A 40 MHz Pipelined Trigger for $K \to 2\pi^0$ Decays for the Cern NA48 Experiment

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NA48 Experiment

The NA48 CERN experiment aims at measuring the CP violation parameter $Re(\varepsilon\prime/\varepsilon)$ with a precision of $\sim 10^{-4}$

This requires to collect $> 10^6$ $K_L \to 2\pi^0$ decays

$\Downarrow$

☞	High beam intensity	1.5×10^{12} ppp (at CERN SPS)
☞	High resolution detector	Liquid Krypton Calorimeter
☞	Fine detector granularity	128 × 128 cells (2 cm × 2 cm each)

$\Downarrow$

challenging trigger design

NA48 Neutral Trigger

To select relevant neutral decays:

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

NA48 has implemented a fully pipelined software trigger based on the ~ 13000 calorimeter cells flash-digitised information

Required performances

- ☞ rate reduction from $\sim 1\,MHz$ to $\sim 2.5\,KHz$
- ☞ $> 99\,\%$ efficiency
- ☞ latency time $\sim 3\,\mu sec$
- ☞ $40\,MHz$ pipeline clock frequency
- ☞ no dead time

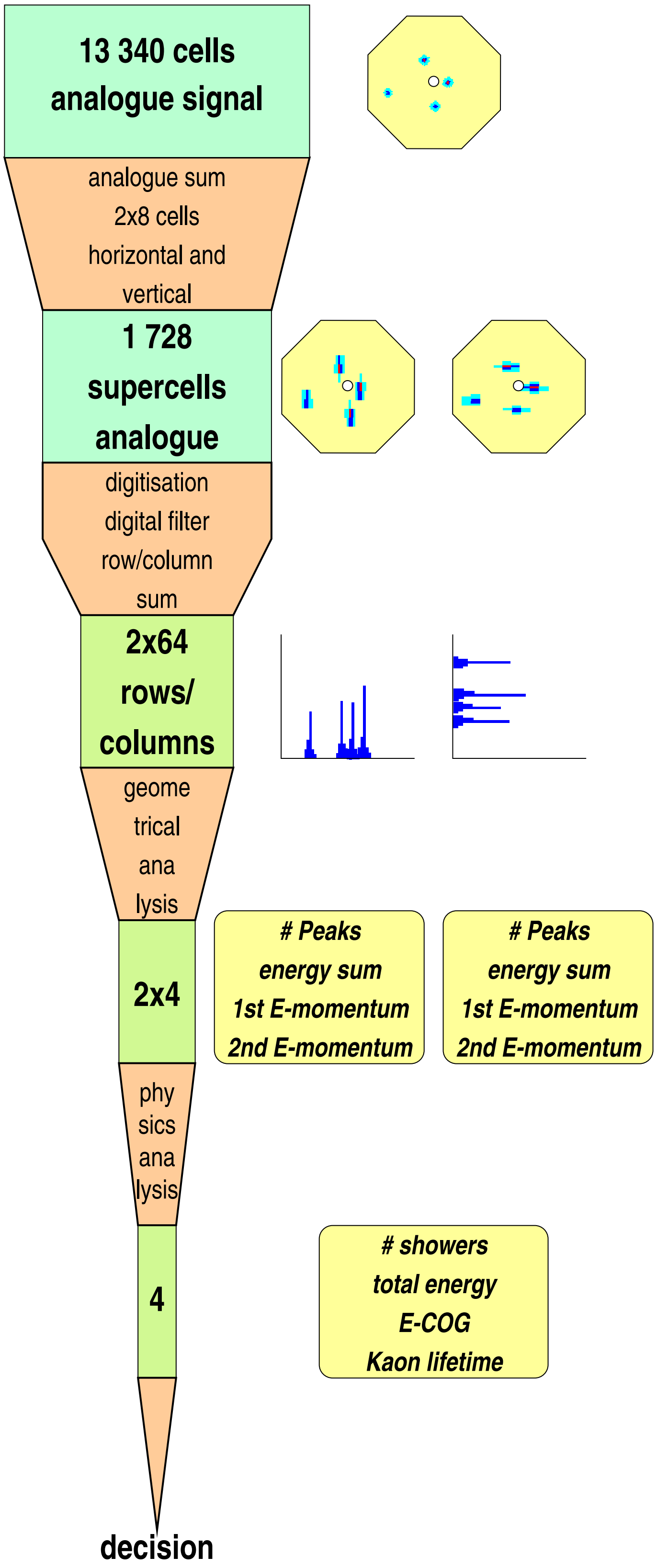
Trigger Algorithms

- ☞ Reduce calorimeter information to 64 vertical and 64 horizontal projections
- ☞ compute and cut on
  - numbers of near-in-time clusters ($\Delta t \leq 9\,nsec$) in each projection
  - total energy in the detector
  - energy center of gravity
  - decay vertex position

