Pulse shape analysis of $LaBr_3$:Ce signals

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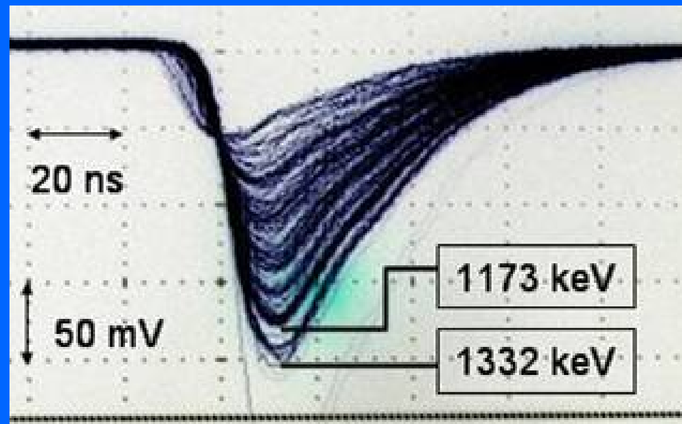
Overview of the $LaBr_3$::Ce activities of the Milano group

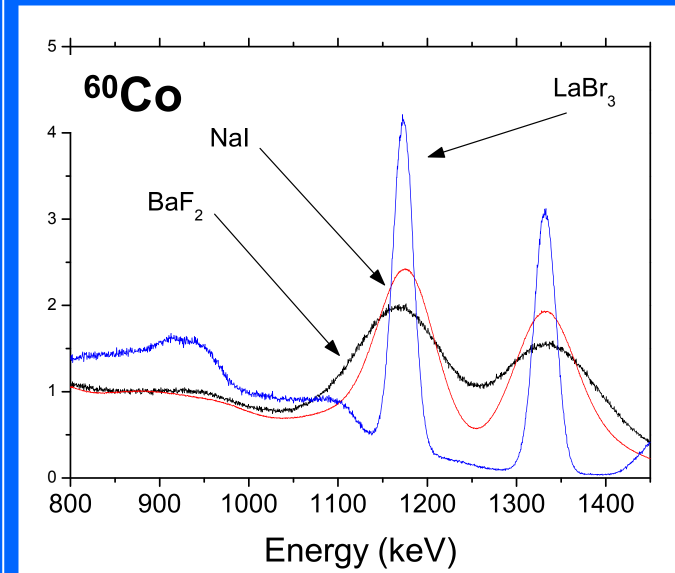
- **Detector Properties Measurements**
- **R&D on PMT and Voltage Dividers**
- **Response to high energy γ-rays**
- **R&D on PSD (BaF_2 to $LaBr_3$)**
- **Position Sensitivity of large volume crystals**
- **R&D on electronics**
- **Plan's for the future**

$LaBr_3$:Ce Scintillators

L.Y. ≈ 63 ph/keV
Rise Time ≈ 16 ns
λ ≈ 380 nm
N ≈ 1.9
ρ = 5.3 g/cm³

RL (661 keV) 1.9 cm



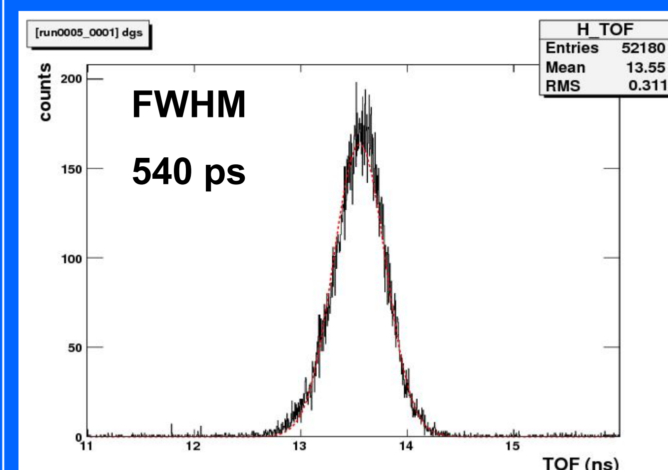


Large Interest in scientific community

- **In 2007 more than 40 papers on $LaBr_3$ / $LaCl_3$ detectors published in IEEE and NIM**

Large Volumes recently available

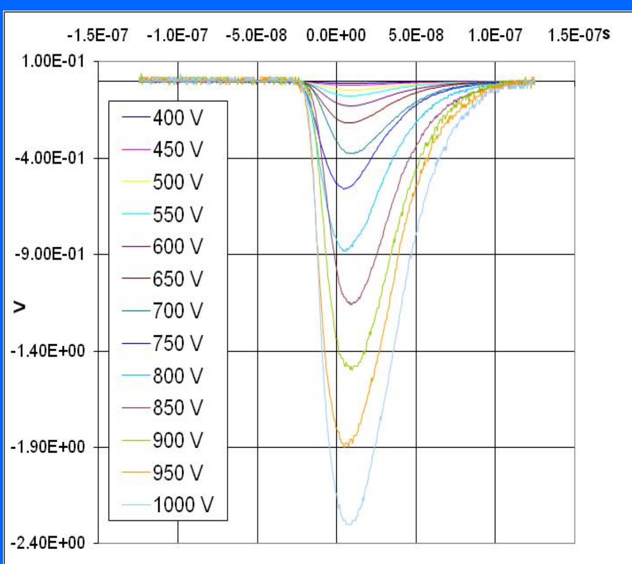
1 - 1"x1" $LaBr_3$:Ce
1 - 1"x1" $LaCl_3$:Ce
1 - 3"x3" $LaBr_3$:Ce
6 - 3.5"x8" $LaBr_3$:Ce

