Charmonium Rare Decays @ BESIII

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Outline

- Why rare decay is interesting?
- Charmonium rare decays @BESIII

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

$J/\psi \to D_s^{*-} e^+ \nu_e + c.c.$

$J/\psi \to D_s^- \rho^+$

$J/\psi \to \overline{D}^0 \overline{K}^{*0}$

$J/\psi \to \gamma\gamma$

$J/\psi \to \gamma\phi$

$J/\psi \to e\mu$

- Discussion and outlook

Why we study rare decays ?

- The discovery of Higgs boson complete the structure of SM, but put High Energy Physics in a turning point. New physics is interesting, which may give us surprises. Rare decays in low energy region may be complementary to high energy colliders

- Charmonium decays are dominated by strong and EM, weak decays is rare → challenges/opportunities of BESIII

- Predicted to be unobservable in SM, but the BF may be enhanced in the presence of New Physics (as large as 10^{-5} -10^{-6} , can be marginally measured by BESIII)

Rare decays of Charmonium

- Semileptonic weak decays:

  $\psi(nS) \to D_q l v,\ \psi(nS) \to \bar{D}^{0/*} l^+ l^-$

- Two-body weak hadronic decays

  $J/\psi \to D_s^- \pi^+ / K^+ + c.c., J/\psi \to D_s^{(*)+} \rho^- / K^{*-} + c.c., \ldots$

- C/P violation decays

  $J/\psi \to \gamma\gamma, \gamma V, VV, PP$

- Lepton flavor violation decays

  $J/\psi \to e\mu, e\tau, \mu\tau$

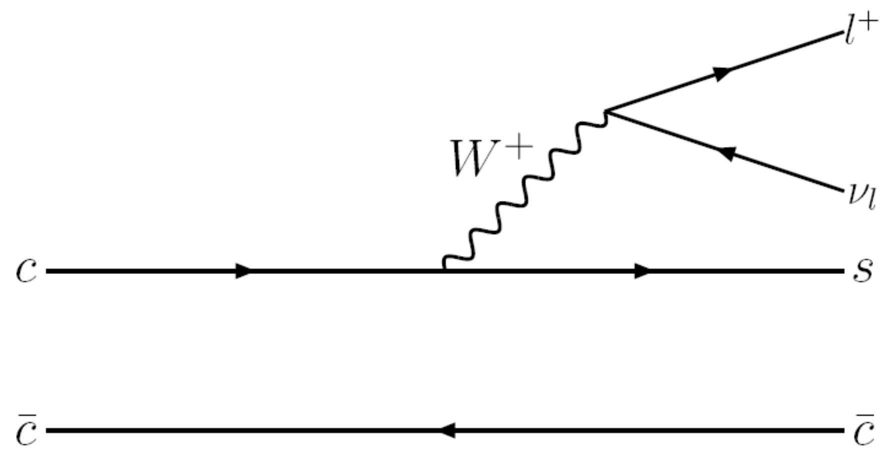
Invisible decays and other quantities violated decays also can be searched

The results shown in this report are based on **2.25×10^8** J/ψ or **1.06×10^8** ψ(3686) events accumulated with BESIII. All upper limit Brs are given at the **90% C.L.**

