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

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The second-class current

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) ←not observed

(P is parity and J is spin of the decay current)

In the Standard Model, the SCC is strongly suppressed due to isospin symmetry and no such current has been observed so far.

The second-class current τ decay mode : $\tau \to \pi\eta\nu$

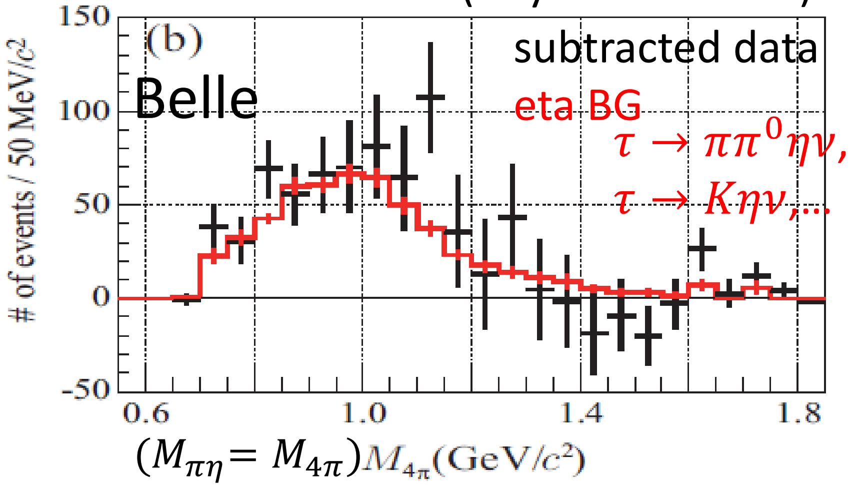
For the second-class current τ decay, $\tau \to \pi\eta\nu$ ($J^{PG} = 0^{+-}$)

⇒ $\tau \to \pi\eta\nu$ can be realized through the SCC.

$\tau \to \pi\eta\nu$ 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.

(Hayasaka PoS'09)



Previous study:

$Br^{Belle}(\tau^- \to \pi^-\eta\nu)$ @ 670fb^{-1}

$= (4.4 \pm 1.6 \pm 0.8) \times 10^{-5}$ (2.4σ)

$< 7.3 \times 10^{-5}$ CL=90% (un-published)

$Br^{BaBar}(\tau^- \to \pi^-\eta\nu)$ @ 470fb^{-1}

$= (3.4 \pm 3.4 \pm 2.1) \times 10^{-5}$

$< 9.9 \times 10^{-5}$ CL=95%

(P.del Amo Sanchez et.al,PRD 83 032002(2011))

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

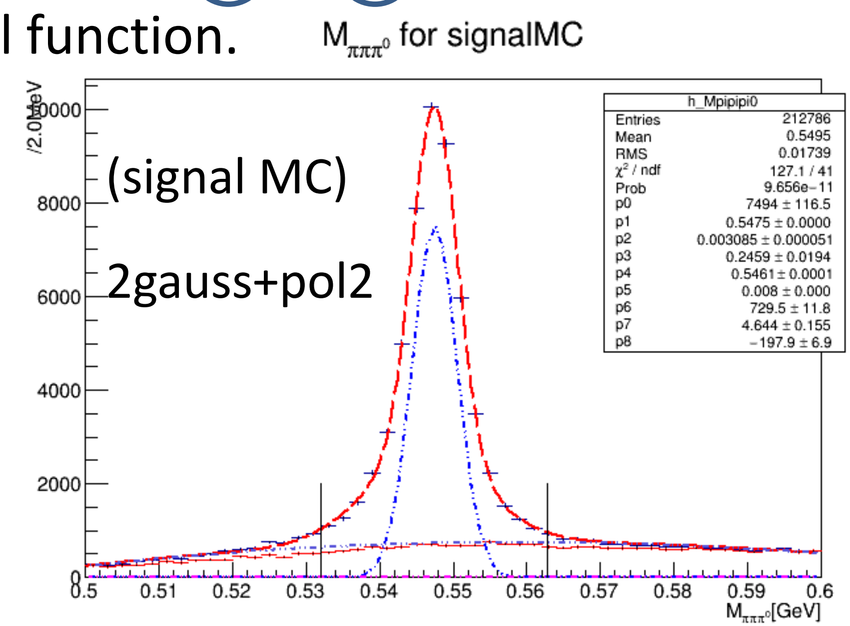
$M_{\pi\pi\pi^0}$ distribution for signal MC

