K± →π±γγ Studies at NA48/2 and NA62 Experiments at CERN

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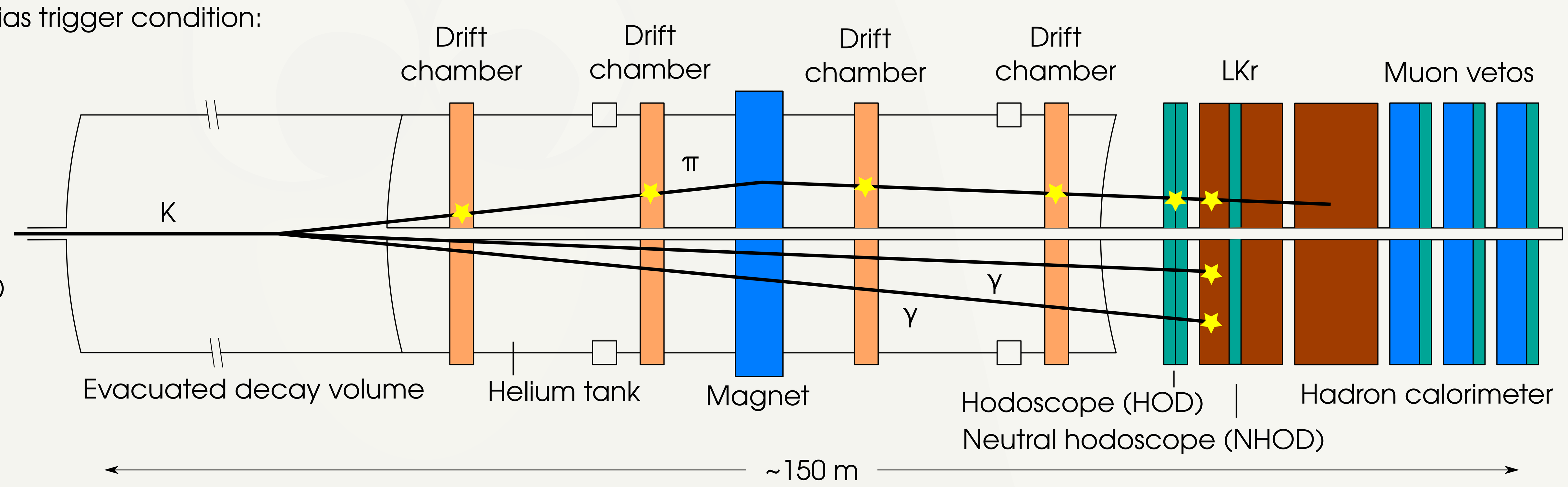
1. NA48/2 and NA62 Beams and Detectors

NA48/2 [1] (2003 and 2004) and NA62 [2] (2007) share the same detectors but have different beam parameters. The spectrometer magnetic field was modified accordingly.

Both K± →π±γγ data sets were collected with a minimum bias trigger condition:
- Time coincidence of signals in the two HOD planes,
- Energy deposit > 10 GeV in LKr.

Unless otherwise stated the plots are from NA62 analysis.

	NA48/2	NA62
Data taking period	12 hours in 2003 54 hours in 2004	4 months in 2007 (Downscaled trigger)
Beam momentum	(60 ± 3) GeV/c	(74 ± 1.4) GeV/c

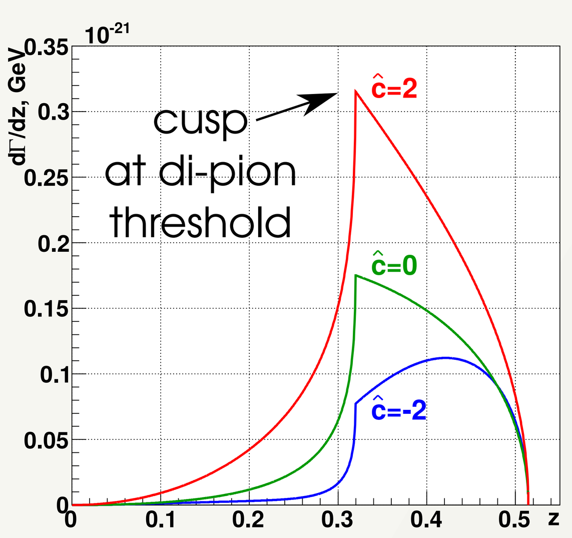


Pion momentum was reconstructed by a magnetic spectrometer while the energy of photons was measured by a liquid krypton calorimeter (LKr).

