Charmonium rare decays at BESIII

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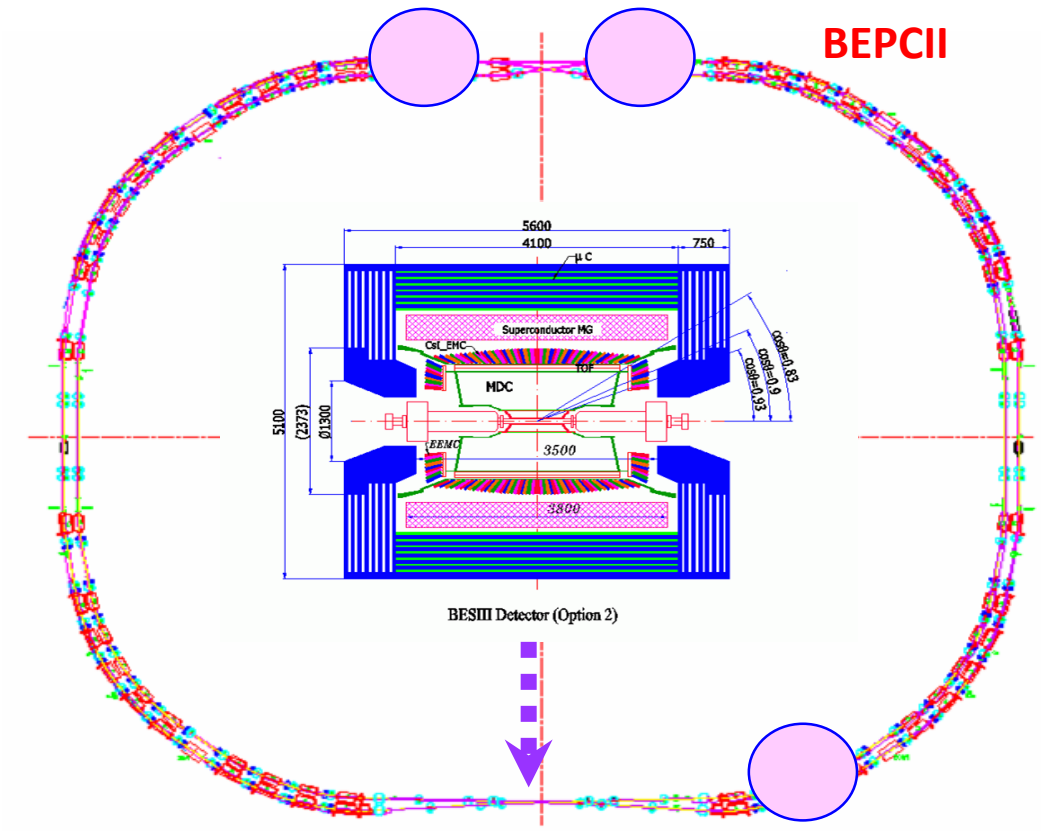
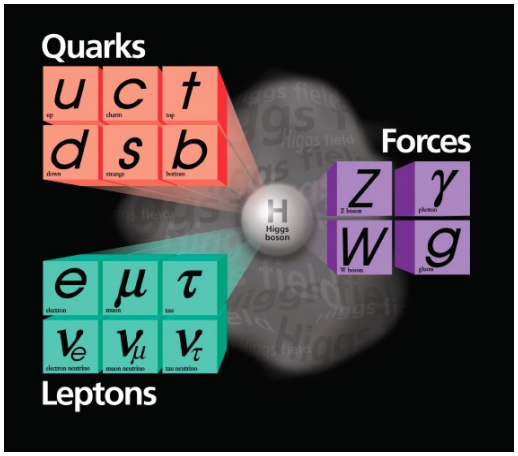
BEPCII/BESIII





MDC: σ_{xy}=130 μm, dE/dx=6%
σ_p/p = 0.5% at 1 GeV

TOF:
Plastic scintillator :σ_T(barrel): 80 ps
MRPC: σ_T(endcap): 70 ps

EMC: CsI(Tl)

