NA48 Results

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On behalf of the NA48 collaboration

"XLIII Recontres de Moriond EW"

01 – 08 March 2008, La Thuile

Outline

- Measurements of BR($K_{l3}^{\pm}$)

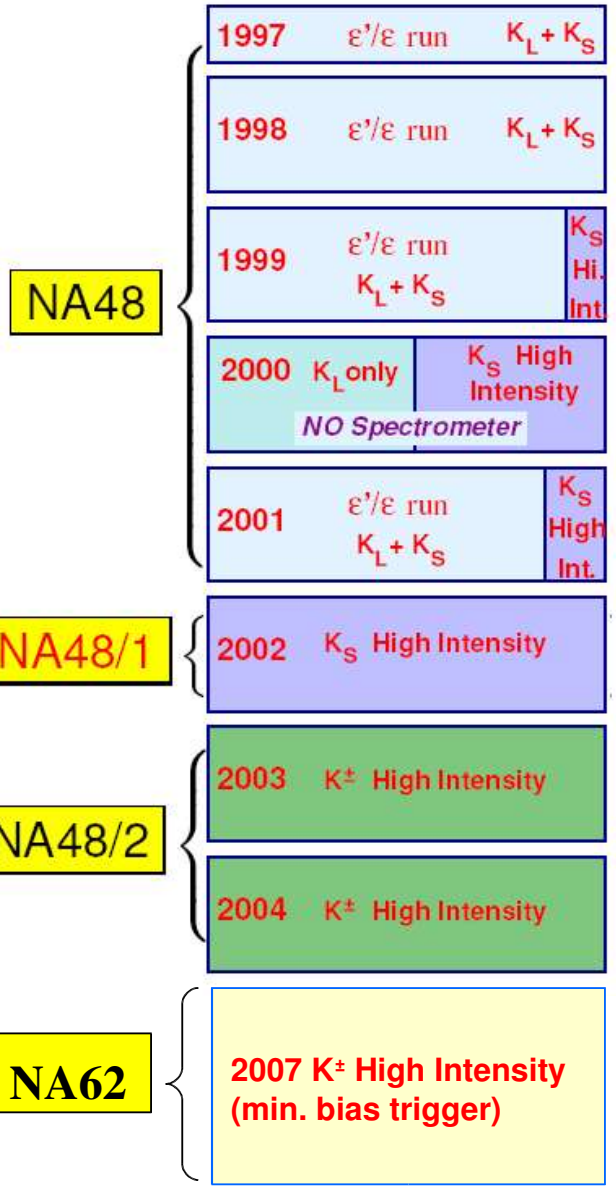
  [Notation: $K_{l3}^{\pm} = K^{\pm} \to l^{\pm} \pi^0 \nu_l$, $l = \mu, e$]

  - Extraction of V_{us}
  - Data analyzed: '03
    $K^{\pm}$ special run (final results)

- Measurement of $R_K \equiv \Gamma(K_{e2(\gamma)})/\Gamma(K_{\mu 2(\gamma)})$

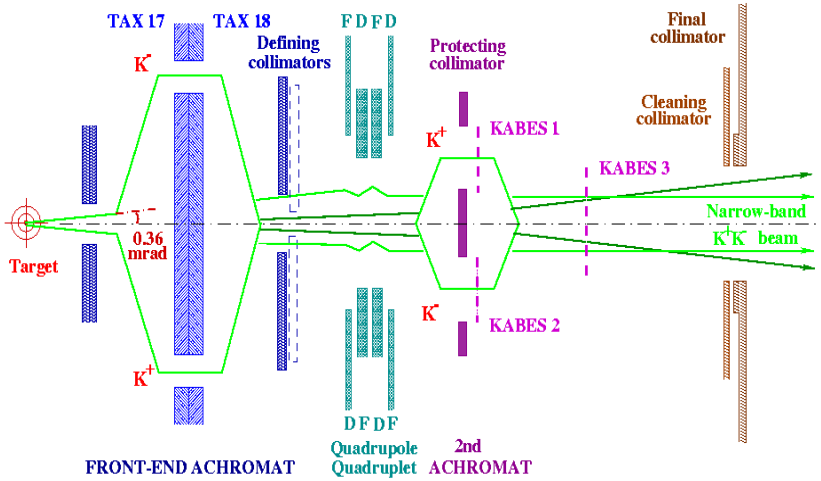
  [Notation: $K_{l2} = K^{\pm} \to l^{\pm} \nu_l$, $l = \mu, e$]

