KTeV
Study of $K_L \rightarrow \pi e \nu e e$

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Why $K_L \rightarrow \pi e \nu ee$?

- Direct Emission(DI) of ee from *Ke3* was studied using 15000 events of Radiative *Ke3*, but the result is consistent with no DI.(E831).
- In Chiral Formalism $K_L \rightarrow \pi e \nu ee$ has three peculiar terms othen thab Radiative *Ke3*.

Only for $K_L \to \pi e \nu e e$ For $K_{e3\gamma}$

$$A = -\left[\frac{1}{2}\right]^{1/2}\left[\frac{F_K}{F_\pi} + \frac{4}{F_\pi^2}(L_9+L_{10})q_1\cdot(p_1-p_2-q_1) + \frac{4}{F_\pi^2}L_9\left[q_1^2 - p_2\cdot(p_1-p_2-2q_1)\right]\right]$$

$$B = \frac{2\sqrt{2}}{F_\pi^2}L_{10} - \left[\frac{1}{2}\right]^{1/2}\left[1+\frac{4L_9}{F_\pi^2}p_1\cdot q_1 + \frac{4}{F_\pi^2}\right]\left[\frac{F_K}{F_\pi^2} + \frac{4L_9}{F_\pi^2}\left[m_\pi^2 - p_2\cdot(p_1-q_1)\right]\right]$$

$$C = \frac{2\sqrt{2}}{F_\pi^2}L_9,$$

Eliminated using gauge-invariance

$$D = -\sqrt{2}\left[1+\frac{2L_9}{F_\pi^2}q_1^2\right]\left[\frac{F_K}{F_\pi^2} + \frac{4L_9}{F_\pi^2}\left[m_\pi^2 - p_2\cdot(p_1-q_1)\right]\right]\frac{1}{q_1^2 - 2p_1\cdot q_1},$$

$$E = \left[\frac{1}{2}\right]^{1/2}\left[1+\frac{4L_9}{F_\pi^2}p_1\cdot q_1 + \frac{4}{F_\pi^2}\right]\left[\frac{F_K}{F_\pi^2} + \frac{4L_9}{F_\pi^2}\left[m_\pi^2 - p_2\cdot(p_1-q_1)\right]\right]\frac{1}{q_1^2 - 2p_1\cdot q_1},$$

$$F = \frac{2\sqrt{2}}{F_\pi^2}(L_9+L_{10}) + \sqrt{2}\left[1+\frac{2L_9}{F_\pi^2}q_1^2\right]\left[\frac{F_K}{F_\pi^2} + \frac{4L_9}{F_\pi^2}\left[m_\pi^2 - p_2\cdot(p_1-q_1)\right]\right]\frac{1}{q_1^2 - 2p_1\cdot q_1},$$

$$G = \frac{2\sqrt{2}}{F_\pi^2}L_9 - \sqrt{2}\left[1+\frac{2L_9}{F_\pi^2}q_1^2\right]\left[2 - \frac{F_K}{F_\pi^2} + \frac{4L_9}{F_\pi^2}\left[(p_1-q_1)^2 - p_2\cdot(p_1-q_1)\right]\right]\frac{1}{q_1^2 - 2p_1\cdot q_1},$$

$$H = -\frac{2\sqrt{2}}{F_\pi^2}L_9, \quad I = \frac{2\sqrt{2}}{F_\pi^2}L_{10},$$

$$J = -\frac{2\sqrt{2}}{F_\pi^2}L_9 + \left[\frac{1}{2}\right]^{1/2}\left[1+\frac{4L_9}{F_\pi^2}p_1\cdot q_1 + \frac{4}{F_\pi^2}\right]\left[2 - \frac{F_K}{F_\pi^2} + \frac{4L_9}{F_\pi^2}\left[(p_1-q_1)^2 - p_2\cdot(p_1-q_1)\right]\right]\frac{1}{q_1^2 - 2p_1\cdot q_1}.$$

$K_L \rightarrow \pi e \nu ee$ sample

- 4Track trigger
- 0.95< E/p <1.05 E/p for electron track
- E/p < 0.8 for pion track
- One pion and three electrons
- Less than 0.02 Pion-probability for electron(TRD)
- Greater than 0.1 Pion probability for pion
- One of track going into Beam hole track was allowed for an electron
- - 0.004~0.048(GeV/c)^2 $(P_{||\nu}{}^*)^2$

