Search for physics beyond the Standard Model in NA48/2 and NA62 @ CERN

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on behalf of the NA48 and NA62 collaborations

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Outline

- Theory for K_{l2} decay and R_K (SM and beyond SM)
- NA48/NA62: detector and data taking periods
- Preliminary results from NA48/2 (2003-2004)
- NA62: status of the analysis on 2007 data
- Conclusions

The ratio R_K

R_K accurately predicted within the SM:

$$R_K = \frac{\Gamma\left(K^\pm \to e^\pm \nu_e\right)}{\Gamma\left(K^\pm \to \mu^\pm \nu_\mu\right)} = \frac{m_e^2}{m_\mu^2}\left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2}\right)^2 \left(1 + \delta R_{QED}\right) = \left(2.477 \pm 0.001\right) \cdot 10^{-5}$$

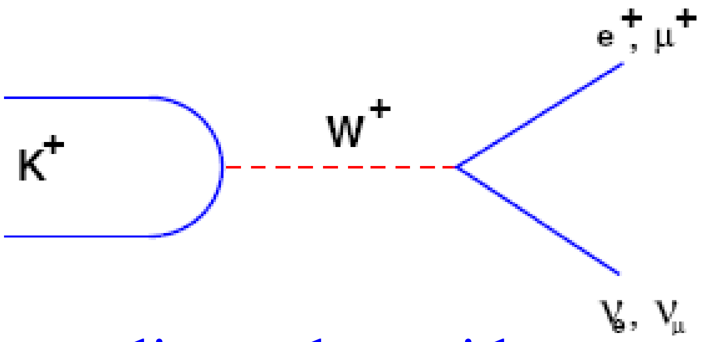
[V. Cirigliano and I Rosell, JHEP 0710:005 (2007)]

ChPT, $O(e^2p^4)$

Helicity suppression

Radiative corrections

Adronic contributions cancel in the ratio



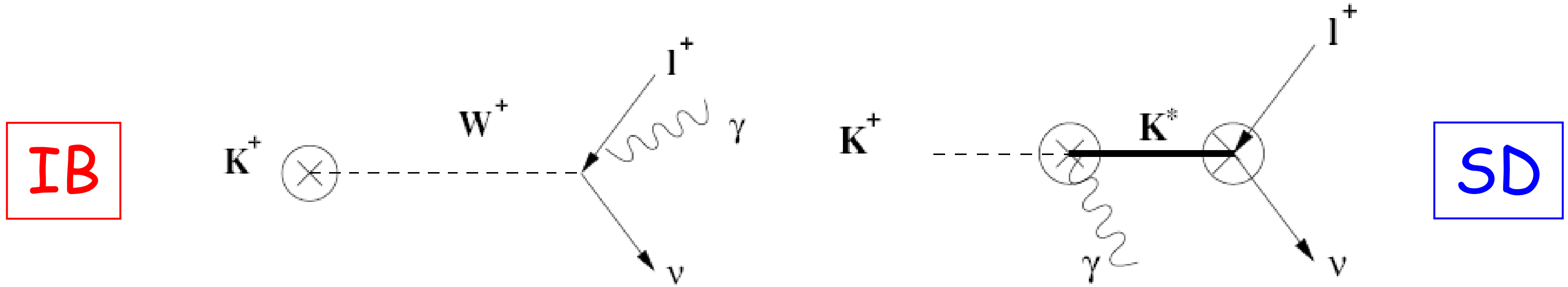
R_K is sensitive to New Physics due to the helicity suppression

A precise measurement of R_K probes μ–e universality and provides a stringent test of the SM.

$\delta R_K = -3.8\%$ compared to $\Delta R_K/R_K \sim 0.04\%$

($K_{\ell 2\gamma}$ and virtual photons)

Radiative corrections



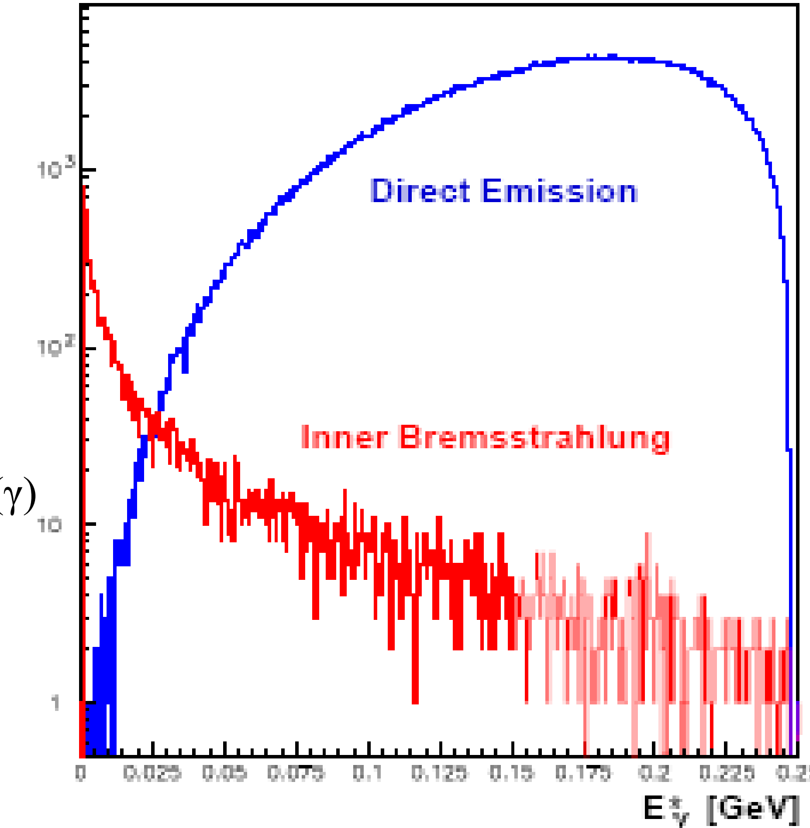
In the R_K computation of SM:

- Inner Bremsstrahlung (IB) contribution is included
- Structure dependent (SD) contribution is not

Experiments measure inclusive $K_{e2(\gamma)}/K_{\mu2(\gamma)}$ and then SD contribution is subtracted

(SD contribution negligible in $K_{\mu2}$, not in K_{e2})

Effects on the acceptance need also to be taken correctly into account

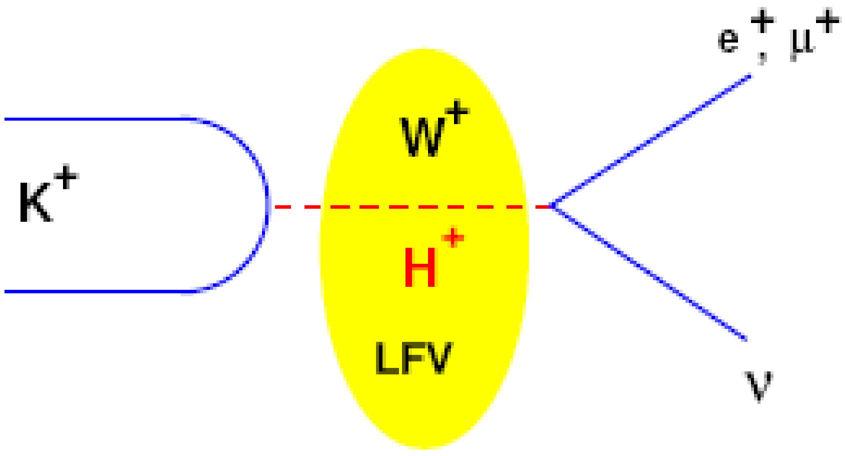


R_K beyond the SM

SUSY effects (MSSM framework) can modify R_K wrt SM up to 3%

(Masiero, P. Paradisi, R. Petronzio hep-ph/0511289 PRD74 (2006))

