A02班

# Belle実験での
# Bとtau物理

居波(名古屋大)

# Bファクトリー

- 高輝度電子・陽電子衝突実験
  - B崩壊におけるCP対称性の破れの発見
    - 小林益川理論の検証
  - b/c/τ粒子の稀崩壊反応による新物理探索
    - B中間子稀崩壊(B→$X_s\gamma$、$K^{(*)}ll$、τνなど)
    - D中間子混合
    - タウLFV崩壊探索
  - 新しいハドロン共鳴
- スーパーBファクトリー、Belle-II実験
  - 測定器開発

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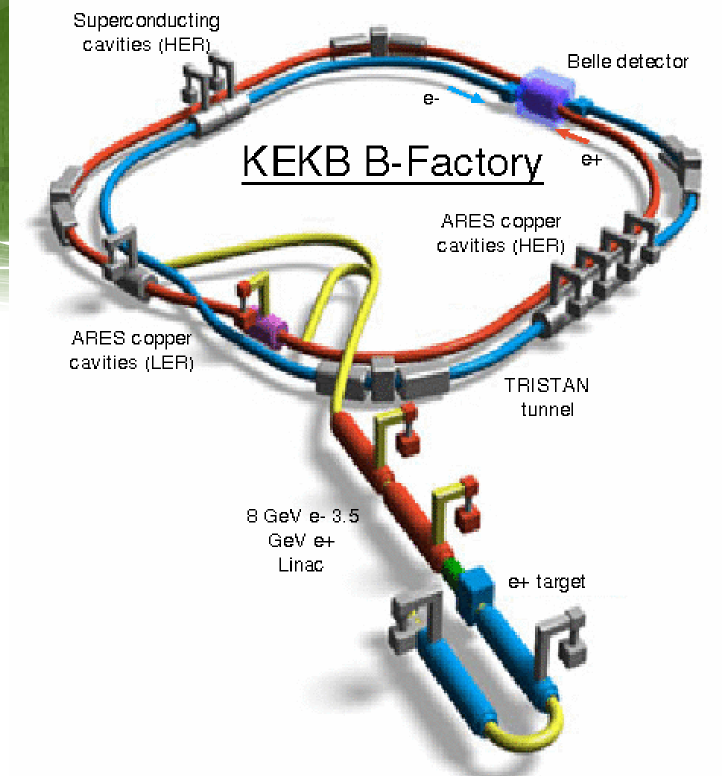
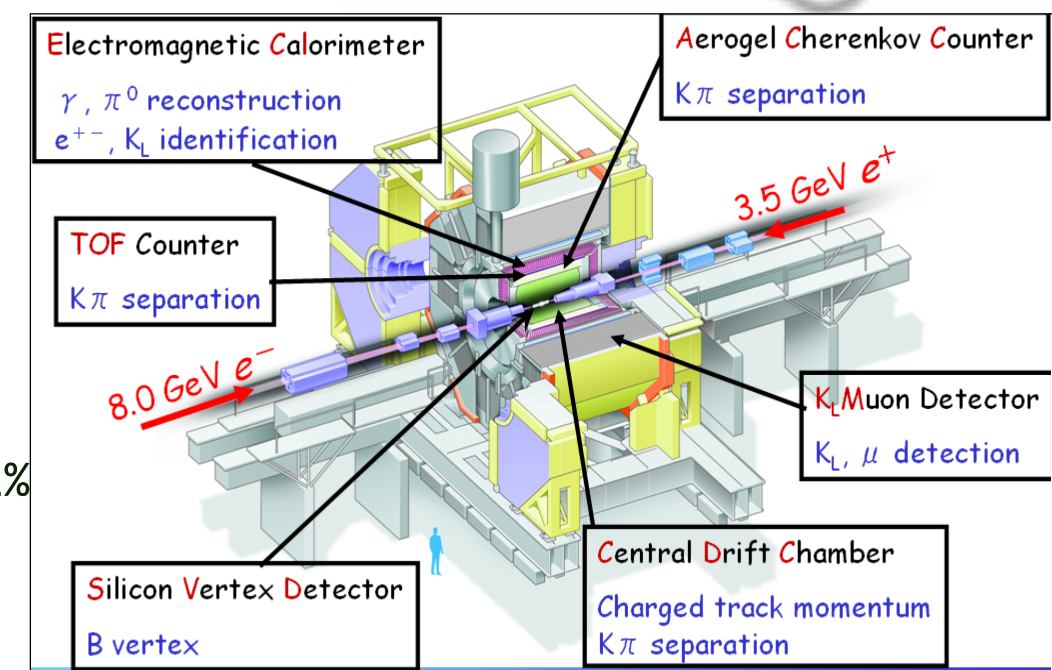
第3世代のb, タウを通した新物理探索

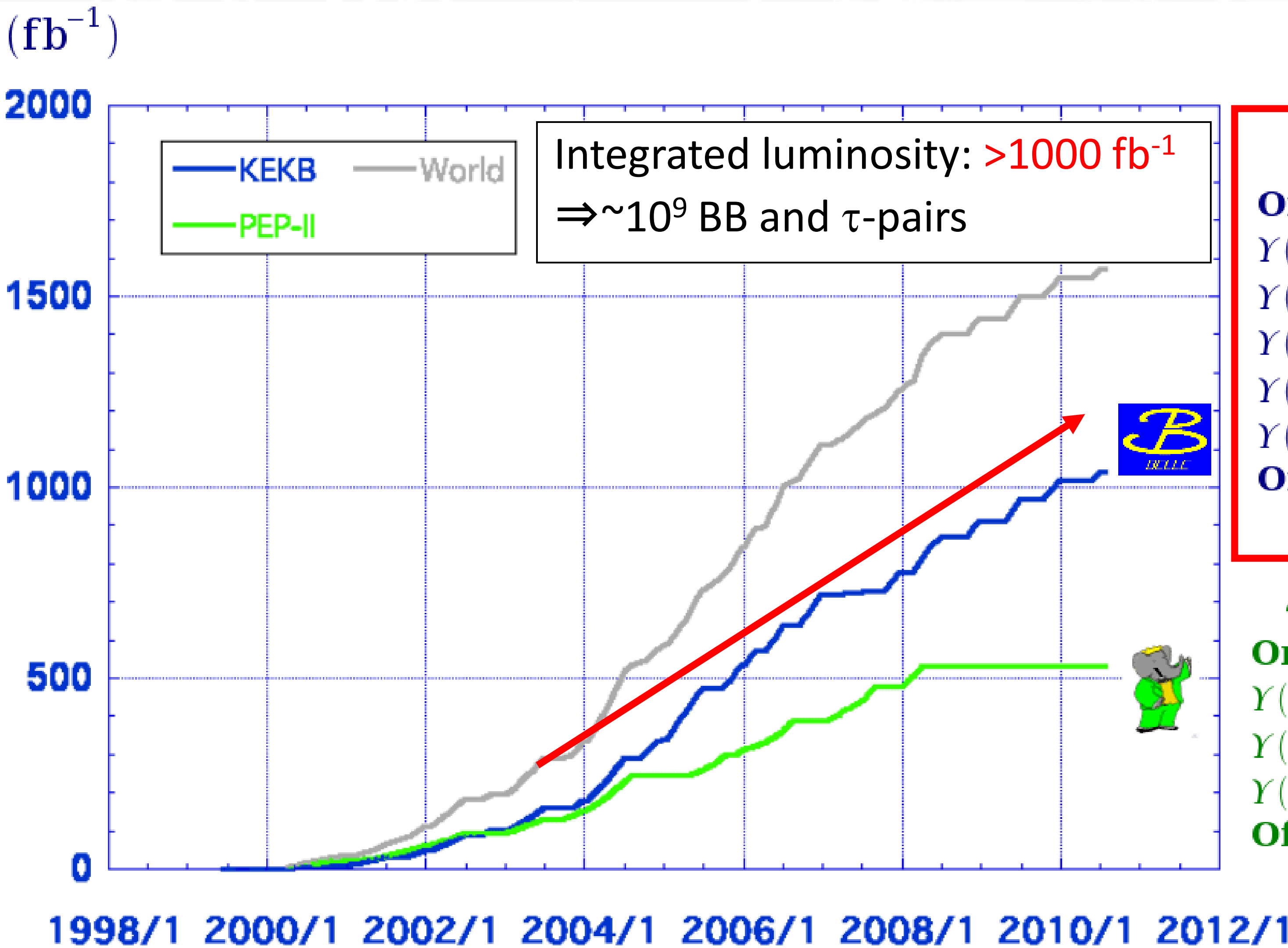
# KEKB/Belle

- KEKB加速器
  - 電子(8GeV)陽電子(3.5GeV)
  - σ(bb)~1.1nb,σ(ττ)~0.9nb
  - Peak luminosity:
    $2.1\text{x}10^{34}/\text{cm}^2/\text{s}$ 世界最高記録
- Belle測定器
  - Good vertex
  - Good PID
    - Kaon ID
    - Lepton ID
      - Eff.:90%
      - Fake rate: 0.1~1%



# Luminosity history




**> 1 ab$^{-1}$**

**On resonance:**

$\Upsilon(5S)$: 121 fb$^{-1}$

$\Upsilon(4S)$: 711 fb$^{-1}$

$\Upsilon(3S)$: 3 fb$^{-1}$

$\Upsilon(2S)$: 24 fb$^{-1}$

$\Upsilon(1S)$: 6 fb$^{-1}$

**Off reson./scan:**

$\sim 100$ fb$^{-1}$

**~ 550 fb$^{-1}$**

**On resonance:**

$\Upsilon(4S)$: 433 fb$^{-1}$

$\Upsilon(3S)$: 30 fb$^{-1}$

$\Upsilon(2S)$: 14 fb$^{-1}$

**Off resonance:**

$\sim 54$ fb$^{-1}$

# B physics analysis

$B \rightarrow \tau\nu$ 2006, 2008, 2012
$B \rightarrow \eta' K_s$ 2006
$B \rightarrow K_s \pi^0 \pi^0$ 2007
$B \rightarrow \pi l \nu$, $\rho l \nu$ 2007
$B \rightarrow D^* \tau\nu$ 2009

# B→τν, D*τν

- 新物理モデル(>2 Higgs doublets)では、tree-levelの荷電ヒッグス交換で新しいフレーバ変換が起こり得る
- $H^+$ couplingはフェルミオン質量に比例
  - ➔ B中間子がタウへ崩壊する反応を調査

$$\mathcal{H}^{\text{eff}} = 2\sqrt{2}\, G_F\, V_{qb}\{(\bar{b}_L\,\gamma^\mu\, q_L)\,(\bar{\nu}_L\,\gamma_\mu\,\tau_L) - \frac{m_b m_\tau}{m_B^2} g_S\,(\bar{b}_R\, q_L)\,(\bar{\nu}_L\,\tau_R)\};$$

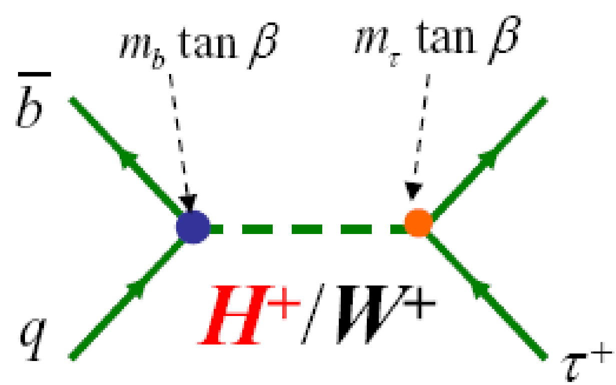
- B→τν transition (MSSM)

Effective scalar coupling;

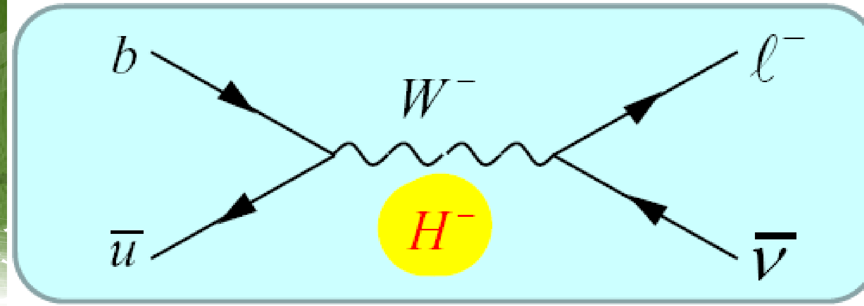
$$g_S = \frac{M_B^2 \tan^2\beta}{M_H^2}\frac{1}{(1+\varepsilon_0\tan\beta)(1+\varepsilon_\tau\tan\beta)}$$

SUSY loop correction

$\varepsilon_0=\varepsilon_\tau=0$ in Type-II 2HDM



# B→τν




- Within SM

$$\mathcal{B}(B^- \to \ell^- \bar{\nu}) = \frac{G_F^2 m_B m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

  - From $f_B$, $|V_{ub}|$

$f_B = 190 \pm 13\ MeV$ HPQCD, 0902.1815v2

$|V_{ub}| = (4.32 \pm 0.16 \pm 0.29) \times 10^{-3}$ HFAG ICHEP08

$\Rightarrow Br_{SM}(\tau\nu) = (1.20 \pm 0.25) \times 10^{-4}$

- With charged Higgs

$$Br = Br_{SM} \times r_H, \quad r_H = |1 - g_s|^2$$

Effective scalar coupling;

$$g_S = \frac{M_B^2 \tan^2\beta}{M_H^2} \frac{1}{(1+\varepsilon_0 \tan\beta)(1+\varepsilon_\tau \tan\beta)}$$

# Analysis procedure

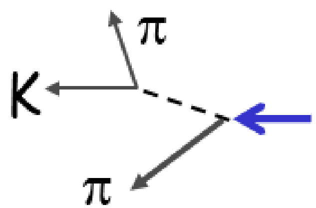
S/N

Eff

## Tagging side:

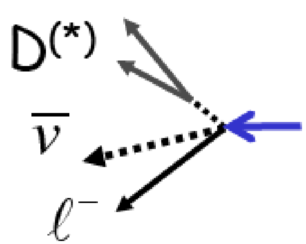
**Hadronic tags**

$B_{tag} \to D^{(*)}\pi/\rho$ etc.



