

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

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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

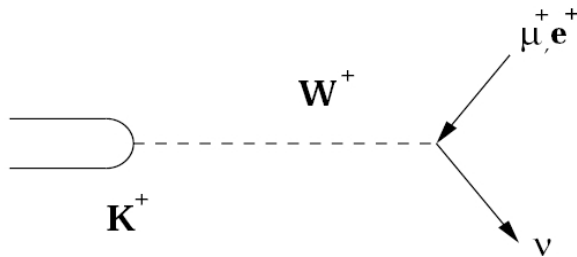


Motivation



Within the Standard Model:

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

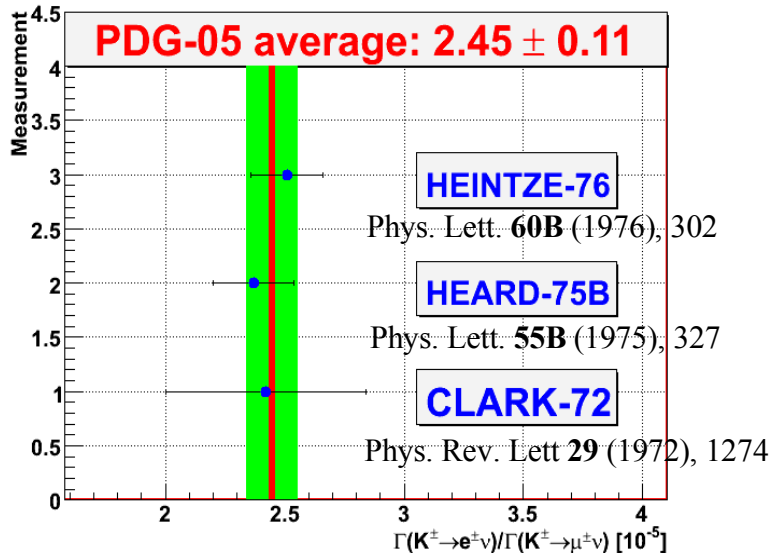


$$R_M := \frac{\Gamma(M \rightarrow e\nu_e(\gamma))}{\Gamma(M \rightarrow \mu\nu_\mu(\gamma))} = \frac{m_e^2}{m_\mu^2} \left(\frac{m_M^2 - m_e^2}{m_M^2 - m_\mu^2} \right)^2 (1 + \delta R_M)$$

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*

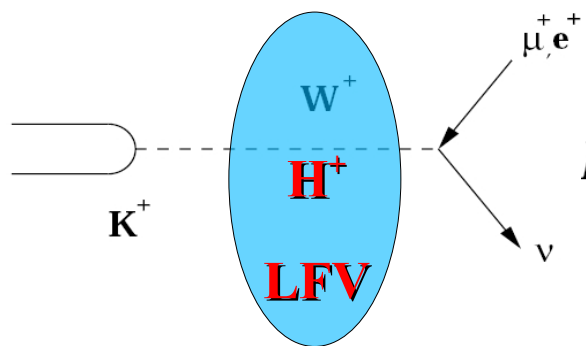


Motivation



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Standard Model prediction:

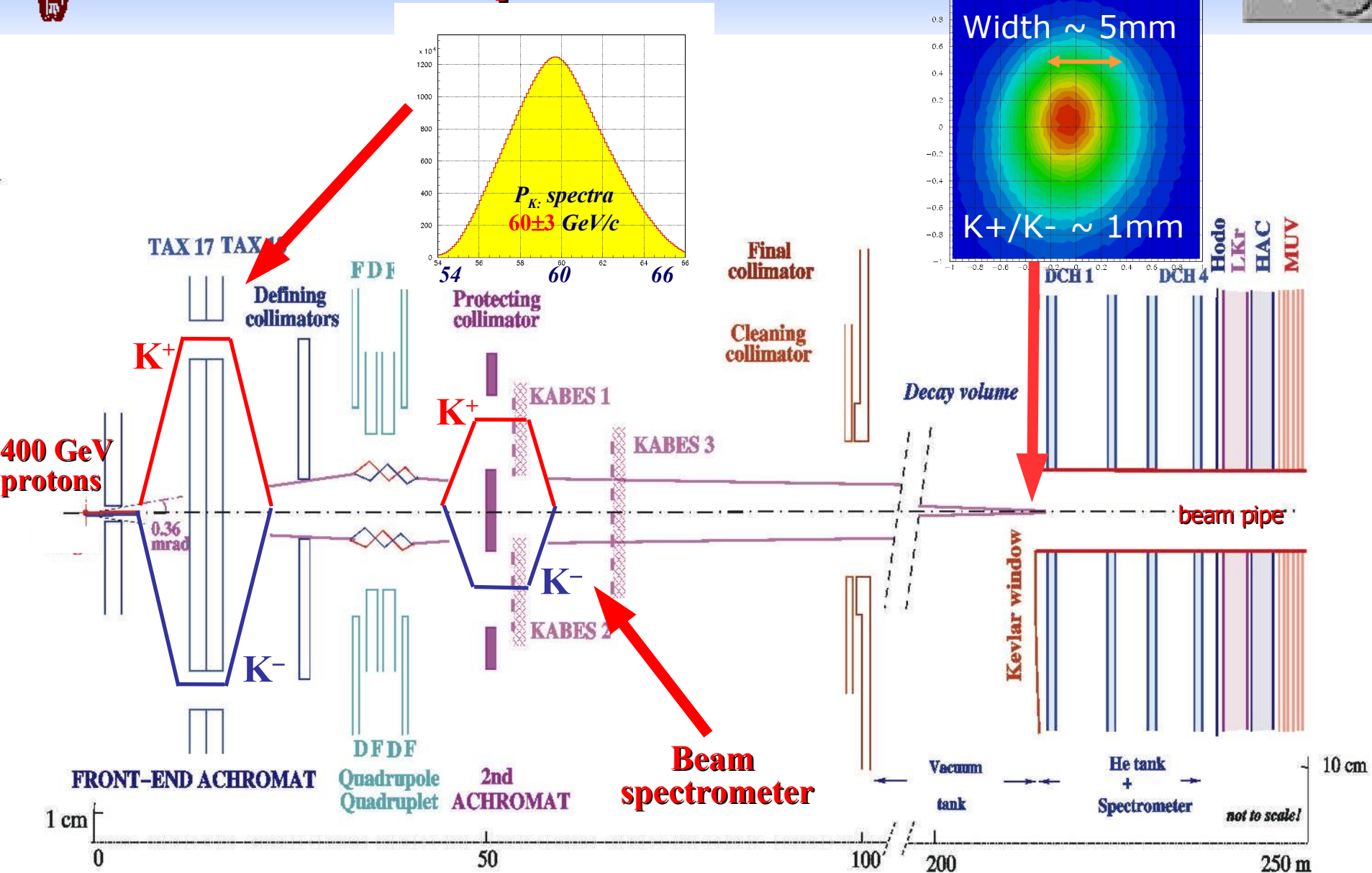
$$R_K = (2.472 \pm 0.001) * 10^{-5}$$

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

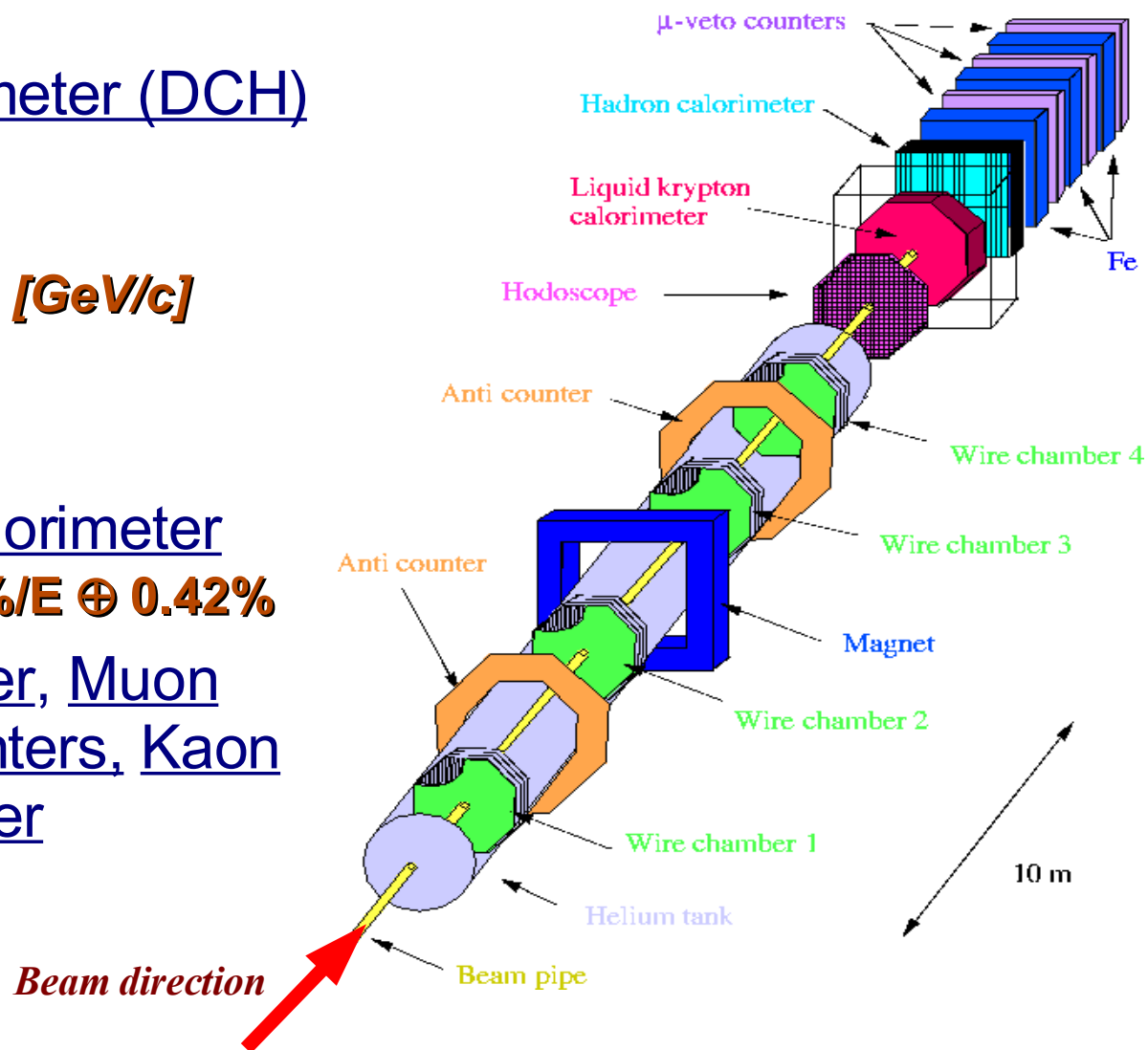




Detector setup



- Magnetic spectrometer (DCH)
4 drift chambers
 $p_{\perp}^{\text{kick}} = 121 \text{ MeV}/c$
 $\Delta p/p = 1\% \oplus 0.044 * p [\text{GeV}/c]$
- Hodoscope
 $\sigma(t) = 150 \text{ ps}$
- Liquid Krypton Calorimeter
 $\Delta E/E \approx 3.2\%/\sqrt{E} \oplus 9\%/E \oplus 0.42\%$
- 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

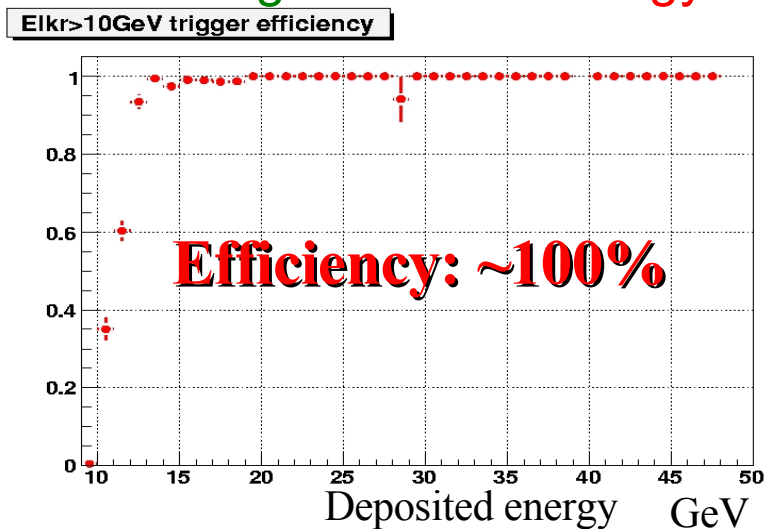
The huge statistics ($\sim 4 \cdot 10^9 K^{\pm} \rightarrow \pi^{+} \pi^{-} \pi^{\pm}$) allows to study rare kaon decays with high precision



