Experimental Program for Super Tau-Charm Facility

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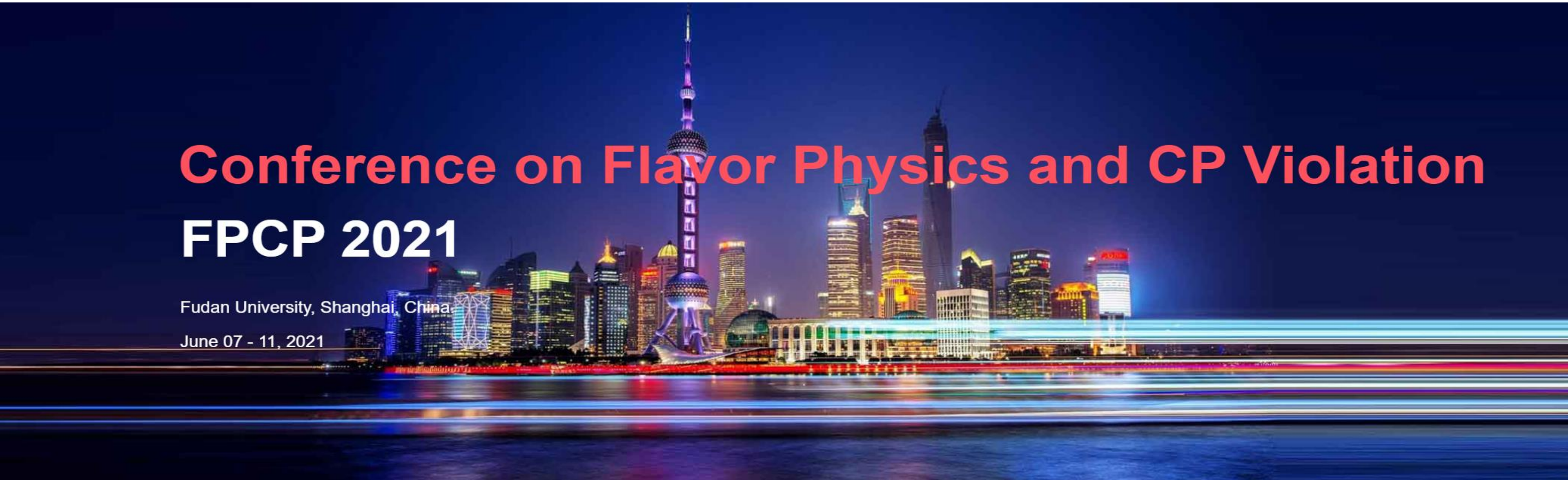
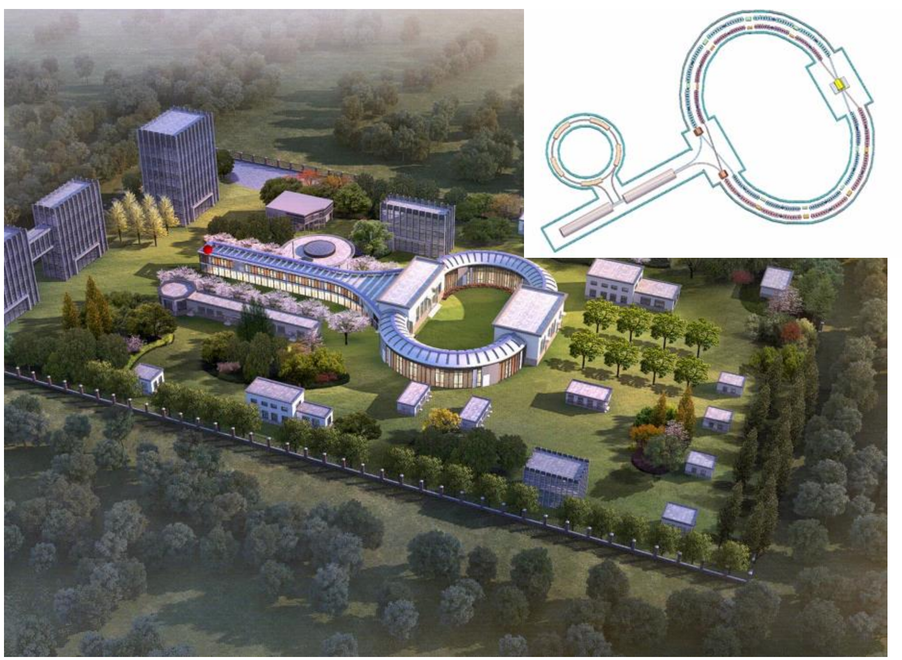
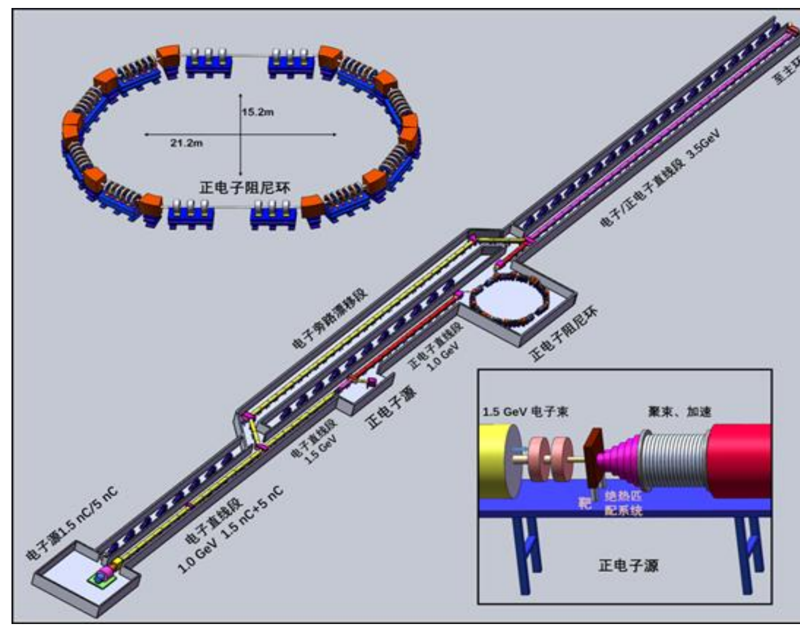


