Study of $\tau^- \to h^- h^+ h^- \nu_\tau$ decays.

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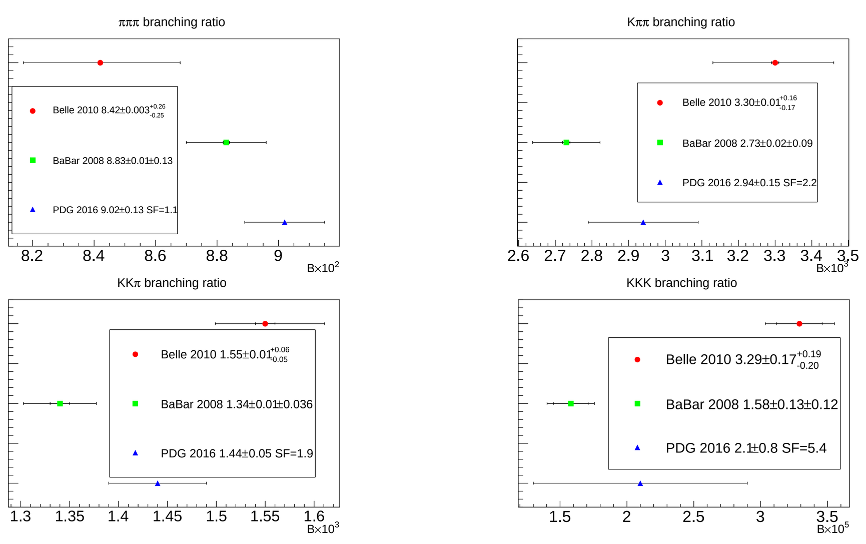
Abstract

We presented a study of $\tau^- \to h^- h^- h^+ \nu_\tau$ decays at Belle. The dominant systematic uncertainties of the branching fraction is related to the K/π identification (PID). There two sources of the uncertainty: insufficient accuracy of the misidentification efficiency data for the low momentum π-s from $\tau\tau$ events and impact of the additional γ-s in the PID efficiency. To improve PID efficiency data we utilize $K_S \to \pi^+\pi^-$ decays. To suppress additional γ-s we elaborate special criteria γ veto. The decrease of the systematic uncertainty is monitored by specially constructed scale factor (SF).

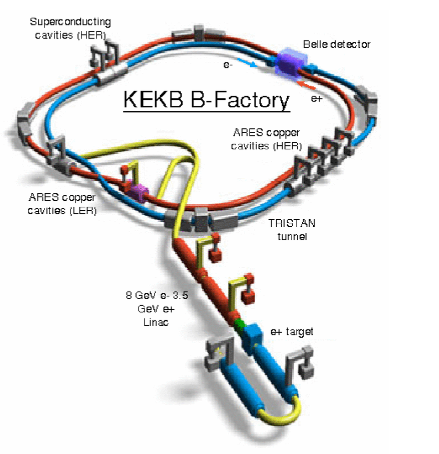
1. Motivation

Recent results from Belle and BABAR on the branching ratios of $\tau^- \to h^- h^- h^+ \nu_\tau$ show notable difference for some modes.

