Recent Results from BESIII

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HNP 2015, July 7-11, 2015, Krabi, Thailand,
Outline

• Introduction
• Status of BESIII
• Selected results from BESIII
• Summary
Beijing Electron Positron Collider (BEPC)

beam energy: 1.0 – 2.3 GeV

2004: started BEPCII upgrade, BESIII construction
2008: test run
2009 - now: BESIII physics run

• 1989-2004 (BEPC):
  \[ L_{\text{peak}} = 1.0 \times 10^{31} \text{ /cm}^2\text{s} \]

• 2009-now (BEPCII):
  \[ L_{\text{peak}} = 0.85 \times 10^{33} /\text{cm}^2\text{s} \]
Upgraded BEPC-BEPCII

Beam energy: **1.0 - 2.3 GeV**
Luminosity: **$0.69 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$ @3770**
Optimum energy: **1.89 GeV**
Energy spread: **$5.16 \times 10^{-4}$**
No. of bunches: **93**
**MDC**
- R inner: 63 mm
- R outer: 810 mm
- Length: 2582 mm
- Layers: 43

**CsI(Tl) EMC**
- Crystals: 28 cm ($15 X_0$)
- Barrel: $|\cos \theta| < 0.83$
- Endcap: $0.85 < |\cos \theta| < 0.93$

**RPC MUC**
- BMUC: 9 layers – 72 modules
- EMUC: 8 layers – 64 modules

**TOF**
- BTOF: two layers
- ETOF: 48 crys. for each
## BESIII Detector

| Exps.       | MDC Wire resolution | MDC dE/dx resolution | EMC Energy resolution |
|-------------|---------------------|----------------------|-----------------------|
| CLEO        | 110 μm              | 5%                   | 2.2-2.4%              |
| Babar       | 125 μm              | 7%                   | 2.67%                 |
| Belle       | 130 μm              | 5.6%                 | 2.2%                  |
| BESIII (XYZ data) | 115 μm             | <5% (Bhabha)         | 2.3%                  |

- New ETOF (MRPC), will be installed
- New Inner MDC, being built

| Exps.       | TOF time resolution |
|-------------|---------------------|
| CDFII       | 100 ps              |
| Belle       | 90 ps               |
| BESIII (XYZ data) | 68 ps (BTOF) | 100 ps (ETOF) |
Data/Monte-Carlo Consistency

- For tracking efficiency, data/MC difference < 1%
- For particle identification efficiency, data/MC difference < 2%
BESIII Collaboration

US (5)
- Univ. of Hawaii
- Carnegie Mellon Univ.
- Univ. of Minnesota
- Univ. of Rochester
- Univ. of Indiana

Europe (13)
- 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, Ferrara Univ.
- Netherland: KVI/Univ. of Groningen
- Sweden: Uppsala Univ.
- Turkey: Turkey Accelerator Center

Mongolia (1)
- Institute of phys. & Tech.
- Seoul Nat. Univ.

Korea (1)
- Japan (1)
- Tokyo Univ.

Pakistan (2)
- Univ. of Punjab
- COMSAT CIIT

China (32)
- IHEP, CCAST, GUCAS, 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.
- Zhongshan Univ., Nankai Univ., Beihang Univ.
- Shanxi Univ., Sichuan Univ., Univ. of South China
- 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.
- Univ. of Sci. & Tech. Liaoning

~400 members from 55 institutions in 12 countries
Features of the BEPC Energy Region

- Rich of resonances: charmonia and charmed mesons
- Threshold characteristics (pairs of $\tau$, D, $D_s$, ...)
- Transition between smooth and resonances, perturbative and non-perturbative QCD
- Energy location of the new hadrons: glueballs, hybrids, multi-quark states
Physics Topics at BESIII

◆ Hadron spectroscopy
  ➢ search for the new forms of hadrons
  ➢ 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.

  Calibrate QCD
  XYZ states

◆ Precise measurement of R values, $\tau$ mass, hadron FF
◆ Precise measurement of CKM matrix
◆ Search for DDbar mixing, CP violation, etc.
Conventional hadrons consist of 2 or 3 quarks:

Naive Quark Model:
- Meson
- Baryon

QCD predicts the new forms of hadrons:
- Multi-quark states: Number of quarks $\geq 4$
- Hybrids: $q\bar{q}g$, $qqqg$ ...
- Glueballs: $gg$, $ggg$ ...

