Summary of Physics Session

康晓琳

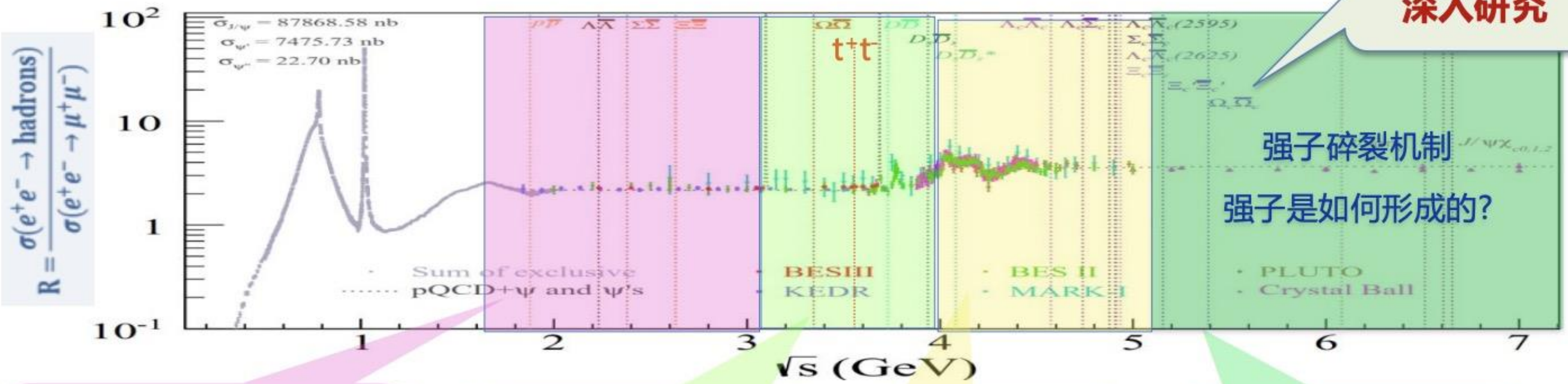
2026年超级陶粲装置研讨会
中国西安 6月30日-7月5日

陶粲能区物理

吕晓睿

- 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
- Mutltiquark 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_{Ds}
- 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

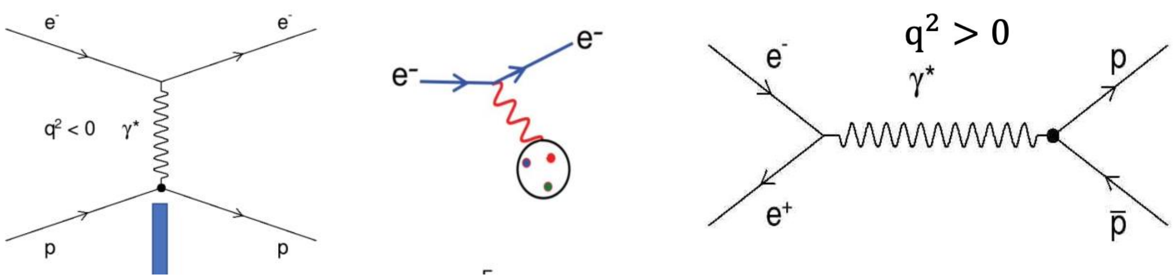
基本物理量精确测量

R值、陶轻子质量

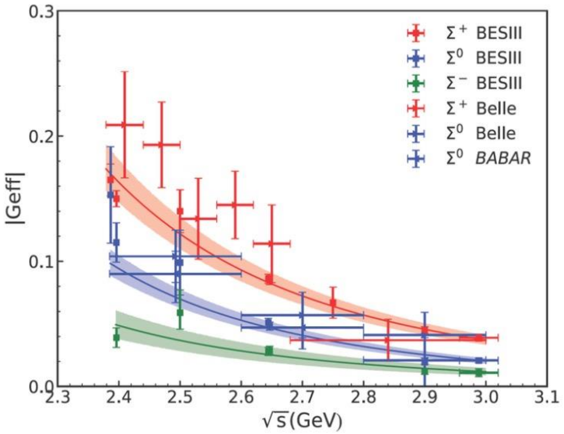
电磁、强跑动耦合常数

CKM矩阵元

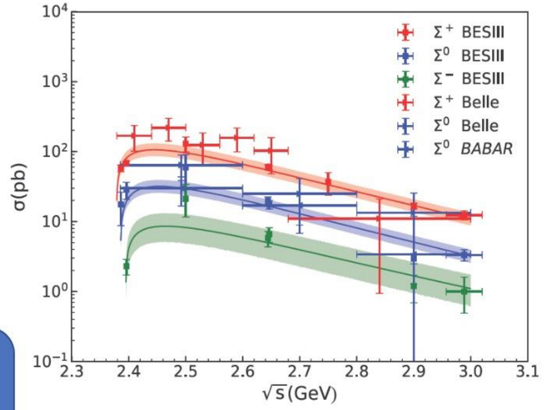
谢聚军：基于VMD模型的重子电磁形状因子



EMFFs of Σ^+, Σ^-, and Σ^0 : Numerical results



Parameter	Value	Parameter	Value
γ (GeV^{-2})	0.527 ± 0.024	$\alpha_{\omega\phi}$	-3.18 ± 0.77
$\beta_{\omega\phi}$	-0.08 ± 0.06	β_ρ	1.63 ± 0.07



With the same value of γ, we can describe all the current experimental data on Σ^+, Σ^-, and Σ^0 EMFFs.

Bing Yan, Cheng Chen, and Ju-Jun Xie, **Phys. Rev. D107, 076008 (2023).**

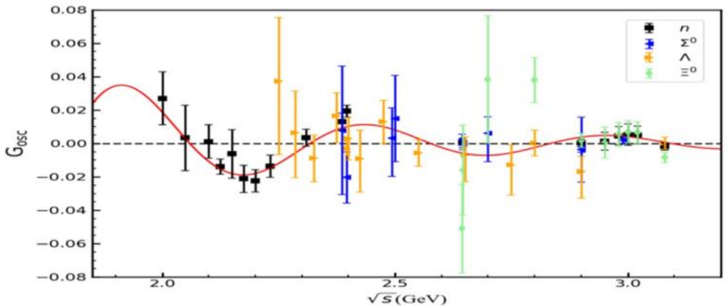
New parametrization for the "oscillation"

$$G_D(q^2) = \frac{c_0}{(1 - \gamma q^2)^2} \qquad G_{osc} = A \cdot \frac{c_0}{(1-\gamma \cdot s)^2} \cdot \cos\left(C \cdot \sqrt{s} + D\right)$$

$$G_{\mathrm{eff}}(s) = G_{\mathrm{D}}(s) + G_{\mathrm{osc}}(s) = \frac{c_0}{(1-\gamma s)^2}\left(1 + A\cos(C\sqrt{s} + D)\right) \rightarrow$$

$$\boxed{data = G_{eff} = G_D + G_{osc}}$$

$$\boxed{G_{osc} = data - G_D}$$



Summary

1、Threshold enhancement

a) Final state interaction

b) vector states (Flatté: strong coupling)

2、 "Oscillation" of baryon effective form factors

a) Phenomenology $\qquad g(q^2) = \frac{1}{(1-\gamma q^2)^2}$

b) **Vector excited states**

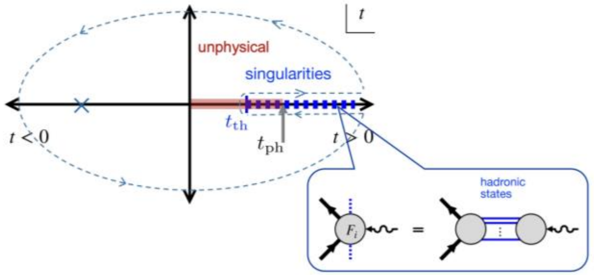
+ Other models

We conclude that

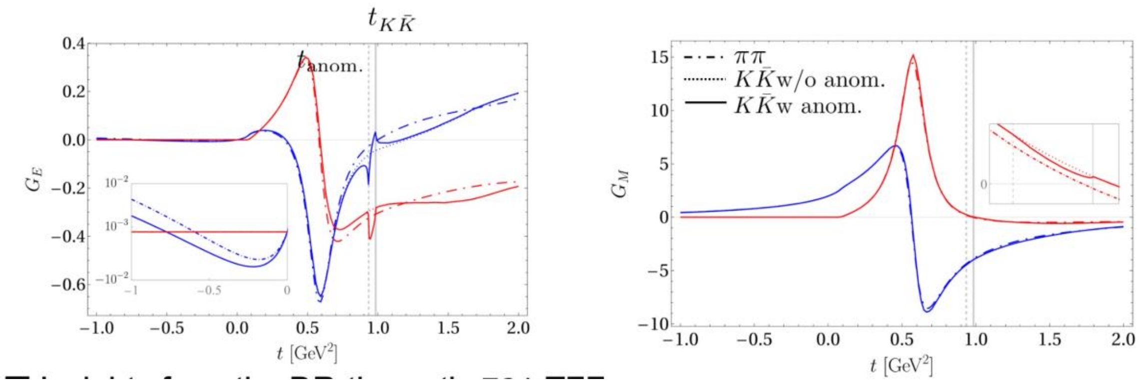
The nonmonotonic structures observed in the line shape of the $e^+e^- \to B\bar{B}$ total cross sections can be naturally explained within the VMD model.

The $e^+e^- \to B\bar{B}$ reactions can be used to study the excited vector states.

林勇辉：超子的电磁结构



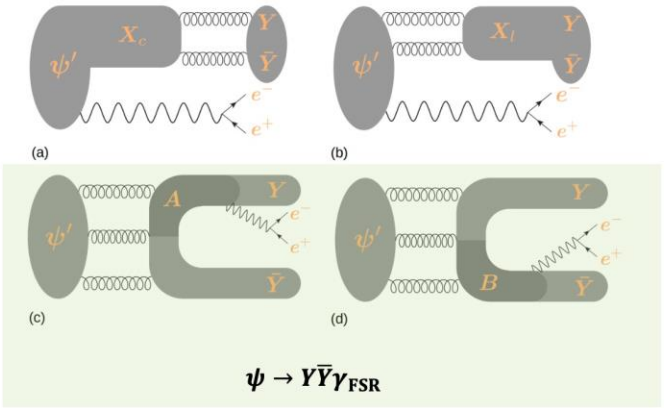
❖ Example1: Σ → Λ transition form factor



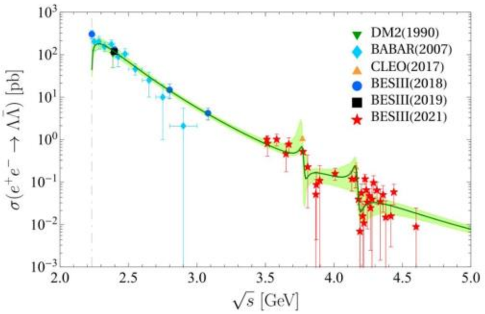
❖ Hyperon radius at STCF

- Radiative Dalitz decay of charmonium

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



❖ Example2: Extraction of Λ magnetic radius



(g_1, g_2)	ω	ϕ
N	$(18.6 \pm 4.3, 8.4 \pm 6.6)$	-
Λ	$(18.04 \pm 0.13, -34.45 \pm 0.24)$	$(-16.81 \pm 0.24, 18.99 \pm 0.25)$

- CHPT constrained magnetic radius

$$r_\Lambda^M = 0.681(2)\ \mathrm{fm}$$

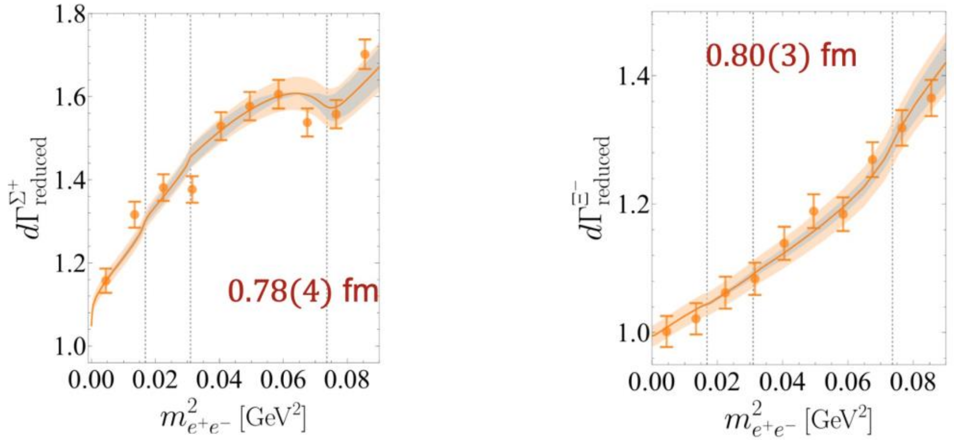
- Test the $SU(3)$ flavor symmetry

$$\frac{g_1^{\omega\Lambda\Lambda}}{g_1^{\omega NN}} = \frac{2}{3}\frac{5\alpha_{BBV}-2}{4\alpha_{BBV}-1} \longrightarrow \alpha_{BBV} \geq 0.82$$

$$\frac{g_1^{\phi\Lambda\Lambda}}{g_1^{\omega NN}} = \frac{-\sqrt{2}}{3}\frac{2\alpha_{BBV}+1}{4\alpha_{BBV}-1} \longrightarrow \alpha_{BBV} \leq 0.8$$

