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Study of $\tau^+ \rightarrow \pi^+ \nu_\tau e^+ e^-$ by Belle data

1. Introduction

Belle detector, located at the interaction point of the electron positron asymmetric energy collider (KEKB), is not only a B-factory but also a Tau-factory. The world's largest statistics of tau, 10^{11} $\tau^+ \tau^-$ pair events have been collected at BELLE.

Belle Detector
Schematic diagram of the Belle detector showing the SuperKEKB accelerator, the Belle detector components (SuperKEKB, Belle, Belle II), and the Belle detector components (SuperKEKB, Belle, Belle II).

NP searches and SM precision measurements of τ are studied at Belle. To probe NP, lepton-flavor violating decays and CPV in the charged lepton sector are required. For SM precision measurements, the mass of τ and the branching fractions of various hadronic decay modes are measured.^[1]

2. Motivation

Feynman diagrams of $\tau^+ \rightarrow \pi^+ \nu_\tau e^+ e^-$. (a), (b) and (c) are internal bremsstrahlung contributions, (d) and (e) are SD contributions mediated by vector and axial vector current.

Due to the γW vertex, the decay mode under consideration is of great importance. Study of $\tau^+ \rightarrow \pi^+ \nu_\tau e^+ e^-$ not only provides information on the relevant form factors, which can be only obtained in the chiral and short-distance limits, but also plays a relevant role in computing the radiative corrections to $\pi \rightarrow e \nu$ and $\tau \rightarrow \nu e$ decays.

3. Selection criteria

and track number = 4;
not charged=0;
the charged π , one virtual gamma producing an e^+ in signal hemisphere (PID>0.8), one charged e^- in tag hemisphere;
angle between π (S6 side) to $e^+ e^- < 90^\circ$;
angle between the e^+ and $e^- < 5^\circ$;
invariant mass of signal $\tau < 1.8$ GeV;
to the events with a π^0 candidate on signal side.
invariant mass of $2 \sqrt{s}$ in $[0.1, 0.16]$ GeV or invariant $e^+ e^-$ and $2 \sqrt{s}$ in $[0.11, 0.17]$ GeV;
to the events with a p candidate on signal side.
invariant mass of the 3 prong in $[0.625, 0.925]$ GeV;
to the events with a K_S ;
the transverse radius of the vertex ($e^+ e^-$) < 5 cm;

4. Background

The selection criteria are applied on 73 million MC events. 8571 BKG events survive. Considering the amount of the experimental data, 25000 BKG events may survive in the measurement.

Constituents of background events:
(55%) $p \nu_\tau \rightarrow \pi^+ \nu_\tau \nu_\tau \rightarrow \pi^+ \nu_\tau \nu_\tau$
(22%) $p \nu_\tau \rightarrow \pi^+ \nu_\tau \nu_\tau \rightarrow \pi^+ e^+ e^- \nu_\tau$
(12%) $A1 \nu_\tau \rightarrow p \pi^+ \nu_\tau \rightarrow \pi^+ \pi^+ \nu_\tau$

5. Toy MC

calculation based on chiral perturbation theory shows that the branching fraction of $\tau^+ \rightarrow \pi^+ \nu_\tau e^+ e^-$ is predicted as 1.5×10^{-6} [2]. However, up to date, due to the low momenta of the lepton pair and the inducing low detection efficiency (at order of 1 percent), this mode has never been measured. In the statistics of Belle, it is now possible to measure it for the first time.

Simulation events are generated and after the selection criteria 010 of them survive. The detection efficiency is 7.5%. Before, approximately 1000 events will be detected in the experimental data.

6. Conclusion

With the current data, the branching fraction of $\tau^+ \rightarrow \pi^+ \nu_\tau e^+ e^-$ events in the signal region is measured. The result indicates further studies are needed. In terms of the γW vertex, the decay mode under consideration is of great importance. Study of $\tau^+ \rightarrow \pi^+ \nu_\tau e^+ e^-$ not only provides information on the relevant form factors, which can be only obtained in the chiral and short-distance limits, but also plays a relevant role in computing the radiative corrections to $\pi \rightarrow e \nu$ and $\tau \rightarrow \nu e$ decays.

