

An aerial night-time rendering of the Super Tau-Charm Facility (STCF) under construction. The central feature is a large, circular accelerator ring with a green infield and a dark blue/purple outfield. The ring is surrounded by a multi-tiered stadium seating area, which is partially illuminated with blue and white lights. Several large, modern buildings with glass facades and flat roofs are situated around the ring, some with "STCF" signage. The entire complex is surrounded by roads, parking lots, and greenery, all lit up with various colors of light, creating a vibrant scene.

Progress of the Super Tau Charm Facility in China

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For Super Tau-Charm Facility working group

19/09/2025, HOL2025, Peking University

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- ◆ Introduction
- ◆ Physics Potential in STCF
- ◆ Accelerator and Detector
- ◆ Project Promotion and Progress
- ◆ Summary



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- ◆ **Introduction**
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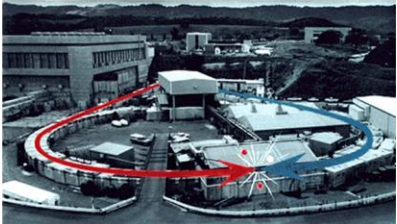


Colliders in Particle Physics

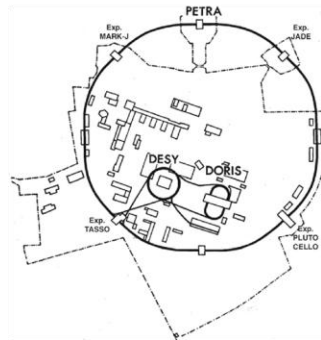


- ◆ The most effective experimental approach, artificially generating massive amounts of elementary particles, and studying the production and decay mechanisms
- ◆ Different energy regions, significant discoveries: heavy flavor quarks, tau leptons, W/Z bosons, and Higgs

SPEAR, USA



1974, Charm quark



PETRA, Germany

1979, Gluon

Tevatron, USA



1995, Top quark

LHC, Switzerland



2012, Higgs

1975, Tau lepton



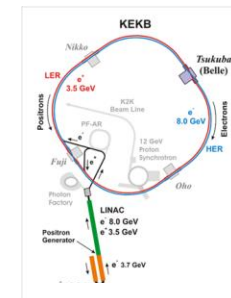
SLAC, USA

1983, W/Z bosons

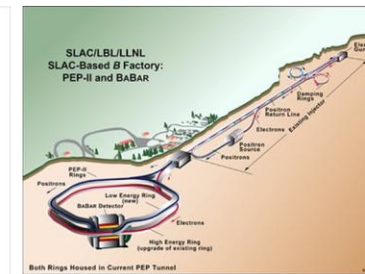


SPS, Switzerland

2001, CPV in B meson



KEKB, Japan



PEP-II, USA

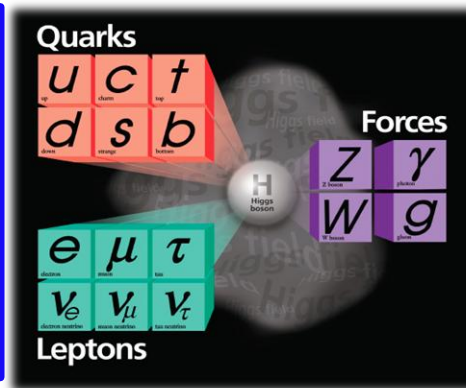
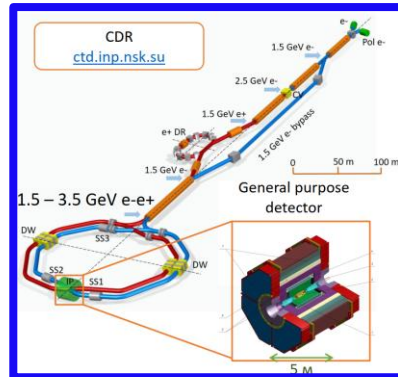
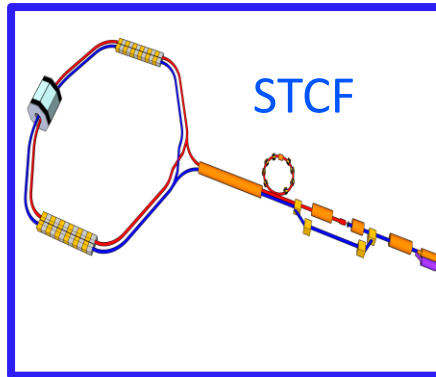
2013, $Z_c(3900)$



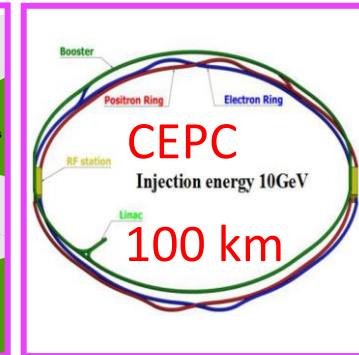
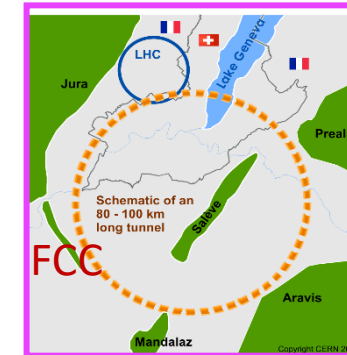
BEPC-II, China

Significantly higher energy, luminosity and detection accuracy

Higher **luminosity** by factor $\sim 50-100$



Higher **energy** by factor $\sim 3-10$

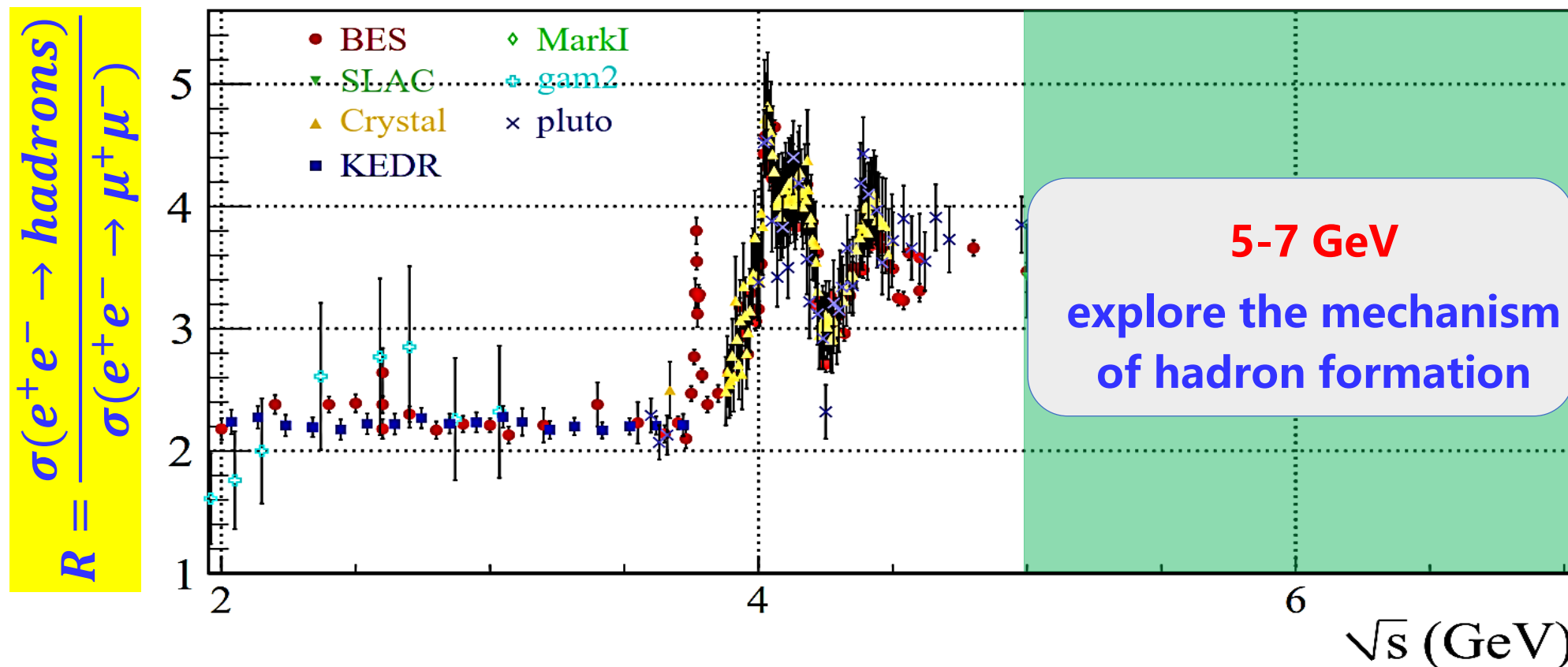


◆ **High luminosity frontier:**
hadron production mechanism and inner structure, exotic states, nature of strong interactions, NP in the c/b quarks and τ -lepton ...

**Complementary
Irreplaceable**

◆ **High energy frontier:**
Origin of elementary particle mass, nature of electroweak, quark-gluon plasma, NP via Higgs particle ...

Unique Physics in τ -Charm Region



- ◆ **Unique Energy Region:** transition Region between Perturbative and Non-perturbative QCD
- ◆ **Rich hadron spectra:** glueballs, multi-quark states, hybrid ...
- ◆ **Ultra high cross-section:** rich resonances, charmonium ...
- ◆ **Threshold effect:** hadron/lepton pairs, quantum correlation

Scientific and Project Objectives



Nuclear Structure:

Understand the mysteries
of Nuclear Form Factors

Asymmetry:

Discover the CP violation in
hyperons

QCD confinement:

Explore quark formation
in hadrons

**A revolutionary new-generation facility, providing
unprecedented data size and measurement precision**

CMS Energy : 2-7 GeV

Peaking Luminosity: $5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$

**Upgrade Potential : Higher energy,
Higher luminosity, Polarization**

Momentum Res.: 0.5%@1GeV

Energy Res. : 2.5%@1GeV

Particle ID : K/π 4σ @2 GeV

Event Rate : 400 kHz

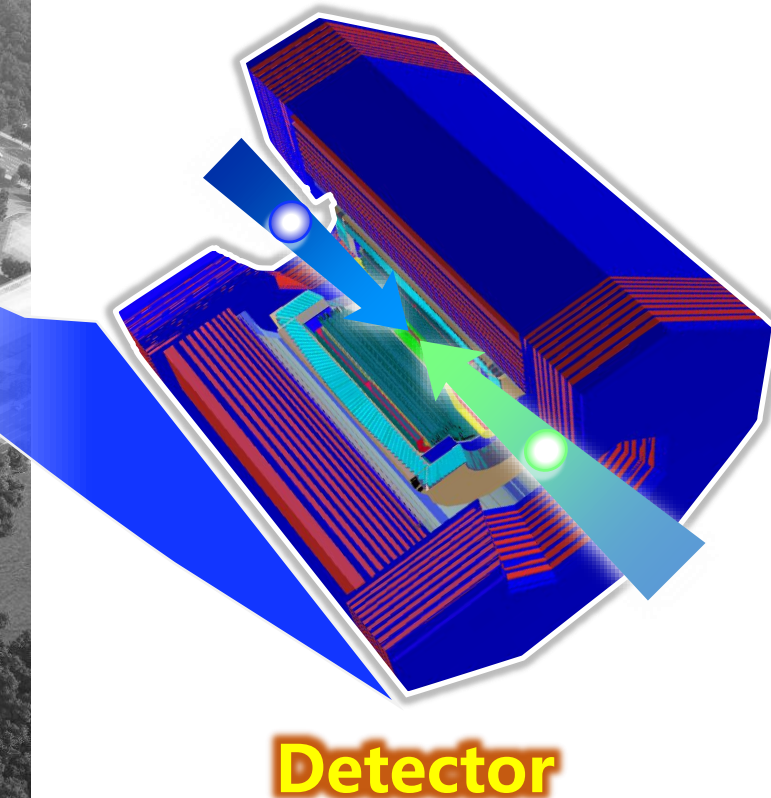
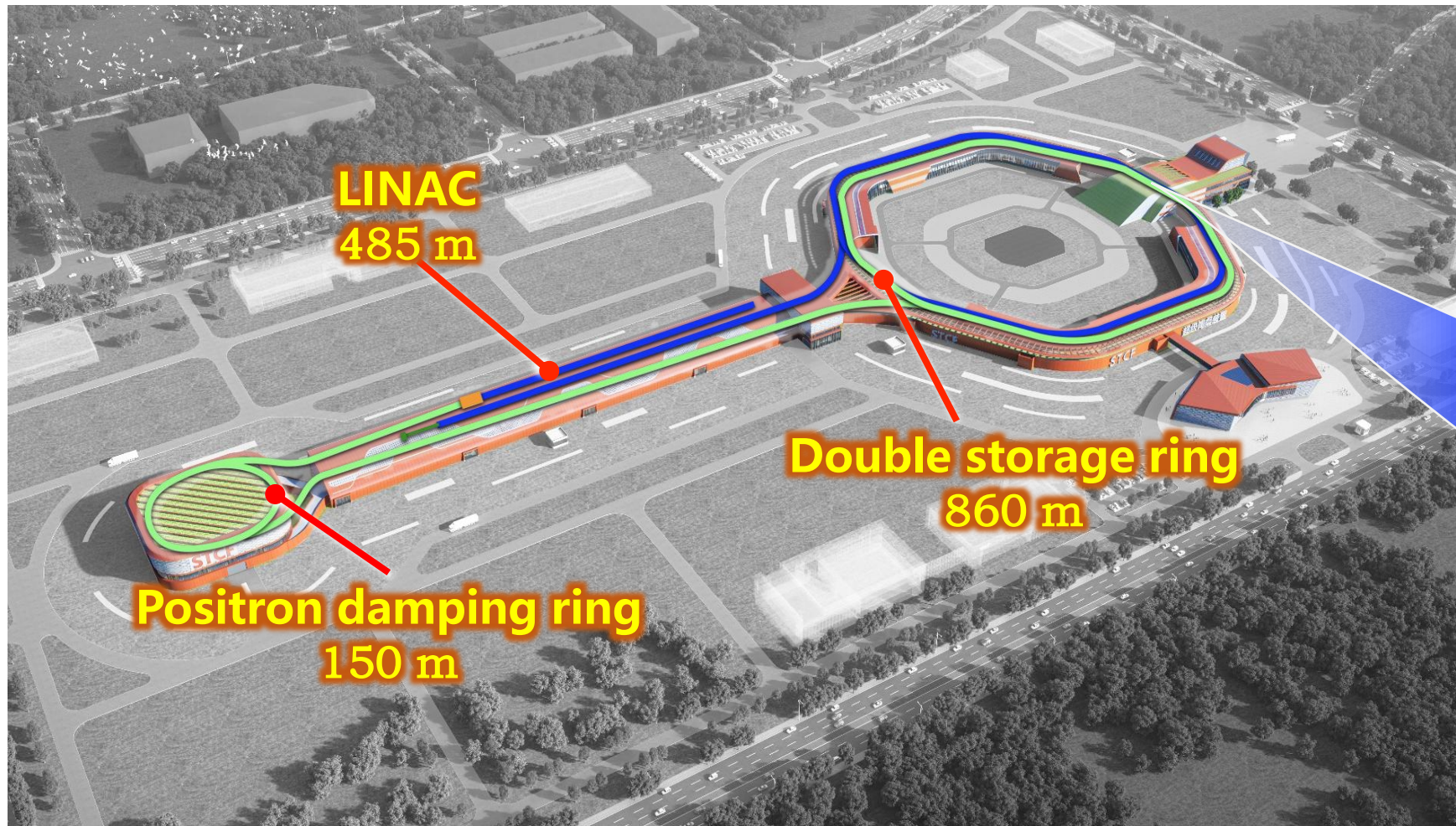
**long-term stable operation within high
luminosity and wide energy range**

**high-precision measurements within
high irradiation and event rate**

New Project: Super Tau-Charm Facility



- ◆ New generation **GeV-region electron-positron collider**
- ◆ Unique platform for exploring hadron structures and fundamental symmetries



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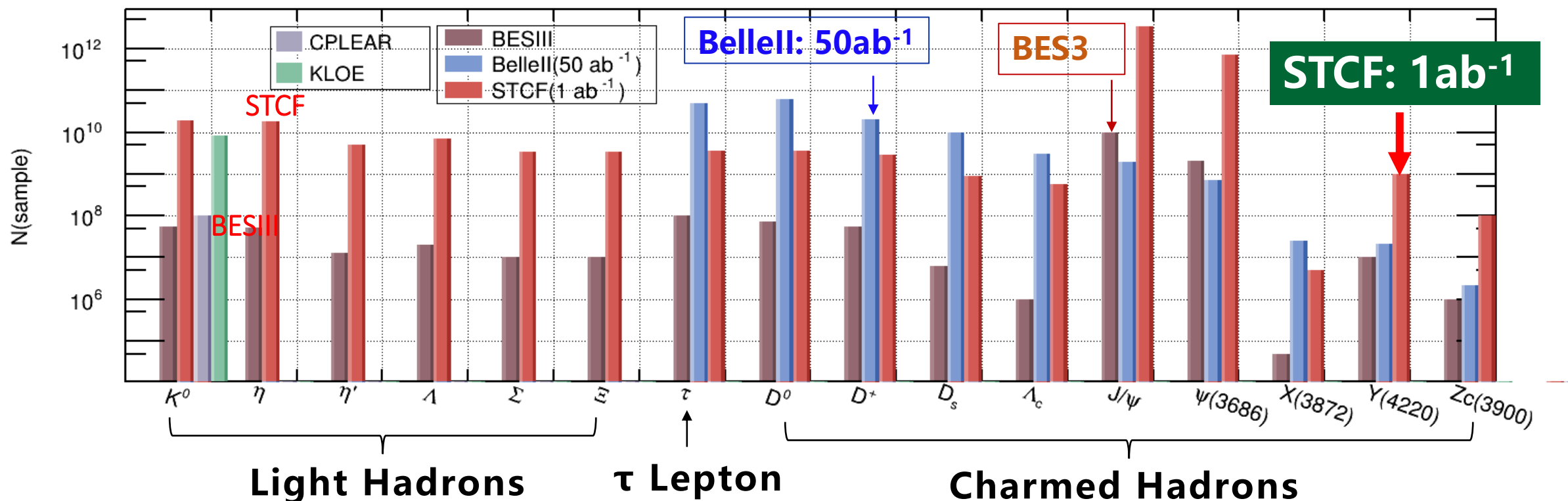
- ◆ Introduction
- ◆ **Physics Potential in STCF**
- ◆ Accelerator and Detector
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Super Large Data Samples

