First result on direct CP violation in Kaon decays from NA48

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NA48 COLLABORATION

Cagliari-Cambridge-CERN-Dubna-Edinburgh-Ferrara-Firenze-Mainz-Orsay-Perugia-Pisa-Saclay-Siegen-Torino-Vienna-Warsaw

Outline

- Direct CP violation
- The NA48 method
- Beams and Detectors
- The 1997 run
- Data analysis
  - Events selection
  - Corrections
- The result
- Perspectives
- Conclusions

Direct CP violation

$\mathrm{K}^0 \equiv \bar{s}d$	$\mathrm{K}_1 = (\mathrm{K}^0 + \bar{\mathrm{K}}^0)/\sqrt{2}$	**CP even**
$\bar{\mathrm{K}}^0 \equiv \mathrm{CP}(\mathrm{K}^0)$	$\mathrm{K}_2 = (\mathrm{K}^0 - \bar{\mathrm{K}}^0)/\sqrt{2}$	**CP odd**

$\mathrm{K_S} \simeq \mathrm{K}_1 + \epsilon_K \mathrm{K}_2$ $\qquad$ $\mathrm{K_L} \simeq \mathrm{K}_2 + \epsilon_K \mathrm{K}_1$

$\hookrightarrow$			$\hookrightarrow$		
	$\pi^+\pi^-$	69 %	CP odd	$3\pi^0$	21 %
	$\pi^0\pi^0$	31 %		$\pi^+\pi^-\pi^0$	13 %
				$\pi\mu\nu$	27 %
				$\pi e\nu$	39 %
			CP even	$\pi^+\pi^-$	0.2 %
			CP even	$\pi^0\pi^0$	0.1 %

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

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

- $\epsilon = (2.28 \pm .02)\ 10^{-3}$
- $\epsilon' = \frac{\mathrm{i}}{\sqrt{2}}\ \mathrm{Im}(\frac{A_2}{A_0})\ \exp(\mathrm{i}(\delta_2 - \delta_0))$

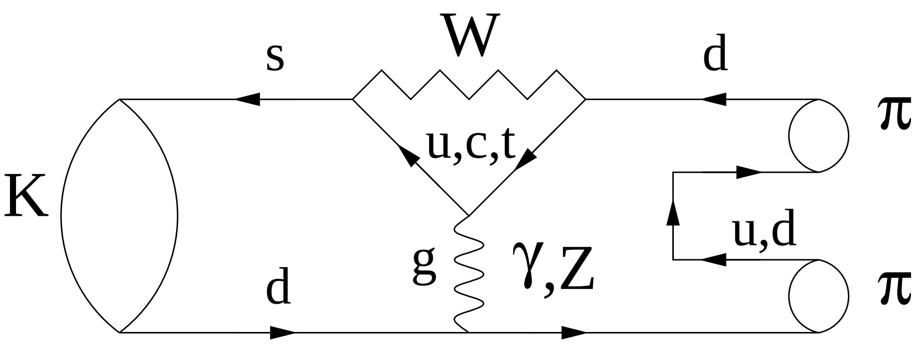
  direct CP violation parameter

ε'/ε in the Standard Model

Origin :

phase difference in $\Delta S = 1$ diagrams

between $\Delta I = 1/2$ and $\Delta I = 3/2$ transistions



$\varepsilon'/\varepsilon \;\propto$	$\lvert V_{ub}\, V_{cb} \rvert\, \eta$	$\left[\frac{1}{m_s}\right]^2$	$P(m_t, \Lambda_{QCD})$
	$(\mathrm{Im}\; V_{td} V^*_{ts})$		
	CKM matrix elements	hadronic matrix elements	penguin diagrams

Typical theoretical estimates of $\mathrm{Re}(\varepsilon'/\varepsilon)$:

- $(3.6 \pm 3.4) \times 10^{-4}$
  (Buras 96)
- $(4.6 \pm 3.0 \pm 0.4) \times 10^{-4}$
  (Ciuchini 97)
- $(17 \,{}^{+14}_{-10}) \times 10^{-4}$
  (Bertolini 98)

NA48 : aim and method

- Aim : measure $\mathrm{Re}(\varepsilon'/\varepsilon)$ with an accuracy of 2×10^{-4}
- Method : double ratio technique

$$\mathrm{R} = \frac{\Gamma(\mathrm{K_L} \to \pi^0\pi^0)}{\Gamma(\mathrm{K_S} \to \pi^0\pi^0)} \Big/ \frac{\Gamma(\mathrm{K_L} \to \pi^+\pi^-)}{\Gamma(\mathrm{K_S} \to \pi^+\pi^-)}$$

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

- High statistics needed :

⇒ Collect $4 - 5 \times 10^6$ $\mathrm{K_L} \to \pi^0\pi^0$ (limiting mode)
Powerful Trigger and DAQ systems

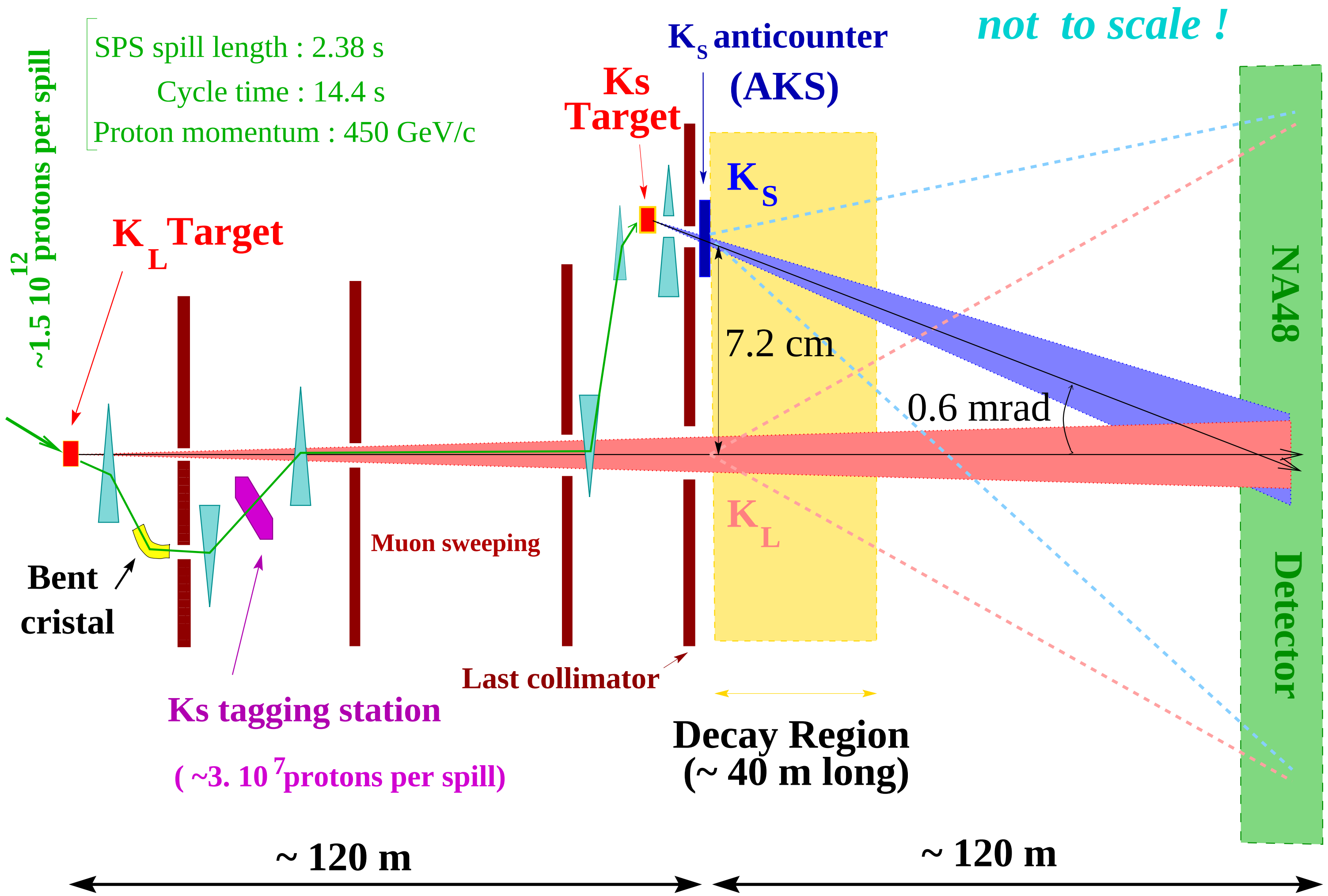
- Minimize corrections → the 4 modes are measured
  - Simultaneously

  ⇒ cancellation of fluxes, inefficiencies, dead time, accidental losses
  - From the same fiducial volume and apply lifetime weighting of Kl to make similar Z vertex distributions for Kl and Ks

  ⇒ small acceptance correction
  - With a high resolution magnetic spectrometer for the $\pi^+\pi^-$ mode
  - With a homogeneous Liquid Krypton calorimeter for the $\pi^0\pi^0$ mode

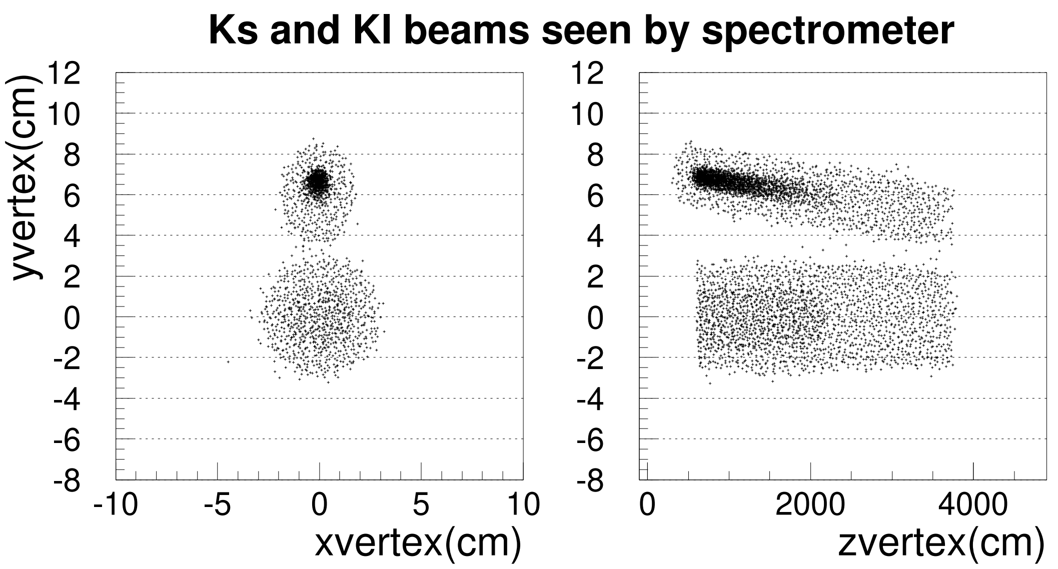
  ⇒ achieve good resolutions and small background levels

The Simultaneous K_S and K_L Beams

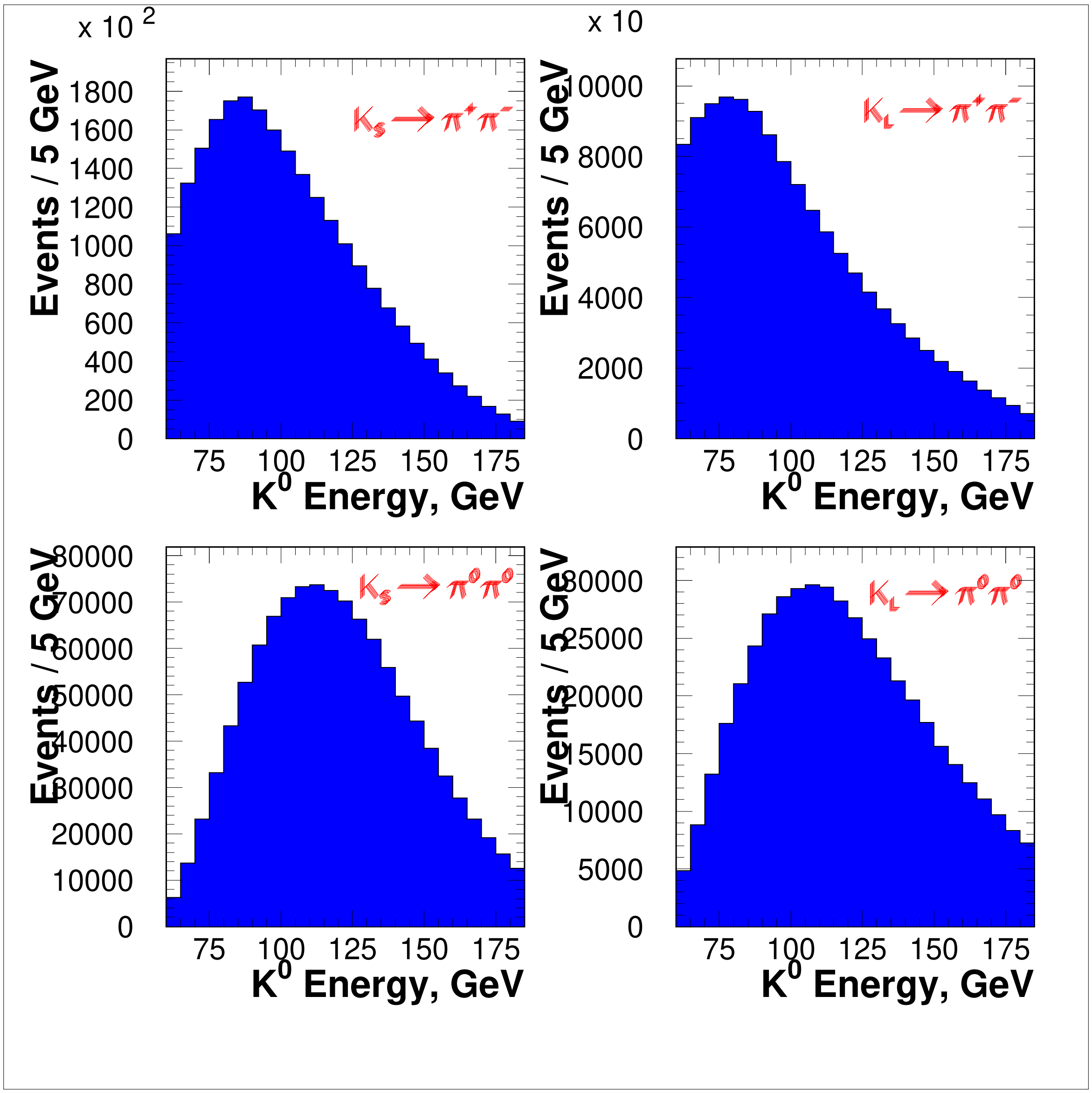


K_S are distinguished from K_L by TAGGING the protons upstream of the K_S target

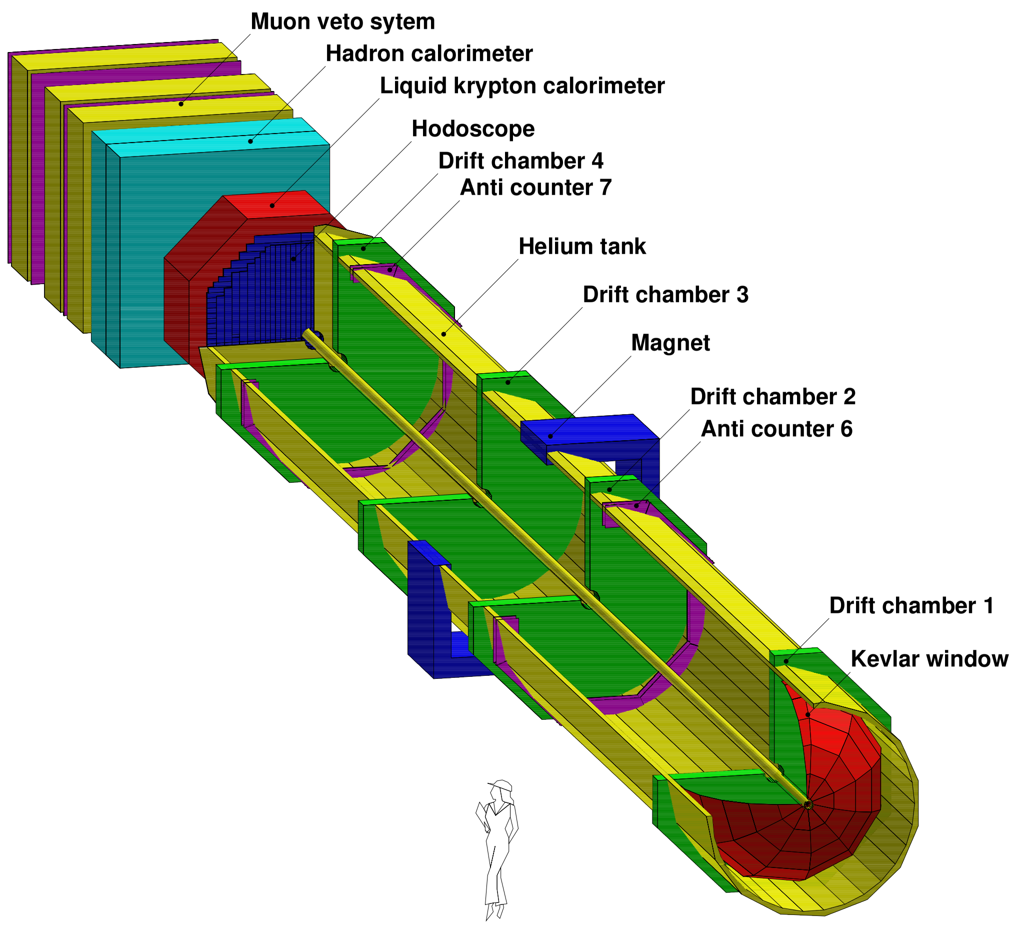
KS and KL beams



Spectra of accepted K decays

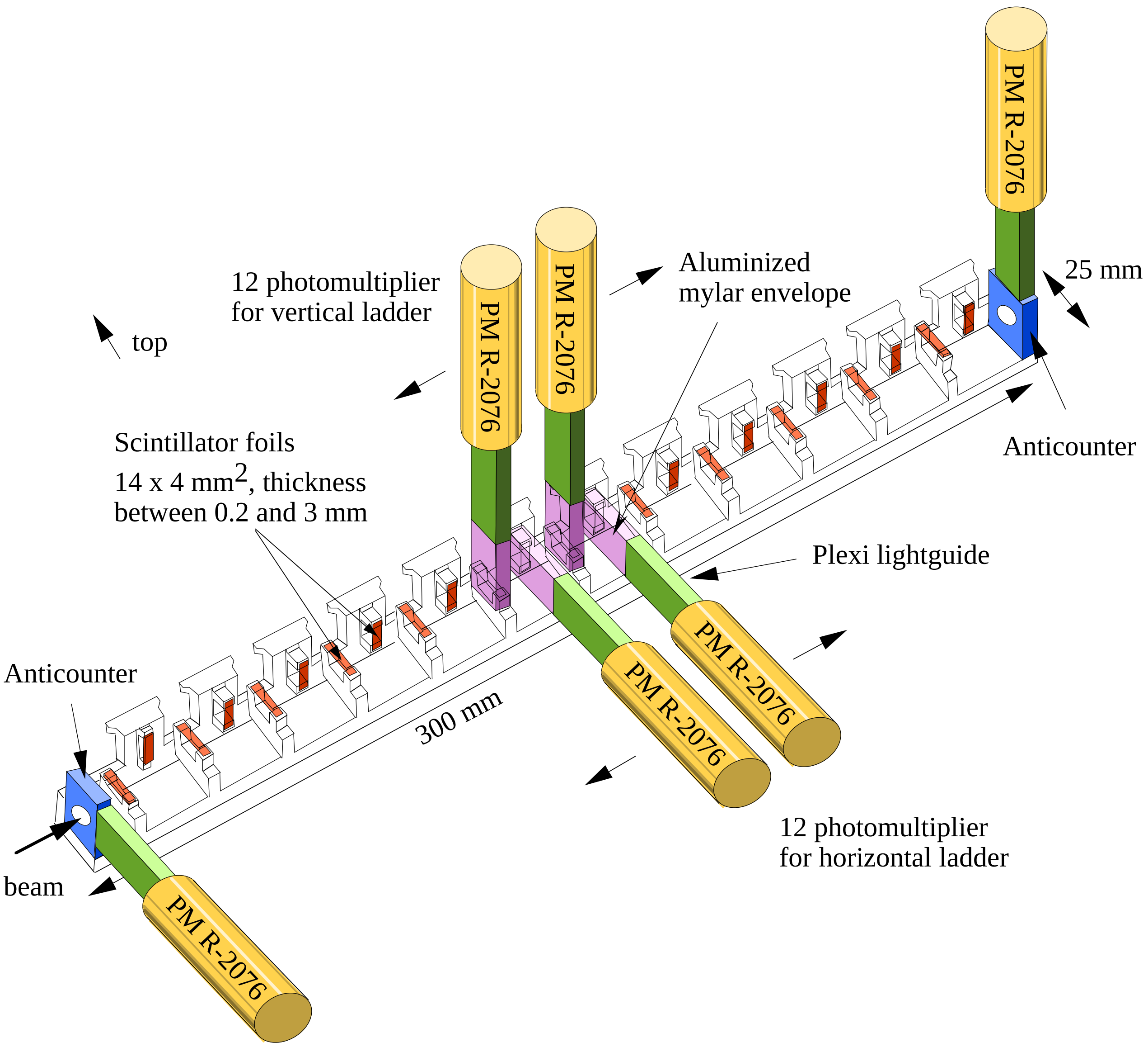


Detectors



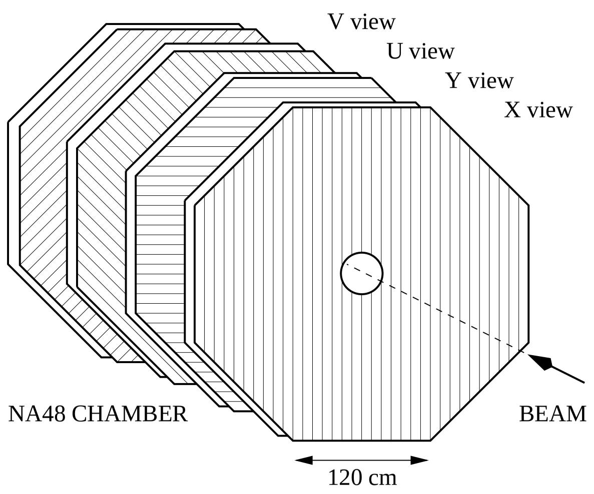
- $K_{\mathrm{L,S}} \rightarrow \pi^+\pi^-$
  - magnetic spectrometer ($\mathrm{P}_{\perp}{}^{kick} \sim 265\mathrm{MeV}/c$)
- $K_{\mathrm{L,S}} \rightarrow \pi^0\pi^0$
  - quasi-homogeneous Liquid Krypton e.m. calorimeter :
    * high granularity (13212 2×2 cm^2 cells)
    * projective geometry

