Recent Results from BESIII

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(For BESIII Collaboration)

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Outline

• Status of BEPCII/BESIII

• Selected Results from BESIII
  — Light hadrons spectroscopy
  — Charmonium transitions decays
  — Charm decays

• Summary
Bird view of BEPCII/BESIII

Beijing electron positron collider BEPCII

Linac

Storage ring

BESIII detector

BSRF

IHEP, Beijing

2004: start BEPCII construction
2008: test run of BEPCII
2009-now: BECPII/BESIII data taking

Beam-Energy 1.0-2.3GeV
Energy Spread 5.16×10⁻⁴

Design luminosity
1 × 10³³/cm²/s @ ψ(3770)

Linac

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1 × 10³³/cm²/s @ ψ(3770)

2004: start BEPCII construction
2008: test run of BEPCII
2009-now: BECPII/BESIII data taking
BEPCII: Large Crossing Angle, Double-ring

Compton back-scattering for high precision beam energy measurement

- **Beam energy:** 1.0-2.3 GeV
- **Energy spread:** \(5.16 \times 10^{-4}\)
- **Optimum energy:** 1.89 GeV
- **Luminosity:** \(1 \times 10^{33} \text{ cm}^{-2}\text{s}\)
- **No. of bunches:** 93
- **Bunch length:** 1.5 cm
- **Total current:** 0.91 A
- **SR mode:** 0.25A@2.5GeV
The BESIII Detector

Drift Chamber (MDC)
\[ \sigma_{P/P} (0/0) = 0.5\% (1\text{GeV}) \]
\[ \sigma_{dE/dx} (0/0) = 6\% \]

Time Of Flight (TOF)
\[ \sigma_T : 90\text{ ps Barrel} \]
\[ 110\text{ ps endcap} \]

\[ \mu\text{Counter} \]
8-9 layers RPC
\[ \delta R\Phi = 1.4\text{ cm} \sim 1.7\text{ cm} \]

Super-conducting magnet (1.0 Tesla)

EMC:
\[ \sigma_{E/\sqrt{E}} (0/0) = 2.5\% (1\text{ GeV}) \]
(Csl)
\[ \sigma_{z,\phi} (\text{cm}) = 0.5 - 0.7\text{ cm/VE} \]
The BESIII Collaboration

http://bes3.ihep.ac.cn

Europe (11)
- Germany: Univ. of Bochum, Univ. of Giessen, GSI
- Univ. of Johannes Gutenberg
- Helmholtz Ins. In Mainz
- Russia: JINR Dubna; BINP Novosibirsk
- Italy: Univ. of Torino, Frascati Lab
- Netherland: KVI/Univ. of Groningen
- Turkey: Turkey Accelerator Center

Korea (1)
- Seoul Nat. Univ.

China (30)
- 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.
- Univ. of South China, GUCAS.

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

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- Germany: Univ. of Bochum, Univ. of Giessen, GSI
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- 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.
- Univ. of South China, GUCAS.

>300 physicists
50 institutions from 10 countries
BESIII commissioning

✓ July 19, 2008: first e^+e^- collision event in BESIII
✓ Nov. 2008: ~14M \(\psi(2S)\) events for detector calibration
✓ 2009: 106M \(\psi(2S)\) 4×CLEO-c
225M \(J/\psi\) 4×BESII
✓ 2010: ~0.9 fb\(^{-1}\) \(\psi(3770)\) [3.5×CLEO-c]
✓ 2011: ~2.0 fb\(^{-1}\) \(\psi(3770)\)
~0.5 fb\(^{-1}\) @ 4.01 GeV
✓ 2012: tau mass scan: ~5.0 pb\(^{-1}\);
\(\psi(2S)\): 0.4 billion; \(J/\psi\): 1 billion (May 22!)

