Testing the μ-e universality with $K^{\pm} \to l^{\pm} \nu$ decays

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Kaon 2007

LNF, Frascati, May 21-25

on behalf of the NA48/2 collaboration

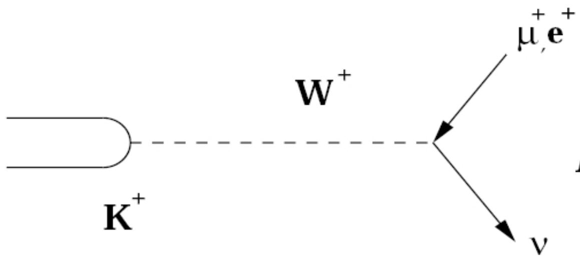
Cambridge, CERN, Chicago, Dubna, Edinburgh, Ferrara, Firenze, Mainz, Northwestern, Perugia, Pisa, Saclay, Siegen, Torino, Vienna

Overview

- Physics motivation
- Experimental setup
- Data analysis
- 2004 data preliminary result
- Conclusions

Motivation

Within the Standard Model:



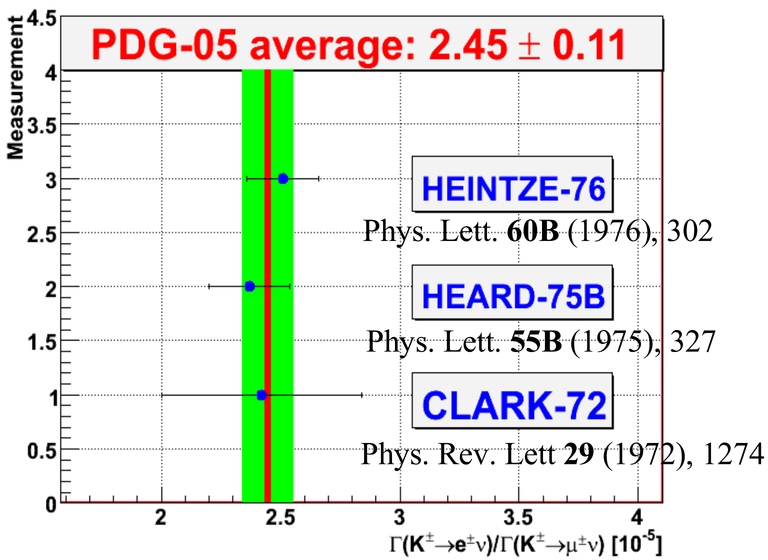
M. Finkemeier: Phys.Lett.B387:391-394,1996

$$R_M := \frac{\Gamma(M \to e\nu_e(\gamma))}{\Gamma(M \to \mu\nu_\mu(\gamma))} = \frac{m_e^2}{m_\mu^2}\left(\frac{m_M^2 - m_e^2}{m_M^2 - m_\mu^2}\right)^2 (1 + \delta R_M)$$

where δR_M arises from the radiative corrections, $M=\pi^\pm, K^\pm$

For $K^\pm$: $\delta R_K = -(3.78 \pm 0.04)\%$, leading to

$R_K = (2.472 \pm 0.001) * 10^{-5}$

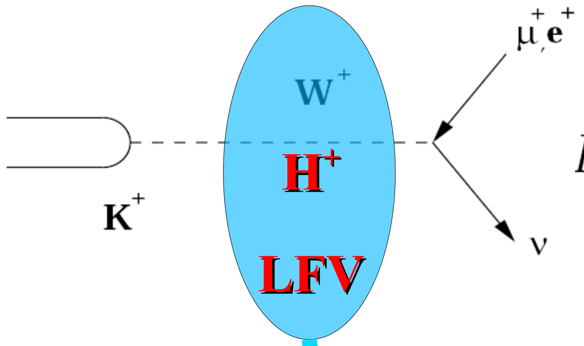


Experimental error on R_K:

two orders of magnitude larger than the theoretical

Motivation

Within the Standard Model:



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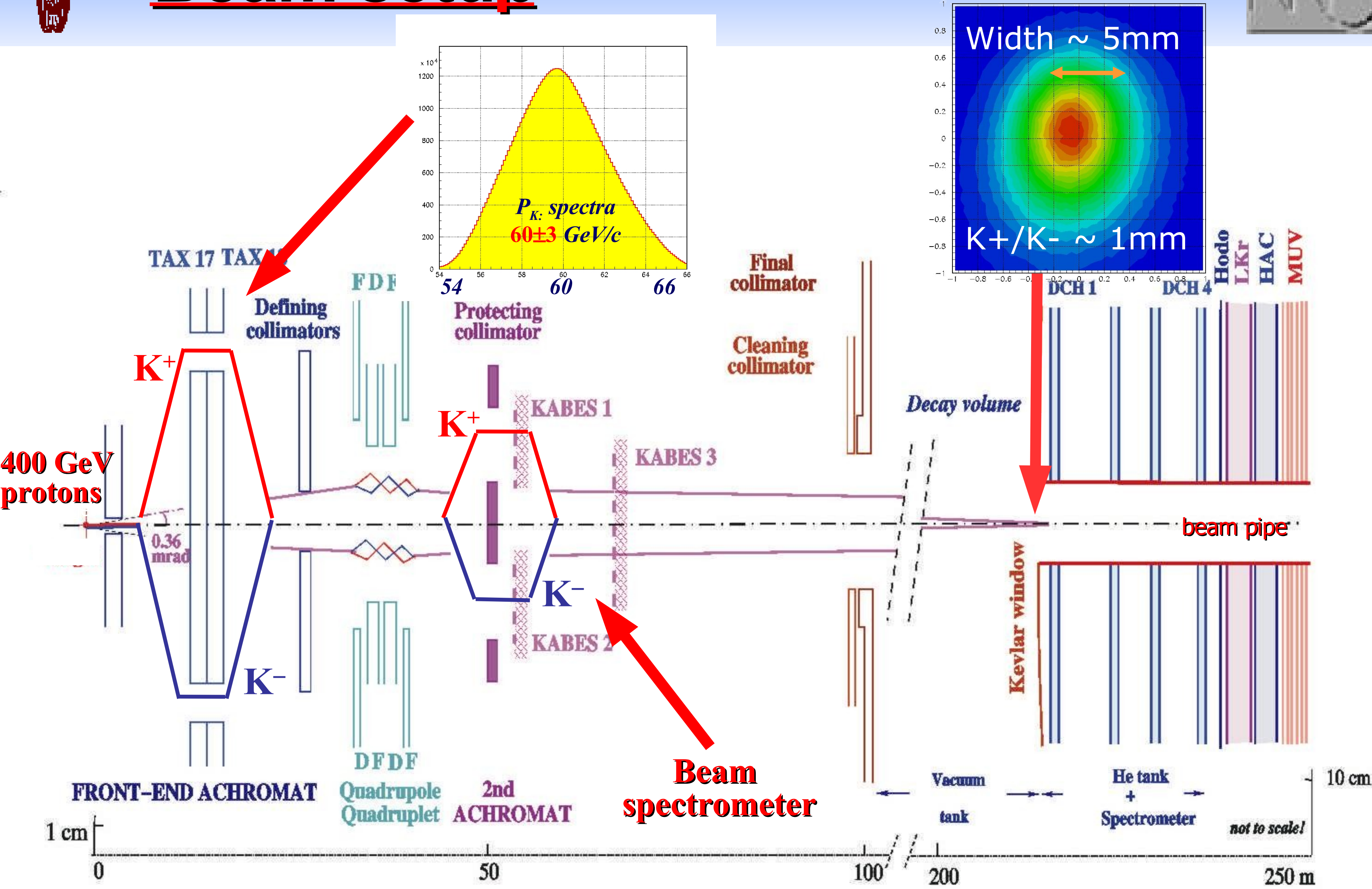
Standard Model prediction:

$R_K = (2.472 \pm 0.001) * 10^{-5}$

A. Masiero et al. Phys.Rev. D74 (2006) 011701

- **The value of R_K could be different in case of SUSY and LFV models – the correction could be as high as 3% in both directions**
- **Measurement of R_K tests the μ-e universality and provides a sensible test of the SM**

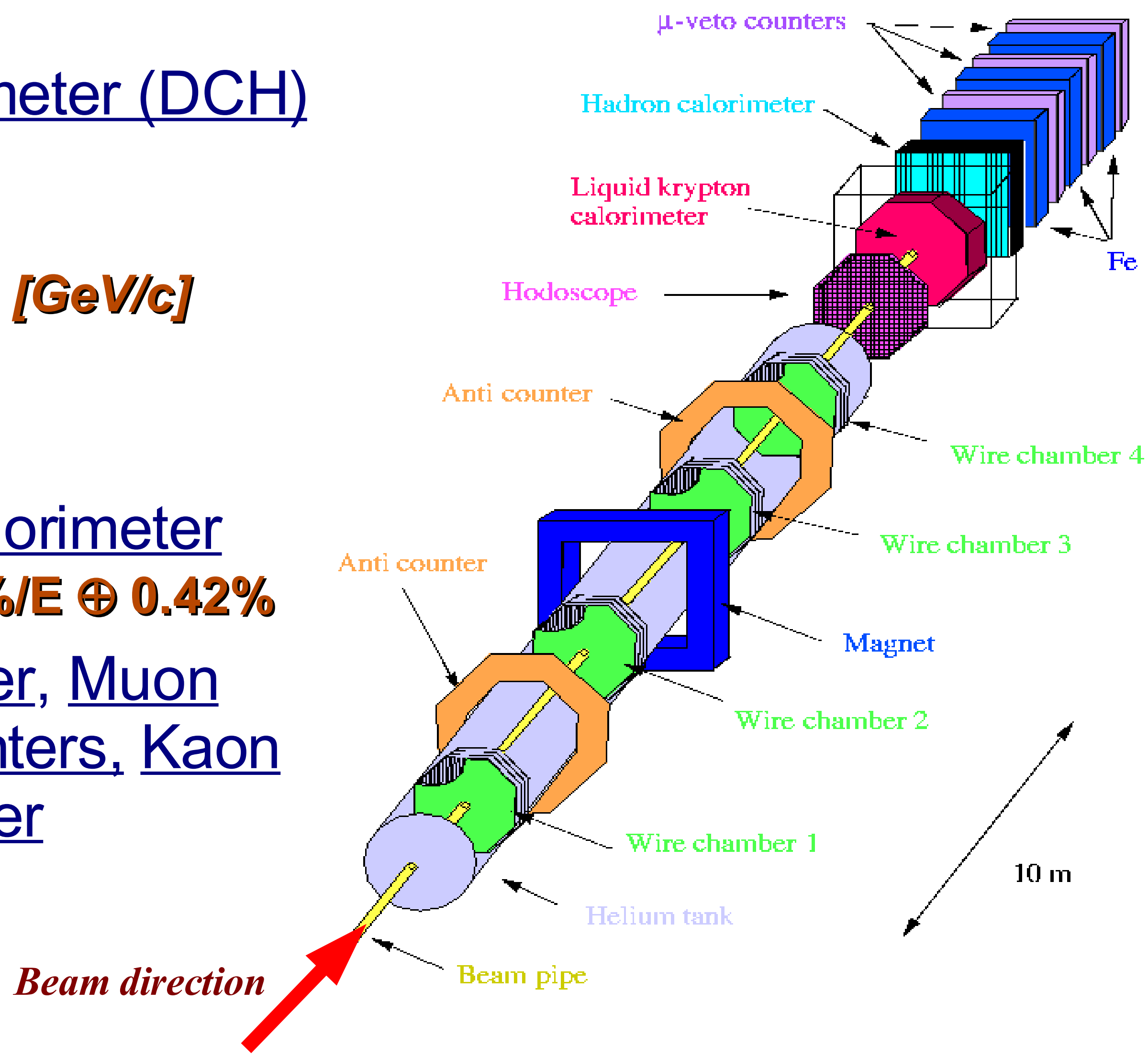
Beam setup



Width ~ 5mm
K+/K- ~ 1mm
P_K: spectra
60±3 GeV/c
54
60
66
TAX 17 TAX 18
Defining collimators
FDF
Protecting collimator
Final collimator
Cleaning collimator
KABES 1
KABES 3
KABES 2
Decay volume
DCH 1
DCH 4
Hodo
LKr
HAC
MUV
400 GeV protons
K+
K−
0.36 mrad
beam pipe
Kevlar window
Beam spectrometer
DFDF
FRONT-END ACHROMAT
Quadrupole Quadruplet
2nd ACHROMAT
Vacuum tank
He tank + Spectrometer
not to scale!
1 cm
10 cm
0
50
100
200
250 m

Detector setup

- Magnetic spectrometer (DCH)
  4 drift chambers
  $p_{\perp}^{kick}$ = 121 MeV/c
  Δp/p = 1% ⊕ 0.044*p [GeV/c]
- Hodoscope
  σ(t) = 150 ps
- Liquid Krypton Calorimeter
  ΔE/E ≅ 3.2%/√E ⊕ 9%/E ⊕ 0.42%
