A High Intensity Electron-Positron Accelerator
— a possible extension of BEPCII

Jianbei Liu
University of Science and Technology of China

October 25, 2016
LAL, Paris
Beijing Electron Positron Collider

- 1989-2004: BEPC/BES(II)
  \[ L_{\text{peak}} = 1.0 \times 10^{31} \text{ cm}^{-2} \text{s}^{-1} \]

- 2004-2008: BEPCII/BESIII upgrade, \( E_{\text{cm}} = 2-4.6 \text{GeV} \)

- 2008: BEPCII/BESIII commissioning

- 2009-now: BEPCII/BESIII physics running
  \[ L_{\text{peak}} = 1 \times 10^{33} \text{ cm}^{-2} \text{s}^{-1} \]
BEPCII

- A major upgrade of BEPC, $L_{\text{peak}} = 1 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$, a high-luminosity collider in the $\tau$-c energy regime.
  - double-ring, large crossing-angle, superconducting RF ...

**Beam energy:** 1.0 - 2.3 GeV
**Luminosity:** $1 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$ @ 3770
**Optimum energy:** 1.89 GeV
**Energy spread:** $5.16 \times 10^{-4}$
**No. of bunches:** 93
### Milestones of BEPCII

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan. 2004</td>
<td>Construction started</td>
</tr>
<tr>
<td>May 4, 2004</td>
<td>Dismount of 8 linac sections</td>
</tr>
<tr>
<td>Dec. 1, 2004</td>
<td>Linac delivered e⁻ beams to 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>Aug. 3, 2007</td>
<td>Shutdown for IR-SCQ installation</td>
</tr>
<tr>
<td>Mar. 28, 2008</td>
<td>Shutdown for BESIII installation</td>
</tr>
<tr>
<td>July 19, 2008</td>
<td>First hadron event observed</td>
</tr>
<tr>
<td>May 19, 2009</td>
<td>Luminosity reached $3.3 \times 10^{32}$ cm$^{-2}$ s$^{-1}$</td>
</tr>
<tr>
<td>July 17, 2009</td>
<td>Pass the National test &amp; check</td>
</tr>
<tr>
<td>April 8, 2011</td>
<td>Luminosity reached $6.5 \times 10^{32}$ cm$^{-2}$ s$^{-1}$</td>
</tr>
<tr>
<td>April 2013</td>
<td>Zc(3900) found &amp; confirmed</td>
</tr>
<tr>
<td>Nov. 20, 2014</td>
<td>Luminosity reached $8.53 \times 10^{32}$ cm$^{-2}$ s$^{-1}$</td>
</tr>
<tr>
<td>April 5, 2016</td>
<td>Luminosity reached $10.0 \times 10^{32}$ cm$^{-2}$ s$^{-1}$</td>
</tr>
<tr>
<td>April 5, 2016</td>
<td>Luminosity reached $10.0 \times 10^{32}$ cm$^{-2}$ s$^{-1}$</td>
</tr>
<tr>
<td>July 17, 2009</td>
<td>Pass the National test &amp; check</td>
</tr>
<tr>
<td>April 8, 2011</td>
<td>Luminosity reached $6.5 \times 10^{32}$ cm$^{-2}$ s$^{-1}$</td>
</tr>
<tr>
<td>April 5, 2016</td>
<td>Luminosity reached $10.0 \times 10^{32}$ cm$^{-2}$ s$^{-1}$</td>
</tr>
<tr>
<td>May 2009</td>
<td>Top-up</td>
</tr>
<tr>
<td>Nov. 2015</td>
<td>Luminosity reached $10.0 \times 10^{32}$ cm$^{-2}$ s$^{-1}$</td>
</tr>
<tr>
<td>May 2010</td>
<td>Luminosity reached $10.0 \times 10^{32}$ cm$^{-2}$ s$^{-1}$</td>
</tr>
</tbody>
</table>

**Luminosity History: Top-up**

<table>
<thead>
<tr>
<th>Date</th>
<th>Luminosity (10^32 cm⁻² s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2010</td>
<td>~500 pb⁻¹ @ 4.26, 4.36</td>
</tr>
<tr>
<td>Nov. 2015</td>
<td>2.00E+32</td>
</tr>
<tr>
<td>2012 – 13</td>
<td>2.50E+32</td>
</tr>
<tr>
<td>2014</td>
<td>3.00E+32</td>
</tr>
</tbody>
</table>
BESIII Detector