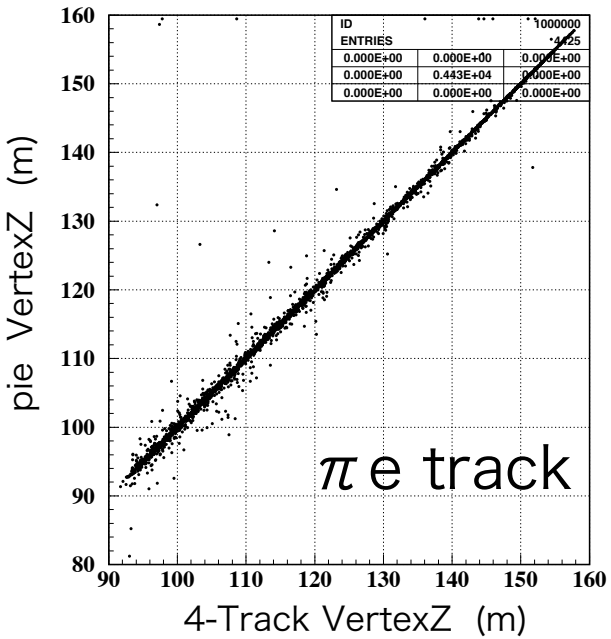
Identifying of $K_L \rightarrow \pi e \nu ee$ from external conversion(Radiative *Ke3*)

- Correlation between 4-Track vertex and 2-Track vertex of :

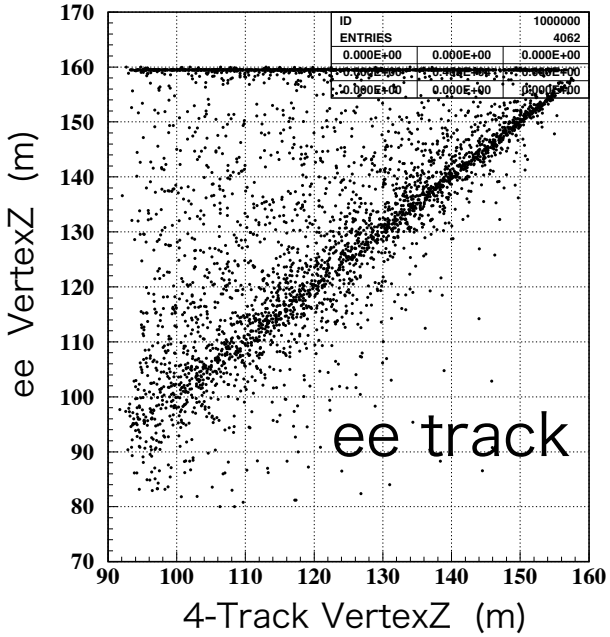
  1. ee pair which has minimum invariant mass
  2. another e and π

- 4-Track vertex was determined using T3FVTX4
- 2-Track vertex was determined using T3VFIT

VertexZ of πe and ee-pair
(vs. Four-track VertexZ)



Some ee vertexZ are distributed in down stream, especially at the vacuum window.



π e tracks well agree with 4track vertex

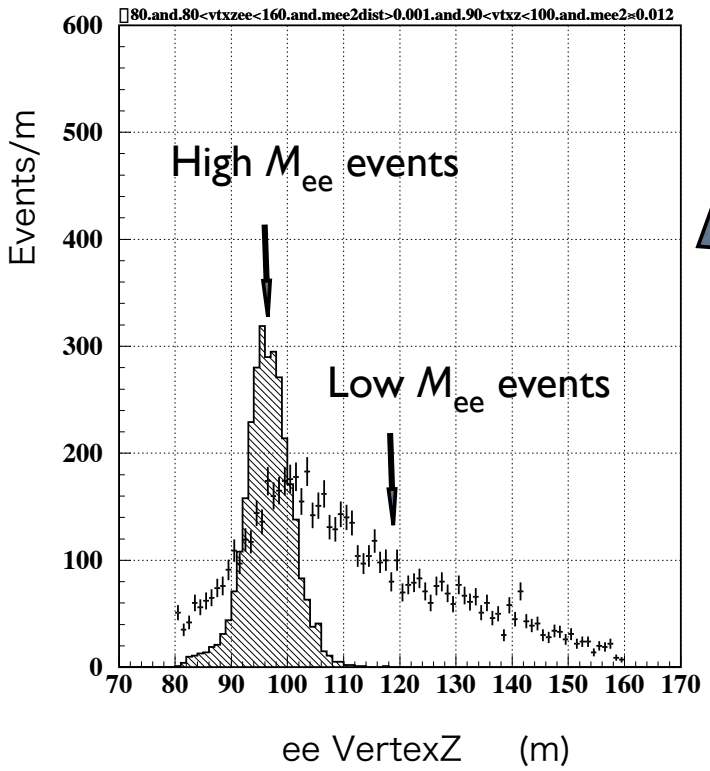
What properties do the down stream events have ?

