$K^0_L \to \pi^\pm e^\mp \nu$ formfactors

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Introduction

- The semileptonic decays of K_L mesons:
  - valuable information on the structure of weak interactions
  - good test for the low-energy models of strong interactions
  - sensitive to possible non vector weak interactions
- Evidence exists for nonzero scalar and tensor formfactors in the case of $K^{\mp} \to \pi^0 e^{\mp} \nu$
- Investigations of the neutral kaon decays do not give any significant deviation from vector type interactions (within errors)

Treatment of semileptonic decays

- Theoretical framework
  - locality of weak interactions
  - $\mu - e$ universality
  - two component neutrino theory
  - $\triangle I = 1/2$ rule (I - isospin)
- A method for determination of the scalar f_S , vector f_+ and f_- and tensor f_T formfactors - by measuring the Dalitz plot density:

$$\rho(\chi_1, \ldots, \chi_n) \equiv \frac{\mathrm{d}^n N}{\mathrm{d}\chi_1 \ldots \mathrm{d}\chi_n} \qquad (1)$$

χ_i - independent kinematical variables describing the process

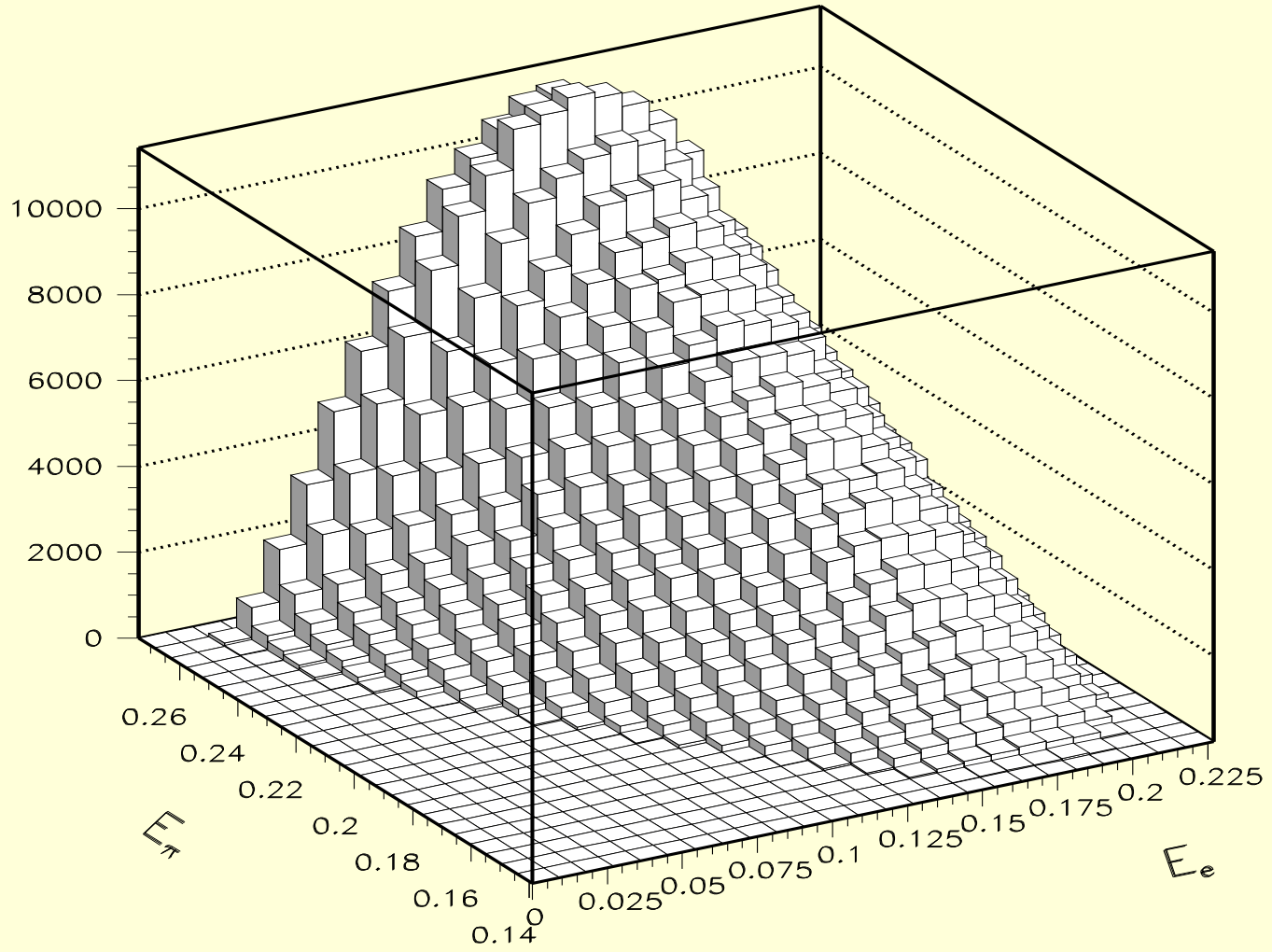
Dalitz plot density

- **Parametrization of the Dalitz plot density in the rest frame of the kaon:**

$$\underline{\rho(E_\pi, E_e) \sim A|V|^2 + C|S|^2}$$

$$V = f_+(q^2) = f_+(0)(1 + \lambda_+ q^2/m_\pi^2)$$
$$S = f_S + \frac{1}{m_K}(E_\nu - E_e) f_T$$
$$A = m_K(2E_e E_\nu - m_K {E_\pi}')$$
$$C = m_K^2 {E_\pi}'$$
$${E_\pi}' = \frac{(m_K^2 + m_\pi^2)}{2m_K} - E_\pi$$
$$q^2 = (m_K^2 + m_\pi^2 - 2m_K E_\pi)$$

