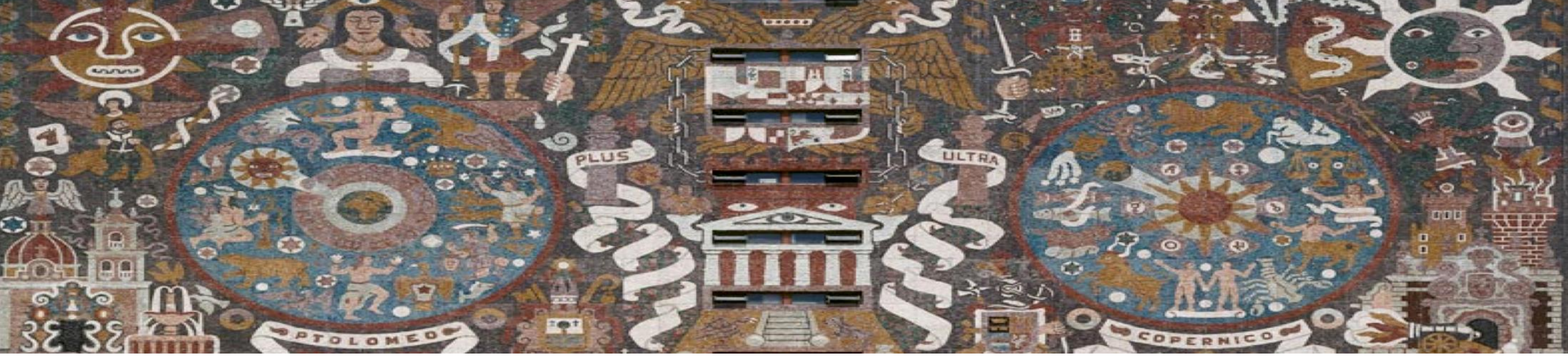

Experimental Program for Super Tau-Charm Facility

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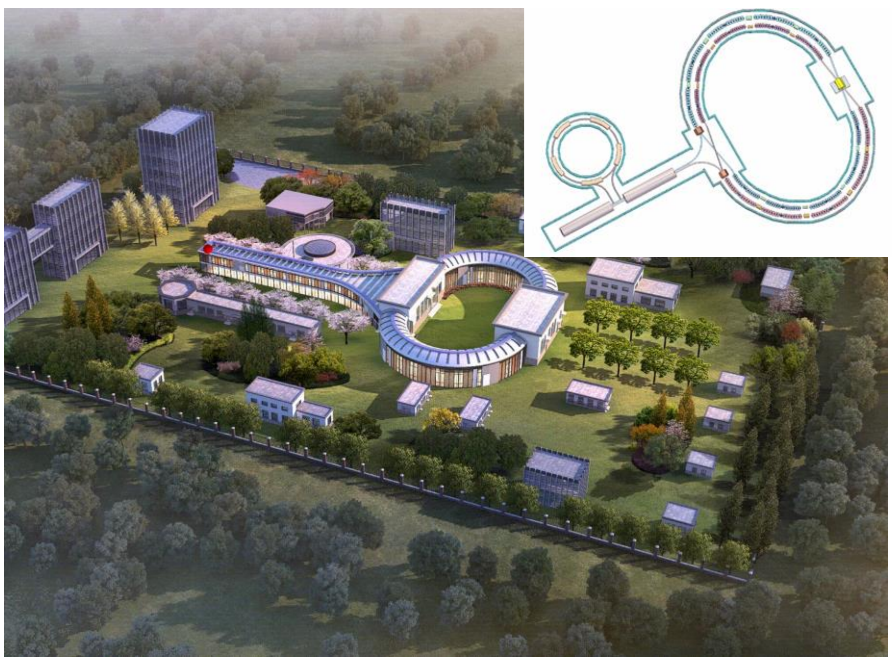
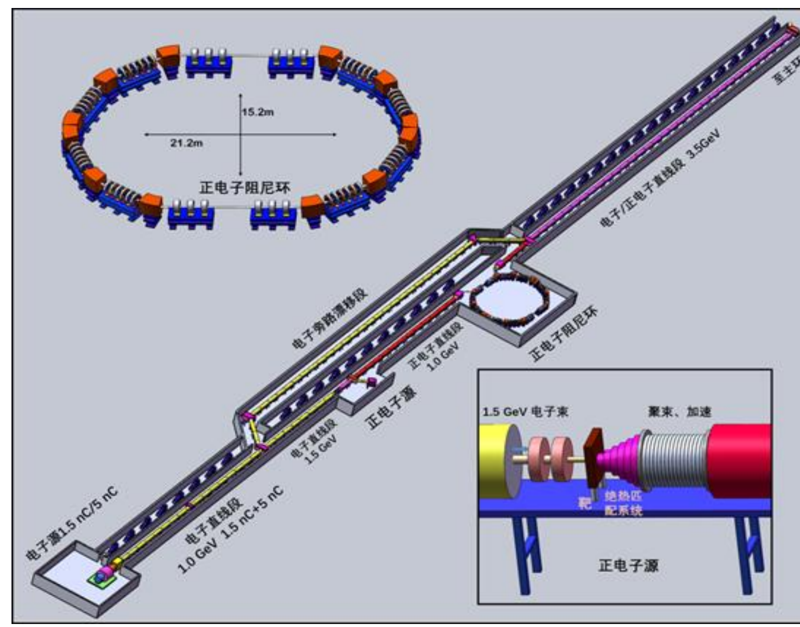
10th International Workshop on Charm Physics (CHARM 2020)
2021.5.31-2021.6.4 (online)

Super Tau-Charm Facility (STCF) in China

- Peaking luminosity >0.5×10^{35} $cm^{-2}s^{-1}$ at 4 GeV
- Energy range E_{cm} = 2-7 GeV
- Potential to increase luminosity and realize beam polarization
- A nature extension and a viable option for China accelerator project in the post BEPCII/BESIII era

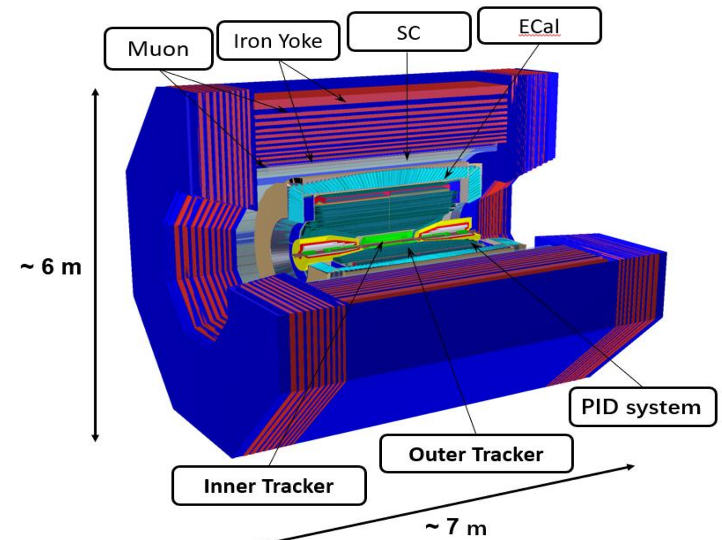


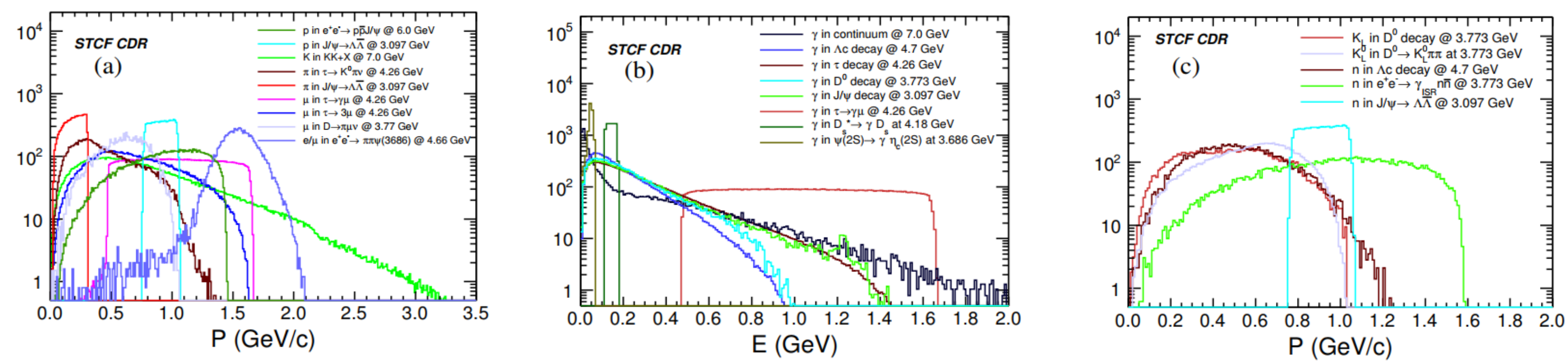


1 ab^{-1} data expected per year

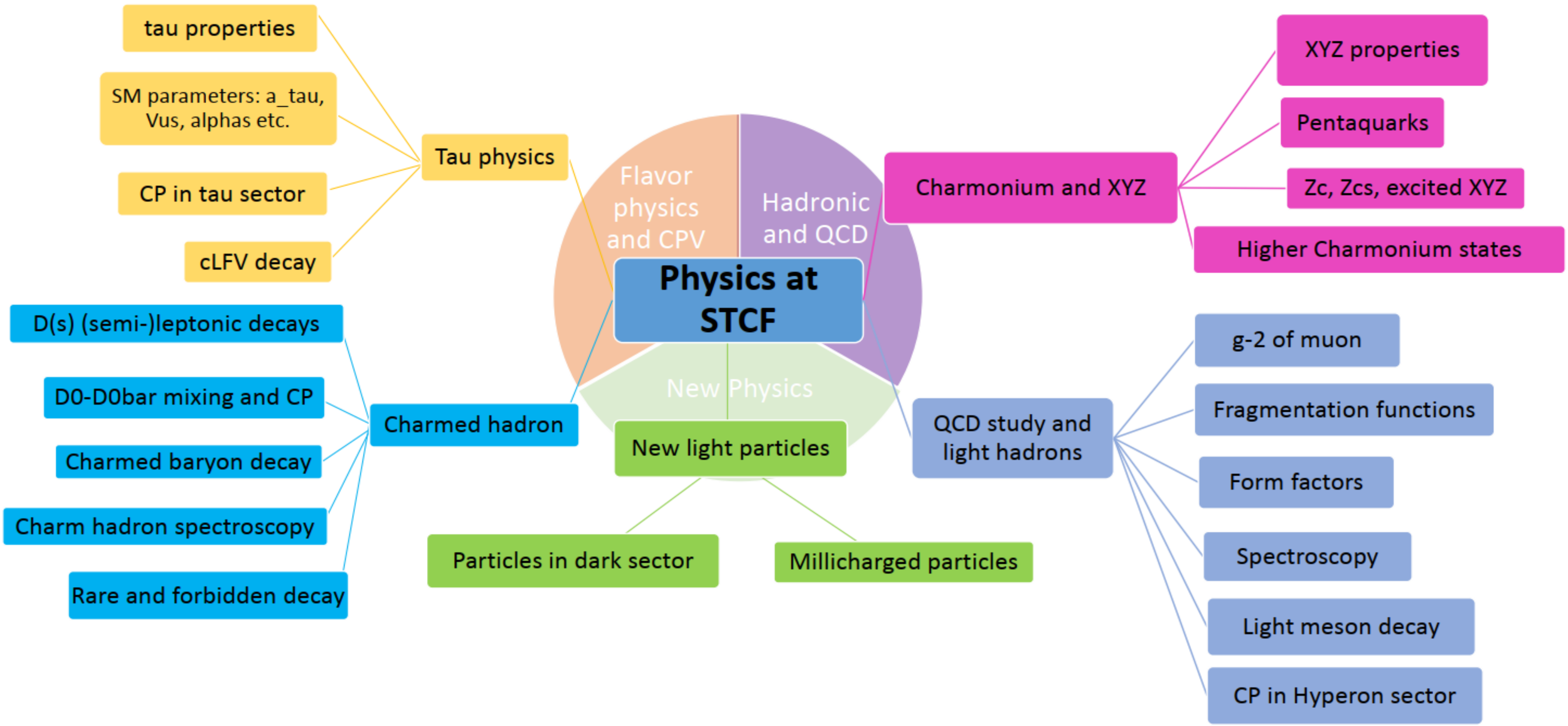
STCF Detector

- **Inner Tracker**
  - ~0.15% X_0 / layer
  - σ_{xy} ~ 50 μm
- **Out Tracker**
  - σ_{xy}~130 μm, σ_p/p~0.5%@1 GeV/c
  - dE/dx ~ 6%
- **PID system**
  - π/K (K/p) 3-4σ separation up to 2 GeV/c
- **Electromagnetic Calorimeter**
  - Range: 0.02 – 3 GeV
  - Resolution (1 GeV): 2.5% (barrel) and 4% (endcap)
- **Muon system**
  - π suppression power: >10 and lower to 0.4 GeV/c





