高統計タウを用いた探索

- Introduction
- Lepton Flavor Violation
  - Recent results
  - Future prospects
- Other studies
- Summary

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Tau-factory

- B factory is tau factory!
  - $\sigma(\tau\tau)$~0.9nb, $\sigma(BB)$~1.1nb
- Integrated luminosity: ~500fb^{-1} in Belle
  - → 5x10^{8} τ-pairs!
- The B factories have sensitivities of Br = O(10^{-7}~10^{-8}).

- Many physics from tau pair reaction
  - Heaviest lepton
  - Decay to quarks and leptons
  - Simple reaction, predictable in SM
  - Sensitive to New Physics

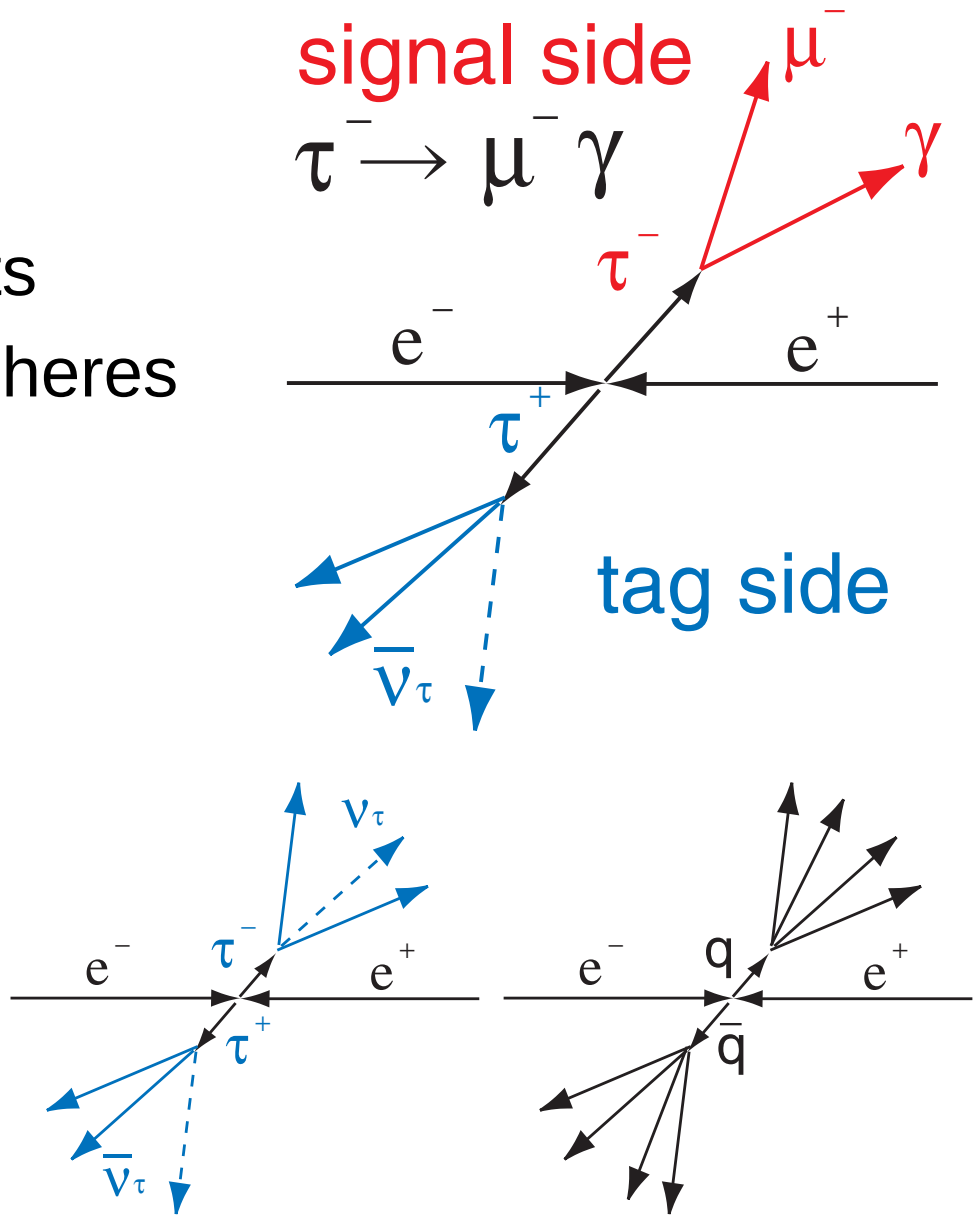
Lepton Flavor Violation

- In the Standard Model, flavor mixing is found in quark sector and neutrino system.
- Charged lepton flavor violating decays is not found and have a very small probability ($10^{\sim -40}$), therefore it is a good probe to search for new physics.
  - New physics effects (SUSY, Extra-D, etc.) allow us to observe LFV with the present experimental sensitivity.

Models	$\tau \to \mu\gamma$	$\tau \to \ell\ell\ell$
mSUGRA + seesaw	10^{-7}	10^{-9}
SUSY + SO(10)	10^{-8}	10^{-10}
SM + seesaw	10^{-9}	10^{-10}
Non-Universal Z'	10^{-9}	10^{-8}
SUSY + Higgs	10^{-10}	10^{-7}

Current situation

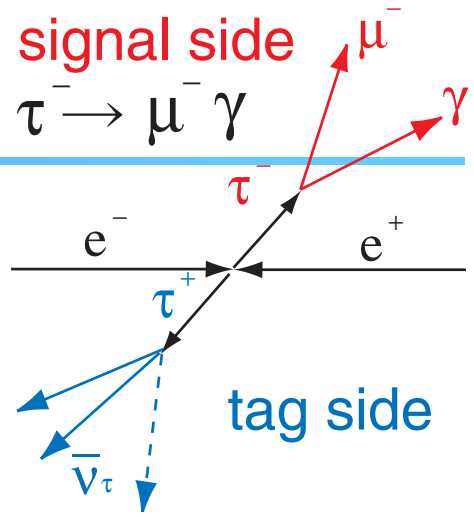
- Analysis method
  - Event Selection
    - Low multiplicity events
    - Separate into hemispheres
      - Signal and tag sides
    - Missing momentum
      - Low missing mass
    - Small Nγ
    - Lepton tag etc.