❖ Hyperon radius at STCF

- Sensitivity analysis by fitting to the Monte Carlo events (2×10^4 about $10^9\ \psi'$)



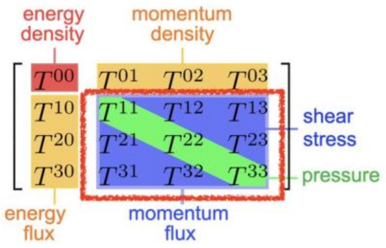
Probes of nucleon structure

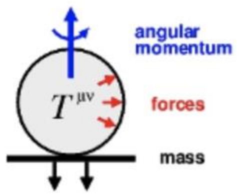
- Electromagnetic, weak, gravitational form factors (GFFs)

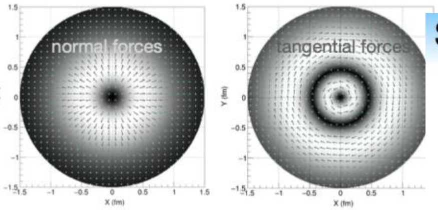
em: $\partial_\mu J^\mu_{\rm em} = 0$	$\langle N'\vert J^\mu_{\rm em}\vert N\rangle$	$\longrightarrow$	$Q = 1.602176487(40)\times 10^{-19}\,\mathrm{C}$ $\mu = 2.792847356(23)\mu_N$
weak: PCAC	$\langle N'\vert J^\mu_{\rm weak}\vert N\rangle$	$\longrightarrow$	$g_A = 1.2694(28)$ $g_p = 8.06(55)$
gravity: $\partial_\mu T^{\mu\nu}_{\rm grav} = 0$	$\langle N'\vert T^{\mu\nu}_{\rm grav}\vert N\rangle$	$\longrightarrow$	$m = 938.272013(23)\,\mathrm{MeV}/c^2$ $J = \frac{1}{2}$ $\boldsymbol{D} = \boldsymbol{?}$

Polyakov & Schweitzer, IJMPA (2018) 1830025

D-term: "Last unknown global property"



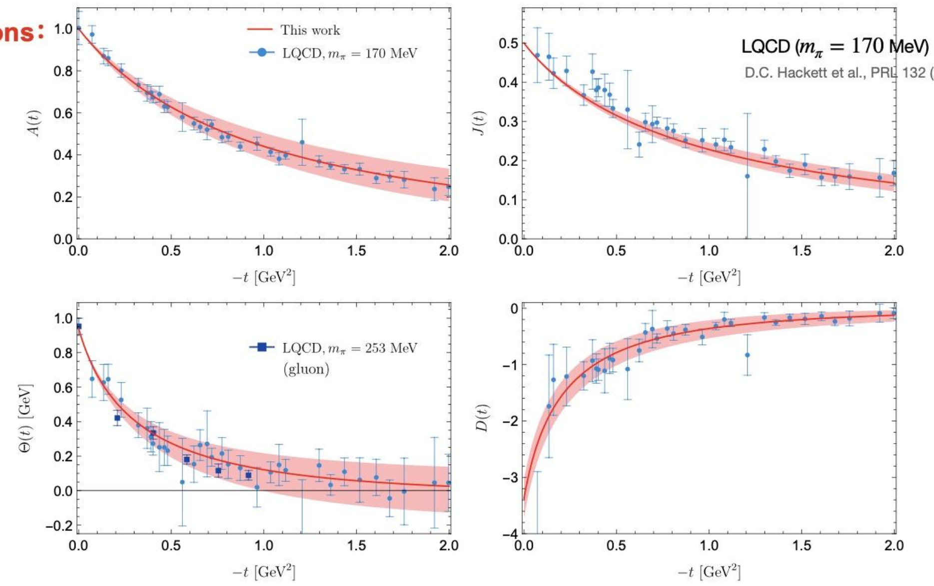




Burkert, et al., Reviews of Modern Physics

Nucleon GFFs

Predictions:



LQCD ($m_\pi = 170$ MeV)

D.C. Hackett et al., PRL 132 (2024) 251904

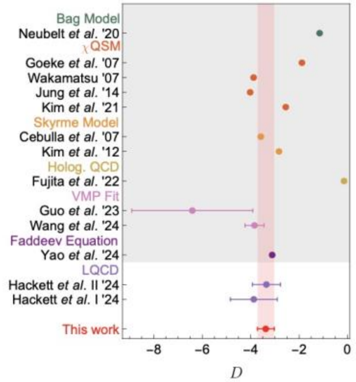
姚德良：核子的引力形状因子

Summary and Outlook

- The nucleon GFFs are precisely determined using dispersive method with inputs:
  - Coupled-channel $\pi\pi$-$K\bar{K}$, $\pi\pi/K\bar{K}\to N\bar{N}$ amplitudes
  - Low energy: NLO ChPT with LECs estimated using resonance saturation, improvable with lattice calculations
  - High energy: highly excited meson resonances
- Nucleon static properties:
  - Precise determination of D term: $D^N = -3.38^{+0.34}_{-0.35}$
  - Suggesting a modern structural view of the nucleon:

$$\sqrt{\langle r^2_\Theta\rangle} = 0.97^{+0.03}_{-0.03}\ \mathrm{fm} > \sqrt{\langle r^2_{E,p}\rangle} \simeq 0.84\ \mathrm{fm} > \sqrt{\langle r^2_{\rm Ener}\rangle} = 0.70^{+0.03}_{-0.04}\ \mathrm{fm}$$

proton electric charge



- **Outlook:**
  - Pion mass dependence
  - Extension to hyperon GFFs

孟雨：LQCD for charm at STCF

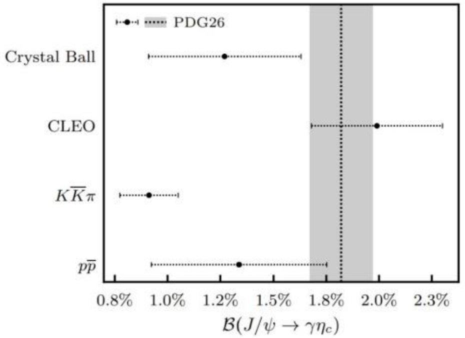
Role of STCF

Based on 10 billion J/ψ samples, BESIII have measured

- $\mathcal{B}(J/\psi \to \gamma\eta_c) \times \mathcal{B}(\eta_c \to 2\gamma) = 5.23(26)(30) \times 10^{-6}$ PRL134,181901(2025)
- $\mathcal{B}(J/\psi \to \gamma\eta_c) \times \mathcal{B}(\eta_c \to p\bar{p}) = 2.11(2)(7) \times 10^{-5}$ PRL136,051901(2026)
- Absolute branching fraction $\mathcal{B}(\eta_c \to 2\gamma) = 2.45(48)(09) \times 10^{-4}$. PRL accepted(2026)

Based on 1000 billion J/ψ samples per year on STCF

- A direct measurement $\mathcal{B}(J/\psi \to \gamma\eta_c)$
- More precise constraints on $\mathcal{B}(J/\psi \to \gamma\eta_c) \times \mathcal{B}(\eta_c \to X_i)$



Summary

Outlook and role of the STCF

- Charmonium decay puzzle
  - $J/\psi \to \gamma\eta_c$ and $\eta_c \to 2\gamma$
  - Model-independent determination of $\mathcal{B}(J/\psi \to \gamma\eta_c)$
- Semileptonic decay
  - $D_s \to \phi$ and $D \to K^*$
  - Real photon radiation: $D \to K\gamma l\nu_l$
- Rare decay
  - $J/\psi \to D_{(s)}$ and $J/\psi \to \gamma\nu\bar{\nu}$
  - Axion-like particle search: $D \to l\nu_l a$

Charmonium weak decay

- Experiments

channels	Upper limit	J/ψ number	Refs
$J/\psi \to D_s e\nu_e$	4.9×10^{-5}	5.8×10^{7}	PLB639,418(2006)
$J/\psi \to D_s e\nu_e$	1.3×10^{-6}	2.3×10^{8}	PRD90,112014(2014)
$J/\psi \to D e\nu_e$	7.1×10^{-8}	1.01×10^{10}	JHEP06,157(2021)
$J/\psi \to D\mu\nu_\mu$	5.6×10^{-7}	1.01×10^{10}	JHEP01,126(2024)
$J/\psi \to D_s e\nu_e$	9.9×10^{-8}	1.01×10^{10}	2510.25100

BES & BESIII collaboration

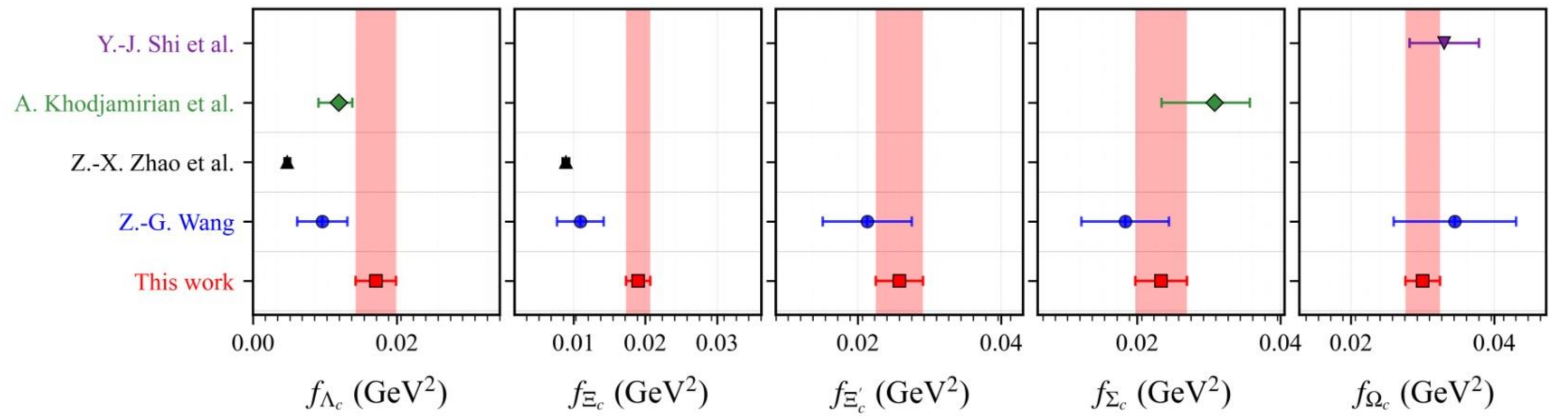
- Future measurements ?

channels	Upper limit	J/ψ number	Refs
$J/\psi \to D_s\mu\nu_\mu$	—	1.01×10^{10}	BESIII
$J/\psi \to D_{(s)} e\nu_e$	—	$\sim 10^{12}$	STCF
$J/\psi \to D_{(s)}\mu\nu_\mu$	—	$\sim 10^{12}$	STCF

$$\mathrm{Br}(J/\psi \to D_s e\nu_e) = 1.90(6)_{\rm stat}(5)_{V_{cs}} \times 10^{-10}$$
$$\mathrm{Br}(J/\psi \to D e\nu_e) = 1.21(6)_{\rm stat}(9)_{V_{cd}} \times 10^{-11}$$

Y.M et al, PRD110,074510(2024).

Charmed baryon decay constants:

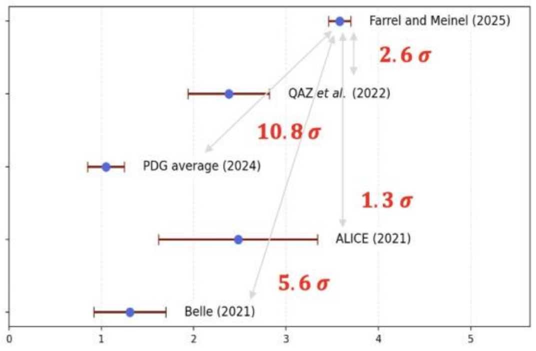


李磊毅：LQCD for baryon at STCF

Puzzle of $\Xi_c^0 \to \Xi^- e^+ \nu_e$ decay

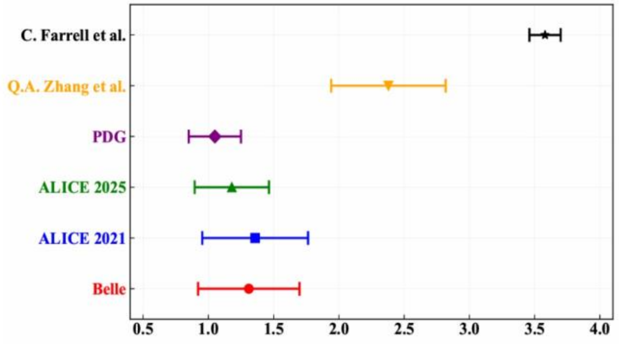
-25-

ALICE's result is updated



by Q.A. Zhang PPT

https://doi.org/10.1142/S0217751X2645003X

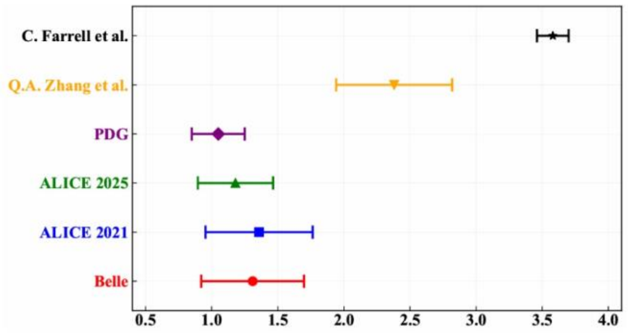


L.Y. Li and W. Wang, Int. J. Mod. Phys. A (2026)

