

Measurement of $K^+ \rightarrow \pi^0 e^+ \nu$ (K_{e3}) Form Factors

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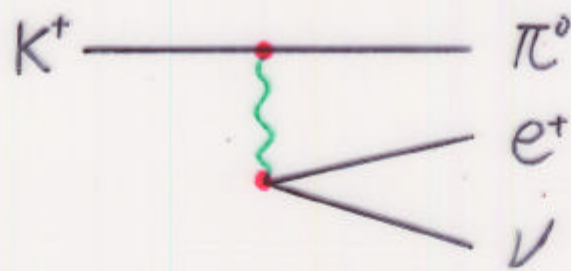
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Introduction

K_{e3} decay



coupling of lepton
hadron current

$$\begin{aligned} \mathcal{M} \propto & f_+(q^2) [(P_K + P_{\pi^0}) \bar{u}_l \gamma_\lambda (1 + \gamma_5) u_\nu] \\ & + f_-(q^2) [\cancel{m_l \bar{u}_l (1 + \gamma_5) u_\nu}] \\ & + 2m_K f_S \bar{u}_l (1 + \gamma_5) u_\nu \\ & + (2f_T/m_K) (P_K)_\lambda (P_{\pi^0})_\mu \bar{u}_l \sigma_{\lambda\mu} (1 + \gamma_5) u_\nu \end{aligned}$$

