Results from NA48/2 and NA62

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on behalf of the NA48/2 and NA62 collaborations

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Outline:

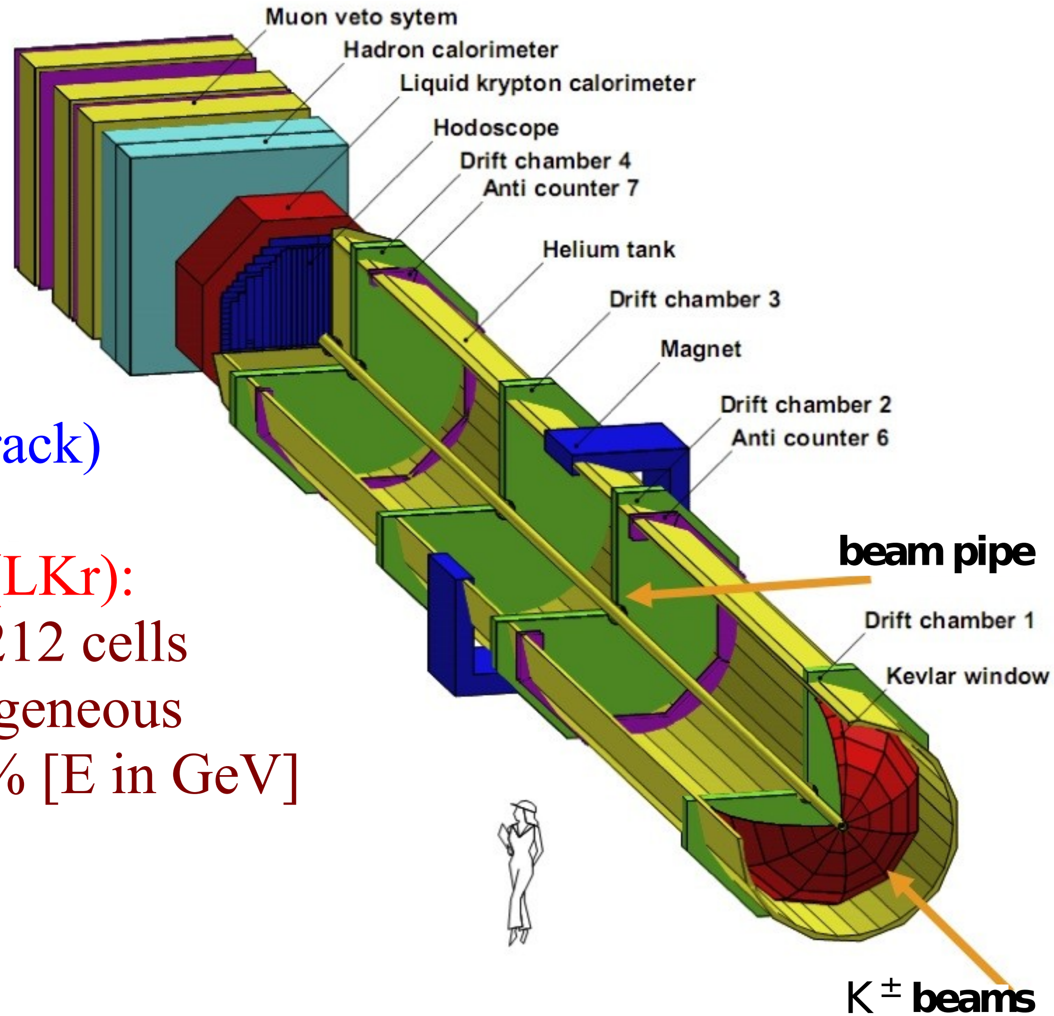
- ✗ The NA48/2 Apparatus
- ✗ R_K final result
- ✗ Chiral Perturbation Theory results
- ✗ $K^{\pm}\rightarrow e^{\pm}\pi^{0}\nu$ and $K^{\pm}\rightarrow \mu^{\pm}\pi^{0}\nu$ Form Factors results
- ✗ Conclusions

The NA48/2 Detector

Magnetic spectrometer (4 DCHs):
4 views: redundancy ⇒ efficiency
$\sigma(p)/p = 1.0\% + 0.044\%\ p$ [GeV/c]

Charged hodoscope (scintillators):
Fast trigger and precise time measurement (~200 ps on single track)

Liquid Krypton E.M. Calorimeter (LKr):
10 m3 (~22 t), 1.25 m (27 X0), 13212 cells
granularity: 2x2 cm2, quasi-homogeneous
$\sigma(E)/E = 3.2\%/\sqrt{E} + 9\%/E + 0.42\%$ [E in GeV]



NA48/2 data taking:

4 months 2003 and 2004
(60±3) GeV/c beam

NA62 data taking:

4 months in 2007 with (74±1.4) GeV/c beam

R_K final result

R_K LFV test

$$R_K = \frac{\Gamma(K^\pm \to e^\pm \nu_e)}{\Gamma(K^\pm \to \mu^\pm \nu_\mu)} = \frac{m_e^2}{m_\mu^2} \cdot \left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2}\right)^2 \cdot (1 + \delta R_{QED})$$

Elicity suppression ~ 10^{-5}

Radiative correction (few %) due to K $\to$ e $\nu\gamma$ (IB) included by definition in the ratio

1) SM value:

R_K = (2.477 ± 0.001) · 10^{-5} [PRL 99 (2007) 231801]

2) Experimental status:

- **R_K = (2.493 ± 0.031) · 10^{-5}** (KLOE [EPJ C64 (2009) 627])

