国家重点研发项目“粲强子衰变和标准模型的精确检验”2025年夏季年会

轻子数/重子数破坏过程寻找
Search for lepton- and baryon-number-violating decays

Guangyi Zhang (张广义)

(Email: zhangguangyi@htu.edu.cn)

Henan Normal University (河南师范大学)

Aug. 12-16, 2025

Outline

- New physics at BESIII
- Lepton-number-violating (LNV) searches
  - $\phi \to \pi^+\pi^+e^-e^- + c.c.$ via $J/\psi \to \phi\eta$
  - $\omega \to \pi^+\pi^+e^-e^- + c.c.$ via $J/\psi \to \omega\eta$
  - $J/\psi \to K^+K^+e^-e^- + c.c.$
  - $D_s^+ \to h^-h^0e^+e^+ \ (h^- = K^-, \pi^-; h^0 = \pi^0, K_S^0, \phi)$
  - Other LNV searches under review
- Baryon-number-violating (BNV) searches
  - $\Lambda - \bar{\Lambda}$ oscillation in $J/\psi \to \Lambda\bar{\Lambda}$ decay
  - $J/\psi \to pe^- + c.c.$ via $\psi(2S) \to \pi^+\pi^-J/\psi$
  - Other BNV searches under review
- Summary

New physics at BESIII

- The world's largest J/ψ $((1.0087 \pm 0.0044) \times 10^{10})$ and $\psi(2S)$ $((2.7124 \pm 0.0143) \times 10^{9})$ data, and other unique data samples, provide a good opportunity to search for new physics at BESIII.

- Rare or forbidden processes searches

  LNV, BNV, CLFV, FCNC, charmonium weak decays, rare semi-leptonic decay, etc.

- Exotic phenomena searches

  Invisible decays, dark photon, light Higgs, light neutralino, CP violation, etc.

- The future program of new physics at BESIII could be found at Chapter 6 of BESIII white paper [1].

[1] Chin. Phys. C 44, 040001 (2020).

1. Lepton-number-violating (LNV) searches

- Neutrinos, described by the Dirac equation and considered as $SU(2)_L$ gauge invariant fields, were accepted in the Standard Model (SM) as massless left-handed Dirac fermions in 1958.
- In 1937, Majorana proposed that neutrinos might be their own antiparticles. Neutrinos can potentially possess mass.
- The discovery of neutrino oscillations and the observation of the θ_{13} mixing angle have convincingly shown that neutrinos have non-zero mass.
- One interesting question is whether neutrinos are Dirac or Majorana neutrinos?
- For Dirac neutrinos, the SM extensions can introduce sterile right-handed neutrinos coupled via Yukawa interactions with the Higgs field, generating Dirac masses similar to other fermions. This requires unnaturally small Yukawa couplings ($\sim 10^{-12}$) to match observed tiny neutrino masses. Lepton number is conserved.

1. Lepton-number-violating (LNV) searches

- For Majorana neutrinos, a popular model that naturally generates light neutrino masses is the so-called “see-saw” mechanism, in which the small value of the observed neutrino masses arises from the existence of a heavy Majorana neutrino state with a mass from a few hundred MeV to a few GeV. Explicitly violates lepton number ($\Delta L = 2$), predicting observable neutrinoless double beta ($0\nu\beta\beta$) decay.

- The most promising way to identify the nature of neutrinos is searching for the $0\nu\beta\beta$ decay with lepton number violation by two units ($\Delta L = 2$).

1.1 LNV: $\phi \to \pi^+\pi^+e^-e^- + c.c.$ via $J/\psi \to \phi\eta$

Tengjiao Wang, Yaxuan Zhang, Nguyen Thi Nin, Minggang Zhao, and Dayong Wang

Chin. Phys. C 49, 043001 (2025)

- Although hadrons comprising first generation quarks have been well explored in $0\nu\beta\beta$, searching for LNV with non-first generation quark decays would be necessary.
- Complementary to those measurements, the study of LNV using ϕ decays involving *s*-quarks is distinctive owing to the different phase space (PHSP) it explores.
- Analysis method:

$$J/\psi \to \phi\eta, \eta \to \gamma\gamma. \quad \phi \to \pi^+\pi^+e^-e^-$$

$$\mathcal{B}(\phi \to \pi^+\pi^+e^-e^-) = \frac{N^{\rm net}_{\pi^+\pi^+e^-e^-}/\varepsilon_{\pi^+\pi^+e^-e^-}}{N^{\rm tot} \times \mathcal{B}(J/\psi \to \phi\eta) \times \mathcal{B}(\eta \to \gamma\gamma)}, \quad (1)$$

Uncertainty: 11%

$$\mathcal{B}(\phi \to K^+K^-) = \frac{N^{\rm net}_{K^+K^-}/\varepsilon_{K^+K^-}}{N^{\rm tot} \times \mathcal{B}(J/\psi \to \phi\eta) \times \mathcal{B}(\eta \to \gamma\gamma)}, \quad (2)$$

$$\mathcal{B}(\phi \to \pi^+\pi^+e^-e^-) = \mathcal{B}(\phi \to K^+K^-) \times \frac{N^{\rm net}_{\pi^+\pi^+e^-e^-}/\varepsilon_{\pi^+\pi^+e^-e^-}}{N^{\rm net}_{K^+K^-}/\varepsilon_{K^+K^-}}, \quad (3)$$

Uncertainty: 1%

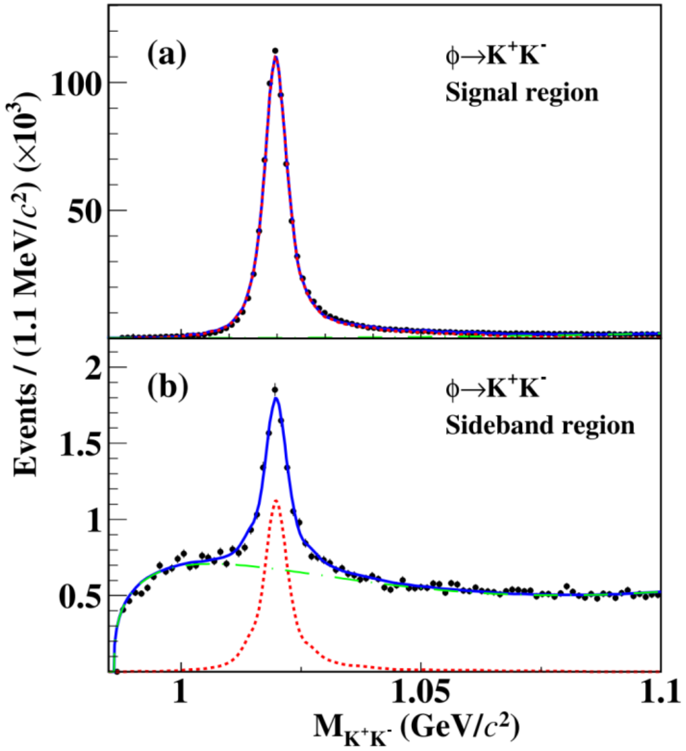
The total systematic uncertainty can be reduced significantly

