BESIII status and results

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Outline

- Introduction
- Status of BESIII
- Recent results from BESIII
- Summary
Beijing Electron Positron Collider (BEPC) at IHEP
beam energy: 1.0 – 2.3(2.5) GeV

Physics goal

1-2.3GeV e+ e- collisions produce charmonium states (J/ψ, ψ(2S), χcJ and ψ(3770) etc.), charm mesons and τ lepton.
We are unique now in the charm region. The Y's are here! In transition region between pQCD and non-pQCD.
In the 1990s, there was discussion of the future. The conclusion was to continue tau-charm physics with a major upgrade of the accelerator and detector (BEPCII/BESIII). Officially approved in 2003.

The physics window is precision charm physics and the search for new physics.

- High statistics: high luminosity machine + high quality detector.
- Small systematic error: high quality detector.
**BEPCII Storage Ring: Double-ring**

**Beam energy:**
- 1.0-2.3 GeV

**Luminosity:**
- $1 \times 10^{33}$ cm$^{-2}$s$^{-1}$

**Optimum energy:**
- 1.89 GeV

**Energy spread:**
- $5.16 \times 10^{-4}$

**No. of bunches:**
- 93

**Bunch length:**
- 1.5 cm

**Total current:**
- 0.91 A

**SR mode:**
- 0.25 A @ 2.5 GeV

**IP**
From BESII to BESIII

<table>
<thead>
<tr>
<th>BESII</th>
<th>BESIII</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MDC</strong></td>
<td></td>
</tr>
<tr>
<td>$\sigma(p)/p = 1.78% \cdot \sqrt{1 + p^2}$</td>
<td>$\sigma(p_t)/p_t = 0.32% \cdot p_t$</td>
</tr>
<tr>
<td>$dE/dx_{reso} = 8%$</td>
<td>$dE/dx_{reso} &lt; 6%$</td>
</tr>
<tr>
<td><strong>TOF</strong></td>
<td></td>
</tr>
<tr>
<td>$180\text{ ps}$ (for bhabha)</td>
<td>$90\text{ ps}$ (for bhabha)</td>
</tr>
<tr>
<td><strong>EMC</strong></td>
<td></td>
</tr>
<tr>
<td>$\sigma(E)/E = 22% \cdot \sqrt{E}$</td>
<td>$\sigma(E)/E = 2.3% \cdot \sqrt{E}$</td>
</tr>
<tr>
<td><strong>MUC</strong></td>
<td></td>
</tr>
<tr>
<td>3 layers for barrel</td>
<td>9 layers for barrel, 8 for endcap</td>
</tr>
</tbody>
</table>
BESIII collaboration: 46 Institutes

US (6)
- Univ. of Hawaii
- Univ. of Washington
- Carnegie Mellon Univ.
- Univ. of Minnesota
- Univ. of Rochester
- Univ. of Indiana

Europe (9)
- Germany: Univ. of Bochum, Univ. of Giessen, GSI
- Russia: Dubna; BINP, Novosibirsk
- Italy: Univ. of Torino, Frascati Lab
- Netherlands: KVI/Univ. of Groningen, JINR

Pakistan (1)
- Univ. of Punjab

China (29)
- IHEP, CCAST, Shandong Univ.
- Univ. of Sci. and Tech. of China
- Zhejiang Univ., Huangshan Coll.
- Huazhong Normal Univ., Wuhan Univ.
- Zhengzhou Univ., Henan Normal Univ.
- Peking Univ., Tsinghua Univ.
- Shanxi Univ., Sichuan Univ
- Hunan Univ., Liaoning Univ.
- Nanjing Univ., Nanjing Normal Univ.
- Guangxi Normal Univ., Guangxi Univ.
- Suzhou Univ., Hangzhou Normal Univ.
- Lanzhou Univ., Henan Sci. and Tech. Univ.
- Hong Kong Univ., Hong Kong Chinese Univ.

Korea (1)
- Seoul Nat. Univ.