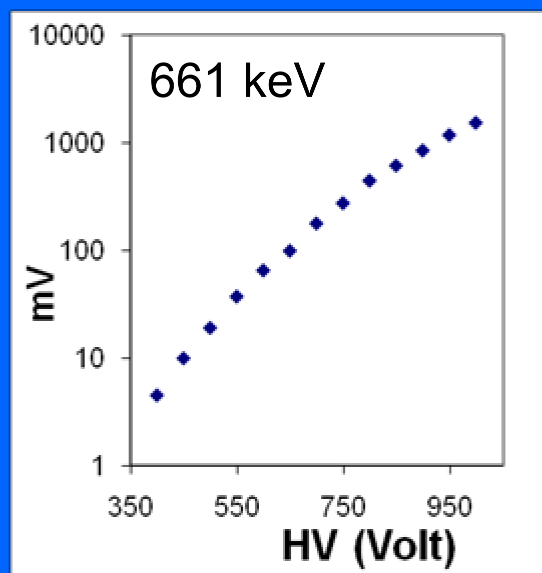


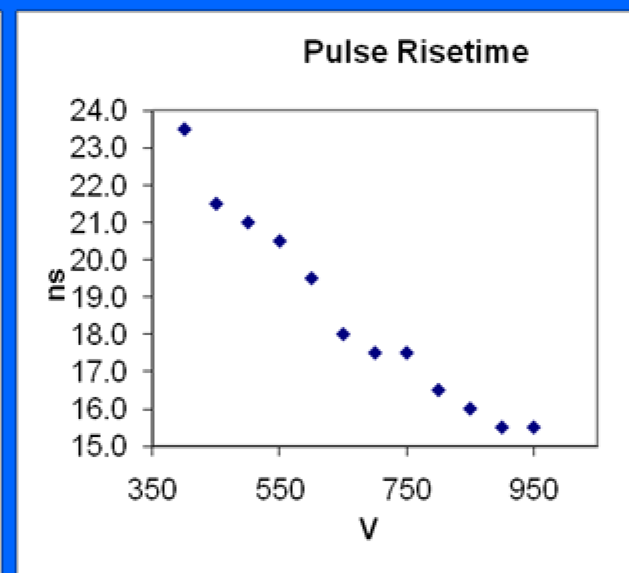
PMT for $LaBr_3$:Ce crystals

At the moment there isn't PMTs especially designed for $LaBr_3$:Ce detectors

PMT Model	# Dynodes	Ø	Cath. Lum. Sens.	Cath. Blue Sens.	Gain - Typical	HV - Typical
Photonis - XP5300	8	3 "		14.4 µa/lmF	2.4 10^5	1000
Photonis – XP5301 - Clarity	8	3"		17.3 µa/lmF	1.8 10^5	1000
Photonis – XP5700	8	3.5"		13 µa/lmF	2.4 10^5	1000
Photonis – XP3540	10	5"		11.9 µa/lmF	6.5 10^5	1200
Hamamatsu – R6233	8	3"	138 µa/lm		2.7 10^5	1000
Hamamatsu – R6233-100S	8	3"	167 µa/lm		2.4 10^5	1000
Hamamatsu – R10233-100	8	3.5 "	137 µa/lm		2.7 10^5	1000

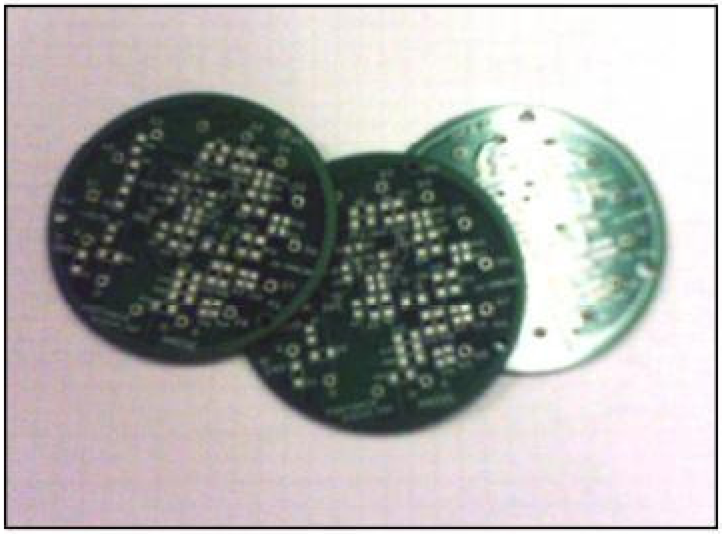






Voltage Divider for $LaBr_3$:Ce crystals

PMT Voltage Divider Network



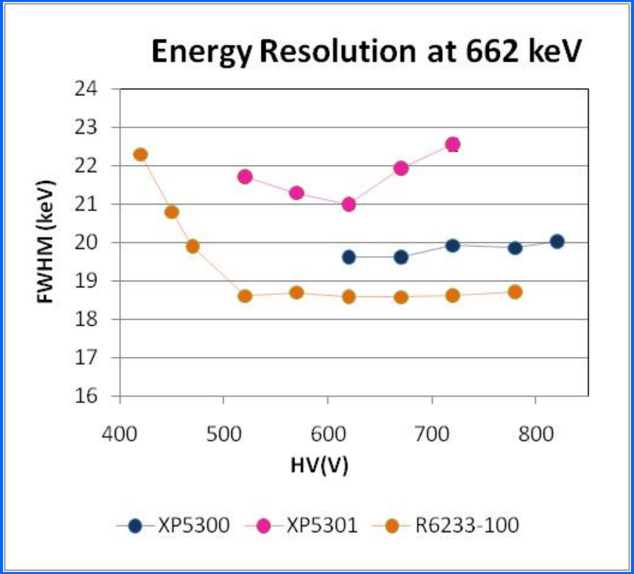
Electric field between dynodes reflects on:

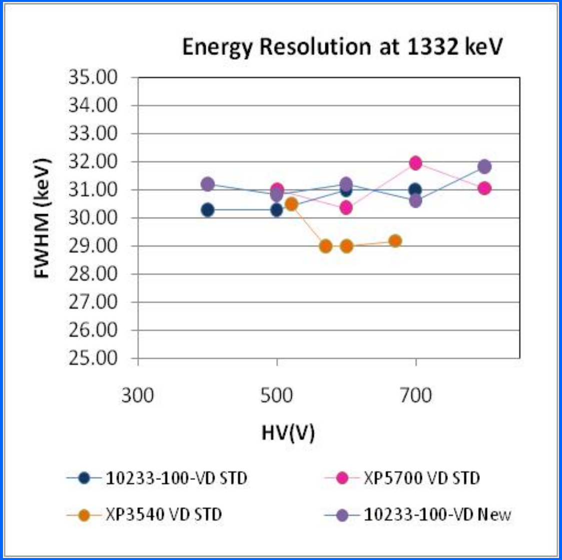
- Linearity of PMT output signal
- Energy resolution
- Time resolution

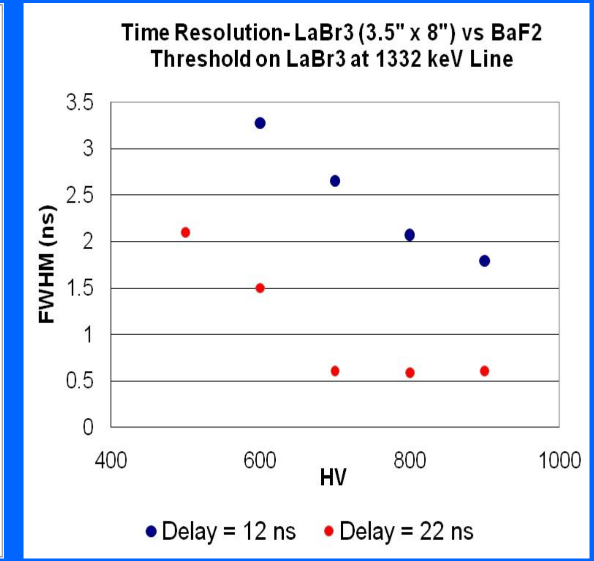
$LaBr_3$ dedicated voltage divider network designed to achieve best compromise among all requirements

3" x 3"

3.5" x 8"







Performances of the different PMTs in terms of Energy and Time resolution using different Voltage Dividers (Hamamatsu E1198-27, Photonis VD202K/01 and one home made .

The measurements with 3"x3" crystal have been done using commercial VD.
Best results with Hamamatsu R6233

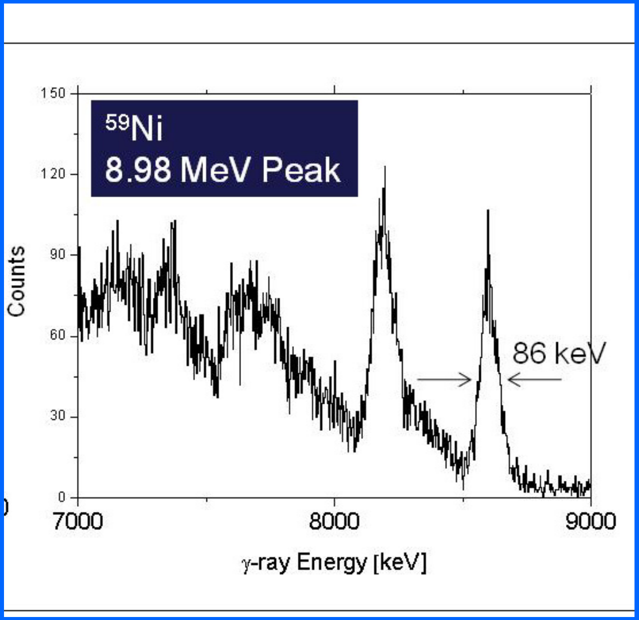
For the 3.5"x8" the measurement has been done using both commercial and home designed VDs.

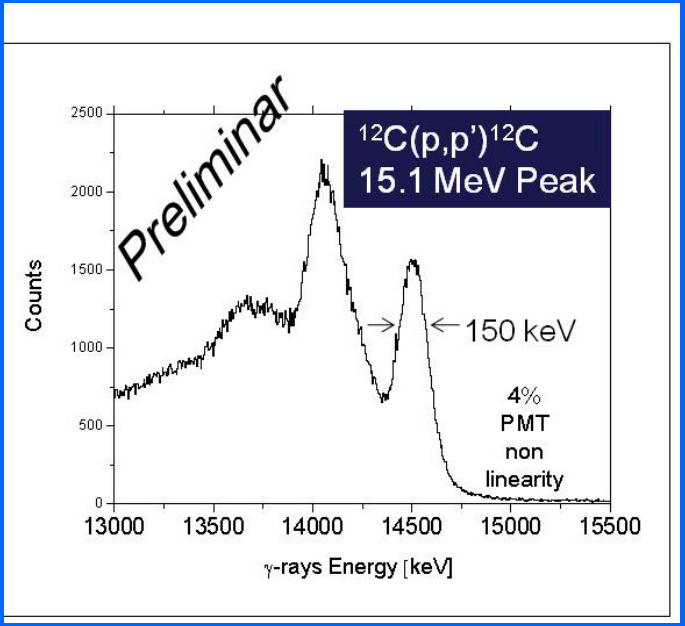
Even with a large volume $LaBr_3$:Ce is possible to achieve good time resolution, but it is necessary to power the PMT with a Voltage higher than 700 V