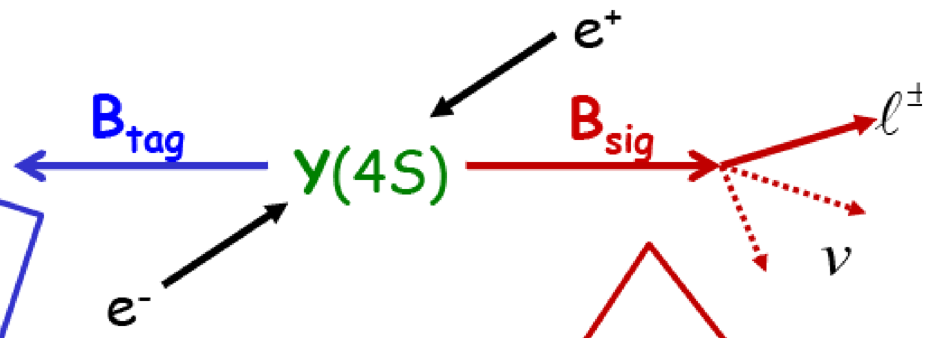

**Semileptonic tags**

$B_{tag} \to D^{(*)} l \nu$ etc.



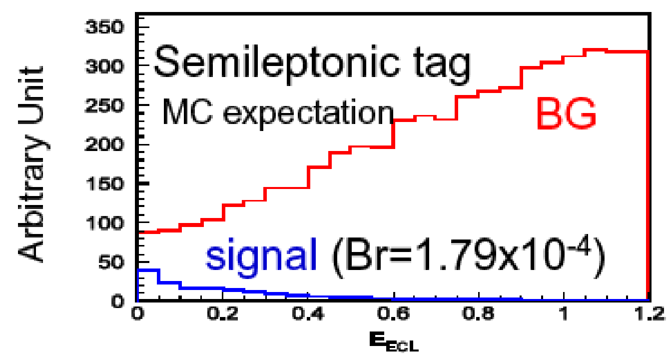

**Inclusive tags**

Used for Belle $B \to D^{*}\tau\nu$




## Signal side: $B_{sig} \to l\,\nu$

- Detect charged track(s)
- Missing energy due to $\nu$'s
- No extra activities in EM calorimeter ($E_{ECL(extra)}$)



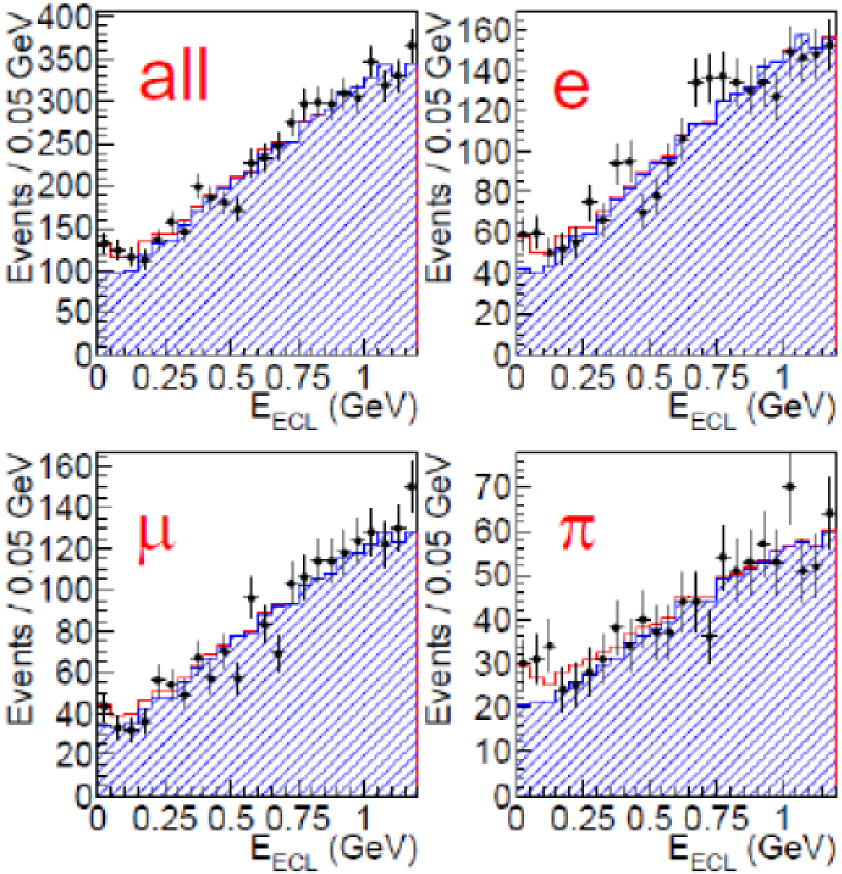
# B→τν with semi-leptonic tag

- 657M BB

$$\mathcal{B} = [1.54^{+0.38}_{-0.37}(\text{stat})^{+0.29}_{-0.31}(\text{syst})] \times 10^{-4}$$

3.6σ evidence

PRD82, 071101(R), (2010)




| Decay mode | Signal yield | ε, $10^{-4}$ | $\mathcal{B}$, $10^{-4}$ |
|---|---|---|---|
| $\tau^- \to e^- \bar{\nu}_e \nu_\tau$ | $73^{+23}_{-22}$ | 5.9 | $1.90^{+0.59+0.33}_{-0.57-0.35}$ |
| $\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$ | $12^{+18}_{-17}$ | 3.7 | $0.50^{+0.76+0.18}_{-0.72-0.21}$ |
| $\tau^- \to \pi^- \nu_\tau$ | $55^{+21}_{-20}$ | 4.7 | $1.80^{+0.69+0.36}_{-0.66-0.37}$ |
| Combined | $143^{+36}_{-35}$ | 14.3 | $1.54^{+0.38+0.29}_{-0.37-0.31}$ |

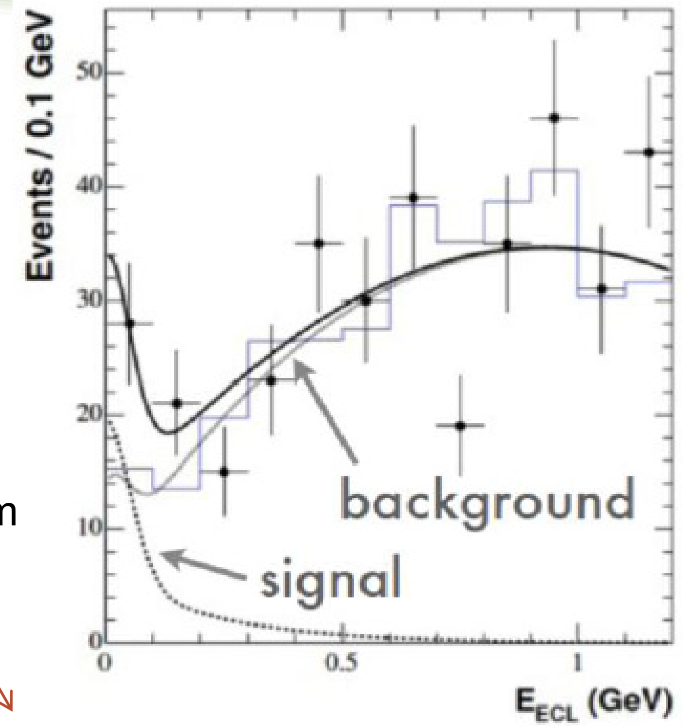
# B→τν with hadronic tag

- 449M BB

$$\mathcal{B} = [1.79^{+0.56}_{-0.49}(\mathrm{stat})^{+0.46}_{-0.51}(\mathrm{syst})] \times 10^{-4}$$

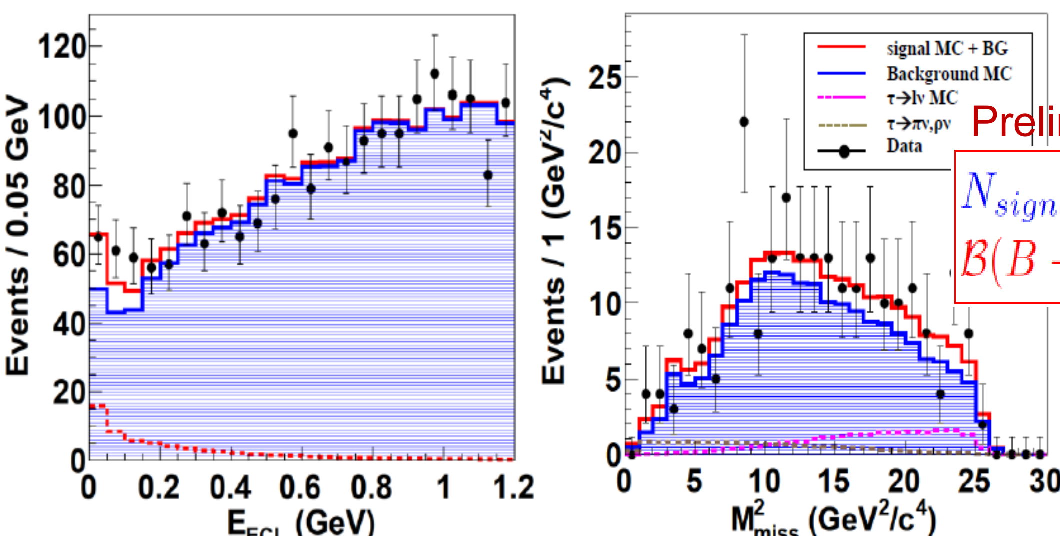
(3.5σ) PRL 97, 251802 (2006)

  - First evidence




Improved tagging algorism

- 771M BB (Reported at ICHEP2012)




Preliminary

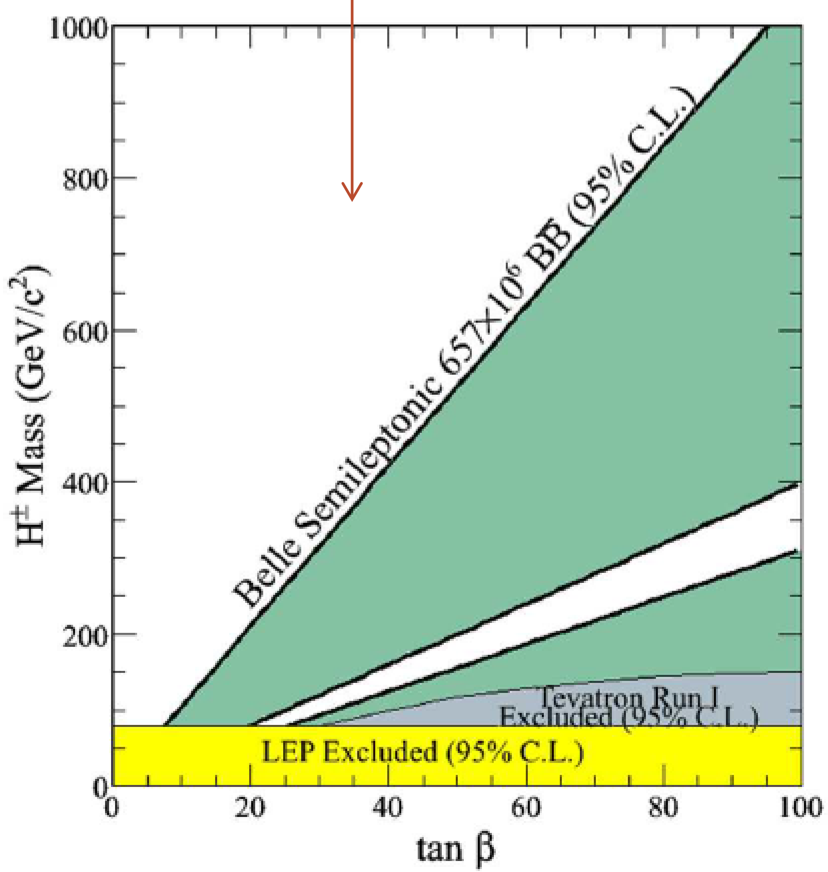
$$N_{signal} = 62.3^{+23.1}_{-21.7}$$

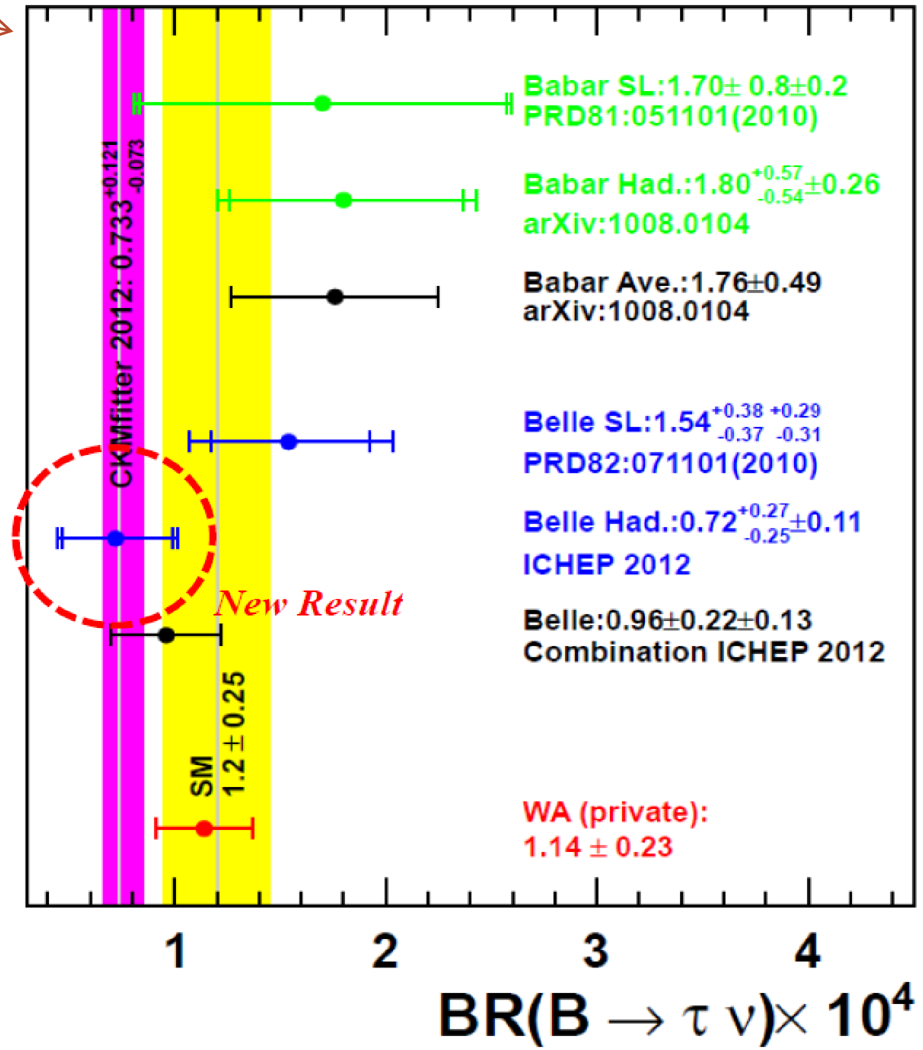
$$\mathcal{B}(B \to \tau\nu) = (0.72^{+0.27}_{-0.25}(\mathrm{stat.}) \pm 0.11(\mathrm{syst.})) \times 10^{-4}$$

