New physics searches at B factories

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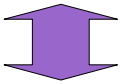
Flavor Physics & CP violation 2006, Vancouver

New physics: new flavor structure

Standard model:

$$\frac{g}{\sqrt{2}} W_\mu^\dagger \left[\bar{\mathbf{u}}\gamma^\mu(1-\gamma_5)\mathbf{V_{CKM}}\mathbf{d}\right] + h.c.$$

- Left-handed coupling only
- Pattern of Cabibbo supression in CKM matrix
- No additional CPV phases



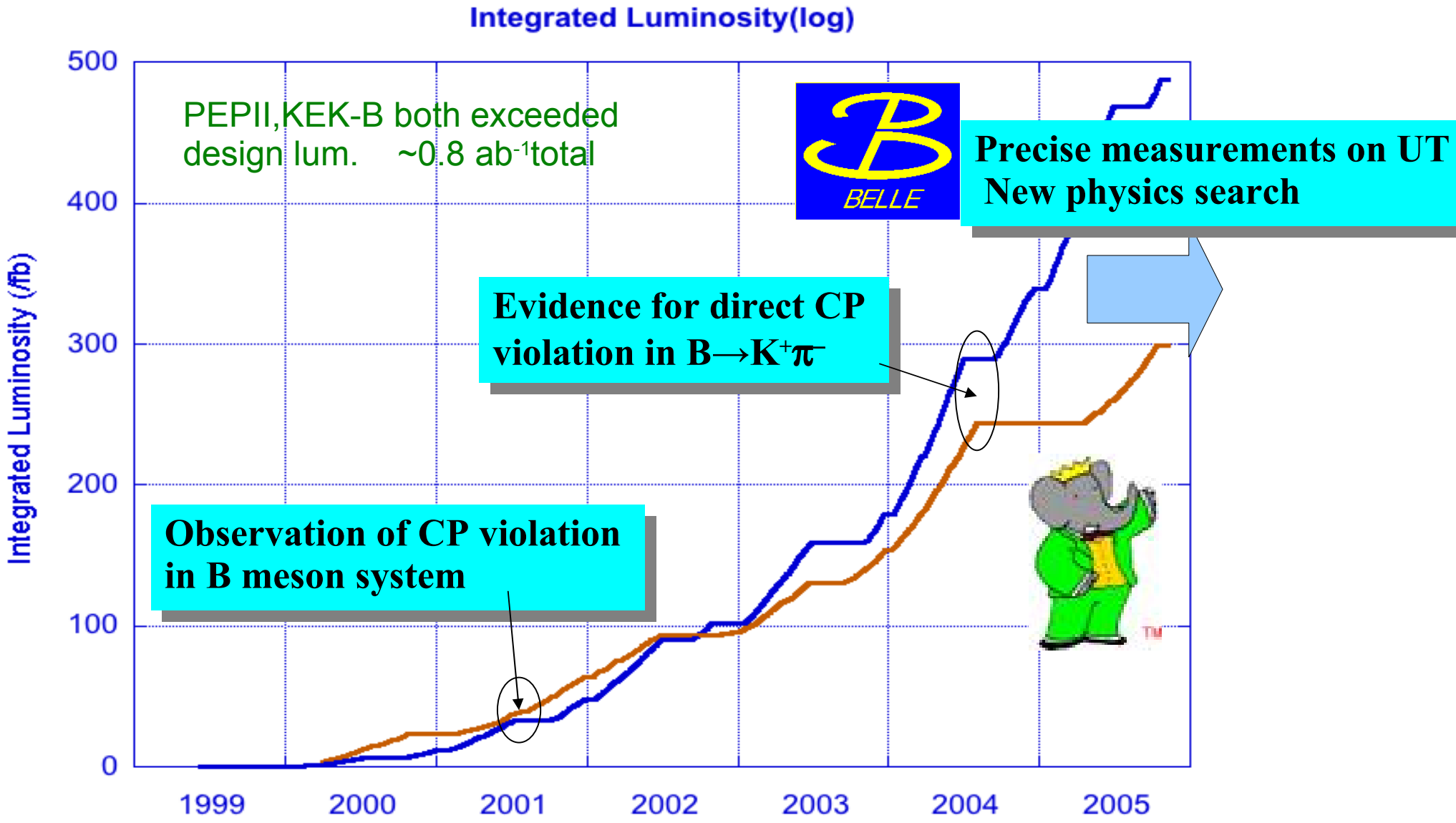
New flavor structure:

- Could be right-handed
- Pattern of mixing matrix element differs from CKM
- New CPV phases

Experimental search of the new flavor structure

→ **B-factories (Belle & BaBar)**

Accumulated Luminosity at B-factories



How do we study the extended flavor structure ?

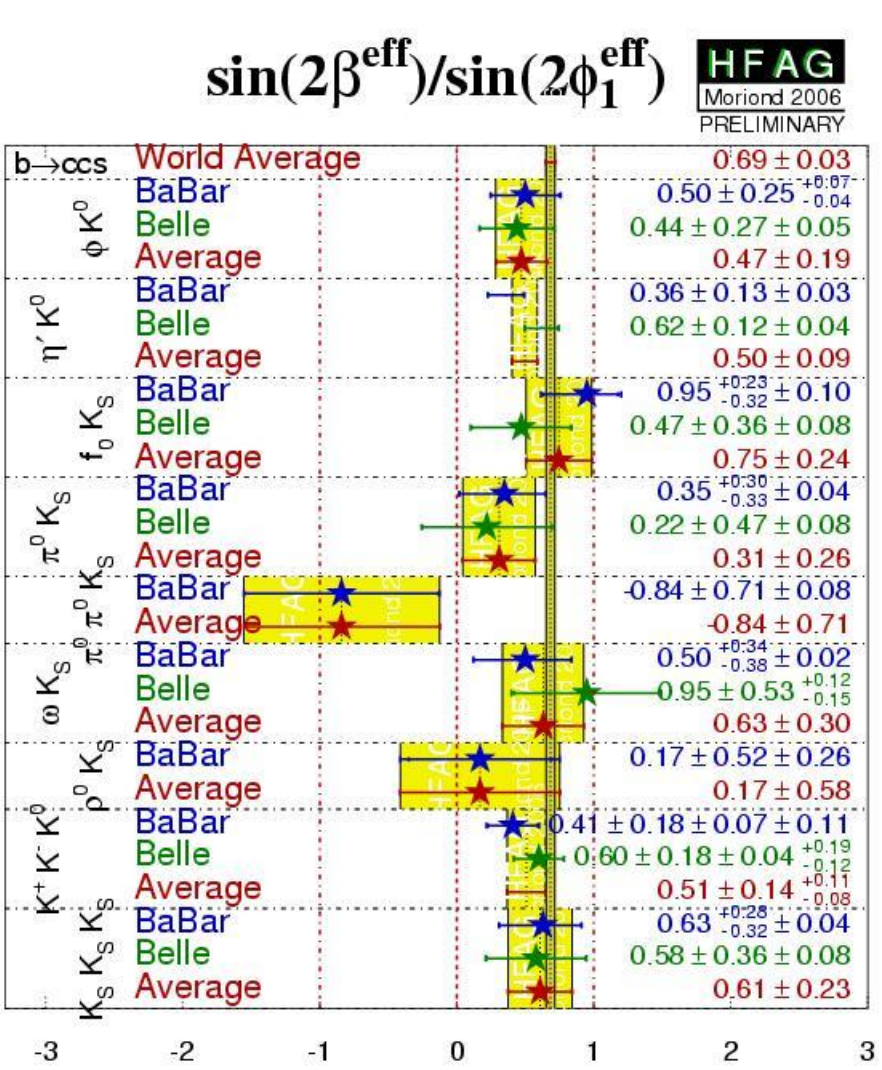
- Besides the unitarity test of the CKM matrix,
  many clean measurements (both exp. & th.) unique
  at e^+e^- B-factory
- Correlations among the measurements:
  → useful to differentiate the New Physics models

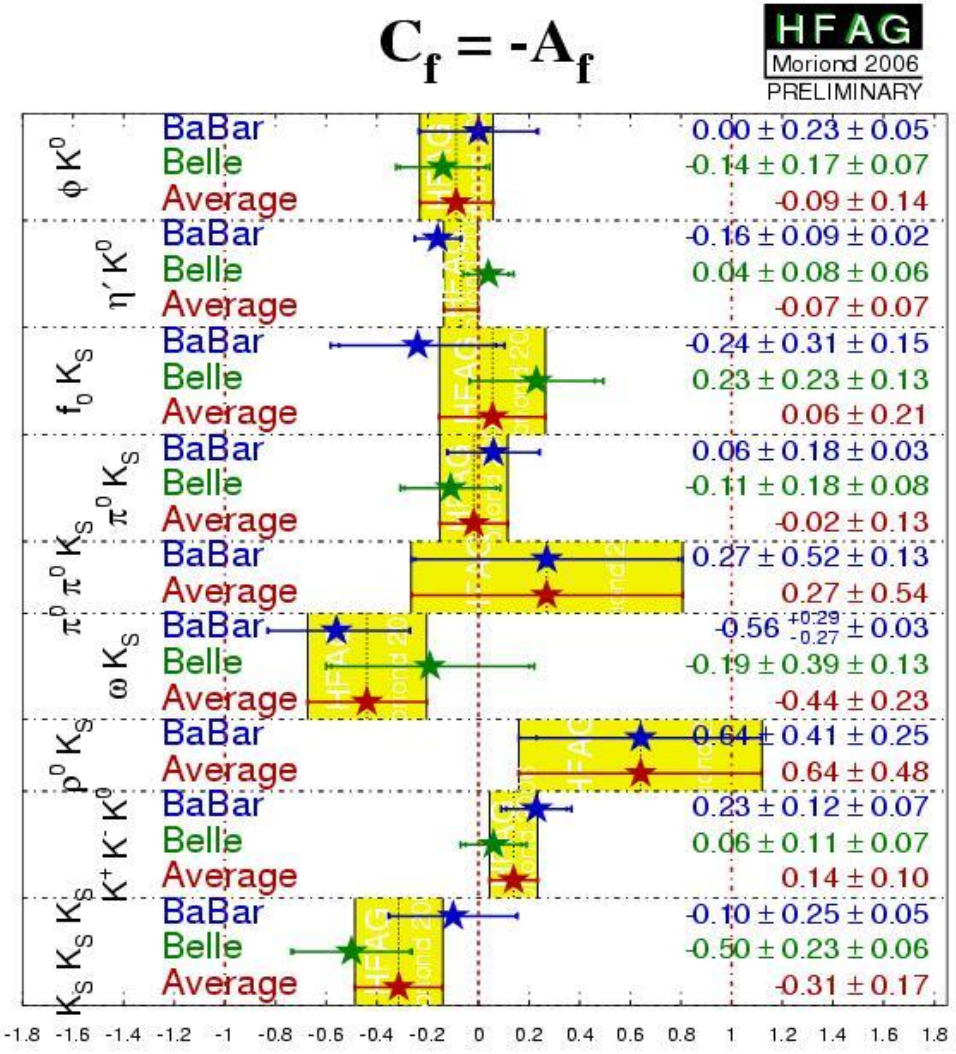
Probes for new flavor structure:

- New CPV phase(s) in b → sqq :e.g. tCPV in $B^0 \to \phi Ks$, $\eta' Ks$, $KsKsKs$
- Right-handed current in b → sγ :e.g. tCPV in $B^0 \to \mathrm{Ks}\pi^0\gamma$
- Lepton A_{FB} in b → s l l
- Lepton flavor violation in τ decays
- Charged Higgs in tree diagram :e.g. $B^+ \to l^+\nu$, $B \to D\tau\nu$
- And more: e.g. $b \to d\gamma$, $B \to K^*\nu\nu$, ...

