The Super Tau-Charm Facility Prospects

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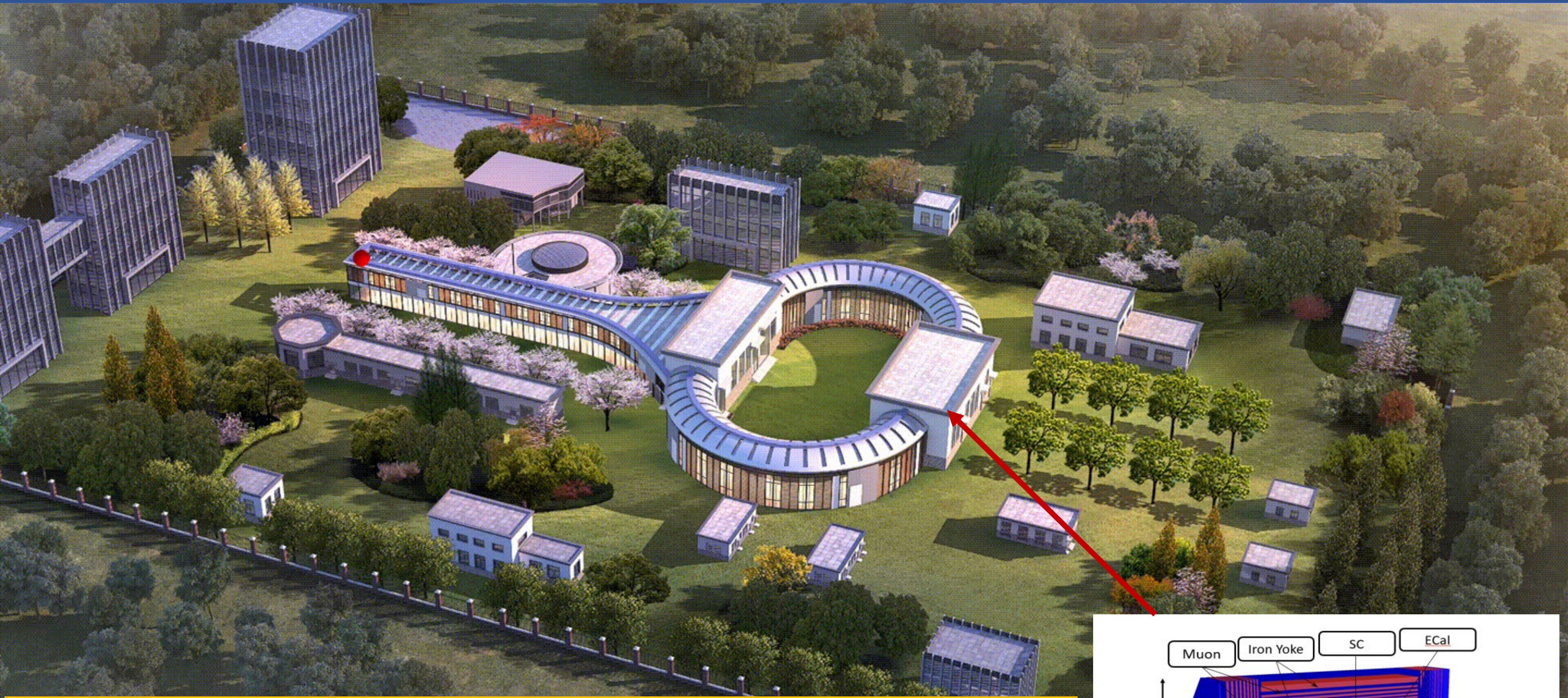
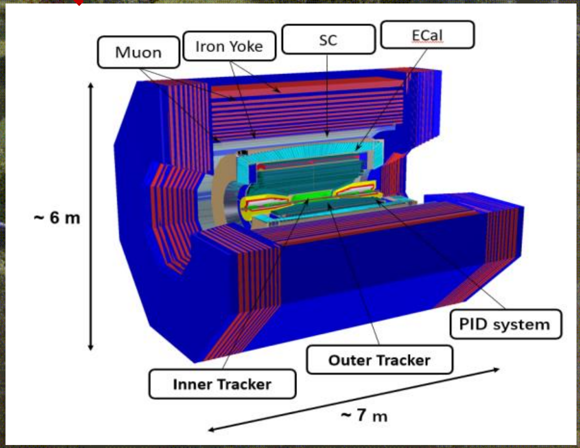
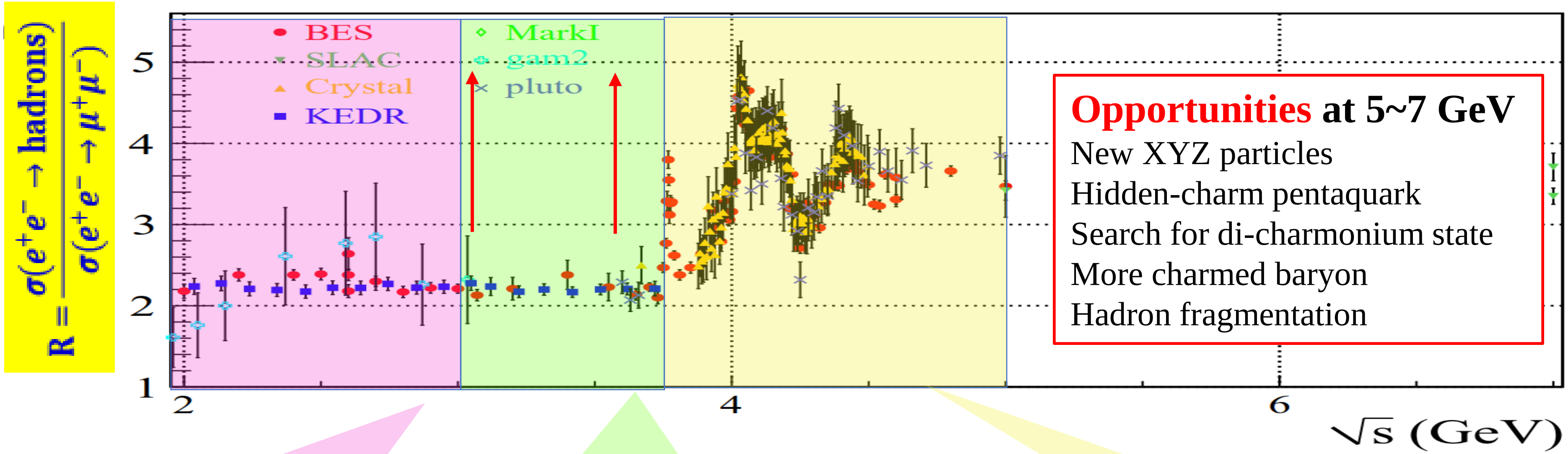
Super tau-Charm Facility in China



- Peaking luminosity $>0.5\times10^{35}$ $cm^{-2}s^{-1}$ 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



Physics in tau-Charm Region



Opportunities at 5~7 GeV
New XYZ particles
Hidden-charm pentaquark
Search for di-charmonium state
More charmed baryon
Hadron fragmentation

- Hadron form factors
- Y(2175) resonance
- Mutltiquark states with s quark,
- 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 τ lepton

- XYZ particles
- Physics with D mesons
- fD and fDs
- D0-D0 mixing
- Charm baryons

- **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.**

Expected Data Samples at STCF

Expected data samples per year

CME (GeV)	Lumi (ab^{-1})	samples	σ(nb)	No. of Events	remark
3.097	1	J/ψ	3400	3.4×10^{12}	
3.670	1	$\tau^+\tau^-$	2.4	2.4×10^{9}	
3.686	1	$\psi(3686)$	640	6.4×10^{11}	
		$\tau^+\tau^-$	2.5	2.5×10^{9}	
		$\psi(3686)\to\tau^+\tau^-$		2.0×10^{9}	
3.770	1	$D^0\bar{D}^0$	3.6	3.6×10^{9}	
		$D^+\bar{D}^-$	2.8	2.8×10^{9}	
		$D^0\bar{D}^0$		7.9×10^{8}	Single Tag
		$D^+\bar{D}^-$		5.5×10^{8}	Single Tag
		$\tau^+\tau^-$	2.9	2.9×10^{9}	
4.040	1	$\gamma D^0\bar{D}^0$	0.40	4.0×10^{6}	$CP_{D^0\bar{D}^0}=+1$
		$\pi^0 D^0\bar{D}^0$	0.40	4.0×10^{6}	$CP_{D^0\bar{D}^0}=-1$
		$D_s^+D_s^-$	0.20	2.0×10^{8}	
		$\tau^+\tau^-$	3.5	3.5×10^{9}	
4.180	1	$D_s^{+*}D_s^-$+c.c.	0.90	9.0×10^{8}	
		$D_s^{+*}D_s^-$+c.c.		1.3×10^{8}	Single Tag
		$\tau^+\tau^-$	3.6	3.6×10^{9}	
4.230	1	$J/\psi\pi^+\pi^-$	0.085	8.5×10^{7}	
		$\tau^+\tau^-$	3.6	3.6×10^{9}	
		$\gamma X(3872)$			
4.360	1	$\psi(3686)\pi^+\pi^-$	0.058	5.8×10^{7}	
		$\tau^+\tau^-$	3.5	3.5×10^{9}	
4.420	1	$\psi(3686)\pi^+\pi^-$	0.040	4.0×10^{7}	
		$\tau^+\tau^-$	3.5	3.5×10^{9}	
4.630		$\psi(3686)\pi^+\pi^-$	0.033	3.3×10^{7}	
	1	$\Lambda_c\bar{\Lambda}_c$	0.56	5.6×10^{8}	
		$\Lambda_c\bar{\Lambda}_c$		6.4×10^{7}	Single Tag
		$\tau^+\tau^-$	3.4	3.4×10^{9}	
4.0-7.0	3	300 points scan with 10 MeV step, 1 fb^{-1}/point			
> 5	2-7	several ab^{-1} high energy data, details dependent on scan results			

