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BELLE における $e^+e^- \to \tau^+\tau^-$ 反応での T/CP 対称性の検証

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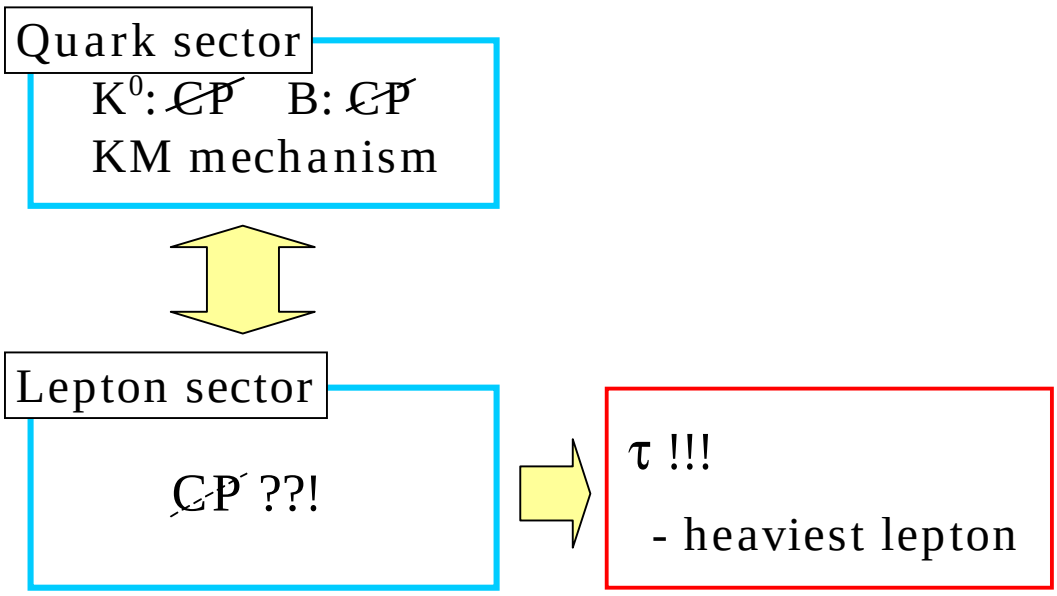
- contents
  - Test of T/CP invariance in $e^+e^- \to \tau^+\tau^-$ reaction
    - Introduction
    - Simulation study
    - Data analysis
    - Summary and plan

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

- Introduction

- motivation



- "τ" at BELLE

  - High luminosity ($10\sim100 fb^{-1}$)
    $\leftrightarrow$ CLEO $\sim19 fb^{-1}$
  - Cross-section of τ pair (~0.91nb)
    almost same as BB (~1.05nb)

  $\to$ High statistics as well as B
  10M ~ 100M sample

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

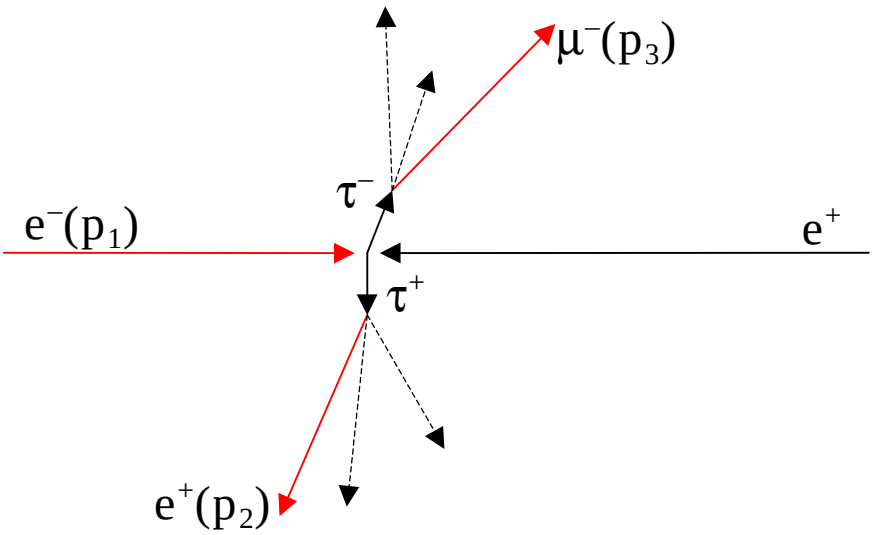
- Introduction

- Reaction

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

- pure leptonic reaction
- BR ~ 6% (~17%×18%×2)

measure directions of 2 leptons(e/μ)



