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

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Trigger 4, NZF002~038

- 3V_TIGHT * 2DC12_MED * ET_THR1 * !MU2 * PHVBAR1* 34HCY * HCC_GE2 *YTF_UDO * HC2XDUM
- ‘97 winter (NZF002~NZF038)

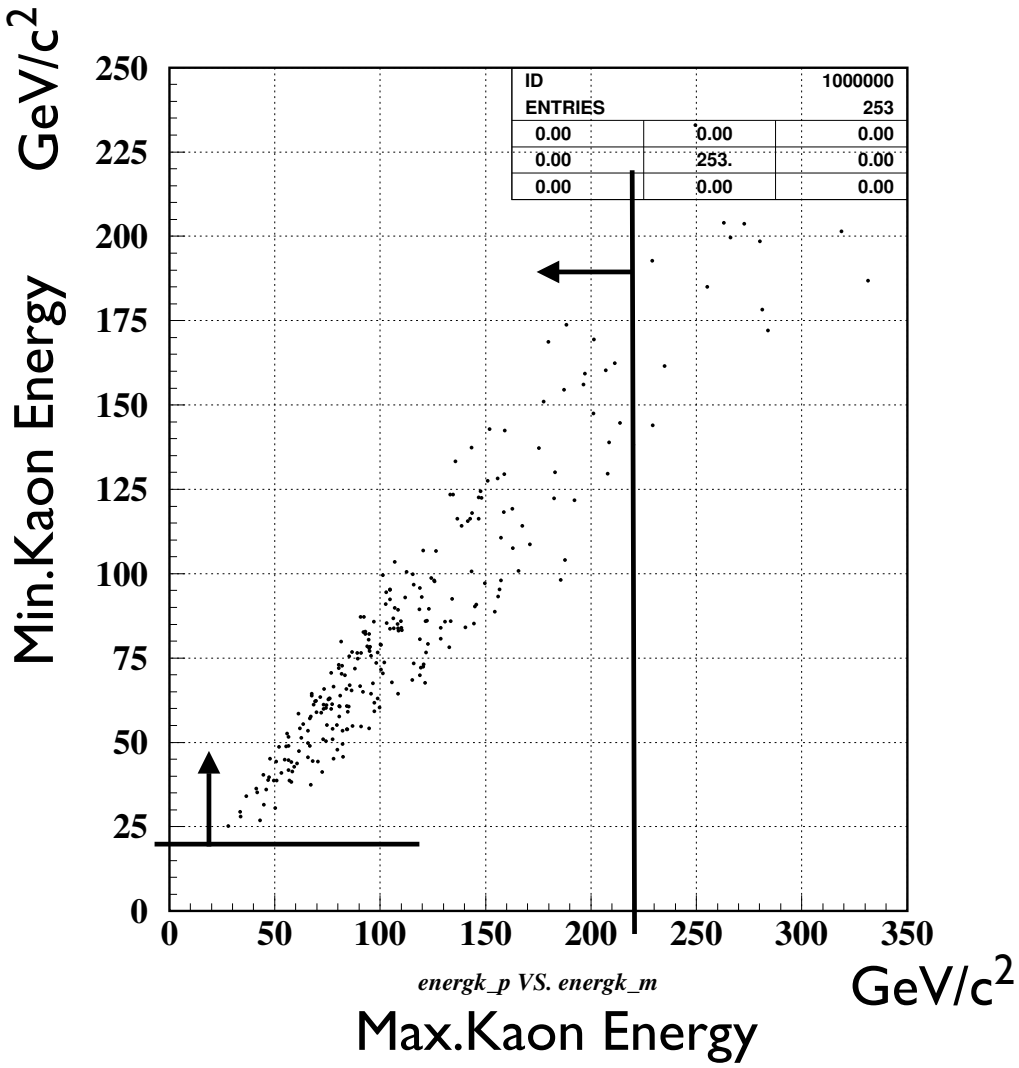
Back ground modes

	Branching ratio
$K_L \to \pi^{\pm} e^{\mp} \nu \pi^0_D$	6.21×10^{-7}
$K_L \to \pi^{\pm} e^{\mp} \nu \gamma \ \ (\gamma \to e^+ e^-, \mathrm{external})$	?
$K_L \to \pi^{\pm} \pi^{\mp} \pi^0 \ (\pi^0 \to e^+ e^- e^+ e^-)$	3.95×10^{-6}
$K_L \to \pi^{\pm} \pi^{\mp} \pi^0_D$	1.51×10^{-3}
$K_L \to \pi^{\pm} \mu^{\mp} \nu e^+ e^-$	?

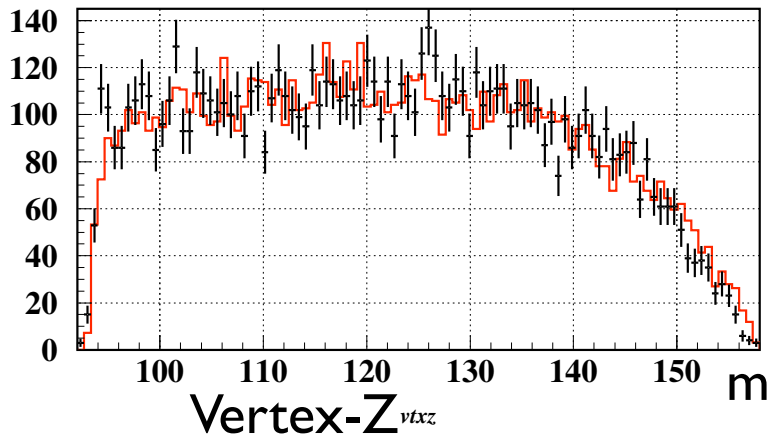
Final cuts

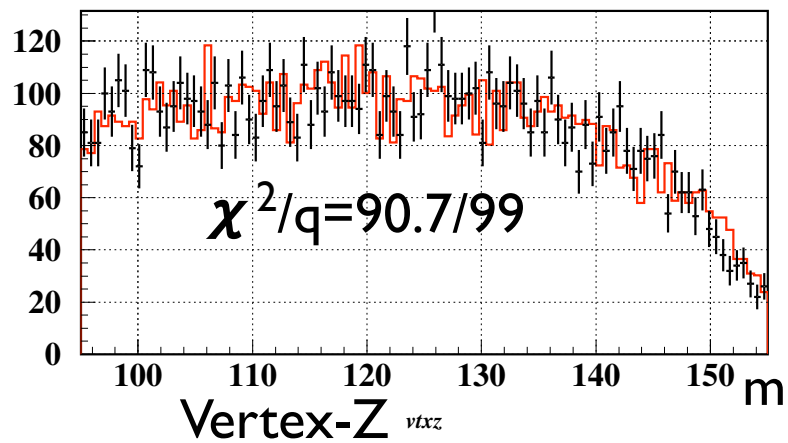
20 GeV/c^2 < EKaon(min), EKaon(max) < 220 GeV/c^2
95 m < VertexZ < 155 M
Vertex χ^2 < 40
0.95 < E/p < 1.05 for electron tracks
E/p <0.8 for pion tracks
TRD probability < 0.02 for electron tracks
TRD probability > 0.1 for pion tracks
pp0kine < -0.005 GeV^2/c^2
0 < Pv//^{*2} < 0.013 GeV^2/c^2
Me+e- > 0.004 GeV/c^2
Each e track goes through different cells of DC1
Epi_cluster < 1 GeV/c^2
Veto extra clustes away 0.3 m from π , 0.1 m from es (*)

