Prospects for Future Tau and Charm Study

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(On behalf STCF Steering Committee)

Gordon Research Conference, Jun. 30-Jul. 05, 2019, HKUST
The asymptotic freedom of QCD in high energy region is precisely tested.

But need more experimental inputs in the low energy region.

τ Lepton and charmed quark provide excellent platform to study the QCD.
Broad Physics at $\tau$-c Energy Region

- Hadron form factors
- $Y(2175)$ resonance
- Multiquark states with $s$ quark, $Z$s
- 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 $\tau$ lepton

- XYZ particles
- Physics with D mesons
- $f_0$ and $f_{0s}$
- $D_0$-$D_0$ mixing
- Charm baryons

Unique features: Rich of resonance, Threshold characteristics, Quantum Correlation

Abundant physics

Opportunities at 5-7 GeV at STCF
Upgrade of BEPC (started 2004, first collisions July 2008)

- Beam energy: 1 GeV to 2.3 GeV
- Optimum energy: 1.69 GeV
- Single beam current: 0.91 A
- Crossing angle: $\pm 11$ mrad

Design luminosity: $1 \times 10^{33}$ cm$^{-2}$/s$^{-1}$

Achieved in 2016

Beam energy measurement:
- Laser Compton backscattering
- $\Delta E/E \approx 2 \times 10^{-5}$

(contributes $\approx 50$ keV to $m_\tau$ uncertainty)
BESIII Experiment

10 years data taking at BESIII
Data sets collected so far include
- $10 \times 10^9 J/\psi$ events
- $448 \times 10^6 \psi'$ events
- scan data between 2.0 and 3.08 GeV, and above 3.735 GeV
- large datasets for XYZ studies

Unique data sets for open charm:

<table>
<thead>
<tr>
<th>$\sqrt{s}$ / GeV</th>
<th>$L$ / fb$^{-1}$</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.77</td>
<td>2.93</td>
<td>$D\bar{D}$</td>
</tr>
<tr>
<td>4.008</td>
<td>0.48</td>
<td>$DD^*$, $\psi(4040)$, $D_s^+D_s^-$</td>
</tr>
<tr>
<td>4.18</td>
<td>3.2</td>
<td>$D_sD_s^*$</td>
</tr>
<tr>
<td>4.6</td>
<td>0.59</td>
<td>$\Lambda_c^+\bar{\Lambda}_c$</td>
</tr>
</tbody>
</table>

The BESIII Collaboration 2019
Fruitful BESIII Results

Most precise measurement for D leptonic decay $Z_c(3900)$

Abrupt structure $X(1835)$

Observe Spin polarization of $\Lambda$

Large Isospin Violation $\eta(1405) \rightarrow f_0(980)\pi^0$

Up to May, 2019: ~20 PhD / year

First $\Lambda c$ at BESIII

Precise measurement
Limitation for BEPCII/BESIII

- BEPCII/BESIII have run 10 years, and are playing a leading role in tau-charm physics area.
- Limited by length of storage ring, no space and potential for the upgrade.
- Physics study limited by the Statistics (luminosity), CME  ······
- Challenged by Belle II
- BEPCII/BESIII will end her mission in 5 - 8 years (?)

A Super τ-charm Facility is the nature extension and a viable option for a post-BEPCII HEP project in China
BEPCII vs STCF in China

BEPCII
- Peak luminosity $0.6 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$
  - at 3.773 GeV
- Energy range $E_{cm} = 2 - 4.6 \text{ GeV}$
- No Polarization

Designed STCF
- Peak luminosity $0.5 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$
  - at 4 GeV
- Energy range $E_{cm} = 2 - 7 \text{ GeV}$
- Potential to increase luminosity and realize beam polarization

$1 \text{ ab}^{-1}$ data is expected per years
Charmonium (Like) Spectroscopy

Excellent platform to explore the QCD
Fruitful results in past decade, a new territory to study exotic hadrons

Godfrey & Isgur, PRD 32, 189 (1985)

Tasks:
- Precisely measurement the transition
- Search for the missing states
- Understand the nature of unknown states
- Search for the new exotic states

