BESIII NPG Workshop 2021

FCNC searches at BESIII

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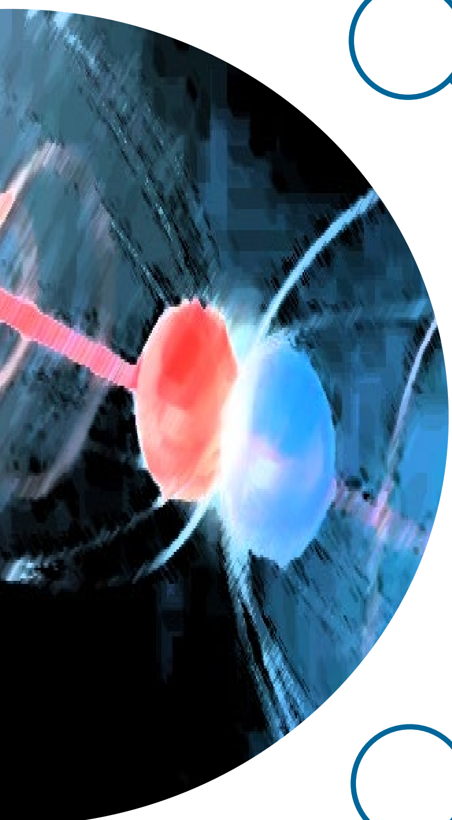
OutLine



Introduction

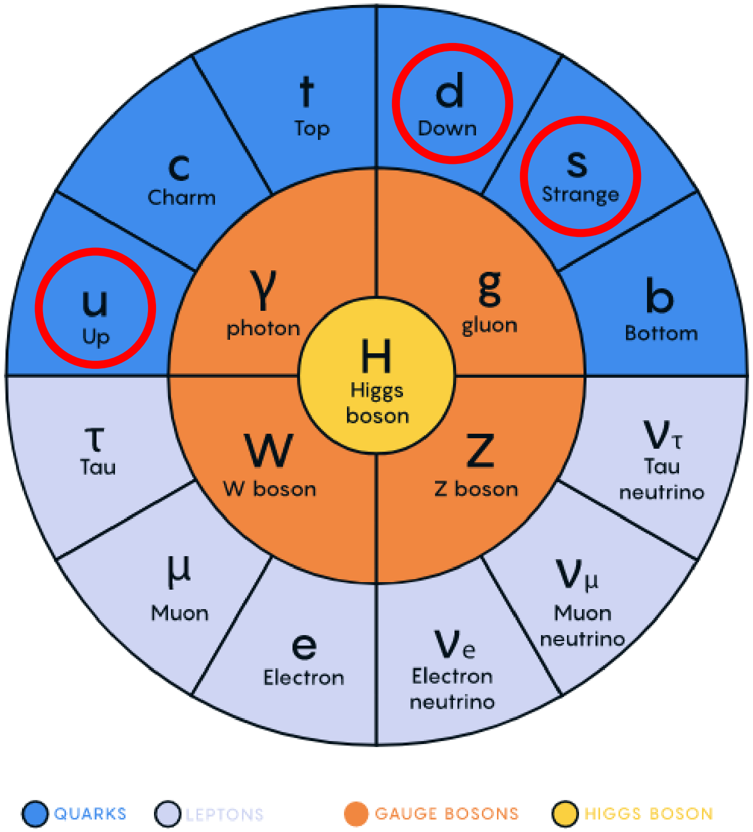
Experiment

Prospect

Summary

Introduction

- Standard Model (SM):



1964, Nicola Cabibbo

$$\bar{u}u + \bar{d'}d' = \bar{u}u + \left(\cos^2\theta_c\,\bar{d}d + \sin^2\theta_c\,\bar{s}s\right) + sin\theta_c cos\theta_c(\bar{d}s + \bar{s}d)$$

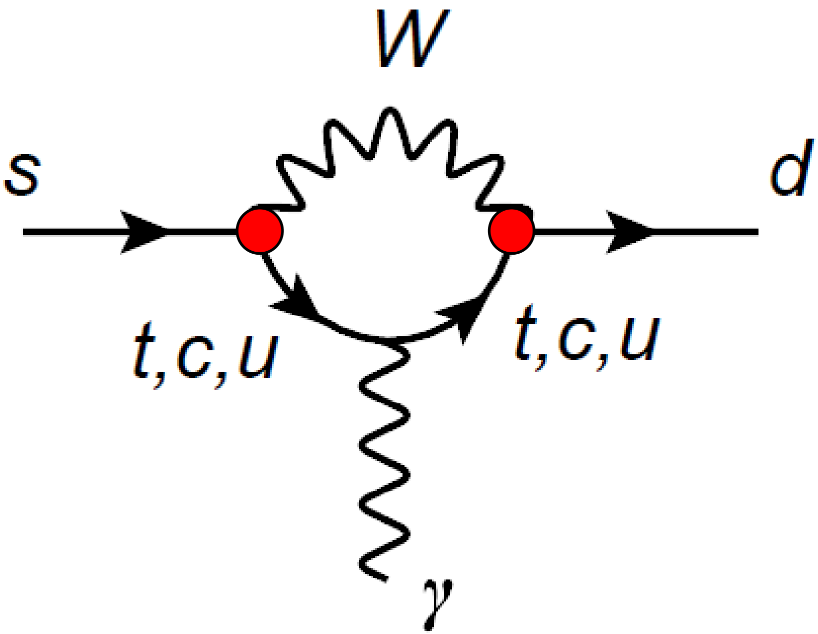
1970, S.Glashow, J.Iliopoulos, L.Maiani

$$\bar{u}u + \bar{c}c + \bar{d'}d' + \bar{s'}s' = \bar{u}u + \bar{c}c + \bar{d}d + \bar{s}s$$

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

Introduction

- Flavor-changing neutral current (FCNC) process:



$$\mathcal{A}_x \propto (V_{ts}V_{td}^\star + V_{cs}V_{cd}^\star + V_{us}V_{ud}^\star)\,,$$

$$V_{ud}^\star V_{us} + V_{cd}^\star V_{cs} + V_{td}^\star V_{ts} = 0\,,$$
$$V_{ud}^\star V_{ub} + V_{cd}^\star V_{cb} + V_{td}^\star V_{tb} = 0\,,$$
$$V_{us}^\star V_{ud} + V_{cs}^\star V_{cd} + V_{ts}^\star V_{td} = 0\,,$$
$$V_{us}^\star V_{ub} + V_{cs}^\star V_{cb} + V_{ts}^\star V_{tb} = 0\,,$$
$$V_{ub}^\star V_{ud} + V_{cb}^\star V_{cd} + V_{tb}^\star V_{td} = 0\,,$$
$$V_{ub}^\star V_{us} + V_{cb}^\star V_{cs} + V_{tb}^\star V_{ts} = 0\,.$$

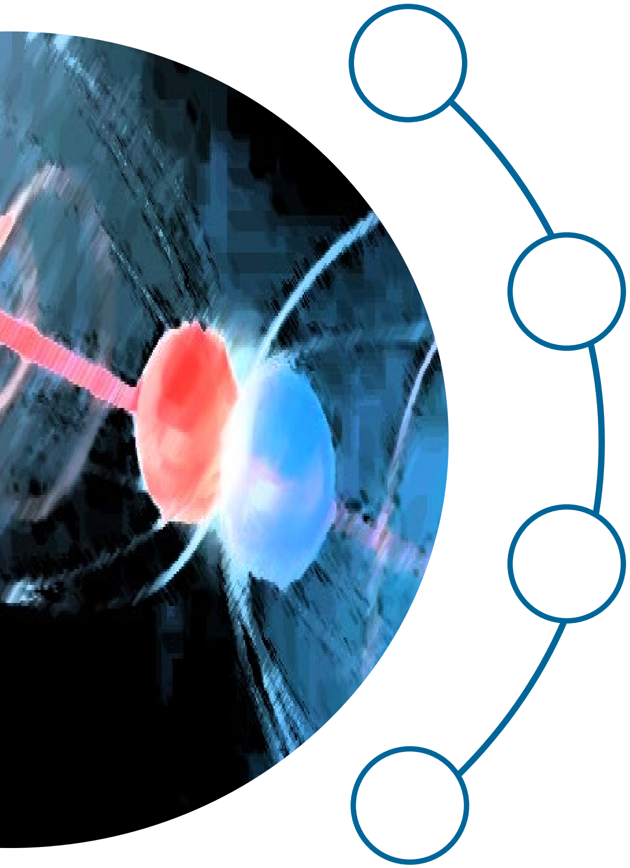
- GIM mechanism

$$\mathcal{A}_y \propto (V_{ts}V_{td}^\star G(m_t) + V_{cs}V_{cd}^\star G(m_c) + V_{us}V_{ud}^\star G(m_u))\,,$$