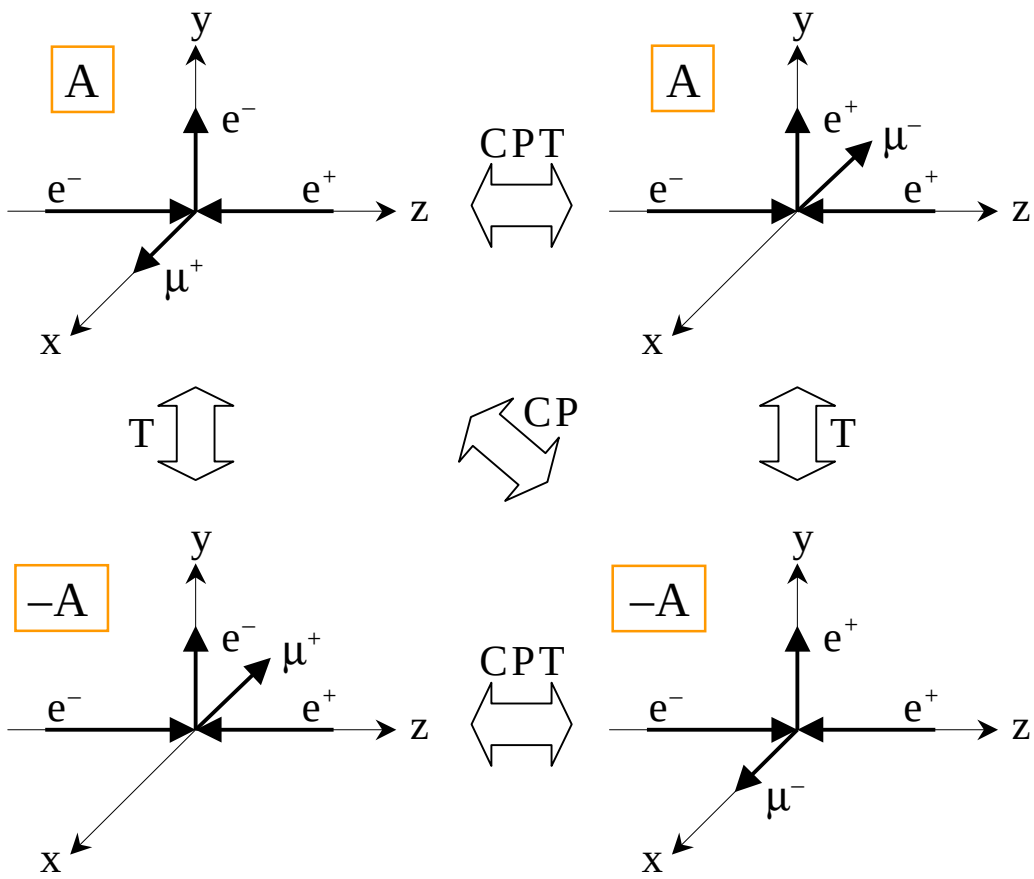
triple momentum correlation A

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

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

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

- T/CP/CPT transformation



- Measurement

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

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

- Introduction

- Measurement

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

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

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

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

δ : T violation portion.
Δ : CPT violation portion.

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 : T/CP violation portion.

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

- Introduction

- control the systematic uncertainty

  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

$\to$ 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 $e^+e^- \to \tau^+\tau^-$ reaction

- Simulation study

Main backgrounds are

- 2 photon($ee\mu\mu$) process
  cross-section ~19nb $\leftrightarrow$ τ pair:0.91nb
- 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)