1.1 LNV: $\phi \to \pi^+\pi^+e^-e^- + c.c.$ via $J/\psi \to \phi\eta$

Tengjiao Wang, Yaxuan Zhang, Nguyen Thi Nin, Minggang Zhao, and Dayong Wang

Chin. Phys. C 49, 043001 (2025)

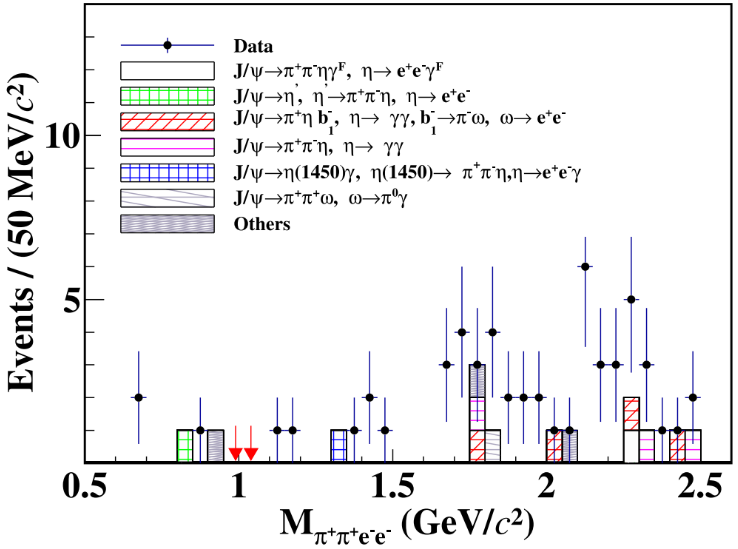
- Analysis of $\phi \to K^+K^-$

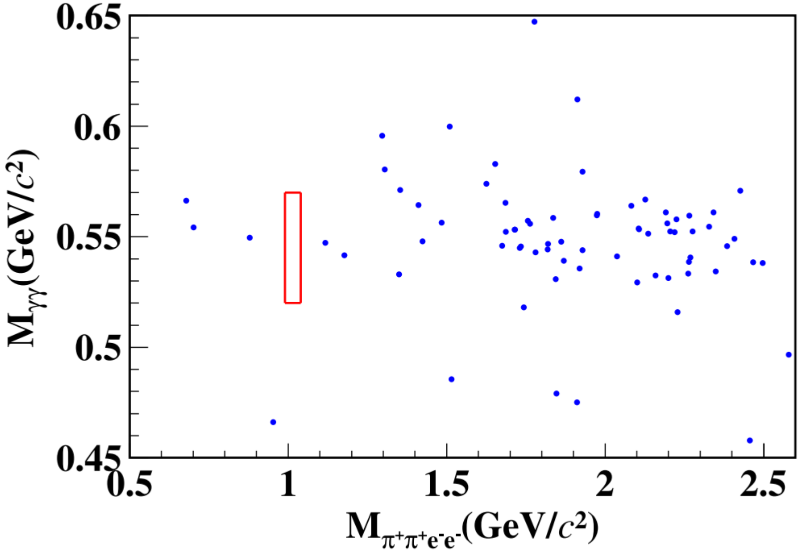


$$N^{net}_{K^+K^-} = N_{signal} - \frac{1}{2} \times N_{sideband} = 823764 \pm 1023.$$

$$\varepsilon_{KK} = \frac{N^{MC}_{obs}}{N^{MC}_{total}} = \frac{471297}{1000000} = (47.1 \pm 0.1)\%$$

- Analysis of $\phi \to \pi^+\pi^+e^-e^-$





No event is observed in the signal region

$$\mathcal{B}(\phi \to \pi^+\pi^+e^-e^-) < 1.3 \times 10^{-5}$$ (90% CL, TRolke)

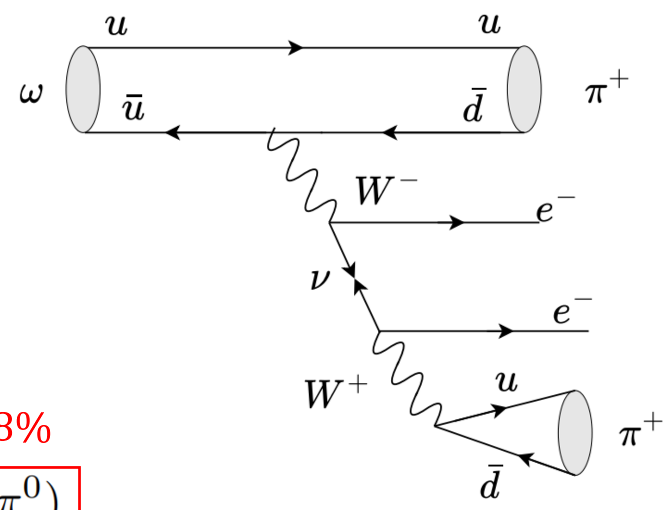
This is the first LNV signal constraint in ϕ meson composed of second generation quarks.

1.2 LNV: $\omega \to \pi^+\pi^+e^-e^- + c.c.$ via $J/\psi \to \omega\eta$

Zhi Gao, Minggang Zhao

Accepted by Chin. Phys. C

- The LNV decay of the ω meson composed of first generation quarks in the process $\omega \to \pi^+\pi^+e^-e^-$ has a unique phase space coverage compared to other measurements and low background contamination.



- Analysis method:

$$J/\psi \to \omega\eta,\ \eta \to \gamma\gamma,\ \omega \to \pi^+\pi^+e^-e^-$$

Uncertainty: 11.5%

$\mathcal{B}(J/\psi \to \omega\eta)$ ⇒

Uncertainty: 0.8%

$$\mathcal{B}(\omega \to \pi^+\pi^+e^-e^-) = \mathcal{B}(\omega \to \pi^+\pi^-\pi^0) \times \mathcal{B}(\pi^0 \to \gamma\gamma) \times \frac{N^{\rm sig}_{\pi^+\pi^+e^-e^-}/\epsilon_{\pi^+\pi^+e^-e^-}}{N^{\rm ref}_{\pi^+\pi^-\pi^0}/\epsilon_{\pi^+\pi^-\pi^0}}, \quad (1)$$

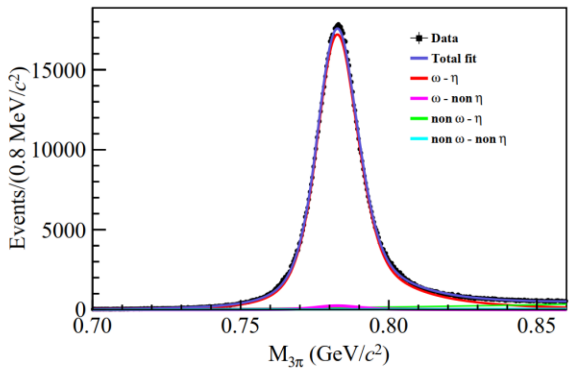
The total systematic uncertainty can be reduced significantly