Challenges and Prospect

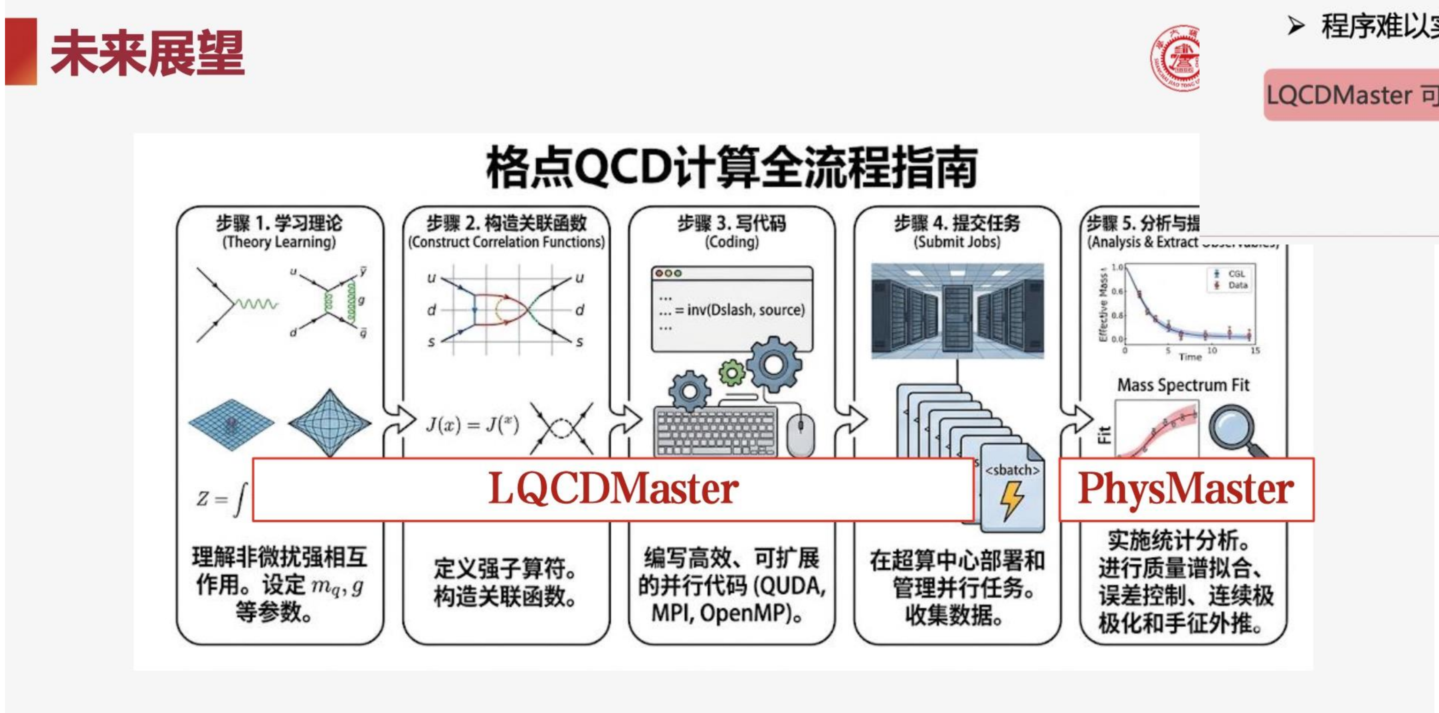
A small mixing angle is not a sufficient to explain Ξ_c decays!

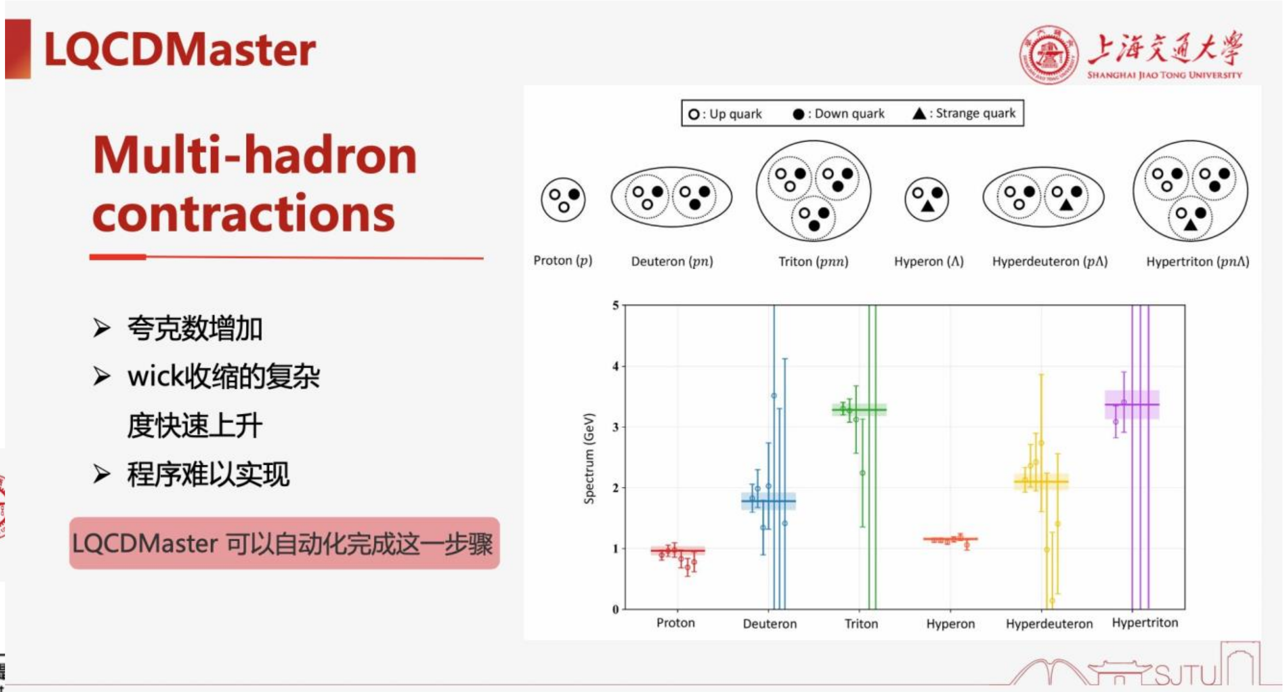
$$\text{Strategy } I: \quad \theta = (1.094 \pm 0.060)^\circ$$
$$\text{Strategy } II: \quad \theta = (0.810 \pm 0.206)^\circ$$



- ✓ A new LQCD calculation using CLQCD configurations is under progress
- ✓ An independent experimental measurement of $\Xi_c^0 \to \Xi^- \pi^+$ is needed.

高浩飞: AI scientist for LQCD: a new tool for flavor physics

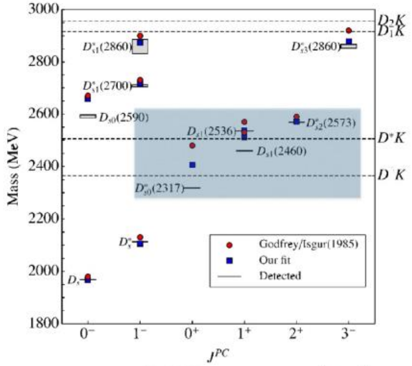




吴佳俊：非微扰哈密顿框架研究强子态

$D_{s0}(2317)$, $D_{s1}(2460)$, $D_{s1}(2536)$, $D_{s2}(2573)$

Z. Yang, G.-J. Wang, J.-j. Wu, S.-l. Zhu, M. Oka Phys.Rev.Lett.128(2022),112001



$\bar{c}s$ cores		channel	
	$B(\lvert^{2S+1}L_J\rangle)$	B(mass)	α	L
$D_{s0}^*(2317)$	$\lvert^3P_0\rangle$	2405.9	DK	S
$D_{s1}^*(2460)$	$0.68\lvert^1P_1\rangle - 0.74\lvert^3P_1\rangle = -0.99\phi_s + 0.13\phi_d$	2511.5	D^*K	S, D
$D_{s1}^*(2536)$	$-0.74\lvert^1P_1\rangle - 0.68\lvert^3P_1\rangle = -0.13\phi_s - 0.99\phi_d$	2537.8	D^*K	S, D
$D_{s2}^*(2573)$	$\lvert^3P_2\rangle$	2571.2	DK, D^*K	D

1. Fix the bare mass and wave function from GI model；
2. The interaction of bare-channel and channel-channel；

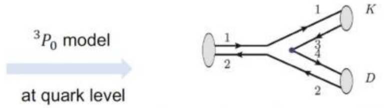
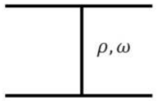
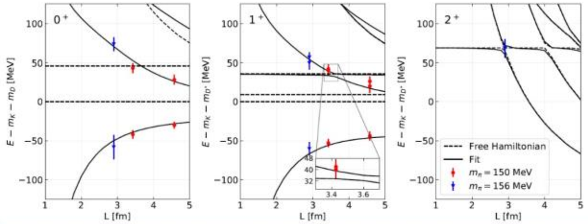


Figure 2: The diagram contribute to the process $D_s^*(2317) \to DK$



	$P(c\bar{s})$
$D_{s0}^*(2317)$	$\approx 32.0\%$
$D_{s1}^*(2460)$	$\approx 52.4\%$
$D_{s1}^*(2536)$	$\approx 98.2\%$
$D_{s2}^*(2573)$	$\approx 95.9\%$

3. Fit Lattice data；



Conclusion：

$D^*_{s0}(2317)$-DK
$D_{s1}(2460)$-D^*K S-wave

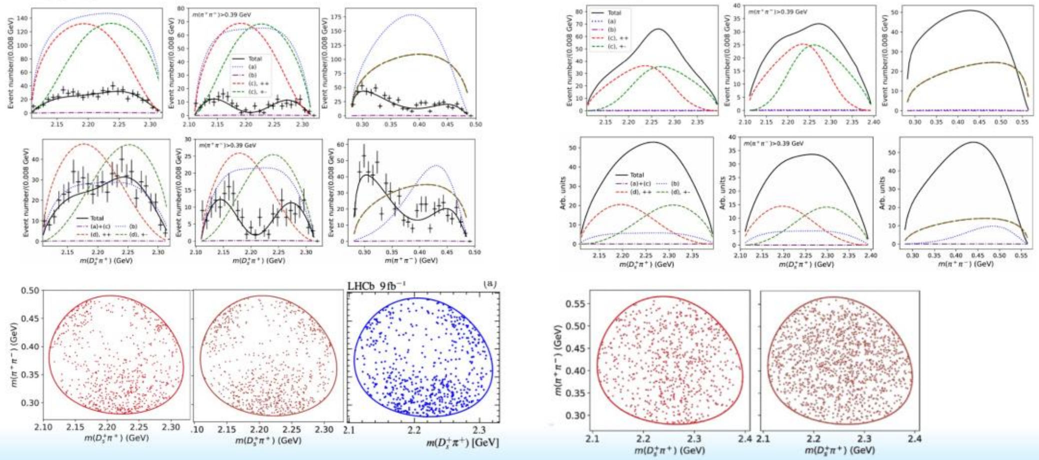
Mass moving vs GI Model

$D_{s1}(2536)$-D^*K
$D_{s2}(2573)$-$D^{(*)}K$ D-wave

Mass stable vs GI model

$D_{s1} \to D_s^+ \pi^+ \pi^-$

$D_{s1}(2460)$ $\chi^2/dof = 1.43/$ $D_{s1}(2536)$



Summary

- The strong interaction involves physics at two distinct levels and is extremely complex.
- We introduce the NonPerturbative Hamiltonian Framework (NPHF) approach, which connects the quark-gluon level to the hadronic level via a bare state, establishing a coupled-channel model with varying numbers of hadrons to achieve a comprehensive understanding of hadron properties.
- Using lattice QCD data, we explain why the masses of $D_{s0}(2317)$ and $D_{s1}(2460)$ are lower than predictions from conventional quark models, while those of $D_{s1}(2536)$ and $D_{s2}(2573)$ agree well.

- It further elucidates the $D_{s1}(2460) \to D_s\pi\pi$, reveals the existence of the $T_{c\bar{s}}$ state, and predicts the $D_{s1}(2536) \to D_s\pi\pi$.

徐吉：Searching SRC (short-range correlations) in BESIII and STCF

Introduction on SRC

- The 2N-SRC is defined operationally in experiments a large relative momentum.

