Testing LFV measuring $K \rightarrow e\nu / K \rightarrow \mu\nu$ in NA48: Status and Prospectives

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Luca Fiorini

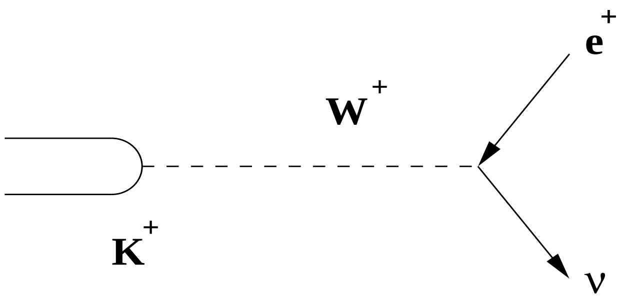
University of Cambridge

on behalf of NA48/2 Collaboration

Cambridge, CERN, Chicago, Dubna, Edimburgh, Ferrara, Firenze, Mainz, Northwestern, Perugia, Pisa, Saclay, Siegen, Torino, Wien

Former Physical Motivations

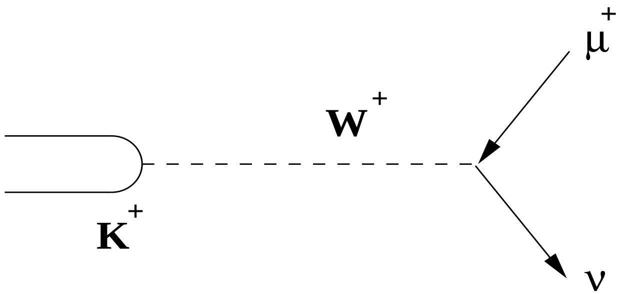
The measurement of $\Gamma(K_{e2})/\Gamma(K_{\mu2})$ ratio is a test of SM *Lepton Universality* and *V-A Coupling*.



Standard Model Prediction of the ratio is:

$$\frac{\Gamma(K\to e\nu(\gamma))}{\Gamma(K\to \mu\nu(\gamma))} = R_K = \frac{m_e^2}{m_\mu^2}\left(\frac{m_K^2-m_e^2}{m_K^2-m_\mu^2}\right)^2(1+\delta R_K)$$

$R_K = R_K^{(0)}(1+\delta R_K) = (2.472 \pm 0.001)\text{x}10^{-5}$



Experimental Results:

PDG Average (2005): $2.45 \pm 0.11 \cdot 10^{-5}$

From experiments with low energy K^+ beam stopped in a target, decay at rest

New Physical Motivations

hep-ph/0511289 (A. Masiero et al.)

This recent paper shows that SUSY LFV contributions could shift R_K by a relative amount of a few per cent (2-3%), with parameters tanβ ~50 and $M_{H^+} \sim 500$ GeV/c^2

These values are are in the range of RPC SUSY models satisfying g-2, WMAP and $b \rightarrow s\gamma$, where χ are CDM primary component: PR D73 015013 (2006) (B. Allanach and C. Lester)

Remarkably, SUSY LFV contributions to pions and tau leptonic decays are far below the present experimental precision, while heavier mesons leptonic decay measurement are experimentally very challenging.

Kaon leptonic decays are golden modes to search for SUSY LFV effects!

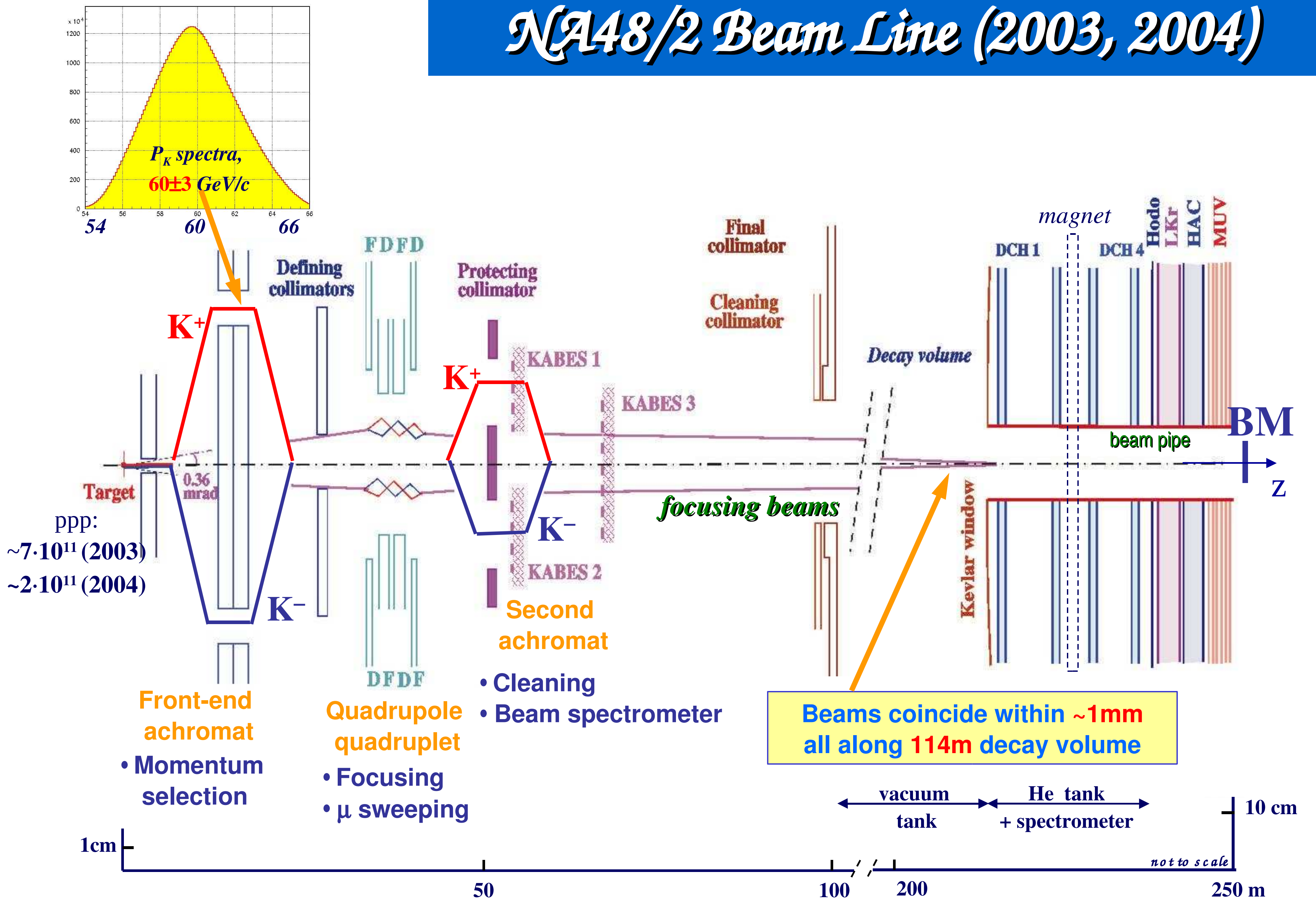
NA48/2 Contribution to R_K measurement

NA48/2 is analyzing 2 sample of Data for R_K measurement:

- A sample collected during 2003 Data taking:
  1 month of Data taking with a downscaled trigger
  - Preliminary result presented at HEP2005 in Lisbon

- A sample collected at the end of 2004 Data taking:
  56 hours with a minimum bias trigger
  - Analysis in progress

NA48/2 Beam Line (2003, 2004)



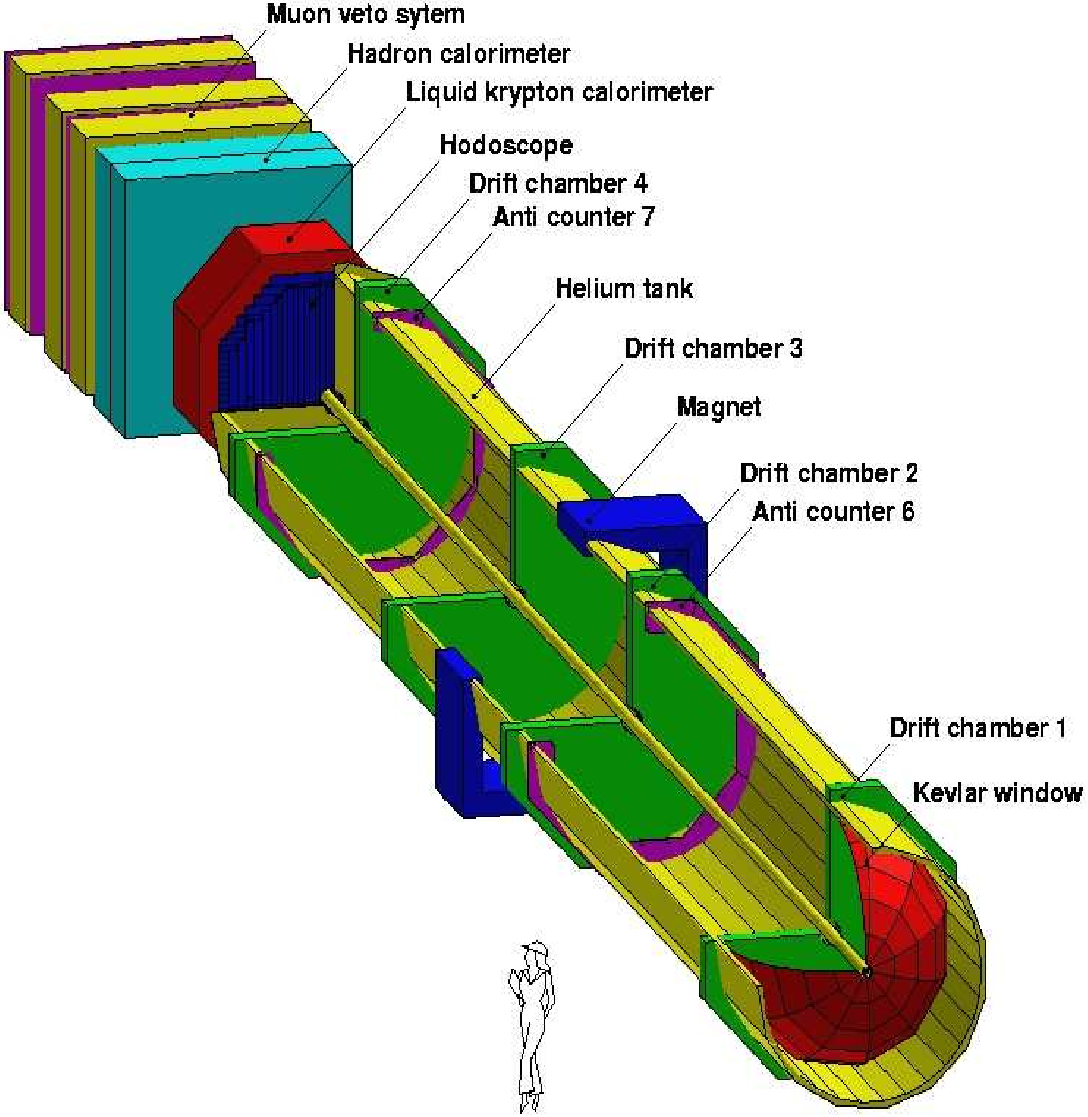
NA48/2 Detectors (2003, 2004)

Main detector components:

- Magnetic spectrometer (4 DCHs): magnet kick of 121 MeV/c
$\Delta p/p = 1.0\% + 0.044\% \cdot p$ [GeV/c]

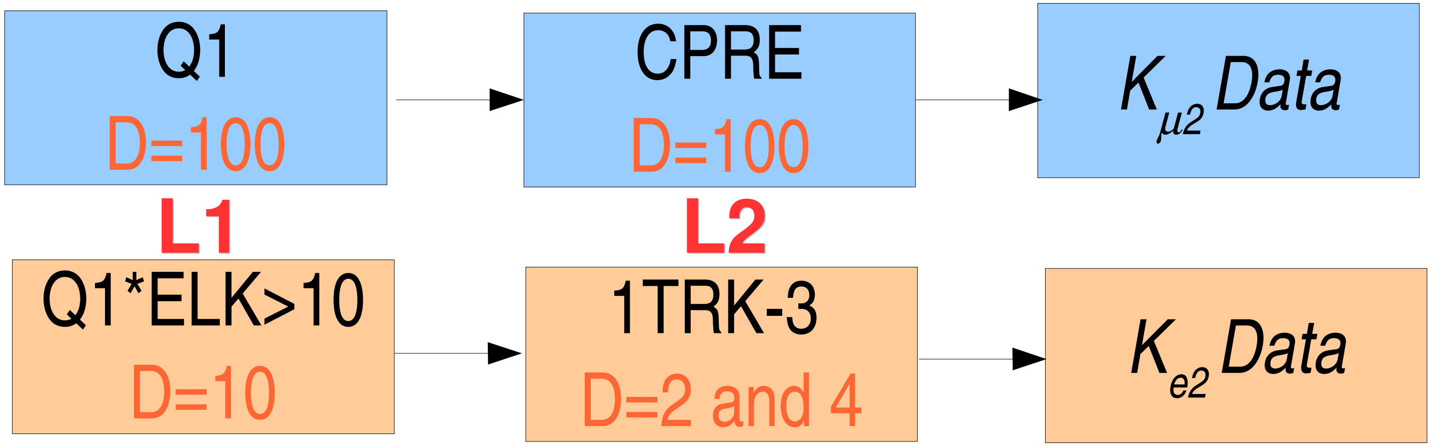
- Liquid Krypton EM calorimeter (LKr)
$\Delta E/E = 3.2\%/\sqrt{E} \oplus 9\%/E \oplus 0.42\%$