Semileptonic weak decays

Within Standard Model

QCD sum rules: ~10^{-10}



Feynman diagram for $J/\psi \to D_s^{(*)-} l^+ \nu$ at the tree level

New Physics

Top color model
Minimal Supersymmetric SM
Two-Higgs-doublet model

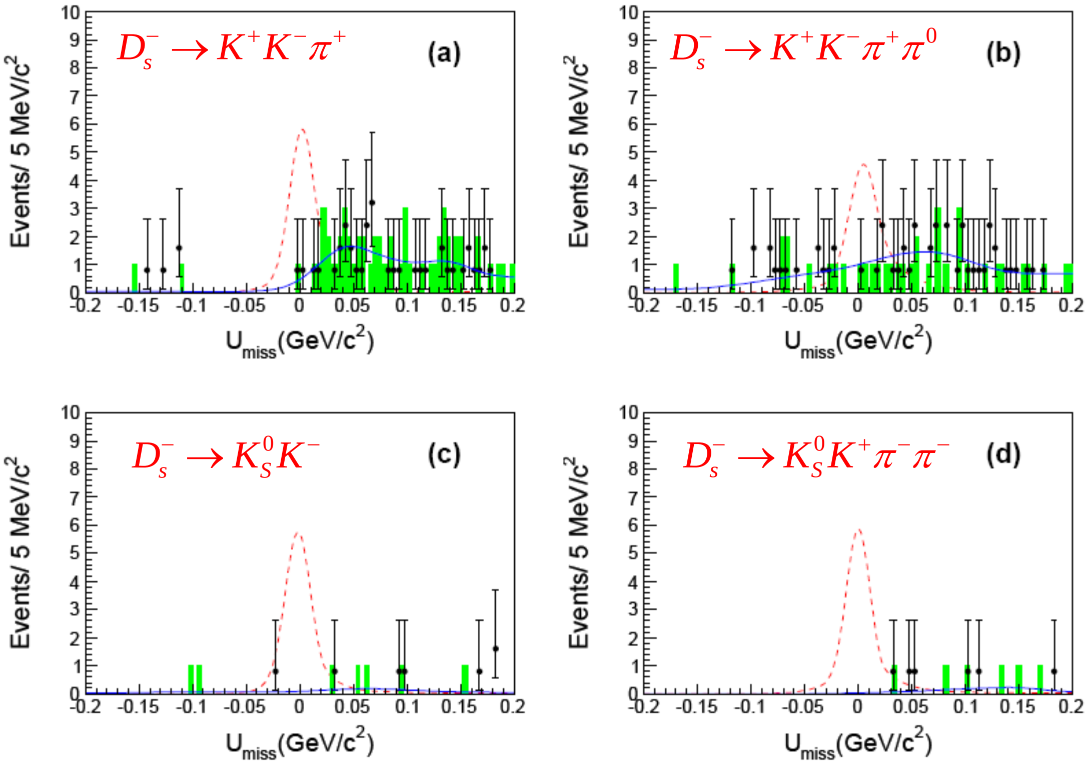
$$\frac{Br(J/\psi \to D_s^* l\nu)}{Br(J/\psi \to D_s l\nu)} \approx 1.5 \sim 3.1$$

Z. Phys. C. 62, 271
Eur. Phys. J. C. 54, 107

Semileptonic weak decays

2.25×10^{8} J/ψ

arXiv: 1410.8426



D_s^- is reconstructed by four channels and the combined likelihood is calculated:

$$\mathcal{L}_k = \prod_{i=1}^{N_k} \frac{N_{\text{total}}\mathcal{B}_k\epsilon_k\mathcal{P}_{i,k}^{\text{sig}} + N_k^{\text{bkg}}\mathcal{P}_{i,k}^{\text{bkg}}}{N_{\text{total}}\mathcal{B}_k\epsilon_k + N_k^{\text{bkg}}}$$

$$\frac{\int_0^{N_{\text{total}}^{\text{up}}} \mathcal{L}(N_{\text{total}})dN_{\text{total}}}{\int_0^{\infty} \mathcal{L}(N_{\text{total}})dN_{\text{total}}} = 0.90$$

$$E_{\text{miss}} = E_{J/\psi} - E_{D_s^-} - E_{e^+} \qquad \vec{p}_{\text{miss}} = \vec{p}_{J/\psi} - \vec{p}_{D_s^-} - \vec{p}_{e^+} \qquad U_{\text{miss}} = E_{\text{miss}} - |\vec{p}_{\text{miss}}|$$

