Performances of the NA48 pipelined trigger for the Kaon neutral decays

Sergio Giudici
Scuola Normale Superiore and INFN - Pisa

Calor2000, Annecy
October 11, 2000

✦ on behalf of the **NA48 COLLABORATION**:
Cagliari-Cambridge-CERN-Dubna-Edinburgh-Ferrara-Firenze-Mainz-Orsay-Perugia-Pisa-Saclay-Siegen-Torino-Vienna-Warsaw

Aim determine the "direct CP violation" parameter $\mathrm{Re}(\varepsilon'/\varepsilon)$ in the system $K_{L,S} \rightarrow \pi\pi$, with an accuracy of $\sim 2 \times 10^{-4}$, measuring the deviation from unity of the so-called double ratio R.

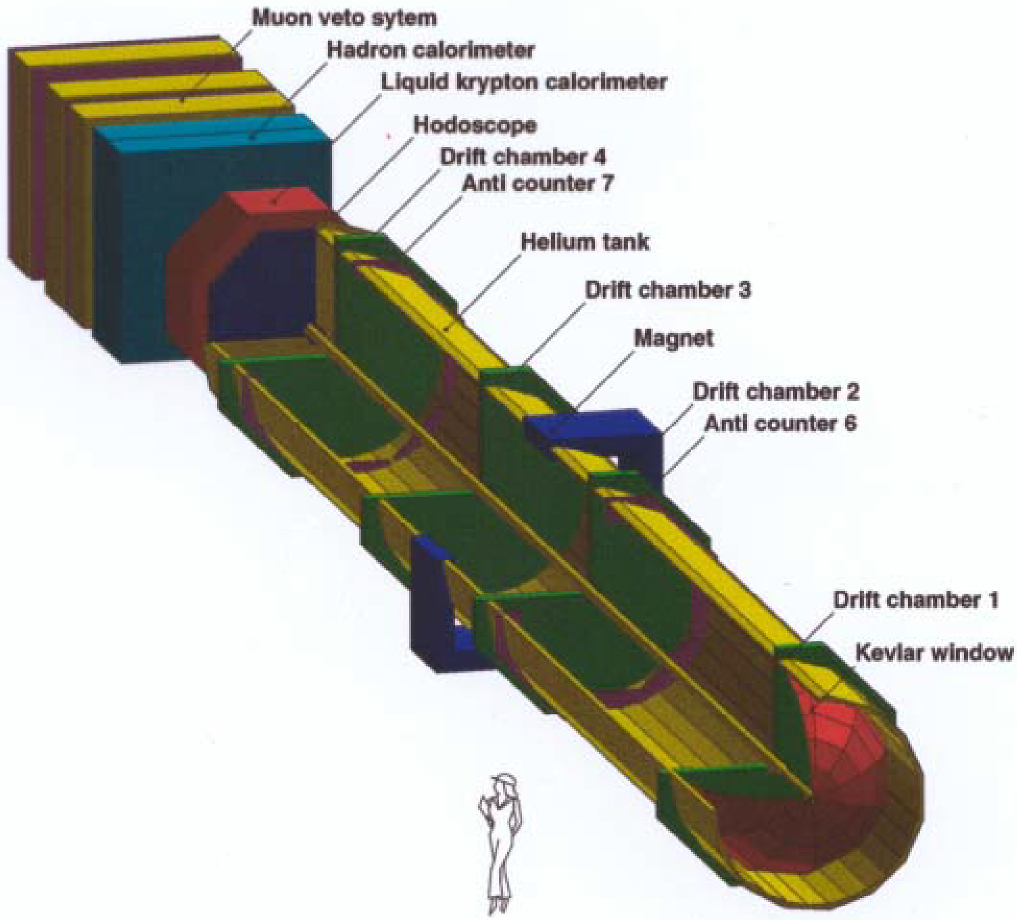
$$R = \frac{K_L^0 \rightarrow \pi^0\pi^0}{K_S^0 \rightarrow \pi^0\pi^0} / \frac{K_L^0 \rightarrow \pi^+\pi^-}{K_S^0 \rightarrow \pi^+\pi^-} \approx 1 - 6 \times \mathrm{Re}(\varepsilon'/\varepsilon)$$

Method Collect the four K^0 decay modes $K_{L,S} \rightarrow \pi^0\pi^0$, $K_{L,S} \rightarrow \pi^+\pi^-$ concurrently in the same detector, with almost collinear K_L and K_S beams.

Statistics to achieve the required accuracy on R, few 10^6 $K_L \rightarrow 2\pi^0$ decays need to be collected.

High intensity 1.5×10^{12} ppp of SPS (CERN)
~ 1 MHz istantaneous particle rate in the detector.

