QCD tests with Kaon decays

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1. Measurement of $\pi\pi$ scattering lengths from "cusp" effect in the decay $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\pi^{0}$ and Ke4 decays $K^{\pm} \rightarrow \pi^{+}\pi^{-}e^{\pm}\nu$

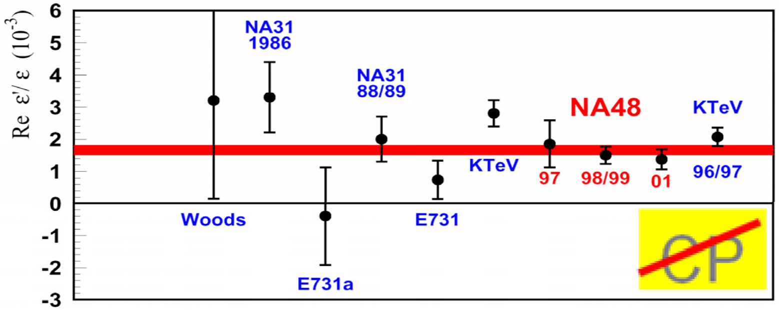
2. Precision measurements of $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$

3. Branching fractions and form factors of the rare decays $K^{\pm} \rightarrow \pi^{\pm}e^{+}e^{-}$ and $K^{\pm} \rightarrow \pi^{\pm}\mu^{+}\mu^{-}$

*On behalf of NA48 Collaboration

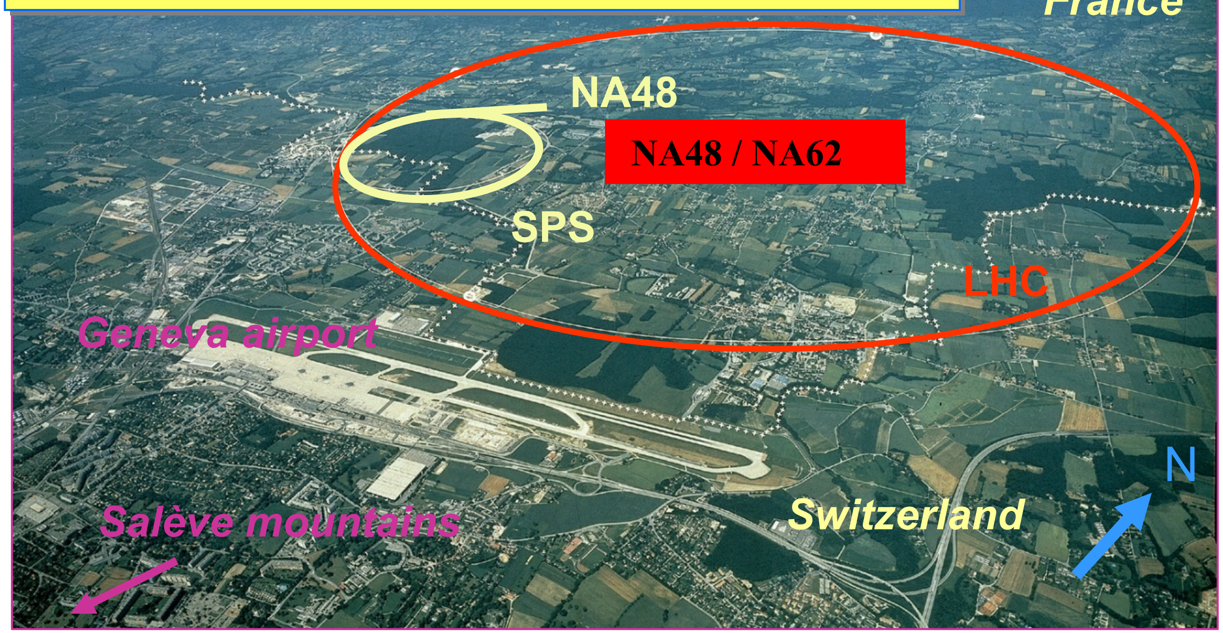
The NA48/NA62 experiment

A fixed target experiment at the CERN SPS dedicated the study of CP violation and rare decays in the kaon sector



Final NA48 result :

$\varepsilon'/\varepsilon = (14.7 \pm 2.2)\, 10^{-4}$



NA48
- 1997 — ε'/ε run — $K_L + K_S$
- 1998 — ε'/ε run — $K_L + K_S$
- 1999 — ε'/ε run $K_L + K_S$ — K_S Hi. Int
- 2000 — K_L only — K_S High Intensity — *NO Spectrometer*
- 2001 — ε'/ε run $K_L + K_S$ — K_S High Int.

NA48/1
- 2002 — K_S High Intensity

NA48/2
- 2003 — $K^\pm$ High Intensity
- 2004 — $K^\pm$ High Intensity

NA62
- 2007 — $K^\pm_{e2}/K^\pm_{\mu2}$ run

NA62 phase II

measurement of the decay

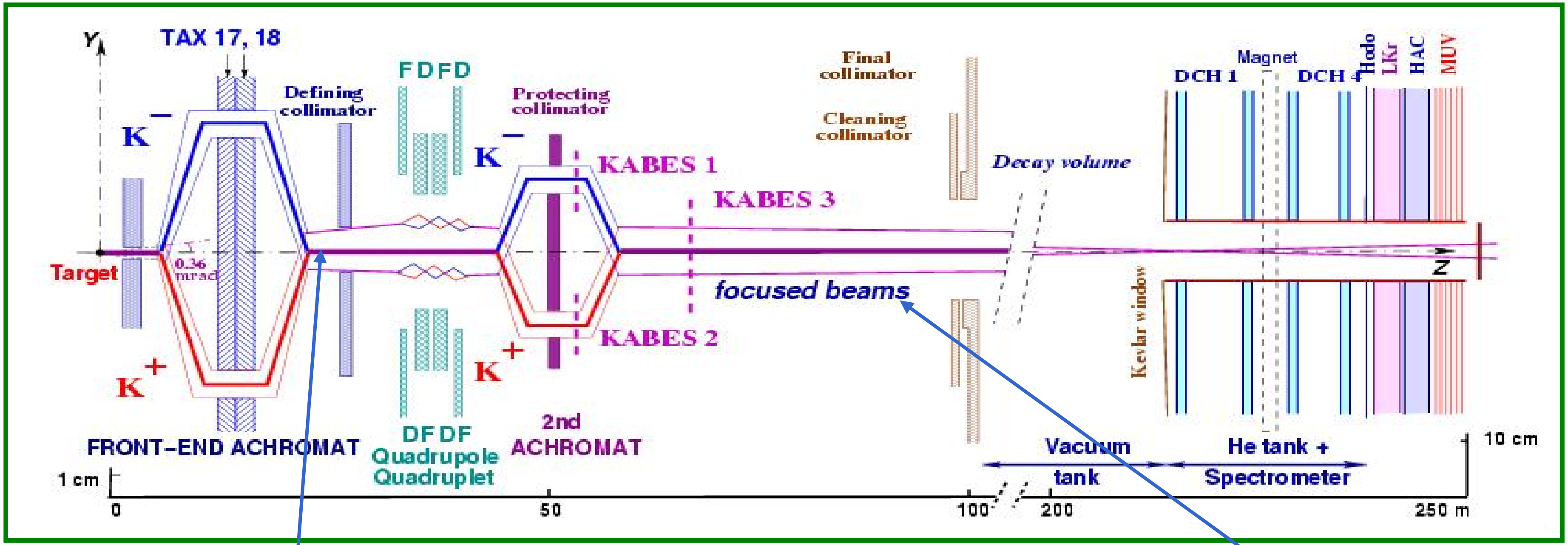
$$K^+ \rightarrow \pi^+ \nu \bar{\nu}$$

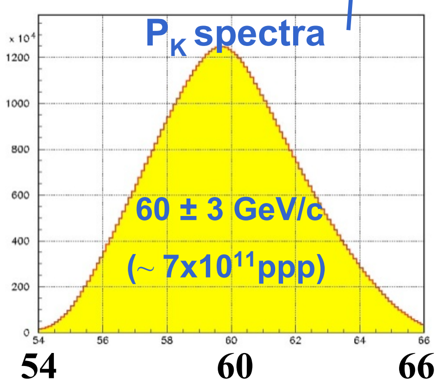
(2008-2010 R&D & construction 2011 start of data taking)

NA48/2 simultaneous $K^{\pm}$ beam

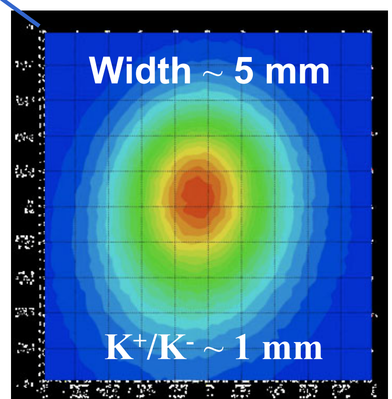
NA48-2 beams: simultaneous K^+/K^-, focused, high momentum, narrow band

designed to precisely measure $K^{\pm} \to \pi^+\pi^-\pi^{\pm}$ ($\pi^0\,\pi^0\,\pi^{\pm}$) Dalitz-plot density to search for direct CPV and **tuned for K_{e2} measurement.**





- Simultaneous, unseparated, focused beams
- Flux ratio: $K^+/K^- \sim 1.8$
- Similar acceptance for K^+ and K^- decays
- Large charge symmetrization of experimental conditions



NA48 detector

- **Magnetic spectrometer (4 DCHs)**
  - 4 views : redundancy ⇒ high efficiency;

$\sigma_p/p = (1.0 \oplus 0.044\ p)\%$ (p in GeV/c)

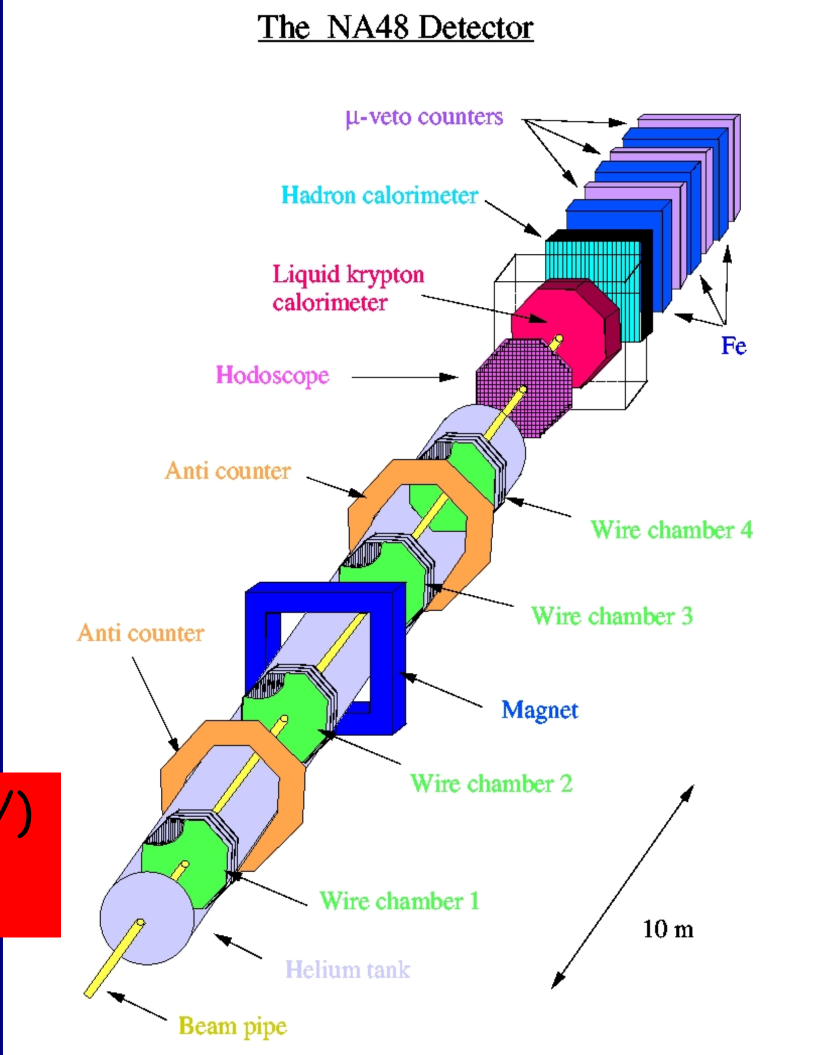
- **Hodoscope**
  - fast trigger;
  - precise time measurement (σ_t = 150 ps) .