- Using selected events:
  - signal: $\boldsymbol{\tau \to \pi\eta(\eta \to \pi\pi\pi^0)\nu}$
  - Tag: $\tau \to l\nu\nu$ (leptonic tag)

(The selection criteria is shown in poster)

- **signal extraction: yield is evaluated by a fit for eta peak on $\boldsymbol{M_{\pi\pi\pi^0}}$ distribution.**
  - using both $\pi^+\pi^-\pi^0$combinations ($\tau^- \to \pi^-\pi^+\pi^-\pi^0\nu$)
- 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%**



Main BG modes

Main BG modes are divided into the following.
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.

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

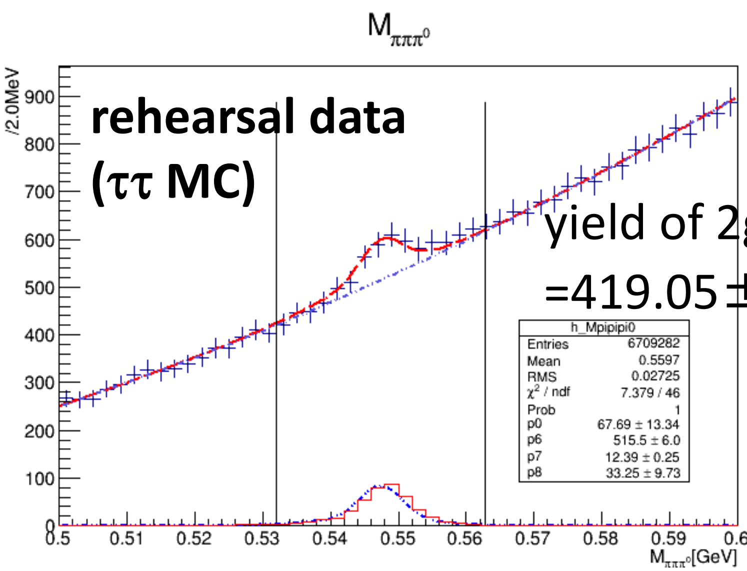
- Non-peaking BG
  - $\tau \to \pi\pi\pi\pi^0\nu$:
    Br=(4.62 $\pm$ 0.05)%
  - $\tau \to \pi\pi\pi\nu$ with fake π^0

η signal extraction

- **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:

$$N_{\pi\pi^0}^{\tau\tau} - \left(N_{\pi\pi^0}^{K\eta\nu} + N_{\pi\pi^0}^{K^*\eta\nu} + N_{\pi\pi^0}^{\pi\pi^0\eta\nu}\left(+N_{\pi\pi^0}^{q\bar{q}}\right)\right) = 16.\ 06 \pm 86.04$$

Since ττ MC don't have τ→πην events, this yield is expected to be 0.



yield of 2gauss: $N_{\pi\pi^0}^{\tau\tau}$ =419.05±82.57

Main peak BG	# of η for 702 fb^{-1} samples
$\tau \to K\eta\nu$	$N_{\pi\pi^0}^{K\eta\nu}$=35.15 ± 2.24
$\tau \to K^*\eta\nu$	$N_{\pi\pi^0}^{K^*\eta\nu}$ =113.98±4.07
$\tau \to \pi\pi^0\eta\nu$	$N_{\pi\pi^0}^{\pi\pi^0\eta\nu}$ =259.09±6.13
$q\bar{q}$	$N_{\pi\pi^0}^{q\bar{q}}$ =72.85±14.10

($N_{\pi\pi^0}^{q\bar{q}}$ is included into error only)

