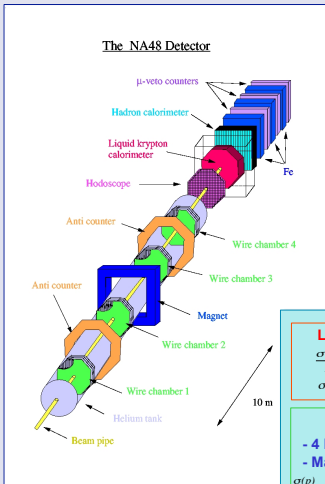
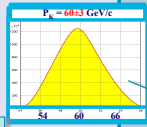


CP measurements in $K^\pm \rightarrow \pi^\pm l^+ e^-$ and $K_S \rightarrow \pi^+ \pi^- e^+ e^-$ decays at NA48



LKr EM calorimeter
 $\frac{\sigma(E)}{E} = \frac{3.2}{\sqrt{E}} \oplus \frac{0.1}{E} \oplus 0.5$
 $\sigma_{xy} < 1.3mm$

Spectrometer
 - 4 Drift Chambers
 - Magnet
 $\frac{\sigma(p)}{p} = 0.48\% \oplus 0.009 \times p(GeV/c) \%$
 $\sigma_{rx}^* \sim 2mm$



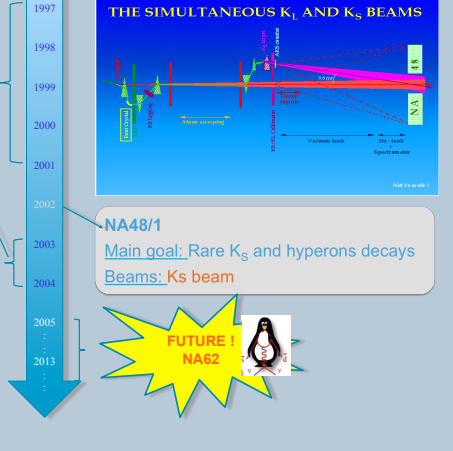
NA48
 Main goal: Search for direct CPV: Measurement of ϵ'/ϵ
 Beams: $K^+ + K^-$ beam

NA48/2
 Main goal: Search for direct CPV: Charge asymmetry measurement
 Beams: $K^+ + K^-$ beam

NA48/1
 Main goal: Rare K_S and hyperons decays
 Beams: K_S beam

FUTURE! NA62

Flux ratio: $K^+/K^- \sim 1.8$



NA48/2 results

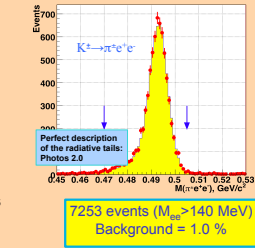
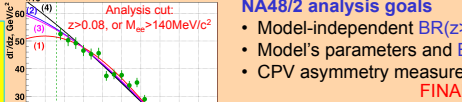
NA48/1 results

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

$d\Gamma_{\pi ee}/dz \sim \rho(z) |W(z)|^2$ $z = (M_{ee}/M_K)^2$
 $\rho(z)$ is a phase space factor

- Form-factor $W(z)$ models:**
- (1) polynomial: $W(z) = G_F M_K^2 f_0 (1 + \delta z)$
 - (2) ChPT $O(p^6)$: $W(z) = G_F M_K^2 (a_+ + b_+ z) + W^{res}(z)$
 - (3) ChPT, large-Nc QCD: $W(z) = W(w, \beta, z)$
 - (4) Meson ChPT: $W(z) = W(M_{\pi^+}, M_{\pi^0}, z)$

(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_{π^+}, M_{π^0}) determine a model-dependent BR

NA48/2 analysis goals

- Model-independent BR ($z > 0.08$) in visible kinematic range
- Model's parameters and BRs in full kinematic range
- CPV asymmetry measurement

FINAL RESULTS
 Including uncertainty due to the model dependence, (full z range):
 $BR = (3.11 \pm 0.04_{stat} \pm 0.05_{syst} \pm 0.08_{ext} \pm 0.07_{model}) \cdot 10^{-7} = (3.11 \pm 0.22) \times 10^{-7}$

Model independent BR ($M_{ee} > 140 \text{ MeV}/c^2$): $(2.28 \pm 0.03_{stat} \pm 0.04_{syst} \pm 0.06_{ext}) \cdot 10^{-7} = (2.28 \pm 0.08) \cdot 10^{-7}$

In agreement with previous measurements

CPV asymmetry (first measurement! correlated K^+/K^- uncer. excluded):
 $\Delta(K_{\pi ee}^\pm) = (BR^+ - BR^-) / (BR^+ + BR^-) = (-2.2 \pm 1.5_{stat} \pm 0.6_{syst}) \%$

Fit results

$\delta = 2.32 \pm 0.18_{stat+sys}$
 $f_0 = -0.531 \pm 0.016_{stat+sys}$

$a_+ = -0.576 \pm 0.016_{stat+sys}$
 $b_+ = -0.779 \pm 0.066_{stat+sys}$

$w = 0.997 \pm 0.007_{stat+sys}$
 $\beta = 3.45 \pm 0.35_{stat+sys}$

$M_{\pi^+} = 0.974 \pm 0.035_{stat+sys} \text{ GeV}$
 $M_{\pi^0} = 0.716 \pm 0.014_{stat+sys} \text{ GeV}$