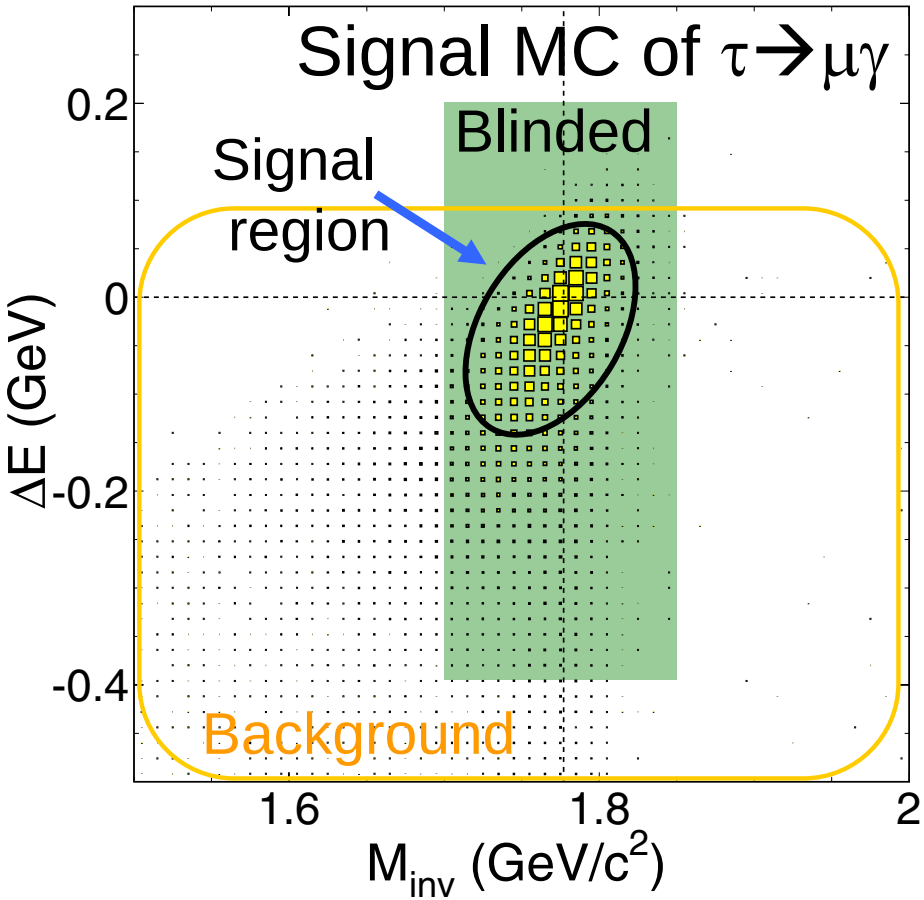


Current Situation (2)

- Signal extraction
  - Calc. M_{inv} and ΔE
    - $\Delta E = E_{rec} - E_{beam}$
  - Blinded signal region
    - → Event selection study
  - Estimate background
    using sideband data
  - Open blind and estimate signal yield
    - Estimate upper limits

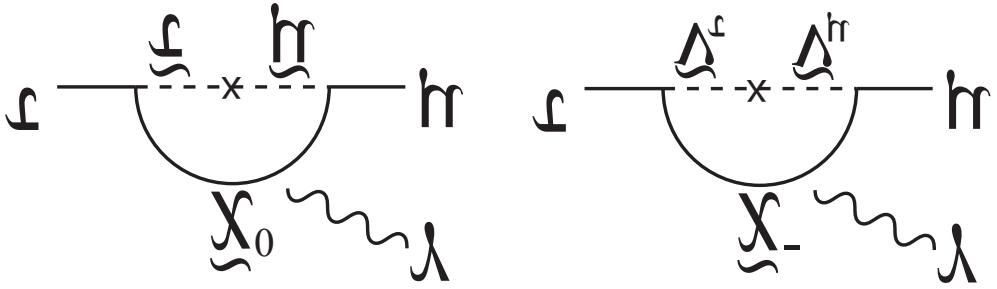
- BG reduction is important to improve the sensitivity.





τ→μγ, eγ

- Most attractive LFV decay mode
  - In SUSY, LFV are generated through the slepton mixing.
  - Independent parameter for μ→eγ



$$\begin{pmatrix} m^2_{\tilde{e}\tilde{e}} & m^2_{\tilde{e}\tilde{\mu}} & m^2_{\tilde{e}\tilde{\tau}} \\ m^2_{\tilde{\mu}\tilde{e}} & m^2_{\tilde{\mu}\tilde{\mu}} & m^2_{\tilde{\mu}\tilde{\tau}} \\ m^2_{\tilde{\tau}\tilde{e}} & m^2_{\tilde{\tau}\tilde{\mu}} & m^2_{\tilde{\tau}\tilde{\tau}} \end{pmatrix}$$

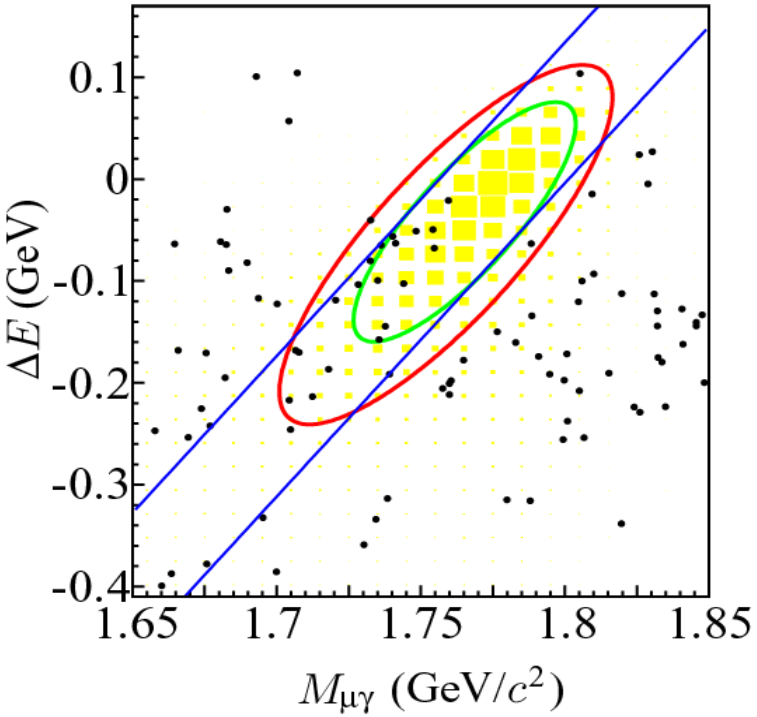
  - Br(τ→μγ):Br(τ→μee)~94:1

- In MSSM+seesaw,

$$\mathcal{B}(\tau \to \mu\gamma) \simeq 3.0 \times 10^{-7} \left(\frac{\tan\beta}{60}\right)^2 \left(\frac{1\ \mathrm{TeV}/c^2}{m_{SUSY}}\right)^4$$