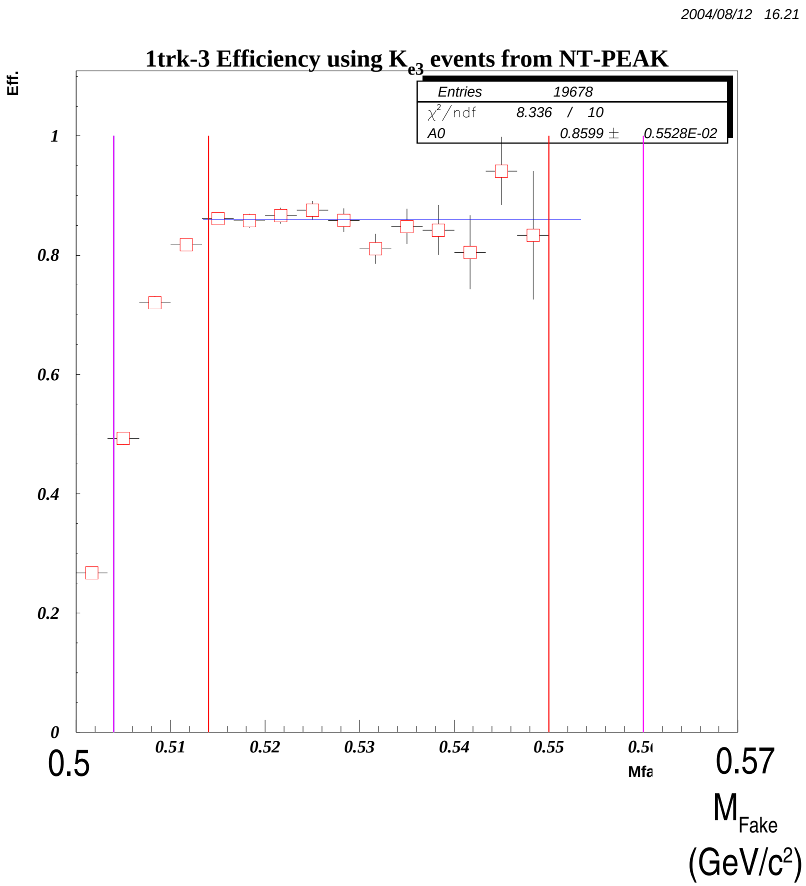
- Kaon Beam spectrometer, Hadron calorimeter, photon vetos, muon veto counters



2003 Analysis

Trigger Logic and Efficiency (2003)





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

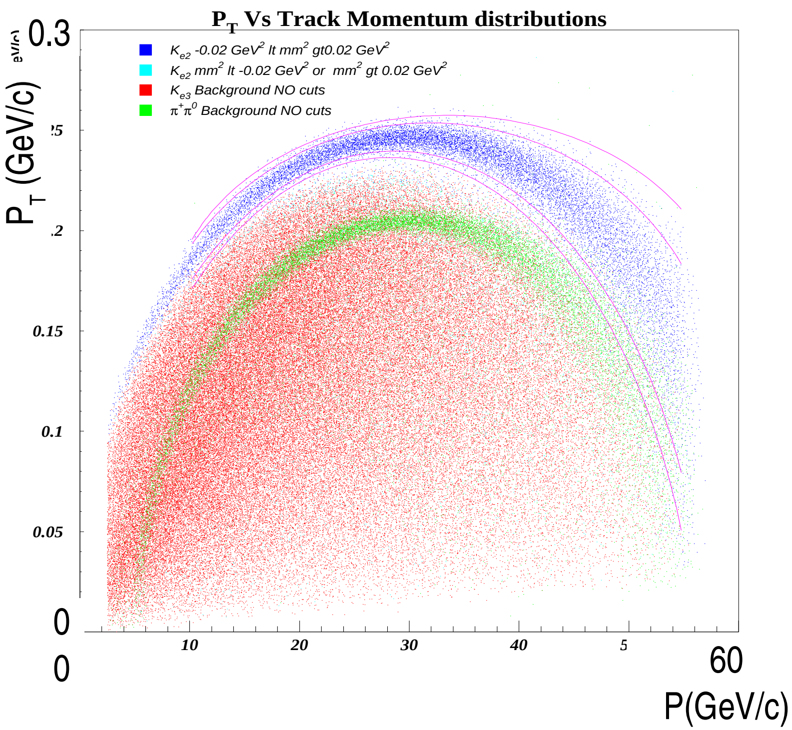
$$S = MM^2(\pi) = (p_K - p_\pi)^2 \qquad p_K \equiv (0,0,60)\ GeV/c$$

1-TRK3 Trigger Eff. (%):

$85.6 \pm 0.5_{(stat)} \pm 0.2_{(syst)}$

Selection and Acceptance (2003)