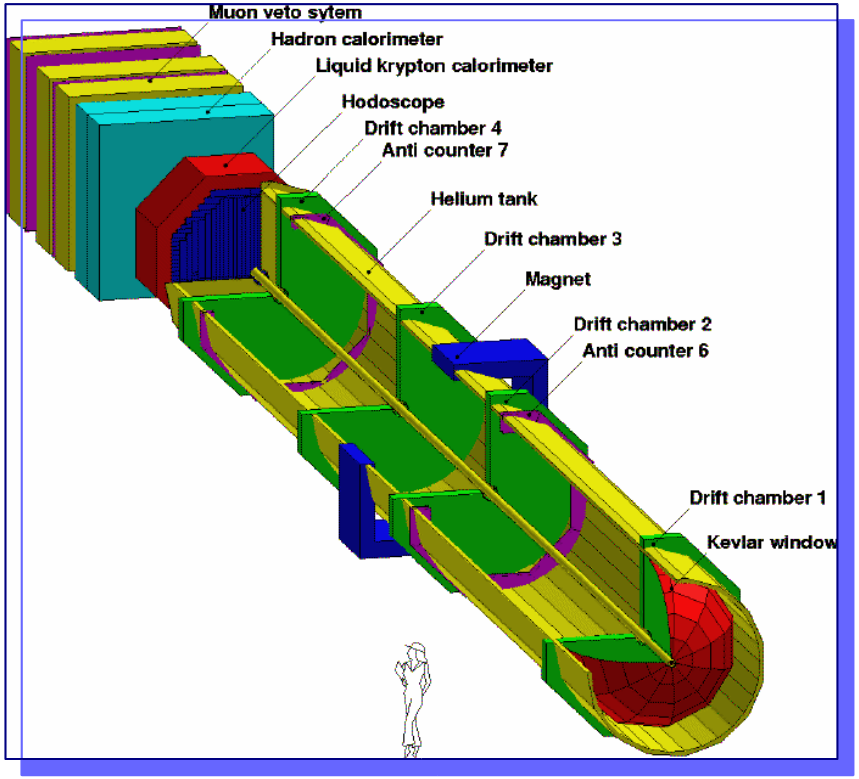
  - Precision test of $\mu - e$ universality
  - Data analyzed: '03
    $K^{\pm}$ run + '04 $K^{\pm}$ special run (preliminary results)
    NA62 '07 $K^{\pm}$ run (status of analysis)



NA48 Detector @ CERN SPS

- Simultaneus $K^{\pm}$ beams
  - P = 60±3 GeV/c (’03-’04), 75±2.5 GeV/c (‘07)





- Detector:
  - LKr: $\sigma(E)/E = 3.2\%/\sqrt{E} \oplus 90\ \mathrm{MeV}/E \oplus 0.42\%$
  - Spectrometer:
    - $\sigma(P)/P = 1.0\% \oplus 0.044\ P(\mathrm{GeV}/c)\%$ $[P_{kick} = 120\ \mathrm{MeV}/c]$ (’03-’04)
    - $\sigma(P)/P = 0.48\% \oplus 0.009\ P(\mathrm{GeV}/c)\%$ $[P_{kick} = 265\ \mathrm{MeV}/c]$ (‘07)
  - Hodoscope: trigger for charged particles and timing of the event ($\sigma_t = 200$ ps)
  - Muon detector: 25 cm wide scintillator strips ($\sigma_t = 350$ ps)

Theoretical aspects of K_{l3} decays

- Clean way to test us transitions

Phase space Integral: depends on the f.f.

This measurement — Extract

$$BR(K_{l3}) \propto \tau_K G_F^2 m_K^5 S_{EW} |V_{us}|^2 |f_+(0)|^2 I_K^l(\lambda_{+,0}) (1+\delta^K_{SU(2)}+\delta^{Kl}_{em})^2$$

Short distance corrections — f.f. @ t = 0 — Long distance corrections

  - Experimental inputs: $BR(K_{l3})$, τ_K, G_F, m_K, λ_{+0}
  - Theoretical inputs: S_{EW}, $|f_+(0)|^2$, $\delta^K_{SU(2)}$, δ^{Kl}_{em}

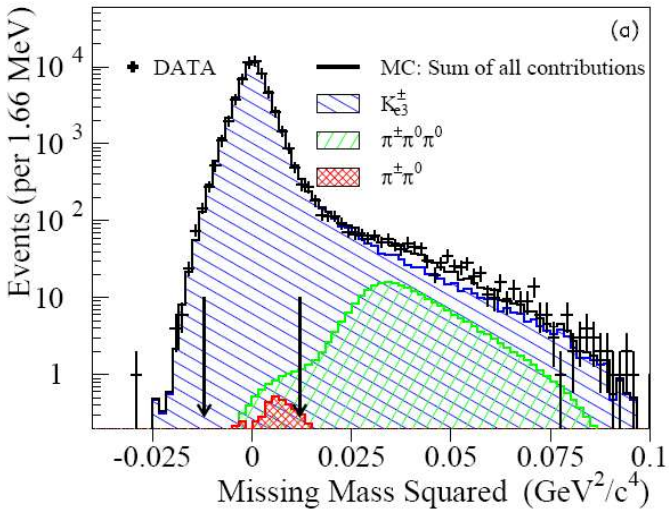
- μ-e universality test — $R_{K\mu 3/Ke3} \equiv \Gamma(K_{\mu 3})/\Gamma(K_{e3}) \propto [g_\mu f_+^\mu(0)/g_e f_+^e(0)]^2$

