D Rare/Fobidden Decays at BESIII

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(On behalf of the BESIII Collaboration)

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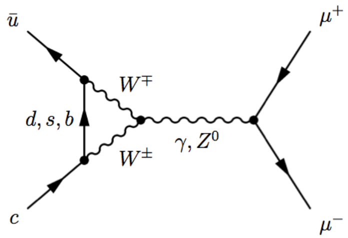
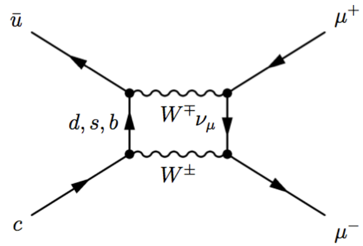
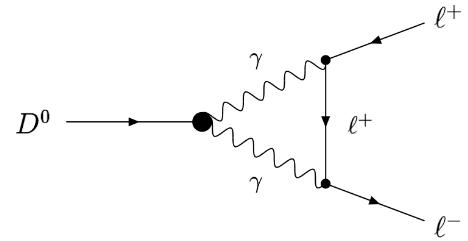
18-22 May 2014, Detroit, USA

Why rare decays so charming ?

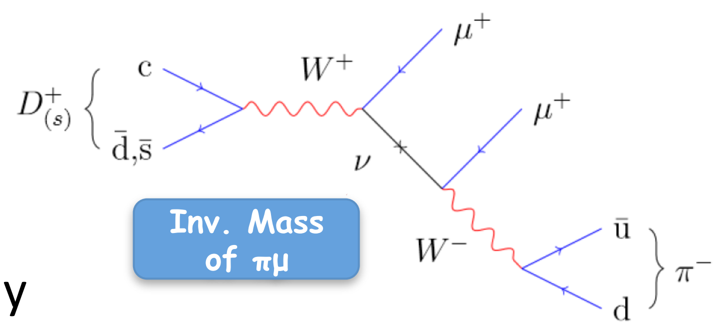
- Rare decay helps to constrain effects from New Physics
- Flavor Changing Neutral Currents (FCNC) are highly suppressed in the Standard model (SM), possibly only via loops





