Search for new physics with charmonium weak decays at BESIII

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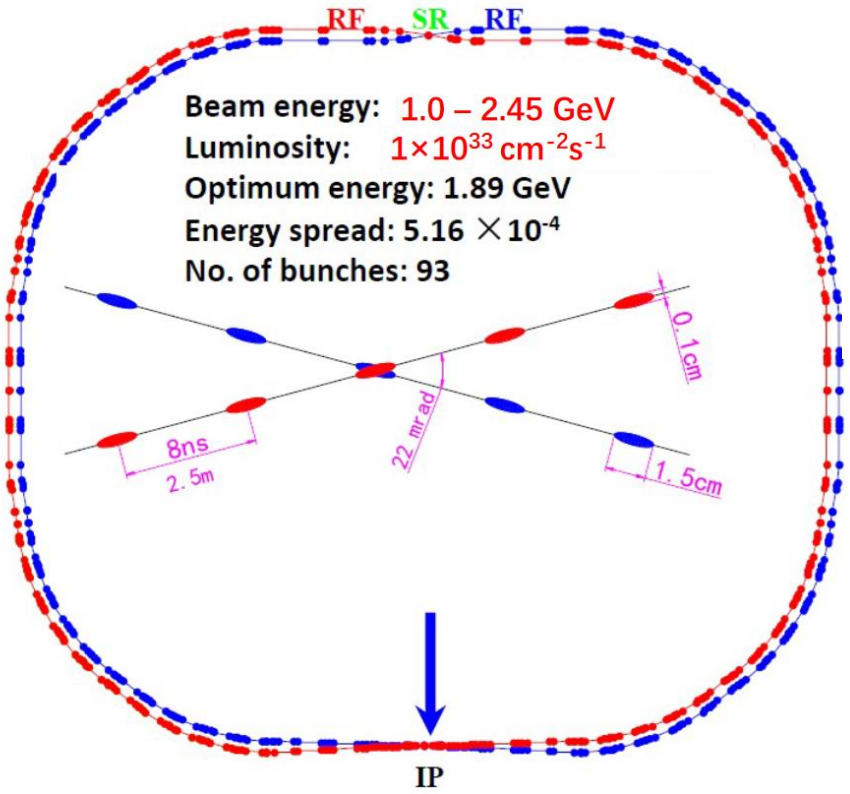
On behalf of BESIII Collaboration

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

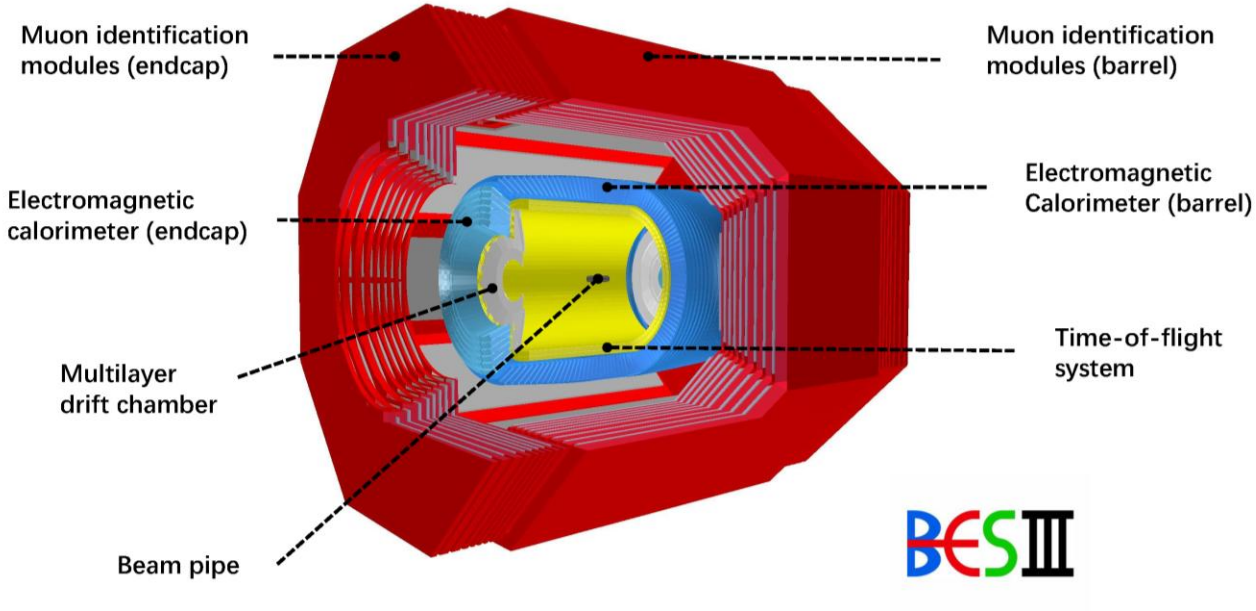
Outline

- BEPCII and BESIII
- Charmonium weak decays
- $J/\psi \to D^- e^+ \nu_e$
- $J/\psi \to D^- \mu^+ \nu_\mu$
- $J/\psi \to D^- + \pi^+/\rho^+$ and $J/\psi \to \bar{D}^0 + \pi^0/\rho^0/\eta$
- $J/\psi \to D_s^- + \pi^+/\rho^+$
- $\psi(3686) \to \Lambda_c^+ \bar{\Sigma}^-$
- Ongoing analyses
- Summary

Beijing Electron Positron Collider II

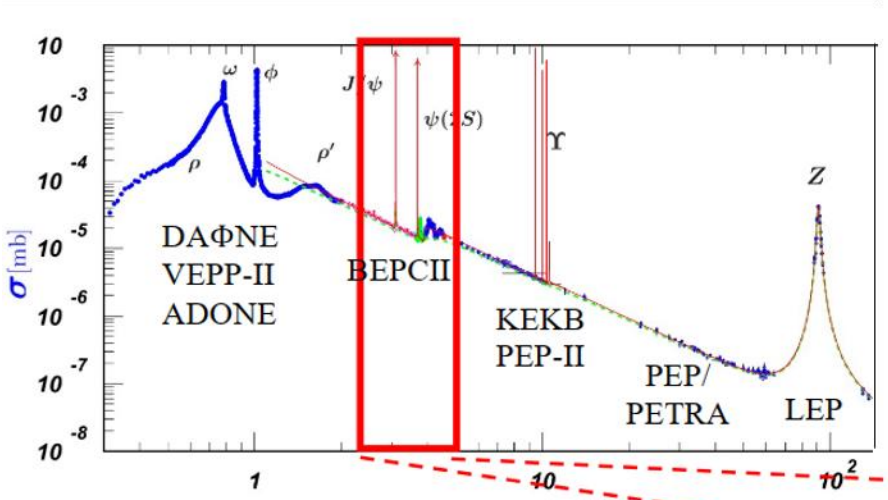


BESIII Detector

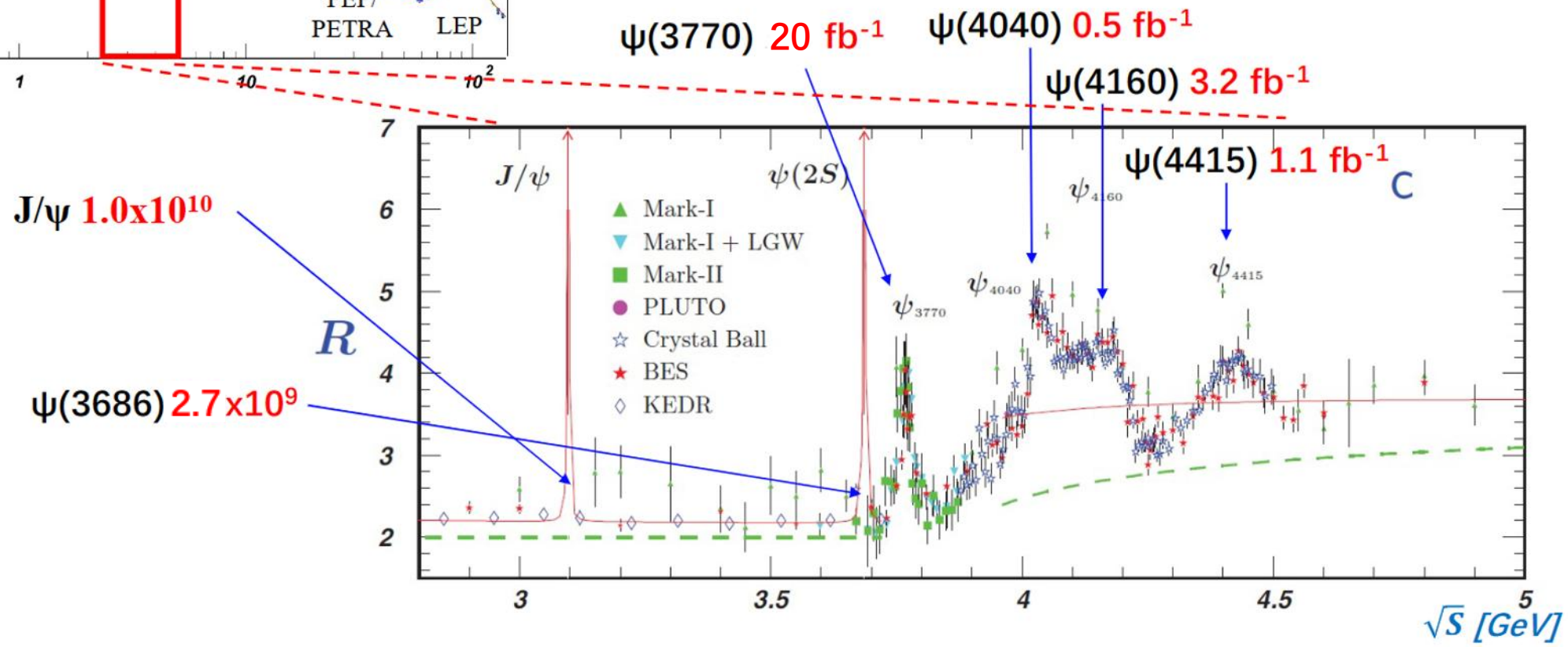


- Multilayer drift chamber (**MDC**)
  - The momentum resolution: 0.5% @ 1GeV/c
  - dE/dx resolution: 6%
- Time-of-flight (**TOF**) system
  - The time resolution: 68ps(barrel)/60ps(endcap)
- CsI(Tl) Electromagnetic calorimeter (**EMC**)
  - The energy resolution: 2.5%(barrel)/5.0%(endcap) @1GeV
- Supercon-ducting solenoidal magnet (1.0 T magnetic field)
- Muon chamber (**MUC**) system

BEPCII and BESIII



- BESIII has collected the largest data samples of J/ψ & $\psi(3686)$ on the threshold in the world.



