The NA48 Liquid Krypton Calorimeter: Description and Performances

http://www.cern.ch/NA48/Welcome.html

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On behalf of the NA48 Collaboration

Cambridge	Cagliari	CERN	Dubna
Edimburgh	Ferrara	Firenze	Mainz
Orsay	Perugia	Pisa	Saclay
Siegen	Torino	Warsaw	Wien

The NA48 Experiment

- AIM

To measure $Re\left(\frac{\varepsilon'}{\varepsilon}\right)$, out of the "double ratio" R:

$$R = \left|\frac{\eta^{00}}{\eta^{+-}}\right|^2 = \frac{\Gamma\left(K_L \to \pi^0\pi^0\right)}{\Gamma\left(K_S \to \pi^0\pi^0\right)} \Big/ \frac{\Gamma\left(K_L \to \pi^+\pi^-\right)}{\Gamma\left(K_S \to \pi^+\pi^-\right)}$$
$$= 1 - 6Re\left(\frac{\varepsilon'}{\varepsilon}\right) + \mathcal{O}\left(\frac{\varepsilon'}{\varepsilon}\right)^2$$

with an accuracy $\simeq 2 \times 10^{-4}$

- MOTIVATION

A non-zero value of ε' would constitute an experimental evidence of *direct* $\mathcal{CP}$ violation

- METHOD

☞ Collect a statistical sample with a few 10^6 $K_L \to 2\pi^0$

☞ Minimise systematic uncertainties

The NA48 Detector

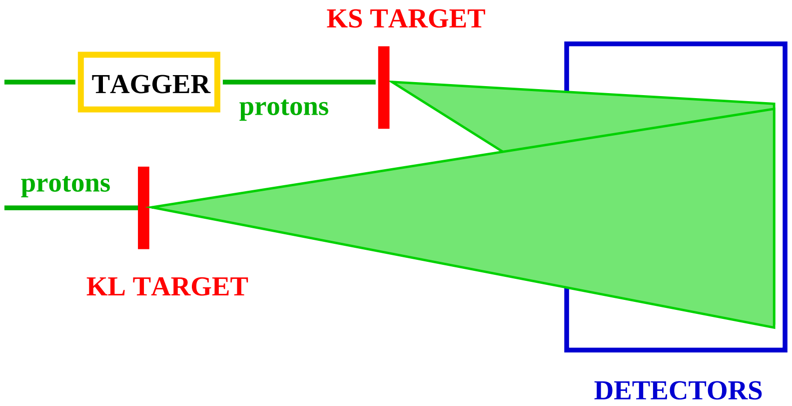
- two simultaneous, quasi-collinear K_L and K_S beams,
- a tagger to identify decays from each beam,
- a magnetic spectrometer to measure the charged modes

$$K_{L,S} \rightarrow \pi^+\pi^-$$

- a liquid krypton calorimeter for the neutral decay modes

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

- other subdetectors for background rejection and redundant identification



Neutral modes detection

☞ Efficient acquisition in a high-rate environment ($\sim MHz$) during several years:

Need for a fast / efficient / stable neutral detector

☞ Decay identification in presence of important background levels:

signal	dominant background
$K_L \to 2\pi^0$ $B.R. \sim 0.09\%$	$K_L \to 3\pi^0$ $B.R. \sim 21.6\%$
$K_L \to \pi^+\pi^-$ $B.R. \sim 0.2\%$	$K_L \to \pi e \nu_e$ $B.R. \sim 37.8\%$

