# TNT2-like digital electronics processing for Phoswich detectors

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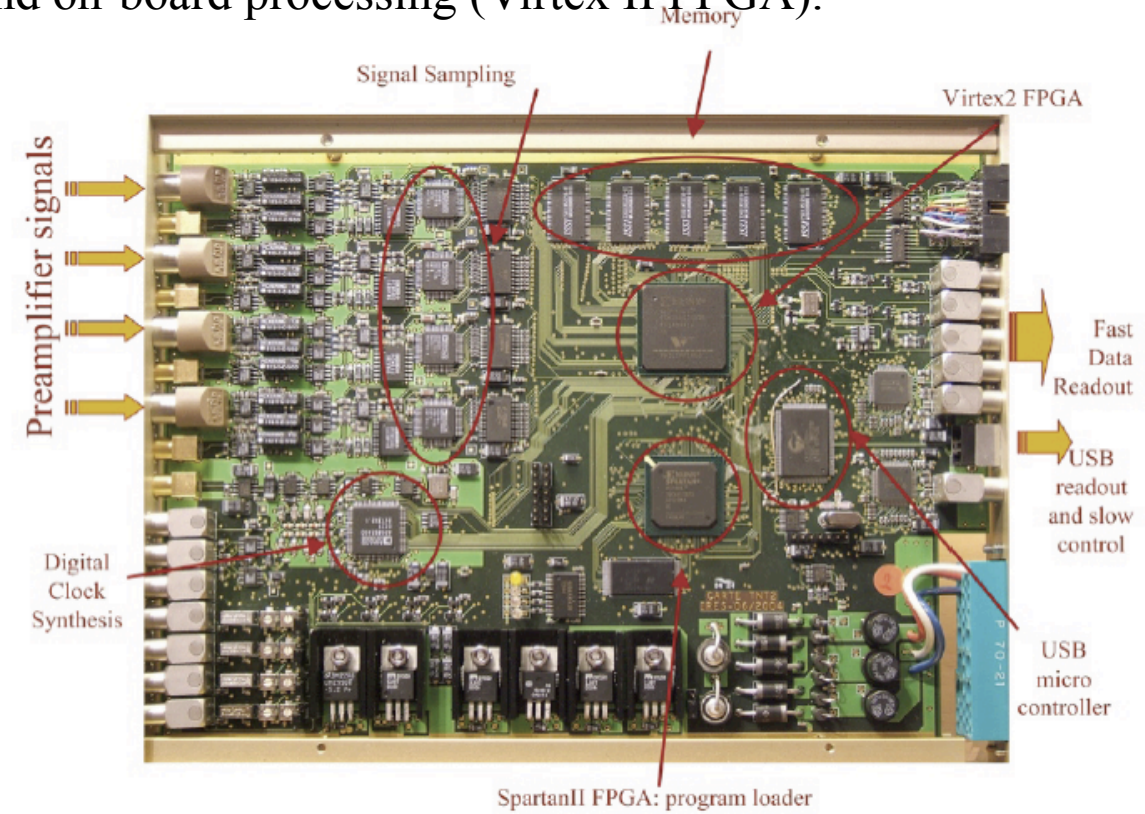
Paris Workshop 2011 January 12-14, Strasbourg

# Summary:

- **Digital electronics development @ IPHC**
  - **TNT2 Card**
  - **Dt5 Card development**
- **Digital QDC analysis of PW**
- **Jordanov Shaping analysis of PW**
- **What next**

# TNT2 Card

TNT2 is a four channel NIM-based card with 14 bits, 100 MHz digitizers (AD6645) and on-board processing (Virtex II FPGA).



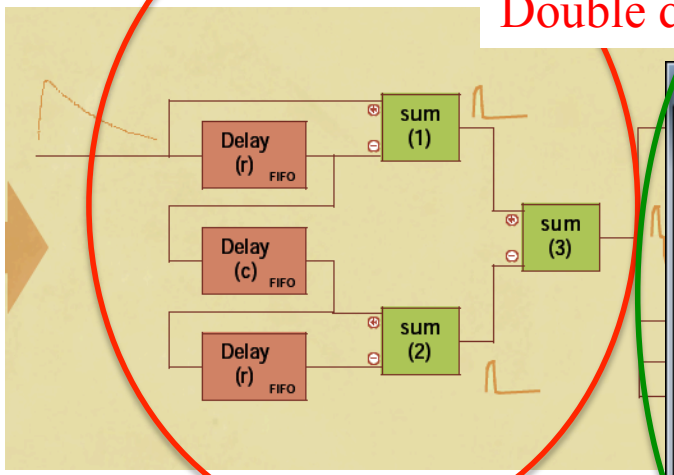

TNT is coupled with the acquisition software TUC which drives slow control, monitoring of the boards and data visualisation and saving

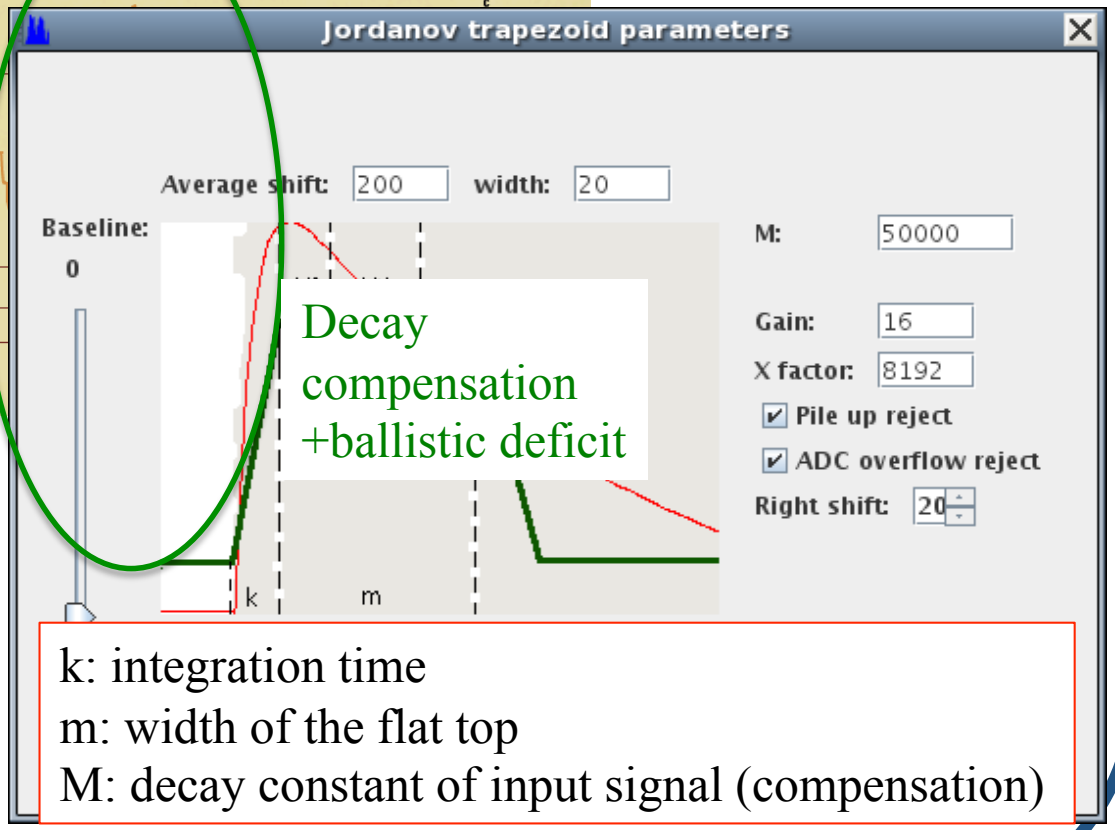
TUC allows the reconfiguration of the embedded functionalities running on the FPGAs.