World’s largest sample of \(J/\psi\), \(\psi(2S)\) and \(\psi(3770)\)
Physics Programs @ BESIII

✓ **Light hardron physics**
- meson & baryon spectroscopy
- threshold effects
- multiquark states
- glueballs & hybrids
- two-photon physics
- form-factors

✓ **Charmonium physics:**
- precision spectroscopy
- transitions and decays

✓ **Charm physics:**
- (semi-)leptonic form factors
- $f_D$ & $f_{Ds}$ decay constants.
- CKM matrix: $V_{cd}$, $V_{cs}$
- $D^0$-$D^0$ mixing and CPV
- strong phases

✓ **QCD & $\tau$-physics:**
- precision $R$-measurement
- $\tau$ mass / $\tau$ decays

✓ **XYZ meson physics:**
- $Y(4260)$ $\pi\pi h_c$ decays
Recent Results on Light Hadron Spectroscopy

- pp⁻ mass threshold structure in $J/\psi \rightarrow \gamma pp⁻$
- $X(1835)$ and two new structures in $J/\psi \rightarrow \gamma \pi^+\pi^-\eta'$
- $\eta(1405)$ in $J/\psi \rightarrow \gamma f_0(980)\pi^0$, $f_0(980) \rightarrow \pi\pi$
Enhancement at $p\bar{p}$ threshold in $J/\psi \rightarrow \gamma p\bar{p}$

- Observed at BESII in 2003:
  - Agree with spin zero expectation
  - $M = 1860_{-10-25}^{+3+5}$ MeV/c$^2$
  - $\Gamma < 38$ MeV/c$^2$ (90% C.L.)

- Confirmed at BESIII in 2010:
  - $M = 1859_{-13-26}^{+6+6}$ MeV/c$^2$
  - $\Gamma < 30$ MeV/c$^2$ (90% C.L.)

- Many theoretical Interpretation:
  - Normal meson/ $p\bar{p}$ bound state/ multiquark/ glueball/ Final state interaction (FSI)……

- Spin-parity analysis:
  - Is essential for determining place in the spectrum and possible nature.
PWA of $J/\psi \rightarrow \gamma pp$ ($M_{pp} < 2.2 GeV$)

- **Four components:**
  - $X(pp)$, $f_2(1910)$, $f_0(2100)$ and $0^{++}$ PS

- **Include the FSI effect**

- **Fit features:**
  - The fit with BW and S-wave FSI ($I=0$) factor can well describe $pp$ mass threshold structure.
  - It is much better than that w/o FSI effect ($7.1\sigma$)
  - Different FSI model $\rightarrow$ Model dependent uncertainty

**BESIII Results:**

- $J^{PC} = 0^{-+}$, $>6.8\sigma$ better than other $J^{PC}$ assignments.
- $M = 1832^{+19}_{-5}(\text{stat})^{+18}_{-17}(\text{syst}) \pm 19(\text{model})$ MeV/c$^2$
- $\Gamma = 13 \pm 39(\text{stat})^{+10}_{-13}(\text{syst}) \pm 4(\text{model})$ MeV/c$^2$ or $\Gamma < 76$ MeV/c$^2$ @ 90 C.L.
- $Br(J/\psi \rightarrow \gamma X(pp)) \times Br(X(pp) \rightarrow pp) = (9.0^{+0.4}_{-1.1}(\text{stat})^{+1.5}_{-5.0}(\text{syst}) \pm 2.3(\text{model})) \times 10^{-5}$
X(1835) in $J/\psi \rightarrow \gamma \pi^+\pi^-\eta'$ @ BESII

**BESII Results:**
- $M = 1833.7 \pm 6.1_{\text{stat}} \pm 2.7_{\text{syst}}$ MeV/c²
- $\Gamma = 67.7 \pm 20.3_{\text{stat}} \pm 7.7_{\text{syst}}$ MeV/c²
- $B(J/\psi \rightarrow \gamma X(1835))B(X(1835) \rightarrow \pi^+\pi^-\eta') = (2.2 \pm 0.4_{\text{stat}} \pm 0.4_{\text{syst}}) \times 10^{-4}$
- Statistical Significance 7.7σ

**Many Theoretical interpretation:**
- $p\bar{p}$ bound state
- $\eta$ excitation
- ....
- Are $X(p\bar{p})$ and X(1835) from the same source?
**X(1835) in J/ψ→γπ⁺π⁻η'@BESIII**

**BESIII Results:**

- \( B(J/ψ→γX(1835))B(X(1835)→π⁺π⁻η') = (2.87 ± 0.09(stat) \pm 0.49(syst)) \times 10^{-4} \)

- The polar angle of the photon is consistent with expectation for a pseudoscalar

- Two more structures are observed.