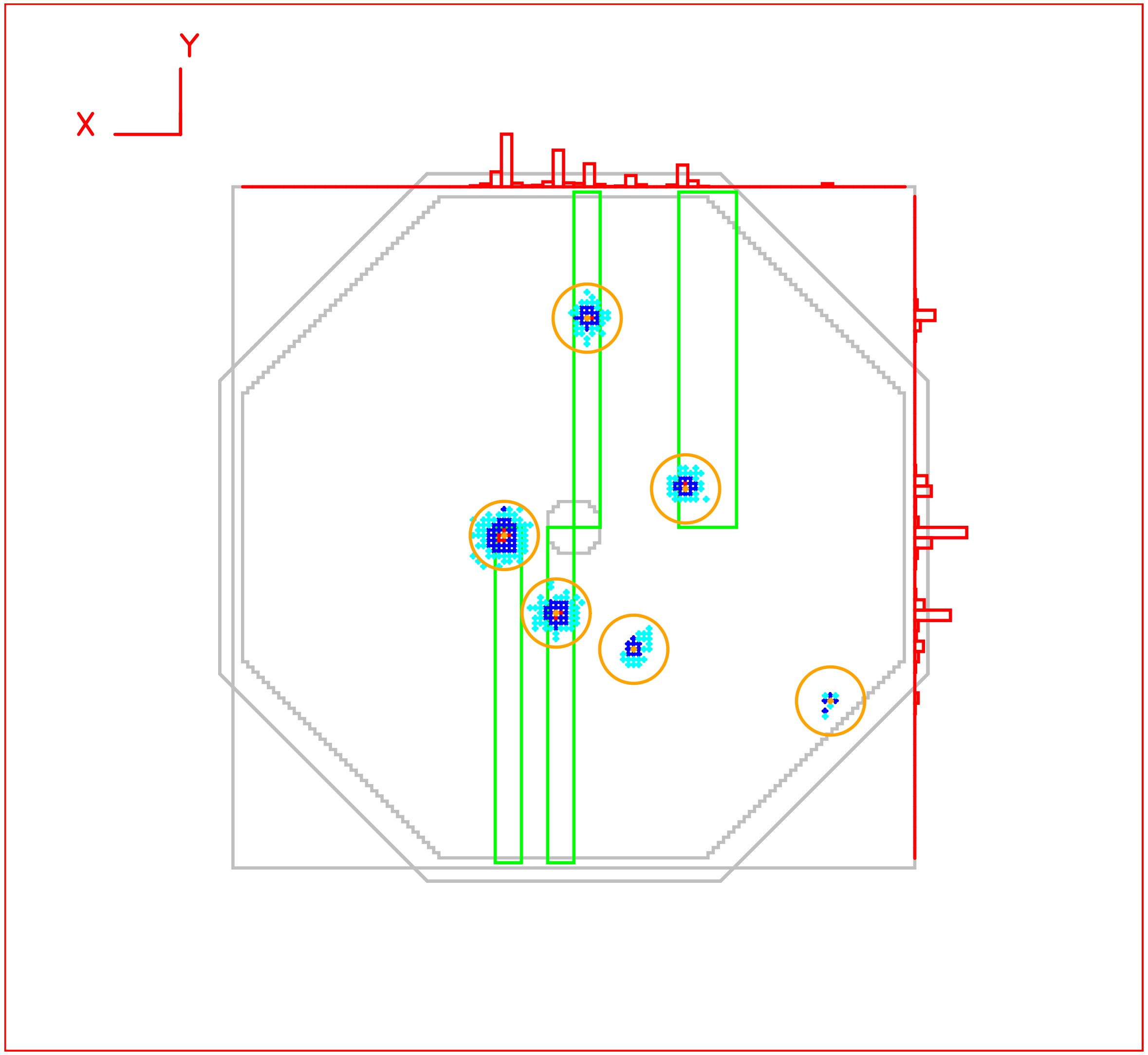
$$\Downarrow$$

generate a trigger decision every 25 nsec

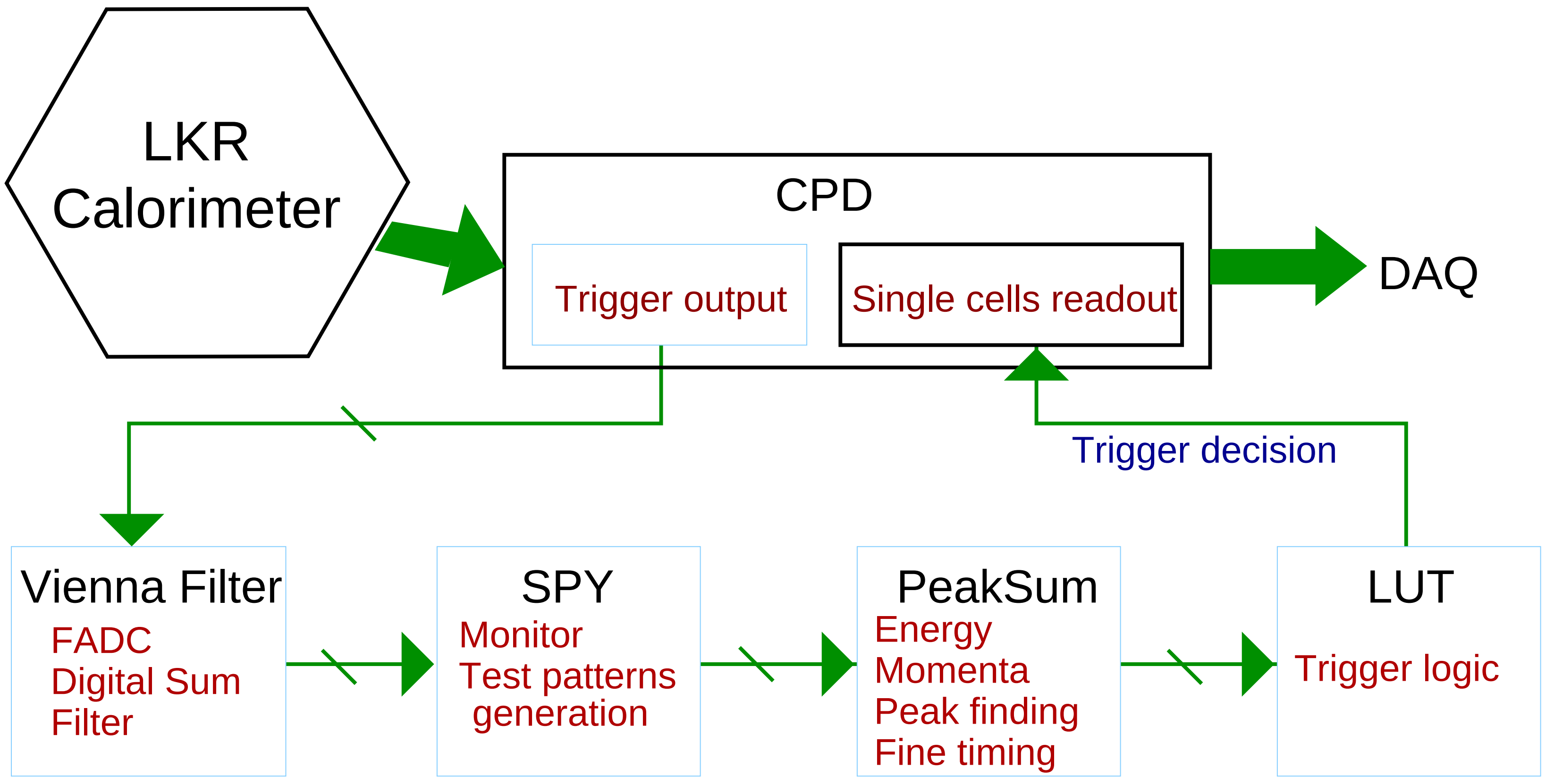
Scheme of Trigger Data Processing



Neutral Event Data



Trigger Components



Calorimeter Pipeline Digitisers

- 216 FASTBUS interfaced modules based on KRYPTON ASIC chip (designed by NA48 CERN group)
- each module handles 8×8 analog calorimeter signals

Provide

☞ single cell signals shaping and digitisation $\longrightarrow$ DAQ

☞ 2×8 and 8×2 analog sums $\longrightarrow$ Trigger

Trigger outputs features

☞ independent 6 bit programmable attenuation factor (0.48-0.82 range) for every calorimeter channel