Activities in Milano

Response with high energy gamma rays

- PuC source - 6.13 MeV γ-rays Catania
- AmBe+Ni source - 8.98 MeV γ-rays Milano_Catania_LNL
- p (20 MeV) + C ⇒ 15.1 MeV - Catania May 2009





$LaBr_3$:Ce Gain Stability

$LaBr_3$:Ce excellent energy resolution suffers from PMTs non idealities

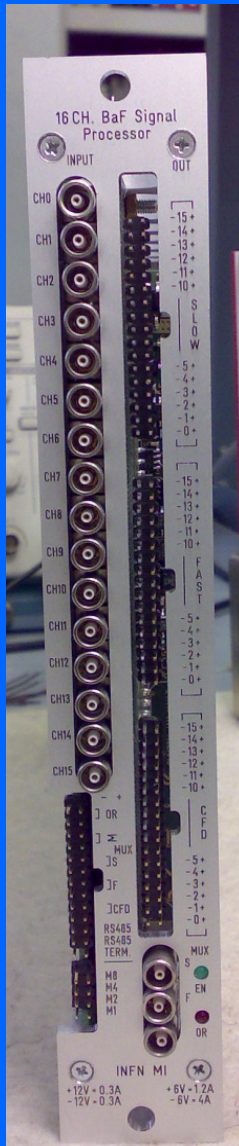
- Temperature drift
- Voltage drift

Suggestion:

- use of stable HV power supply (ORTEC 556 → CAEN N1470)

- LED Pulser

BaFPro (for BaF_2 and … also for $LaBr_3$::Ce)

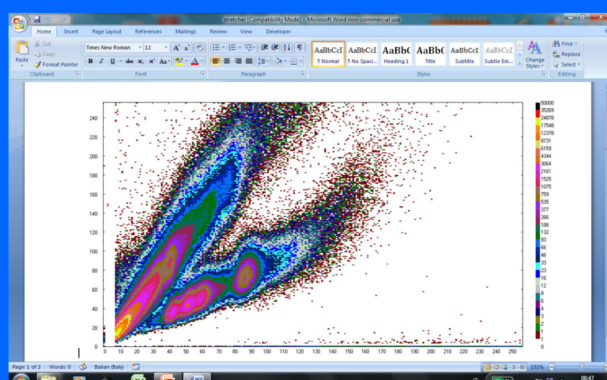


Main functions

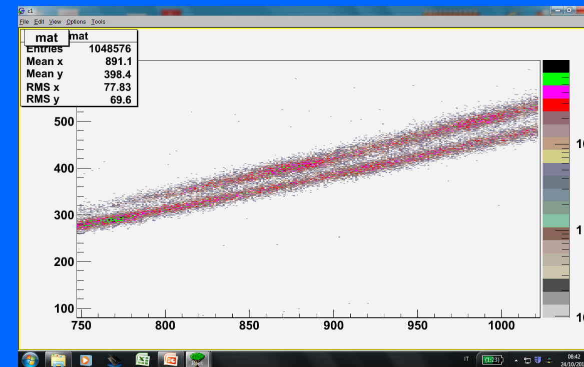
NIM standard module
16 channels
Fast output = 2µS Time to peak
Energy output = 2µS Time to peak