Physics at STCF



- **rich of physics program, unique for physics with c quark and τ leptons,**
- **important playground for study of QCD, exotic hadrons, flavor and search for new physics.**

Data Samples

Expected data samples with 1 ab^{-1} integral luminosity

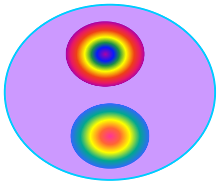
	STCF					Belle II		
Data Set	process	σ/nb	N	ST eff./%	ST N	σ/nb	N	Tag N
J/ψ	–	–	1.0×10^{12}	–	–	–	–	–
$\psi(2S)$	–	–	3.0×10^{11}	–	–	–	–	–
D^0	$D^0\bar{D}^0(3.77)$	~ 3.6	3.6×10^9	10.8	0.78×10^9	–	1.4×10^9	–
D^+	$D^+D^-(3.77)$	~ 2.8	2.8×10^9	9.4	0.53×10^9	–	7.7×10^8	–
D_s	$D_sD_s^*(4.18)$	~ 0.9	0.9×10^9	6.0	0.11×10^9	–	2.5×10^8	–
τ^+	$\tau^+\tau^-(3.68)$	~ 2.4	2.4×10^9	–	–	0.9	0.9×10^9	–
	$\tau^+\tau^-(4.25)$	~ 3.6	3.5×10^9	–	–	–	–	–
Λ_c	$\Lambda_c\Lambda_c(4.64)$	~ 0.6	5.5×10^8	5.0	0.55×10^8	–	1.6×10^8	$3.6 \times 10^{4*}$

The luminosity is 1.0 ab^{-1}. * process $e^+e^- \to D^{(*)-}\bar{p}\pi^+\Lambda_c^+$.

- Belle-II (50/ab) has 50~100 times more statistics
- STCF is expected to have higher detection efficiency and low backgrounds for productions at threshold

XYZ	$Y(4260)$	$Z_c(3900)$	$Z_c(4020)$	$X(3872)$
No. of events	10^{10}	10^9	10^9	5×10^6

Charmonium (Like) Spectroscopy

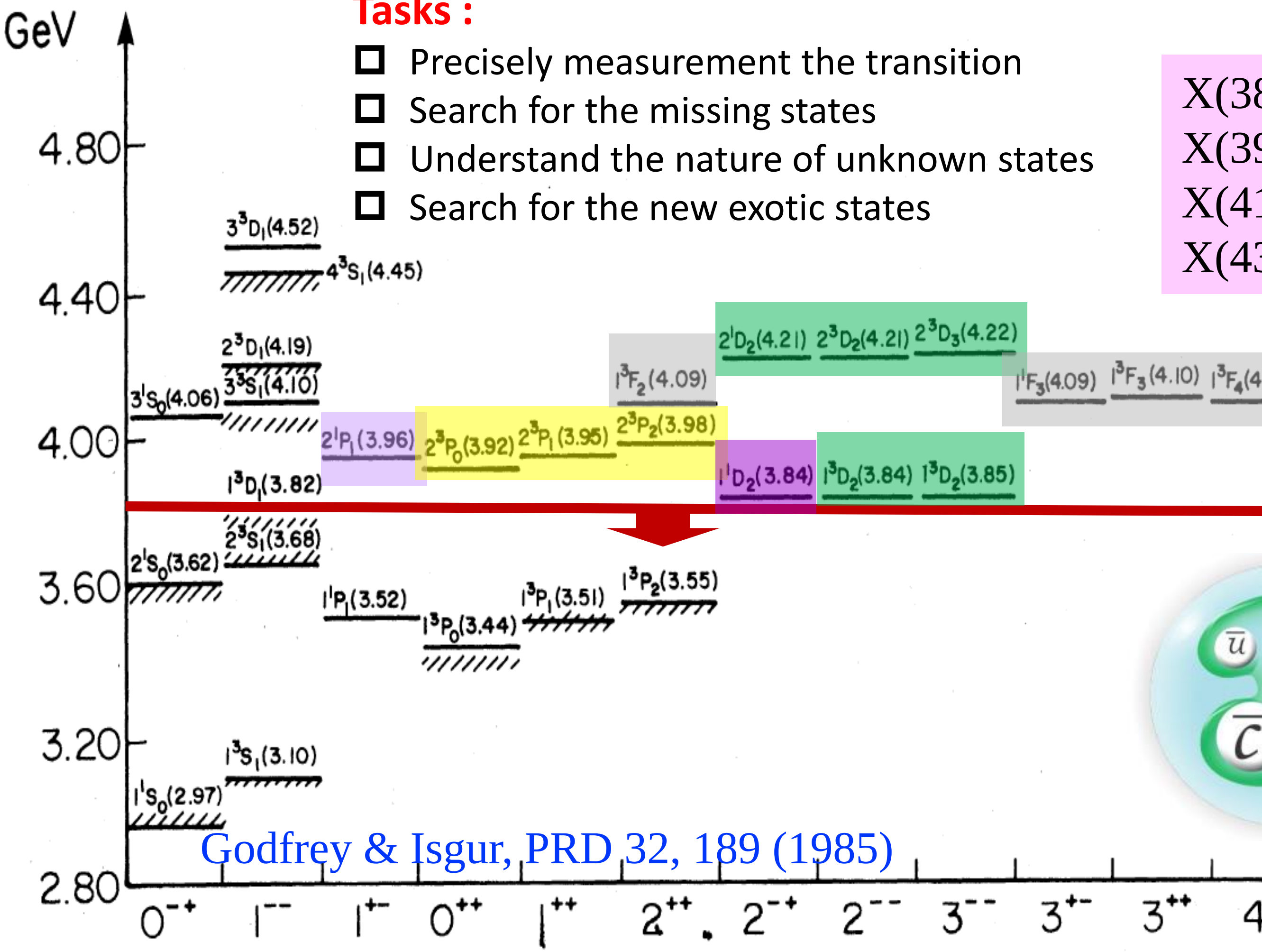


Excellent platform to explore the QCD

Fruitful results in past decade, a new territory to study exotic hadrons

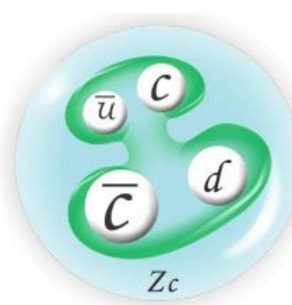
Tasks :

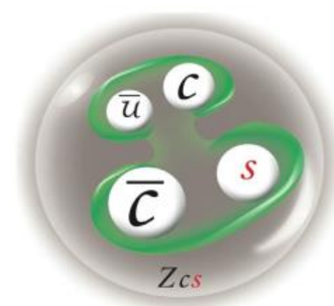
- ☐ Precisely measurement the transition
- ☐ Search for the missing states
- ☐ Understand the nature of unknown states
- ☐ Search for the new exotic states



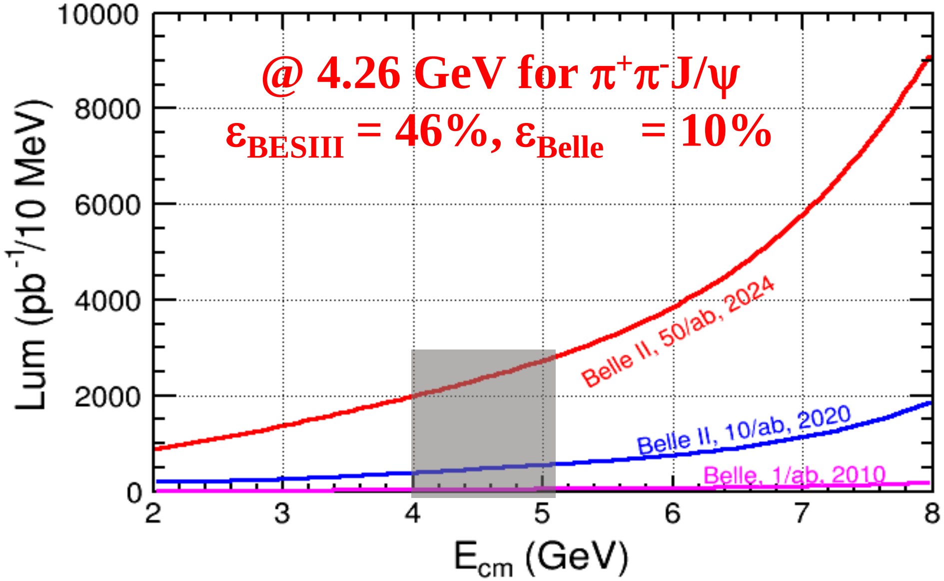
Godfrey & Isgur, PRD 32, 189 (1985)

X	Y	Z
X(3872)	Y(3940)	$Z_c(3900)$
X(3940)	Y(4008)	$Z_c(4020)$
X(4160)	Y(4260)	$Z_c(4050)$
X(4350)	Y(4360)	$Z_c(4200)$
	Y(4660)	$Z_c(4250)$
		$Z_c(4430)$
		$Z_{cs}(3985)$
		$Z_{cs}(4000)$
		$Z_{cs}(4220)$

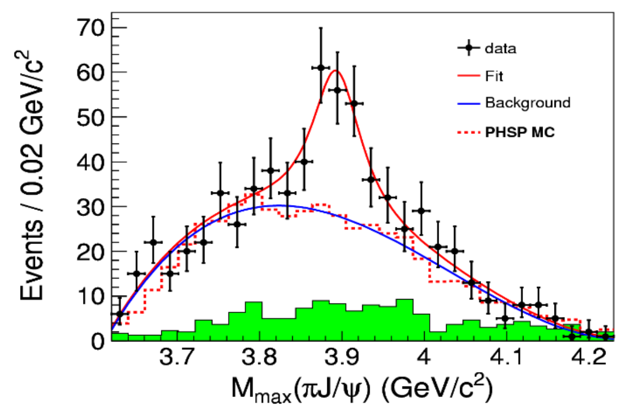




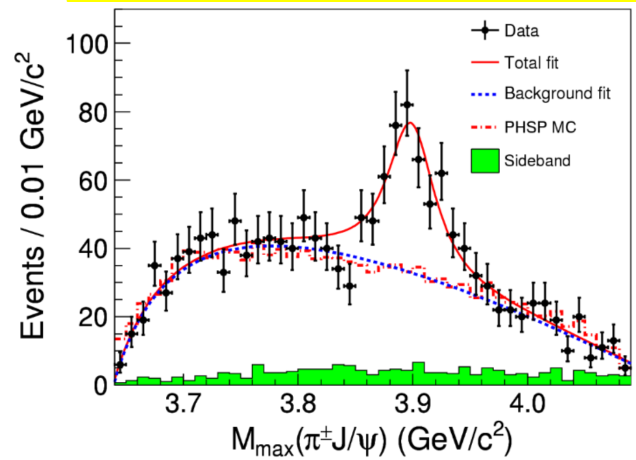
Charmonium(Like) Spectroscopy at STCF



Belle with ISR: PRL110, 252002
967 fb-1 in 10 years running time



BESIII at 4.260 GeV: PRL110, 252001
0.525 fb^{-1} in one month running time



- B factory : Total integrate effective luminosity between 4-5 GeV is 0.23 ab^{-1} for 50 ab^{-1} data
- τ-C factory : scan in 4-5 GeV, 10 MeV/step, every point have 10 fb^{-1}/year, 5 time of Belle II for 50 ab^{-1} data
- τ-C factory have much higher efficiency and low background than B Factory