Super Tau-Charm Facility (STCF) in China

- 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

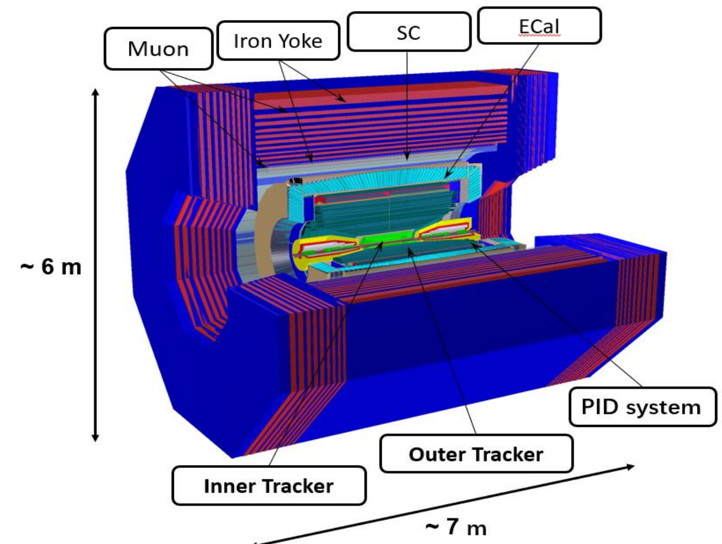


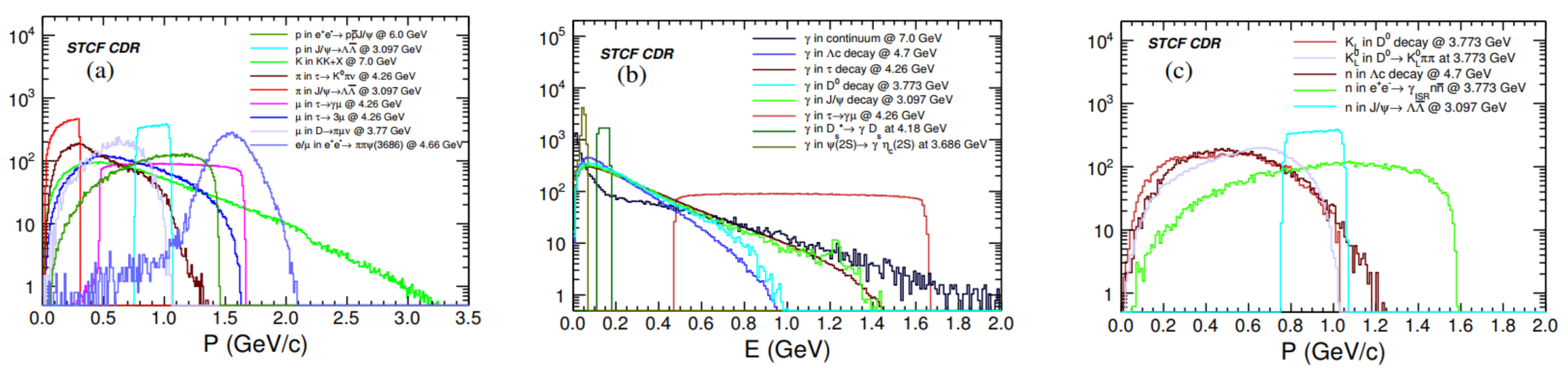


1 ab^{-1} data expected per year

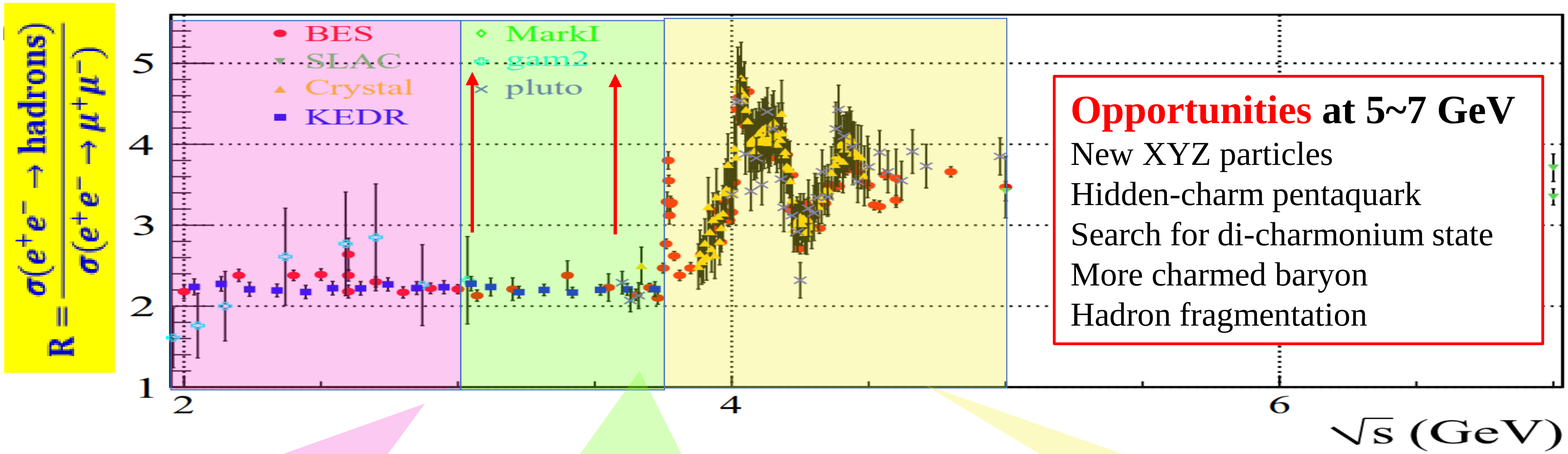
STCF Detector

- **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



- 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.**

Data Samples

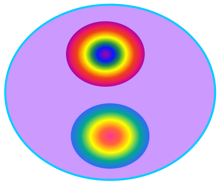
Expected data samples with 1 ab^{-1} integral luminosity

	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

Charmonium (Like) Spectroscopy



Excellent platform to explore the QCD

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

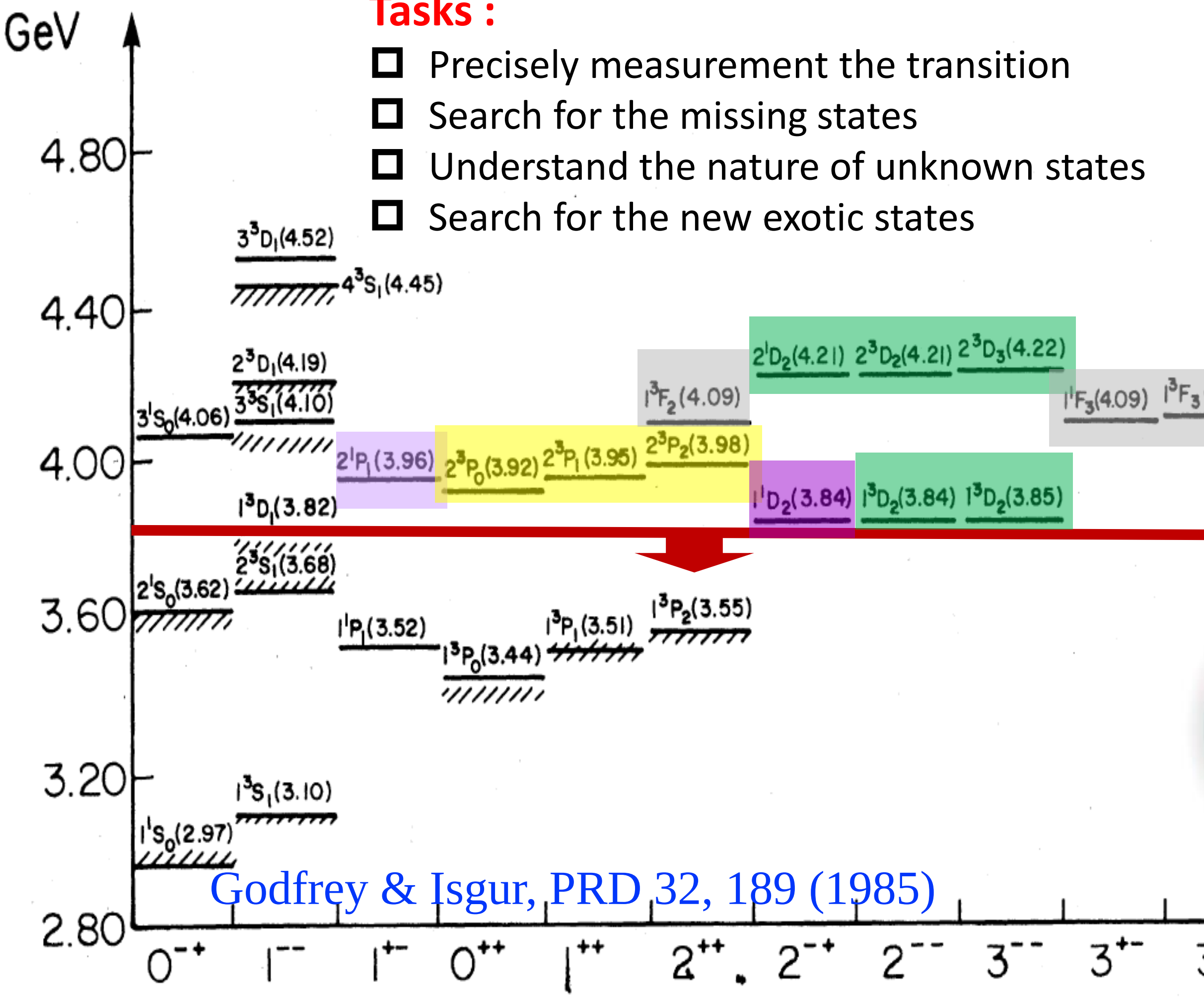
Tasks :

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

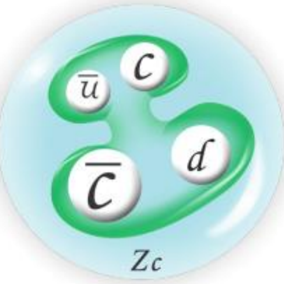
X(3872)
X(3940)
X(4160)
X(4350)

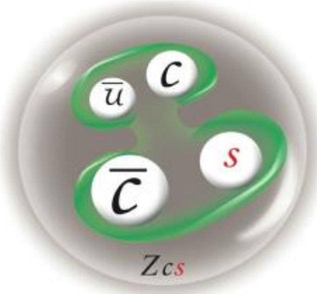
Y(3940)
Y(4008)
Y(4260)
Y(4360)
Y(4660)

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

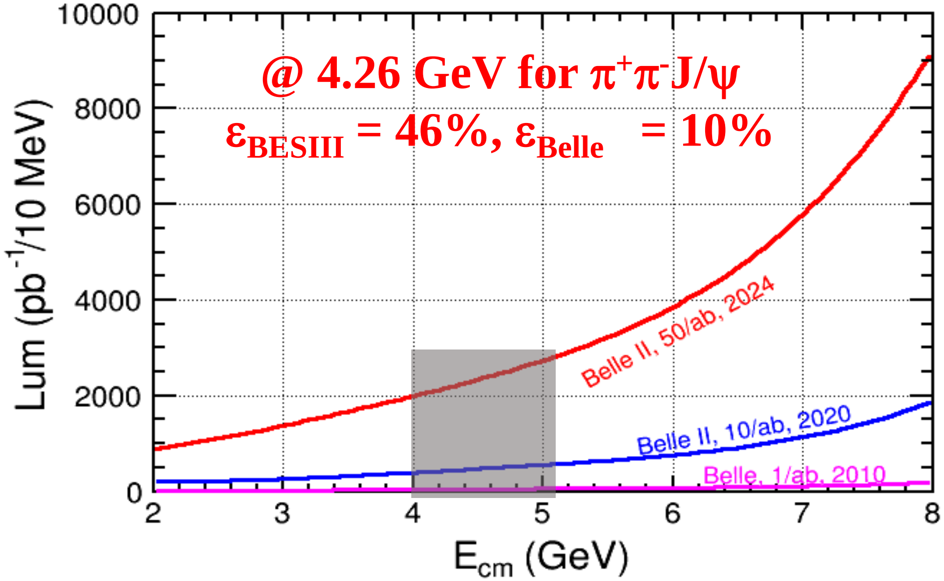


Godfrey & Isgur, PRD 32, 189 (1985)

