

BARYONS 2025

INTERNATIONAL
CONFERENCE ON THE
STRUCTURE OF BARYONS

10-14 NOV 2025
ICC JEJU
KOREA



Status of the **S**uper **T**au **C**harm **F**acility (STCF)

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(On behalf of STCF working group)



Outline

- **Introduction**
- **Physics Opportunities**
- **Accelerator and Detector**
- **Summary and Outlook**

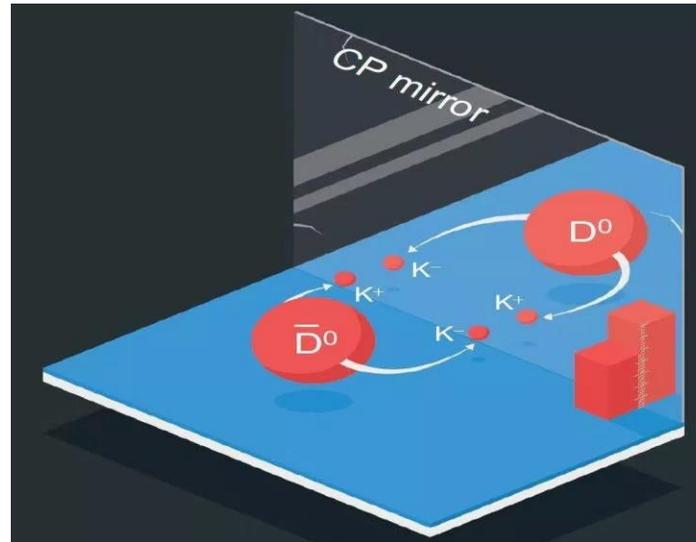
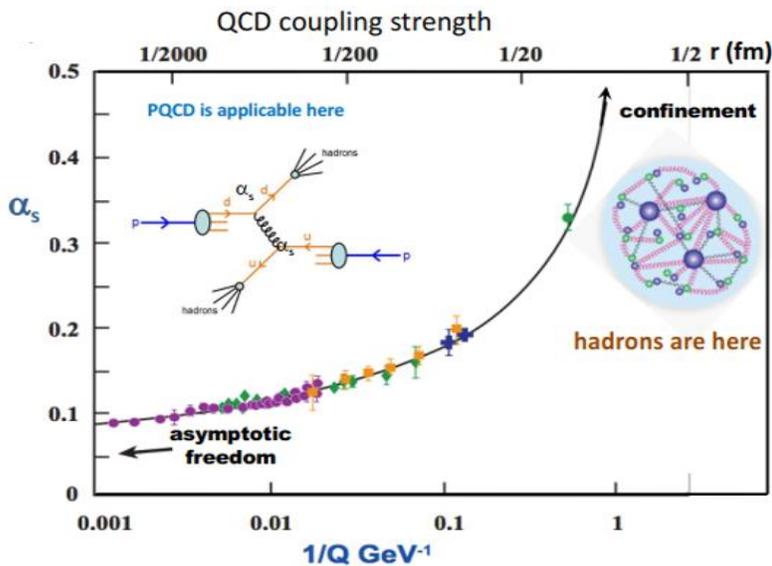
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Challenges of the SM model

The SM is well-tested, however, reminds several fundamental questions :

- **Confinement:** structure of nuclear, formation of colorless bound states — “hadrons”
- Matter-antimatter **asymmetry** of the Universe
- Mass hierarchy, dark matter, numbers of flavors, etc.



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 GeV	Collider
m_b	4.24 GeV	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

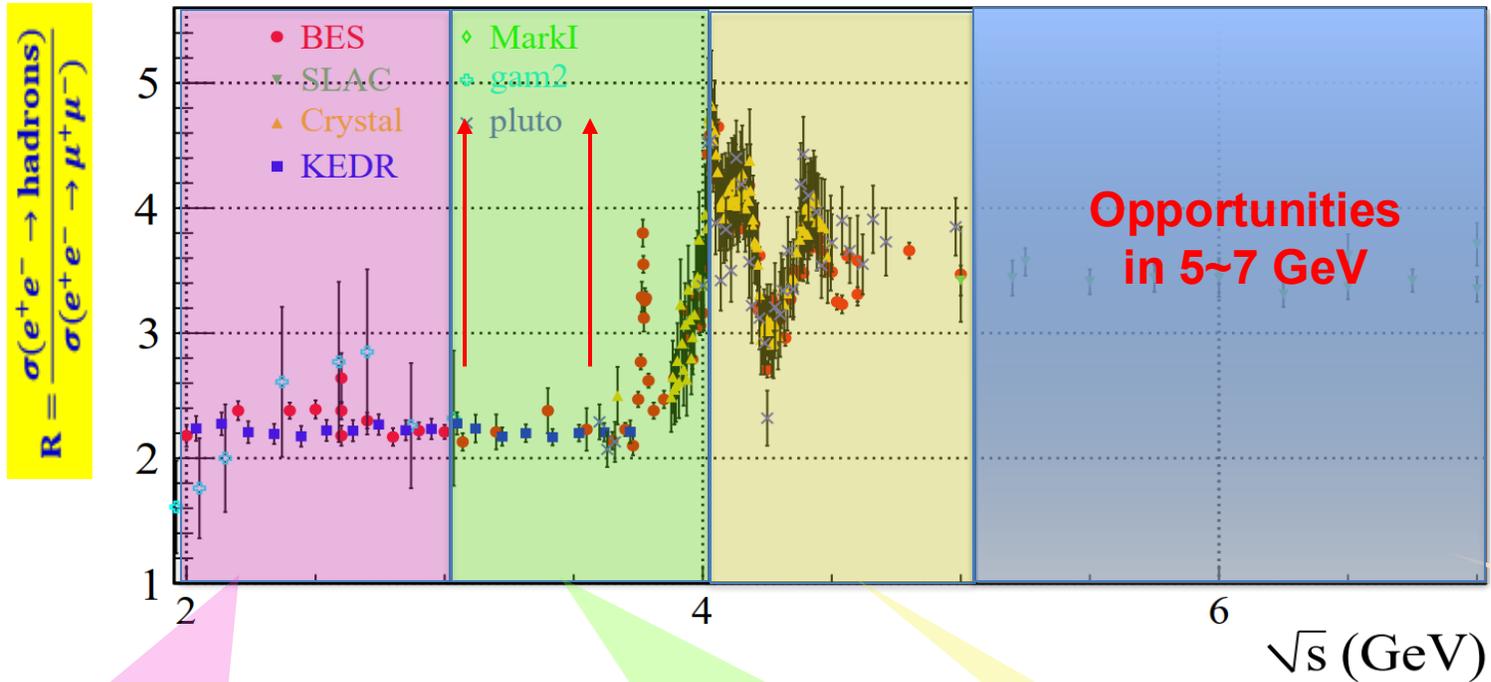
Couplings

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

Unique Physics in Tau-Charm Energy Region



Unique Features τ -c facilities:

- **Transition** region between perturbative and non-perturbative QCD
- **Threshold effects** of pair production of hadrons and τ leptons
- **Rich resonance** structures, **large production X-sec** for charmonium(-like) states and exotics

- Hadron form factors
- $Y(2170)$ resonance
- Multiquark states with s quark
- R value / g-2 related

- Light hadron spectroscopy
- Gluonic and exotic states
- **Processes of LFV and CPV**
- Rare and forbidden decays
- Physics with τ lepton

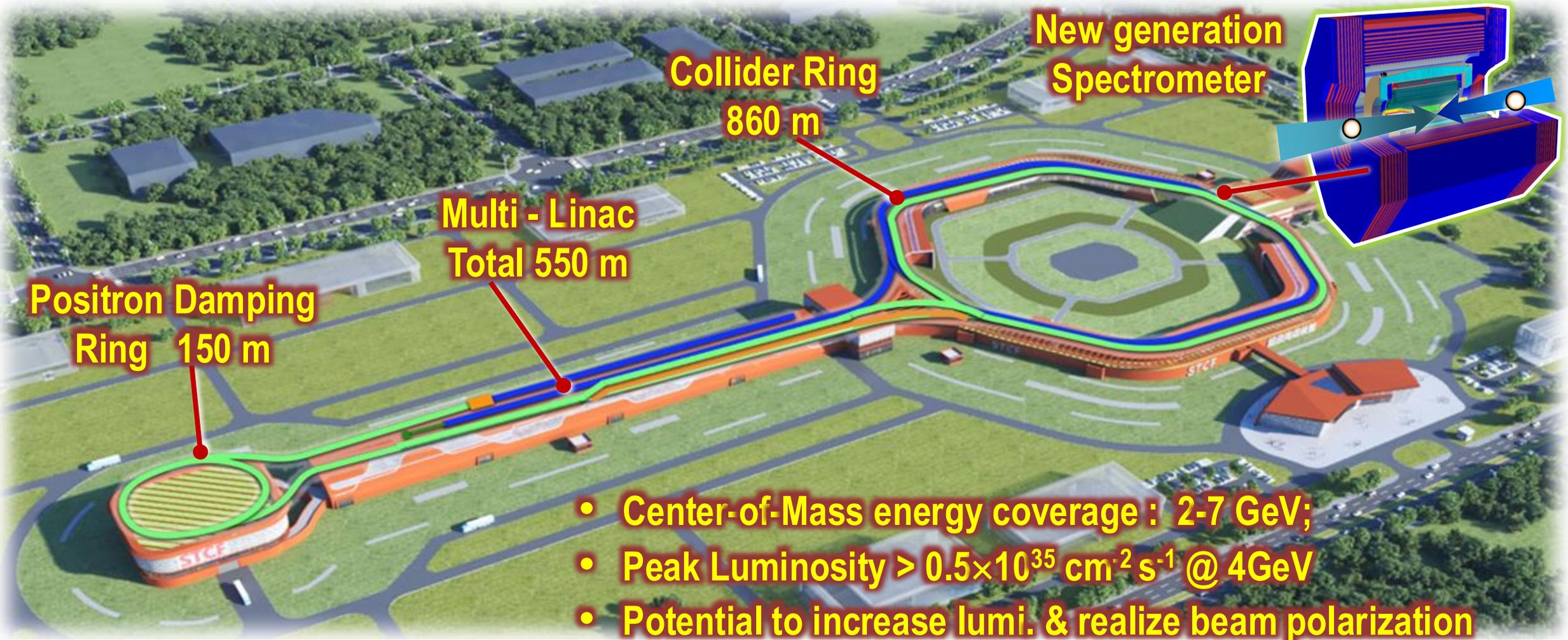
- XYZ particles
- **Physics with D mesons**
- f_D and f_{D_s}
- $D^0 - \bar{D}^0$ mixing
- Charm baryons

- Complete XYZ family
- Hidden-charm pentaquarks
- Search for di-charmonium states
- More charmed baryons
- Hadron fragmentation

Abundant physics topics and fruitful achievements.....

The Super Tau-Charm Facility (STCF)

A factory produced massive **tau lepton** and **hadrons**, to unravel the mystery of **how quarks form matter** and the **symmetries** of fundamental interactions

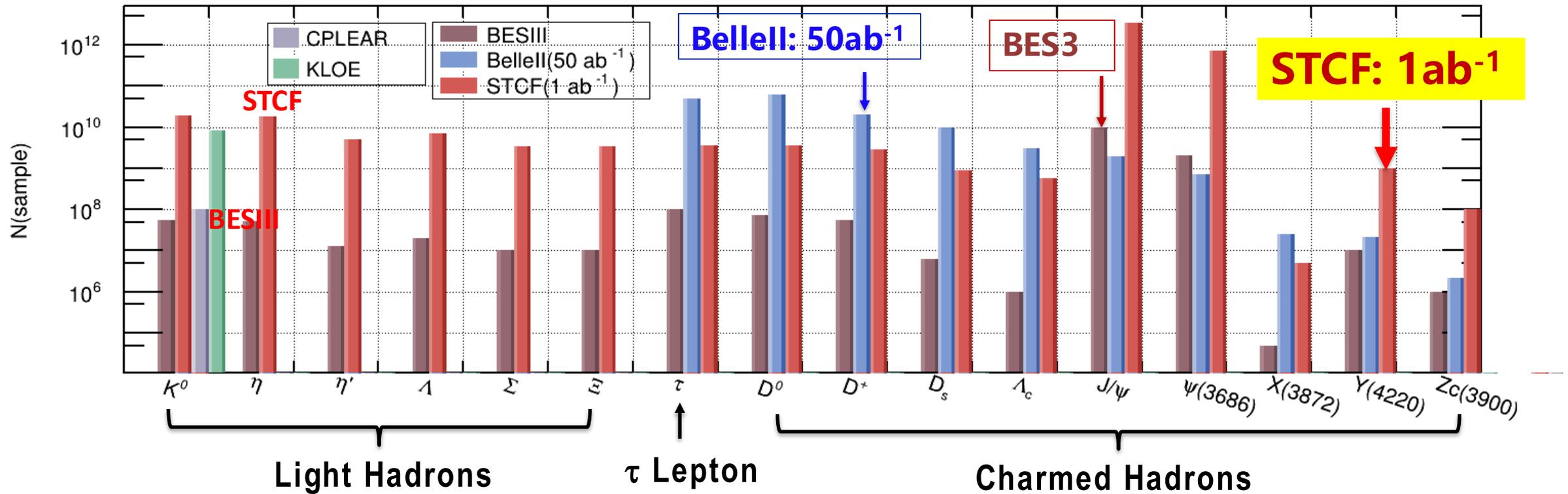


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Unique data sample

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



Super Large Data + High detector performance + Low Bkg \rightarrow High Precision

