Flavour Physics Prospects at BESIII

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11th December 2018
BABAR 25th Anniversary
Physics in the $\tau$-charm region in China

Long and successful history, with major contributions from SLAC:

- **1981** T. D. Lee and W. Panofsky suggest $e^+e^-$ collider in China
- **1982** $e^+e^-$ collider endorsed by Deng Xiaoping
- **1984** Approval, ground breaking (Deng Xiaoping wielding shovel)
- **1988** First collisions in BEPC
- **1991** US scientists join BES ($\approx 145$ authors)
- **2003** Approval of major upgrade: BEPCII and BESIII
- **2008** First hadron events recorded in BESIII
- **2018** BESIII: international collaboration with 450 authors, 228 papers
14 countries
61 institutions
∼ 450 members

The BESIII Collaboration 2018
Achievements: $\tau$

Most precise single measurement of $\tau$ mass, using 24 pb$^{-1}$ using threshold scan and beam energy measurement via Laser Compton backscattering

\[ m_\tau = (1776.91 \pm 0.12^{+0.10}_{-0.13}) \text{MeV}/c^2 \]

New scan data taken in 2018

BESIII, Phys. Rev. D 90, 012001 (2014)
Unique datasets collected so far for open charm

<table>
<thead>
<tr>
<th>$\sqrt{s}$ / GeV</th>
<th>$\mathcal{L}$ / fb$^{-1}$</th>
<th>Comment</th>
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<tbody>
<tr>
<td>3.77</td>
<td>2.93</td>
<td>$D\bar{D}$</td>
</tr>
<tr>
<td>4.08</td>
<td>0.48</td>
<td>$DD^*, \psi(4040)$</td>
</tr>
<tr>
<td>4.18</td>
<td>3.2</td>
<td>$D_sD_s^*$</td>
</tr>
<tr>
<td>4.6</td>
<td>0.56</td>
<td>$\Lambda_c^+\bar{\Lambda}_c^-$</td>
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Threshold production: double-tag method possible, giving access to absolute branching fractions, leptonic and semi-leptonic decays!

Tagged samples of $2.76 \times 10^6$ neutral $D$ and $1.57 \times 10^6$ charged $D$ in 3.77 GeV data sample

$106 \times 10^3 \Lambda_c^+\bar{\Lambda}_c^-$ pairs produced in 4.6 GeV data
$15 \times 10^3$ single-tag $\Lambda_c$ events
Leptonic and semileptonic $D$ decays

Clean way to measure $|V_{cd}|$, $|V_{cs}|$, hadronic decay constants $f_D$, and form factors

Example: $D^+ \rightarrow \mu^+ \nu$, measure $f_{D^+}$ using world average for $|V_{cd}|$

PRD 89, 051104(R) (2014)
Strong phase between $D^0$ and $\bar{D}^0$ decays

Needed for precision measurement of CKM UT angle $\gamma$ via $B \to D(\ast)K(\ast)$ decays

Current best measurement from CLEO-c. Limits systematic uncertainty on $\gamma$ to $2^\circ$, with current LHCb dataset

Strong phases from $2.93 \text{ fb}^{-1}$ at BESIII sufficient for LHCb Run II, but not precise enough beyond that (or for Belle II, eventually)

Joint LHCb-BESIII workshop in February 2018 to discuss synergies, needs …

LHCb-PUB-2016-025

$20 \text{ fb}^{-1}$ on $\psi(3770)$ would give $0.7^\circ$ systematics due to strong phases
Other open charm topics, in particular CPV in Charm

Data sample is small compared to charm samples at B factories, LHCb and (eventually) Belle II.

No Lorentz boost $\Rightarrow$ no decay time information, no time-dependent measurements.

On the other hand, inherently symmetric source of $D^0$ and $\bar{D}^0$ (no production asymmetry).

Rare decays, in particular with neutrals / neutrinos in final state.

Test lepton flavour universality.
Outlook: machine and detector upgrades

Planned and funded upgrades of BEPCII:

- Top-up injection: level off instantaneous luminosity gain $\approx 30\%$ in $\mathcal{L}_{\text{int}}$

- Energy upgrade:
  - currently, $E_{b}^{\text{max}} = 2.3\ \text{GeV}$ due to power supplies, cooling of magnets
  - upgrade I: $E_{b}^{\text{max}} = 2.35\ \text{GeV}$: done in summer shutdown 2018
  - upgrade II: $E_{b}^{\text{max}} = 2.45\ \text{GeV}$: requires rebuilt septum magnets (in progress)

  will give access to resonance around 4.66 GeV seen by Belle in $\Lambda_{c}^{+}\bar{\Lambda}_{c}^{-}$ and much larger $\Lambda_{c}^{+}$ sample

- Detector: replace inner part of drift chamber by Cylindrical GEM detector (Italy, IHEP, Germany, Sweden)
Outlook

Whitepaper with outline of physics programme for the next 5 ~ 10 years in preparation

Wish list for charm physics:

- 20 fb$^{-1}$ on $\psi(3770)$
- 6 fb$^{-1}$ at 4.18 GeV
- 5 fb$^{-1}$ at 4.64 GeV

Competition for beam time from XYZ programme, light hadron spectroscopy

Super-$\tau$-charm factory ($1 \times 10^{35}$ cm$^{-2}$s$^{-1}$)
Hefei, Novosibirsk?