BEPCII/BESIII and Physics Goals

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For BES Collaboration

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The Beijing Electron Positron Collider (BEPC)

$L \sim 5 \times 10^{30} \text{ /cm}^2 \cdot \text{s at } J/\psi$

$E_{\text{beam}} \sim 1 - 2.5 \text{ GeV}$
Running period: 1997 – 2004

- R scan at 95 energy points in 2–5 GeV region
- 58 million J/ψ data
- 14 million ψ(2S) data
- 33pb⁻¹ data at around 3.77GeV
- off peak data

VC: $\sigma_{xy} = 100$ µm  \hspace{1cm} TOF: $\sigma_T = 180$ ps
MDC: $\sigma_{xy} = 220$ µm  \hspace{1cm} BSC: $\Delta E/\sqrt{E} = 21$ %
\hspace{1cm} $\sigma_{dE/dx} = 8.5$ %  \hspace{1cm} $\sigma_\phi = 7.9$ mr
\hspace{1cm} $\Delta p/p = 1.78 \sqrt{1+p^2}$  \hspace{1cm} $\sigma_z = 2.3$ cm
$\mu$ counter: $\sigma_\rho = 3$ cm  \hspace{1cm} B field: $0.4$ T
$\sigma_z = 5.5$ cm
BEPCII: a high luminosity double–ring collider

Government approved, and stared construction from end of 2003
## BEPCII Design goal

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy range</strong></td>
<td>1 – 2.1 GeV</td>
</tr>
<tr>
<td><strong>Optimum energy</strong></td>
<td>1.89 GeV</td>
</tr>
<tr>
<td><strong>Luminosity</strong></td>
<td>$1 \times 10^{33}$ cm$^{-2}$s$^{-1}$ @ 1.89 GeV</td>
</tr>
</tbody>
</table>
| **Injection**            | Full energy injection: 1.55 – 1.89 GeV  
Positron injection speed > 50 mA/min |
| **Synchrotron mode**     | 250 mA @ 2.5 GeV         |

**Dual purpose machine**

*May achieve to Ebeam = 2.3 GeV*
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>BEPCII</th>
<th>BEPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation energy ($E$)</td>
<td>GeV</td>
<td>1.0−2.1</td>
<td>1.0−2.5</td>
</tr>
<tr>
<td>Injection energy ($E_{\text{inj}}$)</td>
<td>GeV</td>
<td>1.55−1.89</td>
<td>1.3</td>
</tr>
<tr>
<td>Circumference ($C$)</td>
<td>m</td>
<td>237.5</td>
<td>240.4</td>
</tr>
<tr>
<td>$\beta^<em>$-function at IP ($\beta_x^</em> / \beta_y^*$)</td>
<td>cm</td>
<td>100/1.5</td>
<td>120/5</td>
</tr>
<tr>
<td>Tunes ($\nu_x/\nu_y/\nu_z$)</td>
<td></td>
<td>6.57/7.61/0.034</td>
<td>5.8/6.7/0.02</td>
</tr>
<tr>
<td>Hor. natural emittance ($\varepsilon_{\text{dho}}$)</td>
<td>mm-mr</td>
<td>0.14 @1.89 GeV</td>
<td>0.39 @1.89 GeV</td>
</tr>
<tr>
<td>Damping time ($\tau_x/\tau_y/\tau_e$)</td>
<td></td>
<td>25/25/12.5 @1.89 GeV</td>
<td>28/28/14@1.89 GeV</td>
</tr>
<tr>
<td>RF frequency ($f_{\text{rf}}$)</td>
<td>MHz</td>
<td>499.8</td>
<td>199.533</td>
</tr>
<tr>
<td>RF voltage per ring ($V_{\text{rf}}$)</td>
<td>MV</td>
<td>1.5</td>
<td>0.6−1.6</td>
</tr>
<tr>
<td>Number of bunches ($N_b$)</td>
<td></td>
<td>93</td>
<td>2×1</td>
</tr>
<tr>
<td>Bunch spacing</td>
<td>m</td>
<td>2.4</td>
<td>240.4</td>
</tr>
<tr>
<td>Beam current</td>
<td>Colliding SR</td>
<td>mA</td>
<td>910 @1.89 GeV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>250 @2.5GeV</td>
</tr>
<tr>
<td>Bunch length (cm) ($\sigma_l$)</td>
<td>cm</td>
<td>~1.5</td>
<td>~5</td>
</tr>
<tr>
<td>Impedance $</td>
<td>Z/n</td>
<td>_0$</td>
<td>$\Omega$</td>
</tr>
<tr>
<td>Crossing angle</td>
<td>mrad</td>
<td>±11</td>
<td>0</td>
</tr>
<tr>
<td>Vert. beam-beam param. ($\xi_y$)</td>
<td></td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Beam lifetime</td>
<td>hrs.</td>
<td>2.7</td>
<td>6−8</td>
</tr>
<tr>
<td>Luminosity@1.89 GeV</td>
<td></td>
<td>$10^{31}$ cm$^{-2}$s$^{-1}$</td>
<td>100</td>
</tr>
</tbody>
</table>
BEPCII Major Milestones

