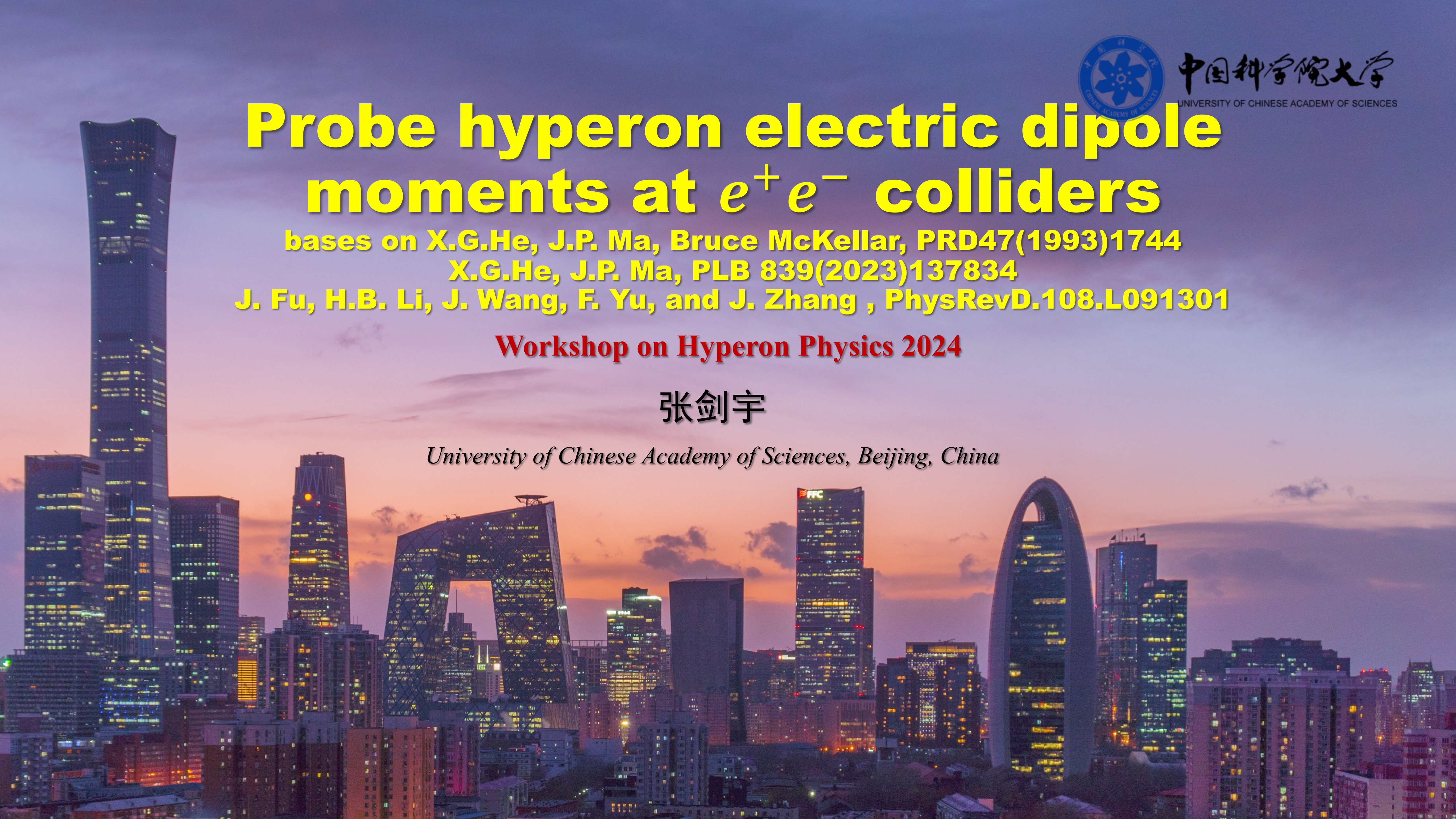


中国科学院大学
UNIVERSITY OF CHINESE ACADEMY OF SCIENCES

Probe hyperon electric dipole moments at e^+e^- colliders

bases on X.G.He, J.P. Ma, Bruce McKellar, PRD47(1993)1744
X.G.He, J.P. Ma, PLB 839(2023)137834
J. Fu, H.B. Li, J. Wang, F. Yu, and J. Zhang , PhysRevD.108.L091301

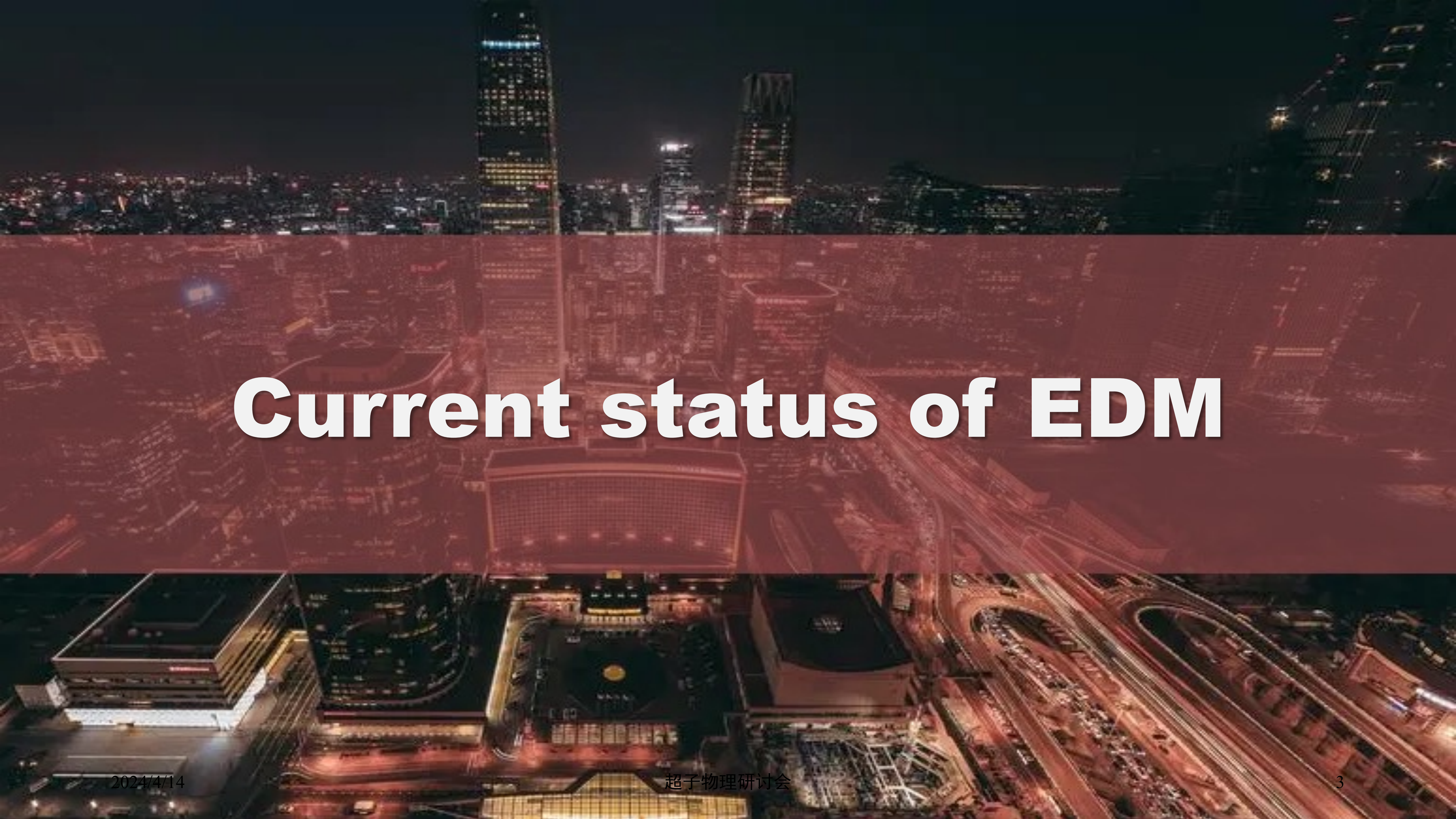
Workshop on Hyperon Physics 2024

张剑宇

University of Chinese Academy of Sciences, Beijing, China

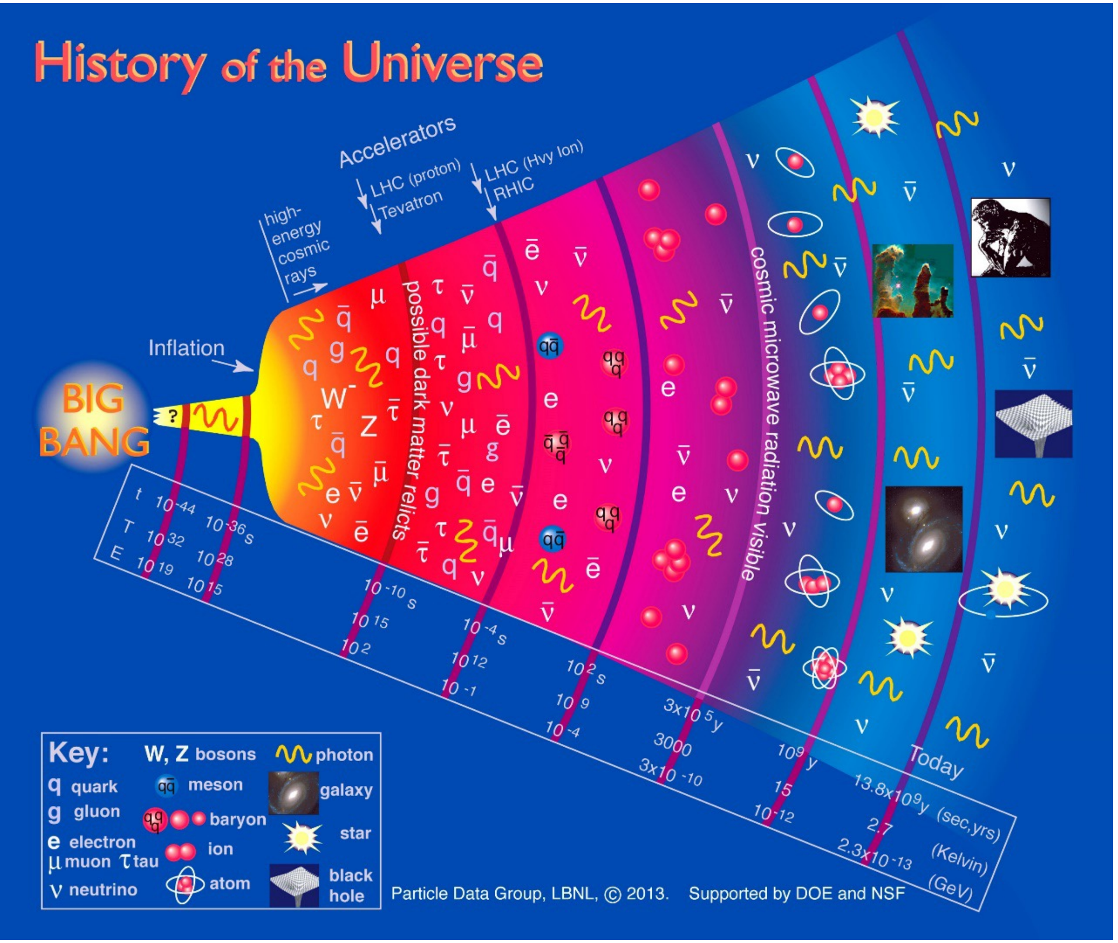
Outline

- Current status of EDM
- Probe hyperon EDM at BESIII and STCF
- Sensitivity study of BESIII and STCF
- Summary and outlooks



