Search for Lepton Flavor Violating τ Decays at Belle Experiment

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On behalf of Belle Collaboration

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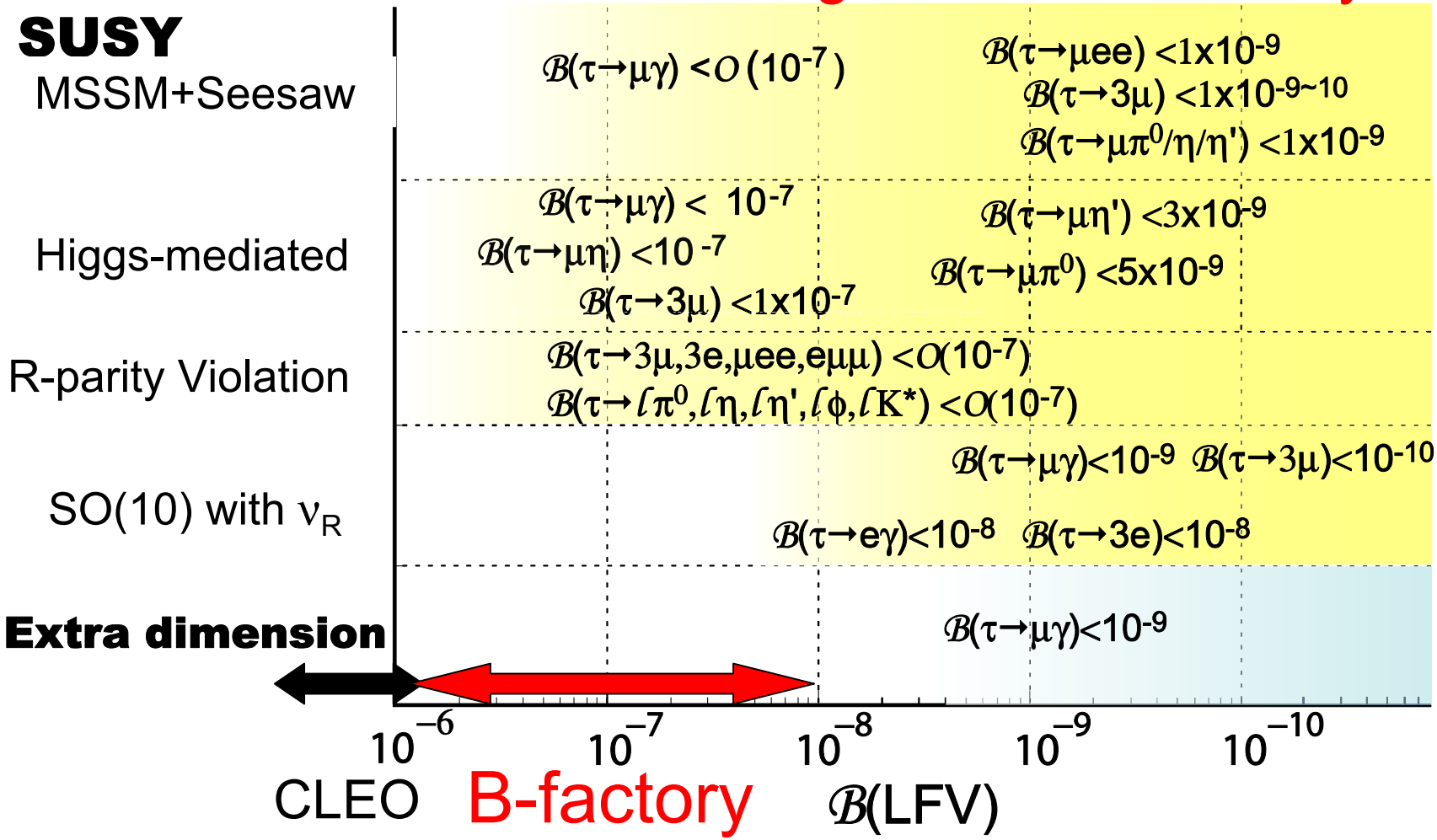
Introduction

Lepton Flavor Violating (LFV) τ decay

Observation of LFV is a clear signature of New Physics!



We reach the level of New Physics predictions

KEKB and Belle

KEKB:

e+(3.5 GeV) e-(8GeV)

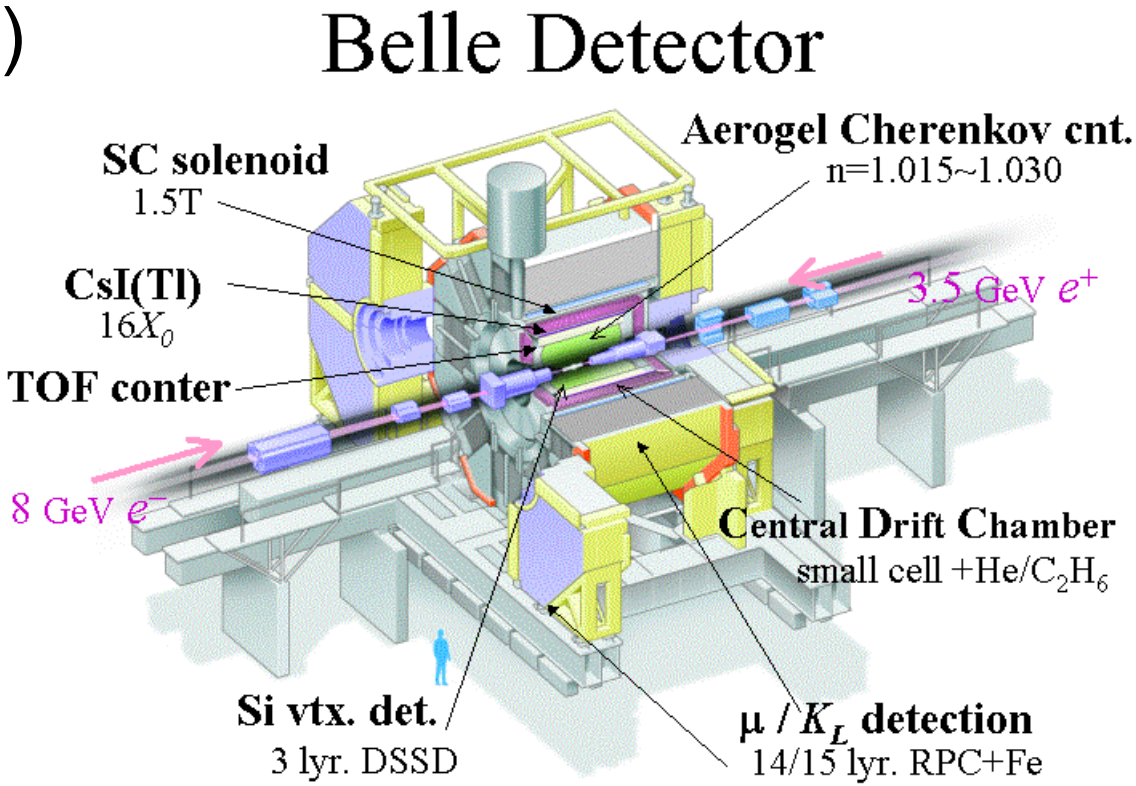
Peak Luminosity

1.7×10^{34} cm^{-2} s^{-1}

⇒World record!!!

Integrated luminosity

>700fb^{-1} collected



$\sigma(\tau\tau)$~0.9nb,σ(bb)~1.1nb

A B-factory is also a τ-factory!