- In 2004, Completed
  - Upgrade of Linac;
  - Moved BES from beam line, and dismounted;
  - Improve infrastructure, including the power station.
- Resumed synchrotron run, till June, 05.
- July 05 – Sep. 06, 2005:
  - Removed everything from ring, tunnel improvement, water pipe and power outlets. finished.
  - Install the main ring components, from 2nd of March, 06.
- Sep. 06 – June. 07, ring commissioning, SCQ moved in later. Synchrotron run.
- Aug. 07, BESIII moved to the beam line.
- Sep. 07, Commissioning ring and detector together.
- Dec. 07, test run.
- Dec. 08, to achieve a lum. of $3 \times 10^{32} \text{cm}^{-2}\text{s}^{-1}$.
BEPCII Status

• BEPCII linac installation complete (new electron gun; new position source; new rf power (klystrons and modulators); and others.

  Most design specifications reached at 1st test run.
Status of Storage ring

- Major magnets; super-conducting RF cavities and super-conducting quadrupole magnets, beam pipes; kicker; beam instruments; control system; vacuum system as well as the cryogenics; most of the systems have been completed;
- Their installation is under way; ~14 magnet sets
- Testing ring in Sep. 2006, without SCQ first;
Magnet System

- Sextupole magnets
- Dipole correctors
Started the installation of magnet sets
Cavities delivered and being tested
Super-conducting Quadra-pole
BESIII Detector

- Muon Counter
- SC magnet
- TOF
- Be beam pipe
- Drift Chamber
- CsI(Tl) calorimeter
**Magnet:** 1 T Super conducting

**MDC:** small cell & He gas
\[ \sigma_{xy} = 130 \, \mu m \]
\[ \sigma_{p/p} = 0.5\% \, @1\, GeV \]
dE/dx = 6%

**TOF:**
\[ \sigma_T = 100 \, ps \] Barrel
110 ps Endcap

**EMCAL:** CsI crystal
\[ \Delta E/E = 2.5\% \, @1 \, GeV \]
\[ \sigma_z = 0.6 \, cm/\sqrt{E} \]

**Muon ID:** 9 layer RPC

**Data Acquisition:**
Event rate = 3 kHz
Thruput ~ 50 MB/s

**Trigger:** Tracks & Showers
Pipeline; Latency = 6.4 \mu s

The detector is hermetic for neutral and charged particle with excellent resolution, PID adequate, and large coverage.