R-parity is the source of new physics effect on R_K



Yukawa LFV effective couplings:

$$lH^{\pm}\nu_{\tau} \rightarrow \frac{g_2}{\sqrt{2}} \frac{m_{\tau}}{M_W} \Delta_R^{3l} \tan^2\beta \qquad l = e, \mu$$

Δ^{31} is the LFV term connected to helicity suppression in Ke2

R_K in SUSY

The measurement of R_k produces limits to the value of $\Delta_{31}=\Delta_{31}(m_{H\pm},\tan\beta)$

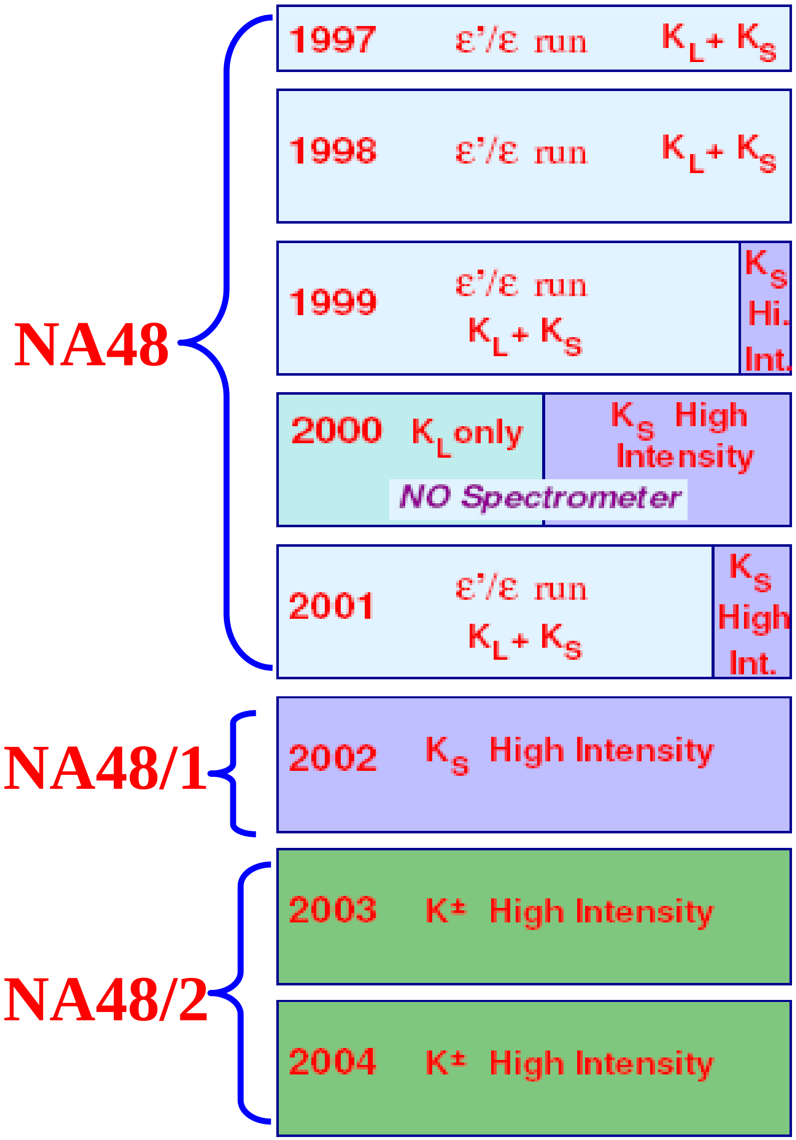
$$R_K^{LFV} \approx R_K^{SM}\left[1+\left(\frac{m_K^4}{m_{H^\pm}^4}\right)\left(\frac{m_\tau^2}{m_e^2}\right)\left|\Delta_{31}\right|^2\tan^6\beta\right]$$

- Loop diagrams mainly contribute
- LFC contributions $O((\tan\beta)^2)$ suppressed
- For large $\tan\beta$ values (still not experimentally excluded) LFV contributions $O(\tan\beta)^6$ dominate producing sizable effects on R_K
- Destructive interference between SM and SUSY LFC (arising from double LFV Mass Insertions) can give negative correction to R_K^{SM}

$\tan\beta=40$ e $M_H=500\ GeV/c^2$

$$R_K^{LFV} = R_K^{SM}(1 + 0.013)$$

NA48 and NA62



NA62 phase I

Dedicated 2007 run to measure:

$$R_K = \frac{\Gamma\left(K^\pm \to e^\pm \nu_e\right)}{\Gamma\left(K^\pm \to \mu^\pm \nu_\mu\right)}$$

NA62 phase II

measurement of the decay

$$K^+ \to \pi^+ \nu \bar{\nu}$$

(2008-2010 R&D
& construction
2011 start of data taking)

The NA48 detector

Magnet spectrometer (4 DCHs):

4 view: redundancy ⇒ efficiency

σ(p)/p =1.0% + 0.044% p [GeV/*c*]

Charged Hodoscope:

Fast trigger and good time resolution

(~200ps on single track)

E.m. calorimeter with Liquid Krypton (LKr):

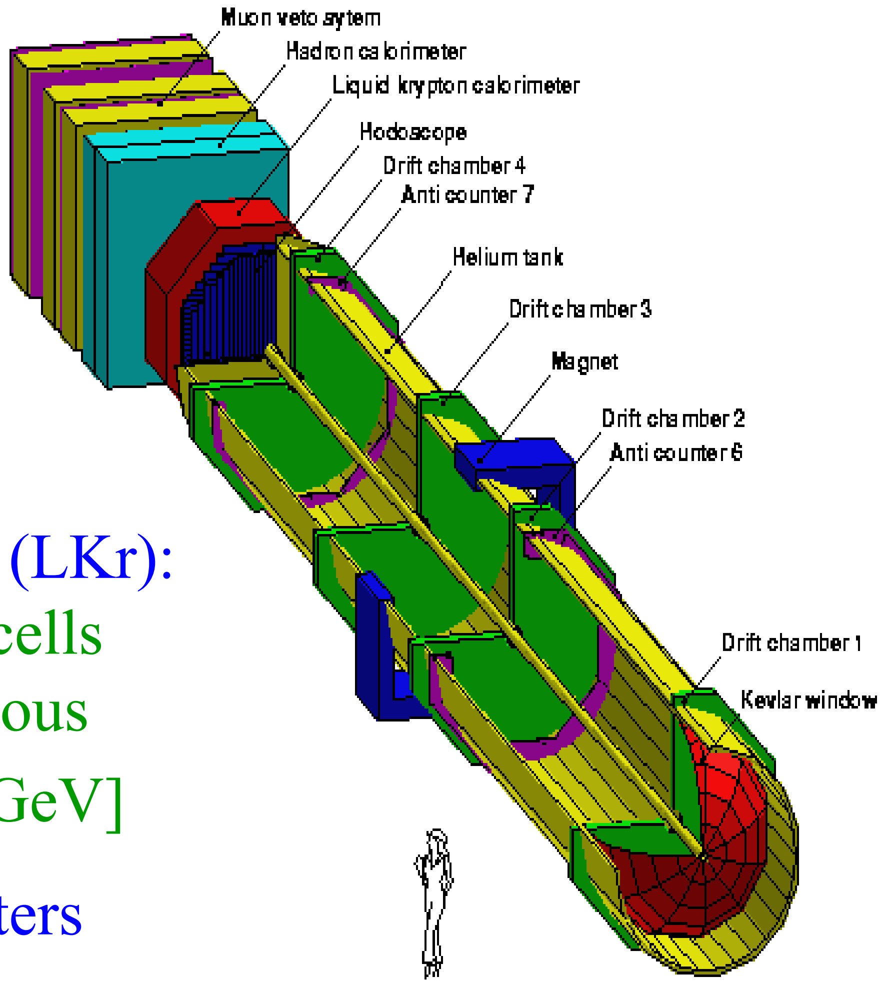
10 m^3 (~22 t), 1.25 m (27 X_0), 13212 cells

granularity:2x2 cm^2, quasi-homogeneous

σ(E)/E = 3.2%/√E + 9%/E + 0.42% [GeV]