- **Liquid Krypton EM calorimeter (LKr)**
  - Quasi-homogeneous ionization chamber
  - 27 electromagnetic radiation lengths long active volume
  - Segmented transversally 13248 cells, 2x2 cm2
  - Energy resolution (E in GeV):

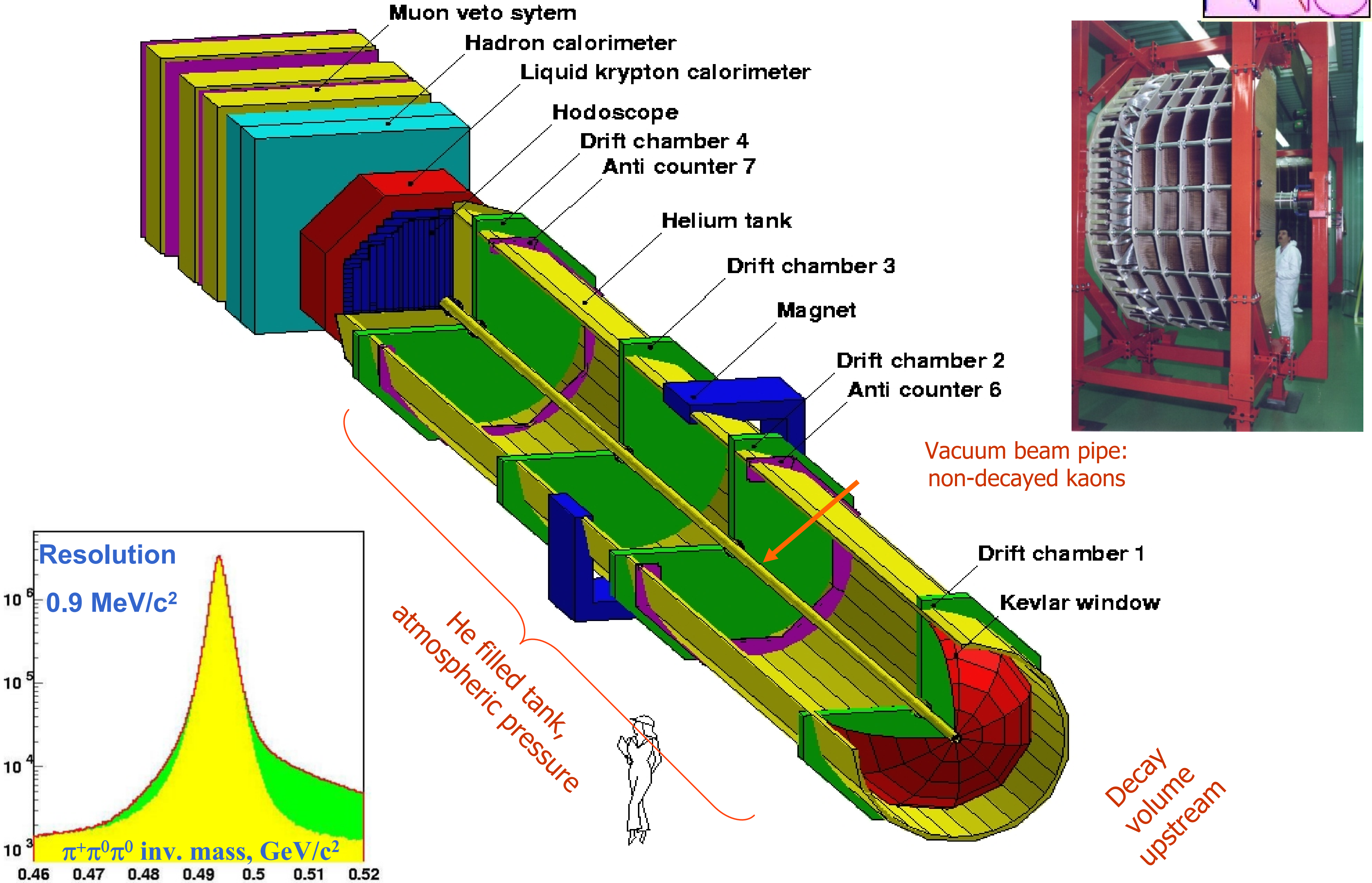
$\sigma_E/E = (3.2/\sqrt{E} \oplus 9.0/E \oplus 0.42)\%$ (E in GeV/)

$\sigma_x = \sigma_y = 0.42/E^{\frac{1}{2}} + 0.6$ mm

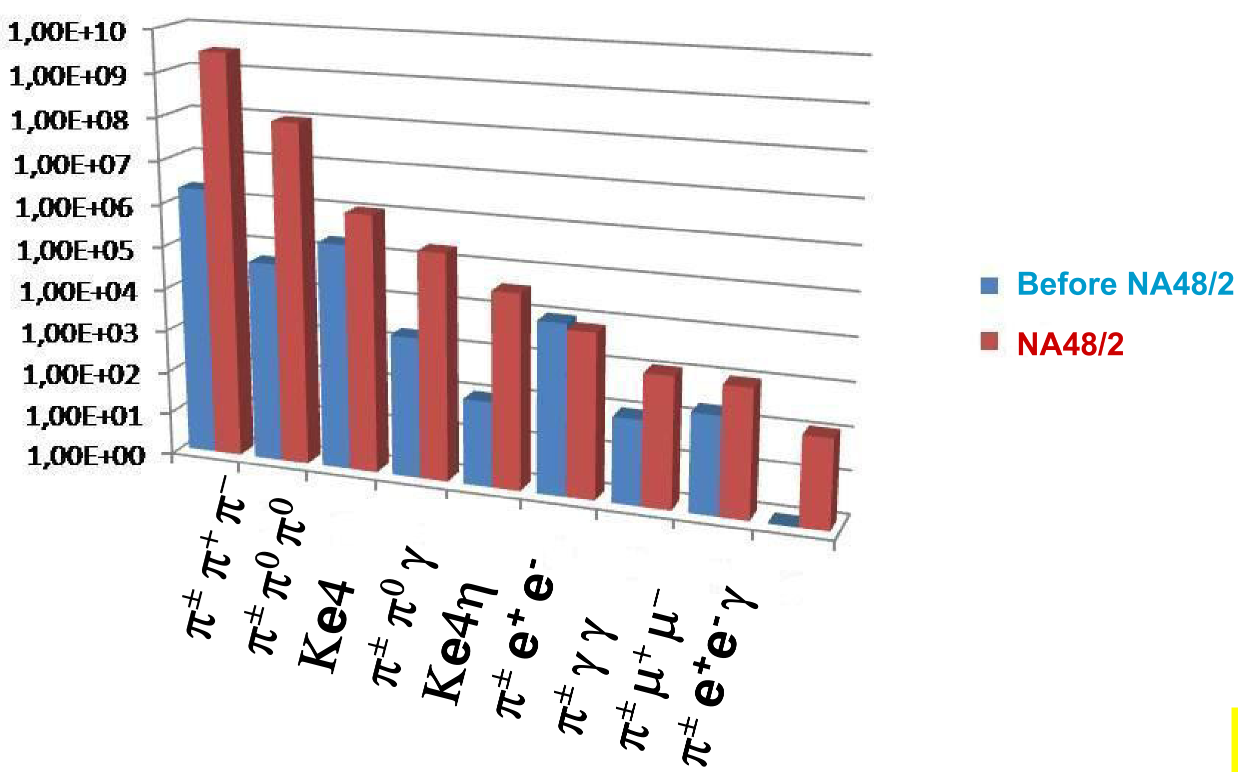
Cambridge, CERN, Chicago, Dubna, Edimburgh, Ferrara, Firenze, Mainz, Northwestern, Perugia, Pisa, Saclay, Siegen, Torino, Vienna



The NA48/NA62 experiment

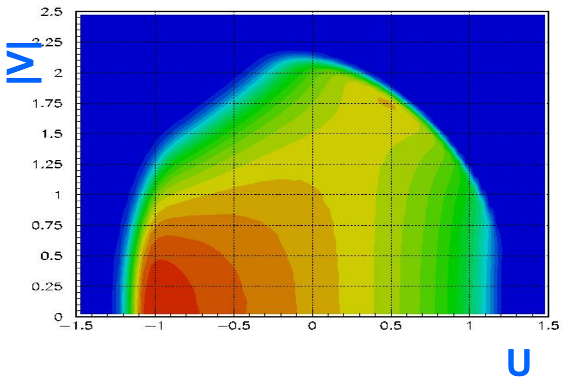


NA48/2 Data taking



NA48 Experimental hall

- Unprecedented statistics in many channels
- Two years of data taking (2003 and 2004)
- Main purpose was to measure direct CP violation in charged kaon decays, through asymmetry in Dalitz plot distribution
- New limits on CP violation in charged kaon decays



$A_g^{ch} = (-1.5 \pm 2.1) \times 10^{-4}$

$A_g^0 = (1.8 \pm 1.8) \times 10^{-4}$

$\pi\pi$ scattering lengths in Ke4 and K3π decays

QCD test with Kaons

The important free parameter of Chiral PerturbationTheory is the quark condensate <qq>, it determines the relative size of mass and momentum terms in the power expansion.

a_0 and **a_2** are the **S-wave** $\pi\pi$ **scattering lengths** in Isospin states **I=0** and **I=2**. They enter in all $\pi\pi$ scattering amplitudes.

The relation between <qq> and the scattering lengths **a_0** and **a_2** is known from this theory with high precision.

The experimental measurement of **a_0** and **a_2** provides important constraints for **ChPT** parameters

QCD test with Kaons in NA48/2

Kaon decays → ideal laboratory to study the low energy (below 1 GeV) regime of hadronic physics

Two different approaches to measure a_0 and a_2

Hadronic decay mode K3π

- large BR's :

  $K^{\pm} \rightarrow \pi^0 \pi^0 \pi^{\pm}$ = 1.7%
- 60 x 10^6 events analyzed

- results on partial sample
  → Phys. Lett. B633 (2006)
- full statistics paper submitted

Semileptonic decay mode Ke4

- small BR's :

  $K^{\pm} \rightarrow \pi^+ \pi^- e^{\pm} \nu = 4.1 \times 10^{-5}$
- 1.1 x 10^6 events analyzed

- results on partial sample
  → EPJ C54 (2008)

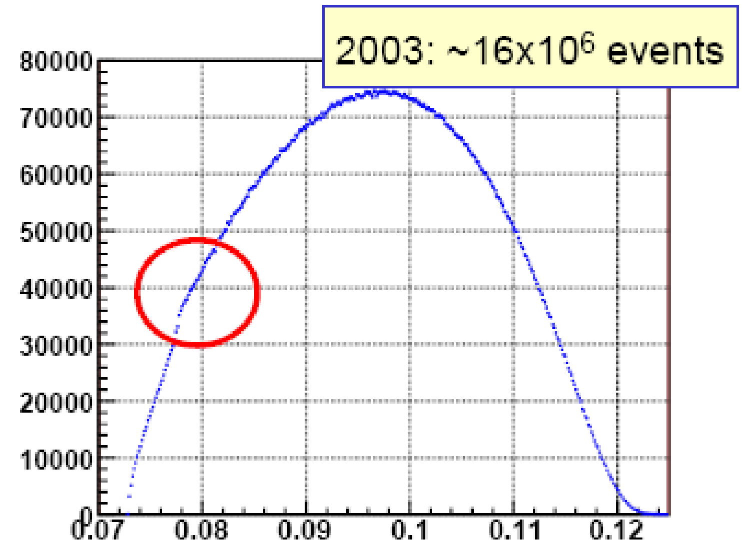
Cusp effect in $K^{\pm} \rightarrow \pi^0\pi^0\pi^{\pm}$

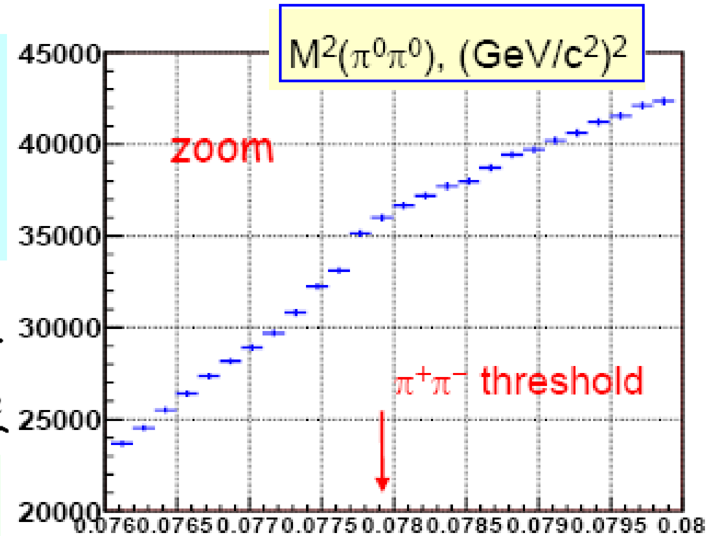
Thanks to:

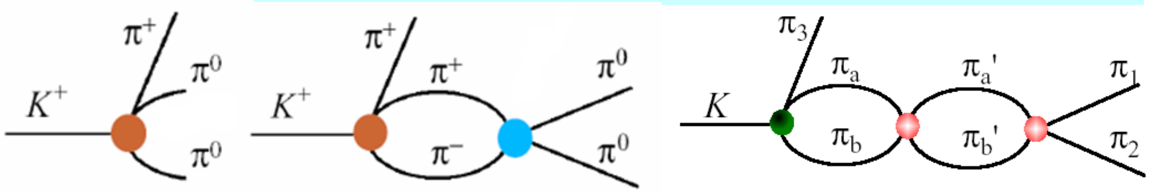
- ✓Very high statistics,
- ✓Very good calorimeter resolution
- ✓Proper M_{00} reconstruction strategy

The $\pi^0\pi^0$ invariant mass distribution shows a **cusp-like anomaly** in the $M_{00}^2 = 4m_{\pi^{\pm}}^2$ region

interpreted as due to the final state charge exchange scattering process $\pi^+\pi^- \rightarrow \pi^0\pi^0$ in $K^{\pm} \rightarrow \pi^{\pm}\pi^+\pi^-$ decays