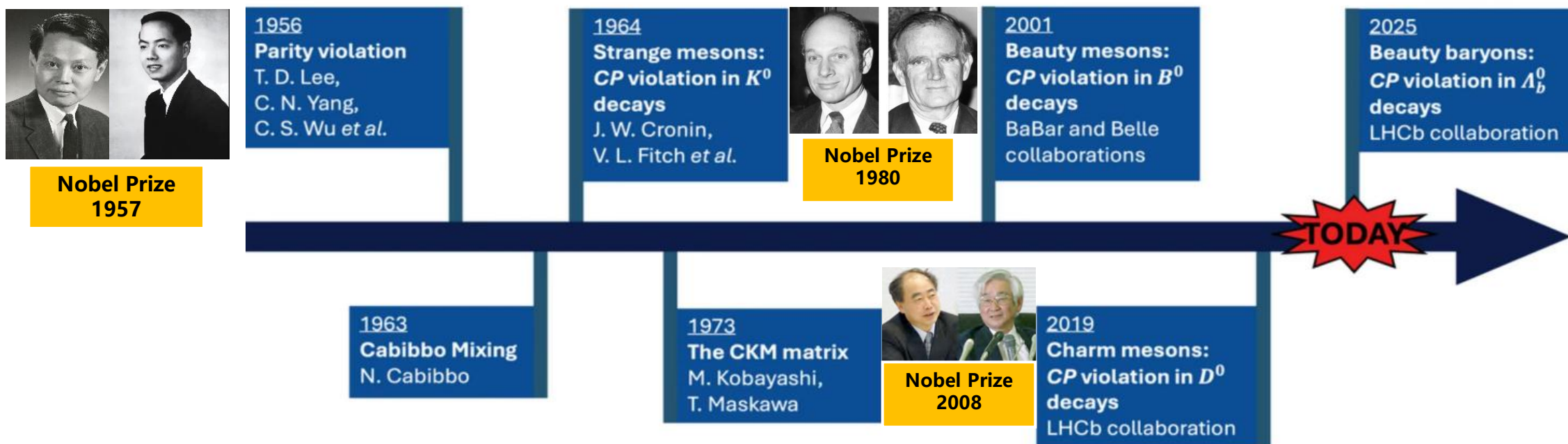


Factory: not only for τ -charm, but also XYZ, hyperons, light hadrons



Super Large Data + High Res. + Low Bkg $\rightarrow$ **High Precision**

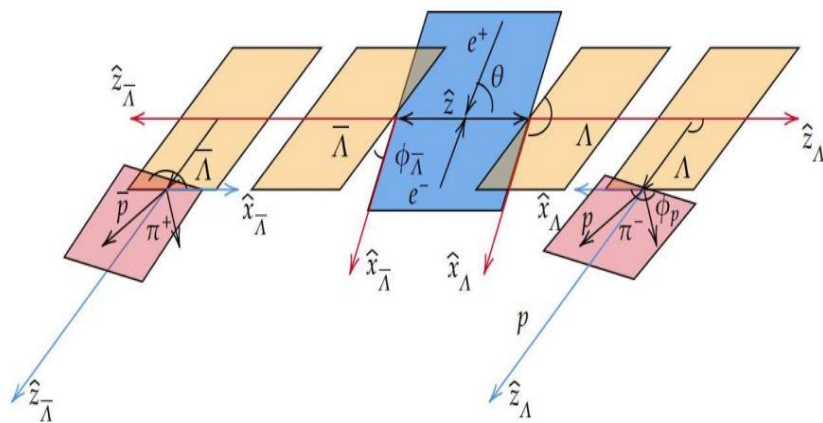
To understand the mysteries of hadron formation and interactions



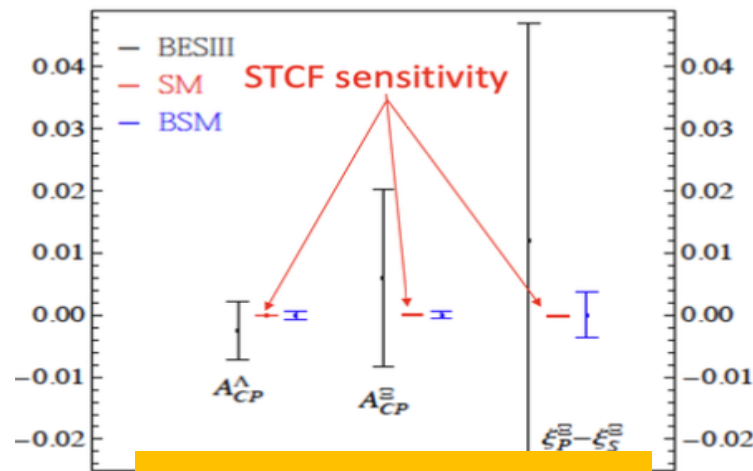
- ◆ The CP violation observed in current experiments is far from sufficient to explain the mystery of antimatter disappearance.
- ◆ Only the CP violation of **hyperons** and **charmed baryons** has not been discovered, which is one of the last unexplored frontiers in hadron physics

CP violation in Hyperons

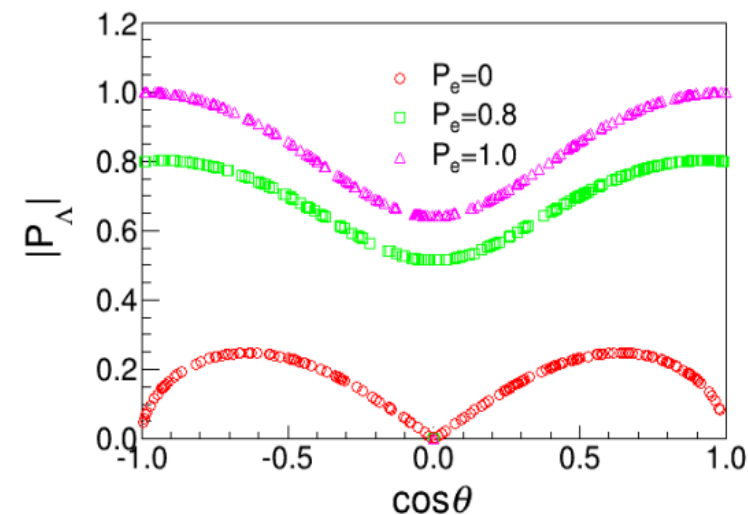
Quantum Correlation



X.G. He et al. Sci.Bull. 67 (2022) 1840-1843:



SM: $10^{-4} \sim 10^{-5}$



$$\sigma_{ACP} \approx \sqrt{\frac{3}{2}} \frac{1}{\alpha_1 \sqrt{N_{sig}} \sqrt{\langle P_B^2 \rangle}}$$

$$\xrightarrow{1 \times 10^9 \Lambda \bar{\Lambda}, \langle P_B^2 \rangle = 0.1} \sigma_{ACP} \sim 1.4 \times 10^{-4}$$

$$\xrightarrow{1 \times 10^9 \Lambda \bar{\Lambda}, \langle P_B^2 \rangle = 0.8} \sigma_{ACP} \sim 5 \times 10^{-5}$$

◆ $e^+ e^- \rightarrow J/\psi \rightarrow Y \bar{Y}$: abundant hyperon pairs

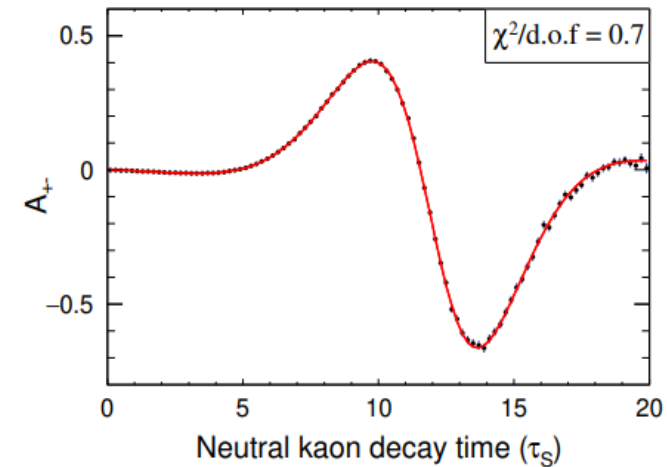
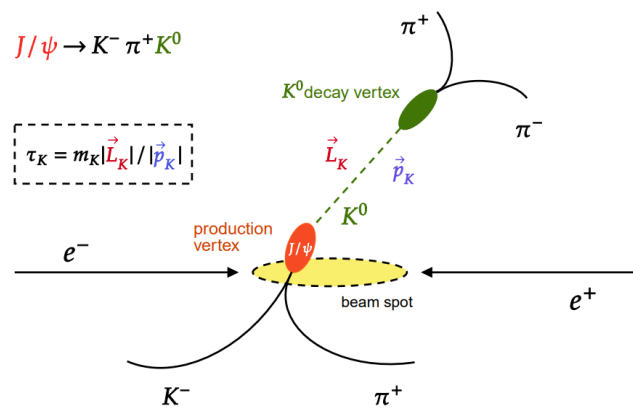
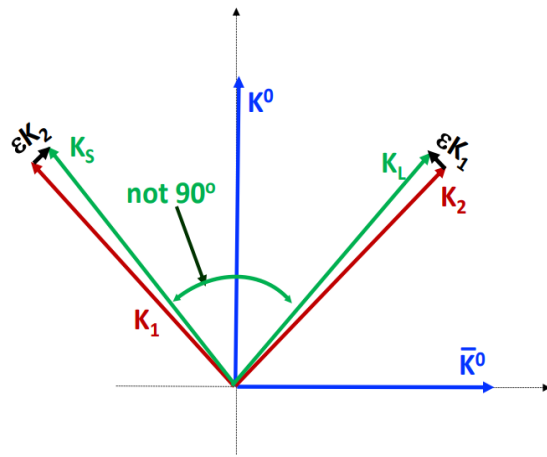
◆ Sensitivity of CPV observable: 10^{-4}

◆ Polarization increases the sensitivity

Reach sensitivity of SM prediction with 1-year data at STCF

CPT test to probe the new physics beyond SM

arXiv : 2209.12551



- ◆ $K^0 - \bar{K}^0$ **flavor tagging** via $J/\psi \rightarrow K^0 K^- \pi^+ / \bar{K}^0 K^+ \pi^-$
- ◆ $K_1 - K_2$ **CP tagging** by reconstructing $\pi^+ \pi^-$ or $\pi^+ \pi^- \pi^0$
- ◆ Precise determination of K^0 decay vertex $\Rightarrow$ essential for time-distribution

- ◆ The phase in CP parameter ϕ_{+-} used to set limits on CPT violation
- ◆ sensitivity of ϕ_{+-} is $\mathcal{O}(10^{-3})$ at STCF $\Rightarrow$ **one magnitude better than PDG average**

CP violation studies at Super tau-charm facility

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Abstract

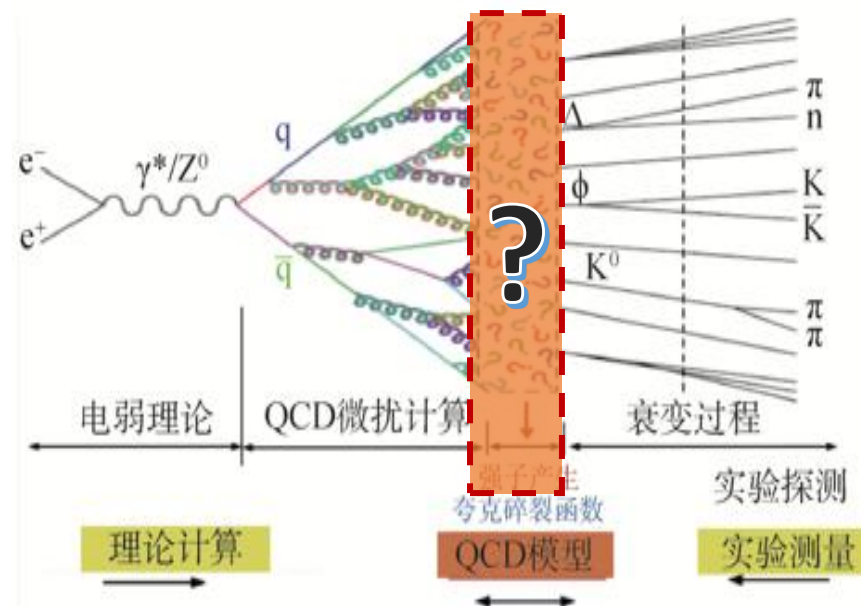
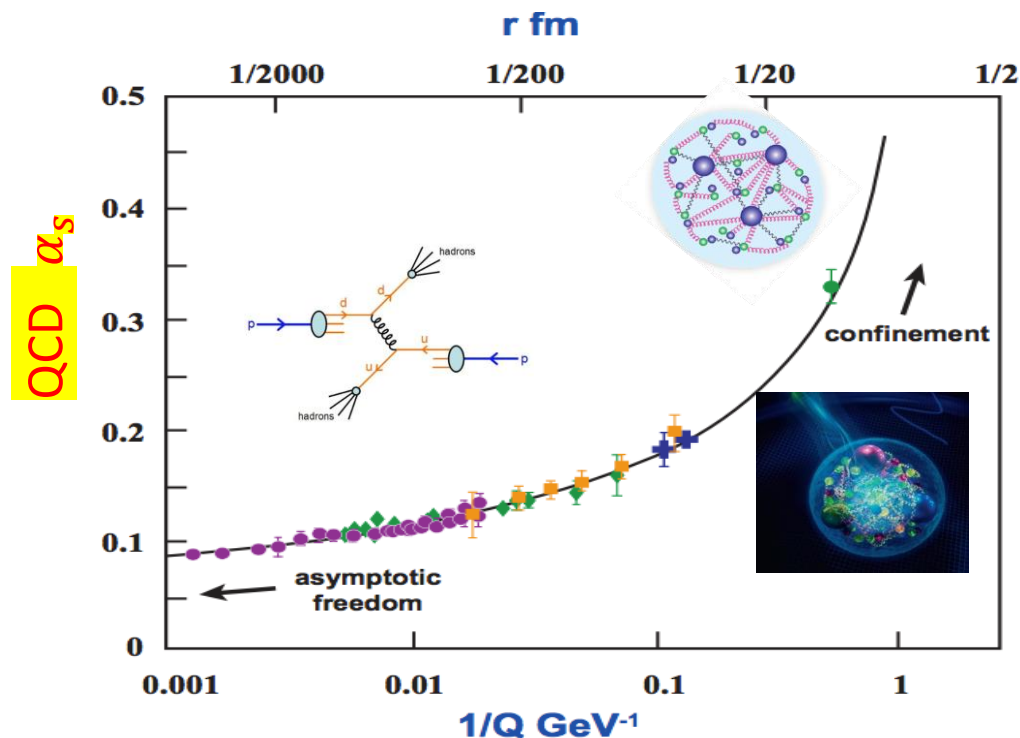
Charge-parity (CP) violation in the tau-charm energy region is one of the promising areas to search for. The future tau-charm facility of next generation is designed to operate in a center-of-mass energy from 2.0 to 7.0 GeV with a peak luminosity of $0.5 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$. Huge amount of hadrons and tau (τ) leptons will be collected with good kinematic constraint and low-background environment. In this report, possibilities of CP violation studies in tau-charm energy region and at the future tau-charm facility are discussed from various aspects, i.e. in the production and decay of hyperons and τ lepton; in the decay of charmed hadrons. The CPT invariance test in $K^0 - \bar{K}^0$ mixing is also presented.