2D ($E_{ECL}$-$M^2_{miss}$) fit for signal extraction
(Improve significance by ~25%)

# Result of B(B→τν)

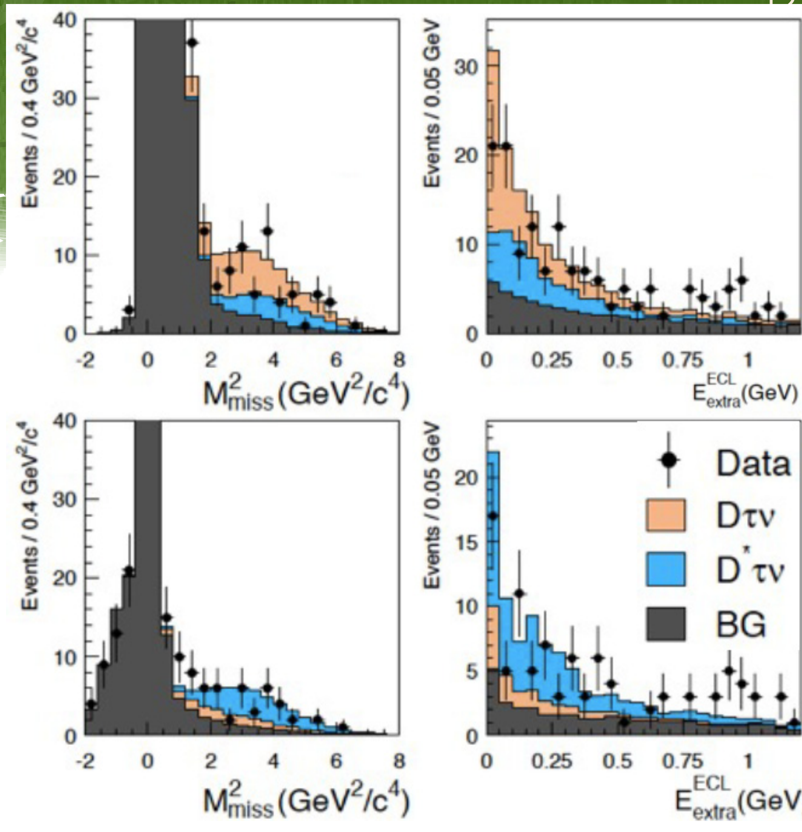
- 崩壊分岐比の比較
- 荷電ヒッグスへの制限
  - Semileptonic-tagの場合



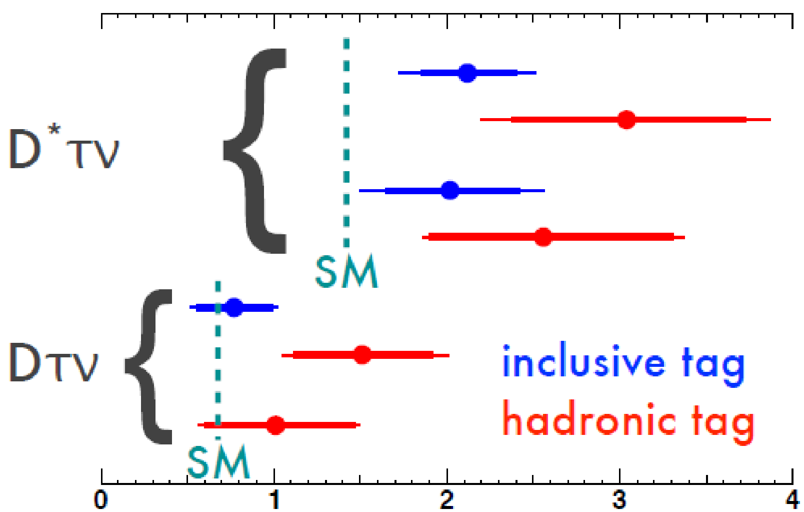
# $B \to D^{(*)}\tau\nu$

- 657M BB
- Hadronic tag
- Signal extraction from simultaneous fit with 2D ($E_{ECL}$-$M^2_{miss}$) parameters




$B^{\pm} \to D^{(*)}\tau\nu$

- No significant difference




$\mathcal{B}(D^{*0}\tau^-\bar{\nu}_\tau) = [2.12^{+0.28}_{-0.27}(\text{stat}) \pm 0.29(\text{syst})]\%$

$\mathcal{B}(D^{*0}\tau^-\bar{\nu}_\tau) = [3.04^{+0.69}_{-0.66}(\text{stat})^{+0.40}_{-0.47}(\text{syst}) \pm 0.22(\text{norm})]\%$

$\mathcal{B}(D^{*+}\tau^-\bar{\nu}_\tau) = [2.02^{+0.40}_{-0.37}(\text{stat}) \pm 0.37(\text{syst})]\%$

$\mathcal{B}(D^{*+}\tau^-\bar{\nu}_\tau) = [2.56^{+0.75}_{-0.66}(\text{stat})^{+0.31}_{-0.22}(\text{syst}) \pm 0.10(\text{norm})]\%$

$\mathcal{B}(D^{0}\tau^-\bar{\nu}_\tau) = [0.77 \pm 0.22(\text{stat}) \pm 0.12(\text{syst})]\%$

$\mathcal{B}(D^{0}\tau^-\bar{\nu}_\tau) = [1.51^{+0.41}_{-0.39}(\text{stat})^{+0.24}_{-0.19}(\text{syst}) \pm 0.15(\text{norm})]\%$

$\mathcal{B}(D^{+}\tau^-\bar{\nu}_\tau) = [1.01^{+0.46}_{-0.41}(\text{stat})^{+0.13}_{-0.11}(\text{syst}) \pm 0.10(\text{norm})]\%$

arXiv:0910.4301

# Time dependent CPV

- $B^0$mixing → $\phi_1$

$$A_{CP}=\frac{\mathcal{P}(\overline{B}^0(t)\to f_{CP})-\mathcal{P}(B^0(t)\to f_{CP})}{\mathcal{P}(\overline{B}^0(t)\to f_{CP})+\mathcal{P}(B^0(t)\to f_{CP})}$$
$$=\boxed{\mathcal{S}}\sin\Delta m_d t+\boxed{\mathcal{A}}\cos\Delta m_d t$$

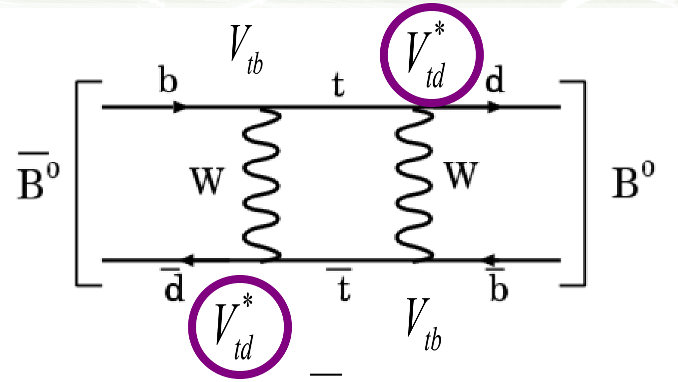
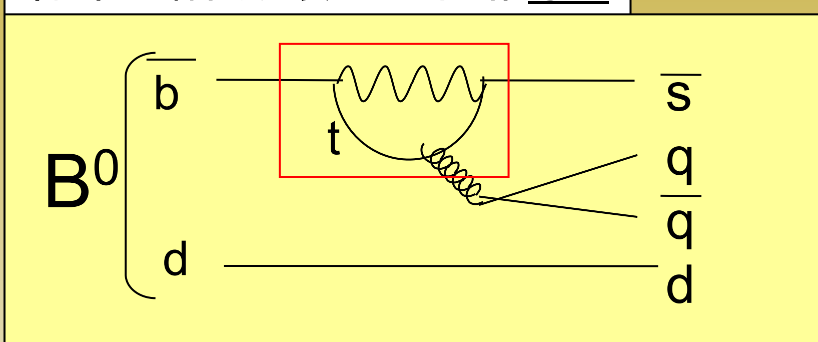



Diagram for $B^0$-$\overline{B}^0$ mixing including **CKM complex phase.**

- + New physics phase in b→s

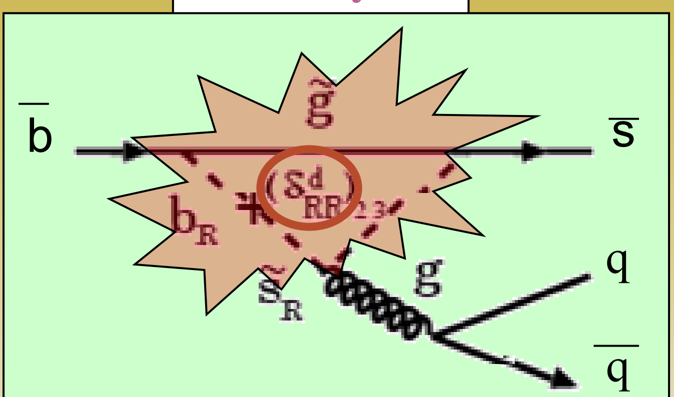
標準理論:崩壊にCP位相なし




$\mathcal{S}$ = - sin2$\phi_1$

$\mathcal{A}$ = 0

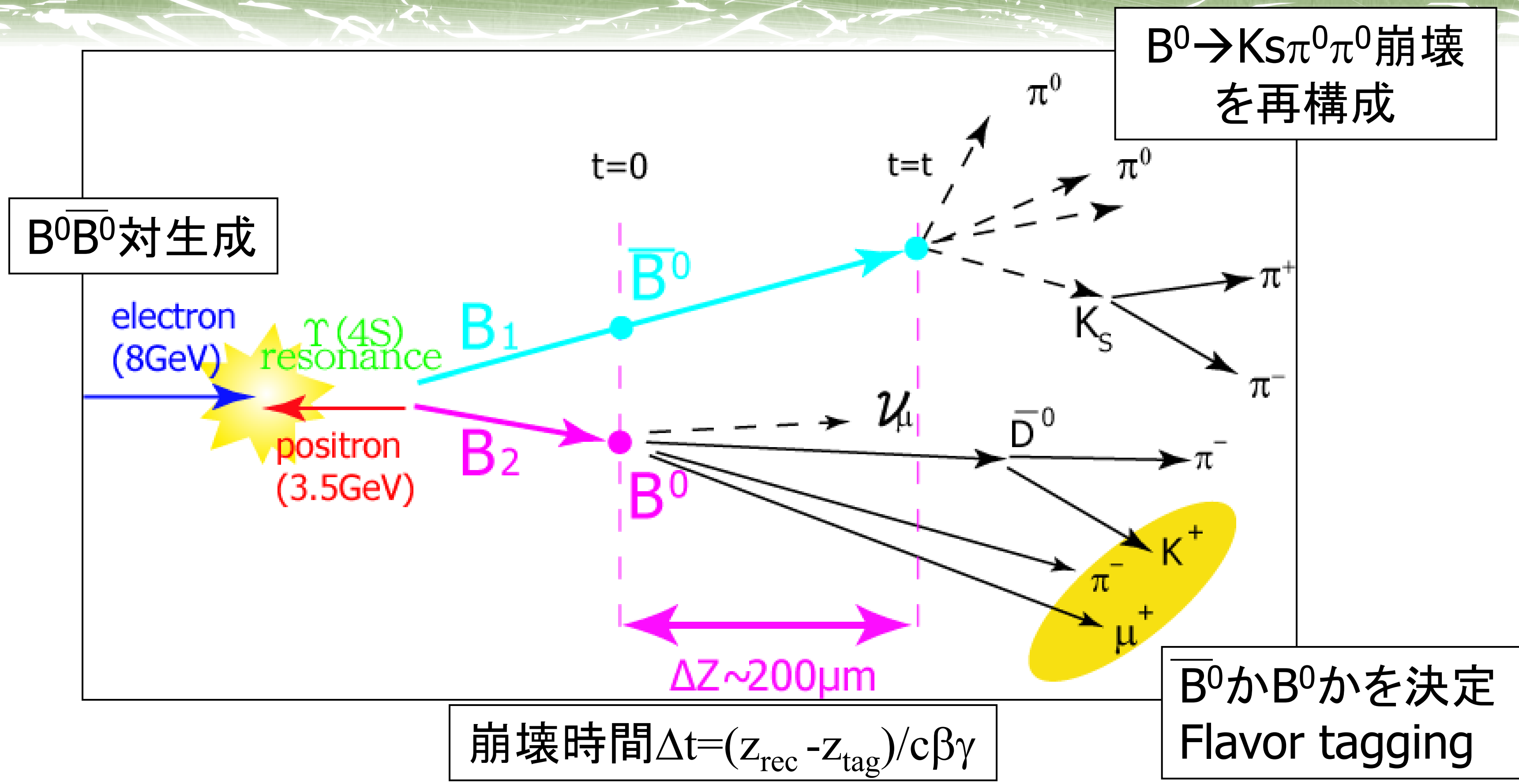
New Physics




New PhysicsのCP位相との干渉

$\mathcal{S}$ $\neq$ - sin2$\phi_1$

# Measurement of tCPV

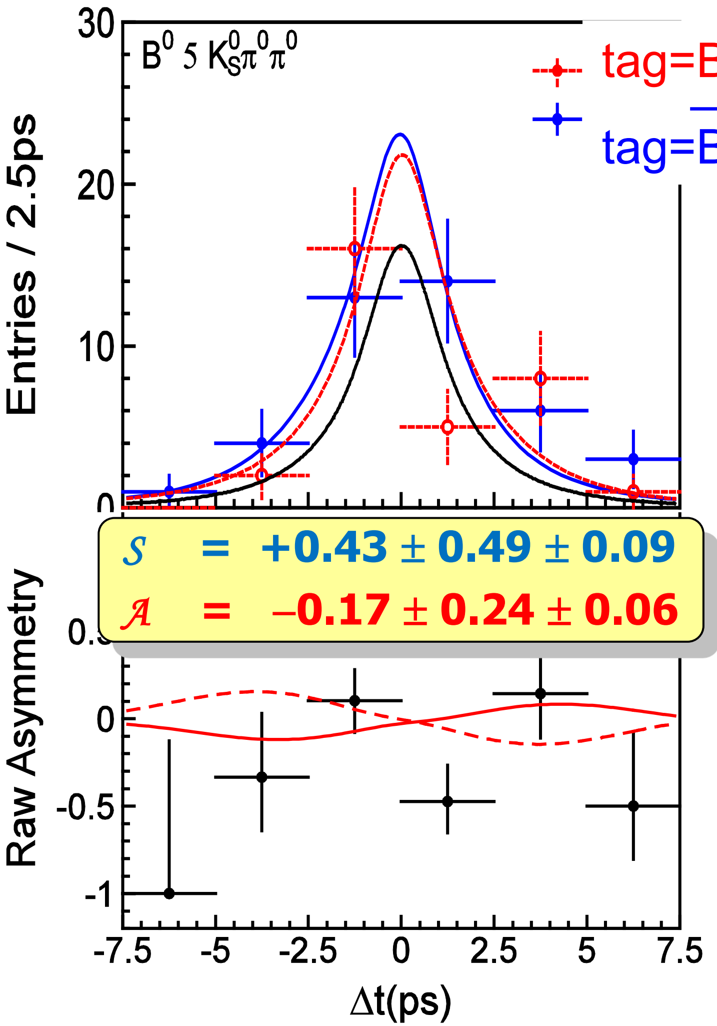



$$A_{CP}(t) \equiv \frac{\Gamma_{\overline{B}^0 \to f_{CP}}(\Delta t) - \Gamma_{B^0 \to f_{CP}}(\Delta t)}{\Gamma_{\overline{B}^0 \to f_{CP}}(\Delta t) + \Gamma_{B^0 \to f_{CP}}(\Delta t)} = \boxed{\mathcal{S}} \sin \Delta m_d \Delta t + \boxed{\mathcal{A}} \cos \Delta m_d \Delta t$$