1.2 LNV: $\omega \to \pi^+\pi^+e^-e^- + c.c.$ via $J/\psi \to \omega\eta$

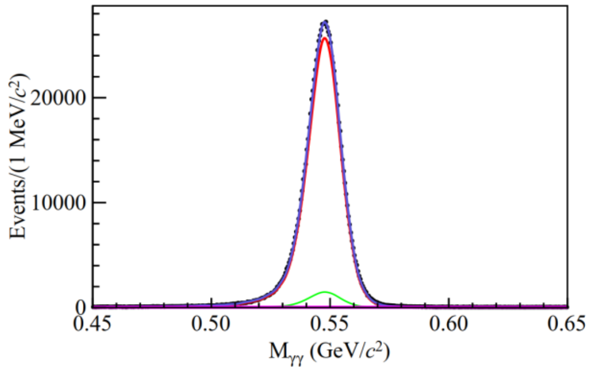
Zhi Gao, Minggang Zhao

Accepted by Chin. Phys. C

- Analysis of $\omega \to \pi^+\pi^-\pi^0$



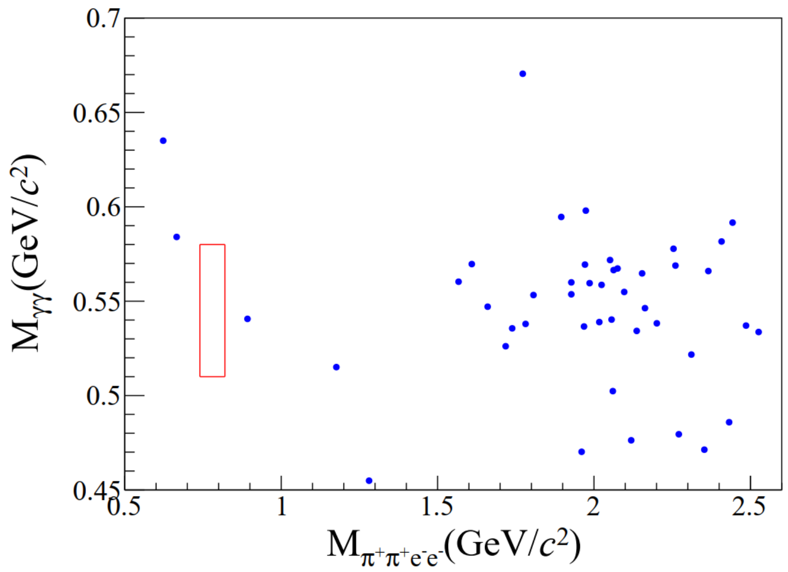
(a)



(b)

The projections of the 2D fit of the (a) $M_{3\pi}$ and (b) $M_{\gamma\gamma}$

- Analysis of $\omega \to \pi^+\pi^+e^-e^-$



No event is observed in the signal region

$\mathcal{B}(\omega \to \pi^+\pi^+e^-e^-) < 2.8 \times 10^{-6}$ (90% CL, Feldman-Cousins intervals)

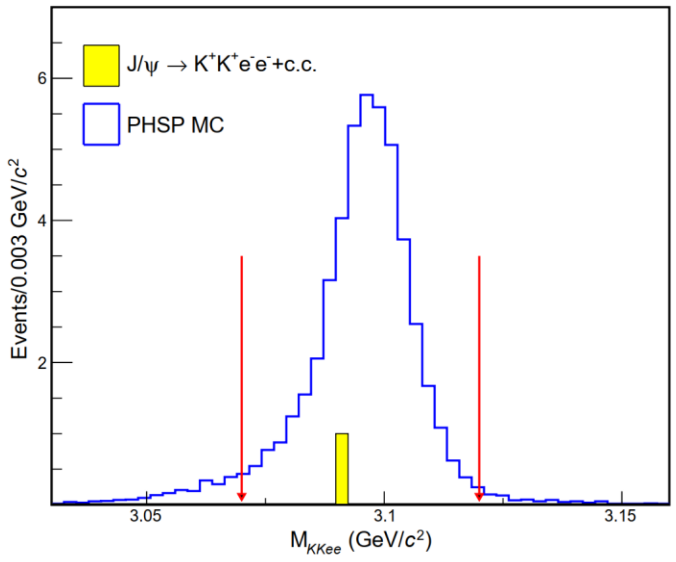
This is the first experimental constraint on the LNV decay of the ω meson composed of first generation quarks.

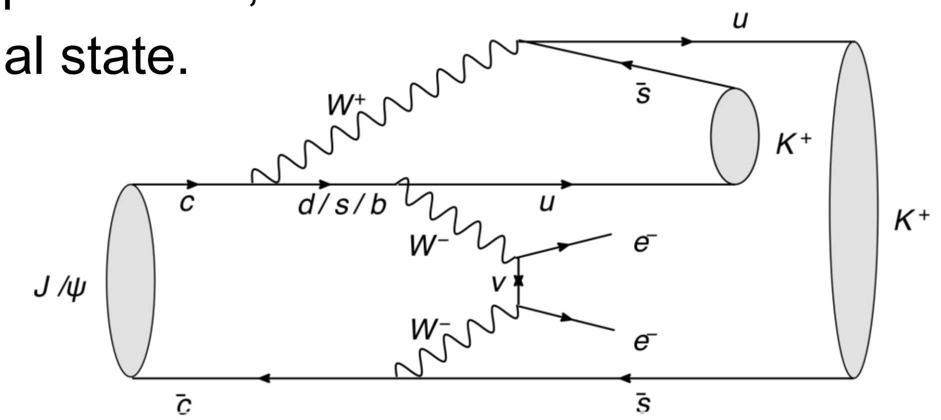
1.3 LNV: $J/\psi \to K^+K^+e^-e^- + c.c.$

Guorong Che, Weike Liu, Yitong Guo, Minggang Zhao, and Hailong Ma

Submitted to Chin. Phys. C

- In the τ-charm energy region, the huge data set of charmonia (such as J/ψ) can be analyzed to search for various LNV processes, such as $J/\psi \to K^+K^+e^-e^-$, involving *c*-quarks in the initial state.





$$N^{\mathrm{data}} = 1$$

$$N^{\mathrm{bkg}} = N^{\mathrm{inc}} + N^{\mathrm{continuum}} = 0$$

$$\mathcal{B}(J/\psi \to K^+K^+e^-e^-) < \mathcal{B}^{\mathrm{UL}}(J/\psi \to K^+K^+e^-e^-) = \frac{N^{\mathrm{up}}_{K^+K^+e^-e^-}}{N^{\mathrm{tot}}_{J/\psi}} = 2.1 \times 10^{-9},$$

(at 90% CL, TRolke method)

