

Semileptonic Decays of Neutral Kaons at NA48

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on behalf of the NA48 collaboration

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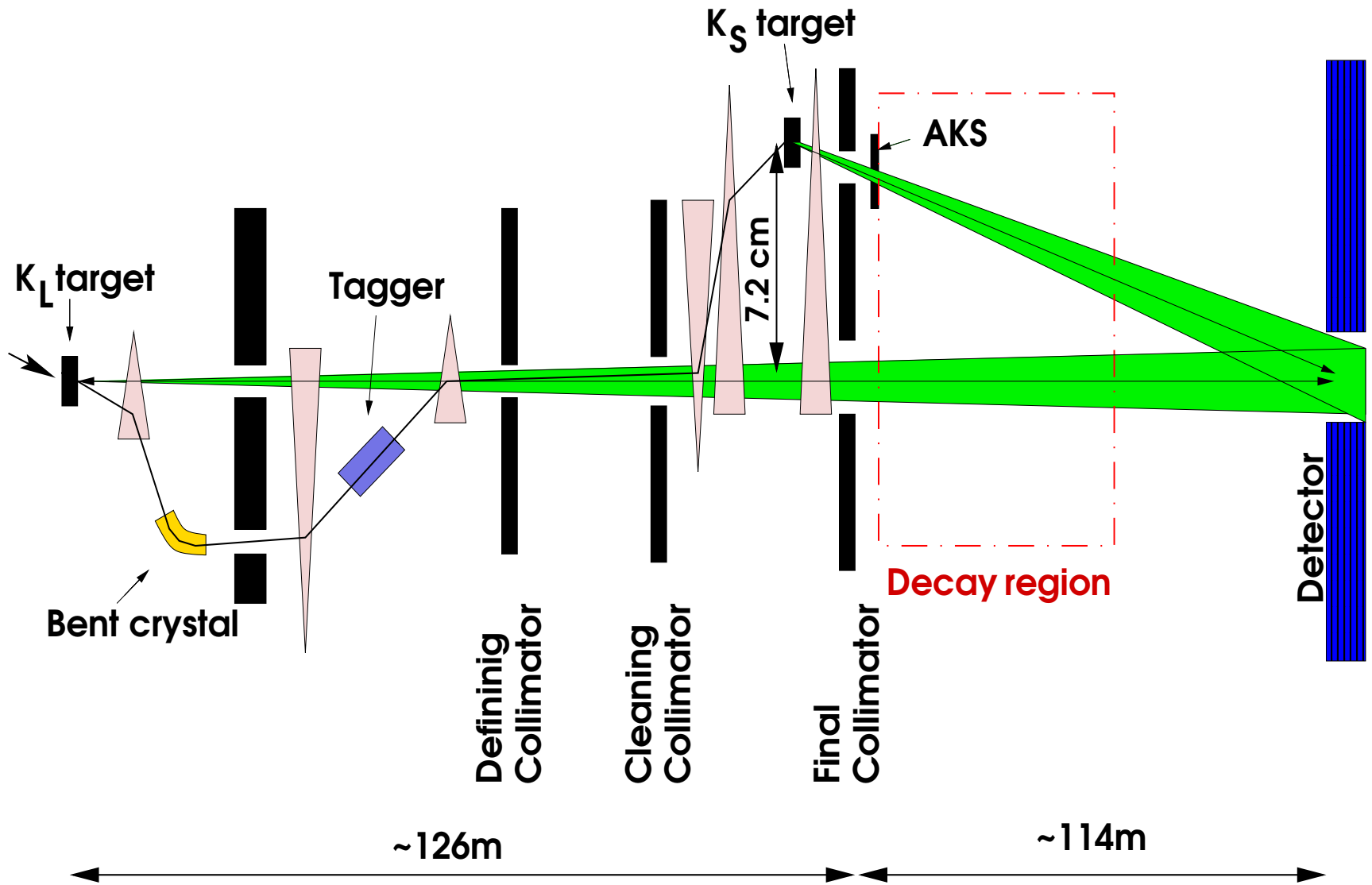
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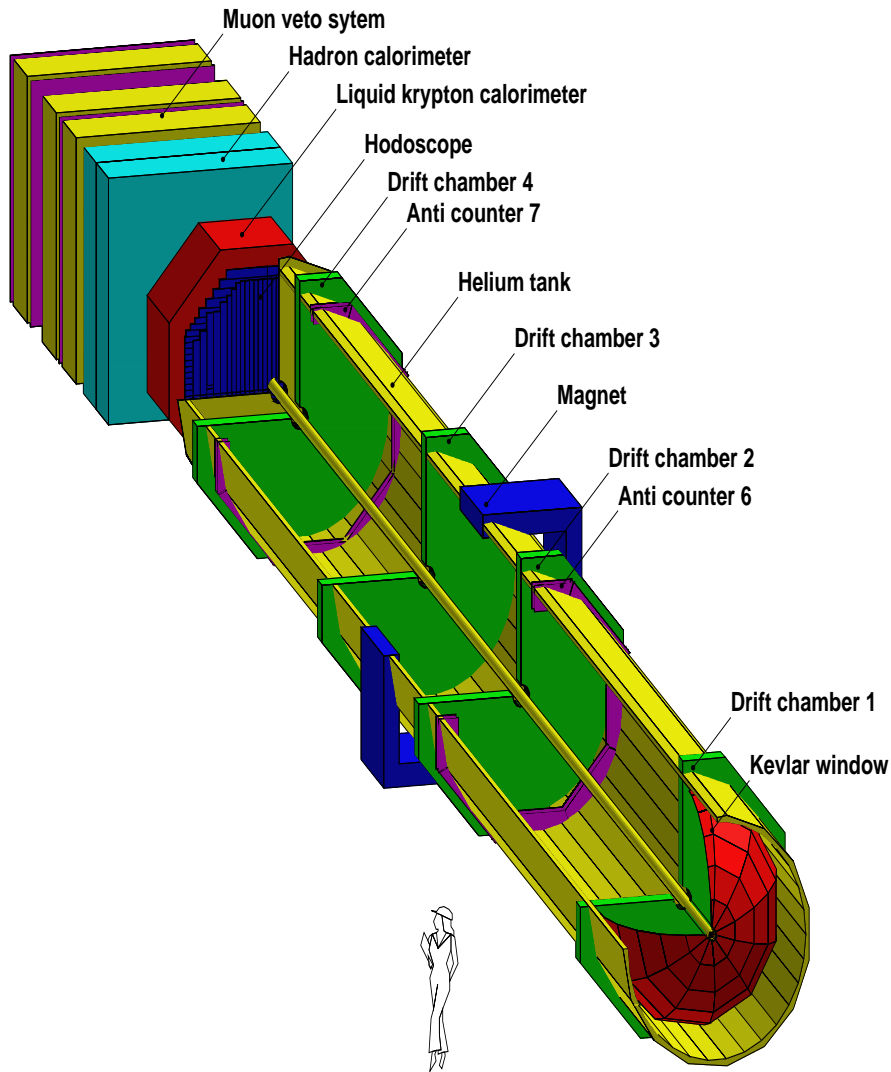
Contents