CFD resolution < 100pS
CFD OR output
Multiplicity Output

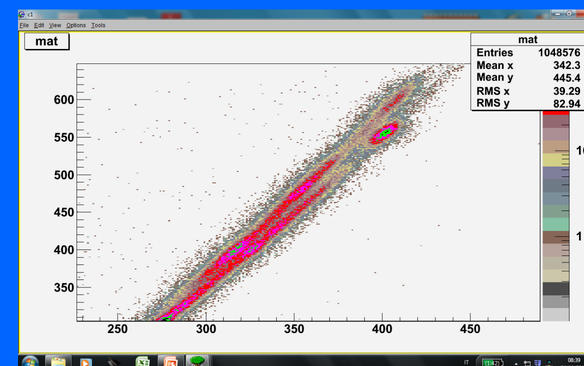
RS485 dedicated software control



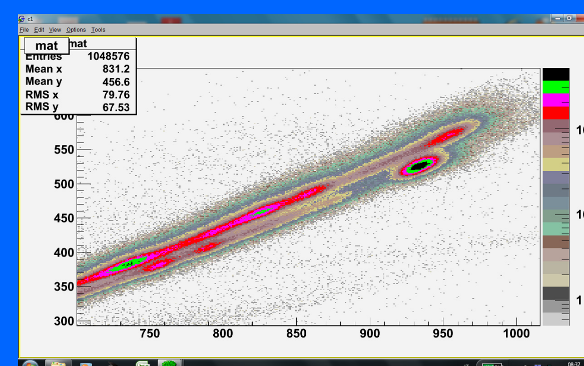
1x1



2x2



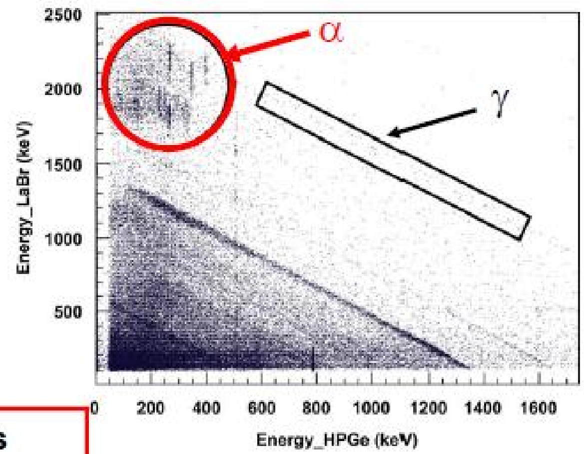
3x3



PSD algorithms for LaBr3, LaCl3

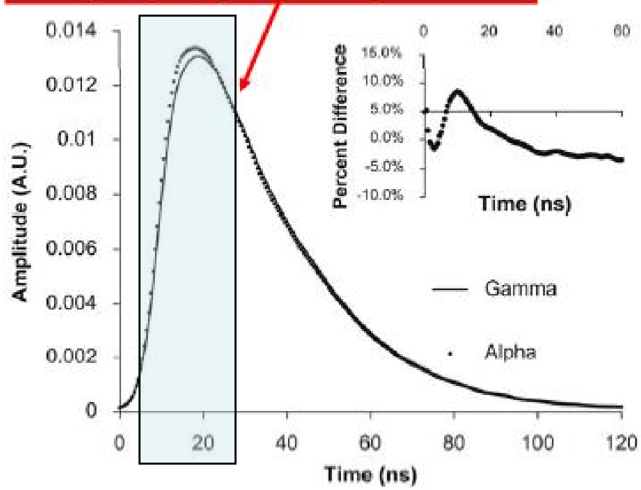
Develop of a VME system

- Standard analog chain (shaping amp. + VME ADC)
- 2 GHz, 12 bits ADC for LaBr3, LaCl3

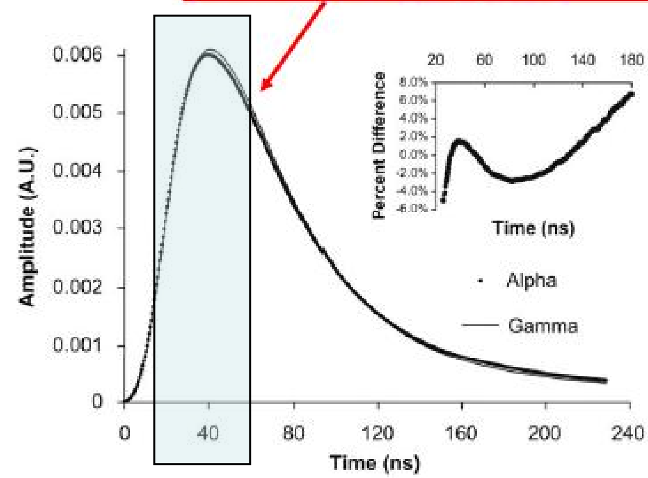


Matrix of coincidence events measured with LaBr3:Ce (*y*-axis) and HPGe (*x*-axis) detectors

Signal shapes of α-particles and γ-rays in LaBr3:Ce



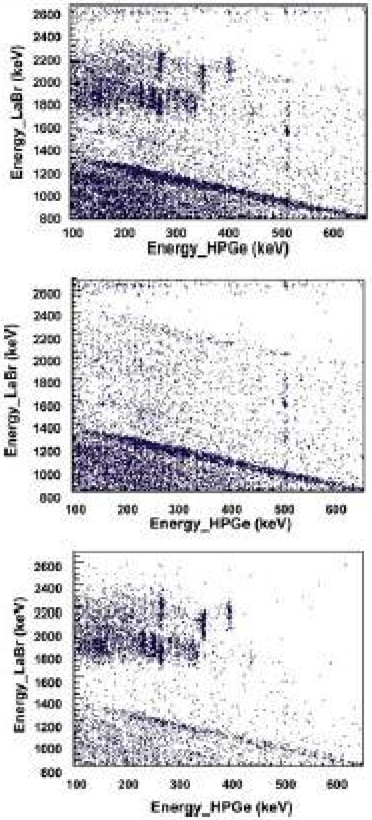
Signal shapes of α-particles and γ-rays in LaCl3:Ce



Application of the algorithm to <u>internal radioactivity and natural background spectra</u>

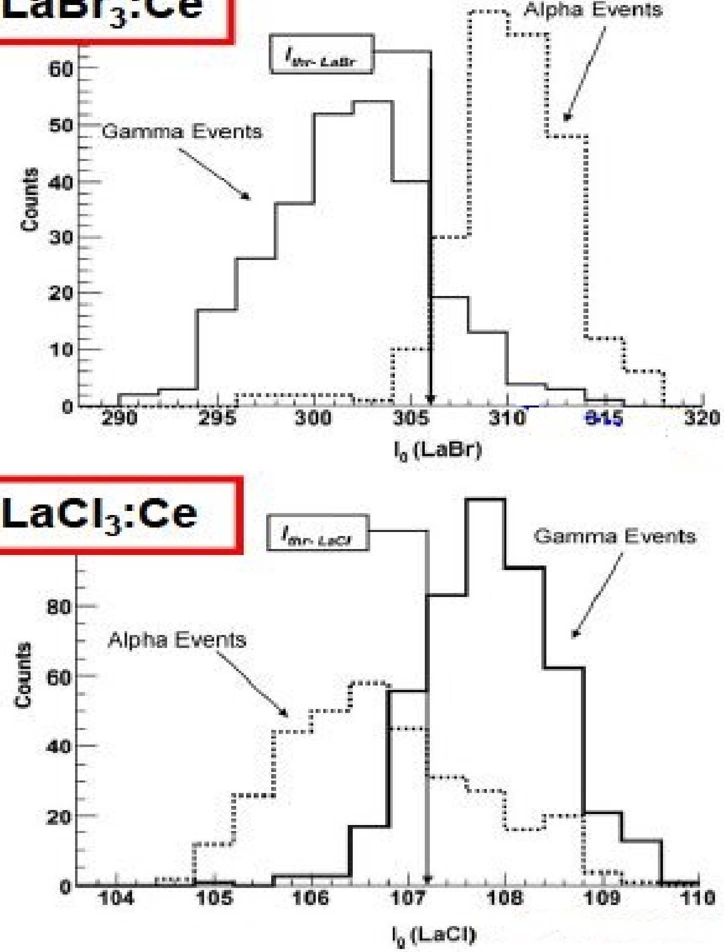
<u>Selected region in the matrix of coincidence events (LaBr-HPGe) when:</u>