Many of these are already experimentally accessible

Searches of new CPV phases in B $\rightarrow s\bar{q}q$

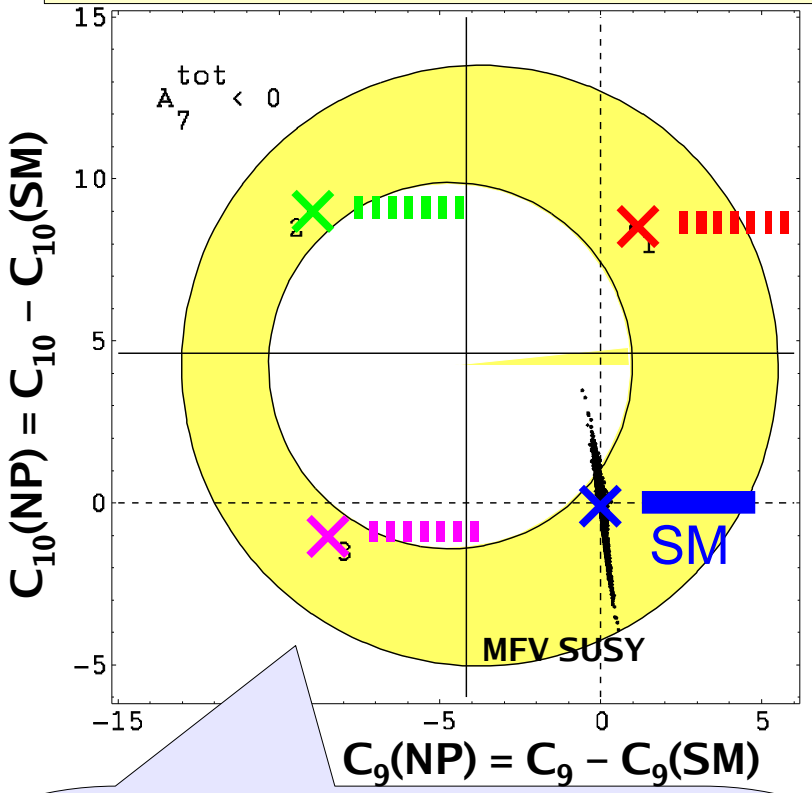


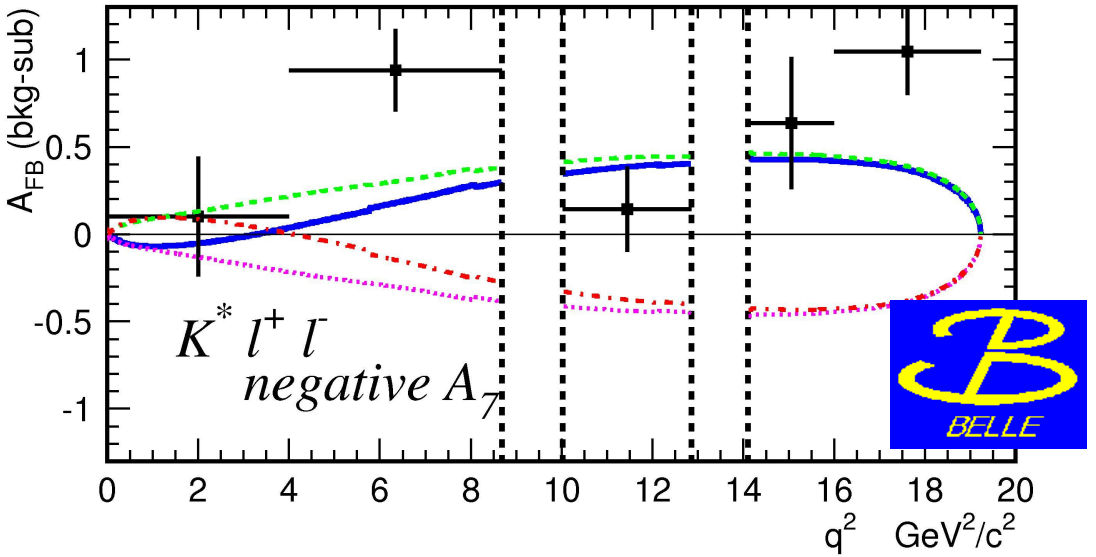


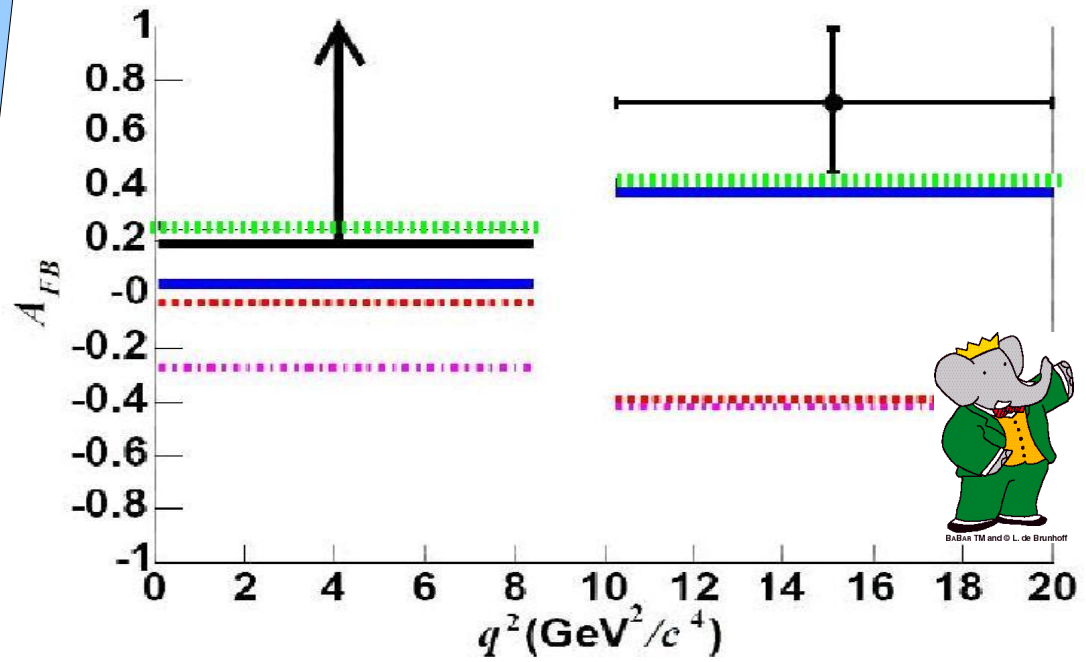
→ *See Mathew Graham's slides for details*

A_{FB} in $B \to K^* l^+ l^-$

- New type of measurement to probe BSM
- More information on the Wilson coefficients: C_7, C_9 and C_{10}







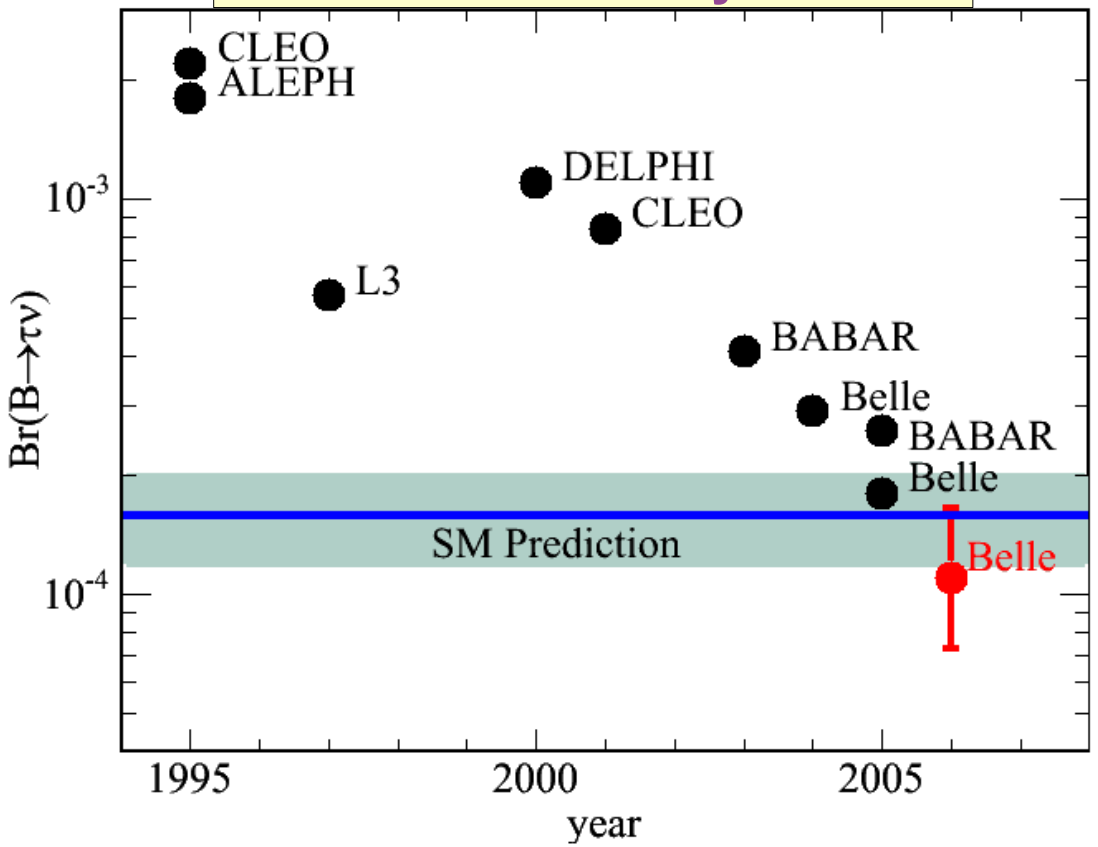
Allowed region at 90% CL, based on NNLO and experimental bounds on
$B \to X_s \gamma$ and $B \to X_s \ell^+ \ell^-$ Br' s; A7<0
A. Ali et al. PRD 66, 034002 (2002)

