New results on kaon decays from NA48

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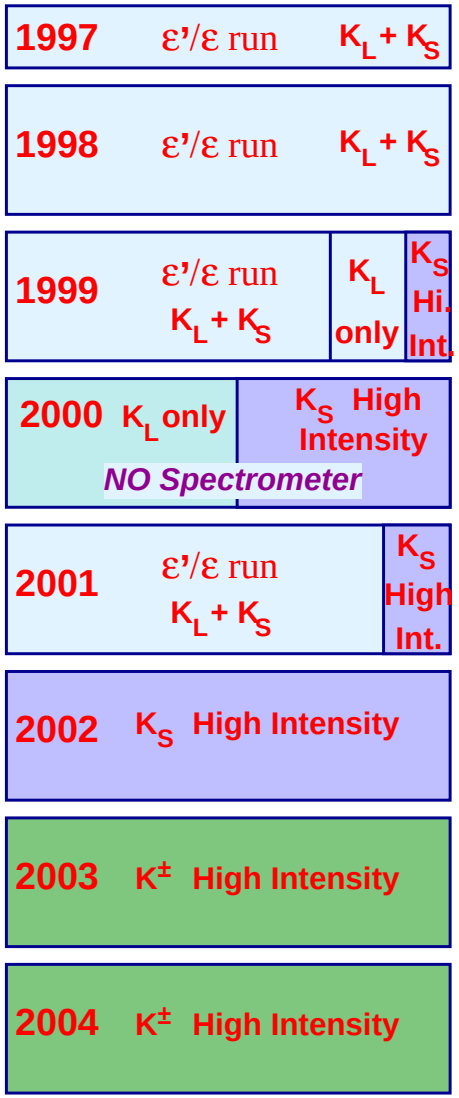
QCD 2006, Montpellier, 04 July 2006

New results on kaon decays from NA48

- The NA48 experiment
- $K_L \to \pi^+\pi^-$ (BR, $|\eta_{+-}|$)
- $K_L \to \pi^\pm\mu^\mp\nu$ (form factors)
- $K^\pm \to \pi^\pm\pi^0\gamma$, (DE, INT)
- Summary