1.3 LNV: $J/\psi \to K^+K^+e^-e^- + c.c.$

Guorong Che, Weike Liu, Yitong Guo, Minggang Zhao, and Hailong Ma

Submitted to Chin. Phys. C

- Majorana mass dependent upper limits
  - Assuming the LNV signal from Majorana neutrino

$$J/\psi \to 2\nu_M \to (K^+e^-)(K^+e^-)$$

  - Majorana neutrino mass:

$$m_K + m_e \le m_{\nu_M} \le \frac{m_{J/\psi}}{2}$$

[0.575, 1.500] GeV with a step of 0.025 GeV

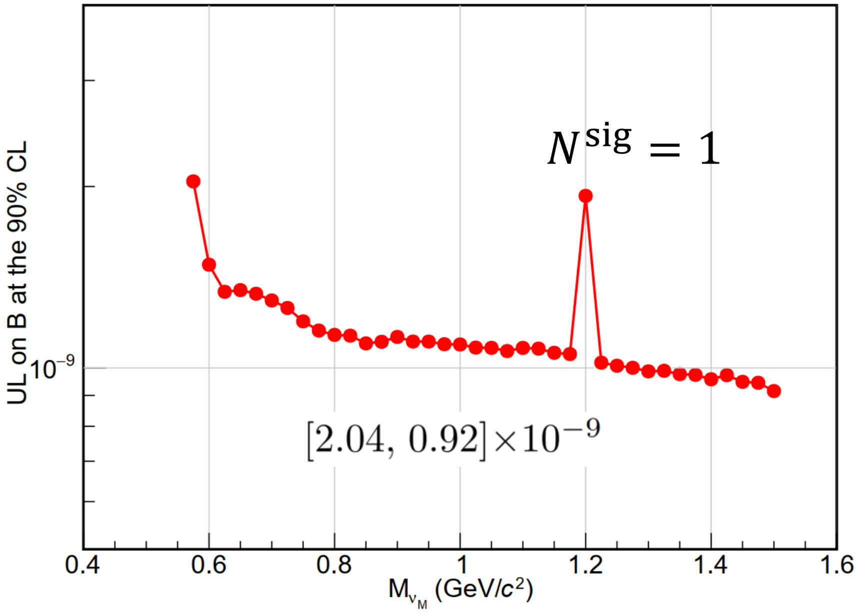


Fig. 3: The ULs at the 90% CL for the data sample as a function of m_{ν_M} for the decay $J/\psi \to 2\nu_M\ (\to K^+e^-)$.

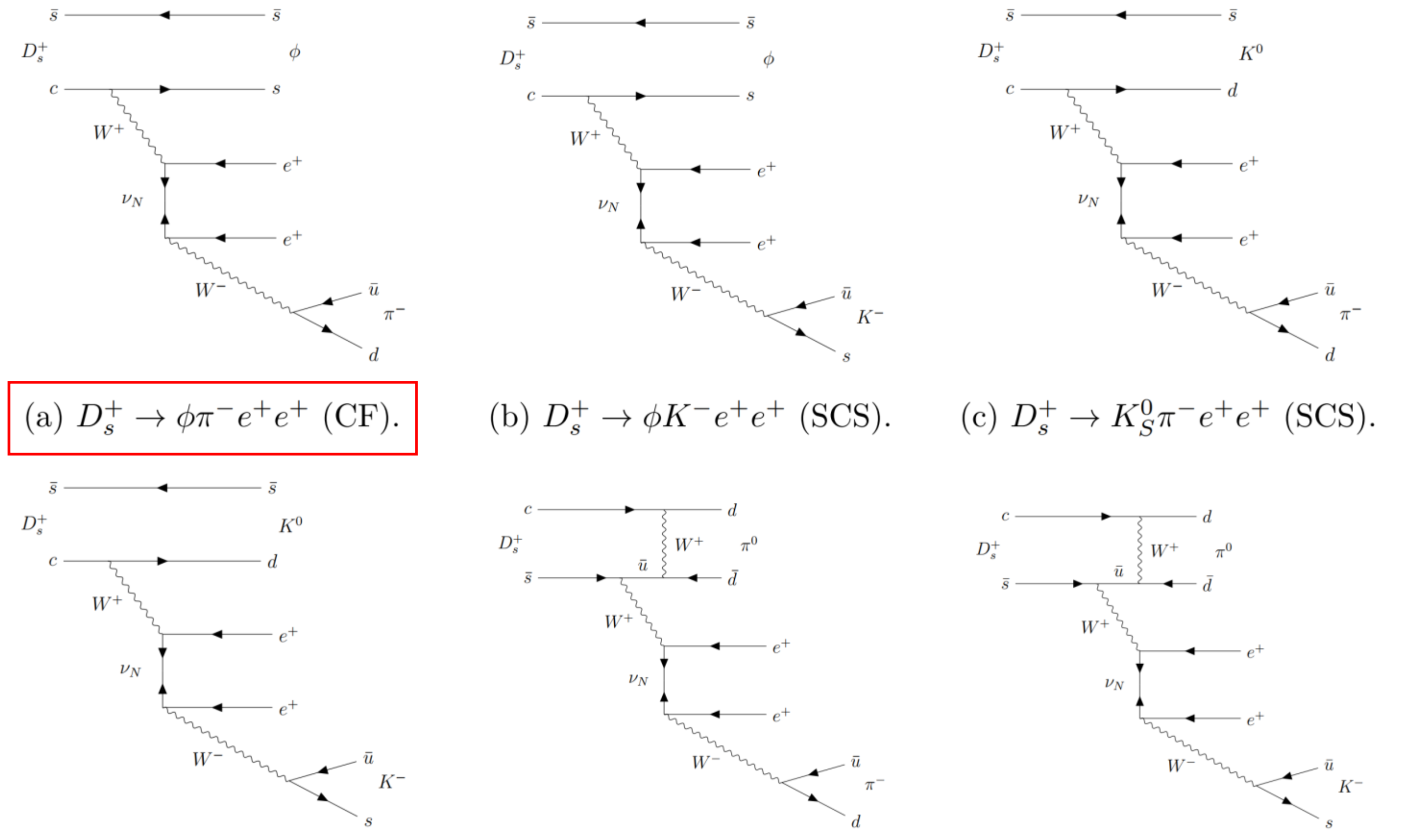
By utilizing these results, constraints on the mixed matrix element $|V_{e\nu_M}|^2$ between the Majorana neutrino and electron can be derived within the theoretical models.

1.4 LNV: $D_s^+ \to h^- h^0 e^+ e^+$ $(h^- = K^-, \pi^-; h^0 = \pi^0, K_S^0, \phi)$

Xueyin Liu, Houbing Jiang, Liang Sun, and Zhiyuan Huang

J. High Energ. Phys. 2025, 109 (2025)

- Among all possible $\Delta L = 2$ processes, interesting sources of LNV reactions are characterized by the exchange of a single Majorana neutrino whose mass is on the scale of heavy flavor mass.
- There is still no result for four-body $\Delta L = 2$ decays of D_s^+.
- Some models predict the BFs of four-body $\Delta L = 2$ charm meson decays to be up to $\mathcal{O}(10^{-6})$, potentially within reach of current experimental data.



(a) $D_s^+ \to \phi\pi^- e^+ e^+$ (CF). (b) $D_s^+ \to \phi K^- e^+ e^+$ (SCS). (c) $D_s^+ \to K_S^0 \pi^- e^+ e^+$ (SCS).

