



超级陶粲装置
Super Tau-Charm Facility

超级陶粲装置综述

周小蓉 (代表STCF工作组)
中国科学技术大学

第三届“有道真论”理论物理前沿研究与教学研讨会
2025年12月5-8日, 山东 济南

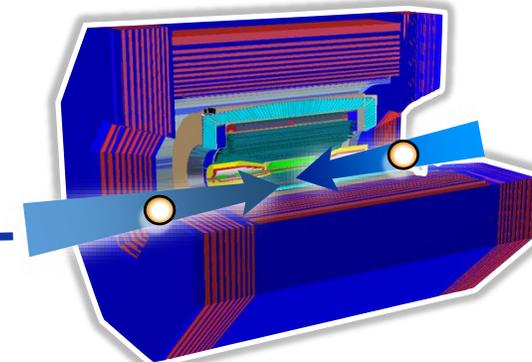
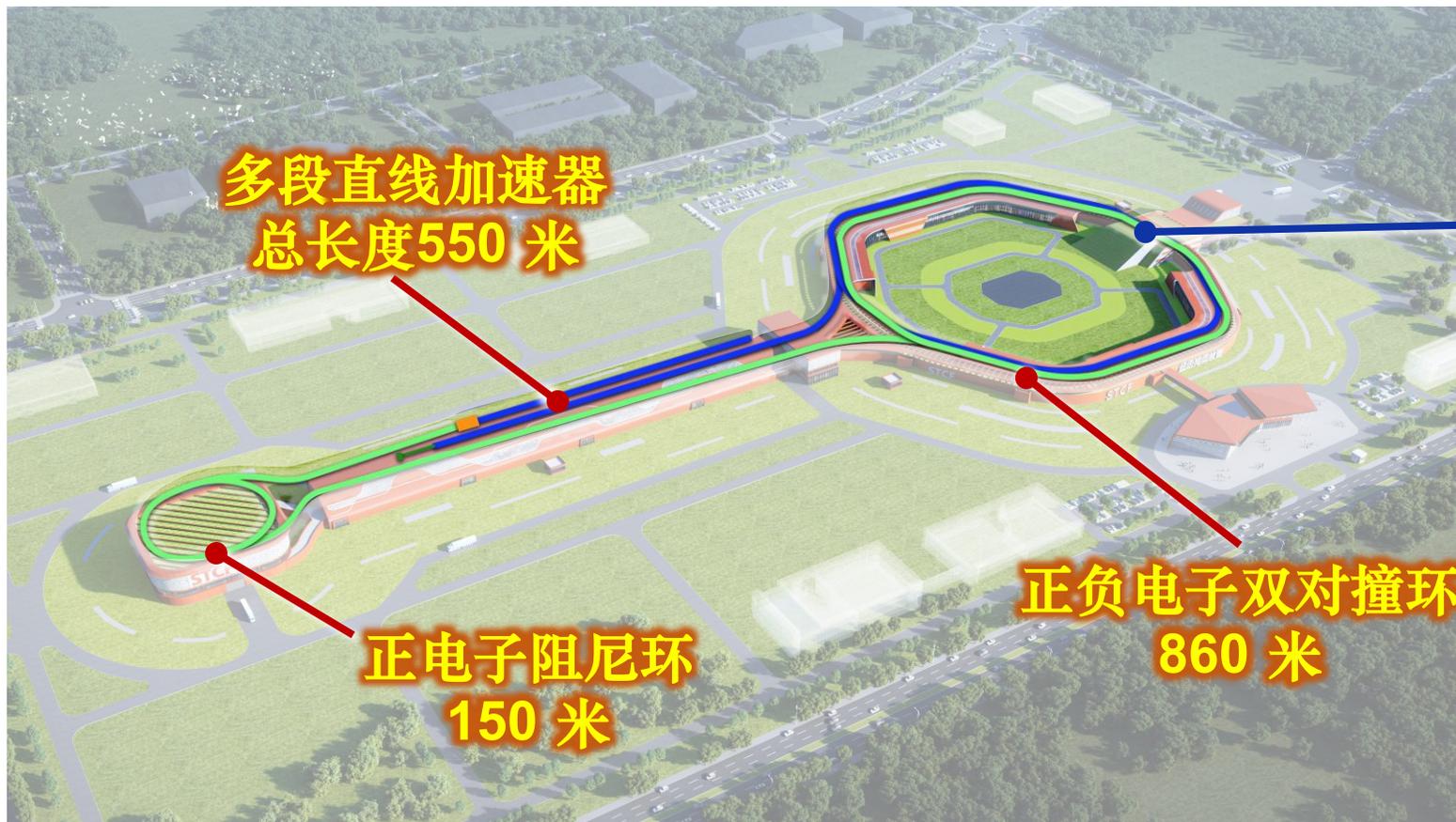
- **超级陶粲装置**
- **物理目标**
- **关键技术预研**
- **项目推进和现状**
- **总结和展望**

- **超级陶粲装置**
- 物理目标
- 关键技术预研
- 项目推进和现状
- 总结和展望

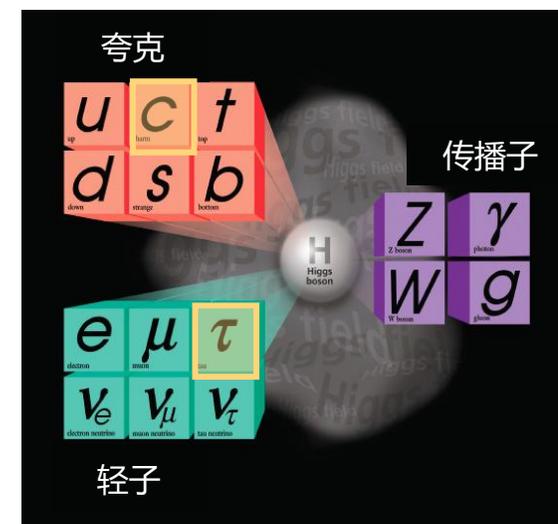
新一代大科学装置：超级陶粲装置



第三代正负电子对撞机，国际粒子物理领域高亮度前沿核心装置之一
研究夸克如何形成物质和基本相互作用对称性的独特平台



粒子探测谱仪



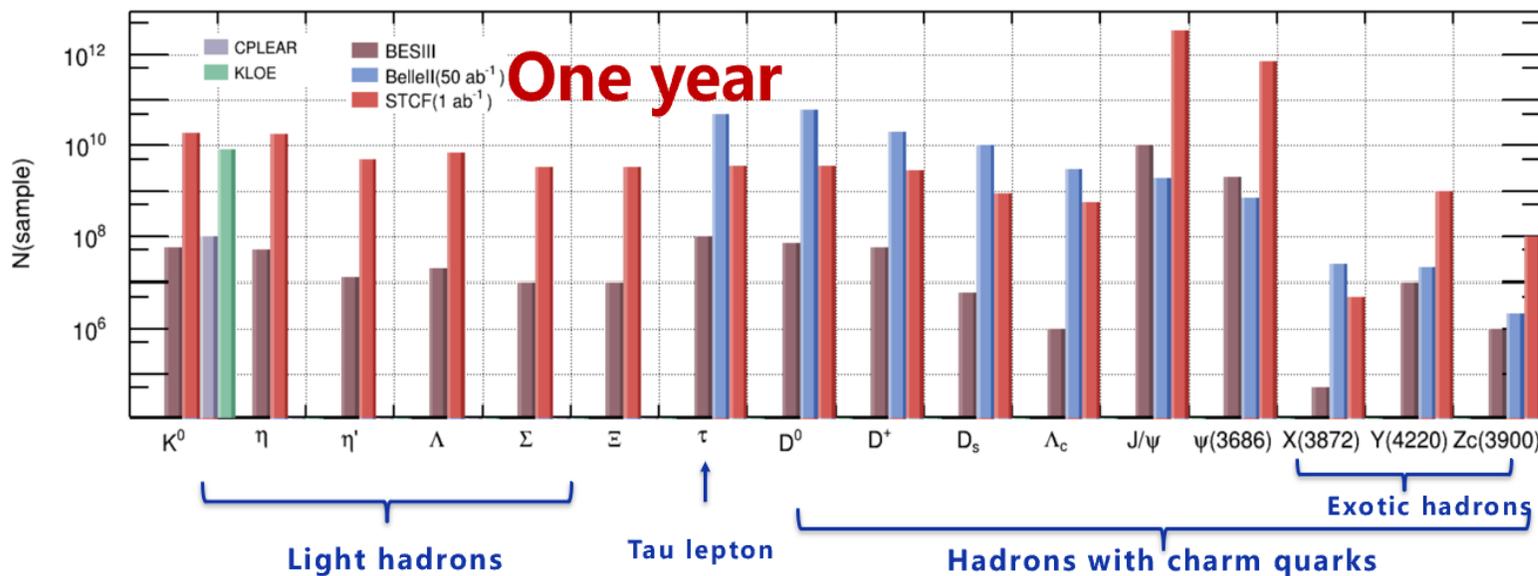
超宽连续可调能量：2 ~ 7 GeV，超高亮度： $0.5 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$

强子化效应最为显著能区，相比其他对撞机有不可比拟的优势

STCF的预期事例数



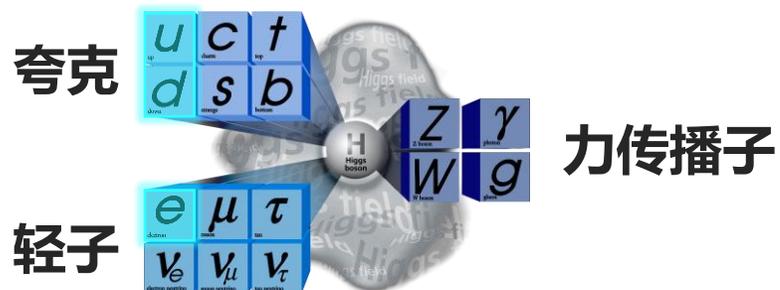
- STCF能够产生**万亿级 ψ 样本**，**数十亿粲强子对和陶轻子对**，以及**大量的XYZ粒子**
- STCF具有**质心能量连续可调**，**成对阈值产生**，**量子关联**等独特性质



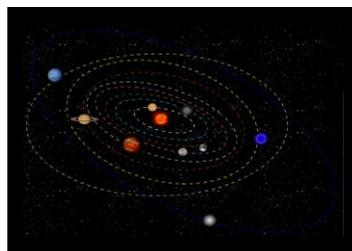
CME (GeV)	Lumi (ab ⁻¹)	Samples	σ (nb)	No. of Events	Remarks
3.097	1	J/ψ	3400	3.4×10^{12}	
3.670	1	$\tau^+\tau^-$	2.4	2.4×10^9	
3.686	1	$\psi(3686)$	640	6.4×10^{11}	
		$\tau^+\tau^-$	2.5	2.5×10^9	
3.770	1	$\psi(3686) \rightarrow \tau^+\tau^-$		2.0×10^9	
		$D^0\bar{D}^0$	3.6	3.6×10^9	Single tag
		$D^+\bar{D}^-$	2.8	2.8×10^9	
		$D^0\bar{D}^0$		7.9×10^8	Single tag
		$D^+\bar{D}^-$		5.5×10^8	
$\tau^+\tau^-$	2.9	2.9×10^9			
4.009	1	$D^{*0}\bar{D}^0 + c.c.$	4.0	1.4×10^9	CP _{D⁰\bar{D}^0} = +
		$D^{*0}\bar{D}^0 + c.c.$	4.0	2.6×10^9	
		$D_s^+D_s^-$	0.20	2.0×10^8	CP _{D⁰\bar{D}^0} = -
		$\tau^+\tau^-$	3.5	3.5×10^9	
4.180	1	$D_s^{*+}D_s^- + c.c.$	0.90	9.0×10^8	Single tag
		$D_s^{*+}D_s^- + c.c.$		1.3×10^8	
4.230	1	$\tau^+\tau^-$	3.6	3.6×10^9	
		$J/\psi\pi^+\pi^-$	0.085	8.5×10^7	
4.360	1	$\gamma X(3872)$		3.6×10^9	
		$\psi(3686)\pi^+\pi^-$	0.058	5.8×10^7	
4.420	1	$\tau^+\tau^-$	3.5	3.5×10^9	
		$\psi(3686)\pi^+\pi^-$	0.040	4.0×10^7	
4.630	1	$\tau^+\tau^-$	3.5	3.5×10^9	
		$\psi(3686)\pi^+\pi^-$	0.033	3.3×10^7	Single tag
		$\Lambda_c\bar{\Lambda}_c$	0.56	5.6×10^8	
		$\Lambda_c\bar{\Lambda}_c$		6.4×10^7	
$\tau^+\tau^-$	3.4	3.4×10^9			
4.0-7.0	3	300-point scan with 10 MeV steps, 1 fb ⁻¹ /point			
> 5	2-7	Several ab ⁻¹ of high-energy data, details dependent on scan results			

- 超级陶粲装置
- **物理目标**
- 关键技术预研
- 项目推进和现状
- 总结和展望

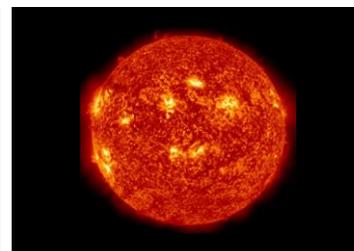
粒子物理的**标准模型**取得了**巨大成功**



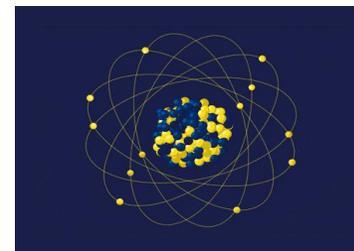
质子和中子由第一代夸克构成
与电子构成稳定的物质世界



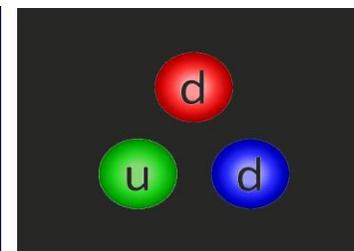
万有引力
Gravity
Magnitude = 1



弱相互作用力
Weak Force
Magnitude = 10^{25}



电磁力
Electromagnetism
Magnitude = 10



强相互作用力
Strong Force
Magnitude = 10^{38}

标准模型面临的**重大挑战**

为什么宇宙正反物质不对称?

夸克如何形成物质?

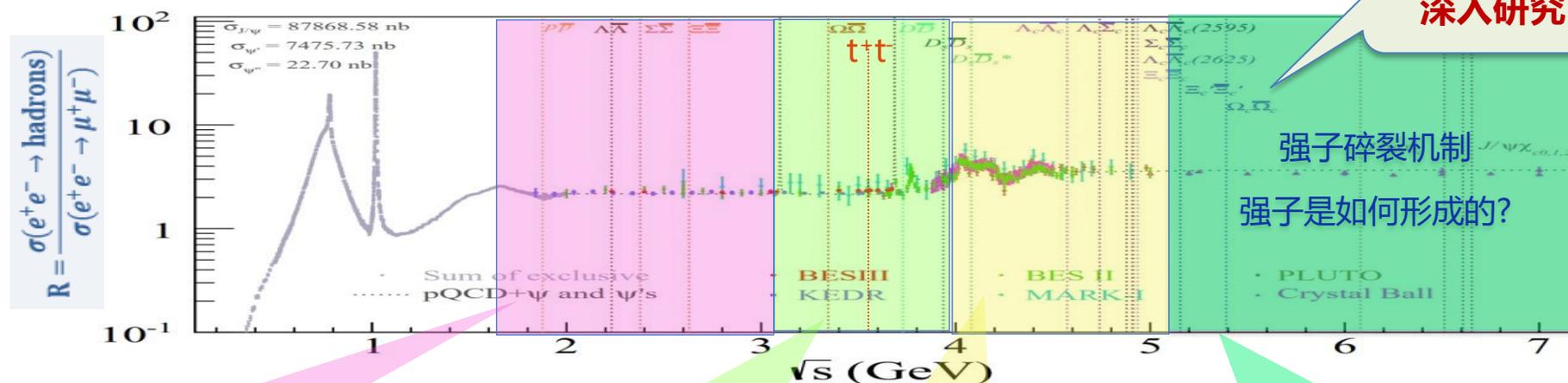
物质深层次结构是什么?

夸克为什么囚禁在物质中?