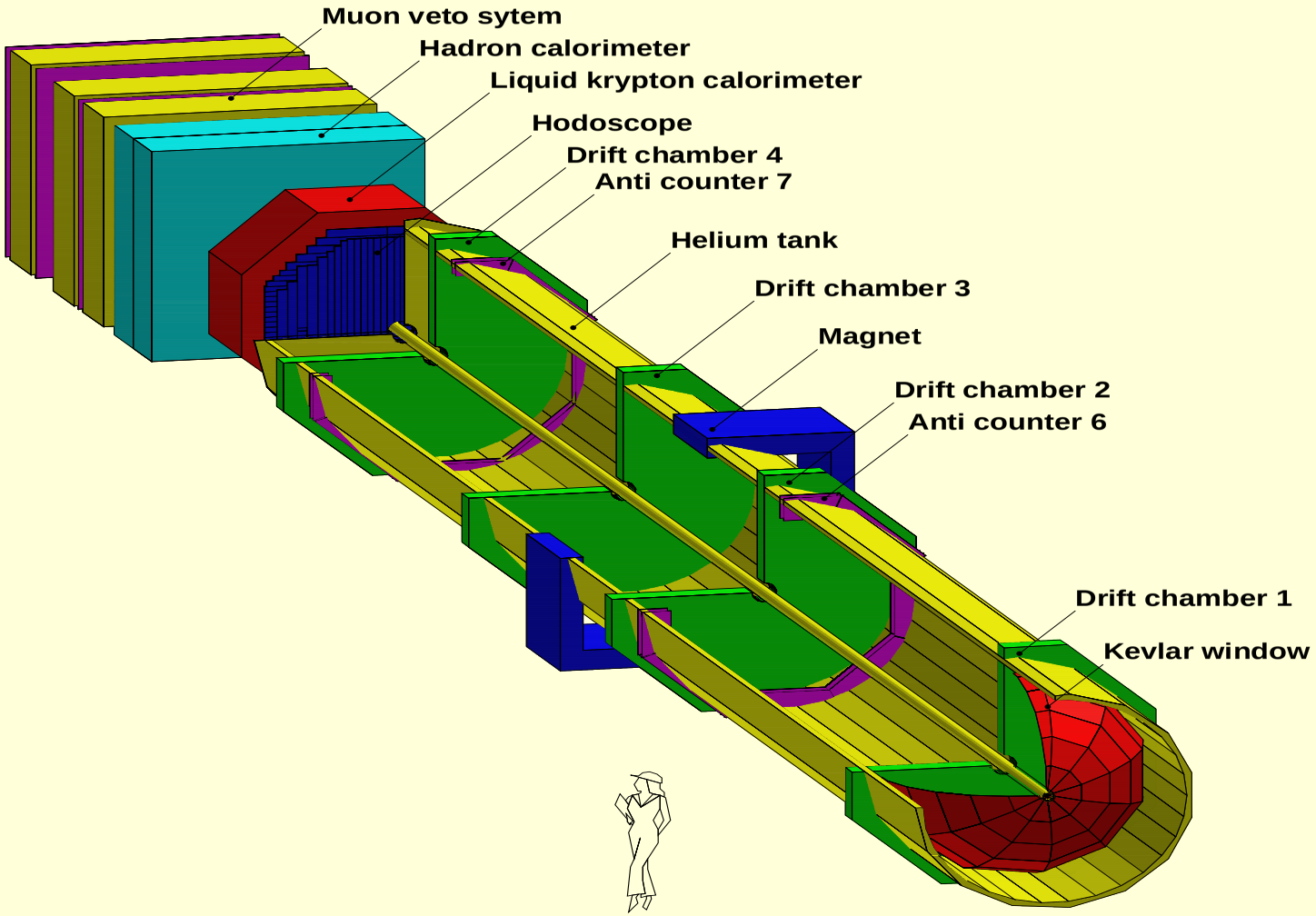
Dalitz plot


10000
8000
6000
4000
2000
0
0.26
0.24
0.22
0.2
0.18
0.16
0.14
E_π
0
0.025
0.05
0.075
0.1
0.125
0.15
0.175
0.2
0.225
E_e

Experimental setup

- The NA48 setup is designed to measure the direct CP violation in the K^0 system
- The neutral beams (K_S and K_L) are derived from 450 GeV/c protons from the CERN SPS
- The decay region is located 120 m downstream after 3 stage collimators and sweeping magnets
- The decay region is contained in an evacuated tube, 90 m long, terminated by a thin kevlar exit-window
- The main detector is situated next to the vacuum tube

Main detector



Data and simulation

- **DATA**
  - **Special $K\mu 3$ run - September 1999. Runs : 9216 $\rightarrow$ 9242**
  - **Run conditions**
    - **No K_S beam**
    - **Alternate magnet polarities**
    - **Trigger - 2 charged tracks and vertex reconstructed**
  - **About 10^8 events recorded**
- **SIMULATION**
  - **MC using nasim031**
  - **K^0_{e3} decay with $\lambda_+ = 0$**
  - **Radiative corrections embeded in the simulation program**
  - **We are using kaon spectrum $\in$ (60,180) GeV (this leads to about 10^7 accepted events - 20 times more than the "richest" experiment by now)**

