BEPC II status and prospects

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- Introduction
- Construction
- Commissioning
- Physics at BESIII
- Summary
Beijing Electron Positron Collider (BEPC) at IHEP

$E_{\text{beam}} \sim 1-2.5$ GeV
$\tau$-charm energy region

BEijing Spectrometer (BES)

BESI: run from 1989-1998
BESII: run from 1999-2004
BESIII: construction completed, running now

A unique $e^+e^-$ machine in the $\tau$-charm energy region from 1989 - till CLEOc (2003).
With BESI and BESII data:

- Precision measurement of $\tau$ mass: 10 times improved. Lepton universality!
- $R$ measurements improve uncertainties by a factor of 2-3 ($\Delta R/R \sim 6\%$). Have great impact to $M_H$. $\alpha(M_z^2)$, g-2
- Some new particles (X(1835) observed. Hard to be interpreted as conventional hadrons.

**Precision measurement requires high statistics and small sys. errors → Major upgrade: BEPCII / BESIII (2004-2008)**
BEPCII: a high luminosity double-ring collider
BEPCII design goal

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy range</td>
<td>1 – 2.1 GeV</td>
</tr>
<tr>
<td>Optimum energy</td>
<td>1.89 GeV</td>
</tr>
<tr>
<td>Luminosity</td>
<td>$1 \times 10^{33} \text{ cm}^{-2} \text{s}^{-1}$ @ 1.89 GeV</td>
</tr>
<tr>
<td>Injection</td>
<td>Full energy injection upto 1.89 GeV</td>
</tr>
<tr>
<td></td>
<td>Positron injection rate &gt; 50 mA/min</td>
</tr>
<tr>
<td># of bunches</td>
<td>93</td>
</tr>
<tr>
<td>Beam Current</td>
<td>0.91 A</td>
</tr>
<tr>
<td>Bunch length</td>
<td>1.5 cm</td>
</tr>
<tr>
<td>Synchrotron mode</td>
<td>250 mA @ 2.5 GeV</td>
</tr>
</tbody>
</table>

Beam energy can reach 2.3 GeV.
<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 2004</td>
<td>Construction started</td>
</tr>
<tr>
<td>May 4, 2004</td>
<td>Dismount of 8 linac sections started</td>
</tr>
<tr>
<td>Dec. 1, 2004</td>
<td>Linac delivered $e^-$ beams for BEPC</td>
</tr>
<tr>
<td>July 4, 2005</td>
<td>BEPC ring dismount started</td>
</tr>
<tr>
<td>Mar. 2, 2006</td>
<td>BEPCII ring installation started</td>
</tr>
<tr>
<td>Nov. 13, 2006</td>
<td>Phase 1 commissioning started</td>
</tr>
<tr>
<td>Aug. 3, 2007</td>
<td>Shutdown for installation of IR-SCQ’s</td>
</tr>
<tr>
<td>Oct. 24, 2007</td>
<td>Phase 2 commissioning started</td>
</tr>
<tr>
<td>Mar. 28, 2008</td>
<td>Shutdown for installation of detector</td>
</tr>
<tr>
<td>June 24, 2008</td>
<td>Phase 3 commissioning started</td>
</tr>
</tbody>
</table>
Linac performance reached design goals and runs stable

<table>
<thead>
<tr>
<th></th>
<th>Design</th>
<th>Measured</th>
<th>BEPC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy (e+ / e-) (GeV)</strong></td>
<td>1.89</td>
<td>1.89</td>
<td>1.30-1.55</td>
</tr>
<tr>
<td><strong>Current (e+) (mA)</strong></td>
<td>37</td>
<td>61</td>
<td>~5</td>
</tr>
<tr>
<td><strong>Current (e-) (mA)</strong></td>
<td>500</td>
<td>&gt;500</td>
<td>~300</td>
</tr>
<tr>
<td><strong>Emittance (e+) (1σ, mm-mrad)</strong></td>
<td>0.40</td>
<td>0.39-0.41</td>
<td>****</td>
</tr>
<tr>
<td></td>
<td>(37 mA)</td>
<td>(40-46 mA)</td>
<td></td>
</tr>
<tr>
<td><strong>Emittance (e-) (1σ, mm-mrad)</strong></td>
<td>0.10</td>
<td>0.09-0.11</td>
<td>****</td>
</tr>
<tr>
<td></td>
<td>(500 mA)</td>
<td>(600 mA)</td>
<td></td>
</tr>
<tr>
<td><strong>Pulse Repe. Rate (Hz)</strong></td>
<td>50</td>
<td>50</td>
<td>12.5</td>
</tr>
<tr>
<td><strong>Energy Spread (e-) (%)</strong></td>
<td>±0.50</td>
<td>±0.44</td>
<td>±0.80</td>
</tr>
<tr>
<td></td>
<td>(500 mA)</td>
<td>(600 mA)</td>
<td></td>
</tr>
<tr>
<td><strong>Energy Spread (e+) (%)</strong></td>
<td>±0.50</td>
<td>±0.50</td>
<td>±0.80</td>
</tr>
<tr>
<td></td>
<td>(37 mA)</td>
<td>(≥37 mA)</td>
<td></td>
</tr>
</tbody>
</table>
Storage Ring installation finished
Commissioning of BEPCII