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- ◆ **Non-perturbative effect** is the major bottleneck for precision measurements
- ◆ Hadrons and nucleons are essential probes: hadron spectra, nuclear structures, fragmentation functions

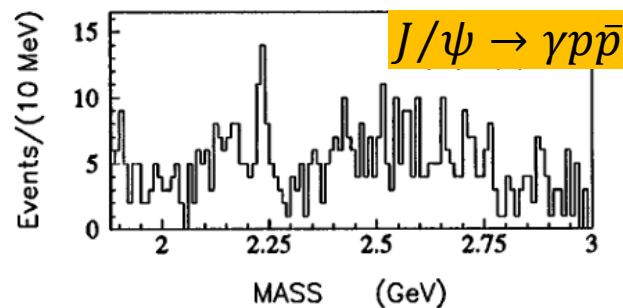


More Data, Finer Structures



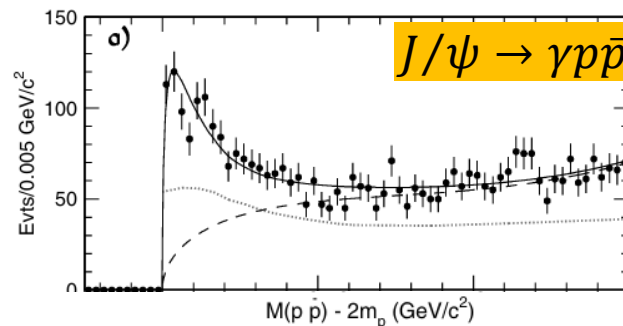
1996, 8 M J/ψ 's

PRL 76, 3602



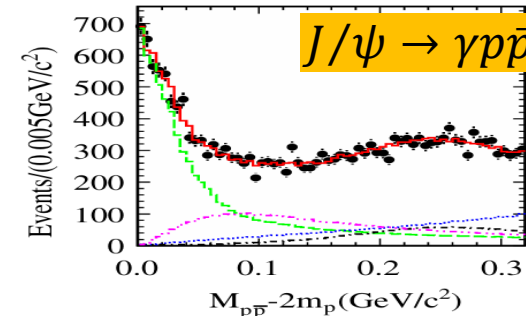
2003, 58 M J/ψ 's

PRL 91, 022001



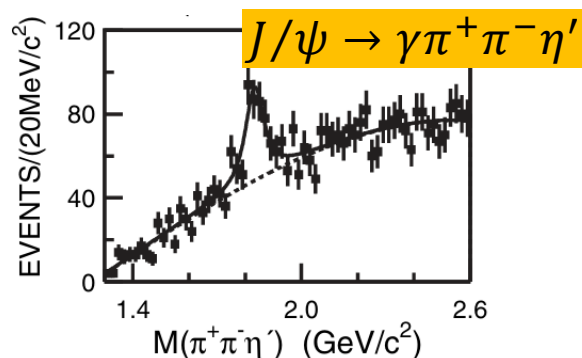
2012, 225 M J/ψ 's

PRL 108, 112003



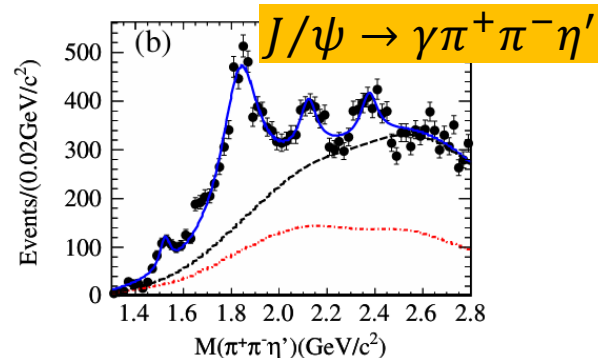
2005, 58 M J/ψ 's

PRL 95, 262001



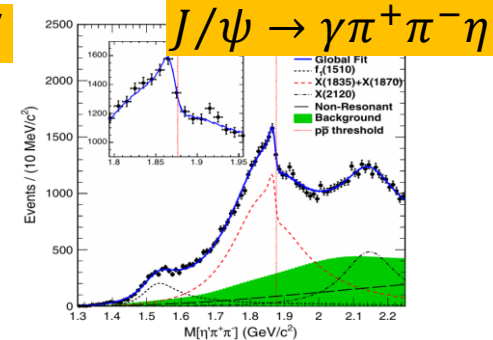
2011, 225 M J/ψ 's

PRL 106, 072002



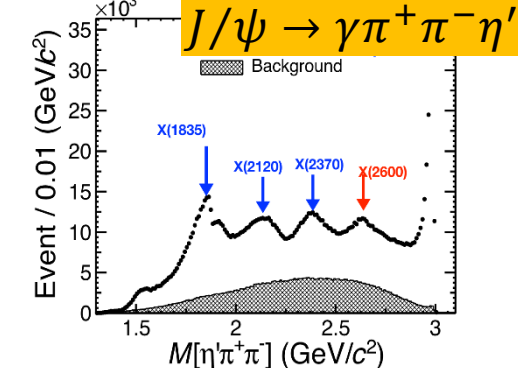
2016, 1.1 B J/ψ 's

PRL 117, 042002



2022, 10 B J/ψ 's

PRL 129, 042001

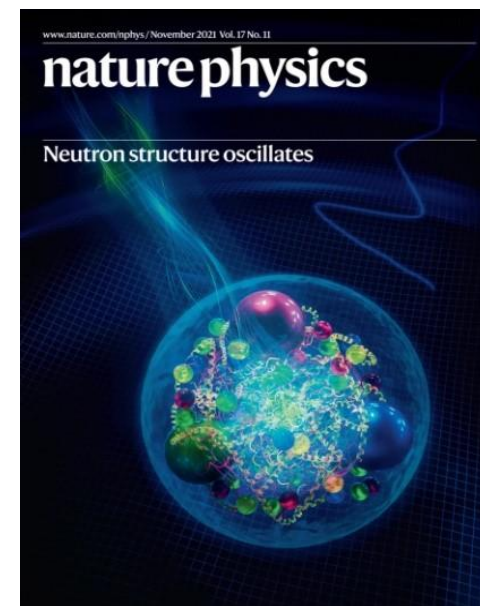
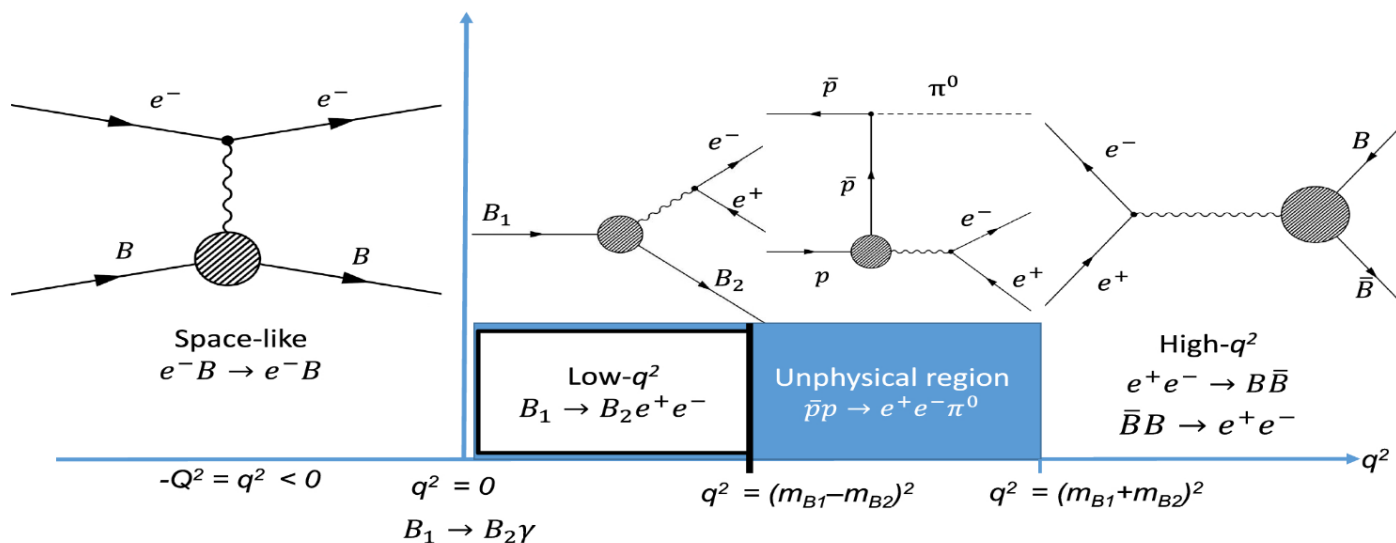


You never have enough J/ψ events!

— Stephen Lars Olsen

Talk on "Symposium on 30 years of BES Physics", (2019)

- ◆ Form Factors: non-perturbative effect, incalculable precisely
- ◆ Essential Input for the PDFs (critical uncertainty in hadron colliders)
- ◆ ee colliders provide the most clean samples



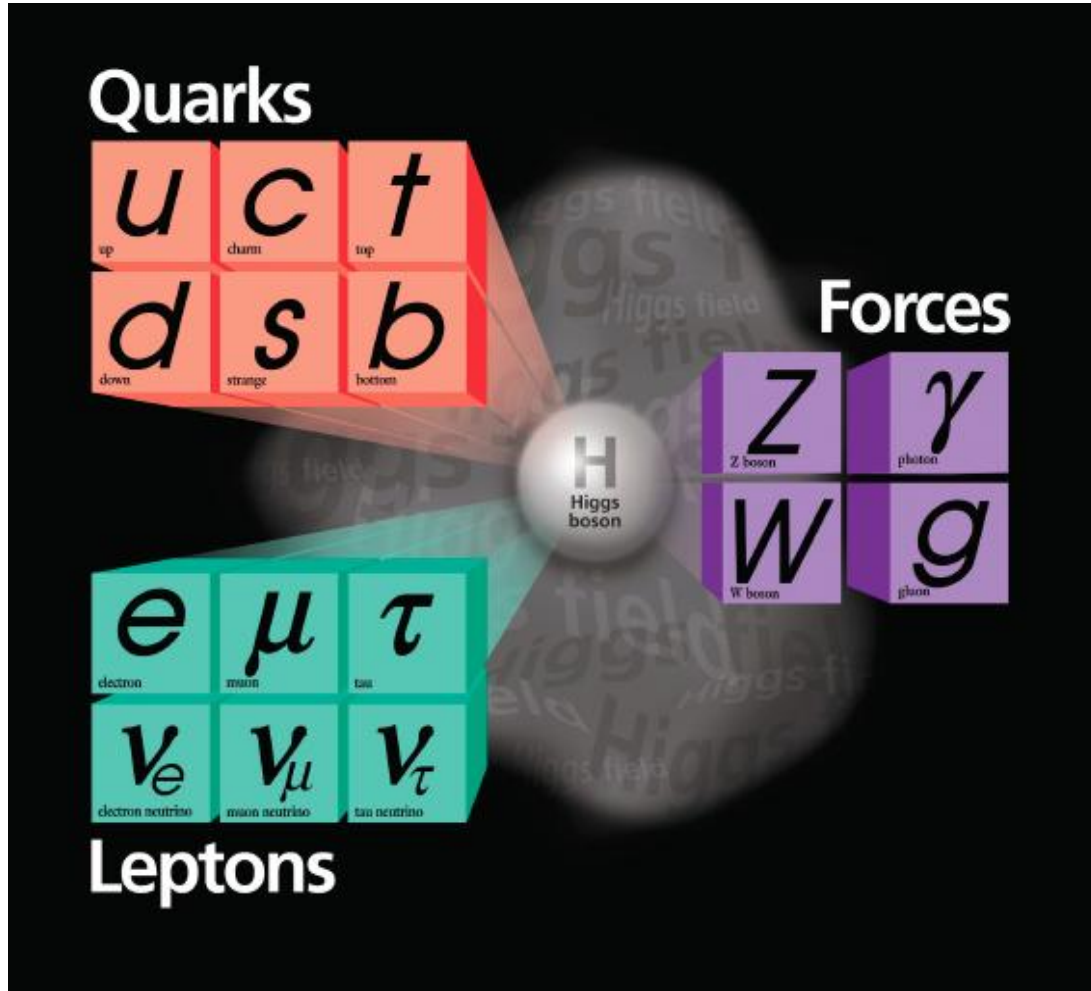
**Year 2021
Neutron EMFFs
measurements**

**First Cover Article
of «Nature-Physics»
at BESIII**

STCF potential:

- Provide the **most precise** multidimensional FFs distributions for $q^2 \sim 4\text{--}50 \text{ GeV}^2$
- Polarized beam can further improve measurement accuracy and quality
- Critical input for experiments EIC, EicC, Jlab

Precise measurement is the critical approach for new physics investigation



Masses

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

Couplings

Parameter	Value	Method
α	0.0073	non-collider + collider
G_F	1.17×10^{-5}	Non-collider
α_s	0.12	Lattice + collider

Flavour and CP violation

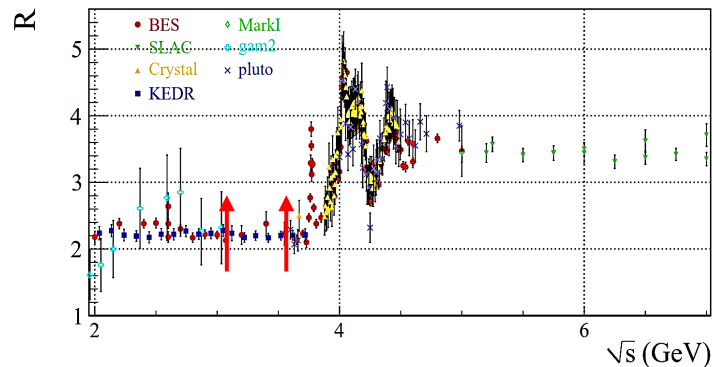
Parameter	Value	Method
θ_{12} (CKM)	13.1°	Collider
θ_{23} (CKM)	2.4°	Collider
θ_{13} (CKM)	0.2°	Collider
δ (CKM-CPV)	0.995	Collider
θ (strong CP)	~ 0	Non-collider

- ◆ SM contains 19 free parameters: Quark and Lepton masses, CKM matrix, Couplings
- ◆ Basic physical quantities: R value etc

R value measurement

One of the most fundamental physical quantities, directly reflecting the quark flavor and color, and providing experimental input for theoretical calculations of fine structure constants and anomalous magnetic moments of muons

$$R = \frac{\sigma(e^+e^- \rightarrow \text{hadrons})}{\sigma(e^+e^- \rightarrow \mu^+\mu^-)}$$



- Running of **fine structure constant** $\Delta\alpha_{\text{em}}$

$$\Delta\alpha(s) = 1 - \alpha(0)/\alpha(s) = \Delta\alpha_{\text{lepton}}(s) + \Delta\alpha_{\text{had}}^{(5)}(s) + \Delta\alpha_{\text{top}}(s)$$

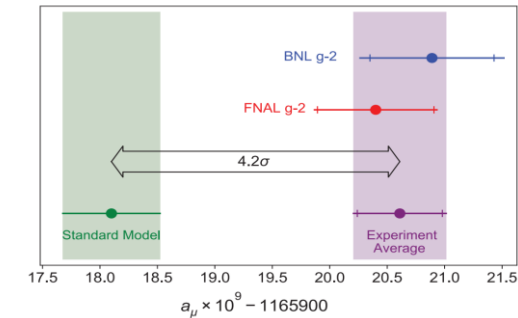
Eur. Phys. J. C 80, 241 (2020)

Source	Contribution($\times 10^{-4}$)
$\Delta\alpha_{\text{lepton}}(M_Z^2)$	314.979 ± 0.002
$\Delta\alpha_{\text{had}}^{(5)}(M_Z^2)$	276.0 ± 1.0
$\Delta\alpha_{\text{top}}(M_Z^2)$	-0.7180 ± 0.0054

- $\Delta\alpha_{\text{had}}^{(5)}(s)$ should be calculated with R value:

$$\Delta\alpha_{\text{had}}^{(5)}(s) = -\frac{\alpha s}{3\pi} \text{Re} \int_{E_{\text{th}}}^{\infty} ds' \frac{R(s')}{s'(s' - s - i\epsilon)}$$

- Muon **anomalous magnetic moment** a_μ

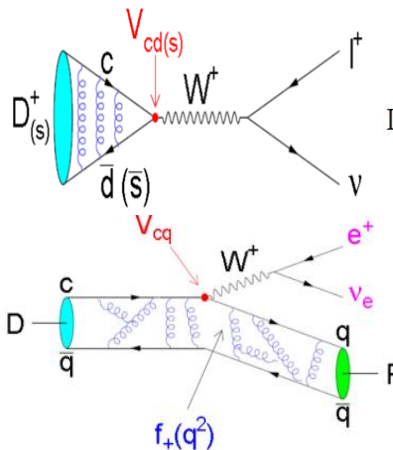


- SM : $a_\mu^{\text{SM}} = a_\mu^{\text{QED}} + a_\mu^{\text{Weak}} + a_\mu^{\text{Had}}$
 - Hadronic **Vacuum Polarization (HVP)** and Light-by-Light (HLbL) in a_μ^{Had} dominate uncertainty
- HVP contribution is calculated with **R value** with **dispersion relation**:

$$a_\mu^{\text{LO-HVP}} = \left(\frac{\alpha m_\mu}{3\pi} \right)^2 \int_{4m_\pi^2}^{\infty} ds \frac{R(s)K(s)}{s^2}$$

Unitarity breaking of the CKM matrix : the new generation quarks !

