On behalf of the NA48 Collaboration

New trends in high energy physics
Yalta - Crimea, 22-29 September 2001
INFN Perugia, Italy
Patrizia Cenci

The future NA48 program at CERN
The NA48 experimental program

MAIN GOAL: precise measurement of the direct CP violation

NA48/I: a high sensitivity investigation of \( \bar{K} \) and neutral hyperon decays using a modified \( K_S \) beam (2002)

NA48/II: a precision measurement of \( \Delta m \) in the neutral K meson system: published results on 1997-1999 data, 2001 run in progress

NA48/I: a precision measurement of charged K meson decay

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The future program at CERN

data taking after the end of the \( \epsilon/\epsilon \) program:

FUTURE: 2 addenda to the NA48 proposal approved in 2000,

IN PARALLEL: many studies of \( K_S \), \( K_L \) rare decays and neutral hyperon decays (concurrently with \( \epsilon/\epsilon \) plus dedicated run).

The NA48 experimental program
The NA48 experiment at CERN

The NA48 method

- Simultaneous K_S/\bar{K}_L beams hitting the same detector region
- Concurrent collection of K_S, K_L \rightarrow \pi^0 \pi^0, \pi^+ \pi^-

- Double ratio technique for Re(\epsilon'/\epsilon) measurement
- K_S identification with proton tagging

Schedule of the forthcoming activity:

2001: End of \epsilon'/\epsilon program
2002: NA48/I: no K_L, modified K_S beam, improved readout/daq capability
2003: NA48/II: new beam line for simultaneous \pi^+ / \pi^- upgrade detector

The NA48 future program at CERN

Patrizia Cenci
The NA48 future program at CERN

**The NA48 detector**

- Kevlar window
- Drift chamber 1
- Anti counter 6
- Drift chamber 2
- Magnet
- Drift chamber 3
- Helium tank
- Anti counter 7
- Drift chamber 4
- Hodoscope
- Liquid krypton calorimeter
- Hadron calorimeter
- Muon veto system

**CHARGED DECAYS:**

\[
\frac{\sigma}{E} > 300 \text{ ps above } 20 \text{ GeV}
\]

\[
\frac{\sigma}{E} > 0.5 \% (E \text{ in GeV})
\]

\[
\sigma(p) = 0.5 \% \oplus 0.009 \%
\]

\[
\sigma(p, GeV/c) = 90 \mu m \oplus 2 \text{ mm} \oplus 200 \text{ ps}
\]

**NEUTRAL DECAYS:**

\[
\frac{\sigma}{E} > 1.3 \text{ mm}
\]

\[
\frac{\sigma}{E} \approx 0.5 \% \oplus 0.10 \% \oplus 0.2 \% = \frac{E}{0.5} \oplus 3.2 \% \oplus \frac{E}{(E)} \oplus 0.5 \%
\]

**Hodoscope**

\[
\frac{\sigma}{d} > 0.5 \% \oplus 0.009 \%
\]

\[
\frac{\sigma}{d} = 1 \text{ MeV/c}
\]

\[
\sigma(x,y) < 1.3 \text{ mm}
\]

**NEUTRAL DECAYS:**

\[
\frac{\sigma}{E} = 3.2 \% \oplus 0.1 \% \oplus 0.5 \%(E \text{ in GeV})
\]

**Magnetic spectrometer and scintillator**

\[
\frac{\sigma}{d} < 300 \text{ ps above } 20 \text{ GeV}
\]

\[
\frac{\sigma}{d} = 265 \text{ MeV/c}
\]

\[
\frac{\sigma}{d} \approx \frac{1}{p_{\text{track}}} \frac{d}{(d)}
\]