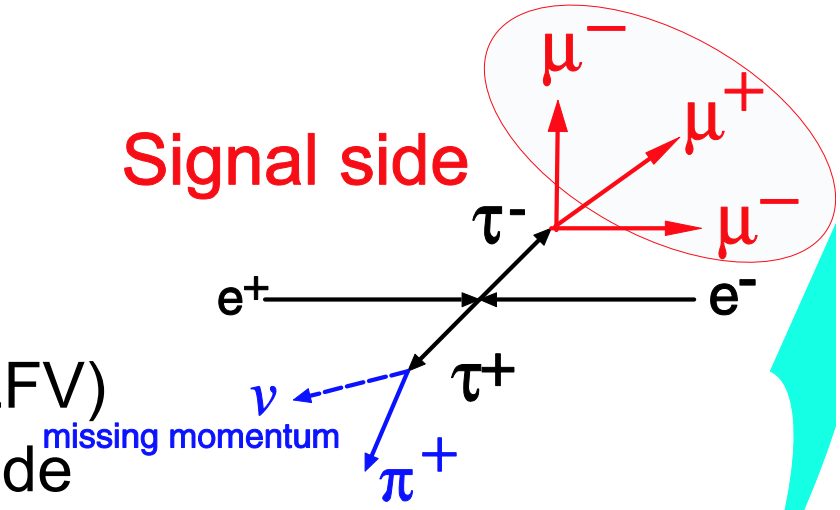
⇒6.3×10^8 τ-pairs

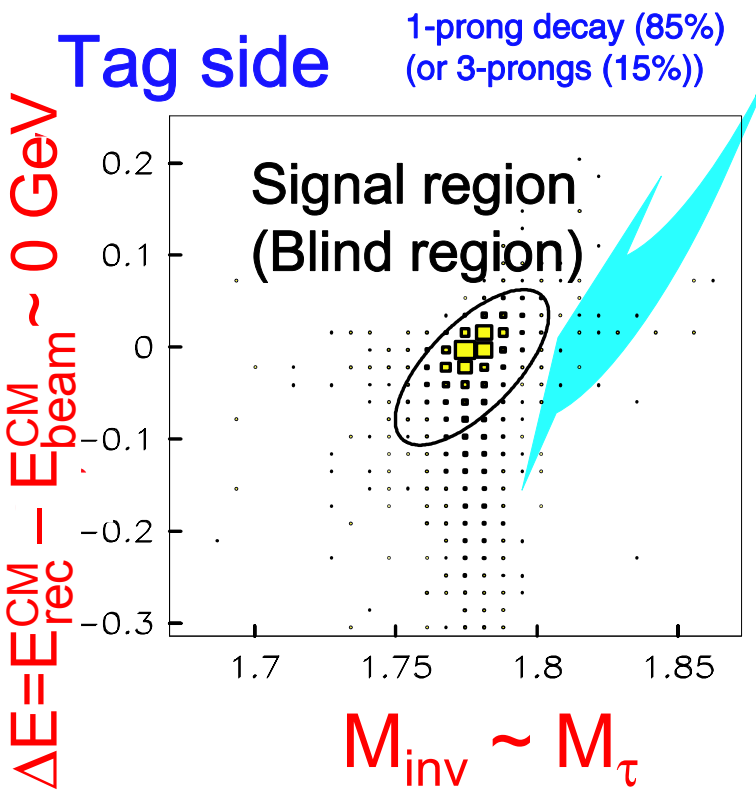
Good track reconstruction and particle identification

Analysis method

Procedure for a LFV τ decay analysis

1. Select events with low multiplicity
   ⇒Signal (charged tracks and γ from LFV) and Tag (generic 1-prong decay) side
2. Reduce background events using PID, kinematical information
3. Calculate M_{inv} and ΔE
   ⇒We perform blind analysis
4. Estimate signal efficiency and # of backgrounds in signal region from sidebands and MC
5. Open the blind region
   ⇒Observe LFV or set upper limits





Results shown last summer

$\tau \to \mu\gamma, e\gamma$

Data: 535fb^{-1}

Br($\tau \to \mu\gamma$)<4.5x10^{-8} at 90%C.L.

Br($\tau \to e\gamma$)<1.2x10^{-7} at 90%C.L.

(hep-ex/0705.0650 submitted to PLB)

$\tau \to e/\mu$+pseudoscalar meson (η, η', π^0)

Data:401fb^{-1}

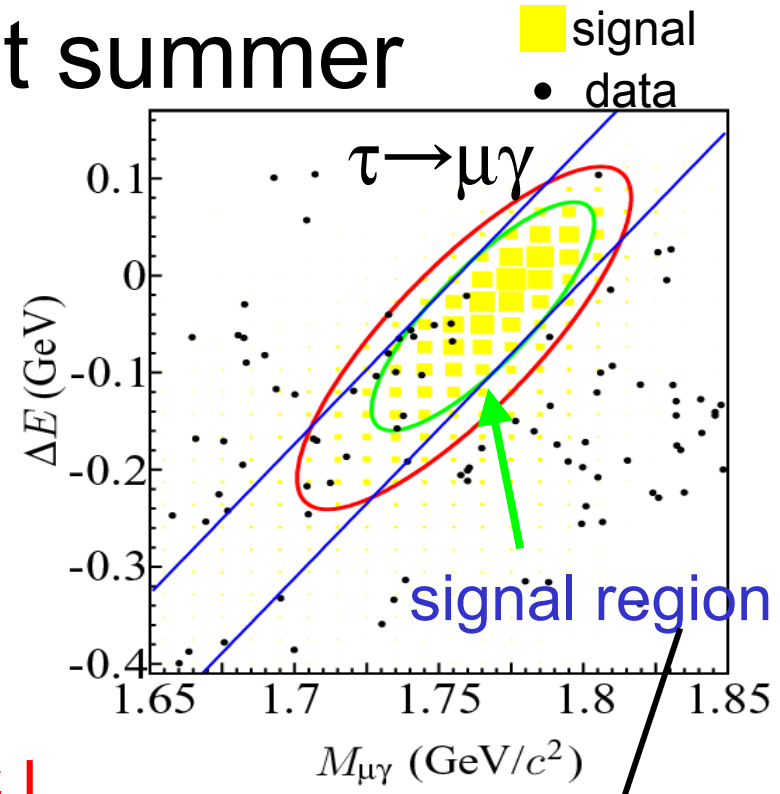
Br($\tau \to l\eta, l\eta', l\pi^0$)<(6.5-16)x10^{-8} at 90%C.L.

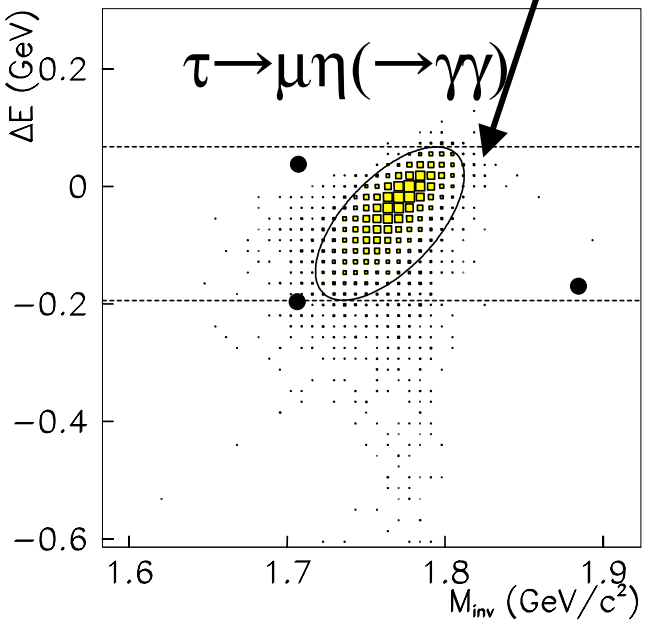
(PLB648, 341 (2007))

⇒Upper limits for LFV τ decays are approaching the O(10^{-8}) level

We proceed now to the updated searches of

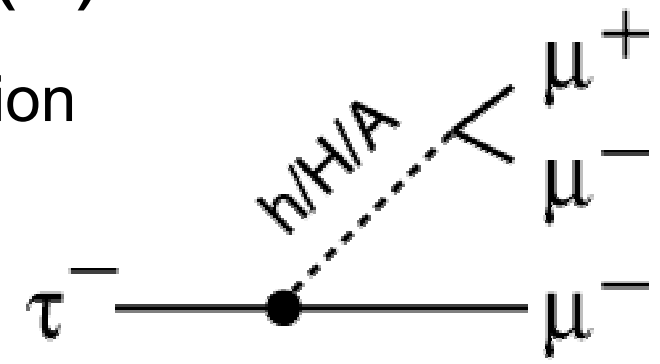
$\tau \to 3$ leptons and $\tau \to lV^0(=\phi, \omega)$





$\tau \rightarrow 3$ leptons (1)

Predicted to have large branching fraction in Higgs mediated LFV models



We consider 6 modes: $\tau^- \rightarrow e^-e^+e^-$, $\mu^-\mu^+\mu^-$, $e^-\mu^+\mu^-$, $\mu^-e^+e^-$, $e^+\mu^-\mu^-$ and $\mu^+e^-e^-$

Previous results at Belle (PLB 598, 103 (2004))