A XYZ factory

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

A Hyperon Factory

Decay mode	$\mathcal{B}$(units 10^{-4})	Angular distribution parameter α_ψ	Detection efficiency	No. events expected at STCF
$J/\psi\to\Lambda\bar{\Lambda}$	$19.43\pm0.03\pm0.33$	0.469 ± 0.026	40%	1100×10^{6}
$\psi(2S)\to\Lambda\bar{\Lambda}$	$3.97\pm0.02\pm0.12$	0.824 ± 0.074	40%	130×10^{6}
$J/\psi\to\Xi^0\bar{\Xi}^0$	11.65 ± 0.04	0.66 ± 0.03	14%	230×10^{6}
$\psi(2S)\to\Xi^0\bar{\Xi}^0$	2.73 ± 0.03	0.65 ± 0.09	14%	32×10^{6}
$J/\psi\to\Xi^-\bar{\Xi}^+$	10.40 ± 0.06	0.58 ± 0.04	19%	270×10^{6}
$\psi(2S)\to\Xi^-\bar{\Xi}^+$	2.78 ± 0.05	0.91 ± 0.13	19%	42×10^{6}

A light meson factory

Decay Mode	$\mathcal{B}$ ($\times10^{-4}$) [2]	η/η' events
$J/\psi\to\gamma\eta'$	52.1 ± 1.7	1.8×10^{10}
$J/\psi\to\gamma\eta$	11.08 ± 0.27	3.7×10^{9}
$J/\psi\to\phi\eta'$	7.4 ± 0.8	2.5×10^{9}
$J/\psi\to\phi\eta$	4.6 ± 0.5	1.6×10^{9}

- **Belle-II (50/ab) has more statistics**
- **LHCb have much more statistics， but huge background**
- **STCF is expected to have higher detection efficiency and low bkgs for productions at threshold**
- **Additionally, STCF excellent resolution, kinematic constraining**

Highlighted physics at STCF

◻QCD and Hadronic Physics

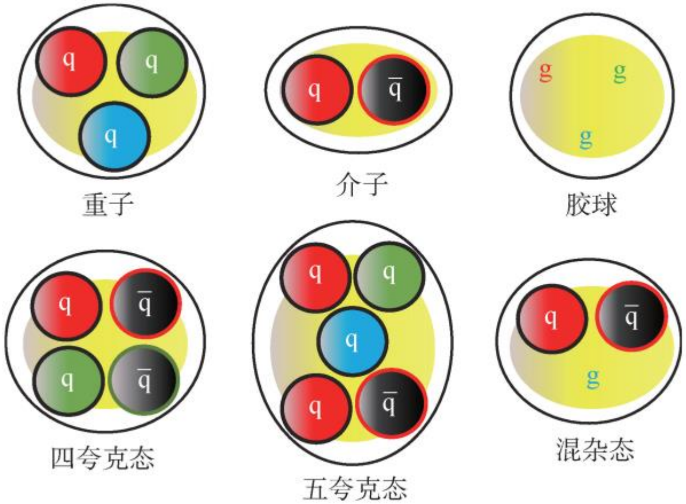
- ➢ Exotic states and hadron spectroscopy
- ➢ Hadron structures
- ➢ Precision test of SM parameters

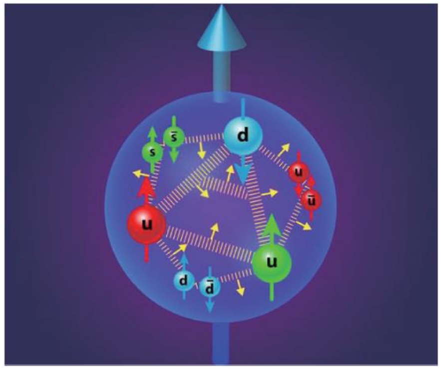
◻Flavor Physics and CP violation

- ➢ CKM matrix, $D^0-\overline{D}^0$ mixing
- ➢ CP violation in lepton, hyperon, charm

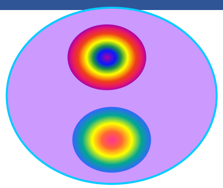
◻New Physics Search

- ➢ Rare/Forbidden
- ➢ Dark particle search





Charmonium (Like) Spectroscopy

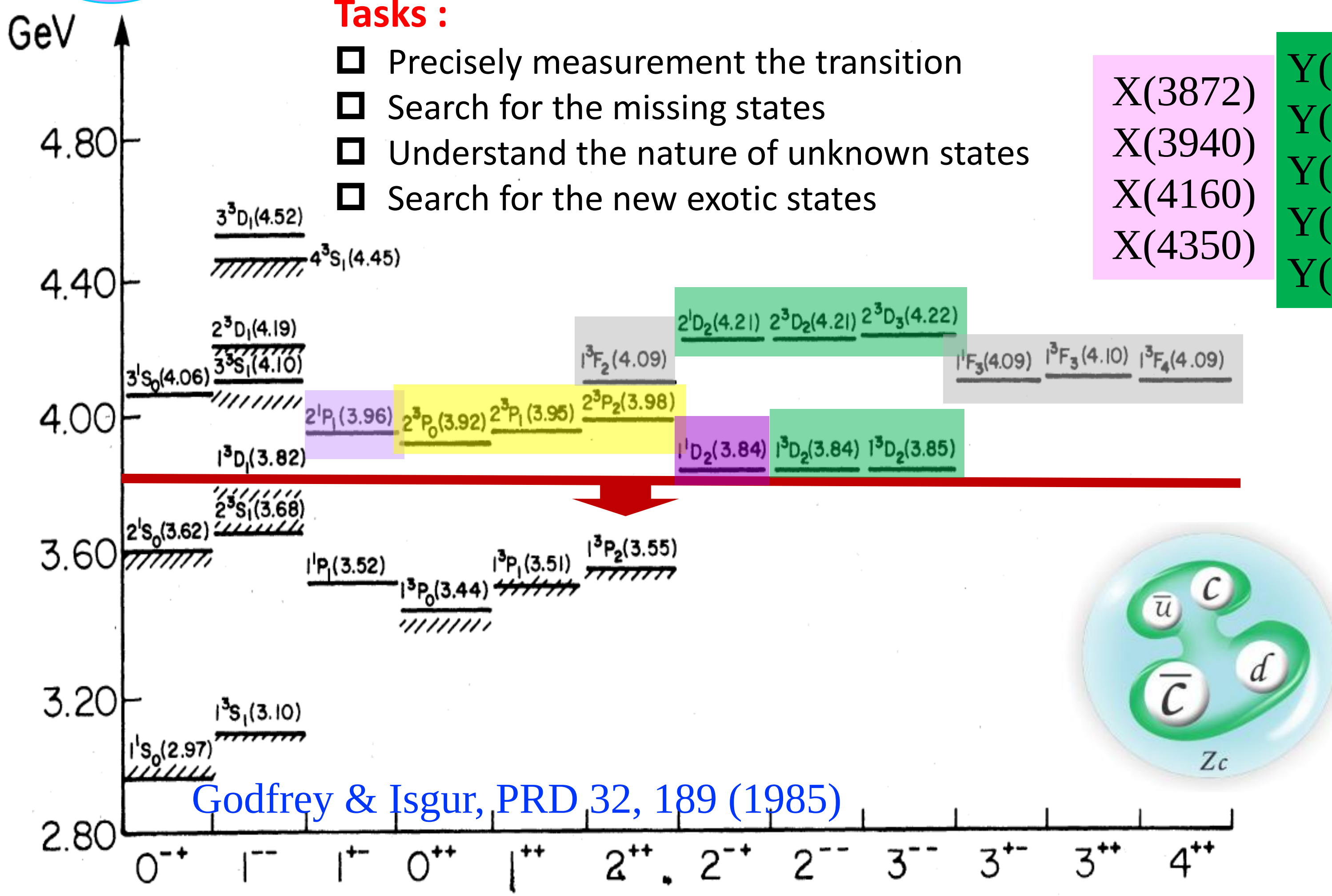


Excellent platform to explore the QCD

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

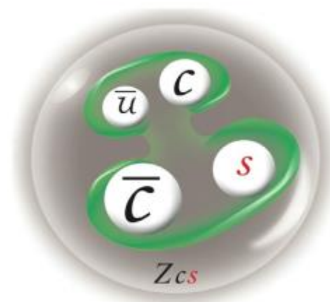


Godfrey & Isgur, PRD 32, 189 (1985)

