τ Physics at the B-Factories

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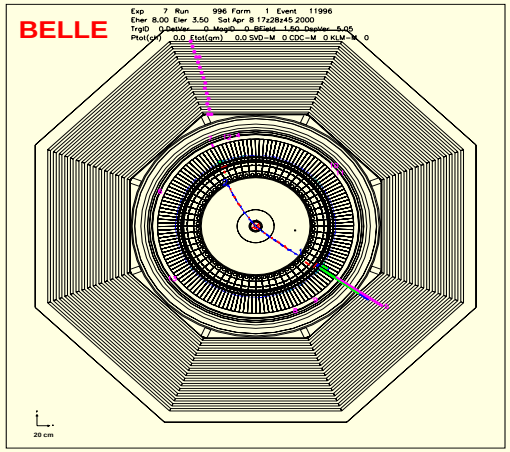
Outline

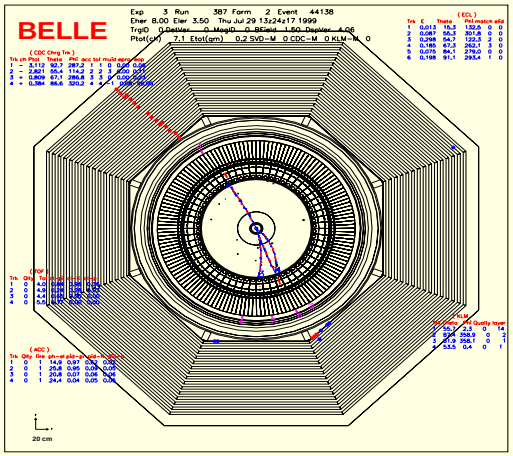
Selected topics of τ-physics from B-factories are presented.

- Lepton Universality
  - tau lepton mass/life time
- High statistic study of $\tau^- \rightarrow \pi^- \pi^0 \nu$ and CVC
- Search for Lepton Flavor Violation in τ decays
- (Decay with Kaons)
- Summary

Typical τ-pair events measured in B-factory experiments.



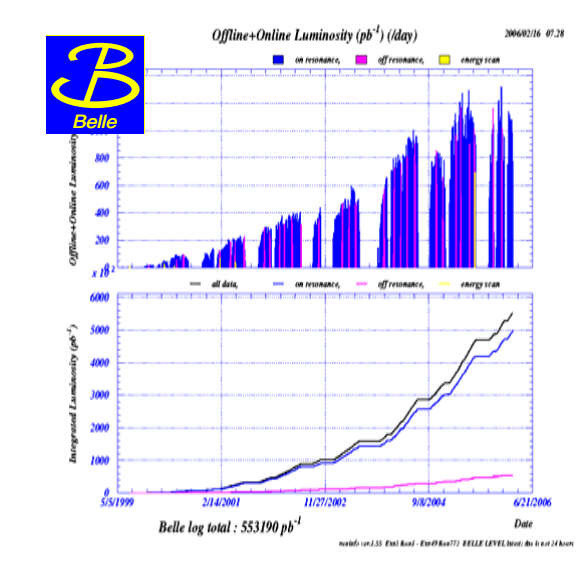
- 1 vs. 1

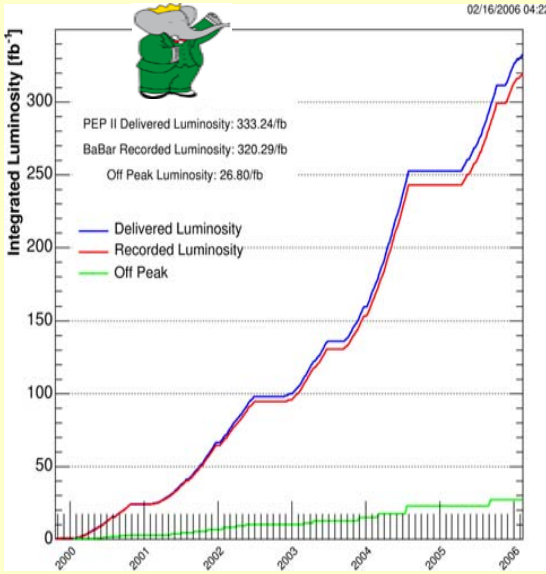


- 1 vs. 3

τ Lepton Factory

Group	Luminosity,fb^{-1}	$N\tau\tau$, 10^6
LEP(Z-peak)	0.34	0.33
CLEO(10.6GeV)	13.8	12.6
Babar(10.6GeV)	300	270
Belle(10.6GeV)	535	477
τ-c(4.2GeV)	10	32
Super-B	50,000	45,000





B-factory is also a τ–factory producing

0.9×10^6 $\tau^+\tau^-$ pairs per each fb^{-1}.

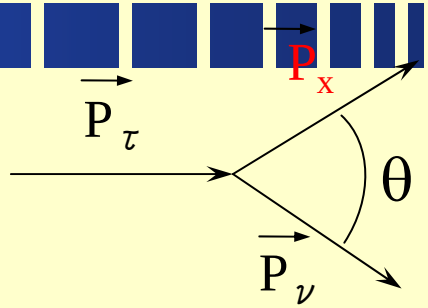
Lepton Universality

$$\Gamma(\tau \to \ell \nu_\tau \bar{\nu}_\ell) = \frac{G_F^2 m_\tau^5}{192\pi} f(m_\tau, m_\ell) r_{EW}$$

$$r = \left(\frac{G_{\tau \to e \nu_\tau \bar{\nu}_e}}{G_{\mu \to e \nu_\tau \bar{\nu}_e}} \right)^2 = \left(\frac{m_\mu}{m_\tau} \right)^5 \left(\frac{\tau_\mu}{\tau_\tau} \right) B(\tau \to e \nu_\tau \bar{\nu}_e) \frac{f_{cor}(m_\mu, m_e)}{f_{cor}(m_\tau, m_e)}$$

r	τ_τ , fs	B(τ→eνν), %	m_τ , MeV	Comments
0.9405 ± 0.0249	305.6 ±6.0 ± 0.0185	17.93 ±0.26 ± 0.0136	1784.1 $\pm^{2.7}_{3.6}$ $\pm^{0.0095}_{0.0071}$	PDG,1992 -2.4 σ
0.9999 ± 0.0069	291.0 ±1.5 ± 0.0052	17.83 ±0.08 ± 0.0045	1777.0 $\pm^{0.30}_{0.27}$ ± 0.0008	PDG, 1996 -0.01σ
1.0020 ±0.0051	290.6 ±1.1 ± 0.0038	17.84±0.06 ± 0.0034	1776.99 $\pm^{0.29}_{0.26}$ ± 0.0008	PDG, 2004 +0.4σ

Tau mass (Belle)

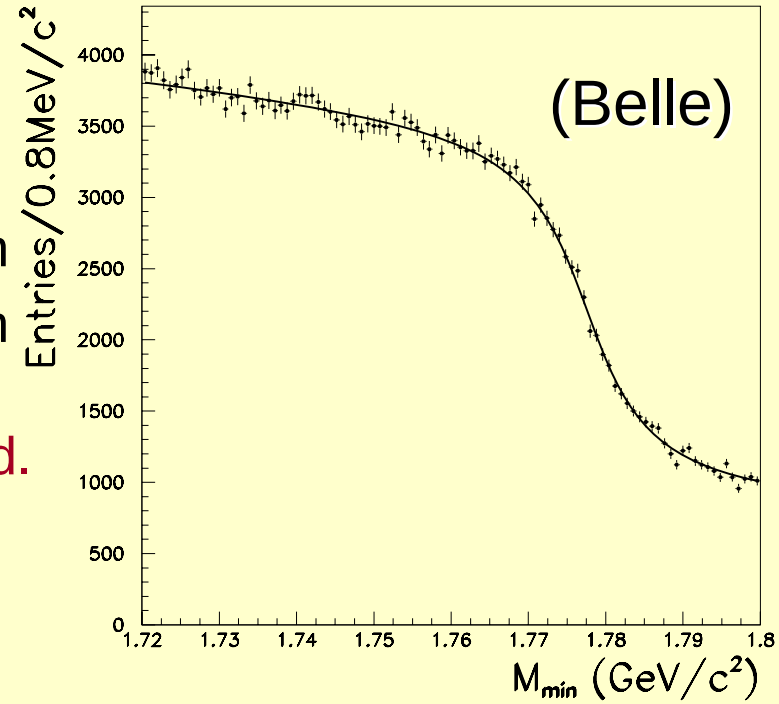


- τ-mass with Pseudo-mass method

$$M_{min}^2 = M_x^2 + 2(E_\tau - E_x)(E_x - P_x)$$

- Mode: $\tau \rightarrow 3\pi\nu$ (441fb^{-1})
- Error is dominated by the beam energy uncertainty, which is calibration by reconstructed-B and μμ.

Group	m_τ, MeV	
PDG,2004	$1776.99 \pm^{0.29}_{0.26}$	
BES,1996	$1776.96 \pm^{0.18}_{0.21} \pm^{0.25}_{0.17}$	scan
KEDR,2006	$1776.80 \pm^{0.25}_{0.23} \pm 0.15$	scan
Belle, 2006	$1776.61 \pm 0.13 \pm 0.35$	



➡ Similar level of accuracy by different method.

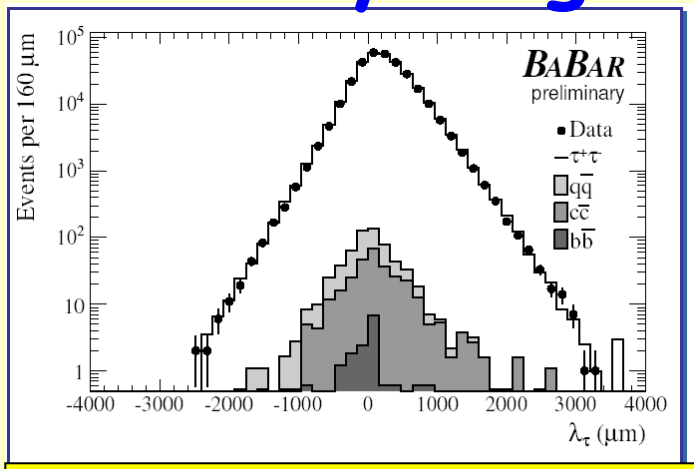
- CPT test by Mτ+ vs. Mτ-

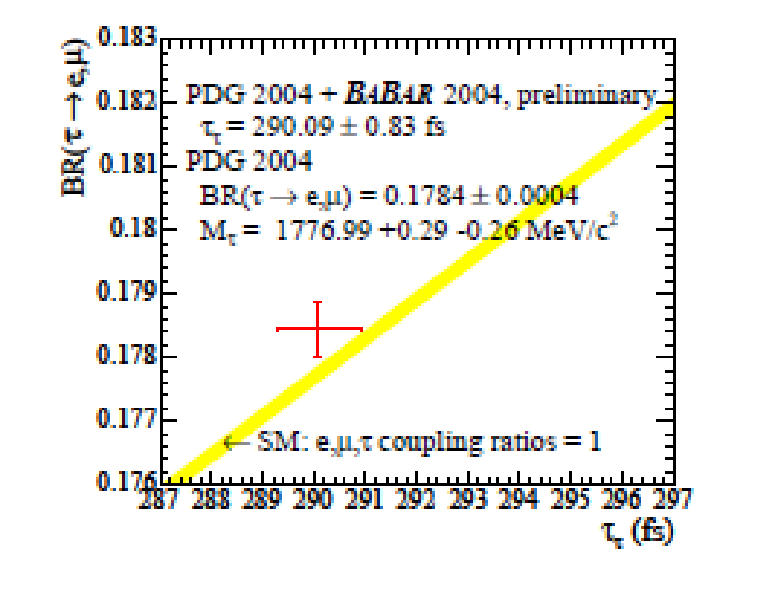
Group	$N_{\tau^+\tau^-}$, 10^3	$\lvert M_{\tau^+} - M_{\tau^-}\rvert / M_\tau$
OPAL,2000	160	$<3.0 \times 10^{-3}$
Belle,2006	370k	$<2.8 \times 10^{-4}$

Improve previous OPAL results by one order of magnitude.

Lifetime τ_τ (Babar)

2D Decay length





$$\tau_\tau = 289.4 \pm 0.91 \pm 0.90 \text{ fs}$$

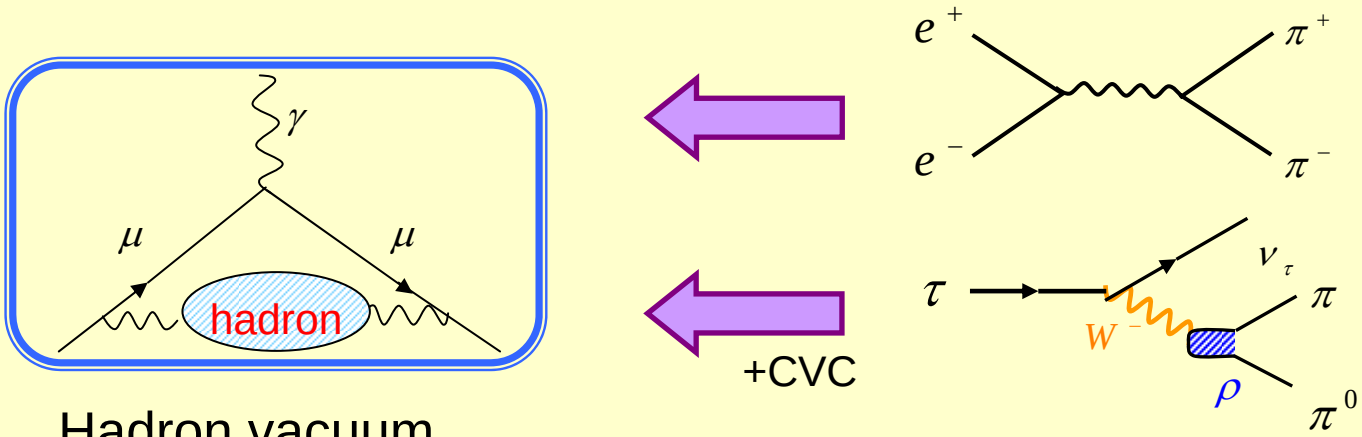
Group	$N_{\tau\tau}$, 10^3	τ_τ, fs	$\delta\tau_{sys}$, %
DELPHI,2004	150	290.9 ±1.4 ±1.0	0.34
PDG,2006	-	290.6 ±1.0	0.28
Babar,2004	79000	289.40±0.91±0.90	0.31

Most precise!