$$\mathcal{A}_y \sim V_{ts}V_{td}^\star G(m_t) \sim V_{ts}V_{td}^\star F\left(\frac{m_t^2}{m_W^2}\right)$$

$$|V_{CKM}| = \begin{pmatrix} 0.97446 \pm 0.00010 & 0.22452 \pm 0.00044 & 0.00365 \pm 0.00012 \\ 0.22438 \pm 0.00044 & 0.97359^{+0.00010}_{-0.00011} & 0.04214 \pm 0.00076 \\ 0.00896^{+0.00024}_{-0.00023} & 0.04133 \pm 0.00074 & 0.999105 \pm 0.000032 \end{pmatrix}$$

OutLine



Introduction

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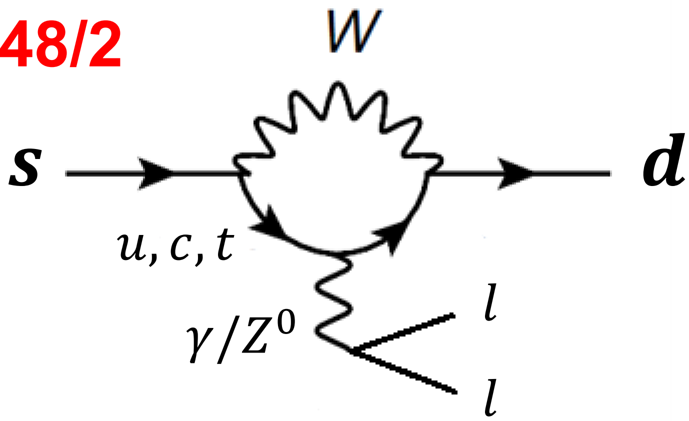
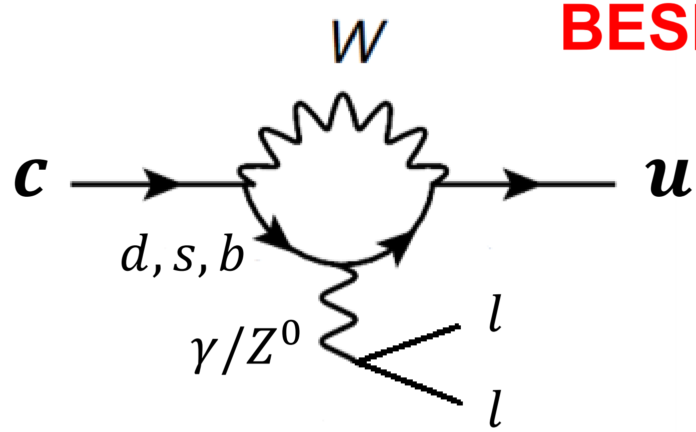
Type of FCNC process

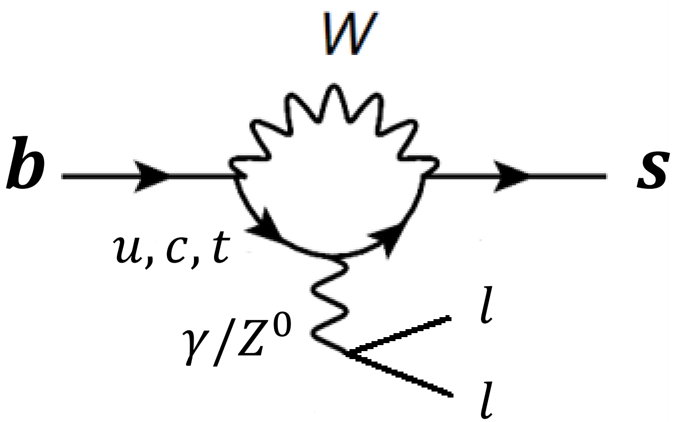
- **FCNC process:**

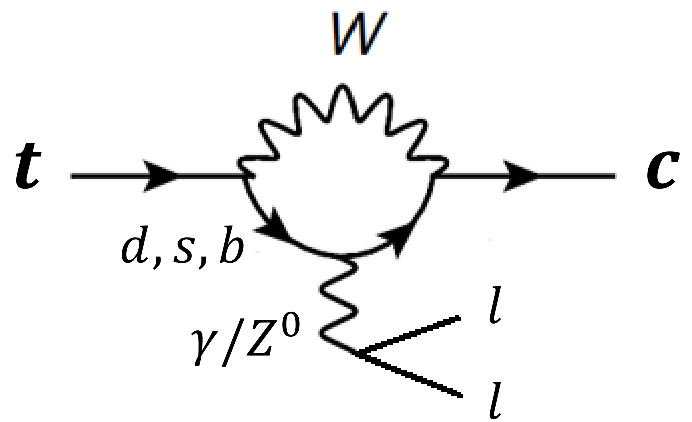
NA48/2



BESIII ✔







Belle, BaBar

Features of FCNC process

- **Features of FCNC:**
  - **Very small Branching fraction:**
    - **10^{-13}~10^{-10} in theoretical prediction in SM.**
    - **Enhanced to above 10^{-6} in other model, e.g. MSSM, 2HDM.**
  - **Hard to fully reconstruct:**
    - **Contains at least a γ (no tracks, fake γ, FSR).**
    - **Contains l^+l^- pairs (identification of l).**
    - **Contains $\nu_l\bar{\nu}_l$ pairs (invisible).**
  - **Confusable background:**
    - **γ conversion ($\gamma \to e^+e^-$).**
    - **Long-distance process (through vector particle).**

FCNC analysis at BESIII

- FCNC at BESIII (from BESIII publication page):
  - $D^0 \to \gamma\gamma$: PRD 91, 112015 (2015)
  - $J/\psi, \psi(3686) \to D^0 e^+ e^-$: PRD 96, 111101(R) (2017)
  - $\psi(3686) \to \Lambda_c^+ \bar{p} e^+ e^-$: PRD 97, 091102(R) (2018)
  - $D^+(D^0) \to h(h') e^+ e^-$: PRD 97, 072015 (2018)