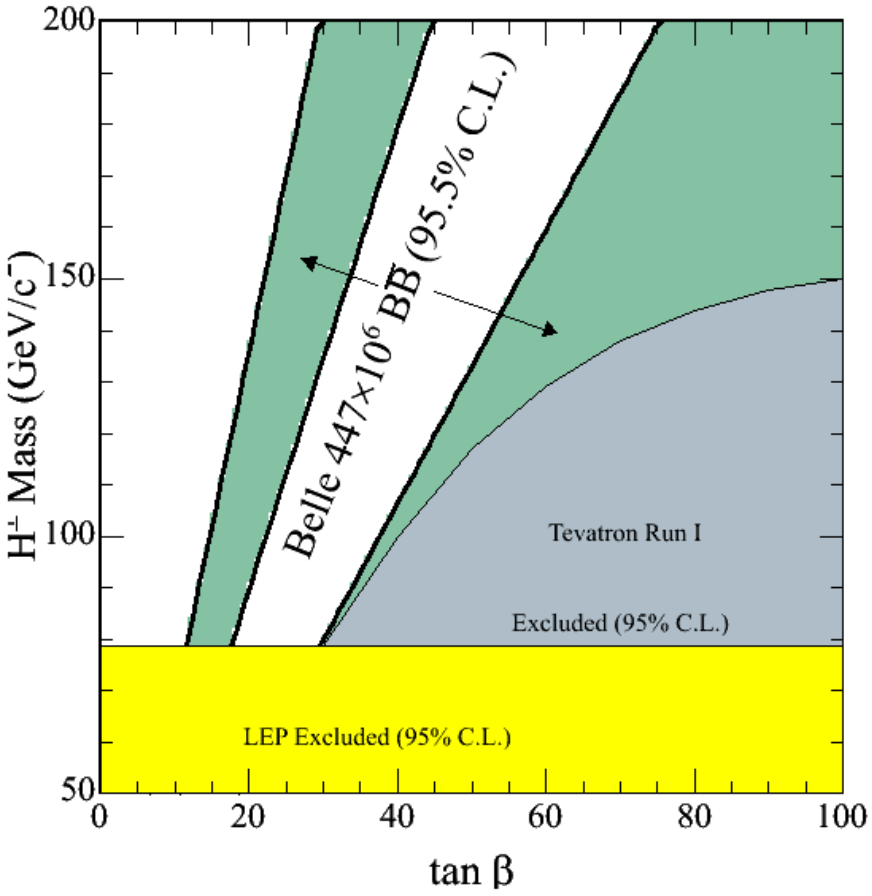
→ *See Veysi Erkcan Ozcan's slides for details*

Constraint for Charged Higgs from $B^+ \to \tau^+ \nu$

Search history of $B^+ \to \tau^+ \nu$

- **First evidence by Belle**





$$\mathcal{B}(B \to \tau\nu) = \mathcal{B}(B \to \tau\nu)_{\mathrm{SM}} \times r_H$$

$$\rightarrow \quad r_H = 0.67^{+0.29}_{-0.26}$$

$$r_H = (1 - \frac{m_B^2}{m_H^2} \tan^2\beta)^2$$

→see Koji Ikado's slides for details

Summary of presentations in FPCP2006

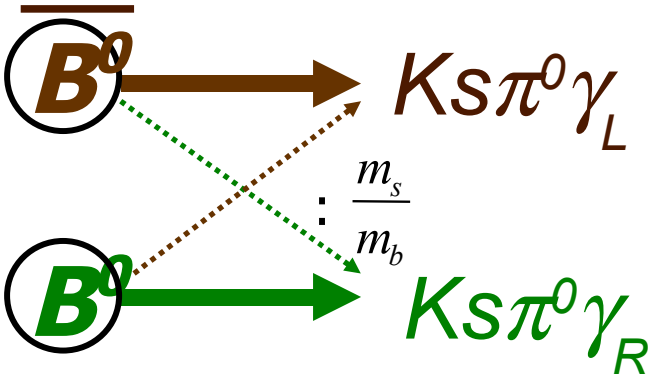
- New CPV phase(s) in b → sqq: e.g. tCPV in $B^0 \to \phi Ks$, $\eta' Ks$, $KsKsKs$
  → *Mathew Graham's talk*
- Right-handed current in b → sγ :e.g. tCPV in $B^0 \to Ks\pi^0\gamma$
  → *this talk*
- Lepton A_{FB} in b → s l l
  → *Veysi Erkcan Ozcan's talk*
- Lepton flavor violation in τ decays
  → *this talk*
- Charged Higgs in tree diagram :e.g. $B^+ \to l^+\nu$
  → *Rick Van Kooten's talk, Koji Ikado's talk*
- And more: e.g. $b \to d\gamma$, $B \to K^*\nu\nu$, ...
  → *Veysi Erkcan Ozcan's talk for* $b \to d\gamma, \gamma\gamma$...
  → *Rick Van Kooten's talk for* $B_s \to \mu^+\mu^-$...

This talk include above two topics

Time dependent CPV in $B^0 \to \mathrm{K}\pi^0\gamma$

Right-handed current in $b \to s\gamma$

D.Atwood, M.Gronau, A.Soni (1997)
D.Atwood, T.Gershon, M.Hazumi, A.Soni (2004)

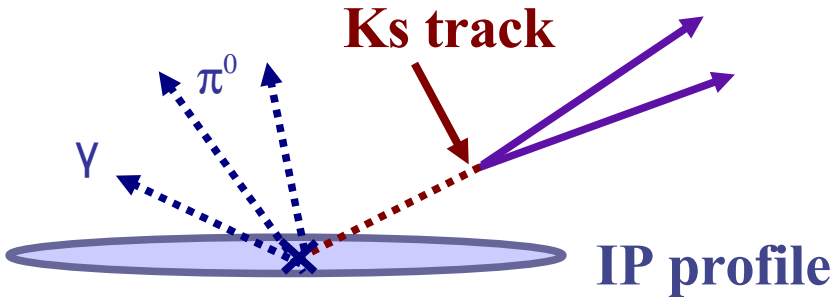


- Time dependent CPV(tCPV) in $B^0 \to Ks\pi^0\gamma$

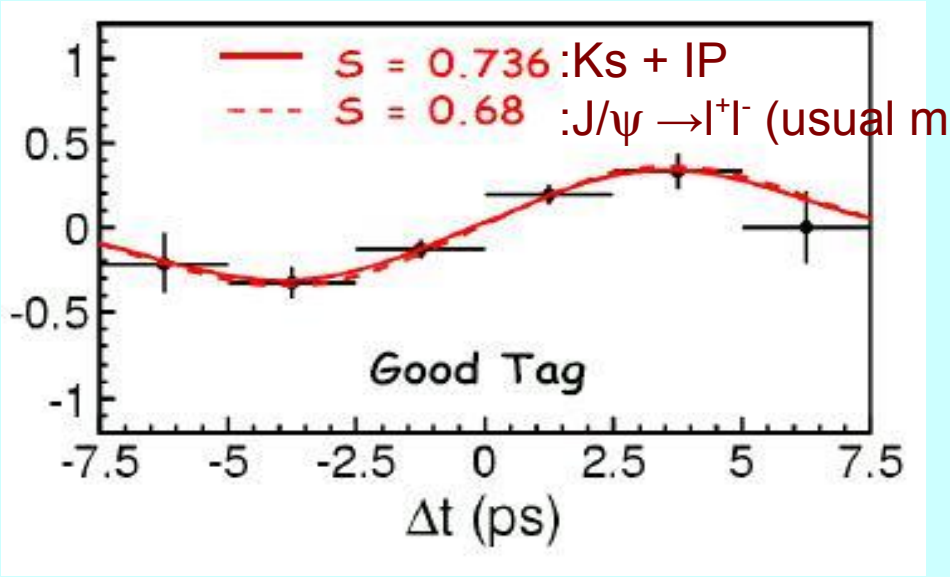
  - SM: γ is polarized, the final state almost flavor-specific.
    $S(Ks\pi^0\gamma) \sim -2m_s/m_b \sin 2\phi_1$
  - m_{heavy}/m_b enhancement for right-handed current in many new physics models
    - LRSM, SUSY, Randall-Sundrum (warped extra dimension) model
  - LRSM: $SU(2)_L \times SU(2)_R \times U(1)$
    - $|S(Ks\pi^0\gamma)| \sim 0.5$ is allowed.
  - No need for a new CPV phase

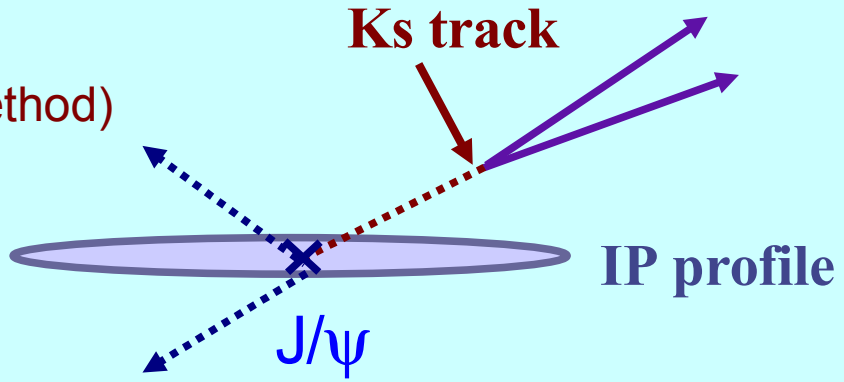
Vertex reconstruction

- Decay vertex of $Ks\pi^0\gamma$ is determined by fitting the Ks track to the IP profile