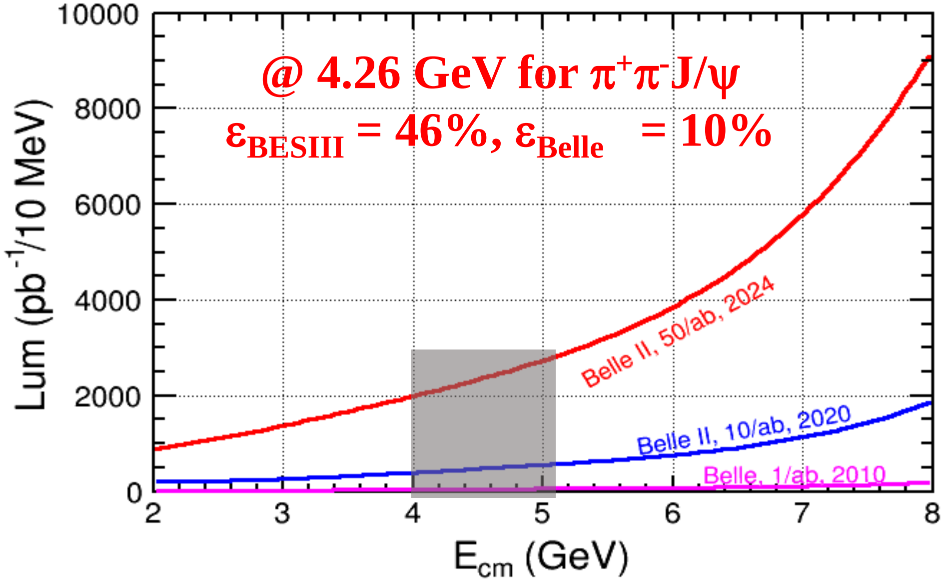
X(3872)
X(3940)
X(4160)
X(4350)

Y(3940)
Y(4008)
Y(4260)
Y(4360)
Y(4660)

$Z_c(3900)$
$Z_c(4020)$
$Z_c(4050)$
$Z_c(4200)$
$Z_c(4250)$
$Z_c(4430)$
$Z_{cs}(3985)$
$Z_{cs}(4000)$
$Z_{cs}(4220)$

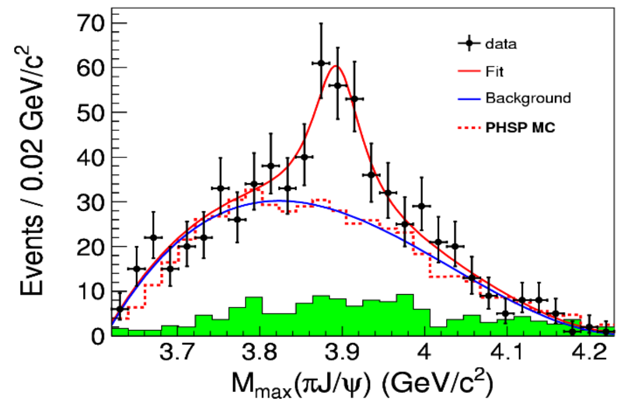


Charmonium(Like) Spectroscopy at STCF

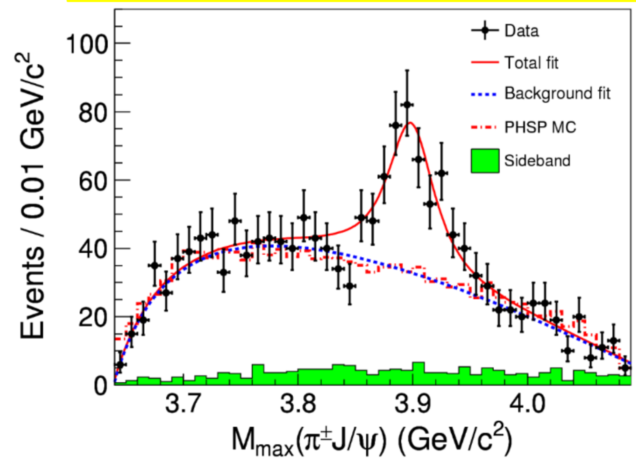


- B factory : Total integrate effective luminosity between 4-5 GeV is 0.23 ab^{-1} for 50 ab^{-1} data
- τ-C factory : scan in 4-5 GeV, 10 MeV/step, every point have 10 fb^{-1}/year, 5 time of Belle II for 50 ab^{-1} data
- τ-C factory have much higher efficiency and low background than B Factory

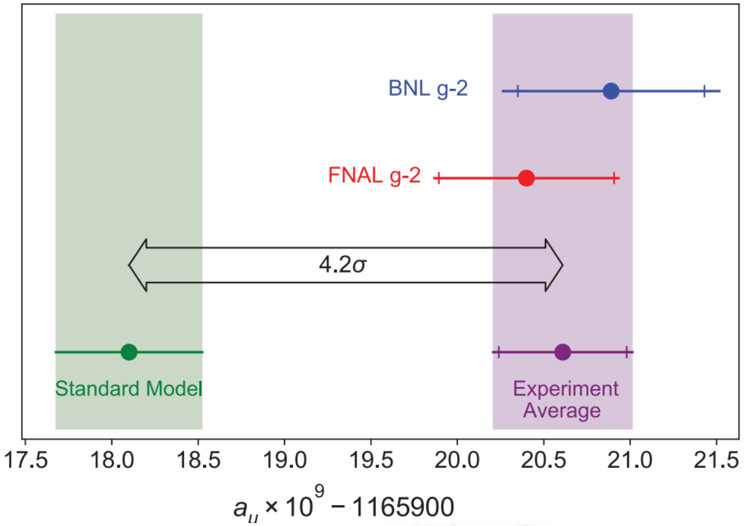
Belle with ISR: PRL110, 252002
967 fb-1 in 10 years running time



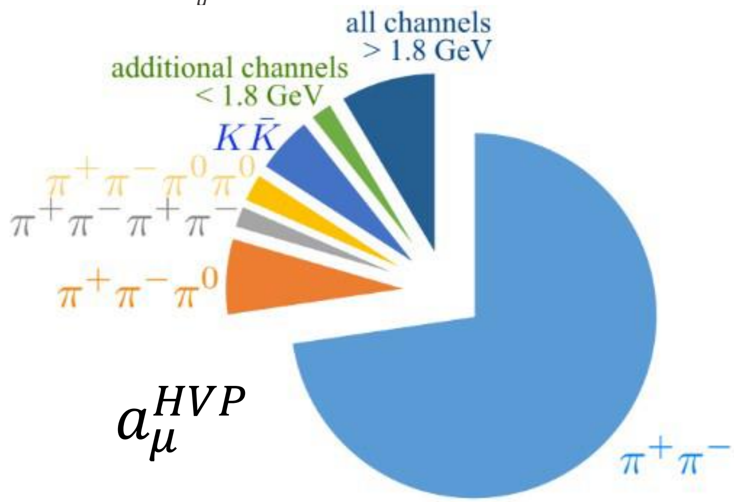
BESIII at 4.260 GeV: PRL110, 252001
0.525 fb^{-1} in one month running time

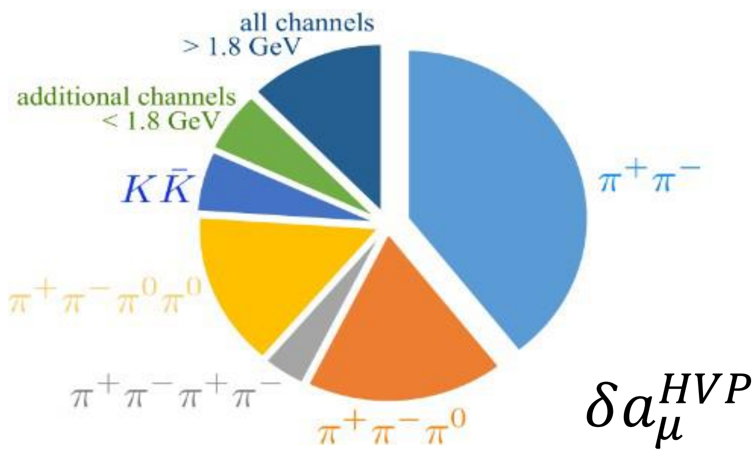


HVP Contribution to $(g-2)_\mu$



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

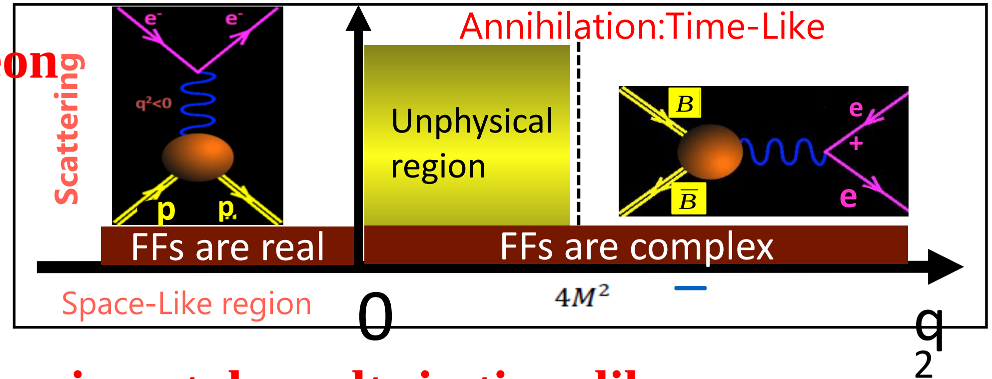




High Luminosity of STCF will largely improve the SM precisions !

