Recent Charmonium rare decays at BESIII

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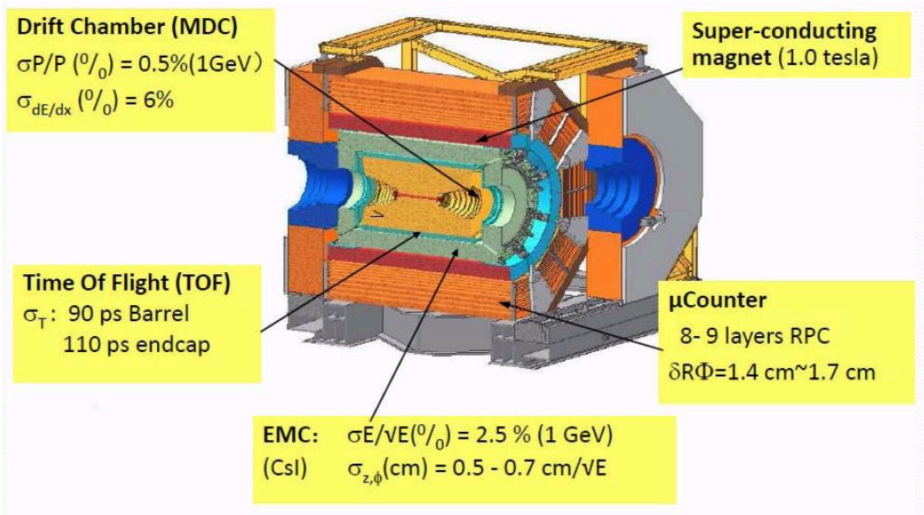
Outline

- Introduction
- Attempt to search rare decays at BESIII
  - Search for rare decay of $\psi(3686) \to \Lambda_c^+ \bar{p}\, e^+ e^-$ + c.c.
  - Search for $J/\psi \to e\tau, \tau \to \mu\nu_\mu\nu_\tau$ and $J/\psi \to \mu\tau, \tau \to e\nu_e\nu_\tau$
- Summary

Introduction

- The huge J/ψ and $\psi(3686)$ data sample collected at BESIII provides an unique opportunity to check SM and look for new physics.
- Measurement in low energy region is complementary to that of high energy colliders.

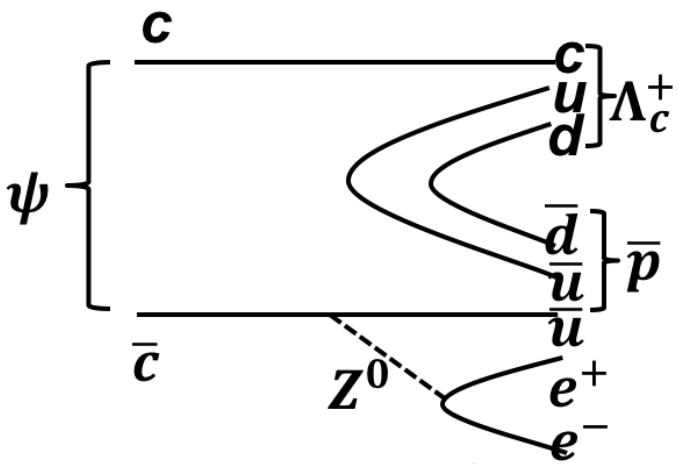


Search for rare decay of $\psi(3686) \to \Lambda_c^+ \bar{p}\, e^+ e^-$ + c.c.

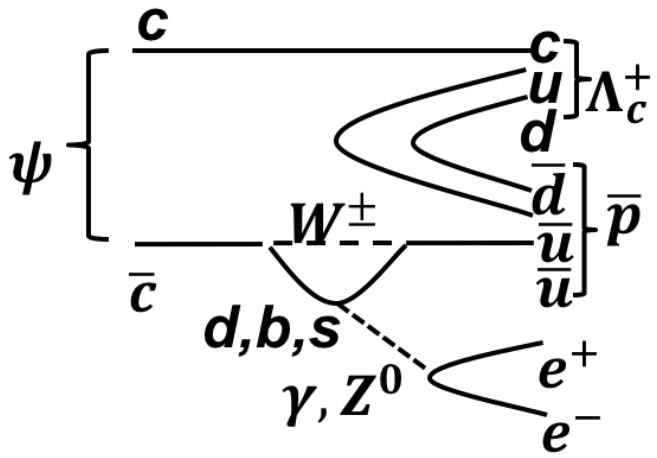
Introduction

- FCNC process is suppressed due to GIM mechanism.
- Experimental test of $\psi(3686) \to \Lambda_c^+ \bar{p}\, e^+ e^-$ + c.c. can be served as a probe for GIM mechanism. *Phys. Rev. D 2, 1285 (1970).*
- Search for new physics beyond SM; In new physics, the BR can be greatly enhanced by several orders of magnitude.

Phys. Rev. D 60, 014011(1999);
Nucl. Phys. 25, 461 (2001); *10^{-6}~10^{-5}*



Zero contribution for tree level.