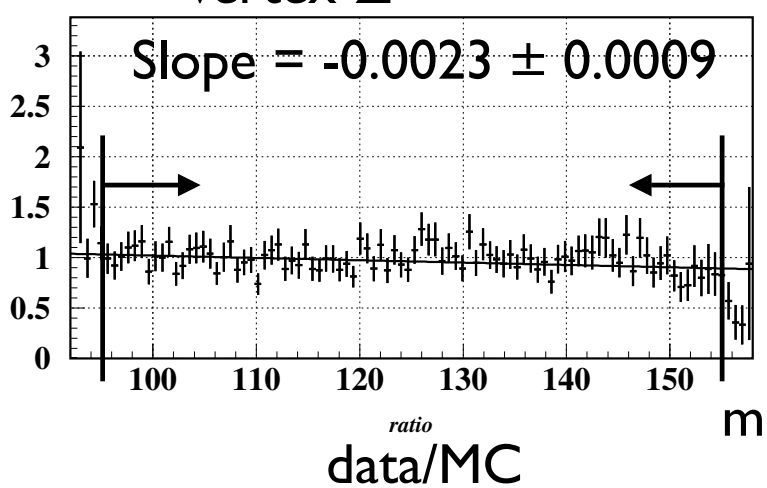
Kaon energy cut

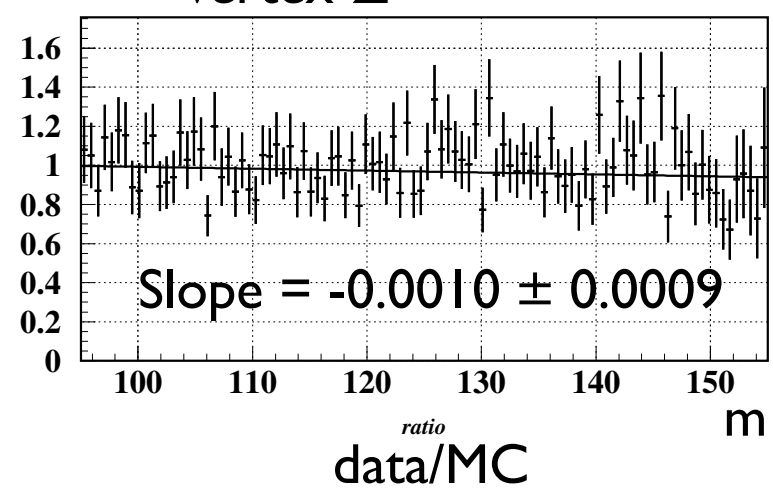


VertexZ cut

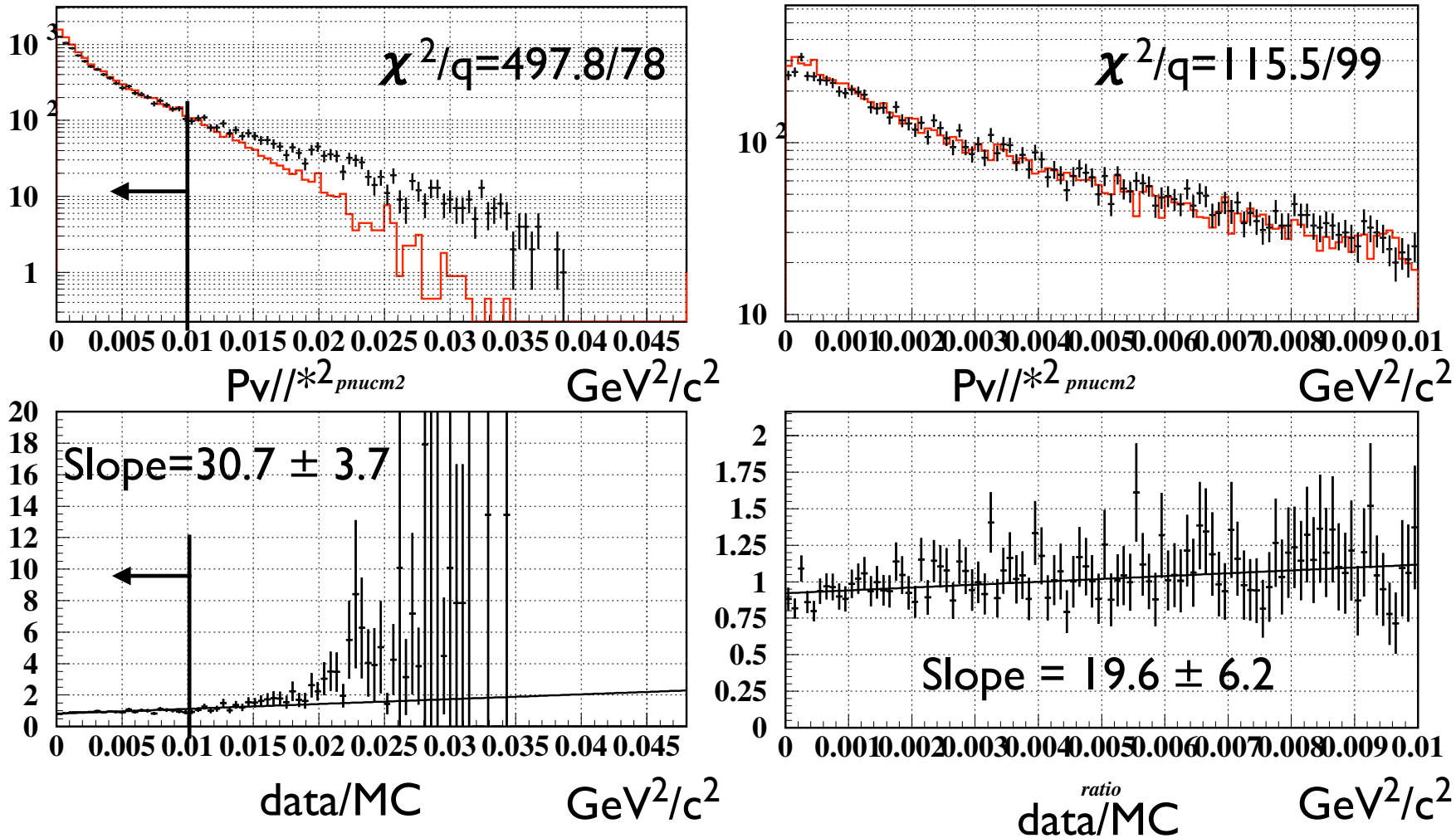

140
120
100
80
60
40
20
0
100
110
120
130
140
150
m
Vertex-Z vtxz


120
100
80
60
40
20
0
χ 2/q=90.7/99
100
110
120
130
140
150
m
Vertex-Z vtxz

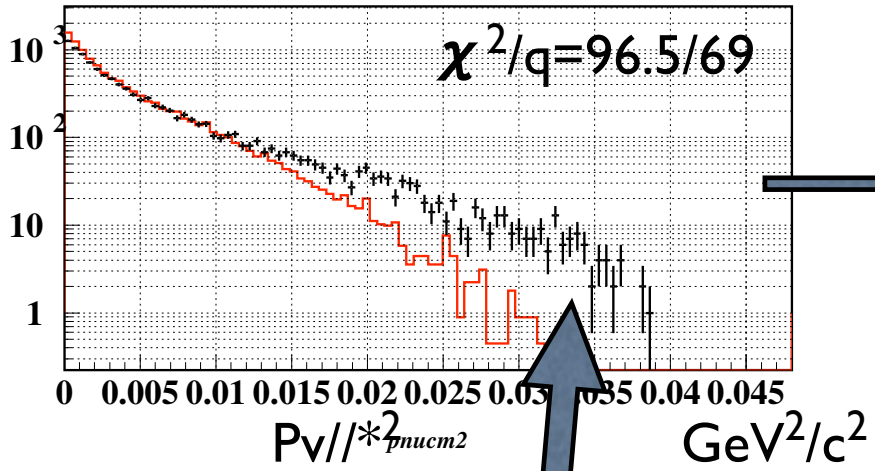

Slope = -0.0023 ± 0.0009
3
2.5
2
1.5
1
0.5
0
