phys. Rev. Lett. 84, 26 (2000) VES[2]:Phys. Atom. Nucl. 68, 372 (2005).

Some comments:

- The errors of our fitted parameter values are smaller than previous published results.
- In the general parametrization, the values of *a* and *b* are consistent with the results from GAMS-4π (PLB177,115), however the values of *c* and *d* are consistent with the results from VES[1].
- A negative value of the coefficient *b* indicates that two kinds of parametrization are not equivalent. This conclusion is consistent with that from GAMS-4π. VES[1] found the fit with linear parametrization yields unsatisfactory $\chi^2/NDF = 170.5/114$ ratio.
- The quadratic term in *X* is unambiguously different from zero. Similarly for the quadratic term in *Y*. The dynamical nature of this term needs clarification.
- The value of the parameter *c* testing C parity violation in strong interaction is consistent with zero within 2σ in both parametrizations.

Summary

- **Nice results are obtained**

  Important BESII results have been confirmed , new improved measurements have been carried out and BESIII have new observations …

- **More results will come soon**

Thank you !

Thank you!