X(3872)  Y(3940)  Z(3900)
X(3940)  Y(4008)  Z(4020)
X(4160)  Y(4260)  Z(4050)
X(4350)  Y(4360)  Z(4200)
Y(4660)  Z(4250)  Z(4430)
Charmonium (Like) states are prominently produced in $e^+e^-$ collision and B decays, thus are competed between $\tau$-charm factory and B factory.
Charmonium (Like) in e⁺e⁻ collision

- **B factory**: Total integrate effective luminosity between 4-5 GeV is 0.23 ab⁻¹ for 50 ab⁻¹ data.
- **BESIII**: 10 MeV/step, every point have 10 fb⁻¹/year, 5 time of Belle II for 50 ab⁻¹ data.
- **Belle II**: have much higher efficiency and low background than B Factory.
- No challenge from Belle II experiment in B decays.

BESIII at 4.26 GeV: PRL 110, 252001, 0.525 fb⁻¹ in one month running time.
Facilities for Charm Study

- **LHCb**: huge x-sec, boost, 9fb⁻¹ now (x40 current B factories)
- **B-factories** (Belle(-II), BaBar): more kinematic constrains, clean environment, ~100% trigger efficiency
- **τ-charm factory**: Low backgrounds and high efficiency, Quantum correlations and CP-tagging are unique

- **STCF**:
  - 4×10⁹ pairs of D±,0 and 10⁷~10⁸Ds pairs per year
    - 10¹⁰ charm from Belle II/year
  - Highlighted Physics programs
    - Precise measurement of (semi-)leptonic decay (f_D, f_{Ds}, CKM matrix…)
    - D⁰ – D̄⁰ mixing, CPV
    - Rear decay (FCNC, LFV, LNV…)
    - Excite charm meson states D_J, D_{sJ} (mass, width, J^{PC}, decay modes)
    - Charmed baryons (J^{PC}, Decay modes, absolute BF)
    - Light meson and hyperon spectroscopy studied in charmed hadron decays
### Features for Charm Study

<table>
<thead>
<tr>
<th>Feature</th>
<th>STCF</th>
<th>Belle(-II)</th>
<th>LHCb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production yields</td>
<td>**</td>
<td>*****</td>
<td>*****</td>
</tr>
<tr>
<td>Background level</td>
<td>*****</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Systematic error</td>
<td>*****</td>
<td>***</td>
<td>**</td>
</tr>
<tr>
<td>Completeness</td>
<td>*****</td>
<td>***</td>
<td>*</td>
</tr>
<tr>
<td>(Semi)-Leptonic mode</td>
<td>*****</td>
<td>***</td>
<td>*</td>
</tr>
<tr>
<td>Neutron/$K_L$ mode</td>
<td>*****</td>
<td>**</td>
<td>☆</td>
</tr>
<tr>
<td>Photon-involved</td>
<td>*****</td>
<td>****</td>
<td>☆</td>
</tr>
<tr>
<td>Absolute measurement</td>
<td>*****</td>
<td>***</td>
<td>☆</td>
</tr>
</tbody>
</table>

- Most are **precision** measurements, which are mostly dominant by the **systematic uncertainty**
- STCF has **overall advantages** in several studies
**Precision measurement of CKM elements**

CKM matrix elements are fundamental SM parameters that describe the mixing of quark fields due to weak interaction.

- A precise test of EW theory
- New physics beyond SM?

\[
\begin{pmatrix}
    d' \\
    s' \\
    b'
\end{pmatrix} =
\begin{pmatrix}
    V_{ud} & V_{us} & V_{ub} \\
    V_{cd} & V_{cs} & V_{cb} \\
    V_{td} & V_{ts} & V_{tb}
\end{pmatrix}
\begin{pmatrix}
    d \\
    s \\
    b
\end{pmatrix}
\]

Three generations of quark?  
Unitary matrix?

