Search for the second class current with the τ decay into πην

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Abstract:
The hadronic weak currents without strangeness can be classified into the first- (second-) class currents, according to their G-transformation properties and defined as having $PG(-1)^J = +1\ (-1)$, where P is parity, G is G-parity and J is spin of the decay current. In the Standard Model, the second-class current is strongly suppressed due to isospin symmetry and no such current has been observed so far. The tau decay $\tau\to\pi\eta\nu$ can be induced through the second-class current only and various theoretical predictions give for its branching fraction O(10^{-5}), that is reachable with the available Belle data sample. We report status of our analysis of $\tau\to\pi\eta\nu$, based on Monte Carlo simulated samples corresponding to Belle full data.

1. Introduction

Belle experiment

The Belle experiment is not only a B-factory but also a τ-factory. The world's largest statistics of tau, ~ 10^9 $\tau\tau$ pair events have been collected at the Belle detector.

KEKB

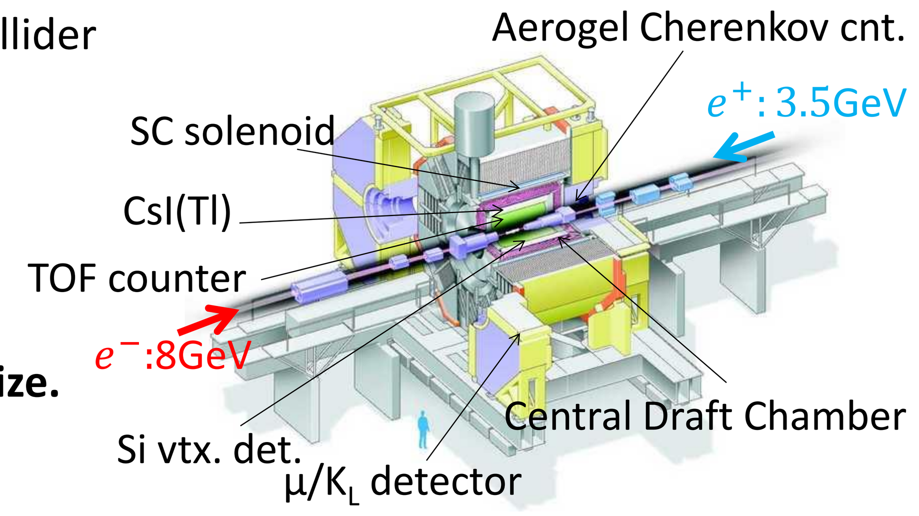
electron – positron asymmetric energy collider

- $E_{e^-} = 8$ GeV, $E_{e^+} = 3.5$ GeV
- Peak luminosity = 2.11 × 10^{34} $cm^{-2}s^{-1}$
- Integrated luminosity $\int Ldt \cong 1\text{ab}^{-1}$

Υ_{4S} = 702.9fb^{-1}
$\Upsilon_{4S}, \Upsilon_{5S}$, continuum $= 915.1\text{fb}^{-1}$

(Basic study is done only with Υ_{4S} data size. And then, the results are normalized $\Upsilon_{4S}, \Upsilon_{5S}$, continuum data size.)

Belle detector



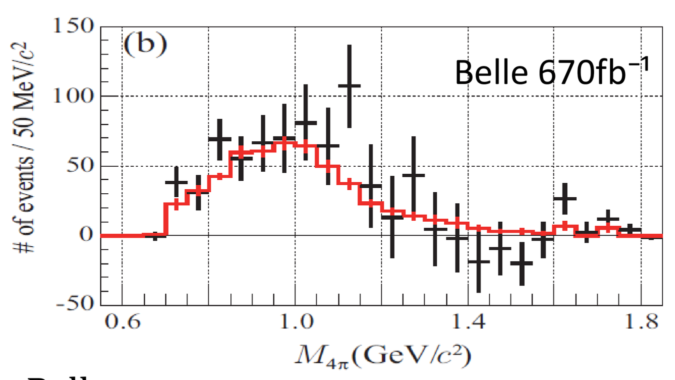
Analysis motivation

The weak hadronic currents without strangeness can be classified into two types depending on G-parity(G);