Hadronic calorimeter, large veto counters

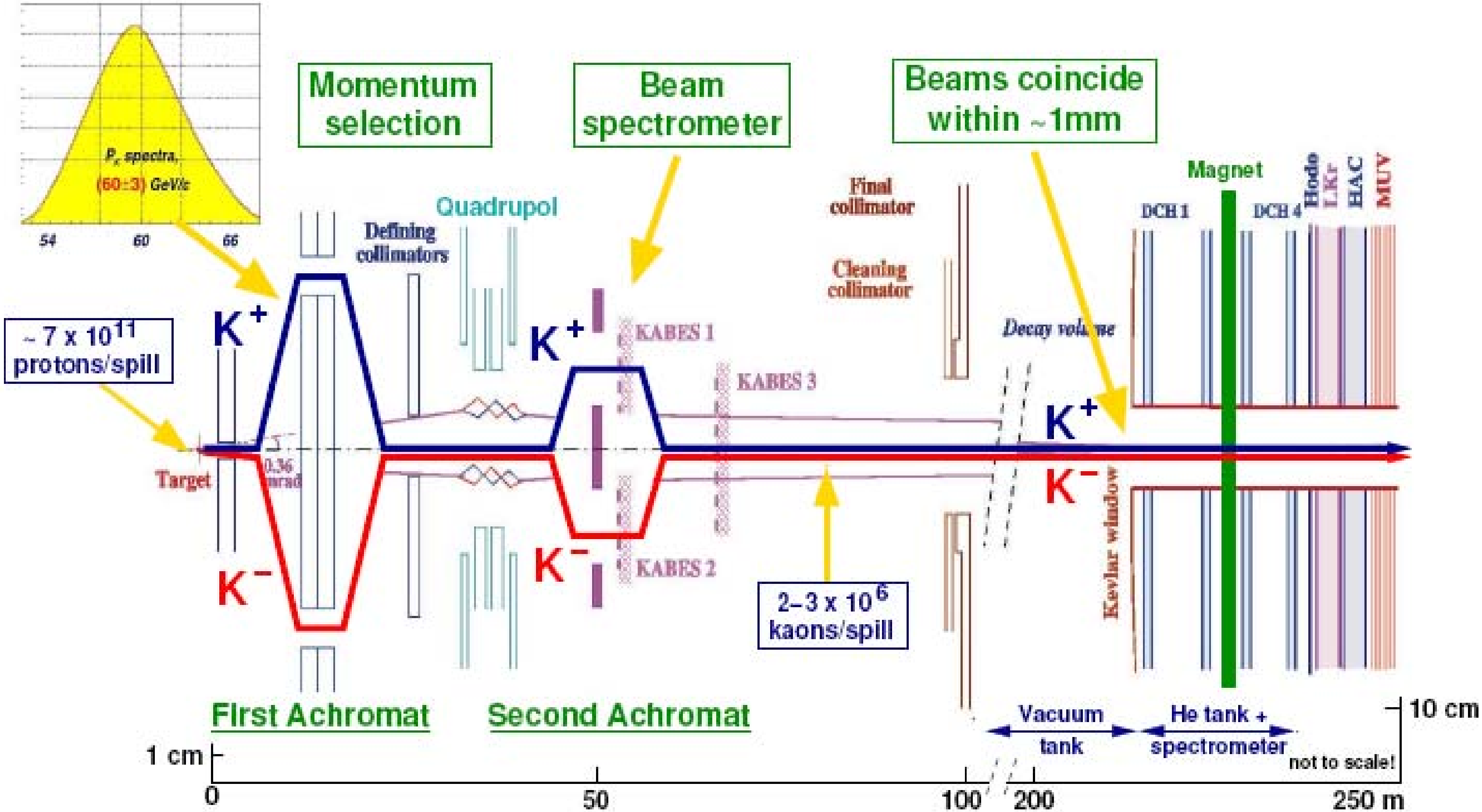
and muon veto counters



The simultaneus K^+/K^- beams

Designed to search for direct CP violation in $K^\pm \rightarrow 3\pi$

Quasi-collinear K^+ and K^- beams @ 60 GeV (K^+/K^- ~1.8)



Measurements of R_K from NA48/2

2003 run

1 month of data taking

trigger: 1 track + energy on LKr + online kinematics

3.4 K K_{e2} candidates collected

High systematic error coming from trigger inefficiency ~ 15 %

2004 run

56 hours of data taking

trigger: 1 track + energy on LKr

4.6 K K_{e2} candidates collected

Systematic error dominated by $K_{\mu 2}$ background to K_{e2}

Analysis strategy

$$R_K = \frac{N(K_{e2}) - N_{BG}(K_{e2})}{N(K_{\mu 2}) - N_{BG}(K_{\mu 2})} \cdot \frac{1}{D} \cdot \frac{Acc(K_{\mu 2}) \cdot \varepsilon_{TR}(K_{\mu 2}) \cdot \varepsilon_{PID}(K_{\mu 2})}{Acc(K_{e2}) \cdot \varepsilon_{TR}(K_{e2}) \cdot \varepsilon_{PID}(K_{e2})}$$

$N(K_{l2})$ = number of candidates evts

$N_{BG}(K_{l2})$ = number of background evts

$Acc(K_{l2})$ = geometrical acceptance (MC)

$\varepsilon_{TR}(K_{l2})$ = trigger efficiency

$\varepsilon_{PID}(K_{l2})$= selection efficiency (no MC!)

D = trigger downscaling

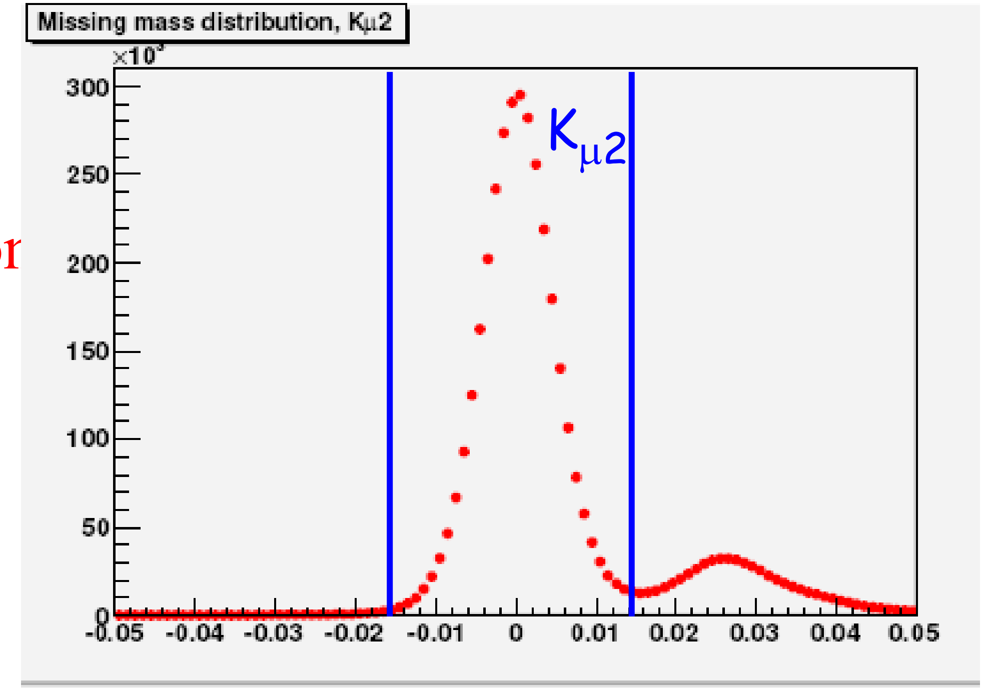
- K_{e2} and $K_{\mu 2}$ collected simultaneously