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Charmonium weak decays

SM contribution is dominant

Good sensitivity to new physics (NP)

SM contribution is highly suppressed

Charmonium weak decays — This work

FCNC (flavor-changing neutral current)

High order — Liao Minghua

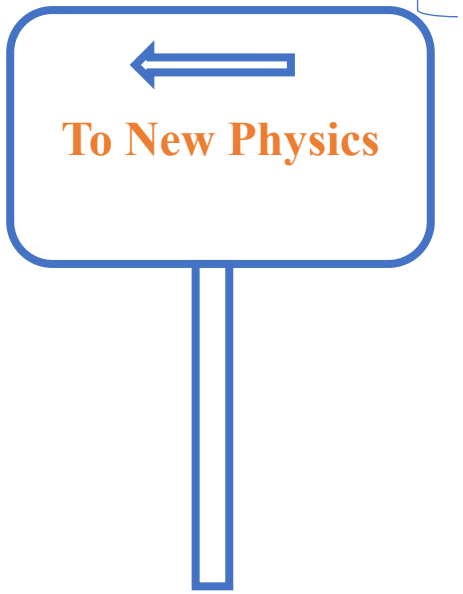
… — Zhang Guangyi

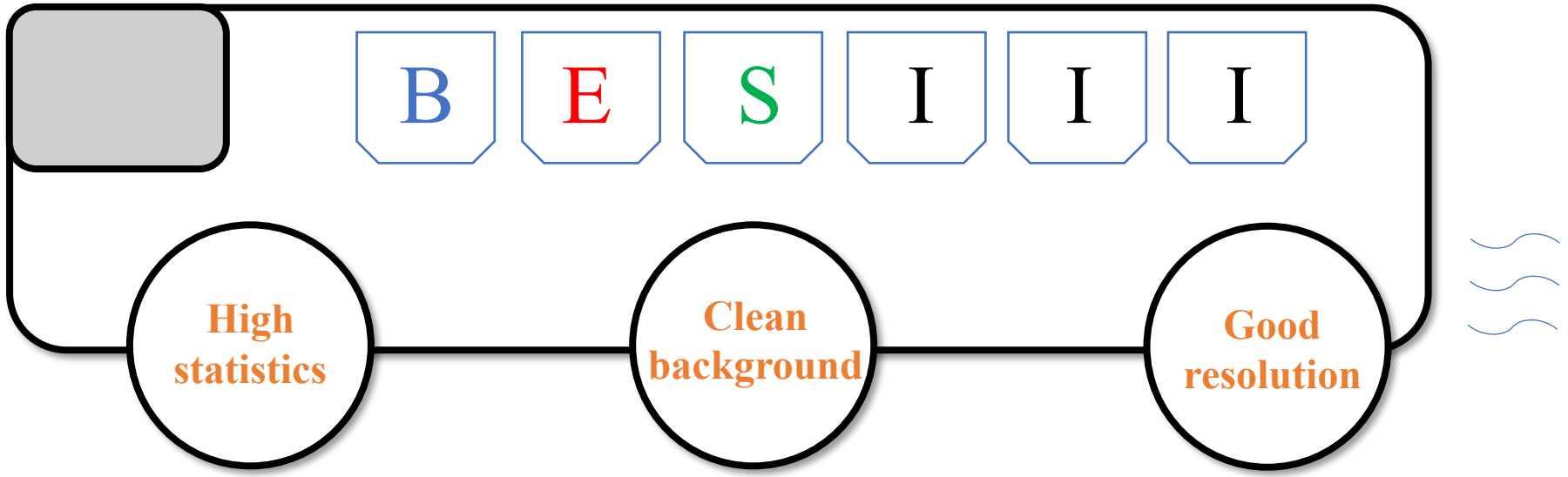
SM contribution is forbidden

BNV/LNV (baryon and lepton number violation)

CLFV (charged lepton flavor violating)

… — Song Tianzi





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Charmonium weak decays

- With a collection of 10^{10} J/ψ events, BESIII is now able to conduct searches for Charmonium weak decays with higher statistics.
- The inclusive branching fraction of these rare weak decays is predicted to be 10^{-8} in the standard model.
- If the branching fractions for weak decays of J/ψ are found to be within the range of 10^{-8} to 10^{-6}, it would suggest the presence of new physics beyond the Standard Model.

Top-color model [1]
The Minimal Super-symmetric SM with or without R-parity [2]
Two-Higgs doublet model [3]
...

Charmonium weak decay	Experimental upper limit (@90% C.L.)	Number of J/ψ or $\psi(3686)$ data events
$J/\psi \to D^- e^+ \nu_e$	$< 7.1 \times 10^{-8}$ [4]	BESIII (1.01×10^{10})
$J/\psi \to D^- \mu^+ \nu_\mu$	$< 5.6 \times 10^{-7}$ [5]	BESIII (1.01×10^{10})
$J/\psi \to D_s^- e^+ \nu_e$	$< 1.3 \times 10^{-6}$ [6]	BESIII (2.25×10^{8})
$J/\psi \to D_s^{*-} e^+ \nu_e$	$< 1.8 \times 10^{-6}$ [6]	BESIII (2.25×10^{8})
$J/\psi \to D^0 e^+ e^-$	$< 8.5 \times 10^{-8}$ [7]	BESIII (13.11×10^{8})
$\psi(3686) \to D^0 e^+ e^-$	$< 1.4 \times 10^{-7}$ [7]	BESIII (44.81×10^{7})

Charmonium weak	Experimental upper limit (@90% C.L.)	Number of J/ψ or $\psi(3686)$ data events
$J/\psi \to \bar{D}^0 \bar{K}^{*0}$	$< 2.5 \times 10^{-6}$ [8]	BESIII (2.25×10^{8})
$J/\psi \to \bar{D}^0 \bar{K}^0$	$< 1.7 \times 10^{-4}$ [9]	BESII (5.77×10^{7})
$J/\psi \to D_s^- \rho^+$	$< 8.0 \times 10^{-7}$ [10]	BESIII (1.01×10^{10})
$J/\psi \to D_s^- \pi^+$	$< 4.1 \times 10^{-7}$ [10]	
$J/\psi \to D^- \rho^+$	$< 6.0 \times 10^{-7}$ [11]	
$J/\psi \to D^- \pi^+$	$< 7.0 \times 10^{-8}$ [11]	
$J/\psi \to \bar{D}^0 \rho^0$	$< 5.2 \times 10^{-7}$ [11]	
$J/\psi \to \bar{D}^0 \eta$	$< 6.8 \times 10^{-7}$ [11]	
$J/\psi \to \bar{D}^0 \pi^0$	$< 4.7 \times 10^{-7}$ [11]	
$\psi(3686) \to \Lambda_c^+ \bar{\Sigma}^-$	$< 1.4 \times 10^{-5}$ [12]	BESIII (44.81×10^{7})

[1] Phys. Lett. B 345, 483 (1995)
[2] Phys. Lett. B 119, 136 (1982)
[3] Phys. Rev. D15, 1958 (1977)
[4] JHEP 06, 157 (2021)
[5] JHEP 01, 126 (2024)
[6] Phys. Rev. D 90, 112014 (2014)
[7] Phys. Rev. D 96, 111101(R) (2017)
[8] Phys. Lett. B 663, 297 (2008)
[9] Phys. Rev. D 89, 071101 (2014)
[10] arXiv:2506.09386
[11] Phys. Rev. D 110, 032020 (2024)
[12] Chin. Phys. C 47, no.1, 013002 (2023)

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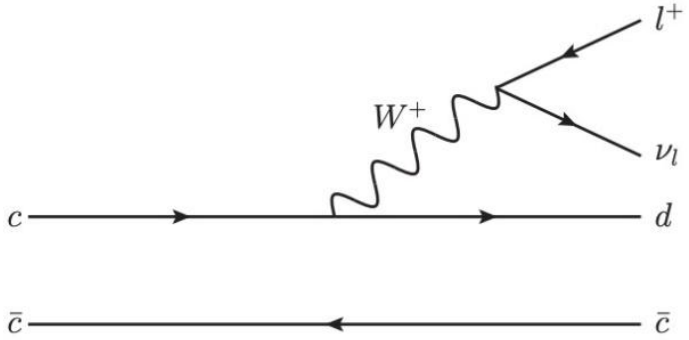
Search for decay $J/\psi \to D^- e^+ \nu_e$

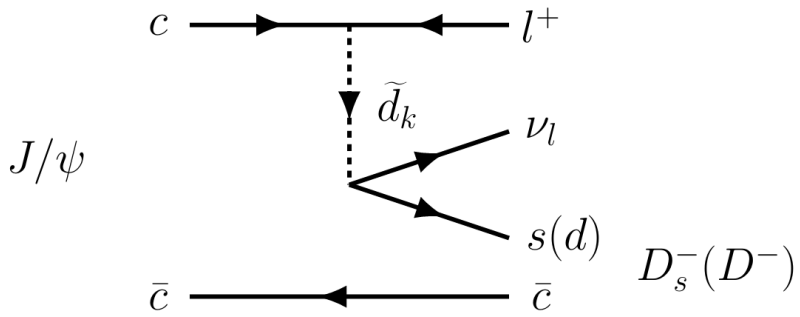
$J/\psi \to D^- e^+ \nu_e$
JHEP 06,157(2021)

$J/\psi \to D^- \mu^+ \nu_\mu$
JHEP 01,126(2024)

- Using $(1.0087 \pm 0.0044) \times 10^{10} J/\psi$ events.
- $J/\psi \to D^- l^+ \nu, D^- \to K^+ \pi^- \pi^-$



Fig(a): The Feynman diagram of $J/\psi \to D^- l^+ \nu$ in SM.



Fig(b): The Feynman diagram of $J/\psi \to D^- l^+ \nu$ in NP model.

Model	BSW [1]	CCQM[2]	BSM[3]	CLFQM[4]	LQCD[5]
$\mathcal{B}(J/\psi \to D^- e^+ \nu_e)(\times 10^{-10})$	$6.0^{+0.8}_{-0.7}$	1.71	$2.03^{+0.29}_{-0.25}$	$6.10^{+0.11+0.10+0.14}_{-0.11-0.12-0.19}$	0.121
$\mathcal{B}(J/\psi \to D^- \mu^+ \nu_\mu)(\times 10^{-10})$	$5.8^{+0.8}_{-0.6}$	1.66	$1.98^{+0.28}_{-0.24}$	$5.78^{+0.11+0.11+0.16}_{-0.10-0.13-0.11}$	0.118

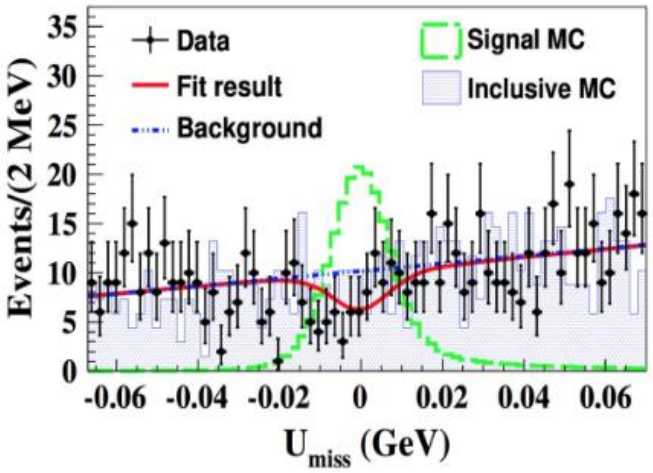
[1] Adv. High Energy Phys. 2013 (2013) 706543
[2] Phys. Rev. D 92 (2015) 074030
[3] J. Phys. G 44 (2017) 045004
[4] Eur. Phys. J. C 84, no.1, 65 (2024)
[5] arXiv:2407.13568

Table: Theoretical results for the BF of the semi-leptonic decay $J/\psi \to D^- l^+ \nu$ within the SM, where BSW is the Bauer-Stech-Wirbel model, CCQM is the confined covariant quark model, BSM is the Bathe-Salpeter-Mandelstam model, CLFQM is the covariant light-front quark model, and LQCD is the lattice QCD calculation.