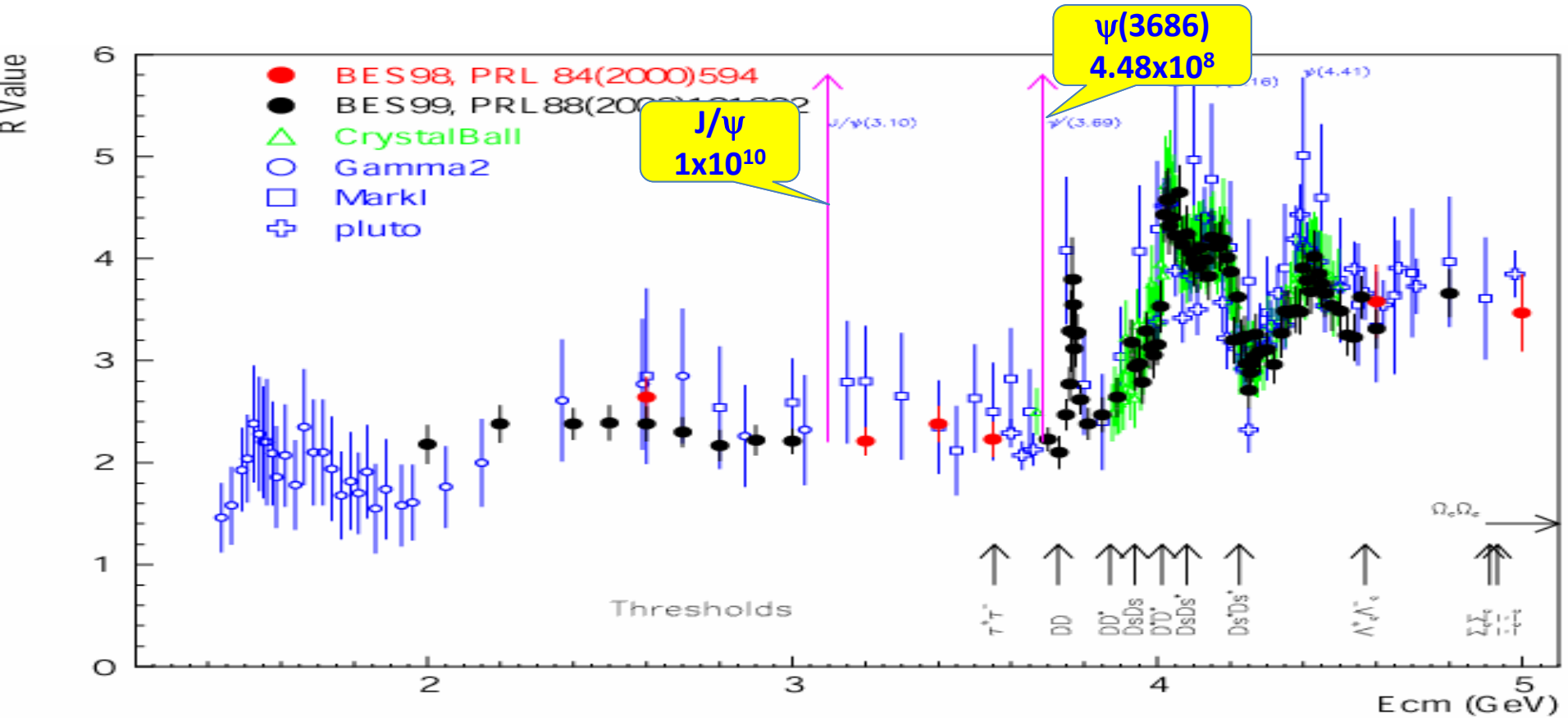
At 1 GeV	σ_E (%)	σ_l(mm)
Barrel:	2.5	6.1
Endcap:	5	9

MUC: $\sigma_{spatial}$: 1.48 cm

The BEPCII has achieved the designed luminosity 1×10^{33} $cm^{-2}s^{-1}$ at Apr. 2016.

Data samples at BESIII

World largest charmonium data sets directly produced from e^+e^- collision on J/ψ and ψ(3686) resonance, large data sets taken at center-of-mass energies 3.773 , 4.008, 4.18 ….. GeV



