New Measurement of Direct CP Violation by NA48 Experiment at CERN

Ivan Mikulec
HEPHY, Austrian Academy of Science, Vienna

Fermilab Seminar
March 15th, 2000

On behalf of the NA48 Collaboration:
Cagliari Cambridge CERN Dubna Edinburgh Ferrara Firenze Mainz
Orsay Perugia Pisa Saclay Siegen Torino Vienna Warsaw

Outline

Our new result is a preliminary measurement of the $\mathrm{Re}(\varepsilon'/\varepsilon)$ parameter based on data collected by NA48 during the 1998 SPS run. The statistics have increased by 2.5 times with respect to the result already published by NA48

- Physics motivation
- NA48 method
  - Beams
  - Detectors
- Analysis of the 1998 data
  - Data sample
  - Trigger efficiencies
  - K_S tagging
  - Background subtraction
  - Relative energy scale
  - K_L proper lifetime weighting
  - Accidental activity
- Result and checks
- Perspectives

CP violation in the K^0–$\overline{K^0}$ system

Strangeness eigenstates:

$$K^0(\bar{s}d)$$
$$\overline{K^0}(s\bar{d})$$

CP eigenstates:

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

Mass eigenstates:

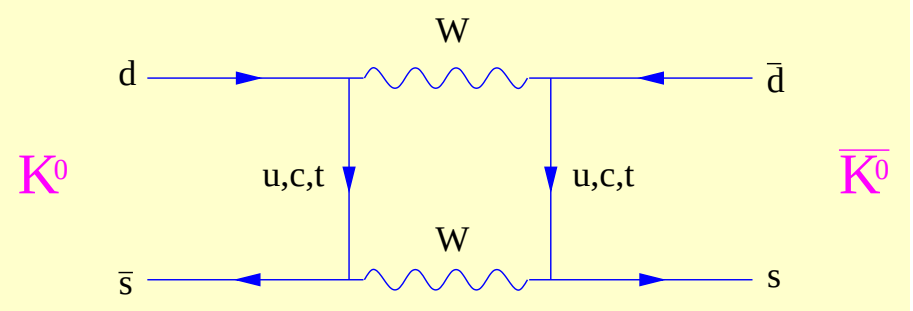
$K_S \simeq K_1 +$		εK_2	$K_L \simeq K_2 +$		εK_1
69 %	$\pi^+\pi^-$		21 %	$3\pi^0$	
31 %	$\pi^0\pi^0$		13 %	$\pi^+\pi^-\pi^0$	
			27 %	$\pi\mu\nu$	
			39 %	$\pi e\nu$	
			0.2 %		$\pi^+\pi^-$
			0.1 %		$\pi^0\pi^0$

$c\tau_S = 2.67$ cm $\qquad$ $c\tau_L = 15.5$ m

$$\varepsilon = (2.28 \pm 0.02) \times 10^{-3}$$

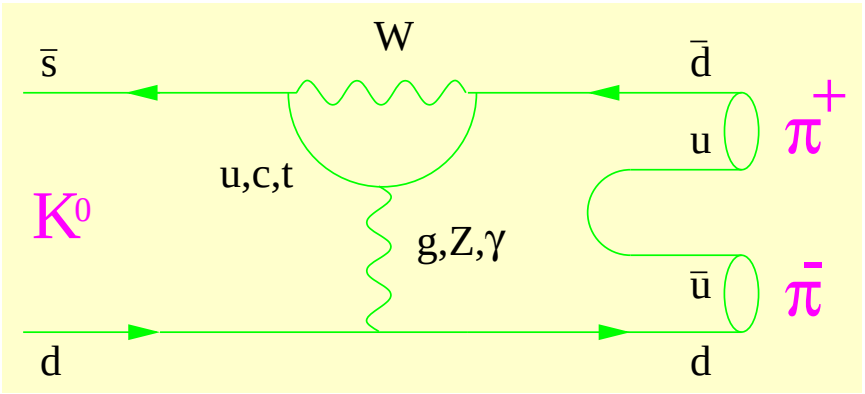
Direct CP violation

$\varepsilon \Rightarrow$ Indirect CP violation via $K^0/\overline{K^0}$ mixing



$$K_L = K_2^{-1} + \varepsilon\, K_1^{+1} \qquad \pi^+\pi^-,\ \pi^0\pi^0$$

CP = +1



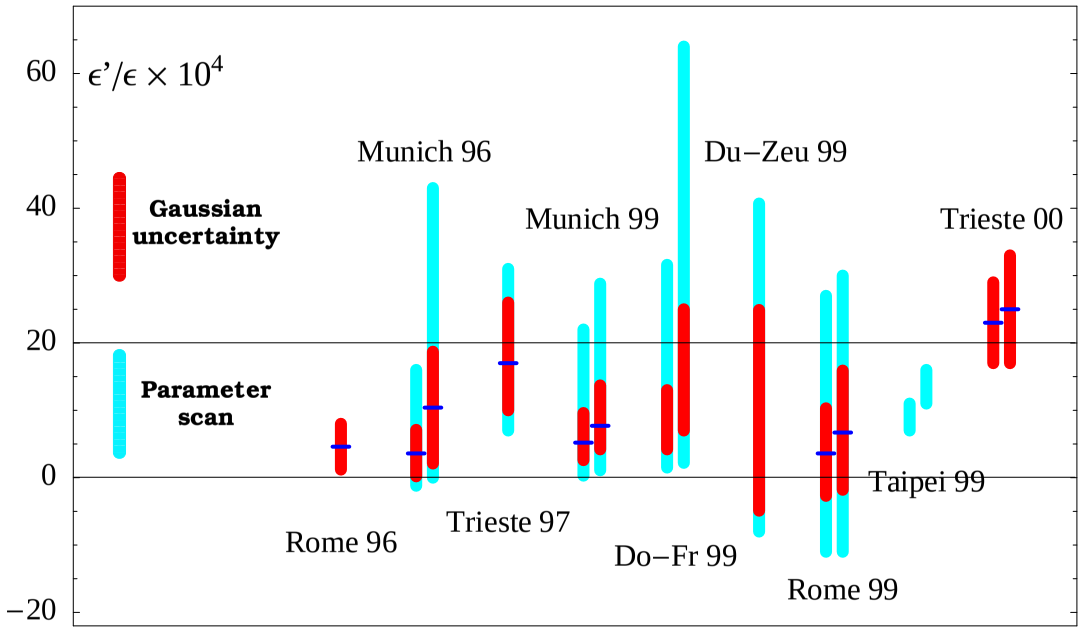
Direct CP violation:

$$\varepsilon' = \frac{i}{\sqrt{2}}\,\mathfrak{Im}\frac{A_2}{A_0}\exp(i(\delta_2-\delta_0))$$

$$A(K^0 \to \pi\pi, I) = A_I \exp(i\delta_I)$$
$$A(\overline{K^0} \to \pi\pi, I) = A_I^* \exp(i\delta_I)$$

$\mathrm{Re}(\varepsilon'/\varepsilon)$: Predictions and measurements

Standard Model Predictions:



Measurements:

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

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

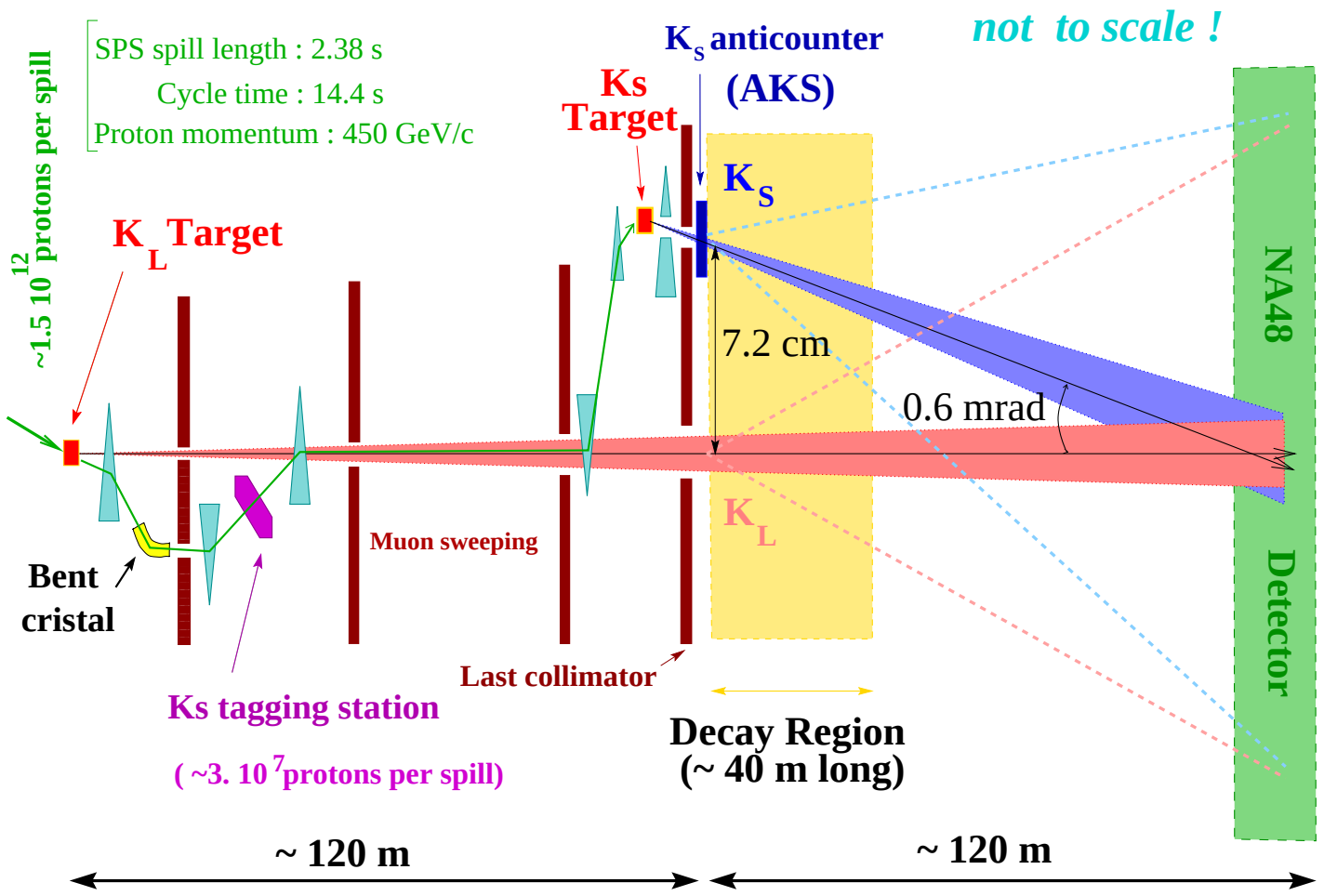
$$R = \frac{\Gamma(\mathrm{K_L}\to\pi^0\pi^0)}{\Gamma(\mathrm{K_S}\to\pi^0\pi^0)} \Big/ \frac{\Gamma(\mathrm{K_L}\to\pi^+\pi^-)}{\Gamma(\mathrm{K_S}\to\pi^+\pi^-)} \simeq 1 - 6\ \mathrm{Re}(\varepsilon'/\varepsilon)$$

$$\mathrm{Re}(\varepsilon'/\varepsilon) \quad = \quad \begin{array}{lll} \mathrm{E731} & 1993 & (7.4 \pm 5.9) \times 10^{-4} \\ \mathrm{NA31} & 1993 & (23.0 \pm 6.5) \times 10^{-4} \\ & & \\ \mathrm{KTeV} & 1999 & (28.0 \pm 4.1) \times 10^{-4} \\ \mathrm{NA48} & 1999 & (18.5 \pm 7.3) \times 10^{-4} \end{array}$$

NA48 method

- Method: double ratio technique
- Aim: measure $\mathrm{Re}(\varepsilon'/\varepsilon)$ with an accuracy of 2×10^{-4}
- High statistics needed:
  - High intensity beam
  - Powerful Trigger and DAQ systems
    $\Rightarrow$ Collect $4 - 5 \times 10^6$ $\mathrm{K_L} \rightarrow \pi^0\pi^0$ (limiting mode)
- Minimize corrections
  $\rightarrow$ the 4 modes are measured:
  - Simultaneously
    $\Rightarrow$ cancellation of fluxes, inefficiencies, dead time, accidental activity
  - From the same fiducial volume and applying lifetime weighting of $\mathrm{K_L}$ to make longitudinal decay distributions similar for $\mathrm{K_L}$ and $\mathrm{K_S}$
    $\Rightarrow$ small acceptance correction
  - With a high resolution magnetic spectrometer for the $\pi^+\pi^-$ mode and with a homogeneous Liquid Krypton calorimeter for the $\pi^0\pi^0$ mode
    $\Rightarrow$ small background levels
  - In bins of energy to eliminate slight differences in energy spectra

Simultaneous K_L and K_S beams



- K_S are distinguished from K_L by tagging the protons upstream of the K_S target
- NA48 detects all four modes from the same decay region

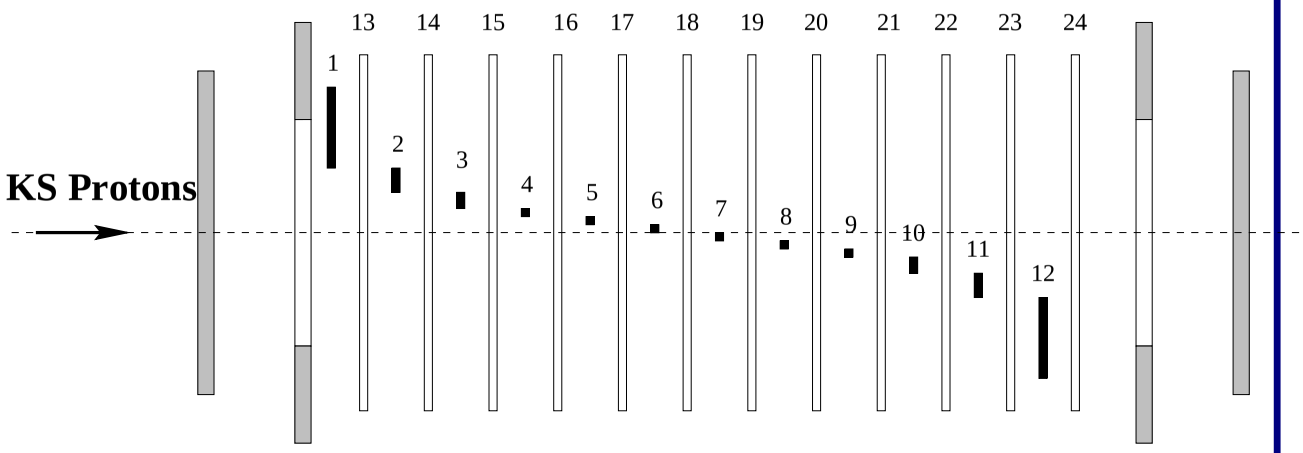
K_S Tagger

T.O.F. between the proton in the Tagger and the detected Kaon decay products:

$|t_K - t_{tagger}| < 2ns \Rightarrow K_S$

$|t_K - t_{tagger}| > 2ns \Rightarrow K_L$

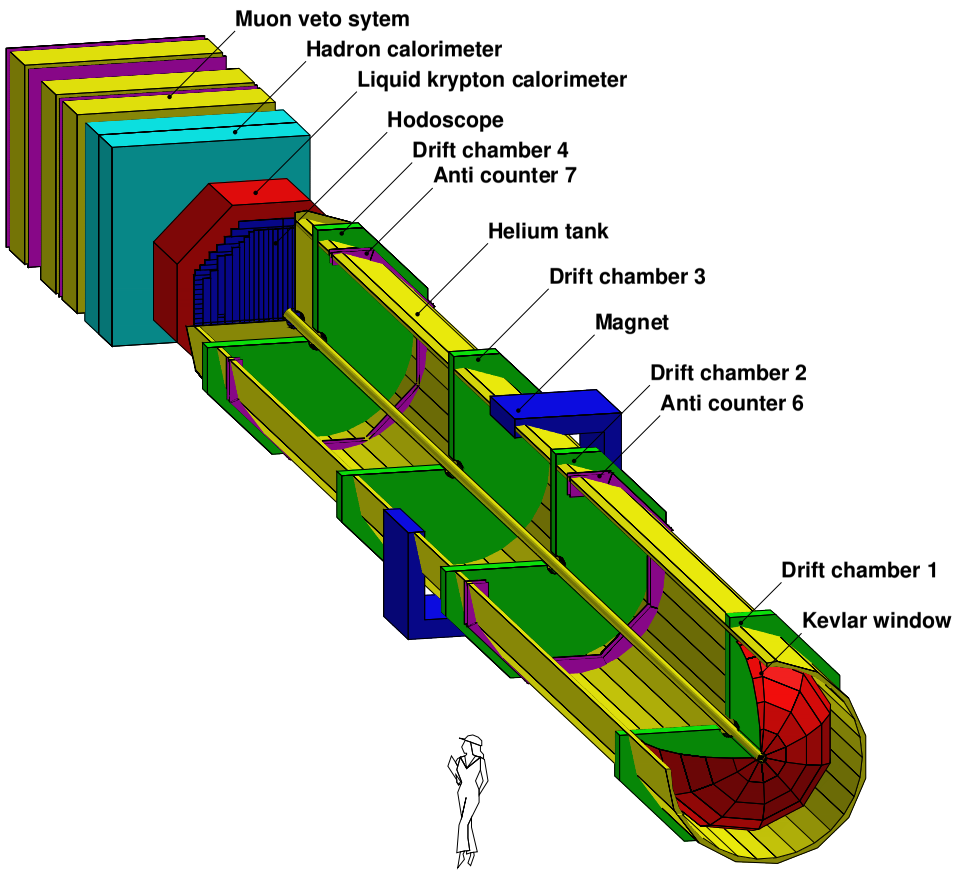
Tagger from side view



▮ : Vertical ladder ▯ : Horizontal ladder

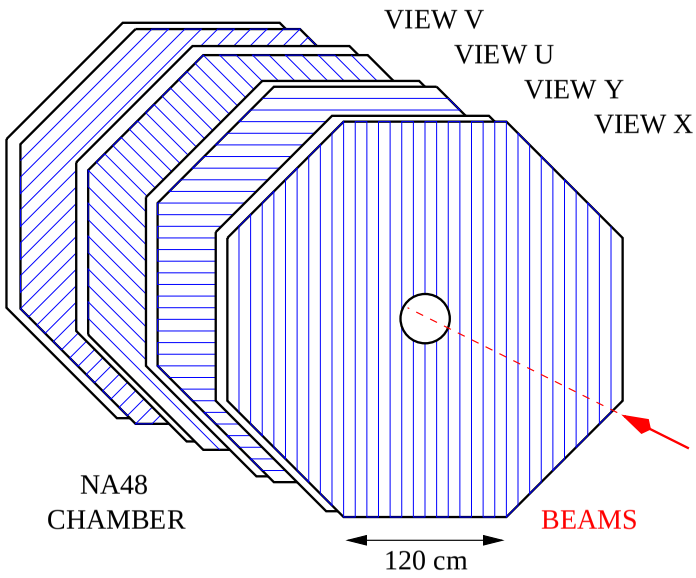
- 8-bit 960MHz FADC read-out
- 200ps time resolution per counter
- 4ns double pulse separation

NA48 detectors



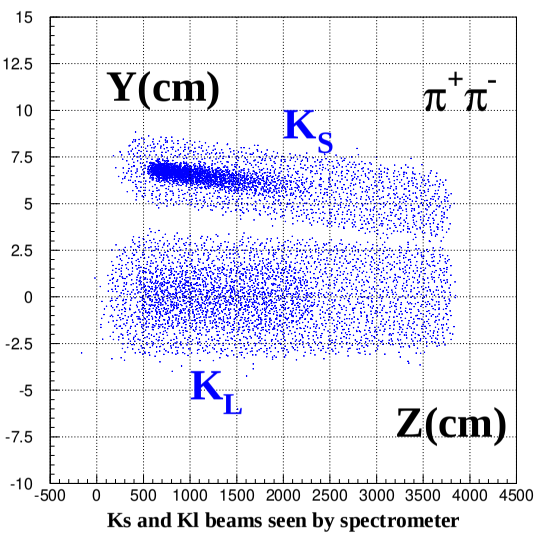
- $K_{L,S} \to \pi^+\pi^-$
  - magnetic spectrometer ($P_T{}^{kick} \sim 265 MeV/c$)
- $K_{L,S} \to \pi^0\pi^0$
  - quasi-homogeneous Liquid Krypton e.m. calorimeter :
    - high granularity (13212 2×2 cm^2 cells)
    - projective geometry