None of the new forms of hadrons is settled!
Charmonium decays provide ideal hunting ground for light glueballs and hybrids

- “Gluon-rich” process
- Clean high statistics data samples from e+e- annihilation
- $I(J^{PC})$ filter in strong decays of charmonium

\[ \Gamma(J/\psi \rightarrow \gamma G) \sim O(\alpha \alpha_s^2), \quad \Gamma(J/\psi \rightarrow \gamma H) \sim O(\alpha \alpha_s^3), \]
\[ \Gamma(J/\psi \rightarrow \gamma M) \sim O(\alpha \alpha_s^4), \quad \Gamma(J/\psi \rightarrow \gamma F) \sim O(\alpha \alpha_s^4) \]
Charmonium spectroscopy

- Charmonium states below open charm threshold are all observed

Above open charm threshold:
- many expected states not observed
- many unexpected observed

from Ryan Mitchell

X(3872)
XYZ(3940)

Z(4430) X(3915) X(4160)
Z(4250) Y(4008)
Z(4050) Y(4140)
Z(3900) Y(4260)
XYZ(3940) Y(4360)
X(4350)
Y(4660)
Precision 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?

Unitary matrix?

\(~5\%\) precision

\(~10\%\) precision

Expected precision < 2\% at BESIII

BESIII + B factories + LQCD

BESIII + B factories + LHCb + LQCD

Precision measurement of CKM matrix elements
-- a precise test of SM model

New physics beyond SM?
Nucleon Form Factor

- Fundamental properties of the nucleon
  - Connected to charge, magnetization distribution
  - Crucial testing ground for models of the nucleon internal structure
  - Necessary input for experiments probing nuclear structure, or trying to understand modification of nucleon structure in nuclear medium

- Can be measured from space-like processes (eN) (precision 1%) or time-like process (e+e- annihilation) (precision 10%-30%)

Space-like: FF real

Time-like: FF complex
BESIII data samples

World largest $J/\psi$, $\psi(2S)$, $\psi(3770)$, $Y(4260)$, ... produced directly from $e^+e^-$ collision
PWA of $J/\psi \rightarrow \gamma \eta \eta$

(Phys. Rev. D87 092009 (2013))

- Br of $f_0(1710)$ and $f_0(2100)$ are $\sim 10\times$ larger than that of $f_0(1500)$
- Possible large overlap with LQCD predictions of $0^+$ Glueball:
  PRL 110 021601 (2013)
- Further studies of $J/\psi \rightarrow \gamma \eta \eta'$ and $J/\psi \rightarrow \gamma \eta' \eta'$ are crucial for glueball ID and solving the mixing scheme.
Model independent PWA of $J/\psi \to \gamma \pi^0 \pi^0$

Significant features of the scalar spectrum include structures near 1.5, 1.7, and 2.0 GeV/c$^2$. 

arXiv: 1506.00546
Charmonium decays provide novel insights into baryons --- complementary to other experiments

- Isospin 1/2 filter: $\psi \rightarrow N\bar{N}\pi$, $\psi \rightarrow N\bar{N}\pi\pi$
- Missing N* with small couplings to $\pi N$ & $\gamma N$, but large coupling to $gggN$: $\psi \rightarrow N\bar{N}\pi/\eta/\eta'/\omega/\phi$, $\bar{p}\Sigma\pi$, $\bar{p}\Lambda K$ ...
- Not only N*, but also $\Lambda^*$, $\Sigma^*$, $\Xi^*$
- Gluon-rich environment: a favorable place for producing hybrid (qqqg) baryons
- Interference between N* and $N^*$ bands in $\psi \rightarrow N\bar{N}\pi$ Dalitz plots may help to distinguish some ambiguities in PWA of $\pi N$
- High statistics of charmonium @ BES III
Study of N* and Ξ*

N* in $\psi' \rightarrow \pi^0 p \bar{p}$

New N*s: N(2300) and N(257)

PRL. 110 (2013) 022001

Ξ* in $\psi' \rightarrow K\Lambda\Xi$

arXiv:1504.02025

N(1440) N(1520) N(1535) N(1650)

New N*s: N(2300) and N(257)

PWA of

- $J/\psi(\psi') \rightarrow \pi^0 p \bar{p}$
- $J/\psi(\psi') \rightarrow \eta p \bar{p}$
- $J/\psi(\psi') \rightarrow pK \bar{\Lambda}$
- ...