$$Br(J/\psi \to D_s^- e^+ \nu_e + c.c.) < 1.3\times10^{-6}$$

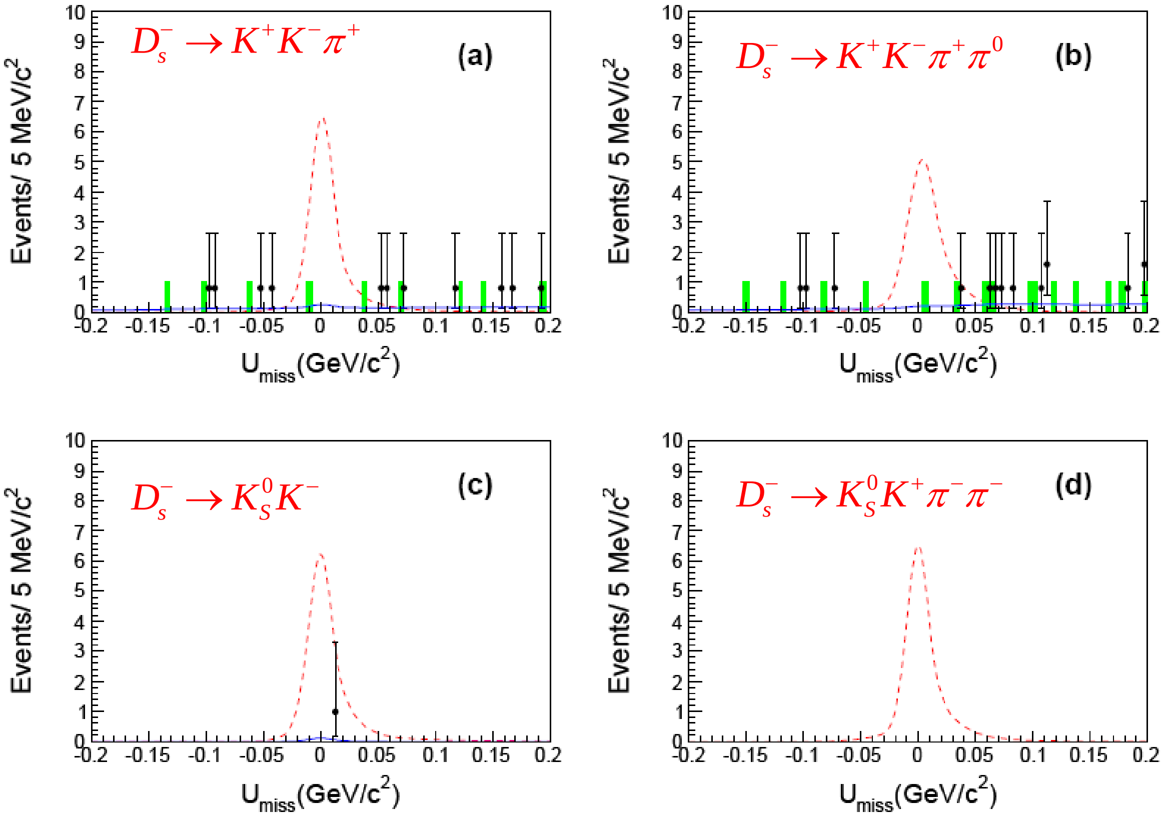
$< 3.6\times10^{-5}$

(best results before)