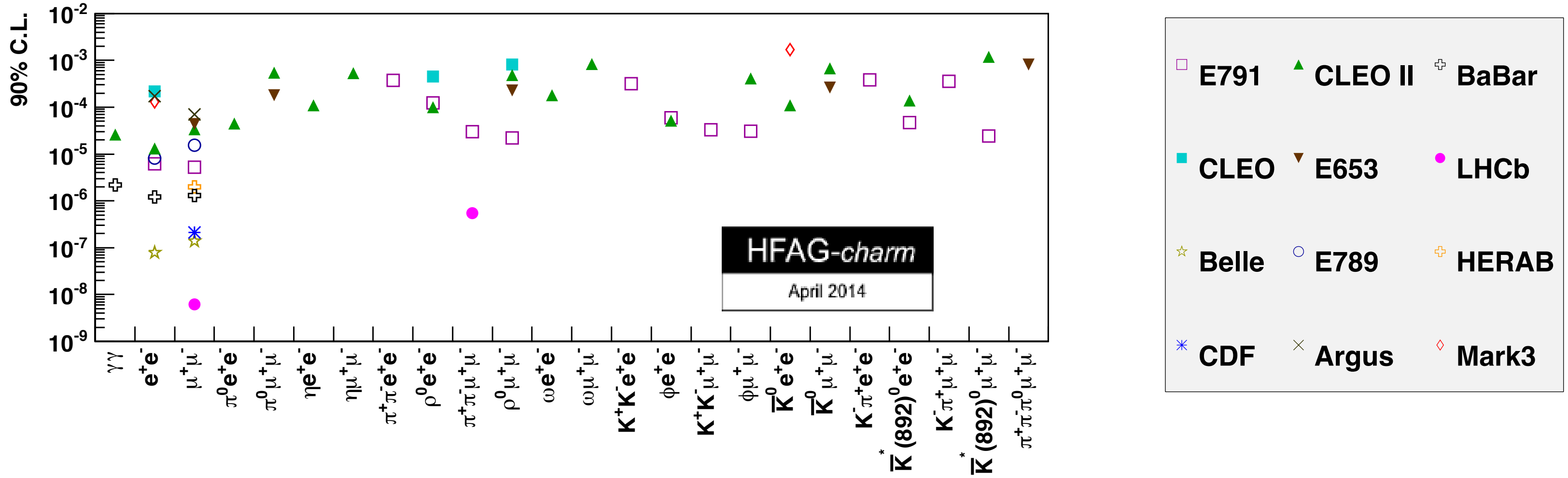


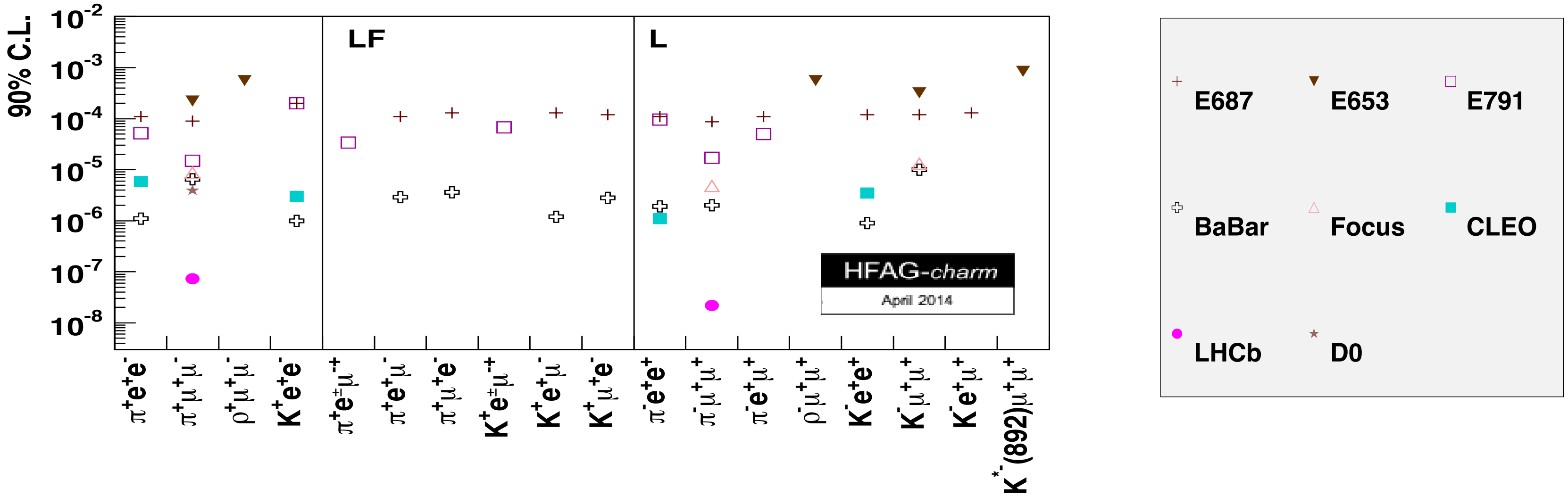
- Indirect: New particles (virtual, high mass) enter loops → enhance BFs → New Physics !
- Direct: New particles (real) can enhance BFs significantly → New Physics !



- GIM mechanism is very strong in charm decay
- Charm is complementary to the B and K sectors: it's a unique window on NP affecting the up-type quark dynamics