- A high-performance detector operating in the $\tau$-c energy regime

**Drift chamber (MDC)**
- Small cell, 43 layer
- Gas He/C$_3$H$_8$=40/60
- $\sigma_{xy}=115 \, \mu$m, $dE/dx\sim 5\%$
- $\sigma_p/p = 0.5\% @ 1 \, \text{GeV}$

**Time-of-flight (TOF)**
- Plastic scintillator/MRPC
- $\sigma_T(\text{barrel}): 68 \, \text{ps}$
- $\sigma_T(\text{endcap}): 60 \, \text{ps}$

**ECAL calorimeter**
- CsI(Tl): $L=28 \, \text{cm (15X}_0)$
- Energy range: 0.02-2GeV
- $\sigma_E/\sqrt{E} = 2.5\% @ 1\, \text{GeV}$
- $\sigma_I = 0.5-0.7 \, \text{cm}/\sqrt{E}$

**Muon counter**
- Resistive plate chamber
- Barrel: 9 layers
- Endcaps: 8 layers
- $\sigma_{\text{spatial}}: 1.4-1.7 \, \text{cm}$

**5.1 m**

**5.6 m**

**1T super-conducting magnet**

**RO channels:** $10^4$
- Event rate: 4 kHz
- Data size: 50 MB/s

**Grid computing**
- CPU: 3200 core
- Storage: 2.2 pB
BESIII Collaboration

~ 450 members from 57 institutions in 13 countries
Collision Data from BEPCII/BESIII

- The world’s largest data samples of $J/\psi$, $\psi(2s)$, $\psi(3770)$, $Y(4260)$ produced in $e^+e^-$ collisions, allowing to deeply explore physics in the $\tau$-c energy regime.
Fruitful Physics Results

Best Precision of tau mass in single experiment

\[ m_\tau = 1776.91 \pm 0.12 \text{ MeV}/c^2 \]

\[ R_{\text{Data/MC}} = 1.05 \pm 0.04, \quad \sigma_p = 0.9 - 1.2 \text{ ph.} \]

Most precise measurement for D leptonic decay

\[ \eta(1405) \rightarrow f_0(980)\pi^0 \]

First absolute measurement of \( \Lambda_c \) semi-leptonic decay

\[ B(\Lambda_c^+ \rightarrow \Lambda e^+\nu_e) = (2.1 \pm 0.6)\% \]

\(~130\) publications up to now, with many significant results

A very successful experiment
Significant Impact

Important role in $\tau$-charm physics
BESIII Upgrade

- **Drift chamber**: Malter effect occurred in the inner chamber in 2012. Cured by addition of water. Inner chamber needs to be replaced. Two options:
  - A new inner drift chamber, which has been built by IHEP, largely identical to the existing one.
  - A cylindrical GEM chamber, which is being built by an Italian group in collaboration with other groups.

- **ETOF**: time resolution compromised by multiple hits on a single scintillator unit. Scintillator-based ETOF has been upgraded with MRPC to mitigate the effect.
  - Pad-readout MRPC

- Other possible upgrade is under discussion
  - Barrel PID ...
Inner Tracker Upgrade

Cylindrical GEM chamber

New inner drift chamber
ETOF upgrade

• A joint project by USTC & IHEP
• All MRPC modules installed. The new ETOF system commissioned and in physics running already.
BEPCII Upgrade

• To increase beam energy (beyond 2.3 GeV)
• Three scenarios under discussion
  – 2.35 GeV: cooling, magnet power supply
  – 2.45 GeV: new ISPB magnets
  – >2.45 GeV: no actual scheme yet
Post-BEPCII

• BEPC made China’s mark in high energy physics on the world stage. BEPCII, as a successor, went on to establish China’s strong position in \( \tau \)-c physics.
  – The two projects have been a big success together, with many world-class achievements made.

• To fully explore the \( \tau \)-c physics, a high intensity electron-positron accelerator (HIEPA, \( L \sim 100 \times \text{BEPCII}, E_{cm} = 2-7 \text{GeV} \)) is considered necessary.

• It would be also a natural extension of BEPCII as a possible option for a post-BEPCII HEP project in China.
**High Intensity Electron Positron Accelerator**

- **HIEPA**: a possible option for a post-BEPCII HEP project in China.
  - To be an ultimate $\tau$-c machine, and moreover, a multifunctional and multidisciplinary complex, far beyond BEPCII.

