1999/09/20 BELLE analysis meeting @KEK

Tau event study

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- contents
  - τ related things
    - ρ^0, a_1 in τ decay (1-3 topology event)
    - τ pseudo-mass
    - π^0, $\rho^{\pm}$ in τ decay (Hayashii)
  - Test of T/CP invariance
    in $e^+e^- \rightarrow \tau^+\tau^-$ reaction
    - Introduction
    - Simulation study
    - Data analysis
  - Summary and plan

- τ related things

"τ" at BELLE

- High luminosity (10~100fb^{-1})
  ↔ CLEO ~19fb^{-1}
- Cross-section of τ pair (0.91nb)
  almost same as BB (1.05nb)

→ High statistics as well as B
10M ~ 100M sample

Data was collected ~25 pb^{-1}
→ τ pair events exist?

1-3 topology event search

- good charged track definition
  Pt ≥ 0.1 GeV/c
  $|dr|<0.5$ cm, -2(or 1)$<dz<2$(or 3) cm (IP shift)
- good gamma definition
  E > 0.1 GeV/c
- electron ID
  eid.le_noeop > 0.6, E/p > 0.6
- muon ID
  mu2.flag ≥ 2

→ Others are defined as pion.

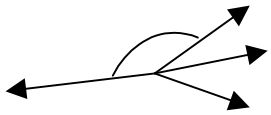
1-3 topology event search

- sample

Data	$20.8pb^{-1}$			
MC	τ pair	cont.	BB	2photon
	400k	500k	100k	800k

- selection criteria
  - # of charged track = 4
  - # of gamma = 0
  - net charge = 0
  - ΣPcm < 10 GeV/c *
  - ΣE(ECL) < 10 GeV *
  - Pt > 0.5 GeV/c for at least 1 track *
  - ΣP > 3 GeV/c
  - 1-prong ID
    - maximum Σangle(i,j)
      - angle(i,j) means the angle between i-th and j-th charged particle
  - 1-prong particle consists with lepton(e/μ)
  - 3-prong particles consist with hadrons.