Facilities for Charm Study

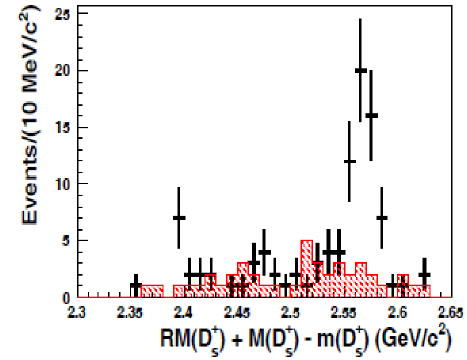
- LHCb: huge x-sec, boost, 9 fb^{-1} now (×40 current B factories)
- B-factories (Belle(-II), BaBar): more kinematic constrains, clean environment, ~100% trigger efficiency
- τ-charm factory : Low backgrounds and high efficiency, Quantum correlations and CP-tagging are unique
- STCF :

- 4×10^9 pairs of $D^{\pm,0}$ and 10^8 D_s pairs per year
  - 10^{10} charm from Belle II/year
- Highlighted Physics programs
  - Precise measurement of (semi-)leptonic decay (f_D, f_{Ds}, CKM matrix…)
  - *D* decay strong phase (Determination of γ/ϕ3 angle)
  - $D^0-\overline{D}^0$ mixing, CPV
  - Rare 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)

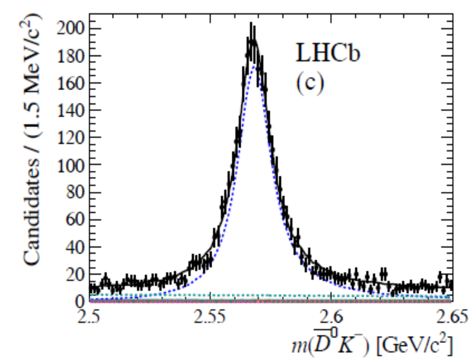
Features in Charm Hadron Decays

	STCF	Belle II	LHCb
Production yields	★★	★★★★	★★★★★
Background level	★★★★★	★★★	★★
Systematic error	★★★★★	★★★	★★
Completeness	★★★★★	★★★	★
(Semi)-Leptonic mode	★★★★★	★★★★	★★
Neutron/K_L mode	★★★★★	★★★	☆
Photon-involved	★★★★★	★★★★	★
Absolute measurement	★★★★★	★★★	☆

0.5 fb^{-1} ~ 80 Events
1.0 ab^{-1}~ 160000 Events



3.0 fb^{-1}~ 4000 Events
60 fb^{-1}~ 80000 Events



- Most are precision measurements, which are mostly dominant by the systematic uncertainty
- STCF has overall advantages in several studies

Precision Measurements 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?

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

BESIII + B factories + LQCD

Three generations of quark?

Unitary matrix?

Expected precision < 2% at BESIII

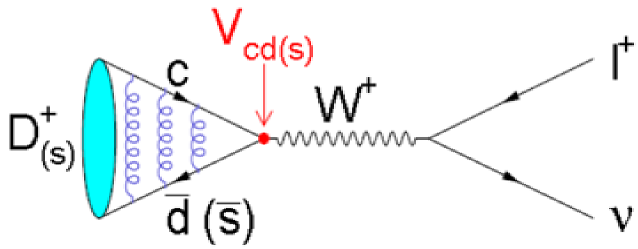
BESIII + B factories + LHCb + LQCD

A direct measurement of $V_{cd(s)}$ is one of the most important task in charm physics

$D_{(s)}$ (Semi-)Leptonic decay

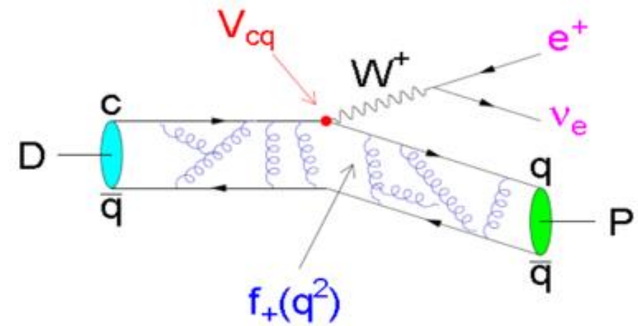
Purely Leptonic:

$$\Gamma(D^+_{(s)} \to \ell^+ \nu_\ell) = \frac{G_F^2 f^2_{D^+_{(s)}}}{8\pi} \mid V_{cd(s)} \mid^2 m_\ell^2 m_{D^+_{(s)}} \left(1 - \frac{m_\ell^2}{m^2_{D^+_{(s)}}}\right)^2$$



Semi-Leptonic:

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



Directly measurement : $|V_{cd(s)}|$ x $f_{D(s)}$ or $|V_{cd(s)}|$ x 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

$D_{(s)}$ (Semi-)Leptonic decay

	BESIII	STCF	Belle II
Luminosity	2.93 fb^{-1} at 3.773 GeV	1 ab^{-1} at 3.773 GeV	50 ab^{-1} at $\Upsilon(nS)$
$\mathcal{B}(D^+ \to \mu^+\nu_\mu)$	$5.1\%_{\rm stat}$ $1.6\%_{\rm syst}$ [8]	$0.28\%_{\rm stat}$	–
f_{D^+} (MeV)	$2.6\%_{\rm stat}$ $0.9\%_{\rm syst}$ [8]	$0.15\%_{\rm stat}$	–
$\lvert V_{cd}\rvert$	$2.6\%_{\rm stat}$ $1.0\%^{*}_{\rm syst}$ [8]	$0.15\%_{\rm stat}$	–
$\mathcal{B}(D^+ \to \tau^+\nu_\tau)$	$20\%_{\rm stat}$ $10\%_{\rm syst}$ [9]	$0.41\%_{\rm stat}$	–
$\frac{\mathcal{B}(D^+ \to \tau^+\nu_\tau)}{\mathcal{B}(D^+ \to \mu^+\nu_\mu)}$	$21\%_{\rm stat}$ $13\%_{\rm syst}$ [9]	$0.50\%_{\rm stat}$	–
Luminosity	3.2 fb^{-1} at 4.178 GeV	1 ab^{-1} at 4.009 GeV	50 ab^{-1} at $\Upsilon(nS)$
$\mathcal{B}(D_s^+ \to \mu^+\nu_\mu)$	$2.8\%_{\rm stat}$ $2.7\%_{\rm syst}$ [10]	$0.30\%_{\rm stat}$	$0.8\%_{\rm stat}$ $1.8\%_{\rm syst}$
$f_{D_s^+}$ (MeV)	$1.5\%_{\rm stat}$ $1.6\%_{\rm syst}$ [10]	$0.15\%_{\rm stat}$	–
$\lvert V_{cs}\rvert$	$1.5\%_{\rm stat}$ $1.6\%_{\rm syst}$ [10]	$0.15\%_{\rm stat}$	–
$f_{D_s^+}/f_{D^+}$	$3.0\%_{\rm stat}$ $1.5\%_{\rm syst}$ [10]	$0.21\%_{\rm stat}$	–
$\mathcal{B}(D_s^+ \to \tau^+\nu_\tau)$	$1.9\%_{\rm stat}$ $2.3\%^{\dagger}_{\rm syst}$	$0.24\%_{\rm stat}$	$0.6\%_{\rm stat}$ $2.7\%_{\rm syst}$
$f_{D_s^+}$ (MeV)	$0.9\%_{\rm stat}$ $1.2\%^{\dagger}_{\rm syst}$	$0.11\%_{\rm stat}$	–
$\lvert V_{cs}\rvert$	$0.9\%_{\rm stat}$ $1.2\%^{\dagger}_{\rm syst}$	$0.11\%_{\rm stat}$	–
$\overline{f}^{\mu\&\tau}_{D_s^+}$ (MeV)	$0.9\%_{\rm stat}$ $1.0\%^{\dagger}_{\rm syst}$	$0.09\%_{\rm stat}$	$0.3\%_{\rm stat}$ $1.0\%_{\rm syst}$
$\lvert \overline{V}^{\mu\&\tau}_{cs}\rvert$	$0.9\%_{\rm stat}$ $1.0\%_{\rm syst}{}^{\dagger}$	$0.09\%_{\rm stat}$	–
$\frac{\mathcal{B}(D_s^+ \to \tau^+\nu_\tau)}{\mathcal{B}(D_s^+ \to \mu^+\nu_\mu)}$	$3.6\%_{\rm stat}$ $3.0\%^{\dagger}_{\rm syst}$	$0.38\%_{\rm stat}$	$0.9\%_{\rm stat}$ $3.2\%_{\rm syst}$

Theory : 0.2%(0.1% expected)

Theory : 0.2%(0.1% expected)

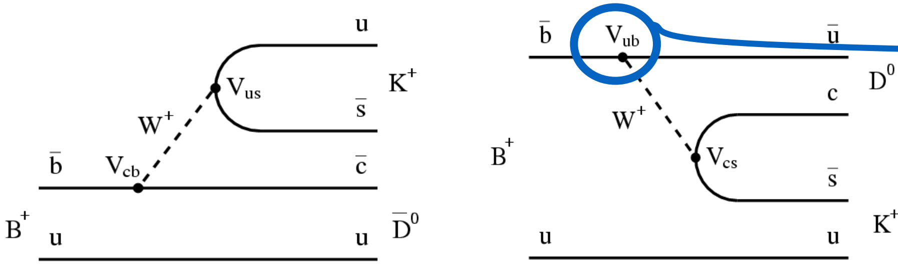
Theory : 0.2%(0.1% expected)

* assuming Belle II improved systematics by a factor 2

Stat. uncertainty is closed to theory precision
Sys. is challenging

Determination of γ/ϕ_3 angle

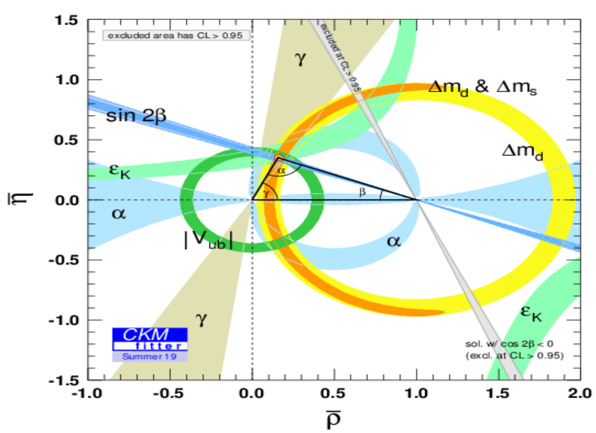
- The cleanest way to extract γ is from B→DK decays:

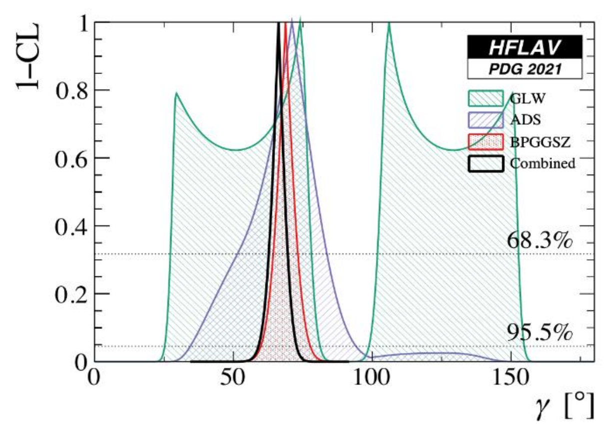


$$\frac{A(B^+ \to D^0 K^+)}{A(B^+ \to \overline{D}^0 K^+)} \equiv r_B e^{i(\delta_B + \phi_3)}$$

  – 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 γ/ϕ_3 angle

Runs	Collected / Expected integrated luminosity	Year attained	γ/ϕ_3 sensitivity
LHCb Run-1 [7, 8 TeV]	3 fb^{-1}	2012	8°
LHCb Run-2 [13 TeV]	5 fb^{-1}	2018	4°
Belle II Run	50 ab^{-1}	2025	1.5°
LHCb upgrade I [14 TeV]	50 fb^{-1}	2030	$< 1^\circ$
LHCb upgrade II [14 TeV]	300 fb^{-1}	(>)2035	$< 0.4^\circ$