诺贝尔奖得主 David Gross:
夸克形成物质的过程 (强子化)
是量子场论重大未解决难题



- 微扰与非微扰量子色动力学的过渡能区
- 丰富的共振结构、巨大的粲偶素态产生截面、阈值产生强子对和 τ 轻子对
- 大量奇特量子数强子、胶子态、多夸克态、夸克胶子混合态



有待进一步
深入研究

- Nucleon/Hadron form factors
- $Y(2175)$ resonance
- Multiquark states with s quark
- MLLA/LPHD and QCD sum rule predictions

- LH spectroscopy
- Gluonic and exotic
- LFV and CPV
- Rare/forbidden decays
- Physics with τ lepton

- XYZ particles
- Physics with D mesons
- f_D and f_{D_s}
- D_0 - D_0 mixing
- Charm baryons

- Di-charmonium state
- New XYZ particle
- Hidden-charm pentaquark
- Multiquark state
- Charm baryons
- Hadron fragmentation

基本对称性检验
超子和陶轻子CP破坏
 $K^0 - \bar{K}^0$ 系统CPT对称性
轻子味破坏等

探索色禁闭之谜
强子谱和强子结构
碎裂函数和能量关联

基本物理量精确测量
R值、陶质量
电磁、强跑动耦合常数
CKM矩阵元

- **时空分立对称性**的守恒和破坏在了解**宇宙演化和自然规律**中起着非常重要的作用。目前已知空间宇称P，时间反演宇称T，电荷宇称C以及CP联合变换对称性的**破缺已被实验证实**。
- **电荷宇称 (CP) 不对称性**是形成正反物质不对称的三大**必要条件**之一，历史上两次CP不对称性研究突破都**获得诺奖**，**但仍然**无法解释正物质多于反物质的谜团，亟需寻找超出标准模型CP不对称性的新来源。
- STCF将产生**高统计量**的J/ψ和ψ(2S)粲偶素粒子、粲强子、超子、陶轻子和轻介子 (K, η, η')等，能够从**多个方面**对各种对称性进行精确检验。

K介子CP破坏[1]

B介子CP破坏 [2,3]

D介子CP破坏 [4]

B重子CP破坏 [5]

1964实验发现K介子



Nobel Prize 1980

1973理论预言，2001实验证实



Nobel Prize 2008

2019实验发现



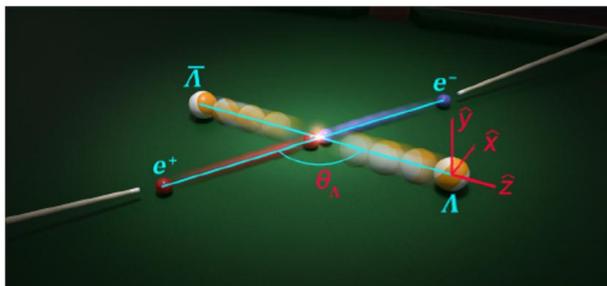
2025实验发现

- [1] Phys. Rev. Lett., 1964, 13: 138-140
- [2] Phys. Rev. Lett., 2001, 87: 091801
- [3] Phys. Rev. Lett., 2001, 87: 091802
- [4] Phys. Rev. Lett., 2019, 122(21): 211803
- [5] arXiv:2503.16954, 2025

STCF上超子CP对称性检验优势



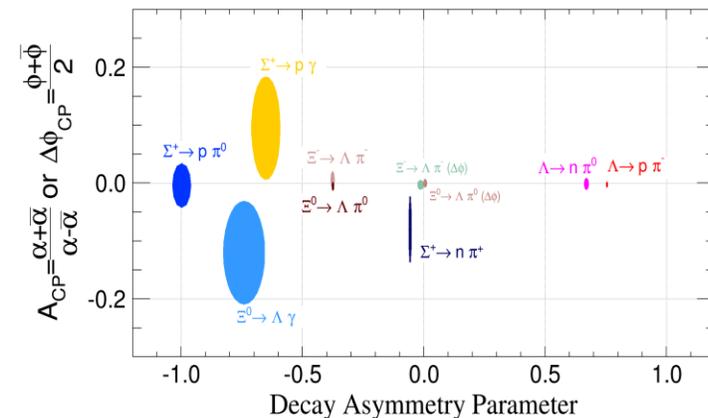
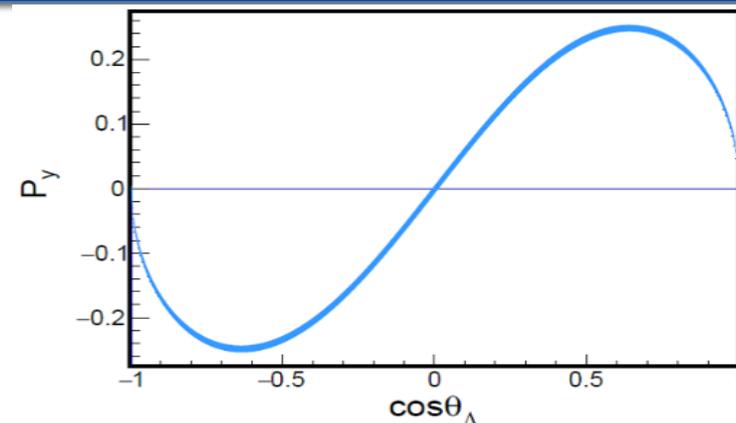
正负电子对撞机上的正反重子成对产生，利用量子纠缠和极化测量方法，相较于传统利用打靶实验的方法，重子CP研究精度能够大幅提高



2019年
首次发现超子自旋极化，
BESIII首篇《自然·物理》



2022年
重子CP不对称性世界最精确值，
BESIII首篇《自然》



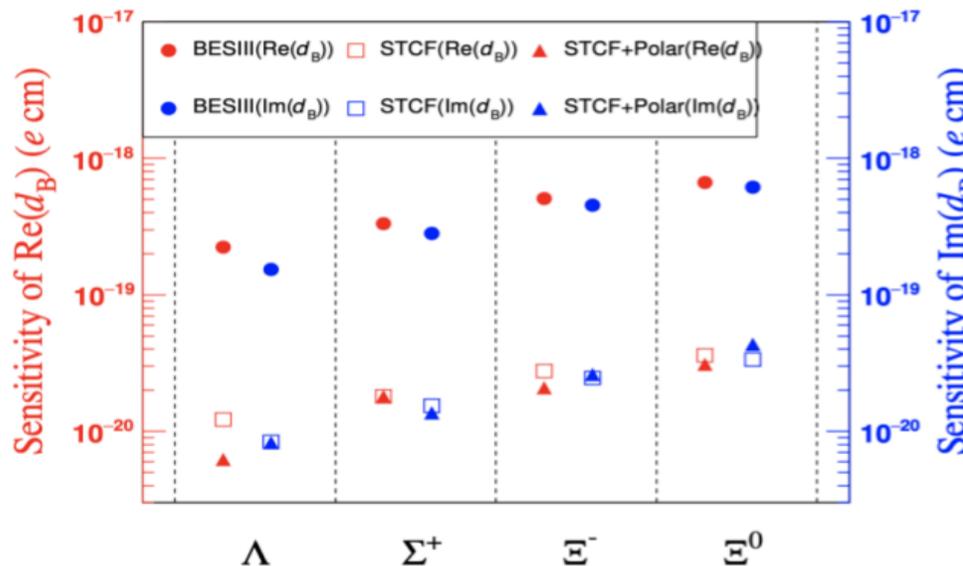
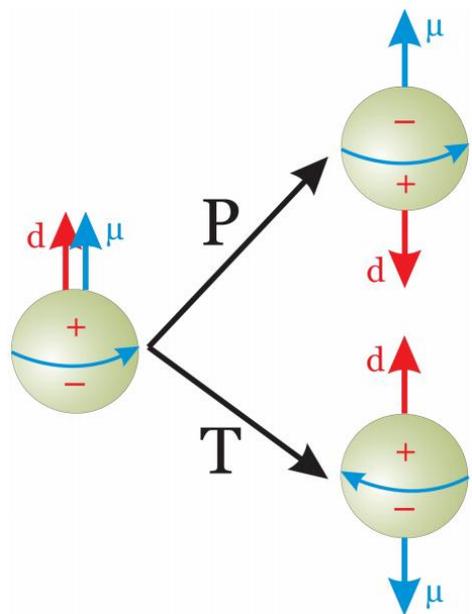
- **产生机制**已知，产生超子的**极化**和**运动学**精确确定，最大极化近30%
- **大量产生**各类超子-反超子对，构造**多个CP破坏观测量**，极化束流能够显著提高CP敏感度
- 系统误差**可控制**在与统计误差相当的量级

Detailed dynamics in J/ψ decay to hyperon pair have been studied:

μ : magnetic dipole moment
 d : electric dipole moment

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

Systematic measurement of the EDMs of the hyperon family!



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

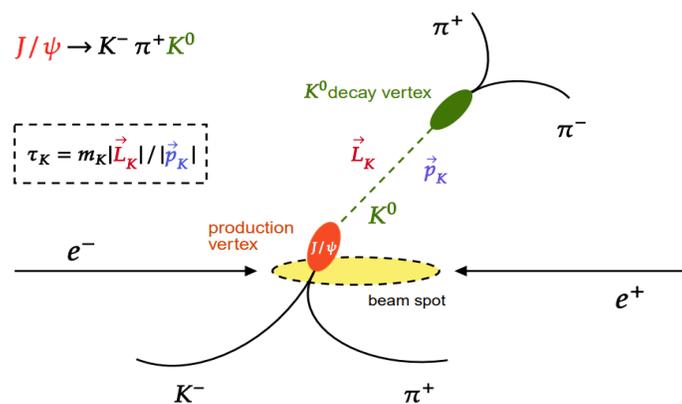
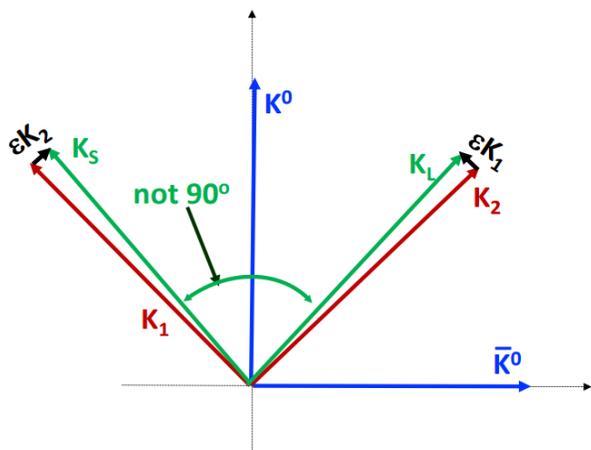
非零的电偶极矩破坏时间反演对称性T, 在CPT联合对称性守恒下, 是**CP破坏**的间接证据

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

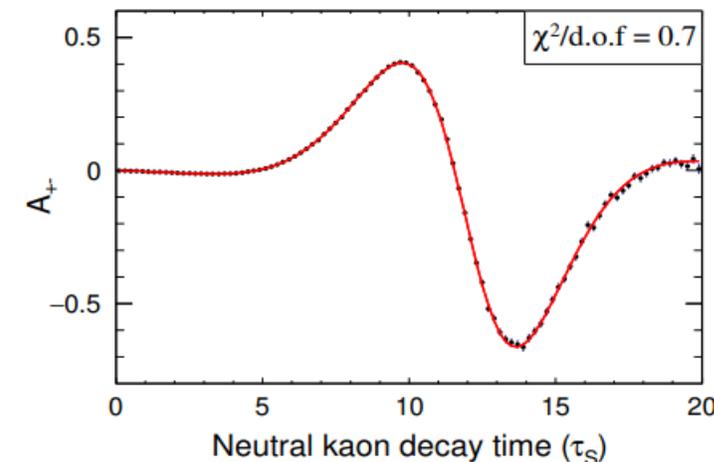
J.L. Fu et al., *Phys.Rev.D* 108, 9 (2023)

X.G.He, J.P. Ma, *Phys.Lett.B* 839, 137834 (2023)

根据量子场论，洛伦兹不变的局域场论中CPT对称，CPT的对称性检验是对超出标准模型的新物理的直接寻找。



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

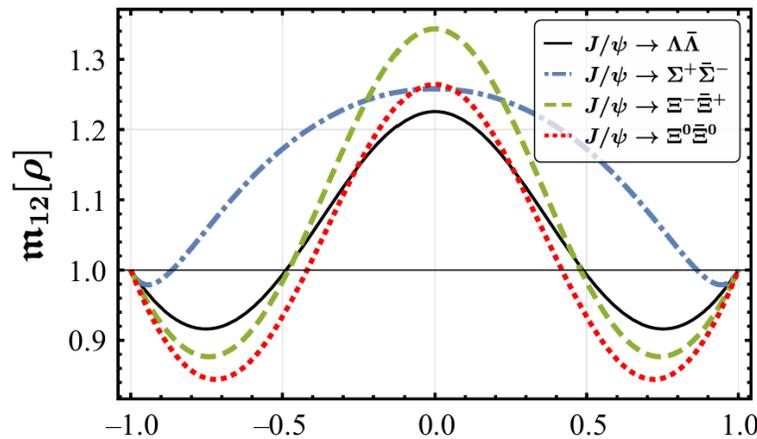
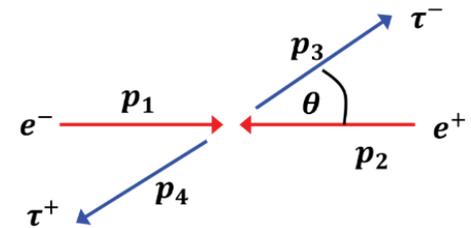
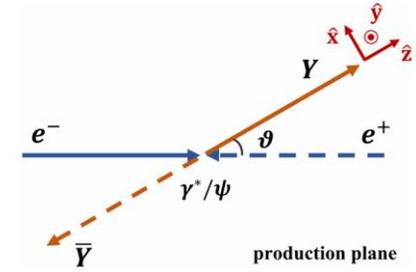
- The phase in CP parameter ϕ_{+-} used to set limits on CPT violation
- sensitivity of ϕ_{+-} is $\mathcal{O}(10^{-3})$ at STCF \Rightarrow **one magnitude better than PDG average**

超子对、陶轻子对的量子纠缠系统

- Quantum state tomography: reconstruct the spin density matrix (SDM) based on decay products.

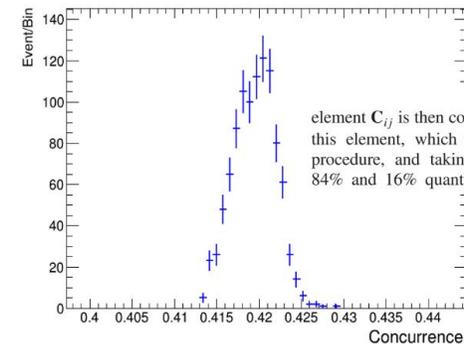
$$\rho = \frac{1}{4} \left[\mathbf{1}_2 \otimes \mathbf{1}_2 + \sum_{i=1}^3 B_i^+ (\sigma_i \otimes \mathbf{1}_2) + \sum_{i=1}^3 B_i^- (\mathbf{1}_2 \otimes \sigma_i) + \sum_{i,j=1}^3 C_{ij} (\sigma_i \otimes \sigma_j) \right],$$

$$\Theta_{\mu\nu} = \frac{1}{1 + \alpha_\psi \cos^2 \vartheta} \begin{bmatrix} 1 + \alpha_\psi \cos^2 \vartheta & 0 & \beta_\psi \sin \vartheta \cos \vartheta & 0 \\ 0 & \sin^2 \vartheta & 0 & \gamma_\psi \sin \vartheta \cos \vartheta \\ \beta_\psi \sin \vartheta \cos \vartheta & 0 & -\alpha_\psi \sin^2 \vartheta & 0 \\ 0 & \gamma_\psi \sin \vartheta \cos \vartheta & 0 & \alpha_\psi + \cos^2 \vartheta \end{bmatrix}$$



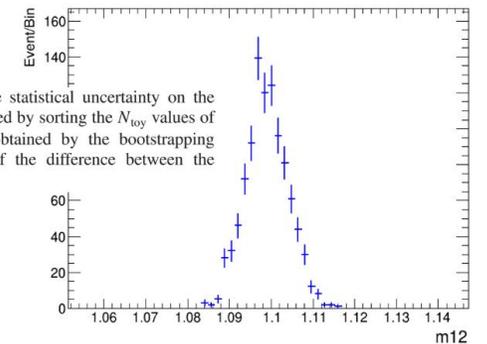
PRD 110.054012(2024)

TOY dist. Of concurrence



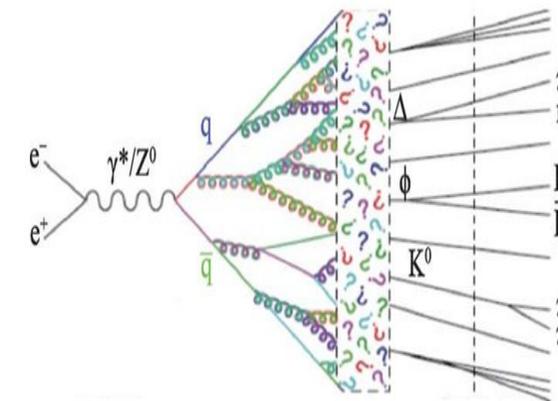
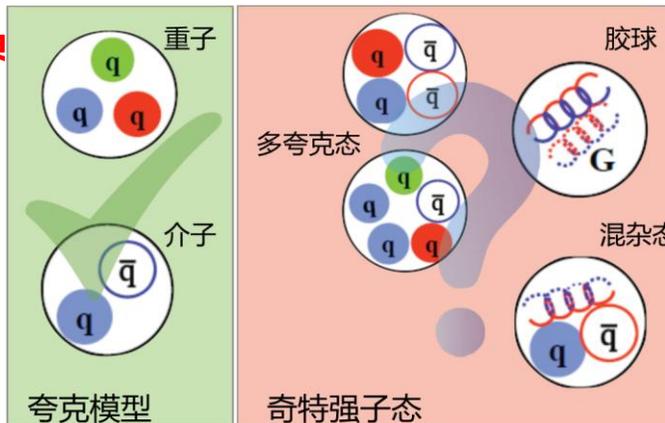
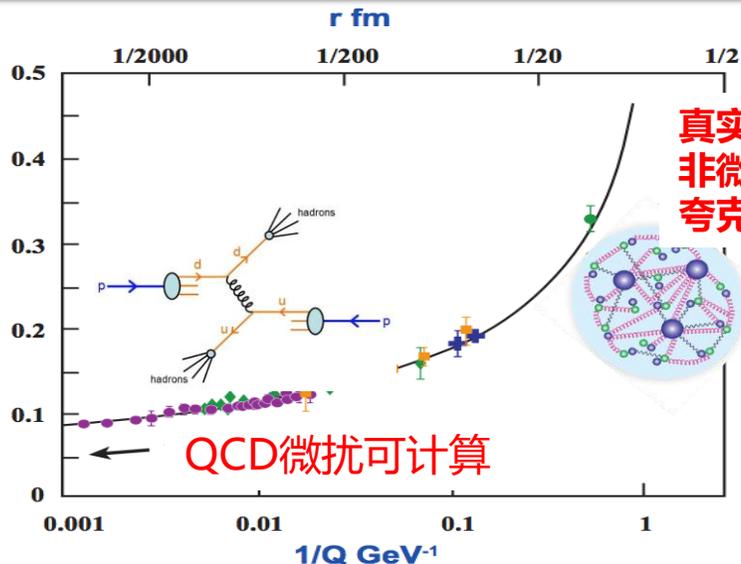
0.41945 +/- 0.00258 > 0

TOY dist. Of Bell inequality



1.09852 +/- 0.00510 > 1

QCD 耦合强度 α_s



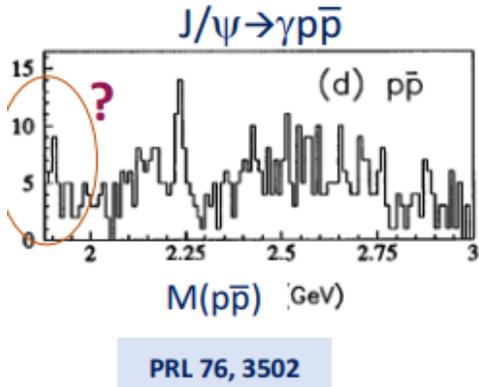
- **强子是物质世界基本组成单元**：理论预期存在胶球、混杂态、分子态、多夸克态等奇特强子态。强子谱的研究是探索与认识**强相互作用理论**的重要手段，STCF可以产生丰富的**奇特强子态**，在强子谱研究中具有**明显优势**。
- **夸克碎裂函数**描述夸克强子化的过程，正负电子对撞实验能够提供最干净的夸克碎了函数信息。**形状因子**是强子的**基本观测量**，能够探针其内部结构信息。

