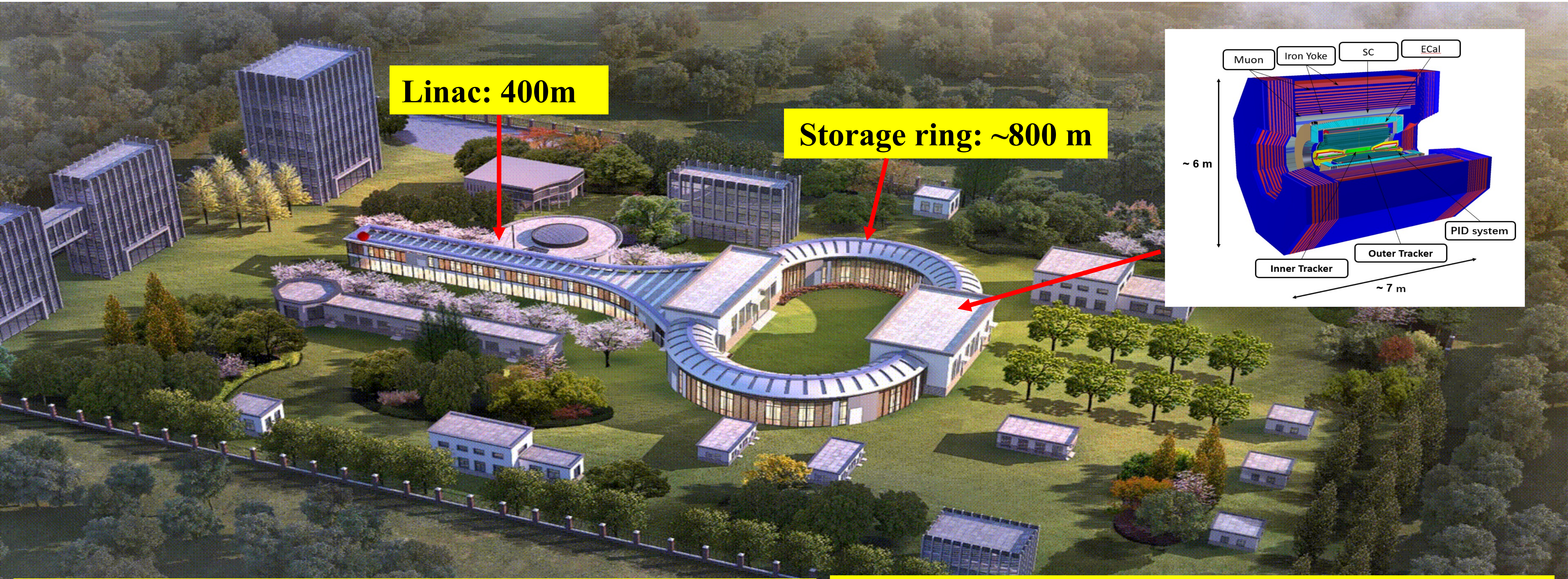
UNIVERSITY OF CHINESE ACADEMY OF SCIENCES

Experimental Program for Super Tau-Charm Facility

张剑宇（Jianyu Zhang）
(on behalf of the STCF working group)
University of Chinese Academy of Sciences

第七届强子谱与强子结构会议
2024.04.27 成都

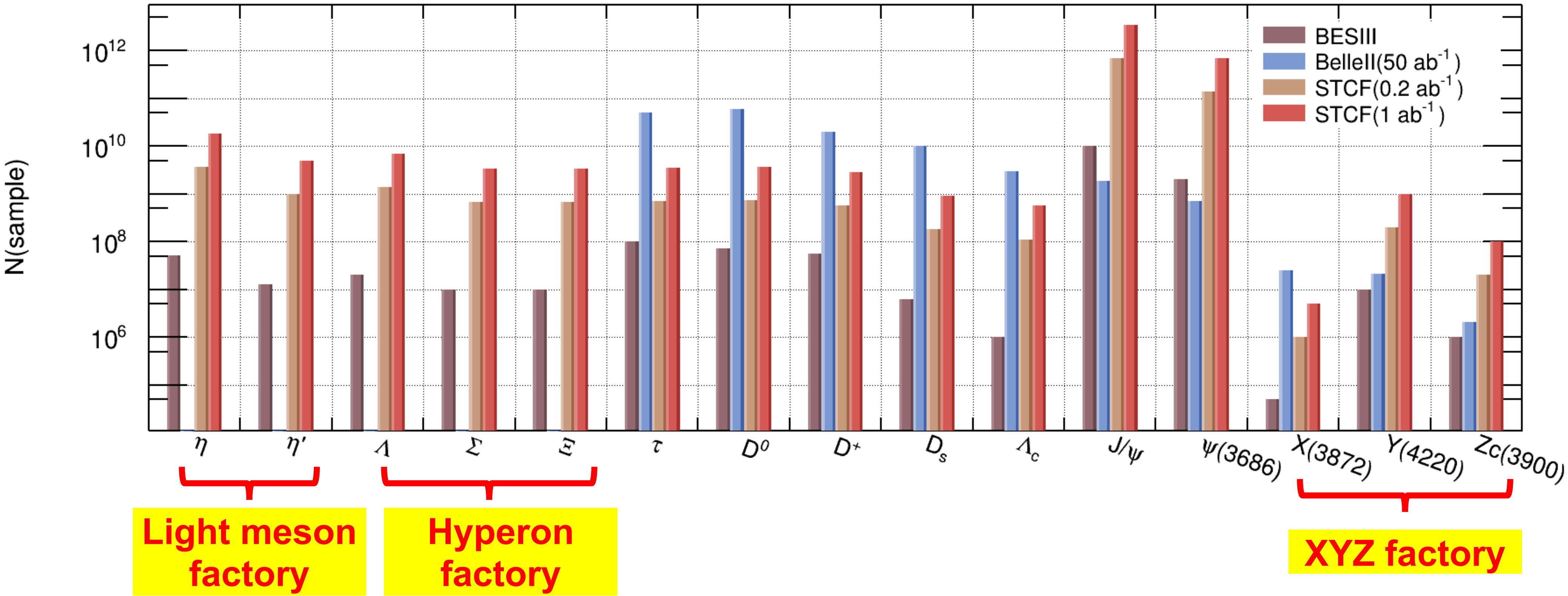
Super tau-charm facility in China



- Peak luminosity $>0.5\times10^{35}$ $cm^{-2}s^{-1}$ at 4 GeV
- Energy range E_{cm} = 2-7 GeV
- Potential to increase luminosity & realize beam polarization
- Total cost: 4.5B RMB

- 1 ab^{-1} data expected per year
- Rich of physics program, unique for physics with *c* quark and τ leptons,
- Important playground for study of QCD, exotic hadrons, flavor physics and search for new physics.

Expected data samples at STCF



- STCF is expected to have higher detection efficiency and low bkg. for productions at threshold
- STCF has excellent resolution, kinematic constraining
- Opportunities at 5-7 GeV which is experimentally blank before

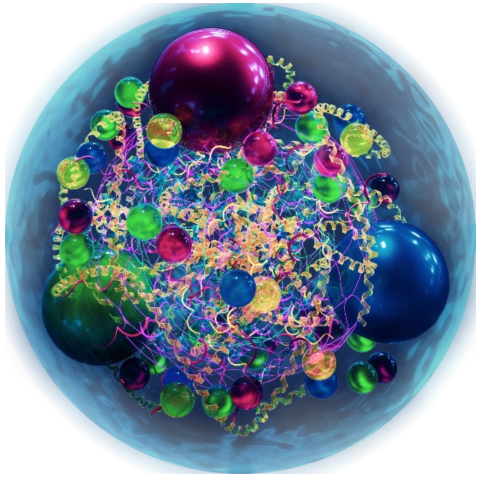
Physics program of STCF

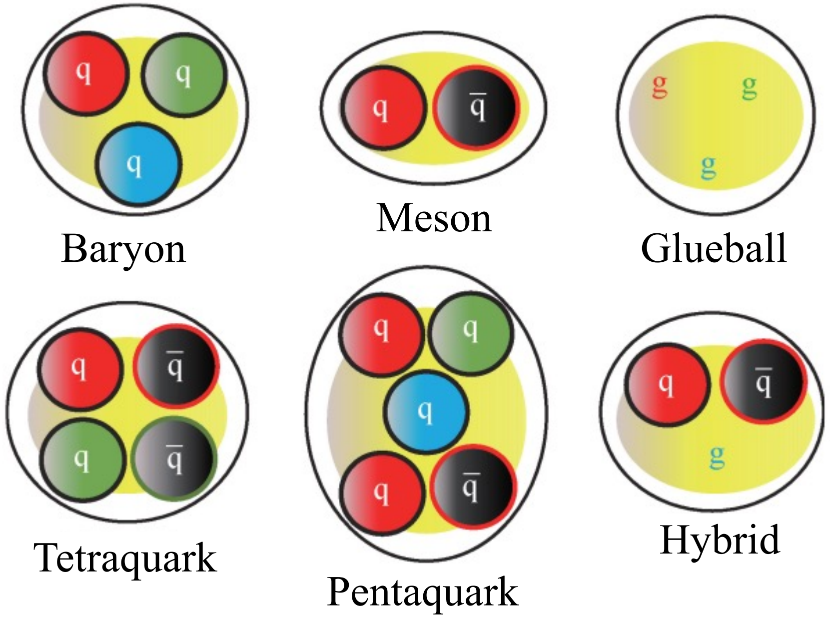
STCF CDR: Volume 1 -- Physics & Detector
Front. Phys. 19(1), 14701 (2024)

- **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+v, D→P l+ v
    - **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 πv, EDM of τ, τ→π/K π0 v 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+ v_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…

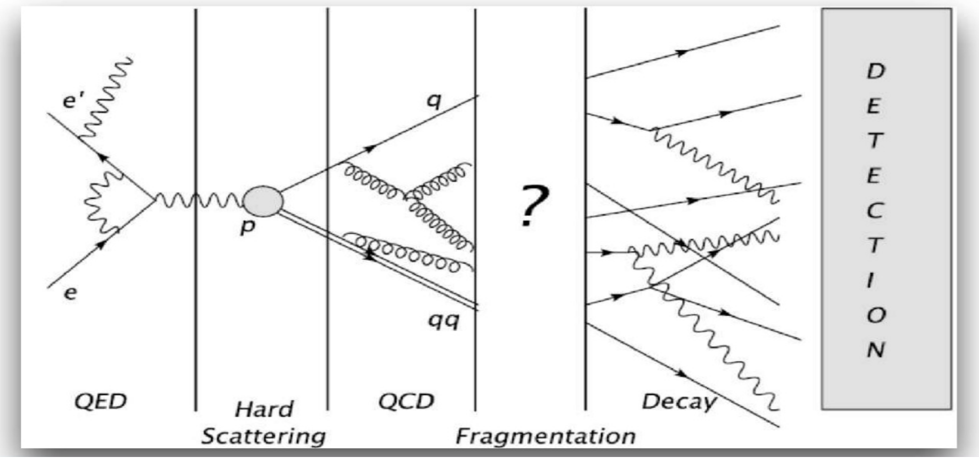
- **Leading role**
- In Competition with Belle II/LHCb
- **Synergy with BelleII/LHCb/Eic/EicC**