The Tagging Detector



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

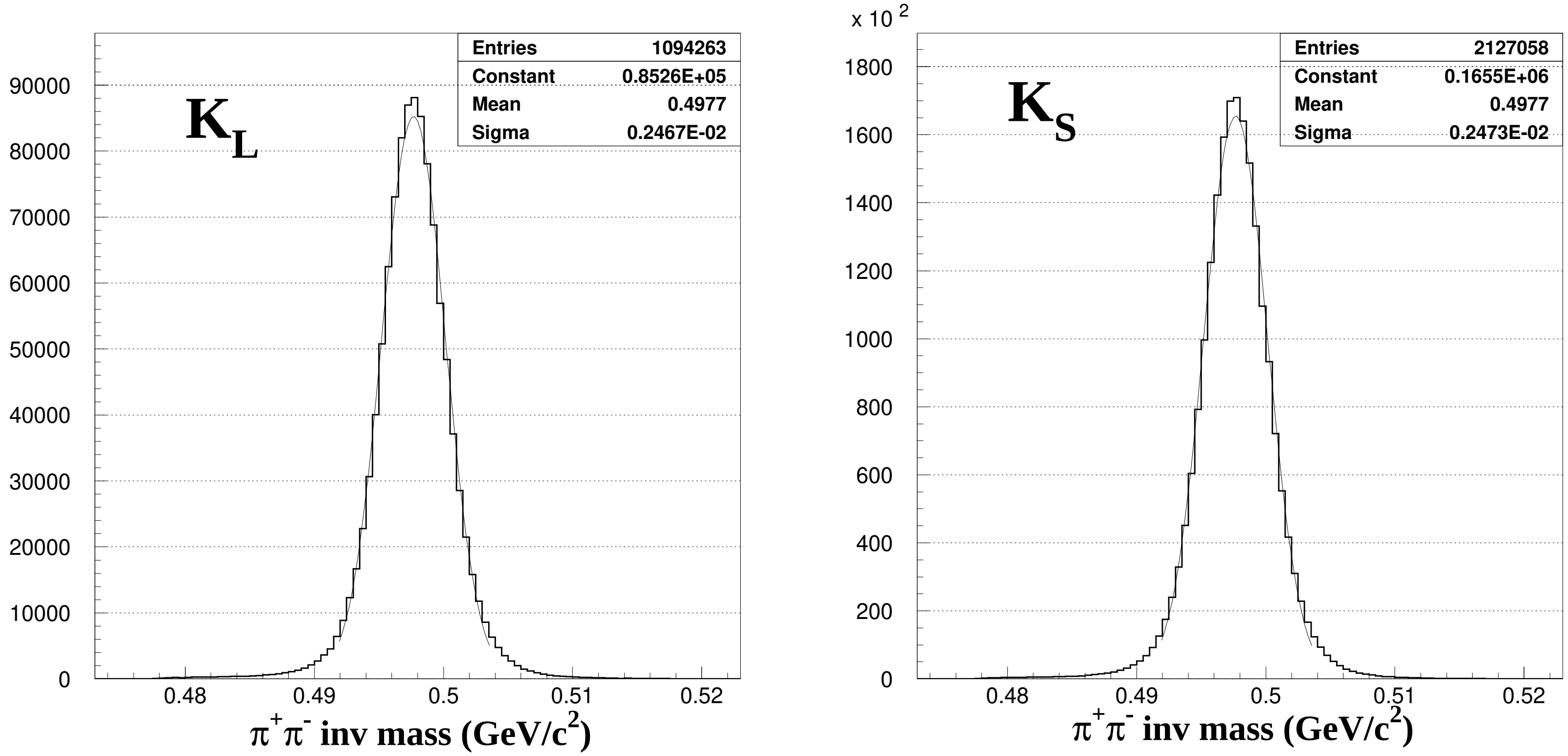
The drift chambers



- 4 Drift Chambers with :
  - High rate capability : 5 mm drift distance (100ns)
  - Redundancy : 4 views with 2 staggered planes
  - 7680 channels in total
  - Absolute position of wires known to better than 100 μm / m

- Gas : Argon/Ethane + 1 % H_2O
- Gain $\sim 6 \times 10^4$
- Readout : 40 MHz TDC's with 25/16 ns fine time - 200 μs ring buffer

$K_{\mathrm{L,S}} \to \pi^+\pi^-$: Spectrometer performance

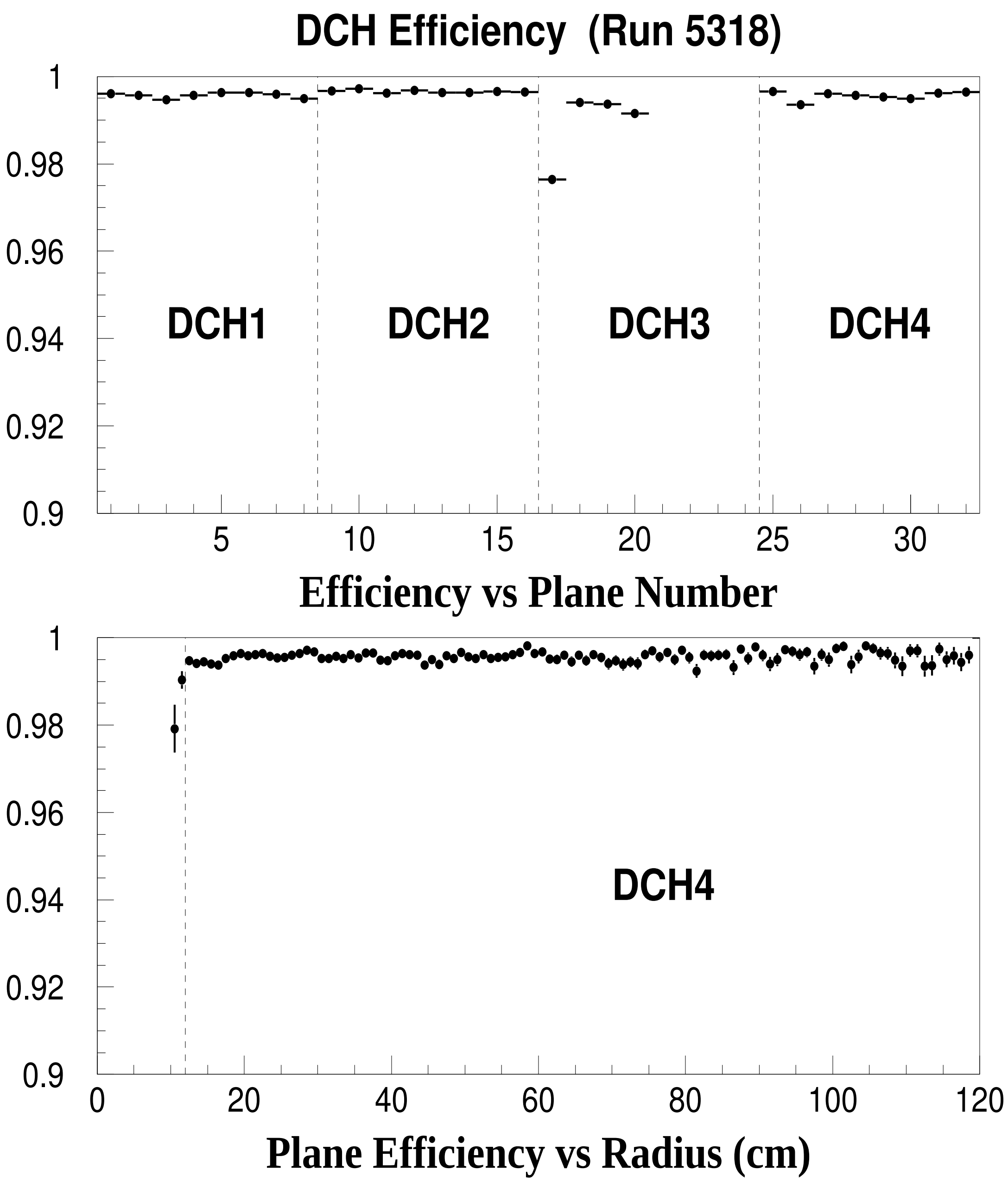


Mass resolution : 2.5 MeV/c^2

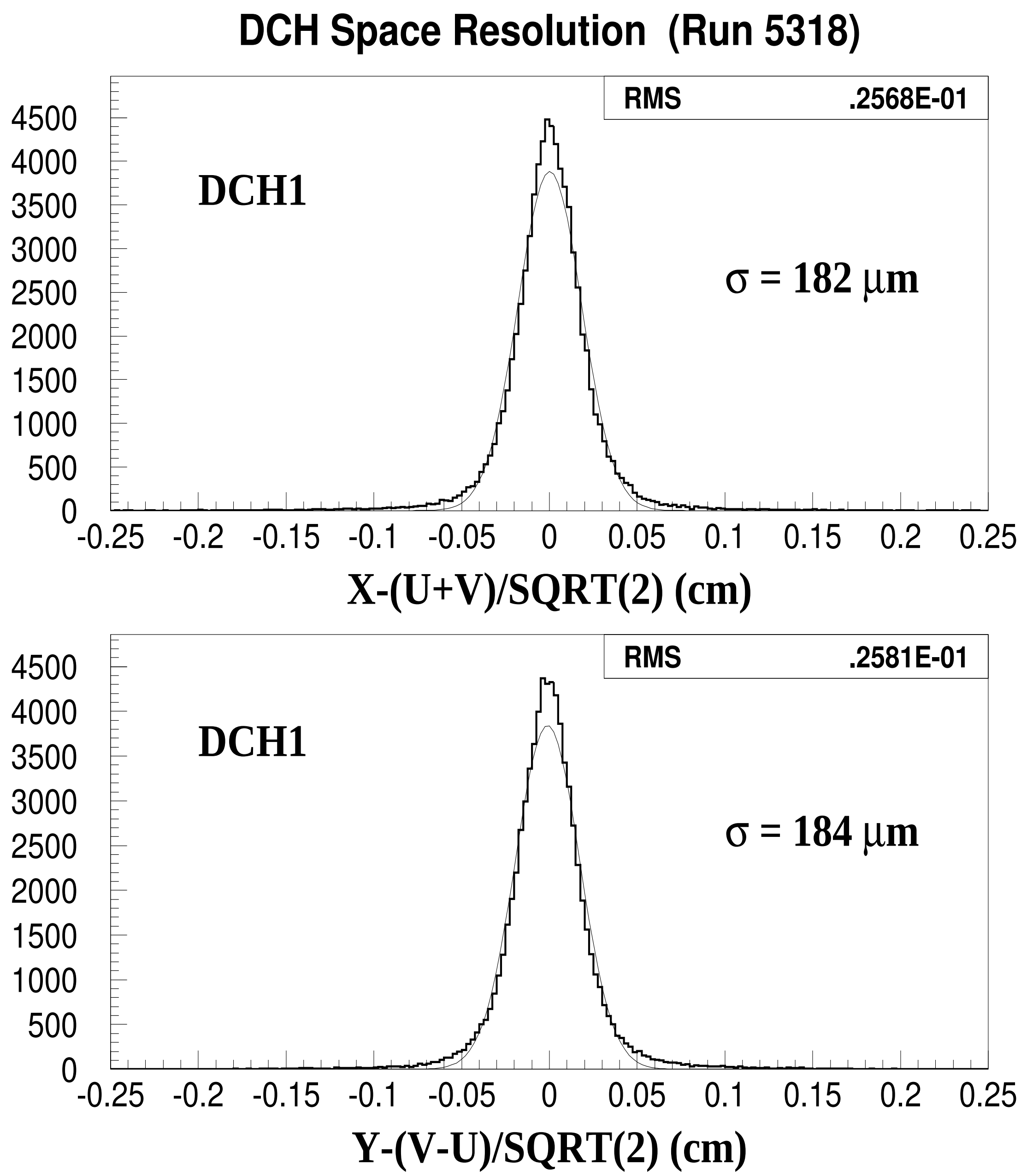
$$\sigma(\mathrm{P})/\mathrm{P} = 0.48\ \% \oplus 0.009\ \mathrm{P[GeV/c]}\ \%$$

(from e^- scan at 25 and 100 GeV)

$K_{L,S} \to \pi^+\pi^-$: Spectrometer performance



$K_{L,S} \to \pi^+\pi^-$: Spectrometer performance

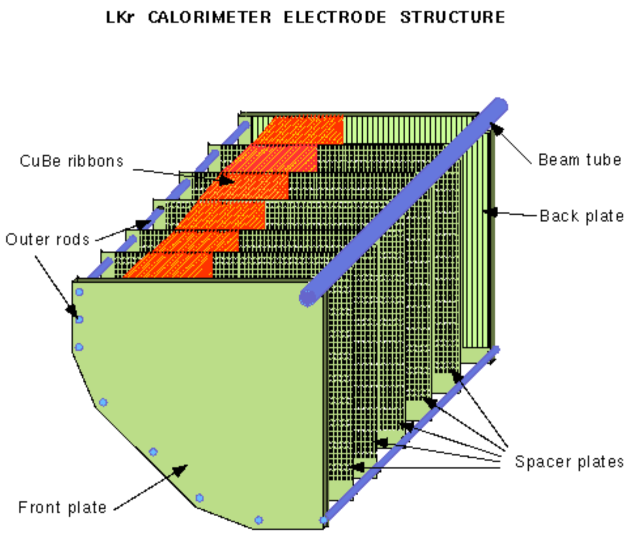


$$\sigma_x \simeq \sigma_y \simeq 90\mu\text{m}$$

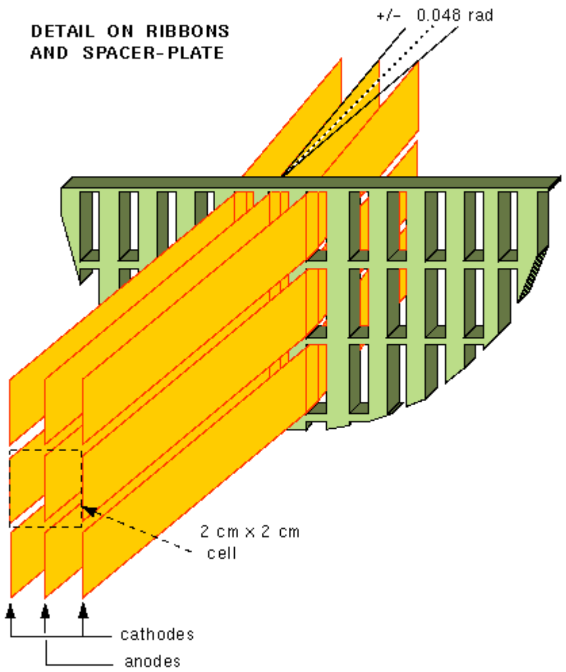
The LKr Calorimeter

- quasi-homogeneous calorimeter
  $\sim 10\ m^3$ of liquid Krypton, $X_0 \sim 4.7\ cm$, $R_M \sim 6.1\ cm$
- 13212 cells, $2 \times 2\ cm^2$ and 1.25 m depth ($\sim 27\ X_0$)
- projective geometry towards decay region ($\sim$ 114 m upstream)
- ribbon electrodes following a 48. $mrad$ zig-zag along the projectivity lines

LKr Calorimeter electrode structure

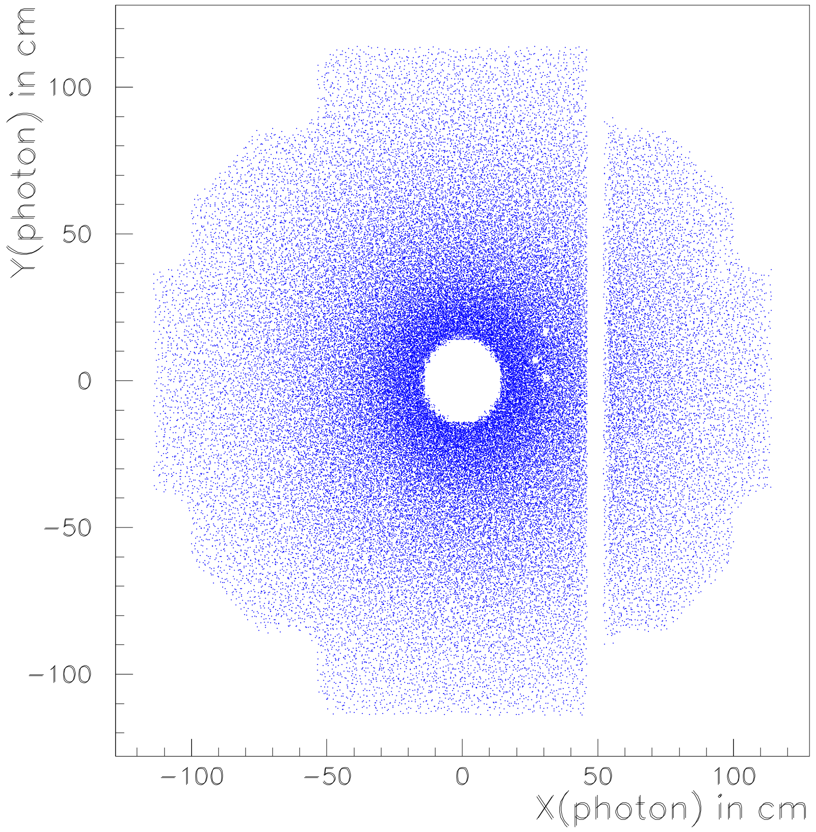
- 

LKr Calorimeter ribbons and spacer

- 

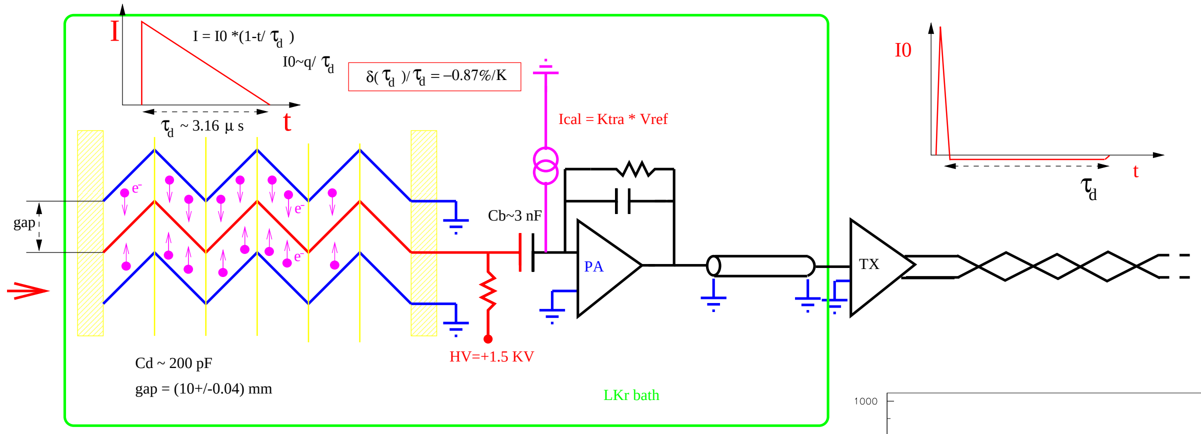
The LKr Calorimeter

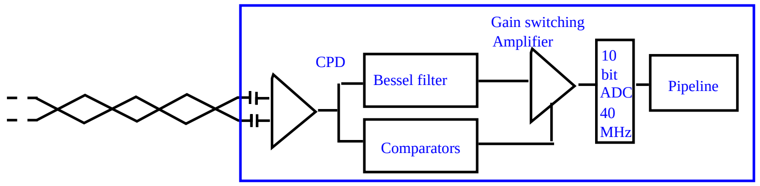
- 1997 Operation :
  - reduced HV (1.5 kV) due to capacitor problem
    $\Rightarrow$ $\sim$ 20% increase in the electronic noise
    $\Rightarrow$ small space charge effect ($<$ 0.5%)
  - One column (4 cm wide) not connected to HV
  - 40 dead channels (.3 % of channels)

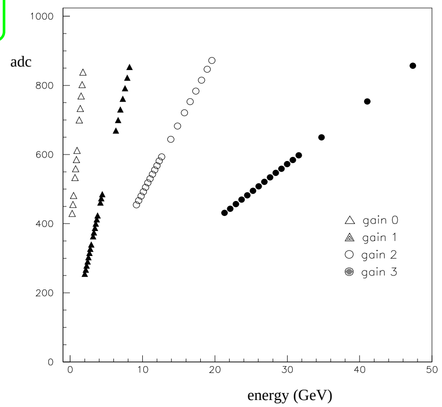


- Calibration :
  - Regular calibrations during data taking
  - Stability with time $\sim$ .1 %
  - 1 correction factor per cell based on electrons from K_{e3} to improve resolution