The NA48 detector
RARE DECAYS IN NA48

✦ 1997-1999 Re(ε′/ε) data taking:
  - 450 GeV/c proton momentum
  - SPS pulse: 2.4s/14.4s
  - $3.0 \times 10^7$ ppp on $K_S$ target ⇒ $\sim 3 \times 10^2$ $K_S$
  - $1.5 \times 10^{12}$ ppp on $K_L$ target ⇒ $\sim 2 \times 10^7$ $K_L$
  - Decays per year (120 days, 50% efficiency):
    - $6.5 \times 10^7$ $K_S$ /year ⇒ SES: $\sim 1.5 \times 10^{-7}$
    - $3.6 \times 10^{10}$ $K_L$ /year ⇒ SES: $\sim 3 \times 10^{-10}$
      ($E_K$: 70–170 GeV, 10% acceptance)

✦ 1999 High Intensity $K_S$ run (48 hours)
  - no $K_L$ beam
  - $\sim 6.0 \times 10^9$ ppp on $K_S$ target (×200)
  - $\sim 2.3 \times 10^8$ $K_S$ decays in $E_K$: 60–190 GeV
    ⇒ SES: $\sim 4 \times 10^{-8}$ (10% acceptance)
    ⇒ 48 hours $\simeq$ 3-4 years of $\epsilon'/\epsilon$ operation

✦ 2000 High Intensity $K_S$ run
  - no charged spectrometer
  - 400 GeV/c proton momentum
  - $\sim 9.0 \times 10^9$ ppp on $K_S$ target
  - modified production angle
  - modified duty cycle (3.2s/14.4s)
  - $\sim 10^{10}$ $K_S$ decays collected in $\sim$ 40 days
<table>
<thead>
<tr>
<th>Decay</th>
<th>NA48 (Preliminary)</th>
<th>Published result</th>
</tr>
</thead>
<tbody>
<tr>
<td>π^0 γγ</td>
<td>3.7 ± 0.5 (1–0.1)</td>
<td>2.7 ± 0.4 (1–0.1)</td>
</tr>
<tr>
<td>π^+ π^− e^+ e^−</td>
<td>6.7 ± 0.4 (1–0.1)</td>
<td>4.9 ± 0.3 (1–0.1)</td>
</tr>
<tr>
<td>π^+ π^− e^+ µ^-</td>
<td>6.9 ± 0.3 (1–0.1)</td>
<td>5.5 ± 0.2 (1–0.1)</td>
</tr>
<tr>
<td>π^+ π^− e^+ γ</td>
<td>6.1 ± 0.2 (1–0.1)</td>
<td>4.4 ± 0.1 (1–0.1)</td>
</tr>
<tr>
<td>K^+ γγ</td>
<td>5.8 ± 0.3 (1–0.1)</td>
<td>4.7 ± 0.2 (1–0.1)</td>
</tr>
</tbody>
</table>

Summary of recent rare decays results in NA48
The NA48/I proposal

✦ A program for $K_S$ rare decay and neutral hyperon search in the year 2002 has been approved by the CERN Research Board (CERN SPSC 2000-002) starting in April 2002.

✦ ≥ 120 days of data taking starting in April 2002

AIM: collect at least 50 times the statistics of the 1999 data

 Proposal: $S_{EES} \approx 3 \times 10^{-11}$ (α: acceptance for the decay after all cuts)

⇒ better sensitivity actually expected due to the upgrade of front end and read out electronics

⇒ optimized design:
  ∗ optimized collimator design
  ∗ optimized read out, data acquisition and trigger systems
  ∗ new drift chamber front end and read out electronics
  ∗ vacuum along the passage of the beam
  ∗ no $K_S$ veto counter

PROPOSALS OF THE NA48 SETUP

"The NA48/I proposal"
The NA48/I beam characteristics

DETAIL OF THE $K_S$ TARGET STATION

SPS proton momentum $400\; GeV/c$
Duty Cycle $5.2\; s/16.8\; s$
Protons per pulse on target $1 \times 10^{10}$
Production angle $-2.5\; mrad$
Total kaon flux/pulse $\sim 1.5 \times 10^5$
$K$-decays (40-240 GeV)/pulse $1.1 \times 10^5$
$K$-decays (40-240 GeV)/year $3.0 \times 10^{10}$
(50% efficiency $\times 120$ days)