STCF上强子谱学和夸克碎裂函数及强子形状因子的精确测量将提供夸克塑造强子内部结构信息，从而破解色禁闭难题。

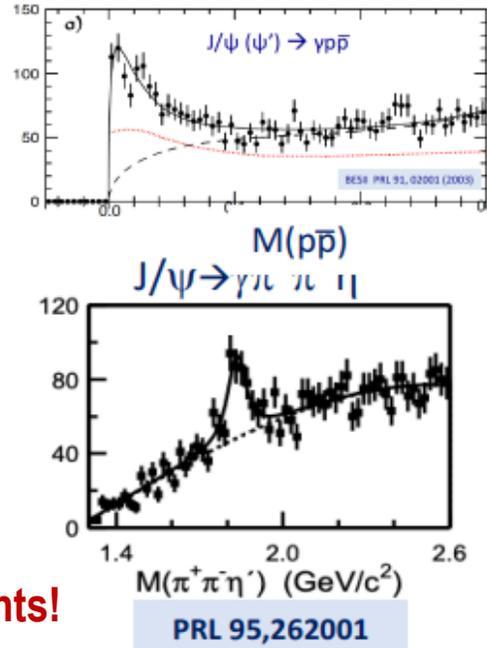
强子谱超精细结构



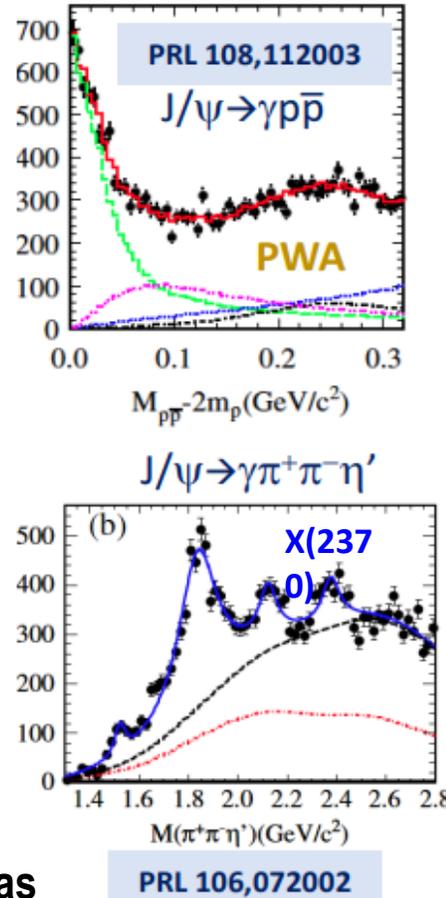
1996: 8 M J/ψ 's



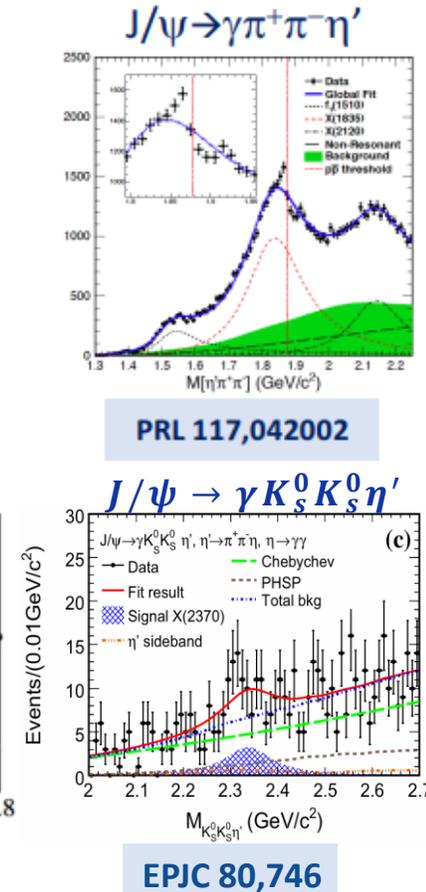
2002: 58 M J/ψ 's



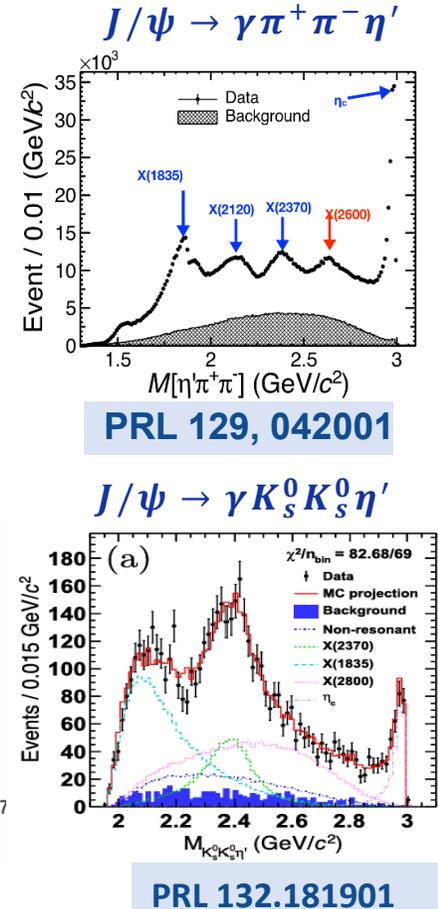
2011: 225 M J/ψ 's



2016: 1.3 B J/ψ 's



2022: 10 B J/ψ 's



You never have enough J/ψ events!

— Stephen Lars Olsen

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

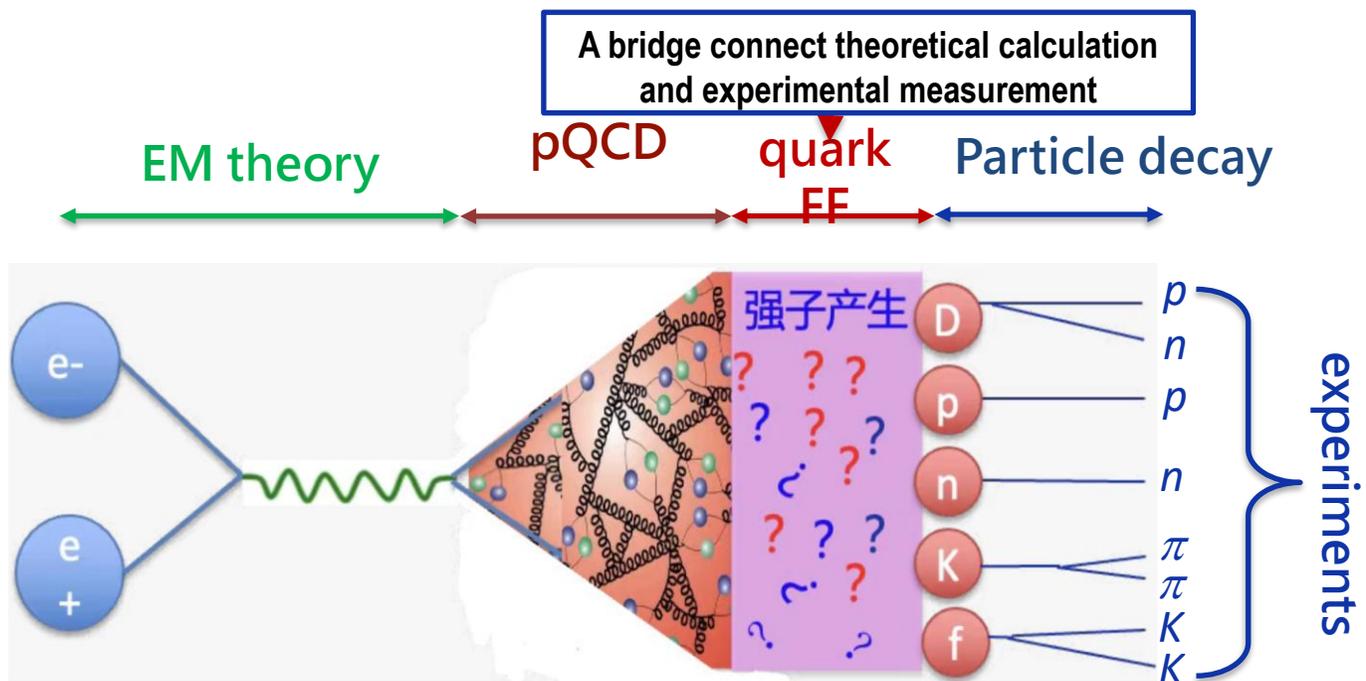
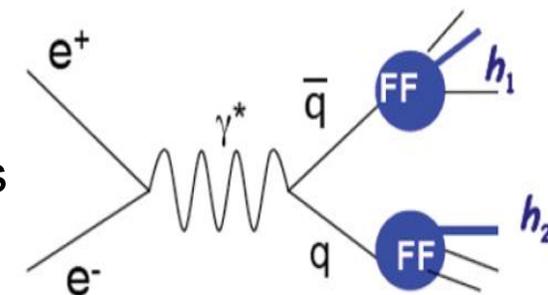
- Base on the **large statistic** and **high precision** data, STCF has an **absolute advantage** in the studying of hadron spectroscopy.

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

$0^- +$ Pseudoscalar Glueball-like

夸克碎裂函数

- Fragmentation function described the processes of quarks/gluon hadronization, is **non-perturbative process**, not be calculated theoretically.
- To accurately extract Parton Distribution Functions (PDFs), more precise FFs are required.
- e^+e^- collider experiment provides the **cleanest** input for fragmentation functions (FFs) fitting. With polarized electron beam, more FFs can be studied.



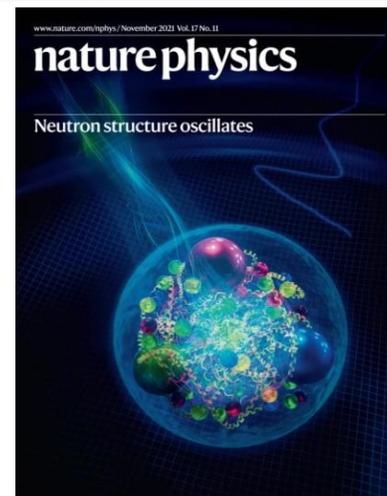
STCF prospects :

- will provide the **most precise** fragmentation function in q^2 range 4-50 GeV^2 with multi-dimensional binning
- Precise test the **universality** of fragmentation function in the different processes, and its **evolution** with q^2

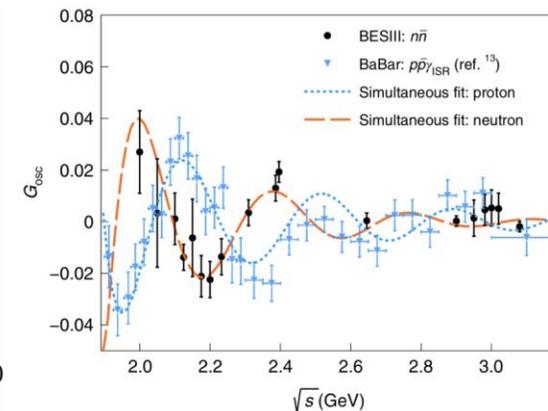
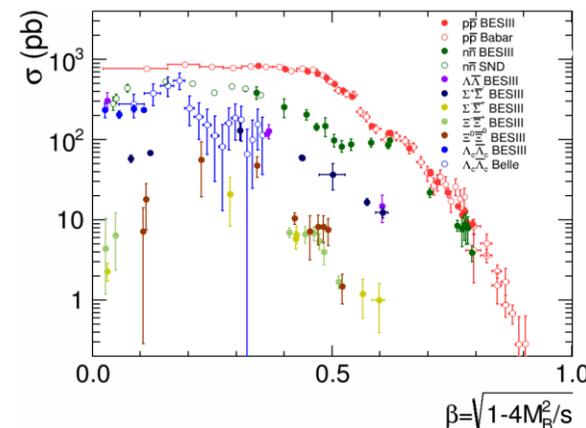
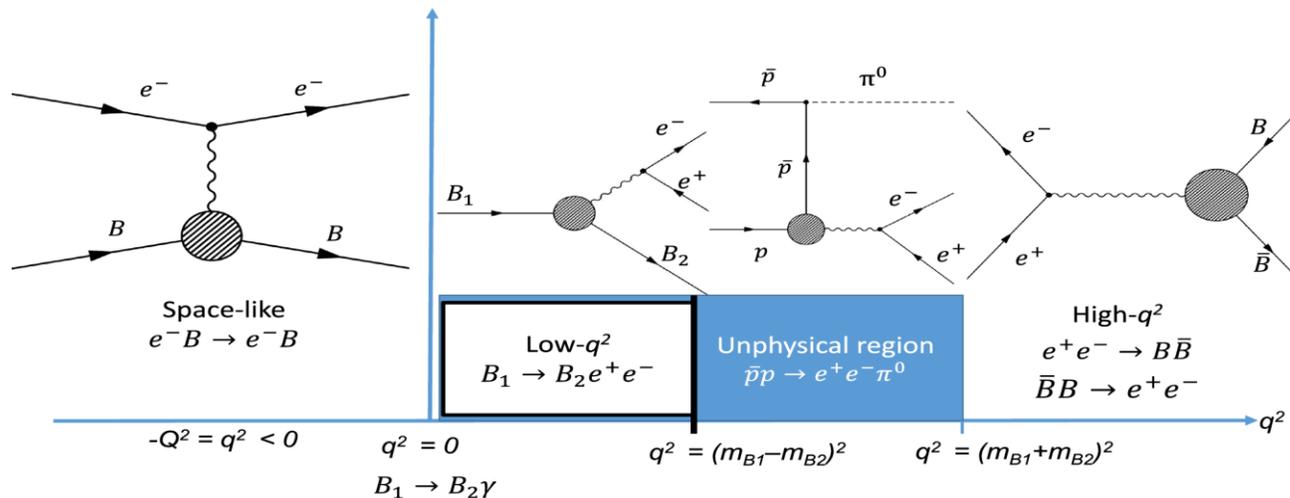
强子形状因子



- **电磁形状因子**是核子**最基本**的观测量之一，提供电和磁密度信息，并对强相互作用相关理论提供严格的验证。
- **由于超子和粲重子束流难以形成**，其内部结构研究只能通过类时空间的电磁形状因子研究获得。
- 高四动量转移的电磁形状因子研究可以抽取核子的光锥波函数，从而确认质子中的夸克成分。

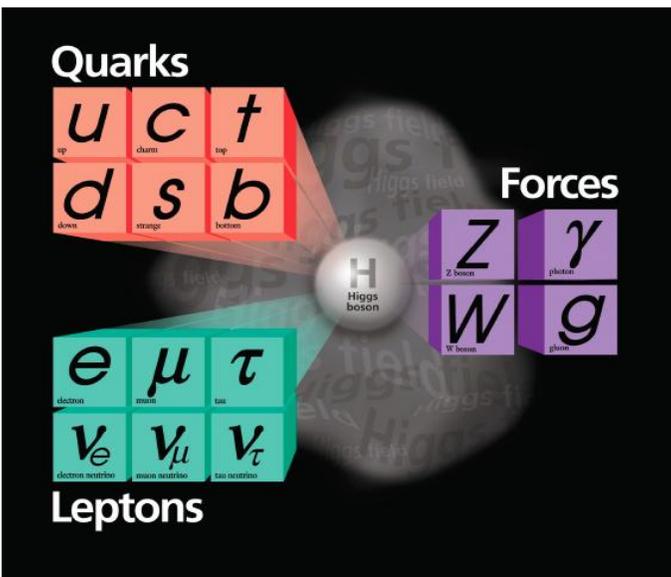


2021年
中子电磁结构精细测量，解决光子-核子耦合之谜，BESIII首篇《自然·物理》封面文章



Natl.Sci.Rev. 8 (2021) 11, nwab187

- **基本物理量**或标准模型**基本参数**的精确测量，是**高精度检验标准模型**，**探索新物理**的重要途径。
- STCF能够对**R值**以及**陶轻子质量**、**CKM矩阵元**以及**强相互作用常数 α_s** 进行高精度测量：
 - **R值测量**：粒子物理中最基本的物理量之一，直接反映**夸克的味道和颜色**，发现**新粒子**，并对**精细结构常数**和**缪子反常磁矩**的理论计算提供实验输入。
 - **陶轻子质量**精度对于**轻子普适性**的精确检验具有重要意义。
 - **CKM矩阵**么正性能够保证是否只有三代夸克，么正性的破坏意味着第四代夸克的存在！
 - **强耦合常数 α_s** 的精度会直接影响希格斯物理、电弱物理和顶夸克物理的理论预言，对理解电弱真空的稳定性具有重要意义。



标准模型自由参数：

Masses			Couplings		
Parameter	Value	Method	Parameter	Value	Method
m_u	1.9 MeV	Lattice	α	0.0073	non-collider + collider
m_d	4.4 MeV	Lattice	G_F	1.17×10^{-5}	Non-collider
m_s	87 MeV	Lattice	α_s	0.12	Lattice + collider
m_c	1.3 MeV	Collider	Flavour and CP violation		
m_b	4.24 MeV	Collider	Parameter	Value	Method
m_t	173 GeV	Collider	θ_{12} (CKM)	13.1°	Collider
m_e	511 keV	Non-collider	θ_{23} (CKM)	2.4°	Collider
m_μ	106 MeV	Non-collider	θ_{13} (CKM)	0.2°	Collider
m_τ	1.78 GeV	Collider	δ (CKM-CPV)	0.995	Collider
m_z	91.2 GeV	Collider	θ (strong CP)	~ 0	Non-collider
m_H	125 GeV	Collider			

R值定义：

$$R \equiv \frac{\sigma^0(e^+e^- \rightarrow \text{hadrons})}{\sigma^0(e^+e^- \rightarrow \mu^+\mu^-)} \equiv \frac{\sigma_{\text{had}}^0}{\sigma_{\mu\mu}^0} \approx N_c \sum_f Q_f^2$$