Hadron structure and hadron spectroscopy



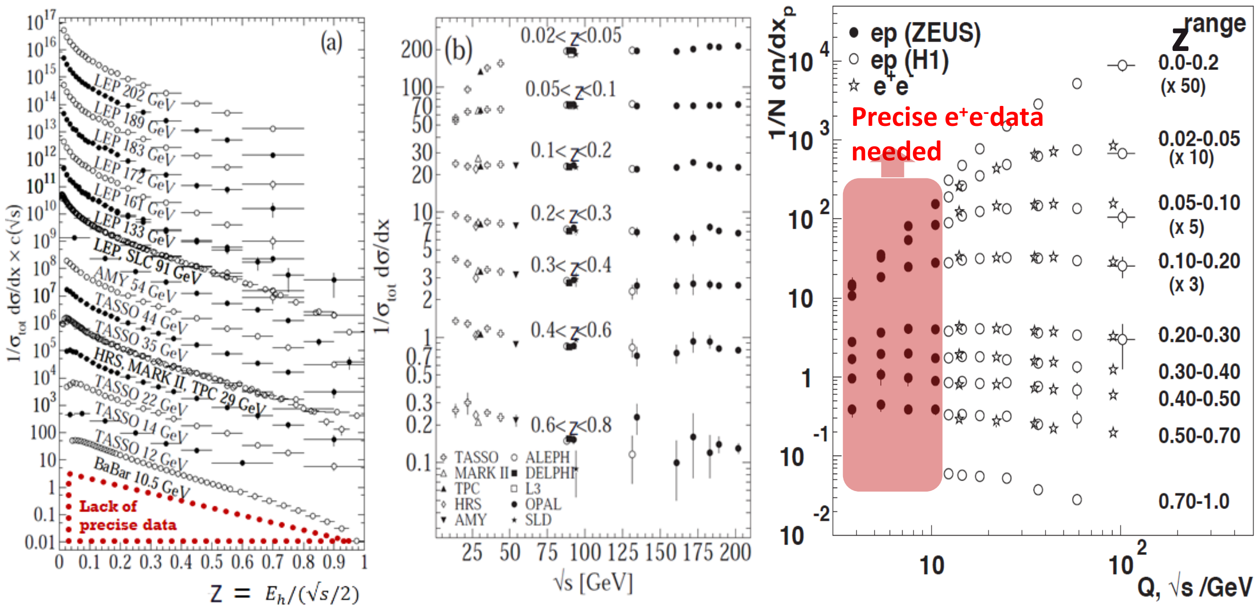


Fragmentation functions

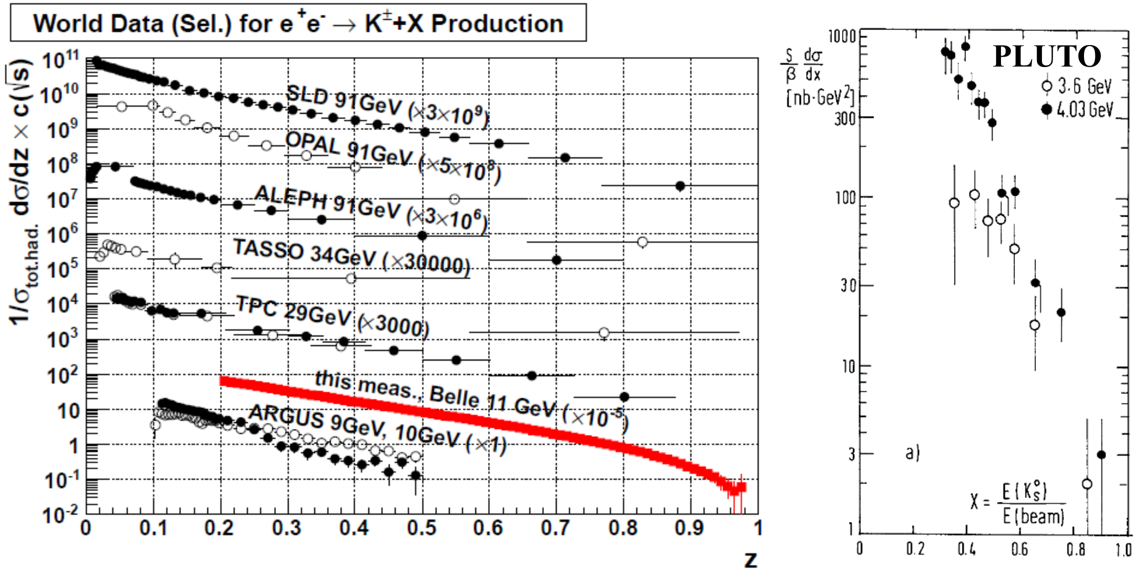


Fragmentation function $D_q^h(z)$: probability that hadron h is found in the debris of a hadron carrying a fraction $z=2E_h/\sqrt{s}$ of parton's momentum.

World data: Pion



World data: Kaon



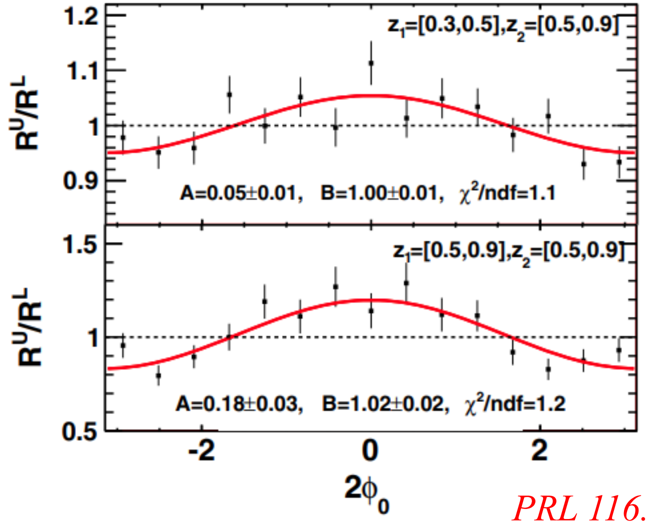
Collins fragmentation function

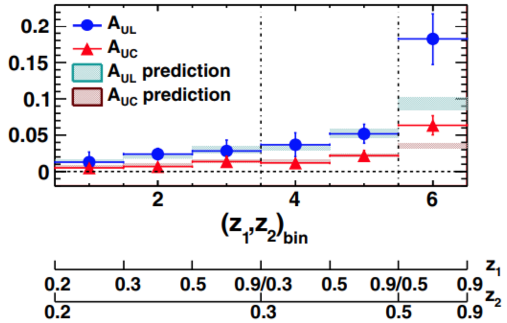
Collins FF

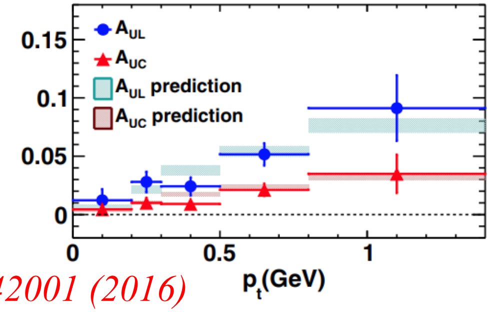
→ describes the fragmentation of a transversely polarized quark into a spin-less hadron *h*.

→ leads to an azimuthal modulation of hadrons around the quark momentum, that can be extract by the double ratio

$$\frac{R^U}{R^{L(C)}} = A\cos(2\phi_0) + B$$





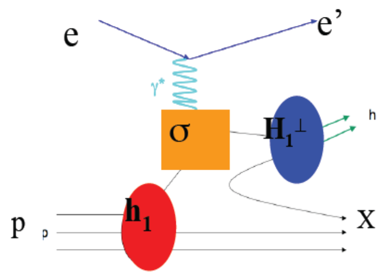


PRL 116.042001 (2016)

Significant Collins asymmetries are observed rise with fractional energies and p_t

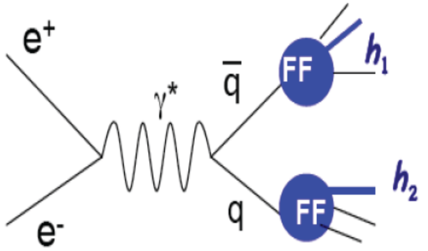
SIDIS

Transversity ⊗ Collins FF



e+ e-

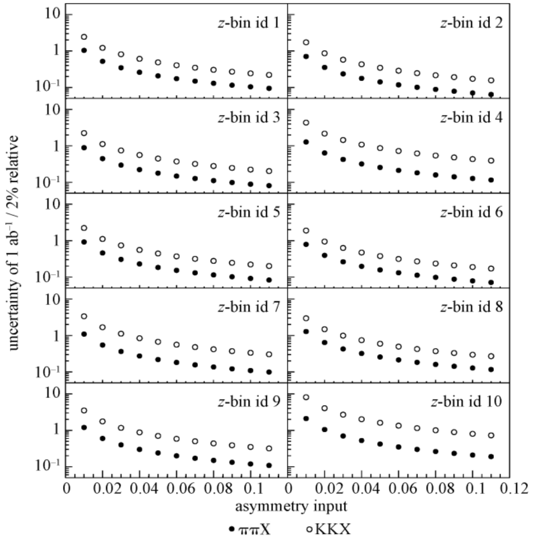
Collins FF ⊗ Collins FF



The statistical uncertainty asymmetry A^{UL} with 1ab^{-1} at 7 GeV:

$(1.4\sim4.2)\times10^{-4}$ for $\pi\pi X$

$(3.5\sim20)\times10^{-3}$ for KKX



The result will provide precision Collins FF input for TMD extraction by EicC (a precision of 2% is required).

Journal of UCAS 38 (2021) 433

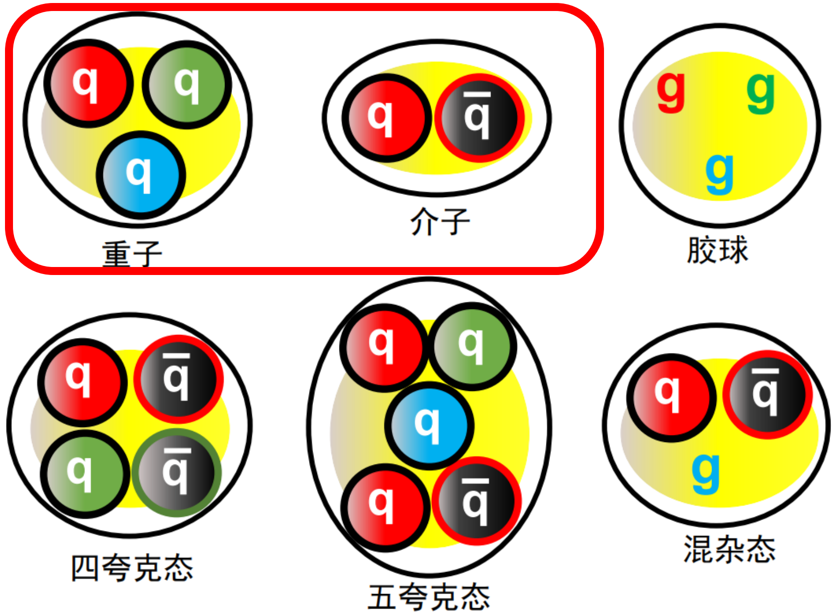
Hadrons Spectrum

- Experiments at particle accelerators in last fifties and sixties created more than 100 hadrons ➔ "hadronic zoo"
- Quark model established order in the hadronic zoo

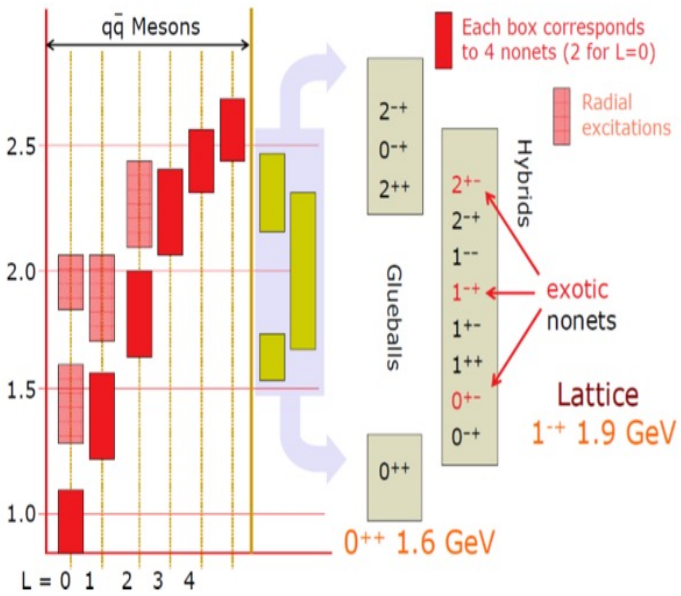
M. Gell-Mann, A schematic model of baryons and mesons: Phys.Lett. 8 (1964) 214-215
"Baryons can now be constructed from quarks by using the combinations (qqq), $(qqqq\bar{q})$, etc., while mesons are made out of $(q\bar{q})$, $(qq\bar{q}\bar{q})$, etc".