Expected precision < 2% at BESIII

A direct measurement of \( V_{cd(s)} \) is one of the most important task in charm physics
The (Semi-)Leptonic decay of $D_{(s)}$ can be described by:

**Purely Leptonic:**

$$\Gamma(D_{(s)}^+ \rightarrow \ell^+ \nu_\ell) = \frac{G_F^2 f_{D_{(s)}^+}^2}{8\pi} |V_{cd(s)}|^2 m_\ell m_{D_{(s)}^+}^2 \left(1 - \frac{m_\ell^2}{m_{D_{(s)}^+}^2}\right)^2$$

**Semi-Leptonic:**

$$\frac{d\Gamma}{dq^2} = \frac{G_F^2}{24\pi^3} |V_{cs(d)}|^2 \left| P_{K(\pi)}^3 \right| f_+^{K(\pi)}(q^2) |q^2|^2$$

**Directly measurement:**

- $|V_{cd(s)}| \times f_{D(s)}$ or $|V_{cd(s)}| \times FF$

- Input $f_{D(s)}$ or $f^{K(\pi)}(0)$ from LQCD $\Rightarrow |V_{cd(s)}|$

- Input $|V_{cd(s)}|$ from a global fit $\Rightarrow f_{D(s)}$ or $f^{K(\pi)}(0)$

- Validate LQCD calculation of Input $f_{B(s)}$ and provide constrain of CKM-unitarity
The best approach to measure $|V_{cd(s)}|$ from pure leptonic decays from BESIII

Semi-leptonic decay suffer large uncertainty of FF from LQCD calculation
D_{(s)} (Semi-)Leptonic decay

Green bands are LQCD results

- BESIII provide the best uncertainties
- LQCD are expected to be improved for semi-leptonic decays
Lepton Flavor universality

LFU is critical to test the SM and search for new physics beyond SM

Purely Leptonic: 

\[ |R_{D^+}^D| = \frac{\Gamma(D^+_s \rightarrow \tau^+ \nu_{\tau})}{\Gamma(D^+_s \rightarrow \mu^+ \nu_{\mu})} = \frac{m_{\tau^+}^2 \left(1 - \frac{m_{\tau^+}^2}{m_{D^+_s}^2}\right)}{m_{\mu^+}^2 \left(1 - \frac{m_{\mu^+}^2}{m_{D^+_s}^2}\right)} \]

Semi-Leptonic:

\[ R_{\mu/e} = \frac{\Gamma_{D \rightarrow h\mu\nu_{\mu}}}{\Gamma_{D \rightarrow he\nu_e}} \]

<table>
<thead>
<tr>
<th>[ R(D^+_{D^0}) ]</th>
<th>[ R(D^+_{D^0}) ]</th>
<th>[ R(K^-) ]</th>
<th>[ R(K^0) ]</th>
<th>[ R(\pi^-) ]</th>
<th>[ R(\pi^0) ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM</td>
<td>19.74(1)</td>
<td>2.66(1)</td>
<td>0.975(1)</td>
<td>0.975(1)</td>
<td>0.985(2)</td>
</tr>
<tr>
<td>BESIII</td>
<td>10.19(52)</td>
<td>3.21(64)</td>
<td>0.974(14)</td>
<td>1.013(29)</td>
<td>0.922(37)</td>
</tr>
</tbody>
</table>

BESIII preliminary 1\(\sigma\) difference 

BESIII publication \(\sim\)2\(\sigma\) difference

Large uncertainty from BESIII, dominant by statistically limited
**$D_{(s)}$ Leptonic decay**

<table>
<thead>
<tr>
<th>BESIII</th>
<th>STCF</th>
<th>Belle II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminosity</td>
<td>2.92 fb$^{-1}$ at 3.773 GeV</td>
<td>1 ab$^{-1}$ at 3.773 GeV</td>
</tr>
<tr>
<td>$\mathcal{B}(D^+ \rightarrow \mu^+\nu_\mu)$</td>
<td>5.1% stat. 1.6% syst.</td>
<td>0.28% stat.</td>
</tr>
<tr>
<td>$f_{D^+}$ (MeV)</td>
<td>2.6% stat. 0.9% syst.</td>
<td>0.15% stat.</td>
</tr>
<tr>
<td>$</td>
<td>V_{cd}</td>
<td>$</td>
</tr>
<tr>
<td>$\mathcal{B}(D^+ \rightarrow \tau^+\nu_\tau)$</td>
<td>20% stat. 10% syst.</td>
<td>0.41%</td>
</tr>
<tr>
<td>$\mathcal{B}(D^+ \rightarrow \tau^+\nu_\tau)$</td>
<td>21% stat. 10% syst.</td>
<td></td>
</tr>
</tbody>
</table>