NEUTRAL REQUIREMENTS

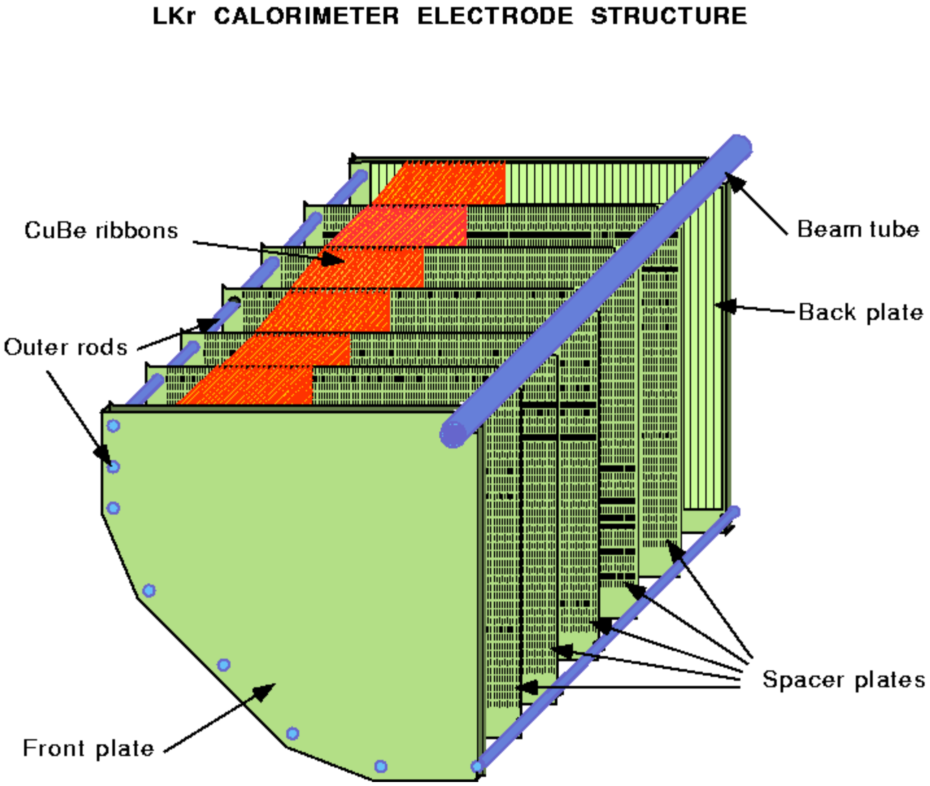
$K_L \to 3\pi^0$ BKG $\lesssim 0.1\%$

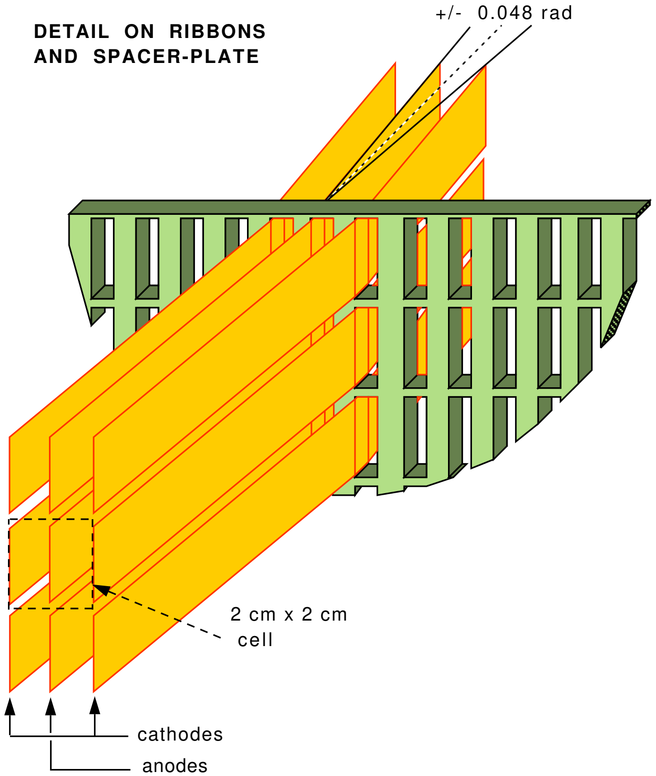
$$\left\{ \begin{array}{llll} \sigma_T & < & 500.\ ps & \\ \sigma_{X,Y} & < & 1.\ mm & \\ \frac{\sigma_E}{E} & \lesssim & 1.\% & (\langle E_\gamma \rangle \sim 25.\ GeV) \\ linearity & \simeq & few\ 10^{-3} & (5. \to 100.\ GeV) \end{array} \right.$$