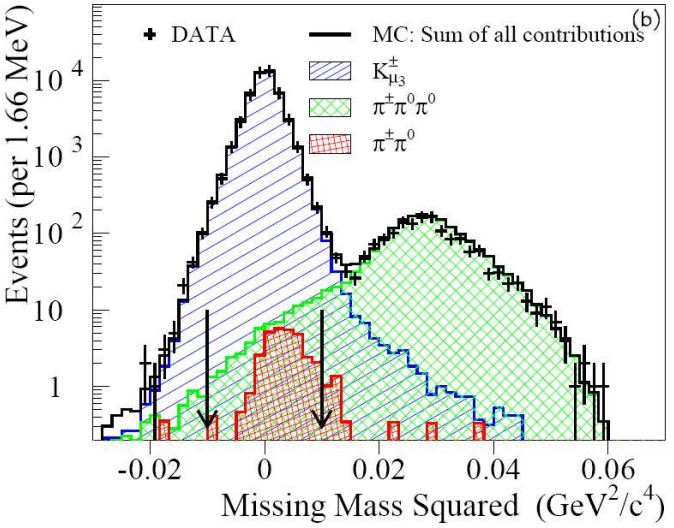
- Form factors consistency check — $R_{K\mu 3/Ke3}$ can be computed using the measured λ_+, λ_0

Analysis of K_{l3} decays

- Measured quantities:
  - $R_{Ke3/K2\pi} \equiv \Gamma(K_{e3})/\Gamma(K^{\pm}\to\pi^{\pm}\pi^{0})$
  - $R_{K\mu3/K2\pi} \equiv \Gamma(K_{\mu3})/\Gamma(K^{\pm}\to\pi^{\pm}\pi^{0})$
  - 1st order cancellation of systematics in ratios
- Data: 2003 special run
  - $P_K = 60 \pm 3$ GeV/c, $P_{kick} = 120$ MeV/c
  - Trigger: minimum bias (1 track topology)
- Selection:
  - Common 1 track selection and π^0 reconstruction (inclusive of radiative γ, $N_{cluster}>2$)
  - Kinematical separation $K_{l3} \div K^{\pm}\to\pi^{\pm}\pi^{0}$
  - Particle ID:
    - $e^{\pm}$: $E_{LKr}/P_{track} > 0.95$
    - μ: hit in muon detector
    - π: $E_{LKr}/P_{track} < 0.95$
- Statistics

K_{e3}	87K
$K_{\mu3}$	77K
$K^{\pm}\to\pi^{\pm}\pi^{0}$	729K





Analysis of K_{l3} decays (cont'd)

- Acceptance
  - Generation according to $\rho(E_l^*, E_\pi^*) \propto A f_+^2(t) + B f_+(t) f_-(t) + C f_-^2(t)$
    - $f_+(t)$ quadratic approximation: $\lambda'_+ = 0.02485 \pm 0.00163 \pm 0.00034$, $\lambda''_+ = 0.00192 \pm 0.00062 \pm 0.00071$ (PDG'06)
    - $f_0(t)$ linear approximation: $\lambda_0 = 0.0192 \pm 0.0012$ (μ-e universality) (PDG '06)
    - Other approximations considered: difference in final results quoted as systematic uncertainty
  - Radiative corrections
    - Daltz plot corrected using Ginsberg prescription *[Phys. Rev. D 1 (1970) 229]*
    - Real bremmstrahlung photons added using PHOTOS (important for K_{e3} only)
    - Checked with Monte Carlo of C. Gatti *[Eur. Phys. J. C 45 (2006) 417]*

- Corrections

	K_{e3}	$K_{\mu 3}$	$K^\pm \to \pi^\pm \pi^0$	
Acceptance	7.1%	9.3%	14.2%	⇨ *Monte Carlo*
$\varepsilon_{trackID}$	98.5 ÷ 99.5 %			⇨ *Data*
Background	<0.1%	0.2%	0.3%	⇨ *Monte Carlo*
$\varepsilon_{trigger}$	>99.8%			⇨ *Data*

Results on K_{l3} decays

[Eur. Phys. J. C50 (2007) 329 + erratum]

- Measured quantities

$R_{Ke3/K2\pi} = 0.2470 \pm 0.0009_{stat} \pm 0.0004_{syst}$

$R_{K\mu3/K2\pi} = 0.1636 \pm 0.0006_{stat} \pm 0.0003_{syst}$

$R_{K\mu3/Ke3} = 0.663 \pm 0.003_{stat} \pm 0.001_{syst}$

- Systematics:
  - Acceptance & radiative effects
  - Particle ID efficiency
  - Trigger efficiency
  - Form factors (input values and models)

- Assuming BR($K^{\pm}\to\pi^{\pm}\pi^0$) PDG'06:

$BR(Ke3) = (5.168 \pm 0.019_{stat} \pm 0.008_{syst} \pm 0.0030_{norm})\%$

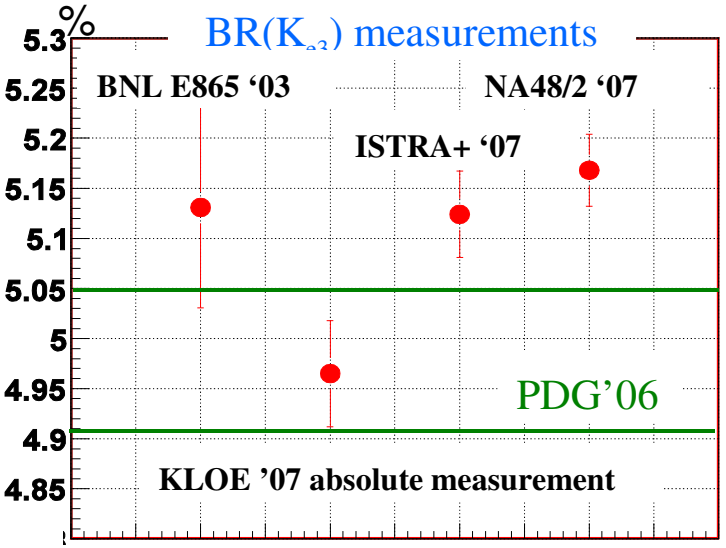
$BR(K\mu3) = (3.425 \pm 0.013_{stat} \pm 0.006_{syst} \pm 0.0020_{norm})\%$