**PWA is needed, interference among the resonances needs to be considered.**
First observed: $\eta(1405) \to f_0(980)\pi^0$ (Large isospin breaking)

- Helicity analysis indicates the peak at 1400MeV is from $\eta(1405)$, not from $f_1(1420)$

- Large Isospin-violating decay rate:
  \[
  \frac{BR(\eta(1405) \to f_0(980)\pi^0 \to \pi^+\pi^-\pi^0)}{BR(\eta(1405) \to a_0(980)\pi^0 \to \pi^0\pi^0\eta)} \approx (17.9 \pm 4.2)\% 
  \]

- In general, magnitude of isospin violation in strong decay should be <1%.

- $a_0$-$f_0$ mixing alone can not explain the branching ratio of $\eta(1405) \to f_0(980)\pi^0$

PRD, 83(2100)032003
Anomalous line shape of $f_0(980)$ in $J/\psi \rightarrow \gamma 3\pi$

Surprising result:

- very narrow $f_0(980)$ width: $< 11.8 \text{ MeV}/c^2$ @90% C.L.
- much narrower than the world average (PDG 2010: 40-100 MeV/$c^2$)

A possible explanation is KK* loop, Triangle Singularity (TS)
(J.J. Wu et al, PRL 108, 081803(2012))
Recent results on Charmonium spectroscopy

- Properties of $h_c$
- Mass and width of $\eta_c$
- Observation evidence of $\psi' \rightarrow \gamma \eta_c(2S)$
- First observation of $\psi' \rightarrow \gamma \gamma J/\psi$
First evidence (E835): \( pp \rightarrow h_c \rightarrow \gamma \eta_c \)

CLEO-c observed: \( \psi' \rightarrow \pi^0 h_c, h_c \rightarrow \gamma \eta_c \)
\( \Delta M_{hf}(1P) = 0.08 \pm 0.18 \pm 0.12 \text{ MeV}/c^2 \)

Study isospin forbidden transition:
\( \psi' \rightarrow \pi^0 h_c \)

Measure as well the E1 transition:
\( h_c \rightarrow \gamma \eta_c \)

\( M(h_c) \) gives access to hyperfine splitting of 1P states:
\( \Delta M_{hf}(1P) = M(h_c) - 1/9(M(\chi_{c0}) + 3M(\chi_{c1}) + 5M(\chi_{c2})) \)

A none zero hyperfine splitting may give indication of nonvanishing spin–spin interactions in Charmonium potential models
$\psi' \rightarrow \pi^0 h_c$

- Select inclusive $\pi^0(\psi' \rightarrow \pi^0 h_c)$
- Select E1-photon in $h_c \rightarrow \gamma \eta_c$ (E1 tagged) or not (E1 untagged)
- E1-tagged selection gives
  - $M(h_c)=3525.40 \pm 0.13 \pm 0.18 \text{MeV}/c^2$
  - $(\Delta M_{hf}(1P)=0.10 \pm 0.13 \pm 0.18 \text{MeV}/c^2)$
  - $\Gamma(h_c)=0.73 \pm 0.45 \pm 0.28 \text{MeV}/c^2$
    ($<1.44 \text{MeV at 90\% C.L.}$)
  - $\text{Br}(\psi' \rightarrow \pi^0 h_c ) \times \text{Br}(h_c \rightarrow \gamma \eta_c)$
    $= (4.58 \pm 0.40 \pm 0.50) \times 10^{-4}$
    (first measurement)
- E1-untagged selection gives
  - $\text{Br}( \psi' \rightarrow \pi^0 h_c ) = (8.4 \pm 1.3 \pm 1.0) \times 10^{-4}$
- Combining Branching fractions leads to
  - $\text{Br}(h_c \rightarrow \gamma \eta_c) = (54.3 \pm 6.7 \pm 5.2)\%$
ψ'→π⁰h_c, h_c→γη_c, η_c exclusive decays

