New results from the NA48 Experiment at CERN

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Outline

- $\mathrm{Re}(\varepsilon'/\varepsilon)$
  - Introduction and experimental approach
  - Data-taking and analysis highlights
  - New result from 2001 data and conclusions
- K_S Lifetime
- $K_{L,S} \to \pi^+\pi^-e^+e^-$
- $K_S \to \gamma\gamma$ and new measurement of $K_L \to \pi^0\gamma\gamma$
- Present (K_S) and future ($K^\pm$)
- Conclusions

Direct CP violation - I

CP violation in the neutral K system is dominated by state mixing: mass eigenstates (K_S, K_L) are not pure CP eigenstates (K_1, K_2):

$$K_1 = (\mathrm{K}^0 + \overline{\mathrm{K}}^0)/\sqrt{2} \quad (\mathrm{CP}{=}{+1})$$
$$K_2 = (\mathrm{K}^0 - \overline{\mathrm{K}}^0)/\sqrt{2} \quad (\mathrm{CP}{=}{-1})$$

$$\mathrm{K_S} \propto K_1 + \varepsilon K_2 \qquad \mathrm{K_L} \propto K_2 + \varepsilon K_1$$

$$|\varepsilon| = (2.27 \pm 0.01) \cdot 10^{-3}$$

Indirect CP violation

Indirect CP violation can be accomodated in a *superweak* scenario for CP violation, restricted to the K system.

Does *direct* CP violation in the decay processes exist in nature
(*i.e.* $K_1 \to 2\pi$) ?

$$|A(\mathrm{K}^0 \to f)| \neq |A(\overline{\mathrm{K}}^0 \to \overline{f})|$$

Direct CP violation - II

Interference of two decay amplitudes with different final state (strong) interactions needed.
$K \to \pi\pi$ decays: two amplitudes A_0, A_2 (final state isospin $I = 0, 2$) with strong phases δ_0, δ_2 interfere:

$$\eta_{+-} \equiv \frac{A(K_L \to \pi^+\pi^-)}{A(K_S \to \pi^+\pi^-)} \simeq \varepsilon + \varepsilon' \qquad \eta_{00} \equiv \frac{A(K_L \to \pi^0\pi^0)}{A(K_S \to \pi^0\pi^0)} \simeq \varepsilon - 2\varepsilon'$$

$$\varepsilon' \simeq \frac{i}{\sqrt{2}} Im\left(\frac{A_2}{A_0}\right) \exp[i(\delta_2 - \delta_0)]$$

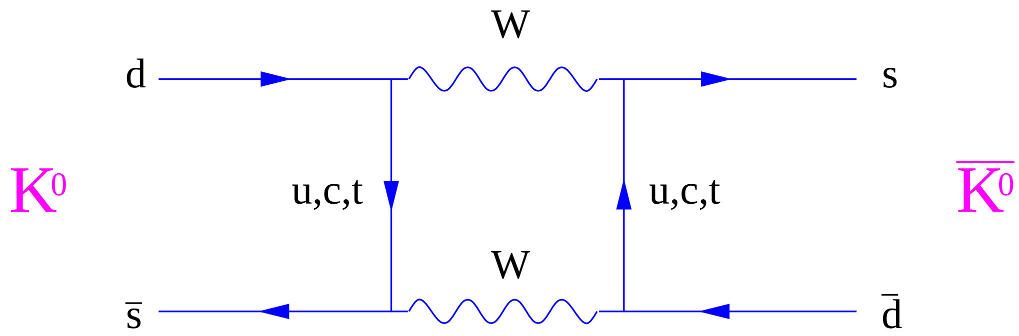
Direct CP violation

The experimental observable is the *double ratio*:

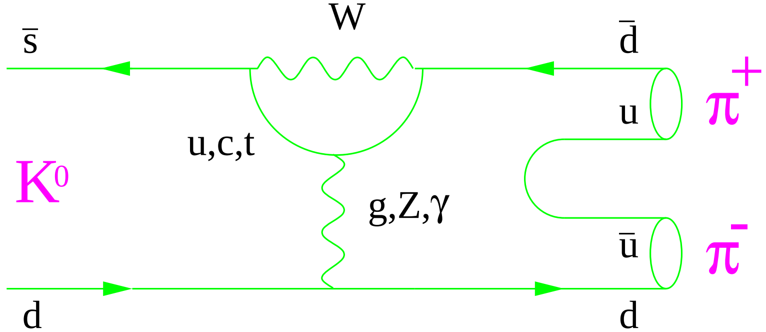
$$R = \frac{\Gamma(K_L \to \pi^0\pi^0)}{\Gamma(K_S \to \pi^0\pi^0)} \Big/ \frac{\Gamma(K_L \to \pi^+\pi^-)}{\Gamma(K_S \to \pi^+\pi^-)} \simeq 1 - 6\ \mathrm{Re}(\varepsilon'/\varepsilon)$$

Standard Model predictions

Indirect CP violation
through mixing
$K^0 / \overline{K}^0$ oscillations
$\Rightarrow \varepsilon$ parameter



Direct CP violation
through decay
Penguin diagrams
$\Rightarrow \varepsilon'$ parameter



Typical theoretical predictions/postdictions:
$\mathrm{Re}(\varepsilon'/\varepsilon) \approx -10^{-4}$ to $\approx +30 \cdot 10^{-4}$ with errors $\approx 5 \div 10 \cdot 10^{-4}$
Very difficult (non-perturbative) problem.

Recent news from from lattice QCD computations:

$(-7 \text{ to } -2) \cdot 10^{-4}$ (CP-PACS collaboration)
$(-8 \text{ to } -4) \cdot 10^{-4}$ (RBC collaboration)

Experimental measurements of $\mathrm{Re}(\varepsilon'/\varepsilon)$

New generation of experiments after inconclusive results in the early '90s:

NA31 / NA48	E731 / KTeV
$(23.0 \pm 6.5) \times 10^{-4}$ (NA31)	$(7.4 \pm 5.9) \times 10^{-4}$ (E731)
3.5 σ effect	No effect
NA48 (CERN)	**KTeV (FNAL)**
$(18.5 \pm 7.3) \cdot 10^{-4}$ (97 data)	$(28.0 \pm 4.1) \cdot 10^{-4}$ (23% 96+97 data)
$(15.3 \pm 2.6) \cdot 10^{-4}$ (97+98+99 data)	$(20.7 \pm 2.8) \cdot 10^{-4}$ (prel. 96+97 data)

Current world average:
$(17.3 \pm 1.7) \cdot 10^{-4}$ with $\chi^2/\mathrm{ndf} = 5.7/3$

Direct CP violation firmly established

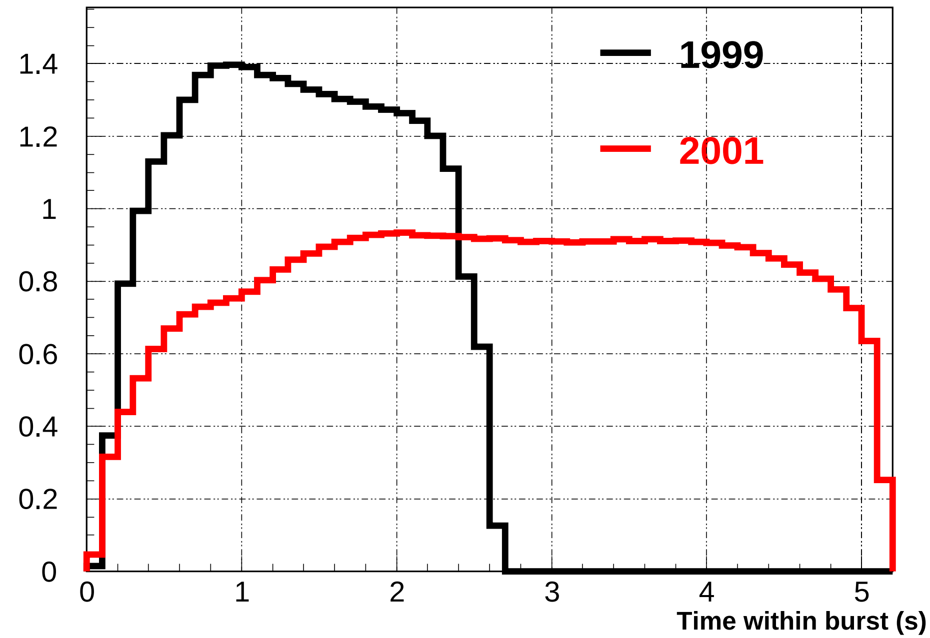
Final NA48/KTeV results for precise measurement

NA48 history

- 1990: proposal
- 1997: $\approx$ 0.5 million $K_L \to \pi^0\pi^0$
  Result published in 1999
- 1998: $\approx$ 1 million $K_L \to \pi^0\pi^0$
  Several improvements (trigger, DAQ, calorimeter)
- 1999: $\approx$ 2 million $K_L \to \pi^0\pi^0$
  Further improvements in trigger and DAQ, higher data-taking efficiency. Result published in 2001
- November 1999 : Beam tube implosion $\Rightarrow$ drift chambers damaged
- 2000: Only neutral data (cross-checks + high intensity K_S runs)
- 2000-2001: Drift chambers repaired
- 2001: $\approx$ 1.5 million $K_L \to \pi^0\pi^0$ with different beam conditions

The 2001 run

The 2001 run had a better duty cycle, and a lower istantaneous intensity



Good K_L Events / 100 ms

	1998-1999	2001
Proton momentum	450 GeV/c	400 GeV/c
SPS cycle time	14.4 s	16.8 s
Spill length (effective)	2.4 s (1.7 s)	5.2 s (3.6 s)
Duty cycle	0.17	0.31
K_L beam intensity	$\approx 1.5 \cdot 10^{12}$ ppp	$\approx 2.4 \cdot 10^{12}$ ppp
K_S beam intensity	$\approx 4 \cdot 10^{7}$ ppp	$\approx 7 \cdot 10^{7}$ ppp