N(940) N(1720) N(2300) N(2570)
PWA of $\psi' \rightarrow \pi^0 p\bar{p}$

BESIII, Phys.Rev.Lett. 110 (2013) 022001

2 New $N^*$ are found (1/2+, 5/2-)

| Resonance   | $M$(MeV/$c^2$)    | $\Gamma$(MeV/$c^2$)  | $\Delta S$ | $\Delta N_{dof}$ | Sig.  |
|-------------|-------------------|----------------------|------------|------------------|-------|
| $N(1440)$   | $1390^{+11+21}_{-21-30}$ | $340^{+46+70}_{-40-15}$ | 72.5       | 4                | 11.5$\sigma$ |
| $N(1520)$   | $1510^{+3+11}_{-7-9}$     | $115^{+20+0}_{-15-40}$ | 19.8       | 6                | 5.0$\sigma$  |
| $N(1535)$   | $1535^{+9+15}_{-5-11}$    | $120^{+20+0}_{-21-42}$ | 49.4       | 4                | 9.3$\sigma$  |
| $N(1650)$   | $1650^{+5+11}_{-5-30}$    | $150^{+32+50}_{-22}$   | 82.1       | 4                | 12.2$\sigma$ |
| $N(1720)$   | $1700^{+30+32}_{-28-35}$  | $450^{+109+149}_{-94}$ | 55.6       | 6                | 9.6$\sigma$  |
| $N(2300)$   | $2300^{+40+109}_{-30-0}$  | $340^{+30+58}_{-30-58}$| 120.7      | 4                | 15.0$\sigma$ |
| $N(2570)$   | $2570^{+19+34}_{-10-10}$  | $250^{+14+69}_{-24-21}$| 78.9       | 6                | 11.7$\sigma$ |

The energy dependent width $BW$ for

$$
\Gamma_{N(1440)} \rightarrow \Gamma_{N(1440)} \left( 0.7 \frac{B_1(q_{\pi N})\rho_{\pi N}(s)}{B_1(q_{\pi N})\rho_{\pi N}(M_{N^*}^2)} + 0.3 \frac{B_1(q_{\pi \Delta})\rho_{\pi \Delta}(s)}{B_1(q_{\pi \Delta})\rho_{\pi \Delta}(M_{N^*}^2)} \right)
$$

$$
\Gamma_{N(1520)} \rightarrow \Gamma_{N(1520)} \left( \frac{B_2(q_{\pi N})\rho_{\pi N}(s)}{B_2(q_{\pi N})\rho_{\pi N}(M_{N^*}^2)} \right)
$$

$$
\Gamma_{N(1535)} \rightarrow \Gamma_{N(1535)} \left( 0.5 \frac{\rho_{\pi N}(s)}{\rho_{\pi N}(M_{N^*}^2)} + 0.5 \frac{\rho_{\eta N}(s)}{\rho_{\eta N}(M_{N^*}^2)} \right)
$$

The other $N^*$ : constant width $BW$
Observation of $Z_c(3900)^\pm$

$Z_c(3900)^+$:

\[
m = (3899.0 \pm 3.6 \pm 4.9) \text{ MeV}/c^2
\]

\[
\Gamma = (46 \pm 10 \pm 20) \text{ MeV}
\]

Mass close to $D\bar{D}^*$ threshold

Decays to $J/\psi \rightarrow$ contains $c\bar{c}$

Electric charge \rightarrow contains $u\bar{d}$

\[
\sigma[e^+e^- \rightarrow \pi^+\pi^- J/\psi] = 62.9 \pm 1.9 \pm 3.7 \text{ pb at } 4.26 \text{ GeV}
\]

\[
\frac{\sigma[e^+e^- \rightarrow \pi^+ Z_c(3900)^\pm \rightarrow \pi^+\pi^- J/\psi]}{\sigma[e^+e^- \rightarrow \pi^+\pi^- J/\psi]} = (21.5 \pm 3.3 \pm 7.5)\% \text{ at } 4.26 \text{ GeV}
\]

Belle with ISR data (PRL 110, 252002)

CLEOc data at 4.17 GeV (PLB 727, 366)
The neutral isospin partner: $Z_c(3900)^0$

Studying the $e^+e^- \rightarrow \pi^0\pi^0 J/\psi$ process

A structure on $\pi^0 J/\psi$ invariant mass spectrum can be observed:

Mass = $3894.8 \pm 2.3 \pm 2.7$ MeV
Width = $29.6 \pm 8.2 \pm 8.2$ MeV
Significance = $10.4 \sigma$

Isospin triplet is established!