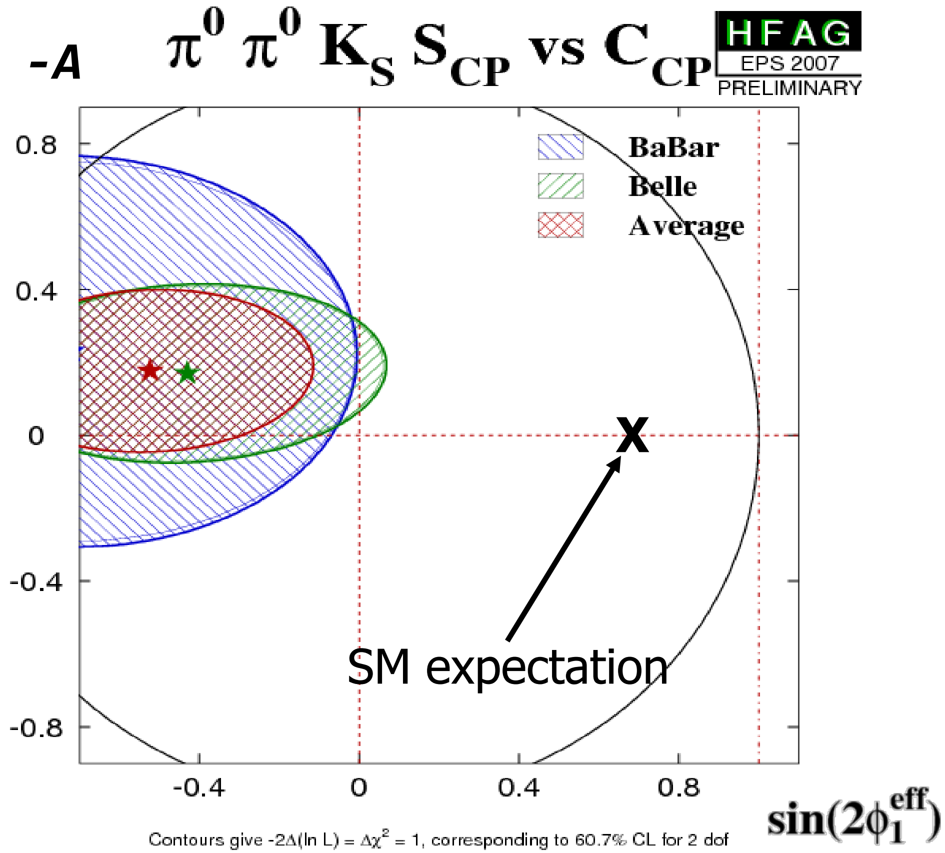
$\overline{B}^0$と$B^0$崩壊の$\Delta t$分布からCP非対称パラメータ $\mathcal{S}$ と $\mathcal{A}$ を求める

# $B^0 \to K_S\pi^0\pi^0$ tCPV 結果

- 657M BB (arXiv:0708.1845)




$\mathcal{S}$ = +0.43 ± 0.49 ± 0.09
$\mathcal{A}$ = −0.17 ± 0.24 ± 0.06




SMから2σ程度のずれ →データ量の増加が必要

# Tau physics analysis

Tau LFV search

$\tau \rightarrow \ell\ell\ell$

$\tau \rightarrow \ell K_s$

$\tau \rightarrow \ell V^0(\rightarrow hh')$

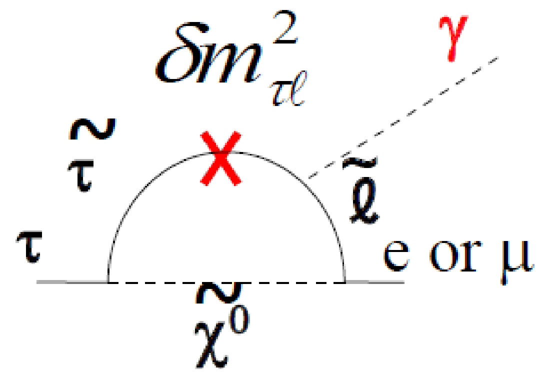
$\tau \rightarrow \ell P^0(\rightarrow \gamma\gamma)$

$\tau \rightarrow \ell hh'$

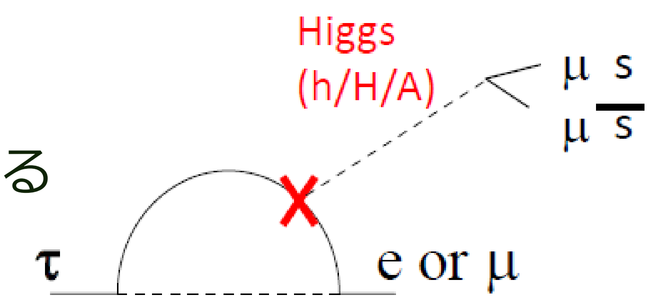
$\tau \rightarrow \ell\gamma$

# Lepton Flavor Violation in tau decay

- SUSYなどの新物理モデルでは、LFV反応を予言
  - LFV at one-loop due to mixing
    - SUSY-seesaw, SUSY-GUT
    - $\tau \rightarrow 1\gamma$が最大の崩壊分岐比

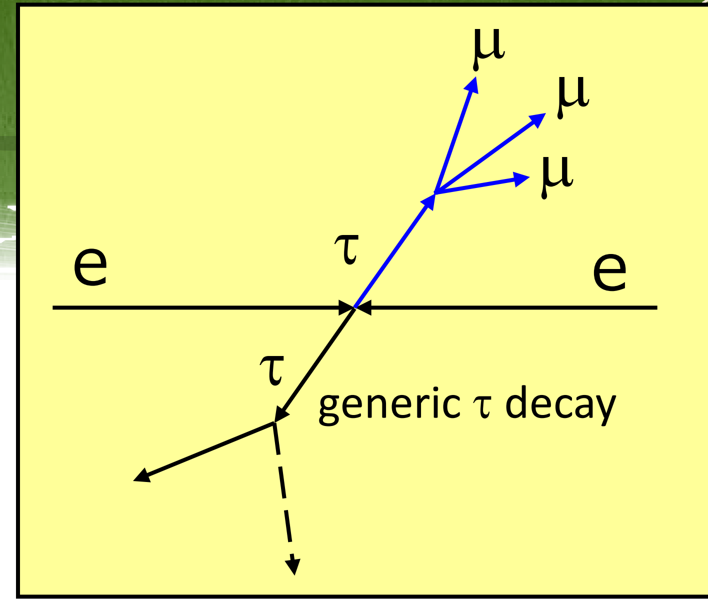



  - LFV associated with bosons
    - SUSY with heavy sleptons
    - 中性ヒッグスボソン
    - $\tau \rightarrow 1\mu\mu$, $1\eta$, $1\eta'$などが優勢になりうる




- すべてのモードの探索がモデルの判別に重要

# Analysis




- $e^+e^- \to \tau^+\tau^-$ Br~85%
  - $\tau^-$ → 1 prong + missing (tag side)
  - $\tau^+$ → μμμ (signal side)

Fully reconstructed

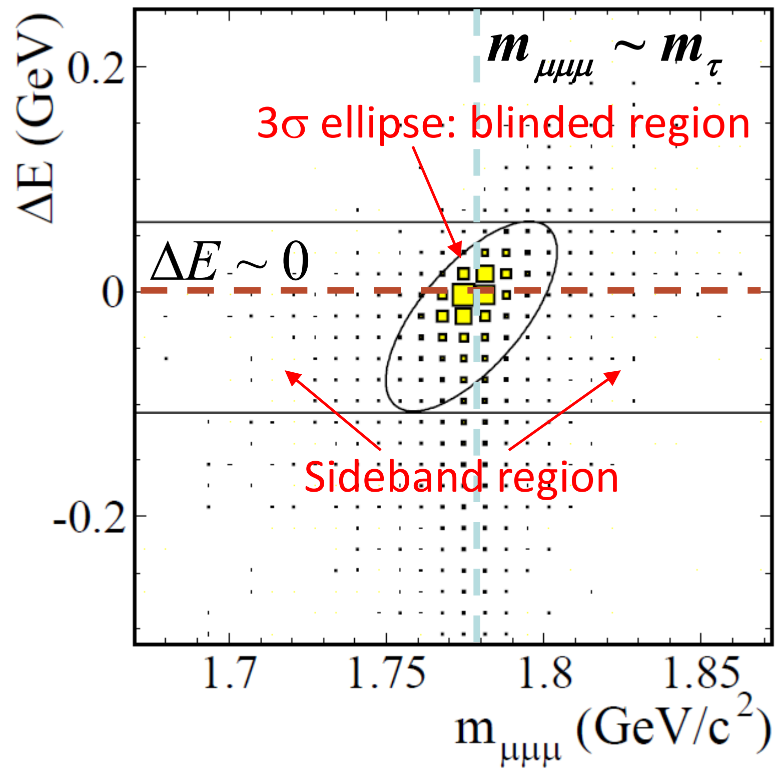
Signal extraction: $m_{\mu\mu\mu}$–$\Delta E$ plane

$$m_{\mu\mu\mu} = \sqrt{(E^2_{\mu\mu\mu} - p^2_{\mu\mu\mu})}$$

$$\Delta E = E^{CM}_{\mu\mu\mu} - E^{CM}_{beam}$$

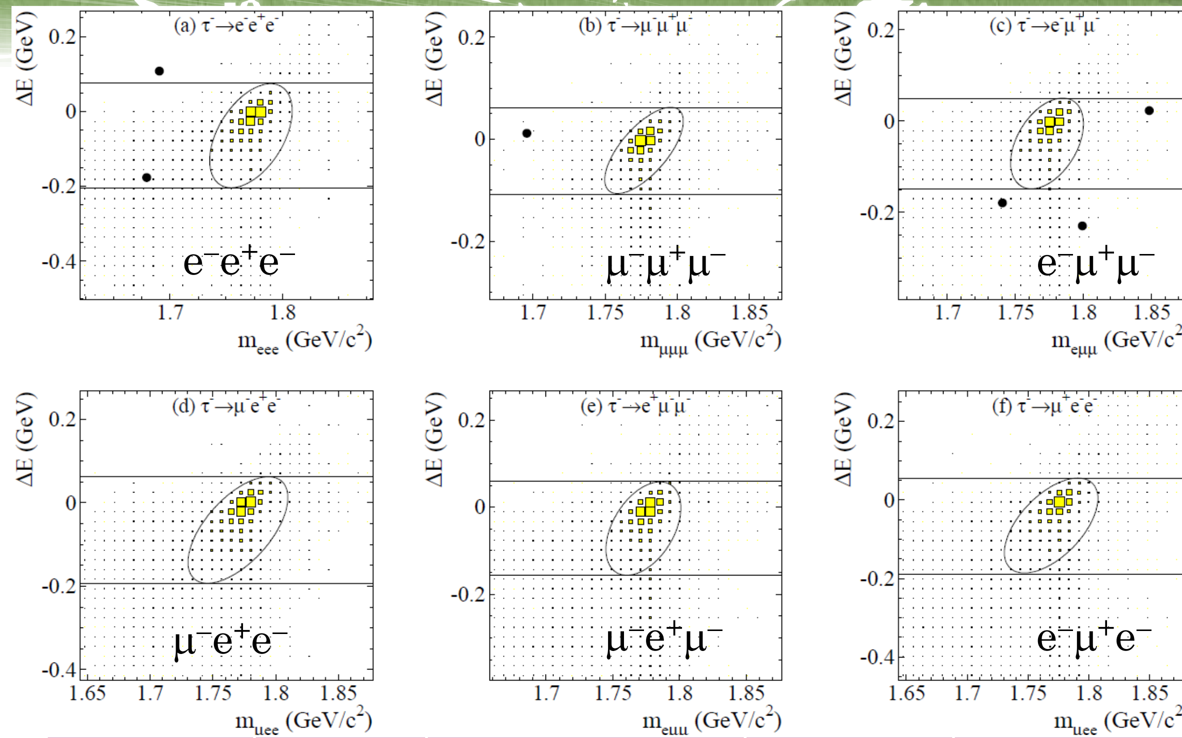
Estimate number of BG in the signal region using sideband data and MC

Tune selection criteria mode by mode



# $\tau \rightarrow 3$leptons ($\mu\mu\mu$, $e\mu\mu$,…)

- Data: 782fb$^{-1}$
- No event is found in the signal region.
- Almost BG free
  - Because of good lepton ID
- Br<(1.5-2.7)x10$^{-8}$ at 90% CL.