- no condition
- selecting γ-rays
- selecting α-particles



$LaBr_3$:Ce

$LaCl_3$:Ce



Doppler Broadening Correction – Detector Position Sensitivity

Gamma Imaging

Simulations + Light tracking

Experimental Test With 1”x1” LaBr3 & 662 keV collimated source

- 1”x1” + Segmented Hamamatsu H8500C-100 Mod 8
- dedicated system with 16 channel shaping amplifier
- 32 channels CAEN VME ADC
- good correspondence between interaction point and pad position

Experimental Test With 3”x3” LaBr3 & 662 keV collimated source

- Shielded PMT
- Segmented Hamamatsu H8500C-100 Mod 8

Mixed A/D Electronics for Scintillator Detectors

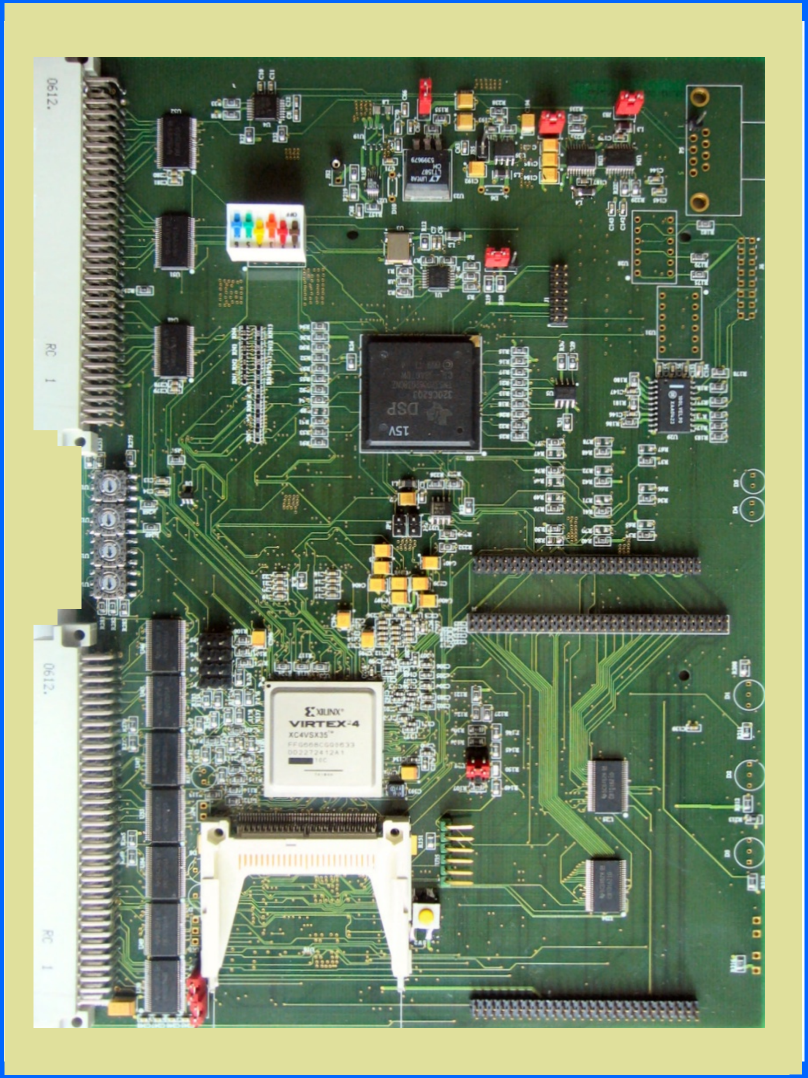
Preliminary activity:

- Idea to develop a VME board in collaboration with Politecnico Milano
- Sampling of LaBr3 signals (1”x1” and 3”x3”) with CAEN VME 2Gs 12 bit board
- Data elaboration in MatLab environment of “direct” signals
- discrimination and cubic interpolation
  - 540 ps timing resolution FWHM
  - 2,3 % energy resolution at 1332 KeV

Moving to reasonable sampling frequency:

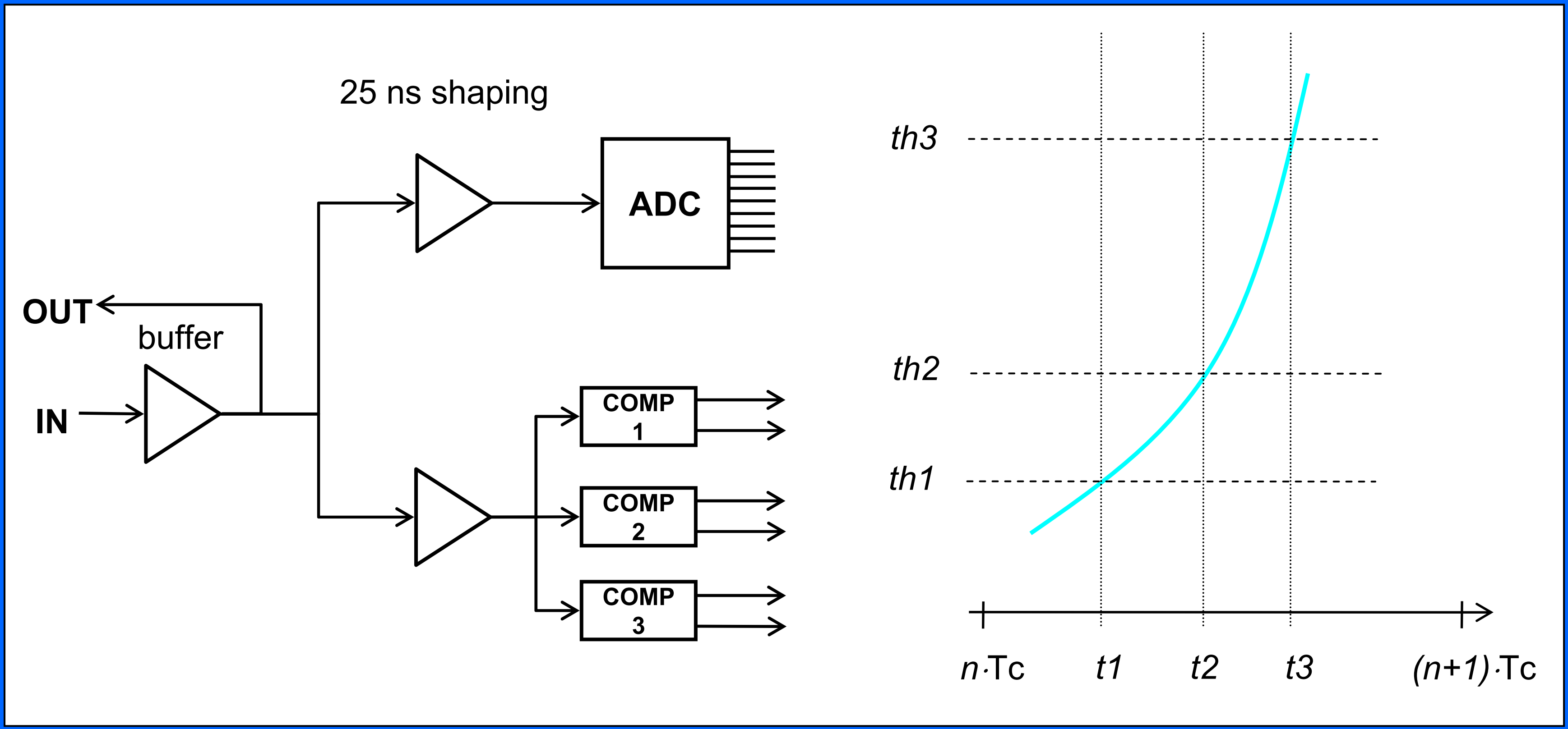
- Factor 16 decimation (one sample every 8ns: 125 Ms/sec)
- Signal shaped with two 25ns poles
- Optimum FIR Filter
  - 630 ps timing resolution FWHM
  - 2,3 % energy resolution at 1332 KeV
- Same results with Struck 100Ms 16 bit
- Also with 14 bit truncation

Mixed A/D Electronics for Scintillator Detectors

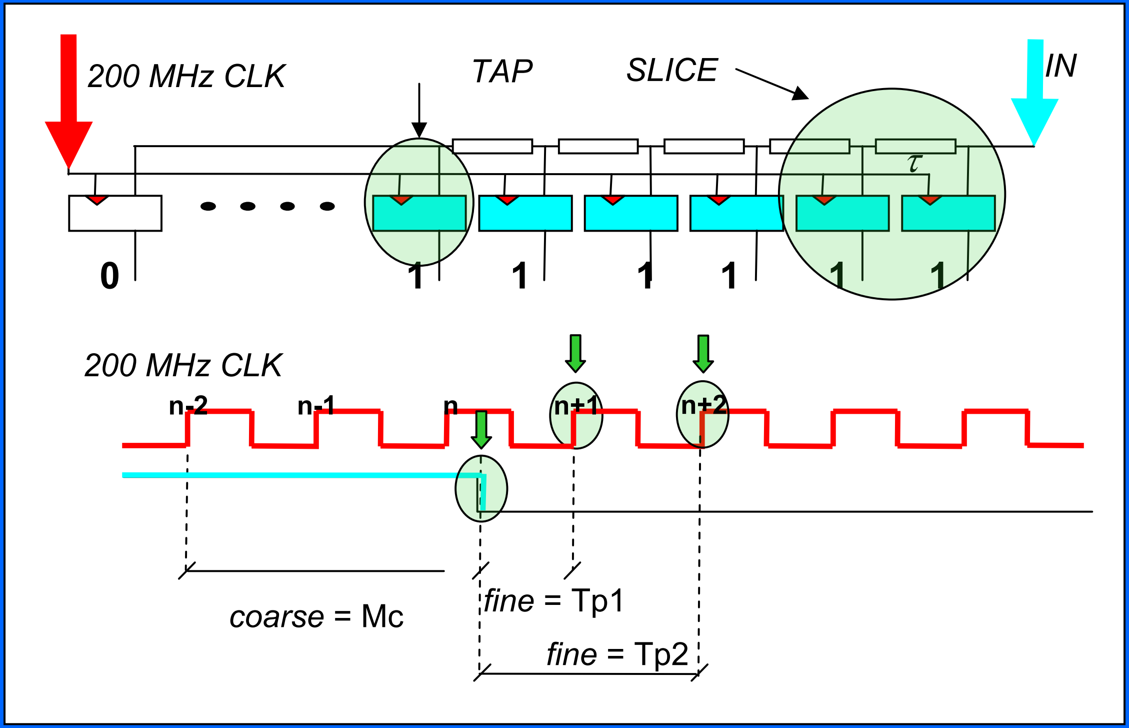


- **2 Channels VME board**
- **Mother Board:**
  - DSP (TI TMS320C6203)
  - FPGA (XILINX XC4VSX35)
- **Piggy-Back Board:** (not shown)
  - Shaping filter: 2 poles at 25 ns
  - variable gain and offset
  - A/D converter: 100-125 MHz, 14 bits
- **VME interface:**
  - A32-D16/D32
  - Multi-event Buffer
  - BLT/CBLT capabilities