2004 Data taking

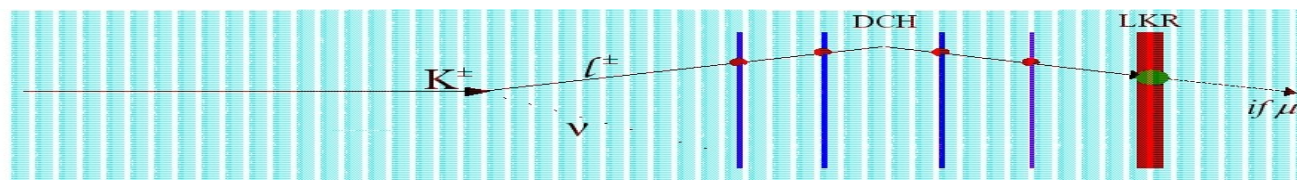


- 2004 data: special run conditions devoted to the study of Kaon semileptonic decays and K_{e2}
 - 60 GeV kaon beam with decreased intensity
 - No Level 2 trigger
- Trigger
 - $K_{\mu 2}$ events: 1 charged track
 - K_{e2} events: 1 charged track + Energy in the LKR > 10 GeV





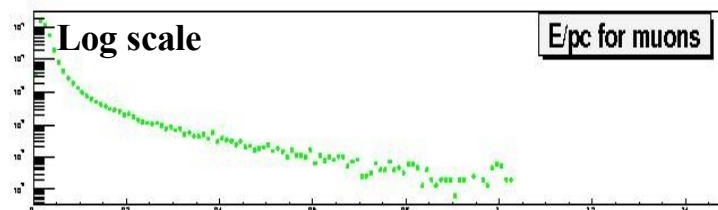
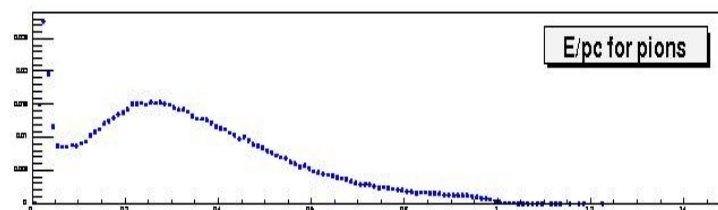
Event selection



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
 $15 \text{ GeV} < P < 50 \text{ GeV}$
- Vertex reconstructed within
 $2000 \text{ cm} < Z_{\text{vtx}} < 7000 \text{ cm}$



Particle identification:

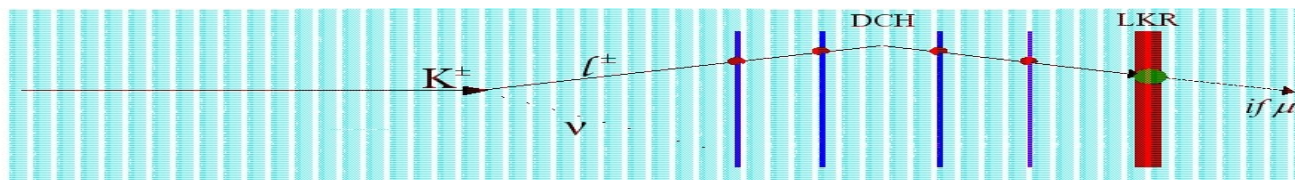
E – energy deposition in LKR

P – momentum from the spectrometer

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



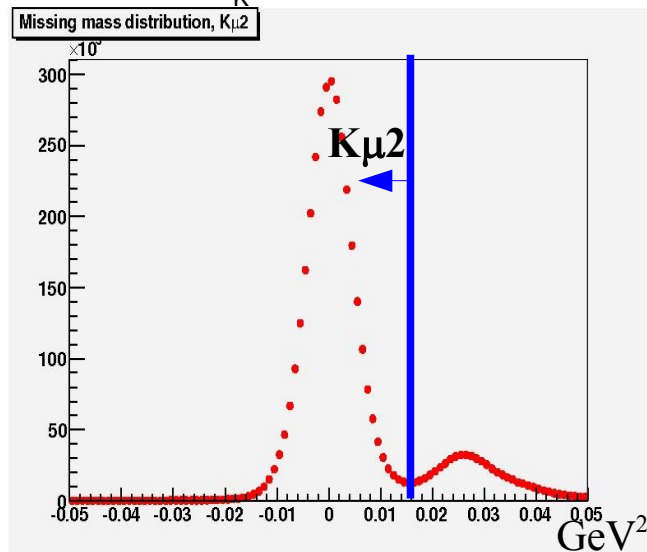
Event selection



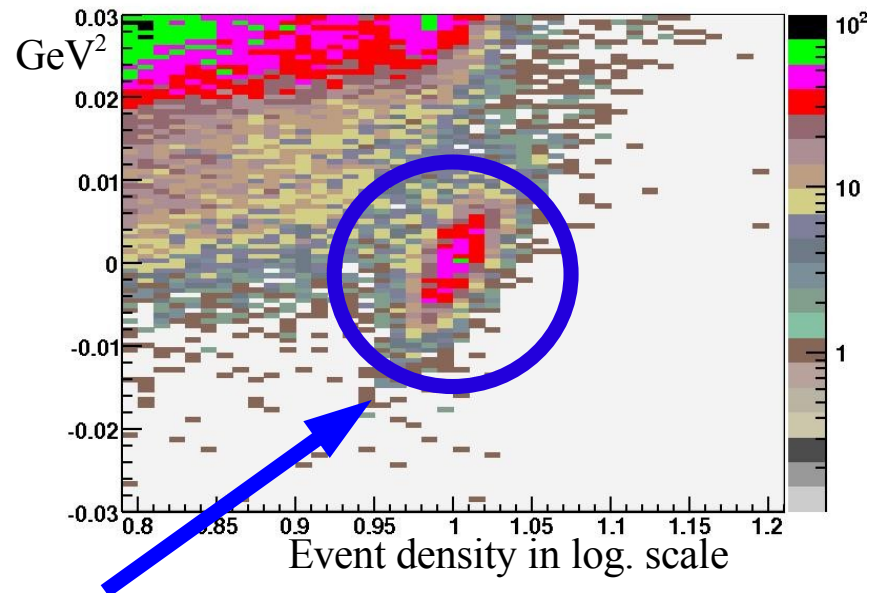
Under the assumption for the type of the lepton,
the missing mass is computed:

