Physics at BESIII: recent highlights

Myroslav Kavatsyuk
KVI, University of Groningen

For the BESIII collaboration

- BESIII and physics goals
- Precision charmonium spectroscopy
- Exotic hadron matter

\[ Z_c(3900) \]

\[ M = 2984.49 \pm 1.16 \pm 0.52 \text{ MeV} \]
\[ \Gamma = 36.4 \pm 3.2 \pm 1.7 \text{ MeV} \]

\[ \eta_c \]

\[ \text{Events / (10 MeV)} \]

\[ M_{\text{hadrons}} \text{ (GeV/c}^2\text{)} \]

\[ \text{Events / 0.01 GeV/c}^2 \]
Hadron Landscape

BESIII has rich physics and high discovery potential

Hadron-physics challenges:

- Understanding of established states: precision spectroscopy
- Nature of exotic states: search and spectroscopy of unexpected states
BESIII Detector

1.0 Tesla super-conducting magnet

Be beam pipe

Muon counters:
9/8 RPC layers (barrel/endcaps)
Cut-off momentum: 0.4 GeV/c

CsI(Tl) ElectroMagnetic Calorimeter:
\( \sigma_{E/E} \) (at 1 GeV): 2.5 %
\( \sigma_{\theta,\phi} \) (at 1 GeV): 6 mm

Time Of Flight (TOF):
\( \sigma_T \): 100/110 ps (barrel/endcaps)

Drift chambers (MDC):
\( \sigma_{p/p} \) (at 1 GeV): 0.5 %
\( \sigma_{dE/dx} \): 6 %

BESIII Milestones

- **July 18, 2008**: First $e^+ e^-$ collision event in BESIII
- **Apr. 14, 2009**:
  - $\sim 108$ M $\Psi'$ events
  - $\sim 42$pb$^{-1}$ at 3.65 GeV
- **July 28, 2009**: $\sim 225$ M $J/\Psi$ events
- **2010-2011**: $\sim 2.9$fb$^{-1}$ $\Psi''$
  - $\sim 70$pb$^{-1}$ scanning of the $\Psi''$ region
- **May 2011**: $\sim 0.5$fb$^{-1}$ 4.01 GeV ($D_s$ and XYZ spectroscopy)
- **2012**: $\sim 0.4$ B $\Psi'$ events
  - $\sim 1$ B $J/\Psi$ events
  - $\sim 525$ pb$^{-1}$ $E_{cm} = 4.26$ GeV
- **2013**: $\sim 520$ pb$^{-1}$ $E_{cm} = 4.36$ GeV
  - $\sim 0.8$ fb$^{-1}$ $E_{cm} = 4.26$ GeV

Record Luminosity so far: $7 \times 10^{32}$ cm$^{-2}$ s$^{-1}$ (8×CESRc or 45×BEPC)

High luminosity, clean environment → Access to weakly populated channels of particular interest
Precision charmonium spectroscopy

Light Mesons
\(\pi, \eta, \omega, \Phi, \rho, f, a, h, K\)

Charmonium
\(J/\psi, \chi, \psi(2S)\)

\(q\bar{q}q\bar{q}\)
\(gqg, u\bar{u}g, s\bar{s}g\)
\(gqg, g g\)

\(\Lambda_{s\bar{A}_{s}}, \Sigma_{s\bar{S}_{s}}, \Xi_{s\bar{E}_{s}}\)
\(\Omega_{s\bar{O}_{s}}, D\bar{D}\)
\(\Lambda_{c\bar{A}_{c}}, \Sigma_{c\bar{S}_{c}}, \Xi_{c\bar{E}_{c}}\)
\(\Omega_{c\bar{O}_{c}}\)

Mass [GeV/c^2]

LEAR
BESIII
Charmonium Physics

Charmonium (a bound state of $c\bar{c}$ quarks) – bridge between perturbative and strong QCD

Strong-interaction coupling constant

Precise data on the key charmonium states and transitions

Insight into the strong interactions at long-distance scales (test of Potential models, lattice QCD, EFT)
State Properties as a Probe