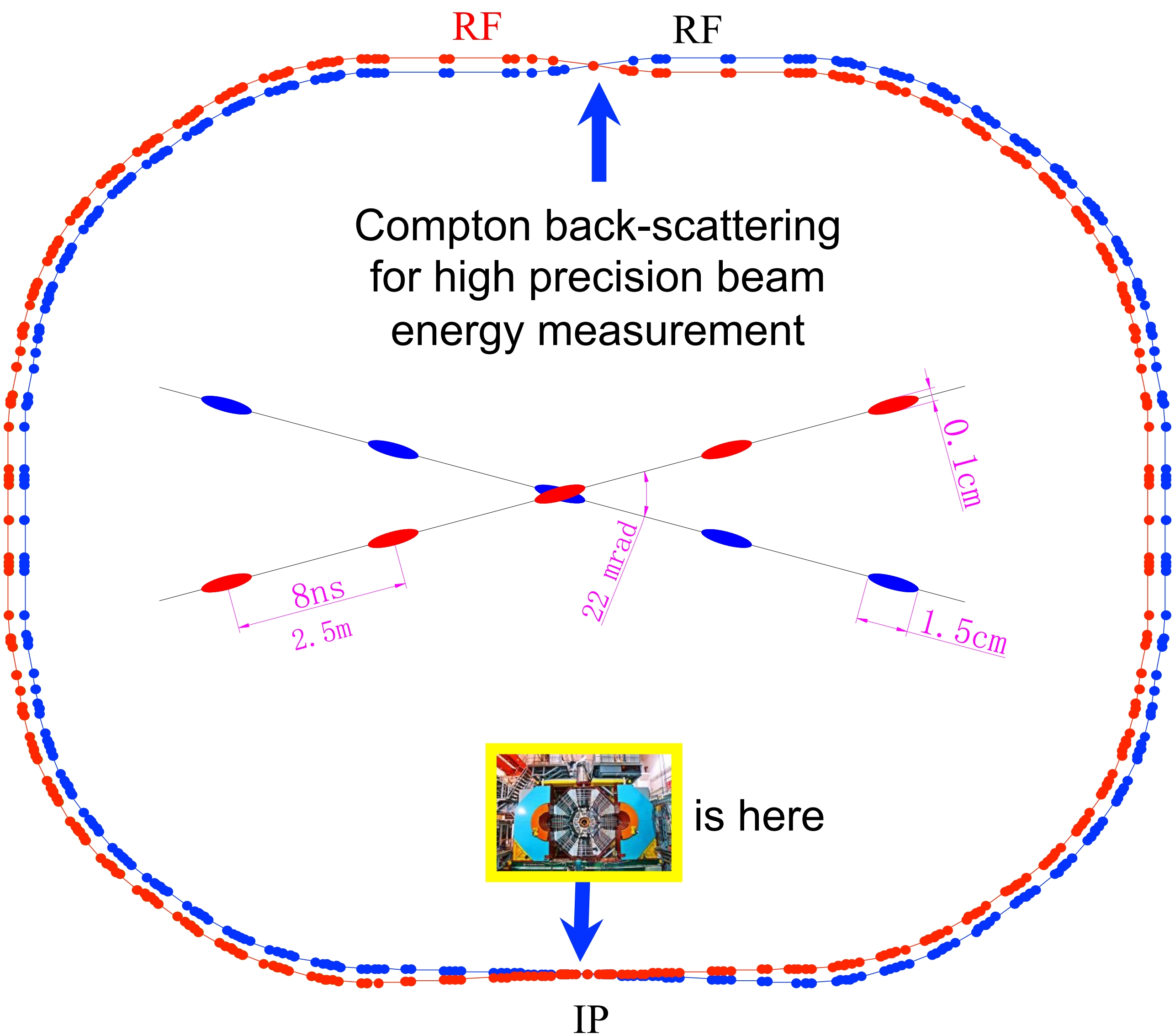
Experimental status up to 2014





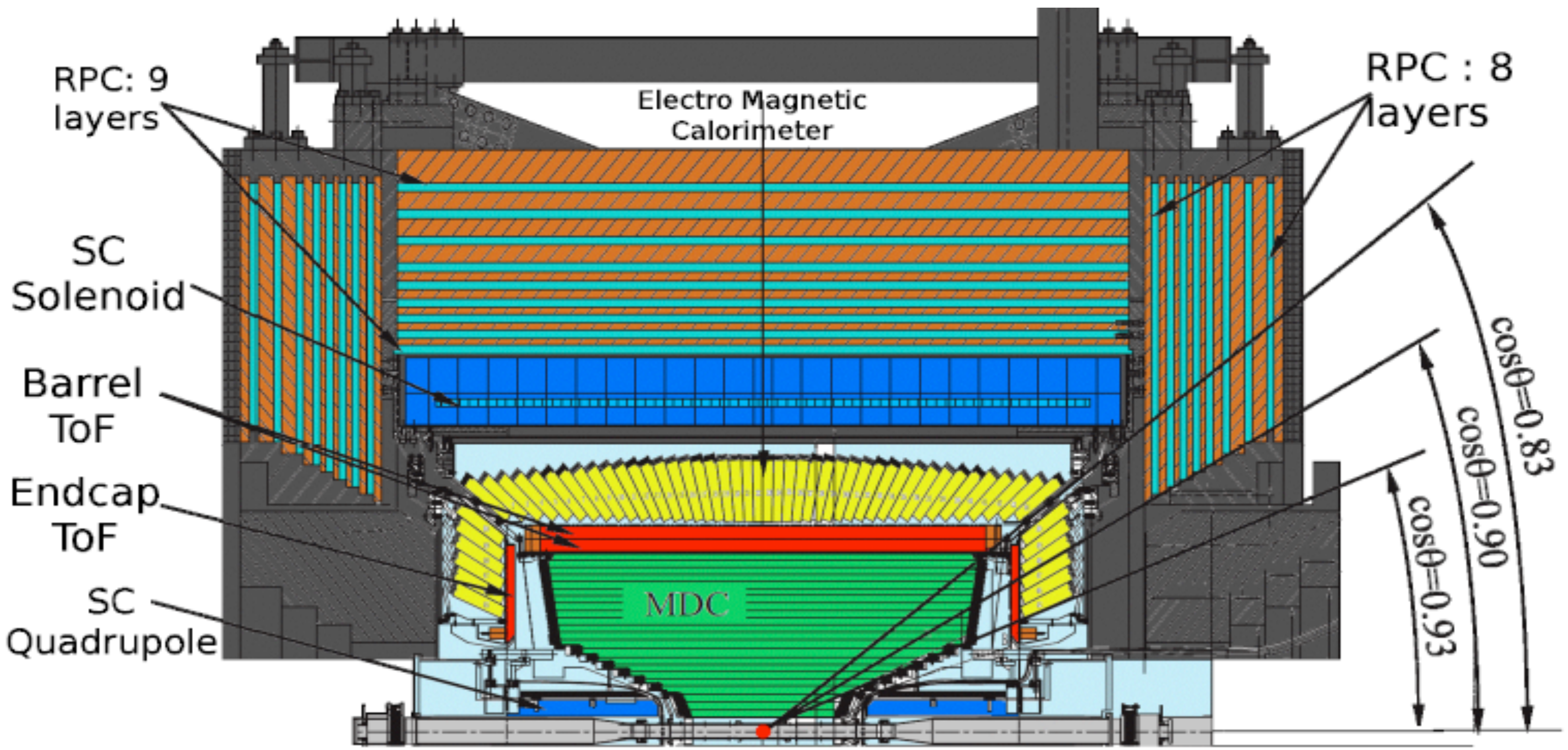
Beijing Electron Positron Collider II (BEPCII)

BEPCII: a double-ring machine



Beam energy:
1-2.3 GeV
Luminosity:
1×10^{33} cm^{-2}s^{-1}
Optimum energy:
1.89 GeV
Energy spread:
5.16×10^{-4}
No. of bunches:
93
Bunch length:
1.5 cm
Total current:
0.91 A
SR mode:
0.25A @ 2.5 GeV

BESIII Detector



Wire tracker (no Si); TOF + dE/dx for PID; CsI Ecal ; RPC muon

BESIII Collaboration

Europe (13)

Germany: Univ. of Bochum, Univ. of Giessen, GSI, Univ. of Johannes Gutenberg, Helmholtz Ins. In Mainz
Russia: JINR Dubna; BINP Novosibirsk
Italy: Univ. of Torino, Univ. of Ferrara, Frascati Lab
Netherland: KVI/Univ. of Groningen
Sweden: Uppsala Univ.
Turkey: Turkey Accelerator Center

US (5)

Univ. of Hawaii
Carnegie Mellon Univ.
Univ. of Minnesota
Univ. of Rochester
Univ. of Indiana

Korea (1)

Seoul Nat. Univ.

Japan (1)

Tokyo Univ.

Pakistan (2)