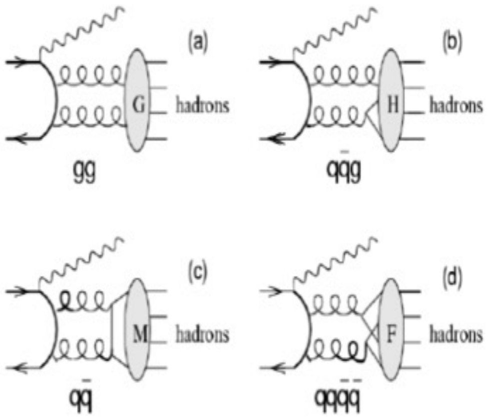
G. Zweig, An SU(3) model for strong interaction symmetry and its breaking. CERN-TH-401
"In general, we would expect that baryons are built not only from the product of these aces, AAA, but also from $\bar{A}AAAA$, $\bar{A}\bar{A}AAAAA$, etc., where $\bar{A}$ denotes an anti-ace. Similarly, mesons could be formed from $\bar{A}A$, $\bar{A}\bar{A}AA$, etc".

- Suggested by self-coupling of gluons of QCD, glueballs and hybrids exist.
- Experimental searches for exotic hadrons have a long history
- Recent high-quality data samples from several experiments allow us study the properties of established mesons, and search for new states.



Glueballs and hybrids



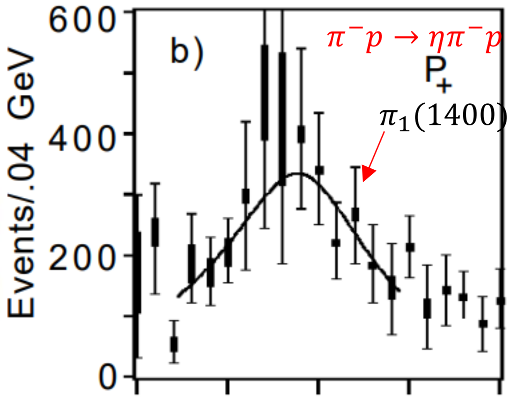


$\Gamma(J/\psi \to \gamma G) \sim O(\alpha\alpha_s^2), \Gamma(J/\psi \to \gamma H) \sim O(\alpha\alpha_s^3),$

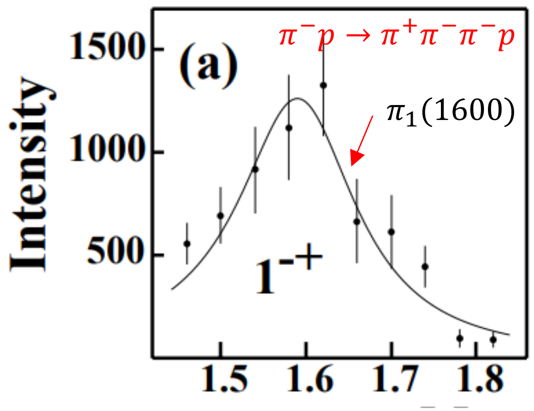
$\Gamma(J/\psi \to \gamma M) \sim O(\alpha\alpha_s^4), \Gamma(J/\psi \to \gamma F) \sim O(\alpha\alpha_s^4)$

- Experimental evidence for isovector/isoscalar states with $J^{PC} = 1^{-+}$, complete the hybrid multiplet.

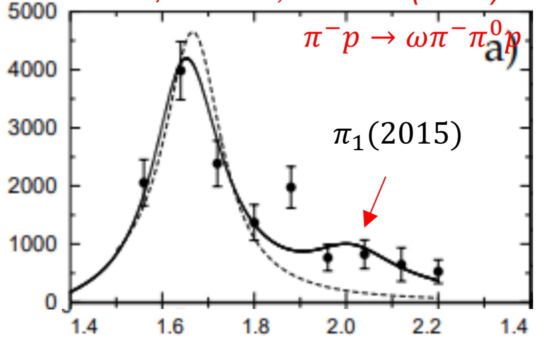
E852, *PRL* 79, 1630 (1997)



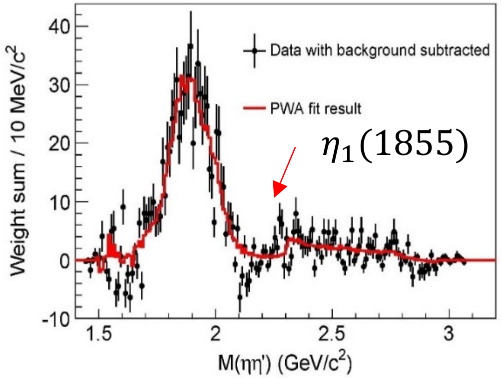
E852, *PRL 81, 5760 (1998)*



E852, *PRL 94, 032002 (2005)*



PRL 129 (2022) 192002



- Charmonium decays are ideal hunting grounds for light glueballs and exotics
  - “Glue-rich” environment
  - Clean high statistics data samples from e^+e^- production

Heavy "nonstandard" hadron candidates

- Large amount of experimental activity on the "nonstandard" heavy sector
  - e^+e^- direct production: BESIII, Belle, BaBar
  - $pp/p\bar{p}$ promote production: LHCb, CMS, ALTAS…
  - Quarkonia decay: BESIII, Belle, BaBar
  - B, Λ_b decays: Belle, Babar, LHCb

2003-
X(3872)

2005-
X(3915)
Y(4260)
Y_b(10860)

2007-
X(3940)
X(4160)
Y(4360)
Y(4660)
X(4050)
X(4250)
Z(4430)

2009-
X(4140)
X(4350)

2011-
Z_b(10610)
Z_b(10650)

2013-
Z_c(3900)
Z_c(4020)
Z(4200)

2015-
P_c(4380)
P_c(4450)

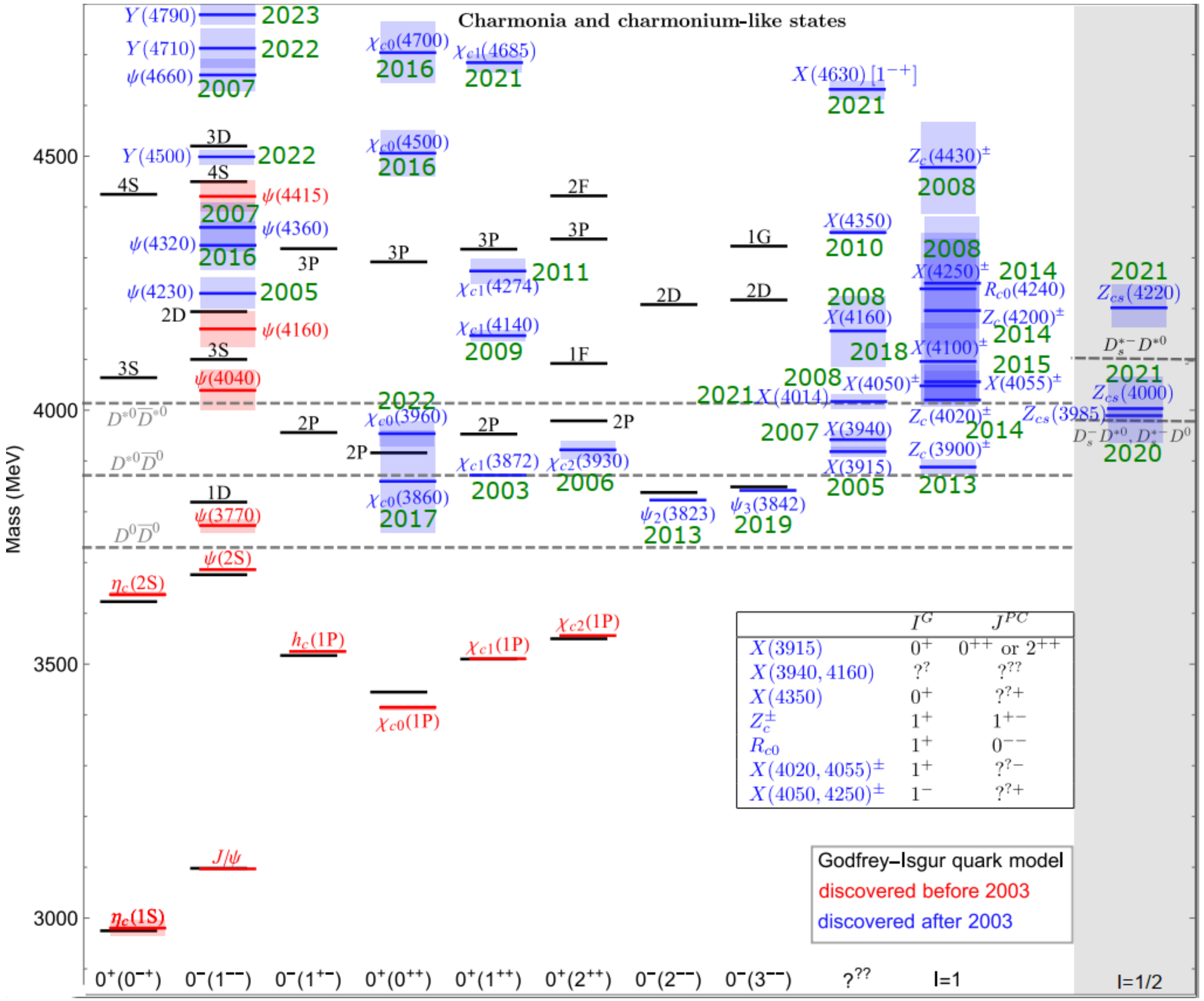
2017-
X(4274)
X(4500)
X(4700)
Y(4220)
Y(4390)

2019-
P_c(4457)
P_c(4440)
P_c(4312)
X(3842)
X(6900)
X_0(2900)
X_1(2900)

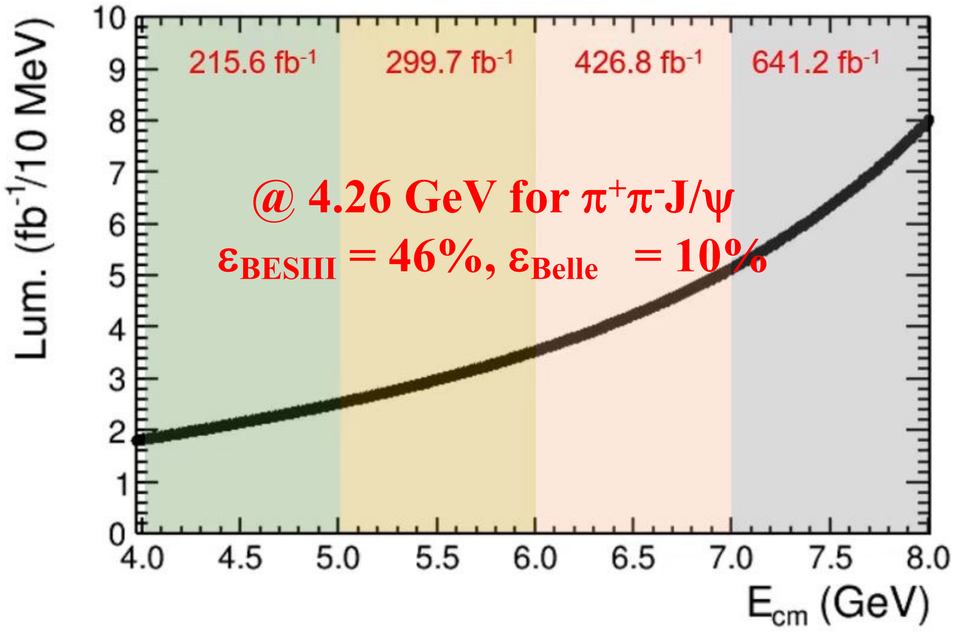
2021-
X(4685)
X(4630)
Z (3985)

- Most of them are with masses in 4-7 GeV.
- However, their properties are still poorly known.