4 FCNC out of 369 papers!

Techniques in FCNC research

- **Techniques in FCNC research:**
  - **Blind analysis**

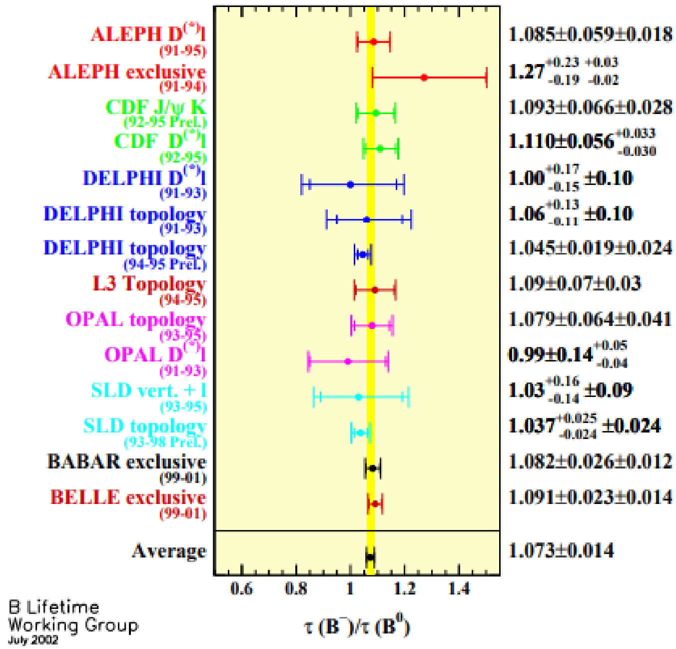
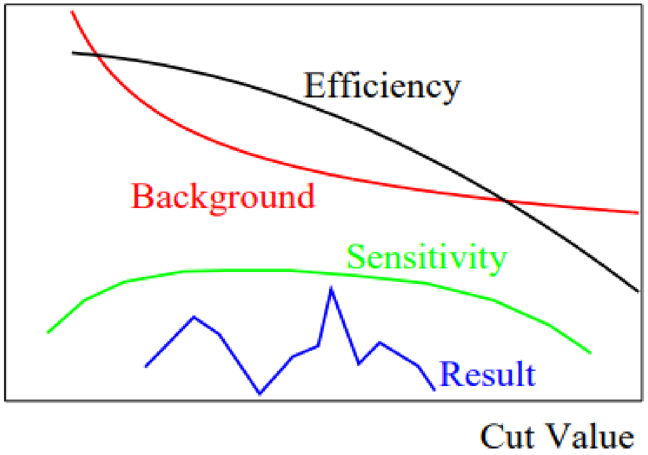


Figure 2: Summary of B meson lifetime ratio measurements. The average has a $\chi^2 = 4.5$ for 13 degrees of freedom.



Hide results to seek the truth

More fields should, like particle physics, adopt blind analysis to thwart bias, urge **Robert MacCoun** and **Saul Perlmutter**.

["Blind Analysis in Particle Physics"]

[Nature volume 526, pages187–189 (2015)]

Techniques in FCNC research

- **Techniques in FCNC research:**

$$N_i^{\text{tag}} = 2N_{D^+D^-} \cdot \mathcal{B}_i^{\text{tag}} \cdot \varepsilon_i^{\text{tag}}$$

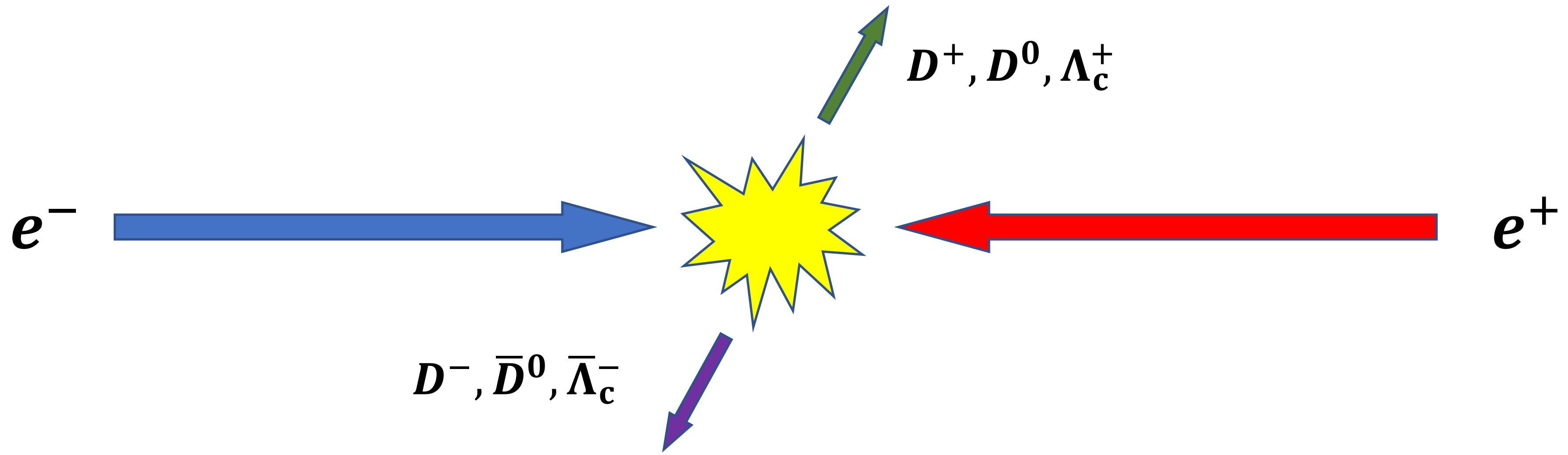
  - **Single-tag/Double-tag:**

$$N_i^{\text{sig}} = 2N_{D^+D^-} \cdot \mathcal{B}_i^{\text{tag}} \cdot \mathcal{B}_i^{\text{sig}} \cdot \varepsilon^{\text{sig}} \cdot \varepsilon_i^{\text{tag}}$$

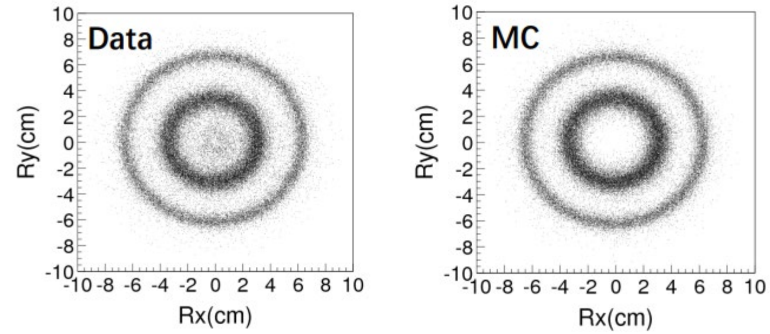
    - **Single-tag -> larger sample, higher background**

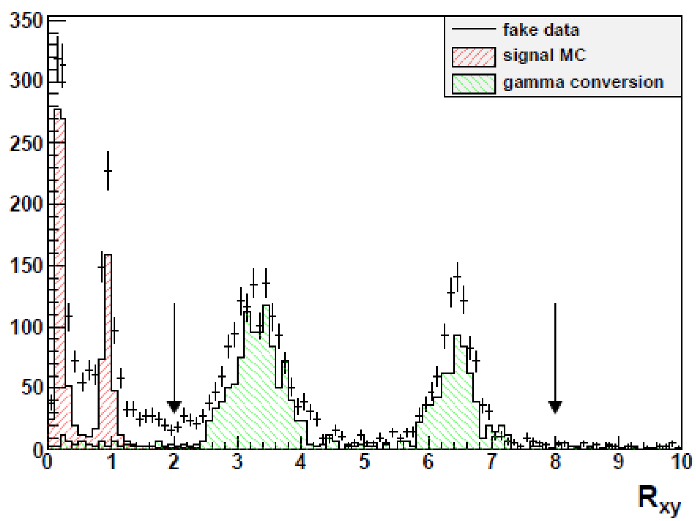
$$\mathcal{B}^{\text{sig}} = \frac{\sum_i N_i^{\text{sig}} / \varepsilon^{\text{sig}}}{\sum_i N_i^{\text{tag}}}$$

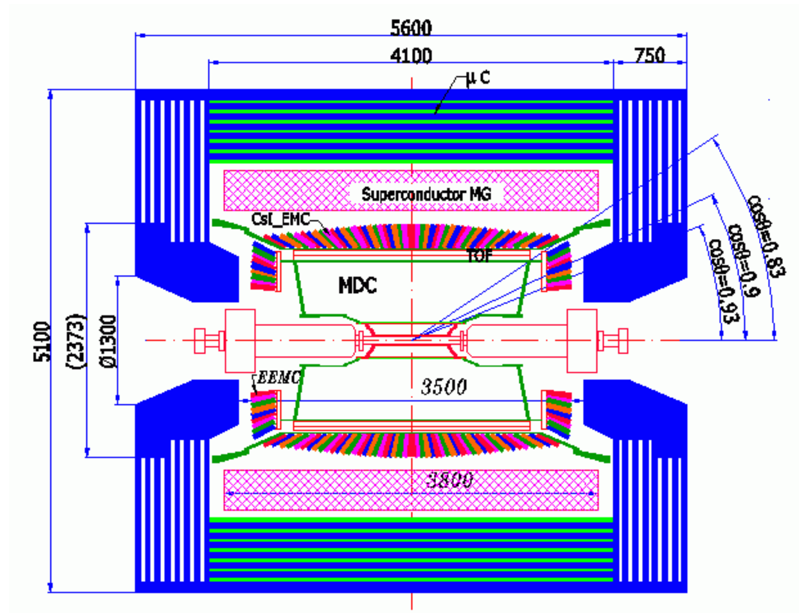
    - **Double-tag -> smaller sample, lower background**