- The NA48 experiment
- $K_L \rightarrow \pi^+ \pi^0 e^- \nu$ (K_{e4})
- $K_L \rightarrow \pi^\pm e^\mp \nu \gamma$ ($K_{e3\gamma}$)
- $K_L \rightarrow \pi^\pm e^\mp \nu$ (K_{e3})
- Prospects for further semileptonic neutral Kaon decays
- Summary/Conclusions

Beam Line - NA48



The NA48 Detector System



- Magnetic spectrometer:
charged particles

- $\frac{\sigma(p)}{p} \approx 0.5\% \oplus 0.009\% p$

- Liquid Krypton em calorimeter
photons and particle id

- $\frac{\sigma(E)}{E} \approx \frac{3.2\%}{\sqrt{E}} \oplus \frac{9\%}{E} \oplus 0.42\%$

- $\sigma(t) < 300\text{ps}$ for $50\text{GeV } e^-$

- $\sigma(r) < \frac{5.4\text{mm}}{\sqrt{E/\text{GeV}}}$

- Muon System:
muon id

- $\sigma(t) \approx 350\text{ps}$

- $25\text{cm} \times 25\text{cm}$ cells

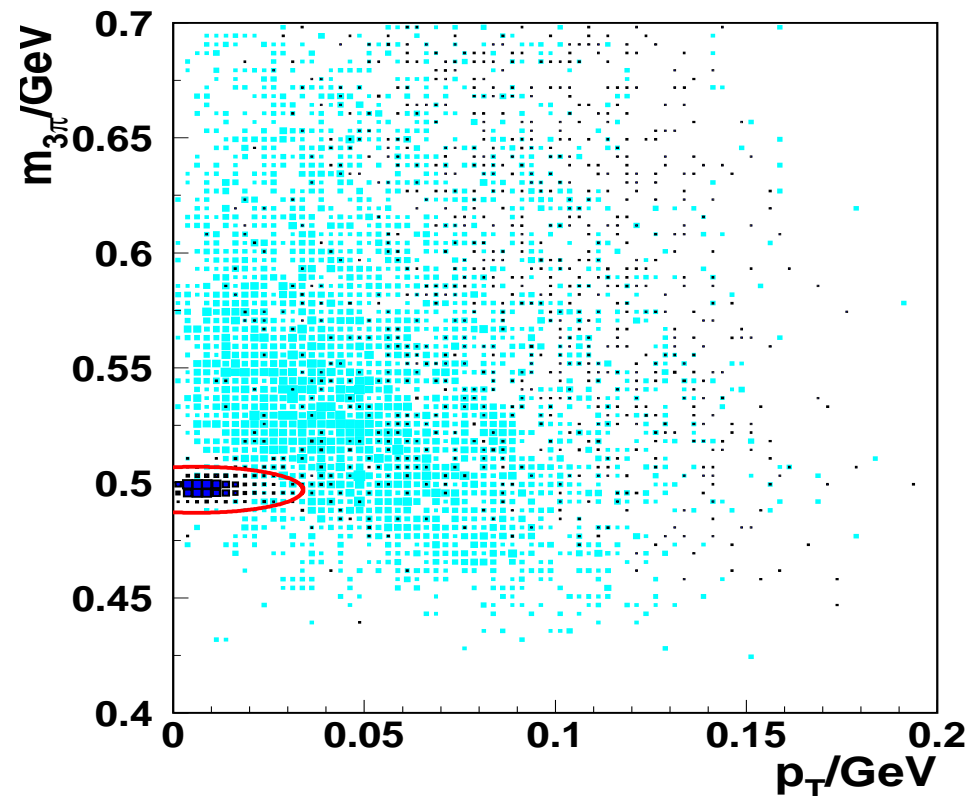
$$K_L \rightarrow \pi^\pm \pi^0 e^\mp \nu_e$$

Branching ratio and Form Factors of $K_L \rightarrow \pi^\pm \pi^0 e^\mp \nu_e$

- good testground for *ChPT* predictions for long distance meson interactions
- form factor measurement allows to deduce parameters of *ChPT*

Main Background

- $K_L \rightarrow \pi^+ \pi^- \pi^0$
with mis-identified e
 \Rightarrow cut on $\chi_{3\pi}^2 > 16$ with
$$\chi_{3\pi}^2 = \left(\frac{M_{3\pi} - M_K}{\sigma_M} \right)^2 + \left(\frac{p_t - p_{t0}}{\sigma_p} \right)^2$$
- employ neural network to improve e/π distinction
(trained with well identified e and π^\pm from $K_{\pi 3}$ and K_{e3})



$$K_L \rightarrow \pi^\pm \pi^0 e^\mp \nu_e$$

- *Previous measurement:*

- E731 (Fermilab) : 729 events

- **Used data sample (run in 2001):**

- protons with $E_{\text{beam}} = 400 \text{ GeV}/c^2$ on beryllium target
- 2 different triggers: **special K_{e4}** and **minimum bias trigger**