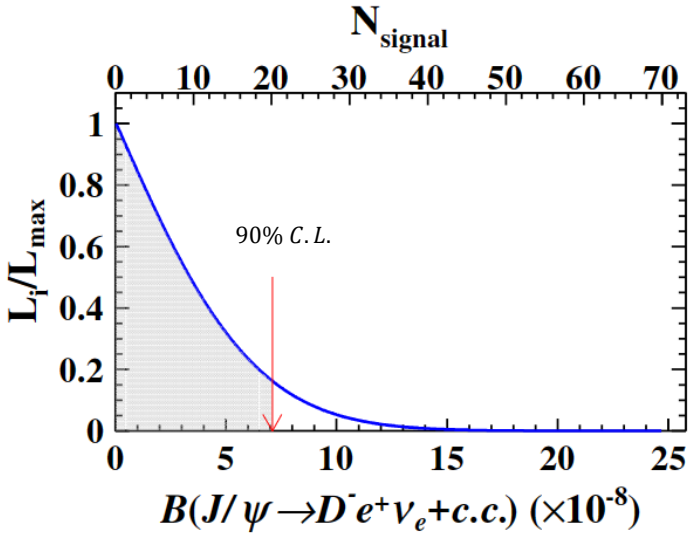
Search for decay $J/\psi \to D^- e^+ \nu_e$

$J/\psi \to D^- e^+ \nu_e$
JHEP 06,157(2021)

- Using $(1.0087 \pm 0.0044) \times 10^{10} J/\psi$ events.
- $J/\psi \to D^- e^+ \nu_e, D^- \to K^+ \pi^- \pi^-$
- Using a fit on $U_{miss} = E_{miss} - c|P_{miss}|$ to extract the signal.



Fig(a) Fitting in full data



Fig(b) Upper limit in full data

$$\mathcal{B}(J/\psi \to D^- e^+ \nu_e + c.c.) = \frac{N_{signal}}{N_{J/\psi} \times \epsilon \times \mathcal{B}_{sub}}$$

- where N_{signal} is the number of signal decays, $N_{J/\psi} = (10087 \pm 44) \times 10^6$ is the number of J/ψ events, ϵ is the signal detection efficiency, and $\mathcal{B}_{sub}$ is the BF of the intermediate decay $D^- \to K^+ \pi^- \pi^-$ quoted from PDG.
- $\mathcal{B}(J/\psi \to D^- e^+ \nu_e) < 7.1 \times 10^{-8}$ @90% C.L.
- Puts a stringent constraint on the parameter spaces for different new physics models predicting BFs at the order of 10^{-5} .

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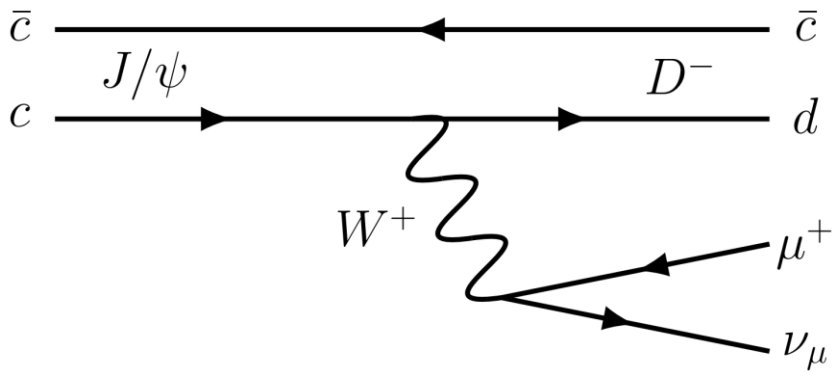
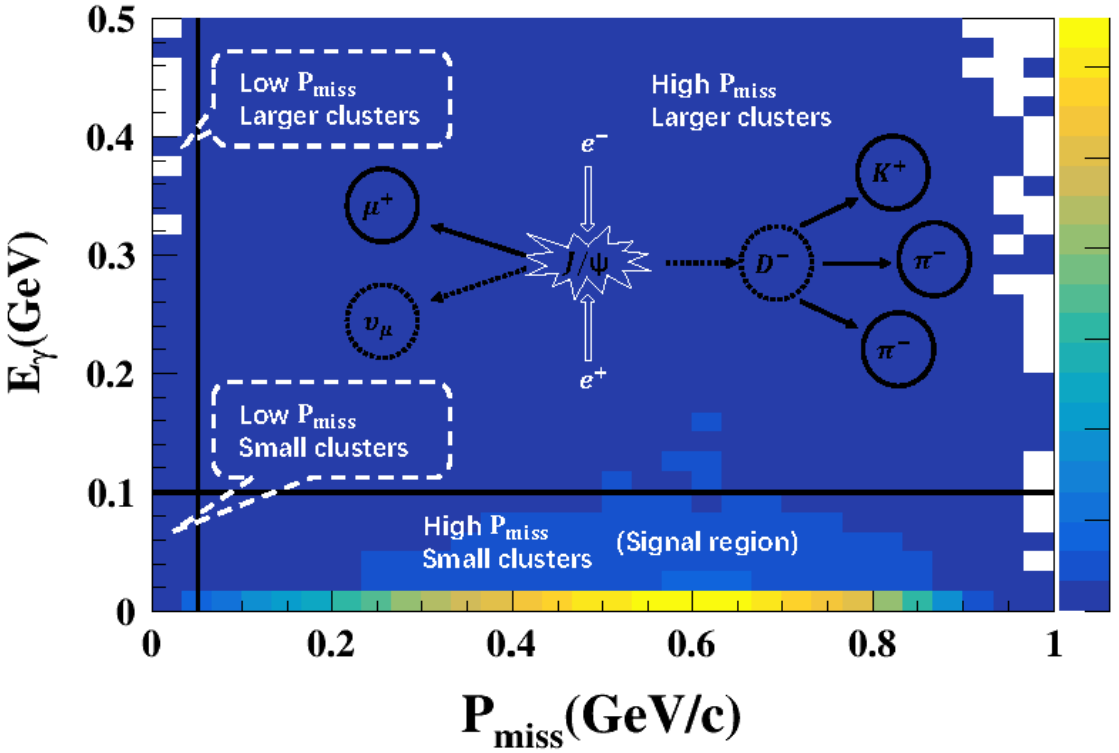


Fig(a) The Feynman diagram of $J/\psi \to D^- \mu^+ \nu_\mu$

- Thus far, the search for weak semi-leptonic charmonium decays has only covered the electron channel.
- A search for the weak decay of charmonium with a muon in the final state is therefore desirable.
- Using $(1.0087 \pm 0.0044) \times 10^{10} J/\psi$ events.
- $J/\psi \to D^- \mu^+ \nu_\mu, D^- \to K^+ \pi^- \pi^-$.
- Since the missing neutrino ν_μ and no extra hard photon in the final state, a large missing momentum P_{miss} and a clean cluster unassociated with the charged track are required.



Fig(b) Event selections associated with missing momentum and clusters

Search for decay $J/\psi \to D^- \mu^+ \nu_\mu$

$J/\psi \to D^- \mu^+ \nu_\mu$
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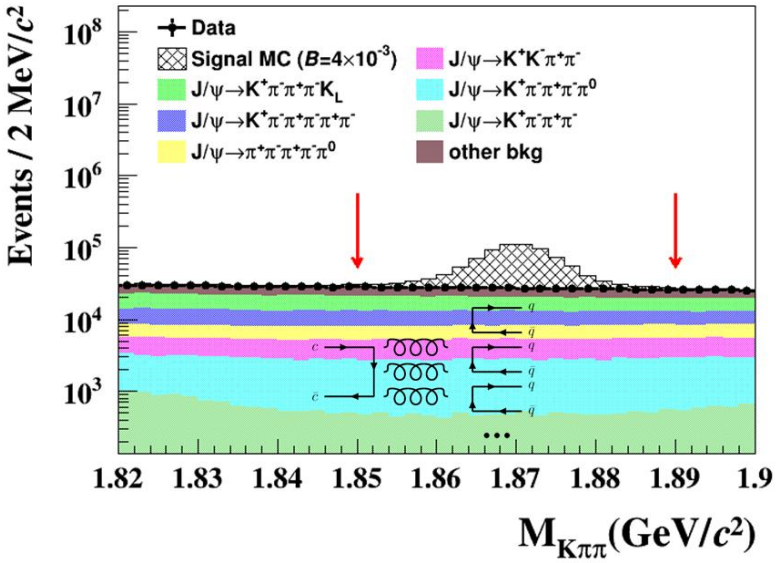
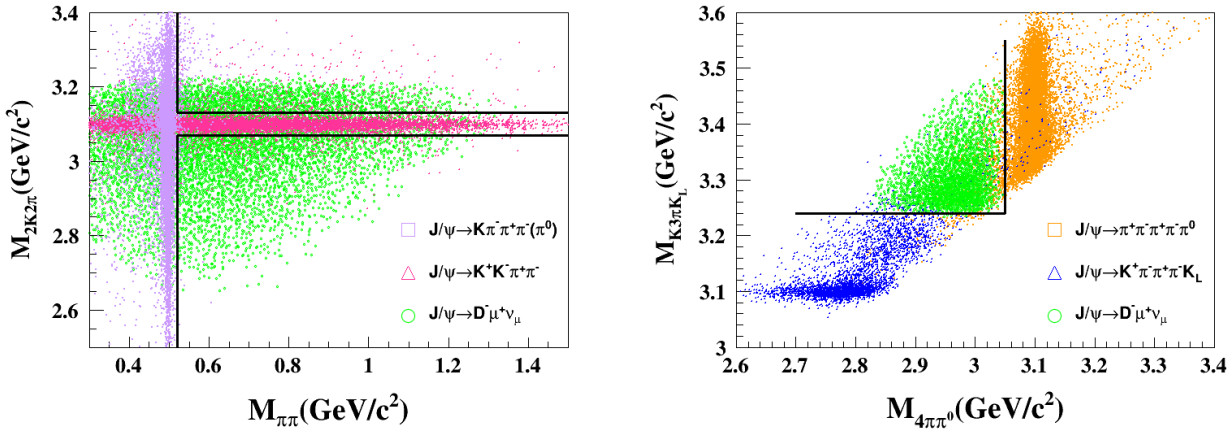
- Compare to electrons, muons are more difficult to be identified due to the muon-pion misidentification.
- Most muons do not provide effective information in the muon identifier because of the low momentum of muons in the three-body decay, leading to a significant background from muon-pion misidentification.



Fig(b) The reconstruction of the D meson, which still includes a huge background in the D mass range.



Fig(a) Kinematic-based PID is used to suppress the background further, where the green dots are the signal events from the simulation.

- The differences in particle mass can manifest as distinct kinematic characteristics in the entire event, leading to the developing of a kinematic-based PID method to further identify particles and effectively suppress misidentified hadronic background.