  $\delta R_K/R_K \approx 1.3\%$

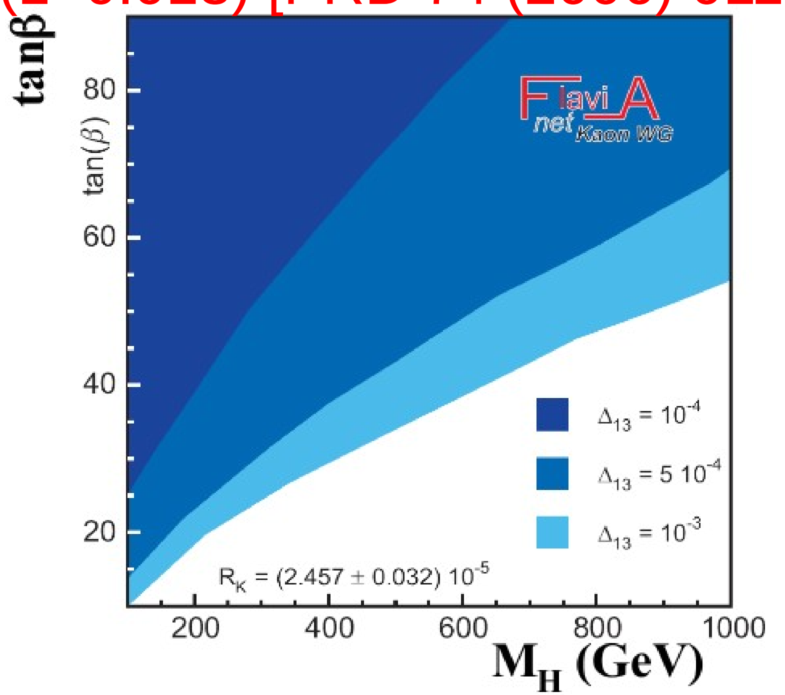
- We have to improve the precision due the very small theoretical accuracy

R_K in case of new Physics (MSSM)

- Expected effects within $\delta R_K/R_K \sim 10^{-4} - 10^{-2}$
- Charged Higgs exchange in SUSY Model with LFV:

$$R_K^{LFV} = R_K^{SM} \cdot [1 + \frac{m_K^4}{m_H^4} \cdot \frac{m_\tau^2}{m_H^2} \cdot |\Delta_{13}|^2 \cdot tan^6\beta]$$

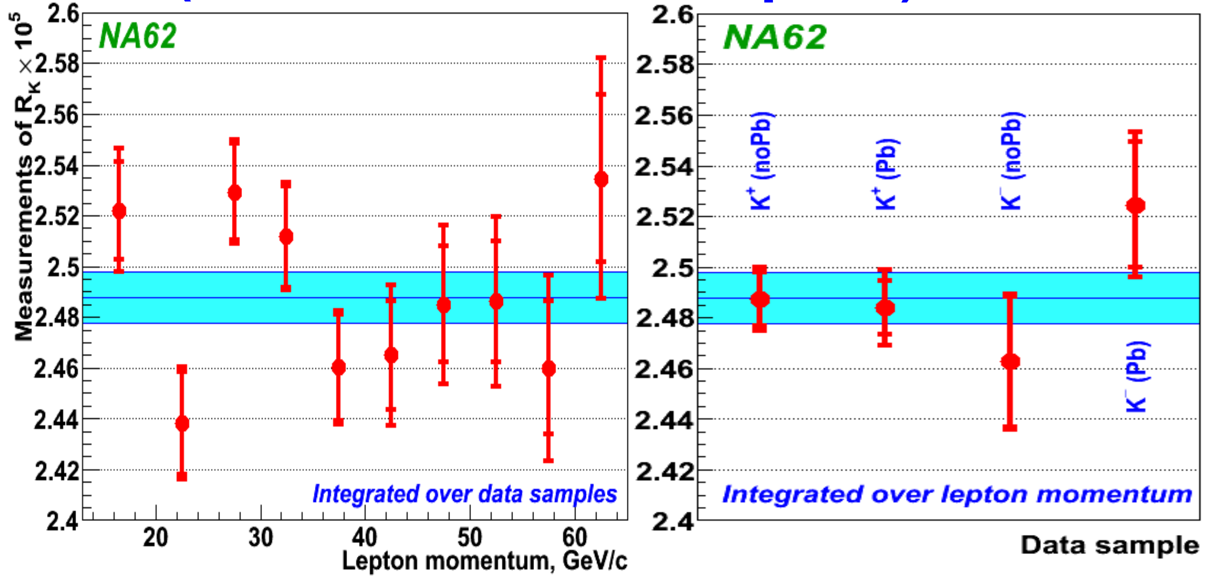
As an example: $\tan\beta = 40$, $m_H = 500$ GeV/c^2 and $|\Delta_{13}| = 5 \times 10^{-4}$
$R^K = R_K(SM) \cdot (1+0.013)$ [PRD 74 (2006) 011701]



R_K final result (full data sample)

Uncertainties

Source	$\delta R_K \times 10^5$
Statistical	0.007
$K \to \mu\nu_\mu$	0.004
$K \to e\nu_e\gamma\ (SD^+)$	0.002
$K \to \pi^0 e\nu_e,\ K \to \pi\pi^0$	0.003
Beam halo	0.002
Matter composition	0.003
Acceptance	0.002
Positron ID	0.001
DCH alignmnent	0.001
1-track trigger	0.001
Total	0.010