The LKr Calorimeter

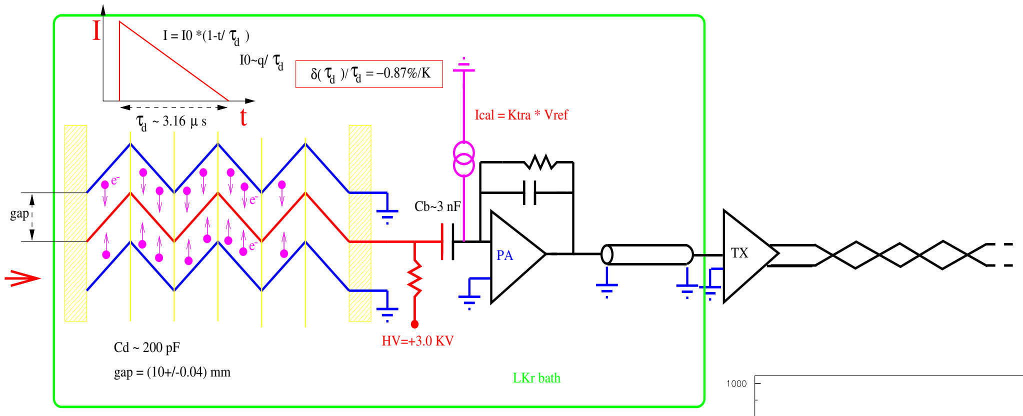
The LKr Calorimeter

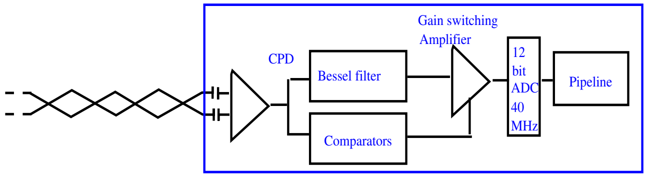
- quasi-homogeneous calorimeter, $\sim 10.\ m^3$ of liquid Krypton, $X_0 \sim 4.7\ cm$, $R_M \sim 6.1\ cm$
- 13212 cells, $2 \times 2\ cm^2$ and $1.25\ m$ depth ($\sim 27\ X_0$)
- projective geometry towards Kaon decay region ($\sim\ 114\ m$ upstream)
- ribbon electrodes following a $48.\ mrad$ zig-zag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