  - $E_{cm} = 2-7$ GeV, $L = 1 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ @ 4 GeV
  - Symmetrical collision
  - Double-ring, 600-1000m
  - Crab waist scheme
  - Single beam polarized
  - Synchrotron radiation
## HIEPA Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam energy (GeV)</td>
<td>2</td>
</tr>
<tr>
<td>Revolution frequency (MHz)</td>
<td>0.302</td>
</tr>
<tr>
<td>Circumference (m)</td>
<td>992.8</td>
</tr>
<tr>
<td>Harmonic number</td>
<td>1656</td>
</tr>
<tr>
<td>Coupling factor</td>
<td>0.005</td>
</tr>
<tr>
<td>$\beta_{x, y} @$ IP (mm)</td>
<td>1000, 1.0</td>
</tr>
<tr>
<td>Emittance (nm.rad)</td>
<td>10</td>
</tr>
<tr>
<td>Beam-beam parameter</td>
<td>0.06</td>
</tr>
<tr>
<td>Bunch length (mm)</td>
<td>10</td>
</tr>
<tr>
<td>Number of bunch</td>
<td>540</td>
</tr>
<tr>
<td>Momentum compaction</td>
<td>0.001</td>
</tr>
<tr>
<td>Bunch current (mA)</td>
<td>5.0</td>
</tr>
<tr>
<td>SR energy loss/turn (MeV)</td>
<td>0.716</td>
</tr>
<tr>
<td>Beam current (A)</td>
<td>2.7</td>
</tr>
<tr>
<td>Synchrotron tune</td>
<td>0.0128</td>
</tr>
<tr>
<td>SR power (MW)</td>
<td>1.93</td>
</tr>
<tr>
<td>RF voltage (MV)</td>
<td>2.0</td>
</tr>
<tr>
<td>Energy spread</td>
<td>8.12E-4</td>
</tr>
<tr>
<td>RF frequency (MHz)</td>
<td>500.06</td>
</tr>
<tr>
<td>Luminosity (cm$^{-2}$s$^{-1}$)</td>
<td>1.05E35</td>
</tr>
</tbody>
</table>

A super $\tau$-charm factory
HIEPA in Perspective

Peak Luminosity Trends ($e^+e^-$ collider)

- SPEAR
- DORIS
- PETRA
- LEP I
- LEP II
- TRISTAN
- DAΦNE
- PEP
- CERN
- KEKB
- BEPC-II
- SKEKB
- HIEPA

Luminosity

Year


10^{30} 10^{31} 10^{32} 10^{33} 10^{34} 10^{35} 10^{36}
R&D Required for HIEPA

- Physics design studies
- Injection technology
- Super-conducting magnets and RF cavities
- Beam polarization technology
- Insertion devices
- Vacuum technology
- High-resolution beam monitoring
- ......
Features of $\tau$-c Energy Region

- Rich in resonances: charmonia and charm mesons
- Threshold production: pair production of $\tau$, D, $D_s$ ...
- Transition between smooth line-shapes and resonances, perturbative and non-perturbative QCD
- Home to exotic hadron states: glue-balls, hybrids and multi-quark states
Rich Physics in $\tau$-c Energy Region

- Hadron form factors
- $Y(2175)$ resonance
- Multiquark states with s quark, Zs
- MLLA/LPHD and QCD sum rule predictions
- Light hadron spectroscopy
- Gluonic and exotic states
- Process of LFV and CPV
- Rare and forbidden decays
- Physics with $\tau$ leptons
- XYZ particles
- Physics with D mesons
- $f_D$ and $f_{D_s}$
- $D^0$-$\bar{D}^0$ mixing
- Charm baryons

$R = \frac{\sigma(e^+e^-\rightarrow \text{hadron})}{\sigma(e^+e^-\rightarrow \mu^+\mu^-)}$
Physics Program at HIEPA

- **Precision test of SM**
  - R Scan, Hadron form factor (nucleon, Λ, π), $\Delta \alpha_{\text{QED}}$, $a_u$
  - tau lepton decays, lepton universality test
  - CKM matrix, Decay constants ($f_D/f_{D_s}$), form factors
  - Neutral D mixing and strong phase