$\tau \rightarrow \mu\gamma$

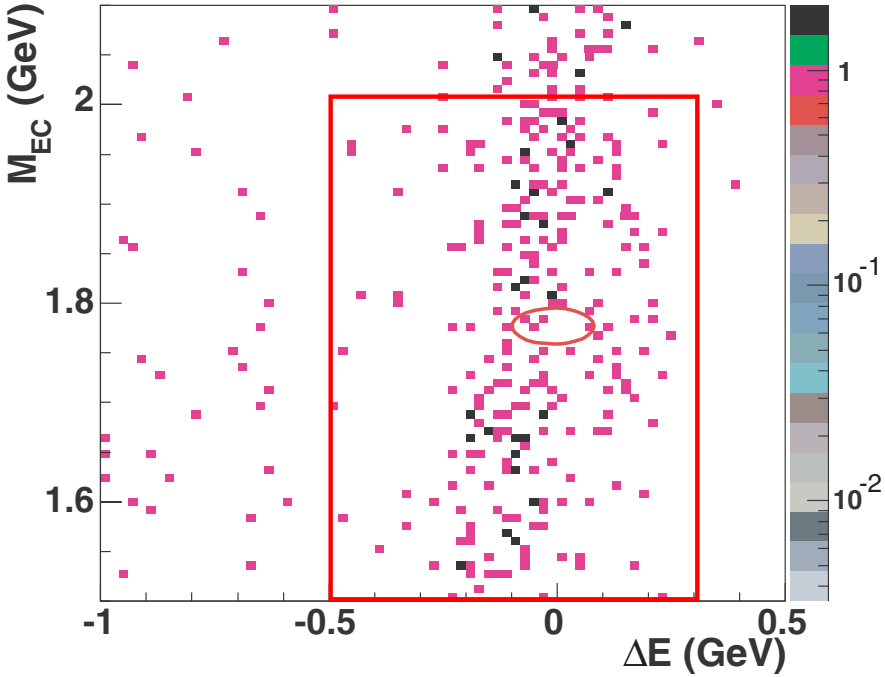
- Belle
  - 535fb^{-1} data



  - Br<4.5x10^{-8} at 90%C.L.

    (2006 summer result)

- BaBar
  - 232fb^{-1} data



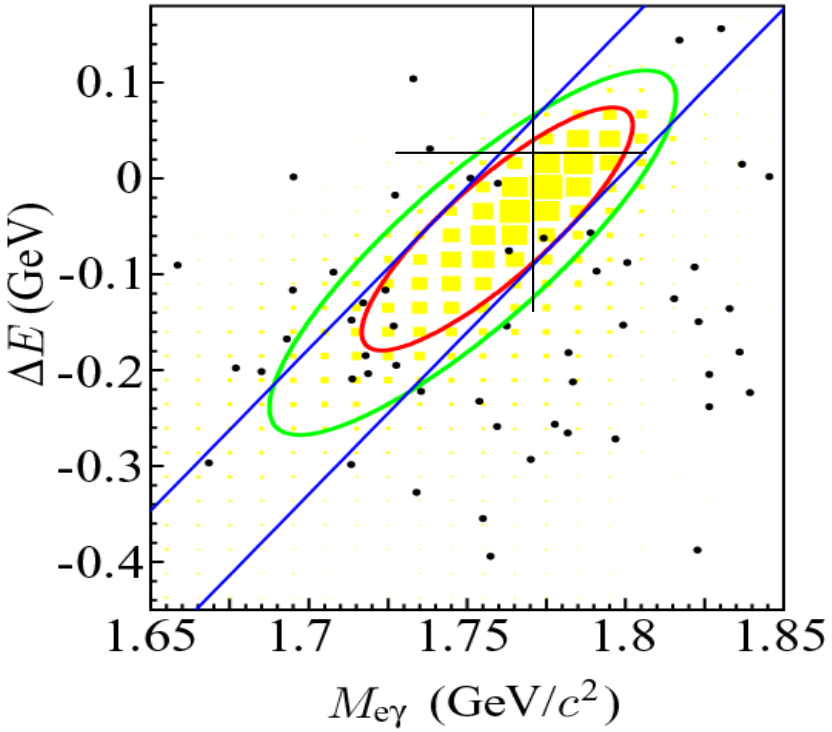
  - Br<6.8x10^{-8}

    PRL 95, 041802 (2005).

- Background: $\tau \rightarrow \mu\nu\nu$ + ISR
  - Small contamination of $\mu\mu$ BG in $\Delta E>0$

$\tau \rightarrow e\gamma$

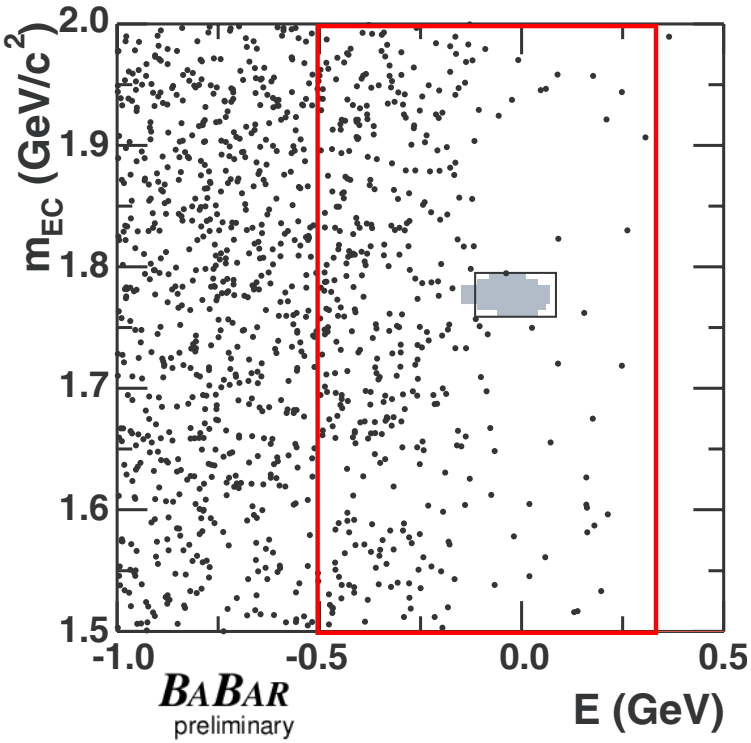
- Belle
  - 535fb^{-1} data



  - Br<1.2x10^{-7} at 90%C.L.

    (2006 summer result)

- BaBar
  - 232fb^{-1} data



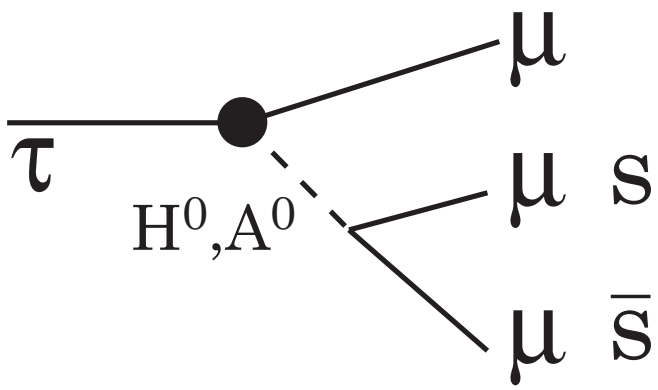
  - Br<1.1x10^{-7}

    PRL 96, 041801 (2006).