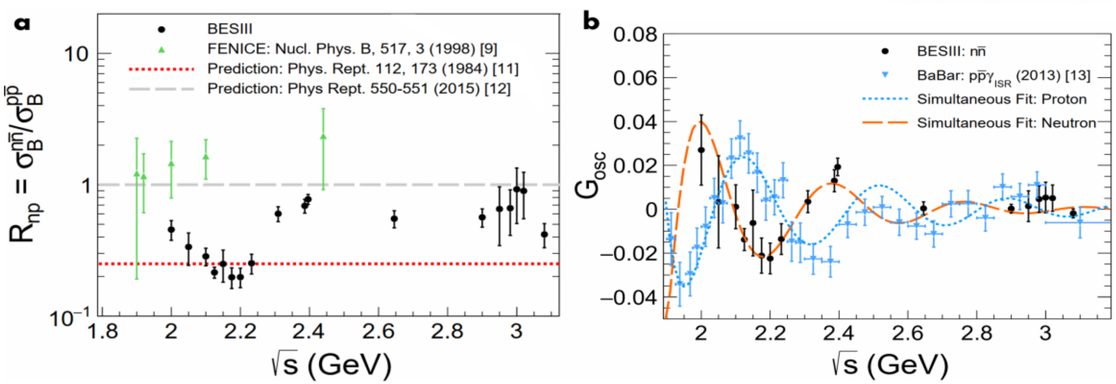
Electromagnetic Form Factors

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

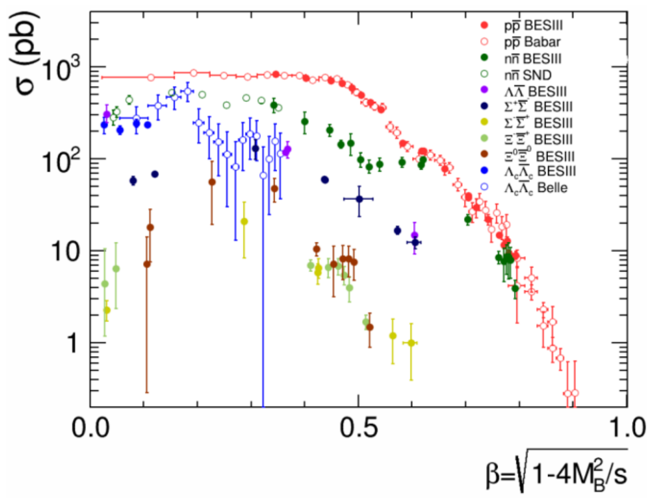


- **Mysteries observed from current experimental results in time-like**

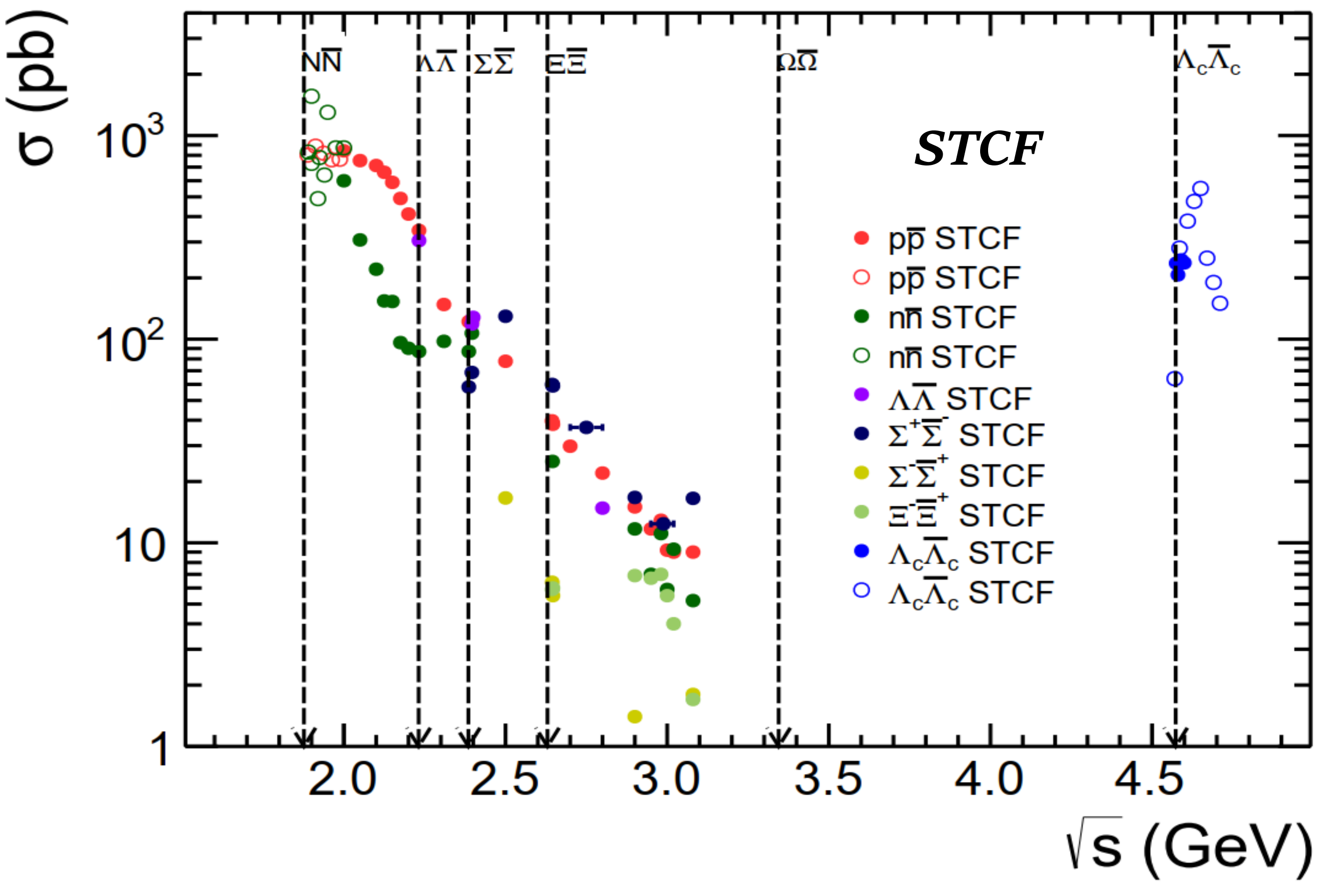
Nature Phys. **17**, 1200–1204 (2021)



National Science Review, nwab187



Electromagnetic Form Factors



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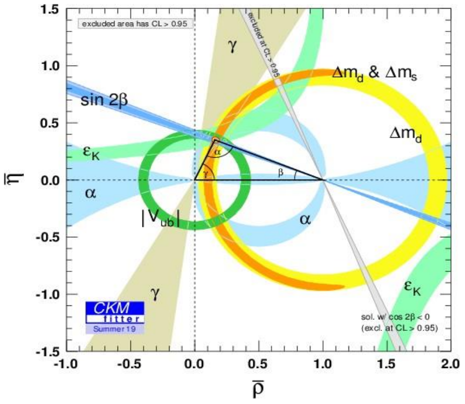

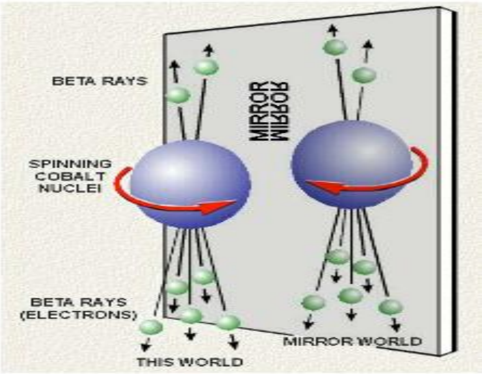

Facilities for Charm Study

- 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)

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

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

Theory : 0.2%(0.1% expected)

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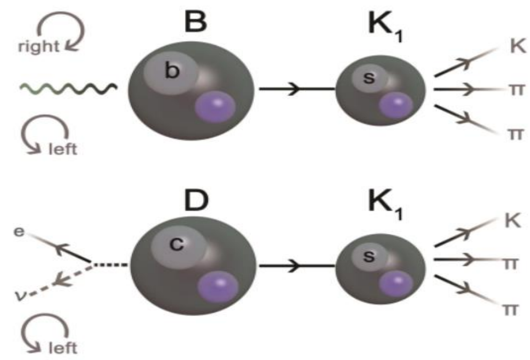
* assuming Belle II improved systematics by a factor 2

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

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

arXiv:2107.06118v2 [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 .