ψ'→π⁰h_c, h_c→γη_c, η_c is reconstructed exclusively with 16 decay modes

Simultaneous fit to π⁰ recoiling mass
- χ²/d.o.f. = 32/46
- M = 3525.31±0.11±0.15 MeV/c²
- Γ = 0.70±0.28 ±0.25 MeV

Consistent with:
- BESIII inclusive results
  PRL104,132002(2010)
- CLEO-c exclusive results
  M = 3525.21±0.27±0.14 MeV/c²
  N = 136±14
  PRL101, 182003(2008)
$\eta_c(1S)$

- Ground state of charmonium discovered in 1980 by MarkII, but its properties are not well known
- Parameters:
  - $J/\psi, \psi'$ radiative transition: $M \sim 2978.0 \text{MeV}/c^2$, $\Gamma \sim 10 \text{MeV}/c^2$
  - $\gamma\gamma$ process: $M = 2983.1 \pm 1.0 \text{MeV}/c^2$, $\Gamma = 31.3 \pm 1.9 \text{MeV}/c^2$
- CLEO-c found the distortion of the $\eta_c$ lineshape in $\psi'$ decays
- Charmonium hyperfine splitting: $M(J/\psi) - M(\eta_c)$ is important experimental input to test the lattice QCD, but is dominated by error on $M(\eta_c)$
ψ' → γ η_c, η_c → exclusive decays

Interference with non-resonant is significant!

- Relative phase φ values from each mode are consistent within 3σ
  - use a common phase value in the simultaneous fit.

M: $2984.4 \pm 0.5 \pm 0.6$ MeV/c²
Γ: $30.5 \pm 1.0 \pm 0.9$ MeV/c²
φ: $2.35 \pm 0.05 \pm 0.04$ rad
The world average in PDG2010 was using earlier measurements.

Hyperfine splitting: $\Delta M_{hf}(1S) = 112.6 \pm 0.8$ MeV/c$^2$

- Consistent with B factory results in other production mechanisms.
- Agree with lattice QCD calculations of the charmonium hyperfine splitting.
$
(2S)$

✓ First “observation” by Crystal Ball’s in 1982:  
  — “Seen” in inclusive photon spectrum of $\psi'$ decay $\psi' \rightarrow \gamma X$  
  — Branch fraction and parameters are far from modern measurements  
  — $M=3.592\text{GeV/c}^2$, $Br = 0.2\%-1.3\%$  
  — Never confirmed by other experiments  

✓ The M1 transition $\psi' \rightarrow \gamma \eta_c (2S)$ have not be observed  
  — CLEO-c not found signal in 25M $\psi'$ samples, $Br(\psi' \rightarrow \gamma \eta_c (2S)) < 7.6 \times 10^{-4}$  
  — Experimental challenge: search for photons $\sim 50\text{MeV/c}^2$  

✓ Observed in different process other than radiative transition  

<table>
<thead>
<tr>
<th>Experiment</th>
<th>$M$ [MeV]</th>
<th>$\Gamma$ [MeV]</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belle [1]</td>
<td>$3654 \pm 6 \pm 8$</td>
<td>—</td>
<td>$B^\pm \rightarrow K^\pm \eta_c (2S), \eta_c (2S) \rightarrow K_SK^{\pm \pi^\mp}$</td>
</tr>
<tr>
<td>CLEO [2]</td>
<td>$3642.9 \pm 3.1 \pm 1.5$</td>
<td>$6.3 \pm 12.4 \pm 4.0$</td>
<td>$\gamma\gamma \rightarrow \eta_c (2S) \rightarrow K_SK^{\pm \pi^\mp}$</td>
</tr>
<tr>
<td>BaBar [3]</td>
<td>$3630.8 \pm 3.4 \pm 1.0$</td>
<td>$17.0 \pm 8.3 \pm 2.5$</td>
<td>$\gamma\gamma \rightarrow \eta_c (2S) \rightarrow K_SK^{\pm \pi^\mp}$</td>
</tr>
<tr>
<td>BaBar [4]</td>
<td>$3645.0 \pm 5.5^{+4.9}_{-7.8}$</td>
<td>—</td>
<td>$e^+e^- \rightarrow J/\psi \bar{c}c$</td>
</tr>
<tr>
<td>PDG [5]</td>
<td>$3638 \pm 4$</td>
<td>$14 \pm 7$</td>
<td>—</td>
</tr>
</tbody>
</table>