$$f_\pm(q^2) = f_\pm(0) [1 + \lambda_\pm (q/m_\pi)^2]$$

Dalitz plot measurement



Determination of the K_{e3} Form Factors

$$\lambda_+, f_S/f_+(0), f_T/f_+(0)$$

Current world average

$$\lambda_+ = 0.0276 \pm 0.0020$$

$$f_S/f_+(0) = 0.084 \pm 0.023$$

$$f_T/f_+(0) = 0.38 \pm 0.11$$

⊖ differ from 2

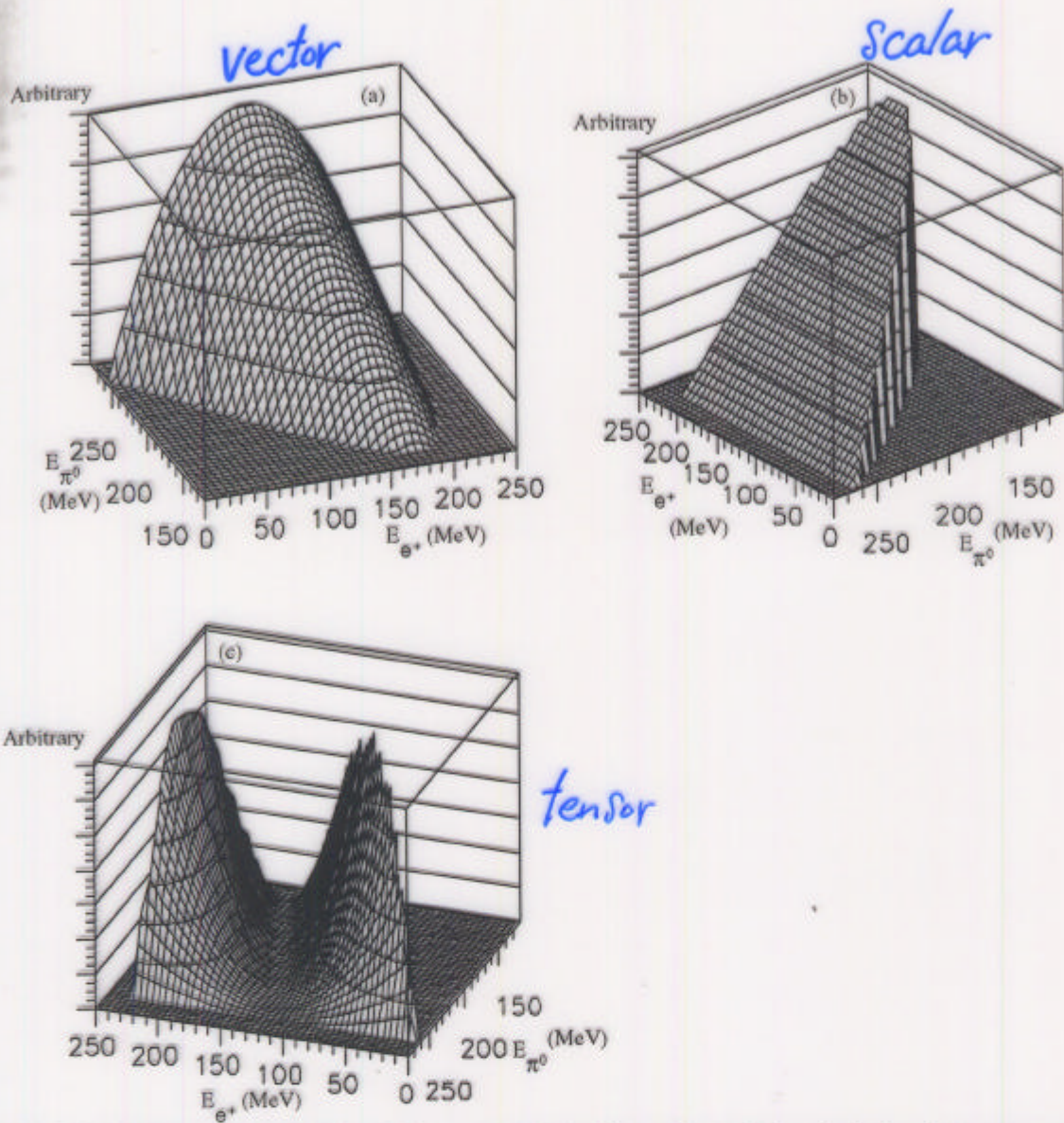


FIG. 1. The Dalitz plot distribution of K_{e3} events obtained by a Monte Carlo calculation. (a) was assuming the pure V-A interaction. (b) and (c) were obtained by assuming a pure scalar interaction, a pure tensor interaction, respectively. It should be noted that the scalar and tensor interaction affect the decay probability in the region near the kinematical boundary, although these shapes are different from each interaction.

B. Previous K_{e3} experiments

So far, several experiments have been carried out to study the form factor of K_{e3} [1-4,12]. Among those experiments two experiments are described briefly.

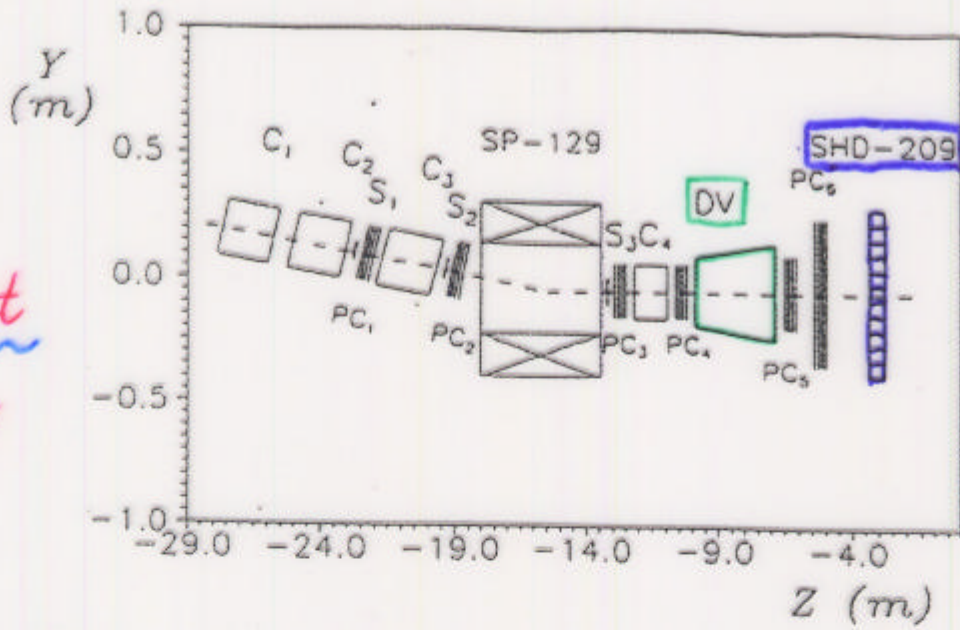
In an old experiment carried out by Braun et al. at CERN in 1974 [4], the events due to K_{e3} decay were detected by a 1.1 m^3 heavy liquid bubble chamber, which was filled with mixture of propane, ethane, and freon operated under the homogeneous magnetic field of 2.7 T. They measured angular distribution of π^0 and ν in the dilepton c.m. system and concluded

$$\begin{aligned} \lambda_+ &= 0.027 \pm 0.008 \\ |f_T/f_+(0)| &= 0.07 \pm 0.37 \\ |f_S/f_+(0)| &= 0.0 \pm 0.10 \end{aligned}$$

Their results are consistent with the values for pure V-A coupling. The number of K_{e3} event used in the analysis was 2827.