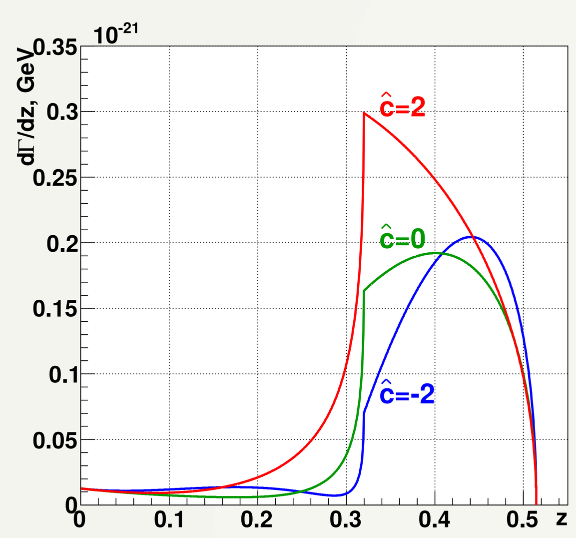
The detector resolutions are $\frac{\sigma_E}{E} = \left(3.2/\sqrt{E} \oplus 9/E \oplus 0.42\right)\%$ for LKr, $\frac{\sigma_p}{p} = (1.02 \oplus 0.044 \cdot p)\%$ for NA48/2 spectrometer and $\frac{\sigma_p}{p} = (0.48 \oplus 0.009 \cdot p)\%$ for NA62 spectrometer. (E): GeV, (p): GeV/c.

2. Chiral Perturbation Theory and K± →π± γγ

K± →π± γγ is a good probe for testing the ChiPT description of low energy weak processes. This channel has been extensively studied by theorists [3].



Leading order $\mathcal{O}\left(p^4\right)$



Next-to-Leading order $\mathcal{O}\left(p^6\right)$

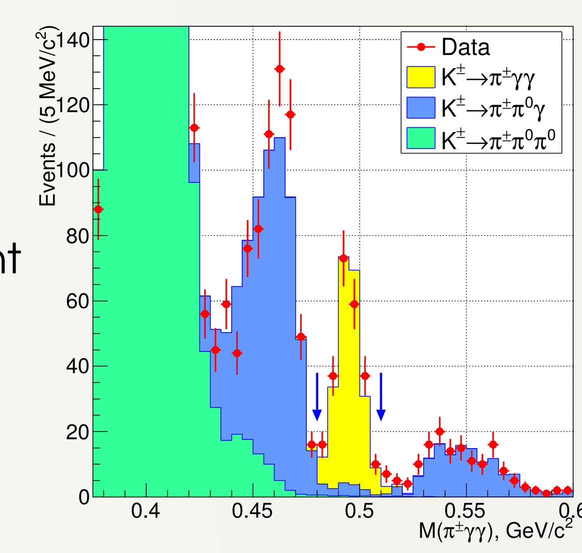
$$z = \left(\frac{m_{\gamma\gamma}}{m_K}\right)^2$$

At leading order the predicted differential decay rate depends exclusively on ĉ.
At next to leading order ĉ enter the decay rate as $\hat{c}^* = \hat{c} - 2\left(m_\pi/m_K\right)^2 \eta_1 - 2\eta_2 - 2\eta_3$.
In this analysis η_i are fixed to 0.

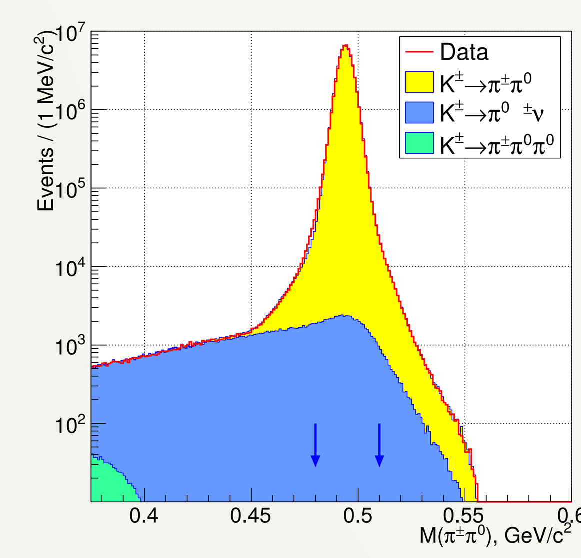
3. Signal Selection and Normalization

K± →π± γγ and K± →π± π^0 are collected with same trigger logic.
This allows a first order cancellation of several systematic effects.