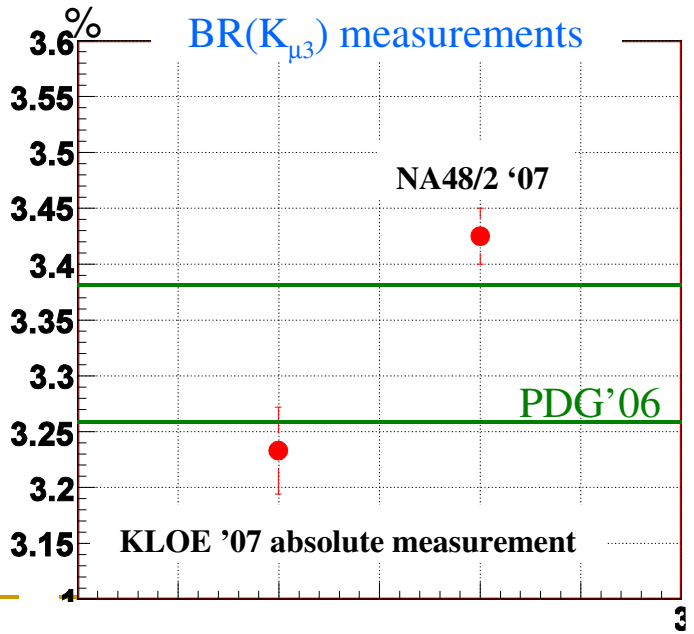
Both measurements above PDG '06

Comparison with KLOE suggests bias in BR($\pi^{\pm}\pi^0$) PDG '06…

PDG'06: BR($\pi^{\pm}\pi^0$) = 0.2092 ± 0.0012

KLOE (preliminary): BR($\pi^{\pm}\pi^0$) = 0.2066 ± 0.0011 *[arXiv:07072654]**





** See talk of Marianna Testa for details*

Discussion of the results on K_{l3} decays

- V_{us} extraction:

$|V_{us}|f_+(0) = 0.2193 \pm 0.0012$ (K_{e3}) ,0.2177 ± 0.0013 ($K_{\mu 3}$)

$|V_{us}|f_+(0) = 0.2188 \pm 0.0012$ (combined)

Values used for $|V_{us}|$ extraction

$S_{ew} = 1.023 \pm 0.0003$ *[Nucl. Phys. B196(1982) 83]*

$I_K^e = 0.1591 \pm 0.0012$ (λ'_+, λ''_+ as in slide 6)

$I_K^\mu = 0.1066 \pm 0.0008$ (λ_0 as in slide 6)

$\delta^K_{SU(2)} = (2.31 \pm 0.22)\%$ } *Eur. Phys. J. C35 (2004) 53, 23 (2002) 121*, *Phys. Rev. D1 (1970) 229*, *CKM 2005 arXiv:hep-ph/0512039*

