超级陶粲装置
Super Tau-Charm Facility

Progress of the Super Tau-Charm Facility (STCF) project in China

Xiaoshuai Qin (Shandong University)
On behalf STCF team

14^{th} International Workshop on $e^{+}e^{-}$ collisions from Phi to Psi 2026 (PHIPSI26)

Pisa, June 8^{th} -11^{th} , 2026

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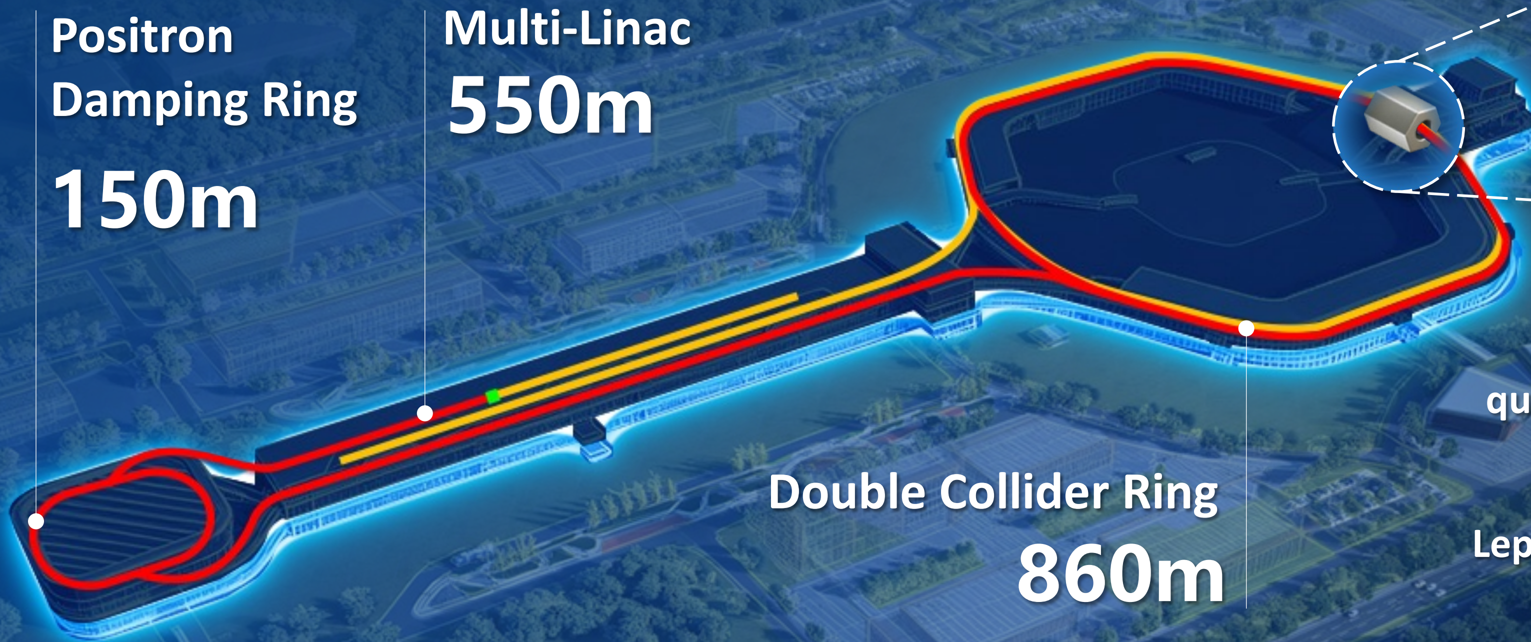
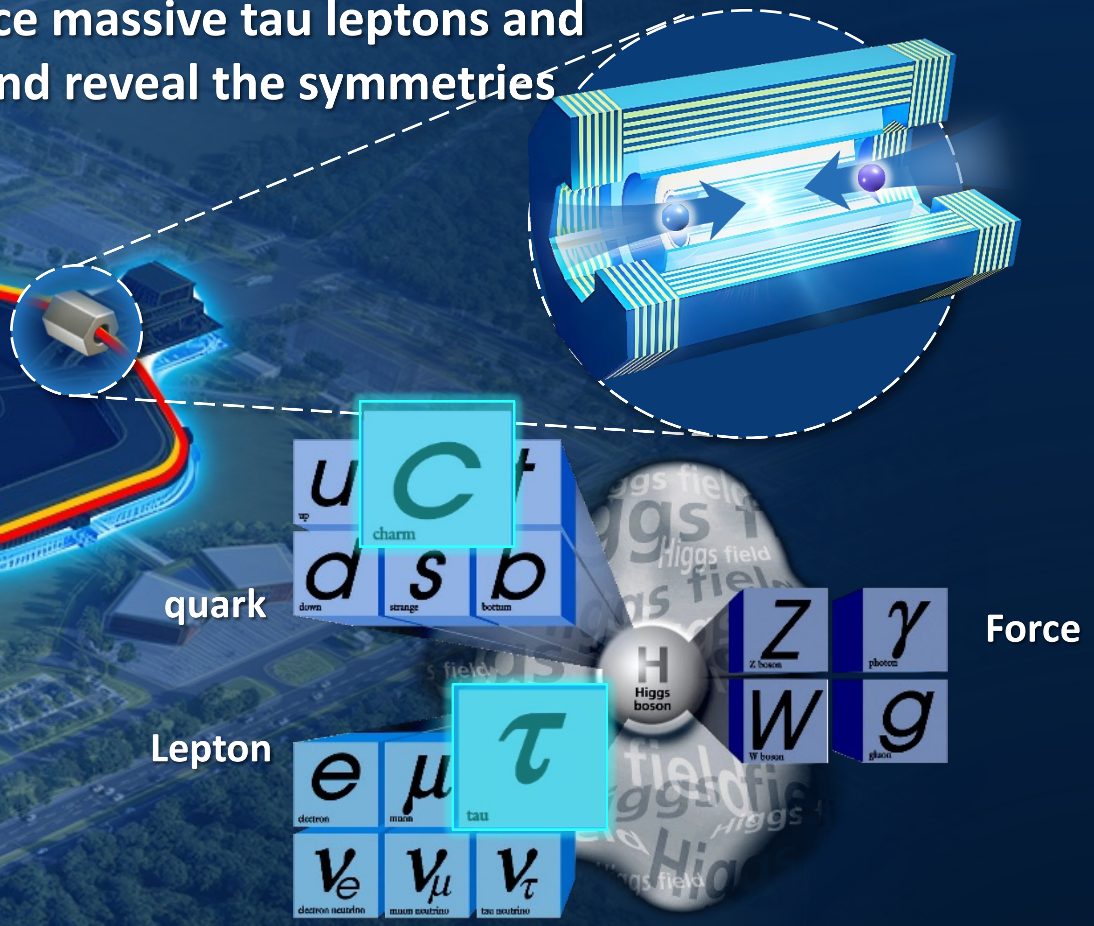
Super Tau-Charm Facility（STCF）

A **New Generation Spectrometer** proposed in China to produce massive tau leptons and hadrons, to unravel the mystery of **how quarks form matter** and reveal the symmetries underlying **fundamental interactions**





Center-of-Mass Energy coverage : 2-7 GeV	Peak Luminosity > 0.5×10^{35} $cm^{-2}s^{-1}$ @ 4GeV	Potential to increase lumi. & realize beam polarization

Construction Site: Hefei City, Anhui Province, China

Future Big Science City
National Comprehensive Science Center

Super Tau-Charm Facility, STCF

Hefei Advance Light Source, HALF

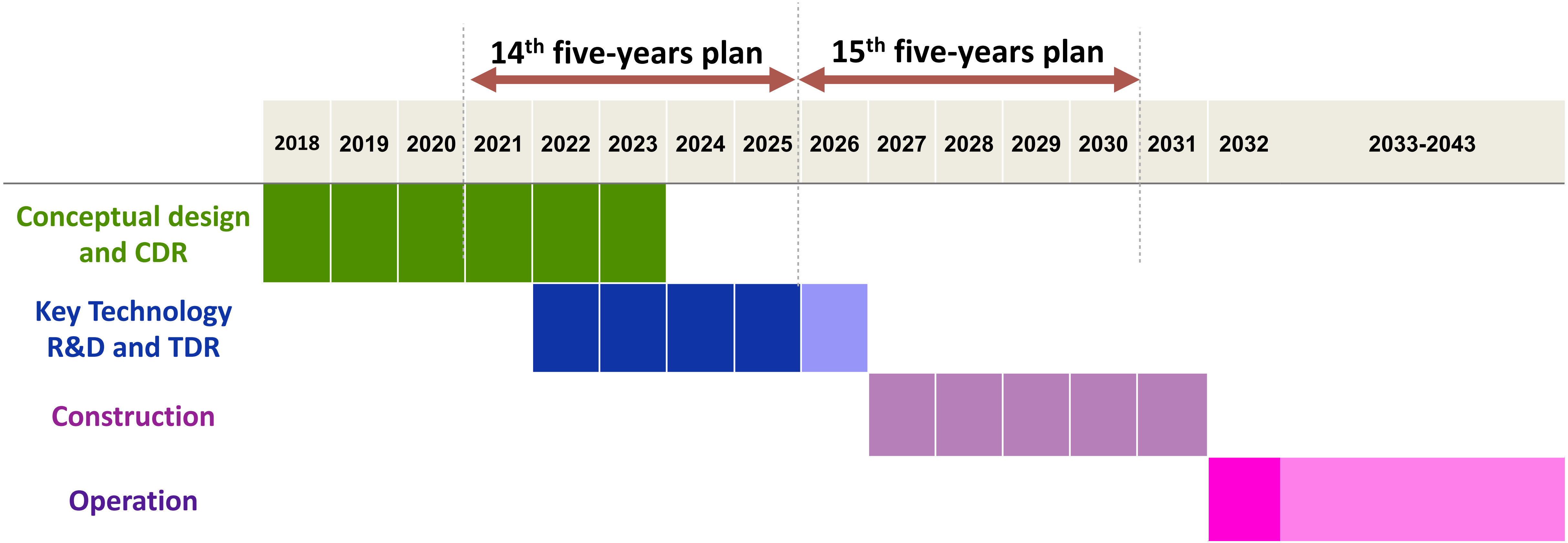
Planetary Environment Simulation and Analysis Facility

Comprehensive Research Facility for Fusion Technology, CRAFT

Burning Plasama Experimental Superconducting Tokamak, BEST

Experimental Advanced Superconducting Tokamak, EAST
Steady High Magnetic Field Facility, SHMFF