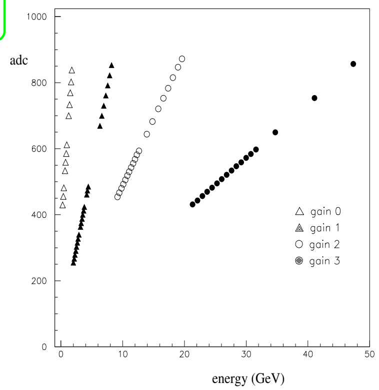


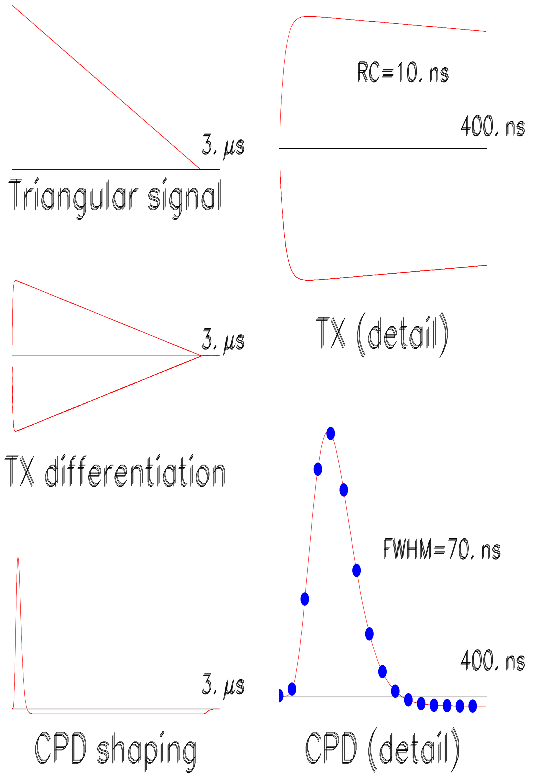


The LKr readout electronics







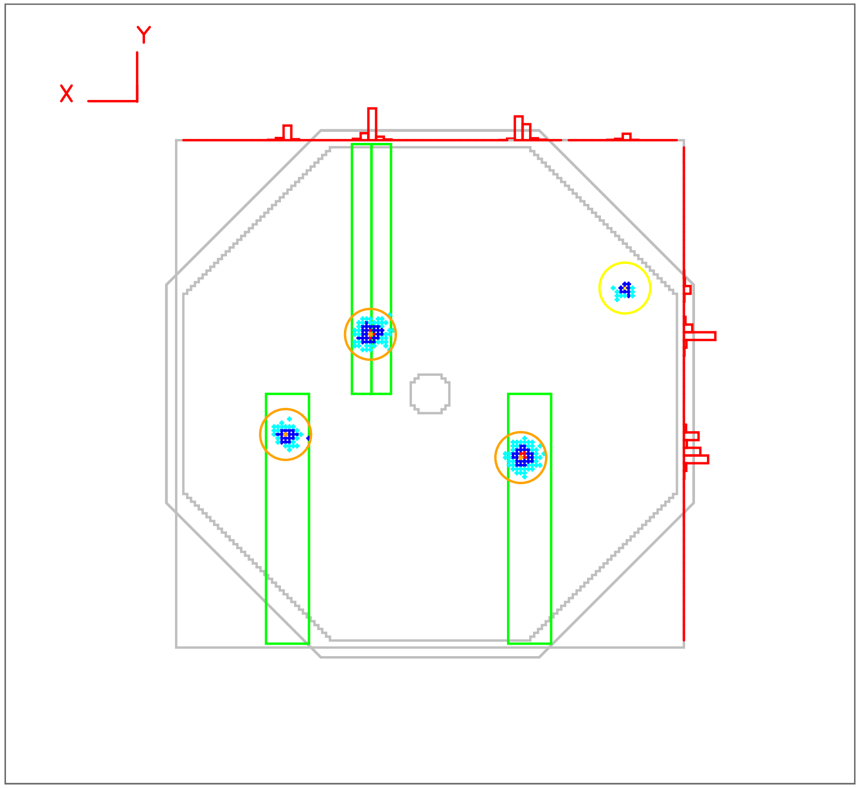


(4 offsets + 4 slopes) * 13212 channels = 105696 constants

- asynchronous, digital sampling (40 MHz)
- 4 gains, 10 ADC bits dynamic range ($\sim$ 3.5 MeV up to $\sim$ 50. GeV per cell)
- gain dispersion ~ 3 %
- calibration in parallel with physics $\rightarrow$ improve gain equalisation, calculate offsets
- gain stability better than 0.1 %, offsets frequently updated