Precise measurement of charmonium masses and widths

Test of potential models and lattice QCD

Potential model: if P-wave spin-spin interaction is non-zero:

$$\Delta M_{hf}(1P) = M(h_c) - \langle m(1^3P_J) \rangle \neq 0$$

$$\langle m(1^3P_J) \rangle = \sum_{J=0}^2 M_{\chi_c J}(2J+1)/9$$

Expected value $\Delta M_{hf}(1P) = 0$

Hyperfine splitting: $M(J/\Psi) - M(\eta_c)$: important input to test lattice QCD, dominated by error on $M(\eta_c)$!

LQCD prediction:

$$\Delta M(1S) = 116.5 \pm 3.2 \text{ MeV}$$

[Phys. Rev. D 86, 094501 (2012)]
State Properties as a Probe

Mass and width measured with comparable or better precision:

<table>
<thead>
<tr>
<th>State</th>
<th>Mass [MeV]</th>
<th>Width [MeV]</th>
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<tbody>
<tr>
<td>( \eta_c' ) (3638)</td>
<td>3637.6 ± 2.9 ± 1.6</td>
<td>16.9 ± 6.4 ± 4.8</td>
</tr>
<tr>
<td>( h_c ) (3525)</td>
<td>3525.40 ± 0.13 ± 0.18</td>
<td>0.73 ± 0.45 ± 0.28</td>
</tr>
<tr>
<td>( \eta_c ) (2980)</td>
<td>2984.3 ± 0.6 ± 0.6</td>
<td>32.0 ± 1.2 ± 1.0</td>
</tr>
</tbody>
</table>

\[ \text{Phys. Rev. Lett. 109, 042003 (2012)} \]

\[ \text{Phys. Rev. Lett. 104, 132002 (2010)} \]

\[ \text{Phys. Rev. D 86, 092009 (2012)} \]

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\[ \text{Phys. Rev. Lett. 108, 222002 (2012)} \]

Mass and width measured with comparable or better precision:

- \( \eta_c' \) (3638)
- \( h_c \) (3525)
- \( \eta_c \) (2980)
State Properties as a Probe

Precise measurement of charmonium masses and widths

Test of potential models and lattice QCD

Potential model: if P-wave spin-spin interaction is non-zero:

$$\Delta M_{hf}(1P) = M(h_c) - \langle m(1^3P_J) \rangle \neq 0$$

$$\langle m(1^3P_J) \rangle = \sum_{J=0}^{2} M_{\chi_{cJ}} (2J+1)/9$$

$$\Delta M_{hf}(1P) = -0.19\pm0.11\pm0.14\text{MeV}$$

Consistent with zero!

Hyperfine splitting: $$M(J/\Psi) - M(\eta_c)$$:
important input to test lattice QCD, dominated by error on $$M(\eta_c)$$!

$$\Delta M(1S) = 112.5 \pm 0.8 \text{ MeV}$$

Good agreement with LQCD
Better precision than LQCD!
\[ \Psi' \rightarrow \pi^0 h_c, \quad h_c \rightarrow \gamma \eta_c \]

- \( \eta_c \)-resonance: interference with non-resonant backgrounds → difficult to measure

- \( h_c \rightarrow \gamma \eta_c \) E1 transition:
  - small non-resonant background → the \( \eta_c \) line shape is less distorted
  - Consistent and precise measurement of \( h_c \) and \( \eta_c \) parameters
  - Determined branching ratios for 16 exclusive \( \eta_c \) decays (5 measured for the first time)

No interference

Sum over 16 exclusive decay modes of \( \eta_c \)

[Phys. Rev. D 86, 092009 (2012)]
Transitions as a Probe

- In the potential approach:
  \[ R = \frac{\Gamma(J/\Psi \to \gamma\gamma\gamma)}{\Gamma(J/\Psi \to e\epsilon)} = \frac{64(\pi^2 - 9)}{243\pi} \alpha(1 - 7.3 \frac{\alpha_s}{\pi}) \]
  [M. B. Voloshin, Prog. Part. Nucl. Phys. 61, 455 (2008)]
  assuming \( \alpha_s = 0.19 \rightarrow R = 3 \times 10^{-4} \)