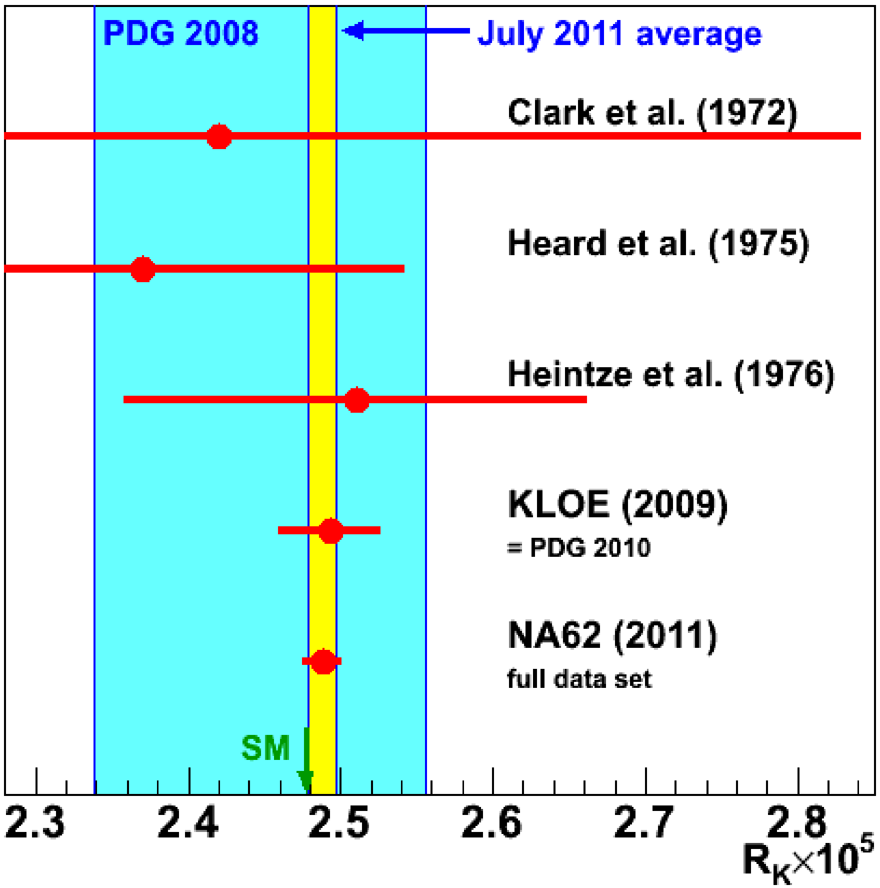


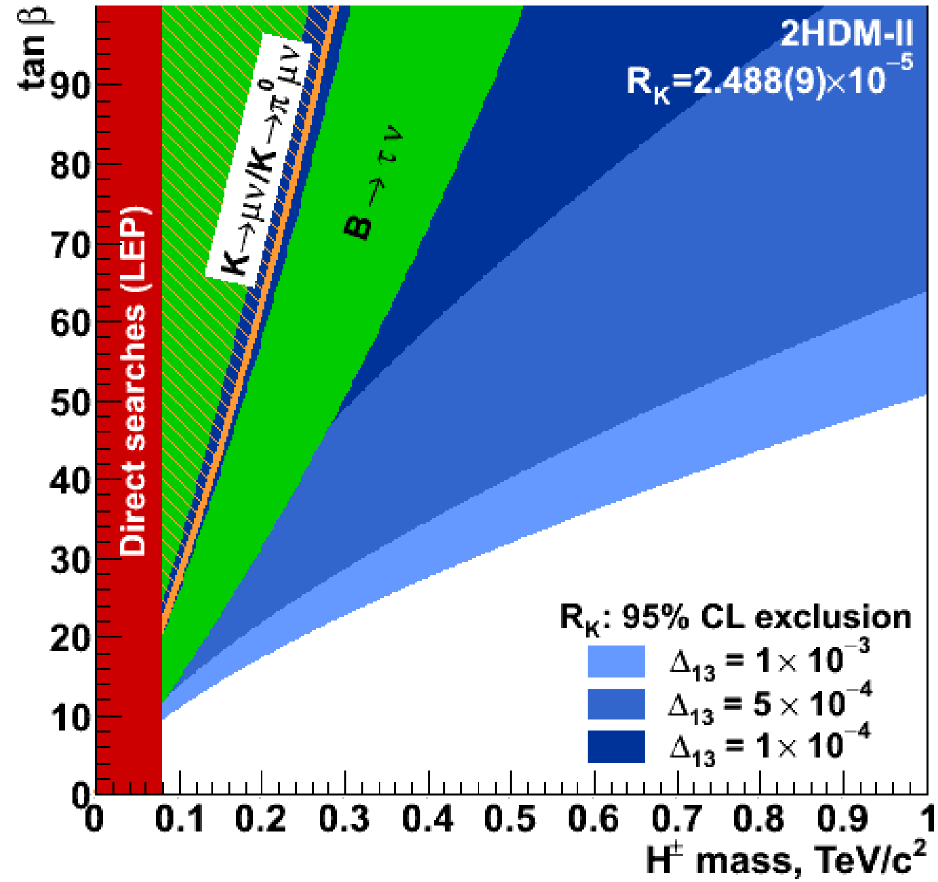
Precision ed accuracy:
145958 Ke2 candidates
Positron ID efficiency (99.28 ± 0.05)%
B/(B+S)= (10.95 ± 0.27)%

Fit over 40 measurement
4 data sample and 10 momentum bins
$\chi^2/ndf = 47/39$

$$R_K = (2.488 \pm 0.007_{stat} \pm 0.007_{syst}) \cdot 10^{-5}$$

R_K World Average





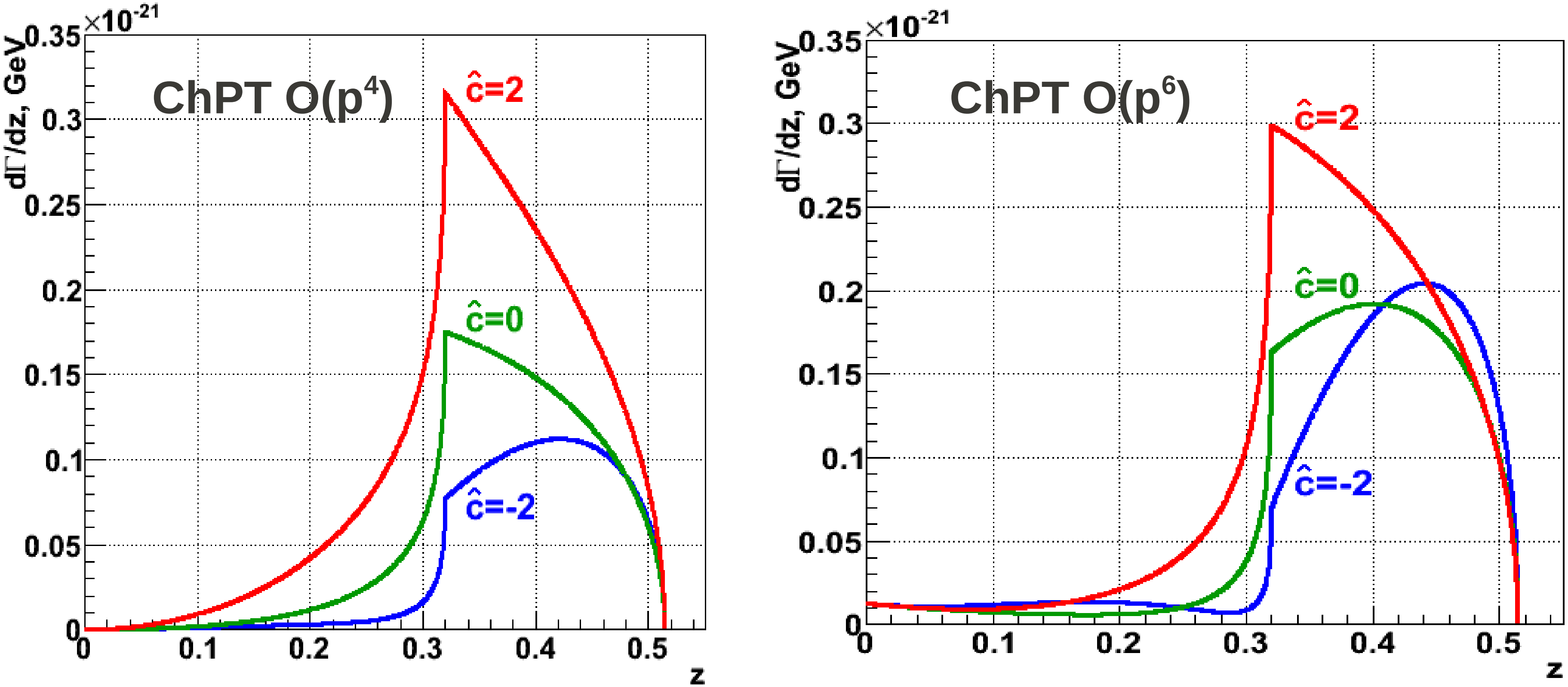
World Average	$R_K \times 10^{-5}$	Precision
PDG 2010	(2.493 ± 0.025)	1%
July 2011	(2.488 ± 0.009)	0.36%