# Jordanov Shaping principle:

Jordanov algorithm was developed to produce trapezoidal shape

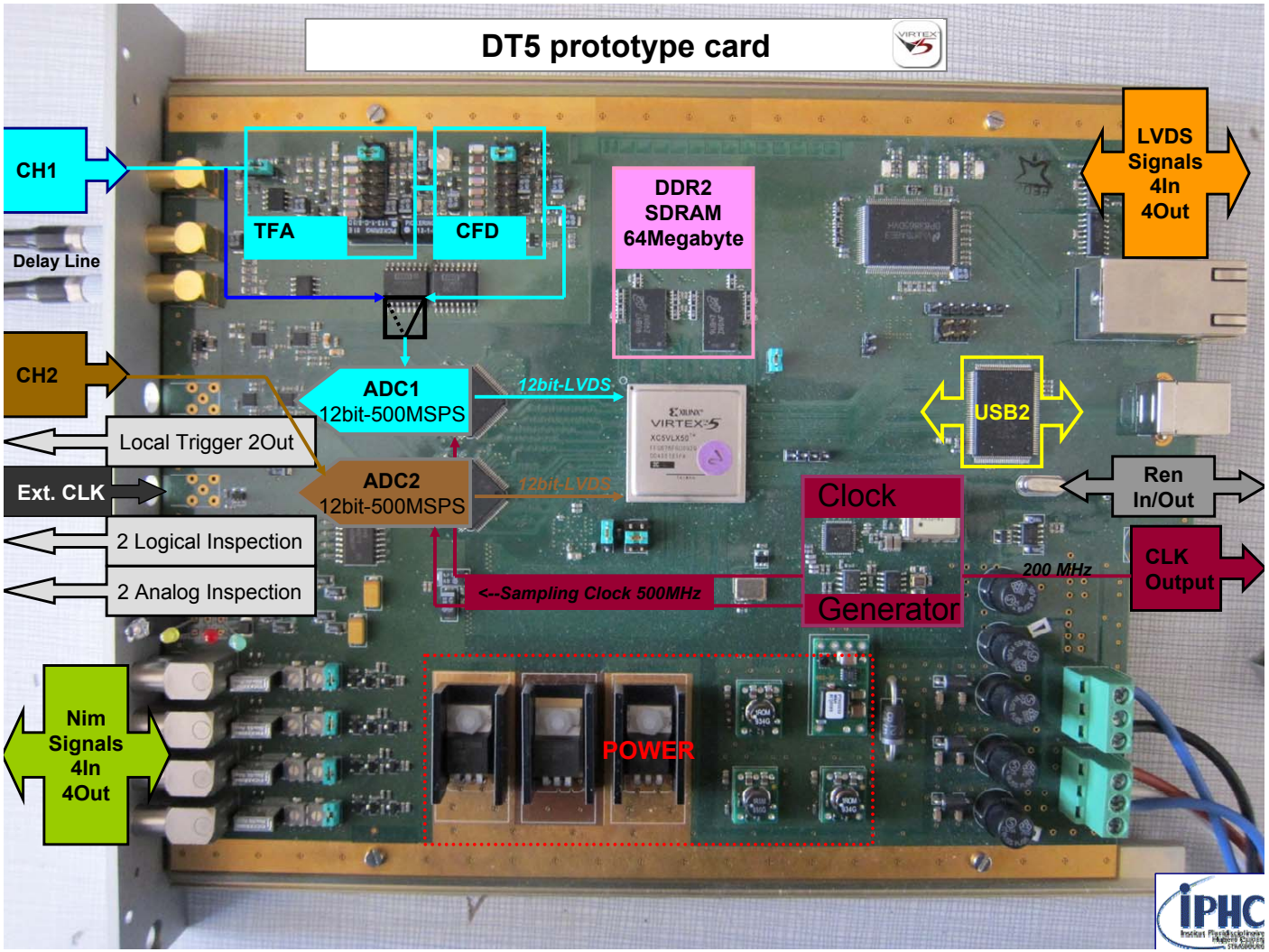
Double delay line system




Provide:
Good energy resolution
Low ballistic deficit
High counting rate
Baseline stability

# DT5 Card Development



# DT5 Card Development

## Now:

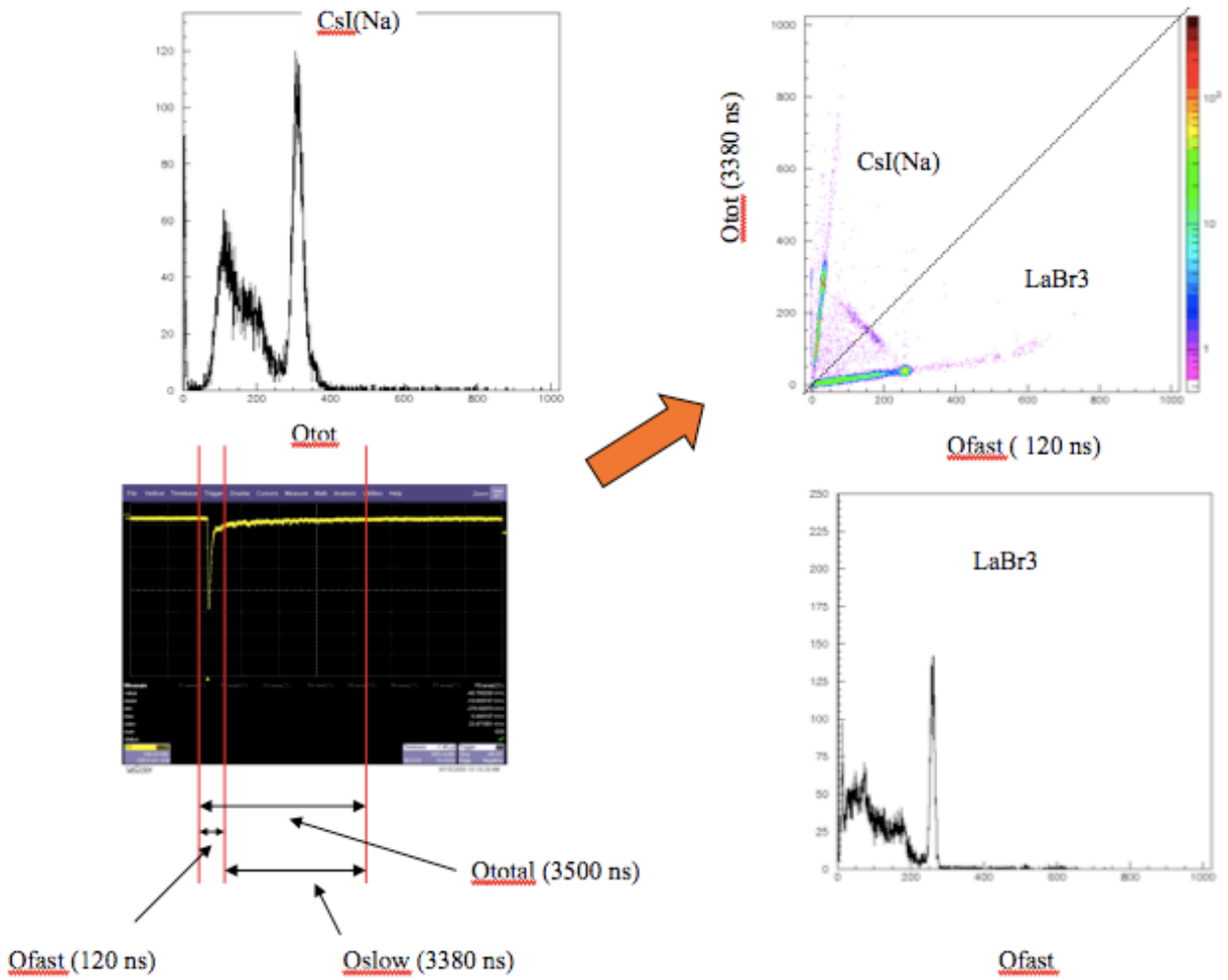
- Production of 2 prototype cards (around 4k€ /card)
- Dvpt of the User Control software (partially based on TUC for TNT2)

## Under development:

- Oscilloscope mode with 2 channels at 250 MHz or 1 channel at 500 MHz
- Energy mode at 250 MHz, next step at 500 MHz
- Analogue CFD & TFA, TDC implemented in the FPGA (60 ps LSB)

# DIGITAL QDC

Measurement principle:
Digitalisation and integration of the output signal in different gates

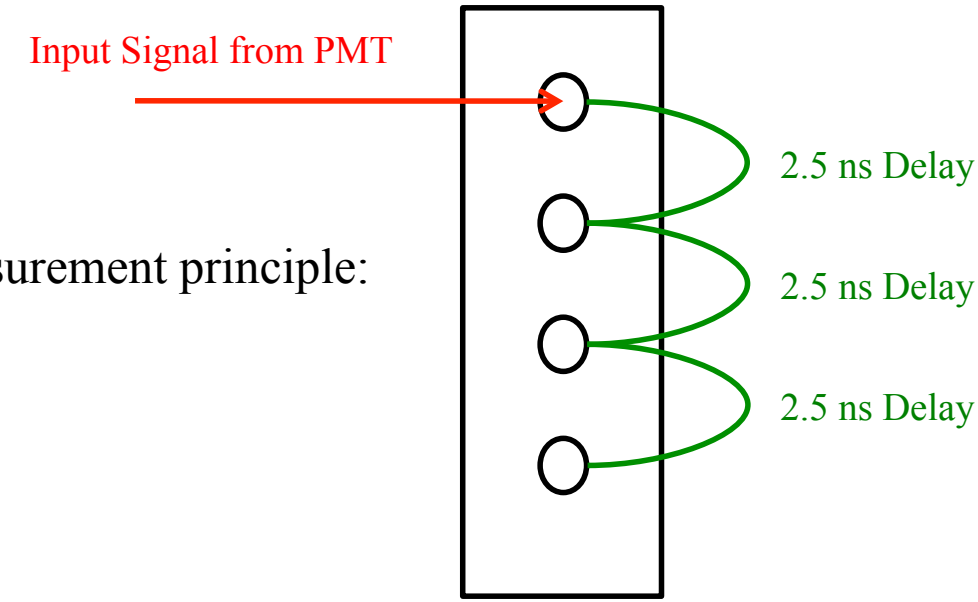


# DIGITAL QDC

Electronics Card used :