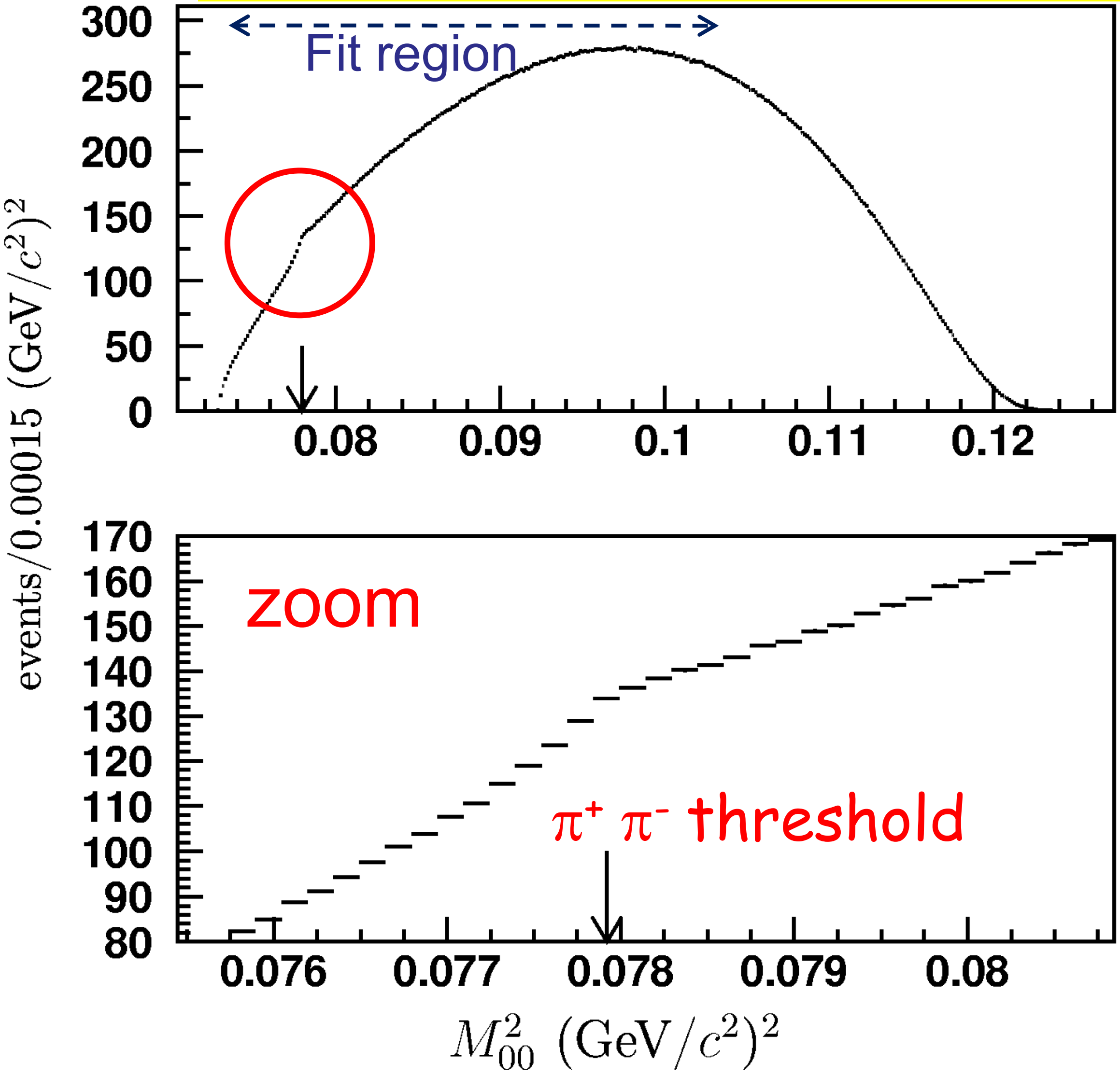




Statistic increased from 16M (2003) (Batley et al., Phys. Lett. B 633 (2006) 173) to 60 M (adding 2004) (paper submitted to EPJ)

Cusp effect in $K^{\pm} \rightarrow \pi^0\pi^0\pi^{\pm}$

2003 & 2004 : ~ 60.31 millions events



Fit region is chosen to reach a minimum total error (systematic contribution grows with upper M^2_{00}).

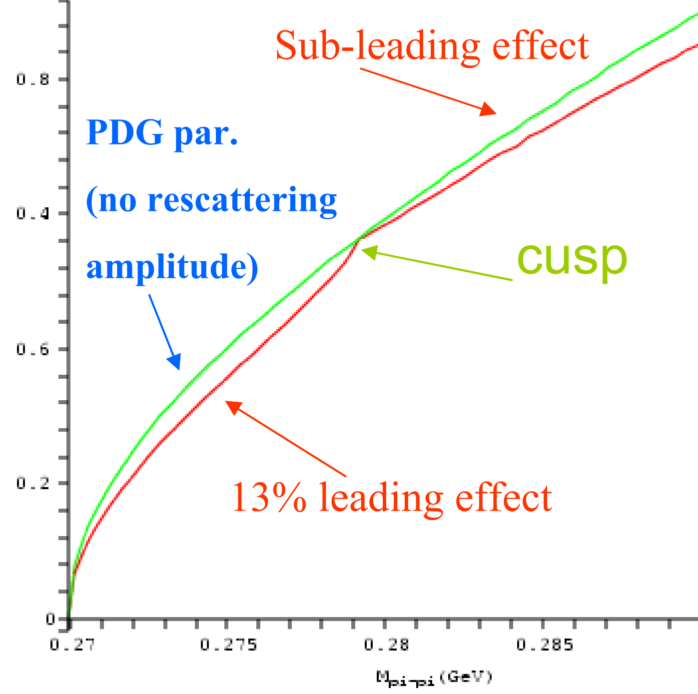
Use 226 bins (instead of 176 as was in our first cusp paper (2006)).

Cusp effect - results

Two approaches to the fitting procedure:

Cabibbo-Isidori → rescattering model
JHEP 0503(2005)

Bern-Bonn → effective field theory
CGKR PLB 638(2006)
BFGKR NPB 806(2009)



a_2 free:

CI $a_0-a_2 = 0.248 \pm 0.005_{stat} \pm 0.002_{syst} \pm 0.001_{ext} \pm 0.009_{theor}$
$a_2 = -0.009 \pm 0.009_{stat} \pm 0.007_{syst} \pm 0.001_{ext} \pm 0.015_{theor}$

BB $a_0-a_2 = 0.257 \pm 0.005_{stat} \pm 0.002_{syst} \pm 0.001_{ext} \pm 0.009_{theor}$
$a_2 = -0.024 \pm 0.013_{stat} \pm 0.009_{syst} \pm 0.002_{ext} \pm 0.015_{theor}$

Using Chiral Perturbation Theory Constraint:

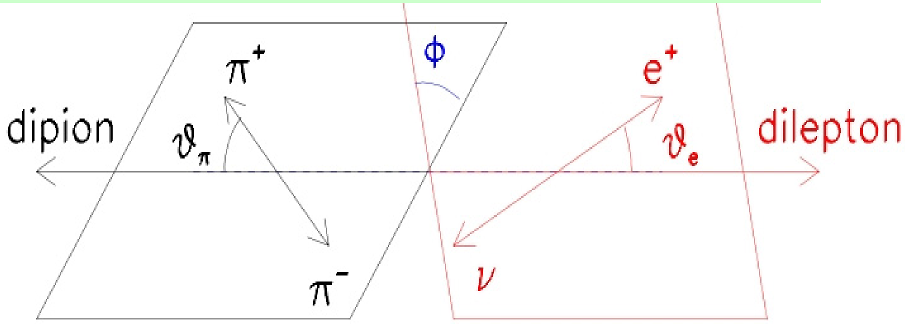
CI $a_0-a_2 = 0.265 \pm 0.002_{stat} \pm 0.001_{syst} \pm 0.002_{ext} \pm 0.005_{theor}$
$(a_0 = 0.2203,\ a_2 = -0.0443)$

BB $a_0-a_2 = 0.263 \pm 0.002_{stat} \pm 0.001_{syst} \pm 0.002_{ext} \pm 0.005_{theor}$
$(a_0 = 0.2186,\ a_2 = -0.0447)$

Ke4 - analysis

$K^{\pm} \rightarrow \pi^{+} \pi^{-} e^{\pm} \nu$ decay used to measure

- Form Factors of the hadronic current (F, G, H)
- s and p-wave $\pi\pi$ scattering phase difference $\delta = \delta_s - \delta_p$
- $\pi\pi$ s-wave scattering lengths a_0 and a_2



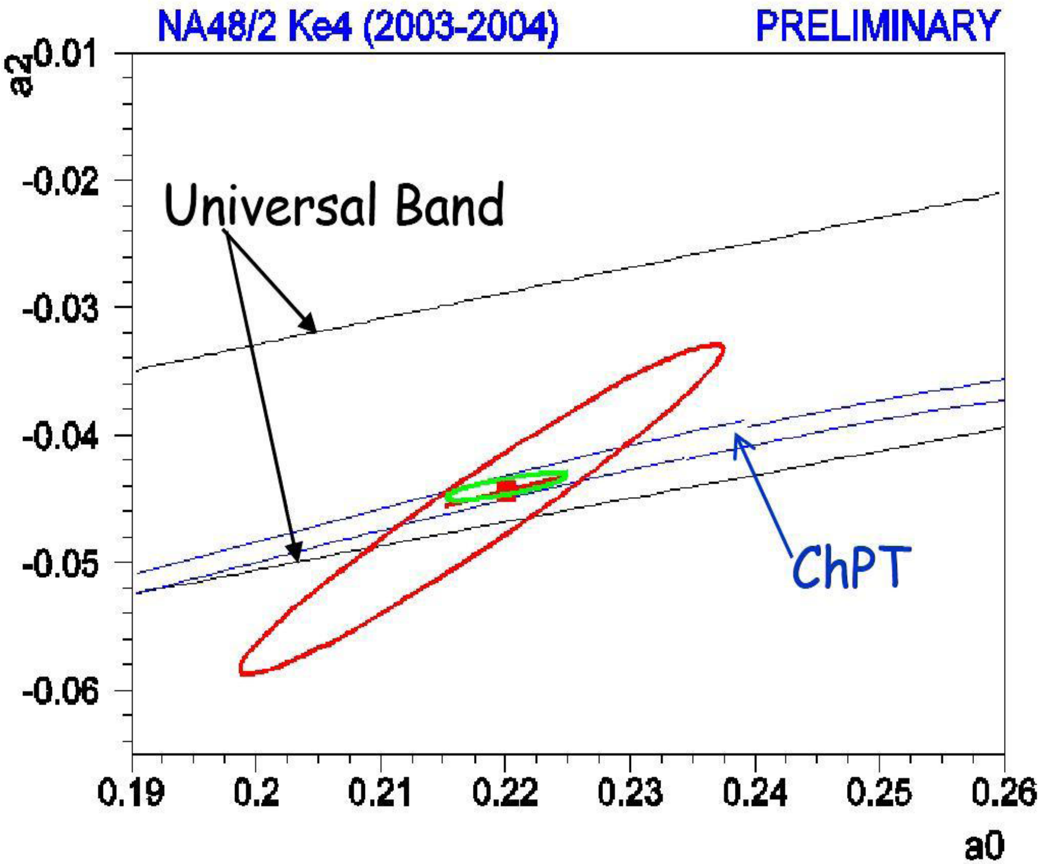
The measurement exploits

- the asymmetry of the dilepton system wrt the dipion system
- dispersion relation based on general properties like analyticity, unitarity and crossing symmetry (Roy equations)
- analytical properties of $\pi\pi$ scattering amplitudes and Roy equations allow to establish a relation between the phase shift δ and the scattering lengths a_0 and a_2