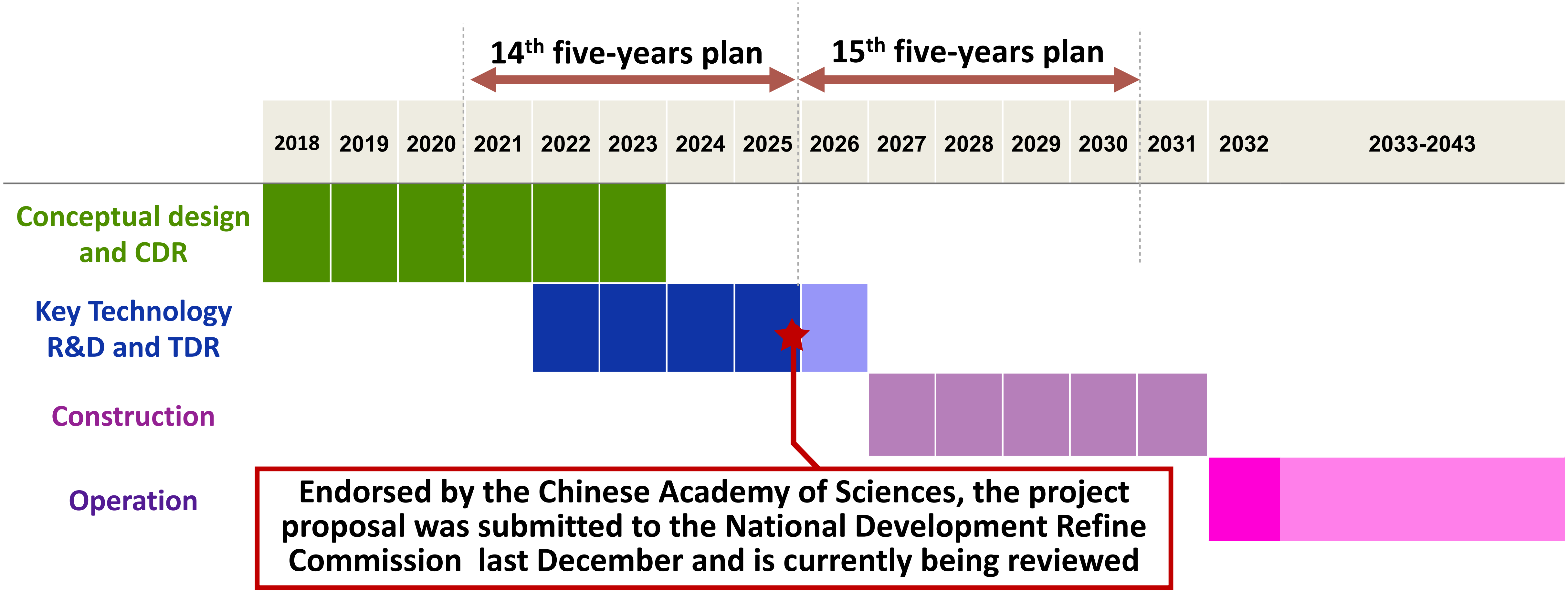
Project Schedule



- 14th five-years plan : Conceptual design and Key technologies R&D, 364 M CNY
- 15th five-years plan : Construction 5 years, ~5 B CNY
- 10-15 years of operation, 3-year upgrade, ~10 years extended operation

STCF 超级陶粲装置 Super Tau-Charm Facility

Project Schedule



- 14th five-years plan : Conceptual design and Key technologies R&D, 364 M CNY
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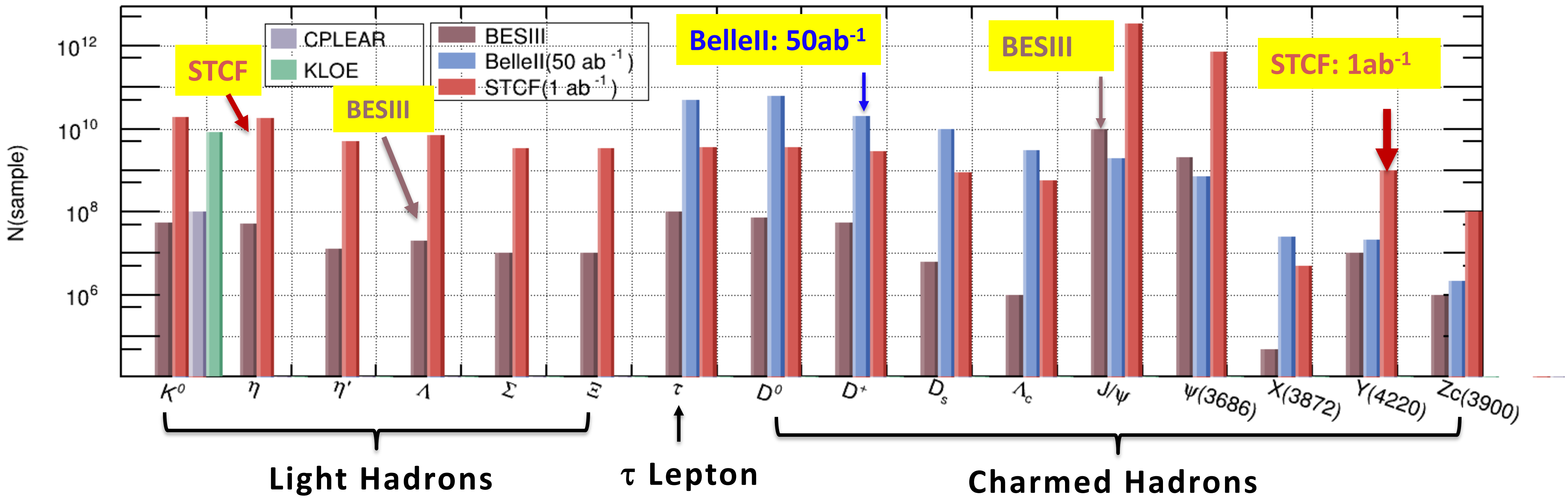
Large Data Samples

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



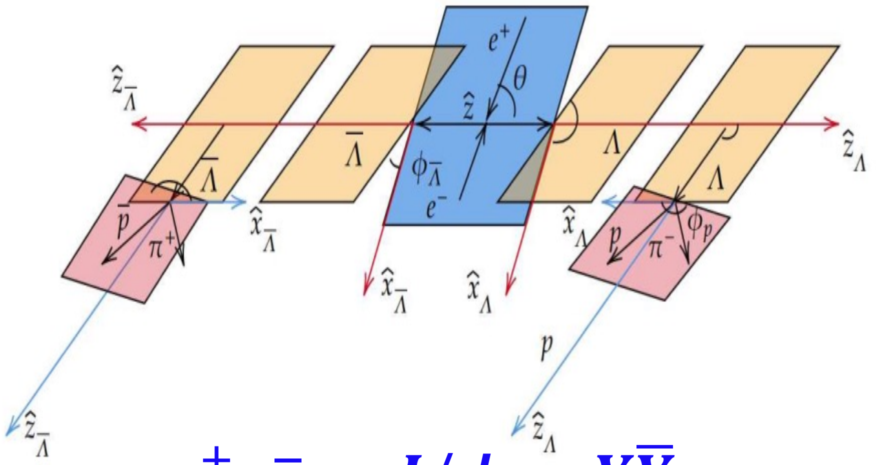
Lage Data Size + High detector performance + Low Bkg ➜ High Precision

Physics I : Asymmetry Test

- The **CP violation** observed in present experiments is inadequate to account for the mystery of antimatter vanishment in the universe
- CP violation in **hyperons** and **charmed baryons** remains undiscovered, representing one of the last uncharted frontiers in hadron physics

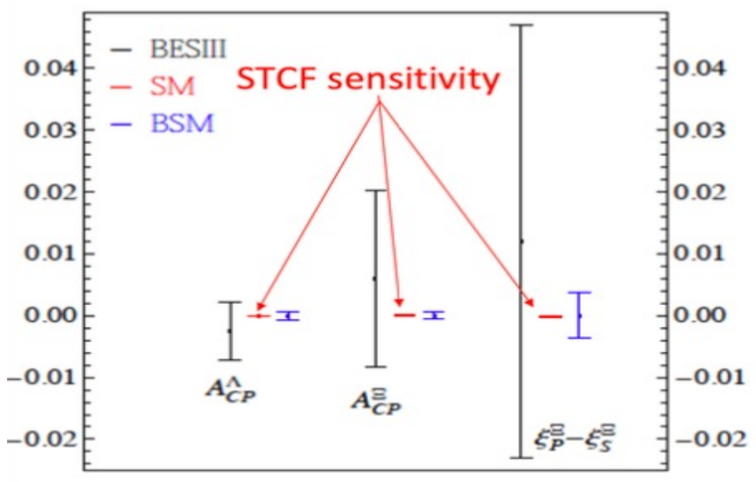
CP Violation in Hyperons

Quantum Correlation

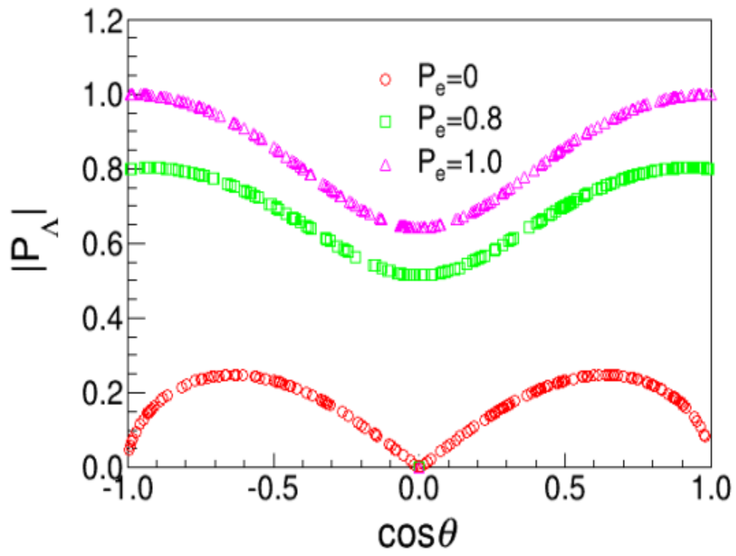


$e^+e^- \to J/\psi \to Y\bar{Y}$

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



SM: 10^{-4}~10^{-5}



- The Polarization feature of hyperon significantly enhances the sensitivity of CP test
- The Large Brs and high statistics J/ψ sample produce abundant hyperon pairs
- Sensitivity of CPV observable with 1 year data: 10^{-5}
- Beam Polarization will further increase the sensitivity