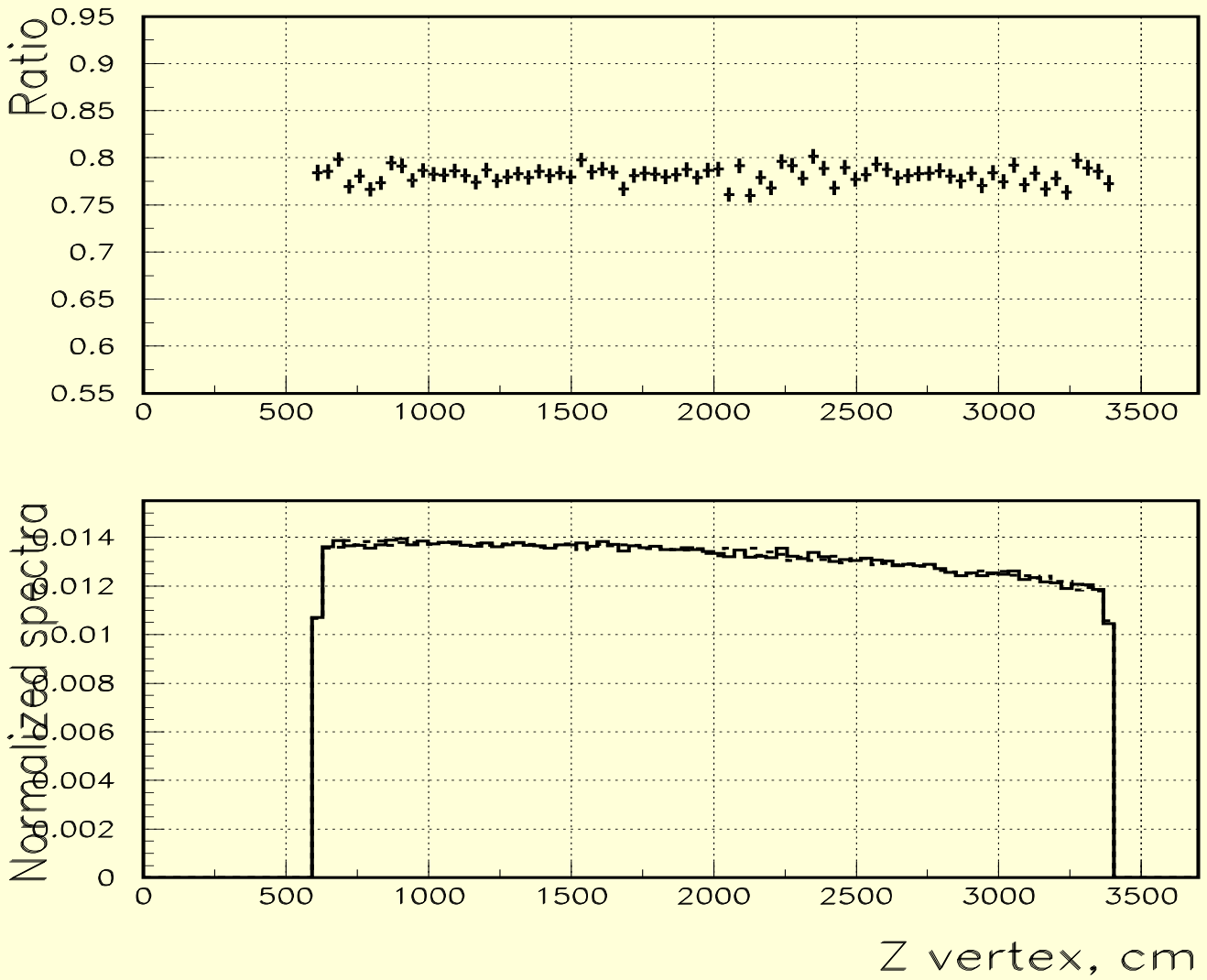
Event selection

- **2 tracks and 1 vertex**
- **Z vertex** $\in (600, 3400)cm$
- **Tracks in the DCH, Lkr and MUVeto acceptance**
- **No in time MUV hit**
- $\frac{E}{p} < 0.9$ **(**$\pi^{\mp}$**) and** $0.93 < \frac{E}{p} < 1.1$ **(**$e^{\pm}$**)**