Chiral Perturbation Theory results

$K^{\pm} \to \pi^{\pm}\gamma\gamma$

✗ $B(z)$, $z = m_{\gamma\gamma}^2/m_K^2$, depends on a single unknown O(1) parameter ĉ

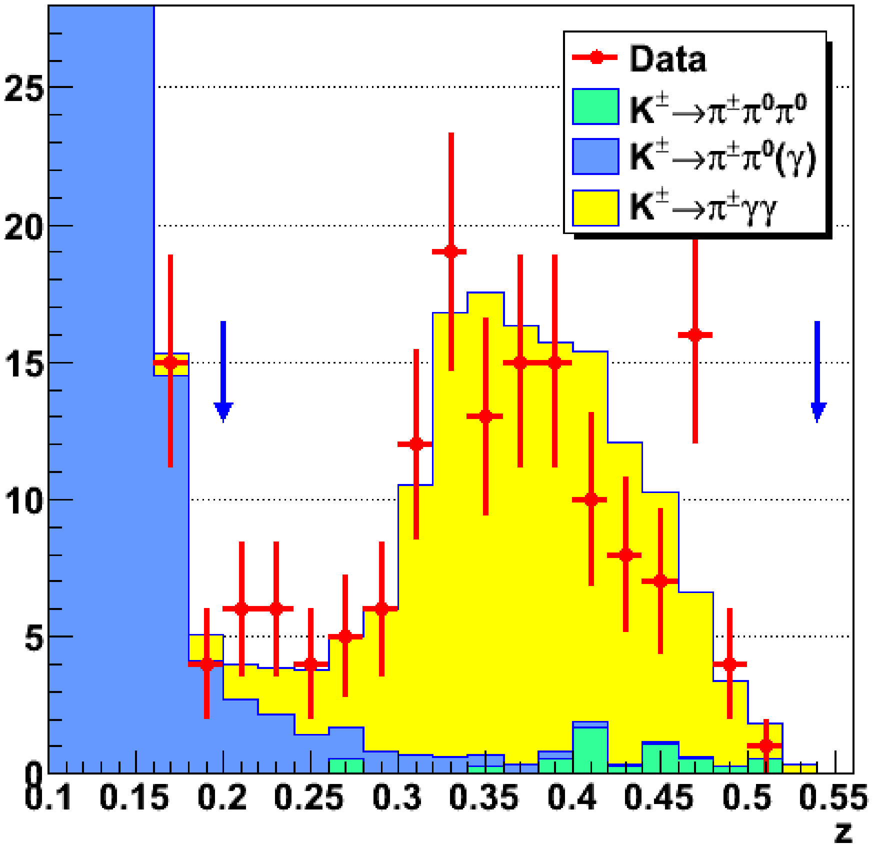
✗ BNL E787: 31 events, *BR* = (1.10 ± 0.32) · 10^{-6} [PRL 79 (1997) 4079]



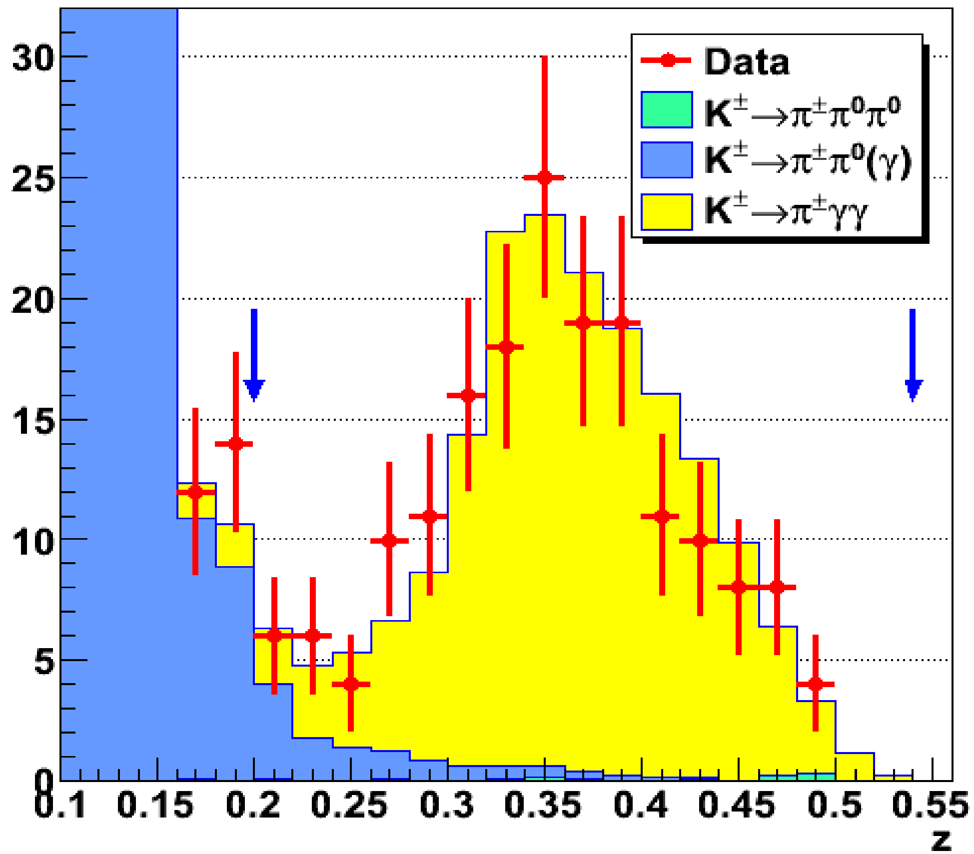
$K^{\pm} \to \pi^{\pm}\gamma\gamma$

✗ ~ 300 event candidates with O(10%) background (z > 0.2)