Oct. 2006 Installation completed with NSCQ@IR
Nov 18, 2006  first beam first stored
Dec. 25, 2006 first SR running started
Mar 26, 2007 First collisions
May 14, 2007  Lumi $10^{32}\text{cm}^{-2}\text{s}^{-1}$ (as BEPC)
2007 July 31  SR mode 250mA

Oct. 2007 Installation completed with SCQ@IR
2007 Nov. 18  First collision
2008 Jan. 29  500mA*500mA,Lum. $>1\times10^{32}$
2008 Feb. 25-Mar. 28 SR operation
2008 June. Installation completed with SCQ-IR

→ Phase 3
The BESIII Detector

Magnet yoke

SC magnet, 1T

RPC: 9 layers

TOF,
\( \sigma_T \) (ps) = 100 ps Barrel
110 ps Endcap

Be beam pipe

MDC,
\( \sigma_{XY} \) (\( \mu \)m) = 130
\( \Delta P/P = 0.5 \% \) (1 GeV)
\( \sigma_{dE/dx} = 6-7 \% \)

CsI(Tl) calorimeter,
\( \Delta E/\sqrt{E} = 2.5 \% \) (1 GeV)
\( \sigma_z, \phi (cm) = 0.5 cm/\sqrt{E} \)
Drift chamber (MDC)

Parameters
R inner: 63mm ; R outer: 810mm
Length (out.): 2582 mm
Sense wire: 25 micron gold-plated tungsten - 6796
Layers (Sense wire): 43 (19 axial, 24 stereo)
Field wire: 110 micron gold-plated Aluminum --- 21884
Gas: He + C3H8 (60/40)
Cell: inner chamber --- 6 mm
    outer chamber --- 8.1 mm
Polar angle: |cos θ| < 0.93

Expected performance

\[ \sigma_x \sim 130 \ \mu m \]
\[ \sigma \frac{dE}{dx} \sim 0.5 \% \ @1\text{GeV/C} \]
\[ \sigma \frac{dE}{dx} \sim 6 \% \]
CsI(Tl) crystal calorimeter (EMC)

- Crystals:
  - L = 28 cm (15 $X_0$)
  - $A = (5.2 \times 5.2 - 6.4 \times 6.4) \text{ cm}^2$
  - Barrel: 5280 w: 21564 kg
  - Endcaps: 960 w: 4051 kg
  - Total: 6240 w: 25.6 T

Design goals:
- Energy: 2.5% @ 1GeV
- Energy range: 20 MeV-2 GeV
- Spatial: 0.6cm @ 1GeV
BESIII installation
Detector installation completed this April, and moved to IR in May, 2008.
Joint Commissioning

- BESIII detector moved into the IR in May
- Joint commissioning started 22 June.
Phase #3 commissioning

June. Installation completed with SCQ @ IR

Jul. 16 First collisions without detector SC magnet
Jul. 19 First collisions with detector SC magnet
Aug.  9 100mA*100mA in 20 bunches
Aug. 16 200mA*200mA in 52 bunches
Sept. 1 300mA*300mA collision in 71 bunches
Sept. 7 400mA*400mA collision in 80 bunches
Oct.7, e+ both e+/e- reach 600mA

Luminosity Record:
Sept. 17, 370×370mA (71 bunches) => 1.15×10^{32}cm^{-2}s^{-1}
• First physics event was detected at BESIII in July 19, 2008.
• MDC noise problem was solved.
• $10M \psi'$ events collected for calibration

$$\psi(3770) \rightarrow D \bar{D}$$
First reach $1 \times 10^{32} \text{cm}^{-2}\text{s}^{-1}$

Stably realized
Main parameters achieved in collision mode

<table>
<thead>
<tr>
<th>parameters</th>
<th>design</th>
<th>Achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>BER</td>
</tr>
<tr>
<td>Energy (GeV)</td>
<td>1.89</td>
<td>1.89</td>
</tr>
<tr>
<td>Beam curr. (mA)</td>
<td>910</td>
<td>630</td>
</tr>
<tr>
<td>Bunch curr. (mA)</td>
<td>9.8</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Bunch number</td>
<td>93</td>
<td>93</td>
</tr>
<tr>
<td>RF voltage</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>*ν_s @1.5MV</td>
<td>0.033</td>
<td>0.032</td>
</tr>
<tr>
<td>β_x*/β_y* (m)</td>
<td>1.0/0.015</td>
<td>~1.0/0.016</td>
</tr>
<tr>
<td>Inj. Rate (mA/min)</td>
<td>200 e^-/ 50 e^+</td>
<td>&gt;200</td>
</tr>
<tr>
<td>Lum. (∗10^{33}cm^{-2}s^{-1})</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
Bottleneck to increase luminosity