Search for decay $J/\psi \to D^- \mu^+ \nu_\mu$

$J/\psi \to D^- \mu^+ \nu_\mu$
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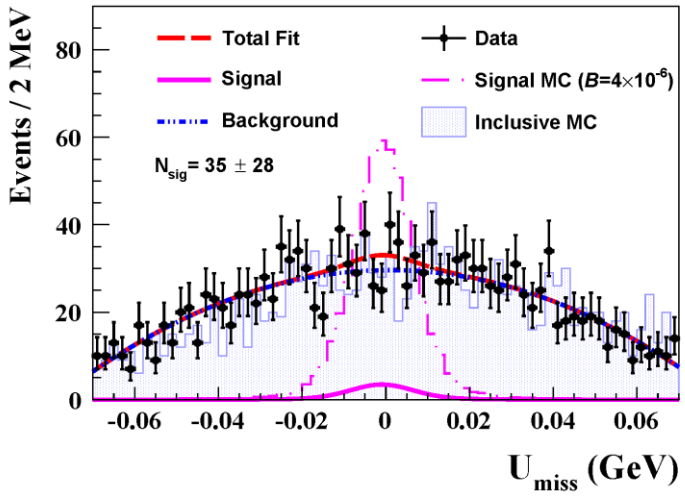

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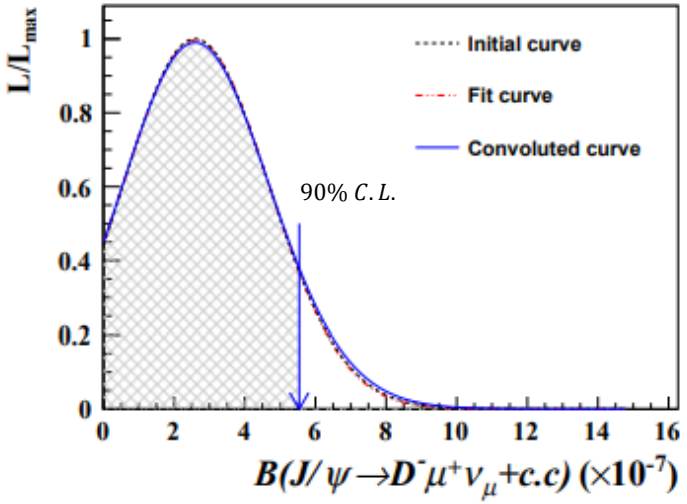
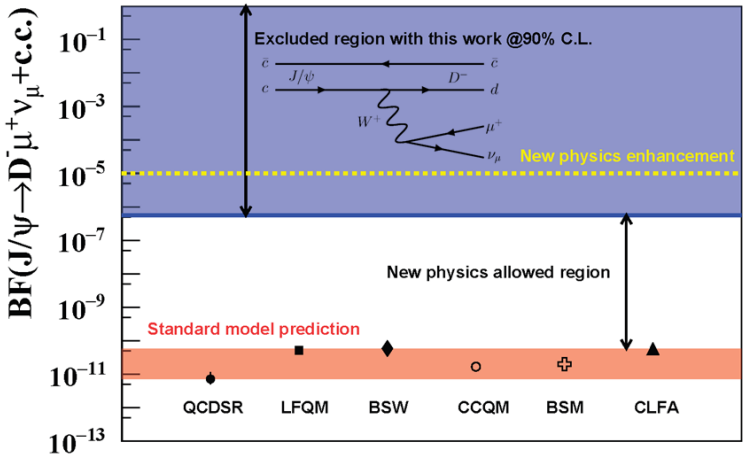


Fig(b) Upper limit in full data

- Using a fit on $U_{miss} = E_{miss} - c|P_{miss}|$ to extract the signal.
- No evidence of NP is found.
- $\mathcal{B}(J/\psi \to D^- \mu^+ \nu_\mu) < 5.6 \times 10^{-7}$ @90% C.L.
- The first search of a charmonium weak decay with a muon in the final state.



Fig(c) The excluded region of $J/\psi \to D^- \mu^+ \nu_\mu + c.c.$ from this measurement.

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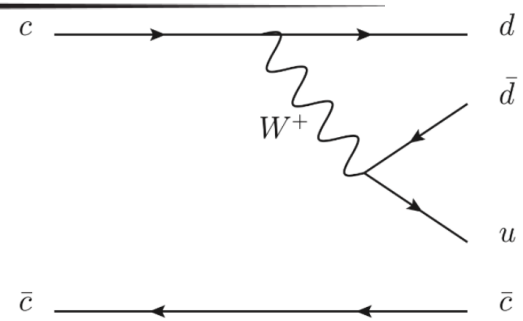
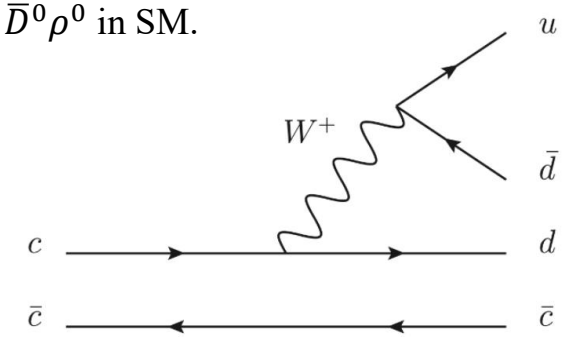
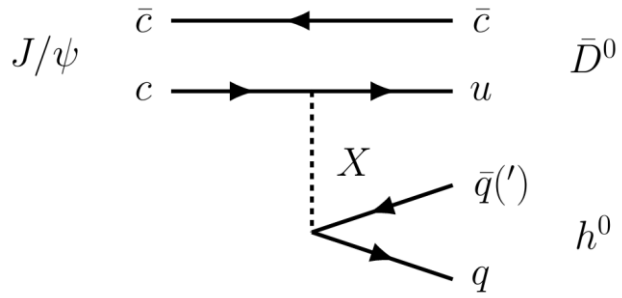


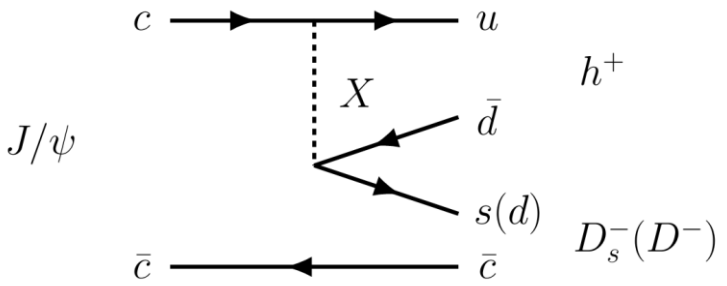
Fig(a) The Feynman diagram of $J/\psi \to \bar{D}^0\pi^0$, $J/\psi \to \bar{D}^0\eta$ and $J/\psi \to \bar{D}^0\rho^0$ in SM.



Fig(b) The Feynman diagram of $J/\psi \to D^-\pi^+$ and $J/\psi \to D^-\rho^+$ in SM.



Fig(c) The Feynman diagram of $J/\psi \to \bar{D}^0\pi^0$, $J/\psi \to \bar{D}^0\eta$ and $J/\psi \to \bar{D}^0\rho^0$ in NP model.



Fig(d) The Feynman diagram of $J/\psi \to D^-\pi^+$ and $J/\psi \to D^-\rho^+$ in NP Model.

$J/\psi \to D^- + \pi^+/\rho^+$
and $J/\psi \to \bar{D}^0 + \pi^0/\rho^0/\eta$
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- Via the weak interaction, the J/ψ can potentially decay into a single charm meson such as D accompanied by some non-charm mesons.
- To avoid high background from conventional J/ψ hadronic decays, the $\bar{D}^0$ and D^- mesons are tagged by the semileptonic decays.

$J/\psi \to \bar{D}^0\pi^0$
$\bar{D}^0 \to K^+e^-\bar{\nu}_e$
$\pi^0 \to \gamma\gamma$

$J/\psi \to \bar{D}^0\eta$
$\bar{D}^0 \to K^+e^-\bar{\nu}_e$
$\eta \to \gamma\gamma$

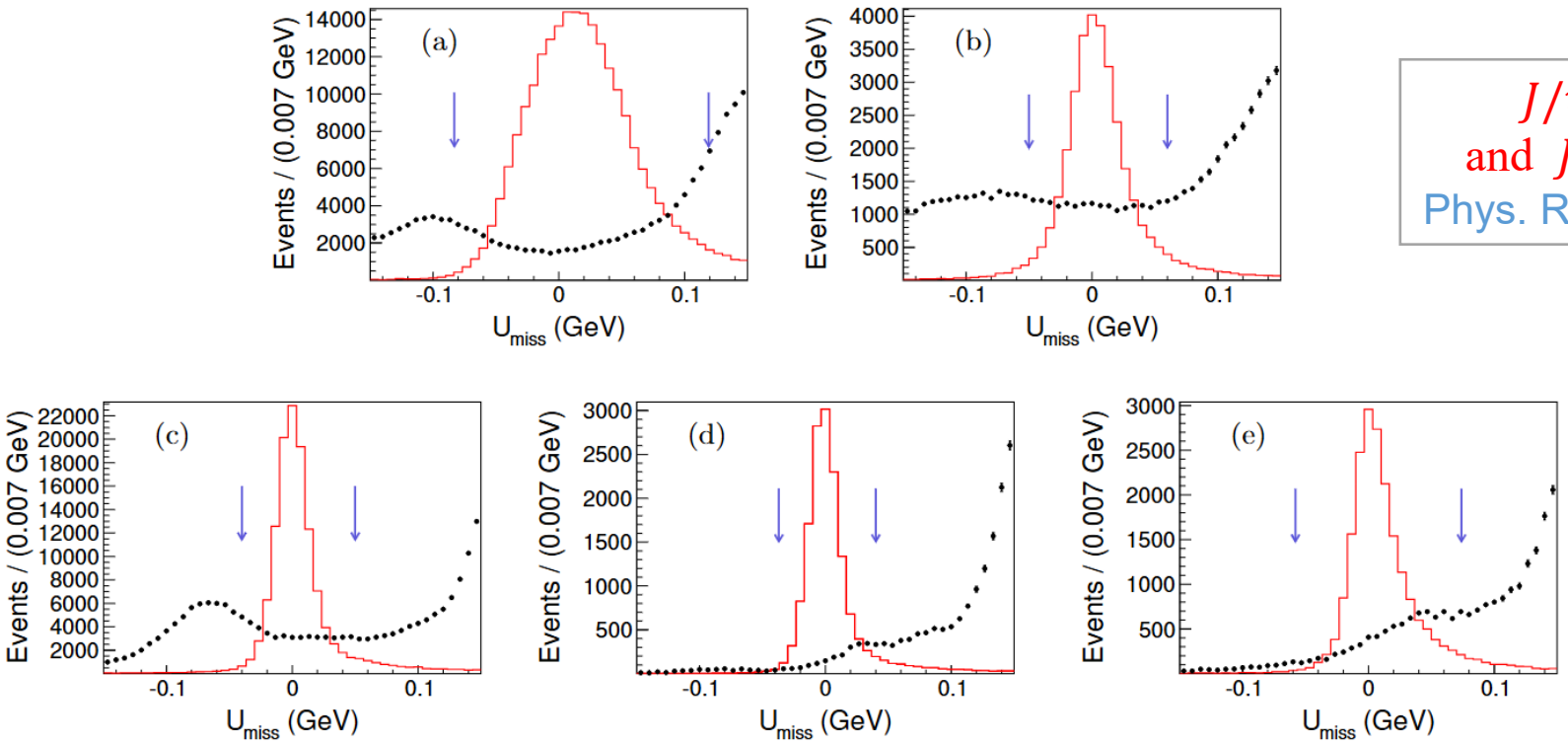
$J/\psi \to \bar{D}^0\rho^0$
$\bar{D}^0 \to K^+e^-\bar{\nu}_e$
$\rho^0 \to \pi^+\pi^-$

$J/\psi \to D^-\pi^+$
$D^- \to K_S^0e^-\bar{\nu}_e$
$K_S^0 \to \pi^+\pi^-$

$J/\psi \to D^-\rho^+$
$D^- \to K_S^0e^-\bar{\nu}_e$
$K_S^0 \to \pi^+\pi^-$
$\rho^+ \to \pi^+\pi^0$
$\pi^0 \to \gamma\gamma$

Search for decay $J/\psi \to D^- + \pi^+/\rho^+$ and $J/\psi \to \bar{D}^0 + \pi^0/\rho^0/\eta$

- The kinematic quantity $U_{miss} = E_{miss} - c|\vec{p}_{miss}|$ is used to identify the missing neutrino and the criterion of U_{miss} is applied to suppress the backgrounds with multi-π^0/γ and the misidentification of electron/pion and kaon/pion in the final states.