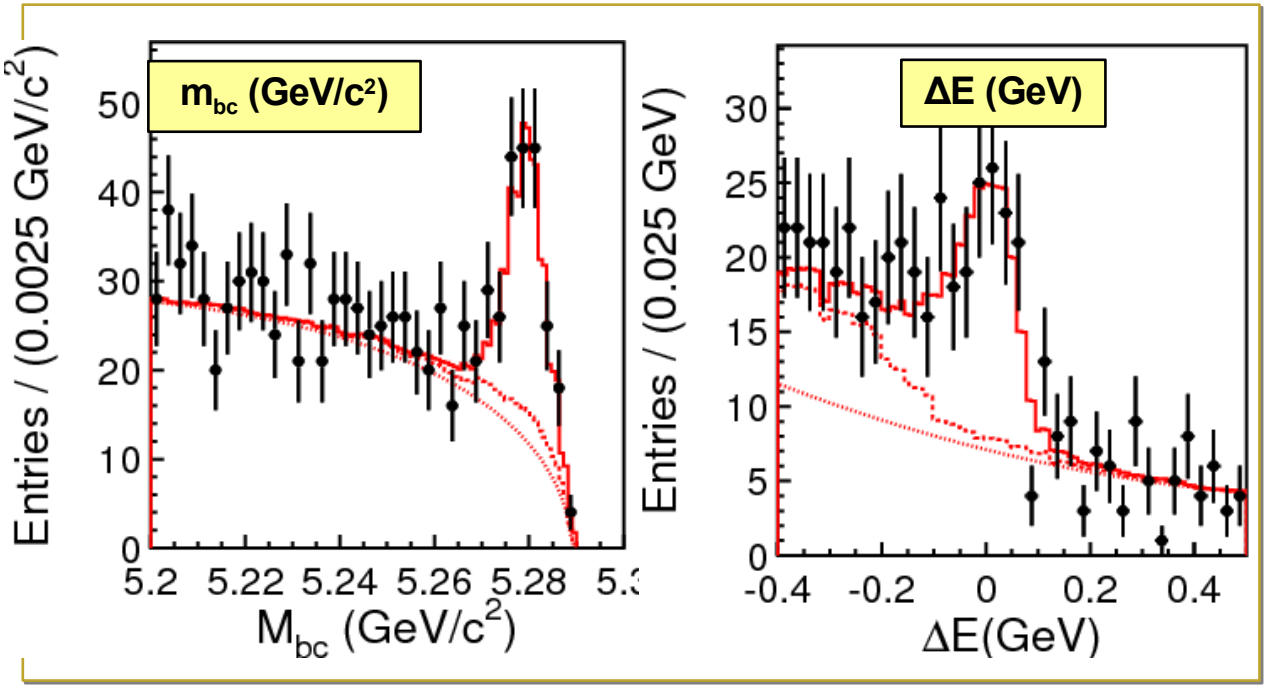


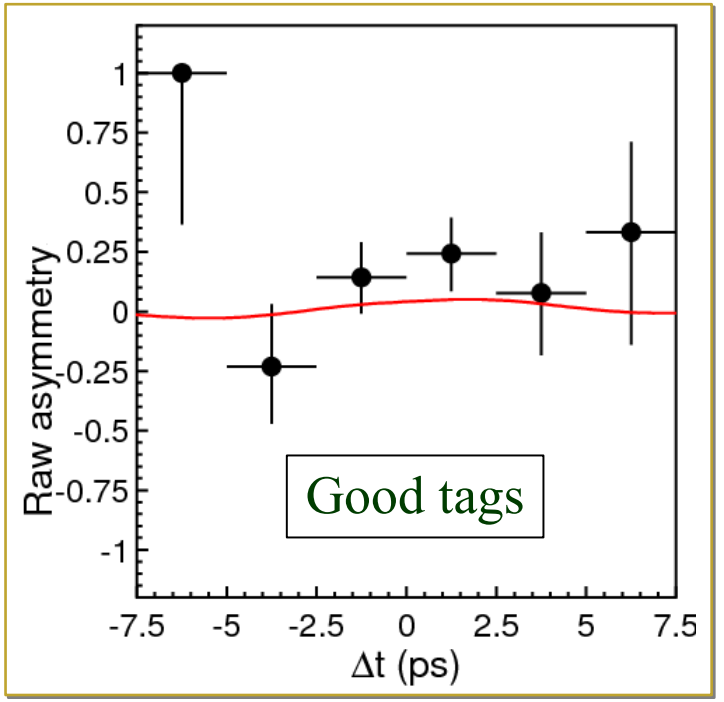
Validation of the Ks+IP method using control sample: J/ψ Ks





TCPV in $B^0 \to K_S\pi^0\gamma$ (Belle)





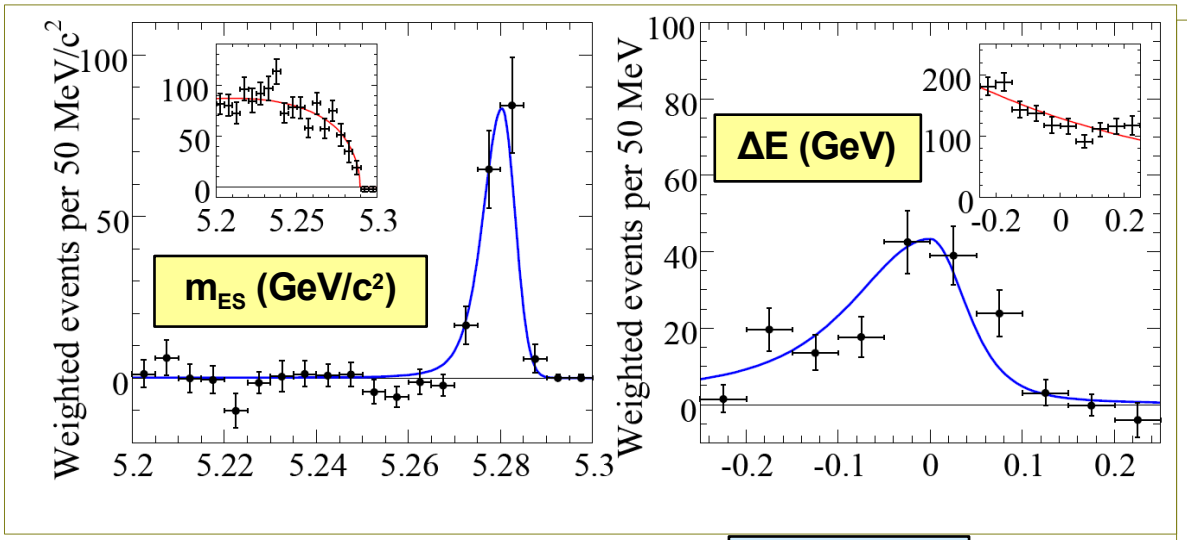
386 x 10^6 BB pairs

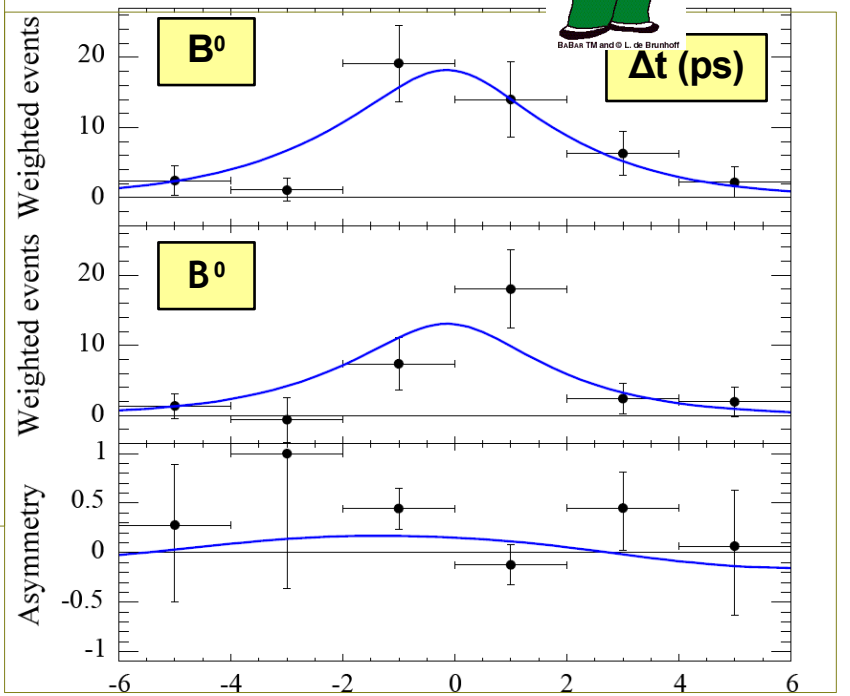
Use $M(K_S\pi^0)<1.8GeV/C^2$ (e.g. K* and non-resonant $K_S\pi^0$ etc. are combined)

$S_{K_S\pi^0\gamma}$=+0.08±0.41±0.10
$A_{K_S\pi^0\gamma}$= +0.12±0.27±0.10

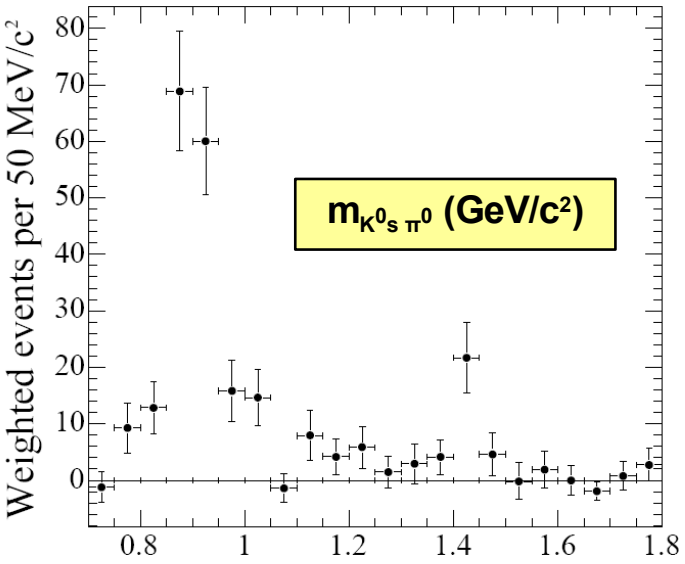
hepex/0507059

TCPV in $B^0 \to K_S \pi^0 \gamma$ (BaBar)