(downscaled by a factor of 50 and 30 respectively)

- Total number of selected K_{e4} events (NA48)

⇒ 5464 with 62 estimated background events

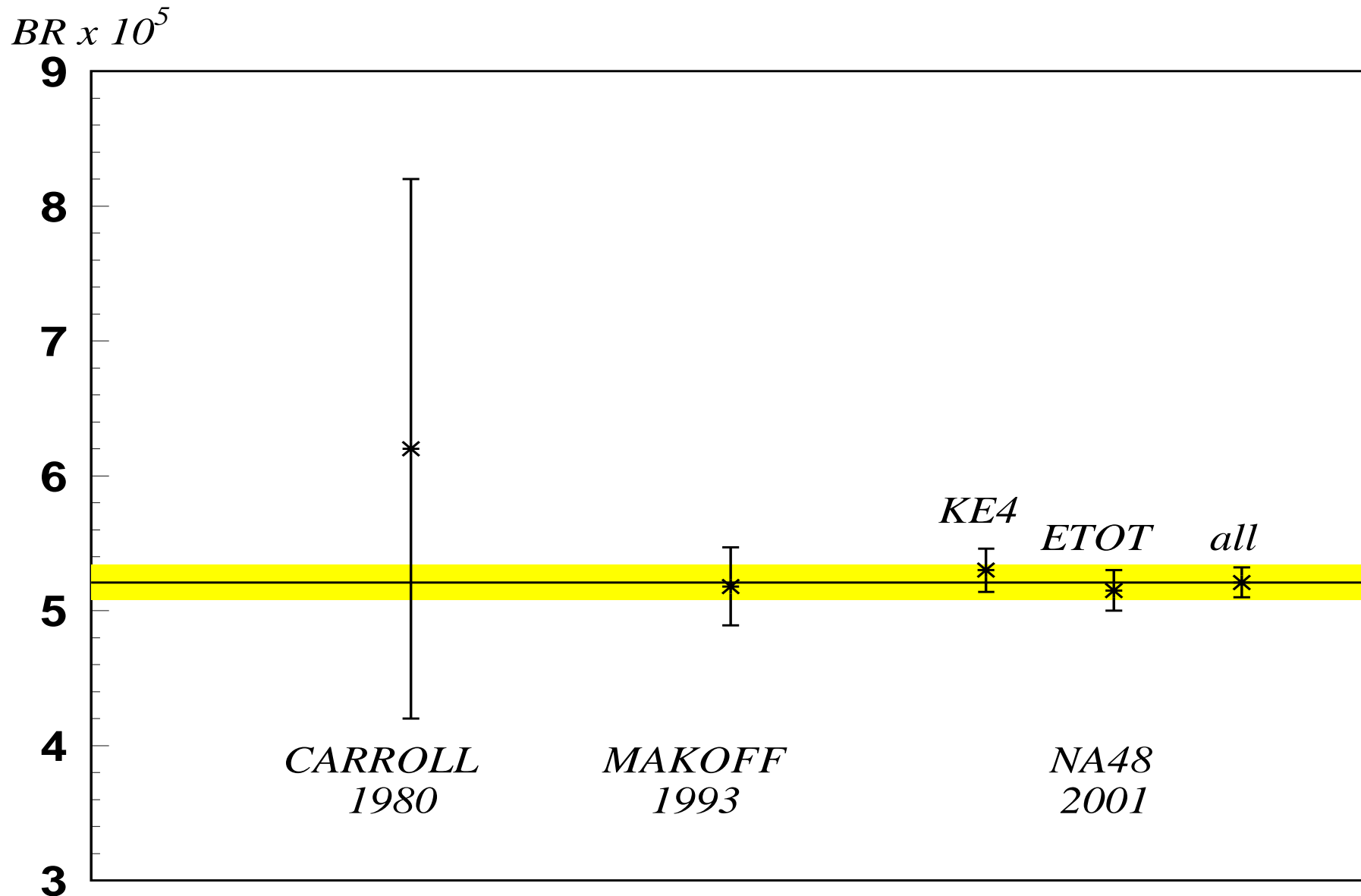
- Branching ratio

$$\Rightarrow \text{BR}(K_{e4}) = (5.21 \pm 0.07_{\text{stat}} \pm 0.09_{\text{syst}}) \times 10^{-5}$$

(normalized to the branching fraction of the reference channel $\text{BR}(K_{\pi 3}) = (12.58 \pm 0.19)\%$)