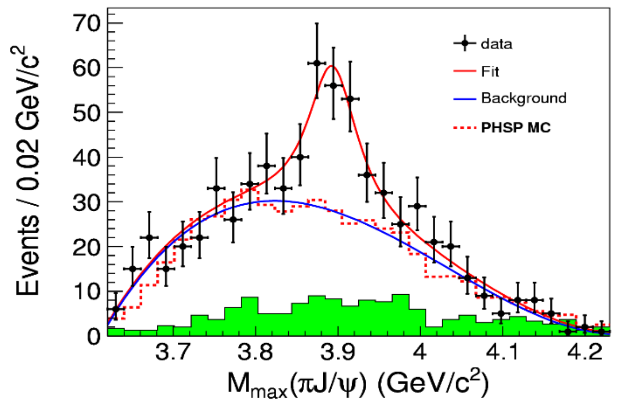




Charmonium(Like) Spectroscopy at STCF

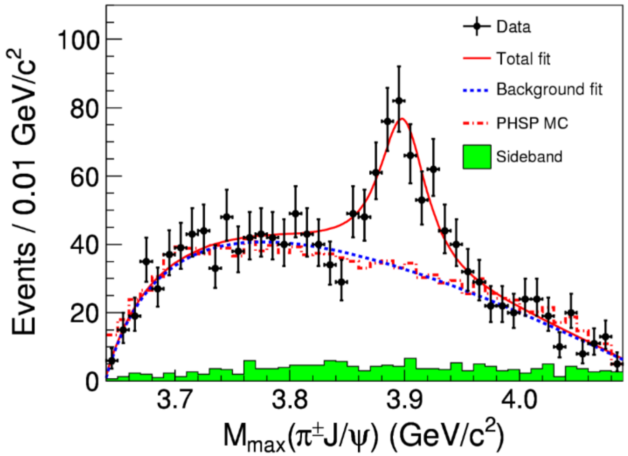


Belle with ISR: PRL110, 252002
967 fb-1 in 10 years running time



- 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

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



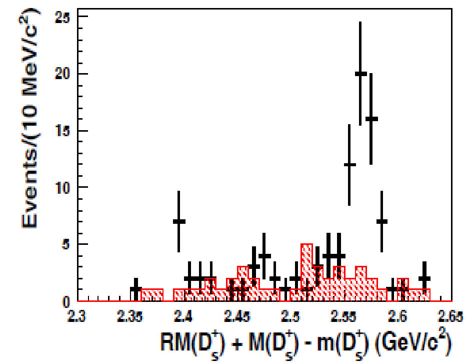
Facilities for Charm Study

- 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)

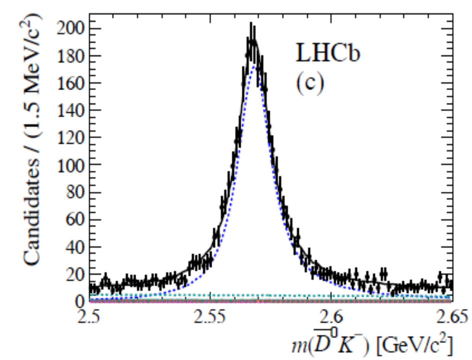
Features in Charm Hadron Decays

	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

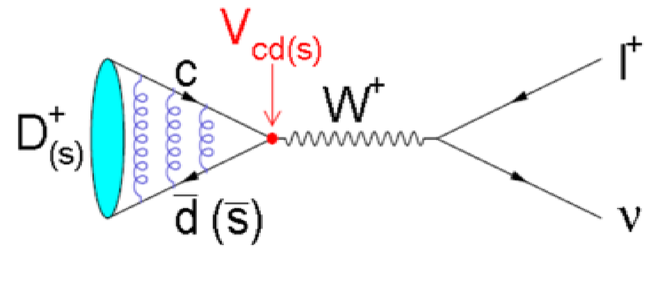
BESIII + B factories + LHCb + LQCD

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

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

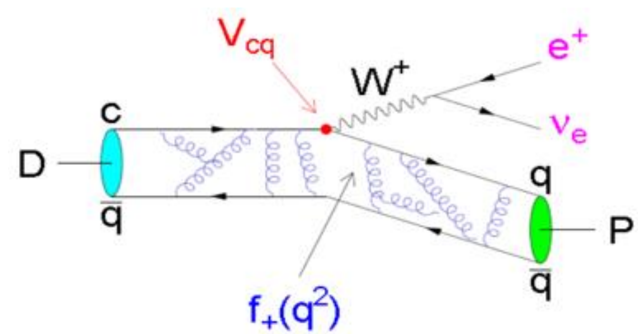
Purely Leptonic:

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



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

- Input $f_{D(s)}$ or $f^{k(\pi)}(0)$ from LQCD $\Rightarrow$ $|V_{cd(s)}|$
- Input $|V_{cd(s)}|$ from a global fit $\Rightarrow$ $f_{D(s)}$ or $f^{k(\pi)}(0)$
- Validate LQCD calculation of Input $f_{B(s)}$ and provide constrain of CKM-unitarity

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

Theory : 0.2%(0.1% expected)

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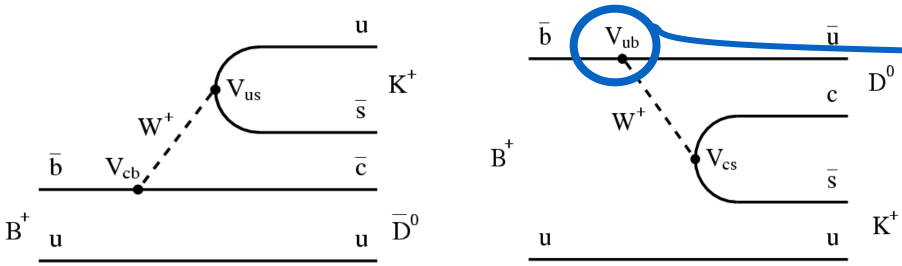
* assuming Belle II improved systematics by a factor 2

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

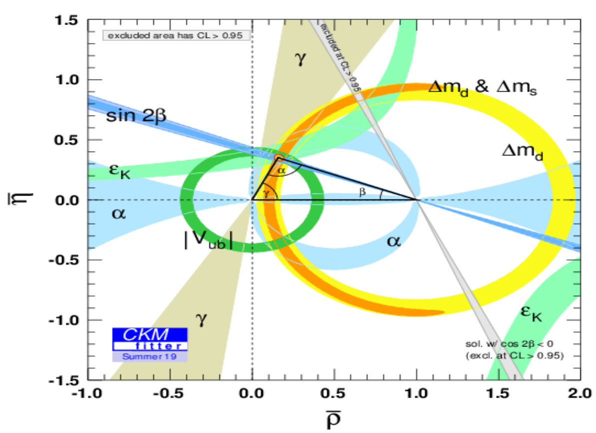
Determination of γ/ϕ_3 angle

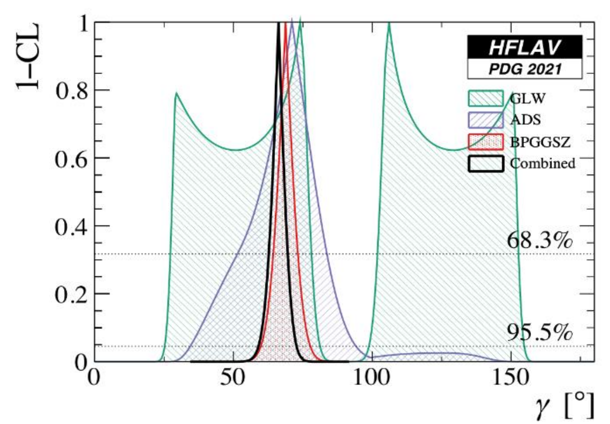
- The cleanest way to extract γ is from B→DK decays:



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

  - 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°
LHCb upgrade II [14 TeV]	300 fb^{-1}	(>)2035	< 0.4°

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

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

- **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

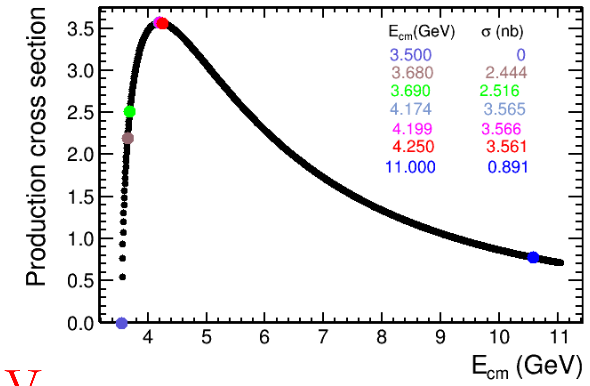
Era of precision study of the charmed baryon (Λ_c, Ξ_c and Ω_c) decays
to help developing more reliable QCD-derived models in charm sector

- **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}

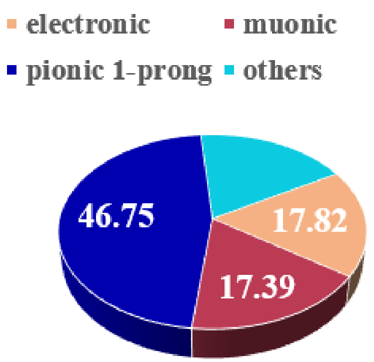
τ Lepton Physics

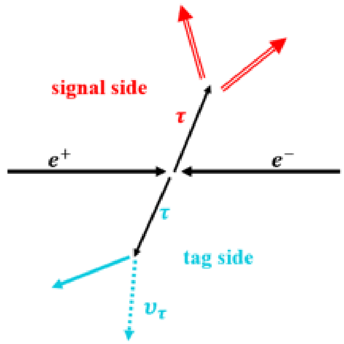
- X sec grows from 0.1nb near threshold to 3.5 nb at 4.25 GeV
  - 1×10^8 tau pairs/year at threshold (0.1 nb)
  - 3.5×10^9 tau pairs/year at 4.25 GeV (3.5 nb)
  - 10^{10} τ pairs per year for Belle II (1 nb)



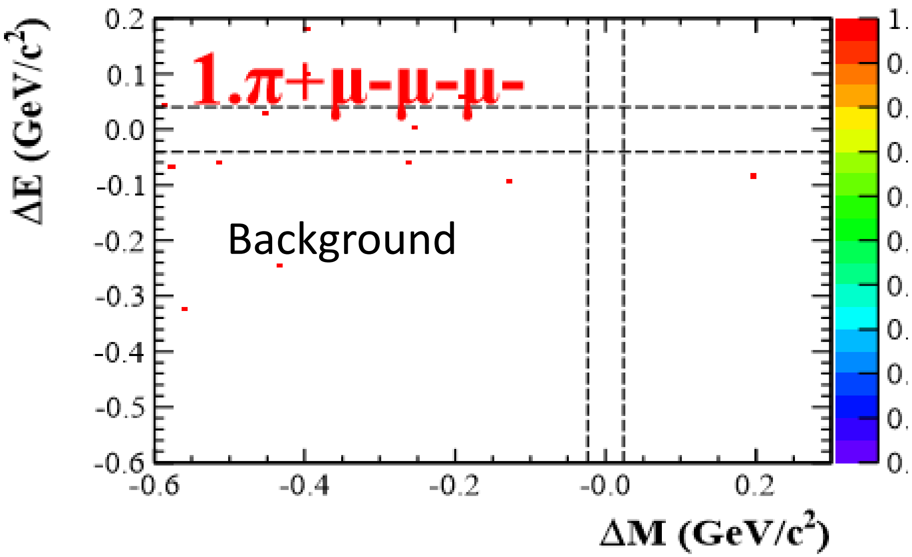
- Highlighted Physics program
  - τ properties : m_τ, $(g\text{-}2)_\tau/2$
  - SM properties : universality test, Michel parameters, α_s, V_{us}
  - CPV test : $\tau^- \to K_S^0 \pi^- \nu_\tau$, T-odd triple product in polarization beam
  - LFV : $\tau \to \ell\gamma$, $\ell\ell\ell$, ℓh
- Comparison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