LKR readout and calibration

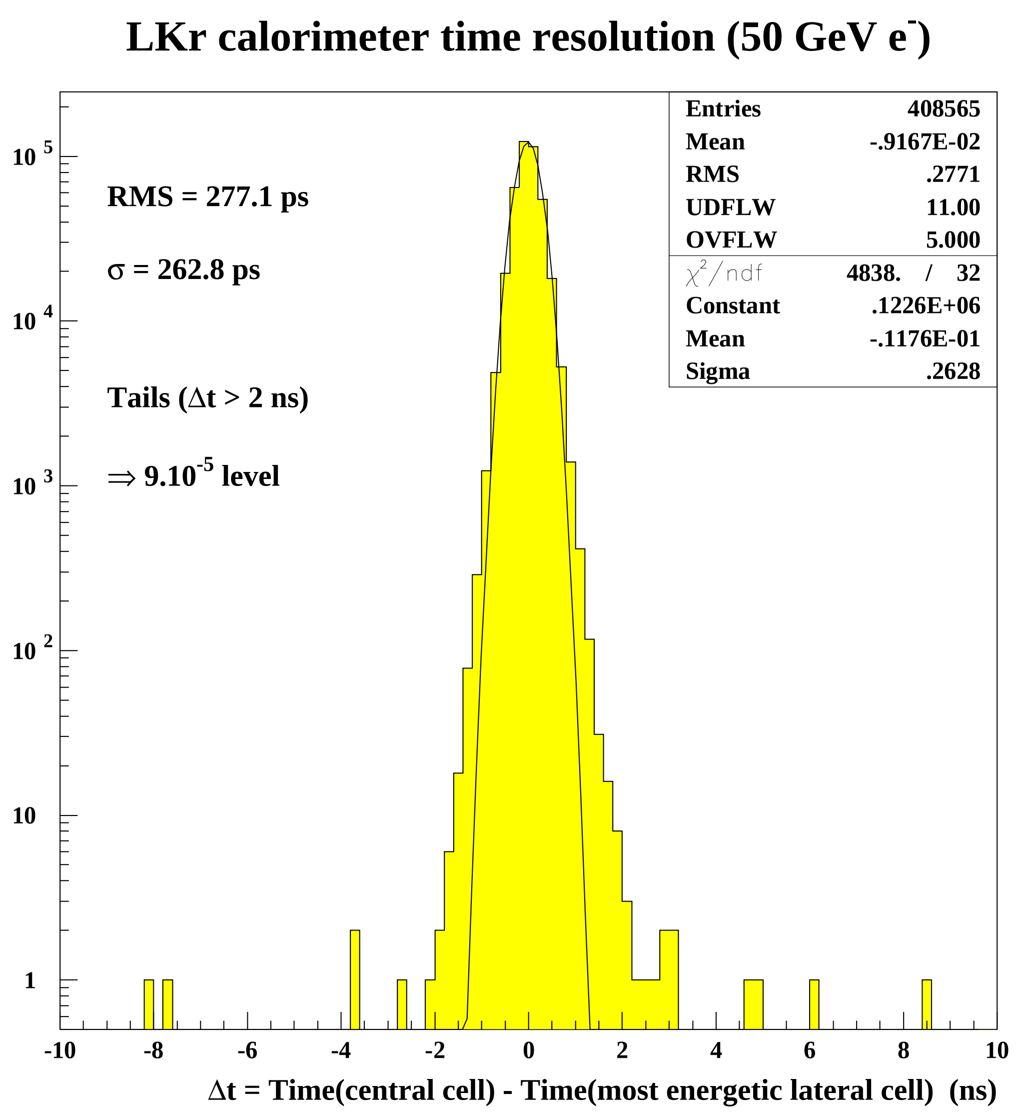




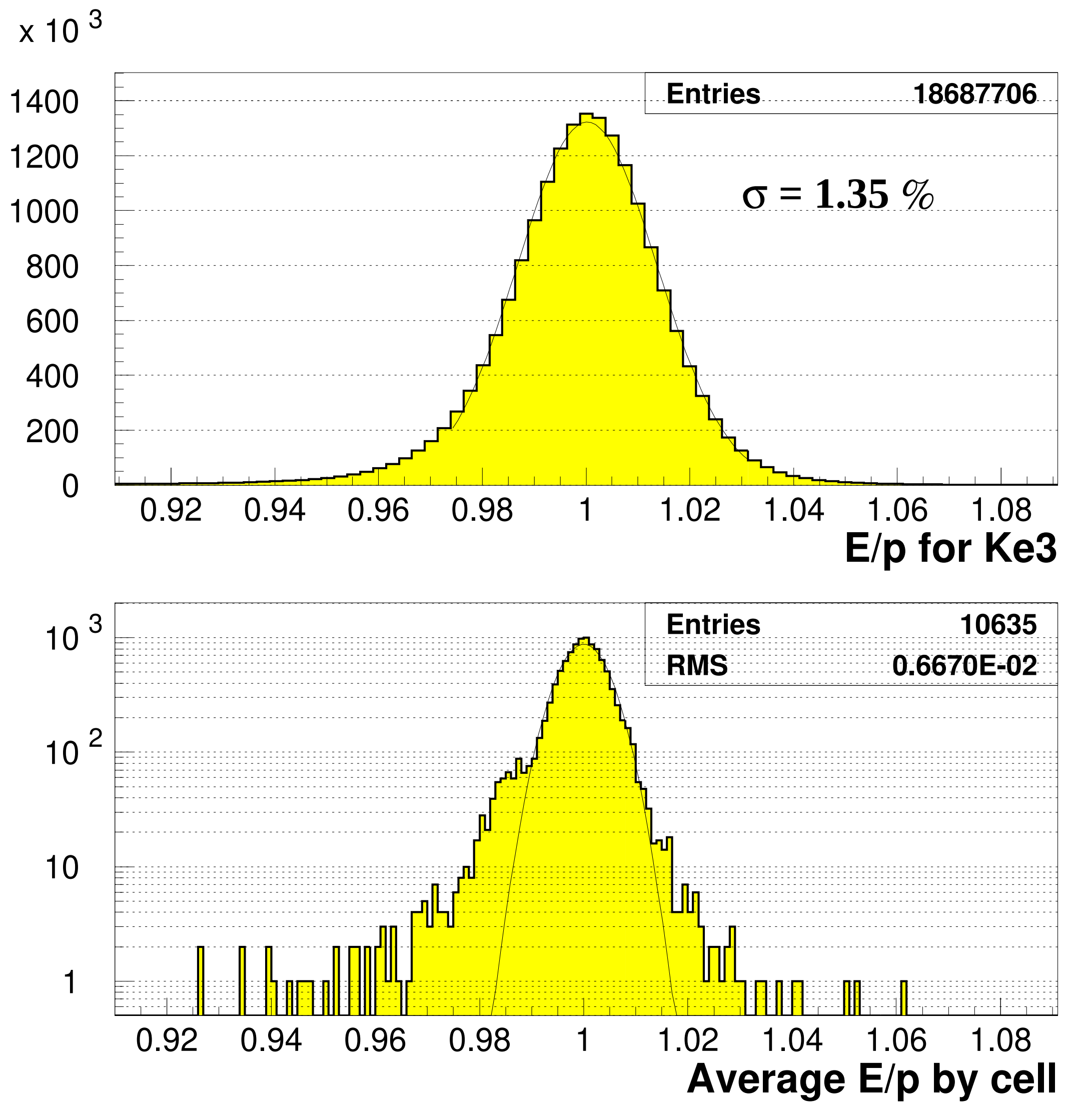


- In the cold : signal pre-amplification
- On feedthroughs : speed-up and differentiate the signal
- CPD's : shaping, 4 gains × 10 bit ADC ⇒
  3.5 MeV to 50 GeV dynamic range per cell,
  asynchronous 40MHz sampling

The LKR calorimeter



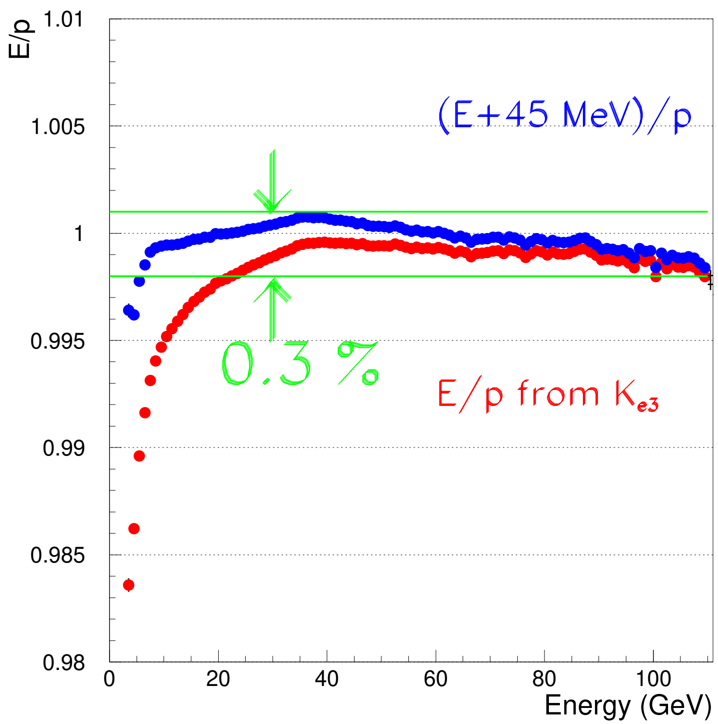
Intercalibration with Ke3

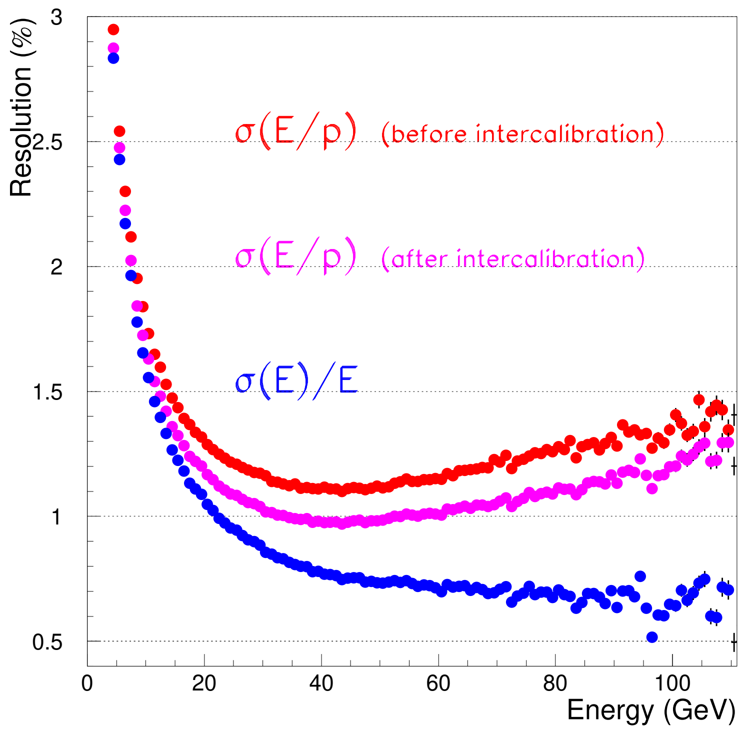


- Corrections factors per cell are determined using electrons from Ke3 decays

Linearity and Resolution in 1997

With electrons from K_{e3}





$10 \rightarrow 100$ GeV : linear within ~ 0.3 %.

$$\frac{\sigma(E)}{E} = \frac{3.2\%}{\sqrt{E}} \oplus \frac{125MeV}{E} \oplus 0.5\%$$

The 1997 Run

- First $\mathrm{Re}(\varepsilon'/\varepsilon)$ run
- 42 days in September/October 1997
- 2/3 of nominal beam intensity : 1×10^{12} ppp
  ~ 500 kHz of $\mathrm{K_L}$ decays in the detector
- 2 level charged trigger, fully pipelined neutral trigger
- ~ 12 K events recorded per 2.4 s spill every 14.4 s
- Read-out 80 Mbytes/s
- 25 Tbytes of data written on tape
- ~ 10 % of expected final statistics

Charged Trigger

- Level 1 :
  - Hits in opposite quadrants of the charged trigger hodoscopes (QX)
  - Total energy in calorimeters above $\sim$ 30 GeV (Etot)
  - Downscaled by a factor 2 $\rightarrow$ 70 kHz output rate

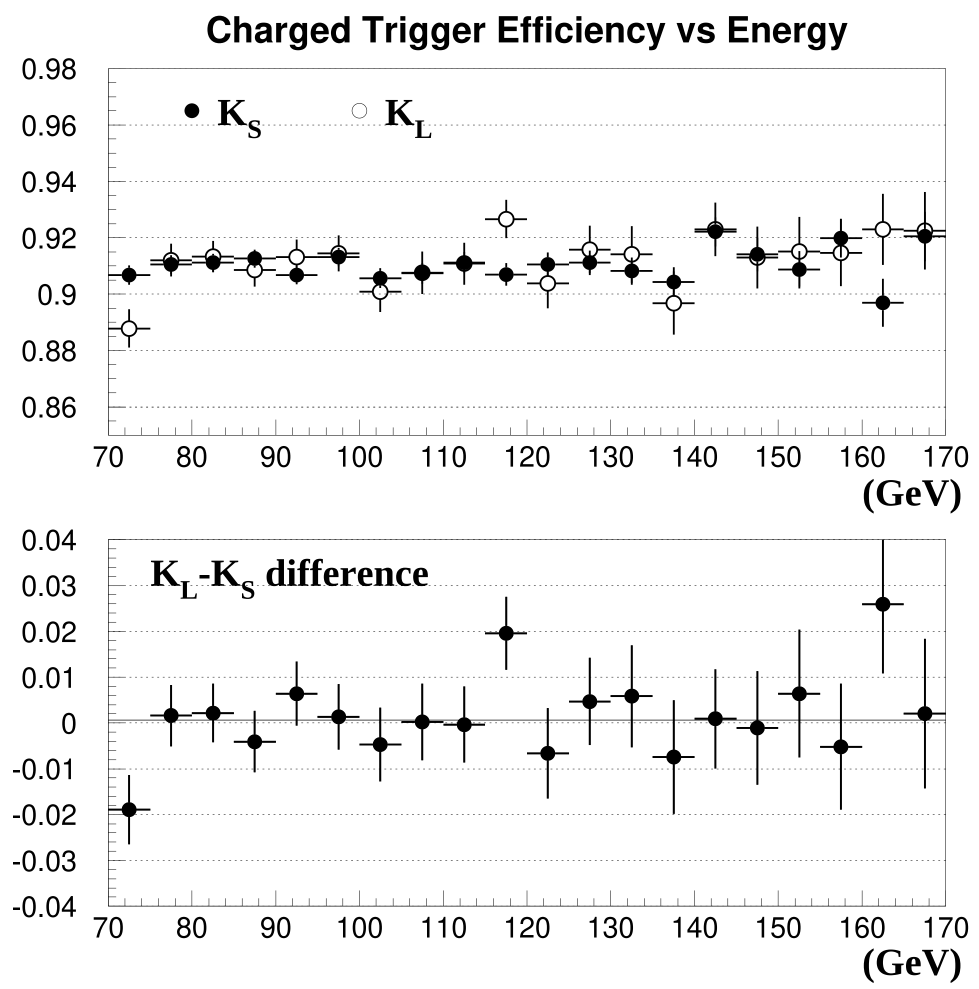
- Level 2 : Online event reconstruction with a farm of processors (100 μs maximal latency)
  - hardware coordinate builder (x,y,u,v) from hits in the drift chambers
  - tracks reconstruction and association
  - computation of vertex, $\pi\pi$ invariant mass, proper time of flight

- Trigger output rate $\sim$ 1.5 kHz
- Dead time : .3 % ; monitored and applied to neutral events

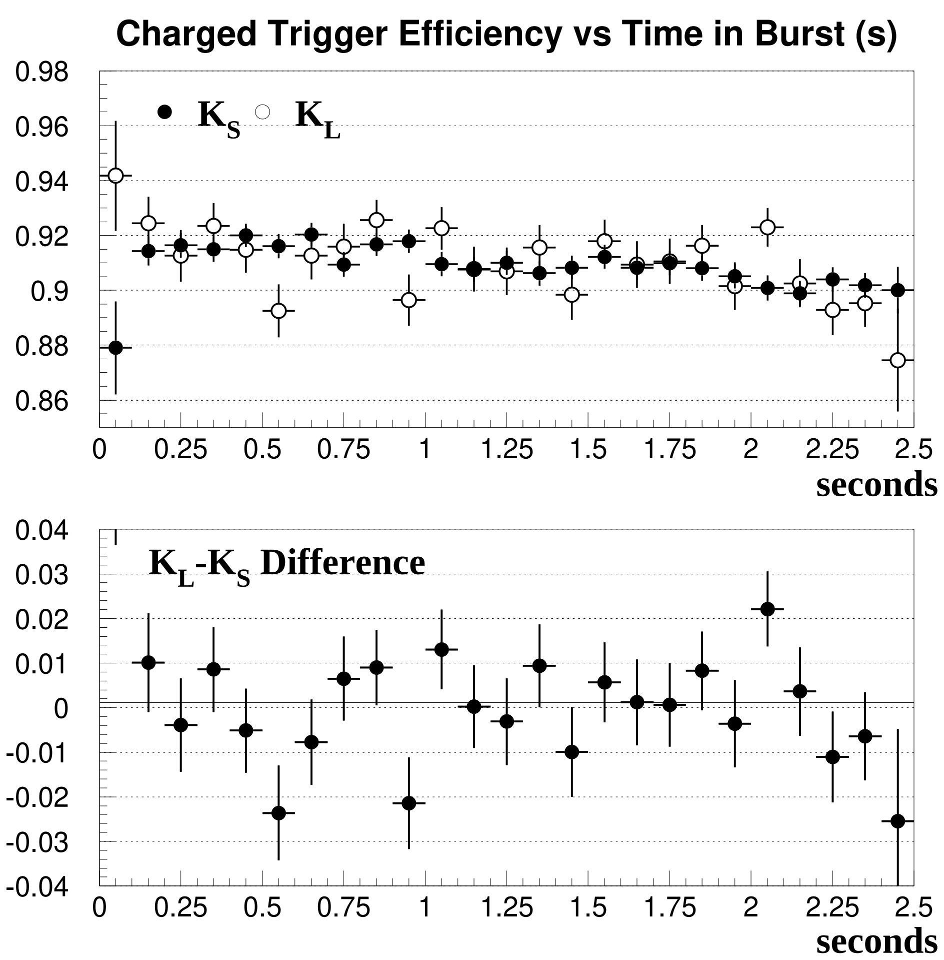
- Efficiency :
  - From minimum bias sample : QX.Etot : 99.4 % (inefficiency comes from individual signals + time jitter)
  - Combined (Ll).(L2) efficiency : (91.68 $\pm$ .09) %

    K_S -K_L difference : (-9 $\pm$ 23) 10^{-4}
  - measurements limited by the **statistics** of test sample

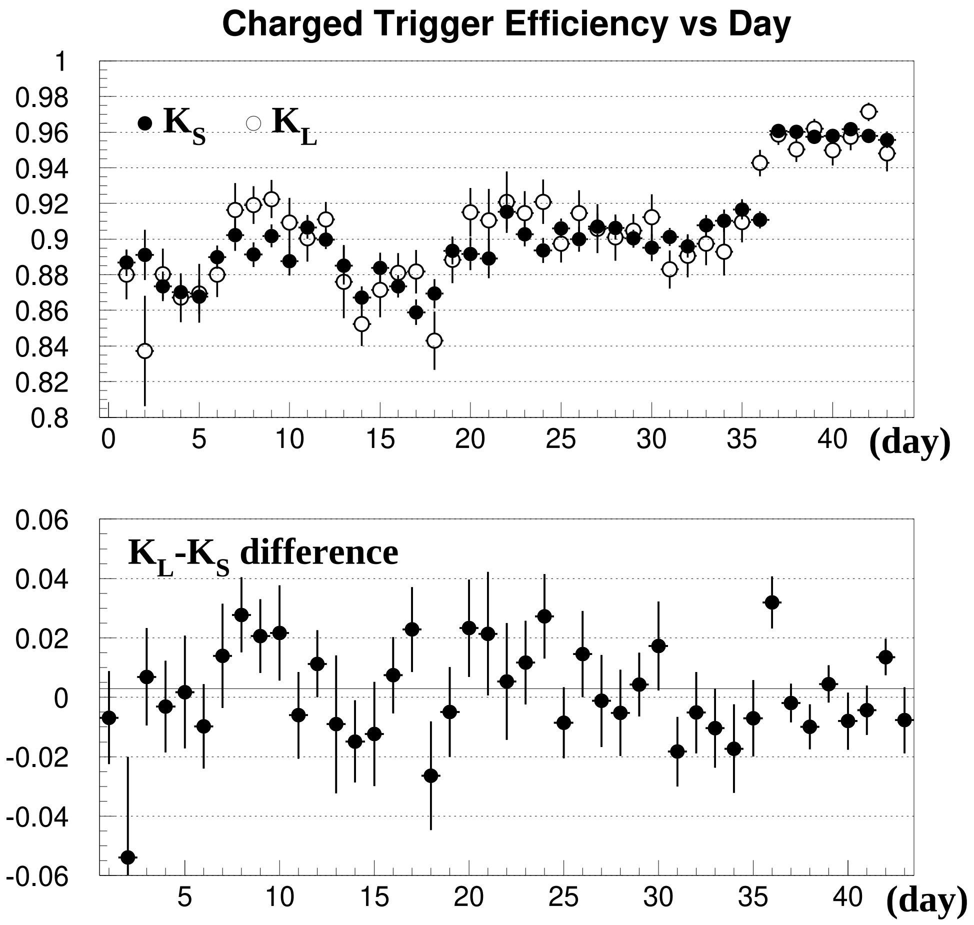
Charged trigger efficiency



Charged trigger efficiency



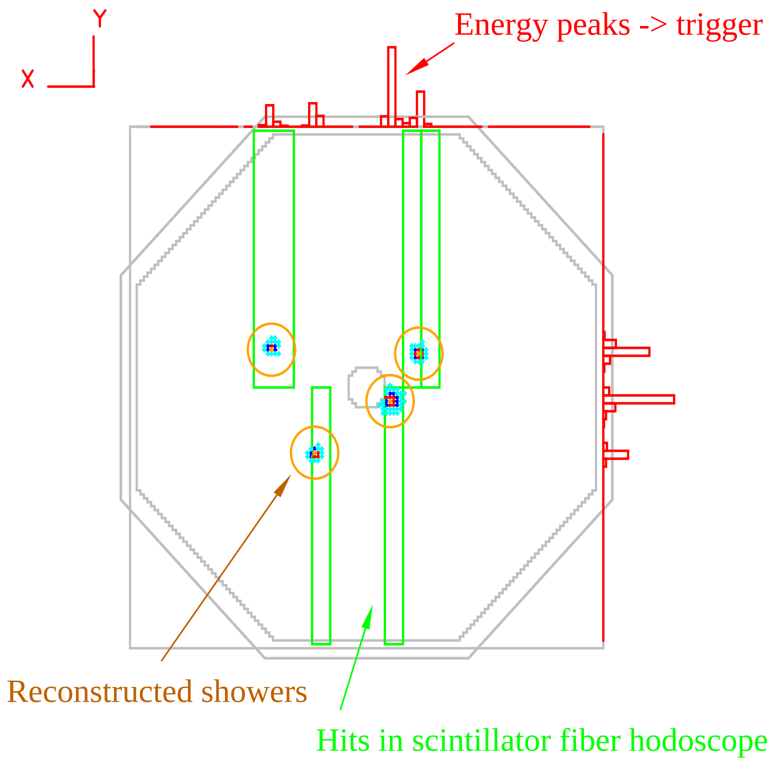
Charged trigger efficiency



Neutral Trigger

- Fully pipelined trigger based on the calorimeter cells information

- Compute and cut on :
  - number of in time clusters per projection
  - total energy in the calorimeters
  - decay vertex position