Charmonium rare decay topics

OZI suppressed Weak semileptonic decay

Inclusive weak decay via single quark decay: ~(2-4)×10^{-8}

Z.Phys.C.62.271

Predicted Br(J/ψ→D$_{(s)}^{(*)}$*l*ν) : ~(0.01-4)×10^{-9}

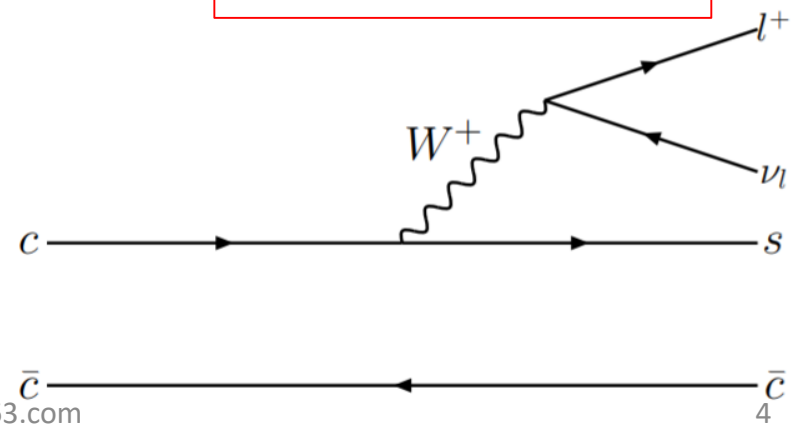
SU(3) symmetry : $\frac{Br(J/\psi\to D_s^- l^+ \nu)}{Br(J/\psi\to D^- l^+ \nu)} = \frac{Br(J/\psi\to D_s^{*-} l^+ \nu)}{Br(J/\psi\to D^{*-} l^+ \nu)} = \frac{|V_{cs}|^2}{|V_{cd}|^2} \approx 18.4$

QCD sum rule: $\frac{Br(J/\psi\to D_s^- l^+ \nu)}{Br(J/\psi\to D^- l^+ \nu)} = 24.7$ $\frac{Br(J/\psi\to D_s^{*-} l^+ \nu)}{Br(J/\psi\to D^{*-} l^+ \nu)} \approx 15.1$

QCD sum rule: $\frac{Br(J/\psi\to D_s^{*-} l^+ \nu)}{Br(J/\psi\to D_s^- l^+ \nu)} = 3.1$

HQSS: $\frac{Br(J/\psi\to D_s^{*-} l^+ \nu)}{Br(J/\psi\to D_s^- l^+ \nu)} = 1.6$

See more in Aloni's talk



BR can be enhanced in MSSM, two higgs-doublet model, top-color model…

Charmonium rare decay topics

FCNC Weak semileptonic decay

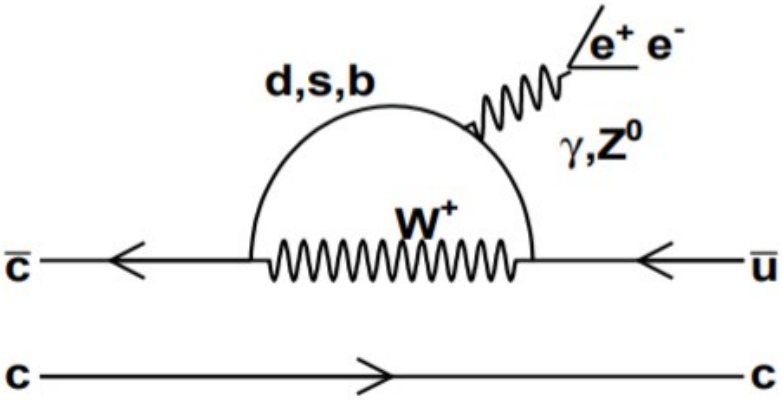
Forbidden at tree level by GIM mechanism

QCD sum rule:

$$Br(J/\psi \to \bar{D}^0 l^+ l^-) \sim 10^{-14}$$
$$Br(J/\psi \to \bar{D}^{*0} l^+ l^-) \sim 10^{-13}$$

New physics: 10^{-5} ~ 10^{-6}

PRD 60 014011

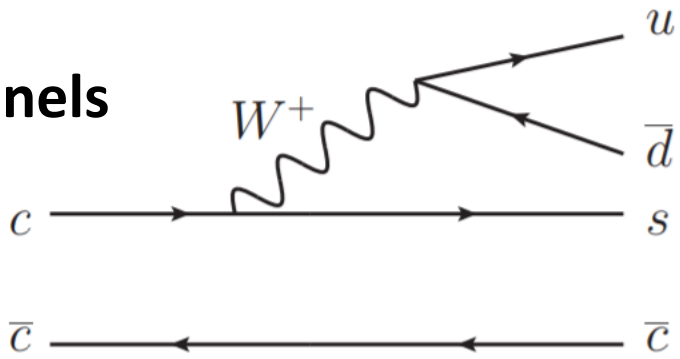


Promising to constraint on new physics models

Charmonium rare decay topics

Weak hadronic decay

Same motivation as semileptonic channels



predictions from HQSS, light-front quark model, factorization approach (in 10^{-10})