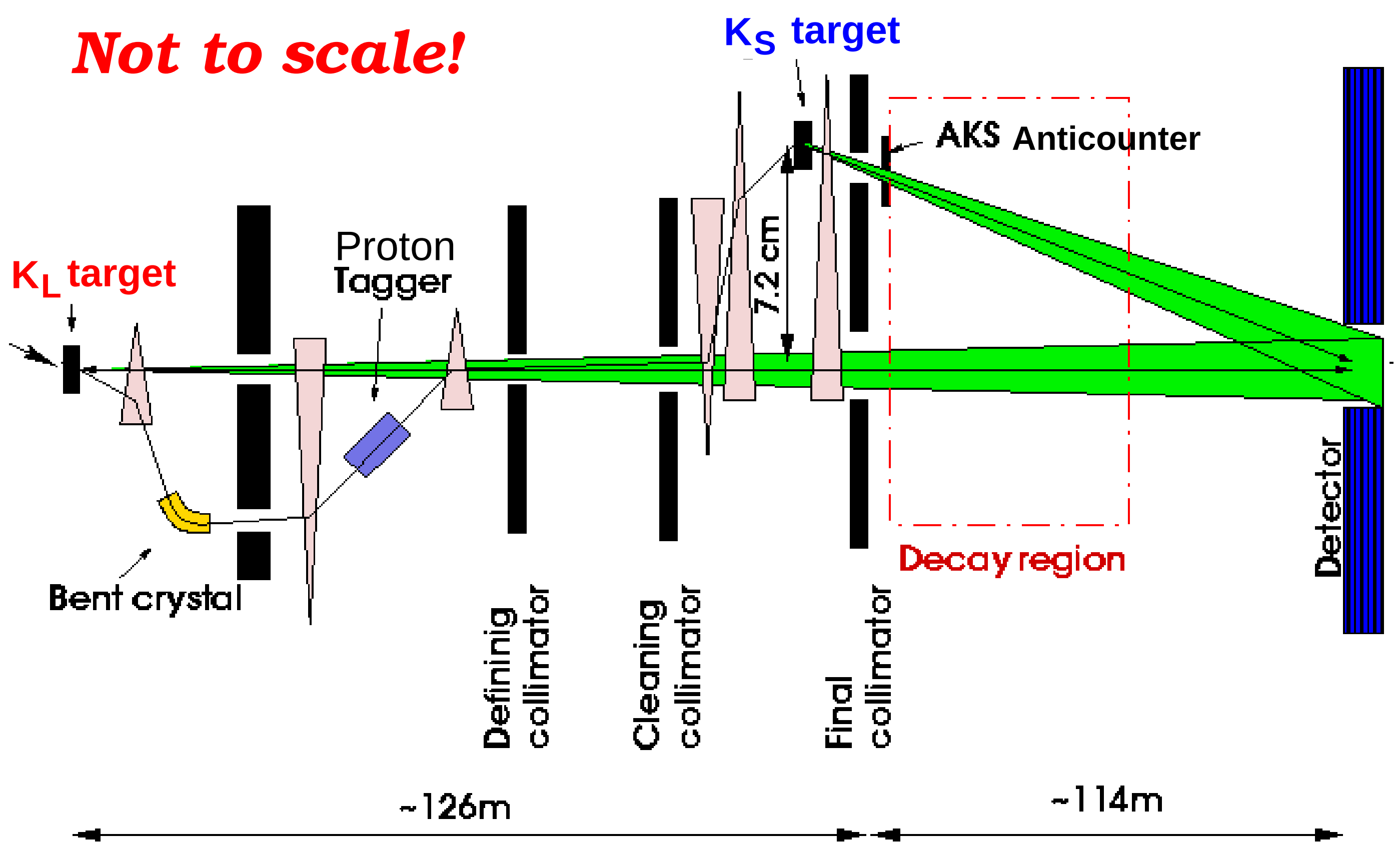
The NA48 approach

$$R = \frac{N(K_L\to\pi^0\pi^0)}{N(K_S\to\pi^0\pi^0)} \Big/ \frac{N(K_L\to\pi^+\pi^-)}{N(K_S\to\pi^+\pi^-)} \simeq 1 - 6\ \mathrm{Re}(\varepsilon'/\varepsilon)$$

The NA48 "philosophy" is to fully exploit the reduction of all systematic effects in the double ratio to minimize the size of all corrections:

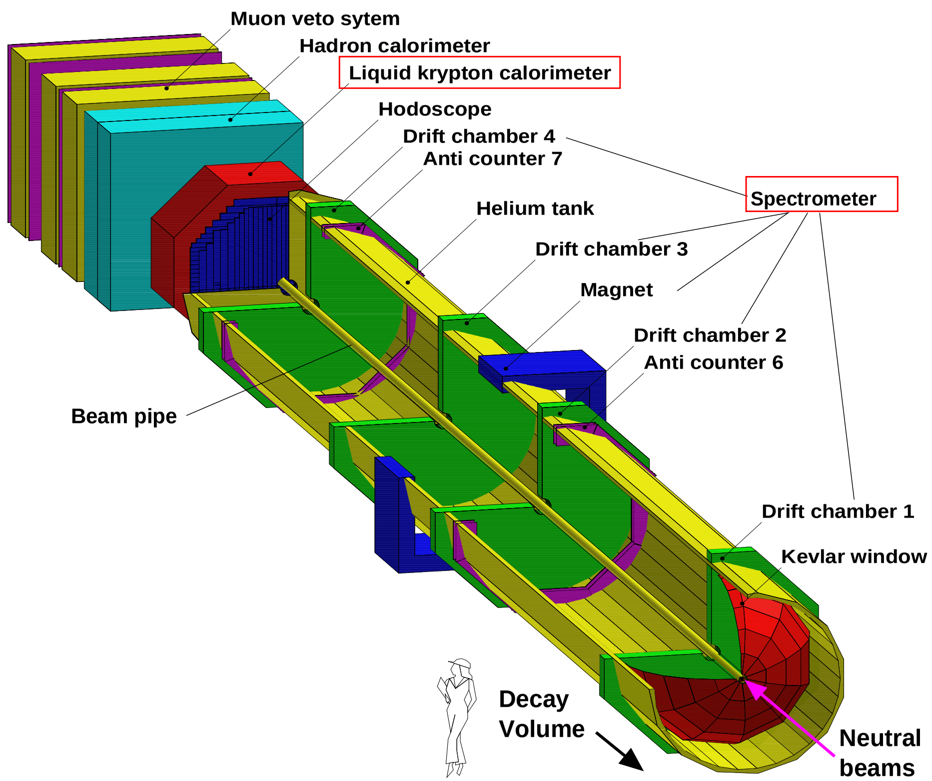
- Simultaneous, almost collinear K_L and K_S beams, allow for concurrent detection of the four modes in the same decay region
  $\Rightarrow$ cancellation of fluxes, inefficiences, dead times, accidental losses;
- K_S identification by time-of-flight proton tagging upstream of K_S production target;
- Detector based on a quasi-homogeneous liquid Krypton calorimeter and a magnetic spectrometer gives high resolutions
  $\Rightarrow$ minimize backgrounds;
- Apply lifetime weighting procedure to equalize K_S and K_L longitudinal decay position distributions
  $\Rightarrow$ minimize acceptance corrections

Simultaneous K_S and K_L Beams



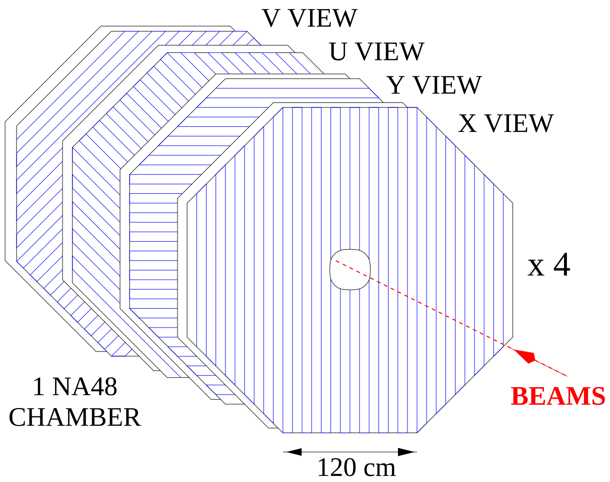
K_S are distinguished from K_L by tagging the protons upstream of their production target.

The NA48 detector



- Magnetic spectrometer to detect $\pi^+\pi^-$ events + scintillator hodoscope for event time measurement
- Quasi homogeneous liquid Krypton calorimeter to detect $\pi^0\pi^0$ events and measure their time
- Anti-counters for photons and muons
- Neutral beams always through vacuum

The magnetic spectrometer

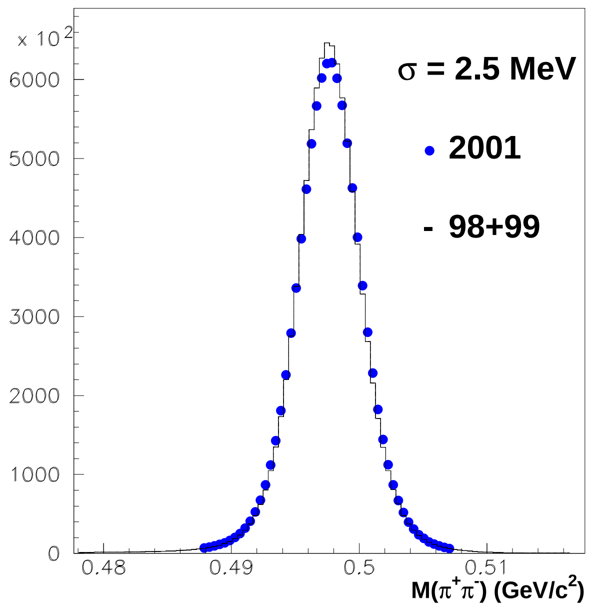


- 2×2 drift chambers + magnet (265 MeV/c p_T kick).
- Plane efficiency $> 99.5\%$
- Space point resolution $\approx 95\mu$m

$$\sigma(P)/P \simeq 0.5\,\% \oplus 0.009\,P[\mathrm{GeV}/c]\,\%$$

Rebuilt drift chambers performed well.