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



$$\Gamma(D_{(s)}^+ \rightarrow \ell^+ \nu_\ell) = \frac{G_F^2 f_{D_{(s)}^+}^2}{8\pi} |V_{cd(s)}|^2 m_\ell^2 m_{D_{(s)}^+}^2 \left(1 - \frac{m_\ell^2}{m_{D_{(s)}^+}^2}\right)^2$$

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

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

**Theory : 0.2%
(0.1% expected)**

**Theory : 0.2%
(0.1% expected)**

**Theory : 0.2%
(0.1% expected)**

- ◆ The stat. errors in $|V_{cs}|$ and $|V_{cd}|$ measurements will reach the expected theoretical level, and syst. errors will become critical.
- ◆ The decay of Tau and hyperons will provide opportunities for improving the measurement accuracy of $|V_{us}|$ and $|V_{ud}|$

STCF Sensitivities and Comparisons



Physics goal	Observable	BESIII	Current world best	STCF prospect(1 ab ⁻¹)
Fundamental Symmetry	A_{CP} in hyperon decay	0.005	0.005	$\mathcal{O}(10^{-4})$
	weak phase in hyperon decay	1.2°	1.2°	0.04°
	Δ_{CP} in tau decay	-	0.25%	$\mathcal{O}(10^{-3})$
	EDM of hyperon	-	$\mathcal{O}(10^{-16})$ ecm	$\mathcal{O}(10^{-21})$ ecm
	EDM of tau	-	$\mathcal{O}(10^{-17})$ ecm	$\mathcal{O}(10^{-18})$ ecm
	cLFV in $\tau \rightarrow \mu\mu\mu$	-	2.1×10^{-8}	$\mathcal{O}(10^{-9})$
	cLFV in $J/\psi \rightarrow e\mu$	4.5×10^{-9}	4.5×10^{-9}	$\mathcal{O}(10^{-11})$
	cLFV in $J/\psi \rightarrow e\tau$	7.5×10^{-8}	7.5×10^{-8}	$\mathcal{O}(10^{-10})$
Quark Confinement	$N_{Y(4260)/Z_c/X(3872)}$	$10^7/10^6/10^4$	$10^6/10^5/10^6$	$10^9/10^8/10^6$
	Pentaquarks	-	P_{cs} in $J/\psi p(\Lambda)$	$\sigma_{J/\psi p\bar{p}} \simeq 4$ fb
	Di-charmonium	-	di- ψ	$\sigma_{J/\psi c\bar{c}} \simeq 10$ fb
	$N_{J/\psi/\psi(3686)}$	$10^{10}/10^9$	$10^{10}/10^9$	$10^{12}/10^{11}$
	Collins effects	0.3	0.3	$\mathcal{O}(10^{-3})$
	Baryon form factors	10%	10%	$\mathcal{O}(10^{-2})$
Physical Quantities	R value	3%	3%	$\mathcal{O}(10^{-3})$
	tau mass	160 keV	120 keV	$\mathcal{O}(10)$ keV
	$ V_{us} $	-	1%	$\mathcal{O}(10^{-3})$
	$ V_{cd} $	1.2%	1%	$\mathcal{O}(10^{-3})$
	$ V_{cs} $	1.4%	1.4%	$\mathcal{O}(10^{-3})$
	Sys. unc. of γ from D decay	0.4°	0.4°	0.1°
	α_s	-	1.5%	$\mathcal{O}(10^{-3})$

CONTENTS



- ◆ Introduction
- ◆ Physics Potential in STCF
- ◆ **Accelerator and Detector**
- ◆ Project Promotion and Progress
- ◆ Summary



Collider Development

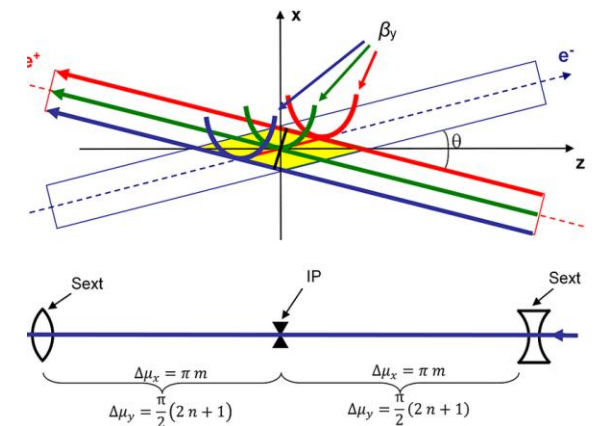
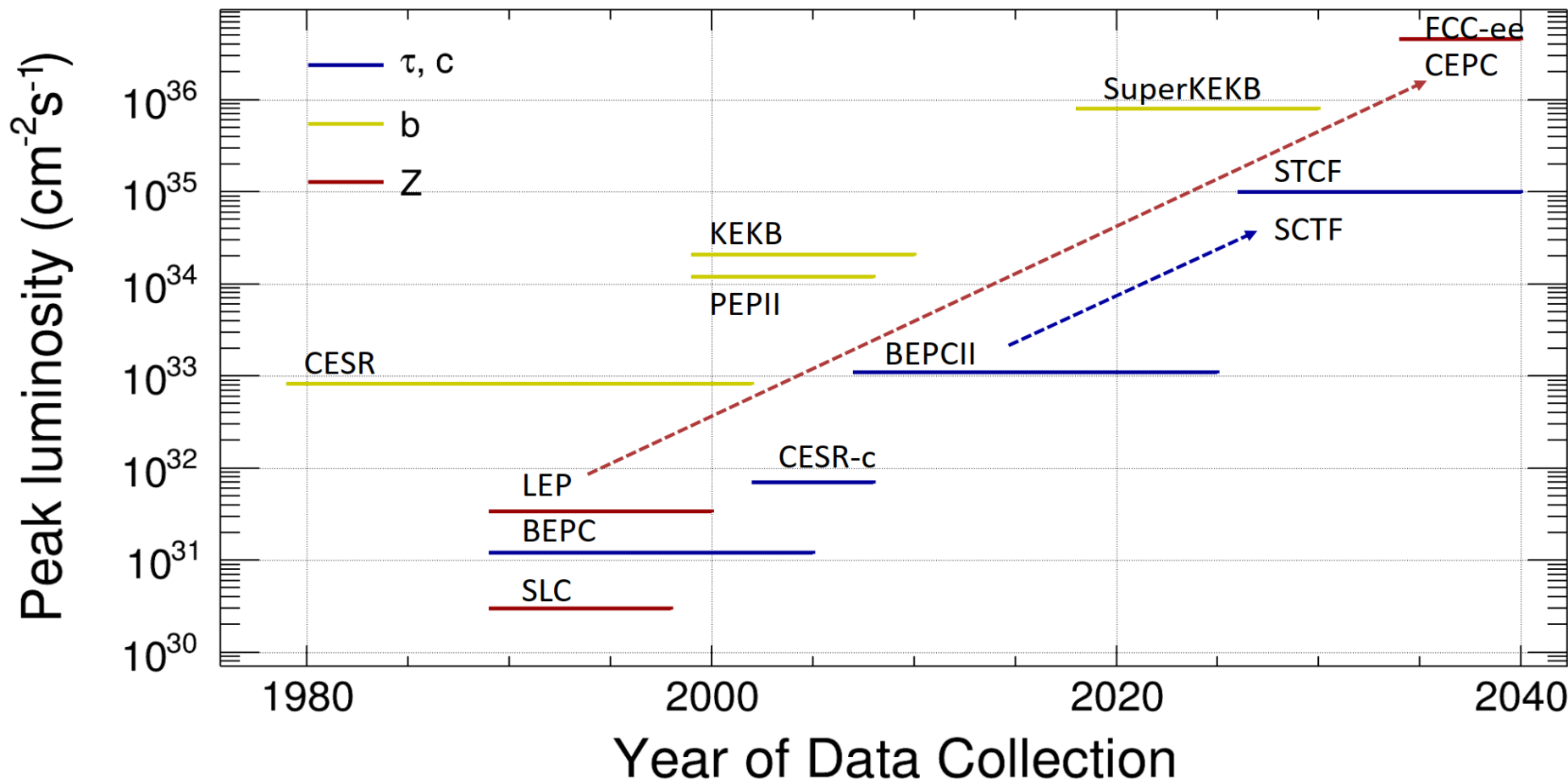


1st Generation
Single ring

2nd Generation
Double-ring
More bunches
Low b_y @IP

3rd Generation
Double-ring
Large I_b and crossing angle
Extremely low b_y @IP

$$L = \frac{\gamma n_b I_b}{2 e r_e \beta_y^*} \xi_y H$$

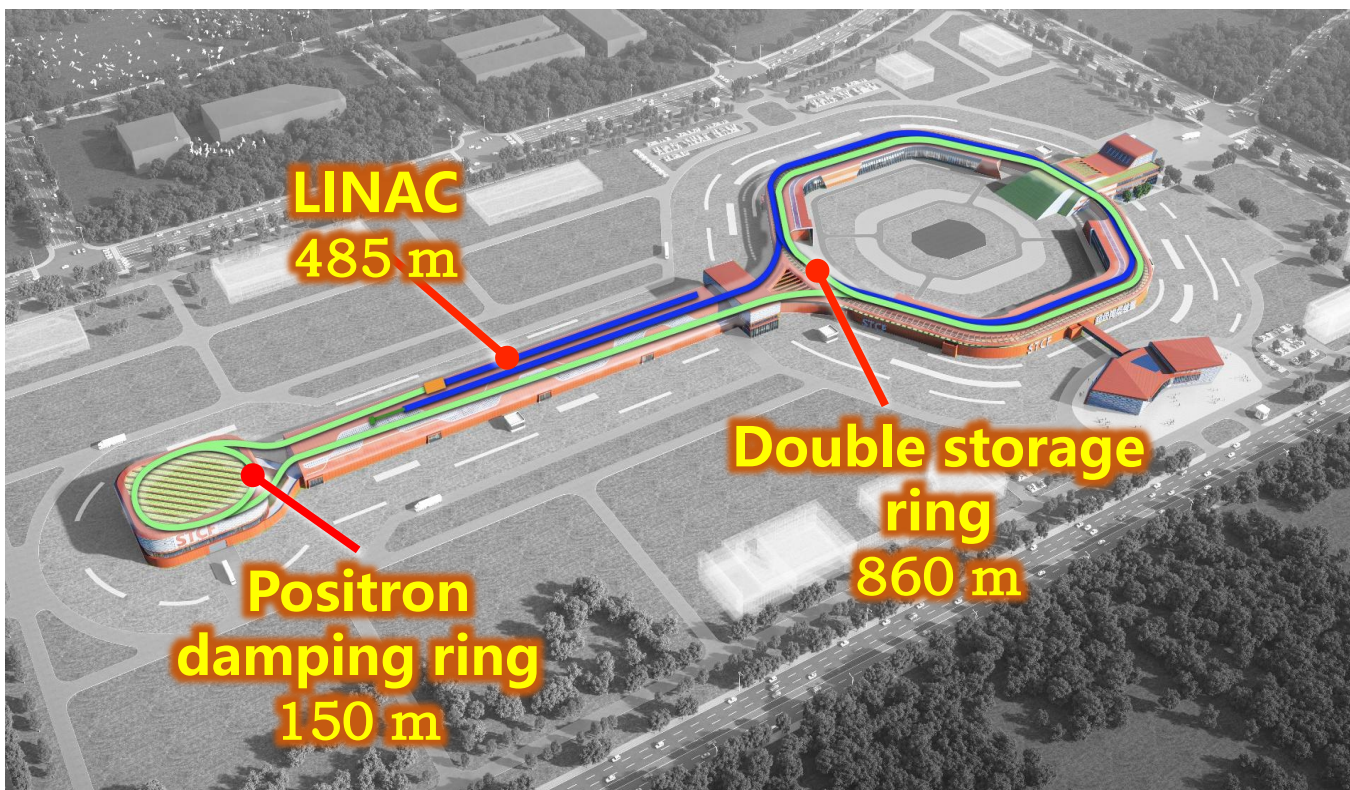


**Large Piwinski Angle
+ Crab Waist**

STCF Design Goals and Accelerator



- ◆ Core design goal:
 - CMS energy: 2-7 GeV
 - Luminosity: $>5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ @ 4GeV
 - Upgrading potential: polarized beam, higher luminosity



arXiv > physics > arXiv:2509.11522

Physics > Accelerator Physics

[Submitted on 15 Sep 2025 (v1), last revised 16 Sep 2025 (this version, v2)]

Conceptual Design Report of Super Tau-Charm Facility: The Accelerator

Jiancong Bao, Anton Bogomyagkov, Zexin Cao, Mingxuan Chang, Fangzhou Chen, Guanghua Chen, Qi Chen, Qushan Chen, Zhi Chen, Kuanjun Fan, Hailiang Gong, Duan Gu, Hao Guo, Tengjun Guo, Chongchao He, Tianlong He, Kaiwen Hou, Hao Hu, Tongning Hu, Xiaocheng Hu, Dazhang Huang, Pengwei Huang, Ruixuan Huang, Zhicheng Huang, Hangzhou Li, Renkai Li, Sangya Li, Weiwei Li, Xuan Li, Xunfeng Li, Yu Liang, Chao Liu, Tao Liu, Xiaoyu Liu, Xuyang Liu, Yuan Liu, Huihui Lv, Qing Luo, Tao Luo, Mikhail Skamarokha, Shaohang Ma, Wenbin Ma, Masahito Hosaka, Xuece Miao, Yihao Mo, Kazuhito Ohmi, Jian Pang, Guoxi Pei, Zhijun Qi, Fenglei Shang, Lei Shang, Caitu Shi, Kun Sun, Li Sun, Jingyu Tang, Anxin Wang, Chengzhe Wang, Hongjin Wang, Lei Wang, Qian Wang, Shengyuan Wang, Shikang Wang, Ziyu Wang, Shaoqing Wei, Yelong Wei, Jun Wu, Sang Wu, Chunjie Xie, Ziyu Xiong, Xin Xu, Jun Yang, Penghui Yang, Tao Yang, Lixin Yin, Chen Yu, Ze Yu, Youjin Yuan, Yifeng Zeng, Ailin Zhang, Haiyan Zhang, Jialian Zhang, Linhao Zhang, Ning Zhang, Ruiyang Zhang, Xiaoyang Zhang, Yihao Zhang, Yangcheng Zhao, Jingxin Zheng, Demin Zhou, Hao Zhou, Yimei Zhou, Zeran Zhou, Bing Zhu, Xinghao Zhu, Zi'an Zhu, Ye Zou

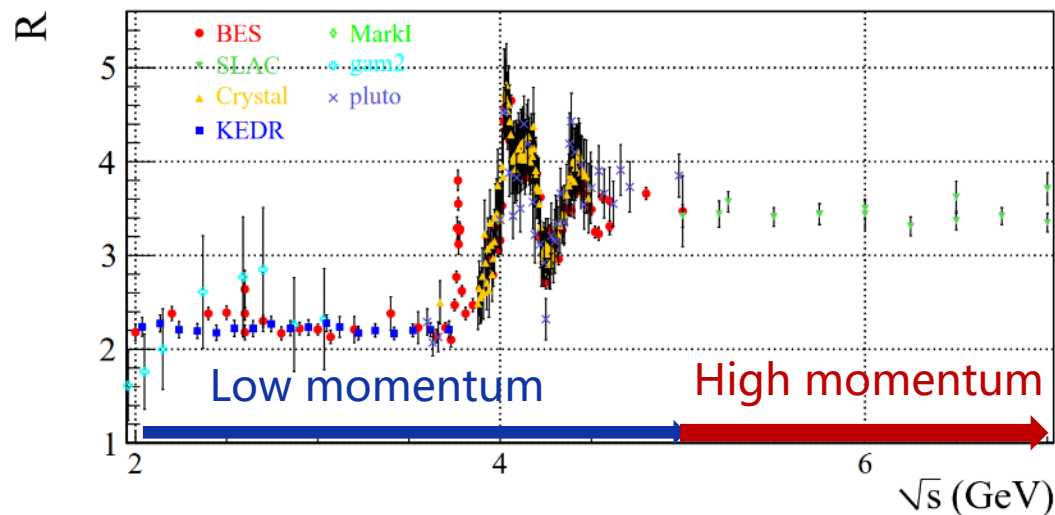
Electron-positron colliders operating in the GeV region of center-of-mass energies or the Tau-Charm energy region, have been proven to enable competitive frontier research, due to its several unique features. With the progress of high energy physics in the last two decades, a new-generation Tau-Charm factory, Super Tau Charm Facility (STCF) has been actively promoting by the particle physics community in China. STCF holds great potential to address fundamental questions such as the essence of color confinement and the matter-antimatter asymmetry in the universe in the next decades. The main design goals of STCF are with a center-of-mass energy ranging from 2 to 7 GeV and a peak luminosity surpassing $5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ that is optimized at a center-of-mass energy of 4 GeV, which is about 50 times that of the currently operating Tau-Charm injector.

CDR released in 15/09/2025
arXiv: 2509.11522

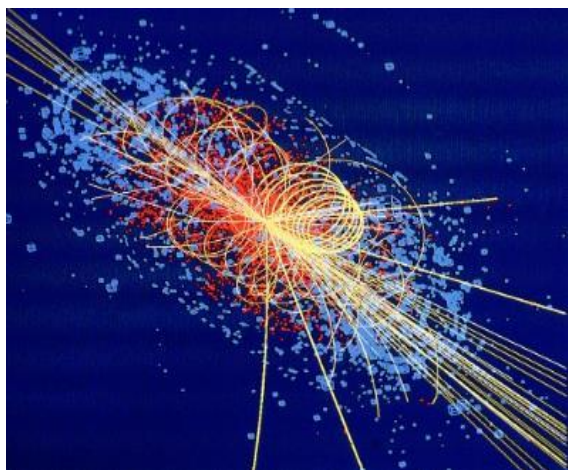
STCF accelerator project aims to secure support from the Chinese central government for its construction during the 15th Five-Year Plan (2026-2030) in China.