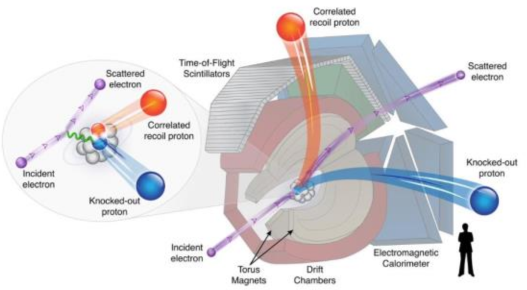
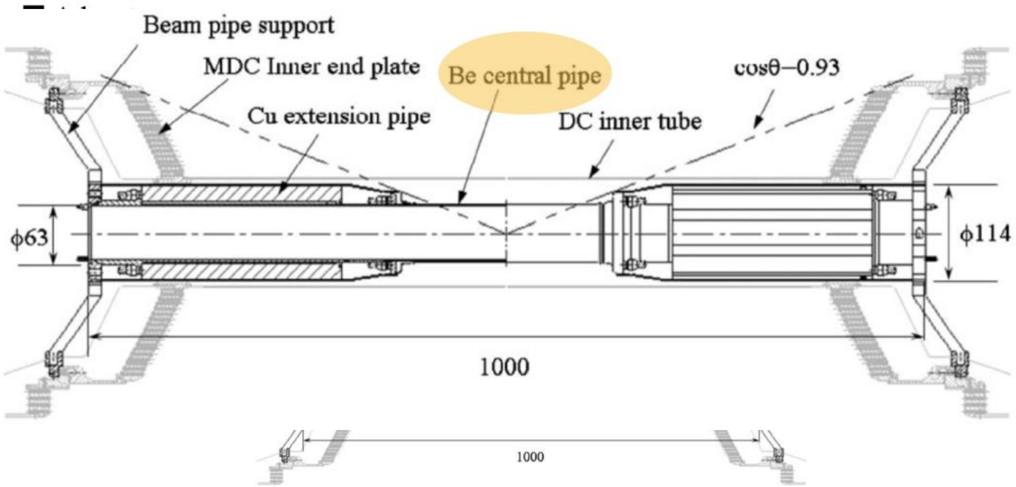


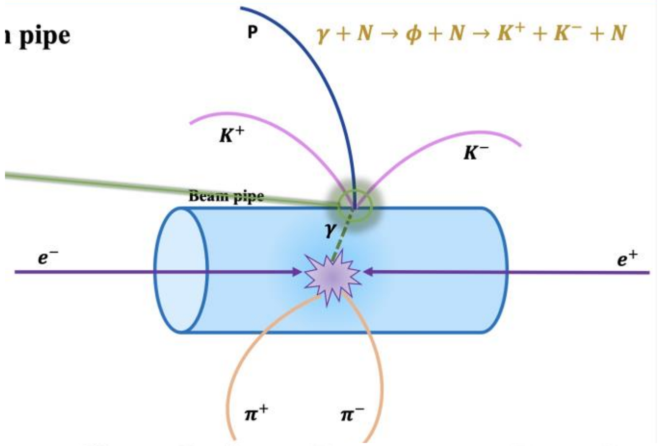
Illustration of a reconstructed two-proton knockout event.

[CLAS, Science 346 (2014)]
[CLAS, Nature 578 (2020)]
[CLAS, PRL 90 (2003)]
[Nguyen et.al, Nature 654 (2026)]

BESIII can be viewed as a fixed-target nuclear experiment



Production of ϕ at BESIII and STCF

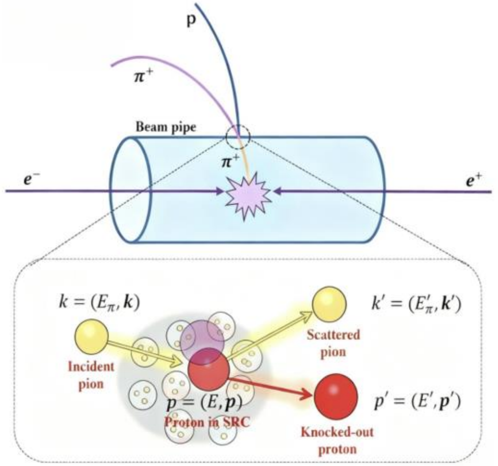


The predicted signal can reach a dozen

[W.Wang, **J.X,** X.H.Yang, S.Zhao, Y.T.Zhang, PLB 875 (2026)]

Searching SRC by πN scattering

- This process can be precisely measured at BESIII.



✓ The typical cross section is ~10 mb.

✓ Tens of thousands of events can be expected.

✓ Essential complementary information on beryllium.

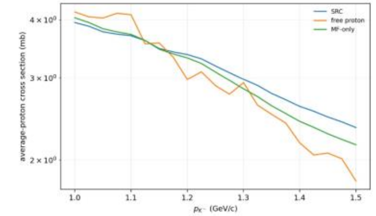
✓ First attempt to study SRC by a meson beam.

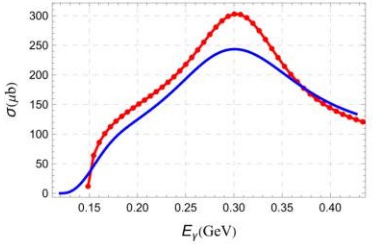
✓ First experiment investigating nuclear corrections at BESIII.

Searching SRC by $K N$ scattering and $\gamma n \to \pi^- p$

- Similarly, the KN can also be utilized to investigate SRC.

- The photoproduction of pion can also be utilized to investigate the momentum distribution of neutrons.





曹须

Spin density matrix of baryon-antibaryon pairs with P & CP violation including electron mass

… enabling the identification of clean observables to probe extremely subtle signals

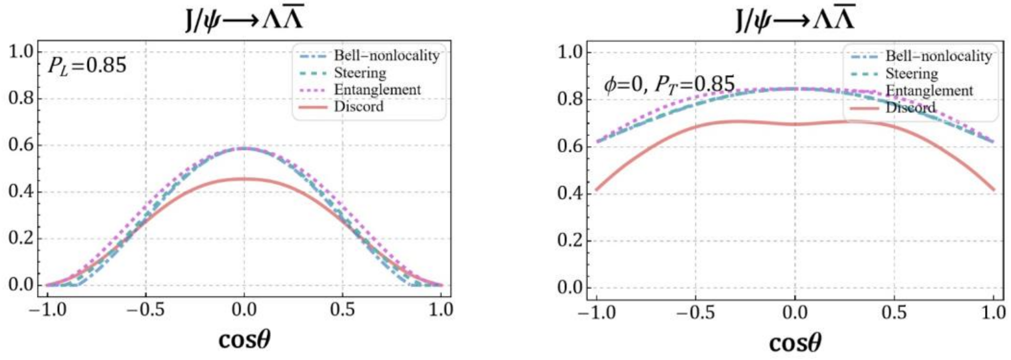
… clarifying the precision at which finite-me corrections must be accounted for: electron mass correction is recommended to be considered at STCF

Polarized beams enhance entanglement

- Loopholes: Test of local-realistic theories via Bell's inequality at colliders? Abel:1992kz,Dreiner:1992gt,Li:2024luk

Bell Nonlocality ⊂ Steering ⊂ Entanglement ⊂ Discord

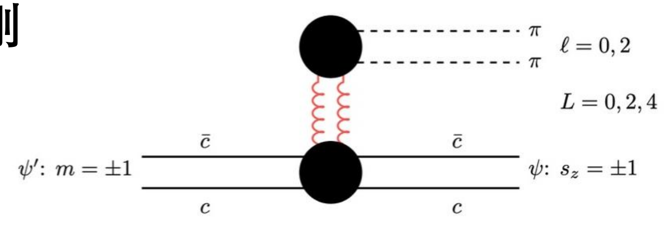
- Anyway, theoretical discussion on entanglement is interesting:
- Hong-Wei Zhang, Xu Cao, and Tai-Fu Feng, Phys. Rev. D 113, 114022 (2026) & arXiv:2605.19642; Cong Li, XC et al., 2602.10398



- Maximal entanglement appeared when maximal transverse polarization of beams
- w/o considering electron mass & P & CP violation

Polarization transfer in $\psi' \to \psi\pi\pi$ alternative J/ψ samples at BESIII and STCF [1]

李刚



Extracting SDM from dilepton angular distributions

- Angular distribution for $\psi^{(\prime)} \to \mu^+\mu^-$:

$$W(\theta,\phi) \propto 1 + \lambda_\theta \cos^2\theta + \lambda_\phi \sin^2\theta \cos 2\phi + \lambda_{\theta\phi} \sin 2\theta \cos\phi$$

- Relation to SDM elements:

$$\lambda_\theta = \frac{\rho_{++} + \rho_{--} - 2\rho_{00}}{\rho_{++} + \rho_{--} + 2\rho_{00}}$$

$$\lambda_\phi = \frac{2\,\mathrm{Re}\,\rho_{+-}}{\rho_{++} + \rho_{--} + 2\rho_{00}}$$

$$\lambda_{\theta\phi} = \frac{\sqrt{2}\,\mathrm{Re}(\rho_{+0} - \rho_{0-})}{\rho_{++} + \rho_{--} + 2\rho_{00}}$$

Statistical sensitivity (Fisher information)

- **BESIII** ψ' sample: 2.7×10^9.
- **STCF** projected ψ' sample: $\sim 10^{11}$ (a year) (factor ~ 40 larger than BESIII).
- Projected uncertainties with Fisher information method:

$$\text{BESIII:}\quad \delta\lambda_\theta \approx 0.0003, \quad \delta\lambda_\phi \approx 0.0002$$

$$\text{STCF:}\quad \delta\lambda_\theta \approx 0.00005, \quad \delta\lambda_\phi \approx 0.00003$$

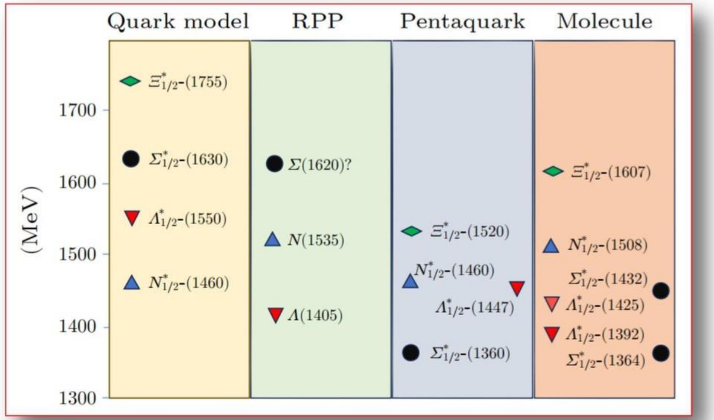
王恩：e+e-对撞过程中缺失的超子激发态 $\Sigma(1/2^-)$

Low-lying baryons

Review on $\Sigma(1/2^-)$, EWang, LSGeng, JJWu, JJXie, and BSZou, CPL41(2024)101401

□mass reverse problem

邹冰松老师报告



$1/2^-$ baryon nonet with strangeness

Zou, EPJA 35 (2008) 325

- Mass pattern : quenched or unquenched ?

  uds (L=1) $1/2^-$ ~ $\Lambda^*(1670)$ ~ $[us][ds]\bar{s}$

  uud (L=1) $1/2^-$ ~ $N^*(1535)$ ~ $[ud][us]\bar{s}$

  uds (L=1) $1/2^-$ ~ $\Lambda^*(1405)$ ~ $[ud][su]\bar{u}$

  uus (L=1) $1/2^-$ ~ $\Sigma^*(1390)$ ~ $[us][ud]\bar{d}$

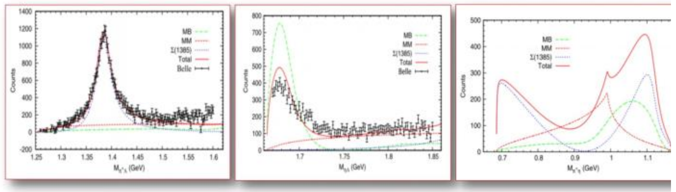
  Zou et al, NPA835 (2010) 199 ; CLAS, PRC87(2013)035206

- Strange decays of $N^*(1535)$ and $\Lambda^*(1670)$:

  $N^*(1535)$ large couplings $g_{N^*N\eta}$, $g_{N^*K\Lambda}$, $g_{N^*N\eta'}$, $g_{N^*N\phi}$

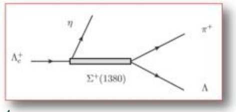
  $\Lambda^*(1670)$ large coupling $g_{\Lambda^*\Lambda\eta}$

□$\Lambda_c \to \Lambda\eta\pi$, GYW-EW-Xie-Geng-Wei, PRD 106, 056001 (2022)



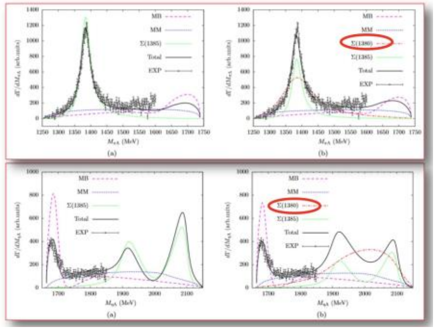
$\Sigma(1/2^-)$ in $\Lambda_c \to \eta\Lambda\pi$

□Intermediate of $\Sigma(1/2^-)$



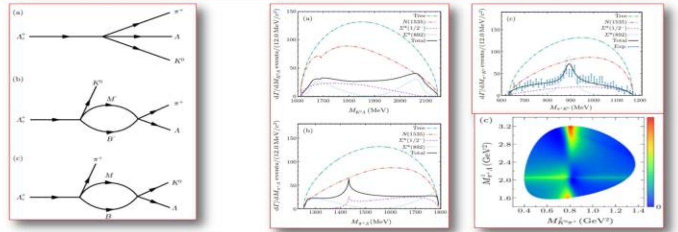
$$= \frac{V^{\Sigma(1/2^-)} M_{\Sigma(1/2^-)} \Gamma_{\Sigma(1/2^-)}}{M^2_{\pi^+\Lambda} - M^2_{\Sigma(1/2^-)} + i M_{\Sigma(1/2^-)} \Gamma_{\Sigma(1/2^-)}},$$

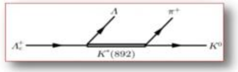
Lyu, Zhang, GYWang, JJWu, JJXie, LSGeng, Phys.Rev.D 110 (2024) 5, 054020



$\Lambda_c^+ \to \Lambda K^0 \pi^+$

Zhang, Lyu, GYWang, EW, Ma, CPL 43, 050203 (2026)





$\mathcal{B}(\Lambda_c^+ \to \Lambda\pi^+ K^0) = (1.5 \pm 0.3) \times 10^{-3}$

$\mathcal{B}(\Lambda_c^+ \to \Lambda K_S^0 \pi^+) = (1.73 \pm 0.27 \pm 0.10) \times 10^{-3}$

BESIII: PRD 109 (2024) 032003

preliminary results of dim6 for Ω_c

表 6: The dim6 term of Ω_c^0, in units of GeV, up to 0th of c_6.

