Performance and Prospects of BEPCII

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Accelerator Center, IHEP
Outline

• Introduction on BEPCII
• Accelerator physics issues
• Hardware improvements
• Routine user operations
• Problems and prospects
• Summary
Beijing Electron Positron Collider (BEPC)
1. Introduction on BEPCII

BEPCII — An upgrade project of BEPC
— A double-ring factory-like machine
— Deliver beams to both HEP & SR
3-ring structure

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Design Goals of BEPCII

- **Collision**
  - Beam energy range: 1-2.1 GeV
  - Optimized beam energy: 1.89 GeV
  - Luminosity: \(1 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1} \ @ 1.89 \text{ GeV}\)
  - Full energy injection: 1-1.89 GeV

- **Synchrotron radiation**
  - Beam energy: 2.5 GeV
  - Beam current: 250 mA
  - Keep the existing beam lines unchanged

BEPCII: One-machine, Two-purpose (HEP, SR)

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## The Milestones

<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>
<tr>
<td>July 19, 2008</td>
<td>First hadron event observed</td>
</tr>
<tr>
<td>May 19, 2009</td>
<td>Luminosity reached $3.3 \times 10^{32} \text{cm}^{-2}\text{s}^{-1}$</td>
</tr>
</tbody>
</table>

### Peak Luminosity History

<table>
<thead>
<tr>
<th>Month</th>
<th>Luminosity ($\times 10^{32}\text{cm}^{-2}\text{s}^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2004</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>May 2005</td>
<td>5.00E+31</td>
</tr>
<tr>
<td>Sep. 2005</td>
<td>1.00E+32</td>
</tr>
<tr>
<td>Oct. 2005</td>
<td>1.50E+32</td>
</tr>
<tr>
<td>Nov. 2005</td>
<td>2.00E+32</td>
</tr>
<tr>
<td>Dec. 2005</td>
<td>2.50E+32</td>
</tr>
<tr>
<td>Jan. 2006</td>
<td>3.00E+32</td>
</tr>
<tr>
<td>Feb. 2006</td>
<td>3.50E+32</td>
</tr>
<tr>
<td>Mar. 2006</td>
<td>4.00E+32</td>
</tr>
<tr>
<td>Apr. 2006</td>
<td>4.50E+32</td>
</tr>
<tr>
<td>May 2006</td>
<td>5.00E+32</td>
</tr>
<tr>
<td>Jun. 2006</td>
<td>5.50E+32</td>
</tr>
<tr>
<td>Jul. 2006</td>
<td>6.00E+32</td>
</tr>
<tr>
<td>Aug. 2006</td>
<td>6.50E+32</td>
</tr>
<tr>
<td>Sep. 2006</td>
<td>7.00E+32</td>
</tr>
<tr>
<td>Oct. 2006</td>
<td>7.50E+32</td>
</tr>
<tr>
<td>Nov. 2006</td>
<td>8.00E+32</td>
</tr>
</tbody>
</table>

### Beam Current

<table>
<thead>
<tr>
<th>Month</th>
<th>Beam Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan. 2007</td>
<td>100</td>
</tr>
<tr>
<td>Feb. 2007</td>
<td>200</td>
</tr>
<tr>
<td>Mar. 2007</td>
<td>300</td>
</tr>
<tr>
<td>Apr. 2007</td>
<td>400</td>
</tr>
<tr>
<td>May 2007</td>
<td>500</td>
</tr>
<tr>
<td>Jun. 2007</td>
<td>600</td>
</tr>
<tr>
<td>Jul. 2007</td>
<td>700</td>
</tr>
<tr>
<td>Aug. 2007</td>
<td>800</td>
</tr>
<tr>
<td>Sep. 2007</td>
<td>900</td>
</tr>
<tr>
<td>Oct. 2007</td>
<td>1000</td>
</tr>
<tr>
<td>Nov. 2007</td>
<td>1100</td>
</tr>
<tr>
<td>Dec. 2007</td>
<td>1200</td>
</tr>
</tbody>
</table>

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**Note:** The data presented above is illustrative and should be considered for educational purposes only.
2. Accelerator Physics Issues

◆ Lattice of collision rings (BER & BPR)
  • Keep the scheme of quasi-FODO lattice in the arcs, same as that in BEPC;
  • Four Dx-free sections (IR, RF, Inj & NCP) connect four arcs;
  • Each quad is independently powered;
  • Lattice symmetry is broken thoroughly!
## Main parameters of BEPCII rings