The LKr in 1997

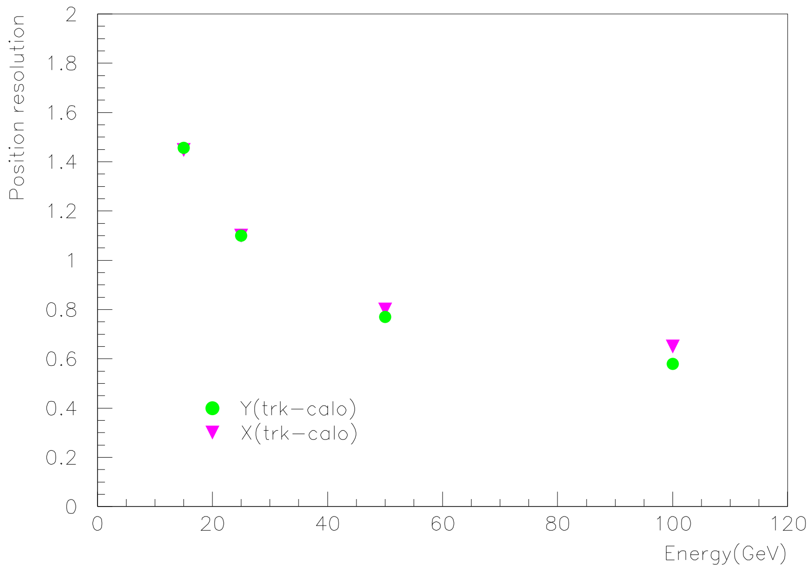
- High voltage set at 1500 Volts to prevent failure of a few blocking capacitors
- One LKr column (out of 64) disconnected from high voltage



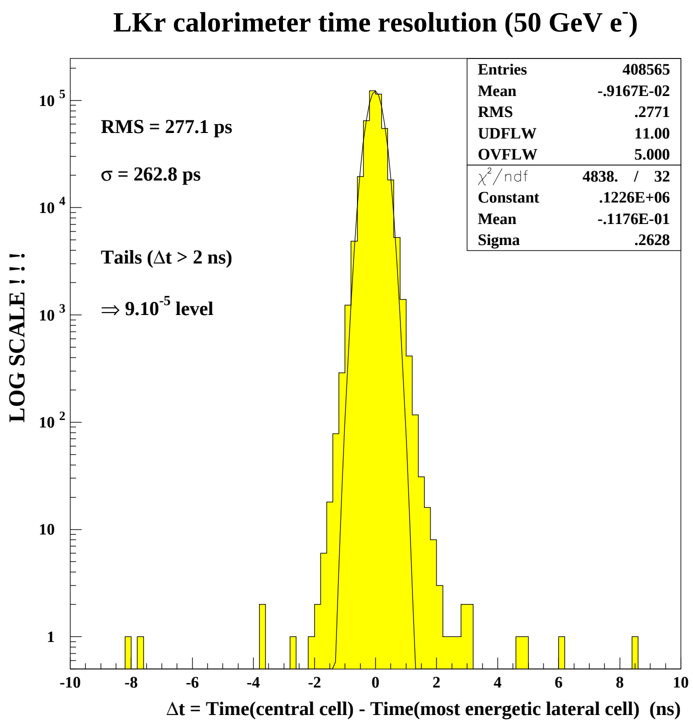
650 000 $K_L \rightarrow 2\pi^0$ recorded during '97 run

LKr time and position resolutions via electrons

An electron scan at fixed energies (15, 25, 50, and $100\ GeV$) was used for precision tests of LKr response