- **Techniques in FCNC research:**
  - **γ conversion veto:**
    - **Occurs when γ through matter. (Beam pipe and inner wall of MDC)**
    - **Veto through vertex fit of e^+e^-.**

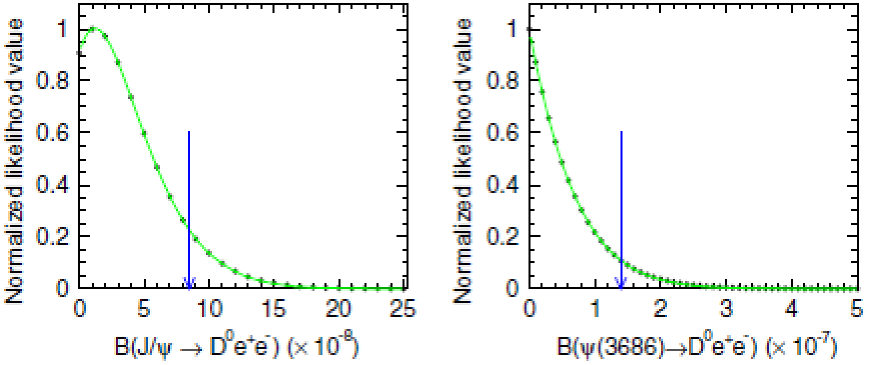






Techniques in FCNC research

- Techniques in FCNC research:
  - Calculate upper limits:
    - Likelihood scan.



    - TRolke package.

TRolke Class Reference

Math » Physics Vectors

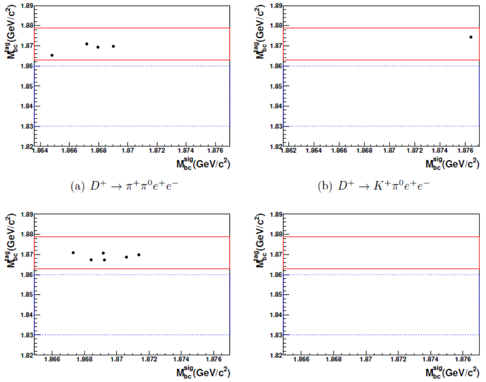
This class computes confidence intervals for the rate of a Poisson process in the presence of uncertain background and/or efficiency.

The treatment and the resulting limits are fully frequentist. The limit calculations make use of the profile likelihood method.

Author

Jan Conrad (CERN) 2004, Updated: Johan Lundberg (CERN) 2009

For a full list of methods and their syntax, and build instructions, consult the header file TRolke.h.



(a) $D^+ \to \pi^+\pi^0 e^+e^-$ (b) $D^+ \to K^+\pi^0 e^+e^-$

(c) $D^+ \to \pi^+K^0_S e^+e^-$ (d) $D^+ \to K^+K^0_S e^+e^-$

Search for $D^0 \rightarrow \gamma\gamma$

- $D^0 \rightarrow \gamma\gamma$: **PRD 91, 112015 (2015)**

  [Hajime Muramatsu, Xianghu Zhao and Daniel Ambrose et al.]

- **Theoretical prediction:**

  MSSM 10^{-6}

  SM long distance 10^{-8}

  SM short ditsance 10^{-13}

- **BaBar previous result:**
  - $< 2.2 \times 10^{-6}$, **based on 250 million D^0.**

- **This analysis:**
  - **Using 2.92 fb^{-1} data taken at $\sqrt{s} = 3.773$ GeV, 20 million D^0.**
  - **Double-tag.**

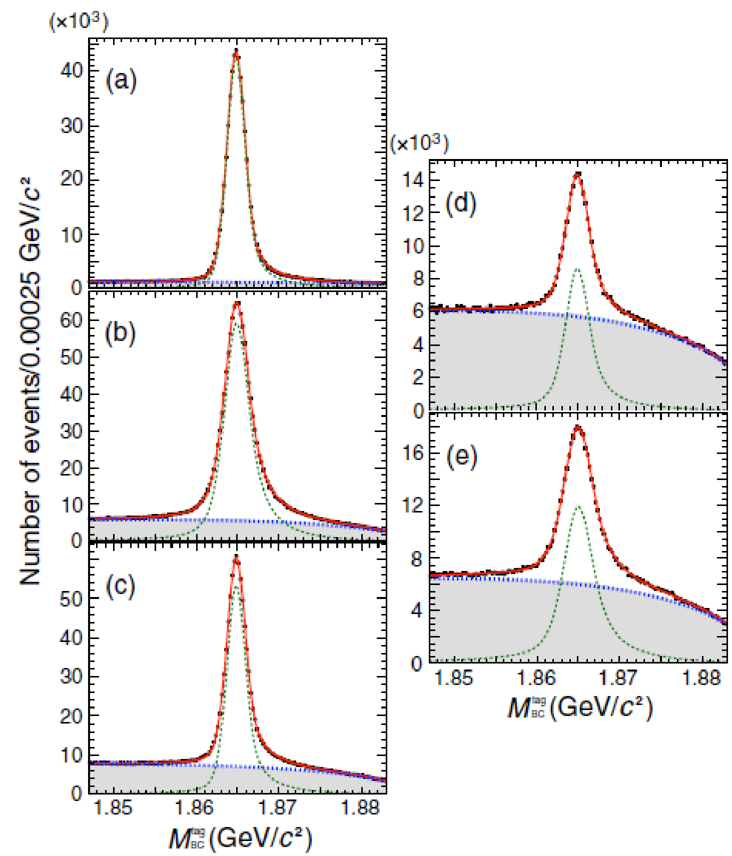
Search for $D^0 \to \gamma\gamma$

- $D^0 \to \gamma\gamma$: **PRD 91, 112015 (2015)**

[Hajime Muramatsu, Xianghu Zhao and Daniel Ambrose et al.]

- **Analysis strategy:**
  - **Tag reconstruction: 5 tag modes.**

modes	$\epsilon^i_{\rm tag}$ (%)	$N^i_{\rm tag}$	$\epsilon^i_{{\rm tag},\gamma\gamma}$ (%)
$K^+\pi^-$	66.12 ± 0.04	551800 ± 936	44.8 ± 0.4
$K^+\pi^-\pi^0$	35.06 ± 0.02	1097113 ± 1386	24.5 ± 0.1
$K^+\pi^-\pi^+\pi^-$	39.70 ± 0.03	734825 ± 1170	24.7 ± 0.2
$K^+\pi^-\pi^+\pi^-\pi^0$	15.32 ± 0.04	155899 ± 872	9.6 ± 0.1
$K^+\pi^-\pi^0\pi^0$	15.23 ± 0.04	268832 ± 976	8.9 ± 0.1
All Tags		2808469 ± 2425	