描述夸克味道的混合的CKM矩阵：

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

强子产生截面：R值

- **R值**是粒子物理中**最基本的物理量之一**，直接反映夸克的味道和颜色，检验夸克模型和QCD，发现新粒子，并对精细结构常数和**缪子反常磁矩**的理论计算提供实验输入

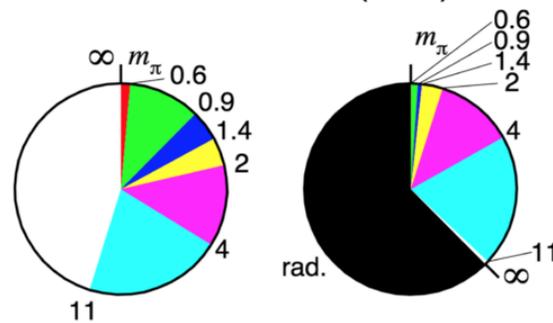
- Running of **fine structure constant** $\Delta\alpha_{em}$

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

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

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

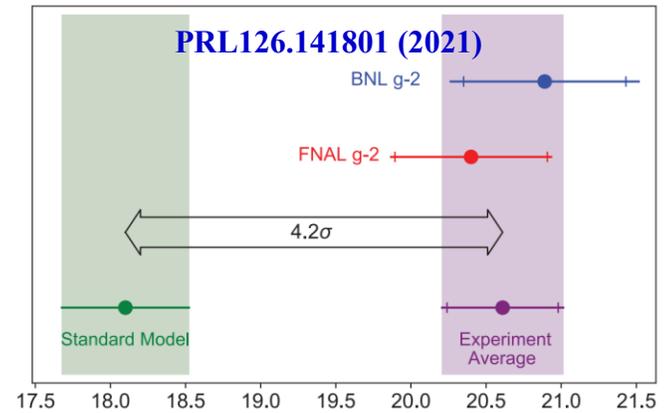
Fractional contribution to $\Delta\alpha_{had}^{(5)}(M_Z^2)$:
Phys. Rev. D 97, 114025 (2018)



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

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

- Muon **anomalous magnetic moment** a_μ



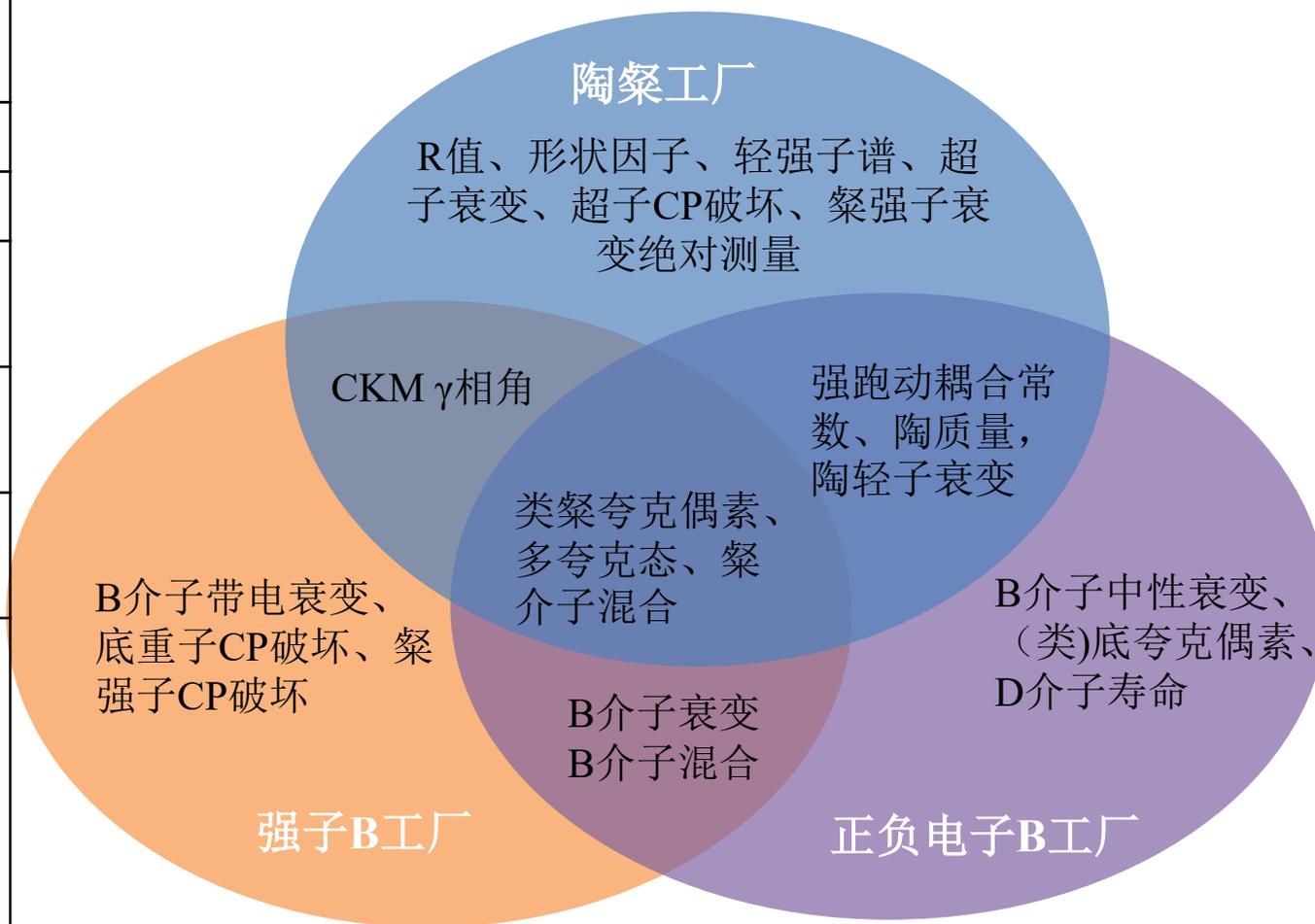
- SM prediction: $a_\mu^{SM} = a_\mu^{QED} + a_\mu^{Weak} + a_\mu^{Had}$
 - Hadronic **Vacuum Polarization (HVP)** and **Light-by-Light (HLbL)** in a_μ^{Had} dominate uncertainty
- HVP contribution is calculated with **R value** with **dispersion relation**:

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

STCF与Belle II, LHCb实验的协作和互补



装置名称	STCF	SuperKEKB/Belle II	LHC/LHCb upgrade I/II
对撞类型	e^+e^-	e^+e^-	pp
质心能量	2-7 GeV	10-11 GeV	13/14 TeV
峰值亮度	$0.5 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$	$8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$	$(1.5-2.0) \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$
预计运行时间	2032-	2019-2043	2024-2033, 2036-2041
预期积分亮度	10 ab^{-1}	50 ab^{-1}	$50/300 \text{ fb}^{-1}$
预期重要成果	确定奇特态强子谱结构; 发现超子CP破坏; 确定标准模型基本物理参数	底介子衰变性质和CKM相位角精确测量; 粲物理和夸克偶素精确研究; 新物理寻找	CKM矩阵参数精确测量; 中性粲介子CP破坏参数精确测量; 底强子中轻子普适性检验和稀有衰变寻找; 奇特强子态研究

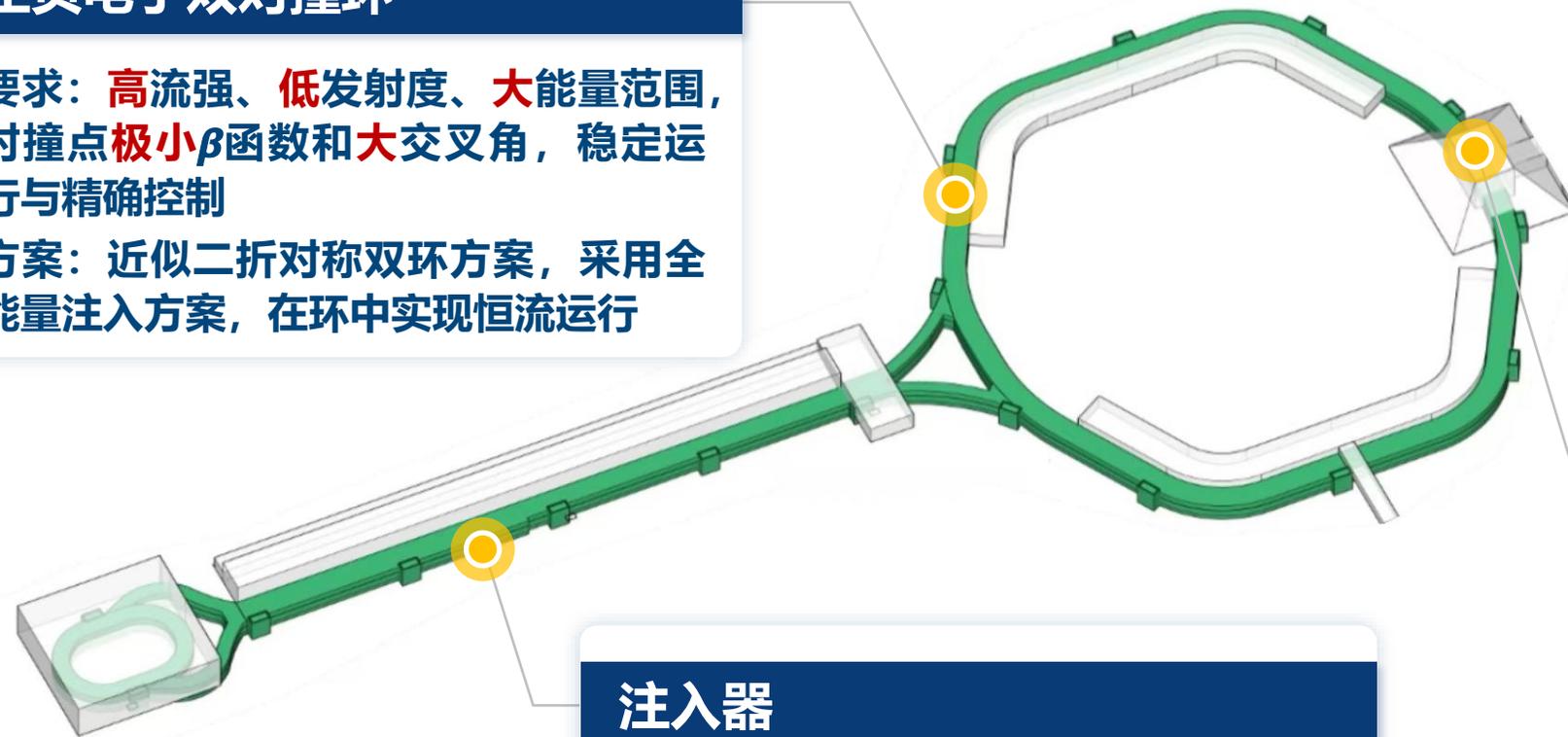


- 超级陶粲装置
- 物理目标
- **关键技术预研**
- 项目推进和现状
- 总结和展望

正负电子双对撞环

要求：**高流强**、**低发射度**、**大能量范围**，**对撞点极小 β 函数**和**大交叉角**，**稳定运行与精确控制**

方案：**近似二折对称双环方案**，采用**全能量注入方案**，在环中实现**恒流运行**



注入器

要求：**高重频注入**、**高电荷量**、**低发射度正负电子束**

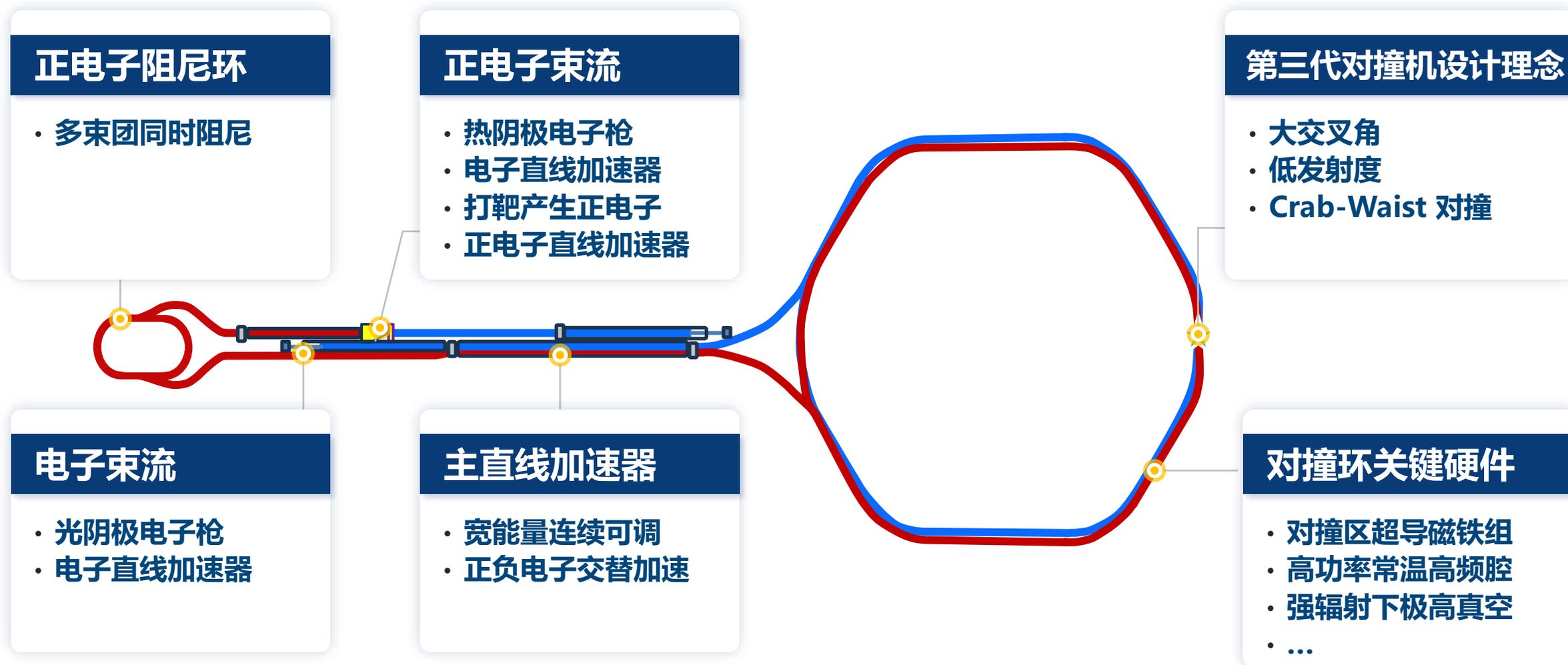
方案：**多段直线加速器 + 正电子阻尼环**，**满能量注入对撞环**

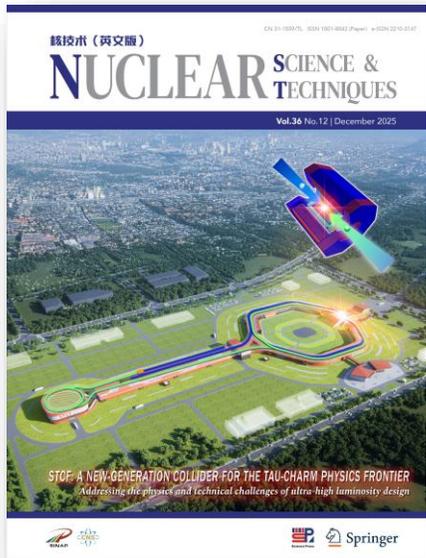
探测谱仪

要求：**在强辐照、高本底、高事例率、宽动态范围**条件下的**超高精度粒子测量和鉴别**

方案：**多种粒子探测器 + 读出电子学系统 + 数据获取系统**

设计目标: **亮度** $\geq 0.5 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ @ 4 GeV, **能区**: 2~7 GeV

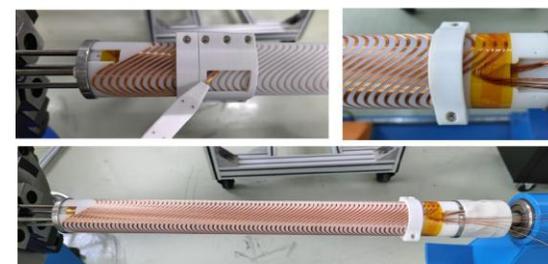




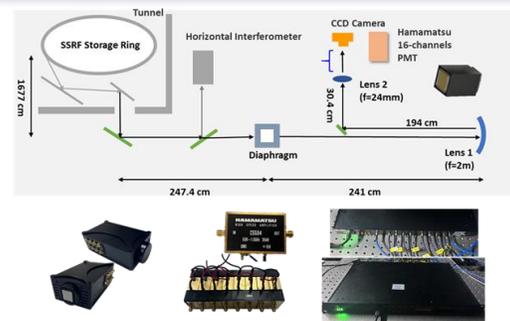
- **已完成概念设计**并通过国际国内评审，设计模拟亮度已达到**设计指标**
- 加速器部分关键技术系统正在进行**技术攻关和样机研制**

参数	单位	模拟数值			
对撞能量	GeV	4.0	2.0	3.0	7.0
亮度	$\text{cm}^{-2}\text{s}^{-1}$	9.4×10^{34}	6.2×10^{33}	2.1×10^{34}	4.5×10^{34}

