Search for Lepton Flavor Violating τ Decays in Belle experiments

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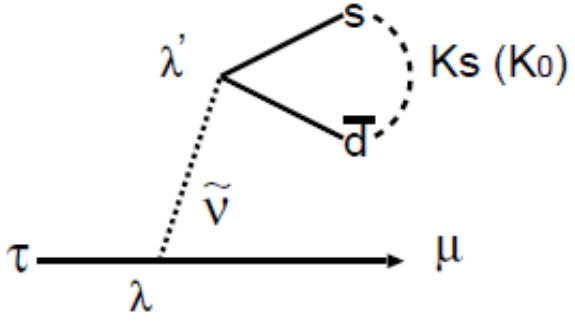
Introduction

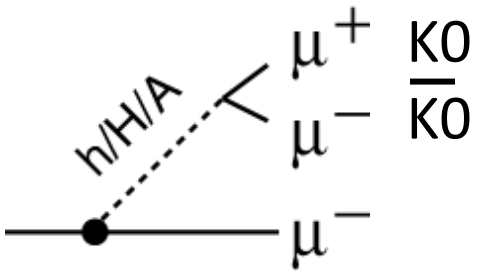
Lepton flavor violation (LFV) in charged lepton sector

Many extensions of the SM predict LFV decays.
Their branching fractions are enhanced as high as current experimental sensitivity
⇒Observation of LFV is a clear signature of New Physics (NP)

Tau lepton : the heaviest charged lepton
- Strong coupling with NP
- Opens many possible LFV decay modes which depend on NP models
⇒Ideal place to search for NP



R-parity violation



Higgs-mediation LFV

KEKB and Belle

KEKB: e^+(3.5 GeV) e^-(8GeV)

$\sigma(\tau\tau)$~0.9nb,$\sigma(b\bar{b})$~1.1nb

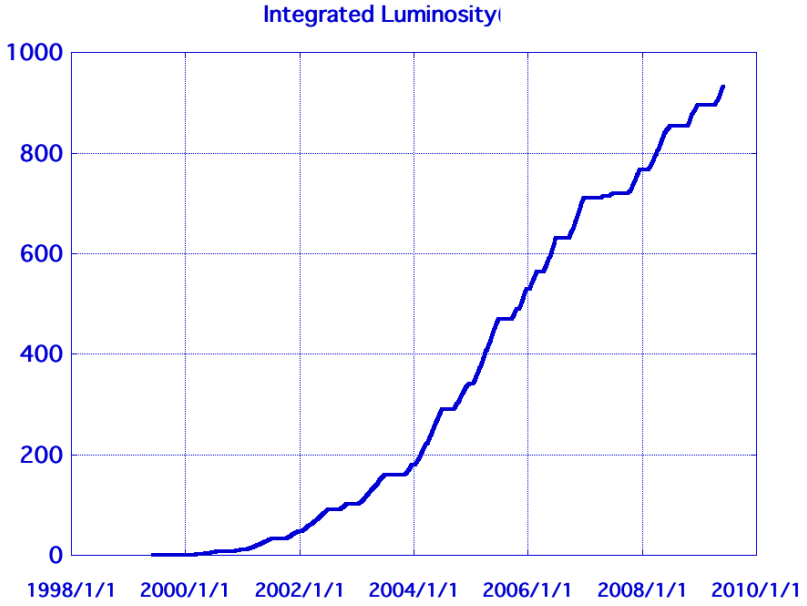
A B-factory is also a τ-factory!

Peak Luminosity 2.1×10^{34} cm^{-2} s^{-1}

⇒ World record!!!