The Detector



charged decays reconstructed by a magnetic spectrometer

$$\sigma(p)/p = 0.5\% \oplus 0.009 \cdot p \ [\mathrm{Ge}V/c^2]$$

neutral decays reconstructed by a quasi-homogeneous Liquid Krypton e.m. calorimeter

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

Sergio Giudici
Scuola Normale Superiore and INFN - Pisa

Neutral Trigger requirments

REQUIREMENTS

- Produce a decision every 25 nsec
- Latency time $\ll$ ring buffer size $\sim 200\mu$ sec.
- Select $\pi^0\pi^0$ events
- Suppress high background

$$K_L \to \pi^0\pi^0\pi^0 \quad \sim 220 \times K_L \to \pi^0\pi^0$$
$$K_L \to \pi^\pm l^\mp \nu \quad \sim 340 \times K_L \to \pi^0\pi^0$$
$$K_L \to \pi^+\pi^-\pi^0 \quad \sim 125 \times K_L \to \pi^0\pi^0$$

OBJECTIVE

- Efficiency greater then 99%
- ~ 1 KHz triggered events rate

DECISION BASED ON:

Number of showers	
Zero moment	$\mathcal{M}_0 = \sum E_i$
First moment	$\vec{\mathcal{M}}_1 = \sum E_i \vec{r_i}/\mathcal{M}_0$
Second moment	$\mathcal{M}_2 = \sum E_i \vec{r_i}^2/\mathcal{M}_0$
Vertex position	$Z_v = \frac{\mathcal{M}_0}{M_K}\sqrt{\mathcal{M}_2 - \vec{\mathcal{M}}_1^2}$
Lifetime	$\frac{M_K}{P_K} \times \frac{Z_{AKS} - Z_v}{c \cdot \tau_s}$

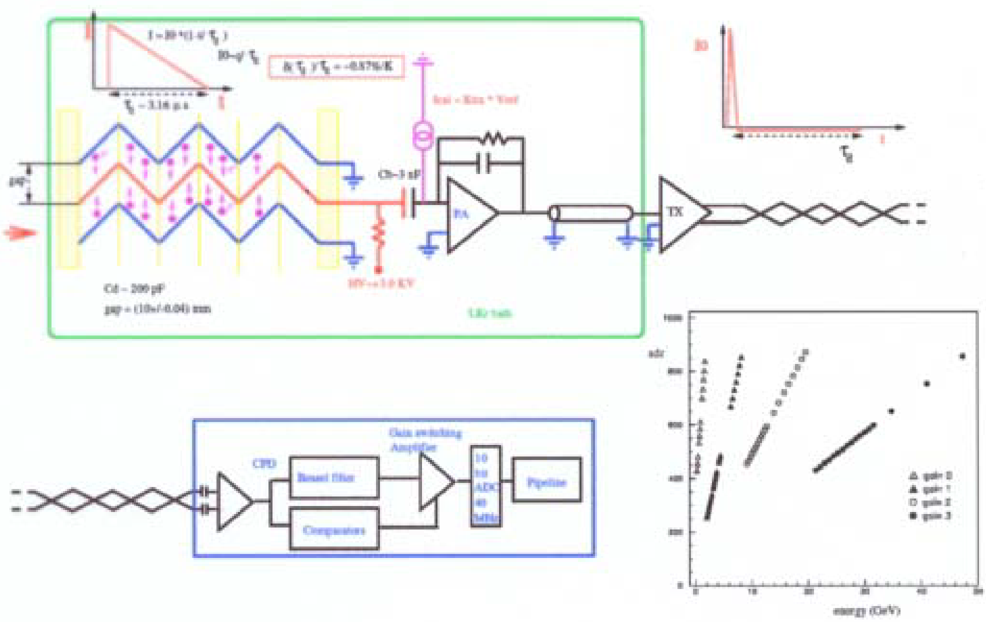
AKS: anti-counter defining the beginning of the decay region