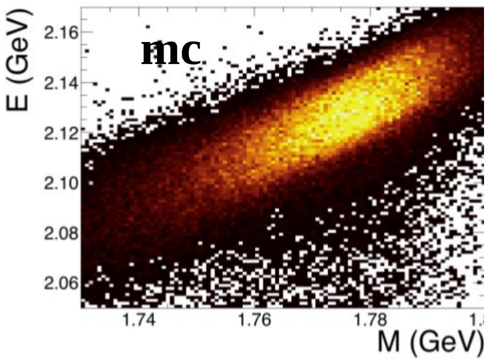
- Signal side: $\tau \to 3leptons$
- Tag side: $\tau \to e\nu\bar{\nu},\ \mu\nu\bar{\nu},\ \pi\nu + n\pi^0$ ($\mathcal{B}r =$ 82%)
- Almost background free, **the sensitivity : $\mathcal{B}_{UL}^{90}(\tau \to \mu\mu\mu) \sim 1/\mathcal{L}$**
- Best efficiency ($\tau \to \mu\mu\mu$): 22.5% **(including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

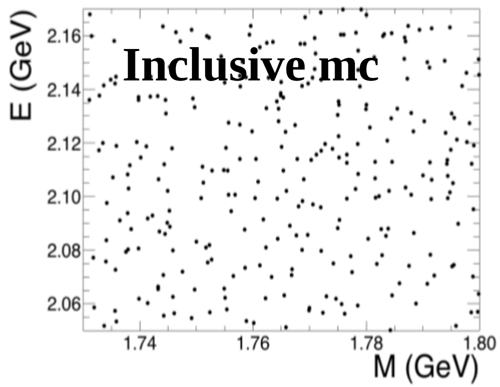


- **STCF with 1ab⁻¹:**

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

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

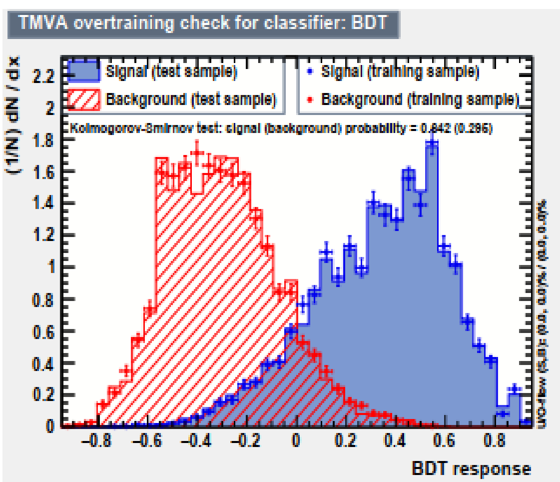


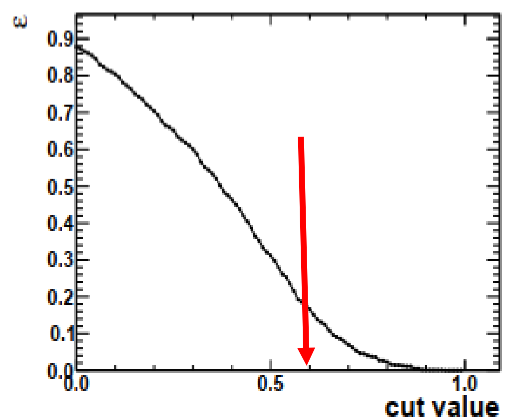


- Signal side $\tau \to \gamma\mu$
- Tag side: $\tau \to e\upsilon\bar{\upsilon},\ \pi\upsilon,\ \pi\pi^0\upsilon(\mathcal{B}r = 54\%)$
- **Dominant background**: $e^+e^- \to \mu^+\mu^-$ and $e^+e^- \to \tau^+\tau^-, \tau^+ \to \pi\pi^0\upsilon, \tau^- \to \mu\upsilon\bar{\upsilon}$

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

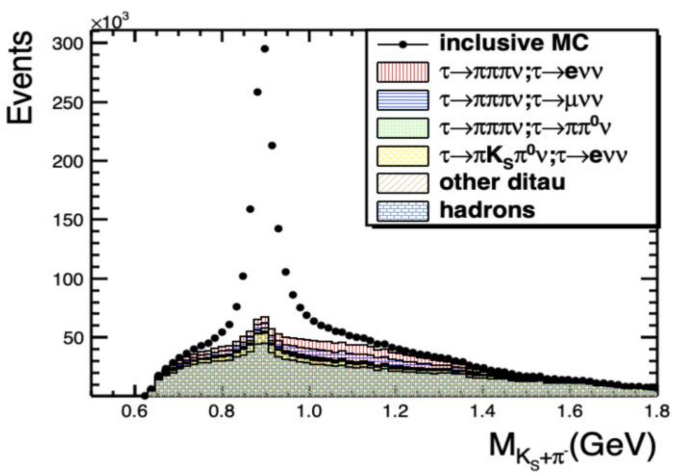
- The CPV source in $K^0 - \bar{K}^0$ **mixing** produces a difference in tau decay rate

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



The CPV sensitivity with 1ab⁻¹ @ 4.26 GeV[1]:

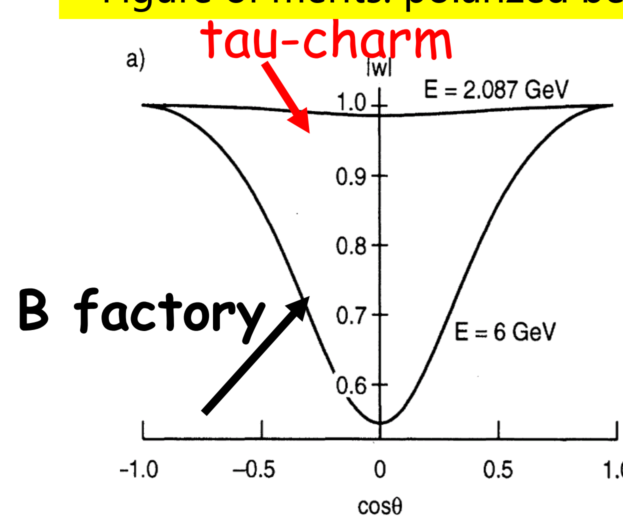
$A_{STCF} \sim 9.7 \times 10^{-4}$

With 10 ab⁻¹ data:

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

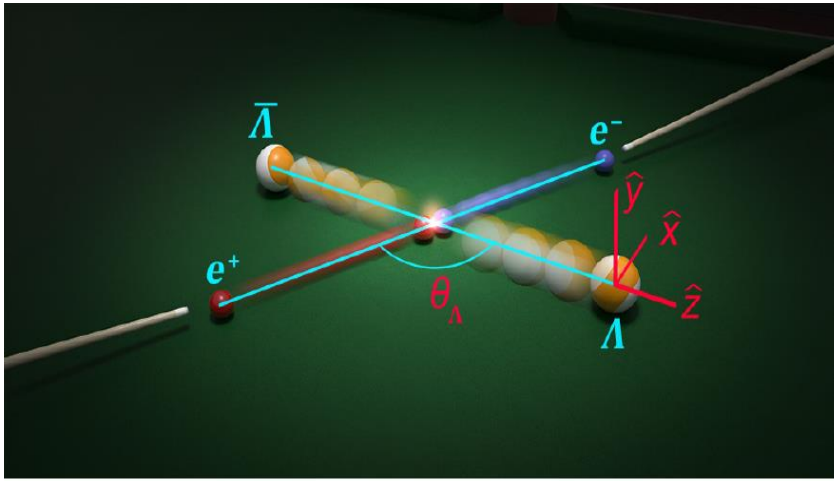
[1]. H. Sang, *et al.*, Chin. Phys. C 45, no.5, 053003 (2021)

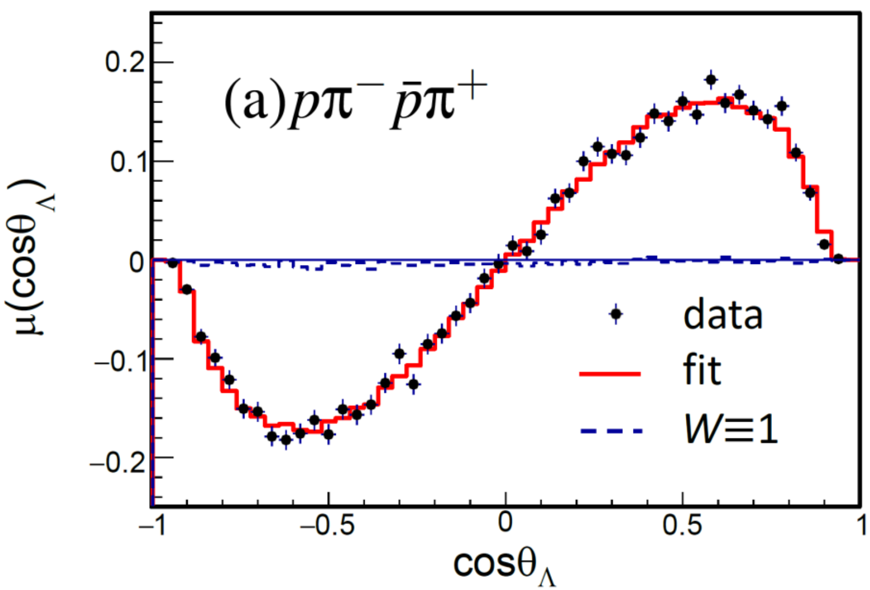
Possible choice to increase the Figure of merits: polarized beam