- $M_{\pi^+\pi^-}$ 3σ **away from** M_K
- $\pi^+\pi^-\pi^0$ **rejection (**$P_0'^2 < -0.004$**)**

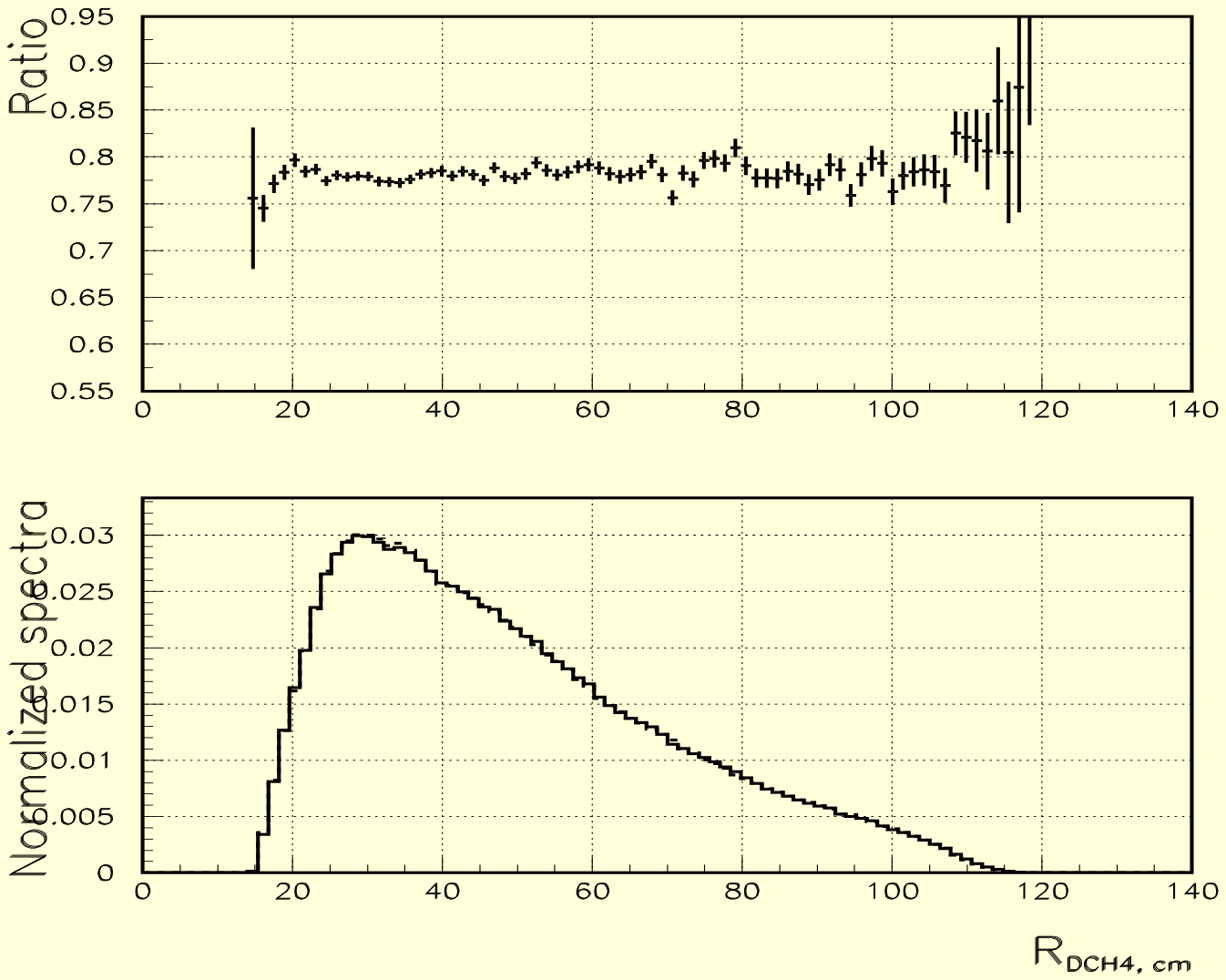
The selection gives 6×10^6 **reconstructed experimental** $Ke3$ **events at estimated background:**