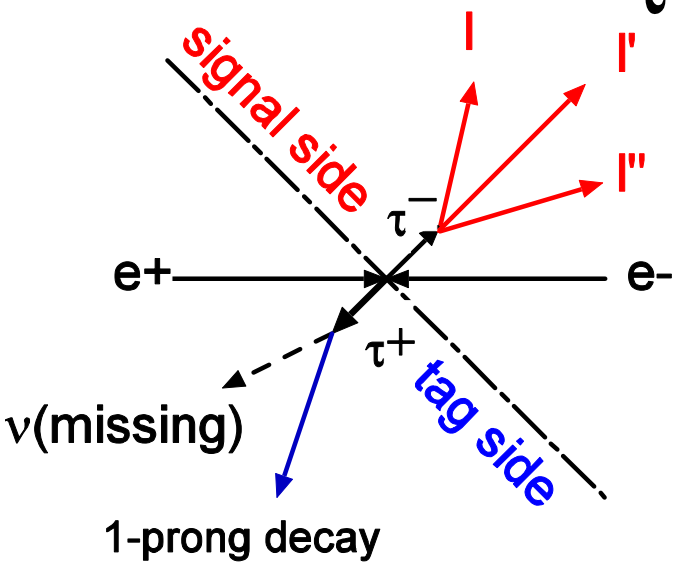
Br$<(1.9\text{-}3.5)\times10^{-7}$ at 90%C.L. (87.1fb^{-1})

(Br$<(1.1\text{-}3.3)\times10^{-7}$ at 90%C.L. (BaBar 91.5fb^{-1}))

We update the analysis of $\tau \rightarrow 3$ leptons modes using 535fb^{-1} of data

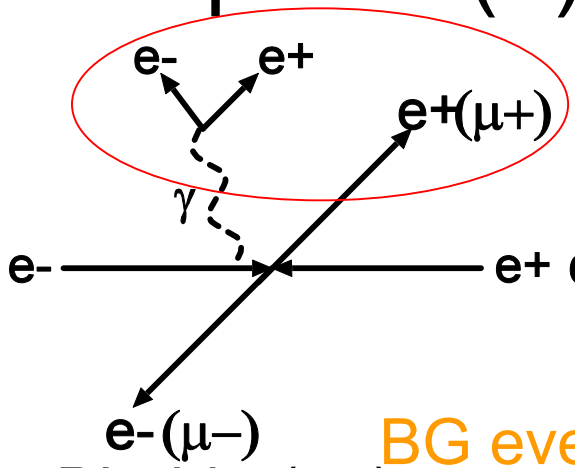
- luminosity is increased by a factor of 6.1 from previous analysis
- optimize event selections for each mode separately taking account of different background compositions

τ→3 leptons (2)



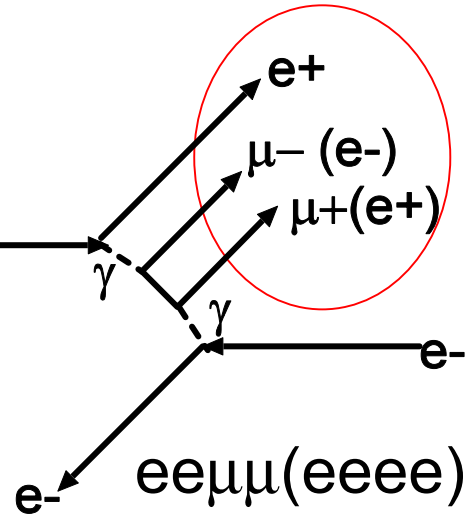
1-prong decay

Signal topology



Bhabha(μμ)

BG events



eeμμ(eeee)

$\tau^- \rightarrow$ Mode	$\mu^-\mu^+\mu^-$	$e^-e^+e^-$	$\mu^-e^+e^-$ $e^-\mu^+\mu^-$	$\mu^+e^-e^-$ $e^+\mu^-\mu^-$
Dominant Background	$\tau\tau$ continuum $\mu\mu\mu\mu$	Bhabha $eeee$ $\tau\tau$	$ee\mu\mu$ $\tau\tau$ $\mu\mu$	$\tau\tau$ continuum

Event selection

For all modes

- $5.29 < E^{CM}_{total} < 9.5$ GeV
- $0.90 < |V_{Thrust}| < 0.97$
- $M_{tag} < M_\tau$
- $-0.0 < \cos\theta^{CM}_{tag\text{-}miss} < 0.98$

For each mode

- electron-veto on the tag-side
  (e-e+e- and e-μ+μ-)
- γ-conversion veto
  (e-e+e- and μ-e+e-)
- m^2_{miss} and p_{miss}
  (e-e+e-, μ–μ+μ-, e-μ+μ-, μ-e+e-)

τ→3 leptons (3)

Efficiency : 6.0 – 12.5%

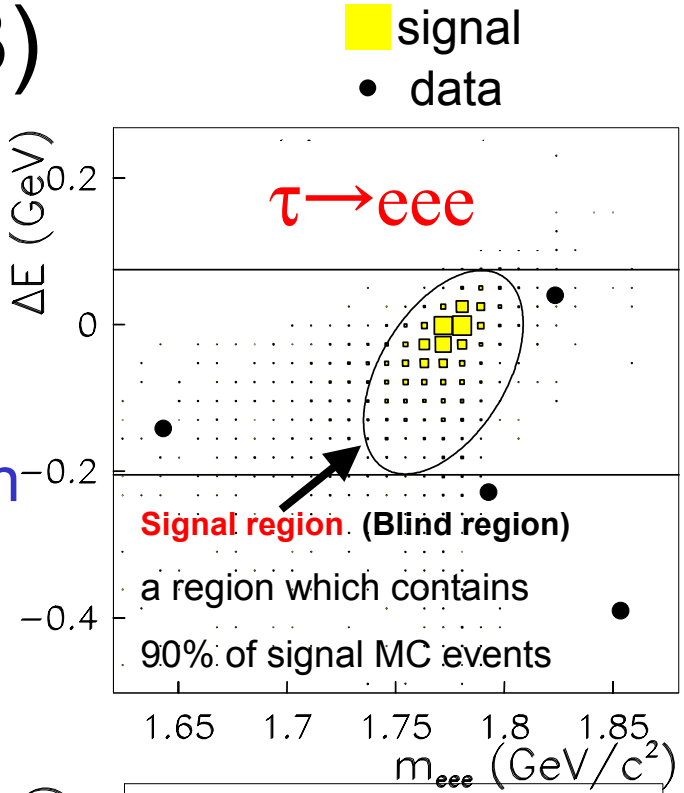
→the same or better than
in the previous analysis

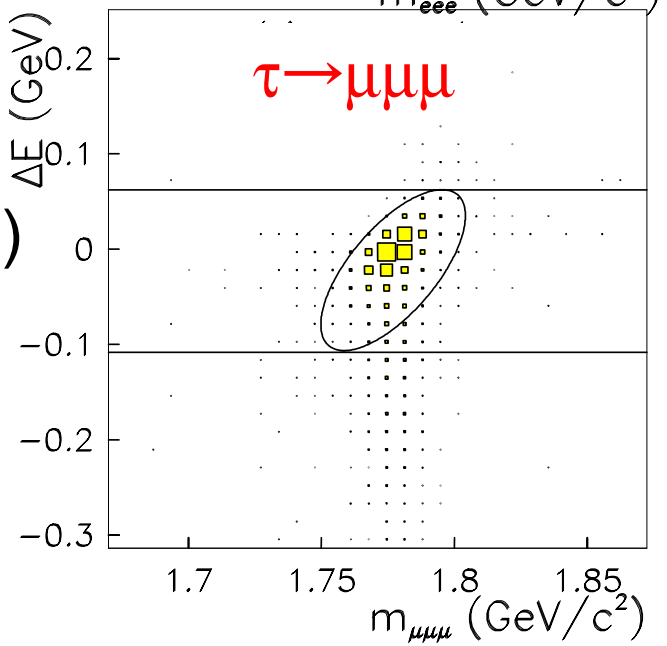
Expected BG : 0.0-0.4 events

We observe no events in the signal region

Mode	Upper limits
$\tau^- \to \mu^-\mu^+\mu^-$	$< 3.4 \times 10^{-8}$
$\tau^- \to e^-e^+e^-$	$< 3.6 \times 10^{-8}$
$\tau^- \to \mu^-e^+e^-$	$< 2.8 \times 10^{-8}$
$\tau^- \to e^-\mu^+\mu^-$	$< 4.3 \times 10^{-8}$
$\tau^- \to \mu^+e^-e^-$	$< 2.1 \times 10^{-8}$
$\tau^- \to e^+\mu^-\mu^-$	$< 2.4 \times 10^{-8}$

(Preliminary)





These results are improved by a factor of 4.7-6.8 the best previous values

⇒The most stringent upper limits among LFV τ decays

$\tau \to l\phi,\ l\omega$

Belle Previously (PLB 640, 138 (2006))