100
110
120
130
140
150
m
ratio
data/MC

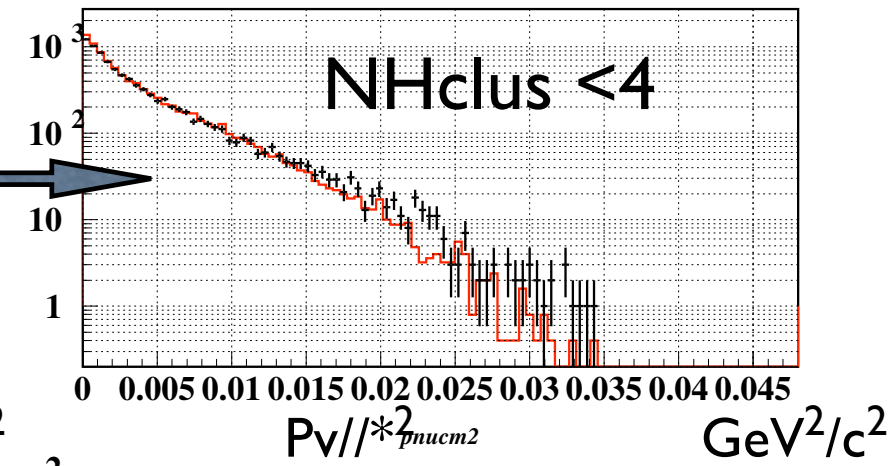

1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Slope = -0.0010 ± 0.0009
100
110
120
130
140
150
m
ratio
data/MC

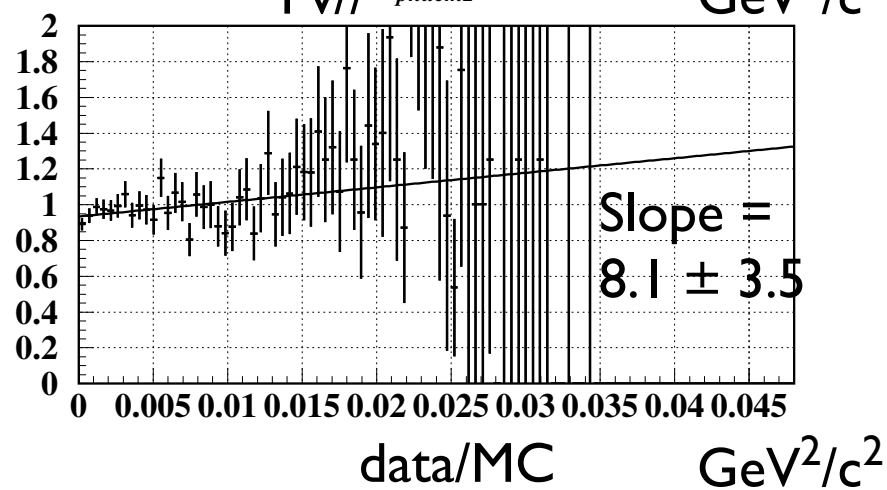
Squared longitudinal neutrino momentum in the CM system ($Pv//^{*2}$)



Squared longitudinal neutrino momentum in the CM system ($Pv//^{*2}$)