DECAY	MC eval.	CL
$K_L^0 \to \pi^{\pm}\mu^{\mp}\nu$	$< 3.5 \cdot 10^{-5}$	90%
$K_L^0 \to \pi^+\pi^-\pi^0$	$< 1.5 \cdot 10^{-5}$	90%
$K_L^0 \to \pi^+\pi^-$	$< 3.5 \cdot 10^{-7}$	90%
$K_L^0 \to (\pi \leftrightarrow e)\nu$	$< 1.0 \cdot 10^{-6}$	90%

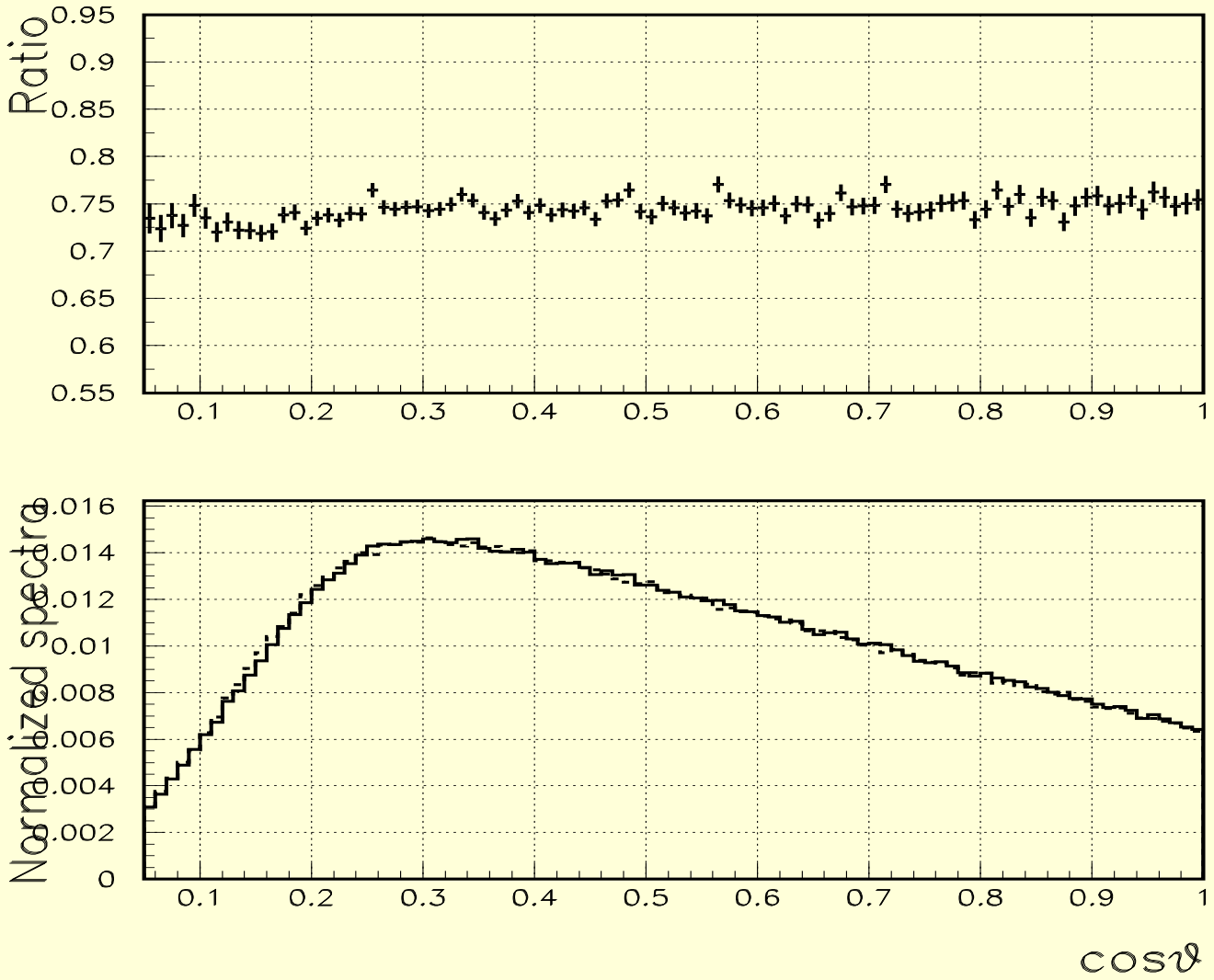
Experiment vs. MC



Experiment vs. MC



Experiment vs. MC



Reconstruction and analysis technique

- The kaon momentum (lab system) is reconstructed up to a quadratic ambiguity
- Our method for the determination of the formfactors:
  - Using Dalitz plots from both solutions and fitting the Exp and MC three dimensional Dalitz plot $N(E_\nu, q_1^2, q_2^2)$
  - The fitting function is MAXIMUM LOGLIKELIHOOD function

Loglikelihood and χ^2 functions

- **Maximum Loglikelihood function**

  $lnL = -2[\sum_i (d_i ln f_i - f_i) + \sum_i (a_{0i} ln A_{0i} - A_{0i})]$

  $f_i = \sum_j A_{0i} w_{ij} p_j \equiv \frac{A_{0i}}{a_{0i}} h_i$

  $h_i \equiv \sum_j a_{0i} w_{ij} p_j$

  $A_{0i} = \frac{d_i + a_{0i}}{1 + \frac{h_i}{a_{0i}}}$

  i - **number of bins ,** j - **MC sources**

  d_i - **experiment,** a_{0i} - **MC**

  w_{ij} - **functions of kinematical variables (**$w_{0i} \equiv 1$**)**

  p_j - **fitted parameters (**$p_j = \frac{p_j}{p_0}$**,** p_0 - **norm. coefficient)**

