Direct CP violation in $K^\pm$ decays by the NA48/2 experiment at CERN

Gianmaria Collazuol
Scuola Normale Superiore
and INFN Pisa

on behalf of NA48/2 collaboration:
Cambridge, CERN, Chicago, Dubna, Edinburgh, Ferrara, Firenze, Mainz, Northwestern, Perugia, Pisa, Saclay, Siegen, Torino, Vienna
Direct CP violation in $K^\pm$ decays by the NA48/2 experiment at CERN

Overview

- *Direct CP violation in charged kaon decays*

- *The NA48 Beam and Detector*

- *Preliminary studies of the charge asymmetry in $K^\pm \rightarrow \pi^\pm \pi^+\pi^-$*
  
  ... status report: no result yet

- *The neutral mode $K^\pm \rightarrow \pi^\pm \pi^0\pi^0$*

- *Rare decay channels*

- *Present data taking, Future and Conclusions*
The study of direct CP violation in kaon decays with high precision and in different channels provides a powerful tool for overconstraining the CKM matrix and searching for new physics.

First NA48 contribution to this quest: established the existence and precisely measured the direct CPV in the neutral kaon system

\[
\frac{\Gamma (K^+ \rightarrow \pi^+ \pi^- \pi^-) - \Gamma (\bar{K}^+ \rightarrow \pi^+ \pi^- \pi^-)}{\Gamma (K^+ \rightarrow \pi^+ \pi^- \pi^-) + \Gamma (\bar{K}^+ \rightarrow \pi^+ \pi^- \pi^-)} = (4.8 \pm 0.7) \times 10^{-6}
\]

Since 2003 NA48 is searching for CPV in the charged kaon system by a very high statistics and very low systematics investigation.
### History of NA48 physics

<table>
<thead>
<tr>
<th>Year</th>
<th>Beam</th>
<th>Physics goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>$K_L + K_S$</td>
<td>$\epsilon'/\epsilon$</td>
</tr>
</tbody>
</table>
| 1998 | $K_L + K_S$ | $\epsilon'/\epsilon$  
Rare $K_L$ decays |
| 1999 | $K_L + K_S$ | $\epsilon'/\epsilon$  
Rare $K_L$ decays |
|      | $K_L$      | $\text{Ke3/K}\mu3$   |
|      | HI $K_S$   | $K_s/\text{hyperon decays}$ |
| 2000 | $K_L$      | $\epsilon'/\epsilon$ checks  
Neutral $K_L$ decays |
|      | $\eta$     | $\epsilon'/\epsilon$ checks  
Neutral $K_S$ decays  
$\eta_{000}$ |
| 2002 NA48/1 | HI $K_S$ | Rare $K_S$ decays  
Hyperon decays |
| 2003 NA48/2 | $K^+/K^-$ | Direct CP-v in $K^\pm \rightarrow (3\pi)^\pm$  
Rare $K^\pm$ decays |
| 2004 NA48/2 | $K^+/K^-$ | Direct CP-v in $K^\pm \rightarrow (3\pi)^\pm$  
Rare $K^\pm$ decays |

**FUTURE (>2005)** = $K^\pm \rightarrow \pi^\pm \nu\bar{\nu}$ ???
\( K^\pm \rightarrow 3\pi \) decays in Dalitz plot

**Kinematics**

\[
s_i = \left( p_k - p_i \right)^2 \\
s_0 = \frac{1}{3} \sum s_i \\
u = (s_3 - s_0) / M^2 \\
v = (s_1 - s_2) / M^2
\]

**Dynamics**

Two Isospin amplitudes: 
\( \Delta I = 1/2 \) dominant, \( \Delta I = 3/2 \) contamination

\[
|A(K \rightarrow 3\pi)|^2 \propto 1 + gu + hu^2 + kv^2
\]