References:
[1] Belle Collaboration, *Phys. Rev. D* **80**, 052002 (2009).
[2] Belle Collaboration, *Phys. Rev. D* **80**, 052002 (2009).

Study of $\tau^{\pm} \rightarrow l^{\pm} l'^{\mp} l''^{\mp} \nu_{\tau} \nu_l \nu_{l'}$ ($l, l' = e, \mu$) at Belle

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1 The Belle experiment (KEK, Japan)

- e^+e^- collider
- $\sqrt{s} = 10.58$ GeV
- Integrated luminosity $\int L dt \sim 1 \text{ ab}^{-1}$
- Products: $B\bar{B}, \tau^+\tau^-, c\bar{c}, \dots$

Belle is a B-meson factory, and also a τ factory.

$N_{\tau\tau} \sim 9.0 \times 10^8$

5. Background (BG) suppression

We study selection criteria to suppress backgrounds.

The backgrounds contamination after the selection

Example:
 $\tau^+ \rightarrow e^+ \nu_e \gamma$
 $\tau^+ \rightarrow \mu^+ \nu_{\mu}$
 $\tau^+ \rightarrow \mu^+ \nu_{\mu} \gamma$
 $\tau^+ \rightarrow \mu^+ \nu_{\mu} \gamma$ (e^+e^-)
 $\tau^+ \rightarrow \mu^+ \nu_{\mu} \gamma$ (e^+e^-)

6 Validation

To validate the MC simulation, we compare the shape of histogram (MC) and data (data).

Discrepancy is observed.

After applying $\tau^{\pm} \rightarrow l^{\pm} l'^{\mp} l''^{\mp} \nu_{\tau} \nu_l \nu_{l'}$ selection, the discrepancy disappears.

7 Conclusion

- Result
- Newly developed parameters.
- Validation of the behavior of MC.

Future Plan

- First, we need to Finalize the selection criteria.
- Evaluate the background contamination.
- Measure the branching ratio.

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The $h \rightarrow \mu\tau$ decay in a two Higgs doublets model with a fourth generation of fermions

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The four family of leptons has survived analyses from EWPOs and flavor observables, but it has been put under serious pressure from Higgs searches. To maintain the viability of a leptonic heavy fourth family (hff), it is necessary to extend the scalar sector of the SM. A version of the Two Higgs Doublet Model able to accommodate the hff, where only one of the Higgs doublets couples to the hff. Then the $h \rightarrow \mu\tau$ decay is induced by flavor changing processes associated with heavy scalar bosons and heavy fourth lepton. We present the contributions of charged scalar bosons and we find that for particular values of the free parameters, the respective branching fraction is the order $10^{-6}-10^{-5}$. While the current upper bound reported by CMS is $\text{Br}(h \rightarrow \mu\tau) < 0.84$.

Fourth generation of fermions?

At the LHC Higgs boson production via gluon fusion is the dominant production mode, can be enhanced strongly if extra heavy quarks exist[1]. But, the data from ATLAS [2] and CMS [3] seems to indicate a Higgs boson that may be consistent with the standard model with three fermion generations. On other hand, the fourth generation is severely constrains on the invisible width of Z boson at the LEP, where the number of light neutrinos is $N=2.9840 \pm 0.0084$. However, a small number of the fourth family is favored in flavor changing neutral currents (FCNC). K, D, B_s, B_d mixing and oscillations are bounded on masses of the new fermions. The mass splittings are given by:

$m_{t_4} > 100.8 \text{ GeV}$

$m_{b_4} > 100.8 \text{ GeV}$

2HDM with fourth generation

The possibility of extending the Standard Model (SM) to include a fourth generation of fermions has been a topic of interest in particle physics. The idea is to introduce a new Higgs doublet, which would couple to the fourth generation of fermions. This would allow for a heavier Higgs boson field, which could then decay into lighter fermions. The interaction between the charged scalar bosons and the fourth generation of fermions is given by:

$H^\dagger \gamma_\mu \ell_j - \frac{g}{\sqrt{2} m_w} \bar{\nu}_j \left[n_{ij} \right]$

where $f_{ij} = \tan(\beta)$ is the ratio of the vacuum expectation values of the two Higgs doublets. The CKM matrix elements V_{ij} are the elements of the Cabibbo-Kobayashi-Maskawa matrix. The general form of the charged scalar boson mass matrix is given by:

$M^2 = \begin{pmatrix} m_{H_u}^2 & m_{H_d}^2 \\ m_{H_d}^2 & m_{H_u}^2 \end{pmatrix}$

The eigenvalues of this matrix are given by:

$m_{H_{\pm}}^2 = \frac{m_{H_u}^2 + m_{H_d}^2}{2} \pm \frac{1}{2} \sqrt{(m_{H_u}^2 - m_{H_d}^2)^2 + 4 |m_{H_d}^2|^2}$

The mathematical expression for the branching fraction is given by:

$\text{Br}(h \rightarrow \mu\tau) = \frac{m_h}{8\pi} (A^\dagger + B^\dagger)^2$

A and B are form factors, for charged scalar boson are given by:

$A = \lambda_{w\tau\mu} U_{\tau\mu}^* U_{\mu\tau} \frac{m_{H_u} g_s^2}{16\pi m_w} [f_B^2(x_\mu^2 + x_\tau^2) + f_A^2(x_\mu^2 - x_\tau^2)]$

$B = \lambda_{wb\tau} U_{\tau\mu}^* U_{\mu\tau} \frac{m_{H_u} g_s^2}{16\pi m_w} [f_B^2(x_\mu^2 + x_\tau^2) + f_A^2(x_\mu^2 - x_\tau^2)] + s_x f_B(x_\mu^2 - x_\tau^2) + s_y f_A(x_\mu^2 - x_\tau^2)$

where it has been assumed that $U_{\tau\mu} = s_x/m_{H_u}$ and the Feynman parameter is the following:

$x_i = \frac{q^2 - m_i^2}{m_H^2 - m_i^2}$

Results

$h \rightarrow \mu\tau$ decay [Phys.Lett.B 709 (2012) 207], we take the $U_{\tau\mu}^* U_{\mu\tau} \sim 10^{-3}$ for our analysis.

$\text{BR}(h \rightarrow \mu\tau) [\%]$

$m_{H_{\pm}} = 500 \text{ GeV}$

$\sin(\beta) = 1$
 $\delta = 0(1)$
 $\sqrt{s} = 500 \text{ GeV}$

$m_{H_{\pm}} = 500 \text{ GeV}$

In the 4C... only by I...





Study of $\tau^\pm \rightarrow \pi^\pm \nu_\tau e^+ e^-$ by Belle data

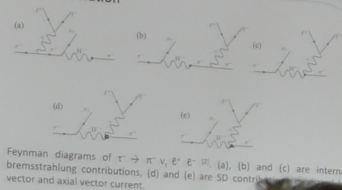
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¹University of Tokyo, ²Budker Institute of Nuclear Physics



1, Introduction

The Belle detector is an asymmetric electron-positron collider. It consists of a 3 GeV electron ring and a 3 GeV positron ring. The collision point is located at the center of the detector. The detector is composed of several sub-detectors: a central silicon vertex detector (SVT), a central silicon tracker (ST), a central silicon calorimeter (SC), and a central silicon calorimeter (SC).

2, Motivation



Due to the γW vertex, the decay mode $\tau^\pm \rightarrow \pi^\pm \nu_\tau e^+ e^-$ is predicted as a great importance. Study of $\tau^\pm \rightarrow \pi^\pm \nu_\tau e^+ e^-$ can provide information on the relevant form factors and the chiral and short-distance contributions in computing the radiative and $\tau \rightarrow \pi \nu$ decays.