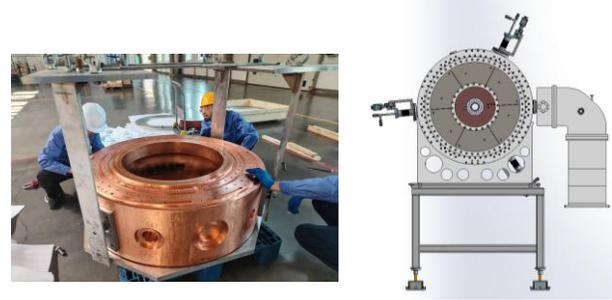
对撞区超导磁体样机



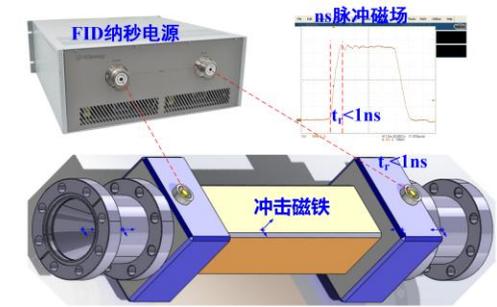
一体化测量技术发展



高功率常温高频腔样机



超快冲击磁铁样机



探测谱仪系统方案

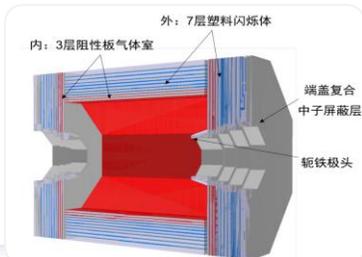


设计目标: **强辐照、高本底、高事例率、大动态范围下的超高精度粒子测量和鉴别**

$$\sigma_p/P \leq 0.5\% @ 1 \text{ GeV}/c, \quad \sigma_E/E \leq 2.5\% @ 1 \text{ GeV}, \quad K/\pi \geq 4\sigma @ 2 \text{ GeV}/c$$

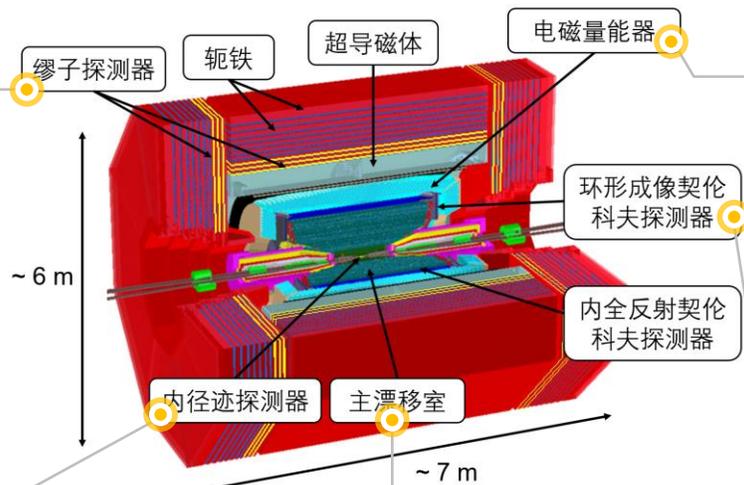
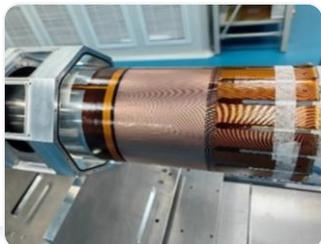
混合式缪子探测器

阻性板室 + 塑料闪烁体探测



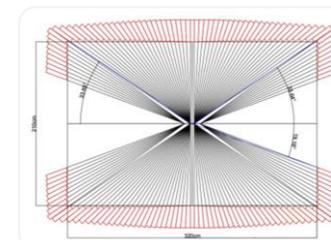
低质量内径迹探测器

阻性微槽型气体探测器



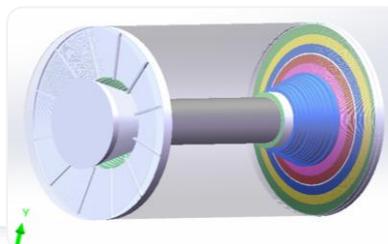
快响应晶体量能器

纯碘化铯+APD



高计数率主漂移室

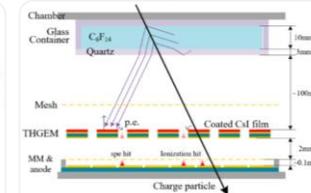
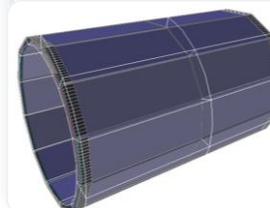
超小单元漂移室



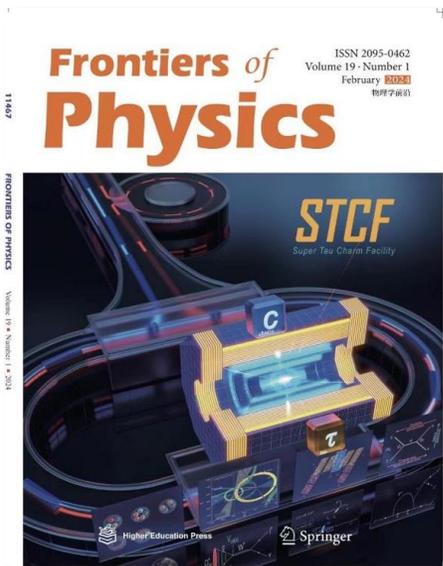
契伦科夫粒子鉴别器

内全反射型

环形成像



- 完成**全部五个子探测器样机**研制，其中**三个已完成束流测试**并**达到或超过设计指标**
- 完成**所有关键部件的技术设计**，研制出**大部分的关键部件原型**



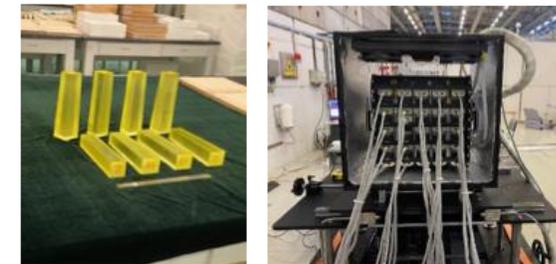
内径迹探测器样机



粒子鉴别器全尺寸样机



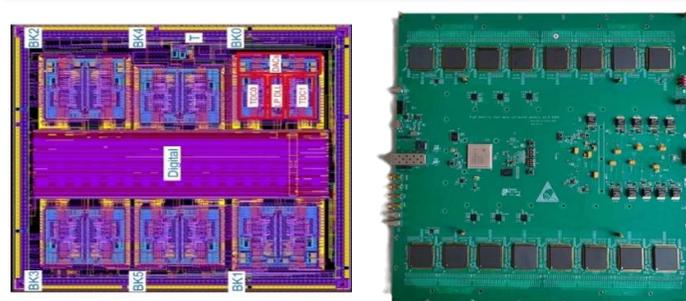
电磁量能器大阵列样机



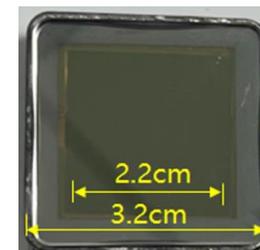
主漂移室全长样机



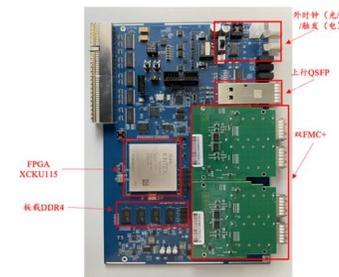
高性能专用集成电路读出芯片

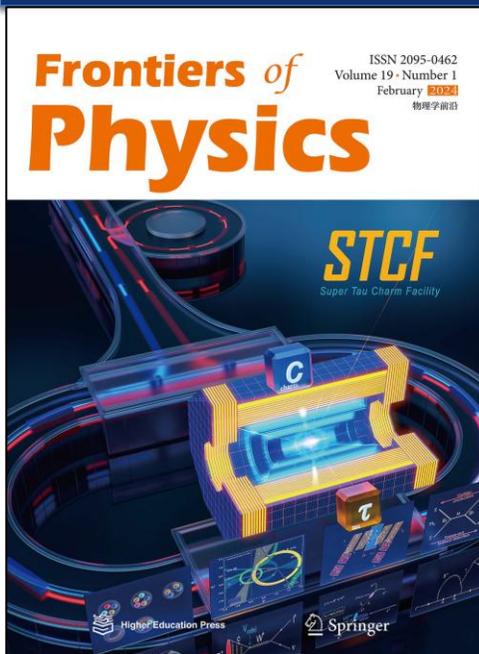


超快多阳极微通道板光电器件



数据获取关键部件





Contents		
1	Introduction	5
2	Physics	8
2.1	Motivation	8
2.1.1	Challenges in particle physics and the τ -charm energy region	8
2.1.2	Physics potential at the STCF	9
2.2	Charmonium and XYZ physics	12
2.2.1	The XYZ puzzles	12
2.2.2	Limitations of current experiments	13
2.2.3	Opportunities for solving the XYZ puzzles	14
2.2.4	Opportunities in higher charmonium states	15
2.3	Charmed hadron physics	16
2.3.1	Charmed mesons	16
2.3.2	Charmed baryons	20
2.4	Tau physics	23
2.4.1	Precision measurement of the τ properties	23
2.4.2	Determination of the SM parameters	24
2.4.3	CP symmetry tests	26
2.4.4	Flavor-violating τ decays	27
2.5	Topics in QCD studies and light hadron physics	27
	Spin 3/2 polarization	28
	Near-threshold resonance	29
	Millicharged particles	30
	Triangle singularity	34
	J/ψ semileptonic decay	36
	Belle locality	37
	D_s^* radiative decay	38
	FCNC	36
	EMFFs	37
	Light-cone distribution amplitudes	38
	$cLFV$	37
	baryogenesis	38
	K0-K0bar	38
	Two-pole	38
	X(6200)	38
	Neutral meson mixing	38
	QCD sum rules	40
	Muon g-2 and $\alpha(M_Z^2)$	36
	$\Lambda - \bar{\Lambda}$ oscillation	37
	Axion-like particle	37
	Chiral theory	37
	Fully charm tetraquarks	37
	Tau EDM	37
	$SU(2)_L$ -singlet vector-like fermion partners	37
	$\Delta S = 2$ Nonleptonic hyperon decay	37
	Hyperon EDM	37
	X(4014)	37
	Excited baryon	37
	Axions	37
	CPT	37
	Proton charge radius	37
	Coupled-channel effect	37
	Hyperon-Nucleus Scattering	37
	$a_0(1710)$	37
	Invisible decay of J/ψ	37
	Phi meson photoproduction	37

Rich physics potential beyond the CDR content

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^{k,l}, Haiping Peng^h, Qin Qin^h, Pablo Roig^{m,n}, Zhi-Zhong Xing^o, Fu-Sheng Yu^p, Yu Zhang^q, Jianyu Zhang^d, Xiaorong Zhou^h

^aInstitute of Physics, Academia Sinica, Taipei, 11529, China
^bHebei Normal University, Shijiazhuang, 050024, China
^cShanghai Jiao Tong University, Shanghai, 200250, China
^dUniversity of Chinese Academy of Sciences, Beijing, 100049, China

^eBeijing I
^fNational Centr
^gUppsala
^hUniversity of Science
ⁱInstitute of Theoretical Ph
^jHigh Energy Physic
^kParticle and Nuclear Physic
^lHuazhong Universi
^mDepartamento de Física, C
ⁿPoliécnico Nac.
^oIFIC, Universi
^pInstitute of High Energy Pl
^qLanzh
^rUniversity

Contents

1 Introduction

2 CP-violation in hyperon sector

- 2.1 Direct CP violation in strange quark systems
- 2.2 Hyperon two-body hadronic weak decays
- 2.3 Spin entangled baryon-antibaryon systems
- 2.4 Radiative and semileptonic decays
- 2.5 CP violation in production via edm
- 2.6 CP violation in charmed baryon decays
- 2.7 Prospect of hyperon CP-violation study at STCF
 - 2.7.1 Event selection
 - 2.7.2 Sensitivity of CP-violation in hyperon decay
 - 2.7.3 Comparison of hyperon CP sensitivity with experiments

3 CP-violation in τ sector

- 3.1 Hadronic form factors in semileptonic τ decays
- 3.2 Structure functions in hadronic τ decays
- 3.3 CP-violation observables in hadronic τ decays
- 3.4 CP violating asymmetries in $\tau \rightarrow K_S \pi \nu$ decays: anomaly and the Belle measurement
- 3.5 CP-violation proposal via EDM
- 3.6 Prospect of τ CP-violation study at STCF
 - 3.6.1 MC simulation of $\tau^- \rightarrow K_S \pi^- \nu_\tau$
 - 3.6.2 Optimization of event selection
 - 3.6.3 Sensitivity of CP-violation in $\tau^- \rightarrow K_S \pi^- \nu_\tau$

4 CP-violation in charm sector

- 4.1 The CKM matrix and its unitarity
- 4.2 Six types of CP violation
 - 4.2.1 CP violation in the direct decays
 - 4.2.2 CP violation from D^0 - \bar{D}^0 mixing
 - 4.2.3 CP violation from the interplay between decay
 - 4.2.4 CP violation in the CP-forbidden coherent L
 - 4.2.5 CP violation due to the final-state K^0 - \bar{K}^0 mi

Abstract

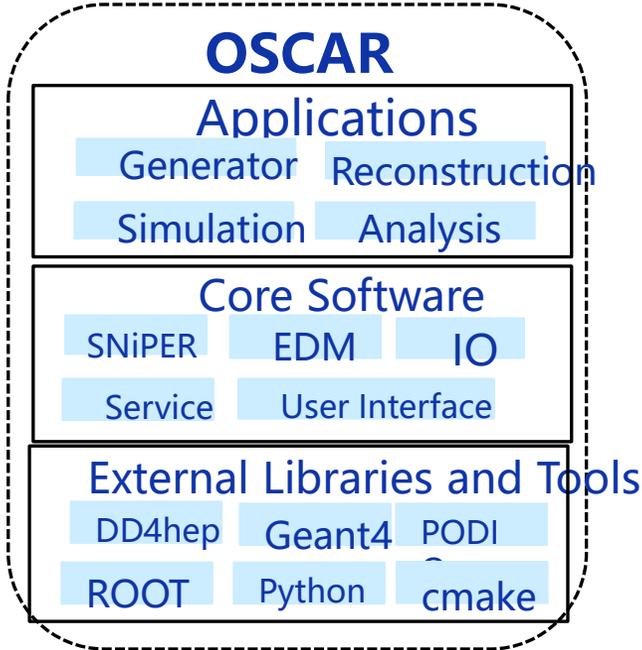
Charge-parity (CP) violating areas to search is designed to operate in a luminosity of 0.5×10^{35} c will be collected with good ment. In this report, possible region and at the future tau in the production and decay hadrons. The CPT invariance

Preprint submitted to PHYSICS

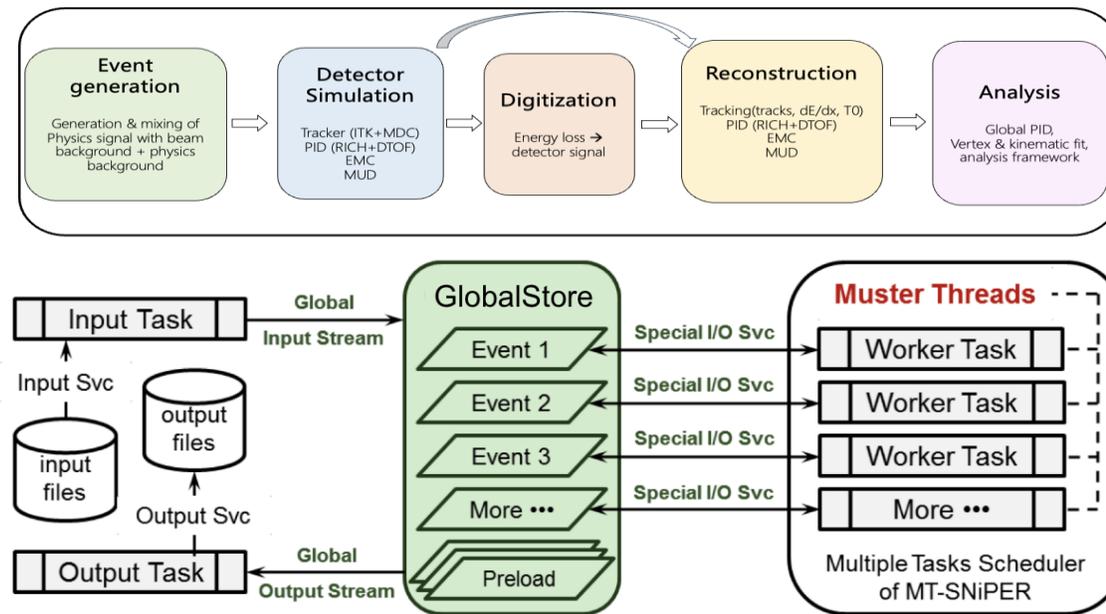
arXiv:2502.08907, submitted to Physics Reports

1	Introduction	4
2	CP-violation in hyperon sector	7
2.1	Direct CP violation in strange quark systems	7
2.2	Hyperon two-body hadronic weak decays	7
2.3	Spin entangled baryon-antibaryon systems	7
2.4	Radiative and semileptonic decays	7
2.5	CP violation in production via edm	7
2.6	CP violation in charmed baryon decays	7
2.7	Prospect of hyperon CP-violation study at STCF	7
2.7.1	Event selection	7
2.7.2	Sensitivity of CP-violation in hyperon decay	7
2.7.3	Comparison of hyperon CP sensitivity with experiments	7
3	CP-violation in τ sector	7
3.1	Hadronic form factors in semileptonic τ decays	7
3.2	Structure functions in hadronic τ decays	7
3.3	CP-violation observables in hadronic τ decays	7
3.4	CP violating asymmetries in $\tau \rightarrow K_S \pi \nu$ decays: anomaly and the Belle measurement	7
3.5	CP-violation proposal via EDM	7
3.6	Prospect of τ CP-violation study at STCF	7
3.6.1	MC simulation of $\tau^- \rightarrow K_S \pi^- \nu_\tau$	7
3.6.2	Optimization of event selection	7
3.6.3	Sensitivity of CP-violation in $\tau^- \rightarrow K_S \pi^- \nu_\tau$	7
4	CP-violation in charm sector	7
4.1	The CKM matrix and its unitarity	7
4.2	Six types of CP violation	7
4.2.1	CP violation in the direct decays	7
4.2.2	CP violation from D^0 - \bar{D}^0 mixing	7
4.2.3	CP violation from the interplay between decay	7
4.2.4	CP violation in the CP-forbidden coherent L	7
4.2.5	CP violation due to the final-state K^0 - \bar{K}^0 mi	7
4.2.6	CP violation due to $D^0 - \bar{D}^0$ and $K^0 - \bar{K}^0$ oscillating interference	52
4.3	Indirect CP violation associated with D^0 - \bar{D}^0 mixing	53
4.3.1	Formulas for incoherent neutral D meson decays	54
4.3.2	Formulas for coherent $(D^0 \bar{D}^0)_{C=\pm 1}$ decays	55
4.3.3	CP violation in $D^0 \rightarrow \pi^+ \pi^-$ and $K^+ K^-$ decays	59
4.3.4	CP violation in $D^0 \rightarrow K^+ K^-$ and $K^+ K^+$ decays	62
4.4	Direct CP violation in the decays of charmed mesons and charmed baryons	64
4.5	Prospect of Charm CP violation studies at STCF	67
4.5.1	Measurements of the $D \rightarrow K^- \pi^+ \pi^+ \pi^-$ decay	67
4.5.2	Measurements of the $D \rightarrow K_S^0 \pi^+ \pi^-$ decay	68
4.5.3	Measurements of the $D \rightarrow K^- \pi^+ \pi^0$ decay	69
4.5.4	Overall prospects	69
5	Tests of the CPT invariance with J/ψ decays	70
5.1	CPT and the Theory of Everything	71
5.2	Neutral K mesons and tests of the CPT theorem	72
5.3	The neutral kaon mass eigenstates with no CPT-invariance related restrictions	73
5.3.1	Properties of ϵ and δ	75
5.4	Interference measurements of the $\phi_{+,-}$ and ϕ_{00} phases	76
5.4.1	Estimated measurement sensitivity with 10^{12} J/ψ -decays	77
5.5	Comment on the Bell Steinberger relation	79
5.6	Comments	82
5.7	Prospects of Kaon CPT study at STCF	82
5.7.1	MC simulation of $J/\psi \rightarrow K^- \pi^+ K^0 + c.c.$	83
5.7.2	Event selection procedure	83
5.7.3	Expected sensitivity at STCF	83
5.7.4	Systematic uncertainty discussion	84
6	Summary	85
	Acknowledgement	87