Challenges for Detector Design

Wide Energy region E_{cm} : 2-7 GeV



Peak Luminosity $\sim 5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$

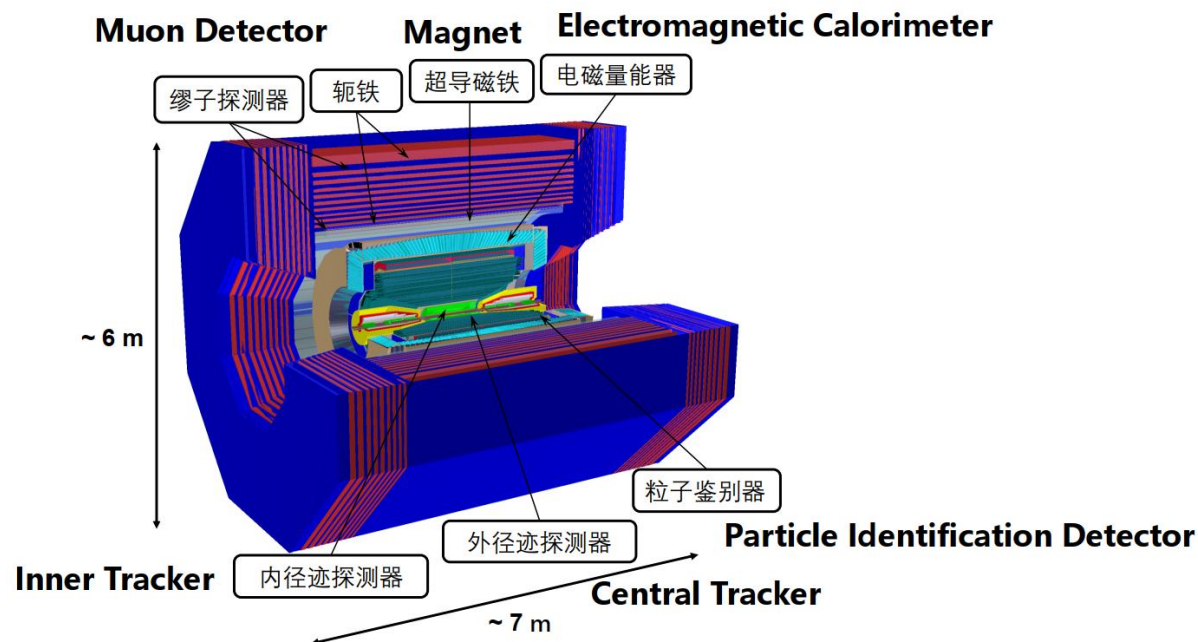


Physical signal rate
 $\sim 400 \text{ kHz}$

High counting rate
 $\sim 1 \text{ MHz/cm}^2$

High data rate
 $\sim 10 \text{ GB/s}$

High radiation background
 $\sim 4 \text{ kGy/y}, \sim 2 \times 10^{11} n_{eq}/\text{cm}^2/\text{y}$



Main performance

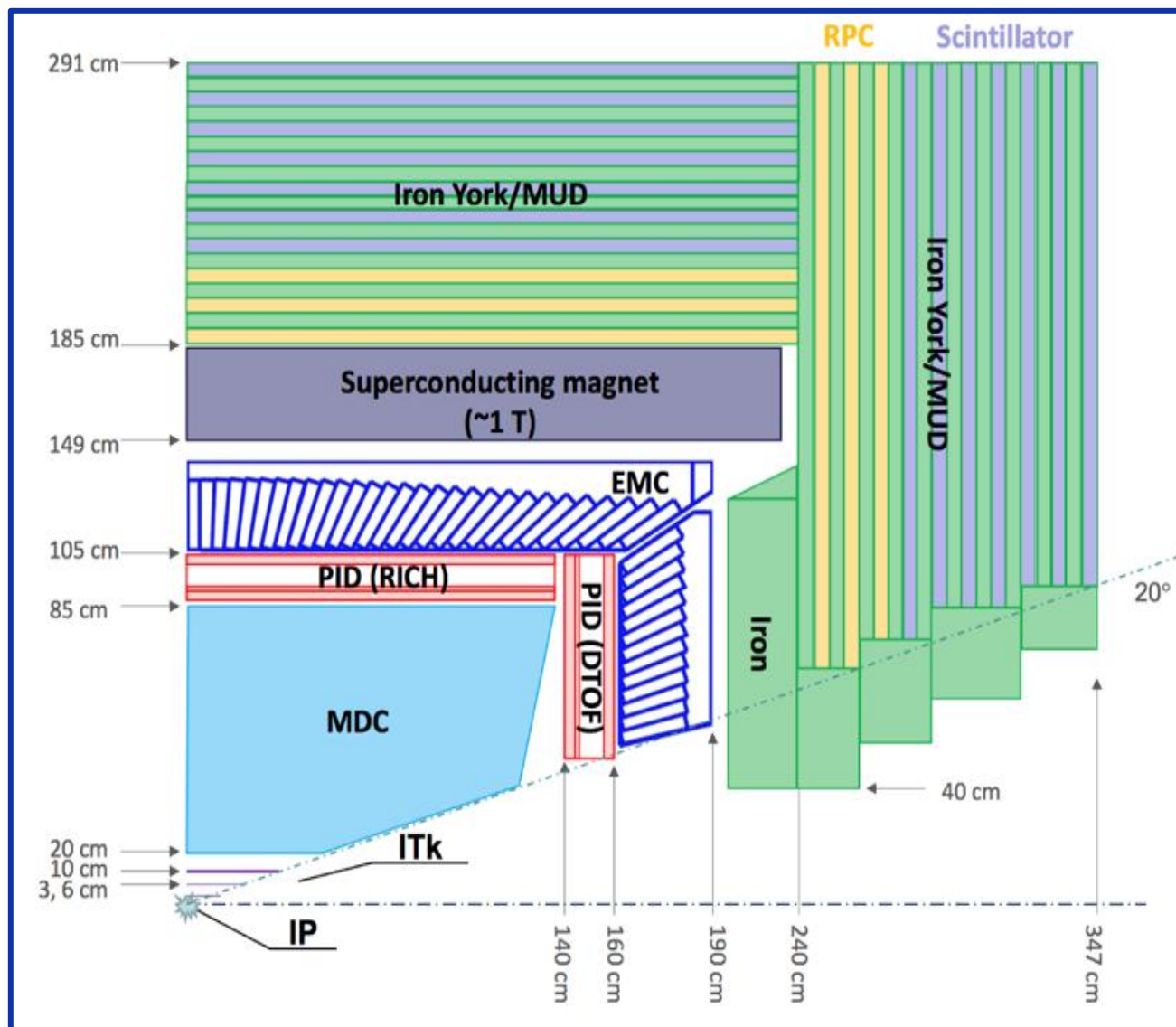
Geometric coverage : $94\% \times 4\pi$

Momentum res. : $\sigma_p/p \sim 0.5\% @ 1\text{GeV}$

Energy res. : $\sigma_E/E \sim 2.5\% @ 1\text{GeV}$

Hadron PID: π/K separation $\sim 4\sigma @ 2\text{GeV}$

Muon ID: $\epsilon_\mu > 95\%, \epsilon_{\text{miss-ID}} < 3\% @ 1\text{GeV}$

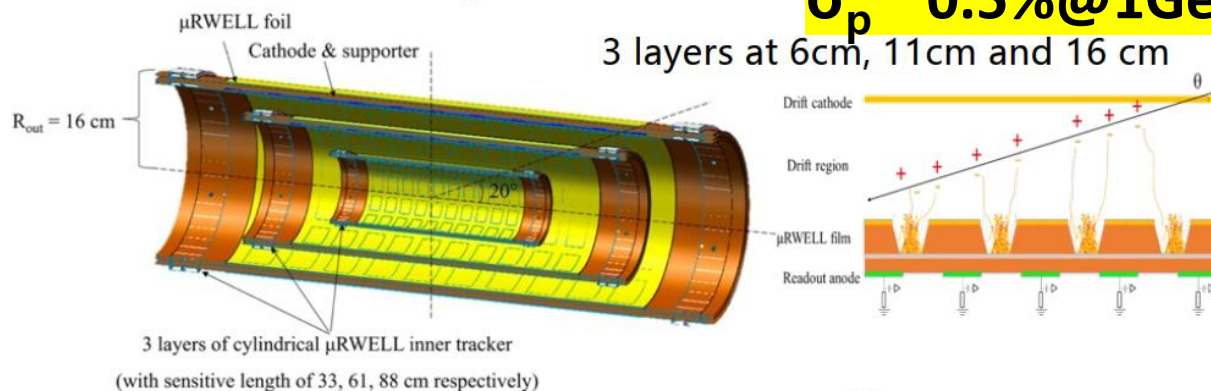


- ◆ Inner tracker (ITK, two options)
 - ❖ MPGD: cylindrical MPGD
 - ❖ Silicon: CMOS MAPS
- ◆ Central tracker
 - ❖ Main drift chamber (MDC)
- ◆ Particle identification (PID)
 - ❖ Barrel (two options):
 1. RICH with CsI-MPGD
 2. Barrel DIRC-like TOF
 - ❖ Endcaps: DIRC-like TOF (DToF)
- ◆ Electromagnetic Calorimeter (EMC)
 - ❖ pure CsI + APD
- ◆ Muon detector (MUD)
 - ❖ RPC + scintillator strips
- ◆ Magnet
 - ❖ Super-conducting solenoid, 1 T

Tracking System: ITK + MDC

$\sigma < 130 \mu\text{m}$, $\text{Trk Eff} > 90\% @ 0.1 \text{ GeV}/c$ and $> 99\% @ 0.3 \text{ GeV}/c$,
 $\sigma_p \sim 0.5\% @ 1 \text{ GeV}/c$

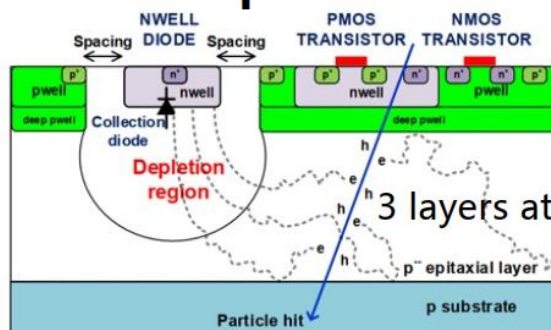
ITK Gaseous option : MPGD



3 layers of cylindrical μRWELL inner tracker
(with sensitive length of 33, 61, 88 cm respectively)

Material budget $\sim 0.3\% X_0/\text{layer}$

ITK Silicon option: CMOS MAPS



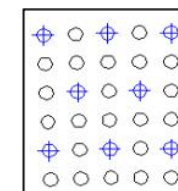
单片有源像素探测器

3 layers at 3.6cm, 9.8cm and 16 cm

Total material budget $\sim 4\% X_0$
(inner and outer walls included)

48 layers

Main Drift Chamber



20 cm

85 cm

$\sim 400 \text{ kHz/ch}$

$\sim 30 \text{ kHz/ch}$

Inner tracker

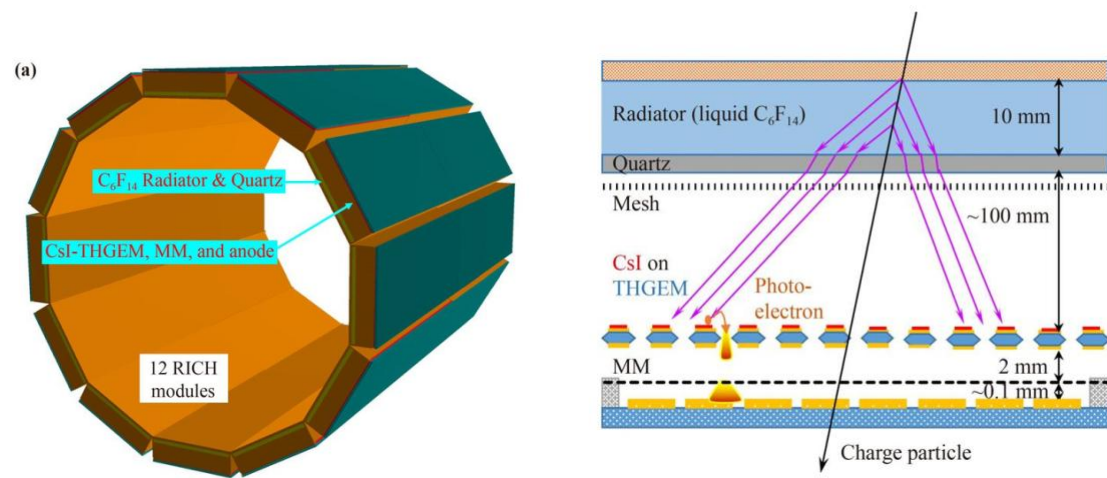
Inner-outer separate designs to accommodate different levels of radiation background

PID System



Barrel PID: A RICH detector using MPGD (THGEM with CsI + MM) for photon detection

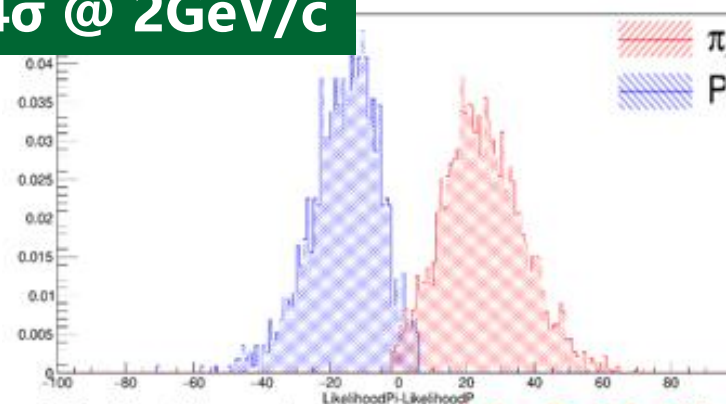
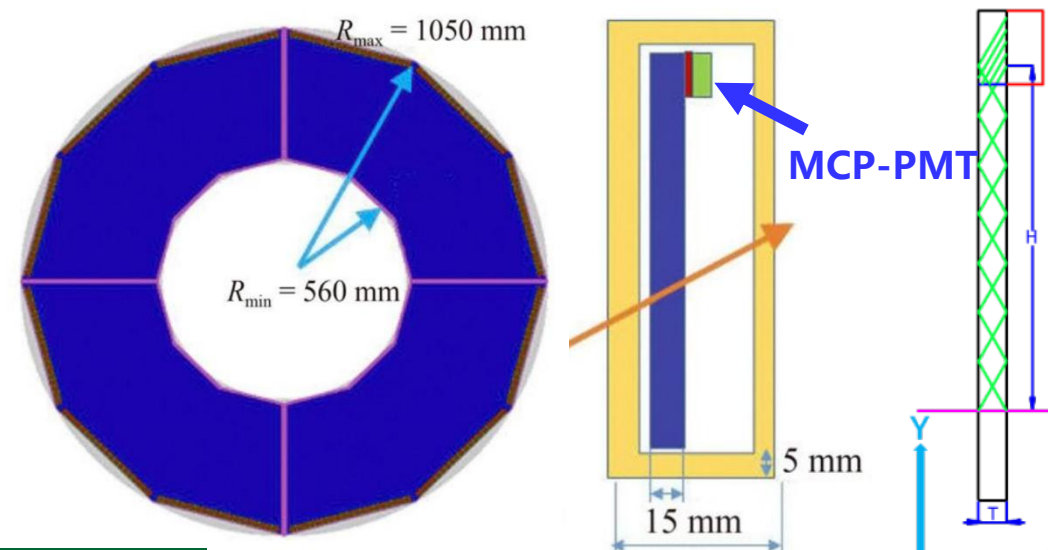
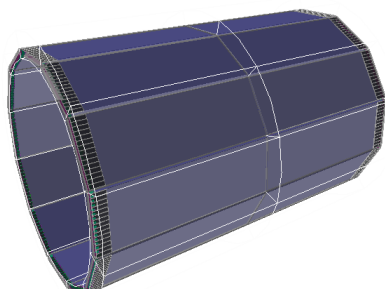
Endcap PID: A DIRC-like high-resolution TOF (~ 30 ps), quartz plate + MCP-PMT