**BR**

\[
\frac{BR(K^\pm \rightarrow \pi^0 \pi^0 \pi^0)}{BR(K^\pm \rightarrow \pi^\pm \pi^0 \pi^0)} = \frac{(5.57 \pm 0.03)}{(1.73 \pm 0.04)}
\]

\[
\Delta I = \frac{1}{2} \rightarrow 4 : 1 \\
\Delta I = \frac{3}{2} \rightarrow 1 : 1
\]

Mixture with \( \Delta I = \frac{1}{2} \) dominance

\[
\omega = \frac{A_{3/2}}{A_{1/2}} = \frac{1}{20}
\]
**K^{±} → 3\pi decays in Dalitz plot**

\[
|A (K \to 3\pi)|^2 \propto 1 + g \times u + hu^2 + kv^2
\]

Phase space is small => the expansion in u,v is rapidly convergent

Linear slope \(g\) dominates over quadratic terms \(h,k\)

**Measurements of linear slope parameters:**

<table>
<thead>
<tr>
<th>(g^+)</th>
<th>(K^{±} \to \pi^+\pi^-\pi^±)</th>
<th>(K^{±} \to \pi^0\pi^0\pi^±)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-0.2154 \pm 0.0035)</td>
<td>0.672 (\pm 0.030)</td>
<td></td>
</tr>
<tr>
<td>(-0.2170 \pm 0.0070)</td>
<td>0.642 (\pm 0.057)</td>
<td></td>
</tr>
</tbody>
</table>

\(\text{(PDG)}\)

\(\text{(PDG + hep-ex/0205027)}\)

\`CHARGE MODE``  \`NEUTRAL MODE``
Direct CP violation in $K^\pm \rightarrow 3\pi$

\[ A(K \rightarrow 3\pi) = a + b \times u \]

(neglecting small quadratic slope parameters $h, k$)

Two $\Delta I = \frac{1}{2}$ amplitudes with different weak and strong phases $\Rightarrow$ interference effects on (possibly not suppressed by $\Delta I = 3/2$)

$$\left| A(K \rightarrow 3\pi) \right|^2 \propto 1 + g \times u$$

Search DCPV by comparing the linear slopes of $K^+$ and $K^-$

If asymmetries $A_{g}^{C,N} \neq 0$ $\Rightarrow$ direct CP violation

\[ A_{g}^{c,n} \text{ def } = \frac{g_+ - g_-}{2g} = \frac{\Delta g}{2g} \]

C: charged mode  
N: neutral mode
Direct CP violation in $K^\pm \to 3\pi$

Theoretical predictions:

Conflicting results in literature: $10^{-6} - 10^{-3}$

E. Shabalin (kaon mini-workshop CERN 5/5/2004)
- $A_g^C \sim 3 \times 10^{-5}$ within SM.

- $A_g^C \sim 10^{-5}$: perfectly compatible with SM
- $3 \times 10^{-5} < A_g^C < 5 \times 10^{-5}$: compatible with SM, but in bad agreement with $\epsilon'/\epsilon$
- $5 \times 10^{-5} < A_g^C$: => New Physics
- $A_g^N$ ? dominated by NLO counterterms:
  New important information on chiral couplings

Note: 1) $A_g^n = A_g^C$ with only $\Delta l = \frac{1}{2}$
2) CP violation in decay widths is much smaller than in Dalitz slopes
Direct CP violation in $K^\pm \rightarrow 3\pi$

Experimental results:

Ford et al. (1970) at BNL
Statistics: 3.2M $K^\pm$

HyperCP (E731) at FNAL
Statistics: 390M $K^+$ and 1.6M $K^-$ (10% only used)
Important systematic due to the knowledge of magnetic fields

Smith et al. (1975) at CERN-PS
Statistics: 28000 $K^\pm$
(Smith et al. NP B91 (1975) 45)

ISTRA+ at TNF-IHEP:
Statistics: 0.52M $K^\pm$ (final result)
(Akopdzhanov et al, hep-ex/04060008, jun 2004)
Direct CP violation in $K^\pm$