- **hadron physics**
  - meson, baryon, hyperon spectroscopy
  - threshold effects
  - Glueball: direct test of QCD at low energy
  - Multiquark, exotics, hybrids.....
  - Charmonium(-like) spectroscopy
  - Charmed baryon decays

- **New physics(tiny/forbidden in SM)**
  - Rare charmonium decays : LFV, LNV, BNV...
  - Rare charm decay : FCNC, LFV, LNV, invisible
  - Rare tau decay : FCNC, LFV, LNV
  - Rare light meson decay : $\eta/\eta'/\omega/\phi$

- **Exotic physics**
  - Light dark matter :
    - light Higgs boson($a_0$), U boson
  - New interactions

- **CP Violation**
  - Unexpected large CPV in tau or charm: tiny in SM
  - CP violation in baryon/hyperon/charm baryon
Highlights

• Precision measurements: hadron EM form factors, CKM, $f_D/f_{D_s}$, tau decays, R scan ...

• Search for new forms of hadrons (glueball, multi-quark, hybrid ...) and studies of their properties.

• Search for new physics (LFV, CPV, exotics ...) beyond the SM

• ......
Physics Potential of HIEPA

- Integrated luminosity for $\tau$-C region:
  - 0.4ab$^{-1}$ from Belle II till 2024
  - 1.0ab$^{-1}$ from HIEPA per year

Ecm~4.26 GeV for $\pi^+\pi^- J/\psi$

$\varepsilon_{\text{HIEPA}} = 46\%$, $\varepsilon_{\text{Belle}} = 10\%$
Charmonium(like) States

$Z_c(3900)$ significance

Belle with ISR, 967 fb$^{-1}$ from 10 years of running

BESIII, 0.525 fb$^{-1}$ from one month of running

10 years @BELLE ~ 1 month @BESIII < 1 day @HIEPA
CPV in $\tau$ decay

Use T-odd rotationally invariant products: e.g.

$$P_2^\tau \cdot (\vec{P}_{\pi^+} \times \vec{P}_{\pi^0})$$

in $\tau^+$ and $\tau^-$ decays to $\geq 2$ hadrons such as:

$\tau^{-} \rightarrow \pi^{-}\pi^{0}\nu_{\tau}/k^{-}\pi^{0}\nu_{\tau}$,  
$\tau^{-} \rightarrow \pi^{-}\pi^{+}\pi^{-}\nu_{\tau}/K^{-}\pi^{+}\pi^{-}\nu_{\tau}$,

polarized beam is needed

“Figure Of Merits”

merit = luminosity $\times \bar{w}_Z \times$ total cross section
$\propto$ luminosity $\times (w_1 + w_2)$
$\times \sqrt{1 - a^2a^2(1 + 2a)}$,

Y. S. Tsai, P.R.D51:3172,1995

BESIII @ 4.25 $(10^{33}\text{cm}^{-2}\text{s}^{-1})$  FoM=1
Super B @ $(10^{36}\text{cm}^{-2}\text{s}^{-1})$  FoM=65
HIEPA @ 4.25 $(10^{35}\text{cm}^{-2}\text{s}^{-1})$  FoM=100
LFV in $\tau$ decay

- **$\tau \rightarrow \mu \gamma$**
  - Current limit: $\sim 4 \times 10^{-8}$ (5 x $10^8$ $\tau$-pairs)
    - BABAR: 516 fb$^{-1}$, BELLE: 545 fb$^{-1}$
  - **Y(4S) @ Super B factory**
    - main background: $e^+ e^- \rightarrow \tau^+ \tau^- \gamma$
    - Expected limit: $3 \times 10^{-9}$ at 75 ab$^{-1}$ (7 x $10^{10}$ $\tau$-pairs)

**Background $e^+ e^- \rightarrow \tau^+ \tau^- \gamma$**
- $E_{cm} = 4.0$ GeV
- $E_{cm} = 10.6$ GeV

**Expected limit @ HIEPA**

<table>
<thead>
<tr>
<th>7 ab$^{-1}$ (2.5 x $10^{10}$ $\tau$ pairs)</th>
<th>$\sigma_E/E = 1.5%$</th>
<th>$\sigma_E/E = 2.5%$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal (Br=10$^{-9}$)</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>Muon background</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Pion background</td>
<td>83</td>
<td>271</td>
</tr>
<tr>
<td>Expected 90% CL upper limit</td>
<td>$1.1 \times 10^{-9}$</td>
<td>$3.0 \times 10^{-9}$</td>
</tr>
<tr>
<td>Expected 90% CL upper limit with stronger pion suppression ($\times 3$)</td>
<td>$3.3 \times 10^{-10}$</td>
<td>$5.1 \times 10^{-10}$</td>
</tr>
</tbody>
</table>
**Proton EM Form Factors**