Semileptonic weak decays

2.25×10^8 J/ψ

arXiv: 1410.8426



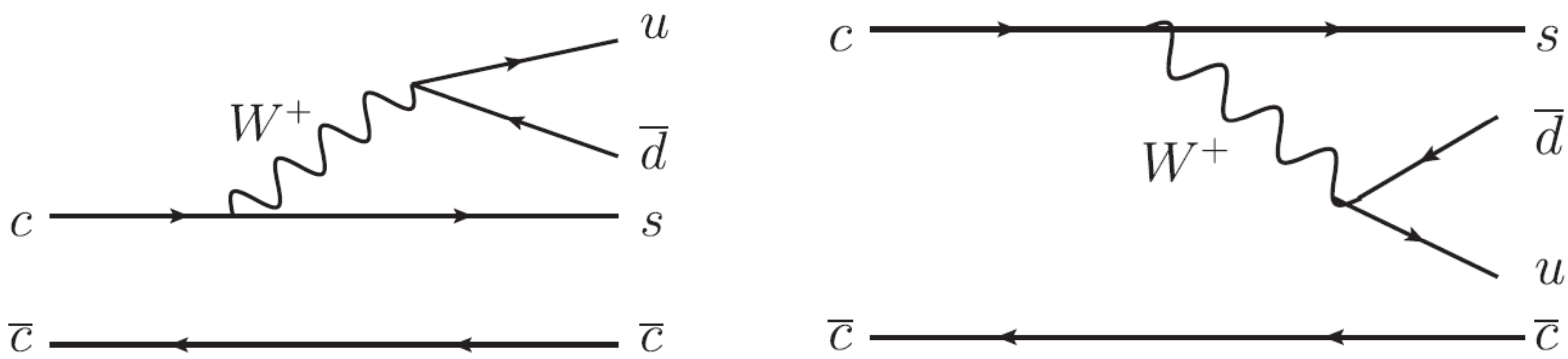
D_s^{*-} is reconstructed by

$$D_s^{*-} \to \gamma D_s^-$$

The same analysis method as $D_s e\nu$

$$Br(J/\psi \to D_s^{*-}e^+\nu_e + c.c.) < 1.8\times 10^{-6}$$

Two-body hadronic weak decays



Within Standard Model

Factorization model: $\sim 10^{-9} \sim 10^{-10}$

New Physics : $\sim 10^{-5} \sim 10^{-6}$

Top color model
Minimal Supersymmetric SM
Two-Higgs-doublet model

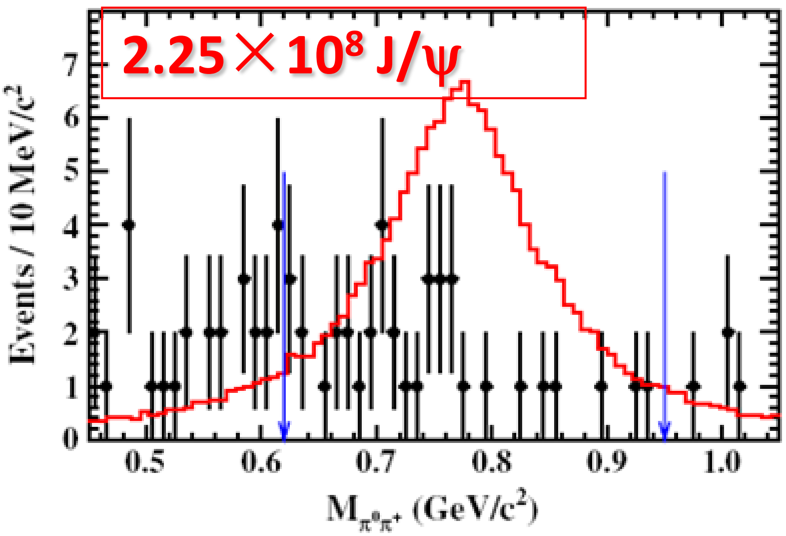
$$\frac{Br(J/\psi \to D_s^+ \rho^-)}{Br(J/\psi \to D_s^+ \pi^-)} \approx 5$$

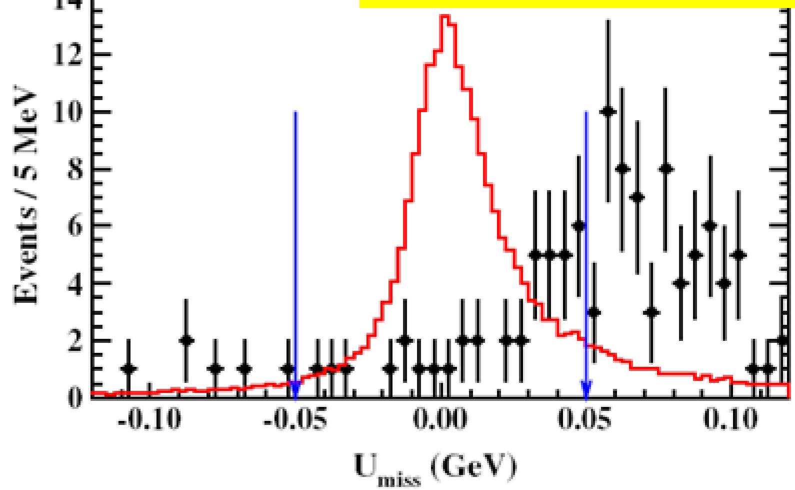
$$\frac{Br(J/\psi \to D^0 K^{*0})}{Br(J/\psi \to D_s^+ \rho^-)} \approx 0.1$$