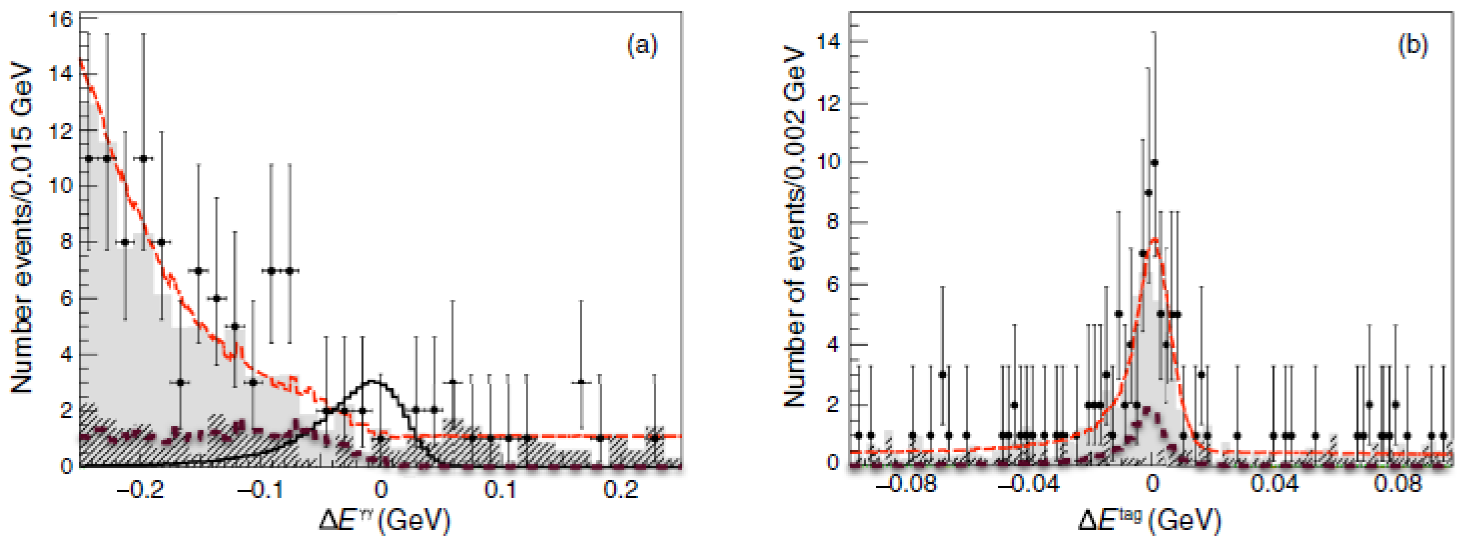


Search for $D^0 \to \gamma\gamma$

- $D^0 \to \gamma\gamma$: **PRD 91, 112015 (2015)**

  [Hajime Muramatsu, Xianghu Zhao and Daniel Ambrose et al.]

- **Analysis strategy:**
  - **Signal reconstruction: $\Delta E_{\gamma\gamma}$, ΔE_{tag}.**



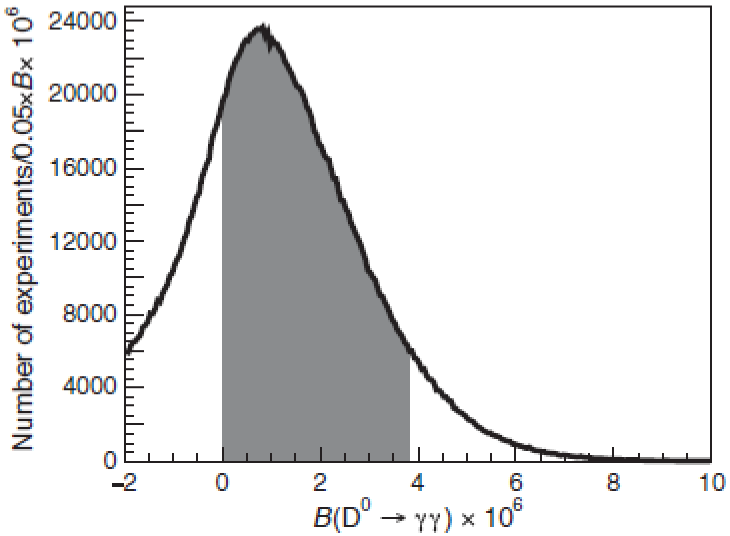
Search for $D^0 \to \gamma\gamma$

- $D^0 \to \gamma\gamma$: **PRD 91, 112015 (2015)**

[Hajime Muramatsu, Xianghu Zhao and Daniel Ambrose et al.]

- **Results:**
  - **Likelihood scan.**
  - **Systematic uncertainties & upper limits.**

Uncertainties independent of fitting procedure	
Source	Relative uncertainty (%)
Photon reconstruction	2.0
$M_{BC}^{\gamma\gamma}$ requirement	3.1
ST D^0 yields	1.0
Total	3.8



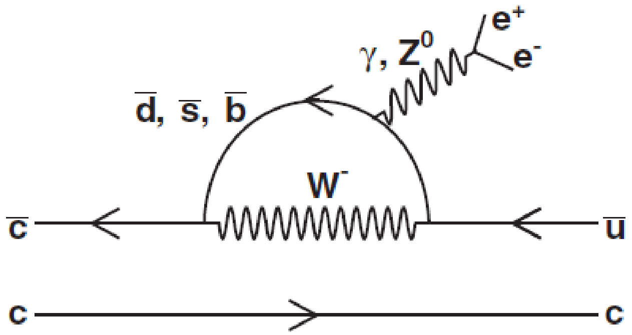
$$\mathcal{B}(D^0 \to \gamma\gamma) < 3.8 \times 10^{-6}$$

Search for $J/\psi, \psi(3686) \to D^0 e^+ e^-$

- $J/\psi, \psi(3686) \to D^0 e^+ e^-$: **PRD 96, 111101(R) (2017)**

[Yateng Zheng et al.]

- **Theoretical prediction: 10^{-13}~10^{-10}**
  - **MSSM/2HDM prediction:**
    enhance 2~3 order



- **BESIII previous result:**
  - **To the order of 10^{-5}, based on 58×10^6 J/ψ data.**

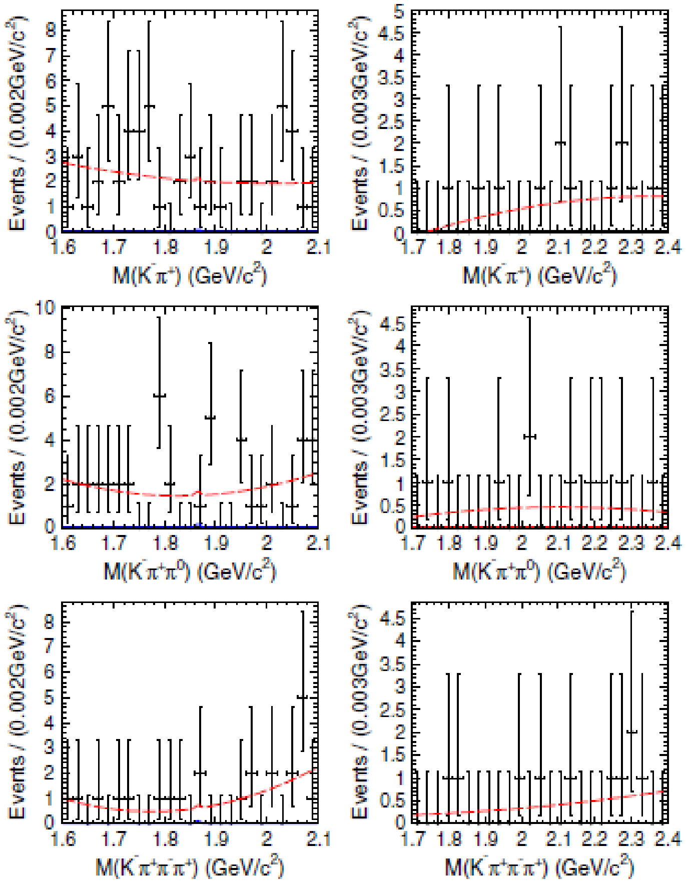
- **This analysis:**
  - **Using 1310×10^6 J/ψ data and 448×10^6 $\psi(3686)$ data.**
  - **Single-tag.**

Search for $J/\psi, \psi(3686) \to D^0 e^+ e^-$

- $J/\psi, \psi(3686) \to D^0 e^+ e^-$: **PRD 96, 111101(R) (2017)**

[Yateng Zheng et al.]