Current status of EDM

Matter-antimatter asymmetry in the universe



Particle Data Group, LBNL, © 2013. Supported by DOE and NSF

- Big matter and anti-matter asymmetry founded in the universe!

  WMAP+COBE(2012):

$$(n_B - n_{\bar{B}})/n_\gamma|_{CMB} = (6.08 \pm 0.09)\times 10^{-10}$$

- Sakharov three conditions require:

  ***C* and *CP* symmetry violation**

Pisma Zh. Eksp. Teor. Fiz., 1967, 5: 32-35.

- CP violation has been founded at K, B, D meson system, but not enough to explain matter dominant universe.

  Standard Model (SM) prediction:

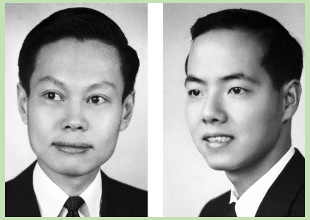
$$\hat{d}_{CP} = \frac{d_{CP}}{D^{12}} \sim 10^{-18} \ll 10^{-10}$$

W. Bernreuther
Lect. Notes Phys.591
(2002) 237-293

Exploring new physics is extremely important

A brief history of Parity and CP violation

Nobel Prize 1957



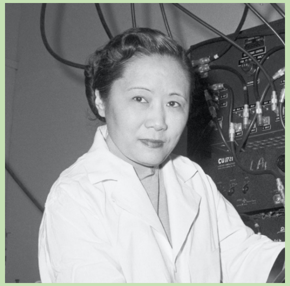
C. N. Yang T. D. Lee

$\theta - \tau$ puzzle [1]

First proposed Parity violation in weak interaction

Confirmed by

1957



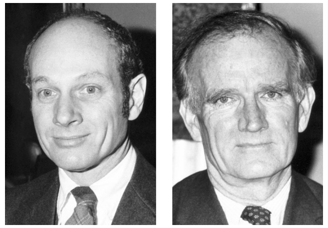
Chien-Shiung Wu

No CPV founded in baryon sector!

K meson *CP* violation[2]

1964

James Watson Cronin



Val Logsdon Fitch

Nobel Prize 1980

B meson *CP* violation [3,4]

2001

Belle II

BABAR

D meson *CP* violation [5]

2019

LHCb

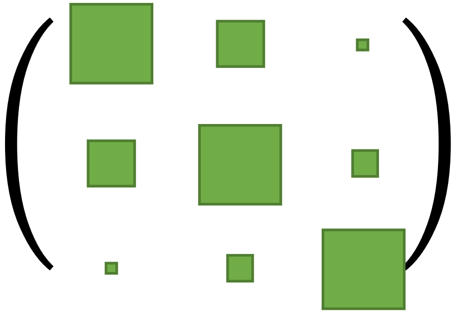
[1] Phys. Rev. 104 (1956) 254-258
[2] Phys. Rev. Lett., 1964, 13: 138-140
[3] Phys. Rev. Lett., 2001, 87: 091801
[4] Phys. Rev. Lett., 2001, 87: 091802
[5] Phys. Rev. Lett., 2019, 122(21): 211803

CPV in Standard Model

CKM mechanism:

$\boxed{CPV \text{ from phase } \delta}$

$$V_{\text{CKM}} = \begin{pmatrix} c_{12}c_{13} & s_{12}c_{13} & \boxed{s_{13}e^{-i\delta}} \\ -s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta} & s_{23}c_{13} \\ \boxed{s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta}} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta} & c_{23}c_{13} \end{pmatrix}$$



Dirac Medal 2010

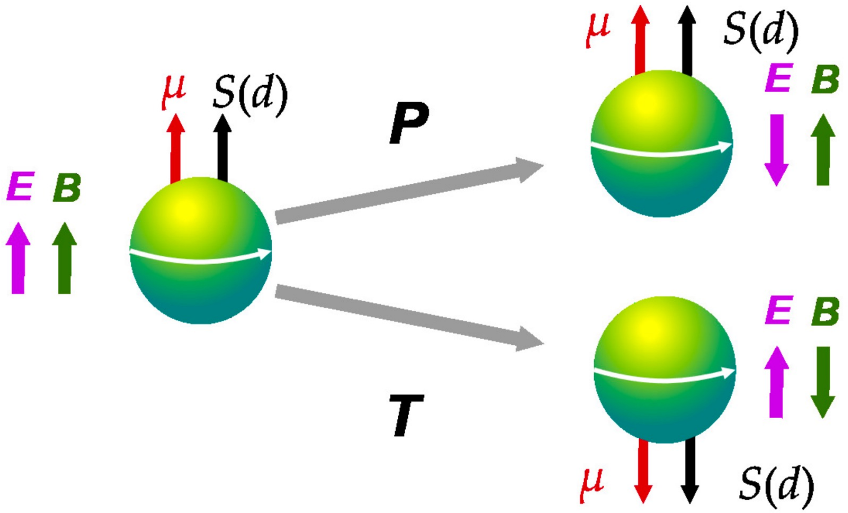
Nobel Price 2008

Strong CP

- $\bar{\theta}$ term： $\mathcal{L}_{\bar{\theta}} = -\frac{\alpha_s}{16\pi^2}\bar{\theta}\mathrm{Tr}(G^{\mu\nu}\tilde{G}_{\mu\nu})$
- Mainly through measuring the Electric Dipole Moment (EDM) of atomic nuclei, atoms, and molecular systems,
- The current most stringent constraints come from the EDM experiments of neutrons and 199Hg： $\bar{\theta} < 10^{-10}$

Electric Dipole Moment

μ: magnetic dipole moment
d: electric dipole moment
S: particle spin



$$\mathcal{H} = -\boldsymbol{\mu}\cdot\mathbf{B} - \boldsymbol{\delta}\cdot\mathbf{E} \xrightarrow{P} \mathcal{H} = -\boldsymbol{\mu}\cdot\mathbf{B} + \boldsymbol{\delta}\cdot\mathbf{E}$$

$$\mathcal{H} = -\boldsymbol{\mu}\cdot\mathbf{B} - \boldsymbol{\delta}\cdot\mathbf{E} \xrightarrow{T} \mathcal{H} = -\boldsymbol{\mu}\cdot\mathbf{B} + \boldsymbol{\delta}\cdot\mathbf{E}$$

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

The contribution of the Standard Model to EDM is very small:

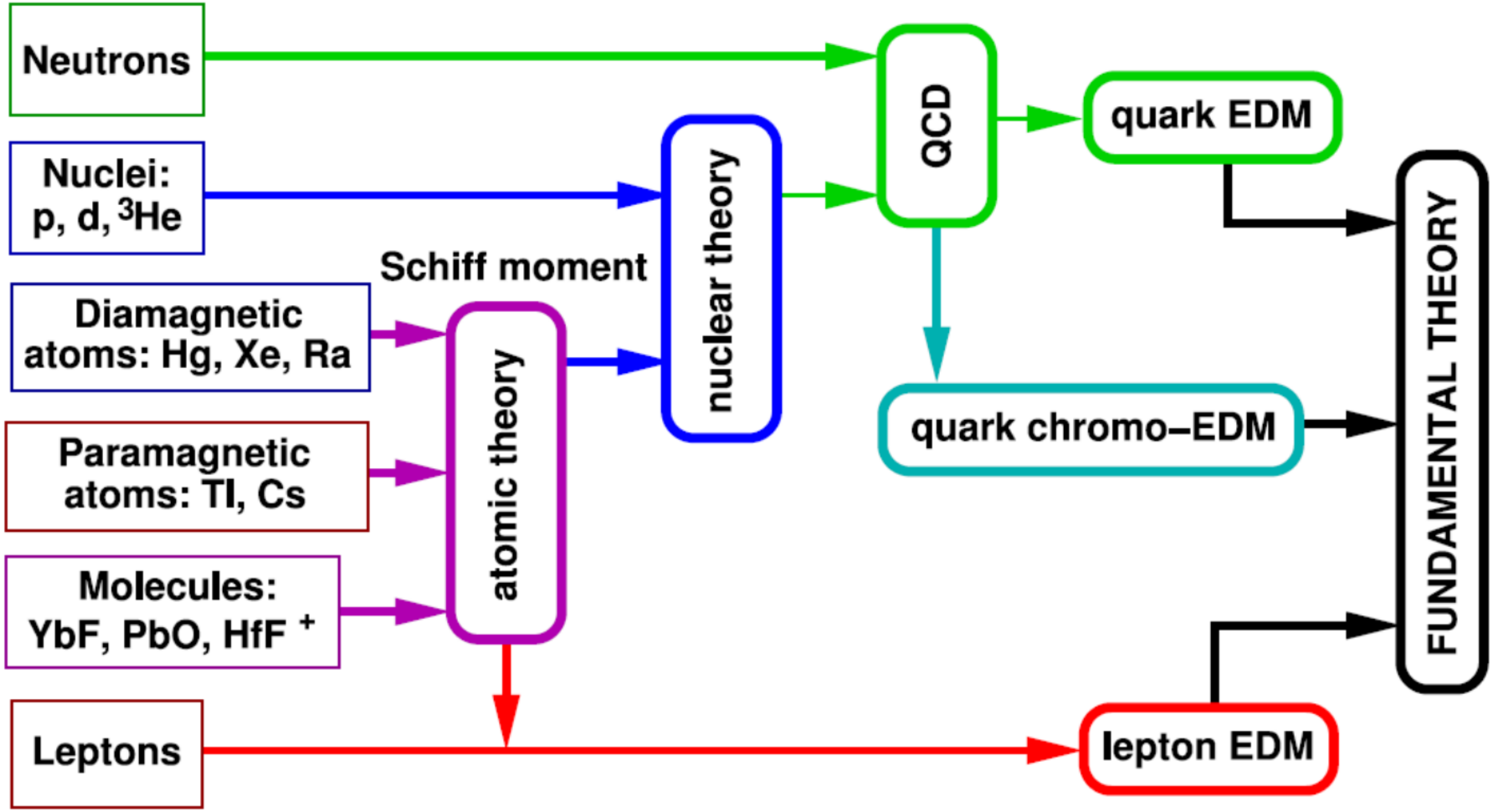
- CKM: highly suppressed by loop level (≥ 3) interaction
- QCD $\bar{\theta}$ term: main SM contributors to the EDM, $\bar{\theta} < 10^{-10}$
  - limited by neutron EDM:

$$d_n < 1.6\times 10^{-26}\ ecm$$

$$\mathcal{L}_{\mathrm{CPV}} = \mathcal{L}_{\mathrm{CKM}} + \mathcal{L}_{\bar{\theta}} + \mathcal{L}_{\mathrm{BSM}}^{\mathrm{eff}}$$

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

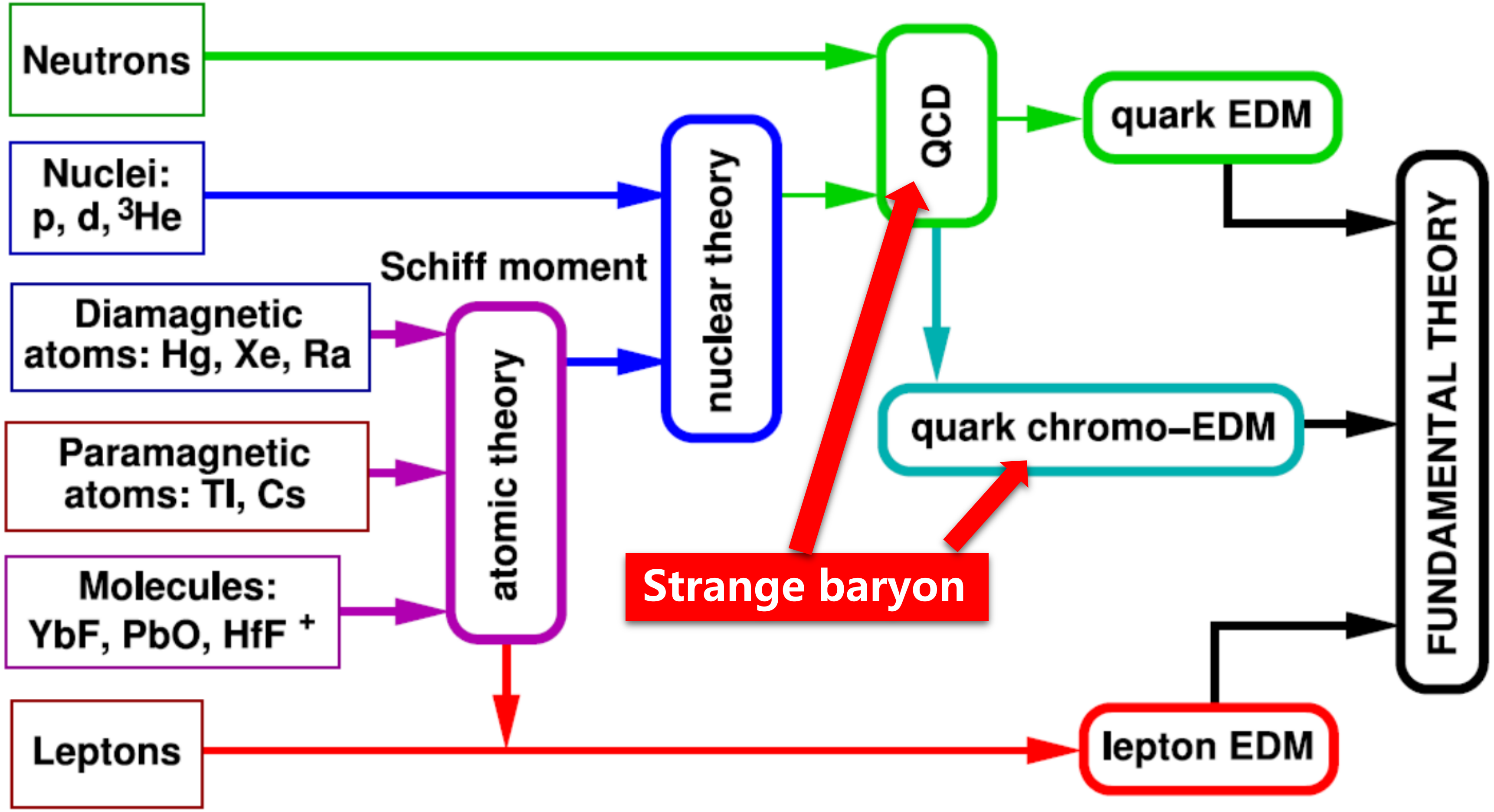
Map of EDM



C. R. Physique 13 168 (2012)

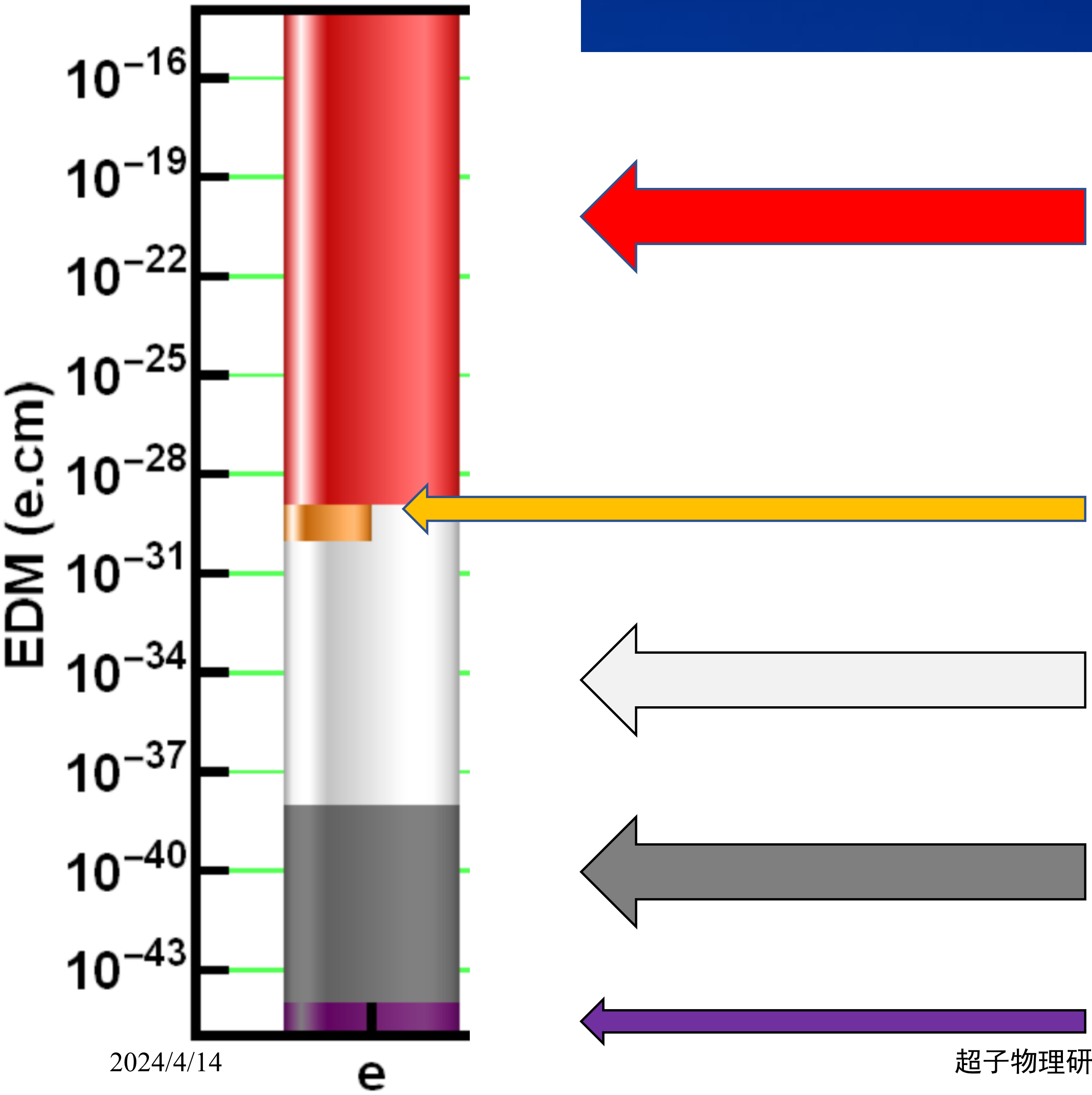
Map of EDM

The identification of the nature of the fundamental CP-violating mechanisms requires the study of EDMs in various systems