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

Polarization of Λ hyperons and CPV





Nature Phys. **15**, 631–634 (2019) BESIII

1.31 B J/ψ events
Quantum correlation in Λ pair

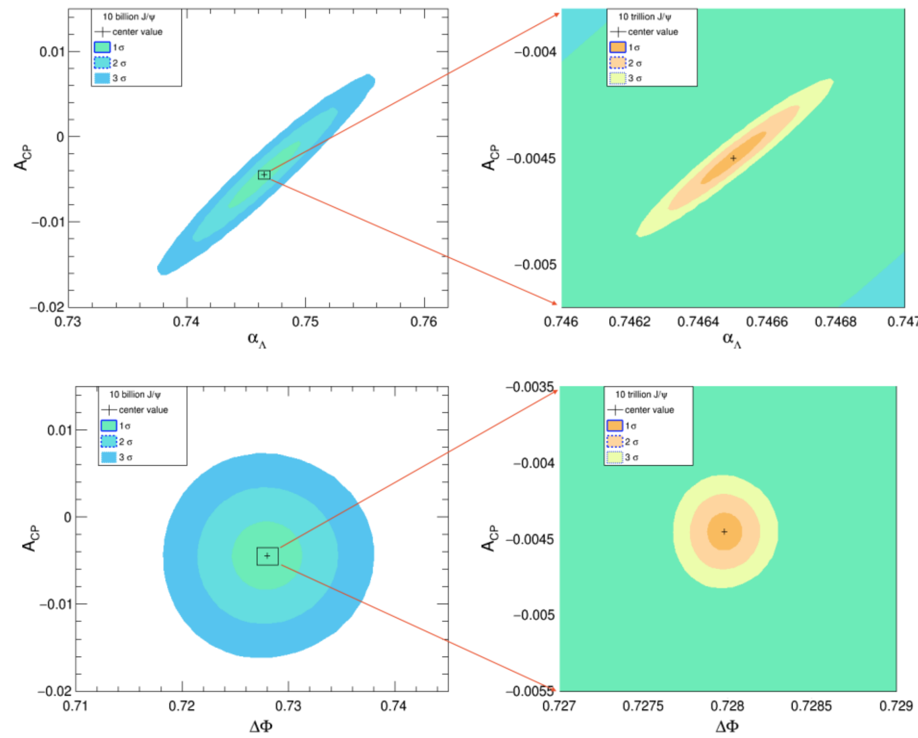
Parameters	This work	Previous results
α_ψ	$0.461 \pm 0.006 \pm 0.007$	0.469 ± 0.027 [14]
$\Delta\Phi$	$(42.4 \pm 0.6 \pm 0.5)^\circ$	–
α_-	$0.750 \pm 0.009 \pm 0.004$	0.642 ± 0.013 [16]
α_+	$-0.758 \pm 0.010 \pm 0.007$	-0.71 ± 0.08 [16]
$\bar{\alpha}_0$	$-0.692 \pm 0.016 \pm 0.006$	–
A_{CP}	$-0.006 \pm 0.012 \pm 0.007$	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: $10^{-4} \sim 10^{-5}$

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

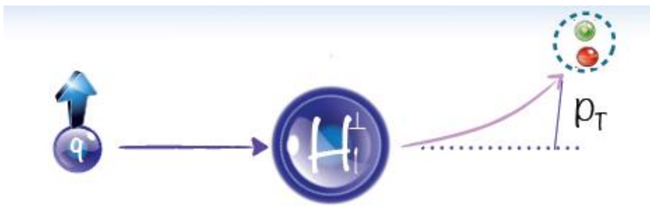
CPV in Hyperon Decays at STCF

- 4 trillion J/ψ events ⇒ $\boldsymbol{A_{CP} \sim 10^{-4}}$
  - 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 ⇒ $\boldsymbol{A_{CP} \sim 10^{-5}}$?
- Challenge: Systematics control, spin procession effect in magnet

Collins Fragmentation Function (FF)



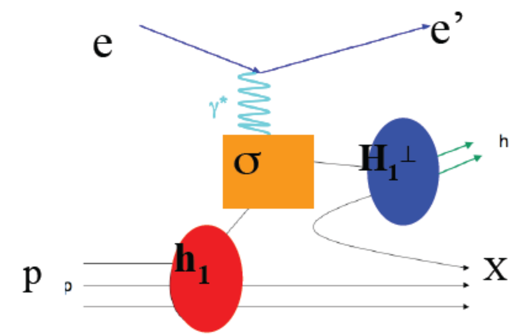
J. C. Collins, Nucl. Phys. B396, 161 (1993)

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

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.

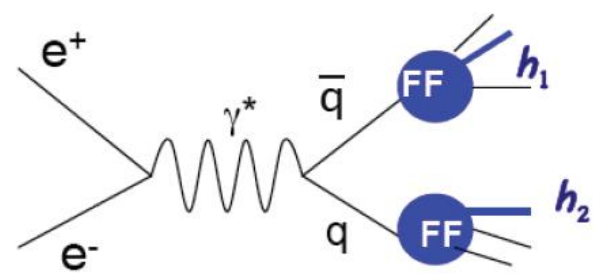
SIDIS

Transversity ⊗ Collins FF



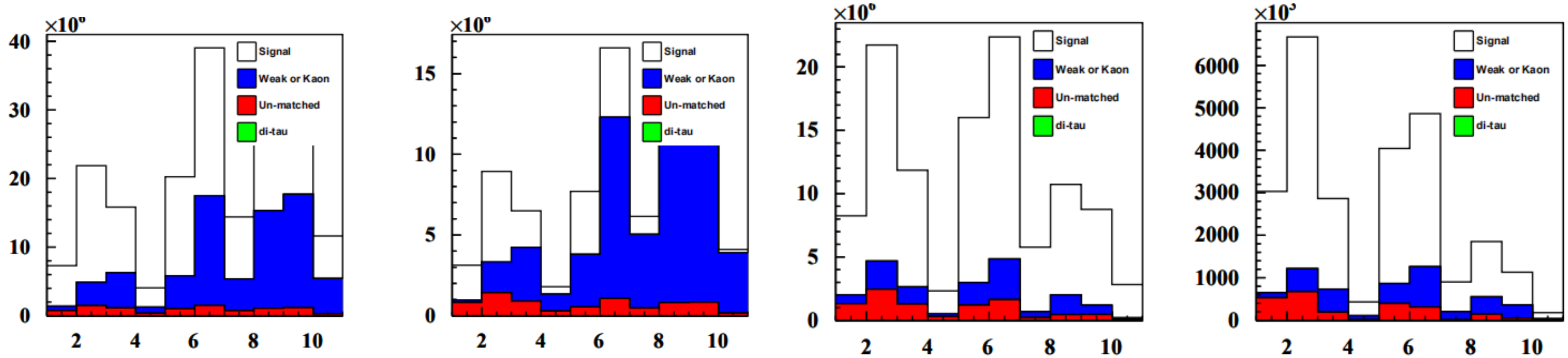
e+ e-

Collins FF ⊗ Collins FF



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.

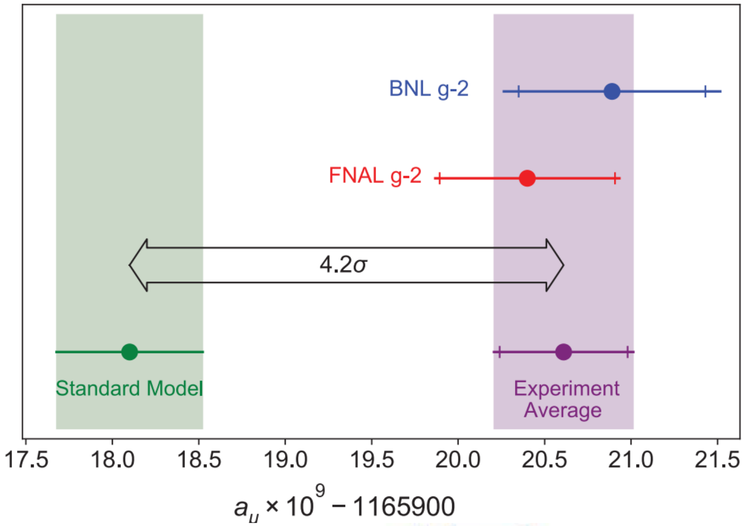


Blue: π/K mis-PID in KK Collins measurement.
Left) de/dx&TOF.   Right) a 1% mis-PID set in FastSim

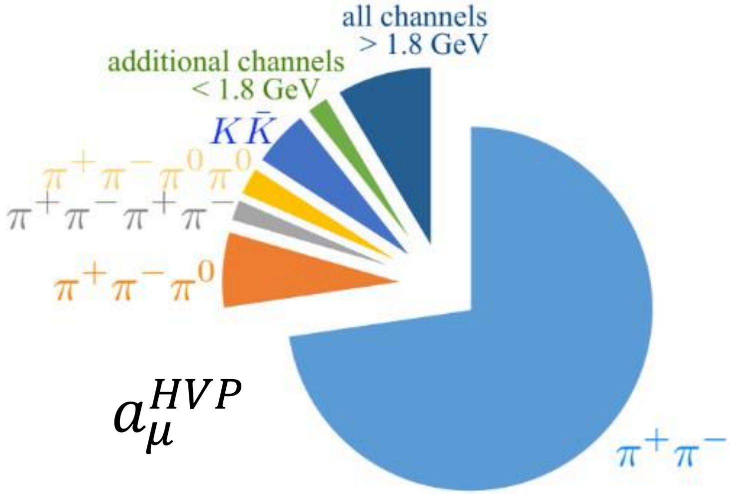
- By setting the K/π mis-PID at 1%,   we obtain[1]:
  - The statistical uncertainty for 25fb^{-1} MC is ~10^{-3} to 10^{-2}
  - The statistical uncertainty for 1ab^{-1} MC is ~10^{-4} to 10^{-3}