Great Discovery Potential

Physics I : Asymmetry Test

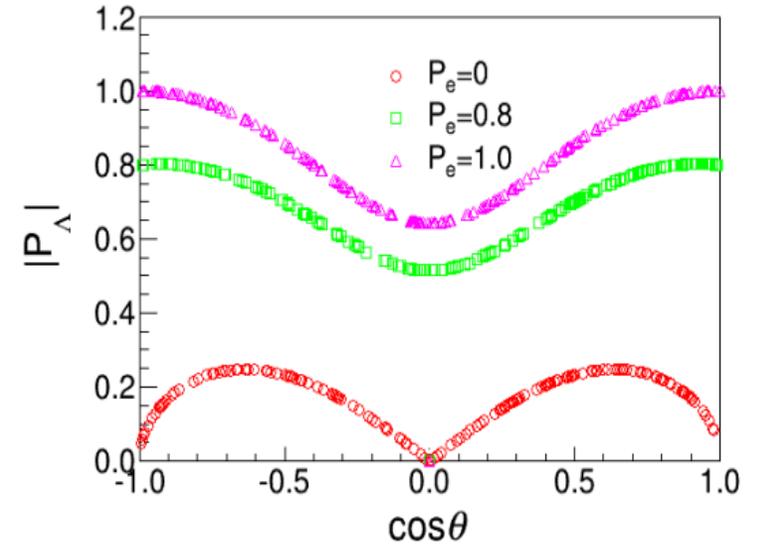
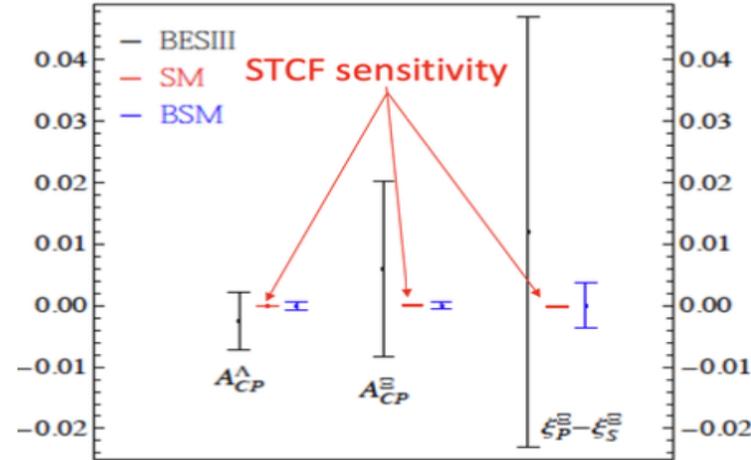
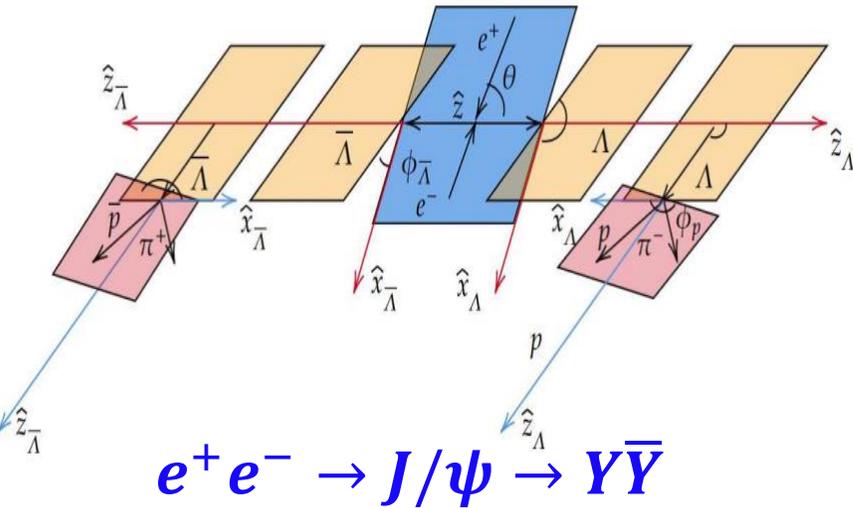


- The **CP violation** observed in current experiments is far from sufficient to explain the mystery of antimatter disappearance.
- Only the CP violation of **hyperons** and **charmed baryons** has not been discovered, which is one of the last unexplored frontiers in hadron physics

CP Violation in Hyperons

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

Quantum Correlation



- Polarization feature of hyperon increases the CP test sensitivity significantly
- Large branching fractions and high statistics J/ψ sample results abundant hyperon pairs
- Sensitivity of CPV observable with 1 year data: 10^{-5}
- Polarization of beam will further increases the sensitivity

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

Will discover CPV of Λ hyperons, comprehensively CPV test for the hyperons family

CP Symmetry in STCF

Conducting CP symmetry test on tau lepton, charm hadrons, kaon, EDM

arXiv:2502.08907,

submit to Physics Report

CP violation studies at Super tau-charm facility

Hai-Yang Cheng^a, Zhi-Hui Guo^b, Xiao-Gang He^c, Yingrui Hou^d, Xian-Wei Kang^e, Andrzej Kupsc^{f,g}, Ying-Ying Li^h, Liang Liu^h, Xiao-Rui Lyu^d, Jian-Ping Maⁱ, Stephen Lars Olsen^{j,k}, Haiping Peng^h, Qin Qin^q, Pablo Roig^{m,n}, Zhi-Zhong Xing^o, Fu-Sheng Yu^p, Yu Zhang^q, Jianyu Zhang^d, Xiaorong Zhou^h

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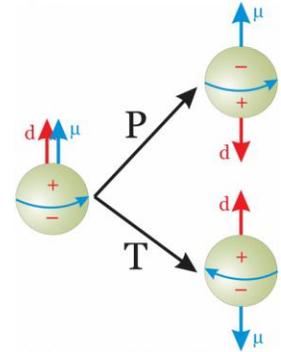
Abstract

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.

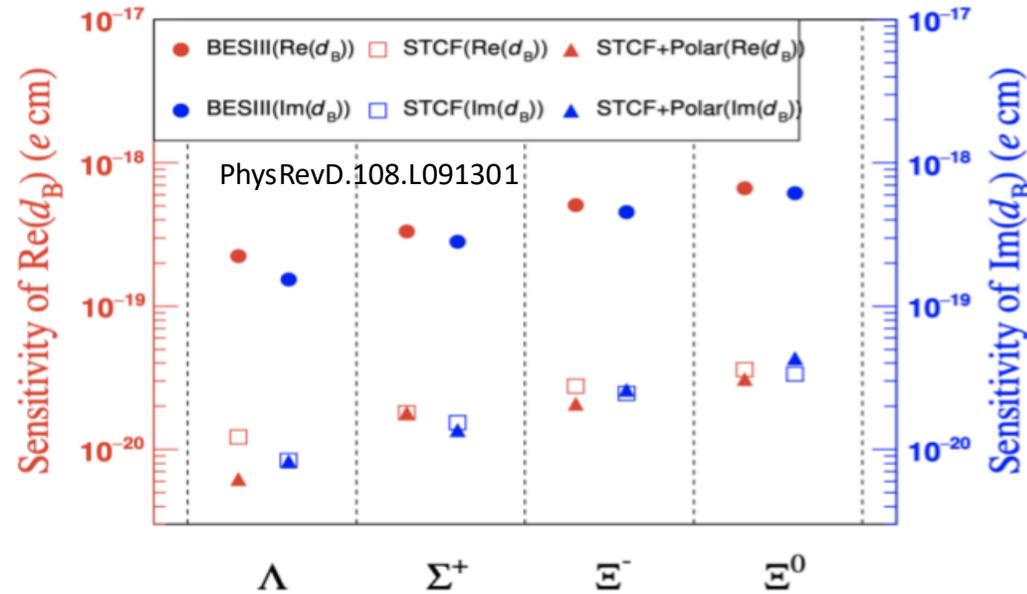
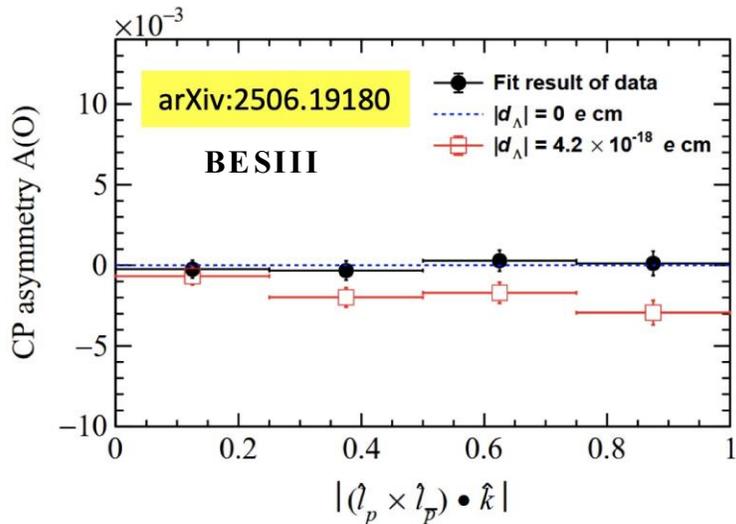
EDM in Hyperon

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

Very sensitive to BSM physics, large windows of opportunity for observing New Physics.



μ : magnetic dipole moment
 d : electric dipole moment



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

$$Re(d_\Lambda) = (-3.1 \pm 3.2 \pm 0.5) \times 10^{-19} e \text{ cm},$$

$$Im(d_\Lambda) = (2.9 \pm 2.6 \pm 0.6) \times 10^{-19} e \text{ cm}.$$

$$|d_\Lambda| < 6.5 \times 10^{-19} e \text{ cm}.$$

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

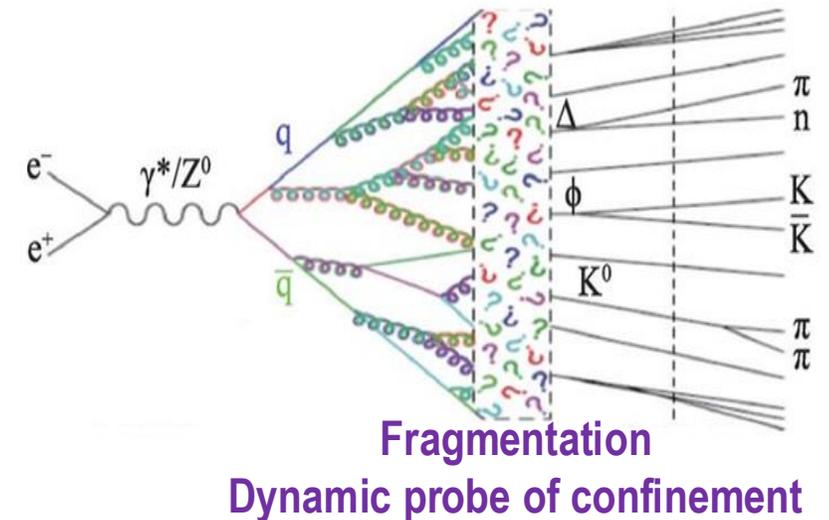
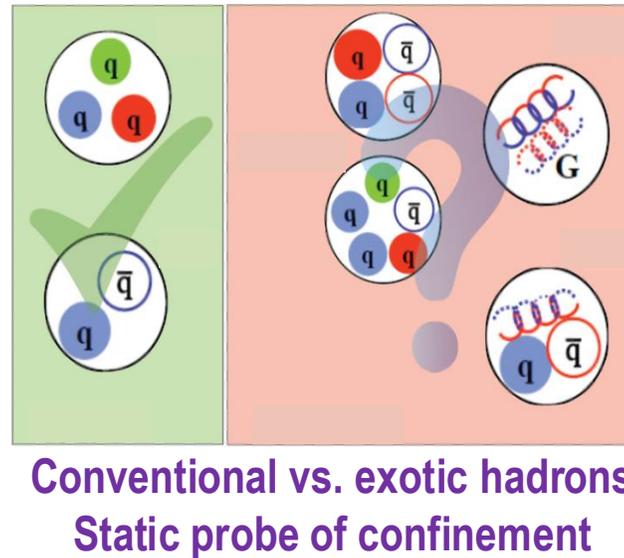
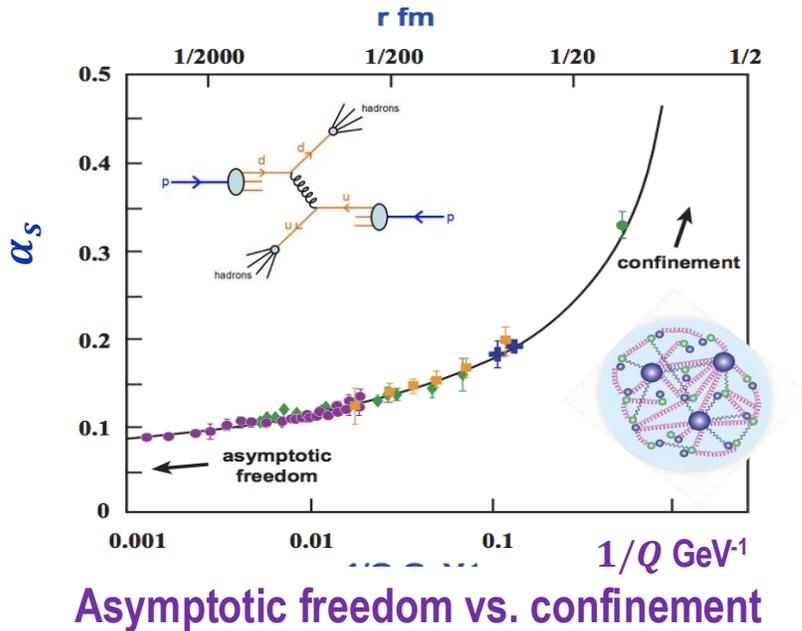
BESIII: milestone for hyperon EDM measurement
 Λ $10^{-19} e \text{ cm}$ (FermiLab $10^{-16} e \text{ cm}$)
 first achievement for Σ^+ , Ξ^- and Ξ^0 at level of $10^{-19} e \text{ cm}$
 a litmus test for new physics

STCF: improved by 2 order of magnitude

Systematic measurement of the EDMs of the hyperon family!