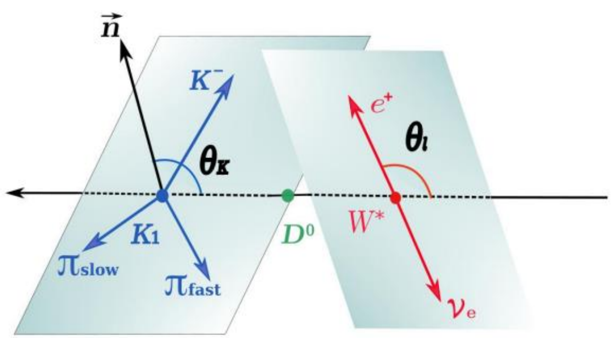


- Hadronic state helicity in $B \to K_1(\to K\pi\pi)\gamma$ [Phys. Rev. Lett.112, 161801 (2014)]

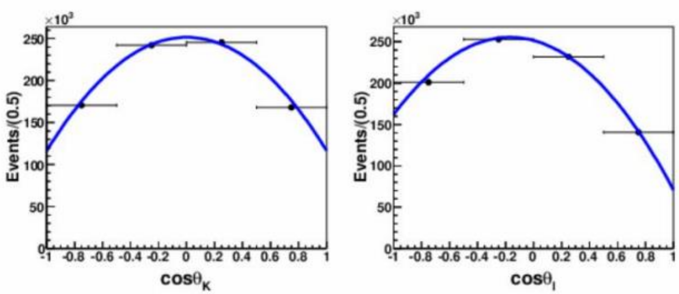
$M_{K\pi\pi}$ in (1.1,1.3) GeV, $\quad A_{UD} = (6.9 \pm 1.7) \times 10^{-2}$

- 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 θ_K and cos θ_l**



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

CPV in τ decay

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

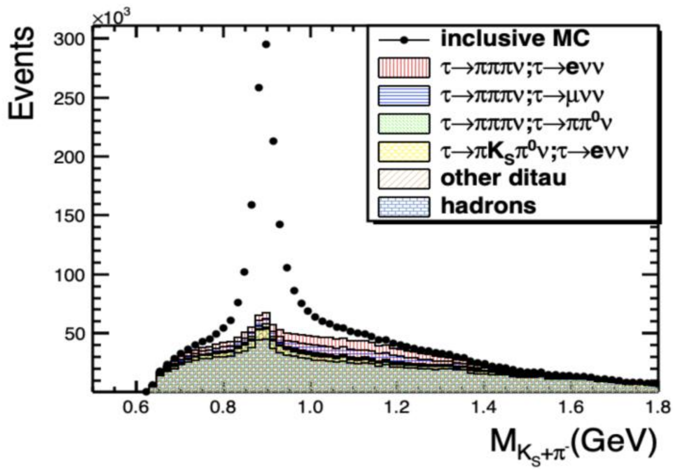
- The CPV source in $K^0 - \bar{K}^0$ **mixing** produces a difference in tau decay rate

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



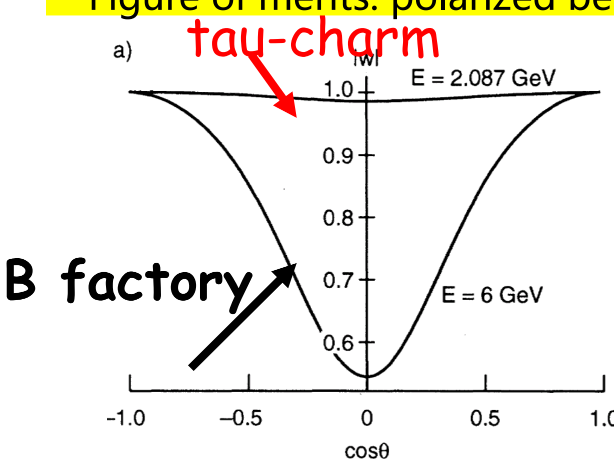
The CPV sensitivity with 1ab^{-1} @ 4.26 GeV[1]:

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

With 10 ab^{-1} data:

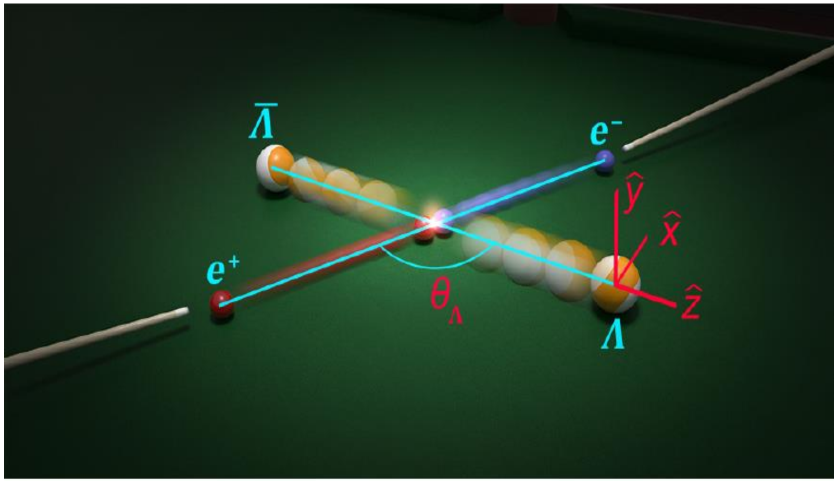
$A_{STCF} \sim 3.1 \times 10^{-4}$

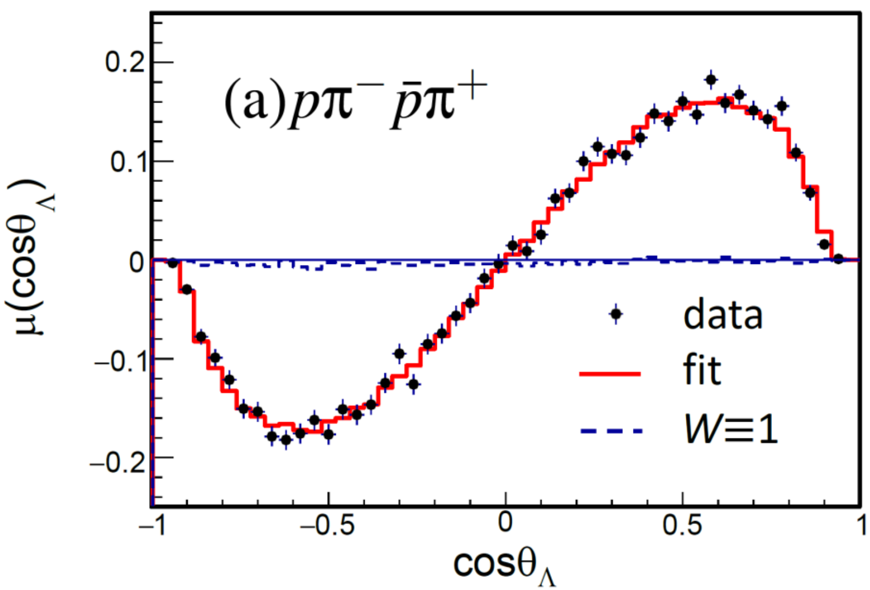
Possible choice to increase the Figure of merits: polarized beam



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

Polarization of Λ hyperons and CPV





Nature Phys. **15**, 631–634 (2019)

1.31 B J/ψ events
Quantum correlation in Λ pair

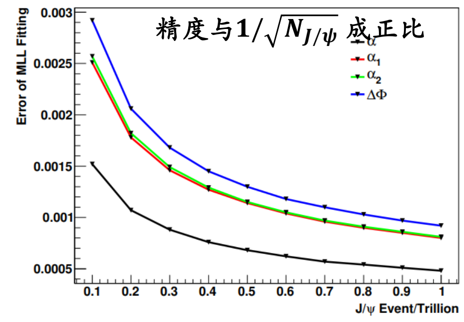
Parameters	This work	Previous results
α_ψ	$0.461 \pm 0.006 \pm 0.007$	0.469 ± 0.027 [14]
$\Delta\Phi$	$(42.4 \pm 0.6 \pm 0.5)^\circ$	–
α_-	$0.750 \pm 0.009 \pm 0.004$	0.642 ± 0.013 [16]
α_+	$-0.758 \pm 0.010 \pm 0.007$	-0.71 ± 0.08 [16]
$\bar{\alpha}_0$	$-0.692 \pm 0.016 \pm 0.006$	–
A_{CP}	$-0.006 \pm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

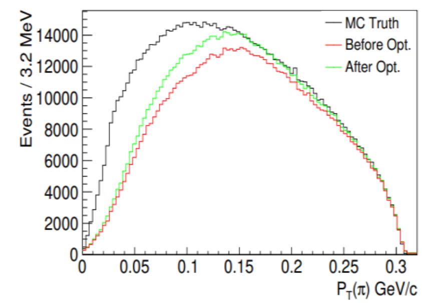
2% level sensitivity for CPV test
SM prediction: 10^{-4}~10^{-5}