Measurement performed using minimization and fitting procedures

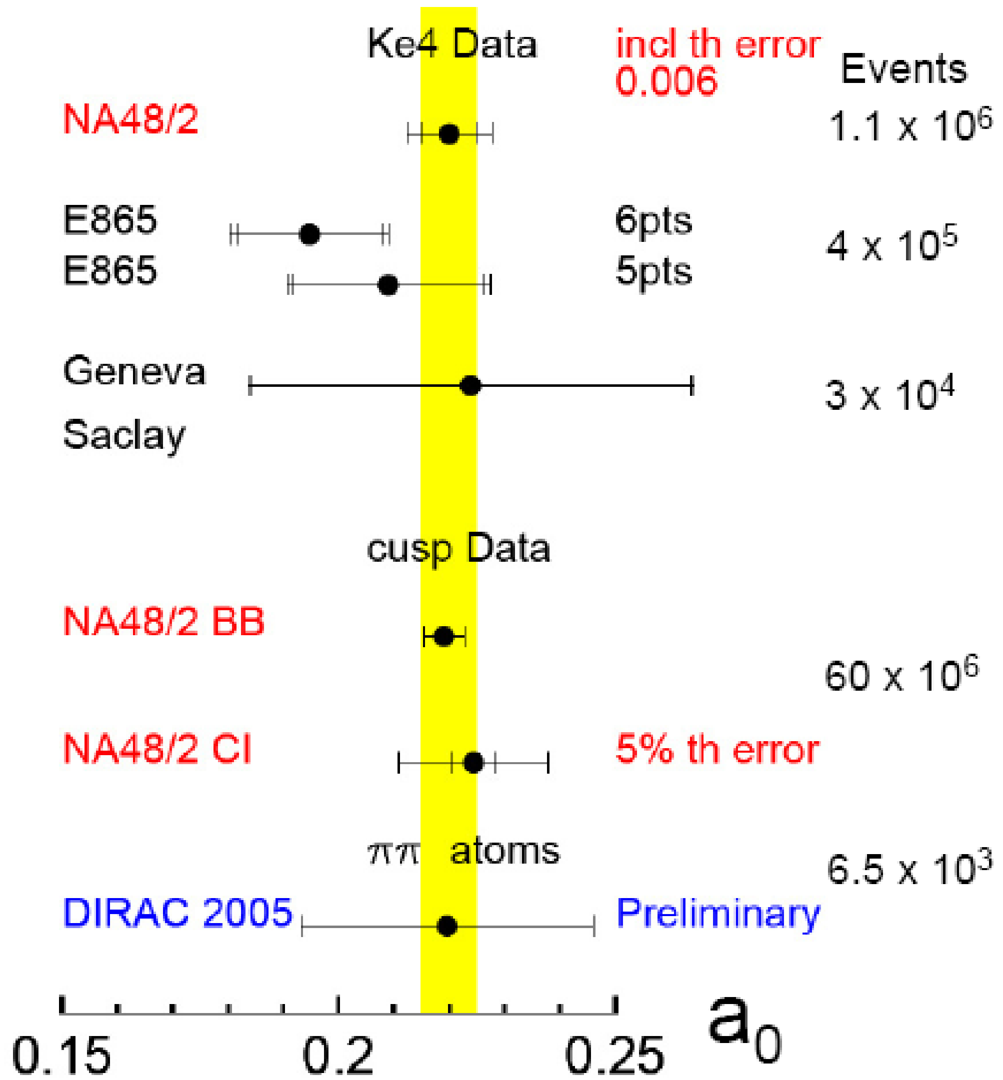
Ke4 - a_0 and a_2 results

1p fit (ChPT)	
a_0	$0.2206 \pm 0.0049_{stat} \pm 0.0018_{syst} \pm 0.0064_{theor}$
2p fit	
a_0	$0.2220 \pm 0.0128_{stat} \pm 0.0050_{syst} \pm 0.0037_{theor}$
a_2	$-0.0432 \pm 0.0086_{stat} \pm 0.0034_{syst} \pm 0.0028_{theor}$



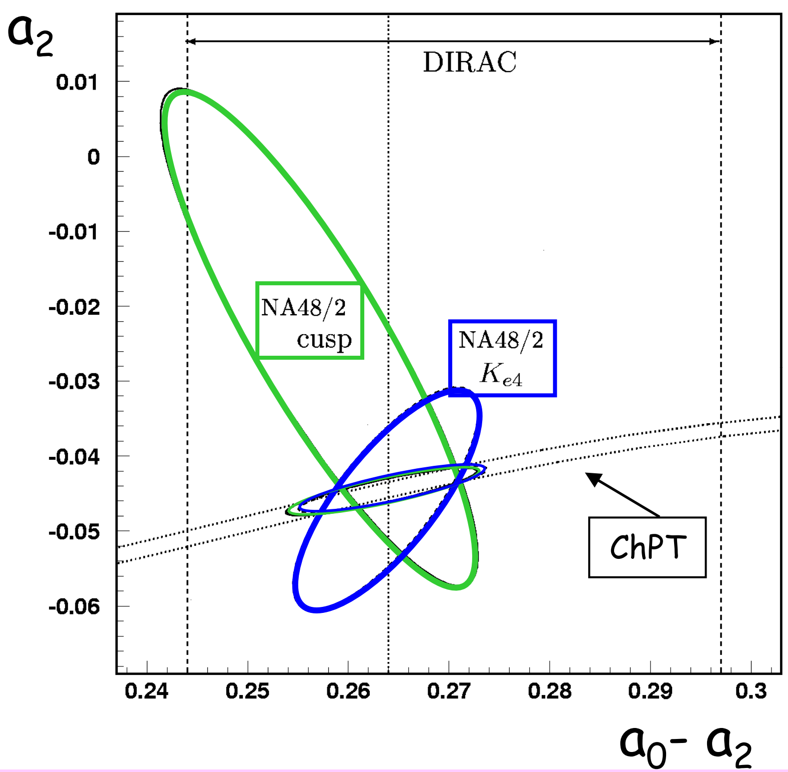
Precise ChPT prediction, CGL NPB 603(2001), PRL86(2001)
$a_0 = 0.220 \pm 0.005$ and $a_2 = -0.0444 \pm 0.0008$
or $(a0 - a2) = 0.265 \pm 0.005$

Ke4 and Cusp a_0 results



Cusp and Ke4 - scattering lengths results

- ✓Two statistically independent measurements by NA48/2:
  60 M K3π ; 1.13 M Ke4
- ✓ Different systematics:
  Cusp: calorimeter and trigger
  Ke4: electron misID and background
- ✓ Different theoretical inputs:
  Cusp: rescattering in final state and ChPT expansion
  Ke4: Roy equation and isospin breaking connection

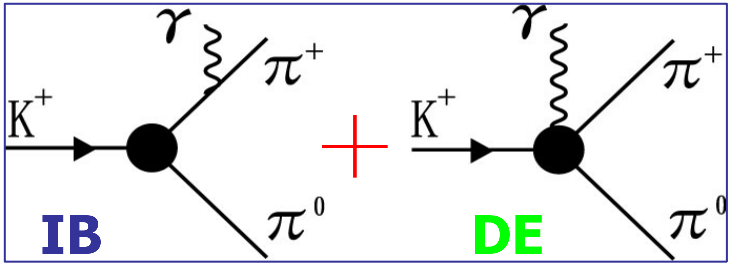


- ✓ Large overlap in the (a_0-a_2, a_2) plane
- ✓ Impressive agreement with ChPT predictions
- ✓ Also shown DIRAC results: $|a_0-a_2|$ extracted from pionium lifetime PLB619(2005)

- ✓ Cusp effect in $K_L \rightarrow \pi^0 \pi^0 \pi^0$ KTeV ($68 \cdot 10^6$) [PRD 78, 032009 (2008)]
  NA48 ($100 \cdot 10^6$) work in progress

$K^{\pm} \rightarrow \pi^{\pm} \pi^{0}\gamma$ rare decay

Theoretical framework and motivation



Lorentz invariant $W^2 = \frac{(P_K^* \cdot P_\gamma^*)(P_\pi^* \cdot P_\gamma^*)}{(m_k m_\pi)^2}$

DE can occur via electric and magnetic dipole transitions $\mathbf{X_E}$ and $\mathbf{X_M}$

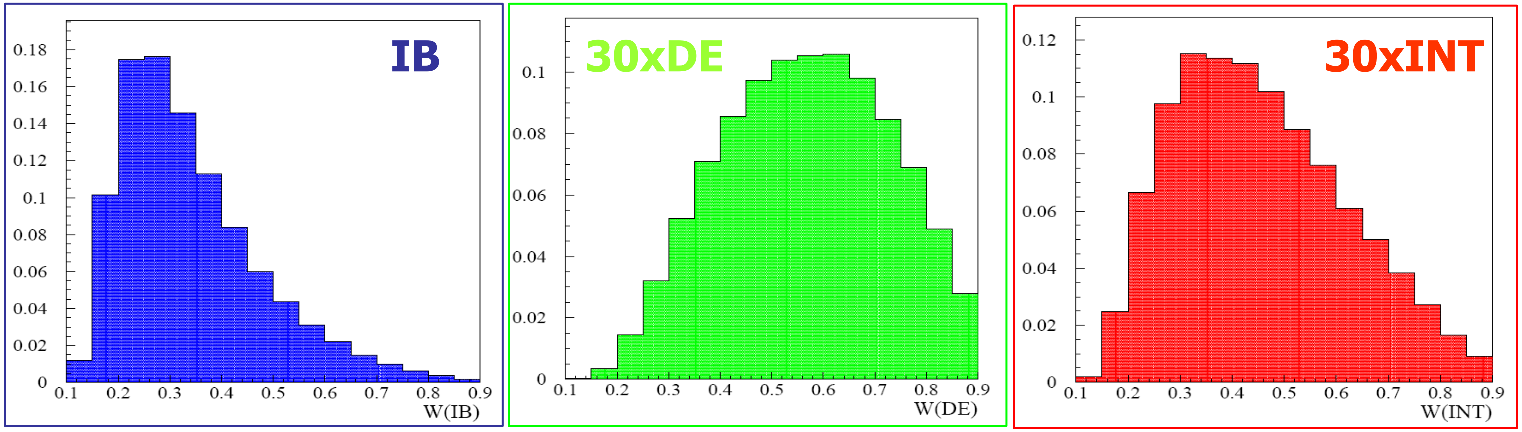
Differential rate

$$\frac{\partial \Gamma^{\pm}}{\partial W} = \frac{\partial \Gamma^{\pm}_{IB}}{\partial W}\left[1 + 2\cos(\pm\phi + \delta_1^1 - \delta_0^2)\, m_\pi^2 m_K^2 \,|X_E|\, W^2 + m_\pi^4 m_K^4 \left(|X_E|^2 + |X_M|^2\right) W^4\right]$$

IB **INT** **DE**

Inner Bremsstrahlung(IB)	:	**BR = $(2.75\pm0.15)\cdot10^{-4}$ PDG ($55<T^*_\pi<90$ MeV)**
Direct Emission (DE)	:	**BR = $(4.3\pm0.7)\cdot10^{-6}$ PDG ($55<T^*_\pi<90$ MeV)**
Interference (INT)	:	**not yet measured**

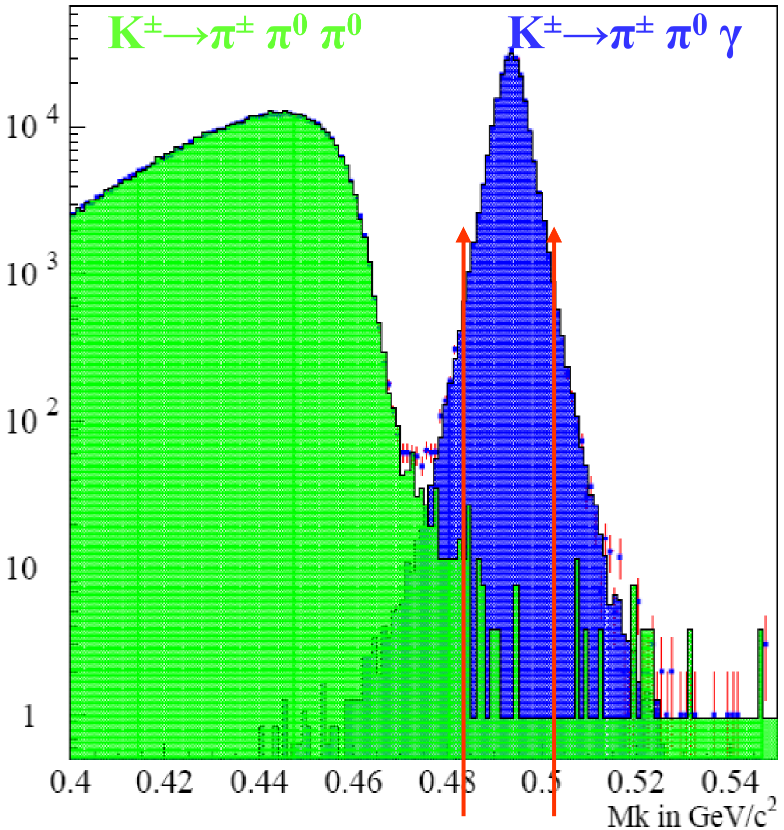
Very different distributions!