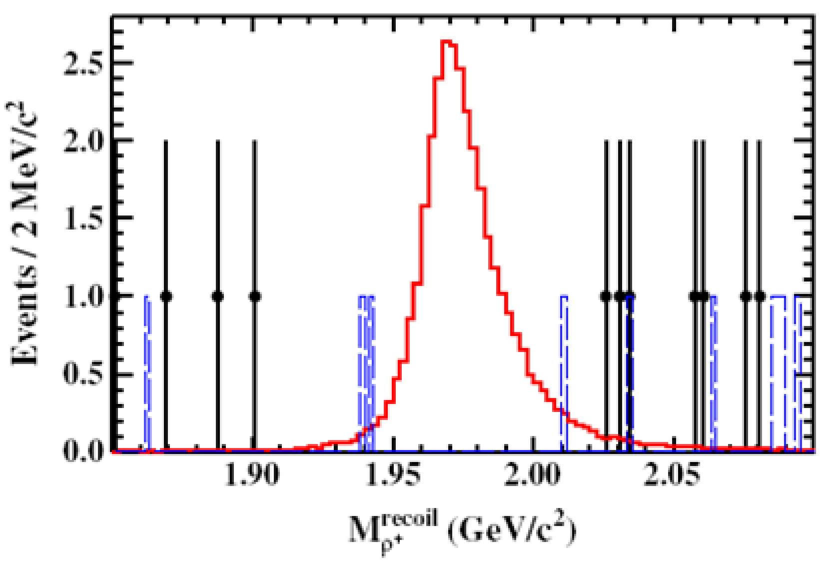
Phys. Lett. B 252, 690

Two-body hadronic weak decays

PRD 89, 071101







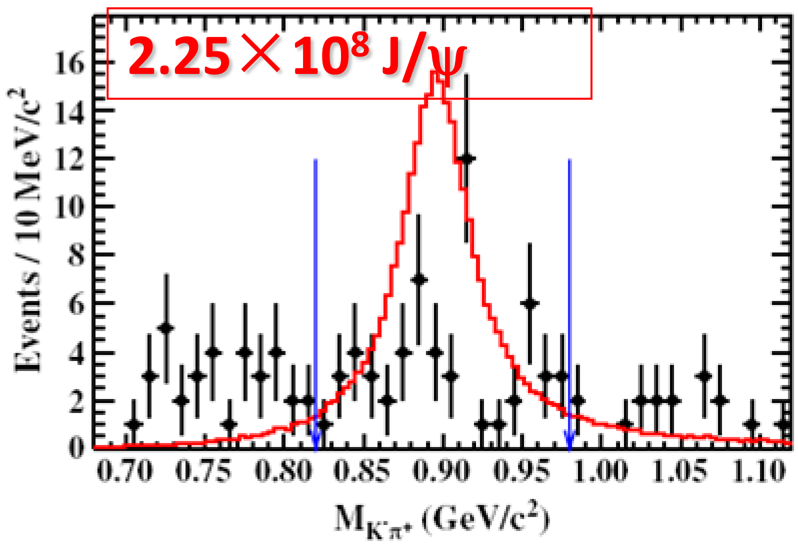
$$J/\psi \to D_s^- \rho^+$$