Using two days data, proton FF can reach a precision of 1% at HIEPA

---

**Figure:**
- **Graph:** Shows data points with error bars for different values of $m_{p\bar{p}}$ in GeV/c², with two datasets: Babar 469fb⁻¹ data (stat) and BES3 energy scan 2-3 GeV proposal. The graph indicates 10-24% precision.
- **Legend:**
  - Babar 469fb⁻¹ data (stat)
  - BES3 energy scan 2-3 GeV proposal

**Table:**

<table>
<thead>
<tr>
<th>Nsig</th>
<th>$\delta R_{EM}/R_{EM}$</th>
<th>$\delta \sigma/\sigma$</th>
<th>Luminosity (pb⁻¹)</th>
<th>comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>$614 \pm 24$</td>
<td>24%</td>
<td>3.9%</td>
<td>2.631</td>
<td>BESIII test run</td>
</tr>
<tr>
<td>$3881 \pm 62$</td>
<td>9.5%</td>
<td>1.6%</td>
<td>16.630</td>
<td>BESIII expected</td>
</tr>
<tr>
<td>$156253 \pm 395$</td>
<td>1.5%</td>
<td>0.25%</td>
<td>669.533</td>
<td>HIEPAF reach 1 (1 day)</td>
</tr>
<tr>
<td>$389898 \pm 624$</td>
<td>0.96%</td>
<td>0.16%</td>
<td>1670.69</td>
<td>HIEPAF reach 2 (2 days)</td>
</tr>
</tbody>
</table>

**Equation:** $E_{cm} = 2.23$ GeV

**Graph:**
- **Title:** 1 day @ HIEPA
- **Data Points:**
  - $c_0 = 1.082 \pm 0.015$
  - $\text{frac2} = 156253 \pm 395$
Search for $Z_{cs}$

$Y(4660) \rightarrow J/\psi K^+K^-$

$\psi(4790) \rightarrow J/\psi K^+K^-$

search for excited $Z_c$ and $Z_{cs}$ @ $E_{cm} > 4.5$ GeV
Detector Requirements for HIEPA

• **Overall requirements**
  – Efficient and fast triggering
  – Efficient and precise reconstruction of exclusive final states
  – High rate capability and radiation tolerance around IP and forward

• **Vertexing (or inner tracking)**
  – Vertexing not very critical for HIEPA, more to combine with a central tracker for tracking, particularly low p tracking (down to \(~50\) MeV)

• **Central tracking**
  – Large acceptance, low mass, high efficiency (p down to \(~0.1\) GeV) and high resolution (p \(<\sim 1\)GeV)

• **PID**
  – \(\pi/K\) separation up to 2GeV, compact and low mass

• **e/\(\gamma\) measurement**
  – Good energy and position resolution in 0.02-2 GeV

• **\(\mu\) detection**
  – Low momentum threshold (p \(<\sim 0.4\)GeV)
  – High \(\mu\) efficiency and \(\pi\) suppression power
Conceptual Detector Layout

**PXD**
- ~0.15%X₀/layer
- $\sigma_{xy} \approx 50 \, \mu m$

**MDC**
- $\sigma_{xy} < 130 \, \mu m$
- $\sigma_p/\rho \approx 0.5\% @ 1 \, GeV$
- $dE/dx \approx 6\%$

**PID**
- $\pi/K$ (and $K/p$) 3-4$\sigma$ separation up to 2GeV/c

**EMC**
- Energy range: 0.02-2GeV
- At 1 GeV $\sigma_E (%)$
- Barrel: 2
- Endcap: 4

**MUD**
- Down to <~0.4GeV
- $\pi$ suppression >10
Inner & Outer Trackers

• Dominant factor in tracking: multiple scattering
• So driving force in design of tracking system: low mass.
• Special design is required for inner tracking to cope with the very high level of radiation close to IP. So an inner-outer separate design is optimal.
• Detector technology options
  – Inner tracker
    • Low mass silicon detectors: DEPFET, MAPS
    • MPGD: cylindrical GEM/MicroMegas
  – Outer tracker: a low mass drift chamber
**DEPFET**
- Two layers of PXD: 1.8 cm and 2.2 cm in radius, consisting of 8 and 12 modules for innermost layer and the second, respectively.
- Pixel size: 29*27 μm, high resistivity epitaxial, deep PWELL, reverse bias, global shutter (<10 μs), triggered or continuous readout, resolution < 5 μm, material budget < 0.3% X₀