CLEOc data at 4.17 GeV (PLB 727, 366)

3.7$\sigma$!
Observation of $Z_c(3885)\pm$ in $e^+e^- \rightarrow \pi^\pm (D\overline{D}^*)\mp$ at $\sqrt{s} = 4.26 \text{GeV}$ using single D tag method

Reconstruct the $\pi^+$ and $D^0 \rightarrow K^-\pi^+$ and infer the $D^{*-}$.  
(Also analyze $\pi^+D^{-}D^{*0}$ with the same method.)

Enhancement at $D\overline{D}^*$ threshold in both channels ($Z_c(3885)^+$):

Mass = $3883.9 \pm 1.5 \pm 4.2$ MeV, (fit with BW function)
Width = $24.8 \pm 3.3 \pm 11.0$ MeV

Fit to angular distribution favors $J^P = 1^+$ over $0^-$ and $1^-$.  

Data
Fit: 1+, 0-, 1-

Preliminary
Observation of $Z_c(4020)^\pm$ in $e^+e^- \rightarrow \pi^+\pi^- h_c$

$h_c \rightarrow \gamma\eta_c,$
$\eta_c \rightarrow 16$ hadronic decay modes

The cross section of $e^+e^- \rightarrow \pi^+\pi^- h_c$ is measured, and the shape is not trivial.

A structure, $Z_c(4020)^\pm$, is observed.

Mass = $4022.9 \pm 0.8 \pm 2.7$ MeV,
Width = $7.9 \pm 2.7 \pm 2.6$ MeV

A weak evidence for $Z_c(3900)^\pm \rightarrow \pi^\pm h_c$
Observed neutral $Z_c(4020)^0$ in $e^+e^- \rightarrow \pi^0\pi^0 h_c$

$$M[Z_c(4020)^0] = 4023.6 \pm 2.2 \pm 3.9 \text{ MeV}$$

$$[M[Z_c(4020)^\pm] = 4022.9 \pm 0.8 \pm 2.7 \text{ MeV}]$$

- Width fixed to charged $Z_c(4020)$
- Significance: $>5\sigma$

**Observation of neutral $Z_c(4020)$**  
**Isovector nature of $Z_c$ states established**

BESIII: PRL113, 212002 (2014)
Observation of $Z_c(4025)^\pm$
\[ e^+ e^- \rightarrow \pi^{\pm} (D^* \bar{D}^*)^{\mp} \] at $\sqrt{s} = 4.26\text{GeV}$

Tag a $D^+$ and a bachelor $\pi^-$, reconstruct one $\pi^0$ to suppress the background.

A structure, named as $Z_c(4025)$, can be observed in the recoil mass of the bachelor $\pi^-$.

\[ M(Z_c(4025)) = 4026.3 \pm 2.6 \pm 3.7 \text{ MeV}; \]
\[ \Gamma(Z_c(4025)) = 24.8 \pm 5.6 \pm 7.7 \text{ MeV} \]

\[ \sigma[e^+ e^- \rightarrow (D^* \bar{D}^*)^{\pm \pi^\mp}] = 137 \pm 9 \pm 15 \text{ pb at 4.26 GeV} \]

\[ \frac{\sigma[e^+ e^- \rightarrow \pi^{\pm} Z_c(4025)^+ \rightarrow (D^* \bar{D}^*)^{\pm \pi^\mp}]}{\sigma[e^+ e^- \rightarrow (D^* \bar{D}^*)^{\pm \pi^\mp}]} = 0.65 \pm 0.09 \pm 0.06 \text{ at 4.26 GeV} \]

Coupling to $\bar{D}^*D^*$ is much larger than to $\pi h_c$ if $Z_c(4025)$ and $Z_c(4020)$ are the same state.
Zc(4025)⁰ observed with $e^+e^- \rightarrow \pi^0 (D^* \overline{D}^*)^0$