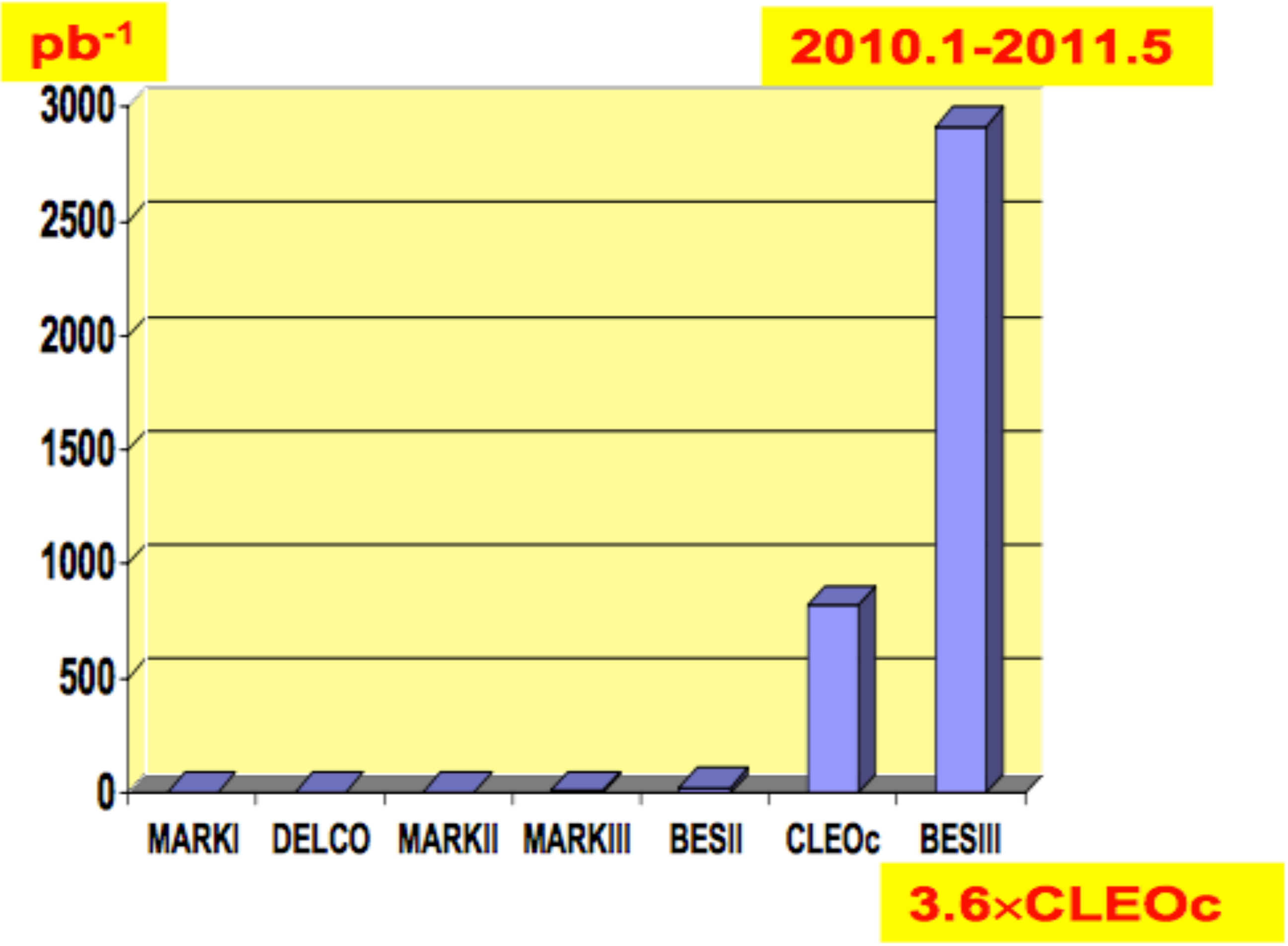
Univ. of Punjab
COMSAT CIIT

China(31)

IHEP, CCAST, GUCAS, Shandong Univ., Univ. of Sci. and Tech. of China
Zhejiang Univ., Huangshan Coll.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ. ,
Zhongshan Univ.,Nankai Univ.
Shanxi Univ., Sichuan Univ., Univ. of South China
Hunan Univ., Liaoning Univ.
Nanjing Univ., Nanjing Normal Univ.
Guangxi Normal Univ., Guangxi Univ.
Suzhou Univ., Hangzhou Normal Univ.
Lanzhou Univ., Henan Sci. and Tech. Univ.
Beihang Univ., Beijing Petrol Chemical Univ.

~400 members
53 institutions from 11 countries

Threshold Charm Data Sample



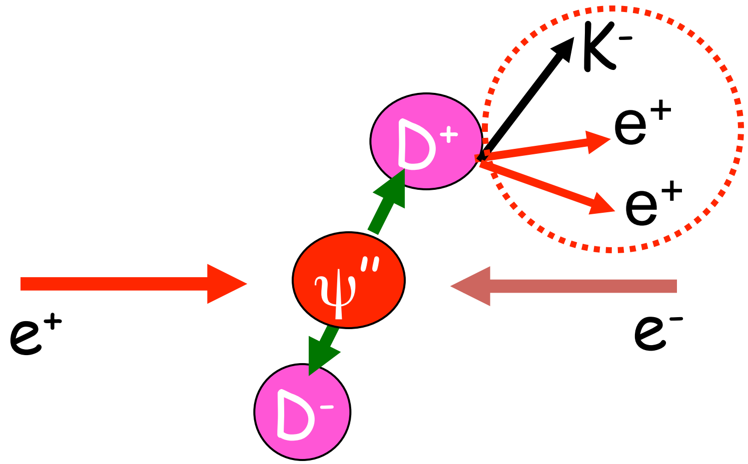
Single Tag VS Double Tag

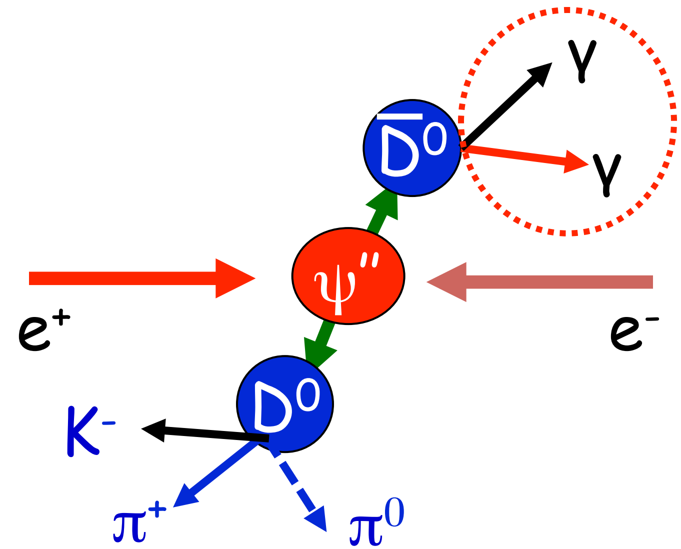
Single tag method:

reconstruct one D meson

Double tag method:

reconstruct a D meson pair

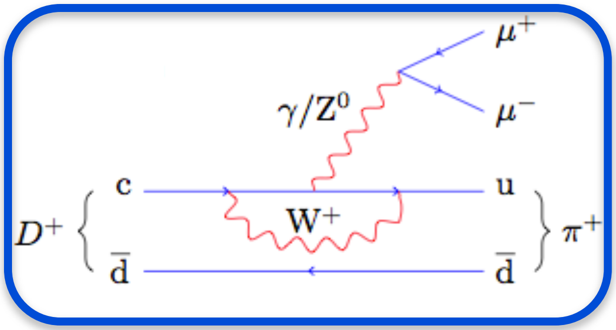


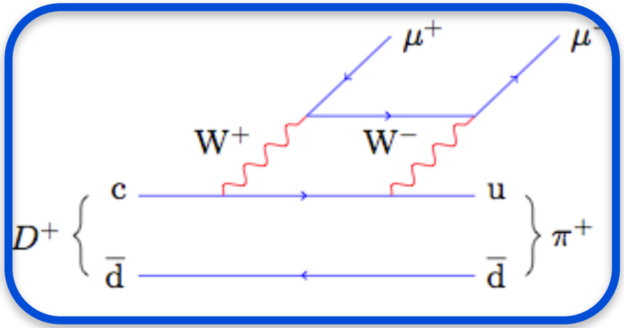


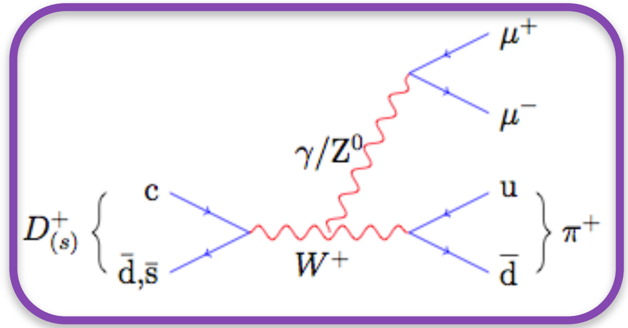
	Statistics （charged/neutral）	Background	Sensitivity
Single Tag Method	1.7×10^7 / 2.1×10^7	not good	Bkg. vs Stat.
Double Tag Method	1.6×10^6 / 2.8×10^6	clean	Bkg. vs Stat.

$D^+ \rightarrow h^{+/-}e^+e^{-/+}$

- FCNC : $c \rightarrow u\mu^+\mu^-$ highly suppressed in SM by GIM mechanism $BF_{th} \sim 10^{-9}$ [PRD64 (2001) 114009] while can be enhanced by physics BSM [PRD 76 (2007) 074010]



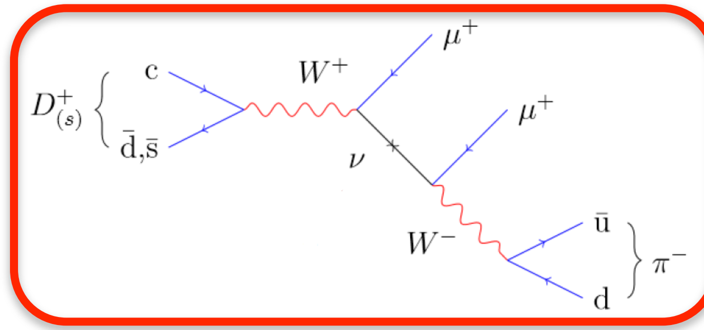




✓ B(res.) ~ 10^{-6} (via ϕ) to 10^{-8} (via η and ρ/ω)
✓ Search for non-resonant signal away from resonances

- LNV : $c \rightarrow u\mu^+\mu^+$ forbidden in SM

✓ Majorana neutrino: ~ $10^{-30\sim-23}$ level, PRD64 (2001) 114009
✓ May be greatly enhanced: ~$10^{-5\sim-6}$ with EPJC71 (2011) 1715)



- Thus, processes of the form $D^+ \rightarrow hee$ provide a sensitive lab for investigating NP. Any observation of definite signals would be clear evidence.

