



Rare Kaon Decays with NA48/2 and NA62 at CERN



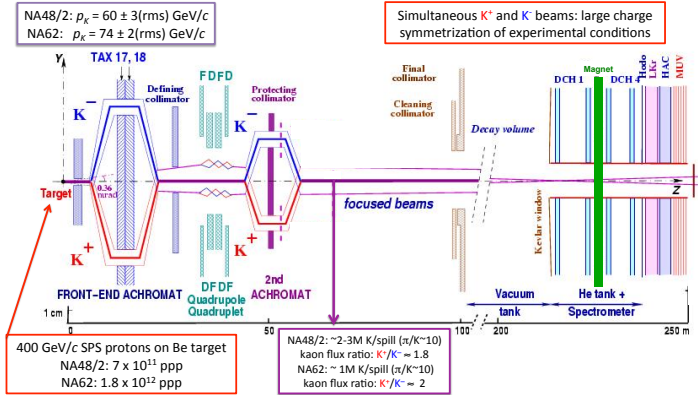
The NA48/2 Collaboration:

Cambridge, CERN, Chicago, Dubna, Edinburgh, Ferrara, Firenze, Mainz, Northwestern, Perugia, Pisa, Saclay, Siegen, Torino, Vienna.

The NA62 Collaboration:

Birmingham, CERN, Dubna, Fairfax, Ferrara, Florence, Frascati, Mainz, Merced, Moscow, Naples, Perugia, Pisa, Protvino, Rome I, Rome II, Saclay, San Luis Potosí, Stanford, Sofia, Turin.

NA48/2 - NA62: Experiment layout



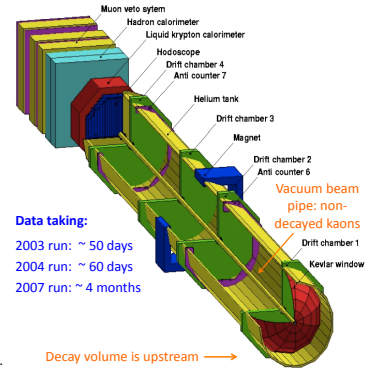
NA48/2 - NA62: Beam Line and Detector

Main Sub-detectors:

- ✓ Magnetic spectrometer (4 DCHs):
4 views/DCH: redundancy \Rightarrow efficiency;
 $\sigma_{\theta}/p = 1.0\% + 0.044\% \cdot p$ [GeV/c] (NA48/2)
 $\sigma_{\theta}/p = 0.48\% + 0.009\% \cdot p$ [GeV/c] (NA62).
- ✓ Hodoscope fast trigger;
precise time measurement (150ps).
- ✓ Liquid Krypton EM calorimeter (LKr)
High granularity, quasi-homogenous;
 $\sigma_{\theta}/E = 3.2\%/E + 9\%/E + 0.42\%$ [GeV].

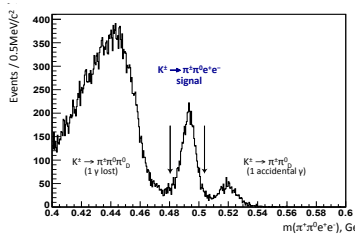
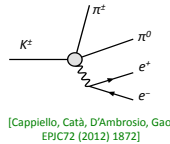
Trigger logic optimized:

- to detect direct CP violating charge asymmetries in K^0 decays (NA48/2, 2003-04);
- to measure the ratio $K^+ \rightarrow e^+ \nu_e / K^+ \rightarrow \mu^+ \nu_\mu$ (NA62, 2007).



$K^+ \rightarrow \pi^+ \pi^0 e^+ e^-$ - Preliminary Study

- $K^+ \rightarrow \pi^+ \pi^0 \gamma$ (10^6 decays measured in NA48/2) with internal conversion $\gamma \rightarrow e^+ e^-$.
- Direct emission depends on electric and magnetic form factors.
- Sensitivity to CPV and New Physics.



NA48/2 (2003-2004 data):

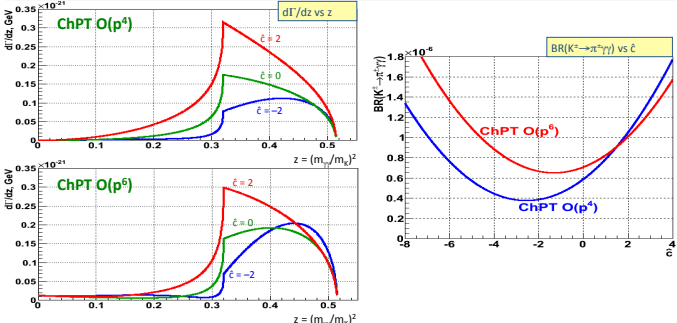
- First observation of $K^+ \rightarrow \pi^+ \pi^0 e^+ e^-$
- ~ 4500 events in signal region

Backgrounds:

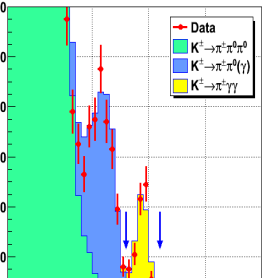
- $K^+ \rightarrow \pi^+ \pi^0 \pi^0$ ($\pi^0_D \rightarrow e^+ e^- \gamma$)
- $K^+ \rightarrow \pi^+ \pi^0$ ($\pi^0_D \rightarrow e^+ e^- \gamma$) + γ_{acc}

$K^+ \rightarrow \pi^+ \gamma \gamma$ - ChPT Description

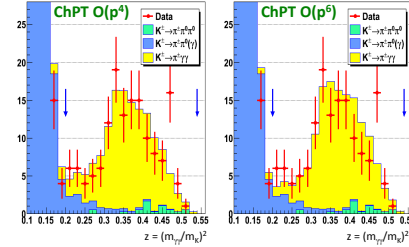
- ChPT spectrum and rate depend on a single unknown parameter \hat{c} .
- Leading contribution at $O(p^4)$ [Ecker, Pich, de Rafael, NPB 303 (1988) 665];
- $O(p^6)$ [D'Ambrosio, Portoles, PLB 386 (1996) 403]: a stringent test of ChPT.



NA48/2 2004 data set (3 days):



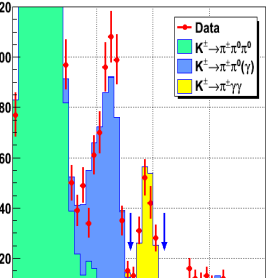
$K^+ \rightarrow \pi^+ \gamma \gamma$ - ChPT Fits



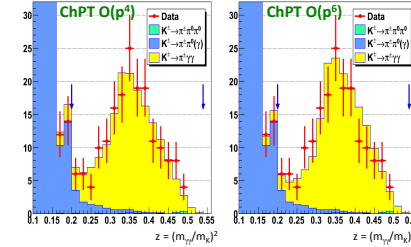
NA48/2 (2004 data - Preliminary)

- ChPT $O(p^4)$ fit:
 $\hat{c} = 1.36 \pm 0.33_{stat} \pm 0.07_{syst} = 1.36 \pm 0.34$
- ChPT $O(p^6)$ fit:
 $\hat{c} = 1.67 \pm 0.39_{stat} \pm 0.09_{syst} = 1.67 \pm 0.40$

NA62 2007 data set (3 months, downscaled trigger):



$K^+ \rightarrow \pi^+ \gamma \gamma$ - ChPT Fits



NA62 (2007 data - Preliminary)

- ChPT $O(p^4)$ fit:
 $\hat{c} = 1.71 \pm 0.29_{stat} \pm 0.06_{syst} = 1.71 \pm 0.30$
- ChPT $O(p^6)$ fit:
 $\hat{c} = 2.21 \pm 0.31_{stat} \pm 0.08_{syst} = 2.21 \pm 0.32$

Combined (2004 + 2007 data) - Preliminary:

- ChPT $O(p^4)$ fit: $\hat{c} = 1.56 \pm 0.22_{stat} \pm 0.07_{syst} = 1.56 \pm 0.23$
- ChPT $O(p^6)$ fit: $\hat{c} = 2.00 \pm 0.24_{stat} \pm 0.09_{syst} = 2.00 \pm 0.26$

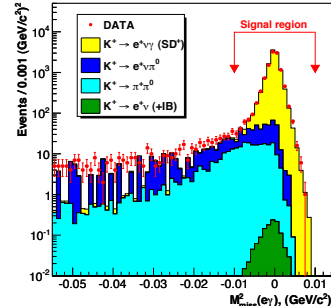
Full kinematic range: $BR = (1.01 \pm 0.06) \times 10^{-6}$
BR computed assuming ChPT $O(p^6)$: consistent with BNL E787
 $BR = (1.10 \pm 0.32) \times 10^{-6}$ [Phys. Rev. Lett. 79 (1997) 4079].
This combined result: factor of 5 improvement.

$K^+ \rightarrow e^+ \nu \gamma$ (SD⁺) - Motivation

- Structure Dependent mode with positive polarization of the radiative photon.
 - Decay rate receives electro-weak and hadronic contributions and is sensitive to the kaon structure.
 - Differential decay rate expressed in terms of vector (V) and axial-vector (A) form factors:
- $$\frac{d^2\Gamma(K^+ \rightarrow e^+ \nu \gamma, SD^+)}{dx dy} = \frac{G_F^2 |V_{us}|^2 M_K^2 \alpha}{64 \pi^2} (V + A)^2 (1-x)(x+y-1)^2$$
- Predictions for V and A exist from ChPT theory and specific models (LFQM, ChPT VMD and ChPT CQM).
- ChPT test to next-to-leading order in chiral expansions (ChPT $O(p^4)$, ChPT $O(p^6)$).
Model-independent form factor extraction allows quantitative comparison with theoretical predictions.

- $K^+ \rightarrow e^+ \nu \gamma$ (SD⁺) candidates: ~ 10000
- Signal acceptance: $\sim 7\%$
- Background contamination: $\sim 5\%$
- Systematics expected to be dominated by the background subtraction

NA62 2007 data set (Preliminary):



Fit data with ChPT at $O(p^6)$