$\delta^{Ke}_{em} = (0.03 \pm 0.10)\%$

$\delta^{K\mu}_{em} = (0.20 \pm 0.20)\%$

$G_F = (1.16637 \pm 0.00001) \times 10^{-5}$ GeV^{-2} *[Phys. Rev. D70 (2004)]*

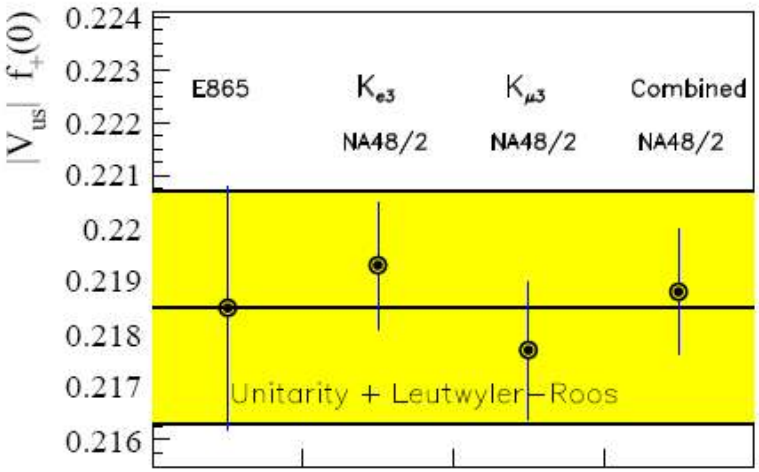
m_K, τ_{K+}, from PDG '06

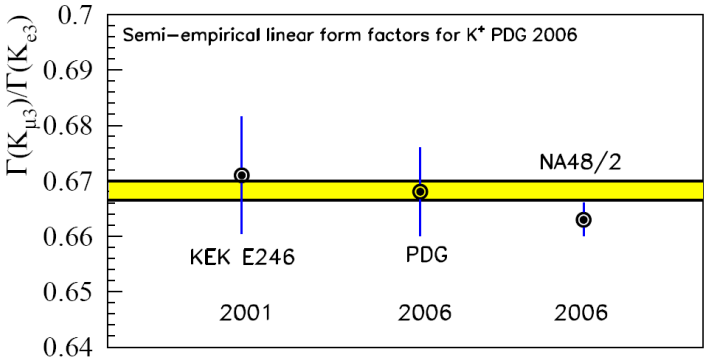
Values used for Vus prediction

~~Unitarity + $|V_{ud}| = 0.9738 \pm 0.0003$ [Phys. Rev. Lett. 96 (2006)]~~

$|V_{ub}| = (3.6 \pm 0.7) \times 10^{-3}$ PDG '06

$f_+(0) = 0.961 \pm 0.008$ *[Z. Phys. C25 (1984) 91]*





- $R_{K\mu 3/Ke3}$ in agreement with measured PDG '06 $\lambda_{+,0}$

- $R_{K\mu 3/Ke3}$ μ – e universality test: $g_\mu f_+^\mu(0)/g_e f_+^e(0) = 0.99 \pm 0.01$

Theoretical aspects of K_{l2} decays

- $R_K \equiv \Gamma(K_{e2(\gamma)})/\Gamma(K_{\mu 2(\gamma)})$ very accurately predicted within the SM *[arXiv:0707.4454]*

$$R_K = \frac{m_e^2}{m_\mu^2}\left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2}\right)^2 (1+\delta R_{QED}) = (2.477 \pm 0.001)\times 10^{-5}$$

  - δR_{QED} = -3.6% due to radiative $K_{l2\gamma}$(IB) and virtual photon processes.

- R_K sensitive to new physics thanks to the helicity suppression
  - Possible deviation up to % level in SUSY model with lepton flavour violation

$$R_K^{LFV} \approx R_K^{SM}\left[1+\left(\frac{m_K}{M_{H\pm}}\right)^4\left(\frac{m_\tau}{M_e}\right)^2 |\Delta_{13}|^2 \tan^6\beta\right]$$

[Phys. Rev. D74 (2006) 011701]

  - No contradiction with present experimental constraints

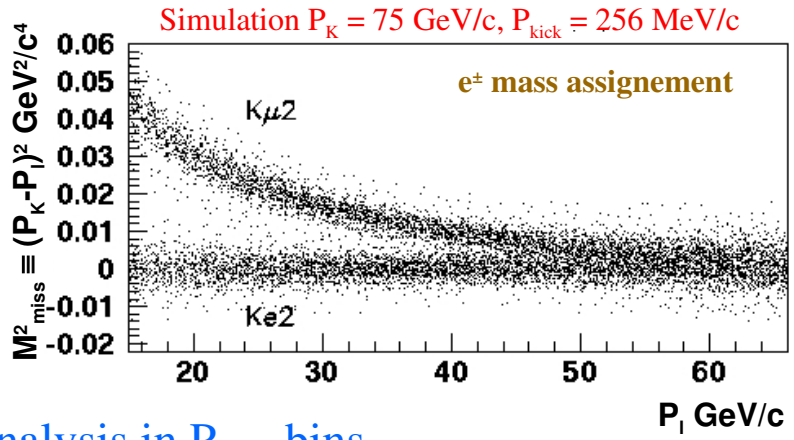
Measurements of R_K

- Measurements of R_K using data from 2003, 2004 and 2007 runs

- 2003 data (preliminary result → 2% level accuracy) :
  - 1 month of data taking, $P_K = 60 \pm 3$ GeV/c, $P_{kick} = 120$ MeV/c
  - Downscaled trigger for K_{e2}: 1 track topology + energy in LKr + L2 kinematical cuts
  - Statistics collected ~4K (K_{e2})
- 2004 data (preliminary result → 2% level accuracy) :
  - 56 hours special run with reduced beam intensity, $P_K = 60 \pm 3$ GeV/c, $P_{kick} = 120$ MeV/c
  - Almost minimum bias trigger for K_{e2}: 1 track topology + energy in LKr
  - Statistics collected ~4K (K_{e2})

- 2007 data (status of the analysis → goal: 0.5% level accuracy) :
  - Dedicated 4 month run from end june to october 2007.
  - New name of the experiment (new physics project): NA62.