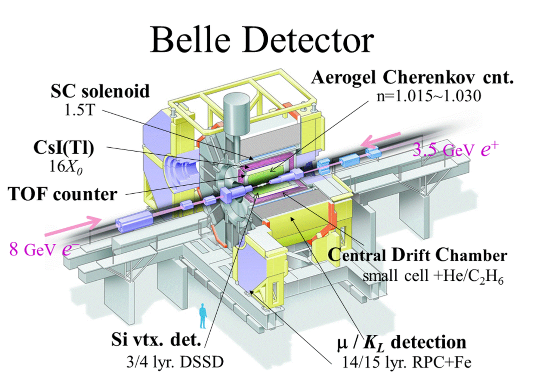


Belle PR D81 113007 BaBar PRL 100011801

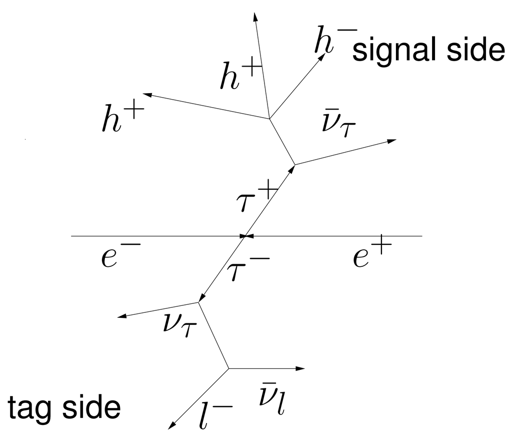
2. KEKB factory and Belle detector



KEKB e^+e^- collider with $\sqrt{s}$=10.58 GeV L=2×10^{34} $cm^{-2}s^{-1}$
Integrated luminosity 980 fb^{-1} or 9×10^8 $\tau\tau$ pairs



3. Selection criteria

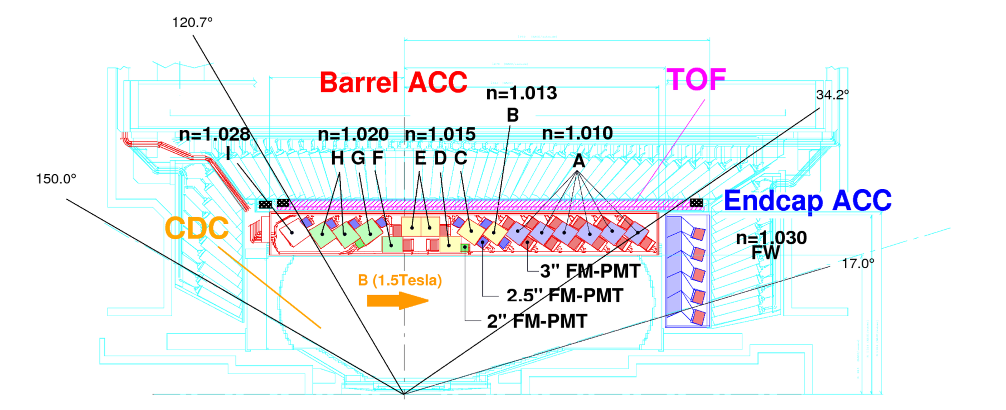


- 4-track events with zero charge
- Lepton (μ, e) and three hadrons (π/K)
- Neutral veto π, K_S
- KID> 0.9 for K; eID> 0.8, μID> 0.8 for leptons
- $v_r < 0.5$ cm $|v_z| < 2.5$ cm
- $max\ P_t > 0.5\,\mathrm{GeV}/c$
- $7\,\mathrm{GeV}/c^2 > m_{miss} > 1\,\mathrm{GeV}/c^2$
- $E_{extra}^{c.m.s.} < 0.3\,\mathrm{GeV}$
- $150° > \Theta_{miss}^{c.m.s.} > 30°$
- $\Theta_{hadrons/lepton}^{c.m.s.} > 90°$

Normalization on $\tau\tau \to e^{\pm}\nu_\tau\nu_e\mu^{\mp}\nu_\tau\nu_e$ events

4. Branching fractions calculation

We analyze $\tau^- \to \pi^-\pi^+\pi^-\nu_\tau, K^-\pi^+\pi^-\nu_\tau, K^-K^+\pi^-\nu_\tau, K^-K^+K^-\nu_\tau$ simultaneously. Take into account cross-feed background from $\pi \to K$ misidentification.