	WE	PI^+	$semi-e$	$semi-\mu$
$c-s,u\bar{d}$		3.32×10^{-12}		
$c-s,u\bar{s}$	5.78×10^{-13}	1.75×10^{-13}	1.08×10^{-12}	1.07×10^{-12}

表 7: The dim6 term of Ω_c^0, in units of GeV, up to 1th of c_6.

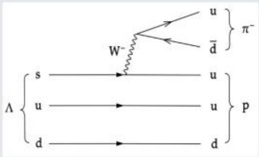
	WE	PI^+	$semi-e$	$semi-\mu$
$c-s,u\bar{d}$		3.09×10^{-13}		
$c-s,u\bar{s}$	1.34×10^{-12}	1.47×10^{-14}	1.00×10^{-13}	8.57×10^{-14}

We need the help of experimentalists here!

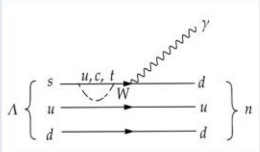
赵振兴：单粲重子的寿命

周小蓉：正负电子对撞机上超子的衰变研究

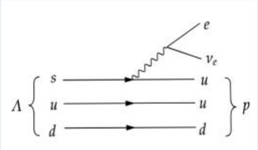
Hyperon decay



- **Hyperon Hadronic Weak Decays $\mathcal{O}(1)$**
  - ➢ $\Delta I = 1/2$ rule
  - ➢ Precise measurements of hyperon decay asymmetry parameters
  - ➢ no CP violation has been discovered so far



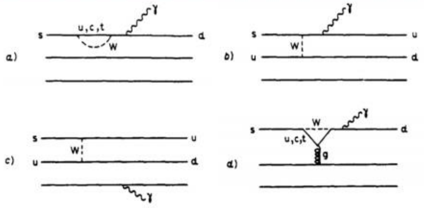
- **Hyperon radiative Weak Decays $\mathcal{O}(10^{-3})$**
  - ➢ Hara's theorem
  - ➢ Mainly from fixed-target experiment and recently e^+e^- collider refreshed the results



- **Hyperon Semileptonic Decays $\mathcal{O}(10^{-3})$** **参考周俊贤、韩许报告**
  - ➢ Cabibbo angle anomaly
  - ➢ Extracting form factors, testing lepton universality, and searching for new physics

Weak Radiative Hyperon Decay

- At the quark level, WRHDs are governed by:
  - **single-quark transition** of $s \to d\gamma$ from penguin diagram that involve gluon exchange, or from single quark diagram
  - **two-quark transition** through an internal conversion, with W boson exchange play an important role
- There are 7 WRHD processes with the BF at the level of $\mathcal{O}(10^{-4}\sim10^{-3})$ except for $\Sigma^0 \to n\gamma$
- $\Xi^- \to \Sigma^-\gamma$ and $\Omega^- \to \Xi^-\gamma$ **are proceeded via a one-quark transition**, and their branching fraction one magnitude smaller than others



Deacay	$\mathcal{B} \times 10^{-3}$	α_γ	Comment
$\Sigma^+ \to p\gamma$	1.23(5)	-0.76(8)	PDG22
	0.996(21)(18)	**−0.652(56)(20)**	BESIII
$\Lambda \to n\gamma$	1.75(15)	-	PDG22
	0.832(38)(54)	**−0.16(10)(5)**	BESIII
$\Xi^0 \to \Sigma^0\gamma$	3.33(10)	−0.69(6)	PDG22
	3.69(21)(12)	**−0.807(95)(11)**	BESIII
$\Xi^0 \to \Lambda\gamma$	1.17(7)	−0.70(7)	PDG22
	1.347(66)(54)	**−0.741(62)(19)**	BESIII
$\Xi^- \to \Sigma^-\gamma$	0.13(2)	1.0(1.3)	PDG26
$\Omega^- \to \Xi^-\gamma$	< 0.46	-	PDG26

$\Sigma^0 \to n\gamma$ is suppressed by the dominant radiative process $\Sigma^0 \to \Lambda\gamma$

Advantages at e^+e^- colliders

- **BESIII** has collected 10 billion J/ψ and 2.7 billion $\psi(3686)$ events
- **STCF** will collect trillions of J/ψ and $\psi(3686)$
- Charmonium has a ~0.1% branching fraction of decaying to hyperons

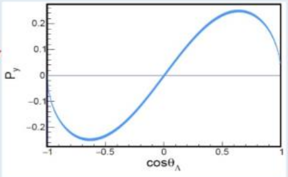
Hyperon species:

- **Various** of **hyperon** and **anti-hyperons** can be produced via the $\psi \to Y\bar{Y}$

Decay mode	$\mathcal{B}(\times10^{-3})$	$N_B\ (\times10^6)$
$J/\psi \to \Lambda\bar{\Lambda}$	1.61 ± 0.15	16.1 ± 1.5
$J/\psi \to \Sigma^0\bar{\Sigma}^0$	1.29 ± 0.09	12.9 ± 0.9
$J/\psi \to \Sigma^+\bar{\Sigma}^-$	1.50 ± 0.24	15.0 ± 2.4
$J/\psi \to \Sigma(1385)^-\bar{\Sigma}^+$ (or c.c.)	0.31 ± 0.05	3.1 ± 0.5
$J/\psi \to \Sigma(1385)^-\bar{\Sigma}(1385)^+$ (or c.c.)	1.10 ± 0.12	11.0 ± 1.2
$J/\psi \to \Xi^0\bar{\Xi}^0$	1.20 ± 0.24	12.0 ± 2.4
$J/\psi \to \Xi^-\bar{\Xi}^+$	0.86 ± 0.11	8.6 ± 1.0
$J/\psi \to \Xi(1530)^0\bar{\Xi}^0$	0.32 ± 0.14	3.2 ± 1.4
$J/\psi \to \Xi(1530)^-\bar{\Xi}^+$	0.59 ± 0.15	5.9 ± 1.5
$\psi(2S) \to \Omega^-\bar{\Omega}^+$	0.05 ± 0.01	0.15 ± 0.03

Polarization:

- The **well-defined topology** of hyperon production allows for a well **determined polarization**



Analysis methods:

- **Absolute measurement of the BF** is available via Double-tag method, which helps cancel systematic uncertainties
- Asymmetry parameters can be extracted by a **multi-dimensional angular distribution**

Test of CP symmetry in WRHDs

CP violation observables in radiative decay:

- Extensive experimental studies on K, D and B meson radiative decays
- Not yet studied in hyperon radiative decays. Sources different from pionic decay
- May be
171801

SM on $\Sigma^+ \to p\gamma$	Δ_{CP}	A_{CP}
PRD51,2271	10^{-5}	

First at

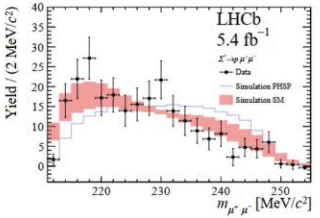
CPV p

Constraint of WRHDs to new physics

- Experimental study of $\Sigma^+ \to p\mu^+\mu^-$:

HyperCP（00s）	LHCb（10s）	LHCb（20s）
3 events	10.2 events	237 events
$\mathcal{B} = (8.6^{+6.6}_{-5.4})\times10^{-8}$	$\mathcal{B} = (2.2 \pm 0.7)\times10^{-8}$	$\mathcal{B} = (1.08 \pm 0.17)\times10^{-}$

LHCb, PRL135 (2025) 5, 051801



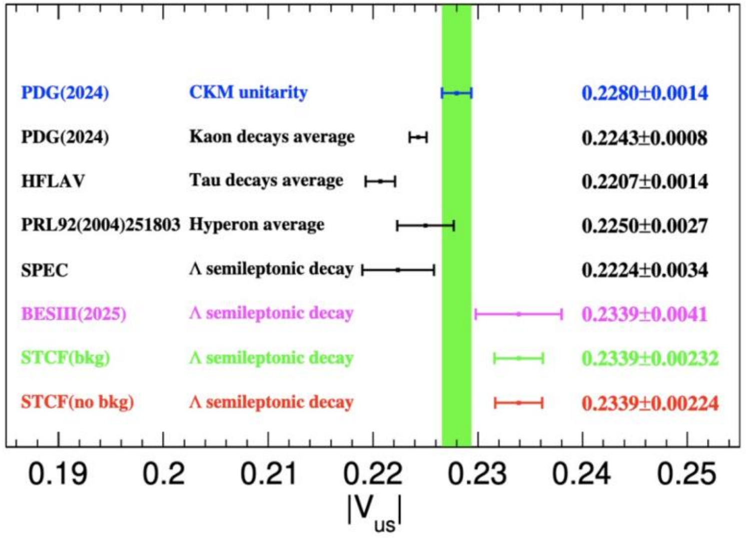
- The theoretical prediction of $\Sigma^+ \to p\mu^+\mu^-$ is dominated by **long-distance** contribution in SM: $\Sigma^+ \to p\gamma^* \to p\mu^+\mu^-$

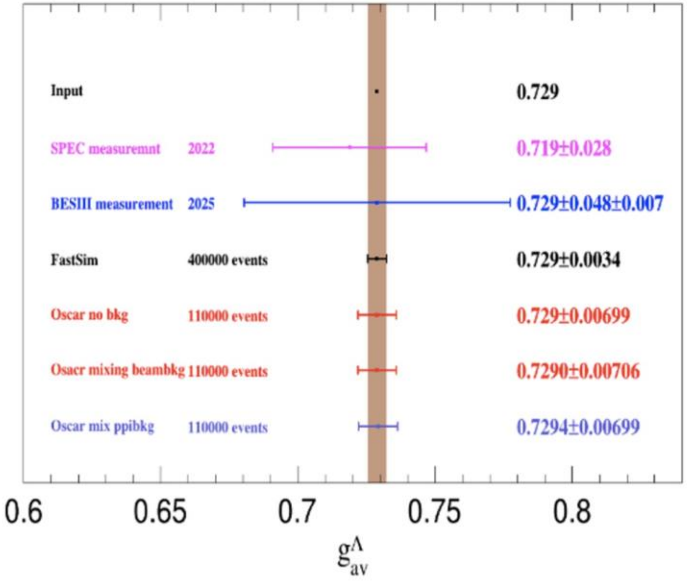
Re a (MeV)	Re b (MeV)	$10^8\,\mathcal{B}_{\mu\mu}$	$10^8\,\mathcal{B}_{\mu\mu}^{\mathrm{Re}(c,d)=0}$	$10^5\,\tilde{A}_{\mathrm{FB}}$	$10^6\,\mathcal{B}_{ee}$	$10^7\,\mathcal{B}_{ee}^{M_{ee}\geq100\,\mathrm{MeV}}$
-12.15 ± 0.24	4.78 ± 0.42	2.7 ± 0.2	1.8 ± 0.1	-1.59 ± 0.04	7.6 ± 0.3	8.5 ± 0.4
-4.78 ± 0.42	12.15 ± 0.24	7.8 ± 0.3	5.8 ± 0.2	-0.32 ± 0.02	8.3 ± 0.3	13.5 ± 0.4
4.78 ± 0.42	-12.15 ± 0.24	4.2 ± 0.2	5.8 ± 0.2	0.91 ± 0.04	7.8 ± 0.3	9.9 ± 0.4
12.15 ± 0.24	-4.78 ± 0.42	1.2 ± 0.1	1.8 ± 0.1	4.55 ± 0.08	7.4 ± 0.3	6.9 ± 0.3

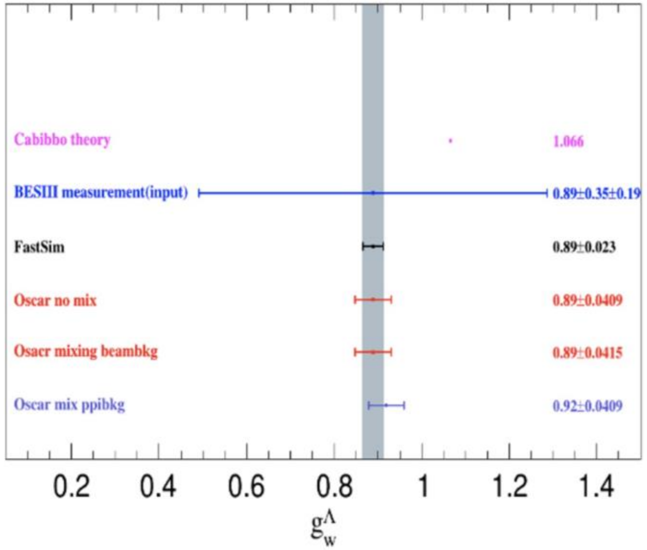
重子半轻衰变过程

The dominant systematic uncertainty comes from the lattice QCD inputs.