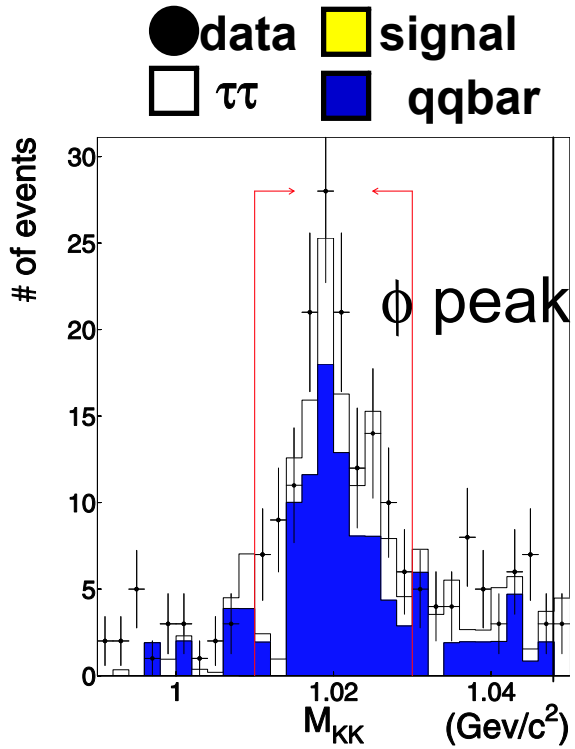
Br ($\tau \to l\phi$) <(7.3-7.7)x10^{-7} @ 154 fb^{-1}

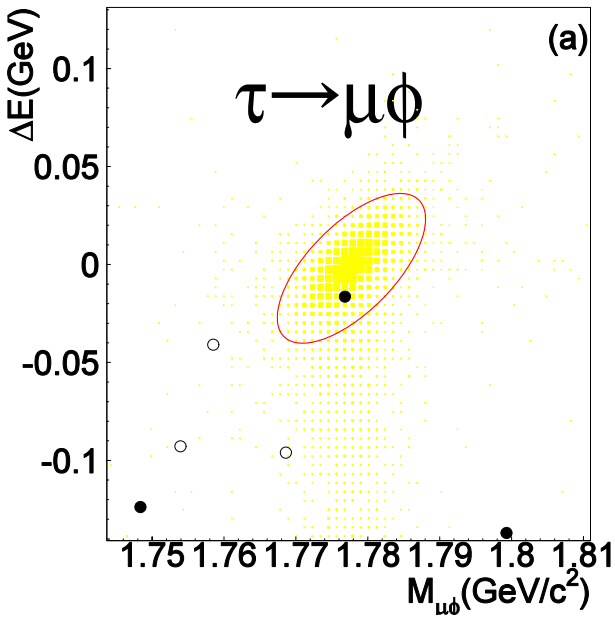
⇒Update using 543 fb^{-1}

- $\phi(\to K^+K^-)$ mode (Eff. 3.1%)
  Improve by a factor of 4.9 for $\mu\phi$ and 9.6 for $e\phi$ modes
- $\omega(\to \pi^+\pi^-\pi^0)$ mode (Eff. 2.5%)
  First search!!

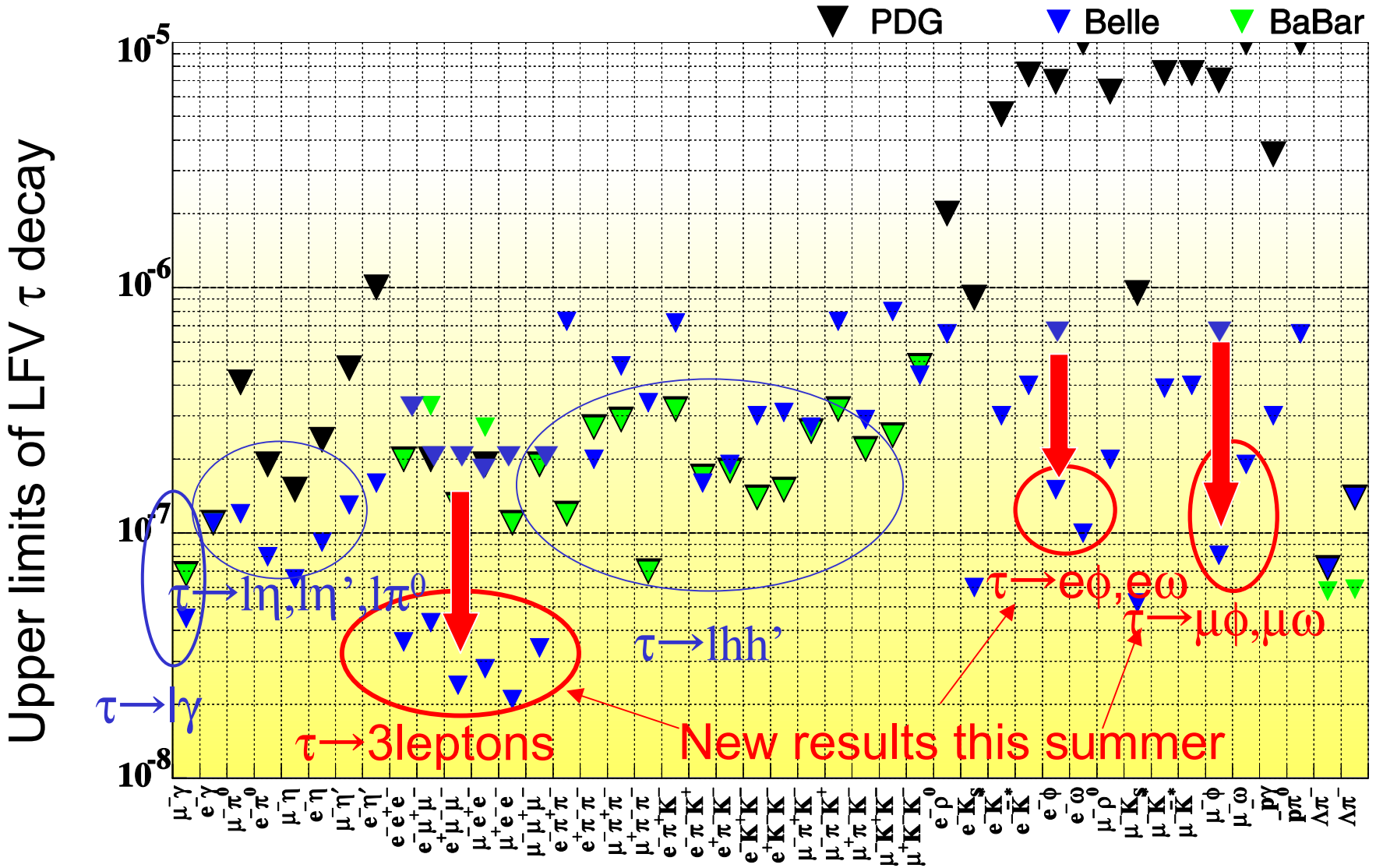
Mode	Expected BG	N_{obs}	Upper limit @90%C.L.
$\tau \to \mu\phi$	0.11 ± 0.08	1	1.5x10^{-7}
$\tau \to e\phi$	0.11 ± 0.08	0	0.8x10^{-7}
$\tau \to \mu\omega$	0.20 ± 0.28	0	1.0x10^{-7}
$\tau \to e\omega$	0.00 ± 0.07	1	1.9x10^{-7}

(Preliminary)





Summary for LFV τ Decays



ULs for all LFV τ decays are approaching the 10^{-8} level

Summary

We update searches for lepton flavor violating τ decays using > 500 fb^{-1} of data at Belle.

⇒ Improved analysis

⇒ Increased luminosity

$Br(\tau \to 3 \text{ leptons}) < (2.1\text{-}4.3) \times 10^{-8}$ @90%C.L.

→improved by factors of 5-7 the best previous values

→the most stringent upper limits among LFV τ decays

$Br(\tau \to l\phi,\ l\omega) < (0.8\text{-}1.9) \times 10^{-7}$ @90%C.L.