* is pre-selection

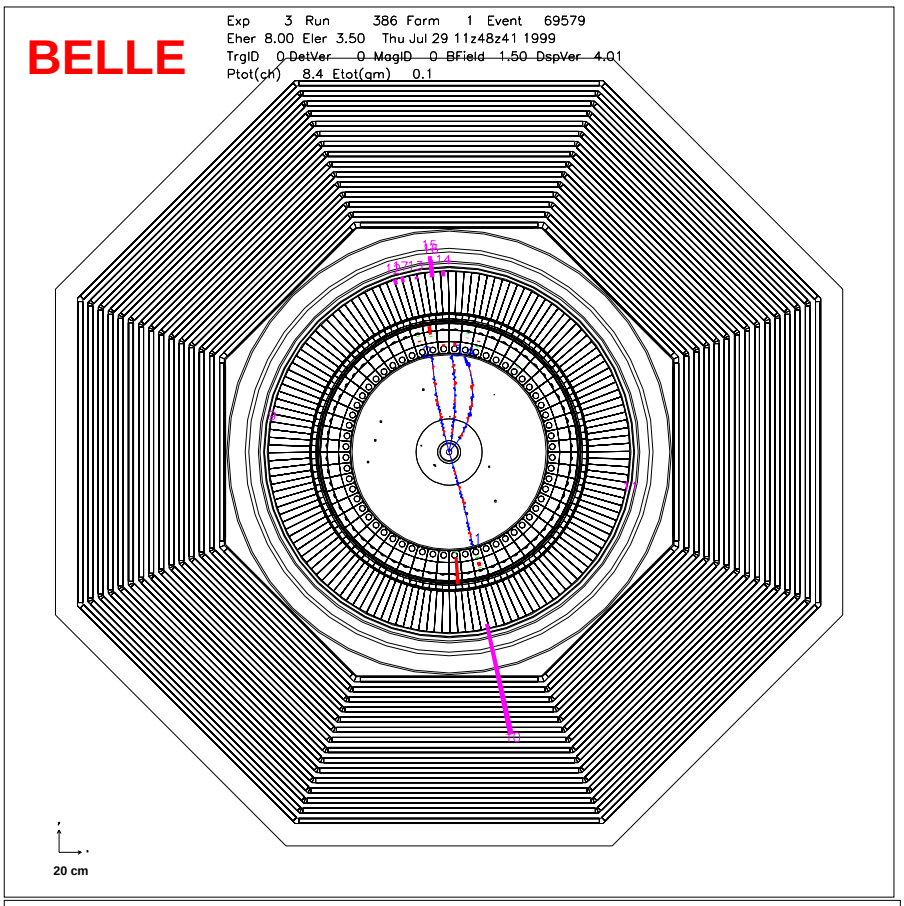


- selected samples

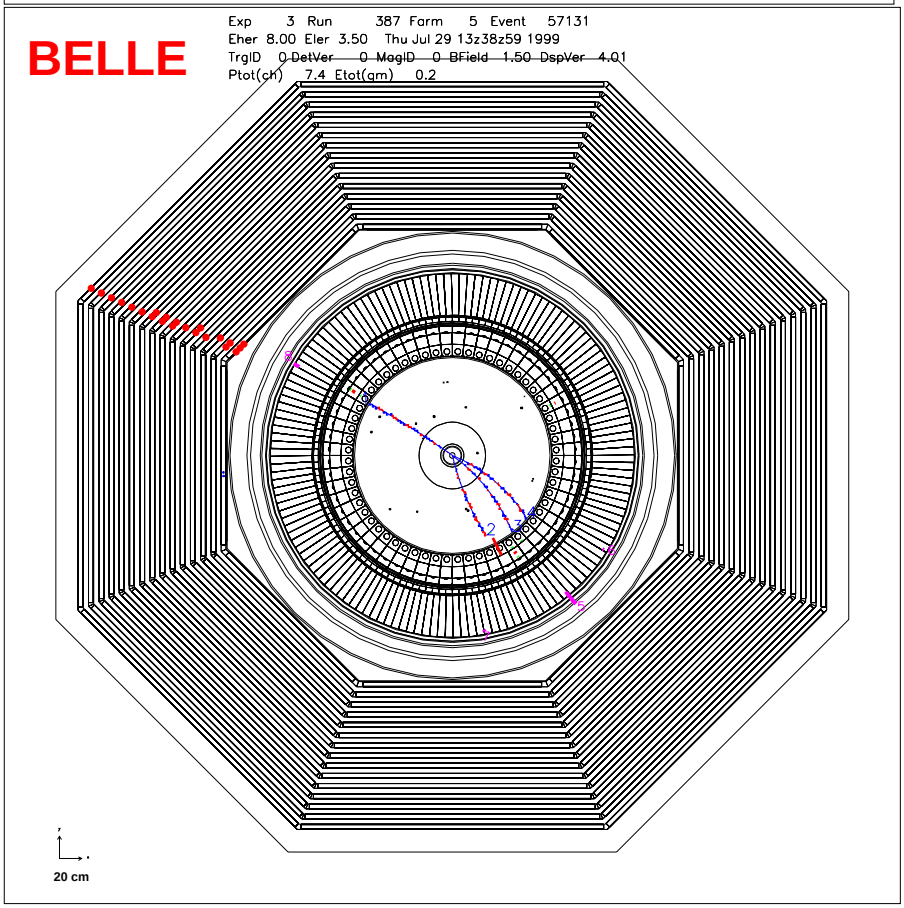
	e - 3h	μ - 3h
Data($20.8pb^{-1}$)	83	52
MC expectation		
τ pair	130	103
hadronic	0.3	0.3