- The rates ratio – sensitive only to QCD radiative corrections:
  Test of understanding of the QCD radiative effects

\[ R = \frac{\Gamma(J/\Psi \to \gamma\gamma\gamma)}{\Gamma(J/\Psi \to e\epsilon)} = \frac{64(\pi^2 - 9)}{243\pi} \alpha(1 - 7.3 \frac{\alpha_s}{\pi}) \]

\[ \Psi' \to \pi^+\pi^- J/\Psi \to \gamma\gamma\gamma \]
\[ \Psi' \to \pi^+\pi^- J/\Psi \to \gamma\eta_c \to \gamma\gamma \]

- The rates ratio is sensitive only to QCD radiative corrections:

\[ \text{Test of understanding of the QCD radiative effects} \]

-\( B(J/\Psi \to 3\gamma) = (11.3 \pm 1.8 \pm 2.0) \times 10^{-6} \)
-\( B(\eta_c \to 2\gamma) = (2.6 \pm 0.7 \pm 0.7) \times 10^{-4} \)

**Measured** \( R = (1.95 \pm 0.37) \times 10^{-4} \)
Consistent with the CLEOc result:
\[ R = (2.0 \pm 0.6) \times 10^{-4} \]

Measurement of transition rates yields necessary information for development of models.
Transitions as a Probe

Transition rates measured with better precision or for the first time:

\[ B(\Psi' \rightarrow \gamma \eta_c' \rightarrow KK\pi) = (1.30 \pm 0.20 \pm 0.30) \times 10^{-5} \]
[Phys. Rev. Lett. 109, 042003 (2012)]

\[ B(\Psi' \rightarrow \pi^0 h_c) = (8.4 \pm 1.3 \pm 1.0) \times 10^{-4} \]

\[ B(h_c \rightarrow \gamma \eta_c) = (54.3 \pm 6.7 \pm 5.2)\% \]

\[ B(\Psi' \rightarrow \gamma\gamma J/\Psi) = (3.3 \pm 0.6 +0.8 -1.1) \times 10^{-4} \]

\[ \Gamma(\chi_{c2} \rightarrow \gamma\gamma) = 0.63 \pm 0.04 \pm 0.04 \text{ keV} \]
\[ \Gamma(\chi_{c0} \rightarrow \gamma\gamma) = 2.33 \pm 0.20 \pm 0.13 \text{ keV} \]
[Phys. Rev. D 85, 112008 (2012)]

BESIII can access suppressed transitions of interest

Talk by Olga Bondarenko (Thursday, 14:30)
Exotic hadron matter
QCD predicts exotic objects:

- hybrids (resonances of quark-antiquark and excited glue)
- glueballs (excited states of glue)

Glueballs and hybrids properties are determined by the long-distance features of QCD