Magnetic spectrometer

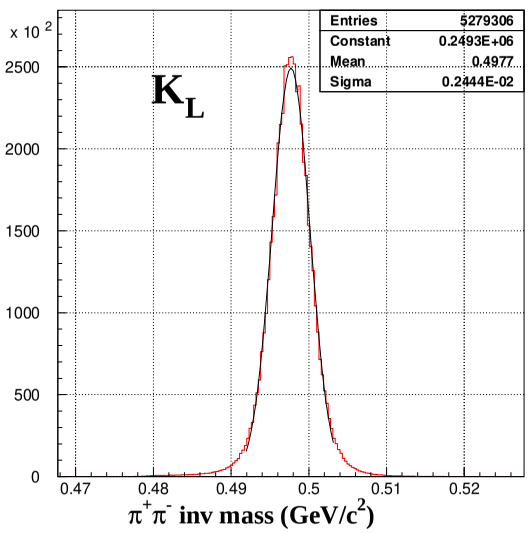


Per Chamber:

- 8 planes of 256 wires
- Positioning of wires to $\leq 100\mu$m/m
- Argon/Ethane
- Gain $\sim 8.10^4$



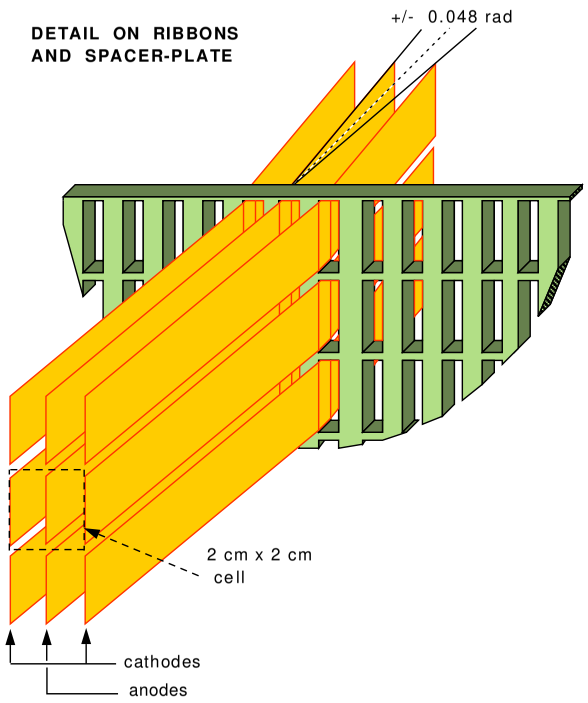
Vertex reconstruction allows beam separation



Kaon mass resolution $\sim$ 2.5 MeV/c^2

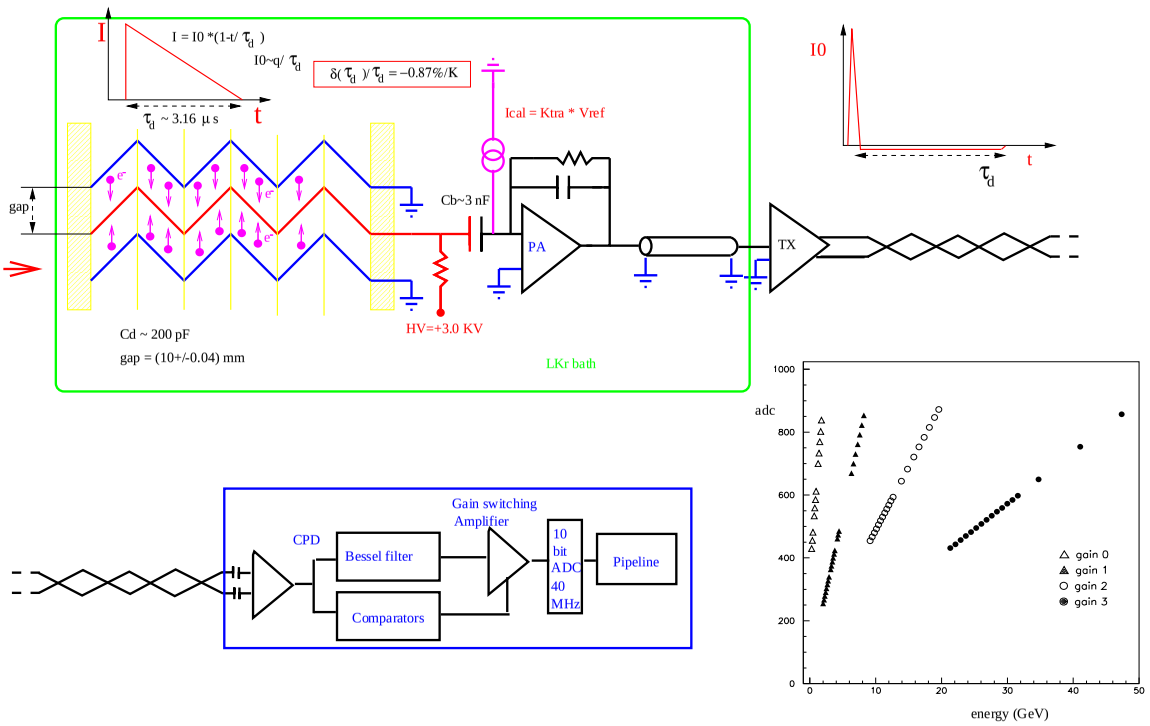
$$\sigma(p)/p \simeq 0.5\,\% \oplus 0.009\; p[\mathrm{GeV/c}]\,\%$$

Liquid Krypton calorimeter



- Contains $\approx 9m^3$ LKr
- Cu-Be electrodes
- Bias HV: +3 KV/cm
- Cell: 2cm×2cm×127cm
- Five Spacer plates
- Electrodes: $\pm$ 48mrad zig-zag in each spacer
- Geometry controlled to ≈0.2mm/1m

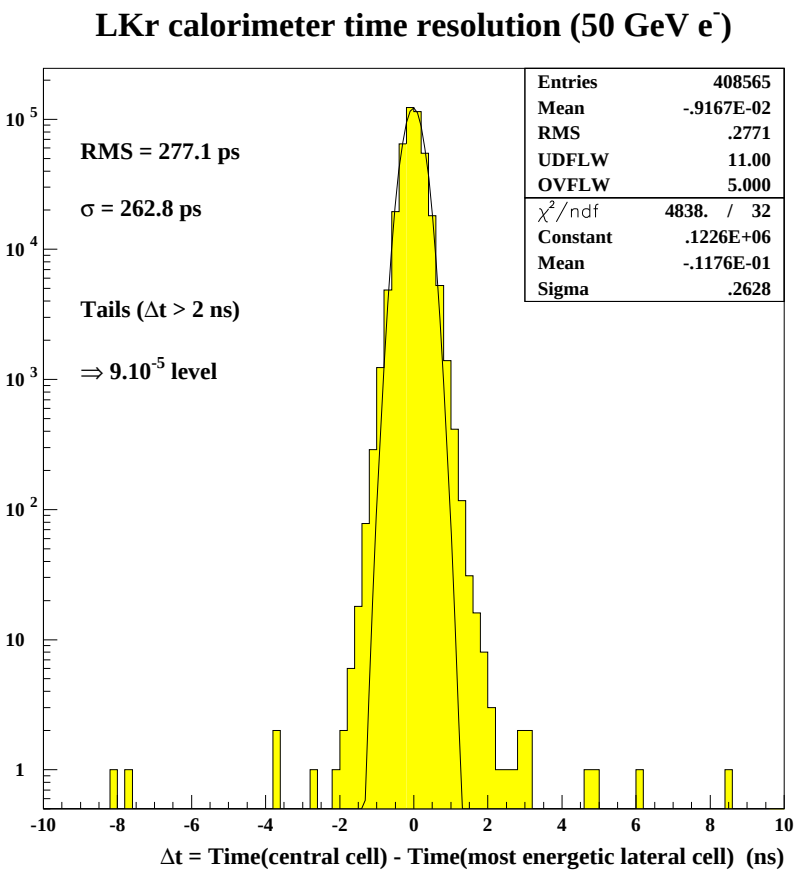
LKr read out and calibration

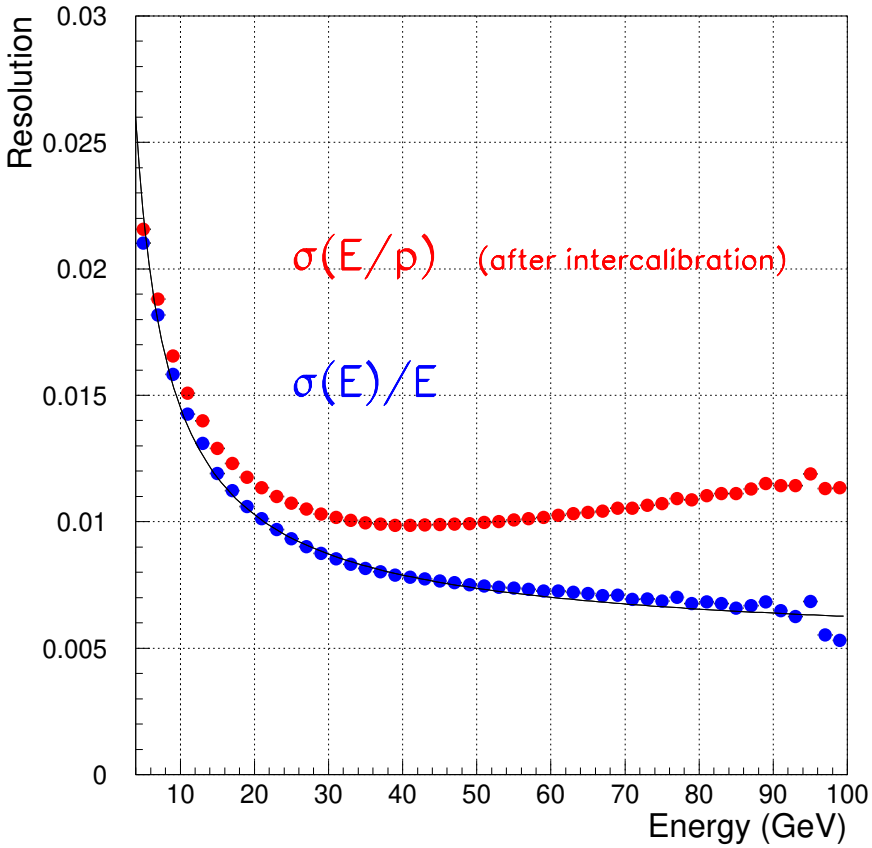


- In cold: Signal pre-amplification
- On feedthroughs: amplify and reshape the signal
- CPD: Shaping, 4 Gains × 10 bit FADC (dynamic range from ≈3.5MeV to ≈50GeV per cell), asynchronous 40MHz sampling

- Regular calibration during data taking to check offset and gain stability to ≈ 0.1%
- Time offsets calculated using Physics events (photons)

Time and energy resolution of LKr





$$\frac{\sigma(E)}{E} = \frac{3.2\%}{\sqrt{E}} \oplus \frac{100MeV}{E} \oplus 0.5\%$$

Data sample

- 1997 : 89 days, 1×10^{12} ppp on K_L target

  $\Rightarrow$ 0.49 million of $K_L \to \pi^0\pi^0$

  PUBLISHED Phys. Lett. B 465 (1999)

  $\mathrm{Re}(\varepsilon'/\varepsilon) = (18.5 \pm 4.5 \pm 5.8) \times 10^{-4}$

- 1998 : 135 days, $\sim 1.4 \times 10^{12}$ ppp on K_L target

  Main improvements :

  - LKr High Voltage 1500 $\to$ 3000 V
  - Charged trigger efficiency 91.3 $\to$ 97.7 %
  - Carbon fibre pipe $\to$ less showers in the detectors
  - New data acquisition system (PC farm) + 30 % rate

  $\Rightarrow$ 1.14 million of $K_L \to \pi^0\pi^0$

  $\Rightarrow$ four-fold increase of $\pi^+\pi^-$

- 1999 : 128 days, $\sim 1.4 \times 10^{12}$ ppp on K_L target

  Further improvements :

  - DCh read-out, dead time, DAQ efficiency, spill length

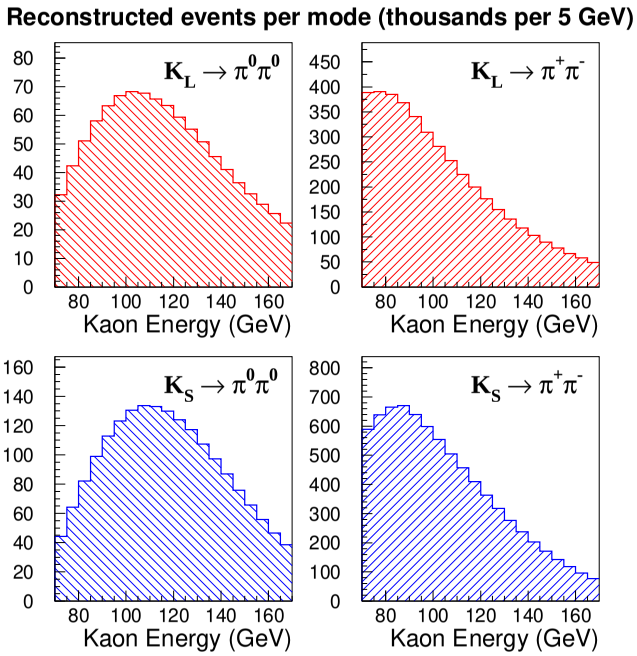
  $\Rightarrow$ Around 2 million of $K_L \to \pi^0\pi^0$

  ANALYSIS in progress...

Analysis strategy

General selection criteria:

- $70 <$ Kaon Energy < 170 GeV
- Centre of Gravity $(R_{\rm cog}) < 10$cm
- Decay region: $0 < \tau < 3.5\tau_{\rm S}$
  For K_S the beginning of the decay volume ($\tau > 0$) is defined by requiring no hits in the anti-counter placed in the K_S beam



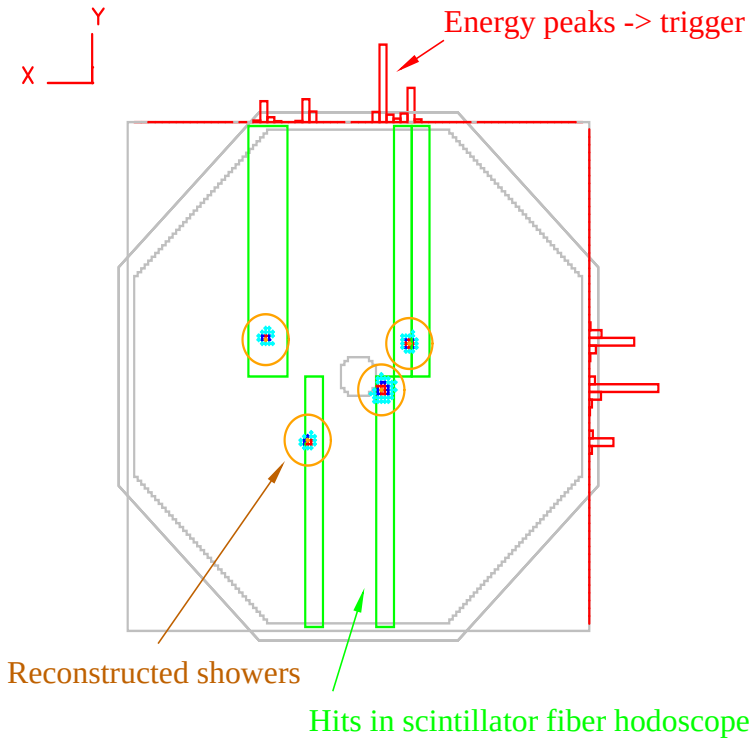
- Reject $\pi^0\pi^0$ events detected during dead time for $\pi^+\pi^-$:
  - <5 % from charged trigger
  - $\approx$ 25 % from multiplicity overflow in the spectrometer
- All corrections are applied in bins of energy, to account for the slight difference in the spectra of K_S and K_L

Trigger $\pi^0\pi^0$

- Fully pipelined system using LKr cell information summed to horizontal and vertical projections to compute energy, centre of gravity, proper lifetime and number of showers
- Output rate $\sim$ 2 kHz
- Latency 5μs
- Negligible dead time
- Efficiency :

$$99.93 \pm 0.02\ \%$$

Control trigger provided by scintilating fibre hodoscope embedded in LKr



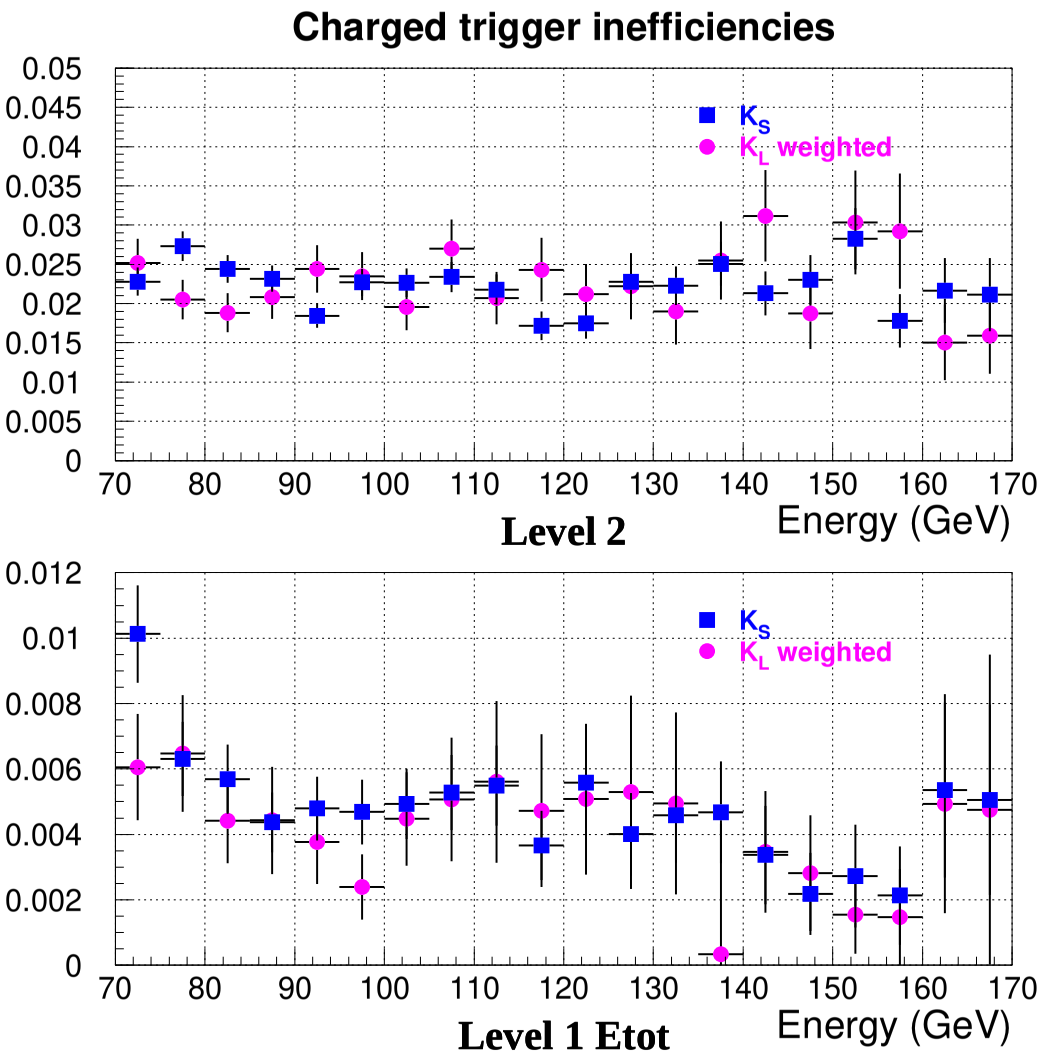
Trigger $\pi^+\pi^-$

- Level 1 :