1-3 topology event search

e - 3h



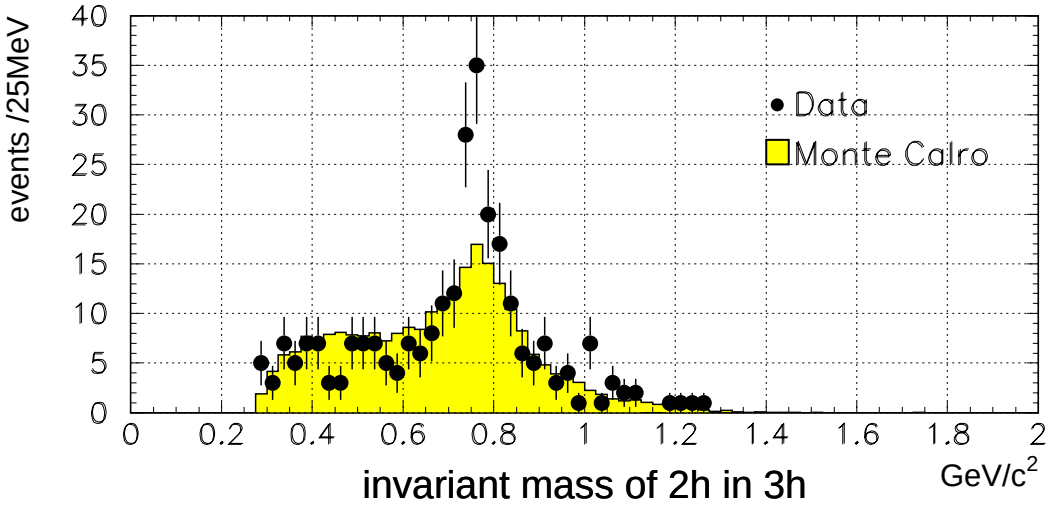
μ - 3h

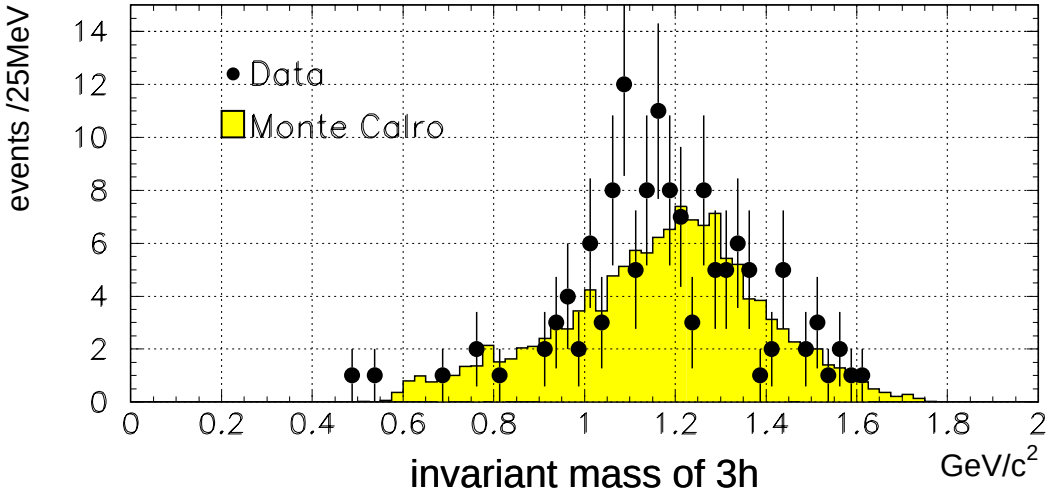


1-3 topology event search

ρ, a_1 resonance

invariant mass of 2 hadrons, 3 hadrons





- unknown sharp peak

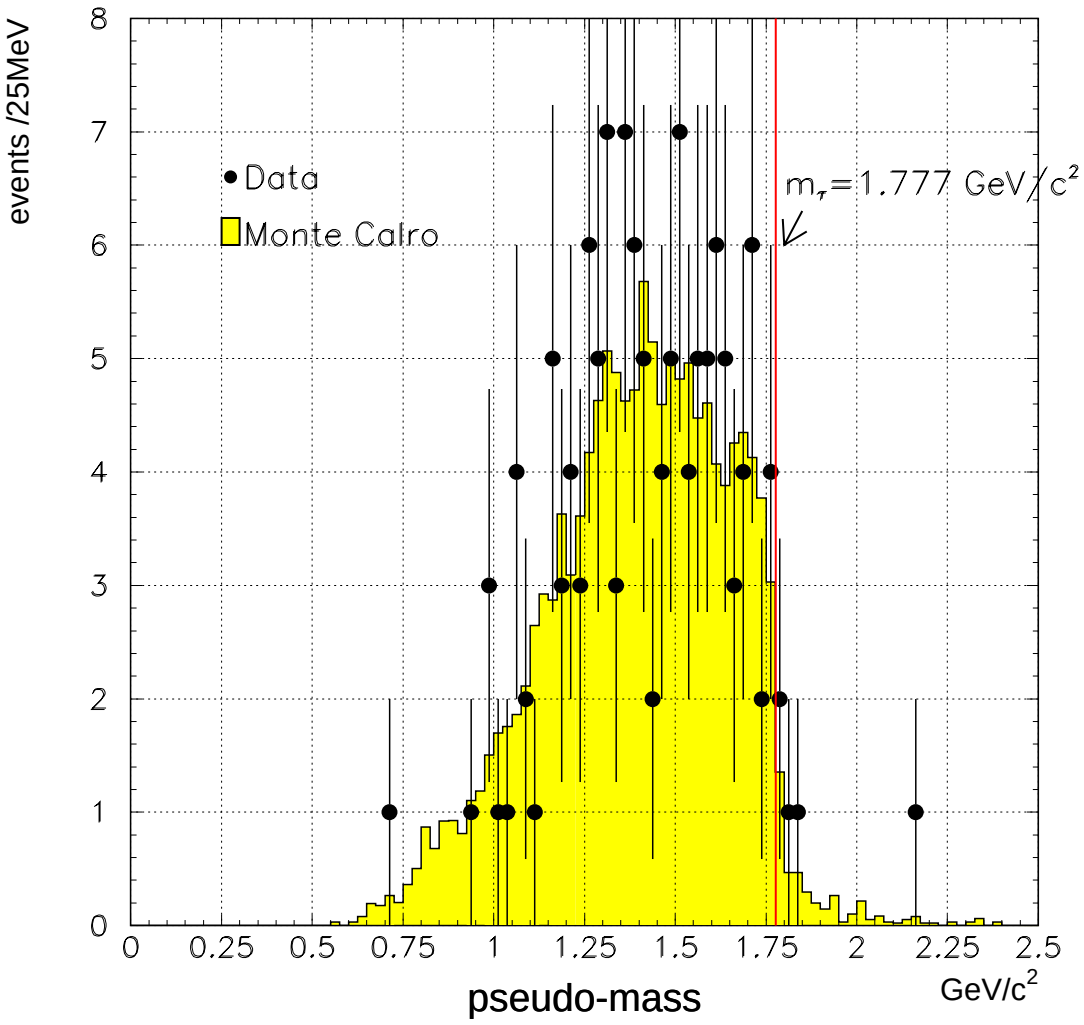
Background of other mode?