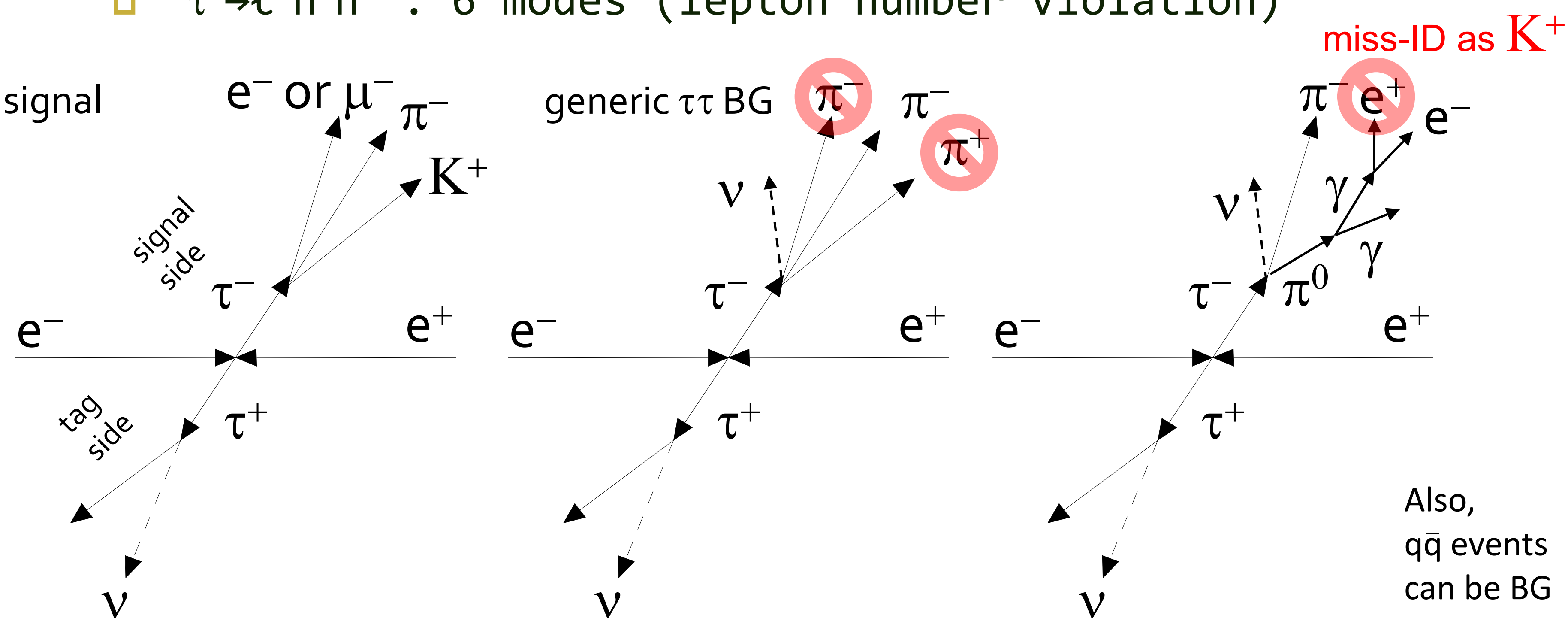



| Mode | $\varepsilon$ (%) | $N_{BG}^{EXP}$ | $\sigma_{syst}$ (%) | UL (x10$^{-8}$) |
|---|---|---|---|---|
| $e^-e^+e^-$ | 6.0 | 0.21+-0.15 | 9.8 | 2.7 |
| $\mu^-\mu^+\mu^-$ | 7.6 | 0.13+-0.06 | 7.4 | 2.1 |
| $e^-\mu^+\mu^-$ | 6.1 | 0.10+-0.04 | 9.5 | 2.7 |
| $\mu^-e^+e^-$ | 9.3 | 0.04+-0.04 | 7.8 | 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 |

Phys.Lett.B 687,139 (2010)

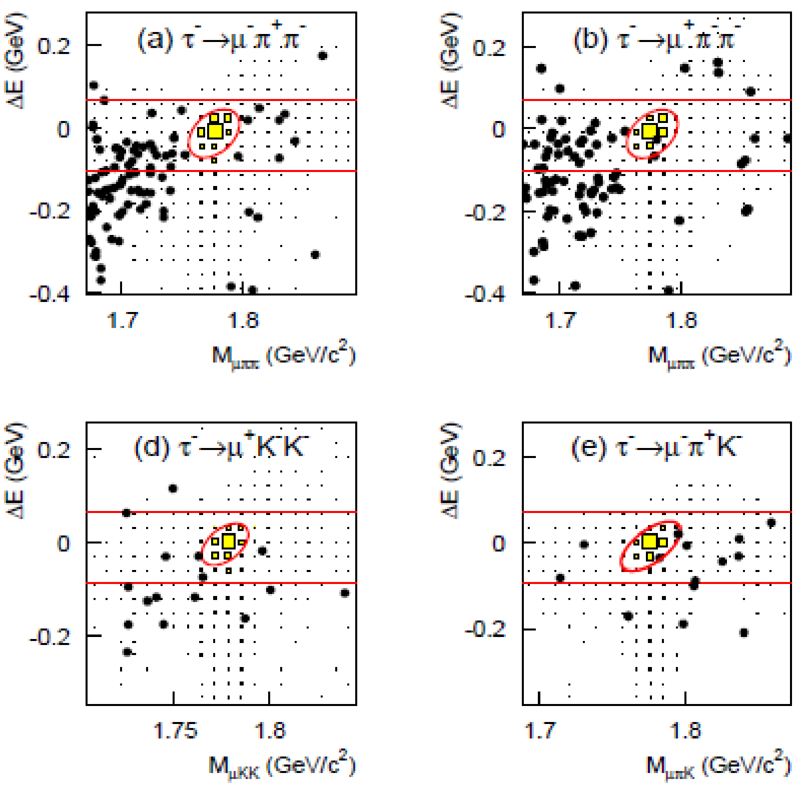
# Search for $\ell$ hh'

- Update with 854fb$^{-1}$ data
  - BaBar; Br<(7-48)x10$^{-8}$ at 221fb$^{-1}$
- 14 modes are investigated (h,h'=$\pi^{\pm}$ and $K^{\pm}$)
  - $\tau^{-}\to\ell^{-}h^{+}h'^{-}$: 8 modes (lepton flavor violation)
  - $\tau^{-}\to\ell^{+}h^{-}h'^{-}$: 6 modes (lepton number violation)




Missing momentum can help to reject this kind of BGs since signal has $\nu$ only on tag side.

# Result for ℓ hh’




In the signal region

1event : in $\mu^+\pi^-\pi^-$ and $\mu^-\pi^+K^-$

no events: in other modes

⇒ no significant excess

| Mode | $\varepsilon$ (%) | $N_{\rm BG}$ | $\sigma_{\rm syst}$ (%) | $N_{\rm obs}$ | $s_{90}$ | $\mathcal{B}$ ($10^{-8}$) |
|---|---|---|---|---|---|---|
| $\tau^- \to \mu^-\pi^+\pi^-$ | 5.83 | $0.63 \pm 0.23$ | 5.3 | 0 | 1.87 | 2.1 |
| $\tau^- \to \mu^+\pi^-\pi^-$ | 6.55 | $0.33 \pm 0.16$ | 5.3 | 1 | 4.02 | 3.9 |
| $\tau^- \to e^-\pi^+\pi^-$ | 5.45 | $0.55 \pm 0.23$ | 5.4 | 0 | 1.94 | 2.3 |
| $\tau^- \to e^+\pi^-\pi^-$ | 6.56 | $0.37 \pm 0.18$ | 5.4 | 0 | 2.10 | 2.0 |
| $\tau^- \to \mu^-K^+K^-$ | 2.85 | $0.51 \pm 0.18$ | 5.9 | 0 | 1.97 | 4.4 |
| $\tau^- \to \mu^+K^-K^-$ | 2.98 | $0.25 \pm 0.13$ | 5.9 | 0 | 2.21 | 4.7 |
| $\tau^- \to e^-K^+K^-$ | 4.29 | $0.17 \pm 0.10$ | 6.0 | 0 | 2.28 | 3.4 |
| $\tau^- \to e^+K^-K^-$ | 4.64 | $0.06 \pm 0.06$ | 6.0 | 0 | 2.38 | 3.3 |
| $\tau^- \to \mu^-\pi^+K^-$ | 2.72 | $0.72 \pm 0.27$ | 5.6 | 1 | 3.65 | 8.6 |
| $\tau^- \to e^-\pi^+K^-$ | 3.97 | $0.18 \pm 0.13$ | 5.7 | 0 | 2.27 | 3.7 |
| $\tau^- \to \mu^-K^+\pi^-$ | 2.62 | $0.64 \pm 0.23$ | 5.6 | 0 | 1.86 | 4.5 |
| $\tau^- \to e^-K^+\pi^-$ | 4.07 | $0.55 \pm 0.31$ | 5.7 | 0 | 1.97 | 3.1 |
| $\tau^- \to \mu^+K^-\pi^-$ | 2.55 | $0.56 \pm 0.21$ | 5.6 | 0 | 1.93 | 4.8 |
| $\tau^- \to e^+K^-\pi^-$ | 4.00 | $0.46 \pm 0.21$ | 5.7 | 0 | 2.02 | 3.2 |

Set upper limits at 90%CL:

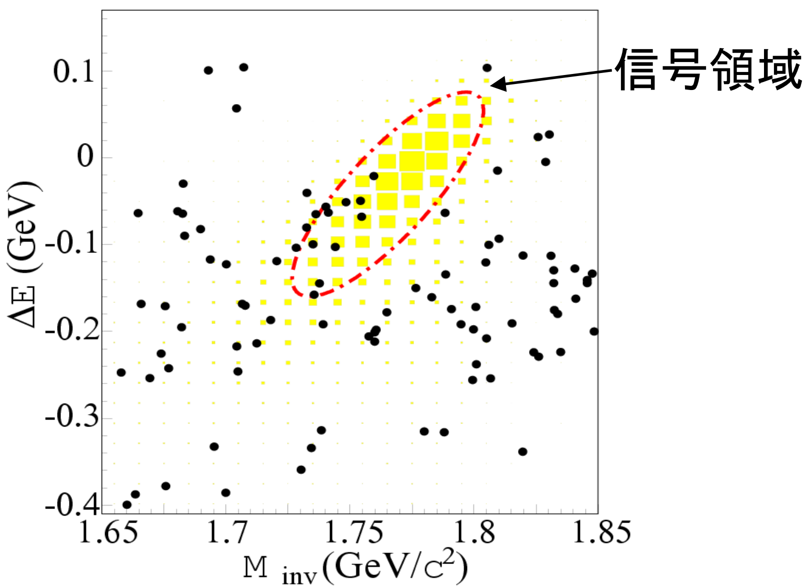
Br(τ→ℓhh’)< (2.0-8.6)x$10^{-8}$

arXiv:1206.5595 (to PLB)

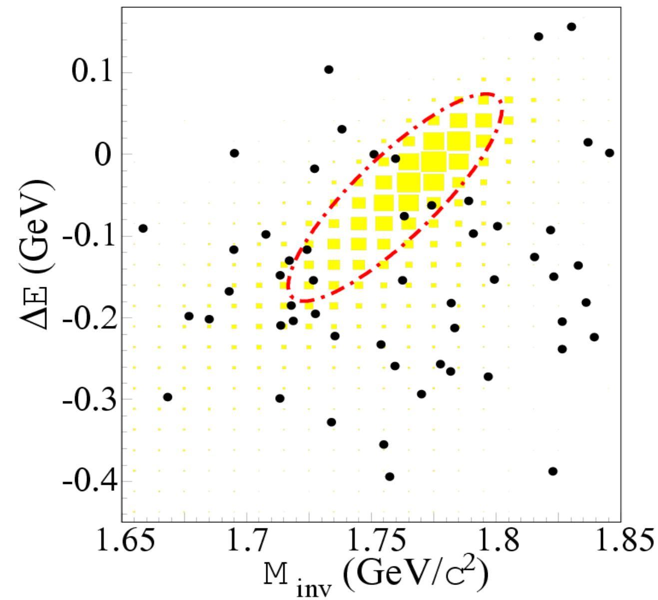
# $\tau \rightarrow \mu\gamma$, $e\gamma$

PLB 666, 16 (2008)

- データ; 535fb$^{-1}$
  - $\tau \rightarrow \mu\gamma$



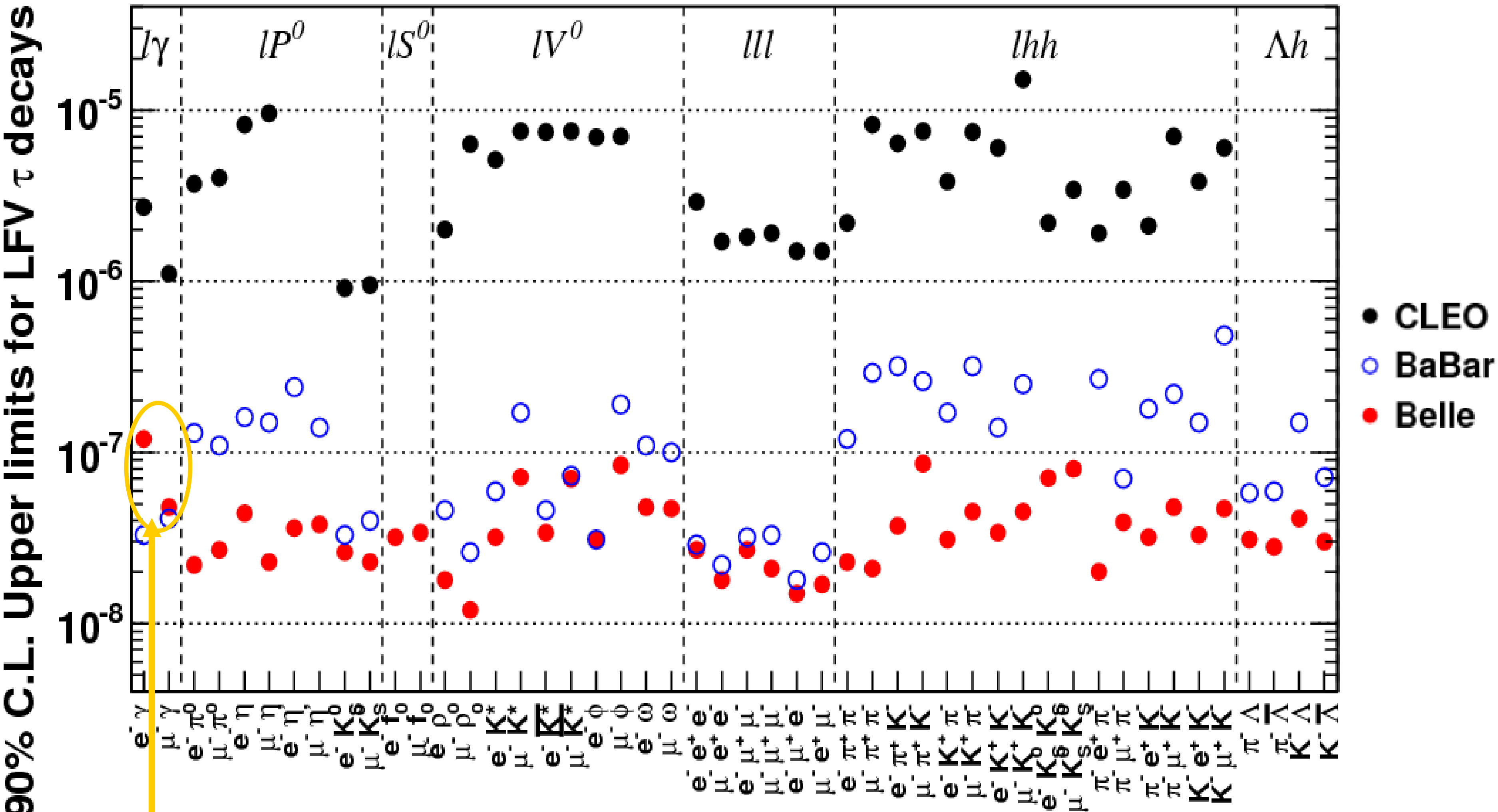

  - Br<4.5x10$^{-8}$ at 90%CL
  - $\tau \rightarrow e\gamma$




  - Br<1.2x10$^{-7}$ at 90%CL

- バックグラウンド; $e^+e^- \rightarrow \tau^+\tau^-\gamma$
- 事象選別の最適化 → 高いS/N
- Likelihood fitによる信号抽出