BESIII preliminary

Phase space + BG

- Measured with data at Ecms=4.23GeV and 4.26GeV
- A simultaneous fit for two energy points gives

| Data sample  | Mass(MeV/c²)       | Width(MeV/c²) | $\sigma(e^+e^- \rightarrow Z_c(4025)^0\pi^0 \rightarrow D^*\overline{D}^*\pi^0)$(pb) |
|--------------|--------------------|---------------|--------------------------------------------------------------------------------|
| @4.23GeV     | 4025.5⁺²⁻₀.⁴.⁷±³.¹  | 23.0 ± 6.0 ± 1.0 | 61.6 ± 8.2 ± 9.0                                                                   |
| @4.26GeV     |                    |               | 43.4 ± 8.0 ± 5.4                                                                  |
Summary on $Z_c$ states

From Kornicer  CHARM 2015

BESIII preliminary

soon ...
## Summary on $Z_c$ states

From Kornicer CHARM 2015

| State         | Mass (MeV)                  | Width (MeV) | Decay mode | Process                                      |
|---------------|----------------------------|-------------|------------|----------------------------------------------|
| $Z_c(3900)^\pm$ | $3899.0^{+3.6}_{-3.3} \pm 4.9$ | $46\pm10\pm20$ | $\pi^\pm \mathrm{J/\psi}$ | $e^+e^-\to \pi^+\pi^-\mathrm{J/\psi}$ |
| $Z_c(3900)^0$  | $3894.8\pm2.3\pm2.7$       | $29.6\pm8.2\pm8.2$ | $\pi^0\mathrm{J/\psi}$ | $e^+e^-\to \pi^0\pi^0\mathrm{J/\psi}$ |
| $Z_c(3885)^\pm$ | $3883.9\pm1.5\pm4.2$ [single D tag] 1 | $24.8\pm3.3\pm11.0$ [single D tag] 1 | $D^0D^{*-}$ | $e^+e^-\to \pi^+D^0\bar{D}^{*-}$ |
|               | $3884.3\pm1.2\pm1.5$ [double D tag] | $23.8\pm2.1\pm2.6$ [double D tag] | $D^-D^{*0}$ | $e^+e^-\to \pi^+D^-\bar{D}^{*0}$ |
| $Z_c(4020)^\pm$ | $4022.9\pm0.8\pm2.7$       | $7.9\pm2.7\pm2.6$ | $\pi^\pm h_c$ | $e^+e^-\to \pi^+\pi^-h_c$ |
| $Z_c(4020)^0$  | $4023.9\pm2.2\pm3.8$       | fixed        | $\pi^0h_c$ | $e^+e^-\to \pi^0\pi^0h_c$ |
| $Z_c(4025)^\pm$ | $4026.3\pm2.6\pm3.7$       | $24.8\pm5.6\pm7.7$ | $D^{*0}D^{*-}$ | $e^+e^-\to \pi^+(D^{*-}\bar{D}^{*})$ |
| $Z_c(4025)^0$  | $4025.5^{+2.0}_{-4.7}\pm3.1$ | $23.0\pm6.0\pm1.0$ | $(D^{*}D^{*})^0$ | $e^+e^-\to \pi^0(D^{*}\bar{D}^{*})^0$ |
$e^+e^- \rightarrow \gamma X(3872)$

- Search for $\gamma X(3872)$ with $X(3872) \rightarrow \pi\pi J/\psi$ at $E_{cm}=4.23$, 4.26 and 4.36 GeV

- summed over all data
  $X(3872)$ significance = 6.3 $\sigma$

- Production in $Y(4260)$ decay suggestive, but not conclusive

- If from $Y(4260)$

$$\frac{B(Y(4260) \rightarrow \gamma X(3872))}{B(Y(4260) \rightarrow \pi^+\pi^- J/\psi)} \sim 0.1$$

[BESIII RPL112,092001]
\( e^+ e^- \rightarrow \pi^+ \pi^- X(3823), X \rightarrow \gamma \chi_{cJ}, \chi_{cJ} \rightarrow \gamma J/\psi \)
$e^+e^- \rightarrow \pi^+\pi^- X(3823), X \rightarrow \gamma\chi_{cJ}, \chi_{cJ} \rightarrow \gamma J/\Psi$

