Search for rare FCNC decays at BESIII

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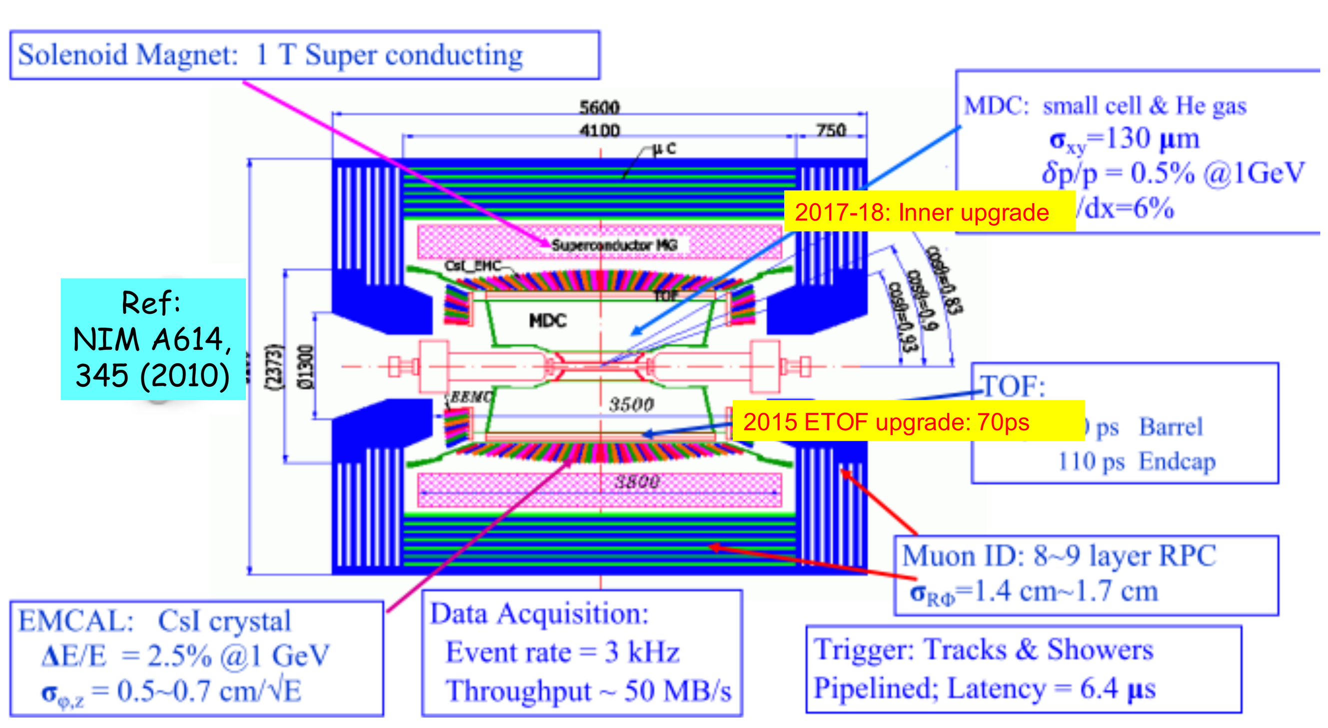
On Behalf of BESIII Collaboration

Introduction

The Flavor Changing Neutral Current decays(FCNC) is forbidden at tree level in the Standard Model (SM) due to GIM mechanism[1] and could only contribute through loops. Any direct observation beyond SM expectations could be a good probe of physics beyond SM. BESIII is a currently running tau-charm factory with the largest samples of on threshold charm meson pairs, directly produced charmonia and some other unique datasets at BEPCII collider. It has great potential to probe these FCNC decays from multiple channels. Here we present some BESIII search results of FCNC decays $J/\psi \to D0e+e-$, $\psi(3686) \to D^0e+e-$, $\psi(3686) \to \Lambda^+_c\, pe+e-$, $D \to h(h')e+e-$ etc. There are more such searches to be probed in future.