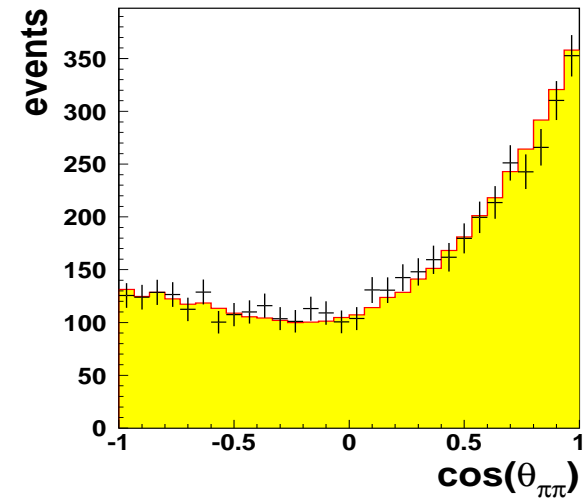
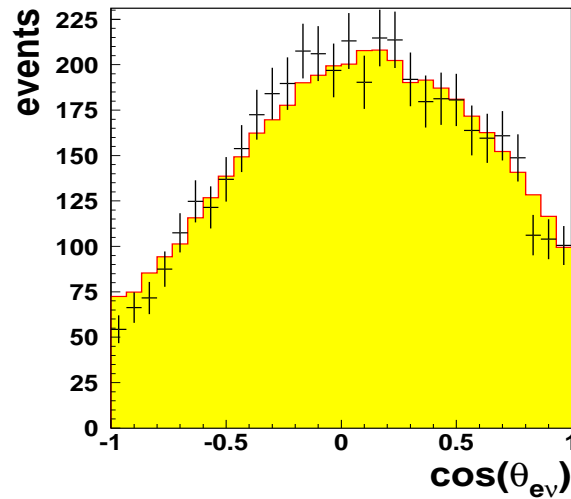
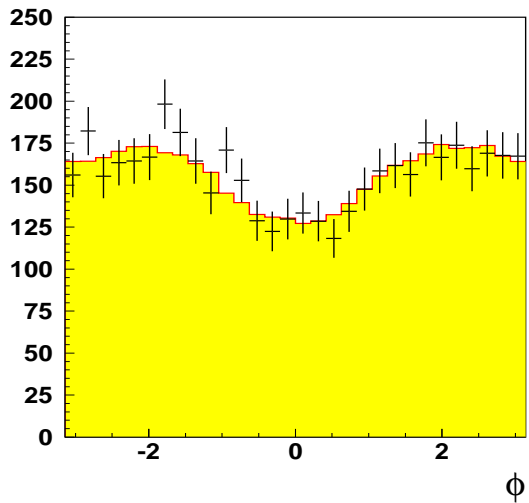
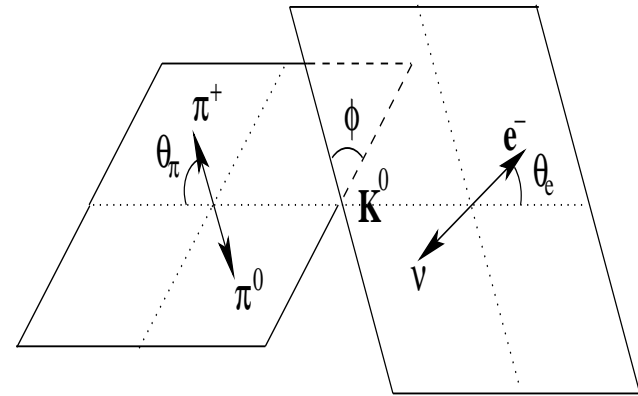
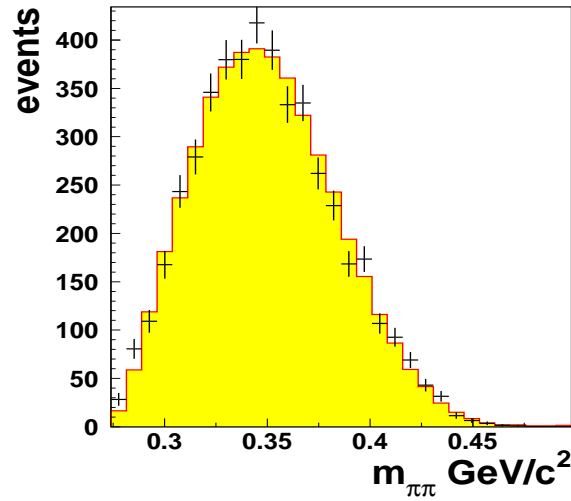
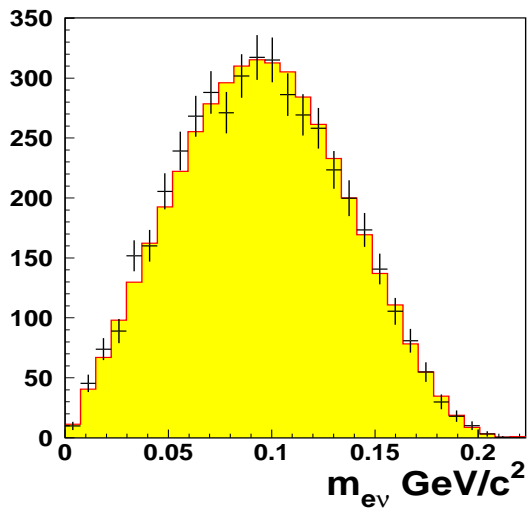
⇒ systematic uncertainty is dominated by the error of $\text{BR}(K_{\pi 3})$ ($\approx 0.08 \cdot 10^{-5}$)

$$K_L \rightarrow \pi^\pm \pi^0 e^\mp \nu_e$$



$$K_L \rightarrow \pi^\pm \pi^0 e^\mp \nu_e$$

Fit of the form factors in terms of *Cabibbo-Maksymowicz* variables:



$$K_L \rightarrow \pi^\pm \pi^0 e^\mp \nu_e$$

Form Factor measurement:

- Hadronic part of the matrix element ($V - A$ structure) can be parametrized by the form factors
 - $\bar{f}_s, \bar{f}_p, \lambda_g$ (vector part)
 - \bar{h} (axial part)

Result of simultaneous fit (C-M variables)

- $\bar{f}_s = 0.052 \pm 0.006_{\text{stat}} \pm 0.002_{\text{syst}}$
- $\bar{f}_p = -0.051 \pm 0.011_{\text{stat}} \pm 0.005_{\text{syst}}$
- $\lambda_g = 0.087 \pm 0.019_{\text{stat}} \pm 0.006_{\text{syst}}$
- $\bar{h} = -0.32 \pm 0.12_{\text{stat}} \pm 0.07_{\text{syst}}$