- **Analysis strategy:**
  - **Fully single-tag reconstruction.**
  - **Reconstruction of D^0.**
  - **Require a pair of e^+e^- to be found.**



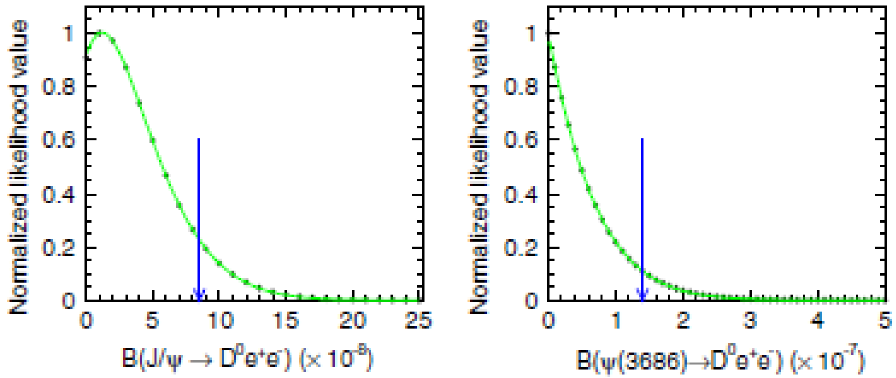
Search for $J/\psi, \psi(3686) \to D^0 e^+ e^-$

- $J/\psi, \psi(3686) \to D^0 e^+ e^-$: **PRD 96, 111101(R) (2017)**

[Yateng Zheng et al.]

- **Results:**
  - **Likelihood scan.**
  - **Systematic uncertainties & upper limits.**

	$D^0 \to K^-\pi^+$		$D^0 \to K^-\pi^+\pi^0$		$D^0 \to K^-\pi^+\pi^+\pi^-$	
	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



$$\mathcal{B}(J/\psi \to D^0 e^+ e^-) < 8.5 \times 10^{-8}$$

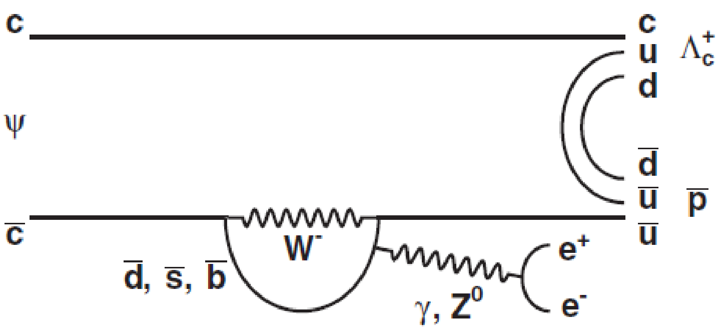
$$\mathcal{B}(\psi(3686) \to D^0 e^+ e^-) < 1.4 \times 10^{-7}$$

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

- $\psi(3686) \to \Lambda_c^+ \bar{p} e^+ e^-$: **PRD 97, 091102(R) (2018)**

  [Yang Zhang et al.]

- **Theoretical prediction: $10^{-14} \sim 10^{-10}$**
  - **MSSM/2HDM prediction: enhance 2~3 order**



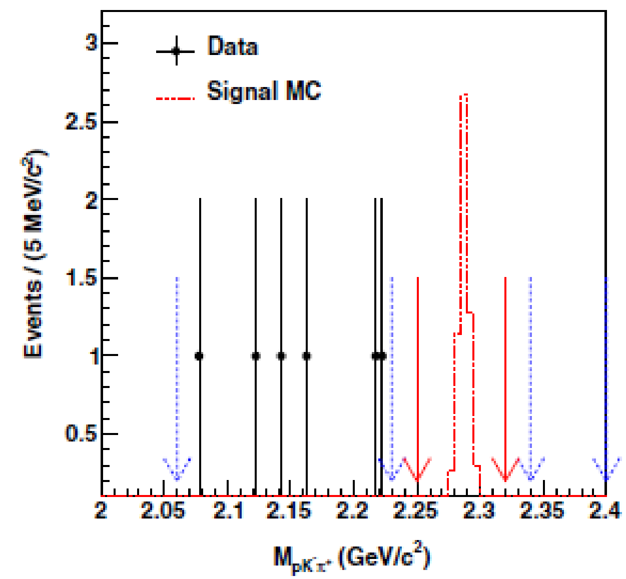
- **This analysis:**
  - **First search.**
  - **Using 448×10^6 $\psi(3686)$ data.**
  - **Single-tag.**

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

- $\psi(3686) \to \Lambda_c^+ \overline{p} e^+ e^-$: **PRD 97, 091102(R) (2018)**

[Yang Zhang et al.]

- **Analysis strategy:**
  - **Fully reconstruct 6 charged tracks.**
  - **Looking at $m_{pK^-\pi^+}$.**



- **Results:**
  - **Using TRolke package.**

$$\mathcal{B} \le \frac{N_{\rm up}}{N_{\psi(3686)} \times {\rm BF}(\Lambda_c^+ \to pK^-\pi^+)},$$

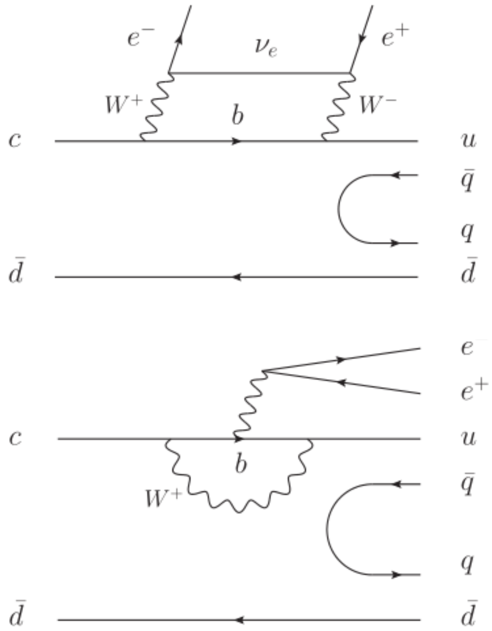
Sources	Systematic uncertainty (%)
Number of $\psi(3686)$ decays	0.6
Track reconstruction	9.0
Particle identification	9.0
4C kinematic fit	1.0
BF of $\Lambda_c^+ \to pK^-\pi^+$	5.2
Signal region	4.0
$M_{p\pi^-}/M_{\bar{p}\pi^+}$ criteria	1.0
Physics model	34.3
Total	37.2

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

Search for $D^+(D^0) \to h(h')e^+e^-$

- $D^+(D^0) \to h(h')e^+e^-$: **PRD 97, 072015 (2018)**

[Dong Xiao, Yu Zhang et al.]



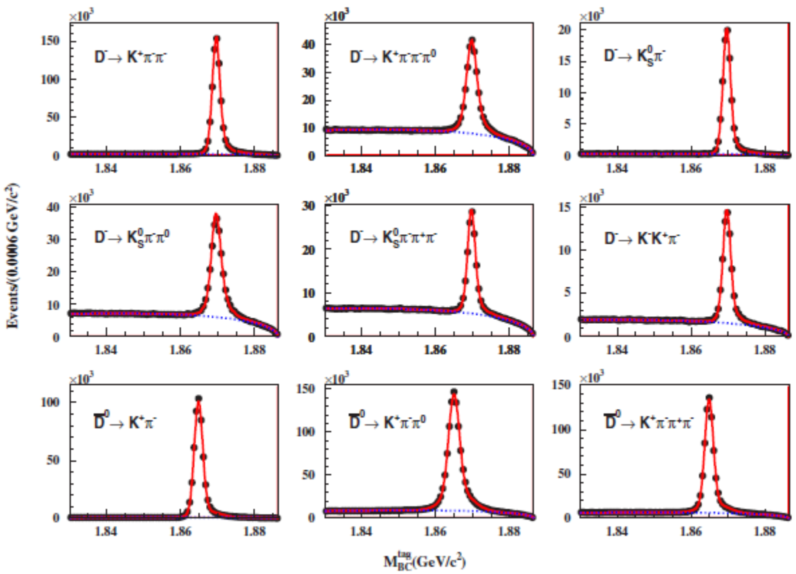
- Theoretical prediction: <10^{-9}
  - MSSM/2HDM prediction: 10^{-6}
- CLEO2 previous results:
  - ~10^{-5}
- This analysis:
  - First search for D^+.
  - Using 2.93 fb^{-1} data at $\sqrt{s} = 3.773$ GeV.
  - Double-tag.