| Luminosity | 3.2 fb$^{-1}$ at 4.178 GeV | 1 ab$^{-1}$ at $\Upsilon(nS)$ |
| $\mathcal{B}(D_{s}^+ \rightarrow \mu^+\nu_\mu)$ | 2.8% stat. 2.7% | 0.8% stat. 1.8% syst. |
| $f_{D_{s}^+}$ (MeV) | 1.5% stat. | | |
| $|V_{cs}|$ | 1.5% stat. | | |
| $f_{D_{s}^+} / f_{D^+}$ | | 0.21% stat. | |
| $\mathcal{B}(D_{s}^+ \rightarrow \tau^+\nu_\tau)$ | | 0.24% stat. | |
| $f_{D_{s}^+}$ (MeV) | | 0.11% stat. | |
| $|V_{cs}|$ | | 0.11% stat. | |

*Assume $f_{D(s)}$ with 0.2% uncertainty; + preliminary results; assume Belle II improved systematics by a factor 2

Stat. uncertainty is closed to theory precision

Theory : 0.2%(0.1% expected)
The cleanest way to extract $\gamma$ is from $B\to DK$ decays:

- Interference between tree-level decays; theoretically clean
- Current uncertainty $\sigma(\gamma) \sim 5^0$
- However, theoretical relative error $\sim 10^{-7}$ (very small!)

Information of $D$ decay strong phase is needed
- Best way is to employ quantum coherence of DD production at threshold
Determination of $\gamma/\phi_3$ angle

<table>
<thead>
<tr>
<th>Runs</th>
<th>Collected / Expected integrated luminosity</th>
<th>Year attained</th>
<th>$\gamma/\phi_3$ sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHCb Run-1 [7, 8 TeV]</td>
<td>3 fb$^{-1}$</td>
<td>2012</td>
<td>$8^\circ$</td>
</tr>
<tr>
<td>LHCb Run-2 [13 TeV]</td>
<td>5 fb$^{-1}$</td>
<td>2018</td>
<td>$4^\circ$</td>
</tr>
<tr>
<td>Belle II Run</td>
<td>50 ab$^{-1}$</td>
<td>2025</td>
<td>$1.5^\circ$</td>
</tr>
<tr>
<td>LHCb upgrade I [14 TeV]</td>
<td>50 fb$^{-1}$</td>
<td>2030</td>
<td>$&lt; 1^\circ$</td>
</tr>
<tr>
<td>LHCb upgrade II [14 TeV]</td>
<td>300 fb$^{-1}$</td>
<td>(&gt;2)035</td>
<td>$&lt; 0.4^\circ$</td>
</tr>
</tbody>
</table>

BESIII 20/fb: $\sigma(\gamma) \sim 0.4^\circ$

STCF is needed!

Three methods for exploiting interference (choice of $D^0$ decay modes):

- Gronau, London, Wyler (GLW): Use CP eigenstates of $D^{(*)0}$ decay,
  e.g. $D^0 \rightarrow K_s\pi^0$, $D^0 \rightarrow \pi^+\pi^-$

- Atwood, Dunietz, Soni (ADS): Use doubly Cabibbo-suppressed decays, e.g. $D^0 \rightarrow K^+\pi^-$
  - With 1 ab$^{-1}$ @ STCF: $\sigma(\cos\delta_{K\pi}) \sim 0.007$; $\sigma(\delta_{K\pi}) \sim 2^\circ \Rightarrow \sigma(\gamma) < 0.5^\circ$

- Giri, Grossman, Soffer, Zupan (GGSZ): Use Dalitz plot analysis of 3-body $D^0$ decays, e.g. $K_s\pi^+\pi^-$; high statistics; need precise Dalitz model
  - STCF reduces the contribution of $D$ Dalitz model to a level of $\sim 0.1^\circ$
$D^0$-$\overline{D}^0$ mixing and CPV