Decay mode	AHEP 706543	PRD 78 074012	EPJC 55 607	IJMPA 14 937
$\psi \to D_s^- \pi^+ + c.c.$	7.36	2.5	2.0	8.7
$\psi \to D^0 K^0 + c.c.$	1.39	0.5	0.36	2.8
$\psi \to D_s^- \rho^+ + c.c.$	50.0	28.0	12.6	36
$\psi \to D_s^{*-} \rho^+ + c.c.$	-	-	52.6	-
$\psi \to D^0 K^{*0} + c.c.$	8.12	5.5	1.54	10.27
$\psi \to D_s^- K^{*+} + c.c.$	2.79	-	0.82	2.12
$\psi \to D^+ \rho^- + c.c.$	2.13	-	0.42	2.20
$\psi \to D_s^- K^+ + c.c.$	0.53	-	0.16	0.55
$\psi \to D^+ \pi^- + c.c.$	0.29	-	0.08	0.55

The ratios also predicted and testable

Most promising

Others:

$\psi \to \Lambda_c^+ \bar{\Sigma}^- + c.c.$

Charmonium rare decay topics

Invisible decay

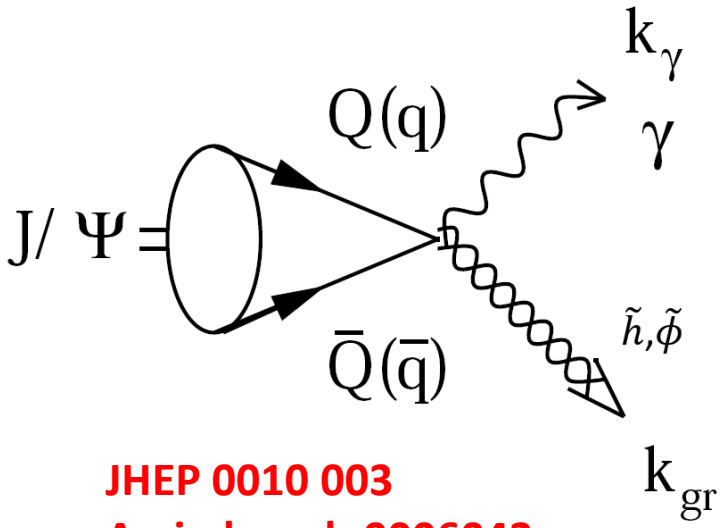
SM predict: $\frac{\Gamma(J/\psi\to\nu\bar{\nu})}{\Gamma(J/\psi\to e^+e^-)}=\frac{27G^2M_{J/\psi}^4}{256\pi^2\alpha^2}(1-\frac{8}{3}sin^2\theta_W)^2$=4.54×$10^{-7}$

Predicted accessible light dark matter particles masses at BESIII, candidates for nonbaryonic dark matter of the universe, if couple to the SM via a new light gauge boson U, or exchange heavy fermions

J/ψ→γ+missing energy

Large extra dimension scenario,
Signals in K and π decays are small,
while large in quarkonium decays

$Br(J/\psi\to\gamma+\tilde{h},\tilde{\phi})=10^{-5}$



JHEP 0010 003
Arxiv-hepph:0006042

Charmonium rare decay topics

Charge-Lepton Flavor Violating decays

Neutrino oscillation violates neutral lepton flavor,
CLFV involving massive neutrino is very tiny, ideal place to probe new physics, predicted by many theoretical modes,
Such as unparticle model, R-parity violating and large tanβ SUSY, leptoquarks ….

See more in Alexey's talk

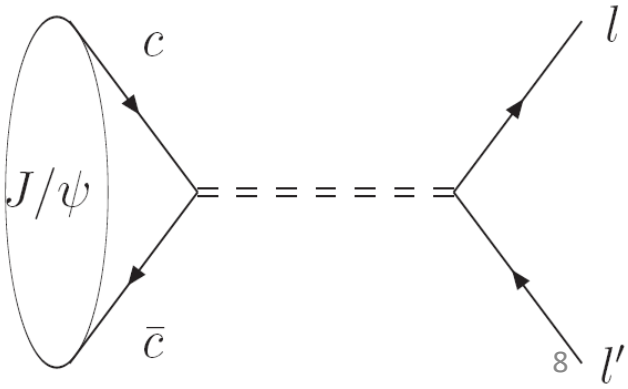
Unparticle model

$$\mathcal{M}(J/\psi(P) \to l(k)l'(k')) = \frac{c_{VV}^{cc} c_{VV}^{ll'}}{\Lambda_U^{2d_U-2}} \frac{A_{d_U} dy}{2sind_U\pi} \frac{m_\psi f_\psi}{s^{2-d_U}} \epsilon_\psi^\mu \bar{u}(k)\gamma_\mu v(k')$$