4, Background

The selection criteria are as follows: 8571 BKG events survive. The experimental data, 25000 measurement.

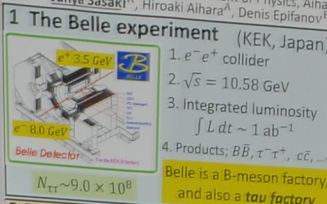
Constituents of background events are as follows: (55%) $p \nu_\tau \rightarrow \pi \pi^0$, (22%) $p \nu_\tau \rightarrow \pi \pi^0$, (12%) $A1 \nu_\tau \rightarrow \pi \pi^0$.

6, Conclusion

With the selection criteria, the background events are reduced. In the future, the background events will be detected in the future.

Study of $\tau^\pm \rightarrow l^\pm l'^+ l'^- \nu_l \nu_{l'}$ ($l, l' = e, \mu$) at Belle

University of Tokyo / Department of Physics, Aihara¹, Junya Sasaki¹, Hiroaki Aihara¹, Denis Epifanov², Nobuhiro Shimizu¹, Yifan Jin¹, and Belle Collaboration



1. e^+e^- collider
2. $\sqrt{s} = 10.58$ GeV
3. Integrated luminosity $\int L dt \sim 1 \text{ ab}^{-1}$
4. Products: $BB, \tau^+\tau^-, c\bar{c}, \dots$

Belle is a B-meson factory, and also a tau factory.

$N_{\tau\tau} \sim 9.0 \times 10^8$

2 Purpose

Check the Standard Model (SM)'s prediction. We measure the branching ratio of $\tau^\pm \rightarrow l^\pm l'^+ l'^- \nu_l \nu_{l'}$ and its Michel-like parameters.

*The Michel-like parameter is the bilinear combination of the Michel parameters.

For example, $Q_{11} = BR_{\text{Measured}}(\tau^\pm \rightarrow l^\pm l'^+ l'^- \nu_l \nu_{l'}) / BR_{\text{SM}}(\tau^\pm \rightarrow l^\pm l'^+ l'^- \nu_l \nu_{l'})$.

Some of Michel-like parameters can be measured by the branching ratio. For example, $Q_{11} = BR_{\text{Measured}}(\tau^\pm \rightarrow l^\pm l'^+ l'^- \nu_l \nu_{l'}) / BR_{\text{SM}}(\tau^\pm \rightarrow l^\pm l'^+ l'^- \nu_l \nu_{l'})$.

The Michel parameter is a bilinear combination of coupling constants G_{ij} .

Measurement of the Michel-like parameter is useful to check the coupling structure in the weak interaction.

Standard Model's prediction is $Q_{11} = 1$.

Experimentally, $Q_{11} = 1.0 \pm 0.1$.

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5. Background(BG) suppression

We study selection criteria to suppress backgrounds.

The backgrounds contamination after the selection

Conversion is the ratio of events remaining BKG for two modes.

Example: $e^+e^- \rightarrow \tau^+\tau^- \rightarrow e^+e^- \nu_e \nu_e$

$e^+e^- \rightarrow \tau^+\tau^- \rightarrow e^+e^- \nu_e \nu_e$

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The $h \rightarrow \mu\tau$ decay in a two Higgs doublet model with a fourth generation of fermions

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The four family of fermions has been analyzed from LEP and LHC observables, but it has been put under serious pressure from Higgs searches. To maintain the validity of a leptonic Higgs decay family (HLL), it is necessary to extend the scalar sector of the SM. A version of the Two Higgs Doublet Model (2HDM) is considered to accommodate the HLL, where only one of the Higgs doublets couples to the HLL. Then the $h \rightarrow \mu\tau$ decay is induced by flavor changing processes associated with heavy scalar bosons and heavy fourth fermions. We present the contributions of charged scalar bosons and see that the $h \rightarrow \mu\tau$ decay is induced by the fourth fermions. The respective branching fraction is the order 10^{-4} . While the current upper bound is 10^{-4} , the new bound is 10^{-5} .