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

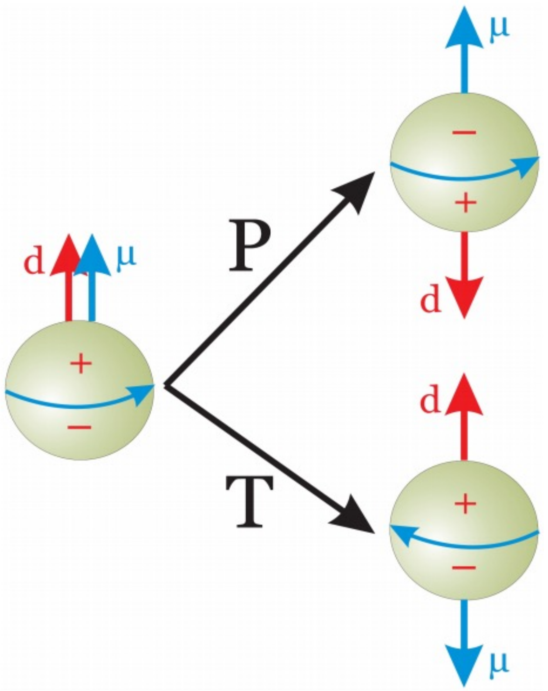
Will discover CPV of Λ hyperons, conduct comprehensive CP tests for the hyperons family ……

EDM in Hyperons

A non-zero electric dipole moment breaks time inversion symmetry, and serves as an indirect evidence of CP violation under the conservation of CPT joint symmetry

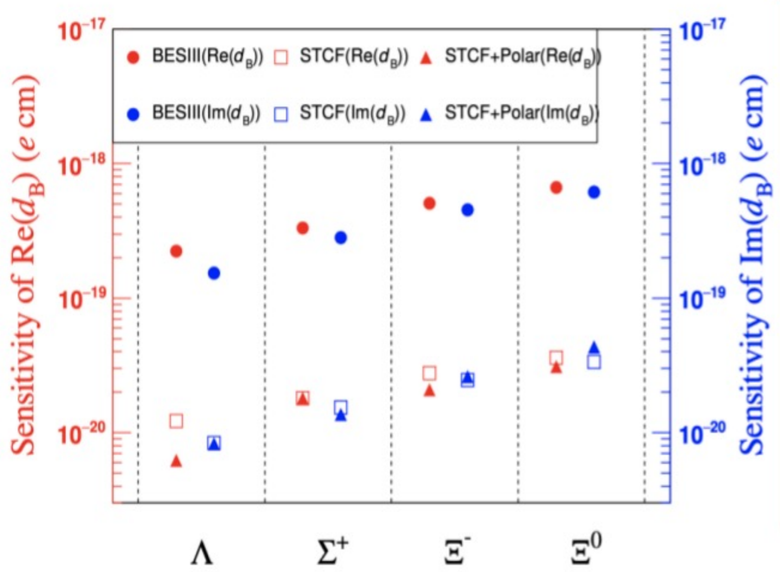
μ: magnetic dipole moment

d: electric dipole moment



Detailed dynamics studied:

$$\mathcal{A} = \epsilon_\mu(\lambda)\bar{u}(\lambda_1)\left(F_V\gamma^\mu + \frac{i}{2M_\Lambda}\sigma^{\mu\nu}q_\nu H_\sigma + \gamma^\mu\gamma^5 F_A + \sigma^{\mu\nu}\gamma^5 q_\nu H_T\right)\nu(\lambda_2)$$



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

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

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

STCF: improved by 2 order of magnitude

Benefiting from polarization and quantum correlation, STCF will achieve world-leading sensitivity in hyperon EDM measurement, and indirectly test CP violation

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CP Symmetry in STCF

Conduct precision tests of CP symmetry on tau lepton, charm hadrons, kaon, EDMs .....

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 0.5×10^{35} cm^{-2}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.

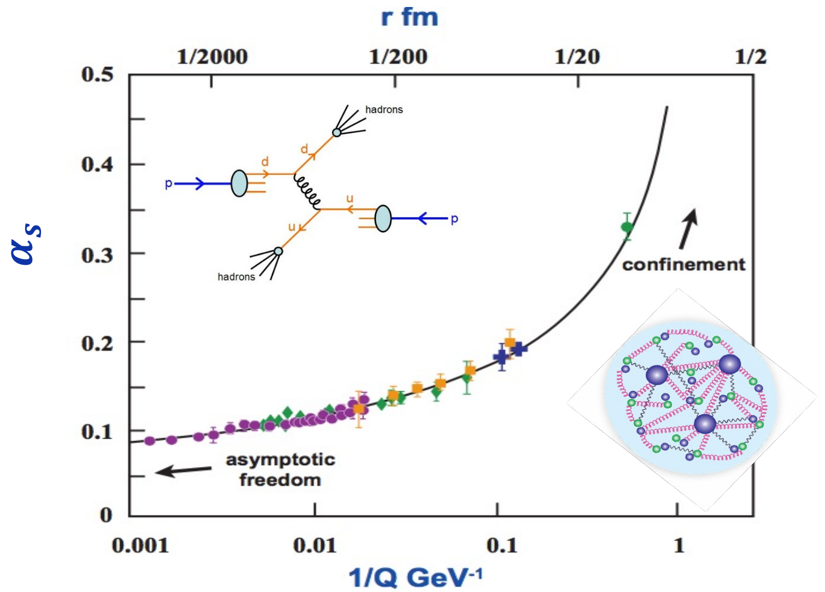
Preprint submitted to PHYSICS REPORTS *September 25, 2024*

Contents

arXiv:2502.08907, submit to Physics Report

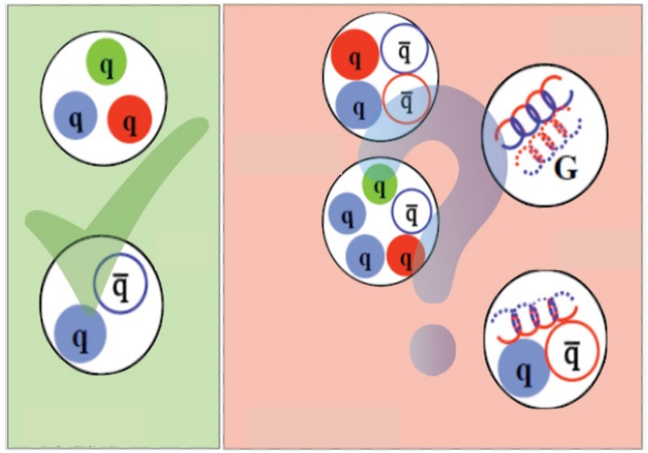
Physics II: Quark Confinement

- Non-perturbative effects represent a major bottleneck for precision measurements and test of SM
- Hadrons and nucleons are essential probes : hadron spectra, nuclear structures, fragmentation functions, EM form factors



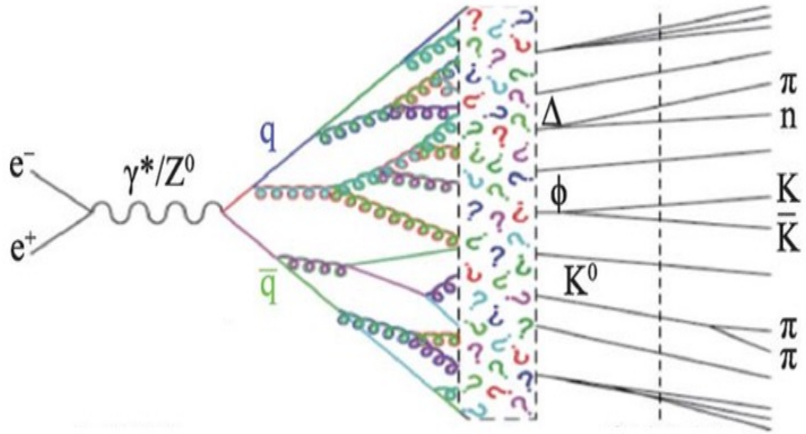
$1/Q$ GeV-1

Asymptotic freedom vs. confinement



Conventional vs. exotic hadrons

Static probe of confinement



Fragmentation

Dynamic probe of confinement

STCF operates in the transition region between perturbative and non-perturbative QCD, providing unique advantages for studying confinement, and enabling breakthrough discoveries

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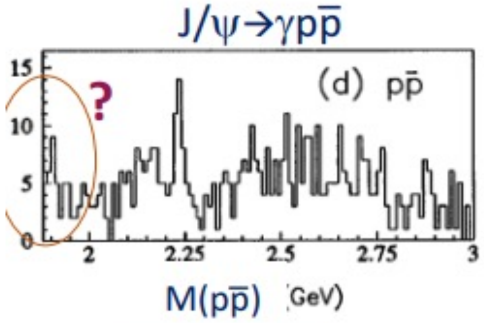
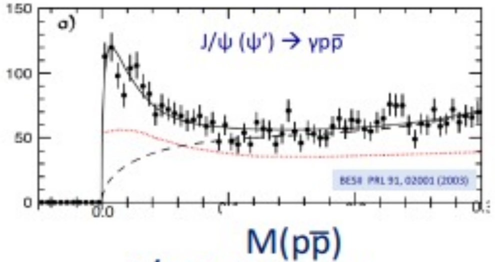
Hadron Spectra: Higher Statistics, Finer Structures