High statistic study of $\tau^- \rightarrow \pi^- \pi^0 \nu$ and CVC

Motivation: $\tau^- \rightarrow \pi^- \pi^0 \nu_\tau$ and $a_\mu = (g_\mu - 2)/2$

- It is known that hadronic vacuum polarization (h.v.p.) term plays an important role in the theoretical calculation of the muon anomalous magnetic moment. $a_\mu = (g_\mu - 2)/2$
- The dominant part of the h.v.p. term can be evaluated from the 2π spectral function measured with e^+e^- or τ –data.
- Recent data indicate that there is a systematic difference in the 2π system between e^+e^- reaction and τ –decays.



Hadron vacuum polarization term

$(g_\mu-2)/2$: Theory vs. Experiment

ICHEP-2006 (M. Davier et al.)

Contribution	a_μ, 10^{-10}
Experiment	11659208.0±6.3
QED	11658471.8±0.016
Electroweak	15.4±0.1±0.2
Hadronic	693.1 ± 5.6 (e^+e^-)
Theory	11659180.3±5.6
Exp.-Theory	27.7±8.4(3.3 σ)

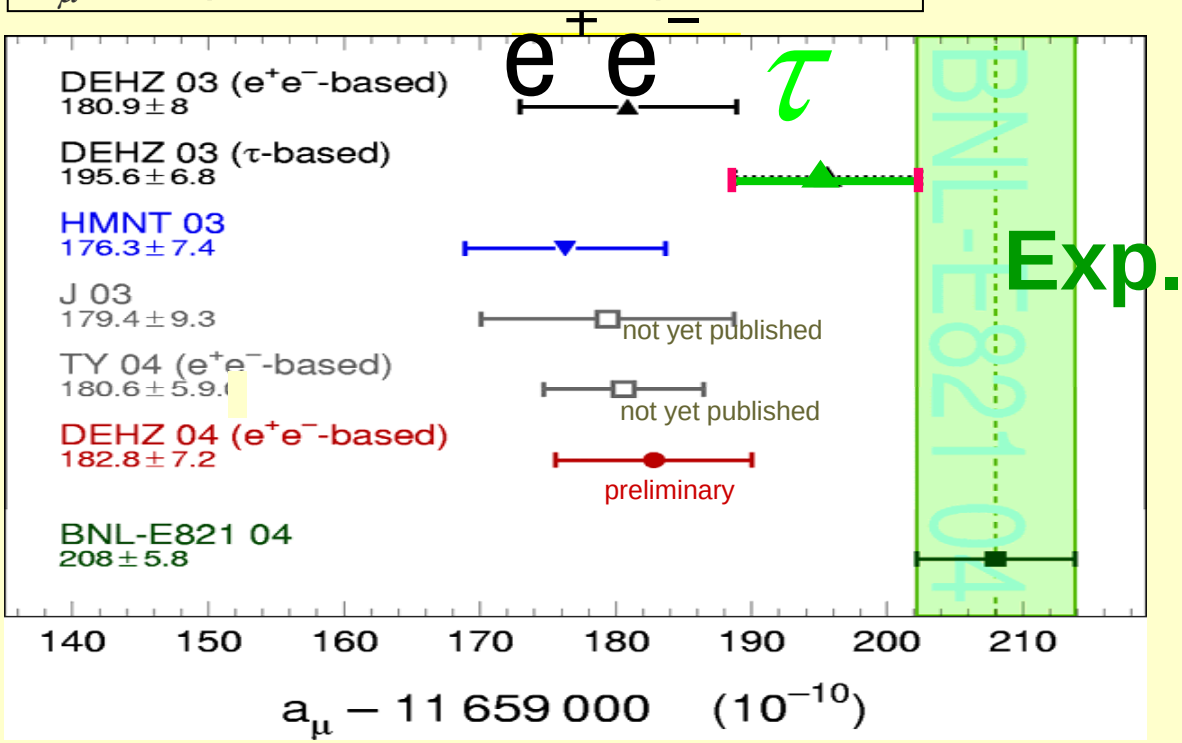
ICHEP-2006(M.Davier et al.): a_μ(exp)-a_μ(th) is 3.3 σ

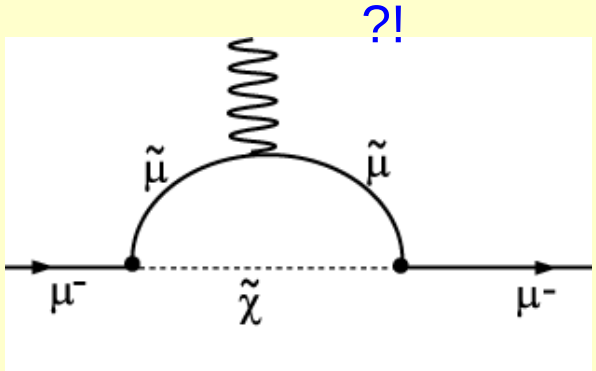
（K.Hagiwara et al.,hep-ph/0611102,claim even 3.4σ!)

Muon anomalous magnetic moment (a_μ)

$a_\mu = (g-2)_\mu/2$

BNL E821 (2004):
$a_\mu^{exp} = (11\,659\,208.0 \pm 5.8) \times 10^{-10}$





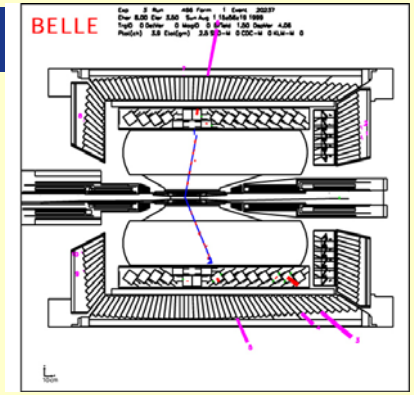
$a_\mu^{SUSY} = 13\times10^{-10}\,(100\text{GeV}/M_{SUSY})^2 \times \tan\beta \times \text{sign}(\mu)$

By A. Czarnecki and W. Marciano (2001)

✓A Hint to New Physics beyond the SM!?

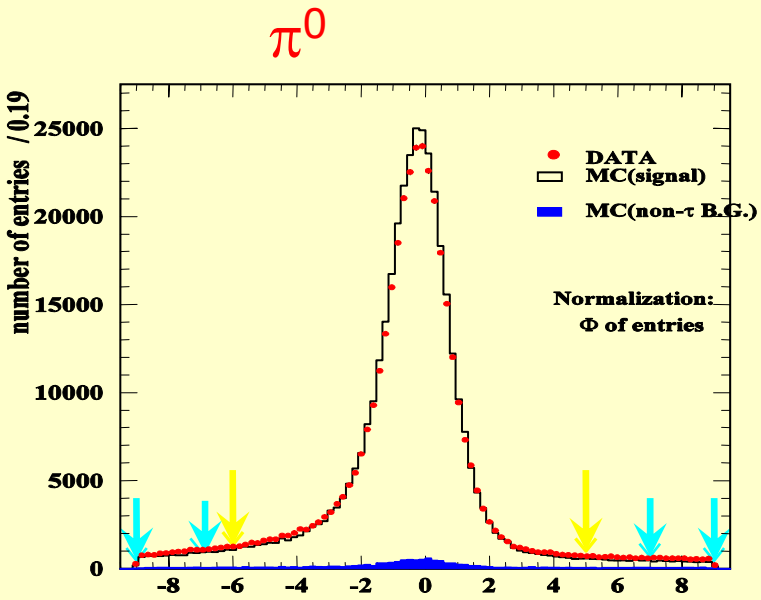
✓How about the τ data ?

Belle New $\tau^- \rightarrow \pi^- \pi^0 \nu_\tau$ Data (72.2/fb)

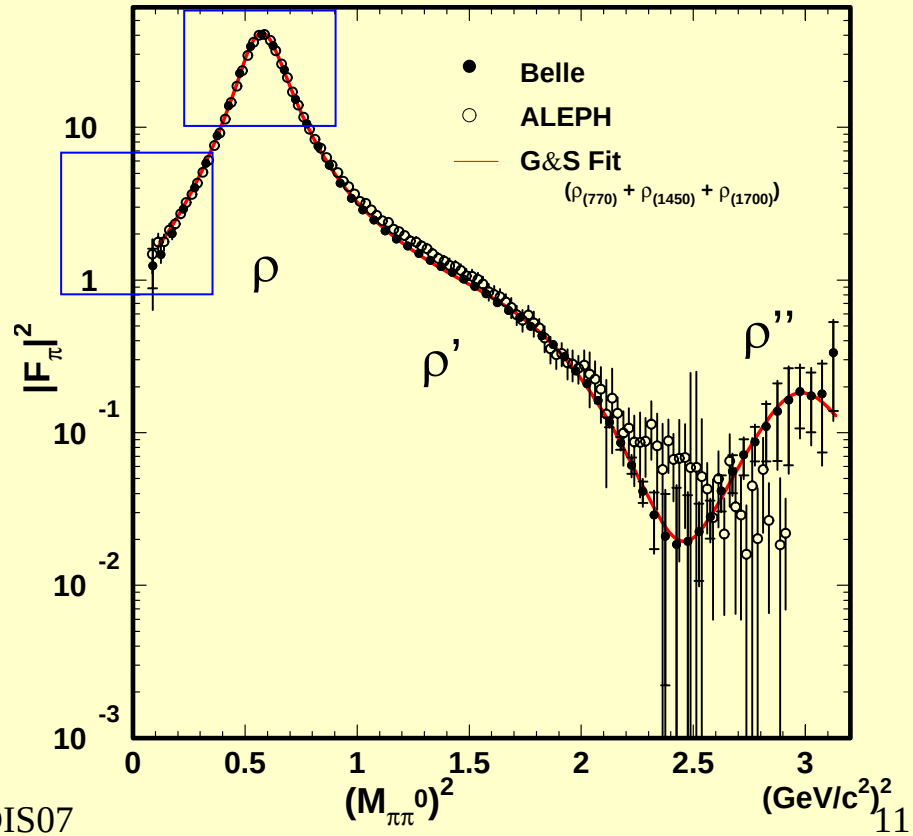


From 64M $\tau^+\tau^-$ pairs, Belle selects 5.5M $\tau^- \rightarrow \pi^- \pi^0 \nu_\tau$ events.

x20 times larger data

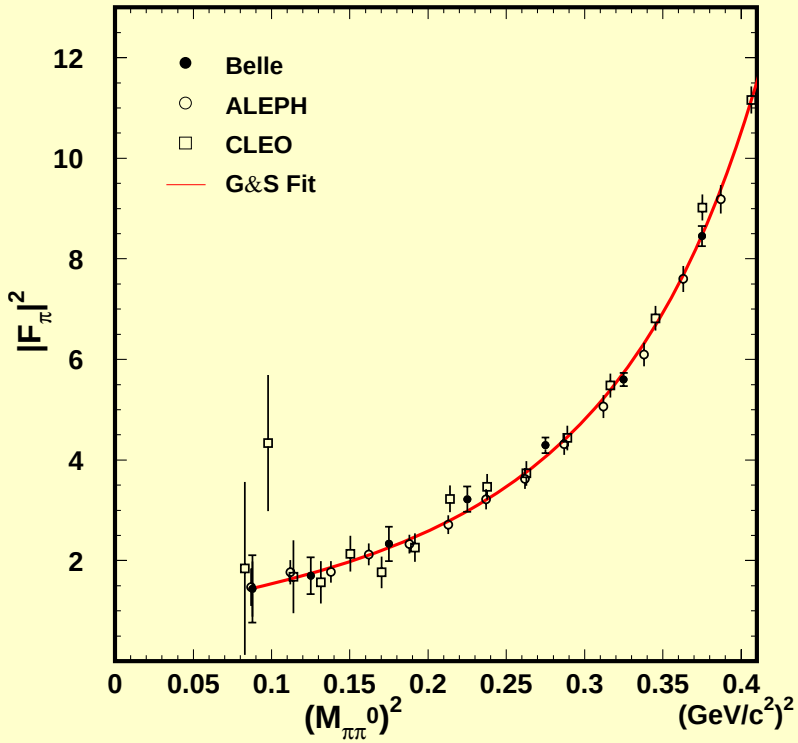


$$S_{\gamma\gamma} \equiv \frac{(m_{\gamma\gamma} - m_{\pi^0})}{\sigma_{\gamma\gamma}}$$

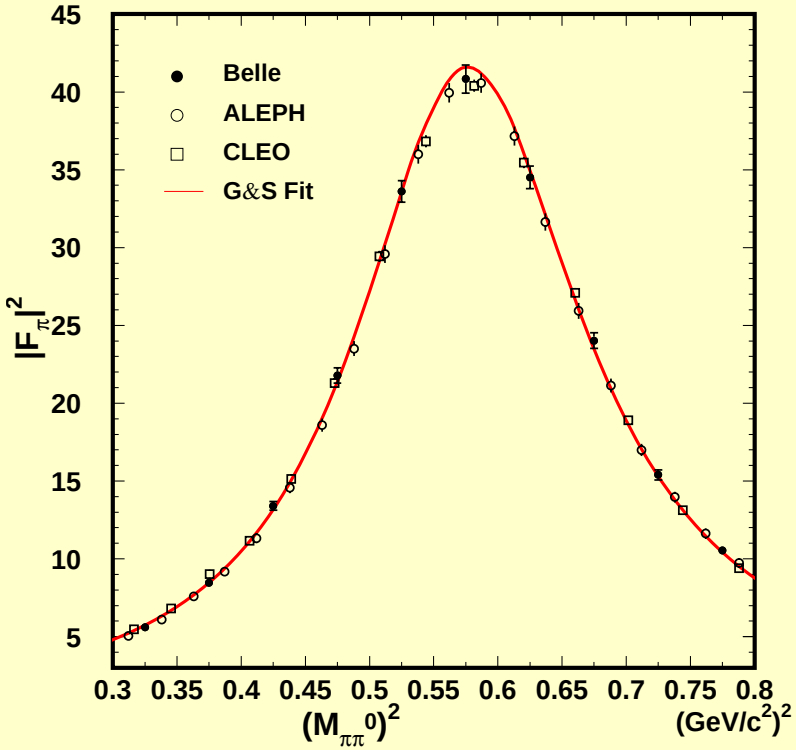


Pion Form Factor $|F_\pi|^2$ (Belle)

Threshold region



ρ region



- Error bars include both stat. and sys. errors.