Integrated luminosity: 945 fb^{-1}

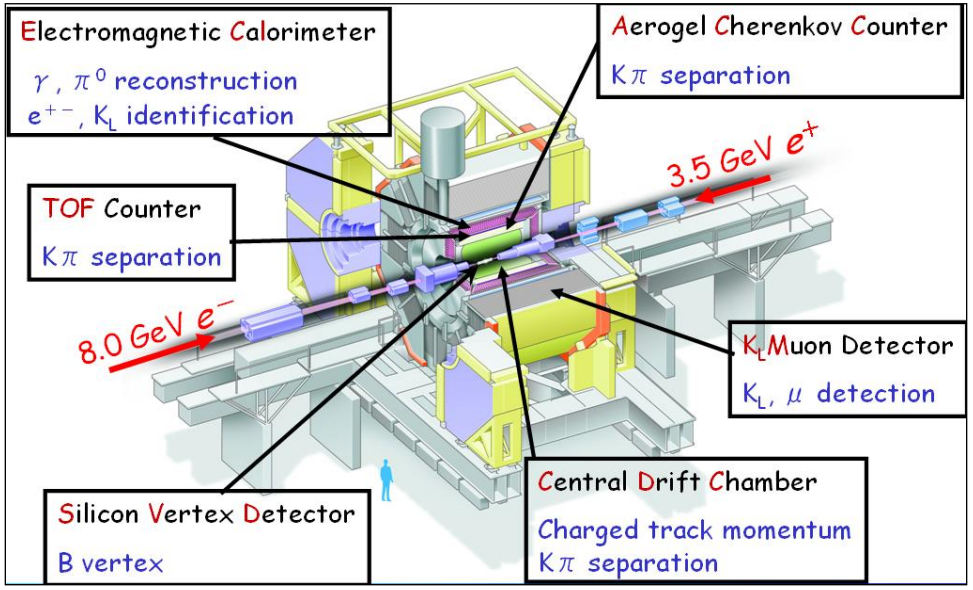
⇒8.7×10^8 τ-pairs



Belle Detector:

Good track reconstruction and particle identifications

Lepton efficiency:90%
Fake rate : O(0.1) % for e
O(1)% for μ



New Results in this summer

- lKs mode

  Update analysis from 261fb^{-1} →671fb^{-1} (x2.4 times)

  Our previous UL is Br(τ→lK^{0}s) < (4.9-5.6)x10^{-8} (PLB639, 159, 2006)

  New BaBar results @469fb^{-1} (PRD97,012004,2009)

  →Br(τ→lK^{0}s) <(3.3–4.0)x10^{-8}

- lKsKs mode

  No study of this mode yet at Belle and BaBar

  Current UL Br(τ→lKsKs)< (2.2-3.4)x10^{-6}@13.9fb^{-1} by CLEO

  Search using 671 fb^{-1} (x48 times CLEO)

- 3leptons

  Update analysis from 543fb^{-1} →872b^{-1}

  Our previous UL is Br(τ→3leptons) < (2.0-4.1)x10^{-8}(PLB660, 154, 2008)

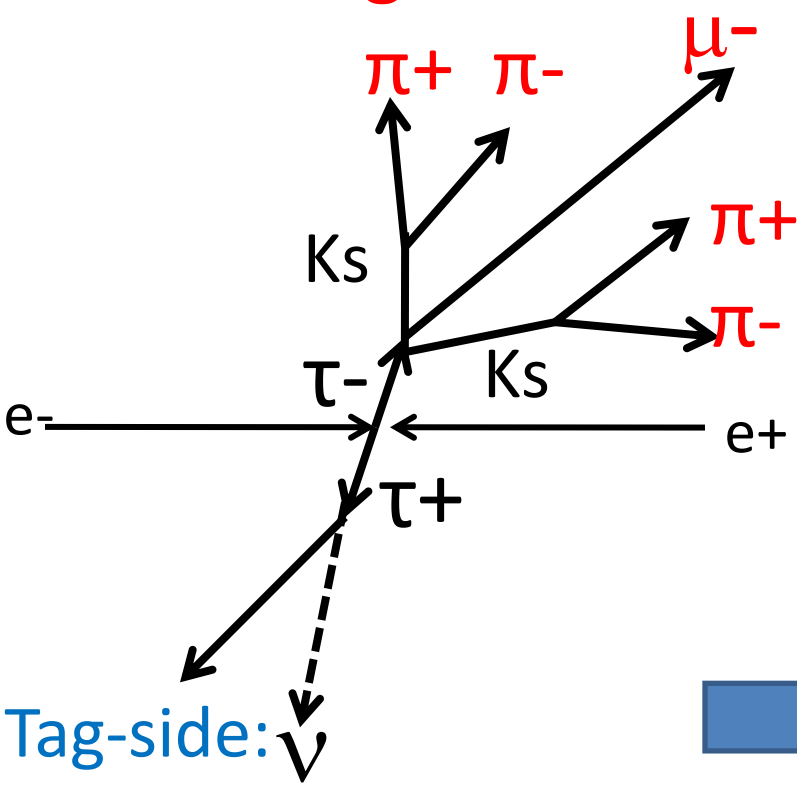
  BaBar updates the results from to 367fb^{-1} to 477fb^{-1}