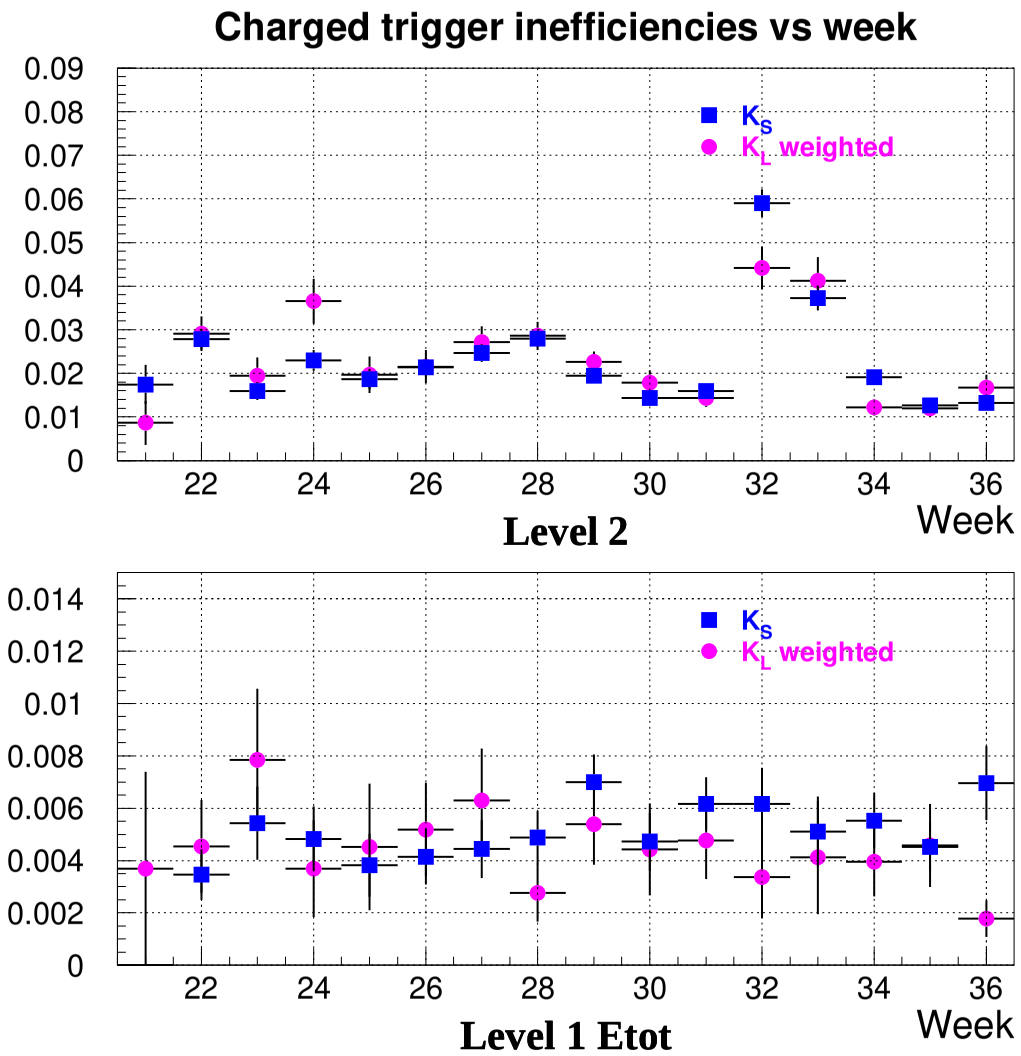
	Efficiency
+ Energy in calorimeters > 35 GeV	99.49 ± 0.03 %
+ Two track topology in hodoscope	99.95 ± 0.01 %
+ Two track multiplicity in chamber 1	> 99.99 %

- Level 2 : on-line processing of vertices and $\pi\pi$ invariant mass from spectrometer hits
  - Output rate ~ 2 kHz
  - Latency : $< 102\ \mu s$
  - Dead Time : $< 5\%$ monitored and applied to $\pi^0\pi^0$
  - Efficiency $\simeq 97.75 \pm 0.05$

Trigger efficiency $\pi^+\pi^-$

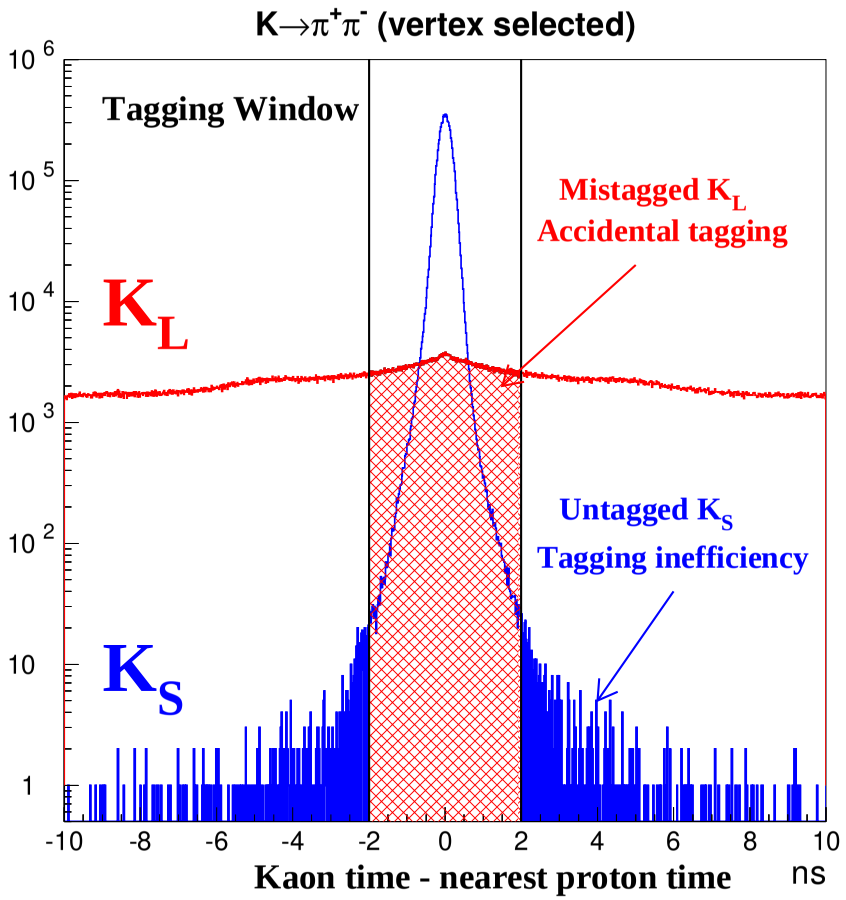


Trigger efficiency $\pi^+\pi^-$, contd.



Tagging principle

- Distinguish K_S from K_L in $2\pi^0$ decays
- To symmetrize it is used also for $\pi^+\pi^-$



- Tagging inefficiency: $\alpha_{\rm SL}$

  Due to tagging inefficiency K_S is identified as K_L . The $\pi^+\pi^+/\pi^0\pi^0$ difference comes from tails in the detector (hodoscope/LKr) time distributions:

$$\Delta R \simeq 6 \times \left(\alpha_{SL}^{00} - \alpha_{SL}^{+-}\right) = 6 \times \Delta\alpha_{\rm SL}$$

- Accidental tagging: $\alpha_{\rm LS}$

  A true K_L is counted as K_S if an accidental proton is found in the ± 2 ns tagging window:

$$\Delta R \simeq 2 \times \left(\alpha_{LS}^{00} - \alpha_{LS}^{+-}\right) = 2 \times \Delta\alpha_{\rm LS}$$

K_S tagging inefficiency

- Charged Mode : Use true K_S (from vertex) and count events outside the tagging window:

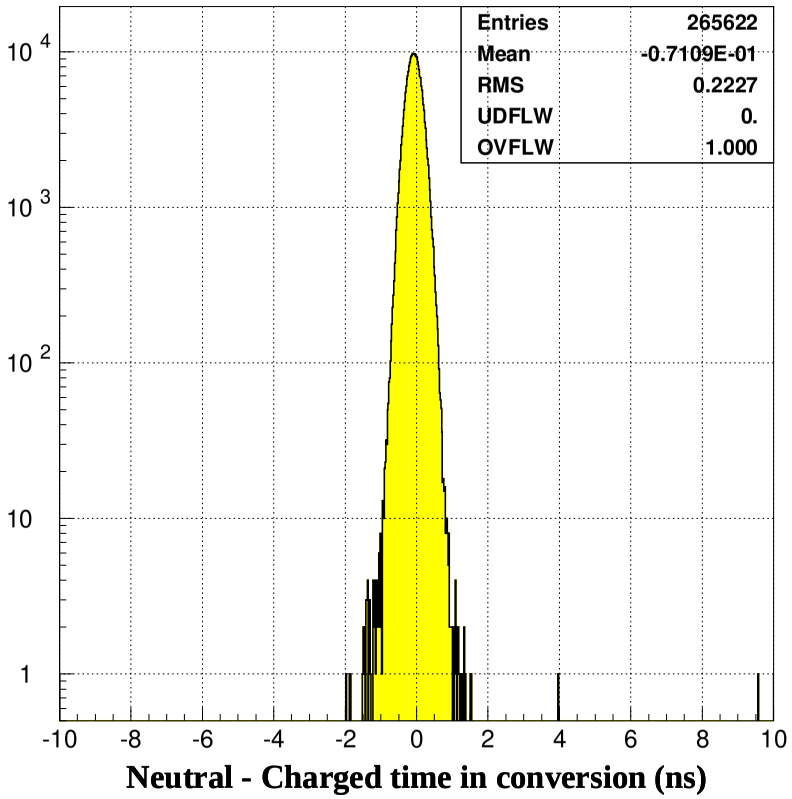
$$\alpha_{SL}{}^{+-} = (1.97 \pm 0.05) \times 10^{-4}$$

Dominant part due to Tagger $\Rightarrow$ charged neutral symmetric

- Neutral Mode : Verified with 3 methods:

1. Comparison of hodoscope and LKr times in K_L and K_S events ($3\pi^0$ and $2\pi^0$) containing a conversion

$|\alpha_{SL}^{+-} - \alpha_{SL}^{00}| < 0.5 \times 10^{-4}$ $\quad \Delta R < 3 \times 10^{-4}$



2. K_S only runs (the K_L beam is stopped)

$$\alpha_{SL}^{00} = (1.3 \pm 0.5) \times 10^{-4}$$

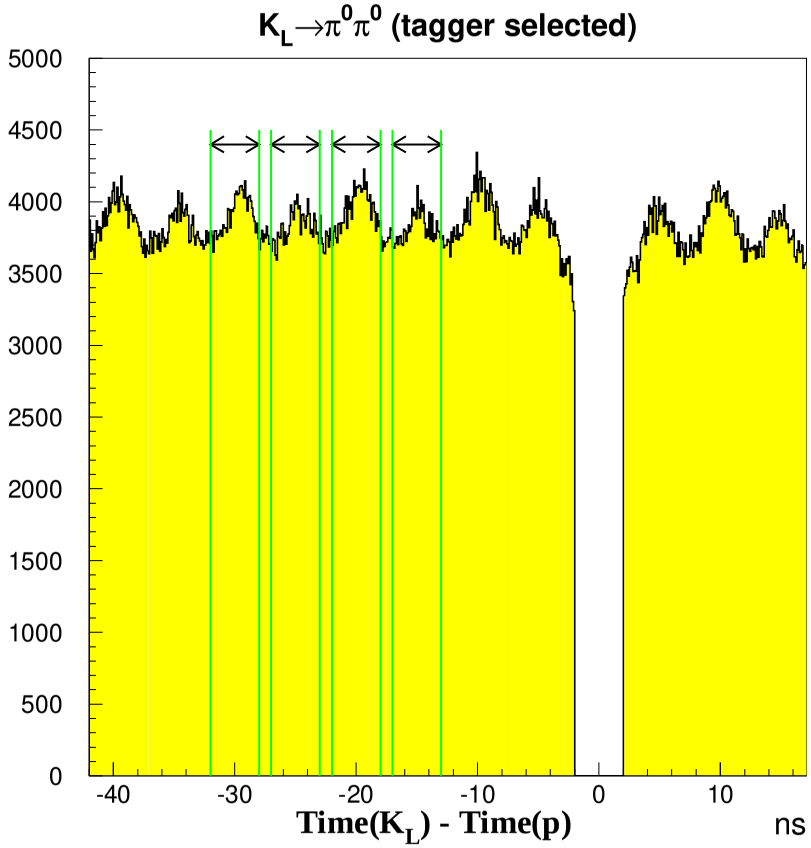
3. $K_S \rightarrow \pi^0 e^+ e^- \gamma$ events

Accidental K_S tagging

Charged mode: $\alpha_{LS}^{+-} = (11.05 \pm 0.01)\%$

$$\alpha_{\rm LS}^{00} - \alpha_{\rm LS}^{+-} = (\beta_{\rm tag}^{00} - \beta_{\rm tag}^{+-}) + ({\rm W}^{00} - {\rm W}^{+-})$$

$\beta_{\rm tag}$ is the rate of protons for untagged (= no in-time proton) K_L events measured in 4 carefully chosen time intervals close to the coincidence time window



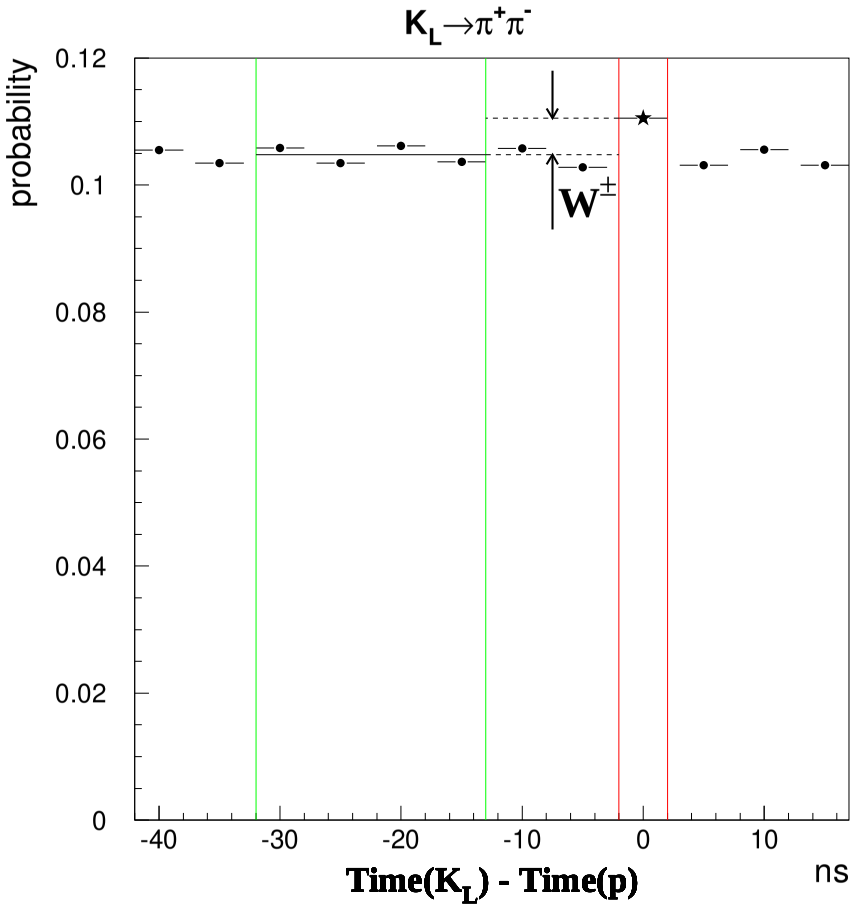
$$\beta_{\rm tag}^{00} - \beta_{\rm tag}^{+-} = (5.3 \pm 1.6) \times 10^{-4}$$

Accidental K_S tagging

W is the difference in the rate of in-time protons for all K_L events and untagged K_L in the side time windows: $W = \alpha_{LS} - \beta_{tag}$

$K_L \rightarrow 3\pi^0$ are used instead of $2\pi^0$.

$$W^{00} - W^{+-} \simeq W^{000} - W^{+-}$$



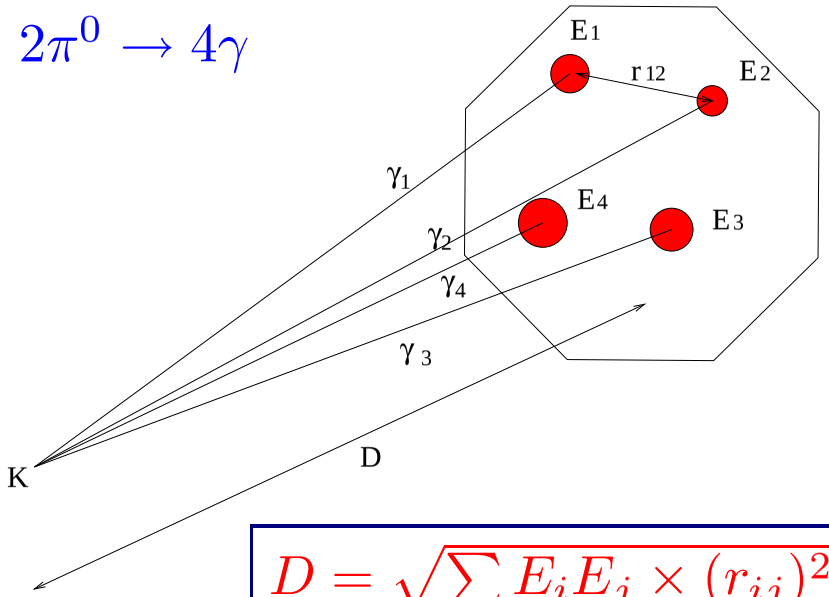
$$W^{00} - W^{+-} = (-5.0 \pm 3.9) \times 10^{-4}$$