Insight into QCD vacuum
Glueball Searches with BESIII

PWA of $J/\psi \rightarrow \gamma\eta\eta$

Radiative $J/\psi$ decay – a gluon-rich process →

one of the most promising hunting grounds for glueballs

<table>
<thead>
<tr>
<th>Resonance $f_0$</th>
<th>Mass(MeV/c²)</th>
<th>Width(MeV/c²)</th>
<th>$B(J/\psi \rightarrow \gamma X \rightarrow \gamma\eta\eta)$</th>
<th>Significance</th>
</tr>
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<tr>
<td>$f_0(1500)$</td>
<td>$1468^{+14+23}_{-15-74}$</td>
<td>$136^{+41+28}_{-26-100}$</td>
<td>$(1.65^{+0.26+0.51}_{-0.31-1.46}) \times 10^{-5}$</td>
<td>8.2 σ</td>
</tr>
<tr>
<td>$f_0(1710)$</td>
<td>$1759\pm6^{+14}_{-25}$</td>
<td>$172\pm10^{+32}_{-16}$</td>
<td>$(2.35^{+0.13+1.24}_{-0.11-0.74}) \times 10^{-4}$</td>
<td>25.0 σ</td>
</tr>
<tr>
<td>$f_0(2100)$</td>
<td>$2081\pm13^{+24}_{-36}$</td>
<td>$273^{+27+70}_{-24-23}$</td>
<td>$(1.13^{+0.09+0.64}_{-0.10-0.28}) \times 10^{-4}$</td>
<td>13.9 σ</td>
</tr>
<tr>
<td>$f_0'(1525)$</td>
<td>$1513\pm5^{+4}_{-10}$</td>
<td>$75^{+12+16}_{-10-8}$</td>
<td>$(3.42^{+0.43+1.37}_{-0.51-1.36}) \times 10^{-5}$</td>
<td>11.0 σ</td>
</tr>
<tr>
<td>$f_2(1810)$</td>
<td>$1822^{+29+66}_{-24-57}$</td>
<td>$229^{+52+88}_{-42-155}$</td>
<td>$(5.40^{+0.60+3.42}_{-0.67-2.33}) \times 10^{-5}$</td>
<td>6.4 σ</td>
</tr>
<tr>
<td>$f_2(2340)$</td>
<td>$2362^{+31+140}_{-30-63}$</td>
<td>$334^{+62+165}_{-84-100}$</td>
<td>$(5.60^{+0.62+2.37}_{-0.65-2.07}) \times 10^{-5}$</td>
<td>7.6 σ</td>
</tr>
</tbody>
</table>

[arXiv:1301.0053 , Accepted by PRD]

- Scalar contributions mainly from $f_0(1500)$, $f_0(1710)$ and $f_0(2100)$
- Production rate of $f_0(1710)$ consistent with predicted glueball production


$f_0(1710)$ has a larger overlap with the glueball

compared to other glueball candidates
Mysterious XYZ States...

... unexpectedly narrow for mesons in the open-charm region, strongly coupled to charmonium: **What is their nature?**

