Recent Results from BESIII

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Outline

- BESIII data

Light Hadron Spectroscopy:

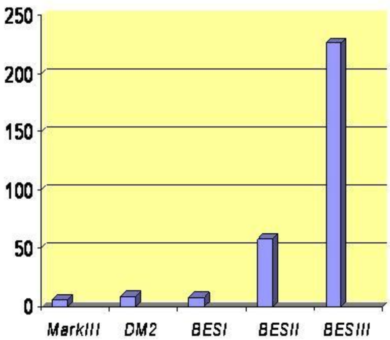
- Measurement of the matrix element for the decay $\eta'(958) \to \eta\pi^+\pi^-$
- Study of $a_0(980) - f_0(980)$ mixing
- Confirmation of X(1835) and observation of two new structures

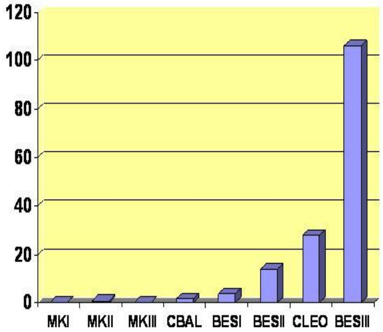
Charmonium decay:

- Evidence for $\psi(2S)$ decays into $\gamma\pi^0$ and $\gamma\eta$
- Two-photon transition from $\psi(2S)$ to J/ψ
- Study of χ_{cJ} radiative decays into a vector meson
- Obervation of $\chi_{cJ} \to VV$ ($V = \omega, \phi$)

All results are preliminary!

World J/ψ and $\psi(2S)$ Samples ($\times 10^6$)



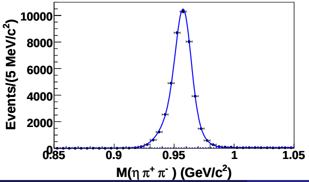


BESIII: J/ψ 2009: $\sim$226M, and $\psi(2S)$ 2009: $\sim$106M .

Measurement of the Matrix Element for the Decay $\eta'(958) \rightarrow \eta\pi^+\pi^-$

Motivation:

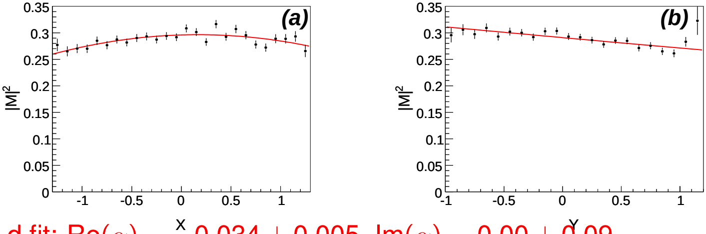
- Important for deeper insight into the dynamics of the process and the structure of the particles.
- Important for studies devoted to chiral theory, the effect of the gluon component, and the possible nonet of light scalars.
- Important for the determination of a possible contribution from $f_0(600)$ (or σ) resonance (even though the $a_0(980)$ is also present).
- Precision measurements on η and $\eta'(958)$ provide useful information in understanding low energy QCD.



$\mathcal{B}(J/\psi \rightarrow \gamma\eta') = (4.84 \pm 0.03(stat) \pm 0.25(sys)) \times 10^{-3}$

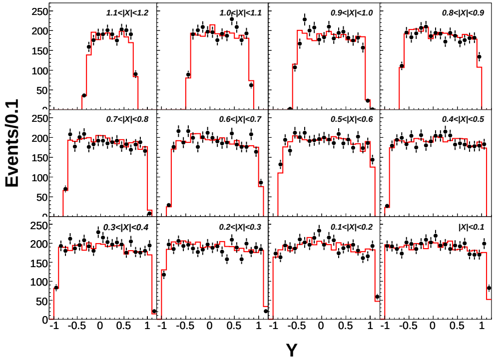
Measurement of the Matrix Element:

- $X = \frac{\sqrt{3}}{Q}(T_{\pi^+} - T_{\pi^-})$, $Y = \frac{m_\eta + 2m_\pi}{m_\pi}\frac{T_\eta}{Q} - 1$,
  $T_{\pi,\eta}$ denote the kinetic energies of mesons in the $\eta'(958)$ rest frame and $Q = T_\eta + T_{\pi^+} + T_{\pi^-} = m_{\eta'(958)} - m_\eta - 2m_\pi$.
- general parametrization: $M^2 = A(1 + aY + bY^2 + cX + dX^2)$
- linear parametrization: $M^2 = A(|1 + \alpha Y|^2 + cX + dX^2)$
  α is a complex parameter. A non-zero value of α may represent the contribution of a gluon component in the wave function of the $\eta'(958)$ in the decay.