BESIII detector[2] and data sets

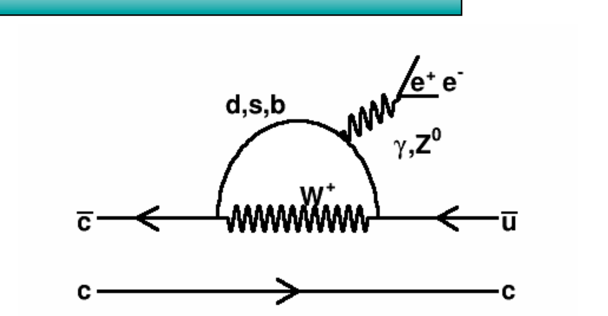
- BEPCII is the only collider currently running at τ-charm energy
- First collision in 2008, physics run started in 2009
- BEPCII reached peak luminosity of $1\text{x}10^{33}$ $cm^{-2}s^{-1}$@1.89GeV in April 2016
- BESIII collaboration includes 71 institutes worldwide, totally ~500 collaborators
- Clean environment and high luminosity at BESIII are helpful for indirect probe of new physics
- BESIII has accumulated huge datasets (those used in this presentation):
  - 1.3B J/ψ events, another 8.7B taken in 2018-2019 on tape, totally 170 times of BESII
  - 0.45B $\psi(3686)$ events , which is 24 times of CLEO_c
  - 2.9/fb at $\psi(3770)$, which is 3.5 times of CLEO↓c
  - And many more: >9/fb above 4 GeV, 3/fb Ds data at 4170 MeV, R&QCD scan data etc



J/ψ→ $D^0e^+e^-$ and ψ(3686)→ $D^0e^+e^-$ [3]

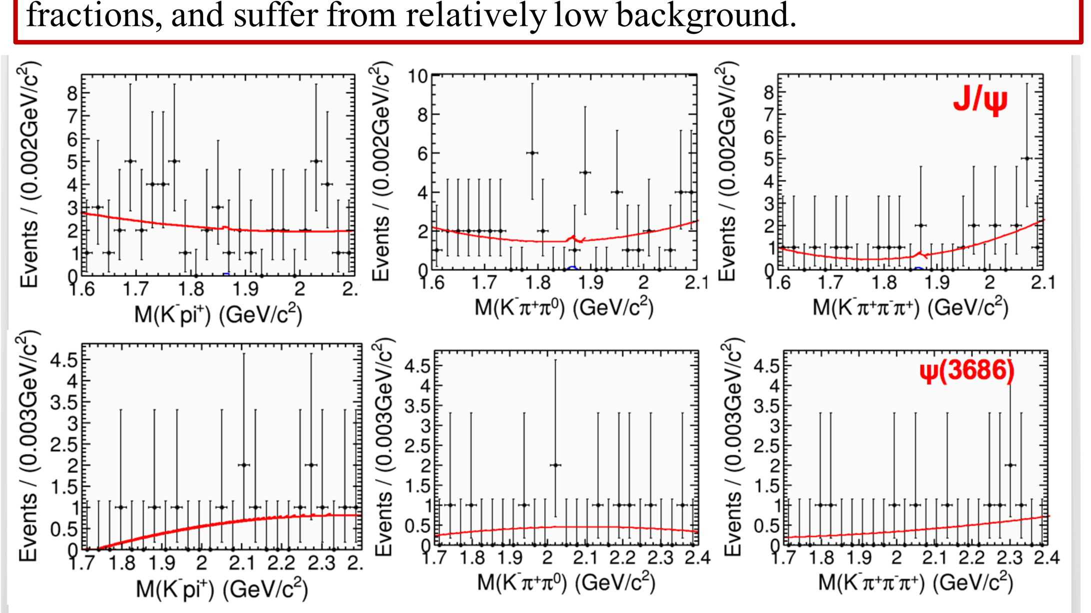
Using the data samples of 1310M J/ψ events[6] and 448M ψ(3686) events[7] collected with the BESIII detector, we search for the rare decays $J/\psi \to D^0e^+e^-$+c.c. and $\psi(3686) \to D^0e^+e^-$+ c.c.

The branching fraction for this kind of rare process is expected to be of order 10^{-10} to 10^{-13}. Some NP models could have several of magnitudes higher decay rates, which could in the reach of BESIII.