  Sys. errors are dominated by background sub. and π^0 efficiency uncertainty.
- Red lines: Fit with BW forms.
- Belle, ALEPH,CLEO data are plotted.

Evaluation of $a_\mu^{\pi\pi}$

$$a_\mu^{\pi\pi,LO} = \frac{\alpha^2}{\pi}\int_{4m_\pi^2}^{\infty} ds\,\frac{K(s)}{s}\,v^{\pi\pi}(s)$$

Ref.Phys.Lett.B513,361(2001)

$$v^{\pi\pi}(s) = \frac{m_{\tau^2}}{6\pi\left|V_{ud}\right|^2 S_{EW}}\cdot\frac{B_{\pi\pi^0}}{B_e}\cdot\left[\left(1-\frac{s}{m_{\tau^2}}\right)^2\left(1+\frac{2s}{m_{\tau^2}}\right)\right]^{-1}\cdot\frac{1}{N_{\pi\pi^0}}\frac{dN_{\pi\pi^0}}{ds}$$

K(s): Known function.

- ✓ Need both mass spectrum $\frac{1}{N_{\pi\pi}}\frac{dN_{\pi\pi}}{ds}$ and $B_{\pi\pi}$
  - ✓ averaged value of Belle and PDG2004 is used.

$B_{Belle} = (25.15 \pm 0.04 \pm 0.31)\%$ $B_{ALEPH} = (25.471 \pm 0.097 \pm 0.085)\%$

- ✓ Isospin breaking correction
  - ρ-ω interference effects
  - $m_{\pi^\pm} \neq m_{\pi^0}$ in the phase space
  - $m_{\pi^\pm} \neq m_{\pi^0}$ in the width
  - radiative corrections

$(-1.8 \pm 2.3)\times10^{-10}$

$m_{\pi\pi}^2 \geq 0.25\,\mathrm{GeV}^2$

total correction is estimated to be small except for threshold region

Experimental Systematic Error

$m^2_{\pi\pi} \geq 0.25 GeV^2$

source	$\Delta a_\mu^{\pi\pi}$ (unit : $\times 10^{-10}$)
Background estimation ・non- τ（ee->hadron） ・feed-down h≥2$\pi^0\nu$ ・feed-down $K^-\pi^0\nu$	 ±0.11 ±0.09 ±0.15
π^0/γ selection efficiency/shape cuts	±0.35
Energy scale	±0.10
Gamma veto	±0.93
γ/track overlap	0.24
Tag-side condition	<0.1
Smearing/Migration effect	<0.1
Total	±1.04

a_μ (2π) from Belle τ data

$$a_\mu(2\pi) = 457.2 \pm 1.0_{SF} \pm 2.3_{BR} \pm 2.3_{SU(2)} \times 10^{-10}$$

$m^2_{\pi\pi} \geq 0.25 GeV^2$

✓Most precise on structure function (SF) measurement

✓Consistent with previous τ data.

SF: structure function error, BR: Br error

SU(2):SU(2) breaking correction error

τ and e^+e^- data are different yet

c.f.

- τ (ALEPH, CLEO)

  $a_\mu(2\pi) = 464.0 \pm 2.2_{SF} \pm 2.3_{BR} \pm 2.3_{SU(2)}$

- e^+e^- (CMD2)

  $a_\mu(2\pi) = 440.8 \pm 4.9 \pm 1.6_{rad}$

Ref. Eur.Phys.C27,497(2003)

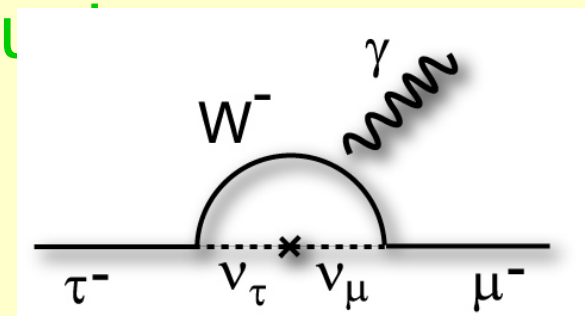
Search for Lepton Flavor Violation in τ Decays

Lepton Flavor Violation

= Clean processes to Look for Beyond the SM

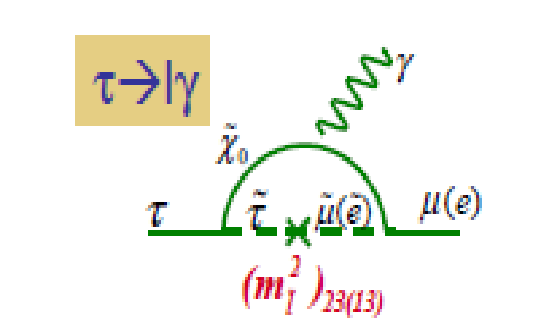
- LFV is not forbidden by any known gauge symmetry
- Neutrino oscillation indicates Lepton Flavor is violated in the Neutral Lepton sector.
- LFV for the Charged Lepton Sector is suppressed strongly in SM due to a tiny neu

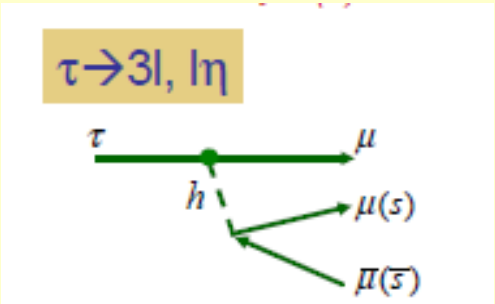
$$\mathrm{BR} \propto \left(\frac{\Delta m_\nu^2}{m_w^2} \right)^2 \approx 10^{-49} - 10^{-52}$$



Charged Lepton Flavor Violation

- LFV is expected to occur in the loops of the new physics processes at TeV scale such as SUSY, Extra-D etc.



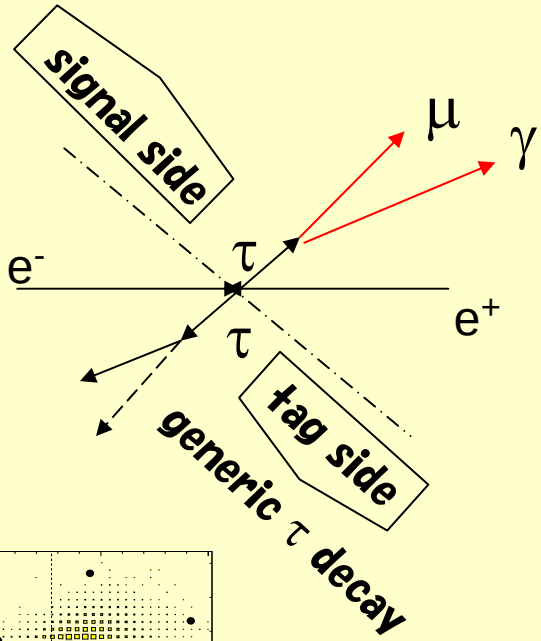


SUSY+ Seesaw, Left-Right etc.

- Correlation between τ -LFV and μ-LFV($\mu \longrightarrow e\gamma$, $\mu \longrightarrow lll$)
- Predicted $Br(\tau^- \rightarrow \mu^- \gamma)$ reach 10^{-8}-10^{-7}
- LFV is related to the physics at GUT scale.

⇨ **44 different modes are studied!.**

General event selection



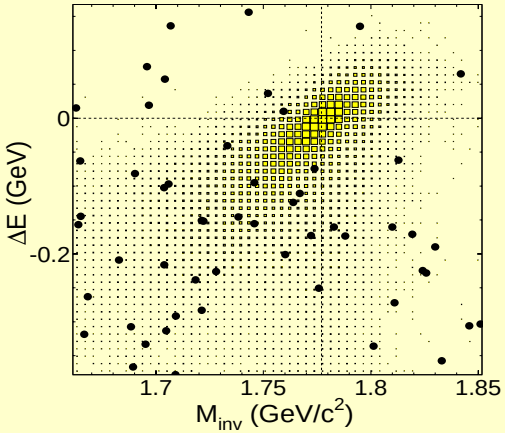
- ✓ $\tau^{\pm}$ **(signal)** → LFV of exclusive decay mode
  & $\tau^{\pm}$ **(tag)** → single track with (n γ) + missing

Single prong mode occupies >80% of decay.

Simple but strong constraints does not exist due to neutrino missing .

- ✓ ***BG's***: $\tau\tau$, ***continuum***, $\mu\mu$, ***ee***, $\gamma\gamma$, ***BB***
- ✓ ***signal evaluation***: $m_{inv} - \Delta E$

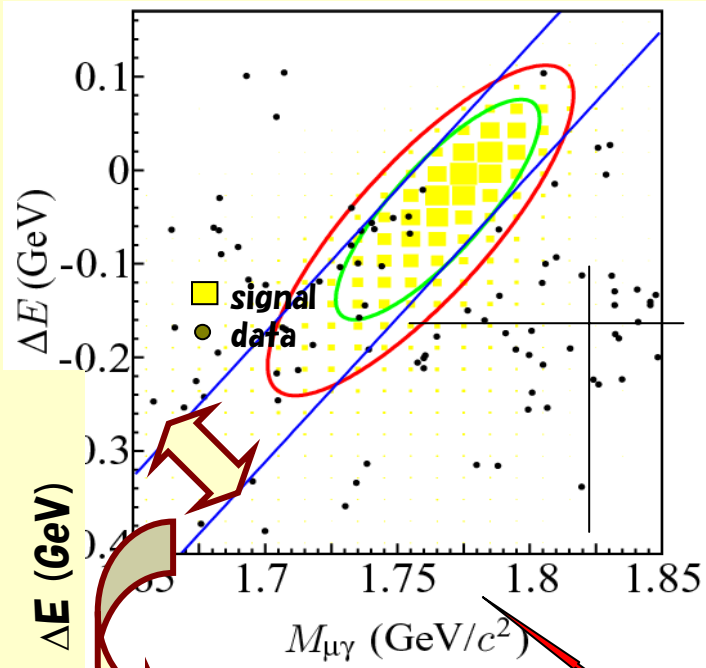
  $m_{inv} \sim m_{tau}$ & $\Delta E = E - E_{beam} \sim 0$
- ✓ ***Blind analysis***



Evaluation of upper limit

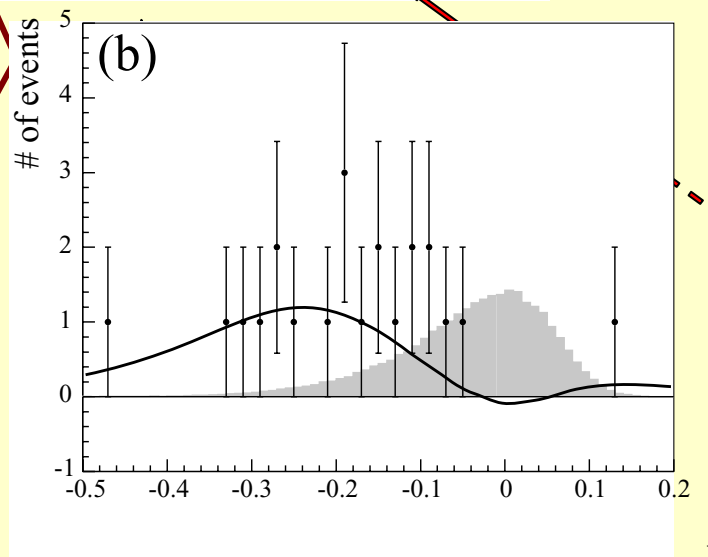
- ✓ **For small numbers of events in signal-region: event-counting is done with Feldman-Cousins method.**
- ✓ **For events >= a few 10's in signal-region: maximum likelihood fit is applied and upper-limit is evaluated with toy-MC.**

New result on $\tau \to \mu\gamma$ (Belle) 535fb^{-1}



ΔE (GeV)

projec



✓ analysis: same with previous one, but with tighter requirements

remaining events:

- 94ev./(535/fb)
- signal detection eff: 6.7%
- signal region: 2σ ellipse
- signal extraction: UEML fit:
- s=−3.9, b=13.9
- (allow negative s and its prob. 25%)

s(90% CL) = 2.0 ev

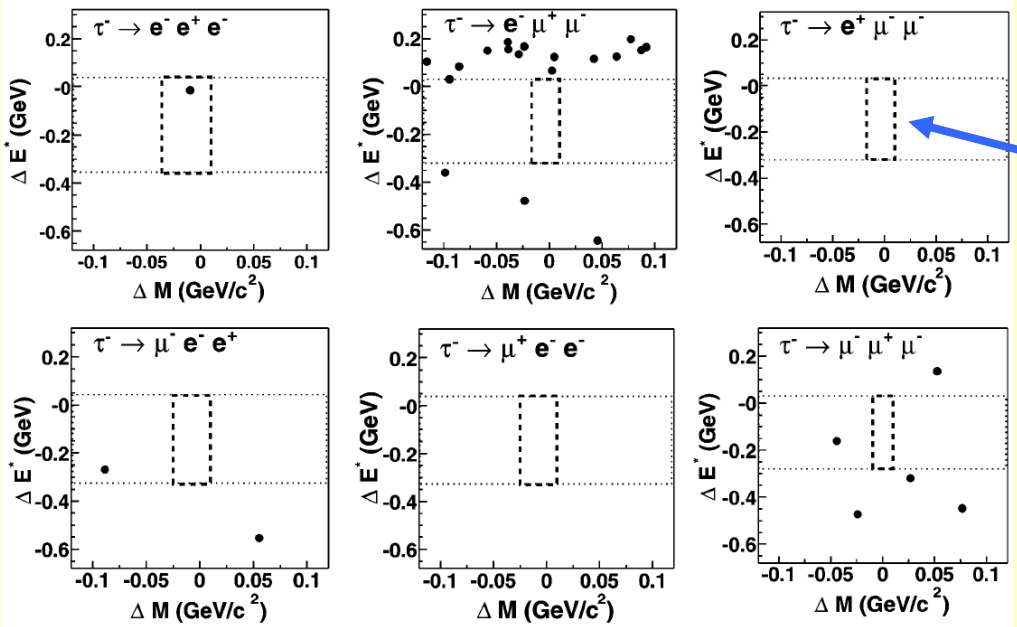
no signal events are found.