Previous experiment

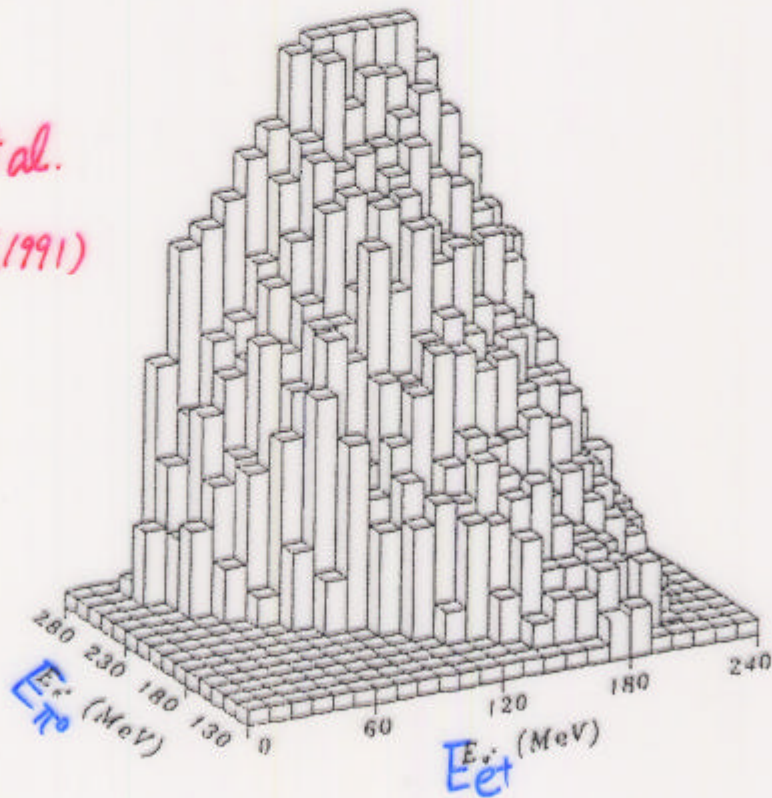
In-flight
 K^+ decay



S.A. Akimenko et al.

Phys. Lett. 259B (1991)

225.



results

$$\lambda_+ = 0.0284 \pm 0.0027 \pm 0.0020$$

$$f_S/f_{+}(0) = 0.070 \pm 0.016 \pm 0.016$$

$$f_T/f_{+}(0) = 0.53 \pm 0.10 \pm 0.10$$

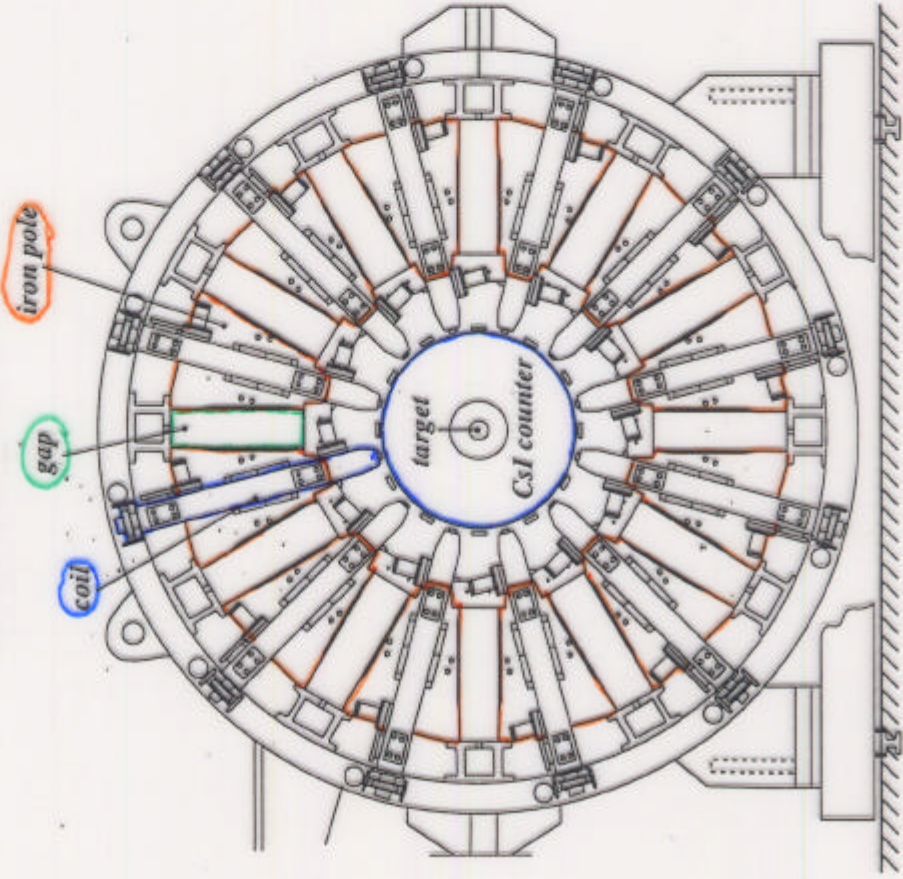
) dominate
current world average

Experimental Setup (KEK-PS E246) T-Violation Search in $K^+ \rightarrow \pi^0 \mu^+ \nu$ decay