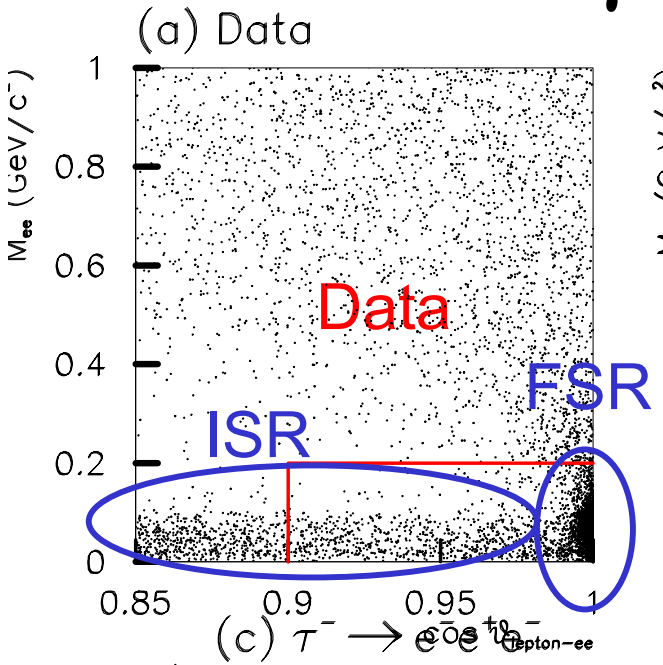
→$l\phi$: improved by factors of 4.9 and 9.6