$choose\ d_U$=1.35, $\Lambda_U = 1$ TeV,

$c_{VV}^{cc} c_{VV}^{ll'}$=0.01

Predicted: $Br(J/\psi \to e\mu) = 7 \times 10^{-8}$



Charmonium rare decay topics

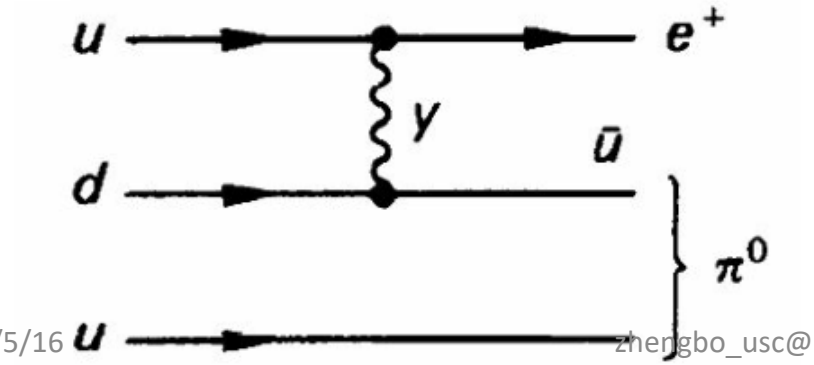
Baryon/Lepton number violated decay

Many SM extensions and GUTs predict proton decays. In this case, baryon number is violated while Δ(B-L) is conserved

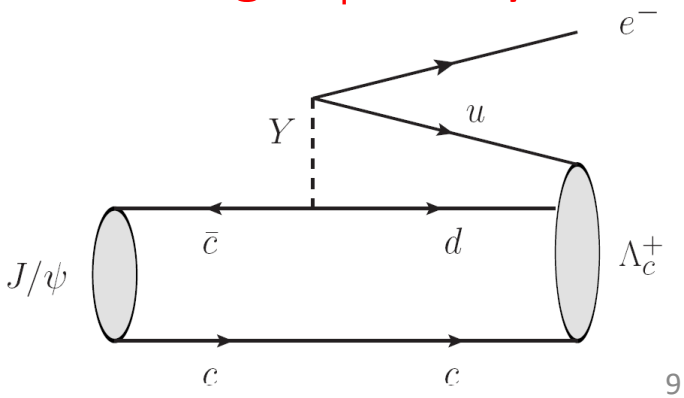
Large matter-antimatter asymmetry observed in the universe, and negative proton decay experimental results, inspire many searches/predicts on BNV

Models: mirror-matter model, flavor model, new gauge boson mechanism…..

Proton decay



Analog J/ψ decay



Charmonium rare decay topics

C, P, CP violated decay

C, P, CP violating processes in J/ψ decays is approaching with high statistic J/ψ sample at BESIII, which can be used to test the SM and uncover deviations.

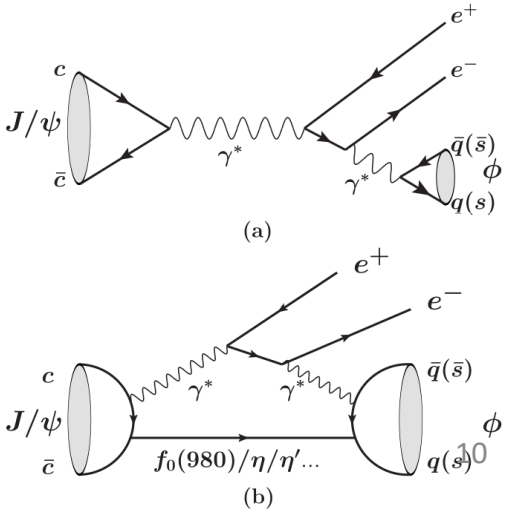
take $J/\psi \to \phi\phi$ as example

$$\frac{\Gamma(J/\psi \to s\bar{s})_{W-\text{exchange}}}{\Gamma(J/\psi \to e^+e^-)} = \frac{1}{2}\left(\frac{M_{J/\psi}}{M_W}\right)^4 \cong 10^{-6}$$