- Hadron Calorimeter, Muon counters, Anticounters, Kaon Beam Spectrometer



Experiment primarily designed for the measurement of the charge asymmetry in $K^{\pm} \rightarrow \pi^{-} \pi^{+} \pi^{\pm}$ and $K^{\pm} \rightarrow \pi^{0} \pi^{0} \pi^{\pm}$ decays

2003 run: ~ 50 days nominal conditions
~ 12 hour special run

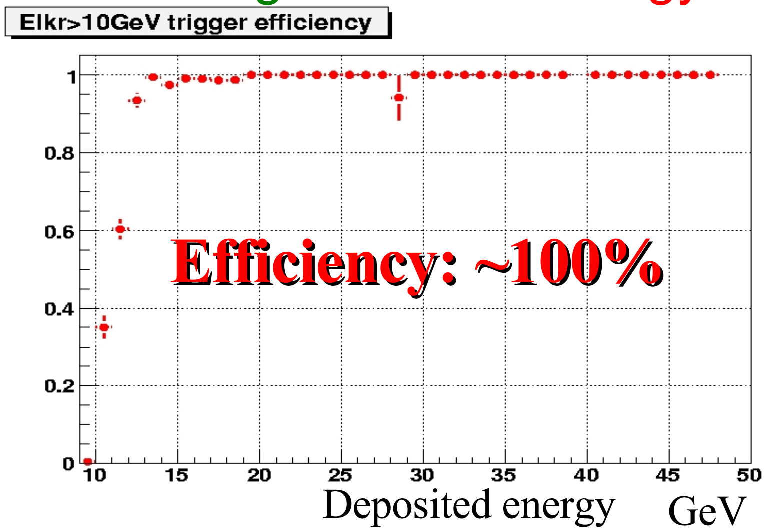
2004 run: ~ 60 days nominal conditions
~ 56 hour special run

~ 200 TB of data recorded

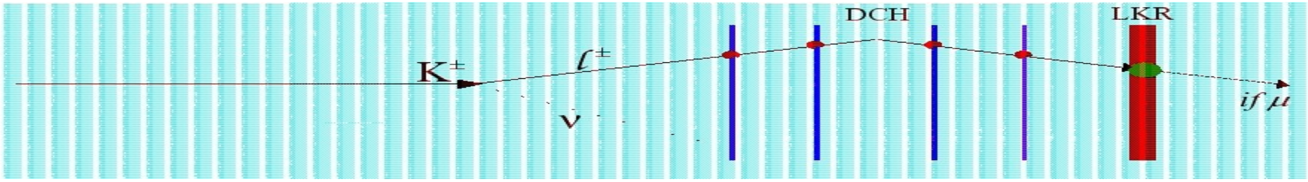
The huge statistics (~$4 \cdot 10^{9}$ $K^{\pm} \rightarrow \pi^{+}\pi^{-}\pi^{\pm}$) allows to study rare kaon decays with high precision

2004 Data taking

- 2004 data: special run conditions devoted to the study of Kaon semileptonic decays and Ke2
  - 60 GeV kaon beam with decreased intensity
  - No Level 2 trigger
- Trigger
  - Kμ2 events: 1 charged track
  - Ke2 events: 1 charged track + Energy in the LKR > 10 GeV



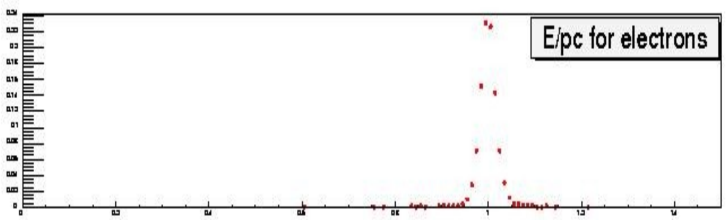
Event selection

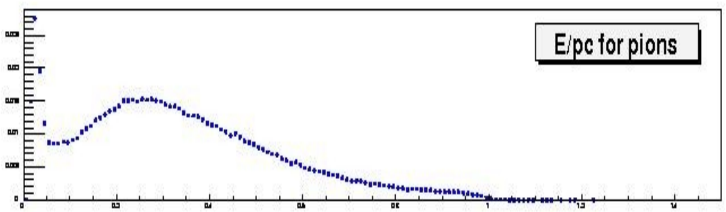


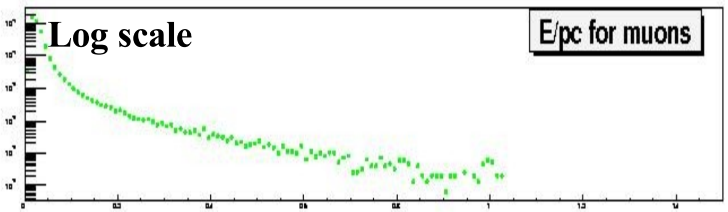
Geometry and kinematics:

The similarity between the decays allows to exploit systematic cancelation

- One charged track in the acceptance of DCH (kinematics), HOD (trigger) and LKR (PID)
- Track momentum
  15 GeV<P<50 GeV
- Vertex reconstructed within
  2000 cm < Zvtx < 7000cm





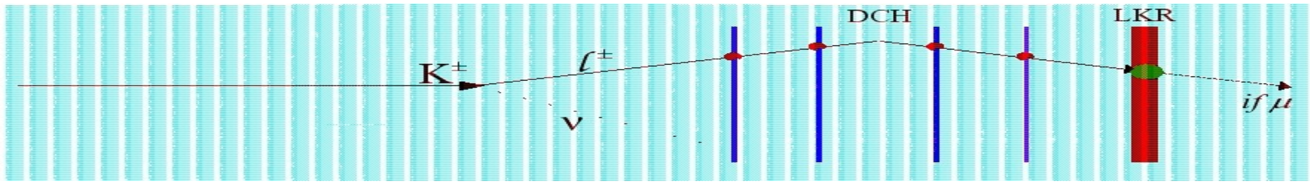


Particle identification:

E – energy deposition in LKR
P – momentum from the spectrometer

- Muons: E/p<0.2
- Electrons: E/p>0.95

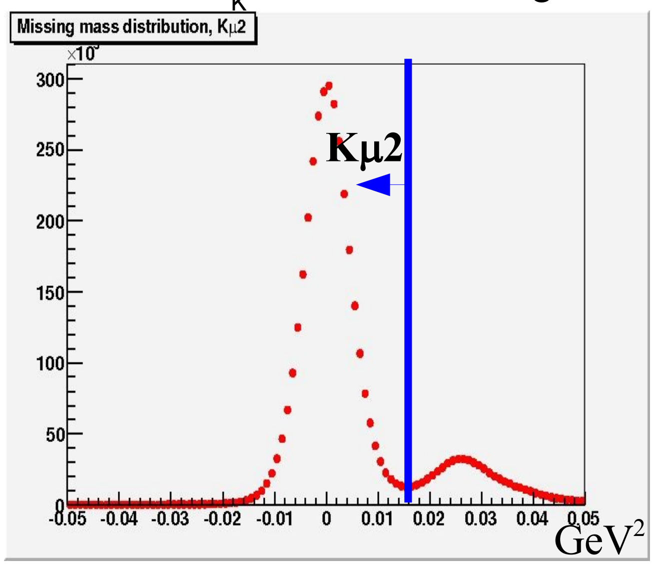
Event selection

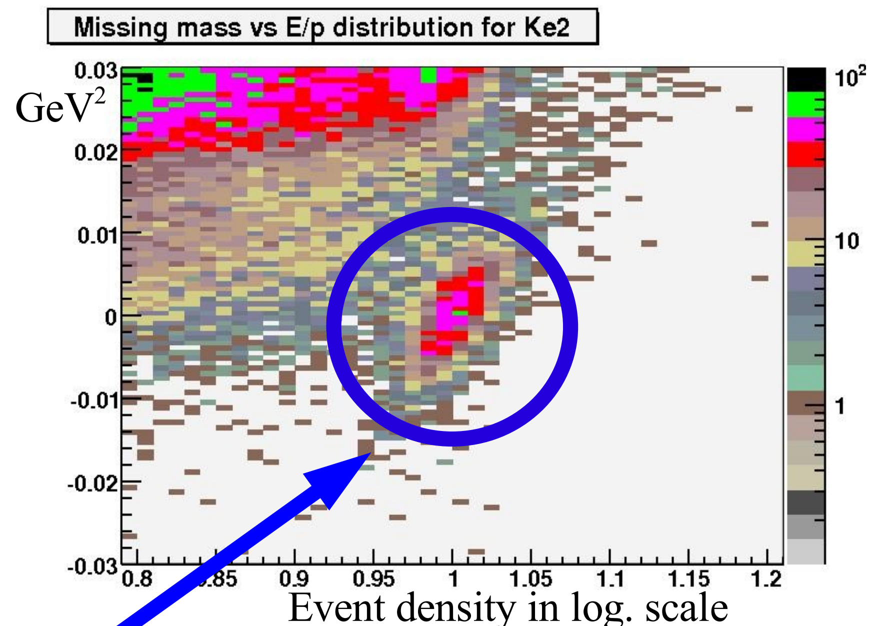


Under the assumption for the type of the lepton, the missing mass is computed:

$$|Mmiss|^2 = (P^4_K - P^4_l)^2$$

P_K: 60 GeV along the beam axis





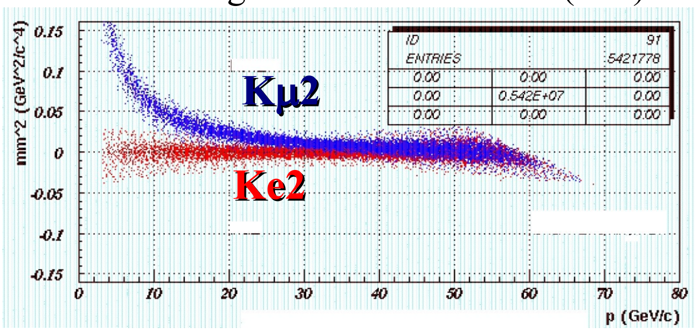
- **Found 3930 Ke2 candidates**

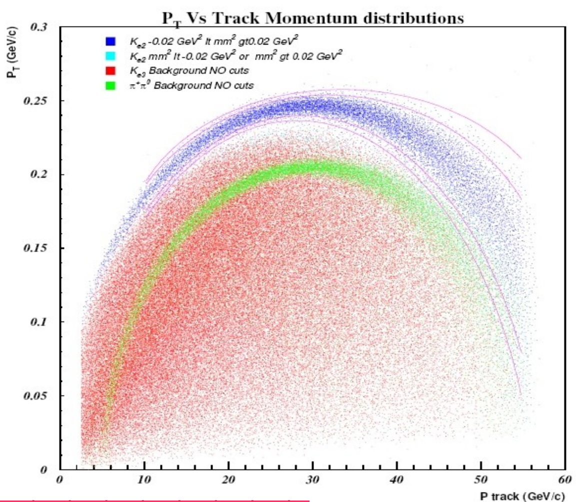
Reconstructed ~3.4*10⁶ Kμ2 events

background at the order of 0.6% from K2π

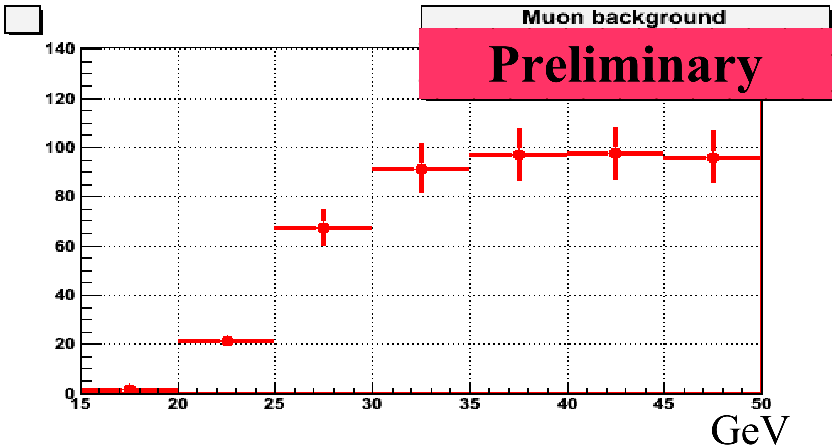
Background estimation

Missing mass vs momentum (MC)





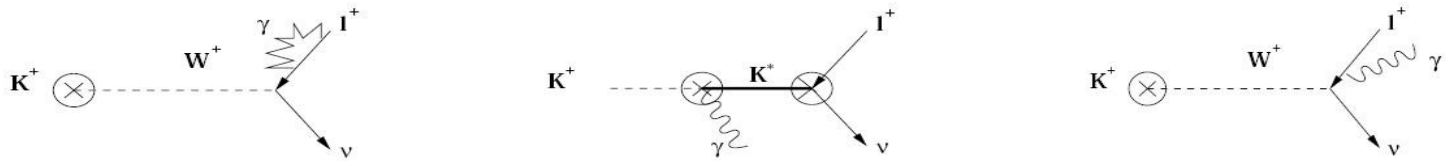
Preliminary



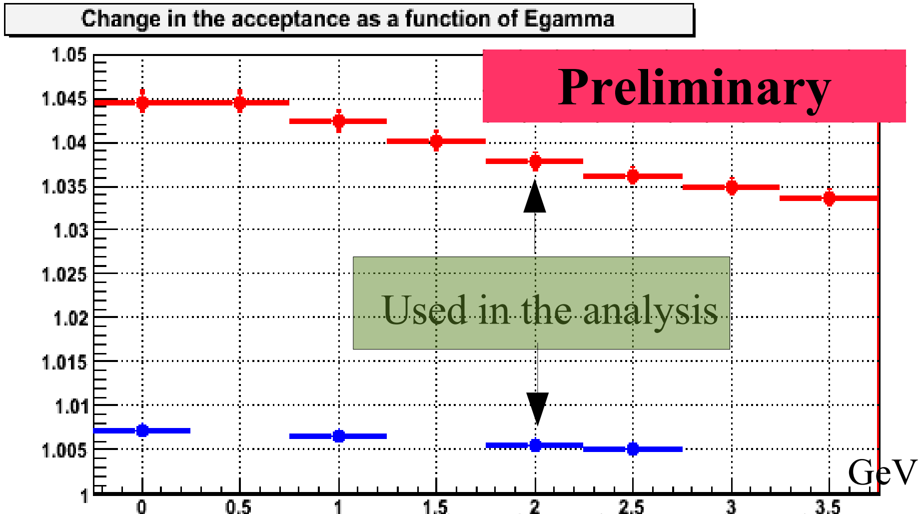
- The dominant background is Kμ2
  - **Measured from the data in momentum bins**
- Ke3 contribution obtained from MC

Total Ke2 events: $(3407 \pm 63_{stat} \pm 54_{syst})$

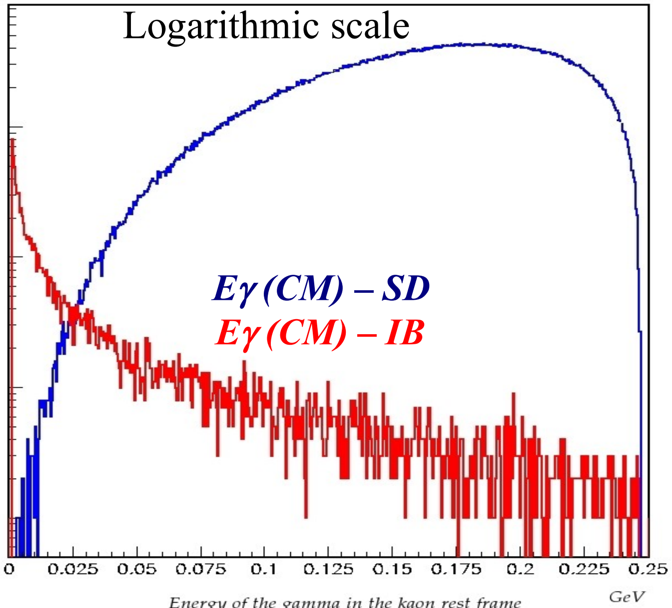
Radiative corrections



- The theory prediction for R_K includes the IB term from Kl2γ decays
- Radiative corrections applied according to the prescription of M. Finkemeier: (Phys.Lett.B387:391-394,1996) using the matrix elements from J. Bijnens et al (Nucl.Phys. B396 (1993) 81-118)