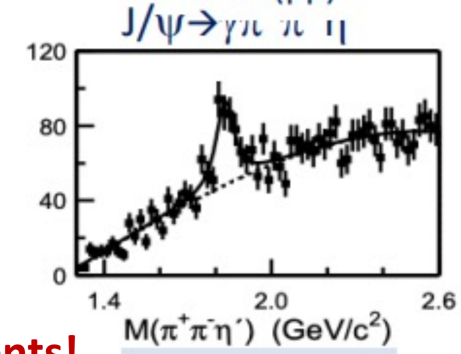
1996: 8 M J/ψ's



PRL 76, 3502

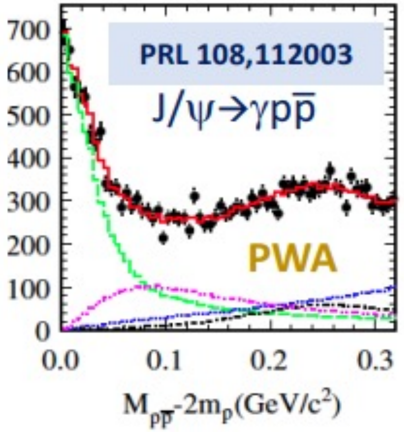
2002: 58 M J/ψ's

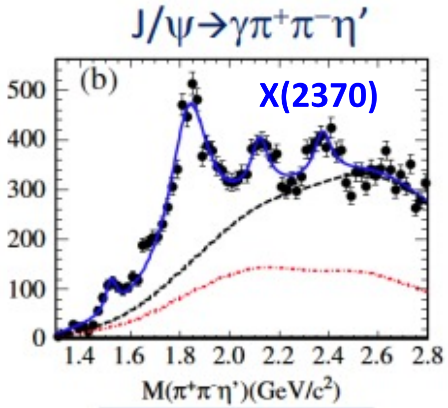




PRL 95,262001

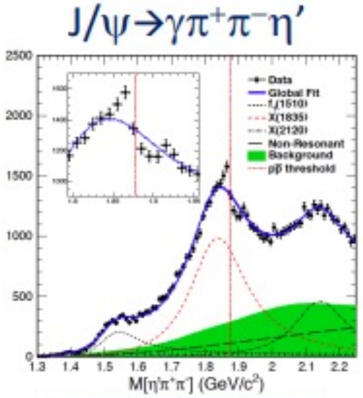
2011: 225 M J/ψ's



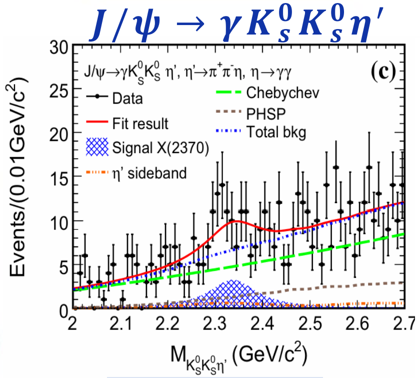


PRL 106,072002

2016: 1.3 B J/ψ's

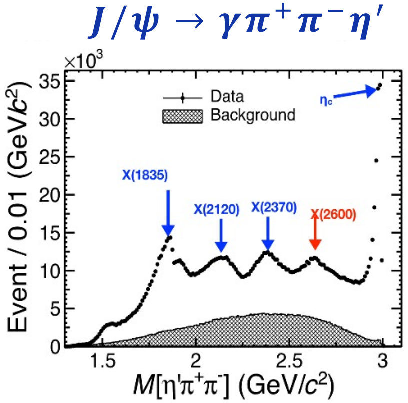


PRL 117,042002

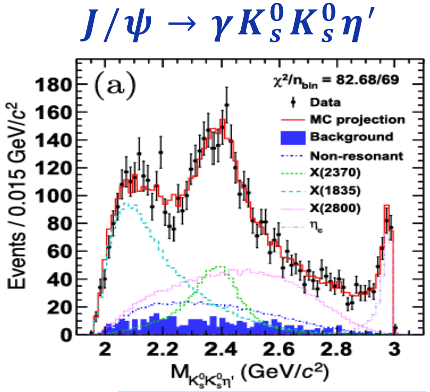


EPJC 80,746

2022: 10B J/ψ's



PRL 129, 042001



PRL 132.181901

0^{-+} Pseudoscalar Glueball-like

You never have enough J/ψ events!

— Stephen Lars Olsen

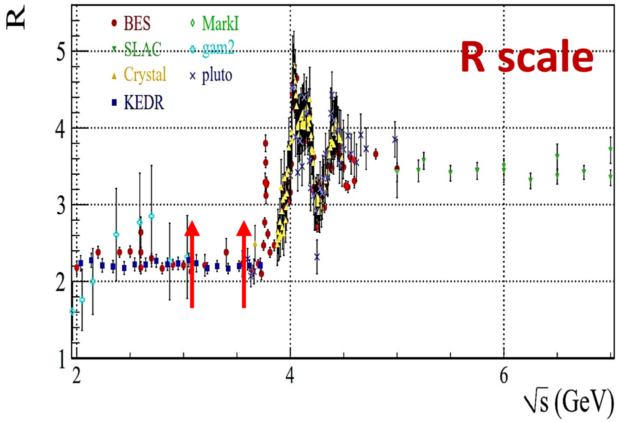
Talk on "Symposium on 30 years of BES Physics", (2019)

- Based on high-statistic and high-precision data, STCF holds a distinct advantage in hadron spectroscopy studies.
- STCF will conduct comprehensive studies on hadron spectroscopy and establish the "Periodic Table of Hadron Elements"

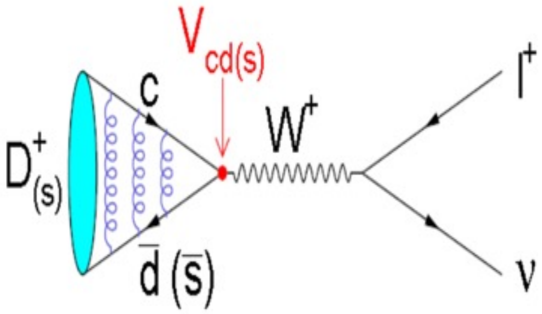
Physics III : Precision measurements and Rare Searches

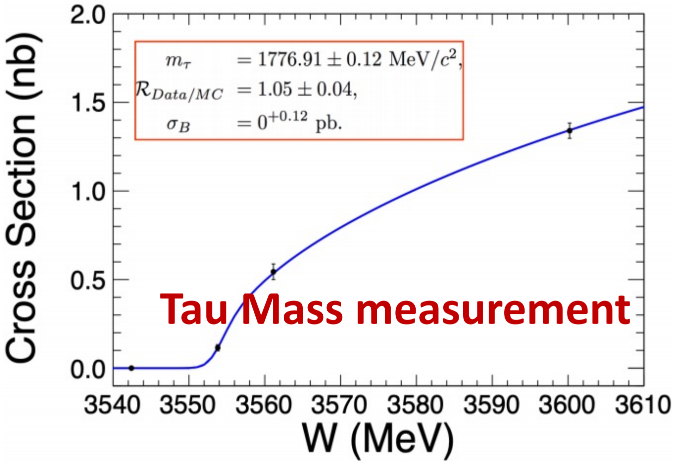
Large statistics, high precision, low background, and threshold effects …..

a series of precise measurements and searches :

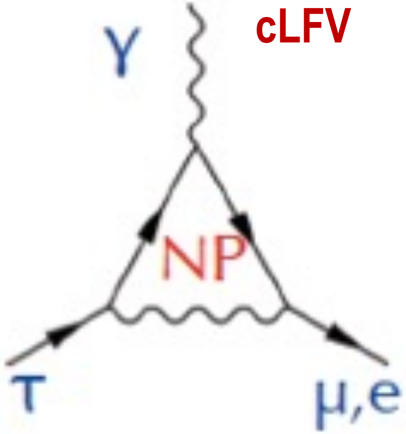


CKM elements





cLFV



Observable	BESIII (2020)	Belle II (50 ab^{-1})	STCF (1 ab^{-1})
Charmonium(like) spectroscopy:			
Luminosity between 4–5 GeV	20 fb^{-1}	0.23 ab^{-1}	1 ab^{-1}
Collins fragmentation functions:			
Asymmetry in $e^+e^- \to KK + X$	0.3 [470]	–	< 0.002 [471]
CP violations:			
A_{cp} in hyperon	0.014 [26]	–	0.00023
A_{cp} in τ	–	$\mathcal{O}(10^{-3})/\sqrt{70}$ [251]	0.0009 [250]
Leptonic decays of $D_{(s)}$:			
V_{cd}	0.03 [472]	–	0.0015
f_D	0.03	–	0.0015
$\frac{\mathcal{B}(D\to\tau\nu)}{\mathcal{B}(D\to\mu\nu)}$	0.2	–	0.005
V_{cs}	0.02 [473]	0.005	0.0015
f_{D_s}	0.02	0.005	0.0015
$\frac{\mathcal{B}(D_s\to\tau\nu)}{\mathcal{B}(D_s\to\mu\nu)}$	0.04	0.009	0.0038
D mixing parameter:			
x	–	0.03	0.05 [474]
y	–	0.02	0.05
τ properties:			
m_τ (MeV/c^{2})	0.12 [475]	–	0.012
d_τ (e cm)	–	2.02×10^{-19}	5.14×10^{-19}
cLFV decays of τ(U.L at 90% C.L.):			
$\tau \to lll$	–	1×10^{-9}	1.4×10^{-9}
$\tau \to \gamma\mu$	–	5×10^{-9}	1.8×10^{-8}
$J/\psi \to e\tau$	7.5×10^{-8}	–	7.1×10^{-10}