NA48/2 Goal
Measure $A_g^C$ and $A_g^N$ with accuracy of $\sim 10^{-4}$ (statistically dominated) by collecting $>2$ Billions of $K^\pm \rightarrow \pi^\pm \pi^+ \pi^-$ and $>100$ Millions of $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$

NA48/2 Method
Two simultaneous $K^+$ and $K^-$ beams, overlapping both in space and time, with narrow band momentum

Detect asymmetry exclusively considering slopes of ratios of normalized $u$ distributions of $K^+$ and $K^-$

Equalize $K^+$ and $K^-$ acceptances by frequently alternating the polarities of the relevant magnets along the particle paths
The NA48/2 K+/K- narrow band beam: simultaneous, coaxial and focused
The NA48/2 K+/K- narrow band beam: simultaneous, coaxial and focused

Primary proton momentum (GeV/c) 400
Duty cycle (s/s) 5.2/16.8
P.o.t. per cycle $10^{12}$
Production angle (mrad) 0°
Beam Acceptance (mrad) ±0.36
Beam Momentum (GeV/c) 60 ± 3
Target to final coll. (m) 102
p/\bar{p} per cycle ($10^6$) 8.6 0.9
$\pi^+/$\pi$^-$ per cycle ($10^6$) 33.2 24.6
K$^+$/K$^-$ per cycle ($10^6$) 3.1 1.8
Fiducial Region (m) 115

... but decay products stay in the beam pipe

Kaon momenta spectrum
Variations of the spectrometer B field are monitored by measuring the current in the dipole, by several Hall probes and by the reconstructed kaon mass in $3\pi$ decays.

Accurately measured maps of B and Bstray are used in the reconstruction programs.
The NA48/2 K+/K- beam: beam geometry, beam movements

Short term beams movement in time (along the 5.8 s extraction)
mean position of the beams
monitored at the end of the beam line
with a dedicated beam monitor

Split due to the spectrometer magnet
=> offset ~ 10cm
The NA48/2 K+/K- beam: beam geometry, beam movements

Long term beams movements in time:

center of gravity of selected $3\pi$ decays measured at DCH1

Positive kaons

Negative kaons
The NA48/2 K+/K- beam: Kaon BEam Spectrometer

Individual K measurement by 3 double stations of projection chambers of MicrOmega type amplification stages placed in second achromat

Measure TIME and VERTICAL POSITION of each beam particle
=> kaon tagging with TOF
=> kaon momentum and charge
  • Redundancy in K₃ analyses
  • Reconstruct K₃ decays with a lost π
  • Resolve K₀π reconstruction ambiguity due to neutrino

• Max rate: 2MHz/strip (1mm)
• σₓ = 50 μm [drift]
• σᵧ = 80 μm [strips]
• σₜ = 0.7 ns
• σₚ//{$p$} < 1%
• Mistagging probability < 2%

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Direct CPV in K⁺ decays by NA48/2
BEACH 2004-Chicago-June 30
The NA48 detector

😊 HIGH RATE, HIGH RESOLUTION
😊 BEAM PIPE

- **MAGNETIC SPECTROMETER**
  - Redundancy → High Efficiency
  - High Resolution
- **HODOSCOPE**
  - Fast & High Granularity Multiplicity Trigger
  - Precise Time Meas. \( \sigma_t \sim 150 \text{ ps} \)
- **MUON VETO** → Off-line Rejection of \( \mu \) Background
- **LIQUID KRYPTON ELECTROMAGNETIC CALORIMETER:**
  - Quasi-Homogeneous & High Granularity
  - Trigger with no dead-time
  - Precise Time Meas. \( \sigma_t \sim 220 \text{ ps} \)
  - High E Resol. \( \sigma_E/E \sim 1\% \) for 20 GeV
  - Powerful \( e/\pi \) discrimin. \( (1 : 10^4) \)
The NA48 detector

Detector resolutions:

- Magnetic spectrometer (4 DCHs):
  \[ \sigma_p/p = 0.5\% + 0.015\% \, p \, [\text{GeV/c}] \]
- Liquid Krypton EM calorimeter (LKr)
  \[ \sigma_E/E = 3.2\%/\sqrt{E} + 9\%/E + 0.42\% \]