✧ Features of the 2002 intense $K_S$ beam (wrt 1999)
⇒ lower proton momentum
⇒ longer duty cycle
⇒ modified production angle
⇒ higher intensity
Physics case: $K_S \rightarrow \pi^0 e^+ e^-$

The measurement of $K_S \rightarrow \pi^0 e^+ e^-$ is essentially a measurement of $K_1 \rightarrow \pi^0 e^+ e^-$ with CP=$+1$ (CPC)

PHYSICS INTEREST:

♦ understand the chiral structure of the $K \rightarrow \pi \gamma^*$ vertex:

$\Rightarrow$ $K_S \rightarrow \pi^0 e^+ e^-$ is dominated by long–distance dynamics through one–photon exchange

$\Rightarrow$ theoretical expectation from $\chi$PT ($a_s \sim O(1)$):

$$BR(K_S \rightarrow \pi^0 e^+ e^-) \sim 5.2 \times 10^{-9} |a_s|^2$$

♦ bound the indirect CPV component of the $K_L \rightarrow \pi^0 e^+ e^-$ decay: 3 components contribute to the decay amplitude:

$\Rightarrow$ CP conserving component

$$BR(K_L \rightarrow \pi^0 e^+ e^-)_{CPC} \leq few \times 10^{-12}$$

dominated by the two-photon process (CP=$-1$)

$K_2 \rightarrow \pi^0 \gamma^* \gamma^*$

$\Rightarrow$ indirect CP violating component due to the fraction $\epsilon$ of $K_1$ in $K_L$:

$$BR(K_L \rightarrow \pi^0 e^+ e^-)_{ind} = |\epsilon|^2 \frac{\tau_L}{\tau_S} BR(K_S \rightarrow \pi^0 e^+ e^-)$$

$\Rightarrow$ direct CP violating component due to the $K_2$ decay in $K_L$
Search for \( \text{K}_S \rightarrow \pi^0 \text{e}^+ \text{e}^- \)

**MEASUREMENT MOTIVATIONS:**

- direct and indirect CPV components of \( \text{K}_L \rightarrow \pi^0 \text{e}^+ \text{e}^- \) interfere, and the indirect contribution is linked to the \( \chi \text{PT} \) parameter \( a_s \)

- Since the \( a_s \) parameter cannot be predicted, a high sensitivity search for \( \text{K}_S \rightarrow \pi^0 \text{e}^+ \text{e}^- \) is needed.

**PRESENT STATUS:**

- Best result (NA48, 2001):
  \[ \text{BR} < 1.4 \times 10^{-7} \text{(90\% CL)} \]
  \( (\text{PDG: BR} < 1.1 \times 10^{-6} \text{ (90\% CL)} \text{ NA31, 1993}) \)

- NA48/I proposal: \( SES \sim 6 \times 10^{-10} \)
  \( (1 \text{ year data taking, MC acceptance} \sim 5\%) \)

- expected signal in one year \( \sim 7 \text{ events} \)
  for \( \text{BR(K}_S \rightarrow \pi^0 \text{e}^+ \text{e}^-) = 5 \times 10^{-9} \)

- main background due to \( \text{K}_S \rightarrow \pi^0 \pi^0_D \) estimated to be \( < 0.3 \text{ events} \) (MC simulation)

- negligible background due to \( \text{K}_S \rightarrow \pi^0_D \pi^0_D \) and \( \text{K}_L,S \rightarrow \text{e}^+ \text{e}^- \gamma \gamma \)
The uncertainty on $\langle \mathcal{G} \rangle$ is dominated by the error on $\eta_{000}$.

K_S and K_L decay amplitudes into all final states.

Relation which couples the CP violation parameter $\eta_{000}$ and $\eta_{000}$ is also important for CP test through the Bell-Steinberger relations.

Physics case: CP violation in $K_S \to \pi_0 \pi_0 \pi_0$.

$\langle \eta_{000} \rangle$ is sensitive to direct CPV in a decay amplitude.

$\eta_{000}$ is also important for CPT test through the Bell-Steinberger relation which couples the CPT violation parameter $\Im(\delta)$ and $K_0 - K_0$ mixing.