Event reconstruction and signal region

- **NA48/2 measurement of $K^{\pm} \rightarrow \pi^{\pm} \pi^{0} \gamma$ decay**

- both K^{+} and K^{-} present in the beam: possibility to study CP violating effects
- Enlarged T^{*}_{π} region in the low energy part ($0 < T^{*}_{\pi} < 80$ MeV) wrt previous experiments
- Background contribution <1% wrt DE, mainly $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\pi^{0}$
- W resolution better than $1\text{x}10^{-2}$
- Order ‰ γ mistagging prob. for IB, DE and INT
- Fit performed with both polynomial and likelihood techniques



- **High statistics:**

- **More than 1 M reconstructed events**
 (the full number is used for the CPV measurements)
- **After a cut on W [0.2, 0.9] and on E_{γ} (> 5GeV), still 600 k events left in the region $M_K \pm 10$ MeV for the measurement of DE and INT fraction**

Fitting techniques and fit results

- Extended Maximum Likelihood Fit *(main method)*

- An algorithm assigns weights to MC W distributions of the 3 components to reproduce data

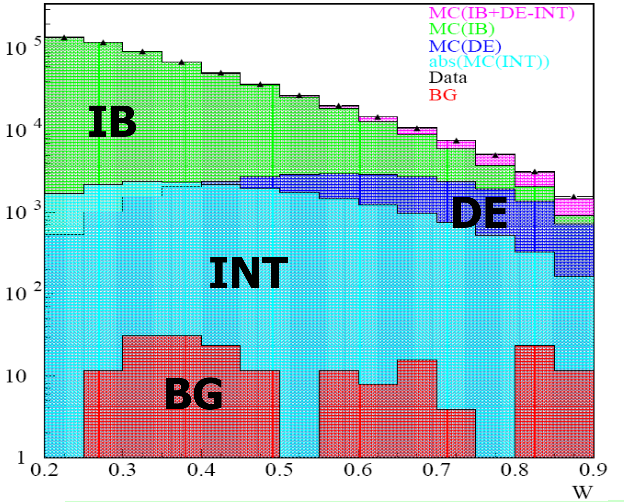
$$Data(i) = (1-\alpha-\beta)\cdot IB(i) + \alpha\cdot DE(i) + \beta\cdot INT(i)$$

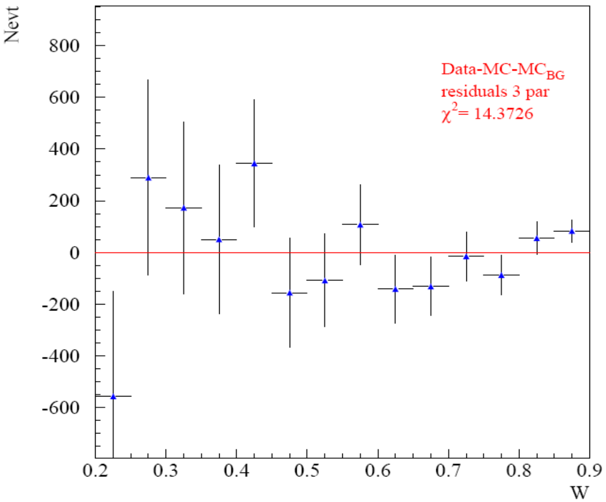
- This algorithm relies on the very different W distributions

- Polynominal Fit *(used as cross-check)*

- The ratio W(Data)/W(IBMC) is fitted
  with polynomial function: $F = c\cdot(1 + aW^2 + bW^4)$

Systematics	DE x 10^{-2}	INT x 10^{-2}
Acceptance	<0.10	<0.15
L1trigger	0.01	0.03
L2 trigger	--	0.30
Energy scale	0.09	0.21
Total	0.14	0.39





INT has never been observed before!

Final result (2003+2004):

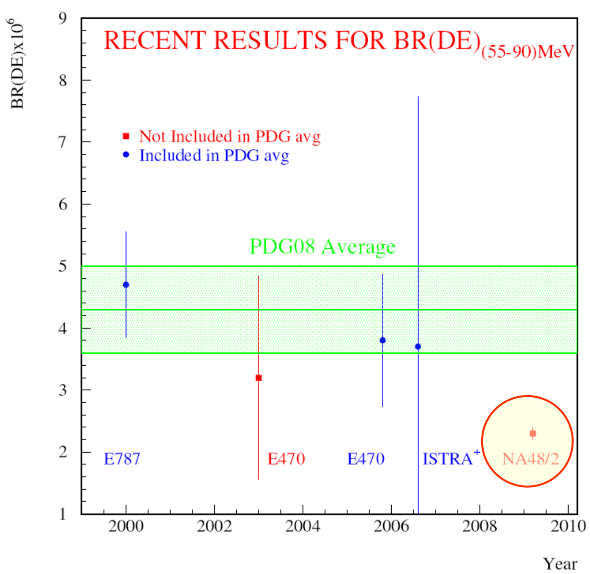
$$Frac(DE)_{T^*\pi(0-80)MeV} = \%DE / \%IB = (3.32 \pm 0.15_{stat} \pm 0.14_{sys})*10^{-2}$$

$$Frac(INT)_{T^*\pi(0-80)MeV} = \%INT / \%IB = (-2.35 \pm 0.35_{stat} \pm 0.39_{sys})*10^{-2}$$

Comparison with previous experiments

The BR(DE) assuming INT=0 (T_π*= 55-90) MeV polynomial fit technique

- **BR(DE) $_{T^*\pi(55\text{-}90)MeV}$ = $(2.32 \pm 0.05_{stat} \pm 0.077_{sys}) \cdot 10^{-6}$**
- **PDG08$_{avg}$ = $(4.3 \pm 0.7) \cdot 10^{-6}$**
- **Bad χ^2 probability of the polynomial fit: indicates that INT=0 is a wrong assumption**



$K^\pm \to \pi^\pm \pi^0 \gamma$ – first extraction of X_E X_M

Under the following approximations:

$\phi = 0$ and $\cos(\delta_1^1 - \delta_0^2) = \cos(6.5°) \sim 1$

X_E and X_M can be extracted using the formulae:

$$X_E = \frac{Frac(INT)}{2 \cdot (0.105 \cdot m_K^2 m_\pi^2)}$$

$$X_M = \sqrt{\frac{Frac(DE) - m_K^4 m_\pi^4 \, |X_E|^2 \, 2.27 \cdot 10^{-2}}{2.27 \cdot 10^{-2} \cdot m_K^4 m_\pi^4}}$$

Magnetic and electric components

$X_E = (-24 \pm 4_{stat} \pm 4_{sys})$ GeV^{-4}

$X_M = (254 \pm 11_{stat} \pm 11_{sys})$GeV^{-4}

WZW reducible anomaly prediction for $X_M \sim 260$ Gev^{-4}

$K^\pm \to \pi^\pm \pi^0 \gamma$ – CPV parameters measurements: asymmetry and ϕ angle: compatible with 0

$K^{\pm} \rightarrow \pi^{\pm} \gamma^{*} \rightarrow \pi^{\pm} l^{+} l^{-}$ rare decays

Theoretical framework and motivation

- **NA48/2 measurement of $K^{\pm} \rightarrow \pi^{\pm} \gamma^* \rightarrow \pi^{\pm} l^+ l^-$ decay**

$$d\Gamma_{\pi ee}/dz \sim \rho(z) \cdot |W(z)|^2$$

$z=(M_{ee}/M_K)^2$, $\rho(z)$ phase space factor

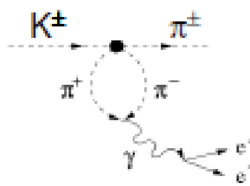
- suppressed FCNC processes
- one-photon exchange
- useful test for ChPT

(1) polynomial: $W(z) = G_F M_K^2 \cdot f_0 \cdot (1+\delta z)$

(2) ChPT $O(p^6)$: $W(z) = G_F M_K^2 \cdot (a_+, b_+, z) + W^{\pi\pi}(z)$

(3) ChPT, large-Nc QCD: $W(z) = W(w, \beta, z)$

(4) Mesonic ChPT: $W(z) = W(M_a, M_\rho, z)$



(2) D'Ambrosio et al. JHEP 8 (1998) 4
(3) S. Friot et al. PLB 595 (2004) 301
(4) Dubnickova et al. hep-ph/0611175

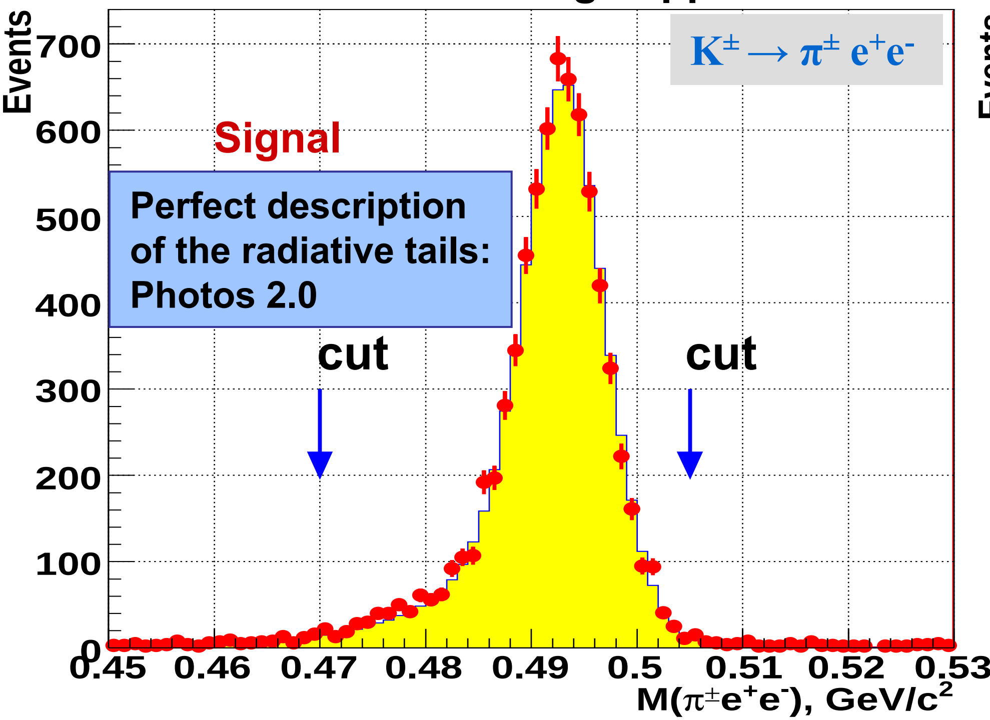
(f_0, δ) or (a_+, b_+) or (w, β) or (M_a, M_ρ) determine a model-dependent BR

- Parameters of models and BR in full kinematical range
- Model-independent BR ($z > 0.08$) in visible kinematical range

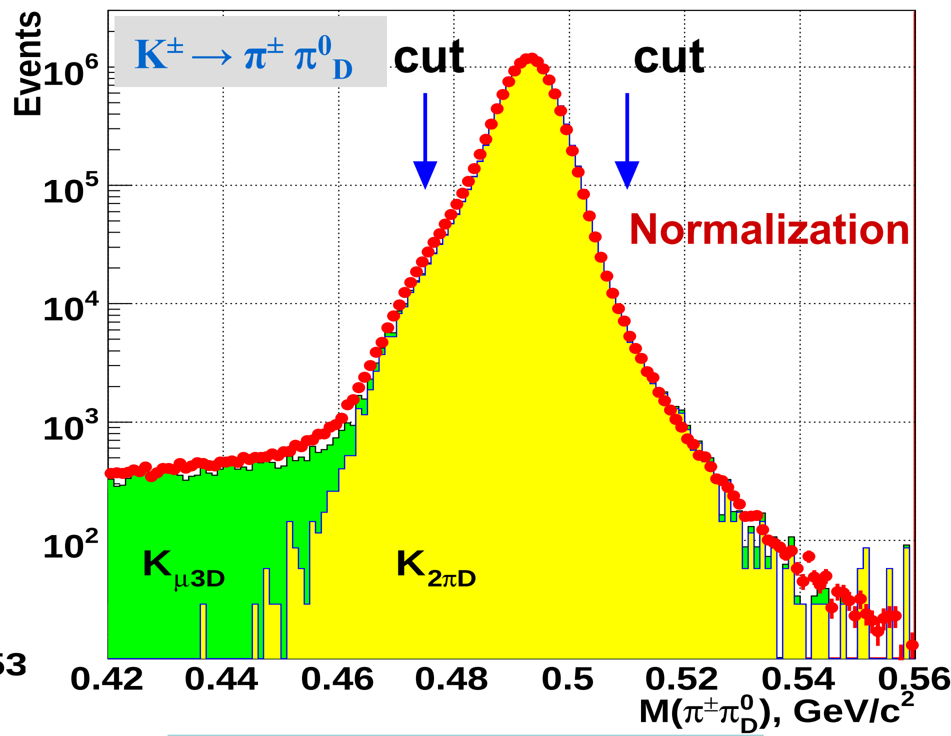
$K^\pm \to \pi^\pm e^+ e^-$ - Signal and normalisation sample

Selections of both channels based on very similar conditions: systematics (trigger, PID) in the BR ratio cancel particially

- **Mee > 140 MeV – cut for bg suppression**



- **Additional γ in the normalisation channel**



7253 candidates
BG: 71 events estimated
with data BG/SIG. ~ 1.0%

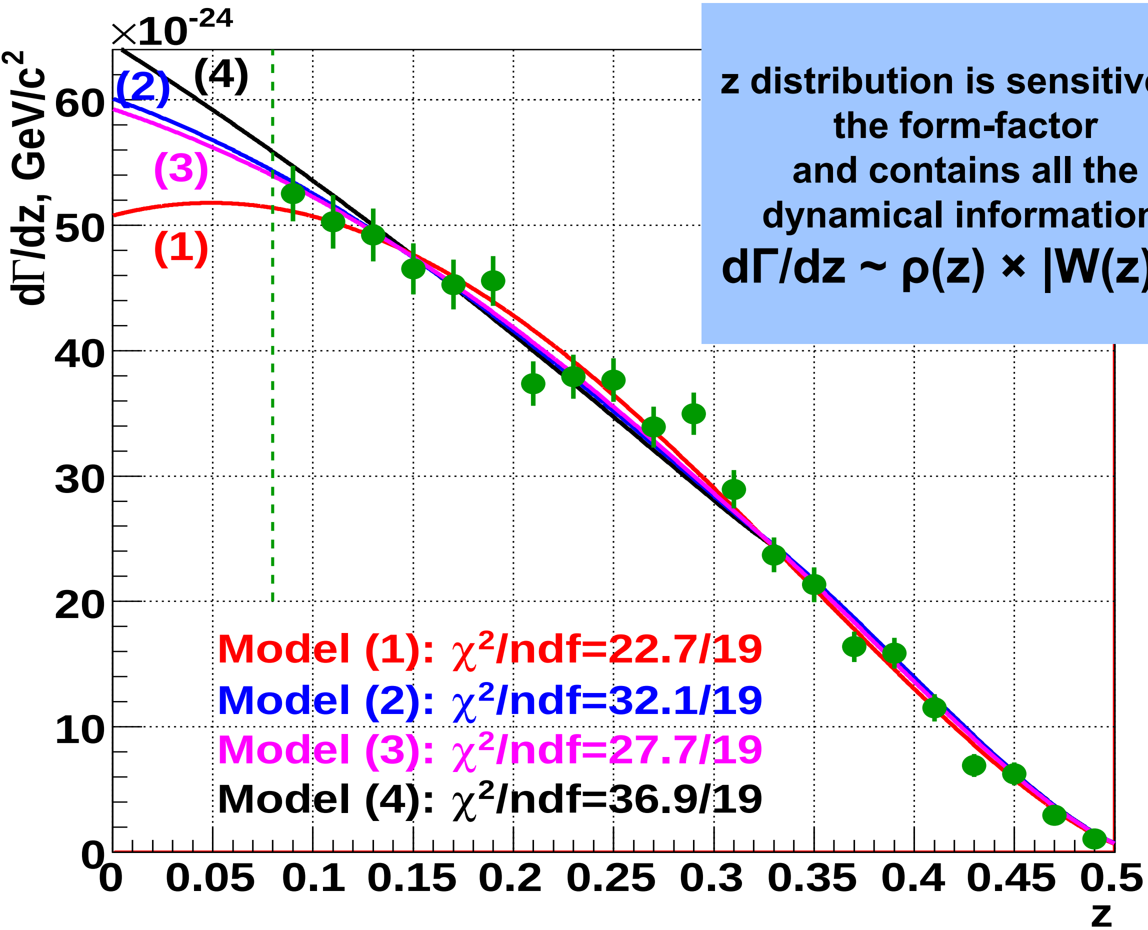
12.12 M candidates
BG/Signal ~ 0.15%
BG subtracted with MC