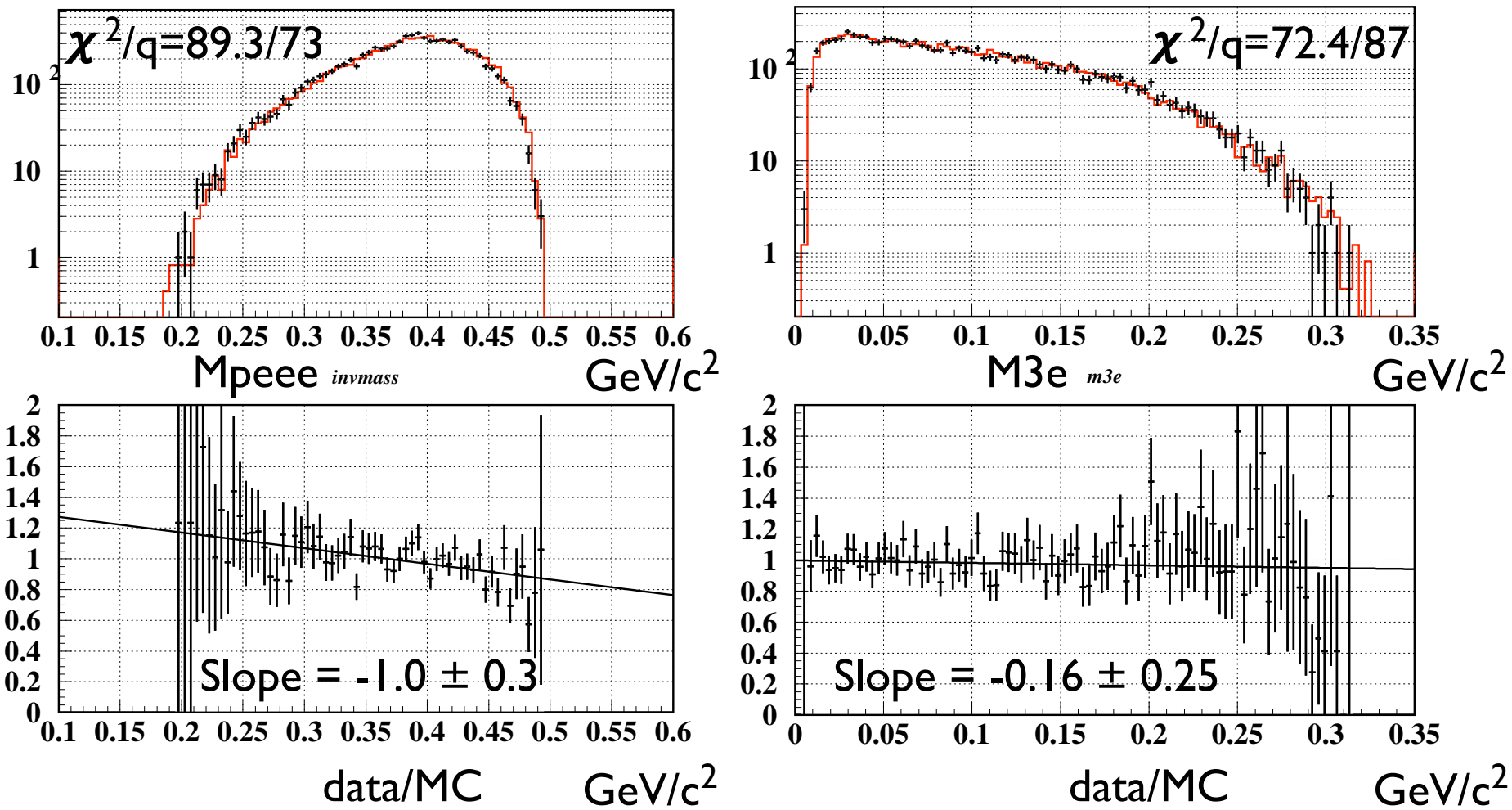




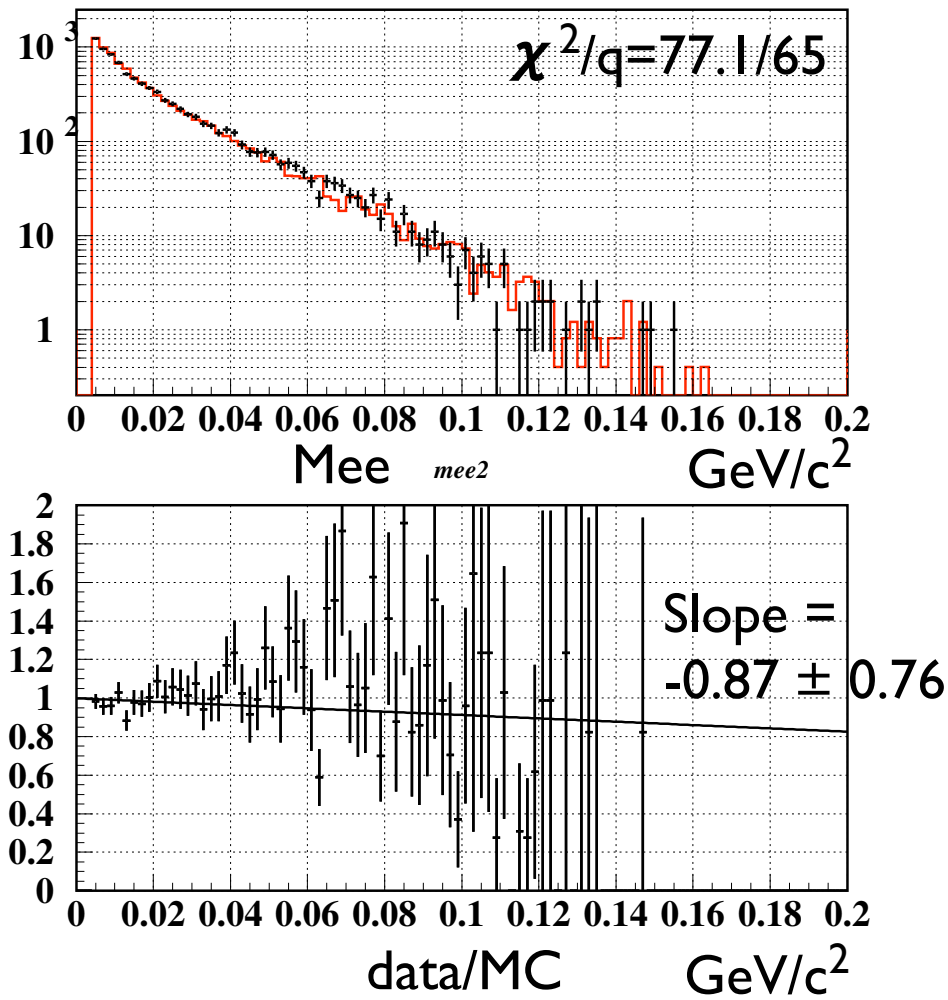
-No extra photon.
-Pion does not make shawer.
-Four Hardware cluster