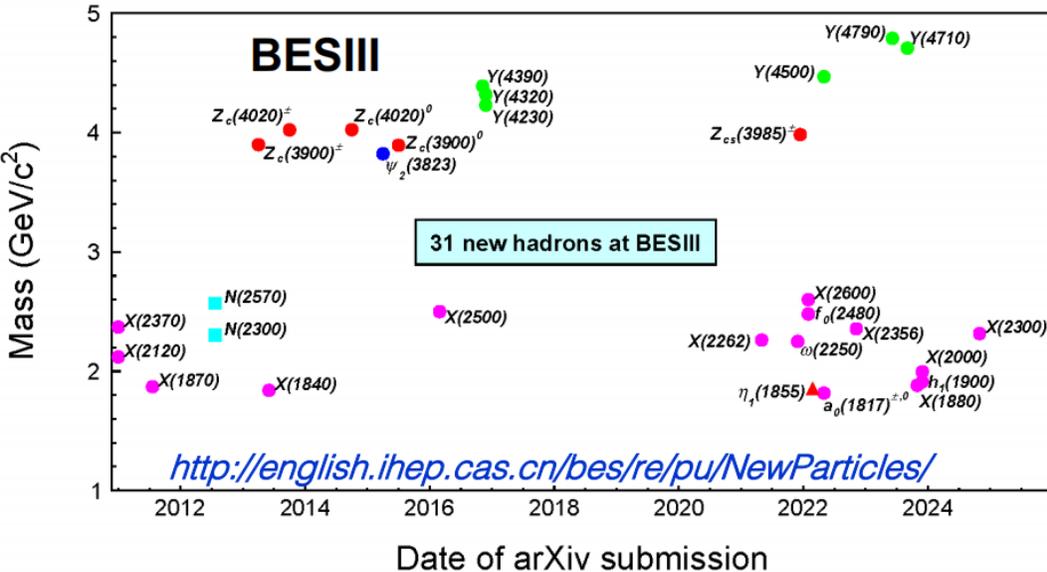
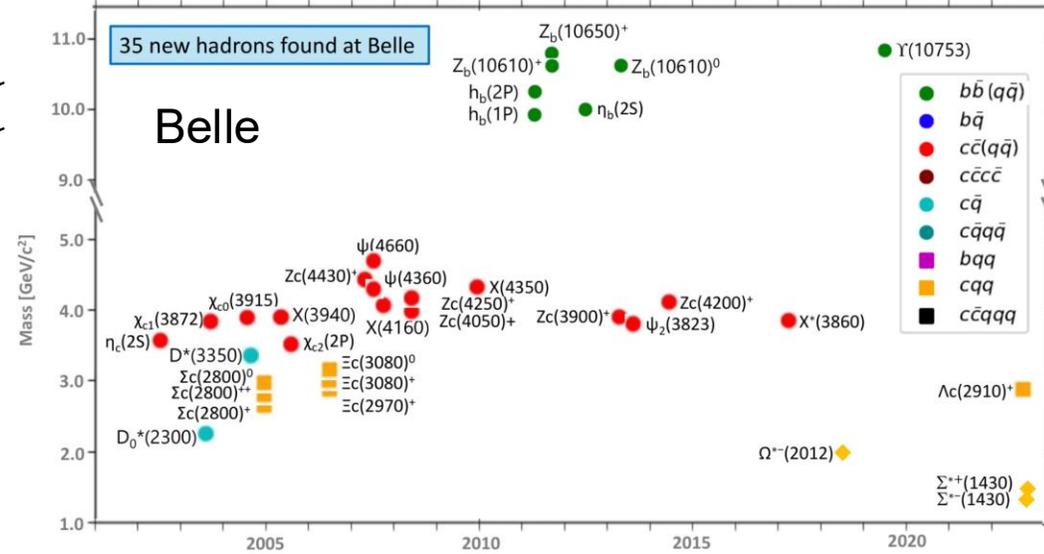
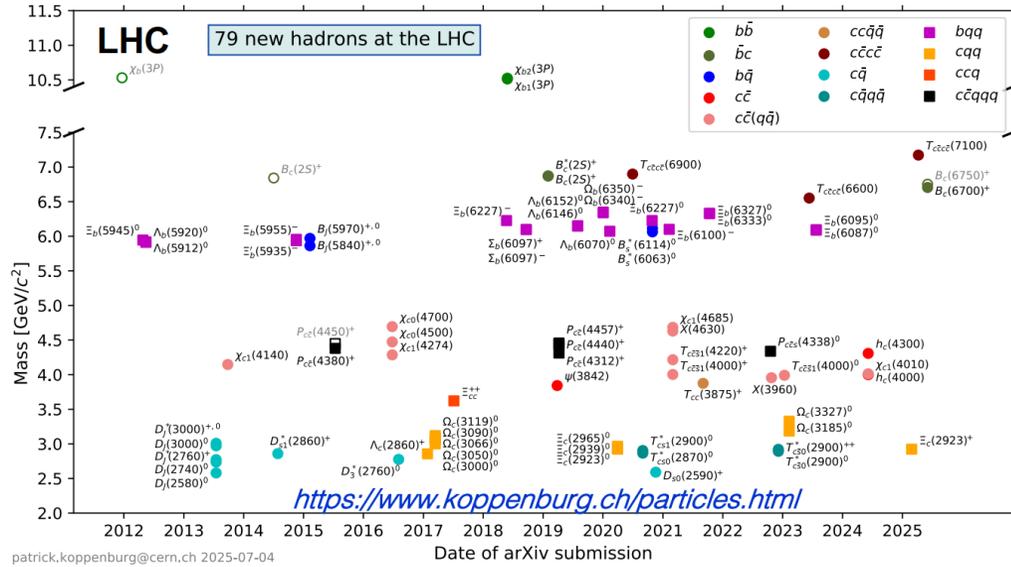
Physics II: Quark Confinement

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



STCF operates in the range at the transition between perturbative and non-perturbative QCD, offers the unique advantages for studying confinement, and will make a breakthrough

Hadron Spectroscopy and exotic state

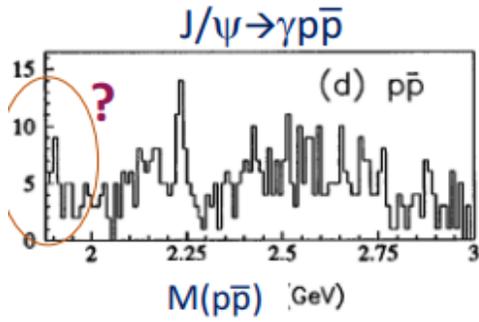


At STCF, two golden ways to study hadron spectra:

- **Light hadrons:** charmonium radiative decays (act as spin filter) for example $3T J/\psi$ and $100B \psi(2S)$
- **Heavy hadrons:** direct production, radiative and hadronic transitions (data between 3.8~7 GeV)

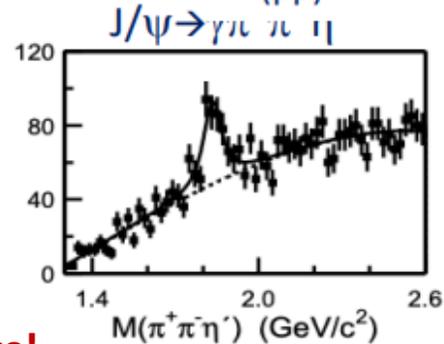
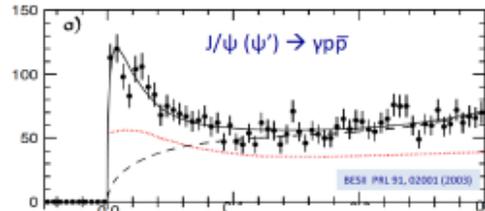
More data, Finer Structures

1996: 8 M J/ψ 's



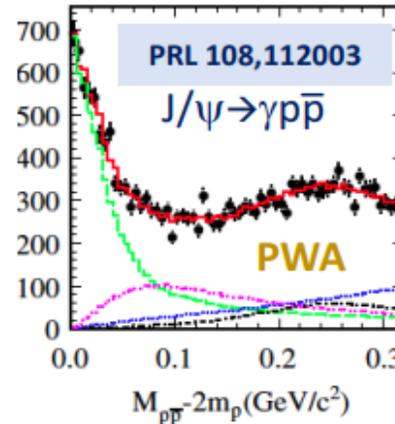
PRL 76, 3502

2002: 58 M J/ψ 's

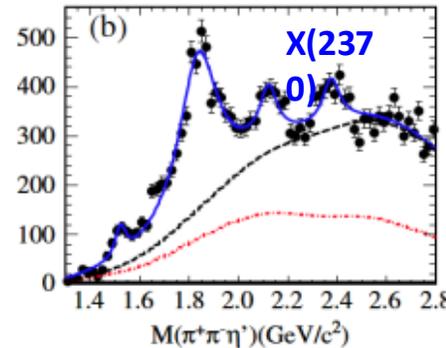


PRL 95, 262001

2011: 225 M J/ψ 's

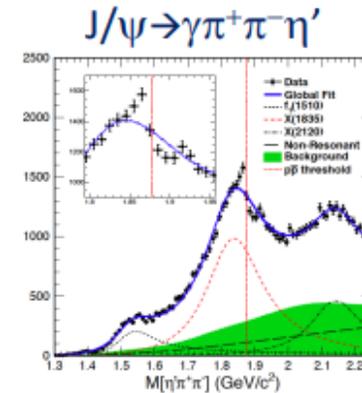


$J/\psi \rightarrow \gamma \pi^+ \pi^- \eta'$



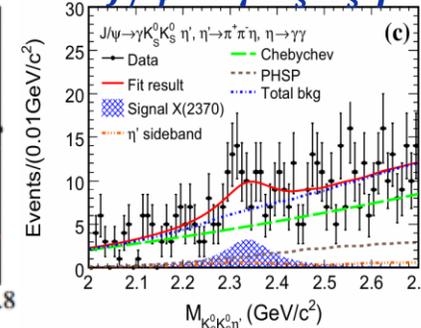
PRL 106, 072002

2016: 1.3 B J/ψ 's



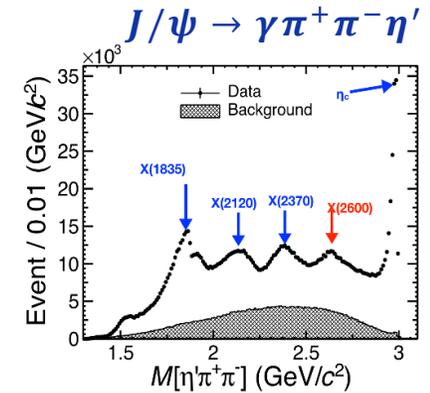
PRL 117, 042002

$J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta'$



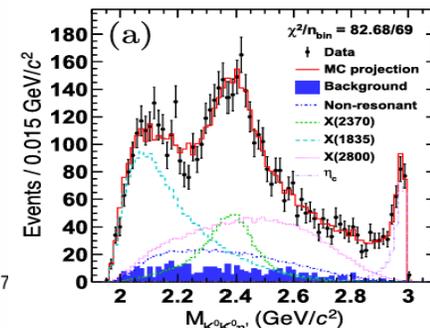
EPJC 80, 746

2022: 10 B J/ψ 's



PRL 129, 042001

$J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta'$



PRL 132, 181901

You never have enough J/ψ events!

— Stephen Lars Olsen

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

- Base on the **large statistic** and **high precision** data, STCF has an **absolute advantage** in the studying of hadron spectroscopy.

- STCF will study hadron spectroscopy comprehensively, and establish the "**periodic table of hadron elements**"

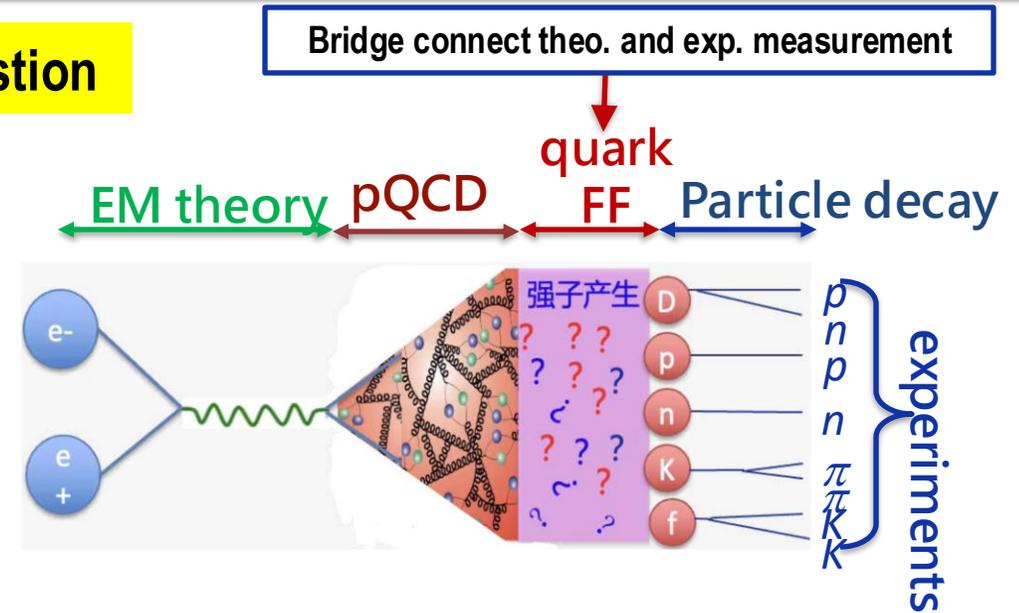
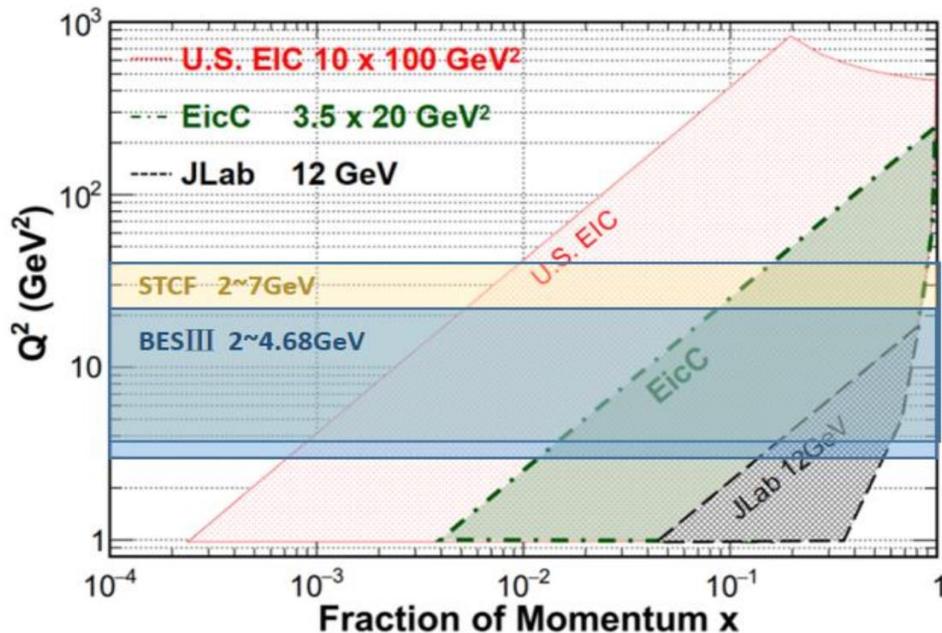
$0^- +$ Pseudoscalar Glueball-like

Hadronization process

How quarks form matter is a major unresolved scientific question

3-D tomographic imaging of hadronic processes:

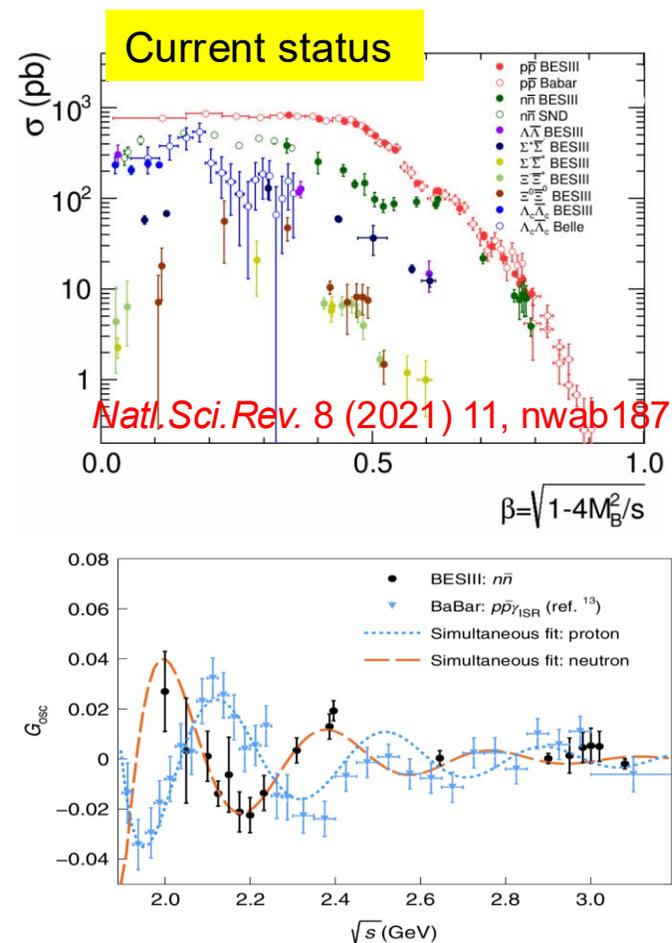
- **Fragmentation function:** for longitudinal momentum transfer in hadronization process
- **Energy correlation:** for the transfer momentum transfer



- FFs and EECs **can't calculated** within LQCD and quantum calculations
- STCF operates at the **most significant** energy region for **hadronization effect**, will provides the most **comprehensive data** for hadronization, and will realize the **first characterization** of the evolution of quark forming matter.