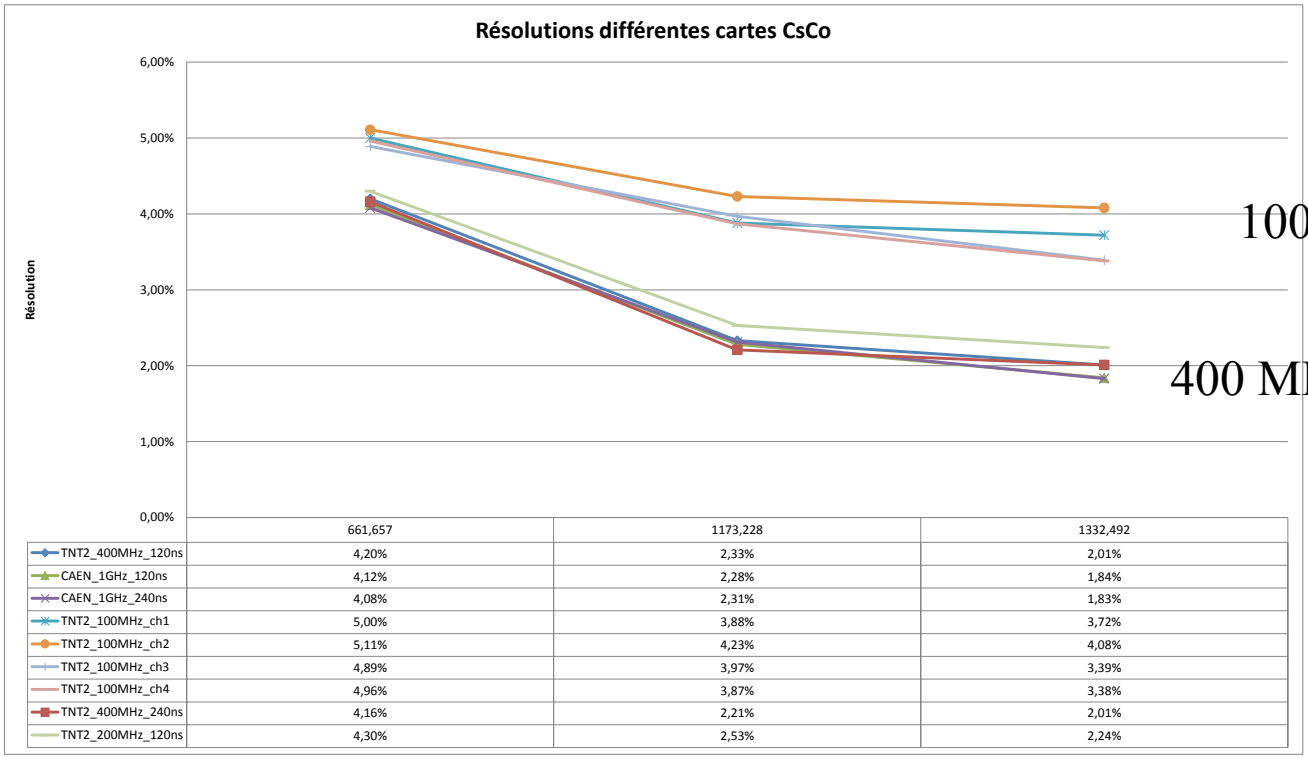
- TNT2 Card at **100 MHz**, with implementation of integration in TUC
- TNT2 Card at **400 MHz**, with implementation of the convolution and integration in the TUC
- V1751 Digitizer Card From CAEN **1GHz.**

400 MHz measurement principle:




The 4 signals are afterward convoluated to create a 400 MHz signal

# Obtained Results:




| | 661,657 | 1173,228 | 1332,492 |
|---|---|---|---|
| TNT2_400MHz_120ns | 4,20% | 2,33% | 2,01% |
| CAEN_1GHz_120ns | 4,12% | 2,28% | 1,84% |
| CAEN_1GHz_240ns | 4,08% | 2,31% | 1,83% |
| TNT2_100MHz_ch1 | 5,00% | 3,88% | 3,72% |
| TNT2_100MHz_ch2 | 5,11% | 4,23% | 4,08% |
| TNT2_100MHz_ch3 | 4,89% | 3,97% | 3,39% |
| TNT2_100MHz_ch4 | 4,96% | 3,87% | 3,38% |
| TNT2_400MHz_240ns | 4,16% | 2,21% | 2,01% |
| TNT2_200MHz_120ns | 4,30% | 2,53% | 2,24% |

100 MHz

400 MHz-1GHz

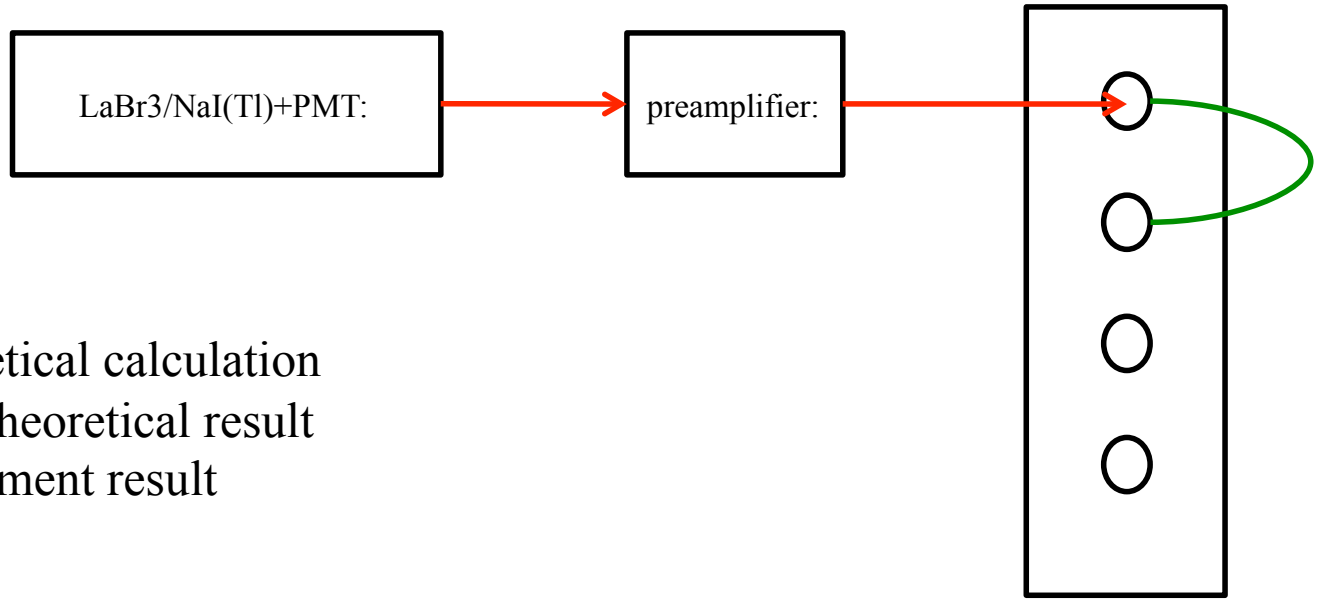
Cs+Co sources with R6236 hamamatsu PMT

100 MHz sampling is not enough to obtain good energy resolution

# Jordanov Shaping with Phoswich:

Is a Classical (With Jordanov shaping) TNT2 Card could be used?

TNT2 Card:



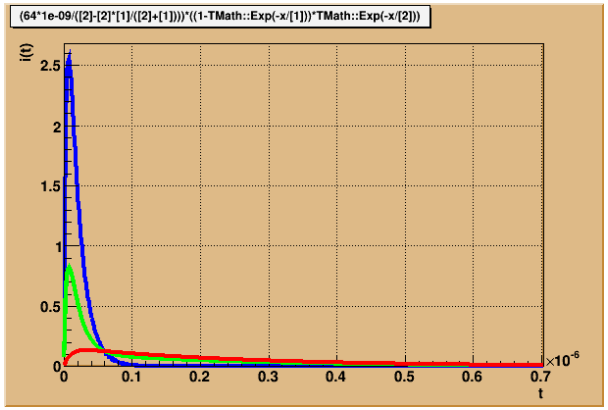

A- Theoretical calculation
B- Semi-theoretical result
C- Experiment result

# Jordanov Shaping with Phoswich:

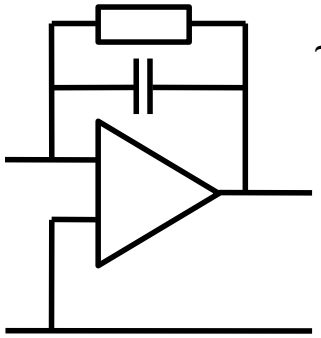
A- “Theoretical” calculation

1- The PMT output signal is simulate by the function:

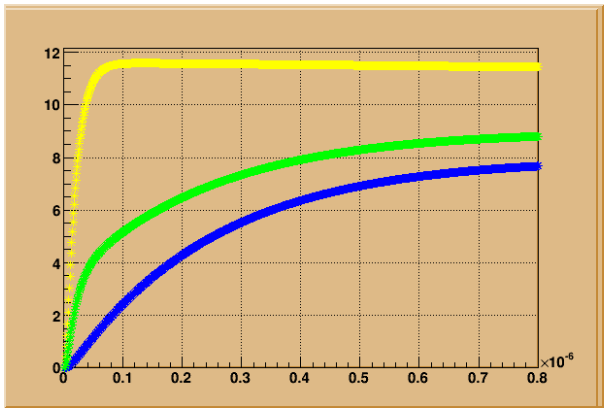
$$V(t) = A\frac{63}{N_1}\underbrace{\left(1-e^{-t/\tau_1}\right)}_{\text{LaBr3 formation}}\underbrace{e^{-t/\tau_2}}_{\text{LaBr3 decay}} + (1-A)\frac{38}{N_2}\left(1-e^{-t/\tau_3}\right)e^{-t/\tau_4}$$