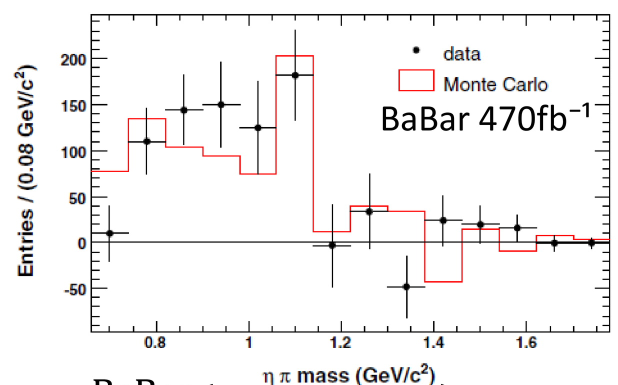
$PG(-1)^J = +1$: first-class current (fcc)
$PG(-1)^J = -1$: second-class current (scc)

(P: parity, J: spin of the decay current)

$\tau\to\pi\eta\nu$ can be realized through SCC.
Theoretical predictions: BR($\tau\to\pi\eta\nu$)~10^{-5}.



$\text{Br}^{\text{Belle}}(\tau^-\to\pi^-\eta\nu)$
$= (4.4\pm1.6\pm0.8)\times10^{-5}$ (2.4σ)
$< 7.3\times10^{-5}$ CL=90%
(Hayasaka, PoS'09)



$\text{Br}^{\text{BaBar}}(\tau^-\to\pi^-\eta\nu)$
$= (3.4\pm3.4\pm2.1)\times10^{-5}$
$< 9.9\times10^{-5}$ CL=95%
(P.del Amo Sanchez et.al,PRD 83 032002(2011))

Hereafter, the $\text{Br}^{\text{Belle}}(\tau^-\to\pi^-\eta\nu)$ = 4.4 × 10^{-5} is used as a reference.

2. Selection criteria of $\tau\to\pi\eta\nu, \eta\to\pi\pi\pi^0$

- Definition of good charged track

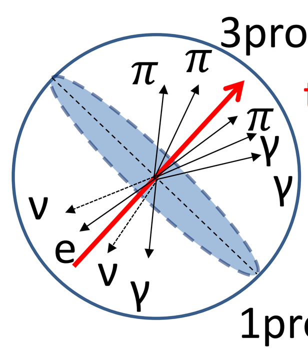
$P_t > 0.06\text{GeV/c}^2$ in Barrel (-0.6235 < cosθ < 0.8332)
$P_t > 0.1\text{GeV/c}^2$ in Endcap (-0.8660 < cosθ ≦ -0.6235, 0.8332 ≦ cosθ < 0.9563)
helix: |dr| ≦ 1cm, |dz| ≦ 5cm

- Definition of good gamma

-0.8660 < cosθ < 0.9563 & $E_\gamma > 0.05$GeV

- Missing angle at lab frame: -0.8660 < $\cos\theta_{miss}$ < 0.9563
- Divide the event by the thrust vector into two hemispheres - the tag and signal sides

Tag-side (leptonic tag; $\tau\to l\nu\nu$):
Allow 1 lepton and ≦1γ (to accept FSR or ISR)
invariant mass of all tag-side: $M_{tag} < 1.8\text{GeV/c}^2$
Signal side:
Allow 3π and 2γ only ($0.105 < M_{\gamma\gamma} < 0.165$GeV).
$M_{sig} < 1.2\text{GeV/c}^2$



3. Main BG modes

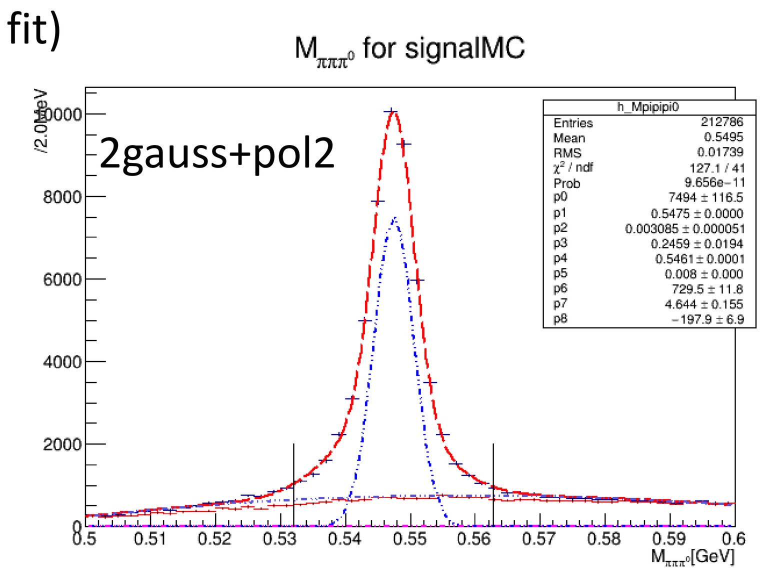
The main background (BG) comes from decay modes in the list to the right.
Since $\tau\to\pi\eta\pi^0\nu$ and $K^*(\to K_L\pi)\eta\nu$ have much larger Br than expected Br for signal, their rates seriously affect the systematics.
The amounts of Monte Carlo samples used for the processes (generic $\tau\tau$, $q\bar{q}$) are at least five times larger than the experimental data.