Photon falls down close to an electron or pion cluster

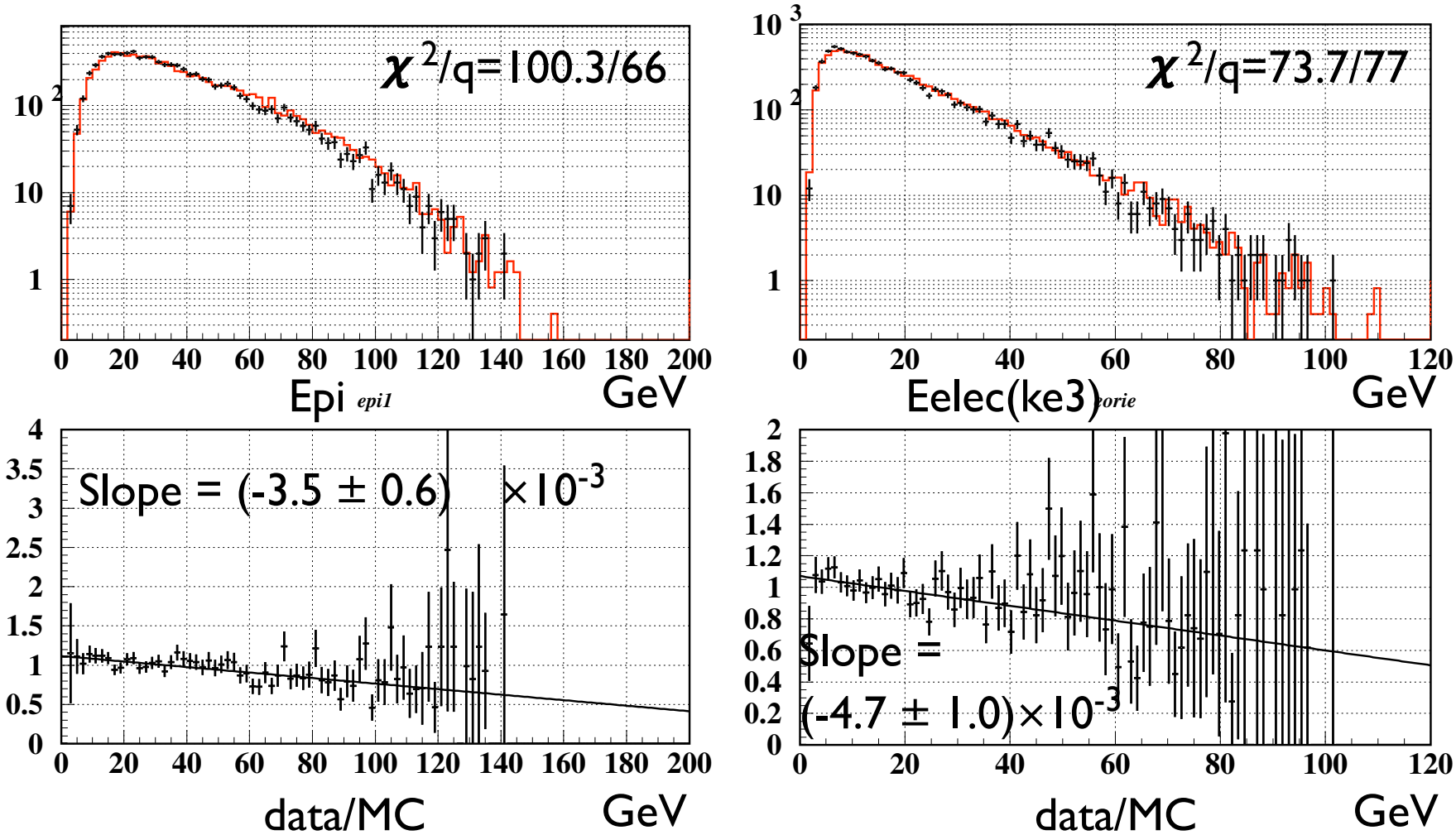
Invariant mass of π eee, eee



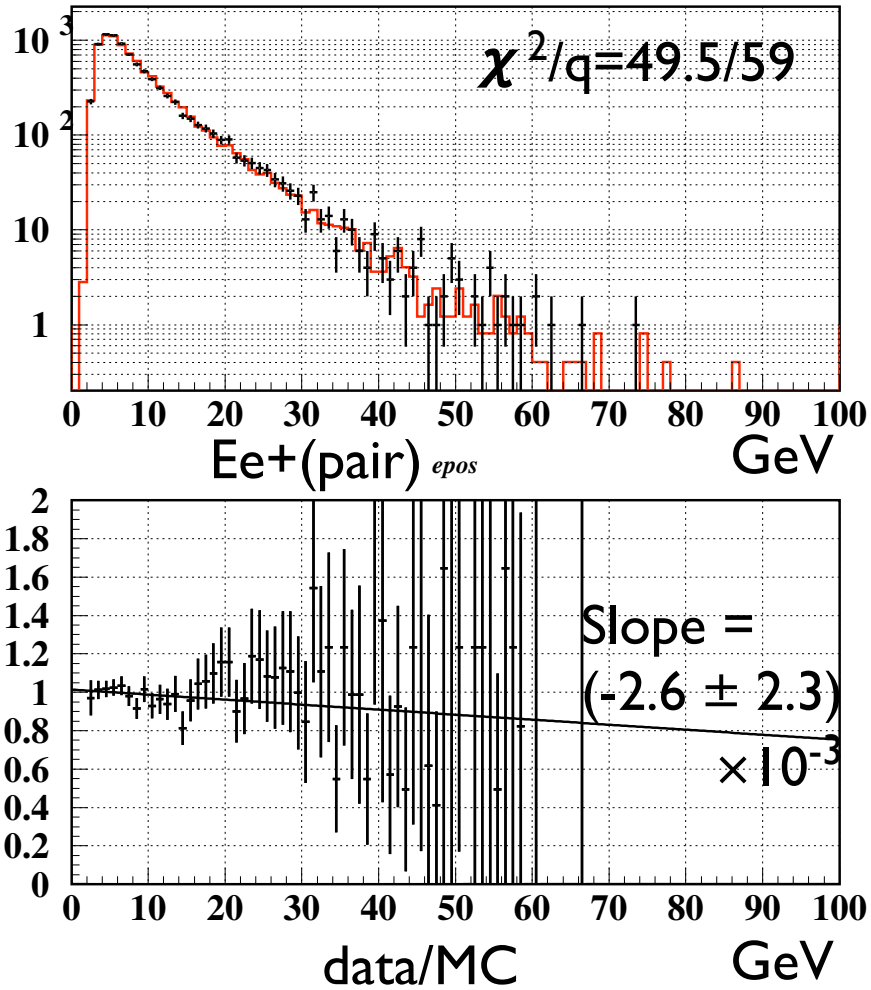
Invariant mass of e+e- pair