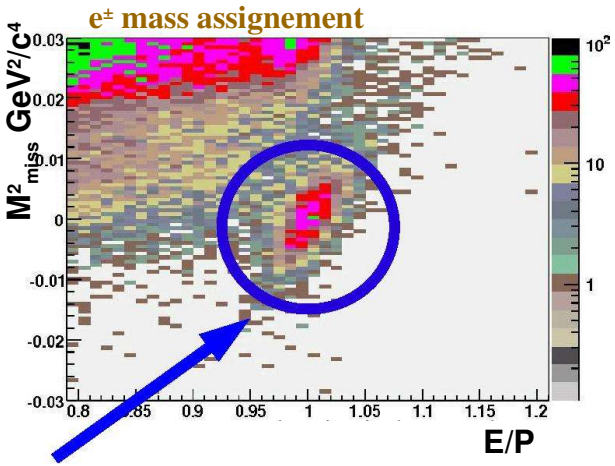
Analysis Strategy



- Selection:
  - 1 track and 2-body kinematics.
  - K_{e2}-$K_{\mu 2}$ kinematical separation
  - Particle ID: K_{e2}:E/P>0.95, $K_{\mu 2}$:E/P<0.2
- 1st order cancellation of systematics in ratio. Analysis in P_{track} bins.
- Accurate background subtraction:
  - $K_{\mu 2}$: $\pi^{\pm}\pi^0$ with π faking μ: <0.5%. Probability of π misidentification from data.
  - K_{e2}: $K_{\mu 2}$ with $\mu^{\pm}$ faking an $e^{\pm}$: ~10%, P_e dependent (relevant at high P_e only). Probability P(μ→e) that a μ lose > 95% of its energy in LKr to be evaluated with % level accuracy (expected ~10^{-6}).
    $K_{e2\gamma}$(SD): ~1÷2% level. K_{e3} : < 1%. Accidentals. To be evaluated with <10% level accuracy.
- Determination of the particle ID efficiency
  - Probability that an $e^{\pm}$ has E/P < 0.95. P_e dependent. Measured on data.
- Evaluation of the geometrical acceptance difference between K_{e2} and $K_{\mu 2}$.
  - P_{track} dependent. Expected > 10%, depending on $K_{e2\gamma}$(IB). Monte Carlo.
- Measurement of the difference in trigger efficiency between K_{e2} and $K_{\mu 2}$.

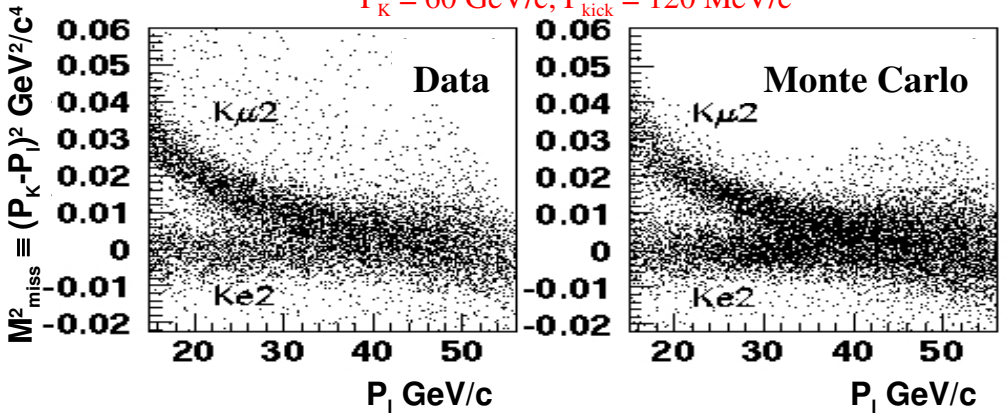
2003-2004 R_K measurements

- K_{e2} (after background subtraction):
  - (2003) $4670 \pm 77_{stat}{}^{+29}_{-8\ syst}$
  - (2004) $3407 \pm 63_{stat} \pm 54_{syst}$

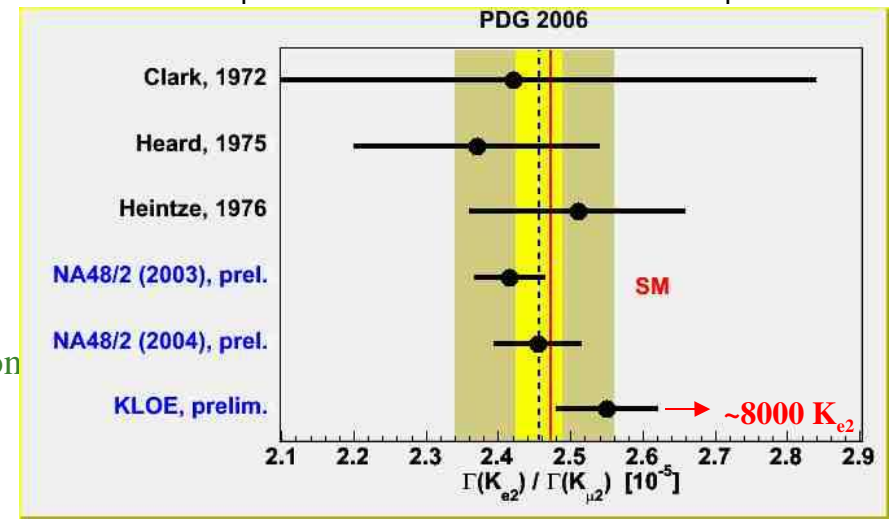


- K_{e2} Background:
  - $K_{\mu 2}$: ~14%. P(μ→e) estimated on data using E/P distribution from μ selected at low P_{track}
  - Other backgrounds from MC.