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

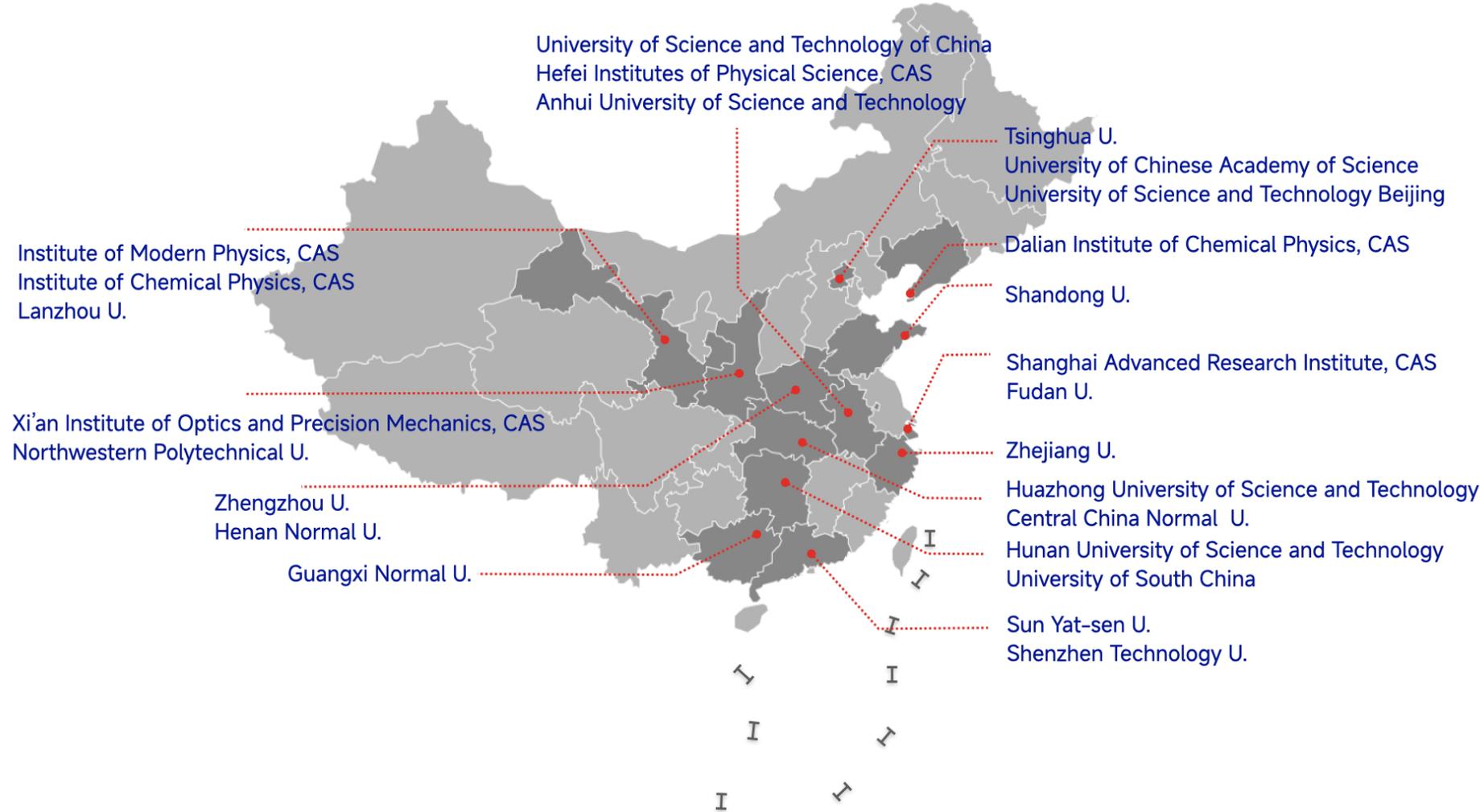
性能检验	物理过程
径迹重建和分辨	$J/\psi \rightarrow \Lambda\bar{\Lambda}, \Xi^+\bar{\Xi}^-, e^+e^- \rightarrow \pi Z_c(3900), e^+e^- \rightarrow P_c\bar{p} \rightarrow J/\psi p\bar{p}, e^+e^- \rightarrow J/\psi\eta_c$
光子/ π^0 重建	C-even correlated $D\bar{D}, \Sigma^+ \rightarrow \pi^0 p, \Sigma^+ \rightarrow \gamma p, \tau \rightarrow \pi(\pi\pi^0)\nu$, 陶轻子辐射衰变, $\Lambda_c^+ \rightarrow \Lambda K^+, \Sigma^0 K^+, \Sigma^+ K_S^0, \eta_c \rightarrow \gamma\gamma$
低能质子重建	$e^+e^- \rightarrow P_c\bar{p} \rightarrow J/\psi p\bar{p}$
π/μ 鉴别	$\tau \rightarrow 3\mu, \tau \rightarrow \pi(\pi\pi^0)\nu, J/\psi \rightarrow l^+l^-\pi^0/\eta, D \rightarrow \pi\mu\nu, D \rightarrow \mu\nu, D \rightarrow inclusive$
π/K 鉴别	$\Lambda_c^+ \rightarrow \Lambda K^+, \Sigma^0 K^+, \Sigma^+ K_S^0, e^+e^- \rightarrow KK, \pi\pi, K\pi, \tau \rightarrow K\nu, \tau \rightarrow K\pi^0\nu_\tau$
轻子鉴别	$J/\psi \rightarrow \gamma ll', \Lambda \rightarrow p e\nu, \Xi^- \rightarrow \Lambda e\nu$
质子鉴别	$e^+e^- \rightarrow p\bar{p}$
运动学拟合	$J/\psi \rightarrow \Lambda\bar{\Lambda}, \Xi^+\bar{\Xi}^-, J/\psi \rightarrow K_S^0 K\pi, \Lambda \rightarrow p e\nu, \Xi^- \rightarrow \Lambda e\nu$
D介子标记	C-even correlated $D\bar{D}, D \rightarrow \pi\mu\nu, D \rightarrow \mu\nu$
能量刻度和分辨	$X(3872)$ 扫描, $e^+e^- \rightarrow \tau^+\tau^-$ near threshold
亮度测量	$e^+e^- \rightarrow hadrons$
前向区	$\gamma\gamma \rightarrow hadrons$

- 超级陶粲装置
- 物理目标
- 关键技术预研
- **项目推进和现状**
- 总结和展望

STCF关键技术预研团队



25 universities/Institutes in R&D project:
170 faculties and 140 graduate students



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
.....

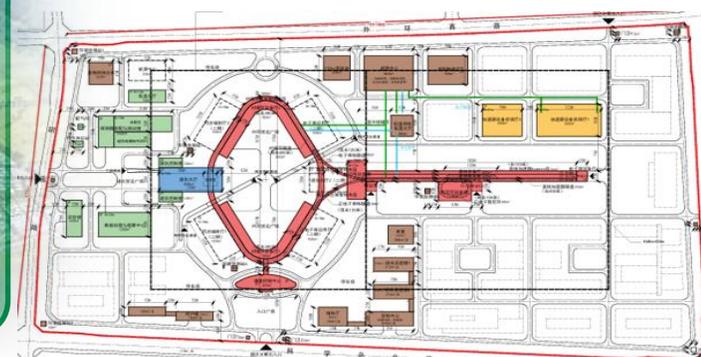
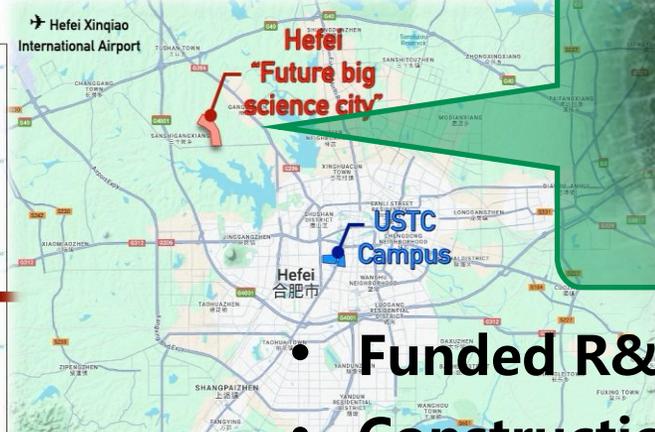
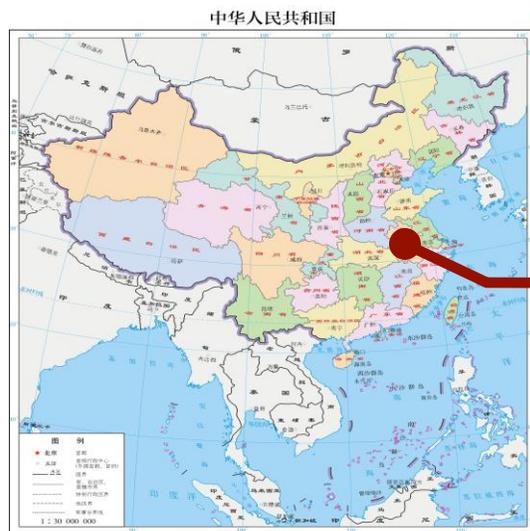
Hefei Comprehensive National Science Center "Future Big Science City", Hefei, Anhui Province



Hefei Advanced Light Facility (HALF) - under construction

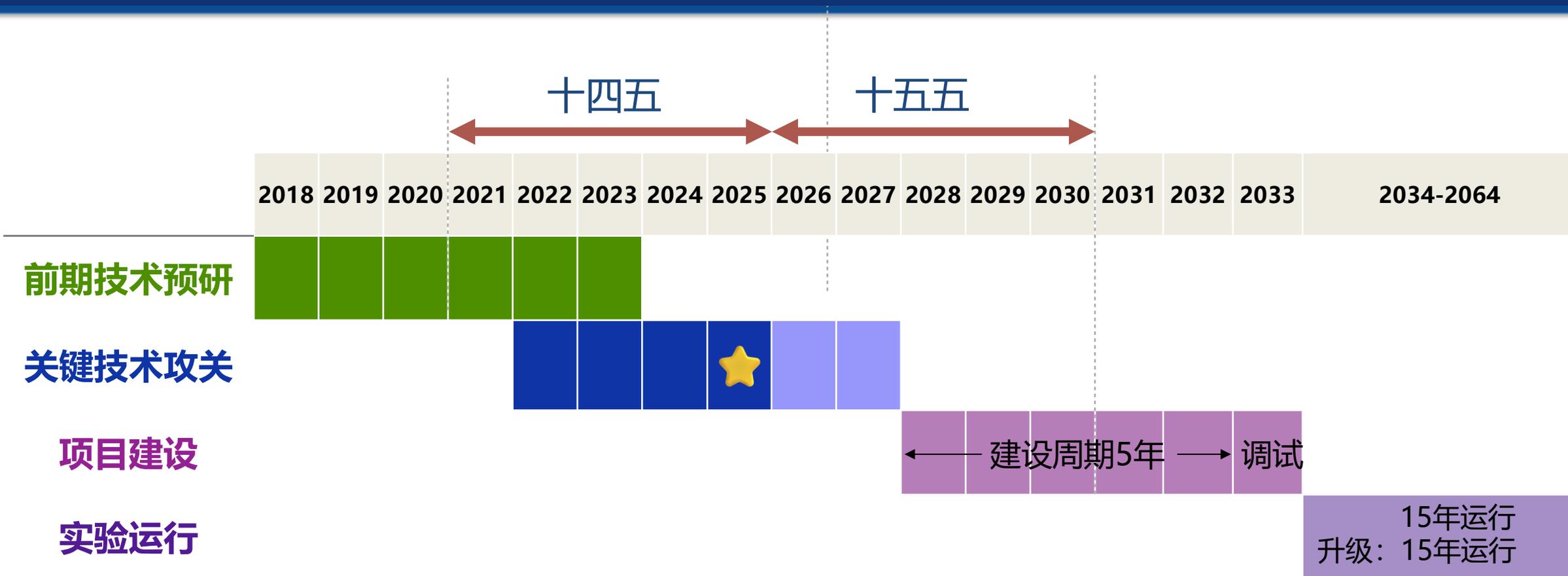


Super Tau-Charm Facility (STCF)



- **Funded R&D : 364 Million CNY by the Anhui government**
- **Construction budget : ~4.8 Billion CNY**
- **Geological prospecting, civil engineering design are ongoing**

STCF计划时间表



- 14th five-years plan : **Conceptual design** and **R&D of Key technology**, 364 M CNY
- 15th five-years plan : **Construction** 6 years, ~5 B CNY
- Operating for 10-15 years, upgrade for 3 years, operating again for ~10 years

STCF相关国际国内研讨会



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	Xiangtan (HUST)	STCF: R&D progress

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



国际顾问委员会会议



International Advisory Committee

主席	Guy Wilkinson	U. of Oxford	英国
副主席	Frank Zimmermann	CERN	瑞士
	Marica Biagini	INFN Frascati-National Lab.	意大利
	Ikaros Bigi	U. of Notre Dame	美国
	Alexander Bondar	BINP	俄罗斯
	Tom Browder	U. of Hawaii	美国
	赵光达	Perking U.	中国
	高原宁	Perking U.	中国
	Wolfgang Gradl	JGUM	德国
	David Hitlin	CIT	美国
	Tord Johansson	Uppsala U.	瑞典
	Marek Karliner	Tel Aviv U.	以色列
成员	Eugeny Levichev	BINP	俄罗斯
	马余刚	Fudan U.	中国
	Mikihiko Nakao	KEK	日本
	Stephen Olsen	Chung Ang U.	韩国
	Alexey Petrov	South Carolina U.	美国
	Antonio Pich	Valencia U. IFIC	西班牙
	Makoto Tobiyama	KEK	日本
	赵红卫	IMP, CAS	中国
	赵振堂	SARI, CAS	中国
	邹冰松	Tsinghua U.	中国



2024 Jan. 1st IAC meeting



2024 Oct. 2nd IAC meeting



2025. May 3rd IAC meeting

Report of third meeting of International Advisory Committee for the Super Tau Charm Facility

Maria Erica Biagini¹, Ikaros Bigi², Alex Bondar³, Tom Browder⁴, Kuang-Ta Chao⁵, Yanning Gao⁶, Wolfgang Gradl⁷, David Hitlin⁸, Tord Johansson⁹, Marek Karliner¹⁰, Eugeny Levichev¹¹, Yungang Ma¹², Mikihiko Nakao¹³, Stephen Olsen¹⁴, Alexey Petrov¹⁵, Antonio Pich¹⁶, Makoto Tobiyama¹⁷, Guy Wilkinson¹⁸, Haogang Zhao¹⁹, Zhenfeng Zhao²⁰, Frank Zimmermann²¹, Bingsong Zou²²

¹ INFN, Frascati National Laboratories, ² University of Notre Dame, ³ Budker Institute of Nuclear Physics (BINP), ⁴ University of Hawaii, ⁵ Peking University, ⁶ Johannes Gutenberg University Mainz, ⁷ California Institute of Technology, ⁸ Uppsala University, ⁹ The Ohio State University, ¹⁰ High Energy Accelerator Research Organization (KEK), ¹¹ Chung Ang University, ¹² University of South Carolina, ¹³ University of Michigan-Ann Arbor, ¹⁴ University of Oxford, ¹⁵ Institute of Modern Physics, CAS, ¹⁶ Shanghai Advanced Research Institute, CAS, ¹⁷ European Organization for Nuclear Research (CERN), ¹⁸ Tsinghua University, ¹⁹ CERN, ²⁰ CERN, ²¹ CERN, ²² CERN.

1 Introduction
The International Advisory Committee (IAC) for the Super Tau Charm Facility (STCF) met for the third time on 09th and 10th June 2024 at USTC, Hefei, with several members participating remotely. Members of the STCF project were in attendance, and presentations were given on the project as a whole, on the progress with the physics studies, the accelerator and the detector. Parallel discussion sessions followed on the physics and detector, and on the accelerator. A visit took place to the proposed site of STCF at the Hefei Future Big Science City. The second day concluded with further discussions in plenary, and then a wrap-up session.

The IAC meeting was preceded by a day-long review of the Conceptual Design Report (CDR) of the accelerator, which was conducted by a committee that included the machine experts of the IAC, plus additional experts from around the world. Several key recommendations on various parts of the accelerator design are presented in this report. A more complete set of observations and recommendations are provided in the separate report from the Accelerator CDR Review.