$$|M_{\text{miss}}|^2 = (P_K^4 - P_l^4)^2$$

P_K : 60 GeV along the beam axis



Missing mass vs E/p distribution for Ke2



- **Found 3930 Ke2 candidates**

Reconstructed $\sim 3.4 \cdot 10^6$ $K\mu 2$ events

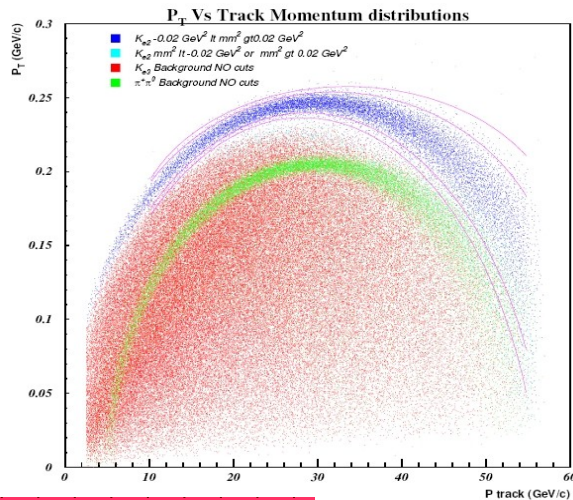
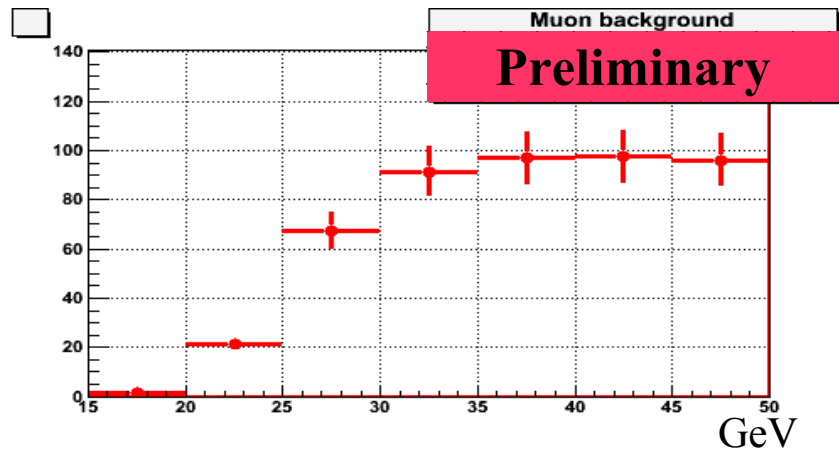
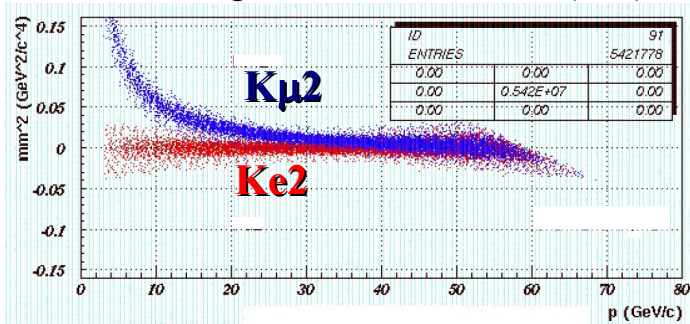
background at the order of 0.6% from $K2\pi$



Background estimation



Missing mass vs momentum (MC)



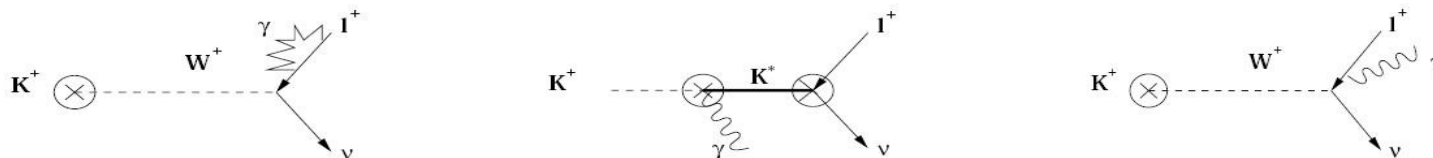
- The dominant background is $K_{\mu 2}$
 - **Measured from the data in momentum bins**
- Ke_3 contribution obtained from MC

Preliminary

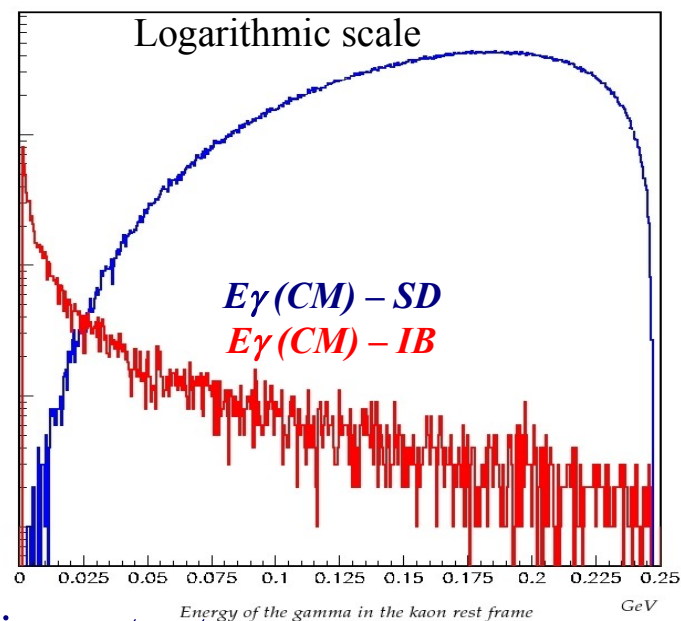
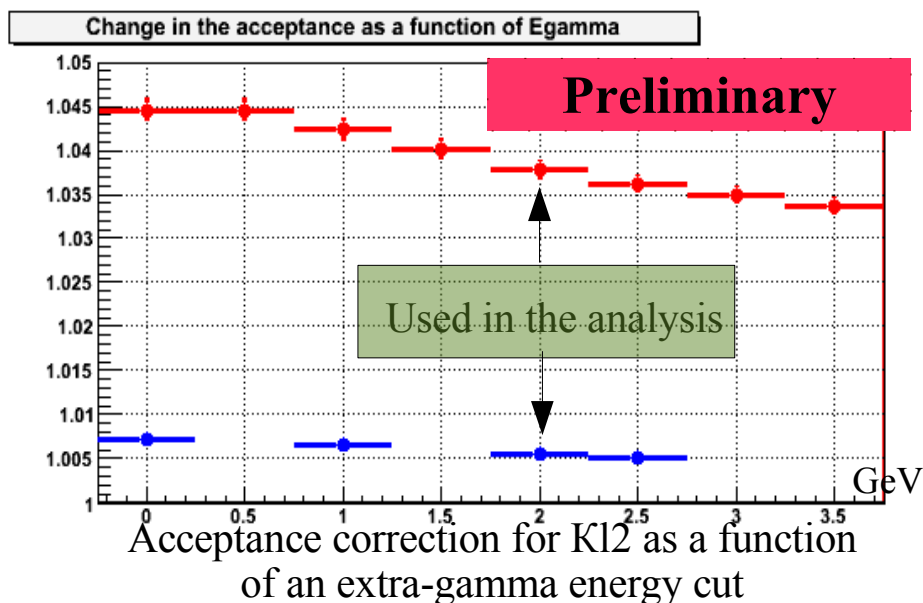
Total Ke_2 events: $(3407 \pm 63 \pm 54)$
stat syst