C. R. Physique 13 168 (2012)

ILLUSTRATION of EDM STATUS



Best measurements
Limits from experimental results

Expected experimental results
in the next few years

Safe BSM discovery territory

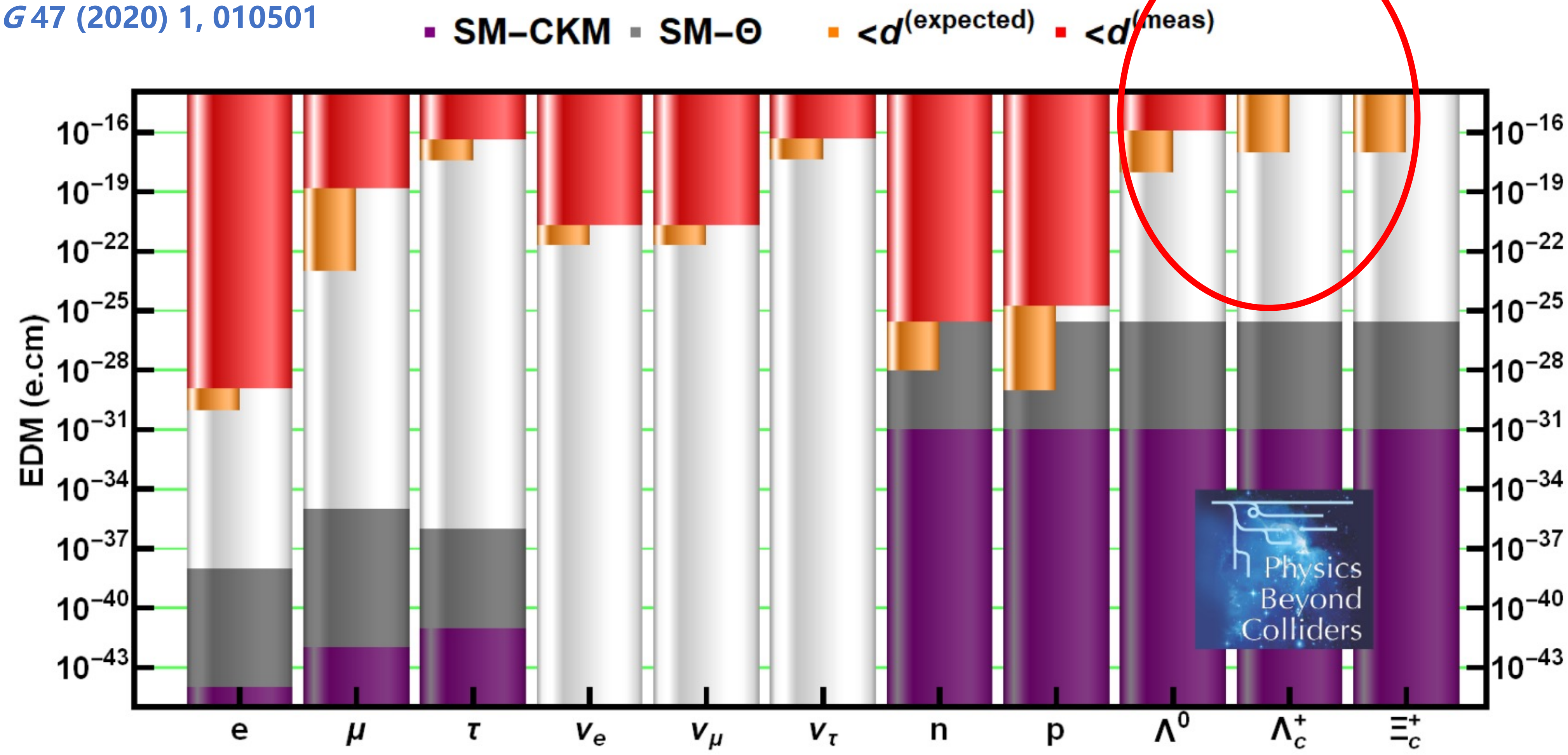
SM estimates from QCD $\bar{\theta}$ term

SM estimates from CKM

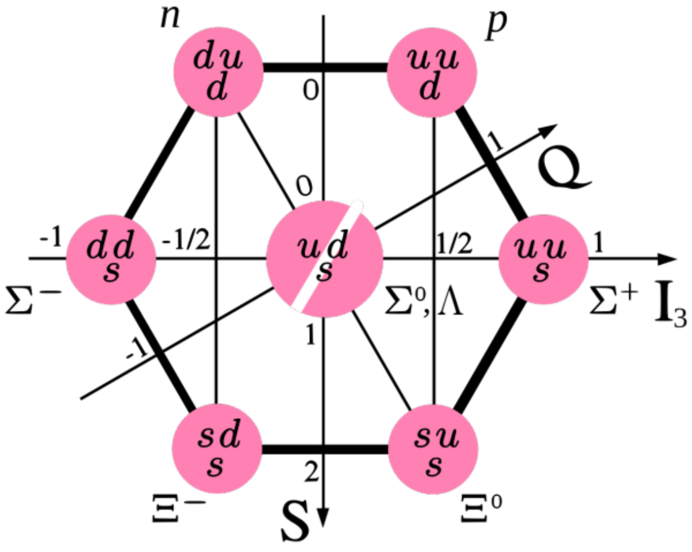
EDM Status

Only Λ hyperon has been measured with a large uncertainty!

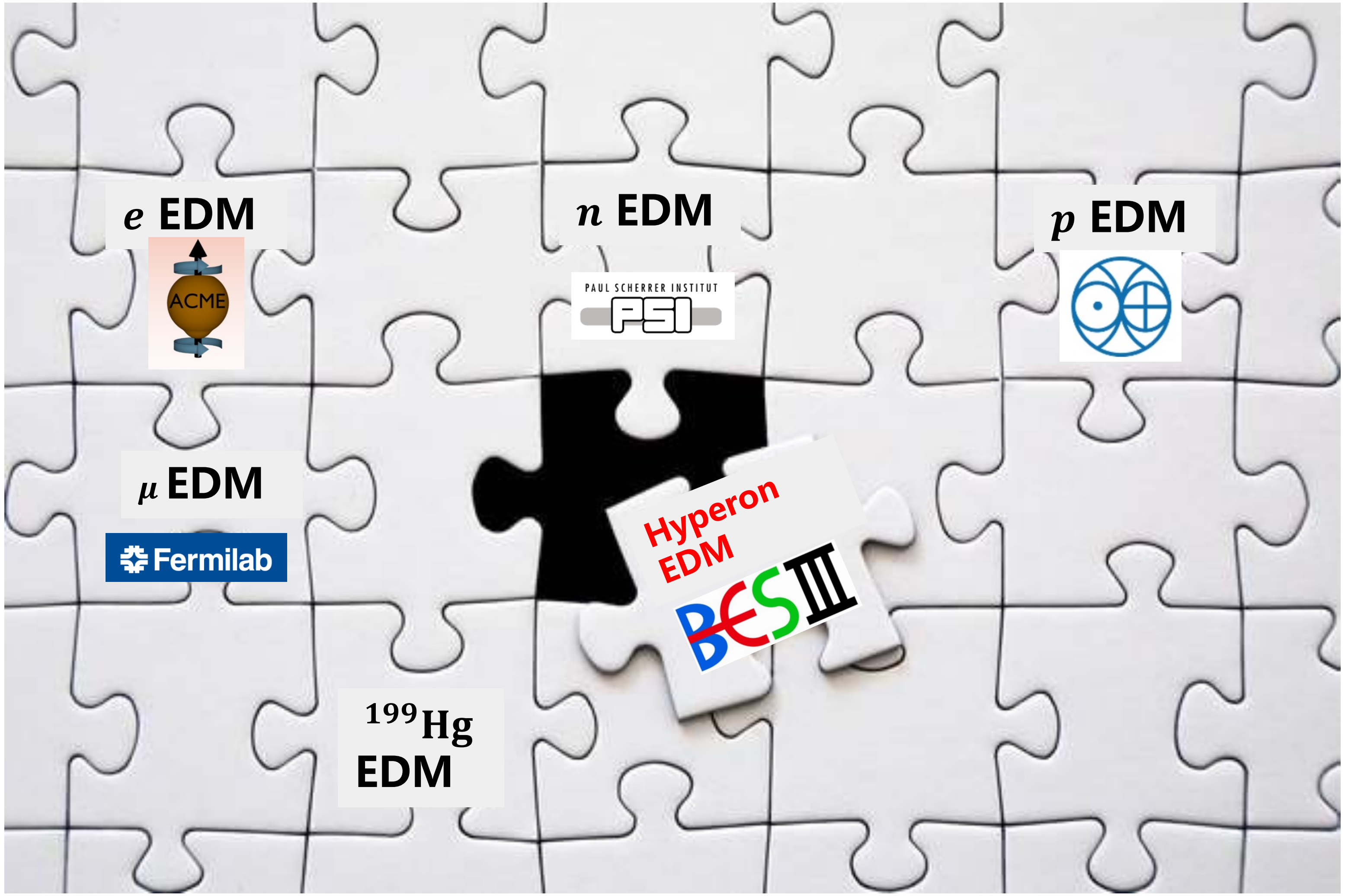
J.Phys.G 47 (2020) 1, 010501



What can BESIII / STCF do for EDM?



$+\ \Omega^-(sss)$ spin-$\frac{3}{2}$



What can BESIII / STCF do for EDM?

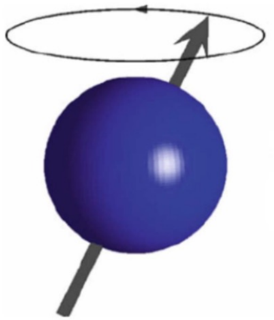
- Direct approach：spin procession 难以用来测量短寿命粒子的EDM

$$\frac{d\mathbf{s}}{dt} = \mathbf{s} \times \mathbf{\Omega}$$

$$\mathbf{\Omega} = \mathbf{\Omega}_{\mathrm{MDM}} + \mathbf{\Omega}_{\mathrm{EDM}} + \mathbf{\Omega}_{\mathrm{TH}}$$

$$\mathbf{\Omega}_{\mathrm{MDM}} = \frac{\boxed{g}\mu_B}{\hbar}\left(\mathbf{B} - \frac{\gamma}{\gamma+1}(\boldsymbol{\beta}\cdot\mathbf{B})\boldsymbol{\beta} - \boldsymbol{\beta}\times\mathbf{E}\right)$$

$$\Omega_{\mathrm{EDM}} = \frac{\boxed{d}\mu_B}{\hbar}\left(\mathbf{E} - \frac{\gamma}{\gamma+1}(\boldsymbol{\beta}\cdot\mathbf{E})\boldsymbol{\beta} - \boldsymbol{\beta}\times\mathbf{B}\right)$$