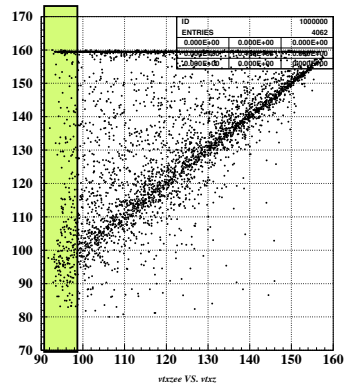
- At the Vacuum window events are expected as Radiative Ke3→Require Track separation at Chamber 1 is larger than 1 mm,

  ⇒ removed the Vacuum window events.

- Poor quality of ee VertexZ detemination ? →Require certain large invariant mass of ee pair ($M_{ee,minimum}$)

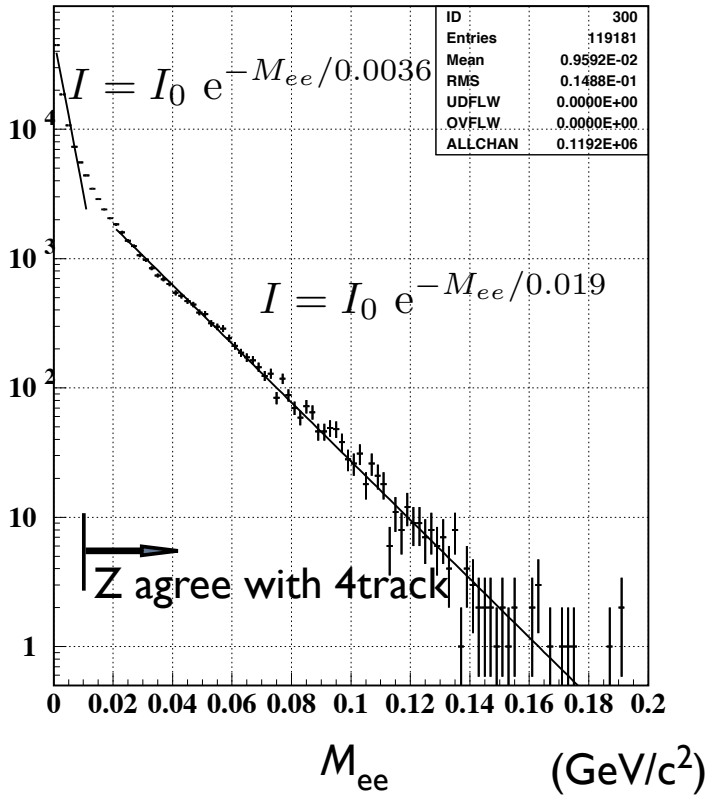
Effect of M_{ee} Cut





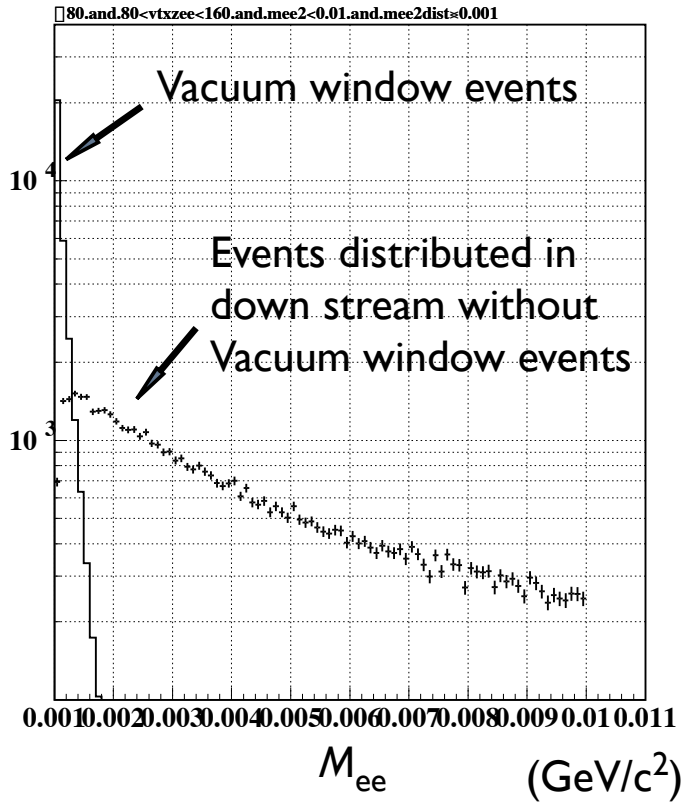
- Events with 90m<4-trackZ<100m
  - Hatched histogram
    :M_{ee} >0.012 (GeV/c^2)
  - Dots
    :M_{ee} <0.012 (GeV/c^2)