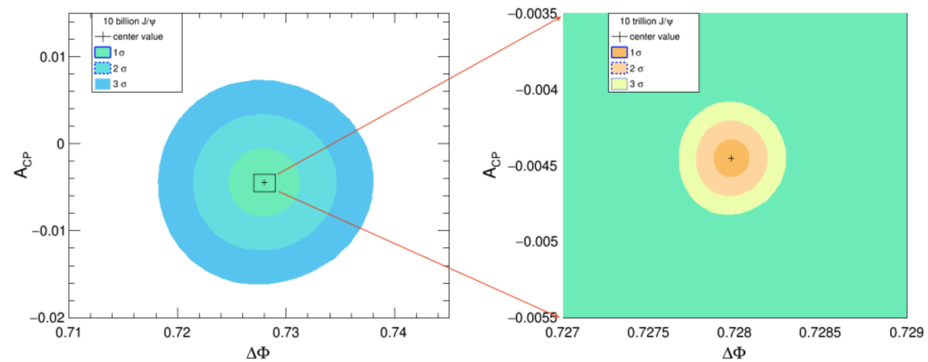
CP test $$A_{CP} = \frac{\alpha_- + \alpha_+}{\alpha_- - \alpha_+}$$

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: × 100
  - 2 – 3 years data taking
  - No polarization beams are needed







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

Highlighted physics at STCF

☐QCD and Hadronic Physics

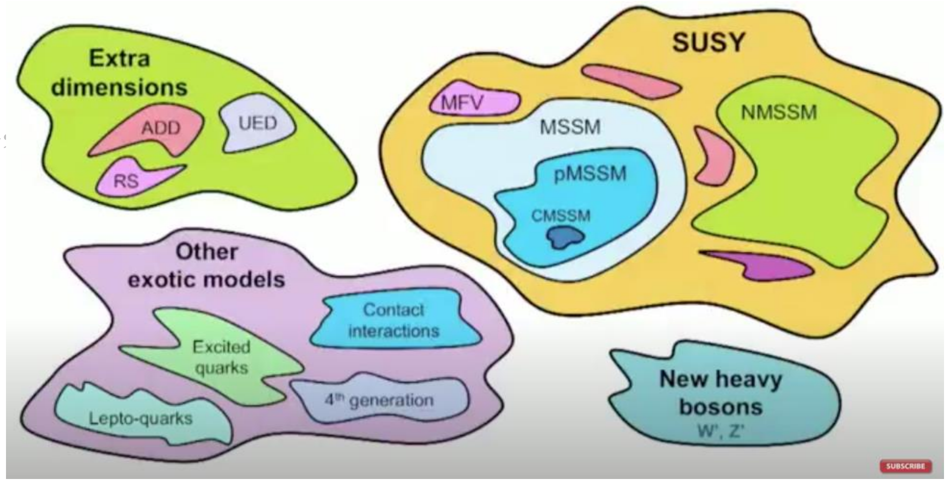
- ➢ Exotic states and hadron spectroscopy
- ➢ Hadron structures
- ➢ Precision test of SM parameters

☐Flavor Physics and CP violation

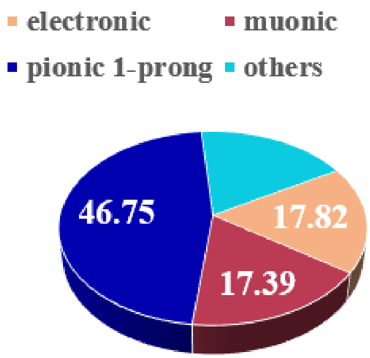
- ➢ CKM matrix, $D^0 - \overline{D}^0$ mixing
- ➢ CP violation in lepton, hyperon,

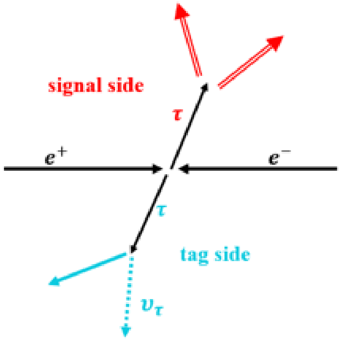
☐New Physics Search

- ➢ Rare/Forbidden
- ➢ Dark particle search

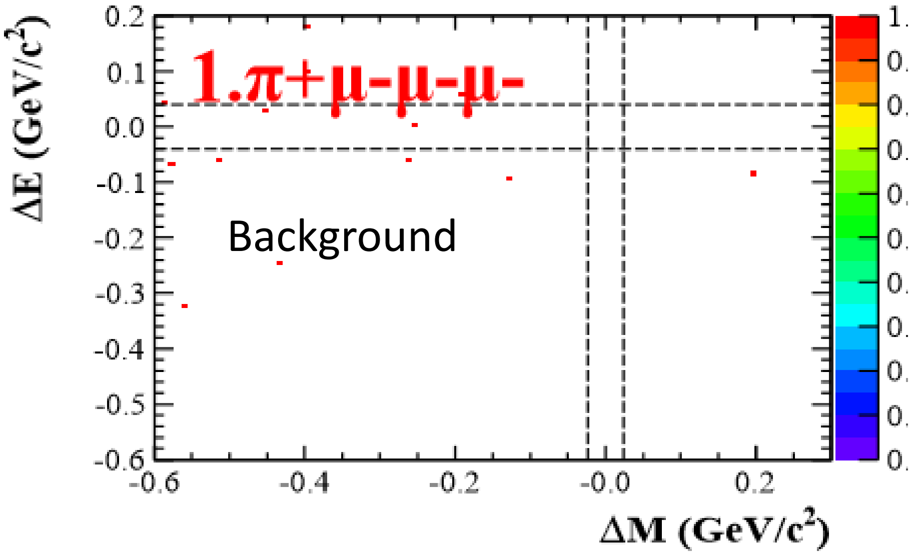


LFV decay of $\tau\to lll$ at STCF





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



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

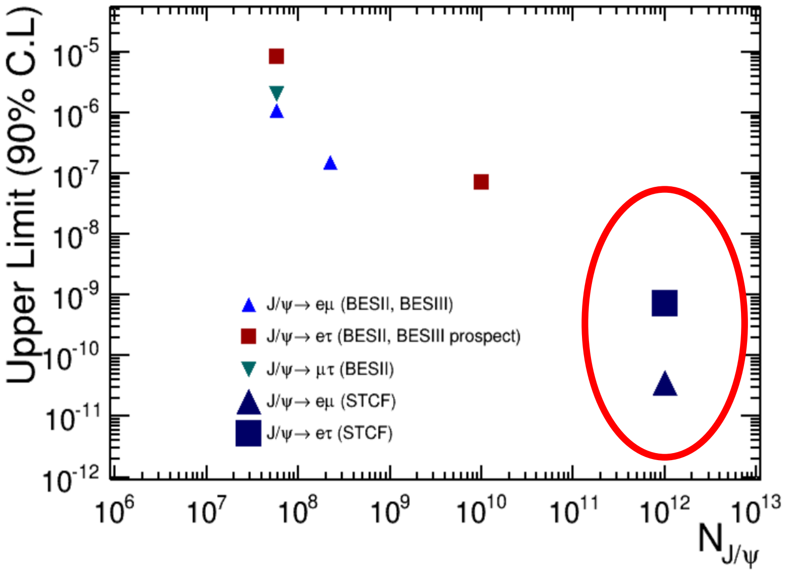
$$\mathcal{B}^{90}_{UL}(\tau \to \mu\mu\mu) < \frac{N^{90}_{UL}}{2\varepsilon N_{\tau\tau}} \sim 1.5 \times 10^{-9}$$

LFV decay of $J/\psi \rightarrow e\tau$ at STCF

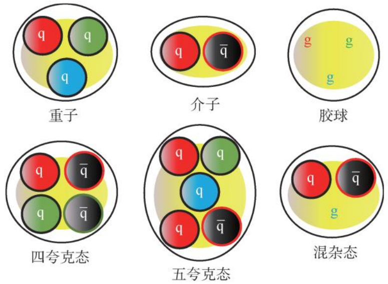
- The cLFV decays of vector mesons $\boldsymbol{V \rightarrow l_i l_j}$ are also predicted **in various of extension models** of SM:
  - $\mathcal{B}_{UL}^{90}(J/\psi \rightarrow e\mu) < 10^{-13}$
  - $\mathcal{B}_{UL}^{90}(J/\psi \rightarrow \mathrm{e}(\mu)\tau)) < 10^{-9}$

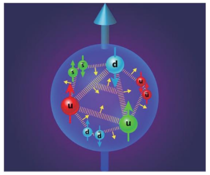
- At **STCF**, **1 trillion $\boldsymbol{J/\psi}$** can be obtained per year, taken efficiency from BESIII, the upper limit can be predicted to be:
  - $\mathcal{B}_{UL}^{90}(J/\psi \rightarrow e\mu) < 3.6 \times 10^{-11}$
  - $\mathcal{B}_{UL}^{90}(J/\psi \rightarrow \mathrm{e}\tau)) < 7.1 \times 10^{-10}$

- The $\boldsymbol{\mathcal{B}_{UL}^{90}(J/\psi \rightarrow \mathrm{e}\tau))}$ can be further **optimized** with better PID.