$\eta_{000}$ is predicted by CPV in the $K_0 - K_0$ mixing.

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The NA48 future program at CERN...
The $\eta_{000}$ measurement

Sensitivity to $\eta_{000}$ in NA48/I

- Method: measure $K_S - K_L$ interference near the production target
  - maximum interference at the $K_S$ target
  - most of the effect within few $K_S$ lifetimes
- Sensitivity to $\Re(\eta_{000})$ and $\Im(\eta_{000})$ evaluated with $3\pi^0$ events (HI $K_S$ run data and MC)
  - high $K^0 \to 3\pi^0$ statistics required to improve limits on $\Re(\eta_{000})$ and $\Im(\eta_{000})$
  - excellent knowledge of detector acceptance

$\Re(\eta_{000}), \Im(\eta_{000})$: statistical and systematic error due to limited knowledge of the acceptance:

$\Longrightarrow$ NA48/I error on $\Re(\eta_{000})$ and $\Im(\eta_{000})$ within $\sim 1\%$ in one year of data taking
Hyperon decays in NA48

The $K_S$ target is source of hyperons: the intense beam will be used to improve NA48 current results on neutral hyperon decays and start new studies.

HYPERON SAMPLE IN NA48 (1999 data): two tracks reconstructed under the $\pi^+\pi^-$ hypothesis ($\sim 41 \times 10^6$ 2–tracks events)

HYPERON TRIGGER IN NA48: apply cuts on anti–$[K_S \rightarrow \pi^+\pi^-]$ mass and $p^+/p^-$ momenta ratio
Neutral hyperon physics

OUTLOOK AND MOTIVATION

✦ precise measurement of $M(\Xi^0)$
  ⇒ check mass splitting among the SU(3) octect members related to radiative corrections
  ⇒ test of theoretical approaches to mass calculation
  ⇒ NA48: $M(\Xi^-) - M(\Xi^0) = 6.5 \pm 0.25 \text{ MeV}/c^2$
  ⇒ NA48/l: improve error to 0.1 MeV/c$^2$

✦ radiative decays $\Xi^0 \rightarrow \Lambda^0 \gamma / \Sigma^0 \gamma$
  ⇒ poor theoretical understanding: predictions of various models over an order of magnitude
  ⇒ NA48 results (preliminary):
    \[ \text{BR}(\Lambda \gamma) = (1.9 \pm 0.2) \times 10^{-3} \quad (497 \text{ events}) \]
    \[ \text{BR}(\Sigma^0 \gamma) = (3.7 \pm 0.5) \times 10^{-3} \quad (380 \text{ events}) \]
  ⇒ NA48/l: increase samples by factor 100 and reduce systematics by factor 2: expect 5% accuracy on BR

✦ hyperon $\beta$ decay $\Xi^0 \rightarrow \Sigma^+ e^- \bar{\nu}$
  ⇒ direct analogue to $n \rightarrow pe^- \bar{\nu}$
  ⇒ study flavor symmetry violation
  ⇒ PDG: $\text{BR}(\Sigma^+ e^- \bar{\nu}) = (2.7 \pm 0.4) \times 10^{-4} \quad (KTeV)$
  ⇒ NA48: observe $\sim 60$ events
  ⇒ NA48/l: expect up to 25000 events

✦ search for $\Xi^0 \rightarrow p\pi^- \Delta S=2$ transitions
  ⇒ predicted $\text{BR}(p\pi^-) \sim 10^{-17}$
  ⇒ current limit: $\text{BR}(p\pi^-) \leq 4 \times 10^{-4} \quad (90\% \text{ CL})$
  ⇒ NA48/l: expect a factor 100 on existing limit
Competition to \( \text{NA48/I} \) is up to one order of magnitude better than \( \text{KTeV} \) (no hole in tracking chambers)