- Background: $\tau \rightarrow e\nu\nu$ + ISR

τ→μη, eη

- Sensitive to Higgs in SUSY



- Higgs mediated model

$$\mathcal{B}(\tau \to \mu\eta) \simeq 8.4 \times 10^{-7} \left(\frac{\tan\beta}{60}\right)^6 \left(\frac{100\ \mathrm{GeV}/c^2}{m_A}\right)^4$$

  - Br(τ→μη) : Br(τ→μγ) : Br(τ→μμμ) = 8.4 : 1.5 : 1
    - Phase space, color factor, mass

  - τ→μη mode may have larger BR than τ→μγ.

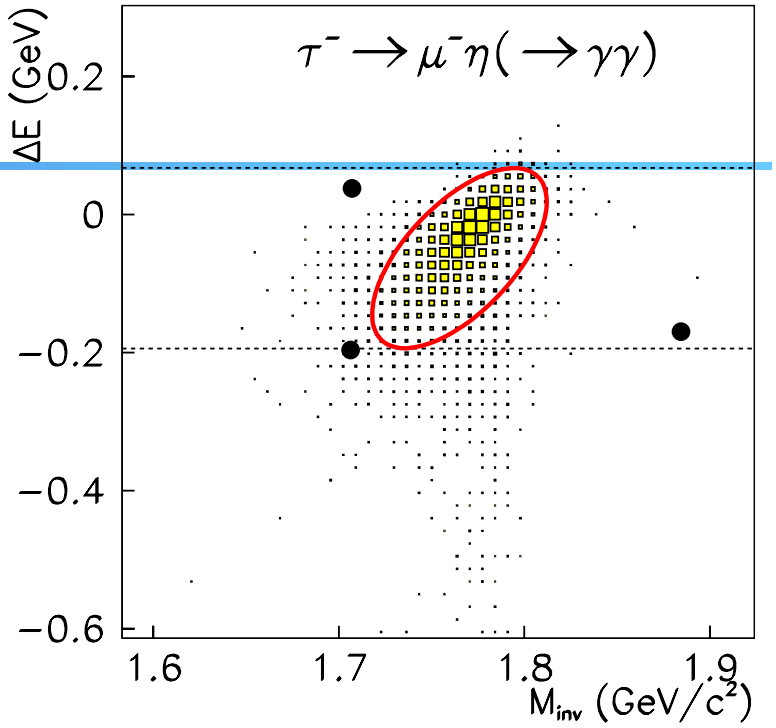
$\tau \rightarrow l\eta/\pi^0/\eta'$

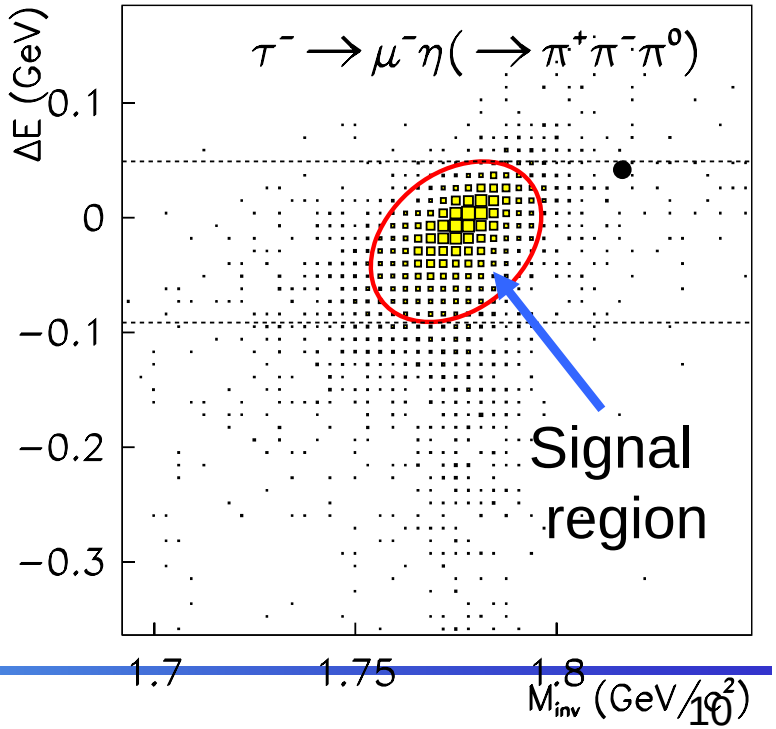
- Data: 401fb^{-1}

- Br($\tau \rightarrow \mu\eta$)<6.5x10^{-8}
- Br < (6.5~16)x10^{-8}

  (2006 summer result)

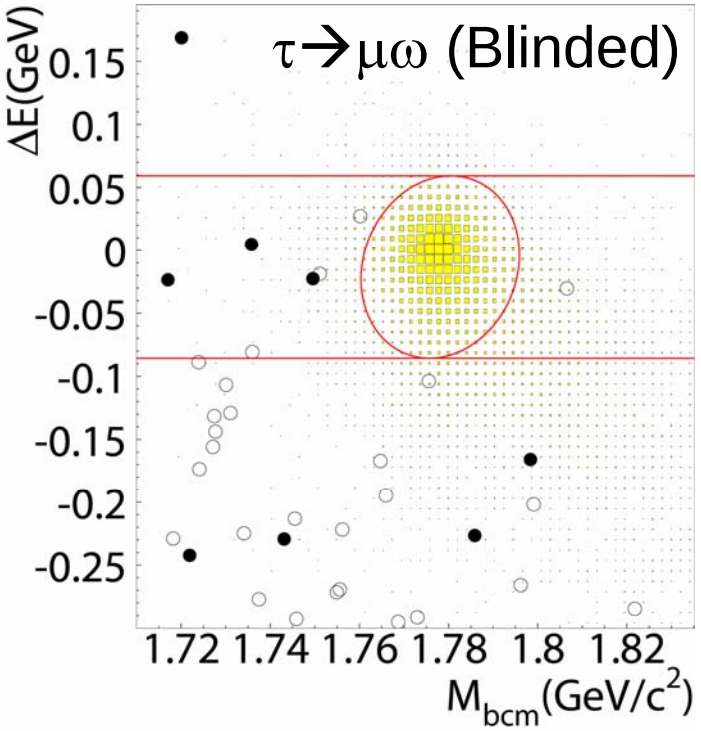
- Background
  - μ: $\tau\tau$ + qq
  - e: negligible