Determination of $ChPT$ parameter L_3 (using the BR):

$$\Rightarrow L_3 = (-4.1 \pm 0.2) \times 10^{-3}$$

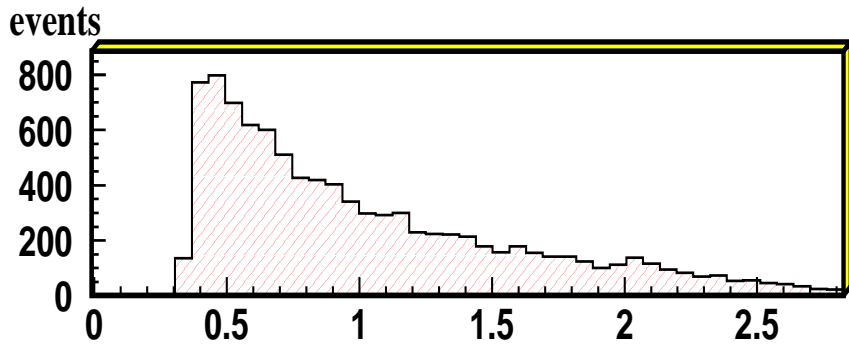
$$K_L \rightarrow \pi^\pm e^\mp \nu \gamma$$

Relative Branching Ratio of $K_L \rightarrow \pi^\pm e^\mp \nu \gamma / K_L \rightarrow \pi^\pm e^\mp \nu$

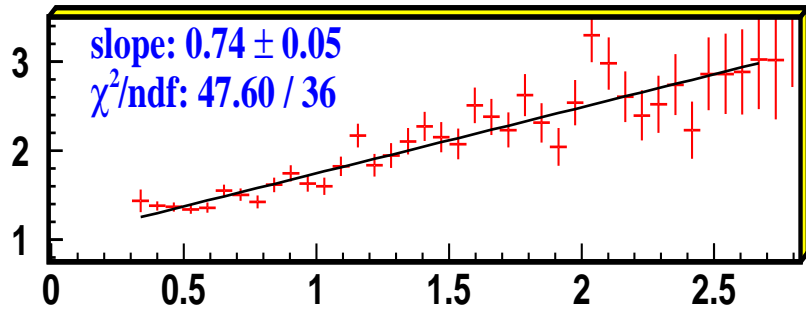
- Most precise measurement so far by *KTeV*
 - $\text{Br}^{\text{exp}}(K_L \rightarrow \pi^\pm e^\mp \nu \gamma / K_L \rightarrow \pi^\pm e^\mp \nu) = 0.908 \pm 0.008_{-0.012}^{+0.013} \%$
 - in disagreement with theoretical predictions:
 $\text{Br}^{\text{theo}}(K_L \rightarrow \pi^\pm e^\mp \nu \gamma / K_L \rightarrow \pi^\pm e^\mp \nu) = (0.95 - 0.99) \%$
- New NA48 measurement on 1999 data
(*special 2 days run, minimum bias trigger*)
 - analysis highly dependent on model for radiative corrections
 - MC simulation uses the *PHOTOS* package
 \Rightarrow not very good agreement with data!
 - weight $\theta_{e\gamma}^*$ to fit the data (Model independent analysis)
 \Rightarrow MC and data show very good agreement for all variables!

$$K_L \rightarrow \pi^\pm e^\mp \nu \gamma$$

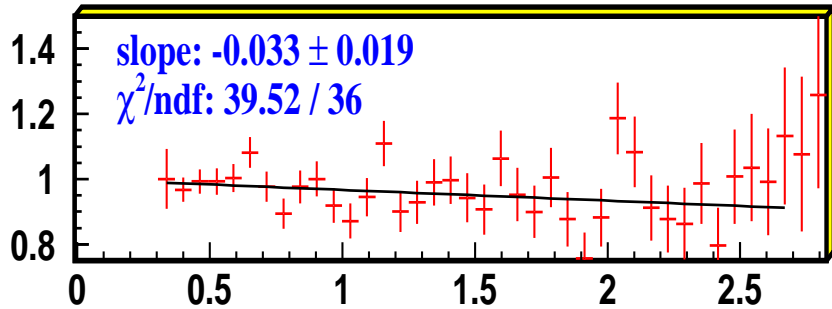
Data distribution and linearly fitted ratio Data/MC



PHOTOS

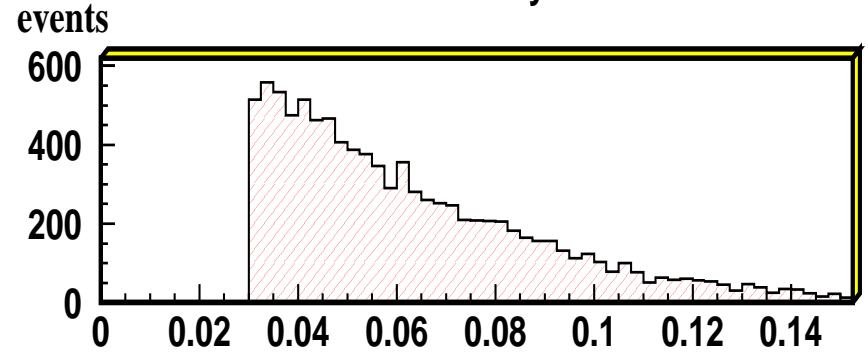


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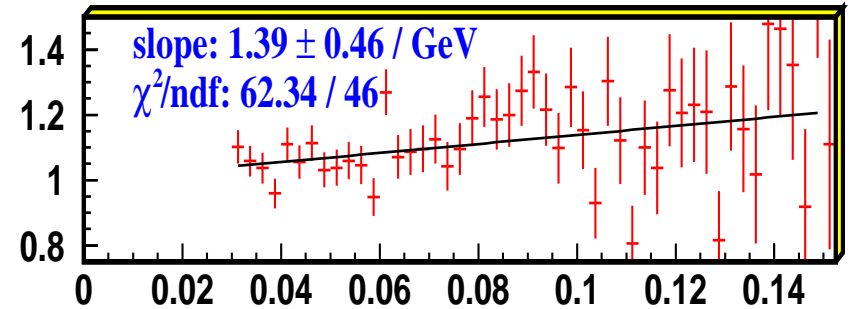