$c \cdot \tau_s \simeq 2.7$ cm

Sergio Giudici
Scuola Normale Superiore and
INFN - Pisa

LKR calorimeter

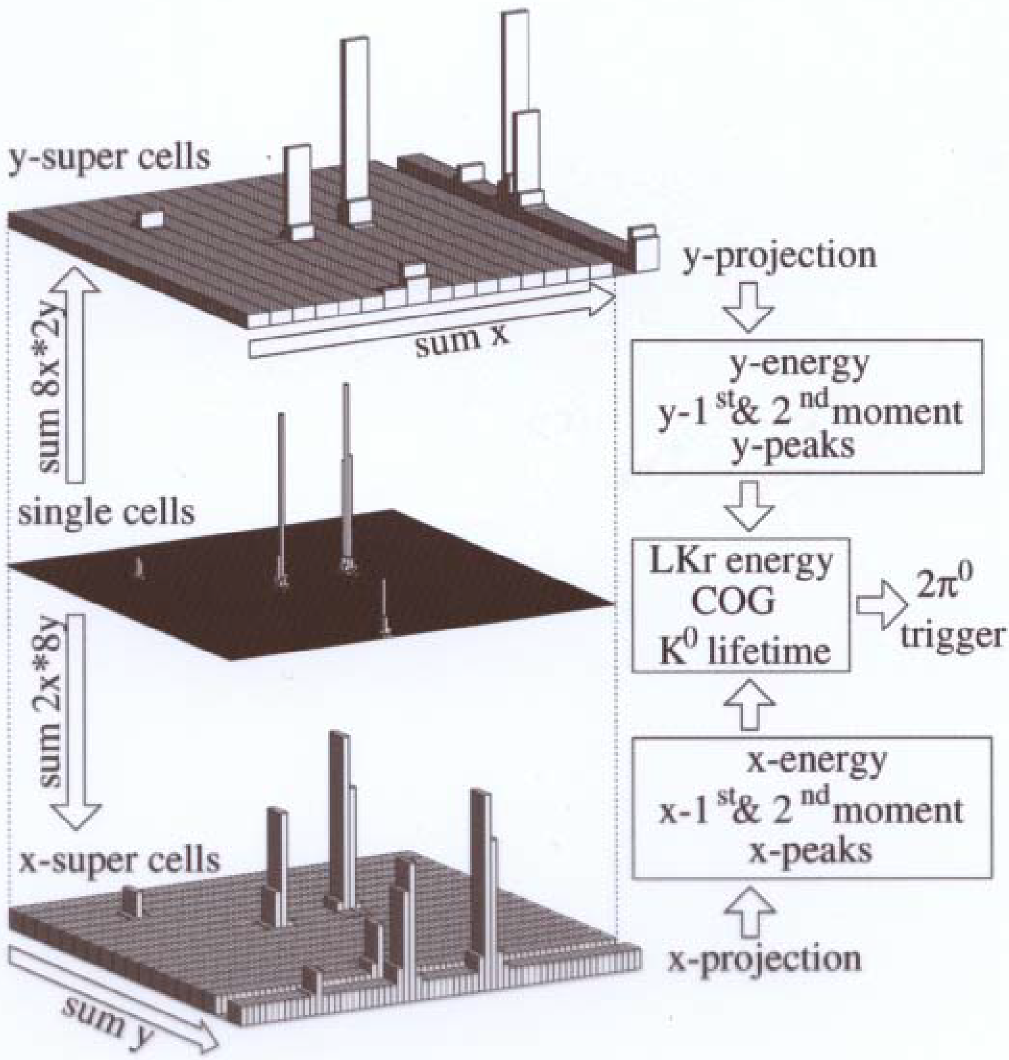
The calorimeter detects $K_{L,S} \rightarrow 2\pi^0 \rightarrow 4\gamma$



- Quasi-homogeneous liquid Krypton ionisation chamber
- Longitudinal tower structure ~ 13500 digitised cells, 1 cell $\sim 20 \times 20 \times 1250\ \mathrm{mm}^3$
- Initial current read out, cold preamplifier
- 40 MHz multirange read out, calibration by precise charge injection
- Data stored in ring-buffer 200 μsec to avoid dead-time

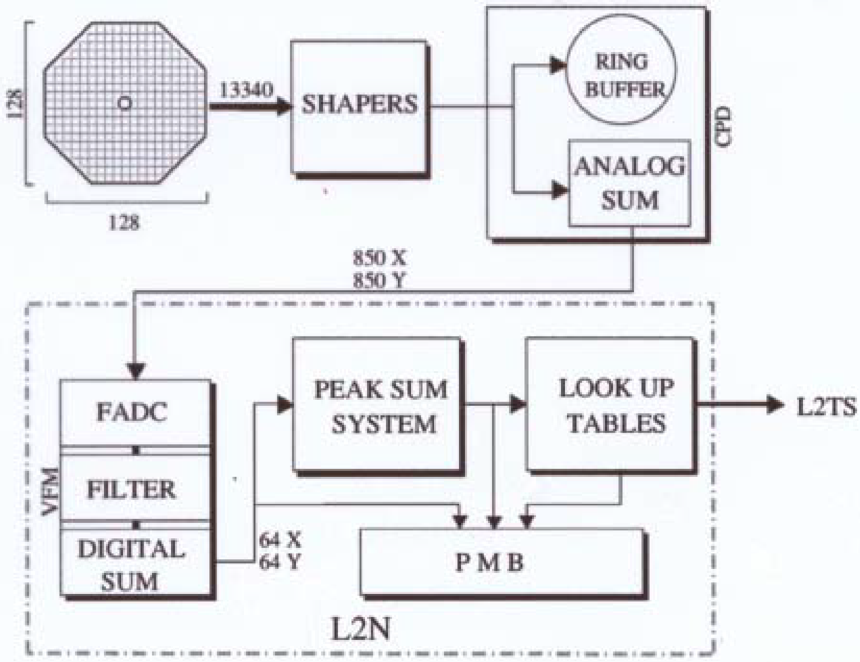
Sergio Giudici
Scuola Normale Superiore and INFN - Pisa