- Trigger output rate ~ 2 kHz
- Dead-time negligible
- Efficiency measured with events triggered by a fiber hodoscope installed inside the LKr calorimeter :

$$99.88 \pm .04\ \%$$

Data analysis

- Select K decays for

$$\begin{cases} 70 < \mathrm{E_K} < 170 \text{ GeV} \\ \tau \text{ from beginning of decay region} < 3.5\ \tau_S \end{cases}$$

- Analyse data in bins of energy :
  20 bins of 5 GeV width

⇒ measurement insensitive to slight $\mathrm{K_S}$ $\mathrm{K_L}$ energy spectra difference

- $\mathrm{K_S}$ and $\mathrm{K_L}$ identified by tagging

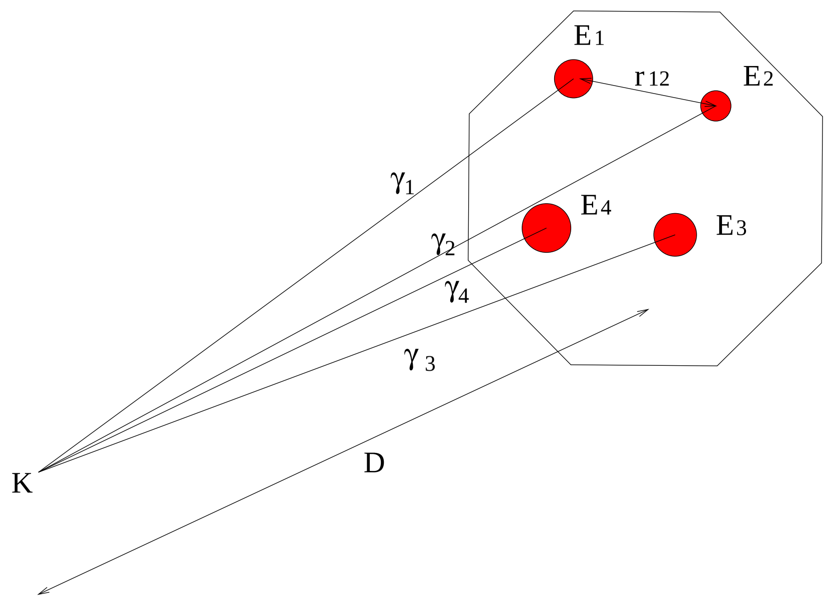
⇒ symmetric for charged/neutral decays to high precision

- $\mathrm{K_L}$ events are weighted to make their longitudinal distribution similar to that of $\mathrm{K_S}$

⇒ small acceptance correction

- Double ratio **R** measured for each energy bin after small corrections :
  - mistagging
  - backgrounds ($3\pi^0$, K_{e3}, $\mathrm{K}_{\mu 3}$)
  - acceptance

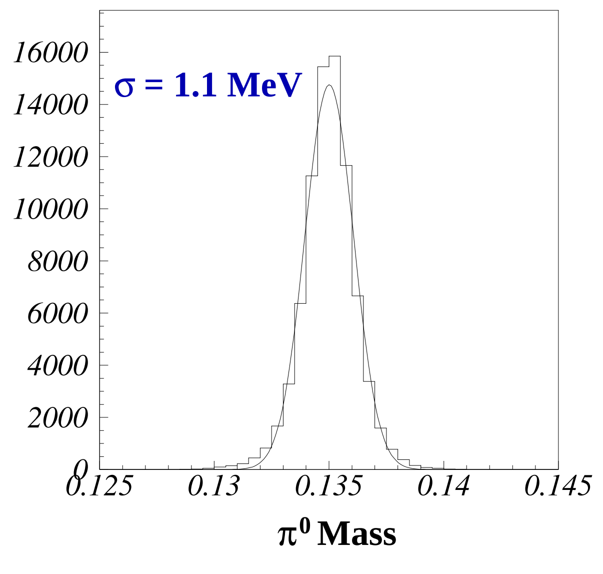
The neutral reconstruction



- Reconstruction of $K_{\mathrm{L,S}} \rightarrow 2\pi^0 \rightarrow 4\gamma$
  - Vertex position imposing the Kaon mass

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

  - Pairing the photons to get the best π^0 combination
    $m_{ij} = \sqrt{E_i E_j \; r_{ij})^2} / D$



Energy Scale and Non linearity

- Fiducial region given in τ units
  For K_L : $0 < \tau < 3.5\ \tau_S$

- For neutral decays : $\tau \propto$ (zvertex - zAKS) / E
- E $\rightarrow$ (1+α) E $\Rightarrow$ Δz $\rightarrow$ (1+α) Δz

- $\Delta\tau$ unchanged $\Rightarrow$ counting of neutral K_L decays unaffected, but for acceptance variation versus z

- Fiducial region for K_S : $\tau < 3.5\ \tau_S$
  beginning of decay region defined by the AKS

$\Rightarrow$ position of AKS fixes absolute energy scale

$\Rightarrow$ counting of K_S decays not very sensitive to energy scale

- Altogether :

– 5 10^{-4} E scale change $\rightarrow$ 5 10^{-4} change of **R**

– .3 % Non linearity $\rightarrow$ 9 10^{-4} change of **R**

- For charged decays :

– zvertex AND E_K from DCH 1 and 2 geometry :

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

$\Rightarrow$ uncertainty of 5 10^{-4} on **R**

The AKS counter

- Defines beginning of decay region
- Used to fix the energy scale
- AKS counter efficiency : .9923 ± .0010

⇒ negligible uncertainty on **R** :
4 % (acc. decays upstream) × .1 % ≃ .4 10^{-4}

- Photon converter :

– iridium crystal 3 mm thick, (2.1 ± .5) mm upstream of counter

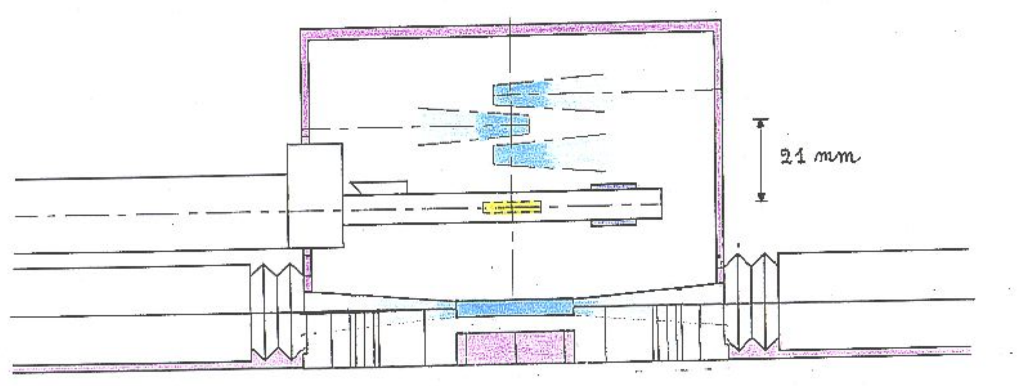
⇒ at 0 angle ≡ 1.79 X_0 instead of .98 X_0 for amorphous iridium

→ better ratio of radiation length/scattering length

– X_0 vs Energy and Angle measured

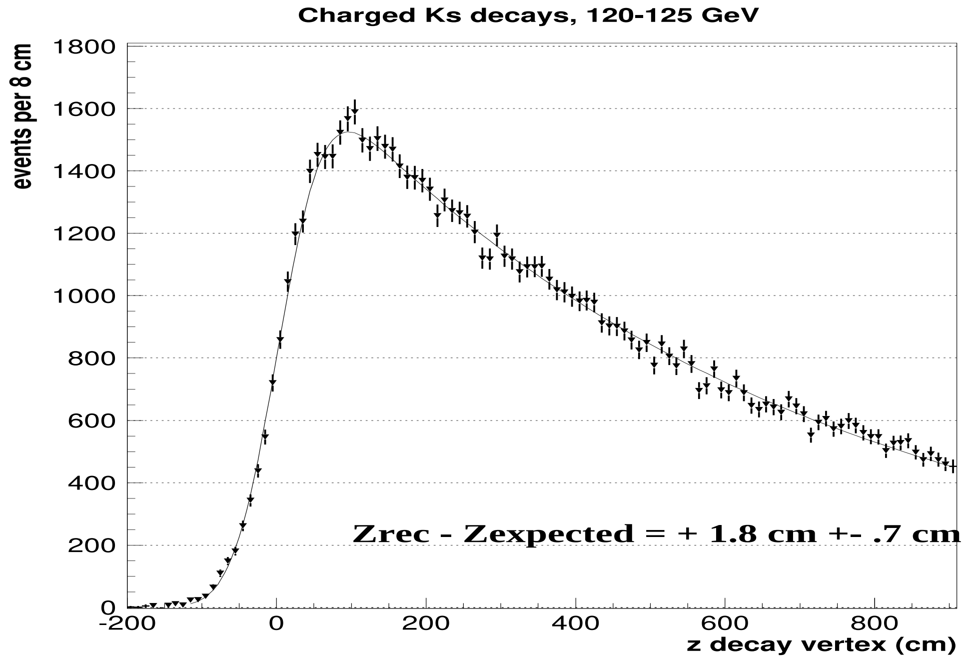
– veto efficiency for K_S : 99.64 ± .03 %

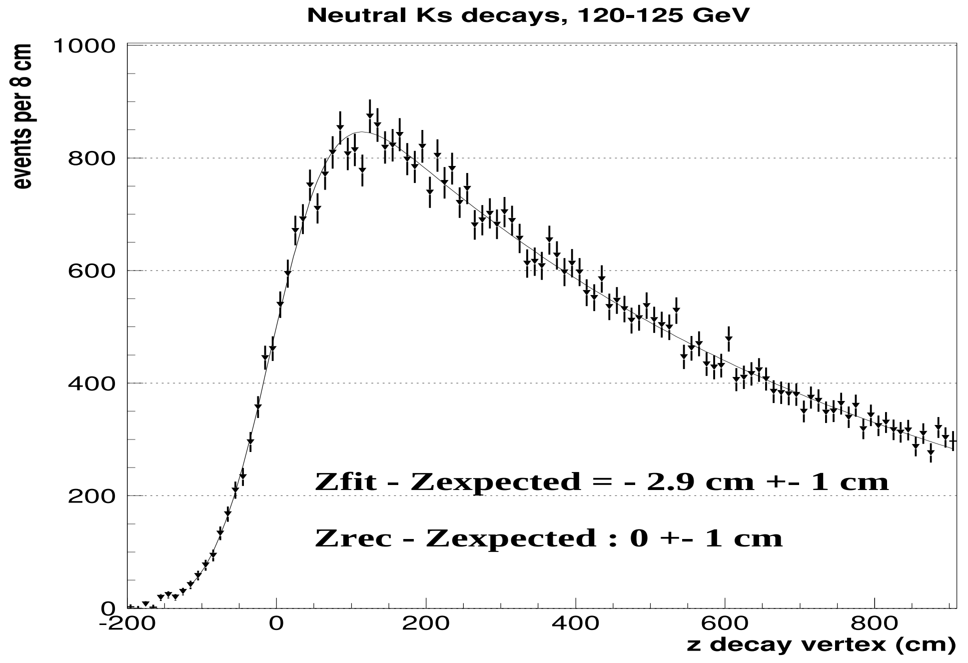
⇒ negligible uncertainty on **R** :
5.8 % (acc. decays upstream) × .03 % ≃ .2 10^{-4}