Electromagnetic form factors (EMFFs)

- EMFFs are fundamental properties, directly connected to charge and current distributions of the nucleon

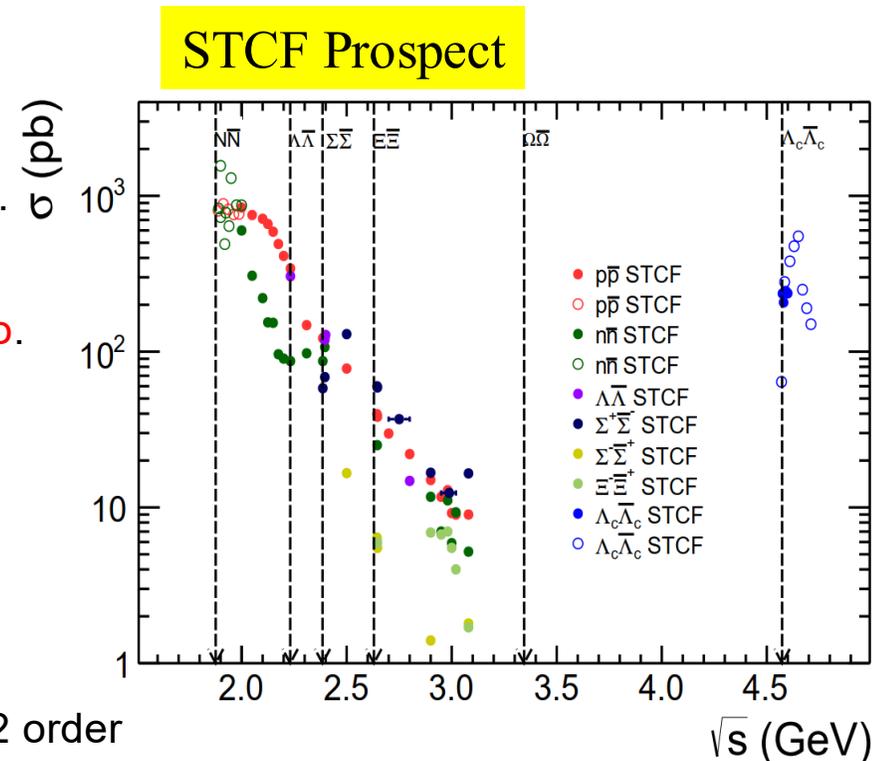


Remaining questions of TL-EMFFs:

- Step-like behavior of production cross section.
- Damped oscillation distribution in effective FF.
- Damped oscillation distribution of $|G_E/G_M|$ ratio.
- Evolution of the phase between G_E and G_M .
- The asymptotic behavior of TL-EMFFs

STCF prospect for TL-EMFFs:

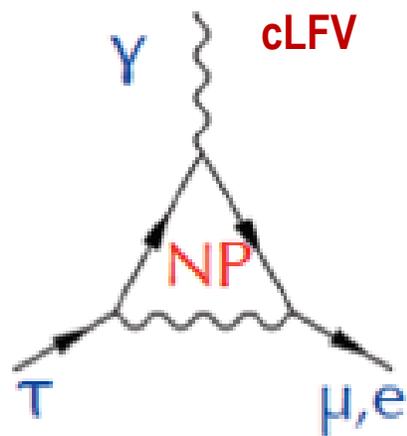
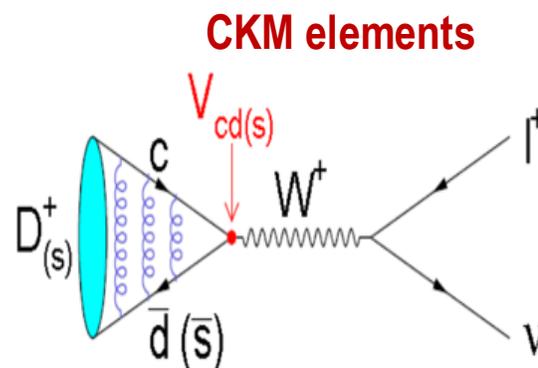
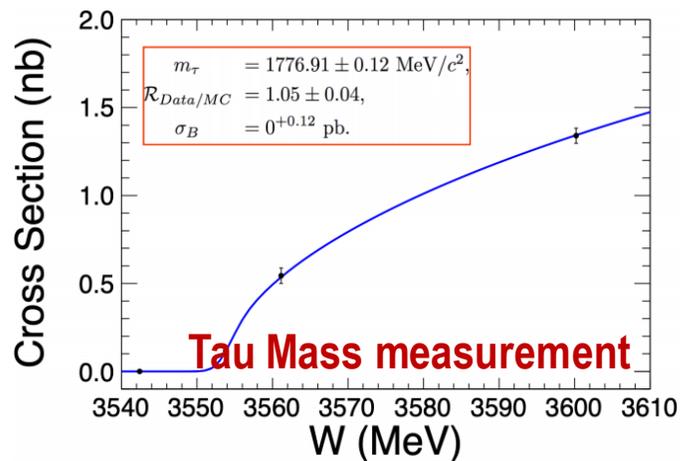
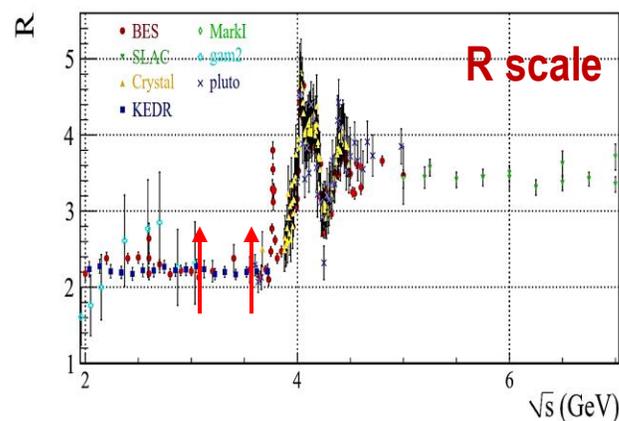
- Improve cross section measurement with 1-2 order
- Reveal the near-threshold cross section singularity and mystery of G_E and G_M .



Physics III : Precision measurements and Rare Searches

Large statistics, high precision, clear background, threshold effects

a lot precision measurements and searches :



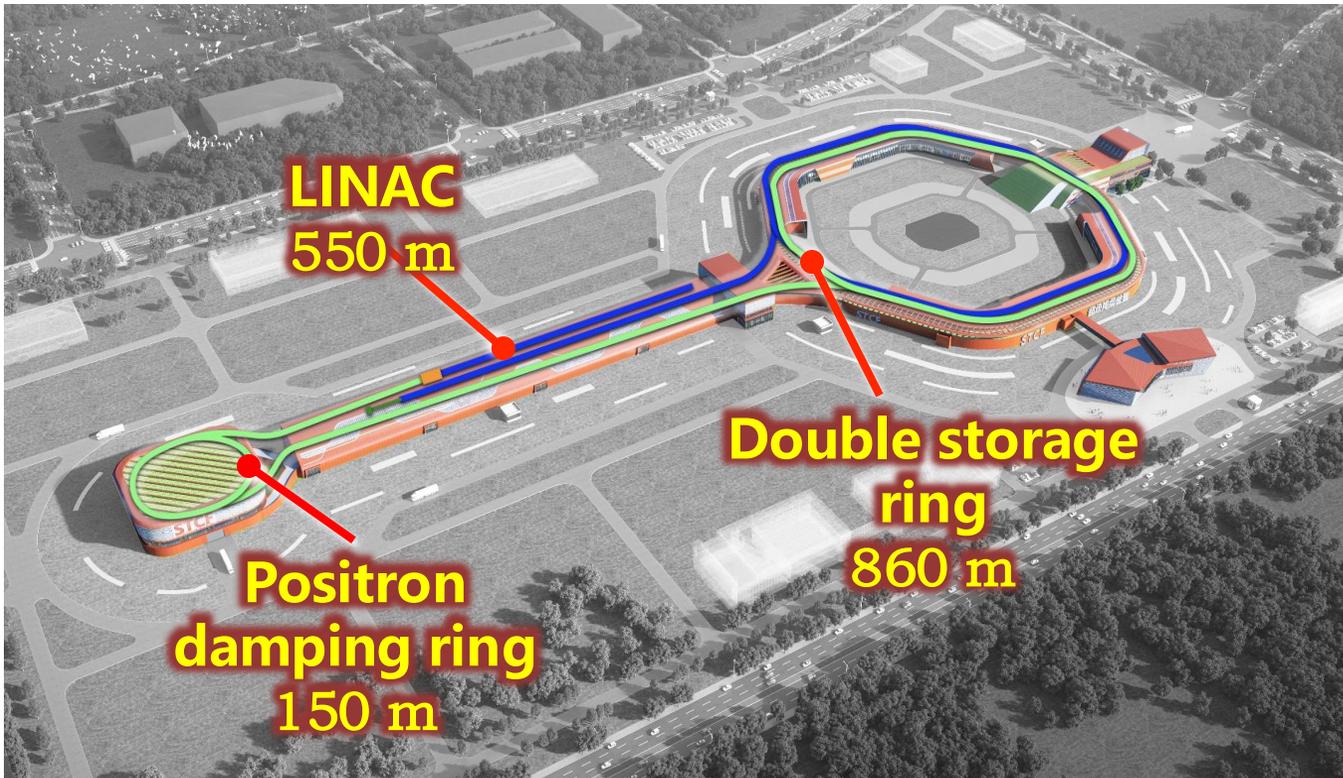
Observable	BESIII (2020)	Belle II (50 ab ⁻¹)	STCF (1 ab ⁻¹)
<i>Charmonium(like) spectroscopy:</i>			
Luminosity between 4-5 GeV	20 fb ⁻¹	0.23 ab ⁻¹	1 ab ⁻¹
<i>Collins fragmentation functions:</i>			
Asymmetry in e ⁺ e ⁻ → KK + X	0.3 [470]	-	< 0.002 [471]
<i>CP violations:</i>			
A _{CP} in hyperon	0.014 [26]	-	0.00023
A _{CP} in τ	-	O(10 ⁻³)/√70 [251]	0.0009 [250]
<i>Leptonic decays of D_s:</i>			
V _{cd}	0.03 [472]	-	0.0015
f _D	0.03	-	0.0015
B(D → τν) / B(D → μν)	0.2	-	0.005
V _{cs}	0.02 [473]	0.005	0.0015
f _{D_s}	0.02	0.005	0.0015
B(D _s → τν) / B(D _s → μν)	0.04	0.009	0.0038
<i>D mixing parameter:</i>			
x	-	0.03	0.05 [474]
y	-	0.02	0.05
<i>τ properties:</i>			
m _τ (MeV/c ²)	0.12 [475]	-	0.012
d _τ (e cm)	-	2.02 × 10 ⁻¹⁹	5.14 × 10 ⁻¹⁹
<i>cLFV decays of τ (U.L at 90% C.L.):</i>			
τ → ll	-	1 × 10 ⁻⁹	1.4 × 10 ⁻⁹
τ → γμ	-	5 × 10 ⁻⁹	1.8 × 10 ⁻⁸
J/ψ → eτ	7.5 × 10 ⁻⁸	-	7.1 × 10 ⁻¹⁰

Outline

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- Physics Opportunities
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- Summary and Outlook

STCF Design Goals and Accelerator

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



arXiv > physics > arXiv:2509.11522

Search...

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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 STCF accelerator project.