**Cylindrical GEM**

**Cylindrical MicroMegas**
- 1152 “C” strips
  - Pitch from 0.67 to 0.33 mm
  - 221 mm radius
  - PCB thickness 100 μm
  - Drift thickness 250 μm
  - Drift Field 2.4kV on 3 mm gap

- 768 “Z” strips
  - 295 mm radius, 0.629 mm pitch
  - PCB thickness 200 μm
  - Drift thickness 250 μm
  - Drift Field 2.4kV on 3 mm gap
  - 0.27% of X₀

**MAPS (ALPIDE)**
- Pixel size: 29*27 μm, high resistivity epitaxial, deep PWELL, reverse bias, global shutter (<10 μs), triggered or continuous readout, resolution < 5 μm, material budget < 0.3% X₀
Outer Tracker: A Drift Chamber

- \( R_{\text{in}} = 15 \ \text{cm}, \ R_{\text{out}} = 85 \ \text{cm}, \ L = 2.4 \ \text{m} \)
- \( B = 1 \ \text{T} \)
- \( \text{He}/\text{C}_2\text{H}_6 (60/40) \)
- Cell size =1.0 cm (inner), 1.6 cm (outer)
- Sense wire: 20 um W
- Field wire: 110 um Al
- \# of layers = 44
- Layer configuration: 8A-6U-6V-6A-6U-6V-6A
- Carbon fiber for both inner and outer walls
- Expected spatial resolution: <130 \( \mu \text{m} \)
- Expected dE/dx resolution: <7%
Combination of inner and outer trackers

### MDC + Belle-II PXD

<table>
<thead>
<tr>
<th>Detector</th>
<th>radius (cm)</th>
<th>material (%$X_0$)</th>
<th>resolution (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDC Outer 9-48</td>
<td>23.5-82</td>
<td>0.0045 /layer</td>
<td>130</td>
</tr>
<tr>
<td>MDC Inner 1-8</td>
<td>15-22</td>
<td>0.0051 /layer</td>
<td>130</td>
</tr>
<tr>
<td>PXD 3rd layer</td>
<td>10</td>
<td>0.15</td>
<td>50</td>
</tr>
<tr>
<td>PXD 2 layers</td>
<td>3/6</td>
<td>0.15 /layer</td>
<td>50</td>
</tr>
<tr>
<td>Beam pipe</td>
<td>2</td>
<td>0.15</td>
<td>–</td>
</tr>
</tbody>
</table>

**Graphs:**

- **Momentum Resolution (%):**
  - BField = 1T
  - Graph shows the momentum resolution for different detectors.

- **Position Resolution (µm):**
  - BField = 1T
  - Graph shows the position resolution for different detectors.
• \( \pi/K \) separation up to 2GeV.
  – Cherenkov-based technology is favorable.
  – Very low p region covered by trackers through dE/dx

• Compact (<20cm) and low mass (<0.5\(X_0\))

• Detector options
  – RICH, DIRC-like
The $\pi/K$ separation requirement can be met with a RICH detector.
• Main performance requirements
  – High efficiency for low energy $\gamma$
  – Good energy resolution in low energy region
  – Position resolution
  – Fast response
  – Radiation hardened

• Technology option
  – Crystal + novel photon detector (e.g. SiPM)
## Crystal Options