NA48/2 2004



NA62 2007

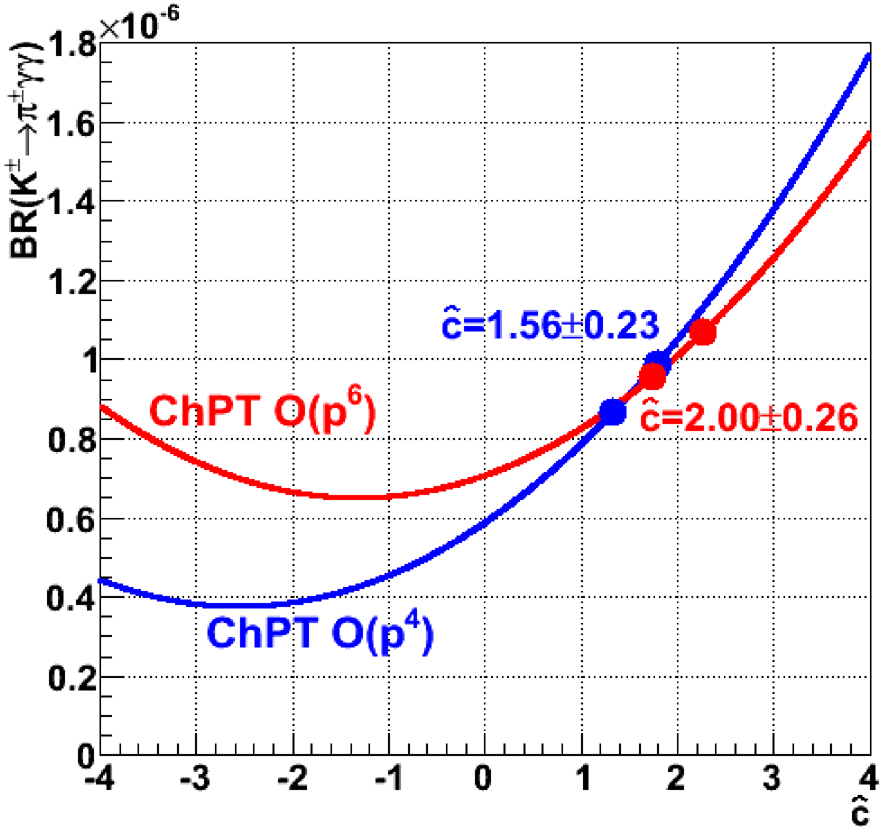


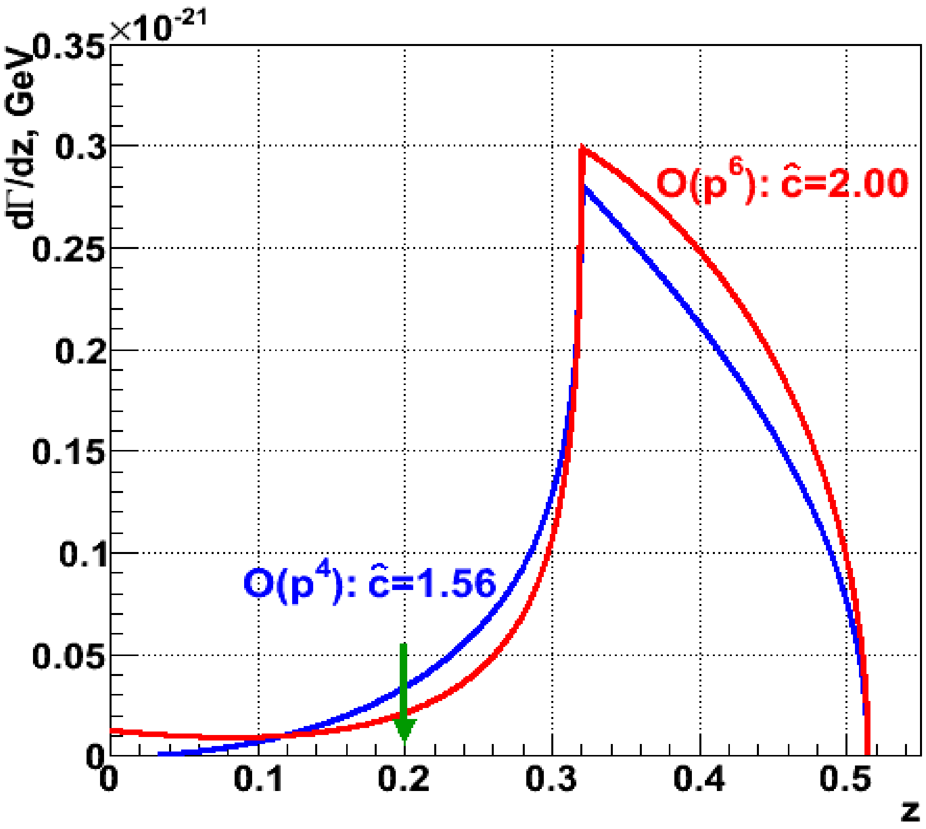
ChPT O(p^6)

$K^{\pm} \to \pi^{\pm}\gamma\gamma$

NA48/2 and NA62 combined preliminary results

- ✗ 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: $\hat{c} = (2.00 \pm 0.24_{stat} \pm 0.09_{syst}) = (2.00 \pm 0.26)$
- ✗ $BR = (1.01 \pm 0.06) \cdot 10^{-6}$ (model dependent)





$K^+ \rightarrow e^+ \nu_e \gamma$ (SD+)

$$\frac{d^2\Gamma}{dxdy}(SD) = \frac{m_K^5 \alpha G_F^2 |V_{us}|^2}{64\pi^2} \cdot \left[(F_V + F_A)^2 f_{SD+}(x,y) + (F_V - F_A)^2 f_{SD-}(x,y)\right]$$