  ⇒ fluxes cancel in the ratio
- Many time-dependent systematic effects also cancel
- The main contribution to systematic error comes from background subtraction (stat. dependent)

Event selection

K_{e2} and $K_{\mu 2}$ decays similar → set of common cuts

- 1 track events
- $15 < p < 50$ GeV/c
- reconstructed decay vertex inside the fiducial decay region
- Geometrical acceptance



Particle ID (E/p):

- e ($E/p > 0.95$)
- μ ($E/p < 0.2$)

Kinematics:

- $M_{miss}^2 = (p_K - p_l)^2$, $-0.015 < M_{miss}^2 < 0.015$

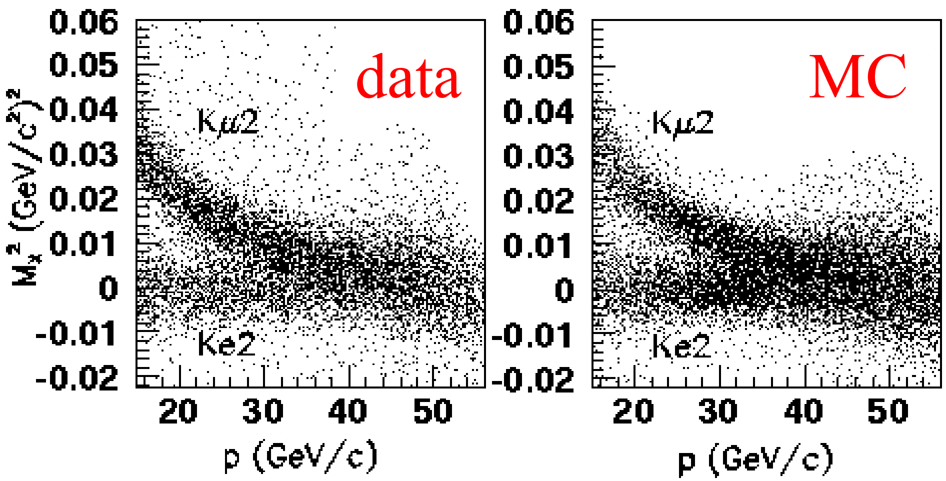
Background/1

The main systematics come from background subtraction

$K_{\mu 2}$ is the main source of background for K_{e2}

- The missing masses for K_{e2} and $K_{\mu 2}$ overlap at high momentum (>35GeV/c)
- The μ has a probability of ~4×10^{-6} to produce a catastrophic bremsstrahlung in the LKr and to be misidentified as an electron, giving an E/p bigger than 0.95

- Background from $K^{\pm}\to\pi^{0}e^{\pm}\nu$ evaluated with MC simulation



run 2003-2004

p_K = 60 GeV, p_{kick} = 120 MeV/c

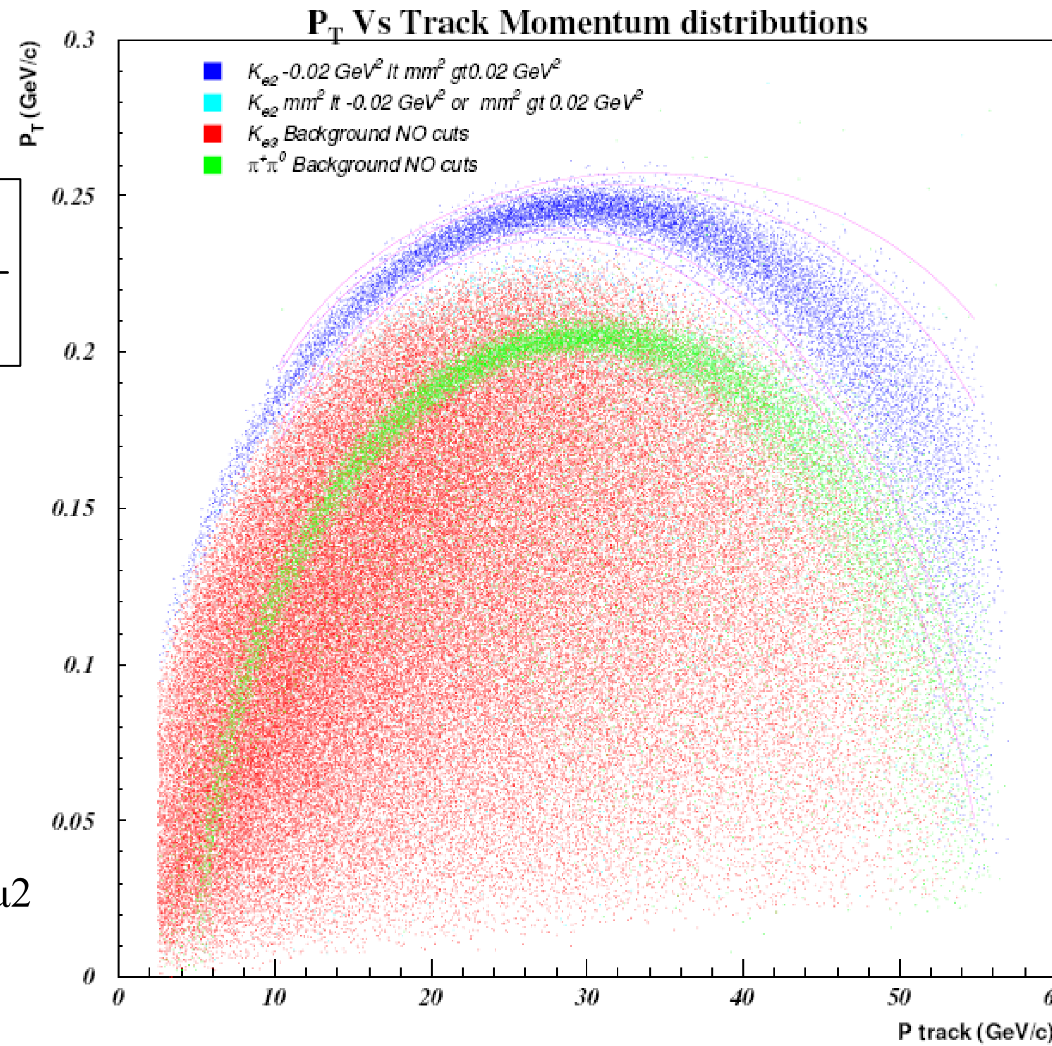
For $K_{\mu 2}$

- Background from $K^{\pm}\to\pi^{\pm}\pi^{0}$ negligible

Background/2

p_t, p_{track} and m_{miss}^2 related with an elliptic equation:

$$m_{miss}^2(e) \cong \frac{m_K^2}{p_K}(p_K - p_e) - p_K \frac{p_t^2}{p_e}$$



K_{e2} decays selected with a cut at 3 σ from the average

The same cut was applied to $K_{\mu 2}$

Results from 2003 and 2004

- Run 2003

final sample: $(4670 \pm 77_{stat})$ K_{e2} candidates

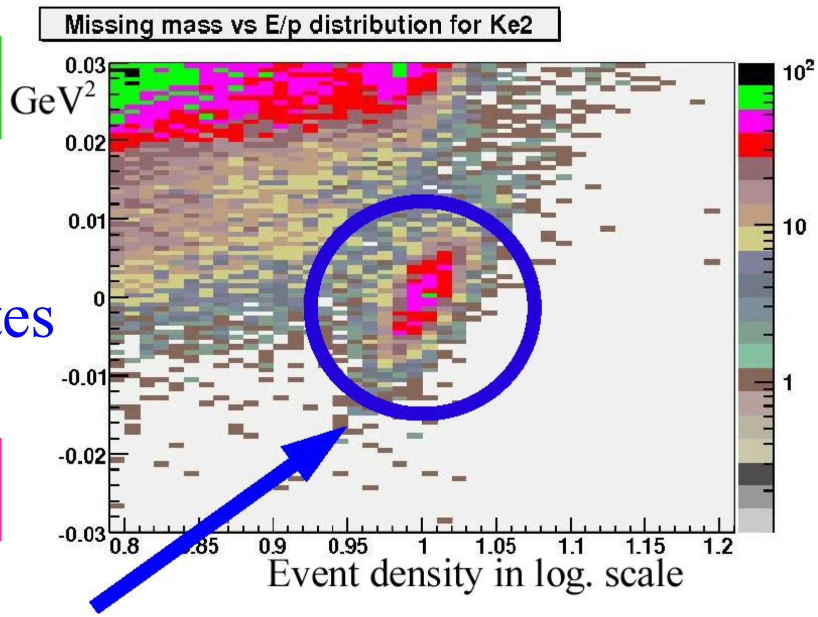
$$R_K = (2.416 \pm 0.043 \pm 0.024) \cdot 10^{-5}$$

- Run 2004

final sample: $(3407 \pm 63_{stat})$ K_{e2} candidates

$$R_K = (2.455 \pm 0.045 \pm 0.041) \cdot 10^{-5}$$

$\Delta R_K / R_K \sim 2\%$



preliminary

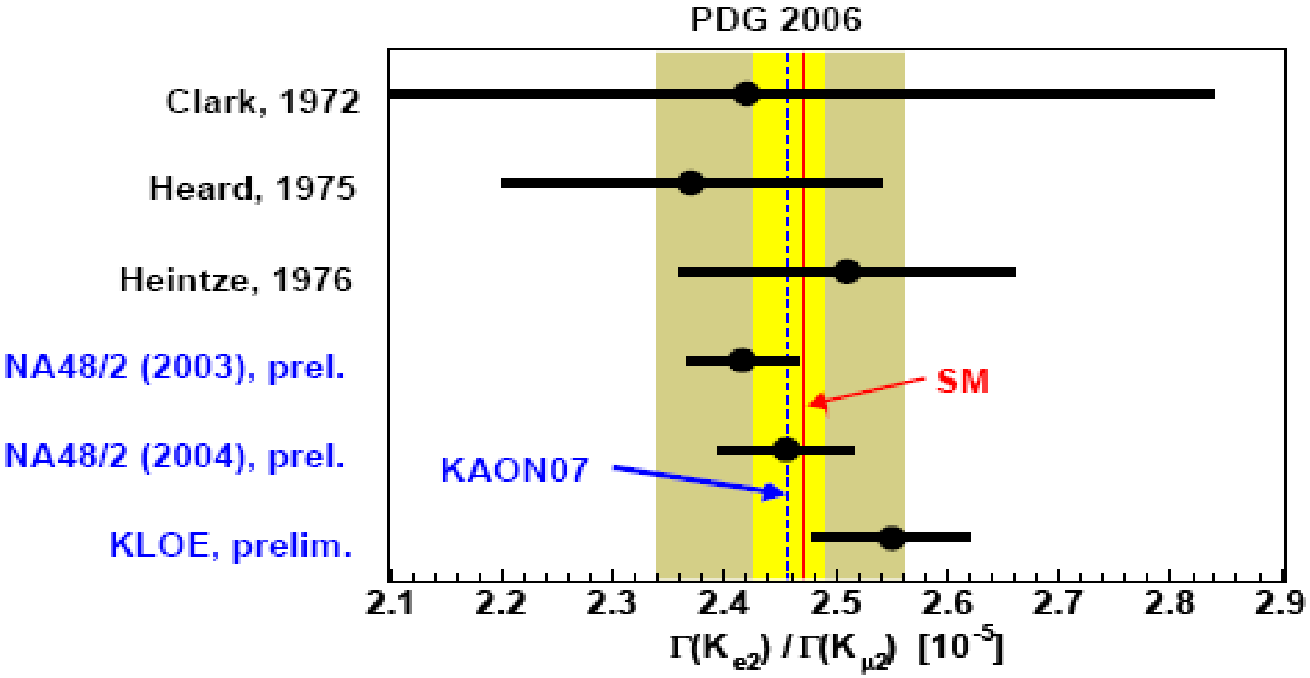
KLOE: $R_K = (2.55 \pm 0.05 \pm 0.05) \cdot 10^{-5}$

~ 8K events published in 2007, error 2.7%,target ~1% [arXiv:0707.4623]

Flavianet fit to R_K

Before NA48/2 and Kloe results → $R_K^{PDG} = (2.45 \pm 0.11) \cdot 10^{-5} \qquad \delta R_K / R_K = 4.5\%$

Flavianet fit to R_K combining PDG 2006, NA48/2 and KLOE results:



$$R_K = (2.457 \pm 0.032) \cdot 10^{-5} \qquad (\chi^2 / ndf = 2.44 / 3)$$

- ✓ Big improvement wrt PDG → now $\delta R_K/R_K \sim 1.3$ %
- ✓ Good agreement with SM prediction

Thinking to a new run

At the end of 2006 we started to think how to reduce the error on R_K with the existing NA48 set-up

- Minimum bias trigger (as it was in 2004)
- Then the main source of systematic becomes the $K_{\mu 2}$ background to the K_{e2} sample:
  - ➡ New beam parameters and new spectrometer configuration to improve the resolution on the missing mass
  - ➡ Direct measurement of the probability for a muon to be misidentified as an electron
- K^+ only beam for most of the data taking to reduce the background coming from beam halo from 20% to 1% (K_{e2} channel)

The new NA62 run

A new run to reduce the error on R_K from 2% to 0.5%

Proposal to the SPSC committee and to CERN Research Board on February 2007 → approved!