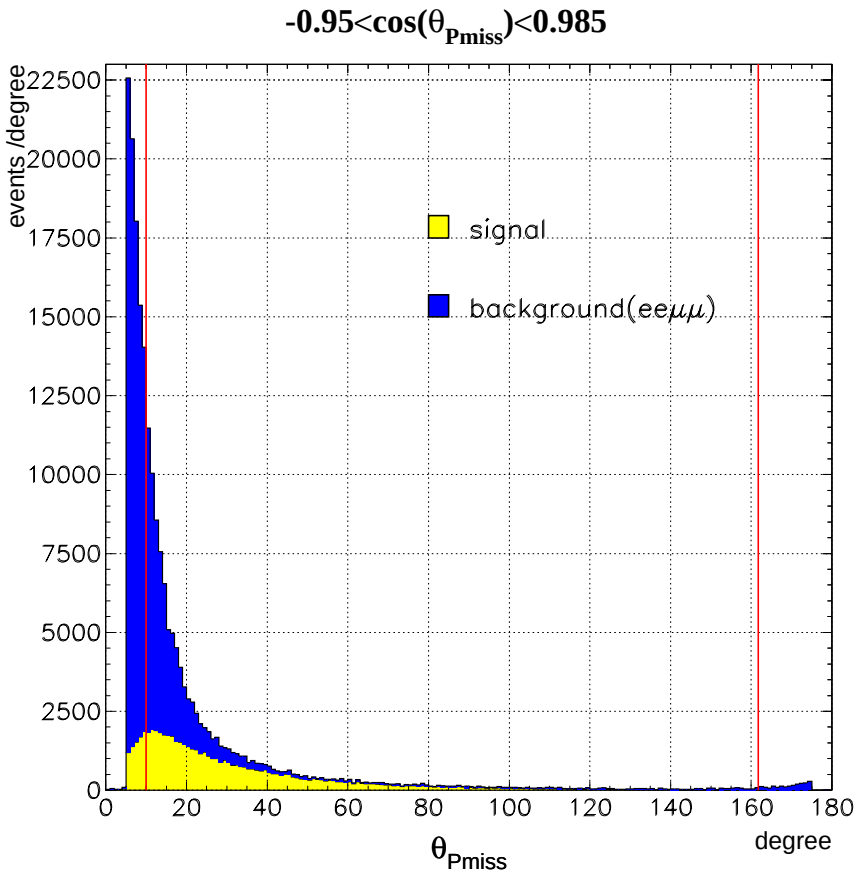
Σ Pcm < 9 GeV/c
Pcm < 5 GeV/c for all track
$-0.950 < \cos(\theta_{Pmiss}) < 0.985$ $\to$ 2photon

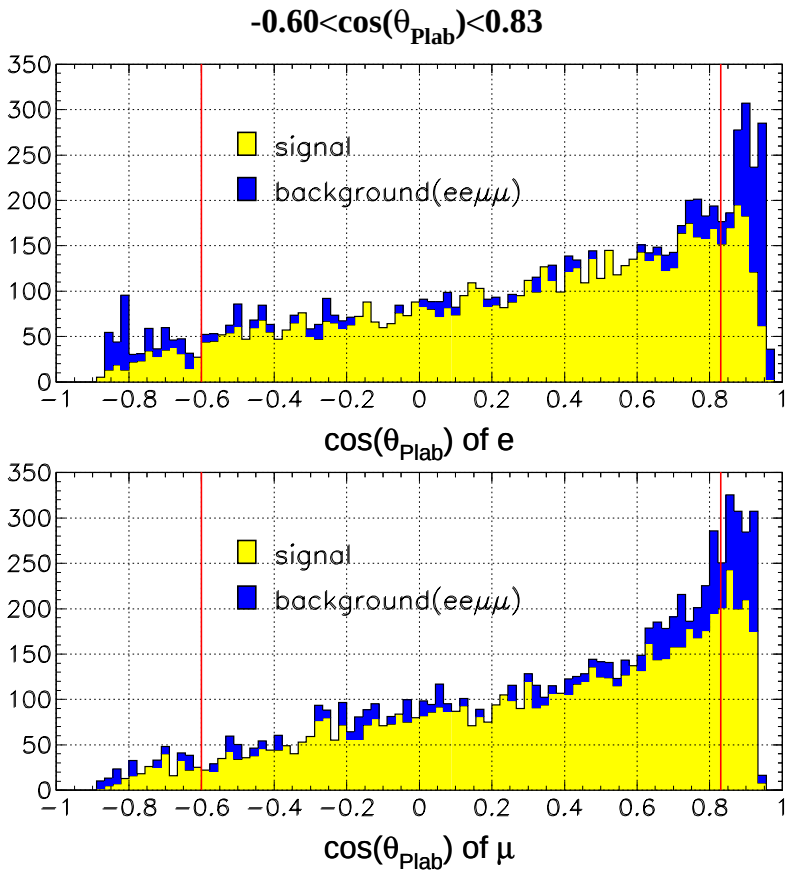
cut-3 (PID)

