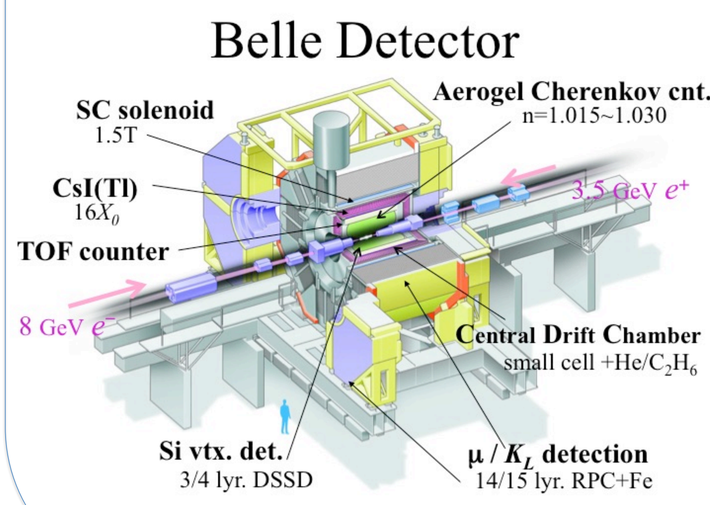
Study of $\tau^{\pm} \to \pi^{\pm} \nu_\tau e^+ e^-$ by Belle data

Yifan Jin[1], Denis Epifanov[2], Nobuhiro Shimizu[1], Junya Sasaki[1], Hiroaki Aihara[1], Belle Collaboration
1. The University of Tokyo, 2. Budker Institute of Nuclear Physics
jin@hep. phys.s.u-tokyo.ac.jp

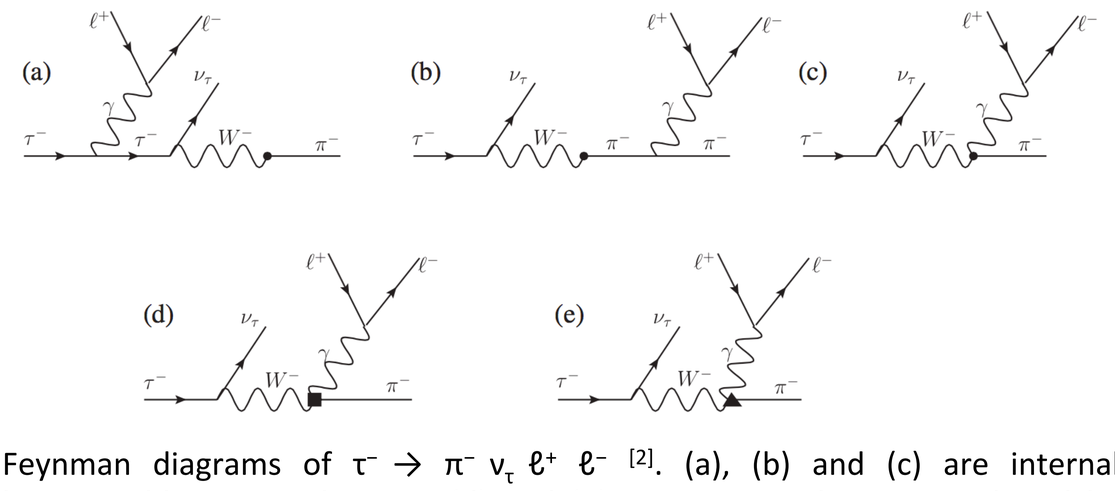
1, Introduction

The 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, 9×10^8 $\tau^+\tau^-$ pair events have been collected at BELLE.