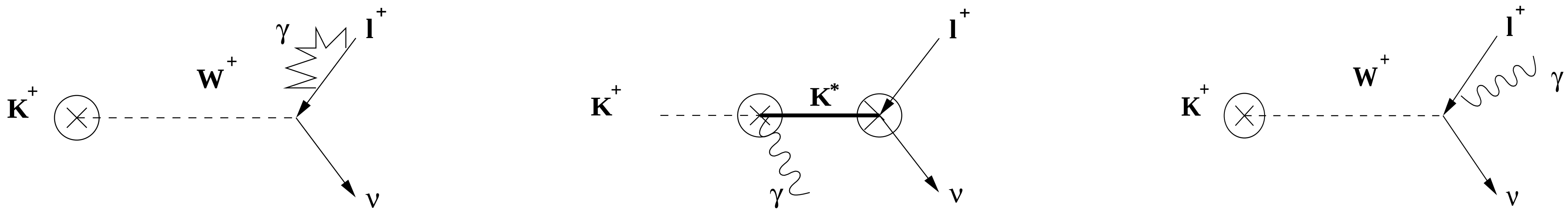
K_{e2} and $K_{\mu 2}$ CUTS



- *<u>At least</u>* 1 track (good χ^2) ; no extra cluster (E_{clu}<1.5 GeV) ; no ghost tracks ;no in time tracks or AKL hits
- 15 GeV/c < P_{track} < 55 GeV/c
- P_T vs P selection
- 2000 cm < Vertex z < 8500 cm
- 0.514 GeV/c^2< M_{Fake} < 0.55 GeV/c^2
- 0.512 GeV/c^2< M_{Fake} < 0.531 GeV/c^2
- -0.02 GeV^2/c^4< MM^2 < 0.02 GeV^2/c^4

$$\Delta(R_K) = 1.116 \pm 0.002_{(stat)} \pm 0.006_{(syst)}$$

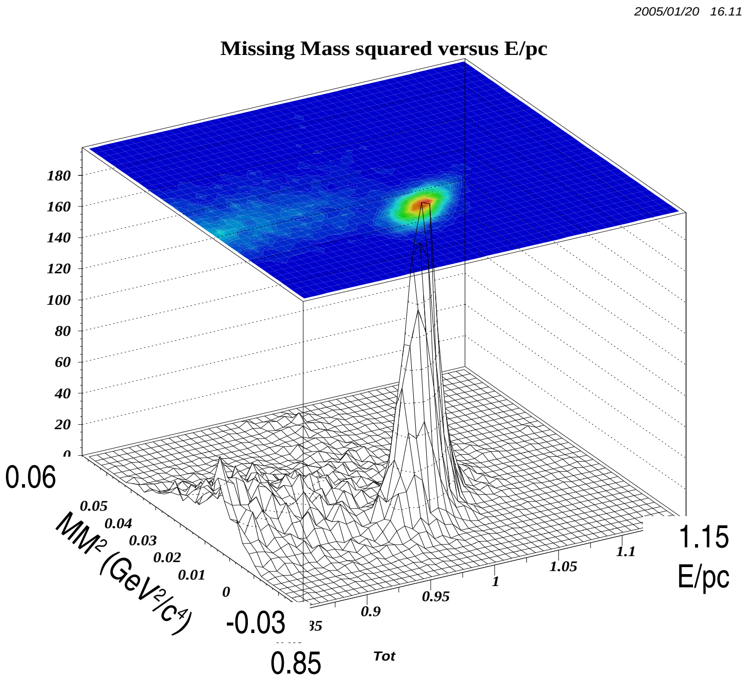
Radiative Corrections (2003)



Decay	B.R.	Acceptance	Correction
Ke2g Eg>3MeV (IB)	$1.56{\cdot}10^{-6}$	0.33 · A(Ke2)	+6.5%
Ke2g SD	$1.5{\cdot}10^{-5}$	$2.4 \cdot 10^{-3} \cdot$ A(Ke2)	-0.22%
Kμ2g Eg>3MeV (IB)	$6.5{\cdot}10^{-3}$	0.37 · A(Km2)	-0.64%

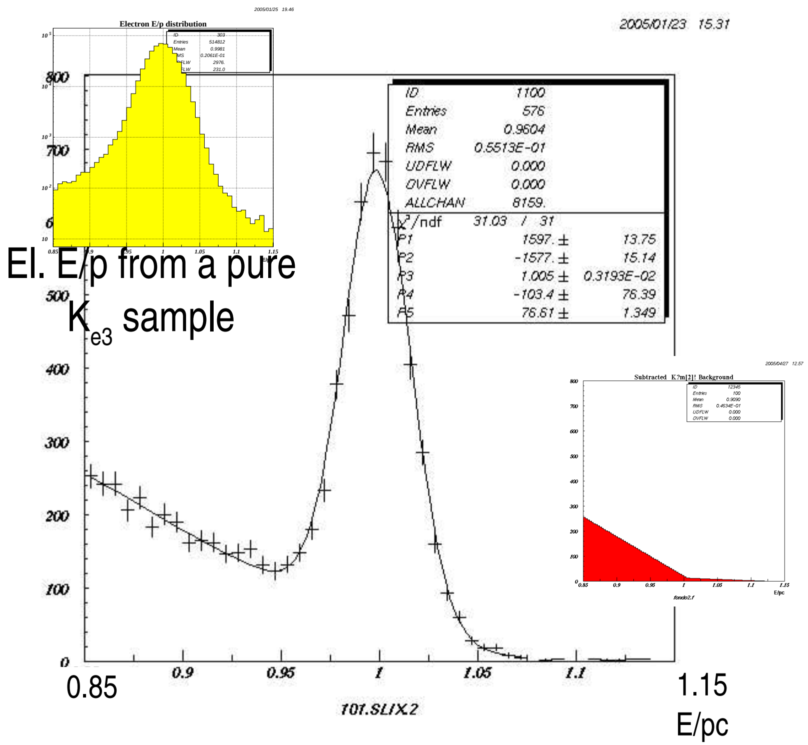
$$\Delta(R_K) = 1.063 \pm 0.005_{(syst)}$$

K_{e2} electron ID and Bkg study(2003)



Signal Region is defined by:

$0.95 < E/pc < 1.05$ and $-0.02 < MM_2 < 0.02$ (GeV^2/c^4)



2003 Data

Total N of Events	5329 ± 73
Background Events	659 ± 26
Signal Events	$4670 \pm 77^{+29}_{-8}$(syst)

2004 Analysis

MB2004: changes w.r.t. 2003 Analysis

- 60 GeV/c $K^{\pm}$ beam with intensity on T10 ~ ¼ I_0

- Different Trigger conditions (no L2 trigger):