☞ possibility of disabling any single channel from sums

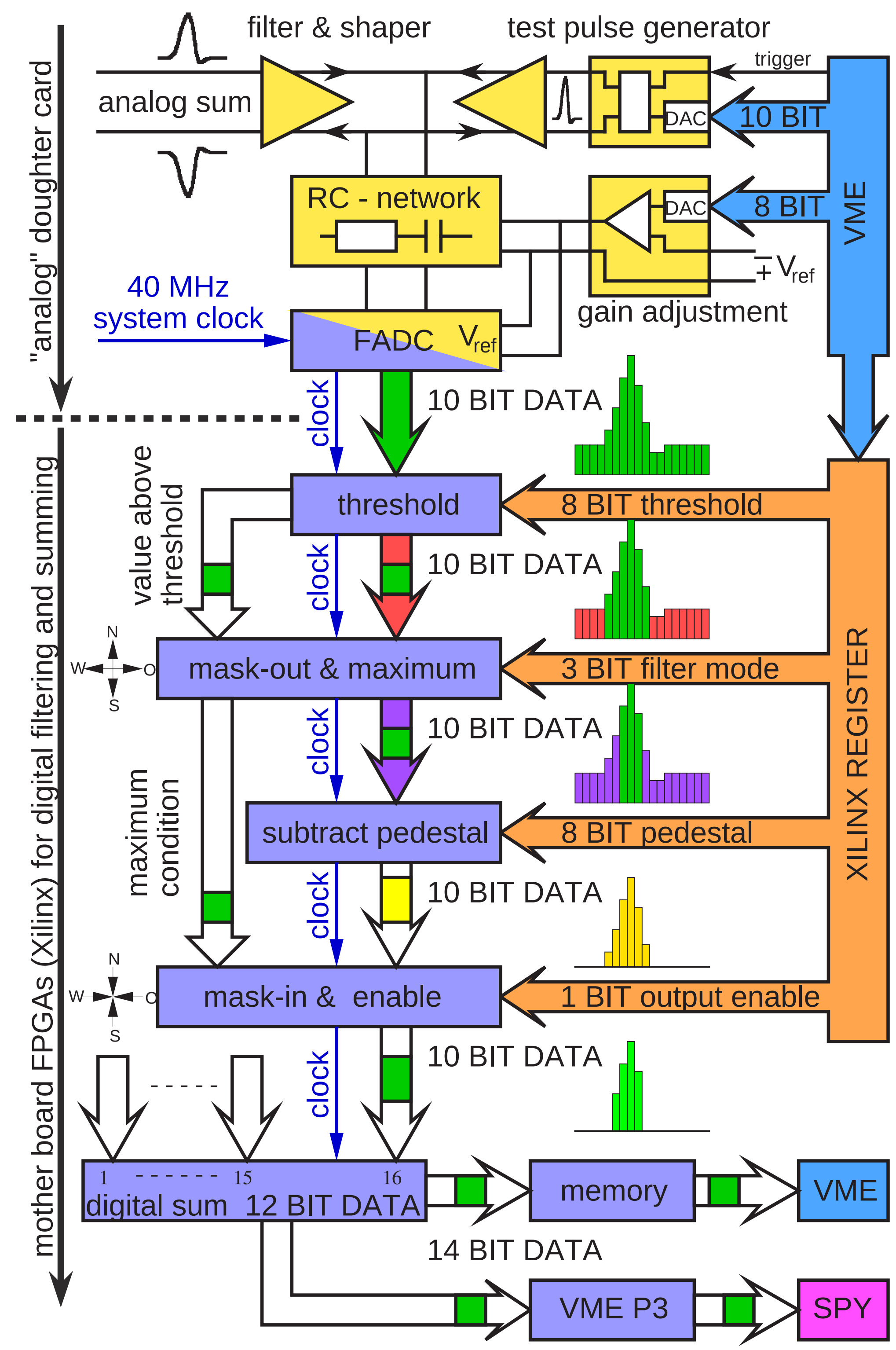
Vienna Filter Modules

- 64 VME 9U modules
- each module has 32 analog inputs
  and 2 digital 14 bit outputs

Features

☞ digitise analog inputs	10 bit FADC
☞ digitally filter data	8 XILINX per board
☞ sum digital pulses to complete calorimeter projections	2 XILINX per board

Vienna Filter Scheme



Peak Sum System

- 2×16 VME 9U SPY modules
  monitor & test
- 2×8 VME 9U PEAK SUM modules
- 2×1 VME 9U FINAL RECOMBINATOR modules
  processors

P.S. and F.R. are based on the NTP VLSI semi-custom CMOS chip (designed by PISA INFN group)

Features

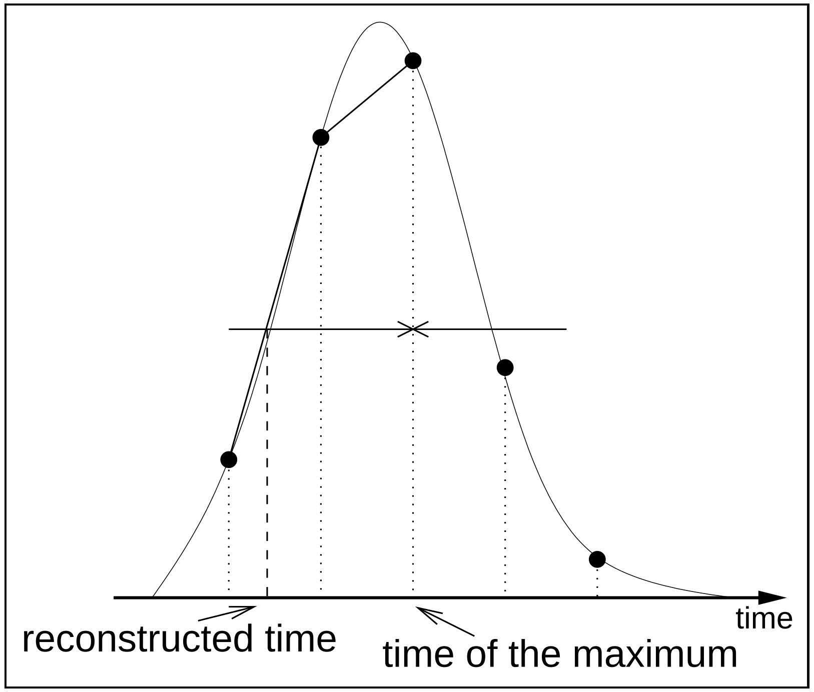
- ☞ compute $\sum_i E_i$, $\sum_i E_i \cdot x_i$ and $\sum_i E_i \cdot x_i^2$ for horizontal and vertical projections
- ☞ find clusters in each of the 2 projections
- ☞ reconstruct time of each cluster in steps of 3.125 nsec
- ☞ full stand-alone testing facility available