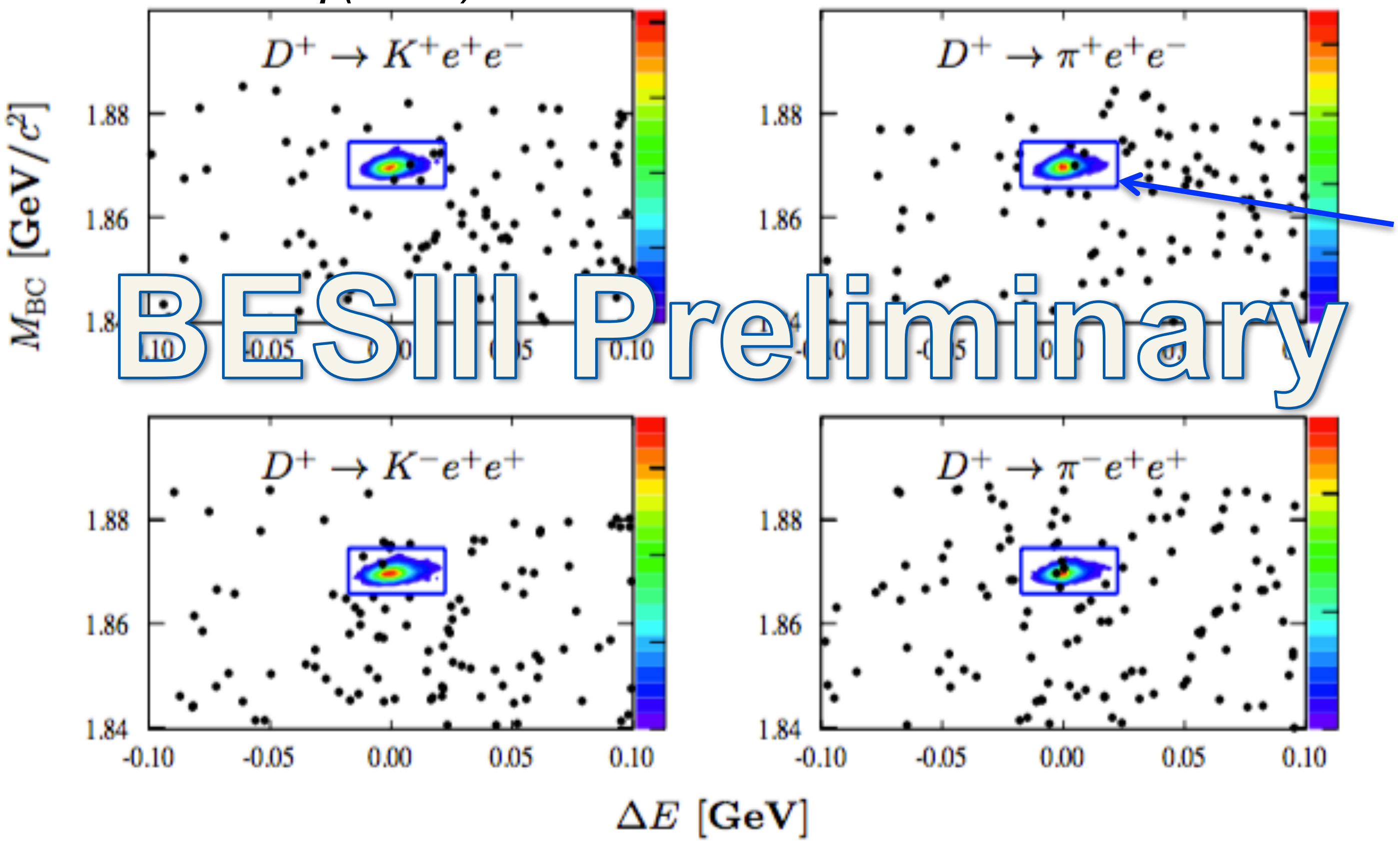
$D^+ \to h^{+/-}e^+e^{-/+}$ with single tag method

$\mathcal{B}(D^+ \to) \setminus [\times 10^{-6}]$	$K^+e^+e^-$	$K^-e^+e^+$	$\pi^+e^+e^-$	$\pi^-e^+e^+$
CLEO[1]	-	-	2600	-
MARK2[2]	4800	9100	2500	4800
E687[3]	200	120	110	110
E791[4]	200	-	52	96
CLEO[5]	3.0	3.5	5.9	1.1
Babar[6]	1.0	0.9	1.1	1.9
PDG[7]	1.0	0.9	1.1	1.1

[1] P. Haas et al. (CLEO Collaboration), Phys. Rev. Lett. 60, 1614 (1988).
[2] A. J. Weir et al. (MarkII Collaboration), Phys. Rev. D 41, 1384 (1990).
[3] P. L. Frabetti et al. (E687 Collaboration), Phys. Lett. B 398, 239 (1997).
[4] E. M. Aitala et al. (E791 Collaboration), Phys. Lett. B 462, 401 (1999).
[5] P. Rubin el al. (CLEO Collaboration), Phys. Rev. D 82, 092007 (2010).
[6] J. P. Lees el al. (BaBar Collaboration), Phys. Rev. D 84, 072006 (2011).
[7] K. A. Olive et al. (Particle Data Group), Chin. Phys. C, 38, 090001 (2014).

$D^+ \rightarrow h^{+/-}e^+e^{-/+}$ with single tag method

2.9 fb^{-1} $\psi(3770)$



Blinding signal region, optimize cuts and study backgrounds based on MC and sideband data.

Scatter plots for M_{BC} versus ΔE, where the signal boxes are shown as a blue rectangle. The contours are determined from MC simulation to enclose 84% of signal events for each channel.

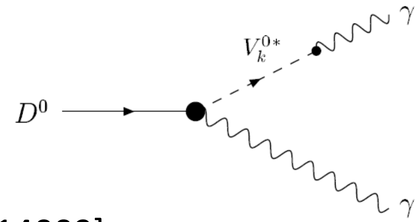
$D^+ \rightarrow h^{+/-}e^+e^{-/+}$ with single tag method

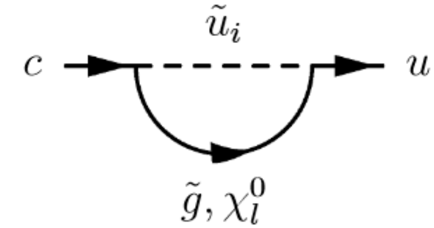
	N^{data}_{inside}	$N^{data}_{outside}$	f_{scale}	ϵ [%]	Δ_{sys} [%]	s_{90}	$\mathcal{B}[\times 10^{-6}]$
$D^+ \rightarrow K^+e^+e^-$	5	69	0.08 ± 0.01	22.53	5.4	19.4	< 1.2
$D^+ \rightarrow K^-e^+e^+$	3	55	0.08 ± 0.01	24.08	6.1	10.2	< 0.6
$D^+ \rightarrow \pi^+e^+e^-$	3	65	0.09 ± 0.02	25.72	5.9	4.2	< 0.3
$D^+ \rightarrow \pi^-e^+e^+$	5	68	0.06 ± 0.02	28.08	6.8	20.5	< 1.2

Where s_{90} is estimated with a profile likelihood method, **TROLKE** program [NIM, A551 (2005) 493], incorporating systematic uncertainties and detection efficiencies

$\mathcal{B}(D^+ \rightarrow) \setminus [\times 10^{-6}]$	$K^+e^+e^-$	$K^-e^+e^+$	$\pi^+e^+e^-$	$\pi^-e^+e^+$
CLEO	3.0	3.5	5.9	1.1
Babar	1.0	0.9	1.1	1.9
PDG	1.0	0.9	1.1	1.1
This work	1.2	0.6	0.3	1.2