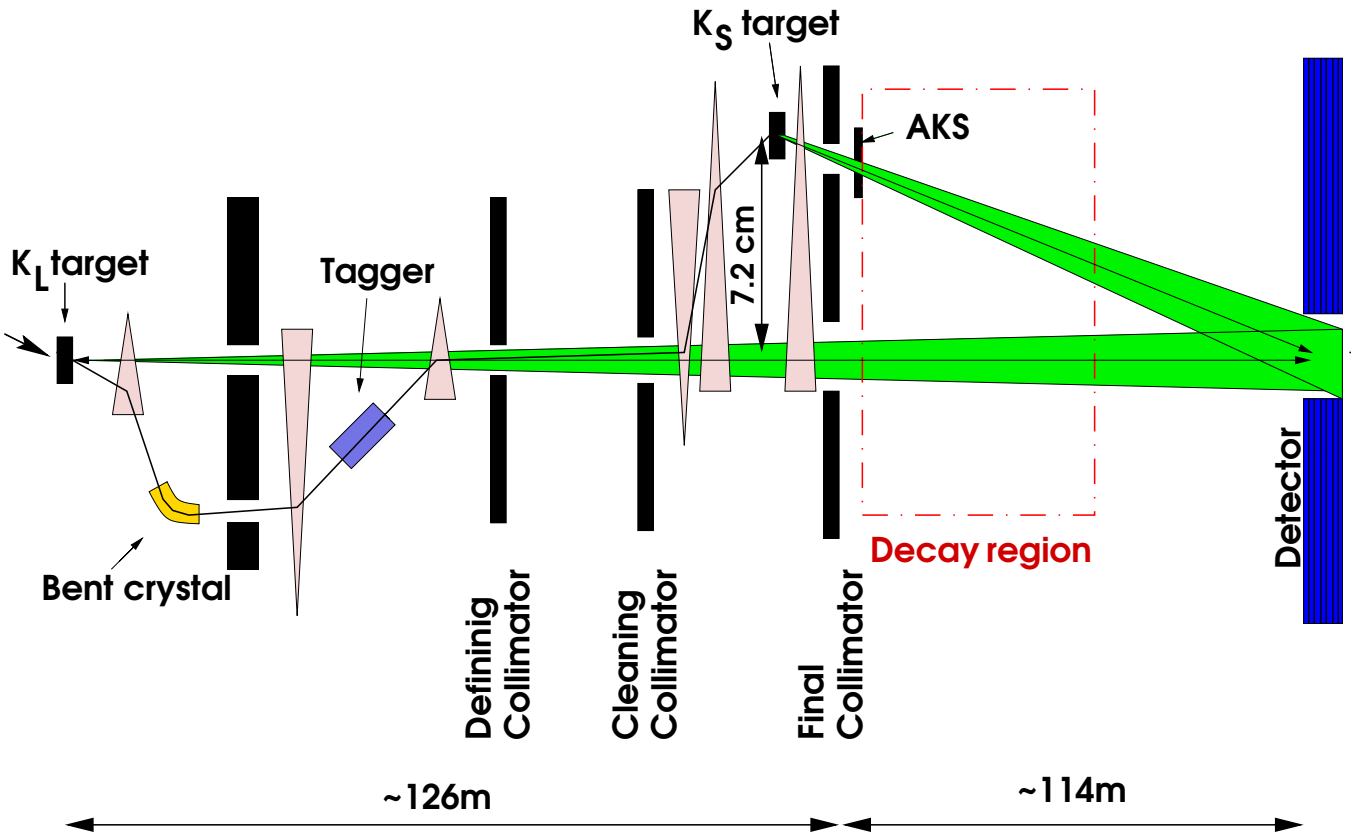
Data taking periods

- NA48 (1997-2001)
  $\Re(\varepsilon'/\varepsilon) = (14.7 \pm 2.2) \times 10^{-4}$
  K_L minimum bias run in 1999
- NA48/1 (2002)
  K_S decays
  hyperon decays (M. Piccini)
- NA48/2 (2003+2004)
  CPV in charged kaons (A. Norton)
  rare decays
  (radiative, K_{l4} (B. Bloch-Devaux), ...)
  semileptonic



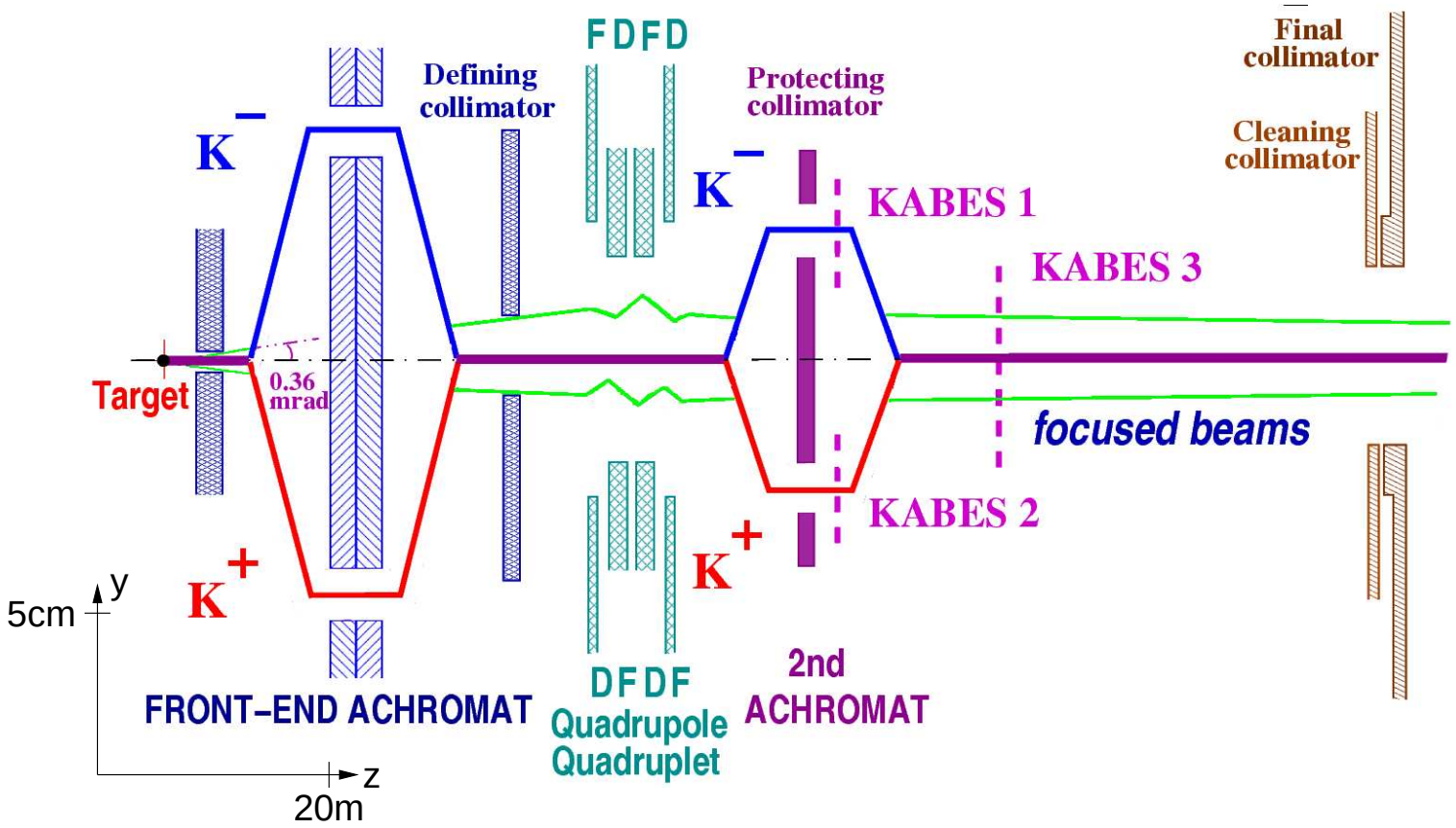
A beamline for neutral kaons

- NA48: K_L and K_S simultaneously
- NA48/1: K_S only



A beamline for charged kaons

- NA48/2: K^+ and K^- simultaneously, $p_K = (60 \pm 3)\ \mathrm{GeV}/c$



The NA48 detector

- Magnetic spectrometer

  Neutral kaons:

  $\sigma(p)/p \approx 0.5\ \% \oplus 0.009\ p\ \%$

  $p_\perp^{kick} = 0.265\ \mathrm{GeV}/c$

  Charged kaons:

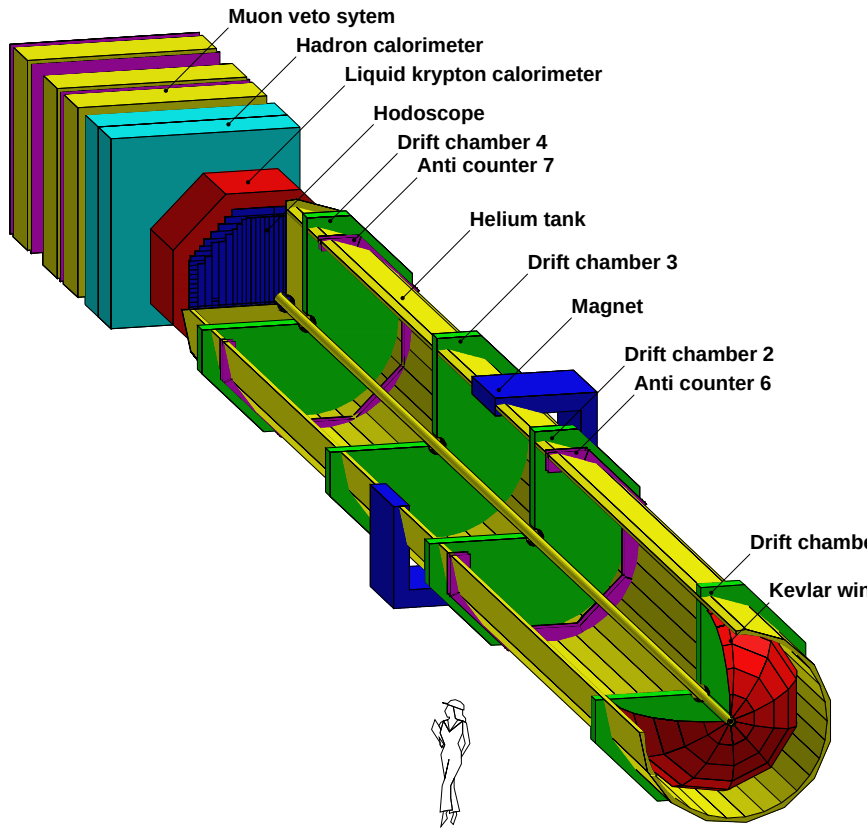
  $\sigma(p)/p \approx 1.02\ \% \oplus 0.044\ p\ \%$

  $p_\perp^{kick} = 0.121\ \mathrm{GeV}/c$

- Liquid Krypton calorimeter

  $\sigma(E)/E \approx$

  $3.2\ \%/\sqrt{E} \oplus 9\ \%/E \oplus 0.42\ \%$



p in GeV/c, E in GeV

$K_L \to \pi^+\pi^-$

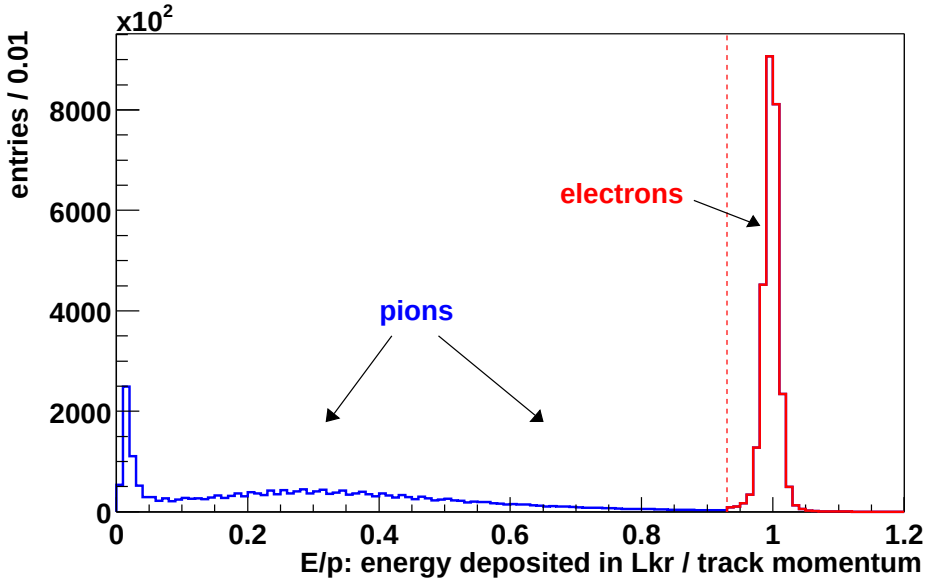
- Measurement of the ratio $\Gamma(K_L \to \pi^+\pi^-)/\Gamma(K_L \to \pi^\pm e^\mp \nu)$
- Extraction of the CP violating parameter $|\eta_{+-}|$

so far:

- Poor agreement of KTeV (2004) and KLOE (2006) measurements of $BR(K_{2\pi})$ and $|\eta_{+-}|$ with PDG (2004) averages
- Possibility for clarification:
  Data from special K_L run in 1999 with simple 2 track trigger

