Physics program and simulations of the STCF experiment

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Joint Workshop on Future Super charm-tau Factory

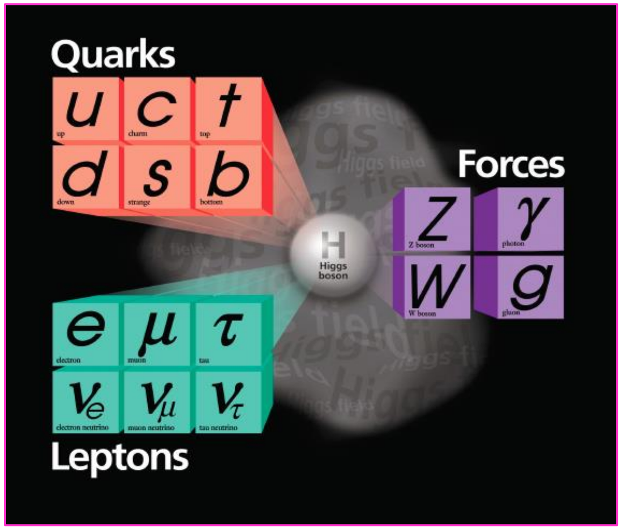
2021.11.15

The Standard Model

The standard model of particle physics is a well-tested theoretical framework,

However, the SM has a number of issues need further investigation:

- The nature of quark confinement
- Matter-antimatter asymmetry of the Universe
- Gravity, dark matter, neutrino masses, numbers of flavors, etc.



19 free parameters of the SM

Masses

Parameter	Value	Method
m_u	1.9 MeV	Lattice
m_d	4.4 MeV	Lattice
m_s	87 MeV	Lattice
m_c	1.3 MeV	Collider
m_b	4.24 MeV	Collider
m_t	173 GeV	Collider
m_e	511 keV	Non-collider
m_μ	106 MeV	Non-collider
m_τ	1.78 GeV	Collider
m_z	91.2 GeV	Collider
m_H	125 GeV	Collider

Couplings

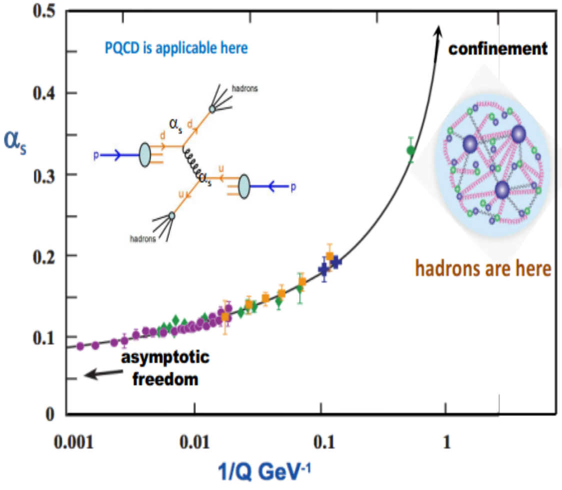
Parameter	Value	Method
α	0.0073	non-collider + collider
G_F	1.17x10^{-5}	Non-collider
α_s	0.12	Lattice + collider

Flavour and CP violation

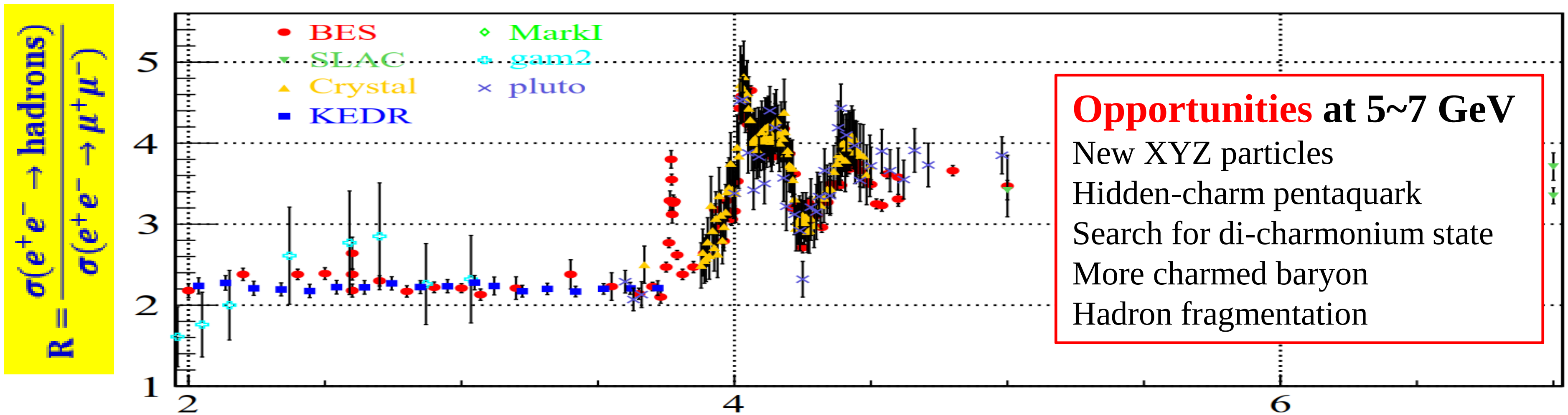
Parameter	Value	Method
θ_{12} (CKM)	13.1°	Collider
θ_{23} (CKM)	2.4°	Collider
θ_{13} (CKM)	0.2°	Collider
δ (CKM-CPV)	0.995	Collider
θ (strong CP)	~0	Non-collider

Does not include neutrino masses and mixing angles

QCD coupling strength



Physics in tau-Charm Region



Expected data with 1ab^{-1} at STCF

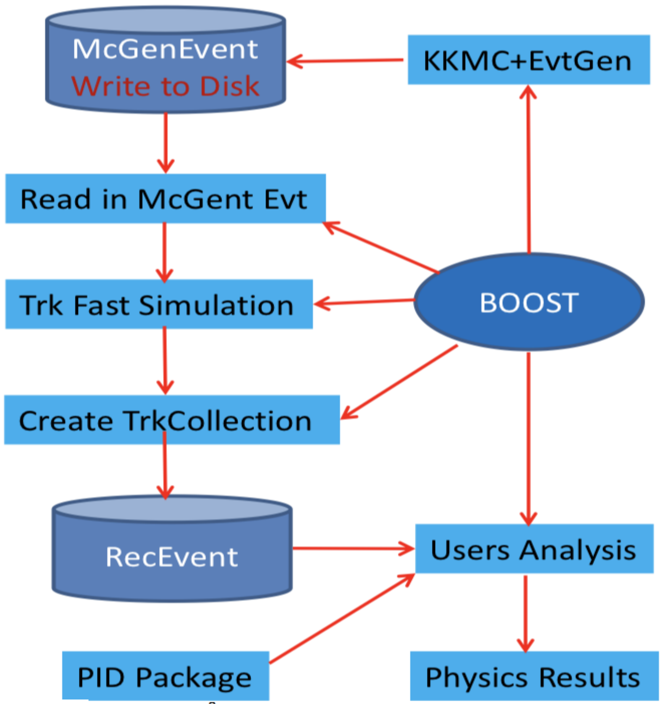
CME (GeV)	No. of Events
3.097	3 T J/ψ
3.686	500 B ψ'
3.77	3.6 B D^0 2.8 B D^+
4.009	0.2 B Ds
4.23	1 B Y(4260) 100 M Zc 5 M X(3872) 3.6 M tau
4.63	0.5 B Λ_c

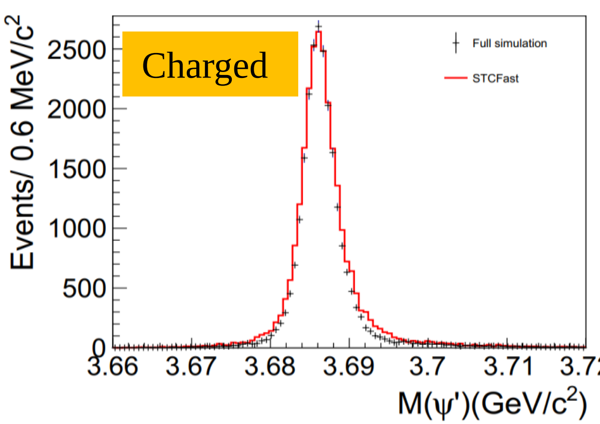
- The interplay of perturbative and nonperturbative dynamics
- Unique features: Rich of resonances, Threshold characteristics, Quantum correlation
  - Hadron spectroscopy and QCD
  - Flavor and CP violation
  - Forbidden/Rare decay and the new particles