Acceptance correction for Kl2 as a function of an extra-gamma energy cut

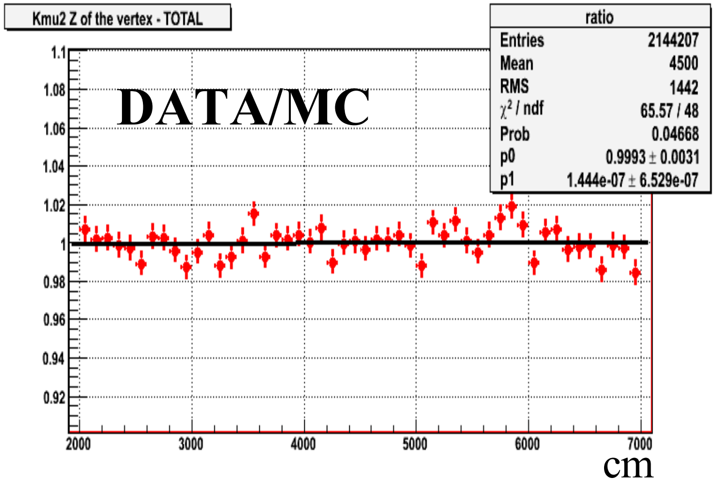


The proper treatment of radiative corrections is important

R_K extraction

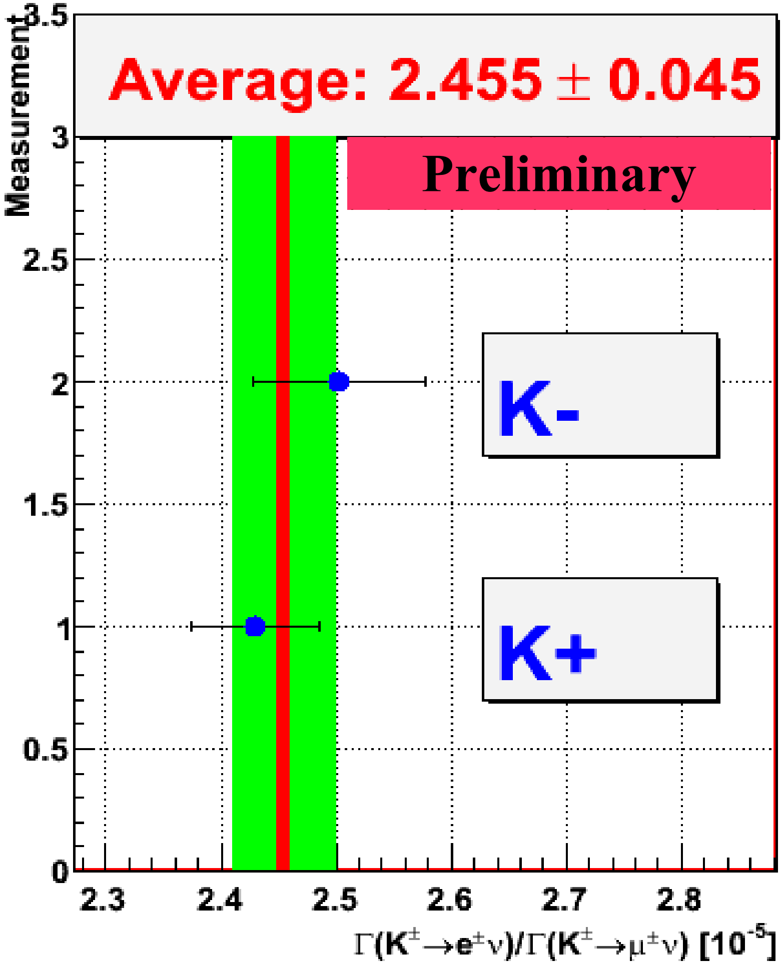
$$R_K = \frac{N_{Ke2raw} - N_{Ke2back}}{TrEff(Ke2) * Acc(Ke2) * C_e} * \frac{Acc(K\mu 2) * C_\mu}{D * (N_{K\mu 2raw} - N_{K\mu 2back})}$$

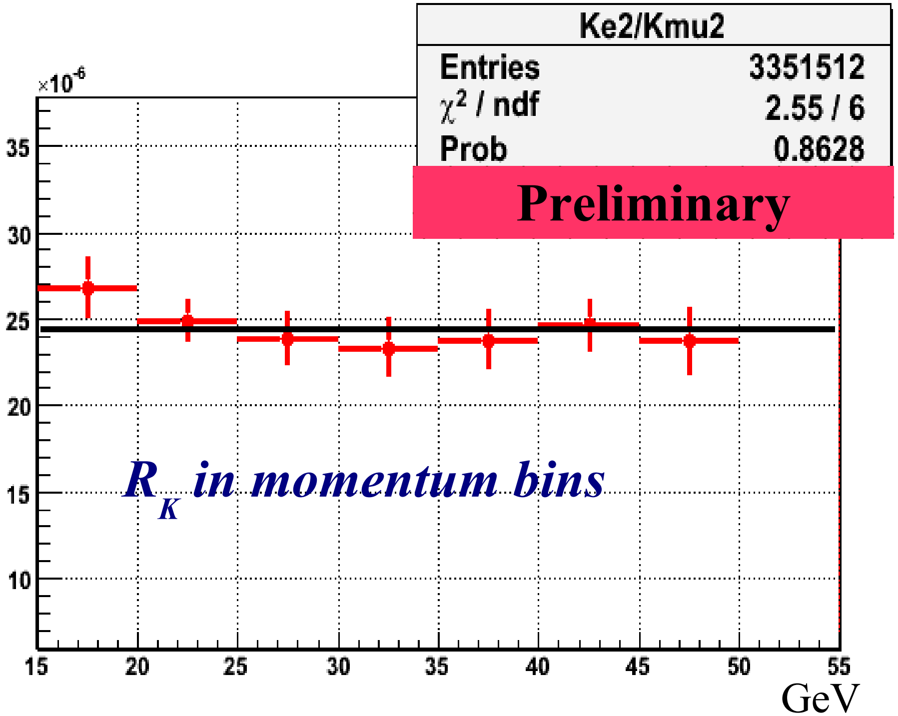
N_{kl2raw}	*Raw Kl2 events*
$N_{kl2back}$	*Background in Kl2*
TrEff(Ke2)	*Ke2 trigger efficiency*
C_l	*Losses due to E/p cut*
Acc(Kl2)	*Kl2 acceptance*