<table>
<thead>
<tr>
<th>Parameters</th>
<th>BER/BPR</th>
<th>BSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam energy (GeV)</td>
<td>1.89</td>
<td>2.5</td>
</tr>
<tr>
<td>Circumference (m)</td>
<td>237.53</td>
<td>241.13</td>
</tr>
<tr>
<td>Beam current (A)</td>
<td>0.91</td>
<td>0.25</td>
</tr>
<tr>
<td>Bunch current (mA) / No.</td>
<td>9.8 / 93</td>
<td>~1 / 160 - 300</td>
</tr>
<tr>
<td>Natural bunch length (mm)</td>
<td>13.6</td>
<td>12.0</td>
</tr>
<tr>
<td>RF frequency (MHz)</td>
<td>499.8</td>
<td>499.8</td>
</tr>
<tr>
<td>Harmonic number</td>
<td>396</td>
<td>402</td>
</tr>
<tr>
<td>Emittance (x/y) (nm·rad)</td>
<td>144/2.2</td>
<td>140</td>
</tr>
<tr>
<td>β function at IP (x/y) (m)</td>
<td>1.0/0.015</td>
<td>10.0/10.0</td>
</tr>
<tr>
<td>Crossing angle (mrad)</td>
<td>±11</td>
<td>0</td>
</tr>
<tr>
<td>Tune (x/y/s)</td>
<td>6.54/5.59/0.034</td>
<td>7.28/5.18/0.036</td>
</tr>
<tr>
<td>Momentum compaction</td>
<td>0.024</td>
<td>0.016</td>
</tr>
<tr>
<td>Energy spread</td>
<td>5.16×10^{-4}</td>
<td>6.67×10^{-4}</td>
</tr>
<tr>
<td>Natural chromaticity (x/y)</td>
<td>-10.8/-20.8</td>
<td>-9.0/-8.9</td>
</tr>
<tr>
<td>Luminosity (cm^{-2}s^{-1})</td>
<td>1×10^{33}</td>
<td>—</td>
</tr>
</tbody>
</table>

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Institute of High Energy Physics
Beam optics correction

- **Method of Response Matrix Analysis**

\[
\begin{pmatrix}
\Delta x \\
\Delta y \\
\end{pmatrix}
= R_{\text{meas}}
\begin{pmatrix}
\Delta \theta_x \\
\Delta \theta_y \\
\end{pmatrix}
\]

\[
\chi^2 = \sum_{i,j} \left( \frac{R_{\text{mod},ij} - R_{\text{meas},ij}}{\sigma_i^2} \right)^2 \equiv \sum_{i,j} V_{ij}^2
\]

\[
\Delta V_{ij} = \sum \frac{\partial V_{ij}}{\partial K_q} \Delta K_q + \sum \frac{\partial V_{ij}}{\partial G_i} \Delta G_i + \sum \frac{\partial V_{ij}}{\partial \theta_j} \Delta \theta_j + \sum \frac{\partial V_{ij}}{\partial \delta_j} \Delta \delta_j + \ldots
\]

- **Fudge factors of quads:**

\[
K = K_0 \ast AF \\
\Delta AF = 1 - AF
\]

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HBPM# and VBPM#

Model - Measured Response Matrix

HCM# and VCM#

Error [mm]

σ = 0.006, BPM resolution = 0.01mm

(Courtesy D.H. Ji)

IPAC'2012
• Gain of correctors’ strength
BPMs’ gain

**BER BPM gain**

**BPR BPM gain**
Difficulties of optics correction in the IR

- Each SCQ has one power supply but shared by two rings.
- One 2-in-1 quads (Q1A) in each side of IP, share one power supply, respectively.
- Insufficient BPMs in the IR for RM measurement.
Beam energy variation

- Energy response due to the change of corrector strengths to the response matrix considered, finding the solution to satisfy both C.O.D. correction and beam energy variation:

\[
\frac{\Delta E}{E} = -\frac{1}{\alpha L_0} \sum_i D_x^i \Delta \theta_{cx}^i
\]

- Correct the energy difference between two rings, making the energy of two rings the same
- Calculated energy difference is the same as the result given by the energy measurement system
With these efforts, and the tool of code LOCO, Twiss functions of storage rings are very close to their setup.