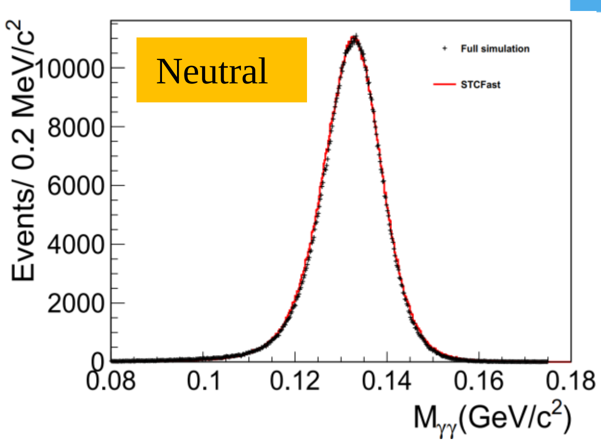
Fast simulation package

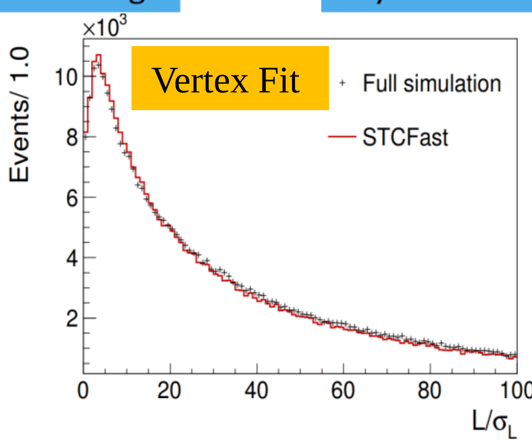
JINST 16 (2021) 03, P03029

- The FastSim can provide a critical tool for exploring **physics requirement** and **physics performance**;
- The FastSim takes the response of physical objects in each sub-detector: resolution, efficiency, helix, error matrix etc.
- Geant4 free, save time and space
- The package is validated well by comparing fast simulation and BESIII's result







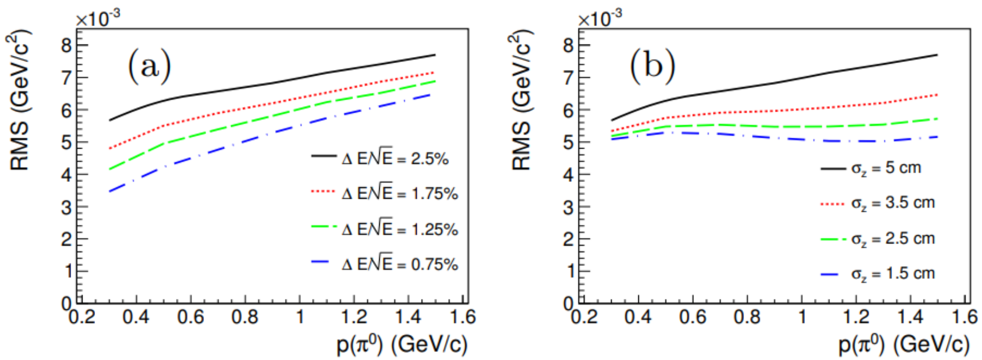


Fast simulation package

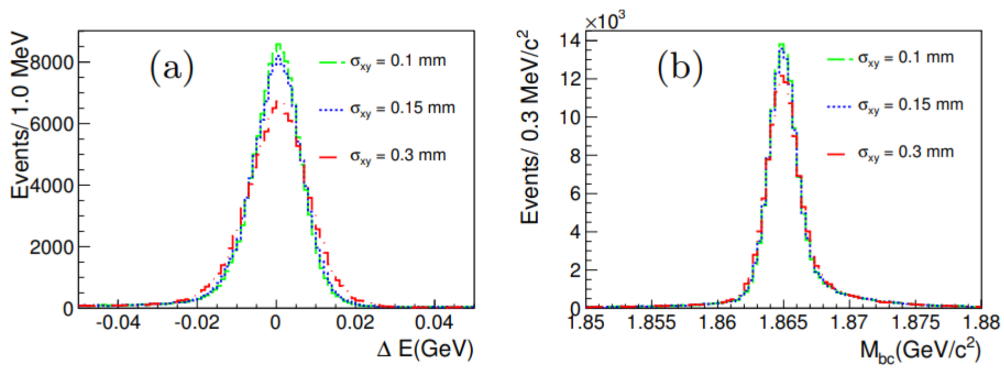
JINST 16 (2021) 03, P03029

- **The FastSimu provide flexibly adjusted responses in each sub-system, which is helpful for the optimization of detector design during R&D.**

  - RMS of π^0 with different energy/position resolution of photon:

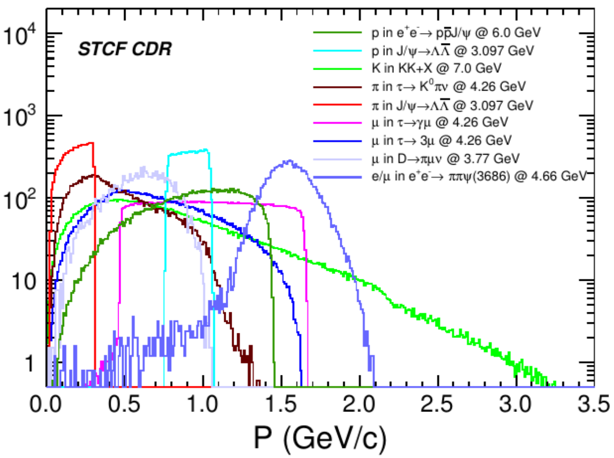


  - D tag with different track resolution:

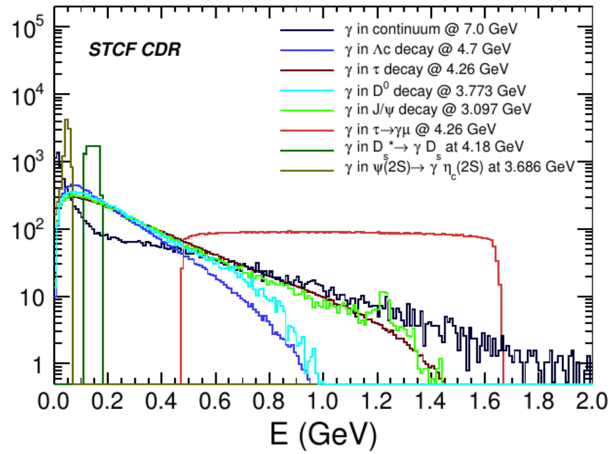


Physics requirements

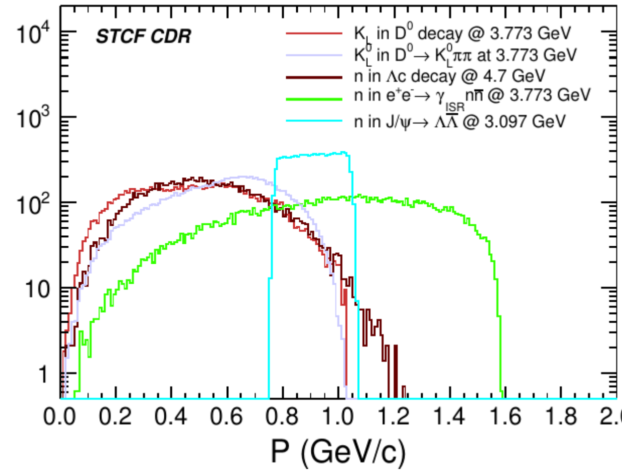
Charged particles



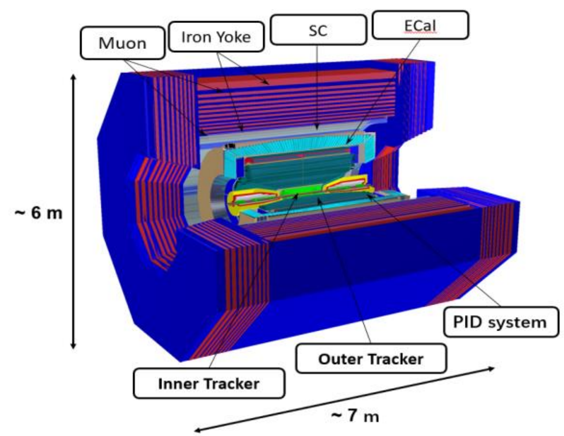
Photons



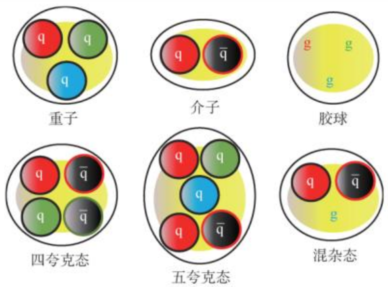
Neutral hadrons

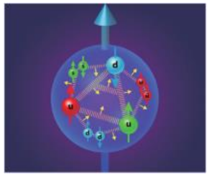


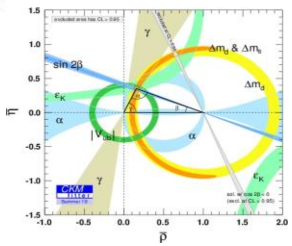
Physics Process	Physical Interest	Optimized Sub-detector	Requirements
$\tau \to K_s \pi \nu_\tau$, $J/\psi \to \Lambda\bar{\Lambda}$, $D_{(s)}$ tag	CPV in τ sector, CPV in hyperon sector, Charm physics	Tracker	acceptance: 93% of 4π; trk. effi.: $> 99\%$ at $p_T > 0.3$ GeV/c; $> 90\%$ at $p_T = 0.1$ GeV/c $\sigma_p/p = 0.5\%$, $\sigma_{\gamma\phi} = 130\ \mu$m at 1 GeV/c
$e^+e^- \to KK + X$, $D_{(s)}$ decays	Fragmention function, CKM matrix, LQCD etc.	PID	π/K and K/π mis-identification rate $< 2\%$ PID efficiency of hadrons $> 97\%$ at $p < 2$ GeV/c
$\tau \to \mu\mu\mu$, $D_s \to \mu\nu$	cLFV decay of τ, CKM matrix, LQCD etc.	MUC, PID	π/μ suppression power over 30 at $p < 2$ GeV/c, μ efficiency over 95% at $p = 1$ GeV/c
$\tau \to \gamma\mu$, $\psi(3686) \to \gamma\eta(2S)$	cLFV decay of τ, Charmonium transition	EMC	$\sigma_E/E \approx 2.5\%$ at $E = 1$ GeV $\sigma_{\text{pos}} \approx 5$ mm at $E = 1$ GeV
$e^+e^- \to n\bar{n}$, $D_0 \to K_L\pi^+\pi^-$	Nucleon structure Unity of CKM triangle	EMC, MUC	$\sigma_T = \frac{300}{\sqrt{p^3(\text{GeV}^3)}}$ ps

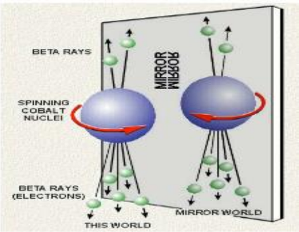


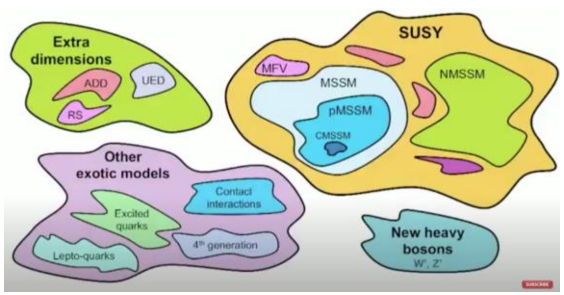
Physics program at STCF











Physics at STCF

QCD and hadronic physics

- **XYZ Properties:** e+e-→Y→γX,ηX,ϕX; e+e-→Y→πZc, KZcs
- **Hadron Spectroscopy:** Excited ccbar and their transition, Charmed hadron spectroscopy, Light hadron spectroscopy
- **R value:** e+e-→inclusive; τ mass: e+e-→τ+τ-
- **Nucleon Form Factors:** e+e-→BBbar from threshold
- **Pentaquarks:** e+e-→J/ψppbar, Λc Dbar pbar, Σc Dbar pbar
  Di-charmonium: e+e-→J/ψηc, J/ψhc
- **Muon g-2:** e+e-→π+ π-, π+ π- π0, 4π, K+ K-, γγ→π0, η(′),π+ π-
- **Fragmentation functions:** e+e-→(π,K,p,Λ,D)+X, e+e-→(ππ,KK,πK)+X

Flavor Physics and CP Violation

- **CKM matrix (Vcd, Vcs):** D_(s)+→l+ν, D→P l+ ν
- **Charm hadron decay:** Λc+, Σc, Ξc, Ωc decay
- **CPV in Hyperons:** J/ψ→ΛΛbar, ΣΣbar, Ξ- Ξ+bar, Ξ0 Ξ0bar
- **D0-D0bar mixing:** ψ(3770)→(D0 D0bar)(CP=-), ψ(4140)→π0 (D0 D0bar)(CP=-) or γ(D0 D0bar)(CP=+)
- **CPV in τ:** τ→Ks πν, EDM of τ, τ→π/K π0 ν for polarized e- beam
- **CPV in Charm:** D0→K+K-/π+π-, Λc→pK-π+π0/Λπ+π+π-/pKs π+π-
- **γ/ϕ3 measurement:** D0→K(s/L) π+ π-, K(s/L) K+ K-,K3π, 4π
- **γ polarization:** D0→K1 e+ ν_e

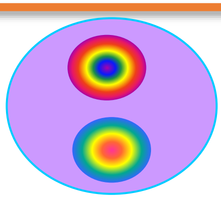
Forbidden/Rare decay and New Particle

- **LNV, BNV:** D(s)+→l+ l+ X-, J/ψ→Λc e-, B→Bbar…
- **Symmetry violation:** η(′)→llπ0, η′→ηll…
- **FLV decays:** τ→γl, lll,l P1 P2 , J/ψ→ll′, D0→ll′ (l′≠l)…
- **FCNC:** D→γV, D0→l+ l-, e+e-→D∗ , Σ+→pl+ l-…
- **Dark photon:** e+e-→γA′(→l+ l-), J/ψ→e+e-A′…
  Millicharged: e+e-→χχ̄γ…

- Leading role
- In Competition with BelleII/LHCb
- Synergy with BelleII/LHCb/Eic/EicC