Charmonium (Like) states at STCF

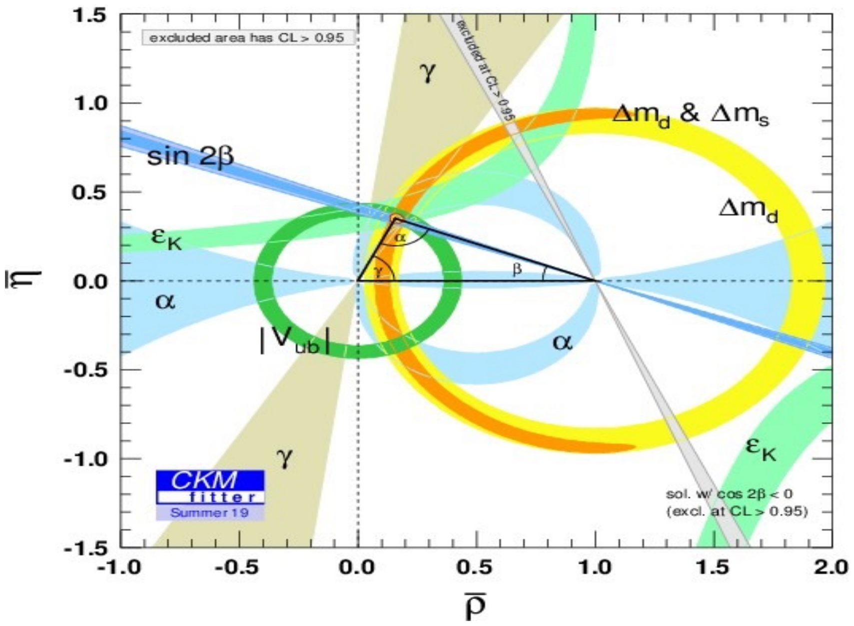


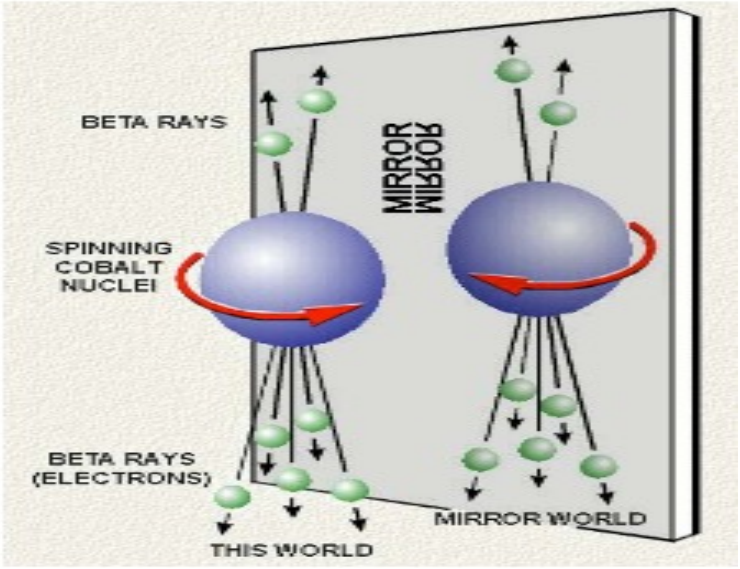
arXiv: 2203.07141



- **Belle II :** ISR approach; B meson decay ($m_R <$ 4.8 GeV)
- **LHCb:** B/Λ_b decay; Prompt production
- **STCF:** Scan with 10 MeV/step, every point has 10 fb^{-1}/year, 3 ab^{-1} in 4-7 GeV

Flavor physics and CPV study





Charm physics

- 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 $\gamma/\phi3$ angle)
    - $D^0-\bar{D}^0$ 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)

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

arXiv:2203.03211

Precision measurements of CKM elements

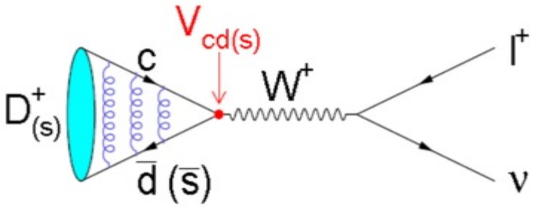
CKM matrix elements are fundamental SM parameters that describe the mixing of quark fields due to weak interaction.

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

Leptonic and semileptonic decays of charmed hadrons (D^0, D^+, D_s^+, Λ_c^+) provide ideal testbeds to explore weak and strong interactions

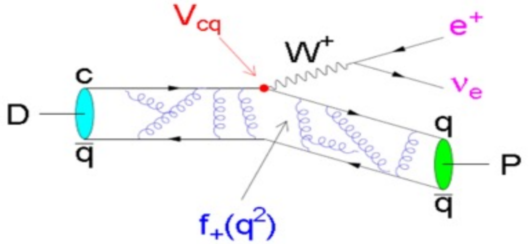
1. $|V_{cs(d)}|$: better test on CKM matrix unitarity
2. (Semi-)leptonic D(s) decays allow for LFU tests
3. $f_{D(s)^+}$, $f^{+K(\pi)}(0)$: test of LQCD

Purely Leptonic:



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

Semi-Leptonic:



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

Prospect of charm leptonic decay at STCF

	BESIII	STCF	Belle II
Luminosity	2.93 fb^{-1} at 3.773 GeV	1 ab^{-1} at 3.773 GeV	50 ab^{-1} at $\Upsilon(nS)$
$\mathcal{B}(D^+ \to \mu^+\nu_\mu)$	$5.1\%_{\rm stat}$ $1.6\%_{\rm syst}$	$0.28\%_{\rm stat}$	$2.8\%_{\rm stat}$
$f^{\mu}_{D^+}$ (MeV)	$2.6\%_{\rm stat}$ $0.9\%_{\rm syst}$	$0.15\%_{\rm stat}$	
$\lvert V_{cd}\rvert$	$2.6\%_{\rm stat}$ $1.0\%^{*}_{\rm syst}$	$0.15\%_{\rm stat}$	
$\mathcal{B}(D^+ \to \tau^+\nu_\tau)$	$20\%_{\rm stat}$ $10\%_{\rm syst}$	$0.41\%_{\rm stat}$	–
$\frac{\mathcal{B}(D^+ \to \tau^+\nu_\tau)}{\mathcal{B}(D^+ \to \mu^+\nu_\mu)}$	$21\%_{\rm stat}$ $13\%_{\rm syst}$	$0.50\%_{\rm stat}$	–
Luminosity	6.3 fb^{-1} at (4.178, 4.226) GeV	1 ab^{-1} at 4.009 GeV	50 ab^{-1} at $\Upsilon(nS)$
$\mathcal{B}(D_s^+ \to \mu^+\nu_\mu)$	$2.4\%_{\rm stat}$ $3.0\%_{\rm syst}$	$0.30\%_{\rm stat}$	$0.8\%_{\rm stat}$ $1.8\%_{\rm syst}$
$f^{\mu}_{D_s^+}$ (MeV)	$1.2\%_{\rm stat}$ $1.5\%_{\rm syst}$	$0.15\%_{\rm stat}$	
$\lvert V_{cs}\rvert$	$1.2\%_{\rm stat}$ $1.5\%_{\rm syst}$	$0.15\%_{\rm stat}$	
$\mathcal{B}(D_s^+ \to \tau^+\nu_\tau)$	$1.7\%_{\rm stat}$ $2.1\%_{\rm syst}$	$0.24\%_{\rm stat}$	$0.6\%_{\rm stat}$ $2.7\%_{\rm syst}$
$f^{\tau}_{D_s^+}$ (MeV)	$0.8\%_{\rm stat}$ $1.1\%_{\rm syst}$	$0.11\%_{\rm stat}$	
$\lvert V_{cs}\rvert$	$0.8\%_{\rm stat}$ $1.1\%_{\rm syst}$	$0.11\%_{\rm stat}$	–
$\overline{f}^{\mu\&\tau}_{D_s^+}$ (MeV)	$0.7\%_{\rm stat}$ $0.9\%_{\rm syst}$	$0.09\%_{\rm stat}$	$0.3\%_{\rm stat}$ $1.0\%_{\rm syst}$
$\lvert \overline{V}^{\mu\&\tau}_{cs}\rvert$	$0.7\%_{\rm stat}$ $0.9\%_{\rm syst}$	$0.09\%_{\rm stat}$	–
$f_{D_s^+}/f_{D^+}$	$1.4\%_{\rm stat}$ $1.7\%_{\rm syst}$	$0.21\%_{\rm stat}$	–
$\frac{\mathcal{B}(D_s^+ \to \tau^+\nu_\tau)}{\mathcal{B}(D_s^+ \to \mu^+\nu_\mu)}$	$2.9\%_{\rm stat}$ $3.5\%_{\rm syst}$	$0.38\%_{\rm stat}$	$0.9\%_{\rm stat}$ $3.2\%_{\rm syst}$

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

Probe CP violation at tau-charm factory

Billions hyperon pairs from J/ψ decay, clean topology, background free

Transversely polarized, spin correlation

Sensitivity: $A_{CP} \sim 10^{-4}$, $\xi \sim 0.05^{\circ}$

Peak cross section in $\sqrt{s}$ =4-5 GeV, $\sigma_{\tau\tau} \approx 3.5$ nb, 10 ab^{-1} data in total

Sensitivity of τ decay with 1ab^{-1} @ 4.26 GeV $\sim 9.7 \times 10^{-4}$

CP in hyperon decay

CP in tau decay/production

CP in charm mixing

CPT in kaon mixing

Billions $D^0/\bar{D}^0$, threshold production, quantum coherence with $(D^0\bar{D}^0)_{CP=-}$ or $(D^0\bar{D}^0)_{CP=+}$

Sensitivity: $x \sim 0.035\%$, $y \sim 0.023\%$, $r_{CP} \sim 0.017$, $\alpha_{CP} \sim 1.3^{\circ}$

CP tagging and flavor tagging of $K^0/\bar{K}^0$ available from J/ψ decay

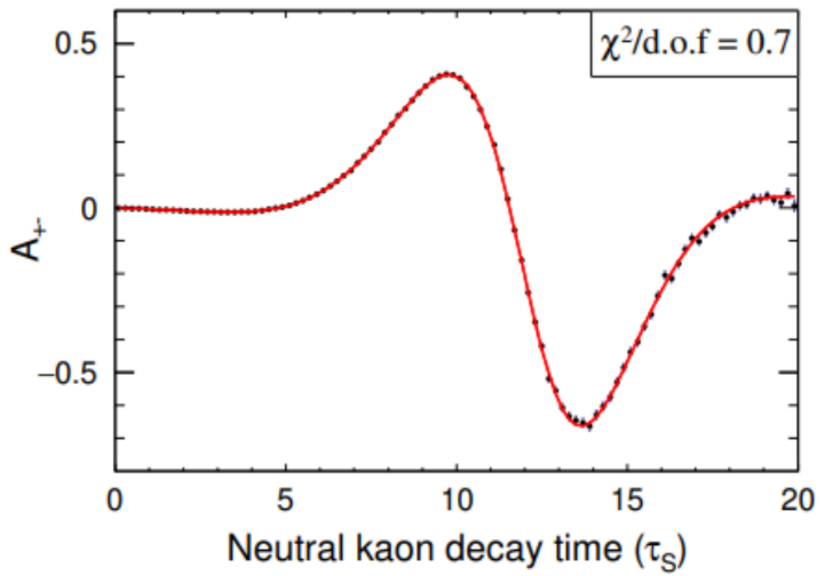
CP variables determined with time-dependent decay rate

CPT Sensitivity: $\eta_{\pm} \sim 10^{-3}$, $\Delta\phi_{\pm} \sim 0.05^{\circ}$

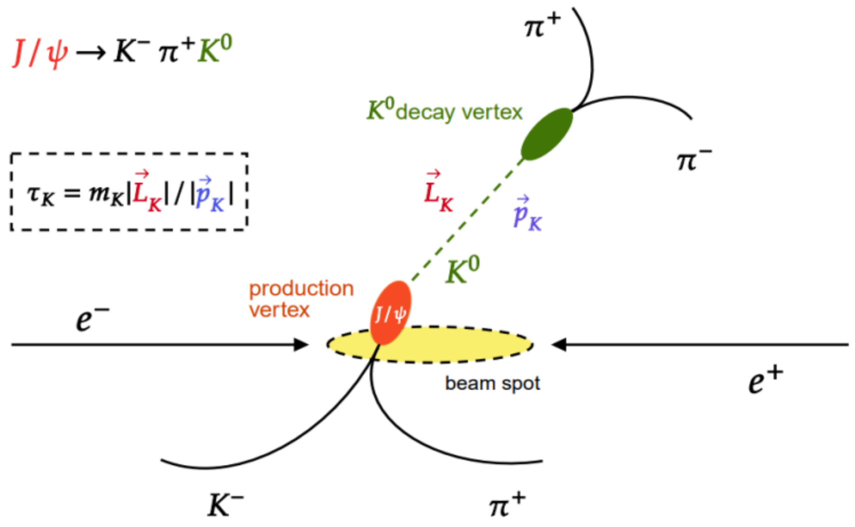
Testing CPT with neutral kaons

CPV parameters $|\eta_{+-}|$, ϕ_{+-} can be determined from difference of time-dependent decay rates of K^0 and $\bar{K}^0$ to $\pi^+\pi^-$:

$$A_{CP}^{+-}(\tau) = \frac{\bar{R}_f(\tau) - R_f(\tau)}{\bar{R}_f(\tau) + R_f(\tau)} \propto \frac{|\eta_{+-}| e^{\frac{1}{2}\Delta\Gamma\tau} \cos(\Delta m\tau - \phi_{+-})}{1 + |\eta_{+-}|^2 e^{\Delta\Gamma\tau}}$$