Algorithm



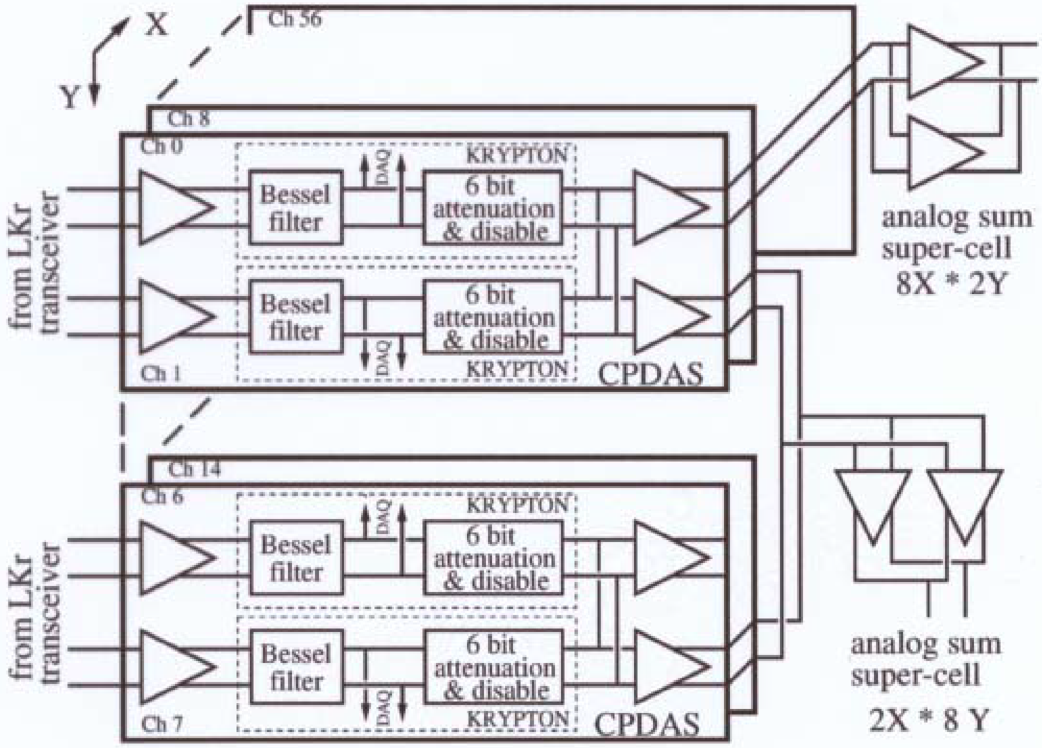
Sergio Giudici
Scuola Normale Superiore and
INFN - Pisa

Neutral Trigger Pipeline

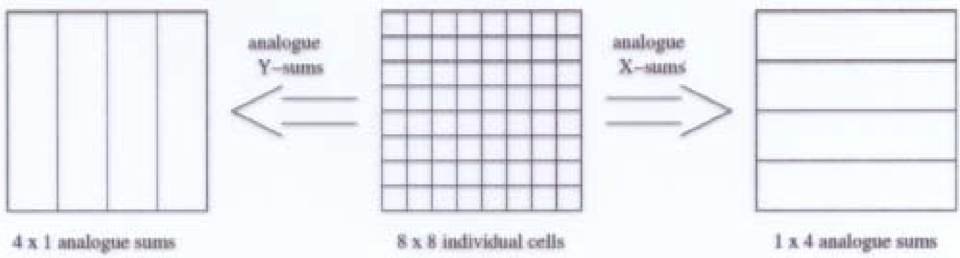


- CPD (Calorimeter Pipeline Digitiser): reduces the granularity, analogue sum circuits form supercells 2×8
- VFM (Vienna Filter Module): Digitises super-cell signals 10-bit 40-MHz FADC, filters the digital signals, sums up the digital super-cell signals into 64 vertical and 64 horizontal projections
- SPY: fans out the content of the projections to the PMB (Pipeline Memory Board) and to the PSS (Peak Sum System). Data recorded into PMB are used in offline analysis to monitor the trigger system.
- PSS: calculates $\mathcal{M}_0$, $\vec{\mathcal{M}}_1$, $\mathcal{M}_2$, the number of peaks in the two views. Peaks are counted in bins of 3.125 nsec to identify accidental hits
- LUT (Look up table): merges both views, calculates physical quantities, applies the trigger cuts, sends to the TS (Trigger Supervisor) the final decision.