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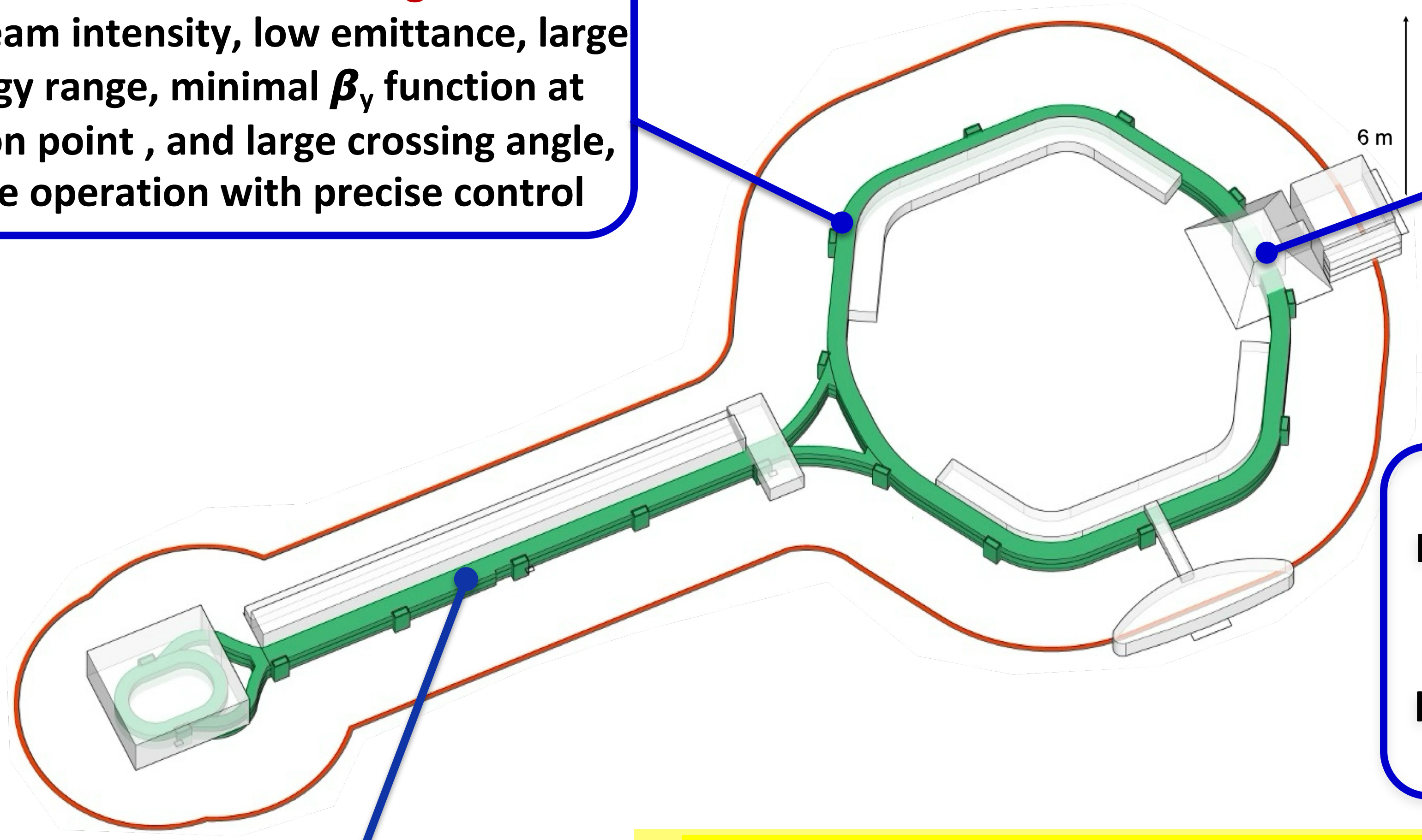
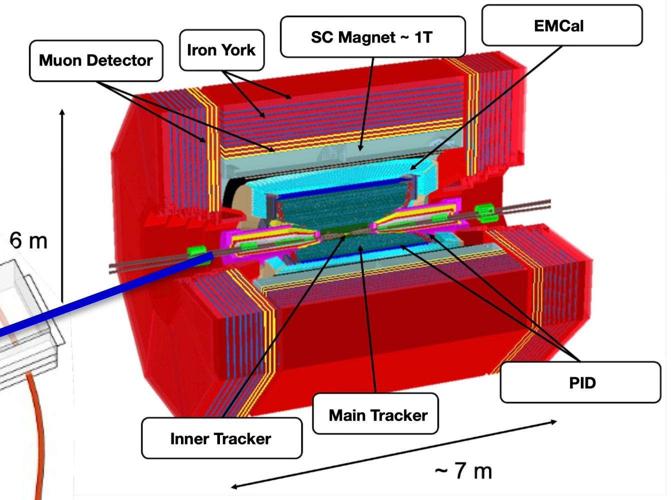
STCF Layout and Key technologies

Double collider ring

High beam intensity, low emittance, large energy range, minimal β_y function at collision point , and large crossing angle, stable operation with precise control





Detector

High precision measurement and particle Identification under Conditions of strong irradiation, high background, high count rate, and wide dynamic range

Beam and Injector

High intensity, high frequency, high quality

The facility faces severe challenges, with system parameters approaching extreme condition …

Accelerator Design

Design goal: CM Energy 2-7 GeV, Luminosity > 5×10^{34} $cm^{-2}s^{-1}$ @ 4 GeV

- A **double Ring Collider** with high current and low emittance beam, crab-waist collision scheme
- An **injector compatible with** both off-axis and swap-out modes (for future upgrades)

arXiv: 2509.11522 [physics.acc-ph] published at NST

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

arXiv: 2509.11522v1 [physics.acc-ph] 15 Sep 2025

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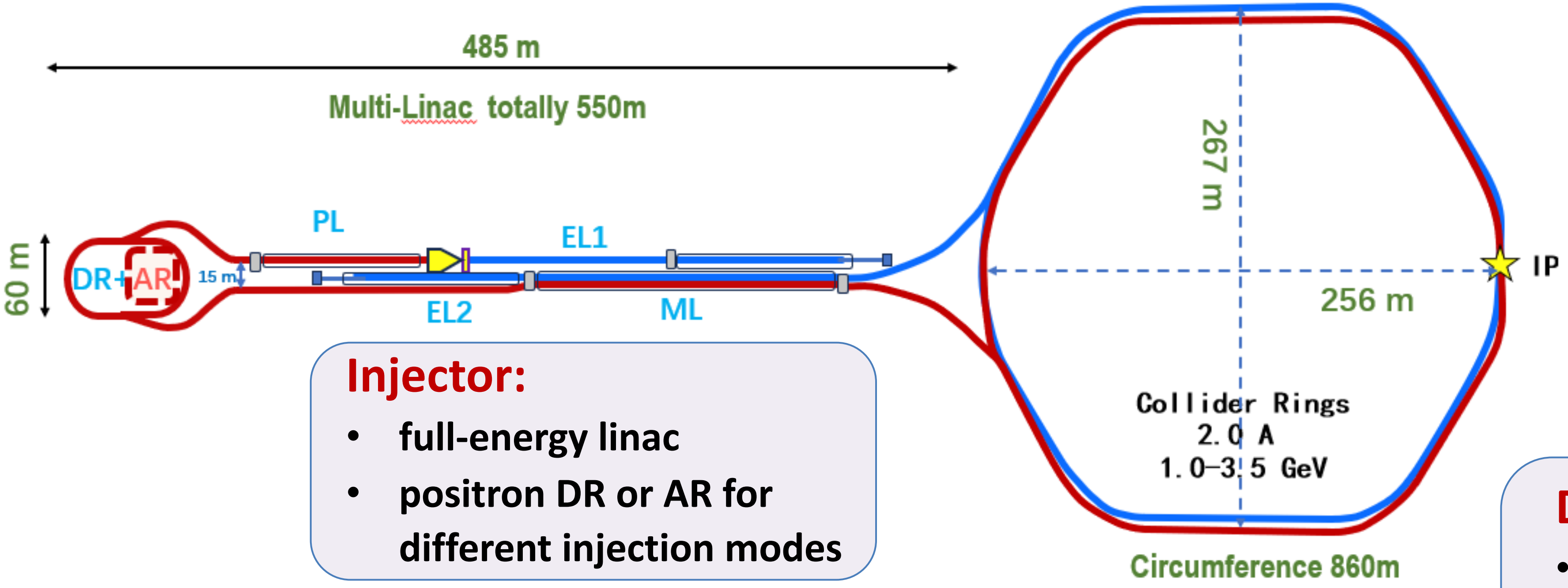


Injector:
- full-energy linac
- positron DR or AR for different injection modes

CM	GeV	4.0	2.0	3.0	7.0
Luminosity	$cm^{-2}s^{-1}$	9.4×10^{34}	6.2×10^{33}	2.1×10^{34}	4.5×10^{34}

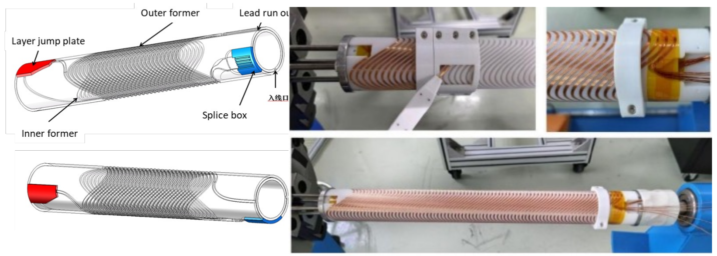
Double-Ring Collider
- low emittance
- high current
- large Piwinski angle
- Crab-waist collision scheme

Key Technologies R&D

Key technology R&D and prototyping underway

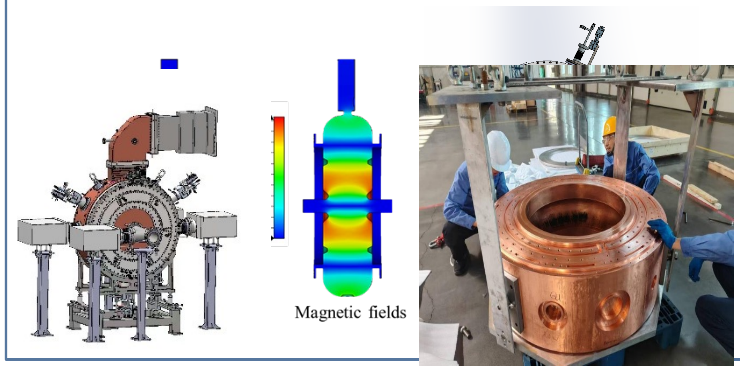
IR SC Magnets

Focus on the QD0, CCT, Vertical test in early 2026

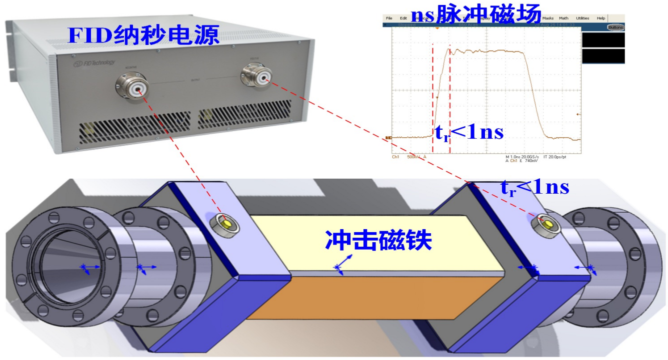


Room-Temperature RF Cavity

TM020-mode

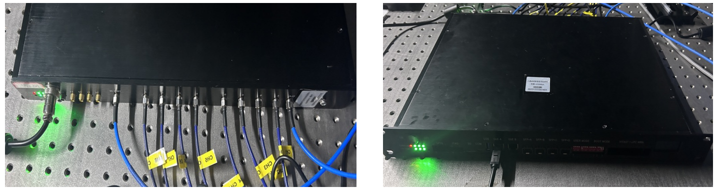


Kicker Magnets



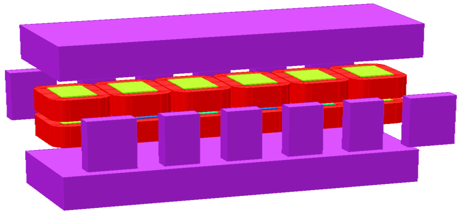
Bunch by Bunch Profile Monitor

Beam tests in different facilities (SSRF, HLS, DLS)