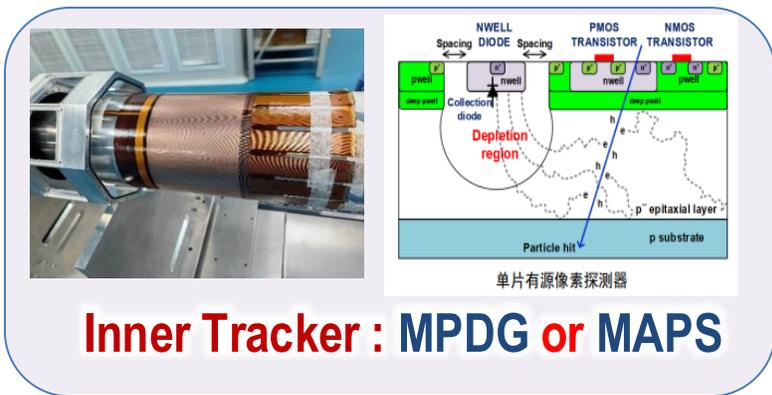
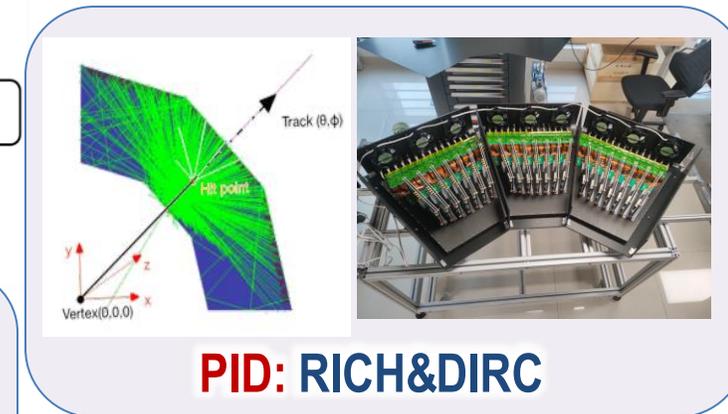
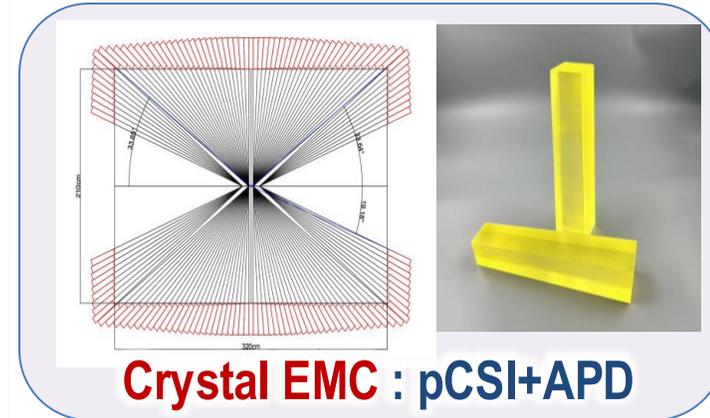
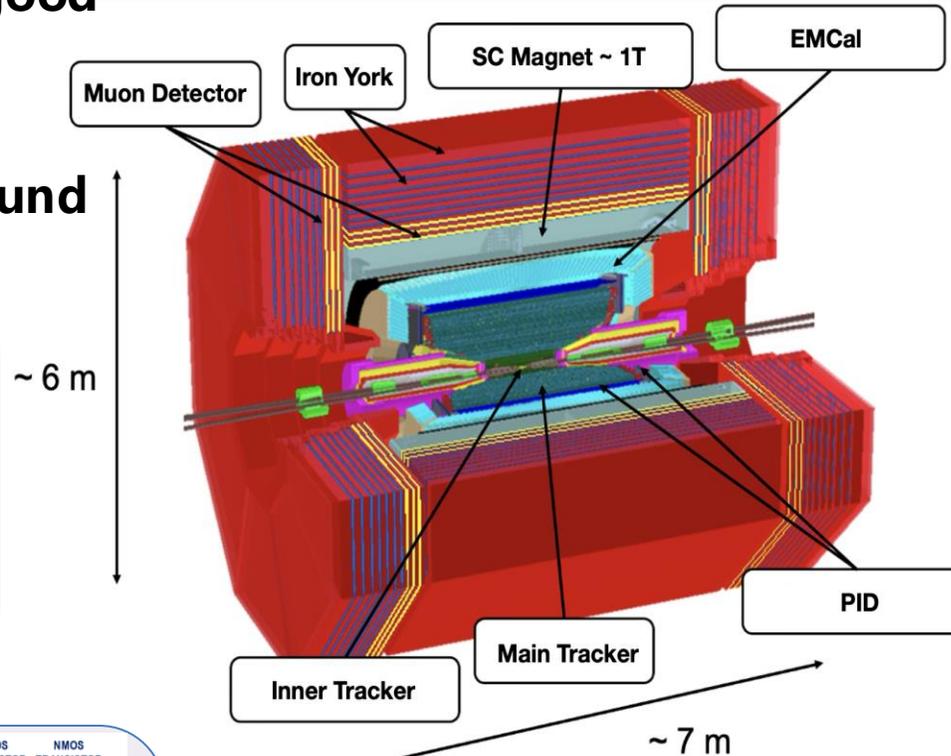
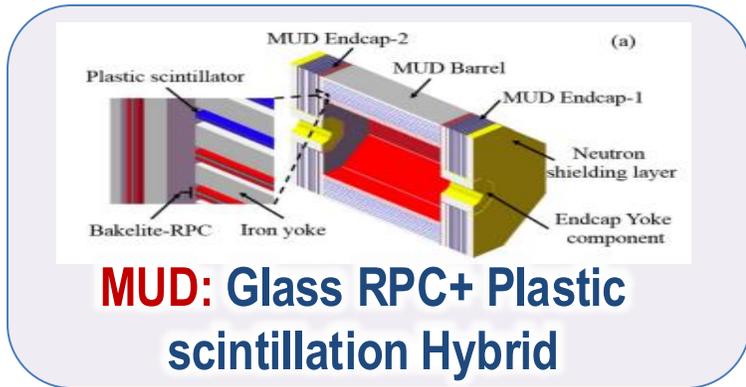
CDR released in 15/09/2025
arXiv: 2509.11522

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

Detector Design

The design is well done, and is optimizing...

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



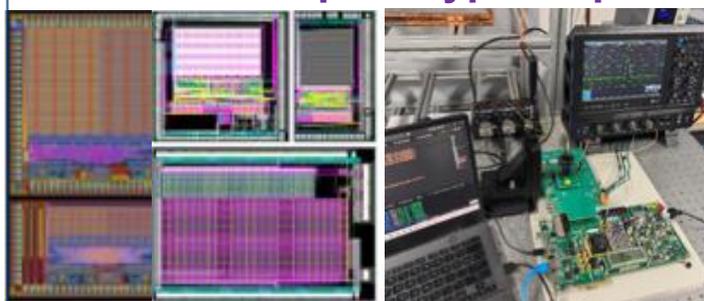
Key Technologies R&D

Great progress achieved, All system prototypes have be established

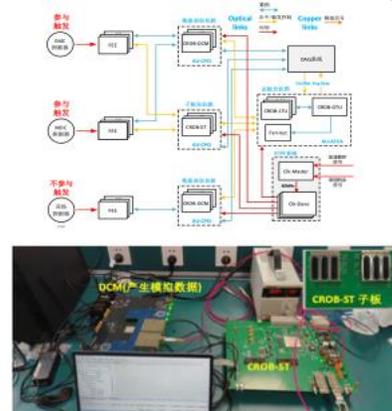
Cylindrical μ RGroove prototype



ITK: CMOS prototype chips



Trigger



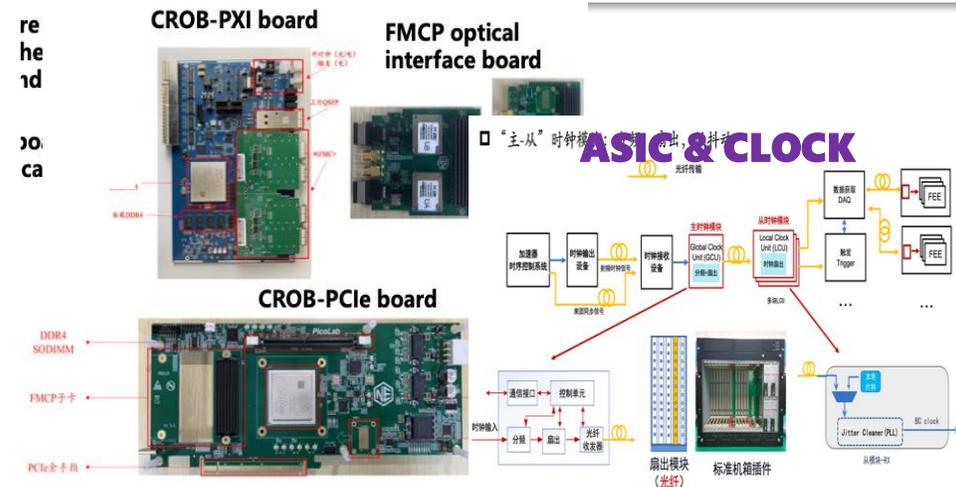
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物理学前沿

Frontiers of Physics



Detector and Physics CDR published in 2023

DAQ



Main tracker full length prototype



PID prototype



EMCal: 5 X 5 prototype



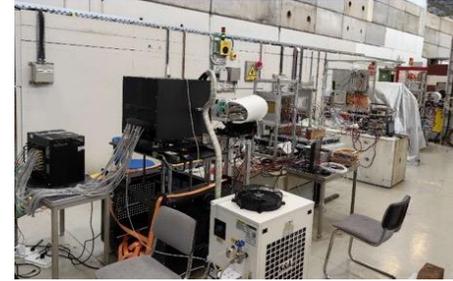
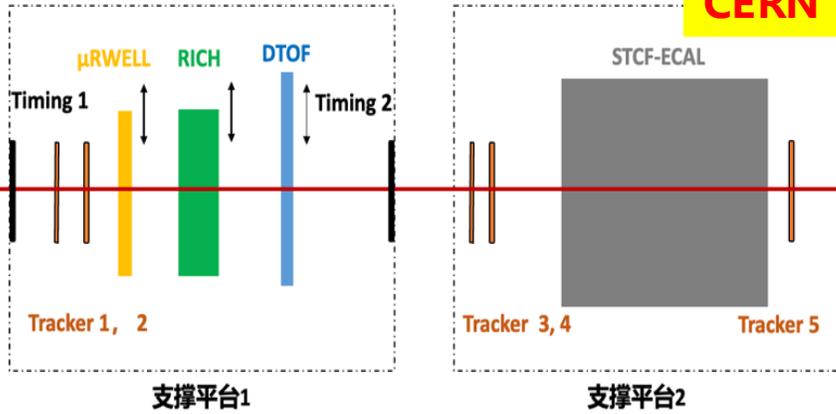
Muon: Plastic Scintillator+ RPC



Beam Test

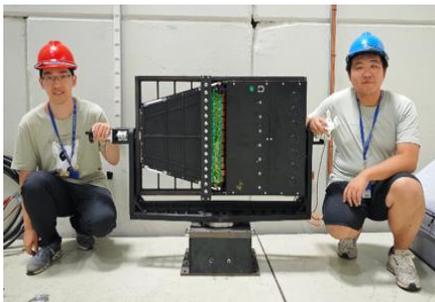
- A test beam campaign for a combined system (**DTOF, EMC, DAQ**)
- A new beam test campaign with almost full chain at CERN in Oct.15-29, 2025

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



CERN Oct. 15 – 29, 2025

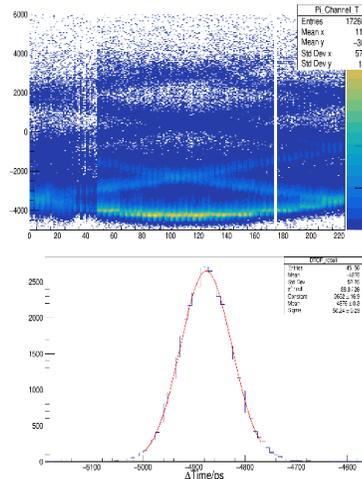
DTOF



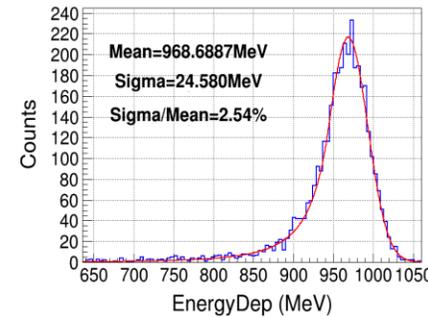
EMC



$\sigma_t \sim 25 \text{ ps}$

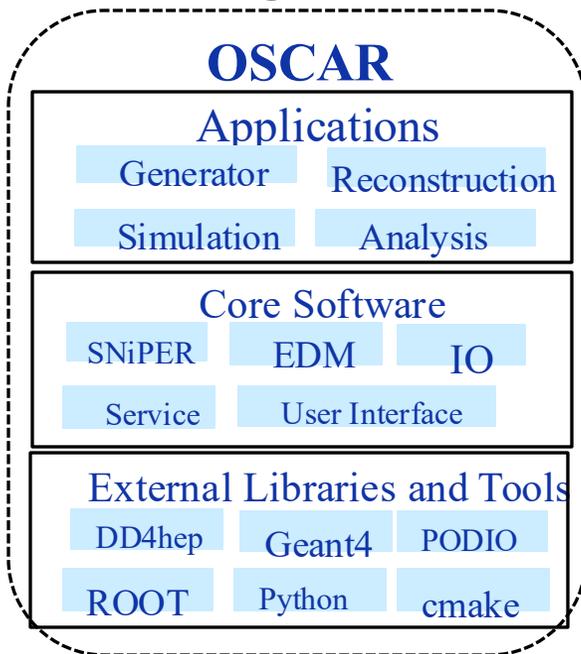


$\sigma_E/E \sim 2.5\%$

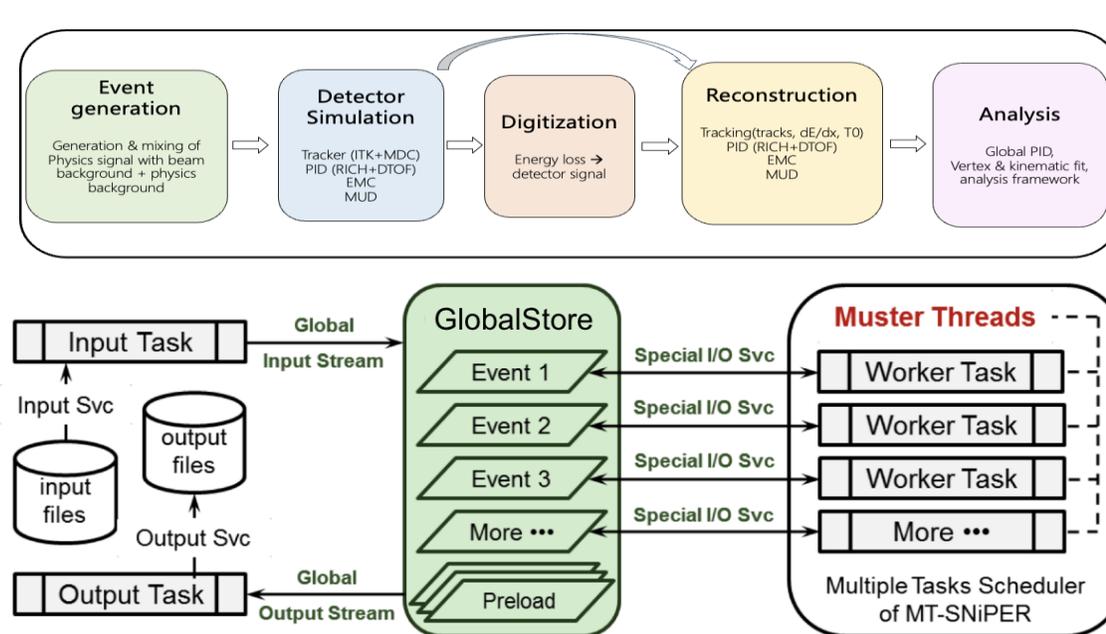


Offline Software and full simulation

- ❑ Offline Software System of Super Tau-Charm Facility (**OSCAR**)
 - External Interface+ Framework +Offline
- ❑ **SNiPER framework** provides common functionalities for whole data processing
- ❑ Offline including Generator, Simulation, Calibration, Reconstruction and Analysis



[W.H. Huang et al 2023 JINST 18 P03004](#)