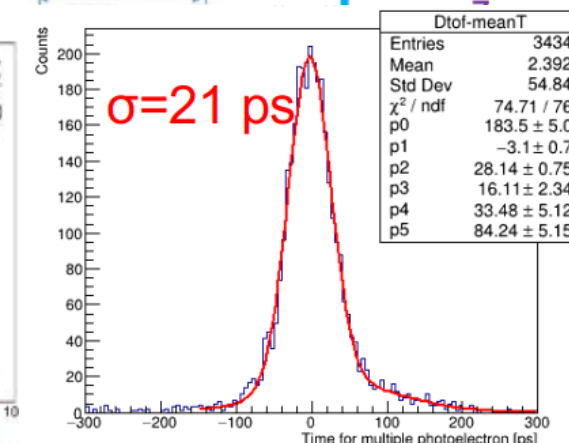
Material Budget $< 0.3X_0$

π/K separation 4σ @ 2GeV/c

Alternative option, BTOF: the same technology as the endcap PID



2D likelihood result $\sim 4.0\sigma$ @ 98.4% ϵ



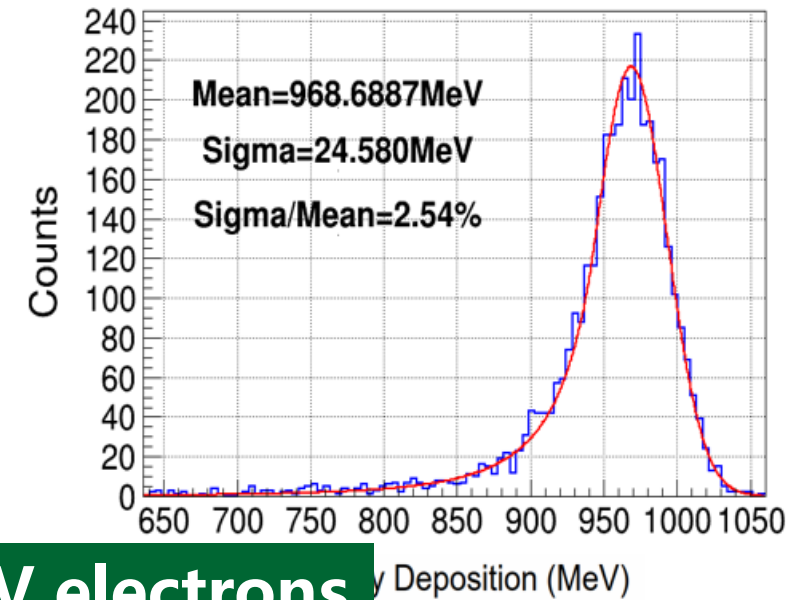
Single track time resolution

Electromagnetic Calorimeter

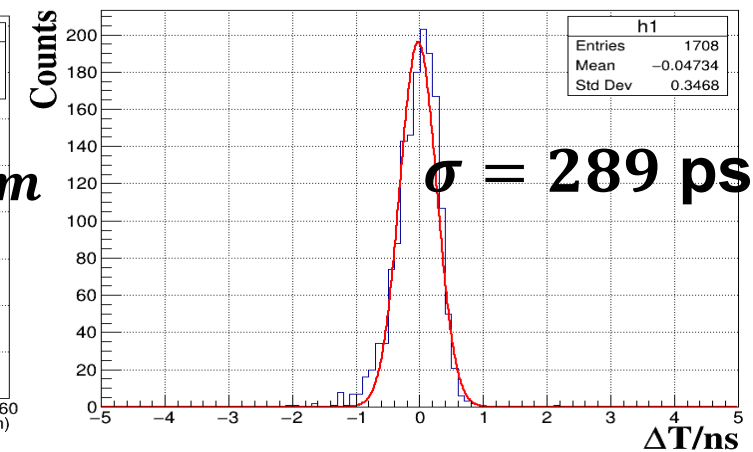
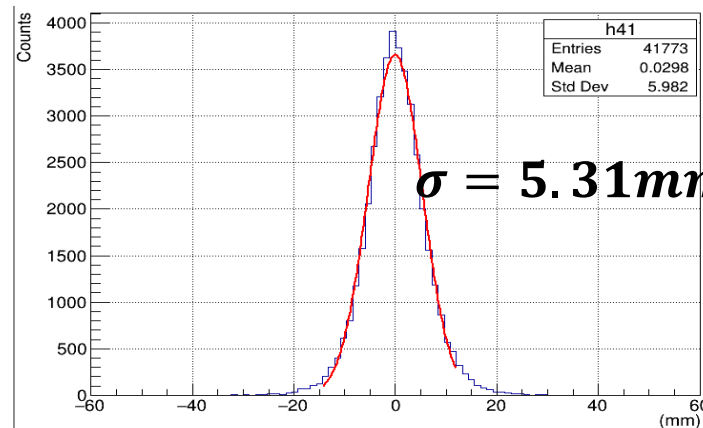
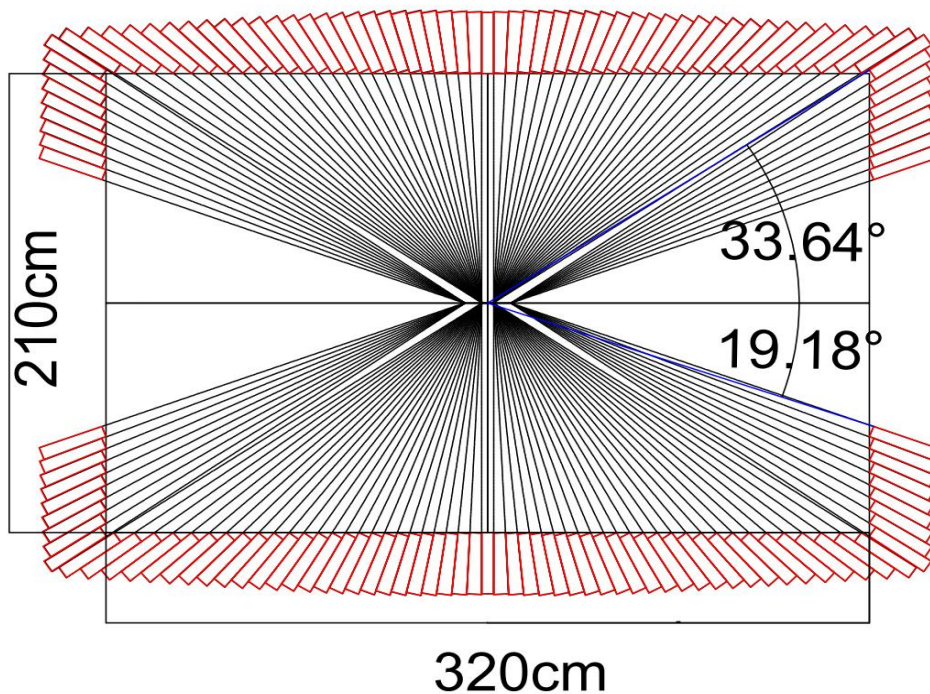


EMC: A **pure-CsI** crystal calorimeter to tackle a high level of background ($\sim 1\text{MHz/ch}$)

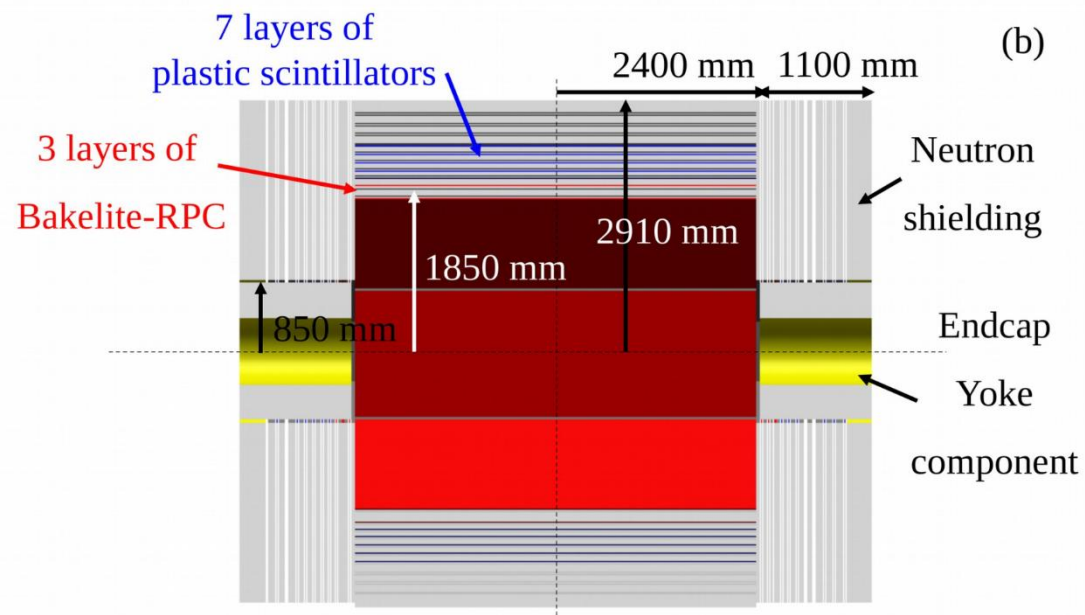
- Crystal size : 28cm ($15X_0$) $5\times 5\text{ cm}^2$
- ~ 8670 crystals
- 4 large area APDs, ($1\times 1\text{ cm}^2$) to enhance light yield



1 GeV electrons

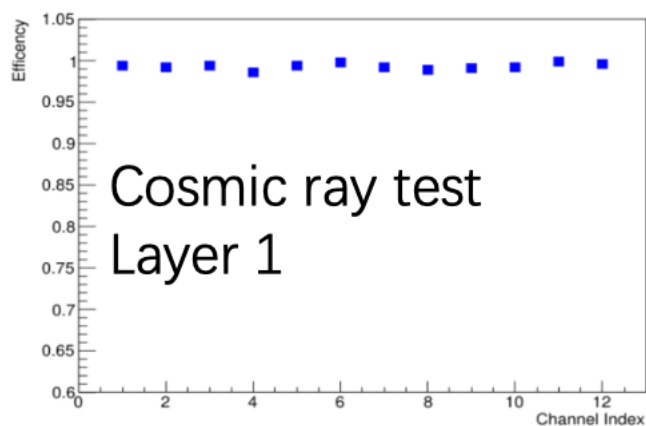


MUD: A **RPC-scintillator hybrid** detector to optimize muon and neutral hadron ID

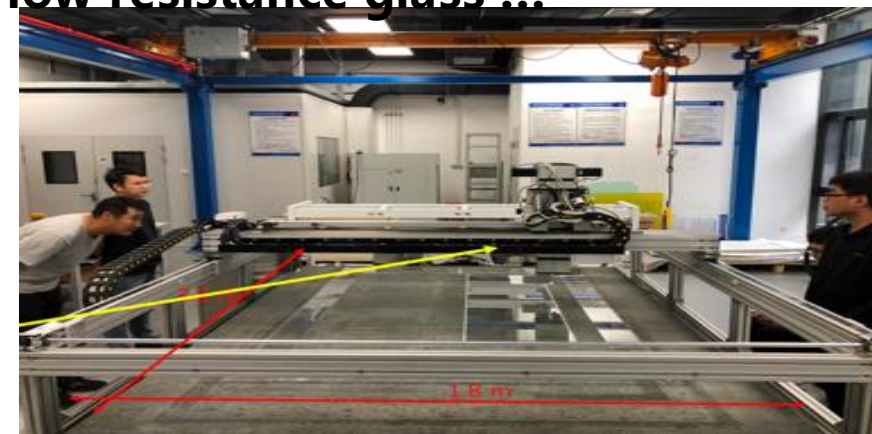


Parameter	Baseline design
R_{in} [cm]	185
R_{out} [cm]	291
R_e [cm]	85
L_{Barrel} [cm]	480
T_{Endcap} [cm]	107
Segmentation in ϕ	8
Number of detector layers	10
Iron yoke thickness [cm] ($\lambda=16.77$ cm)	4/4/4.5/4.5/6/6/6/6/8/8 cm Total: 51 cm, 3.04λ
Solid angle	$79.2\% \times 4\pi$ in barrel $14.8\% \times 4\pi$ in endcap $94\% \times 4\pi$ in total
Total area [m ²]	Barrel ~717 Endcap ~520 Total ~1237

Scintillator prototype



RPC prototype: different air gaps, low resistance glass ...



Conceptual Design Report



FRONTIERS OF PHYSICS



REPORT

Volume 19 / Issue 1 / 14701 / 2024

STCF conceptual design report (Volume 1): Physics & detector

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REPORT

FRONTIERS OF PHYSICS



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1 Introduction

Starting with the discovery of the charmed quark and the τ lepton during the 1974 and 1975 [1], the results from low-energy e^+e^- collider experiments with a center-of-mass energy (CME) in the 2–6 GeV (near-threshold) region have played a key role in elucidating the properties of these intriguing particles. Historically, there have been several generations of τ -charm facilities (TCFs) in the world, including the Mark II and Mark III detectors [2, 3], DM2 [4], CLEO-c [5], and BEPC/BES [6], which have produced numerous critical contributions to the establishment of the SM and to searches for new physics beyond the Standard Model (SM). Of these, the BEPC/BS facility in Beijing, China, is no doubt one of the most prolific TCFs. This program, which started in the late 1980s, has produced many interesting physics results, such as precision measurements of the τ -lepton mass [7, 8] and the e^+e^- annihilation cross section [9], the first observations of purely leptonic charmed meson decays [10], the discovery of the $X(1835)$ as a baryonium state candidate [11–14], and clear elucidation of the $e^+(500)$ [15] and κ ($K_0^*(700)$) [16], the lowest-lying scalar mesons.

The currently operating BEPCII/BESIII [17, 18] complex, which is a major upgrade of BEPC/BESII [6] that includes separate electron and positron magnet

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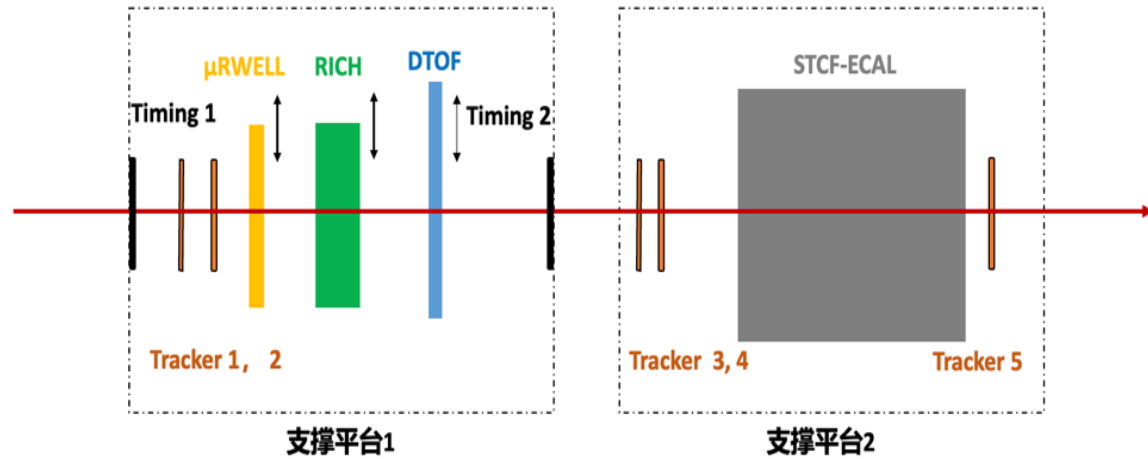
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82 institutions, 453 authors

arXiv:2303.15790

Combined Beam Test

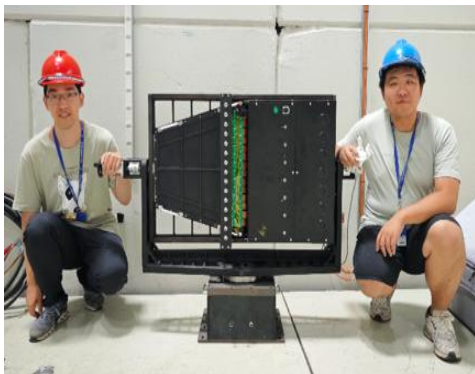
A test beam campaign for a combined system (**DTOF, EMC, DAQ**)



CERN PS T9 beam line (July 31 – August 14, 2024)