Cluster Finding Algorithm

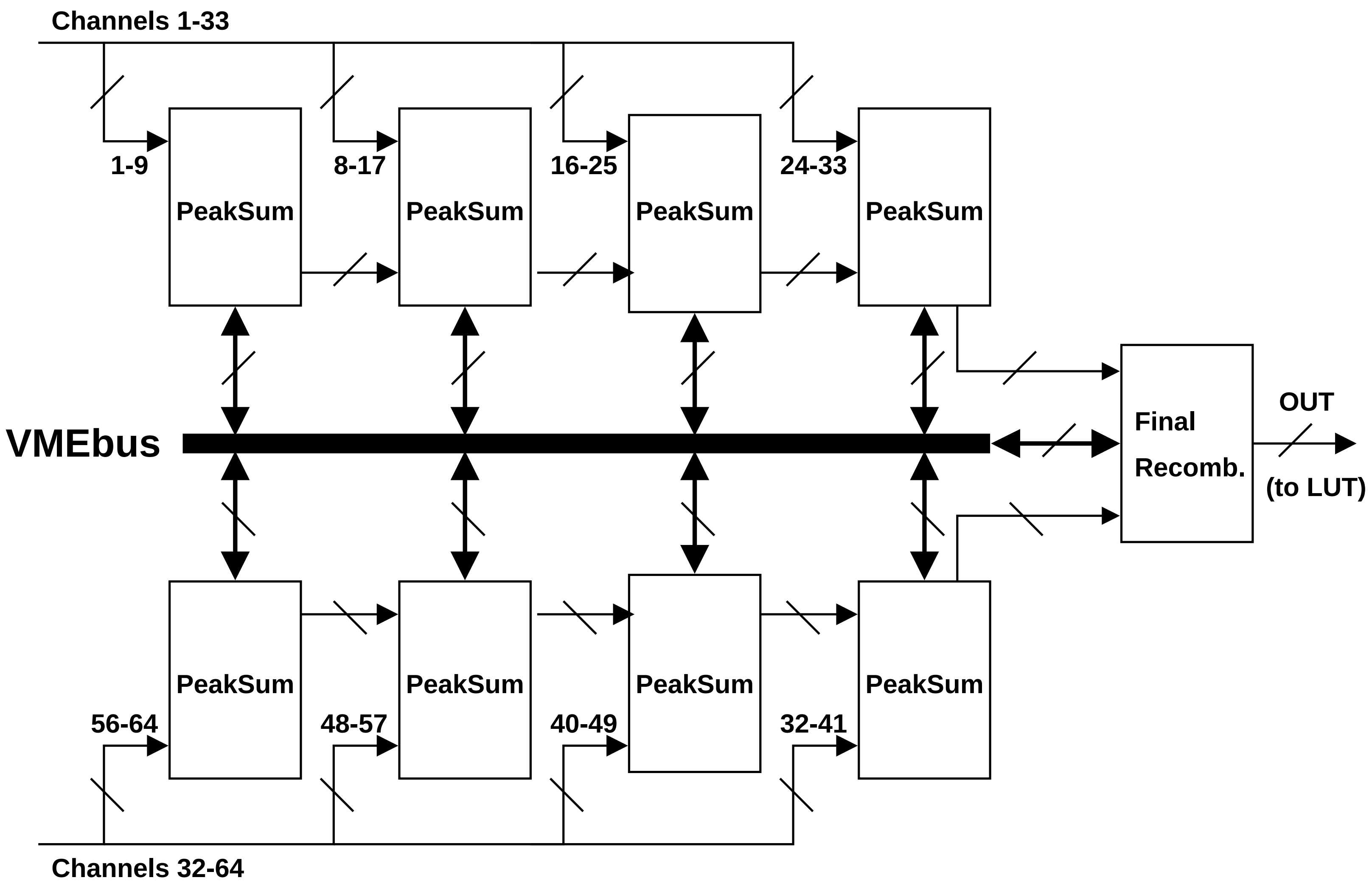
A projection cluster is defined by the coincidence of a SPACE and TIME peak