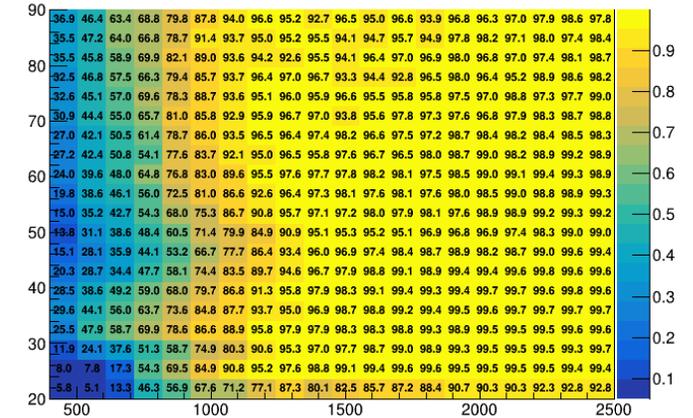
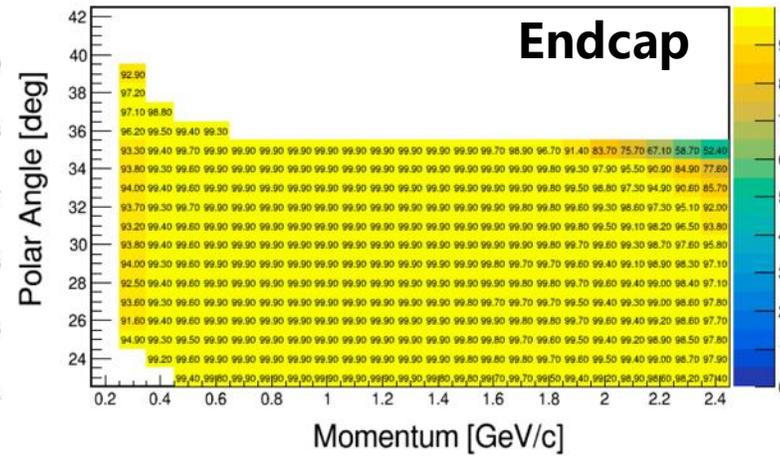
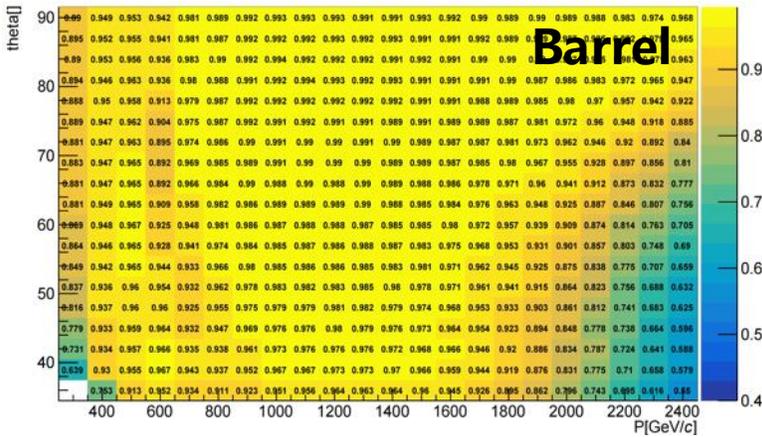


- ❑ Full simulation under OSCAR is undergoing: $e^+ e^- \rightarrow \pi^+ \pi^- J/\psi, \Lambda \bar{\Lambda}, \pi\pi/K\pi/KK + X, D^0 \bar{D}^0 \dots$

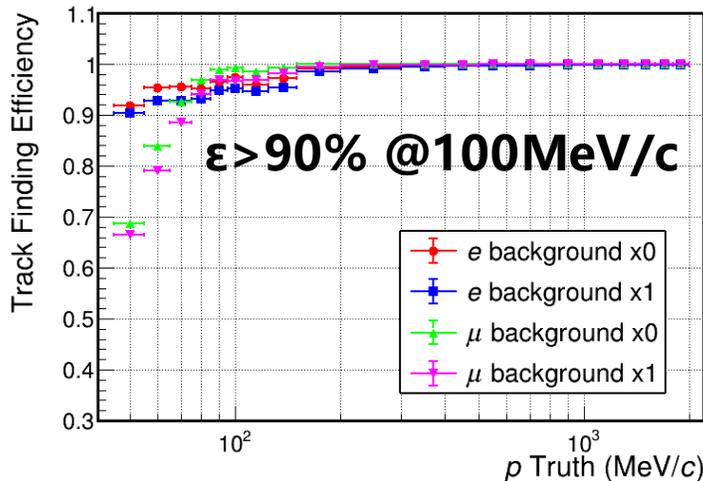
Performances with Full Simulation

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

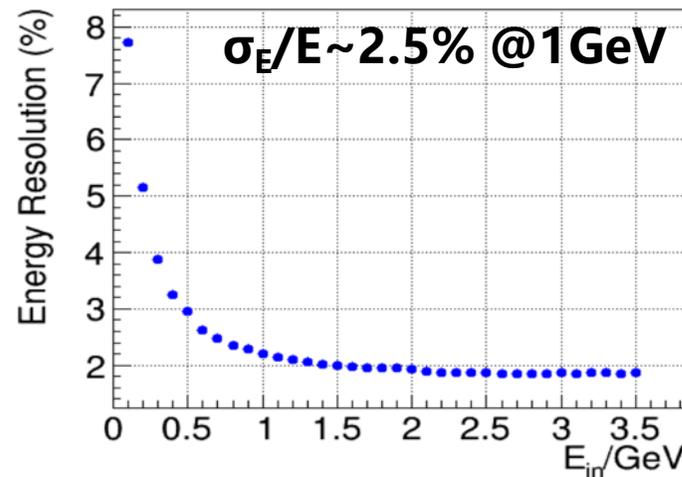
Muon ID eff. @ pi suppression=30



Tracking efficiency

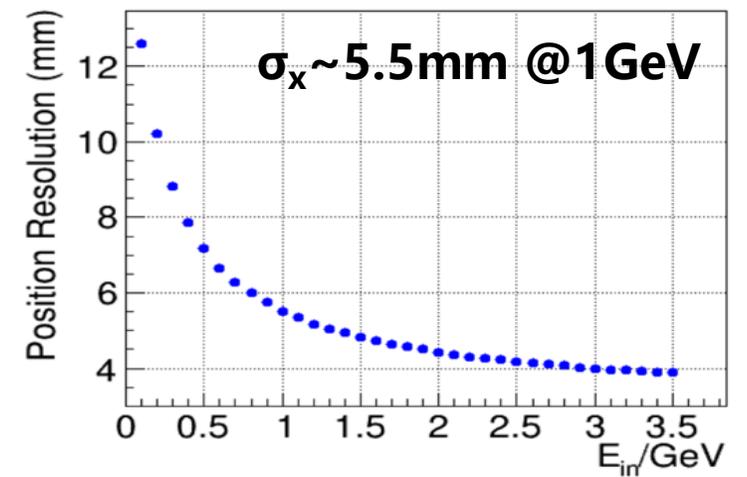


EMC energy resolution

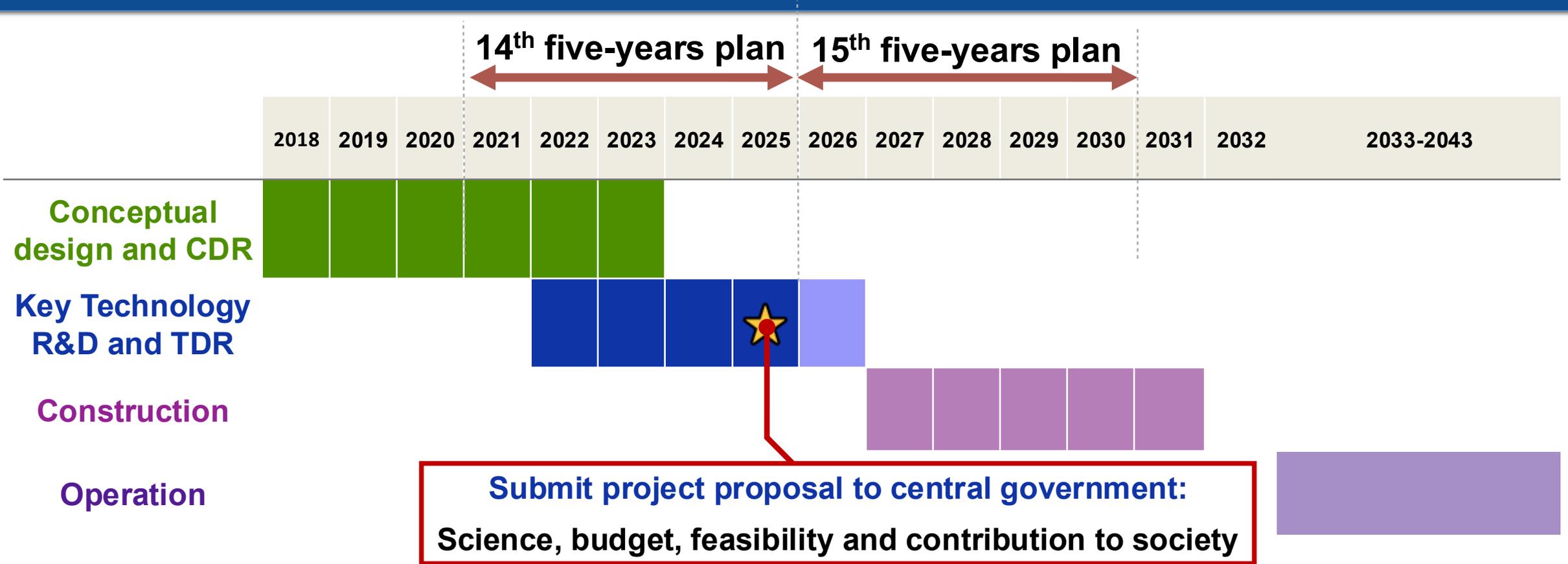


eff. $\sim > 90\%$ when $p \sim > 1 \text{ GeV/c}$

EMC position resolution



Tentative Project Schedule

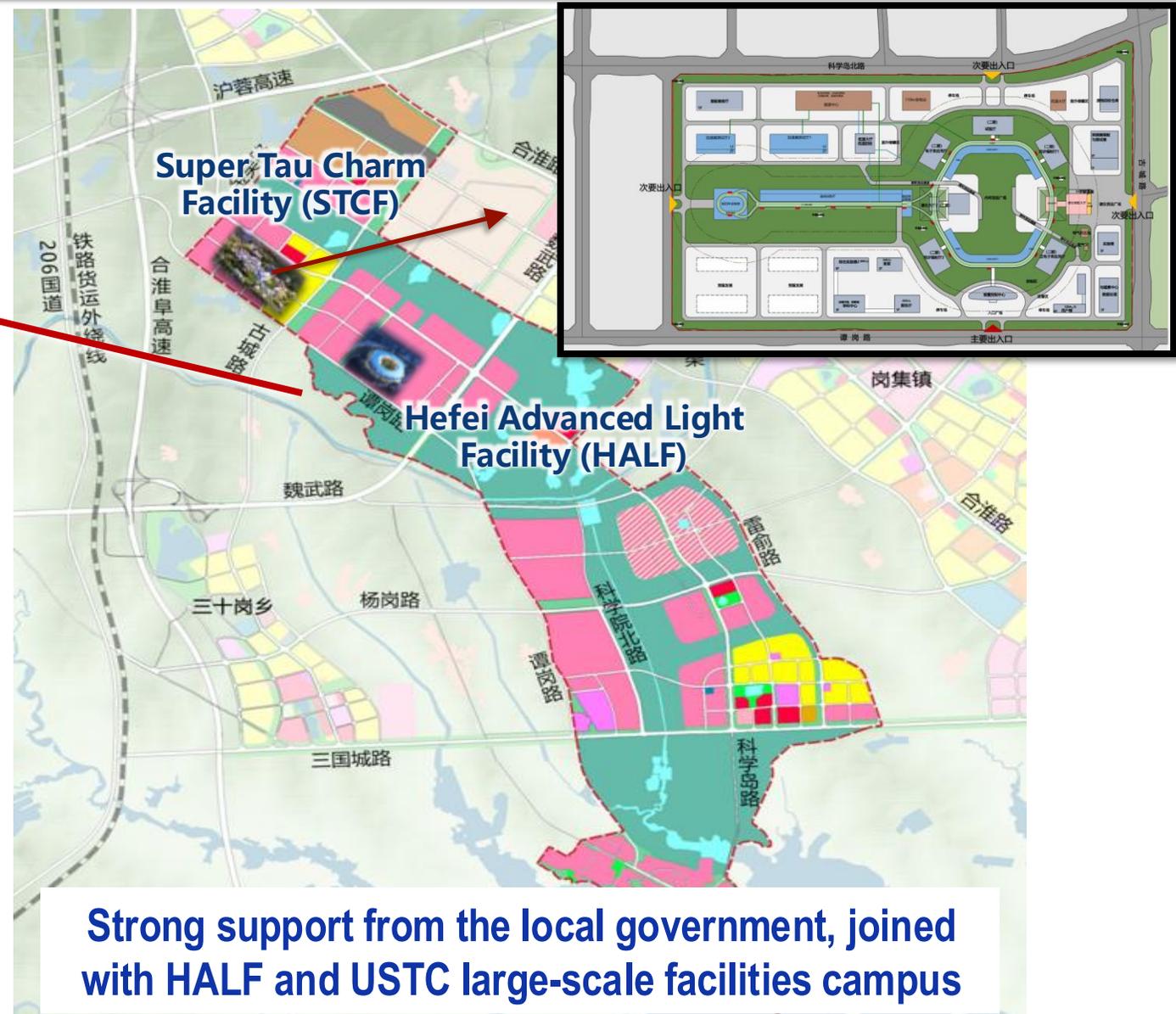
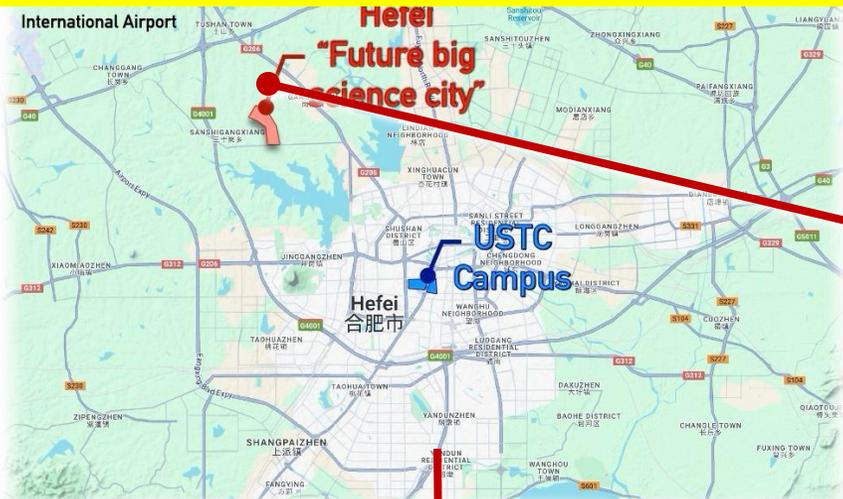


**Submit project proposal to central government:
Science, budget, feasibility and contribution to society**

- 14th five-years plan : **Conceptual design** and **R&D of Key technology**, 364 M CNY
- 15th five-years plan : **Construction** 5 years, ~5 B CNY
- Operating for 10-15 years, upgrade for 3 years, operating again for ~10 years

Construction Site

National comprehensive Science Center
Future Big Science City, Hefei, Anhui province



Strong support from the local government, joined with HALF and USTC large-scale facilities campus



FTCF2025

The 7th International Workshop on Future Tau Charm Facilities

FTCF2025, Huangshan
November 23rd - 27th, 2025



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Detector:
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Software & Computing:
Xingtao Huang
Xiaocong Ai
Alexey Zhemchugov



<https://indico.pnp.ustc.edu.cn/event/4580/overview>
Huangshan University

- The 7th International **Workshop on Future Tau Charm Facilities** (FTCF2025) will be hosted by Huangshan University

Huangshan (aka. Yellow Mountain), China
Nov. 23 - 27, 2025

<https://indico.pnp.ustc.edu.cn/event/4580/>



Outline

- Introduction
- Physics Opportunities
- Accelerator and Detector
- **Summary and Outlook**

Summary

- STCF has a rich **physics program** in tau-charm region: **how quarks form matter? symmetry of fundamental interactions (CPV)**, and **precision physical parameters**, ...
- **Key technology R&D** are on track; **significant progresses** achieved
- **International collaboration** and **synergies** with global projects are actively pursued.