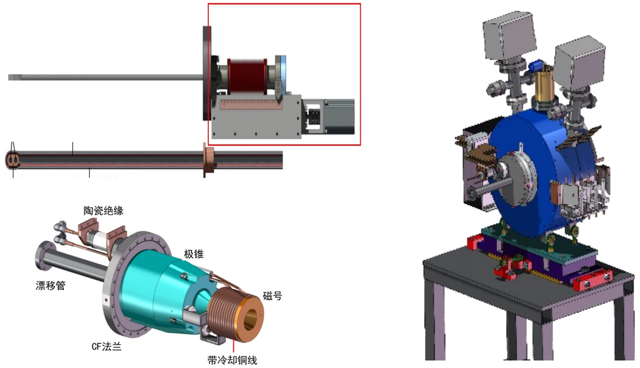


Damping Wigglers

RT electromagnetic wigglers, hybrid structure with permanent magnet blocks

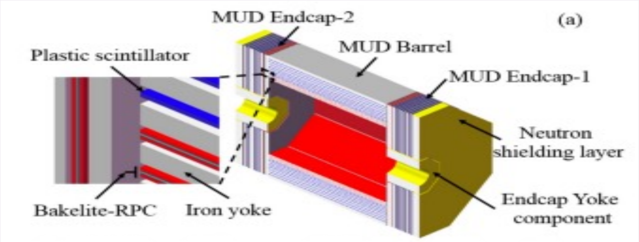


Conventional Positron Source

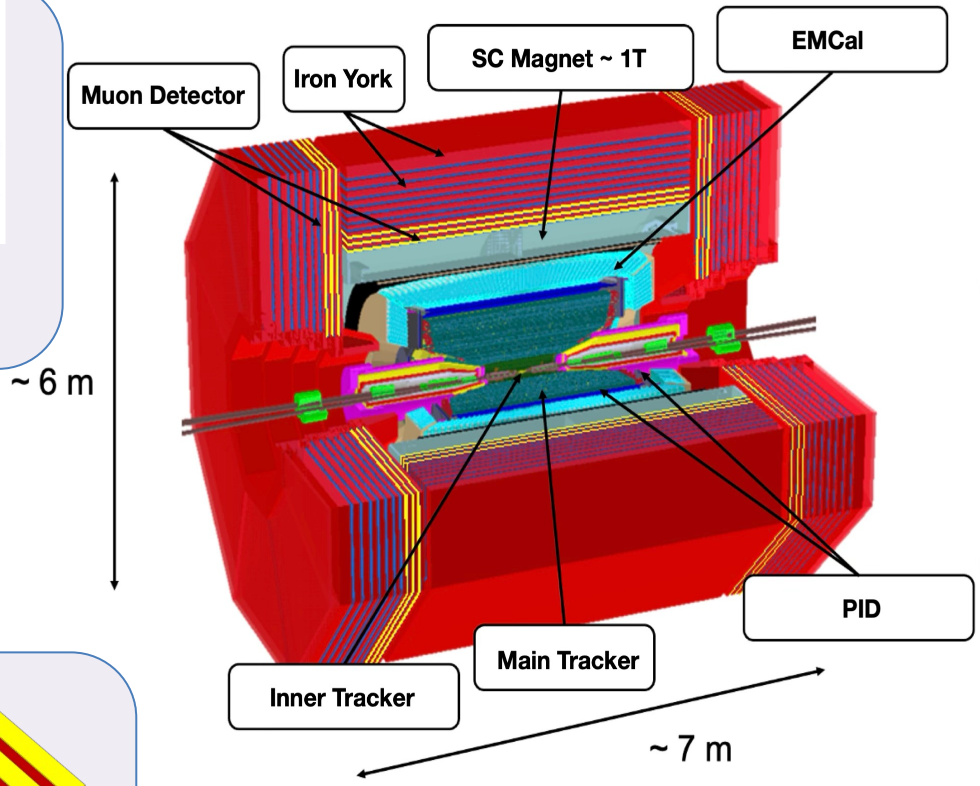


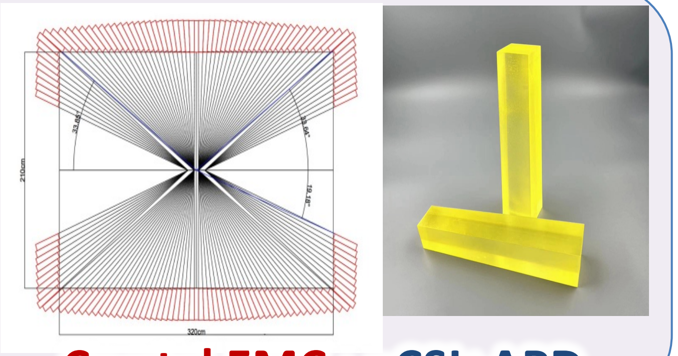
Detector Design

The design is complete and is being optimized

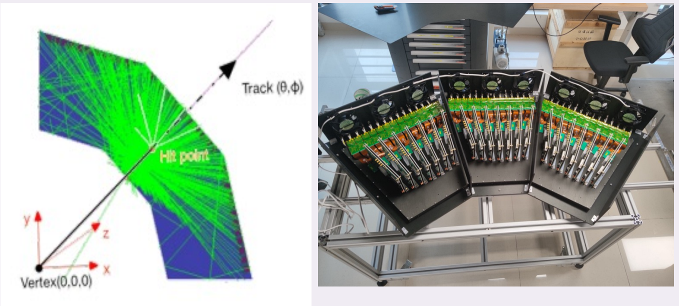


MUD: Glass RPC+ Plastic scintillation Hybrid

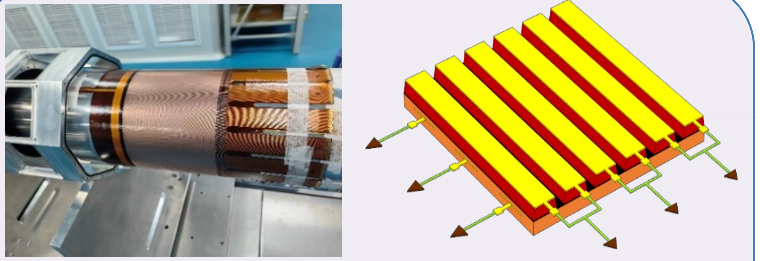




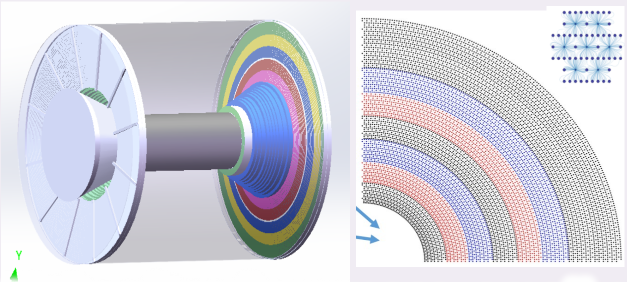
Crystal EMC : pCSI+APD



PID: RICH&DIRC



Inner Tracker :MPGD μRGroove



MDC : ultra-low mass, small cell

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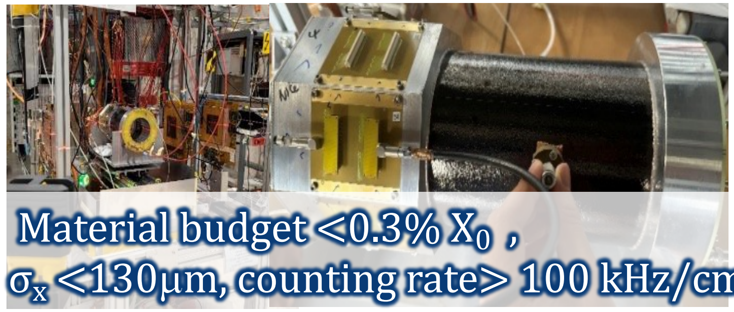
Key Technologies R&D

Excellent progress achieved, All system prototypes established

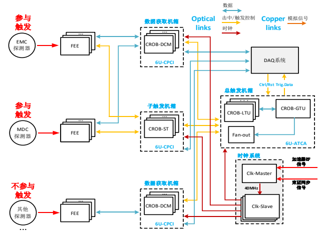
Cylindrical µRGroove prototype

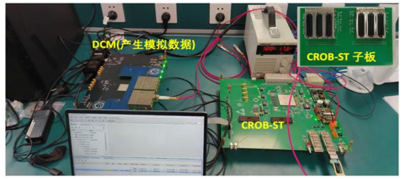


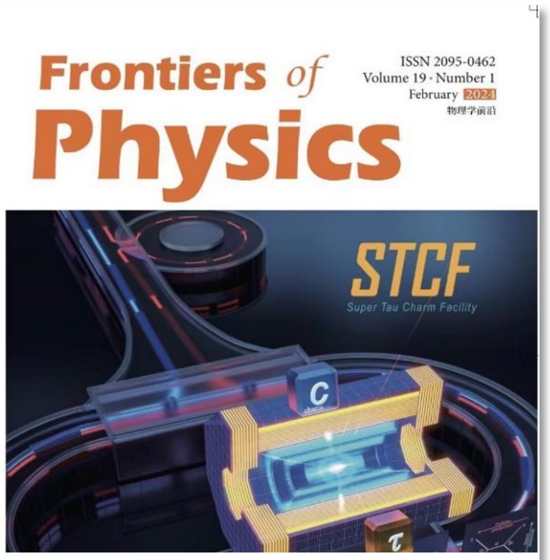
Material budget <0.3% X_0 ,
σ_x <130µm, counting rate> 100 kHz/cm^2