- Indirect approach：time-like dipole form factors ($q^2 \neq 0$)

$$L_{\mathrm{dipole}} = i\frac{d_\Lambda}{2}\bar{\Lambda}\sigma_{\mu\nu}\gamma_5\Lambda F^{\mu\nu}$$

$$L_{c-\Lambda} = -\frac{2}{3M^2}ed_\Lambda(p_1^\mu - p_2^\mu)\bar{c}\gamma_\mu c\bar{\Lambda}i\gamma_5\Lambda$$

X.G.He, J.P. Ma, Bruce McKellar, Phys.Rev.D47(1993)1744
X.G.He, J.P. Ma, Phys.Lett.B 839(2023)137834

Prob hyperon EDM at BESIII and STCF

BESIII and STCF : a hyperon factory

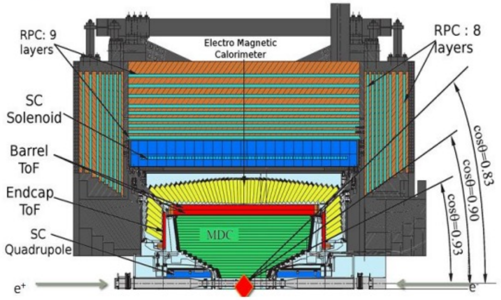
10 billion J/ψ events collected at BESIII:
- **Large Br. in J/ψ decay**
- **Quantum entangled pair productions**
- **High efficiency, background free**

Decay	$\mathcal{B}$ (10^{-5})	Events at BESIII
$J/\psi \to \Lambda\bar{\Lambda}$	189 ± 9	18.9×10^6
$J/\psi \to \Sigma^+\bar{\Sigma}^-$	150 ± 24	15.0×10^6
$J/\psi \to \Xi\bar{\Xi}$	97 ± 8	9.7×10^6
$\psi(2S) \to \Sigma\bar{\Sigma}$	23.2 ± 1.2	116×10^3
$\psi(2S) \to \Omega\bar{\Omega}$	5.66 ± 0.30	28×10^3

Front. Phys. 12(5), 121301 (2017)
Phys. Rev. D 100, 114005 (2019)

Electromagnetic Calorimeter
CsI(Tl): L=28 cm
Barrel σ_E=2.5%
Endcap σ_E=5.0%

Muon Counter
RPC
Barrel: 9 layers
Endcap: 8 layers
$\sigma_{spatial}$=1.48 cm



Main Drift Chamber
Small cell, 43 layer
σ_{xy}=130 μm
dE/dx~6%
σ_p/p= 0.5% at 1 GeV

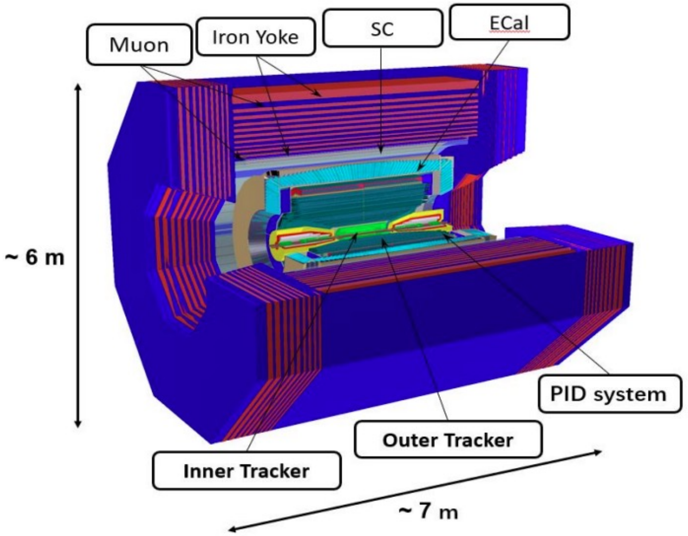
Time Of Flight
Plastic scintillator
σ_T(barrel)=80 ps
σ_T(endcap)=110 ps
(update to 65 ps with MRPC)

BESIII Detector

With 10 billion J/ψ collected at BESIII and $\sim 10^7$ entangled hyperon pairs can be studied.

At future, the STCF will collect 1 trillion J/ψ per year, and will provide $\sim 10^9$ hyperon pairs.

Proposed: Super Tau-Charm Facility (STCF)



ITK: ~0.15% X_0 / layer
σ_{xy}~50 μm

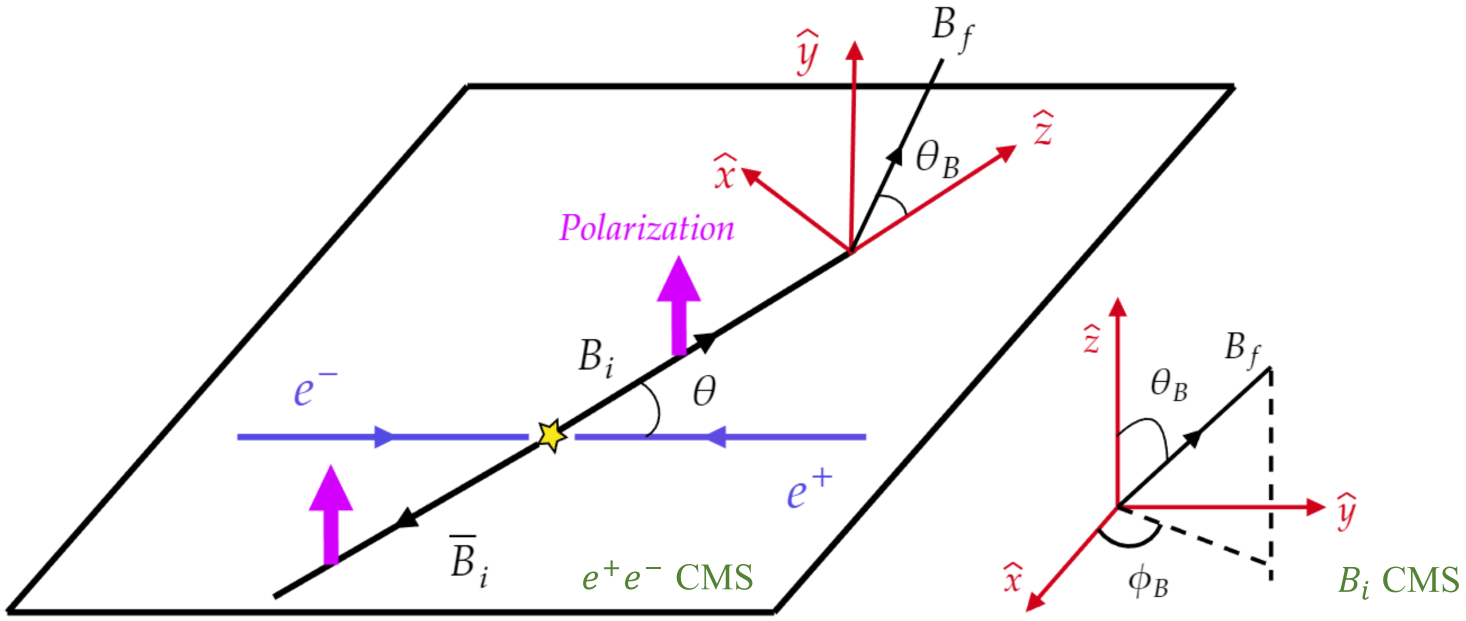
MDC: σ_{xy}~130 μm
σ_p/p~0.5%@1GeV/c
dE/dx~6%

PID: $\pi K(Kp)$ 3~4 σ separation up to 2 GeV/c

EMC: range 0.02~2GeV
σ_E@1GeV: 2.5% in barrel, 4% at endcaps

MUD: 0.4~1.8GeV, π suppression > 30

Polarized hyperon pairs produced in e^+e^- collisions



Two form factors are used to describe the production of hyperon pair: G_1, G_2, which also known as $G_M = \frac{G_1}{e_g}$, $G_E = \frac{G_2}{e_g}$

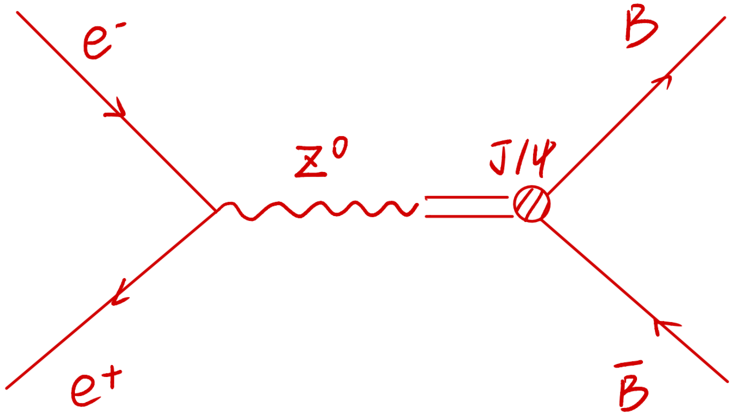
$$\alpha_\psi = \frac{s^2|G_1|^2-4m^2|G_2|^2}{s^2|G_1|^2+4m^2|G_2|^2}, \quad \frac{G_1}{G_2} = \left|\frac{G_1}{G_2}\right| e^{-i\Delta\Phi}$$

Polarization:

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

- Angular distribution of $\frac{d\Gamma}{d\Omega} \propto 1 + \alpha_\psi \cos^2\theta$, $\alpha_\psi \in [-1.0, 1.0]$
- If $\Delta\Phi \neq 0$, the hyperon will have transverse polarization even e^+e^- beams are unpolarized.