Search for $D^+(D^0) \to h(h')e^+e^-$

- $D^+(D^0) \to h(h')e^+e^-$: **PRD 97, 072015 (2018)**

[Dong Xiao, Yu Zhang et al.]

- **Analysis strategy:**
  - **Tag reconstruction: 6 tag modes for D^+, 3 tag mods for D^0.**



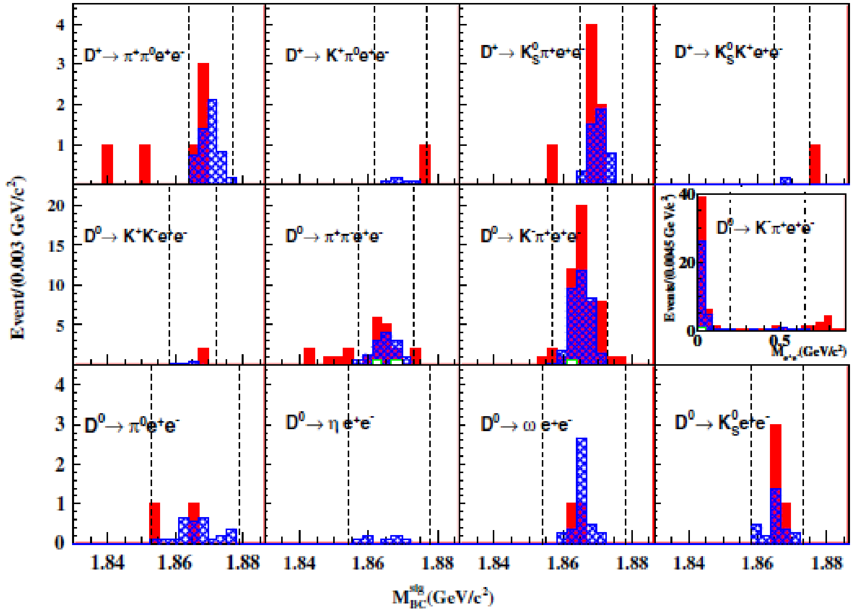
D^- decays	ΔE_{tag} (GeV)	$\epsilon_{tag}^{i,MC}$ (%)	n_{tag}^i
$K^+\pi^-\pi^-$	$(-0.022, 0.021)$	50.47 ± 0.06	755661 ± 922
$K^+\pi^-\pi^-\pi^0$	$(-0.060, 0.034)$	24.65 ± 0.05	231322 ± 729
$K_S^0\pi^-$	$(-0.019, 0.021)$	54.44 ± 0.17	95346 ± 330
$K_S^0\pi^-\pi^0$	$(-0.071, 0.041)$	27.44 ± 0.06	210535 ± 638
$K_S^0\pi^+\pi^-\pi^-$	$(-0.025, 0.023)$	31.80 ± 0.09	119249 ± 451
$K^+K^-\pi^-$	$(-0.019, 0.018)$	40.71 ± 0.16	64904 ± 259
$\bar{D}^0$ decays	ΔE_{tag} (GeV)	$\epsilon_{tag}^{i,MC}$ (%)	n_{tag}^i
$K^+\pi^-$	$(-0.023, 0.022)$	64.64 ± 0.03	523265 ± 763
$K^+\pi^-\pi^0$	$(-0.064, 0.035)$	33.60 ± 0.01	1022697 ± 1448
$K^+\pi^-\pi^+\pi^-$	$(-0.026, 0.023)$	38.26 ± 0.02	707936 ± 1129

Search for $D^+(D^0) \to h(h')e^+e^-$

- $D^+(D^0) \to h(h')e^+e^-$: **PRD 97, 072015 (2018)**

[Dong Xiao, Yu Zhang et al.]

- **Analysis strategy:**
  - **Signal reconstruction: count & sideband subtraction & MC.**



D^+ decays	ΔE_{sig} (GeV)	M_{BC}^{sig} (GeV/c^2)	n_{obs}	n_{bkg1}^{SB}	$n_{bkg2}^{MC} \pm \sigma_{bkg2}^{MC}$
$\pi^+\pi^0e^+e^-$	(−0.060, 0.030)	(1.864, 1.877)	4	0	5.3 ± 0.7
$K^+\pi^0e^+e^-$	(−0.063, 0.037)	(1.862, 1.877)	1	0	0.5 ± 0.2
$K_S^0\pi^+e^+e^-$	(−0.038, 0.020)	(1.865, 1.877)	6	0	4.6 ± 0.7
$K_S^0K^+e^+e^-$	(−0.038, 0.021)	(1.865, 1.875)	0	0	0.2 ± 0.1

D^0 decays	ΔE_{sig} (GeV)	M_{BC}^{sig} (GeV/c^2)	n_{obs}	n_{bkg1}^{SB}	$n_{bkg2}^{MC} \pm \sigma_{bkg2}^{MC}$
$K^-K^+e^+e^-$	(−0.044, 0.015)	(1.858, 1.872)	2	0	0.9 ± 0.3
$\pi^+\pi^-e^+e^-$	(−0.053, 0.020)	(1.857, 1.873)	11	2	11.8 ± 1.1
$K^-\pi^+e^+e^-$	(−0.040, 0.018)	(1.857, 1.873)	49	1	32.4 ± 1.7
$\pi^0e^+e^-$	(−0.043, 0.020)	(1.853, 1.879)	2	0	2.1 ± 0.4
ηe^+e^-	(−0.094, 0.031)	(1.854, 1.878)	0	0	0.6 ± 0.3
ωe^+e^-	(−0.086, 0.035)	(1.854, 1,878)	2	0	4.0 ± 0.6
$K_S^0e^+e^-$	(−0.078, 0.035)	(1.858, 1.873)	4	0	2.2 ± 0.5

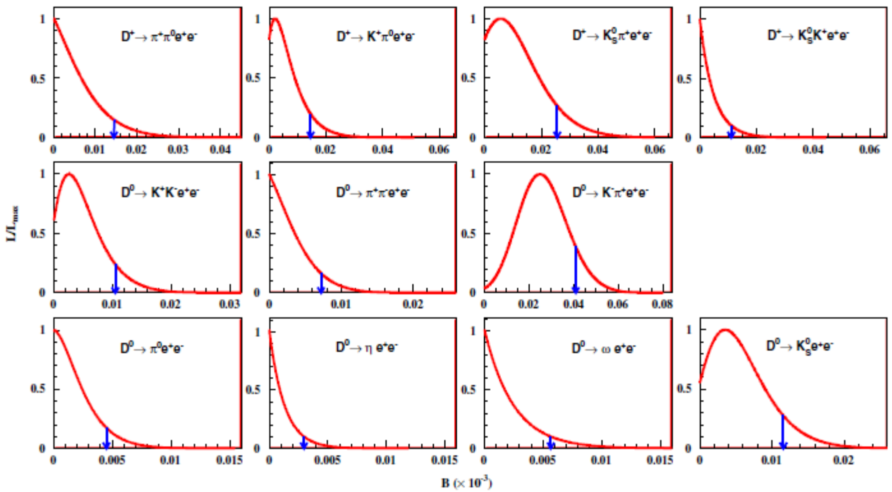
Search for $D^+(D^0) \to h(h')e^+e^-$

- $D^+(D^0) \to h(h')e^+e^-$: **PRD 97, 072015 (2018)**

[Dong Xiao, Yu Zhang et al.]