1-3 topology event search

pseudo-mass m_τ^*

$$m_\tau^{*\,2} = 2\,(E_\tau - E_{3\pi})\,(E_{3\pi} - P_{3\pi}) + m_{3\pi}^{\,2}$$

← Kinematical limit is τ mass



- τ mass limit was seen.

- π^0, $\rho^{\pm}$ in τ decay

by Hayashii

- Data: run114 - 498
- Code: b19990903

- Separate two hemisphere in the c.m. system
- Select 1-1 and 1-3 topology
- $E\gamma > 20$ MeV
- Selection Efficiency ~40%

- result

	Data	MC
m_{π^0}	133 ± 0.2 MeV	132.9MeV
σ_{π^0}	5.4 MeV	5.1 MeV
$\rho(\pi^{\pm}\pi^0)$		
M_ρ	746 ± 4 MeV	762 ± 1.5 MeV
Γ	164 MeV	152 MeV
Yield	1385 ± 80	~1500

- Test of T/CP invariance in $e^+e^- \to \tau^+\tau^-$ reaction

- Introduction

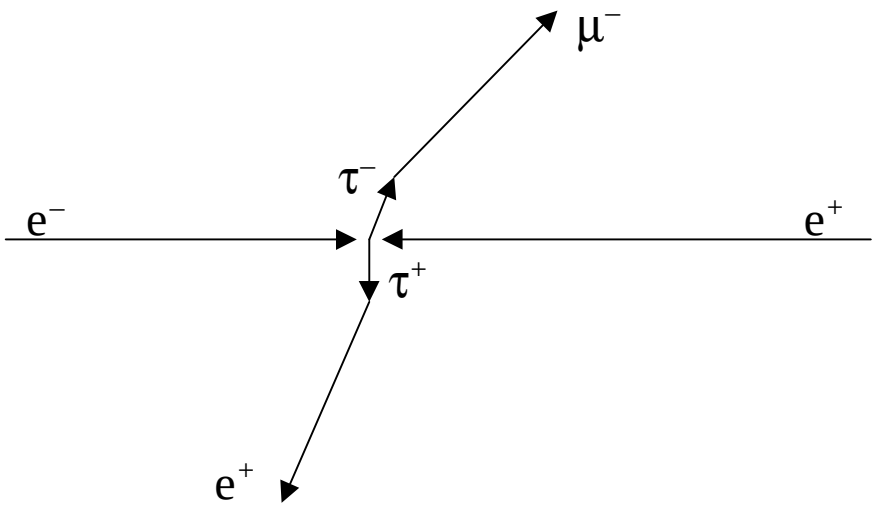
CP violation exists in K^0 system,
BELLE confirm CP violation exists in B system, and KM mechanism.

In the lepton sector,
we can expect the existence of CP violation.
τ ,the heaviest lepton, could exhibit a larger violation than others, like B.

- Reaction

$$e^+e^- \to \tau^+\tau^- \to (e^+/\mu^+)\ \nu\ \nu\ (e^-/\mu^-)\ \nu\ \nu$$

measure directions of 2 leptons(e/μ)