Polarization of J/ψ



Considering Z^0 contribution:
J/ψ has longitude polarization:
denoted by P_L

$\rho_{mm'}$: J/ψ spin density matrix

No beam polarization：

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

$$P_L = \mathcal{A}^0_{LR} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} = \frac{-\sin^2\theta_W^{\text{eff}} + 3/8}{2\sin^2\theta_W^{\text{eff}}\cos^2\theta_W^{\text{eff}}} \frac{M^2_{J/\psi}}{m_Z^2}$$

With beam polarization：

$$\xi = \frac{\sigma_R(1+P_e)/2 - \sigma_L(1-P_e)/2}{\sigma_R(1+P_e)/2 + \sigma_L(1-P_e)/2} = \frac{\mathcal{A}^0_{LR} + P_e}{1 + P_e\mathcal{A}^0_{LR}} \approx P_e$$

Can be used for precise measurement beam polarization

Spin density matrix of hyperon-antihyperon

Polarization effects encoded in hyperon pair spin density matrix

$$R(\lambda_1,\lambda_2;\lambda_1',\lambda_2') \propto \sum_{m,m'} \rho_{m,m'} d^{j=1}_{m,\lambda_1-\lambda_2}(\theta) d^{j=1}_{m',\lambda_1'-\lambda_2'}(\theta) \times \mathcal{M}_{\lambda_1,\lambda_2} \mathcal{M}^*_{\lambda_1',\lambda_2'} \delta_{m,m'},$$

Lorentz invariance introduces P and CP violation form factors in helicity amplitude

$$\mathcal{M}_{\lambda_1,\lambda_2} = \epsilon_\mu(\lambda_1-\lambda_2)\bar{u}(\lambda_1,p_1)\Big(F_V\gamma^\mu + \frac{i}{2M_\Lambda}\sigma^{\mu\nu}q_\nu H_\sigma + \gamma^\mu\gamma^5 F_A + \sigma^{\mu\nu}\gamma^5 q_\nu H_T\Big)v(\lambda_2,p_2).$$

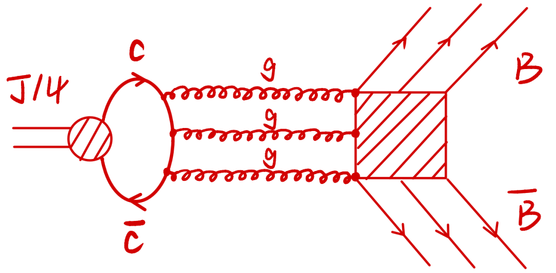
X.G.He, J.P. Ma, Bruce McKellar,
Phys.Rev.D47(1993)1744

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

Dynamics in $J/\psi \to B\bar{B}$

Detailed dynamics in J/ψ decay to hyperon pair, have been studied: X.G.He, J.P. Ma, Phys.Lett.B 839(2023)137834

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



Dominant contribution

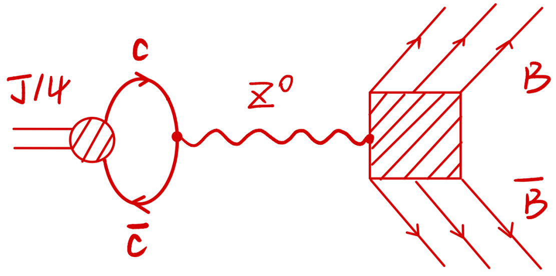
arXiv:hep-ph/0412158

Psionic form factor

$\boldsymbol{F_V}$ and $\boldsymbol{H_\sigma}$

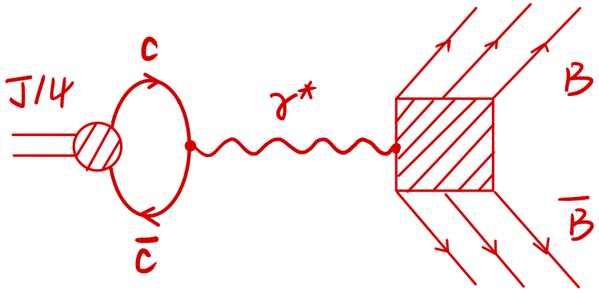
can also be represented

as $\boldsymbol{G_1}$ and $\boldsymbol{G_2}$



F_A : P violation term

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



H_T: CP violation term

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

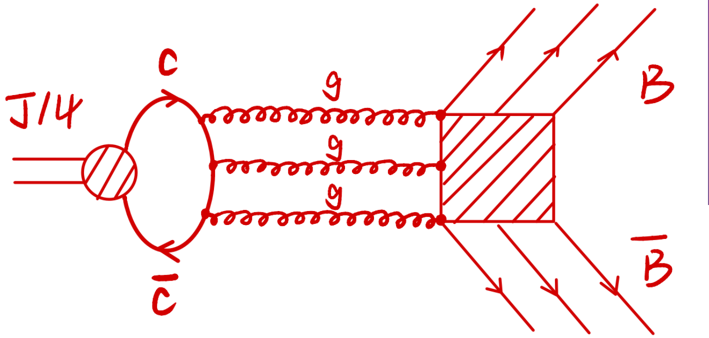
Assuming $d_B(q^2) \equiv d_B(0)$

$d_B(q^2)$: electric dipole form factor

$d_B(0)$: electric dipole moment

Physics Letters B 551 (2003) 16–26

Psionic form factors G_1, G_2



Psionic form factors

$$F_V = G_1 - \frac{4M^2}{Q^2}(G_1 - G_2) \qquad H_\sigma = \frac{4M^2}{Q^2}(G_1 - G_2)$$

Hyperon polarization parameters

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

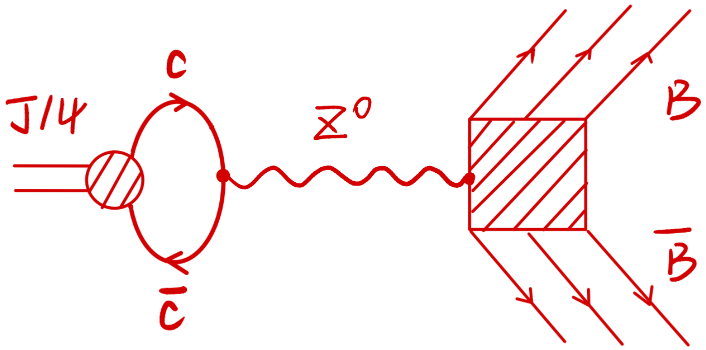
X.G.He, J.P. Ma, Bruce McKellar,
Phys.Rev.D47(1993)1744

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

Gŏran Fǎldt, Andrzej Kupsc
Physics Letters B 772 (2017) 16–20

- G_1 can be extracted from the measurement of $\Gamma(J/\psi \to B\overline{B})$

P violation form factor F_A



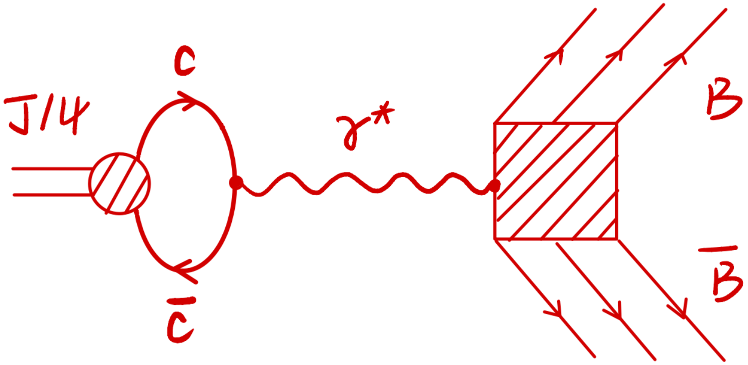
Primarily from Z-boson exchange between $c\bar{c}$ and light quark pairs

Related to weak mixing angle in SM

$$F_A \approx -\frac{1}{6} D g_V \frac{g^2}{4\cos^2\theta_W^{\text{eff}}} \frac{1-8\sin^2\theta_W^{\text{eff}}/3}{m_Z^2} \approx -1.07\times 10^{-6}$$

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

CP violation form factor H_T



Several CPV sources contributed to H_T

Take hyperon EDM as the major source for H_T

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

Neglect q dependence, d_B for hyperon EDM

X.G.He, J.P. Ma, Bruce McKellar, Phys.Rev.D47(1993)1744

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

Full angular helicity amplitude of $e^+e^- \to J/\psi \to B\bar{B}$

J. Fu, H.B. Li, J. Wang, F. Yu, and J. Zhang, PhysRevD.108.L091301

Angular formular based on helicity amplitude are developed:

$$R(\lambda_1,\lambda_2;\lambda_1',\lambda_2') \propto \sum_{m,m'} \rho_{m,m'} d^{j=1}_{m,\lambda_1-\lambda_2}(\theta) d^{j=1}_{m',\lambda_1'-\lambda_2'}(\theta) \mathcal{M}_{\lambda_1,\lambda_2} \mathcal{M}^*_{\lambda_1',\lambda_2'} \delta_{m,m'}$$

Total angular distribution of J/ψ to spin-1/2 baryon pair:

- $J/\psi \to B\bar{B}, B = \Lambda^0, \Sigma^-, \Sigma^+$

$$\frac{d\sigma}{d\Omega_k d\Omega_p d\Omega_{\bar{p}}} = \boldsymbol{N} \sum_{[\lambda]} \boldsymbol{R(\lambda_1,\lambda_2;\lambda_1',\lambda_2')}\, \boldsymbol{D^{j=1/2}_{\lambda_1,\lambda_p}(\theta_1,\phi_1) D^{*j=1/2}_{\lambda_1',\lambda_p}(\theta_1,\phi_1) \left|h_{\lambda_p}\right|^2 D^{j=1/2}_{\lambda_2,\lambda_{\bar{p}}}(\theta_2,\phi_2) D^{*j=1/2}_{\lambda_2',\lambda_{\bar{p}}}(\theta_2,\phi_2) \left|h_{\lambda_{\bar{p}}}\right|^2}$$

- $J/\psi \to B\bar{B}, B = \Xi^0, \Xi^-$

$$\frac{d\sigma}{d\Omega_k d\Omega_\Lambda d\Omega_{\bar{\Lambda}} d\Omega_p d\Omega_{\bar{p}}} = \boldsymbol{N} \sum_{[\lambda]} \boldsymbol{R(\lambda_1,\lambda_2;\lambda_1',\lambda_2')}\, \boldsymbol{D^{*j=1/2}_{\lambda_1,\lambda_\Lambda}(\theta_1,\phi_1) D^{\,j=1/2}_{\lambda_1',\lambda'_\Lambda}(\theta_1,\phi_1) \mathcal{H}_{\lambda_\Lambda} \mathcal{H}^*_{\lambda_\Lambda'} D^{*j=1/2}_{\lambda_2,\lambda_{\bar{\Lambda}}}(\theta_2,\phi_2)}$$

$$\boldsymbol{D^{\,j=1/2}_{\lambda_2',\lambda'_{\bar{\Lambda}}}(\theta_2,\phi_2) \mathcal{H}_{\lambda_{\bar{\Lambda}}} \mathcal{H}^*_{\lambda_{\bar{\Lambda}}'} D^{*j=1/2}_{\lambda_\Lambda,\lambda_p}(\theta_3,\phi_3) D^{*j=1/2}_{\lambda_\Lambda',\lambda_p}(\theta_3,\phi_3) \left|h_{\lambda_p}\right|^2 D^{*j=1/2}_{\lambda_{\bar{\Lambda}},\lambda_{\bar{p}}}(\theta_4,\phi_4) D^{\,j=1/2}_{\lambda_{\bar{\Lambda}}',\lambda_{\bar{p}}}(\theta_4,\phi_4) \left|h_{\lambda_{\bar{p}}}\right|^2}$$