1-d fit: $\mathrm{Re}(\alpha) = -0.034 \pm 0.005$, $\mathrm{Im}(\alpha) = 0.00 \pm 0.09$, $c = 0.019 \pm 0.009$, $d = -0.058 \pm 0.012$.

- $\chi^2(N, a, b, c, d) = \sum_i^{n_{bin}} \frac{(D_i - NM_i)^2}{\sigma_i^2}$
  M_i and D_i are the numbers of (weighted) entries in the i-th bin of the 2-d Dalitz plot for MC and data, respectively.
- general parametrization: $M_i = \sum_{j=1}^{N_{ev}} (1 + aY_j + bY_j^2 + cX_j + dX_j^2)$
  j is an index over the MC events, and X_j and Y_j are the true generated values of Dalitz variables. Similarly for the linear parametrization



Experimental distributions of the variable Y in various intervals of X with fitting function (histogram) for the general decomposition parametrization.

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

Study of $a_0(980) - f_0(980)$ mixing

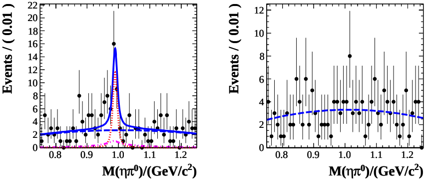
Motivation:

- There has been much argument whether the $a_0^0(980)$ and the $f_0(980)$ are part of the ground-state quark-antiquark family or whether they are 4-quark states, hybrids or $K\overline{K}$ molecules.
- The mixing between $a_0^0(980)$ and $f_0(980)$ is expected to shed light on the nature of these two resonances.
- Two kinds of mixing intensities ξ_{af} and ξ_{fa} for the $a_0^0(980) \to f_0(980)$ and $f_0(980) \to a_0^0(980)$ transitions are expressed as:

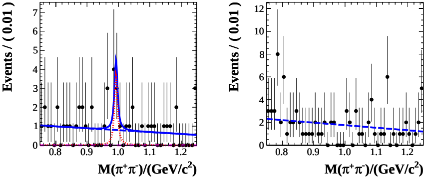
$$\xi_{fa} = \frac{Br(J/\psi \to \phi f_0(980) \to \phi a_0^0(980) \to \phi\eta\pi^0)}{Br(J/\psi \to \phi f_0 \to \phi\pi\pi)},$$

$$\xi_{af} = \frac{Br(\psi' \to \gamma\chi_{c1} \to \gamma\pi^0 a_0^0(980) \to \gamma\pi^0 f_0(980) \to \gamma\pi^0\pi^+\pi^-)}{Br(\psi' \to \gamma\chi_{c1} \to \gamma\pi^0 a_0^0 \to \gamma\pi^0\pi^0\eta)}.$$

Measurement of $J/\psi \to \phi f_0(980) \to \phi a_0^0(980) \to \phi\eta\pi^0$ and $\psi' \to \gamma\chi_{c1} \to \gamma\pi^0 a_0^0(980) \to \gamma\pi^0 f_0(980) \to \gamma\pi^0\pi^+\pi^-$



(a). ϕ signal region. (b). ϕ sidebands region. The fitted results:



(a). χ_{c1} signal region. (b). χ_{c1} sidebands region.

$\mathcal{B}(J/\psi \to \phi f_0(980) \to \phi a_0^0(980) \to \phi\eta\pi^0) = (3.2 \pm 1.1 \pm 0.8) \times 10^{-6}$ ($< 5.1 \times 10^{-6}$) @ 90% C.L.

$\mathcal{B}(\psi' \to \gamma\chi_{c1} \to \gamma\pi^0 a_0^0(980) \to \gamma\pi^0 f_0(980) \to \gamma\pi^0\pi^+\pi^-)$ = $(2.7 \pm 1.4 \pm 0.7) \times 10^{-7}$ ($< 5.9 \times 10^{-7}$ @ 90% C.L.).