$K_S \rightarrow \pi^+ \pi^- e^+ e^-$

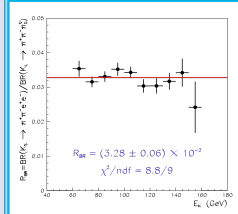
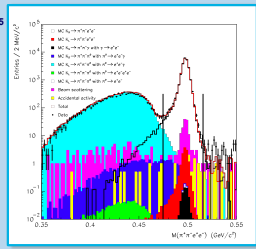
First observation by NA48 with '98 data (56 evts)

Full data set ('98+'99, HI KS):
 677 candidates (1 evt bkg)
 $BR(K_S \rightarrow \pi^+ \pi^- e^+ e^-) = (4.69 \pm 0.30) \times 10^{-5}$
 $A_{CP} = (-1.1 \pm 4.1) \%$

2002 NA48-1 goals:

- Improve significantly BR measurement
- Accuracy on A_{CP} better than 1%
- Look for direct emission (E1)

22966 candidate events, 103 bkg events (mainly from normalization channel $K_L \rightarrow \pi^+ \pi^- \pi^0 \pi^0$)



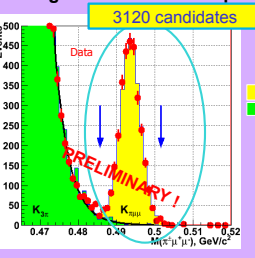
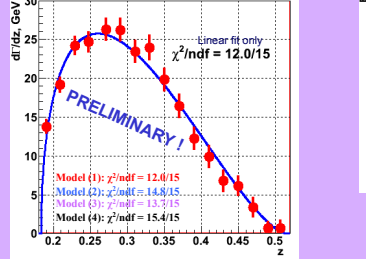
In agreement with '98+'99 results
 Using $BR(K_S \rightarrow \pi^+ \pi^- e^+ e^-) / BR(K_S \rightarrow \pi^+ \pi^- \pi^0 \pi^0) = |\eta^+ - \eta^-| (r_1/r_2)$
 $BR(K_S \rightarrow \pi^+ \pi^- e^+ e^-) = (1.41 \pm 0.04) \times 10^{-7}$
 CP violating part

Consistent with Sehgal and Waininger ('92)

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

World PDG average based on ~ 700 events coming from 3 different experiments

Shares theoretical framework with $\pi^+ e^+ e^-$



Fit results

Linear
 $f_0 = 0.470 \pm 0.039_{stat+sys}$
 $\delta = 3.11 \pm 0.56_{stat+sys}$

ChPT
 $a_+ = -0.575 \pm 0.035_{stat+sys}$
 $b_+ = -0.812 \pm 0.142_{stat+sys}$

ChPT + large Nc QCD
 $w = 0.983 \pm 0.013_{stat+sys}$
 $\beta = 3.17 \pm 0.81_{stat+sys}$

"Meson" ChPT
 $M_{\pi^+} = 1.014 \pm 0.090_{stat+sys} \text{ GeV}$
 $M_{\pi^0} = 0.725 \pm 0.028_{stat+sys} \text{ GeV}$

Model independent BR (full range) = $(9.62 \pm 0.23) \times 10^{-8}$

Result in agreement with all (but earliest) previous measurements but the precision is much better!

CPV charge asymmetry:
 $\Delta(K^\pm \rightarrow \pi^\pm \mu^\pm) = (1.1 \pm 2.3) \times 10^{-2}$
 Forward-backward asymmetry: (First measurement!)
 $A_{FB} = (-2.4 \pm 1.8) \times 10^{-2}$

Search for a direct emission E1

$M = \epsilon [g_{EM}^{had} (p_+ \cdot p_- - k \cdot p_+ / p_- \cdot k) + g_{EM}^{had} [(p_- \cdot k) p_+ - (p_+ \cdot k) p_-]] [d(k, y) v(k, y) / \epsilon^2]$

$g_{E1} / g_{EM} = 1.5 \pm 1.1$
 $(\chi^2/n.d.f. = 12.8/17)$

$|g_{E1}| / |g_{EM}| < 3.0$ @ 90% CL
 $(\pm 0.8\% \text{ contribution to BR})$

Search for CPV

$BR(K_S \rightarrow \pi^+ \pi^- e^+ e^-)$

Source	$\sigma_{sys} (\%)$
Radiative corrections	± 0.1
Geometrical cuts	± 0.1
Kinematical cuts	± 0.2
$\pi - \pi$ separation	± 0.1
Trigger	± 0.1
π decay	± 0.1
Total	± 0.4

$A_{CP} = (-0.4 \pm 0.7_{stat} \pm 0.4_{syst}) \%$
 or $|A_{CP}| < 1.5 \%$ @ 90% CL

No evidence for a CP-violating contribution in the $K_S \rightarrow \pi^+ \pi^- e^+ e^-$ decay amplitude was observed.