STCF provide a unique place for the study of $D^0$-$\overline{D}^0$ mixing and CPV by means of quantum coherence of $D^0$ and $\overline{D}^0$ produced through

$$\psi(3770) \to (D^0\overline{D}^0)_{CP=-} \text{ or } \psi(4140) \to D^0\overline{D}^0 \to \pi^0(D^0\overline{D}^0)_{CP=-} \text{ or } \gamma(D^0\overline{D}^0)_{CP=+}$$

- Mixing rate $R_M = \frac{x^2+y^2}{2} \approx 10^{-5}$ with 1 ab$^{-1}$ data at 3.773 GeV via same charged final states $(K^\pm\pi^\mp)(K^\pm\pi^\mp)$ or $(K^\pm l^\mp\nu)(K^\pm l^\mp\nu)$
- Mixing parameter $(x, y) \approx 0.05\%$ with 1 ab$^{-1}$ data at 4.040 by $e^+e^- \to \gamma D^0\overline{D}^0$
- $\Delta A_{CP} \approx 10^{-3}$ for KK and $\pi\pi$ channels
Precision study of the $B_c$ decay

Era of precision study of the charmed baryon ($\Lambda_c$, $\Xi_c$ and $\Omega_c$) decays
to help developing more reliable QCD-derived models in charm sector

- Hadronic decays:
  to explore as-yet-unmeasured channels and understand full picture of intermediate structures in $B_c$ decays, esp., those with neutron/$\Sigma$//$\Xi$ particles

- Semi-leptonic decays:
  to test LQCD calculations and LFU

- CPV in charmed baryon: BP and BV two-body decay asymmetry, charge-dependent rate of SCS

- Charmed Baryons Spectroscopy : (63 P wave states from QM, 16 observed!)

- Rare decays: LFV, BNV, FCNC

**STCF will provide very precise measurements of their overall decays, up to the unprecedented level of $10^{-6} \sim 10^{-7}$**
τ Lepton Physics

- X sec grows from 0.1nb near threshold to 3.5nb at 4.25GeV
  - 1×10^8 tau pairs/year at threshold (x-sec = 0.1nb)
  - 3.5×10^9 tau pairs/year at 4.25GeV (x-sec = 3.5nb)
  - 10^{10} tau pairs per year for Belle II (x-sec = 1nb)

- Highlighted Physics program
  - τ properties: m_τ, (g-2)_τ/2
  - SM properties: universality test, Michel parameters, α_s, V_{us}
  - CPV test: τ^−→K_S^0 π^− ν_τ, T-odd triple product in polarization beam
  - LFV: τ→ℓγ, ℓℓℓ, ℓh

- Competition to Belle II
  - Threshold effect is important for controlling and understanding background
  - Relatively high efficiency
  - Longitudinal polarization of the initial beams will significantly increase sensitivity in searches for CPV in lepton decays.
LFV Decay $\tau \rightarrow \gamma \mu$

B Factory:
- Dominant background: $\tau^- \rightarrow \mu^- \nu_\tau \bar{\nu}_\mu$ with ISR
- BaBar: $B(\tau^- \rightarrow \gamma \mu^-) < 4.5 \times 10^{-8}$
- Belle II with 50 ab$^{-1}$: $B(\tau^- \rightarrow \gamma \mu^-) < 6 \times 10^{-9}$
- STCF with 3 ab$^{-1}$: $B(\tau^- \rightarrow \gamma \mu^-) < 5 \times 10^{-9}$
CPV in \( \tau \) decays

CPV in SM is not enough to explain the asymmetry of matter and anti-matter in universe, new CPV source are demanded. \( \tau \) Lepton decays are a potential place where new CPV may show up.