↓

time at half maximum of cluster pulses is reconstructed by linear interpolating 3 rise time samples



Peak Sum Scheme

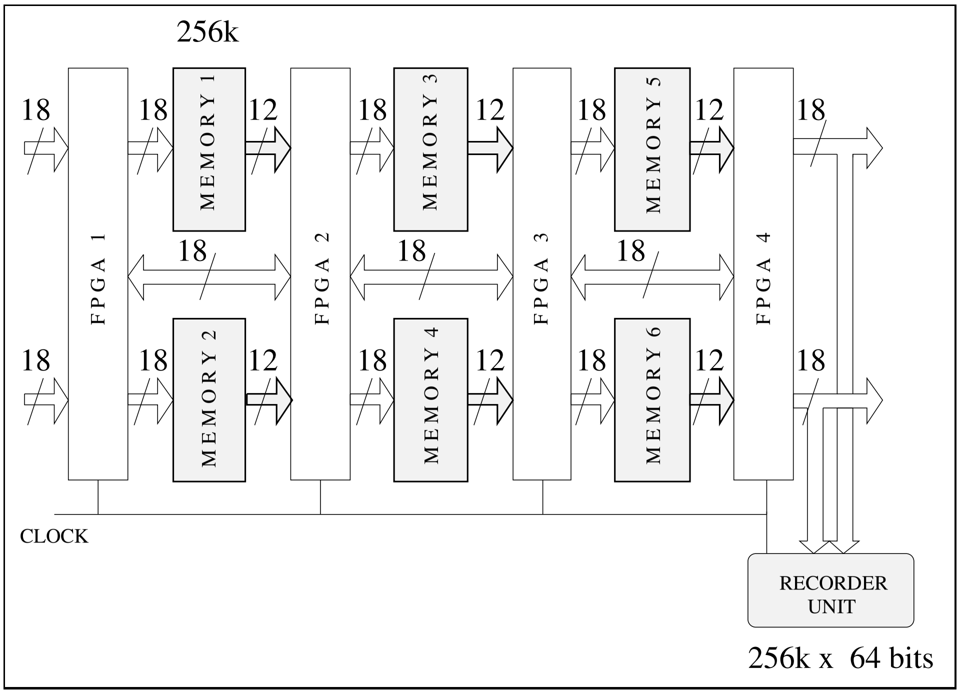


(Module to module connections are made customizing J2 and J3 VME buses)