CPD

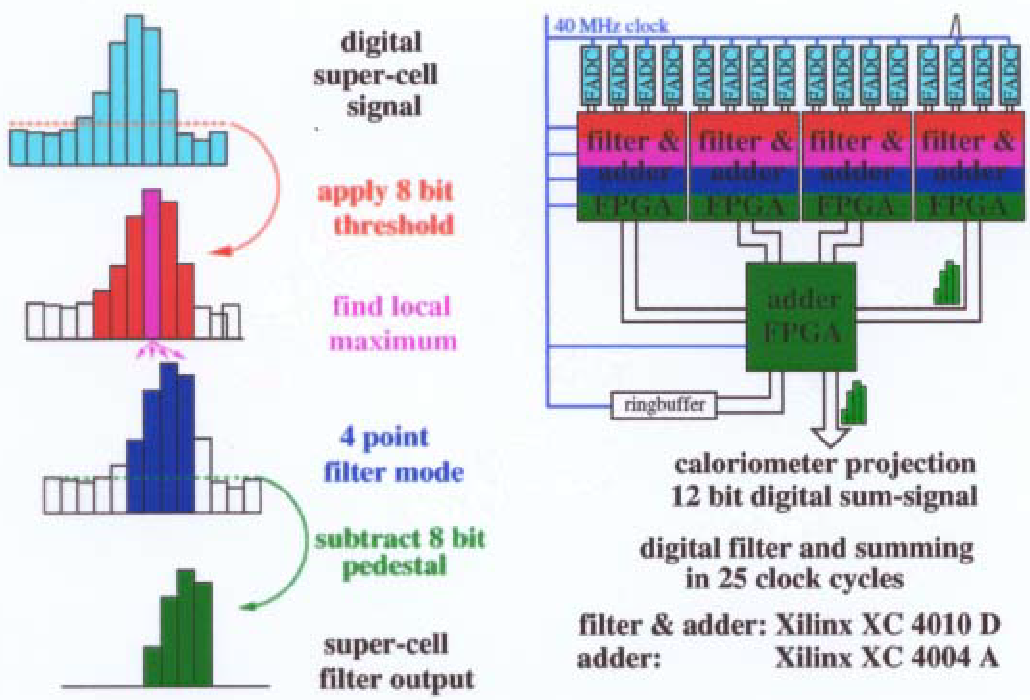


- Bessel filter shapes signal: 70 ns FWHM and flat undershoot 3% of the maximum pulse height
- Signal are summed by analogue electronics
- 64 channels are merged into 4 horizontal and 4 vertical output
- 6-bit attenuator to improve the intercalibration and to disable noisy cells from the sums