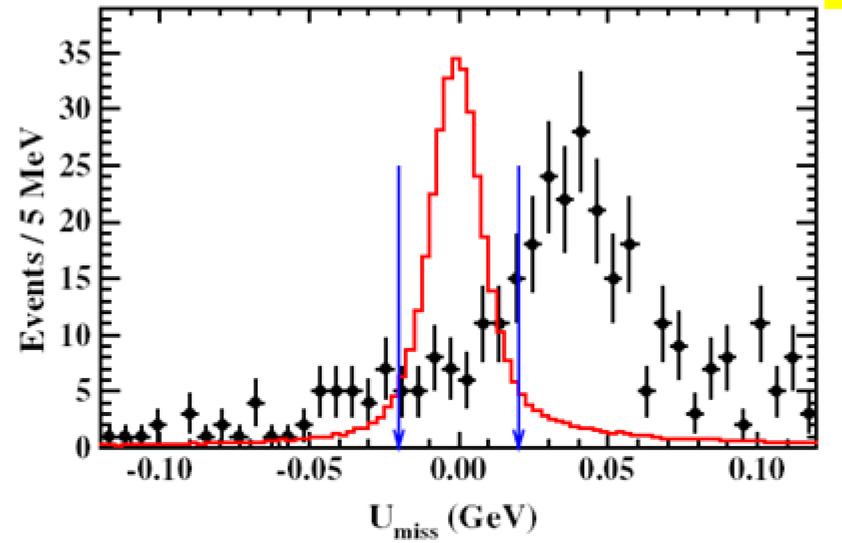
$$D_s^- \to \phi e^- \overline{\nu}_e, \phi \to K^+K^-$$

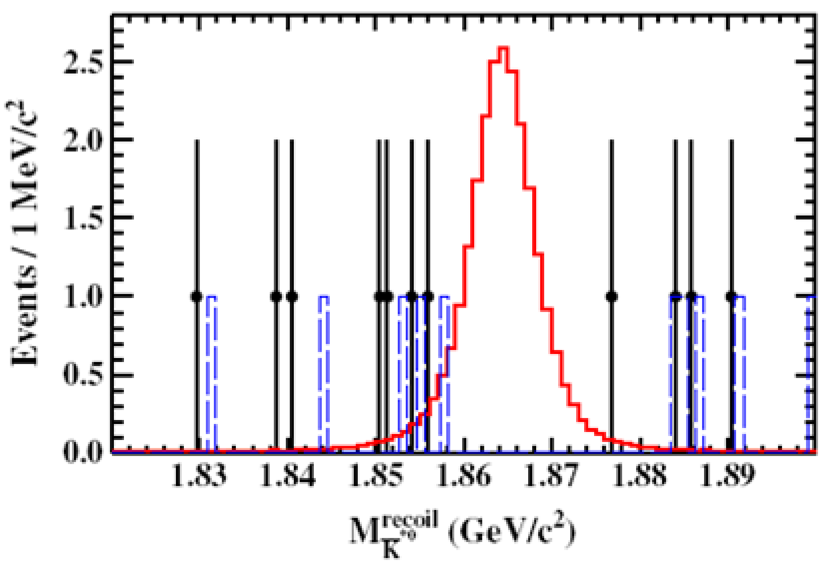
$$Br(J/\psi \to D_s^- \rho^+) < 1.3\times10^{-5}$$