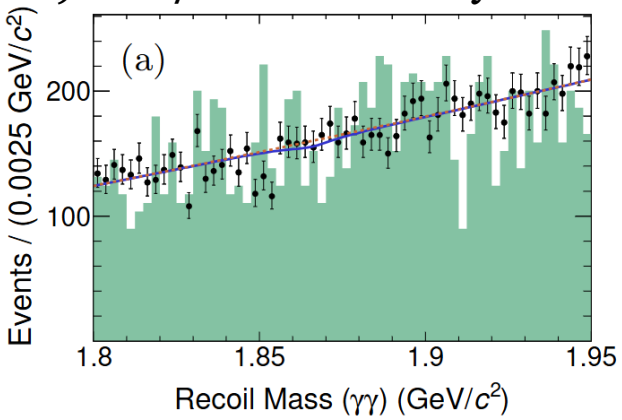


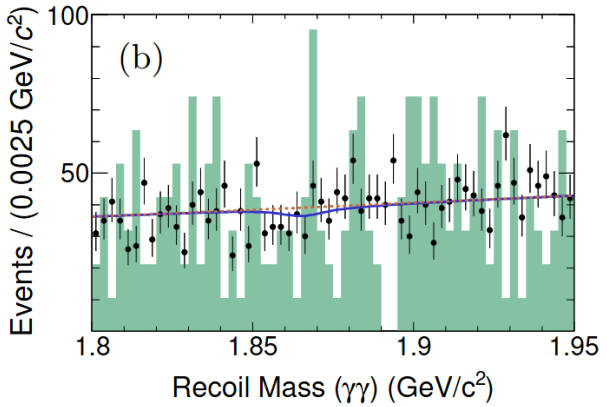
$J/\psi \to D^- + \pi^+/\rho^+$
and $J/\psi \to \bar{D}^0 + \pi^0/\rho^0/\eta$
Phys. Rev. D 110, 032020(2024)

Figure: Distribution of U_{miss} from $(a)\ J/\psi \to \bar{D}^0\pi^0, (b)\ J/\psi \to \bar{D}^0\eta, (c)\ J/\psi \to \bar{D}^0\rho^0, (d)\ J/\psi \to D^-\pi^+ and\ (e)\ J/\psi \to D^-\rho^+$. The black dots with error bars represent data and the red thick lines show the signal MC sample. The region between the two blue arrows marks the signal region of U_{miss}.

Search for decay $J/\psi \to D^- + \pi^+/\rho^+$ and $J/\psi \to \bar{D}^0 + \pi^0/\rho^0/\eta$

- Select those events for which the recoiling mass against the $\pi^0, \eta, \rho^0, \pi^+$, and ρ^+ falls within the mass window $(1.80, 1.95)\ GeV/c^2$ for all decay modes.





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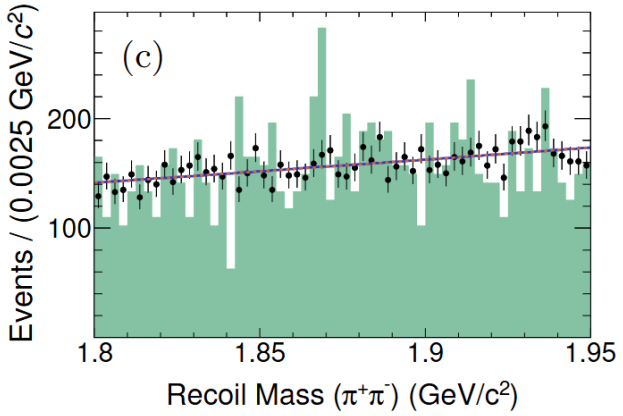
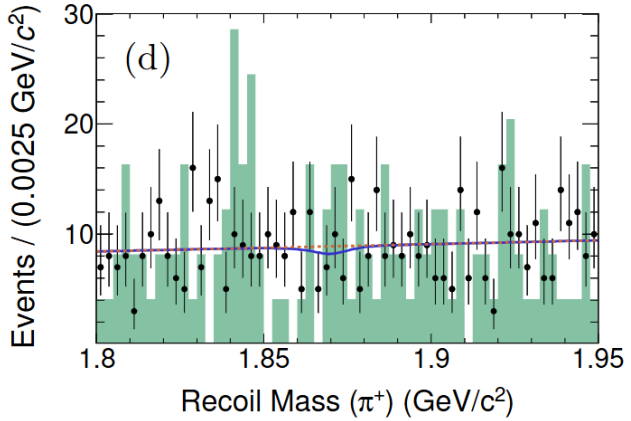
and $J/\psi \to \bar{D}^0 + \pi^0/\rho^0/\eta$
Phys. Rev. D 110, 032020(2024)





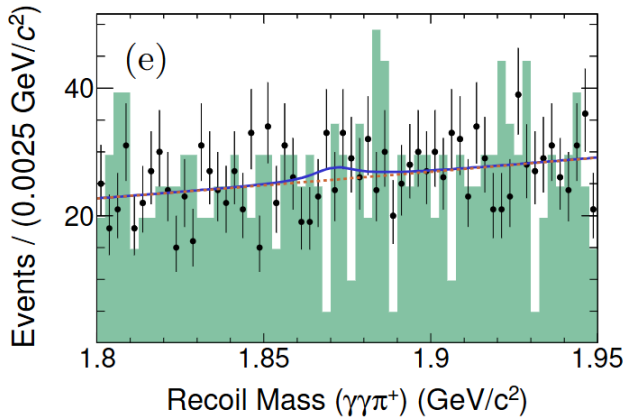


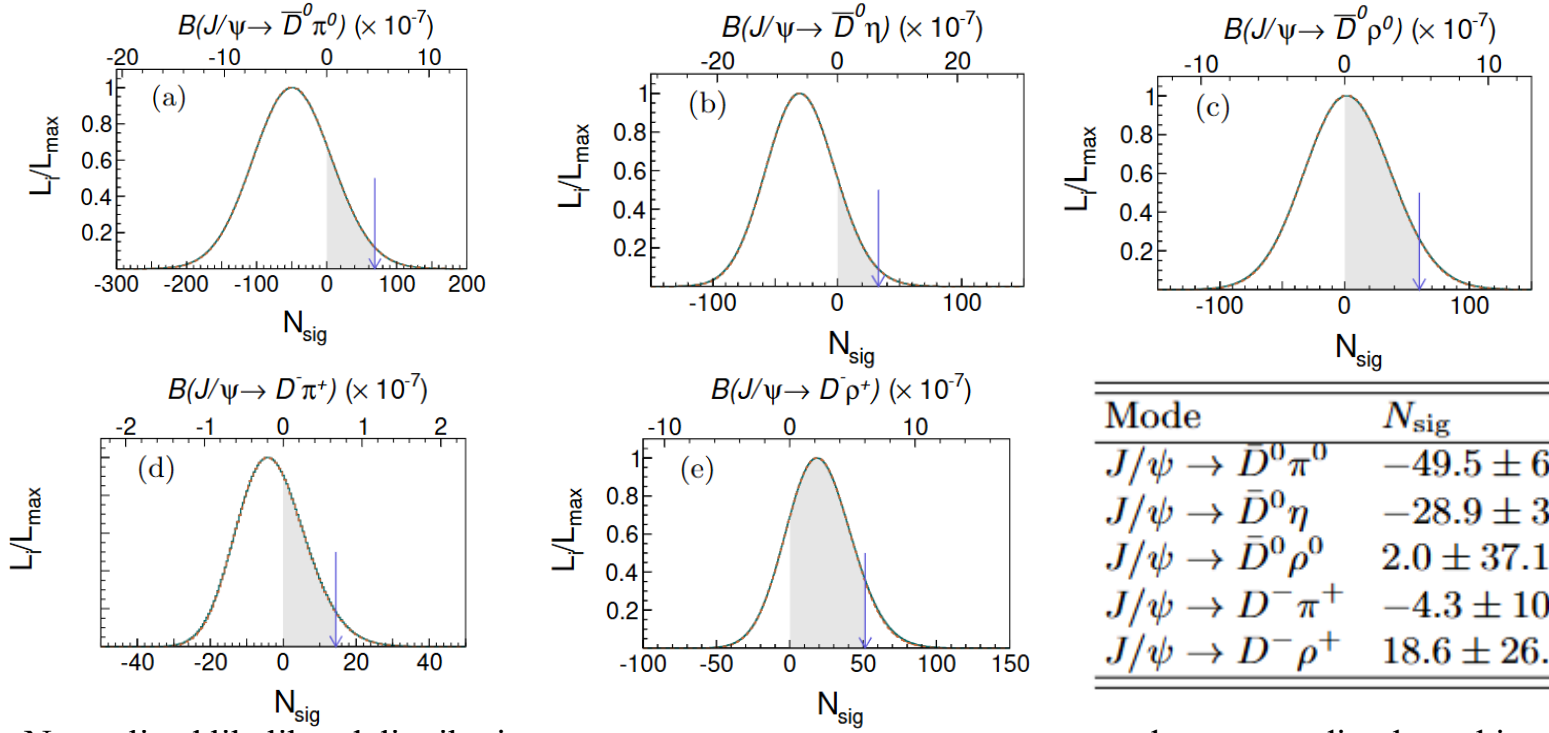
Figure: Fits of the accepted candidates to the recoiling mass spectra for $(a)\ J/\psi \to \bar{D}^0\pi^0$, $(b)\ J/\psi \to \bar{D}^0\eta$, $(c)\ J/\psi \to \bar{D}^0\rho^0$, $(d)\ J/\psi \to D^-\pi^+ and\ (e)\ J/\psi \to D^-\rho^+$. The dots with error bars are data and the orange dotted lines are polynomial functions describing the background. The blue solid curves are the total fits. The inclusive MC samples are shown by the green filled histograms.

Search for decay $J/\psi \to D^- + \pi^+/\rho^+$ and $J/\psi \to \bar{D}^0 + \pi^0/\rho^0/\eta$

- No significant signal is observed in any of the decay modes. The branching fraction of signal decay is calculated as

$$\mathcal{B}(J/\psi \to DM(N)) = \frac{N_{\rm sig}}{N_{J/\psi} \times \epsilon \times \mathcal{B}_{\rm sub}}$$

- where N_{sig} is the number of signal events, $N_{J/\psi}$ is the total number of J/ψ events, ε is the signal detection efficiency, and B_{sub} is the product of the branching fractions of all possible intermediate decays.