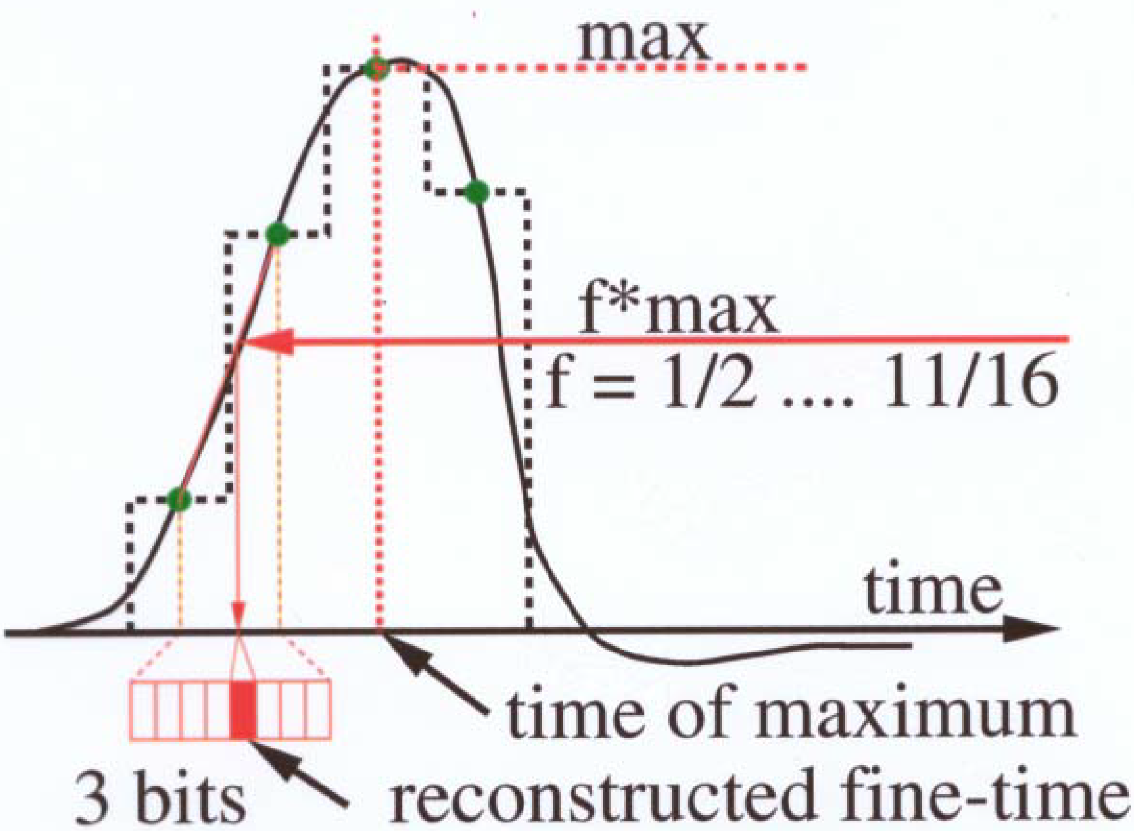
Sergio Giudici
Scuola Normale Superiore and INFN - Pisa

VFM



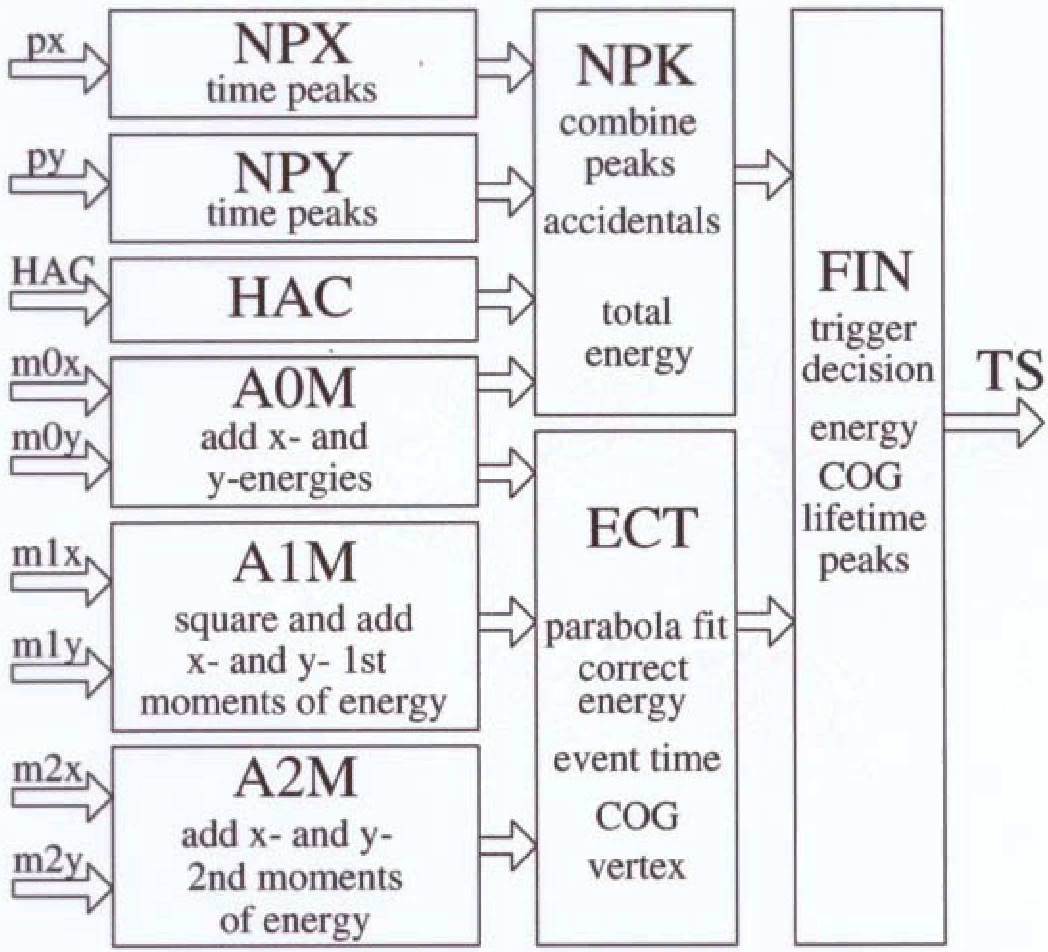
- Analogue sums are filtered and digitised by 10-bits 40 MHz FADC (Philips TDA8760)
- The full sum is done in 25 clock cycles