Signal signature

- $\psi(3686) \to \Lambda_c^+ \, \bar{p} \, e^+ e^-$ + c.c.
  - $\Lambda_c^+ \to p \, K^- \, \pi^+$
- Final state
  - $p \, \bar{p} \, K^- \, \pi^+ (K^+ \pi^-) e^+ e^-$

Event selection (1)

- Charged tracks
  - Polar angle: $|\cos\theta|<0.93$
  - Vertex cut: $|V_z|<10$ cm and $|V_r|<1$ cm
  - At least 3 positive and 3 negative charged tracks are required.
  - Net charge is required to be zero.
- PID
  - Each track is identified with the highest probability (e, π, K, p).
- Good photons
  - Energy cut: >25 MeV for barrel ($|\cos\theta|<0.8$) and >50 MeV for end-cap ($0.86<|\cos\theta|<0.92$)
  - TDC cut: [0, 14] in the unit of 50 ns
  - $\theta \geq 10^{\circ}$ or $\geq 30^{\circ}$ for $\bar{p}$

Event selection (2)

- Vertex fit
  - Successful
- 4C kinematic fit
  - Successful
- Require $M(\bar{p}\pi^+)$>1.13 GeV and $M(p\pi^-)$> 1.13 GeV to remove background with Λ particle
- χ^2 cut
  - No requirement.
- Study on Λ_c^+ mass distribution
  - Define 2.25$\leq m(\Lambda_c^+) \leq$2.32 GeV as signal region (>99%).

Background Study

- 29 events are remained after 4C kinematic fit using the inclusive MC sample of 506 M events.
- Most of the background contain Λ or $\overline{\Lambda}$ particle.
- To further remove the background, we
  - Remove events via Λ mass requirement $M(\bar{p}\pi^+)$>1.13 GeV and $M(p\pi^-)$> 1.13 GeV

Continuum background

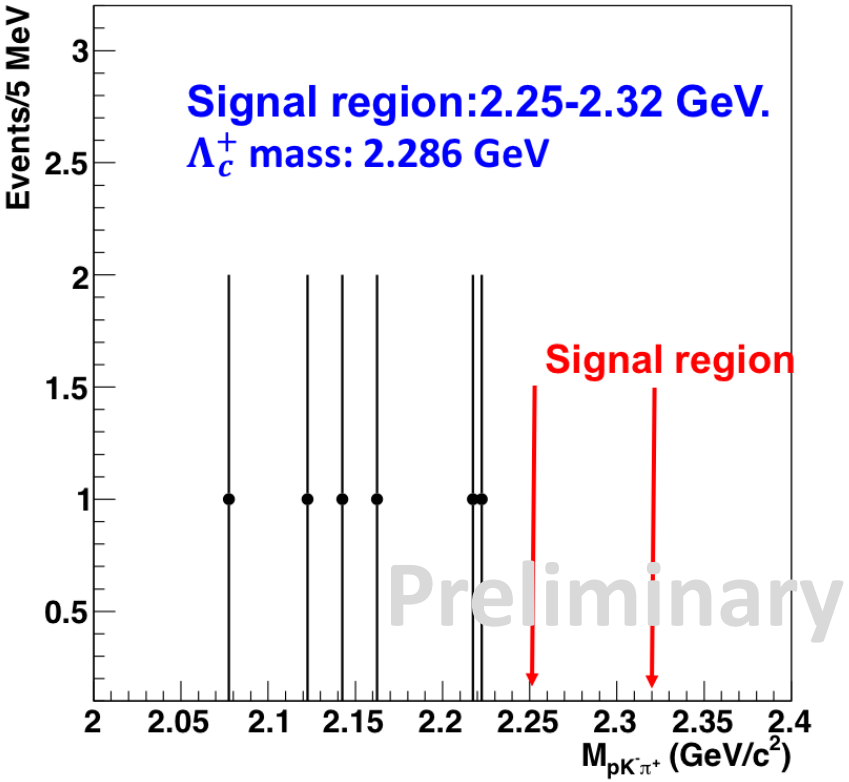
- No event survives in 3.65 GeV continuum sample of 44 pb^{-1}.
- No event survives in $\psi(3770)$ data with 2.92 fb^{-1}

Scale factor $f = \frac{L_{3686}\times 3.77^2}{L_{3770}\times 3.686^2}$=0.25; where L_{3686}=670 pb^{-1}.

$$\sigma \propto \frac{1}{s}$$

- Hence, the continuum background in the $\psi(3686)$ data is negligible.

Result



- Rolke Method is used to calculate the upper limit (N_{up}=45.8) by taking into account the efficiency and systematic uncertainty.

Nucl. Instrum. Methods A 551 (2005) 493– 503.