Simultaneous fit of $\gamma\chi_{c1}$ (left) and $\gamma\chi_{c2}$ (right) events

$M(X(3823)) = (3821.7 \pm 1.3\text{(stat)} \pm 0.7\text{(syst)})\text{ MeV}/c^2$

$\Gamma(X(3823)) < 16 \text{ MeV}$ at 90% C. L. consist with Belle

$\psi(1\ 3^3D_2)$

D-wave is expected.
Limited statistics
Limited information
Charm physics at BESIII

Advantage of open charm at threshold

$e^+e^-\text{ colliders@threshold:}$

\[
e^+e^- \rightarrow \psi(3770) \rightarrow D^0\bar{D}^0 \ [C = -1] \quad \text{OR} \quad e^+e^- \rightarrow \gamma^* \rightarrow D^0\bar{D}^0\gamma \ [C = +1]
\]

Good for charm flavor physics:

- Threshold production: clean
- Known initial energy and quantum numbers
- Both D and Dbar fully reconstructed (double tag)
- Absolute measurements
**Leptonic decays**

\[
(D^+ \rightarrow \ell^+ \nu) = f_D^2 |V_{cd}|^2 \frac{G_F^2}{8} m_D m_\ell \left(1 - \frac{m_\ell^2}{m_D^2}\right)
\]

\[B(D^+ \rightarrow \mu^+ \nu) = (3.72 \pm 0.19 \pm 0.06) \times 10^{-4}\]

\[f_{D^+} = (203.4 \pm 5.2 \pm 1.9) \text{ MeV}\]

\[|V_{cd}| = 0.2212 \pm 0.0056 \pm 0.0047\]

\[\Leftarrow \text{LQCD calculated } f_D = 207 \pm 4 \text{ MeV} \]

[PRL100(2008)062002]
\[ B(D^+ \rightarrow \mu^+\nu) \]

**BESIII:** 2.7\% with 2.92 fb\(^{-1}\)

**BESIII final:** 1.5\% with 10 fb\(^{-1}\)
Nucleon Form Factor

- Fundamental properties of the nucleon
  - Connected to charge, magnetization distribution
  - Crucial testing ground for models of the nucleon internal structure
  - Necessary input for experiments probing nuclear structure, or trying to understand modification of nucleon structure in nuclear medium

- Can be measured from space-like processes (eN) (precision 1%) or time-like process (e+e- annihilation) (precision 10%-30%)

**Space-like:** FF real

**Time-like:** FF complex
Proton FF measurement at BESIII

Phys.Rev. D91 (2015) 11, 112004

Analysis Features:
• Radiative corrections from Phokhara8.0 (scan)
• Normalization to $e^+e^- \rightarrow e^+e^-, e^+e^- \rightarrow \gamma\gamma$ (BABAYAGA 3.5)
• Efficiencies 60% (2.23 GeV) .... 3% (~4 GeV)
• $|G_E/G_M|$ ratio obtained for 3 c.m. energies

| $E_{cm}/GeV$ | $L_{int}/pb^{-1}$ |
|--------------|------------------|
| 2.23         | 2.6              |
| 2.40         | 3.4              |
| 2.80         | 3.8              |
| 3.05, 3.06, 3.08 | 60.7            |
| 3.40, 3.50, 3.54, 3.56 | 23.3            |
| 3.60, 3.65, 3.67 | 63.0            |
**Precise study of $\Lambda_c$ decays**

stringent test on Heavy Quark Effective Theory

- absolute branching fractions (BF) of $\Lambda_c^+$ decays suffers from large uncertainties since its discovery 30 years ago
- hadronic decays: to explore as-yet-unmeasured channels and understand full picture of intermediate structures
- semi-leptonic decays: test on form factor predictions