PSS



- Builds $\mathcal{M}_0$,$\vec{\mathcal{M}}_1$,$\mathcal{M}_2$
- Finds peak in space and time
- Fine time peaks counting using a leading edge interpolation
- 31 clock cycle to get the full information from the projections

LUT

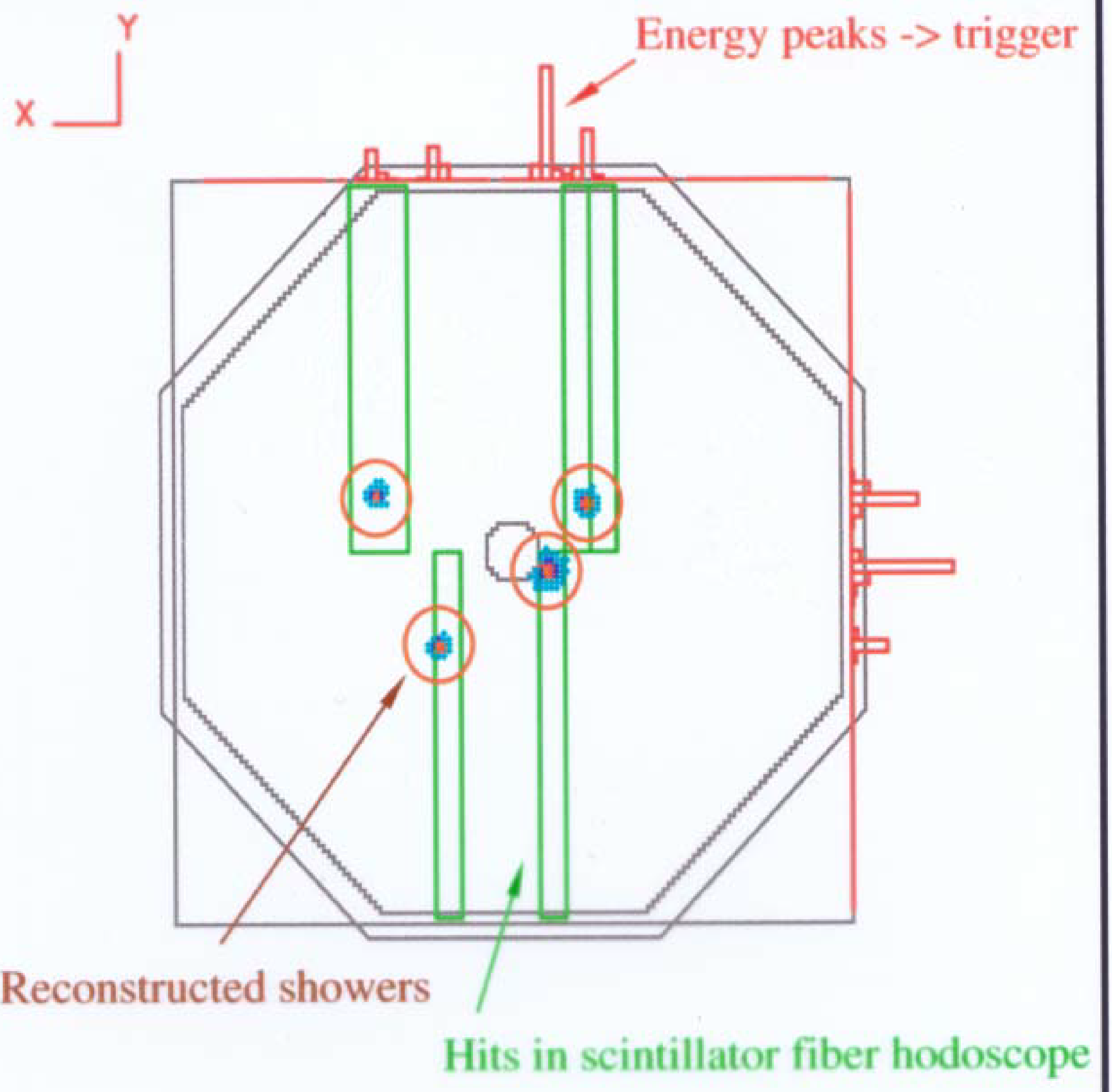


- Combines the result of each view
- Mathematical functions pre-calculated and loaded into the memories
- Latency of the calculation 24 clock cycles
- 3 time slices around the maximum are used for parabolic interpolation to improve energy resolution