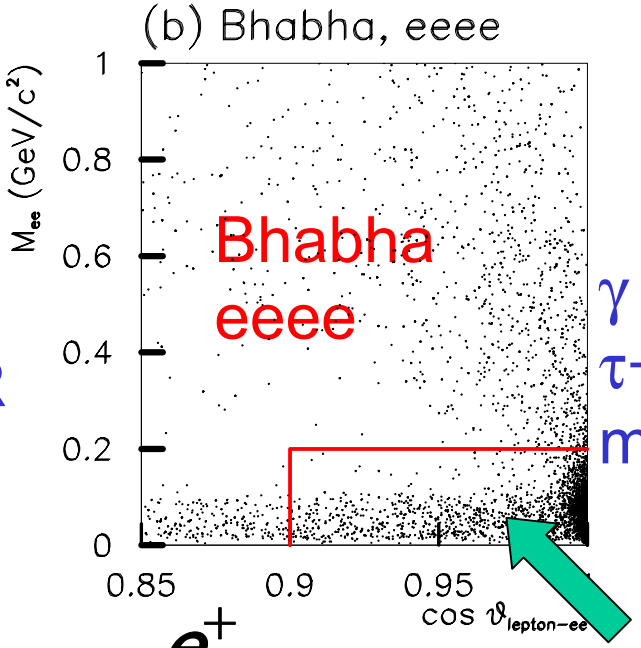
→$l\omega$: first search

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

Backup

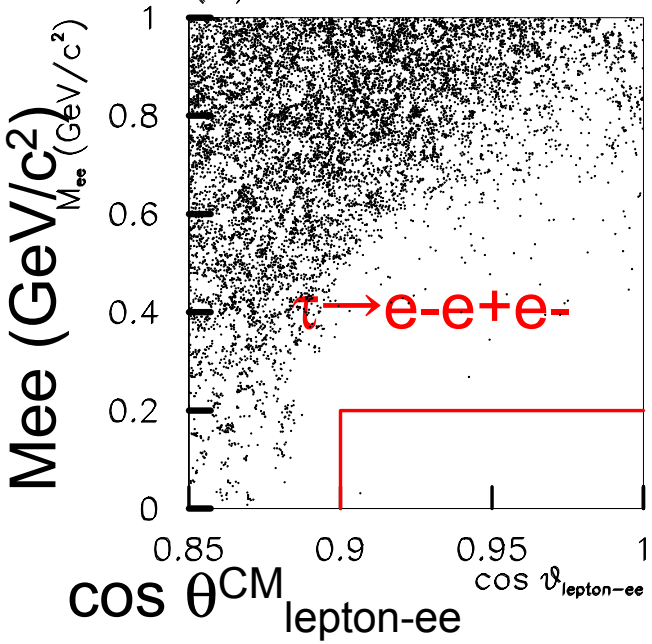
γ-conversion Veto

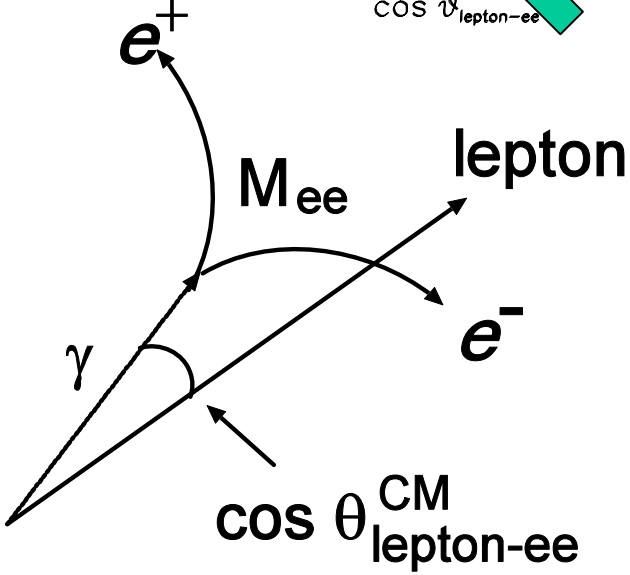




γ conversion veto for τ→e-e+e- and μ-e+e- modes

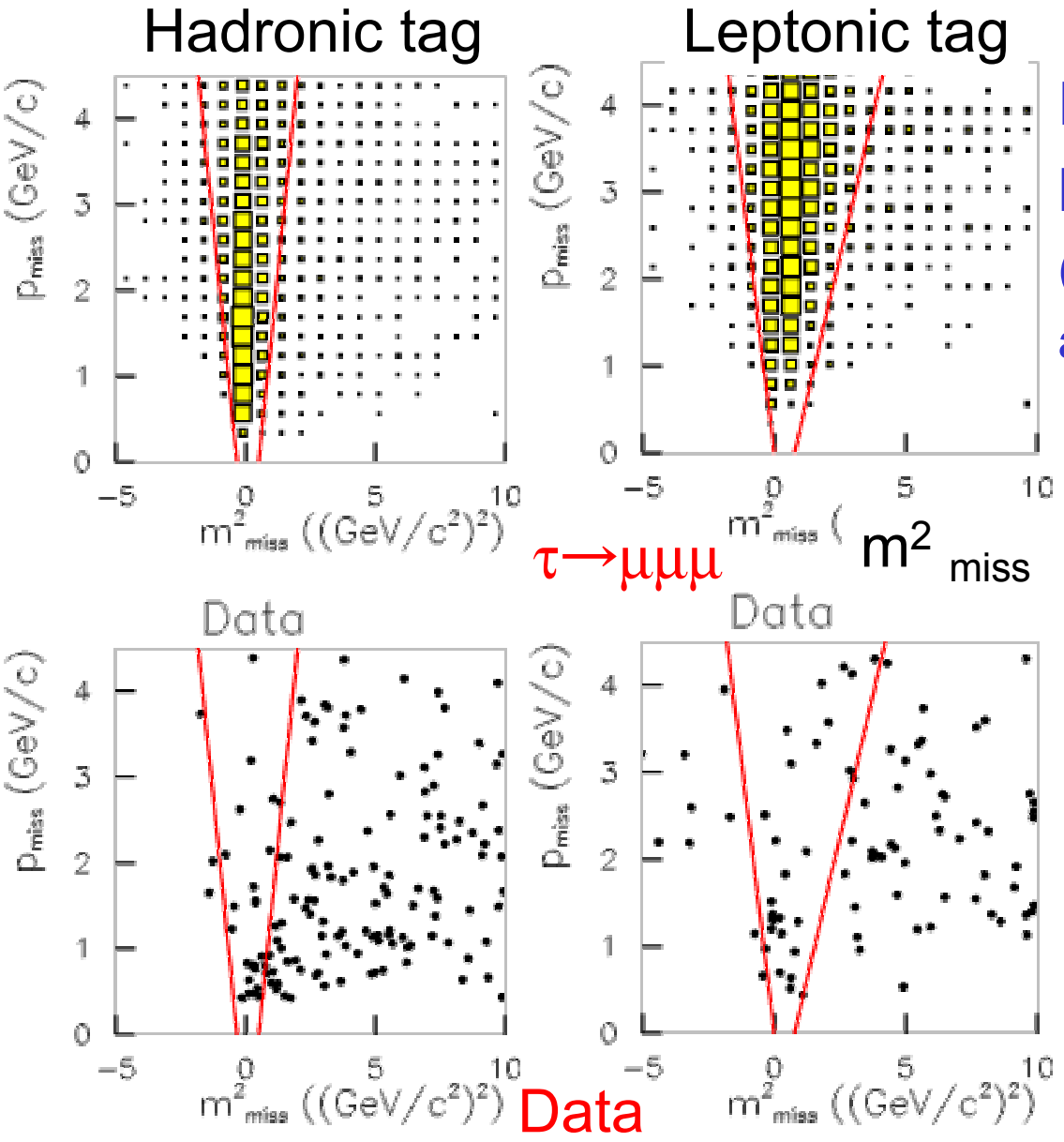
Remove events with γ conversion





in signal side

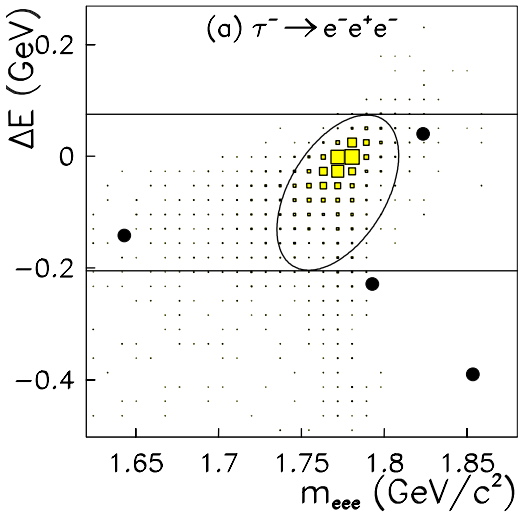
m^2_{miss} and p_{miss} cut

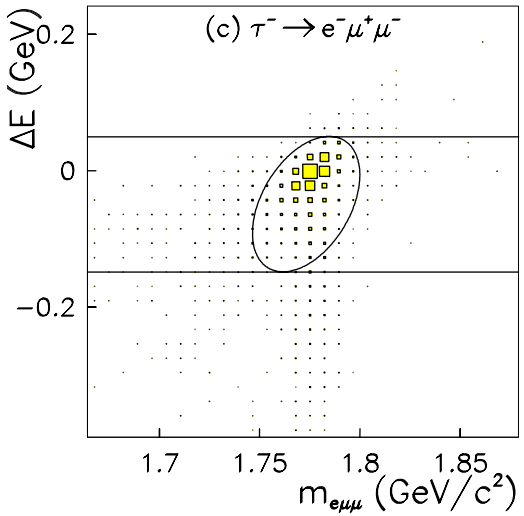


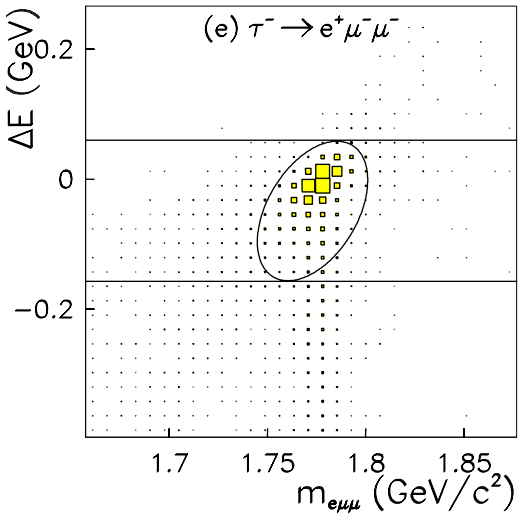
Requirement on correlation between m^2_{miss} and p_{miss} (e-e+e-, μ-μ+μ-, e-μ+μ- and μ-e+e- modes)

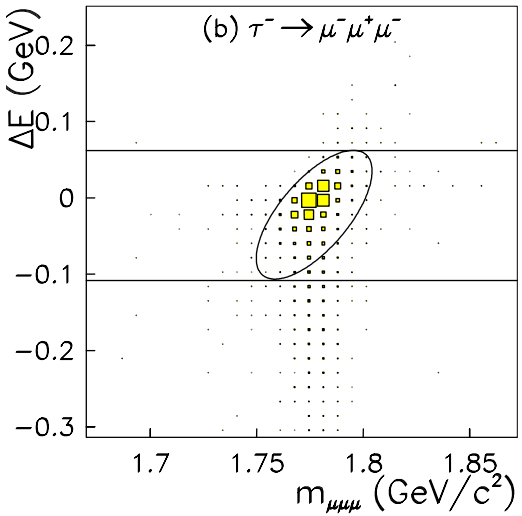
Apply different cuts by
hadronic tag (1ν)
leptonic tag (2ν)