Test of T/CP invariance in $e^+e^- \to \tau^+\tau^-$ reaction

- Introduction

- T/CP transformation

triple momentum correlation A

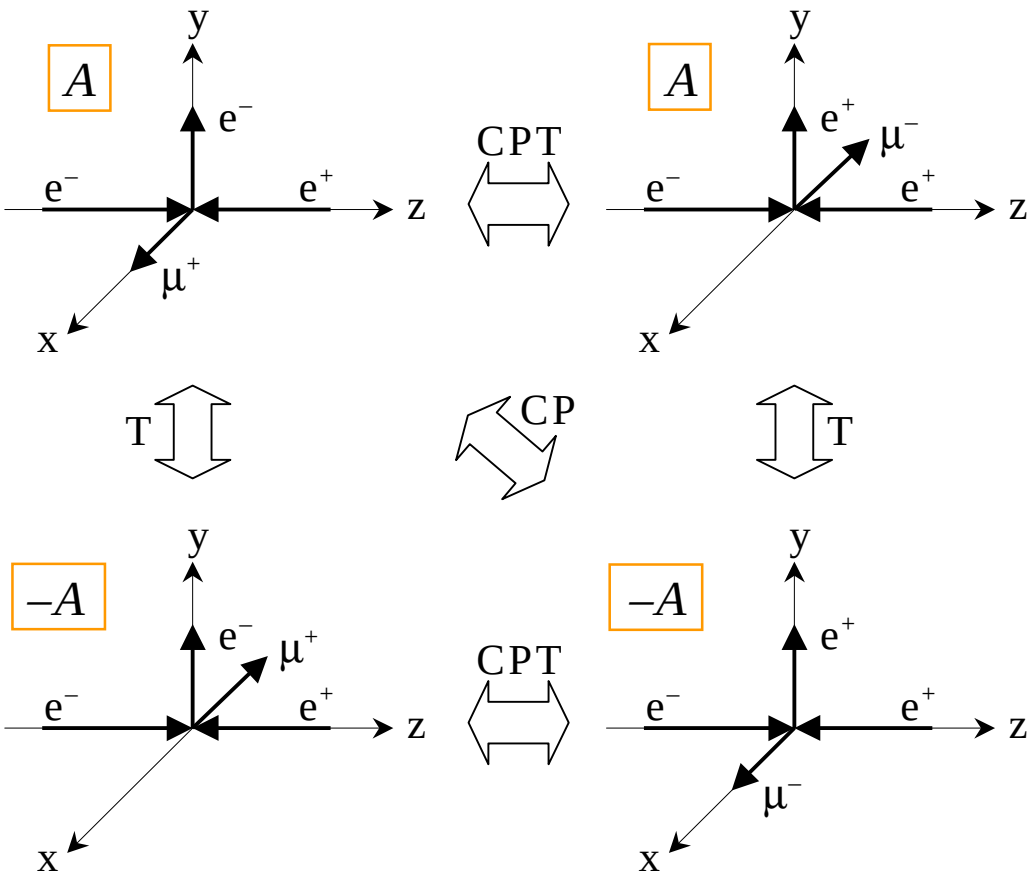
$A = p_1 \cdot (p_2 \times p_3)$

p_1: unit vector of e^- beam momentum

p_2: unit vector of e^+/μ^+ momentum

p_3: unit vector of e^-/μ^- momentum

A is odd under P and T transformation.



Test of T/CP invariance in $e^+e^- \to \tau^+\tau^-$ reaction

- Introduction

- Measurement

$N(l_2^+l_3^- ; >)$ ← the number of samples with $A>0$

$N(l_2^+l_3^- ; <)$ ← $A<0$

$$R^T(\mu^+e^-) = \frac{N(\mu^+e^- ; >)}{N(\mu^+e^- ; <)} = 1+2\delta \quad N(\mu^+e^- ; >)=N_0(1+\delta)$$

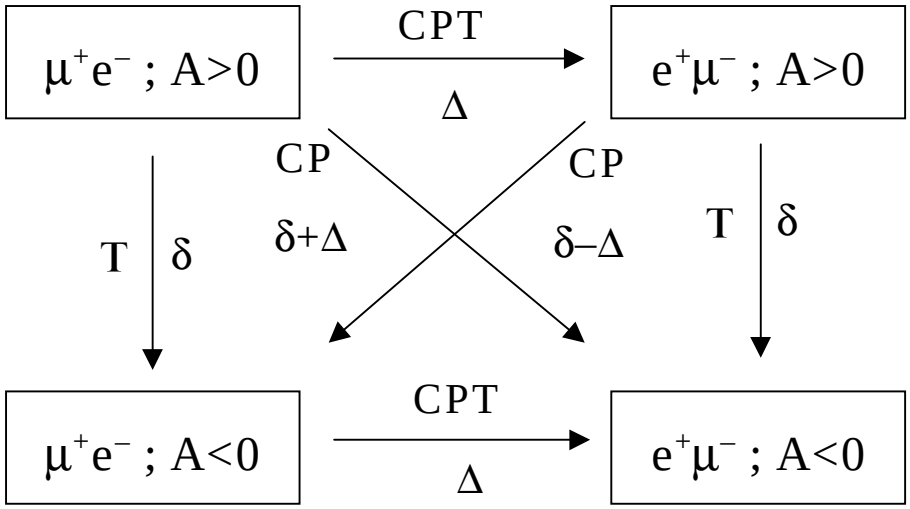
$$R^T(e^+\mu^-) = \frac{N(e^+\mu^- ; >)}{N(e^+\mu^- ; <)} = 1+2\delta$$

$$R^{CP}(\mu^+e^-) = \frac{N(\mu^+e^- ; >)}{N(e^+\mu^- ; <)} = 1+2(\delta+\Delta)$$

$$R^{CP}(e^+\mu^-) = \frac{N(e^+\mu^- ; >)}{N(\mu^+e^- ; <)} = 1+2(\delta-\Delta)$$

δ denotes T violation portion.