NA62 phase 1

(Phase II: measurement of the decay $K^+ \rightarrow \pi^+\nu\nu$)

4 months of data taking for the measurement
(+1 month for the test of prototypes for phase II)

Goal → to collect **$\sim 1 \times 10^5$ K_{e2} candidates**

The new analysis strategy

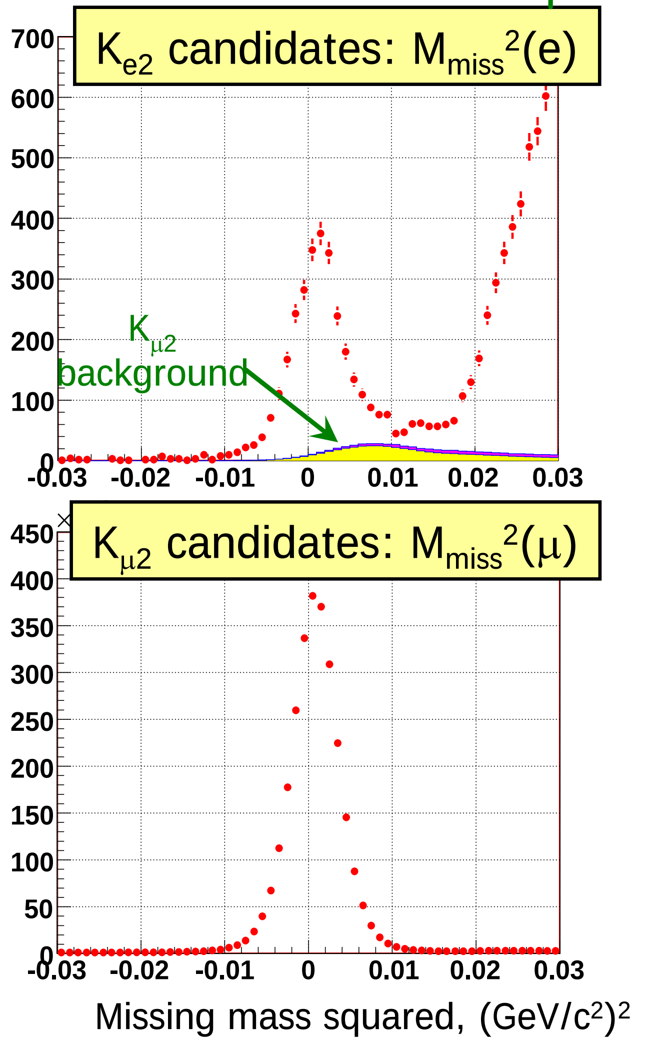
2007 analysis in many aspects similar to the 2003 and 2004 analyses

- K_{e2} and $K_{\mu 2}$ collected simultaneously
- MC used only for geometrical acceptance
- R_K measured in bins of track momentum

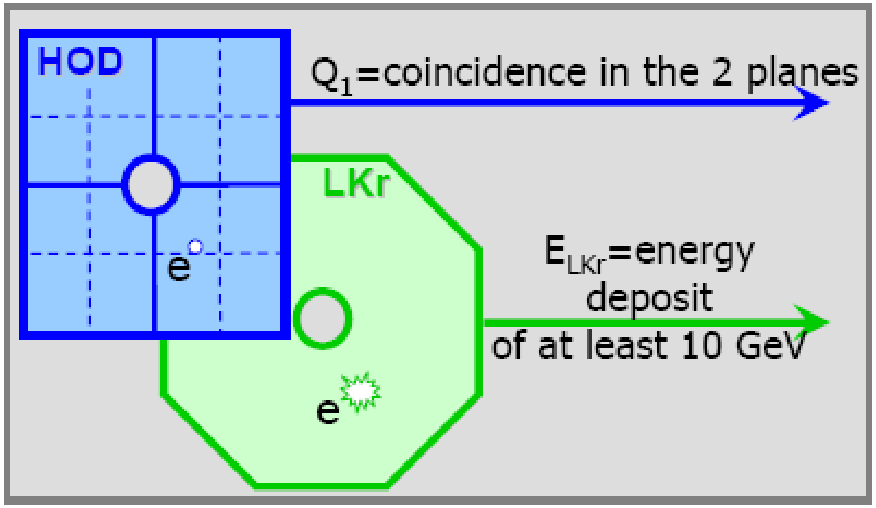
In each beam the following corrections will be applied to the raw ratio:

- Geometrical acceptance
- trigger efficiency
- Particle ID efficiency
- Background subtraction

Express analysis:
~3% of the 2007 K+ sample



Trigger



Many improvements during data taking to increase the number of K_{e2} collected:

1) Drift chambers multiplicity (1TRK)
2) Optimization of trigger downscaling
3) Beam steering
4) Removal of the lead wall

Trigger	Condition		Rates/SPS spill		Purity	
	Start-up	End-of-run	Start-up	End-of-run	Start-up	End-of-run
K_{e2}	$Q_1 \times E_{LKr}$	$Q_1 \times E_{LKr} \times 1TRK$	0.23	0.54	0.6×10^{-5}	1.3×10^{-5}
$K_{\mu 2}$	$Q_1/50$	$Q_1 \times 1TRK/150$	290	160	1.8%	1.8%

- The $K_{\mu 2}$ trigger also used as control trigger for K_{e2} trigger
- Other minimum bias control triggers included
- Small trigger inefficiencies (~0.1%) directly measured from data

$K_{\mu 2}$ background below 40 GeV/c

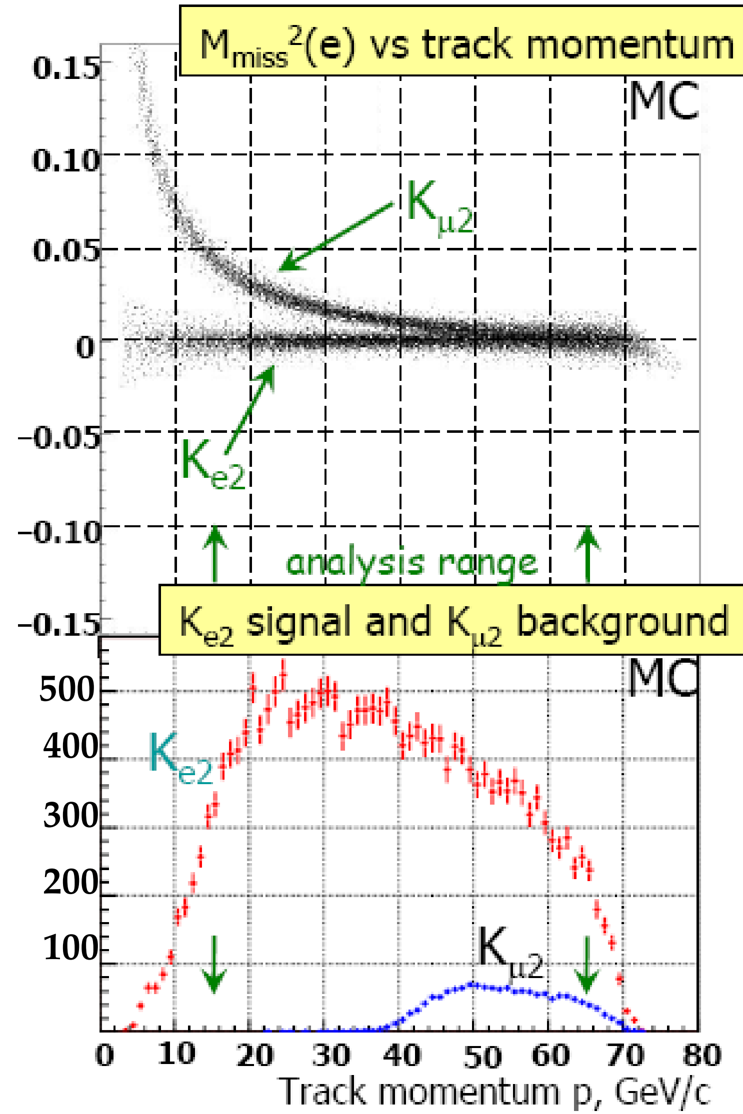
p < 40 GeV/c ~ 43% events

K_{l2} identified with M_{miss}^2 (assuming m_l)

$$M_{miss}^2\,(l) = (p_K - p_l)^2$$

In 2007 the resolution on M_{miss}^2 was improved in the following way:

- p_K → Kaon momentum:
  (60 ± 3) GeV/c → (75.0 ± 2.5) GeV/c
  2003-04 $\Delta p_K/p_K$ 3% vs 2% on 2007
- p_l → momentum kick of the magnet
  120 MeV/c → 263 MeV/c
  $\delta p/p = 0.47\% + 0.020p$ (p in GeV)