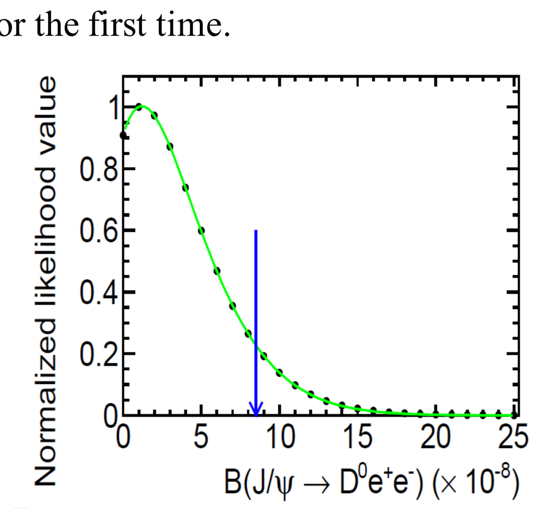


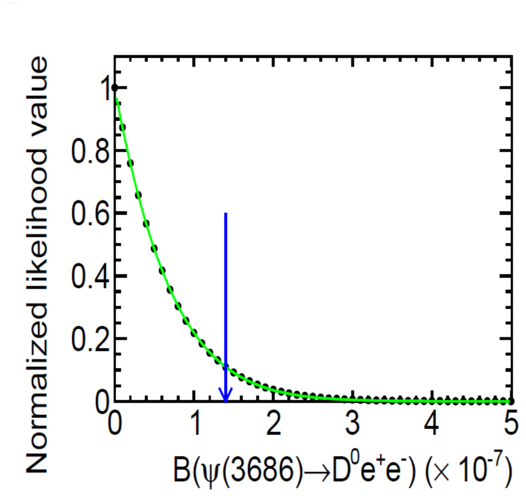
Feynman diagram of $J/\psi(\psi(3686)) \to D^0e^+e^-$

we reconstruct the D^0 signal through its three prominent exclusive hadronic decay modes, $D^0 \to K^-\pi^+$(I), $D^0 \to K^-\pi^+\pi^0$ (II), $D^0 \to K^-\pi^+\pi^+\pi^-$ (III) These decay modes have relatively large branching fractions, and suffer from relatively low background.



No signal is observed, and we compute the upper limits(UL) on the branching fraction at the 90% C.L. using a Bayesian method with a flat prior, the correlated and un-correlated systematic uncertainties are incorporated. The results are $B(J/\psi \to D^0e^+e^-) < 8.5 \times 10^{-8}$ and $B(\psi(3686) \to D^0e^+e^-) < 1.4 \times 10^{-7}$, respectively. The limit on $B(J/\psi \to D^0e^+e^-)$ is more stringent by two orders in magnitude compared to the previous results, and the $B(\psi(3686) \to D^0e^+e^-)$ is set for the first time.



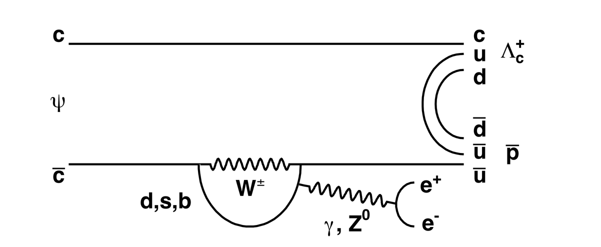


The sources of systematic uncertainty include the detection efficiencies of charged tracks and photons, the PID efficiency, the kinematic fit, γ conversion veto, mass window requirements, the fit procedure, the decay branching fractions of intermediate states, as well as the total numbers of ψ events. The individual systematic uncertainties are estimated. The sources of the uncertainties tagged with '*' are assumed to be 100% correlated among the three different D^0 decay modes.

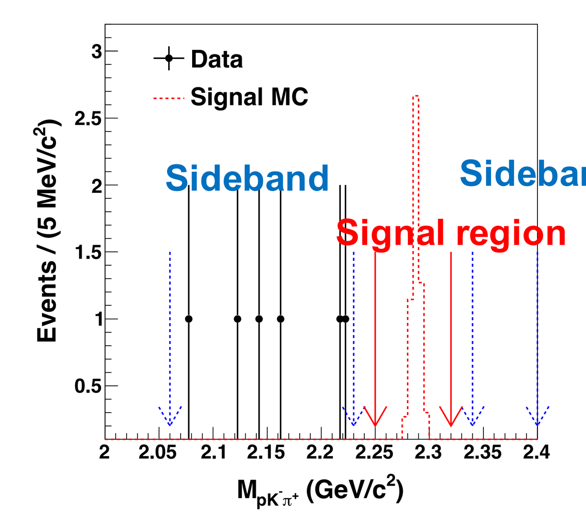
	$D^0 \to K^-\pi^+$		$D^0 \to K^-\pi^+\pi^0$		$D^0 \to K^-\pi^+\pi^+\pi^-$	
	J/ψ	$\psi(3686)$	J/ψ	$\psi(3686)$	J/ψ	$\psi(3686)$
Tracking*	4.0	4.0	4.0	4.0	6.0	6.0
PID*	6.0	6.0	6.0	6.0	8.0	8.0
γ detection	...	...	1.2	1.2	...	...
Kinematic fit	1.7	1.6	1.1	1.8	2.2	2.0
Veto γ conversion*	1.7	1.7	1.7	1.7	1.7	1.7
Veto $K_S \to \pi^0\pi^0$	...	...	0.6	...	...	
Veto $K_S \to \pi^+\pi^-$	...	...	...	...	2.1	2.2
Veto $J/\psi \to e^+e^-$	...	0.1	...	...		...
Branching fraction	1.3	1.3	3.6	3.6	2.6	2.6
ψ total number*	0.55	0.62	0.55	0.62	0.55	0.62
Others	1.0	1.0	1.0	1.0	1.0	1.0
Total	7.8	7.8	8.5	8.7	11.0	10.9