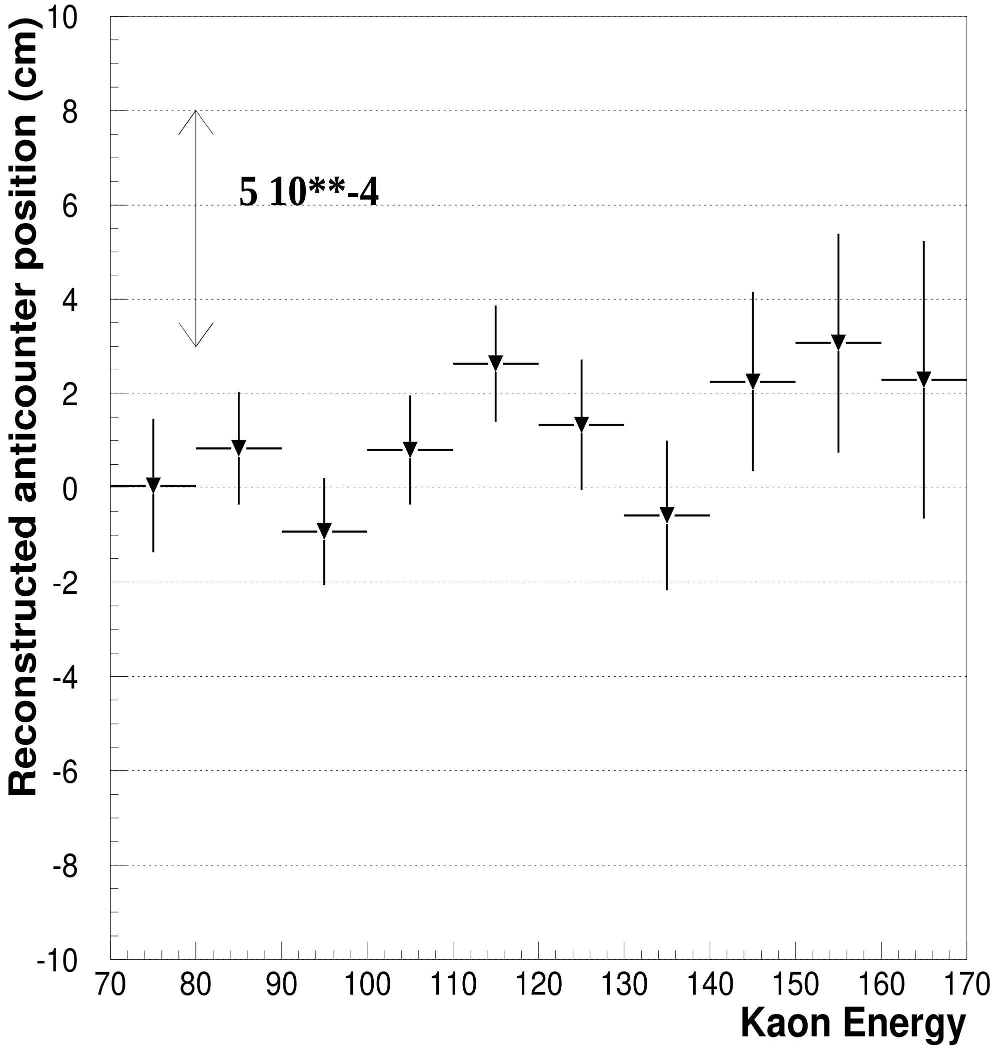
Energy scale and Non linearity

- 10^{-3} variation of E scale $\equiv$ 10 cm shift of AKS position

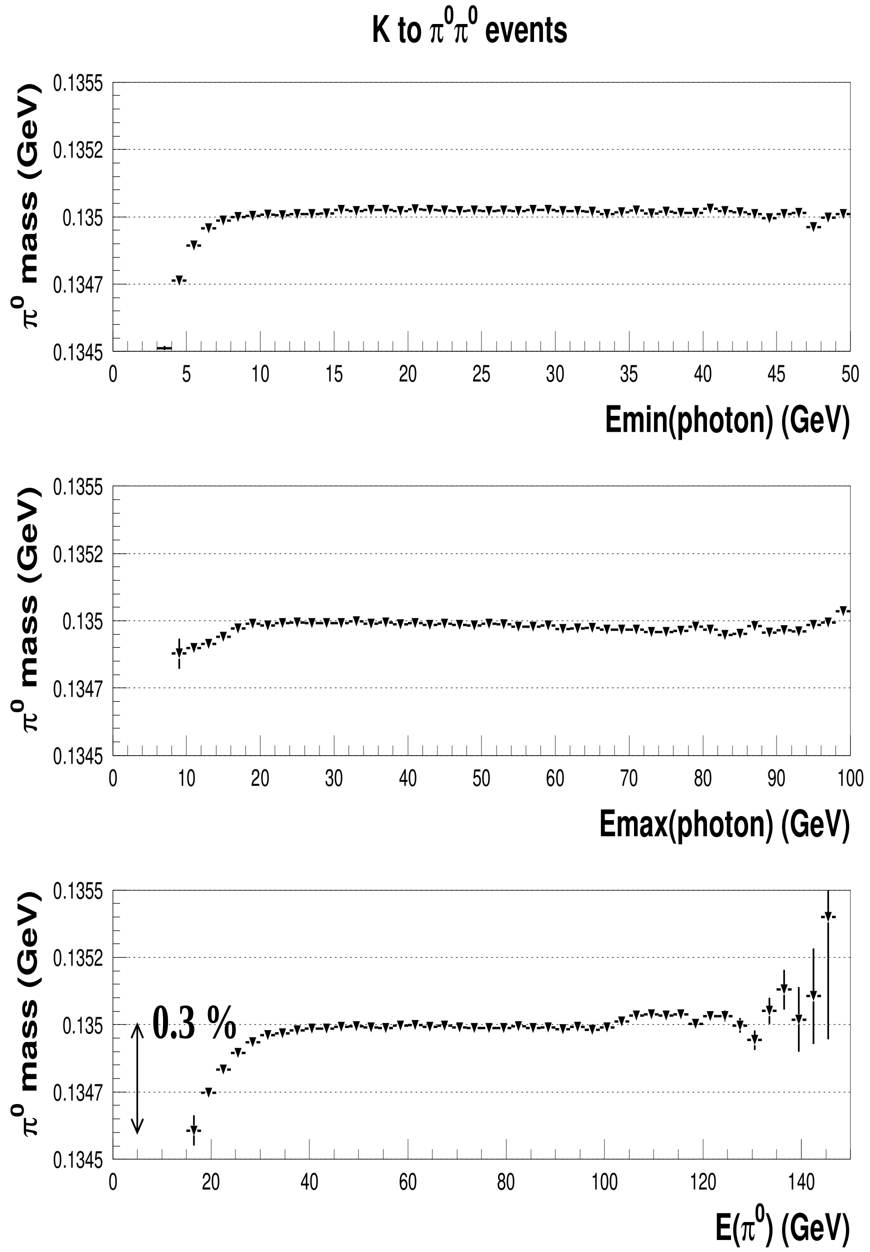




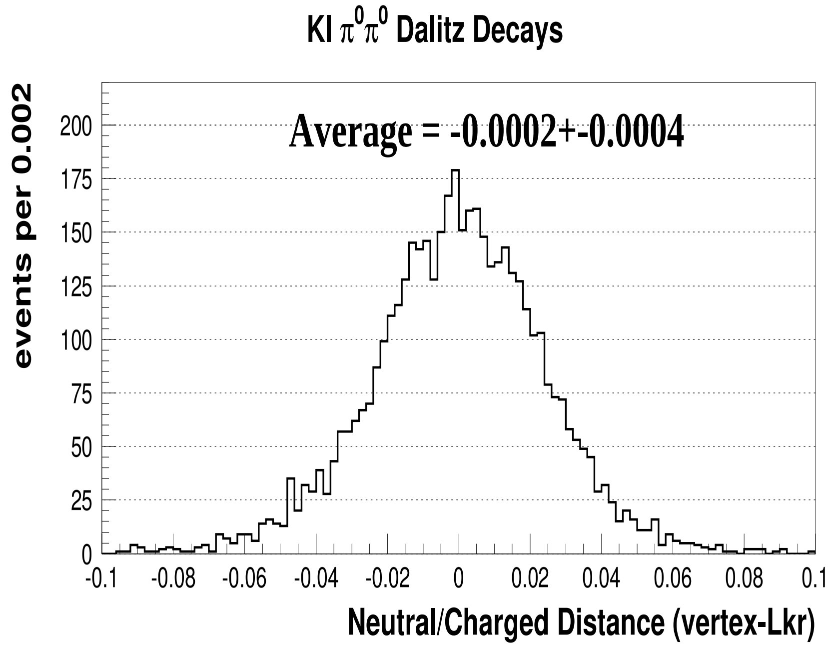
Energy scale and Non linearity

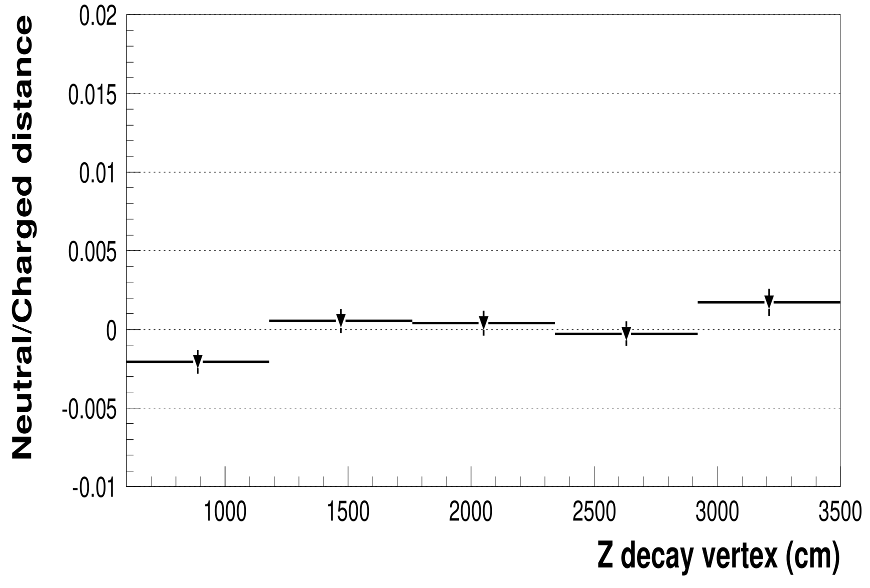


Energy scale and Non linearity



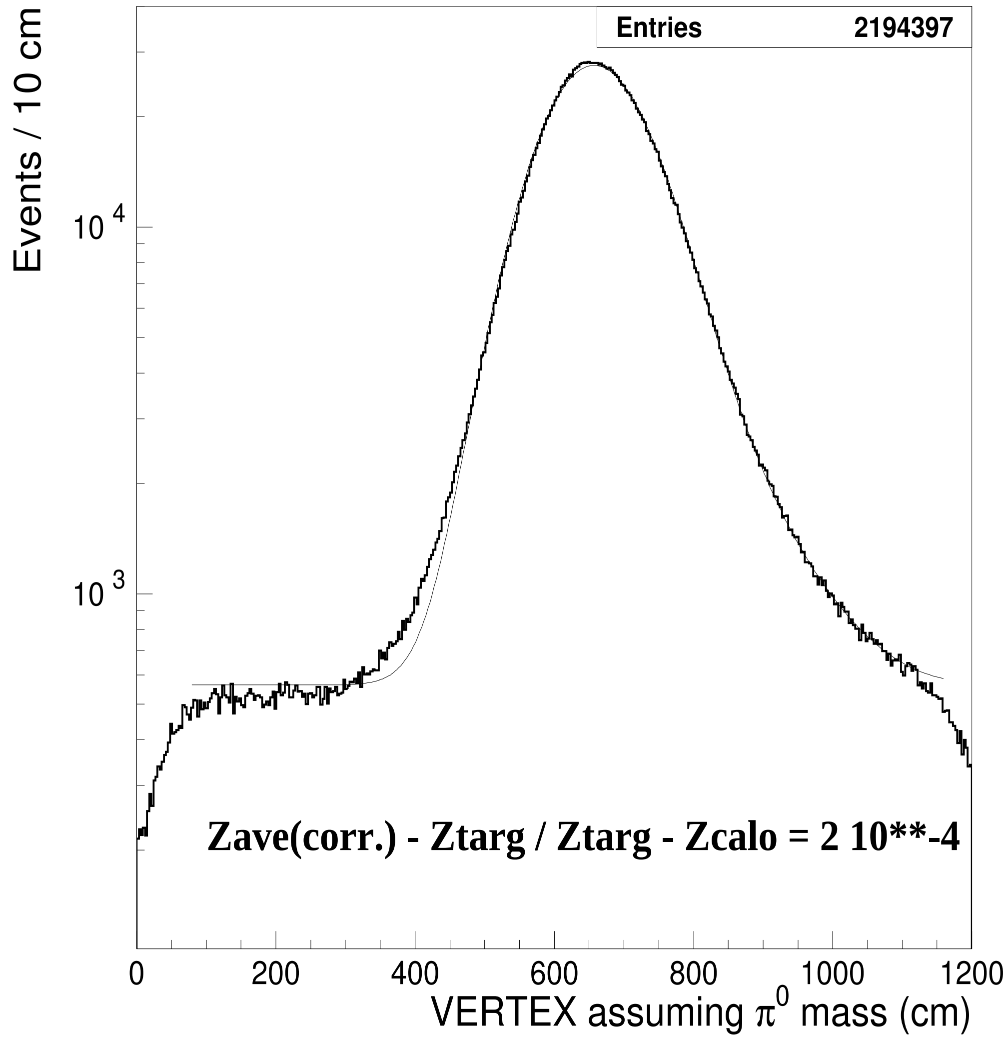
Energy scale and Non linearity





Energy scale and Non linearity

- Special Run at the end of data taking
- Thin (3.5 cm) target (CH2) placed about 30 cm downstream of AKS
- Reconstruct π^0's produced by impinging π^- beam
- Check Energy Scale by comparing the mean Zv with the known position of the target



Event selection

- $\pi^+\pi^-$ candidates
  - $\geq$ 2 tracks with P $\geq$ 10 GeV/c and :
    - position at DCH 1 2 and 4 $\geq$ 12 cm from K_L beam axis
    - impact at calorimeter within acceptance

    - E of associated cluster / P $\leq$ .8

    - |track time - trigger time| $\leq$ 20 ns
    - track time consistent with event time from charged hodoscope

    - impact at muon veto within acceptance
    - no associated hit in muon veto within $\pm$ 4 ns
  - $|(P_1 - P_2)/(P_1 + P_2)| \leq$ min(.62,1.08-.0052*P(GeV))
  - $\pi^+\pi^-$ invariant mass within 3 σ of K mass
  - *reduced transverse momentum* $\leq$ 200 $(\mathrm{MeV/c})^2$

Event selection

- $2\pi^0$ candidates
  - $\geq$ 4 clusters with 3 GeV $\leq$ E $\leq$ 100 GeV
  - clusters position :
    - $\geq$ 15 cm from K_L beam axis
    - $\geq$ 11 cm from outeredges of the LKr calorimeter
    - $\geq$ 2 cm away from any dead cell and not in missing HV columns
    - $\geq$ 10 cm apart from one another
  - |cluster time - average time| $\leq$ 5 ns
  - no extra cluster within $\pm$ 3ns of average time
  - $R_{ell} \leq 13.5$
- Common cuts
  - 70 $\leq$ E(GeV) $\leq$ 170
  - no AKS hit within $\pm$ 3 ns
  - proper time of flight from AKS $\leq 3.5\ \tau_S$
  - proper time of flight from AKS $\geq$ 0 for K_L candidates
  - center of gravity $\leq$ 10 cm from K_L beam axis
  - no high multiplicity event within a 625 ns time window around the trigger time

The High multiplicity event cut

- Ask for no plane with a hit multiplicity above 7 within a 625 ns window

$\Rightarrow$ Absolute loss of events ~ 20 %

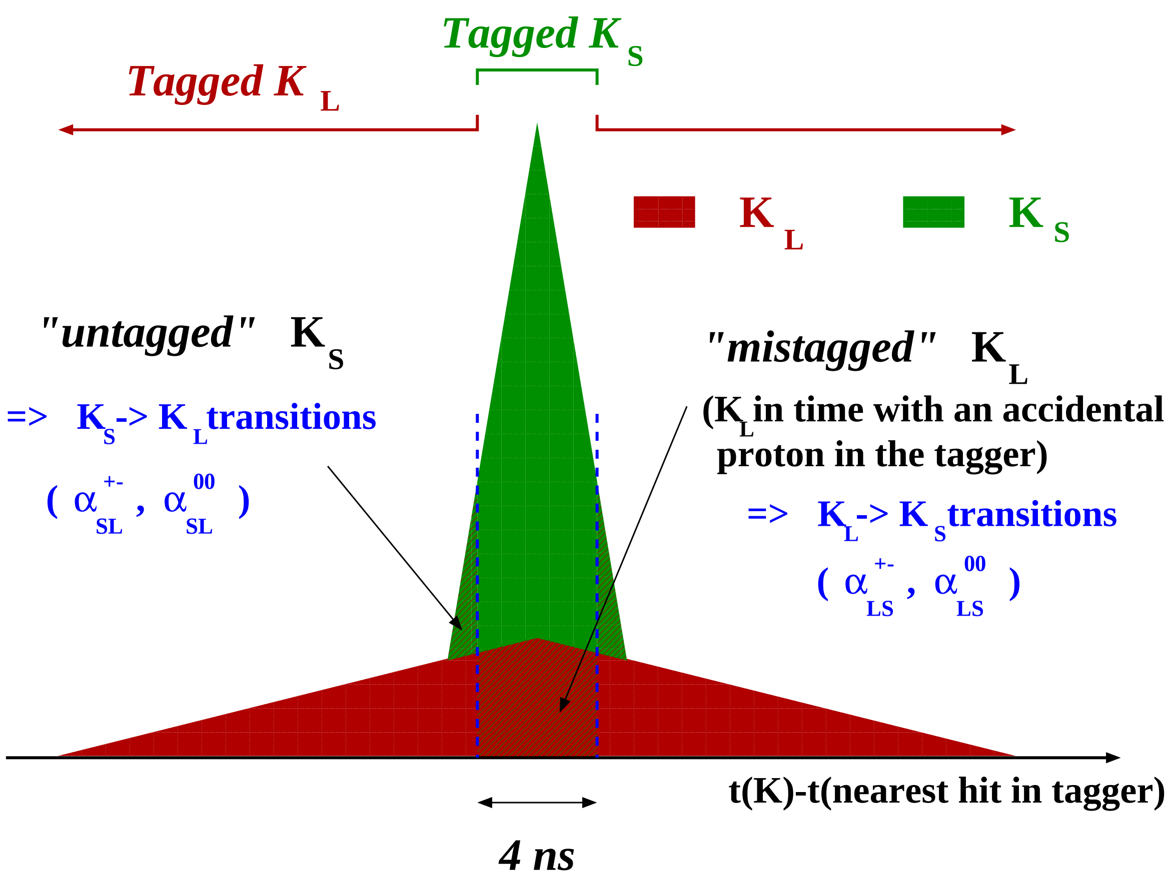
- K_L /K_S differential loss for $\pi^+\pi^-$ decays is estimated by looking at the hit multiplicity before the previous window, it amounts to $(.02 \pm .03)$ %

- for $\pi^0\pi^0$ decays it can be measured directly : $(-.02 \pm .06)$ %

- Cut applied to $\pi^+\pi^-$ AND $\pi^0\pi^0$ events

$\Rightarrow$ **no significant effect on** ε'/ε

K_L - K_S identification : Tagging principle



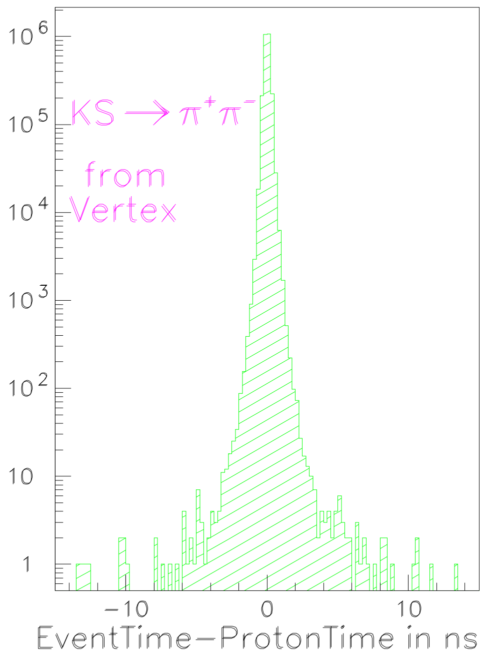
- $K_L \to K_S$ transitions "dilute" the value of R

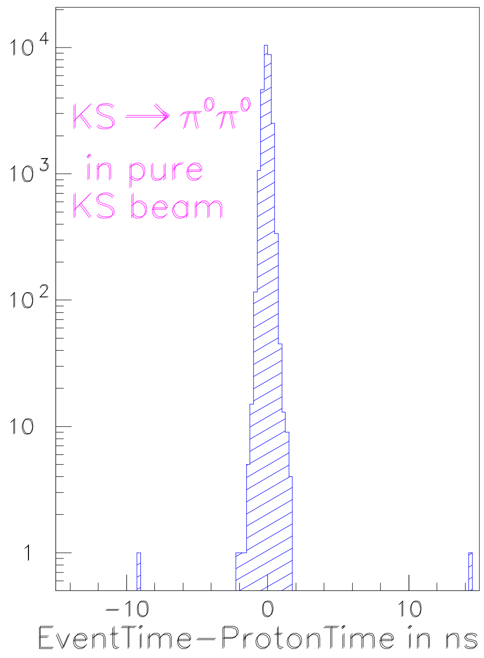
  $\Delta\mathrm{Re}(\varepsilon'/\varepsilon) \simeq .3\ \Delta({\alpha_{LS}}^{00} - {\alpha_{LS}}^{+-})$

- $K_S \to K_L$ transitions
  From tails in time reconstruction of decays

  $\Delta\mathrm{Re}(\varepsilon'/\varepsilon) \simeq .9\ \Delta({\alpha_{SL}}^{+-} - {\alpha_{SL}}^{00})$

Tagging efficiency





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

$$\alpha_{SL}{}^{+-} = (1.5 \pm 0.1) \times 10^{-4}$$

  !! Redundant time measurement (DCH's, Tagger) :
  2/3 of the inefficiency is due to the tagger ⇛ charged neutral democratic

- Neutral Mode : Three methods

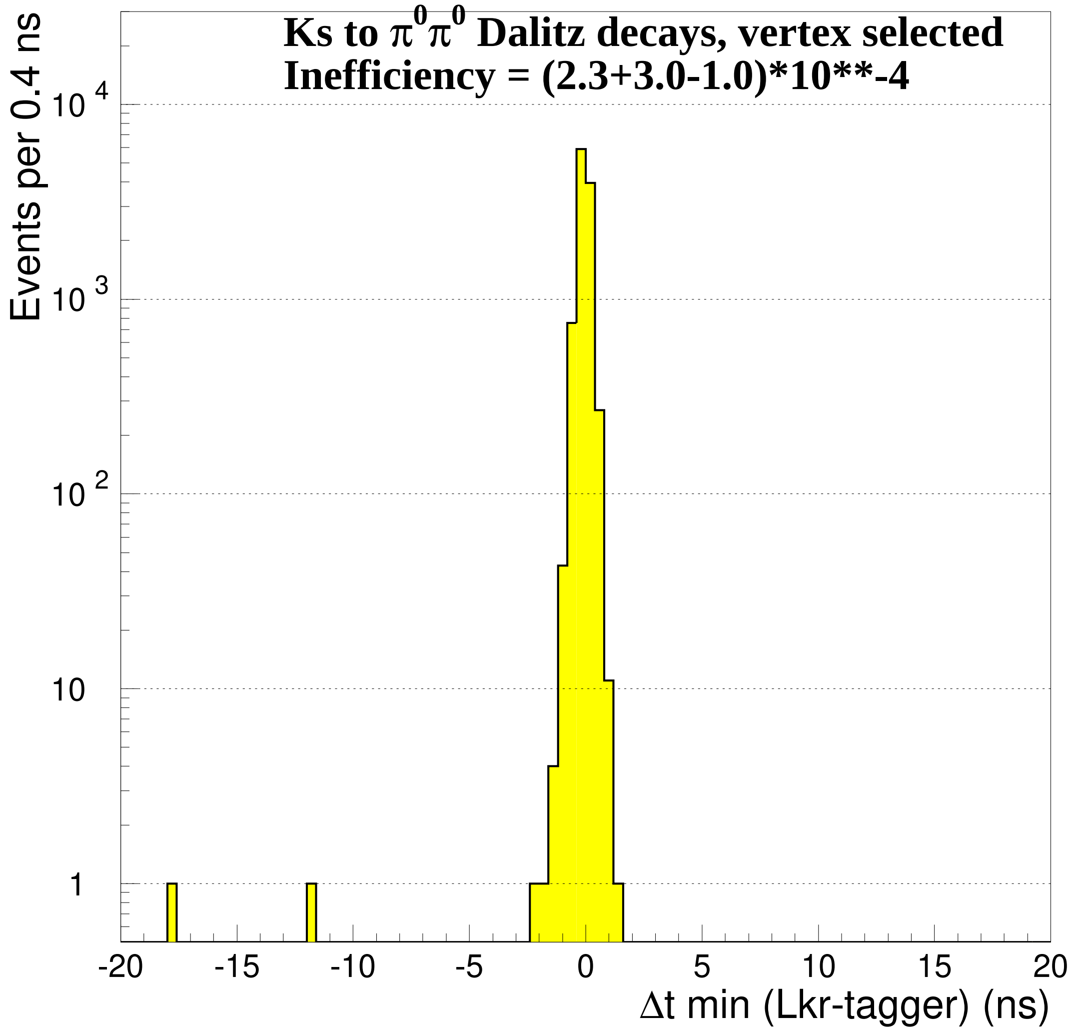
– Pure K_S runs : $\alpha_{SL}^{00} = (.9 \pm 0.7) \times 10^{-4}$

– $K_S \rightarrow \pi^0 e^+ e^- \gamma$: $\alpha_{SL}^{00} = (2.3 {}^{+3}_{-1}) \times 10^{-4}$

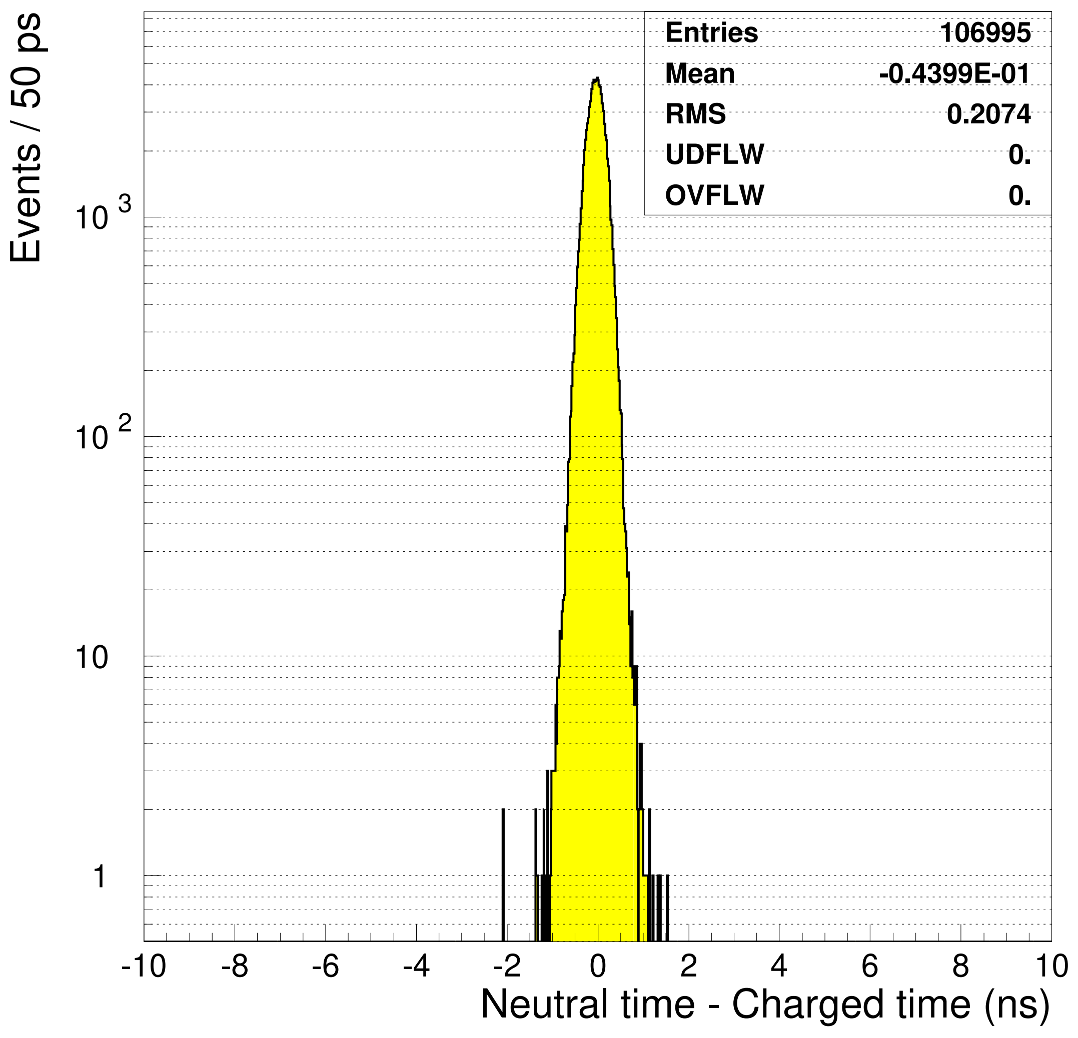
– Compare charged and neutral event times in neutral $K_L + K_S$ decays with conversions :

$$|\alpha_{SL}^{+-} - \alpha_{SL}^{00}| < 1.10^{-4}$$

Tagging efficiency from $K_S \to \pi^0 e^+ e^- \gamma$



Event time from hodoscope and calorimeter



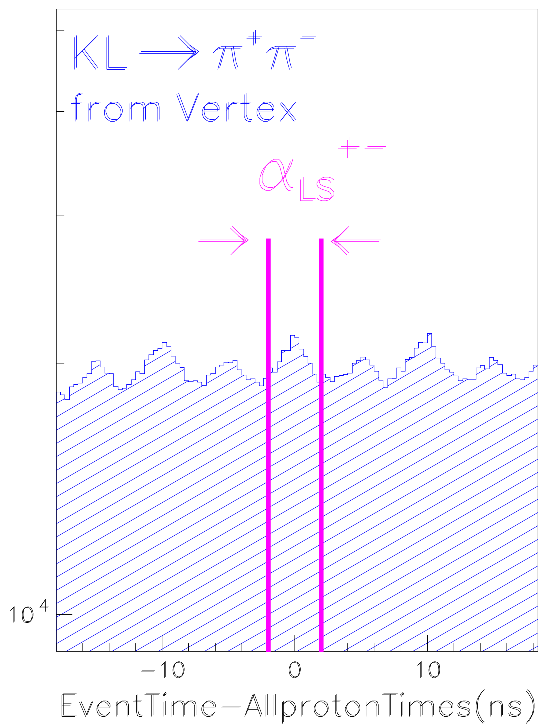
Accidental tagging

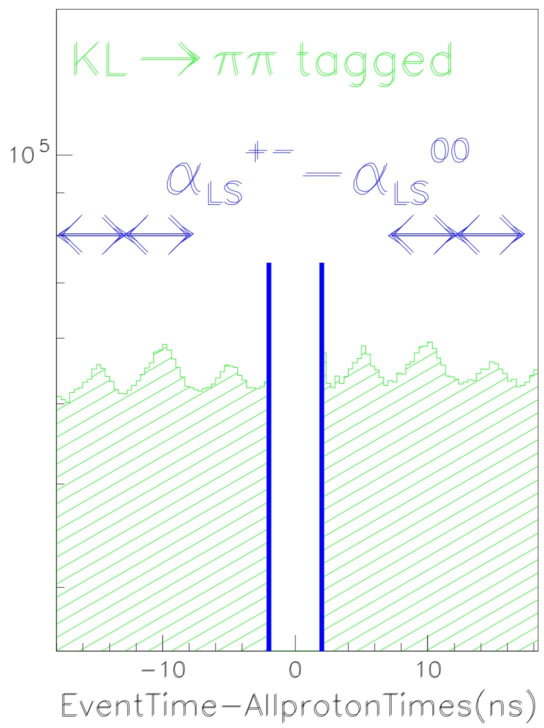
- Rate in tagger $\sim$ 28 MHz $\Rightarrow$ probability of accidental in 4 ns window $\sim$ 11 %
- From $K_L \rightarrow \pi^+\pi^-$ events :