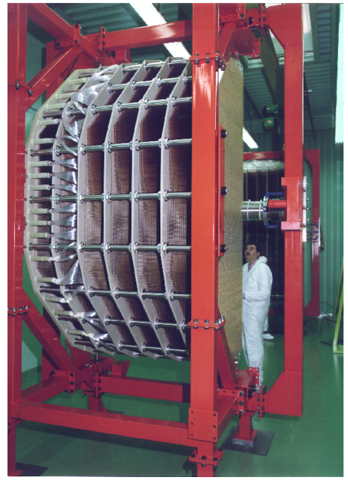
K^0 energy measured from tracks' opening angle and energy ratio: depends on geometry and not on magnetic field.



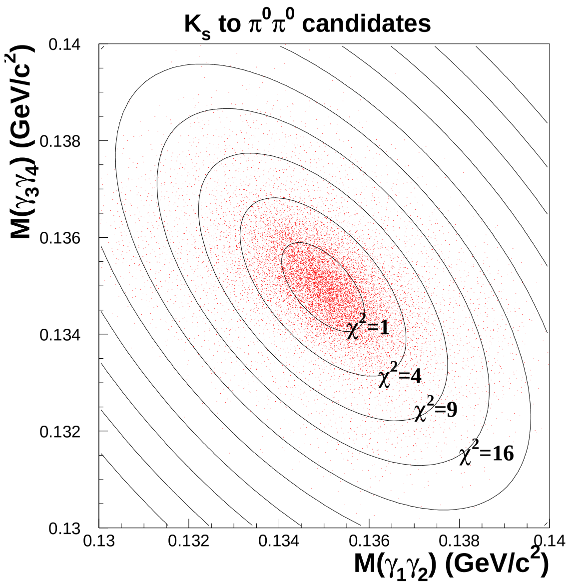
The LKr calorimeter

Quasi-homogeneous liquid Krypton calorimeter, $\approx 12000\ 2\times 2$ projective towers with accordion geometry, fast initial current readout

- Better than 250 ps time resolution
- Better than 1 mm space resolution
- $\sim 0.5\%(0.2\%)$ uniformity before (after) corrections



$$\sigma(E)/E \simeq 3.2\%/\sqrt{E(\mathrm{GeV})} \oplus 90\,\mathrm{MeV}/E \oplus 0.42\%$$



(E_i,x_i,y_i) + K^0 mass constraint:

$\Rightarrow D \equiv z_{LKr} - z = \frac{1}{M_K}\sqrt{\Sigma_{ij}E_iE_jd_{ij}^2}$

Longitudinal decay position $\Leftrightarrow$ energy scale

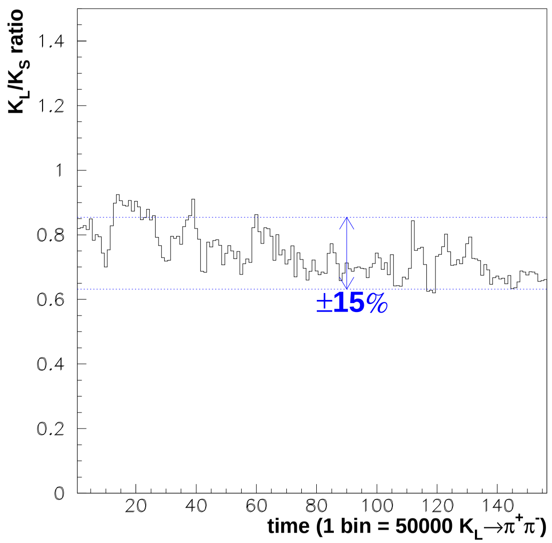
Pair photons to get best π^0 masses

$m_{ij} = \frac{1}{D}d_{ij}\sqrt{E_iE_j}$

(resolution ≈ 0.9 MeV$/c^2$)

Data Analysis

- Measure R in Kaon energy bins (5 GeV wide)
  $\Rightarrow$ insensitive to K_S-K_L energy spectra differences
- Apply lifetime weighting to K_L
  $\Rightarrow$ minimize effect of K_S- K_L acceptance differences
- Record dead time conditions during simultaneous data-taking ($\approx$ 0.3% (was 1.5%) from $\pi^+\pi^-$ trigger, $\approx$ 11% (was 20%) from chambers' hit multiplicity) and apply them offline to all events

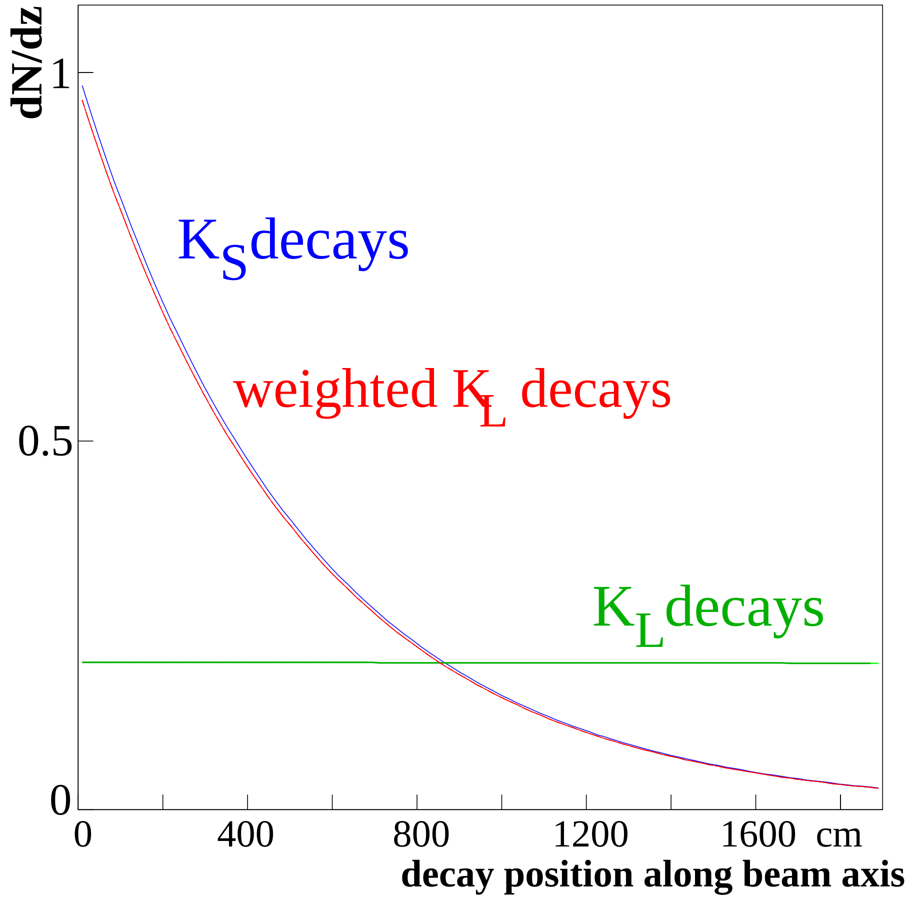


- Reweight K_S to keep K_S/K_L intensity ratio constant
  $\Rightarrow$ minimize effect of K_S-K_L beam intensity differences
- First 200 ms of burst not used in 2001 because of strong beam structures

Lifetime weighting

Acceptance $K_S = K_L$ at any given decay point but very different decay lengths: $\tau(K_L) \approx 600\,\tau(K_S)$

$\Rightarrow$ Different acceptances for K_S and K_L and large correction on R



Solution: Only use $\tau < 3.5\,\tau_S$ where K_S are present and weight K_L events with

$$W = \frac{\pi\pi \text{ decay rate in } K_S \text{ beam}}{\pi\pi \text{ decay rate in } K_L \text{ beam}}$$

$$\approx e^{-z/(\beta\gamma c)(1/\tau(K_S) - 1/\tau(K_L))}$$

$\Rightarrow$ Same longitudinal decay vertex distribution for K_S and weighted K_L

$\Rightarrow$ Acceptance correction cancels

Price: $\approx$ 35% increase in statistical error

Data Analysis - II

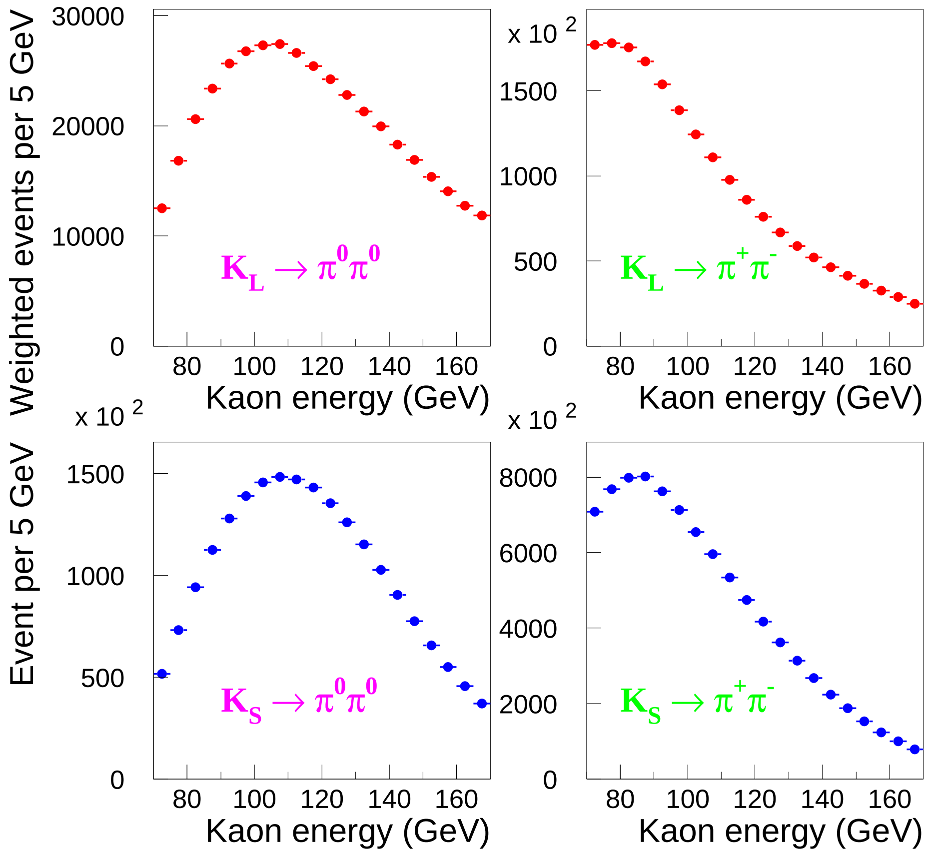
At first order, almost all effects cancel in R