Japan (1)
- Tokyo Univ.

~ 300 collaborators
Physics Topics at BES

◆ Study of Light hadron spectroscopy
  ◆ search for non-qq̅ or non-qqqq states
  ◆ meson spectroscopy
  ◆ baryon spectroscopy

◆ Study of the production and decay mechanisms of charmonium states: \( J/\psi, \psi(2S), \eta_c(1S), \chi_c(0,1,2), \eta_c(2S), h_c(1P_1), \psi(3770), \) etc.

New Charmonium states above open charm threshold.

◆ Precise measurement of R values, \( \tau \) mass, ...
◆ Precise measurement of CKM matrix
◆ Search for DDbar mixing, CP violation, etc.
Hadrons consist of 2 or 3 quarks:

**Naive Quark Model**:
- Meson \((q \bar{q})\)
- Baryon \((qqq)\)

**QCD predicts the new forms of hadrons**:
- Multi-quark states: Number of quarks \(\geq 4\)
- Hybrids: \(qqg, qqqg\)...
- Glueballs: \(gg, ggg\)...
Study of the spectroscopy – a way of understanding the internal structure

**Motivation:**
- Establish spectrum of light hadrons
- Search for non-conventional hadrons
- Understand how hadrons are formed

**Why at a $\tau$-charm collider?**
- Gluon rich
- Clean environment
- $J^{PC}$ filter, isospin filter

*Y. Chen et al., PRD 73 (2006) 014516*
Physics Topics at BES

- Study of Light hadron spectroscopy
  - search for non-qqbar or non-qqq states
  - meson spectroscopy
  - baryon spectroscopy

- Study of the production and decay mechanisms of charmonium states: $J/\psi$, $\psi(2S)$, $\eta_c(1S)$, $\chi_c(0,1,2)$, $\eta_c(2S)$, $h_c(^1P_1)$, $\psi(3770)$, etc.

  New Charmonium states above open charm threshold.

- Precise measurement of R values
- Precise measurement of CKM matrix
- Search for DDbar mixing, CP violation, etc.
Charmonium physics

- What to study?
  - Production, decays, transition, spectrum

- For what?
  - A lab for pQCD and non-pQCD
  - Calibrate LQCD
  - How quarks form a hadron?

- Why at a tau-charm collider?
  - A clean environment
  - Tagging possible
  - Abundantly produced

Examples of interesting/long standing issues:
- $\rho\pi$ puzzle
- Missing states?
- Mixing states?
- New states above open charm thre. ($X, Y, Z, ...$)
Physics Topics at BES

◆ Study of Light hadron spectroscopy
  ◆ search for non-qqbar or non-qqq states
  ◆ meson spectroscopy
  ◆ baryon spectroscopy

◆ Study of the production and decay mechanisms of charmonium states: J/ψ, ψ(2S), η_c(1S), χ_{c\{0,1,2\}}, η_c(2S), h_c(^1P_1), ψ(3770), etc.

  New Charmonium states above open charm threshold.

◆ Precise measurement of R values
◆ Precise measurement of CKM matrix
◆ Search for DDbar mixing, CP violation, etc.
R measurement

R : one of the most important and fundamental quantities in particle physics.

\[ R \equiv \frac{e^{+}e^{-} \rightarrow \bar{q}q}{e^{+}e^{-} \rightarrow \mu^{+}\mu^{-}} = \sum Q_f^2 \]

Why precise R important?

Essential for precise tests of SM.

- the global fit of Higgs mass
- anomalous \( \mu \) magnetic moment from \( g-2 \)
Physics Topics at BES

- Study of Light hadron spectroscopy
  - search for non-qqbar or non-qqq states
  - meson spectroscopy
  - baryon spectroscopy

- Study of the production and decay mechanisms of charmonium states: J/ψ, ψ(2S), η_c(1S), χ_{c(0,1,2)}, η_c(2S), h_c(^1P_1), ψ(3770), etc.