- Capability of \( \text{KTeV} \) to track the leading baryon in the beam
- Region
- Only hyperons with very high energy decay in \( \text{KTeV} \) fiducial
- KLOE collects neutral hyperons from the vacuum beam
- Competition from the \( \text{KTeV} \) experiment (FNAL – USA) which

\[ \begin{align*}
\text{NEUTRAL HYPERON PHYSICS} \\
\text{NA48/I proposal} \\
\text{However, the sensitivity per year for } K^0 \rightarrow \pi^0 e^+ e^- \text{ is less than} \\
\text{at the full } \text{DAΦNE} \text{ design luminosity of } 5 \times 10^{32} \text{ cm}^{-2} \text{s}^{-1} \\
\text{KLOE} \\
\text{Complementary experimental technique due to the } K_S \text{ tagging in} \\
\text{KLOE experiment (Frascati – Italy)}
\end{align*} \]

\[ \begin{align*}
\text{RARE } K_S \text{ DECAYS} \\
\text{Competition to NA48/I}
\end{align*} \]
Summary of NA48/I physics topics

K^0 \to \pi^+ \pi^- \gamma \gamma

(\times 10^9)

\frac{1.5}{2.6} \times 10^6

\frac{3.4}{5.3} \times 10^6

\frac{5.4}{9.6} \times 10^5

\frac{9.0}{1.8} \times 10^4

Dalitz decays (\gamma \gamma^*)

\text{Non-Leptonic decays (\chi PT)}
The NA48/II proposal

A new program has been approved by the CERN RB to study with high statistics specific properties of the decay of charged kaons (CERN SPSC 2000-003):

- **direct CP violation in** $K \rightarrow 3\pi$
- **$q\bar{q}$ condensate in QCD vacuum** ($K_{e4}$)
- **possible deviations from V-A and Standard Model**
- **measurement of rare charged kaon decays involving photons and/or $e^+e^-$ pairs**

✦ **use new simultaneous charged kaon beams**
✦ **upgrade the NA48 detector with a TRD for $\pi/e$ rejection and with a small beam spectrometer for better $K$ position and momentum measurement**
✦ **optimize trigger system**
✦ **data taking in the year 2003**
Direct CP Violation in $K^{\pm}$ decays

High precision study of charged kaon decays:
⇒ important new possibility to search for direct CP violation additional to that of the neutral kaon sector without the complications induced by mixing
⇒ any difference in $K^{\pm}$ decay matrix elements indicates direct CP violation

NA48/II proposal: high statistics comparison of $K^{\pm} \rightarrow \pi^{\pm}\pi^{+}\pi^{-}$, $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\pi^{0}$
⇒ most promising processes
⇒ decay matrix element parametrized as:

$$|M(u,v)|^2 \sim 1 + gu + hu^2 + kv^2$$

$$u = (s_3 - s_0)/m_\pi^2 \quad v = (s_1 - s_2)/m_\pi^2$$

$$s_0 = (s_1 + s_2 + s_3)/3$$

$$s_i = (P_K - P_i)^2 \quad (i = 3 \text{ for the odd pion})$$

⇒ direct CPV measured through the asymmetry:

$$A_g = \frac{g^+ - g^-}{g^+ + g^-}$$

⇒ observable quantity:

$$R(u) = \frac{\int dv |M^+(u,v)|^2}{\int dv |M^-(u,v)|^2} \approx 1 + u \cdot (g^+ - g^-) = \frac{N^+(u)}{N^-(u)}$$

⇒ any variation of $R(u)$ as a function of $u$ is evidence of direct CPV.
The $A_g$ measurement

PRINCIPLE OF $A_g$ MEASUREMENT IN NA48/II

- Systematic uncertainties on $A_g$ can create a slope different from zero (studied with MC):
  - different $K^+$ and $K^-$ energy distributions
  - local inefficiencies in drift chambers
  - differences between the magnetic field in the two polarities
  - relative offset of the two beams
  - relative asymmetry in the profile of the two beams
  - differences in the punch-through probabilities for positive and negative pions
  - difference in the interaction probability in the spectrometer for positive and negative pions