$K_{\mu 2}$ background above 40 GeV/c

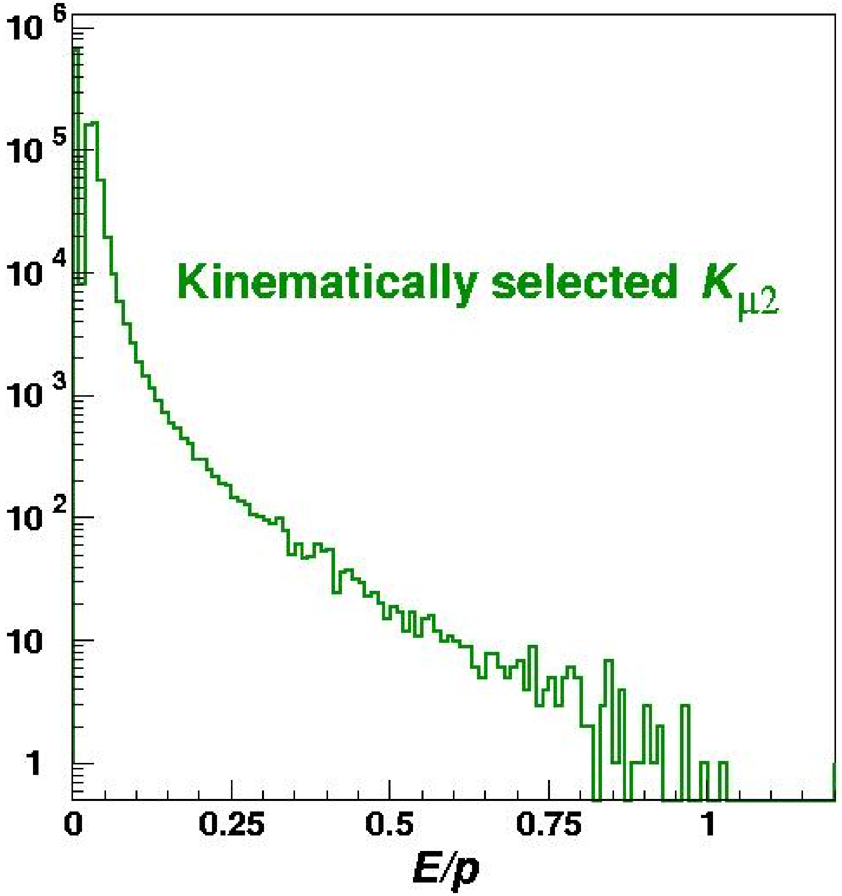
p > 40 GeV/c ~ 57% events

Electron identification relays on E/p:
$0.95 < E_{LKr}/p_{tr} < 1.05$

<u>But:</u>
A non-negligible fraction of muons has a catastrophic bremsstrahlung in the LKr

→ μ misidentified as electrons

$P(\mu \rightarrow e) \sim 4 10^{-6}$, depending from p (according to bremsstrahlung cross section)



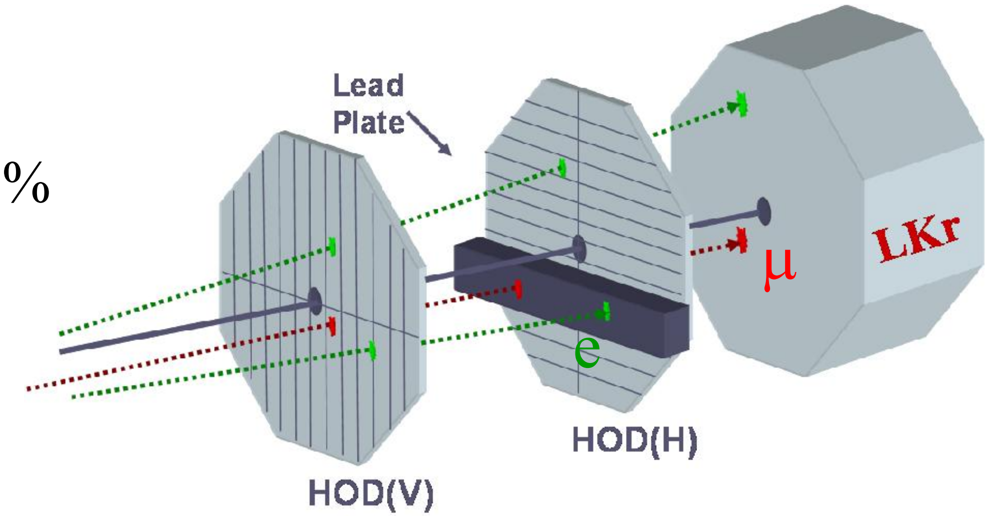
Measurement of P(μ→e)

Direct measurement

Lead wall placed in front of the LKr
(between the two planes of the charged hodoscope)

Track crossing the lead wall + 1 MIP in the hodoscope

Pure sample of μ



- The acceptance was reduced by 18%
- E/p distribution for muons can be measured in the desired momentum range

Samples collected:

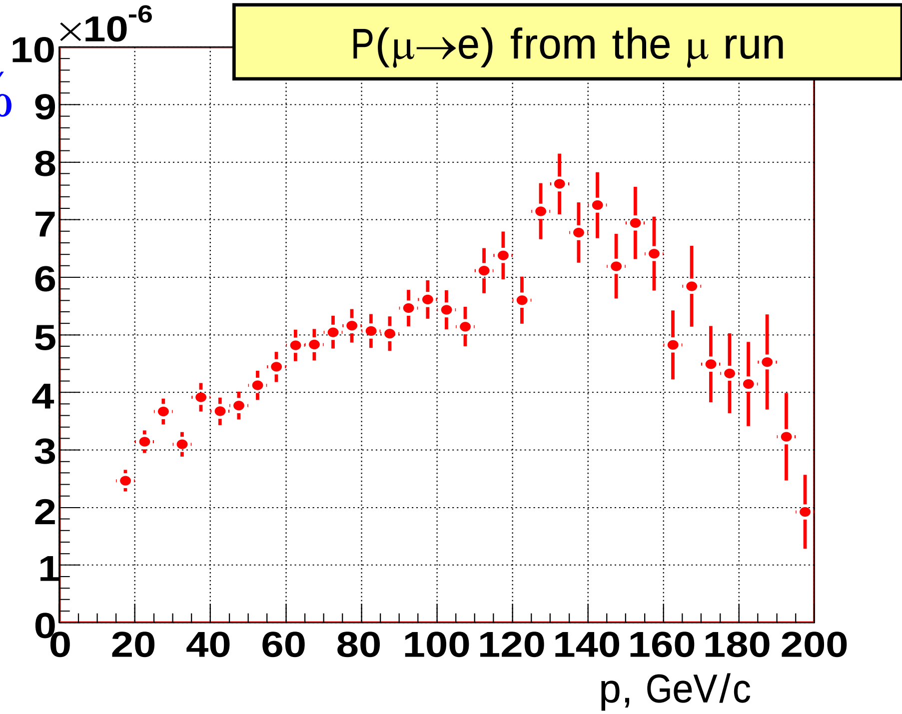
1) $K_{\mu 2}$ from standard data taking
2) Special runs with μ beam

- thickness: Pb(4.5 cm) + Fe (2.0 cm)= $9X_0$
- 18 cm high = 3 hodoscope counters

Background summary

sample K_{e2}

1) $K_{\mu 2}$: Evaluated with the direct measurement of P(m→e)
2) Beam halo: (1.3 ± 0.1)% estimated with K-less runs
3) $K_{e2\gamma}$ (SD): Evaluated from MC: (0.7 ± 0.1)%
4) K_{e3}: Evaluated with MC: < 1%
5) $K^+ \rightarrow \pi^+\pi^0$: Evaluated with MC: < 1%