**Two rings, 93 bunches:**
- Luminosity
  - \(10^{33} \, cm^{-2} s^{-1} \, @1.89\, GeV\)
  - \(6 \times 10^{32} \, cm^{-2} s^{-1} \, @1.55\, GeV\)
  - \(6 \times 10^{32} \, cm^{-2} s^{-1} \, @2.1\, GeV\)
MDC

Parameters

R inner: 63mm ; R outer: 810mm
Length (out.): 2582 mm
Inner cylinder: 1.2 mm Carbon fiber
Outer cylinder: 11.5 mm CF with 8 windows
Sense wire: 25 micron gold-plated tungsten (plus 3% Rhenium) -- 6796
Layers (Sense wire): 43

Field wire: 110 micron gold-plated Aluminum --- 21884
Gas: He + C3H8 (60/40)
Cell: inner chamber --- 6 mm
outer chamber --- 8.1 mm

Expected performance

\[ \sigma_x \sim 130 \ \mu m \]
\[ \frac{\sigma_p}{P} \sim 0.5 \% \text{ @}1\text{GeV/C} \]
\[ \frac{\sigma}{dE/dx} \sim 6 \% \]
MDC
Wire Stringing Completed
Beam test at KEK

Prototype tested in a 1T magnetic field at KEK 12GeV PS last year.

Results:

- spatial resolution better than 130 µm
- cell efficiency over 98%
- dE/dX resolution better than 5% (3 $\sigma$ $\pi$ /K separation exceeding 700MeV/c).
CsI(Tl) crystal calorimeter

- **Design goals:**
  - Energy: 2.5% @ 1GeV
  - Spatial: 0.6cm @ 1GeV

- **Crystals:**
  - Barrel: 5280 w: 21564 kg
  - Endcaps: 960 w: 4051 kg
  - Total: 6240 w: 25.6 T
CsI Calorimeter

Testing:
• Size
• Source tests ($^{137}$ Cs)
• LED tests
• PD tests
• Preamp tests
• Cosmic ray tests
• Beam tests (6 x 6 array):

Energy resolution (1 GeV)
$\sigma_E = 2.62\%$

Position resolution (1 GeV)
$\sigma_{x-y} = 6\ mm$

X position

ADC
Mechanical structure

A 1/60 prototype

Status:
• Assembly will start soon. Should be completed by end of year.
• By the end of the year, all FED boards should be tested and installed.
Crucial for particle ID

- **Barrel**
  - 50mm x 60mm x 2320 mm (inner layer).
  - BC408
  - 2 layers 88x2
- **Endcap**
  - 48 fan shaped pieces - each end.
  - BC404
- **PMT:** Hamamatsu R5942
TOF Performance

- Time resolution 1-layer (intrinsic):
  - Beam tests: < 90 ps
  - Simulation: < 90 ps

- Time resolution of two layers is 100ps to 110ps for kaon and pions.

- K/π separation: 2 σ separation up to 0.9 GeV/c.
Beam tests of TOF module

- **TOF module** includes: scintillator, PMTs, preamps, 18m cable, VME readout board of FEE.

Pion: $104 \pm 11$ ps

proton: $70 \pm 2$ ps

Electron: $94 \pm 3$ ps

Time resolution from beam test of prototype (including scintillator, PMT, preamp, electronics, cable).
Time difference of two TOF layers: no errors from reference time ($T_0$) or position.
Superconducting Magnet

Coil: single layer solenoid
Cooling mode: two phase helium force flow
Superconductor: Al stabilized NbTi/Cu
Winding: inner winding
Cold mass support: tension rod
Thermal shield: LN₂ shield, MLI
Flux return: barrel/end yoke, pole tip

<table>
<thead>
<tr>
<th>Cryostat</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Inner radius</td>
<td>1.375m</td>
</tr>
<tr>
<td>Outer radius</td>
<td>1.7m</td>
</tr>
<tr>
<td>Length</td>
<td>3.91m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coil</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean radius</td>
<td>1.482m</td>
</tr>
<tr>
<td>Length</td>
<td>3.52m</td>
</tr>
<tr>
<td>Cable dimension</td>
<td>3.7mm*20mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Electrical parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Central field</td>
<td>1.0T</td>
</tr>
<tr>
<td>Nominal current</td>
<td>3650A</td>
</tr>
<tr>
<td>Inductance</td>
<td>2H</td>
</tr>
<tr>
<td>Stored energy</td>
<td>10MJ</td>
</tr>
<tr>
<td>Cold mass</td>
<td>3.6ton</td>
</tr>
<tr>
<td>Total Weight</td>
<td>15ton</td>
</tr>
<tr>
<td>Radiation thickness</td>
<td>2X₀</td>
</tr>
</tbody>
</table>
Value box tested successfully, will be assembled and plan to start cooling in June 06.
Computer controlled 3D mapping machine is under development.