$J/\psi \to D^- + \pi^+/\rho^+$
and $J/\psi \to \bar{D}^0 + \pi^0/\rho^0/\eta$
Phys. Rev. D 110, 032020(2024)

Mode	$N_{\rm sig}$	$N_{\rm sig}^{\rm UL}$	$\mathcal{B}$ (90% C.L.)	$\mathcal{B}$ (90% C.L.)
$J/\psi \to \bar{D}^0\pi^0$	-49.5 ± 69.3	< 68.8	$< 4.7 \times 10^{-7}$	···
$J/\psi \to \bar{D}^0\eta$	-28.9 ± 34.5	< 32.9	$< 6.8 \times 10^{-7}$	···
$J/\psi \to \bar{D}^0\rho^0$	2.0 ± 37.1	< 59.9	$< 5.2 \times 10^{-7}$	···
$J/\psi \to D^-\pi^+$	-4.3 ± 10.3	< 14.4	$< 7.0 \times 10^{-8}$	$< 7.5 \times 10^{-5}$ [3]
$J/\psi \to D^-\rho^+$	18.6 ± 26.2	< 51.4	$< 6.0 \times 10^{-7}$	···

Figure: Normalized likelihood distributions for the fitted yields of signal events and corresponding branching fractions of $(a)\ J/\psi \to \bar{D}^0\pi^0$, $(b)\ J/\psi \to \bar{D}^0\eta$, $(c)\ J/\psi \to \bar{D}^0\rho^0$, $(d)\ J/\psi \to D^-\pi^+ and\ (e)\ J/\psi \to D^-\rho^+$, with (green solid curves) and without (orange dashed lines) smearing the systematic uncertainties. The blue arrows mark the upper limits at the 90% C.L..

Outline

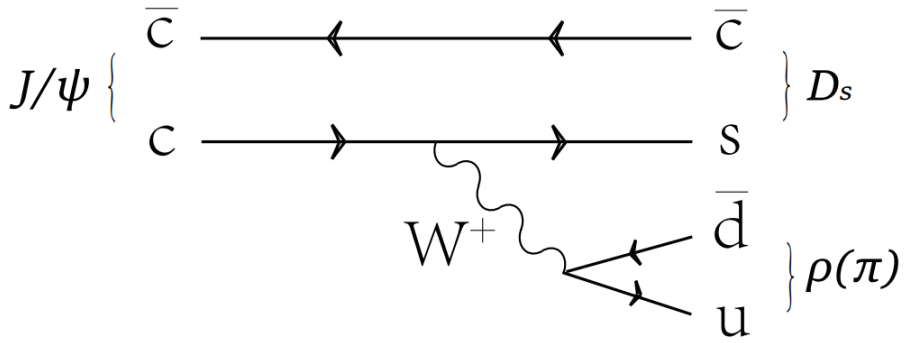
- BEPCII and BESIII
- Charmonium weak decays
- $J/\psi \to D^- e^+ \nu_e$
- $J/\psi \to D^- \mu^+ \nu_\mu$
- $J/\psi \to D^- + \pi^+/\rho^+$ and $J/\psi \to \bar{D}^0 + \pi^0/\rho^0/\eta$
- $J/\psi \to D_s^- + \pi^+/\rho^+$
- $\psi(3686) \to \Lambda_c^+ \bar{\Sigma}^-$
- Ongoing analyses
- Summary

Search for decay $J/\psi \to D_s^- + \pi^+/\rho^+$

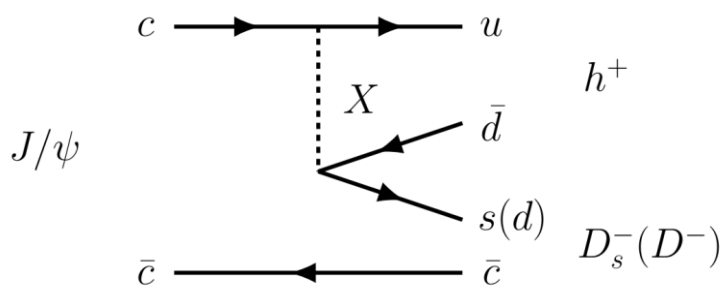
$J/\psi \to D_s^-\rho^+$ and $J/\psi \to D_s^-\pi^+$
arXiv:2506.09386

- Decay： $J/\psi \to D_s^-\rho^+$ and $J/\psi \to D_s^-\pi^+$
- Predicted relative ratio[1]： $\frac{\mathcal{B}(J/\psi \to D_s^-\rho^+)}{\mathcal{B}(J/\psi \to D_s^-\pi^+)} = 4.2$

[1] Int. J. Mod. Phys. A 14, 937-946 (1999)



Fig(a) The Feynman diagram of $J/\psi \to D_s^-\pi^+$ and $J/\psi \to D_s^-\rho^+$ in SM.



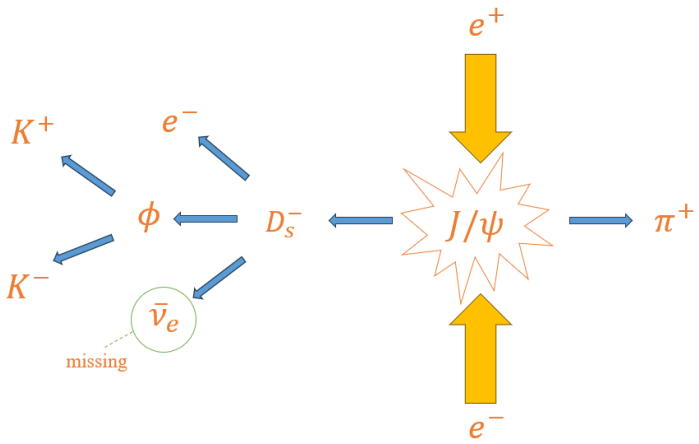
Fig(b) The Feynman diagram of $J/\psi \to D_s^-\pi^+$ and $J/\psi \to D_s^-\rho^+$ in NP Model.

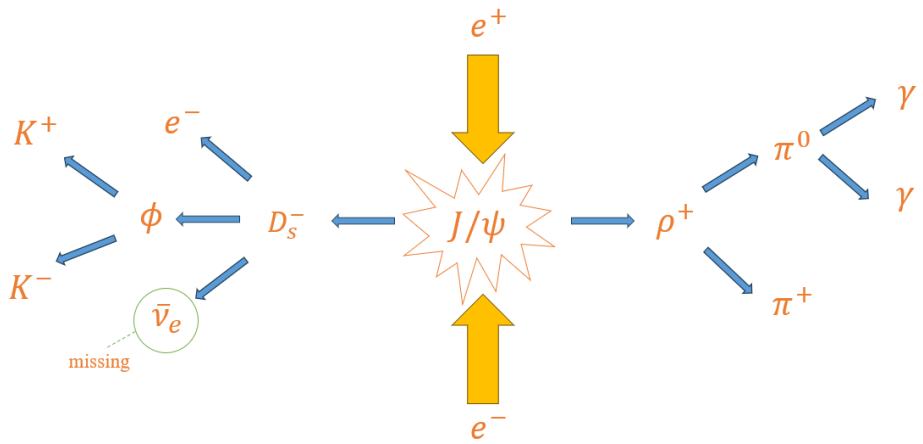
Model	QCDSR [2]	BSW [3]	CLFQM (2008) [4]	CLFQM (2024) [5]
$\mathcal{B}(J/\psi \to D_s^-\rho^+)(\times 10^{-10})$	$12.6^{+7.6}_{-6.0}$	$51.1^{+7.6}_{-6.0}$	28^{+0}_{-9}	$29.5^{+0.6+1.1+1.5}_{-0.5-1.4-1.9}$
$\mathcal{B}(J/\psi \to D_s^-\pi^+)(\times 10^{-10})$	$2.0^{+4.0}_{-0.2}$	$7.41^{+0.13}_{-0.23}$	$2.5^{+0.0}_{-0.1}$	$3.64^{+0.06+0.34+0.78}_{-0.06-0.38-0.96}$

[2] Eur. Phys. J.C 55, 607-613 (2008)
[3] High Energy Phys. 2013, 706543 (2013)
[4] Phys. Rev. D 78, 074012 (2008)
[5] Eur. Phys. J.C 84, no.1, 65 (2024)

Search for decay $J/\psi \to D_s^- + \pi^+/\rho^+$

$J/\psi \to D_s^-\rho^+$ and
$J/\psi \to D_s^-\pi^+$
arXiv:2506.09386



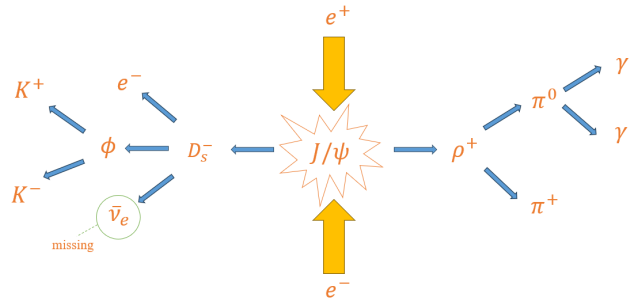


- The non-leptonic decay modes of D_s mesons do not provide good sensitivity due to the presence of J/ψ hadronic decay backgrounds.
- Therefore, the D_s candidates are reconstructed via semi-leptonic decay mode $D_s^- \to \phi e^- \bar{\nu}_e$.
- Since D_s^- cannot be reconstructed with their invariant mass due to the missing neutrino, the recoil momentum is used to reconstruct D_s^-.
- We use the ratio of EMC deposited energy E and MDC momentum P for charged particles and dE/dx information from MDC to suppress the main background due to e/π misidentification.

Search for decay $J/\psi \to D_s^- + \pi^+/\rho^+$

$J/\psi \to D_s^-\rho^+$ and
$J/\psi \to D_s^-\pi^+$
arXiv:2506.09386

➢ Decay： $J/\psi \to D_s^-\rho^+$



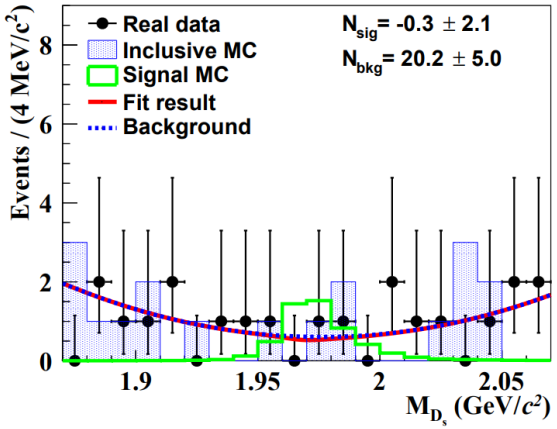


Figure (a): The M_{D_s} distributions of the $J/\psi \to D_s^-\rho^+$ Candidate events.