<table>
<thead>
<tr>
<th>Tune</th>
<th>BPR</th>
<th>BER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hori.</td>
<td>6.509</td>
<td>6.510</td>
</tr>
<tr>
<td>Vert.</td>
<td>5.581</td>
<td>5.584</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>β_y @ IP</th>
<th>Theo.</th>
<th>After corrected</th>
</tr>
</thead>
<tbody>
<tr>
<td>BER W/E (cm)</td>
<td>1.5/1.5</td>
<td>1.54/1.51</td>
</tr>
<tr>
<td>BPR W/E (cm)</td>
<td>1.5/1.5</td>
<td>1.47/1.43</td>
</tr>
</tbody>
</table>
β-beating after optics correction

(Courtesy Y.Y. Wei)
Luminosity commissioning

~ 70 parameters to tune luminosity

- \( e^+ e^- \beta @ IP \)
- \( e^+ e^- \beta y^* \) waist
- \( e^+ e^- \eta @ IP \)
- \( e^+ e^- v_x v_y v_s \)
- \( e^+ e^- \) Global coupling
- \( e^+ e^- \) Tilt angle @ IP
- \( e^+ e^- \) Chromat.

Luminosity & Background

- \( e^+ e^- \) Parasitic collision
- \( e^+ e^- \) Nominal IP
- \( e^+ e^- \) V. offset

Coupled bunch instabilities

ECI

RF parameters
Low level

Injection system
Fill uniform

Stability control of Power supply

Fill pattern
Impedance Profile HOM
Environment temperature
Gain of transverse feedback system
Ways to tune Luminosity

Single bunch collision
Multi-bunch collision

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Big background of detector @ $\nu_x=0.51$

Optimize beam orbit, working point, coupling coefficient, collimator position, etc.
Source of the background

- Vacuum
- Touschek effect
- Dynamic effect (beta function, emittance) of beam-beam when $\nu_x \to 0.5$
- Vertical separation @ NCP
- Others

(Courtesy Y. Zhang)
Luminosity at different tune regions

Working point close to half integer caused ~ 30% increase of luminosity

(Courtesy Y. Zhang)
Local coupling correction

- **4×4 One turn map**

\[
T = \begin{pmatrix} M & m \\ n & N \end{pmatrix} = VUV^{-1}
\]

where,

\[
U = \begin{pmatrix} A & 0 \\ 0 & B \end{pmatrix}; V = \begin{pmatrix} \gamma I & C \\ -C^+ & \gamma I \end{pmatrix}; \gamma^2 + |C| = 1
\]

\[
A = \begin{pmatrix} \cos 2\pi \nu_A + \alpha_A \sin 2\pi \nu_A & \beta_A \sin 2\pi \nu_A \\ -\gamma_A \sin 2\pi \nu_A & \cos 2\pi \nu_A - \alpha_A \sin 2\pi \nu_A \end{pmatrix}
\]

\[
C^+ = \begin{pmatrix} C_{22} & -C_{12} \\ -C_{21} & C_{11} \end{pmatrix}
\]

- **One turn coupled transfer matrix:**

\[
T = G^{-1} \bar{V} \bar{U} \bar{V}^{-1} G
\]

\[
\bar{V} = GVG^{-1} = \begin{pmatrix} \gamma I & G_A CG_B^{-1} \\ -G_B C^+ G_A^{-1} & \gamma I \end{pmatrix}
\]

\[
\bar{U} = GUG^{-1} = \begin{pmatrix} R(2\pi \nu_A) & 0 \\ 0 & R(2\pi \nu_B) \end{pmatrix}
\]

For weak coupling, closed orbit response due to corrector kick can be

\[ \Delta x_{cod} = \frac{\theta_x}{2 \sin \pi \nu_x} \sqrt{\beta_{b,x} \beta_{c,x}} \cos(\Delta \phi_x - \pi \nu_x) \]

\[ \Delta y_{cod,1} = -\frac{\theta_x}{2 \sin \pi \nu_x} \sqrt{\beta_{c,x} \beta_{b,y}} \bar{C}_{b,22} \cos(\Delta \phi_x - \pi \nu_x) \]

\[ -\frac{\theta_x}{2 \sin \pi \nu_x} \sqrt{\beta_{c,x} \beta_{b,y}} \bar{C}_{b,12} \sin(\Delta \phi_x - \pi \nu_x) \]

\[ \Delta y_{cod,2} = +\frac{\theta_x}{2 \sin \pi \nu_y} \sqrt{\beta_{c,x} \beta_{b,y}} \bar{C}_{c,21} \cos(\Delta \phi_y - \pi \nu_y) \]

\[ +\frac{\theta_x}{2 \sin \pi \nu_y} \sqrt{\beta_{c,x} \beta_{b,y}} \bar{C}_{c,12} \sin(\Delta \phi_y - \pi \nu_y) \]

\[ \frac{\Delta y_{cod}}{\Delta x_{cod}} = \bar{C}_{b,22} \text{Cof}_1 + \bar{C}_{b,12} \text{Cof}_2 + \bar{C}_{c,11} \text{Cof}_3 + \bar{C}_{c,12} \text{Cof}_4 \]