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<th>State</th>
<th>m (MeV)</th>
<th>Γ (MeV)</th>
<th>J^{PC}</th>
<th>Process (mode)</th>
<th>Experiment (#σ)</th>
<th>Year</th>
<th>Status</th>
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<tr>
<td>X(3872)</td>
<td>3871.52±0.20</td>
<td>1.3±0.6</td>
<td>1^{++}/2^{++}</td>
<td>$B \rightarrow K(\pi^+\pi^- J/\psi)$</td>
<td>Belle [85, 86] (12.8), BaBar [87] (8.6)</td>
<td>2003</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$pp \rightarrow (\pi^+\pi^- J/\psi) + ...$</td>
<td>CDF [88–90] (np), DØ [91] (5.2)</td>
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<td></td>
<td>$B \rightarrow K(\omega J/\psi)$</td>
<td>Belle [92] (4.3), BaBar [93] (4.0)</td>
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<td></td>
<td>$B \rightarrow K(D_{0}\pi^{0} D_{0}^{*})$</td>
<td>Belle [94, 95] (6.4), BaBar [96] (4.9)</td>
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<td></td>
<td></td>
<td>$B \rightarrow K(\gamma J/\psi)$</td>
<td>Belle [92] (4.0), BaBar [97, 98] (3.6)</td>
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<td></td>
<td>$B \rightarrow K(\gamma J/\psi(2S))$</td>
<td>BaBar [98] (3.5), Belle [99] (0.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X(3915)</td>
<td>3915.6 ± 3.1</td>
<td>28±10</td>
<td>0/2^{++}</td>
<td>$B \rightarrow K(\omega J/\psi)$</td>
<td>Belle [100] (8.1), BaBar [101] (19)</td>
<td>2004</td>
<td>OK</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>$e^+e^- \rightarrow e^+e^- (\omega J/\psi)$</td>
<td>Belle [102] (7.7)</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>$e^+e^- \rightarrow J/\psi(DD^{*})$</td>
<td>Belle [103] (6.0)</td>
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<td></td>
<td>$e^+e^- \rightarrow J/\psi (\pi^{0} J/\psi)$</td>
<td>Belle [54] (5.0)</td>
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</tr>
<tr>
<td>G(3900)</td>
<td>3943 ± 21</td>
<td>52±11</td>
<td>1^{--}</td>
<td>$e^+e^- \rightarrow \gamma (DD)$</td>
<td>BaBar [27] (np), Belle [21] (np)</td>
<td>2007</td>
<td>OK</td>
</tr>
<tr>
<td>Y(4008)</td>
<td>4008_{-21}^{+21}</td>
<td>226±97</td>
<td>1^{--}</td>
<td>$e^{+}e^{-}\rightarrow\gamma (\pi^{+}\pi^{-} J/\psi)$</td>
<td>Belle [104] (7.4)</td>
<td>2007</td>
<td>NC!</td>
</tr>
<tr>
<td>Z_{1}(4050)^{+}</td>
<td>4051_{-49}^{+43}</td>
<td>82_{-5}^{+51}</td>
<td>?</td>
<td>$B \rightarrow K(\pi^{+}\chi_{c1}(1P))$</td>
<td>Belle [105] (5.0)</td>
<td>2008</td>
<td>NC!</td>
</tr>
<tr>
<td>Y(4110)</td>
<td>4143.4 ± 3.0</td>
<td>15_{-1}^{+11}</td>
<td>?^{+}</td>
<td>$B \rightarrow K(\phi J/\psi)$</td>
<td>CDF [106, 107] (5.0)</td>
<td>2009</td>
<td>NC!</td>
</tr>
<tr>
<td>X(4160)</td>
<td>4156_{-25}^{+29}</td>
<td>139_{-65}^{+113}</td>
<td>?^{+}</td>
<td>$e^+e^- \rightarrow J/\psi(DD^{*})$</td>
<td>Belle [103] (5.5)</td>
<td>2007</td>
<td>NC!</td>
</tr>
<tr>
<td>Z_{2}(4250)^{+}</td>
<td>4248_{-45}^{+185}</td>
<td>177_{-72}^{+321}</td>
<td>?</td>
<td>$B \rightarrow K(\pi^{+}\chi_{c1}(1P))$</td>
<td>Belle [105] (5.0)</td>
<td>2008</td>
<td>NC!</td>
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<tr>
<td>Y(4260)</td>
<td>4263 ± 5</td>
<td>108±14</td>
<td>1^{--}</td>
<td>$e^+e^- \rightarrow \gamma (\pi^{+}\pi^{-} J/\psi)$</td>
<td>BaBar [108, 109] (8.0)</td>
<td>2005</td>
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<td></td>
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<td></td>
<td>$e^{+}e^{-}\rightarrow (\pi^{+}\pi^{-} J/\psi)$</td>
<td>CLEO [110] (5.4)</td>
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<td></td>
<td>$e^{+}e^{-}\rightarrow (\pi^{0}\pi^{0} J/\psi)$</td>
<td>Belle [104] (15)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>$e^{+}e^{-}\rightarrow (\pi^{0}\pi^{0} J/\psi)$</td>
<td>CLEO [111] (11)</td>
<td></td>
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<td>$e^{+}e^{-}\rightarrow (\pi^{0}\pi^{0} J/\psi)$</td>
<td>CLEO [111] (5.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y(4274)</td>
<td>4274.4_{-6.7}^{+8.4}</td>
<td>32_{-15}^{+22}</td>
<td>?^{+}</td>
<td>$B \rightarrow K(\phi J/\psi)$</td>
<td>CDF [107] (3.1)</td>
<td>2010</td>
<td>NC!</td>
</tr>
<tr>
<td>X(4350)</td>
<td>4350.6_{-6.1}^{+8.6}</td>
<td>13.3_{-10.5}^{+18.4}</td>
<td>0.2^{++}</td>
<td>$e^{+}e^{-}\rightarrow e^{+}e^{-} (\phi J/\psi)$</td>
<td>Belle [112] (3.2)</td>
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<td>Y(4360)</td>
<td>4353 ± 11</td>
<td>96±42</td>
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<td>$e^{+}e^{-}\rightarrow \gamma (\pi^{+}\pi^{-}\gamma J/\psi(2S))$</td>
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<td>Z(4430)^{+}</td>
<td>4443_{-18}^{+28}</td>
<td>107_{-71}^{+113}</td>
<td>?</td>
<td>$B \rightarrow K(\pi^{+}\psi(2S))$</td>
<td>Belle [115, 116] (6.4)</td>
<td>2007</td>
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<tr>
<td>X(4634)</td>
<td>4634_{-11}^{+9}</td>
<td>92_{-32}^{+41}</td>
<td>1^{--}</td>
<td>$e^{+}e^{-}\rightarrow \gamma (\Lambda_{c}^{+}\Lambda_{c}^{-})$</td>
<td>Belle [25] (8.2)</td>
<td>2007</td>
<td>NC!</td>
</tr>
<tr>
<td>Y(4660)</td>
<td>4664±12</td>
<td>48±15</td>
<td>1^{--}</td>
<td>$e^{+}e^{-}\rightarrow \gamma (\pi^{+}\pi^{-}\gamma J/\psi(2S))$</td>
<td>Belle [114] (5.8)</td>
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<tr>
<td>Y_{6}(10888)</td>
<td>10888.4±3.0</td>
<td>30.7±9.8</td>
<td>1^{--}</td>
<td>$e^{+}e^{-}\rightarrow (\pi^{+}\pi^{-} nS)$</td>
<td>Belle [37, 117] (3.2)</td>
<td>2010</td>
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[EPJ C71, 1534 (2011)]
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Systematic studies at BESIII of Y(4260), Y(4360)
Studies of Y(4260) at BESIII