(d) $D_s^+ \to K_S^0 K^- e^+ e^+$ (DCS). (e) $D_s^+ \to \pi^- \pi^0 e^+ e^+$ (W-exc.). (f) $D_s^+ \to K^- \pi^0 e^+ e^+$ (W-exc.).

Figure 1. Feynman diagrams for four-body LNV decays of D_s^+, where SCS represents singly Cabibbo suppressed, DCS represents doubly Cabibbo suppressed, and W-exc. represents W-exchange.

1.4 LNV: $D_s^+ \to h^- h^0 e^+ e^+$ $(h^- = K^-, \pi^-; h^0 = \pi^0, K_S^0, \phi)$

Xueyin Liu, Houbing Jiang, Liang Sun, and Zhiyuan Huang

J. High Energ. Phys. 2025, 109 (2025)

- Methodology

$e^+e^- \to D_s^{*\pm} D_s^{\mp}$ $D_s^+ \to h^- h^0 e^+ e^+$ $(h^- = K^-, \pi^-; h^0 = \pi^0, K_S^0, \phi)$

$\sqrt{s} = 4.128 — 4.226\,\mathrm{GeV}$

- A single tag (ST) method is applied, where only one D_s^+ meson is fully reconstructed

$$M_{\rm rec} = \sqrt{\left(E_{\rm cm}/c^2 - \sqrt{|\vec{p}_{D_s^+}|^2/c^2 + m^2_{D_s^+}}\right)^2 - |p_{D_s^+}|^2/c^2},$$

$$\Delta M = M(D_s^+\gamma) - M(D_s^+),$$

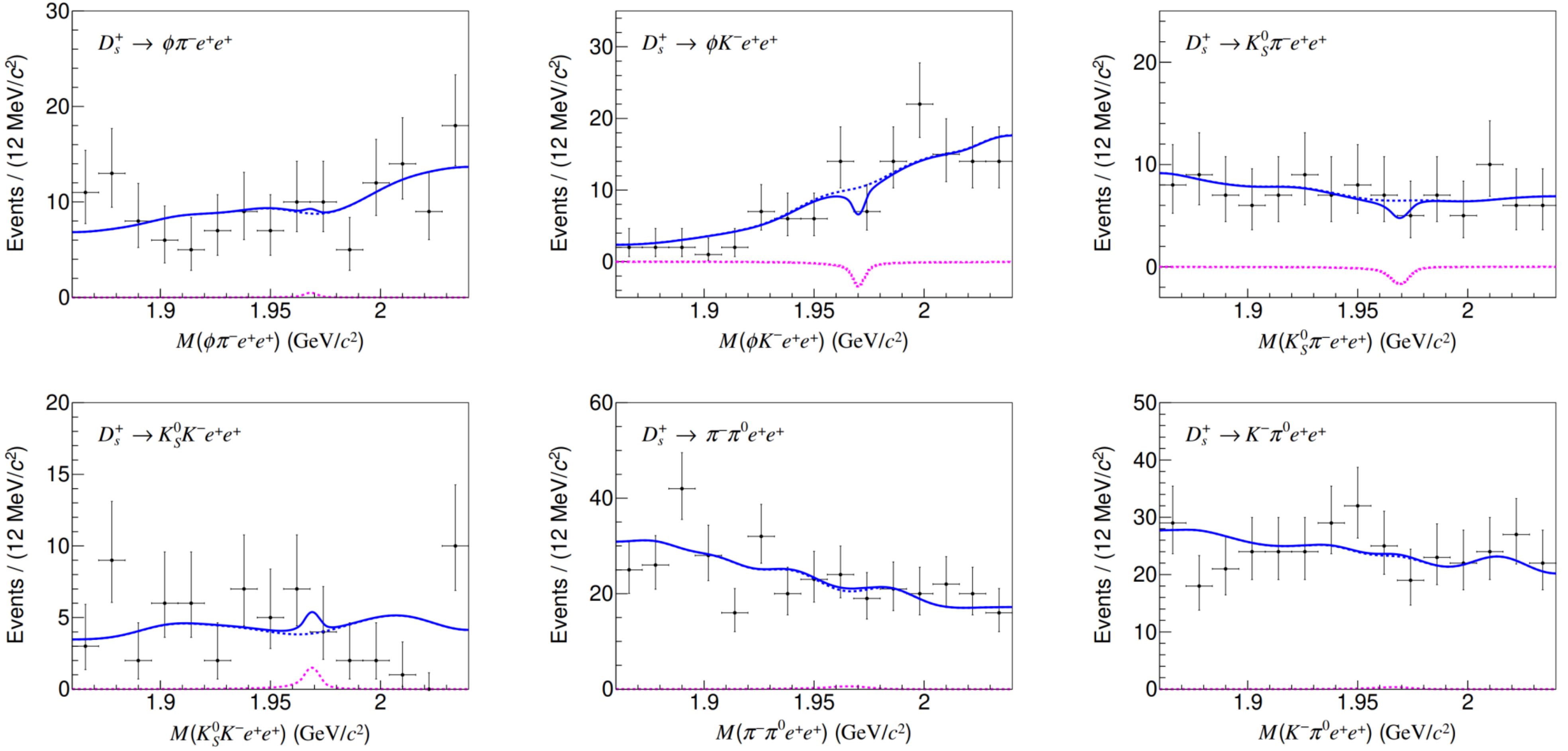
Signal candidates must be located within the defined signal regions on the two-dimensional plane of $M_{\rm rec}$ vs. ΔM.

$$\mathcal{B}(D_s^+ \to h^- h^0 e^+ e^+) = \frac{N_{\rm sig}}{2 \cdot N_{D_s^{*\pm} D_s^{\mp}} \cdot \epsilon \cdot \mathcal{B}_{\rm inter}}$$