$$\alpha_{LS}^{+-} = (11.19 \pm 0.03)\%$$

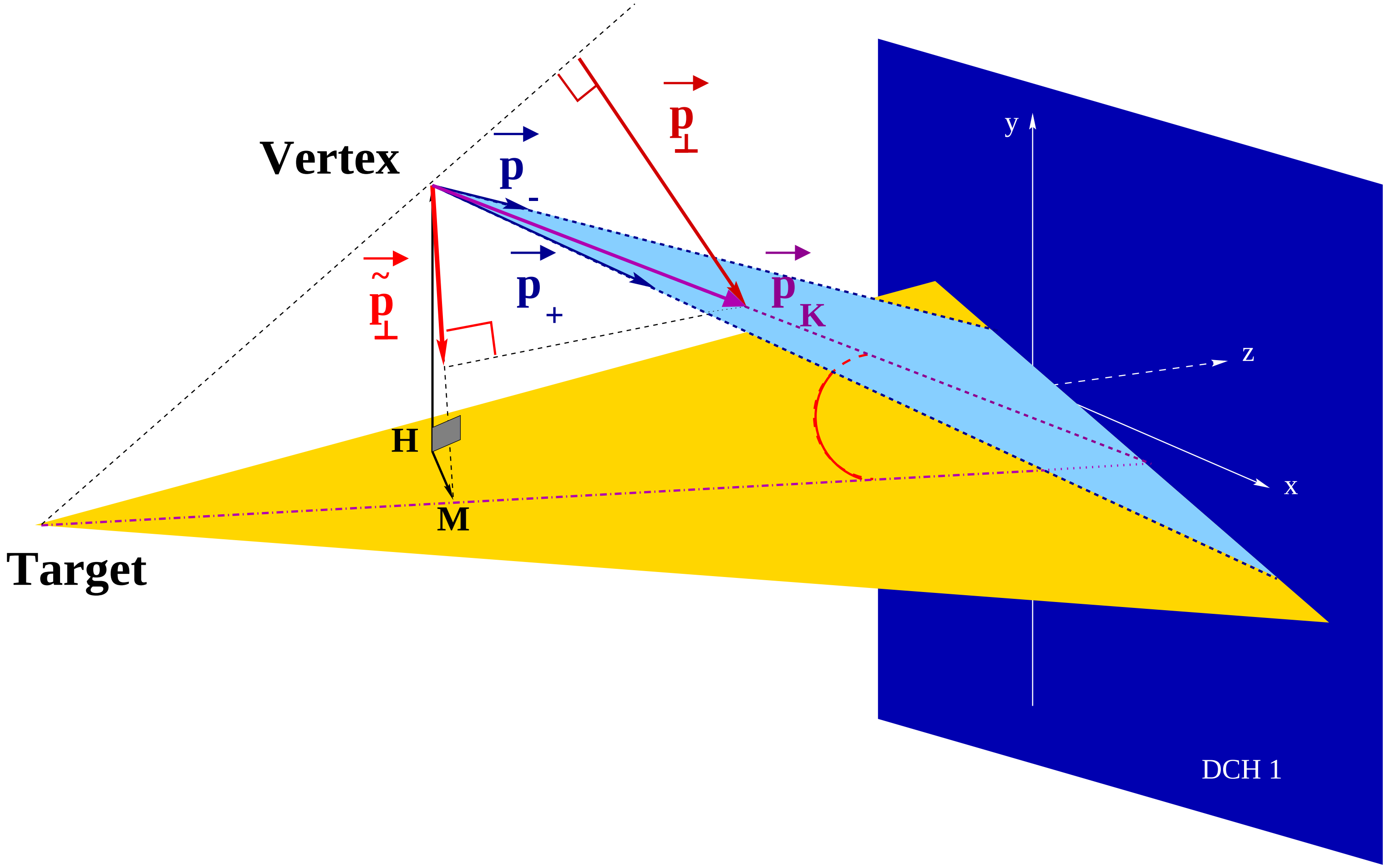
- FromK_L tagged charged and neutral OUTSIDE the $\pm$ 2ns window, get $\alpha_{LS}^{+-} - \alpha_{LS}^{00}$ in side bands $\pm$2ns wide

$$\alpha_{LS}^{00} - \alpha_{LS}^{+-} = (0.10 \pm 0.05)\%$$





Charged Background : $P_\perp{}^2$

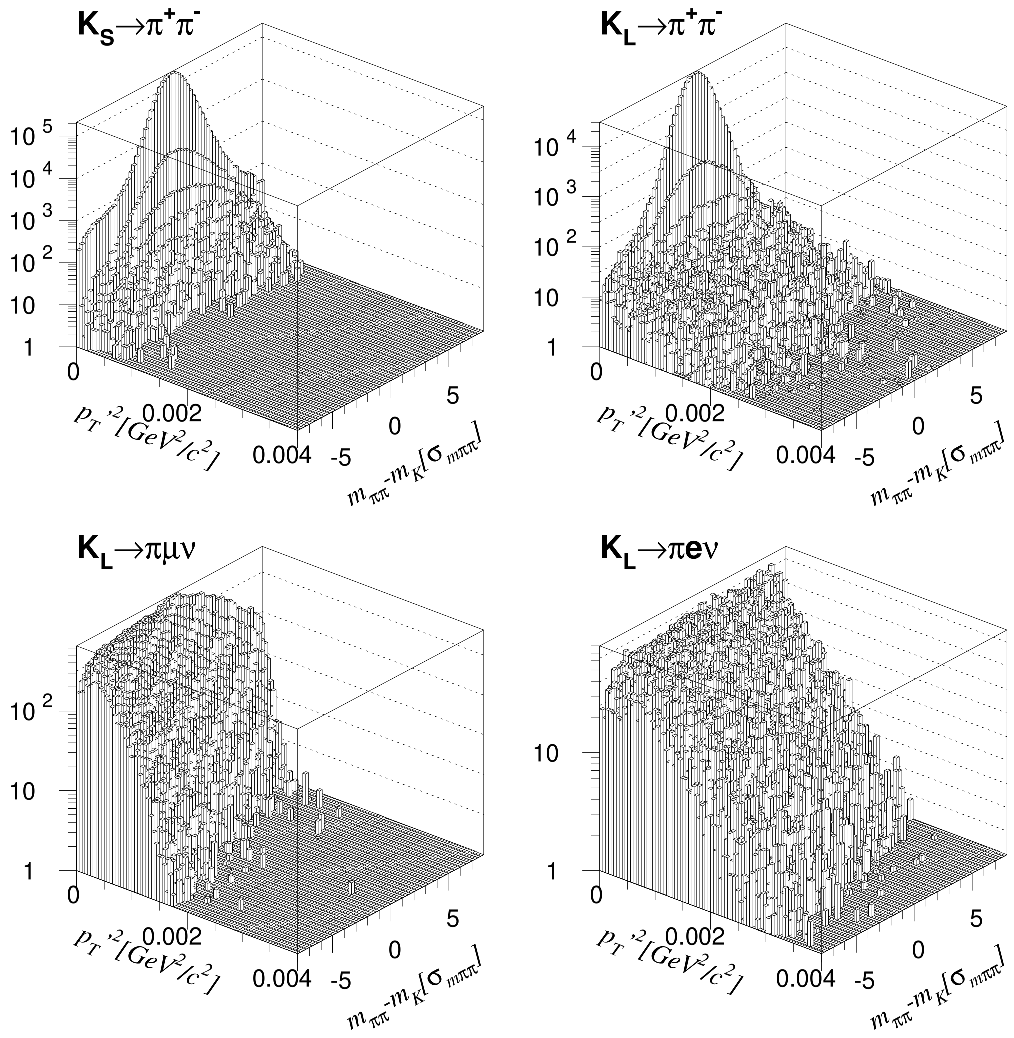


- Different target positions $\Rightarrow$ $P_\perp{}^2$ very different for K_S and K_L .
- $\tilde{P}_\perp{}^2$: more suitable variable

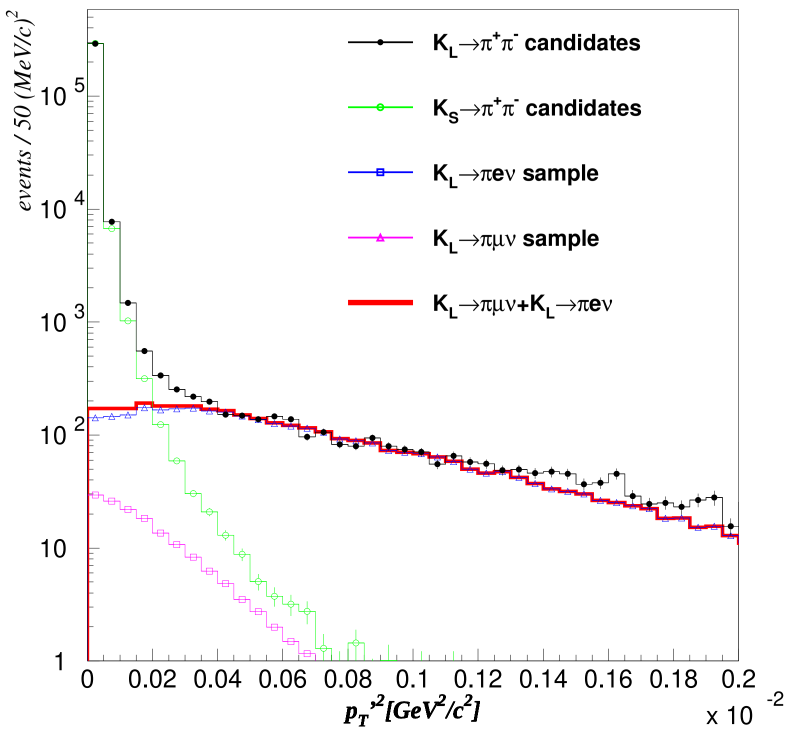
Charged background

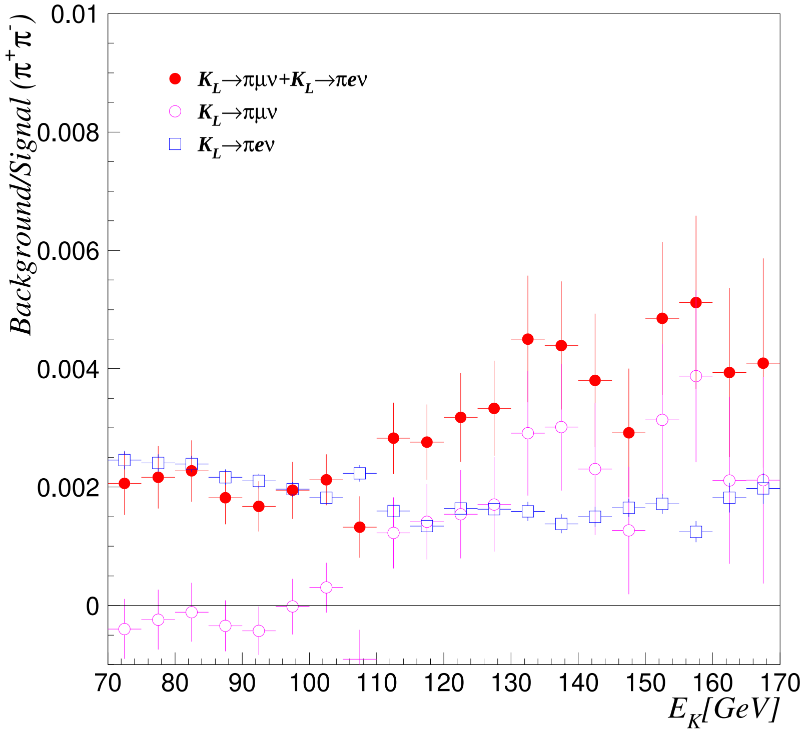
- Distributions in the $m_{\pi\pi} \times p_t'^2$ plane are made for :
  - K_S decays identified by vertex
  - Ke3 decays identified by E/p close to 1
  - $K_{\mu 3}$ decays identified with Muon Counters
- K_L candidates sample distribution is fitted in a control region as the sum of the 3 previous ones ($|m_{\pi\pi} - m_K| < 8\ \sigma_m$; $400 < p_t'^2 < 2000 (MeV/c)^2$)

$\rightarrow$ background = $(2.3 \pm .4)\ 10^{-3}$



Charged background

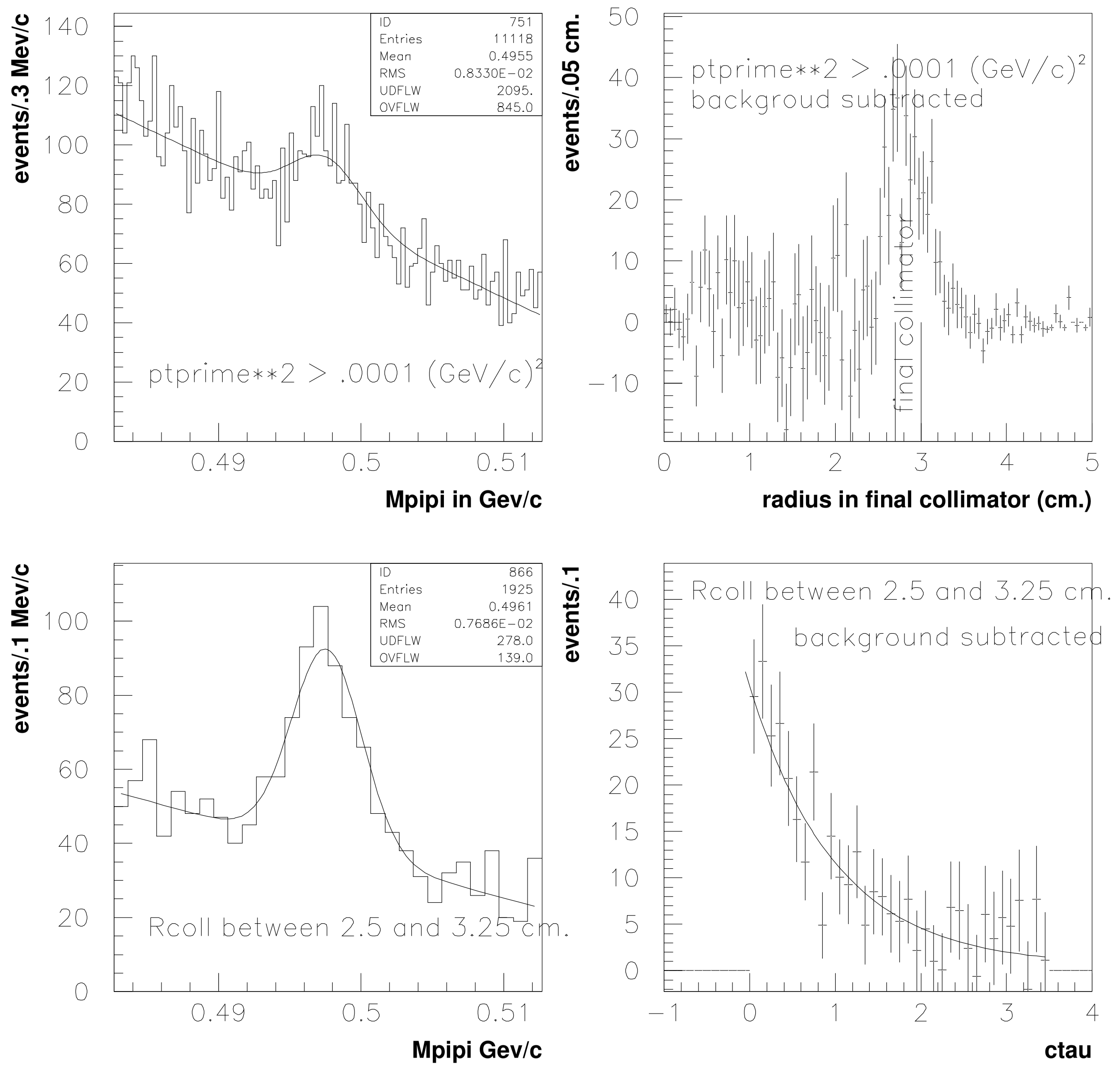




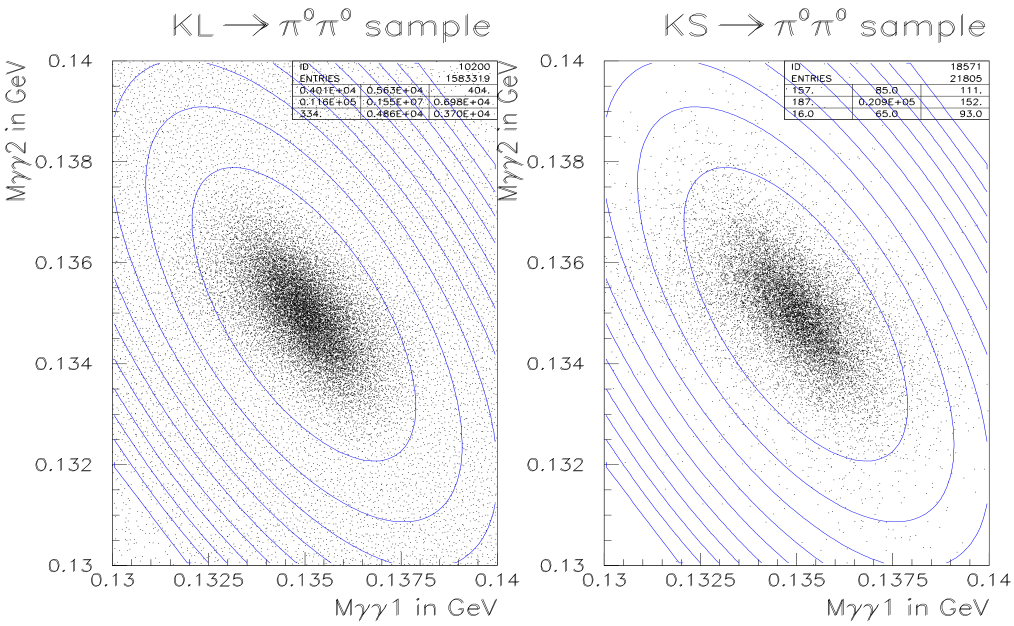
Beam scattering

- Few Kaons scattered off the collimators in K_L beam get back into the center of gravity acceptance defined at the LKr position
- Rejected by the $P_t'^2$ cut in the charged decays selection
- Not rejected in the neutral decays selection

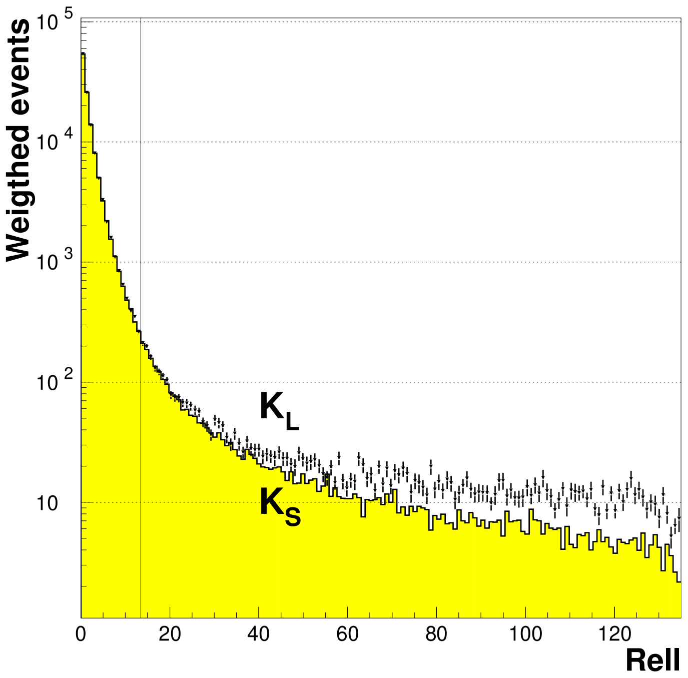
$\Rightarrow$ small correction to **R** : $(-12 \pm 3) \times 10^{-4}$



Neutral Background



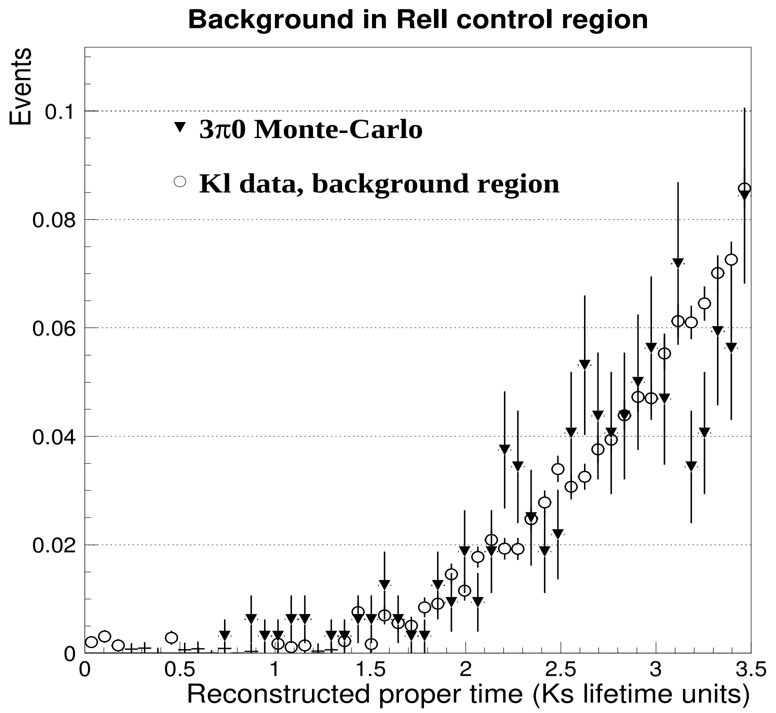
$$R_{ell} \equiv \left\{ \left(\frac{\frac{m_1+m_2}{2} - m_{\pi^0}}{\sigma_{\frac{m_1+m_2}{2}}} \right)^2 + \left(\frac{\frac{m_1-m_2}{2}}{\sigma_{\frac{m_1-m_2}{2}}} \right)^2 \right\}$$