$\theta_{e\gamma}^*$ - first solution, rad

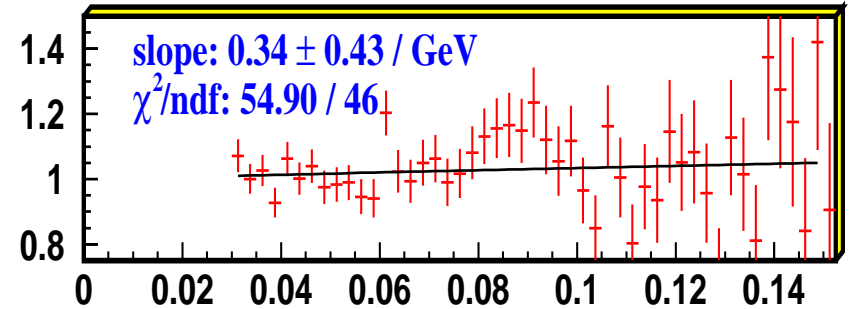
Data distribution and linearly fitted ratio Data/MC



PHOTOS



MI

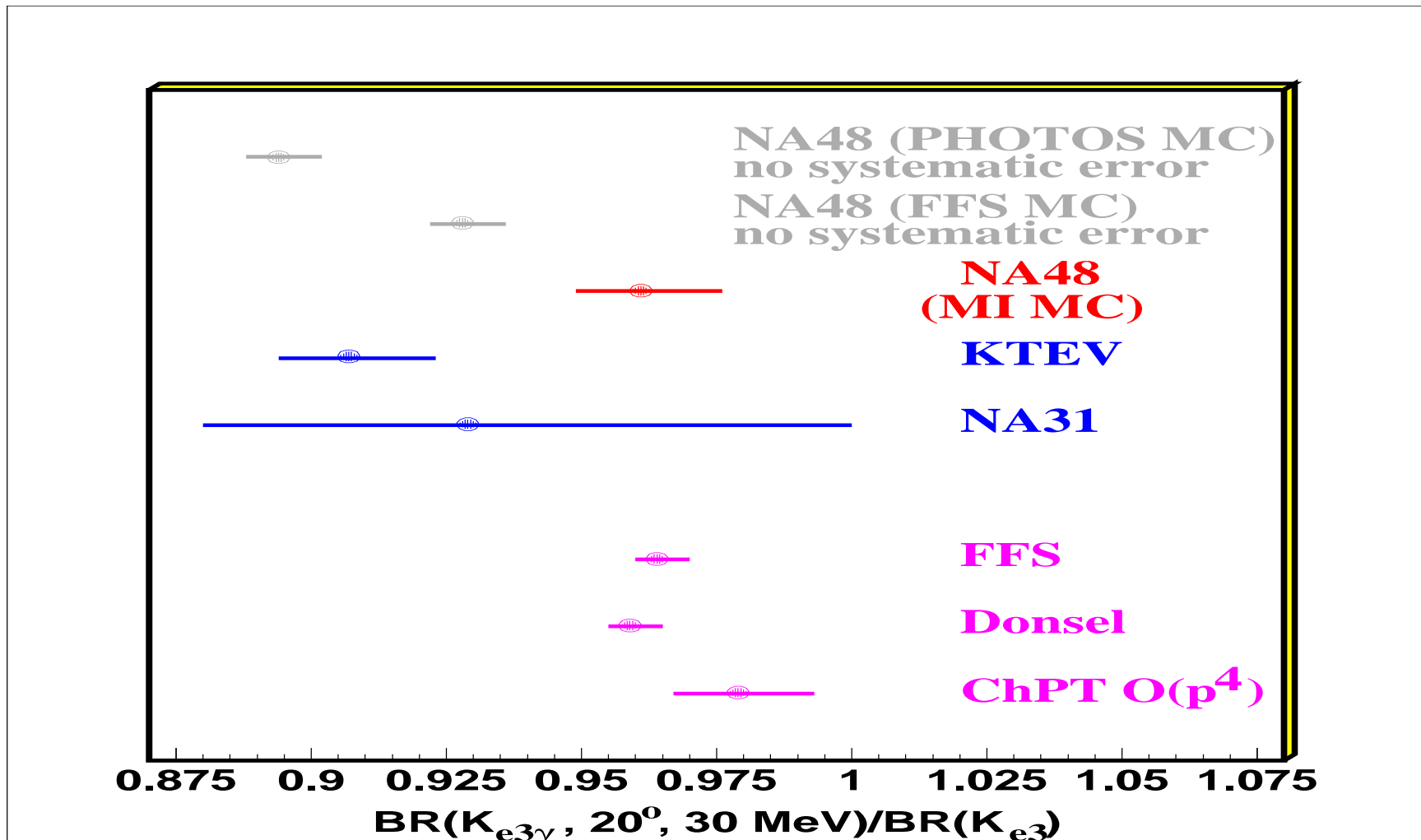


E_γ^* - first solution, GeV

$$K_L \rightarrow \pi^\pm e^\mp \nu \gamma$$

Result based on 9572 $K_{e3\gamma}$ and 2722118 K_{e3} reconstructed events:

● $\text{Br}_{\text{NA48}}^{\text{exp}}(K_L \rightarrow \pi^\pm e^\mp \nu \gamma / K_L \rightarrow \pi^\pm e^\mp \nu) = 0.960 \pm 0.07^{+0.012}_{-0.011}\%$



$$K_L \rightarrow \pi^\pm e^\mp \nu$$

Measurement of Form Factors in $K_L \rightarrow \pi^\pm e^\mp \nu$

- Sample from 1999 of $5.6 \cdot 10^6$ fully reconstructed K_{e3} events
- Measurement of the Dalitz plot density admitting all possible Lorentz-covariant couplings: measure form factors for
 - vector interaction ($f_+(q^2) = f_+(0)(1 + \lambda_+ q^2/m_\pi^2)$)
 - scalar interaction (f_S)
 - tensor interaction (f_T)
- Theory prediction $\lambda_+ = 0.028$
- *Akimenko et al. (1991), Steiner et al. (1971)* reported evidence for nonzero scalar and tensor form factors for K_{e3}^+
- *recent measurements of charged and neutral kaon decays show no deviation from vector type interaction*