Searches for $J/\psi \to V_1V_2$ (V=γ, ω, ρ, ϕ …) are feasible at BESIII

Suppressed EM decay

$$\mathcal{M}_{EM} = \bar{u}(p_1)[(-ie\gamma^\nu)\frac{\not{p}_2+\not{p}_\phi+m_e}{(p_2+p_\phi)^2-m_e^2}(-ie\gamma^\mu) + (-ie\gamma^\mu)\frac{-(\not{p}_1+\not{p}_\phi)+m_e}{(p_1+p_\phi)^2-m_e^2}(ie\gamma^\nu)]v(p_2)\frac{1}{q_\phi^2}g_{\phi\gamma}\varepsilon_\phi^\mu\frac{1}{p_\psi^2}g_{\psi\gamma}\varepsilon_\psi^{*\nu}$$



Predicted: $Br(J/\psi \to \phi e^+e^-) = 2.26 \times 10^{-8}$

Searches at BESIII

Topics	Channels	Publications
Weak decay (FCNC)	$J/\psi \to D_s^- e^+ \nu$ $J/\psi \to D_s^{*-} e^+ \nu$ $J/\psi \to \bar{D}^0 e^+ e^-$ $\psi(3686) \to \bar{D}^0 e^+ e^-$ $\psi(3686) \to \Lambda_c^+ \bar{p} e^+ e^-$ $J/\psi \to D_s^- \rho^+$ $J/\psi \to D^0 K^{*0}$	PRD 90 112014 PRD 96 111101 PRD 97 091102 PRD 89 071101
CLFV	$J/\psi \to e\mu$	PRD 87 112007
BNV	$J/\psi \to \Lambda_c^+ e^-$	PRD 99 072006
Rare EM	$J/\psi \to \phi e^+ e^-$	PRD 99 052010
C/P/CP	$J/\psi \to \gamma\gamma, \gamma\phi$ $J/\psi \to K_S^0 K_S^0$	PRD 90 092002 PRD 96 112001
Invisible	$J/\psi \to$invisible	Ongoing

Many other analysis are ongoing,
charge conjugation is implied.

Searches at BESIII

Topics	Channels	Publications
Weak decay (FCNC)	$J/\psi \to D_s^- e^+ \nu$ $J/\psi \to D_s^{*-} e^+ \nu$ $J/\psi \to \bar{D}^0 e^+ e^-$ $\psi(3686) \to \bar{D}^0 e^+ e^-$ $\psi(3686) \to \Lambda_c^+ \bar{p} e^+ e^-$ $J/\psi \to D_s^- \rho^+$ $J/\psi \to D^0 K^{*0}$	PRD 90 112014 PRD 96 111101 PRD 97 091102 PRD 89 071101
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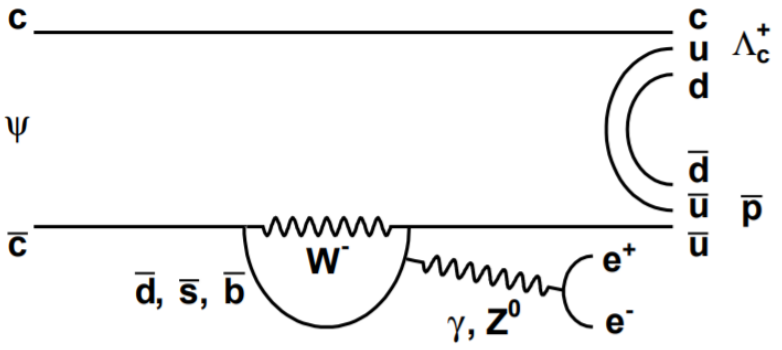
Invisible	$J/\psi \to$invisible	Ongoing