Choose \( \bar{C}_{b,12} \) to do coupling correction

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• **BEPCII case:**
  - 4 skew quads in each ring, not enough to do global correction
  - 36 sextupoles in each ring, well distributed for coupling correction

• **Way to realize coupling correction:**

  Model $\xrightarrow{\text{simulate the response of } \tilde{C}_{b,12}}$ due to vertical corrector strength change
  $\xrightarrow{\text{get the strength of correctors from measured } \tilde{C}_{b,12}}$
Local coupling measurement and correction in e-ring with solenoid off (left) and on (right)
• Two knobs of coupling correction were done for luminosity optimization
  --- vertical local bump in sextupoles
  --- global vertical orbit tuning to minimize vertical emittance by reducing $C_{12}$ at BPMs
• Measurement of coupling was done by turn-by-turn BPM data

- Luminosity enhanced: $\nu_x \rightarrow 0.5 (0.506)$, reducing emittance coupling, and increasing beam current.
Beam instability issues

- Very important issue at the stage of design
- An impedance “police” was assigned during the construction
- Didn’t appear in the first phase of commissioning
- Show it’s power when beam current increased

<table>
<thead>
<tr>
<th>Component</th>
<th>Number of items</th>
<th>Inductance L (nH)</th>
<th>Loss factor $k_i$ (V/pC)</th>
<th>HOM power (kW) (9.8mA, 93)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRF</td>
<td>1</td>
<td>~0.69</td>
<td>0.11</td>
<td>4.74</td>
</tr>
<tr>
<td>Resist. wall</td>
<td></td>
<td></td>
<td></td>
<td>0.78</td>
</tr>
<tr>
<td>BPM</td>
<td>68</td>
<td>3.3</td>
<td>0.08</td>
<td>0.57</td>
</tr>
<tr>
<td>Bellows</td>
<td>67</td>
<td>0.48</td>
<td>0.02</td>
<td>0.14</td>
</tr>
<tr>
<td>RF seals</td>
<td>200</td>
<td>3.0</td>
<td>0.003</td>
<td>0.02</td>
</tr>
<tr>
<td>Mask</td>
<td>40</td>
<td>2.8</td>
<td>0.06</td>
<td>0.42</td>
</tr>
<tr>
<td>Pumping ports</td>
<td></td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taper</td>
<td>8</td>
<td>4.4</td>
<td>0.05</td>
<td>0.35</td>
</tr>
<tr>
<td>Injection kicker</td>
<td>2</td>
<td>0.8</td>
<td>0.04</td>
<td>0.28</td>
</tr>
<tr>
<td>Y-shape</td>
<td>2</td>
<td>2.2</td>
<td>0.19</td>
<td>1.34</td>
</tr>
<tr>
<td>X-cross</td>
<td>1</td>
<td>0.8</td>
<td>0.03</td>
<td>0.21</td>
</tr>
<tr>
<td>IR</td>
<td>1</td>
<td>0.8</td>
<td>0.01</td>
<td>0.07</td>
</tr>
<tr>
<td>Collimator</td>
<td>3</td>
<td>3.81</td>
<td>0.06</td>
<td>0.42</td>
</tr>
<tr>
<td>Feedback kicker</td>
<td>2</td>
<td>6.0</td>
<td>0.44</td>
<td>2.82</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>28.9</td>
<td>1.76</td>
<td>12.5</td>
</tr>
</tbody>
</table>
Single bunch instability – Bunch lengthening

- Bunch lengthening is more than 10% @ $I_b = 9.8\text{mA}$.
- Longitudinal low frequency impedance is $\sim 3$ times higher than design value.
- The way of reducing $\beta_y^*$ doesn’t look effective as it was expected.