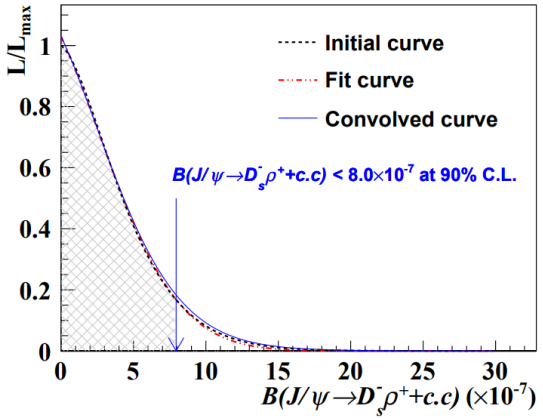
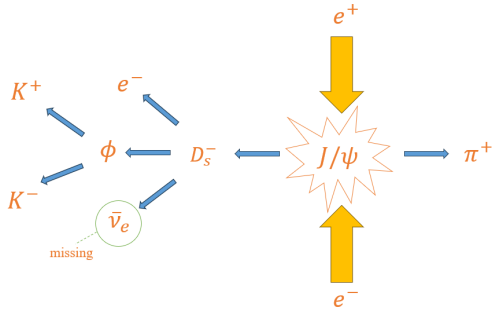


Figure (a): The distributions of the likelihood scan values for $J/\psi \to D_s^-\rho^+$.

➢ $\mathcal{B}(J/\psi \to D_s^-\rho^+) < 8.0 \times 10^{-7}$ @90% C.L.

➢ The UL for $J/\psi \to D_s^-\rho^+$ has been improved by about an order of magnitude.

➢ Decay： $J/\psi \to D_s^-\pi^+$



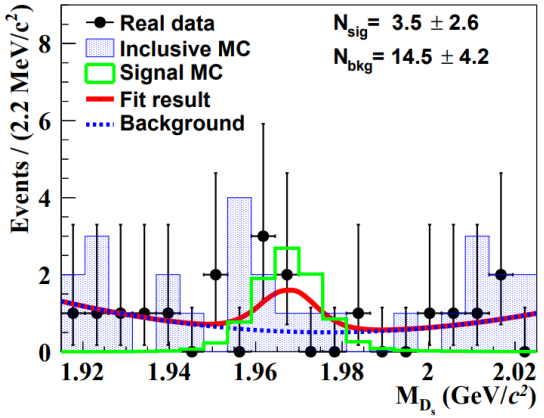


Figure (c): The M_{D_s} distributions of the $J/\psi \to D_s^-\pi^+$ Candidate events.

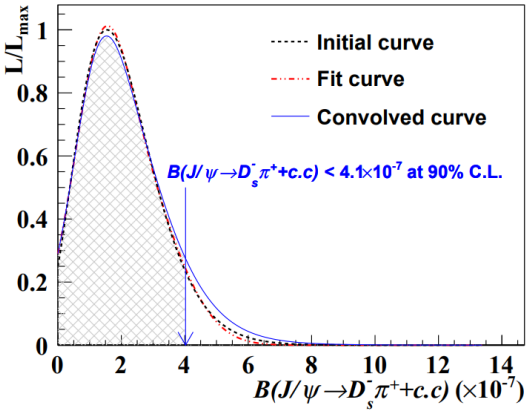


Figure (d): The distributions of the likelihood scan values for $J/\psi \to D_s^-\pi^+$.

➢ $\mathcal{B}(J/\psi \to D_s^-\pi^+) < 4.1 \times 10^{-7}$ @90% C.L.

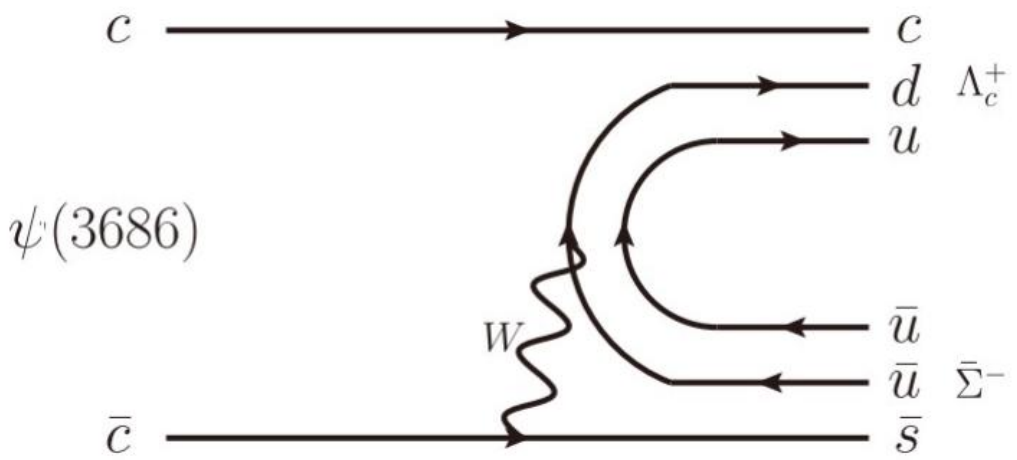
➢ The UL for $J/\psi \to D_s^-\pi^+$ has been improved by about three orders of magnitude.

Outline

- BEPCII and BESIII
- Charmonium weak decays
- $J/\psi \to D^- e^+ \nu_e$
- $J/\psi \to D^- \mu^+ \nu_\mu$
- $J/\psi \to D^- + \pi^+/\rho^+$ and $J/\psi \to \bar{D}^0 + \pi^0/\rho^0/\eta$
- $J/\psi \to D_s^- + \pi^+/\rho^+$
- $\psi(3686) \to \Lambda_c^+ \bar{\Sigma}^-$
- Ongoing analyses
- Summary

Search for decay $\psi(3686) \rightarrow \Lambda_c^+ \bar{\Sigma}^-$

$\psi(3686) \rightarrow \Lambda_c^+ \bar{\Sigma}^-$
Chinese Phys. C 47 013002 (2023)



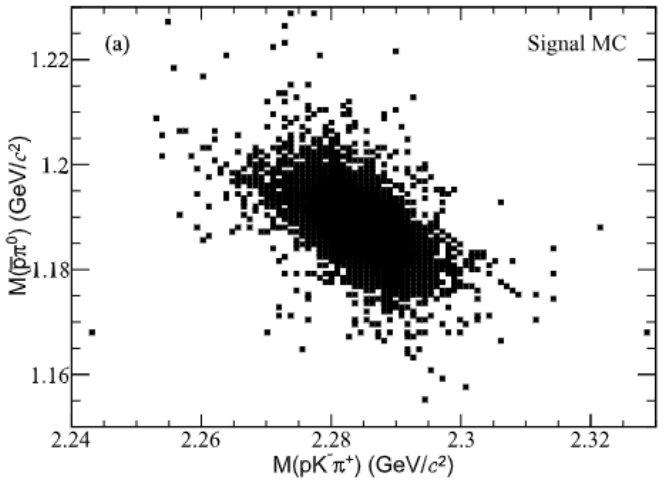
Figure(a) The Feynman diagram of $\psi(3686) \rightarrow \Lambda_c^+ \bar{\Sigma}^-$

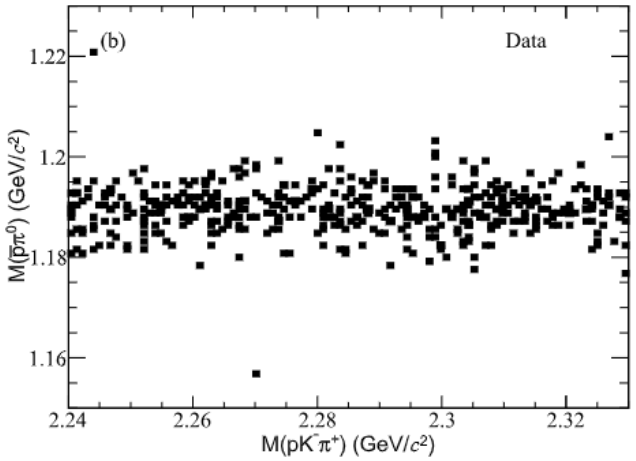
- Searches for purely baryonic weak $\psi(3686)$ decays involving a charmed baryon Λ_c^+ in the final state have not been previously performed.
- The branching fraction of $\psi(3686) \rightarrow \Lambda_c^+ \ \bar{\Sigma}^-$ is predicted to be of the order of 10^{-9} to 10^{-11} in the SM[1].
- Using $(448.1 \pm 2.9) \times 10^6$ $\psi(3686)$ events.
- $\psi(3686) \rightarrow \Lambda_c^+ \bar{\Sigma}^-, \Lambda_c^+ \rightarrow pK^-\pi^+, \bar{\Sigma}^- \rightarrow \bar{p}\pi^0$

[1] Chin. Phys. Lett. 28, 071301 (2011)

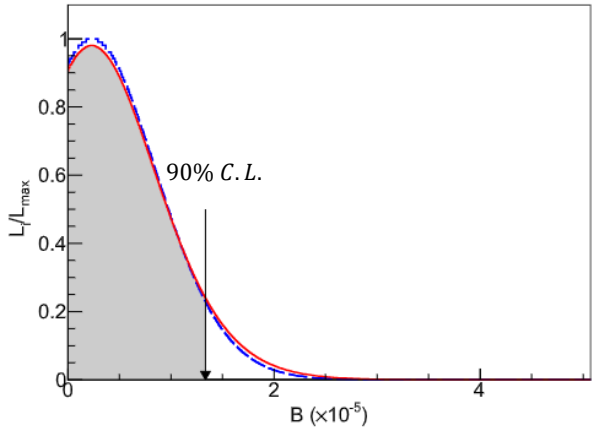
Search for decay $\psi(3686) \rightarrow \Lambda_c^+ \bar{\Sigma}^-$

$\psi(3686) \rightarrow \Lambda_c^+ \bar{\Sigma}^-$
Chinese Phys. C 47 013002 (2023)



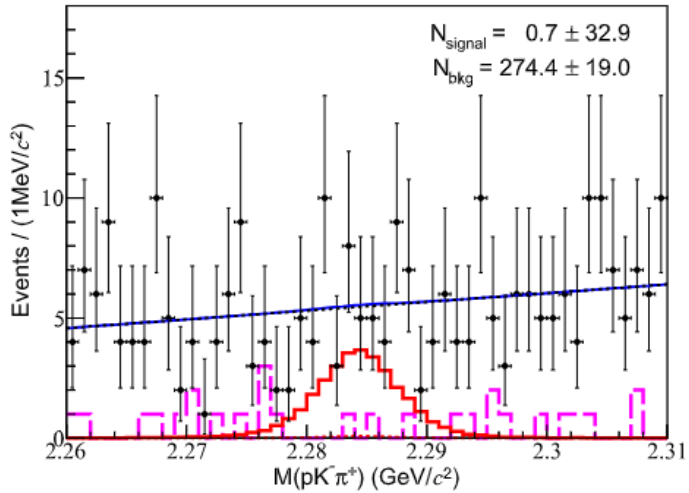


(a)(b) Distribution of M ($\bar{p}\pi^0$) versus M ($pK^-\pi^+$) for the accepted candidate events in the signal MC sample and data.



(c) Upper limit in full data

- Signal yield is extracted from an unbinned maximum likelihood fit to the $M(pK^-\pi^+)$ distribution.
- $\mathcal{B}(\psi(3686) \rightarrow \Lambda_c^+ \bar{\Sigma}^-) < 1.4 \times 10^{-5}$ @90% C.L.