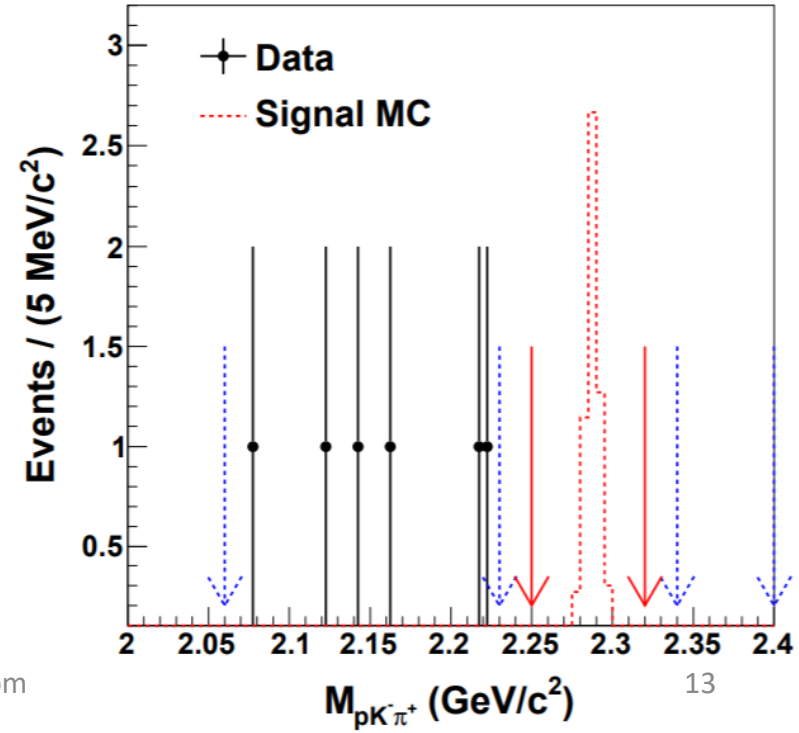
Search for $\psi(3686) \to \Lambda_c^+ \bar{p} e^+ e^-$

PRD 97 091102

- 448 million $\psi(3686)$
- First search of $\psi(3686) \to \Lambda_c^+ \bar{p} e^+ e^-$
- Check $M_{pK\pi}$ distribution, no signal is found in the signal region
- Large systematic uncertainty in MC modelling (~34%)
- Upper limits on BF (90% C.L.)