- The BF upper limit @90% C.L. is determined to be 1.6×10^{-6}

Systematic uncertainty due to physics model

- To estimate the systematic uncertainty due to the physics model, we use
  - PHSP model: efficiency difference is 8.3% (7.2%→6.6%)
  - Extreme case: $\psi(3686) \to X\,\bar{p}$, which follows an angular distribution of $1+\cos^2\theta$; and X has a large width of 500 MeV; $X \to \Lambda_c^+ e^+ e^-$ with VMD model, where e^+e^- decays from a virtual photon. Efficiency difference is large, i.e. 34.3% (7.2%→4.7%), which is mainly due to geometry setting and low moment of e^+e^-.

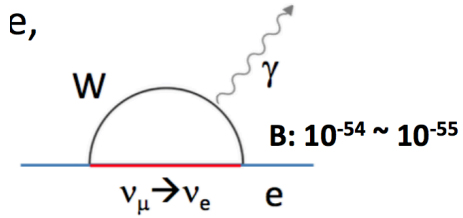
Sectional Summary

- The upper limit on the BR of $\psi(3686) \rightarrow \Lambda_c^+ \bar{p}\, e^+ e^-$ is set to be 1.6×10^{-6} for the first time.
- The result is within the framework of standard model.
- No new physic is found.

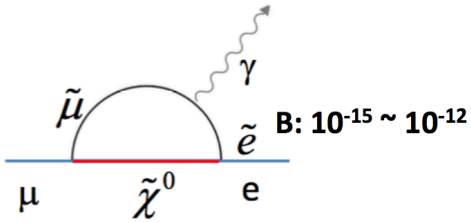
Search for $J/\psi \to e\tau, \tau \to \mu\nu_\mu\nu_\tau$ and $J/\psi \to \mu\tau, \tau \to e\nu_e\nu_\tau$

Introduction

- The non-zero neutrino masses and mixing can introduce flavor transitions, but the expected branching fractions are at an extremely rare level. For example, with the present knowledge on neutrino mixing parameters, the branching fraction of the cLFV process $\mu \rightarrow e\gamma$ is only about 10^{-55}.



- SM prediction
- SM + ν oscillation



- Beyond SM (e.g. SUSY)

- Thus, searching for the cLFV events which are SM forbidden would be clear signal of physics beyond the SM.

BESIII previous lepton flavor violation results

Decay mode	BESII upper limit	BESIII upper limit	Other experiment
$J/\psi \rightarrow e\mu$	1.1×10^{-6} (58M)	1.6×10^{-7} (225M)	-
$J/\psi \rightarrow e\tau$	8.3×10^{-6} (58M)	-	-
$J/\psi \rightarrow \mu\tau$	2.0×10^{-6} (58M)	-	-

With 225M J/ψ data

Phys. Rev. D 87 (2013) 112007

$$\mathcal{B}(J/\psi \rightarrow e\mu)^{\text{sensitivity}} < N_{obs}^{UL}/(N_{J/\psi}\epsilon) < 1.6\times10^{-7}@90\%\ C.L.$$

where N_{obs}^{UL} is calculated based on the POLE program which is a Feldman-Cousins method including the number of background events and its uncertainty, and the systematic uncertainties

Prospect for $J/\psi \to e\tau$ and $J/\psi \to \mu\tau$ at BESIII

- $J/\psi \to e\tau, \tau \to \mu\nu_\mu\nu_\tau$ and $J/\psi \to \mu\tau, \tau \to e\nu_e\nu_\tau$ with 1300M J/ψ data
- Event topology: two opposite charged tracks, two missing tracks
- Most of the backgrounds are from $J/\psi \to \pi^+K_LK^-, J/\psi \to K_LK_L, J/\psi \to K^{*0}K^0$
- Simulated based on BESIII software and hardware systems, the detection efficiency is estimated to be 14% after background suppression

$$\mathcal{B}(J/\psi \to e\tau)^{\text{sensitivity}} < N_{obs}^{UL}/(N_{J/\psi}\epsilon) < 6.3\times10^{-8}@90\%\ C.L.$$

$$\mathcal{B}(J/\psi \to \mu\tau)^{\text{sensitivity}} < N_{obs}^{UL}/(N_{J/\psi}\epsilon) < 7.3\times10^{-8}@90\%\ C.L.$$

where N_{obs}^{UL} is calculated based on the POLE program which is a Feldman-Cousins method including the number of background events and its uncertainty, and the systematic uncertainties is assumed to be 5%, where the number of observed events is set to be zero.

Sectional summary

- Better upper limits on $J/\psi \to e\tau$ and $J/\psi \to \mu\tau$ based on 1300M J/ψ events are coming soon.
- New data taking plan has been approved! Better constraints can be expected.

Summary

- With The huge J/ψ and $\psi(3686)$ data sample collected at BESIII, we have searched for one rare charmonium decay $\psi(3686) \to \Lambda_c^+ \bar{p}\, e^+ e^-$ + c.c.
- No obvious signal is found and the upper limits are provided.
- We also discuss the opportunity to search $J/\psi \to e\tau$ and $J/\psi \to \mu\tau$ at BESIII.
- New data taking plan of J/ψ has been approved, better constraints even maybe signal of new physics are expected!

Thanks!