  h_i - **summed [MC-sources]x[**p_j**]**

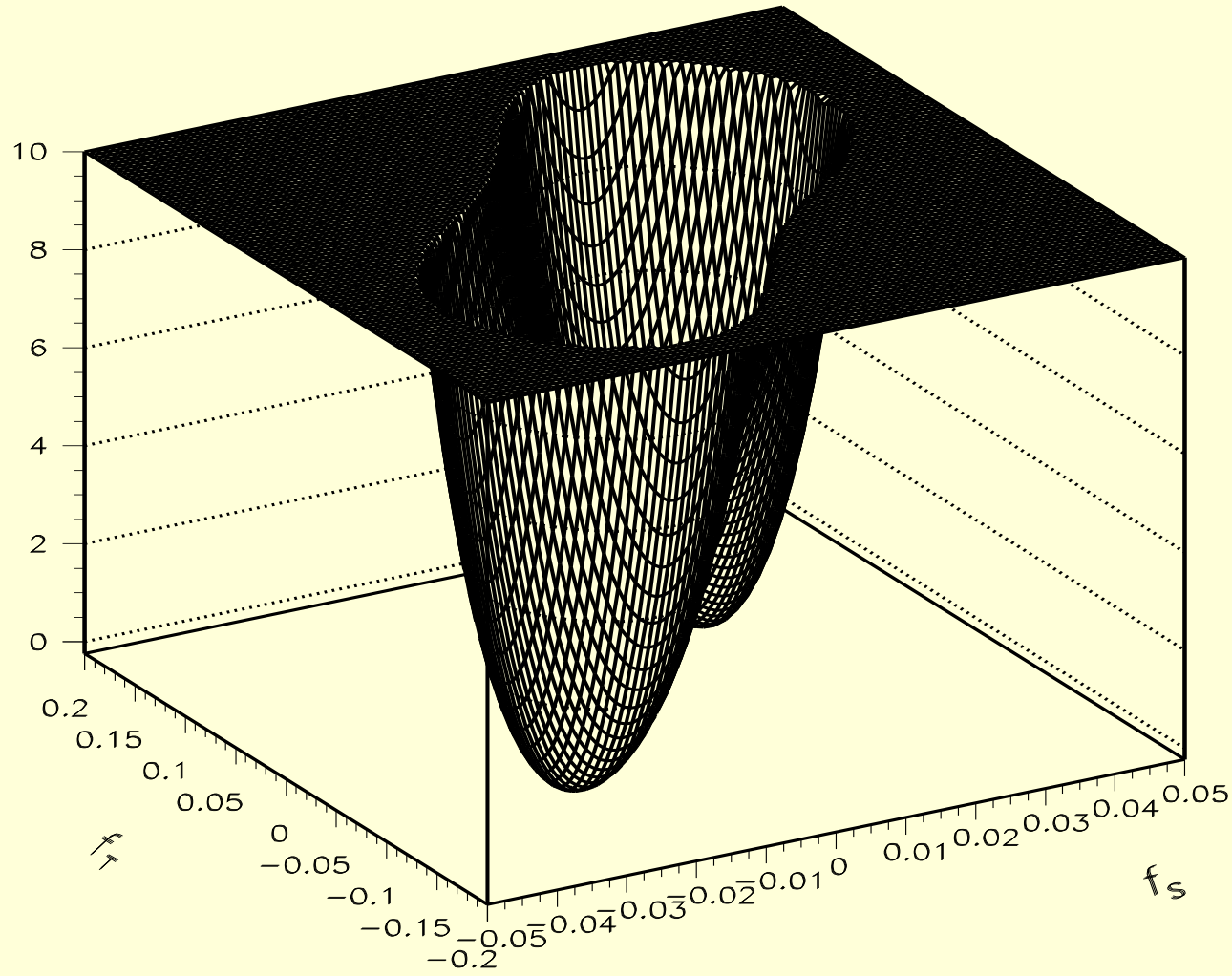
- χ^2 **function**

  $\chi^2 = \sum_i \frac{(d_i + h_i)^2}{d_i + p_0^2 a_{0i}}$