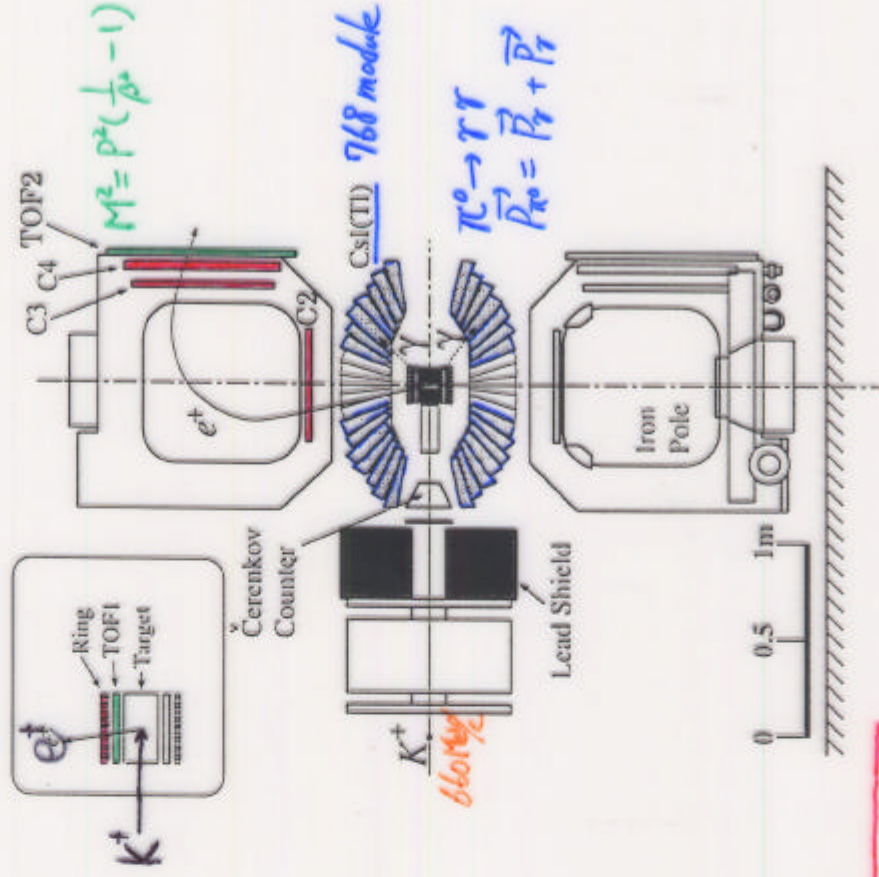
Stopped K^+

Toroidal Spectrometer

$B=0.65$ and 0.90 T



Special Trigger Condition
Not require muon decay



$K^+ \rightarrow \pi^0 e^+ \nu$

Advantage to use stopped kaon beam

- 1, Rotational symmetry of 12 identical gaps
Large directional acceptance π^0 detector