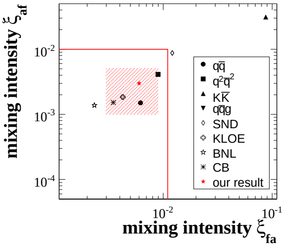
Discussion:

The mixing intensity ξ_{fa} for the $f_0(980) \to a_0^0(980)$ transition is calculated to be:

$$\xi_{fa} = \frac{Br(J/\psi \to \phi f_0(980) \to \phi a_0^0(980) \to \phi\eta\pi^0)}{Br(J/\psi \to \phi f_0 \to \phi\pi\pi)}$$
$$= 0.6 \pm 0.2(stat.) \pm 0.2(sys.)\%$$

The mixing intensity ξ_{af} for the $a_0^0(980) \to f_0(980)$ transition is calculated to be:

$$\xi_{af} = \frac{Br(\psi' \to \gamma\chi_{c1} \to \gamma\pi^0 a_0^0(980) \to \gamma\pi^0 f_0(980) \to \gamma\pi^0\pi^+\pi^-)}{Br(\psi' \to \gamma\chi_{c1} \to \gamma\pi^0 a_0^0 \to \gamma\pi^0\pi^0\eta)}$$
$$= 0.3 \pm 0.2(stat.) \pm 0.1(sys.)\%$$

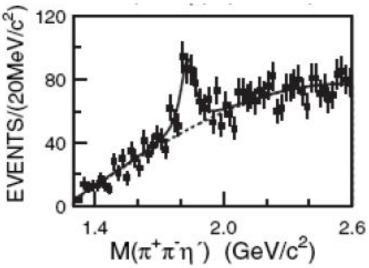


The mixing intensities and predictions with various theoretical predictions. The shaded region is our measurement with error bars and the red lines are our limits.

Confirmation of X(1835) and observation of two new structures in $J/\psi \to \gamma\eta'(958)\pi^+\pi^-$

Motivation:

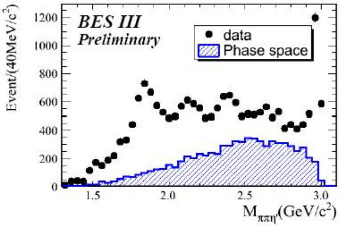
- Confirmation of X(1835) is necessary with high statistic data sample.
- LQCD predicts the 0^{-+} glueball mass is 2.3 GeV/c^2.
- A 0^{-+} glueball may have similar property as η_c (the main η_c decay mode is $\eta'(958)\pi^+\pi^-$).



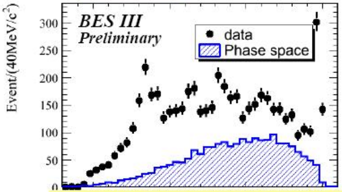
BESII results:
signal significance is 7.7 σ
$M = 1833.7 \pm 6.1(stat) \pm 2.7(sys)$ MeV/c^2
$\Gamma = 67.7 \pm 20.3(stat) \pm 7.7(sys)$ MeV/c^2
Phys. Rev. Lett. 95, 262001 (2005)

Mass spectrum of $\pi^+\pi^-\eta'$

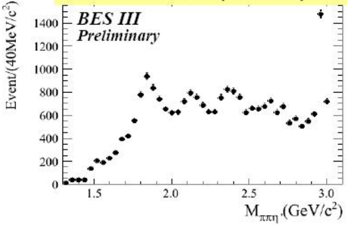
$\eta' \to \gamma\rho$



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



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

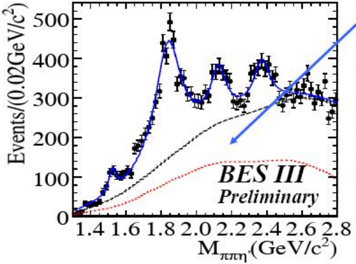


- X(1835) and η_c is observed.
- Two additional structures at M~2.1GeV and 2.3GeV
- There maybe some $f_1(1510)$.