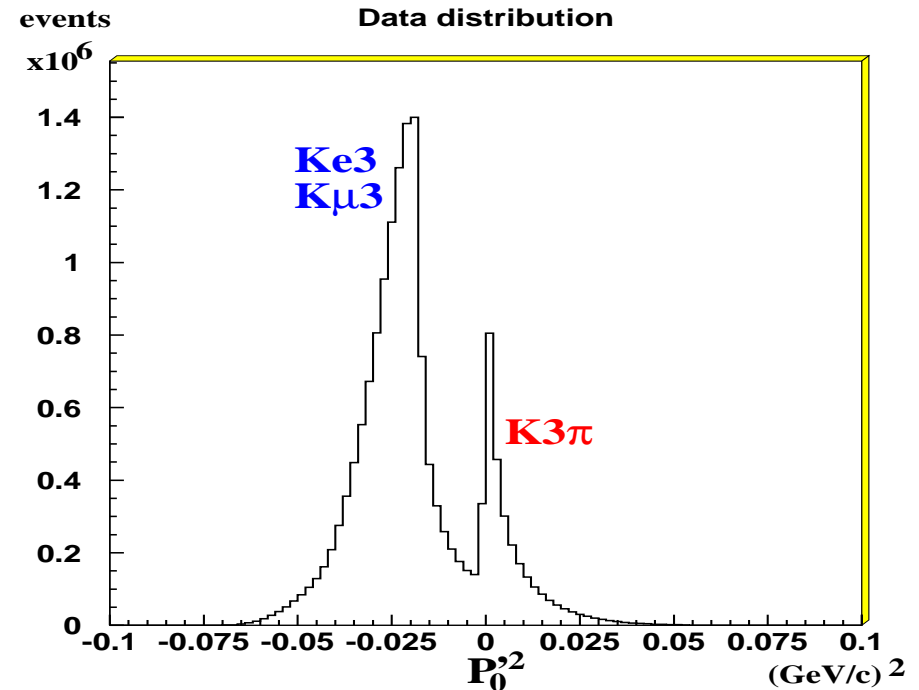
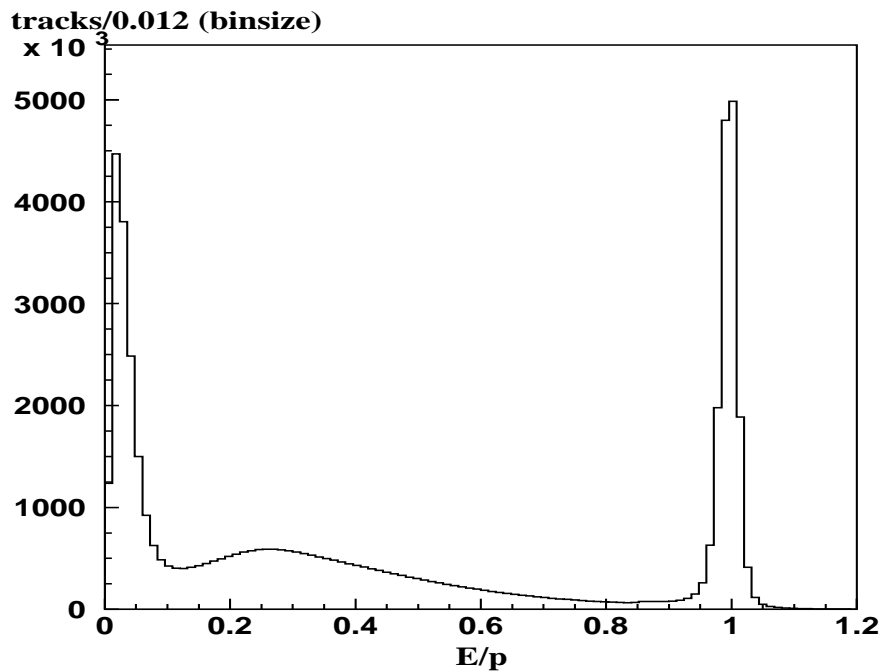
$$K_L \rightarrow \pi^\pm e^\mp \nu$$

- Main backgrounds from $K_L \rightarrow \pi^\pm \mu^\mp \nu$ and $K_L \rightarrow \pi^+ \pi^- \pi^0$
 - suppress $K_{3\pi}$ by cut on $P_0'^2 < -0.004 \text{ (GeV/c)}^2$

$$\left(P_0'^2 = \frac{(m_K^2 - m_{+-}^2 - m_{\pi^0}^2)^2 - 4(m_{+-}^2)m_{\pi^0}^2 + m_K^2 p_\perp^2}{4(p_\perp^2 + m_{+-}^2)} \right)$$