2 Executive summary
STCF will be a unique facility with a broad and impressive physics reach. It will allow for results of world-leading precision in many important topics, and has significant discovery potential. It will ideally complement the other facilities that are currently operational or are foreseen for the 2030s and 2040s, and will be of great interest to the international particle physics community. The principal challenge of the project lies in the accelerator. Here the intended luminosity will exceed by two orders of magnitude that previously achieved in the same energy regime.

The IAC is pleased to note the substantial progress made in physics, detector and accelerator studies since the last review in October 2024. An accelerator CDR has been written, which was reviewed immediately prior to the IAC meeting. Progress on both the accelerator and the detector has been aided by a growth in the number of Chinese institutes involved in the project

and from international collaboration, particularly from Japan and Russia. Involvement of STCF institutes in detector and parallel experimental initiatives at CERN are further benefiting the project. A suitable site has been chosen for the facility at the Hefei Future Big Science City. Important documents are planned over the coming year, including both Accelerator and Physics and Detector Technical Design Reports (TDRs).

The IAC continues to endorse the very high scientific merit of the project, it congratulates the STCF team on the excellent progress made over the past year. Although substantial challenges remain to be overcome, the IAC considers that STCF will be able to achieve its design goals within the timescale specified, and that the facility will be capable of delivering world-leading physics results that will address a wide range of extremely important fundamental questions.

3 Joint physics-accelerator comments and recommendations
The IAC has certain observations and recommendations that concern both physics and the accelerator.
- There are several measurements within the STCF physics programme that may benefit from longitudinal polarisation. Longitudinal polarisation is not foreseen for the initial phase of STCF operation, but has been mentioned as a goal for a second phase of operation. It may be, however, that provisions need to be made even in the design for the first phase machine, to keep this option open.

- The IAC recommends that the Physics and Detector TDR includes discussion of which measurements will benefit from polarisation, and quantifies the gains that this will bring, in order to decide whether polarisation remains a long-term goal of the project.

- At the same time, it should be understood whether any features of the machine layout will prevent the implementation of polarisation in the longer term, e.g. lack of space for rotator magnets. However, the IAC is not suggesting that significant resources be devoted to polarisation studies prior to project approval.

- It has been suggested that provision be made for a second interaction point (IP) to allow deployment of another detector, that would both allow for attracting international partners and could perhaps provide higher performance for certain measurements, e.g. physics below charm threshold.

- The IAC recommends that the machine layout should allow for a second IP only if this does not introduce significant complications to the design, and if the physics reach in important measurements could be significantly enhanced by two detectors with different attributes.

- Some measurements could in principle benefit from monochromatisation, that is a reduction in the spread of the collision energy. In practice this is non-trivial to achieve without a reduction in luminosity.

- The Physics and Detector TDR should identify any measurements for which monochromatisation would be desirable, and ascertain how essential this attribute would be. If deemed necessary, then the consequences for the machine should be established, for either the first or second phase of operation.

- The IAC is not aware of any consideration being made to the calibration of the collision energy. Precise knowledge of the collision energy is important for, e.g. measurement of the tau mass.

Various techniques exist to calibrate beam energy, for example Compton backscattering or resonant depolarisation, but implementing any of these would have implications for the machine design.

- The requirements on the calibration of the collision energy should be determined, and a strategy decided upon for meeting these requirements.

- STCF will be capable of running at a range of collision energies, at each of which different physics questions can be addressed, but it is not known in which order these energy points will be explored or how much data will be taken at each.

- The IAC advises that a baseline run plan be devised for the first phase of STCF operation, showing how much integrated luminosity will be collected at each energy point, and the corresponding physics deliverables.

Such a schedule would be useful for conveying to the international community the key priorities and ultimate physics reach of STCF, and could also be helpful for machine planning, and in justifying the length of the initial phase of the project.

Finally, it is noted that interesting physics lies just beyond the nominal upper limit of the STCF energy range ($\sqrt{s} = 7.6$ GeV). The threshold for the pair production of the doubly charmed baryon Ξ_{cc}^{++} occurs at 7.244 GeV, and that of the undiscovered Υ_c is most likely below 7.4 GeV. Still higher in energy, the threshold for pair production of the recently discovered T_c tetraquark lies at 7.50 MeV.

- Consideration should be given to whether studies of these states are of interest, and the theoretical community should be asked to estimate the production cross sections. The feasibility, implications and likely performance of operating the machine at these higher energies should be investigated.

4 Physics and detector
Comments

Impressive progress has been made since the last IAC meeting in October 2024. The goals of the physics programme are now presented in a focused and effective manner under the headings of 'tests of fundamental symmetries', 'exploring the nature of QCD and confinement' and 'precision measurements of fundamental physical parameters'. An extensive discussion of the capabilities of STCF in CP violation has recently been released (arXiv:2502.18007). Full simulation is underway across a range of processes; these are essential for understanding how well the detector meets the physics requirements and for identifying possible limiting systematics. Detector R&D is now at an advanced stage, helped by a significant increase in the number of participating institutions, with several prototype systems having been constructed and evaluated in test-beam campaigns. Readout ASICs are under development for many sub-detectors. These advances in hardware are being complemented with software developments and an improved understanding of the data acquisition and processing. A draft of a Physics and Detector TDR is foreseen for the end of the year.

Concerning the physics:

- The IAC is pleased to see that full simulation studies are underway for a wide range of physics topics, and encourages that these are all pursued as far as possible, in order to identify any possible systematic limitations.

STCF will be a **unique facility with a broad and impressive physics reach**. It will allow for results of **world-leading precision** in many important topics, and has **significant discovery potential**. It will **ideally complement** the other facilities that are currently operational or are foreseen for the 2030s and 2040s, and will be of **great interest** to the international particle physics community.....
The IAC is pleased to note **the substantial progress made in physics, detector and accelerator studies**

The IAC continues to **endorse the very high scientific merit of the project**. It congratulates the STCF team on **the excellent progress** made over the past year. Although substantial challenges remain to be overcome, the IAC considers that STCF will be able to **achieve its design goals within the timescale specified,.....**

Very High rating, excellent comments and recommendations!

例行工作组会



项目官网 <https://stcf.ustc.edu.cn/>
会议信息 <https://indico.pnp.ustc.edu.cn/category/10/>

STCF

1,874 events

STCF公共信息	7 events	🛡️ ➡️
Accelerator	320 events	🛡️ ➡️
Detector	516 events	🛡️ ➡️
Physics & Software	670 events	🛡️ ➡️
Accelerator-Detector Joint meetings	empty	🛡️ ➡️
Conference Talk Review & Rehearsal	7 events	🛡️ ➡️
项目办公室	163 events	🛡️ ➡️
STCF项目总体例会	86 events	🛡️ ➡️
Management Meetings	77 events	🛡️ ➡️
建议书撰写小组	4 events	🛡️ ➡️
学术秘书组会议	4 events	🛡️ ➡️
园区规划和设计	2 events	🛡️ ➡️
国际顾问委员会 (International Advisory Committee)	3 events	➡️
咨询委员会 (National Consultative Committee)	1 event	➡️
Steering Committee	1 event	🛡️ ➡️
Domestic Meeting	4 events	➡️
STCF publication	6 events	➡️
Event	2 events	➡️
Interviews	1 event	🛡️ ➡️

2025年 秋季学期	周一	周二	周三	周四	周五	
上午	每周 (01) STCF基本对称性检验全模拟周会 周小琴 10: 00-11: 00	每两周 (01) 桶部粒子鉴别双周会 9: 00-11: 00 刘倩 每两周 (02) 物理模拟双周会 09: 00-11: 00 周小琴	每两周 (01) 电磁量能器双周会 9: 00-11: 00 张云龙 每两周 (03) 端盖粒子鉴别双周会 09: 00-11: 00 邵明	每周 (03) STCF项目办公室周会 9: 00-11: 00 邵明 双周 (02) 数字化全模拟双周会 09: 00-12: 00 方竹君 双周 (02) 触发与数据获取双周会 09: 00-12: 00 方竹君	每周 (02) STCF管理周会 9: 50-12: 00 胡启鹏、彭海平	每两周 (01) 时钟与数据传输双周会 10: 00-12: 00 王进红 每两周 (02) 向阳区双周会 10: 30-12: 30 陈海、刘明依
下午		每周 (04) 注入器物理设计周会 14: 00-16: 00 原石进、谷端、张艾霖 每两周 (01) 软件框架双周会 16: 00-17: 00 李燕	每两周 (03) 束流测试、微波联合周会 15: 30-17: 30 罗菁、庞健	每周 (04) 对撞环物理设计周会 14: 00-16: 30 邹野 每两周 (02) 硅内径迹探测器双周会 14: 00-16: 00 徐来林 每两周 (01) 主漂移室、气体内径迹探测器双周会 14: 00-16: 00 周意、曹喆	每周 (04) 环高轨系统周会 16: 30-18: 00 韦业龙 腾讯会议: 552-8740-4576	每周 (01) 径迹与缪子重建周会 14: 00-16: 00 周小琴 每周 (05) STCF基本物理量精确测量全模拟周会 16: 00-17: 30 周小琴 每两周 (02) STCF项目总体双周会 16: 00-17: 30 张艾霖、彭海平 每两周 (03) 粒子鉴别器和电磁量能器重建双周会 14: 00-16: 00 齐斌斌
晚上	每周 (01) 软件周会 19:00-21: 00 艾小聪			每两周 (01) 月中&月底 谱仪机械双周会 19: 00-22: 30 康玲、沈刚	每两周 (01) 超导螺线管磁体双周会 朱自安、张小涛 20: 30-21: 30	

2025年 秋季学期	九月	十月	十一月	十二月	26年一月	26年二月
下午	每月 9月22日 加速器分总体月例会 14: 00-16: 00 唐靖宇、罗菁	每月 10月27日 加速器分总体月例会 14: 00-16: 00 唐靖宇、罗菁	每月 11月24日 加速器分总体月例会 14: 00-16: 00 唐靖宇、罗菁	每月 12月29日 加速器分总体月例会 14: 00-16: 00 唐靖宇、罗菁	每月 最后一周 周一 加速器分总体月例会 14: 00-16: 00 唐靖宇、罗菁	每月 最后一周 周一 加速器分总体月例会 14: 00-16: 00 唐靖宇、罗菁
	每月 (02) 谱仪分总体月例会 14: 00-18: 00 刘建北、赵雷	每月 (02) 谱仪分总体月例会 14: 00-18: 00 刘建北、赵雷	每月 (02) 谱仪分总体月例会 14: 00-18: 00 刘建北、赵雷	每月 (02) 谱仪分总体月例会 14: 00-18: 00 刘建北、赵雷	每月 (02) 谱仪分总体月例会 14: 00-18: 00 刘建北、赵雷	每月 (02) 谱仪分总体月例会 14: 00-18: 00 刘建北、赵雷
晚上	每月 (01) 9月4日 谱仪控制组月例会 19: 00-22: 30 胡东栋	每月 (01) 第一周周四 谱仪控制组月例会 19: 00-22: 30 胡东栋	每月 (01) 11月6日 谱仪控制组月例会 19: 00-22: 30 胡东栋	每月 (01) 12月4日 谱仪控制组月例会 19: 00-22: 30 胡东栋	每月 (01) 第一周周四 谱仪控制组月例会 19: 00-22: 30 胡东栋	每月 (01) 第一周周四 谱仪控制组月例会 19: 00-22: 30 胡东栋

- STCF是我国提出的**新一代**GeV能区高亮度正负电子对撞机，致力于深入探索粒子物理中的独特能区——**陶粲能区**。它能够在阈值处产生大量粲偶素、粲强子、轻强子和陶轻子对。有望在**基本对称性检验、色禁闭之谜、基本物理量的基本测量**等前沿方向取得重要突破。
- STCF目前已完成加速器和探测器的概念设计，并在关键技术预研方面取得系列技术突破。当前，项目正积极推动国家重大科技基础设施的申请与立项。
- **诚挚欢迎更多专家加入，并期待开展更广泛的学术交流与合作！**

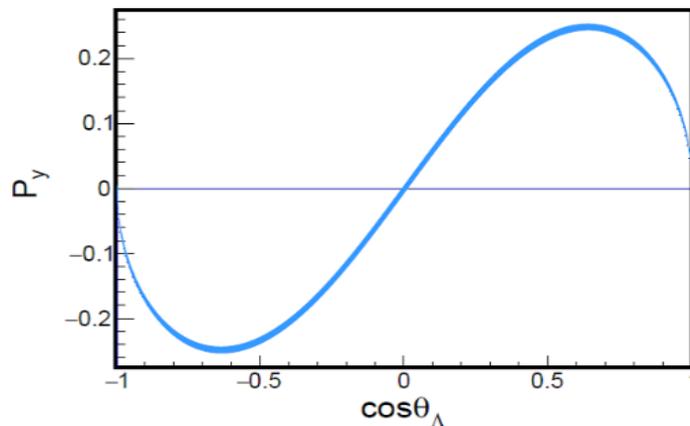
谢谢!

CP Tests in Hyperons Decays

- ★ *Certain analyses, such as the search for CP violation in hyperons, will require excellent **systematic control** in order to be sensitive to the very small size of signal expected and to match the foreseen statistical precision.*

Features of hyperon CP tests at STCF:

- Hyperon production, polarization and kinematics established
- Numerous CPV observables
- **Systematic uncertainties control**



Statistics related

- Data/MC difference in tracking, PID etc. → Two orders in magnitude improve of control sample → 10^{-4} or better
- Input-output check → Larger MC statistics → negligible

Theoretical calculation related

- NLO production → complete form factor function → negligible
- Precession in magnetic field/de-coherence → include the effects in MC → negligible

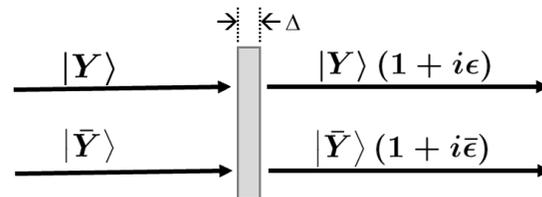
Detector and software related

- Detection resolution effect → examine the decay parameter bin-by-bin → 10^{-4} or better
- Kinematic fits, photon noise, background etc. → Novel MC tool and reconstruction → 10^{-4} ?

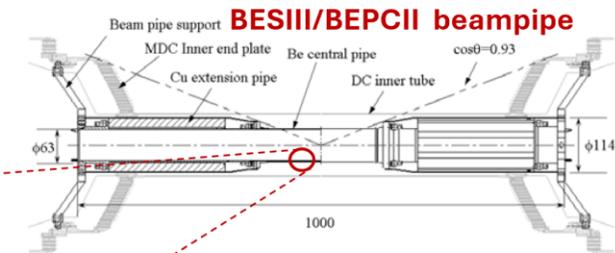
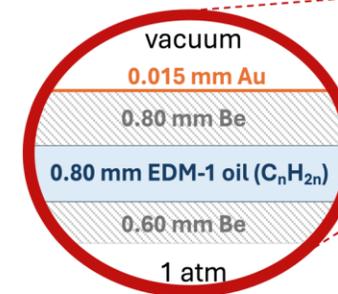
CP Tests in Hyperons Decays

As the **detector resolution is a big issue in the uncertainty estimation**. A series of attempts are undergoing in the tracking reconstruction, which include:

- Improve tracking efficiency from **long-life particle decay**
- Improve tracking efficiency for **low-momentum particles**
- Study the impact of electron **bremstrahlung**
- Optimize of the **secondary vertex fitting**
- Impact of **magnetic field non-uniformity**
- Impact of **material budget**
- Impact of **background contamination**
- **How Y and \bar{Y} affect $Y - \bar{Y}$ spin correlations?**



Beampipe-ology



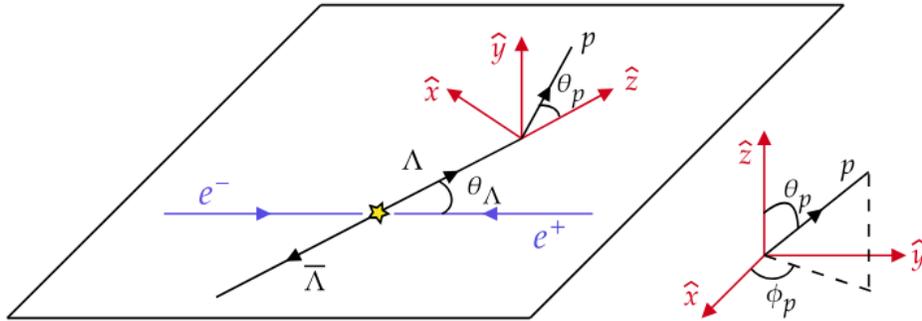
requirements

low-impedance conduction of 1 A beam image currents:	30 mg/cm ² Au
support the SMO-vacuum pressure difference:	150 mg/cm ² Be
remove the beam-induced RF-generated heat:	70 mg/cm ² oil
support the SMO-atmosphere pressure difference:	110 mg/cm ² Be
	360 mg/cm²

irreducible effective radial thickness $\Delta r \approx 2.0$ mm Be

average thickness seen by a hyperon is $\langle \Delta r / \sin \theta \rangle \approx 4$ mm

Search for CPV and d_Λ in $J/\psi \rightarrow \Lambda \bar{\Lambda}$ decay



Angular distribution of hyperon production

Described by EM form factors $G_{1,2}$

$$\alpha_\psi = \frac{s^2|G_1|^2 - 4m^2|G_2|^2}{s^2|G_1|^2 + 4m^2|G_2|^2}, \quad \frac{G_1}{G_2} = \left| \frac{G_1}{G_2} \right| e^{-i\Delta\Phi}$$

$$\frac{d\Gamma}{d\Omega} \propto 1 + \alpha_\psi \cos^2 \theta$$

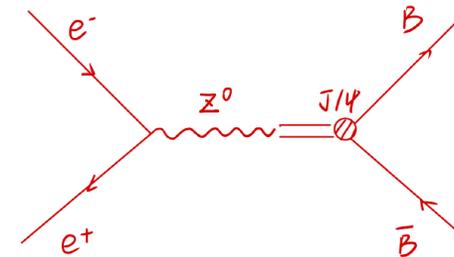
Non-zero $\sin(\Delta\Phi)$ signatures hyperon polarization

$$P_y(\cos \theta) = \frac{\sqrt{1 - \alpha_\psi^2 \sin(\Delta\Phi) \cos \theta \sin \theta}}{1 + \alpha_\psi \cos^2 \theta}$$