  Main (K_{e2}) : Q1x(E_{LKr}>10) D=1 ~45K Trigger/burst

  Control Trigger ($K_{\mu 2}$): Q1/10 D=5 ~10K Trigger/burst

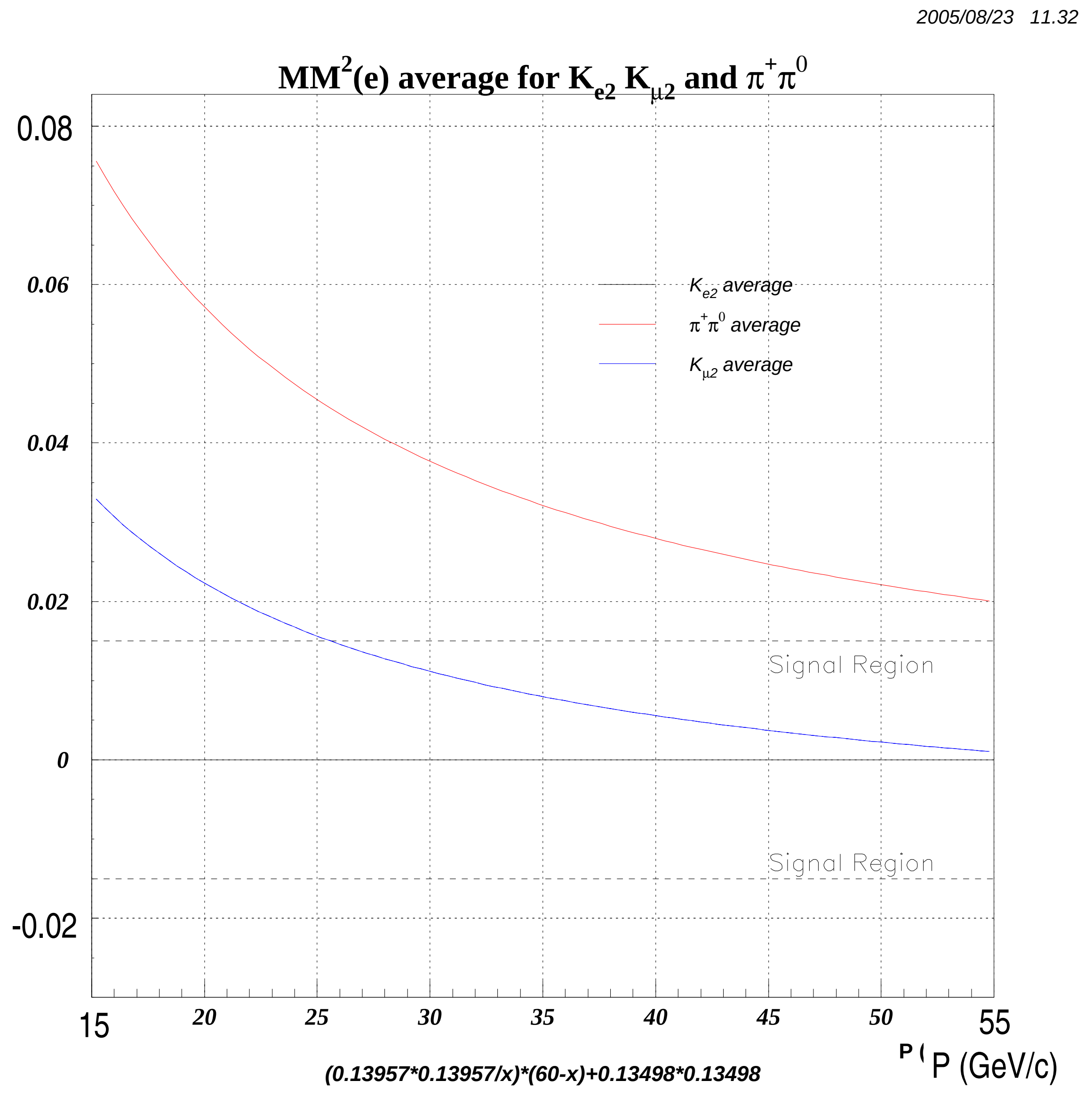
- Different selection cuts : better Trigger conditions allow a simpler selection with less systematics

- Analysis in momentum bins It leads to better background subtraction and allows to check for systematic dependences of the result as a function of the momentum.

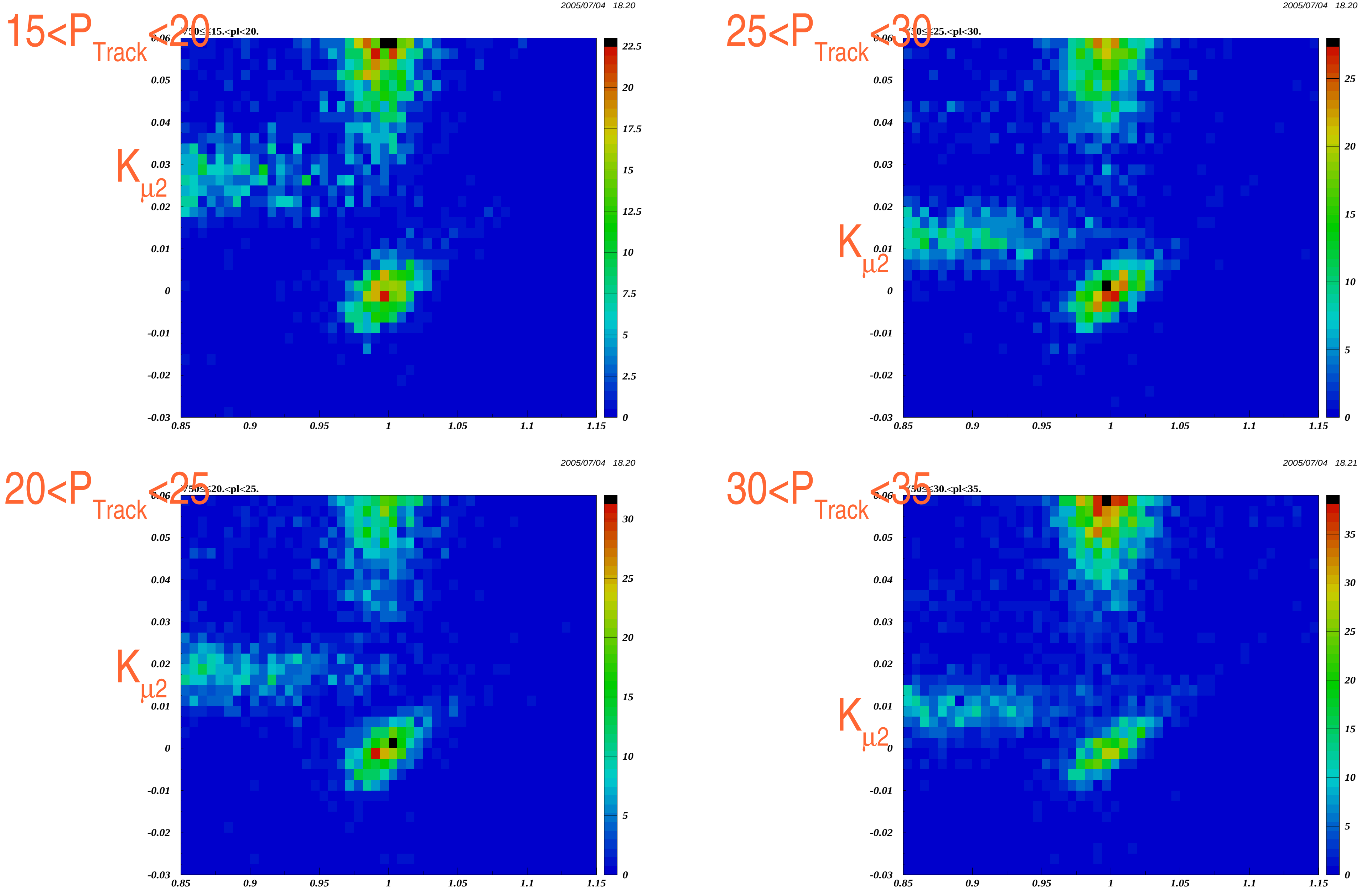
Background subtraction in momentum bins (MB2004)