- Precise determination of K^0 decay vertex is crucial to time-dependence measurement



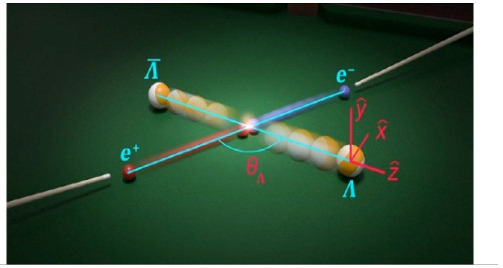
- $|\eta_{+-}|$ reveals direct CPV in kaon meson
- ϕ_{+-} will be used to set limits on CPT violation
- With over 10 billion $K^0/\bar{K}^0$ events from J/ψ decay, the sensitivity of $|\eta_{+-}|$, ϕ_{+-} are $\mathcal{O}(10^{-3}) \Rightarrow$ one magnitude better than PDG average

J. Y. Zhang et al., arXiv:2209.12551

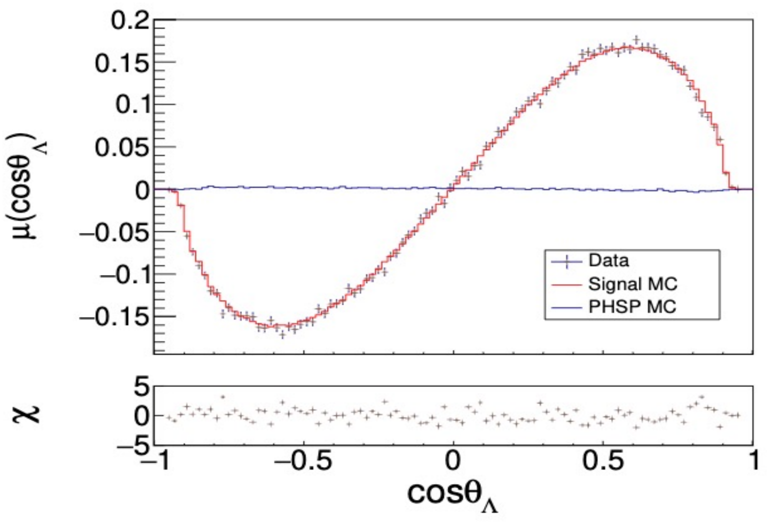
Polarization of Λ hyperons and CPV

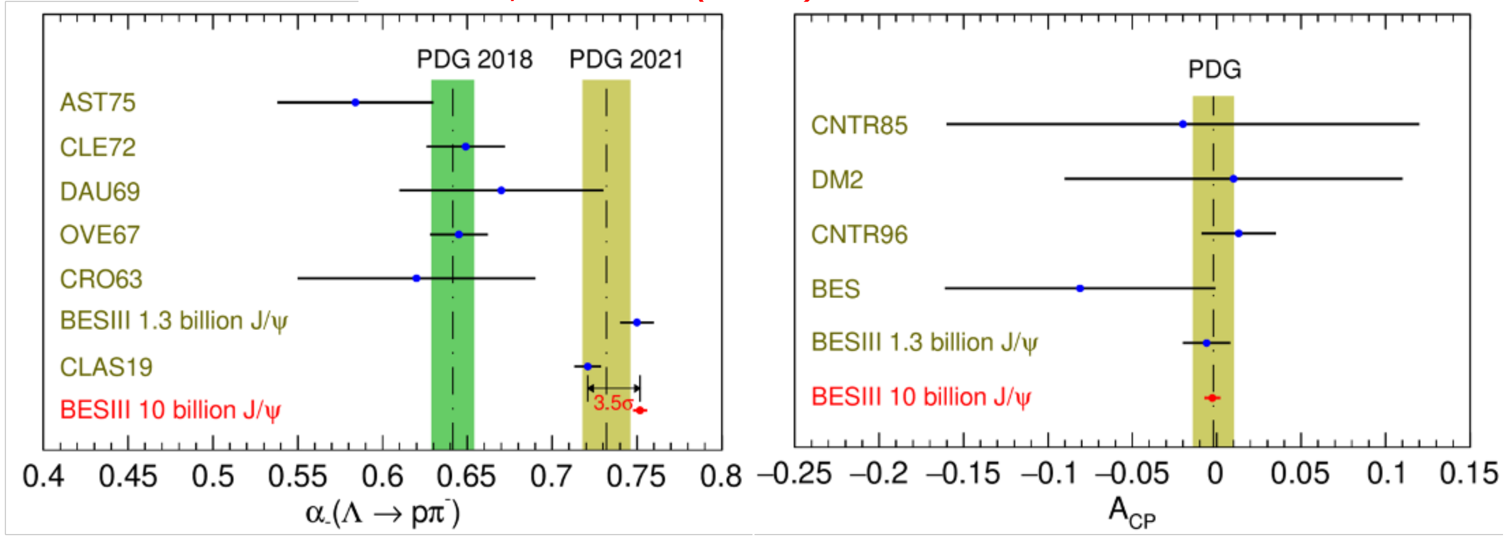
- Updated results based on 10B J/ψ events: ~0.42M signals
- Decay asymmetries with best precisions ever

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



PRL 129, 131801 (2022)



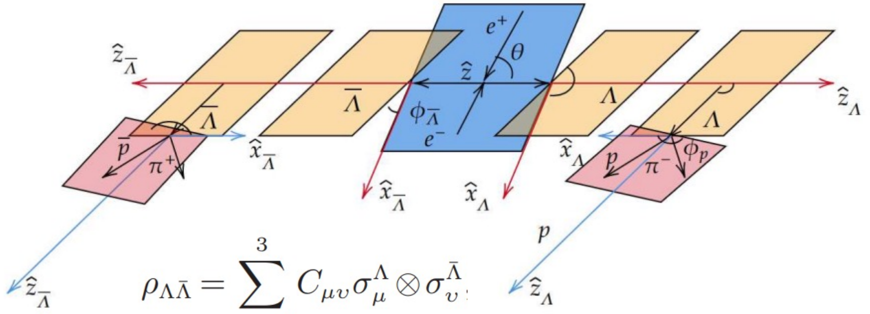


Par.	This Work*	Previous results **	PDG 2018 ***
$\alpha_{J/\psi}$	$0.4748 \pm 0.0022 \pm 0.0024$	$0.461 \pm 0.006 \pm 0.007$	0.469 ± 0.027
$\Delta\Phi$	$0.7521 \pm 0.0042 \pm 0.0080$	$0.740 \pm 0.010 \pm 0.009$	-
α_-	$0.7519 \pm 0.0036 \pm 0.0019$	$0.750 \pm 0.009 \pm 0.004$	0.642 ± 0.013
α_+	$-0.7559 \pm 0.0036 \pm 0.0029$	$-0.758 \pm 0.010 \pm 0.007$	-0.71 ± 0.08
A_{CP}	$-0.0025 \pm 0.0046 \pm 0.0011$	$0.006 \pm 0.012 \pm 0.007$	-
$\alpha_{\pm,avg.}$	$0.7542 \pm 0.0010 \pm 0.0020$	$0.754 \pm 0.003 \pm 0.002$	-

~7σ upward shift from all previous measurements

0.5% level sensitivity for CPV test
SM prediction: 10^{-4}~10^{-5}

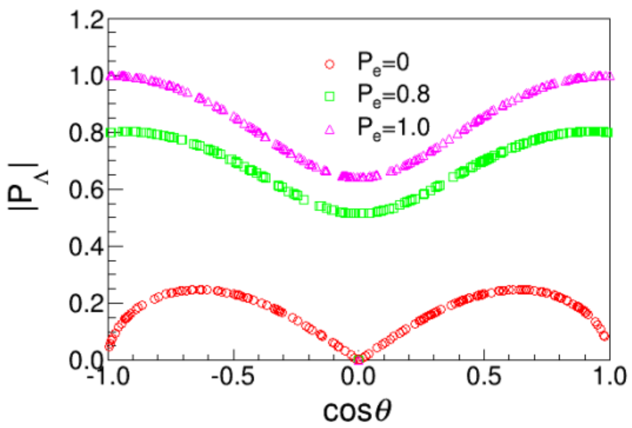
CPV in Λ decay with polarized electron beam

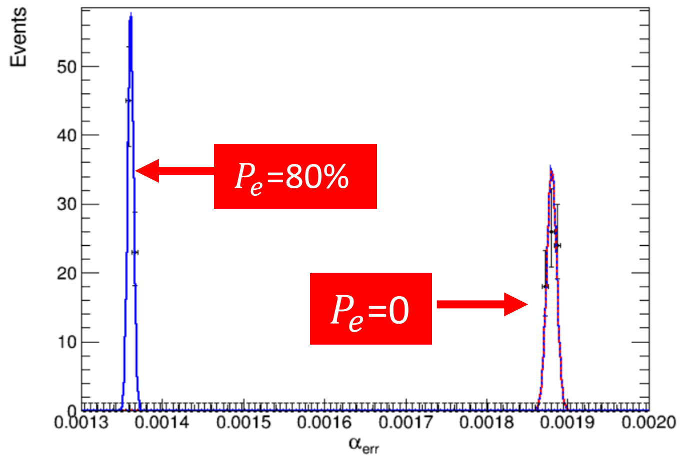


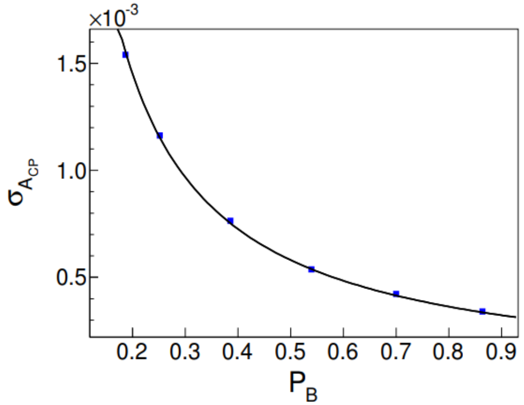
$$\rho_{\Lambda\bar{\Lambda}} = \sum_{\mu\upsilon=0}^{3} C_{\mu\upsilon}\sigma_{\mu}^{\Lambda} \otimes \sigma_{\upsilon}^{\bar{\Lambda}}$$

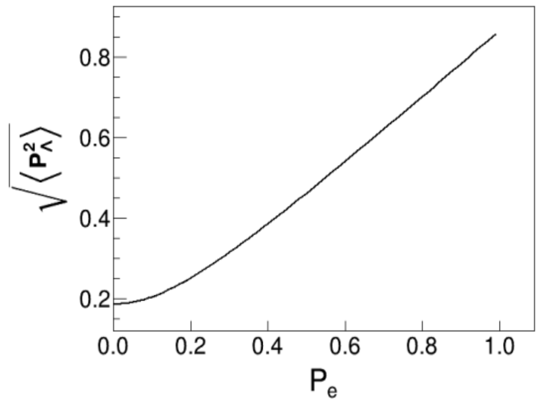
$$\begin{bmatrix} 1+\alpha_\psi\cos^2\theta & \gamma_\psi P_e\sin\theta & \beta_\psi\sin\theta\cos\theta & (1+\alpha_\psi)P_e\cos\theta \\ \gamma_\psi P_e\sin\theta & \sin^2\theta & 0 & \gamma_\psi\sin\theta\cos\theta \\ -\beta_\psi\sin\theta\cos\theta & 0 & \alpha_\psi\sin^2\theta & -\beta_\psi P_e\sin\theta \\ -(1+\alpha_\psi)P_e\cos\theta & -\gamma_\psi\sin\theta\cos\theta & -\beta_\psi P_e\sin\theta & -\alpha_\psi-\cos^2\theta \end{bmatrix},$$

$$\mathbf{P}_{\Lambda} = \frac{\gamma_\psi P_e\sin\theta\hat{x}_1 - \beta_\psi\sin\theta\cos\theta\hat{y}_1 - (1+\alpha_\psi)P_e\cos\theta\hat{z}_1}{1+\alpha_\psi\cos^2\theta}.$$