Integration of 12 gaps and π^0 direction



Suppression of systematic error

- 2, Kinematical resolution is better

Observables: E_e , E_π , and $\theta_{e\pi}$



Instead of E_π , $\theta_{e\pi}$ was used

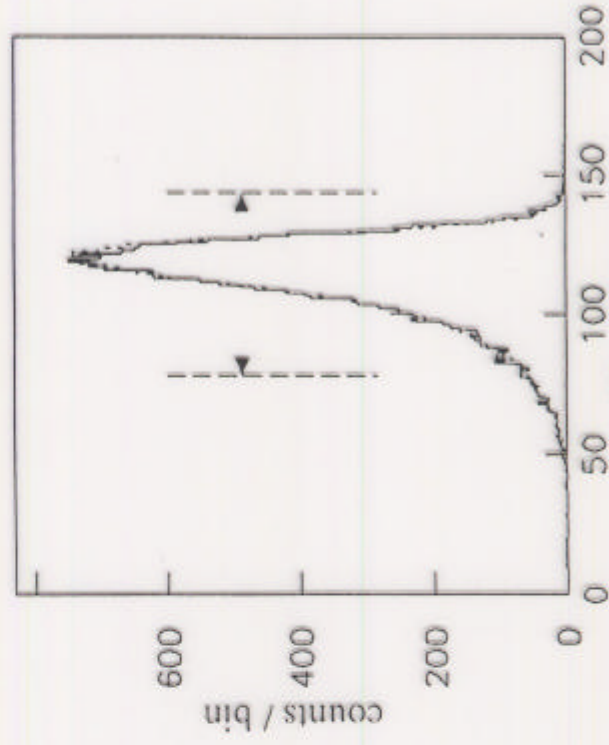
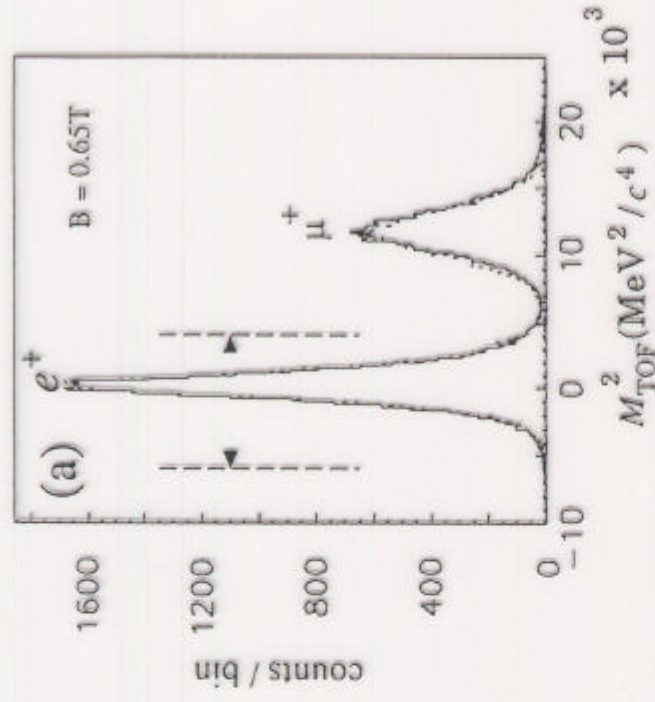


Suppression of systematic error

- 3, No influence from the beam history

Kes event selection

- K^+ decay time \rightarrow K^+ arrival time
5 nsec later
- $p_0 < M_{TTP} < 140 \text{ MeV}/c^2$
- M_{TOF}
- $\theta_{rec} < 166^\circ$