Physics program at STCF

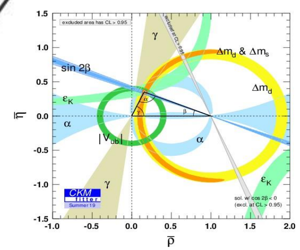


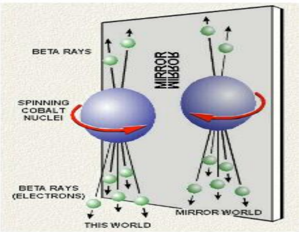


Physics at STCF

QCD and hadronic physics

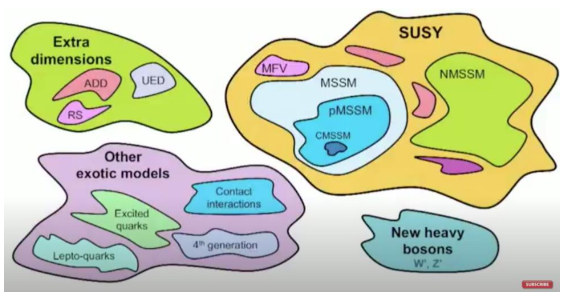
- **XYZ Properties:** e+e-→Y→γX,ηX,φX; e+e-→Y→πZc, KZcs
- **Hadron Spectroscopy:** Excited ccbar and their transition, Charmed hadron spectroscopy, Light hadron spectroscopy
- **R value:** e+e-→inclusive; τ mass: e+e-→τ+τ-
- **Nucleon Form Factors:** e+e-→BBbar from threshold
- **Pentaquarks:** e+e-→J/ψppbar, 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+
- **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

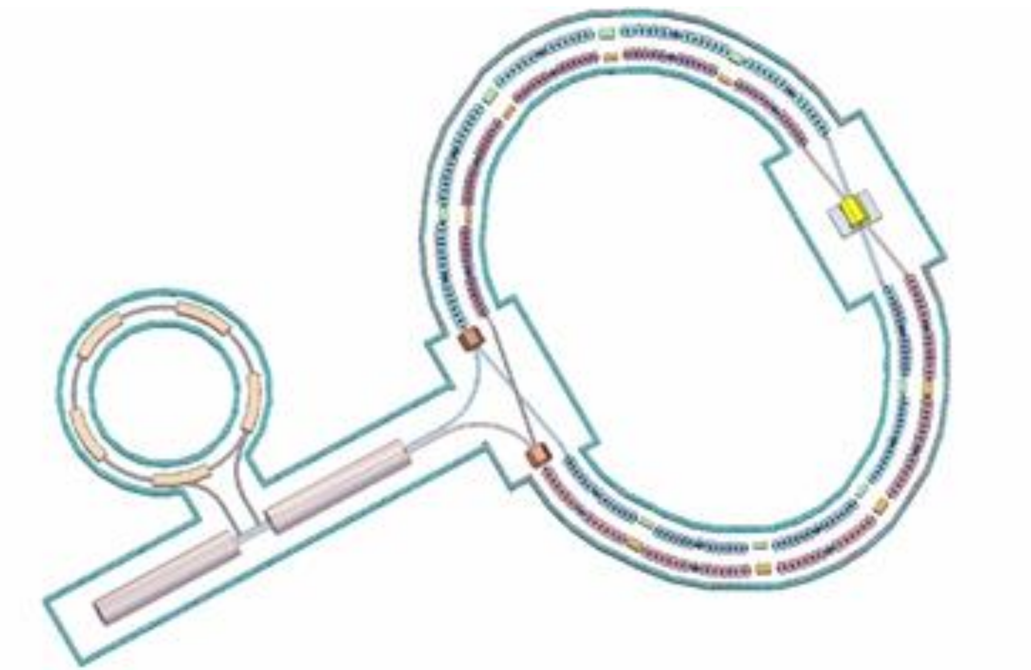
Tentative Plan

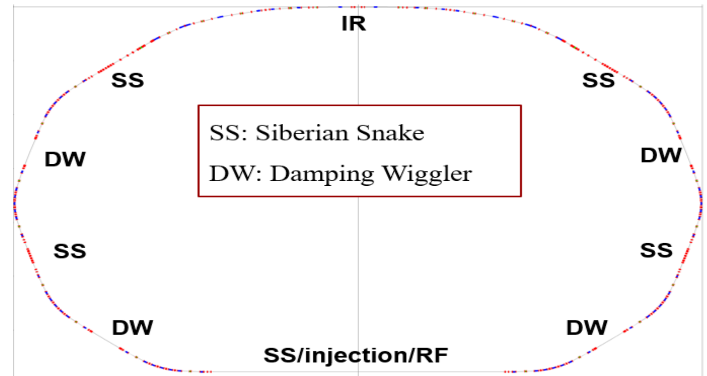
	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031-2040	2041-2042
Form Group	■	■	■	■											
CDR	■	■	■	■											
TDR	■	■	■	■	■	■	■								
Construction							■	■	■	■	■	■	■		
In operation														■	
Upgrade															■

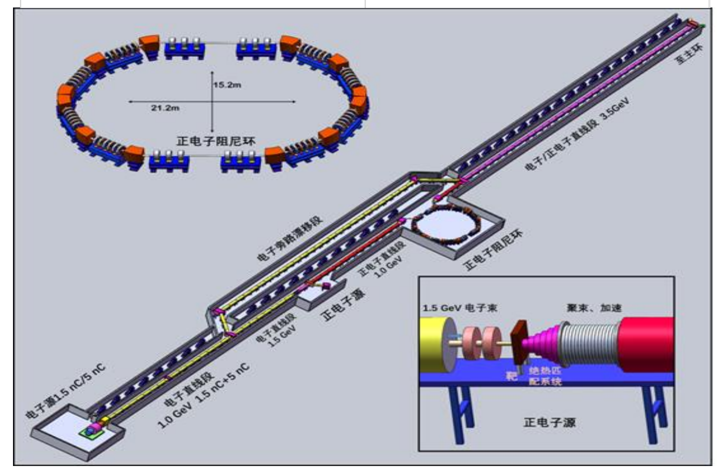
The first version of CDR (three volumes) has finished

STCF Accelerator

Interaction Region : Large Piwinski Angle Collision + Crabbed Waist







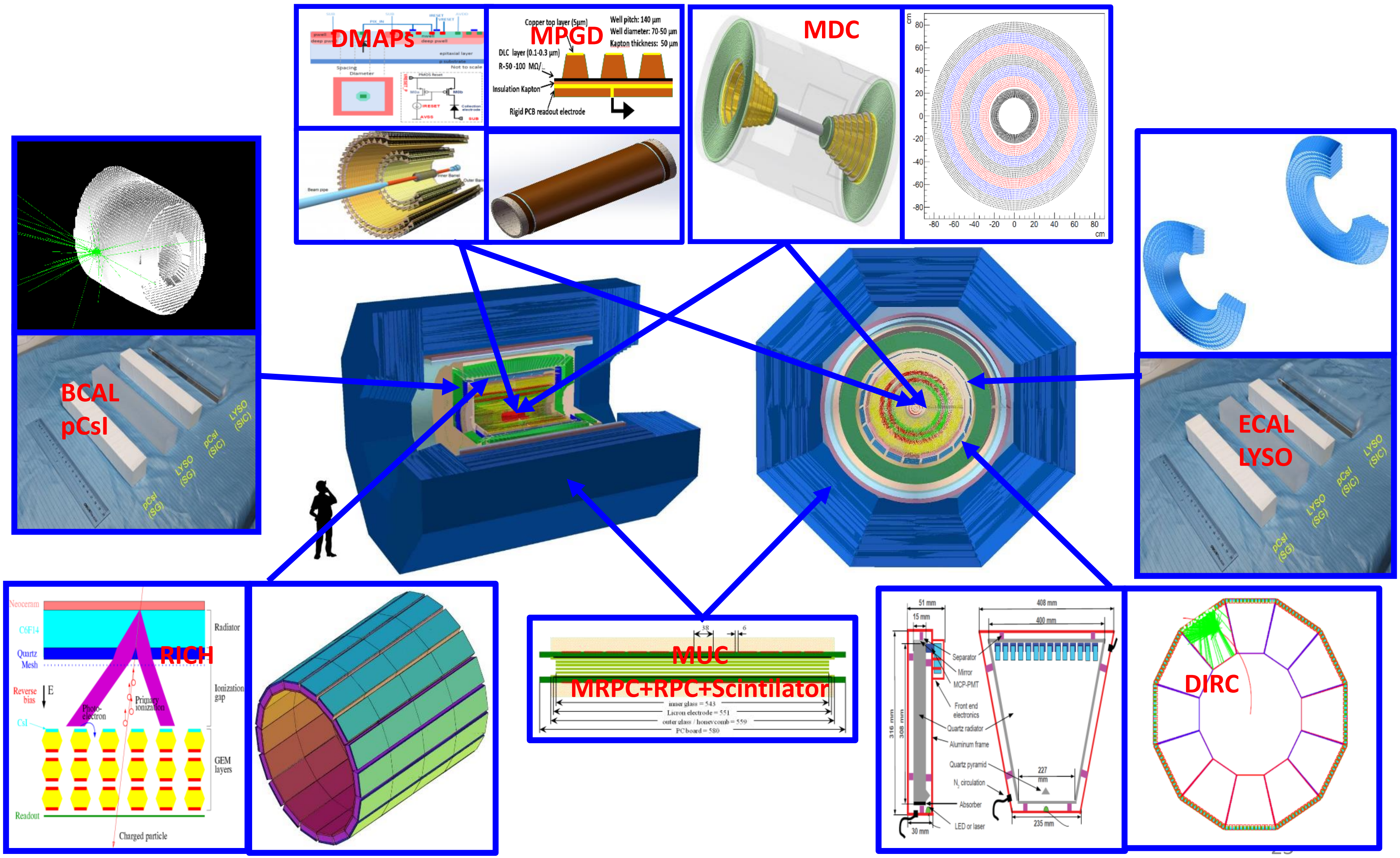
Injector:

- 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	1.5	2.0
Emittance $(\varepsilon_x/\varepsilon_y)$/nm·rad	6/0.06	5/0.05
β Function @IP (β_x^*/β_y^*)/mm	60/0.6	50/0.5(estimated)
Full Collision Angle 2θ/mrad	60	60
Tune Shift ξy	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

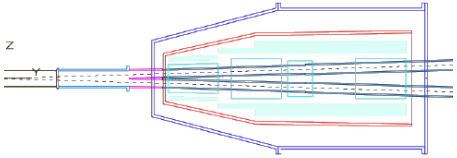
STCF detector

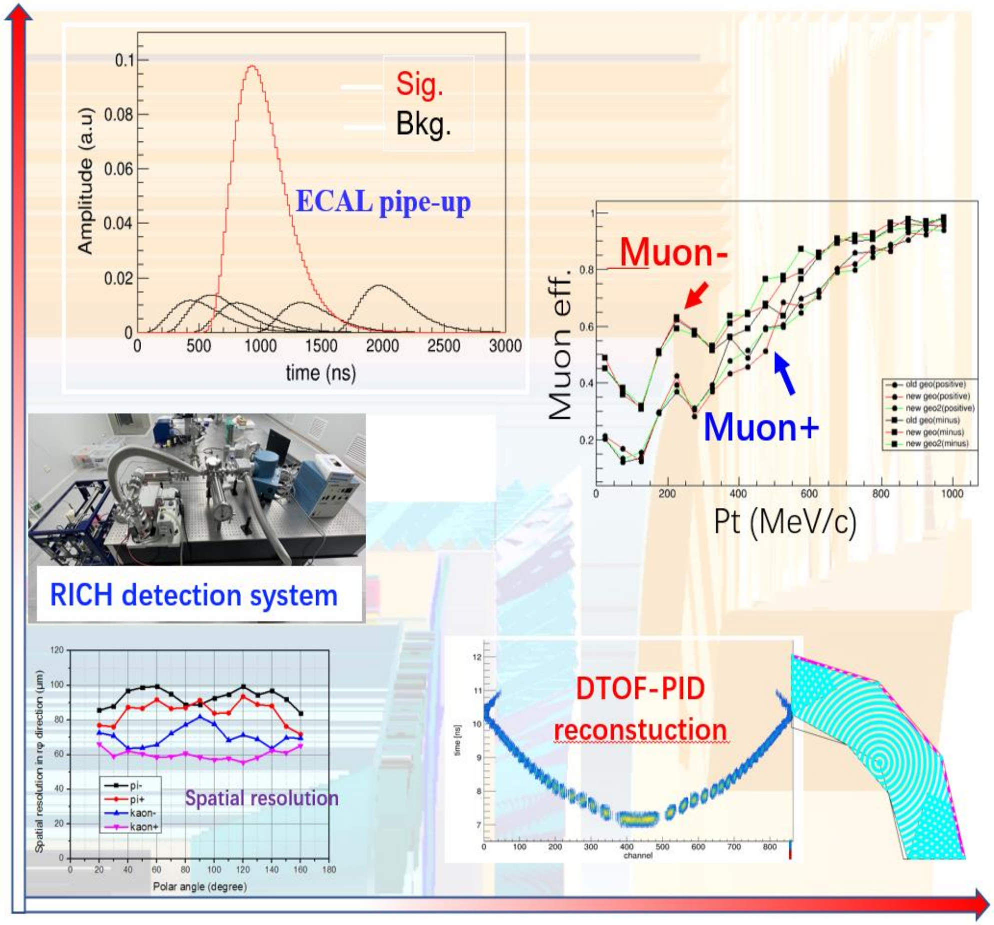


STCF detector

- **MDI**： CDR finished; beam/physics background estimation;
- **Inner Tracker**： MPGD CDR finished, in optimizing; Silicon tracker ongoing
- **MDC**： CDR finished
- **PID**： CDR finished; Prototyle of RICH (2^{nd} version) and DTOF
- **ECAL**： CDR finished; optimizing crystal and electronics
- **MUC**： CDR finished; optimizing

MDI design





Activities: group discussion

High Luminosity Tau Charm Physics

Indico for High Luminorcity Tau Charm Physics R&D

STCF Steering Committee	1 event
STCF Accelerator	124 events
STCF Physics	24 events
STCF Detector	417 events
STCF Accelerator-Detector Joint meetings	15 events
STCF International Conference	13 events
STCF Domestic meeting	13 events
香山会议	2 events
Coordinator Meeting	2 events
Informal Discussions	7 events
Mini Workshop	2 events
Monthly Meeting	3 events
Physics Weekly Meeting	6 events
Workshop	13 events
Collaborations-RD	10 events
Documents	
Public	

STCF Detector

STCF Tracker&Muon Working Group	14 events
STCF PID Working Group	78 events
STCF ECAL Working Group	75 events
STCF Software group meeting	130 events
STCF Physics Simulation Working Group	72 events
Joint Meeting on Software/Physics with Russian Group	8 events
Management Group Meeting	2 events
Informal Meetings	28 events
Share	10 events

- **Working groups for Accelerator / Detector(trk, PID, EMC,MUC) / Software / PhysicsSimulation**
- **Extensive discussions of each group every (two) week**
- **Accelerator-detector Joint meetings every two months**

Activities: workshops

- Domestic Workshops (2011, 12, 13, 14, 16, 20)
- International Workshops (2015, 18, 19, 20)

- **Workshop on future Super c-tau factories 2021 (international)**

  时间：2021年11月15日-17日

  地点：online

  会议网页：https://indico.inp.nsk.su/event/62/

- **超级陶粲装置研究进展研讨会 （国内）**

  时间：2021年12月9日-13日

  地点：中山大学，广州

  会议网页: http://cicpi.ustc.edu.cn/indico/conferenceDisplay.py?ovw=True&confId=3752

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
  - 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**

Thanks for your attention!

Welcome to join the effort!

QCD and Hadronic Physics

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

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

Flavor Physics and CP violation

Physics at STCF	Benchmark Processes	Key Parameters*	Remarks
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%	**Leading role**
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°	**Synergy with BelleII/LHCb**
$D^0 - \bar{D}^0$ 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%	In Competition with BelleII/LHCb
Charm hadron decay	$D_{(s)}, \Lambda_c^+, \Sigma_c, \Xi_c, \Omega_c$ decay	$N_{D/D_s/\Lambda_c}$~$10^9/10^8/10^8$	**Leading role**
γ polarization	$D^0 \to K_1e^+\nu_e$	$\Delta A'_{UD}$~0.015	**Synergy with BelleII/LHCb**
CPV in Hyperons	$J/\psi \to \Lambda\bar{\Lambda}, \Sigma\bar{\Sigma}, \Xi^-\bar{\Xi}^-, \Xi^0\bar{\Xi}^0$	ΔA_Λ~10^{-4}	**Leading role**
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)	In Competition with BelleII
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}	In Competition with BelleII/LHCb

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

Forbidden/Rare decay and New Particle Search

Physics at STCF	Benchmark Processes	Key Parameters* (U.L. at 90% C.L.)	Remarks
FLV decays	$\tau \to \gamma l, lll, lP_1P_2$ $J/\psi \to ll', D^0 \to ll'(l' \neq l)\ldots$	$\mathcal{B}(\tau \to \gamma\mu/\mu\mu\mu)$<$12/1.5\times 10^{-9}$; $\mathcal{B}(J/\psi \to e\tau)$<$0.71\times 10^{-9}$	In Competition with BelleII
LNV, BNV	$D^+_{(s)} \to l^+l^+X^-, J/\psi \to \Lambda_c e^-$, $B \to \bar{B}\ldots$	$\mathcal{B}(J/\psi \to \Lambda_c e^-)$< 10^{-11}	**Leading role**
Symmetry violation	$\eta^{(\prime)} \to ll\pi^0, \eta' \to \eta ll\ldots$	$\mathcal{B}(\eta' \to ll/\pi^0 ll)$< $1.5/2.4 \times 10^{-10}$	**Leading role**
FCNC	$D \to \gamma V, D^0 \to l^+l^-, e^+e^- \to D^*$, $\Sigma^+ \to pl^+l^-\ldots$	$\mathcal{B}(D^0 \to e^+e^-X)$< 10^{-8}	In Competition with BelleII
Dark photon, millicharged	$e^+e^- \to (J/\psi) \to \gamma A'(\to l^+l^-)\ldots$ $e^+e^- \to \chi\bar{\chi}\gamma\ldots$	Mixing strength $\Delta\epsilon_{A'}\sim 10^{-4}$; $\Delta\epsilon_{\chi}\sim 10^{-4}$	**Synergy with BelleII/…**

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

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, 21)
- International Workshops (2015, 18, 19, 20, 21)

Funding support for R&D

- Double First-Class university project foundation of USTC
- CAS international cooperation and exchange project
- National Science Foundation of China (Key/General programs)
- The 14th five-year planning, National Key Basic Research Program of China