232 x 10^6 BB pairs



K* region:

$S_{K^*\gamma} = -0.21 \pm 0.40 \pm 0.05$

$C_{K^*\gamma} = -0.40 \pm 0.23 \pm 0.03$

Non-K* region:

$S_{K_S\pi^0\gamma} = +0.9 \pm 1.0 \pm 0.2$

$C_{K_S\pi^0\gamma} = -1.0 \pm 0.5 \pm 0.2$

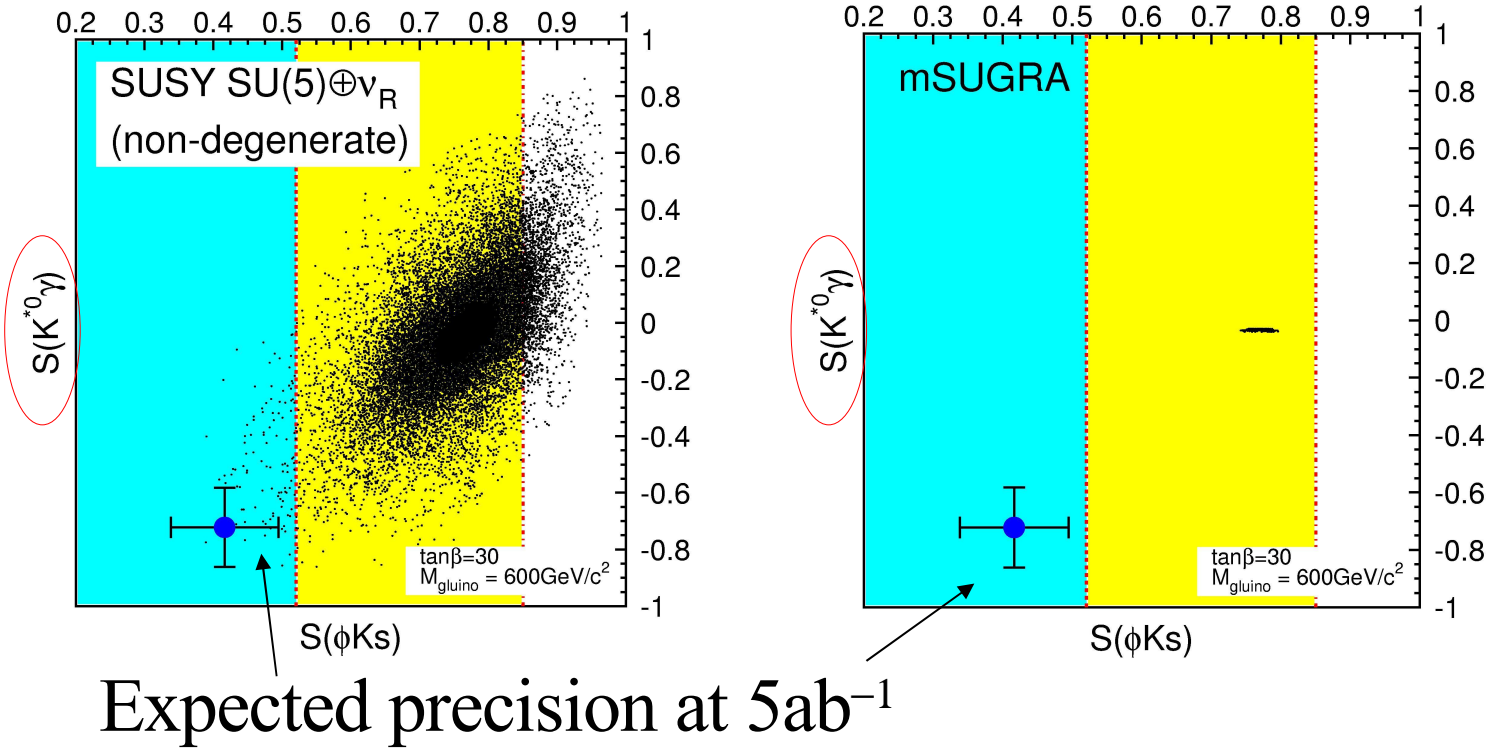
C(Babar)= -A(Belle)

PRD **72,** 051103 (R)

TCPV in $B \to K_S \pi^0 \gamma$ (future prospect)

Current $S_{K_S \pi^0 \gamma}$ error: ~0.4
→need much more data

It gets down to 0.14 @ 5 ab^{-1} at Super-B factory



Expected precision at 5ab^{-1}

T.Goto, Y.Okada, Y.Shimizu,T.Shindou, M.Tanaka (2002, 2004) + SuperKEKB LoI

Lepton flavor violation in τ decays

Lepton flavor violation in τ decays

- Lepton flavor violating decays have a very small probability in the Standard Model
- New physics effects (SUSY, Extra-D, etc.) may allow us to observe LFV with the present experimental sensitivity.

B-factory = "Tau-factory"
Accumulated data:

- >4.5x10^8 τ-pairs at Belle, >3.0x10^8 τ-pairs at BaBar

Search for the LFV tau decays at B-factories!

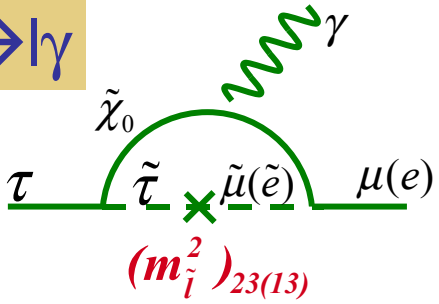
New physics in LFV τ decay

- MSSM with Seesaw

  PRD 60, 055008 (1999).

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

τ→lγ

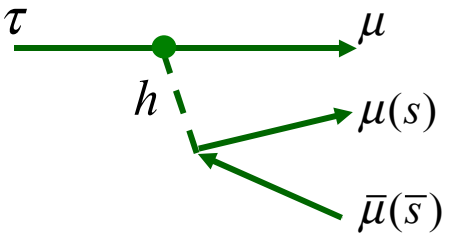


- Higgs mediated in MSSM

  PRD 66, 057301 (2002).

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

τ→3l, lη



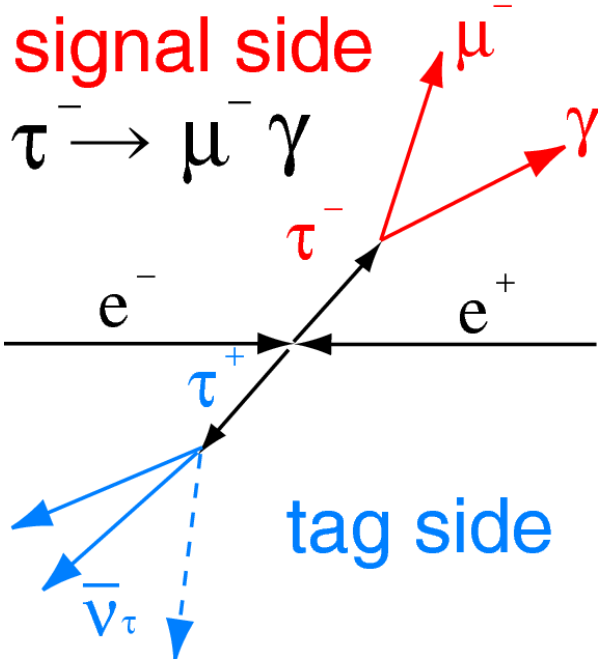
BR can be O($10^{-7\sim9}$)

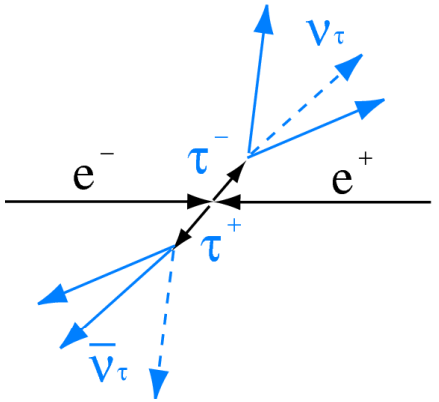
Previous results from CLEO were sensitive to Br~O(10^{-6}).

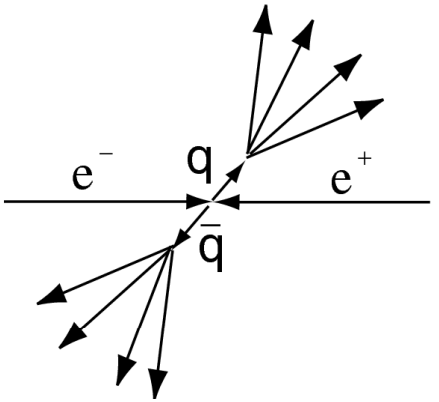
The B factories (Belle and BaBar) have sensitivities of O(10^{-7}~10^{-8}).

Analysis method

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



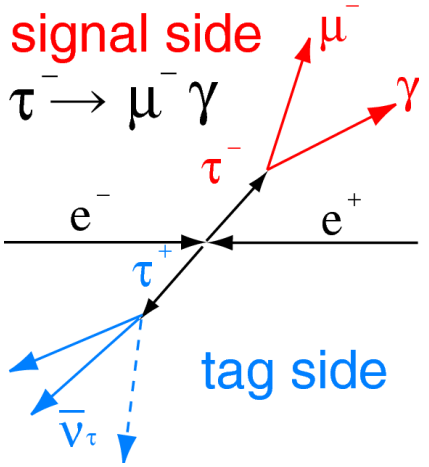


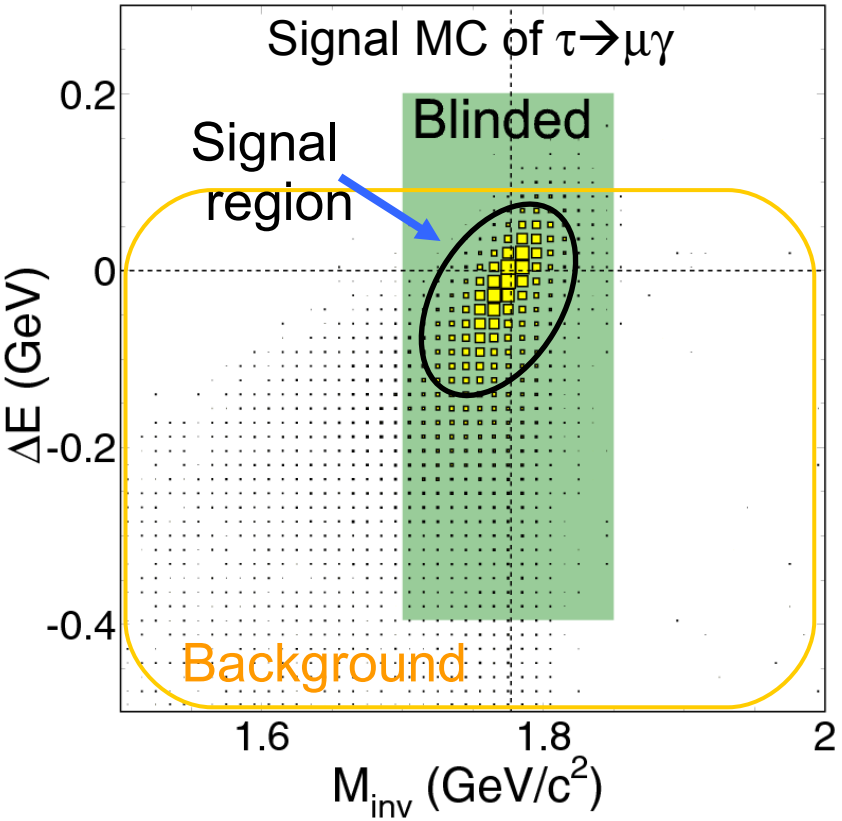


Analysis method (cont'd)

- 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.