周俊贤：$\Lambda \to p e^- \overline{\nu_e}$

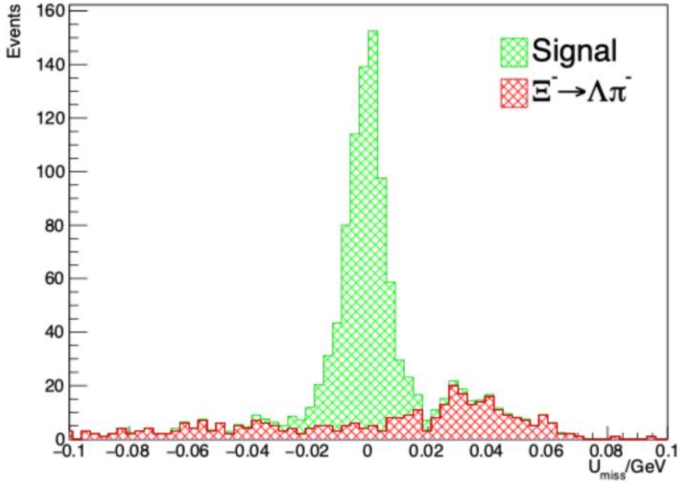


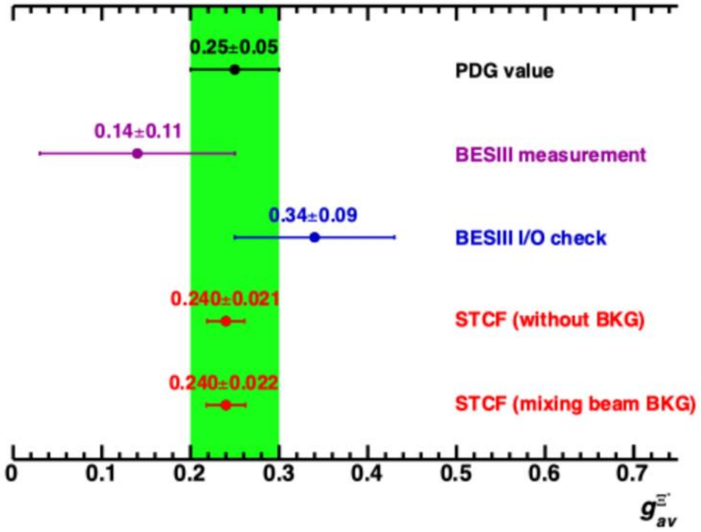


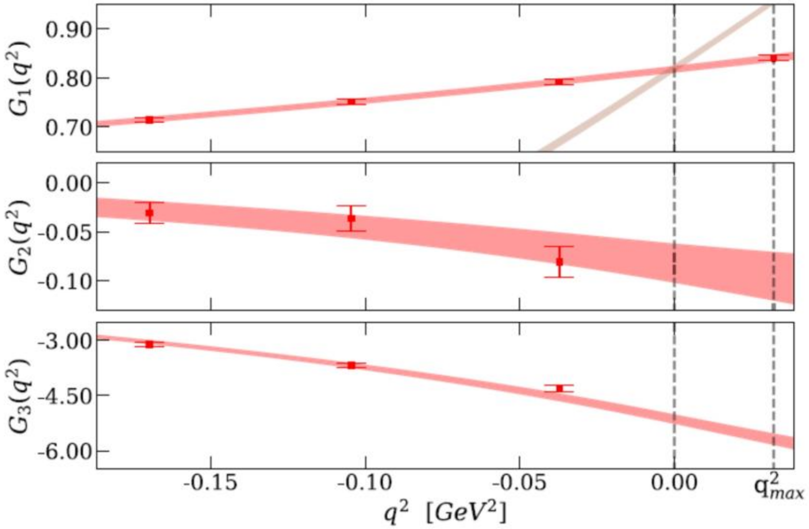


李磊毅：LQCD for $\Lambda \to p l \nu$

韩许: $\Xi^- \to \Lambda e^- \nu_e$



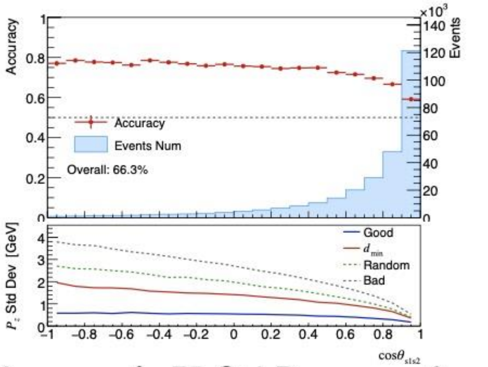




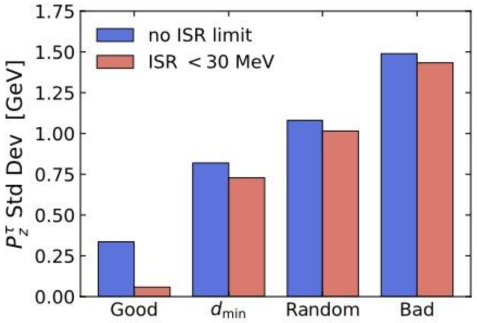
Reconstruction of τ-pairs at STCF

鲍晨涛 Vertex Reconstruction for ττ pairs

τ Reconstruction — Conclusion



- Accuracy & P_z^τ Std Dev vs $\cos\theta_{s_1 s_2}$



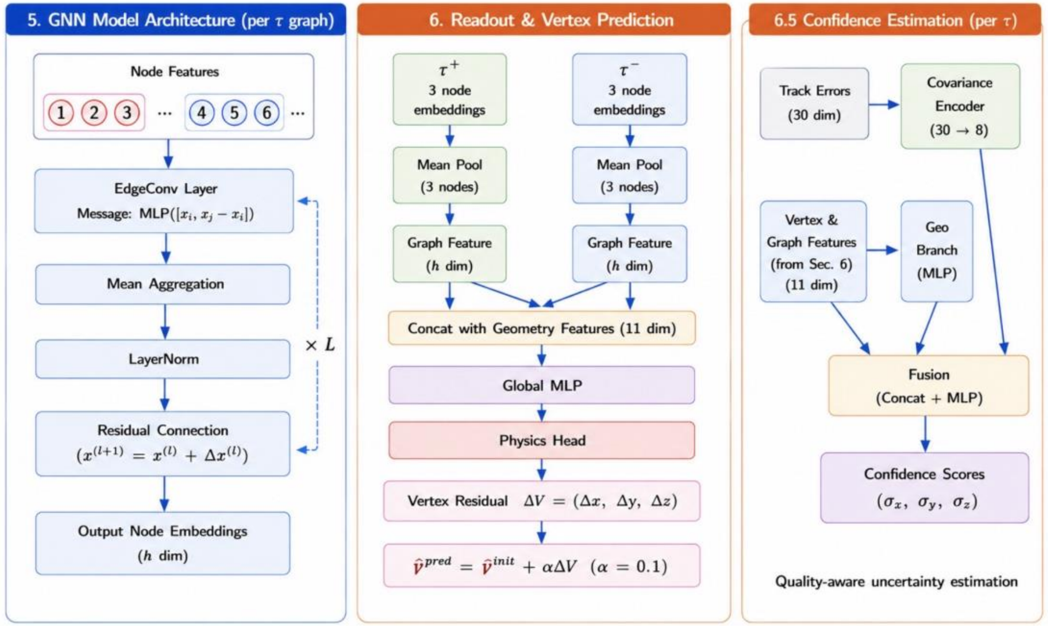
- P_z^τ Std Dev in different cases.

Method Crosscheck

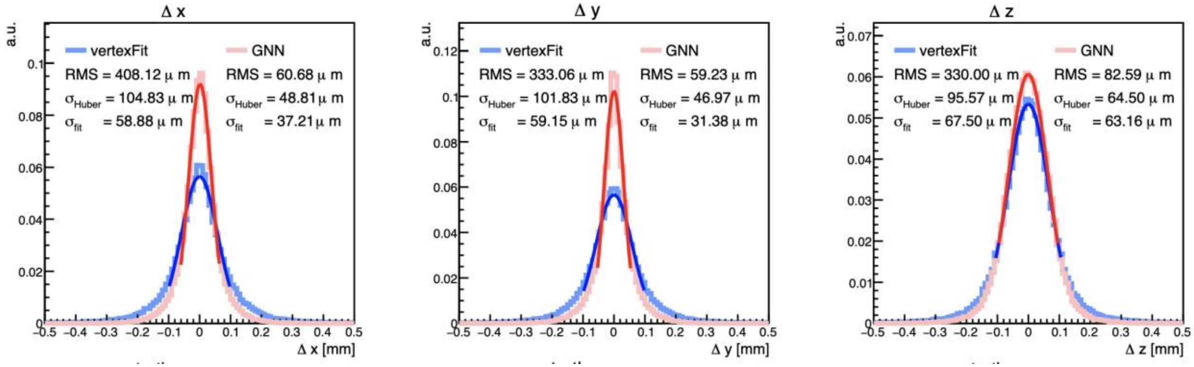
- Momentum resolution is dominated by the small fraction of bad solutions.
- d_{min} and z-scan agree: same accuracy (66%) and same $\cos\theta_{s_1 s_2}$ dependence.
  - Close (60%): hard to distinguish, but also not necessary.
  - Different (80%): easy to distinguish, and these dominate the resolution.
- POCA-based two-fold resolution reaches its limit — set by the limited detector resolution, not the bunch length.

Quantum entanglement study from 李小康

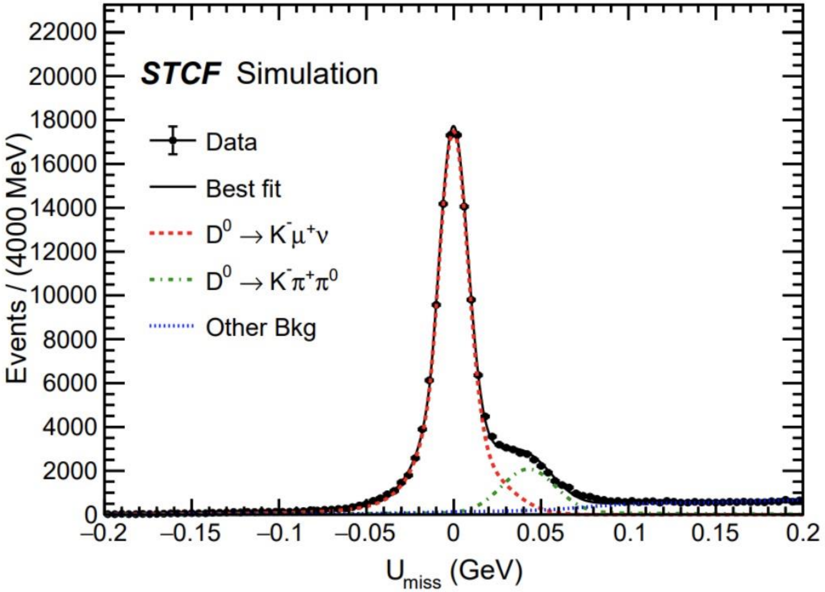
Physics-Informed GNN Architecture Overview