Fitting the mass spectrum:

- Three background components:
  - ① Contribution from non-η' events estimated by η' mass sideband
  - ② Contribution from $J/\psi \to \pi^0\pi^+\pi^-\eta'(\eta' \to \gamma\rho)$ with re-weighting method
  - ③ 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	$> 6.7\sigma$

Stat. sig. is conservatively estimated:

fit range, background shape,
contribution of extra resonances

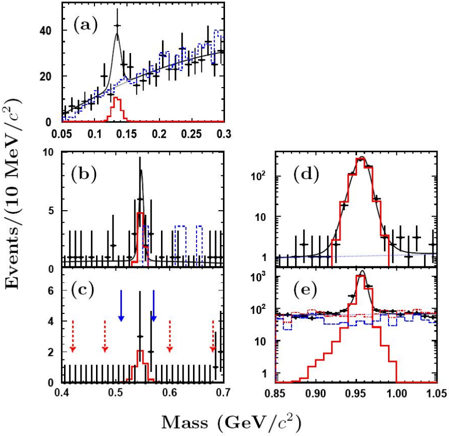
- X(1835) resonance is confirmed at BESIII, but the width is significantly larger than that measured at BESII with one resonance in the fit.
- Two new resonances, X(2120) and X(2370), are observed.
- PWA is needed

Evidence for $\psi(2S)$ decays into $\gamma\pi^0$ and $\gamma\eta$

Motivation:

- Important tests for various phenomenological mechanisms, such as vector meson dominance model, two-gluon couplings to $q\bar{q}$ states, mixing of $\eta_c - \eta^{(\prime)}$, and final-state radiation by light quarks.
- The ratio of $R_{J/\psi} = \mathcal{B}(J/\psi \to \gamma\eta)/\mathcal{B}(J/\psi \to \gamma\eta')$ can be predicted by the first order of perturbation theory, and $R_{J/\psi} = R_{\psi(2S)}$ is expected (CLEO: $R_{\psi(2S)} < 1.8\%$ at 90% C.L. and $R_{J/\psi} = (21.1 \pm 09)\%$. PRD79,111101 (2009))
- The decay $\psi(2S) \to \gamma\pi^0$ is suppressed because the photon can only be from final state radiation off one of the quarks.
- $\mathcal{B}(\psi(2S) \to \gamma\pi^0) = 2.19 \times 10^{-7}$: calculated in PRD79,097301. CLEO: $< 5.0 \times 10^{-6}$ at 90% C.L. (PRD79,111101).
- $e^+e^- \to \psi(2S)/\gamma^\star \to \gamma\pi^0$ will be very useful in testing the form factor for timelike photons $Q^2 = -q^2 < 0$ (PRD79,097301).

Results:



(a) $\gamma\pi^0$; (b) $\gamma\eta(\pi^+\pi^-\pi^0)$; (c) $\gamma\eta(3\pi^0)$; (d) $\gamma\eta'(958)[\pi^0\pi^0\eta(\gamma\gamma)]$; and (e) $\gamma\eta'(958)(\gamma\pi^+\pi^-)$.

Signal significances are 4.1 σ for $\psi(2S) \to \gamma\pi^0$, 3.2 σ for $\psi(2S) \to \gamma\eta$

$R_{\psi(2S)} = (1.10 \pm 0.38 \pm 0.07)\%$: it is the first measurement and it is much smaller than $R_{J/\psi} = (21.1 \pm 0.9)\%$.

Table: Branching fractions (10^{-6}).

Mode	BESIII	Combined BESIII	PDG
$\psi(2S) \to \gamma\pi^0$	$1.58 \pm 0.40 \pm 0.13$	$1.58 \pm 0.40 \pm 0.13$	≤ 5
$\psi(2S) \to \gamma\eta(\pi^+\pi^-\pi^0)$	$1.78 \pm 0.72 \pm 0.17$		
$\to \gamma\eta(\pi^0\pi^0\pi^0)$	$1.07 \pm 0.65 \pm 0.08$	$1.38 \pm 0.48 \pm 0.09$	≤ 2
$\psi(2S) \to \gamma\eta'(958)(\pi^+\pi^-\eta)$	$120 \pm 5 \pm 8$		
$\to \gamma\eta'(958)(\pi^+\pi^-\gamma)$	$129 \pm 3 \pm 8$	$126 \pm 3 \pm 8$	121 ± 8

Two-photon transition from $\psi(2S)$ to J/ψ

Motivation:

On experimental side:

- not seen previously in $\psi(2S)$ decays
- analogous process to positronium and hydrogen two-photon transition
- CLEO reported $\Upsilon(3S) \to \gamma\gamma\Upsilon(2S)$ (Phys. Rev. D 49, 40 (1994))

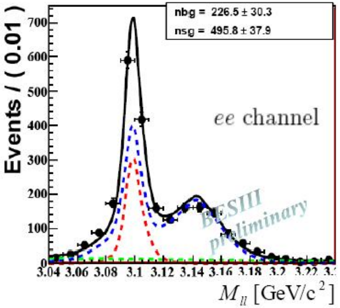
On theoretical side:

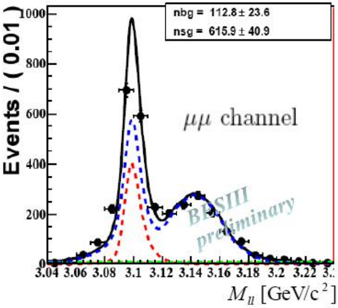
- order α^2 QED transition between two hadrons
- Similar process has been studied in heavy-light quark system
- improve understanding of heavy quarkonium such as spectrum, decay et al, and the strong interaction
- possibility of testing the hadron-loop effect

Signal Estimation

unbinned maximum likelihood fit with composition of three PDFs:

- **signal (red)**: shape from phase-space-like MC simulation
- **ψ(2S) bkg.(blue)**: shape and magnitude from exclusive MC simulation
- **other bkg.(green)**: 1st-order polynominal





Combined with e^+e^- and $\mu^+\mu^-$ modes, the branching fraction is measured to be $\mathcal{B}(\psi(2S) \to \gamma\gamma J/\psi) = (1.02 \pm 0.05(\text{stat})^{+0.18}_{-0.20}(\text{sys})) \times 10^{-3}$.

Study of χ_{cJ} radiative decays into a vector meson

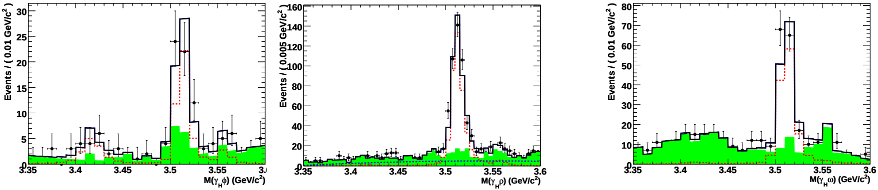
Motivation:

- $\psi \to \gamma X \to \gamma\gamma V$ (ρ^0, ω, ϕ) provide a favorable place to extract information on the flavor content of the C-even resonance X to study gluon hadronization dynamics.
- By including hadronic loop contributions, a recent pQCD calculation (arXiv:1005.0066) obtains results in agreement with the experimental measurements of $\mathcal{B}(\chi_{c1} \to \gamma V)$.

Table: Theoretical predictions(in units of 10^{-6}) and results from the CLEO.

Mode	CLEO[1]	pQCD[2]	QCD[3]	QCD+QED[3]
$\chi_{c0} \to \gamma\rho^0$	< 9.6	1.2	3.2	2.0
$\chi_{c1} \to \gamma\rho^0$	$243 \pm 19 \pm 22$	14	41	42
$\chi_{c2} \to \gamma\rho^0$	< 50	4.4	13	38
$\chi_{c0} \to \gamma\omega$	< 8.8	0.13	0.35	0.22
$\chi_{c1} \to \gamma\omega$	$83 \pm 15 \pm 12$	1.6	4.6	4.7
$\chi_{c2} \to \gamma\omega$	< 7.0	0.5	1.5	4.2
$\chi_{c0} \to \gamma\phi$	< 6.4	0.46	1.3	0.03
$\chi_{c1} \to \gamma\phi$	< 26	3.6	11	11
$\chi_{c2} \to \gamma\phi$	< 13	1.1	3.3	6.5

1. PRL 101,151801 (2008). 2. Chin. Phys. Lett. 23, 2376 (2006). 3. hep-ph/0701009



Invariant mass distributions of (a) $\gamma\phi$, (b) $\gamma\rho^0$, and (c) $\gamma\omega$. Dots with error bars are data; histograms are the best fit; dashed lines are signal shapes; and the shaded histograms are vector meson sideband background plus a 2nd order polynomial background.