### K\(^{\pm}\)π\(^{\pm}\)π\(^{\pm}\)π\(^{0}\)π\(^{0}\):
reconstructed K mass: resolution ~ 1.7 MeV

Used to calibrate and to monitor the small instabilities of the spectrometer

### K\(^{\pm}\)π\(^{\pm}\)π\(^{0}\)π\(^{0}\):
reconstructed K mass: resolution ~ 1.2 MeV
Multilevel deadtimeless Trigger

Neutral

- Input rate capability: up to few MHz
- Fully pipelined system using LKr cell information summed to horizontal and vertical projections to compute energy, centre of gravity, $\pi^0$ vertices position and number of showers
- Latency 5$\mu$s
- Negligible Dead Time

Charged

- Level 1: Fast Trigger
  - Input rate capability: up to few MHz
  - Track multiplicity in hodoscope
  - Track multiplicity in DCH (opt.)
  - Energy in calorimeter (opt.)
  - ANTI-counters and $\mu$-VETO (opt.)

- Level 2: On-line Processing of tracks
  - Input rate capability: 200 KHz
  - Latency < 100 $\mu$s
  - Small Dead Time < 0.1%
  - with the NEW DCH READ-OUT
Trigger for $K^\pm$ data taking

- **3-track events (3 track topology trigger)**
  - $K^\pm \rightarrow \pi^\pm \pi^+ \pi^-$
  - $Ke4$, Dalitz decays, $K \rightarrow lllv$

- **1-track events with** $(P_K - P_\pi)^2 > m_{\pi^0}^2$ (missing mass) + neutrals
  - $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$
  - $K^\pm \rightarrow \pi^\pm \pi^0 \gamma$, $K^\pm \rightarrow \pi^\pm \gamma \gamma$
  - Rejected $K^\pm \rightarrow \pi^\pm \pi^0$

- **Control triggers (downscaled D~100)**
  - Trigger efficiencies
  - Many 1-track channels: $Ke2(\gamma)$, $Ke3(\gamma)$, ...

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Direct CPV in $K^\pm$ decays by NA48/2

BEACH 2004-Chicago-June 30
Data taking

• **Data taking period 2003**
  ~50 days effective

• **Data presented here: last 28 days of data taking 2003 (stable running conditions)**

• **Data taking period 2004 started:**
  ~60 days scheduled
Asymmetry measurement in the “charged” mode $K^{\pm} \rightarrow \pi^\pm \pi^+ \pi^-$

- Strategy of the measurement
- Preliminary analysis of the main systematics

(As in the $\epsilon'/\epsilon$ analysis the whole game is played on the best detailed understanding of the systematics)
!!! SELECTION AS SIMPLE AS POSSIBLE:

- Select the 3 tracks from the vertex with smallest $\chi^2$
- $|t_{\text{track}} - <t_{\text{track}}>| < 15$ ns
- $z_{\text{vertex}} < 85$ m
- $54 < P_K < 66$ GeV
- $P_t < 30$ MeV
- $|m_{3\pi} - M_K| < 9$ MeV
  - $|r_{\text{COG}} - <r_{\text{COG}}>| < 3$ cm at DCH1, DCH4
  - $|r_{\text{track}} - <r_{\text{COG}}>| > 11.5$ cm at DCH1
  - $|r_{\text{track}} - <r_{\text{COG}}>| > 13.5$ cm at DCH4

!!! ONLY SPECTROMETER INVOLVED

NO Muon Veto, EM calo, Hadron calo

!!! NO BACKGROUND FOR THIS DECAY
Dalitz plot of $K^{\pm} \rightarrow \pi^{\pm} \pi^{+} \pi^{-}$

Asymmetry measurement in the “charged” mode $K^{\pm} \rightarrow \pi^{\pm} \pi^{\mp}$

### Lorentz-invariants

- $u = (s_3 - s_0)/m_\pi^2$
- $v = (s_2 - s_1)/m_\pi^2$
- $s_i = (P_K - P_{\pi_i})^2$, $i=1,2,3$
- $s_0 = (s_1 + s_2 + s_3)/3$

### Center of mass frame

- $u = 2m_K(m_K/3 - E_{odd})/m_\pi^2$
- $v = 2m_K(E_1 - E_2)/m_\pi^2$

The analysis is performed by comparing $K^+$ and $K^-$ distributions after they are projected on the $u$ axis.