  New Charmonium states above open charm threshold.

- Precise measurement of R values

- Precise measurement of CKM matrix

- Search for D+D̅ bar mixing, CP violation, etc.
Precise measurement of CKM elements
-- Test EW theory

CKM matrix elements are fundamental SM parameters that describe the mixing of quark fields due to weak interaction.

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Three generations of quark?

Expect precision < 2% at BESIII

Unitary matrix?

Improve the precision at BESIII

Precision measurement of CKM matrix elements
--a precise test to SM model
New physics beyond SM?
Decay constants vs LQCD

CLEO-c $f_{Ds} = 259.5 \pm 6.6 \pm 3.1$ MeV
Lattice: $241 \pm 3$ MeV [HPQCD-UKQCD]
249 \pm 11 MeV [Fermilab-MILC]

CLEO-c $f_D = 205.8 \pm 8.5 \pm 2.5$ MeV
Lattice: $208 \pm 4$ MeV [HPQCD-UKQCD]
207 \pm 11 MeV [Fermilab-MILC]

CLEO-c $f_{Ds}/f_D = 1.26 \pm 0.06 \pm 0.02$
Lattice: $1.16 \pm 0.009$ [HPQCD-UKQCD]
1.200 \pm 0.027 [Fermilab-MILC]

2.3 $\sigma$ difference for $f_{Ds}$. Real? BESIII may resolve this issue, reach the precision of LQCD.
CP violation is regarded as the origin of asymmetry of the matter and anti-matter.

- CP violation predicted by theoretical models is not big enough to describe the asymmetry.
- CP violation is observed in K and B decays, but has never been in charm sector.

\[ e^+ e^- \rightarrow \psi(3770) \rightarrow D^0 \bar{D}^0 \]

In SM, the mixing is very small.

At BESIII, the sensitivity of the mixing rate: \( 1.5 \times 10^{-4} \)

\[ D^0 - \bar{D}^0 \text{ mixing: a good place to search for CP violation} \]
BESIII commissioning and data taking milestones

- Mar. 2008: first full cosmic-ray event
- April 30, 2008: Move the BESIII to IP
- July 19, 2008: First e⁺e⁻ collision event in BESIII
- Nov. 2008: ~14M ψ(2S) events
- April 14, 2009: ~106M ψ(2S) events
- May 30, 2009: ~42 pb⁻¹ at continuum (3.65 GeV)
- July 28, 2009: ~226M J/ψ events
- Aug. – Dec., 2009: summer maintenance, SR run
- June 2-15, 2010: scan at around 3770 MeV

Peak Lumi. @ May 2009: 3.2×10³² cm⁻² s⁻¹
Inclusive photon spectrum of $\psi(2S)$

Excellent photon resolution

$\eta_c (2^1S_0)$ $\psi (2^3S_1)$ $\chi_{c2} (1^3P_2)$
$\eta_c (1^1P_1)$ $\chi_{c1} (1^3P_1)$ $\chi_{c0} (1^3P_0)$
$J/\psi (1^3S_1)$
$\eta_c (1^1S_0)$

$\chi_{c1,2} \rightarrow \gamma J/\psi$

BESIII preliminary
Results from BESIII

- Confirm BESII results
  - threshold enhancement in \( \gamma p\bar{p}, \chi(1835) \), ...

- New improved measurements
  - \( h_c, \eta_c, \chi_{cJ}, \ldots \)

- New observations
  - \( \chi_{cJ} \) decays
  - \( h_c \) decays
  - Light hadrons, ...

![Graph showing J/\(\psi\) and \(\psi(2S)\) counts]
The charmonium family has been studied for many years, the knowledge on \( h_c^{(1P_1)} \) is limited.