(Courtesy Y. Li)
Beam-beam interaction

BEPC

\( e^- \rightarrow \text{IP} \rightarrow e^+ \)

BEPCII

\( e^- \rightarrow \text{IP} \rightarrow e^+ \)

22 mrad
Strong-strong simulation results in different tune region

(Courtesy Y. Zhang)
• Weak-strong model simulation study:

--- Hirata’s BBC as a pass method in AT
--- Element-by-element tracking in arc
--- Synchrotron oscillation (RF on)
--- Radiation damping and quantum excitation included

(Courtesy Y. Zhang)
Parasitic beam-beam interaction @ NCP

- At the north crossing point (NCP), two beams are separated vertically by ~5mm, with a full horizontal angle of $2 \times 155$ mrad.

At NCP, $\Delta y = 5\text{mm ($\sim$}4\sigma_x \text{ and } 50\sigma_y)$

$\beta_x / \beta_y = 12\text{m} / 8.5\text{m}$

$(\tan \theta \sigma_z) / \sigma_x = 1.8$
• Effect of non-linear arc + NCP separation
Furthermore, horizontal separation @ NCP also affect the beam-beam interaction.
What we did in last summer shutdown

- At the NCP region, the chambers of two rings were shifted by 15 cm, \( \frac{1}{4} \) of the space of two successive rf buckets, towards west of the NCP.
- New results of luminosity will be shown in the run 2011–12.

The BEMS @ NCP region was moved by 15 cm too
3. Hardware Improvements

- Linac energy promotion
  
  Max. $e^-$ beam energy = 2.5 GeV
  
  Max. $e^+$ beam energy = 2.1 GeV

  HEP experiment requires: 2.3 GeV * 2.3 GeV

  4 sets of power source are added (klys., mod., SLED, load, etc)

$\Delta E = 20 \times 1.5 \times (40)1/2 = 190\text{MeV}$

$190\text{MeV} / 12m = 16\text{ MV/m}$

$\Delta E = 14 \times 1.5 \times (40)1/2 \times 2 = 266\text{ MeV}$

$266\text{MeV} / 12m = 22\text{ MV/m}$

(Courtesy Y.L. Chi)
e+ energy: $190\text{MeV} \times 8 + 70\text{MeV} + 133\text{MeV} \times 2 \times 3 = 2.38\text{ GeV}$

e- energy: $190\text{MeV} \times 8 + 70\text{MeV} + 133\text{MeV} \times 2 \times 3 + 250\text{MeV} = 2.63\text{ GeV}$

Old power sources

New 4 sets of power source 8A, 9A, 11A, 13A

Will be finished at the end of 2012
• Longitudinal feedback system

Luminosity increased ~20%

Energy spread decreased

Cross section @J/ψ increased
2000nb of BEPC, 1999, to
2860nb of BEPCII, 2009, and
3100nb of BEPCII, 2012
4. Operation of BEPCII

- 5 – 6 months operation for HEP experiments @ different beam energy: $\psi(3770)$, $D_s$, $\psi'$, $\tau$, $J/\psi$, etc.
- 3 months for SR users, dedicated SR mode @ 2.5GeV

Data taking @ $\psi(3770)$

Peak luminosity: $6.5 \times 10^{32} \text{cm}^{-2} \text{s}^{-1}$ @ $719 \times 732 \text{mA} (e^+ \times e^-)$
• Data taking @ Ds, June 2011

Peak luminosity reached $6.5 \times 10^{32} \text{cm}^{-2}\text{s}^{-1}@711 \times 711 \text{mA}$
• Integrated luminosity in the run of 2010 – 2011

Int. Lum at $\psi(3770)$ in 2011

~150% improved

Int. Lum at $\psi(3770)$ in 2010

Int. Lum at Ds, 2011
J/ψ operation in April – May, 2012

Peak luminosity: $2.923 \times 10^{32} \text{cm}^{-2}\text{s}^{-1}$@ $448 \times 451 \text{mA}$, $\xi_y = 0.028$
Data accumulation for physics

- July 19, 2008: first $e^+e^-$ collision event in BESIII
- Nov. 2008: ~14M $\psi(2S)$ events for detector calibration
- 2009: 106M $\psi(2S)$ 4*CLEOc
  225M $J/\psi$ 4*BESII
- 2010: 900 pb$^{-1}$ $\psi(3770)$
- 2011: 1800 pb$^{-1}$ $\psi(3770)$ 3.5*CLEOc
  470 pb$^{-1}$ @ 4.01 GeV
- 2012: ~0.4 billion $\psi(2S)$
- 04/05 to 05/22, 2012: 1 billion $J/\psi$
Running as a 2nd generation synchrotron radiation facility
--- deliver beam to users for 3 months every year
--- 500 – 600 experiments done among 2000 applications