1.4 LNV: $D_s^+ \to h^- h^0 e^+ e^+$ $(h^- = K^-, \pi^-; h^0 = \pi^0, K_S^0, \phi)$

Xueyin Liu, Houbing Jiang, Liang Sun, and Zhiyuan Huang

J. High Energ. Phys. 2025, 109 (2025)

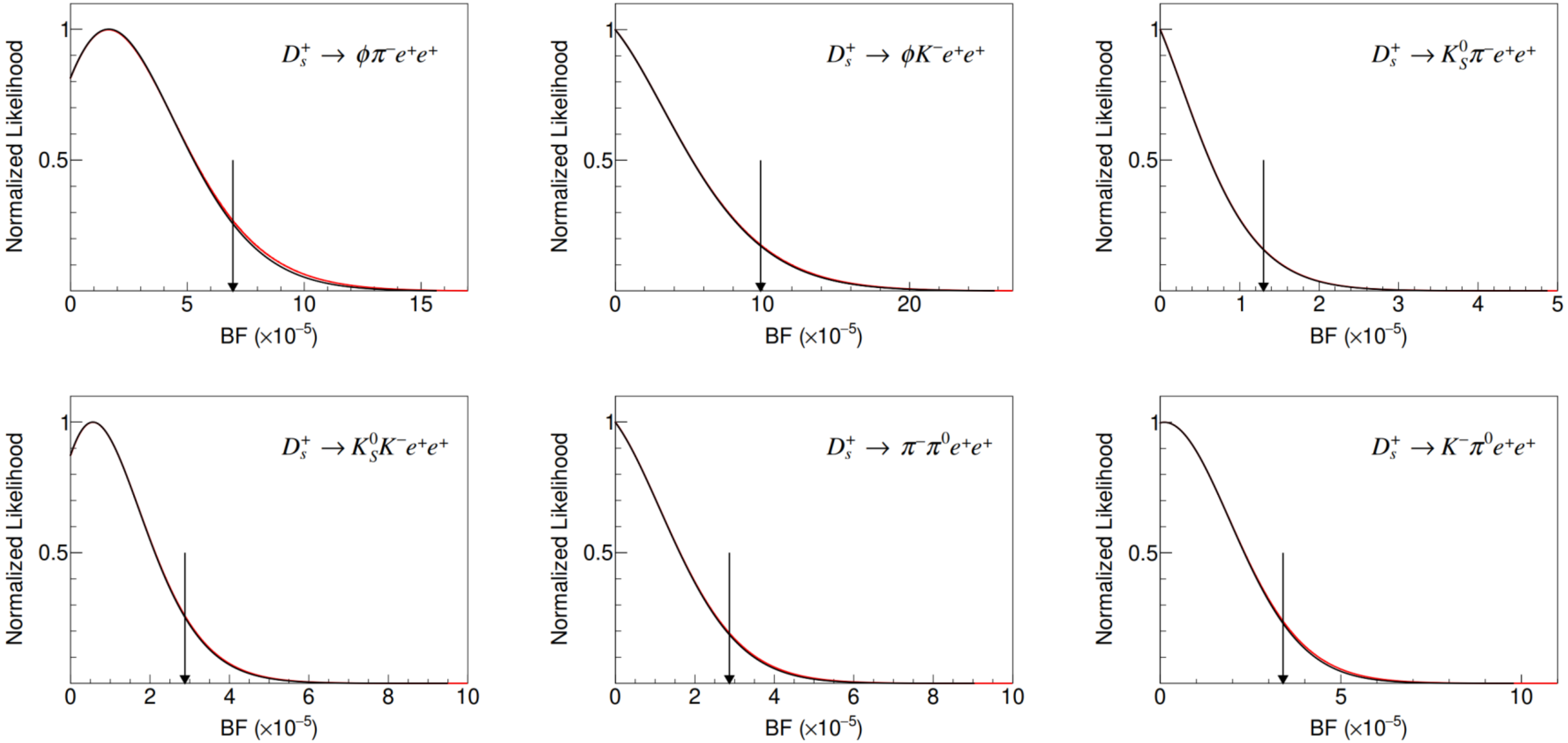


No obvious signal is observed.

1.4 LNV: $D_s^+ \to h^- h^0 e^+ e^+$ $(h^- = K^-, \pi^-; h^0 = \pi^0, K_S^0, \phi)$

Xueyin Liu, Houbing Jiang, Liang Sun, and Zhiyuan Huang

J. High Energ. Phys. 2025, 109 (2025)



$\mathcal{B}(D_s^+ \to h^- h^0 e^+ e^+) < (1.3 - 9.9) \times 10^{-5})$ (90% CL, Bayesian method)

1.4 LNV: $D_s^+ \to h^- h^0 e^+ e^+ \;\; (h^- = K^-, \pi^-; h^0 = \pi^0, K_S^0, \phi)$

Xueyin Liu, Houbing Jiang, Liang Sun, and Zhiyuan Huang

J. High Energ. Phys. 2025, 109 (2025)

- Search for Majorana neutrino in $D_s^+ \to \phi\pi^- e^+ e^+$ decay
  - Assuming the LNV signal from Majorana neutrino

$$D_s^+ \to \phi e^+ \nu_m (\to \pi^- e^+)$$

  - Majorana neutrino mass:

    [0.20, 0.80] GeV in intervals of 0.05 GeV
  - Further requirement on the invariant mass of any $\pi^- e^+$ combination
  - Upper limits are calculated using Trolke due to the limited events.

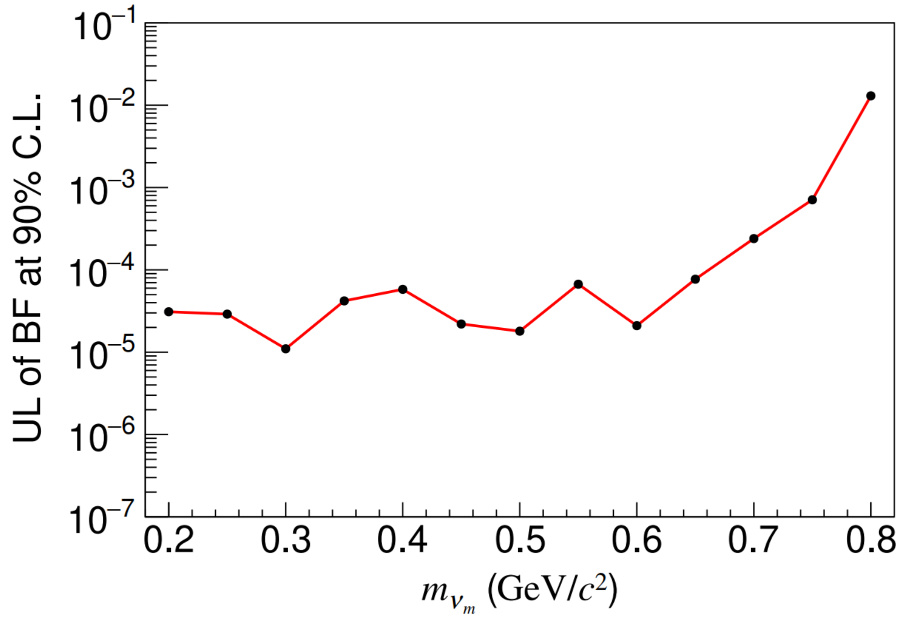


Figure 4. The ULs of the BFs at the 90% C.L. as a function of m_{ν_m} for the $D_s^+ \to \phi e^+ \nu_m (\to \pi^- e^+)$ decay.

1.5 Other LNV searches under review

- LNV: BAM-00770 (SP's review): $\boldsymbol{\eta \to \pi^+\pi^+e^-e^- + c.c.}$ via $J/\psi \to \phi\eta$

  Xinping Liu, Yaxuan Zhang, Minggang Zhao

- LNV: BAM-00651 (draft review): $\boldsymbol{K^0 \to \pi^-\pi^-e^+e^+ + c.c.}$ via $J/\psi \to \bar{K}^{*0}K^0$

  Su Xu and Minggang Zhao

- LNV: BAM-00926 (draft review): $\boldsymbol{\Xi^- \to \Sigma^+e^-e^-}$ via $J/\psi \to \Xi^-\bar{\Xi}^+$

  Xinyu Chai, Xiaoxuan Ding, Dayong Wang, Yajun Mao

2. Baryon-number-violating (BNV) searches

- Matter-antimatter asymmetry is a primary issue in the standard cosmology model.
- According to the Big Bang theory, matter and antimatter in the universe should be produced equally and exist in equal amounts. However, observations show that the number of baryons in the universe is $10^9 - 10^{10}$ times that of antibaryons.
- Sakharov proposed the three conditions to understand this puzzle, the first of which is that the baryon number conservation must be violated.
- In the SM, baryon number is strictly conserved. In many theoretical models, baryon number is not a natural exact symmetry. For example, in some grand unified theories, protons can decay to light quarks in a variety of ways. This mechanism simultaneously breaks the conservation of baryon number (B) and lepton number (L) while keeping their difference B−L constant.