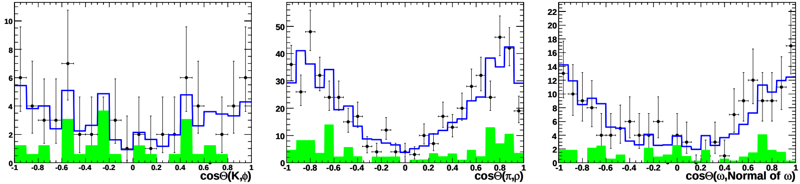
Table: Results of $\chi_{cJ} \to \gamma V$. The upper limits are at the 90% C.L.

Decay mode	Number of events	Efficiency (%)	Systematic error (%)	Branching fraction ($\times 10^{-6}$)	Statistical significance
$\chi_{c0} \to \gamma\phi$	15.0 ± 6.6	32.4	8.1	$9.5 \pm 4.2 \pm 0.8$	2.9σ
$\chi_{c1} \to \gamma\phi$	42.6 ± 8.6	34.6	7.8	$25.8 \pm 5.2 \pm 2.0$	6.4σ
$\chi_{c2} \to \gamma\phi$	4.6 ± 4.9	32.6	8.8	<8.0	
$\chi_{c0} \to \gamma\rho^0$	6 ± 12	22.6	7.4	<10.2	
$\chi_{c1} \to \gamma\rho^0$	432 ± 25	19.4	7.2	$228 \pm 13 \pm 16$	$\gg 10\sigma$
$\chi_{c2} \to \gamma\rho^0$	13 ± 11	15.7	7.9	<20.4	
$\chi_{c0} \to \gamma\omega$	5 ± 11	18.6	8.3	<12.7	
$\chi_{c1} \to \gamma\omega$	136 ± 14	22.7	8.0	$69.7 \pm 7.2 \pm 5.6$	$\gg 10\sigma$
$\chi_{c2} \to \gamma\omega$	1 ± 6	19.2	8.9	<6.0	

The longitudinal (transverse) polarization exhibits a $\cos^2\Theta$ ($\sin^2\Theta$) dependence, and the angular distribution is expressed as:

$$\frac{dN}{d\cos\theta} \propto |A_L|^2\cos^2\Theta + \frac{1}{2}|A_T|^2\sin^2\Theta \ ,$$

where A_L and A_T are the longitudinal and transverse polarization amplitudes, and Θ is defined as the angle between the vector meson flight direction in the χ_{cJ} rest frame and either the π^+/K^+ direction in the ρ^0/ϕ rest frame or the normal to the ω decay plane in the ω rest frame.



Results: The transverse component fraction:
$f_T = |A_T|^2/(|A_T|^2 + |A_L|^2) = N_T/(N_T + R*N_L)$, where $R = \varepsilon_T/\varepsilon_L$
f_T are $0.29^{+0.13+0.10}_{-0.12-0.09}$ for $\chi_{c1}\to\gamma\phi$, $0.158\pm0.034^{+0.015}_{-0.014}$ for $\chi_{c1}\to\gamma\rho^0$, and $0.247^{+0.090+0.044}_{-0.087-0.026}$ for $\chi_{c1}\to\gamma\omega$.

Observation of $\chi_{cJ} \to \omega\omega$, $\phi\phi$ and $\omega\phi$

Motivation:

Important laboratory to test QCD:

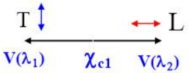
- ❑ **Previous measurements from BESII.**
- ❑ **Only χ_{c0} and χ_{c2} decays into $\phi\phi$ and $\omega\omega$ are observed.**

BR(10^{-3})	χ_{c0}	χ_{c2}	
$\to \phi\phi$	0.94±0.21±0.13	1.70±0.30±0.25	BESII, PLB 642, 197 (2006)
$\to \omega\omega$	2.29±0.58±0.41	1.77±0.47±0.36	BESII, PLB 630, 7 (2005)

- ❑ **$\chi_{c1} \to V\,V$ is suppressed due to helicity selection rule in pQCD**

$$Br[\chi_{c1} \to V(\lambda_1)V(\lambda_2)] \sim \left(\frac{\Lambda^2_{QCD}}{m_c^2}\right)^{|\lambda_1+\lambda_2|+2}$$

Nucl. Phys. B201,492

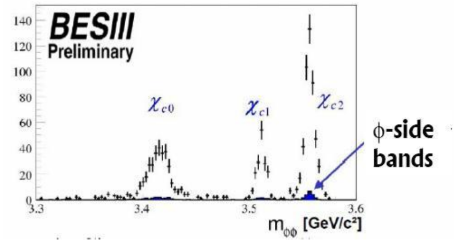


P-parity conservation requires the two vectors having different polarization, so it is suppressed.