Limited for now by the statistics of reprocessed $3\pi^0$

$$\Delta R = (1 \pm 8) \times 10^{-4}$$

$K^0 \to \pi^0\pi^0$ identification

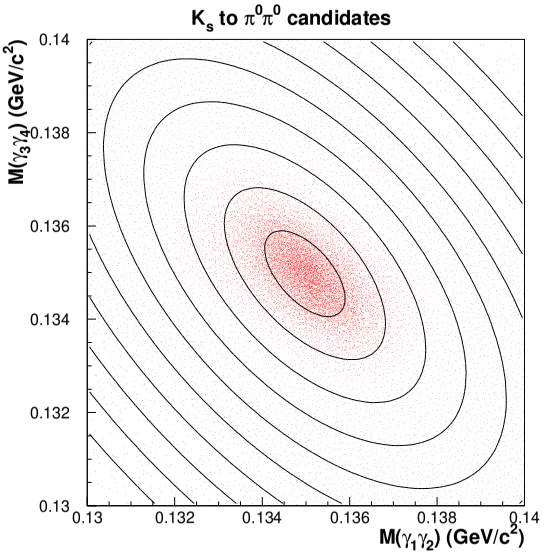
$K_{L,S} \to 2\pi^0 \to 4\gamma$

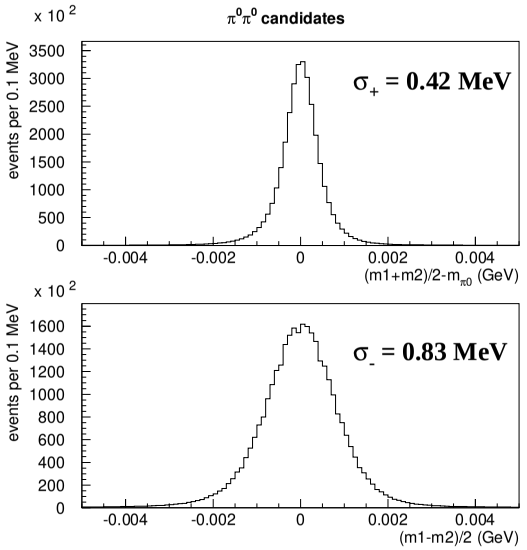


$$D = \sqrt{\sum E_i E_j \times (r_{ij})^2} \; / M_K$$

- Vertex position computed assuming the mass of K^0
- Photon pairing to get best π^0 masses :

$$m_{ij} = \sqrt{E_i E_j} \; . \; r_{ij}/D$$



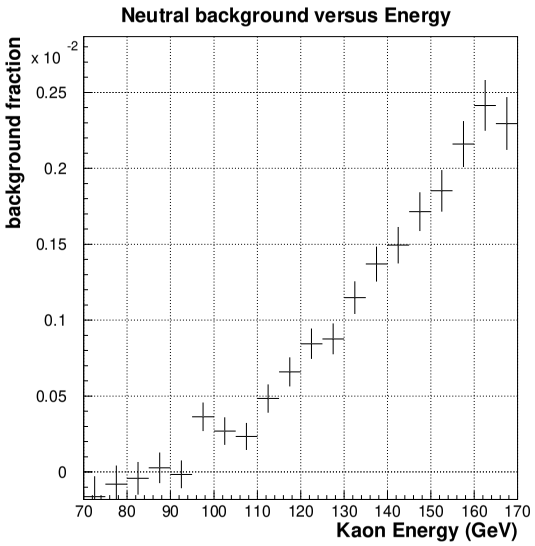


Background to $\pi^0\pi^0$

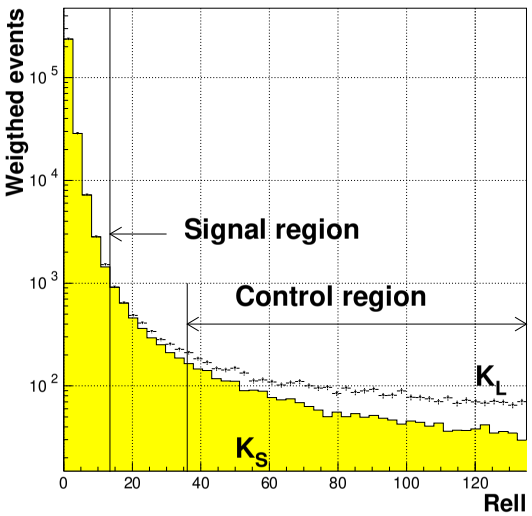
Background rejection

Main background:
$K_L \to 3\pi^0$

Events with extra in-time ($\pm$3ns) shower rejected



$$R_{ell} \equiv \left\{ \left(\frac{\frac{m_1+m_2}{2} - m_{\pi^0}}{\sigma_+(E_{min})} \right)^2 + \left(\frac{\frac{m_1-m_2}{2}}{\sigma_-(E_{min})} \right)^2 \right\}$$



Background subtraction

Signal region :
$R_{ell} < 13.5$

$\mathrm{K_L} - \mathrm{K_S}$ in control region
$\to 3\pi^0$ background

$= (6.6 \pm 2.0).10^{-4}$

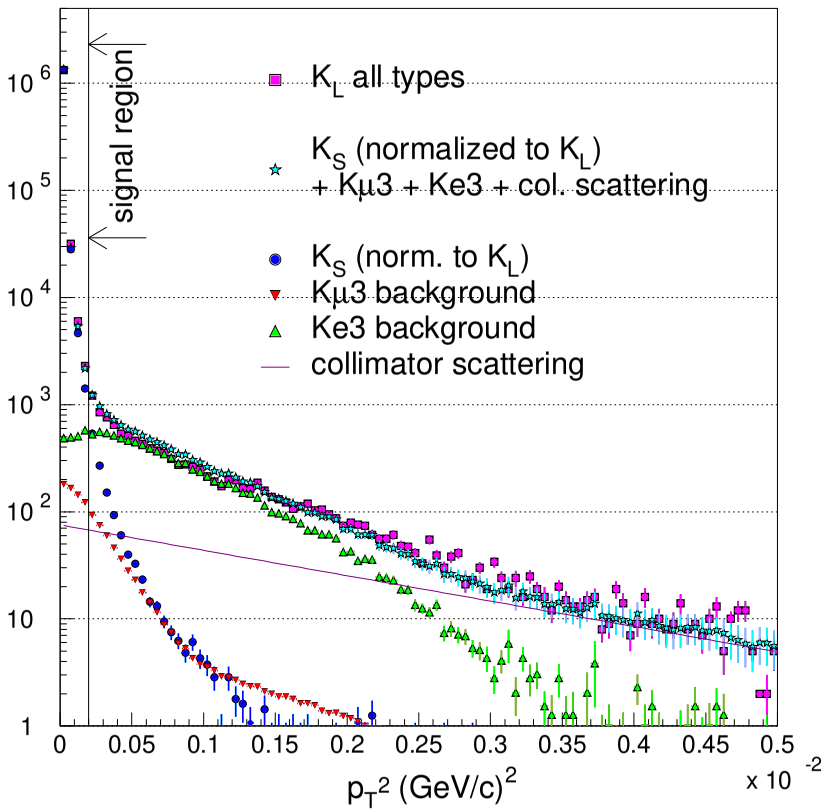
$$\Delta \mathrm{R} = (-7 \pm 2) \times 10^{-4}$$

Background to $\pi^+\pi^-$

Dominated by $K_L \to \pi e \nu$ and $K_L \to \pi \mu \nu$

Rejected using:

- muon veto counters
- $E_{LKr}/P_{Spectrometer} < 0.8$
- invariant mass $|m_{\pi\pi} - M_{K^0}| < 3\sigma$
- total transverse momentum $p_T^{'2} < 200$ (MeV/c)^2

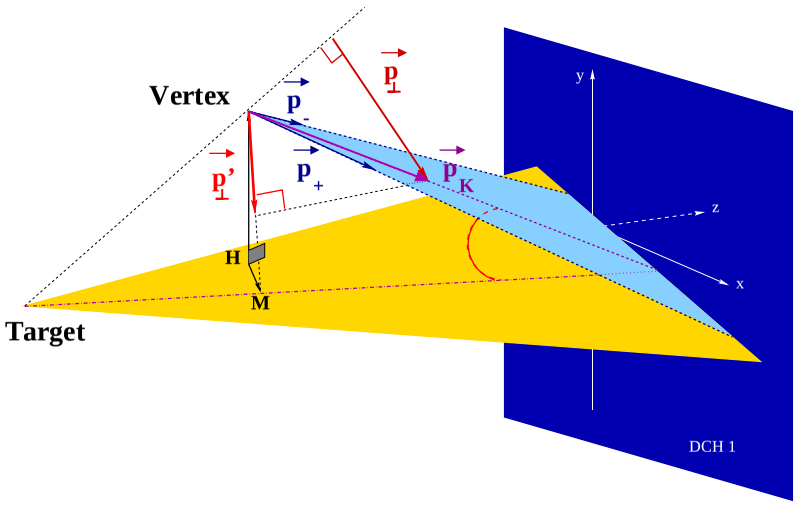


Estimated by fitting the distributions of $K_S \to \pi^+\pi^-$ + K_{e3} + $K_{\mu 3}$ in a control region in the plane of $(m_{\pi\pi}, p_T^{'2})$ to the K_L shape

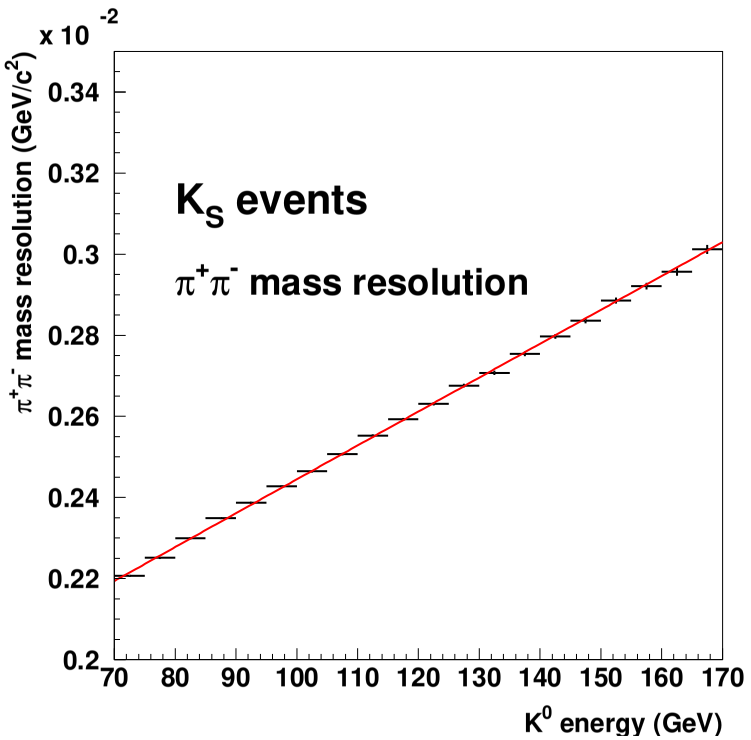
$$\Delta R = (+19 \pm 3) \times 10^{-4}$$

Background to $\pi^+\pi^-$

- $p_T'^2 < 200(\mathrm{MeV/c})^2$

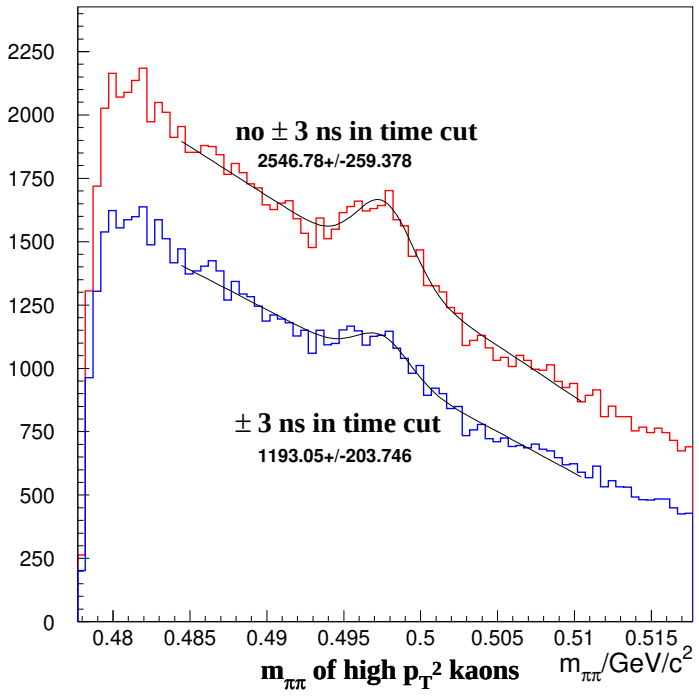


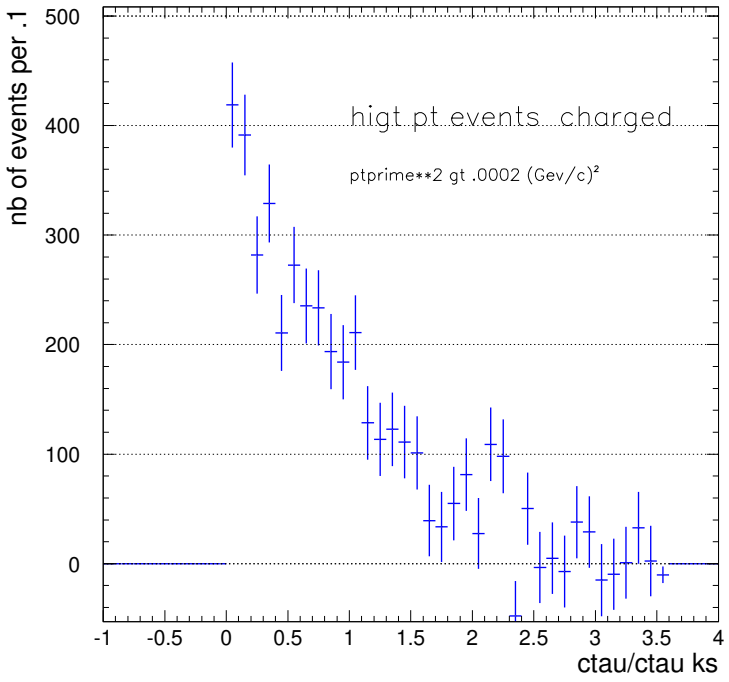
- $\pm 3\sigma$ $m_{\pi^+\pi^-}$ mass cut



Scattered Events in the K_L beam

- There are $K \to \pi^+\pi^-$ with a large $p_T'^2$ mainly originating from the K_L final collimator and with a typical K_S decay distribution

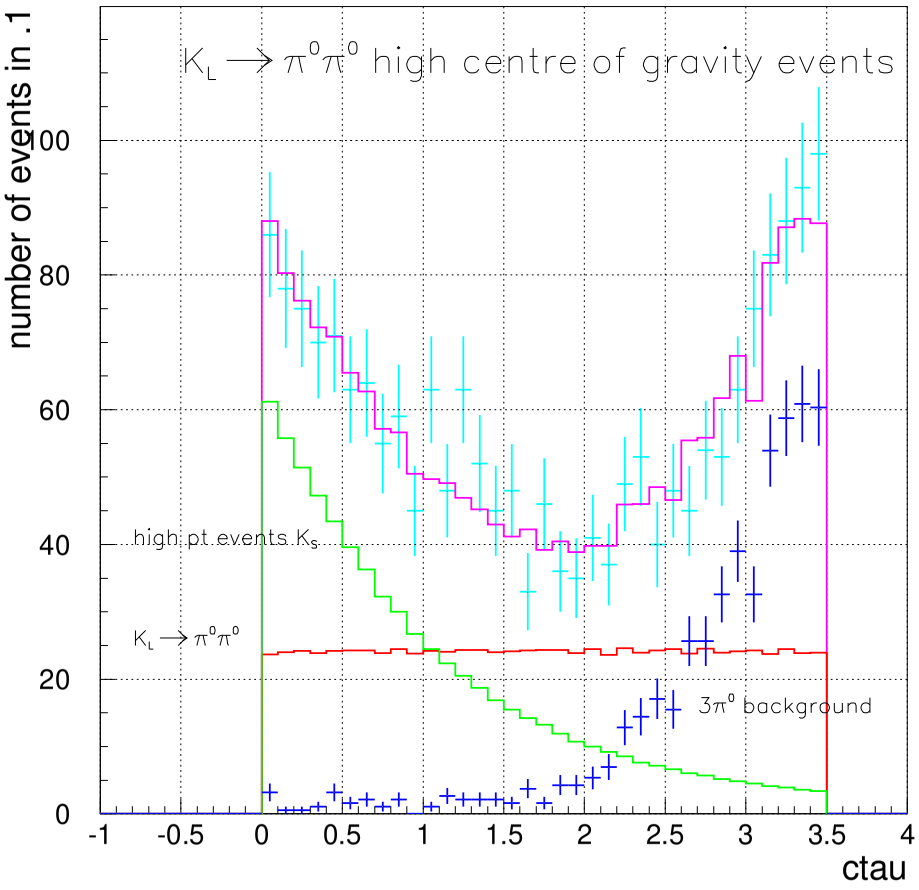




- They are rejected by the $p_T'^2$ cut applied to $\pi^+\pi^-$ but not to $\pi^0\pi^0$

Scattered Events in the K_L beam

- They can be identified in the $\pi^0\pi^0$ sample at a large centre of gravity (R_{cog})



- The relative amount of scattered Kaons found in $\pi^0\pi^0$ and $\pi^+\pi^-$ agrees within the quoted systematic error

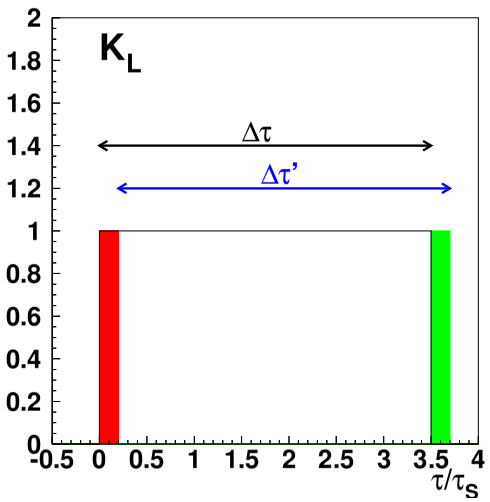
$$\Delta R = (-10 \pm 3) \times 10^{-4}$$

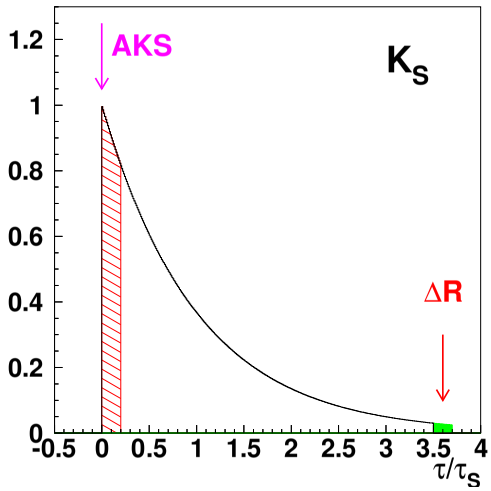
$\pi^0\pi^0/\pi^+\pi^-$ energy scale

Fiducial region given in τ_S units: $0 < \tau < 3.5\ \tau_S$
$\tau \propto (z_{vertex}$ - $z_{AKS})$ / E

The energy of the $\pi^0\pi^0$ is determined by the Lkr $\Rightarrow$ it relies on the calibration of the calorimeter

Energy scale $\Leftrightarrow$ Distance scale:
E $\rightarrow$ (1+α) E $\Rightarrow$ Δz $\rightarrow$ (1+α) Δz
BUT $\Delta\tau \rightarrow \Delta\tau$





The uncertainty introduced on R is small (0.6α) if the beginning of the K_S decay region is defined by an anti-counter (AKS)

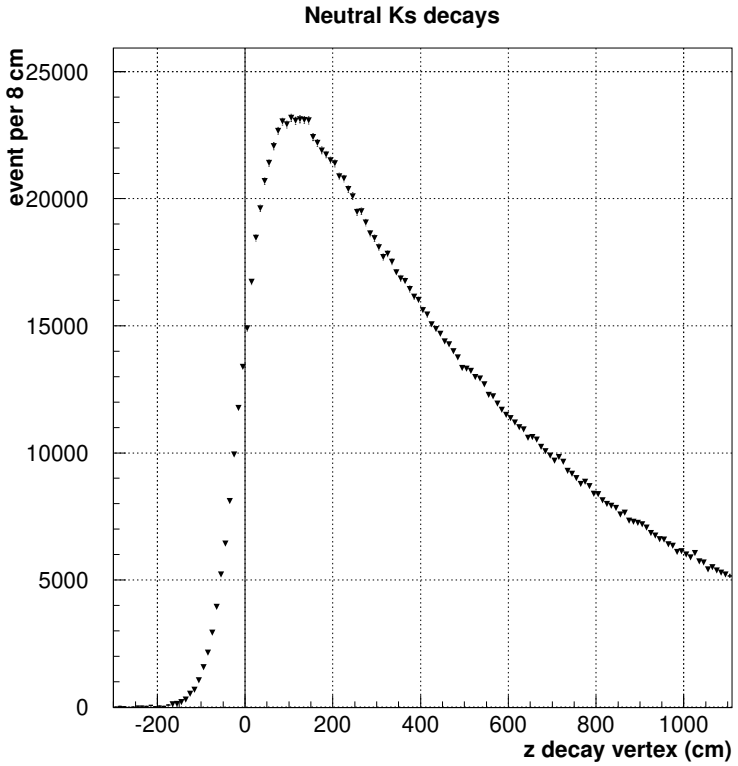
The energy for a $\pi^+\pi^-$ is determined from the opening angle and the ratio of the energy of the two tracks:

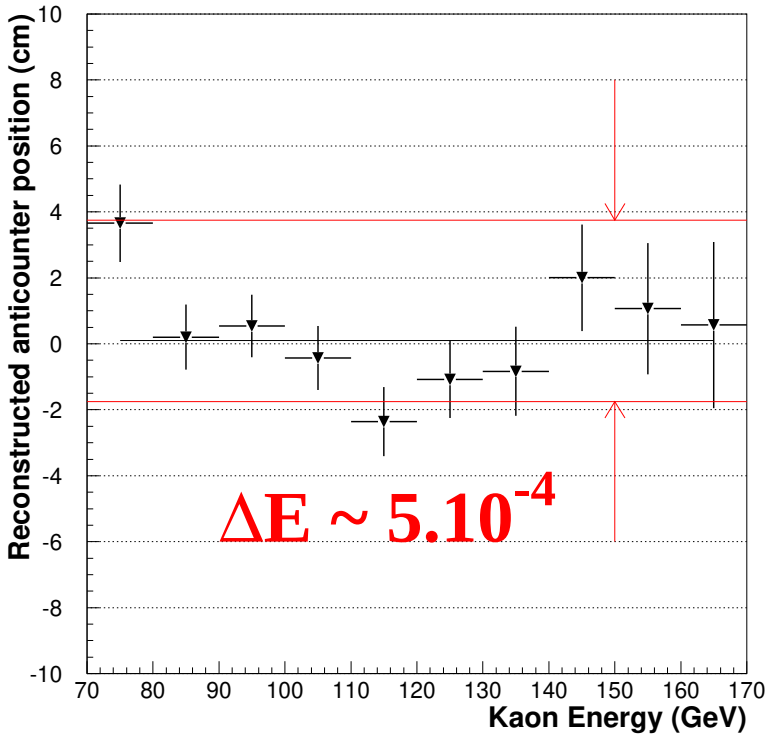
$$E_K^2 = (C/\theta^2)\left\{m_K^2 - C\ m_\pi^2\right\}$$
$$C = 2 + E_{\pi 1}/E_{\pi 2} + E_{\pi 2}/E_{\pi 1}$$

$\Rightarrow$ defined by the geometry of the drift chambers

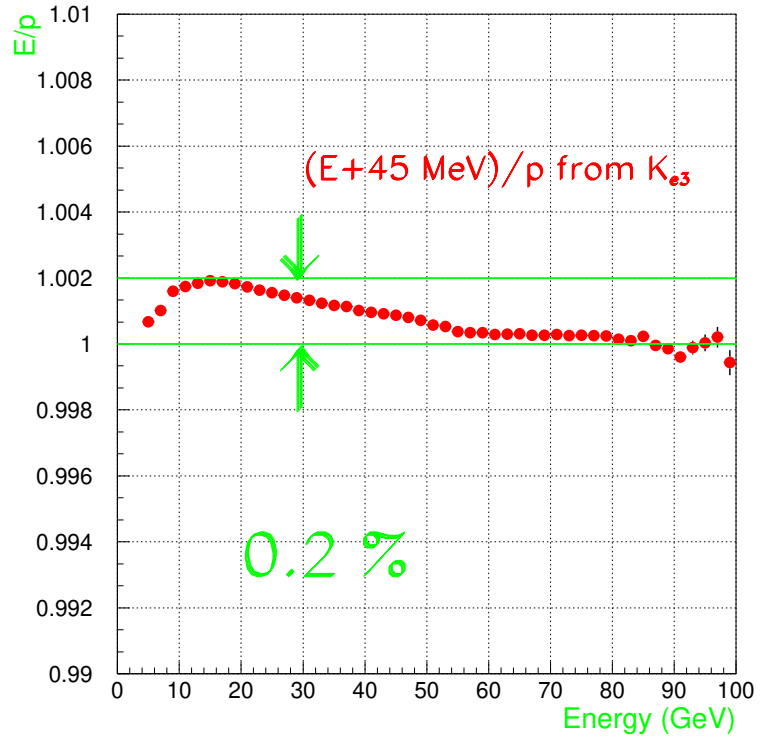
$\pi^0\pi^0$ distance/energy scale

To set the overall distance/energy scale, the position of the K_S anti-counter is used as a reference in $K_S \rightarrow \pi^0\pi^0$ events



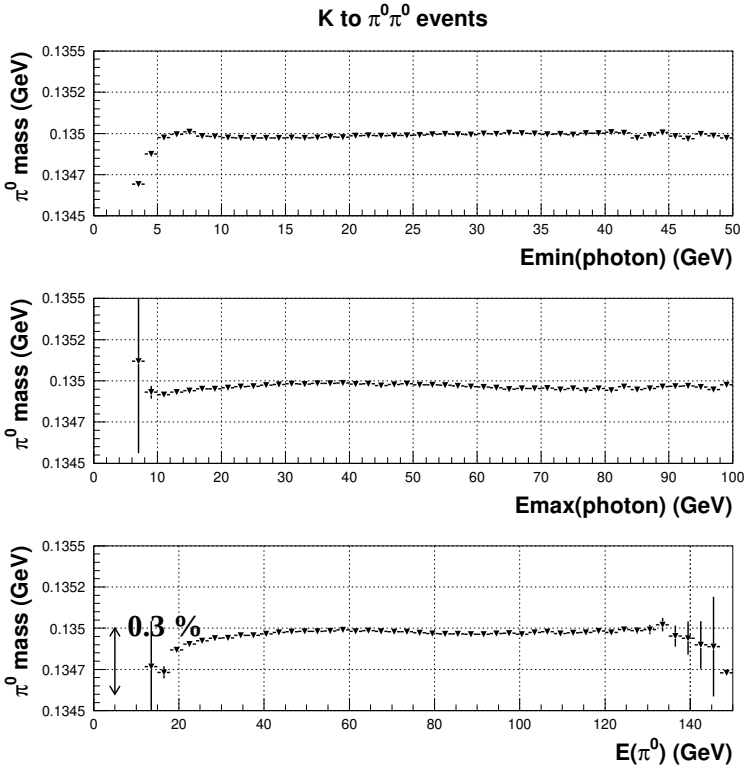


Linearity



$$\frac{E}{P} = \frac{\text{Energy from LKr}}{\text{Momentum from spectrometer}}$$

for Ke3 electrons as a function of the energy



Stability of m_{π^0} in $K \to 2\pi^0$ decays

Neutral systematics

Neutral reconstruction systematics	
Source	ΔR (units 10^{-4})
Non linearity	$\pm$ 5
Non Gaussian tails in σ_E	$\pm$ 5
Transverse scale	$\pm$ 3
Intercalibration	$\pm$ 3
Distance/Energy scale	$\pm$ 3
Other sources	$\pm$ 4

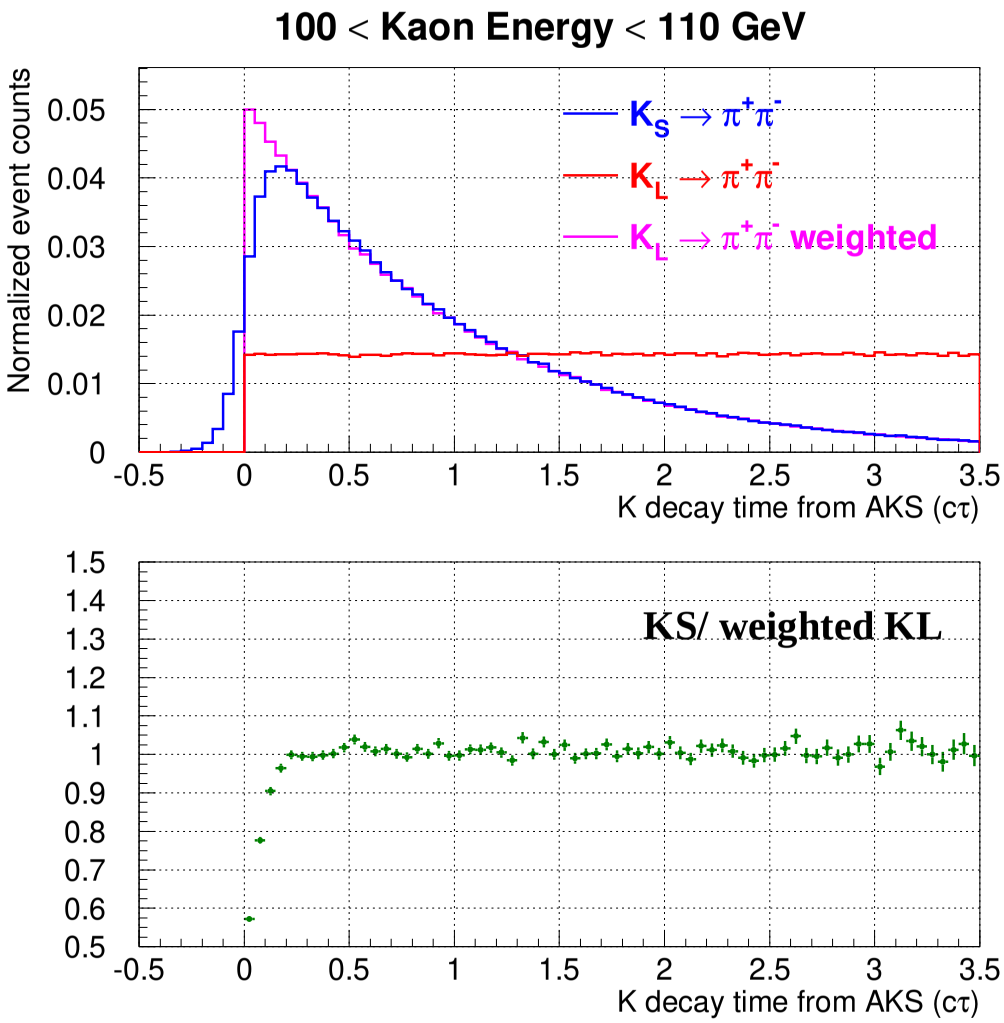
- We employ a π^- beam and two 3.5cm thick polyethylene targets, to produce $\eta, \pi^0 \rightarrow \gamma\gamma$ decays to cross check the distance scale using the published π^0 and η masses.
- A discrepancy at the level of 2 σ is found reconstructing the vertex for $\eta \rightarrow \gamma\gamma$

A dedicated η run will take place later this year to verify the effect

For the time being, we have increased the scale and/or the non linearity error to also cover the $\eta \rightarrow \gamma\gamma$ result.

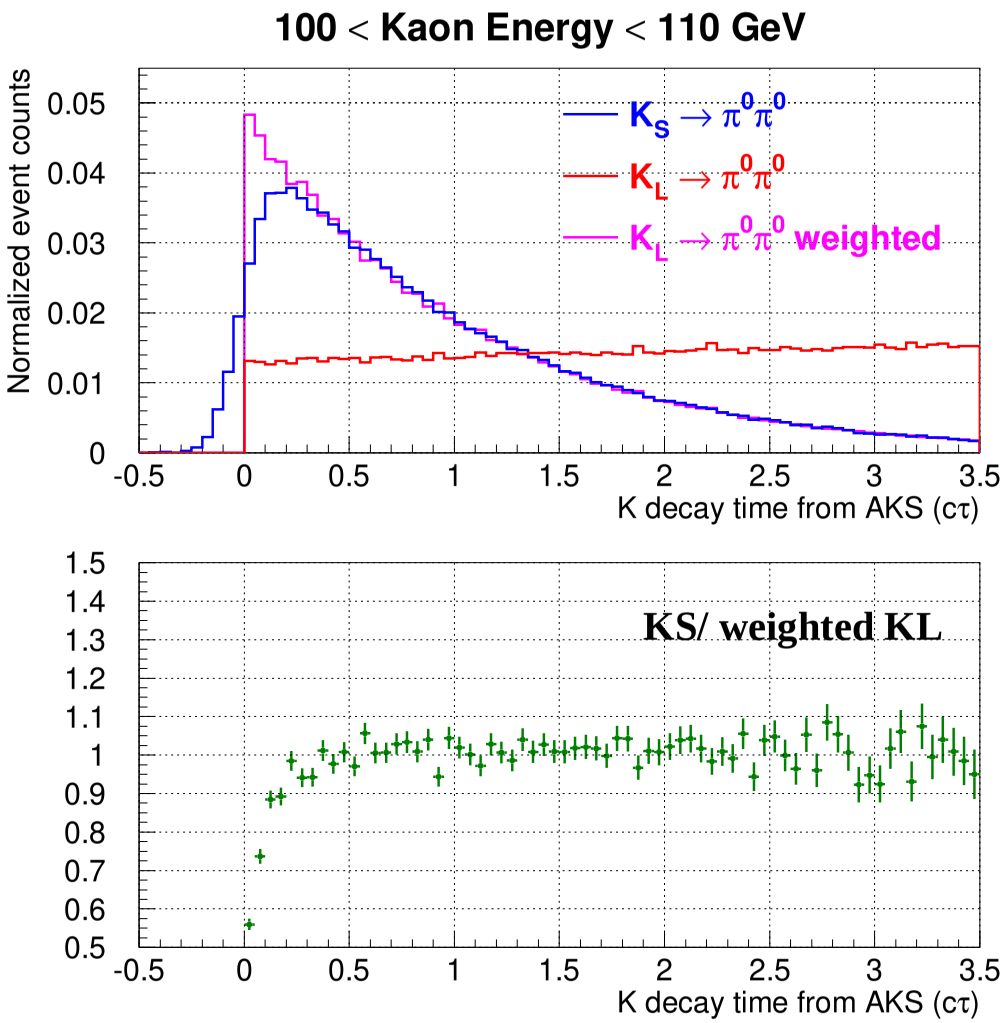
$$\Delta R < 10 \times 10^{-4}$$

Weighting $\pi^+\pi^-$

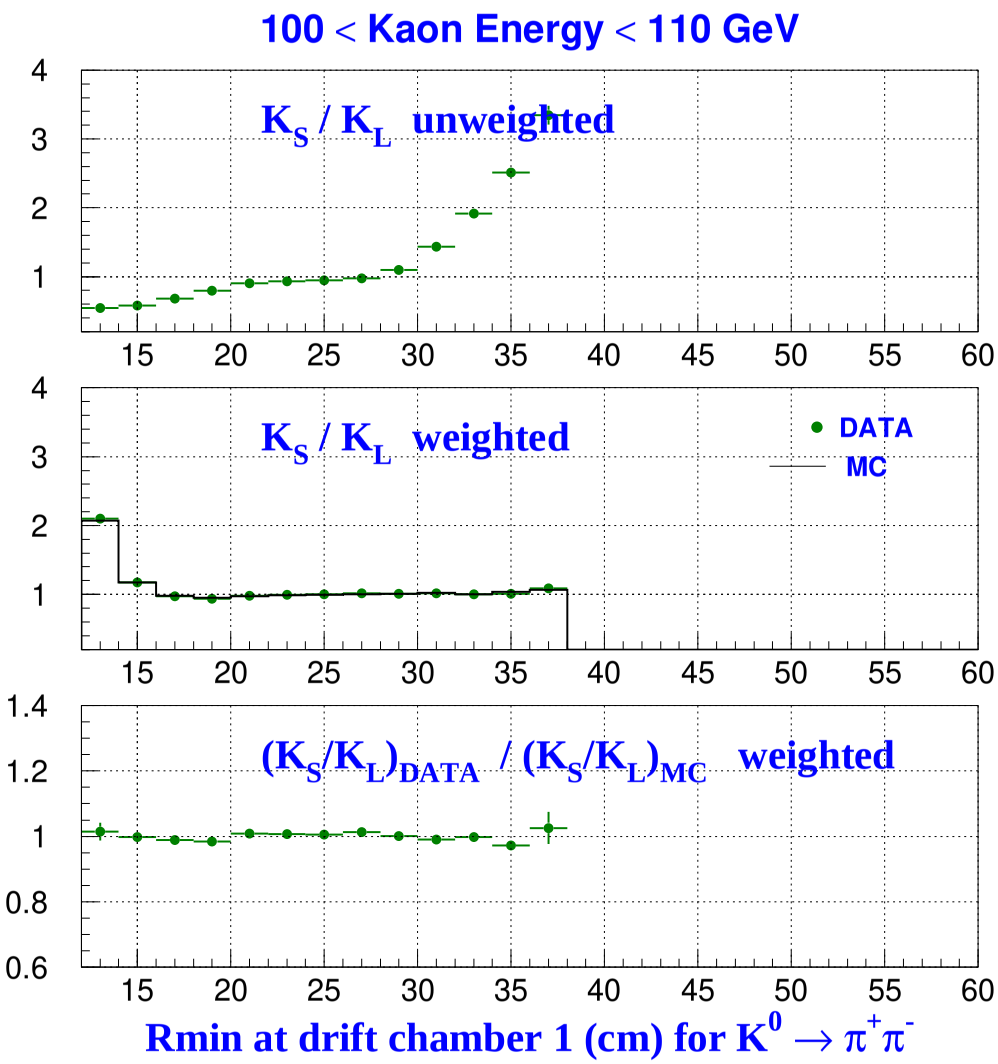


- The K_L events are weighted according to the ratio of the proper lifetime distribution of K_S
- This reduces the acceptance correction to few per mill