Some Physics Performance

Charmonium (Like) Spectroscopy



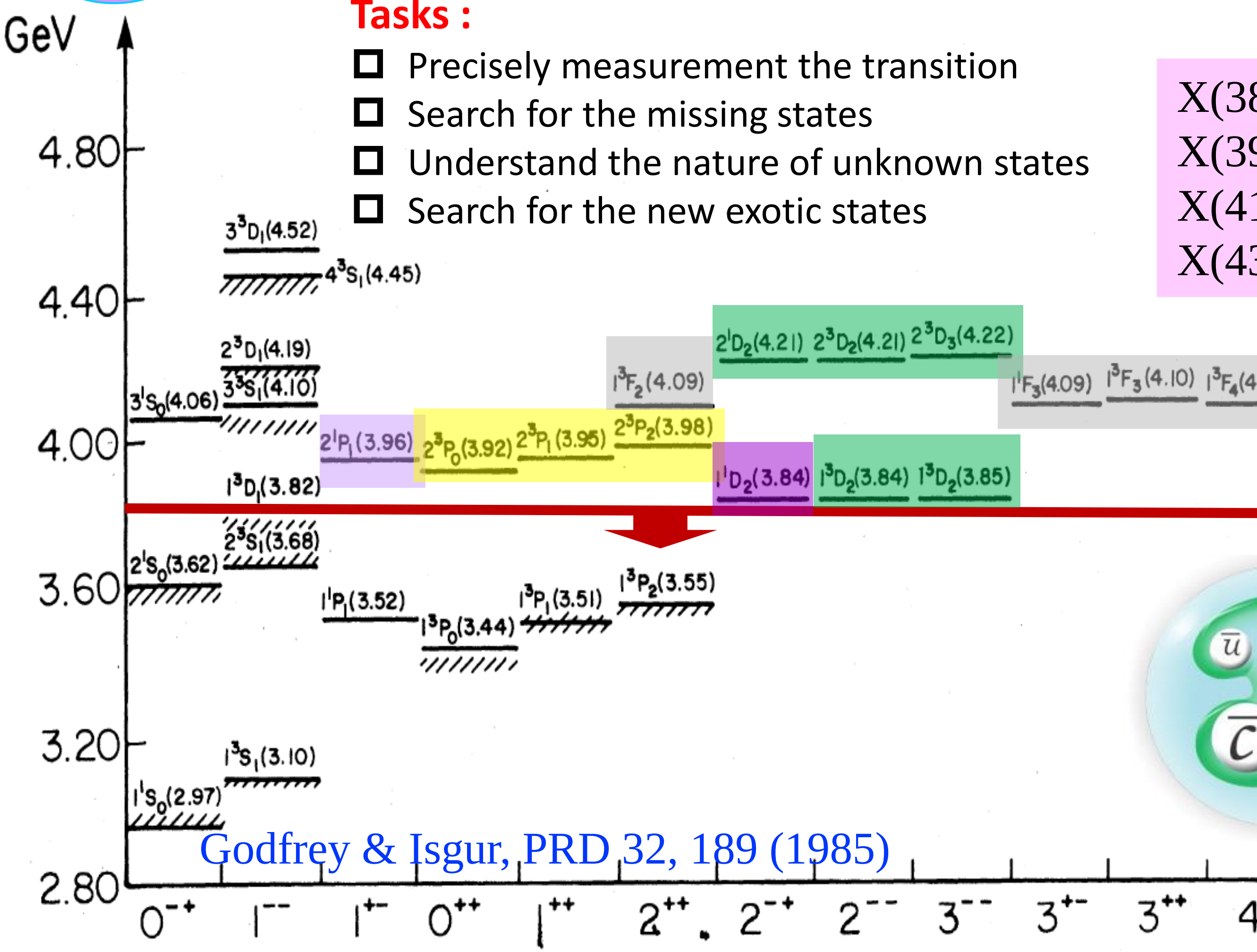
Excellent platform to explore the QCD

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

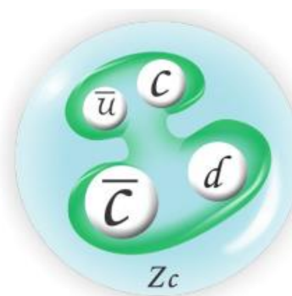
Tasks :

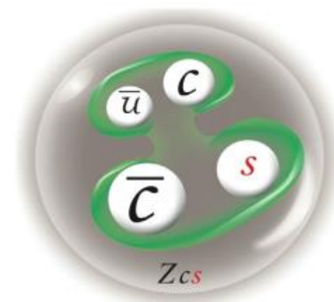
- ☐ Precisely measurement the transition
- ☐ Search for the missing states
- ☐ Understand the nature of unknown states
- ☐ Search for the new exotic states

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)	$Z_c(4250)$
		$Z_c(4430)$
		$Z_{cs}(3985)$
		$Z_{cs}(4000)$
		$Z_{cs}(4220)$

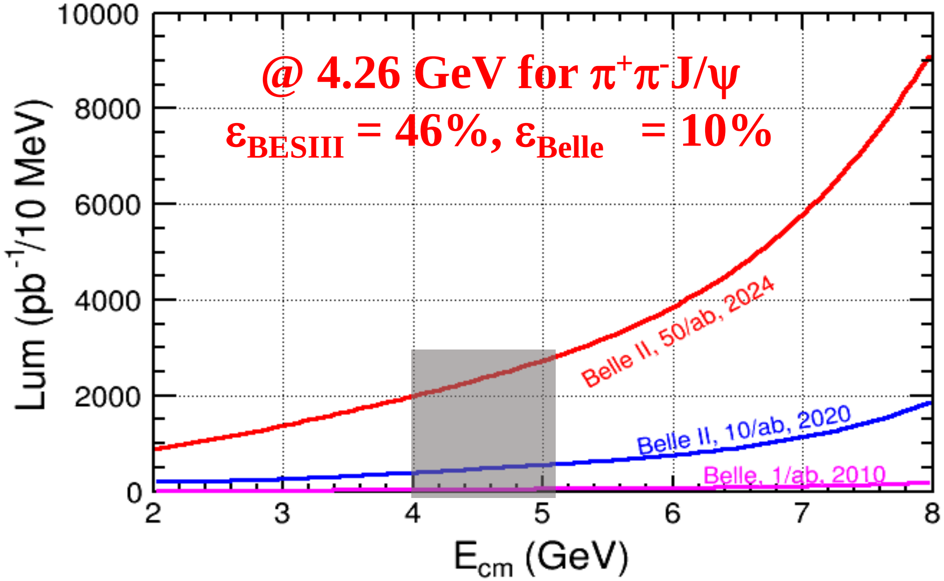


Godfrey & Isgur, PRD 32, 189 (1985)



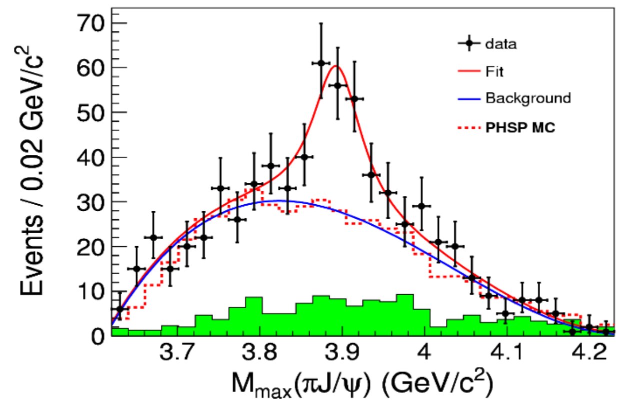


Charmonium(Like) Spectroscopy at STCF

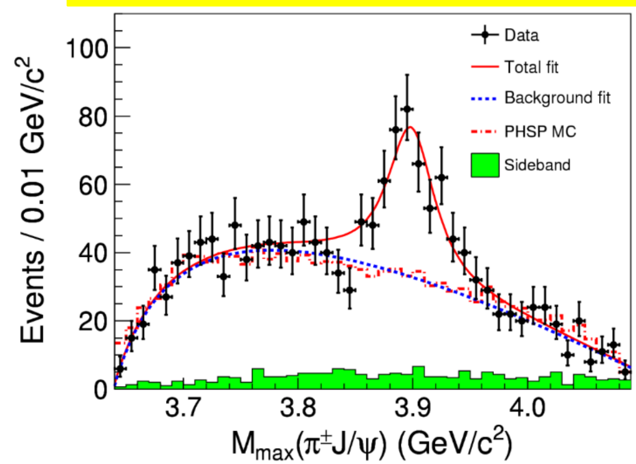


- B factory : Total integrate effective luminosity between 4-5 GeV is 0.23 ab^{-1} for 50 ab^{-1} data
- τ-C factory : scan in 4-5 GeV, 10 MeV/step, every point have 10 fb^{-1}/year, 5 time of Belle II for 50 ab^{-1} data
- τ-C factory have much higher efficiency and low background than B Factory

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

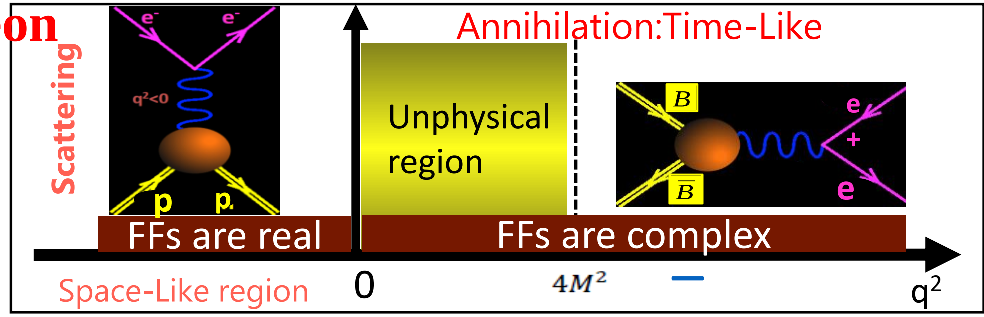


BESIII at 4.260 GeV: PRL110, 252001
0.525 fb^{-1} in one month running time



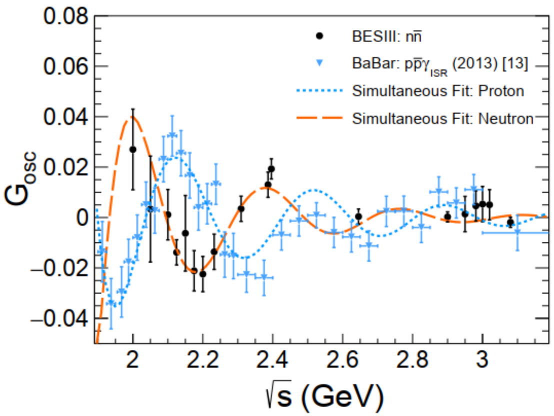
Electromagnetic Form Factors

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

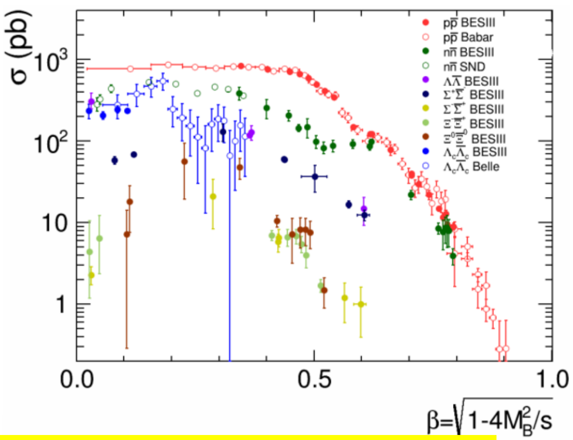


- **Mysteries observed from current experimental results in time-like**

Nat. Phys. 17, 1200–1204 (2021)