2. Baryon-number-violating (BNV) searches

- The violation of baryon number implies the instability of the proton and the atomic nucleus, which would occur on a timescale comparable to the lifetime of the Universe.

- Experimental constraints on proton decay have largely ruled out the simplest GUT models.

- It is essential to explore other hadrons containing second-generation quarks, such as Λ and J/ψ, in both theory and experiment.

2.1 BNV: $\Lambda - \bar{\Lambda}$ oscillation in $J/\psi \to \Lambda\bar{\Lambda}$ decay

Shaojie Wang, Fengfei Sui, Jianbin Jiao, Tabassum Khan, Haibo Li,
Lianliang Ma, Haiping Peng, Vindhyawasini Prasad, and Tianyu Xing

Phys. Rev. D 111, 052014 (2025)

- If neutrinos are Majorana particles with small masses, this would imply the presence of $\Delta(B-L)=2$ interactions, thereby suggesting the existence of $n-\bar{n}$ oscillation.
- Many experiments have been carried out to search for $n-\bar{n}$ oscillation, but few results have been reported related to hyperons.
- To investigate $\Lambda - \bar{\Lambda}$ oscillation, we search for the presence of $J/\psi \to \Lambda\bar{\Lambda}$ starting with the coherent production of $\Lambda\bar{\Lambda}$ pairs.

- The oscillation rate:
  (generating a $\bar{\Lambda}$ with a beam of free Λ after time t)

$$P(\bar{\Lambda}, t) = \sin^2(\delta m_{\Lambda\bar{\Lambda}} \cdot t) e^{-t/\tau_\Lambda}$$

The time-integrated oscillation probability:

$$P(\bar{\Lambda}) = \frac{\int_0^\infty \sin^2(\delta m_{\Lambda\bar{\Lambda}} \cdot t) e^{-t/\tau_\Lambda} dt}{\int_0^\infty e^{-t/\tau_\Lambda} dt}$$

The transition mass between the Λ and $\bar{\Lambda}$:

$$\delta m_{\Lambda\bar{\Lambda}} = \sqrt{\frac{P(\bar{\Lambda})}{2\tau_\Lambda^2}}.$$

2.1 BNV: $\Lambda - \bar{\Lambda}$ oscillation in $J/\psi \to \Lambda\bar{\Lambda}$ decay

Shaojie Wang, Fengfei Sui, Jianbin Jiao, Tabassum Khan, Haibo Li, Lianliang Ma, Haiping Peng, Vindhyawasini Prasad, and Tianyu Xing

Phys. Rev. D 111, 052014 (2025)

- Analysis method:

  $J/\psi \to \Lambda\bar{\Lambda}$ $\qquad$ $J/\psi \to \Lambda\Lambda + \text{c.c.}$

  fully reconstruct the $\Lambda/\bar{\Lambda}$ with $p\pi^-/\bar{p}\pi^+$:

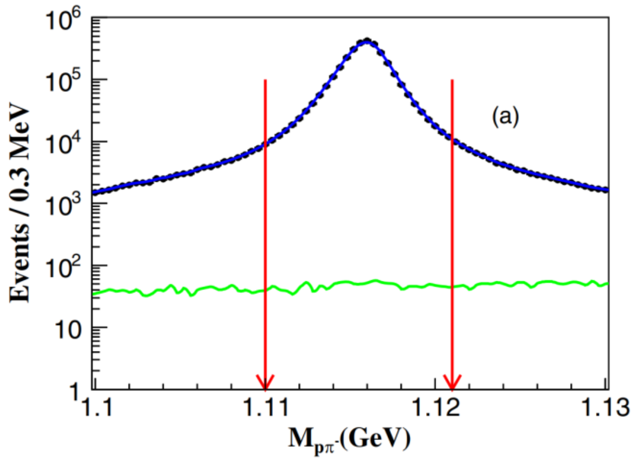
  - right sign (RS) events:

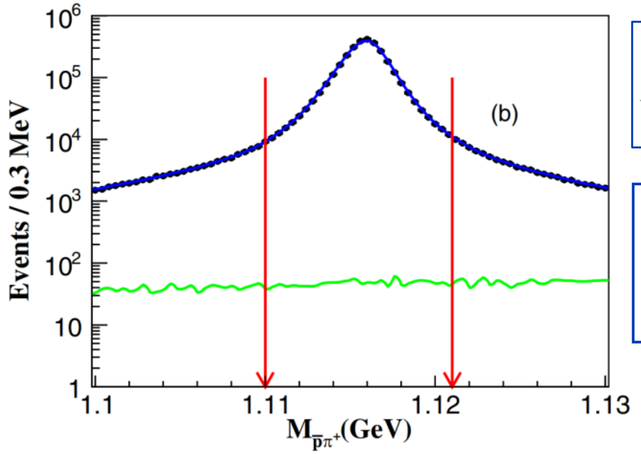
    $(p\pi^-)(\bar{p}\pi^+)$ from the decay $J/\psi \to \Lambda\bar{\Lambda}$

  - wrong sign (RS) events:

    $(p\pi^-)(p\pi^-)$ or $(\bar{p}\pi^+)(\bar{p}\pi^+)$

    from the decay $J/\psi \to \Lambda\Lambda + c.c.$





simultaneous fit

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

3123264±1767 events

$J/\psi \to \Lambda\Lambda + c.c.$

0 events (<13.0, 90% CL)

no signal is found

$$P(\Lambda) = \frac{\mathcal{B}(J/\psi \to \Lambda\Lambda + \text{c.c.})}{\mathcal{B}(J/\psi \to \Lambda\bar{\Lambda})} < \frac{N_{\text{WS}}^{\text{UL}}}{N_{\text{RS}}^{\text{obs}}/\epsilon_{\text{RS}}} = 1.4 \times 10^{-6},$$

$$\delta m_{\Lambda\bar{\Lambda}} = \sqrt{\frac{P(\Lambda)}{2\tau_{\Lambda}^2}} < 2.1 \times 10^{-18}\ \text{GeV}$$