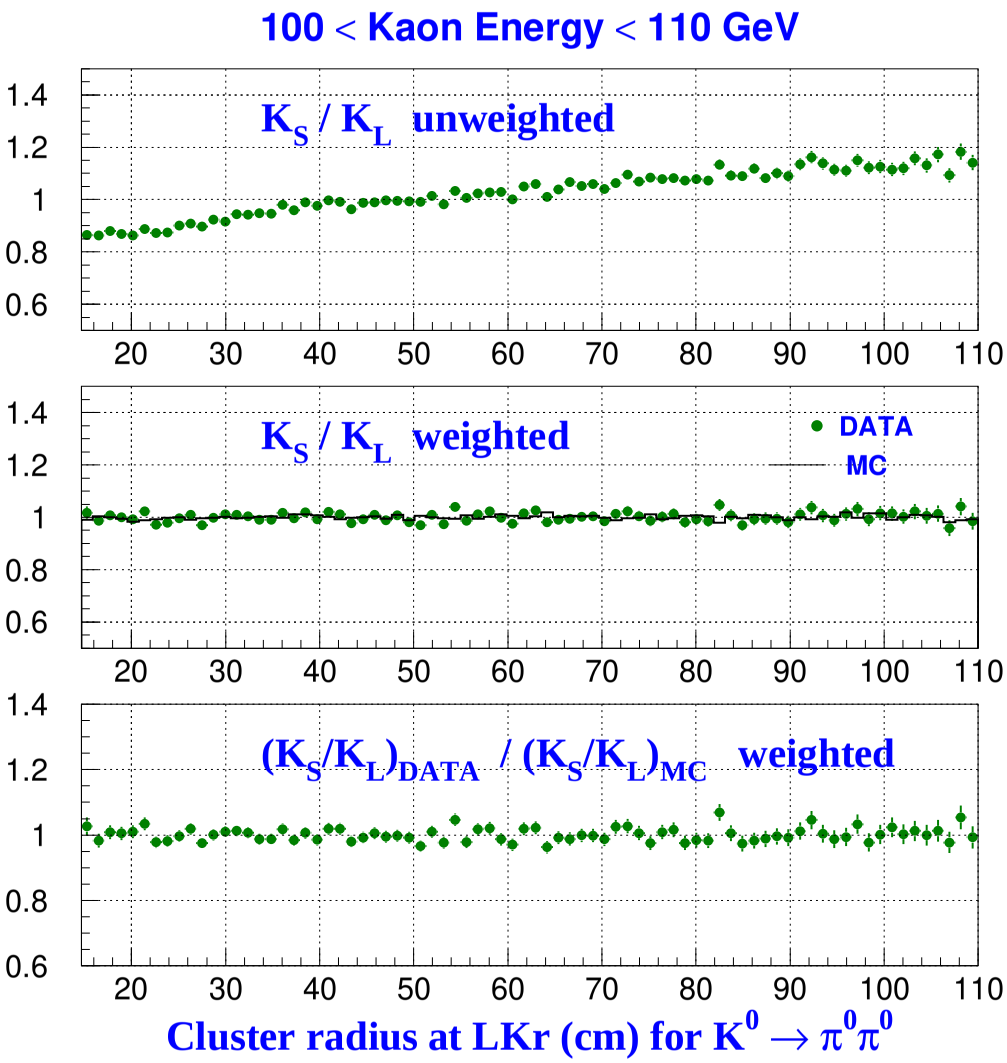
Weighting $\pi^0\pi^0$



DATA/MC: $\pi^+\pi^-$

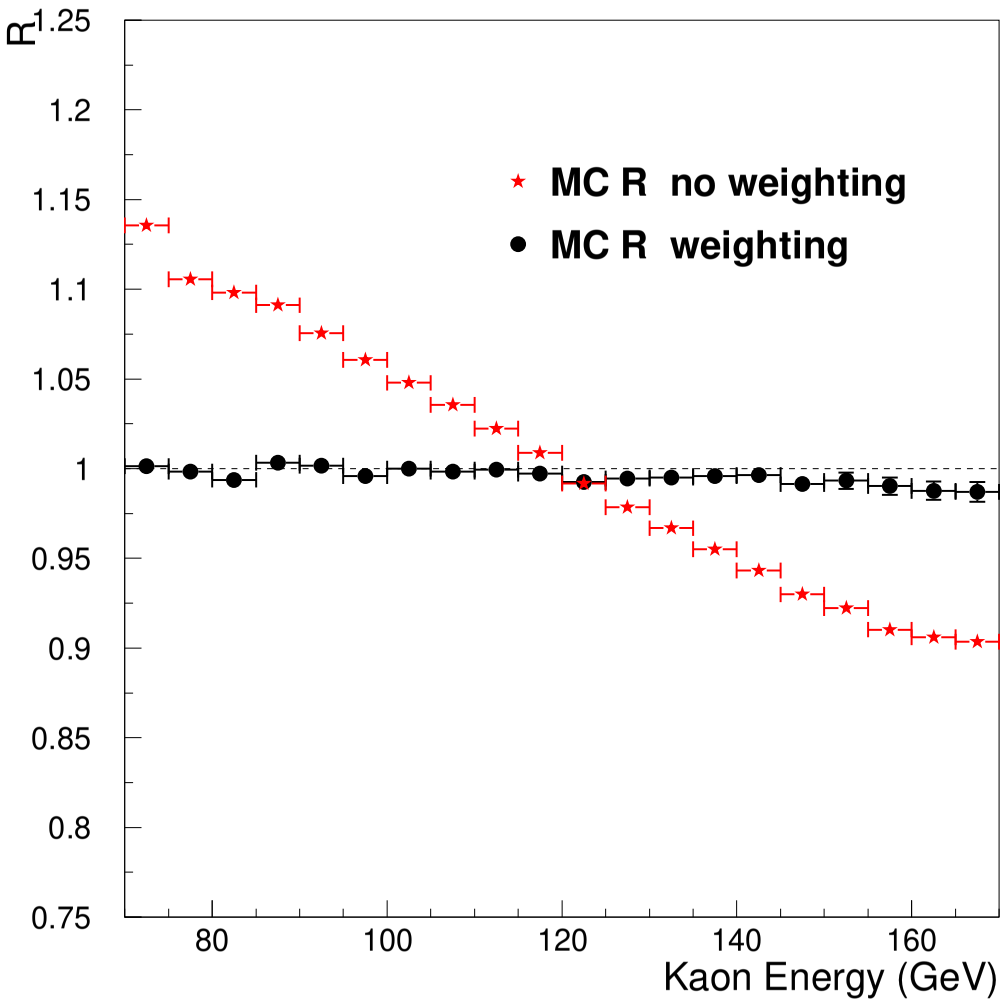

100 < Kaon Energy < 110 GeV
K_S / K_L unweighted
K_S / K_L weighted
DATA
MC
(K_S/K_L)_DATA / (K_S/K_L)_MC weighted
Rmin at drift chamber 1 (cm) for K^0 → π^+π^-

DATA/MC: $\pi^0\pi^0$



Acceptance

The increase of the statistical error due to weighting is 35%



$$\Delta \mathrm{R} = (+31 \pm 6(stat) \pm 6(syst)) \times 10^{-4}$$

accidental activity

To account for the geometric difference of the K_S and K_L beams, we overlay events collected proportionally to the beam intensity (*randoms*) to $\pi^+\pi^-$ and $\pi^0\pi^0$ events and evaluate the gain and losses induced by the analysis cuts

$$\Delta R = (2 \pm 6) \times 10^{-4}$$

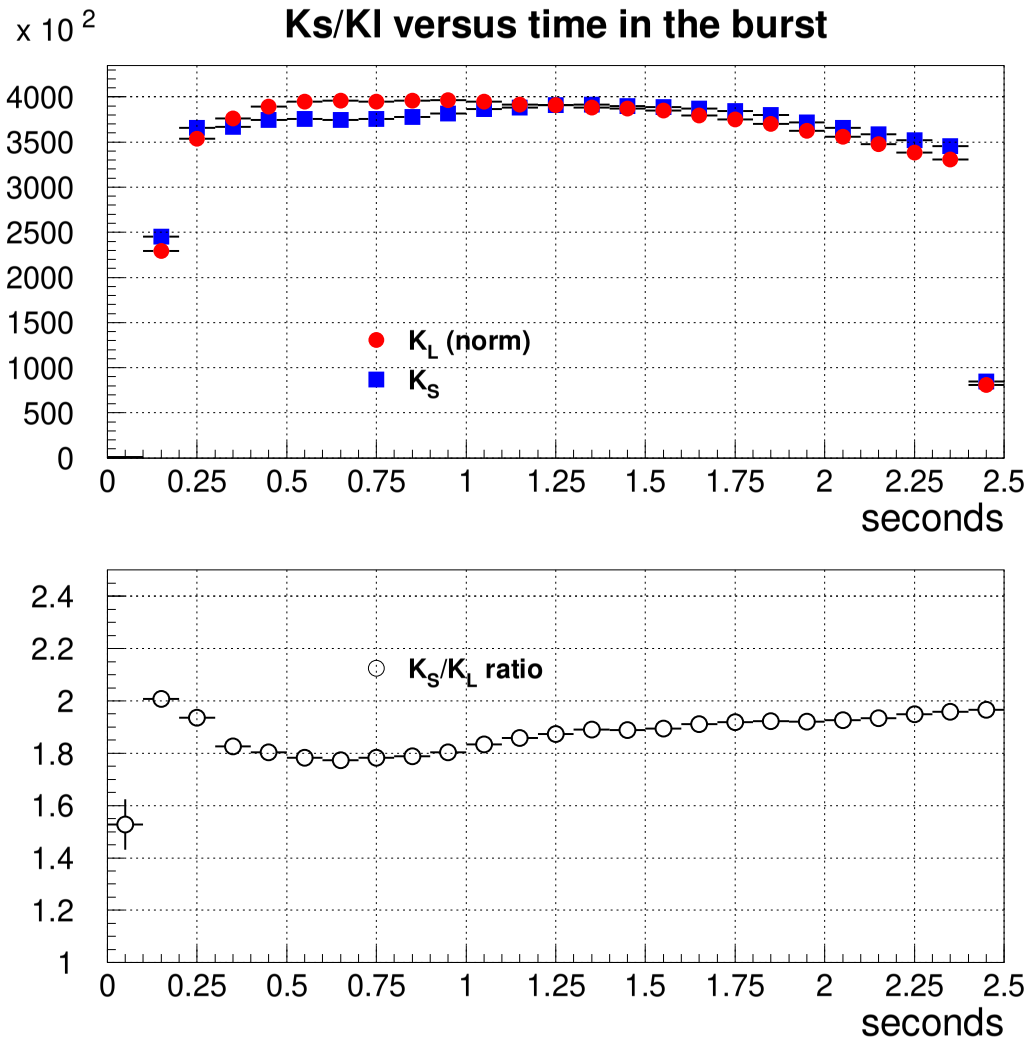
To put bounds on the effects related to the variation of the K_S / K_L ratio (R.M.S. 10 %) and the effects which are not related to the K_L accidental activity, we use the following inputs:

- the difference in accidental activity seen by K_S and K_L events is < 1 %
- The asymmetric losses on $\pi^+\pi^-$ and $\pi^0\pi^0$ induced by the noise in the DCH are $< 2.5\%$
- the noise in the detector does not change by more than a factor of two as a function of time

$$\Delta R < 10 \times 10^{-4}$$

In the future, we will overlay the randoms to the MC data to reduce the effect of doubling the noise.

K_S /K_L over during the spill



Result 1998: statistics

Statistics (millions) 1998			
$K_S \to \pi^+\pi^-$	7.46	$K_L \to \pi^+\pi^-$	4.87
$K_S \to \pi^0\pi^0$	1.80	$K_L \to \pi^0\pi^0$	1.14

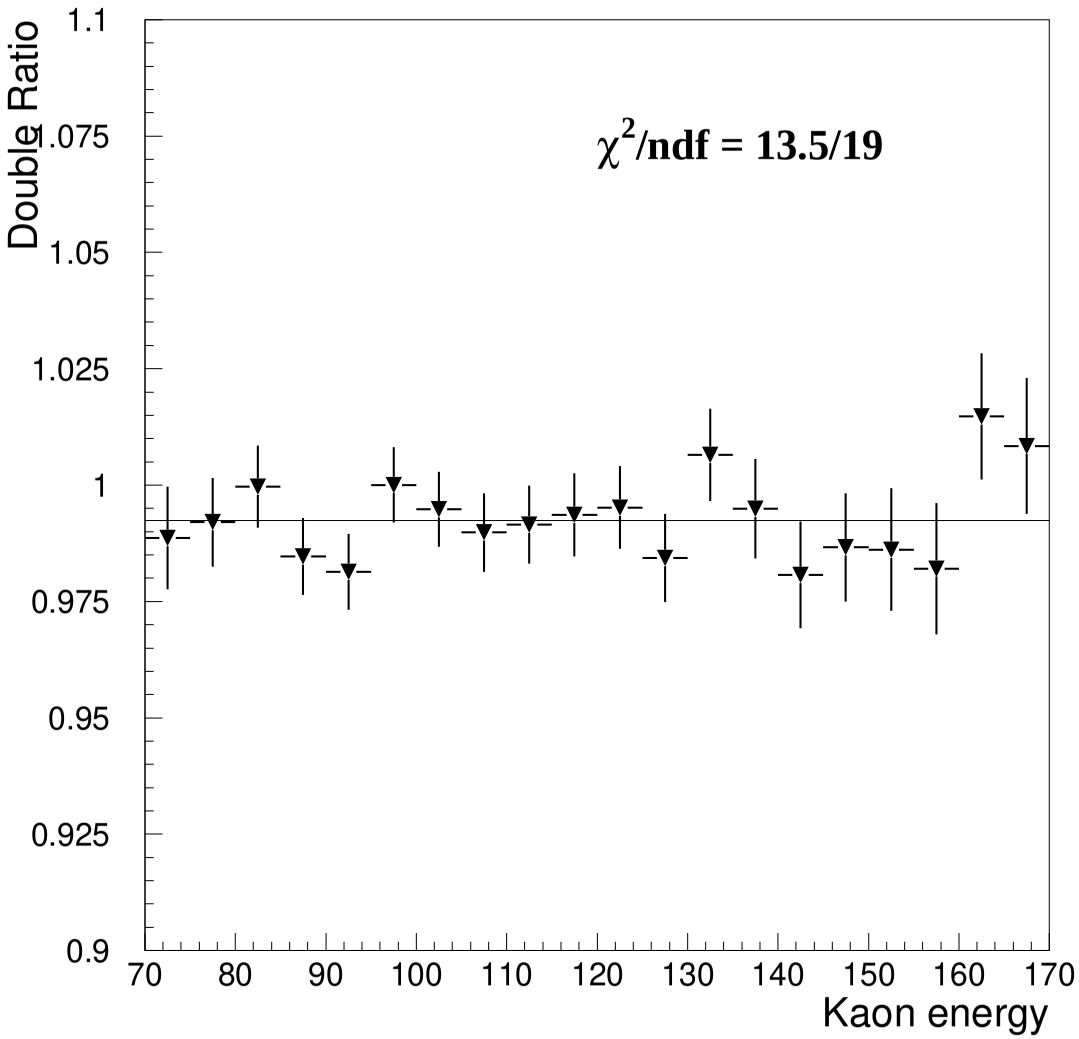
Result 1998: systematic uncertainties

Corrections and systematic uncertainties on R (Units = 10^{-4})			
Source	1998 sample		Limitation
Charged trigger	–1	± 11	(stat.)
Accidental tagging	+1	± 8	(stat.)
Tagging efficiency	–	± 3	
Neutral rec. systematics	–	± 10	
Charged vertex	+2	± 2	
Acceptance and K_S anti-counter	+31	± 9	
Neutral BKG	–7	± 2	
Charged BKG	+19	± 3	
Beam scattering	–10	± 3	
Accid. activity and in-time BKG	+2	± 12	
Total	+37	± 24	

$$\mathrm{Re}(\varepsilon'/\varepsilon) = \frac{1}{6} \times (1 - R)$$

Result 1998

PRELIMINARY RESULT ON 1998 DATA



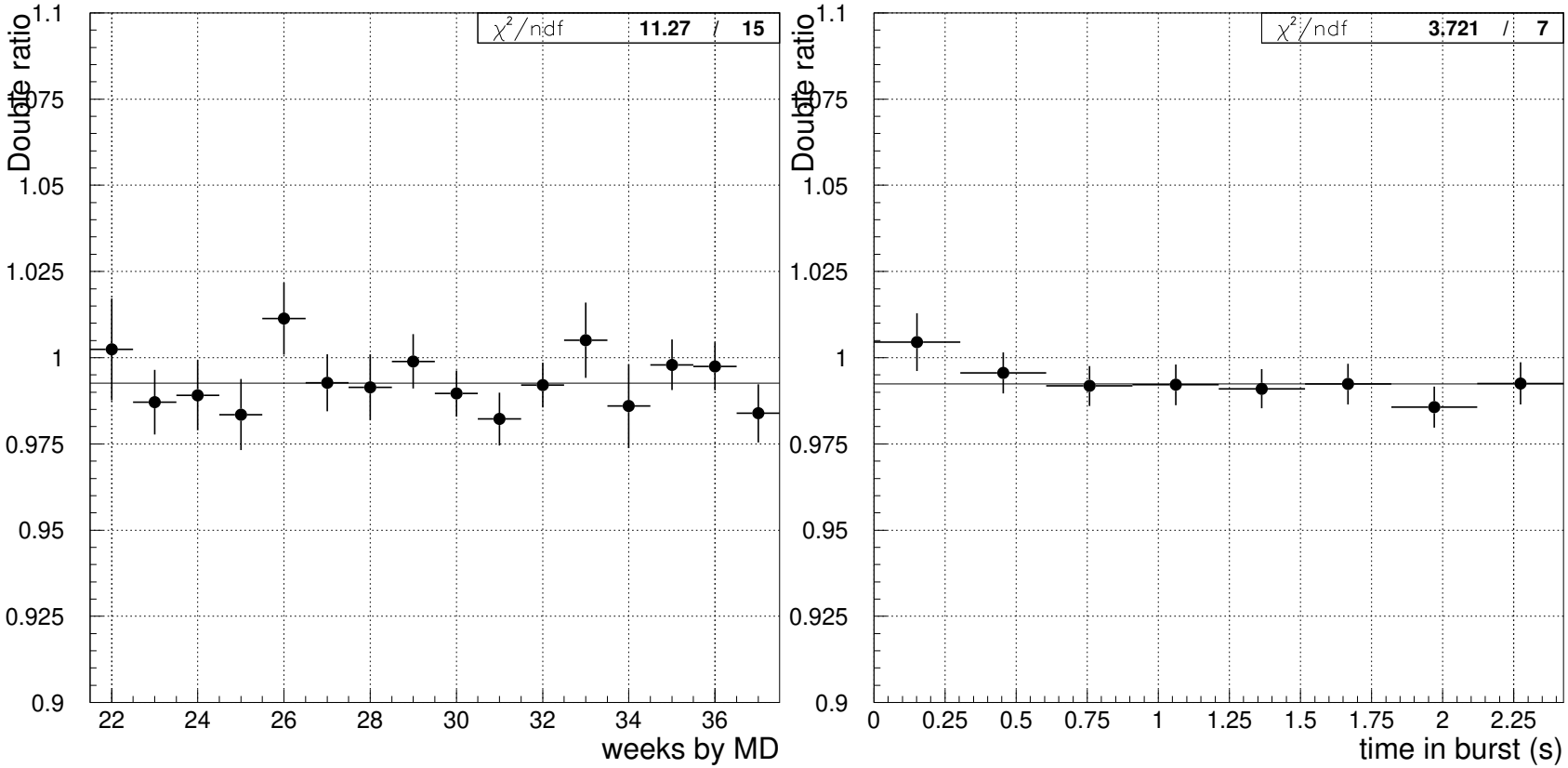
$$R = 0.99267 \pm 0.00173(stat.) \pm 0.00238(syst.)$$

$$\mathrm{Re}(\varepsilon'/\varepsilon) = (12.2 \pm 2.9\ (\mathrm{stat.}) \pm 4.0\ (\mathrm{syst.})) \times 10^{-4}$$

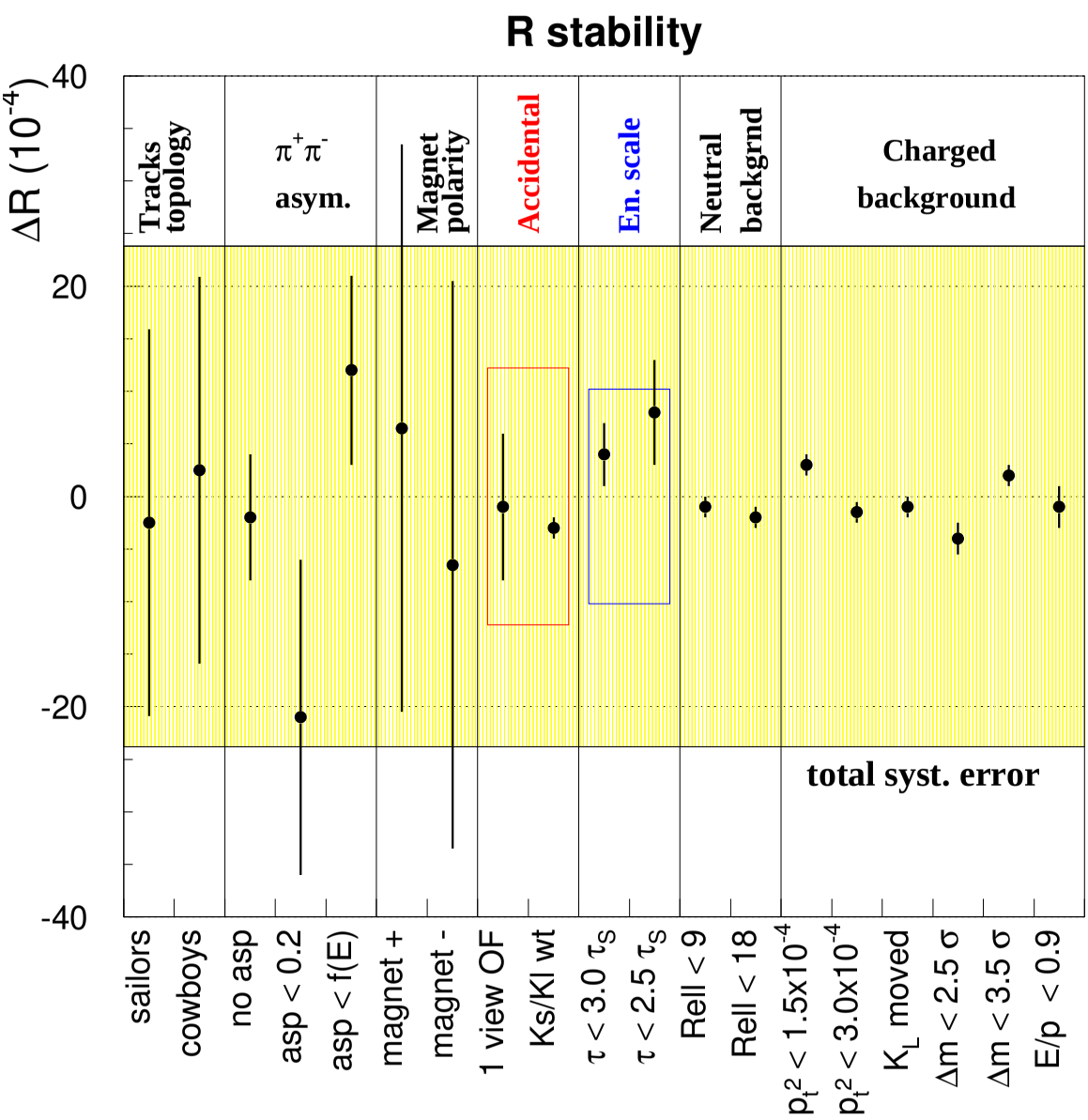
$$\boxed{\mathrm{Re}(\varepsilon'/\varepsilon) = (12.2 \pm 4.9) \times 10^{-4}}$$