Fourth generation of fermions?

At the LHC, Higgs boson production via gluon fusion is the dominant production mode, can be enhanced strongly by heavy quarks exist [1]. But, the data from ATLAS [2] and CMS [3] seems to indicate a Higgs boson that may be compatible with the standard model with three fermion generations. However, the fourth generation is severely constrained on the one hand by the LEP where the number of light fermions is $N_f = 2.984 \pm 0.004$. However, a small mixing with the fourth fermion is allowed in flavor changing neutral current processes. The D, B, B_s mixing and other precision observables bounds on masses of the charged lepton, heavy neutral fermions are given by:

$m_e > 100.8 \text{ GeV}$, $m_\mu > 80.5 - 101.5 \text{ GeV}$

$m_\tau > 100.8 \text{ GeV}$, $m_\nu > 100.8 \text{ GeV}$

$m_{\nu_\tau} > 100.8 \text{ GeV}$, $m_{\nu_\mu} > 100.8 \text{ GeV}$

$m_{\nu_e} > 100.8 \text{ GeV}$, $m_{\nu_\tau} > 100.8 \text{ GeV}$

$m_{\nu_\mu} > 100.8 \text{ GeV}$, $m_{\nu_e} > 100.8 \text{ GeV}$

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$m_{\nu_\tau} > 100.8 \text{ GeV}$, $m_{\nu_\mu} > 100.8 \text{ GeV}$

$m_{\nu_e} > 100.8 \text{ GeV}$, $m_{\nu_\tau} > 100.8 \text{ GeV}$

$m_{\nu_\mu} > 100.8 \text{ GeV}$, $m_{\nu_e} > 100.8 \text{ GeV}$

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$m_{\nu_\mu} > 100.8 \text{ GeV}$, $m_{\nu_e} > 100.8 \text{ GeV}$

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$m_{\nu_\mu} > 100.8 \text{ GeV}$, $m_{\nu_e} > 100.8 \text{ GeV}$

$m_{\nu_\tau} > 100.8 \text{ GeV}$, $m_{\nu_\mu} > 100.8 \text{ GeV}$

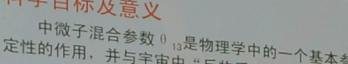
源 (CSNS)

散裂中子源将为物理学、化学、生命科学、材料科学、纳米科学、医药、国防科研和新型核能开发等学科前沿领域的基础研究和高新技术开发研究提供一个先进、功能强大的研究平台。

它就像一台“超级显微镜”，研究诸如DNA、蛋白质、飞机材料等等的结构。

中国科学院高能物理研究所

大亚湾反应堆中微子实验



中微子混合参数 θ_{13} 是物理学中的一个基本参数,其数值的大小对未来中微子物理的发展方向起着决定性的作用,并与宇宙中“反物质消失之谜”有关。大亚湾反应堆中微子实验的目标就是测量 θ_{13} 。大亚湾是世界上目前发现的最适合进行 θ_{13} 实验的地方。核电站在发电过程中会产生海量的中微子,由山腹内的三个实验大厅——大亚湾近点、岭南近点和远点+中微子反应堆堆芯,通过液闪探测器、水契仑科夫探测器、中微子探测器

$\sin^2 2\theta_{13} = 0.092 \pm 0.016(\text{stat}) \pm 0.005(\text{syst})$

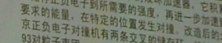
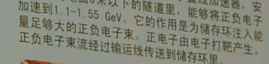


2012年3月8日，大亚湾反应堆中微子实验国际合作组发言人王贻芳在北京宣布，发现新的中微子振荡。并通

该成果入选美国《科学》杂志2012年十大科学突破、
瀚霖杯两院院士评选2012年中国十大科技进展新闻。以

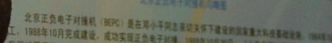
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