Thanks for your attention!

Backup

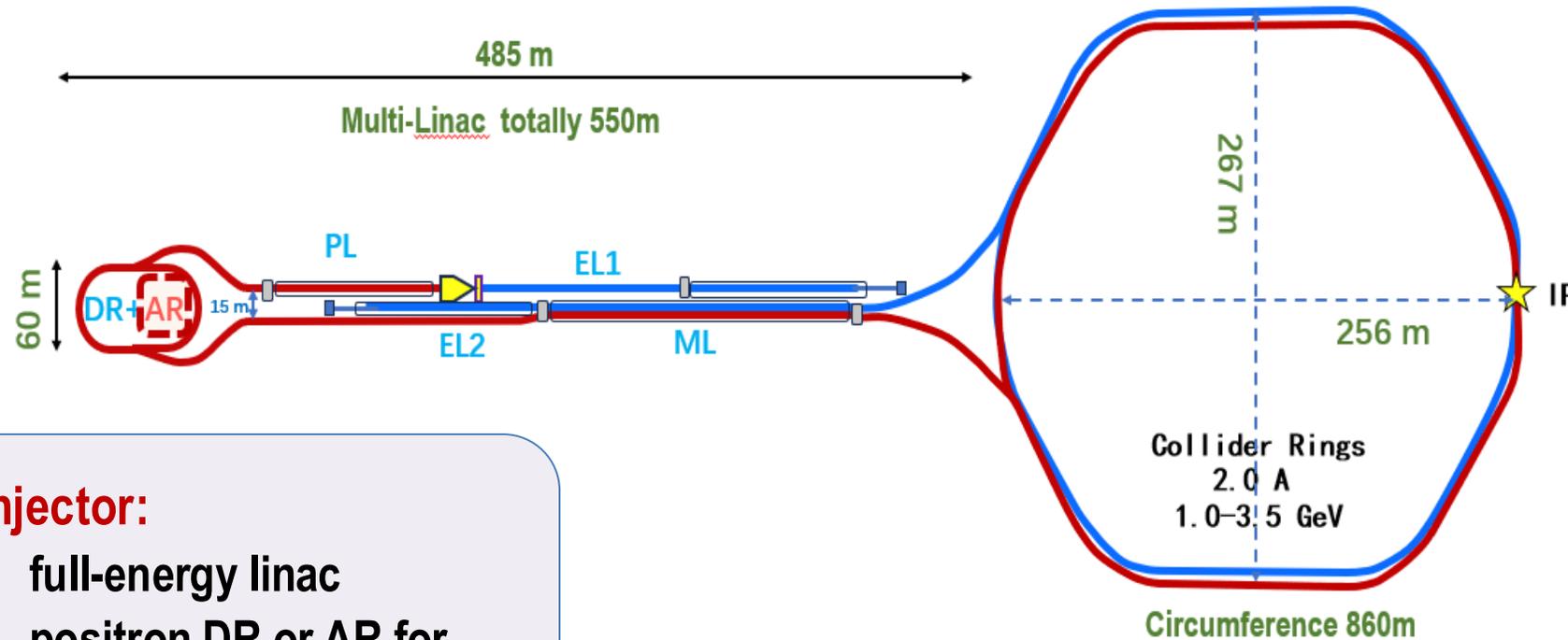
Accelerator Design

Core design goal: CM energy 2-7 GeV, Luminosity $> 5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ @ 4 GeV

arXiv: 2509.11522

[physics.acc-ph]

Will be published at NST



Injector:

- full-energy linac
- positron DR or AR for different injection modes

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

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¹¹ High Energy Accelerator Research Organization, Tsukuba, Japan
¹² Budker Institute of Nuclear Physics, Novosibirsk, Russia

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Double-Ring Collider

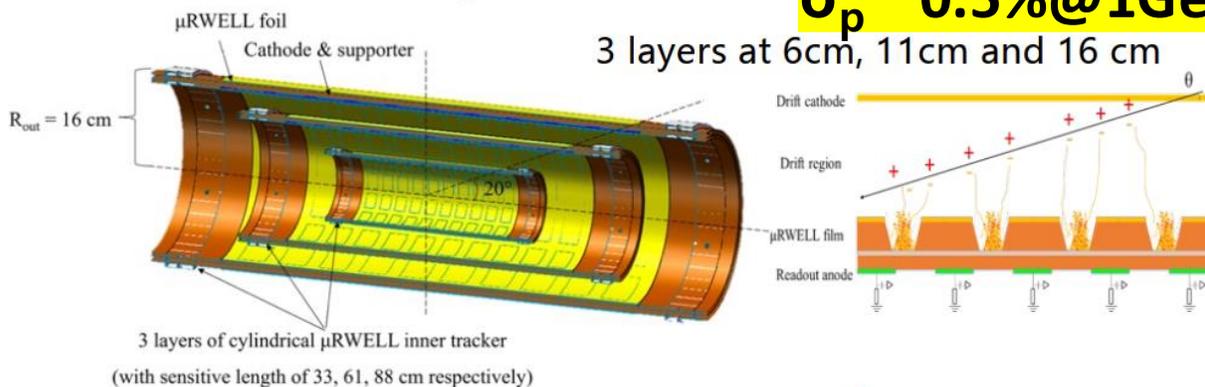
- low emittance
- high current
- large Piwinski angle
- Crab-waist collision scheme

CM (GeV)	2.0	3.0	4.0	7.0
Simulated lumi. (cm ⁻² s ⁻¹)	6.2×10^{33}	2.1×10^{34}	9.4×10^{34}	4.5×10^{34}

Tracking System: ITK + MDC

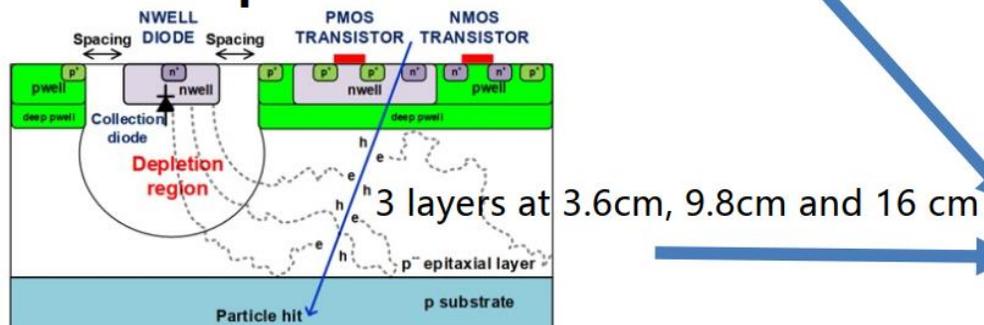
$\sigma < 130 \mu\text{m}$, $\text{Trk Eff} > 90\%$ @ $0.1 \text{ GeV}/c$ and $> 99\%$ @ $0.3 \text{ GeV}/c$,
 $\sigma_p \sim 0.5\%$ @ $1 \text{ GeV}/c$

ITK Gaseous option : MPGD



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

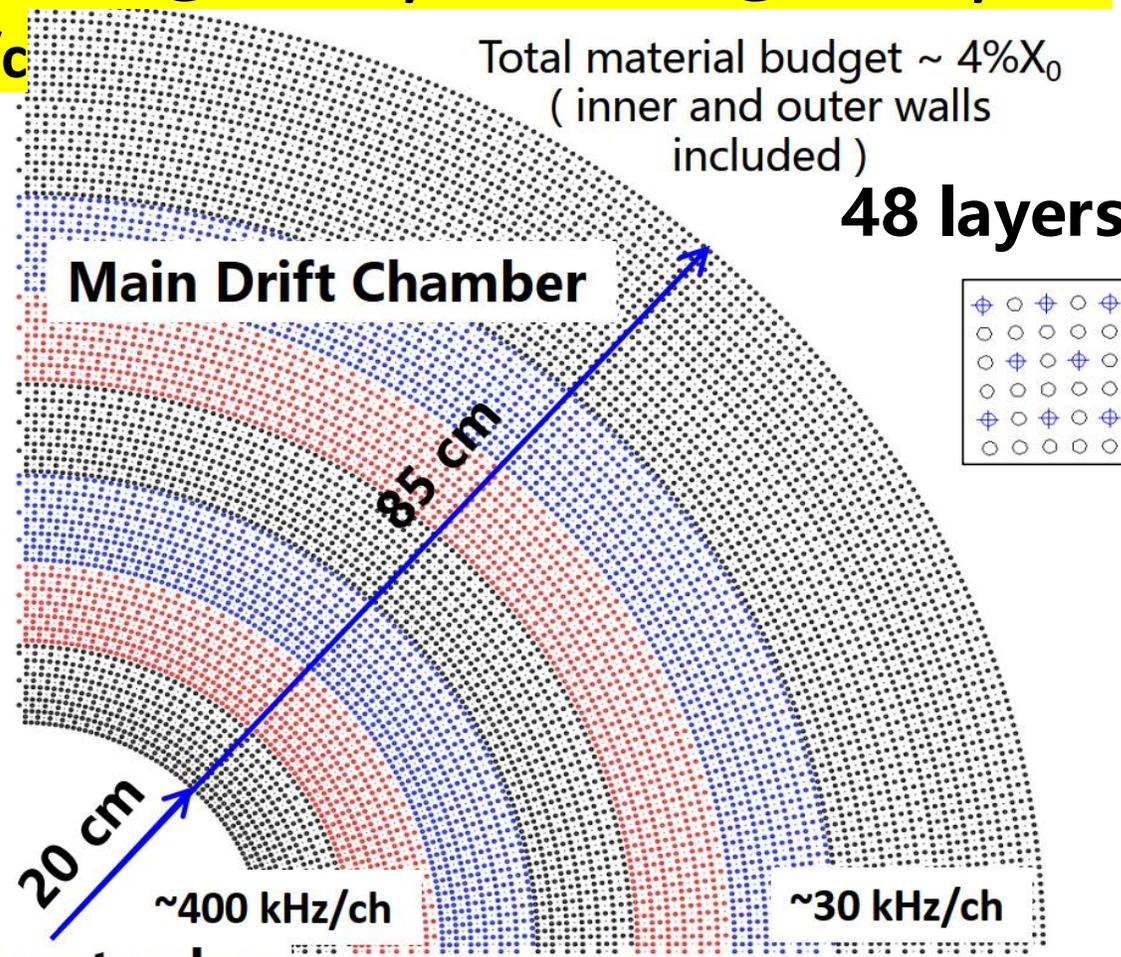
ITK Silicon option: CMOS MAPS



单片有源像素探测器

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

48 layers



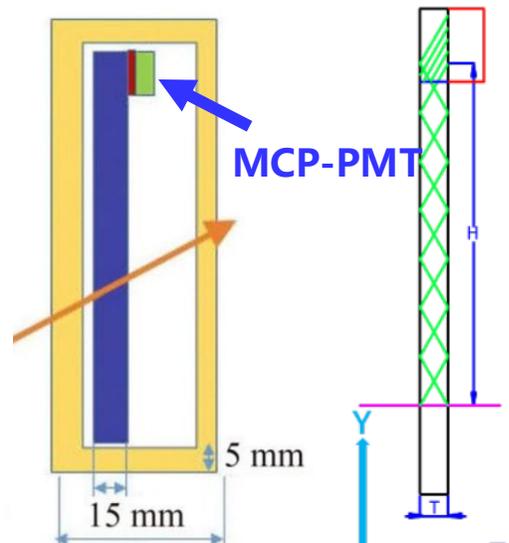
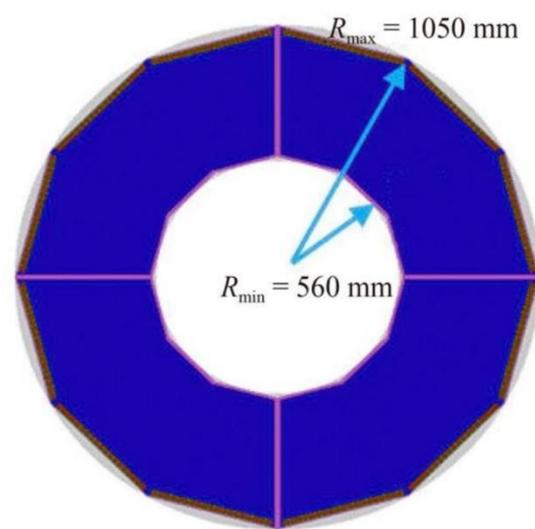
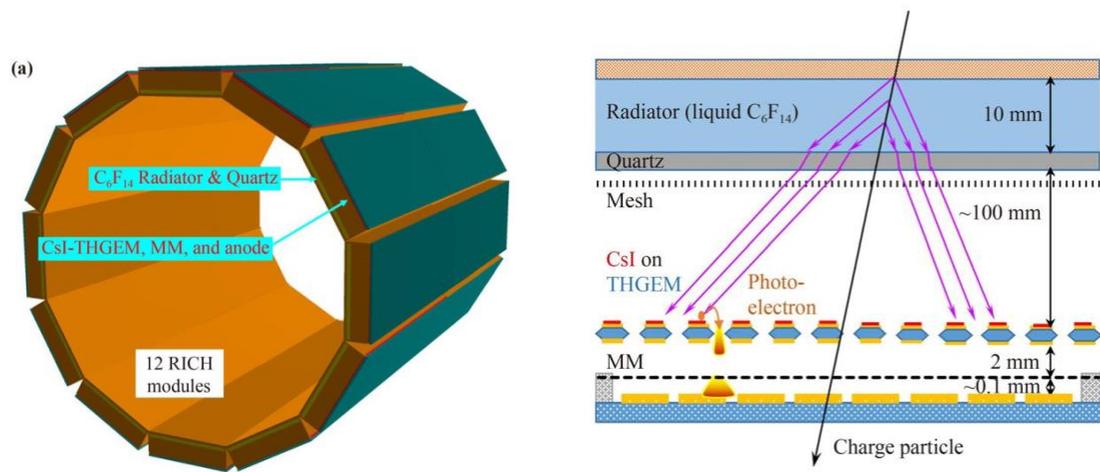
Inner tracker