CPV sourced \( K^0 \) – \( \bar{K}^0 \) mixing

Theory:

\[
A_Q = \frac{B(\tau^+ \rightarrow K_S^0 \pi^+ \nu_\tau) - B(\tau^- \rightarrow K_S^0 \pi^- \bar{\nu}_\tau)}{B(\tau^+ \rightarrow K_S^0 \pi^+ \nu_\tau) + B(\tau^- \rightarrow K_S^0 \pi^- \bar{\nu}_\tau)} = (0.36 \pm 0.01)\%
\]

BaBar experiments:

\[
A_Q = (-0.36 \pm 0.23 \pm 0.11)\% \quad 2.8\sigma \text{ away from the SM prediction}
\]

Theorist try to reconcile the deviation, but not coverage even NP included

STCF can provide a crucial validation since the background can be well controlled.
CPV in $\tau$ decays

New T-odd observables

Use T-odd rotationally invariant triple products in $\geq 2$ hadrons such as $\tau^- \rightarrow \pi^0 \nu_\tau / k^- \pi^0 \nu_\tau$, $\tau^- \rightarrow \pi^- \pi^+ \pi^- \nu_\tau / K^- \pi^+ \pi^- \nu_\tau$

Figure of Merits

Y. S. TSAI, PRD 51 (1995) 3172

BESIII @ 4.25 (10$^{33}$ cm$^{-2}$s$^{-1}$) FOM=1
STCF @ 4.25 (10$^{35}$ cm$^{-2}$s$^{-1}$) FOM=100
SuperKEKB @ (8x10$^{35}$ cm$^{-2}$s$^{-1}$) FOM=52

Experimental challenge:
reconstruction of $\tau$ (No secondary vertices)
In 1958, Okubo: CPV in hyperon-antihyperon allows ⇒ “Okubo effect” (Direct CPV) \( \text{Phys. Rev. 109, 984 (1958)} \).

In 1959, Pais: extended Okubo’s proposal to asymmetry parameters in \( \Lambda \) and \( \Lambda \) decays. \( \text{Phys. Rev. Lett. 3, 242 (1959)} \).

In the 1980s, a number of calculations were made. CKM predictions, CPV in \( \Lambda \): \( 10^{-4} \sim 10^{-5} \)

One example: \( \text{Phys. Rev. D34, 833 (1986)} \).
Spin polarization of $\Lambda$ in $J/\psi \rightarrow \Lambda \bar{\Lambda}$

Quantum correlation in $\Lambda$ pair

<table>
<thead>
<tr>
<th>Parameters</th>
<th>This work</th>
<th>Previous results</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_\psi$</td>
<td>$0.461 \pm 0.006 \pm 0.007$</td>
<td>$0.469 \pm 0.027$ $^{14}$</td>
</tr>
<tr>
<td>$\Delta \Phi$</td>
<td>$(42.4 \pm 0.6 \pm 0.5)^\circ$</td>
<td>$-$</td>
</tr>
<tr>
<td>$\alpha_-$</td>
<td>$0.750 \pm 0.009 \pm 0.004$</td>
<td>$0.642 \pm 0.013$ $^{16}$</td>
</tr>
<tr>
<td>$\alpha_+$</td>
<td>$-0.758 \pm 0.010 \pm 0.007$</td>
<td>$-0.71 \pm 0.08$ $^{16}$</td>
</tr>
<tr>
<td>$\bar{\alpha}_0$</td>
<td>$-0.692 \pm 0.016 \pm 0.006$</td>
<td>$-$</td>
</tr>
<tr>
<td>$A_{CP}$</td>
<td>$-0.006 \pm 0.012 \pm 0.007$</td>
<td>$0.006 \pm 0.021$ $^{16}$</td>
</tr>
<tr>
<td>$\bar{\alpha}<em>0 / \alpha</em>+$</td>
<td>$0.913 \pm 0.028 \pm 0.012$</td>
<td>$-$</td>
</tr>
</tbody>
</table>

$A_{CP} = \frac{\alpha_- + \alpha_+}{\alpha_- - \alpha_+}$

1.31 B $J/\psi$ events


arXiv:1808.08917
$A_{CP}$ Sensitivities in STCF

- 4 trillion $J/\psi$ events $\Rightarrow A_{CP}\sim 10^{-4}$
  - Luminosity optimized at $J/\psi$ resonance
  - Luminosity of STCF: $\times 100$
  - 2 – 3 years data taking
  - No polarization beams are needed

- Beam energy trick $\Rightarrow$ small beam energy spread $\Rightarrow J/\psi$
  cross-section: $\times 10 \Rightarrow A_{CP}\sim 10^{-5}$?