$\Rightarrow$ Measure small second order differential effects

- Tag K_S and K_L decays and correct for misidentification
- Identify $\pi^+\pi^-$ and $\pi^0\pi^0$ and subtract residual backgrounds
- Evaluate effects due to non-linearities, energy scale
- Compute residual K_S-K_L acceptance differences
- Evaluate residual effects from accidental-induced event losses

WARNING: All corrections/uncertainties are quoted on R:
factor 1/6 to get effect on ε'/ε

The 2001 data sample



$K_L \to \pi^0\pi^0$: 1.55×10^6

$K_S \to \pi^0\pi^0$: 2.16×10^6

$K_L \to \pi^+\pi^-$: 7.14×10^6

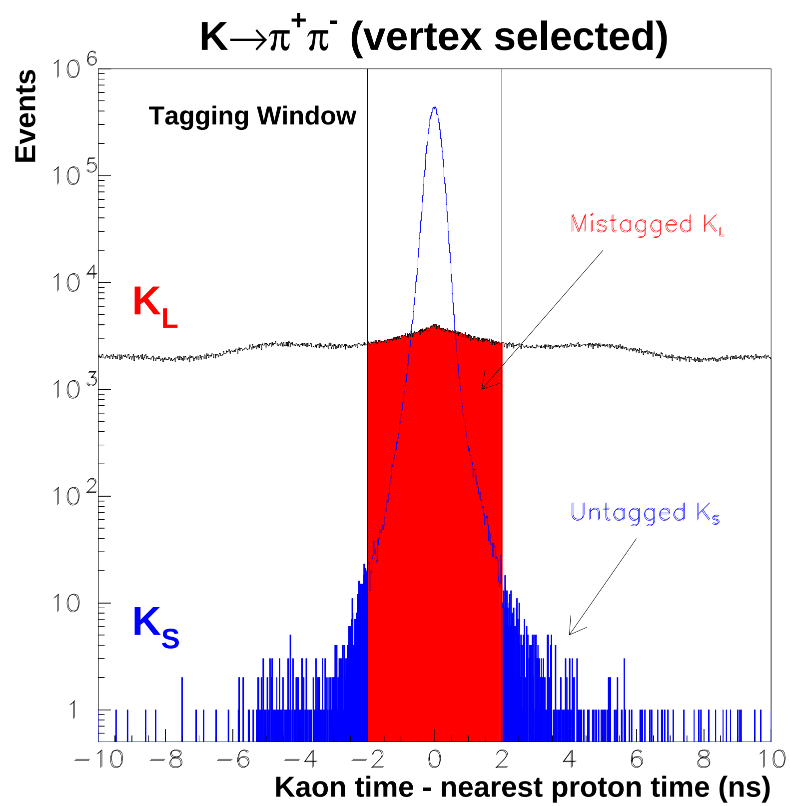
$K_S \to \pi^+\pi^-$: 9.61×10^6

(corrected for mistagging)

K_S-K_L tagging

Use difference of event time and closest proton in tagger:

- $\Delta t \leq 2$ ns $\Rightarrow K_S$
- $\Delta t > 2$ ns $\Rightarrow K_L$



2 possible mistakes

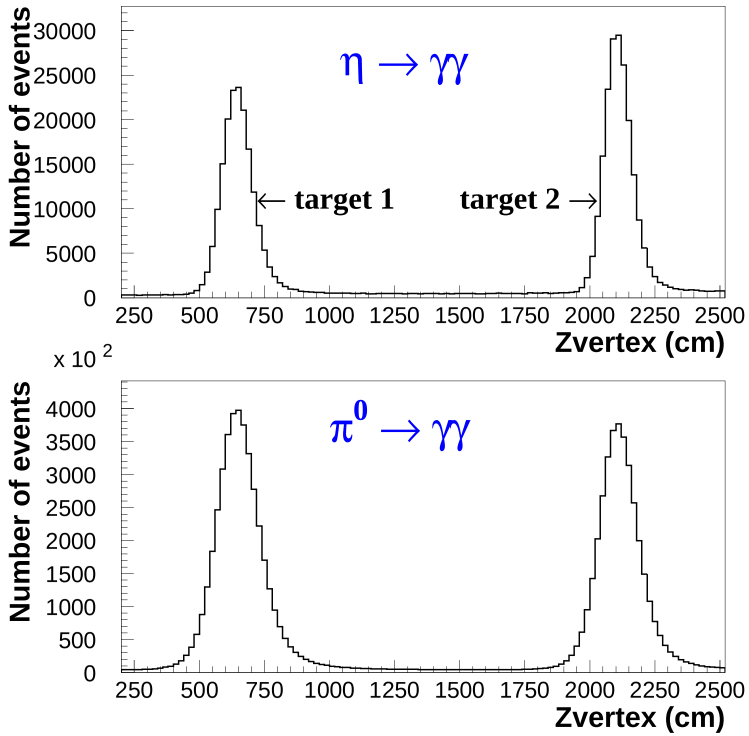
dangerous only if different for $\pi^+\pi^-$ and $\pi^0\pi^0$

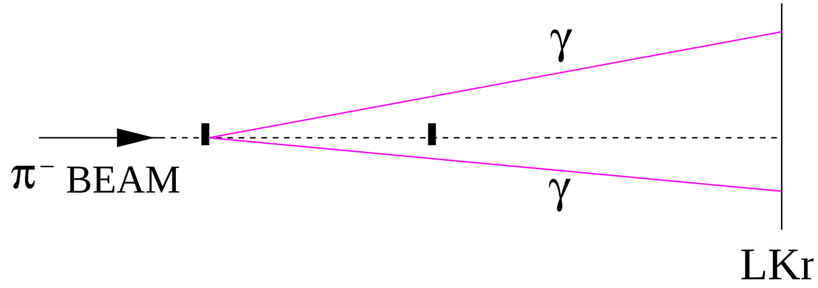
Direct measurement possible for $\pi^+\pi^-$ by tagging with transverse vertex position.

- K_S mistagged as K_L (α_{SL}): tails in time measurement
  $\alpha_{SL}^{+-} = (1.12 \pm 0.03) \cdot 10^{-4}$
- K_L mistagged as K_S (α_{LS}): accidental proton coincidence with K_L (rate $\approx$ 30 MHz), a priori $\pi^+\pi^-$-$\pi^0\pi^0$ symmetric
  $\alpha_{LS}^{+-} = (8.115 \pm 0.010)\%$ (was $(10.649 \pm 0.008)\%$ in 98-99)

Energy scale check

Special runs with π^- beam to two thin targets





- Produce π^0 and η with known decay position
- Use $\gamma\gamma$ decays to reconstruct production/decay vertex (assuming π^0 or η mass)
  $D = \frac{1}{M} d_{12} \sqrt{E_1 E_2}$
  $\Rightarrow$ Compare to known target positions

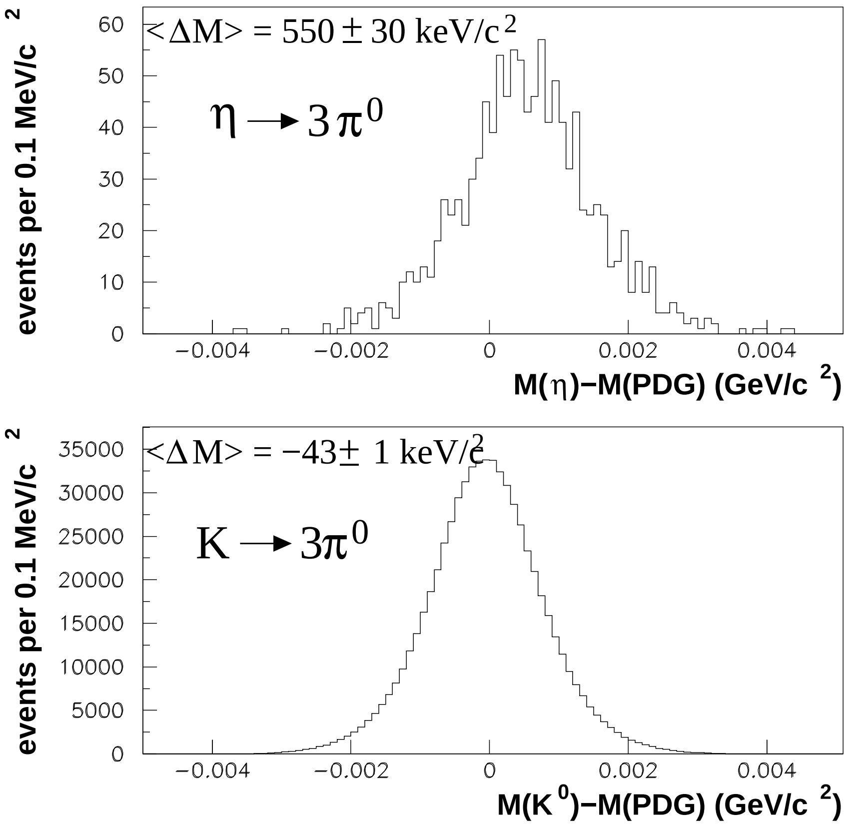
Agreement checks neutral energy scale

Can also check non-linearity and uniformity of energy response

Total uncertainty on energy scale:

$$\Delta R = \pm 5.3 \cdot 10^{-4}$$

Intermezzo: η (and K^0) mass measurements



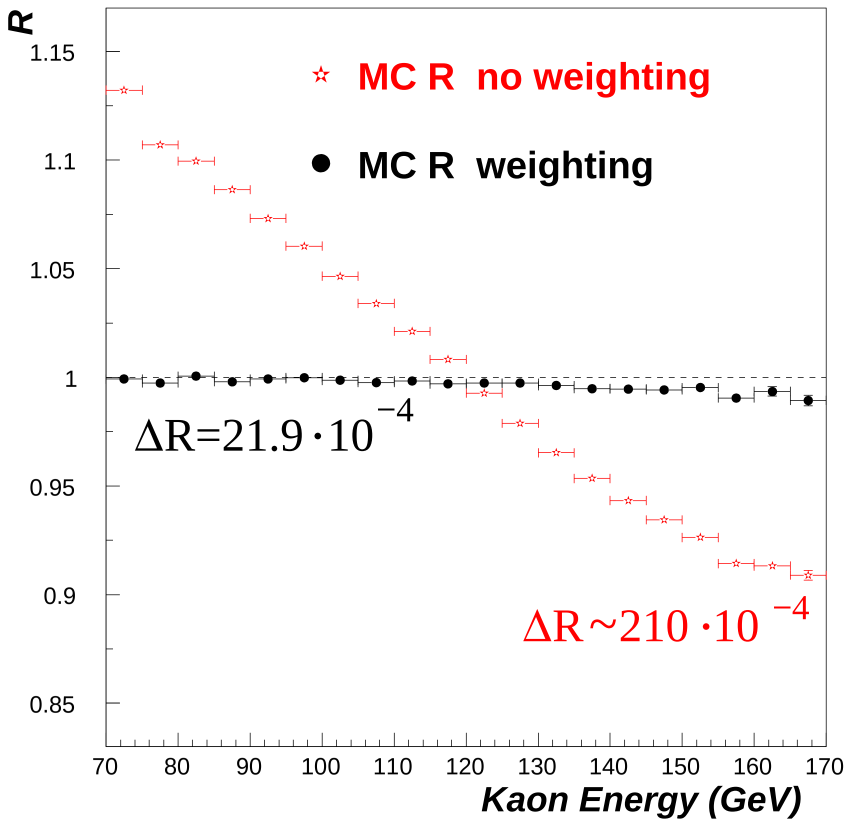
- Use $\eta \to 3\pi^0 \to 6\gamma$ decays (background free, no K_S beam) from year 2000
- Decay vertex from π^0 mass constraint $\Rightarrow M_{\eta(K)}/M_{\pi^0}$
- Independent of energy scale
- Symmetric decays: reduced non-linearities sensitivity
- Check using $K_L \to 3\pi^0$

4.2 σ shift (0.1%) from PDG on M_η, used to check energy scale with $\eta \to \gamma\gamma$

$$M_\eta = 547.843 \pm 0.030_{stat} \pm 0.041_{syst}\ \text{MeV}/c^2$$
$$M_{K^0} = 497.625 \pm 0.001_{stat} \pm 0.031_{syst}\ \text{MeV}/c^2$$

(Preprint: hep-ex/0204008)

Acceptance correction



- Acceptance correction: $+21.9\times10^{-4}$
- MC stat. error: $\pm3.3\times10^{-4}$ ($\sim10\times$ data statistics)
- Syst. error: $\pm4.0\times10^{-4}$
  - Beam positions and shapes
  - Comparison of fast MC vs. GEANT based spectrometer simulation

Accidental activity

Accidental activity $\Rightarrow$ event losses. Cancel at first order in R.
Residual effects: $\Delta R \approx \Delta(\pi^0\pi^0 - \pi^+\pi^-) \times \Delta(K_L - K_S)$

- $\Delta(\pi^0\pi^0 - \pi^+\pi^-)$: loss difference; minimized by applying dead time conditions to all modes: $(1.0 \pm 0.5)\%$
- $\Delta(K_L - K_S)$: intensity difference; small by design

  Simultaneous beams $\Rightarrow$ K_L and K_S events see the same activity, within 1% (checked in data)

  Lifetime weighting $\Rightarrow$ K_L and K_S events illuminate the detector in a similar way

Measure K_L and K_S intensities on (200 ns - 15 μs) time scales with beam integrators
Overlay beam-monitor events to data and MC events

Uncertainty on R:

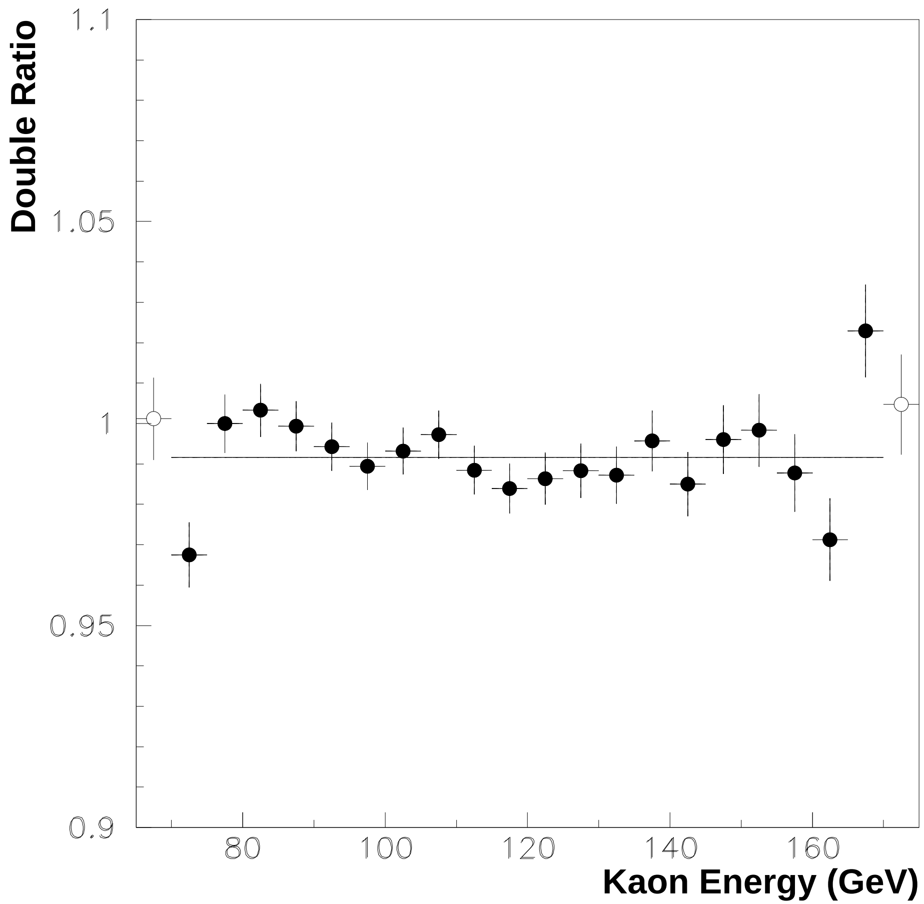
- Intensity difference: $\Delta R = (0 \pm 1.1) \times 10^{-4}$ (was $(0 \pm 3) \cdot 10^{-4}$ in 98-99)
- Illumination difference: $\Delta R = (0 \pm 3) \times 10^{-4}$

Corrections and systematic errors

Corrections and statistical or systematic uncertainties (units = 10^{-4}) on R:

Correction	2001	1998-1999
$\pi^+\pi^-$ background	14.2 ± 3.0	16.9 ± 3.0
$\pi^0\pi^0$ background	-5.6 ± 2.0	-5.9 ± 2.0
Beam scattering	-8.8 ± 2.0	-9.6 ± 2.0
Tagging inefficiency	± 3.0	± 3.0
Accidental tagging	6.9 ± 2.8	8.3 ± 3.4
$\pi^+\pi^-$ scale	± 2.8	2.0 ± 2.8
$\pi^0\pi^0$ scale	± 5.3	± 5.8
AKS inefficiency	1.2 ± 0.3	1.1 ± 0.4
Acceptance	21.9 ± 3.5	26.7 ± 4.1
	± 4.0	± 4.0
$\pi^+\pi^-$ trigger	5.2 ± 3.6	-3.6 ± 5.2
Accidental activity (intensity)	± 1.1	± 3.0
Accidental activity (illumination)	± 3.0	± 3.0
K_S in-time activity	± 1.0	± 1.0
Total	$+35.0 \pm 6.5$	$+35.9 \pm 8.1$
	± 9.0	± 9.6