E835 made scans of \( \bar{p}p \) energy for the reaction
\[
par{p} \rightarrow h_c \rightarrow \gamma \eta_c, \quad \eta_c \rightarrow \gamma \gamma, \quad \sim 3\sigma \text{ level}
\]
The results from the year 1997 scan and the year 2000 scan were combined to obtain
\[
M(h_c) = 3525.8 \pm 0.2 \pm 0.2 \text{ MeV}.
\]
No evidence was found for \( h_c \) in the previously reported reaction
\[
par{p} \rightarrow h_c \rightarrow \pi^0 J/\psi \ (E760, \ 1992)
\]
The \( h_c^{(1P_1)} \) state was observed by CLEO_c in 2005.

For \( \psi(2S) \), only observed in \( \psi(2S) \rightarrow \pi^0 h_c \)
The main decay mode of \( h_c \): E1 transition \( h_c \rightarrow \gamma \eta_c \).
**h_c at CLEOc (with whole data set)**

**CLEOc’s Result – \( \psi' \to \pi^0 h_c, h_c \to \gamma \eta_c \), E1-tagged**

**PRD80, 051106(2009).**

**CLEOc’s Result – \( \psi' \to \pi^0 h_c, h_c \to 2(\pi^+ \pi^-)\pi^0 \)**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Efficiency (%)</th>
<th>Yield</th>
<th>( B_1 \times B_2 \times 10^5 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \pi^+ \pi^- \pi^0 )</td>
<td>27.0</td>
<td>1.62^{+0.5}_{-0.9}</td>
<td>&lt; 0.10</td>
</tr>
<tr>
<td>( 2(\pi^+ \pi^-)\pi^0 )</td>
<td>18.8</td>
<td>9.9^{+5.5}_{-2.2}</td>
<td>(1.88^{+0.48}_{-0.26})</td>
</tr>
<tr>
<td>( 3(\pi^+ \pi^-)\pi^0 )</td>
<td>11.5</td>
<td>35 ± 26</td>
<td>(1.2 ± 0.9 ± 0.3) (&lt; 2.5)</td>
</tr>
</tbody>
</table>

In previous experiments, the absolute branching ratio \( B(\psi(2S) \to \pi^0 h_c) \) and \( B(h_c \to \gamma \eta_c) \) has not been measured.
\( h_c \) at BESIII

- Inclusive analysis of \( \psi(2S) \rightarrow \pi^0 h_c \)
  identify \( h_c \) in the inclusive recoiling mass spectrum of \( \pi^0 \).

- E1-tagged analysis of \( \psi(2S) \rightarrow \pi^0 h_c, \ h_c \rightarrow \gamma \eta_c \)
  tag E1 photon (\( \sim 503 \) MeV) in \( h_c \rightarrow \gamma \eta_c \)
  \( h_c \) significance improved in inclusive \( \pi^0 \) spectrum

- Exclusive analysis of \( \psi(2S) \rightarrow \pi^0 h_c, \ h_c \rightarrow \gamma \eta_c \)
  fully reconstruct the exclusive \( \eta_c \) decays
Observation of $h_c$: Inclusive $\psi(2S) \rightarrow \pi^0 h_c$

- Select inclusive $\pi^0$
- A fit of D-Gaussian signal + 4th Poly. bkg
- Combined inclusive and E1-photon-tagged spectrum

\[
\text{Br}(\psi(2S) \rightarrow \pi^0 h_c) = (8.4 \pm 1.3 \pm 1.0) \times 10^{-4} \quad \text{(First measurement)}
\]

\[
\text{Br}(h_c \rightarrow \gamma \eta_c) = (54.3 \pm 6.7 \pm 5.2)\% \quad \text{(First measurement)}
\]
Observation of $h_c$: E1-tagged $\psi(2S) \rightarrow \pi^0 h_c, h_c \rightarrow \gamma \eta_c$

- Select E1-photon to tag $h_c$
- A fit of D-Gaussian signal+ sideband

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

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

(First measurement)

$\text{Br}(\psi(2S) \rightarrow \pi^0 h_c) \times \text{Br}(h_c \rightarrow \gamma \eta_c) = (4.58 \pm 0.40 \pm 0.50) \times 10^{-4}$
The $\chi_{cJ}$ decays provide good place to:

- **study gluonium:** $\chi_c \rightarrow gg \rightarrow (q\bar{q})(q\bar{q})$
- **test COM**

- Improved measurement of $\chi_{cJ} \rightarrow \pi^0\pi^0, \eta\eta, \ldots$
- First measurement of $\chi_{cJ} \rightarrow \omega\phi$
- First measurement of $\chi_{c1} \rightarrow \omega\omega, \phi\phi$
- First measurement of $\chi_{cJ} \rightarrow \gamma\phi$
Study of $\psi(2S) \rightarrow \gamma \chi_{cJ}; \chi_{cJ} \rightarrow \pi^0\pi^0, \eta\eta$

($\eta, \pi^0 \rightarrow \gamma\gamma$)

BESIII: PRD 81, 052005 (2010).

$\chi_{c1} \rightarrow \pi\pi, \eta\eta$ not allowed by parity conservation.

<table>
<thead>
<tr>
<th>Decay mode</th>
<th>$\chi_{c0} (10^{-3})$</th>
<th>$\chi_{c2} (10^{-3})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi^0\pi^0$</td>
<td>BESIII: $3.23 \pm 0.03 \pm 0.23 \pm 0.14$</td>
<td>$0.88 \pm 0.02 \pm 0.06 \pm 0.04$</td>
</tr>
<tr>
<td>PDG08</td>
<td>$2.43 \pm 0.20$</td>
<td>$0.71 \pm 0.08$</td>
</tr>
<tr>
<td>CLEOc</td>
<td>$2.94 \pm 0.07 \pm 0.32 \pm 0.15$</td>
<td>$0.68 \pm 0.03 \pm 0.07 \pm 0.04$</td>
</tr>
<tr>
<td>$\eta\eta$</td>
<td>BESIII</td>
<td>$3.44 \pm 0.10 \pm 0.24 \pm 0.20$</td>
</tr>
<tr>
<td>PDG08</td>
<td>$2.4 \pm 0.4$</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>CLEOc</td>
<td>$3.18 \pm 0.13 \pm 0.31 \pm 0.16$</td>
<td>$0.51 \pm 0.05 \pm 0.05 \pm 0.03$</td>
</tr>
</tbody>
</table>

CLEOc used their own branching ratios for $\psi' \rightarrow \gamma \chi_{cJ}$. 

\( \chi_{cJ} \rightarrow \gamma V, \ V=\phi, \rho, \omega \)

**BESIII preliminary**

<table>
<thead>
<tr>
<th>( \chi_{c1} \rightarrow \gamma \phi )</th>
</tr>
</thead>
<tbody>
<tr>
<td>BESIII</td>
</tr>
<tr>
<td>( \chi_{c0} \rightarrow \gamma \phi )</td>
</tr>
<tr>
<td>( \chi_{c1} \rightarrow \gamma \phi )</td>
</tr>
<tr>
<td>( \chi_{c2} \rightarrow \gamma \phi )</td>
</tr>
<tr>
<td>( \chi_{c0} \rightarrow \gamma \rho^0 )</td>
</tr>
<tr>
<td>( \chi_{c1} \rightarrow \gamma \rho^0 )</td>
</tr>
<tr>
<td>( \chi_{c2} \rightarrow \gamma \rho^0 )</td>
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<tr>
<td>( \chi_{c0} \rightarrow \gamma \omega )</td>
</tr>
<tr>
<td>( \chi_{c1} \rightarrow \gamma \omega )</td>
</tr>
<tr>
<td>( \chi_{c2} \rightarrow \gamma \omega )</td>
</tr>
</tbody>
</table>

- \( \chi_{c1} \rightarrow \gamma \phi \) observed for the first time.
- pQCD predictions too low.
- Difference may be explained by non-perturbative QCD “loop corrections”.