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

$\tau \rightarrow 3l$

- 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.



Signal region

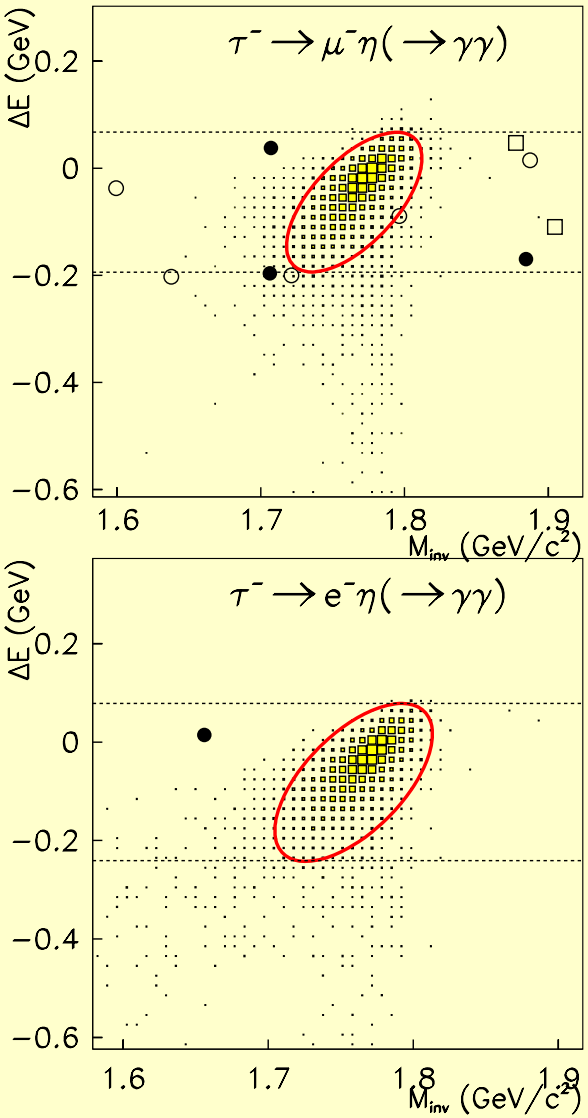
Belle

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

$\tau \to l\eta$

- Data: 401fb^{-1} (Belle)
- $\tau \to l\eta$; $\eta \to \gamma\gamma$, $\pi^+\pi^-\pi^0$

- Br($\tau \to \mu\eta$)<0.65x10^{-7}
- Br($\tau \to e\eta$)<0.92x10^{-7}
  - Efficiency x Br(η); 4.1%, 2.9%
  - Low background
- Background: <1 event
  - $\tau \to \mu\eta$: a little $\tau \to \pi\pi^0\nu$



Status of LFV Studies-I ($\tau \rightarrow l\gamma$, lll)

τ^- mode	Belle		Babar		CLEO	
	Br, 10^{-7}	Lum. fb^{-1}	Br, 10^{-7}	Lum. fb^{-1}	Br,10^{-7}	Lum,fb^{-1}
$\mu^-\gamma$	<0.45	535	<0.68	232	<11	13.8
$e^-\gamma$	<1.2	535	<1.1	232	<27	4.68
$\mu^- e^+ \mu^-$	<2.0	87.1	<1.3	91.5	<15	4.79
$\mu^- e^- e^+$	<1.9	87.1	<2.7	91.5	<17	4.79
$\mu^- \mu - \mu +$	<2.0	87.1	<1.9	91.5	<19	4.79
$e - \mu - \mu +$	<3.3	87.1	<2.0	91.5	<18	4.79
$\mu + e - e -$	<2.0	87.1	<1.1	91.5	<15	4.79
$e - e - e +$	<3.5	87.1	<2.0	91.5	<29	4.79

Status of LFV Studies-II ($\tau \rightarrow$ l+Hadron)

τ^- mode	Belle		Babar		CLEO	
	Br, 10^{-7}	Lum. fb^{-1}	Br, 10^{-7}	Lum. fb^{-1}	Br,10^{-7}	Lum,fb^{-1}
$e^- K^0_s$	<0.56	281			9.1	13.9
$\mu^- K^0_s$	<0.49	281			9.5	13.9
$\mu^- \pi^0$	<1.2	401	<1.1	339	40	4.68
$\mu^- \eta$	<0.65	401	<1.5	339	96	4.68
$\mu^- \eta'$	<1.3	401	<1.4	339	-	-
$e^- \pi^0$	<0.8	401	<1.3	339	40	4.68
$e^- \eta$	<0.92	401	<1.6	339	96	4.68
$e^- \eta'$	<1.6	401	<2.4	339	-	-

Status of LFV Studies-IV ($\tau^- \to l^- V^0$)

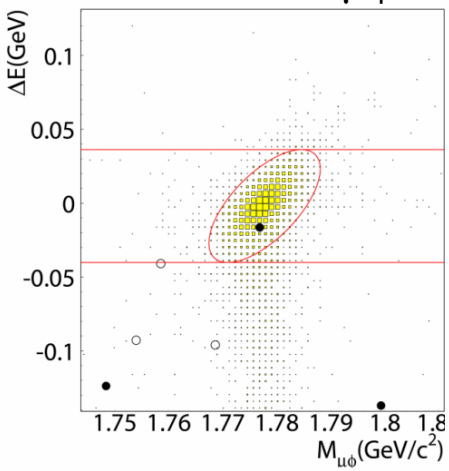
τ^- mode	Belle		Babar		CLEO	
	Br, 10^{-7}	Lum. fb^{-1}	Br, 10^{-7}	Lum. fb^{-1}	Br,10^{-7}	Lum,fb^{-1}
$e^-\rho^0$	<6.4	158	-	-	<20	4.79
$e^-K^*(892)^0$	<3.0	158	-	-	<51	4.79
$e^-K^*(892)^0$	<4.0	158	-	-	<74	4.79
$e^-\phi$	<1.5	545	-	-	<69	4.79
$\mu^-\rho^0$	<2.0	158	-	-	<63	4.79
$\mu^-K^*(892)^0$	<3.9	158	-	-	<75	4.79
$\mu^-K^*(892)^0$	<4.0	158	-	-	<75	4.79
$\mu^-\phi$	<0.8	545	-	-	<70	4.79
$e^-\omega$	<1.0	545				
$\mu^-\omega$	<1.9	545				

543/fb

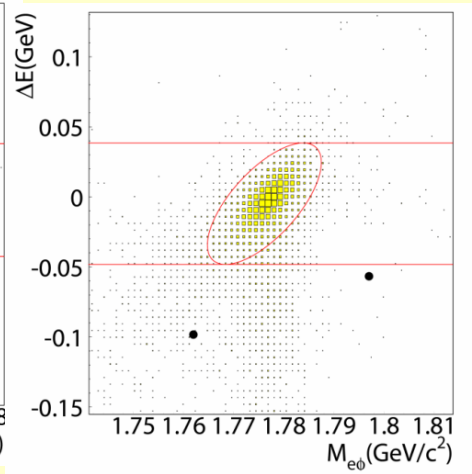
τ->l φ, lω first searches

preliminary

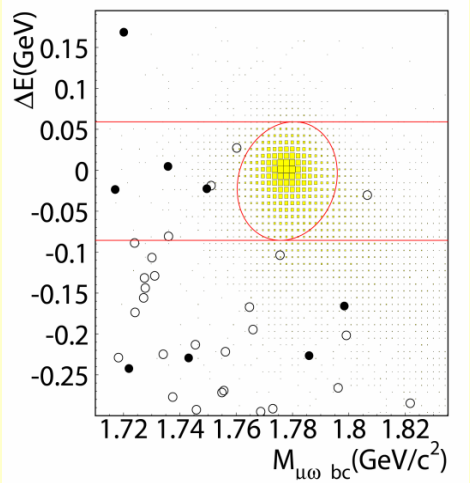
τ→μφ



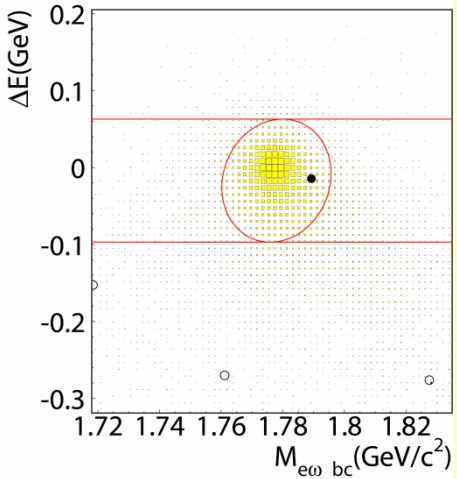
τ→eφ



τ→μω



τ→eω

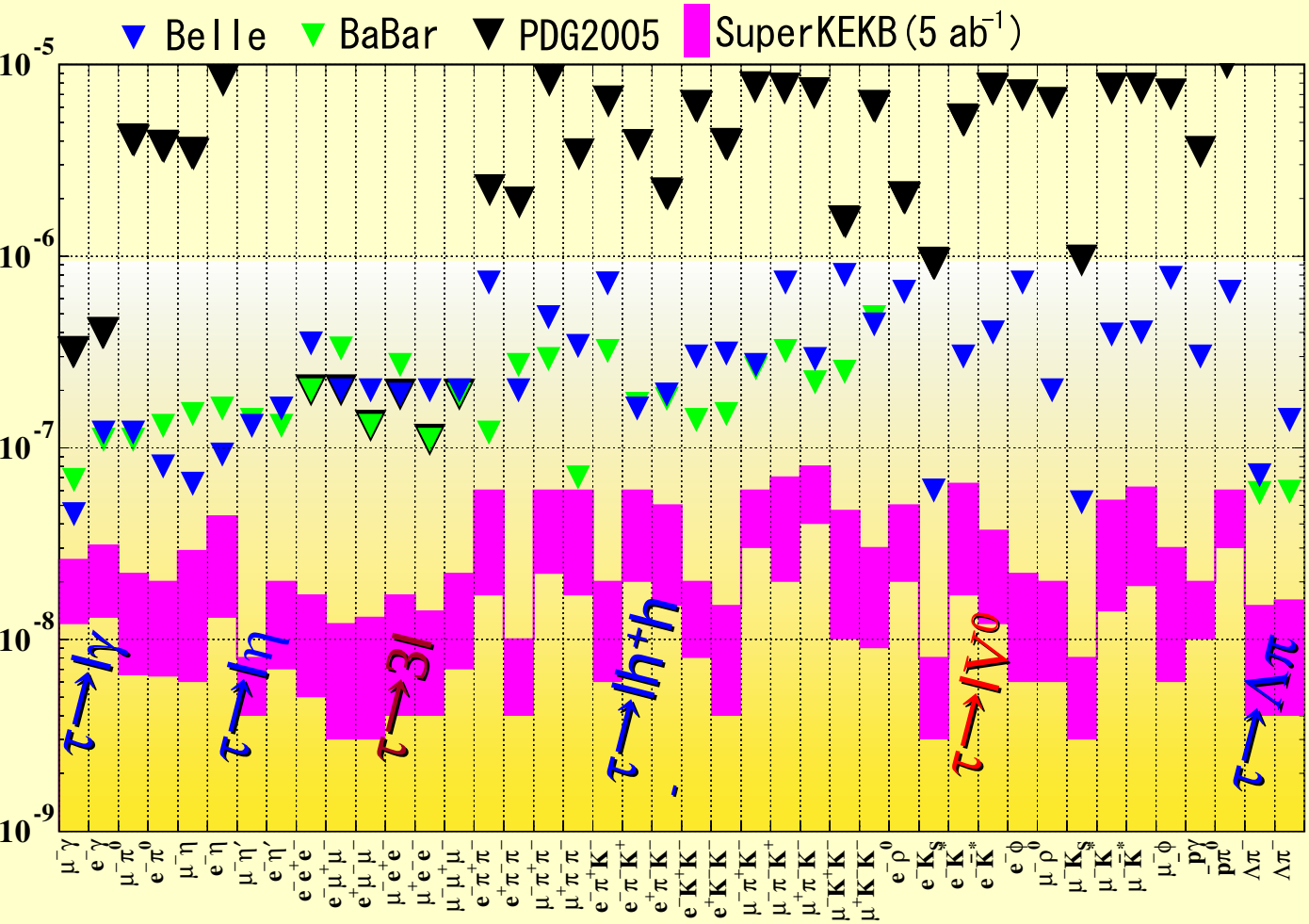


Mode	Expected BG (small !)	N_{obs}	s_0	Upper Limit @90%C.L.
τ→μφ	0.11±0.08	1	4.5	1.5×10^{-7}
τ→eφ	0.11±0.08	0	2.4	8.1×10^{-8}
τ→μω	0.20±0.28	0	2.5	1.0×10^{-7}
τ→eω	0+0.07	1	4.6	1.9×10^{-7}