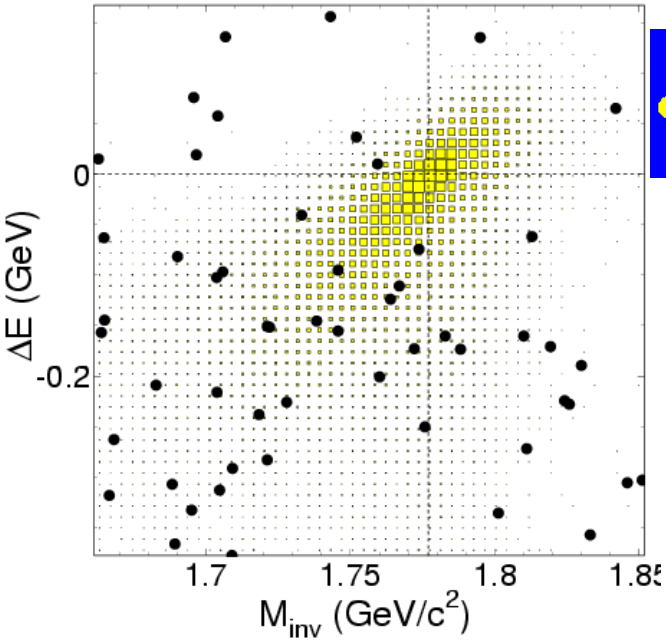




$\tau \to \mu\gamma$

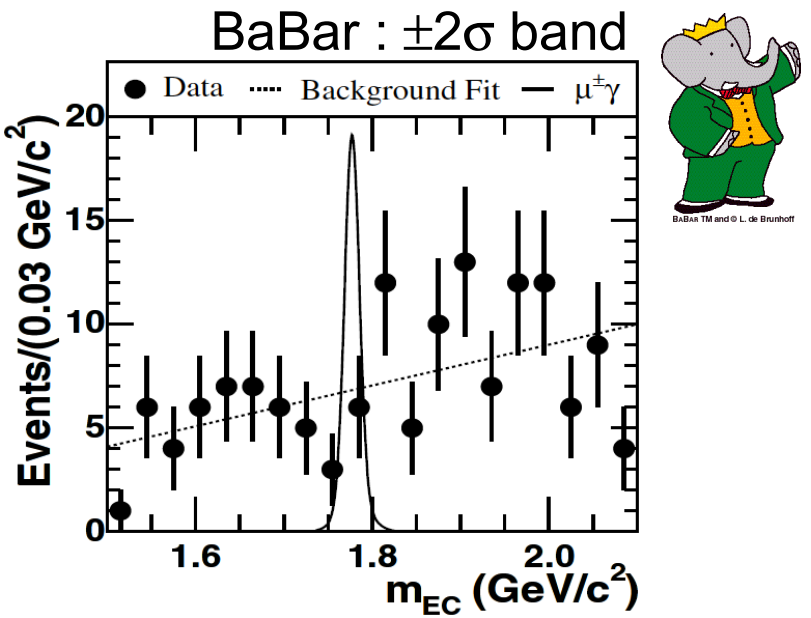
- Belle : Br<3.1×10^{-7} / 86.3 fb^{-1}
  - ε = 11.1%
  - 2D EML fit with $\pm5\sigma$ signal box
  - N_{signal}= 0, N_{BG}= 54
    - N_{signal} is constrained to be ≥ 0.

PRL 92, 171892 (2005)



- BaBar : Br<0.68×10^{-7} / 232 fb^{-1}
  - ε = 9.4%
  - 1D EML fit with $\pm2\sigma$ ΔE band
  - N_{signal}= $\underline{-2.2}$, N_{BG}= 143
    - N is allowed to be negative.
  - Negative yield gives lower U.L. than expected.

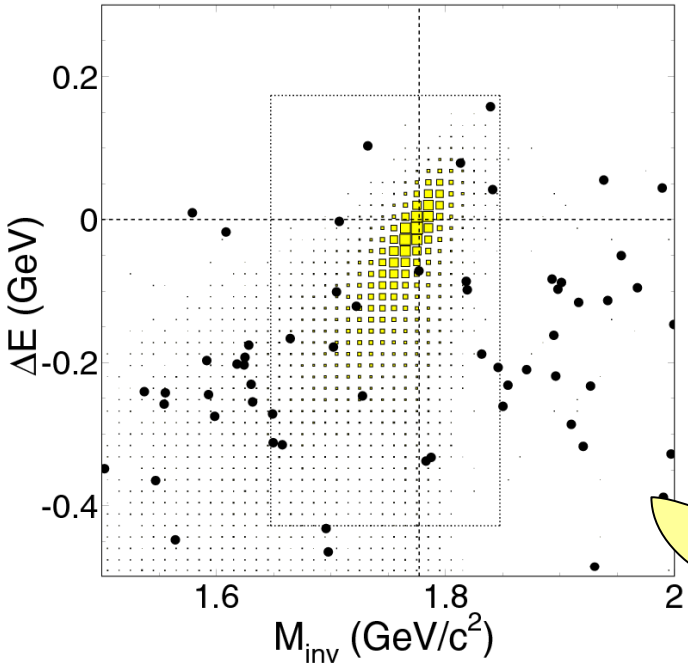
PRL 95, 041802(2005)



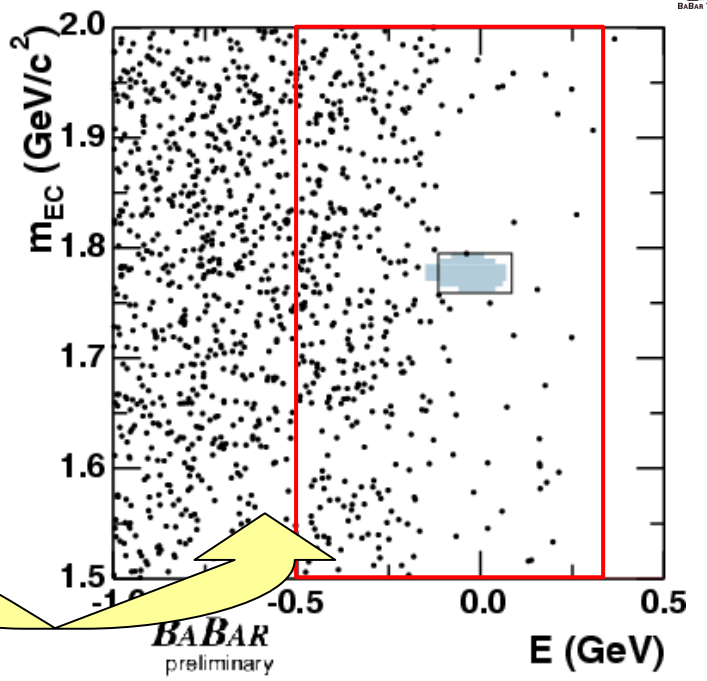
- Major Background: $\tau \to \mu\nu\nu$ + ISR

$\tau \rightarrow e\gamma$

- Belle
  - 86.7fb^{-1} data



- BaBar
  - 232fb^{-1} data

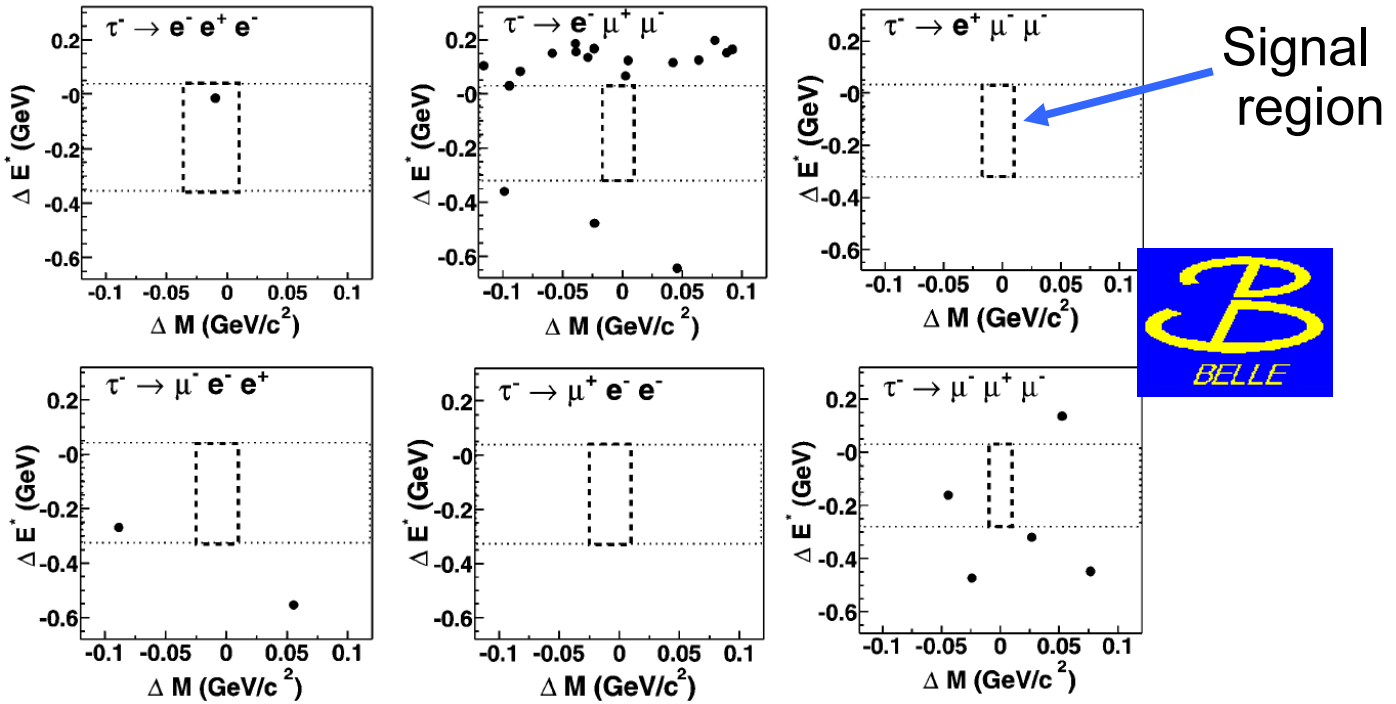


  - Br<3.9x10^{-7} at 90%C.L.
    PLB 613, 20 (2005).