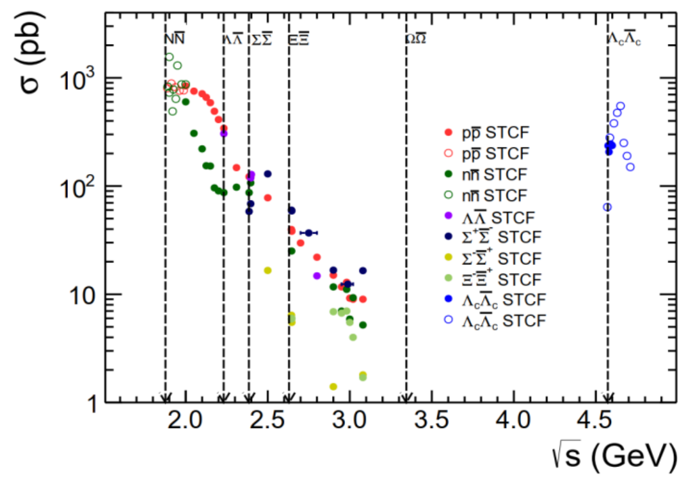


National Science Review, nwab187

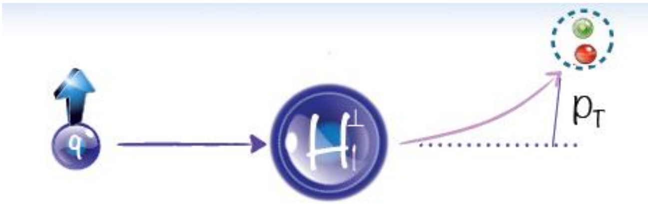


- **Oscillation features in form factors**
- **Threshold effect of baryon pair production**

STCF prospect

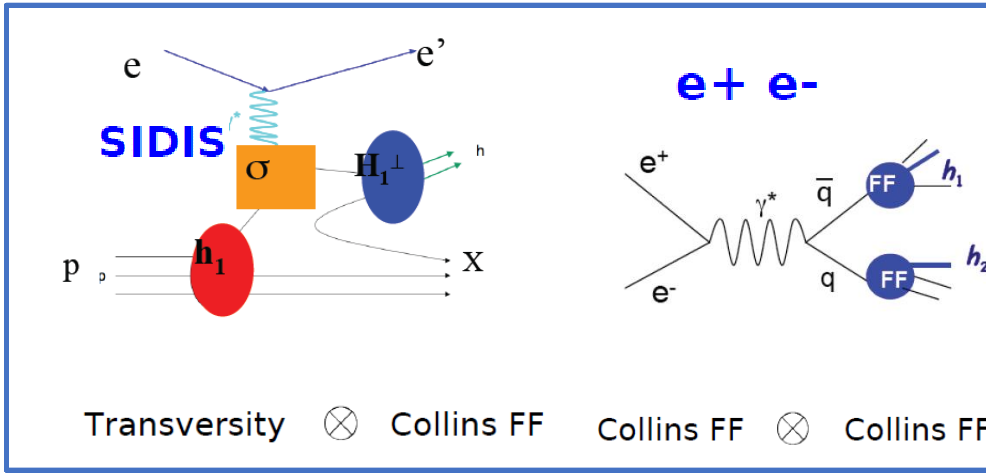


Collins Fragmentation Function (FF)

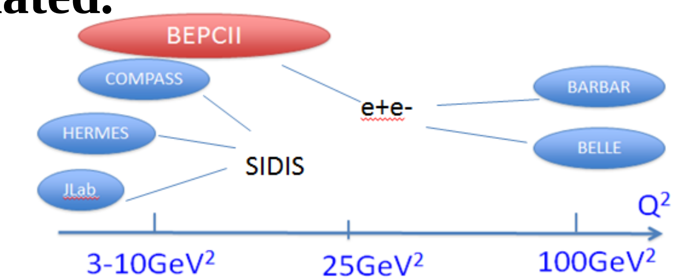


J. C. Collins, Nucl. Phys. B396, 161 (1993)

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



- [ ] **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**



STCF is a perfect machine for studying Collins effect
The statistical uncertainty of $\pi\,\pi$/ KK Collins with 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

For more about FFs, please see Yuxiang Zhao's talk on Nov.15th

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?

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

TCF + B factories + LQCD

Three generations of quark?

Unitary matrix?

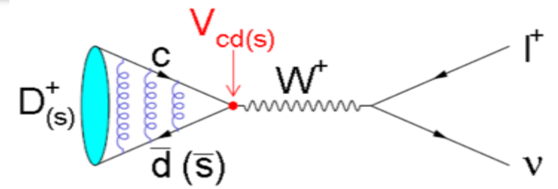
Expected precision < 2% at BESIII
How about at STCF

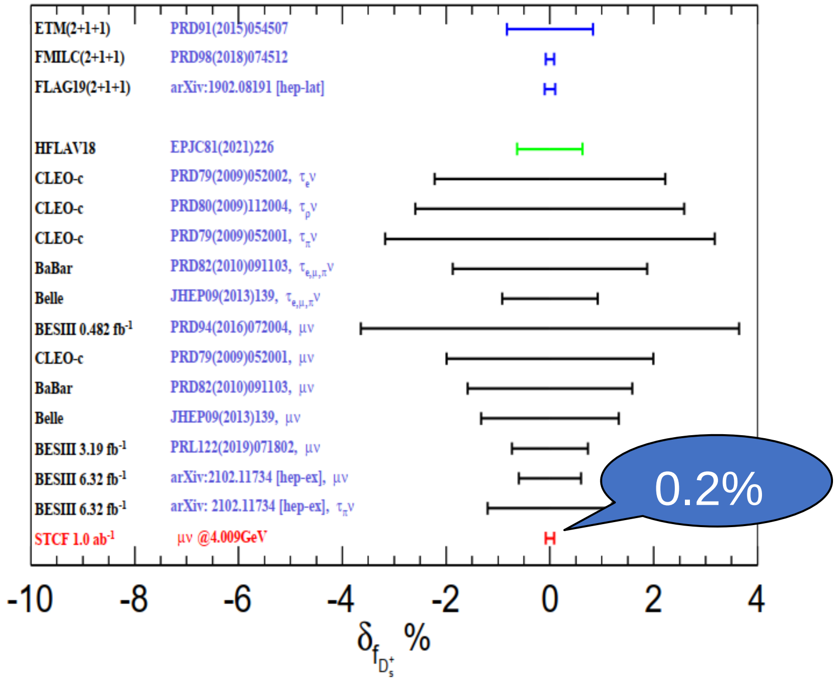
TCF + B factories + LHCb + LQCD

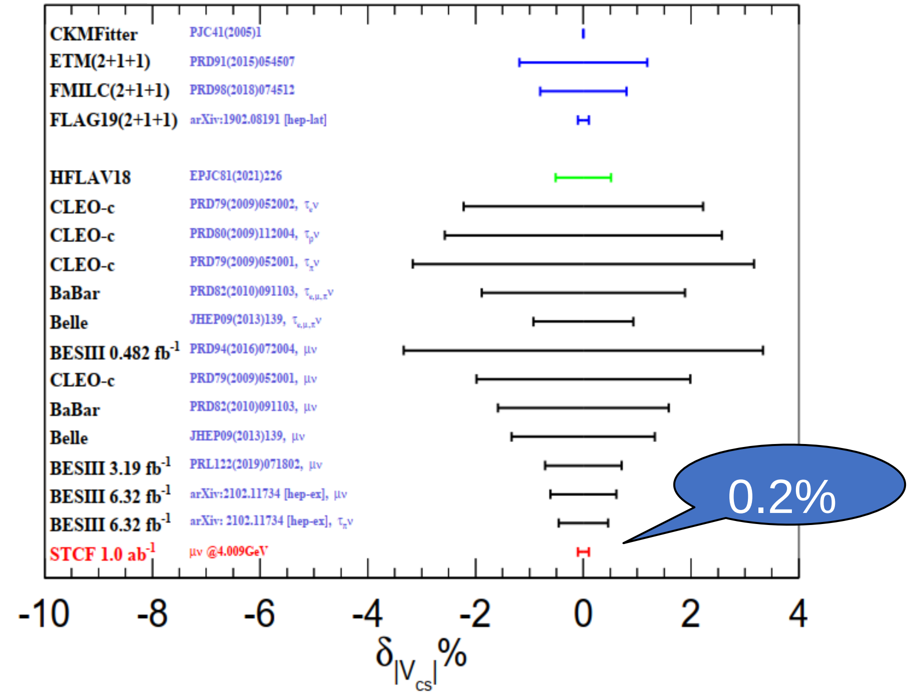
A direct measurement of $V_{cd(s)}$ is one of the most important task in charm physics