CLEOc: PRL 101, 151801 (2008)
pQCD: Y.J. Gao et al., hep-ph/0701009
Study of $\chi_{cJ} \rightarrow VV$, $V = \omega, \phi$

$\text{BR}(10^{-3})$ | $\chi_{c0}$ | $\chi_{c2}$  
---|---|---
$\rightarrow \phi \phi$ | $0.94 \pm 0.21 \pm 0.13$ | $1.70 \pm 0.30 \pm 0.25$  
$\rightarrow \omega \omega$ | $2.29 \pm 0.58 \pm 0.41$ | $1.77 \pm 0.47 \pm 0.36$

BESII, PLB 642, 197 (2006)
BESII, PLB 630, 7 (2005)

• $\chi_{c1} \rightarrow \phi \phi$ (and $\omega \omega$) should be highly suppressed because C-parity requires $L = 2$.

BESIII sees clear $\chi_{cJ} \rightarrow \phi \phi$ → 4K signals

<table>
<thead>
<tr>
<th>$\text{BR}(10^{-3})$</th>
<th>BESIII</th>
<th>PDG08</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\chi_{c0} \rightarrow \phi \phi$</td>
<td>$0.80 \pm 0.04$</td>
<td>$0.93 \pm 0.20$</td>
</tr>
<tr>
<td>$\chi_{c1} \rightarrow \phi \phi$</td>
<td>$0.42 \pm 0.03$</td>
<td>----</td>
</tr>
<tr>
<td>$\chi_{c2} \rightarrow \phi \phi$</td>
<td>$1.15 \pm 0.04$</td>
<td>$1.54 \pm 0.30$</td>
</tr>
</tbody>
</table>

Errors: statistical only.
clear $\chi_{cJ} \rightarrow \omega\omega$

$\rightarrow 2(\pi^+\pi^-\pi^0)$

First observation of $\chi_{c1} \rightarrow \omega\omega$.

Doubly OZI suppressed $\chi_{cJ} \rightarrow \omega\phi$ observed for the first time.
mass threshold study at BES

\( p\bar{p} \) mass threshold study at BES

\[ J/\psi \rightarrow \gamma p\bar{p} \]

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

**PRL 91 (2003) 022001**

**theoretical speculation:**
- \( p\bar{p} \) bound state (baryonium)
- FSI effect
- ......
mass spectrum in other channels

The narrow threshold enhancement is not observed in those channels

\[
\Upsilon(1S) \rightarrow \gamma \, pp@CLEO
\]

\[
J/\psi \rightarrow \omega \, pp@BESII
\]

No significant narrow strong enhancement near threshold (~2\,\sigma if fitted with X(1860))
**pp̅ threshold enhancement @ CLEOc**

- **fit with one resonance as BES did:**
  
  \[
  M(R_{thr}) = 1861^{+6}_{-16} \text{ (MeV)}, \quad \Gamma(R_{thr}) = 0^{+32}_{-0} \text{ (MeV)}, \\
  B_1(J/\psi\rightarrow\gamma R_{thr}) \times B_2(R_{thr} \rightarrow p\bar{p}) = (5.9^{+2.8}_{-3.2}) \times 10^{-5}
  \]

  agree with BESII results

- **fit with three contributions:**

  \[
  R_{thr} + f_0(2100) + PS \\
  (1) \quad (2) \quad (3)
  \]

  \[
  M(R_{thr}) = 1837^{+10}_{-12} -0_{+7} \text{ (MeV)}, \\
  \Gamma(R_{thr}) = 0^{+44}_{-0} \text{ (MeV)}, \quad \text{CL} = 26.1\%
  \]

  \[
  B_1(J/\psi\rightarrow\gamma R_{thr}) \times B_2(R_{thr} \rightarrow p\bar{p}) = (11.4^{+4.3}_{-3.0} +^{4.2}_{-2.6}) \times 10^{-5}
  \]

  BES considered these (2) and (3) as systematic errors.
mass spectrum and Dalitz plot at BESIII