- The efficiency of the cuts and the background contribution is **obtained in momentum bins** from the **DATA**
- MC used for acceptance calculation
  - Full Geant3 based simulation of the detector response
  - Geometry of the beam tuned with $K^\pm \to \pi^\pm\pi^+\pi^-$ decays run by run

R_K checks





$R_{K+} = (2.430 \pm 0.056) * 10^{-5}$

$R_{K-} = (2.502 \pm 0.075) * 10^{-5}$

Only statistical error included

Results

Source	Preliminary	Relative error
Ke2 sample statistics		**1.85%**
Kmu2 sample statistics		**0.05%**
E/p correction for the electrons (E/p>0.95 cut)		0.18%
E/p correction for the electrons (flatness with Ptrk)		0.16%
E/p correction for the muons (E/p<0.2 cut)		Negligible
Trigger efficiency		0.3%
MC statistics Ke2		0.3%
Acceptance systematics		0.07%
Radiative corrections		0.12%
Muons with E/p>0.95 flatness		0.2%
Background subtraction		1.59%
Total statistical error		***1.85%***
Total systematics error		***1.66%***

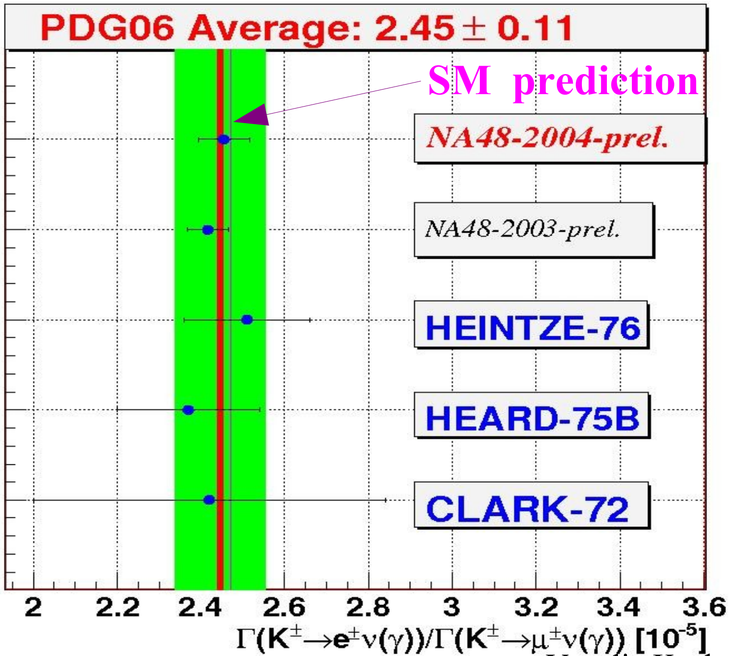
NB: The dominant contribution to the systematics, the background subtraction error, scales with the statistics

Results

Preliminary

$R_K = \Gamma(ke2)/\Gamma(K\mu 2) = (2.455 \pm 0.045_{stat} \pm 0.041_{syst})*10^{-5}$

Standard Model	$(2.472 \pm 0.001) * 10^{-5}$
PDG	$(2.45 \pm 0.11) * 10^{-5}$
NA48: 2004 data	$(2.455 \pm 0.045 \pm 0.041) * 10^{-5}$



The NA48 measurement based on the 2004 data is ***two times*** more precise than the world average

Conclusion

- $K^{\pm} \to l^{\pm}\nu$ decays provide a very challenging opportunity to search for physics beyond the Standard Model
- Preliminary result for R_K based on 2004 data sample presented
- A sub-percent precision measurement of R_K will allow to probe for New Physics or rule out regions in the parameters space in different models
- A run dedicated to the R_K measurement will take place this year in the frame of P326 experiment

Spares

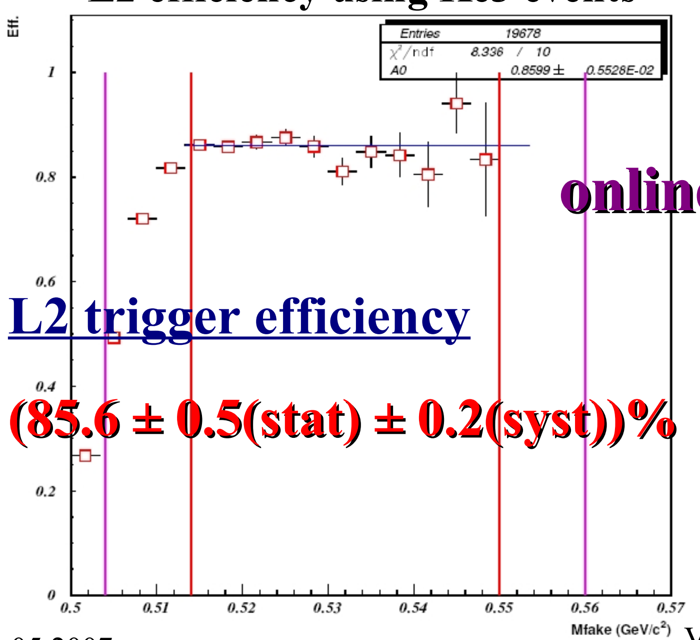
2003 data

- $K\mu 2$ events: **signal from the charged hodosope**
- Ke2 events
  - **L2 trigger:**
    online kinematics reconstruction