2- we calculated the response after a Charge Preamplifier

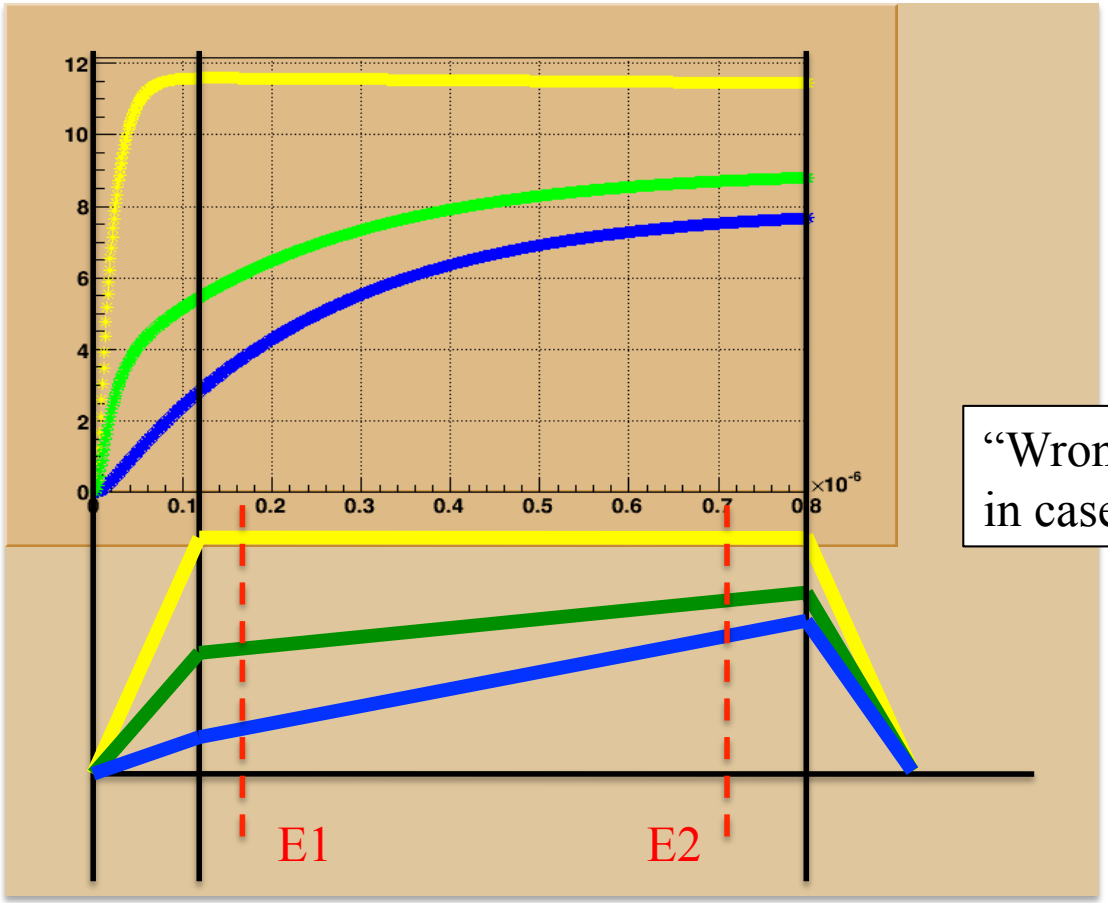


τ=50µs



3- Creation of the Trapeze by Jordanov shaping TNT2 DAQ System TUC

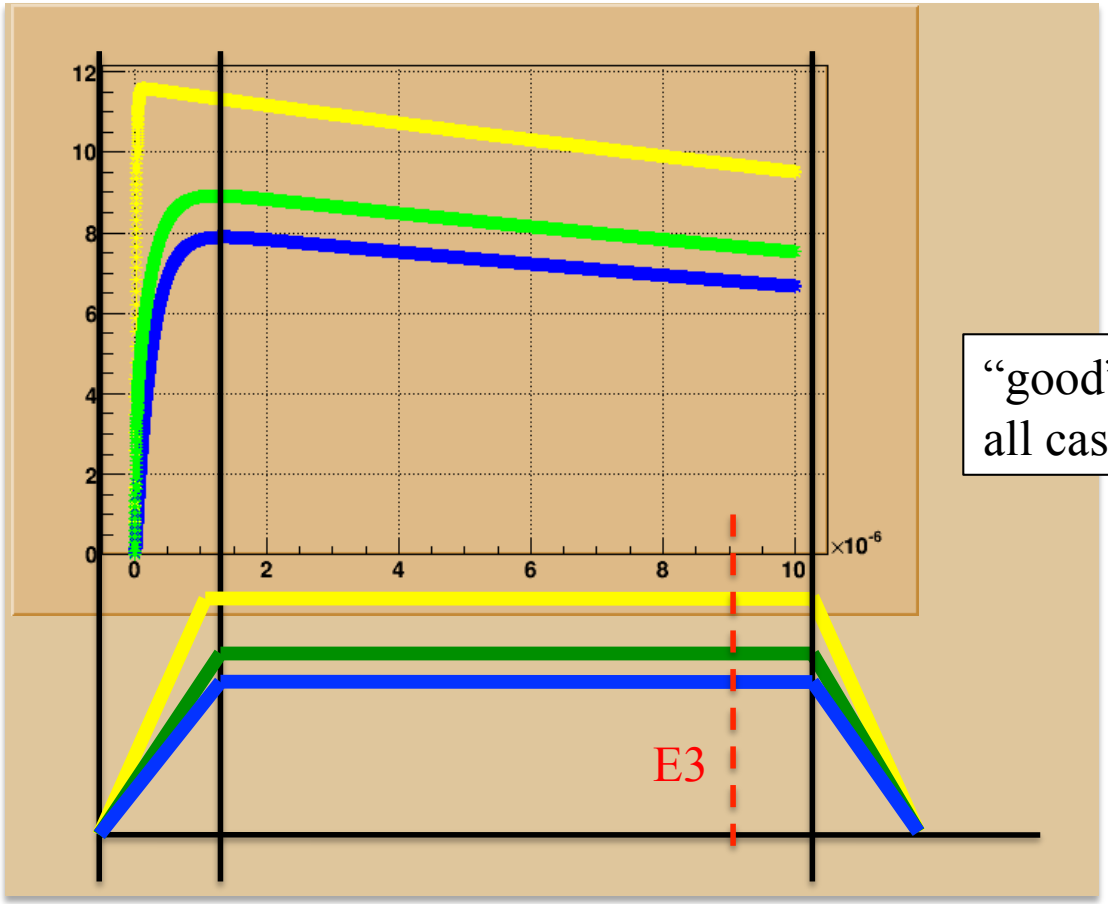
# Jordanov Shaping with Phoswich:
## Case of "fast" trapeze k=120 ns




"Wrong" decay compensation in case of NaI signal

By measuring energy E1 and E2 the ratio E1/E2 should discriminate between events…..

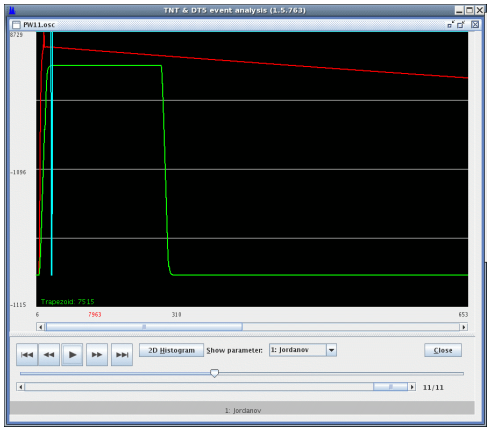
# Jordanov Shaping with Phoswich:
## Case of "long" trapeze k=1500 ns



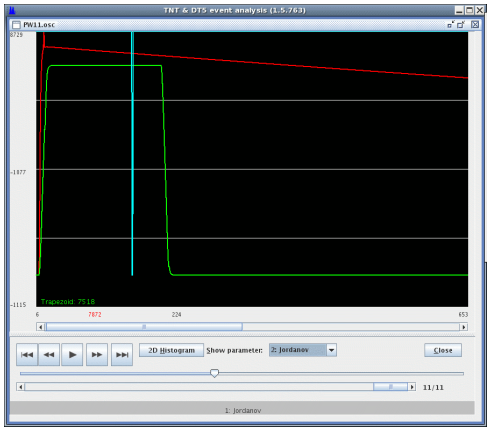

"good" decay compensation in all cases.