  - Br<1.1x10^{-7}
    PRL 96, 041801 (2006).

$\tau \rightarrow 3l$

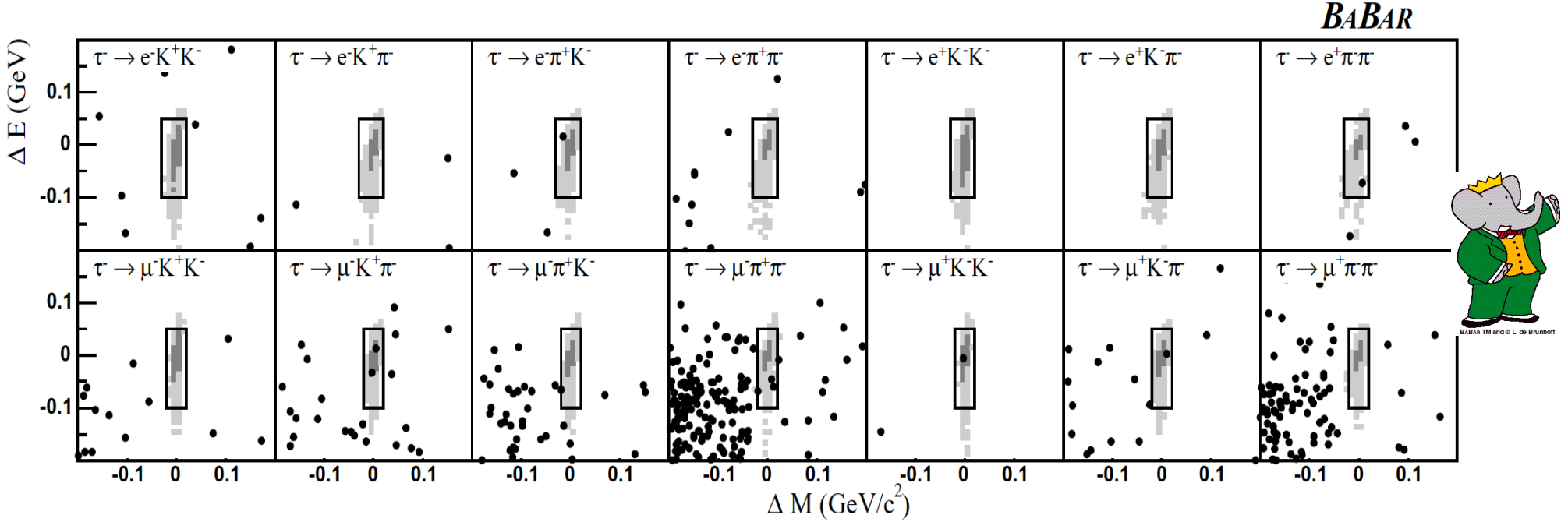
- Belle: 87.1fb^{-1}, BaBar: 91.5fb^{-1}
  PLB 598, 103 (2004), PRL 92, 121801 (2004).
- Br<(1.1~3.5)x10^{-7} at 90%C.L.



- Background: low level
  - qq around $\Delta E<0$, QED($\mu\mu$ or Bhabha) around $\Delta E>0$

τ→lhh

- Belle: 158fb^{-1}, BaBar: 221fb^{-1}
- Br<(1.6~8.0)x10^{-7} by Belle (preliminary)
- Br<(0.7~4.8)x10^{-7} by BaBar, PRL 95, 191801 (2005).



- Background: qq(flat) and ττ(corner)
  - τ→ehh: negligible BG level

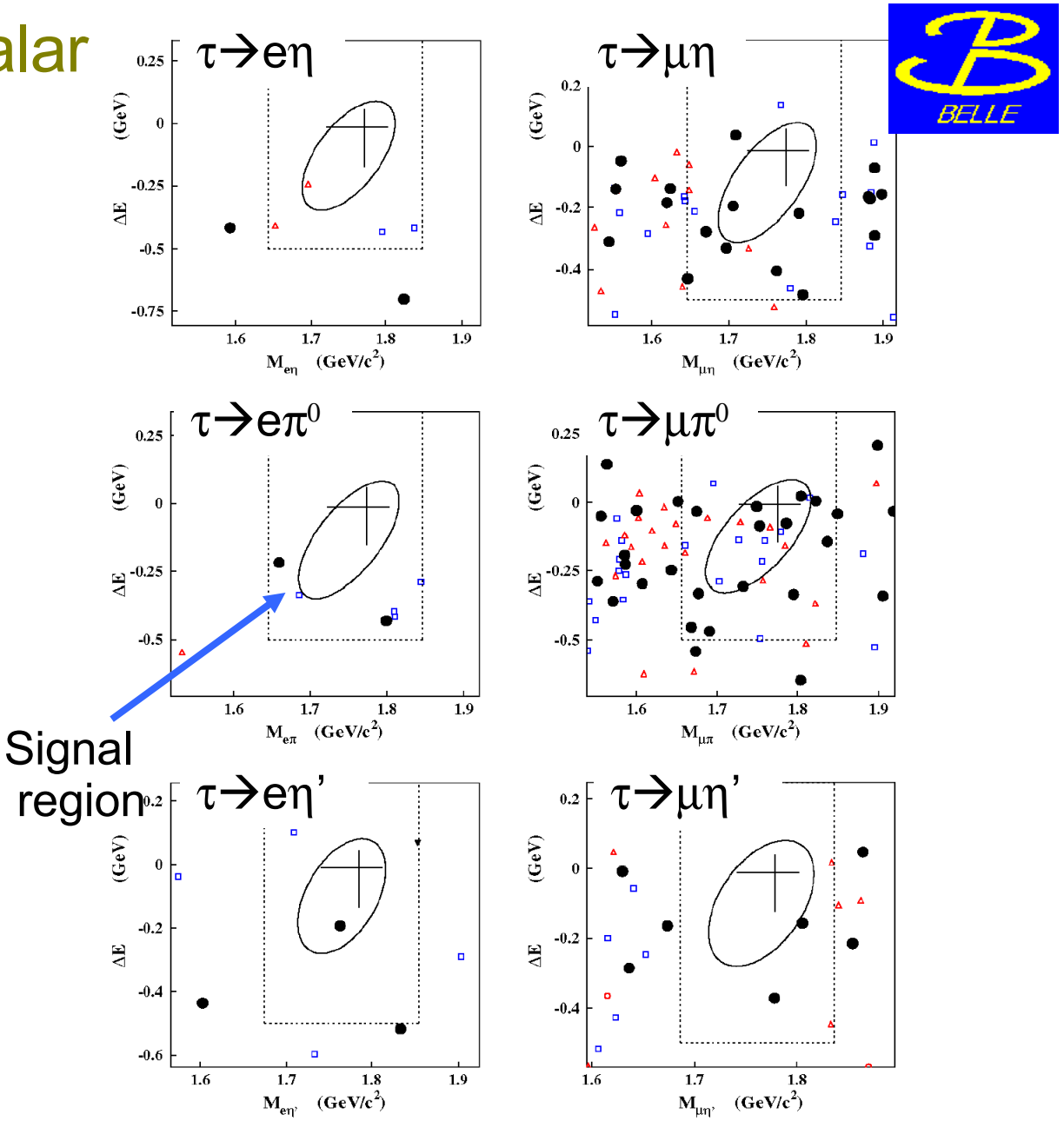
$\tau \to l\pi^0/\eta/\eta'$

- Lepton + Pseudoscalar meson

- Belle: 154fb^{-1}
- Br($\tau \to \mu\eta$)<1.5x10^{-7}
- Br < (1.5~10)x10^{-7}

  PLB 622, 218 (2005).