ITK: CMOS prototype chips

Trigger

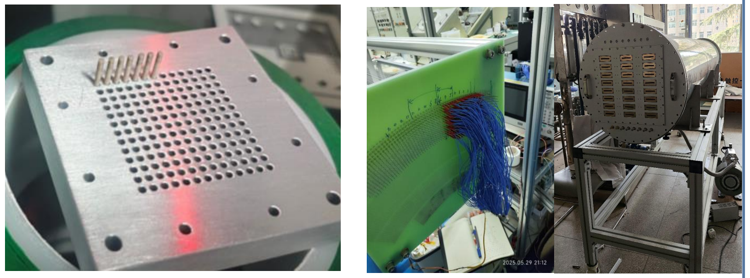




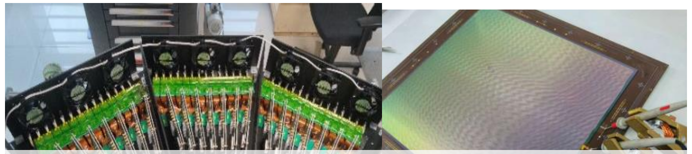


Detector and Physics CDR published in 2023

Main tracker full length prototype



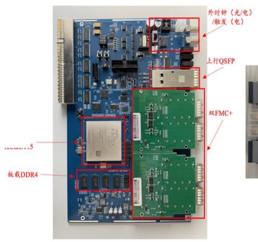
PID prototype



Area>0.6m^2,
time resolution < 30 ps (100 MHz bkg)
π/K 4.4σ seperation@ 4 GeV/c

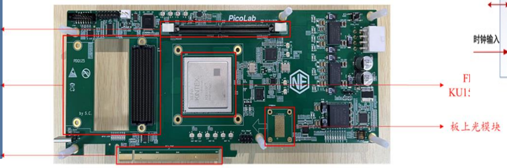
DAQ

CROB-PXI board



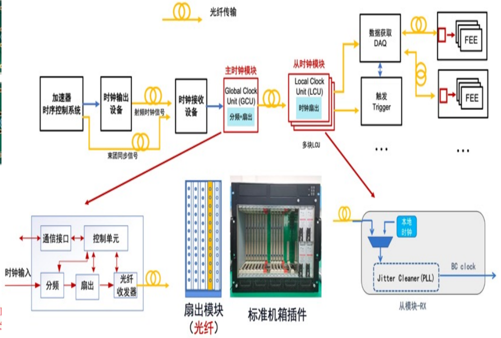
FMCP optical interface board

CROB-PCIe board



ASIC & CLOCK

□ "主-从" 时钟模块：分频、扇出，低抖动



EMCal: 5 X 5 prototype

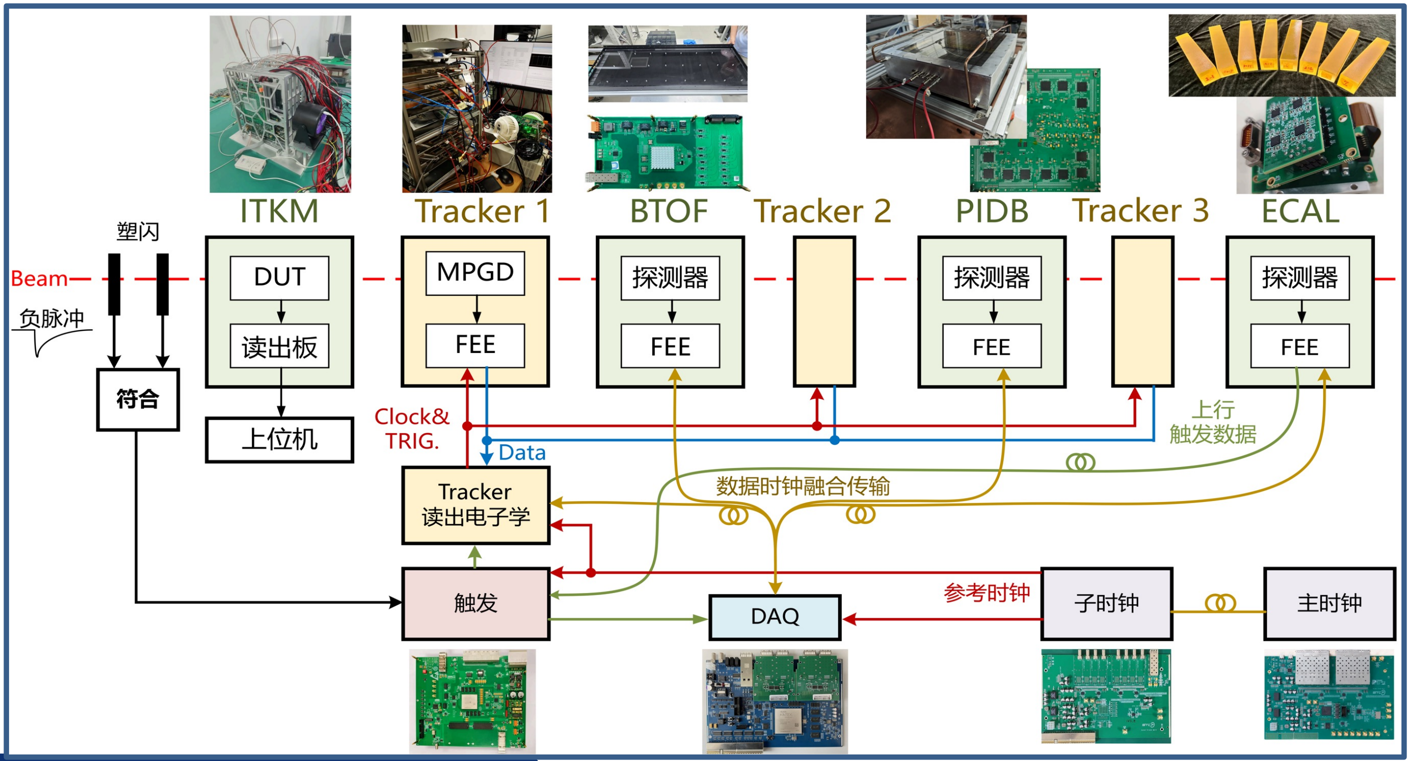
Muon: Plastic Scintillator+ RPC

Joint Beam Test

A test beam for a combined system (DTOF, EMC, DAQ) on Jul. 31 – Aug.14, 2024

Second beam test with all systems was carried out at CERN from Oct.15 to 29, 2025

- **Involving larger-scale systems, including ITK, PID, EMC, Clock system, trigger system, and DAQ.**
- **Based on the STCF software framework, modeling and simulation of beam test joint system, a full chain data processing and analysis workflow was established**

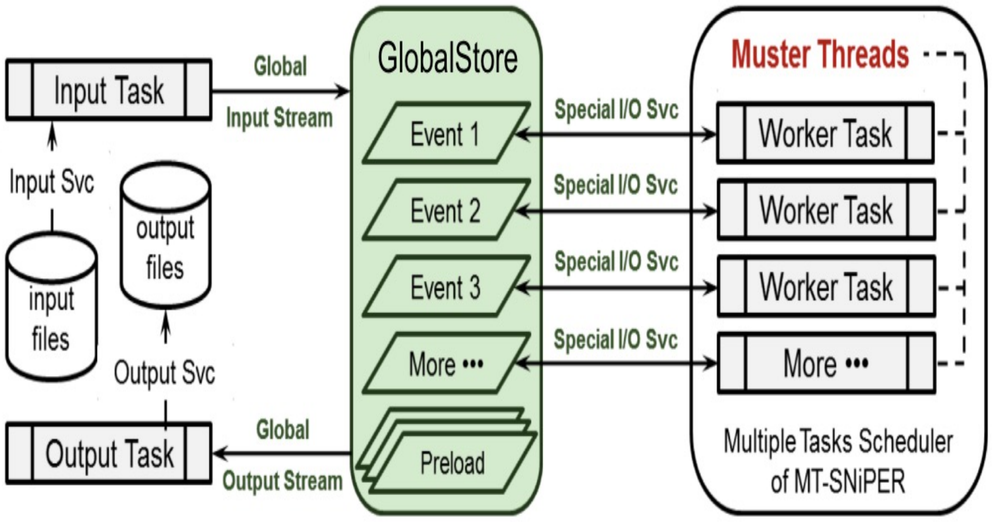


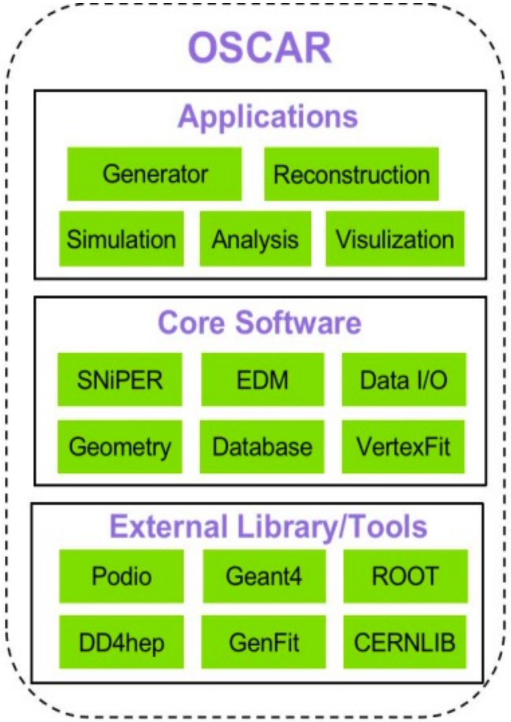
Offline Software and full simulation

STCF 超级陶粲装置 Super Tau-Charm Facility

The STCF offline software system (OSCAR) is developed based on SNiPER and the state-of-the-art technologies, such as:

- Event Data Model based on **podio**
- Geometry based on **DD4hep**
- Fast simulation (**GAN and sampling)**
- Tracking with **ACTS** (as an option)
- Analysis framework with **RDataFrame**
- ML inference with **ONNX**
- Parallel computing with **TBB**
- Software deployment with **Spack**
- Modern CI powered by **LLM**
- Support for **heterogenous** resources





Comput.Softw.Big Sci. 9 (2025) 1, 3
Mod.Phys.Lett.A 39 (2024) 40, 2440006
JINST 18 (2023) 03, P03004
J.Phys.Conf.Ser. 2438 (2023) 1, 012054

JINST 18 P03004

Offline software has been used for detector design/optimization and physics potential studies
A TDR will be ready in summer