  $d_i > N_{min}$**,** $a_{0i} > N_{min}$

  $N_{min} = 20, (30), ...$

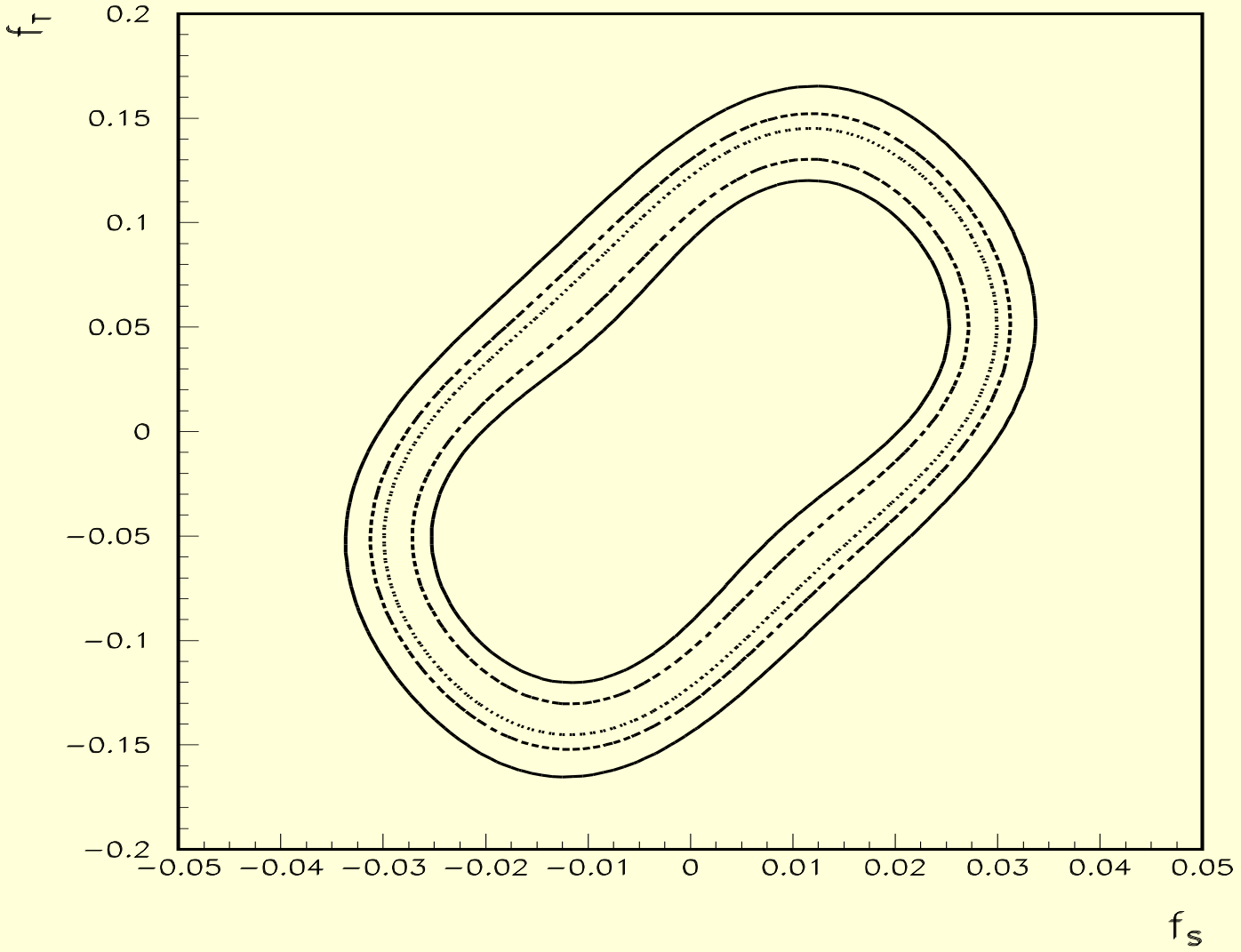
Our Loglikelihood function (graphics)