$$M_{Fake}^2 = M_K^2 + M_\pi^2 - S$$

$$S=(p_K-p_\pi)^2, \ \ p_K=(0,0,60)\ GeV/c$$

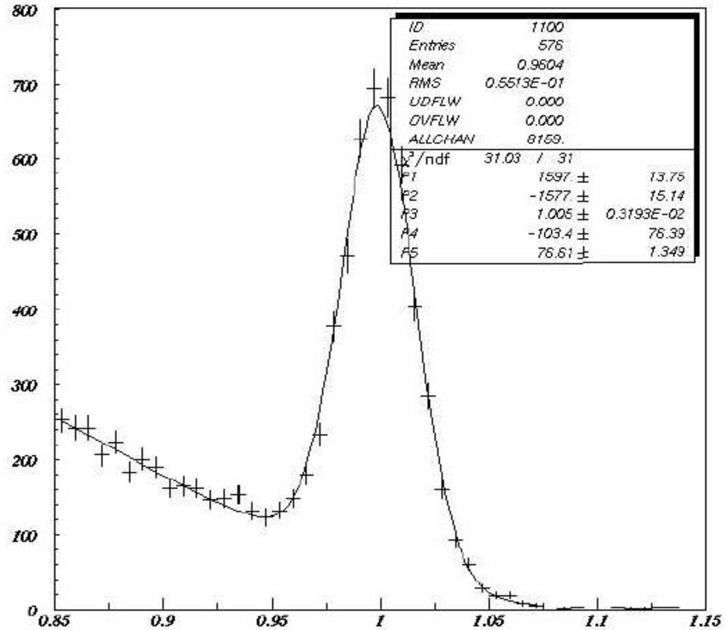
L2 efficiency using Ke3 events



online cut

L2 trigger efficiency

(85.6 ± 0.5(stat) ± 0.2(syst))%



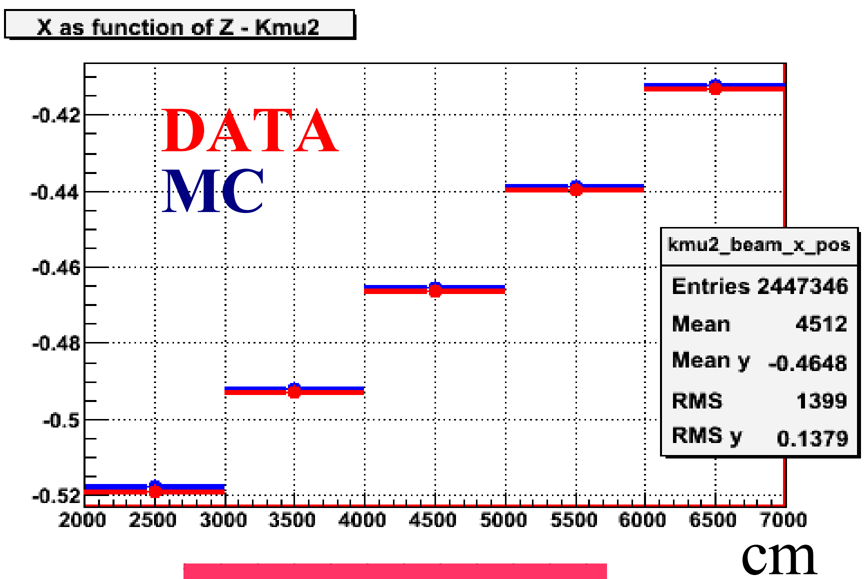
Background events: 659 ± 26

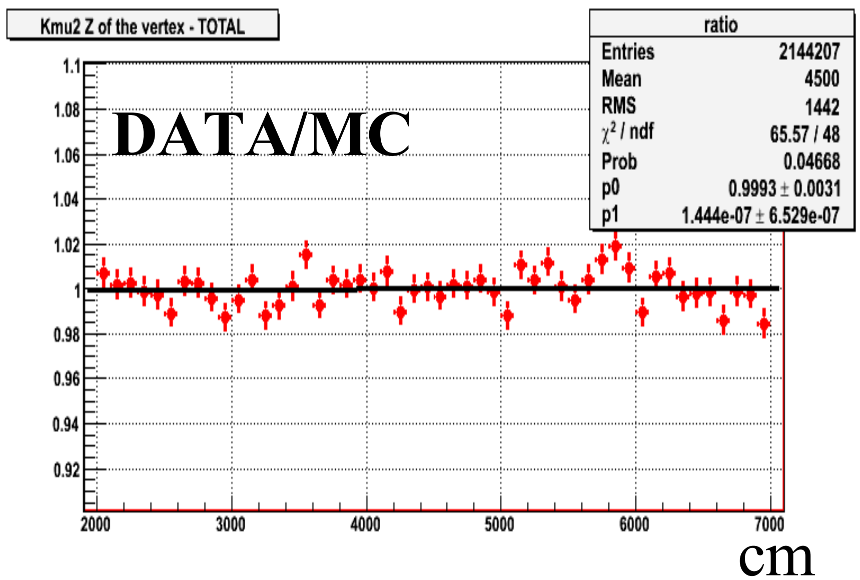
Signal events: $4670 \pm 77(stat)^{+29}_{-8}(syst)$

$$R_K = (2.416 \pm 0.049) * 10^{-5}$$

Simulation

- Full Geant3 based simulation of the detector response
  - Geometry of the beam tuned with $K^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$ decays run by run





Preliminary

Km2 acceptance: **(58.818 ± 0.019)%**

Ke2 acceptance: **(48.963 ± 0.15)%**