- η peaking BG
  - $\tau\to\pi\eta\pi^0\nu$(π^0 missing): Br=(1.39±0.07) × 10^{-3}
  - $\tau\to K^*\eta\nu, K^*\to K_L\pi$ (K_L missing): Br=(1.38±0.15) × 10^{-4}
  - $\tau\to K\eta\nu$ (Pid misidentification): Br= (1.55±0.08) × 10^{-4}
  - $q\bar{q}$ including π and η
- Non-peaking BG
  - $\tau\to\pi\pi\pi\pi^0\nu$: Br=(4.62±0.05)%
  - $\tau\to\pi\pi\pi\nu$ with fake π^0

4. MC Study

Signal MC study

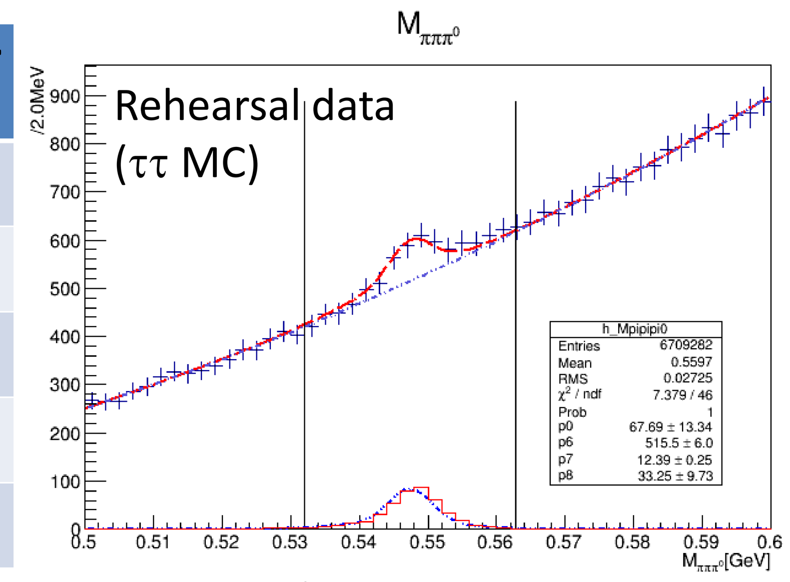
signal extraction:
yield is evaluated by a fit for the eta peak in the $M_{\pi\pi\pi^0}$ distribution.
using both $\pi^+\pi^-\pi^0$combinations ($\tau^-\to\pi^-\pi^+\pi^-\pi^0\nu$) from signal-side particles
(π^0 4momentum is obtained from Kinematical fit)
Fit with 2Gaussian + 2nd polynomial function.
Signal region is defined as 547±15MeV that corresponds to mean ± 5σ region of the main peak of the signal shape (blue gauss).
(4.64±0.03) × 10^4 events are obtained from 1.3 × 10^7 events.
→ **Efficiency is 0.350±0.002%**



Estimation for eta peaking BGs

- using generator info., pick up BG mode
- make $M_{\pi\pi\pi^0}$ histogram
- perform a fit with signal shape and 2nd polynomial (signal shape is fixed and evaluated using signal MC)
- yield and its statistical error are obtained by the fit.

	# of η (fit result) for 702 fb^{-1} samples
yield for rehearsal data ($\tau\tau$MC)	419.05 ± 82.57
yield for $M_{\pi\pi\pi^0}$ of $\tau\to K\eta\nu$	35.15 ± 2.24
yield for $M_{\pi\pi\pi^0}$ of $\tau\to K^*\eta\nu$	113.98±4.07
yield for $M_{\pi\pi\pi^0}$ of $\tau\to\pi\pi^0\eta\nu$	259.09±6.13
$q\bar{q}$BG	72.85±14.10



For the demonstration, we consider ττ MC sample as a 702 fb^{-1} data samples here. (rehearsal data)
The signal yield is estimated by the difference (null result):

$$N^{\tau\tau}_{\pi\pi\pi^0} - \left(N^{K\eta\nu}_{\pi\pi\pi^0} + N^{K^*\eta\nu}_{\pi\pi\pi^0} + N^{\pi\pi^0\eta\nu}_{\pi\pi\pi^0}(+N^{q\bar{q}}_{\pi\pi\pi^0})\right) = 16.06 \pm 86.04$$

Since ττ MC don't have τ→πην events, this yield is expected to be 0.
($N^{q\bar{q}}_{\pi\pi\pi^0}$is included into error only)

significance

When number of signal N_{sig} and significance are defined as $2\epsilon' N_{\tau\tau pair} Br(\tau\to\pi\eta\nu)$ and $\frac{N_{sig}}{N_{sigerr}}$, significances for each assumption of luminosity L and $Br(\tau\to\pi\eta\nu)$ are shown in the table below.