$-0.60 < \cos(\theta_{Plab}) < 0.83$ $\to$ 2photon
(barrel region)
muon ID: by KLM detector
$P_{lab} > 1.2$ GeV/c
fake rate: a few %
electron ID: by CsI calorimeter, dE/dx(CDC)
$P_{lab} > 0.5$ GeV/c
fake rate: < 1 %

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

2 photon(eeμμ) background rejection





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

-Simulation result

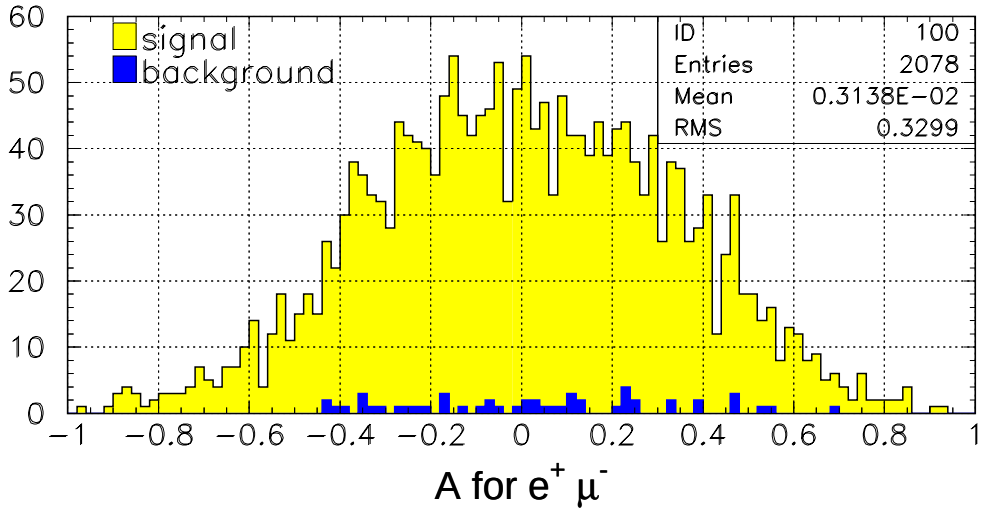
* Old MC data

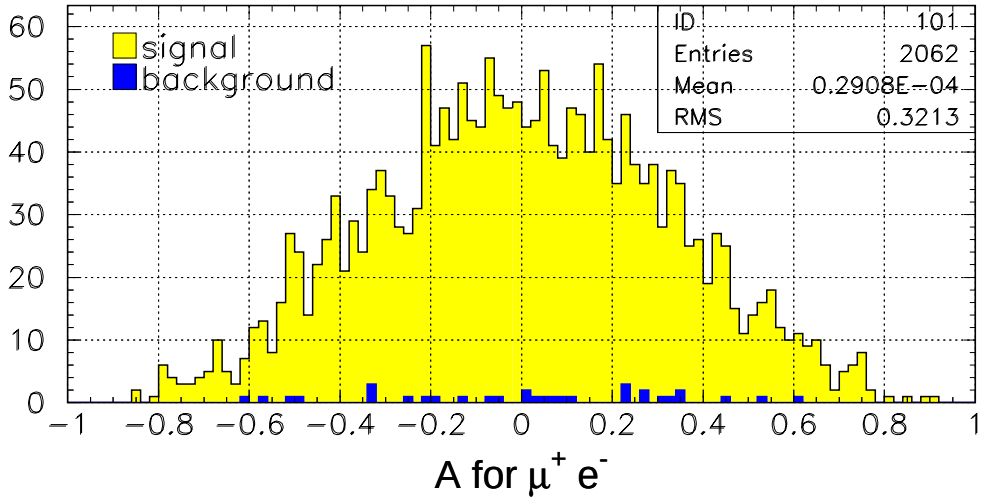
mode	$\tau\tau$	$ee\mu\mu$	BB	conti.
Generated	400k	1M	500k *	700k *
	0.91nb	18.80nb	1.05nb	3.39nb
Pre-selected	76.3%	22.3%	––	––
Passed cut-1	14.2%	17.7%	0	0.7%
cut-2	12.2%	7.7%	0	0.2%
observed cross-section (pb)				
$e^+\mu^-$	4.7 (0.52%)	0.1 (~10^{-5})	0	0
mis-PID	2.5%			
μ^+e^-	4.7 (0.52%)	0.1 (~10^{-5})	0	0
mis-PID	1.6%			

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

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

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 τ pair sample at $0.44 fb^{-1}$

$e^+\mu^-$ 2078 events (A>0:1041 A<0:1037)
μ^+e^- 2062 events (A>0:1024 A<0:1038)