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 searched. For SM precision measurements, the mass of τ and the branching fractions of various hadronic decay modes are measured.[1]

2, Motivation

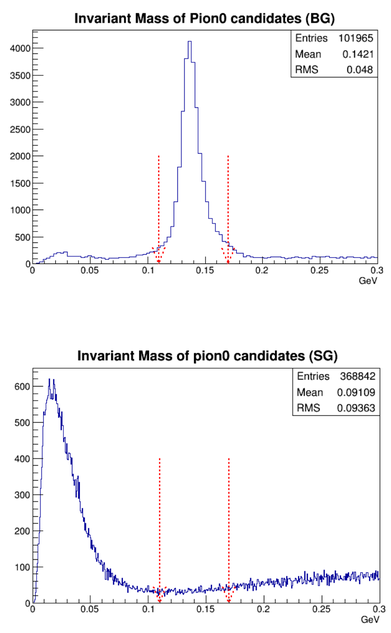


Feynman diagrams of $\tau^- \to \pi^- \nu_\tau \ell^+ \ell^-$ [2]. (a), (b) and (c) are internal bremsstrahlung contributions, (d) and (e) are SD contributions mediated by vector and axial vector current.

Due to the $\gamma W\pi$ vertex, the decay mode under consideration is of great importance. Study of $\tau^{\pm} \to \pi^{\pm} \nu_\tau e^+ e^-$ 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 $\pi \to \ell \nu$ and $\tau \to \pi \nu_\tau$ decays.

3, Selection criteria

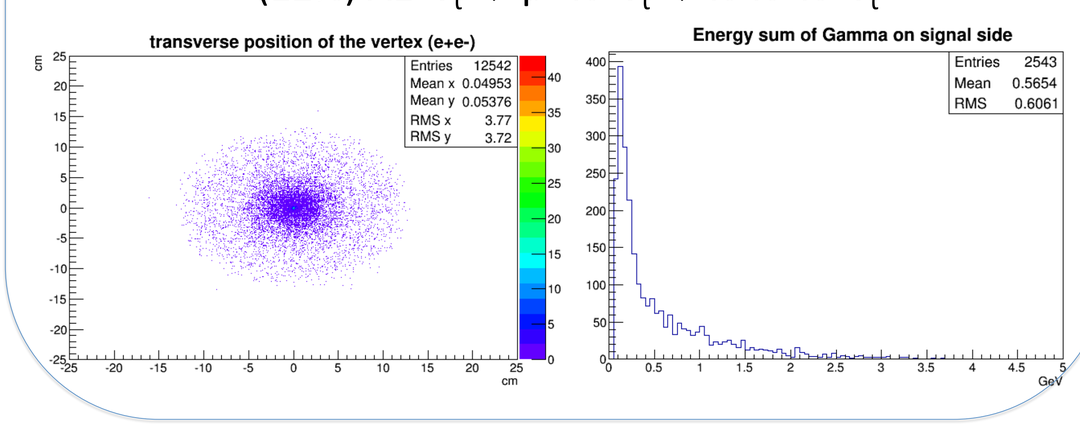
1, good track number =4;
2, net charge=0;
3, one charged π, one virtual gamma producing an e^+ e^- pair in signal hemisphere (PID>0.8), one charged particle in tag hemisphere;
4, the angle between π (SG side) to e^+/e^- < 90°;
5, the angle between the e^+ and e^- < 5°;
6, invariant mass of signal τ < 1.8 GeV;
7, veto the events with a π^0 candidate on signal side. (invariant mass of 2 γ's in [0.1, 0.16] GeV or invariant mass of e^+e^- and 1 γ in [0.11, 0.17] GeV);
8, veto the events with a ρ^- candidate on signal side. (invariant mass of the 3 prong in [0.625, 0.925] GeV);
9, veto the events with a Ks;
10, 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.