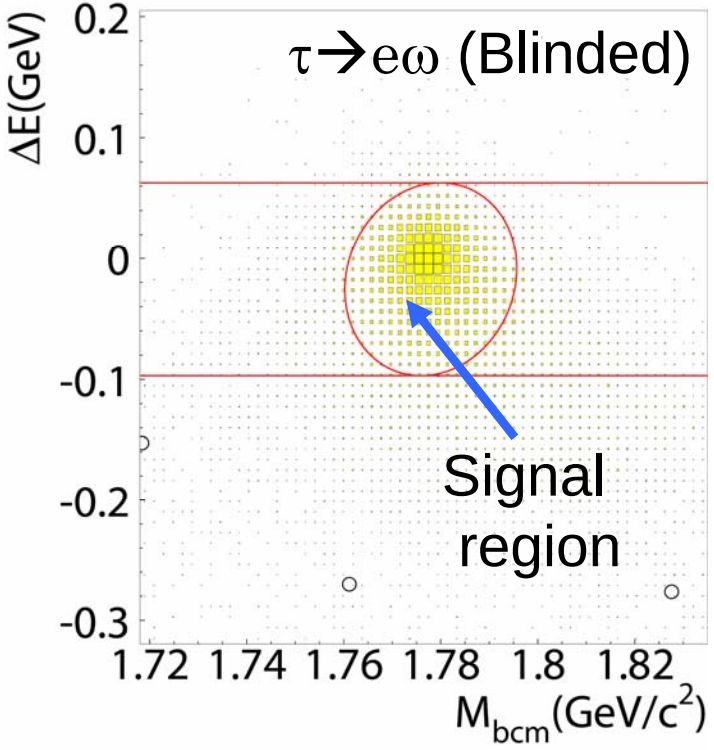




$\tau \rightarrow l\phi/\omega/K_S$

- Lepton + Vectors
  - $\tau \rightarrow l\omega$: First search
- Data: 543fb^{-1}
  - Not finalized yet
- Expected sensitivity
  - Br($\tau \rightarrow l\phi$)<0.8x10^{-7}
  - Br($\tau \rightarrow l\omega$)<1.0x10^{-7} (if no signal)
- Background
  - ϕ: $\tau \rightarrow \pi\phi\nu$ (Br~10^{-5})
  - ω: $\tau \rightarrow \pi\omega\nu$ (Br~2%)





For Future

- Super B factory will provide many tau samples.
  - Need statistics. No way to improve efficiency.
- To be considered
  - Non-negligible backgrounds

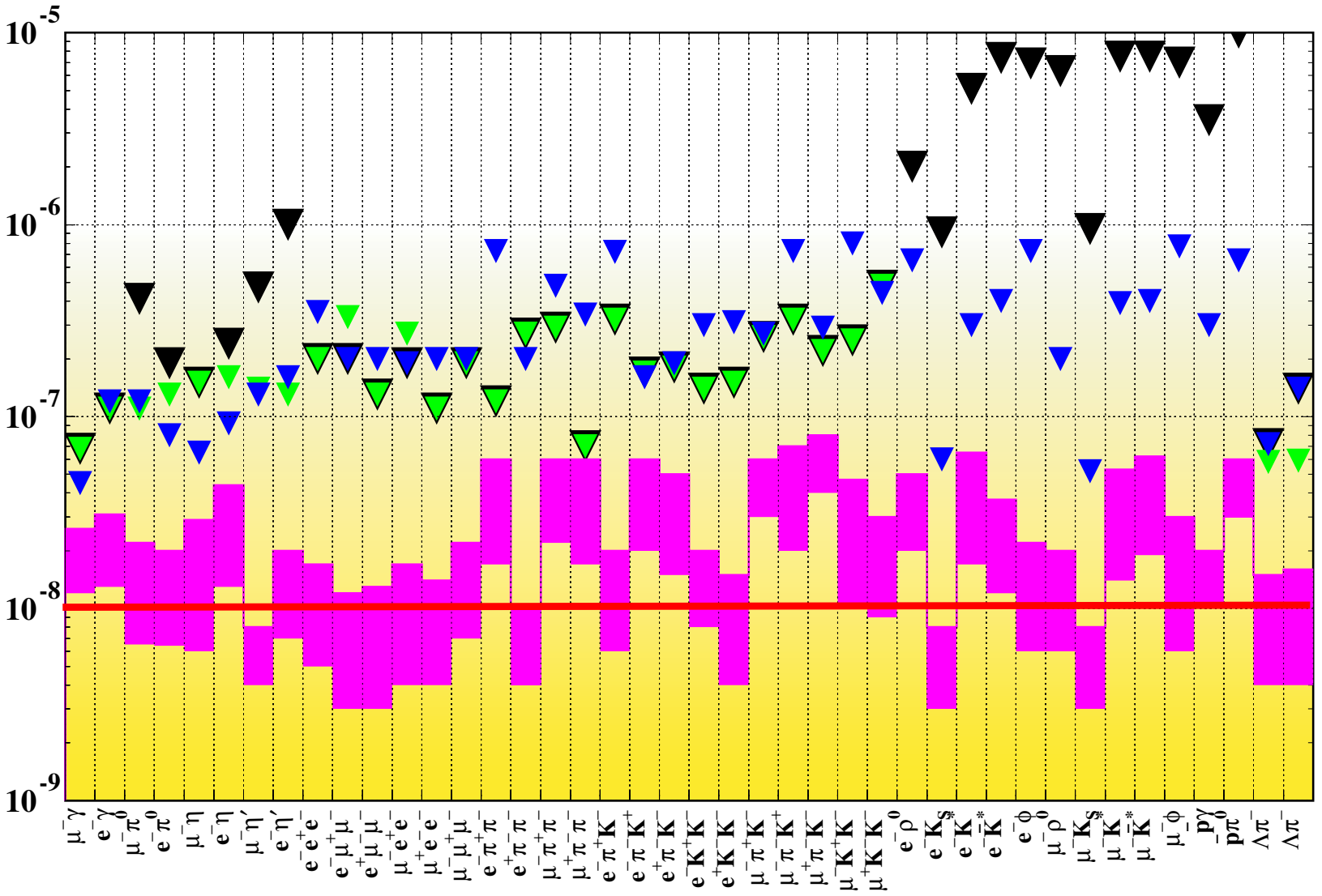
$\tau \to \mu\gamma \,/\, e\gamma$	△	$\tau \to l\nu\nu +$ ISR
$\tau \to \mu\pi^0$	×	$\tau \to \pi n\pi^0\nu,\ q\bar{q}$
$\tau \to \mu\eta$	△	$q\bar{q},\ \tau\tau$
$\tau \to lll$	○	
$\tau \to \mu hh$	△	$q\bar{q},\ \tau\tau$
$\tau \to ehh$	○	