- Challenge: Systematics control
Others interested

- Baryon Form Factors (produced at threshold)
- Collins Fragmentation function
- Two photon physics
- ..........
Strategy & Activities

CDR → TDR → project application → construction → commissioning

• Strategy: focus on CDR (3 years) and TDR (6 years) depend on the available resources. The construction site open.


• Domestic Workshops (2011, 12, 13, 14, 16)

• International Workshops (2015, 18)

• 2015 Fragrance Hill-Science Conference (No. 533)

• Report to USTC Scientific Committee and USTC presidents

• Report to local government

• Form the Organization (including project manager, physics/detector/accelerator work groups ....)

• Regular weekly meetings for Accelerator/Detector/physics!
# Activities

## High Luminosity Tau Charm Physics

Indico for High Luminosity Tau Charm Physics R&D

<table>
<thead>
<tr>
<th>Committee/Meeting Type</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>STCF Steering Committee</td>
<td>1 event</td>
</tr>
<tr>
<td>STCF Accelerator</td>
<td>27 events</td>
</tr>
<tr>
<td>STCF Physics</td>
<td>6 events</td>
</tr>
<tr>
<td>STCF Detector</td>
<td>99 events</td>
</tr>
<tr>
<td>STCF Accelerator-Detector Joint meetings</td>
<td>4 events</td>
</tr>
<tr>
<td>STCF International Conference</td>
<td>7 events</td>
</tr>
<tr>
<td>STCF Domestic meeting</td>
<td>7 events</td>
</tr>
</tbody>
</table>
Physics Progress

Studying the physics *sensitivity*, guiding the *optimization of Detector design*

- Same as BESIII for `McGenEvt`, and keep events in storage.
- **Fast simulation** for charge and neutral tracks (resolution, efficiency, error matrix etc.).
- Do not keep `RecEvt` information, fix random seed for repeating analysis.
- User analysis the *same as BESIII jobs*.
- Optimize STCF detector by scaling.

Fast simulation for several interested physics processes are going on.
Injected:
- No booster, 0.5GeV→1~3.5GeV
- e+, a convertor, a linac and a damping ring, 0.5GeV
- e-, a polarized e- source, accelerated to 0.5GeV
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Phase1</th>
<th>Phase2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumference/m</td>
<td>600~800</td>
<td>600~800</td>
</tr>
<tr>
<td>Optimized Beam Energy/GeV</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Beam Energy Range/GeV</td>
<td>1-3.5</td>
<td>1-3.5</td>
</tr>
<tr>
<td>Current/A</td>
<td>1.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Emittance $(\varepsilon_x/\varepsilon_y)/\text{nm}\cdot\text{rad}$</td>
<td>6/0.06</td>
<td>5/0.05</td>
</tr>
<tr>
<td>$\beta$ Function @IP $(\beta_x^<em>/\beta_y^</em>)$/mm</td>
<td>60/0.6</td>
<td>50/0.5(estimated)</td>
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<tr>
<td>Full Collision Angle 20/mrad</td>
<td>60</td>
<td>60</td>
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<tr>
<td>Tune Shift $\xi_y$</td>
<td>0.06</td>
<td>0.08</td>
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<tr>
<td>Hourglass Factor</td>
<td>0.8</td>
<td>0.8</td>
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<tr>
<td>Aperture and Lifetime</td>
<td>15$\sigma$, 1000s</td>
<td>15$\sigma$, 1000s</td>
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<tr>
<td>Luminosity @Optimized Energy/× 10^{35}\text{cm}^{-2}\text{s}^{-1}</td>
<td>~0.5</td>
<td>~1.0</td>
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</tbody>
</table>
Lattice with FODO-Like Arc

1. Interaction region
2. Long arc section
3. Short arc section
4. Technical section

Circumference: 707.258m,
Revolution frequency: 0.4237288MHz
RF frequency: 500MHz
Harmonic number: 1180
8 dispersion free long straight section (10 m)
5 Siberian snakes, interval by 72° angle