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

\[ \psi(2S) \to \pi\pi \ J/\psi, \ J/\psi \to \gamma p\bar{p} \]

\[ M = 1859 \pm 10 \pm 25 \text{ MeV}/c^2 \]
\[ \Gamma < 30 \text{ MeV}/c^2 \ (90\% \ CL) \]

\[ M = 1865 \pm 5 \text{ MeV}/c^2 \]
\[ \Gamma < 33 \text{ MeV}/c^2 \ (90\% \ CL) \]

PRL 91 (2003) 022001
$J/\psi \rightarrow \gamma p\bar{p}$

BESIII preliminary

**Fit result:**

Mass = 1861.6 ± 0.8 MeV/$c^2$

$\Gamma < 8$ MeV (90% CL)
$p\bar{p}$ threshold mass spectrum in $\psi'$ radiative decay

**BESII**

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

No significant narrow strong enhancement near threshold ($\sim 2\sigma$ if fitted with $X(1860)$)

**BESIII preliminary**

No significant narrow threshold enhancement

FSI interpretation of the narrow and strong $p\bar{p}$ threshold enhancement is disfavored.
CLEO-c preliminary

\[ \psi(2S) \rightarrow \gamma pp \]

\[ \Delta M = M(pp) - 2m_p \text{ (GeV)} \]

CLEO:

\[ N_{ev} = 9 \times 10^9, \quad \chi^2 / \text{d.o.f.} = 53/58 \]

\[ B(\psi(2S) \rightarrow \gamma R) \times B(R \rightarrow pp) = (0.66^{+0.73}_{-0.86}) \times 10^{-6} \]

\[ B(\psi(2S) \rightarrow \gamma R) \times B(R \rightarrow pp) < 1.6 \times 10^{-6} \quad 90\% \text{ CL} \]


\[ N_{ev} = 11.7 \pm 6.7, \quad \text{sig.}=2.0s \]

\[ B(\psi(2S) \rightarrow \gamma R) \times B(R \rightarrow pp) < 5.4 \times 10^{-6} \]

- Confirm the no observation of enhancement in \( \psi(2S) \) channel

\[ \Rightarrow \text{pure FSI effect unlikely} \]
X(1835) @ BESII

- LQCD predicts the glueball mass of $0^{-+}$ is $\sim 2.3$ GeV
- For $0^{-+}$ glueball, it may have similar property as $\eta_c$ (mainly decay to $\pi\pi\eta'$)
- $J/\psi \rightarrow \gamma\pi\pi\eta'$ is specially interested and was studied with 57M J/$\psi$ @ BESII

Need to confirm it with BESIII $\sim 220$M J/$\psi$ data !!!
**X(1835) @ BESIII**

\[ J / \psi \rightarrow \gamma \pi^+ \pi^- \eta' (\eta' \rightarrow \gamma \rho, \rho \rightarrow \pi^+ \pi^-) \]

**BESIII preliminary**

\[ J / \psi \rightarrow \gamma \pi^+ \pi^- \eta' (\eta' \rightarrow \pi^+ \pi^- \eta) \]

**BESIII preliminary**

**BESIII preliminary**
Whether there are two new resonances, further careful study is needed.

**Fit result (Statistic significant ~ 21σ):**

\[
M = 1842.4 \pm 2.8\,(stat)\,MeV
\]
\[
\Gamma = 99.2 \pm 9.2\,(stat)\,MeV
\]

**BESII result (Statistic significant ~ 7.7σ):**

\[
M = 1833.7 \pm 6.1\,(stat) \pm 2.7\,(syst)\,MeV
\]
\[
\Gamma = 67.7 \pm 20.3\,(stat) \pm 7.7\,(syst)\,MeV
\]
Study of $a_0(980) - f_0(980)$ mixing from