M_{ee} distribution(full events including events from the Vacuum window)



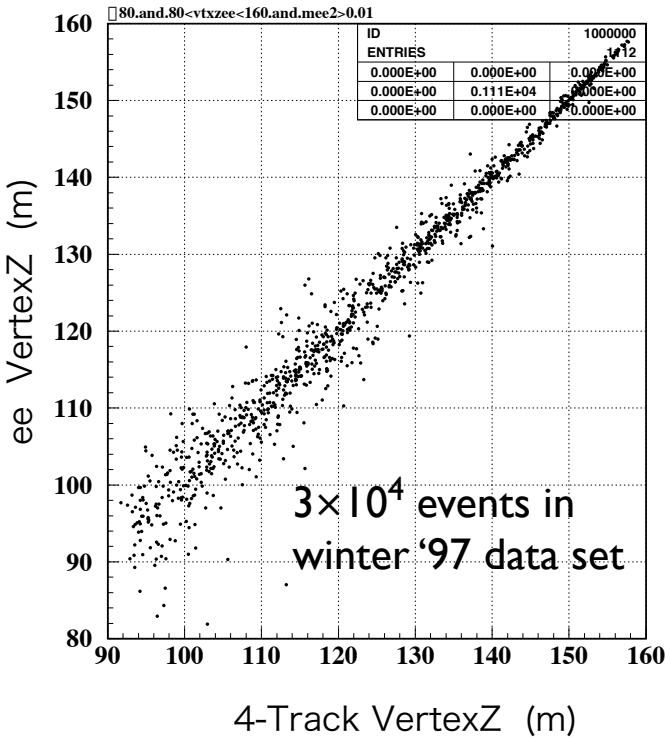
- At least there are two components
- About at 0.01 GeV/c^2 dominated component changes
- High M_{ee} events exponentially decreas

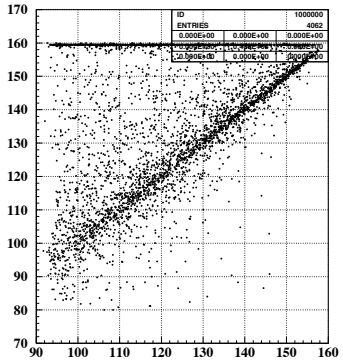
M_{ee} distribution(M_{ee} < 0.01 GeV/c^2)



- There are 3 components we should study
  1. Conversion at the Vacuum window.
  ⇨ Dominated by Radiative *Ke3*
  2. Distributed events. ?
  3. M_{ee} is greater than 0.01 GeV/c^2.
  ⇨ Expectable as $K_L \rightarrow \pi e \nu ee$