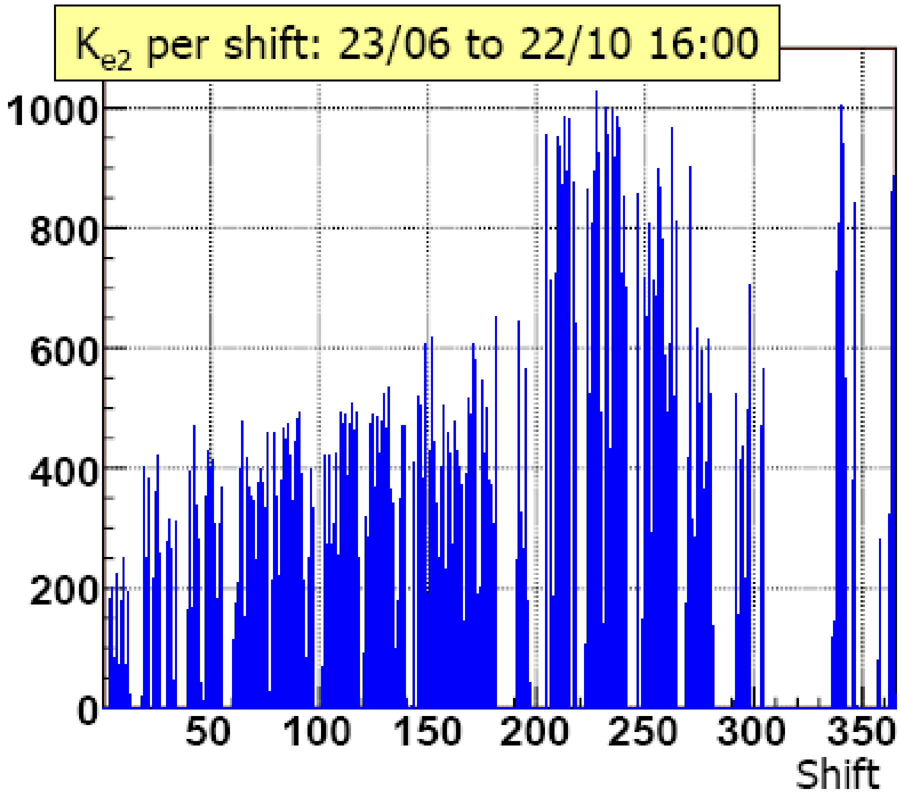
sample $K_{\mu 2}$

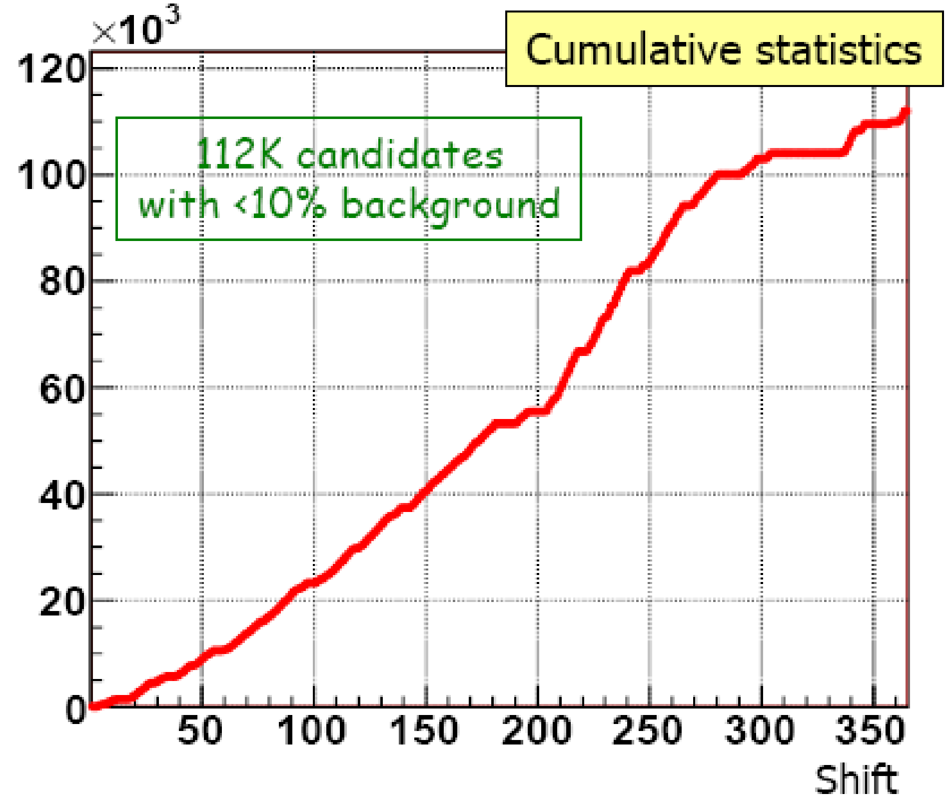
1) Beam halo ~ 0.1%
2) $K^+ \rightarrow \pi^+\pi^0$ < 0.5%

Data collected

Data taking period: from June, 23th to October,22th in 2007

112 K candidates selected, background < 10%



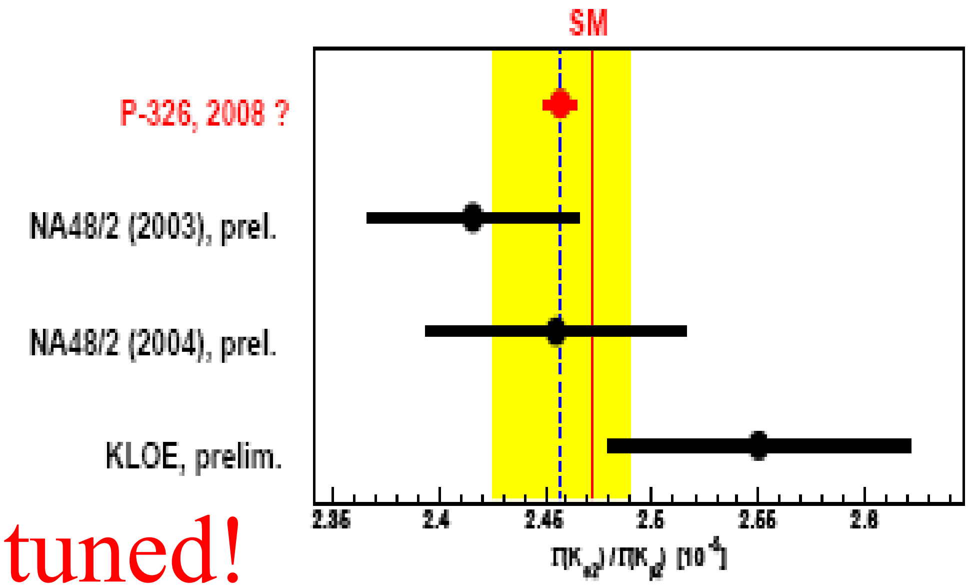


Statistical error on R_K ~ 0.3%, total error < 0.5 %

Conclusion

- K_{l2} decays represent a good opportunity to test the SM,
- In some SUSY framework, deviation from SM up to 3%
- 2003 e 2004 results from Na48/II has been shown
- During 2007 the NA62 experiment has collected more than 100 K K_{e2} candidates
- The status of the analysis going on on 2007 data has been shown
- Statistical error ~ 0.3%, total error on R_K < 0.5%

Unique opportunity to find New Physics or to strongly constrain SUSY models



Stay tuned!