| Decay modes | global fit $B$ | PDG $B$ | Belle $B$ |
|-------------|----------------|---------|-----------|
| $pK_S$      | 1.48 ± 0.08    | 1.15 ± 0.03 | 0.84 ± 0.24 ± 0.21 |
| $pK^-\pi^+$ | 5.77 ± 0.27    | 5.4 ± 1.3    |           |
| $pK_S\pi^0$ | 1.77 ± 0.12    | 1.65 ± 0.20  |           |
| $pK_S\pi^+\pi^-$ | 1.43 ± 0.10 | 1.30 ± 0.35  |           |
| $pK^-\pi^+\pi^0$ | 4.25 ± 0.22 | 3.4 ± 1.0     |           |
| $\Lambda\pi^+$ | 1.20 ± 0.07    | 1.07 ± 0.28  |           |
| $\Lambda\pi^+\pi^0$ | 6.70 ± 0.35 | 3.6 ± 1.3     |           |
| $\Lambda\pi^+\pi^-\pi^+$ | 3.67 ± 0.23 | 2.6 ± 0.7     |           |
| $\Sigma^0\pi^+$ | 1.28 ± 0.08    | 1.05 ± 0.28  |           |
| $\Sigma^+\pi^0$ | 1.18 ± 0.11    | 1.00 ± 0.34  |           |
| $\Sigma^+\pi^+\pi^-$ | 3.58 ± 0.22 | 3.6 ± 1.0     |           |
| $\Sigma^+\omega$ | 1.47 ± 0.18    | 2.7 ± 1.0    |           |

Only stat. errors

- $\mathbf{B(pK^-\pi^+)}$: BESIII precision comparable with Belle’s result
- BESIII rate $\mathbf{B(pK^-\pi^+)}$ is smaller
- Improved precisions of the other 11 modes significantly

567/pb @4.6 GeV
BESIII upgrade

- MDC: Malter effect found in inner chamber in 2012, add water vapor to the chamber to cure the aging problem.
  - New inner chamber is being built at IHEP. Will be ready this summer.
  - CGEM as the inner chamber ongoing: Italy group in collaboration with groups in Germany, Sweden and IHEP.

- New ETOF (built by USTC & IHEP) will be installed this summer to improve the time resolution (100ps $\rightarrow$ 55ps)
# BESIII data taking status & plan (run ~8 years)

|                          | Previous data | BESIII present & future                                                                 | Goal |
|--------------------------|---------------|----------------------------------------------------------------------------------------|------|
| **J/ψ**                  | BESII 58M     | 1.2 B 20* BESII                                                                         | 10 B |
| **ψ’**                   | CLEO: 28 M    | 0.5 B 20* CLEOc                                                                         | 3B   |
| **ψ”**                   | CLEO: 0.8/fb  | 2.9/fb 3.5*CLEOc                                                                       | 20/fb|
| Above open charm         | CLEO: 0.6/fb  | 0.5/fb @ ψ(4040) 2.3/fb@~4260, 0.5/fb@4360 0.5/fb@4600, 1/fb@4420                   | 5-10/fb|
| threshold                | @ ψ(4160)     |                                                                                        |      |
| **R scan & Tau**         | BESII         | 3.8-4.6 GeV at 105 energy points 2.0-3.1 GeV at 20 energy points                      |      |
| **Y(2175)**              |               | 100 pb⁻¹ (taking data now)                                                             |      |
| **ψ(4170)**              |               | 3 fb⁻¹ (next run)                                                                       |      |

Thank you!
Backup slides
CLEO-c: 2.5% with 0.68 fb$^{-1}$
BESIII final: 1.25% with 5 fb$^{-1}$
Form Factors: Semileptonic decays

\[ \frac{d}{dq^2} \left( D \rightarrow K(e) \right) = \frac{G_F^2 |V_{cs(d)}|^2 P_{K_{+}}^3}{24} \left| f_+(q^2) \right|^2 \]

Theory:
- HPQCD (2010) \(0.747 \pm 0.011 \pm 0.015\)
- Fermilab/MILC (2005) \(0.73 \pm 0.08 \pm 0.07\)
- Sum Rules (2009) \(0.75^{+0.11}_{-0.08}\)

Experiment:
- CLEO-c (2009) \(0.739 \pm 0.007 \pm 0.005 \pm 0.000\)
- Belle (2006) \(0.695 \pm 0.007 \pm 0.022\)
- BaBar (2007) \(0.727 \pm 0.007 \pm 0.005 \pm 0.007\)
- BESIII (2014) \(0.7360 \pm 0.0026 \pm 0.0036\)

Based on preliminary result

Gang Rong
CKM2014
In summer of 2014, two MRPC modules were installed to replace previous scintillators. Real data obtained in Feb., 2015.

Two-end: 55 ps

Left: 71 ps

Right: 71 ps