Branching fraction has the following hierarchy: $\frac{\mathcal{B}_{\pi\pi\pi}}{\mathcal{B}_{K\pi\pi}} \sim 30, \frac{\mathcal{B}_{K\pi\pi}}{\mathcal{B}_{KK\pi}} \sim 2, \frac{\mathcal{B}_{KKK}}{\mathcal{B}_{KK\pi}} \sim 50.$

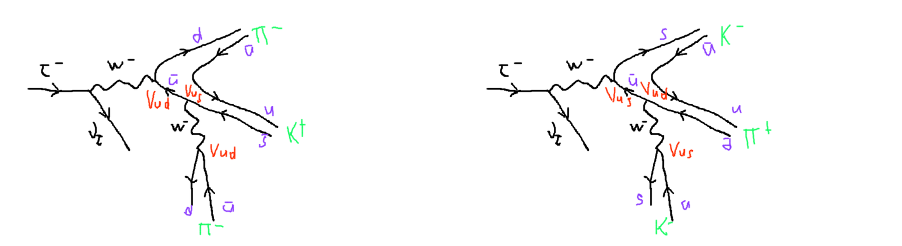
$N_k^{rec} - N_k^{bg} = \sum_p \mathcal{E}_p^k N_{true}^p$ system of linear equations

$\mathcal{B}_i = N_{true}^i/2N_{\tau\tau}$ $N_{\tau\tau} = (N_{e\mu} - N_{e\mu}^{bg})/\mathcal{B}_{\tau\to e\nu\bar{\nu}}\mathcal{B}_{\tau\to\mu\nu\bar{\nu}}\mathcal{E}_{e\mu}$

Particle identification is not simulated well. General approach is to calculate correction factor from experimental data. To calculate EXP/MC KID/πID efficiency correction $D^\star$ sample is used at Belle. It gives net samples of π and K. All tracks are divided into bins according charge (2), momentum (32) and polar angle (12). And correction factor calculated for each bin.

5. Events with wrong charge configuration

An idea is to take into account $K^-K^-\pi^+$ and $\pi^-\pi^-K^+$ events. We assume that $\mathcal{B}_{\tau^-\to K^-K^-\pi^+\nu_\tau} = \mathcal{B}_{\tau^-\to\pi^-\pi^-K^+\nu_\tau} = 0$, 2 additional equations. Number of signal events can be obtained from fit $\chi^2(N_{true}^p) = \sum_{k=1}^{k=6}(N_k^{rec} - N_k^{bg} - \sum_{p=1}^{p=4}\mathcal{E}_p^k N_{true}^p)^2/\sigma_k^2$, here k - all possible combinations, p - tau decay modes ($\pi^\mp\pi^\pm\pi^\mp$, $K^\mp\pi^\pm\pi^\mp$, $K^\mp K^\pm\pi^\mp$, $K^\mp K^\pm K^\mp$, $\pi^\mp K^\pm\pi^\mp$, $K^\mp\pi^\pm K^\mp$).



$\Gamma_{\tau^-\to\pi^-\pi^-K^+\nu_\tau} < (G_F m_\tau^2|V_{ud}|^2)^2\Gamma_{\tau^-\to K^-\pi^-\pi^+\nu_\tau} \sim 10^{-9} \times \Gamma_{\tau^-\to K^-\pi^-\pi^+\nu_\tau}$
$\mathcal{B}_{\tau^-\to\pi^-\pi^-K^+\nu_\tau} < 3 \times 10^{-12}$

$\Gamma_{\tau^-\to K^-K^-\pi^+\nu_\tau} < (G_F m_\tau^2|V_{ud}V_{us}|)^2\Gamma_{\tau^-\to K^-\pi^-K^+\nu_\tau} \sim 5 \times 10^{-11} \times \Gamma_{\tau^-\to K^-\pi^-K^+\nu_\tau}$
$\mathcal{B}_{\tau^-\to K^-K^-\pi^+\nu_\tau} < 10^{-13}$.