- Systematics could be kept at a level of $< 10^{-4}$ under the following conditions:
  - use simultaneous $K^+$ and $K^-$ beams overlapping in space and time, and within a narrow range of momentum such that $K^+$ and $K^-$ decay in the same fiducial volume
  - alternate the sign of the spectrometer field to equalize acceptances for $K^+$ and $K^-$ decays in presence of localized imperfection in the detector
  - bin data in kaon momentum and average $R(u)$ over different field orientations in each bin for a measurement independent of acceptance
The simultaneous $K^+$ and $K^-$ beams

$K^+$ and $K^-$ beam parameters

<table>
<thead>
<tr>
<th></th>
<th>$K^+$</th>
<th>$K^-$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>400 GeV/c</td>
<td></td>
</tr>
<tr>
<td>Duty cycle</td>
<td>5.2s/16.8s</td>
<td></td>
</tr>
<tr>
<td>Proton per pulse</td>
<td>$10^{12}$</td>
<td></td>
</tr>
<tr>
<td>Production angle, mrad</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Acceptance angle, mrad</td>
<td>±0.36</td>
<td></td>
</tr>
<tr>
<td>Momentum, GeV/c</td>
<td>60±3</td>
<td></td>
</tr>
<tr>
<td>proton flux/pulse ($10^6$)</td>
<td>8.6</td>
<td>0.9</td>
</tr>
<tr>
<td>pion flux/pulse ($10^6$)</td>
<td>33.2</td>
<td>24.6</td>
</tr>
<tr>
<td>kaon flux/pulse ($10^6$)</td>
<td>3.1</td>
<td>1.8</td>
</tr>
<tr>
<td>$K_3\pi$(in 100m)/year ($10^{10}$)</td>
<td>1.4</td>
<td>0.8</td>
</tr>
</tbody>
</table>
The precision of $A_g$ measurement

RECONSTRUCTION OF $K^{\pm} \rightarrow 3\pi^{\pm}$ IN NA48/II

<table>
<thead>
<tr>
<th>Decay</th>
<th>$\pi^{\pm}\pi^{\mp}\pi^{-}$</th>
<th>$\pi^{\pm}\pi^{0}\pi^{0}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance (%)</td>
<td>45</td>
<td>6.5</td>
</tr>
<tr>
<td>$K^+/K^-$ decays/pulse ($10^4$)</td>
<td>2.3/1.4</td>
<td>0.05/0.03</td>
</tr>
<tr>
<td>$K^+/K^-$ decays/year ($10^9$)</td>
<td>7.3/4.4</td>
<td>0.15/0.09</td>
</tr>
<tr>
<td>$M_K$ resolution ($MeV/c^2$)</td>
<td>1.6</td>
<td>1.2</td>
</tr>
<tr>
<td>$P_K$ resolution ($MeV/c$)</td>
<td>460</td>
<td>360</td>
</tr>
<tr>
<td>z resolution ($cm$)</td>
<td>65</td>
<td>60</td>
</tr>
<tr>
<td>u resolution</td>
<td>0.035</td>
<td>0.02</td>
</tr>
<tr>
<td>STATISTICAL ERROR</td>
<td>$0.7 \times 10^{-4}$</td>
<td>$&lt; 2.2 \times 10^{-4}$</td>
</tr>
</tbody>
</table>

SYSTEMATICS UNCERTAINTIES ON $A_g$

<table>
<thead>
<tr>
<th>Source</th>
<th>Uncertainty on $A_g (10^{-5})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam non collinearity</td>
<td>$&lt; 3.8$ (MC stat.)</td>
</tr>
<tr>
<td>$P_{K^+} \neq P_{K^-}$</td>
<td>$\sim 1.0$ (Kabes)</td>
</tr>
<tr>
<td>Accidentals in detector</td>
<td>$&lt; 2.0$ (MC stat.)</td>
</tr>
<tr>
<td>$\pi^+/\pi^-$ cross section difference</td>
<td>$&lt; 0.07$ (MC stat.)</td>
</tr>
<tr>
<td>Pion punch-through effects</td>
<td>$&lt; 0.5$ ($K_e3$ stat.)</td>
</tr>
<tr>
<td>Parasitic B, resolution on u,p...</td>
<td>negligible</td>
</tr>
<tr>
<td>TOTAL SYSTEMATICS</td>
<td>$\sim 5$</td>
</tr>
</tbody>
</table>