$D^0 \to \gamma\gamma$

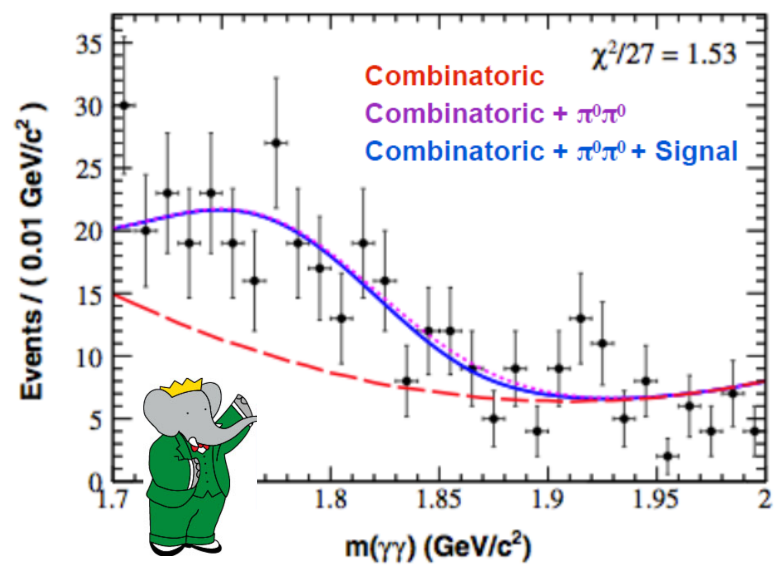




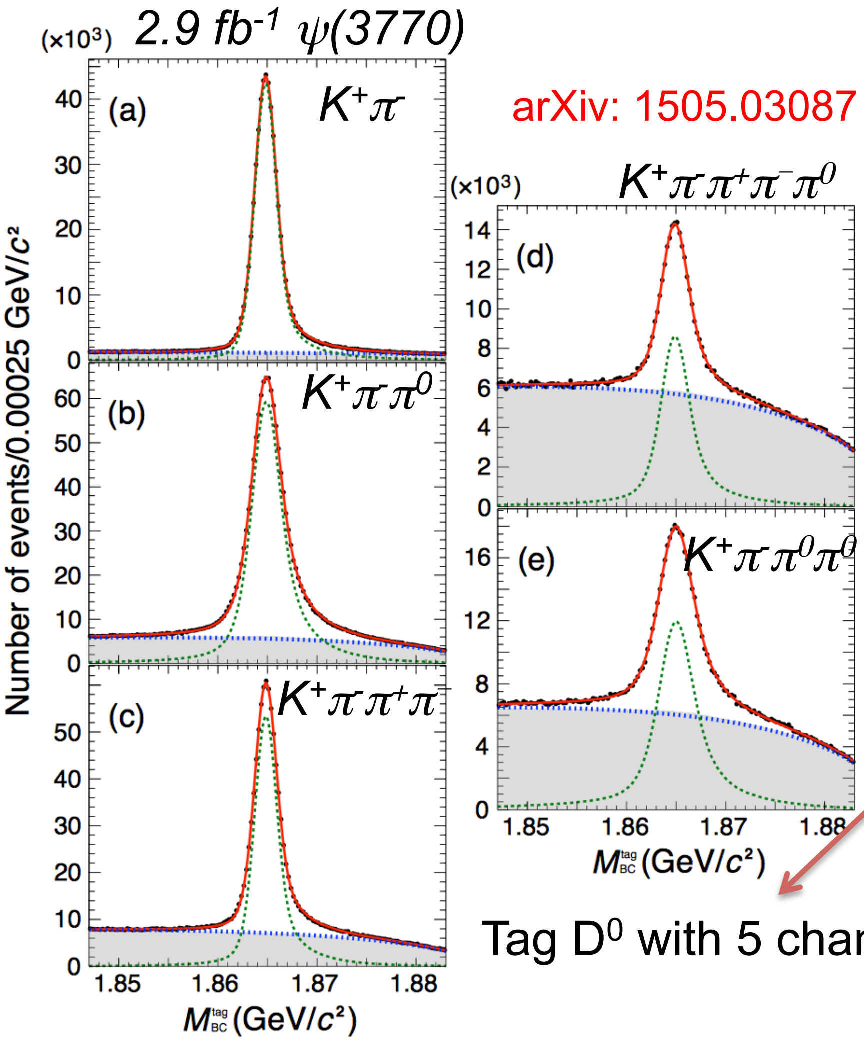
- FCNC mode, forbidden at tree level
  - → Larger GIM suppression
  - → Short distance: BF~10^{-11} [PRD66 (2002) 014009]
  - → Long distance due to VDM: BF~10^{-8} [PRD66 (2002) 014009]
  - → MSSM up to BF~10^{-6} [PLB500(2001)304], i.e. $c \to u\gamma$ via gluino exchange

- BaBar (PRD85, 091107(R) (2012)):
  - Reconstruct through $D^{*+} \to D^0(\to \gamma\gamma)\,\pi^+$, normalized by $D^{*+} \to D^0(\to K_S\pi^0)\,\pi^+$.
  - Peaking background from $D^0 \to \pi^0\pi^0$.
  - $B(D^0 \to \gamma\gamma) < 2.2\times10^{-6}$ @ 90% C.L.