# Search results



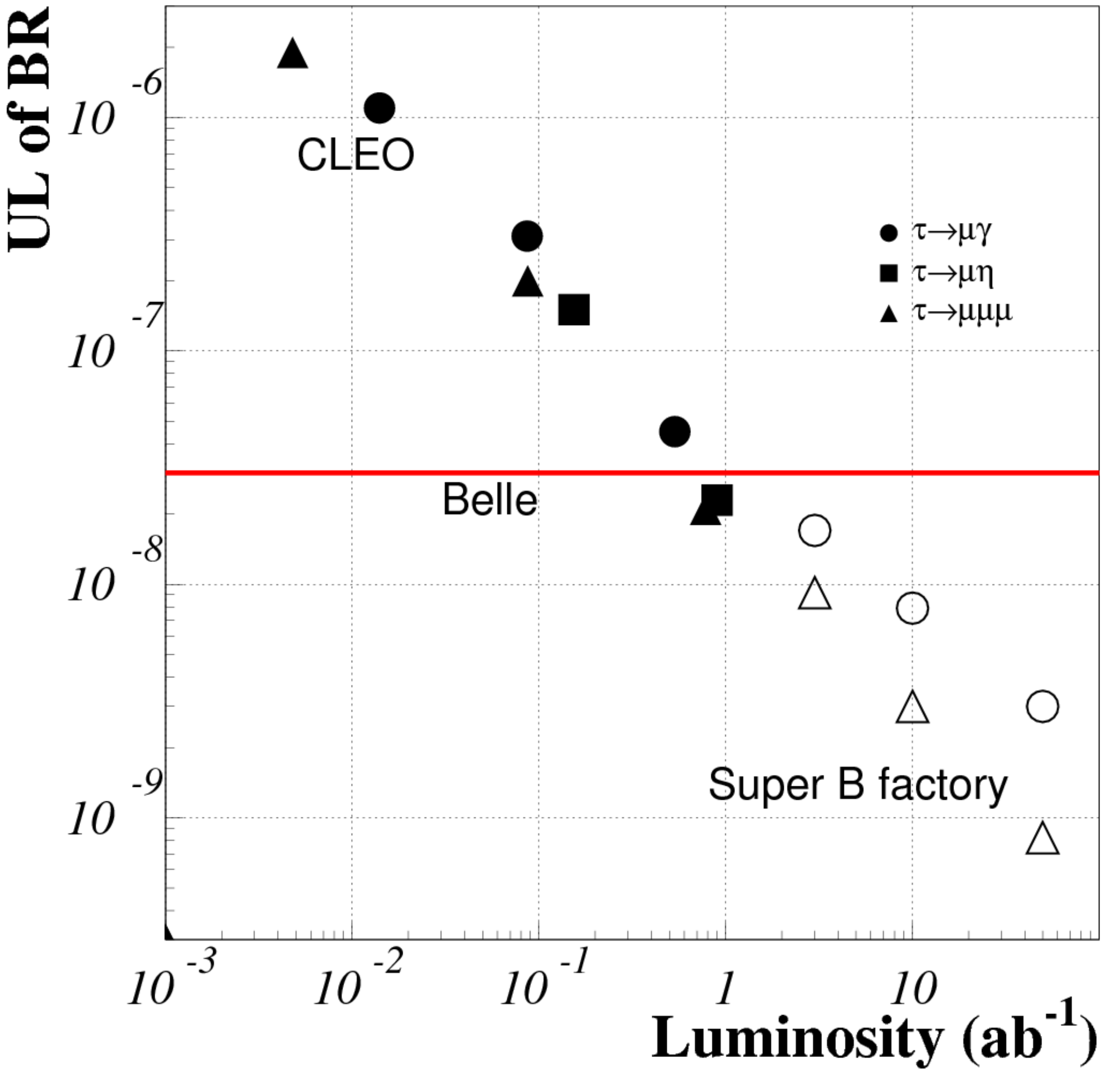

Under studying with full data sample

# LFV探索現状

- 新物理モデルのパラメータ空間を制限しつつある
  - tanβが大きくSUSY/Higgs質量が小さい部分は探索した

| | reference | $\tau \to \mu\gamma$ | $\tau \to \mu\mu\mu$ |
|---|---|---|---|
| SM+ $\nu$ mixing | PRD45(1980)1908, EPJ C8(1999)513 | Undetectable | |
| SM + heavy Maj $\nu_R$ | PRD 66(2002)034008 | $10^{-9}$ | $10^{-10}$ |
| Non-universal Z’ | PLB 547(2002)252 | $10^{-9}$ | $10^{-8}$ |
| SUSY SO(10) | PRD 68(2003)033012 | $10^{-8}$ | $10^{-10}$ |
| mSUGRA+seesaw | PRD 66(2002)115013 | $10^{-7}$ | $10^{-9}$ |
| SUSY Higgs | PLB 566(2003)217 | $10^{-10}$ | $10^{-7}$ |

# Future prospects at Belle-II




- 解析技術の向上
  - バックグラウンド抑制

→到達感度が向上

- $\tau \to \mu\gamma$

  ~$2 \times 10^{-9}$ at $50ab^{-1}$

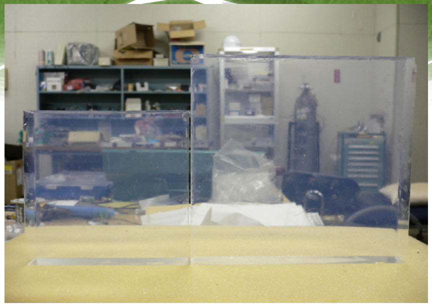
- $\tau \to \mu\mu\mu$

  ~$8 \times 10^{-10}$ at $50ab^{-1}$

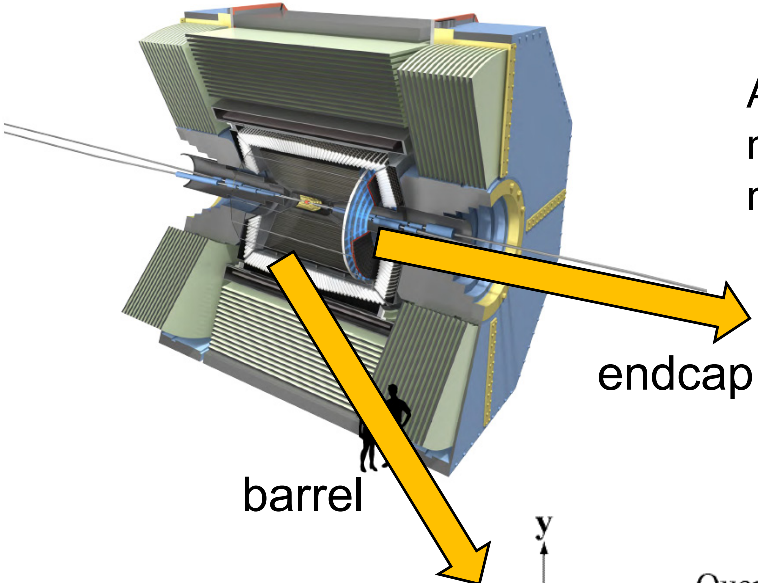
- さらなる測定精度・解析技術の向上が重要

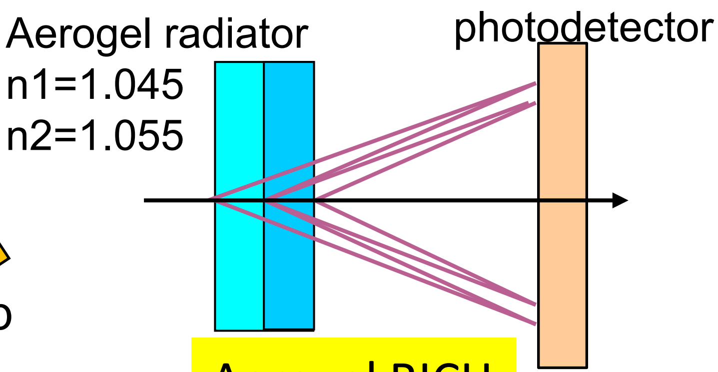
# 測定器開発

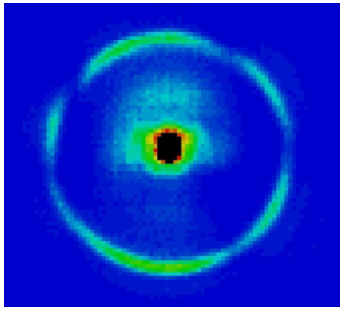
# 粒子識別装置の開発



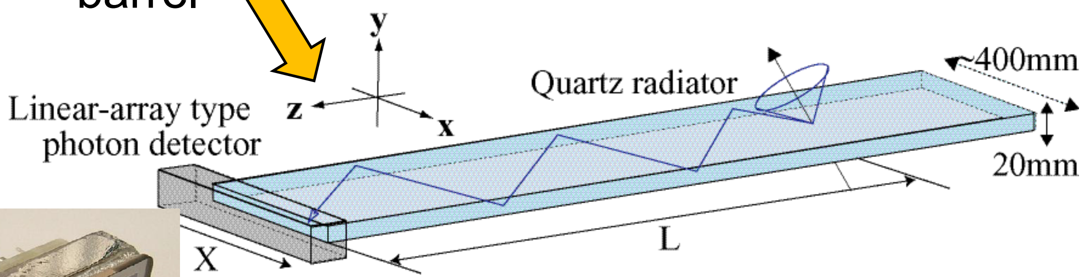
- Ring Imaging Cherenkov detectors
  - 2~5 times less fake rate for K/p separation

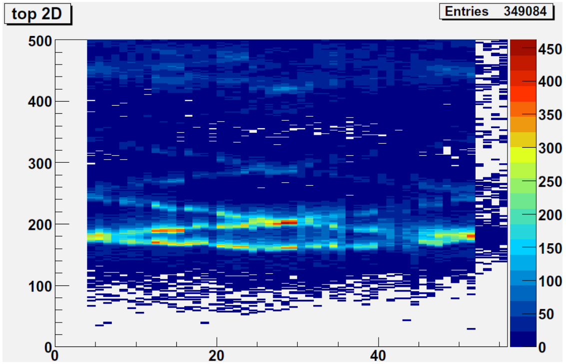


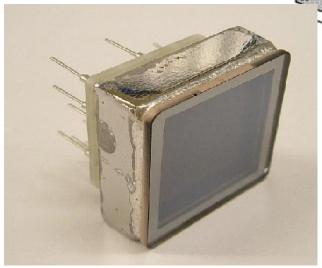



Aerogel RICH



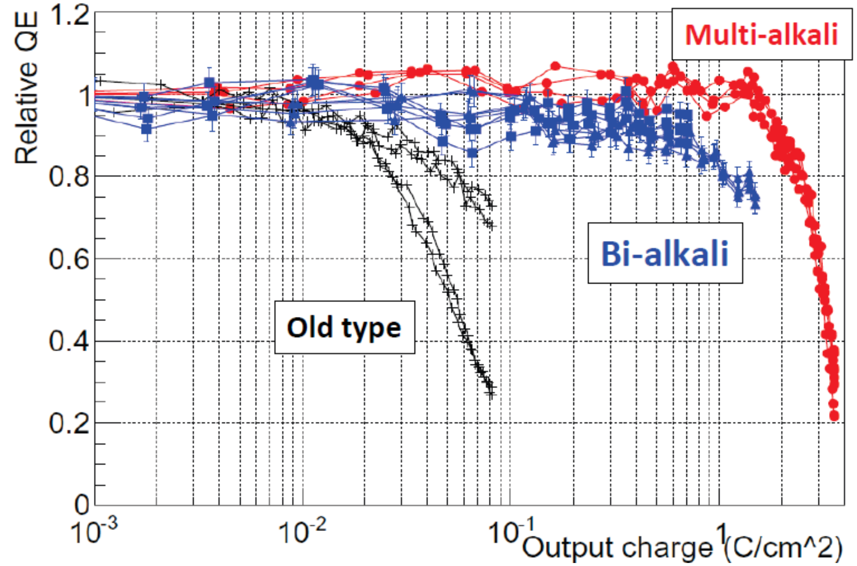



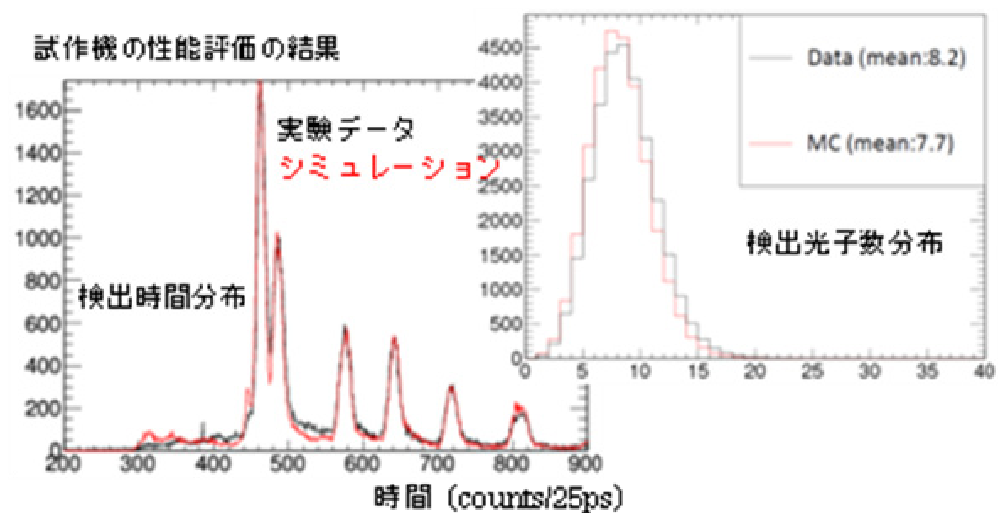
TOP（Time-Of-Propagation）Counter

Japan, Slovenia, US.