μ/π

  - Want better μ/π separation, gamma resolution
  - Need suppress beam BG

Future prospect

- Possible sensitivity at $5ab^{-1}$



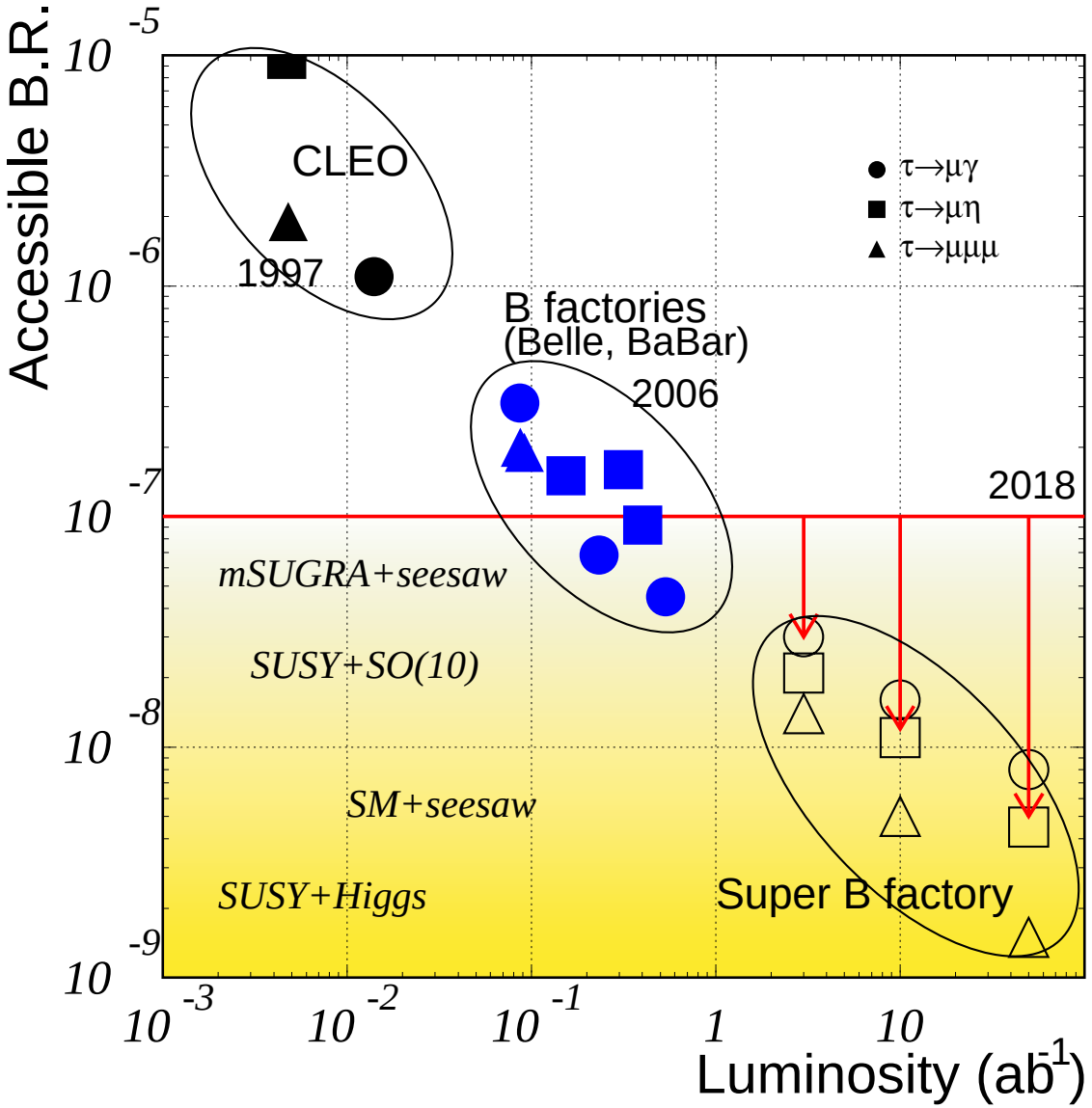
PDG2006
Belle
Babar

based on eff. and N_{BG} of most sensitive analysis

Estimated upper limit range of Br

Future prospect

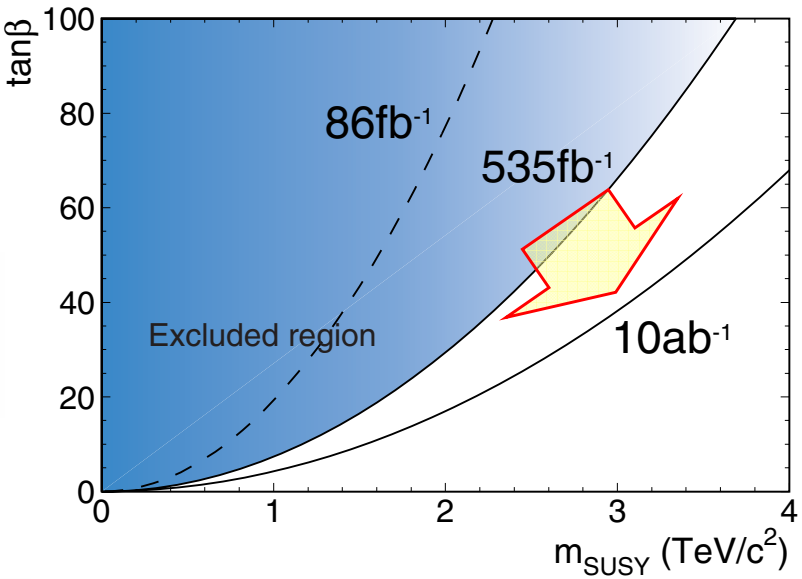
- Br~O(10^{-9}) at Super B factory



Physics impact

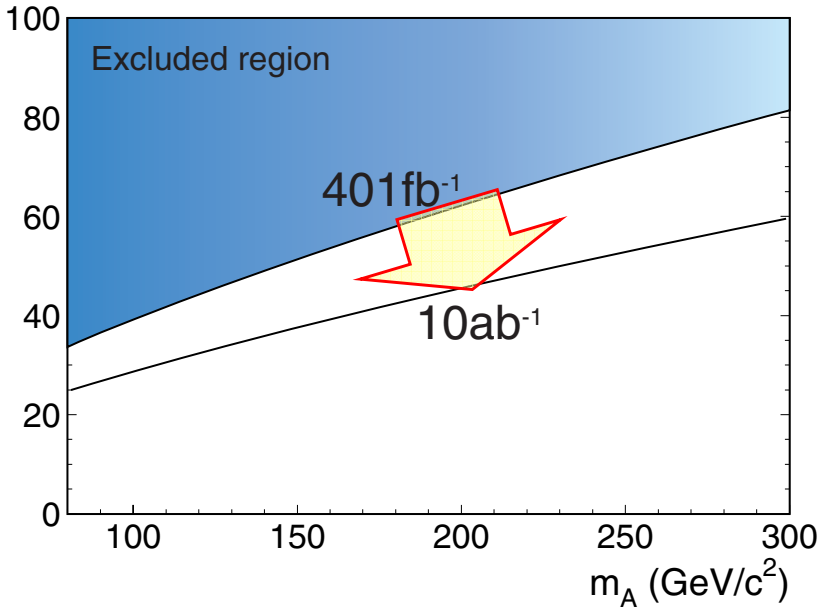
- Physics reach for SUSY parameters
  - $\tau \rightarrow \mu\gamma$

$$\mathcal{B}(\tau \to \mu\gamma) \simeq 3.0 \times 10^{-7} \left(\frac{\tan\beta}{60}\right)^2 \left(\frac{1\ \mathrm{TeV}/c^2}{m_{SUSY}}\right)^4$$