Phys. Rev. D 85 (2012) 091107R



$D^0 \to \gamma\gamma$ with double tag method

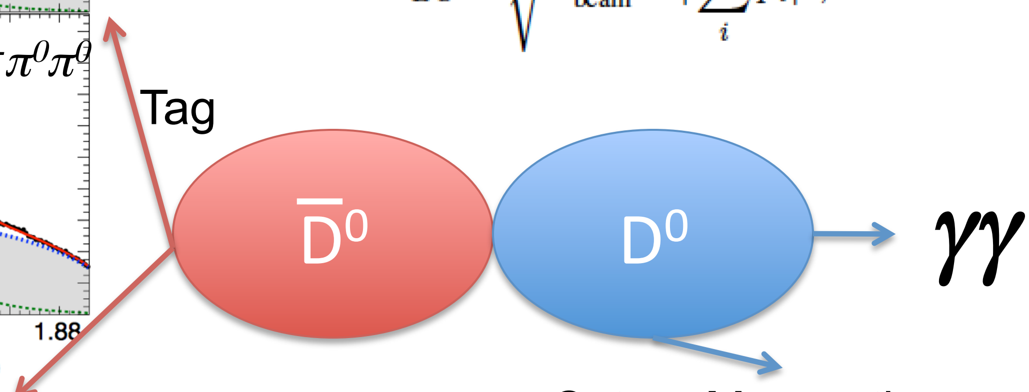


arXiv: 1505.03087

The $\psi(3770)$ resonance is below the threshold for $D\bar{D}\pi$ production, so the events from $e^+e^- \to \psi(3770) \to D\bar{D}$ have D mesons with energies equal to the beam energy ($E_{\rm beam}$) and known momentum. Thus, to identify $\bar{D}^0$ candidate, we define the two variables ΔE and $M_{\rm BC}$, the beam-constrained mass:

$$\Delta E \equiv \sum_i E_i - E_{\rm beam},$$

$$M_{\rm BC} \equiv \sqrt{E^2_{\rm beam} - |\sum_i \vec{p}_i|^2},$$

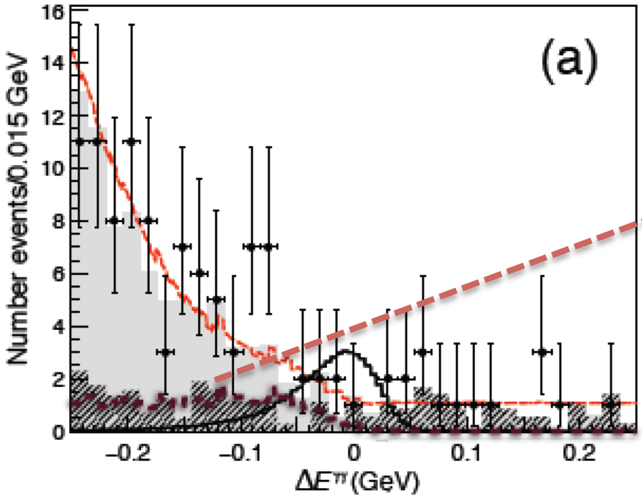


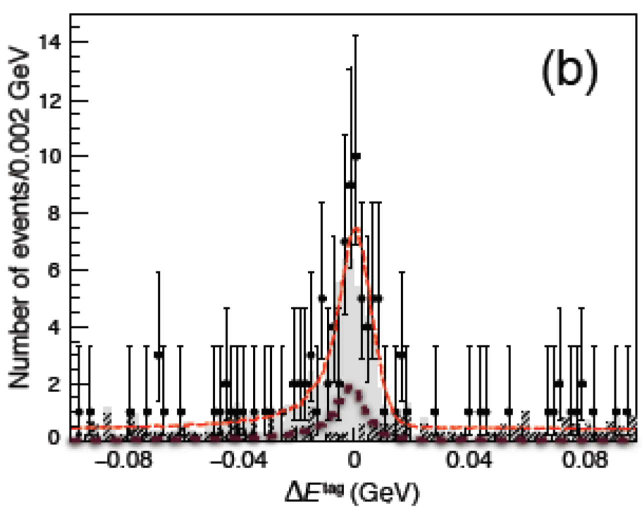
Tag D^0 with 5 channels on tag side.

Cut on M_{BC} on the tag side, and search for γγ by calculating $\Delta e_{\gamma\gamma}$ in the recoiling side

$D^0 \to \gamma\gamma$ with double tag method

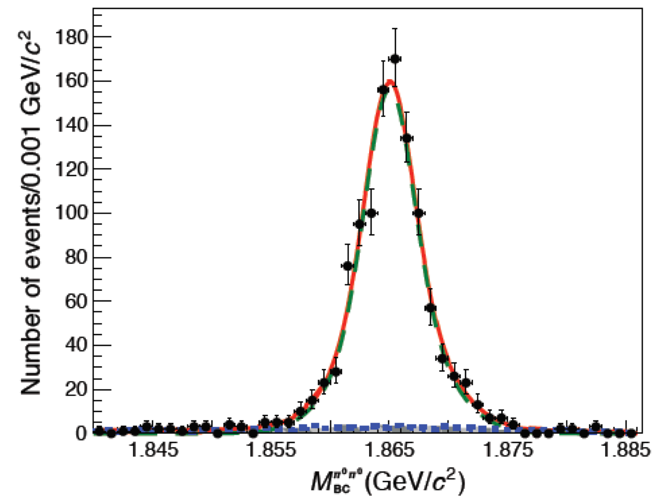
arXiv: 1505.03087





Major background $D^0 \to \pi^0\pi^0$ is determined in data with similar double-tag method.

arXiv: 1505.03087



Simultaneously fit to ΔE in both tag side and $\gamma\gamma$ sides to determine $D^0 \to \gamma\gamma$ yield.

$$B(D^0 \to \gamma\gamma) < 3.8 \times 10^{-6}$$

consistent with BaBar result

Summary

- With the world largest threshold D meson sample, BESIII got the (leading) upper limits on $D^0 \to \gamma\gamma$, $D^+ \to hee$ decays.
- Present upper limits still above SM predictions, no NP effects have been found yet.
- BESIII will take 3 fb^{-1} data at 4.17 GeV in 2016 and 10 fb^{-1} more data at 3.773 GeV in the future.
- More results can be expected soon


Thank you !