- Specific Lum. \[ L/(n^*I_b^*I_b) \]

For multi-bunch, ideally:
\[ \text{Lum} = L_{bunch} \times N_b \]

But Spec. L decreased while bunch number increase, i.e.:
\[ \text{Lum} < L_{bunch} \times N_b \]

? Coupled bunch instability
? Bunch size increase due to ECI

=> Systematic observation is under way

=> Cure method (solenoid winding, feedback, etc.)
Physics at BEPCII/BESIII

- Precision measurement of CKM matrix elements
- Precision test of Standard Model
- QCD and hadron production
- Light hadron spectroscopy
- Charmonium production/decays
- Search for new physics/new particles
Physics at BEPCII/BESIII

Statistics at BESIII at peak Luminosity
(assuming $10^7$ s data taking time each year)

<table>
<thead>
<tr>
<th>Physics</th>
<th>Energy (GeV)</th>
<th>Peak Luminosity $(10^{33} , \text{cm}^{-2}\text{s}^{-1})$</th>
<th>Events/year</th>
<th>Existing data</th>
</tr>
</thead>
<tbody>
<tr>
<td>J/ψ</td>
<td>3.097</td>
<td>0.6</td>
<td>$10 \times 10^9$</td>
<td>$60 \times 10^6$ (BESII)</td>
</tr>
<tr>
<td>τ</td>
<td>3.67(?)</td>
<td>1.0</td>
<td>$12 \times 10^6$</td>
<td>--</td>
</tr>
<tr>
<td>ψ’</td>
<td>3.686</td>
<td>1.0</td>
<td>$3 \times 10^9$</td>
<td>$27 \times 10^6$ (CLEOc)</td>
</tr>
<tr>
<td>D</td>
<td>3.77</td>
<td>1.0</td>
<td>$3 \times 10^6$</td>
<td>$5 \times 10^6$ (CLEOc)</td>
</tr>
<tr>
<td>Ds</td>
<td>4.03</td>
<td>0.6</td>
<td>$1 \times 10^6$</td>
<td>$4 \times 10^3$ (BESI)</td>
</tr>
<tr>
<td>Ds</td>
<td>4.17</td>
<td>0.6</td>
<td>$3 \times 10^6$</td>
<td>$0.3 \times 10^6$ (CLEOc)</td>
</tr>
<tr>
<td>R scan</td>
<td>3.0-4.6</td>
<td>0.6(?)-1.0</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>
• LQCD predicts the lowest glueball state is $0^{++}$. The mass is around 1.5 GeV – 1.7 GeV.

• LQCD predicts the next lightest glueball is $2^{++}$. The mass is around 2.4 GeV.

• LQCD predicts the $0^{-+}$ glueball mass in the range of 2.3–2.6 GeV.

• The mix of glueball with ordinary $qq$ meson makes the situation more difficult.

Glueball candidates: $f_0(1500)$, $f_0(1700)$, $f_J(2220)$, …
Glueball search and study at BESIII

study $f_0(1370)$, $f_0(1500)$, $f_0(1710)$ and $f_0(1790)$ in

$$J / \psi \rightarrow \gamma + \{ \pi\pi, K\bar{K}, \eta\eta, \ldots \}$$

- study 1.4 GeV 0-+’s ($\eta_L$, $\eta_H$) in

$$J / \psi \rightarrow \gamma + \{ \rho\rho, \eta\pi\pi, K\bar{K}\pi, \ldots \}$$

- study high mass 0-+’s in

$$J / \psi \rightarrow \gamma + \{ \omega\omega, \rho\rho, \eta\pi\pi, K^*\bar{K}^*, \ldots \}$$

study $f_J(2220)$ in

$$J / \psi \rightarrow \gamma + \{ \pi\pi, K\bar{K}, p\bar{p}, \phi\phi, \omega\omega, \eta\eta, \eta\eta', \ldots \}$$
Example: \( X(1835) \) at BESIII (58\,M \,J/\psi)

\( \sigma \) at BESIII

2 years' data taking

\( \eta' \rightarrow \eta \pi^+ \pi^- \)

\( M(\eta'\pi\pi) \, \text{GeV/c}^2 \)

\( M(\eta'\pi\pi) \, \text{GeV/c}^2 \)