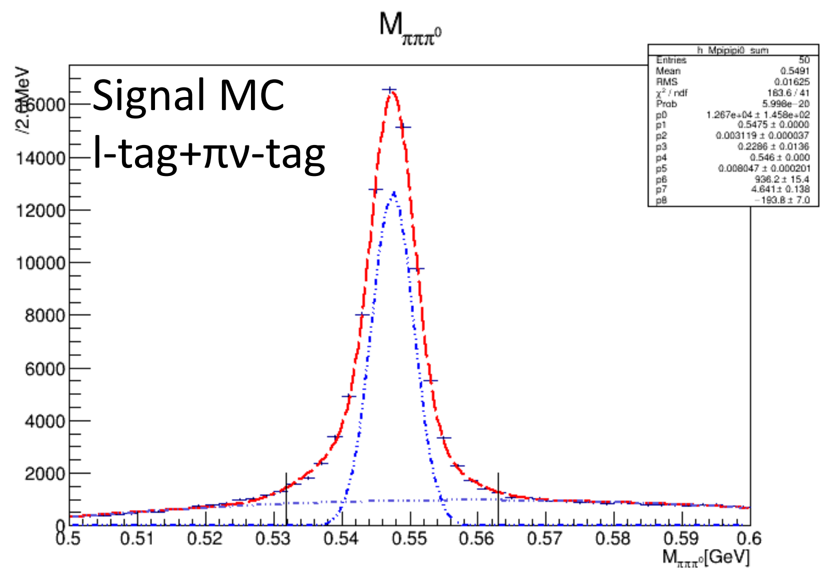
Evaluated significance

- Evaluate significance with Υ_{4s} data (703fb^{-1}) and full data (915fb^{-1}: $\Upsilon_{4s}, \Upsilon_{5s}$, continuum)
- When number of signal N_{sig} and significance are defined as $2\epsilon' N_{\tau\tau pair} Br(\tau \to \pi\eta\nu)$ and $\frac{N_{sig}}{N_{sigerr}}$ (detection efficiency ϵ'=0.350% by signal MC), 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**

Included hadronic tag ($\tau \to \pi\nu$)

- Allow not only leptonic tag but $\tau \to \pi\nu$ (Br=10.82%) in tag side
- According to naive estimation that multiplied by square root of efficiency increase, the significance is **3.4σ** ($=2.6\sigma \times \sqrt{\frac{0.582}{0.350}}$) for $\mathrm{Br}(\tau \to \pi\eta\nu) = 4.4 \times 10^{-5}$ and full data.



eff=0.582+-0.003%

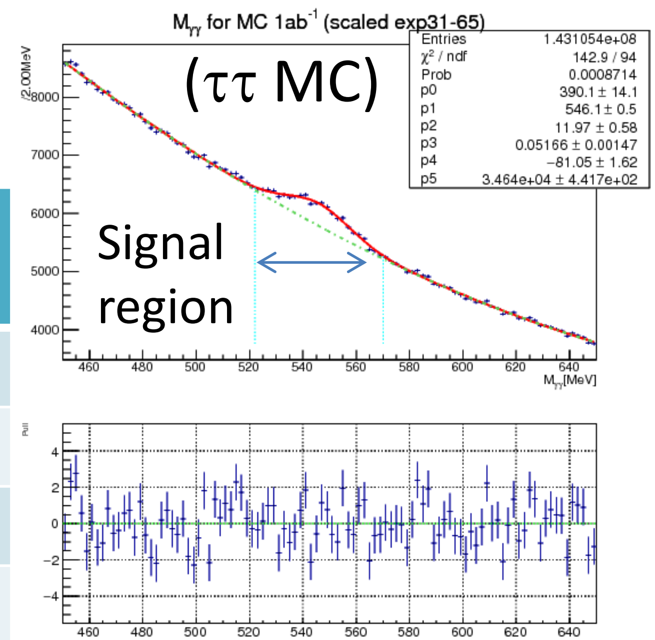
$\tau \to \pi\eta\nu, \eta \to \gamma\gamma$

- According to rough estimations, the rough significance is 0.7σ for $\mathcal{L} = 915.1\text{fb}^{-1}$ and $\text{Br}(\tau \to \pi\eta\nu) = 1.0 \times 10^{-5}$.
- But it turns out that this also has similar significance.
  This should be also seriously considered later.

Efficiency for signal MC $= 1.50\%$.