Search for $\psi(3686) \to \Lambda_c^+\, \bar{p}\, e^+e^-$ [4]

This analysis is performed with 448M ψ (3686) events [7] collected by BESIII. The decay $\Lambda^+_c \to pK^-\pi^+$ is reconstructed with six charged tracks with zero net charge. The number of signal events is determined by examining the Λ^+_c signal in the $M_{pK\pi}$ distribution



Feynman diagram of $\psi(3686) \to \Lambda_c^+\bar{p}e^+e^-$



Signal region:2.25-2.32 GeV.
Λ_c^+ mass: 2.286 GeV

sources	systematic uncertainty(%)
Number of $\psi(3686)$	0.6
Track reconstruction	9.0
Particle identification	9.0
4C kinematic fit	1.0
$BF(\Lambda_c^+ \to pK^-\pi^+)$	5.2
Signal region	4.0
Λ mass window	1.0
Physics model	34.3
Total	37.2

Physics model:
- **Nominal:**
  - **VMD model with FF from ρ → $\pi^+\pi^-e^+e^-$**
- **1)Extreme case**
  - **$\psi(2S) \to X\,\bar{p}$; $1+\cos^2\theta$**
  - **$X \to \Lambda_c^+e^+e^-$ (VMD); 7.2%→4.7%**
- **2) PHSP model. 7.2%→6.6%**

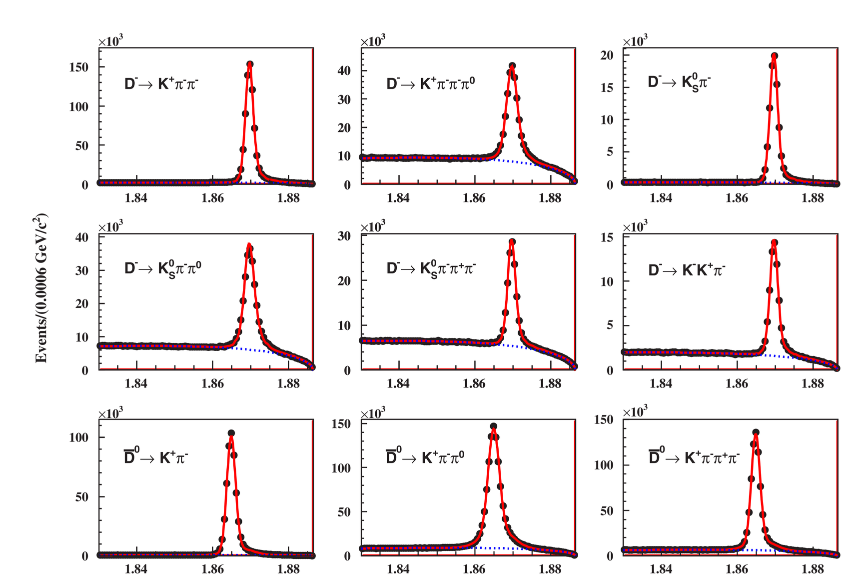
- **No signal is found.**
- **the 90% C.L. upper limit (Nup=47.3) is obtained taking into account the efficiency and systematic uncertainties.**
- **The BF upper limit @90% C.L. is determined to be 1.7×10^{-6} with systematic uncertainties taken into account.**
- **It is the first search of this process**

Search for D → h(h')ee [5]