Prospects of $|V_{cs}|$ and $f_{D_s^+}$ in $D_s^+ \to l^+\nu_l$

$$\Gamma_{D_s^+ \to \ell^+ \nu_\ell} = \frac{G_F^2}{8\pi} |V_{cs}|^2 f_{D_s^+}^2 m_\ell^2 m_{D_s^+} \left(1 - \frac{m_\ell^2}{m_{D_s^+}^2}\right)^2,$$







Parameters	Value	Uncertainty
G_F	$(1.1663787 \pm 0.0000006) \times 10^{-5}$ GeV^2	$\mathcal{O}(10^{-7})$
m_μ	$105.6583745 \pm 0.0000024$ MeV/c^2	$\mathcal{O}(10^{-8})$
$m_{D_s^+}$	1968.35 ± 0.07 MeV/c^2	0.003%
$\tau_{D_s^+}$	$(504 \pm 4) \times 10^{-15}$s	0.7%
$f_{D_s^+}$ (LQCD)	249.9 ± 0.5 MeV	0.2%
$\lvert V_{cs}\rvert$(global fit)	0.97320 ± 0.00011	0.01%

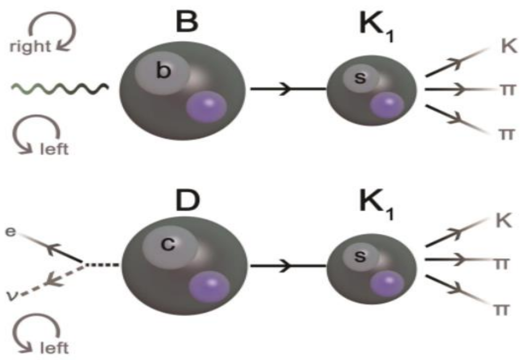
$$\sigma_{\text{syst.}} = \sqrt{\sigma_{\text{red.}}^2 \times (3.19^* \sigma_{4.18})/(1000^* \sigma_{4.01}) + \sigma_{\text{irred.}}^2 + \sigma_{\text{pre.}}^2}$$

Sys. Unc. : 1.0%

For details, please see Huijing Li's talk and Jiajun's poster on Nov.16th

Measuring $b \to s\gamma$ photon polarization in $D^0 \to K_1(1270)e\nu_e$

Yulan Fan *et al.*, arXiv:2107.06118 [hep-ex]

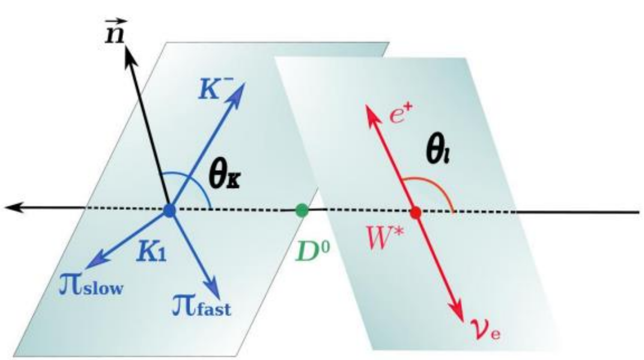


- The photon helicity in $b \to s\gamma$ is predominantly left-handed and its measurements plays a unique role in right-handed coupled in New Physics .
- Hadronic state helicity in $B \to K_1(\to K\pi\pi)\gamma$ Phys. Rev. Lett.112, 161801 (2014)

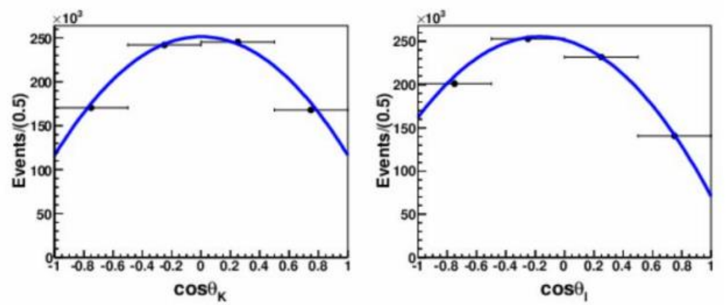
$$M_{K\pi\pi} \text{ in } (1.1,1.3) \text{ GeV}, \quad A_{UD} = (6.9 \pm 1.7) \times 10^{-2}$$

- A novel method is provided to combine the $B \to K_1\gamma$ and $D \to K_1 l^+\nu$ to determine the photon helicity $\lambda_\gamma = \frac{4\mathcal{A}_{UD}}{3\mathcal{A}'_{UD}}$ Phys. Rev. Lett. 125, 051802 (2020)

➢ **Kinematics for $D^0 \to K_1(1270)^- e^+\nu_e \to K^-\pi^+\pi^- e^+\nu_e$**



➢ **2-D χ^2 fit to $\cos\theta_K$ and $\cos\theta_l$**



statistical sensitivity 1.8×10^{-2} @$1ab^{-1}$ MC sample

For details, please see Yulan Fan's talk on Nov.16th

CPV in τ decay

H. Y. Sang, *et al.*, Chin. Phys. C 45, 053003 (2021)

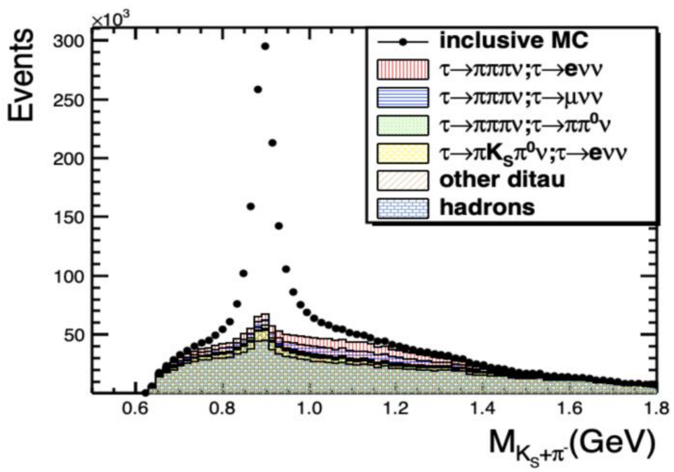
- The CPV source in $K^0 - \bar{K}^0$ **mixing** produces a difference in tau decay rate

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



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

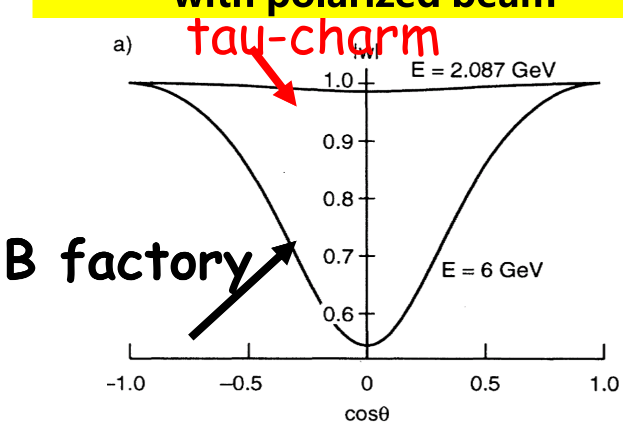
$A_{STCF} \sim 9.7 \times 10^{-4}$

With 10 ab^{-1} data:

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

Y.S Tai, Phys.Rev.D 51 (1995) 3172-3181

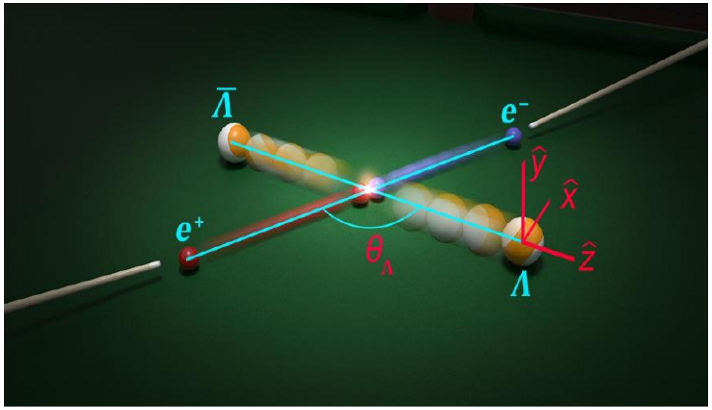
Possible choice of CPV study with polarized beam

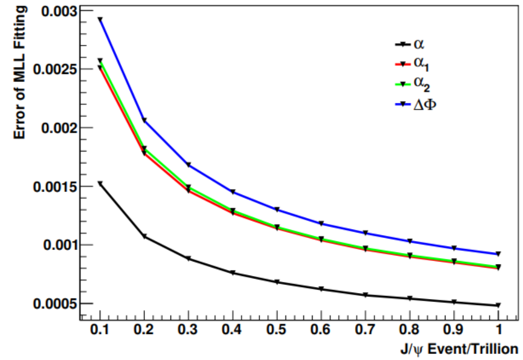


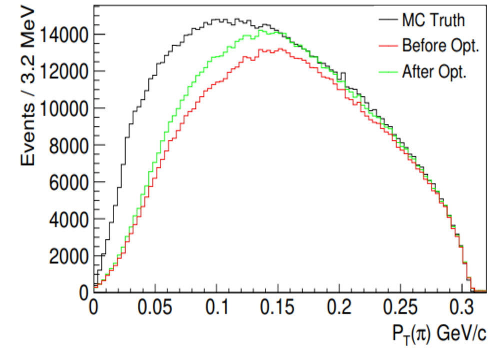
$$\text{merit} = \text{luminosity} \times \bar{w}_Z \times \text{total cross section}$$
$$\propto \text{luminosity} \times (w_1 + w_2)$$
$$\times \sqrt{1 - a^2} a^2 (1 + 2a) ,$$

Merit (STCF: B factory) = 7.7:1

CPV in Λ decay

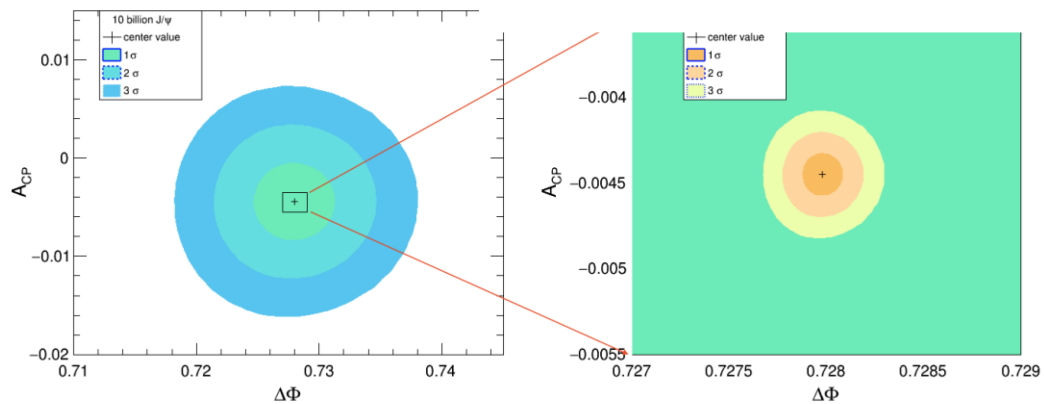






$$\mathcal{W}(\xi) = \mathcal{F}_0(\xi) + \alpha\mathcal{F}_5(\xi) + \alpha_1\alpha_2(\mathcal{F}_1(\xi) + \sqrt{1-\alpha^2}\cos(\Delta\Phi)\mathcal{F}_2(\xi) + \alpha\mathcal{F}_6(\xi)) + \sqrt{1-\alpha^2}\sin(\Delta\Phi)(\alpha_1\mathcal{F}_3(\xi) + \alpha_2\mathcal{F}_4(\xi)),$$

$$A_{CP} = \frac{\alpha_1+\alpha_2}{\alpha_1-\alpha_2}, \qquad P_y = \frac{\sqrt{1-\alpha^2}\sin\theta\cos\theta}{1+\alpha\cos^2\theta}\sin(\Delta\Phi).$$



- 3.4 trillion J/ψ events ⇒ $A_{CP} \sim 10^{-4}$
  - Luminosity optimized at J/ψ resonance
  - No polarization beams are needed
  - Optimized the efficiency of low momentum tracks

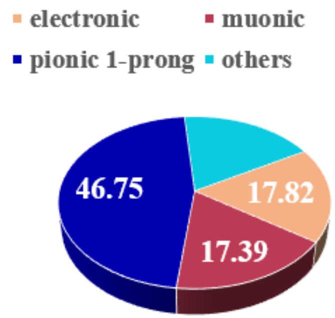
$-3 \times 10^{-5} \le A_\Lambda \le 4 \times 10^{-5}$
$-2 \times 10^{-5} \le A_\Xi \le 1 \times 10^{-5}$
$-5 \times 10^{-5} \le A_{\Xi\Lambda} \le 5 \times 10^{-5}$

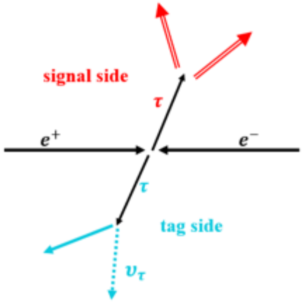
CKM

Tandean, Valencia PRD67, 056001

- feasibility study of Λ CPV with polarized e+ beam is undergoing

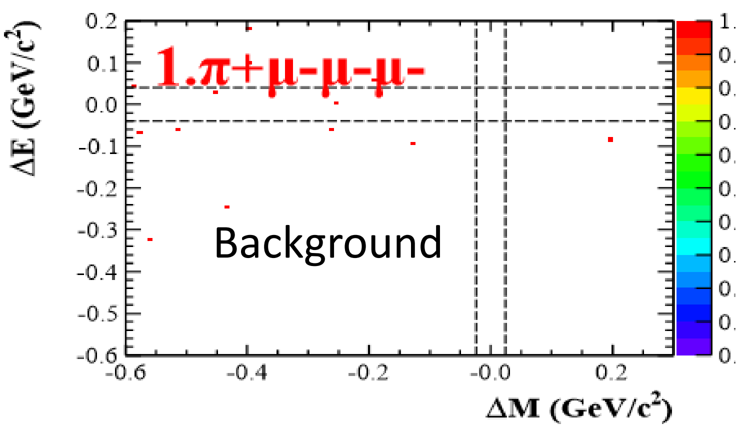
LFV decay of τ at STCF





- Precisely known kinematics of initial state
- Full reconstruction of signal side
- Neutrino in tag side is missing

- 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 :** $\boldsymbol{\mathcal{B}_{UL}^{90}\ (\tau \to \mu\mu\mu) \sim 1/\mathcal{L}}$
- Best efficiency ($\tau \to \mu\mu\mu$): 22.5% **(including tag branching fraction)**

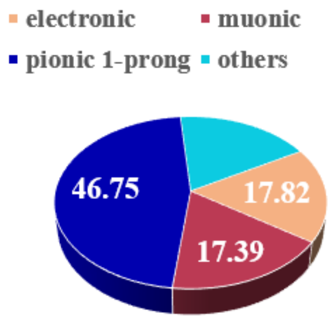


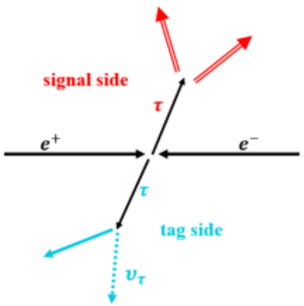
- **STCF with 1ab^{-1}:**

$$\mathcal{B}_{UL}^{90}(\tau \to \mu\mu\mu) < \frac{N_{UL}^{90}}{2\varepsilon N_{\tau\tau}} \sim 1.4 \times 10^{-9}$$