Y(4260):
- Does not fit any potential model.
- Has a small coupling to open charm
- \( J^{PC} = 1^- \)
- A hybrid candidate according to Lattice QCD calculations!

\[ \sigma(e^+e^- \rightarrow J/\psi\pi^+\pi^-) \]

\[ \text{E}_{\text{cm}} \text{(GeV)} \]

BESIII: \( \sigma^B = 62.9 \pm 1.9 \pm 3.7 \text{ pb} \)

\[ \text{PRL99, 182004 (2007)} \]

[Phys. Rev. Lett. 110, 252001 (2013)]
Dalitz Plot: $\text{e}^+\text{e}^- \rightarrow \pi^+\pi^-\text{J}/\psi$

- Clear peak at 3.9 GeV: $Z_c^{\pm}(3900)$,
- Peak at lower energy – kinematic reflection
  (changes its position with $\text{e}^+\text{e}^-$ CM energy)

![Dalitz Plot Diagram](image)
The $Z_c(3900)$

- Fit with S-wave Breit-Wigner
- $M = (3899.0 \pm 3.6 \pm 4.9) \text{ MeV/c}^2$
- $\Gamma = (46 \pm 10 \pm 20) \text{ MeV}$

Discovered by BESIII, promptly confirmed by:

**Belle:** [Phys. Rev. Lett. 110, 252002 (2013)]
$M = 3894.5 \pm 6.6 \pm 4.5 \text{ MeV/c}^2$
$\Gamma = 63 \pm 24 \pm 26 \text{ MeV}$

**Cleo-c:** [arXiv:1304.3036]
Mysterious XYZ States...

... unexpectedly narrow for mesons in the open-charm region, strongly coupled to charmonium: What is their nature?