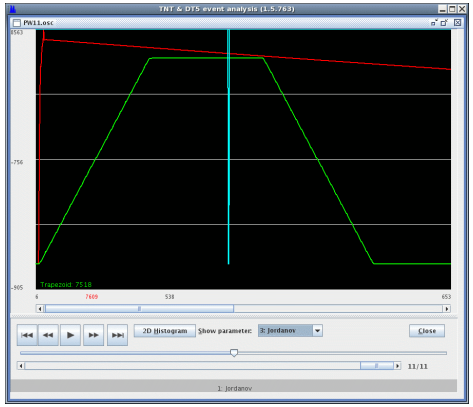
By measuring energy E1 (fast) and E3 (long) the ratio E1/E3 should discriminate between events (equ. to Qfast vs. Qtot) ….

# Jordanov Shaping with Phoswich:



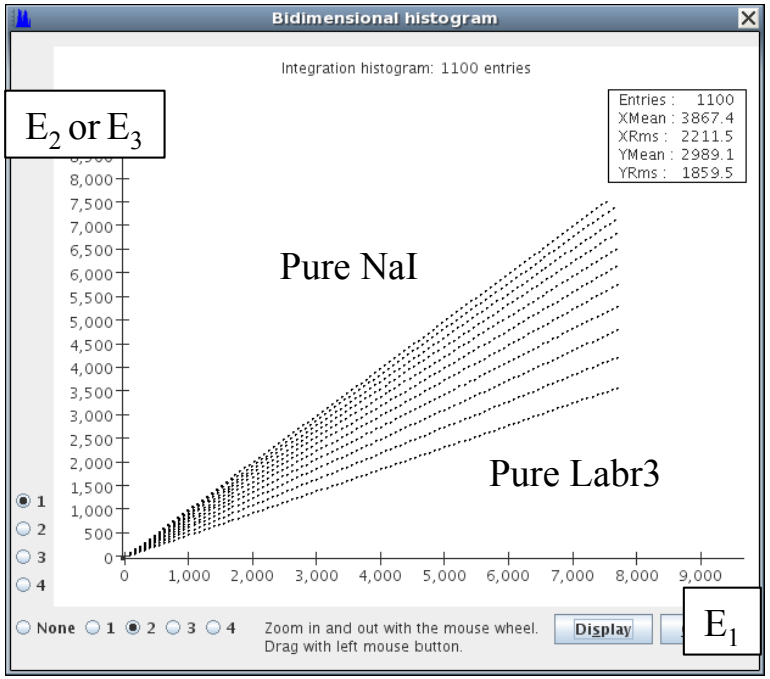
k=120 ns

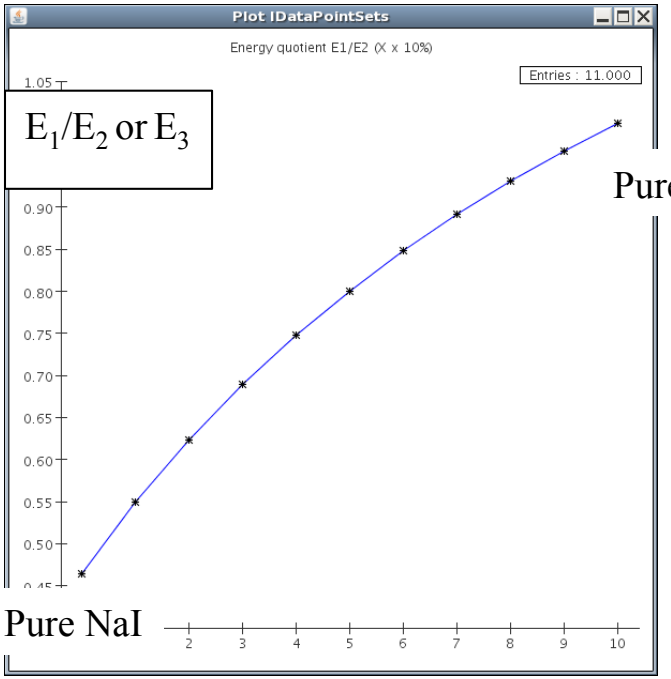




k=1500 ns

# Jordanov Shaping with Phoswich:



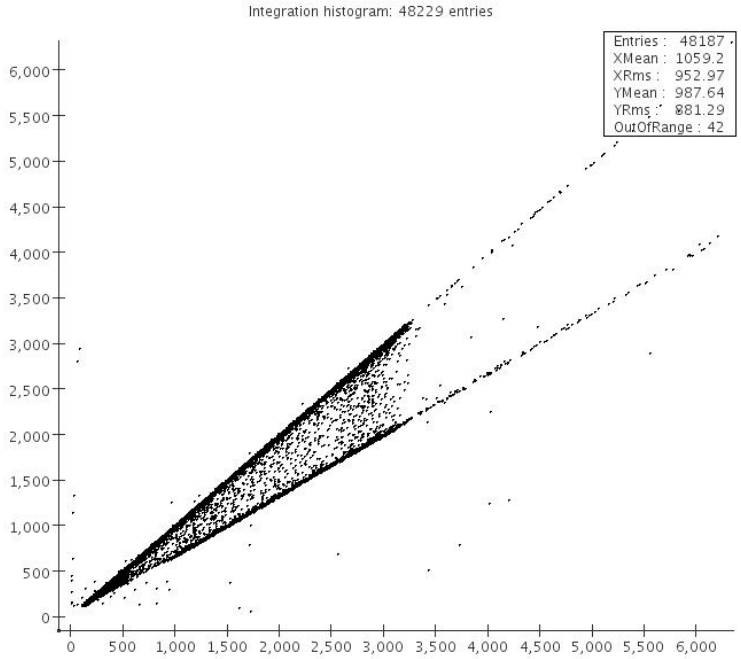



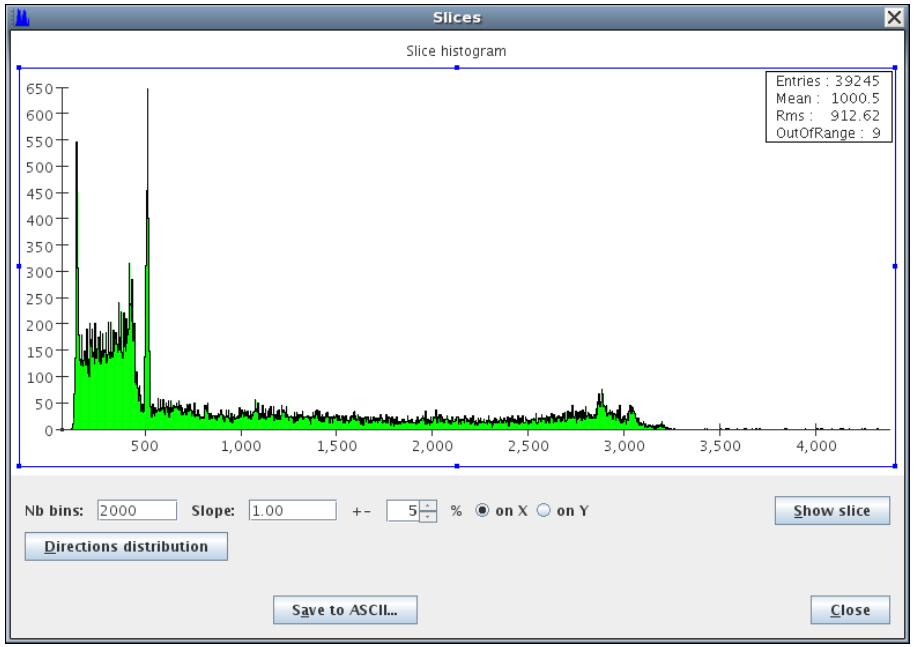

Classical (With Jordanov shaping) TNT2 Card should work

# Jordanov Shaping with Phoswich:

B- “semi-Theoretical” results

Used of digitized signal (V1751) recorded at the R7723 PMT anode during $^{27}Al$ (p,γ) experiment performed at Strasbourg instead of mathematical signal as input