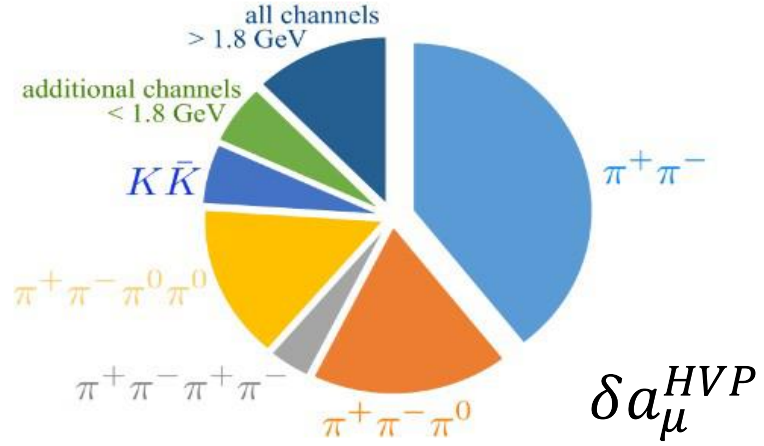
[1]. Wang B L, Lv X R, Zheng Y H. Journal of University of Chinese Academy of Sciences, 2021, 38(4):433-441

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)**

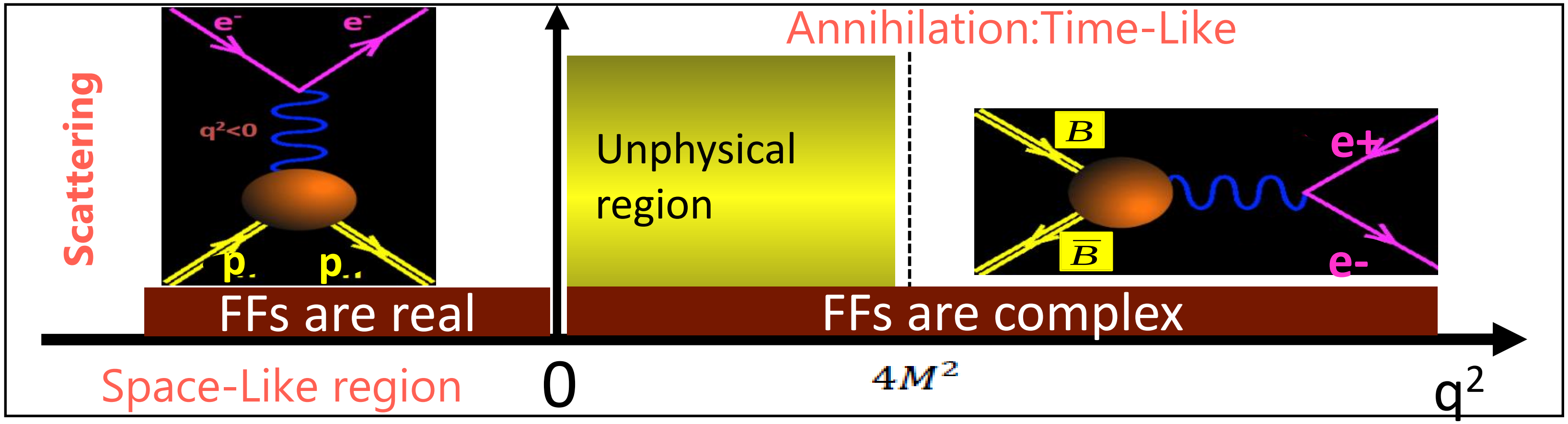




High Luminosity of STCF will largely improve the SM precisions !

Electromagnetic Form Factors

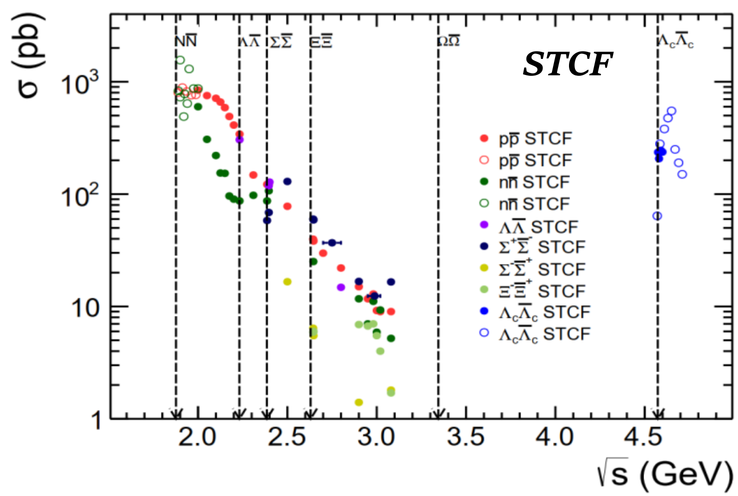
- **Fundamental properties of the nucleon**
  - **Connected to charge, magnetization distribution**
  - **Crucial testing ground for models of the nucleon internal structure**