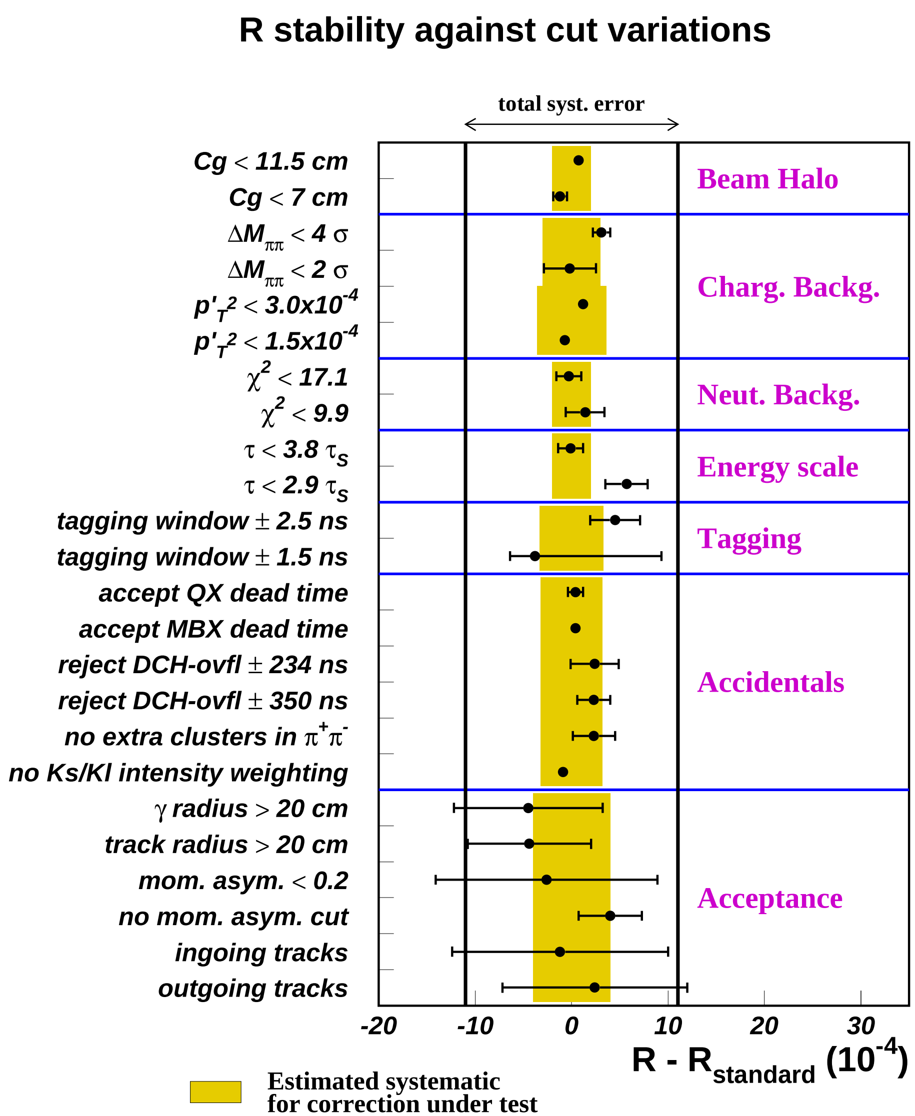
The double ratio



$$R = 0.99181 \pm 0.00147_{stat} \pm 0.00110_{syst}$$

In systematic error ± 0.00065 due to statistics of the control samples

Systematic checks



$\mathrm{Re}(\varepsilon'/\varepsilon)$ **result**

From 2001 data:

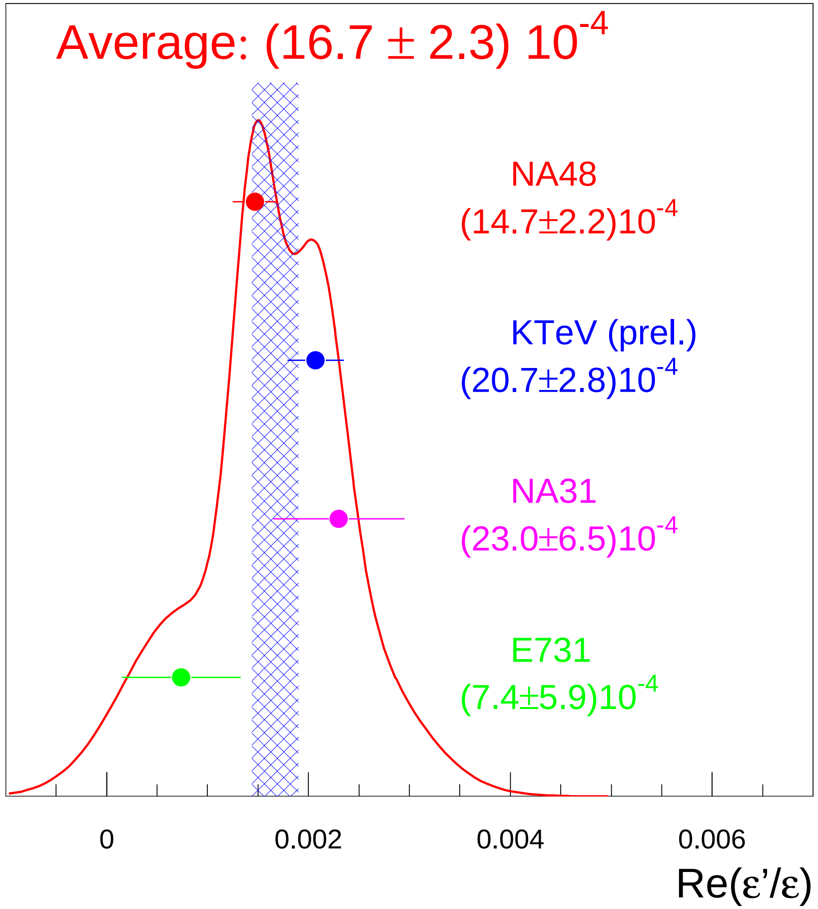
$$\varepsilon'/\varepsilon = (13.7 \pm 3.1) \times 10^{-4}$$

Combining with 97+98+99 result $(15.3 \pm 2.6) \times 10^{-4}$

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

6.7 σ away from 0 (was 5.9 σ)
2001 result in agreement with previous ones
Paper ready for publication

Experimental values of $\mathrm{Re}(\varepsilon'/\varepsilon)$

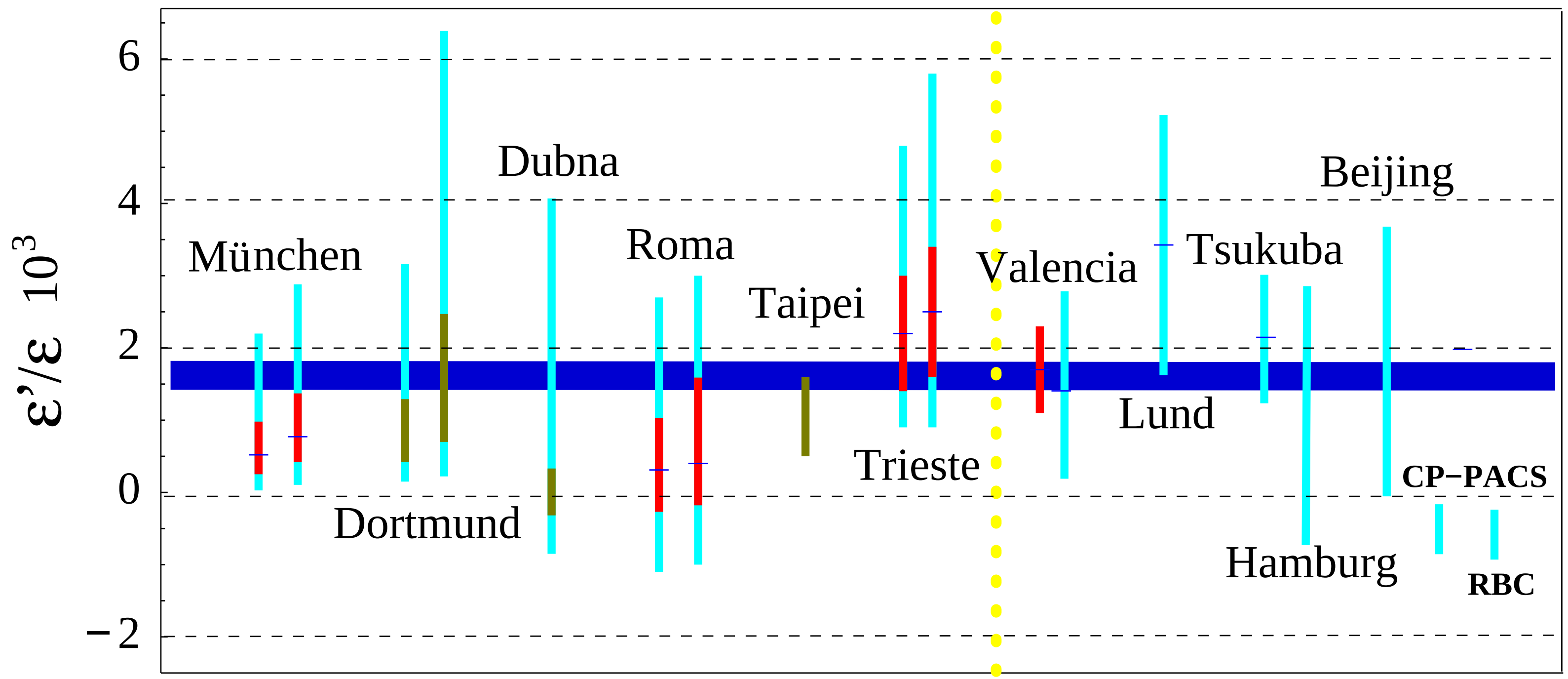


Naive average: $\mathrm{Re}(\varepsilon'/\varepsilon) = (16.6 \pm 1.6) \cdot 10^{-4}$