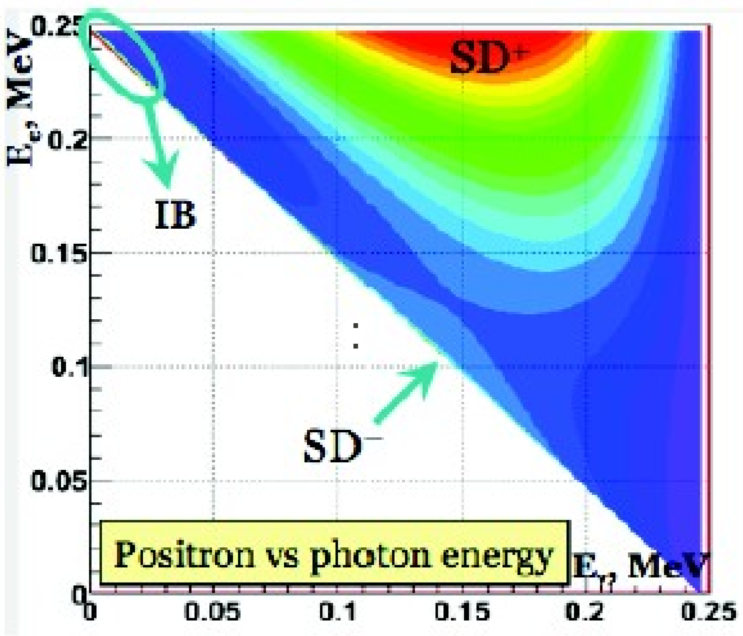
$$x = \frac{2E_\gamma^*}{m_K} \qquad y = \frac{2E_e^*}{m_K}$$

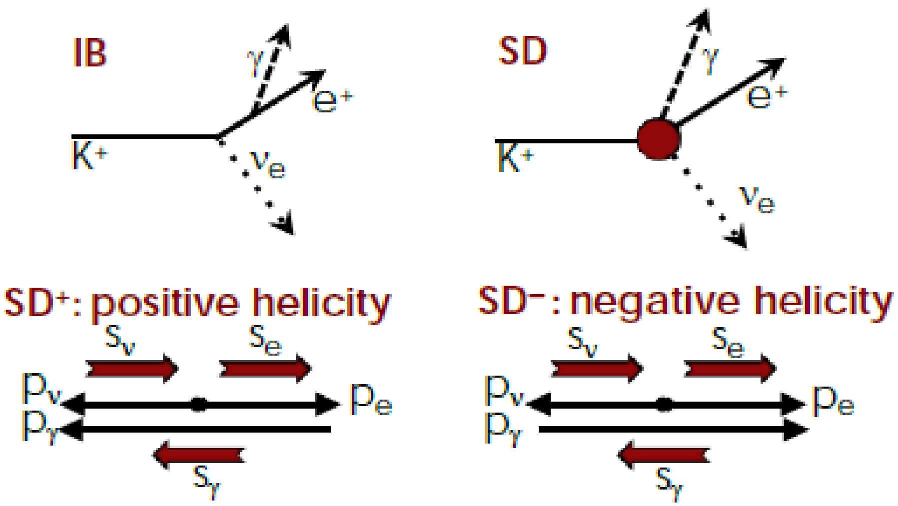
F_V and F_A: vector and axial Form Factors

ChPT $O(p^4)$: F_V,F_A costants

ChPT $O(p^6)$: F_V linear dependence from x [PR D77 (2008) 014004]

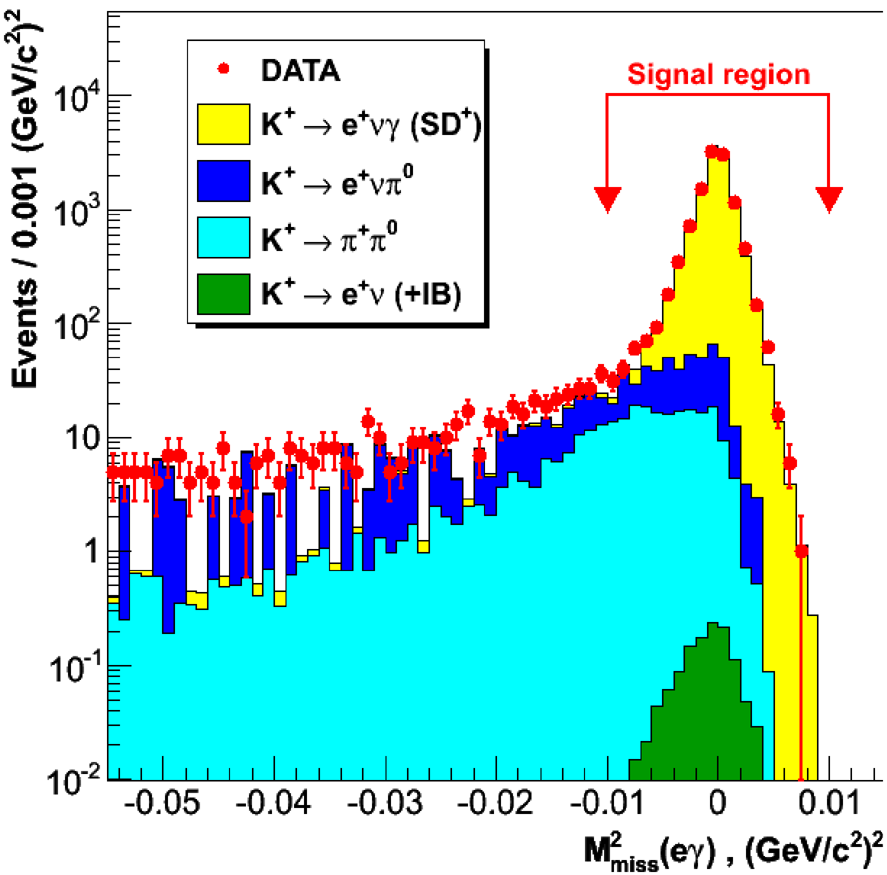
KLOE 2009: 1484 events with $E^*_\gamma > 10$ MeV and $p^*_e > 200$ MeV/c
~4% accuracy
Data suggest a slope for F_V, $\lambda = 0.38 \pm 0.20_{stat} \pm 0.02_{syst}$ (can't state $\lambda \neq 0$ @>2σ)