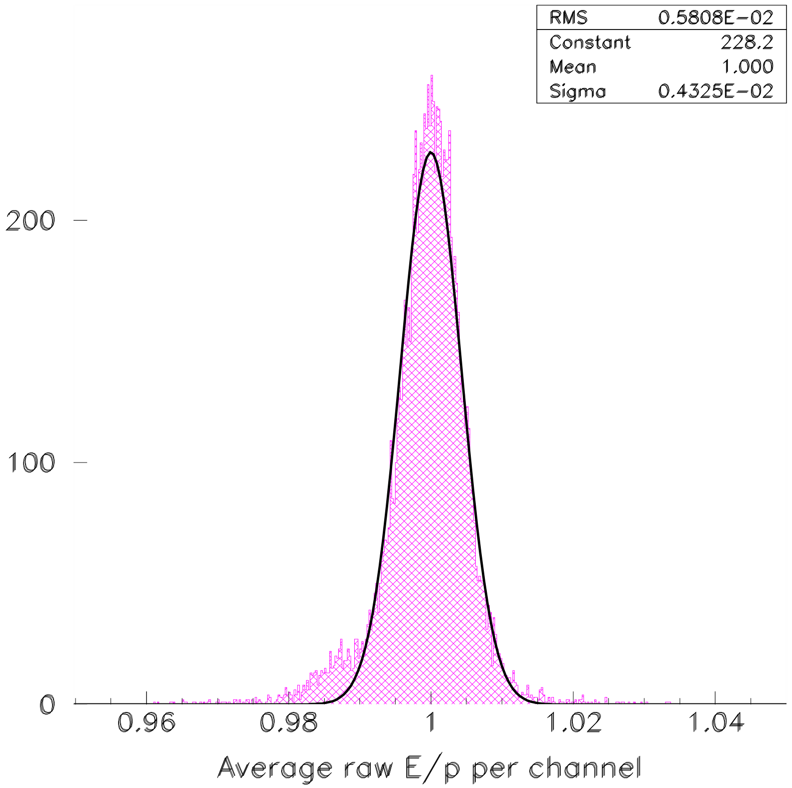
Horizontal and vertical resolutions better than $1\ mm$ above $25\ GeV$
(Spectrometer tracks extrapolation to LKr contribute $\sim\ 100\ \mu m$ to resolution)



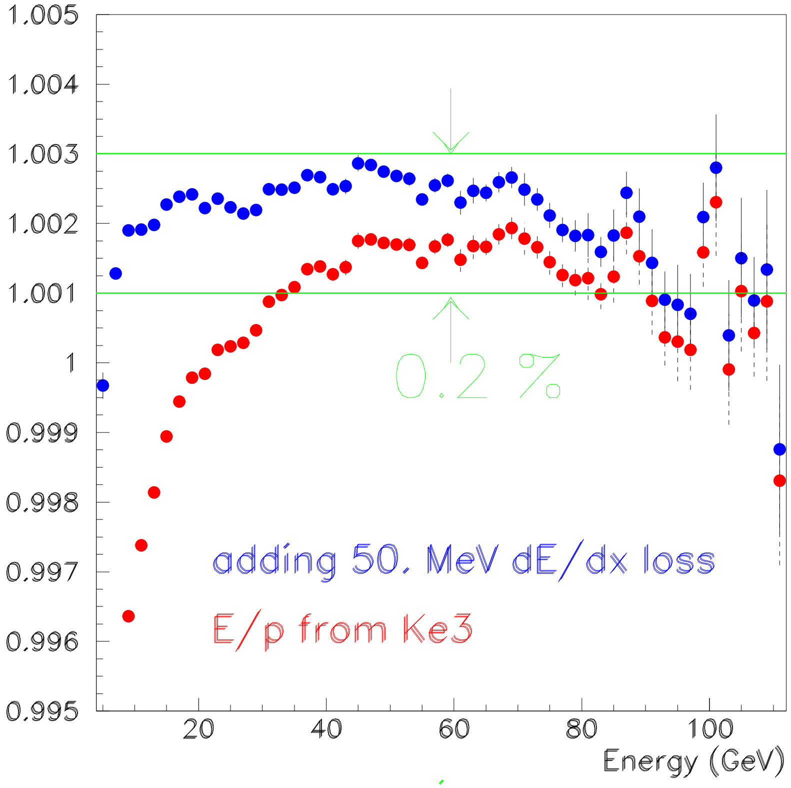
Intrinsic LKr time resolution $\sim\ 260\ ps$
Inefficiencies below 10^{-4} (mainly due to accidentals)

LKr energy performances via K_{e3}

☞ $\frac{E}{p}$ from K_{e3} decays is used to test calibration, energy resolution and linearity