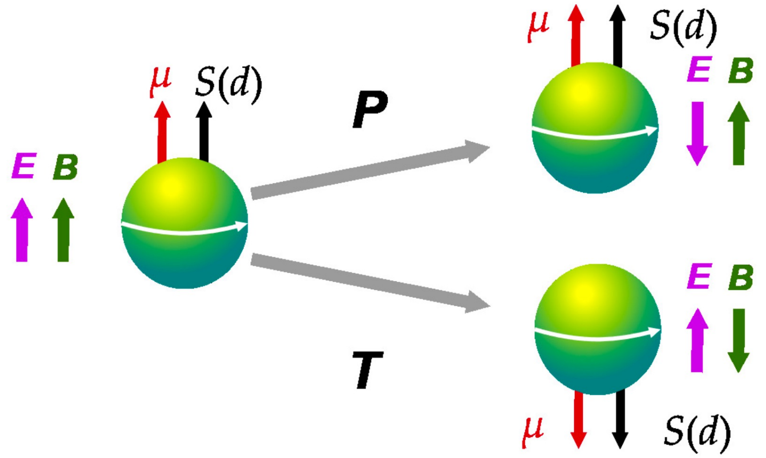




- Large statistics and electron polarization will improve the sensitivity of CPV significantly.
- The sensitivity of CPV follows : $\sigma_{A_{CP}} \approx \sqrt{\frac{3}{2}} \frac{1}{\alpha_1\sqrt{N_{sig}}\sqrt{\langle P_B^2 \rangle}}.$

Searching for hyperon EDM at STCF

μ: magnetic dipole moment
d: electric dipole moment
S: particle spin



$$\mathcal{H} = -\boldsymbol{\mu}\cdot\mathbf{B} - \boldsymbol{\delta}\cdot\mathbf{E} \xrightarrow{P} \mathcal{H} = -\boldsymbol{\mu}\cdot\mathbf{B} + \boldsymbol{\delta}\cdot\mathbf{E}$$

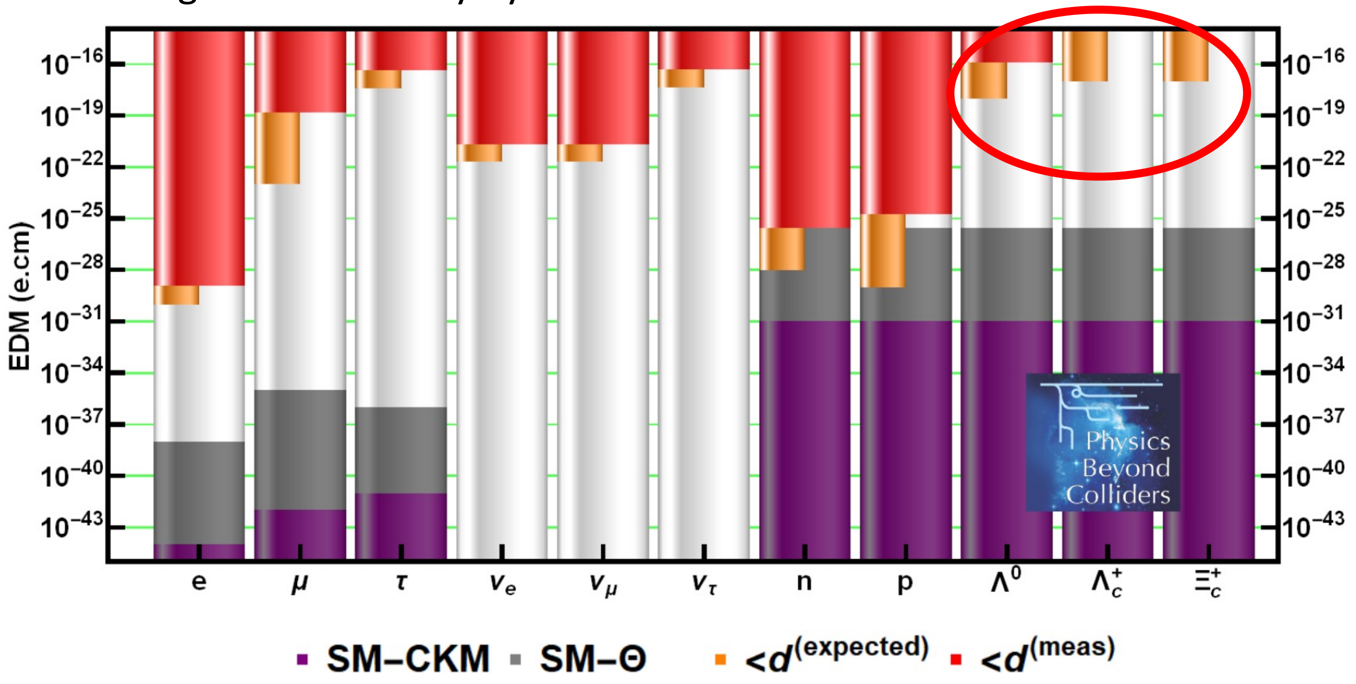
$$\mathcal{H} = -\boldsymbol{\mu}\cdot\mathbf{B} - \boldsymbol{\delta}\cdot\mathbf{E} \xrightarrow{T} \mathcal{H} = -\boldsymbol{\mu}\cdot\mathbf{B} + \boldsymbol{\delta}\cdot\mathbf{E}$$

Non-zero EDM will violate P and T symmetry:
T violation ↔ CP violation, if CPT holds.

PRD47(1993)1744, PLB 839(2023)137834, PRD.108.L091301

Systematic measurement of the EDMs of the hyperon family!

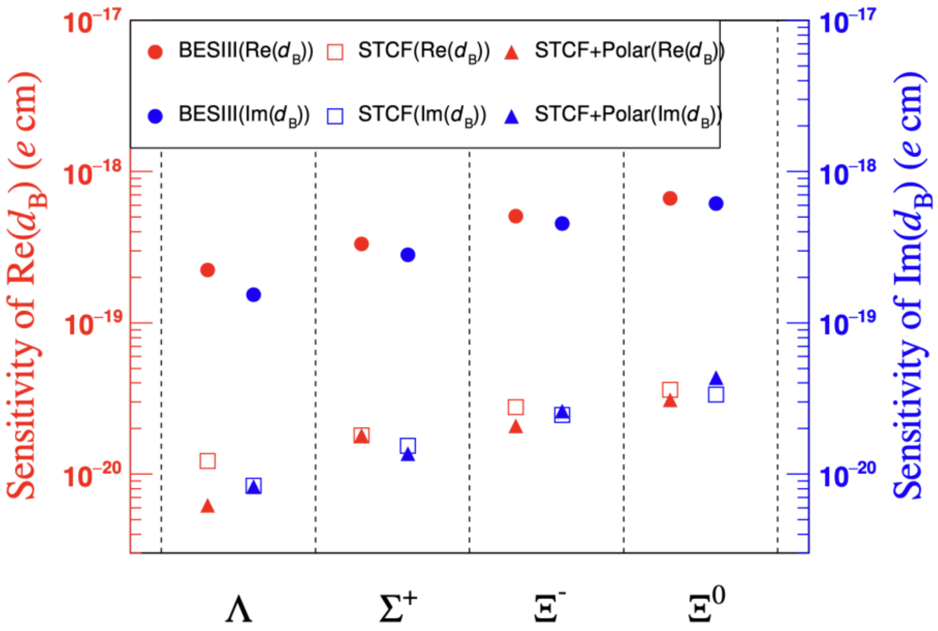
Only the EDM of Λ in the hyperon family has been measured (with low precision). Based on massive quantum-correlated hyperon pairs, BESIII is expected to improve the measurement precision of the Λ EDM by a factor of **1000**, and will be improved 2 order of magnitude furtherly by STCF.



J.Phys.G **47 (2020) 1, 010501**

Sensitivity of hyperon EDM measurements

reminder: $H_T = \frac{2e}{3M_{J/\psi}^2} g_V d_B$



(a)Sensitivity of $Re(d_B)$ and $Im(d_B)$

J. Fu, H.B. Li, J. Wang, F. Yu, and J. Zhang , PhysRevD.108.L091301

SM: $\sim 10^{-26}$ *e* cm

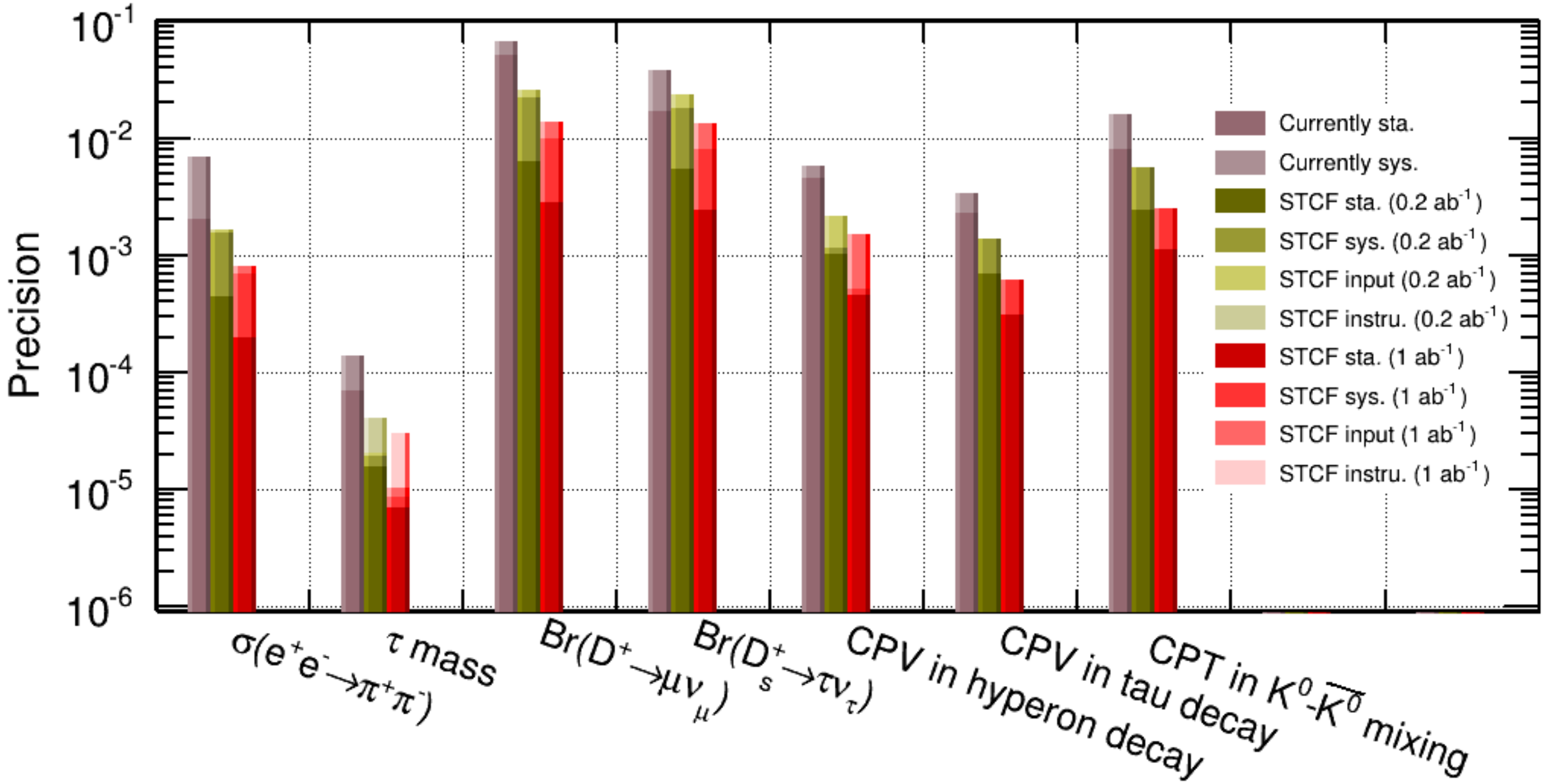
BESIII: milestone for hyperon EDM measurement
Λ 10^{-19}*e* cm (FermiLab 10^{-16} e cm)