This result is preliminary. The systematic uncertainty is partly of statistical nature

Checks: R vs time



Checks


R stability
ΔR (10^-4)
40
20
0
-20
-40
Tracks topology
π+π- asym.
Magnet polarity
Accidental
En. scale
Neutral backgrnd
Charged background
total syst. error
sailors
cowboys
no asp
asp < 0.2
asp < f(E)
magnet +
magnet -
1 view OF
Ks/Kl wt
τ < 3.0 τS
τ < 2.5 τS
Rell < 9
Rell < 18
pt2 < 1.5x10-4
pt2 < 3.0x10-4
KL moved
Δm < 2.5 σ
Δm < 3.5 σ
E/p < 0.9

Comparison of the 1997 and 1998 results

Corrections and syst. uncertainties on R (Units = 10^{-4})				
Source	1997 sample		1998 sample	
Charged trigger	+9	± 23	–1	± 11
Accidental tagging	+18	±9	+1	±8
Tagging efficiency	–	±6	–	± 3
Neutral rec. systematics	–	±12	–	±10
Charged vertex	–	±5	+2	±2
Acceptance	+29	±12	+31	±9
Neutral BKG	–8	±2	–7	±2
Charged BKG	+23	±4	+19	±3
Beam scattering	–12	±3	–10	±3
Accid. activity	–2	±14	+2	±12
Total	+57	±35	+37	±24

Combined 1997 and 1998 result

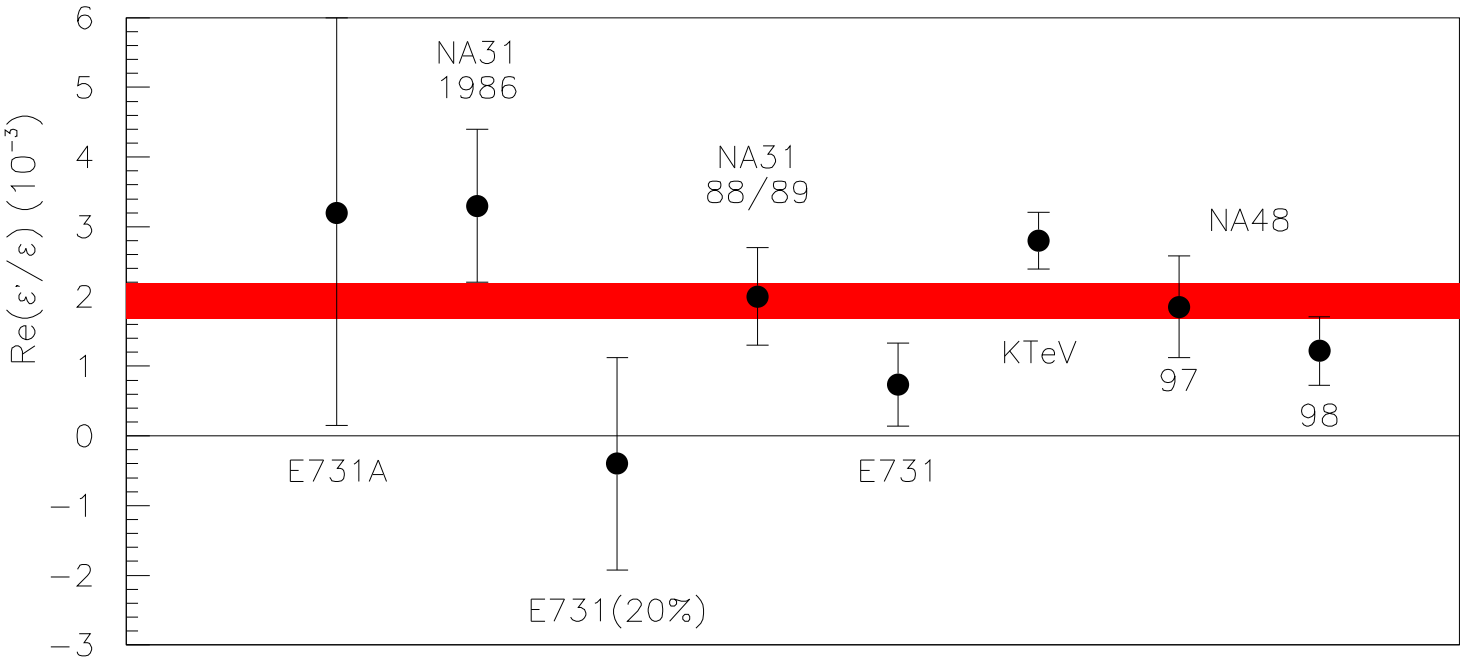
Combined 1997 and preliminary 1998 NA48 result

$$1998\ \mathrm{Re}(\varepsilon'/\varepsilon) = (12.2 \pm 2.9(stat.) \pm 4.0(syst.) \times 10^{-4}$$
$$1997\ \mathrm{Re}(\varepsilon'/\varepsilon) = (18.5 \pm 4.5(stat.) \pm 5.8(syst.) \times 10^{-4}$$

$$\boxed{\mathrm{Re}(\varepsilon'/\varepsilon) = (14.0 \pm 4.3) \times 10^{-4}}$$

(taking into account the small correlated systematics)

New world average

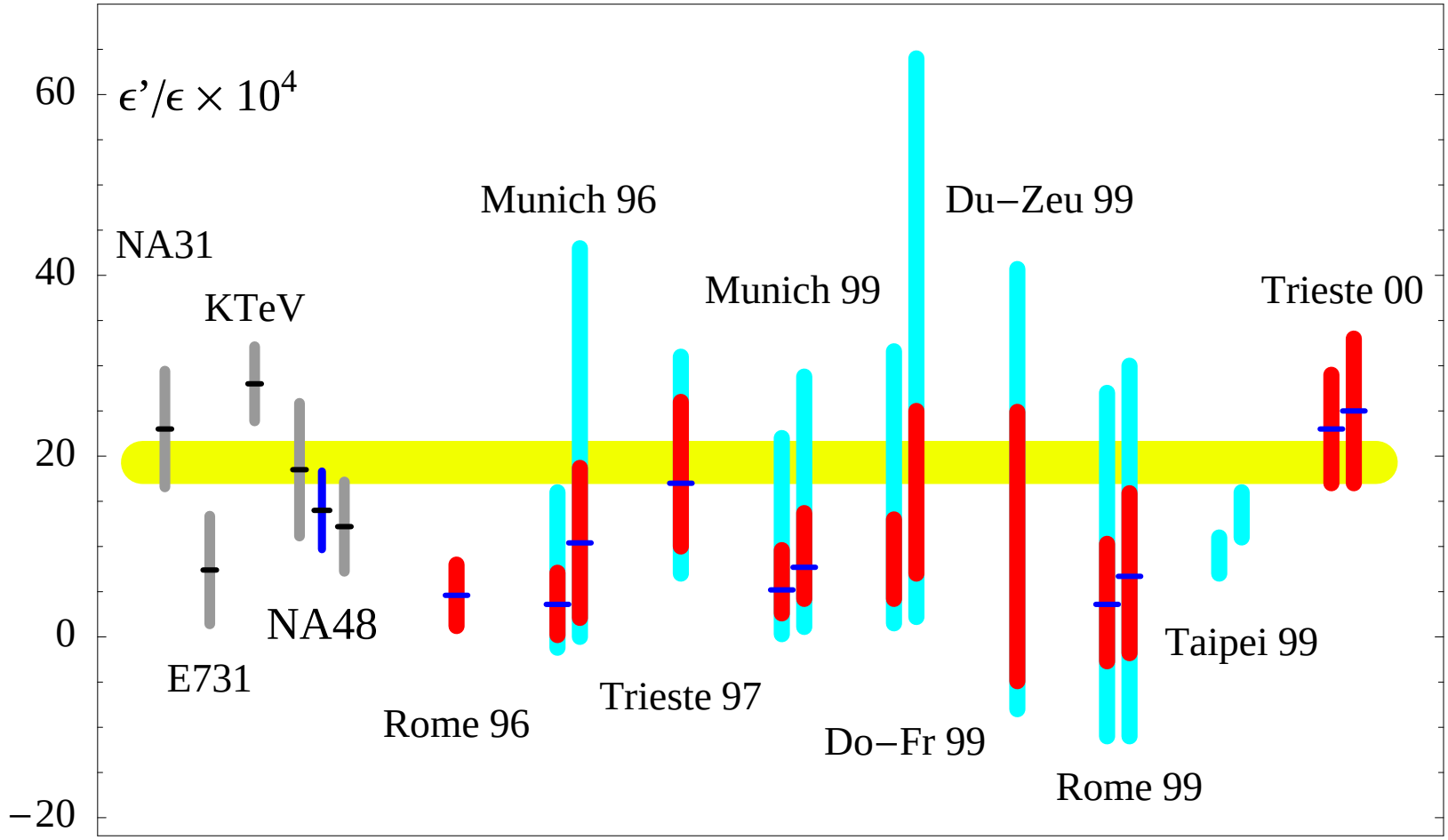


New world average:

$$\mathrm{Re}(\varepsilon'/\varepsilon) = (19.3 \pm 2.4) \times 10^{-4}$$

$$(\chi^2/ndf = 10.5/4)$$

Experiment vs. Theory



Experiments versus Theory

Perspective

- The systematic error of the 1998 result should be reduced in the future
- The analysis of the 1999 data is in progress
- The implosion of the carbon fibre beam tube on November 1999 has damaged all four drift chambers
- NA48 has obtained approval to repair the chambers in order to bring to a proper completion the $\mathrm{Re}(\varepsilon'/\varepsilon)$ measurement
- We plan to collect more data in 2000 and 2001 to reduce the systematic errors

Conclusions

- NA48 has presented a new preliminary measurement of $\mathrm{Re}(\varepsilon'/\varepsilon)$ based on the 1998 data sample:

$$\mathrm{Re}(\varepsilon'/\varepsilon) = (12.2 \pm 4.9) \times 10^{-4}$$

- Combining this result with the NA48 published data and taking into account the (small) correlated systematics, we obtain:

$$\mathrm{Re}(\varepsilon'/\varepsilon) = (14.0 \pm 4.3) \times 10^{-4}$$

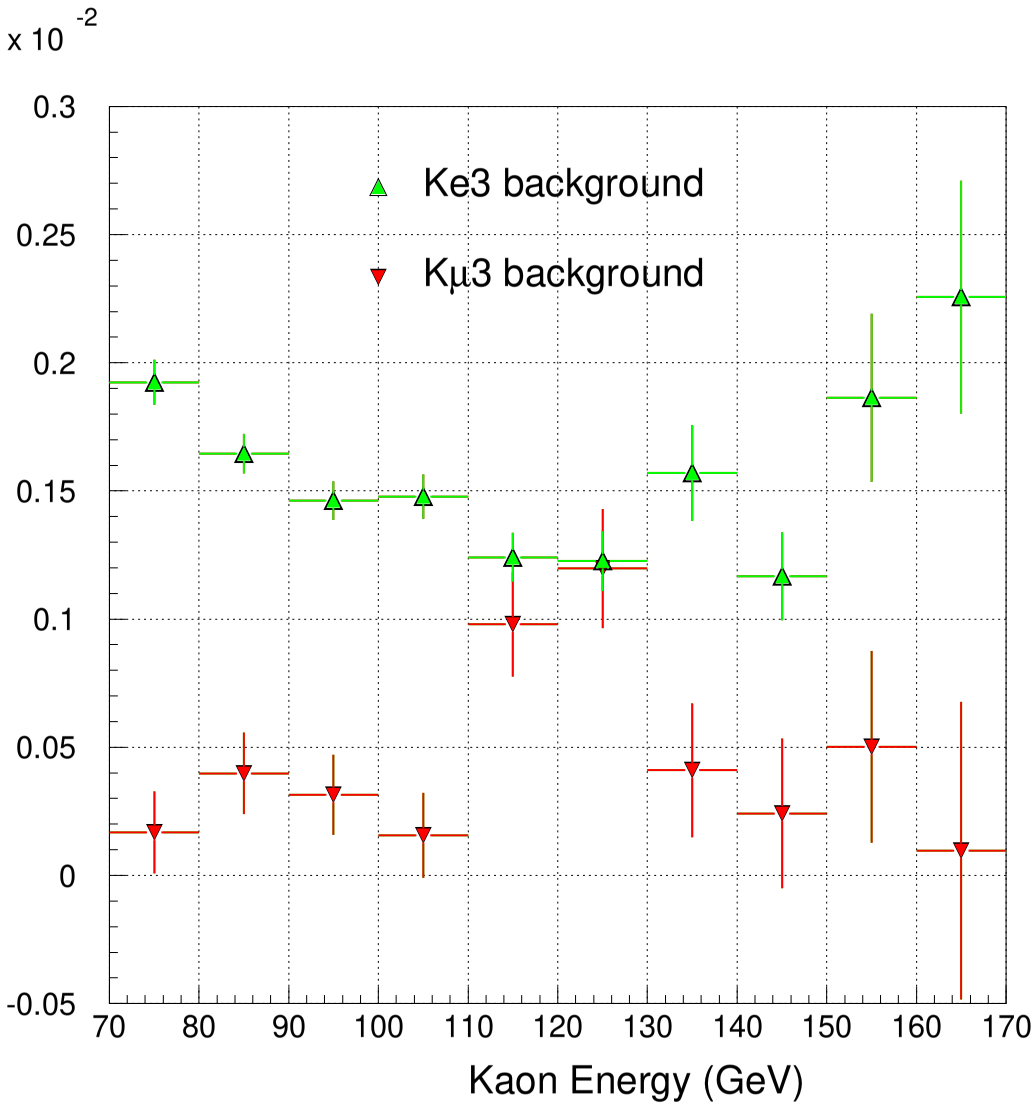
- The result confirms a non-zero, positive value for $\mathrm{Re}(\varepsilon'/\varepsilon)$

- It will be very interesting to compare this result with those expected from KTEV (FNAL) and KLOE (DAΦNE)

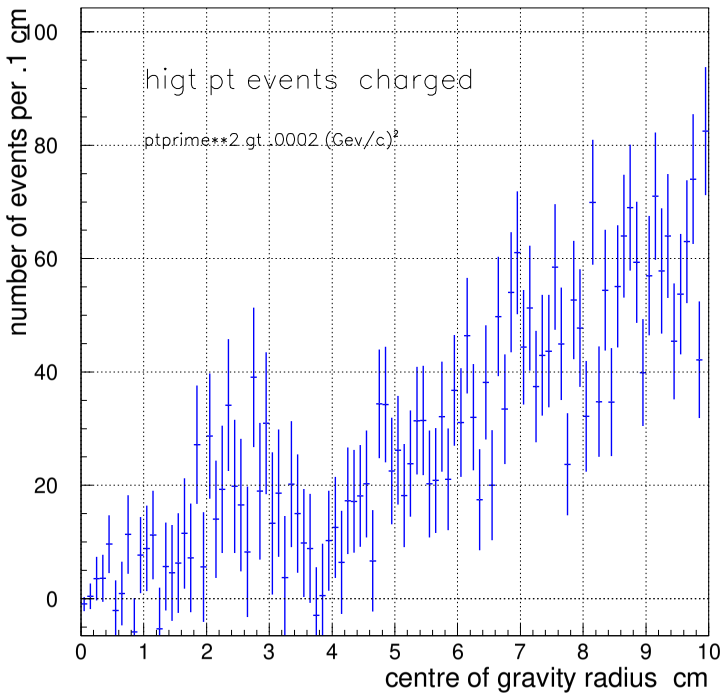
Spare material

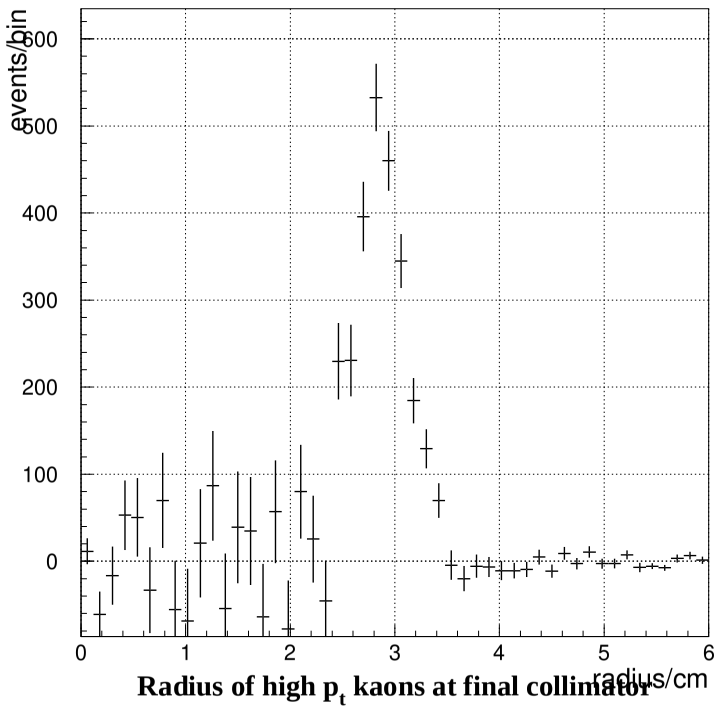
The following slides are kept as spare material in case of questions