(d) Fit to the M ($pK^-\pi^+$) distribution. Points with error bars are data. The red (black) dashed line is the signal (background), and the blue solid curve is the total fit. The pink dashed line is the inclusive MC sample. The red solid curve is the signal shape enlarged by a factor of 100

Outline

- BEPCII and BESIII
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- $J/\psi \to D_s^- + \pi^+/\rho^+$
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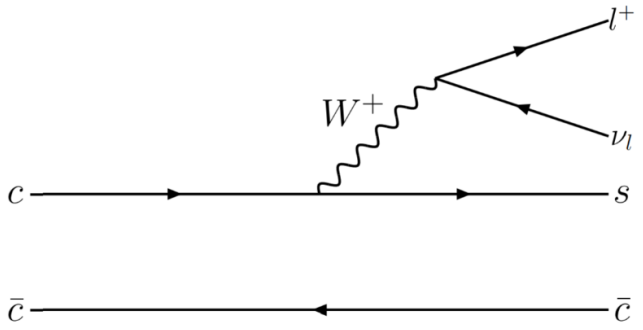
- Summary

Ongoing analyses

Semileptonic weak decay

- $J/\psi \to D_s^- e^+ \nu_e + c.c$
- $\psi(3686) \to D_s^- e^+ \nu_e + c.c.$

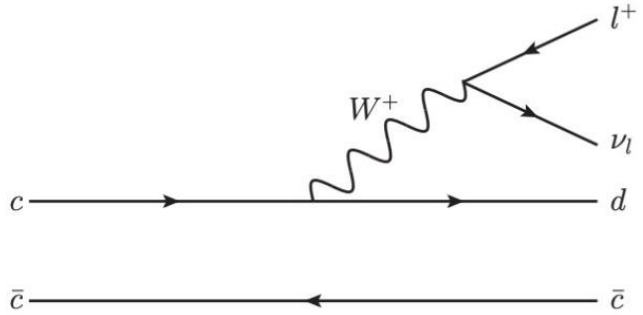
Tag mode:
- $D_s^- \to K_s^0 K^-$
- $D_s^- \to K^+ K^- \pi^-$
- $D_s^- \to K^+ K^- \pi^- \pi^0$
- $D_s^- \to K_S^0 K^- \pi^+ \pi^-$



Fig(a) The Feynman diagram of $J/\psi \to D_s^- l^+ \nu$ and $\psi(3686) \to D_s^- l^+ \nu$

- $\psi(3686) \to D^- e^+ \nu_e + c.c.$

Tag mode:
- $D^- \to K^+ \pi^- \pi^-$
- $D^- \to K^+ \pi^- \pi^- \pi^0$
- $D^- \to K_s^0 \pi^-$
- $D^- \to K_s^0 \pi^- \pi^0$
- $D^- \to K_s^0 \pi^- \pi^- \pi^+$
- $D^- \to K^+ K^- \pi^-$



Fig(b) The Feynman diagram of $J/\psi \to D^- l^+ \nu$ and $\psi(3686) \to D^- l^+ \nu$

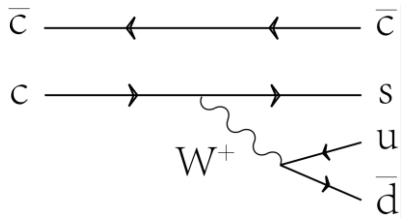
Model	BSW [1]	CCQM[2]	BSM[3]	CLFQM[4]	LQCD[5]
$\mathcal{B}(J/\psi \to D_s^- e^+ \nu_e)(\times 10^{-10})$	$104^{+9.0}_{-7.5}$	33	$36.7^{+5.2}_{-4.4}$	$10.21^{+0.19+0.66+0.56}_{-0.18-0.61-1.41}$	1.90
$\mathcal{B}(\psi(3686) \to D_s^- e^+ \nu_e)(\times 10^{-10})$				$7.20^{+0.20+0.97+0.60}_{-0.19-0.44-0.92}$	
$\mathcal{B}(\psi(3686) \to D^- e^+ \nu_e)(\times 10^{-10})$				$3.45^{+0.10+0.49+0.23}_{-0.09-0.20-0.25}$	

[1] Adv. High Energy Phys. 2013 (2013) 706543
[2] Phys. Rev. D 92 (2015) 074030
[3] J. Phys. G 44 (2017) 045004
[4] Eur. Phys. J. C 84, no.1, 65 (2024)
[5] arXiv:2407.13568

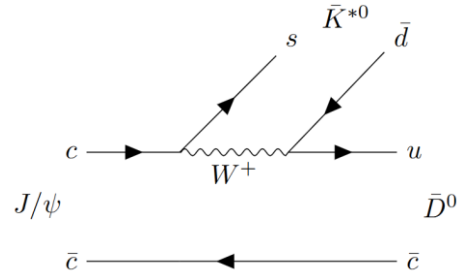
Ongoing analyses

Nonleptonic weak decays

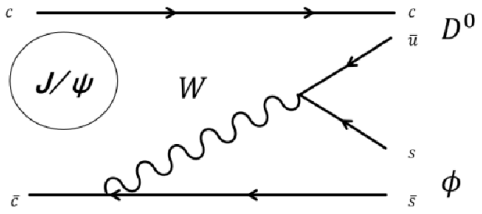
- $\psi(3686) \to D_s^- \rho^+ + c.c.$ → Decay chain:
  - $D_s^- \to \phi e^- \bar{\nu}_e$
  - $\rho^+ \to \pi^0 \pi^+$
  - $\pi^0 \to \gamma\gamma$
- $\psi(3686) \to D_s^- \pi^+ + c.c.$ → Decay chain:
  - $D_s^- \to \phi e^- \bar{\nu}_e$
- $J/\psi \to \bar{D}^0 \bar{K}^{*0} + c.c.$ → Decay chain:
  - $\bar{D}^0 \to K^+ e^- \bar{\nu}_e$
  - $\bar{K}^{*0} \to K^- \pi^+$
- $J/\psi \to \bar{D}^0 \bar{K}^0 + c.c.$ → Decay chain:
  - $\bar{D}^0 \to K^+ e^- \bar{\nu}_e$
  - $\bar{K}^0 \to K_s^0$
  - $K_s^0 \to \pi^- \pi^+$
- $J/\psi \to D^0 \phi + c.c.$ → Decay chain:
  - $D^0 \to K^- \pi^+$
  - $\phi \to K^+ K^-$



Fig(a) The Feynman diagram of $\psi(3686) \to D_s^- \rho^+$, and $\psi(3686) \to D_s^- \pi^+$



Fig(b) The Feynman diagram of $J/\psi \to \bar{D}^0 \bar{K}^{*0}$ and $J/\psi \to \bar{D}^0 \bar{K}^0$



Fig(c) The Feynman diagram of $J/\psi \to D^0 \phi$

Model	QCDSR [1]	BSW [2]	CLFQM (2024) [3]
$\mathcal{B}(\psi(3686) \to D_s^- \rho^+)(\times 10^{-10})$			$12.2^{+0.3+0.1+4.1}_{-0.3-1.0-1.9}$
$\mathcal{B}(\psi(3686) \to D_s^- \pi^+)(\times 10^{-10})$			$12.3^{+0.3+0.8+5.9}_{-0.3-1.8-5.1}$
$\mathcal{B}(J/\psi \to \bar{D}^0 \bar{K}^{*0})(\times 10^{-10})$	$1.54^{+0.68}_{-0.38}$	$7.61^{+1.6}_{-1.2}$	
$\mathcal{B}(J/\psi \to \bar{D}^0 \bar{K}^0)(\times 10^{-10})$	$0.36^{+0.10}_{-0.08}$	$1.39^{+0.10}_{-0.14}$	
$\mathcal{B}(J/\psi \to D^0 \phi)(\times 10^{-10})$		$0.42^{+0.08}_{-0.07}$	

- ✓ QCDSR is the QCD sum rule model.
- ✓ BSW is the Bauer-Stech-Wirbel model.
- ✓ CLFQM is the covariant light-front quark model.

[1] Eur. Phys. J.C 55, 607-613 (2008)
[2] High Energy Phys. 2013, 706543 (2013)
[3] Eur. Phys. J.C 84, no.1, 65 (2024)

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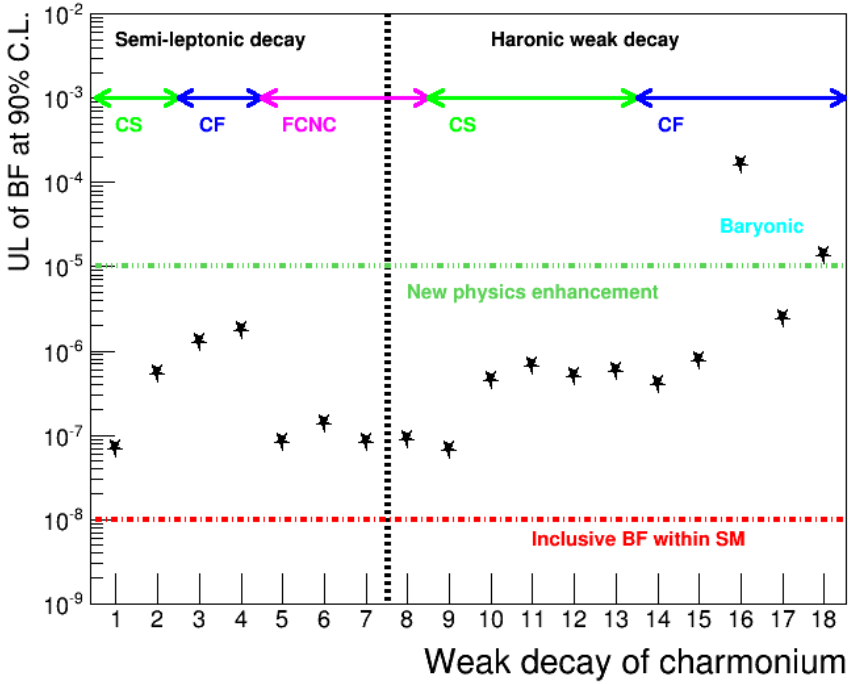
- Summary

- BESIII performed a wide range study of new physics, with many first searches or best limits.
- The latest search results for rare Charmonium decays in BESIII are reported.



1: $J/\psi \to D^- e^+ \nu_e + c.c.$
2: $J/\psi \to D^- \mu^+ \nu_\mu + c.c.$
3: $J/\psi \to D_s^- e^+ \nu_e + c.c.$
4: $J/\psi \to D_s^{*-} e^+ \nu_e + c.c.$
5: $J/\psi \to D^0 e^+ e^- + c.c.$
6: $\psi(2S) \to D^0 e^+ e^- + c.c.$
7: $J/\psi \to D^0 \mu^+ \mu^- + c.c.$
8: $J/\psi \to \gamma D^0 + c.c.$
9: $J/\psi \to D^- \pi^+ + c.c.$
10: $J/\psi \to D^0 \pi^0 + c.c.$
11: $J/\psi \to D^0 \eta + c.c.$
12: $J/\psi \to D^0 \rho^0 + c.c.$
13: $J/\psi \to D^- \rho^+ + c.c.$
14: $J/\psi \to D_s^- \pi^+ + c.c.$
15: $J/\psi \to D_s^- \rho^+ + c.c.$
16: $J/\psi \to D^0 K^0 + c.c.$
17: $J/\psi \to D^0 K^{*0} + c.c.$
18: $\psi(2S) \to \Lambda_c^+ \bar{\Sigma}^- + c.c.$

Figure: The summary of charmonium weak decay

Thanks

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