● data ● signal ○ ττ

- N_{obs}: # of Observed Ev.
- S_0: Ev. Upper Limit @90%

LFV searches: Summary



CLEO

Belle/Babar

Achieving <10^{-7} with full sample

Super-B

- with 5 -10 ab^{-1} ➡ O(10^{-8}-10^{-9})

Progress of LFV Studies- $\tau^- \rightarrow \mu^- \gamma$

Group	Date	Lum, fb^{-1}	$N_{\tau\tau}$, 10^6	B^{90}_{UL}
MARK II	1982	0.017	0.048	5.5×10^{-4}
ARGUS	1992	0.387	0.374	3.4×10^{-5}
DELPHI	1995	0.070	0.081	6.2×10^{-5}
CLEO	2000	13.8	12.6	1.1×10^{-6}
Belle	2004	86.3	78.5	3.1×10^{-7}
Babar	2005	232.2	207	6.8×10^{-8}
Belle	2006	535	477	4.5×10^{-8}
Babar&Belle	2006	767.2	684	1.6×10^{-8}

Combining results. S.Banerjee at Tau2006

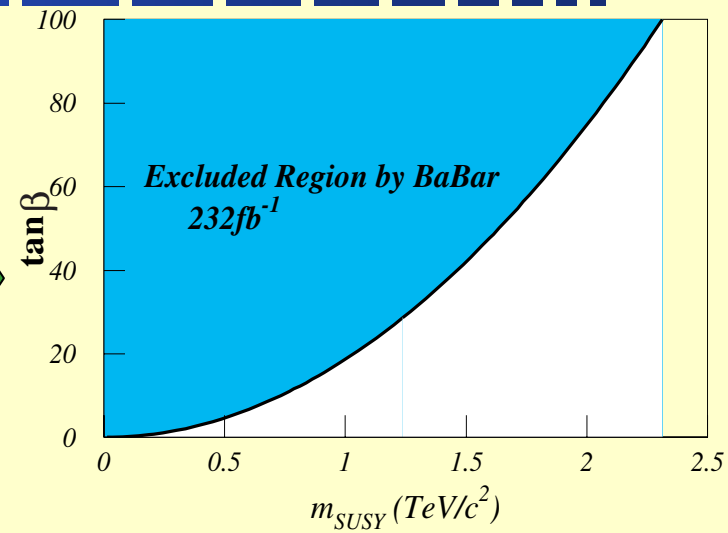
4 order of magnitude improvement by 25 years.

Implications of LFV Studies for SUSY

- $\tau^- \rightarrow \mu^- \gamma$
  - ✓ MSSM with Seesaw

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

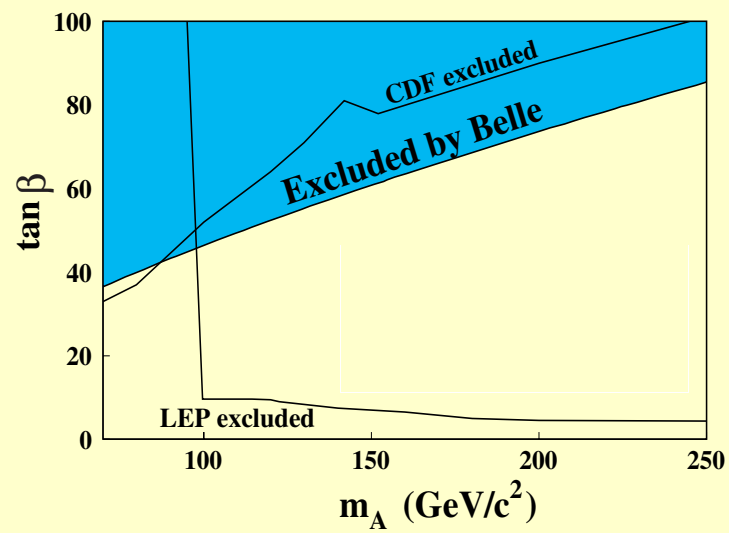
✓ PRD 60, 055008 (1999).



- $\tau^- \rightarrow \mu^- \eta$
  - ✓ Higgs mediated in MSSM

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

(M. Sher, 2002)



LEP: $e^+e^- \to h^0 Z^0, h^0 A^0, f\bar{f}\phi, b\bar{b}b\bar{b}, b\bar{b}\tau^+\tau^-$

CDF: $pp \to b\bar{b}\phi \to b\bar{b}b\bar{b}$

Summary

- B-factories (Belle & Babar) has recorded 10^9 τ –decays which are now under analysis.
- Big advantage in statistical accuracy and searches for rare modes.
- Lepton universality holds. New measurements on M_{τ}, τ_{τ}.
- Upper limit on $|M_{\tau+} - M_{\tau-}|/M\tau$ is 2.8×10^{-4} at 90%C.L.
  (10 times improvement of the previous results.)
- Precise $|F_{\pi}|^2$ is measured in 2π decay. Problems with CVC still exist
- First observation of τ decay including ϕ – meson is made.

  $Br(\tau \longrightarrow \phi K \nu) = (4.0 \pm 0.25 \pm 0.26) \times 10^{-5}$

  Three Kaon modes are best place for neutrino-mass measurement up to 1MeV order.

- Sensitivity of LFV searches better than 10^{-7}.
  The most stringent limit is

  $Br(\tau^- \longrightarrow \mu^- \gamma) < 1.6 \times 10^{-8}$ (Belle+Babar comb.)

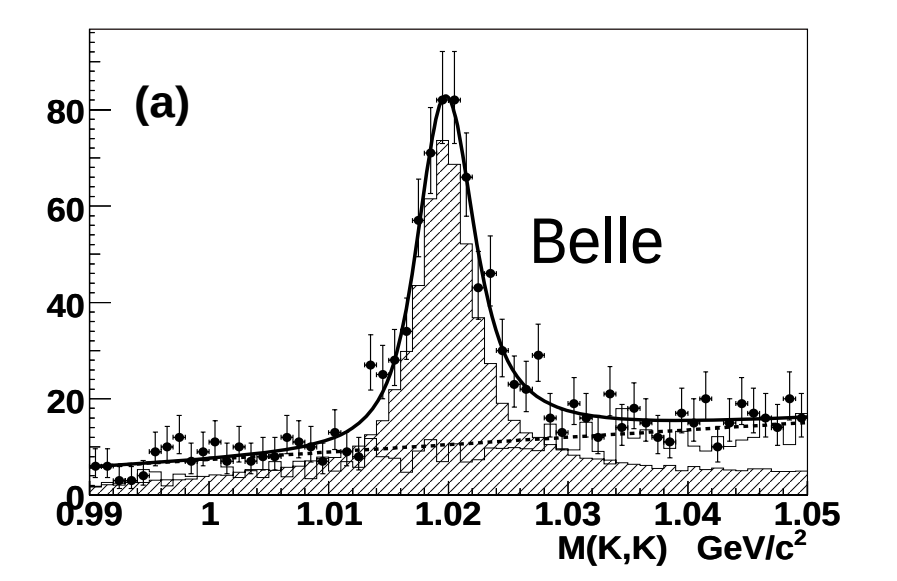
  - Exploring possible parameter space of New Phys.

Backup

Decay with Kaons

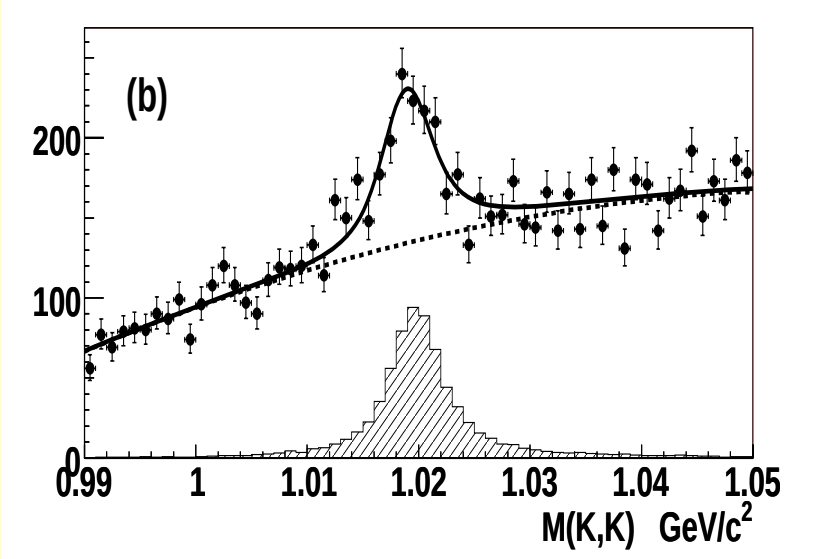
First Observation of the Decay with ϕ meson

$\tau \to \phi K \nu$



M_{K+K-}

$\tau \to \phi \pi \nu$



M_{K+K-}

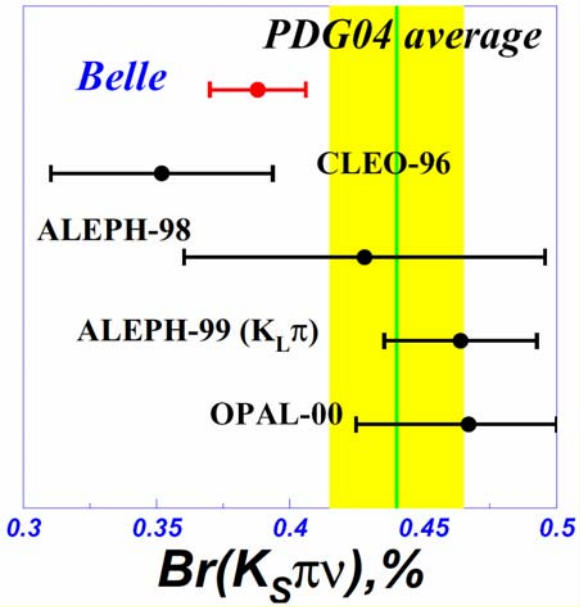
Group	$N_{\tau\tau}$, 10^6	Nev	$Br(\phi K^- \nu_\tau)$, 10^{-5}
Belle	358	551±33	4.05±0.25±0.26
Babar	306	274±16	3.48 ±0.20±0.26

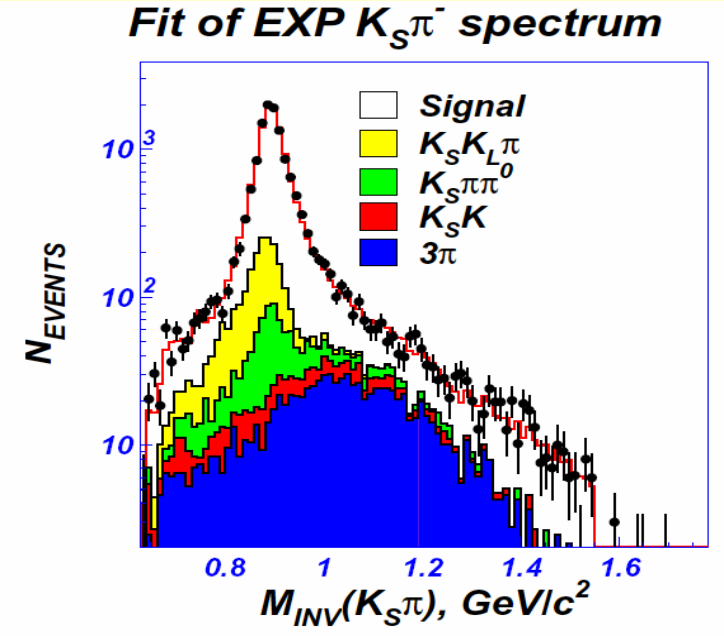
$400 fb^{-1}$

Hi-statistic Study of $\tau^- \rightarrow K_s\pi^-\nu_\tau$

Belle

- Data: 351fb^{-1}





$M_{K\pi}$ spectrum is dominated by K*(892),K*(800)i.e.κ and $K^*_0(1430)$.