6. Scale factor for π misID

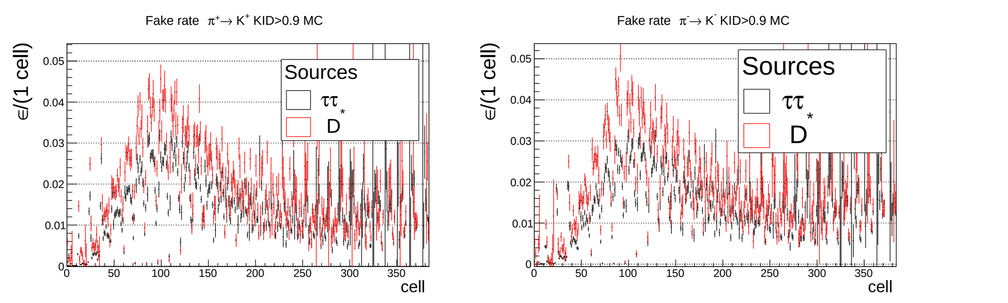
The consistency of the procedure was tested with large MC sample. However in the fit of experimental data we got large χ^2, which indicates systematic effect in the K/π separation. We introduce additional factor SF to correct $\mathcal{E}(\pi \to K)$.

$SF = 1.140 \pm 0.015(\mathrm{stat}) \pm 0.03(syst)$.

Generated / Reconstructed	$\pi^\mp\pi^\mp\pi^\pm\nu_\tau$	$K^\mp\pi^\mp\pi^\pm\nu_\tau$	$\pi^\mp K^\mp K^\pm\nu_\tau$	$K^\mp K^\mp K^\pm\nu_\tau$
$\pi^\mp\pi^\mp\pi^\pm\nu_\tau$	1.0	1.0	1.0	1.0
$K^\mp\pi^\mp\pi^\pm\nu_\tau$	SF	1.0	1.0	1.0
$\pi^\mp K^\mp K^\pm\nu_\tau$	SF^2	SF	1.0	1.0
$K^\mp K^\mp K^\pm\nu_\tau$	SF^3	SF^2	SF	1.0
$\pi^\mp\pi^\mp K^\pm\nu_\tau$	SF	SF	1.0	1.0
$K^\mp K^\mp\pi^\pm\nu_\tau$	SF^2	SF	SF	1.0

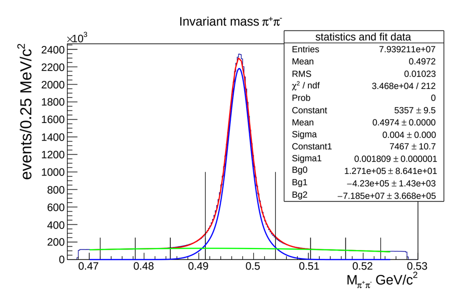
7. PID in $\tau\tau$ and $D^\star$ MC samples

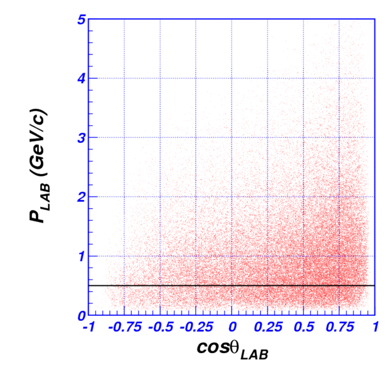
1. We found that the absolute values of MC efficiencies in $\tau\tau$ MC sample and D^* sample are different
2. To calculate efficiency for $\tau\tau$ events the KID/πID efficiency should take into account this difference



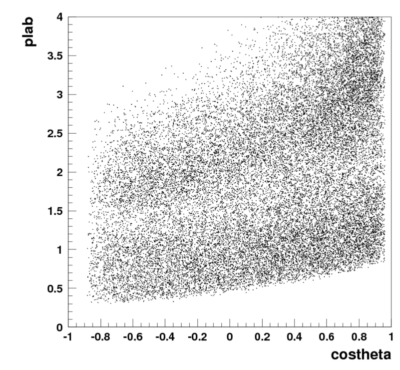
Cell number is coded by the following formula: cell=polar angle range+12*momentum range.