Event selection

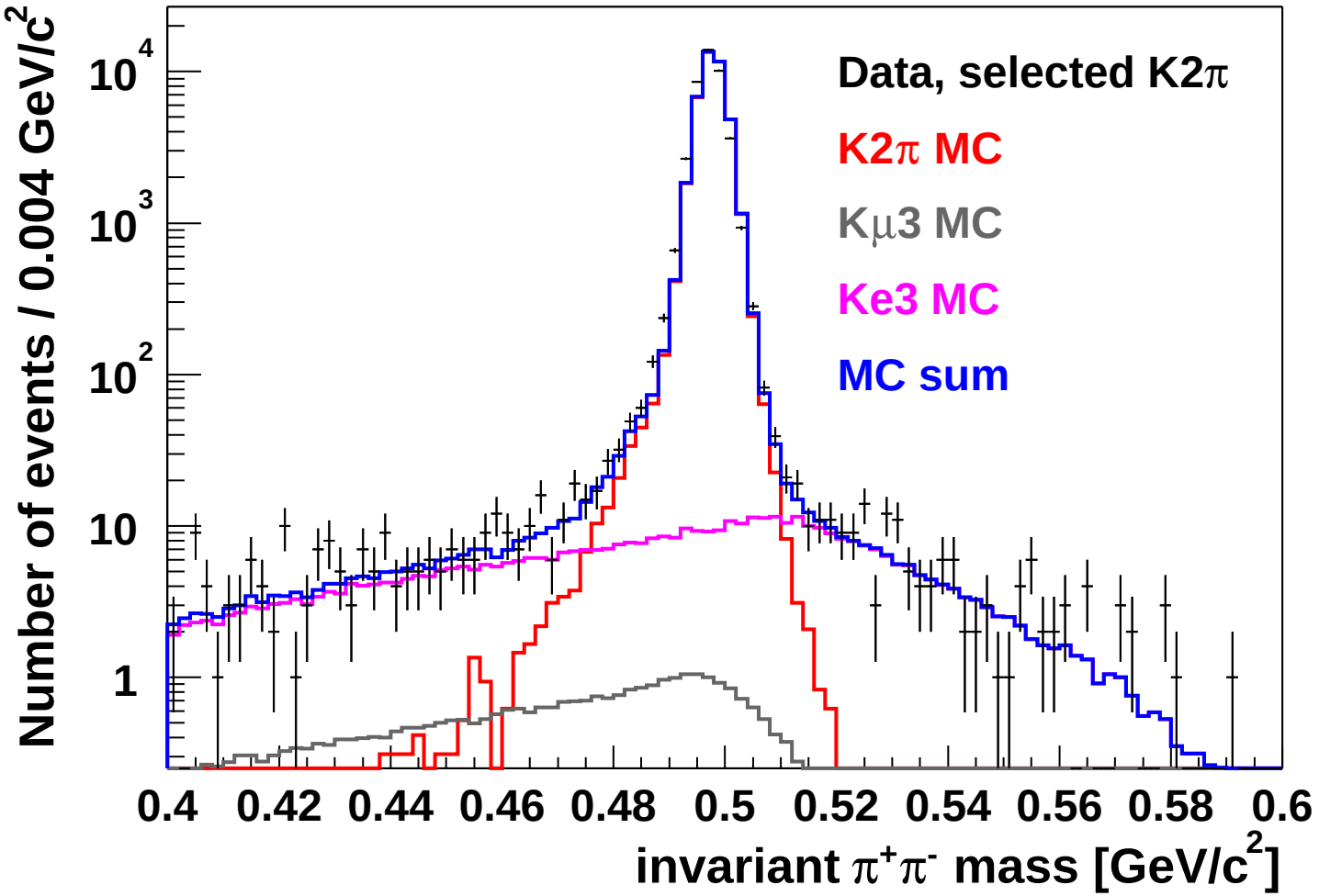
- 2 good tracks with common vertex in decay region
- $K_{2\pi}$:
  $0.48\ \mathrm{GeV}/c^2 < m_{\pi\pi} < 0.51\ \mathrm{GeV}/c^2$
  small $p_\perp$, no muon
  $E/p < 0.93$ for both tracks
  41473 selected events
- K_{e3}:
  one track with $E/p > 0.93$
  2663759 selected events



Corrections

- Pions producing hits in muon veto
- Trigger efficiency
- E/p efficiency
- background ($< 0.5\%$ in both channels)
- Radiative corrections:
  KLOR used for K_{e3}
  PHOTOS (real photon prod. only) used for $K_{2\pi}$