<table>
<thead>
<tr>
<th>State</th>
<th>m (MeV)</th>
<th>Γ (MeV)</th>
<th>J^{PC}</th>
<th>Process (mode)</th>
<th>Experiment (#σ)</th>
<th>Year</th>
<th>Status</th>
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<td>X(3872)</td>
<td>3871.52±0.20</td>
<td>1.3±0.6</td>
<td>1^{++}/2^{−}</td>
<td>B → K(π^+ π^- J/ψ)</td>
<td>Belle [85, 86] (12.8), BABAR [87] (8.6)</td>
<td>2003</td>
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<td></td>
<td>(&lt;2.2)</td>
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<td>B → K(ω J/ψ)</td>
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<td>B → K(D^0 D^0)</td>
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<td>B → K(γ J/ψ(2S))</td>
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<td>X(3915)</td>
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<td>Y(4140)</td>
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<tr>
<td>Y(4260)</td>
<td>4263±5</td>
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<td>1^{−}−</td>
<td>e^+ e^- → γ(π^+ π^- J/ψ)</td>
<td>BABAR [108, 109] (8.0), CLEO [110] (5.4), Belle [104] (15)</td>
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<td>e^+ e^- → (π^+ π^- J/ψ)</td>
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<td>e^+ e^- → (π^+ π^- J/ψ)</td>
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<td>e^+ e^- → (π^+ π^- T(nS))</td>
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<td>2010</td>
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</table>

Z_c (3900) – first confirmed Z state!
Mysterious XYZ States...

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<td>e+e− → (π+π− T(nS))</td>
<td>Bell [37, 117] (3.2)</td>
<td>2010 NC!</td>
</tr>
</tbody>
</table>

Z states:
- Charged states
- Strongly coupled to charm
can not be conventional mesons
Nature of the Z (3900)  
**Most popular models**

### Tetraquark

- Interact by gluonic color force  
  - [arXiv:1303.6857]  
  - [arXiv:1304.0345, 1304.1301]

### Hadronic molecule

- 2 color-neutral mesons  
  - Interact by pion exchange  
  - [arXiv:1303.6608]  
  - [arXiv:1304.2882, 1304.1850]

- Other models:  
  - Meson loop [arXiv: 1303.6355, 1304.4458]  
  - Initial State Pion Emission (ISPE) model [arXiv: 1303.6842, 1304.5845]
Nature of the $Z_c(3900)$

Sensitive probes?

- **Heavier/lighter states**
  - Hadronic molecule
    [PRD 77, 014029 (2008)]
  - Tetraquark
    [arXiv:1303.6857]

- **Decay modes and rates**
  - Hadronic molecule:
    decays mainly to its constituents
  - Tetraquark:
    $\Gamma(Z_c^+ \rightarrow \pi^+ J/\psi) \approx 29$ MeV
    $\Gamma(Z_c^+ \rightarrow D^+D^{\ast0}, \overline{D}^0D^{\ast+}) \approx 4$ MeV

Measurement coming soon... Stay tuned!

To be confirmed
A lot of interesting results are already published by the BESIII collaboration.

New exciting results are coming soon!
Summary

• BESIII is operational since 2008 and already has world's largest data samples of various Y and charmonium states

• BESIII – an ideal tool for precision studies of suppressed channels:
  • clean environment
  • well controlled systematics

• A lot of interesting results have been obtained:
  • Precise measurements of resonance properties
  • Discovery of unexpected states

• ... and we are looking forward to the future:
  • More data available than presented in current analysis

Stay tuned!
Thank you for your attention
and
to the BESIII collaboration!

BESIII collaboration: >360 members in 53 institutions from 11 countries
Physics at BESIII

Charm physics:
- (semi)leptonic + hadronic decays
- decay constant, form factors
- CKM matrix: $V_{cd}$, $V_{cs}$
- $D_0 - D_0$ mixing and CP violation
- rare/forbidden decays

Charmonium physics:
- transitions and decays
- spectroscopy of exotic states

Light hadron physics:
- meson & baryon spectroscopy
- glueball & hybrid
- two-photon physics
- e.m. form factors of nucleon

Tau physics:
- systematics under control → high precision
- tau decays near threshold
- tau mass scan
Dalitz Plot: $e^+ e^- \rightarrow \pi^+ \pi^- J/\psi$

- Decay via $f_0(980)$ and $\sigma(500)$
- No peak is generated by these resonances in the $\pi^+ J/\Psi$ spectrum