Invariant masses



Signal selection



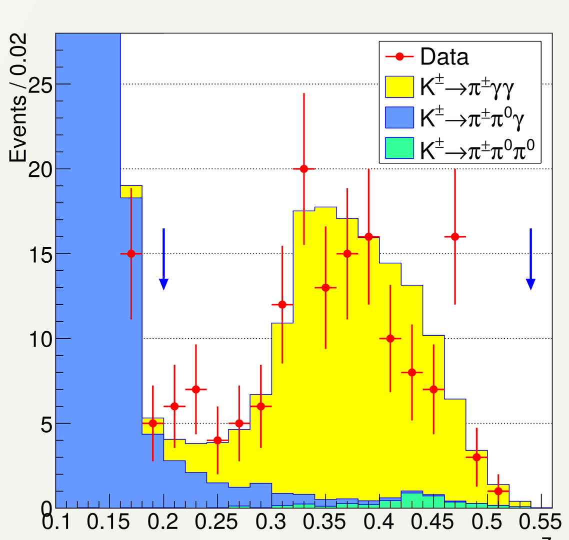
Normalization selection

Branching ratio is given by $\mathcal{B}\left(K_{\pi\gamma\gamma}\right) = \frac{N'_{\pi\gamma\gamma}}{N'_{2\pi}} \cdot \frac{A_{2\pi}}{A_{\pi\gamma\gamma}} \cdot \frac{\epsilon_{2\pi}}{\epsilon_{\pi\gamma\gamma}} \cdot \mathcal{B}\left(K_{2\pi}\right) \cdot \mathcal{B}\left(\pi^0_{\gamma\gamma}\right)$

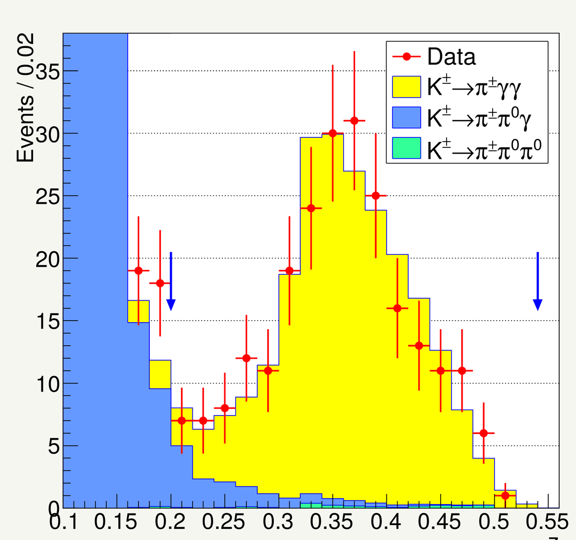
where N' are # events after background subtraction, A are acceptances and ε are trigger efficiencies. For K±→π± π^0, di-photon mass has to be consistent with π^0.

4. Reconstructed z Spectrum

Simulated signal with the best ĉ value in the O(p^6) fit:



NA48/2



NA62

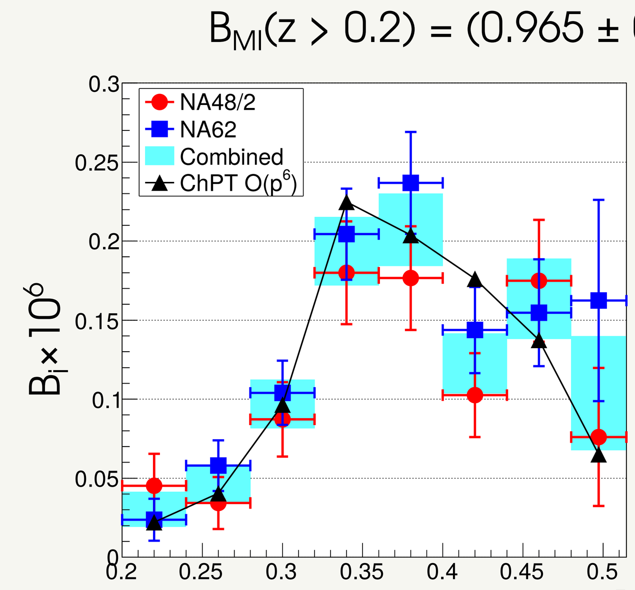
Main background to signal is due to K± →π±π^{0}γ followed by a π^0 →γγ decay, with two photons producing a merged LKr energy cluster.