Δ denotes CPT violation portion.



Test of T/CP invariance in $e^+e^- \to \tau^+\tau^-$ reaction

- Introduction

When CPT holds (Δ=0)

$R^T(\mu^+e^-)=R^T(e^+\mu^-)$
$=R^{CP}(\mu^+e^-)=R^{CP}(e^+\mu^-)= 1+2\delta$

δ denotes T/CP violation portion.

In order to control the systematic uncertainty (the geometrical acceptance, detection and reconstruction efficiency, …)

$$R = R^T(\mu^+e^-)R^T(e^+\mu^-) = R^{CP}(\mu^+e^-)R^{CP}(e^+\mu^-)$$
$$= 1+4\delta$$
$$= \frac{N(\mu^+e^- ; >)}{N(\mu^+e^- ; <)} \frac{N(e^+\mu^- ; >)}{N(e^+\mu^- ; <)}$$

Deviation of *R* from 1 indicates T/CP violation.

- Statistical sensitivity

$$\left(\frac{\Delta R}{R}\right)^2 = 4\left[\left(\frac{\Delta N_0}{N_0}\right)^2 + \left(\frac{\Delta N_{BG}}{N_{BG}}\right)^2\right]$$

N_0: average of $N(l^+l^-;)$

When $\Delta N_{BG} << \Delta N_0$

$$\Delta R = 2\frac{R}{\sqrt{N_0}} \qquad \Delta\delta = \frac{1}{2\sqrt{N_0}}$$

Test of T/CP invariance in $e^+e^- \rightarrow \tau^+\tau^-$ reaction

- Simulation study

Main backgrounds are
- 2 photon(eeμμ) process
- mis-PID of π as μ

- selection criteria

cut-1 (multiplicity)
# of good charged track = 2
Net charge = 0
# of good gamma = 0

cut-2 (momentum)
Σ Pcm < 9 GeV/c
Pcm < 5 GeV/c for all track
$-0.950 < \cos(\theta_{Pmiss}) < 0.985$ → 2photon

cut-3 (PID)
$-0.60 < \cos(\theta_{Plab}) < 0.83$ → 2photon
(barrel region)

muon ID:
$P_{lab} > 1.2$ GeV/c
mu2.flag >=2

electron ID:
$P_{lab} > 0.5$ GeV/c
eid.le_noeop > 0.6, E/p > 0.6

Test of T/CP invariance in $e^+e^- \to \tau^+\tau^-$ reaction

-Simulation result

* Old MC data

mode	$\tau\,\tau$	$ee\mu\mu$	BB	conti.	$\mu\,\mu$	bhabha
Generated	400k	1M	500k *	700k *	500k *	500k *
	0.91nb	18.80nb	1.05nb	3.39nb	0.94nb	1249nb
Pre-selected	76.3%	22.3%	––	––	5.5%	0.5%
Passed cut-1	14.2%	17.7%	0	0.7%	2.2%	0.3%
cut-2	12.2%	7.7%	0	0.2%	0.7%	0.1%
observed cross-section (pb)						
$e^+\mu^-$	4.7pb	0.1	0	0	0	0
μ^+e^-	4.7	0.1	0	0	0	0
e^+e^-	5.9	0	0	0	0	20
$\mu^+\mu^-$	3.5	3.4	0	0	1.9	0

for $\tau\,\tau$	accepted rates	mis-PID rate
$e^+\mu^-$	0.52%	2.5%
μ^+e^-	0.52%	1.6%
e^+e^-	0.65%	0.3%
$\mu^+\mu^-$	0.41%	7.6%

$$\text{accepted rate} = \frac{\#\text{ of selected samples}}{\#\text{ of generated events}}$$