✓ Better chance to observe $\eta_c (2S)$ in $\psi'$ radiative transition with $\sim 106M$ $\psi'$ data at BESIII  
  — Decay mode studied: $\psi' \rightarrow \gamma \eta_c (2S) \rightarrow \gamma K_S K^\pi/K^+ K^- \pi^0$
Observation of $\psi' \rightarrow \gamma \eta_c (2S)$

Simultaneous fit with:

- $\eta_c (2S)$ signal:
  - PDF: $(E_3^3 \times BW(m) \times d\text{amping}(E_\gamma)) \otimes Gauss(0, \sigma)$

- $\chi_{cJ}$ signal:
  - MC shape smeared with Gaussian

- Background:
  - $e^+e^- \rightarrow KK\pi$ (ISR), $\psi' \rightarrow KK\pi$ (FSR), $\psi' \rightarrow \pi^0KK\pi$
  - Measured from data

BESIII results:

- Statistical significance > 10$\sigma$
- $M = 3637.6 \pm 2.9 \pm 1.6 \text{MeV/c}^2$
- $\Gamma = 16.9 \pm 6.4 \pm 4.8 \text{MeV/c}^2$
- Branching fraction:
  - $Br(\psi' \rightarrow \gamma \eta_c (2S) \rightarrow \gamma KK\pi) = (1.30 \pm 0.20 \pm 0.30) \times 10^{-5}$
  - $Br(\eta_c (2S) \rightarrow KK\pi) = (1.9 \pm 0.4 \pm 1.1)\%$ from BaBar (PRD78 012006 (2008))
  - $Br(\psi' \rightarrow \gamma \eta_c (2S)) = (6.8 \pm 1.1 \pm 4.5) \times 10^{-4}$

Potential model predicts (0.1 ~ 6.2)$\times 10^{-4}$

CLEO-c: <7.6$\times 10^{-4}$

arXiv:1205.5103, submit to PRL

06/07/12 H. Peng

PLHC2012
Two photon transitions are well known in excitations of molecules, atomic hydrogen, and positronium.

- Never been observed in the quarkonium system.
  - CLEO-c: upper limit of $\text{Br}(\psi' \rightarrow \gamma \gamma J/\psi)$ is $1 \times 10^{-3}$

Observation helpful to understand heavy quarkonium spectrum & strong interaction

Theoretically:

- Potential models give discrete spectra
  $(\psi' \rightarrow \gamma \chi_{cJ}, \chi_{cJ} \rightarrow \gamma J/\psi)$

- Possibility of testing the hadron-loop effect

- Coupled channel: the hadron-loop effect also may play an important role in the continuous spectra

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F. Bassani et al, PRL 39, 1070 (1977); A. Quattropani et al., PRL 50, 1258 (1983)

PRD 78, 011102(2008)
First evidence of $\psi' \rightarrow \gamma \gamma J/\psi$

Select $\psi' \rightarrow \gamma \gamma J/\psi$, $J/\psi \rightarrow e^+e^-/\mu^+\mu^-$ events

Global fit of the $\gamma \gamma$ process and cascade $\chi_{cJ}$ processes

See clear excess over BG+continuum

$\text{Br}(\psi' \rightarrow \gamma \gamma J/\psi) = (3.3 \pm 0.6^{+0.8}_{-1.1}) \times 10^{-4}($both $e^+e^-$ and $\mu^+\mu^-$)