  - $\tau \rightarrow \mu\eta$

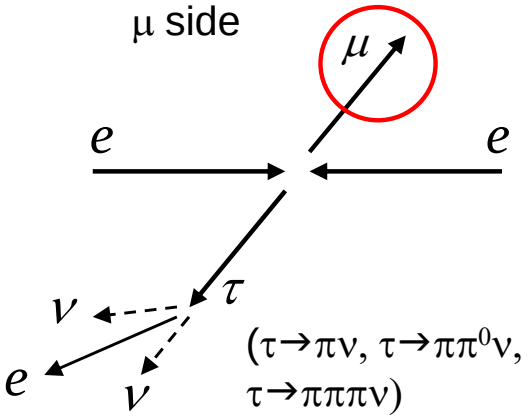
$$\mathcal{B}(\tau \to \mu\eta) \simeq 8.4 \times 10^{-7} \left(\frac{\tan\beta}{60}\right)^6 \left(\frac{100\ \mathrm{GeV}/c^2}{m_A}\right)^4$$



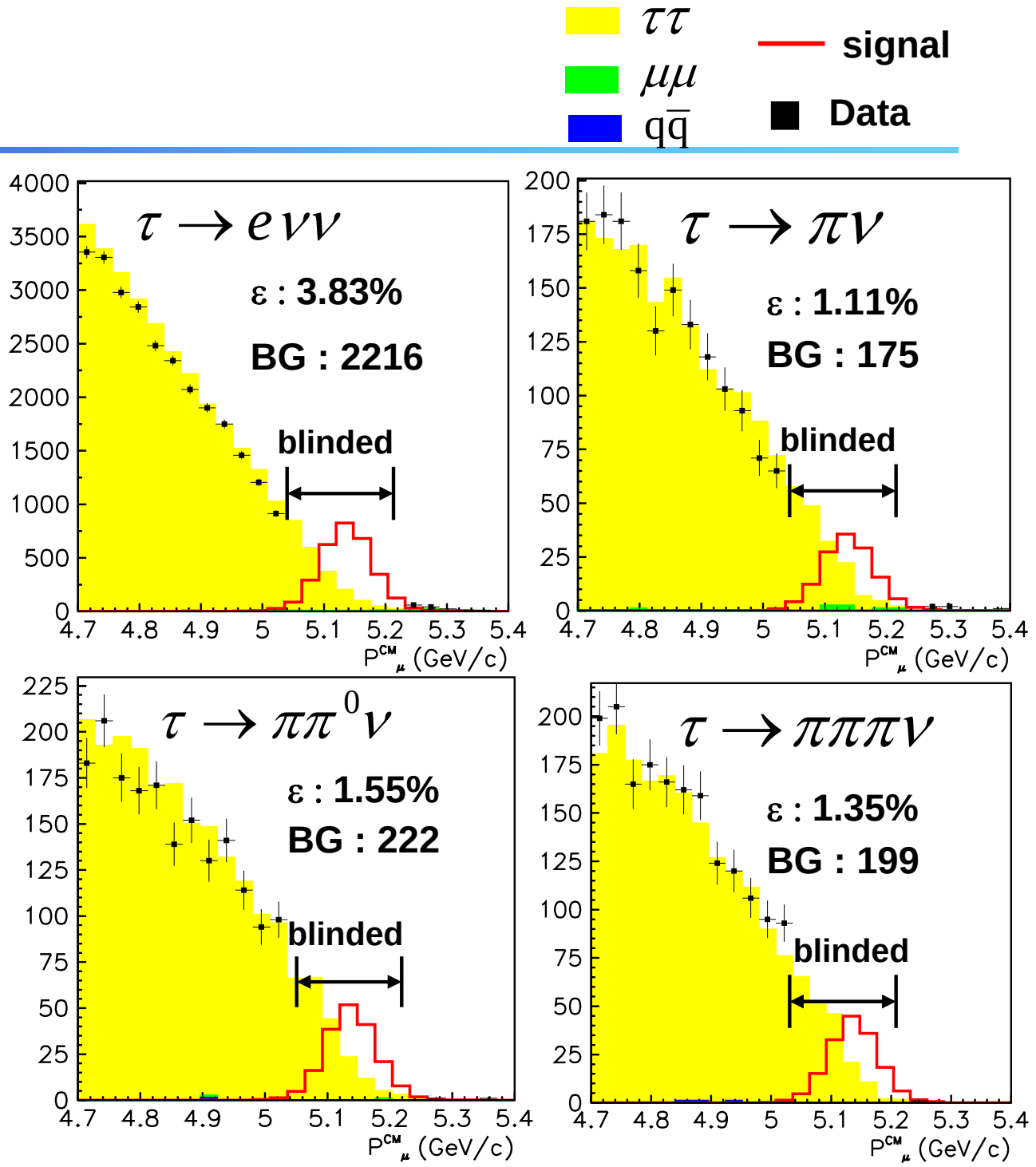
- After observation!
  - To specify the model,
  - Angular correlation
  - Muon polarization, etc.