Field measuring accuracy < 0.25%.

Measure ~90000 points with 0.5 mm position accuracy.

Status:
• Complete cooling test of the magnet before summer.
• Complete the field mapping together with SCQ before Dec. 31, 2006.
Muon Chamber

Barrel + EndCap;

RPC as $\mu$ detector;
Barrel : 9 layers
EndCap: 8 layers

One dimension read-out strips;
RPCs

- Extensive testing and long term reliability testing are being done.
(RPC module)

- Total of 64 endcap modules, 72 barrel modules;
- Gas: Ar:C2H2F4:Iso_Butane = 50:42:8
- HV voltage: 8000V;
- One module contains two RPC layers and one readout layer.
All RPC production, assembly, testing, and installation completed.
Test Result after installation - endcap

Average strip efficiency: 0.97
Spatial resolution: 16.6mm

Mean of 64 endcap
RPC = 0.95
μ / π Identification

From Simulation

Using Muc Info only

Design Goal

Ratio of π decay to μ before entering Muc

μ efficiency

fake rate

GeV/c

%
Trigger and DAQ

- The trigger design is almost finalized; uses FPGA.
- By the end of the year, all the boards should be tested and installed.
- The whole DAQ system tested to 8K Hz for the event size of 12Kb, a factor of two safety margin.
- The whole DAQ system tested during beam test with MDC and EMC

- L1 trigger rate: 4 KHz
- Event Size: 12 KBytes
- Bandwidth after L1: 48 MByte/sec
- Dead time: < 5%

1000 * BESII DAQ system
Offline software

BOSS - BES Offline Software System based on Gaudi.

BES III Software

- Framework Core Software
- Calibration & Database
- Reconstruction
- Physics Analysis Software

Tremendous amount accomplished so far. Much more to do.
Event Display Tool: BesVis

- Based on ROOT, OpenGL, X3D and XML
- Support both 2D and 3D view
- Operations and controls available through menu and toolbar items
- First version was released in December 2005.
**SIMULATION – Based on Geant4**

**MDC tracking performance:**

<table>
<thead>
<tr>
<th>Sub-detector</th>
<th>Design</th>
<th>MC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MDC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma_w$ ($\mu m$)</td>
<td>130</td>
<td>110</td>
</tr>
<tr>
<td>$\sigma_p/p$</td>
<td>0.5%</td>
<td>0.4%</td>
</tr>
<tr>
<td>$\sigma_{dE/dx}$</td>
<td>6-7%</td>
<td>6%</td>
</tr>
<tr>
<td><strong>TOF</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma_t$ (ps)</td>
<td>90</td>
<td>85</td>
</tr>
<tr>
<td><strong>EMC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma_{E/E}$</td>
<td>2.5%</td>
<td>2.2%</td>
</tr>
<tr>
<td>$\sigma_{xy}$ (mm)</td>
<td>6</td>
<td>4.8</td>
</tr>
<tr>
<td><strong>MUC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\varepsilon$ ($\mu_{ID}$)</td>
<td>95%</td>
<td>96%</td>
</tr>
<tr>
<td>$\varepsilon$ ($\pi \rightarrow \mu$)</td>
<td>6%</td>
<td></td>
</tr>
</tbody>
</table>

**EMC (barrel) Energy Resolution -single $\gamma$**

- $\mu$ - at $p_t = 1$ GeV/c
- Momentum resolution
- $\sigma = 0.4$ MeV

\[
\mu - at \ p_t = 1 GeV/c \\
\text{Momentum resolution} \\
\sigma = 0.4 \text{ MeV}
\]
BESIII and CLEOc comparison