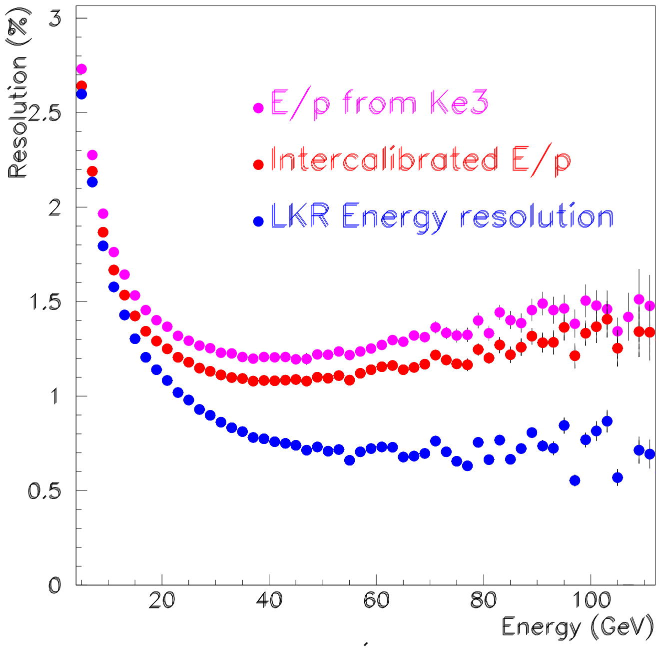


cell-to-cell energy uniformity (i.e. average energy read by a single channel) shows a 0.43% dispersion, partially due to uncertainties in the calibration electronics



LKr energy response is linear within 0.2% in the $5. \rightarrow 100.\ GeV$ range

LKr energy performances via K_{e3}

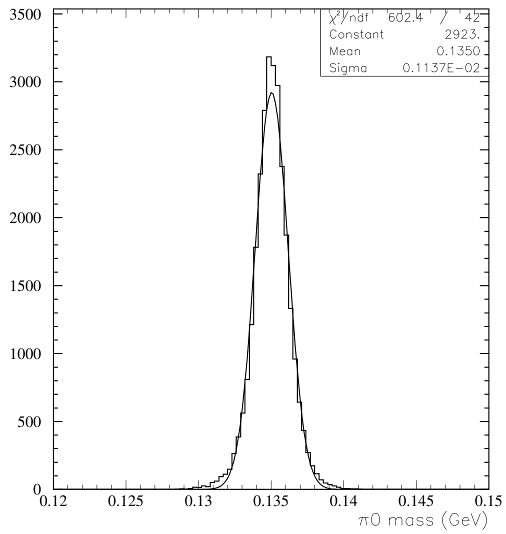


Energy corrected for $\frac{E}{p}$ intercalibration, spectrometer term substracted from resolution to give

PURE LKr ENERGY RESOLUTION

$$\frac{\sigma(E)}{E} = \frac{3.5\%}{\sqrt{E}} \oplus \frac{110\ MeV}{E} \oplus 0.6\%$$

The π^0 mass is measured by the LKr with an $1.1\ MeV$ resolution. The background $K_L \rightarrow 3\pi^0$ under the signal is reduced to $\lesssim 0.1\%$ (after K_L weighting)



Conclusions

- the LKr was completely setup for the '97 $\frac{\varepsilon'}{\varepsilon}$ data-taking period
- LKr performances were evaluated, and are within the design requirements
- background to the neutral modes was rejected up to a residual $\lesssim 0.1\%$ level
- the blocking capacitors were replaced during the '97-'98 winter shutdown
- '98 data-taking was achieved successfully. The LKr was safely operated at 3000 Volts, obtaining a $\sim 20\%$ signal gain
- about 2 million $K_L \to 2\pi^0$ events were addded to the $NA48$ statistics
- there will be another $\frac{\varepsilon'}{\varepsilon}$ data-taking in 1999