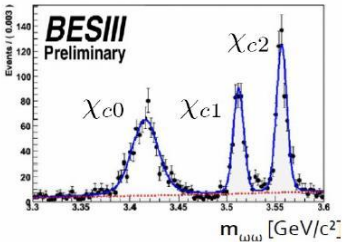
So $\lambda_1+\lambda_2 \neq 0$

- ❑ **$\chi_{cJ} \to \omega\phi$ is doubly OZI suppressed.**

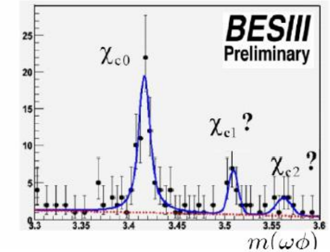
$\psi(2S) \to \gamma\phi\phi$



$\psi(2S) \to \gamma\omega\omega$



$\psi(2S) \to \gamma\omega\phi$



First observation of $\omega\phi$ which is a doubly OZI suppressed decay, long distance contribution may be important in charmonium decays.

Other recent results from BESIII that have not been included here.

- Analysis of $J/\psi \to \omega\eta\pi^+\pi^-$: A structure denoted as X(1870) is seen in $\eta\pi^+\pi^-$ mass spectrum. For details, see Yanping HUANG's report at ICHEP10:

  http://indico.cern.ch/contributionDisplay.py?contribId=1210&sessionId=46&confId=73513

- Analysis of $\chi_{cJ} \to 4\pi^0$: it is the first measurement. For details, see Ronggang PING's report at ICHEP10.

  http://indico.cern.ch/contributionDisplay.py?contribId=1233&sessionId=50&confId=73513

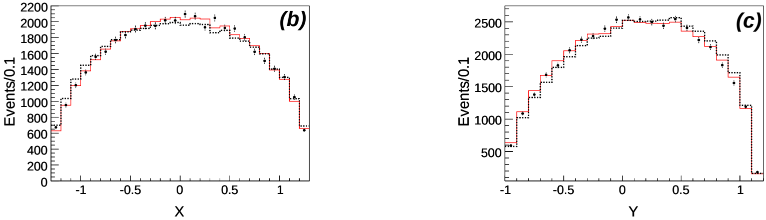
Summary

Some preliminary results from BESIII have been shown here.

- ✍ The Dalitz plot of $\eta'(958) \to \eta\pi^+\pi^-$ decay is studied in a generalized and a linear representation.
- ✍ We perform direct measurements of $a_0^0(980) - f_0(980)$ mixing.
- ✍ $X(1835) \to \eta'(958)\pi^+\pi^-$ is confirmed and two new resonances, X(2120) and X(2370), are observed.
- ✍ $\psi(2S) \to \gamma\pi^0$ and $\psi(2S) \to \gamma\eta$ are observed for the first time with signal significance of 4.1σ and 3.2σ, respectively.
- ✍ A significant enhancement of two-photon transition of ψ(2S) to J/ψ was observed for the first time
- ✍ The decays $\chi_{cJ} \to \gamma V$ ($V = \phi, \rho^0, \omega$) are studied. The fractions of the longitudinal polarization component of V in $\chi_{c1} \to \gamma V$ are measured.
- ✍ χ_{cJ} signals are observed in the decays $\chi_{cJ} \to \omega\omega, \phi\phi$ and $\omega\phi$.

Thanks! 谢谢！

Backup



The corresponding projections on variables X and Y in (b) and (c), respectively, where the dashed histograms are from MC signal sample with $\eta'(958) \to \eta\pi^+\pi^-$ events produced with phase space and the blank histograms are the fitted results described in the text.