$\chi^2/\mathrm{ndf} = 6.2/3$ PDG scaled error $2.3 \cdot 10^{-4}$

$\mathrm{Re}(\varepsilon'/\varepsilon)$ **pre(post)dictions in SM**

Most predictions below $10 \cdot 10^{-4}$



SM can stretch to accomodate experimental value

K_S lifetime

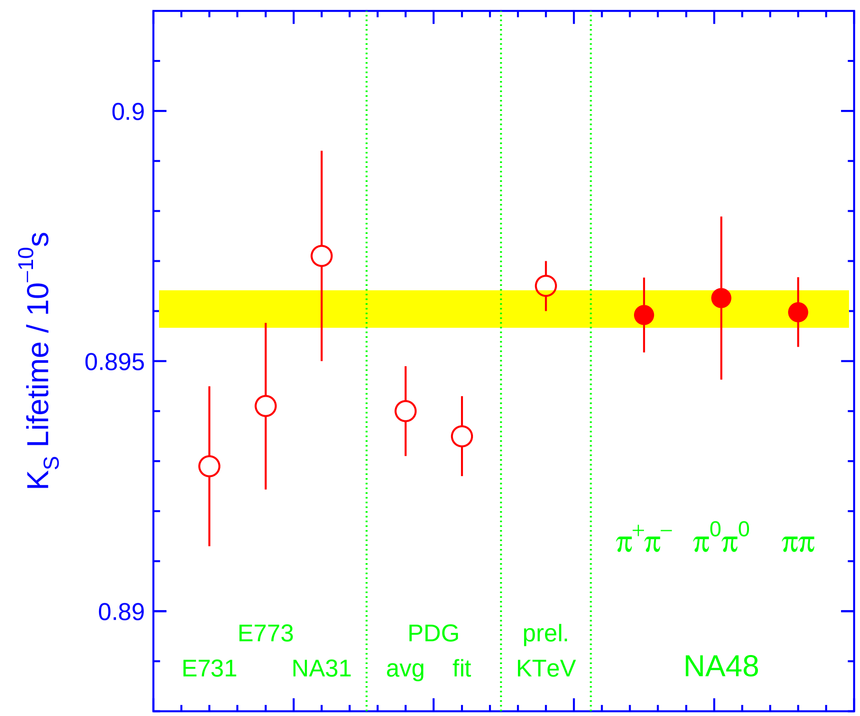
- Use the same samples as in the $\mathrm{Re}(\varepsilon'/\varepsilon)$ analysis of 1998-1999.
- Decay region: $0.5 \leq \tau/\tau_S \leq 3.5$ to avoid resolution biases
- Analysis in 5 GeV energy and 0.1 τ_S lifetime bins
- Two measurements ($\pi^+\pi^-$ and $\pi^0\pi^0$) averaged
- Use K_L to measure acceptance $\Rightarrow$ minimize dependence on MC

	$\pi^+\pi^-$		$\pi^0\pi^0$	
	$\tau_S/10^{-10}$	χ^2/dof	$\tau_S/10^{-10}$	χ^2/dof
1998	0.89578 ± 0.00109	628.2/573	0.89606 ± 0.00247	551.0/573
1999	0.89598 ± 0.00072	601.2/573	0.89635 ± 0.00167	543.5/573

$$\tau_S = (0.89598 \pm 0.00048_{\mathrm{stat}} \pm 0.00043_{\mathrm{syst}} \pm 0.00027_{\mathrm{MCstat}}) \cdot 10^{-10}\ \mathrm{s}$$

Systematics dominated by fit method and beam geometry uncertainties
1.7 σ shift from PDG average (preprint hep-ex/0205008)

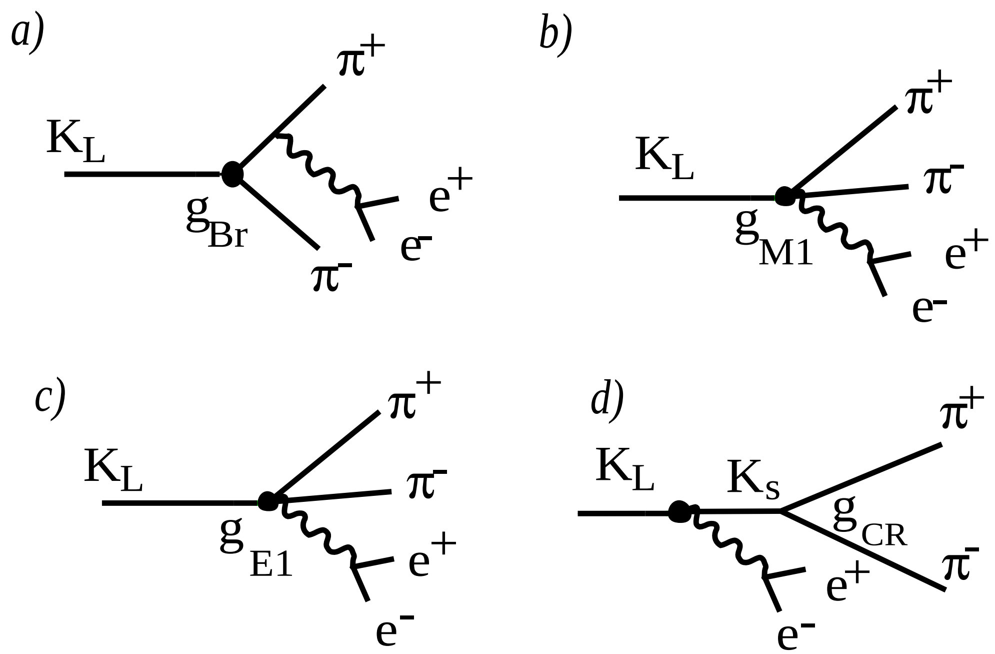
K_S lifetime



NA48: $\tau(K_S) = 0.89598 \pm 0.00048 \pm 0.0051) \cdot 10^{-10}$ s

$K_S, K_L \rightarrow \pi^+\pi^- e^+ e^-$ - **Physics**

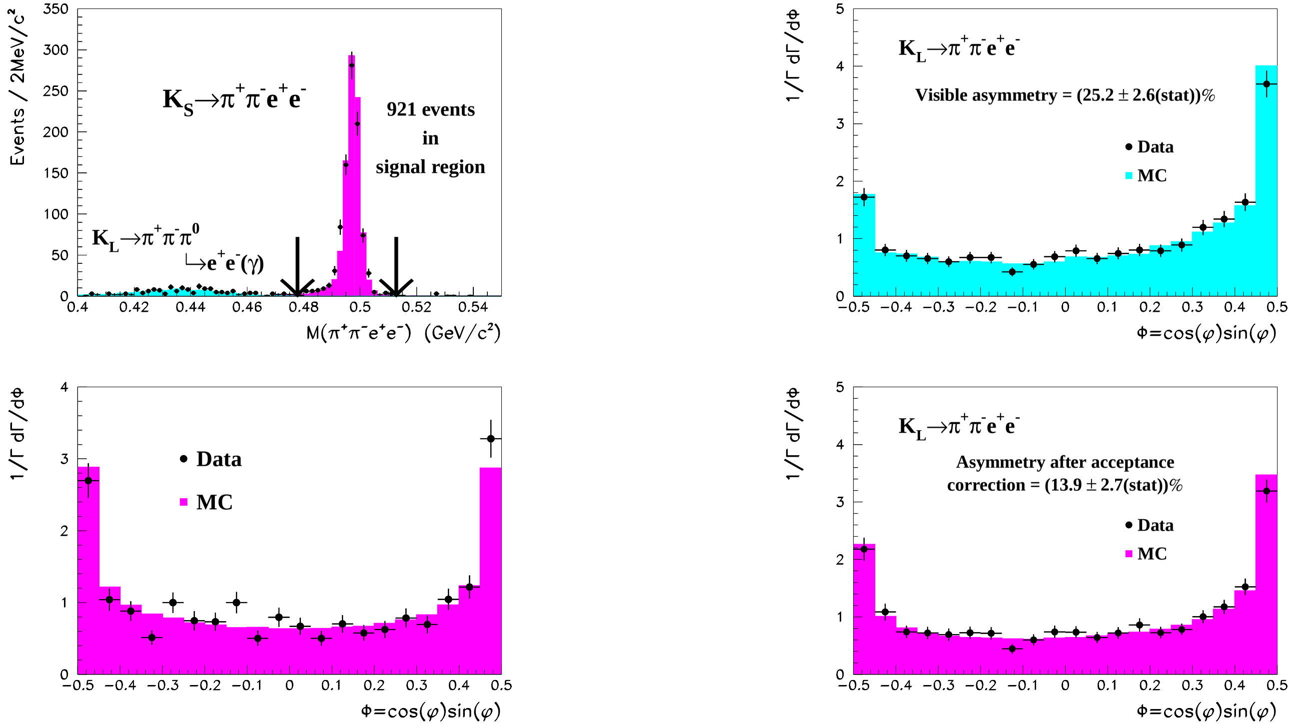
For K_L, interference between M1 and IB amplitudes give large T-odd asymmetry in the azimuthal distribution between the $\pi^+\pi^-$ and e^+e^- decay planes in the CM system[a]: $A(\phi) \approx 14\%$



No CP-violating asymmetry is expected in K_S decay.

[a] Heiliger, Sehgal - PR D48, 4146 (1998)

$K_S, K_L \to \pi^+\pi^-e^+e^-$ - Results



1998+1999 data (921 K_S events, 1337 K_L events):

$$BR(K_S \to \pi^+\pi^-e^+e^-) = (4.3 \pm 0.2 \pm 0.3) \cdot 10^{-5}$$

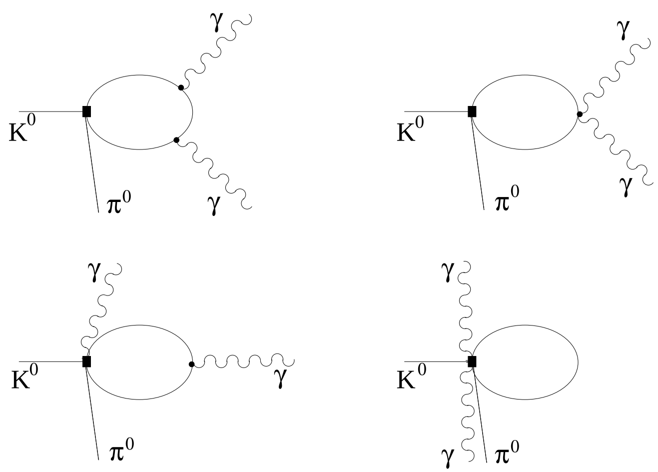
No K_S asymmetry: $A_S(\phi) = (-0.2 \pm 3.4 \pm 1.4)\%$

$$BR(K_L \to \pi^+\pi^-e^+e^-) = (3.1 \pm 0.1 \pm 0.2) \cdot 10^{-7}$$

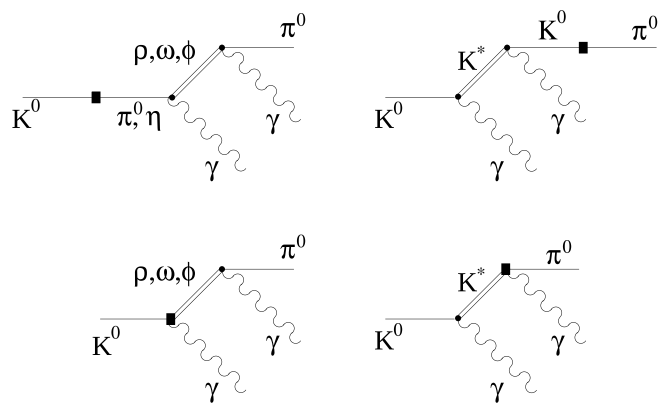
K_L asymmetry: $A_L(\phi) = (13.9 \pm 2.7 \pm 2.0)\%$