Radiative corrections



- The theory prediction for R_K includes the IB term from $Kl2\gamma$ 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)



The proper treatment of radiative corrections is important

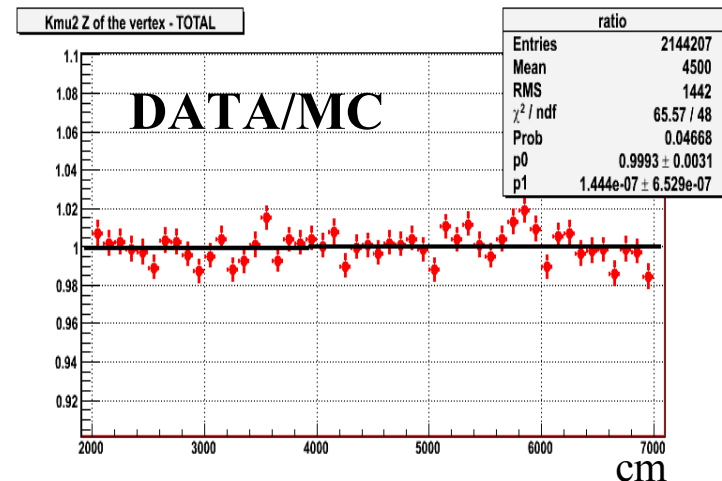


R_K extraction



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

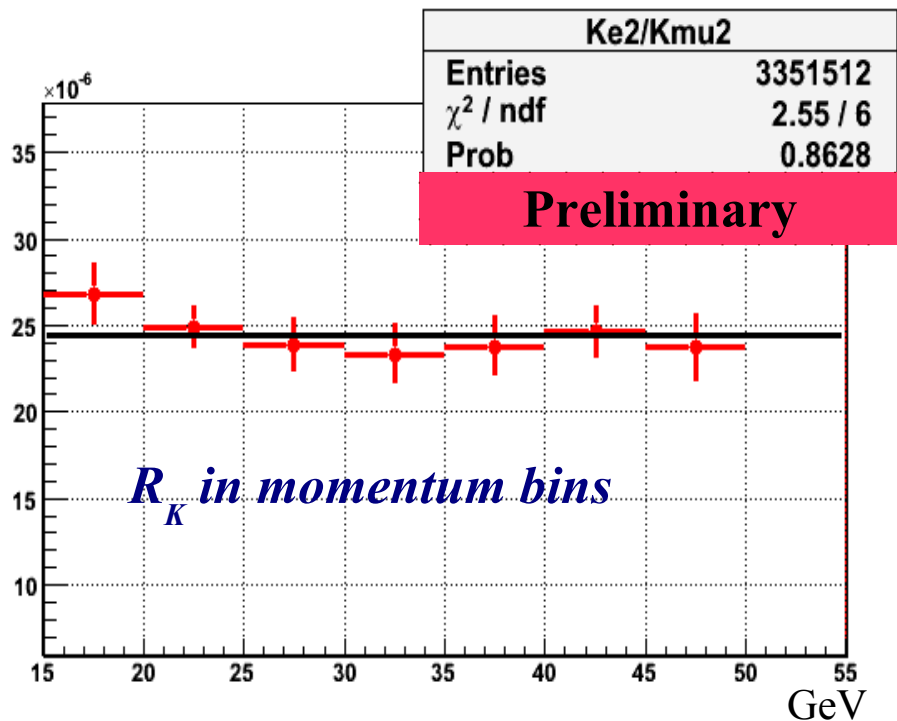
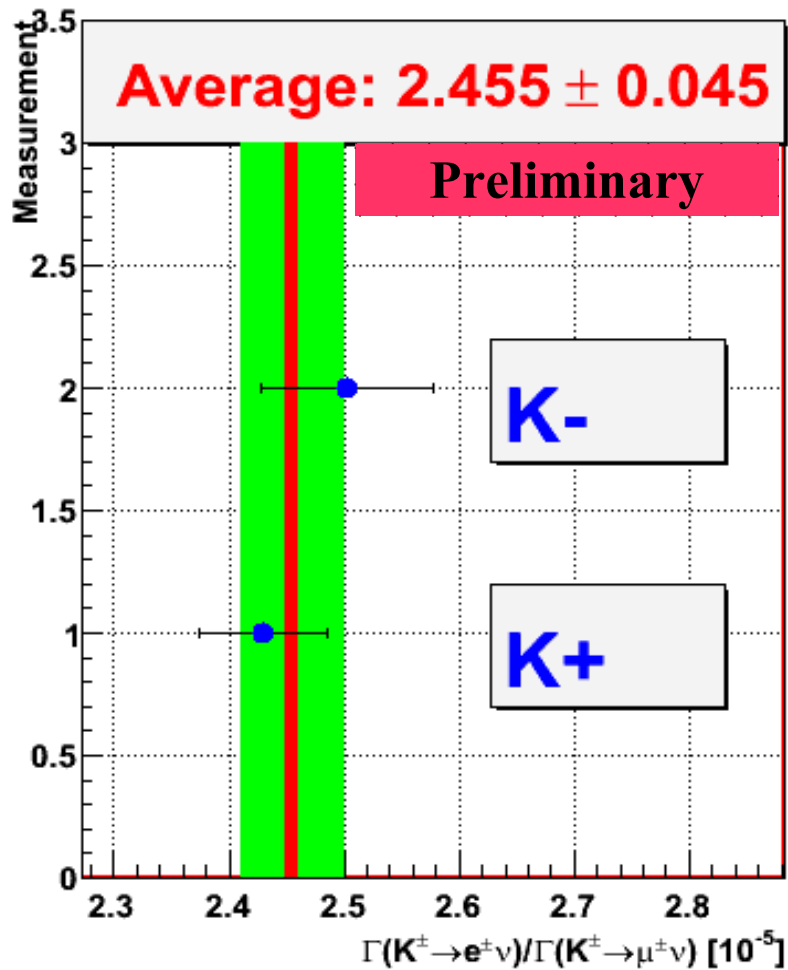
- N_{kl2raw} *Raw KI2 events*
- $N_{kl2back}$ *Background in KI2*
- $TrEff(Ke2)$ *Ke2 trigger efficiency*
- C_l *Losses due to E/p cut*
- $Acc(KI2)$ *KI2 acceptance*