**Availability**

**MTBF**

**MDF**

**IPAC’2**
Two modes running for users:

Dedicated mode, \( E = 2.5 \text{ GeV} \), 15 beam lines on

Parasitic mode, 6 beam lines on when running for HEP

Regional distribution of user
Dedicated synchrotron radiation operation
5. Problems and prospects

- Hardware failures due to high beam current
Machine studies with more bunches

160 bunches, \(0 \sim 318/2\), 
708×708mA 658×684@3.546E32

124 bunches, \(0 \sim 369/3\), 
705×704mA, 517×537@2.955E32
### Luminosity calculations in different scenarios

<table>
<thead>
<tr>
<th>Case</th>
<th>Coupling</th>
<th>$\beta_y^*$ (cm)</th>
<th>$I_b$(mA)</th>
<th>$N_b$</th>
<th>$\Sigma I$(mA)</th>
<th>Luminosity ($\text{cm}^{-2}\text{s}^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>0.01</td>
<td>1.5</td>
<td>8.2</td>
<td>140</td>
<td>1150</td>
<td>$1.03 \times 10^{33}$</td>
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<tr>
<td>Case 2</td>
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<td>1.3</td>
<td>8.2</td>
<td>120</td>
<td>980</td>
<td>$1.02 \times 10^{33}$</td>
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<tr>
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<td>8.2</td>
<td>110</td>
<td>900</td>
<td>$1.01 \times 10^{33}$</td>
</tr>
<tr>
<td>Case 1’</td>
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<td>9.8</td>
<td>120</td>
<td>1150</td>
<td>$1.03 \times 10^{33}$</td>
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<td>100</td>
<td>1000</td>
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<td>900</td>
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<td>1.5</td>
<td>9.8</td>
<td>93</td>
<td>910</td>
<td>$1.0 \times 10^{33}$</td>
</tr>
</tbody>
</table>

**Higher beam current is the most important!**
Summary

- A lot of work, including AP and hardware improvements have been done from the beginning of the machine commissioning to the routine operation.
- Luminosity goes up with the optics optimization, instability cure, beam-beam study, and LFS.
- Integrated lum @ different energies to HEP, and beam to SR users with different mode during routine operations.
- Further luminosity enhancement is foreseen, by the means of increasing bunch current and bunch number, etc.
- Possibility of polarized e- beam is investigated for more physics results.

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Main parameters of BEPCII achieved in operation

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Design</th>
<th>Achieved</th>
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<td>BER</td>
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<td>BPR</td>
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<td>Energy (GeV)</td>
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<td>Beam current (mA)</td>
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<td>Bunch current (mA)</td>
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<tr>
<td>Bunch number</td>
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<td>80 – 88</td>
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<tr>
<td>RF voltage (MV)</td>
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<td>1.5 – 1.7</td>
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<tr>
<td>( \beta_y^* ) (cm)</td>
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<td>1.4 – 1.5</td>
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<td>Lifetime (hrs)</td>
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<td>~1.8@720mA</td>
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<td>Beam–beam parameter</td>
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<td>0.0327</td>
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<td>Lum. ( \times 10^{32} \text{cm}^{-2}\text{s}^{-1} )</td>
<td>10</td>
<td>6.492</td>
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</tbody>
</table>
BEPCII Luminosity Roadmap

$L (10^{33})$ vs. Year

- **2009**
  - $3.3 \times 10^{32} \text{cm}^{-2}\text{s}^{-1}$
  - $523 \times 529 \text{mA}$
- **2011**
  - $v_x = 0.51$ $eta_y^* = 1.2 \text{cm}$
  - $900 \text{mA} \times 900 \text{mA}$
  - $6.5 \times 10^{32} \text{cm}^{-2}\text{s}^{-1}$
  - $720 \times 730 \text{mA}$
- **2013?**
  - $v_x = 0.51$ $eta_y^* = 1.5 \text{cm}$
  - $1.2 \text{A} \times 1.2 \text{A}$
Peak Luminosity trends in last 40 years

Peak luminosity (cm$^{-2}$ s$^{-1}$)

Year


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Acknowledgement

• The commissioning and operation group of BEPCII.
• Great helps from KEK, SLAC, BNL, etc., in past several years.
Thanks for your attention!