Ring β function

Ring Dispersion function
Lattice with MBA-Like Arc

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Achieved Now</th>
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</thead>
<tbody>
<tr>
<td>Circumference/m</td>
<td>~540</td>
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<tr>
<td>Beam Energy/GeV</td>
<td>2, 1-3.5tunable</td>
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<tr>
<td>Current/A</td>
<td>1.5</td>
</tr>
<tr>
<td>Emittance ($ε_x/ε_y$)/nm·rad</td>
<td>2.4/0.03</td>
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<tr>
<td>$β$ Function @ IP ($β_x^<em>/β_y^</em>$)/mm</td>
<td>60/0.6</td>
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<tr>
<td>$ν_x/ν_y$</td>
<td>17.2/10.7</td>
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<tr>
<td>Collision Angle(full 0)/mrad</td>
<td>60</td>
</tr>
<tr>
<td>Tune Shift $ξ_y$</td>
<td>0.06-0.1 (estimated)</td>
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<tr>
<td>Hour-glass Factor</td>
<td>0.8 (estimated)</td>
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<tr>
<td>Luminosity/×10^{35} cm^{-2}s^{-1}</td>
<td>0.8-1.3 (estimated)</td>
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### Key technologies

#### 关键技术研究内容与路线

<table>
<thead>
<tr>
<th>内容</th>
<th>技术路线</th>
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</thead>
<tbody>
<tr>
<td>束流测量</td>
<td>能量、位置、极化度，束团尺寸，束流反馈，亮度反馈</td>
</tr>
<tr>
<td>微波高频</td>
<td>超导高频腔，低电平控制系统</td>
</tr>
<tr>
<td>真空</td>
<td>真空室镀膜，异形真空室研制，阻抗优化与测量</td>
</tr>
<tr>
<td>磁铁</td>
<td>超导磁铁，超导螺线管，永磁铁，异形铁……</td>
</tr>
<tr>
<td>极化束技术</td>
<td>试制光阴极极化电子枪</td>
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</tbody>
</table>

#### 数字化仿真研究，制定技术方案

- 样机设备的加工，离线测试
- 搭建集成测试平台，预研样机测试与定型
Spectrometer

Conceptual design almost done, some components (PID, Ecal) enter technological design.
## Tentative Plan

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### R&D budget: 200M RMB

### Total budget: 4B RMB (estimated in 2014)

<table>
<thead>
<tr>
<th></th>
<th>eLinac</th>
<th>4.0+1.0 (阻尼环)</th>
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<tbody>
<tr>
<td>Electron ring</td>
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<td>Positron ring</td>
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<td>低线</td>
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<td>实验谱仪</td>
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<td>低温</td>
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<tr>
<td>配套设施</td>
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<td>装置土建</td>
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<td>不可预见</td>
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<td>合计</td>
<td>40</td>
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</table>
USTC president agreed, and scientific committee endorsed supporting R&D → 10 M RMB (2018)
Agree to support another 10-20 M RMB (2019)
Super Charm-Tau at **Novosibirsk**, RUSSIA, **Budker Institute** of Nuclear Physics Long history.....

- **Pre-Agreement of Joint effort** on R&D, details are under negotiation
- **Joint workshop** between China, Russia, and Europe
  - 2018 UCAS (March), Novosibirsk (May), Orsay (December)
  - 2019 Moscow(September)
Summary

- **Super τ-c Factory (STCF):**
  - double ring with circumference around 600~1000 m
  - e^+e^- collision with \( E_{cm} = 2 - 7 \) GeV, \( L = 1 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1} \)

- **STCF is one of the crucial precision frontier**
  - rich of physics program
  - unique for physics with c quark and τ leptons,
  - important playground for study of QCD, exotic hadrons and search for new physics.

- We initialized 10 M CNY (2018), 10-20M CNY(2019) for start R&D.

- Project organization is setup, a working group is toward for CDR/TDR.

- An International collaboration is essential for promoting the project.
Welcome to join the effort

谢谢

Thanks.