GNN Result



X、Y方向顶点的分辨分别由60mum提高到37um和32um



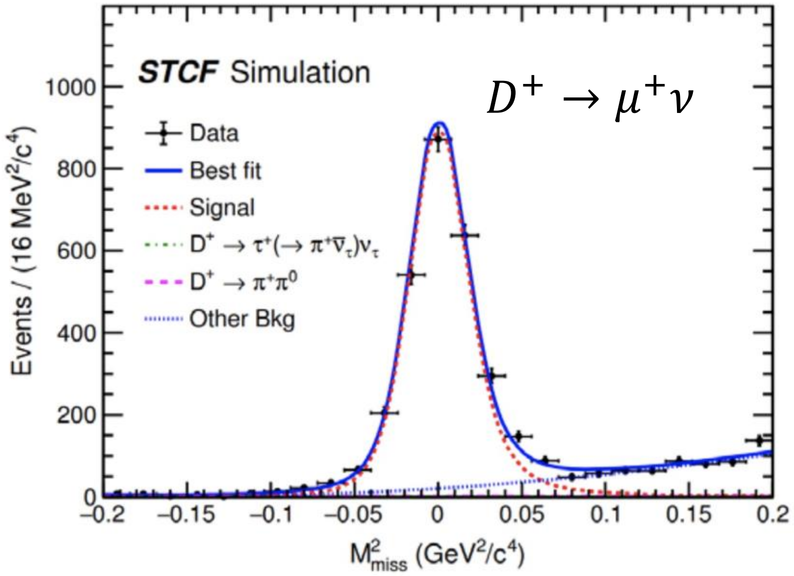
$D^0 \to K^-\mu^+\nu$

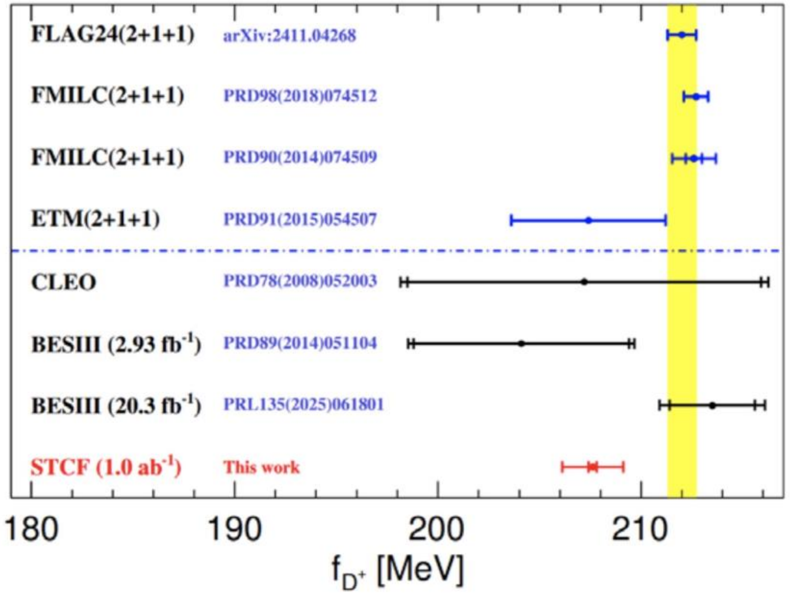
N_sig = 11311740

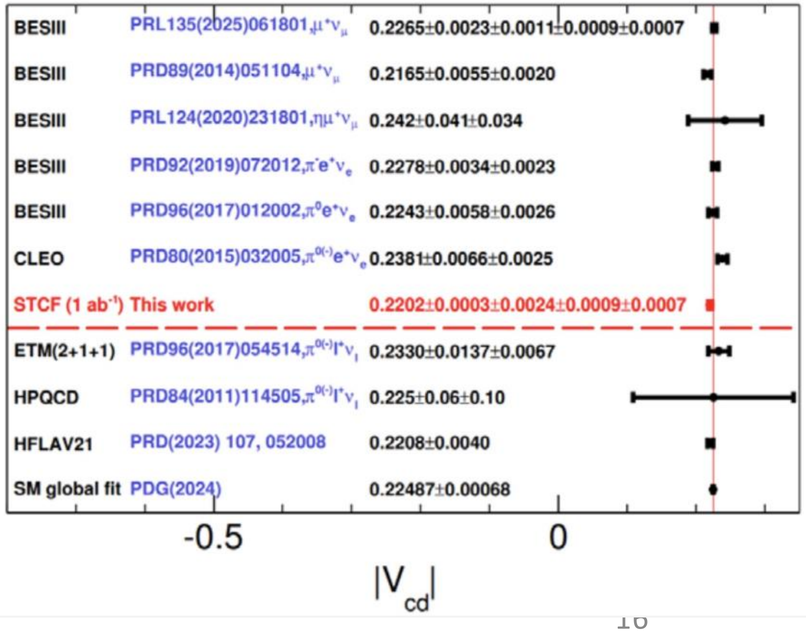
err = √ N_sig = 3363

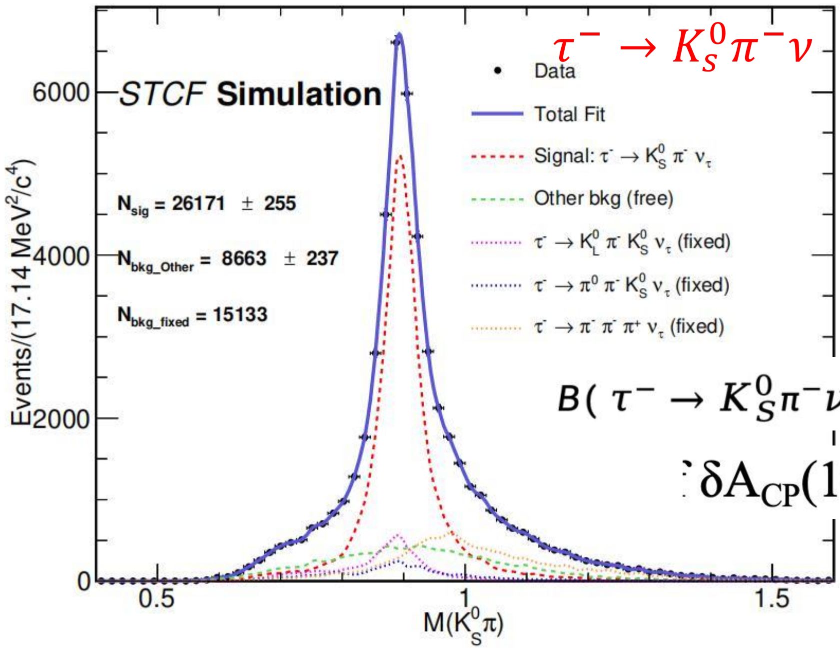
$\frac{\delta B}{B}$ = 0.03%

乔家辉： $D^0 \to K^-\mu^+\nu$ && $D^+ \to \mu^+\nu$





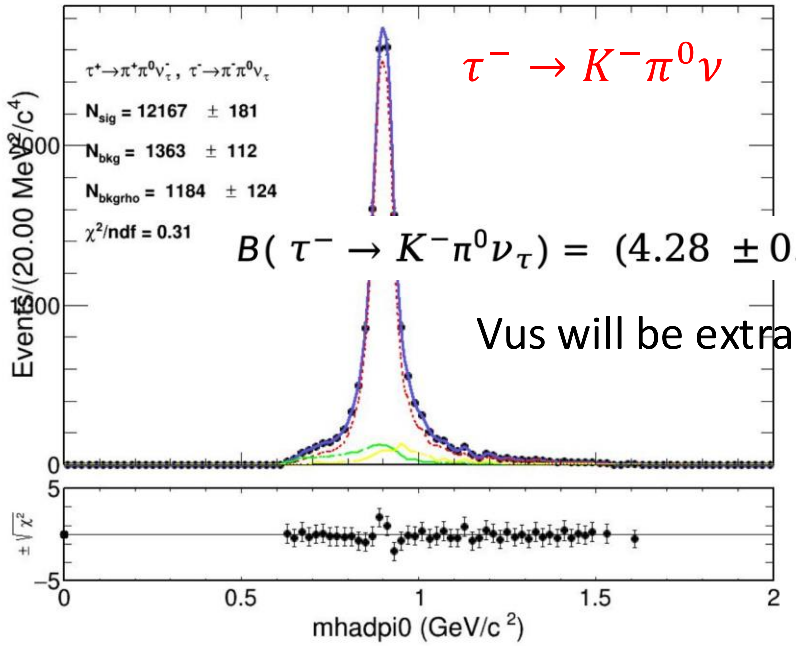




$\tau^- \to K_S^0 \pi^- \nu$

$B(\tau^- \to K_S^0 \pi^- \nu_\tau) = (4.18 \pm 0.05) \times 10^{-3}$

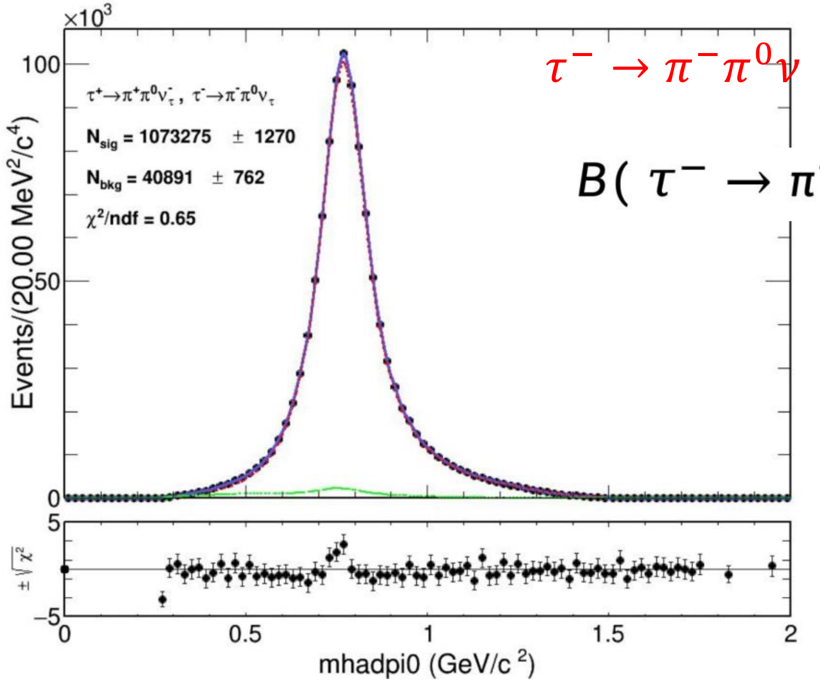
$\delta A_{CP}(10\ ab^{-1}) \approx 0.055\%.$



$\tau^- \to K^- \pi^0 \nu$

$B(\tau^- \to K^- \pi^0 \nu_\tau) = (4.28 \pm 0.075) \times 10^{-3}$

Vus will be extracted



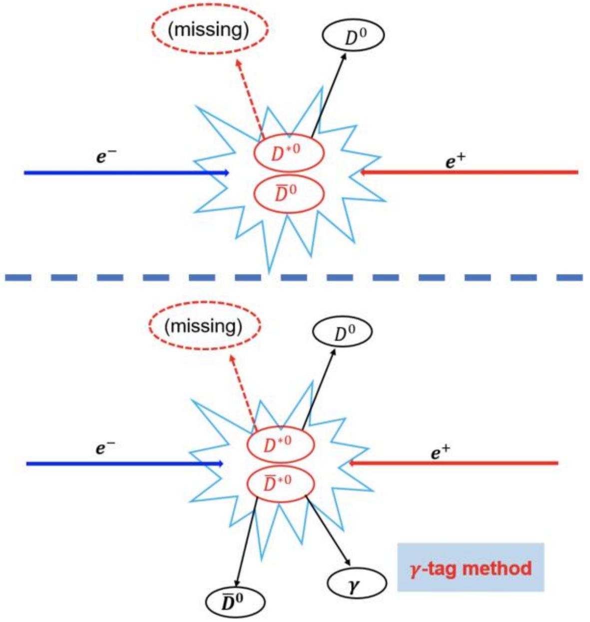
$\tau^- \to \pi^- \pi^0 \nu$

李珊珊： $\tau^- \to h \pi^- \nu$

$B(\tau^- \to \pi^- \pi^0 \nu_\tau) = (25.43 \pm 0.039)\%$

Observable	Current	Projected 1 ab^{-1}
D^{10}	0.714818 ± 0.000094	0.714818 ± 0.000009
D^{11}	0.160603 ± 0.000027	0.160603 ± 0.000003
D^{12}	0.059314 ± 0.000023	0.059314 ± 0.000002
D^{13}	0.026843 ± 0.000016	0.026843 ± 0.000002
$\alpha_s(m_\tau^2)$	0.32036 ± 0.00863	0.32036 ± 0.00862

王英豪：STCF上量子关联D$\bar{D}$衰变性质



强子参数敏感度研究：

- 与当前实验结果相比，STCF预计可显著提高多体D介子衰变相干因子和强相位差参数的测量精度
- $r_D^{K\pi}$已受到现有时间相关测量的较强约束，而STCF预计可以高精度测量$\delta_D^{K\pi}$。
- 高精度的强子参数输入有助于提高中性D介子混合参数和CKM相角 γ 的测量精度

参数	STCF预期精度	当前实验结果
$r_D^{K\pi\pi^0}$ (%)	0.013	4.41 ± 0.08
$R_{K\pi\pi^0}$	0.0021	0.75 ± 0.03
$\delta_D^{K\pi\pi^0}$ (°)	0.41	209^{+7}_{-8}
$r_D^{K3\pi}$ (%)	0.011	5.51 ± 0.05
$R_{K3\pi}^{(1)}$	0.0083	0.72 ± 0.14
$R_{K3\pi}^{(2)}$	0.0043	$0.65^{+0.08}_{-0.07}$
$R_{K3\pi}^{(3)}$	0.0032	$0.80^{+0.07}_{-0.06}$
$R_{K3\pi}^{(4)}$	0.0098	$0.54^{+0.18}_{-0.19}$
$\delta_D^{K3\pi,(1)}$ (°)	0.50	124^{+10}_{-8}
$\delta_D^{K3\pi,(2)}$ (°)	0.99	170^{+14}_{-12}
$\delta_D^{K3\pi,(3)}$ (°)	0.79	179 ± 11
$\delta_D^{K3\pi,(4)}$ (°)	0.48	260^{+10}_{-13}
$r_D^{K\pi}$ (%)	0.015	$5.855^{+0.009}_{-0.010}$
$\delta_D^{K\pi}$ (°)	0.36	191.4 ± 2.4

混合参数与间接CPV参数灵敏度研究：

- $D \to K\pi\pi^0$相空间进行分 bin 后，混合参数和间接 CP破坏参数的预期精度均得到改善
- STCF有望测量中性D介子混合及间接CP破坏参数，并利用阈值量子关联样本提供独立约束，与时间相关测量形成互补。

参数	STCF预期精度 $K\pi\pi^0$ 不分 bin	STCF预期精度 $K\pi\pi^0$ 分 bin	HFLAV 2025
x (10^{-3})	0.405	0.293	4.05 ± 0.43
y (10^{-3})	0.221	0.195	6.36 ± 0.24
$\|q/p\|$	0.0227	0.0210	$0.983^{+0.015}_{-0.014}$
ϕ (°)	1.55	1.44	$-1.51^{+1.03}_{-1.06}$