<table>
<thead>
<tr>
<th>Crystal</th>
<th>CsI(Tl)</th>
<th>CsI</th>
<th>BSO</th>
<th>PbWO₄</th>
<th>LYSO(Ce)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (g/cm³)</td>
<td>4.51</td>
<td>4.51</td>
<td>6.8</td>
<td>8.3</td>
<td>7.40</td>
</tr>
<tr>
<td>Melting Point (°C)</td>
<td>621</td>
<td>621</td>
<td>1030</td>
<td>1123</td>
<td>2050</td>
</tr>
<tr>
<td>Radiation Length (cm)</td>
<td>1.86</td>
<td>1.86</td>
<td>1.15</td>
<td>0.89</td>
<td>1.14</td>
</tr>
<tr>
<td>Molière Radius (cm)</td>
<td>3.57</td>
<td>3.57</td>
<td>2.2</td>
<td>2.0</td>
<td>2.07</td>
</tr>
<tr>
<td>Interaction Len. (cm)</td>
<td>39.3</td>
<td>39.3</td>
<td>23.1</td>
<td>20.7</td>
<td>20.9</td>
</tr>
<tr>
<td>Hygroscopicity</td>
<td>Slight</td>
<td>Slight</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Peak Luminescence (nm)</td>
<td>550</td>
<td>310</td>
<td>480</td>
<td>425/420</td>
<td>420</td>
</tr>
<tr>
<td>Decay Time (ns)</td>
<td>1220</td>
<td>30</td>
<td>100</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Light Yield (%)</td>
<td>165</td>
<td>3.6</td>
<td>3.4</td>
<td>0.30</td>
<td>85</td>
</tr>
<tr>
<td>LY in 100 ns</td>
<td>13</td>
<td>4.6</td>
<td>2.9</td>
<td>0.37</td>
<td>78</td>
</tr>
<tr>
<td>LY in 30 ns</td>
<td>4</td>
<td>3.3</td>
<td>1.5</td>
<td>0.26</td>
<td>45</td>
</tr>
<tr>
<td>d(LY)/dT (%)</td>
<td>0.4</td>
<td>-1.4</td>
<td>-2.0</td>
<td>-2.5</td>
<td>-0.2</td>
</tr>
<tr>
<td>Radiation hardness (rad)</td>
<td>10³</td>
<td>10⁴⁻⁵</td>
<td>10⁶⁻⁷</td>
<td>10⁶⁻⁷</td>
<td>10⁸</td>
</tr>
<tr>
<td>Dose rate dependent</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Experiment</td>
<td>CLEO,BABAR, Belle, BES III</td>
<td>KTeV,E787 Belle2 1st, SuperB 2nd</td>
<td>Belle2 3rd</td>
<td>CMS, ALICE PANDA Belle2 2nd</td>
<td>SuperB 1st (Hybrid)</td>
</tr>
</tbody>
</table>

### Different options for barrel and endcaps
SiPM Technology

• SiPM: a novel and rapidly-developing photo-sensor technology
  – High gain, low equivalent noise, B-field resistant, good time resolution

• R&D ongoing at USTC
Muon Detector

- Idea to lower muon detection threshold: measuring time of flight at entrance to iron yoke, a timing muon detector.
- Can be realized with MRPC technology
  - Rate capability a concern in certain detector regions

Long-Strip MRPC Module
- Active area: 87 x 52 cm²
- Read out strip: 87 cm x 3.8 cm
- Gas gaps: 0.25 mm x 5

Performance:
- Efficiency: > 98%
- Time resolution: < 80 ps
- Spatial resolution: 0.6 cm
μ/π separation power

- Inner: 3 MRPC layers
  - for precise timing
- Outer: 8 RPC layers

- Below 400MeV, μ and π can be well separated
- Below 300MeV, μ can’t reach iron yoke
Summary

• BEPC(II)/BES(II)(III) have accomplished significant achievements in particle physics with world impact, and established China’s strong position in $\tau$-c physics in the world.

• Still very rich and yet unexplored physics in the $\tau$-c regime with lots of pressing fundamental questions to be addressed.

• HIEPA would be a natural and yet much enhanced extension of BEPCII to continue with the success of BEPC(II) to fully explore the physics in the $\tau$-c regime.
  
  – A possible option for a post-BEPCII HEP project in China
HEP Strategy Discussion in China

• The high energy physics association of China has organized 6 workshops dedicated to discussion on strategy for future development of China’s accelerator-based high energy physics in the past few years
  – Three options: CEPC, SZF, HIEPA
• Consensus reached in the latest strategy discussion
  – CEPC (incorporating SZF) is the first priority
  – Chinese HEP community should work together aiming to make CEPC eventually an international HEP project launched by China.
  – BEPCII/BESIII should be fully exploited (including upgrading the existing facilities in a proper way) in the process of achieving the above strategic goal.