\( \text{bakfrac} = 96 \pm 13 \)

\( p0 = 7606007208 \pm 1871895000 \)

\( p1 = -2944656838 \pm 2173289029 \)

\( p2 = -1507468153 \pm 1470808968 \)

\( \text{sigfrac} = 162 \pm 16 \)

\( \text{width} = 0.0650 \pm 0.0091 \, \text{GeV} \)

\( x1835 = 1.8373 \pm 0.0038 \, \text{GeV} \)
Charmonium production and decay

Charmonium spectroscopy

\[ n^{2S+1}L_J \]
"$\rho \pi$ puzzle"

$\psi(3770)$ non-$D\bar{D}$ decay

**BESII**: $\sim 30$ pb$^{-1}$

**BESIII**: $\sim 60$ pb$^{-1}$

PQCD prediction

$\Gamma_{\psi(3770)}^{\text{tot}}$: $26.8 \pm 0.5$ MeV

$\Gamma_{\psi(3770)}^{\text{hadron}}$: $256 \pm 9$ eV

$B[\psi(3770) \rightarrow D\bar{D}]$: $(88.2 \pm 2.4 \pm 2.0)$ %

BES-III MC simulation
### Impact of Charm Physics - I

**Precision CKM**

| $|V_{us}|$ | $|V_{ub}|$ | $|V_{cd}|$ | $|V_{cs}|$ | $|V_{cb}|$ | $|V_{td}|$ | $|V_{ts}|$ | $|V_{tb}|$ |
|---------|---------|---------|---------|---------|---------|---------|---------|
| 0.97377 ± 0.00027 | 0.2257 ± 0.0021 | 0.00431 ± 0.00030 | 0.230 ± 0.011 | 0.957 ± 0.017 | 0.0416 ± 0.0006 | 0.0074 ± 0.0008 | >0.78 |

**BES accuracy**

- For leptonic $D$ decays
  
  \[
  \sigma(|V_{cd}|)/(|V_{cs}|) = 2.3\% \\
  \sigma(|V_{cs}|)/|V_{cs}| = 1.7\% \\
  \frac{\sigma(|V_{cd}|)/|V_{cd}|}{|V_{cd}|/|V_{cs}|} = 1.3\%
  \]

- For semileptonic $D$ decays ($D_s \to K$ and $D_s \to \phi$):
  
  \[
  \sigma(|V_{cd}|)/(|V_{cd}|) = 2.4\% \\
  \sigma(|V_{cs}|)/|V_{cs}| = 1.3\%
  \]

**BESIII** improves precision indirectly

\[|V_{td}/V_{ts}| = 0.208 \pm 0.007\]

- BESIII: < 2%
Impact of Charm Physics - II

- Search for New Physics in Charm Sector
  - Rare Charm Decays
    - FCNC decays only occur in loop diagrams in the SM:
  - Charm Mixing (Large CPV in mixing indicates New Physics)

\[ R_M < 1.5 \times 10^{-4} \ @ \ 90\% \ C.L. \]
for 20 fb\(^{-1}\) BESIII \(\psi(3770)\)

- CP Violation

\[ A_{CP} < 2.5 \times 10^{-2} \ @ \ 90\% \ C.L. \ for \ 4 \ fb^{-1} \]
BESIII collaboration

Totally 37 institutions now

USA (7)
Univ. of Hawaii
Univ. of Washington
Carnegie Mellon Univ.
Univ. of Florida
Univ. of Minnesota
Rensselaer Polytechnic Institute
Univ. of Rochester

Europe (5)
GSI,
Univ. of Bochum,
Univ. of Giessen
JINR, Dubna
BINP

China (24)
IHEP, CCAST, GUCAS,
Univ. of Sci. and Tech. of China
Shandong Univ., Zhejiang Univ.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ.,
Zhongshan Univ., Nankai Univ.
Shanxi Univ., Sichuan Univ
Hunan Univ., Liaoning Univ.
Nanjing Univ., Nanjing Normal Univ.
Guangxi Normal Univ., Guangxi Univ.
Hong Kong Univ.
Chinese Univ. of Hong Kong

Japan (1)
Tokyo Univ.

"Spectators": four institutes from Italy
Summary

- The construction of BEPCII/BESIII fully completed on schedule and within budget.
- Commissioning of machine and detector goes smoothly, Lumi. of $1.15 \times 10^{32}$ obtained. Detector works well, its performance satisfactory, and noise problem solved.
- Synchrotron radiation running started by end of 2006.
- More efforts on increasing Lumi. And reducing dark current of MDC.
- 10M $\psi^\prime$ events collected. Calibration are under way.
- Physics data taking will be started soon.
- Expecting exciting physics results coming out.

Thank you!