Kaon decay flux (2003+2004): Φ_K=1.70×10^{11} with Flavianet'08 $K^\pm \to \pi^\pm\pi^0$ BR

$K^{\pm} \rightarrow \pi^{\pm}e^{+}e^{-}$ - form factor measurement

GOALS

- Model-independent BR integrating dΓ/dz in the observable z region
- Model dependent BRs using fit parameters.
- All models agree reasonably well with data



z distribution is sensitive to the form-factor and contains all the dynamical information:

$$d\Gamma/dz \sim \rho(z) \times |W(z)|^2$$

Fit results

$\delta = 2.32 \pm 0.18_{stat+syst}$

$|f_0| = 0.531 \pm 0.016_{stat+syst}$

$a_+ = -0.578 \pm 0.016_{stat+syst}$

$b_+ = -0.779 \pm 0.066_{stat+syst}$

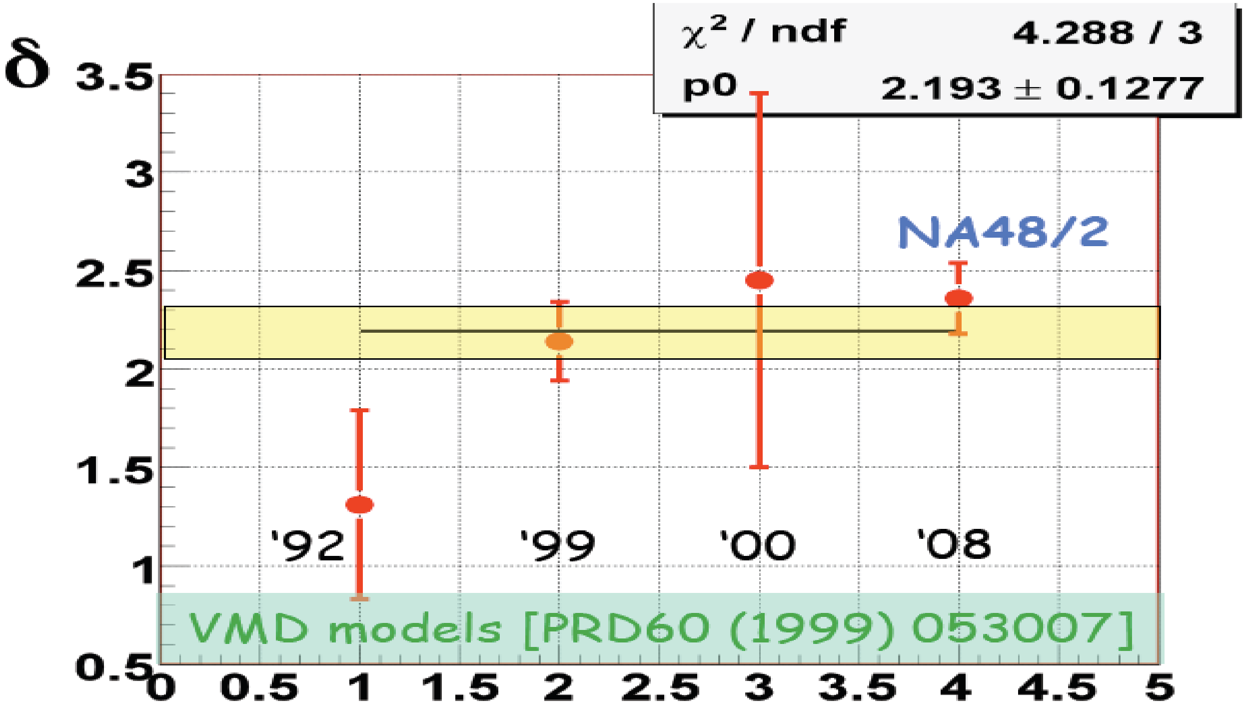
$w = 0.057 \pm 0.007_{stat+syst}$

$\beta = 3.45 \pm 0.30_{stat+syst}$

$M_a = 0.974 \pm 0.035_{stat+syst}$ GeV

$M_\rho = 0.716 \pm 0.014_{stat+syst}$ GeV

$K^{\pm} \longrightarrow \pi^{\pm} e^{+} e^{-}$ - Results



Form Factor δ	Process δ	value
Alliegro et al	K+→π+e+e–	1.31±0.48
Appel et al.[E865]	K+→π+e+e–	2.14±0.20
Ma et al.[E865]	K+→π+μ+μ–	2.45+1.30–0.95
NA48/2	K±→π±e+e–	2.32±0.18

$K^{\pm} \rightarrow \pi^{\pm}e^{+}e^{-}$ - Results

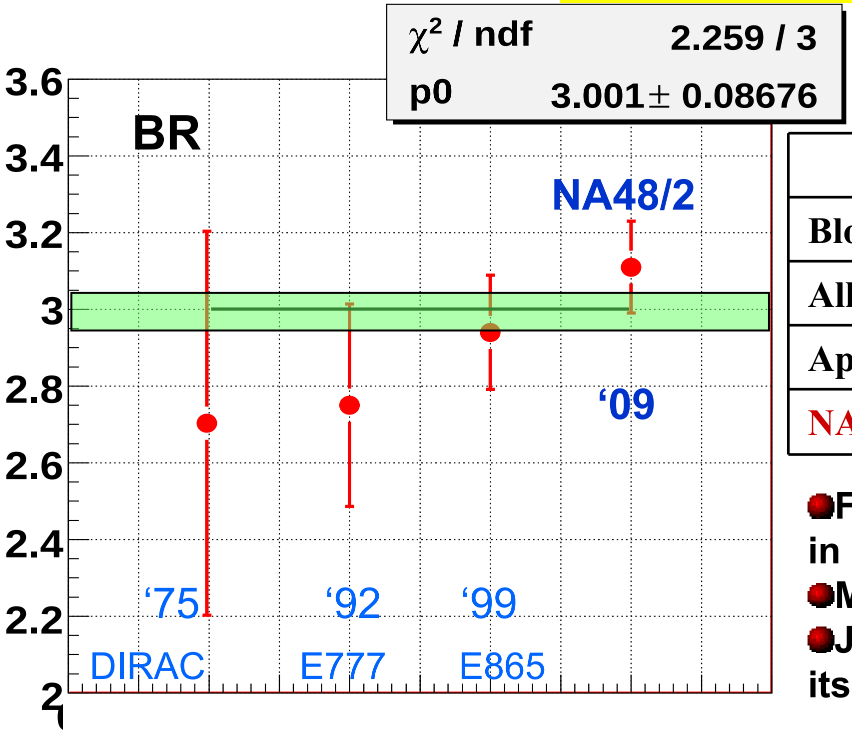
$BR_{mi}\times10^{7}$ ($M_{ee}>140 MeV/c^{2}$) $= 2.28 \pm 0.03_{stat} \pm 0.04_{syst} \pm 0.06_{ext} = 2.28 \pm 0.08$

Combined result of the 4 models

$BR = (3.11\pm0.04_{stat}\pm0.05_{syst}\pm0.08_{ext}\pm 0.07_{model})\times10^{-7} = (3.11\pm0.12)\times10^{-7}$

CP violating asymmetry (first measurement! correlated K^{+}/K^{-} uncertainties excluded):

$\Delta(K^{\pm}_{\pi ee}) = (BR^{+}-BR^{-}) / (BR^{+}+BR^{-}) = (-2.2\pm1.5_{stat}\pm0.6_{syst})\%$

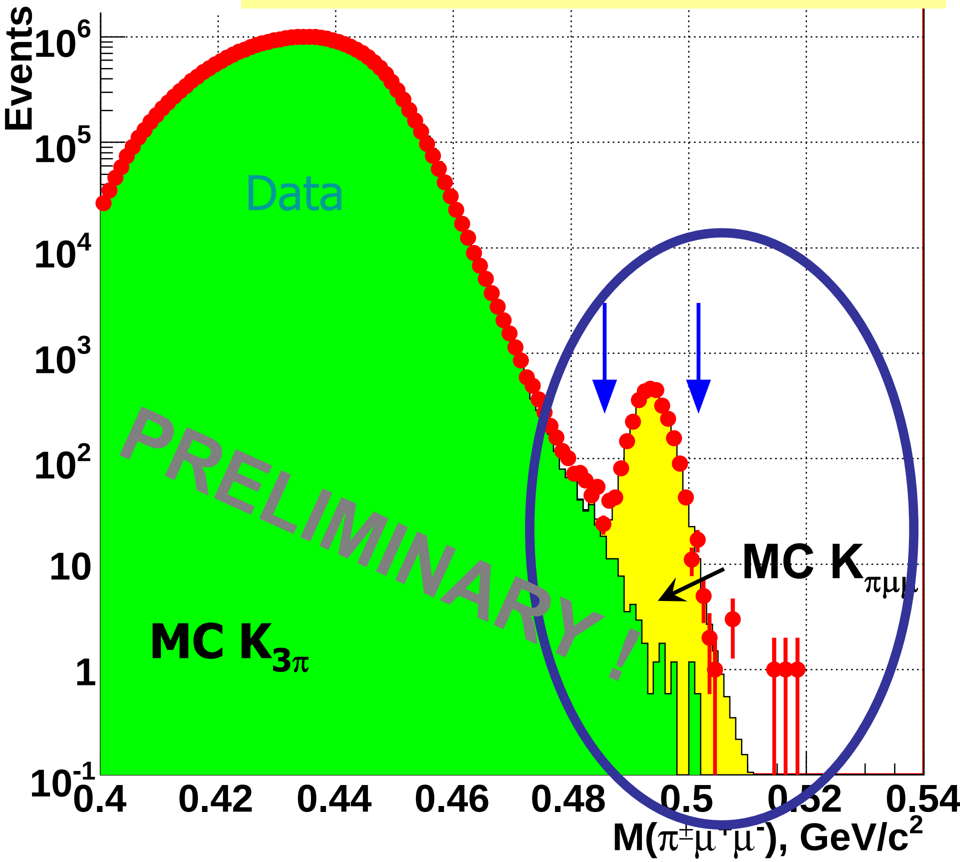


Measurement	events	$BR\times10^{7}$
Bloch et al., PL 56 (1975) B201	(41)	2.70±0.50
Alliegro et al.[E777], PRL 68 (1992) 278	(500)	2.75±0.26
Appel et al. [E865], PRL 83 (1999) 4482	(10000)	2.94±0.15
NA48/2 final (2009)	(7253)	3.11±0.12

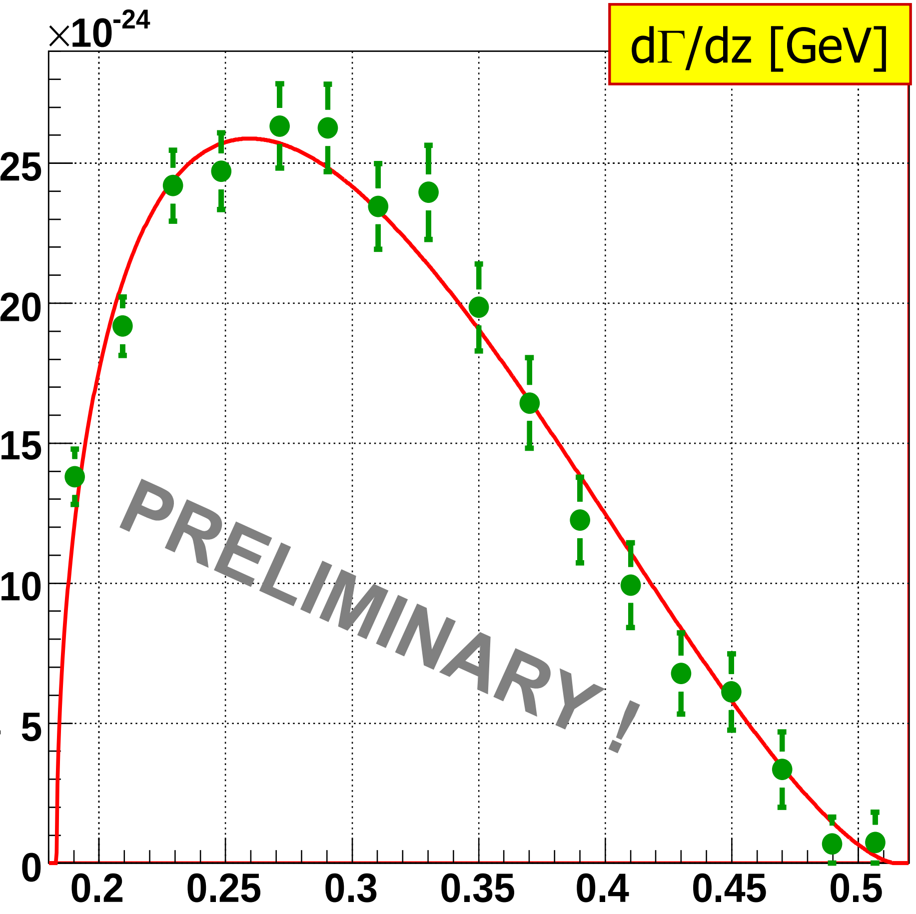
- Form factor measurements for Model 1, 2 and 3* in agreement with previous measurements
- Model 4 – never tested before
- J.Prades, e-Print: arXiv:0707.1789 [hep-ph], predicts (up to its sign) $a_{+} = -(0.6\ ^{+0.6}_{-0.23})$, in agreement with our result

*fit done by the authors of Model 3 using BNL E865 data

$K^{\pm} \to \pi^{\pm}\mu^{+}\mu^{-}$ - Signal region and fit



Fit to the linear form-factor



~3100 reconstructed events in the signal region:
4 times larger sample than the existing world statistics!