Dalitz plot affected by the presence of the beam pipe

- Even pion in beam pipe
- Odd pion in beam pipe

720 mln $K^+$ events
(A) Only the slopes of ratios of normalized u-distributions are considered.

(B) In order to compensate for left/right detector asymmetries, the polarity of the relevant magnets are periodically inverted:
- Every day: spectrometer magnetic field (B) up/down (B+/B-), K+/K- decay products illuminate different detector regions.
- Every week: achromat magnetic field (A) up/down (A+/A-), K+/K- follow a bit different paths (<1mm).

(C) Basic observables for the asymmetry measurement:
Compare u distributions of K+ with B+ and K- with B-.
They illuminate the same region of the detector (downstream the spectrometer magnet) and the resulting asymmetry ($A_{\text{jura}}$) is independent of acceptance:
$$P(u,K+,B+)/P(u,K-,B-) = N(1+g+u)/(1+g-u) = N(1+2g+A_{\text{jura}}u)$$
From the ratio of u distributions of K+ with B- and K- with B+ an independent measurement ($A_{\text{saleve}}$) is obtained.
Measurement strategy

The adopted strategy ensures the highest immunity even to minor perturbations:

The result might be distorted only the contemporary presence of TIME INSTABILITY between data samples and RIGHT-LEFT asymmetry

• In the detector acceptance or
• in the beam position
Observables

Physical asymmetries:
- $A_S$  slope of ratio $U(B+K+)/U(B-K^-)$
- $A_J$  slope of ratio $U(B-K+)/U(B+K^-)$

$A_{SJ} = (A_S + A_J)/2 \Rightarrow \Delta g = 2g \Delta g$

Apparatus-induced asymmetries:
- $A_+^+$ slope of ratio $U(B+K+)/U(B-K^+)$
- $A_-^-$ slope of ratio $U(B+K^-)/U(B-K^-)$

$A_{\pm} = (A_+ + A_-)/2 = (A_S - A_J)/2$

- $A_{SL}$ measures CPV
- $A_{\pm}$ only as indicator of systematic effects
Systematic effects

1) variations in time of detector geometry
   mainly due to variations of the transverse alignment of the chambers (they drifted by small amounts)

2) variation in time of the spectrometer magnetic field
   value of magnet current cannot be inverted with relative accuracy better than $10^{-3}$

3) variation in time of the beam geometry
   beams' drift and non perfect overlap/coaxiality coupled to acceptance selections

4) stray fields along the decay region
   residual earth and stray magnetic fields in vacuum volumes (cannot be inverted! Break +/- symm.)

5) other effects
   trigger efficiency, accidentals, pion interactions, resolution, non-linearity, reconstruction efficiency
Systematic effects

The RIGHT-LEFT accuracy of the relative transverse DCH's alignment is obtained by adjusting the transverse position of DCH4 or equivalently by imposing that K+ and K- into $3\pi$ decays have the same reconstructed invariant mass, on average over periods of ~1 hour.

Sensitivity of $M_{K\rightarrow3\pi}$ is ~ 150 keV for 100 $\mu$m displacement along the horizontal direction.

Asymmetry measurement in the "charged" mode $K^\pm \rightarrow \pi^\pm \pi^\pm \pi^\pm$
TIME STABILITY between periods with opposite direction of the spectrometer magnetic field is obtained by tuning the effective momentum scale in such a way that the reconstructed invariant mass of $3\pi$ decays equals the PDG value for the kaon mass, on average over periods of ~ 1 hour.