first achievement for Σ^+,Ξ^- and Ξ^0 at level of 10^{-19}*e* cm

a litmus test for new physics

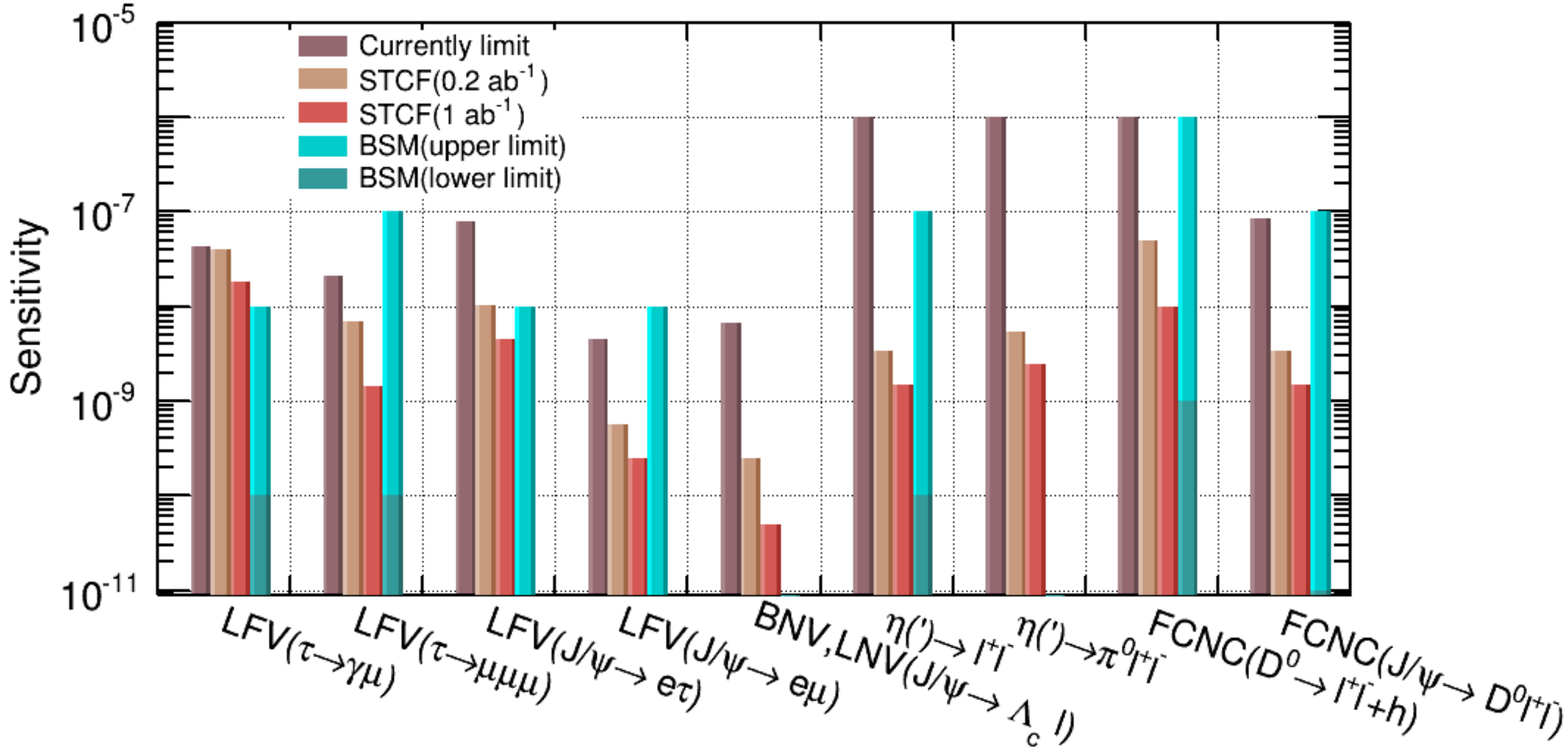
STCF: improved by 2 order of magnitude

Sensitivity of precision measurements



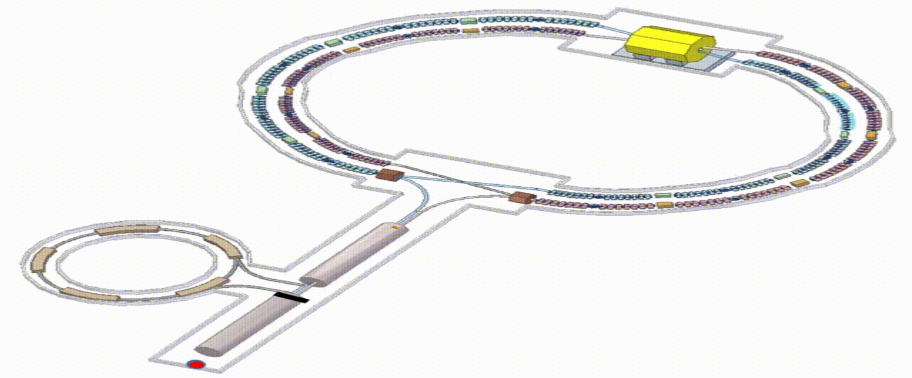
➢ Precision frontier for testing of SM parameters, uncertainties from reducible (selection-based), and irreducible sources (theoretical input, instrument effect).

Sensitivity of rare/forbidden decays



- ➢ Sensitivity of various rare/forbidden decays from STCF measurements are compared with various BSM models.
- ➢ The excellent precision from STCF can be used to distinguish from various BSM models.

STCF accelerator

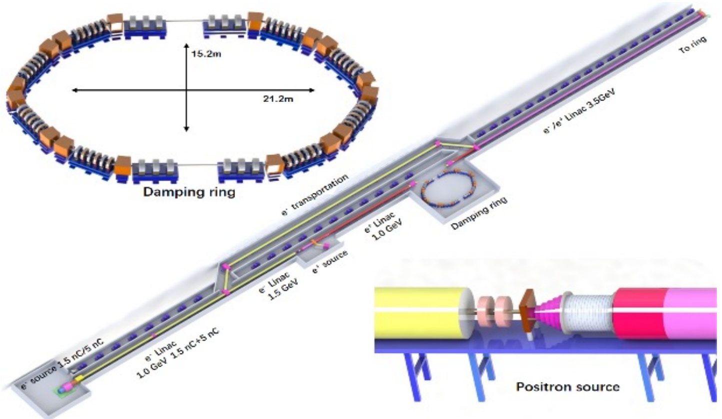


Challenge： realize luminosity of >0.5x10^{35} cm^{-2} s^{-1}

$$L(cm^{-2}s^{-1}) = \frac{\gamma\, n_b\, I_b}{2\, e\, r_e \beta_y^*} H\, \xi_y$$

Interaction Region: Large Piwinski Angle Collision + Crabbed Wais

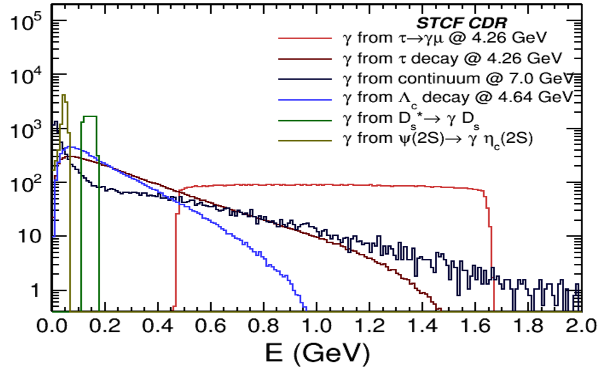
Parameters	Phase1	Phase2
Circumference/m	600~800	600~800
Optimized Beam Energy/GeV	2.0	2.0
Beam Energy Range/GeV	1-3.5	1-3.5
Current/A	1.5	2.0
Emittance $(\varepsilon_x/\varepsilon_y)$/nm·rad	6/0.06	5/0.05
β Function @IP (β_x^*/β_y^*)/mm	60/0.6	50/0.5(estimated)
Full Collision Angle 2θ/mrad	60	60
Tune Shift ξy	0.06	0.08
Hourglass Factor	0.8	0.8
Aperture and Lifetime	15σ, 1000s	15σ, 1000s
Luminosity @Optimized Energy/×10^{35}cm^{-2}s^{-1}	~0.5	~1.0

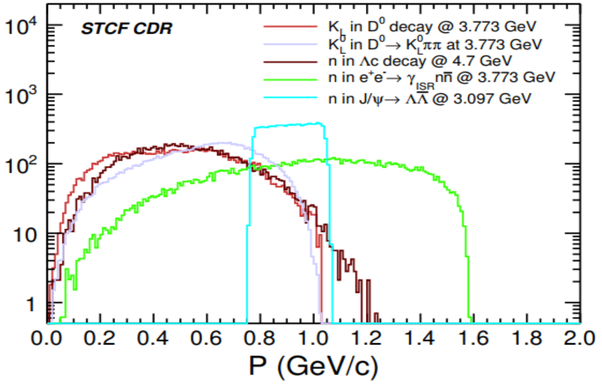


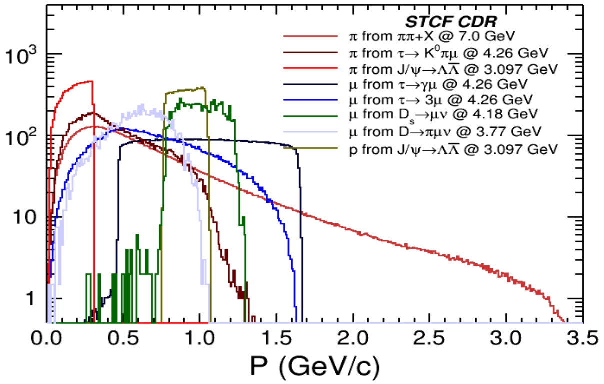
Injector:

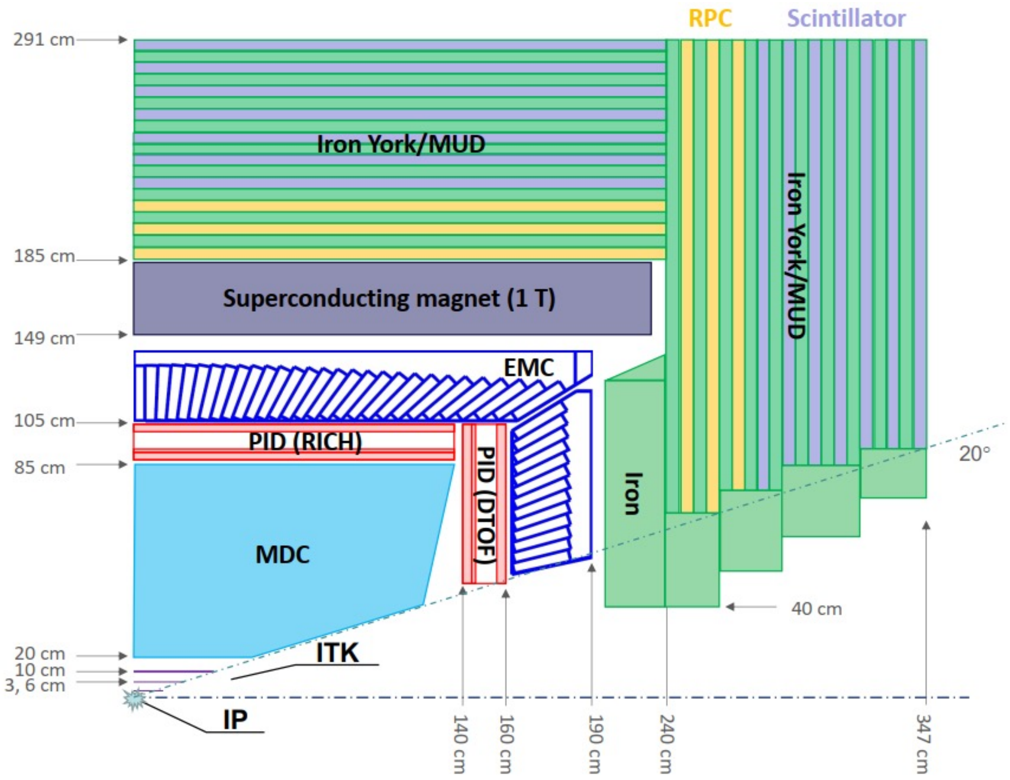
- Length: 400m
- e$^+$, a convertor, a linac and a damping ring, 0.5 GeV
- e$^-$, accelerated to 0.5 GeV
- No booster, 0.5 GeV→1~3.5 GeV