Conclusions on QCD tests in NA48/2

$\pi\pi$ scattering lengths in Ke4 and K3π

- NA48/2 has recorded and analyzed $1.15 \cdot 10^6$ Ke4 and $60 \cdot 10^6$ K3π events
- $\pi\pi$ scattering lengths results from Ke4 and K3π are fully consistent
- the experimental results are in very good agreement with ChPT
- the achieved experimental precision on a_0 is now competitive with the theoretical precision (± 0.005) in both decay modes

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

- Precise measurement of DE contribution and first measurement of INT term
- Extraction of XM and XE values
- The BR(DE), assuming INT=0 (55-90) MeV, gives bad $\chi 2$ fit
- Measurements of CPV parameters
- Final result, paper in preparation

$K^\pm \to \pi^\pm e^+ e^-$

- Precision comparable with world's best
- BR and form factor measurements in agreement with ChPT and other measurements
- First limit on CPV asymmetry
- Paper published in PLB

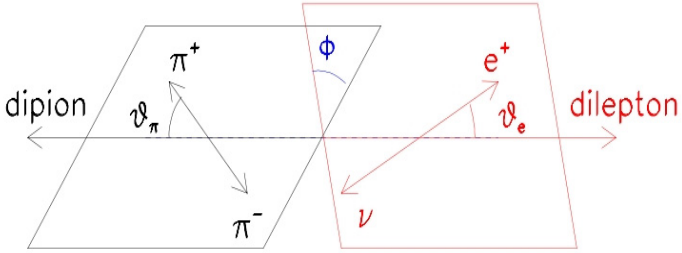
$K^\pm \to \pi^\pm \mu^+ \mu^-$

- Four times larger sample than the existing world statistics has been collected
- Analysis is well advanced. Aim to bless preliminary results this year.

Spares

Ke4 analysis

- Use 5 kinematic variables (Cabibbo-Maksymowicz 1965) S_π ($M^2_{\pi\pi}$), S_e ($M^2_{e\nu}$), $\cos\theta_\pi$, $\cos\theta_e$, ϕ



- partial wave expansion of the amplitudes (s and p)
- → 2 axial form factors (F and G) + 1 vector (H)
- map the 5D space of variables with 4 form factors + 1 phase
- fitting parameters: F_s, F_p, G_p, H_p, $\delta = \delta_s - \delta_p$
- Define iso-populated boxes in the 5-dimension space: $10(M_{\pi\pi})\times5(M_{e\nu})\times5(\cos\theta_p)\times5(\cos\theta_e)\times5(\phi) = 15000$ boxes
- The form factors and phase shift are extracted by minimizing a log-likelihood estimator in 10 independent $M_{\pi\pi}$ bins
- Only relative form factors (F_p/F_s, G_p/F_s, H_p/F_s) are measured (no overall normalization from BR)
- The variation of the form factors with $M_{\pi\pi}$ is then fitted to extract the form factors parameters
- analytical properties of $\pi\pi$ scattering amplitudes and dispersion relations (Roy equations) allow to establish a relation between the phase shift δ and the scattering lengths a_0 and a_2

Ke4 – Form Factors results

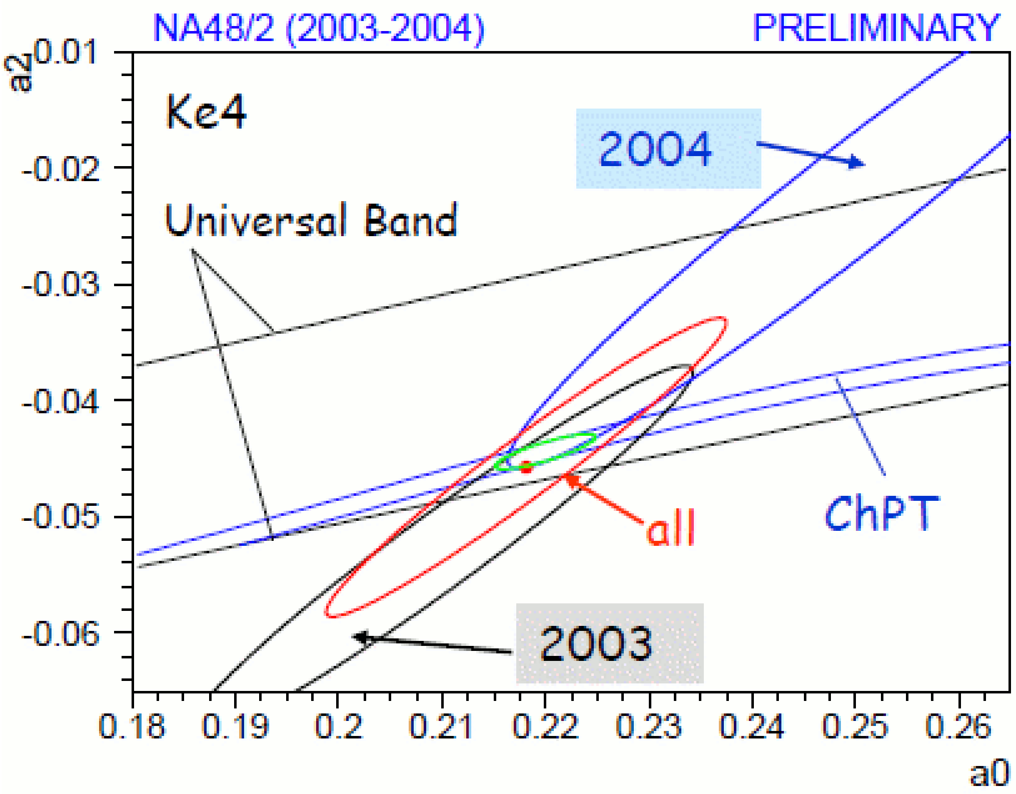
preliminary 2003+ 2004

		stat		syst
f'_s/f_s	= 0.158	± 0.007	±	0.006
f''_s/f_s	=-0.078	± 0.007	±	0.007
f'_e/f_s	= 0.067	± 0.006	±	0.009
f_p/f_s	=-0.049	± 0.003	±	0.004
g_p/f_s	= 0.869	± 0.010	±	0.012
g'_p/f_s	= 0.087	± 0.017	±	0.015
h_p/f_s	= -0.402	± 0.014	±	0.008

Results in agreement with published 2003 data analysis

Ke4 - a_0 and a_2 results

1p fit (ChPT)	
a_0	$0.2206 \pm 0.0049_{stat} \pm 0.0018_{syst} \pm 0.0064_{theor}$
2p fit	
a_0	$0.2220 \pm 0.0128_{stat} \pm 0.0050_{syst} \pm 0.0037_{theor}$
a_2	$-0.0432 \pm 0.0086_{stat} \pm 0.0034_{syst} \pm 0.0028_{theor}$



Precise ChPT prediction, CGL NPB 603(2001), PRL86(2001)

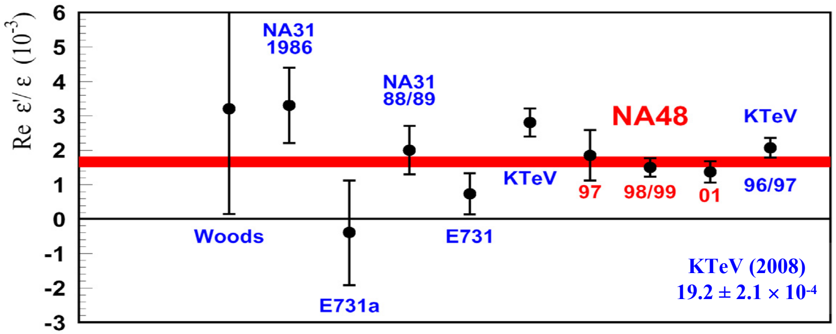
$a_0 = 0.220 \pm 0.005$ and $a_2 = -0.0444 \pm 0.0008$

or $(a0 - a2) = 0.265 \pm 0.005$

The NA48/NA62 experiment

- **NA48 (1997-2001):**
  Direct CP-Violation in neutral K

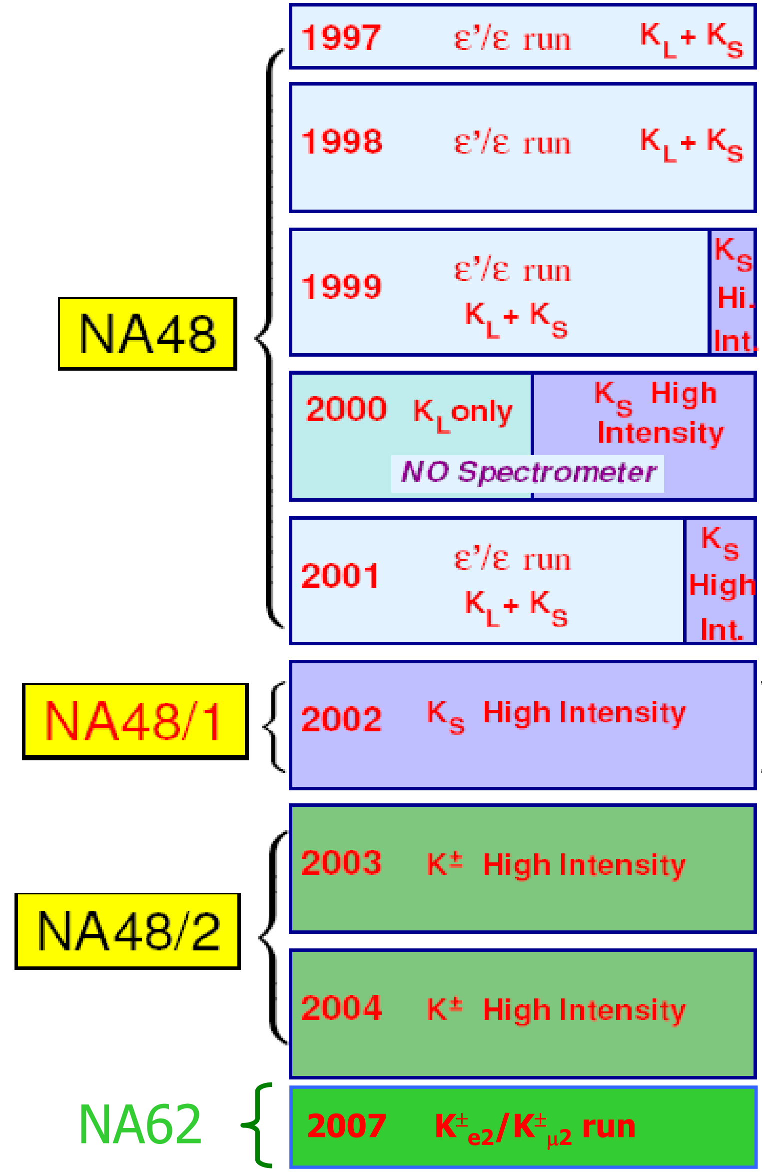
  $Re(\varepsilon'/\varepsilon) = (14.7 \pm 2.2)\cdot 10^{-4}$