Results

- **Latest (CPLEAR, PL B473(2000) 186) :**
  $\lambda_+ = 0.0245 \pm 0.0012 \pm 0.0022$
- **World average (PDG 2000)**
  $\lambda_+ = 0.0288 \pm 0.0015$ **(Error scaled by 1.3)**
  $|f_S/f_+(0)| < 0.04 \quad$, $CL = 68\%$
  $|f_T/f_+(0)| < 0.23 \quad$, $CL = 68\%$
- **Our results**
  - **"+" magnetic field**
    $\lambda_+ = 0.03097 \pm 0.00118$
    $|f_S/f_+(0)| = 0.016 \pm 0.020$
    $|f_T/f_+(0)| = 0.06 \pm 0.10$
  - **"-" magnetic field**
    $\lambda_+ = 0.03012 \pm 0.00135$
    $|f_S/f_+(0)| = 0.014 \pm 0.025$
    $|f_T/f_+(0)| = 0.06 \pm 0.10$

Scalar and tensor formfactors - slides



Results, stability, systematics

Dalitz	λ_+	$\lvert\frac{f_S}{f_+(0)}\rvert$	$\lvert\frac{f_T}{f_+(0)}\rvert$
	.03036	.010	.04
stat err.	$\pm$0.00135	$\pm$0.020	$\pm$0.10
MUV eff	$^{+.00001}_{-.00000}$	$^{+.001}_{-.001}$	$^{+.01}_{-.01}$
3π **rej cuts**	$^{+.00000}_{-.00013}$	$^{+.001}_{-.002}$	$^{+.01}_{-.01}$
2π **rej cuts**	$^{+.00001}_{-.00002}$	$^{+.000}_{-.000}$	$^{+.00}_{-.01}$
Z vertex	$^{+.00005}_{-.00000}$	$^{+.001}_{-.001}$	$^{+.01}_{-.01}$
Y vertex	$^{+.00012}_{-.0000}$	$^{+.001}_{-.001}$	$^{+.01}_{-.01}$
X vertex	$^{+.00007}_{-.0000}$	$^{+.001}_{-.001}$	$^{+.01}_{-.01}$
DCH cuts	$^{+.00000}_{-.00010}$	$^{+.001}_{-.001}$	$^{+.01}_{-.01}$
LKr cuts	$^{+.00015}_{-.00010}$	$^{+.001}_{-.001}$	$^{+.01}_{-.01}$
MUV cuts	$^{+.00000}_{-.00000}$	$^{+.000}_{-.000}$	$^{+.00}_{-.00}$
# of bins(resolution)	$^{+.00015}_{-.00030}$	$^{+.010}_{-.003}$	$^{+.02}_{-.02}$
$\frac{E}{P}$ **cuts**	$^{+.00005}_{-.00015}$	$^{+.001}_{-.003}$	$^{+.02}_{-.02}$
K_L **spectrum**	$^{+.00000}_{-.00035}$	$^{+.001}_{-.001}$	$^{+.01}_{-.01}$

Conclusions

- We have obtained the folowing values for the formfactors:
  $\lambda_+ = 0.03060 \pm 0.00089\ ^{+.00027}_{-.00052}$
  $|f_S/f_+(0)| = 0.015 \pm 0.016\ ^{+.011}_{-.006}$
  $|f_T/f_+(0)| = 0.06 \pm 0.07\ ^{+.05}_{-.05}$
- The result is stable upon various acceptance cuts
- We don't see significant divergence vrom V-A model of the weak interaction
- Our value for λ_+ is in an agreement with world average (PDG)