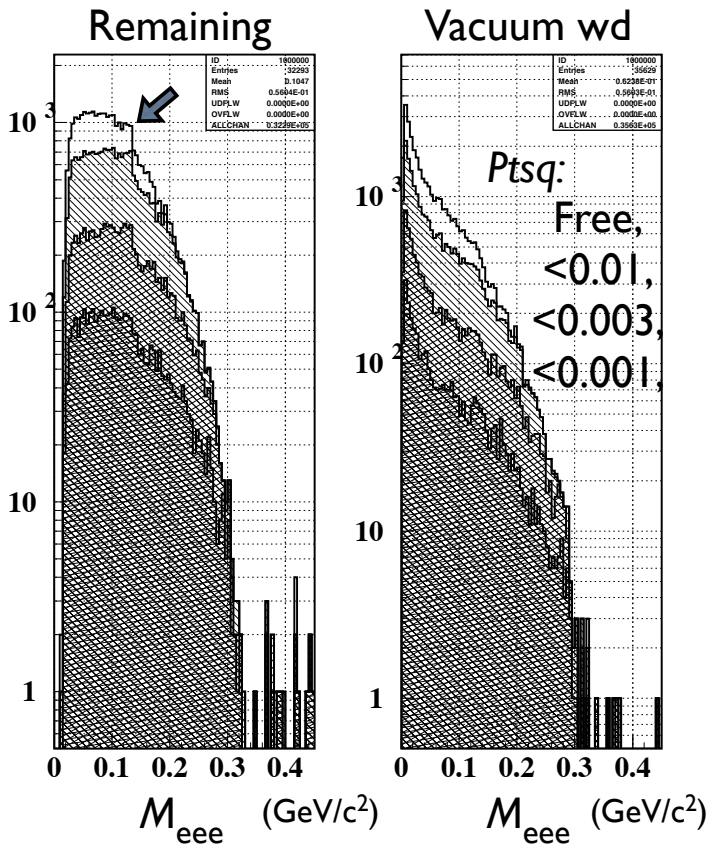
Choose M_{ee} greater than 0.01 GeV/c^2





- $M_{ee,minimum}$ cut well remove the events which have different vertexZ of ee pair and 4-track(distributed events).

M_{eee} distribution depending on the events

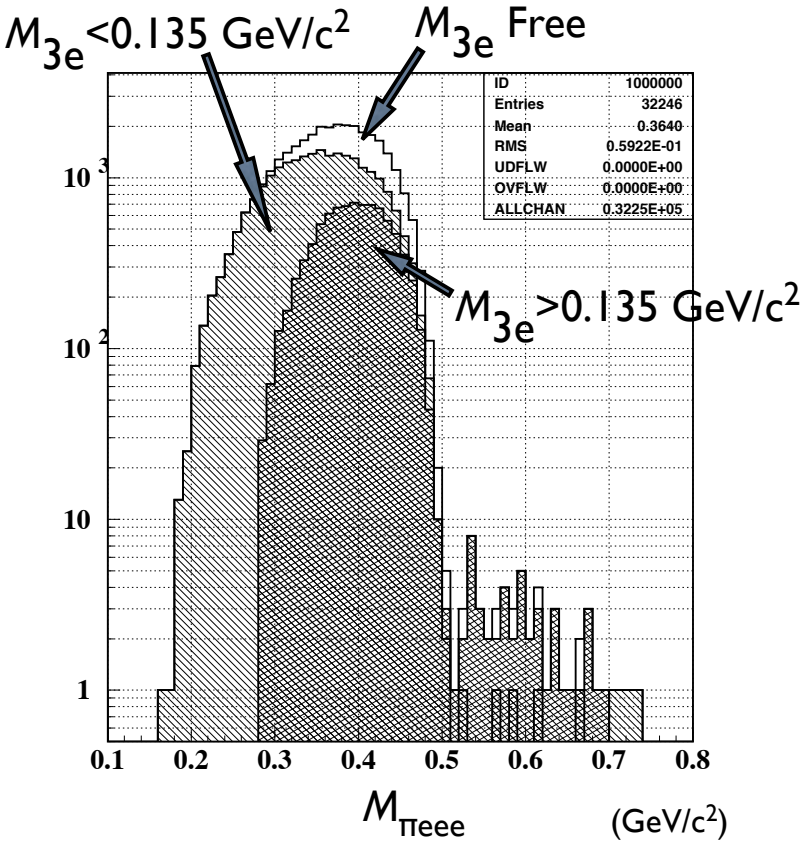


- There is large difference of M_{eee} distribution between Remaining events and Radiative *Ke3*.
  - The M_{eee} distribution of remaining events has a shoulder at M_{π^0}

→

If $K_L \to \pi^+\pi^-(\pi^0 \to eeee)$ is missing one charged pi and an electron,
invariant mass of $K_L \to \pi eee$ should be less than $M_K - M_\pi$

$M_{\pi eee}$ distribution depending on M_{3e}



- $M_{\pi eee}$ goes all the way up to the M_K, even if with M_{3e}< 0.135 GeV/c^2. Therefore, $K_L \to \pi^+\pi^-(\pi^0 \to eeee)$ is not dominamt

Conclusion and next steps

Conclusion

- Using M_{ee} distribution, We separated πeee events in
  1. Ke3 γ with external conversion at the Vacuum wd.
  2. Unknown distributed events.
  3. $K_L \rightarrow \pi e \nu ee$ *candidate*.
- There is large difference of M_{eee} distribution between $K_L \rightarrow \pi e \nu ee$ *candidate* and Radiative *Ke3* with external conversion at the vacuum window.

Next steps

- To compare M_{eee} distribution of $K_L \rightarrow \pi e \nu ee$ candidate and MC.
- About distributions of other variable too.