P_K = 60 GeV/c, P_{kick} = 120 MeV/c

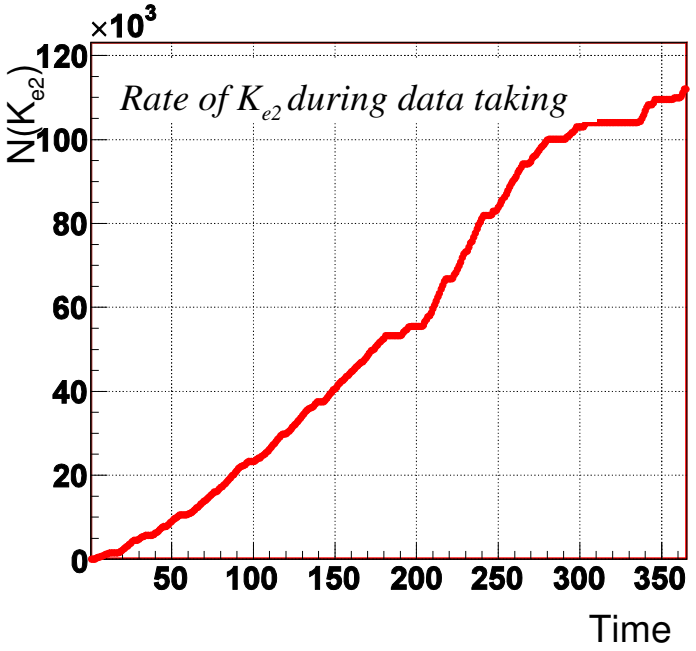


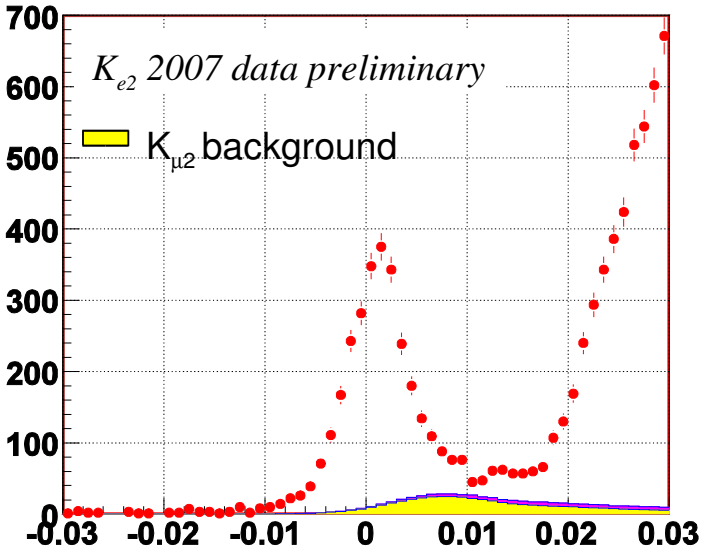
- Results:
  - (2003) $R_K = (2.416 \pm 0.043 \pm 0.024) \times 10^{-5}$
    - Systematics dominated by trigger efficiency
  - (2004) $R_K = (2.455 \pm 0.045 \pm 0.041) \times 10^{-5}$
    - Systematics dominated by background subtraction
    - Other systematics below 0.2%



2007 NA62 run

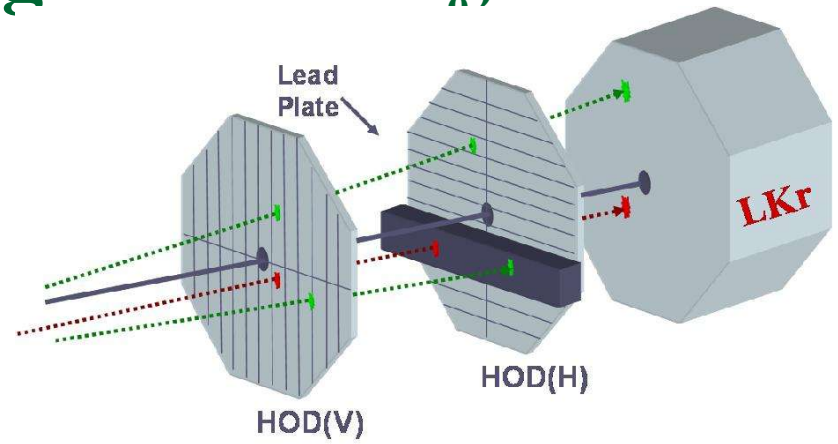
- Running conditions:
  - P_K = 75 GeV/c and P_{kick} = 256 MeV/c (better K_{e2} – $K_{\mu 2}$ separation wrt 2003-2004)
  - Trigger (as in 2004):
    - K_{e2}: 1 track topology + energy in LKr
    - $K_{\mu 2}$: 1 track topology (downscaling D = 50 ÷ 150)
  - 3 months run with 6.5 cm wide, $9X_0$ lead bar in front of the LKr to measure P(μ→e)
  - Run mainly with K^+ only to minimize the accidental background
  - Special runs with K_L to measure $e^\pm$ ID efficiency and with μ to measure P(μ→e)
  - Special runs with the Kaon beam dumped to measure the accidental background
- Statistics: ~110×10^3 K_{e2}
- Goal: total uncertainity ~0.5%