Two-body hadronic weak decays

PRD 89, 071101







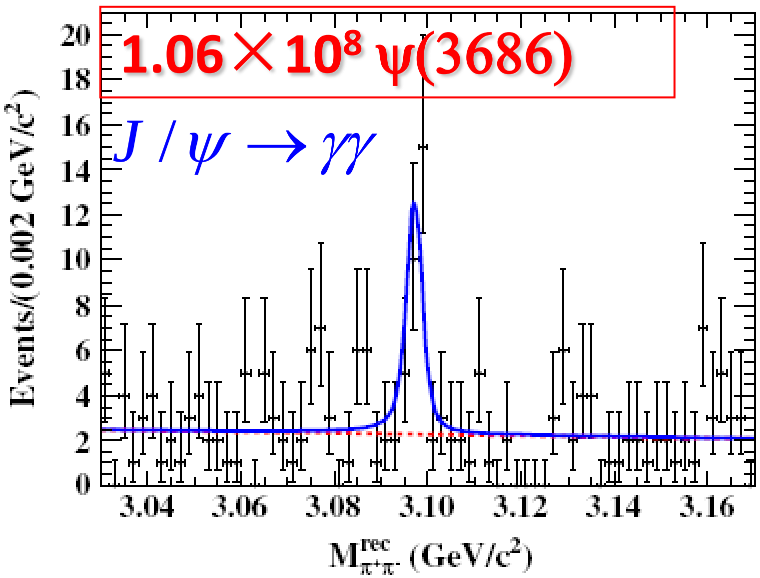
$$J/\psi \to \bar{D}^0 \bar{K}^{*0}$$

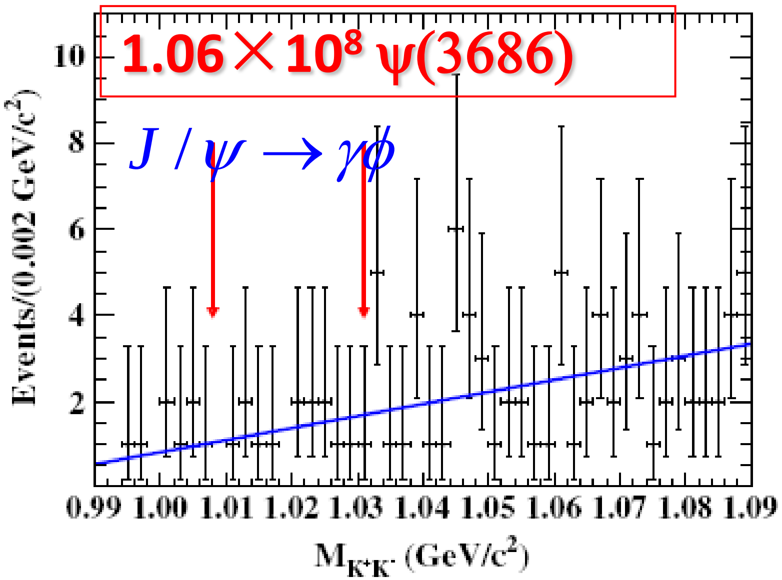
$$\bar{D}^0 \to K^+ e^- \nu_e$$

$$\bar{K}^{*0} \to K^- \pi^+$$

$$Br(J/\psi \to \bar{D}^0 \bar{K}^{*0}) < 2.5 \times 10^{-6}$$

C-parity violation decays





PRD 90, 092002

The J/ψ→γγ and γφ are studied via ψ(3686)→J/ψ $\pi^+\pi^-$

The peak of J/ψ→γγ is dominated by background contribution

(best results before)