$e^+e^- \rightarrow \mu\tau$

- LFV at production vertex



- Expected sensitivity
  - σ<1.3 fb
    - x3 better than previous result



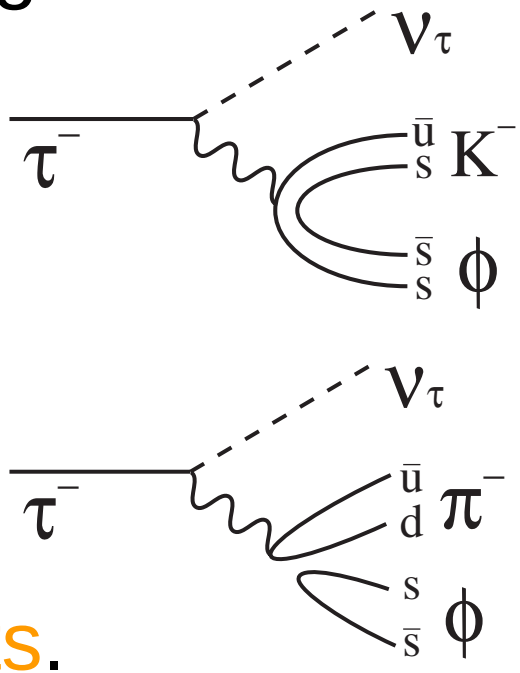
Hadronic tau decays

- Can investigate SM very precisely
  - QCD behavior
  - Strange structure function, m_s
  - CP violation

- On going Items
  - $\tau \rightarrow \phi\ K/\pi\ \nu$
  - $\tau \rightarrow \eta\ K/\pi\ \nu$
    - Second class current
  - $\tau \rightarrow K^*\ K/\pi\ \nu$
    - Precise mass spectrum

$\tau \rightarrow \phi K/\pi \nu$

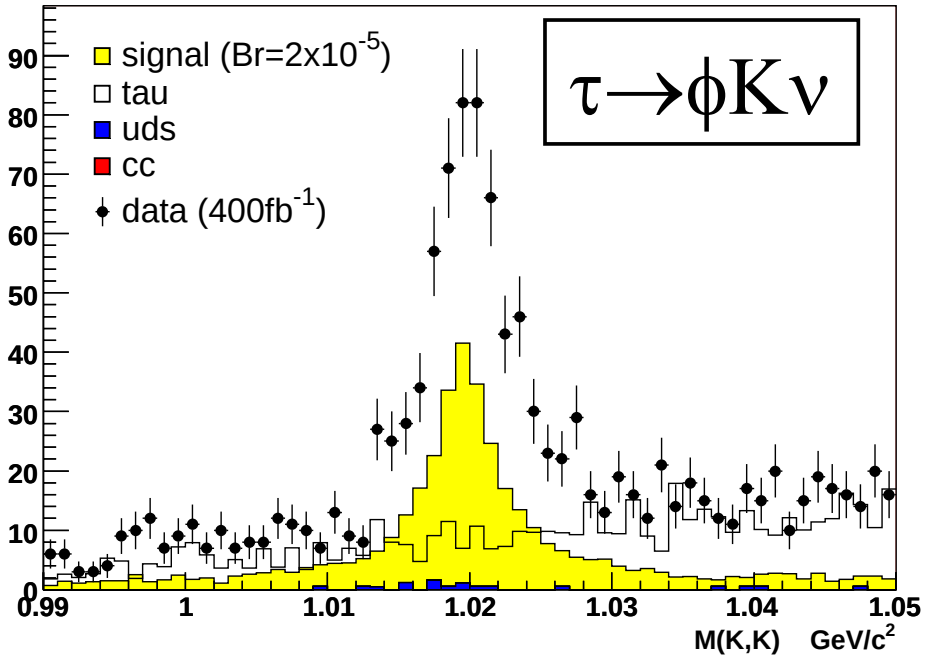
- Tau decay including ϕ was not observed yet.
- $\tau \rightarrow \phi h \nu$ is useful for the understanding of the QCD behavior in low mass scale.
- Predicted branching ratio:
  - ~2×10^{-5} : $\tau \rightarrow \phi K \nu$
  - $(1.20 \pm 0.48) \times 10^{-5}$: $\tau \rightarrow \phi \pi \nu$

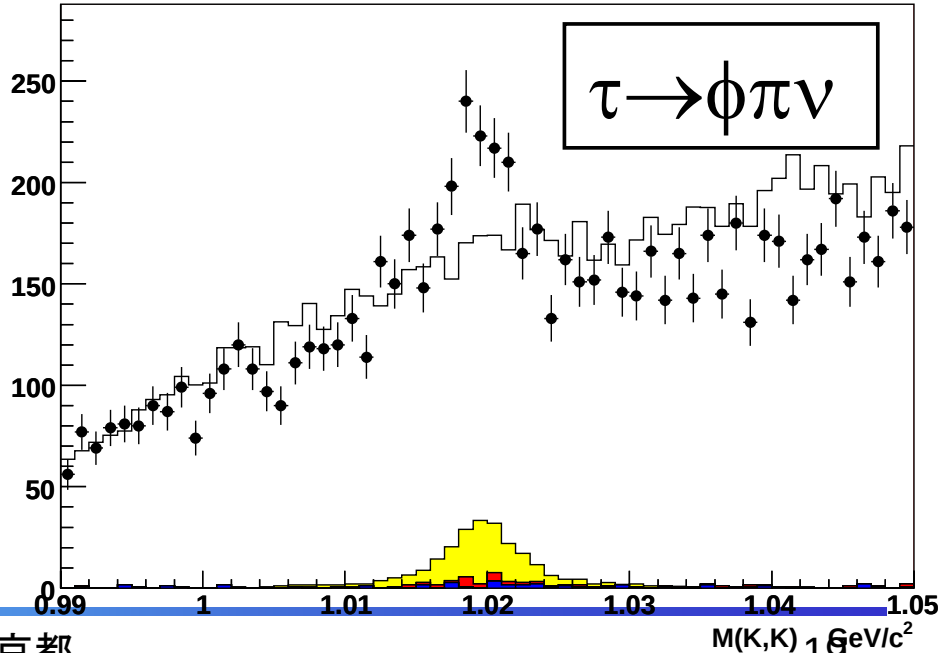


- CLEO have measured the upper limits.
  - With $3.1 fb^{-1}$ data
  - $Br(\tau \rightarrow \phi K \nu) < (5.4 \sim 6.7) \times 10^{-5}$ at 90%C.L.
  - $Br(\tau \rightarrow \phi \pi \nu) < (1.2 \sim 2.0) \times 10^{-4}$ at 90%C.L.

$\tau \rightarrow \phi K/\pi \nu$ (2)

- Select KKh + lepton tag
- Main background
  - $\tau \rightarrow KK\pi\nu$
    - $Br(KK\pi\nu)=(1.55\pm0.07)\times10^{-3}$
  - qq process; ~2%
- $B(\tau \rightarrow \phi K\nu)=$
  $(4.06\pm0.25\pm0.26)\times10^{-5}$
  - First observation!
  - $B(\phi\pi\nu)=(6.07 \pm 0.71)\times10^{-5}$





まとめ

- Bファクトリーはタウファクトリー
- ~10^9 タウ粒子対を精度良く収集
- LFVの感度はBr~7×10^{-8}になりつつある
  - 新しい物理が示すパラメータ空間を探索中
- ハドロニックタウ崩壊; Br~10^{-5}を発見しつつある

- 次のステップ
  - 解析上重大な問題は無い。より多くのタウ粒子対を用いる。
  - 他のLFV崩壊(3 leptons, lepton+hadrons etc.)や新しい物理の効果(EDM etc.)の探索
  - ハドロン崩壊の精密測定
    - Kを含む崩壊, second class currentなど