Ke3 spectra

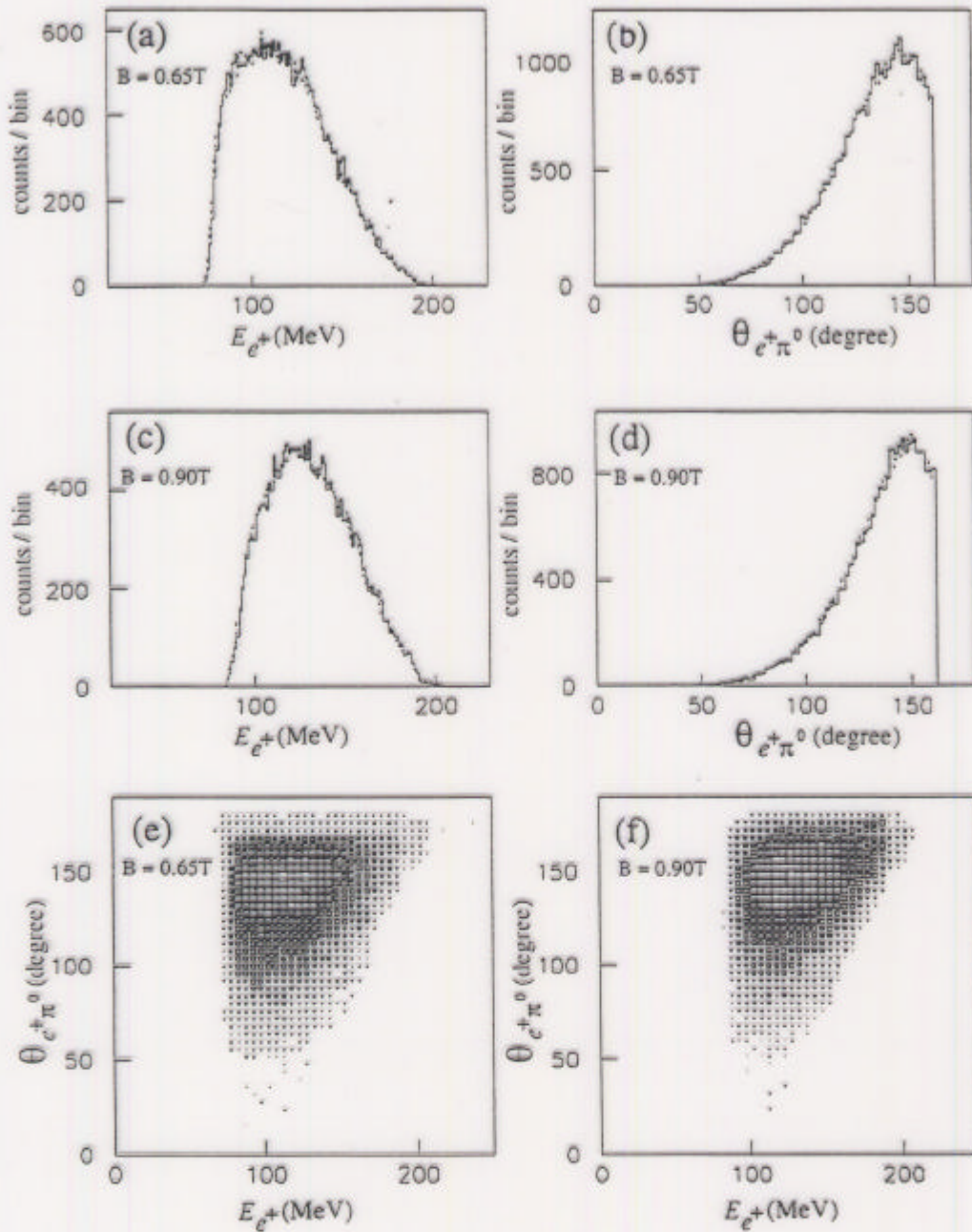


Fig. 4. Experimental spectra (solid line) of E_{e^+} (a,c) and $\theta_{e^+\pi^0}$ (b,d) for K_{e3} decay, and Monte Carlo simulation (dotted line) with the best fit λ_+ , $f_S/f_+(0)$, and $f_T/f_+(0)$ values for the settings of 0.65 and 0.90 T. The Dalitz density plots (e,f) are also shown.

Statistic

$B = 0.65$ T 24 k events

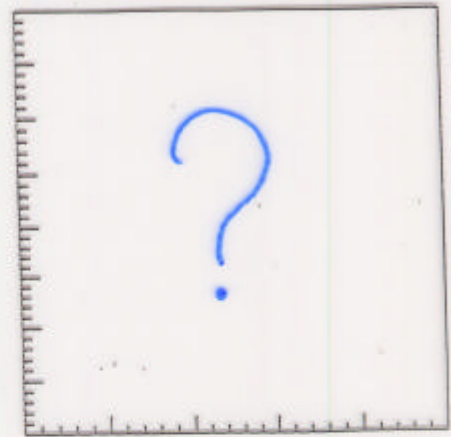
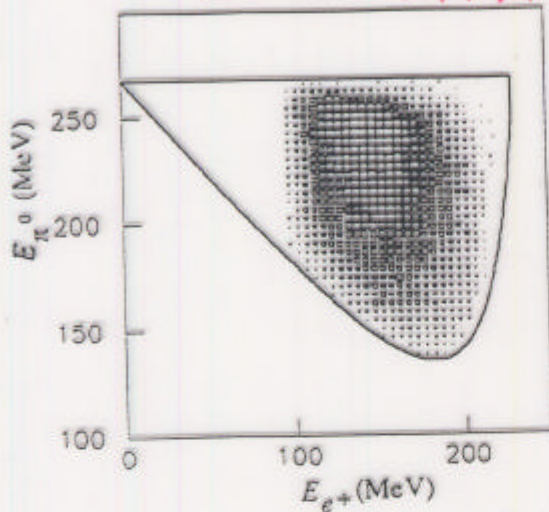
0.90 T 17 k events

Determination of form factors

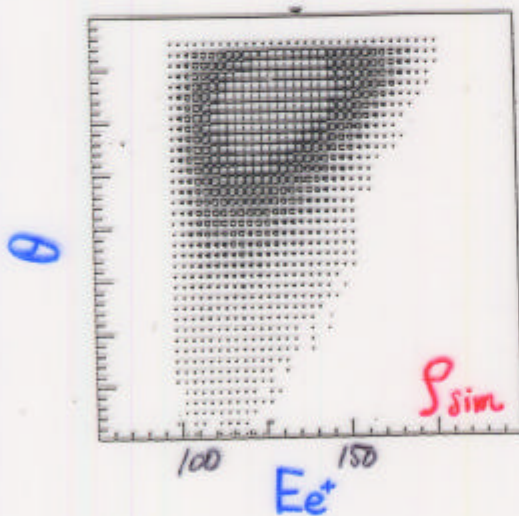
M.C. Simulation

$$P_{\text{mea}}(E_e, \theta) = \iint R(E_e, \theta : E_e^{\text{orig}}, E_{\pi}) P_{\text{og}}(E_e^{\text{orig}}, E_{\pi}) dE_e^{\text{orig}} dE_{\pi}$$