→ efficiency ~ 17%

Backgrounds
ee$\mu\mu$ ~2%
mis-PID ~2%
Others are less than the above.
→ almost negligible

$R = 0.990 \pm 0.062$

$\Delta\delta = 0.016$ 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	98
ee$\mu\mu$	2.0	2.7

$R = 1.35 \pm 0.42$

$\Delta\delta = 0.079$

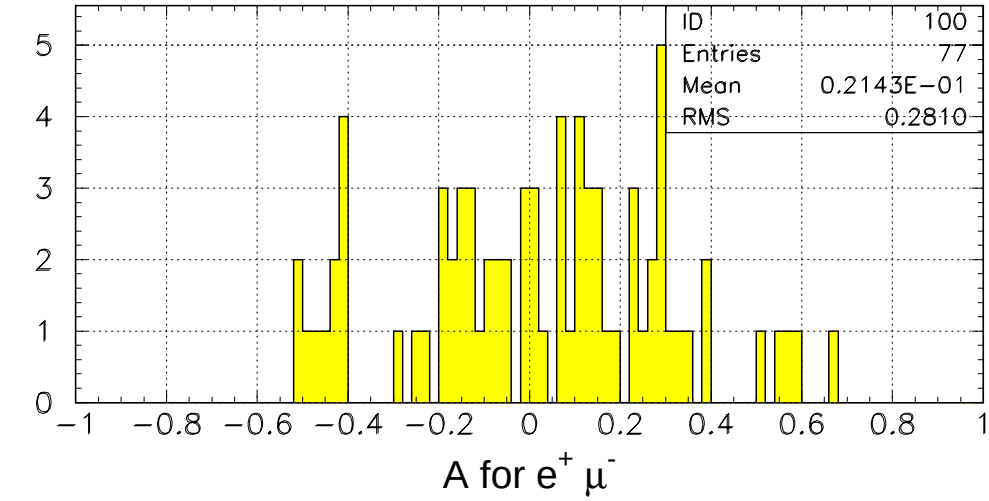
→ # of selected sample difference (Data ↔ MC)

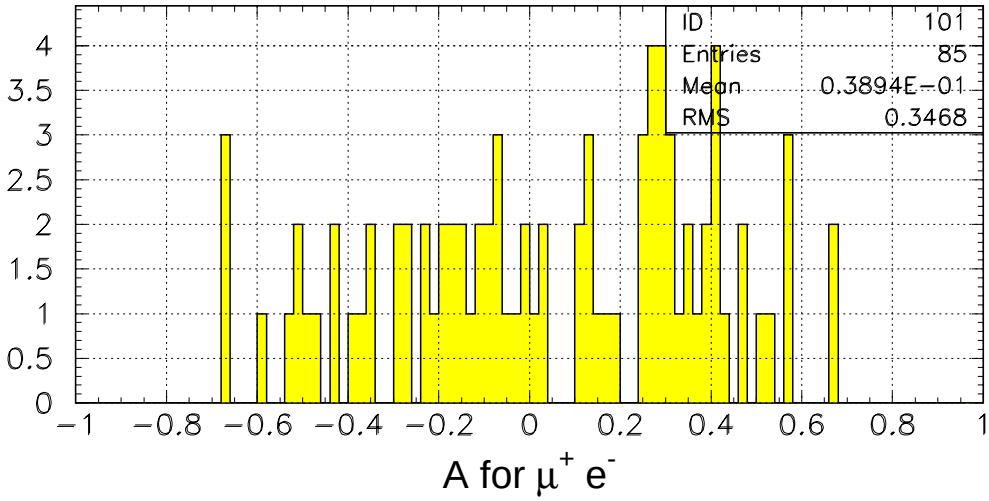
- Hardware trigger effect

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

- Test of T/CP invariance

$e^+e^- \to \tau^+\tau^- \to e\,\mu\,4\nu$ (pure leptonic reaction)
triple momentum correlation A
$\to R$ ratio

- Simulation study

  $N_{e+\mu-} + N_{\mu+e-} \sim 4{,}000$ events at 0.44fb^{-1}

  efficiency 17% (accepted rate 0.52%)

  Background 2 photon($ee\mu\mu$) ~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

  $R = 1.35 \pm 0.42$
  $\Delta\delta = 0.079$

  $\to$ need more data…

$\to$ first target: a few fb^{-1}
$\Delta\delta < 1\%$