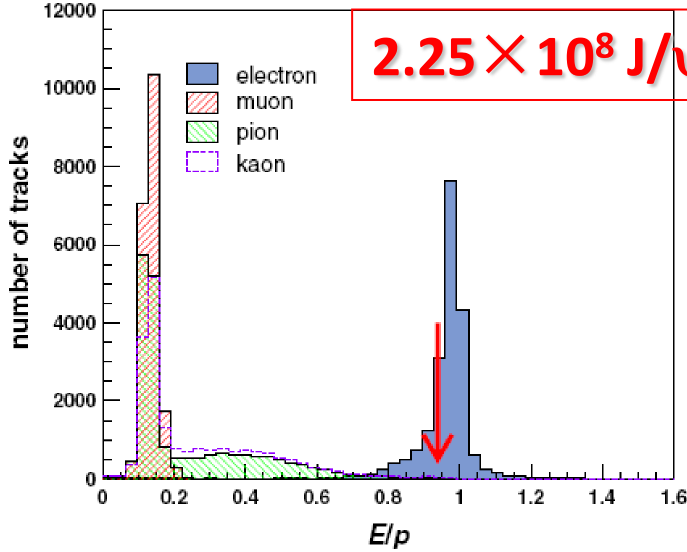
$< 5\times10^{-6}$

$$Br(J/\psi \to \gamma\gamma) < 2.7\times10^{-7}$$

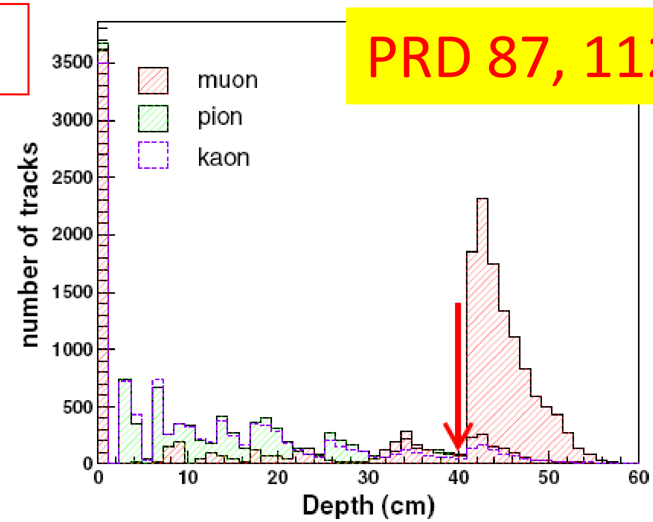
$$Br(J/\psi \to \gamma\phi) < 1.4\times10^{-6}$$

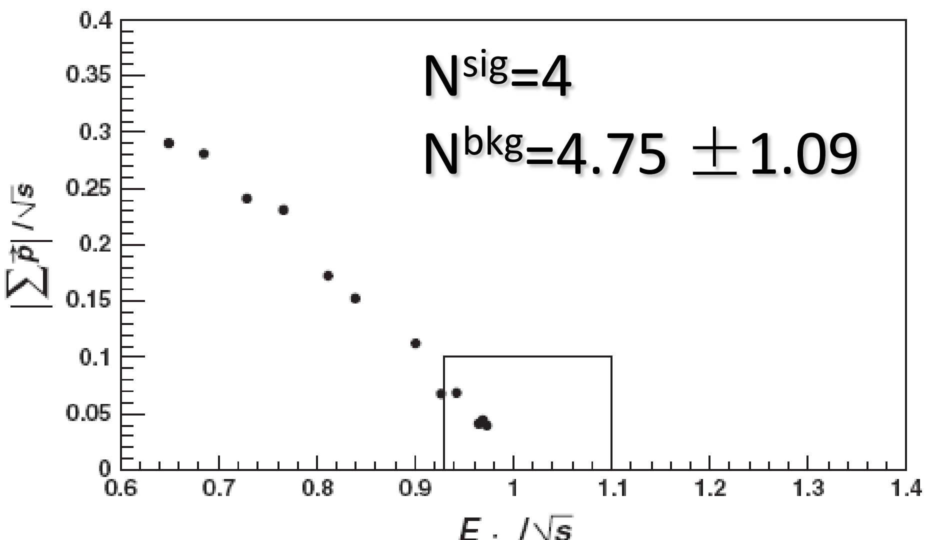
Lepton flavor violation decays

$2.25\times10^{8}\ J/\psi$



PRD 87, 112007





$N^{sig}=4$

$N^{bkg}=4.75\pm1.09$

$$Br(J/\psi\to e\mu)<1.6\times10^{-7}$$

$<1.1\times10^{-6}$

(best results before)

Discussion and outlook

- BESIII collaboration has performed dedicated studies on charmonium rare decays and the best upper limit branching fractions (@90% C.L.) of the world are obtained (some first searches), with 225M J/ψ and 106 M ψ(3686). There are:

$$Br(J/\psi \to D_s^- e^+ \nu_e + c.c.) < 1.3\times10^{-6} \qquad < 3.6\times10^{-5}$$

$$Br(J/\psi \to D_s^{*-} e^+ \nu_e + c.c.) < 1.8\times10^{-6}$$

$$Br(J/\psi \to D_s^- \rho^+) < 1.3\times10^{-5}$$

$$Br(J/\psi \to \bar{D}^0 \bar{K}^{*0}) < 2.5\times10^{-6}$$

$$Br(J/\psi \to \gamma\gamma) < 2.7\times10^{-7} \qquad < 5\times10^{-6}$$

$$Br(J/\psi \to \gamma\phi) < 1.4\times10^{-6}$$

$$Br(J/\psi \to e\mu) < 1.6\times10^{-7} \qquad < 1.1\times10^{-6}$$

The red numbers show the best results before and others are first measurements.

- 1.3 B J/ψ and 0.5B ψ(3686) events has been collected with BESIII and more searches of charmonium rare decays with better precision can be obtained in near future.

Thanks for your attention!