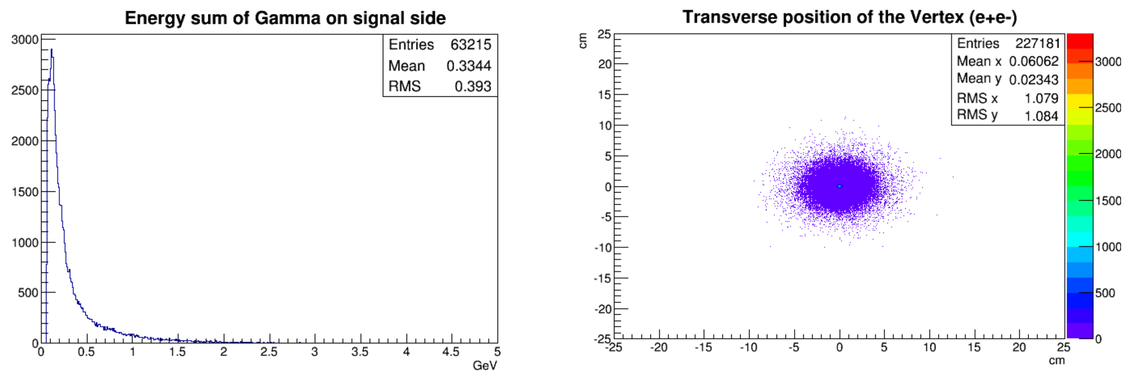
Constituents of background events:
(55%) $\rho^- \nu_\tau \to \pi^- \pi^0 \nu_\tau \to \pi^- \gamma \gamma \nu_\tau$
(22%) $\rho^- \nu_\tau \to \pi^- \pi^0 \nu_\tau \to \pi^- e^- e^+ \gamma \nu_\tau$
(12%) $A1^- \nu_\tau \to \rho^- \pi^0 \nu_\tau \to \pi^- \pi^0 \pi^0 \nu_\tau$



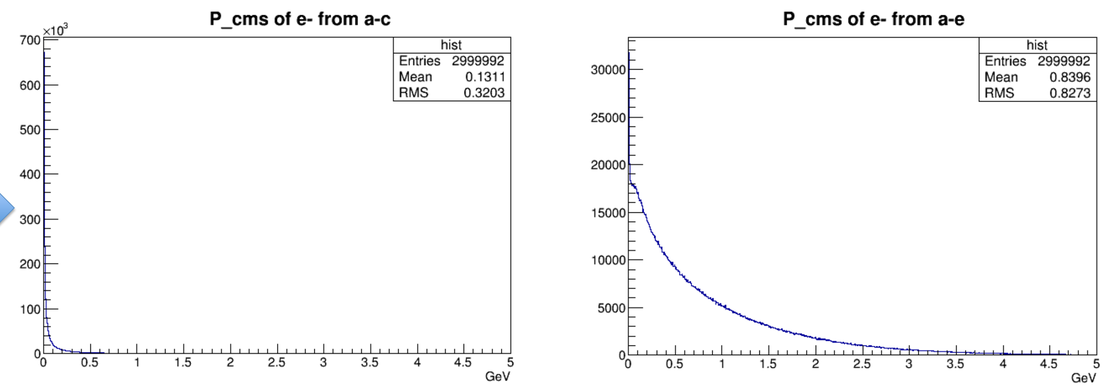
5, Toy MC

The calculation based on chiral perturbation theory shows that the branching fraction of $\tau^{\pm} \to \pi^{\pm} \nu_\tau e^+ e^-$ is predicted as $1.7^{+1.1}_{-0.3}\times10^{-5}$ [2]. However, up to date, due to the low momenta of the lepton pair and the inducing low detection efficiency (at the order of 1 percent), this mode has never been measured. Given the statistics of Belle, it is now possible to measure it for the first time.

3 million events are generated and after the selection criteria 225,010 of them survive. The detection efficiency is 7.5%. Therefore, approximately 1000 events will be detected in the experimental data.



By the use of the event generator, it is showed that based on diagrams a-c, the momenta of the electron pair are quite low. However, when taking into account diagrams d and e, the distribution of electron momentum differs. This feature can function as a good signature to identify the origin of the events.



6, Conclusion

With the current detection efficiency, approximately 1000 signal events can be detected, contaminated by around 25000 BKG events in the experimental data. The purity is only 4%, which indicates further suppression on BKG is needed.
In terms of the momenta of the electron pair, the contribution from SD terms mediated by vector and axial-vector current can be identified, which can help to test the chiral perturbation theory.

Reference:

[1], Brodzicka J, et al. Physics achievements from the Belle experiment [J]. Progress of Theoretical and Experimental Physics, 2012, 2012(1): 04D001.
[2], Roig P, Guevara A, Castro G L. Weak radiative pion vertex in $\tau^- \to \pi^- \nu_\tau \ell^+ \ell^-$ decays [J]. Physical Review D, 2013, 88(3): 033007.