Model	Ref.	τ→μγ	τ→μμμ
SM + heavy majorana	PRD 66.034008	10^{-9}	10^{-10}
Non-universal Z'	PLB 547(3)252	10^{-9}	10^{-8}
SUSY + seesaw	PRL 89:241802	10^{-10}	10^{-7}
SM + 4th generation	arXiv.1006.5306	10^{-8}	10^{-8}

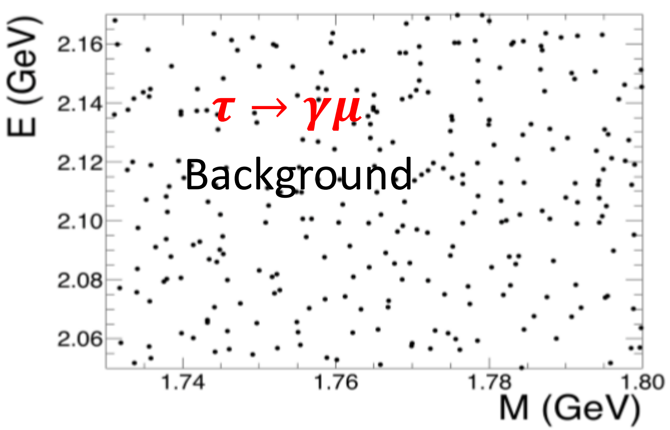
LFV decay of τ at STCF





- 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 $e^+e^- \to \tau^+\tau^-, \tau^+ \to \pi\pi^0\upsilon, \tau^- \to \mu\upsilon\bar{\upsilon}$

- **Stringent** selection criteria applied to remove the backgrounds
- Efficiency: 4.2%~8.5% depending on loose/strict cut **(include tag branching fraction)**
- **The sensitivity: $\mathcal{B}_{UL}^{90}(\tau \to \gamma\mu) \sim 1/\sqrt{\mathcal{L}}$**



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

$$\mathcal{B}_{UL}^{90}(\tau \to \gamma\mu) < \frac{N_{UL}^{90}}{2\varepsilon N_{\tau\tau}} \sim 1.6 \times 10^{-8}$$

For details, please see Teng Xiang's poster on Nov.16th

Summary

- **Super τ-c Facility** (STCF):
  - e^+e^- collision with $E_{cm} = 2 – 7$ GeV, $L > 0.5 \times 10^{35}\ cm^{-2}s^{-1}$
- **STCF is one of the crucial precision frontier**
  - rich of physics program
  - important playground for study of exotic hadrons, hadron structures, flavor physics, CPV and search for new physics.
- **Complementary to Belle-II and LHCb in understanding the QCD/EW models and searching for new physics**

Thanks for your attention!

Prospects of Physics Highlights

QCD and Hadronic Physics

not all-inclusive

Physics at STCF	Benchmark Processes	Key Parameters*
XYZ properties	$e^+e^- \to Y \to \gamma X, \eta X, \phi X$ $e^+e^- \to Y \to \pi Z_c, KZ_{cs}$	$N_{Y(4260)/Z_c/X(3872)}$~ $10^{10}/10^9/10^6$
Pentaquarks, Di-charmonium	$e^+e^- \to J/\psi p\bar{p}$, $\Lambda_c \bar{D}\bar{p}$, $\Sigma_c \bar{D}\bar{p}$ $e^+e^- \to J/\psi\eta_c$, $J/\psi h_c$	$\sigma(e^+e^- \to J/\psi p\bar{p})$~4 fb; $\sigma(e^+e^- \to J/\psi c\bar{c})$~10 fb (prediction)
Hadron Spectroscopy	Excited $c\bar{c}$ and their transition, Charmed hadron spectroscopy, Light hadron spectroscopy	$N_{J/\psi/\psi(3686)/\Lambda_c}$~ $10^{12}/10^{11}/10^8$
Muon g-2	$e^+e^- \to \pi^+\pi^-, \pi^+\pi^-\pi^0, K^+K^-$ $\gamma\gamma \to \pi^0, \eta^{(\prime)}, \pi^+\pi^-$	$\Delta a_\mu^{HVP} \ll 40 \times 10^{-11}$
R value, τ mass	$e^+e^- \to inclusive$ $e^+e^- \to \tau^+\tau^-$	Δm_τ~0.012 MeV (with 1 month scan)
Fragmentation functions	$e^+e^- \to (\pi, K, p, \Lambda, D) + X$ $e^+e^- \to (\pi\pi, KK, \pi K) + X$	$\Delta A^{\text{Collins}} < 0.002$
Nucleon Form Factors	$e^+e^- \to B\bar{B}$ from threshold	δR_{EM}~1%

*Sensitivity estimated based on $\mathcal{L} = 1\ \text{ab}^{-1}$

Flavor Physics and CP violation

not all-inclusive

Physics at STCF	Benchmark Processes	Key Parameters*
CKM matrix	$D^+_{(s)} \to l^+\nu_l, D \to Pl^+\nu_l$	$\delta V_{cd/cs}$~0.15%; $\delta f_{D/D_s}$~0.15%
γ/ϕ_3 measurement	$D^0 \to K_s\pi^+\pi^-, K_sK^+K^-$ ...	$\Delta(\cos\delta_{K\pi})$ ~0.007; $\Delta(\delta_{K\pi})$ ~2°
$D^0 - \bar{D}^0$ mixing	$\psi(3770) \to (D^0\bar{D}^0)_{CP=-}$, $\psi(4140) \to \gamma(D^0\bar{D}^0)_{CP=+}$	Δx~0.035%; Δy~0.023%
Charm hadron decay	$D_{(s)}, \Lambda_c^+, \Sigma_c, \Xi_c, \Omega_c$ decay	$N_{D/D_s/\Lambda_c}$~$10^9/10^8/10^8$
γ polarization	$D^0 \to K_1 e^+\nu_e$	$\Delta A'_{UD}$~0.015
CPV in Hyperons	$J/\psi \to \Lambda\bar{\Lambda}, \Sigma\bar{\Sigma}, \Xi^-\bar{\Xi}^-, \Xi^0\bar{\Xi}^0$	ΔA_Λ~10^{-4}
CPV in τ	$\tau \to K_s\pi\nu$, EDM of τ, $\tau \to \pi/K\pi^0\nu$ for polarized e^-	$\Delta A_{\tau\to K_s\pi\nu}$~$10^{-3}$; Δd_τ~5×10^{-19} (e cm)
CPV in Charm	$D^0 \to K^+K^-/\pi^+\pi^-$, $\Lambda_c \to pK^-\pi^+\pi^0$ ...	ΔA_D~10^{-3}; ΔA_{Λ_c}~10^{-3}

*Sensitivity estimated based on $\mathcal{L} = 1\ \text{ab}^{-1}$

Forbidden/Rare decay and New Particle Search

not all-inclusive

Physics at STCF	Benchmark Processes	Key Parameters* (U.L. at 90% C.L.)
LFV decays	$\tau \to \gamma l, lll, lP_1P_2$ $J/\psi \to ll', D^0 \to ll' (l' \neq l)$...	$\mathcal{B}(\tau \to \gamma\mu/\mu\mu\mu)$<16/1.5× 10^{-9}; $\mathcal{B}(J/\psi \to e\tau)$<0.71× 10^{-9}
LNV, BNV	$D^+_{(s)} \to l^+l^+X^-, J/\psi \to \Lambda_c e^-$, $B \to \bar{B}$...	$\mathcal{B}(J/\psi \to \Lambda_c e^-)$< 10^{-11}
Symmetry violation	$\eta^{(\prime)} \to ll\pi^0, \eta' \to \eta ll$...	$\mathcal{B}(\eta' \to ll/\pi^0 ll)$< $1.5/2.4 \times 10^{-10}$
FCNC	$D \to \gamma V, D^0 \to l^+l^-, e^+e^- \to D^*, \Sigma^+ \to pl^+l^-$...	$\mathcal{B}(D^0 \to e^+e^-X)$< 10^{-8}
Dark photon, millicharged	$e^+e^- \to (J/\psi) \to \gamma A' (\to l^+l^-)$... $e^+e^- \to \chi\bar{\chi}\gamma$ ...	Mixing strength $\Delta\epsilon_{A'} \sim 10^{-4}$; $\Delta\epsilon_{\chi} \sim 10^{-4}$

*Sensitivity estimated based on $\mathcal{L} = 1\ \mathrm{ab}^{-1}$