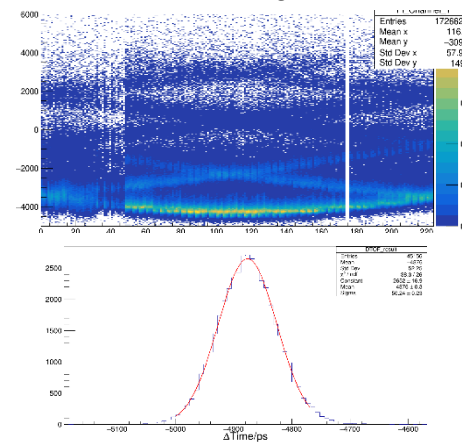
DTOF prototype



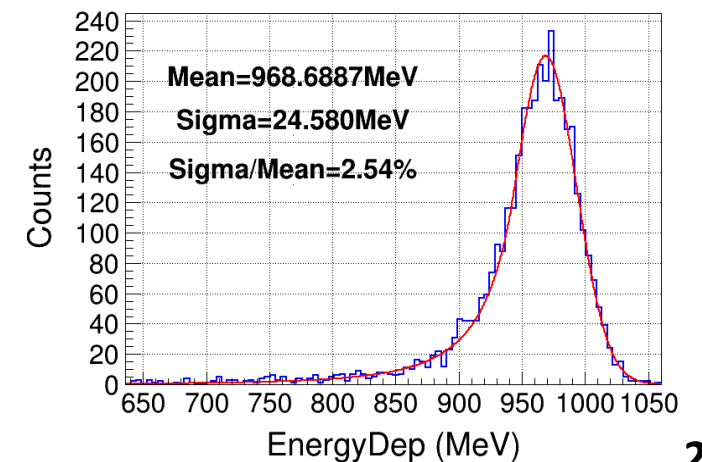
EMC prototype



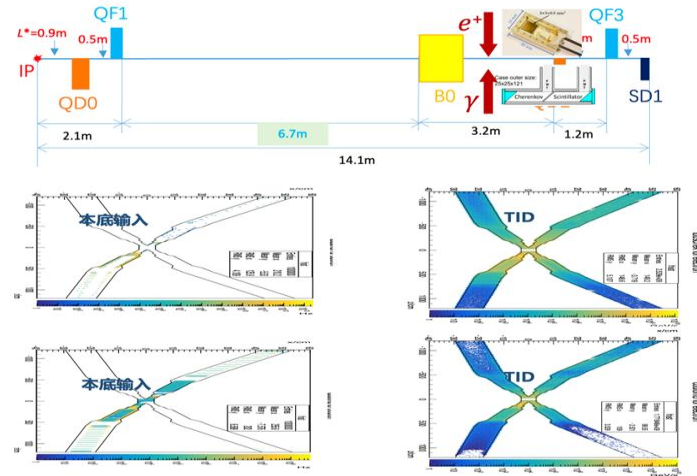
DTOF: $\sigma_t \sim 25$ ps



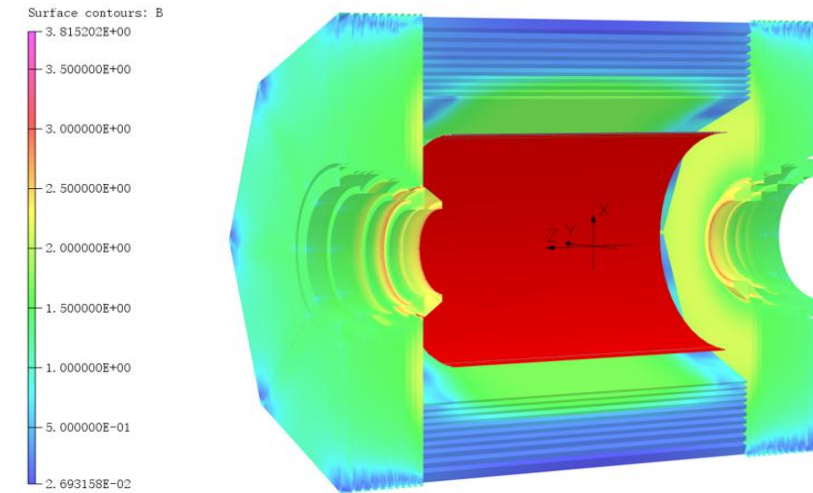
EMC: $\sigma_E/E \sim 2.5\%$



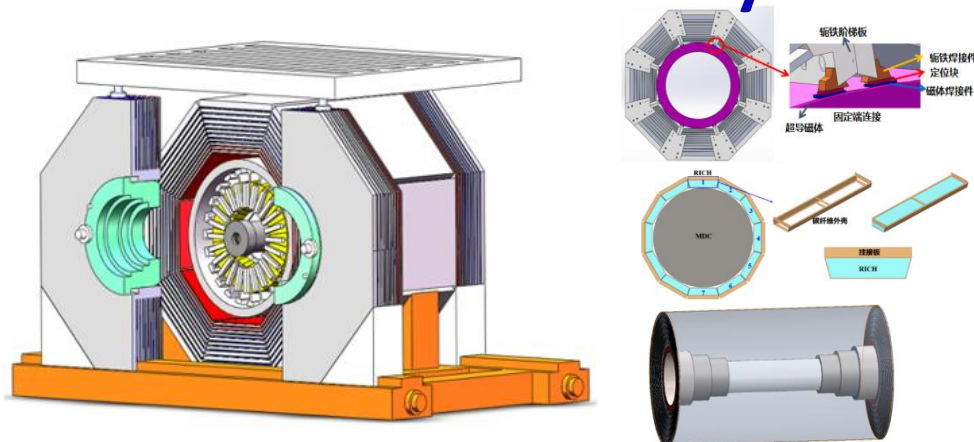
Forward System



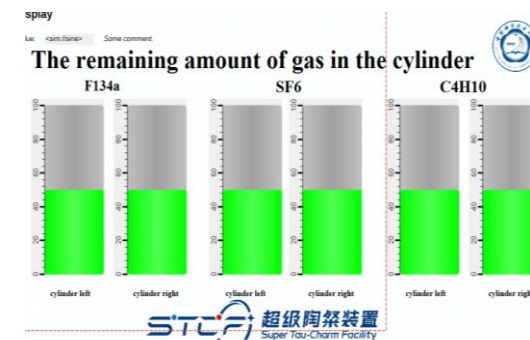
Superconducting magnet



Detector mechanical system



Detector control system



Slow Control

Software()		Database()	Hardware()
Core() EPICS IOC ROOT	GUI() JSGUI Pheobus	PostgreSQL/ TimescaleDB	Firmware() Device driver
JSGUI() JSROOT PyROOT		Device driver() PLC Wiener series MFC series	
		CAEN series thermo meter	

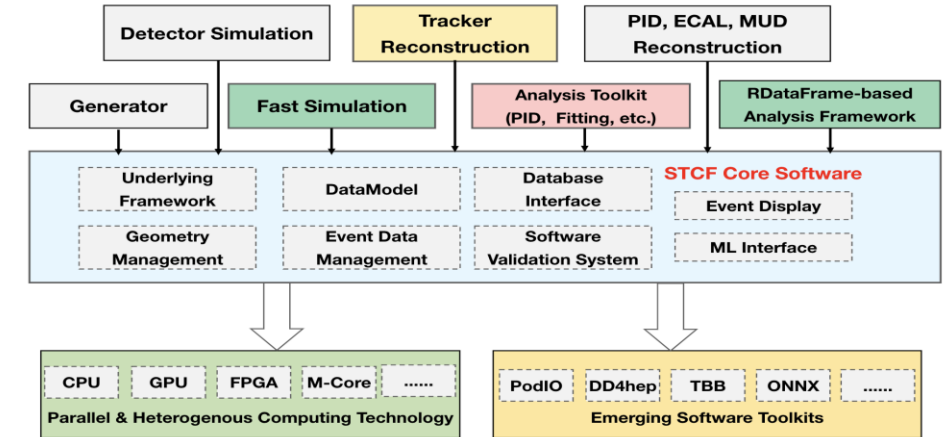
Software Progress and Achievements



◆ Offline software system **OSCAR** (Offline Software of Super Tau Charm Facility) : performance and scheme optimization of detectors, and physics feasibility study

International advanced technology:

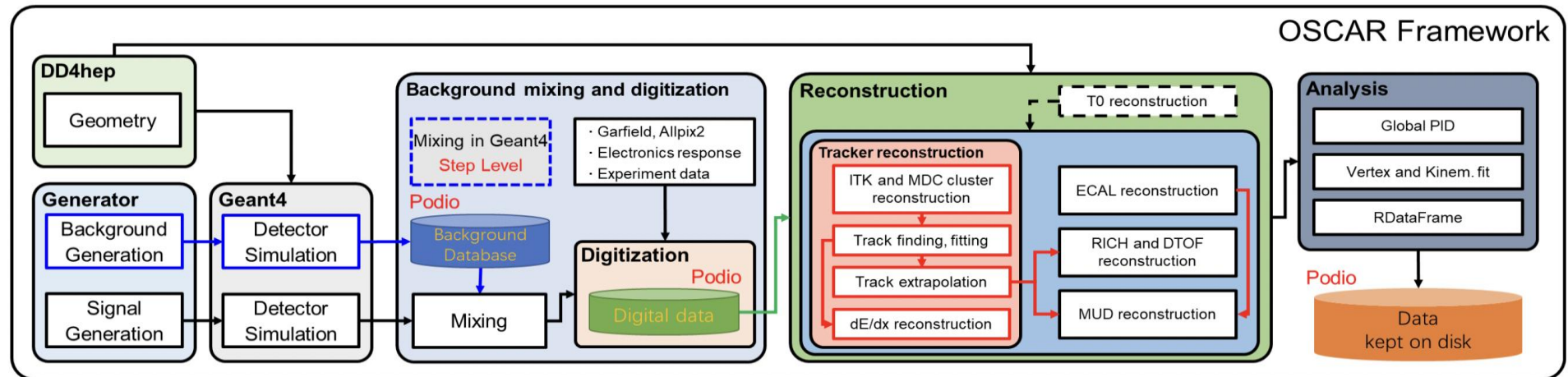
- **PODIO**: Efficient and Rapid Event Model Definition Tool
- **DD4hep**: Efficient and flexible geometric definition Tool for detectors
- **TBB**: Intel Multi Threading Building Module
- **OneAPI**: Intel's Cross Architecture Programming Model
- **ONNX**: Open source for deep learning model
- **SNiPER**: China's independently developed new software framework
- **ACTS**: track reconstruction software tool at ATLAS



◆ Developed OSCAR important component, built a complete offline data processing and analysis process; released more than 20 versions

Core components:

- Core software
- Event generation
- Detector simulation
- Background mixing
- Event reconstruction
- Physics analysis
- Event display
- Performance test

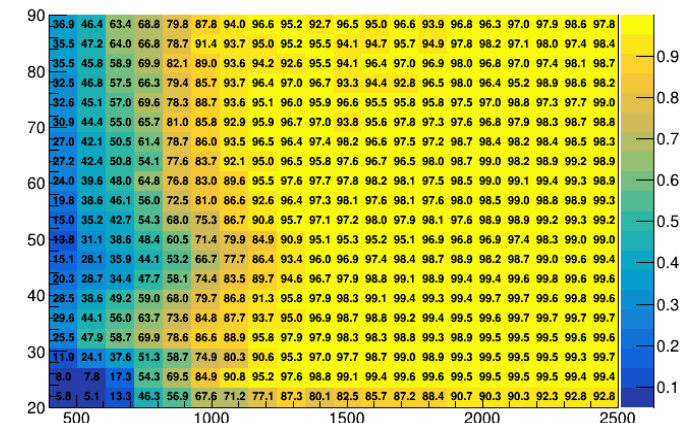
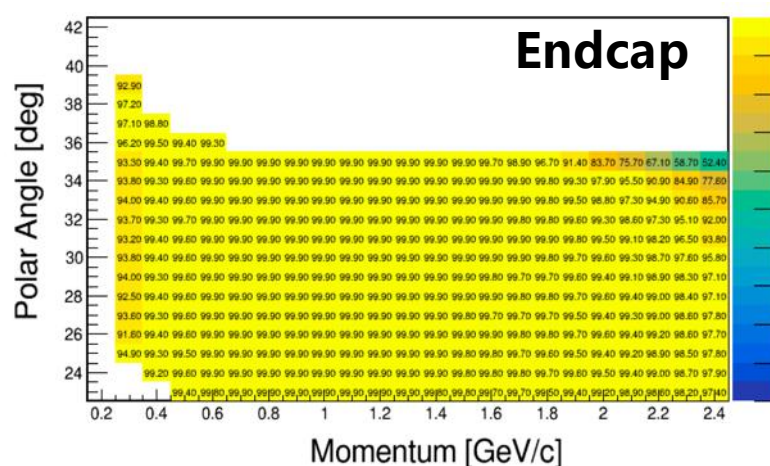
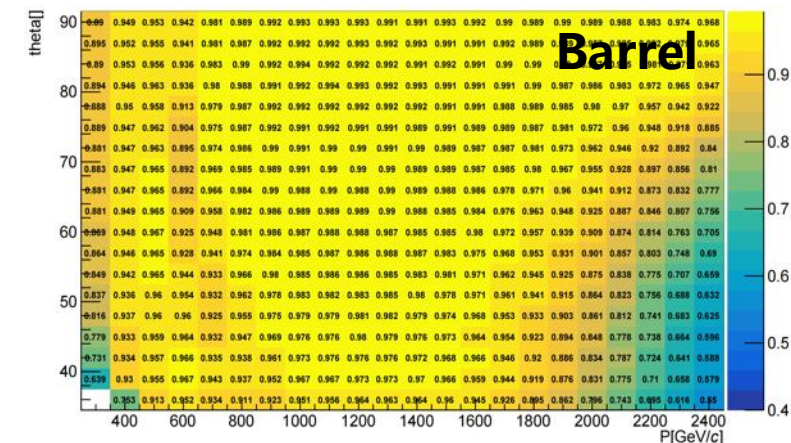


Performances with Full Simulation

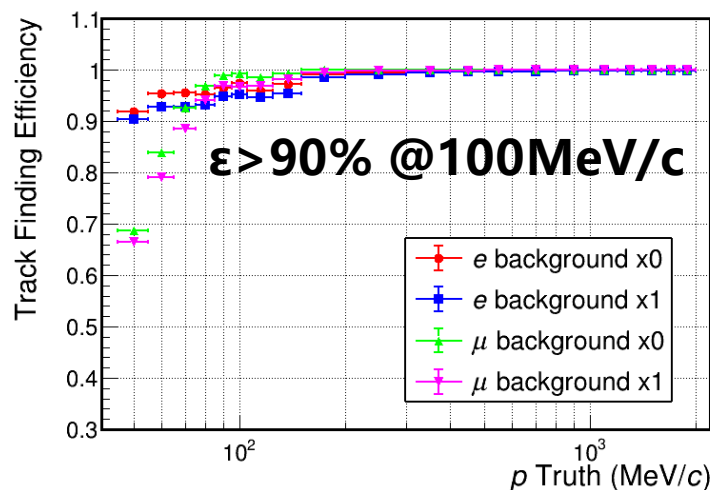


PID: Pion ID eff. >97% @ mis-ID (K- $\rightarrow$ pi)=2%

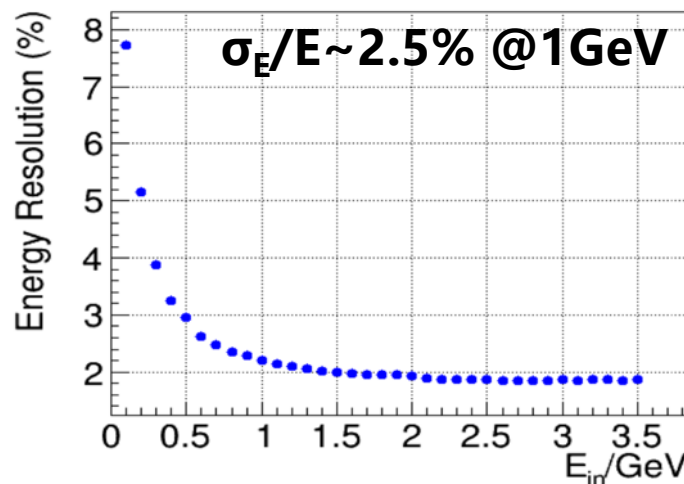
Muon ID eff. @ pi suppression=30



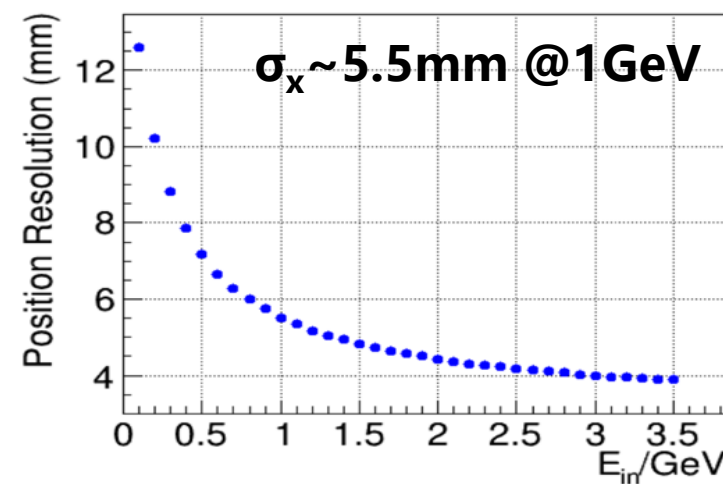
Tracking efficiency



EMC energy resolution



eff. $\sim$ > 90% when $p \sim$ > 1 GeV/c
EMC position resolution



Physics Tasks with Full Simulation



Symmetry

Topics	Processes	Students
Baryon CPV and EDM	$J/\psi \rightarrow \Lambda \bar{\Lambda}, \Xi^+ \bar{\Xi}^-$	Mingyu Yu (SDU), Jianyu Zhang (UCAS), Xiao Chu (FDU), Yue Xu (FDU)
τ physics (QE, CPV and LFV)	$\tau \rightarrow \pi(\pi\pi^0)\nu, \tau \rightarrow 3\mu, \tau \rightarrow K_S\pi\nu$, Radiative decays	Mingyi Liu/Chentao Bao (USTC), Hailin Li (ZZU), Ruixiang Li (USTC)
Charm mixing and CPV	C -even correlated $D\bar{D}$	Yinghao Wang (LZU), Qiang Lan (USC)
CPV in Λ_c^+ decays	$\Lambda_c^+ \rightarrow \Lambda K^+, \Sigma^0 K^+, \Sigma^+ K_S$	Hongjian Wang (LZU)
CP and CPT in $K_S \rightarrow \pi^+\pi^-$	$J/\psi \rightarrow K_S K\pi$	Huibin Zhang (UCAS)

Confinement

Topics	Processes	Students
Di-Charmonium	$e^+e^- \rightarrow J/\psi\eta_c, J/\psi J/\psi$	Zhuojuan Dong (SYSU), Xiaoshen Kang (LNU)
Exotic States	$Z_c(3900), J/\psi p\bar{p}$	Hang Zhou (USTC), $\pi\pi$ Zikang Chen (SYSU)
Hyperon Decays	$\Sigma^+ \rightarrow \gamma p, \Lambda \rightarrow p e \nu, \Xi^- \rightarrow \Lambda e \nu$	Junxian Zhou (FDU), Xu Han (USTC), Yong Song (USTC),
Form Factorrs and Fragmentation Functions	$e^+e^- \rightarrow p\bar{p}, KK, \pi\pi, K\pi$	Yuncong Zhai (SDU), Wenhui Tian (SYSU), Dejie Wei (JNU)

SM parameters

Topics	Processes	Students
R-value related	Two photon physics	Jie Wang/Chunhui Chen (CUG)
τ mass	$e^+e^- \rightarrow \tau\tau$	Hailin Song (USTC)
CKM elements	$D \rightarrow \pi\mu\nu, D_s \rightarrow \mu\nu, \tau\nu$ $D \rightarrow$ inclusive	Qingyuan Huang (UCAS), Jiahui Qiao (USC), Hongrui Liu (CCNU)
Strong Phase	$D_0 \rightarrow K\pi\pi^0$	Chen Wang (LZU)
Strong Coupling α_s	$\tau \rightarrow \ell\nu\nu, \pi\pi^0\nu$	Shanshan Li (HNU)