$K_L \to \pi^0\gamma\gamma$ - Physics

- Finite at one loop χ PT, $O(p^4)$ prediction is 1/3 of expt.
  Theory: BR $\sim 0.6 \cdot 10^{-6}$
- At $O(p^6)$, including vector mesons exchange, can reproduce the rate; sensitive to tail at low $m_{\gamma\gamma}$. VMD contribution parameterised by a_V, to be determined experimentally.



$O(p^4)$



VMD

- a_V contribution leads to CP-conserving component to $K_L \to \pi^0 e^+ e^-$
- KTeV results: $a_V = -0.72 \pm 0.05 \pm 0.06$
  $BR(K_L \to \pi^0\gamma\gamma) = (1.68 \pm 0.07 \pm 0.08) \times 10^{-6}$

$K_L \to \pi^0\gamma\gamma$ - **Data**

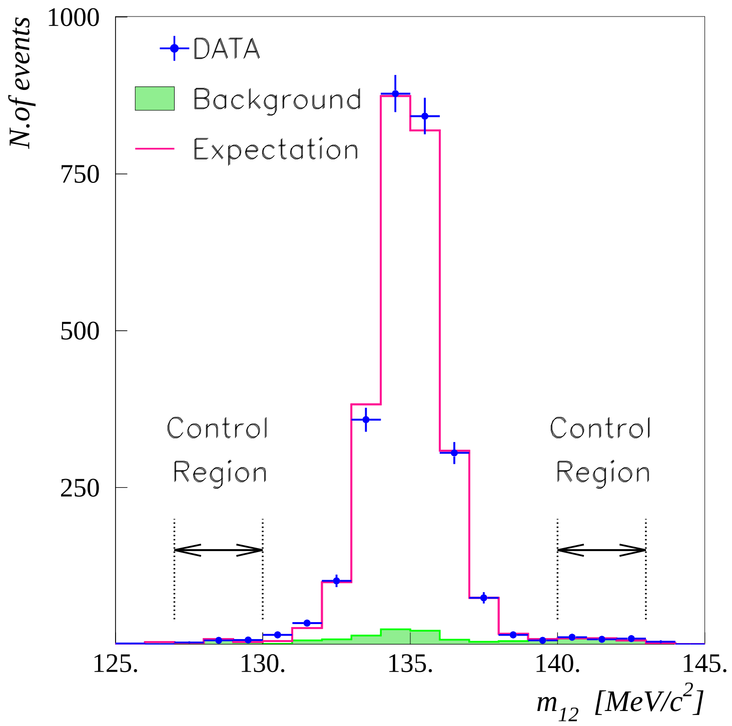
- Rare process without a clear signature but a very high background
- Normalisation to $K_L \to \pi^0\pi^0$: most of the systematic uncertainties cancel.
- Background sources:

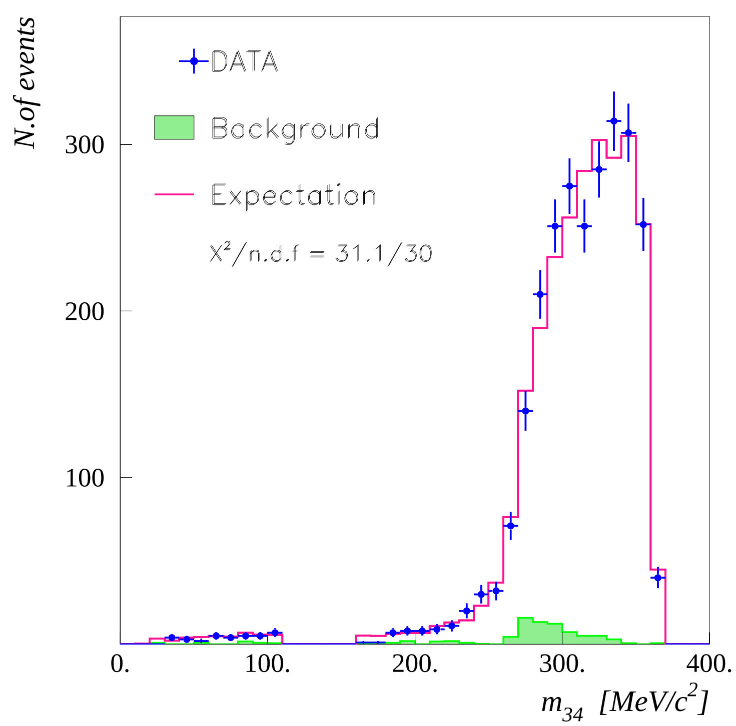
  $K_L \to 2\pi^0$ with badly reconstructed showers: evaluated from $K_S \to 2\pi^0$ tails: $(0.16 \pm 0.08)\%$

  $K_L \to 3\pi^0$ with missing or overlapped showers: evaluated from normalized MC sample: $(2.74 \pm 0.42)\%$

  Pile-up events: evaluated from tails of R_{COG} distribution and events with out-of-time cluster: $(0.32 \pm 0.21)\%$
- Using 1998 + 1999 data, $\approx$ 2500 candidates in the signal region $132 < m_{1,2} < 138$ MeV$/c^2$

$K_L \to \pi^0\gamma\gamma$ - Results





Keeping only non-ambiguous events: $a_V = -0.46 \pm 0.03_{stat} \pm 0.04_{syst}$

Using fitted value of a_V and all events:

$$BR(K_L \to \pi^0\gamma\gamma) = (1.36 \pm 0.03_{stat} \pm 0.03_{syst} \pm 0.03_{norm}) \cdot 10^{-6}$$

Systematics dominated by acceptance and background (hep-ex/0205010)

Implies negligible CP-conserving amplitude in $K_L \to \pi^0 e^+ e^-$

NA48/1

NA48/1 is a high-sensitivity search for rare K_S decays
No K_L beam, high-intensity ($\times$ several hundred) K_S beam.

- 40 h run in 1999:
  Measurement of $BR(K_S \to \gamma\gamma)$[a] $=$
  $(2.78 \pm 0.06_{stat} \pm 0.02_{MCstat} \pm 0.04_{syst}) \cdot 10^{-6}$
  Limit on $BR(K_S \to \pi^0 e^+ e^-)$[b] $< 1.4 \cdot 10^{-7}\,(90\% CL)$

- Presently running (80 days scheduled)
  Aim at $\sim 3 \cdot 10^{-10}$ SES for $K_S \to \pi^0 e^+ e^-$
  Search for CPV in $K_S \to 3\pi^0$ and $K_S \to \pi^+\pi^-\pi^0$
  Rare hyperon decays

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[a] PL B493 (2000) 29
[b] PL B514 (2001) 253

NA48/2

NA48/2 is an approved experiment scheduled for 2003, for the measurement of direct CP violation in $K^{\pm}$ decays.

- Simultaneous, collinear, momentum-selected $K^{\pm}$ beams (60 GeV/c ± 5%)
- Measurement of odd-pion Dalitz plot slope asymmetry in $K^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$ and $K^{\pm} \to \pi^{\pm}\pi^{0}\pi^{0}$ decays

$$|M(u,v)|^2 \propto 1 + gu + hu^2 + jv + kv^2 + \cdots$$
$$A_g \equiv (g^+ - g^-)/(g^+ + g^-)$$

Theoretical predictions for A_g in the O(10^{-6} to 10^{-4}) range.

Experiment: $A_g = (-7 \pm 5) \cdot 10^{-3}$ (Ford, 1970)

With more than $2 \cdot 10^9 K^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$ decays/year, NA48/2 can measure A_g with a precision $\delta A_g < 2 \cdot 10^{-4}$

- Study low-energy $\pi^{+}\pi^{-}$ interaction in $K^{\pm} \to \pi^{+}\pi^{-}e^{\pm}\nu(\overline{\nu})$ (K_{e4}) decays to extract size of quark condensate $\langle 0|q\overline{q}|0\rangle$ (to understand chiral symmetry breaking mechanism)

Expect $\delta a_0^0 \simeq 0.007$ (stat) with $10^6 K_{e4}$ events

Conclusions

- New NA48 result on direct CP violation from 4 years of data taking:

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

  Direct CP violation in K^0 system:

$$\frac{\Gamma(K^0 \to \pi^+\pi^-) - \Gamma(\overline{K^0} \to \pi^+\pi^-)}{\Gamma(K^0 \to \pi^+\pi^-) + \Gamma(\overline{K^0} \to \pi^+\pi^-)} = (4.8 \pm 0.7) \times 10^{-6}$$

- New measurements of $K_L \to \pi^0\gamma\gamma$ and $K_S \to \gamma\gamma$, tests of χPT
- New measurements of K_S lifetime, K^0 and η masses
- Active program for measurement of rare K_S decays and CP violation in $K^\pm$ decays

The kaon system, central in the development of particle physics, is still delivering exciting results!