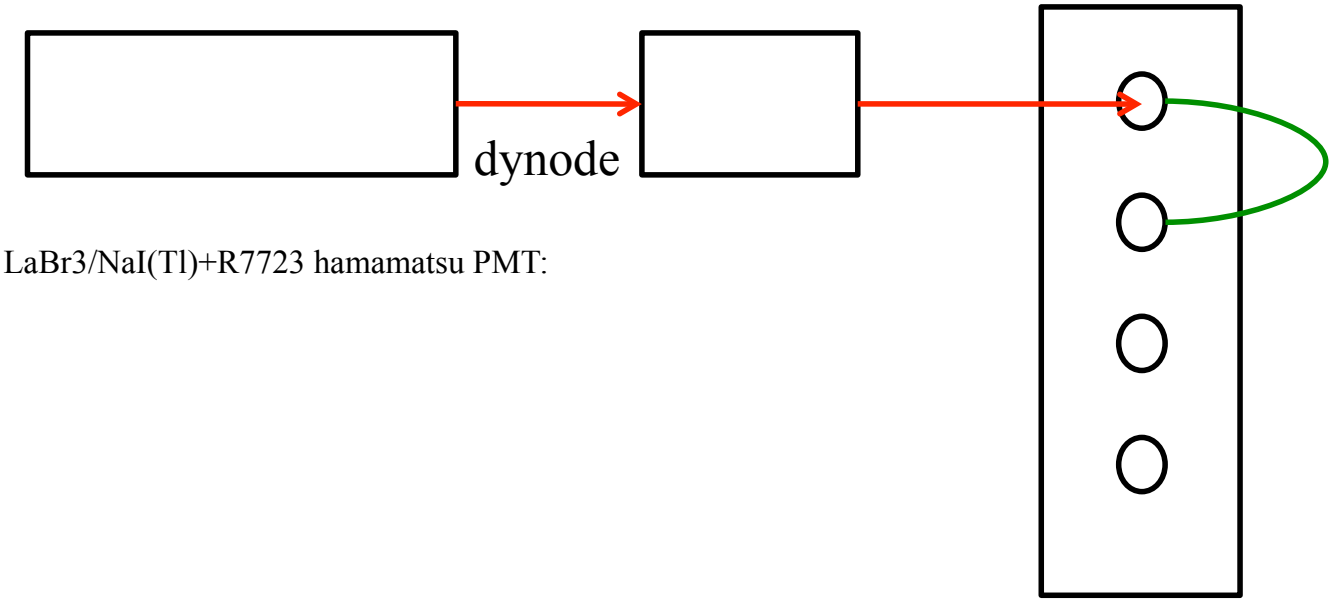

Resolution obtained: 2.9% at 1779 keV and 1.2 % at 10.25 MeV for LaBr branch

# Jordanov Shaping with Phoswich:

Experimental Set up:

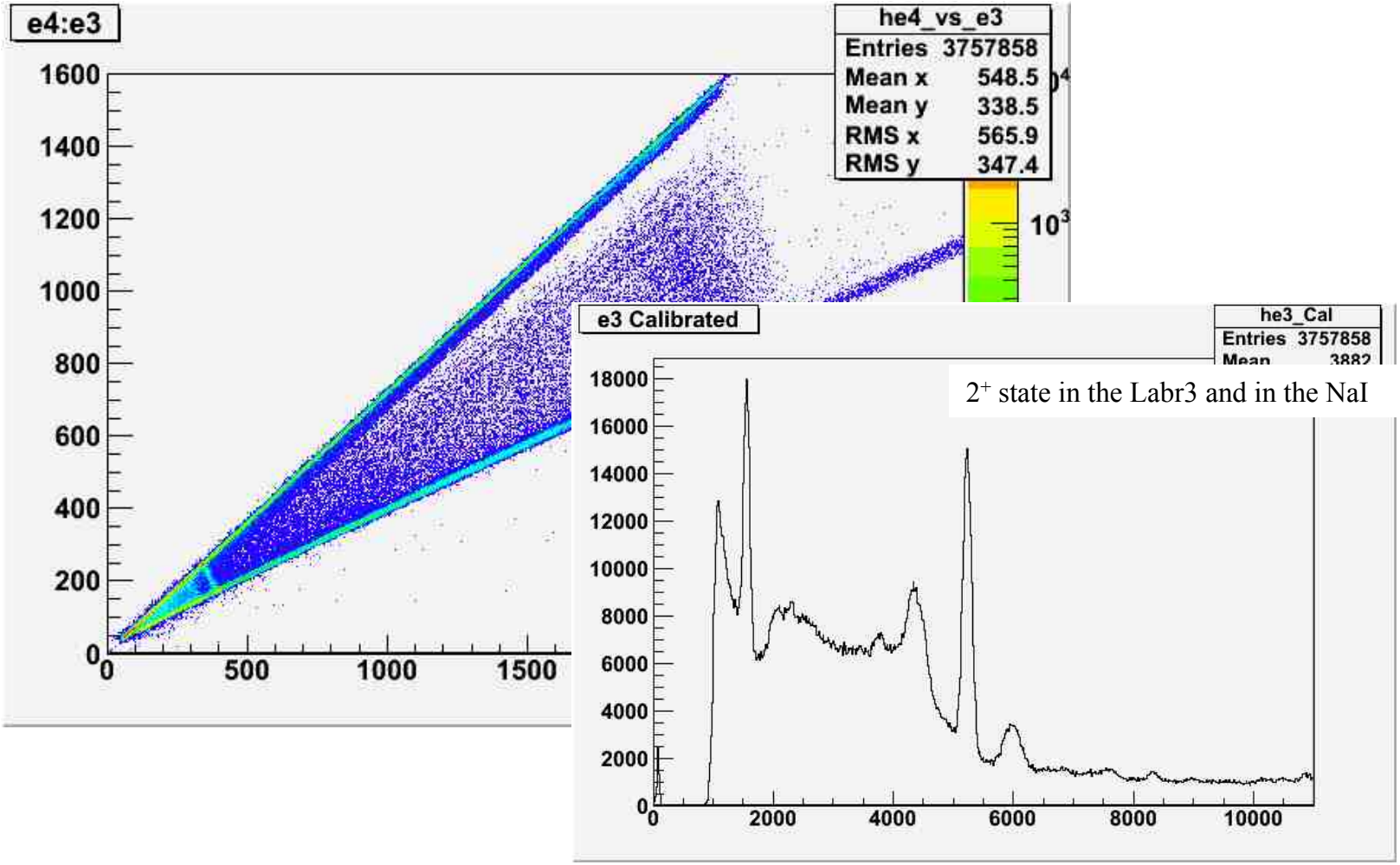
Ortec 113 preamplifier:

TNT2 Card:

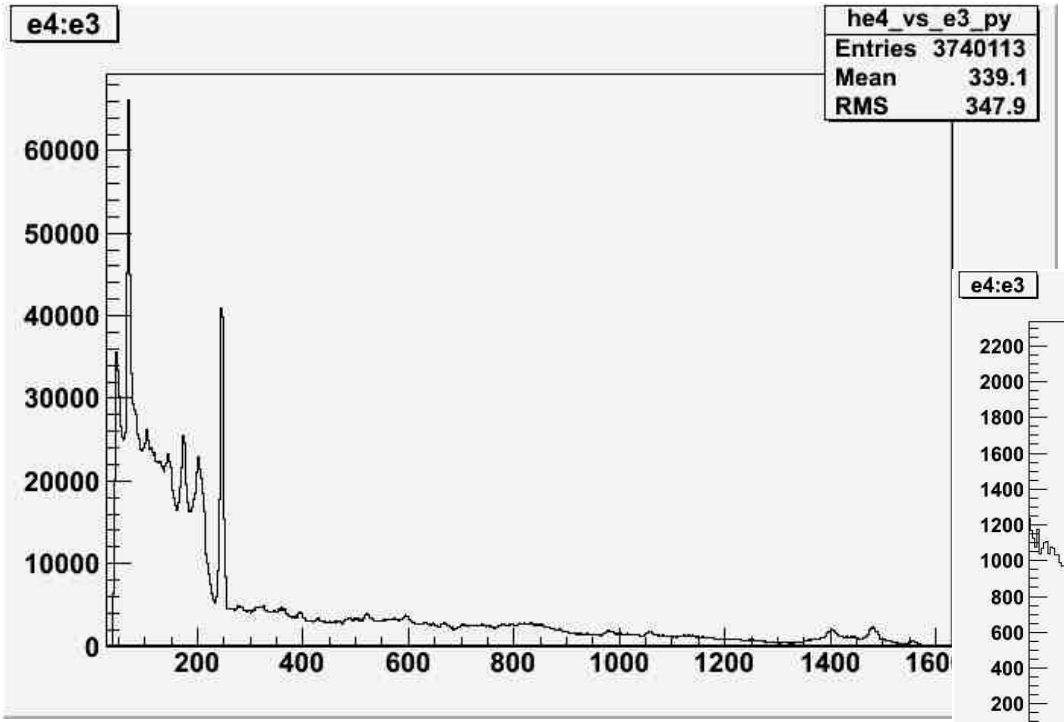


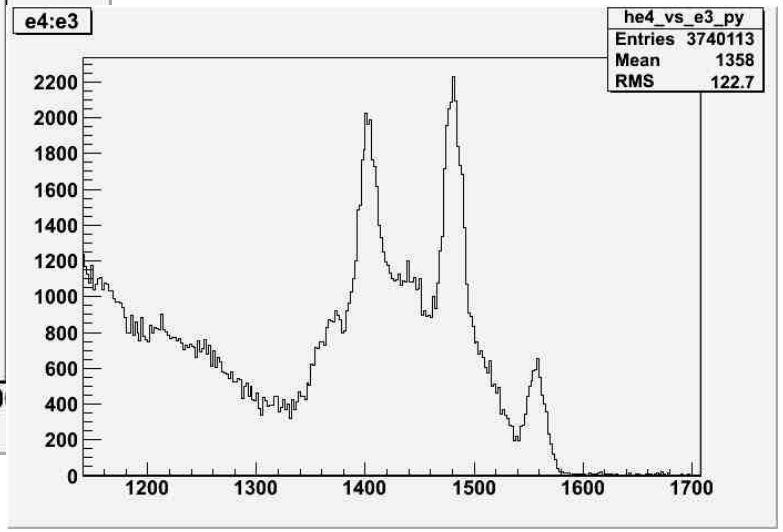

LaBr3/NaI(Tl)+R7723 hamamatsu PMT:

# Jordanov Shaping with Phoswich:



# Jordanov Shaping with Phoswich:




Resolution obtained:

- 3.2% at 1779 keV and 0.98 % at 10.25 MeV for LaBr branch
- 5.1% at 1779 keV and 1.1 % at 10.25 MeV for NaI branch

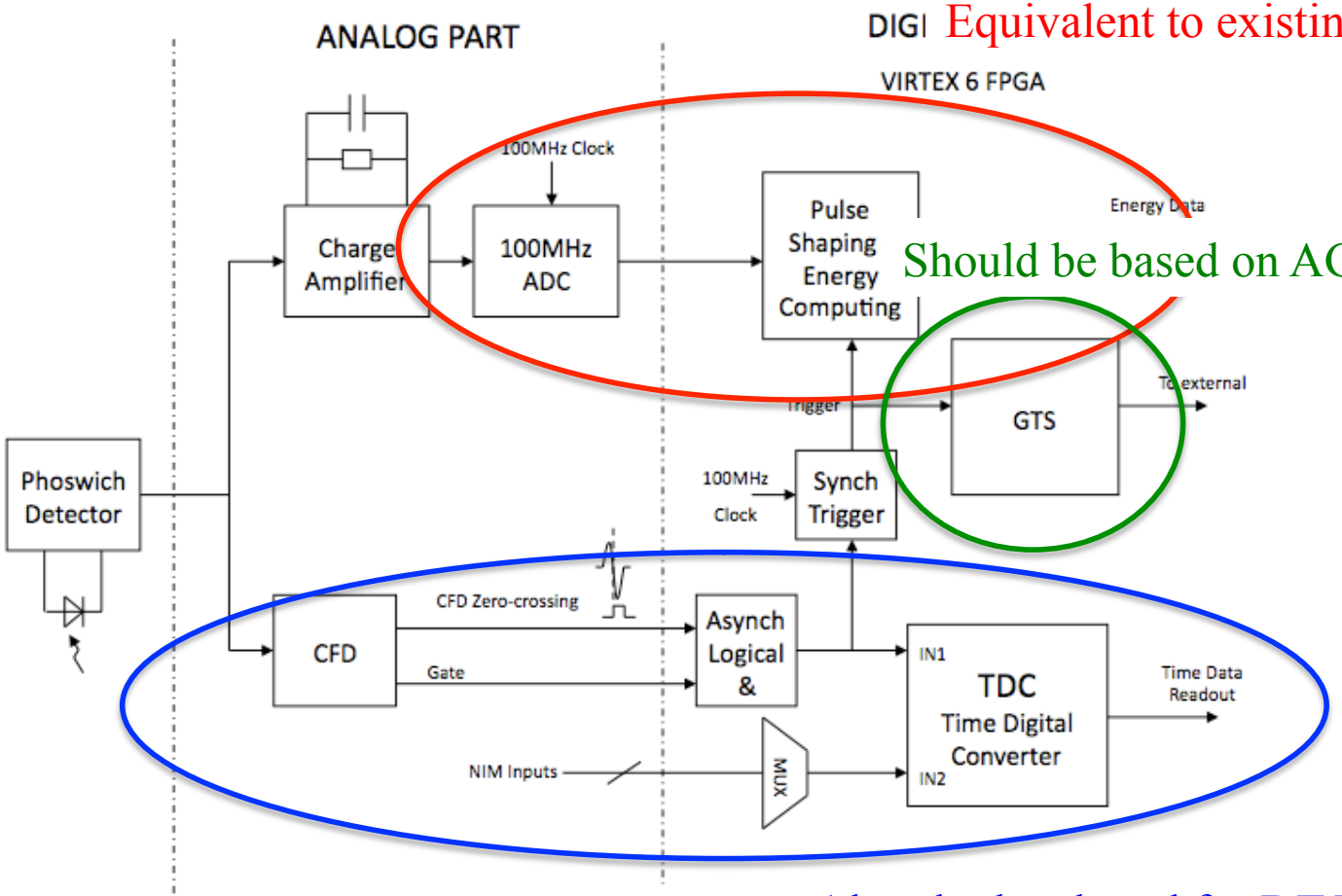
# Summary of results:

| | QDC | Semi Theo. Jordanov | Exp.erimental Jordanov | |
|---|---|---|---|---|
| | anodes | anodes | dynodes | |
| | LaBr3 | LaBr3 | LaBr3 | NaI |
| 1779 keV | 2.2 | 2.9 | 3.2 | 5.1 |
| 10252 keV | 1.0 | 1.17 | 0.98 | 1.1 |

Same data

Next to do: PMT-Preamplifier coupling and a better tune of trapeze parameters.

# A possible "design" of PARIS electronic Card




Equivalent to existing TNT2 Card

Should be based on AGATA design

Already developed for DT5 Card

4 to 8 channels by FPGA

# Summary:

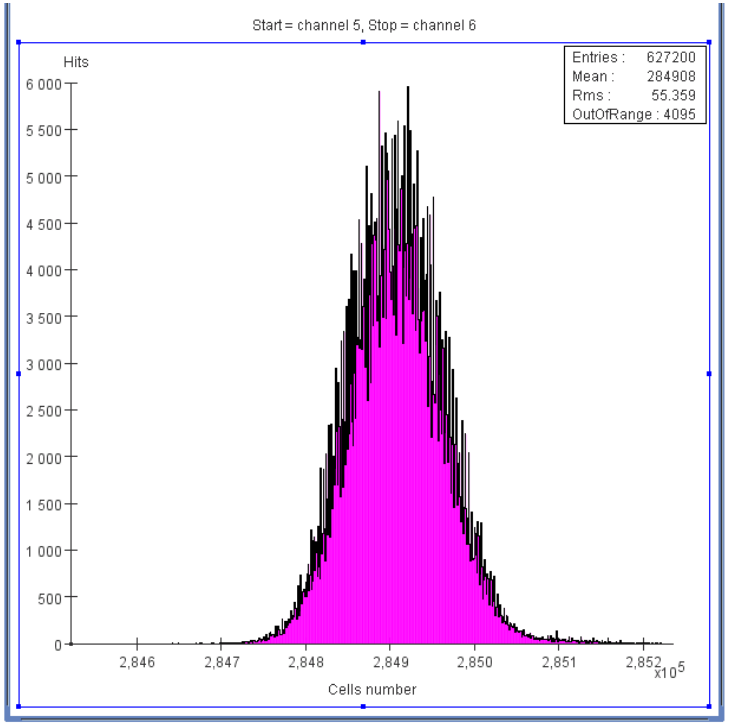
- Digital electronics is necessary for PARIS (almost in the Phoswich Case):
  - Discrimination (PSA) between 2 shells
  - Dead Time

- QDC processing, need more than 100 MHz sampling card (dvpt of new card). More expensive but more challenging, what about dead time?

- Jordanov processing, should work with “standard” 100 MHz sampling card. Need more work on the analogue part ( PMT-Preamplifier coupling) and a better understanding of trapeze parameters.

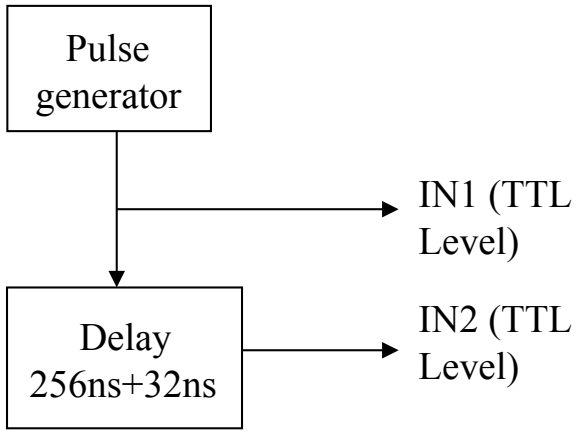
- What about dynamic problem, how to measure gammas from 40 keV to few ten of MeV? In the Strasbourg $^{27}Al(p,\gamma)$ experiment we measured 10 MeV gammas but with a very high threshold…

# Obtained result on timing with DT5




FWHM = [200ps-300ps]