<table>
<thead>
<tr>
<th>Detector</th>
<th>BES III</th>
<th>CLEOc</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDC</td>
<td>$\sigma_{xy} = 130 , \mu m$</td>
<td>$90 , \mu m$</td>
</tr>
<tr>
<td></td>
<td>$\Delta P/P (0/\circ) = 0.5 % (1 , GeV)$</td>
<td>$0.5 %$</td>
</tr>
<tr>
<td></td>
<td>$\sigma_{dE/dx (0/\circ)} = 6 - 7 %$</td>
<td>$6%$</td>
</tr>
<tr>
<td>EMC</td>
<td>$\Delta E/\sqrt{E (0/\circ)} = 2.5 % (1 , GeV)$</td>
<td>$2.2%$</td>
</tr>
<tr>
<td></td>
<td>$\sigma_z (cm) = 0.5 cm/\sqrt{E}$</td>
<td>$0.5 , cm/\sqrt{E}$</td>
</tr>
<tr>
<td>TOF</td>
<td>$\sigma_T (ps) = 100-110$/layer Double layer</td>
<td>Rich</td>
</tr>
<tr>
<td>$\mu$ counter</td>
<td>9 layers</td>
<td>----</td>
</tr>
<tr>
<td>magnet</td>
<td>$1.0 , T$</td>
<td>$1.0 , T$</td>
</tr>
</tbody>
</table>
### Yearly Event Production

Average Lum: $\mathcal{L} = 0.5 \times \text{Peak Lum.}$; data taking time: $T = \int_{0}^{\infty} dW' \sigma_{\text{r.c.}}(W')G(W', W)$

$$N_{\text{event/year}} = \sigma_{\text{exp}} \times \mathcal{L} \times T$$

<table>
<thead>
<tr>
<th>Resonance</th>
<th>Energy (GeV)</th>
<th>Peak Lum. ($10^{33} \text{cm}^{-2} \text{s}^{-1}$)</th>
<th>Physics Cross Section (nb)</th>
<th>Nevents/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>$J/\psi$</td>
<td>3.097</td>
<td>0.6</td>
<td>3400</td>
<td>$10 \times 10^9$</td>
</tr>
<tr>
<td>$\tau$</td>
<td>3.670</td>
<td>1.0</td>
<td>2.4</td>
<td>$12 \times 10^6$</td>
</tr>
<tr>
<td>$\psi(2S)$</td>
<td>3.686</td>
<td>1.0</td>
<td>640</td>
<td>$3.2 \times 10^9$</td>
</tr>
<tr>
<td>$D^0D^0\bar{\text{D}}$</td>
<td>3.770</td>
<td>1.0</td>
<td>3.6</td>
<td>$18 \times 10^6$</td>
</tr>
<tr>
<td>$D^+D^-$</td>
<td>3.770</td>
<td>1.0</td>
<td>2.8</td>
<td>$14 \times 10^6$</td>
</tr>
<tr>
<td>$DsDs$</td>
<td>4.030</td>
<td>0.6</td>
<td>0.32</td>
<td>$1.0 \times 10^6$</td>
</tr>
<tr>
<td>$DsDs$</td>
<td>4.140</td>
<td>0.6</td>
<td>0.67</td>
<td>$2.0 \times 10^6$</td>
</tr>
</tbody>
</table>

**Huge $J/\psi$ and $\psi(2S)$ samples at BESIII**

Below are a few examples of physics reach
Physics Simulations

50,000 $\psi^-$ Inclusive event sample.

We can learn a lot from CLEOc experience

$K_S \rightarrow \pi^+ \pi^-$

~3MeV

$\Lambda \rightarrow p\pi$

~1.2MeV
50,000 $\psi^-$ Inclusive event sample.