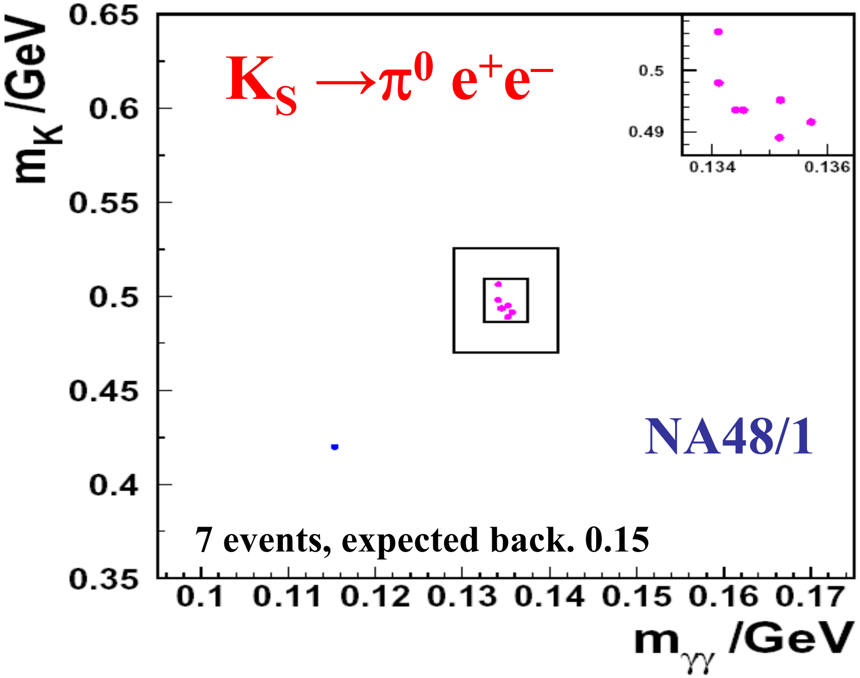
- **NA48/1 (2002):**
  Rare K_S decays and hyperons

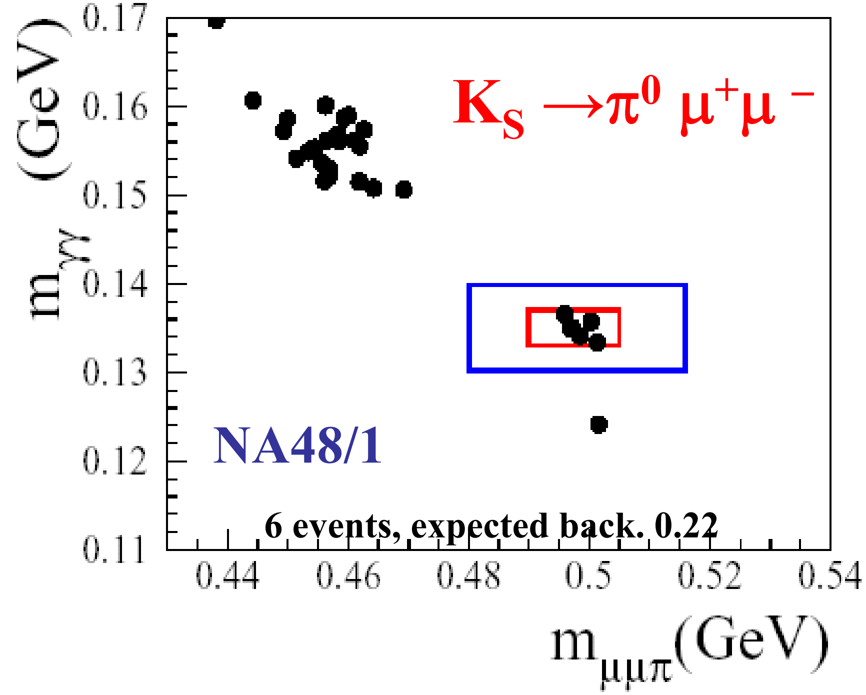
- **NA48/2 (2003-2004):**
  Direct CP-Violation in charged K

- **NA62 (2007-2008) and P326 (2008…):**
  $R(K_{e2}/K_{\mu 2})$, and new experiment $K^+ \rightarrow \pi^+\nu\nu$



$K^0_{S,L} \to \pi^0 e^+e^-$ and $K^0_{S,L} \to \pi^0 \mu^+\mu^-$





$BR(K_L \to \pi^0 ee) = (5.8^{+2.8}_{-2.3}\ \text{stat} \pm 0.8\ \text{syst}) \times 10^{-9}$ NA48/1 PLB 576 (2003)

$BR(K_L \to \pi^0 \mu\mu) = (2.9^{+1.4}_{-1.2}\ \text{stat} \pm 0.2\ \text{syst}) \times 10^{-9}$ NA48/1 PLB 599 (2004)

$BR(K_L \to \pi^0 ee) < 2.8 \times 10^{-10}$ @90%CL *KTeV* PRL93, 021805 (2004)
$BR(K_L \to \pi^0 \mu\mu) < 3.8 \times 10^{-10}$ @90%CL *KTeV* PRL86, 5425 (2001)

$K^0_L \to \pi^0 e^+e^-$ ($\mu^+\mu^-$) in SM

- Using the K_S measurements, the K_L BR can be predicted (extracting the short-distance physics contribution)
- Interference between short and long distance physics

Constructive

$$B_{K^0_L \to \pi^0 e^+ e^-} = 3.7^{+1.1}_{-0.9} \times 10^{-11}$$

$$B_{K^0_L \to \pi^0 \mu^+ \mu^-} = 1.5^{+0.3}_{-0.3} \times 10^{-11}$$

now favored by two independent analyses*

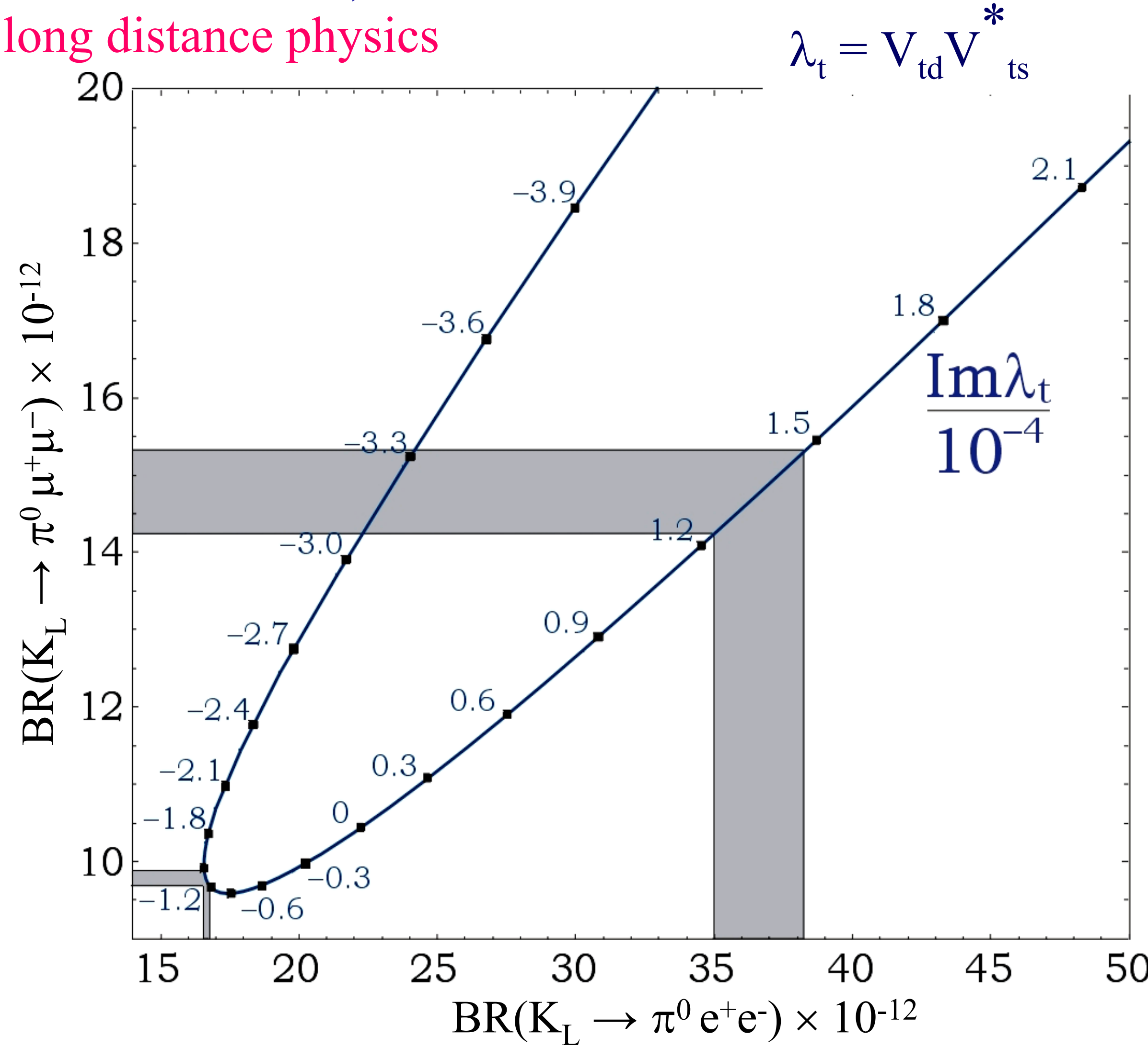
Destructive

$$B_{K^0_L \to \pi^0 e^+ e^-} = 1.7^{+0.7}_{-0.6} \times 10^{-11}$$

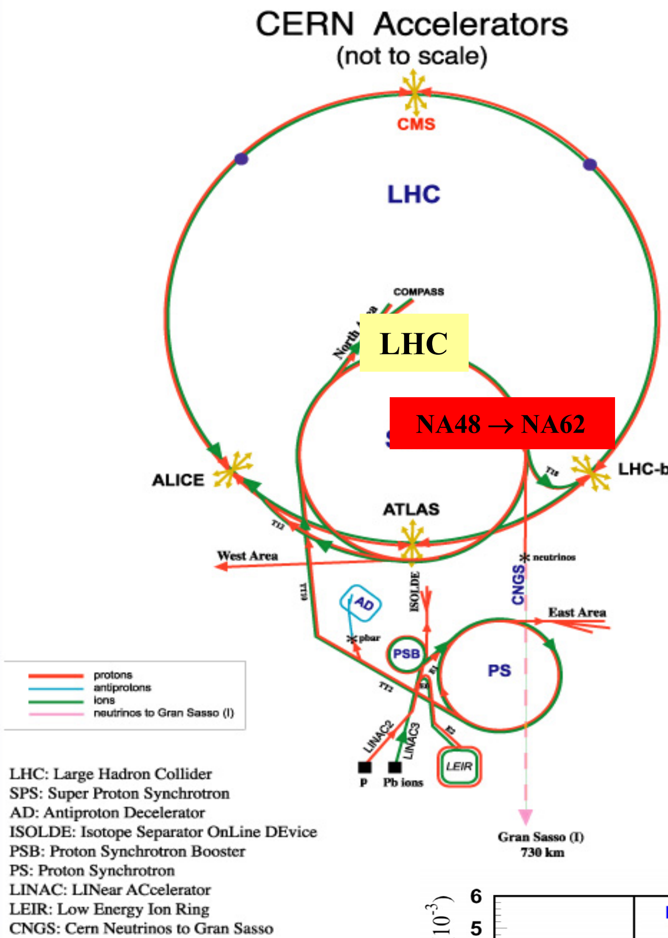
$$B_{K^0_L \to \pi^0 \mu^+ \mu^-} = 1.0^{+0.2}_{-0.2} \times 10^{-11}$$

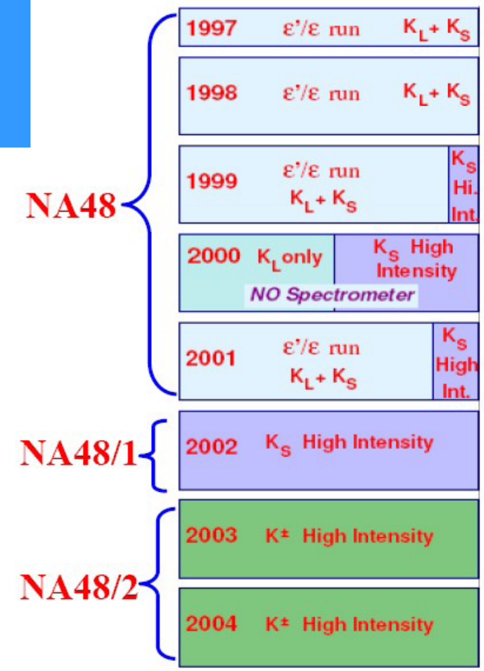
* G. Buchalla, G. D'Ambrosio, G. Isidori, Nucl.Phys.B 672, 387 (2003)

* S. Friot, D. Greynat, E. de Rafael, hep-ph/0404136, PL B 595



The NA62 experiment

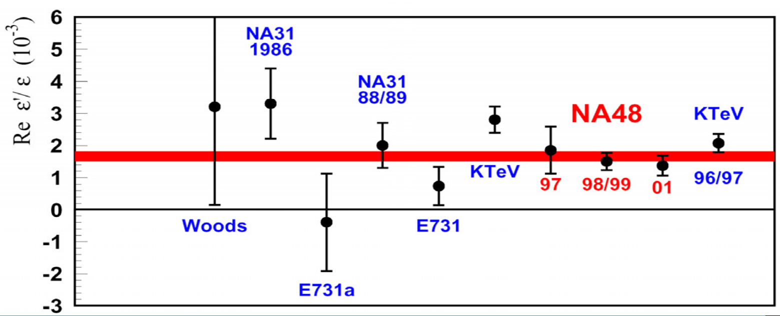




NA62 phase I

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)