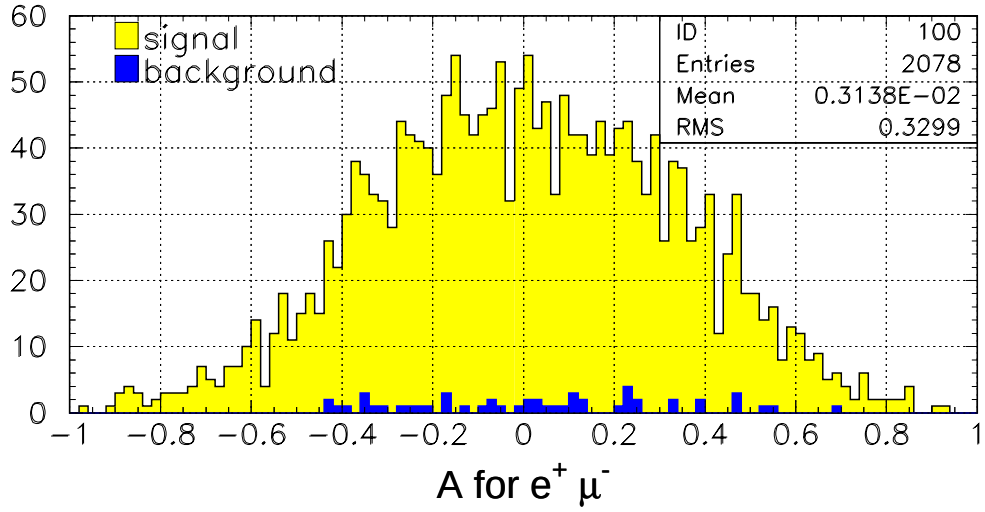
Test of T/CP invariance in $e^+e^- \rightarrow \tau^+\tau^-$ reaction

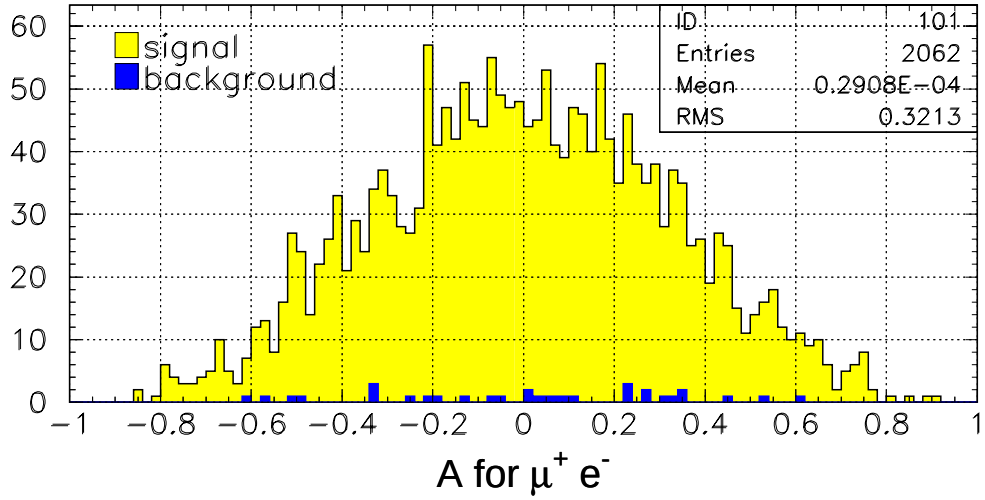
- Simulation result

triple momentum correlation $A = p_1 \cdot (p_2 \times p_3)$

p_1: unit vector of e^- beam momentum
p_2: unit vector of e^+/μ^+ momentum
p_3: unit vector of e^-/μ^- momentum

Triple momentum correlation A for MC





- A distribution is symmetric.
- Background is small and also symmetric.
  → Background does not affect R.

Test of T/CP invariance in $e^+e^- \to \tau^+\tau^-$ reaction
- Simulation result

for $\tau\,\tau$ 400k sample ($0.44 fb^{-1}$)

$e^+\mu^-$ 2078 events

$A>0$ 1041

$A<0$ 1037

μ^+e^- 2062 events

$A>0$ 1024

$A<0$ 1038

Backgrounds

eeμμ	~2%	$(\Delta N_{BG}/\Delta N_0)^2 \sim 0.02$
mis-PID	~2%	$(\Delta N_{BG}/\Delta N_0)^2 \sim 0.02$

Others are less than the above.

$$\Delta R = 2\frac{R}{\sqrt{N_0}}\sqrt{1+\left(\frac{\Delta N_{BG}}{\Delta N_0}\right)^2}$$

$\to$ not effective to R and δ.