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

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. $D^0 \to K_s\pi^0$, $D^0 \to \pi^+\pi^-$
- Atwood, Dunietz, Soni (ADS): Use doubly Cabibbo-suppressed decays, e.g. $D^0 \to K^+\pi^-$
  - With 1 ab^{-1} @ STCF : $\sigma(\cos\delta_{K\pi}) \sim 0.007$; $\sigma(\delta_{K\pi}) \sim 2^o \to \sigma(\gamma) < 0.5^o$
- 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 $\sim 0.1^o$

D^0-$\bar{D}^0$ Mixing and CPV

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

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

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

Precision Study of Charm Baryon

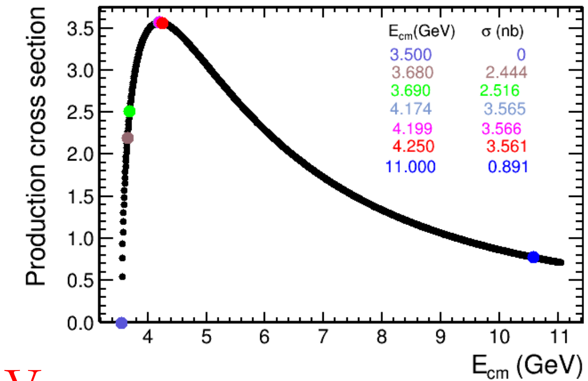
Era of precision study of the charmed baryon (Λ_c, Ξ_c and Ω_c) decays
to help developing more reliable QCD-derived models in charm sector

- **Hadronic decays:**
  to explore as-yet-unmeasured channels and understand full picture of intermediate structures in B_c decays, esp., those with neutron/Σ/Ξ 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, less than 20 are observed!)
- Rare decays: LFV, BNV, FCNC

STCF will provide very precise measurements of their overall decays, up to the unprecedented level of 10^{-6} ~10^{-7}

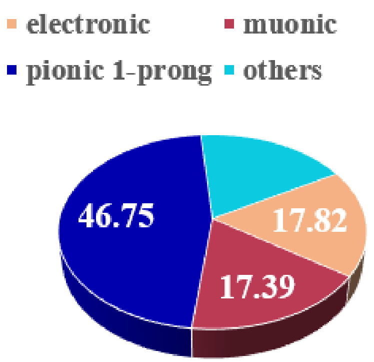
τ Lepton Physics

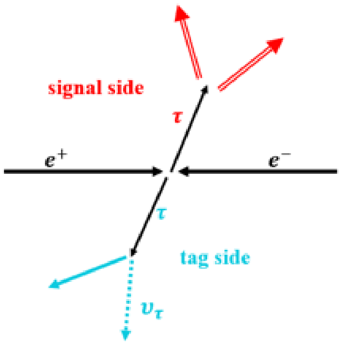
- X sec grows from 0.1nb near threshold to 3.5 nb at 4.25 GeV
  - 1×10^8 tau pairs/year at threshold (0.1 nb)
  - 3.5×10^9 tau pairs/year at 4.25 GeV (3.5 nb)
  - 10^{10} τ pairs per year for Belle II (1 nb)



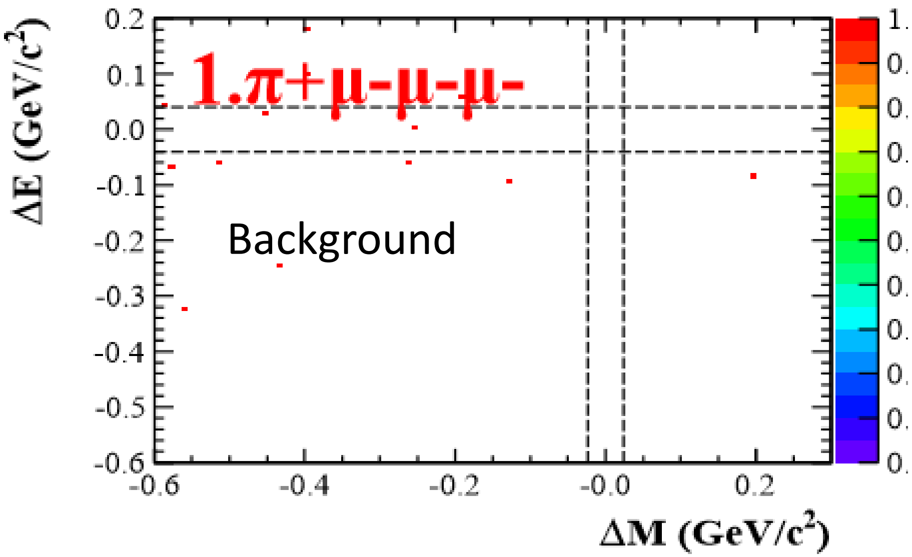
- Highlighted Physics program
  - τ properties : m_τ, $(g\text{-}2)_\tau/2$
  - SM properties : universality test, Michel parameters, α_s, V_{us}
  - CPV test : $\tau^- \to K_S^0 \pi^- \nu_\tau$, T-odd triple product in polarization beam
  - LFV : $\tau \to \ell\gamma$, $\ell\ell\ell$, ℓh
- Comparison 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 of $\tau \to lll$ at STCF





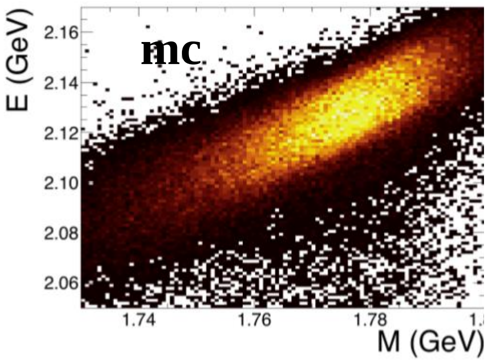
- Signal side: $\tau \to 3leptons$
- Tag side: $\tau \to e\upsilon\bar{\upsilon},\ \mu\upsilon\bar{\upsilon},\ \pi\upsilon + n\pi^0$ ($\mathcal{B}r =$ 82%)
- Almost background free, **the sensitivity : $\mathcal{B}_{UL}^{90}(\tau \to \mu\mu\mu) \sim 1/\mathcal{L}$**
- Best efficiency ($\tau \to \mu\mu\mu$): 22.5% **(including tag branching fraction)**

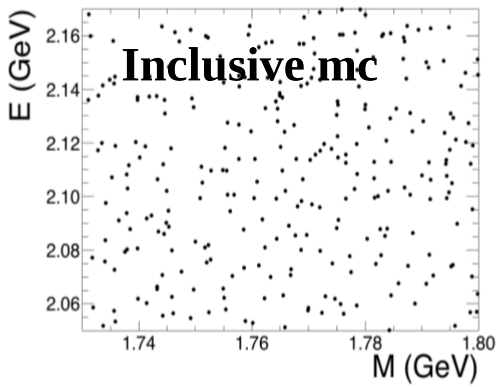


- **STCF with 1ab^{-1}:**

$$\mathcal{B}_{UL}^{90}(\tau \to \mu\mu\mu) < \frac{N_{UL}^{90}}{2\varepsilon N_{\tau\tau}} \sim 1.5 \times 10^{-9}$$

LFV decay of $\tau \to \gamma\mu$ at STCF

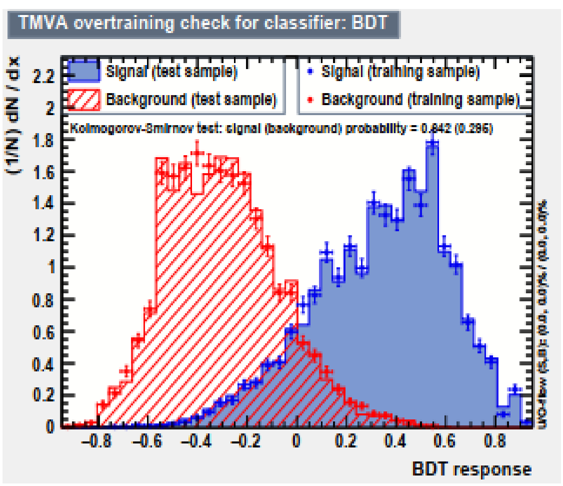


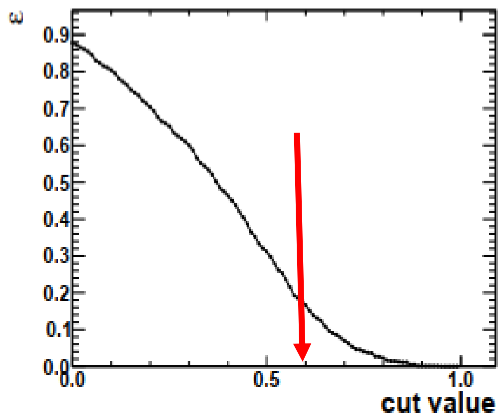


- Signal side $\tau \to \gamma\mu$
- Tag side: $\tau \to e\upsilon\bar{\upsilon},\ \pi\upsilon,\ \pi\pi^0\upsilon(\mathcal{B}r = 54\%)$
- **Dominant background**: $e^+e^- \to \mu^+\mu^-$ and $e^+e^- \to \tau^+\tau^-, \tau^+ \to \pi\pi^0\upsilon, \tau^- \to \mu\upsilon\bar{\upsilon}$

TABLE II. Optimization for pion/muon separation.

	μ eff. at 1 GeV	$UL(\mathcal{B}(\tau \to \gamma\mu))/10^{-8}$
3 %	96.7 %	1.2
1.7 %	92.6 %	1.5
1 %	87.3 %	1.8





- **STCF with 1ab^{-1}:**

$$\mathcal{B}_{UL}^{90}(\tau \to \gamma\mu) < \frac{N_{UL}^{90}}{2\varepsilon N_{\tau\tau}} \sim 1.2 \times 10^{-8}$$

CPV in τ decay

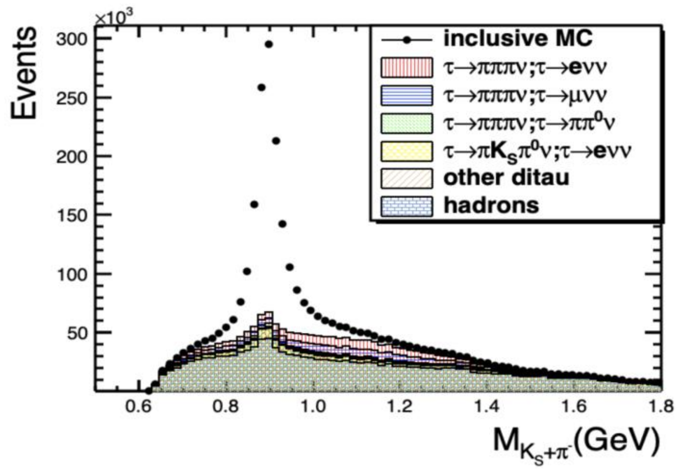
- The CPV source in $K^0 - \bar{K}^0$ **mixing** produces a difference in tau decay rate

In Theory : $A_Q = \frac{B(\tau^+ \to K_S^0\pi^+\bar{\nu}_\tau) - B(\tau^- \to K_S^0\pi^-\nu_\tau)}{B(\tau^+ \to K_S^0\pi^+\bar{\nu}_\tau) + B(\tau^- \to K_S^0\pi^-\nu_\tau)} = (+0.36 \pm 0.01)\%$

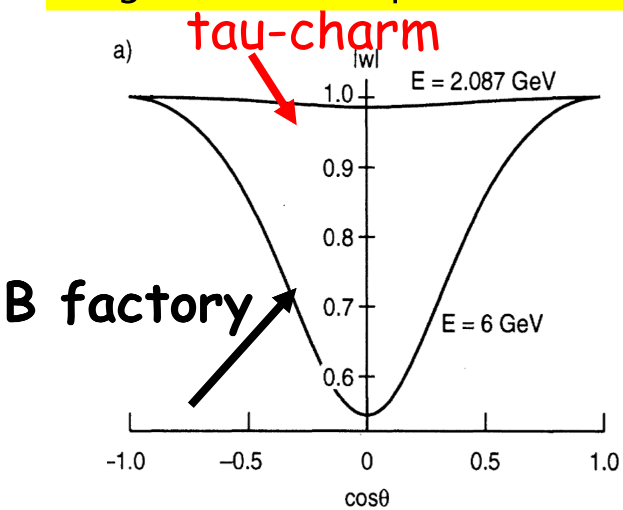
BaBar experiments : $A_{CP}(\tau^- \to K_S\pi^-\nu[\geq 0\pi^0]) = (-0.36 \pm 0.23 \pm 0.11)\%$