⇨ Indication of the S-wave contribution

Mode	Br, %	Br(PDG-06), %
$K^0_s\pi^-\nu_\tau$	Belle: 0.395±0.002±0.014	0.45±0.02
$K^-\pi^0\nu_\tau$	Babar:0.439±0.003±0.021	0.452±0.027

Mass (Belle systematics)

- Beam energy and tracking system 0.26 MeV
- Edge parameterization 0.18 MeV
- Limited MC statistics 0.14 MeV
- Fit range 0.04 MeV
- Momentum resolution 0.02 MeV
- Model of $\tau \to 3\pi\nu$ 0.02 MeV
- Background 0.01 MeV

Total: 0.35 MeV

Group	m_τ, MeV	
PDG,2004	$1776.99 \pm^{0.29}_{0.26}$	
BES,1996	$1776.96 \pm^{0.18}_{0.21} \pm^{0.25}_{0.17}$	scan threshold
KEDR,2006	$1776.80 \pm^{0.25}_{0.23} \pm 0.15$	scan threshold
Belle, 2006	$1776.61 \pm 0.13 \pm 0.35$	pseudo mass

Sensitivity to the MSSM parameter space

- WMAP, a_μ, $b \longrightarrow s\gamma$

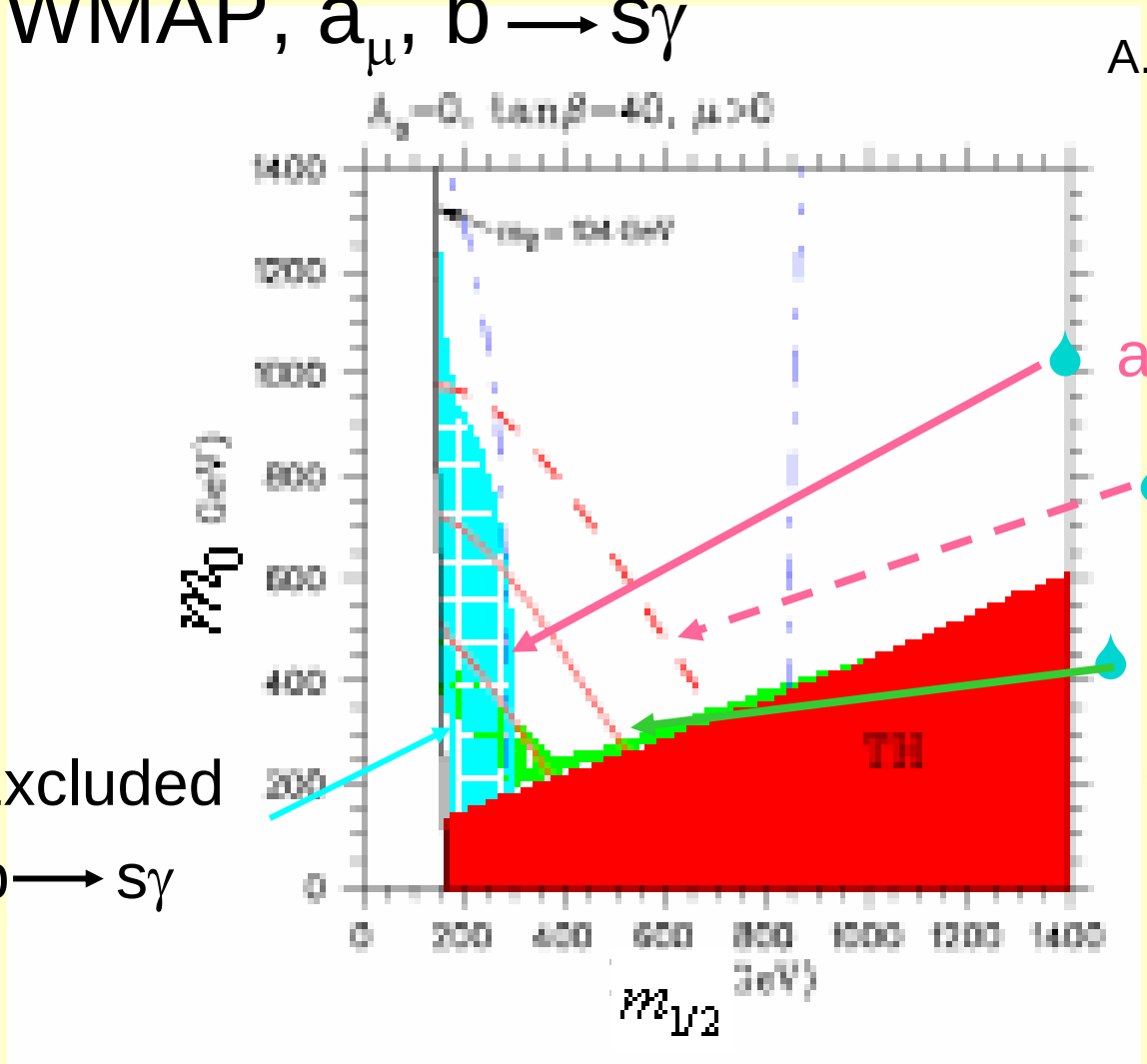
Ref. Phys.Lett.B568 (2003)55,

A.Lahanas and Nanopoulos

Similar work by

J. Ellis,K. Olive et al.(2003)、

. Baer, X. Tata et al.(2003)



$a_\mu^{susy}=(36^{+}_{-}11)\times10^{-10}$

$a_\mu^{susy}=14\times10^{-10}(-2\sigma)$

$0.094<\Omega_\chi h^2<0.129$

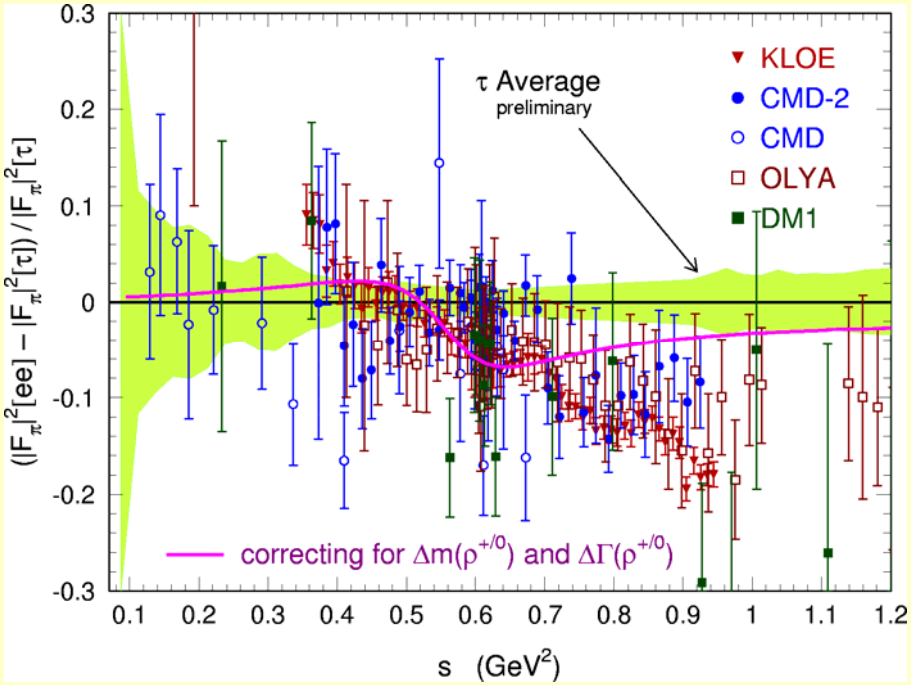
(LSP density; WMAP)

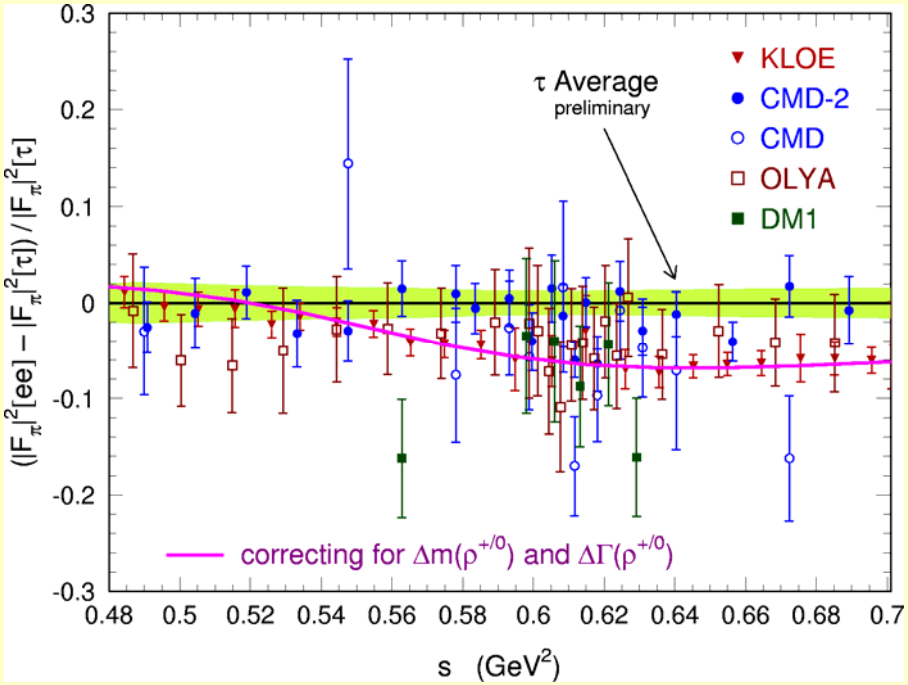
Excluded by $b \longrightarrow s\gamma$

The Problem (revisited)

Relative difference between τ and e^+e^- data:

zoom



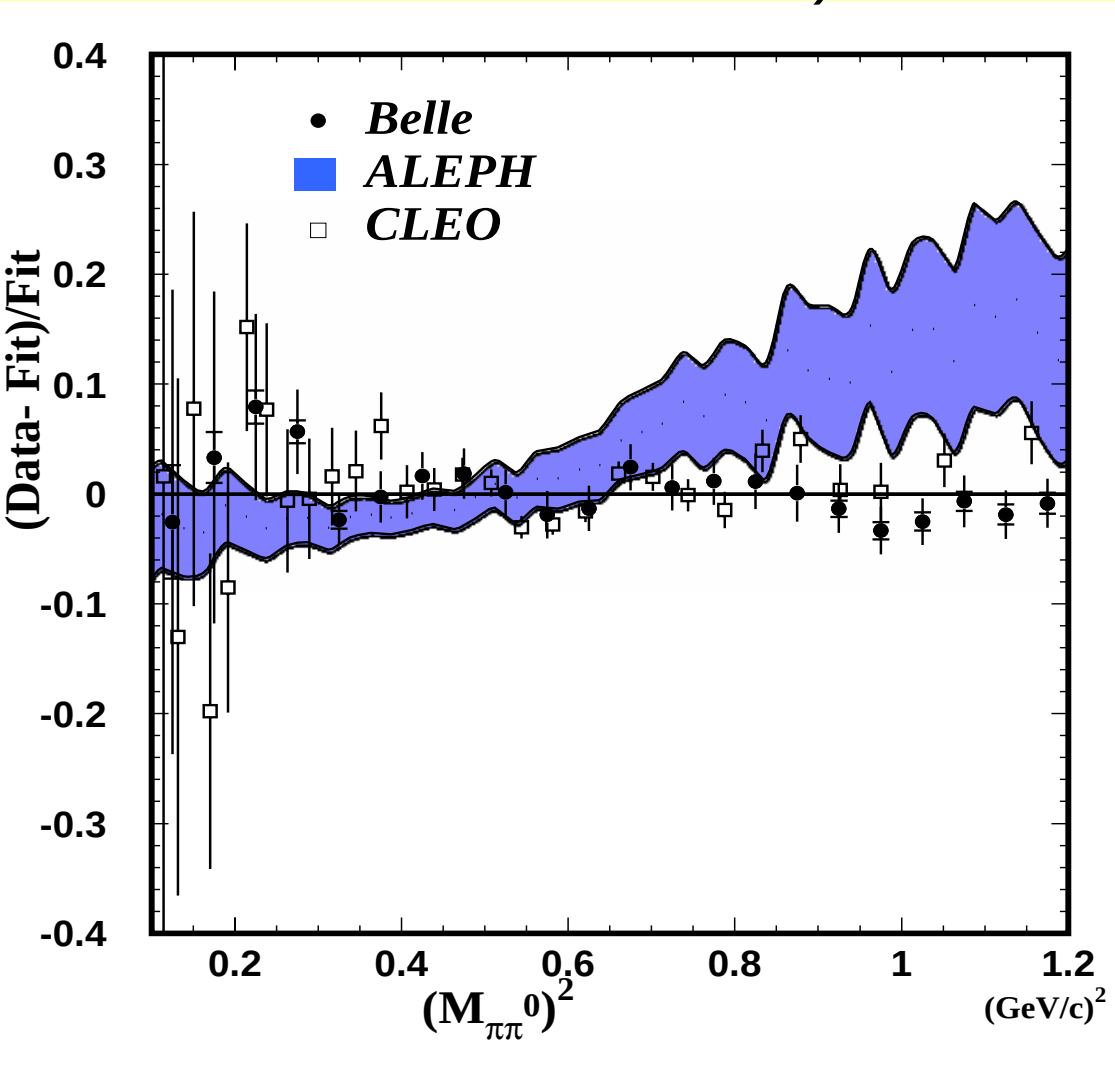


No correction for $\rho^{\pm}-\rho^{0}$ mass (~ 2.3 ± 0.8 MeV) and width (~ 3 MeV) splitting applied

Davier, hep-ex/0312064

Jegerlehner, hep-ph/0312372

Relative difference between τ data (ALEPH,CLEO and Belle)



- $M_{\pi\pi}^2 < 0.8\ GeV^2$; consistent each other.
- $M_{\pi\pi}^2 > 0.8\ GeV^2$; Belle-CLEO consistent, ALEPH is higher.

$a_\mu^{2\pi}$ is dominated in the lower $M_{\pi\pi}^2$ region.

Systematic in the mass distribution

- Unfolding procedure
  - Checked by Signal MC（UNF①）
  - Unfolding condition : value±5 （UNF②）
- Acceptance (Accept.)
  - π^0 efficiency ±3%
  - Effect of γ-track isolation
    - ✓Change a cut on the cluster-track distance（default and tighter one(30cm)）
- Momentum or energy scale (ENS)
  - Change $E\gamma$ by it's uncertainty estimated from the π^0 mass peak position.

(±0.2%)

Systematic in the mass distribution

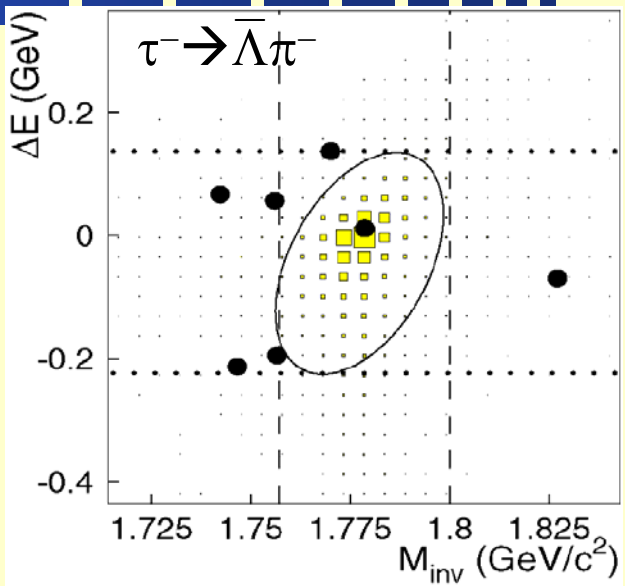
- Background
  - **continuum BG (BKG①)**
    - ✓ estimate at the mass region higher than m_τ
    - ✓ uncertainty is estimated to be 10%
  - **Feed down BG (BKG②)**
    - ✓ dominated by $\tau^- \rightarrow \pi^- 2\pi^0 \nu_\tau$
    - ✓ Other contribution from $\tau \rightarrow \omega\, \pi^0\, \nu$ ($\omega \rightarrow \pi^0 \gamma$)
    - ✓ systematic is estimated by changing the Br in PDG by 1σ
  - **non-π^0 BG (BKG③)**
    - ✓ dominated in the low $(M_{\pi\pi 0})^2$region.
    - ✓ In this region, the size of the non-π^0 background in the lower $M_{\gamma\gamma}$ side is different between data and MC. This differences is estimated as a systematic.