  - Br(τ→3leptons) < (1.8–3.3) x 10^{-8} (Preliminary)

Event Selection

5-1 (3-1) prong events for lKsKs (lKs and 3leptons)

Signal side:



Tag-side:
Generic 1-prong decay
(Br(τ→1-prong+ν) ～85%)

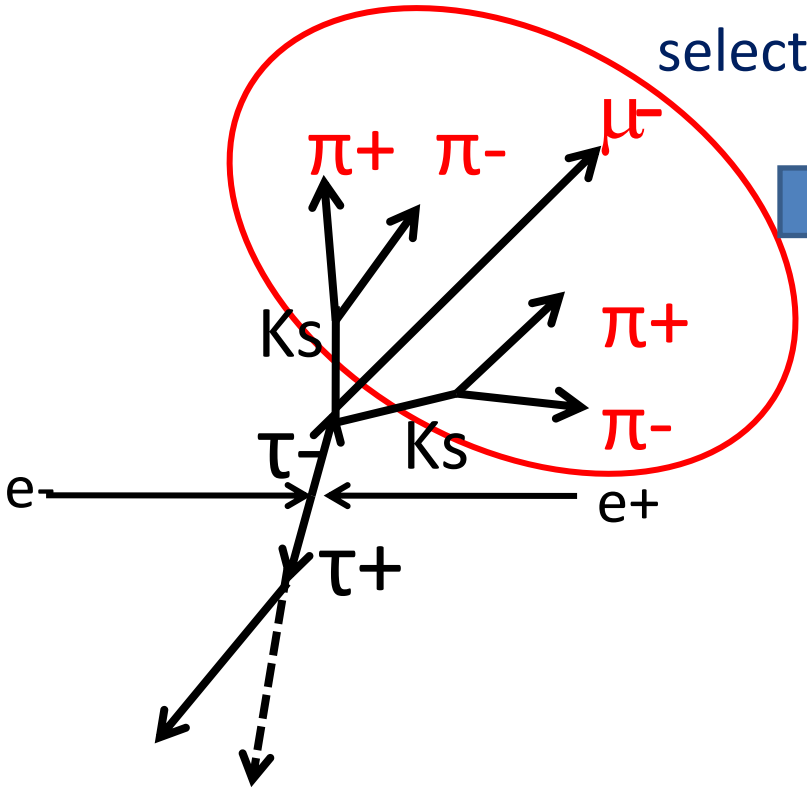
Select events with low multiplicity and separate two sides using thrust
- Signal (charged tracks from LFV)
- Tag (generic 1-prong decay)

Reduce background events using PID, kinematical information

optimize the event selection for each mode separately

Analysis method

Signal side:

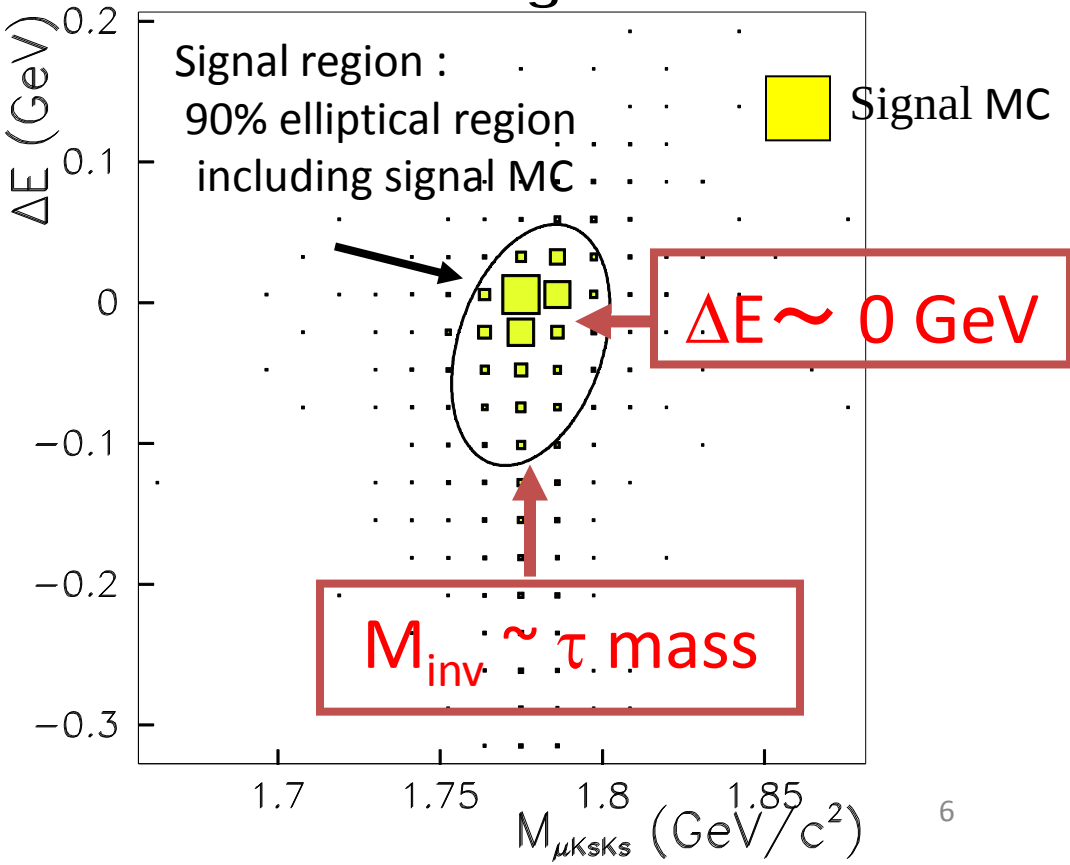


After event selection

Signal Extraction using particles in signal side

$$M_{inv} = \sqrt{E_{signal}^2 - p_{signal}^2}$$

$$\Delta E = E_{signal}^{CM} - E_{beam}^{CM}$$



Blind analysis

⇒Blind signal region

Estimate number of BG using sideband data

Optimization

To find the LFV signature

we optimize the selection criteria to obtain a good sensitivity for the signal discovery, not for a lower UL.

To state 99% C.L. evidence

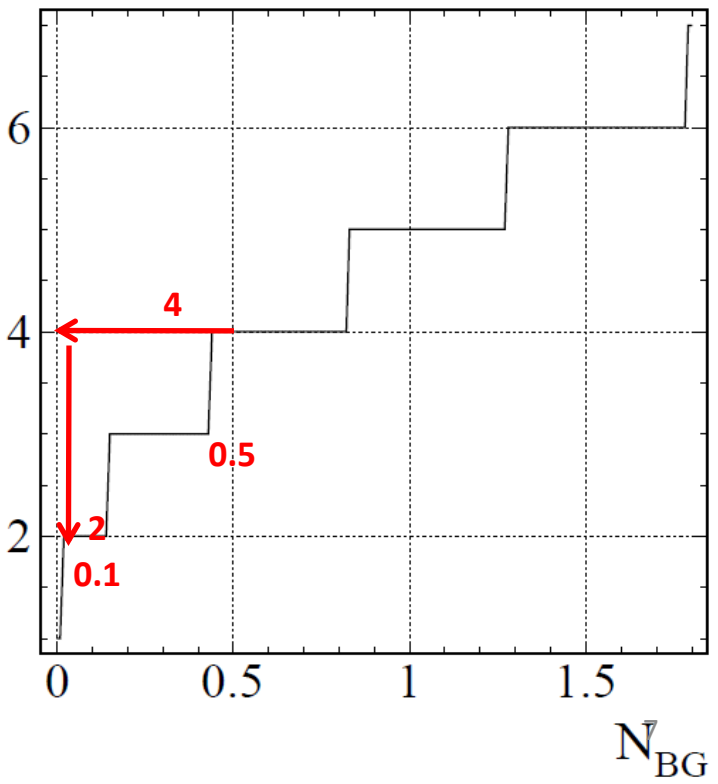
— Need 2events for N_{BG}~0.1

— Need 4events for N_{BG}~0.5

→ Diff. of effective efficiency is 2.

Unless the efficiency drops significantly, we set the criteria to reduce N_{BG} as much as possible.