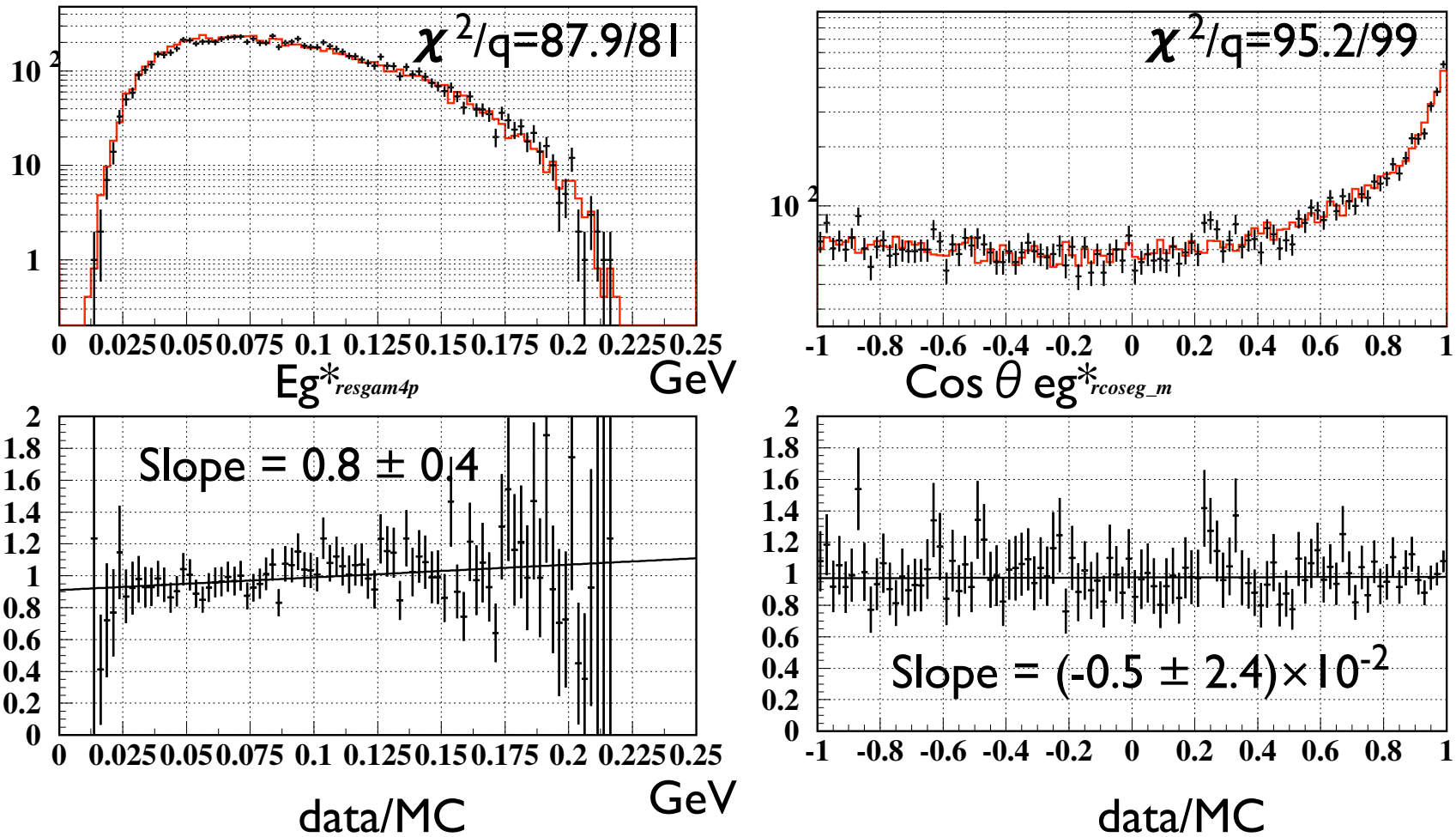
Energy distribution of charged particle(pion,e±;Ke3)



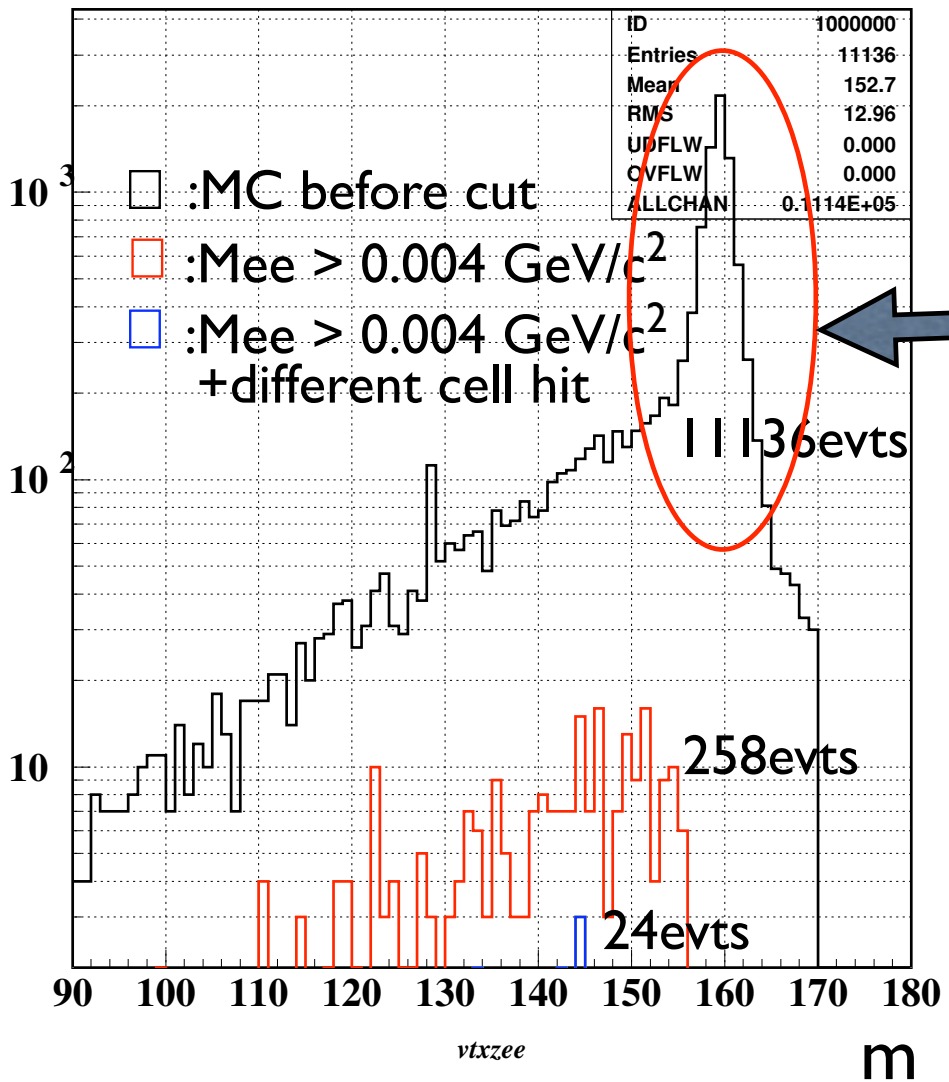
Energy distribution of charged particle(e+;pair)