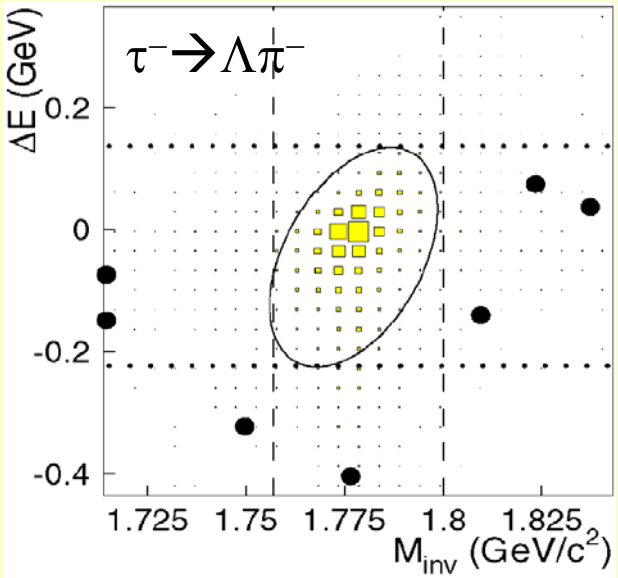
$\tau \rightarrow$ Baryons

- $\tau \rightarrow p\gamma$, $p\pi^0$
  - 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: $154 fb^{-1}$
  - $B(\tau \rightarrow \Lambda\pi) < 1.4 \times 10^{-7}$
  - $B(\tau \rightarrow \Lambda\pi) < 0.72 \times 10^{-7}$

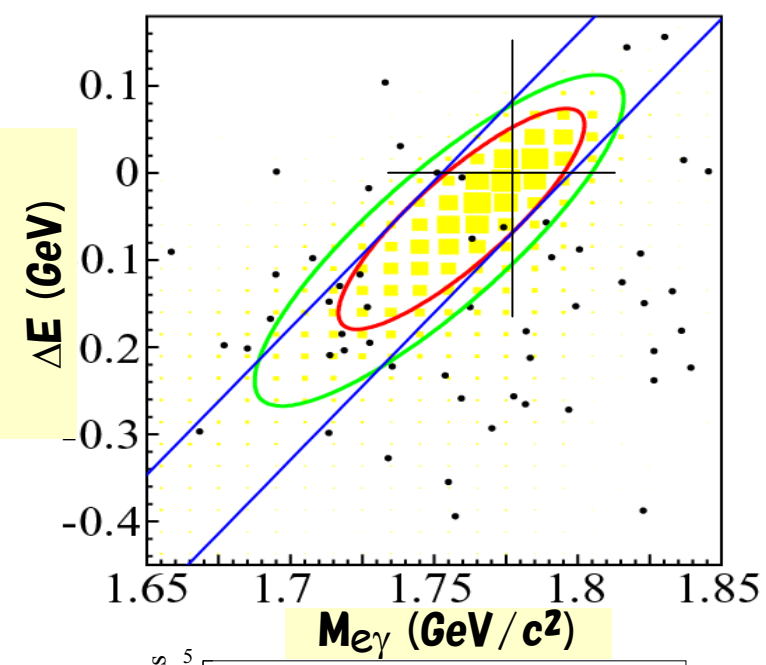
    PLB 632, 51 (2006).
  - Background: $\tau\tau(a_1\nu)$, qq

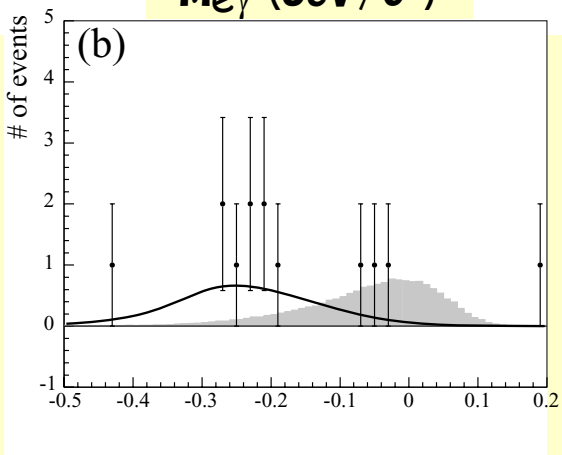




New result on $\tau \to e\gamma$ (Belle)

(535/fb)





✓ analysis: same with previous one, but with tighter requirements

- remaining events:
  5ev./2σ vs 20ev./5σ
  signal detection eff: 3%
- signal region: 2σ ellipse
- signal extraction: UEML fit:
- s=−0.14, b=5.14
  (allow negative s and its prob. 48%)
  s(90% CL) = 3.34 ev

✓ Br<1.2x10^{-7} at 90%CL

preliminary

Status of LFV Studies-III ($\tau^- \to e^- h^+ h'^-$)

τ^- mode	Belle		Babar		CLEO	
	Br, 10^{-7}	Lum. fb^{-1}	Br, 10^{-7}	Lum. fb^{-1}	Br,10^{-7}	Lum,fb^{-1}
$e^-\pi^+\pi^-$	<7.3	158	<1.2	221	<22	4.79
$e^+\pi^-\pi^-$	<2.0	158	<2.7	221	<19	4.79
$e^-\pi^+K^-$	<7.2	158	<3.2	221	<64	4.79
$e^-\pi^-K^+$	<1.6	158	<1.7	221	<38	4.79
$e^+\pi^-K^-$	<1.9	158	<1.8	221	<21	4.79
$e^-K^+K^-$	<3.0	158	<1.4	221	<60	4.79
$e^+K^-K^-$	<3.1	158	<1.5	221	<38	4.79

Status of LFV Studies-V ($\tau^- \to l^{-+}$Baryon)

τ^- mode	Belle		Babar		CLEO	
	Br, 10^{-7}	Lum. fb^{-1}	Br, 10^{-7}	Lum. fb^{-1}	Br,10^{-7}	Lum,fb^{-1}
$\bar{p}\gamma$	<3.0	158	-	-	<35	4.7
$\bar{p}\pi^0$	<6.5	158	-	-	<150	4.7
$\bar{\Lambda}\pi^-$	<1.4	158	<0.59	237	-	-
$\Lambda\pi^-$	<0.72	158	<0.58	237	-	-
$\bar{\Lambda}K^-$	-	-	<0.72	237	-	-
ΛK^-	-	-	<1.5	237	-	-

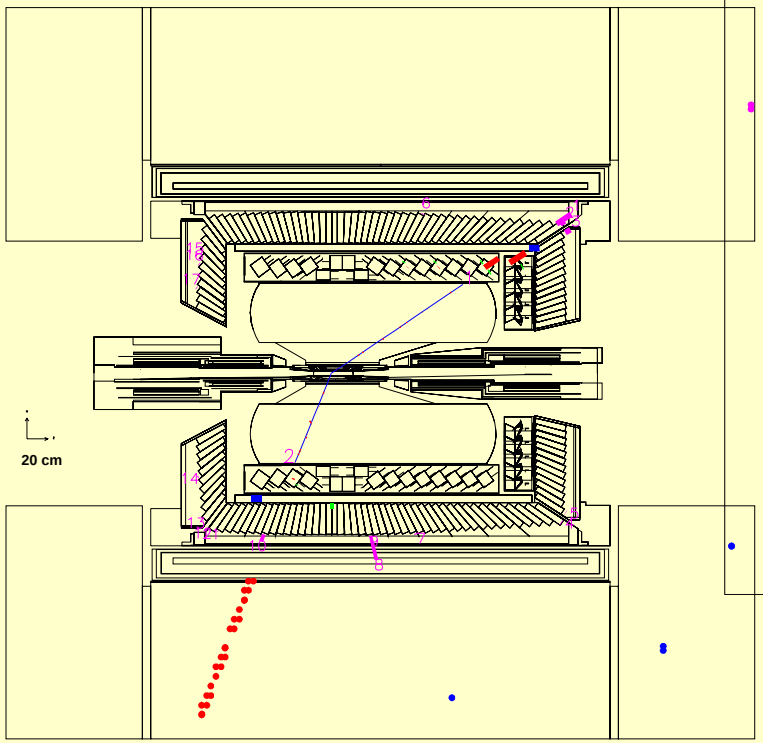
Event display

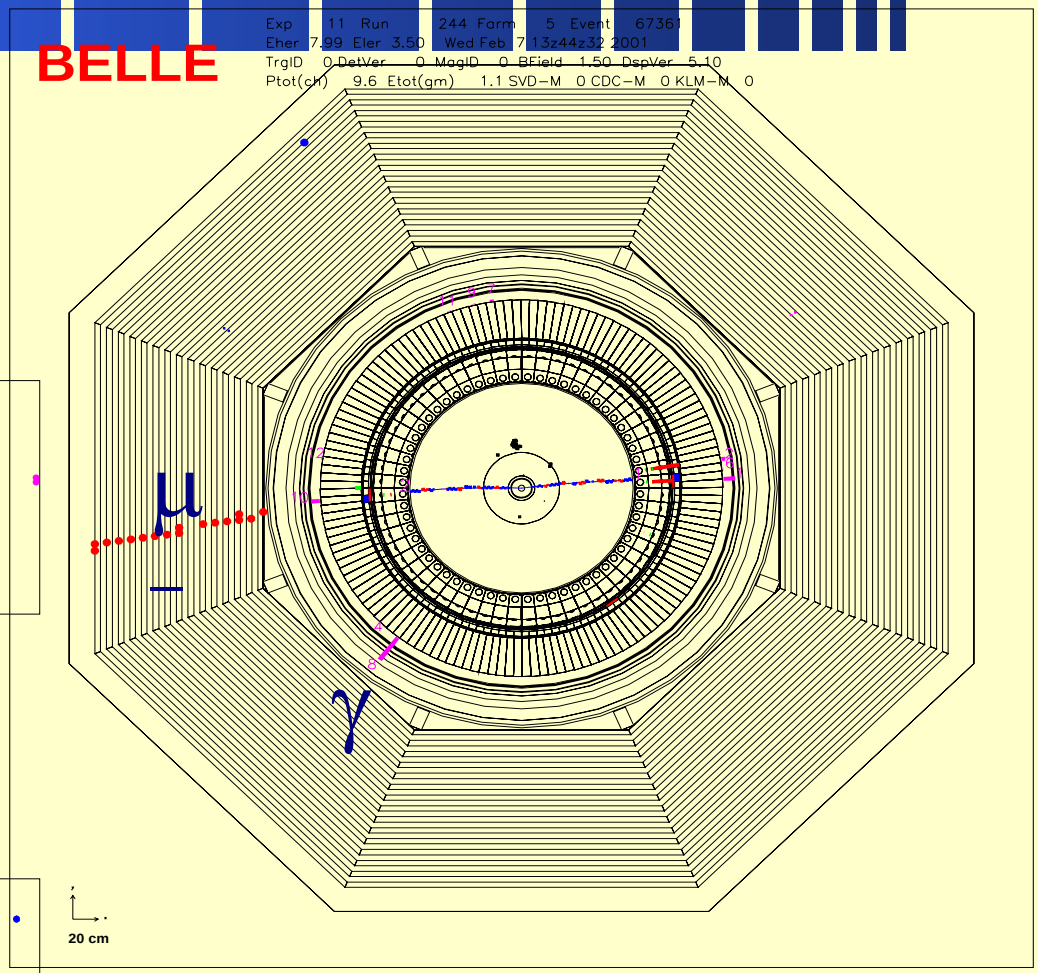
($\tau \longrightarrow \mu\gamma$ ***candidate***)