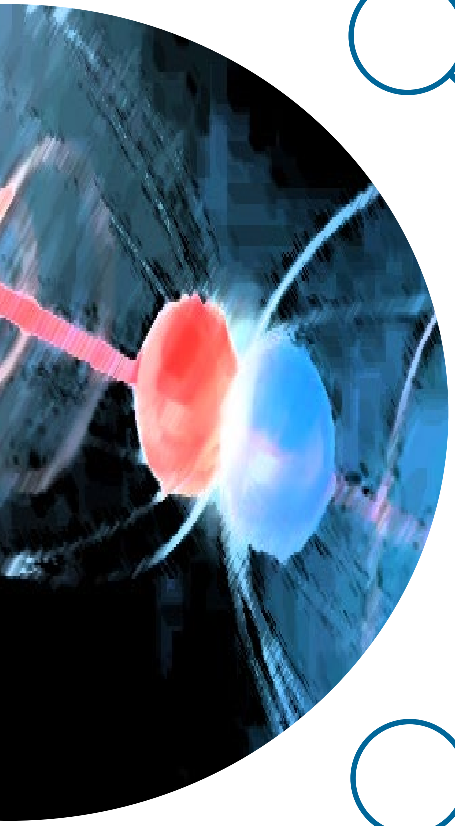
Source (%)	$K^-K^+e^+e^-$	$\pi^+\pi^-e^+e^-$	$K^-\pi^+e^+e^-$	$\pi^0e^+e^-$	ηe^+e^-	ωe^+e^-	$K_S^0e^+e^-$	$\pi^+\pi^0e^+e^-$	$K^+\pi^0e^+e^-$	$K_S^0\pi^+e^+e^-$	$K_S^0K^+e^+e^-$
$K^\pm/\pi^\pm$ tracking	2.0	2.0	2.0	···	···	2.0	···	1.0	1.0	1.0	1.0
$K^\pm/\pi^\pm$ PID	1.0	1.0	1.0	···	···	1.0	···	0.5	0.5	0.5	0.5
$e^\pm$	6.9	2.8	4.5	0.8	1.8	3.6	2.0	3.9	5.2	5.2	6.7
K_S^0	···	···	···	···	···	···	1.5	···	···	1.5	1.5
π^0	···	···	···	2.0	···	2.0	···	2.0	2.0	···	···
η	···	···	···	···	1.2	···	···	···	···	···	···
γ-conversion veto	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
MC modeling	3.0	12.8	24.6	12.6	13.6	13.1	6.6	2.1	5.6	4.9	4.9
$B_{\rm inter}$	···	···	···	0.1	0.5	0.8	0.1	0.1	0.1	0.1	0.1
Total	8.0	13.4	25.2	12.9	13.9	14.0	7.3	5.3	8.2	7.5	8.6

- **Results:**
  - Likelihood scan.
  - Systematic uncertainties & upper limits.



Signal decays	$\mathcal{B}$ ($\times 10^{-5}$)	PDG [9] ($\times 10^{-5}$)
$D^+\to\pi^+\pi^0e^+e^-$	<1.4	···
$D^+\to K^+\pi^0e^+e^-$	<1.5	···
$D^+\to K_S^0\pi^+e^+e^-$	<2.6	···
$D^+\to K_S^0K^+e^+e^-$	<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
$D^0\to K_S^0e^+e^-$	<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 $(1.0^{+0.5}_{-0.4})$	···

OutLine



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BESIII data set & capability

- **BESIII data set: (from BESIII physics page)**

For J/Ψ

Sample type	Ecms (GeV)	Run ID	Event number (Int. luminosity)
On-J/ψ (2009)	3.097	9947-10878	224.0±1.3M (80 pb-1)
On-J/ψ (2012)	3.097	27255-28236	1088.5±4.4M (315 pb-1)
On-J/ψ (2017-2019)	3.097	52940-54976 55861-56546 56788-59015	8774.0±39.4M (2571 pb-1)

For $\Psi(3686)$

Sample type	Ecms (GeV)	Run ID	Event number (Int. luminosity)
On-ψ(3686) (2009)	3.686	8093-9025	107.0±0.8M (161.63±0.13 pb-1)
On-ψ(3686) (2012)	3.686	25338-27090	341.1±2.1M (506.92±0.23 pb-1)

For $\Psi(3770)$

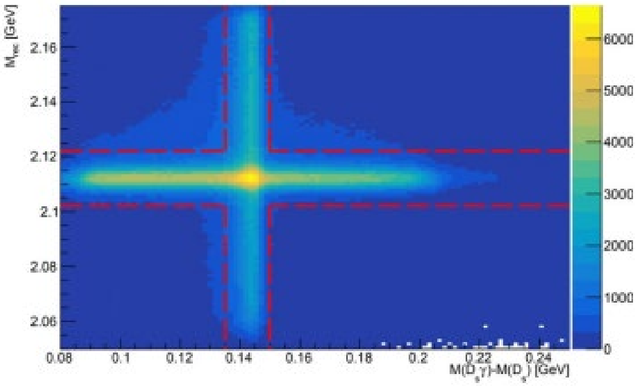
Sample type	Ecms (GeV)	Run ID	Int. luminosity
On-ψ(3770) (2010)	3.773	11414-13988 14395-14604	2931.8±0.2±13.8 pb-1
On-ψ(3770) (2011)	3.773	20448-23454	

For above 4.6 GeV:

Energy points	4.600 GeV	4.612 GeV	4.628 GeV	4.641 GeV	4.661 GeV	4.682 GeV	4.698 GeV
Lumi(pb^{-1})	566.90	103.45	519.93	548.15	527.55	1664.34	534.40

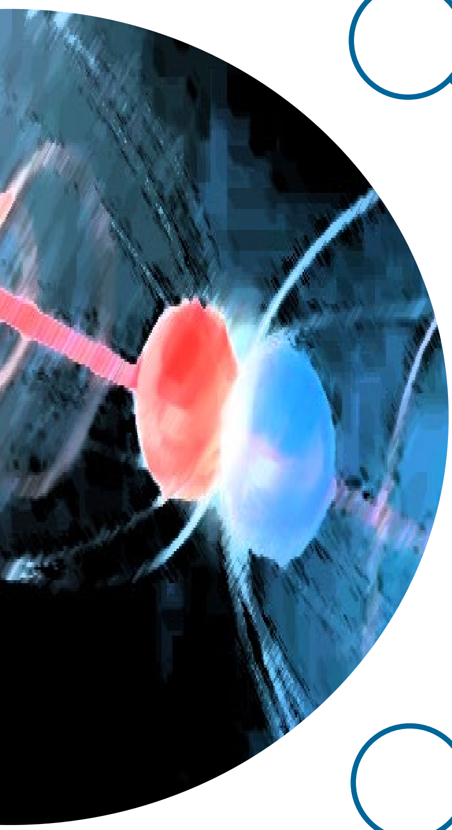
FCNC analysis in future

- **On-going analysis:**
  - $D_s^+ \to h(h')e^+e^-$, [Liang Sun, WHU] [NPG Group meeting Report]



- **Analysis suggest in future:**
  - Update of $J/\psi \to D^0 e^+e^-$: **more data sample**
  - Update of $J/\psi \to \Lambda_c^+ \bar{p} e^+e^-$: **more data sample**
  - Search for $\Lambda_c^+ \to p e^+e^-$: **large data sample + sufficient tag modes**
  - **Other suggestion ? ...**

OutLine



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Summary

- **BESIII has advantages in search for $c \rightarrow u$ FCNC process.**

- **4 Analysis of different kind FCNC have been carried out at BESIII, 4 papers produced.**
  - $D^0 \rightarrow \gamma\gamma$: **PRD 91, 112015 (2015)**
  - $J/\psi, \psi(3686) \rightarrow D^0 e^+ e^-$: **PRD 96, 111101(R) (2017)**
  - $\psi(3686) \rightarrow \Lambda_c^+ \bar{p} e^+ e^-$: **PRD 97, 091102(R) (2018)**
  - $D^+(D^0) \rightarrow h(h') e^+ e^-$: **PRD 97, 072015 (2018)**

- **Techniques are mature for FCNC analysis at BESIII.**

- **More data sample is needed.**

- **More analysis can be studied in future.**

Thanks for your attention!