Number of observed event, $N^{99}_{obs.}$ which we need for 99% CL evidence, as a function of Expected of BG, N_{BG}



lKs and lKsKs

Apply optimized event selections

Dominant BG in signal region

⇒ Fake lepton + real Ks from

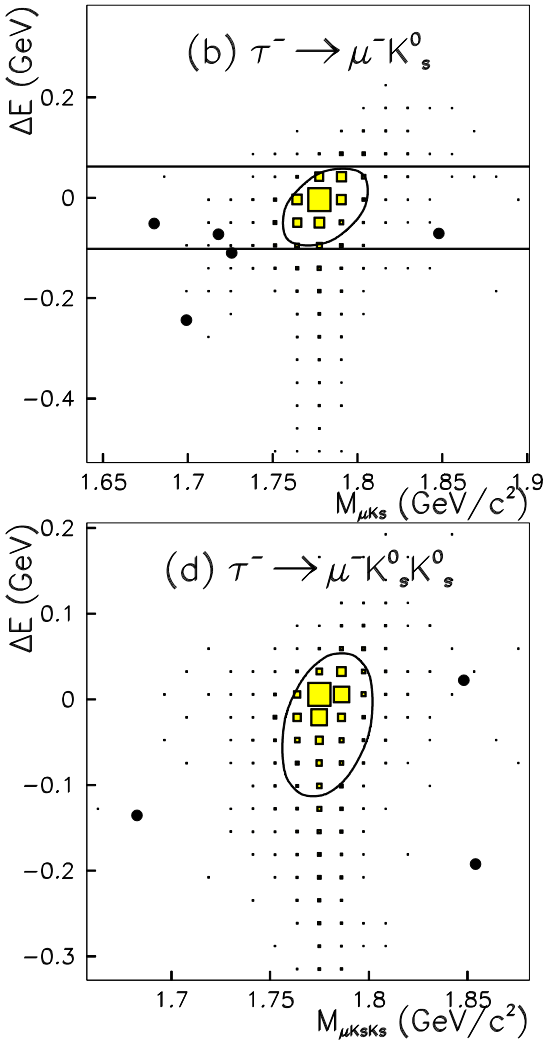
ee→$q\bar{q}$(=u,d,s and c) for both modes

We observe no events in signal region

⇒Set upper limits at 90% C.L.

Mode	ε (%)	$N_{\rm BG}$	$\sigma_{\rm syst}$ (%)	$N_{\rm obs}$	s_{90}	$\mathcal{B}$ ($\times 10^{-8}$)
$\tau^- \to e^- K^0_S$	10.2	0.18±0.18	6.6	0	2.25	2.6
$\tau^- \to \mu^- K^0_S$	10.7	0.35±0.21	6.8	0	2.10	2.3
$\tau^- \to e^- K^0_S K^0_S$	5.82	0.07±0.07	11.2	0	2.44	7.1
$\tau^- \to \mu^- K^0_S K^0_S$	5.08	0.12±0.08	11.3	0	2.40	8.0

(dominant sys, 4.5% per Ks , 1.0% per track)