2.8σ away from the SM prediction

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



Possible choice to increase the Figure of merits: polarized beam



The CPV sensitivity with 1ab^{-1} @ 4.26 GeV[1]:

$A_{STCF} \sim 9.7 \times 10^{-4}$

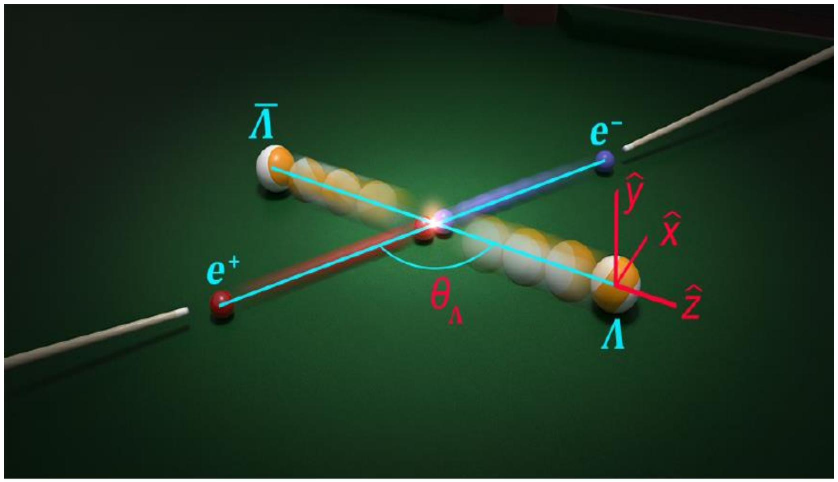
With 10 ab^{-1} data:

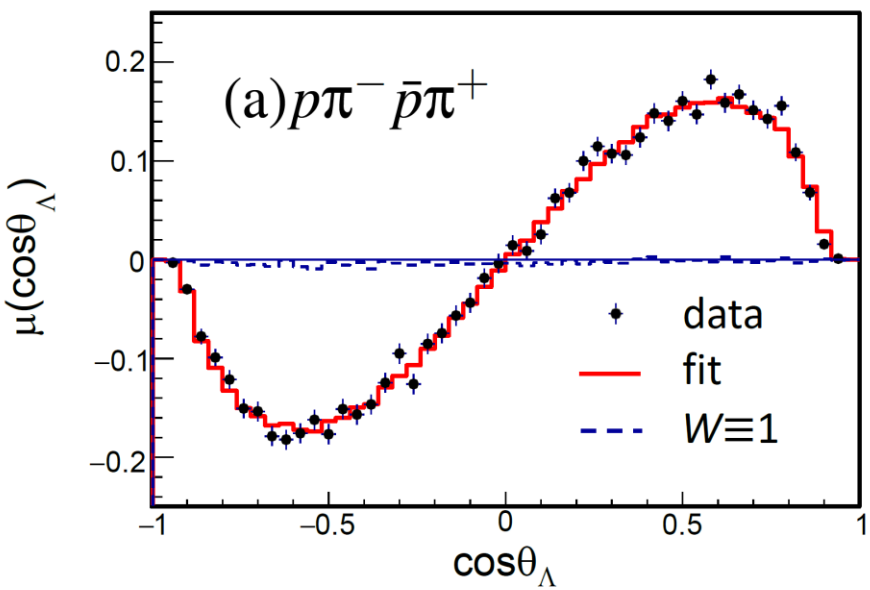
$A_{STCF} \sim 3.1 \times 10^{-4}$

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

[1]. H. Sang, *et al.,* Chin. Phys. C 45, no.5, 053003 (2021)

Polarization of Λ hyperons and CPV





Nature Phys. **15**, 631–634 (2019)

1.31 B J/ψ events
Quantum correlation in Λ pair

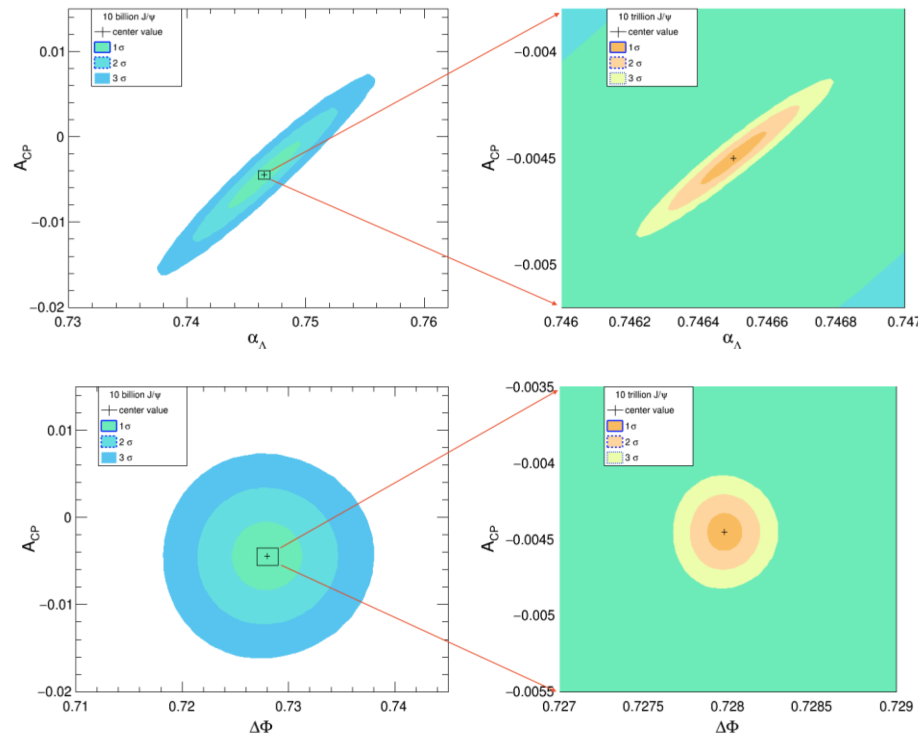
Parameters	This work	Previous results
α_ψ	$0.461 \pm 0.006 \pm 0.007$	0.469 ± 0.027 [14]
$\Delta\Phi$	$(42.4 \pm 0.6 \pm 0.5)^\circ$	–
α_-	$0.750 \pm 0.009 \pm 0.004$	0.642 ± 0.013 [16]
α_+	$-0.758 \pm 0.010 \pm 0.007$	-0.71 ± 0.08 [16]
$\bar{\alpha}_0$	$-0.692 \pm 0.016 \pm 0.006$	–
A_{CP}	$-0.006 \pm 0.012 \pm 0.007$	0.006 ± 0.021 [16]
$\bar{\alpha}_0/\alpha_+$	$0.913 \pm 0.028 \pm 0.012$	–

2% level sensitivity for CPV test
SM prediction: 10^{-4}~10^{-5}

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

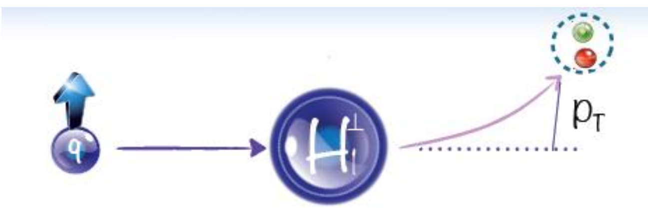
CPV in Hyperon Decays at STCF

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



- Beam energy trick
  ⇒ small beam energy spread
  ⇒ J/ψ cross-section: $\times$ 10 ⇒ $A_{CP} \sim 10^{-5}$?
- Challenge: Systematics control, spin procession effect in magnet

Collins Fragmentation Function (FF)

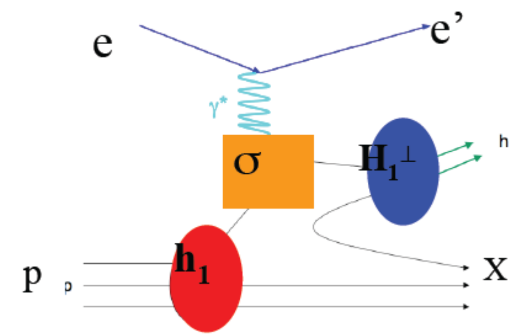


J. C. Collins, Nucl. Phys. B396, 161 (1993)

$$D_{hq^\uparrow}(z, P_{h\perp}) = D_1^q(z, P_{h\perp}^2) + H_1^{\perp q}(z, P_{h\perp}^2)\frac{(\hat{\mathbf{k}} \times \mathbf{P}_{h\perp}) \cdot \mathbf{S}_q}{zM_h},$$

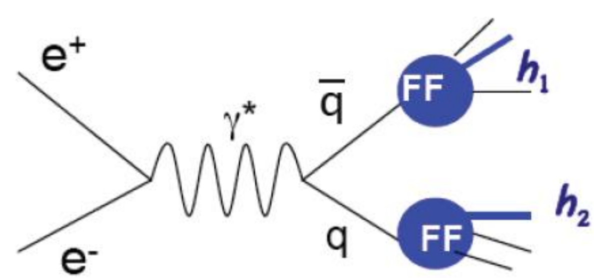
SIDIS

Transversity ⊗ Collins FF



e+ e-

Collins FF ⊗ Collins FF

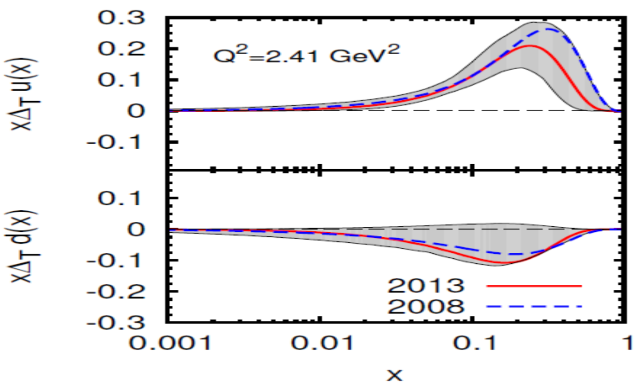


D_1: the un-polarized FF
H_1: Collins FF
→ describes the fragmentation of a transversely polarized quark into a spin-less hadron *h*.
→ depends on $z = 2E_h/\sqrt{s}$,
→ leads to an azimuthal modulation of hadrons around the quark momentum.

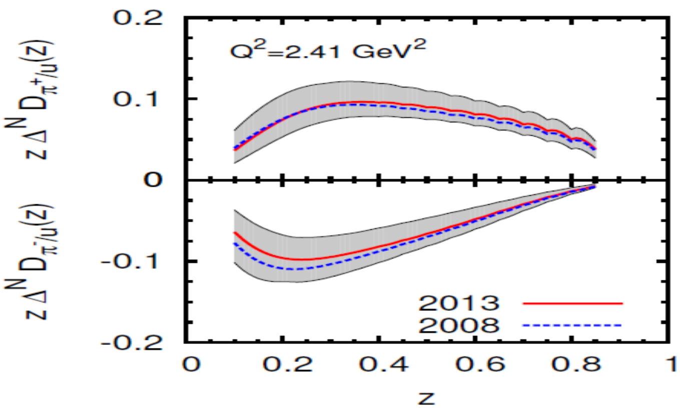
Collins Fragmentation Function (FF)