$\Rightarrow$ the precision of $A_g$ measurement in NA48/II is limited by statistics

$\Rightarrow$ total systematics $\sim 5 \times 10^{-5}$

$\Rightarrow$ with $\sim 10^{10}$ $K^{\pm} \rightarrow \pi^{\pm}\pi^{\mp}\pi^{-}$ decays/year

NA48/II aims at a precision of $\sim 10^{-4}$ on $A_g$
Outlook on $A_g$ measurement

✦ The precision of $A_g$ measurement in NA48/II is limited by statistics
✦ Present experimental limit:

$$A_g = (-7 \pm 5) \times 10^{-3} \quad Ford \ et \ al. \ (1970)$$

✦ Status of $A_g$ measurement:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>$K^\pm$ decays</th>
<th>Statistics</th>
<th>$\delta A_g$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HyperCP</td>
<td>$\pi^\pm \pi^\mp \pi^0$</td>
<td>$4.5 \times 10^8$</td>
<td>$\sim 6 \times 10^{-4}$</td>
</tr>
<tr>
<td>KLOE (1 year)</td>
<td>$\pi^\pm \pi^\mp \pi^0$</td>
<td>$1.5 \times 10^8$</td>
<td>$\sim 4.4 \times 10^{-4}$</td>
</tr>
<tr>
<td></td>
<td>$\pi^\pm \pi^\mp \pi^0$</td>
<td>$0.6 \times 10^8$</td>
<td>$\sim 6.3 \times 10^{-4}$</td>
</tr>
<tr>
<td></td>
<td>$\pi^\pm \pi^\mp \pi^0$</td>
<td>$1.17 \times 10^{10}$</td>
<td>$\sim 0.7 \times 10^{-4}$</td>
</tr>
<tr>
<td></td>
<td>$\pi^\pm \pi^\mp \pi^0$</td>
<td>$2.4 \times 10^8$</td>
<td>$&lt; 2.2 \times 10^{-4}$</td>
</tr>
</tbody>
</table>

✦ Status of theoretical calculations:

<table>
<thead>
<tr>
<th>Author</th>
<th>$A_g$ prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Belkov et al.</td>
<td>$(2-4) \cdot 10^{-4}$</td>
</tr>
<tr>
<td>E. Shabalin</td>
<td>$4 \cdot 10^{-4}$</td>
</tr>
<tr>
<td>D’Ambrosio</td>
<td>$4 \cdot 10^{-5}$</td>
</tr>
<tr>
<td>L.Maiani, N.Paver</td>
<td>$(2.3 \pm 0.6) \cdot 10^{-6}$</td>
</tr>
<tr>
<td>D’Ambrosio et al.</td>
<td>$\sim 10^{-4}$</td>
</tr>
</tbody>
</table>

✦ CP can also be investigated in NA48/II (limited statistics) in decays such as: $K^\pm \rightarrow \pi^\pm \pi^0 \gamma$
CONCLUSIONS

✦ NA48 is concluding with the last data taking in 2001 a successful experimental program:

⇒ direct CP violation in the neutral kaon system has been clearly established

⇒ the rare decay program has provided very interesting physics results in the field of $\chi$PT and of CP violation in the neutral kaon sector and in the field of neutral hyperon physics

✦ two addenda to the NA48 proposal have been approved for further running after the end of $Re(\varepsilon'/\varepsilon)$ program to get a deeper knowledge of kaon and hyperon physics:

NA48/I will take data in 2002 using the present beam line and detector with improved readout capability to probe the $K_S$ and neutral hyperon decays physics with a beam intensity $\sim 500$ times the actual one.

NA48/II will take data in 2003 using an upgraded detector and simultaneous charged kaon beams to study direct CP violation in the decay $K^{\pm} \to \pi^{\pm} \pi^+ \pi^-$. 

✦ The $K$ sector has still great potentialities for exiting physics in the framework of direct CP violation investigation