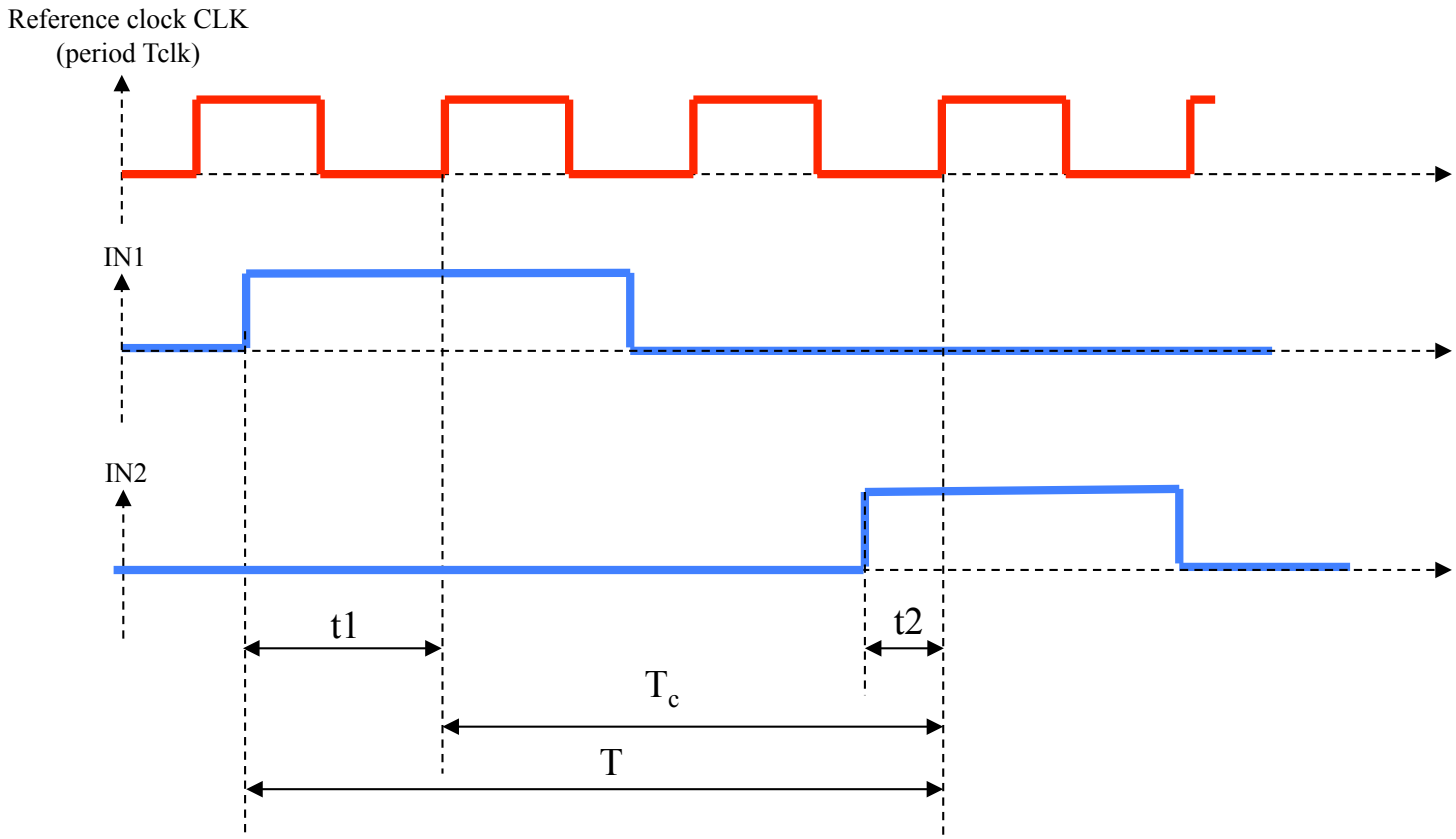
But “infinite” range




✓Accuracy errors :

- Measure made in TTL (rise time 30 ns) and not in NIM Level (150ps)
- Clock Jitter
- Skew (on clock signal for each cell)
- Propagation time for each cell not really similar

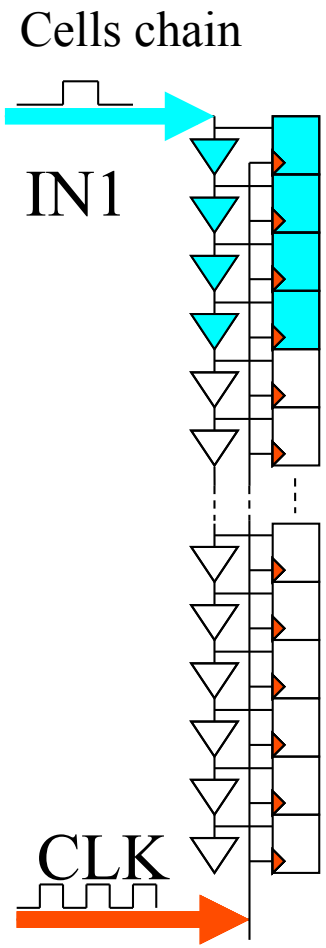
# TDC by Interpolation




$$T = t1 - t2 + Tc$$

- Tc : coarse time (number of Tclk periods)
- t1,t2 : fine times to estimate

# How to estimate the fine time t1 (idem for t2)?




- Compute the number of cells which covers one CLK period => Nref1 cells
- Compute the number of cells between the rising edge of the input IN1 and the following rising edge of the CLK => N1
- **t1 = (N1 / Nref1) x Tclk**
- NB :
  - Cells chain used into the FPGA : carry chain (faster chain)
  - Propagation time for each cell is considered as constant. Its value depends on the model of FPGA (see Datasheet)
    - Virtex 2Pro (Speed -1) : ~50ps
    - Virtex 5 (Speed -3) : ~30ps

# Implementation of the cells chain into the VIRTEX 5 LX50 – DT5 Card

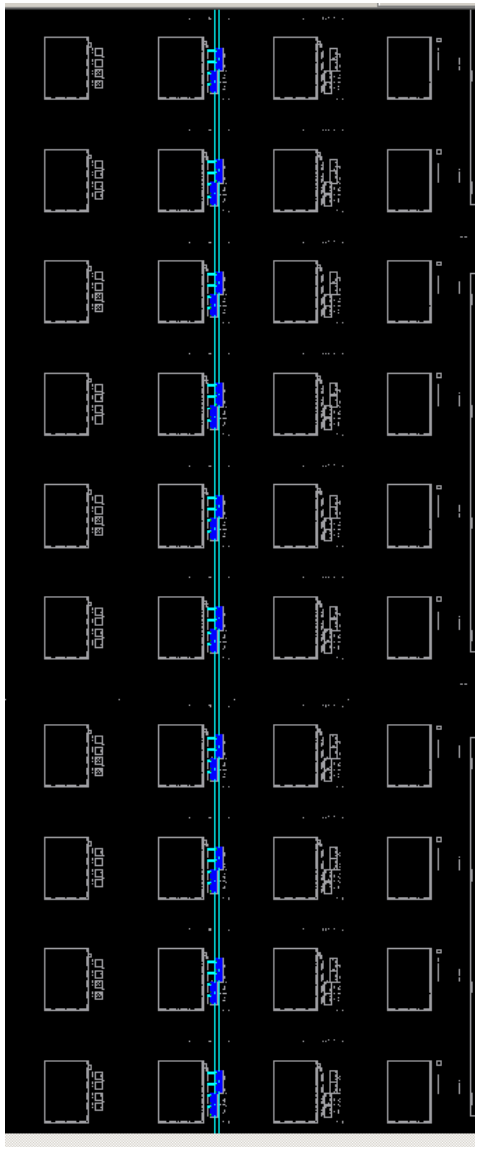
✓Propagation time for a cell for this VIRTEX model : ~30ps (bin resolution)

✓Fastidious Work : Not VHDL coding but Place & Route made manually (on one column) to avoid hazardous placement by the synthesizer

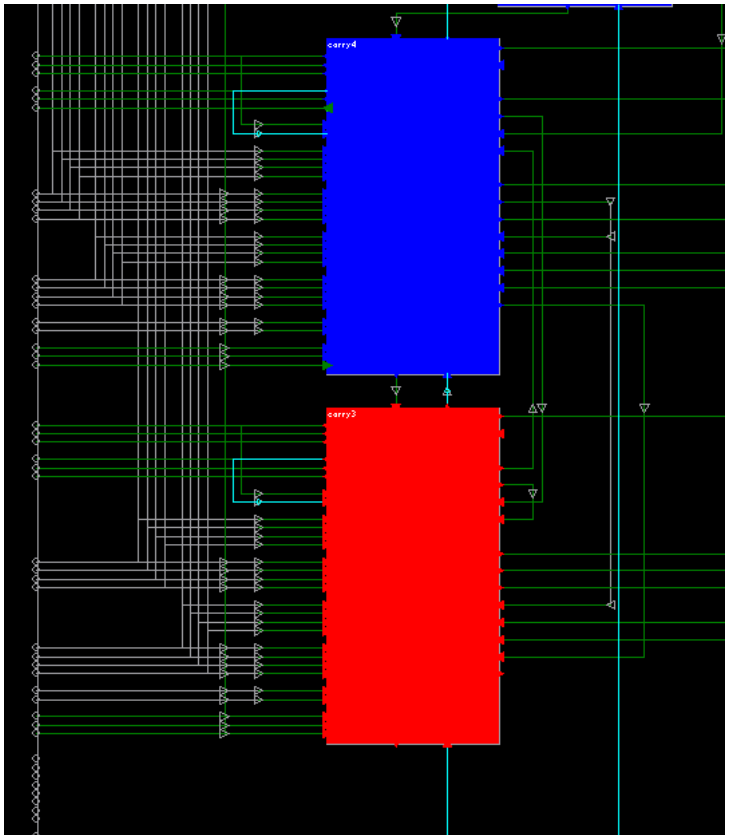
✓Maximum cells available into one column : 240

✓CLK frequency used : 250MHz (Tclk=4000ps)

- ➢Minimum cells number to cover one period : 4000/30 ~ 140



# Implementation of the cells chain into the VIRTEX 5 LX50 – DT5 Card




2 slices connected via carry chain

Inside a slice : 2 cells available