张慧斌：$J/\psi \to K_S K \pi$中的中性K介子混合与CP破坏

测量$|\eta_{+-}|$和$|\phi_{+-}|$

Phys. Rept., 2003, 374: 165-270

衰变率$K^0/\bar{K}^0 \to \pi\pi$：

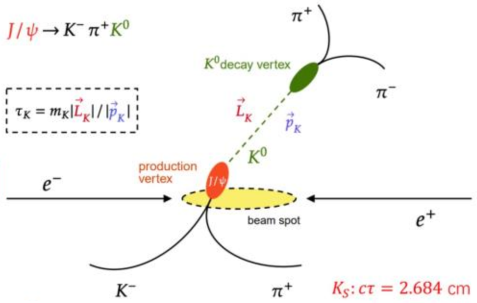
$$R_f(\tau)/\bar{R}_f(\tau) = \frac{[1 \mp 2\,\mathrm{Re}(\epsilon-\delta)]}{2}\Gamma_S^f \times \left[e^{-\Gamma_S\tau} + |\eta_f|^2 e^{-\Gamma_L\tau} \pm 2\boxed{|\eta_f|} e^{-(1/2)(\Gamma_S+\Gamma_L)\tau}\cos\left(\Delta m\tau - \boxed{\phi_f}\right)\right]$$

$f = \pi^+\pi^-, \pi^0\pi^0$

衰变率不对称量A_{CP}^f：

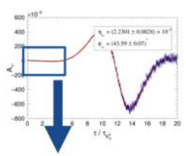
待测量

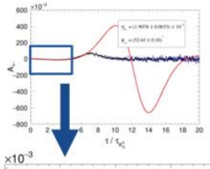
$$A_{\mathrm{CP}}^f = \frac{\bar{R}_f(\tau) - R_f(\tau)}{\bar{R}_f(\tau) + R_f(\tau)} = 2\mathrm{Re}(\epsilon-\delta) - 2\cdot\frac{\boxed{|\eta_f|}\cdot e^{\frac{1}{2}(\Gamma_{K_S}-\Gamma_{K_L})\cdot\tau}\cdot\cos(\Delta m\cdot\tau - \boxed{\phi_f})}{1+|\eta_f|^2\cdot e^{(\Gamma_{K_S}-\Gamma_{K_L})\cdot\tau}}$$



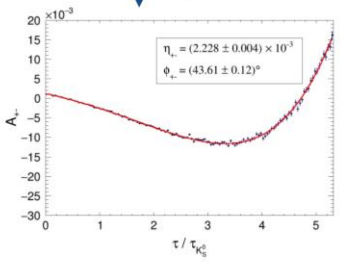
拟合结果

$|\eta_{+-}| = (2.232 \pm 0.011)\times 10^{-3}$
$\phi_{+-} = 43.51° \pm 0.5°$ PDG average





$$A_{\mathrm{CP}}^{+-} = \frac{\bar{R}_{+-}(\tau) - R_{+-}(\tau)}{\bar{R}_{+-}(\tau) + R_{+-}(\tau)} = 2\mathrm{Re}(\epsilon-\delta) - 2\cdot\frac{|\eta_{+-}|\cdot e^{\frac{1}{2}(\Gamma_{K_S}-\Gamma_{K_L})\cdot\tau}\cdot\cos(\Delta m\cdot\tau - \phi_{+-})}{1+|\eta_{+-}|^2\cdot e^{(\Gamma_{K_S}-\Gamma_{K_L})\cdot\tau}}$$



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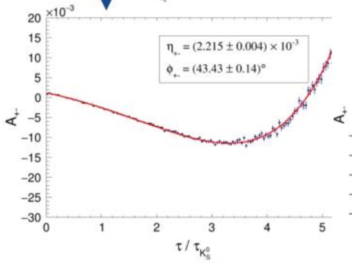
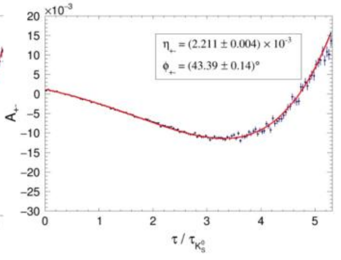
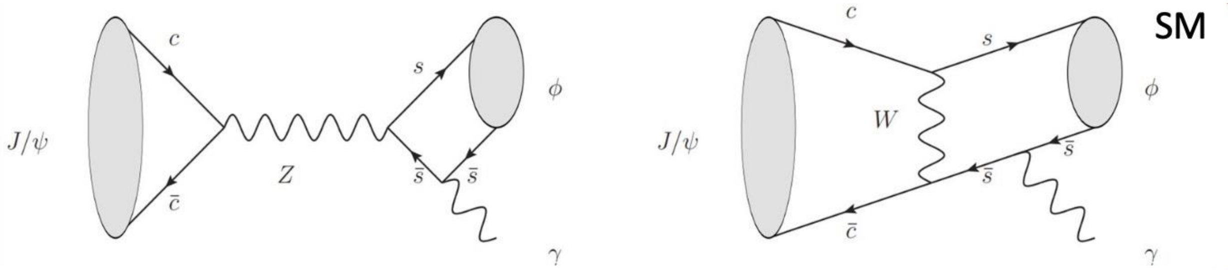


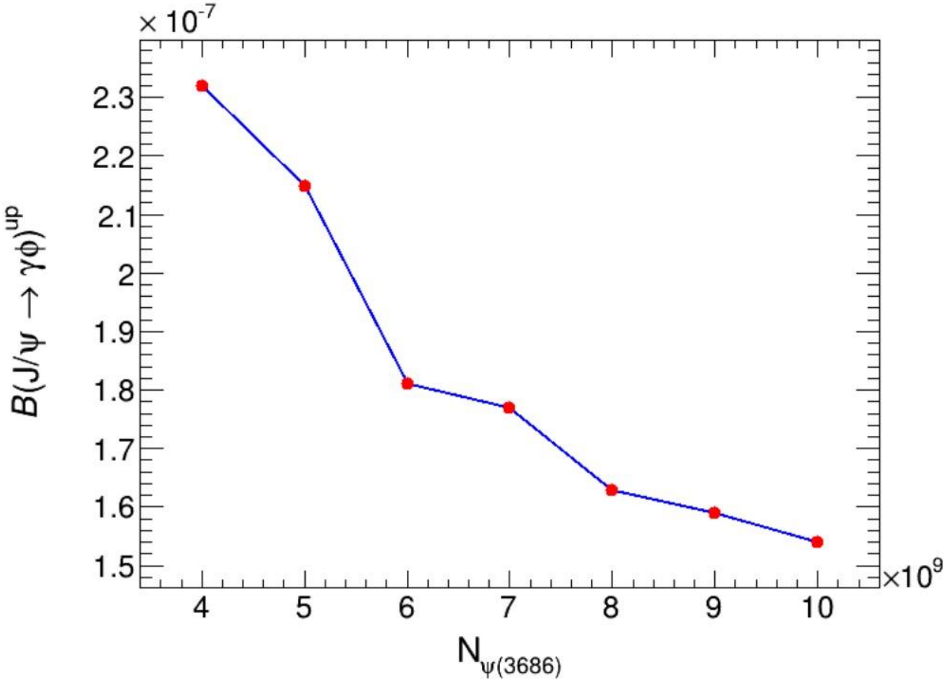
加入测量误差与效率



考虑本底

中国科学院大学 University of Chinese Academy of Sciences 15

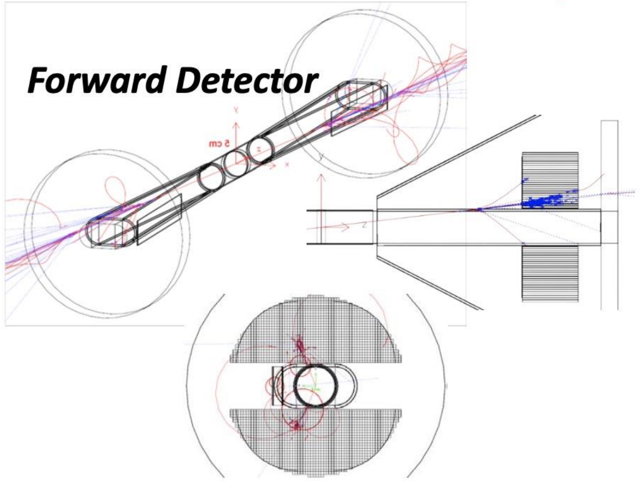




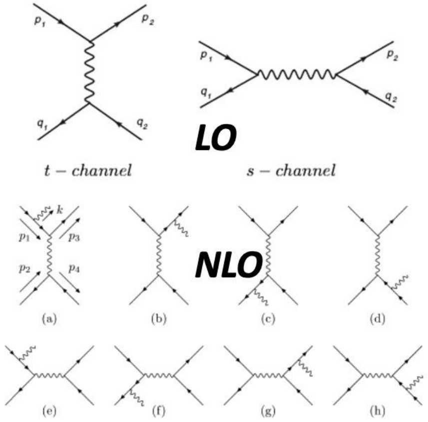
康晓珅：C破坏过程 J/ψ → $\gamma\phi$灵敏度研究

Precision test of QED on radiative Bhabha photons

侯书云Suen Hou
Academia Sinica
2026.07.02



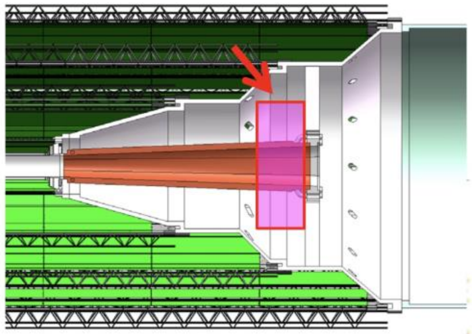
Radiative Bhabha elastic scattering

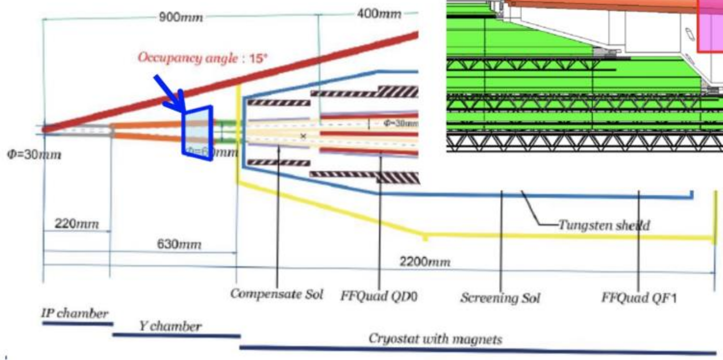


Forward Calorimeter @ STCF

60 – 240 mRad (3.4°-14°), Z = 350 – 500 mm

- Precision QED radiative Bhabha to **better than 10^{-3}**
- e/γ by Si-det + Crystal
  2D, Si strip, 50 μm pitch
  LYSO, 2x2 mm^2, 50 mm long





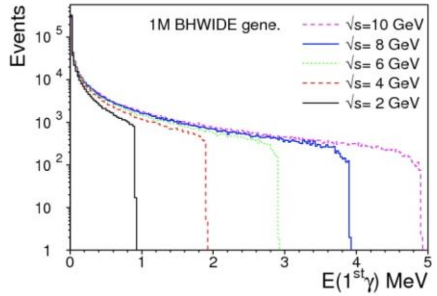
Perspective for measuring Bhabha @ STCF

BHWIDE √s = 2 – 10 GeV
scattered e$^\pm$ > 0.1 GeV; Ω(e$^+$e$^-$) : 0-π
CMS generted for σ(1-20°)

Acceptance **e$^+$e$^-$** in FWD **= 16.5%**

Both **e$^+$e$^-$** fall in FWD
event ratio with

- **0/nγ** generated
- **γ^{1st}** Eγ>0.1 GeV, Ω(e$^\pm$,γ^{1st})>10 mR



Detected in each z-side	√s =	10 GeV	8 GeV	6 GeV	4 GeV	2 GeV
both e$^+$e$^-$ in FWD	e$^\pm$,0γ	56.1 %	57.1 %	59.1 %	61.6 %	66.0 %
	e$^\pm$,nγ	43.9 %	42.9 %	40.9 %	38.4 %	34.0 %
e$^\pm$,γ^{1s} in FWD E$_\gamma$> 0.1GeV, Ω(e$^\pm$,γ^{1st})>10mR	e$^\pm$,γ^{1s}	ISR 0.63 % FSR 1.69 %	ISR 0.64 % FSR 1.62 %	ISR 0.58 % FSR 1.47 %	ISR 0.50 % FSR 1.26 %	ISR 0.40 % FSR 0.94 %

Discussion

- **Proposal for detecting QED radiative photons**
  Forward Bhabha high statstics
  Better than 10-3 prevision
- **Forward detector within ITKM cone**
  Si + LYSO for e/γ measurements
- **Be beam pipe**
  Minimized preshower
  minimum upstream background to tracking volume

Summary of the summary

- The physics session contributes 13 theory or review talks and 10 STCF experiment talks in 6 parallel sessions
  - **Apologies for not covering all the aspects…However**
- Strong synergies between theorists and experimentalists
  - Cover all the three-fold physics flag ships and more
  - Inspiring ideas, suggestions and works from theorists
  - Progressing in STCF full simulation experimentally
- Thanks to all the speakers and audience!