Reconstructed kaon mass



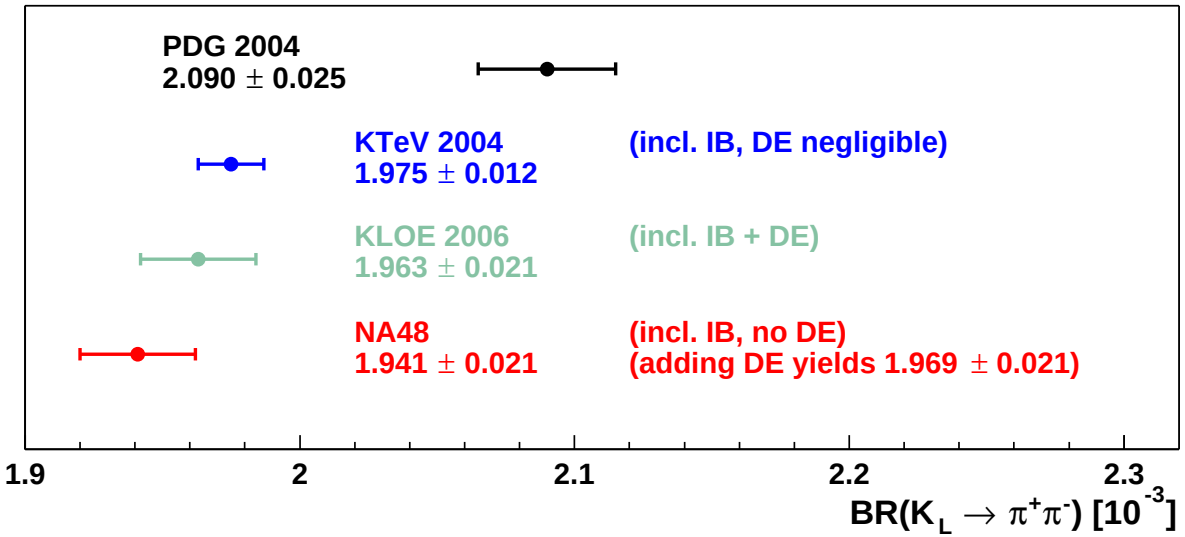
Results

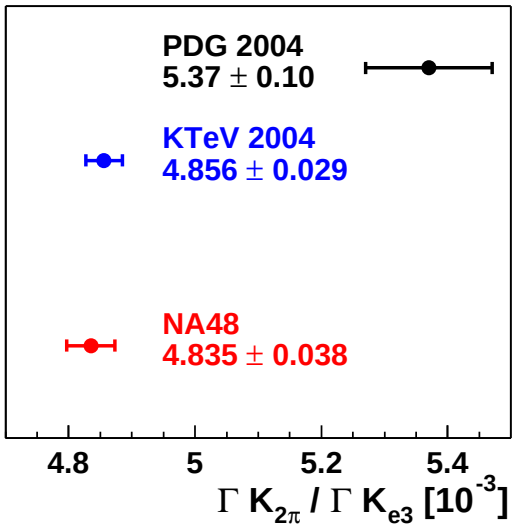
- $\Gamma(K_{2\pi})/\Gamma(K_{e3}) = (4.835 \pm 0.038) \times 10^{-3}$
  substract $(0.180 \pm 0.009)\%$ coming from $K_L \to \pi^+\pi^-\gamma(DE)$

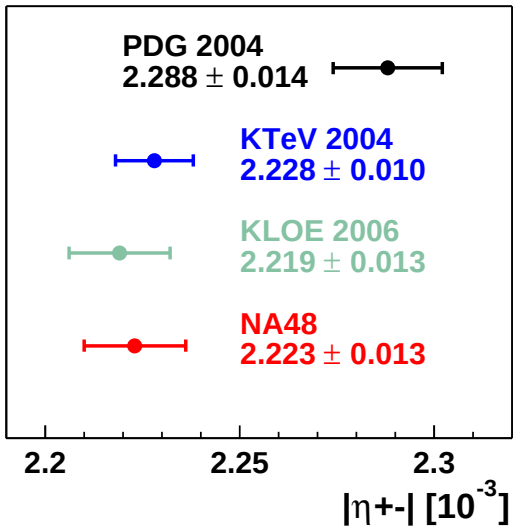
- $BR(K_L \to \pi^+\pi^- + \pi^+\pi^-\gamma(IB)) = (1.941 \pm 0.021) \times 10^{-3}$
  using $BR(K_L \to \pi e\nu) = 0.4022 \pm 0.0031$
  (NA48 updated due to change in $BR(K_L \to \pi^0\pi^0\pi^0)$)

- $|\eta_{+-}| = \sqrt{\frac{BR(K_L \to \pi^+\pi^-)}{BR(K_S \to \pi^+\pi^-)} \cdot \frac{\tau_{KS}}{\tau_{KL}}} = (2.223 \pm 0.013) \times 10^{-3}$
  using $\tau_{KS} = (0.89598 \pm 0.00070) \times 10^{-10}$s (NA48 2002),
  $\tau_{KL} = (5.084 \pm 0.023) \times 10^{-8}$s (KLOE 2006),
  $BR(K_S \to \pi^+\pi^-) = 0.69169 \pm 0.00051$ (KLOE 2006)

Comparison with other results







Measurement of form factors

$2.6 \cdot 10^6$ selected $K_L \to \pi^\pm\mu^\mp\nu$ events from min. bias K_L run in 1999