Background to $\pi^+\pi^-$

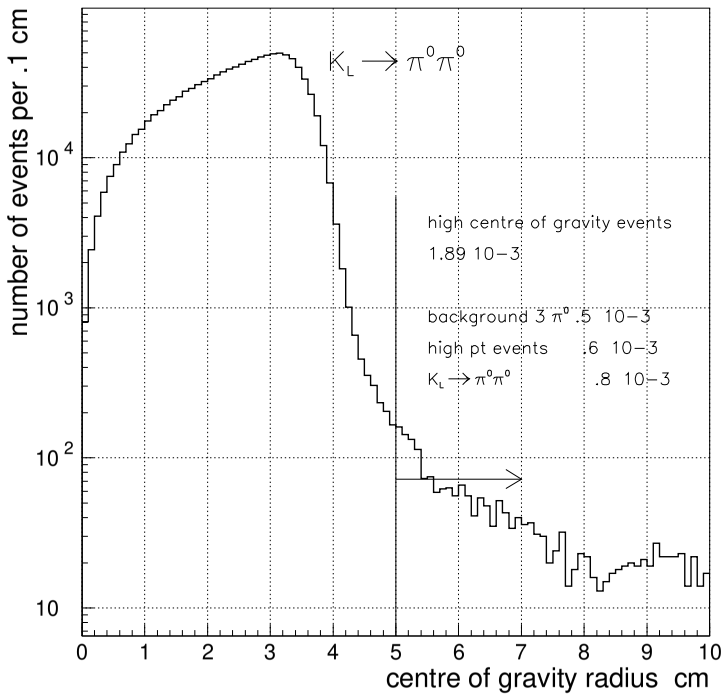


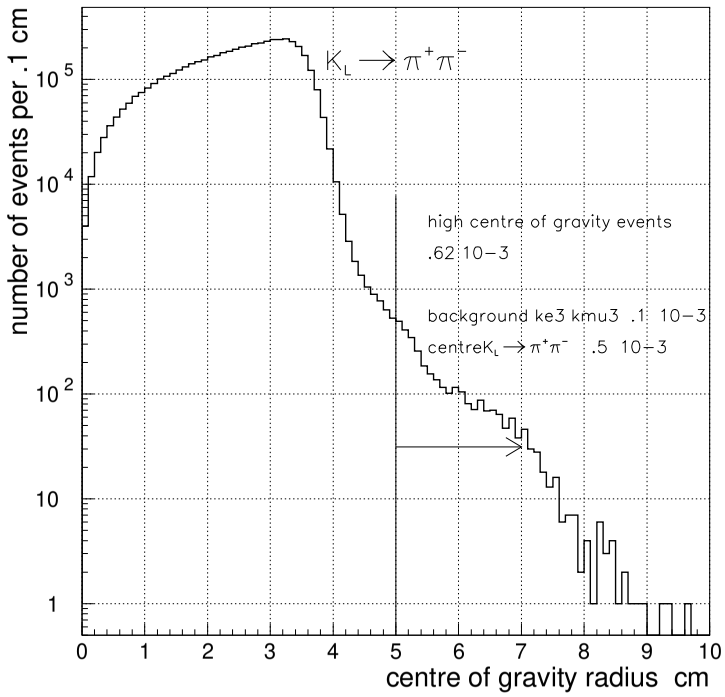
Scattered Events in the K_L beam



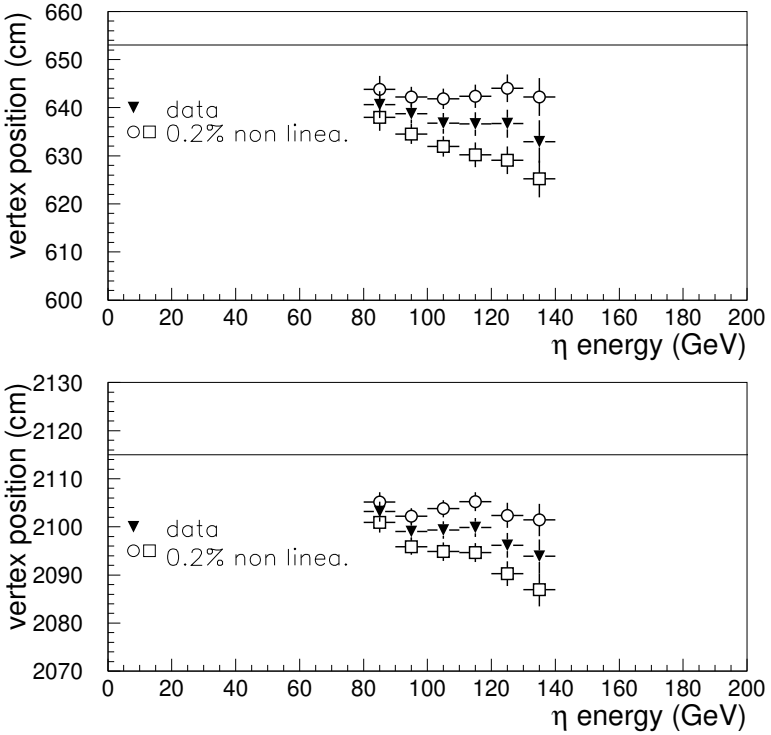


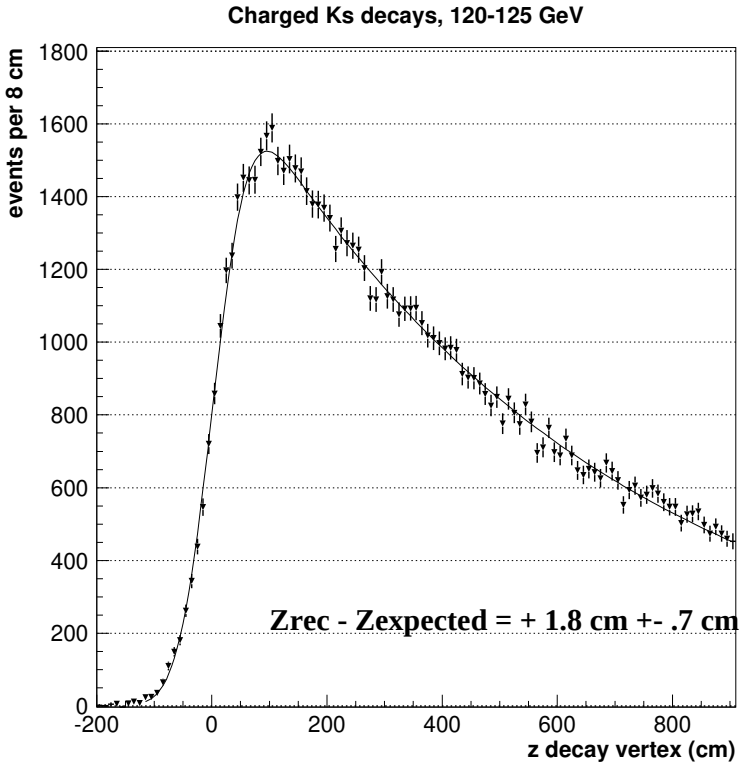
Centre of gravity distribution



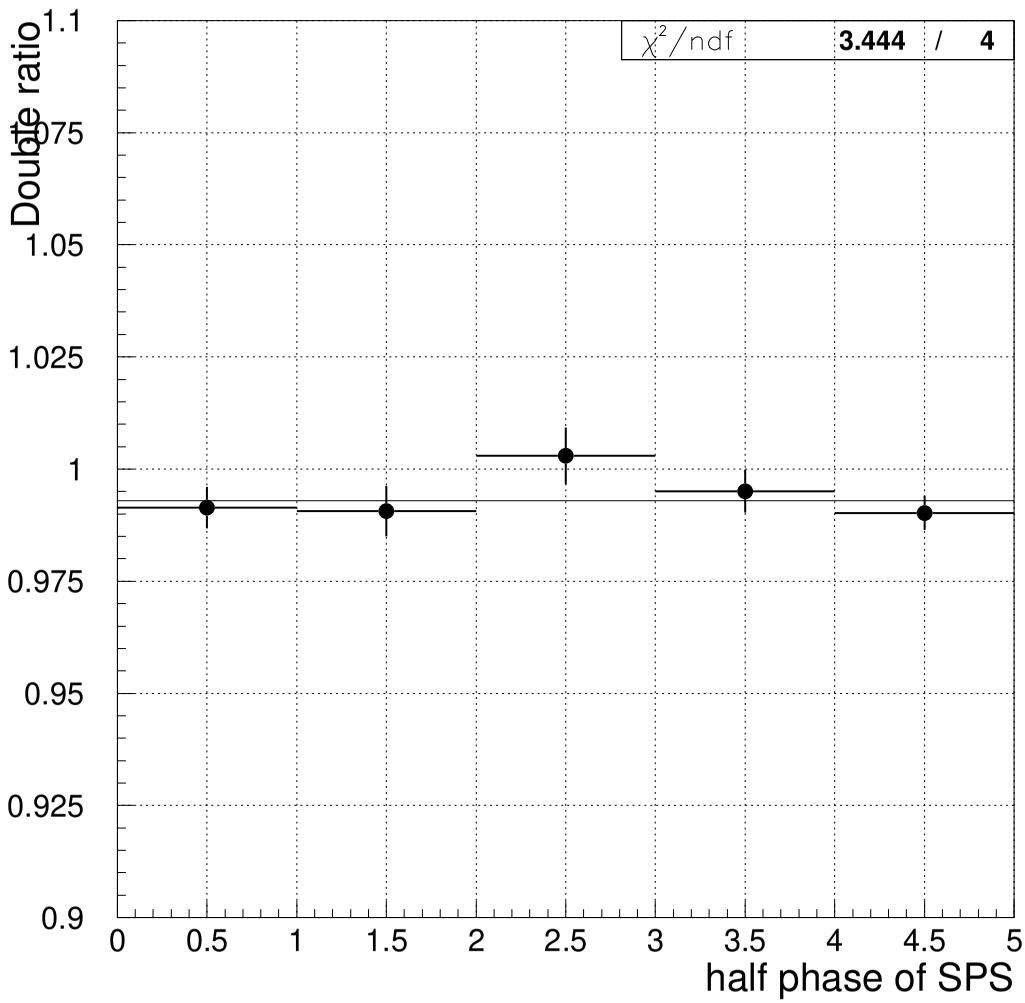


Energy scale / Linearity

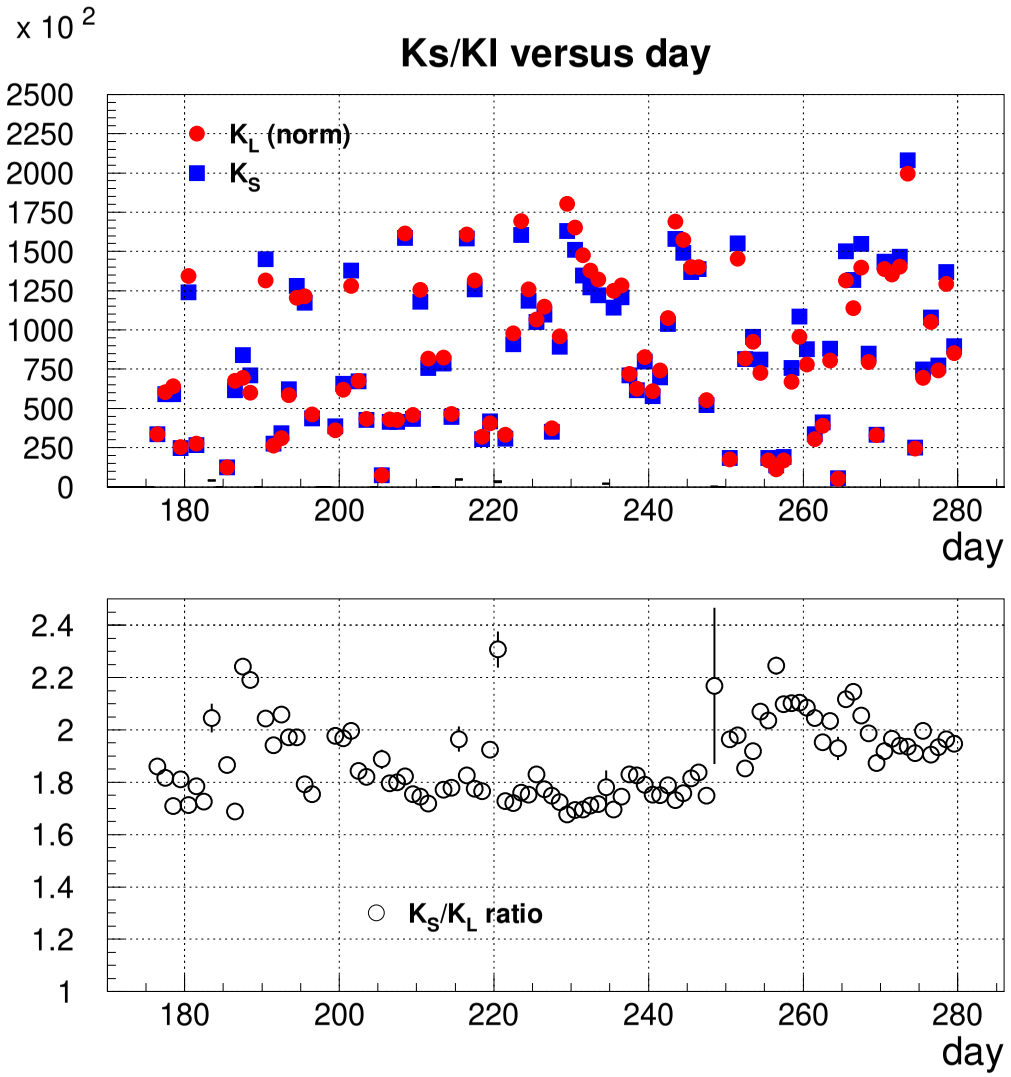




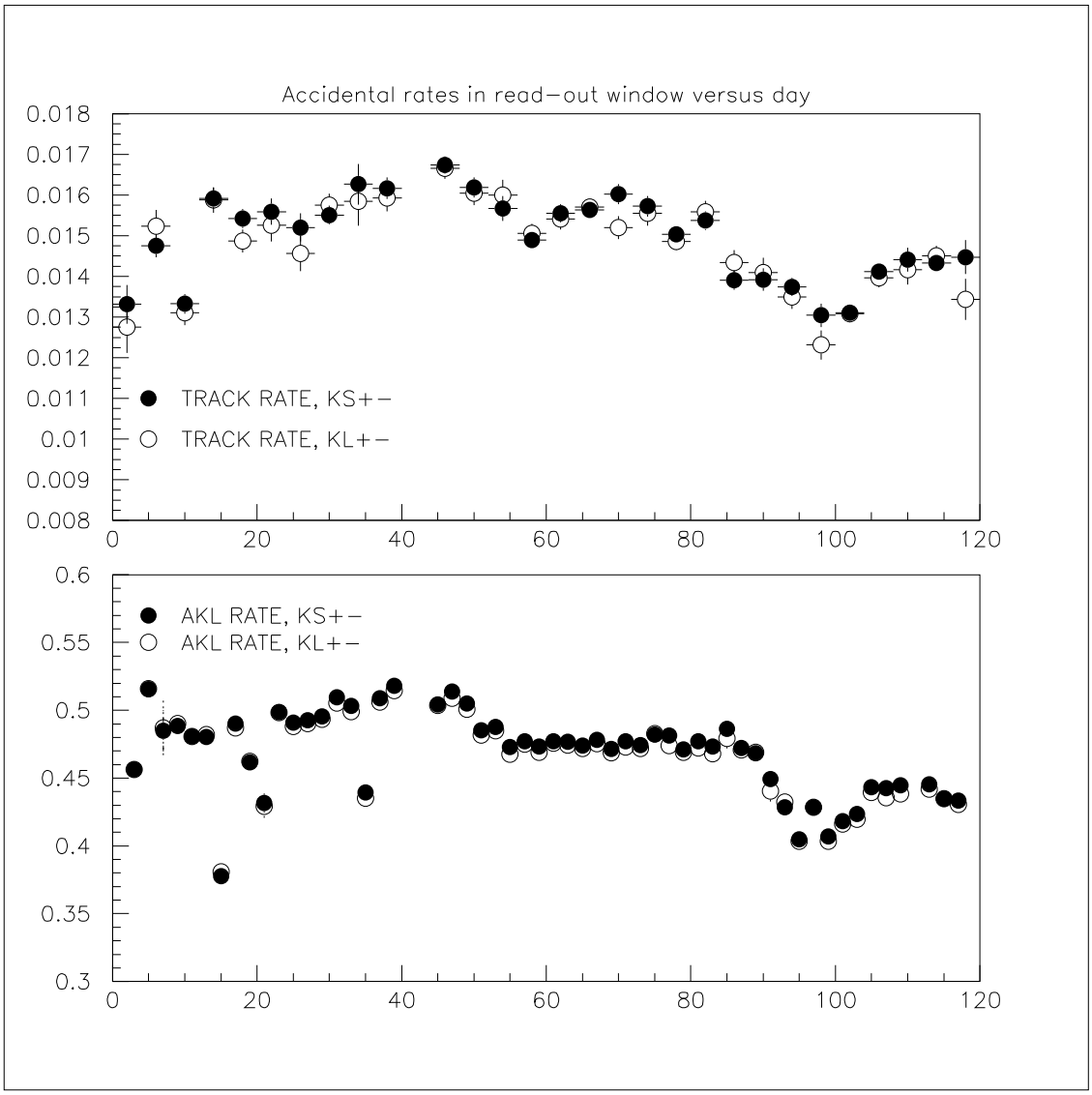
Result 1998: checks



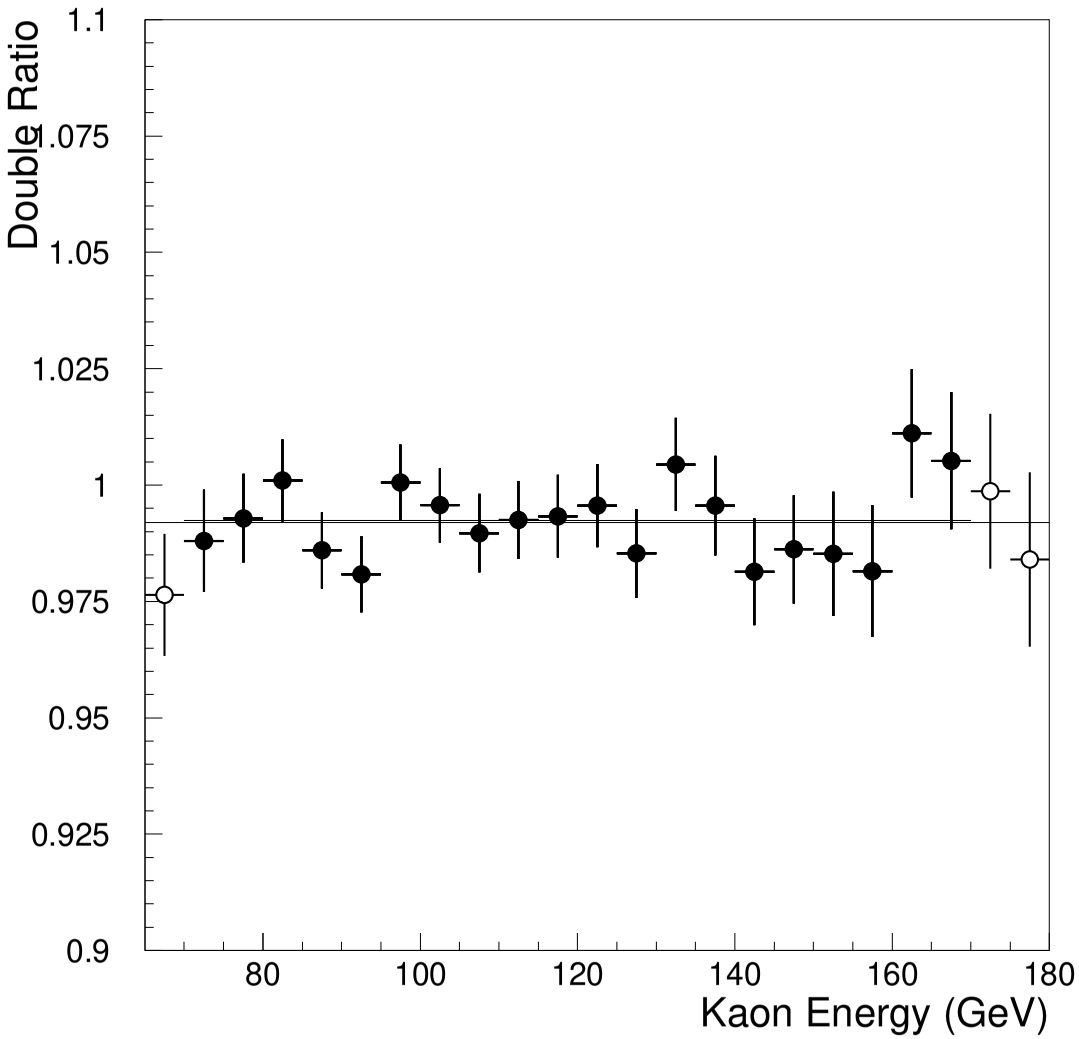
K_S /K_L over during the run



Accidental rate seen by K_S and K_L



Result 1998: checks



Running in 2000 and 2001

- Year 2000 With no Spectrometer available we will focus on the neutral decays.

  – We want to measure the difference in accidental tagging for $\pi^0\pi^0$ and $\pi^0\pi^0\pi^0$

  – We want to improve the understanding of the distance/energy scale and non linearity of the LKr using dedicated runs with the negative π beam to produce large amount of $\eta \to \gamma\gamma$ and $\eta \to 3\pi^0$

- Year 2001 We plan to collect data with the restored drift chambers. The aim is to address in particular the systematic errors related to the beam intensity variation