$D^0 \to K^-\pi^+$

$\sigma(m_{BC}) \sim 1.2$ MeV/$c^2$

$\sigma(\Delta E) = 7$ MeV

$D^0 \to K^-\pi^+\pi^+\pi^-$

$D^0 \to K^-\pi^+\pi^0$

$D^0 \to K_S\pi^+\pi^-$
**BESIII: (8M, M.C.)**

\( m(\chi_{c1}) = 3.508 \text{GeV}, \)
\( m(\chi_{c2}) = 3.553 \text{GeV}; \)
\( \sigma(\chi_{c1}) = 8.1 \text{MeV}, \)
\( \sigma(\chi_{c2}) = 9.4 \text{MeV}. \)

\[\Psi' \rightarrow \gamma \chi_{cJ}, \ \chi_{cJ} \rightarrow \gamma J/\psi\]

\( \chi_{c1} \)
\( \chi_{c2} \)

\( m(\eta) = 549 \text{ MeV} \)
\( m(\pi^0) = 135 \text{ MeV} \)

\( \pi^0 \)
\( \eta \)

\( m(\chi_{c-}) = 3.413 \text{GeV}, \)
\( \sigma(\chi_{c0}) = 9.0 \text{MeV}. \)
$\Psi' \rightarrow \gamma \chi_{cJ}, \chi_{cJ} \rightarrow \text{multi-tracks}$

$\Psi' \rightarrow \gamma \chi_{cJ}, \chi_{cJ} \rightarrow \pi \pi \pi \pi$

$\chi_{c0}, \chi_{c1}, \chi_{c2}$

$\chi_{c1}, \chi_{c2}$

$\eta_c$

BESIII: (0.5 M, M.C.)

$\Psi' \rightarrow \gamma \chi_{cJ}, \chi_{cJ} \rightarrow \pi \pi K K$

$\chi_{c0}, \chi_{c1}, \chi_{c2}$

$\Psi' \rightarrow \gamma \chi_{cJ}, \chi_{cJ} \rightarrow (6\pi)$

$\chi_{c0}, \chi_{c1}, \chi_{c2}$

Inv. mass of chrg. trks. (GeV)
Physics Topics at BESIII

- Charmonium: $J/\psi$, $\psi(2S)$, $\eta_c(1S)$ in $J/\psi$ decay, $\chi_{c\{0,1,2\}}$, $\eta_c(2S)$ and $h_c(^1P_1)$ in $\psi(2S)$ decay, $\psi(1D)$ and so on
- Exotics: hybrids, glueballs and other exotics in $J/\psi$ and $\psi(2S)$ radiative decays;
- Baryons and excited baryons in $J/\psi$ and $\psi(2S)$ hadronic decays;
- Mesons and mixing of quark and gluon in $J/\psi$ and $\psi(2S)$ decays;
Open charm factory:

- Absolute BR measurements of D and Ds decays; 1-2%
- Rare D decay; D⁰-D⁰̅bar mixing; CP violation;
- \( f_{D^+}, f_{D_s} \), form factors in semi-leptonic D decays;
- precise measurement of CKM (V_{cd}, V_{cs});
- CP violation and strong phase in D Dalitz Decays;
- light spectroscopy in D⁰ and D⁺ Dalitz Decays.

- Electromagnetic form factors and QCD cross section;
- New Charmonium states above open charm threshold
- R values.; aim at < 3% error
- tau physics near the threshold.
BESIII Collaboration

Institute of High Energy Physics
University of Science and Technology
Peking University
Tsinghua University
Shangdong University
Nankai University
Central China Normal University
University of Anhui
University of Zhejiang
University of Zhengzhou
Nanjing Normal University
Nanjing University
Shanxi University
Sichuan University
Henan Normal University

University of Hawaii
University of Washington
University of Tokyo
Joint Institute of Nuclear Research, Dubna
GSI
University of Bochum
University of Giessen
Summary

• BEPCII linac installation complete.
• Elements for collider complete; installation begins.
• BESIII hardware and software progressing rapidly, although still much to do.
• Machine/detector Commissioning expected in 2007.
• Rich physics after CLEO-c.
• More Collaborators welcomed!
Thanks

谢谢