Two kinematic variables in the CM system



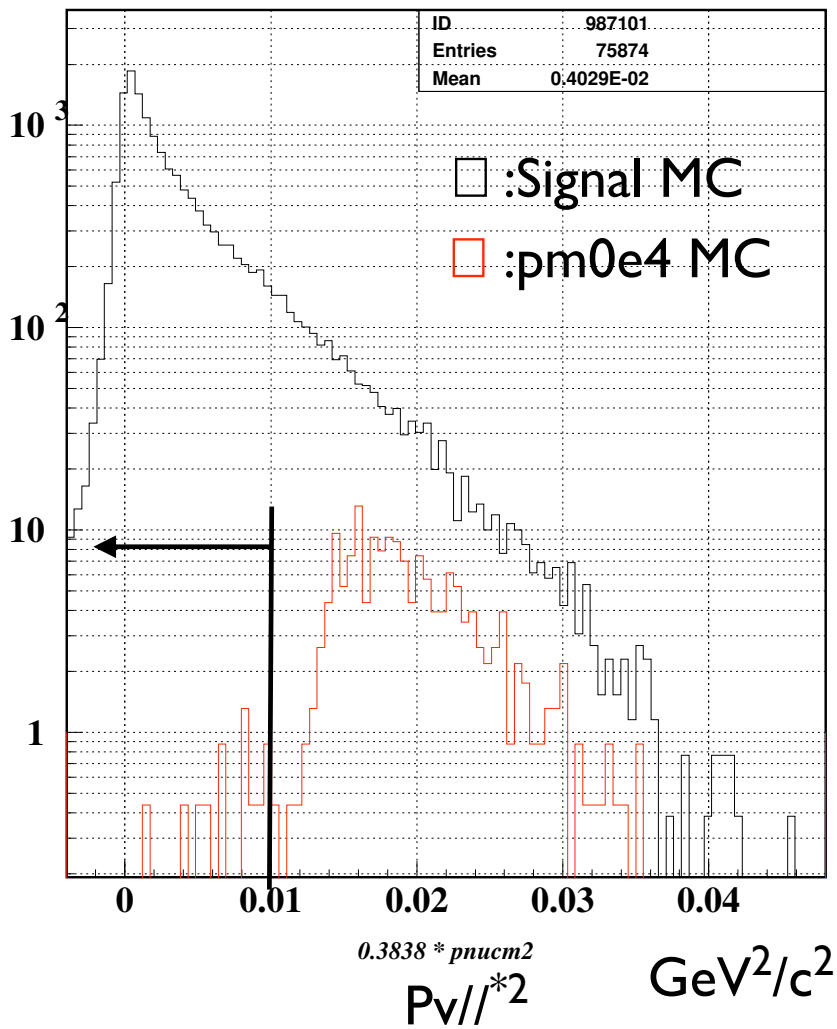
Cuts to reject Rad Ke3



e+e- Vertex z

Amount of Rad Ke3 with external conversion events are estimated by fitting this distribution to data.

Cuts to reject $K_L \to \pi^{\pm}\pi^{\mp}\pi^0\ (\pi^0 \to e^+e^-e^+e^-)$



Rimaining BG

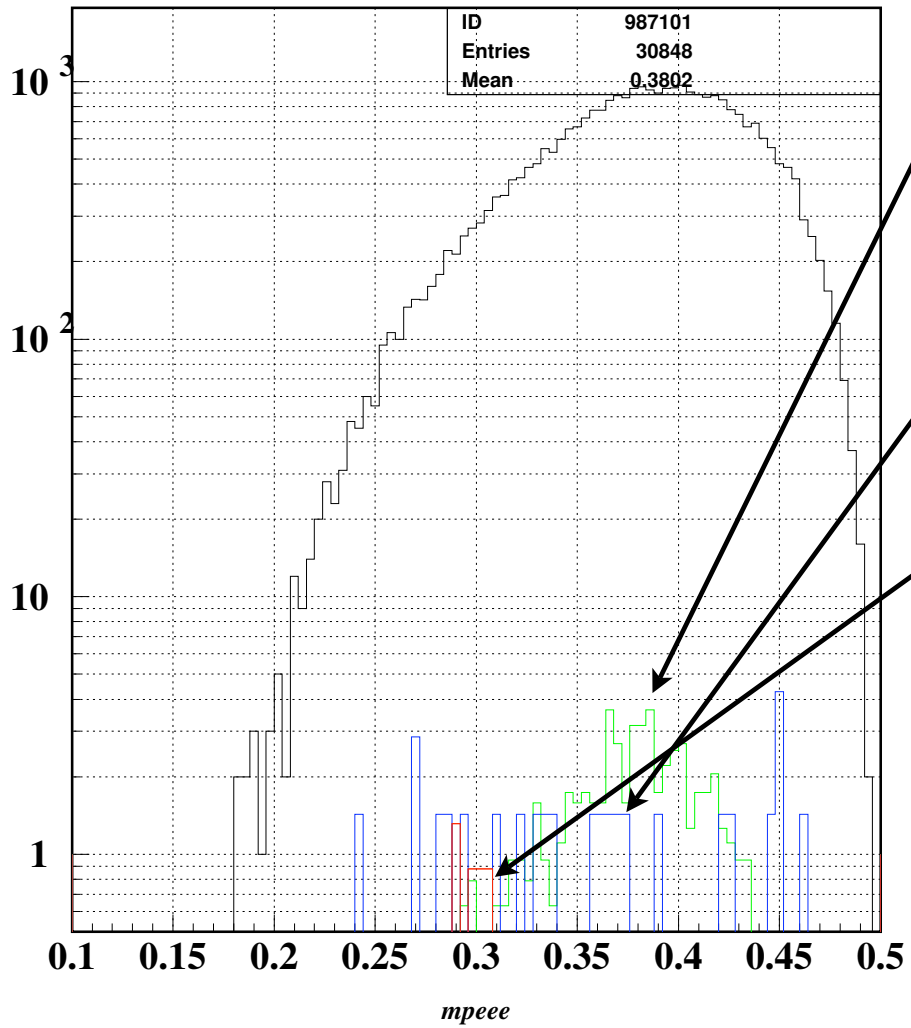
		N/S
$K_L \to \pi^{\pm} e^{\mp} \nu \pi^0_D$	58.9±3.1±2.6	0.0050
$K_L \to \pi^{\pm} e^{\mp} \nu \gamma \ (\gamma \to e^+ e^-, \mathrm{external})$	34±7	0.0029
$K_L \to \pi^{\pm} \pi^{\mp} \pi^0 \ (\pi^0 \to e^+ e^- e^+ e^-)$	8.8±2.0±0.5	0.0007
$K_L \to \pi^{\pm} \pi^{\mp} \pi^0_D$	4.1±0.9±0.1	0.0003
$K_L \to \pi^{\pm} \mu^{\mp} \nu e^+ e^-$	0.0±0.4	-
$K_L \to \pi^{\pm} e^{\mp} \nu e^+ e^-$ (signal)	$(1.183 \pm 0.011) \times 10^4$	

N/S total <1 %

The first error is statistic error and second error was calculatied with only branching ratios.

This is not final results!!

Amount of each BG



$K_L \to \pi^{\pm} e^{\mp} \nu \pi^0_D$

$K_L \to \pi^{\pm} e^{\mp} \nu \gamma$
$(\gamma \to e^+ e^-$,external$)$

$K_L \to \pi^{\pm} \pi^{\mp} \pi^0$
$(\pi^0 \to e^+ e^- e^+ e^-)$

$K_L \to \pi^{\pm} \pi^{\mp} \pi^0_D$

$K_L \to \pi^{\pm} \mu^{\mp} \nu e^+ e^-$

Normalization mode

$$K_L \to \pi^{\pm}\pi^{\mp}\pi^0_D$$

- Signal mode has one pion, however Normalization mode has two pion. I have to study pion loss in TRD.

- Now I am making a crunch code for simultaneous analysis for signal mode and normalization mode. However the code hangs in T3FVTX4 ??

Ke3ee radiative mode

- Ke3ee has three electrons, therefore we must treat radiative mode of Ke3ee like in the study of Ke3.