The sensitivity is such that a change of 10^{-3} in the magnitude of the magnet field induces a relative change in mass of about 20 KeV.
Systematic effects

Asymmetry measurement in the "charged" mode $K^\pm \rightarrow \pi^+\pi^+\pi^-$

Effective momentum scale is tuned such that on average (over 1 hour data samples) $M_{K^+ \rightarrow 3\pi} = M_{K^- \rightarrow 3\pi} = M_{PDG}$

$$P = p(1 + \alpha)(1 + \beta q bp)$$

Where:
- $P$ – effective track momentum
- $p$ – measured track momentum
- $q$ – measured charge of the track
- $b$ – sign of magnetic field $B$

and

- $\alpha \rightarrow$ Correct for DCH misalignment by fixing $M_{K^+ \rightarrow 3\pi} = M_{K^- \rightarrow 3\pi}$
- $\beta \rightarrow$ Corrects for magnetic field by fixing $M_{K \rightarrow 3\pi} = M_{PDG}$
(3) variation in time of the beam geometry

Systematic effects

Due to the presence of the beam pipe at $R<11$ cm pions are lost

$\Rightarrow$ NECESSITY OF A RADIAL CUT

but WARNING: the +/- beams overlap is not perfect

$\Rightarrow$ if the cut is centered on nominal beam axis then acceptance is $K+/K-$ asymmetric

$\Rightarrow$ Event are rejected if any pion is intersecting the volume of a cylinder of appropriate radius and with axis centered on the barycenter (cog) of the positive (negative) Kaon beam as seen by the detector.

The radial acceptance cut is momentum and time (short and long term) dependent in order to follow the movement of each beams $\Rightarrow$ acceptances are equalized.

In addition, due to the achromat inversion, the beams path trough the beam line are swapped every week.
Asymmetry measurement in the “charged” mode $K^± \rightarrow \pi^+\pi^+\pi^-$

$p_{\text{kick}}(\text{stray field}) \leq 10^{-4}$

The field $B_{\text{stray}}$ along the decay volume is measured => the field map is used in the reconstruction program to correct the reconstructed decay kinematics at vertex $p_{\text{kick}}$.

Quality of the correction checked looking at $M_K$ VS odd pion azimuthal angle $\phi$.

Only 10% $B_{\text{stray}}$ residual effect.

Systematic effect on $A_g$ is expected $< 10^{-5}$ from preliminary MC studies.
Systematic effects

- Residual acceptance studies with MC
- Trigger efficiency
  -- rate dependent inefficiency  ~ 1.5 % -- expected effect on asymmetry \( \ll 10^{-4} \)
  -- geometry related inefficiency  ~ 0.5 % -- expected effect on asymmetry \( \leq 10^{-4} \)
- Accidental particle effects
  -- rate related are expected to be harmless (on the average \( A_J + A_S /2 \))
  -- geometry related, expected \( \leq 10^{-4} \)
- Resolution and non-linearity effects
  -- on measurement of \( u \), range of \( u \) for fitting the slope
  -- on \( P_k \) measurement, coupled with (small) difference in \( P \) spectra of \( K^+ \) and \( K^- \)
- Interaction of pion with the detector material
- Reconstruction efficiency
- Residual background, pion decays

Asymmetry measurement in the "charged" mode \( K^+ \to \pi^+ \pi^+ \pi^- \)
Time stability of the asymmetry

Asymmetry measurement in the “charged” mode $K^\pm \rightarrow \pi^\pm \pi^\pm \pi^\pm$

\[ \chi^2/\text{ndf} \, 13,5/12 \]
\[ \chi^2/\text{ndf} \, 5,6/12 \]

\[ (A_S + A_J)/2 + \text{offset} \]
\[ (A_+ + A_-)/2 \]
Asymmetry vs Kaon momentum

Asymmetry measurement in the “charged” mode $K^\pm \rightarrow \pi^\pm \pi^\pm \pi^\pm$.