15 institutions
35 graduate students, 23 faculties

Software -- Core Software Meeting	4 个事件
Software -- General Weekly Meeting	251 个事件
Software -- Digitization Meeting	48 个事件
Software -- Tracking Weekly Meeting	71 个事件
Software -- PID Biweekly Meeting	22 个事件
Physics -- Physics/Simulation Meeting	43 个事件
Physics -- Symmetry	43 个事件
Physics -- Confinement	8 个事件
Physics -- SM parameters	7 个事件

Regular meetings

CONTENTS



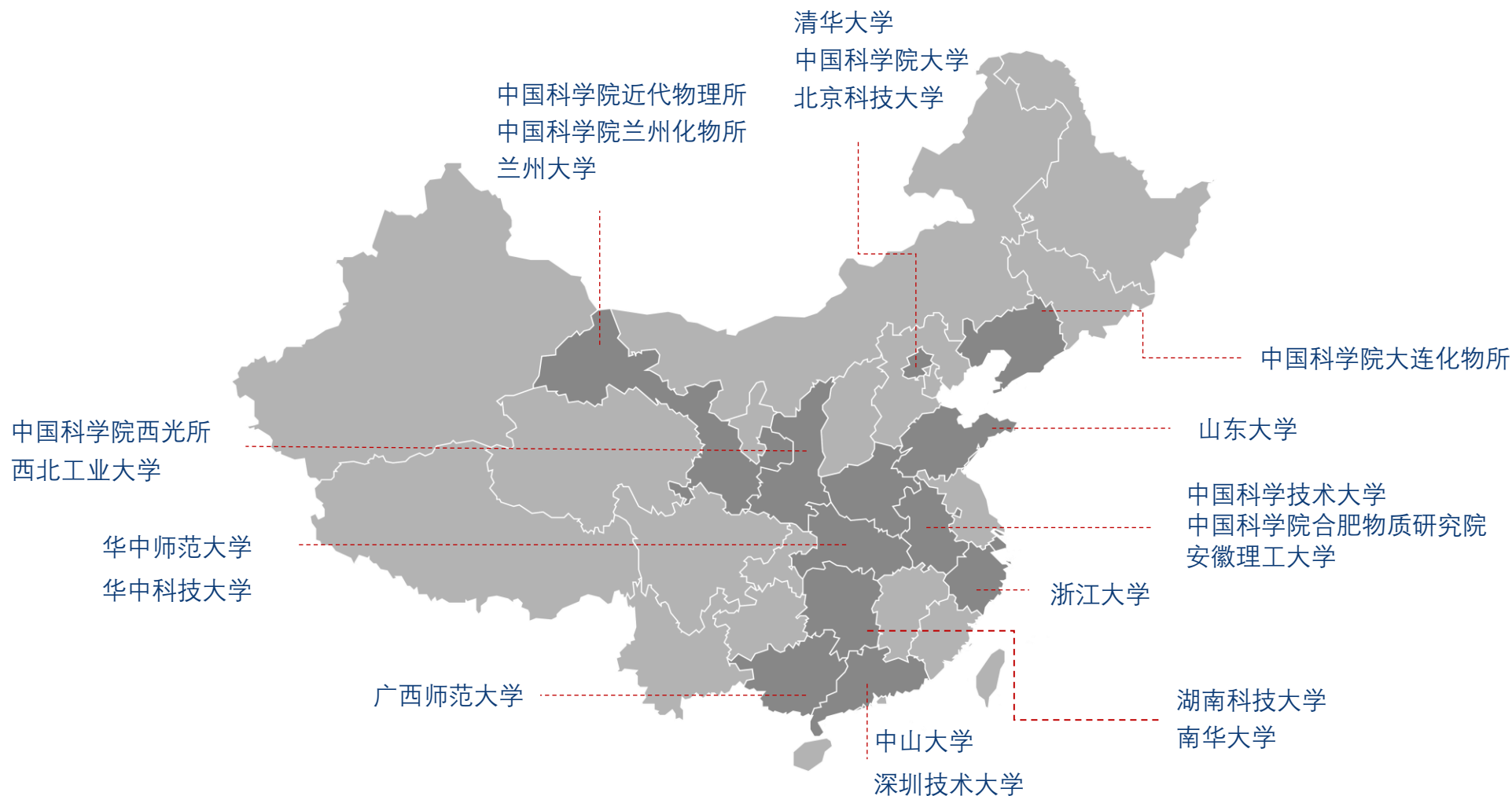
- ◆ Introduction
- ◆ Physics Potential in STCF
- ◆ Accelerator and Detector
- ◆ **Project Promotion and Progress**
- ◆ Summary



Domestic Institutions in R&D



Key technology R&D : 25 Institutions, more than 170 researchers and 140 graduate students



其他参与物理研究单位:

北京大学
中科院高能所
中科院理论所
上海交通大学
北京师范大学
武汉大学
中国地质大学
辽宁大学
南京师范大学
南京大学
河北师范大学
南开大学
华南师范大学

Meetings and Conferences



Time	Place	Content
2018.10	Hengyang (USC)	STCF
2019.03	Beijing (UCAS)	STCF: Physics
2019.07	Hefei (USTC)	STCF: Accelerator
2019.08	Hefei (USTC)	STCF: Phys. & simulations
2019.11	Beijing (UCAS)	STCF: CDR
2020.08	Hefei (USTC)	STCF: From CDR to TDR
2022.12	Guangzhou (SYSU)	STCF: R&D kick-off
2023.07	Zhengzhou (ZZU)	STCF: Collaboration
2024.07	Lanzhou (LZU)	STCF: R&D progress
2025.07	Xiantan (HUST)	STCF: R&D progress



- 200+ attendees from 20+ countries
- 125 talks: 20 plenary, 105 parallel
- Several other experiments

Intensively, fruitfully and impressively

Time	Place	Content
2015.01	Hefei, China	Workshop on Super tau-Charm Facility in China
2018.03	Beijing, China	Workshop on Super tau-Charm Facility in China
2018.05	Novosibirsk, Russia	Workshop on Super tau-Charm Facility in Russia
2018.12	Paris, France	1 st FTCF (Joint International Workshop)
2019.08	Moscow, Russia	2 nd FTCF
2020.11	Online, China	3 rd FTCF
2021.11	Online, Russia	4 th FTCF
2024.01	Hefei, China	5 th FTCF
2024.11	Guangzhou, China	6 th FTCF
2025.11	Huangshan, China	7 th FTCF

Hunan University of Science and Technology



International Cooperation



Collaboration with **CERN**, **BINP/JINR** (Russia), **KEK** (Japan), **IJCLab** (France), and other organizations. Extensive and in-depth technical exchanges and substantive cooperation



Collaboration with LHCb-TORCH group



Collaboration with CERN Thin Film Deposition Laboratory



Collaboration with CERN gas detector



Collaboration with BINP accelerator experts



Communication with the JINR team

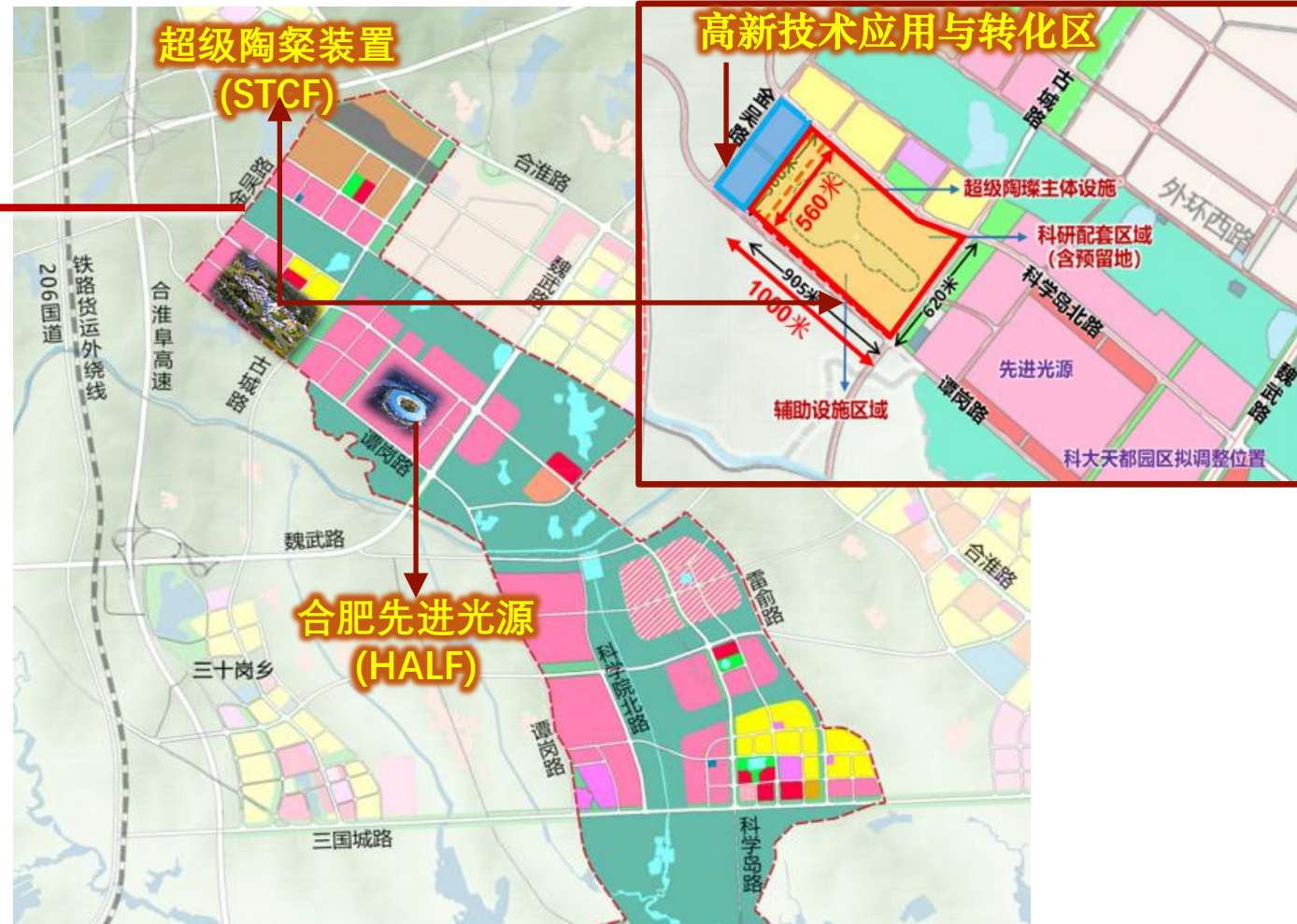
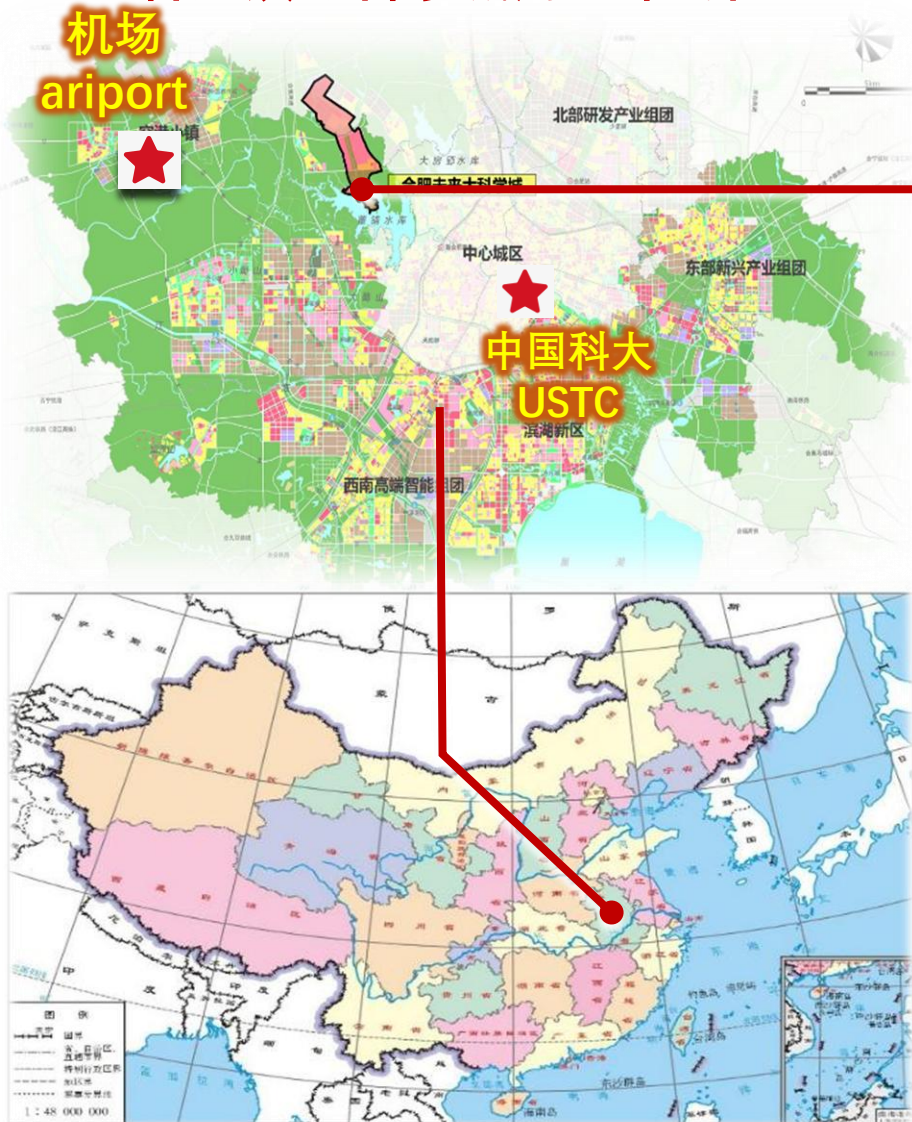


Collaboration with KEK accelerator experts

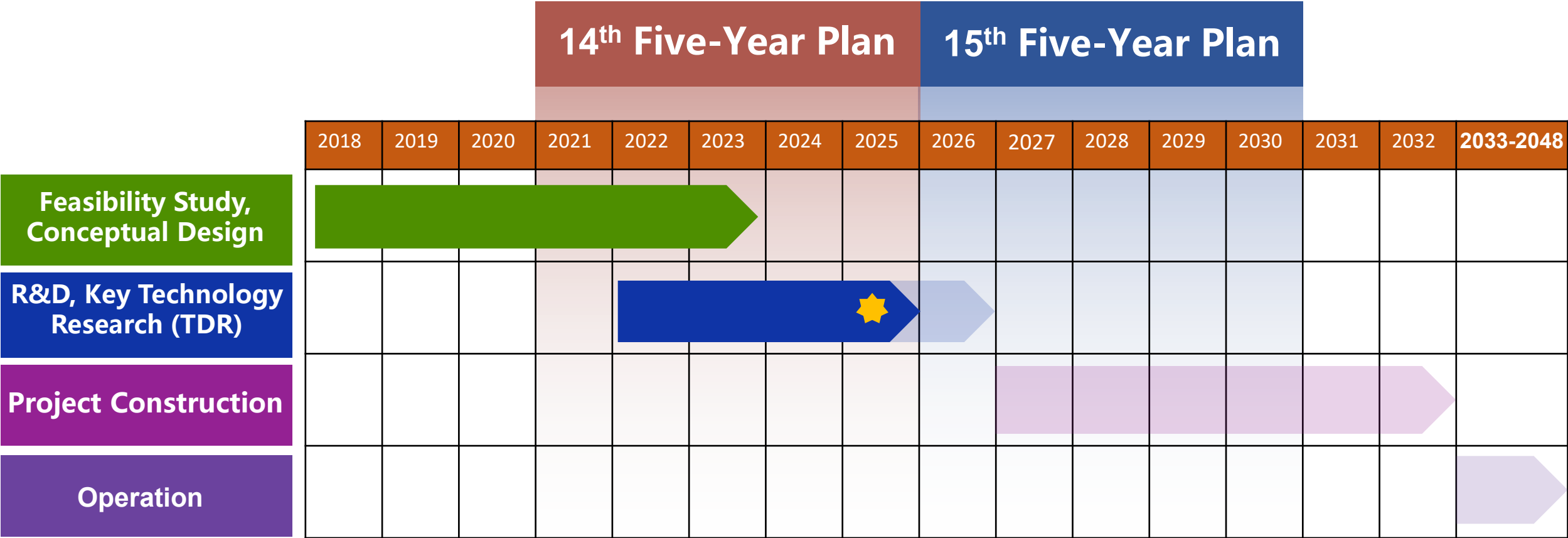
Site : Hefei Future Big Science City



合肥滨湖科学城用地布局图



8 big scientific projects under construction or planned in the “city”.



CONTENTS



- ◆ Introduction
- ◆ Physics Potential in STCF
- ◆ Accelerator and Detector
- ◆ Project Promotion and Progress
- ◆ **Summary**



- ◆ STCF has a rich physics program with breakthrough potential in the studies of how quarks form matter and symmetry of fundamental interactions (CPV), and beyond. It is, therefore, an important project in the precision frontier of HEP and of great interest to the international HEP community.
- ◆ With the strong backing from the local governments, the key technology R&D project is progressing as expected in the past a few years, and significant progress has been made. The project organization has been further strengthened, and the flagship physics objectives have been refined.
- ◆ Aiming for construction approval from central government during the 15th Five-Year Plan (2026-2030).
- ◆ Expanding international collaboration and exploring synergies with other projects are crucial. **All forms of collaboration are welcome.**

Thanks !

谢谢！

Thanks for the invitation !

感谢组委会的邀请！