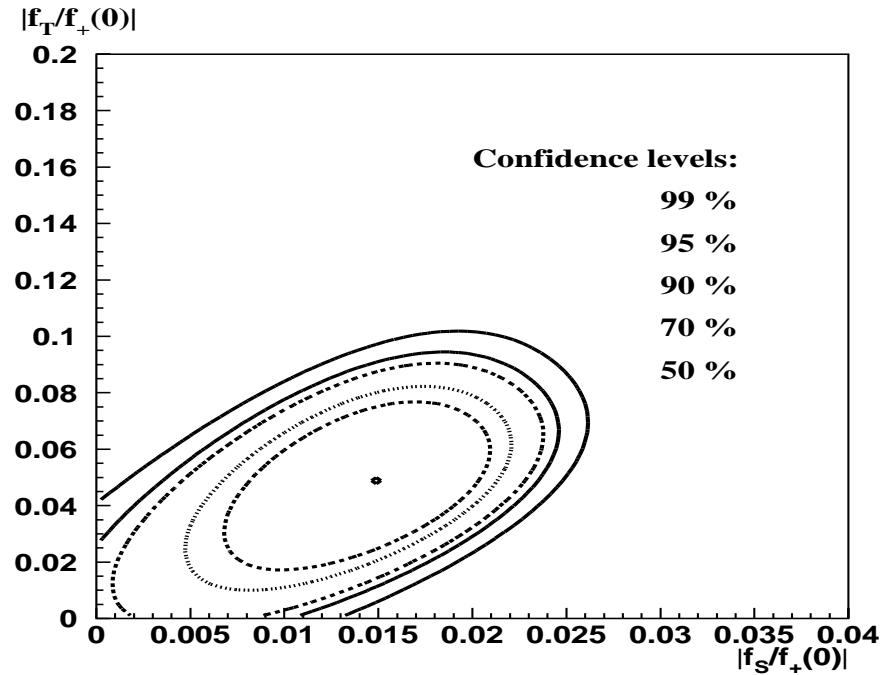
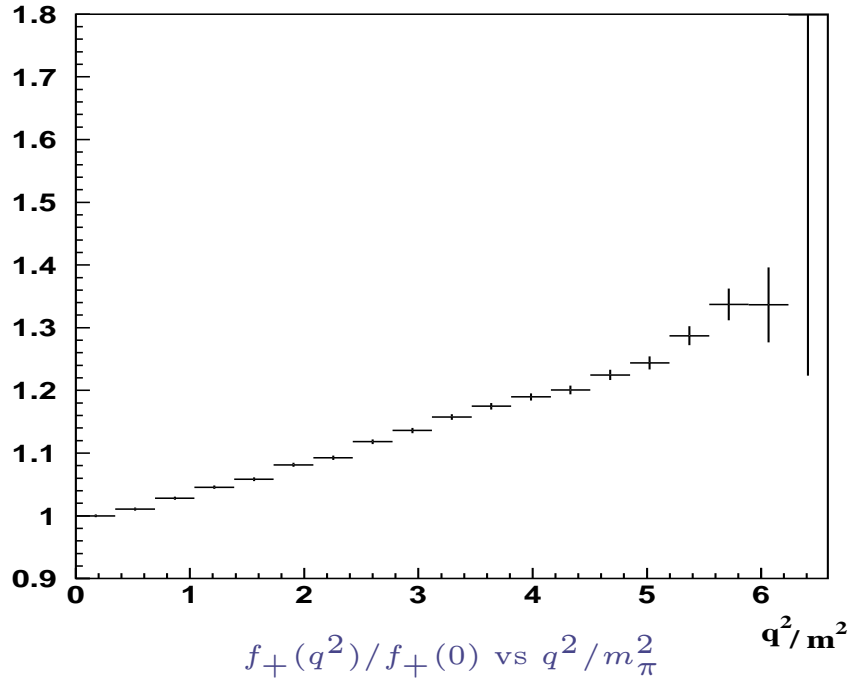
⇒ remaining with **20 background events** from this source
 - suppress $K_{\mu 3}$ by muon veto signal and E/p cut

⇒ remaining with **400 ± 100 background events** from this source



$$K_L \rightarrow \pi^\pm e^\mp \nu$$

data/MC



Results 3 form factor fit:

- $\lambda_+ = 0.0284 \pm 0.0007_{\text{stat}} \pm 0.0013_{\text{syst}}$
- $\left| \frac{f_S}{f_+(0)} \right| = 0.015_{-0.010}^{+0.007} \pm 0.012_{\text{syst}}$
- $\left| \frac{f_T}{f_+(0)} \right| = 0.05_{-0.04}^{+0.03} \pm 0.03_{\text{syst}}$

Result pure vector interaction:

- $\lambda_+ = 0.0288 \pm 0.0005_{\text{stat}} \pm 0.0011_{\text{syst}}$

current PDG Limits:

- $f_S/f_+ < 0.04$ (CL 68%)
- $f_T/f_+ < 0.23$ (CL 68%)

> No evidence for scalar or tensor couplings!

Prospects...

- **Measurement of Form Factors in $K_L \rightarrow \pi^\pm \mu^\mp \nu$**
 - Sample from 1999 of $2.3 \cdot 10^6$ fully reconstructed $K_{\mu 3}$ events
 - Measurement of the **Dalitz plot density** (analog to K_{e3})
- **Measurement of the BR($K_L \rightarrow \pi^\pm e^\mp \nu$)**
 - Sample from dedicated minimum bias run (2 days) with $6.7 \cdot 10^6$ reconstructed K_{e3} events
 - Determination of V_{us}
 - Error is expected to be of the order of 1% (*limited by theoretical uncertainty*)

⇒ Results will be published soon..

Conclusions/Summary

Measured form factors and branching ratios for semileptonic neutral Kaon decays:

- $\text{BR}(K_{e4}) = (5.21 \pm 0.07_{\text{stat}} \pm 0.09_{\text{syst}}) \times 10^{-5}$
 - $\bar{f}_s = 0.052 \pm 0.006_{\text{stat}} \pm 0.002_{\text{syst}}$
 - $\bar{f}_p = -0.051 \pm 0.011_{\text{stat}} \pm 0.005_{\text{syst}}$
 - $\lambda_g = 0.087 \pm 0.019_{\text{stat}} \pm 0.006_{\text{syst}}$
 - $\bar{h} = -0.32 \pm 0.12_{\text{stat}} \pm 0.07_{\text{syst}}$
- $\text{Br}_{\text{NA48}}^{\text{exp}}(K_L \rightarrow \pi^\pm e^\mp \nu \gamma / K_L \rightarrow \pi^\pm e^\mp \nu) = (0.960 \pm 0.07_{-0.011}^{+0.012})\%$
- $\lambda_+(K_{e3}) = 0.0288 \pm 0.0005_{\text{stat}} \pm 0.0011_{\text{syst}}$
⇒ No hint of *scalar* or *tensor* couplings

Expect from 2003/2004 data (NA48/2)

new exciting results for semileptonic charged Kaon decays!