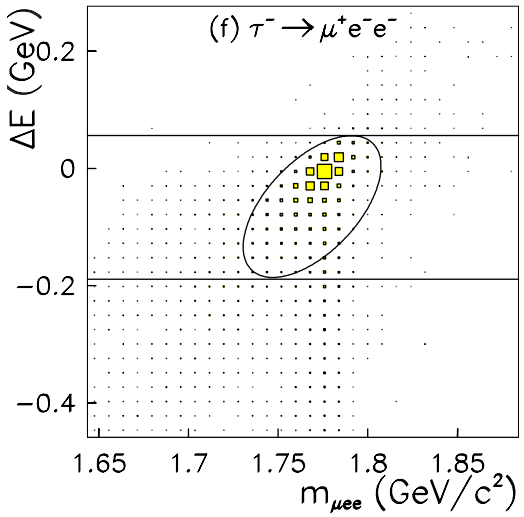
$\tau \rightarrow$ 3 leptons

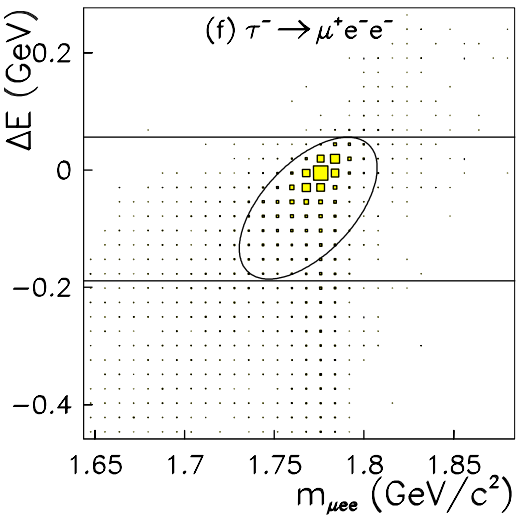








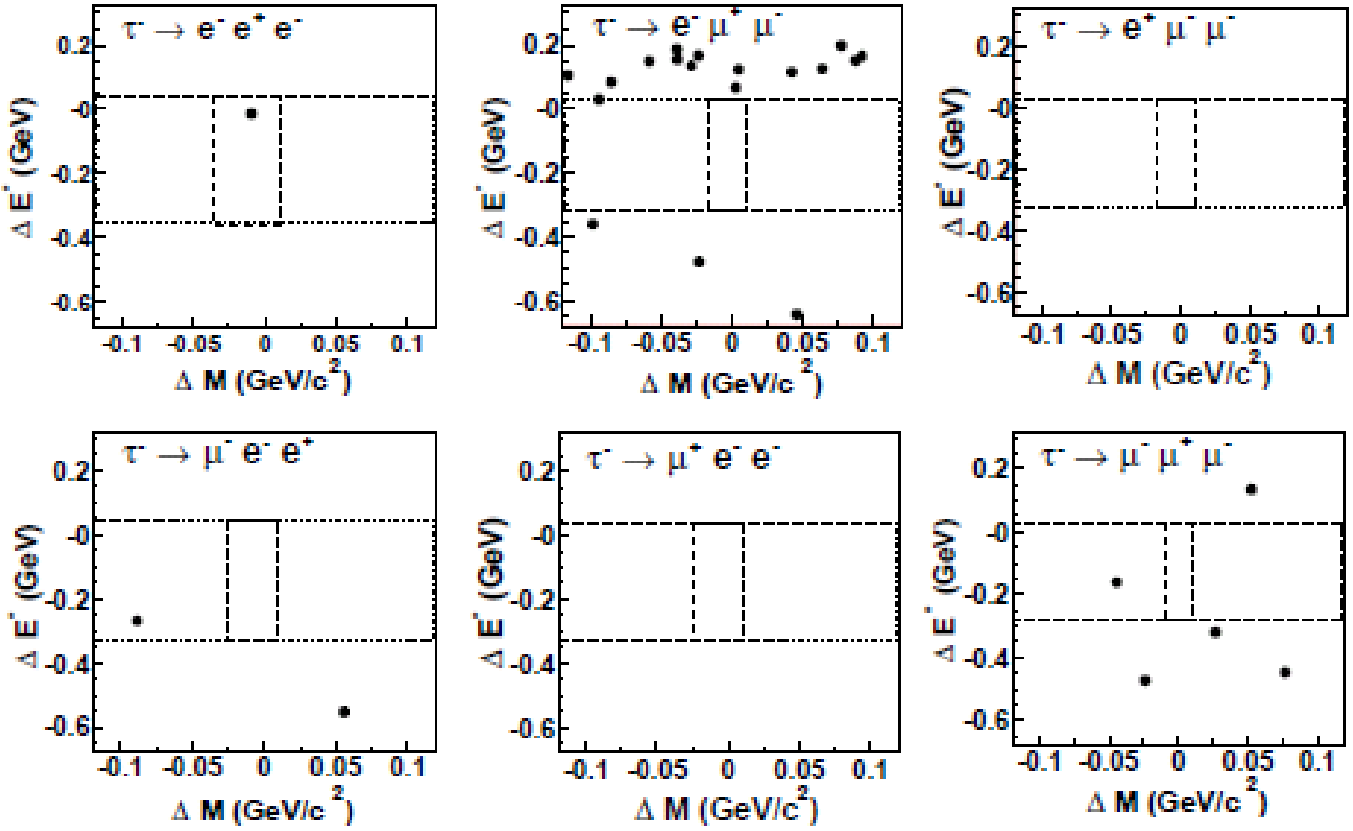




Summary for $\tau \rightarrow$ 3leptons

Mode	ε (%)	b_0	s	Total Sys. (%)	s_{90}	Upper limit $\mathcal{B}$
$\tau^- \rightarrow e^- e^+ e^-$	6.00	0.40 ± 0.28	0	9.8	2.1	3.6×10^{-8}
$\tau^- \rightarrow \mu^- \mu^+ \mu^-$	7.64	$0.0^{+0.15}_{-0.0}$	0	7.4	2.5	3.4×10^{-8}
$\tau^- \rightarrow e^- \mu^+ \mu^-$	6.08	$0.0^{+0.18}_{-0.0}$	0	9.5	2.5	4.3×10^{-8}
$\tau^- \rightarrow \mu^- e^+ e^-$	9.29	$0.0^{+0.20}_{-0.0}$	0	7.8	2.5	2.8×10^{-8}
$\tau^- \rightarrow e^+ \mu^- \mu^-$	10.8	$0.0^{+0.15}_{-0.0}$	0	7.6	2.5	2.4×10^{-8}
$\tau^- \rightarrow \mu^+ e^- e^-$	12.5	$0.0^{+0.19}_{-0.0}$	0	7.7	2.5	2.1×10^{-8}

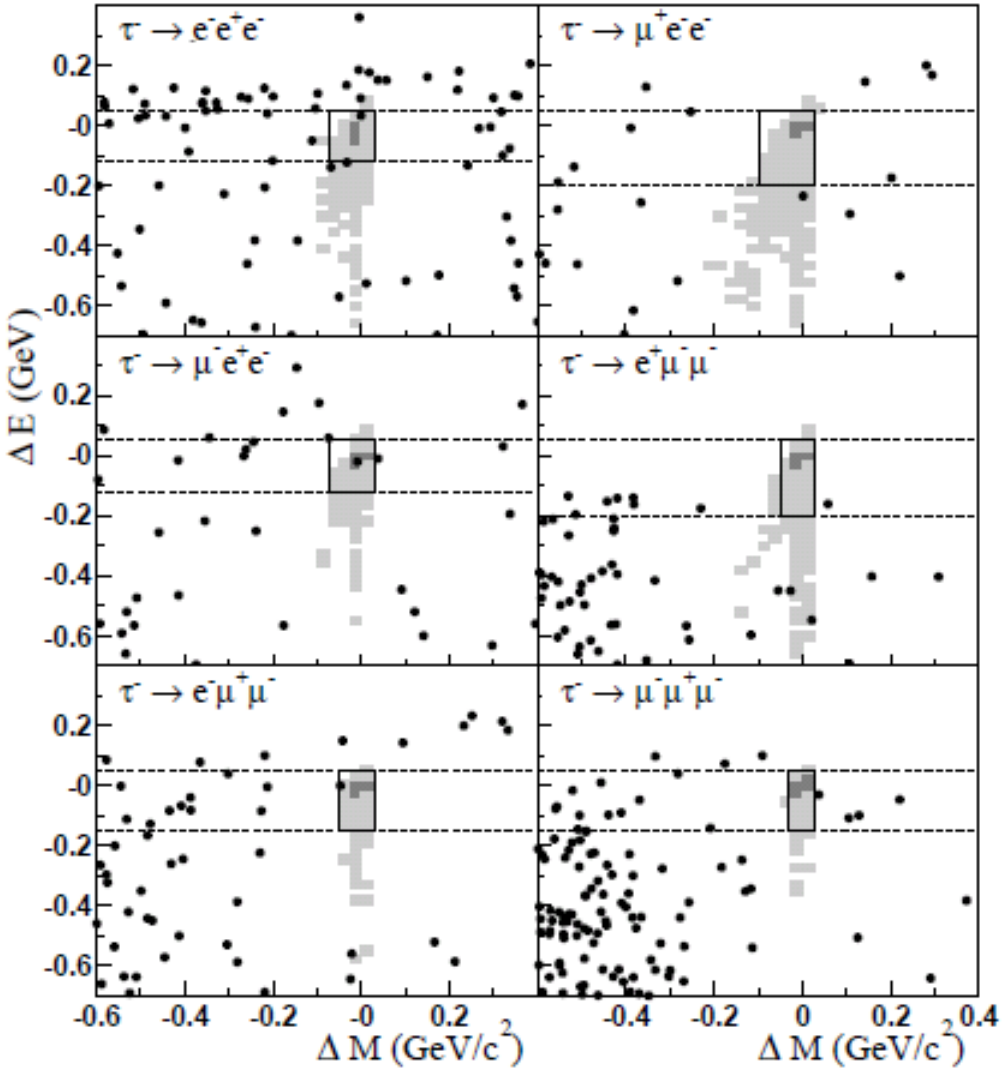
$\tau \to$ 3lepton from Belle using 87.1fb^{-1}



Mode	$e^-e^+e^-$	$\mu^-\mu^+\mu^-$	$e^-\mu^+\mu^-$	$\mu^-e^+e^-$	$e^+\mu^-\mu^-$	$\mu^+e^-e^-$
Eff.	9.2	9.0	9.2	9.4	9.2	9.5
#(BG)	<0.2	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.2	<0.3	<0.2
#(Obs)	1	0	0	0	0	0
U.L.	$<3.5\times10^{-7}$	$<2.0\times10^{-7}$	$<2.0\times10^{-7}$	$<1.9\times10^{-7}$	$<2.0\times10^{-7}$	$<2.0\times10^{-7}$

(Final eff = eff.$\times$1-prong sel.(85%) $\sim$ 7.7%)