$R = 0.990 \pm 0.062$

$\Delta\delta = 0.016$ at $0.44 fb^{-1}$

Test of T/CP invariance in $e^+e^- \to \tau^+\tau^-$ reaction

- Data analysis

Data 20.8pb^{-1}

- selected samples

	$e^+\mu^-$	μ^+e^-
Data	77	85
$A>0$	42	45
$A<0$	35	40
MC expectation		
τ pair	98	96
ee$\mu\mu$	3.9	5.9

$R = 1.35 \pm 0.42$

$\Delta\delta = 0.079$

$\to$ # of selected sample difference (Data $\leftrightarrow$ MC)

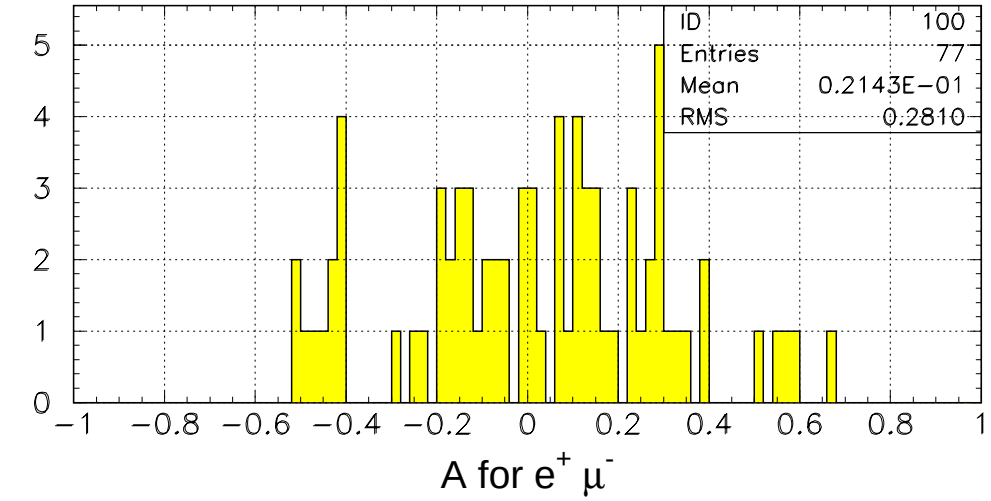
- Hardware trigger effect

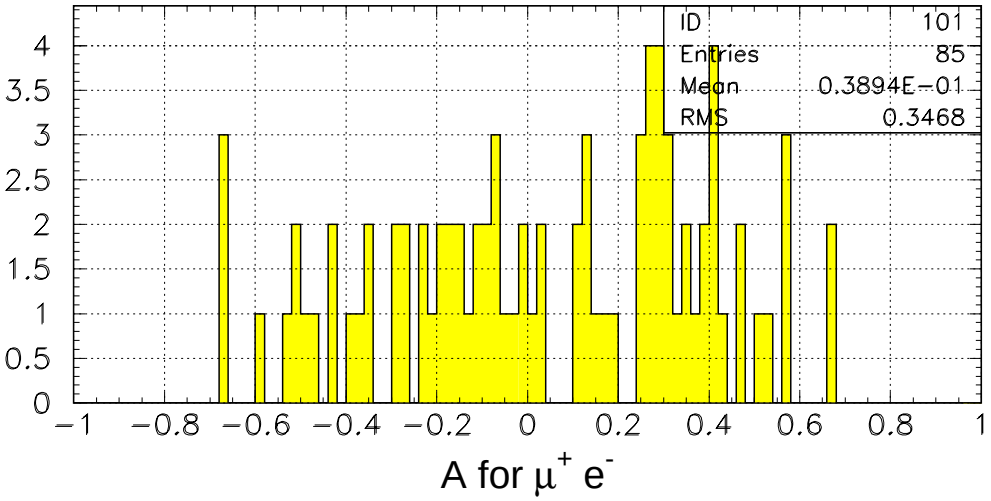
$\to$ use trigger simulator for MC.

Test of T/CP invariance in $e^+e^- \rightarrow \tau^+\tau^-$ reaction - Data analysis result

triple momentum correlation A

Triple momentum correlation A for data





Statistics is low…

- Summary and plan

- τ related things
  clear $\rho^{\pm}$ resonance from τ
  pseudo-mass disribution → τ mass
  - need more event selection study (1-3)

- Test of T/CP invariance
  $e^+e^- \to \tau^+\tau^- \to e\ \mu\ 4\nu$ (pure leptonic reaction)
  triple momentum correlation A
  → R ratio

  - Simulation study
    $N_{e^+\mu^-} + N_{\mu^+e^-}$ ~ 4,000 events at 0.44fb^{-1}
    Background 2 photon(eeμμ) ~2%
    mis-PID (μ/π) ~2%
    $R = 0.990 \pm 0.062$
    $\Delta\delta = 0.016$
  - Data analysis (20.8pb^{-1})
    $N_{e^+\mu^-} + N_{\mu^+e^-}$ = 162 events
    $R = 1.35 \pm 0.42$
    $\Delta\delta = 0.079$

  - Plan
    - use trigger simulator for MC
    - Background study
      2 photon background in real data
      Muon ID study (by τ → hadrons)