- B(τ→lK^0s) < (2.3-2.6) x 10^{-8}

  ⇒ Obtain lower ULs than BaBar's ones (3.3-4.4)x10^{-8}

- B(τ→lK^0sK^0s) < (7.1-8.0)x10^{-8}

  ⇒ improve in a factor of (31-43) from CLEO's results

Preliminary

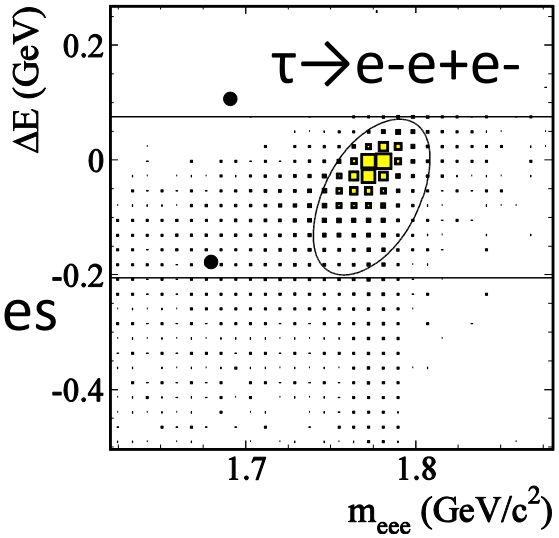
τ→3leptons

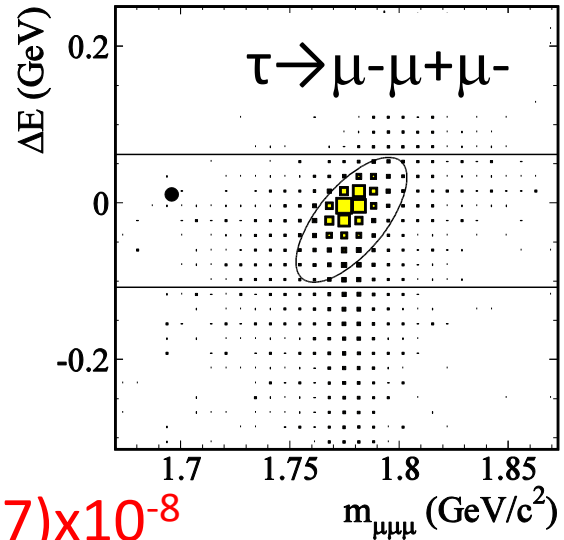
Apply almost same event selection as previous analysis

We observe no events in signal region for all modes

Mode	ε (%)	N_{BG}^{EXP}	σ_{syst} (%)	UL (x10^{-8})
$e^-e^+e^-$	6.0	0.21+-0.15	9.8	**2.7**
$\mu^-\mu^+\mu^-$	7.6	0.13+-0.06	7.4	**2.1**
$e^-\mu^+\mu^-$	6.1	0.10+-0.04	9.5	**2.7**
$\mu^-e^+e^-$	9.3	0.04+-0.04	7.8	**1.8**
$\mu^-e^+\mu^-$	10.1	0.02+-0.02	7.6	**1.7**
$e^-\mu^+e^-$	11.5	0.01+-0.01	7.7	**1.5**

Preliminary





We obtain upper limit as Br(τ→3leptons) < (1.5-2.7)x10^{-8}

- Improved the sensitivities along with the increasing luminosity
- Obtained lower ULs than BaBar's ones(< (1.8-3.3)x10^{-8})

Discussion

- In Feldman-Cousins approach, we can obtain lower UL if we obtain less number of observation than expected background.
- As another strategy, we set loose criteria, in which N_{BG}~0.5.

⇒We demonstrate using 3leptons modes with loose cuts

Mode	ε (%)	N_{BG}^{EXP}	N_{obs}	UL (x10^{-8})	BaBar's
$e^-e^+e^-$	6.0 → 7.9	0.21+-0.15 → 0.48+-0.21	0→0	**2.7→1.8**	2.9
$\mu^-\mu^+\mu^-$	7.6 → 8.9	0.13+-0.06 → 0.42+-0.17	0→0	**2.1→1.6**	3.3
$e^-\mu^+\mu^-$	6.1 → 6.8	0.10+-0.04 → 0.52+-0.21	0→0	**2.7→2.0**	3.2
$\mu^-e^+e^-$	9.3 → 12.1	0.04+-0.04 → 0.41+-0.20	0→0	**1.8→1.2**	2.2
$\mu^-e^+\mu^-$	10.1 → 11.8	0.02+-0.02 → 0.09+-0.09	0→1	**1.7→2.5**	2.6
$e^-\mu^+e^-$	11.5 → 13.1	0.01+-0.01 → 0.01+-0.01	0→0	**1.5→1.3**	1.8

We can obtain lower ULs than original ULs if we apply loose cuts.

Br(τ→3leptons) < (1.5–2.7) x 10^{-8} with original cuts → (1.3–2.5) x 10^{-8} with loose cuts

Summary

We have updated searches for lepton flavor violating τ decays using >600 fb^{-1} of data obtained by Belle

No LFV signals are observed yet and we set limits of the branching fraction at 90%CL around $O(10^{-8})$

- $Br(\tau \to lK^0s) < (2.3\text{-}2.6)\times10^{-8}$
- $Br(\tau \to lK^0sK^0s) < (7.1\text{-}8.0)\times10^{-8}$
- $Br(\tau \to 3leptons) < (1.5\text{-}2.7)\times10^{-8}$

Preliminary

Succeed to reject BG ~O(0.1) effectively but keeping higher efficiencies

We provide the highest sensitivities to New Physics via lepton flavor violating τ decays