$\tau \to$ 3lepton from BaBar using 91.5fb^{-1}

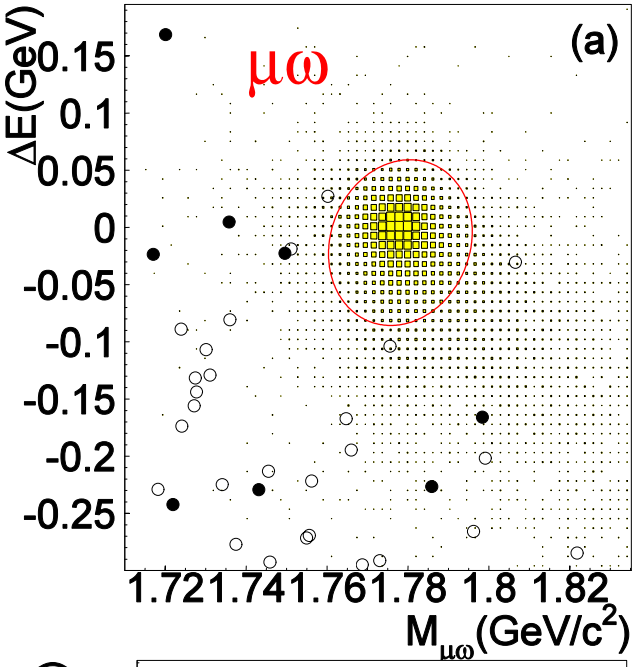


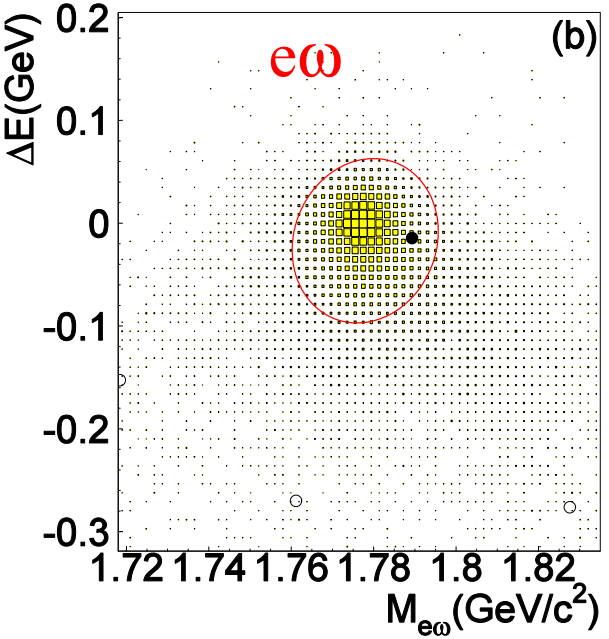
Mode	$\mu^-\mu^+\mu^-$	$e^-e^+e^-$
Eff.	6.5±0.5%	7.3±0.2%
#(BG)	0.31±0.09	1.51±0.11
#(Obs)	0	1
U.L.	$<1.9\times10^{-7}$	$<2.0\times10^{-7}$

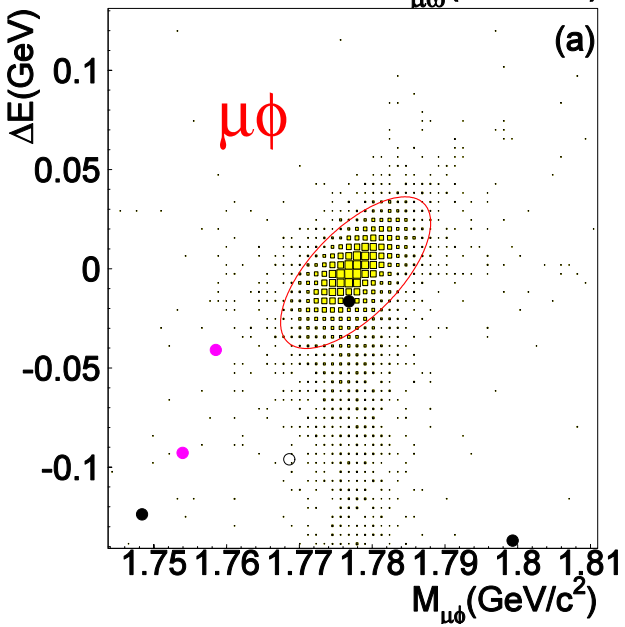
Mode	$e^-\mu^+\mu^-$	$\mu^-e^+e^-$
Eff.	6.8±0.4%	7.7±0.3%
#(BG)	0.39±0.08	0.62±0.10
#(Obs)	1	1
U.L.	$<3.3\times10^{-7}$	$<2.7\times10^{-7}$

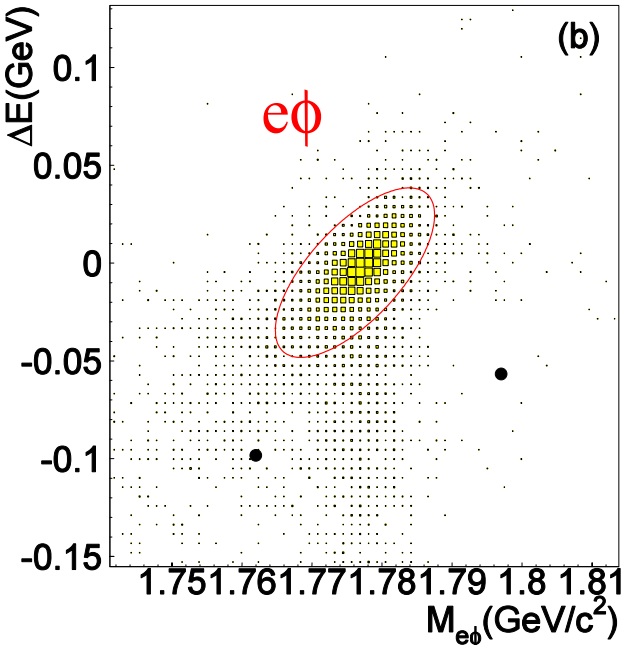
Mode	$e^+\mu^-\mu^-$	$\mu^+e^-e^-$
Eff.	9.8±0.5%	11.6±0.4%
#(BG)	0.21±0.07	0.37±0.08
#(Obs)	1	1
U.L.	$<1.3\times10^{-7}$	$<1.1\times10^{-7}$

τ→lepton + Vector meson

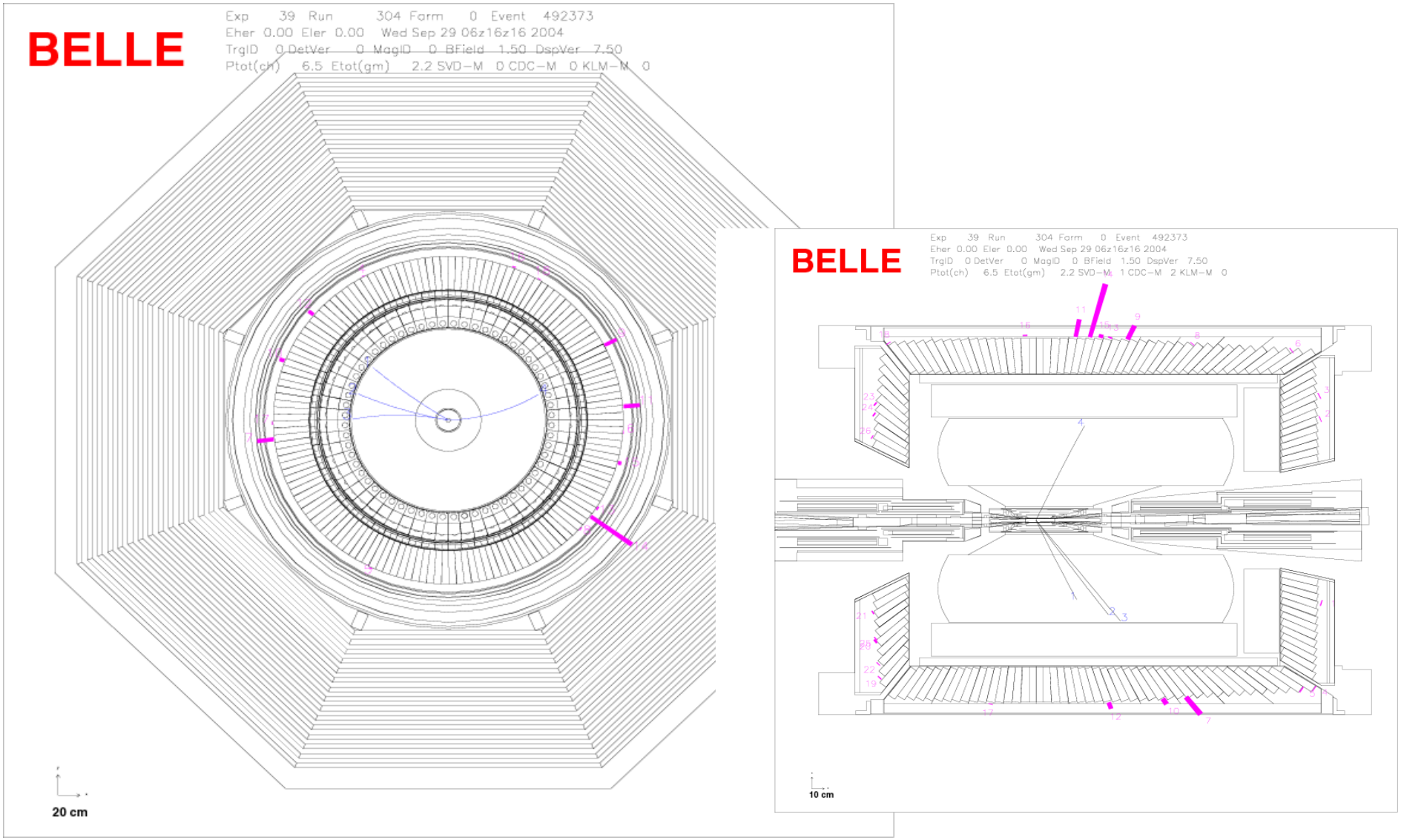








Event Display of observed data in $\tau \rightarrow \mu\phi$



Event display of observed data in $\tau \rightarrow e\omega$