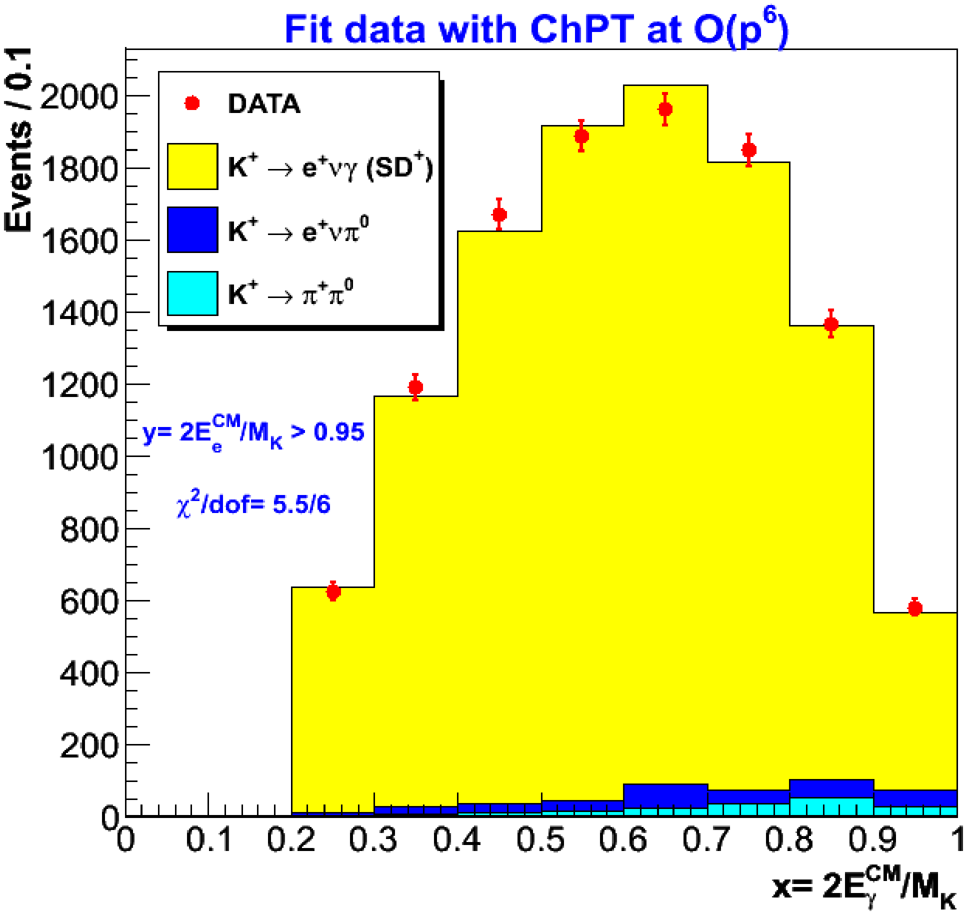




$K^+ \rightarrow e^+ \nu_e \gamma$ (SD+)

- ✔~10K events with p^*_e > 234 MeV/c and E^*_γ > 50 MeV
- ✔~7% of acceptance and ~5% of background ($K^+ \rightarrow e^+\pi^0\nu$, $K^+ \rightarrow \pi^+\pi^0$)





$K^{\pm}\rightarrow e^{\pm}\pi^{0}\nu$ and $K^{\pm}\rightarrow \mu^{\pm}\pi^{0}\nu$ Form Factors results

K_{l3} Form Factors

K_{l3} decays are described by **two form factors** $f_{\pm}(t)$:

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

$t = q^2$ is the square of the four-momentum transfer to the lepton neutrino system

$f_{\pm}(t)$ are the **vector form factors**

$f_0(t)$ the **scalar form factor is** given by:

$$f_0(t) = f_+(t) + \frac{t}{(m_K^2 - m_\pi^2)} f_-(t)$$

$f_-(t)$ can only be measured in Kμ3 decays because of $m_e << m_K$

$f_+(0)$ cannot be measured directly, therefore the form factors are normalised to $f_+(0)$:

Pole parametrization (based on physical quantities):

Assumes the exchange of vector and scalar resonances K^* with spin-parity $1^-/0^+$ and masses m_V/m_S, $f_+(t)$ can be described by $K^*(892)$, for $f_0(t)$ no obvious dominance is seen:

$$\bar{f}_{+,0}(t) = \frac{m_{V,S}^2}{m_{V,S}^2 - t}$$

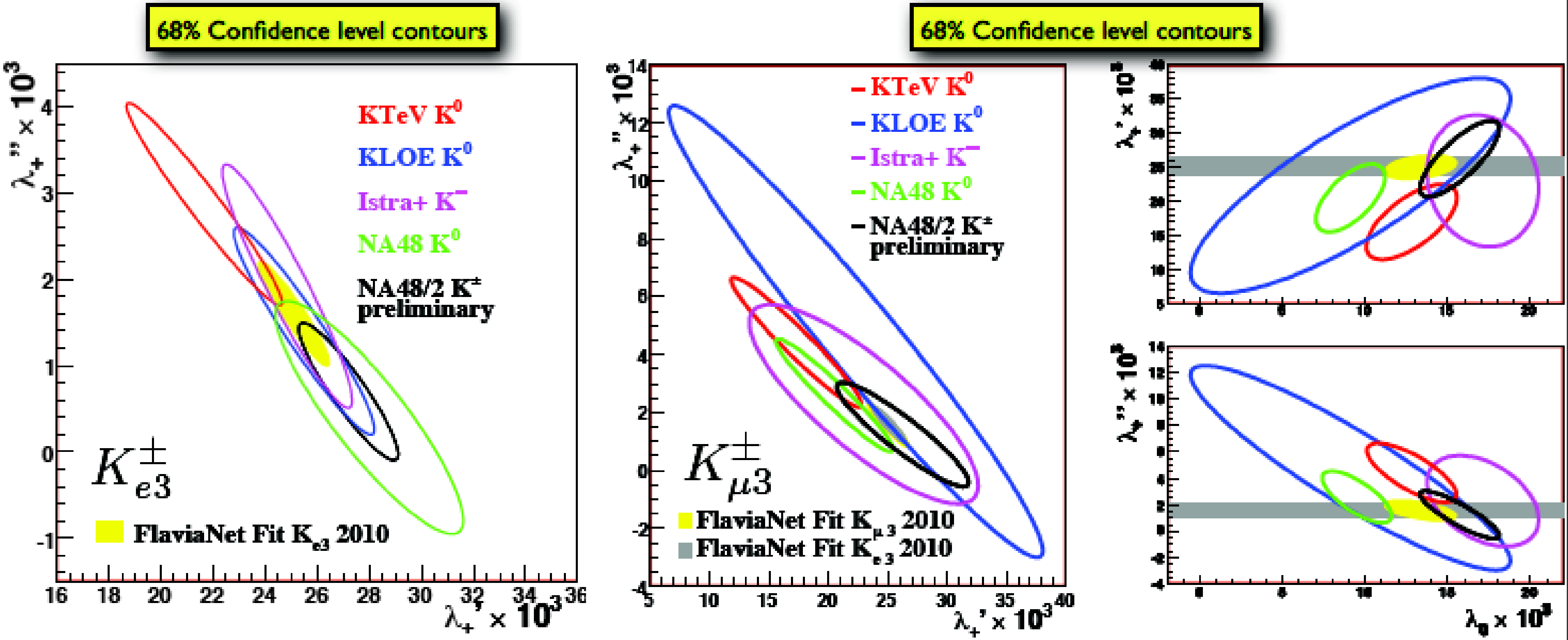
Linear and quadratic parametrization:

$$\bar{f}_{+,0}(t) = \left[1 + \lambda_{+,0} \frac{t}{m_\pi^2}\right] \quad \textbf{Linear}$$

$$\bar{f}_{+,0}(t) = \left[1 + \lambda'_{+,0} \frac{t}{m_\pi^2} + \frac{1}{2}\lambda''_{+,0} \left(\frac{t}{m_\pi^2}\right)^2\right] \quad \textbf{Quadratic}$$

K_{l3} Form Factors

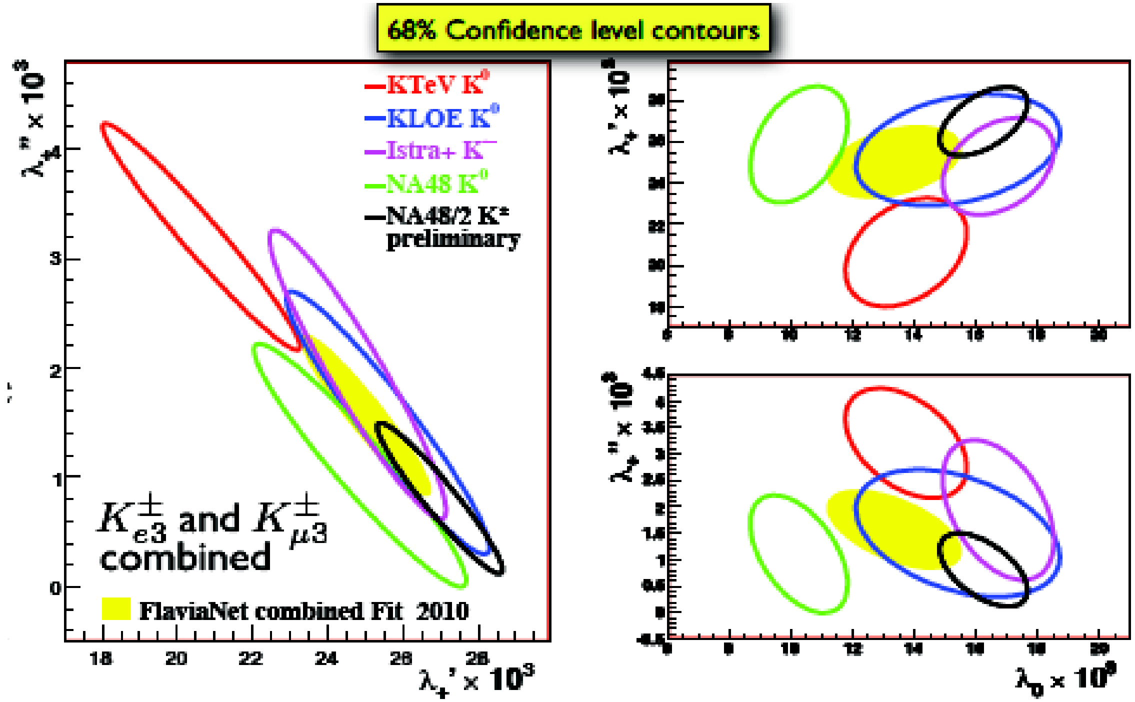
Quadratic ($\times 10^{-3}$)	λ'_+	λ''_+	λ_0
$K^{\pm}_{\mu 3}$	$26.3 \pm 3.0_{stat} \pm 2.2_{syst}$	$1.2 \pm 1.1_{stat} \pm 1.1_{syst}$	$15.7 \pm 1.4_{stat} \pm 1.0_{syst}$
$K^{\pm}_{e3}$	$27.2 \pm 0.7_{stat} \pm 1.1_{syst}$	$0.7 \pm 0.3_{stat} \pm 0.4_{syst}$	
Pole (MeV/c^2)	m_V		m_S
$K^{\pm}_{\mu 3}$	$873 \pm 8_{stat} \pm 9_{syst}$		$1183 \pm 31_{stat} \pm 16_{syst}$
$K^{\pm}_{e3}$	$879 \pm 3_{stat} \pm 7_{syst}$		



K_{l3} Form Factors

Quadratic ($\times 10^{-3}$)	λ'_+	λ''_+	λ_0
$K^\pm_{\mu 3} K^\pm_{e3}$ combined	26.98 ± 1.11	0.81 ± 0.46	16.23 ± 0.95
Pole (MeV/c^2)	m_V		m_S
$K^\pm_{\mu 3} K^\pm_{e3}$ combined	877 ± 6		1176 ± 31

- The NA48/2 measurement is the first with both charged K_{l3} decays



Conclusions

- The final NA62 measurement of $R_K = (2.488 \pm 0.009) \cdot 10^{-5}$ is in perfect agreement with the SM

- Recent preliminary results has been released on $\pi\gamma\gamma$:
- $BR(K \rightarrow \pi\gamma\gamma) = (1.01 \pm 0.06) \cdot 10^{-6}$
- $\hat{c} = (1.56 \pm 0.23)$ ChPT $O(p^4)$
- $\hat{c} = (2.00 \pm 0.26)$ ChPT $O(p^6)$

- Advanced analysis is in progress in the $e\nu\gamma$ SD+ channel

- The NA48/2 charged K_{l3} Form Factors measurement is:
- Very competitive with the other results in $K_{\mu3}$ and smallest error in K_{e3}
- Offers the combined result with the smallest error.