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

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

- Mixing intensity provides important information in understanding 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.
\[ \xi_{fa} = \frac{\text{Br}(J/\psi \rightarrow \phi f_0(980) \rightarrow \phi a_0(980) \rightarrow \phi \eta \pi^0)}{\text{Br}(J/\psi \rightarrow \phi f_0(980) \rightarrow \phi \pi \pi)} \]

\[ = (0.6 \pm 0.2\text{ (stat.)} \pm 0.2\text{ (sys.)})\% \text{ (} < 1.1\% \text{ at 90\% C.L.)} \]

- \text{N(mixing)} = 24.7 \pm 8.6 \text{ (} < 36.7 \text{ at 90\% C.L.), } S = 3.3 \sigma ;

\[ \xi_{af} = (0.32 \pm 0.16\text{ (stat.)} \pm 0.12\text{ (sys.)})\% \text{ (} < 0.91\% \text{ at 90\% C.L.)} \]
Comparison of BESIII results with others
Summary

- BEPCII/BESIII upgrade completed successfully:
  - Peak Luminosity of $3.2 \times 10^{32}$ achieved.
  - $\sim 106 \text{ M } \psi(2S)$ and $\sim 226 \text{ M } J/\psi$ events obtained in 2009.
  - $\sim 950 \text{ pb}^{-1}$ at $\psi(3770)$ so far in 2010.

- Nice results are obtained

- More results will come soon
Thank you!
First collision event on July 19, 2008

$e^+e^- \rightarrow \psi(3770) \rightarrow D^0\bar{D}^0$
MDC performance & data/MC

Reso. 135 μm

σ = 135 μm

σ_p = 11.0 MeV/c
Double-layer TOF

<table>
<thead>
<tr>
<th>Time Resolution (ps)</th>
<th>Design Target</th>
<th>Bhabha</th>
<th>Dimu</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Barrel Single Layer</strong></td>
<td>100~110</td>
<td>98.0</td>
<td>95.3</td>
</tr>
<tr>
<td><strong>Barrel Double Layer</strong></td>
<td>80~90</td>
<td>78.9</td>
<td>76.3</td>
</tr>
<tr>
<td><strong>Endcap</strong></td>
<td>110~120</td>
<td>136.4</td>
<td>95.0</td>
</tr>
</tbody>
</table>
EMC (CsI(Tl))

**Barrel energy resolution**

Energy resolution for $e^+e^- \rightarrow \gamma\gamma$

- MC single photon
- $\pi^0$ and $e^+e^- \rightarrow \gamma\gamma$
- $e^+e^- \rightarrow e^+e^-\gamma$
- $\psi \rightarrow \gamma\gamma$

**Position resolution for Bhabha**

4.4 mm

**Energy deposit for $e^+e^- \rightarrow \gamma\gamma$**

Entries 1026070
Mean 1.712
RMS 0.08715
First observation of $\psi(2S) \rightarrow \gamma\gamma J/\psi$

- Two photon transitions are well known in excitations of molecules, atomic hydrogen, and positronium.
  

- CLEO observed two photon transitions in $\Upsilon(3S) \rightarrow \Upsilon(2S)$.
  

- Never been observed in the charmonium system.
- Observation helpful to understand QCD.

Theoretically:
- potential models give discrete spectra ($\psi(2S) \rightarrow \gamma\chi_{cJ},\chi_{cJ} \rightarrow \gamma J/\psi$)
- coupled channel models can give continuous spectra.
- theoretical work ongoing.
• select $\psi(2S) \rightarrow \gamma\gamma J/\psi$, $J/\psi \rightarrow l^+ l^-$ events.

• $J/\psi \rightarrow$ ee channel ($\mu\mu$ similar):

$\gamma_1$ - high energy gamma, $\gamma_2$ - low energy gamma

- select events in box to enhance signal.
- see clear excess over BG + continuum in $M_{J/\psi}$ distribution. Significance $\geq 10\sigma$

$B(\psi(2S) \rightarrow \gamma\gamma J/\psi)$ [both ee and $\mu\mu$]

$= (1.02 \pm 0.05^{+0.19}_{-0.20}) \times 10^{-3}$

BESIII preliminary