Anselmino et al., PRD 87, 094019 (2013)
Using data from HERMES, COMPASS, Belle

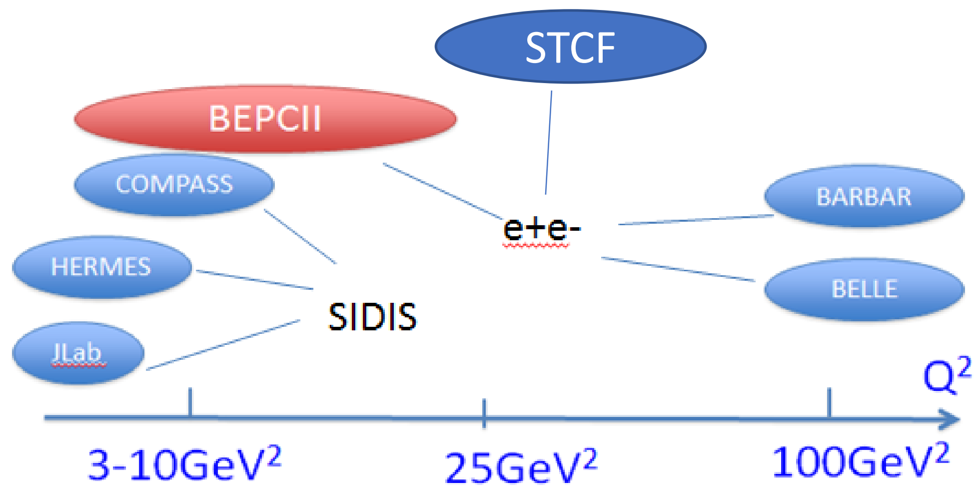
Transversity



Collins pion FF

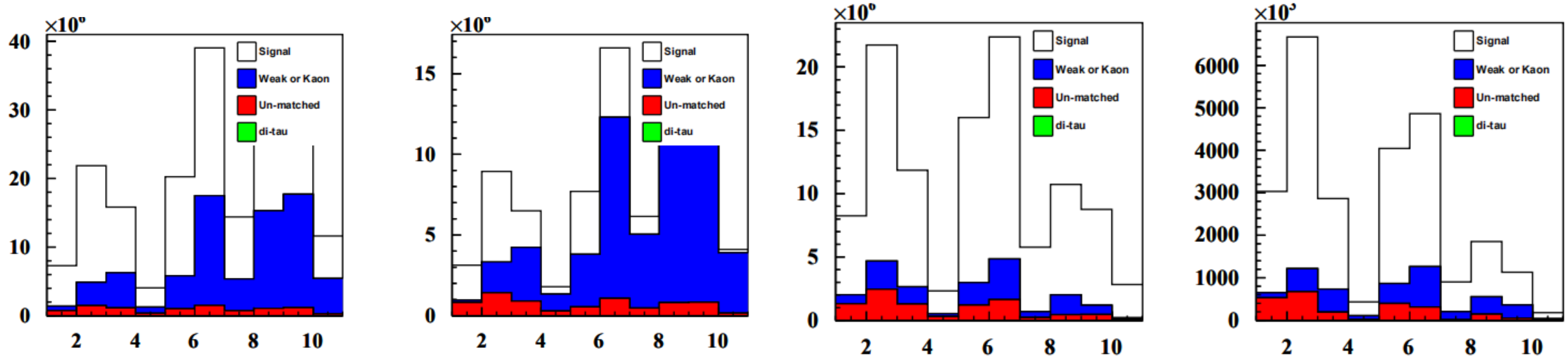


- ☐ **The Q^2 evolution of Collins FFs was assumed following the extrapolation in the unpolarized FF, and this has not been validated.**
- ☐ **Low Q^2 data from e^+e^- collider is useful.**
- ☐ **BEPCII / STCF**
  - **Similar Q^2 coverage with SIDIS in EicC**



Collins FF at STCF

- STCF is a perfect machine for studying Collins effect
- Poor performance for the traditional dE/dx & TOF PID system for tracks > 0.8GeV
- This measurement suffer from systematic uncertain from $K-\pi$ mis-PID.
- The mis-PID is even worse in the case of KK Collins measurement.
- With 2.5 fb^{-1} 7GeV $q\bar{q}$ MC ($\sigma \approx$ 5nb LundArlw), we study Collins effect at STCF.

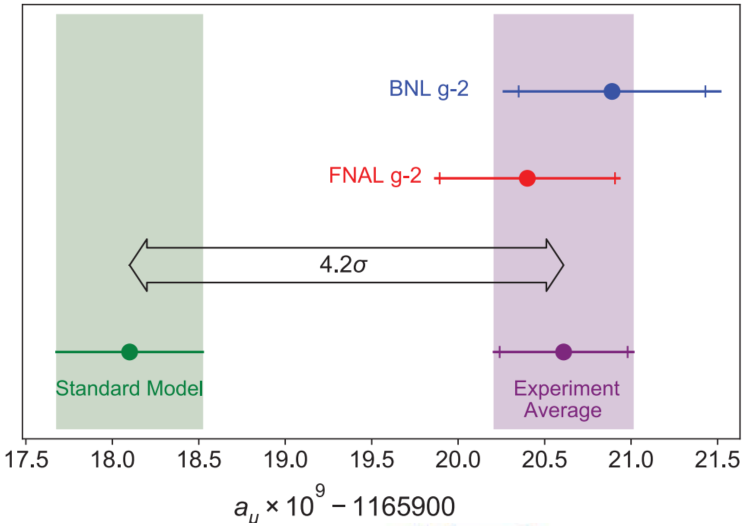


Blue: π/K mis-PID in KK Collins measurement.
Left) de/dx&TOF.   Right) a 1% mis-PID set in FastSim

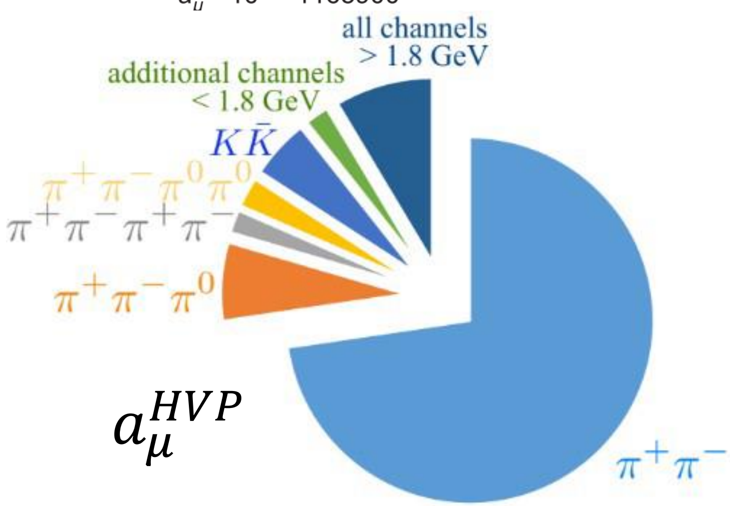
- By setting the K/π mis-PID at 1%,   we obtain[1]:
  - The statistical uncertainty for 25fb^{-1} MC is ~10^{-3} to 10^{-2}
  - The statistical uncertainty for 1ab^{-1} MC is ~10^{-4} to 10^{-3}

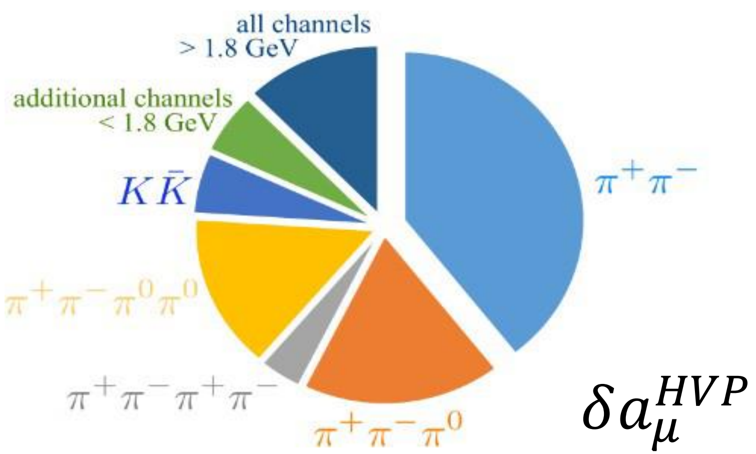
[1]. Wang B L, Lv X R, Zheng Y H. Journal of University of Chinese Academy of Sciences, 2021, 38(4):433-441

HVP Contribution to $(g-2)_\mu$



- **4.2σ discrepancy => Strong indication for physics beyond the SM?**
- **Dominant uncertainty of SM prediction comes from Hadronic vacuum polarization (HVP)**

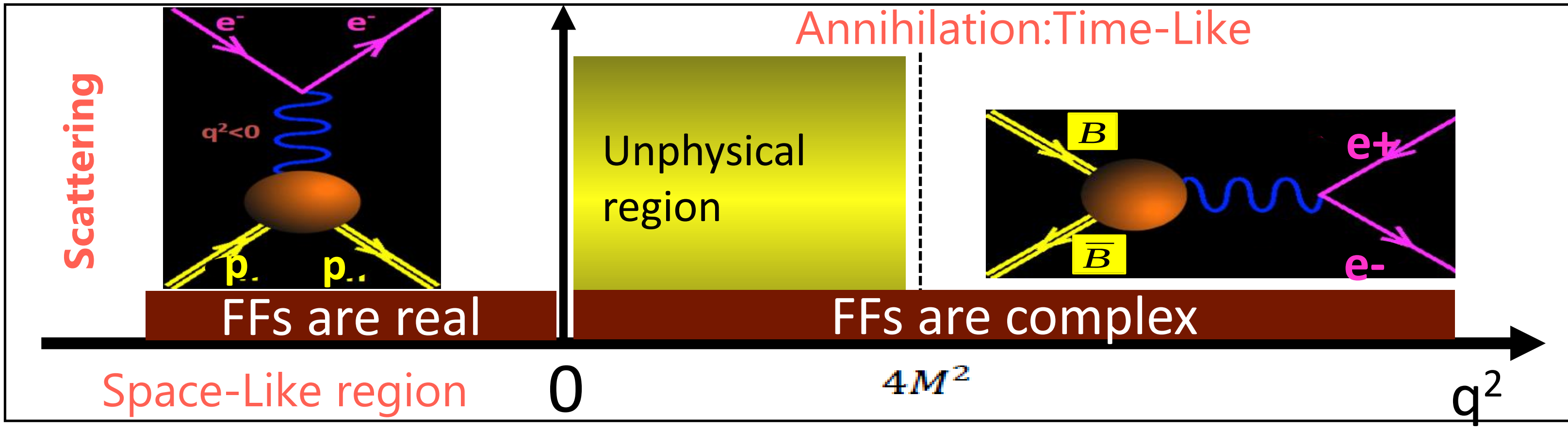




High Luminosity of STCF will largely improve the SM precisions !

Electromagnetic Form Factors

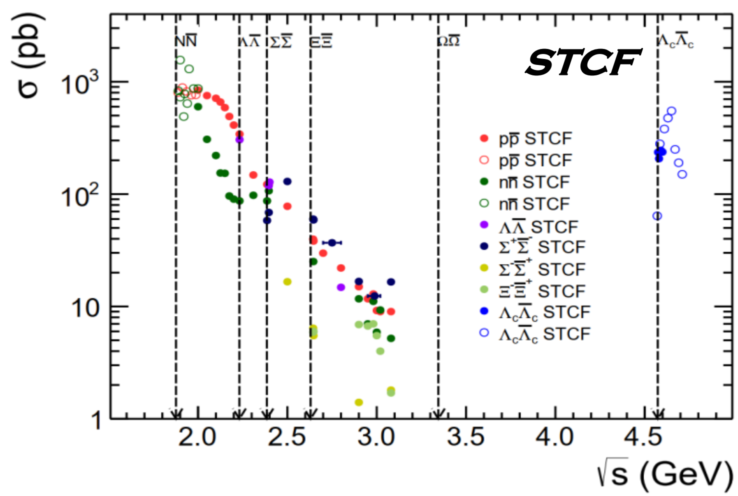
- **Fundamental properties of the nucleon**
  - ➢ **Connected to charge, magnetization distribution**
  - ➢ **Crucial testing ground for models of the nucleon internal structure**



$$\Gamma_\mu(p',p) = \gamma_\mu F_1(q^2) + \frac{i\sigma_{\mu\nu}q^\nu}{2m_p} F_2(q^2)$$

$$G_E(q^2) = F_1(q^2) + \tau\kappa_p F_2(q^2),$$

$$G_M(q^2) = F_1(q^2) + \kappa_p F_2(q^2)$$



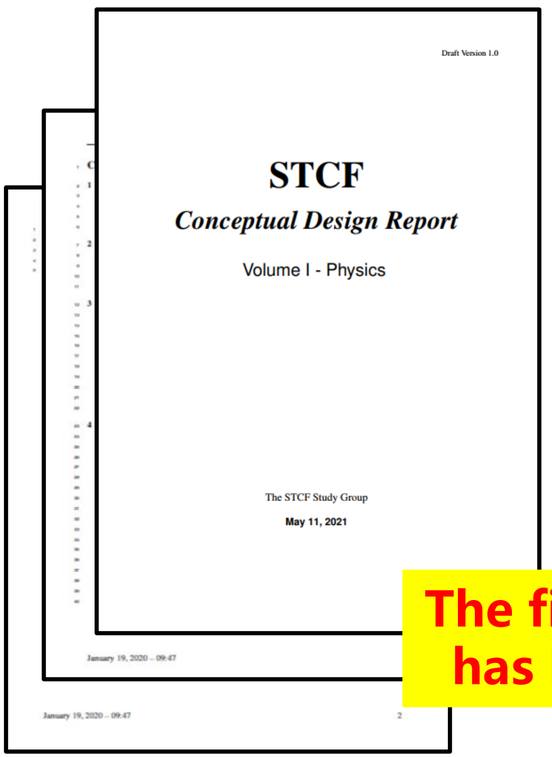
Strategy & Activities

CDR → TDR → project application → construction → commissioning

- Strategy: focus on CDR (4 years) and TDR (7 years) depend on the available resources. the construction site open.
- Domestic Workshops (2011, 12, 13, 14, 16, 20)
- International Workshops (2015, 18, 19, 20)
- 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 !