- Statistical error of $A_g$: $2.7 \times 10^{-4}$
- $\chi^2/\text{ndf} = 6/11$
- $A_{SJ} + \text{offset} = 0 \pm 0.117 \times 10^{-3}$
- Statistical error on $\Delta g = 1.2 \times 10^{-4}$
- Corresponding to $A_g = 2.7 \times 10^{-4}$

- $\chi^2/\text{ndf} = 6.7/11$
- $A_\pm = (0.131 \pm 0.117) \times 10^{-3}$
- $(A_+ + A_-)/2$

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BEACH 2004-Chicago-June 30
The “neutral” mode $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$

- Charge Asymmetry analysis
- A surprise: $a_0-a_2$ scattering length
Asymmetry measurement in the “neutral” mode $K^\pm \to \pi^\pm \pi^0\pi^0$

The analysis status is less advanced than for the ``charged mode''

The event selection is based only on the spectrometer and the Lkr calorimeter information. KABES is used also, for redundancy.

Different sources of systematics w.r.t. the ``charged'' mode are expected eg. in this channel the role of radial acceptance should be less critical

Also this channel is BACKGROUND FREE

**Stat. (millions of events)**

<table>
<thead>
<tr>
<th>Process</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K^+ \to \pi^+ \pi^0\pi^0$</td>
<td>23</td>
</tr>
<tr>
<td>$K^- \to \pi^- \pi^0\pi^0$</td>
<td>13</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td><strong>36</strong></td>
</tr>
</tbody>
</table>

Statistical error on $\Delta g = 6,5 \times 10^{-4}$

Corresponding to $A_g = 5 \times 10^{-4}$

**NOTE:** charged mode is statistically favoured

but in neutral mode $g$ is 3 time larger !!!!!!
Asymmetry measurement in the “neutral” mode $K^{\pm} \rightarrow \pi^{\pm} \pi^0 \pi^0$

The variable $u$ can be reconstructed

- either from the information of LKr Calorimeter only, independent of the spectrometer information
- or from the spectrometer and KABES information, independently of the LKr Calorimeter

This is important in the identification and study of the systematic uncertainties.
The charge exchange process is not negligible under threshold and interferes (destructively) with the direct emission. (N. Cabibbo's idea)

The ch.ex. coupling constant, ie pion scattering length $a_2 - a_0$ can be measured with very small experimental and theoretical error.

Here the excellent resolution on $M_{\pi\pi} \sim 0.4$ MeV allow a clean search for $\pi\pi$ bound state, ie pionium (I. Mannelli's idea).
Rare $K^\pm$ decay channels

- $K^\pm \rightarrow \pi^\pm\gamma, \pi^0\pi^0e^+e^-$
- $K^\pm \rightarrow \pi^+\pi^-\nu, \pi^0\pi^0\nu$
- $K^\pm \rightarrow \pi^0\nu(\gamma)$
- $K^\pm \rightarrow \pi^\pm\gamma\gamma, \pi^\pm\gamma\gamma\gamma$
- $K^\pm \rightarrow \pi^\pm\nu(\gamma)$
- $K^\pm \rightarrow l^+l^-\nu \ldots \text{etc...}$
Conclusions

- Largest samples of $K^\pm$ decays ever are being collected
- $K^\pm \rightarrow \pi^\pm \pi^+ \pi^-$
  - $>1.1 \times 10^9$ decays in one month of run 2003;
  - Major sources of systematics identified (No showstopper)
  - Statistical error of $A_g$ is $2.7 \times 10^{-4}$
  - Uncertainty dominated by statistical error!
- $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$
  - $\sim 4 \times 10^7$ decays in one month of run 2003
  - Expected statistical error of $A_g$ is $5 \times 10^{-4}$
  - $\pi \pi$ scattering length measured with high precision
- Almost the same amount of $K^\pm \rightarrow 3\pi$ data with $1\pi$ lost
- High precision measurement allowed in rare $K^\pm$ decays
- Year 2004 data taking started with good efficiency
- Year $>2005 = K^\pm \rightarrow \pi^\pm \nu \bar{\nu}$ ???