- 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 $K^\pm \rightarrow \pi^\pm \pi^+ \pi^-$ 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%
<u>Total statistical error</u>		<u>1.85%</u>
<u>Total systematics error</u>		<u>1.66%</u>

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



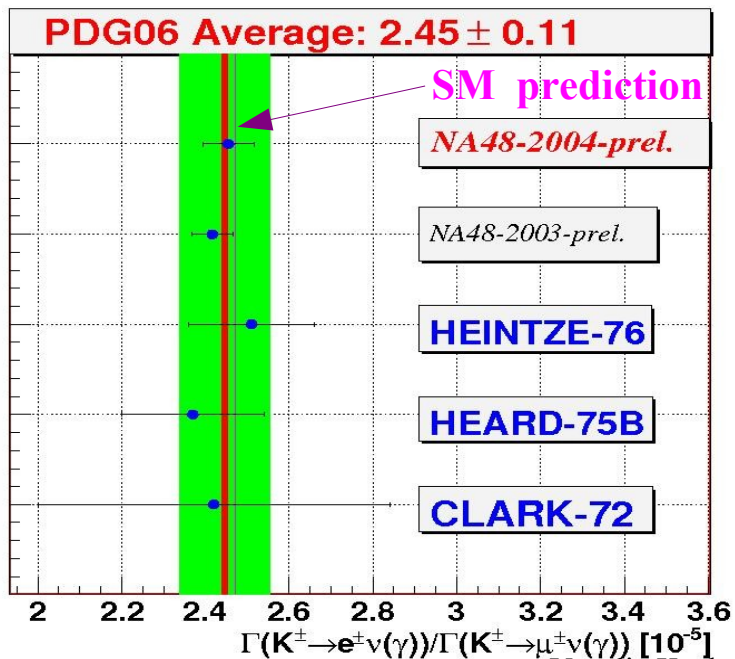
Results



Preliminary

$$R_K = \Gamma(ke2)/\Gamma(K\mu2) = (2.455 \pm 0.045_{stat} \pm 0.041_{syst}) * 10^{-5}$$

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



- $K^{\pm} \rightarrow l^{\pm} \nu$ 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