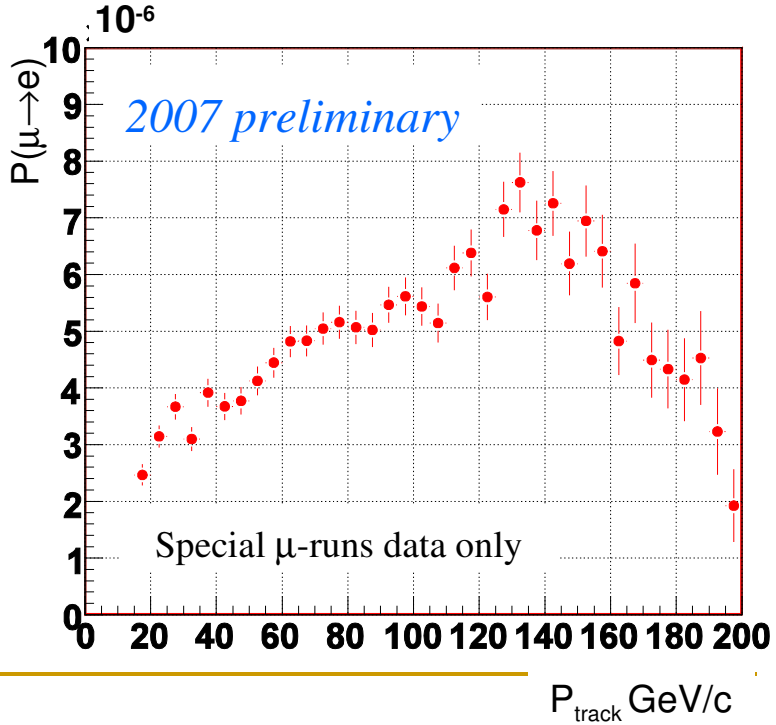




2007 data analysis: background to $K_{\mu 2}$

- Relevant for P_{track}>35 GeV/c
- Measurement of P(μ→e) on data
  - $9X_0$ lead bar in front of one hodoscope plane (~18% acceptance loss)
  - Use hodoscope scintillator pulse height to select only MIP in lead
  - All electrons killed: only muons pass
  - Measure the E_{LKr}/P_{track} of the muons and compute P(μ→e) vs P_{track}
- Collected samples of μ faking $e^{\pm}$ (P_{track} > 35 GeV/c)
  - ~2000 μ from $K_{\mu 2}$ (collected simultaneously with the main data)
  - ~2000 μ from special μ-runs
- $K_{\mu 2}$ background:
  - (7.5±0.1)% *(preliminary)*

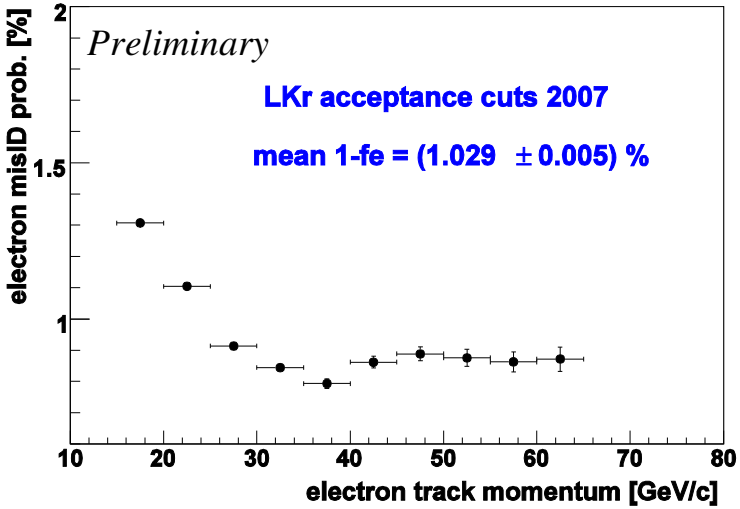




2007 data analysis (cont'd)

- Other backgrounds to K_{e2}
  - Accidentals: (1.3 ± 0.1)% (from data with K beam dumped)
  - $K_{e2\gamma}$ (SD): (0.7 ± 0.1)% (without lead bar, estimated with Monte Carlo)
    - The precision is limited by the present experimental knowledge of the BR($K_{e2\gamma}$(SD))
    - An independent measurement of the branching ratio is foreseen

- Electron ID efficiency
  - Measured with $K^{\pm} \to e^{\pm}\pi^0\nu_e$ and $K_L \to e^{\mp}\pi^{\pm}\nu_e$
  - The entire momentum spectrum covered



- Trigger efficiency
  - LKr energy condition for electron < 0.1%
  - Measured using control samples

Status of the analysis and future prospects

- Present status:
  - 2007 data taking finished in october 2007.
  - Preliminary fast analysis demonstrated the possibility to achieve an uncertainty < 0.5%
  - Data reprocessing with final detector calibrations under way

- Future improvements:
  - During the approved 2008 run of NA62 at SPS, data for further systematic checks can be collected, if needed.

Conclusions

- Analysis on semileptonic and leptonic decays obtained by the NA48 (NA62) experiment presented.

- Precise measurements of the BR($K^{\pm} \to l^{\pm} \pi^0 \nu_l$) [*Eur. Phys. J. C50 (2007) 329 + erratum*]
  - Agreement with other experiments normalizing to $\pi^{\pm}\pi^0$
  - Disagreement with PDG '06
  - Disagreement with absolute measurements (KLOE)
  - Extracted $|V_{us}|$ in agreement with unitarity

- Precise measurements R_K
  - Preliminary results from 2003-2004 data presented (~4K+4K data):
    - Precision at the level of 2%.
    - In agreement with SM.
  - >100K K_{e2} collected by NA62 in 2007
    - Preliminary study demonstrated the possibility to reach 0.5% uncertainty (stat+syst)

  Stay tuned for the future developments !