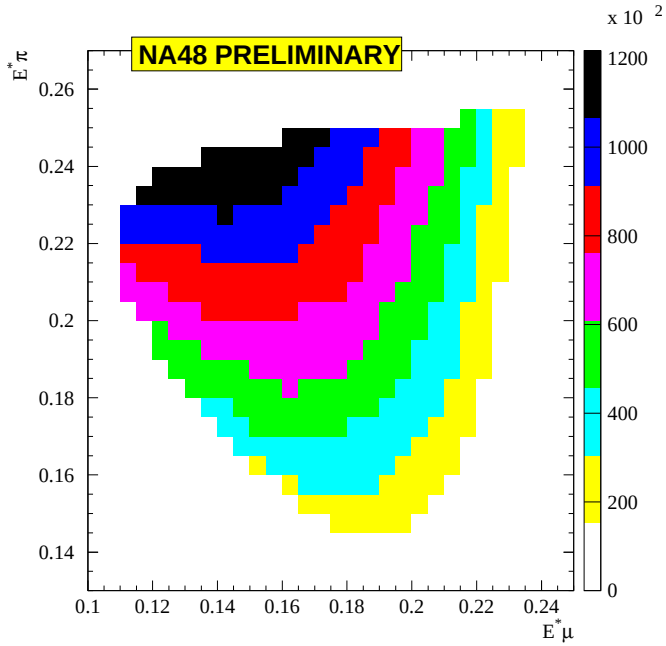
$$\mathcal{M} = \frac{G}{\sqrt{2}} V_{us} [f_+(t)(P_K + P_\pi)^\mu \bar{u}_l \gamma_\mu (1+\gamma_5) u_\nu + f_-(t) m_l \bar{u}_l (1+\gamma_5) u_\nu]$$

$$f_0(t) = f_+(t) + \frac{t}{(m_K^2 - m_\pi^2)} f_-(t), \quad \text{with} \quad f_{\pm 0}(t) = f_{\pm 0}(0)(1 + \lambda_{\pm 0} t/m_\pi^2)$$

for $f_{+0}(t)$ to be linear in $t = (P_K - P_\pi)^2$, λ_- has to be 0

Preliminary results from dalitz plot fit:

$$\lambda_+ = 0.0260 \pm 0.0007_{stat} \pm 0.0010_{syst}$$
$$\lambda_0 = 0.0120 \pm 0.0008_{stat} \pm 0.0015_{syst}$$



$K^\pm \to \pi^\pm\pi^0\gamma$

Measurement of Inner Bremsstrahlung (IB), Direct Emission (DE), and their Interference (INT) in the decay $K^\pm \to \pi^\pm\pi^0\gamma$

$$\Gamma \sim \underbrace{\frac{p_\pi^2 \sin^2\theta}{(m_K/2-\omega_0)^2}}_{IB}\left[1+\underbrace{2(\frac{m_\pi}{m_K})^2 W^2 |E|\cos(\delta\pm\phi)}_{INT}+\underbrace{(\frac{m_\pi}{m_K})^4 W^4(|E|^2+|M|^2)}_{DE}\right]$$

with $W^2 = \frac{(P_K P_\gamma)(P_\pi P_\gamma)}{(m_K m_\pi)^2}$

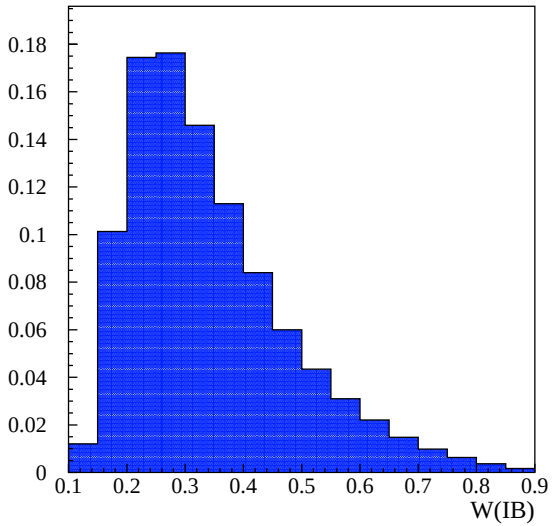
INT only due to electric amplitude E,
DE caused by electric *and* magnetic amplitude

Method

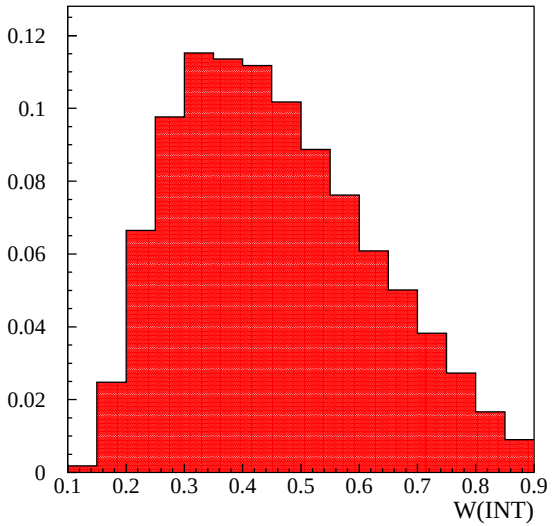
- IB: soft γ radiated off from π
- DE: hard γ produced in decay vertex
- W is product of γ energy in pion and kaon CMS respectively
- W distribution different for IB and DE
- Fit W distribution to obtain relative contributions of IB, DE and INT

W distributions (MC)