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

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

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



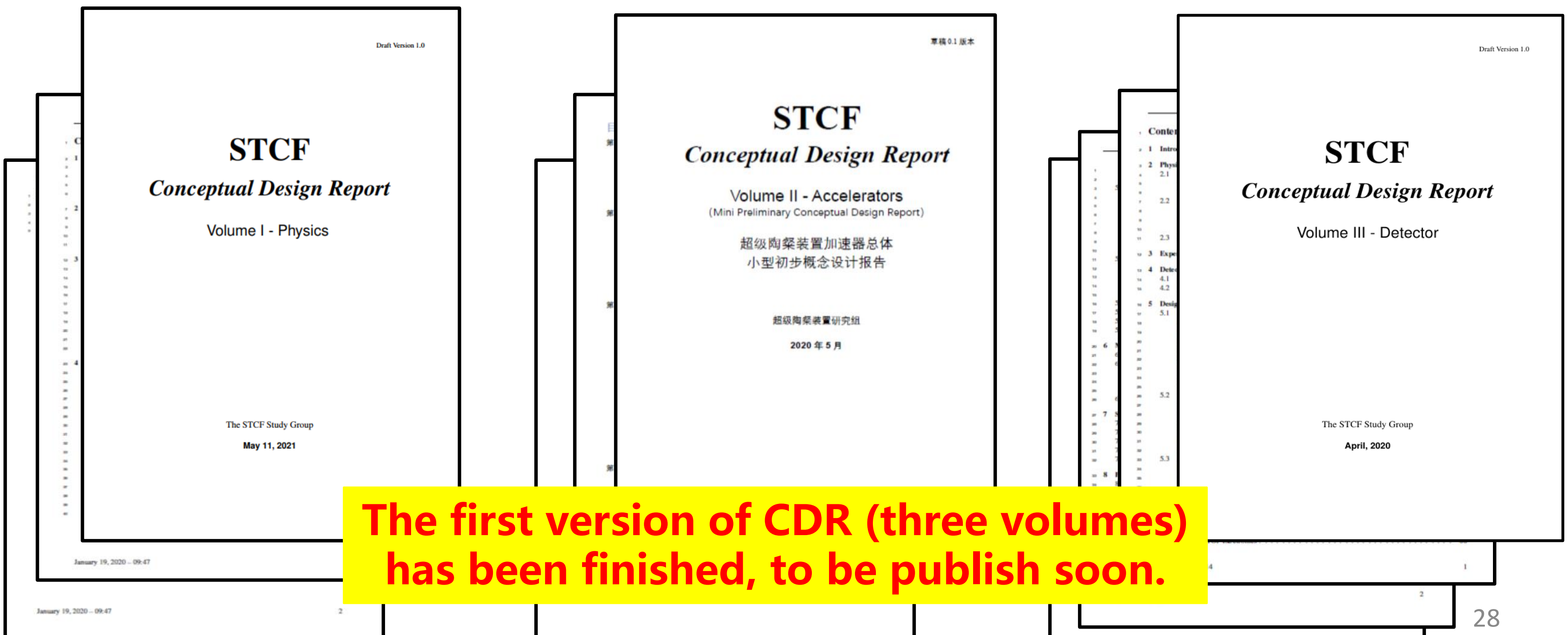
Strategy & Activities

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														■



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

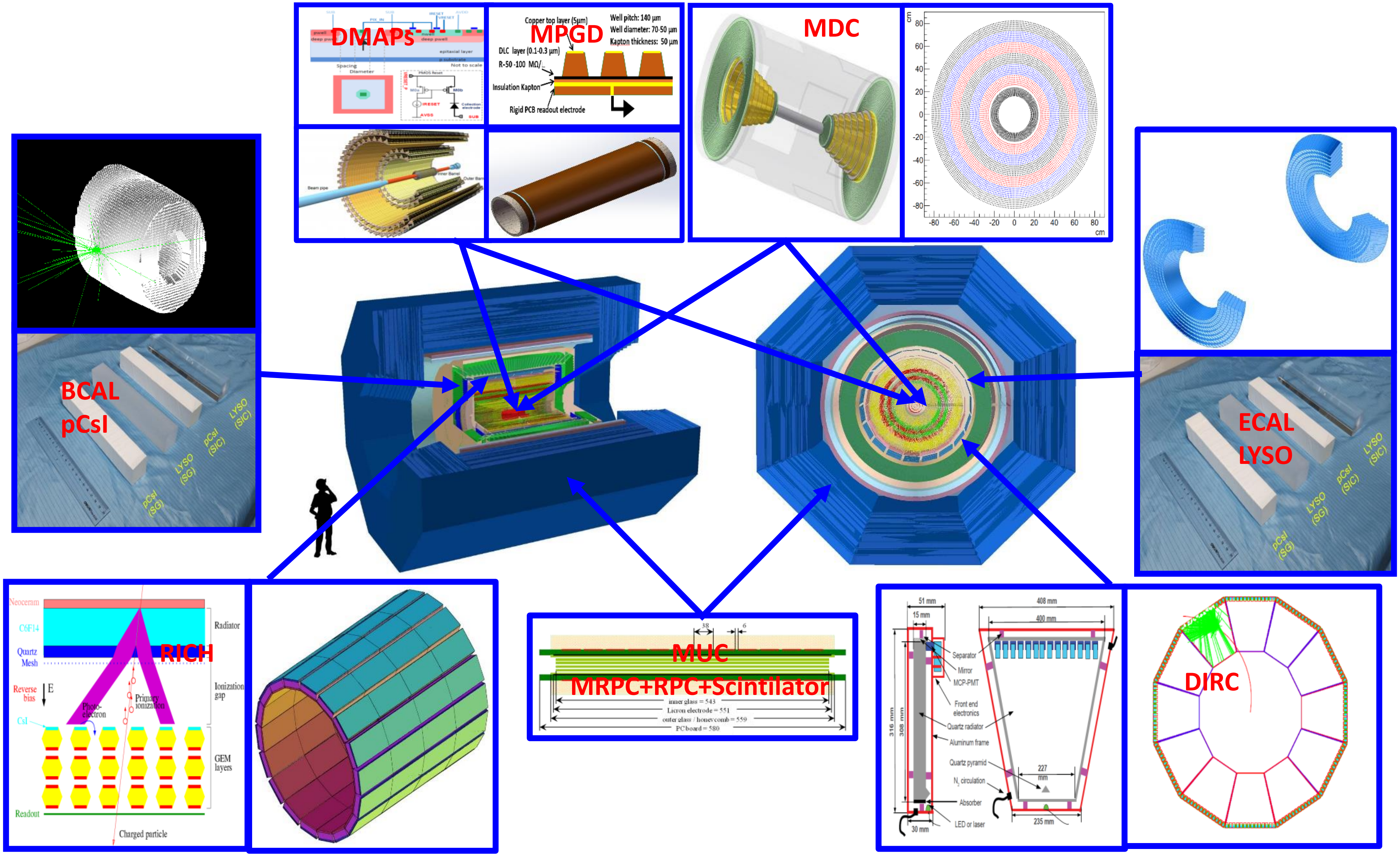
Indico for High Luminorcity Tau Charm Physics R&D

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

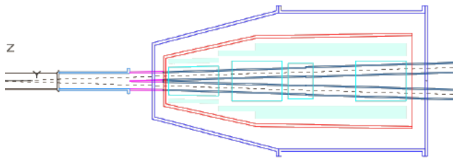
Spectrometer

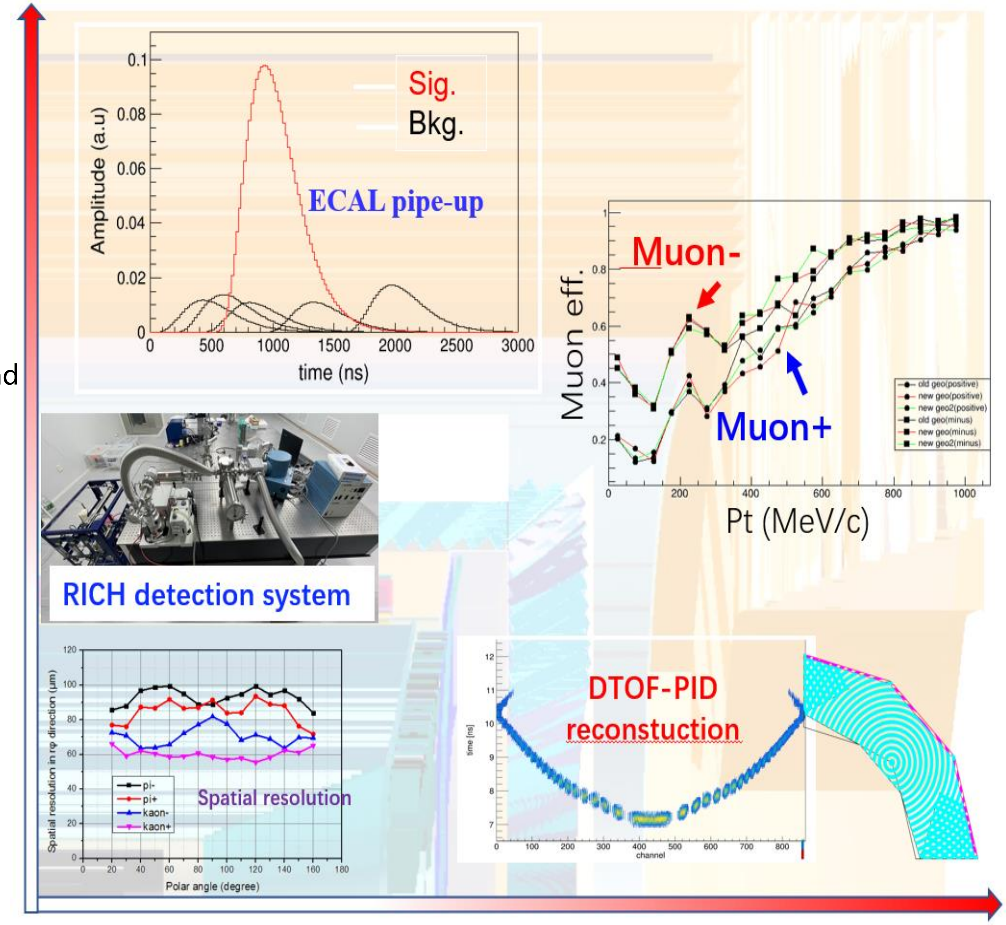


Spectrometer

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

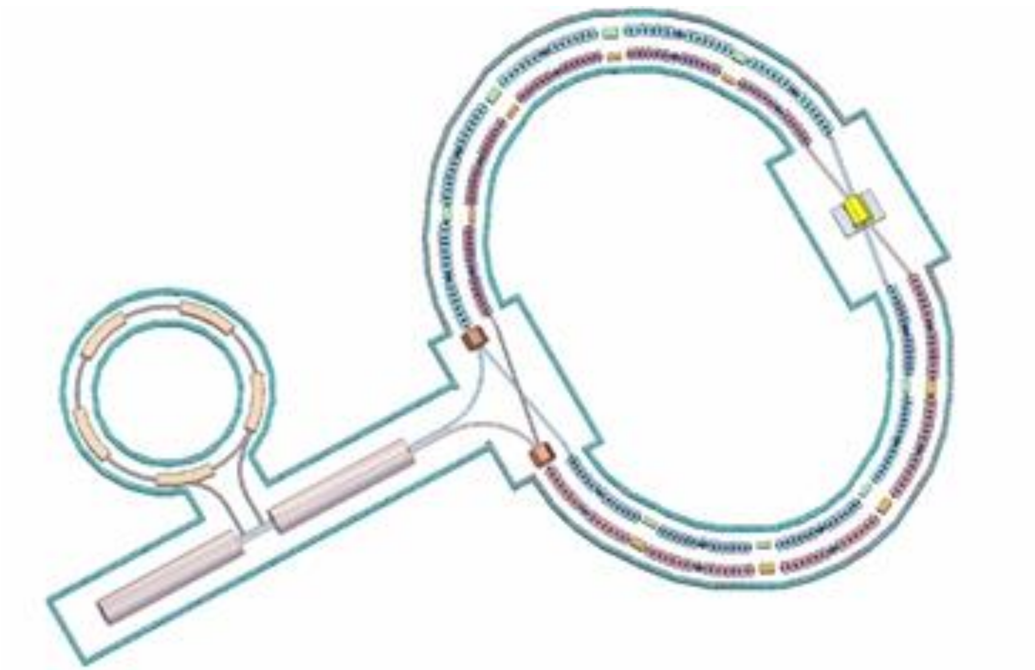
MDI设计

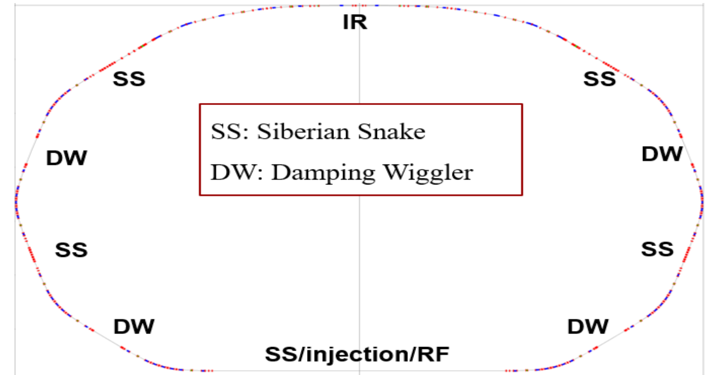


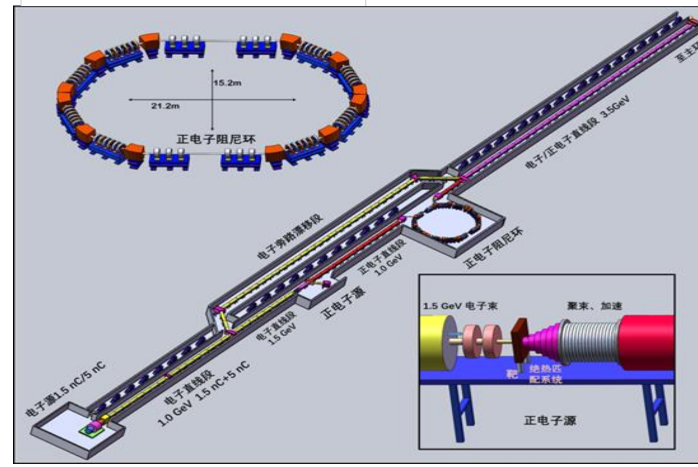


Accelerator

Interaction Region : Large Piwinski Angle Collision + Crabbed Waist







Injector:

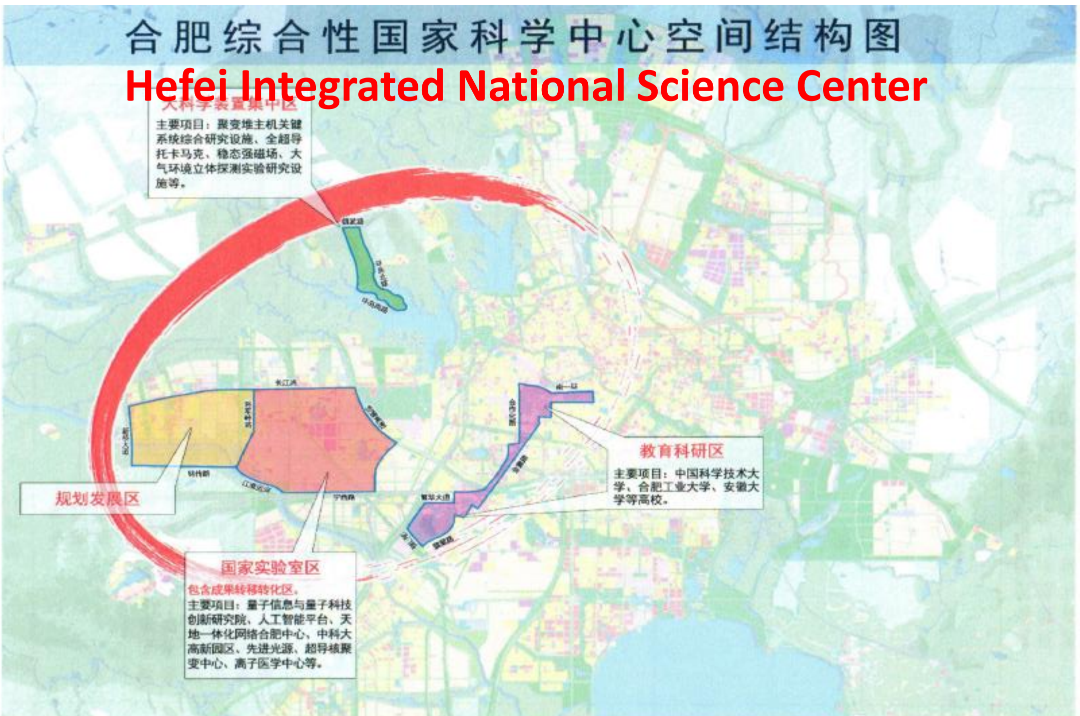
- No booster, 0.5 GeV→1~3.5 GeV
- e+, a convertor, a linac and a damping ring, 0.5 GeV
- e-, a polarized e- source, accelerated to 0.5 GeV

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

Candidate Site : Hefei

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



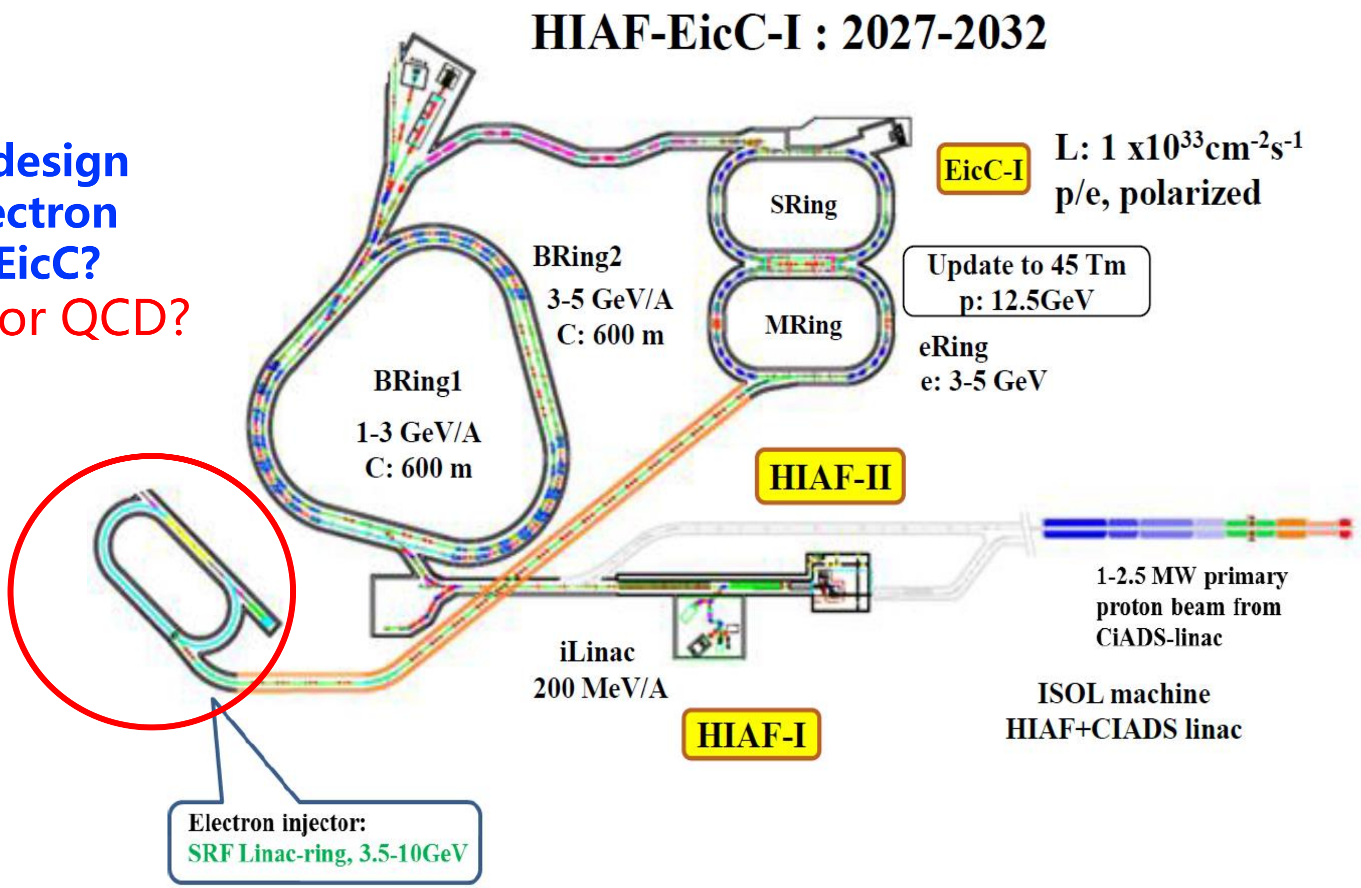
- University of Science and Technology of China (USTC)
- National Synchrotron Radiation Lab and Hefei Light Source, operated by USTC
- The only National Lab operated by University in China. (Totally Four officially approved National Labs in China)

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

Candidate Site : Huizhou

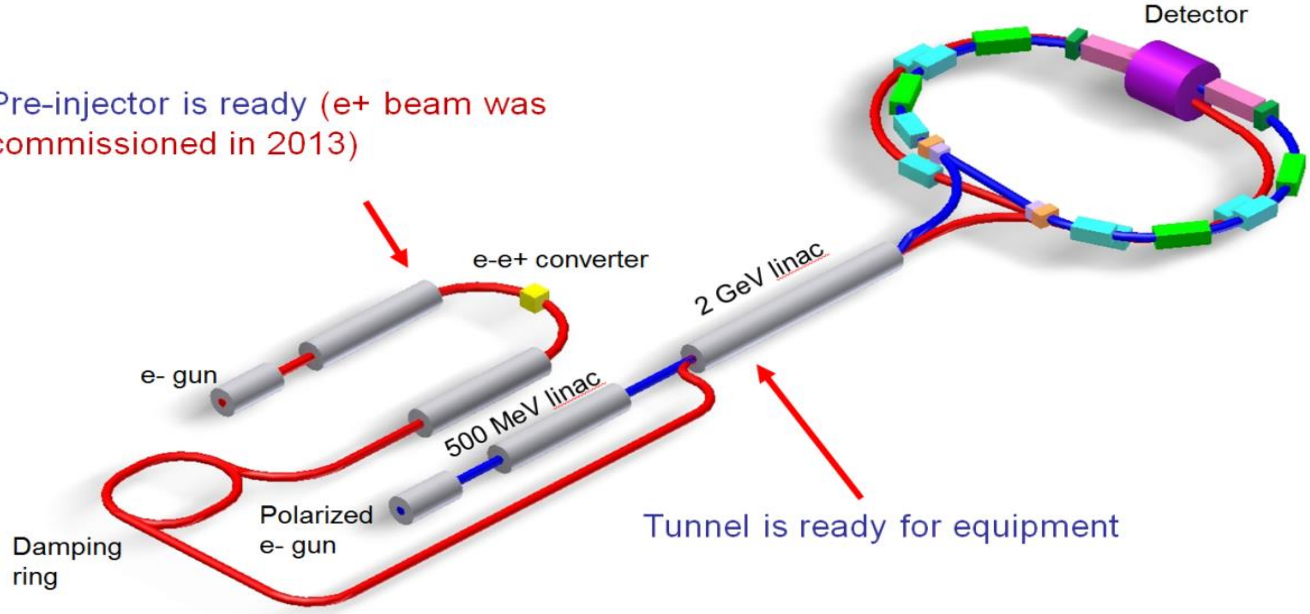
Institute of Modern Physics, CAS, proposed building HIAF-EicC in Huizhou, Canton

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!