Sergio Giudici
Scuola Normale Superiore and
INFN - Pisa

DISPLAY

From the Online Event Display



Sergio Giudici
Scuola Normale Superiore and INFN - Pisa

Performance during the 1997 data taking

Run condition:

- 10% of the final expected statistics
- LKR operating @ 1.5 KV (3.0 KV from 1998)
- Beam intensity @ $\frac{2}{3}$ of the nominal

Configuration for $2\pi^0$ selection:

TRIGGER CUTS	OFFLINE CUTS
$E_K > 50$ GeV	$70 < E_K < 170$ GeV
C.O.G. < 15 cm	< 10 cm
lifetime $< 5.5 \times \tau_{K_S}$	$< 3.5 \times \tau_{K_S}$
X,Y peaks ≤ 5	4 γ clusters

Rates:

Trigger	K_S only (Hz)	K_S+K_L (KHz)
minimum bias ($E_{tot} > 30$ Gev)	1800	110
$2\pi^0$ trigger	26	1.8
$2\pi^0$ trigger no lifetime,no peaks	80	17
Control trigger NHOD $\otimes \bar{\mu} \otimes A\bar{K}L$	125	31

In the Off-line reconstruction ~ 10 decays $K_S \rightarrow \pi^0\pi^0$ and ~ 5 decays $K_L \rightarrow \pi^0\pi^0$ are reconstructed per spill (2.58 s nominal SPS spill lingth)

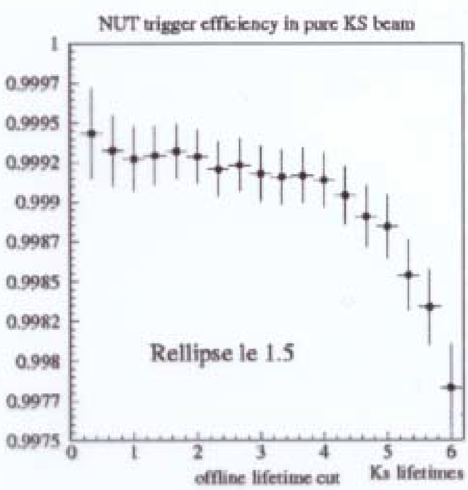
Efficiency during the 1997 data taking

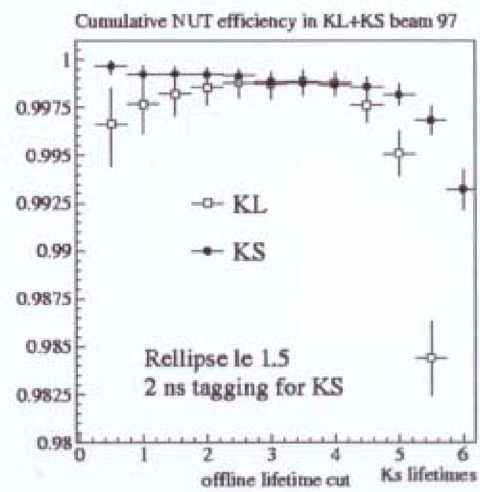
- Control Trigger provided by Sci. Fi. (NHOD) is used to monitor the neutral trigger (NUT) efficiency ϵ
- Efficiency is computed by comparing the number of offline reconstructed events triggered by NHOD and NUT with the number of offline reconstructed events triggered only by NHOD

$$\epsilon = (NHOD \bigcap NUT)/NHOD$$

- Binomial error is quoted

$$\sigma^2(\epsilon) = \epsilon(1-\epsilon)/NHOD$$





(Figures from Gunther Fischer 's PHD thesis)

$\epsilon = 99.91 \pm 0.02$ % pure K_S beam (1997)
$\epsilon = 99.88 \pm 0.04$ % $K_S \oplus K_L$ beam (1997)
$\epsilon = 99.93 \pm 0.02$ % $K_S \oplus K_L$ beam (1998)

REFERENCE: Fischer et al., **NIM** A 419,623-631,(1998)

- A fully-pipelined trigger to select $2\pi^0$ events has been implemented
- The system is dead-time free
- Total latency time 128 clock cycles $\sim 3.2\mu$sec
- High Rate Reduction
- The system is measured to be highly efficient
- No systematic effect on $\mathrm{Re}(\varepsilon'/\varepsilon)$ is expected from the neutral trigger