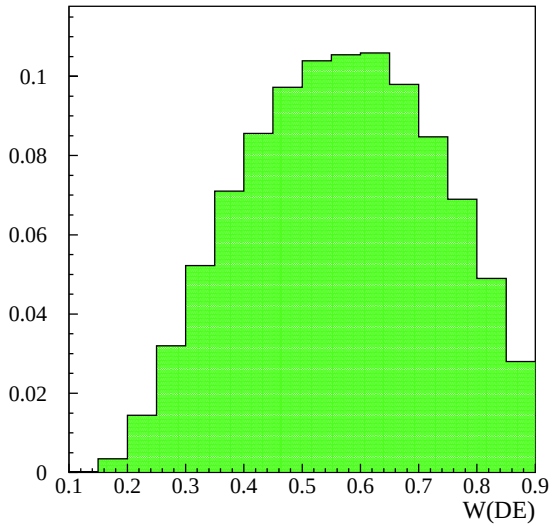
IB



INT

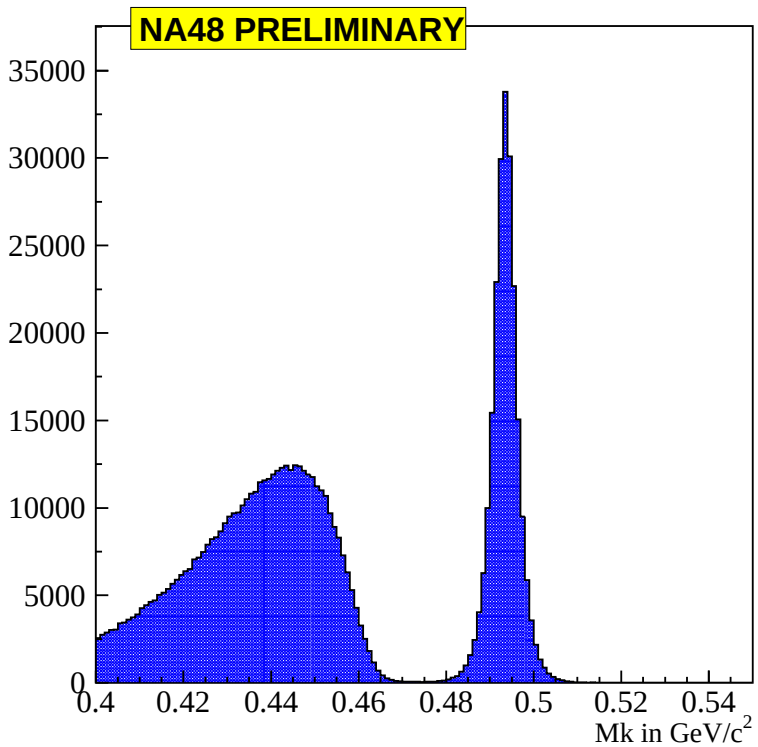


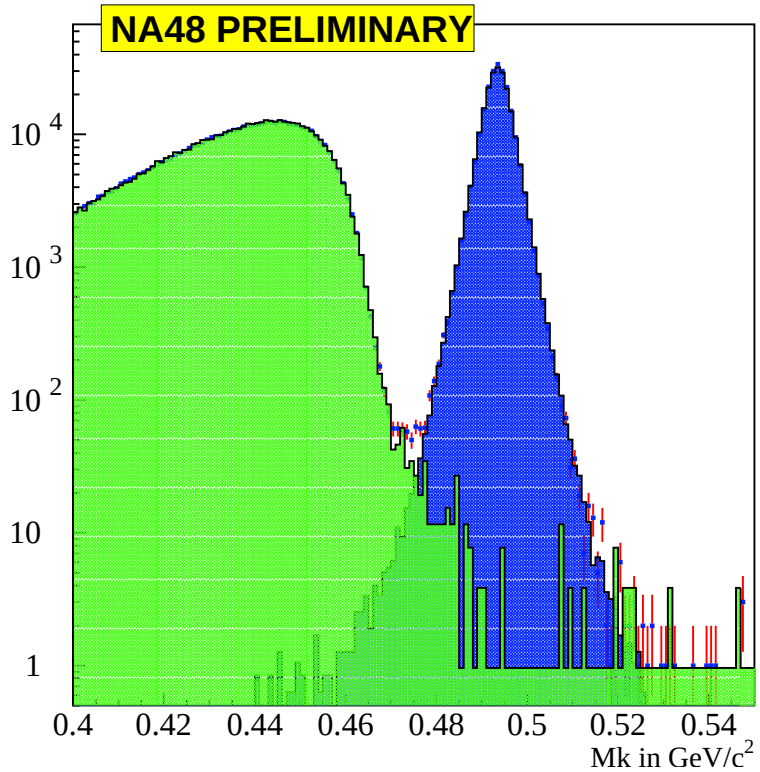
DE



Recontructed kaon mass

230317 selected $K^\pm \to \pi^\pm\pi^0\gamma$ events with
$0.48\ \mathrm{GeV}/c^2 < m_K < 0.51\ \mathrm{GeV}/c^2$
from $\sim$ 1 month data taking in 2003





W distribution (data)