8. PID correction from $K_S \to \pi^+\pi^-$ decays

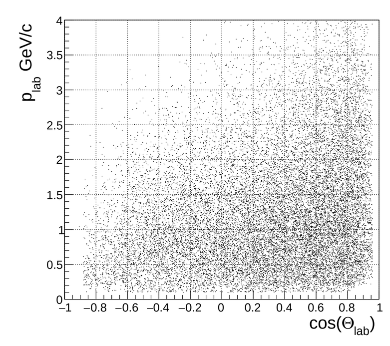




momentum vs polar angle for π from K_S-decays

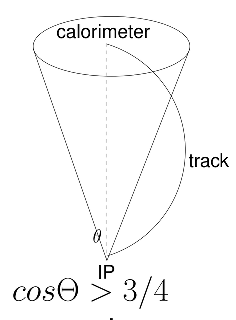


momentum vs polar angle for π from $D^\star$-decays



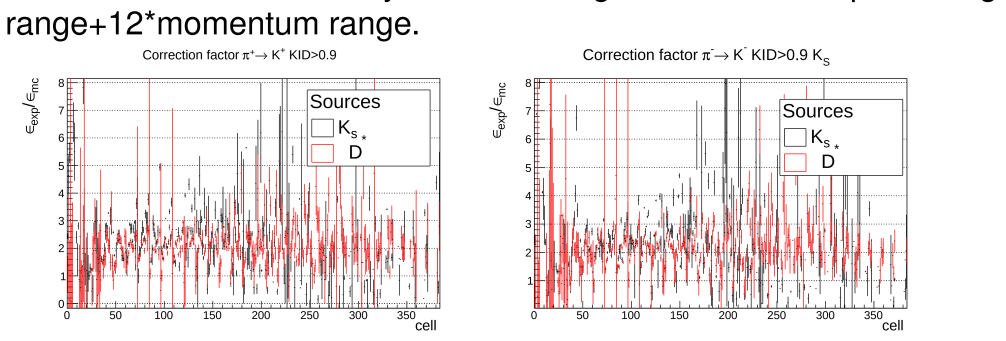
momentum vs polar angle for π from $\tau\tau$-decays

- The accuracy of the efficiency correction that calculated from $D^\star$ sample is low
- K_S sample was used to tabulate precisely correction at small momenta
- $K_S \to \pi^+\pi^-$ decays were reconstructed inclusively, $N_{K_S} = N_{sig} - N_{sideband}^{up}/2 - N_{sideband}^{down}/2$
- Interaction of the track with material of the detector produces extra clusters in calorimeter and impacts π/K identification
- Tracks without extra clusters in calorimeter around point, where track hits calorimeter were selected for the analysis (γ veto)



$cos\Theta > 3/4$
γ veto

Cell number is coded by the following formula: cell=polar angle range+12*momentum range.



9. Results

With the new PID correction for experimental data $SF = 1.03\pm0.01(\mathrm{stat})\pm0.03(syst)$) This indicate that the new πID efficiency data (K_S sample + γ-veto) agree better with real experimental PID efficiencies.

Branching fractions variation

mode	$\pi\pi\pi$	$K\pi\pi$	$KK\pi$	KKK
$\frac{\mathcal{B}(SF=1.14)-\mathcal{B}(SF=1.0)}{\mathcal{B}}_{old}$	$+1.6\%$	-25%	-5%	-30%
$\frac{\mathcal{B}(SF=1.03)-\mathcal{B}(SF=1.0)}{\mathcal{B}}_{new}$	$+0.3\%$	-6%	-2%	-14%

10. Conclusions

- We developed procedure the branching fractions measurement
- It was tested with large MC sample
- Identification efficiency data for π has insufficient accuracy
- Additional γ-s impact to the PID
- To improve the accuracy of the PID efficiency data we use $K_S \to \pi^+\pi^-$ events
- To suppress influence additional γ-s we elaborate special cut - γ veto
- Systematic uncertainty due to PID significantly decreased

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