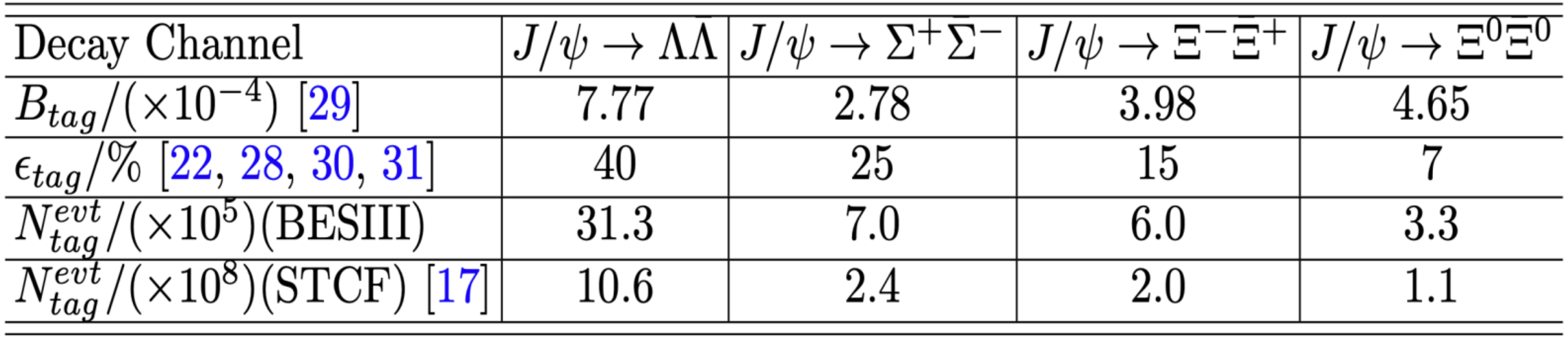
Sensitivity study of BESIII and STCF

Sensitivity study of BESIII and STCF

Sensitivity assessed from 500 psudoexperiments generated and fitted by using a probability density function based on the full angular distribution

Expected yields, Form Factors and decay parameters are fixed to known values for generation: G_1, $\alpha_{J/\psi}$, $\Delta\Phi$, F_A, H_T, α_B, $\alpha_{\overline{B}}$, ϕ_B and $\phi_{\overline{B}}$

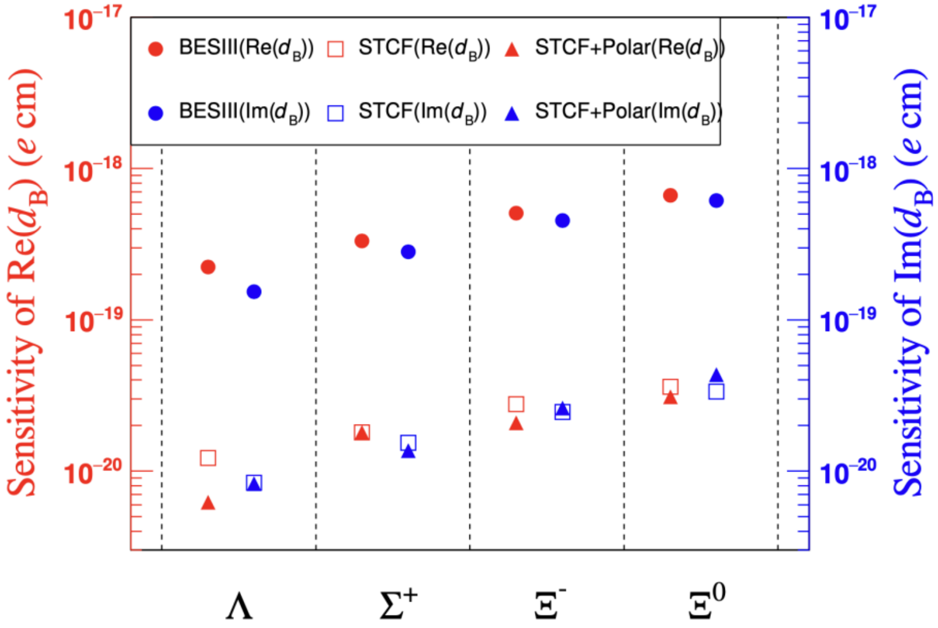
$P_L \sim 10^{-4}$ (80%) for unpolarized (longitudinally polarized) electron beam



Decay Channel	$J/\psi \to \Lambda\bar{\Lambda}$	$J/\psi \to \Sigma^+\bar{\Sigma}^-$	$J/\psi \to \Xi^-\bar{\Xi}^+$	$J/\psi \to \Xi^0\bar{\Xi}^0$
$B_{tag}/(\times 10^{-4})$ [29]	7.77	2.78	3.98	4.65
$\epsilon_{tag}/\%$ [22, 28, 30, 31]	40	25	15	7
$N_{tag}^{evt}/(\times 10^5)$(BESIII)	31.3	7.0	6.0	3.3
$N_{tag}^{evt}/(\times 10^8)$(STCF) [17]	10.6	2.4	2.0	1.1

Sensitivity of hyperon EDM measurements

reminder: $H_T = \frac{2e}{3M_{J/\psi}^2} g_V d_B$



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

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

BESIII: milestone for hyperon EDM measurement
Λ 10^{-19}e cm (FermiLab 10^{-16} *e* cm)

first achievement for Σ^+,Ξ^- and Ξ^0 at level of 10^{-19}e cm

a litmus test for new physics

STCF: improved by 2 order of magnitude

Sensitivity of CP violation in hyperon decay

N.G.Deshpande et al, PLB326(1994)307

J.Tandean et al, PRD67(2003)056001

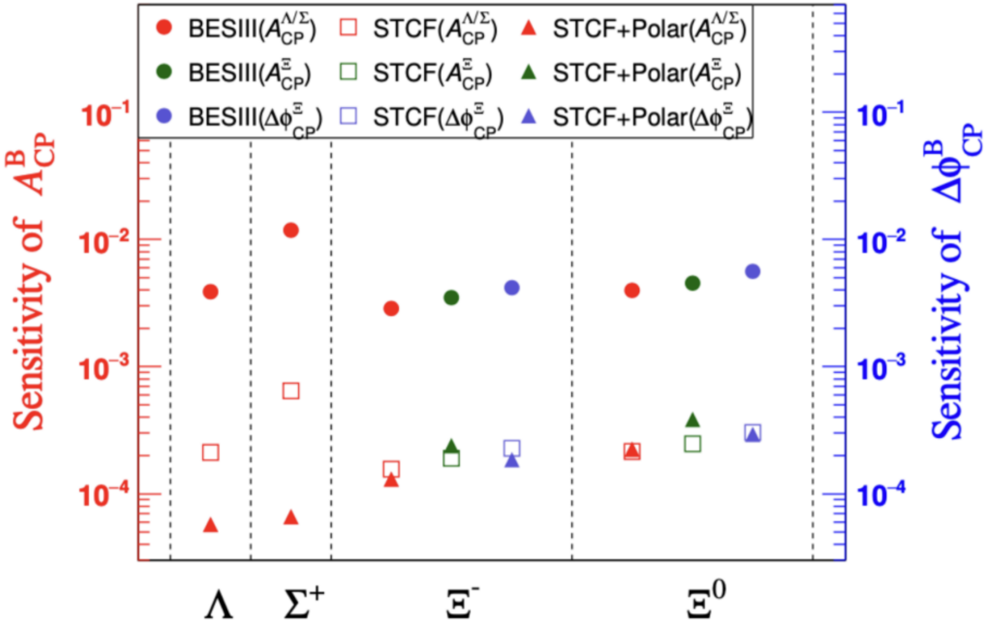
J.F.Donoghue et al, PRD34(1986)833

reminder:

$$A^B_{CP} = (\alpha_B + \bar{\alpha}_B)/(\alpha_B - \bar{\alpha}_B)$$

$$\Delta\phi^B_{CP} = (\phi_B + \bar{\phi}_B)/2$$

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



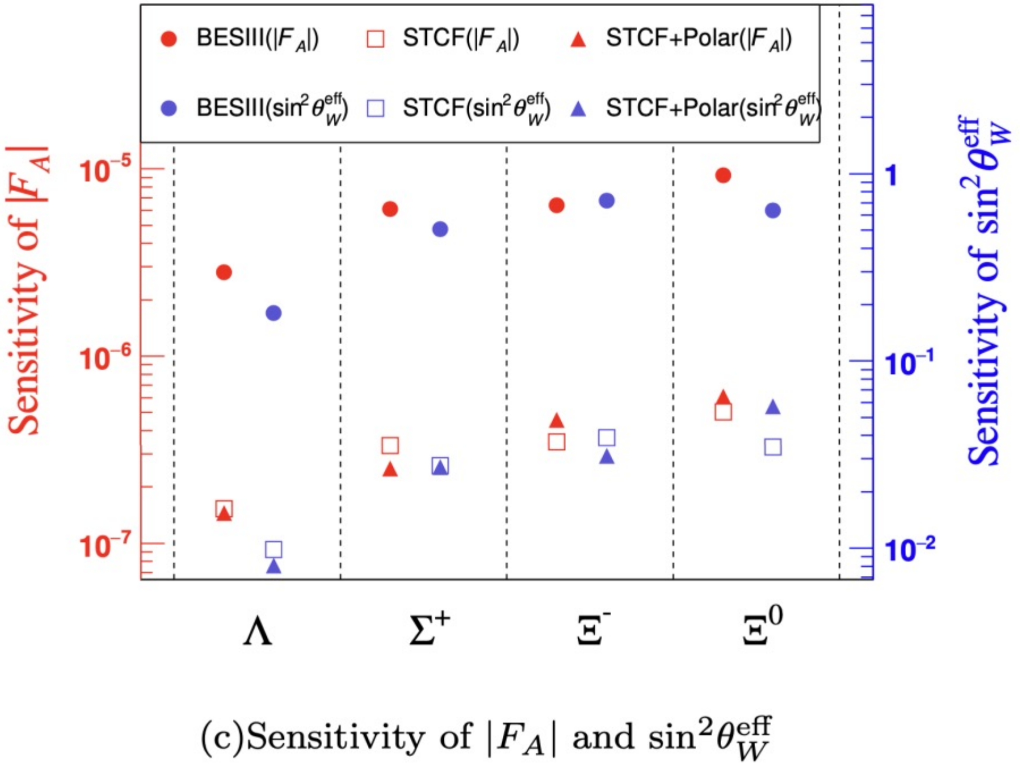
(b)Sensitivity of A^B_{CP} and $\Delta\phi^B_{CP}$