# TOPカウンター開発

- MCP-PMT開発
  - 光電面劣化の原因を突き止め、内部構造変更により寿命を向上
- 試作機開発
  - 焦点鏡による分解能の向上をビームテストで確認



# まとめ

- 第3世代のb，タウフレーバを通じた新物理探索
  - Ｂファクトリーによる世界最多のデータ
    - 約20億個のb，タウ崩壊現象
- Ｂ中間子崩壊
  - B→τν、D*τνの崩壊分岐比測定
    - 世界に先駆けてB→τν崩壊事象を確認
    - 荷電ヒッグスのパラメータ領域に制限
  - b→sクォーク遷移でのCP非保存測定など
- タウ粒子崩壊
  - LFV崩壊探索を46モードで探索。世界最高感度O($10^{-8}$)を達成
- 次世代測定器開発
  - 光検出器の改良：10倍以上の寿命向上
  - 試作機による性能評価：焦点鏡による性能向上を確認

スーパーＢファクトリー、Belle-II実験へ
世界最高輝度の増強＋測定器精度の向上
➔ 検出感度のフロンティアを切り開く

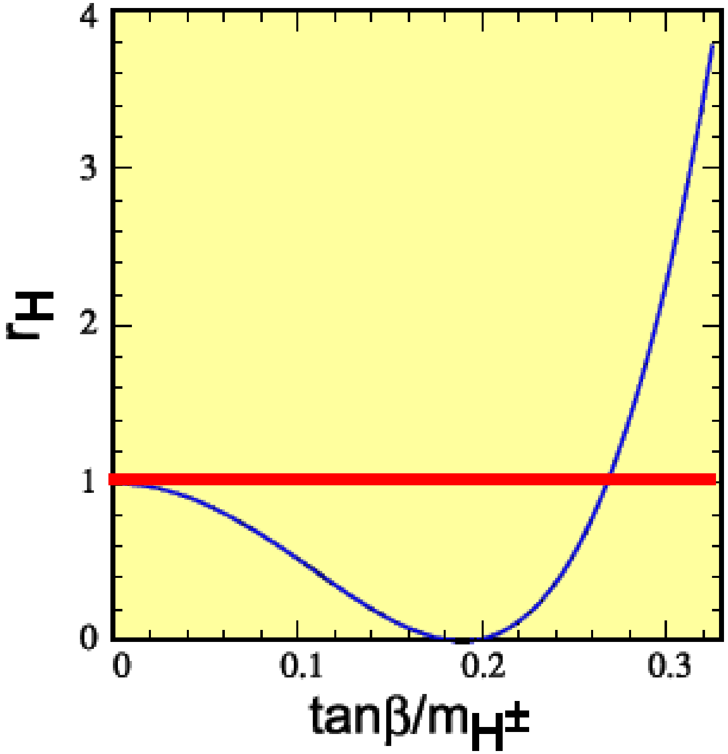
# Charged Higgs effect in B→τν

- Charged Higgs exchange interferes with the helicity suppressed W-exchange.
  ➔ Br becomes larger or smaller

$$Br = Br_{SM} \times r_H, \quad r_H = |1 - g_s|^2$$

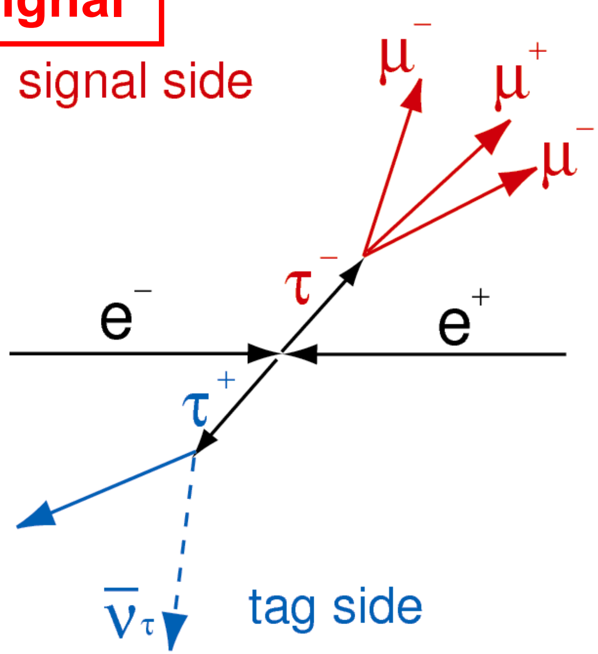
$$Type-II\ 2HDM$$

$$Br = Br_{SM} \times r_H, \quad r_H = \left(1 - \frac{m_B^2}{m_H^2} \tan^2 \beta\right)^2$$



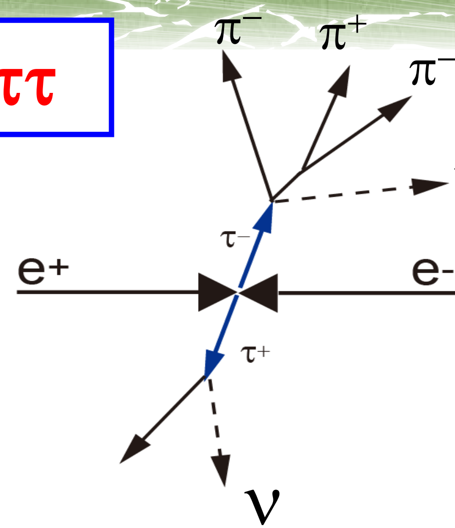
# Signal and Background

**signal**




- Neutrino(s) in tag side
- Particle ID
- Mass of mesons

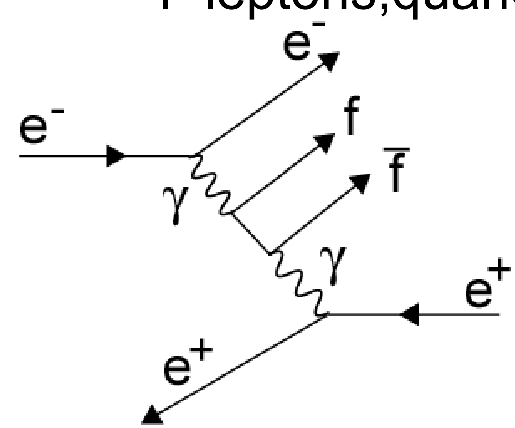
**ττ**



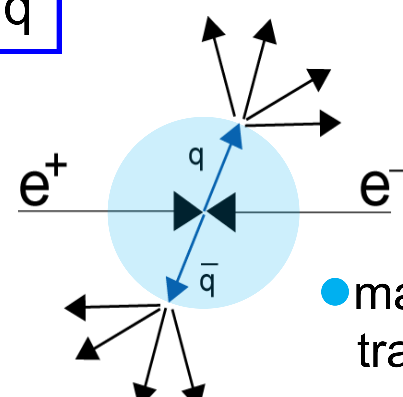

- Neutrinos in both side
- Missing energy in signal side

**2photon process**

f=leptons,quarks

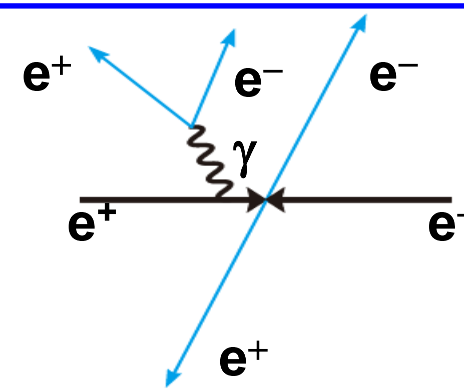



**$q\bar{q}$**



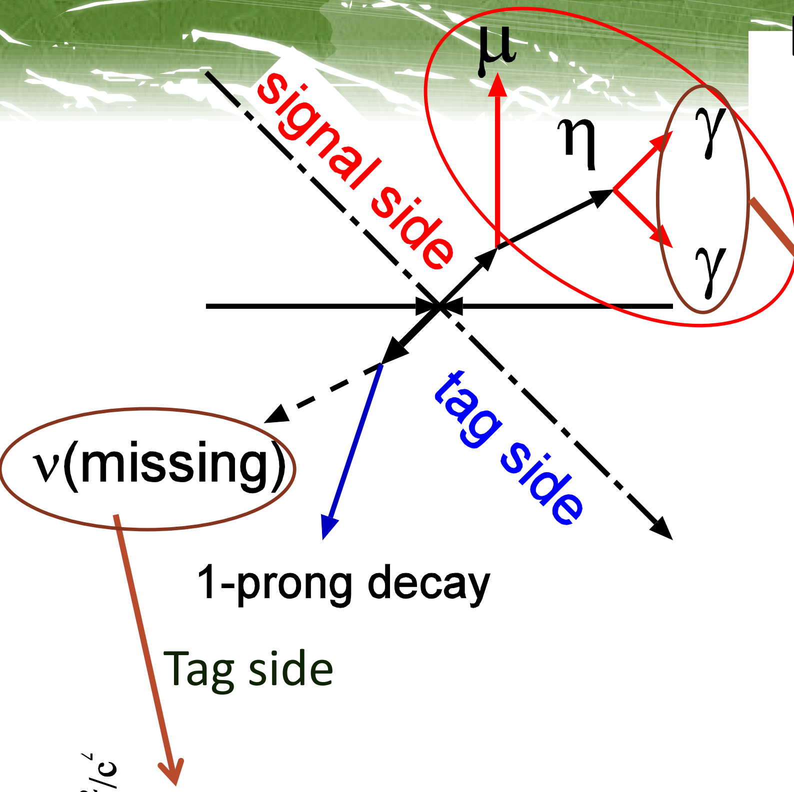

- many tracks

**radiative Bhabha process**



# Search for $\tau \rightarrow \ell P^0 (=\pi^0, \eta, \eta')$

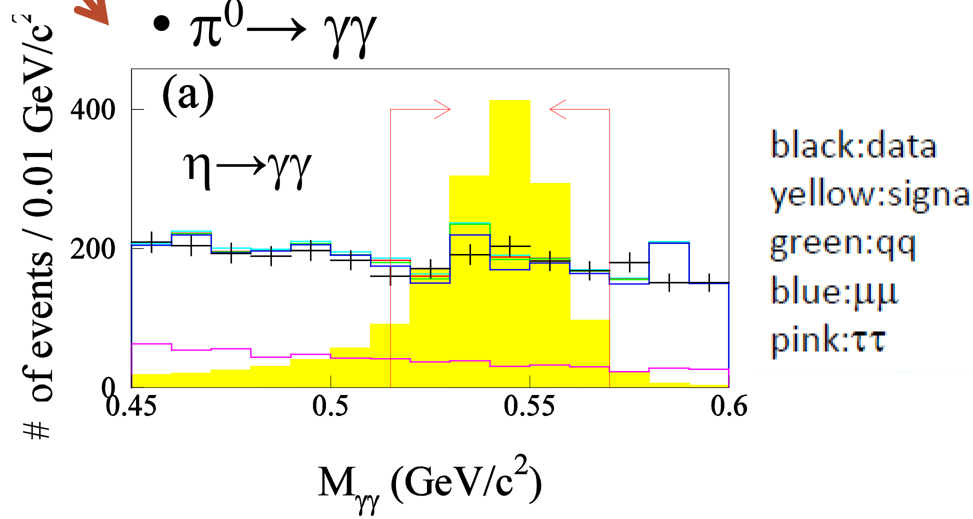
Data: $901 fb^{-1}$, $1.64 \times 10^9$ $\tau$ decays

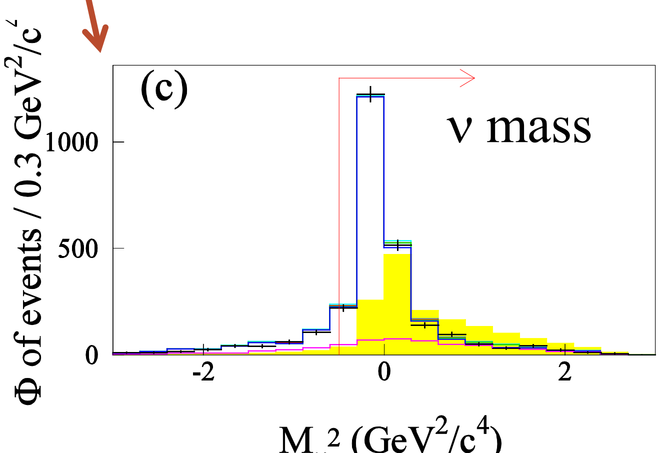



Signal side

- Lepton
- Meson reconstruction

• $\eta \rightarrow \gamma\gamma$, $\pi^+\pi^-\pi^0$
• $\eta' \rightarrow \eta(\rightarrow \gamma\gamma)\pi^+\pi^-$, $\rho\gamma$
• $\pi^0 \rightarrow \gamma\gamma$