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

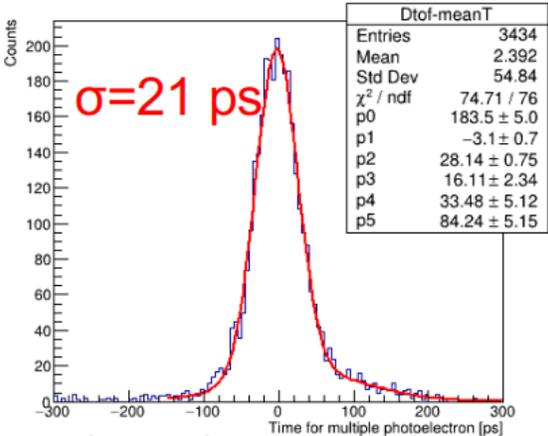
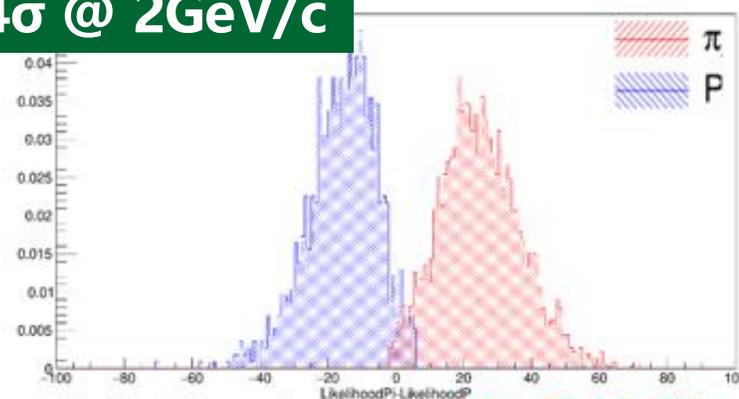
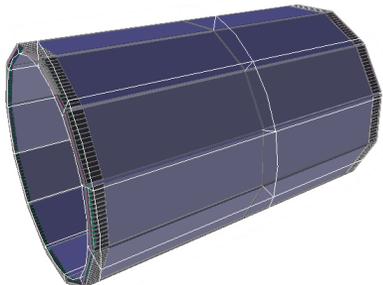
Endcap PID: A DIRC-like high-resolution TOF (~ 30 ps), quartz plate + MCP-PMT



Material Budget < 0.3X₀

π/K separation 4σ @ 2GeV/c

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

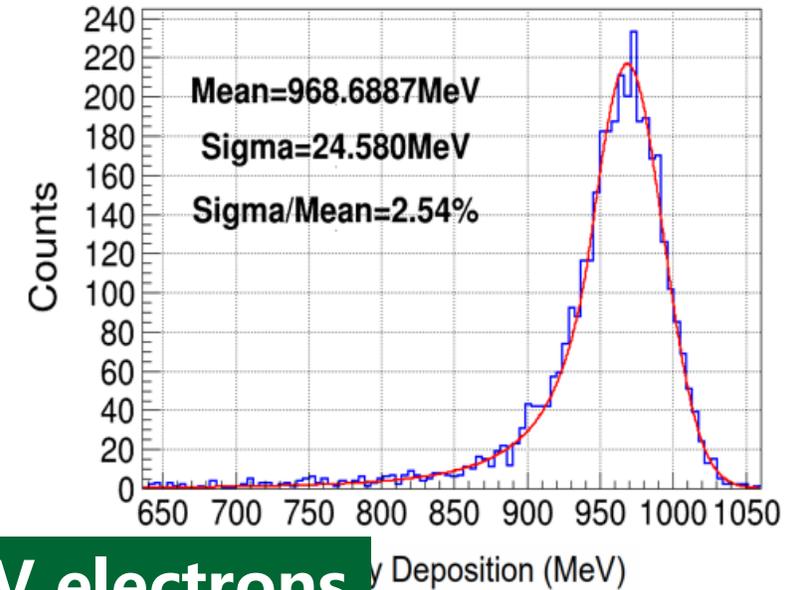


2D likelihood result ~4.0σ @ 98.4% Single track time resolution

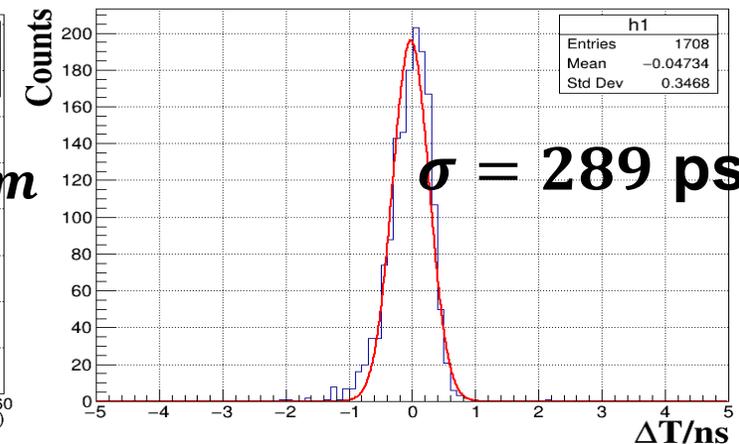
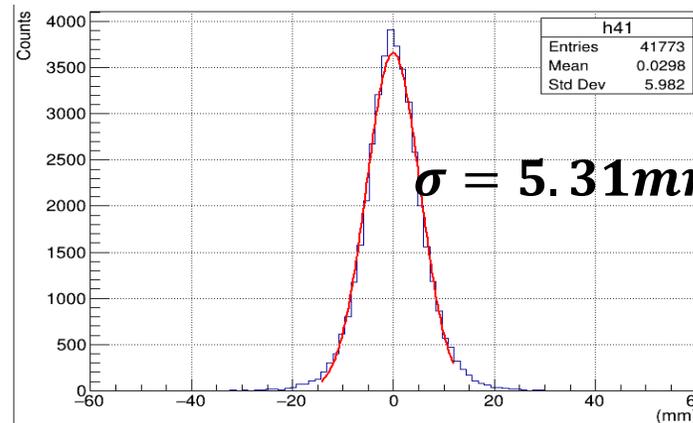
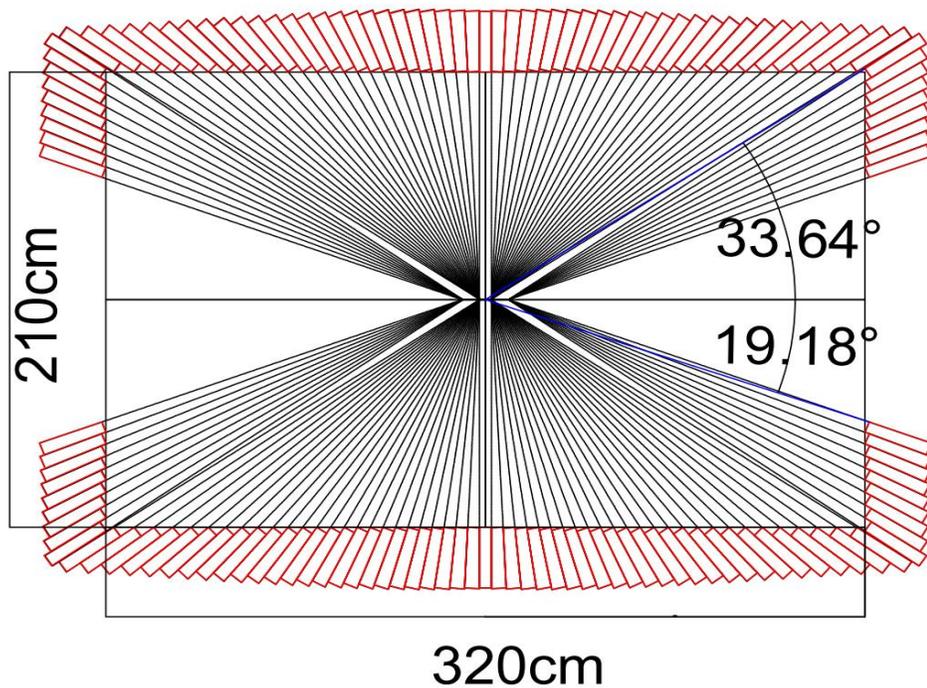
Electromagnetic Calorimeter

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

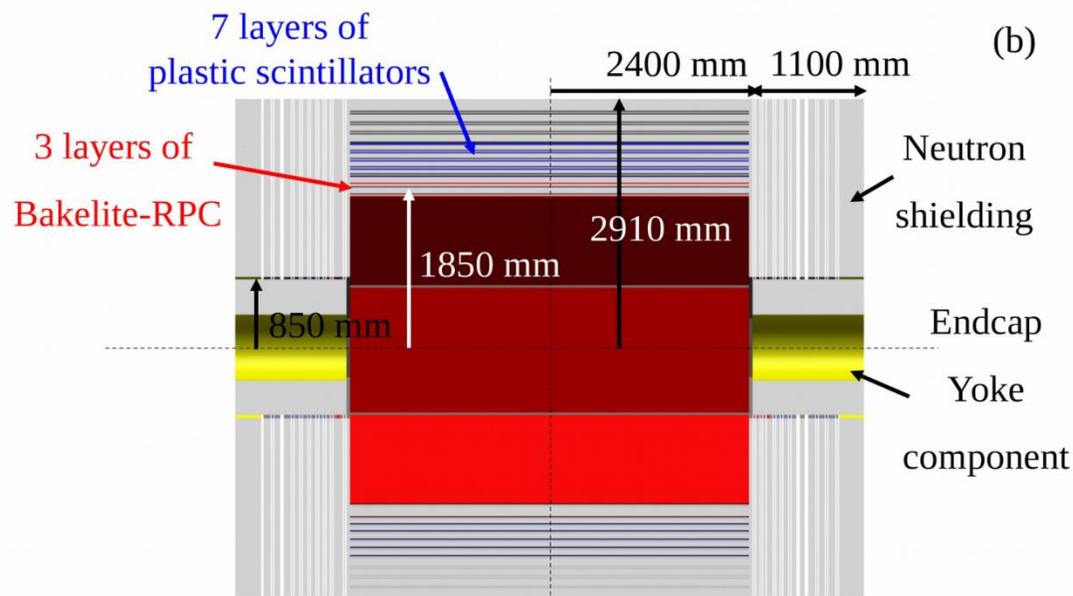


1 GeV electrons



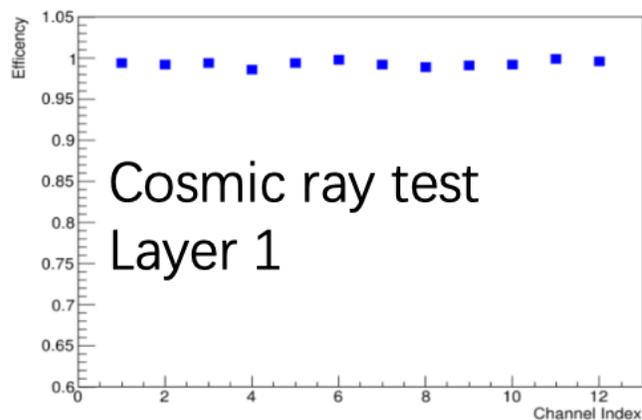
Muon Detector

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

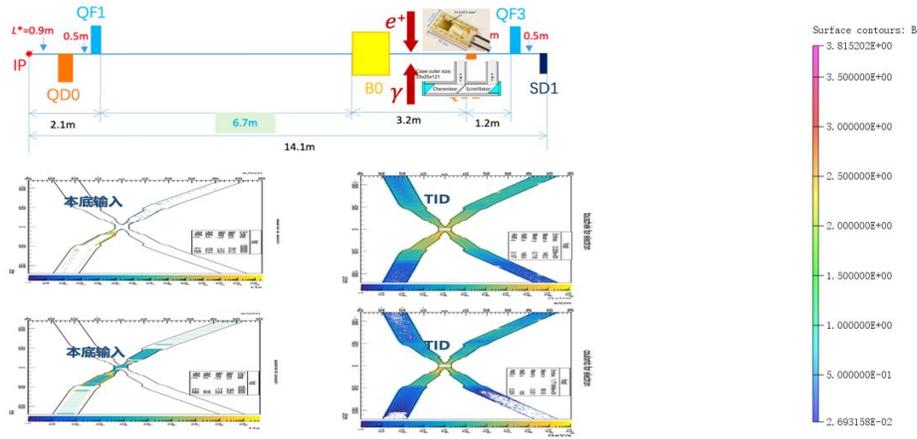


RPC prototype: different air gaps, low resistance glass ...

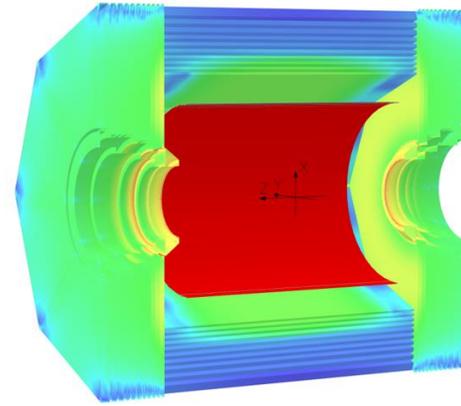


Other Systems

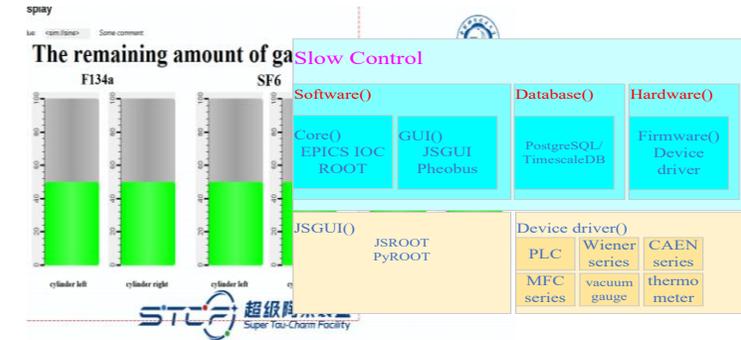
Forward System



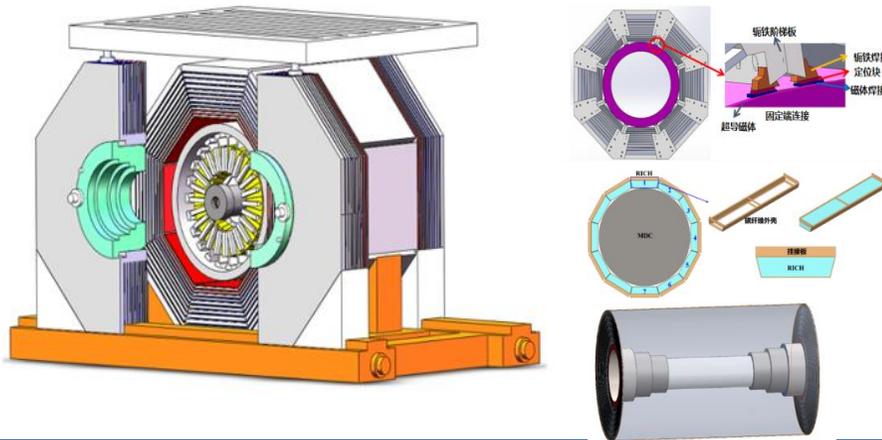
Superconducting magnet



Detector control system



Detector mechanical system



MDI