STCF:

SM prediction can be reached and further improved with a longitudinally polarized electron beam

Sensitivity of F_A and $\sin^2\theta_W^{\text{eff}}$ measurements

reminder: $F_A \approx -\frac{1}{6} D g_V \frac{g^2}{4\cos^2\theta_W^{\text{eff}}} \frac{1 - 8\sin^2\theta_W^{\text{eff}}/3}{m_Z^2}$



(c)Sensitivity of $|F_A|$ and $\sin^2\theta_W^{\text{eff}}$

SM: $F_A \sim 10^{-6}$

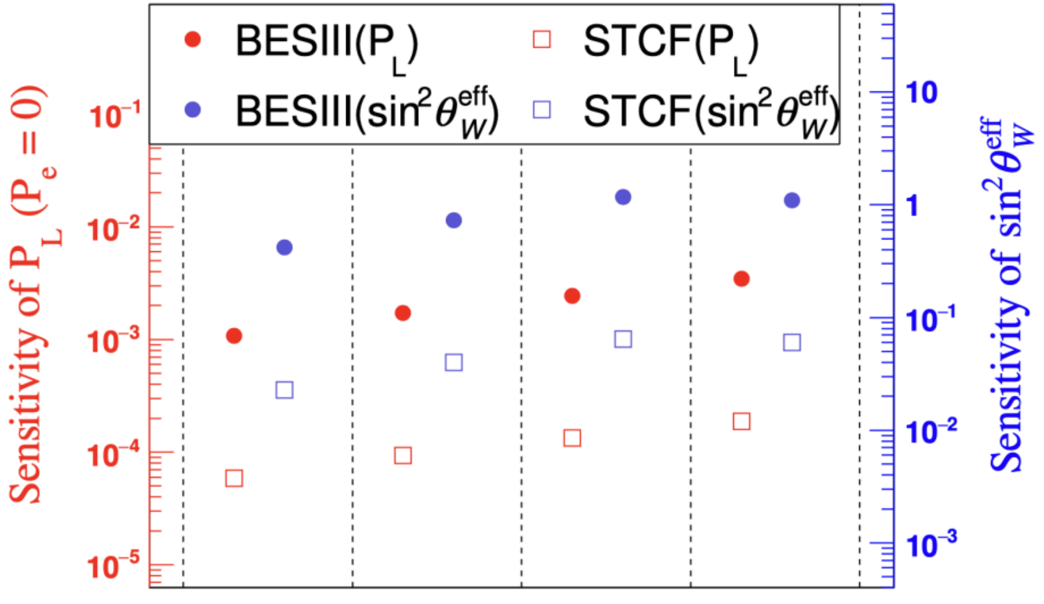
$\sin^2\theta_W^{\text{eff}} \sim 0.235$

STCF:

Weak mixing angle at $Q = M_{J/\psi}$ can be determined at the level of 8×10^{-3}

Sensitivity of P_L and $\sin^2\theta_W^{\text{eff}}$ measurements

reminder: $$P_L = \mathcal{A}_{LR}^0 = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} = \frac{-\sin^2\theta_W^{\text{eff}} + 3/8}{2\sin^2\theta_W^{\text{eff}}\cos^2\theta_W^{\text{eff}}}\frac{M_{J/\psi}^2}{m_Z^2}$$



(d)Sensitivity of P_L

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

$\sin^2\theta_W^{\text{eff}} \sim 0.235$

STCF:

Weak mixing angle at $Q = M_{J/\psi}$ can be determined at the level of 2×10^{-2}

Sensitivity of $\sin^2\theta_W^{\mathrm{eff}}$ by simultaneous fit

$J/\psi \to \Lambda\bar{\Lambda}$

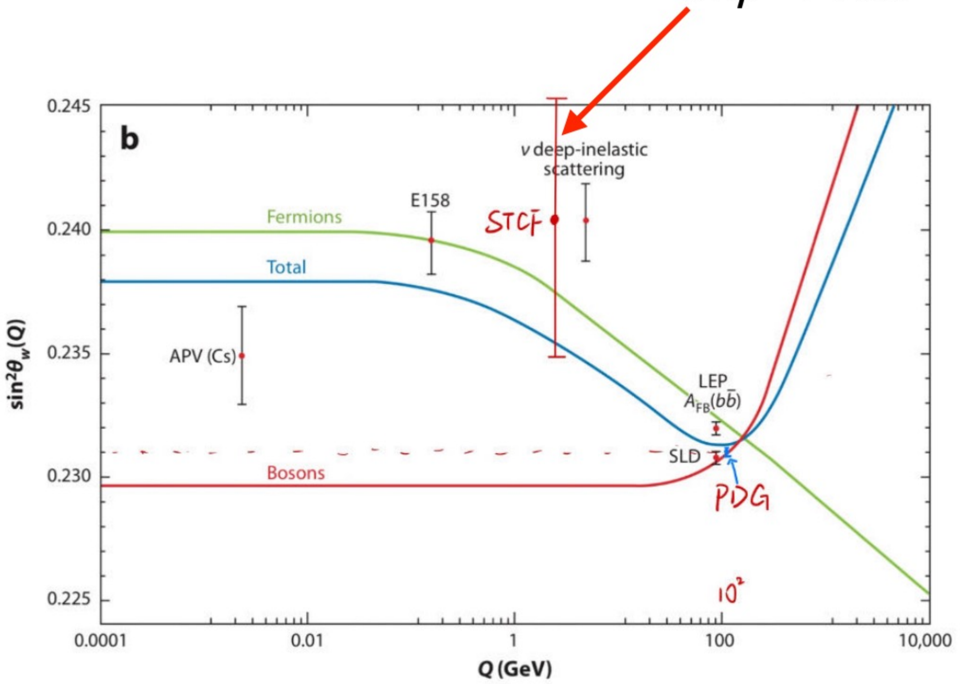


Figure 1

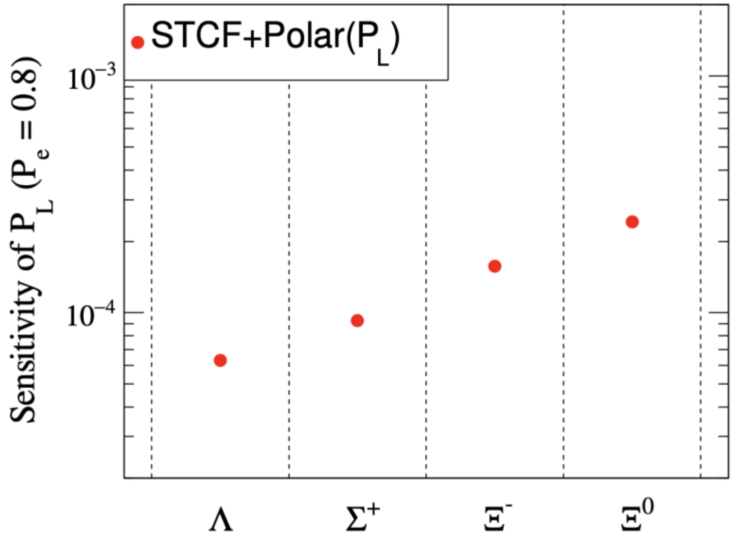
(*a*) $\sin^2\theta_W(\mu)_{\overline{\mathrm{MS}}}$ (29) with an updated atomic parity violation (APV) result. (*b*) $\sin^2\theta_W(Q^2)$, a one-loop calculation dominated by $\gamma - Z^0$ mixing (52). The red and green curves represent the boson and fermion contributions, respectively.

K.S.Kumar et al, Ann.Rev.Nucl.Part.Sci.
63 (2013) 237-267

Weak mixing angle shared by F_A and P_L

Sensitivity improved at the level 5×10^{-3}

Sensitivity of beam polarization measurements



Precisely measured beam polarization (10^{-5}) as input value for $\sin^2\theta_W^{\text{eff}}$ measurement

A. Bondar et al, JHEP 03 (2020) 076

$$\boxed{\mathcal{A}_{\text{LR}} \equiv \frac{\sigma_{\mathcal{P}_e} - \sigma_{-\mathcal{P}_e}}{\sigma_{\mathcal{P}_e} + \sigma_{-\mathcal{P}_e}}} = \mathcal{A}^0_{\text{LR}}\boxed{\mathcal{P}_e}$$

$$\sigma_{\mathcal{P}_e} = \frac{N_{\mathcal{P}_e}}{\mathcal{L}_{\mathcal{P}_e}\varepsilon_{\text{eff}}}$$

$$\sigma_{-\mathcal{P}_e} = \frac{N_{-\mathcal{P}_e}}{\mathcal{L}_{-\mathcal{P}_e}\varepsilon_{\text{eff}}}$$

analysis Bhabha scattering events

$$\mathcal{A}^0_{LR} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} = \frac{-\sin^2\theta_W^{\text{eff}} + 3/8}{2\sin^2\theta_W^{\text{eff}}\cos^2\theta_W^{\text{eff}}}\frac{M^2_{J/\psi}}{m_Z^2}$$

Summary and Outlooks

- To measure EDM, we developed a set of helicity amplitude formulas describing the J/ψ decay to $\Lambda, \Sigma, \Xi, \Omega$ pairs

- Pseudo experiments are performed and the sensitivity of the hyperon EDM
  - The prospect sensitivity of Λ EDM at BESIII is 1000 times higher than the world's best measurement under the same statistical condition.
  - BESIII has the opportunity of first measurements of the EDM of Σ^+, Ξ^-, Ξ^0 hyperons , and the sensitivity are at the order of 10^{-19}(BESIII) and 10^{-20}(STCF).

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