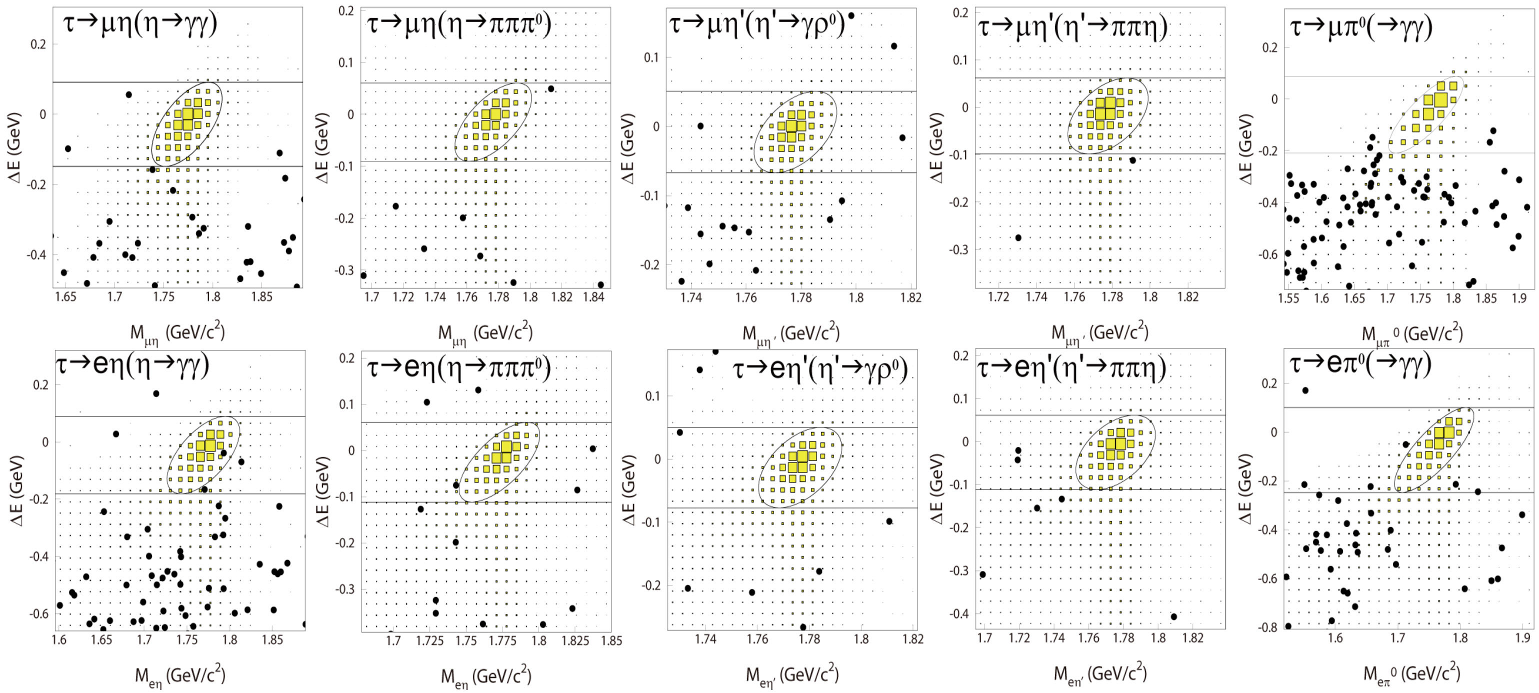



Optimization of event selection

Use neural-net for $\mu\eta(\rightarrow\gamma\gamma)$

# Result for $\tau \to \ell P^0 (=\pi^0, \eta, \eta')$

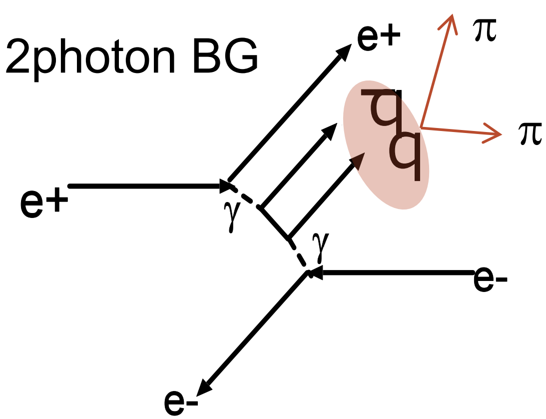


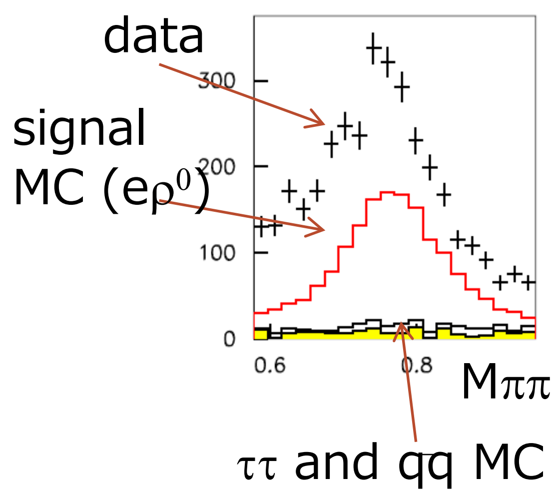

→(2.1-4.4) times more stringent results than previous Belle result (401fb$^{-1}$)

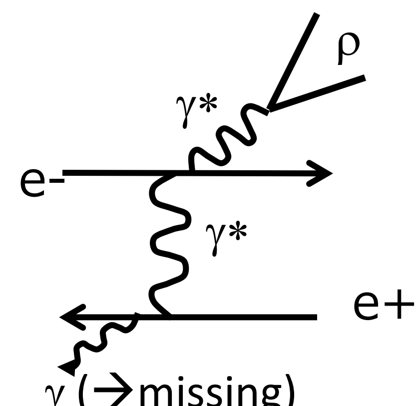
| $\tau\to$ | Eff. % | $N_{BG}^{exp}$ | $N_{obs.}$ | UL x$10^{-8}$ |
|---|---|---|---|---|
| $\mu\eta(\to\gamma\gamma)$ | 8.2 | 0.63±0.37 | 0 | 3.6 |
| $\mu\eta(\to\pi\pi\pi^0)$ | 6.9 | 0.23±0.23 | 0 | 8.6 |
| $\mu\eta$(comb.) | | | | **2.3** |
| $e\eta(\to\gamma\gamma)$ | 7.0 | 0.66±0.38 | 1 | 8.2 |
| $e\eta(\to\pi\pi\pi^0)$ | 6.3 | 0.69±0.40 | 0 | 8.1 |
| $e\eta$(comb.) | | | | **4.4** |
| $\mu\eta'(\to\pi\pi\eta)$ | 8.1% | $0.00^{+0.16}_{-0.00}$ | 0 | 10.0 |
| $\mu\eta'(\to\rho^0\gamma)$ | 6.2% | 0.59±0.41 | 0 | 6.6 |
| $\mu\eta'$ (comb.) | | | | **3.8** |
| $e\eta'(\to\pi\pi\eta)$ | 7.3% | 0.63±0.45 | 0 | 9.4 |
| $e\eta'(\to\rho^0\gamma)$ | 7.5% | 0.29±0.29 | 0 | 6.8 |
| $e\eta'$ (comb.) | | | | **3.6** |

# Search for $\ell V^0(=\rho^0, K^{*0}, \omega, \phi)$

- Search with $854 fb^{-1}$ data sample
  - Select one lepton and two hadrons
  - Require invariant mass to be a vector meson mass
    → The requirement reduces background rather easily.
- Possible background
  - For $\ell=\mu$, hadronic tau decay and qq with miss $\mu$-ID
  - For $\ell$=e, 2photon process could be large BG.
  - It turns out that not only 2photon process but also ee+X process become large background. → Reduced using missing-momentum direction



# eK*, $e\bar{K}^*$, eρ modes

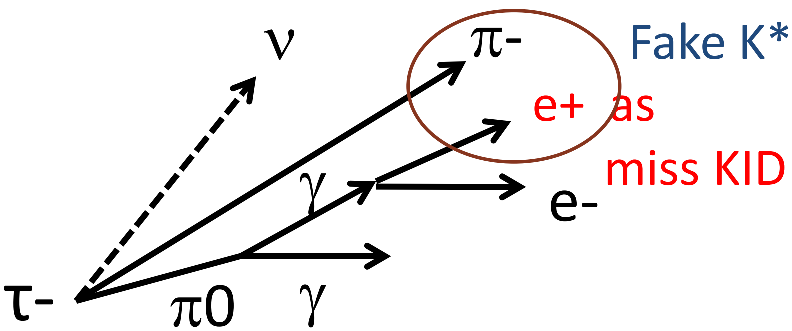
Other BG for eK*, $e\bar{K}^*$ and eρ

⇒ Event with γ conversion

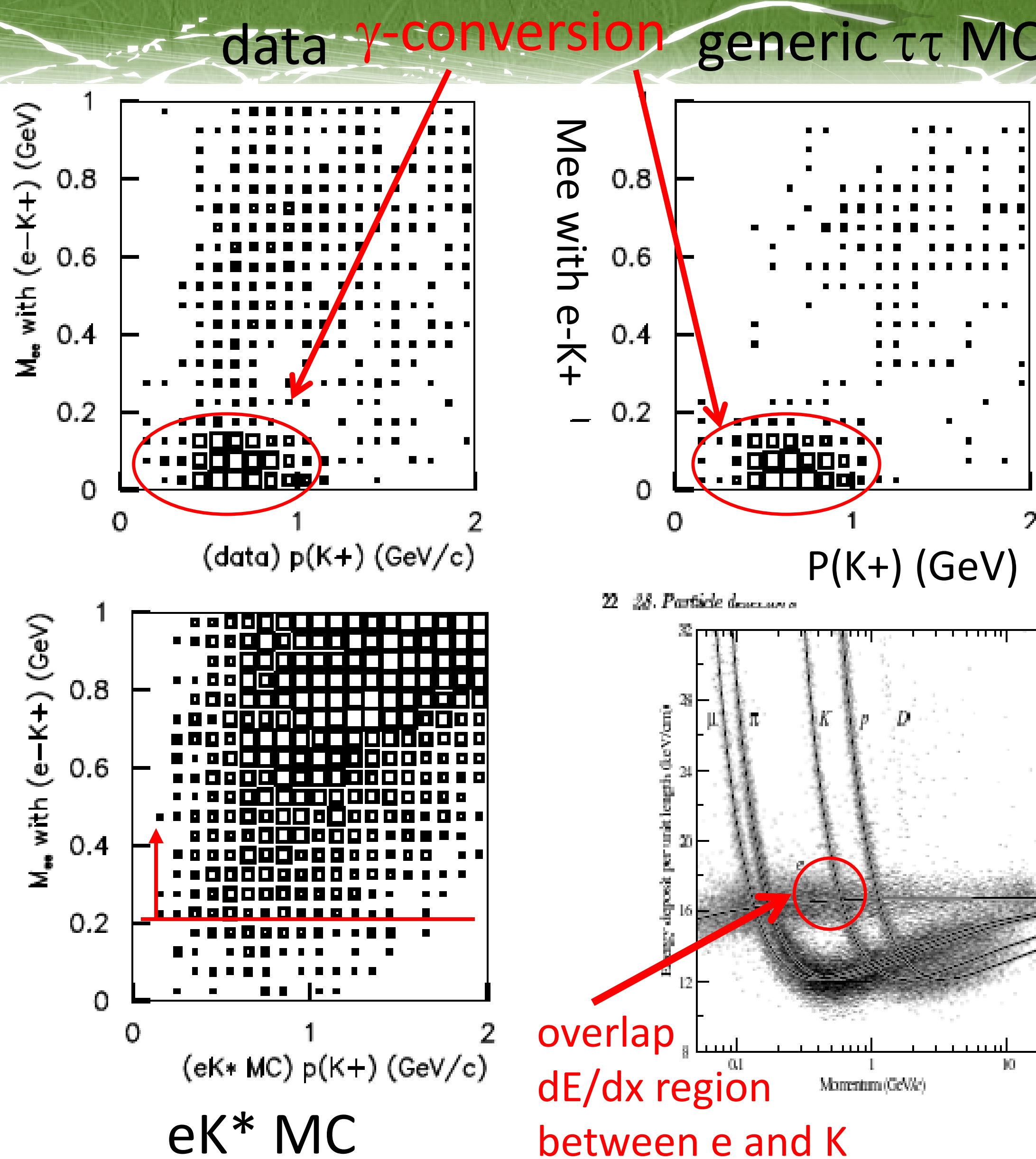
For example, eK*mode

$\tau^- \rightarrow \pi^- \pi^0 \nu$

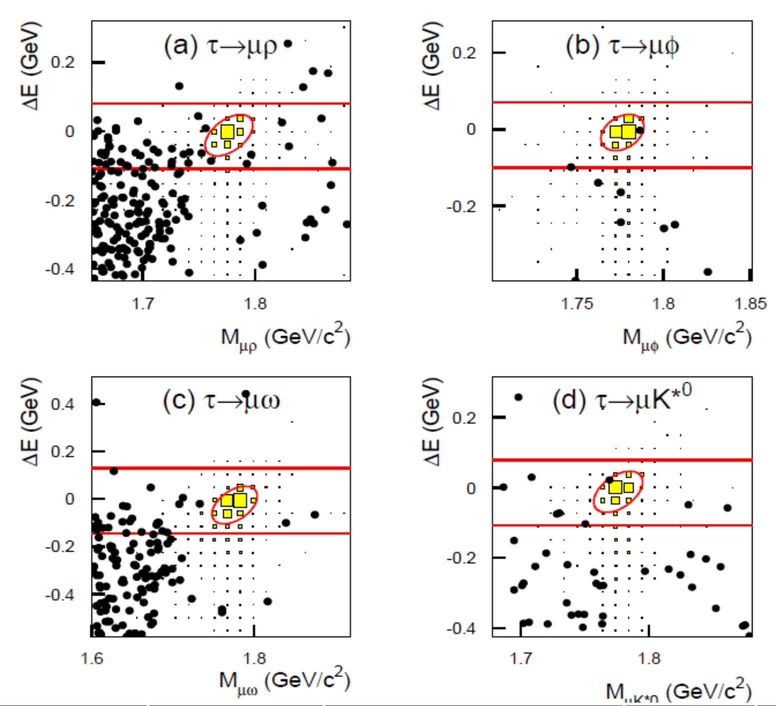
with γ conversion from $\pi^0$




Finally, higher or similar efficiency is kept (around 1.2x in average), while similar background level is achieved.



# Result for $\ell V^0(=\rho^0, K^{*0}, \omega, \phi)$




After event selection

- 1 event $\mu\phi$, $\mu K^{*0}$, $\mu\overline{K}^{*0}$
- 0 events others

No signal compared to expected BG

Expected number of background (0.1-1.5) events

$Br(\tau \to \ell V^0) < (1.2\text{-}8.4)\times 10^{-8}$

| $\tau^- \to$ | Eff. | $N_{BG}^{exp}$ | $N_{obs.}$ | UL $\times 10^{-8}$ |
|---|---|---|---|---|
| $e^-\rho^0$ | 7.6% | 0.29±0.15 | 0 | **1.8** |
| $\mu^-\rho^0$ | 7.1% | 1.48±0.35 | 0 | **1.2** |
| $e^-\phi$ | 4.2% | 0.47±0.19 | 0 | **3.1** |
| $\mu^-\phi$ | 3.2% | 0.06±0.06 | 1 | **8.4** |
| $e^-\omega$ | 2.9% | 0.30±0.14 | 0 | **4.8** |

| $\tau^- \to$ | Eff. | $N_{BG}^{exp}$ | $N_{obs.}$ | UL $\times 10^{-8}$ |
|---|---|---|---|---|
| $e^-K^{*0}$ | 4.4% | 0.39±0.14 | 0 | **3.2** |
| $\mu^-\overline{K}^{*0}$ | 3.4% | 0.53±0.20 | 1 | **7.2** |
| $e^-\overline{K}^{*0}$ | 4.4% | 0.08±0.08 | 0 | **3.4** |
| $\mu^-K^{*0}$ | 3.6% | 0.45±0.17 | 1 | **7.0** |
| $\mu^-\omega$ | 2.4% | 0.72±0.18 | 0 | **4.7** |

Phys.Lett.B 699,251 (2011)