I'm trying to patch PHOTOS in my MC code.

MC generation(1)

- Despite of our very simple invariant matrix element (only leading order), many kinematic variables agree between data and MC.

$$T = \frac{G_F}{\sqrt{2}} e V_{us}^* \bar{\epsilon}^\mu(q) \Big[\bar{u}(k_2) \Big(\frac{2 q_\nu p_{2\mu}}{2 p_2 q + q^2} - g_{\mu\nu} \Big) \gamma^\nu (1-\gamma_5)$$

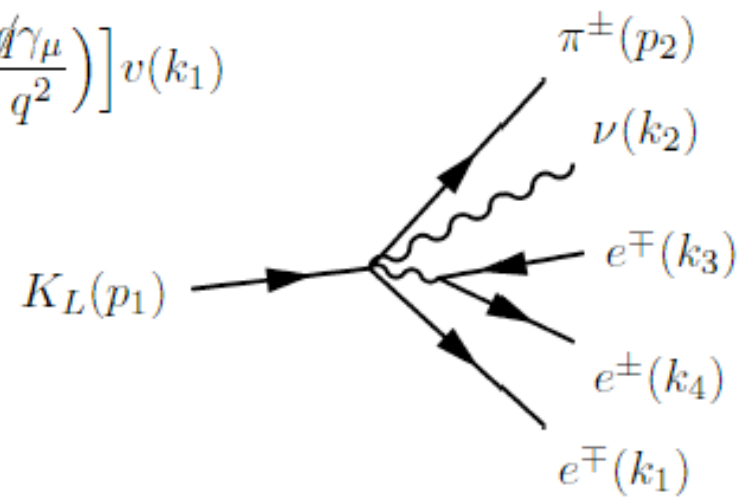
$$F_\nu^0 \bar{u}(k_2) \gamma^\nu (1-\gamma_5) \Big(\frac{2 p_{2\mu}}{2 p_2 q + q^2} - \frac{2 k_{1\mu} + \not{q} \gamma_\mu}{2 k_1 q + q^2} \Big) \Big] v(k_1)$$

$$\bar{\epsilon}^\mu(q) = \bar{u}(k_4) \gamma^\mu v(k_3)$$

$$q_\mu = (k_4 + k_3)_\mu$$

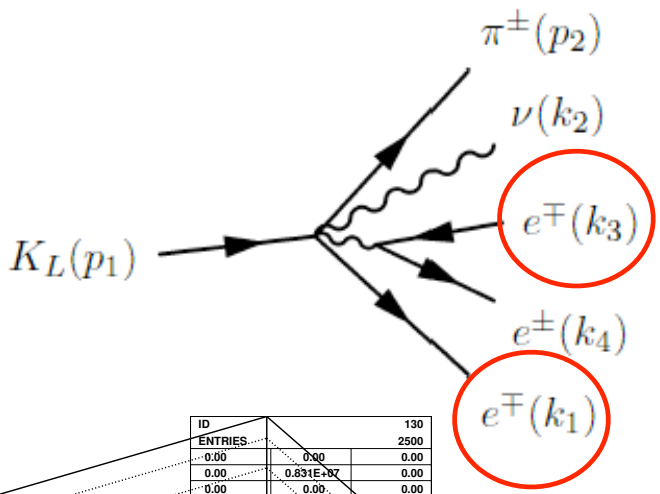
$$\boxed{F_\mu^0 = (p_1 + p_2)_\mu,}$$

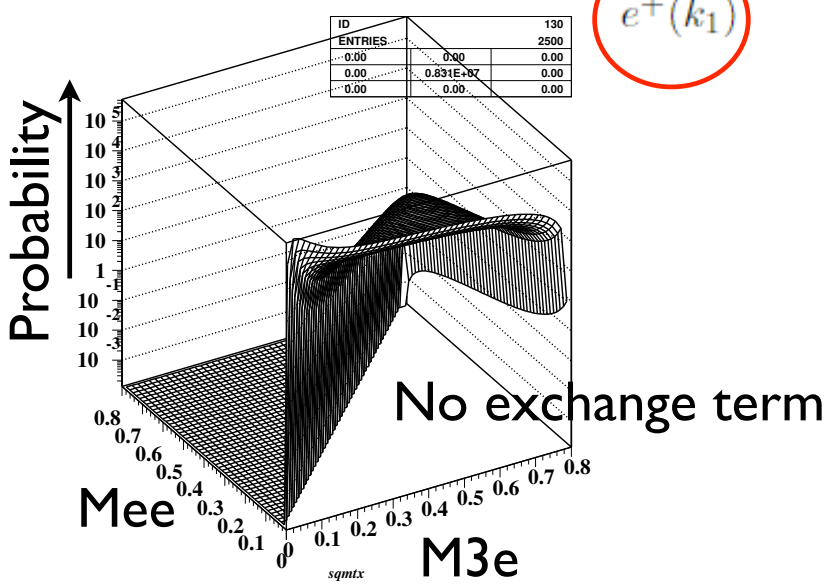
very simple form factor

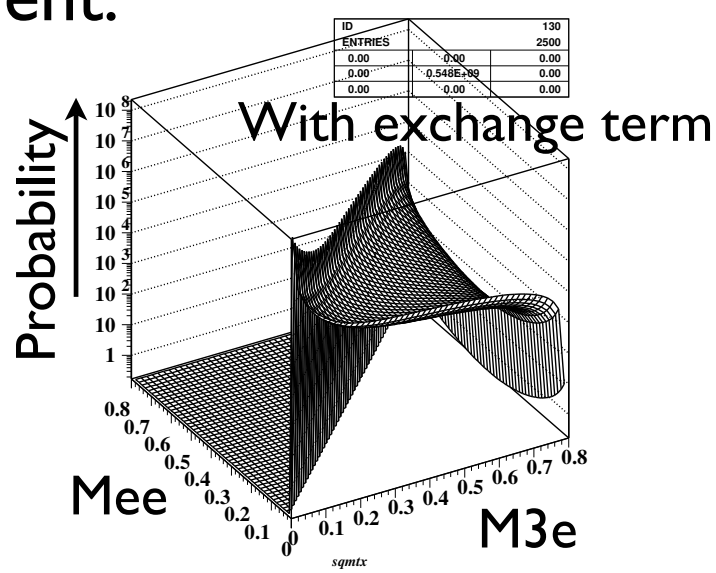


MC generation(2)

- Ke3ee has same charged electrons, therefore the matrix element must include exchange term.
The results I've shown today were accomplished using non exchange term matrix element.







Conclusion

- Many variables have agreement between Data and MC
- 10^4 signal events remain in '97 winter Data set.
- Back graound events are less than 1 % totally.

Plan

- Analyze Pm0dal decay mode (Normalization mode)
- Study of Pion loss in DC and TRD
- Integrate PHOTOS8 into Ke3ee MC (radiative Ke3ee)
- Systematic error analyses