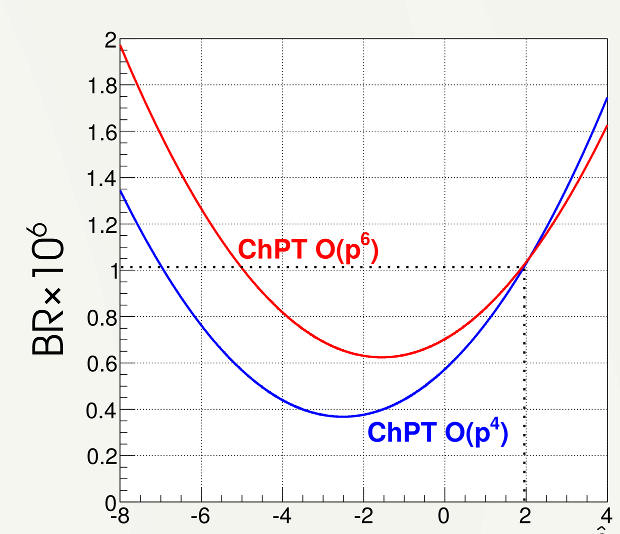
5. Branching Ratio

Acceptances and differential decay rate are model dependent but for small width z bins these dependences become negligible. This allows to extract a model independent decay rate B_{MI} by summing over the z bins for z > 0.2.

Combined NA48/2 and NA62 model independent branching ratio:

B_{MI}(z > 0.2) = (0.965 ± 0.063) × 10^{-6}.





Assuming an O(p^6) description we can compute the total decay rate B_6 for a given ĉ.

6. Extraction of the ĉ Parameter

O(p^6) differential decay rate can be written as [3]:

$$\frac{\partial\Gamma}{\partial y \partial z}\left(\hat{c}, y, z\right) = \frac{m_K}{2^9 \pi^3}\left[z^2\left(\left|A\left(\hat{c}, z, y^2\right) + B\left(z\right)\right|^2 + \left|C\left(z\right)\right|^2\right) + \left(y^2 - \frac{1}{4}\lambda\left(1, r_\pi^2, z\right)\right)^2 \left|B\left(z\right)\right|^2\right]$$

where $\lambda\left(a,b,c\right) = a^2 + b^2 + c^2 - 2\left(ab + ac + bc\right)$, A and B are loop amplitudes and C pole amplitude.

Values of all the external parameters used in the NA48/2 and NA62 analyses are detailed in [1] and [2].

ĉ parameter is extracted by fitting the reconstructed z spectrum, maximizing the log-likelihood $\ln\mathcal{L} = \sum_{i=1}^{N}\left[n_i \ln m_i - m_i - \ln\left(n_i!\right)\right]$. The sum is running over N bins of the reconstructed z spectrum, m_i is the # of expected events for a given ĉ and n_i is the # of observed events.

7. Take Home Message

Current experimental state of the art is the following:

	BNL E787 [4]	NA48/2	NA62
Candidates	31	149	232
Background Events	5.1 ± 3.3	15.5 ± 0.7	17.4 ± 1.1
B_{MI} (z > 0.2) × 10^6	0.6 ± 0.15 ± 0.07*	0.877 ± 0.087 ± 0.017	1.088 ± 0.093 ± 0.027
$\hat{c}_4$	1.6 ± 0.6	1.37 ± 0.33 ± 0.14	1.93 ± 0.26 ± 0.08
$\hat{c}_6$	1.8 ± 0.6	1.41 ± 0.38 ± 0.11	2.10 ± 0.28 ± 0.18
B_6 × 10^6	1.1 ± 0.3 ± 0.1	0.910 ± 0.072 ± 0.022	1.058 ± 0.066 ± 0.044

* 0.157 < z < 0.384

Combining the NA48/2 and NA62 results:

B_{MI}(z > 0.2) = (0.965 ± 0.063) ×10^{-6}
$\hat{c}_4$ = 1.72 ± 0.21
$\hat{c}_6$ = 1.86 ± 0.25
B_6 = (1.003 ± 0.056) ×10^{-6}

NA48/2 and NA62 results are in good agreement with the earlier E787 results and considerably improve our experimental knowledge of K±→π±γγ.
We observed the predicted cusp at the di-pion threshold (z = 0.320).

8. References

[1] Batley, J.R. et al. (NA48/2 collab.), Phys. Lett. B 730 (2014) 141
[2] Lazzeroni, C. et al. (NA62 collab.), Phys. Lett. B 732 (2014) 65
[3] D'Ambrosio, G. and Portolés, J, Phys. Lett. B 386 (1996) 403
[4] Kitching, P. et al., Phys. Rev. Lett. 79 (1997) 4079

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