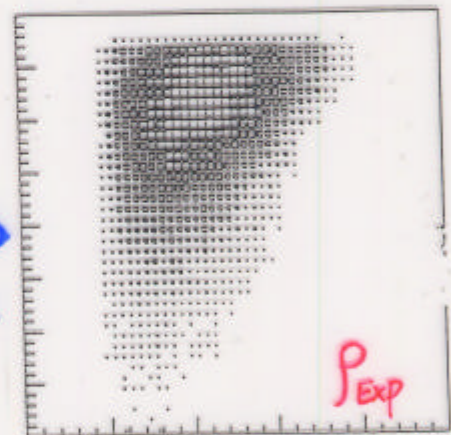
assume λ_+, f_s, f_T



reconstruct

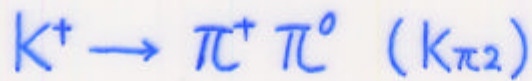


Compare

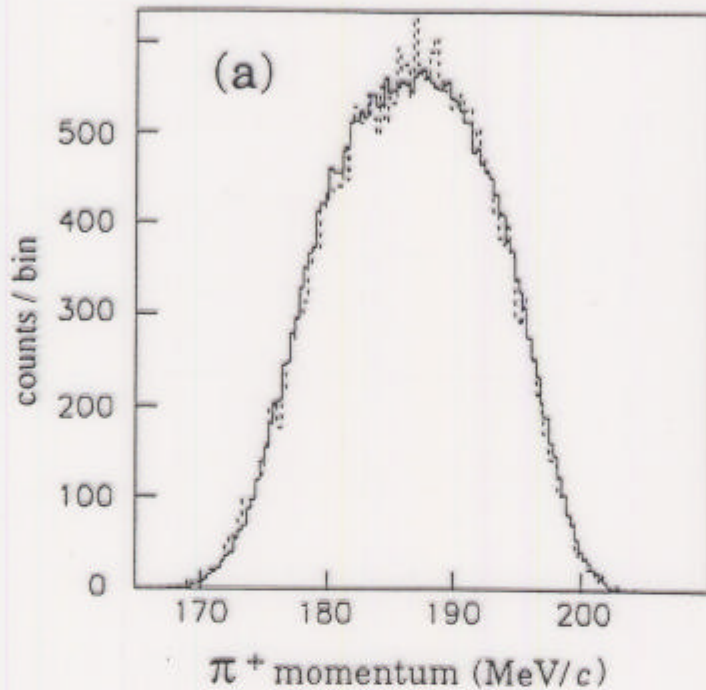


- assume λ_+, f_s, f_T
 - reconstruct $P_{\text{sim}}(E_e, \theta)$
 - compare $P_{\text{sim}}(E_e, \theta)$ and $P_{\text{exp}}(E_e, \theta)$
- minimize χ^2

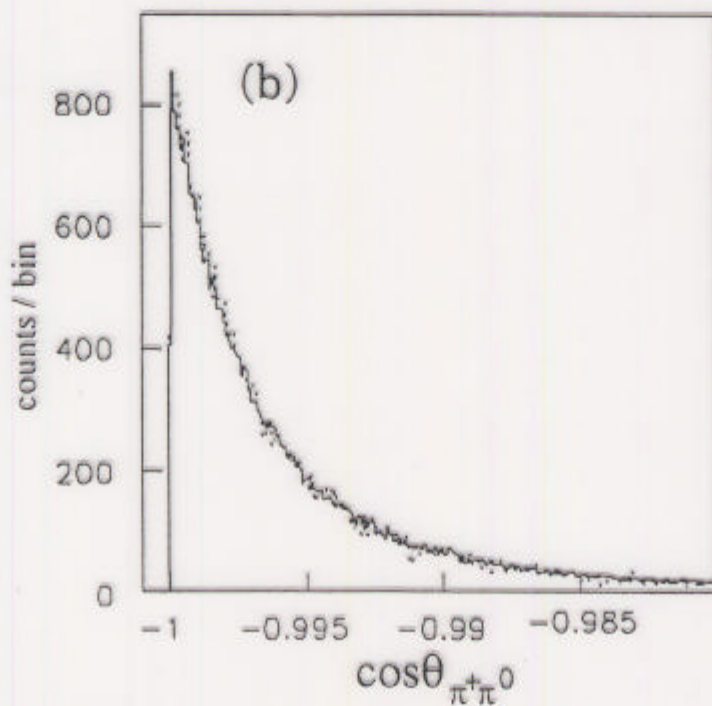
Validity of Monte Carlo Simulation



Compare π^+ momentum and $\theta_{\pi^+\pi^0}$
with simulation.