tag-side: m to detector gap

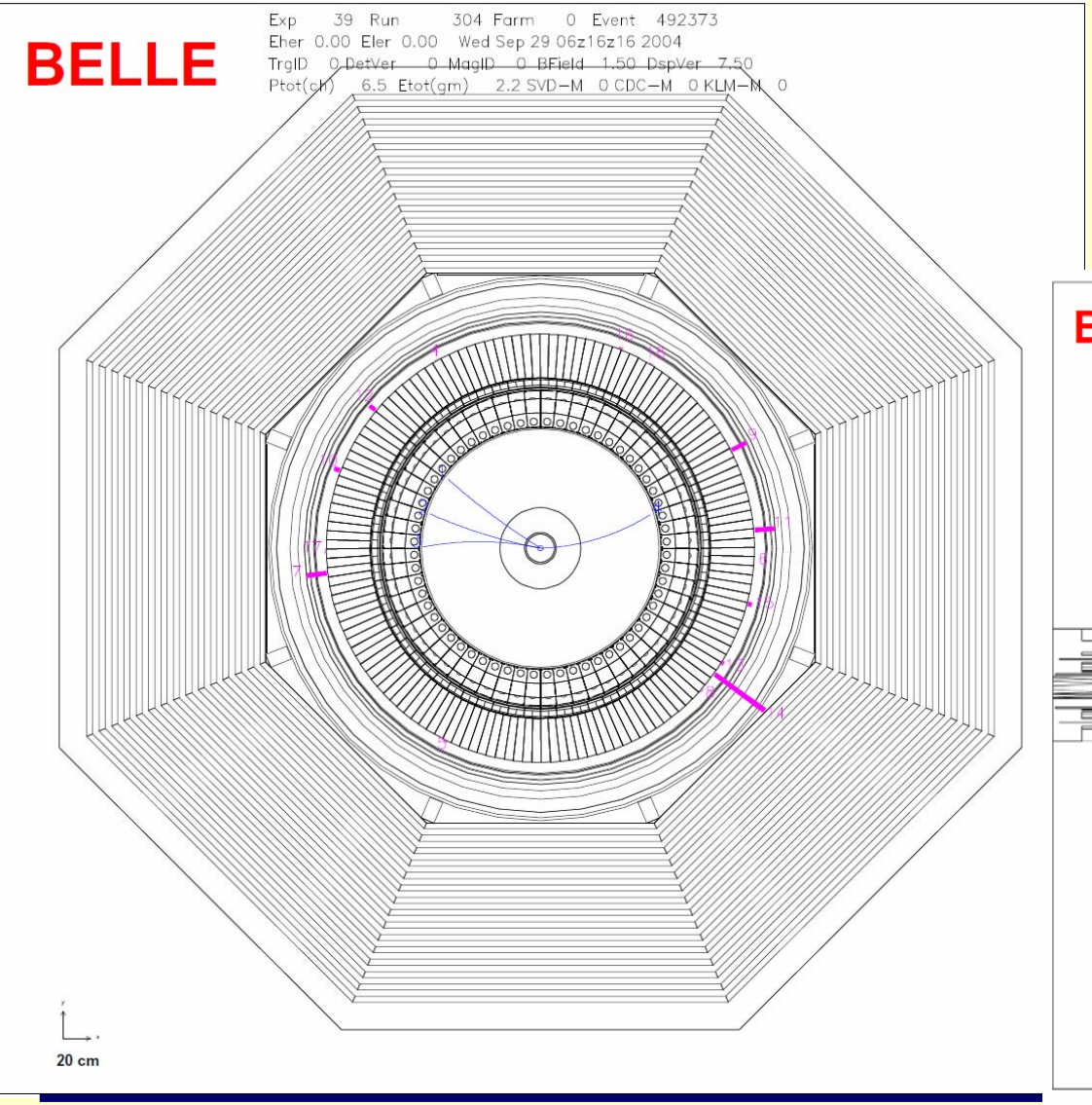
low energy γ

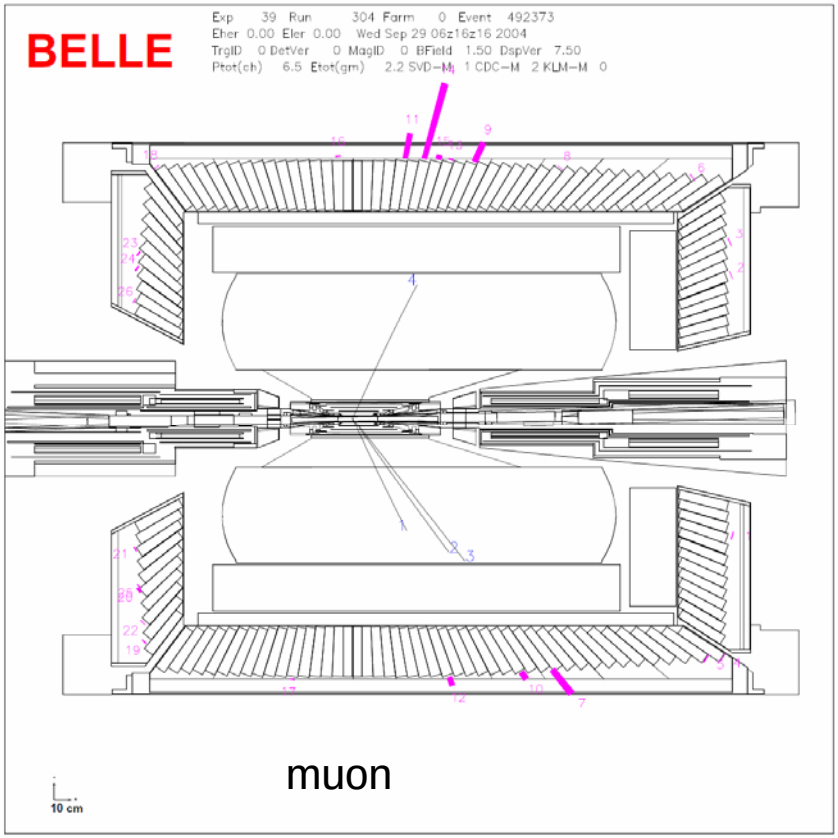
radiative $\mu\mu$ event (?)



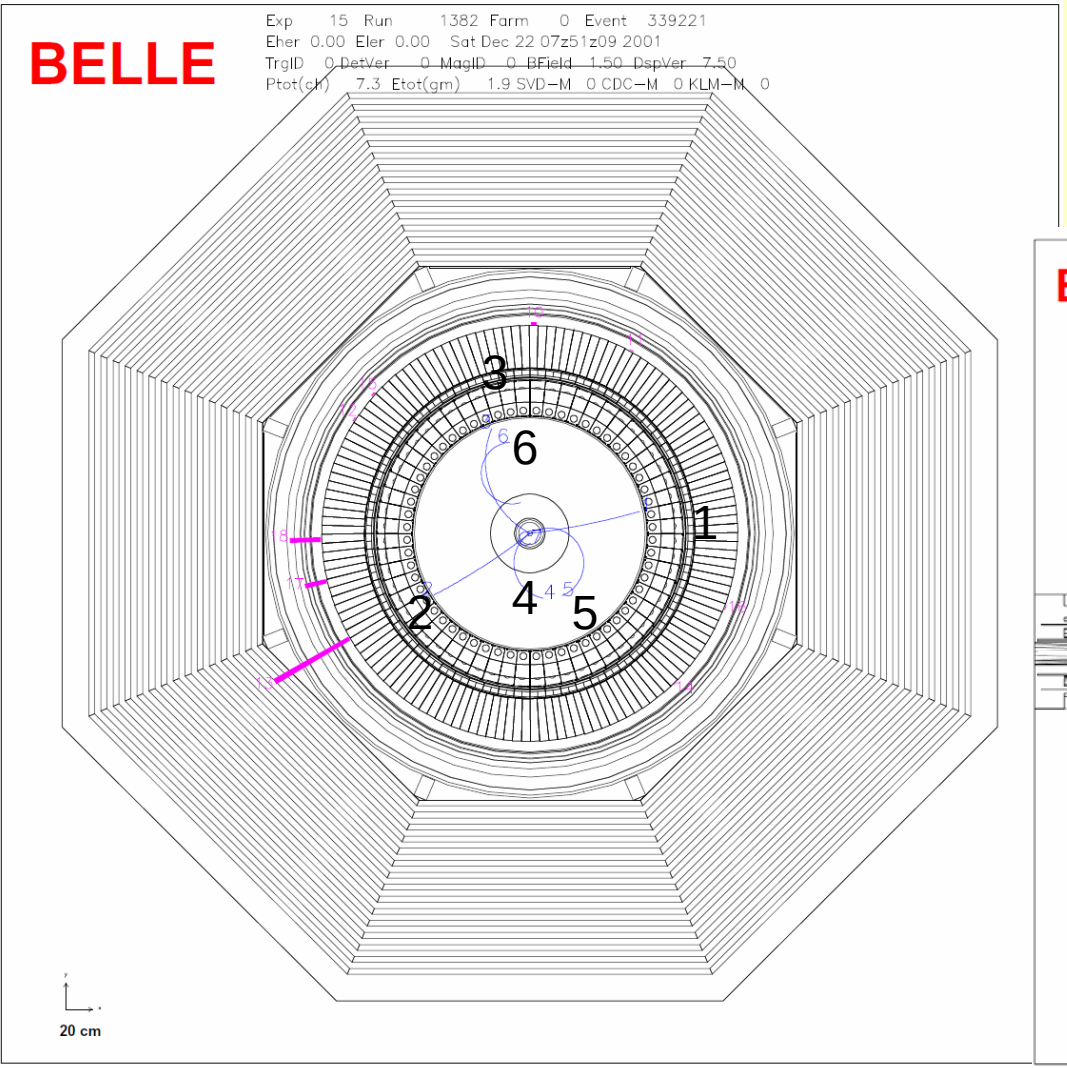


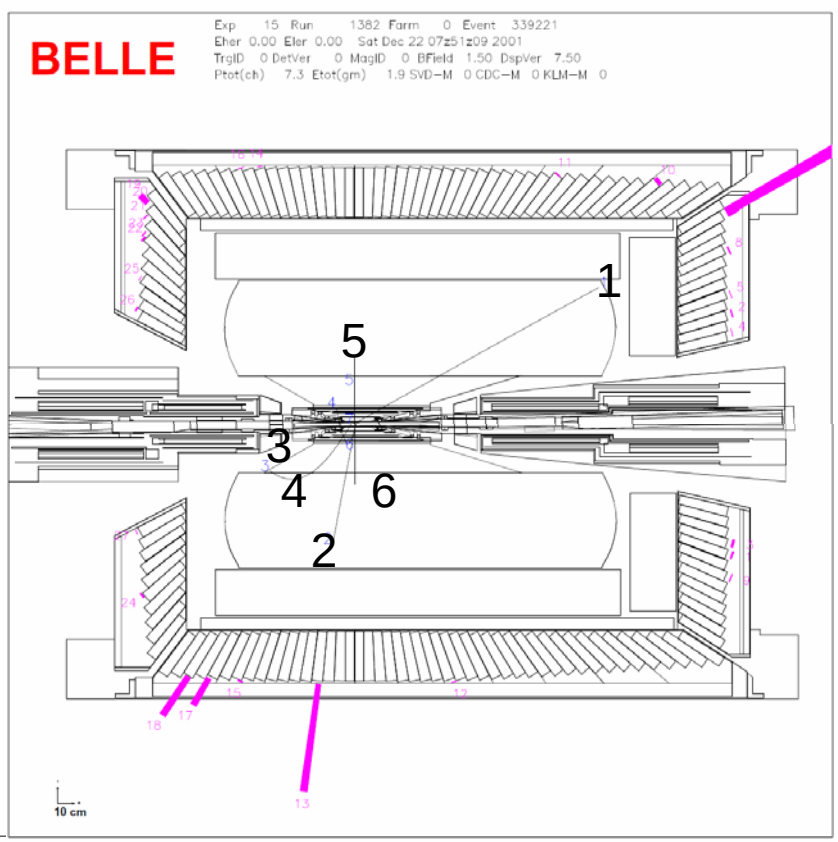
Event display : $\tau \to \mu\phi$



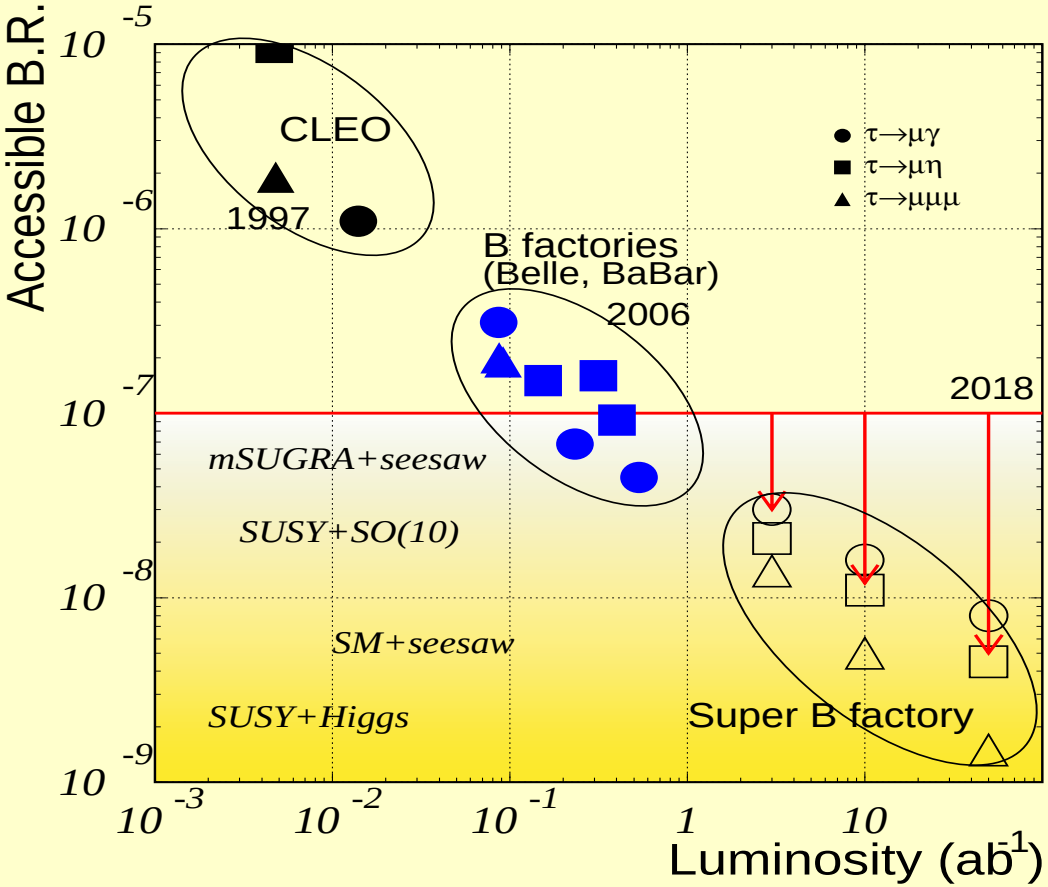


Event display : $\tau \rightarrow e\omega$





Future prospect for LFV searches



Sensitivity achieves 10^{-9} area by Super-B factory

Based on MC simulation assuming the current level of efficiency and background.