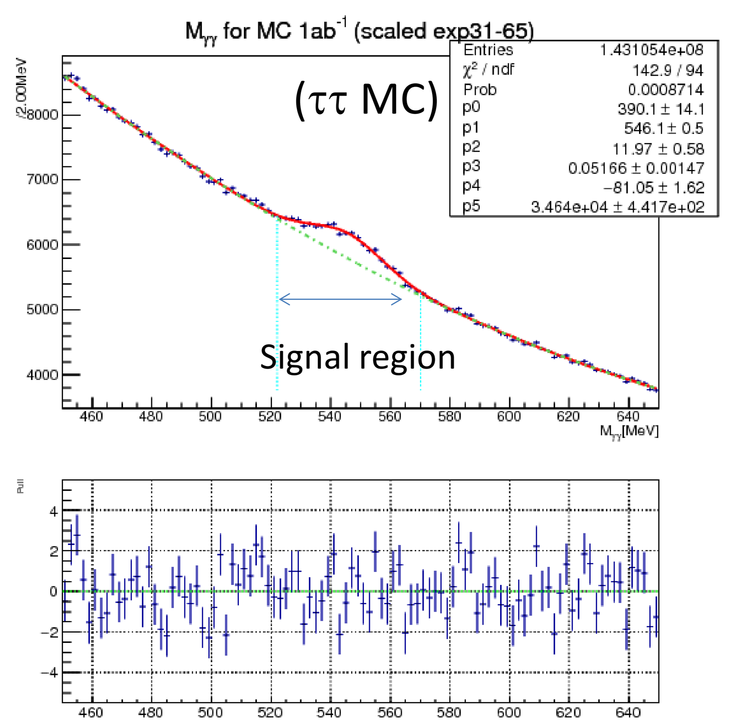
$Br(\tau\to\pi\eta\nu)$	L, fb^{-1}	N_{sig}	significance, σ
4.4×10^{-5}	702.9	245	2.3
	915.1	259	2.6
1.0×10^{-5}	702.9	45	0.5
	915.1	59	0.6

5. $\tau\to\pi\eta\nu, \eta\to\gamma\gamma$

In the previous study, this process is not considered since it has huge BG.
But according to rough estimations, it turns out that this also has similar significance.
This should be also seriously considered later.

Efficiency for signal MC = 1.50%.
In the case of $Br(\tau\to\pi\eta\nu) = 4.4\times10^{-5}$ and $\mathcal{L} = 915.1\text{fb}^{-1}$, $\#\ of\ signal = 1111$ and yield for rehearsal data ($\tau\tau MC$) = 1.3 × 10^5.
rough significance[σ]=

$$\frac{\#\ of\ Signal}{\sqrt{\#\ of\ BG + \#\ of\ Signal}} = 3.0\sigma$$



6. Summary & discussion

- In order to search for $\tau\to\pi\eta\nu$, we study the sensitivity using $\tau\to\pi\eta\nu$ with $\eta\to\pi\pi\pi^0$, based on Monte Carlo simulated samples corresponding to Belle's full data.
- We evaluate significance with full data (915fb^{-1}: $\Upsilon_{4S}, \Upsilon_{5S}$, continuum). It is 2.6σ for $Br(\tau\to\pi\eta\nu) = 4.4\times10^{-5}$ or 0.6σ for $Br(\tau\to\pi\eta\nu) = 1.0\times10^{-5}$.
- For $\tau\to\pi\eta\nu$ with $\eta\to\gamma\gamma$, 3.0σ may be expected with $Br(\tau\to\pi\eta\nu) = 4.4\times10^{-5}$ and full data. We need to study it more seriously to combine.
- If the hadronic tag ($\tau\to\pi\nu$) is included, according to naive estimation that multiplied by square root of efficiency increase, the significance is 3.4σ for $Br(\tau\to\pi\eta\nu) = 4.4\times10^{-5}$ and full data.
- **We aim for the first evidence of second class current !**