Reconstructed $MM^2(e)$ of background events is systematically shifted towards higher values, because the mass term of the charged particle is neglected.

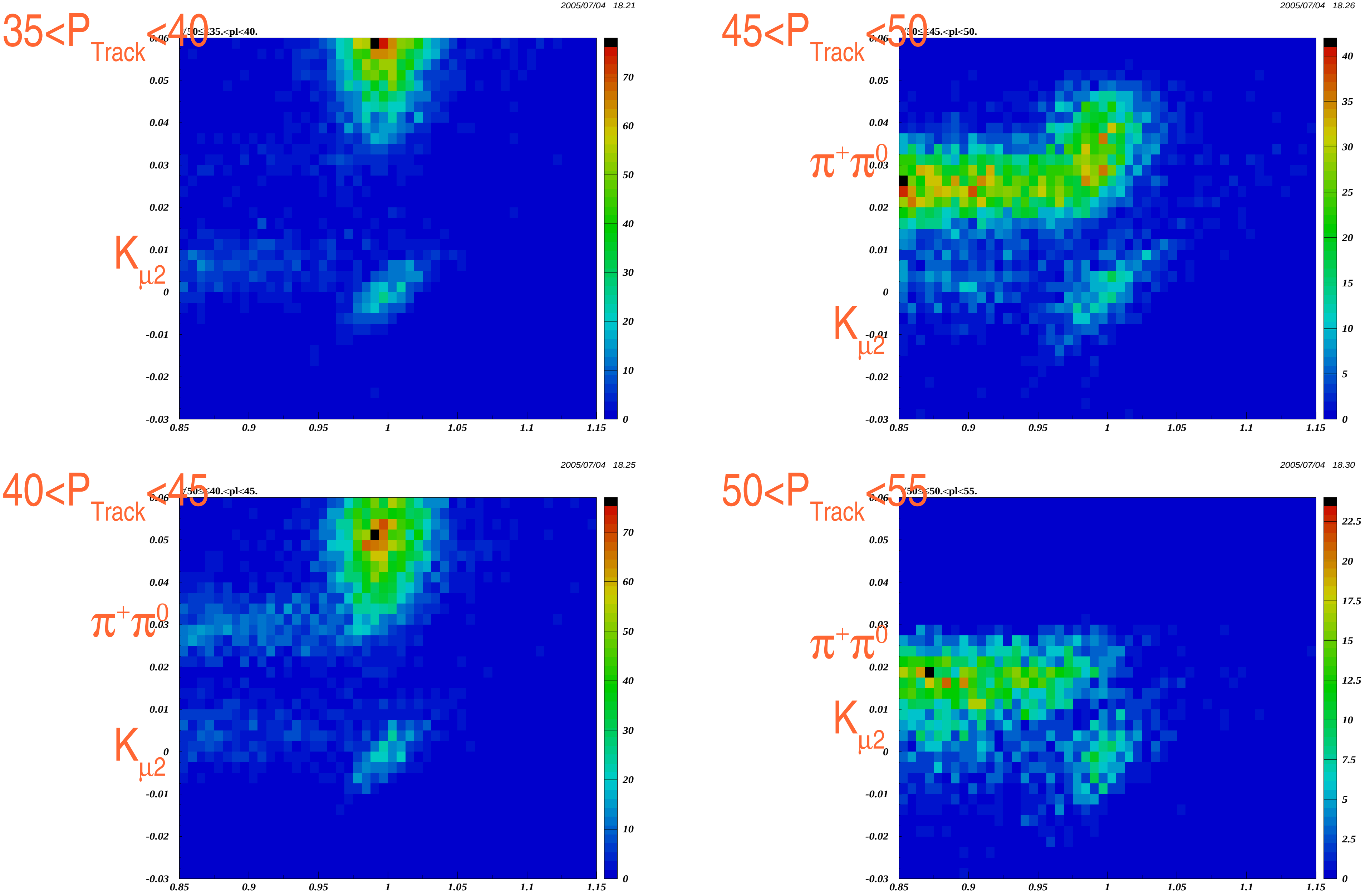
Better separation at low momentum than high momentum.