$$\chi^2 = 114 \text{ (107 bins)}$$



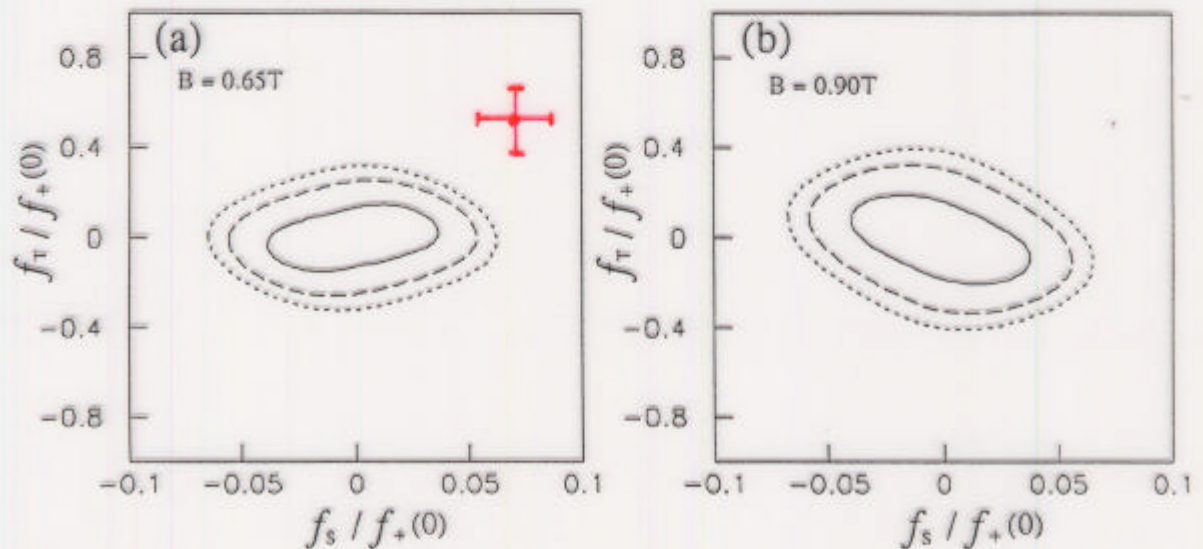
$$\chi^2 = 183 \text{ (191 bins)}$$

Fitting results

Table 1
Fitting results of the K_{e3} form factor parameters.

Data	Analysis	Reduced χ^2	λ_+	$f_S/f_+(0)$	$f_T/f_+(0)$
0.65 T	V-A	1.25	0.0288 ± 0.0033		
0.90 T	V-A	1.10	0.0266 ± 0.0038		
combined	V-A		0.0278 ± 0.0025		
0.65 T	V-A,S,T	1.25	0.0288 ± 0.0033	-0.002 ± 0.033	-0.02 ± 0.15
0.90 T	V-A,S,T	1.10	0.0266 ± 0.0039	-0.001 ± 0.040	0.01 ± 0.24
combined	V-A,S,T		0.0278 ± 0.0026	-0.002 ± 0.026	-0.01 ± 0.14
Akimenko <i>et al.</i> [1]			0.0284 ± 0.0029	0.070 ± 0.016	0.53 ± 0.14
world average [2]			0.0276 ± 0.0021	0.084 ± 0.023	0.38 ± 0.11

Contour plot



Systematic error

Error source	$\Delta\lambda_+$	Δf_S	Δf_T
[π^0 detection]			
misalignment of the CsI(Tl) barrel	0.0014	< 0.001	< 0.01
cut point dependence	0.0002	< 0.001	< 0.01
beam background	0.0010	< 0.001	< 0.01
[e^+ detection]			
misalignment of the MWPCs	0.0007	< 0.001	< 0.01
chamber spatial resolution	0.0005	< 0.001	< 0.01
field strength of the toroidal spectrometer	0.0009	< 0.001	< 0.01
e^+ identification	0.0002	< 0.001	< 0.01
cut point dependence for the tracking	0.0006	< 0.001	< 0.01
cut point dependence for e^+ identification	0.0007	< 0.001	< 0.01
[MC simulation]			
photon conversion in the target	0.0004	0.004	0.03
e^+ bremsstrahlung in the target	0.0018	0.013	0.08
total	0.0030	0.014	0.09

Conclusion

PLB 495(2000) 33.

$$\lambda_+ = 0.0278 \pm 0.0026(stat) \pm 0.0030(syst)$$

$$f_S/f_+(0) = -0.002 \pm 0.026(stat) \pm 0.014(syst)$$

$$f_T/f_+(0) = -0.01 \pm 0.14(stat) \pm 0.09(syst)$$

@ λ_+ is consistent with the current world average

@ f_S, f_T is consistent with the V-A coupling.