Significance: $3.8\sigma$ including systematics

$\text{Br}(\psi' \rightarrow \gamma \chi_{cJ}, \chi_{cJ} \rightarrow \gamma J/\psi)$ are also measured

3.44 < RM($\gamma_{\text{sm}}$) < 3.48 GeV

arXiv: 1204.0246 Submitted to PRL
Preliminary results on D analysis

✓ Leptonic Decays

✓ Semi-leptonic Decays
Preliminary results of $D^+ \rightarrow \mu^+ \nu$

✓ In the system recoiling against the tagged $D^-$ with 9 different decay modes, select leptonic decay for $D^+ \rightarrow \mu^+ \nu$

they require:

• One charged track only
• Positively identified $\mu$
• No isolate photon

425 candidates for $D^+ \rightarrow \mu^+ \nu$
Preliminary results of $D^+ \rightarrow \mu^+ \nu$

Results:

$N(D^+ \rightarrow \mu \nu) = 377.3 \pm 20.6 \pm 2.6$

$BF(D^+ \rightarrow \mu \nu) = (3.74 \pm 0.21 \pm 0.06) \times 10^{-4}$

$\Gamma(D^+ \rightarrow l^+ \nu_l) = \frac{G_F^2 f_{D^+}^2}{8\pi} |V_{cd}|^2 m_l^2 m_{D^+} (1 - \frac{m_l^2}{m_{D^+}^2})^2$

$f_{D^+} = (203.91 \pm 5.72 \pm 1.97) \text{ MeV/c}^2$

$|V_{cd}| = (0.222 \pm 0.006 \pm 0.005)$

$f_{D^+} = (207 \pm 4) \text{ MeV/c}^2$ LQCD

$|V_{cd}| = (0.2252 \pm 0.007) \text{ CKMFitter}$
Preliminary results of $D^+ \rightarrow \mu^+ \nu$

- The most precise measurement is provided by BESIII
- the error is still dominated by statistics, needing more data taken at 3773 GeV to reduce it.
Semi-leptonic Decays $D^0 \rightarrow K/\pi$ e\nu

Differential decay rate function:

$$\frac{d\Gamma}{dq^2} = \frac{G_F^2}{24\pi^3} |V_{cx}|^2 P_X^3 |f_+(q^2)|^2$$

$q^2$ - the invariant mass square of the lepton-neutrino system

<table>
<thead>
<tr>
<th>Mode</th>
<th>Data Yield</th>
<th>Fraction of All Tags (%)</th>
<th>Tag Efficiency(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D^0 \rightarrow K^- \pi^+$</td>
<td>159,929 $\pm$ 413</td>
<td>20.7</td>
<td>62.08$\pm$0.07</td>
</tr>
<tr>
<td>$D^0 \rightarrow K^- \pi^+ \pi^0$</td>
<td>323,348 $\pm$ 667</td>
<td>41.8</td>
<td>33.56$\pm$0.03</td>
</tr>
<tr>
<td>$D^0 \rightarrow K^- \pi^+ \pi^0 \pi^0$</td>
<td>78,467 $\pm$ 480</td>
<td>10.1</td>
<td>14.93$\pm$0.04</td>
</tr>
<tr>
<td>$D^0 \rightarrow K^- \pi^- \pi^- \pi^+$</td>
<td>211,910 $\pm$ 550</td>
<td>27.4</td>
<td>36.80$\pm$0.04</td>
</tr>
</tbody>
</table>

4 tag modes, 0.92 fb$^{-1}$ data @3.773 (BESIII Preliminary)
Semi-leptonic Decays $D^0 \rightarrow K/\pi \ e\nu$

BESIII Preliminary (~$0.92fb^{-1}$)