Contents

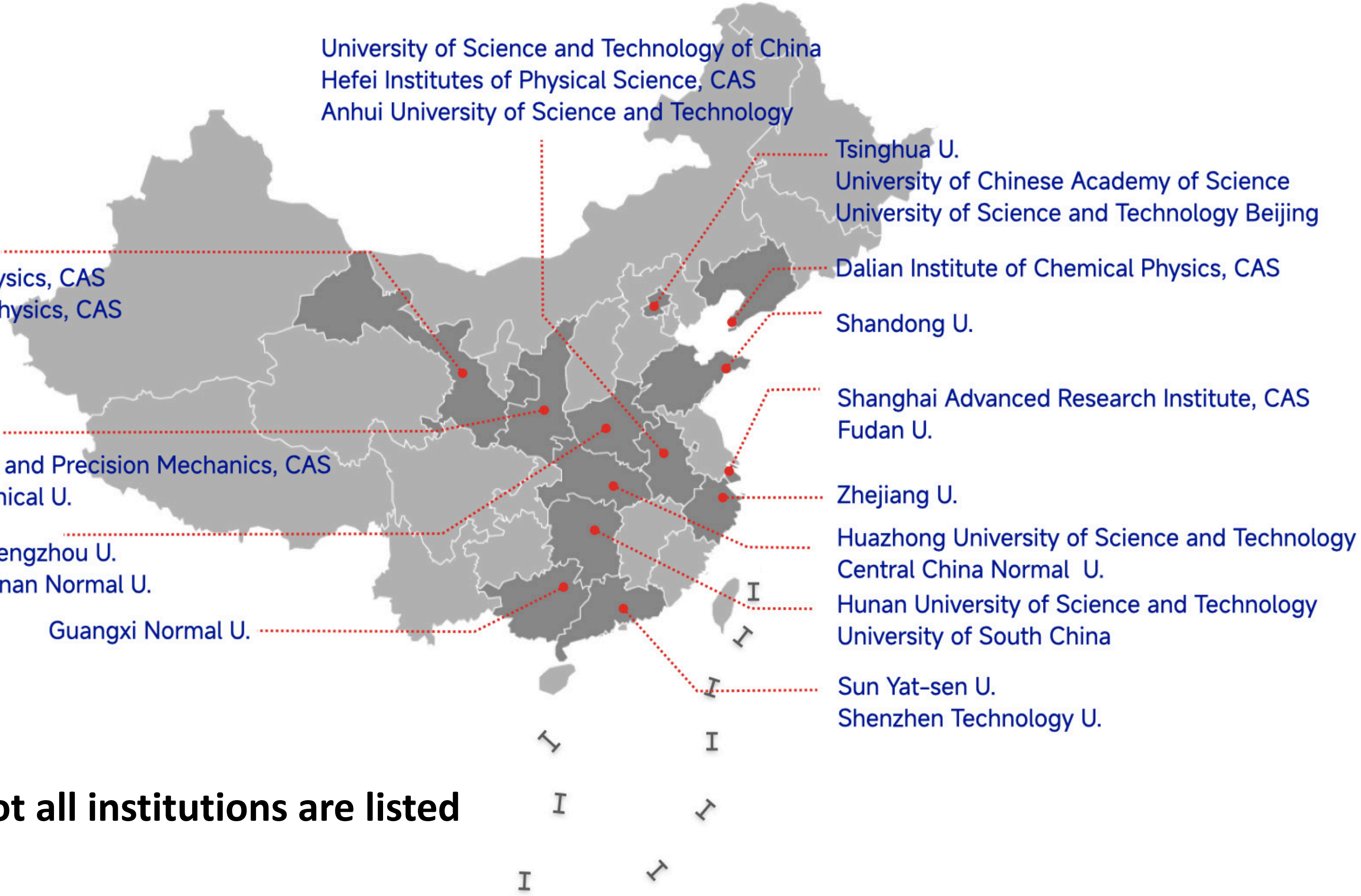
Funding for R&D project

	Funding Agency	Project type	Amount (CNY)
2023 - 2026	Local Government	Key Technology R&D Project	364.0 M
2018 - 2021	USTC	Double First-Class key project	15.0 M
2020 - 2022	CAS	Key Technology Team Project	15.0 M
2021 - 2026	CAS	International Partnership program	5.0 M
2022 - 2027	MOST	National Key R&D Program of China	17.5 M
2023 - 2027	NSFC	Key Group Project	14.0 M

Super Tau-Charm Facility

Key Tech. R&D Team

41 Universities/Institutes in R&D project:
240 faculties and 300 graduate students



Not all institutions are listed

Physics Research

Institute of theoretical physics, CAS
Institute of High energy physics, CAS
Tsung-Dao Lee Institute
Perking University
Shanghai Jiao Tong University
Nanjing University
Wuhan University
Nankai University
South China Normal University
Beijing Normal University
China University of Geosciences
Liaoning University
Nanjing Normal University
Hebei Normal University
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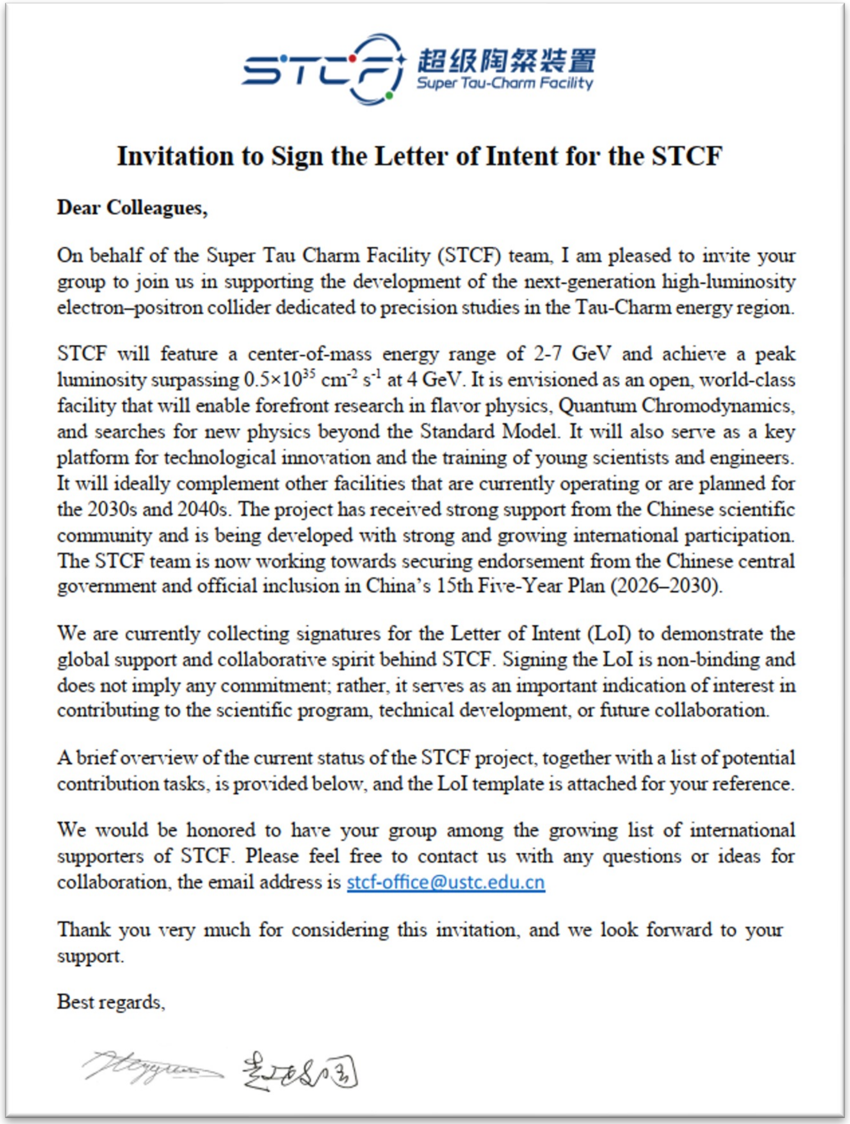
Letter of Intent


Invitation to Sign the Letter of Intent for the STCF

Dear Colleagues,

On behalf of the Super Tau Charm Facility (STCF) team, I am pleased to invite your group to join us in supporting the development of the next-generation high-luminosity electron–positron collider dedicated to precision studies in the Tau-Charm energy region.

STCF will feature a center-of-mass energy range of 2-7 GeV and achieve a peak luminosity surpassing 0.5×10^{35} cm^{-2} s^{-1} at 4 GeV. It is envisioned as an open, world-class facility that will enable forefront research in flavor physics, Quantum Chromodynamics, and searches for new physics beyond the Standard Model. It will also serve as a key platform for technological innovation and the training of young scientists and engineers. It will ideally complement other facilities that are currently operating or are planned for the 2030s and 2040s. The project has received strong support from the Chinese scientific community and is being developed with strong and growing international participation. The STCF team is now working towards securing endorsement from the Chinese central government and official inclusion in China's 15th Five-Year Plan (2026–2030).

We are currently collecting signatures for the Letter of Intent (LoI) to demonstrate the global support and collaborative spirit behind STCF. Signing the LoI is non-binding and does not imply any commitment; rather, it serves as an important indication of interest in contributing to the scientific program, technical development, or future collaboration.

A brief overview of the current status of the STCF project, together with a list of potential contribution tasks, is provided below, and the LoI template is attached for your reference.

We would be honored to have your group among the growing list of international supporters of STCF. Please feel free to contact us with any questions or ideas for collaboration, the email address is stcf-office@ustc.edu.cn

Thank you very much for considering this invitation, and we look forward to your support.

Best regards,

27 Countries,
160 Institutions

Oversea
72 Institutions

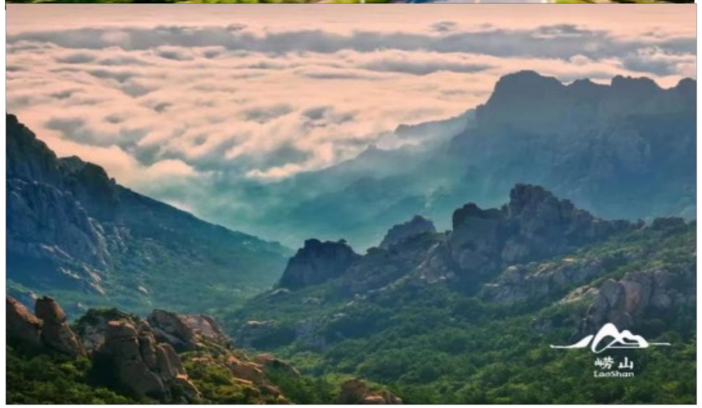
China, the United States, the United Kingdom, France, Germany, Japan, Italy, Spain, Sweden, Switzerland, Poland, Russia, Slovenia, Ireland, Brazil, Turkey, Georgia, Israel, Australia, Peru, Colombia, Mexico, the Republic of Korea, Thailand, India, Pakistan, Philippines

Workshops: Future Tau Charm Facilities

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	1st FTCF (Joint International Workshop)
2019.08	Moscow, Russia	2nd FTCF
2020.11	Online	3rd FTCF
2021.11	Online	4th FTCF
2024.01	Hefei, China	5th FTCF
2024.11	Guangzhou, China	6th FTCF
2025.11	Huangshan, China	7th FTCF
2026.11	Qingdao, China	8th FTCF

The 8th International Workshop on Future Tau Charm Facilities (FTCF 2026)

Qingdao (aka. Tsingtao), China
Nov. 22 - 26, 2026
https://indico.pnp.ustc.edu.cn/event/6379/



Contents

Summary

- STCF features a rich physics program in tau-charm sector, addressing: how quarks form matter, symmetry in fundamental interactions (CP violation), and high-precision measurements of fundamental parameters
- Key technology R&D is on track and critical challenges are being addressed
- The project is well organized and has achieved significant progresses.
- The project is being reviewed by the National Development Refine Commission(NDRC) endorsed by Chinese Academy of Science (CAS)
- International collaboration is expanding; synergies and in-depth collaboration with global projects are being actively pursued

Thank you for your attention!