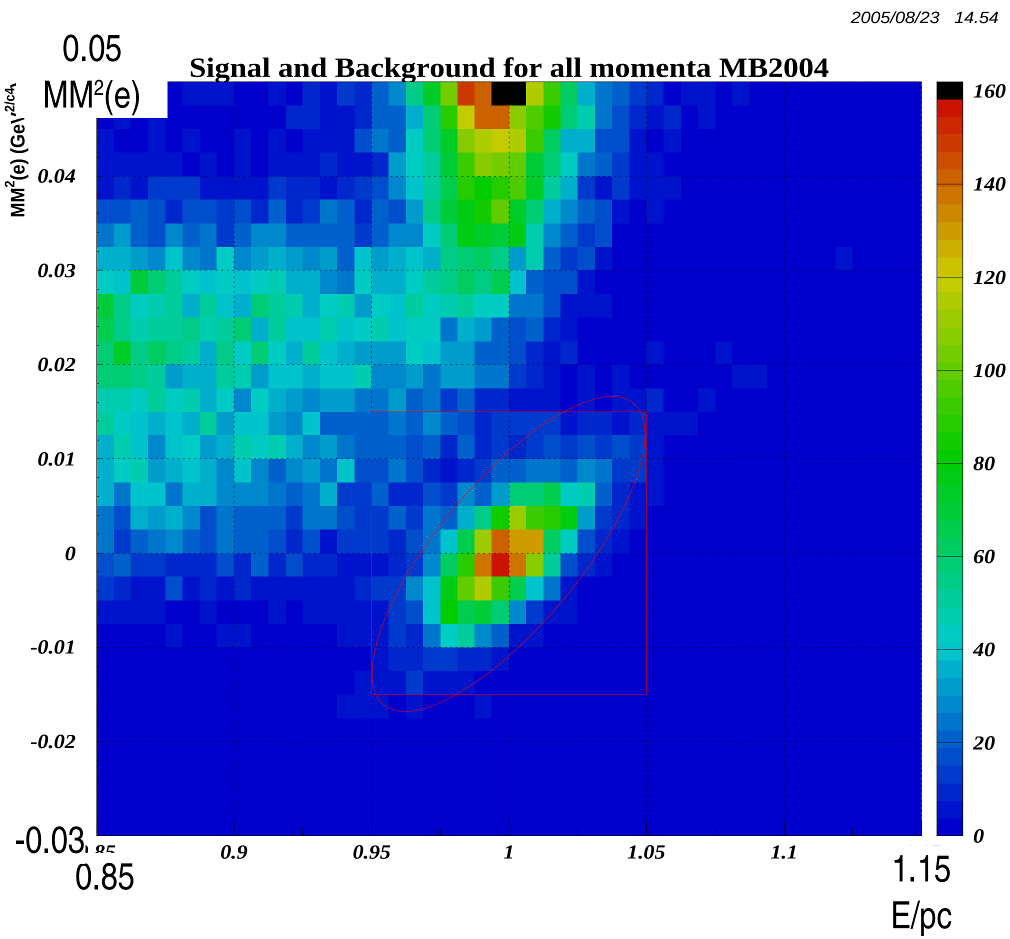
Background study in momentum bins (MB2004)



Background study in momentum bins (MB2004)



Background in momentum bins (MB2004)



$K_{\mu 2}$ is the main background, contributing in all momentum bins.

K_{e3} only contributes at low momentum, while $\pi^+\pi^0$ contributes at very high momentum only.

K_{e2} Background Subtraction: Results (MB2004)

Events in Signal Region

Mom (GeV/c)	Total	Background	**Difference**
15-20	510	4.7	**505.3**
20-25	606	33.6	**572.4**
25-30	684	100	**584**
30-35	715	136	**579**
35-40	674	136.3	**537.7**
40-45	650	144.3	**505.7**
45-50	610	153.3	**456.7**
50-55	484	209.9	**274.1**
All	4933	918.1	**4014.9**

Results and comparison

	$\frac{\Gamma(K \to e\nu(\gamma))}{\Gamma(K \to \mu\nu(\gamma))} \cdot 10^5$
SM prediction	**2.472 ± 0.001**
PDG value	**2.45 ± 0.11**
NA48/2 (2003)	**$2.416 \pm 0.043_{(stat)} \pm 0.024_{(syst)}$**
NA48/2 (2004)	*Analysis in progress*

- R_K measurement with 2003 statistics is already 2 times more precise than PDG world average. MB2004 Statistics is similar in size, with a better systematic error.
- 2003 + 2004 yield is NOT sufficient to measure accurately a possible

ΔR_K(LFV)~ 2-3%

Future Prospects

Present statistics is not sufficient to measure R_K with a precision better than 1% .

Could NA48/2 at CERN collect enough statistics to measure R_K with such precision, while keeping under control systematic effects?

Requirements:

- *Magnetic Spectrometer* composed by 4 drift chambers and a dipole magnet and equipped with a L2 trigger system;
- *Scintillator hodoscope* providing a fast L1 trigger for charged tracks;
- *Liquid Kripton Calorimeter* with L1 trigger system;
- *PC Farm* for filtering and Data recording;
- *SPS Beam Time.*

Beam Requests

Beam requests are compatible with both filling LHC and running CNGS

	2004 special run	Possible new run	
		Scenario I	Scenario II
	value	value (gain)	value (gain)
SPS duty cycle (s/s)	4.8/16.8	4.8/34.8 (0.48)	9.6/39.6 (0.84)
Eff.× no. of days	$\sim 0.9 \times 2.3 = 2.1$		
Eff. no of pulses	$1.08 \cdot 10^4$		
Protons per pulse	$2.5 \cdot 10^{11}$		
K12 beam: p (GeV/c)	± 60	± 75	
$d\sigma/d\Omega d(\Delta p/p)$		(~ 1.5)	
Acceptance (mr^2)	0.36×0.36	0.18×0.18 (0.25)	
$\Delta\Omega$ (sr)	$4 \cdot 10^{-7}$	$1 \cdot 10^{-7}$	
$\Delta p/p$ effective (%)	± 3	± 2.5 (0.83)	
RMS (%)	~ 3.0	~ 1.8 (0.83)	
TRIM3 x' (mr)	0	∓ 0.3	
p_T (MeV/c)	0	∓ 22.5	
MNP33 x' (mr)	± 2.0	± 3.5	
p_T (MeV/c)	± 120	± 263	
$K^{\pm}$ flux/pulse			
Good K_{e2}/pulse	~ 0.3		