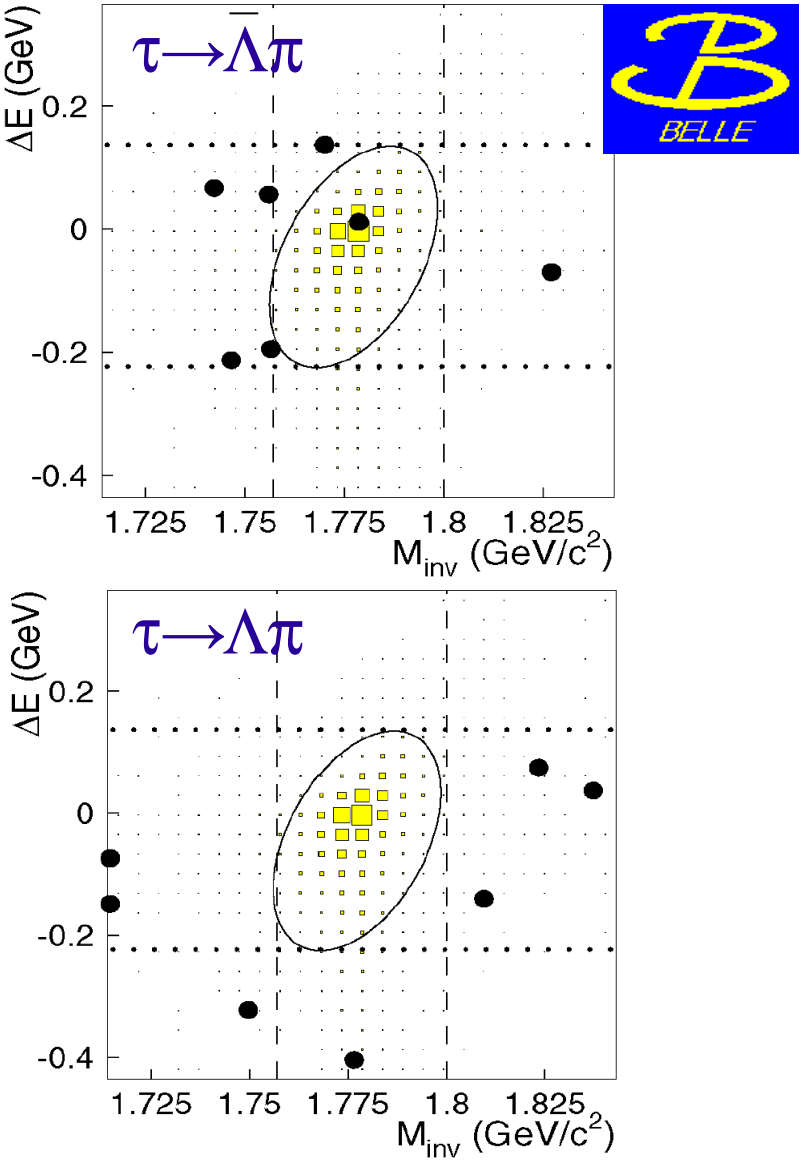
- Background
  - μ: $\tau\tau$ + qq
  - e: negligible



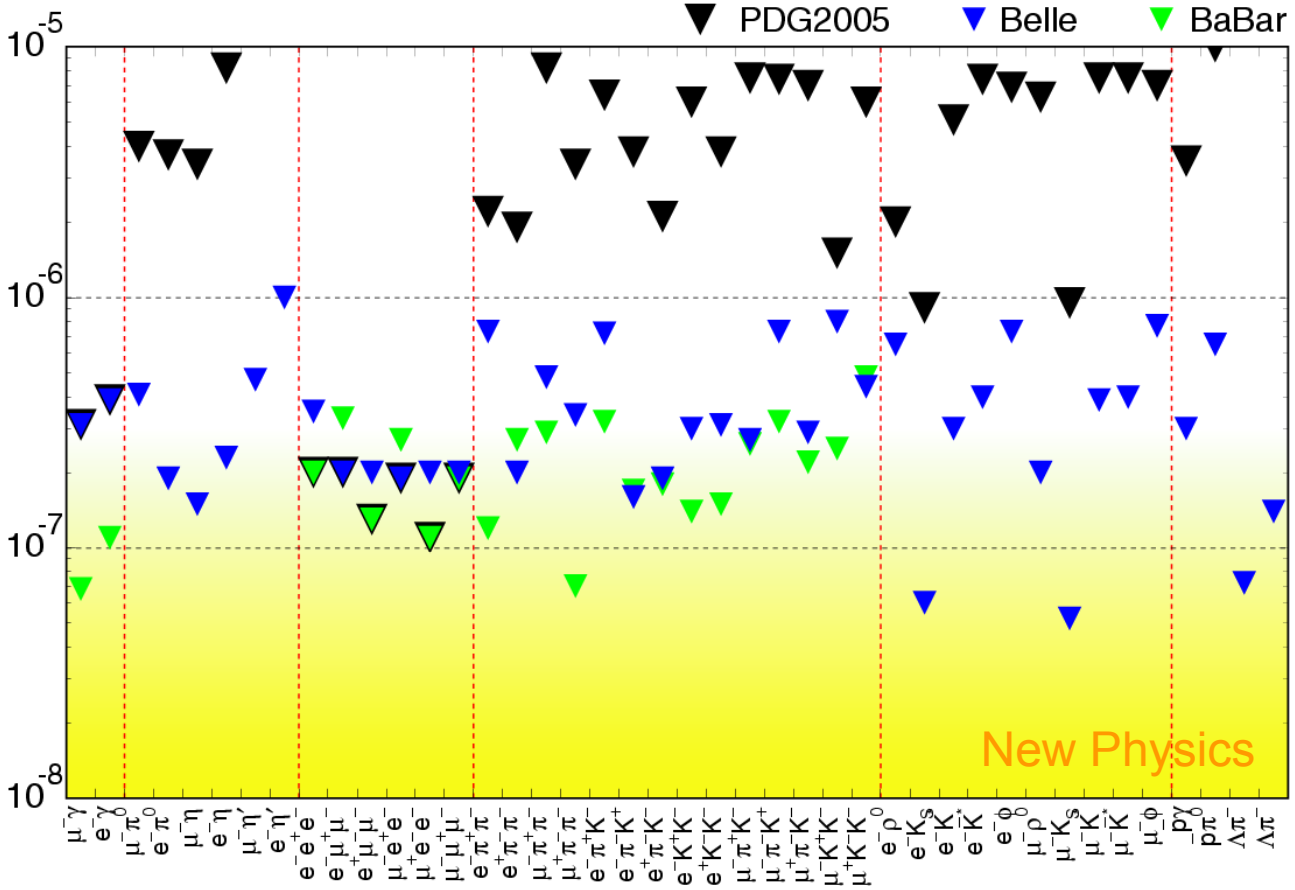
$\tau \rightarrow$ Baryons

- $\tau \rightarrow p\gamma$, $p\pi^0$
  - Belle (preliminary)
  - $B(\tau \rightarrow p\gamma) < 3.0 \times 10^{-7}$ ($87 fb^{-1}$)
  - $B(\tau \rightarrow p\pi^0) < 6.5 \times 10^{-7}$ ($154 fb^{-1}$)
  - Background: many $\tau\tau$, qq
    - p/π misidentification

- $\tau \rightarrow \Lambda \pi$
  - Belle: $154 fb^{-1}$
  - $B(\tau \rightarrow \bar{\Lambda}\pi) < 1.4 \times 10^{-7}$
  - $B(\tau \rightarrow \Lambda\pi) < 0.72 \times 10^{-7}$
    PLB 632, 51 (2006).
  - Background: $\tau\tau(a_1\nu)$, qq



Summary of B.R.s for LFV τ decays



- Br < O(10^{-6}) in PDG (by CLEO)

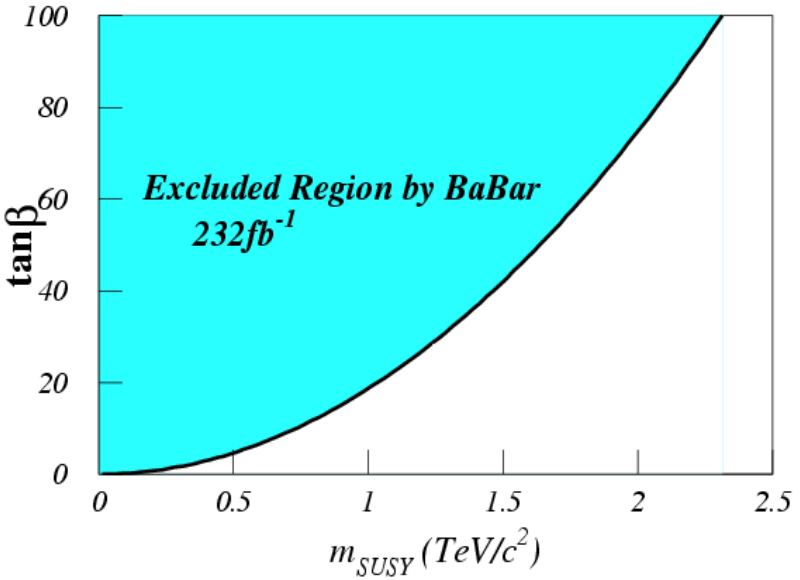
➔ Br < O(10^{-7}) by Belle and BaBar

Constraint for New Physics

- MSSM with Seesaw

  PRD 60, 055008 (1999).

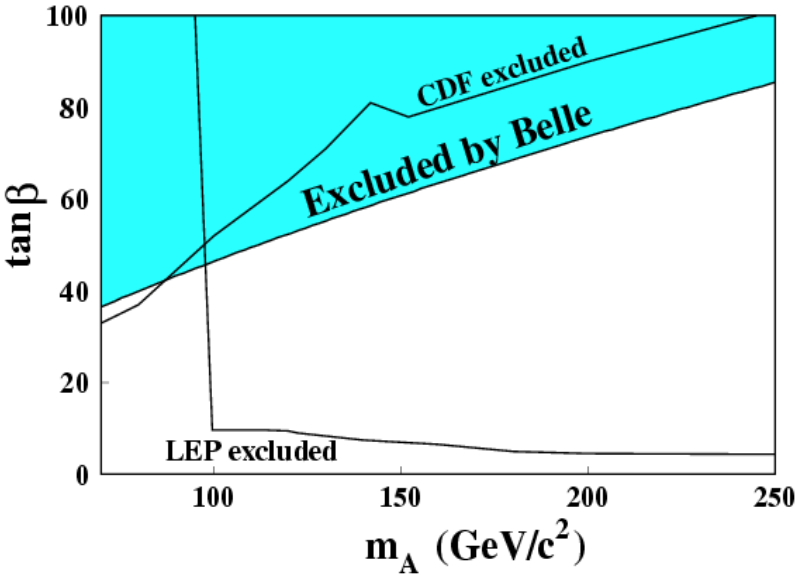
$$\mathcal{B}(\tau \to \mu\gamma) \simeq 7 \times 10^{-7} \left(\frac{\tan\beta}{60}\right)^2 \left(\frac{1\ \mathrm{TeV}/c^2}{m_{SUSY}}\right)^4$$



- Higgs mediated in MSSM

  PRD 66, 057301 (2002).

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



Summary

- B-factories (Belle & BaBar) have accumulated $> 0.8 ab^{-1}$ in total, and is searching for new physics:

- Hot topics: $B \rightarrow K^* ll$, $B^+ \rightarrow \tau^+ \nu$, ... many others
- TCPV in $B \rightarrow K_S \pi^0 \gamma$
  - New technique to search for Right-handed current
- Searches LFV in τ decays
  - LFV sensitivities are $Br \sim 1 \times 10^{-7}$.
    - Exploring possible parameter space of New Physics
    - For some modes, it will be hard to improve the sensitivity due to backgrounds.
- Many new physics phenomena will be within reach with Super B-factory

➔ See Nobu Katakama's talk