P , CP violating terms in J/ψ production and decay

- P_L : J/ψ longitudinal polarization induced by Z boson
- F_A : P violating form factors
- H_T : CP violating form factors associated with EDM

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



$$P_L = \frac{\rho_{++} - \rho_{--}}{\rho_{++} + \rho_{--}}$$

F_A : P violation term

Complex form factor, $F_A \neq 0$ indicate P violation

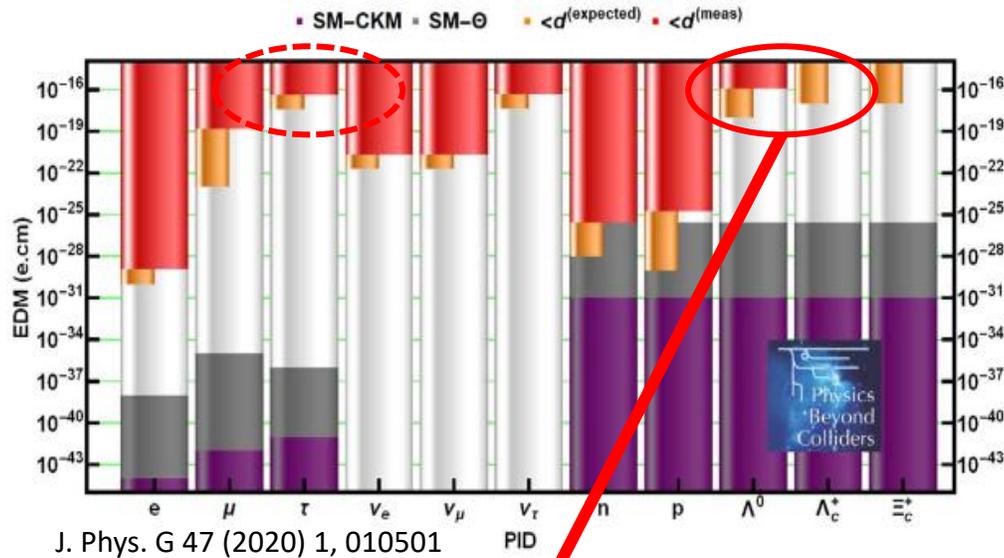
H_T : CP violation term

$$H_T(q^2) = \frac{2e}{3m_{J/\psi}^2} g_V d_B(q^2)$$

Assuming $d_B(q^2) \equiv d_B(0)$

$d_B(q^2)$: electric dipole form factor
 $d_B(0)$: electric dipole moment
 Physics Letters B 551 (2003) 16–26

Search for CPV and d_Λ in $J/\psi \rightarrow \Lambda \bar{\Lambda}$ decay



- EDM measurement only performed for Λ hyperon
- d_Λ can be improved 10,000 in STCF
- Search for EDM of the other strange and charmed baryons

- Based on OSCAR simulation, **statistical precision** improved by more than one order comparing to BESIII
- **Systematic uncertainty** dominated by **detector resolution effects**, could be improved by correcting resolution effect in MC with control samples, which is under study

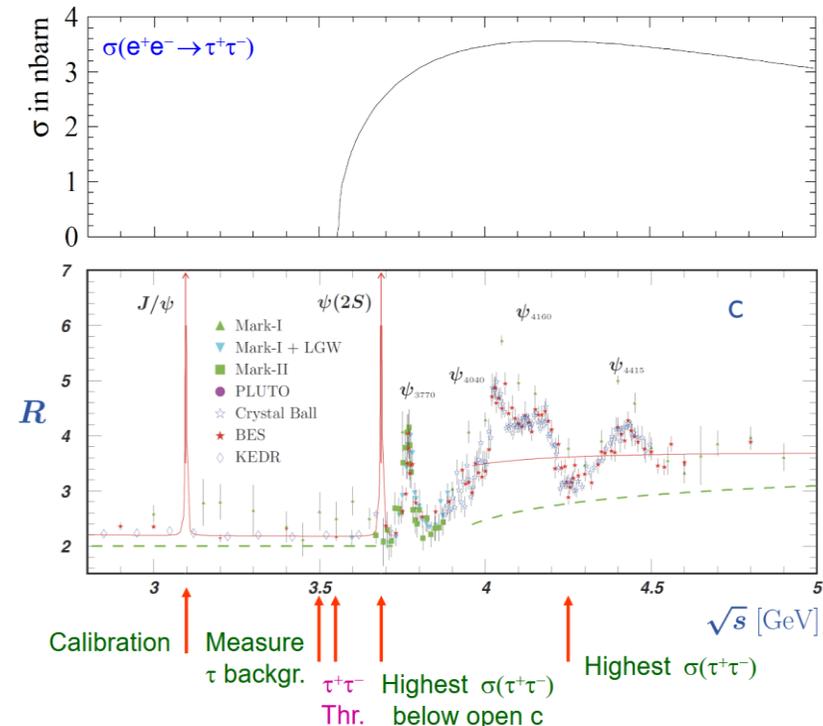
Parameter	Stat.	BESIII Stat.	BESIII Sys.
$\alpha_{J/\psi}$	1.4×10^{-4}	2.2×10^{-3}	1.7×10^{-3}
$\Delta\Phi$	2.7×10^{-4}	4.2×10^{-3}	1.3×10^{-3}
A_{cp}	3.0×10^{-4}	4.6×10^{-3}	1.1×10^{-3}
$\sin W^2$	6.4×10^{-4}	1.2×10^{-3}	2.6×10^{-3}
$Re(d_\Lambda)$	2.1×10^{-20}	3.2×10^{-19}	0.5×10^{-19}
$Im(d_\Lambda)$	1.6×10^{-20}	2.6×10^{-19}	0.6×10^{-19}

Tau physics at STCF

★ The IAC notes and approves of the three physics topics that have been identified as flagship measurements, but suggests that the list could be extended to around five. In particular, it considers that it would be appropriate to include a **topic in tau physics**.

- Tau pairs in e^+e^- collider produced back-to-back in center-of-mass system
- At **tau-charm factory**: different energy region, different potential, runs near the tau pair threshold

Exp.	Lum.	\sqrt{q}	Number of tau pairs
ALEPH	200 pb ⁻¹	91.2 GeV	3.3 × 10 ⁵ reconstructed
BaBar	467 fb ⁻¹	~10.58 GeV	4.3 × 10 ⁸
Belle	988 fb ⁻¹	~10.58 GeV	9.12 × 10 ⁸
Belle II (prospect)	50 ab ⁻¹	~10.58 GeV	4.6 × 10 ¹⁰
BESIII	~35 fb ⁻¹	From threshold to 4.95 GeV	~1.2 × 10 ⁸
STCF (prospect)	1 ab⁻¹ per year	From threshold to 7 GeV	~3.5 × 10⁹

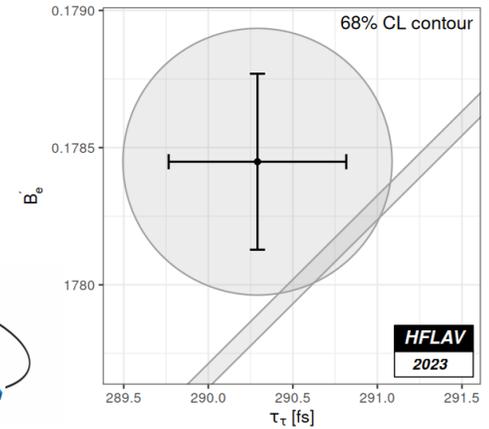
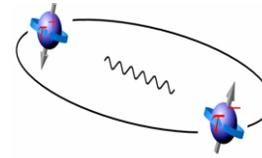


Tau physics potential at STCF



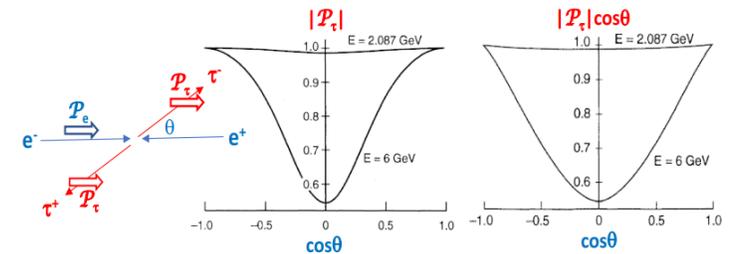
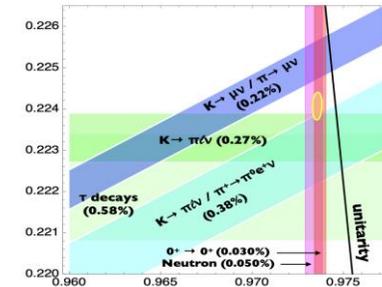
- **Properties of tau lepton**

- **τ -lepton mass (Challenge from uncertainties in energy calibration and spread)**
- **Tauonium** Enhanced significance with improved energy spread
- **EDM** evolution of EDM form factors with energy
- **Quantum entanglement**



- **Tau decay**

- **cLFV** systematically studies via leptonic decays
- **Cabibbo angle anomaly, CPV** studies via hadronic decays
- **Amplitude/form factor** studies via many-body decays
- **α_s and muon g-2**



5-7 GeV physics potential at STCF

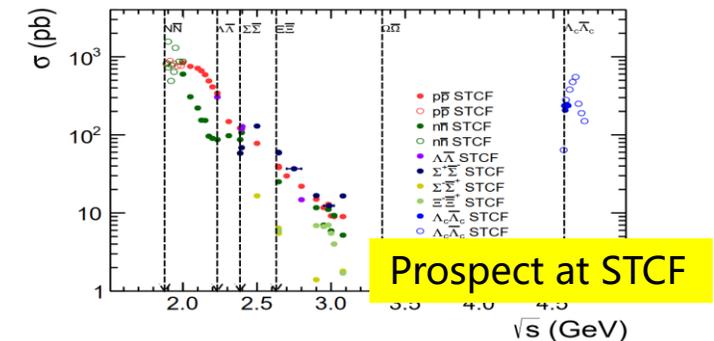
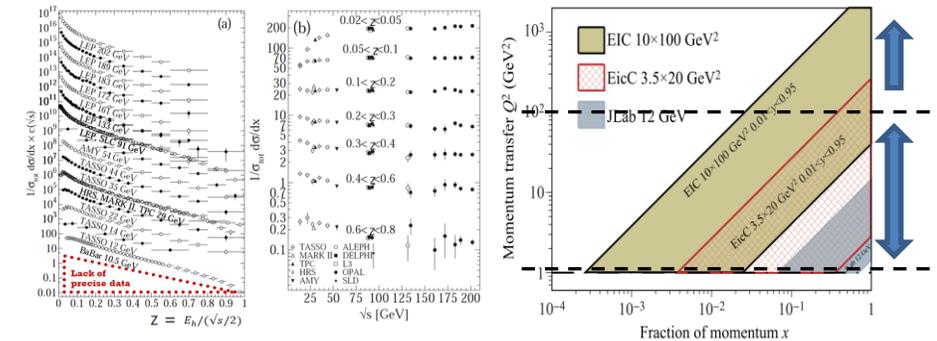
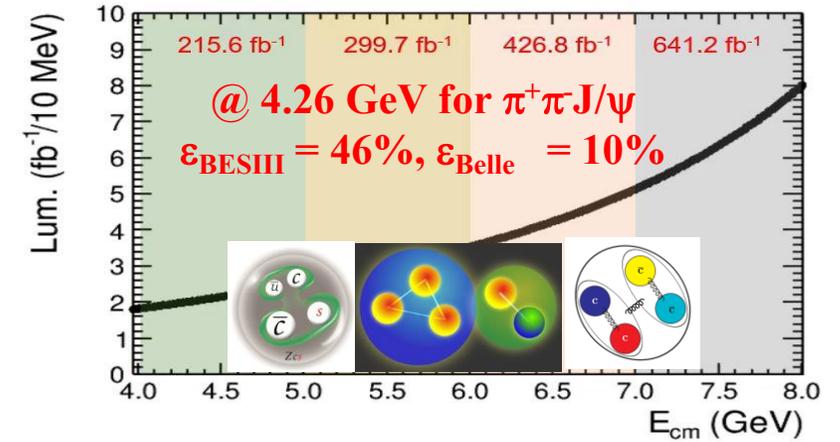


- **Hadron spectroscopy**

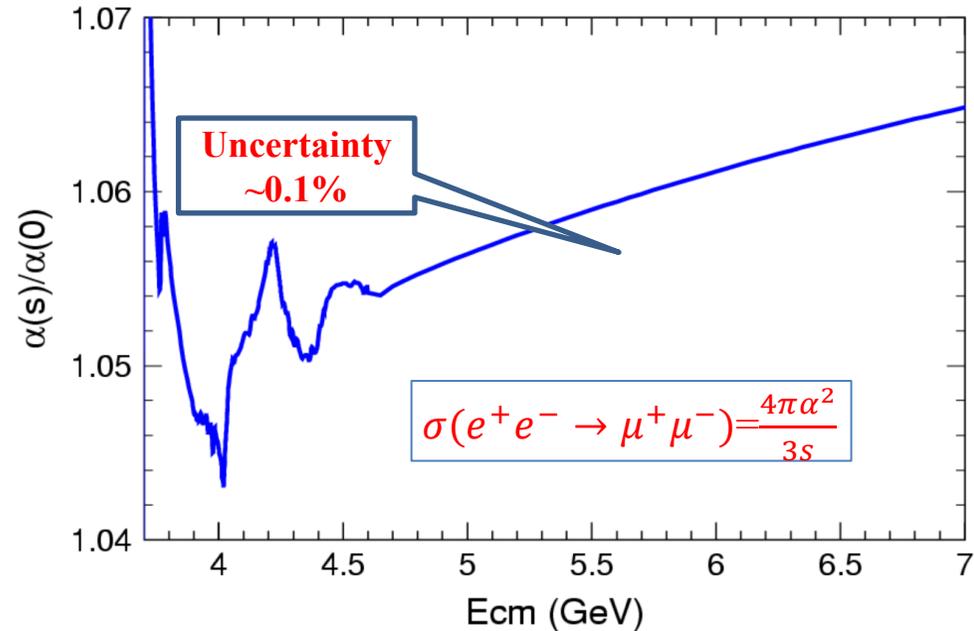
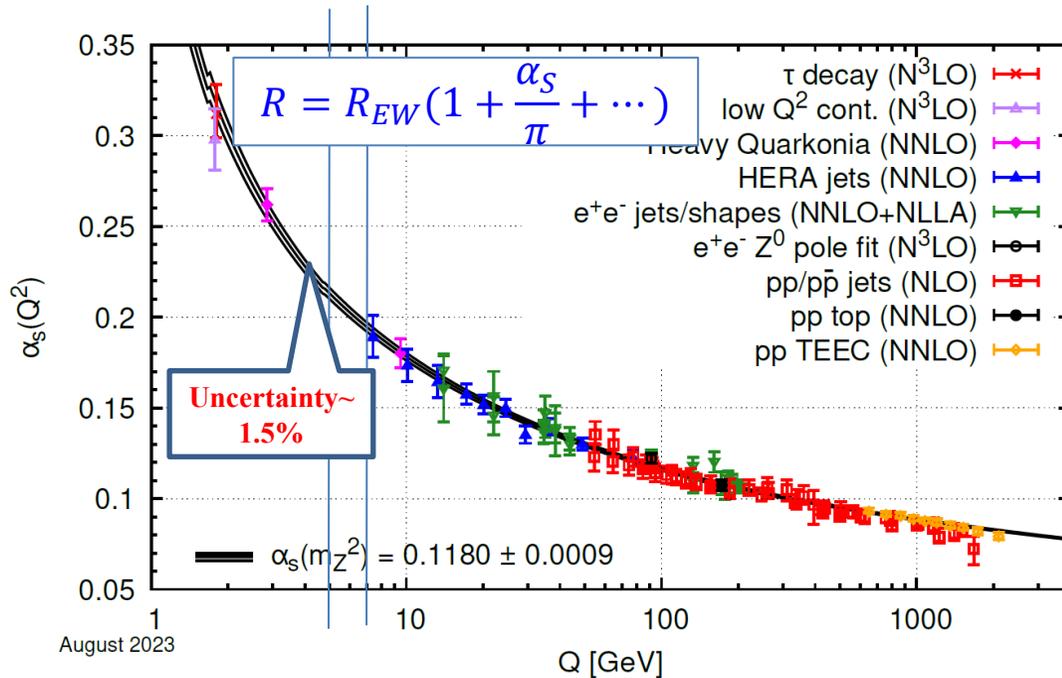
- Many threshold opens in 5-7 GeV which yield more potentials for hadron studies
- Structures in more channels for **XYZ physics**, with larger production rates above 5 GeV
- **P_c pentaquarks** in $e^+e^- \rightarrow J/\psi h \bar{h}$ for hidden-charm and $e^+e^- \rightarrow \Lambda_c \bar{D}^* \bar{p}, \Sigma_c^* \bar{D}^{(*)} \bar{p}$ for open-charmed pentaquarks
- Energy region above 6 GeV is ideal for **fully charmed tetraquark states** via $e^+e^- \rightarrow J/\psi c \bar{c}$ etc.

- **Hadronization and hadron structure**

- **Fragmentation functions** for charmed quark is available
- Synergy with Eic(C) facilities for FF studies
- A non-zero Pauli **Form factors** provides evidence for the existence of higher Fock states, that require higher energies



强相互作用耦合常数 α_S



- Finding invisible states in e^+e^- annihilation: Compare α_{QED} from $\sigma(e^+e^- \rightarrow \mu^+\mu^-)$ and that calculated from $\sigma(e^+e^- \rightarrow \text{hadrons})$
- $\sigma(e^+e^- \rightarrow \text{hadrons})$ & $\sigma(e^+e^- \rightarrow \mu^+\mu^-)$
 - 100 fb⁻¹ data (~1 month @ $L_{\text{peak}} \sim 5 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$) →
 - 2-4 x 10⁶ $e^+e^- \rightarrow \mu^+\mu^-$ events → 0.2% or better precision?
 - 7-14 x 10⁶ $e^+e^- \rightarrow \text{hadrons}$ events → 0.4% or better precision?
 - Bhabha or $e^+e^- \rightarrow \gamma\gamma$ for integrated luminosity measurements