Spare



2003 data



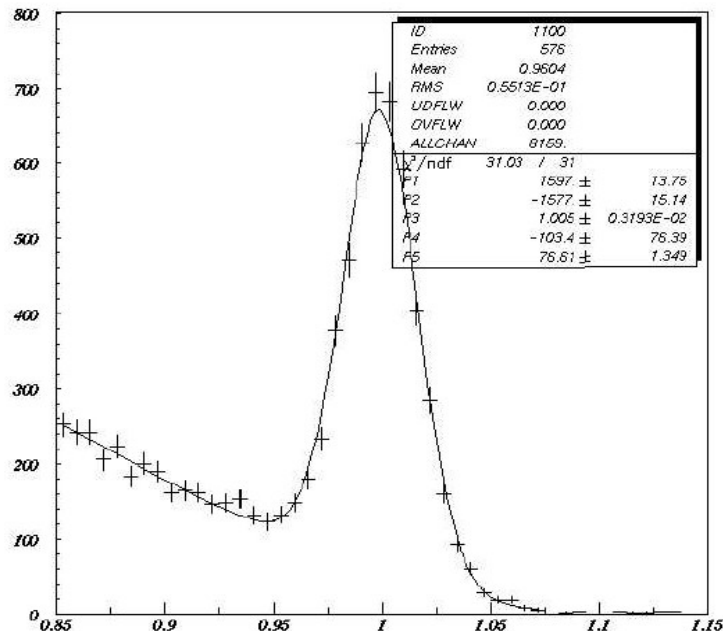
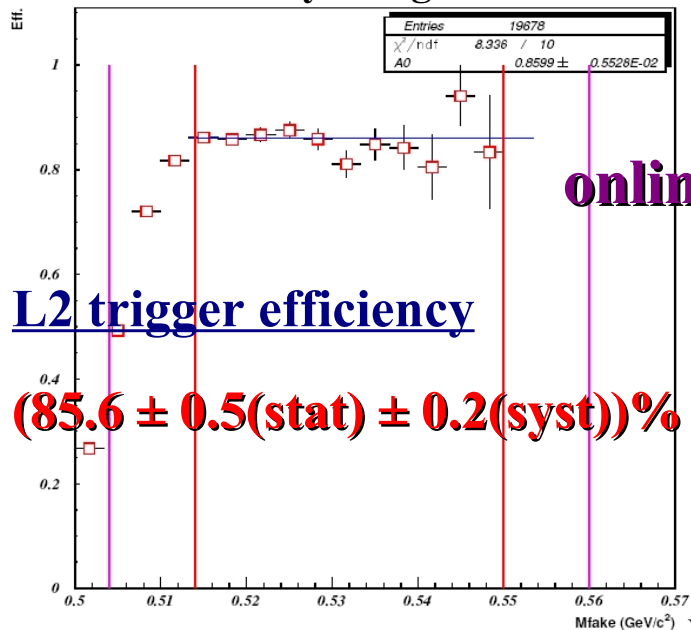
- $K_{\mu 2}$ events: signal from the charged hodoscope
- Ke2 events

- **L2 trigger:**
online kinematics reconstruction

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

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

L2 efficiency using Ke3 events



Background events: 659 ± 26

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

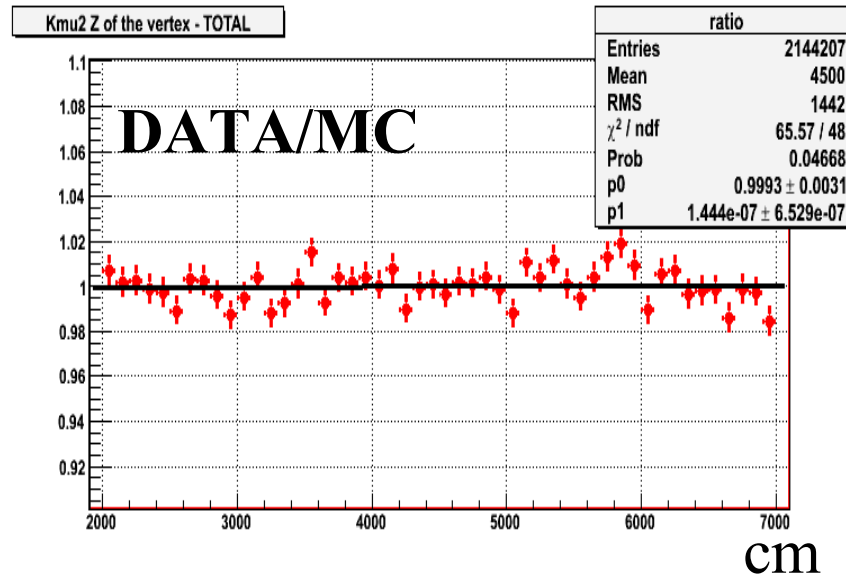
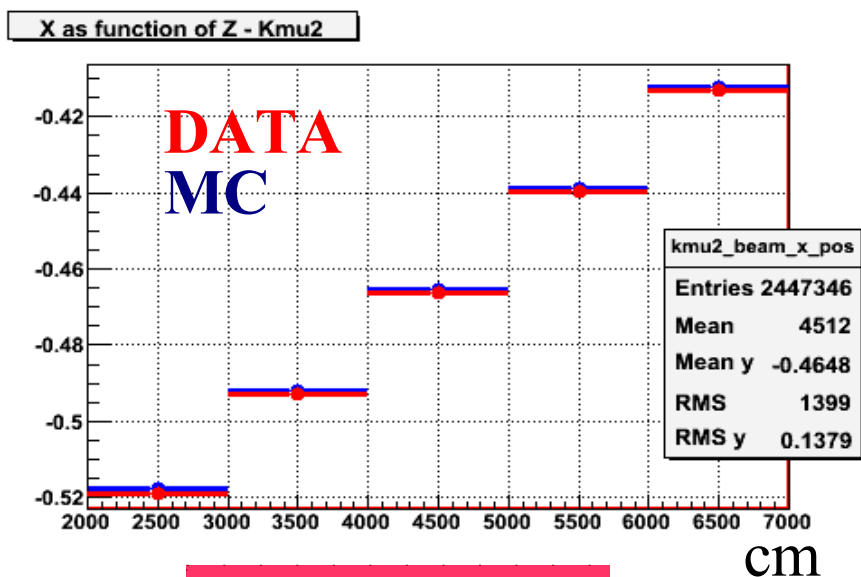
$$R_K = (2.416 \pm 0.049) * 10^{-5}$$



Simulation



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



Preliminary

Km2 acceptance: $(58.818 \pm 0.019)\%$
Ke2 acceptance: $(48.963 \pm 0.15)\%$