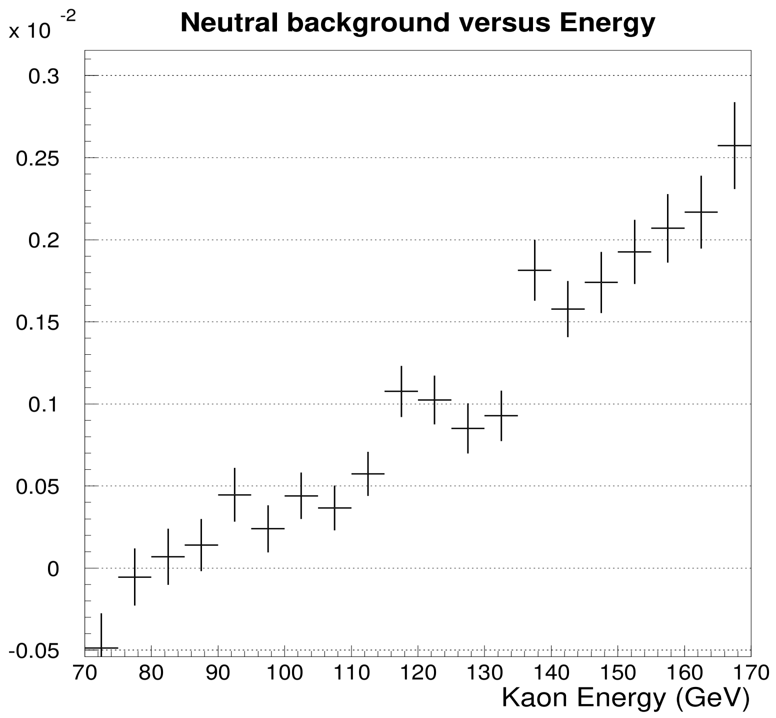


Signal region :
$R_{ell} < 13.5$
Background level :

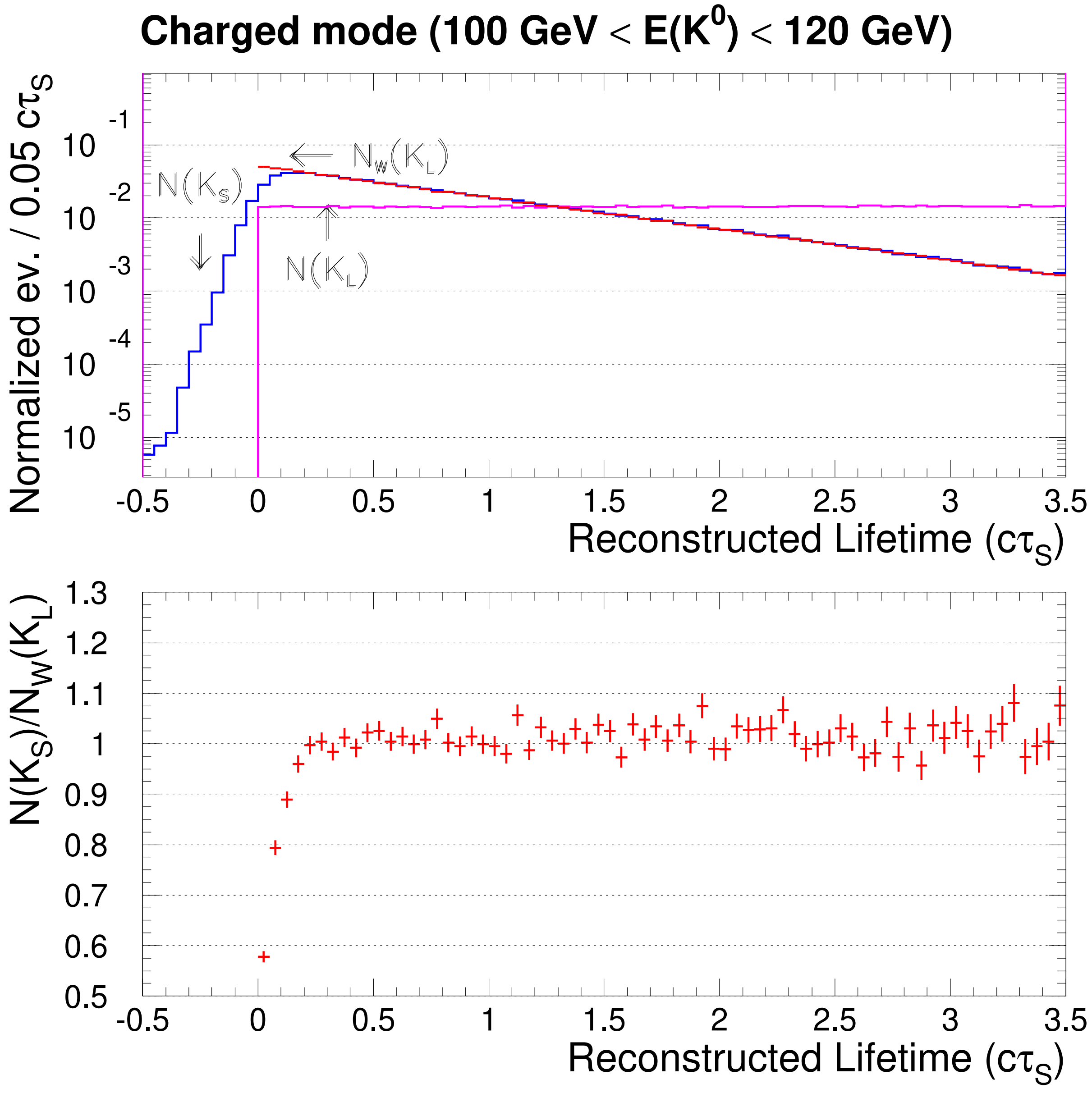
$(8 \pm 2)\ 10^{-4}$

Neutral Background

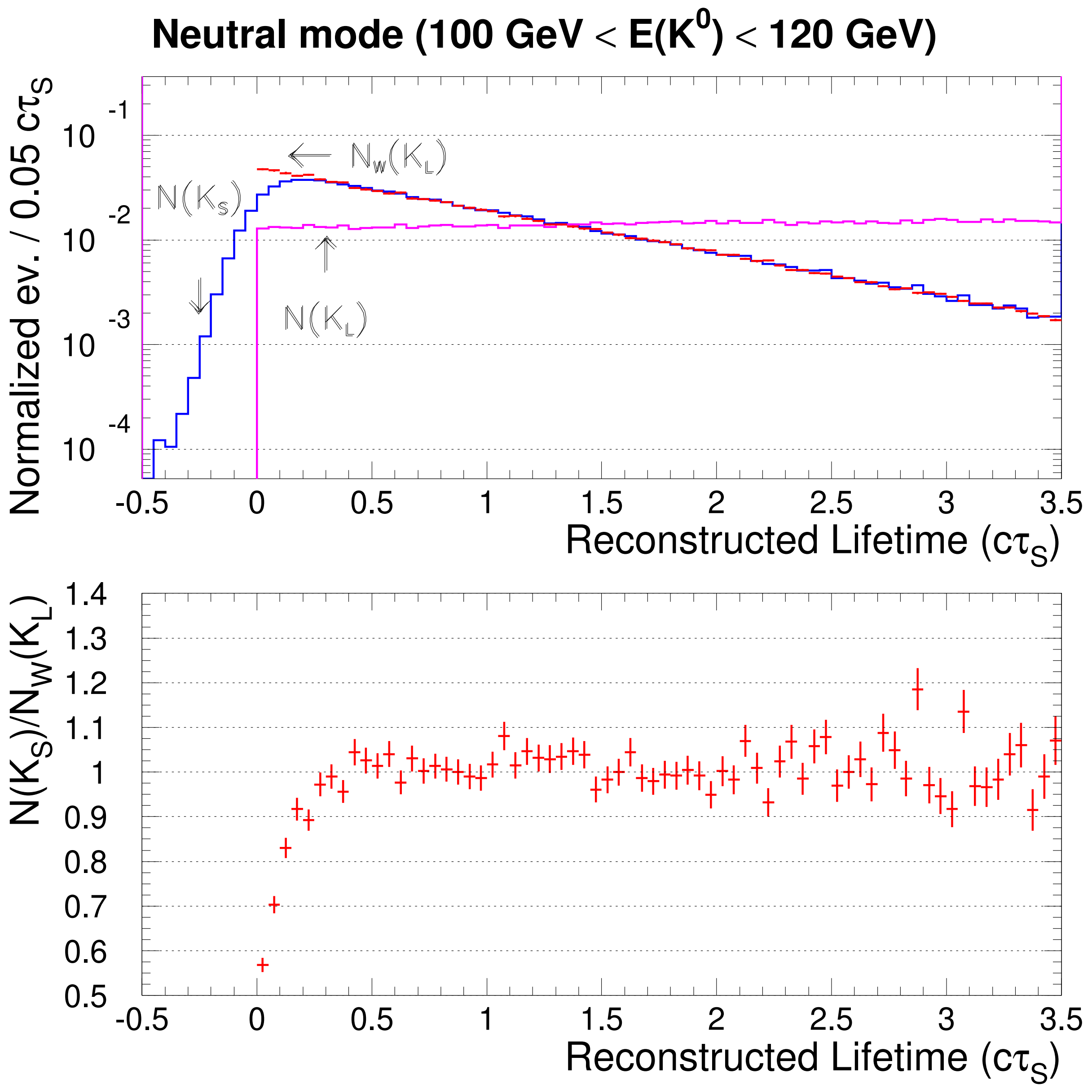




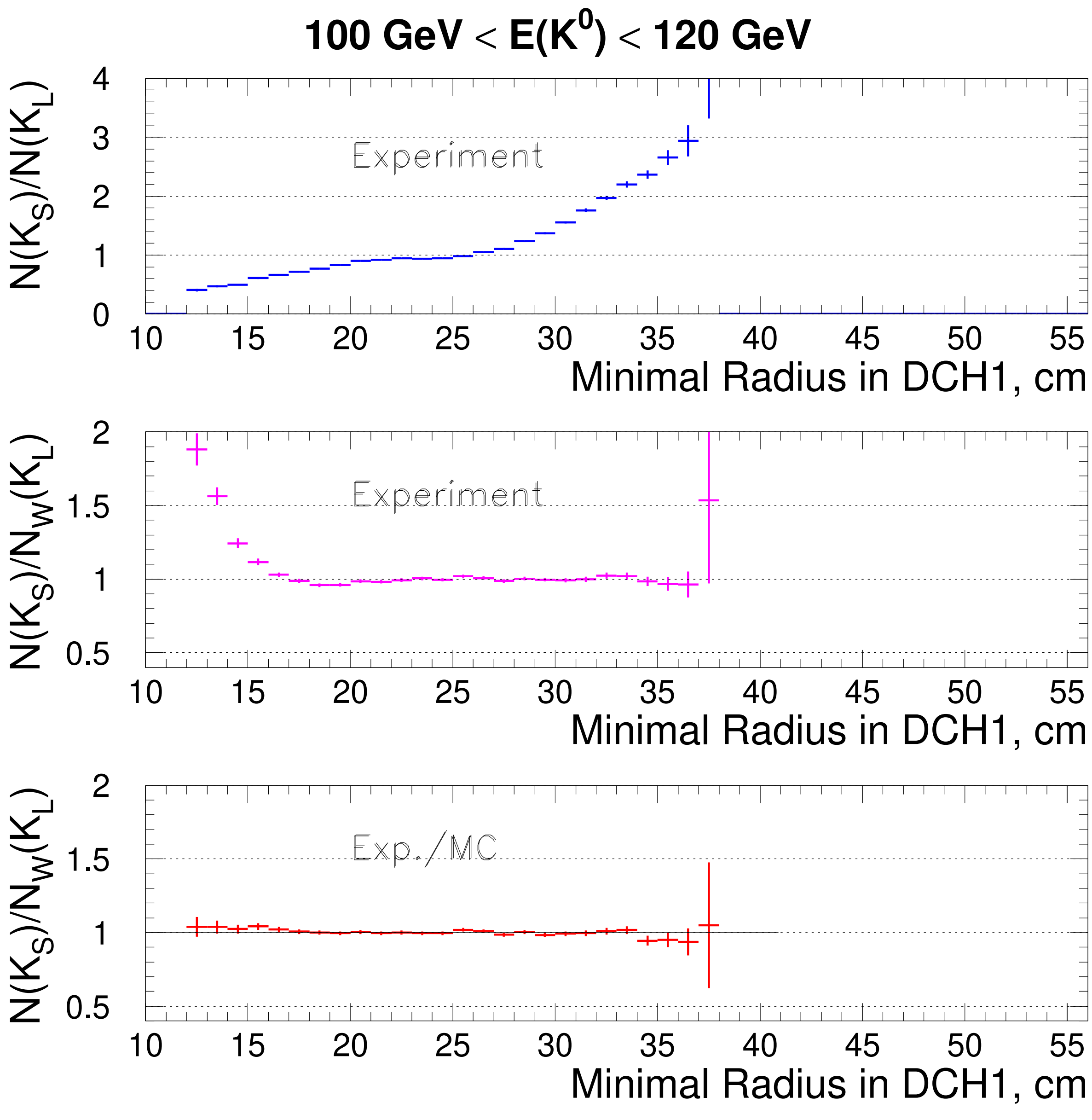
Weighting procedure



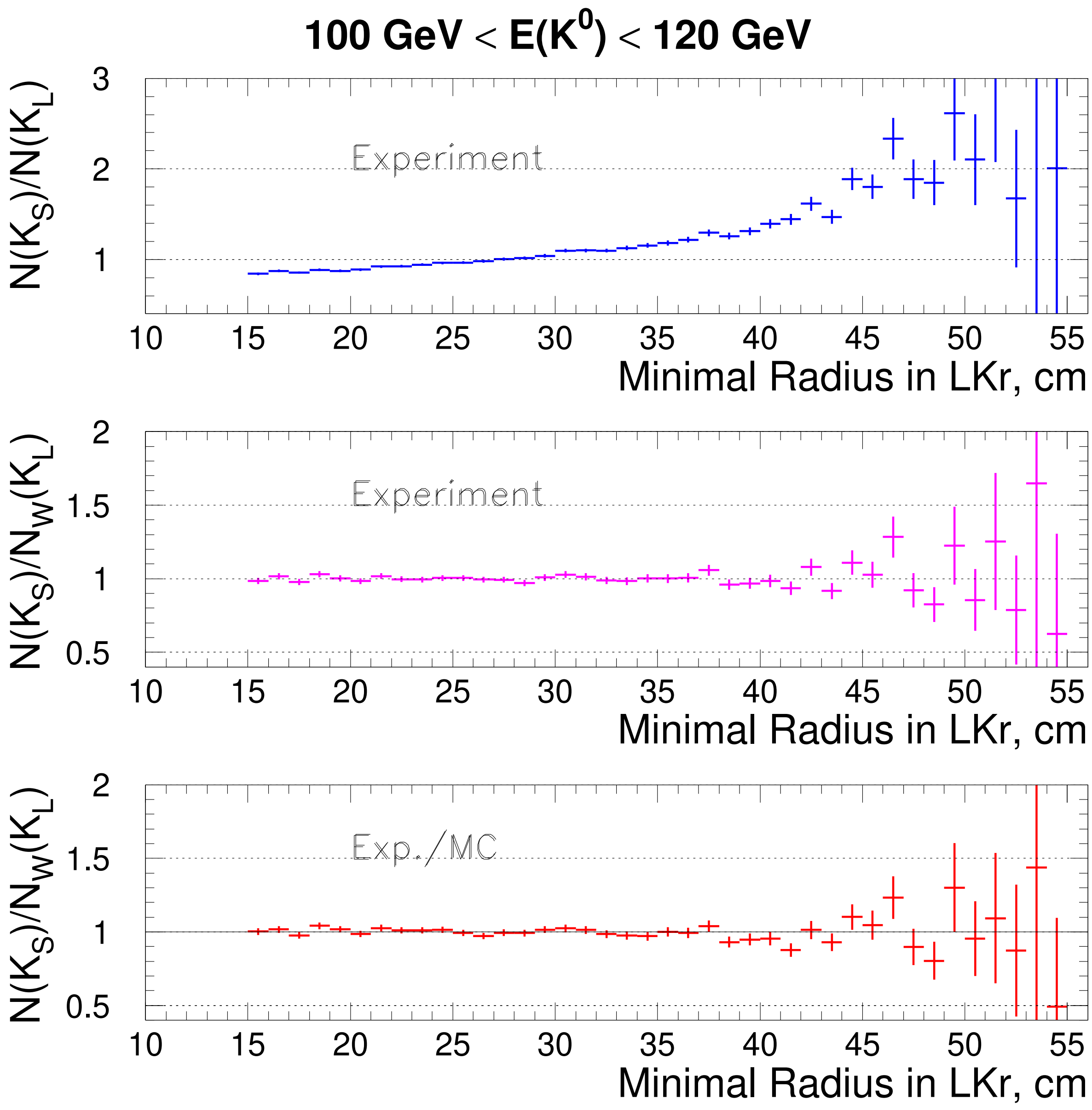
Weighting procedure



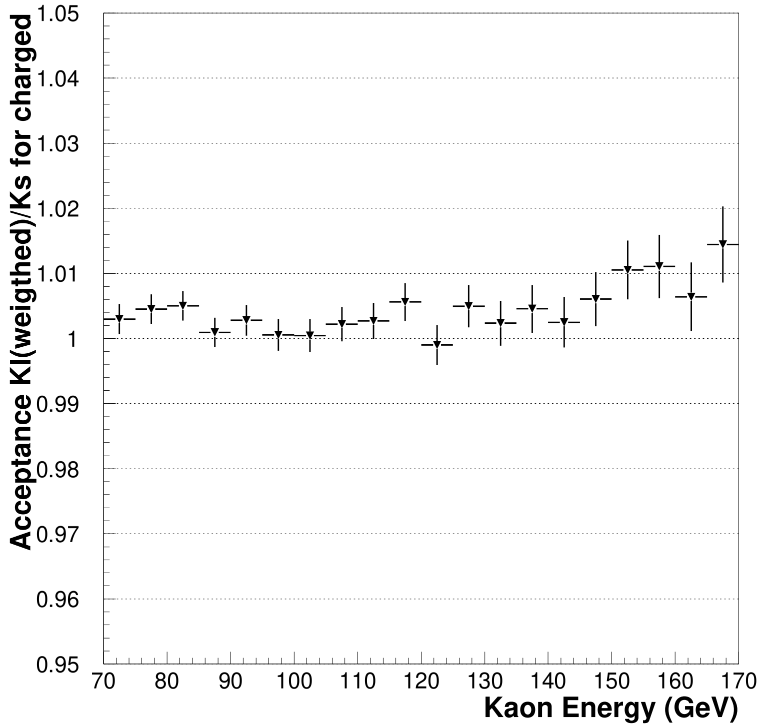
Weighting procedure

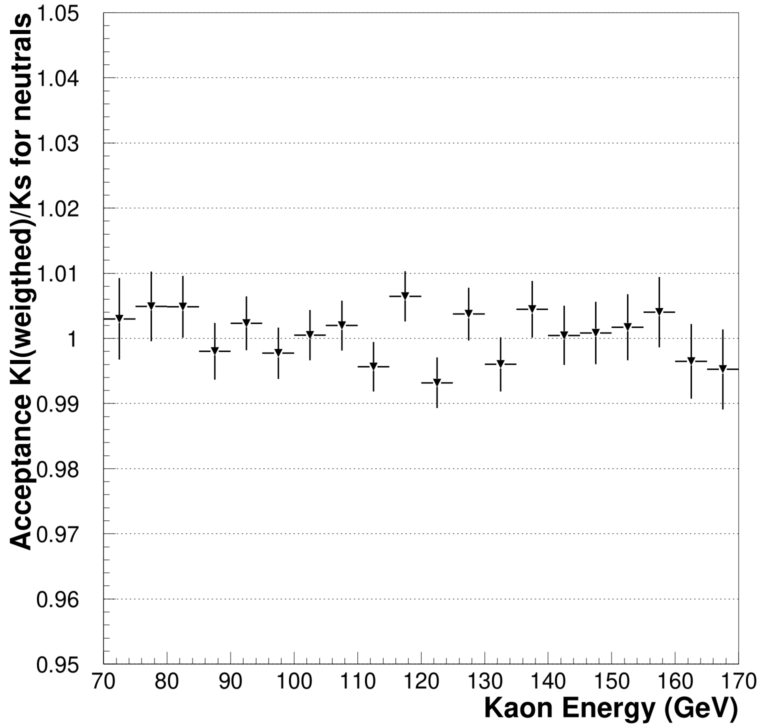


Weighting procedure

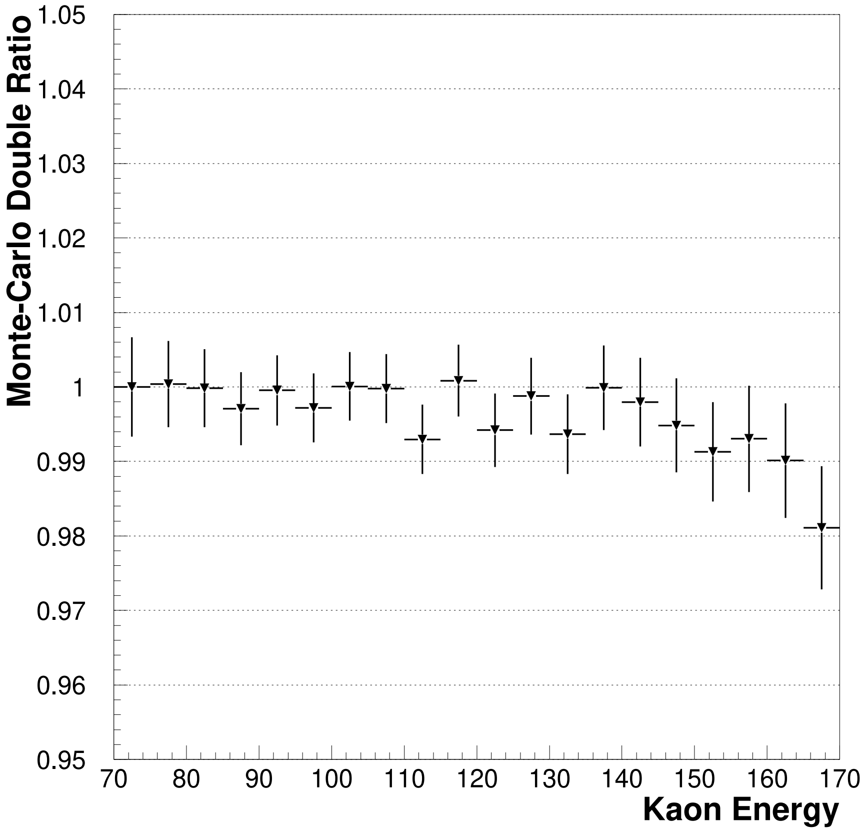


Acceptance correction





Acceptance correction



$\rightarrow$ Acceptance correction on $\mathbf{R} = (29 \pm 12)\ 10^{-4}$

Extra activity in the detector

Accidental activity

- Simultaneous K_L and K_S beam $\Rightarrow$ K_S /K_L differential loss expected very small
- Instantaneous intensity for K_S and K_L measured by searching for :
  - extra clusters above 1.5 GeV
  - extra tracks

  around the event time

$\rightarrow$ found to be the same with a precision of 1 %

- Overlay "random" events triggered proportionally to K_L and K_S beam intensities onto normal $\pi\pi$ events

$\rightarrow$ measure gains and losses of events :

$\pi^+\pi^-$ decays :
losses - gains $\simeq$ 2.7 % ; K_S - K_L symmetric
$\pi^0\pi^0$ decays :
losses - gains $\simeq$ 2.5 % ; K_S -K_L symmetric

- Effect on double ratio : $(\delta R = -2 \pm 14) \times 10^{-4}$
- Expected effect $\sim< 1\% \times 2\% = 2 \times 10^{-4}$!