Statistics Improvements

Conservative estimates in Scenario with beam conditions as in 2003 and 2004

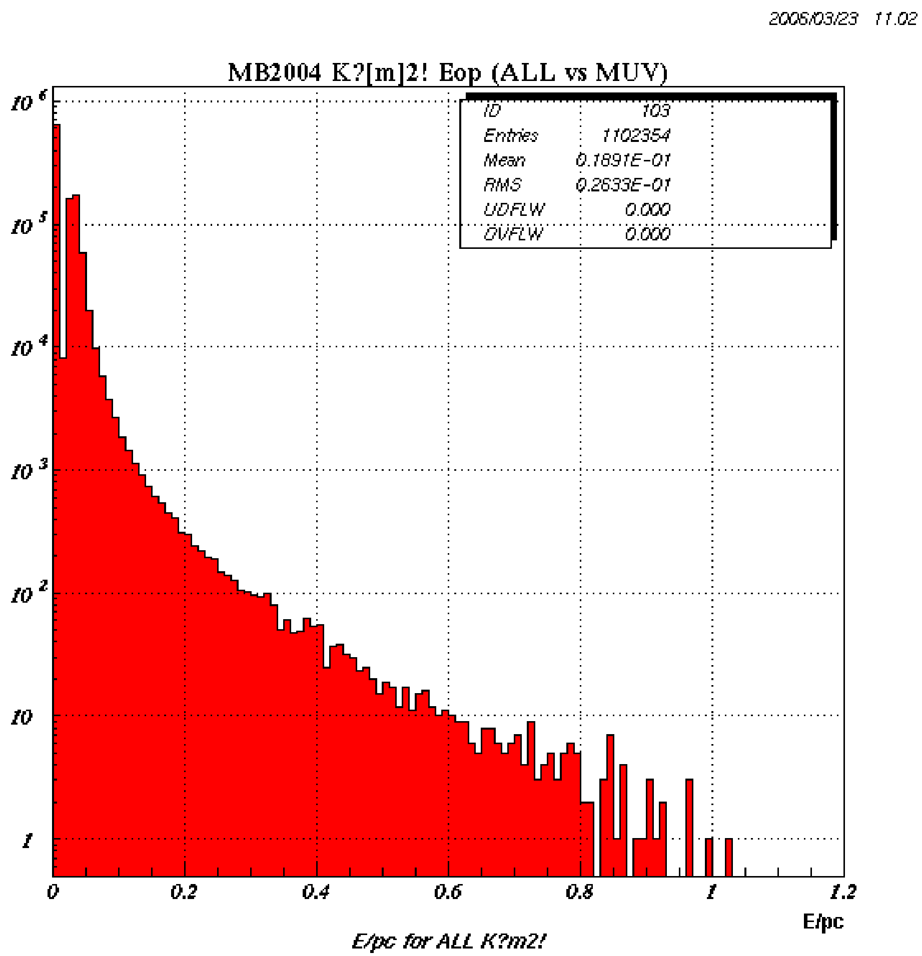
- Beam intensity ½ of 2003
- Same L1 AND L2 triggers as 2003
- Control Trigger (Q1 x E_{LKR}>10 GeV)/4
- Control Trigger (Q1)/100 used also to record $K_{\mu2}$

During a fully efficient run of 3 weeks, corresponding to ~90000 good K_{e2} events with a 25% background, the statistical uncertainty would be of **0.40%**

The statistical uncertainty on the trigger efficiency would be of **0.22%**

The overall statistical uncertainty would be **±0.46%**

Background control



K_{e2} main background is due to $K_{\mu2}$ with high E/p.

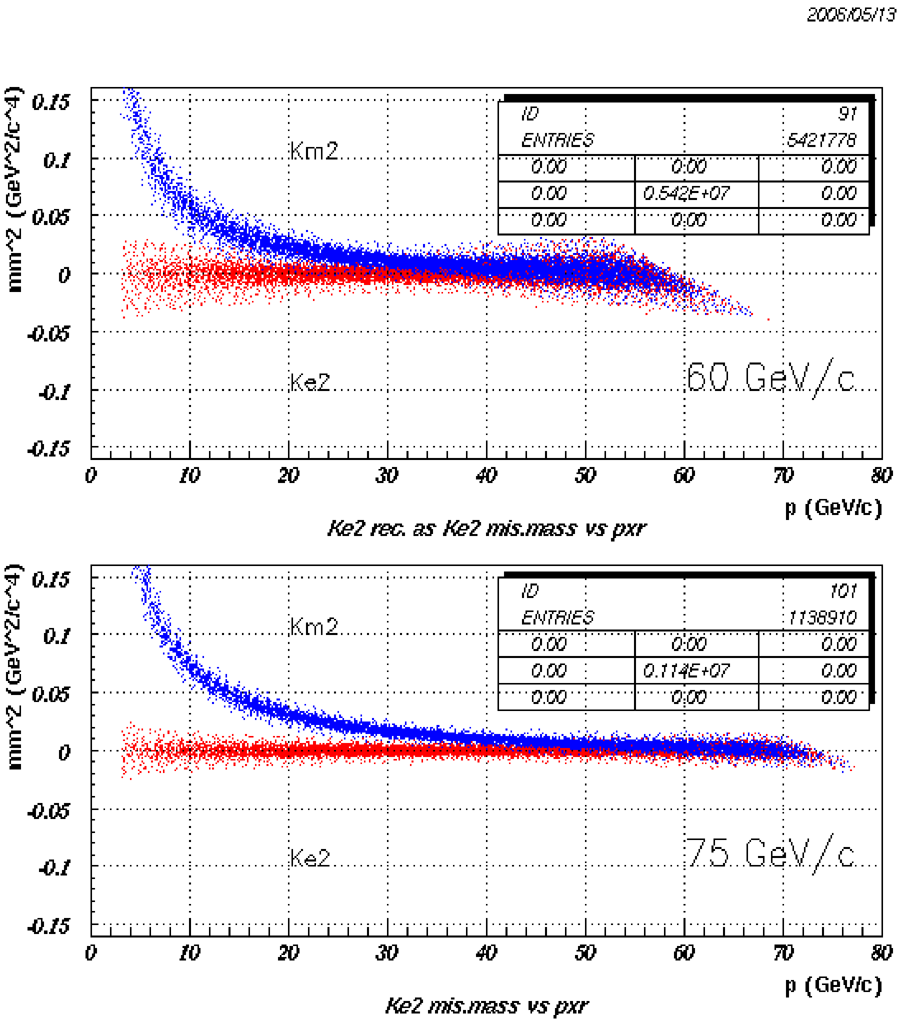
To study precisely these events it has been proposed to put a layer of Pb 5 cm thick in front of 9 vertical counters of th HOD.

The loss in statistics would be of 15% rising the statistical error to **0.49%**

The systematic error on the background subtraction will be <**0.43%**

Other systematics can be controlled to the level of **0.3%**

Other possible improvements



Lowering the beam momentum dispersion to 1.8%, while rising the beam average momentum to 75 GeV/c and the transverse kick momentum of the spectrometer to ~240 MeV/c will improve the Missing Mass resolution and K_{e2} - $K_{\mu 2}$ separation over the whole lepton momentum spectrum.

This will improve also the online trigger efficiency to 90% and lower the background contamination in the K_{e2} signal region.

Conclusions

- Using the whole statistics, NA48/2 is able to measure R_K with a precision of ~2% dominated by statistics uncertainty.
- A sub-percent precision measurement of R_K would be capable of probing New Physics or ruling out some region of the parameter space in realistic models.
- CERN and NA48/2 are the only laboratory and apparatus capable of such measurement in the near future.
- The collaboration is discussing practical issues for a dedicated run of **6 calendar weeks** (at 50% efficiency): it would yield a measurements of R_K with a precision of:

$$(0.49_{(stat)} \oplus 0.52_{(syst)})\% = 0.71\%$$

neglecting possible improvements on the beam (75 GeV/c with 1.8% RMS) and spectrometer resolution.