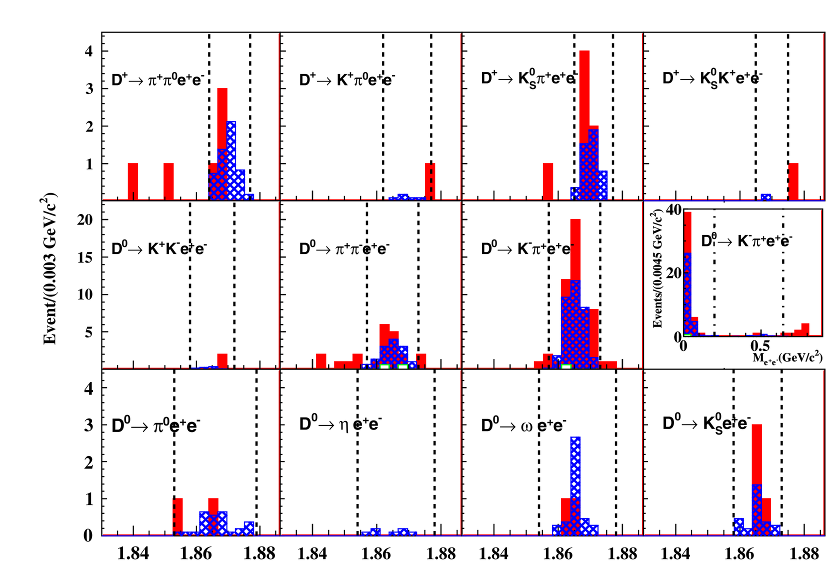
Using the 2.9fb^{-1} data taken at sqrt(s) = 3.773 GeV[8], we perform a search for the rare decays of $D \to h(h')e+e-$, where $h(')$ are hadrons. Double tagging(DT) method is used in the analysis. For each signal mode, ΔE_{sig} is required to be within 3σ of the nominal value, and only the combination with the smallest $|\Delta E_{sig}|$ is kept.

Blind analysis based on Monte Carlo (MC) simulations to validate the analysis strategy,

Data
Inclusive MC
sideband



Six ST modes used to tag D^- candidates, with $\pi0 \to \gamma\gamma$ and $K^0_S \to \pi^+\pi^-$, and three ST modes are used to tag D^0-bar. The sum of the BFs is about 27.7% for the six D^- decays, and 26.7% for the three D^0-bar decays.



Distributions of M_{BC} for the signal modes after applying all selection criteria. The inset shows the M_{ee} distribution for $D^0 \to K^-\pi^+e^+e^-$, which is divided into three regions distinguished by the dot-dashed lines

Signal decays	$\mathcal{B}$ ($\times10^{-5}$)	PDG [9] ($\times10^{-5}$)
$D^+ \to \pi^+\pi^0e^+e^-$	<1.4	...
$D^+ \to K^+\pi^0e^+e^-$	<1.5	...
$D^+ \to K^0_S\pi^+e^+e^-$	<2.6	...
$D^+ \to K^0_SK^+e^+e^-$	<1.1	...
$D^0 \to K^-K^+e^+e^-$	<1.1	<31.5
$D^0 \to \pi^+\pi^-e^+e^-$	<0.7	<37.3
$D^0 \to K^-\pi^+e^+e^{-\dagger}$	<4.1	<38.5
$D^0 \to \pi^0e^+e^-$	<0.4	<4.5
$D^0 \to \eta e^+e^-$	<0.3	<11
$D^0 \to \omega e^+e^-$	<0.6	<18
$D^0 \to K^0_Se^+e^-$	<1.2	<11
† in $M_{e^+e^-}$ regions:		
[0.00, 0.20) GeV/c^2	<3.0 ($1.5^{+1.0}_{-0.9}$)	...
[0.20, 0.65) GeV/c^2	<0.7	...
[0.65, 0.90) GeV/c^2	<1.9 ($1.0^{+0.5}_{-0.4}$)	...

- With double tag technique at threshold, both D^0 and D^+ FCNC are studied.
- UL for D^+ 4-track events are provided for 1st time
- other FCNC upper limits are greatly improved
- divide the M(ee) distribution into 3 regions for Kpiee to help separate LD effect

References

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[7] The BESIII Collaboration, Chin. Phys. C 37, 063001 (2013); Chin. Phys. C 42, 023001 (2018).
[8] BESIII Collaboration, Chin. Phys. C 37, 123001 (2013); Phys. Lett. B 753, 629 (2016).

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