$Br(\psi(3686) \to \Lambda_c^+ \bar{p} e^+ e^-) < 1.7 \times 10^{-6}$



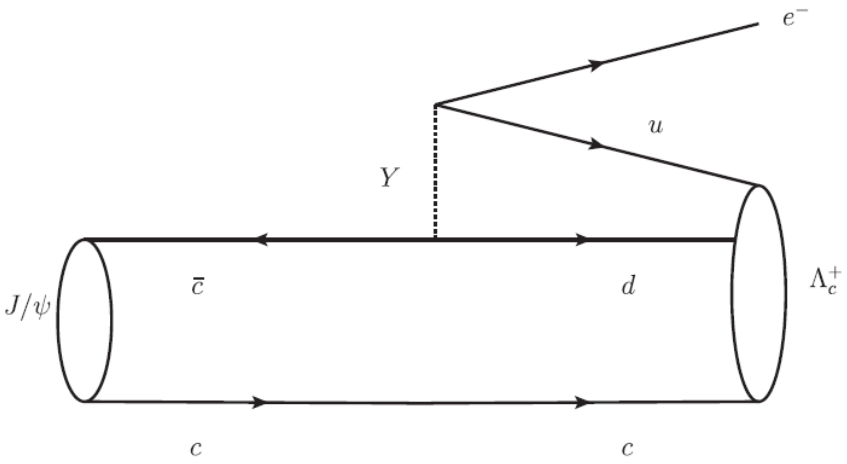


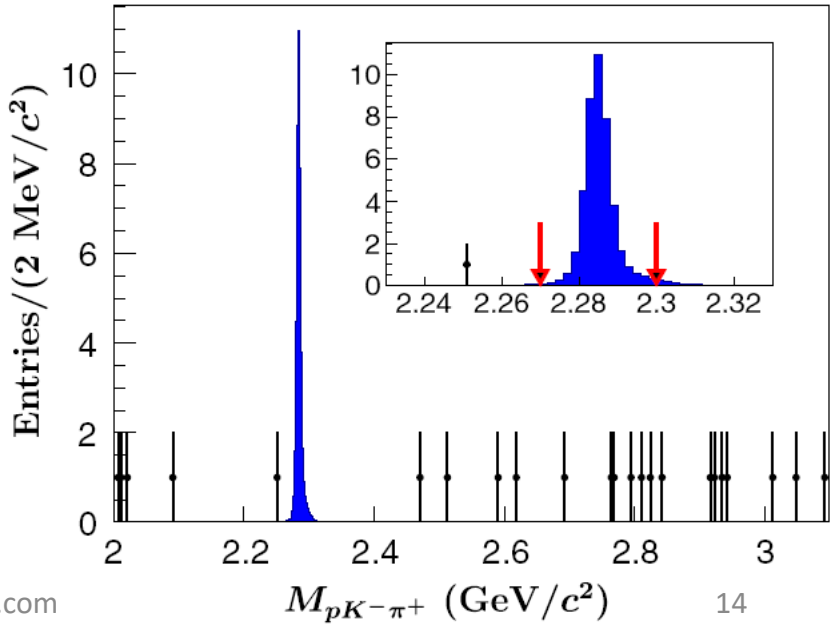
Search for $J/\psi \to \Lambda_c^+ e^-$

PRD 99 072006

- 1.3 billion J/ψ
- First search of $J/\psi \to \Lambda_c^+ e^-$
- Check $M_{pK\pi}$ distribution, no signal events in the signal region
- Total systematic uncertainty : ~7%
- Upper limits on BF (90% C.L.)

$$Br(J/\psi \to \Lambda_c^+ e^-) < 6.9 \times 10^{-8}$$





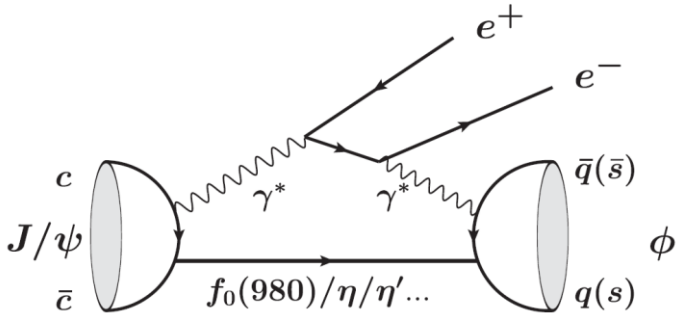
Search for $J/\psi \to \phi e^+ e^-$ via $\psi(3686) \to J/\psi \pi^+ \pi^-$

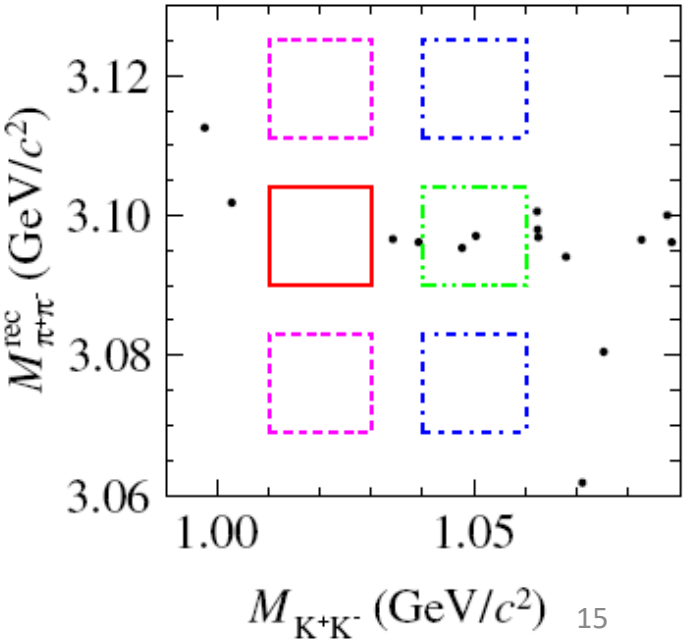
- 448 million $\psi(3686)$
- First search for new physics at EM rare decay $J/\psi \to \phi e^+ e^-$
- Check M_{KK} distribution in J/ψ signal region, no events observed in the signal region
- Total systematic uncertainty: ~9%
- Upper limits on BF (90% C.L.)

$$Br(J/\psi \to \phi e^+ e^-) < 1.2 \times 10^{-7}$$

One order higher than SM prediction in Chin. Phys. C 40 073104

PRD 99 052010





Summary

- **A brief review on the charmonium rare decay topics**
- **Summary of BESIII studies on charmonium rare decays**
- **Report three new charmonium rare decay results**

World largest e+e- collision charmonium data sets at BESIII provide opportunity to study charmonium rare decays: **high statistics, low background, close to boundary of new physics limit**

Many results are promising with currently 10 billion J/ψ and planned 3.2 billion $\psi(3686)$

Thanks for your attention!