In time activity from the K_S target

- measured using K_S only runs :
  extra cluster ($>$ 1.5 GeV) probability $< 3 \times 10^{-4}$
  extra track probability is even less and does not lead to event loss
- also checked by looking at activity in time with a proton going through the tagger in "random" events
- Uncertainty on double ratio : 3×10^{-4}

Result

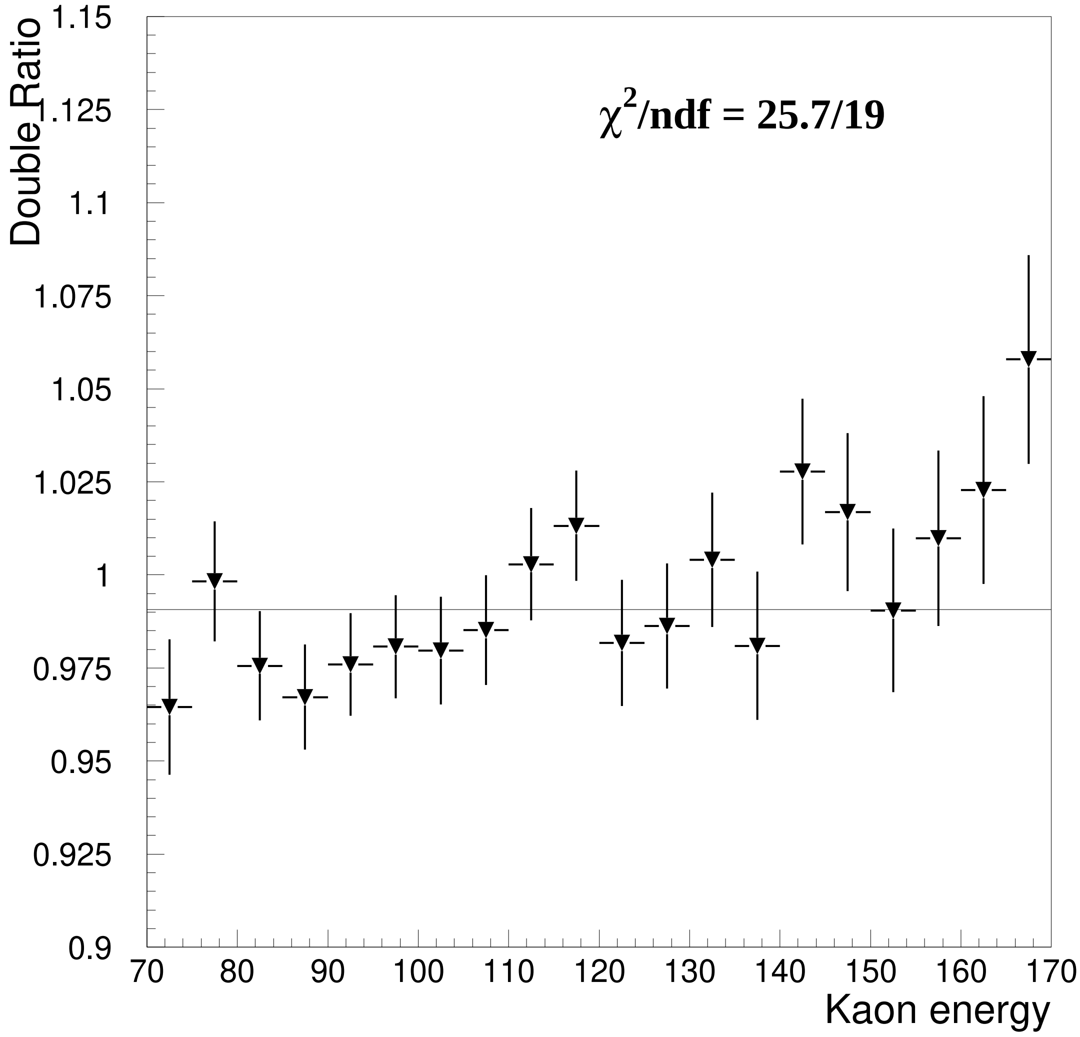
Events statistics ($\times 10^6$)			
$K_S \rightarrow \pi^+\pi^-$	2.087	$K_L \rightarrow \pi^+\pi^-$	1.071
$K_S \rightarrow \pi^0\pi^0$	.975	$K_L \rightarrow \pi^0\pi^0$	.489

Systematic uncertainties

Corrections and systematic uncertainties on R			
Source	Correction (10^{-4})	Uncertainty (10^{-4})	
Charged trigger	+9	23	(stat.)
Reconstruction	-	3	
Tagging dilution	+18	9	(stat.)
Tagging efficiency	0	6	(stat.)
Energy scale, non linearity	-	12	
Charged vertex	-	5	
Acceptance	+29	12	(MC stat.)
Neutral background	-8	2	
Charged background	+23	4	
Beam scattering	-12	3	
Accidental activity	-2	14	(stat.)
All	+57	35	(stat.)

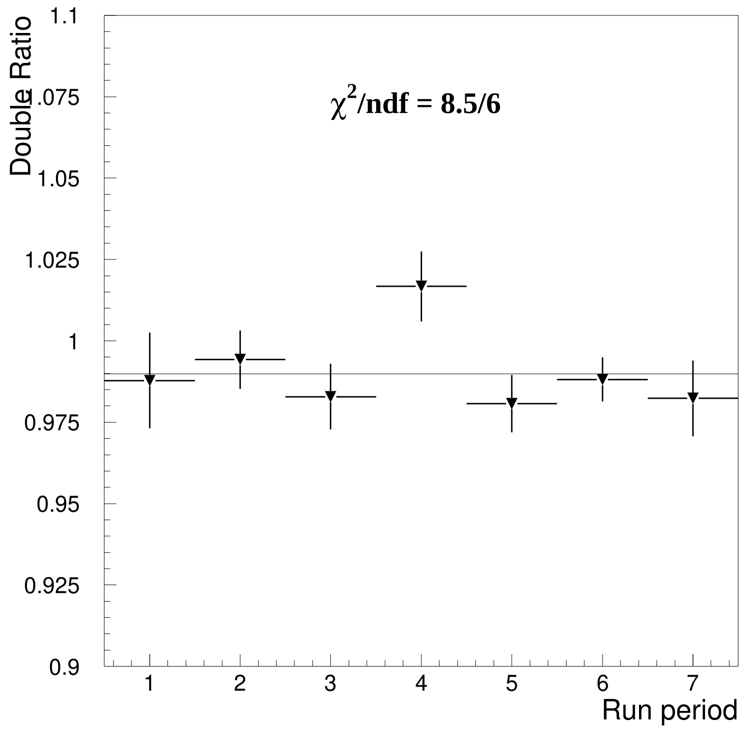
$$R = 1 - 6 \times \mathrm{Re}(\varepsilon'/\varepsilon)$$

Result

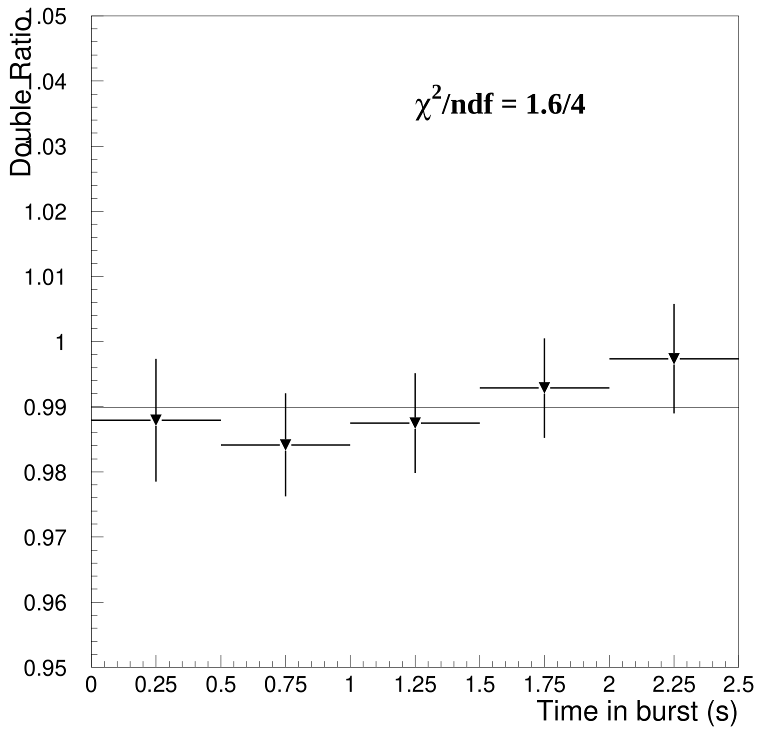


Double_Ratio
χ^2/ndf = 25.7/19
1.15
1.125
1.1
1.075
1.05
1.025
1
0.975
0.95
0.925
0.9
70
80
90
100
110
120
130
140
150
160
170
Kaon energy

Result

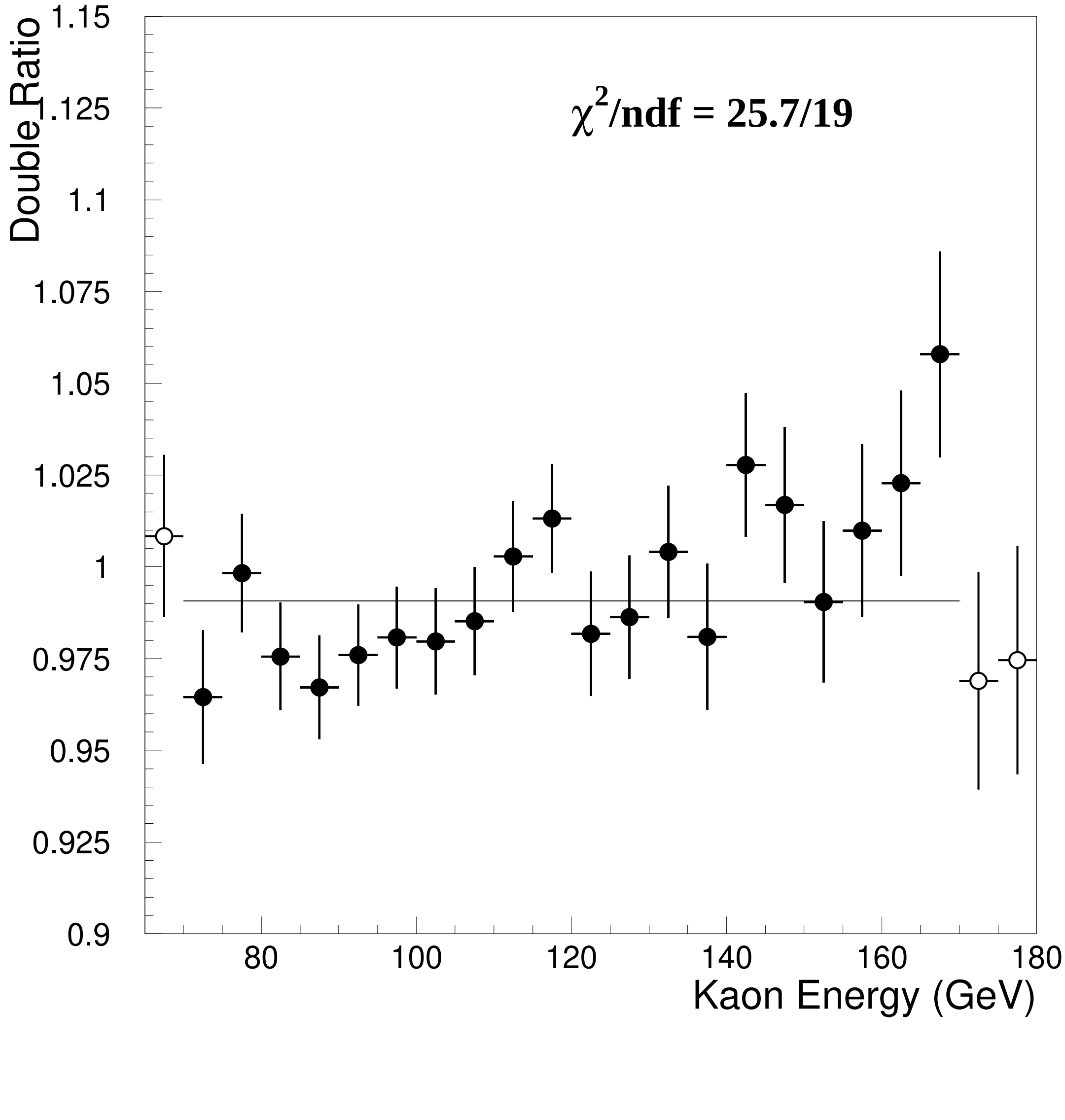


Double Ratio
1.1
1.075
1.05
1.025
1
0.975
0.95
0.925
0.9
χ^2/ndf = 8.5/6
1
2
3
4
5
6
7
Run period



Double Ratio
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
χ^2/ndf = 1.6/4
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time in burst (s)

Result



Double_Ratio
1.15
1.125
1.1
1.075
1.05
1.025
1
0.975
0.95
0.925
0.9
80
100
120
140
160
180
Kaon Energy (GeV)
χ^2/ndf = 25.7/19

Result

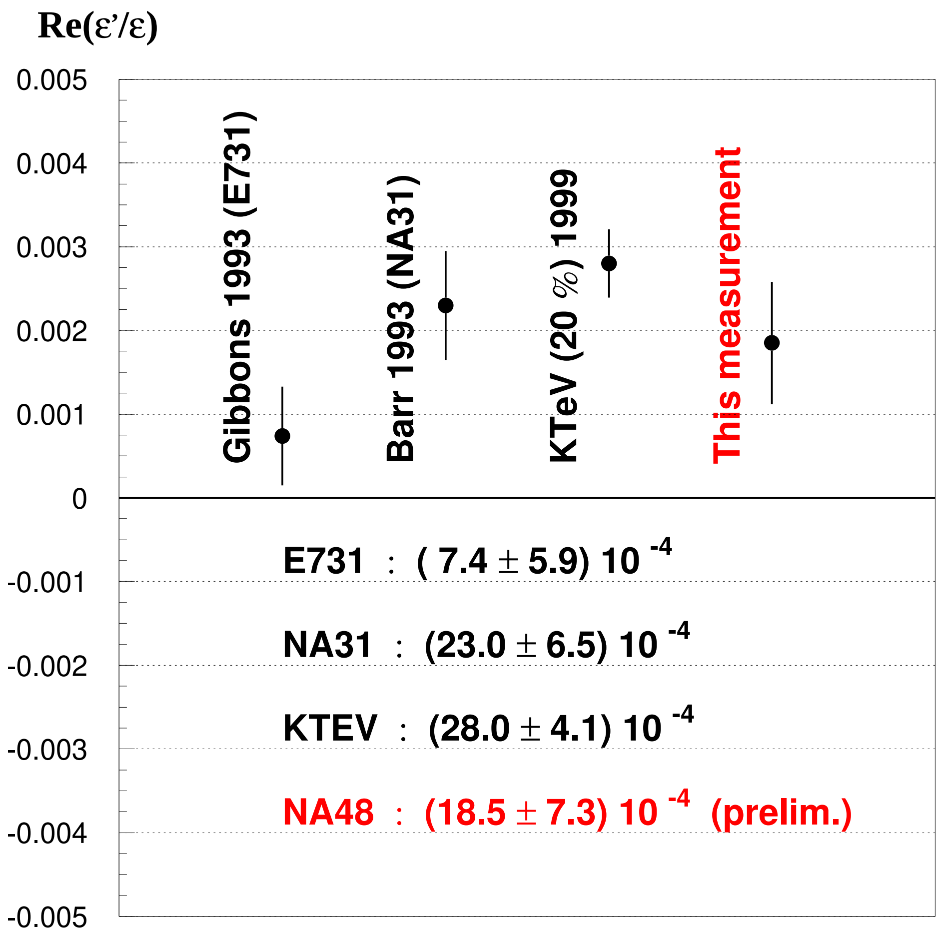
$$\mathrm{Re}(\varepsilon'/\varepsilon) \;=(18.5 \;\pm\; 4.5 \text{ (ev. stat.)} \pm\; 5.8 \text{ (syst.)}) \times 10^{-4}$$

Combining errors in quadrature :

$$\mathrm{Re}(\varepsilon'/\varepsilon) \;=(18.5 \;\pm\; 7.3) \times 10^{-4}$$

(PRELIMINARY)

ε'/ε measurements



- World Average before this measurement :

  $(21.7 \pm 3.0) \times 10^{-4}$ $(\chi^2/\mathrm{ndf} = 8.3/2)$

- World Average after this measurement :

  $(21.2 \pm 2.8) \times 10^{-4}$ $(\chi^2/\mathrm{ndf} = 8.4/3)$

Perspectives for the measurement of ε'/ε

Run 1998 (mid-may $\rightarrow$ september)

- all HV blocking capacitors of LKr calorimeter replaced $\Rightarrow$ stable operation at 3 kV
- New carbon-fibre beam pipe
- Charged trigger upgrade (200 MHz processors) and higher efficiency ($\sim$ 97 %)
- New DAQ system : $\sim$ 30 % trigger rate increase
- 3 times more 2 π^0 decays, 6 times more $\pi^+\pi^-$ decays
- Statistical error on $\varepsilon'/\varepsilon \sim 3\ 10^{-4}$

Run 1999 started

- Drift Chamber readout improved
- Central data recording moved from the CS2 to a PC farm
- expect 1999 statistics > 1998 statistics

Year 2000

- Complement statitics and systematic studies

Conclusion

- With data taken in 1997
  ($\sim$ 10 % of the expected final statistics)
  NA48, using a **new** technique, measures :

  $$\mathrm{Re}(\varepsilon'/\varepsilon) \ = (18.5 \pm 7.3) \times 10^{-4}$$

  (preliminary)

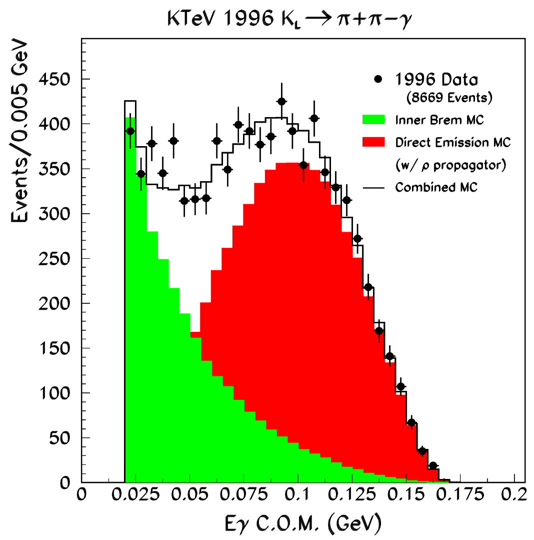
- The uncertainty is dominated by statistics

- This measurement favours a non zero value of $\mathrm{Re}(\varepsilon'/\varepsilon)$

- NA48 is analysing data from 1998, has started its 1999 run, and will take data in year 2000 to reach its ultimate precision on $\mathrm{Re}(\varepsilon'/\varepsilon)$

$\mathbf{K}^0 \rightarrow \pi^+\pi^-\gamma$

- for $\mathrm{K_L}$ only : direct emission
  cut by invariant $\pi^+\pi^-$ mass cut at about 7 MeV/c^2
  $\mathrm{BR}(\mathrm{K}_L^0 \rightarrow \pi^+\pi^-\gamma) = (3.19 \pm .09) \times 10^{-5}$
  (direct emission only and $\mathrm{E}_\gamma^* > 20$ MeV)
- for $\mathrm{K_L}$ and $\mathrm{K_S}$: internal bremstrahlung
  $\Rightarrow$ rates proportional to $\pi^+\pi^-$ decay rates
  $\Rightarrow$ possible effect on ε'/ε from P_t'^{2} cut



- For $\mathrm{K_S}$: P_t'$^2 \leq 200\ (\mathrm{MeV/c})^2 \equiv \mathrm{P}_t \lesssim 100$ MeV/c
- For $\mathrm{K_L}$: P_t'$^2 \leq 200\ (\mathrm{MeV/c})^2 \equiv \mathrm{P}_t \lesssim 23$ MeV/c

BUT γ with more than $\simeq 7$ MeV are already removed by the invariant mass cut

$\Rightarrow$ **negligible effect on** ε'/ε

Theoretical estimates