Tentative Plan

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030-2040	2041-2042
Form Group	■	■	■	■										
CDR	■	■	■	■										
TDR	■	■	■	■	■	■	■							
Construction							■	■	■	■	■	■		
In operation													■	
Upgrade														■


Draft Version 1.0

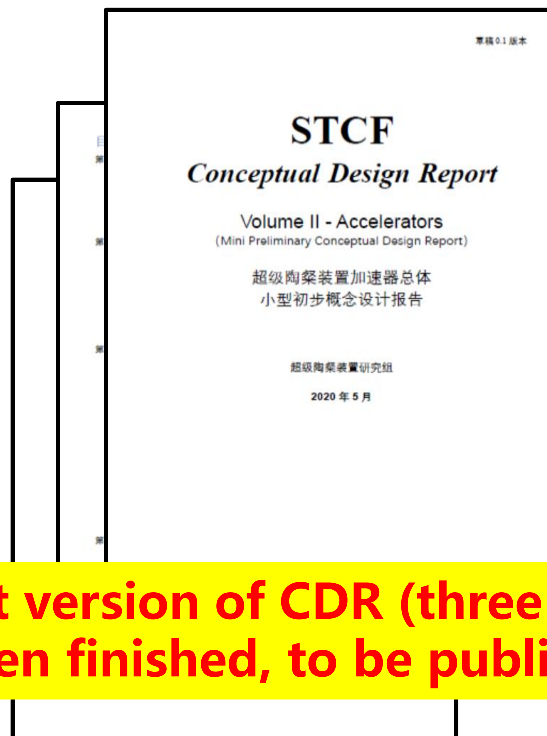
STCF

Conceptual Design Report

Volume I - Physics

The STCF Study Group

May 11, 2021


草稿 0.1 版本

STCF

Conceptual Design Report

Volume II - Accelerators

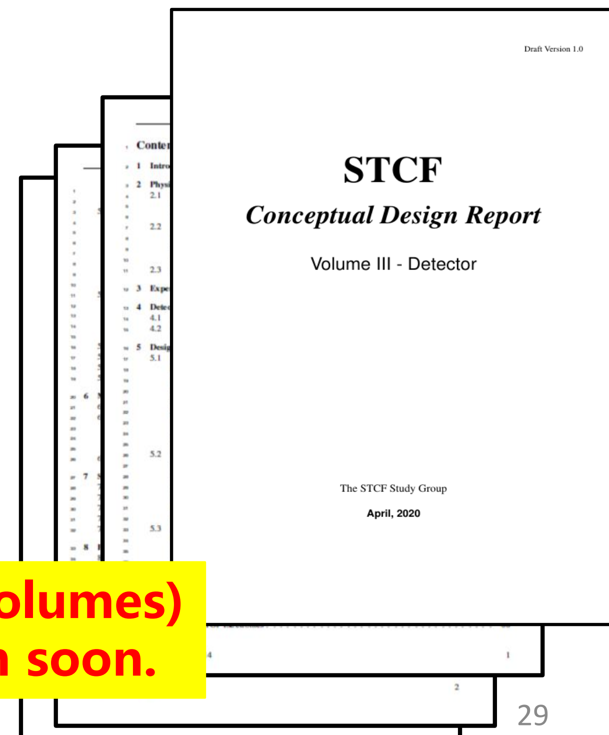
(Mini Preliminary Conceptual Design Report)

超级陶粲装置加速器总体

小型初步概念设计报告

超级陶粲装置研究组

2020 年 5 月


Draft Version 1.0

STCF

Conceptual Design Report

Volume III - Detector

The STCF Study Group

April, 2020

The first version of CDR (three volumes) has been finished, to be publish soon.

Activities

Website: http://cicpi.ustc.edu.cn/indico/categoryDisplay.py?categId=2

High Luminosity Tau Charm Physics

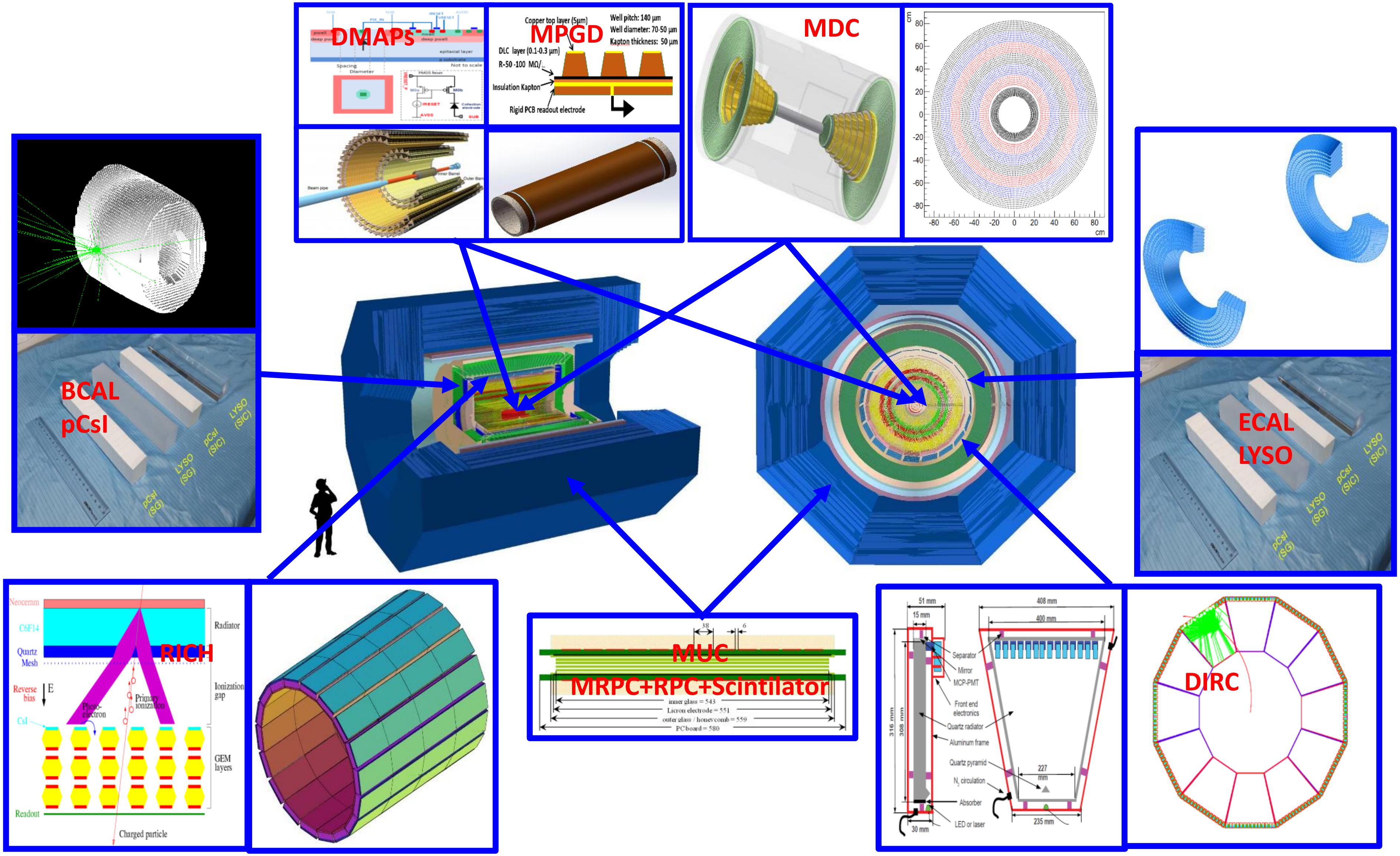
Indico for High Luminorcity Tau Charm Physics R&D

STCF Steering Committee	1 event
STCF Accelerator	103 events
STCF Physics	24 events
STCF Detector	
STCF Accelerator-Detector Joint meetings	
STCF International Conference	
STCF Domestic meeting	

STCF Detector

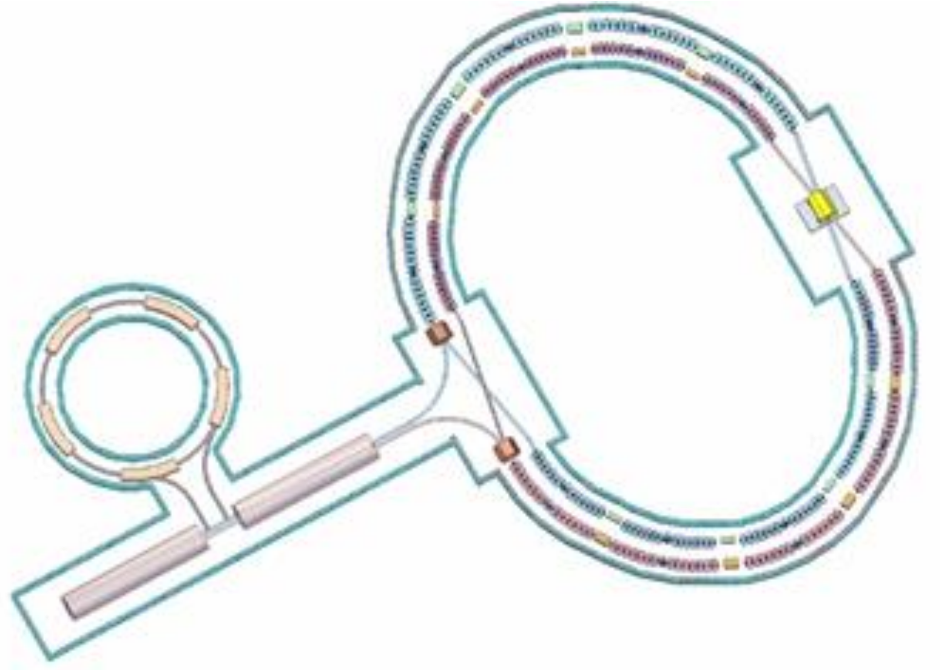
STCF Tracker&Muon Working Group	5 events
STCF PID Working Group	68 events
STCF ECAL Working Group	64 events
STCF Software group meeting	112 events
STCF Physics Simulation Working Group	61 events
Joint Meeting on Software/Physics with Russian Group	8 events
Management Group Meeting	2 events
Informal Meetings	17 events
Share	10 events

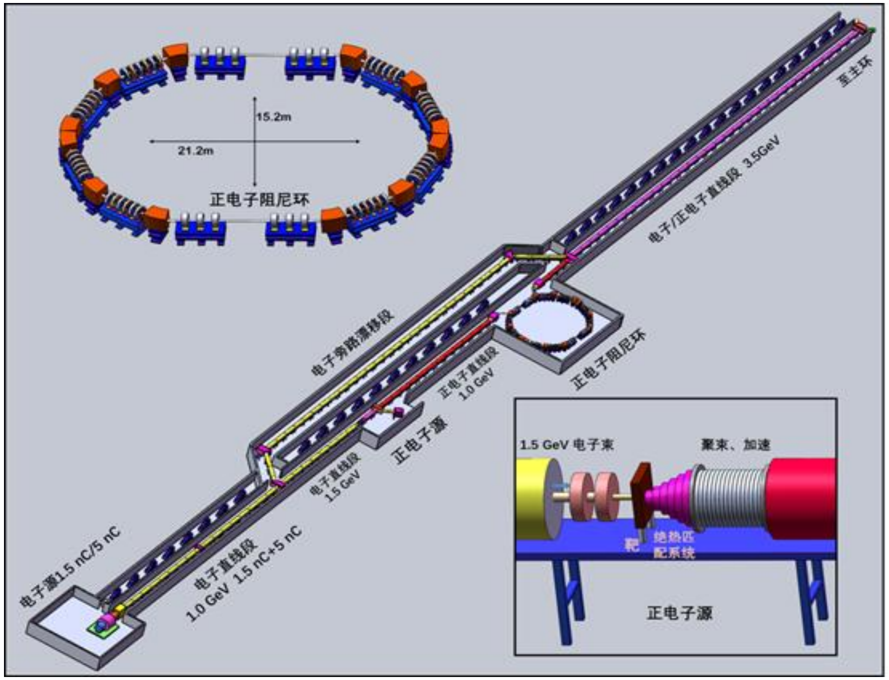
Spectrometer



Accelerator

Interaction Region : Large Piwinski Angle Collision + Crabbed Waist





Injector:

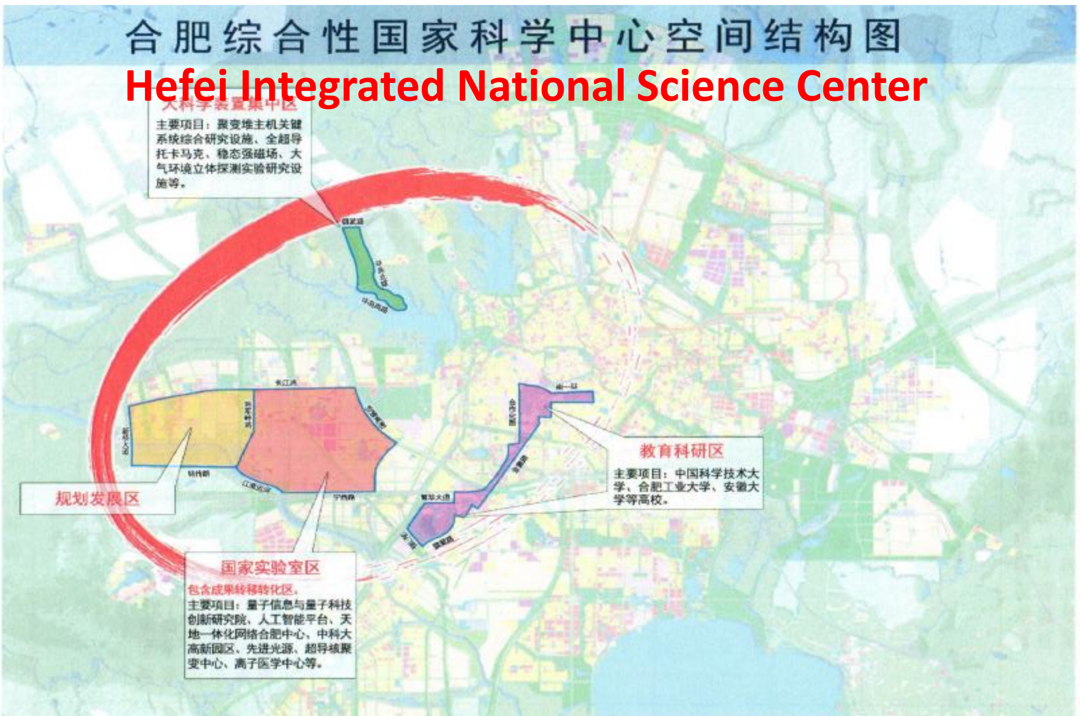
- No booster, 0.5 GeV→1~3.5 GeV
- e+, a convertor, a linac and a damping ring, 0.5 GeV
- e-, a polarized e- source, accelerated to 0.5 GeV

Machine Parameters

Parameters	Phase1	Phase2
Circumference/m	600~800	600~800
Optimized Beam Energy/GeV	2.0	2.0
Beam Energy Range/GeV	1-3.5	1-3.5
Current/A	2.0	2.0
Emittance($\varepsilon_x/\varepsilon_y$)/nm·rad	6/0.06	5/0.05
β Function @ IP (β_x^*/β_y^*)/mm	90/0.9	50/0.5
Full Collision Angle 2θ/mrad	60	60
Tune Shift ξ_y	0.06	0.08
Hourglass Factor	0.8	0.8
Aperture and Lifetime	15σ, 1000s	15σ, 1000s
Luminosity @ Optimized Energy / $\times 10^{35}$ cm^{-2}s^{-1}	~0.5	~1.0

Candidate Site : Hefei

One of three integrated national science centers, which will play important role in 'Megascience' of China in near future



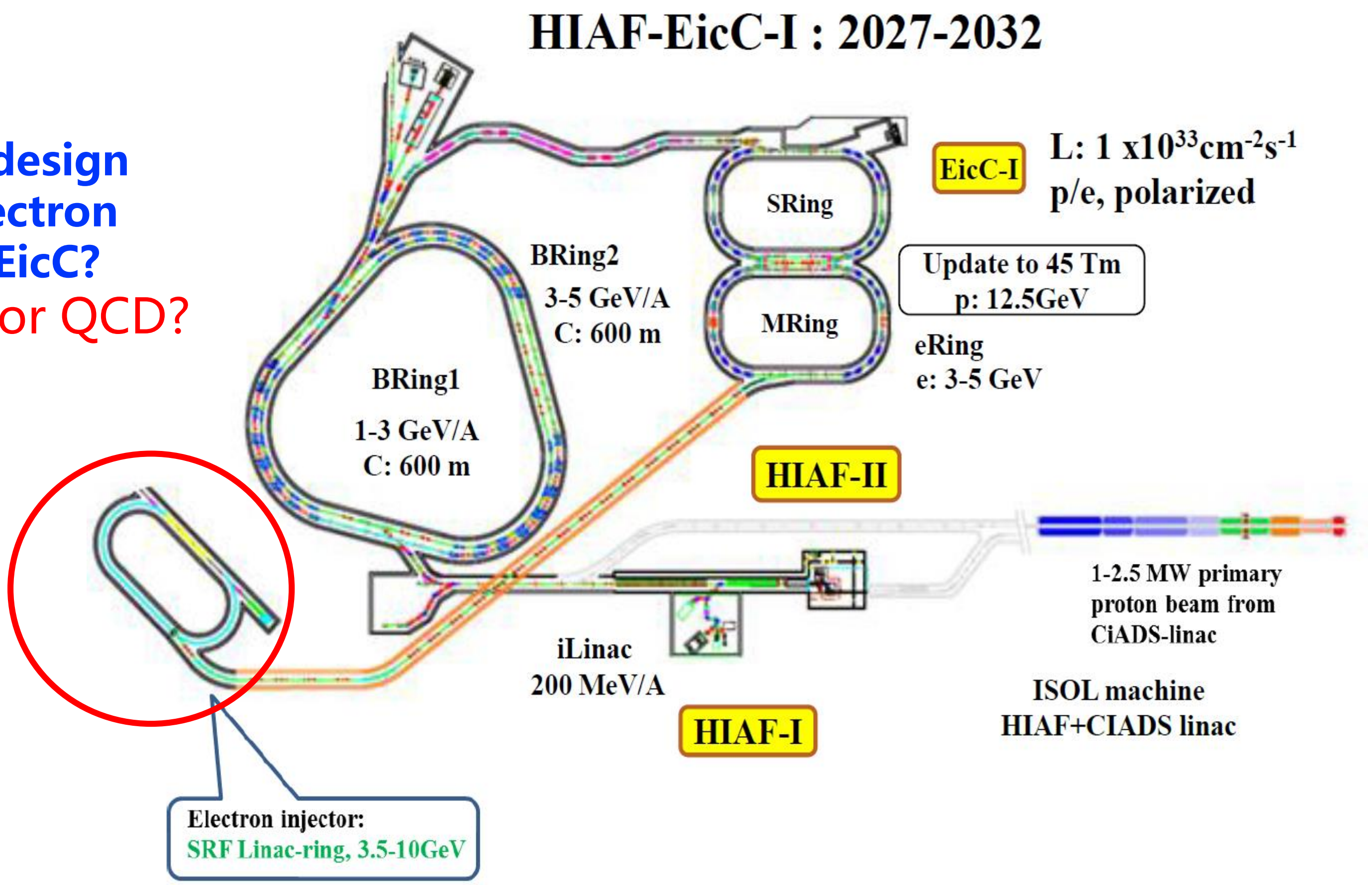
- University of Science and Technology of China (USTC)
- National Synchrotron Radiation Lab and Hefei Light Source, operated by USTC
- The only National Lab operated by University in China. (Totally Four officially approved National Labs in China)

- **Pay a lot of attention on accelerator facilities**
- **Hefei Advanced light source is under design**
- **STCF is listed in future plan**

Candidate Site : Huizhou

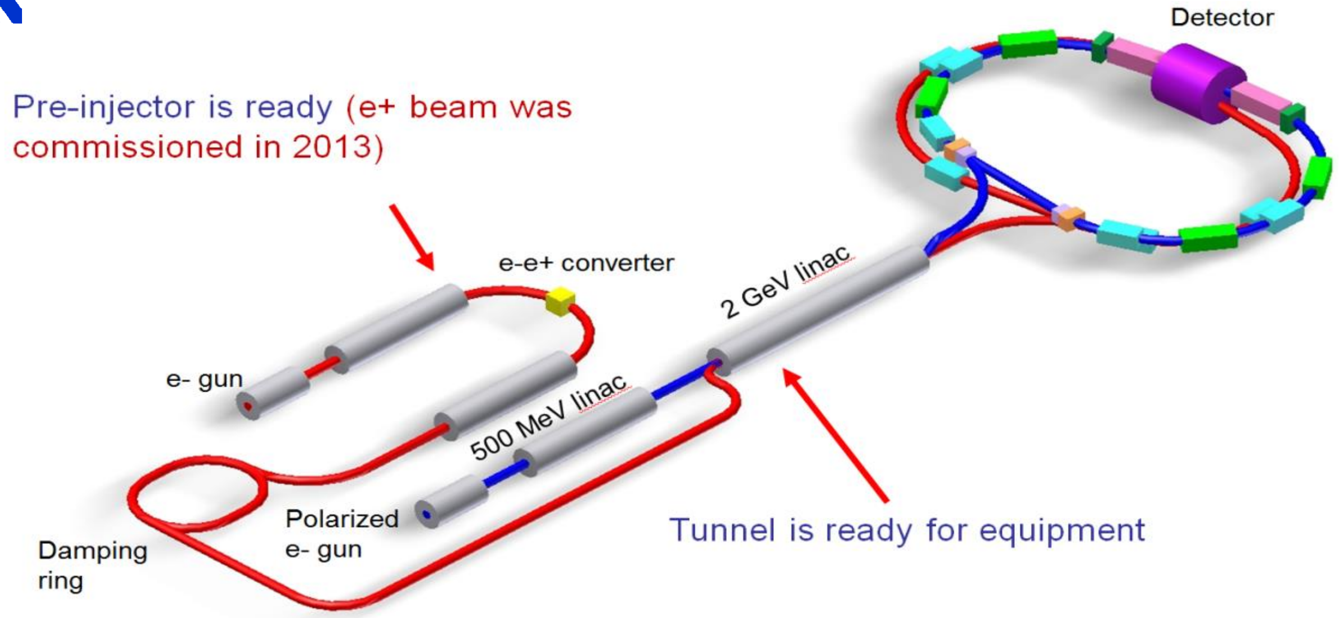
Institute of Modern Physics, CAS, proposed building HIAF-EicC in Huizhou, Canton

STCF Share the design effort of the electron accelerator of EicC?
National Center for QCD?



International Collaboration

Super Charm-Tau at Novosibirsk, RUSSIA,
Budker Institute of Nuclear Physics (BINP)



- 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), 2020 Online (November)

Summary

- **Super τ-c Facility** (STCF):
  - e^+e^- collision with E_{cm} = 2 – 7 GeV, L > 0.5 × 10^{35} $cm^{-2}s^{-1}$
- **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.
- **Complementary to Belle-II and LHCb in understanding the QCD/EW models and searching for new physics**
- **Project organization is setup and a working group is toward for CDR/TDR**
- **An International collaboration is essential for promoting the project.**

Welcome to join the effort

Thank you!