Rough significance[σ]= $\frac{N_{sig}}{\sqrt{\# \ of \ BG + N_{sig}}}$

$Br(\tau \to \pi\eta\nu)$	L, fb^{-1}	N_{sig}	# of BG	Rough significance, σ
4.4×10^{-5}	702.9	853	1.0×10^5	2.7
	915.1	1111	1.3×10^5	**3.0**
1.0×10^{-5}	702.9	194	1.0×10^5	0.6
	915.1	253	1.3×10^5	**0.7**



Summary

- 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 $Br(\tau \to \pi\eta\nu) = 4.4 \times 10^{-5}$ or 0.6σ for $Br(\tau \to \pi\eta\nu) = 1.0 \times 10^{-5}$.
- 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 $Br(\tau \to \pi\eta\nu) = 4.4 \times 10^{-5}$ and full data.
- For $\tau \to \pi\eta\nu$ with $\eta \to \gamma\gamma$, 3.0σ may be expected with $Br(\tau \to \pi\eta\nu) = 4.4 \times 10^{-5}$ and full data. We need to study it more seriously to combine.

Back Up

$\tau \to \pi\eta\nu, \eta \to \pi\pi\pi^0$ selection criteria

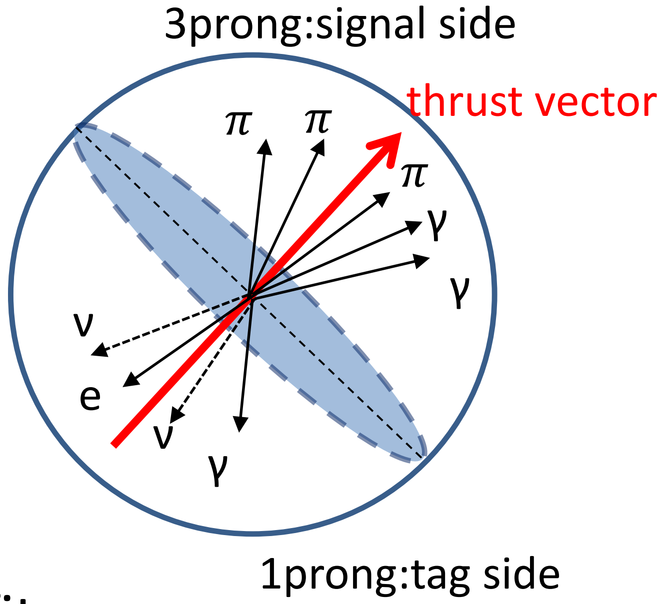
- Definition of good charged track
  - $P_t > 0.06\mathrm{GeV/c^2}$ in Barrel（-0.6235＜cosθ＜0.8332）
    $P_t > 0.1\mathrm{GeV/c^2}$ in Endcap
    （-0.8660＜cosθ≦-0.6235, 0.8332 ≦ cosθ＜0.9563）
  - helix:|dr|≦1cm,|dz|≦5cm
- Definition for good gamma
  - -0.8660＜cosθ＜0.9563 & $E_\gamma > 0.05\mathrm{GeV}$
- Missing angle at lab frame: -0.8660＜$\cos\theta_{miss}$＜0.9563

θ_{miss} is the polar angle for missing momentum P_{miss} (difference between four-momentums for beam and sums of them for tracks and gammas).

$$P_{miss} = P_{beam} - \Sigma P^{tracks} + \Sigma P^{\gamma}$$

$\tau \to \pi\eta\nu, \eta \to \pi\pi\pi^0$ selection criteria

- Divide the event by the thrust vector into two hemispheres - the tag and signal sides which have 3-1 prong and net charge = 0.
  - Tag side (leptonic tag; $\tau \to l\nu\nu$) :
    Allow 1 lepton and ≦1γ
    to accept FSR or ISR from lepton.
    invariant mass of all tag-side γ and track:
    $M_{tag} < 1.8\text{GeV}/\text{c}^2$
  - Signal side :
    Allow 3π and 2γ only
    ($0.105 < M_{\gamma\gamma} < 0.165\text{GeV}$).
    $M_{sig} < 1.2\text{GeV}/\text{c}^2$



- signal extraction: yield is evaluated by a fit for eta peak on $M_{\pi\pi\pi^0}$ distribution.