$D^0 \rightarrow K e\nu$

$N_{\text{sig}} = 18460 \pm 143$

$D^0 \rightarrow \pi e\nu$

$N_{\text{sig}} = 1677 \pm 45$

<table>
<thead>
<tr>
<th>Mode</th>
<th>measured branching fraction(%)</th>
<th>PDG</th>
<th>CLEOc</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{D}^0 \rightarrow K^+ e^- \bar{\nu}$</td>
<td>$3.542 \pm 0.030 \pm 0.067$</td>
<td>$3.55 \pm 0.04$</td>
<td>$3.50 \pm 0.03 \pm 0.04$</td>
</tr>
<tr>
<td>$\bar{D}^0 \rightarrow \pi^+ e^- \bar{\nu}$</td>
<td>$0.288 \pm 0.008 \pm 0.005$</td>
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</tr>
</tbody>
</table>

- Systematics are preliminary
- Will improve with full data set 2.9/fb in the near future
- Form factor measurement is ongoing
BESIII is successfully operating since 2008:
- World largest data sample of J/$\psi$, $\psi'$, $\psi(3770)$, $\psi(4040)$, still growing....

A lot of results have been obtained:

- Light quark states:
  - Confirmation the enhancement at $p\bar{p}$ threshold in $J/\psi \rightarrow \gamma p\bar{p}$, $J^{pc}=0^{-+}$.
  - Confirmation $X(1835)$ with two new structures in $J/\psi \rightarrow \gamma \pi \pi \eta'$.
  - First observation: $\eta(1405) \rightarrow f_0(980)\pi^0$ (isospin breaking).
  - ......

- Charmonium transitions:
  - Precision measurements of $h_c$ and $\eta_c(1S)$ properties.
  - First observation of $\eta_c(2S)$ in $\psi' \rightarrow \gamma \eta_c(2S)$ decay.
  - First evidence of $\psi' \rightarrow \gamma \gamma J/\psi$
  - ......

- Charm decays:
  - Leptonic decay $D^+ \rightarrow \mu^+\nu$
  - Semi-Leptonic decay $D^0 \rightarrow K/\pi$ ev
  - ......

Expect many more results from BESIII in the future
Thank you
Backup
The $\eta_c$ lineshape is not distorted in the $h_c \rightarrow \gamma \eta_c$, non-resonant bkg is small. This channel will be best suited to determine the $\eta_c$ resonance parameters.
Is the $X(1835)$ from the same source of $X(p\bar{p})$?

• The mass of $X(p\bar{p})$ is consistent with $X(1835)$

• The width of $X(p\bar{p})$ is much narrower.

Possible reasons:

– $X(p\bar{p})$ and $X(1835)$ come from different sources

– Interference effect in $J/\psi \rightarrow \gamma\pi\pi\eta'$ process should not be ignored in the determination of the $X(1835)$ mass and width

– There may be more than one resonance in the mass peak around 1.83GeV in $J/\psi \rightarrow \gamma\pi\pi\eta'$ decays.
M\overline{p} threshold structure of \psi' \rightarrow \gamma p\overline{p}@BESIII

Obviously different line shape of p\overline{p} mass spectrum near threshold from that in J/\psi decays

\textbf{PWA results:}

- Significance of X(p\overline{p}) is > 6.9\sigma.
- The production ratio R:

\[ R = \frac{B(\psi' \rightarrow \gamma X(p\overline{p}))}{B(J / \psi \rightarrow \gamma X(p\overline{p}))} \]

\[ = (5.08^{+0.71}_{-0.45}\text{(stat)}^{+0.67}_{-3.58}\text{(syst)}\pm0.12\text{(mod))\%} \]

- It is suppressed compared with “12% rule”.

\textbf{PWA Projection:}

PRL 108,112003(2012)
Why are $X(2120)/X(2370)$ interesting?

- It is the first time in $J/\psi$ radiative decays resonant structures are observed in the 2.4 GeV/c$^2$ region, it is interesting since:
  - LQCD predicts that the lowest lying pseudoscalar glueball: around 2.4 GeV/c$^2$.
  - $J/\psi \rightarrow \gamma \pi \pi \eta'$ decay is a good channel for finding $0^+$ glueballs.