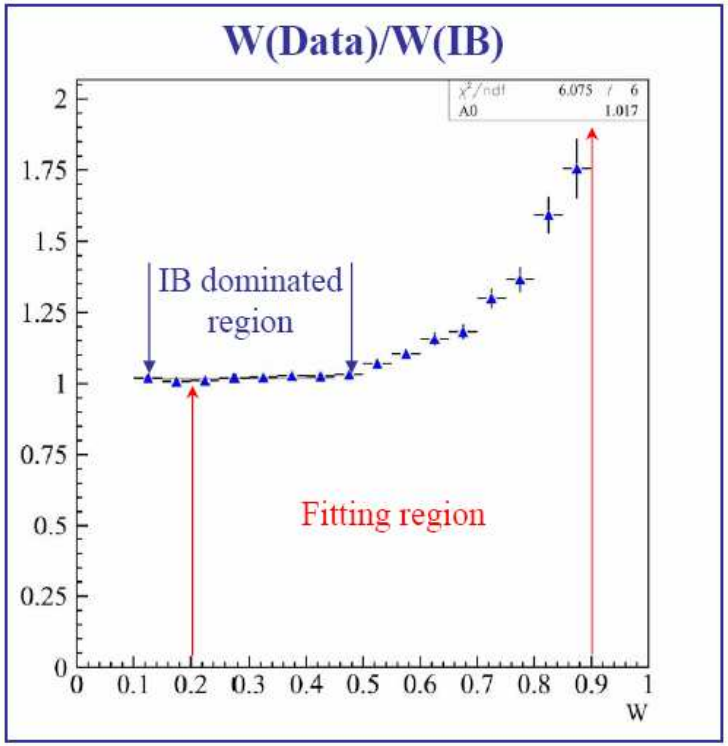
Further cuts:

$E_\gamma > 5$ GeV to avoid large L1 trigger ineffi ciencies

$0.2 < W < 0.9$ to avoid resolution effects at very low/high values for W

$0\ \text{MeV} < T_\pi^* < 80\ \text{MeV}$, upper cut due to trigger cut against $K^\pm \to \pi^\pm\pi^0$ events, lower cut applied by other experiments to suppress $K^\pm \to \pi^\pm\pi^0\pi^0$ events not necesary

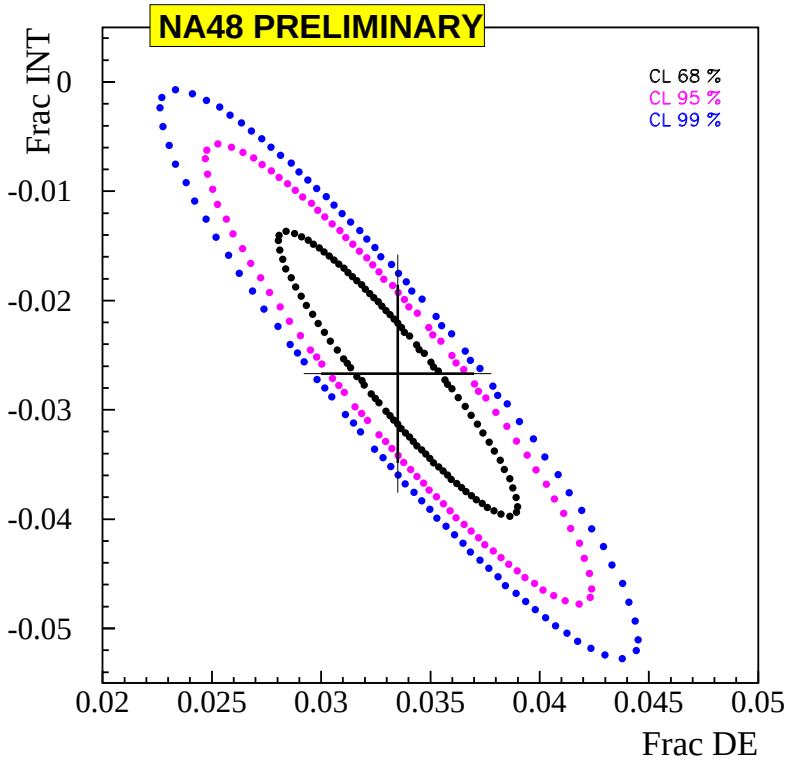
result: $\sim$ 124000 events used for fit



Preliminary result

$$frac(DE) = (3.35 \pm 0.35_{stat} \pm 0.25_{syst})\%$$

$$frac(INT) = (-2.67 \pm 0.81_{stat} \pm 0.73_{syst})\%$$



For comparison: Fit with $INT = 0$ and $55\ \mathrm{MeV} < T_\pi^* < 90\ \mathrm{MeV}$ results in a value $\sim 1.5\sigma$ lower than BNL E787 (2005) and KEK E470 (2006).

- Summary
  - $K_L \to \pi^+\pi^-$: results contradicting PDG04 confi rmed
  - $K_L \to \pi^\pm\mu^\mp\nu$: precise form factor measurement
  - $K^\pm \to \pi^\pm\pi^0\gamma$: 3σ evidence for INT

- Outlook
  - Some analyses on neutral kaons still ongoing
  - Many more rare and semileptonic charged kaon decays being analysed, partly close to publication
  - More results in the following talks
  - Future experiment to measure $K^\pm \to \pi^\pm\nu\overline{\nu}$ in R&D phase