STCF detector









Requirement:

- High detection efficiency and good resolution
- Superior PID ability
- Tolerance to high rate/background environment

ITK

$<0.25\%X0$ / layer

$\sigma_{xy} < 100\ \mu m$

MDC

$\sigma_{xy} < 130\ \mu m$

$\sigma p/p \sim 0.5\%$ @ 1 GeV

PID

π/K (and K/p): 3-4σ separation up to 2GeV/c

EMC

E range: 0.025-3.5 GeV

σ_E @ 1 GeV: 2 .5% in barrel, 4% at endcaps

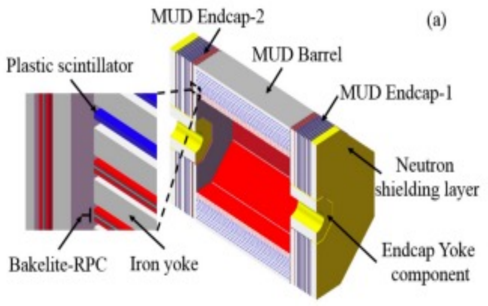
Pos. Res. : ~ 4 mm

MUD

0.4 - 1.8 GeV

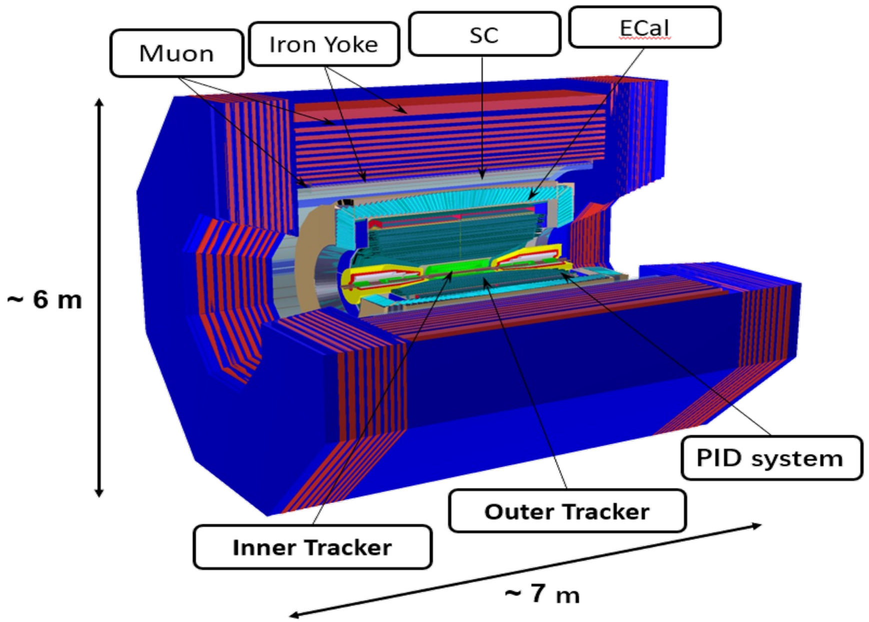
π suppression >30

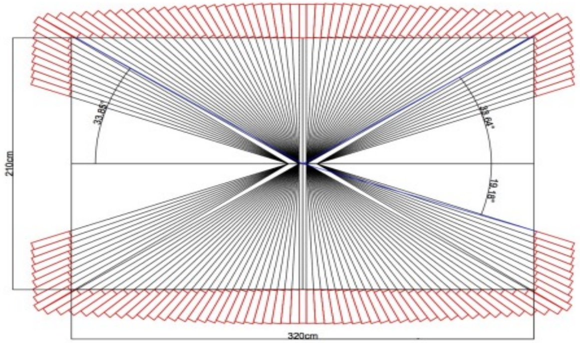
Detector options



Muon detector

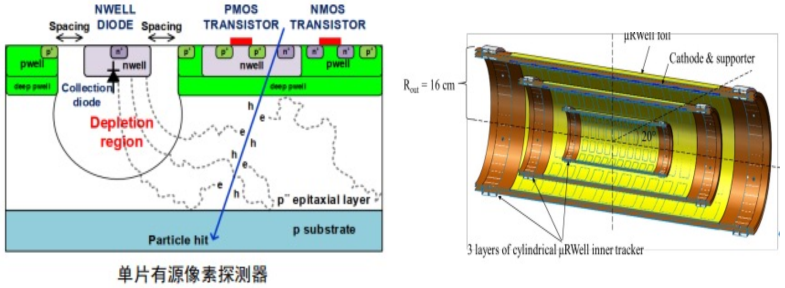
- Bakelite RPC + Scintillator strips





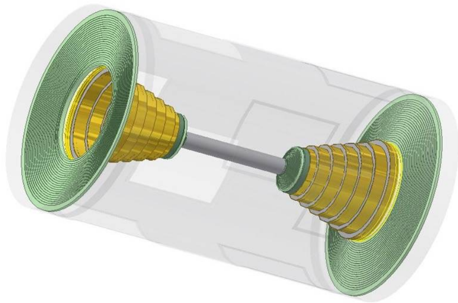
EM calorimeter

- Pure CsI crystal + APD



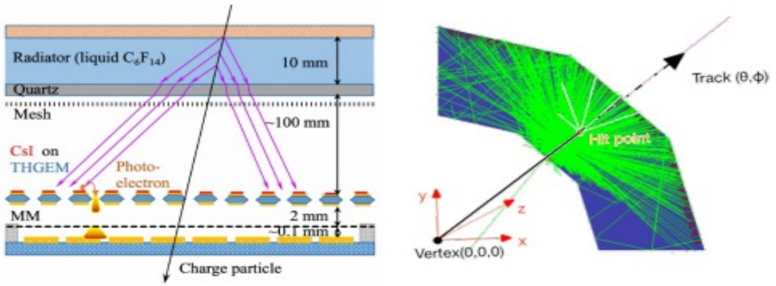
Inner Tracker

- MPGD: Cylindrical μRWELL
- Silicon: CMOS MAPS



Central Tracker

- Drift Chamber with extra-low mass and small cell



Particle Identification

- Barrel: RICH
- EndCap: DIRC-Like TOF

Tentative plan of STCF

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032-2042	2043-2046
Form collaboration																
Conception design CDR																
R&D (TDR)																
Construction																
Operation																
Upgrade																

Summary

- STCF is the next generation tau-charm factory, one of the crucial precision frontier aiming for understanding QCD, testing EW models and probing new physics.
- Many activities on physics/detector/accelerator, three volumes CDR finished.
- Key technology R&D project is now fully funded by Anhui Province, Hefei city and USTC (0.42 B RMB). The project is being conducted.
- An International collaboration is necessary to boost the construction of the project.

Thanks

Backup

Status of project promotion

Proposed at "Workshop for acc. based high energy physics development strategy"

2011

Super Charm-tau Factory

Zhengguo Zhao

On behalf of ???

香山科学会议简报

Fragrant Hills Science Forum

11 academicians

2015

Demonstrated importance and necessity of STCF, Urging to lauch fesibility study and R&D as soon as possible

中共安徽省委文件

Notice of the People's Government of Anhui Province and the CAS on the Implementation Plan of Hefei Comprehensive National Science and Technology Center

2017

STCF was listed as large scientific facility that about to promote. Proposed to start fesibility study, and R&D.

USTC Scientific Committee Meeting

2018

Demonstrated the significance of STCF. USTC President ratify 20 M CYN to support feasibility study

Conceptual Design Report

(CDR)

2021

STCF
Conceptual Design Report
Volume I - Physics

STCF
Conceptual Design Report
Volume II - Accelerators
(Mini Preliminary Conceptual Design Report)
超级陶粲装置（STCF）加速器总体
小型初步概念设计报告

STCF
Conceptual Design Report
Volume III - Detector

The STCF Study Group
September 23, 2021

Project review for R&D of key technologies organized by Anhui Province.

2022.4.24

"超级陶–粲装置关键技术攻关"项目论证意见

Endorsed 420 M CYN for R&D

论证专家委员会主任：

2022 年 4 月 24 日

USTC formed project leadership team headered by USTC president

2022.9.24

中国科学技术大学文件

校科字〔2022〕190 号

Implement funds; Coordinate with CAS and National Development and Reform Commission to promote projects

Key technology R&D project

新一代正负电子对撞机——超级陶粲装置

关键技术攻关项目

A new generation of e^+e^- collider —STCF Key Technolgy R&D

April of 2022

Identified 31 items for R&D

Year	Budget (M CYN)
2022	40
2023	190
2024	120
2025	62
Total	420

目 录

Total 120 pages

Chapter 1. Instroduction

Chapter 2. Background and necessity of STCF

Chapter 3. Physics opportunities and the key technologies

Chapter 4. Contents of the R&D

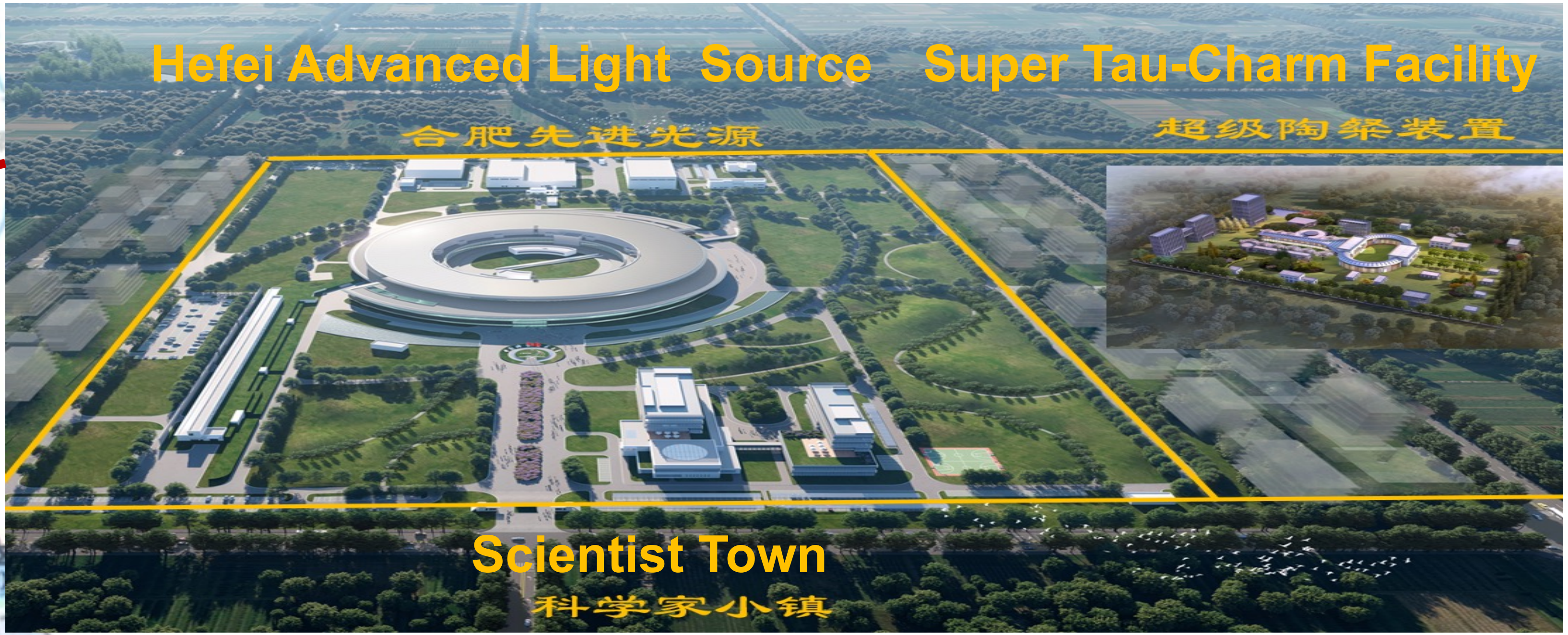
Chapter 5. Project management and implementation scheduling

Chapter 6. Project risks and countermeasures

Chapter 7. Conclusions

Chapter 8. Appendix

Site - Hefei



- **6 big facilities** for science and technologies (17155 acres).
- Ecological green space and modern agricultural (11815 acres)
- **HALF (4th generation light source)** was **approved** by central government， and just began **construction**
- **STCF** site is **preliminarily decided** by local government in Apr. 2023， **geological exploration** and **engineering design** is ongoing