- Nature of $X(2120)/X(2370)$ pseudoscalar glueball?
- $\eta/\eta'$ excited states?
- $\Delta\Delta$ bound state?

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PRD73,014516(2006) Y.Chen et al

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PRD82,074026,2010 (J.F. Liu, G.J. Ding and M.L.Yan)
PRD83:114007,2011 (J.S. Yu, Z.-F. Sun, X. Liu, Q. zhao), and more...
Partial Decay Rates Results

- Measured in each $q^2$ bin, by fitting U distribution
- Compare results from each tag mode
**f(q^2) Results**

- Points: data with stat. error only
- Curves: from Fermilab-MILC within one stat. error, preliminary, arXiv:1111.5471 (XXIX International Symposium on Lattice Field Theory);
- Other theoretical work: HPQCD, arXiv:1111.0225
- Comparing shape only here (f_+(0) not known)

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![Graph 1: D^0 \rightarrow K e \nu](image1)

![Graph 2: D^0 \rightarrow \pi e \nu](image2)
Form Factor Fits

**BESIII Preliminary**

\[ f_+(q^2) = \frac{f_+(0)}{1 - q^2/m_{pole}^2} \]

- **Simple pole model:**

- **Modified pole model:**
  - Series expansion:
    - Becher and Hill PLB 633, 61 (2006)

Could fit: \( f_+(0), \; r_1 = a_2/a_1, \; r_2 = a_3/a_1 \)

**Graphs:**
- \( D^0 \rightarrow K e v \)
- \( D^0 \rightarrow \pi e v \)
## Form Factor Results

### BESIII Preliminary

| Form Factor | $f^+(0)|V_{cd(s)}|$ | $m_{pole}$ | $\alpha$ | $r_1$ | $r_2$ |
|-------------|----------------------|------------|---------|------|------|
| Simple Pole | $D^0 \to K\nu$      | 0.729±0.005±0.007 | 1.943±0.025±0.003 |      |      |
|             | $D^0 \to \pi\nu$    | 0.142±0.003±0.001 | 1.876±0.023±0.004 |      |      |
| Modified Pole | $D^0 \to K\nu$      | 0.725±0.006±0.007 | 0.265±0.045±0.006 |      |      |
|             | $D^0 \to \pi\nu$    | 0.140±0.003±0.002 | 0.315±0.071±0.012 |      |      |
| 2 par. series | $D^0 \to K\nu$      | 0.726±0.006±0.007 | -2.034±0.196±0.022 |      |      |
|             | $D^0 \to \pi\nu$    | 0.140±0.004±0.002 | -2.117±0.163±0.027 |      |      |
| 3 par. series | $D^0 \to K\nu$      | 0.729±0.008±0.007 | -2.179±0.355±0.053 | 4.539±8.927±1.103 |
|             | $D^0 \to \pi\nu$    | 0.144±0.005±0.002 | -2.728±0.482±0.076 | 4.194±3.122±0.448 |
BESIII commissioning

 ✓ July 19, 2008: first e+e- collision event in BESIII
 ✓ Nov. 2008: ~14M ψ(2S) events for detector calibration
 ✓ 2009: 106M ψ(2S) 4×CLEO-c
         225M J/ψ 4×BESII
 ✓ 2010: ~0.9 fb⁻¹ ψ(3770) 3.5×CLEO-c
 ✓ 2011: ~2.0 fb⁻¹ ψ(3770) ~0.5 fb⁻¹ @ 4.01 GeV
 ✓ 2012: tau mass scan: ~5.0 pb⁻¹ ;
         ψ(2S): 0.4 billion; J/ψ: 1 billion (May 22!)

 Tentative future running plans (not Approved yet):

 ✓ 2013: D_s physics (E_{cm}=4170 MeV) + R scan (E_{cm} > 4 GeV)
 ✓ 2014: ψ(2S) / τ / R scan (E_{cm} > 4 GeV);
 ✓ 2015: ψ(3770): 5-10 fb⁻¹ for DD physics

World’s largest sample of J/ψ, ψ(2S) and ψ(3770) (and still growing)