more stringent constraints than previous result of BESIII

2.2 BNV: $J/\psi \to pe^- + c.c.$ via $\psi(2S) \to \pi^+\pi^- J/\psi$

Guorong Che, Yufei Kong, Minggang Zhao

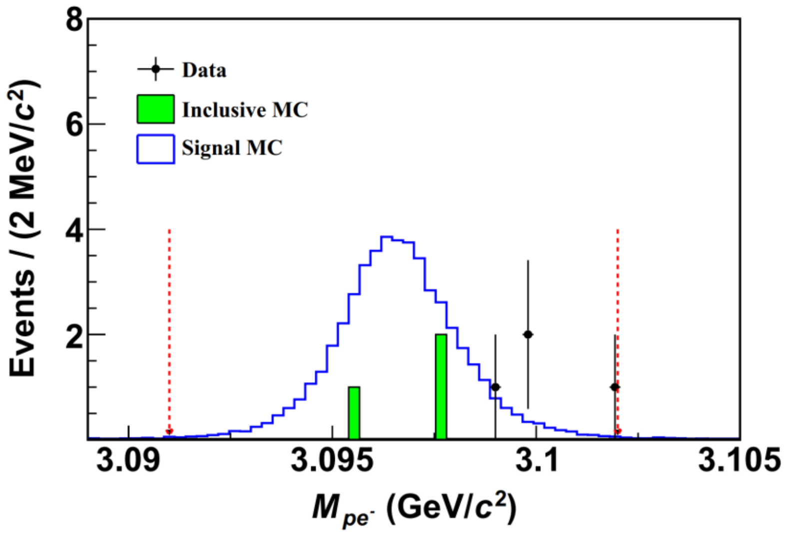
Phys. Rev. D 111, 112010 (2025)

- Experimental constraints on proton decay have largely ruled out the simplest GUT models. Therefore, it is essential to explore other hadrons containing second-generation quarks.
- Search for the BNV/LNV decay $J/\psi \to pe^- + c.c.$ for the first time.
- Analysis:

$$\psi(2S) \to \pi^+\pi^- J/\psi \qquad J/\psi \to pe^- + c.c.$$

$$\mathcal{B}(J/\psi \to pe^-) = \frac{N^{\rm sig}}{N^{\rm tot}_{\psi(2S)} \cdot \mathcal{B}(\psi(2S) \to \pi^+\pi^- J/\psi) \cdot \epsilon}$$

$N^{\rm inc} = 3 \quad \psi(3686) \to \pi^+\pi^- J/\psi, J/\psi \to e^+e^-\gamma^f\gamma^f$ or $e^+e^-\gamma^f$



$N_{\rm obs} = 4$

No obvious signal is observed

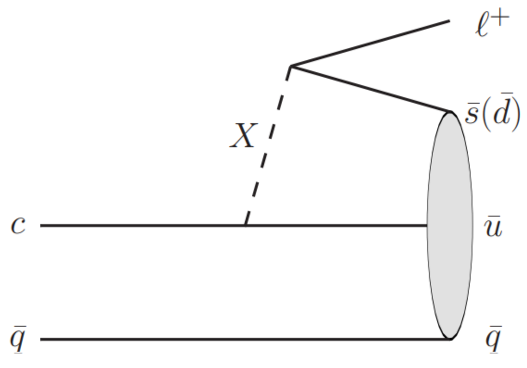
$$\mathcal{B}(J/\psi \to pe^-) < \frac{N^{\rm up}}{\mathcal{B}_\psi N^{\rm tot}_{\psi(3686)}} = 3.1 \times 10^{-8}$$ (90% CL, TRolke)

This result provides stronger experimental constraints compared to similar scenarios, such as $D^0 \to \bar{p}e^+$ and $J/\psi \to \Lambda_c^+ e^-$

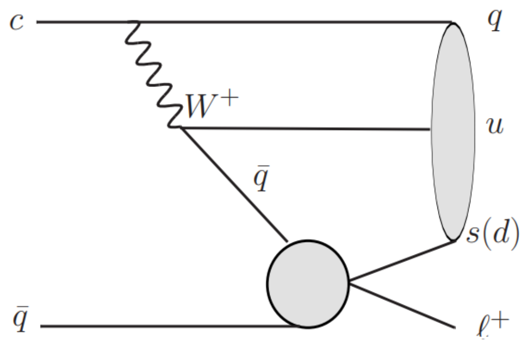
2.3 other BNV searches under review

- BNV: Memo review @NPG: $\boldsymbol{D^{\pm} \to B\ell^{\pm}}$ $(\boldsymbol{B = \Lambda, \bar{\Lambda}, \Sigma^0, \bar{\Sigma}^0; \ell = e, \mu})$
  via $\psi(3770) \to D^+D^-$
  Liangchen Liu, Yijia Zeng, Hailong Ma, and Minggang Zhao

Single-tag method:
reconstruct $\boldsymbol{D^{\pm}}(\to \boldsymbol{B\ell^{\pm}})$, extract the signal using $M_{\rm BC}^{\rm sig} = \sqrt{E_{\rm beam}^2 - |\vec{p}_{D^{\pm}}|^2}$



(a) $\Delta(B-L) = 0$



(c) $\Delta(B-L) = 2$,

- BNV: Memo review @NPG: $\boldsymbol{D_s^+ \to B\ell^+}$ $(\boldsymbol{B = \Lambda, \bar{\Lambda}, \Sigma^0, \bar{\Sigma}^0; \ell = e, \mu})$
  via $e^+e^- \to D_s^+ D_s^{*-}(\to \gamma D_s^-)$ at $\sqrt{s} = 4.128 - 4.226$ GeV
  Chao Chen, Hailong Ma

Double-tag method:
reconstruct $D_s^{*-}(\to \gamma D_s^- \to \gamma \text{hardon})$ and $D_s^+ \to B\ell^+$

Summary

- BESIII collaboration searched for LNV/BNV decays using the world's largest J/ψ and $\psi(2S)$ data, and other unique data samples produced in e^+e^- annihilation:
  - LNV searches (90% CL)
    - ✓ $\phi \to \pi^+\pi^+e^-e^- + c.c.$ $\mathcal{B}(\phi \to \pi^+\pi^+e^-e^-) < 1.3\times10^{-5}$
    - ✓ $\omega \to \pi^+\pi^+e^-e^- + c.c.$ $\mathcal{B}(\omega \to \pi^+\pi^+e^-e^-) < 2.8\times10^{-6}$
    - ✓ $J/\psi \to K^+K^+e^-e^- + c.c.$ $\mathcal{B}(J/\psi \to K^+K^+e^-e^-) < 2.1\times10^{-9}$
    - ✓ $D_s^+ \to h^-h^0e^+e^+$ $\mathcal{B}(D_s^+ \to h^-h^0e^+e^+) < (1.3-9.9)\times10^{-5}$

No obvious signals are observed.

  - BNV searches (90% CL)
    - ✓ $\Lambda - \bar{\Lambda}$ oscillation $P(\Lambda) < 1.4\times10^{-6}$ $\delta m_{\Lambda\bar{\Lambda}} < 2.1\times10^{-18}$ GeV
    - ✓ $J/\psi \to pe^- + c.c.$ $\mathcal{B}(J/\psi \to pe^-) < 3.1\times10^{-8}$
  - More results of different LNV/BNV decays will come soon.

Thanks for your attention!