Look Up Table Modules

- 8 FASTBUS modules

highly flexible design



☞ compute total energy
energy center of gravity
K vertex position

☞ merge cluster information
in ~ 9 nsec intervals

☞ take final trigger decision

Trigger Performances

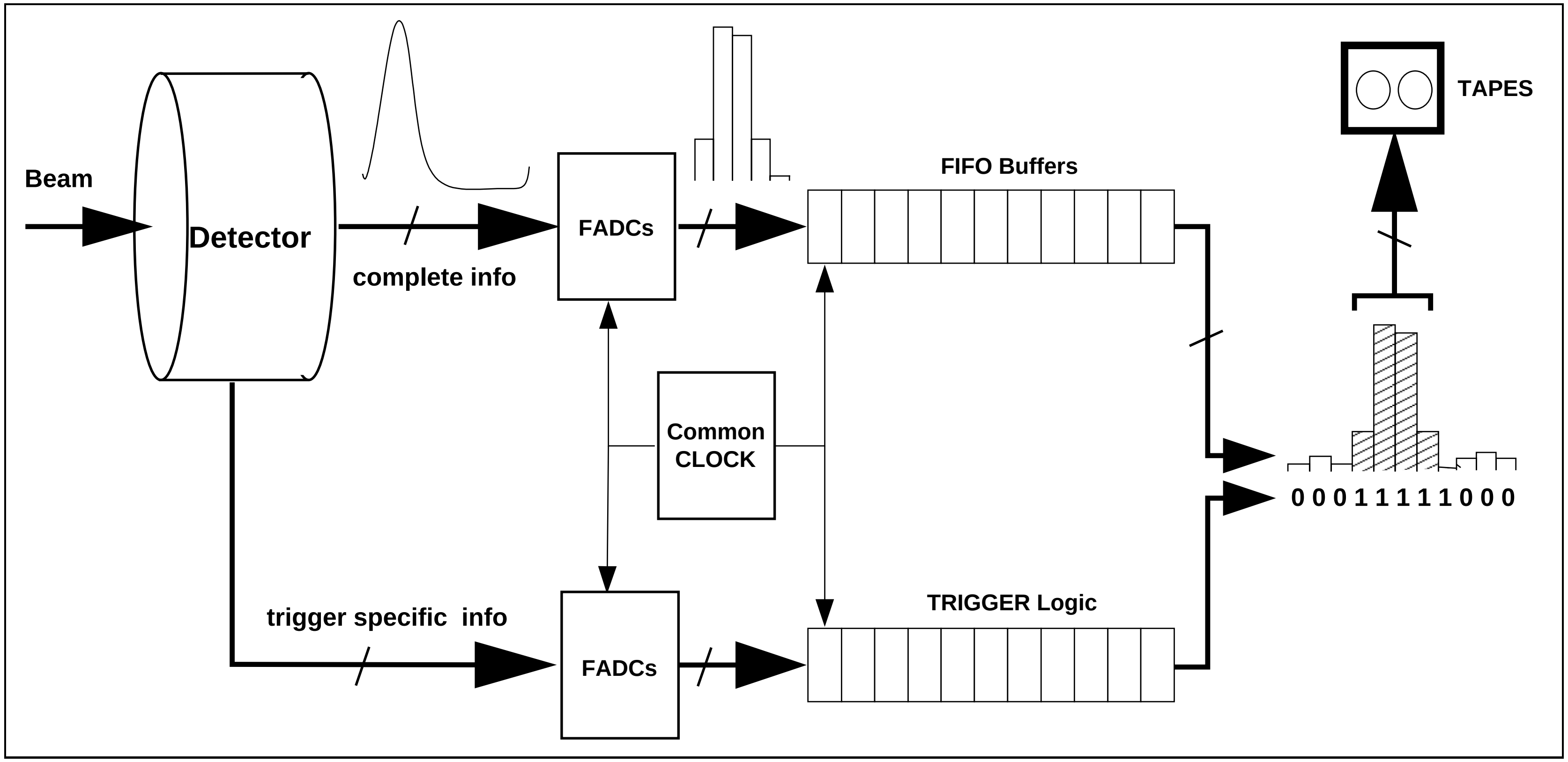
the complete trigger system

- ☞ has been installed in NA48 apparatus
- ☞ is working in stable conditions
  with $10^{12}\,ppp$ beam intensity
- ☞ output rate: ~ 4600 events per burst $\Rightarrow$ $(\approx 2.5\,KHz)$

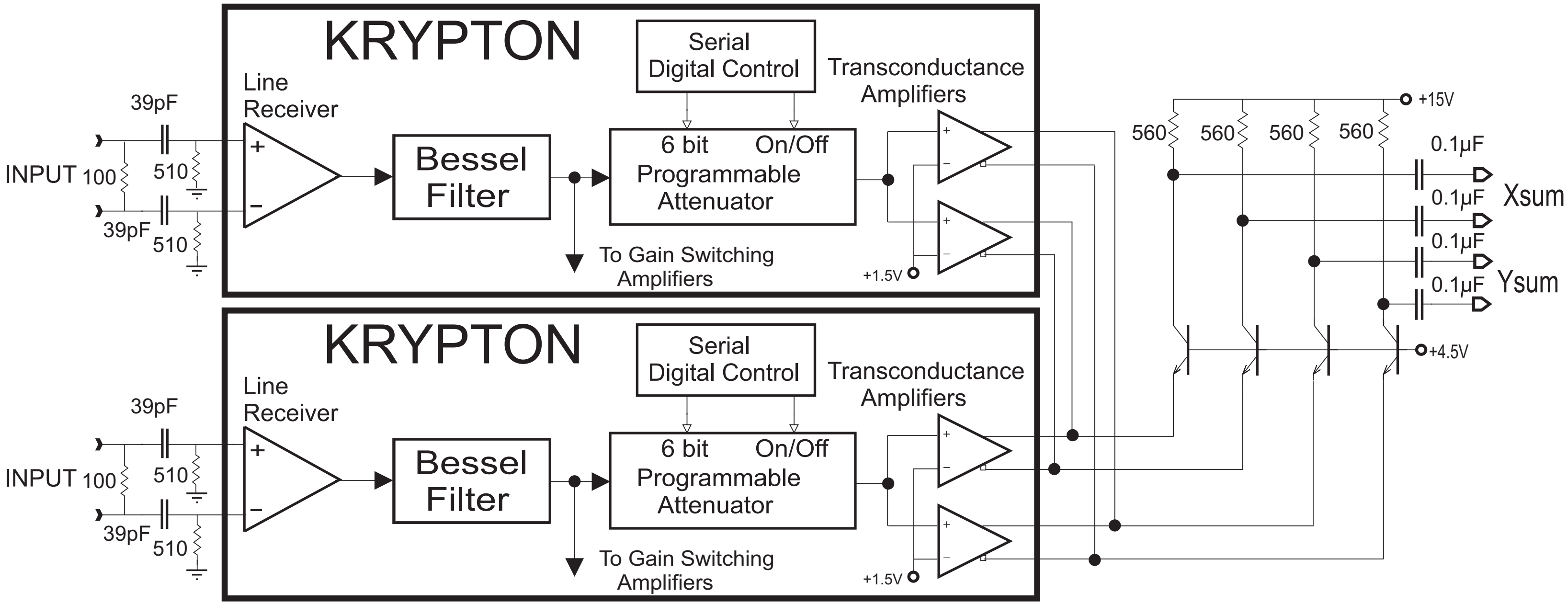
preliminary data analysis shows an efficiency

$$\boxed{\varepsilon\ >\ 99\%}$$

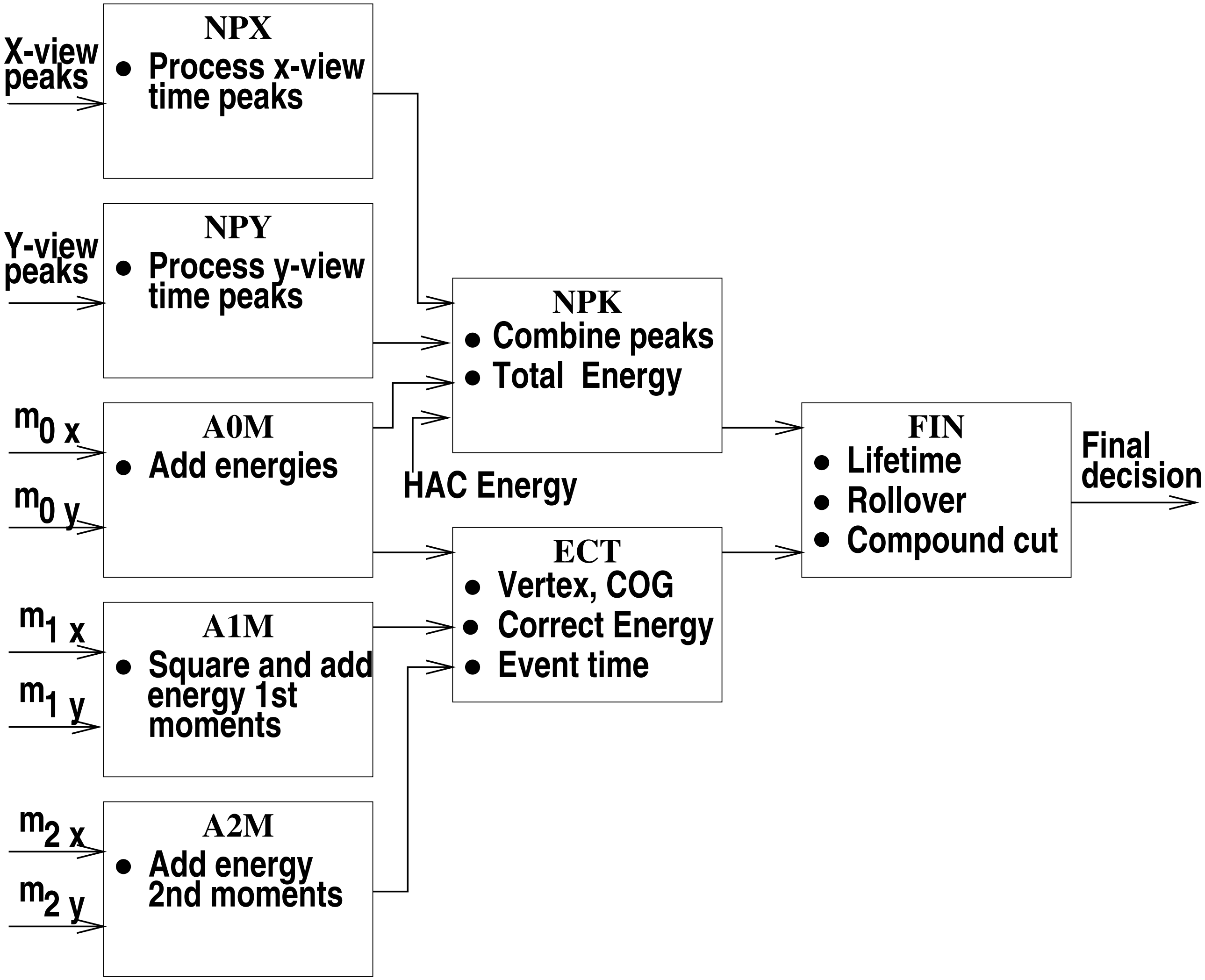
Pipeline Scheme



CPD Trigger Outputs



L.U.T. Connections



Calorimeter Readout Scheme