Mixed A/D Electronics for BaF_2 Scintillators



- Programmable gain, offset, thresholds (th1, th2, th3)
- Discriminators to generate digital differential signals
- 7 TDC's in FPGA (trigger + 6 comparators)
- DPLMS algorithm to combine time information's



- C.M. Based on FPGA main clock (200MHz 16 bit counter)
- F.M. Based on the "Delay line technique" number of flip-flop set to 1
- Propagation time 70ps/slice ($\tau \approx$ 35ps/tap)
- Temperature and power supply τ dependence on line correction
- Estimation of time based on the number of thresholds

1 thr ➔ $T = T_{trig} - Tarr_1 - W_{1s}$

2 thr ➔ $T = T_{trig} - [(C1_{2s} \cdot Tarr_1) + (C2_{2s} \cdot Tarr_2)] - W_{2s} \cdot Tc$

3 thr ➔ $T = T_{trig} - [(C1_{3s} \cdot Tarr_1) + (C2_{3s} \cdot Tarr_2) + (C3_{3s} \cdot Tarr_3)] - W_{3s} \cdot Tc$

Obtained Performances:

Linearity:

MG delayed in steps of 4ns	± 35 ps

Intrinsic TDC resolution

Pulser, Linear Fan-In/Fan-Out, CFD come MG	128 ps

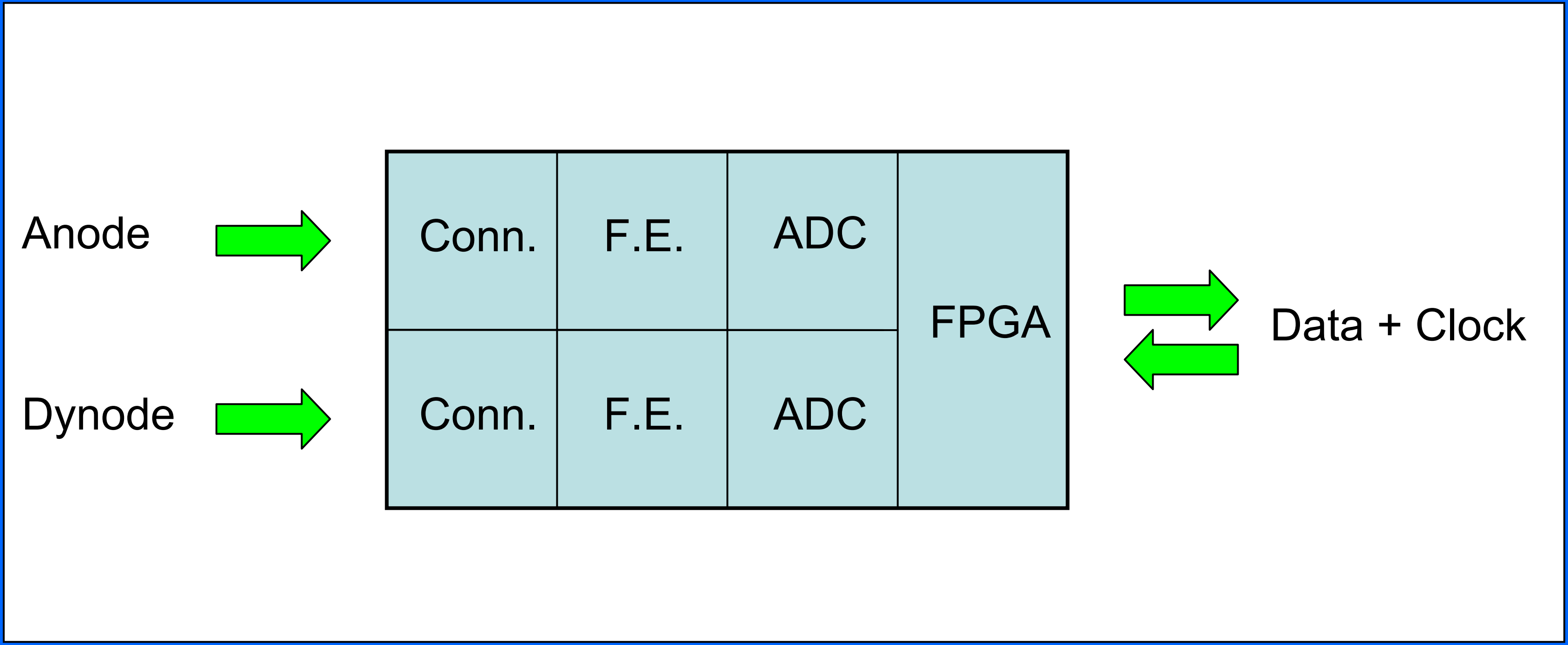
Timing two 3"x3" BaF_2 (^{60}Co**) (**Thr. 150KeV**)**

1 set of coefficients	660 ps
16 set of coefficients	480 ps

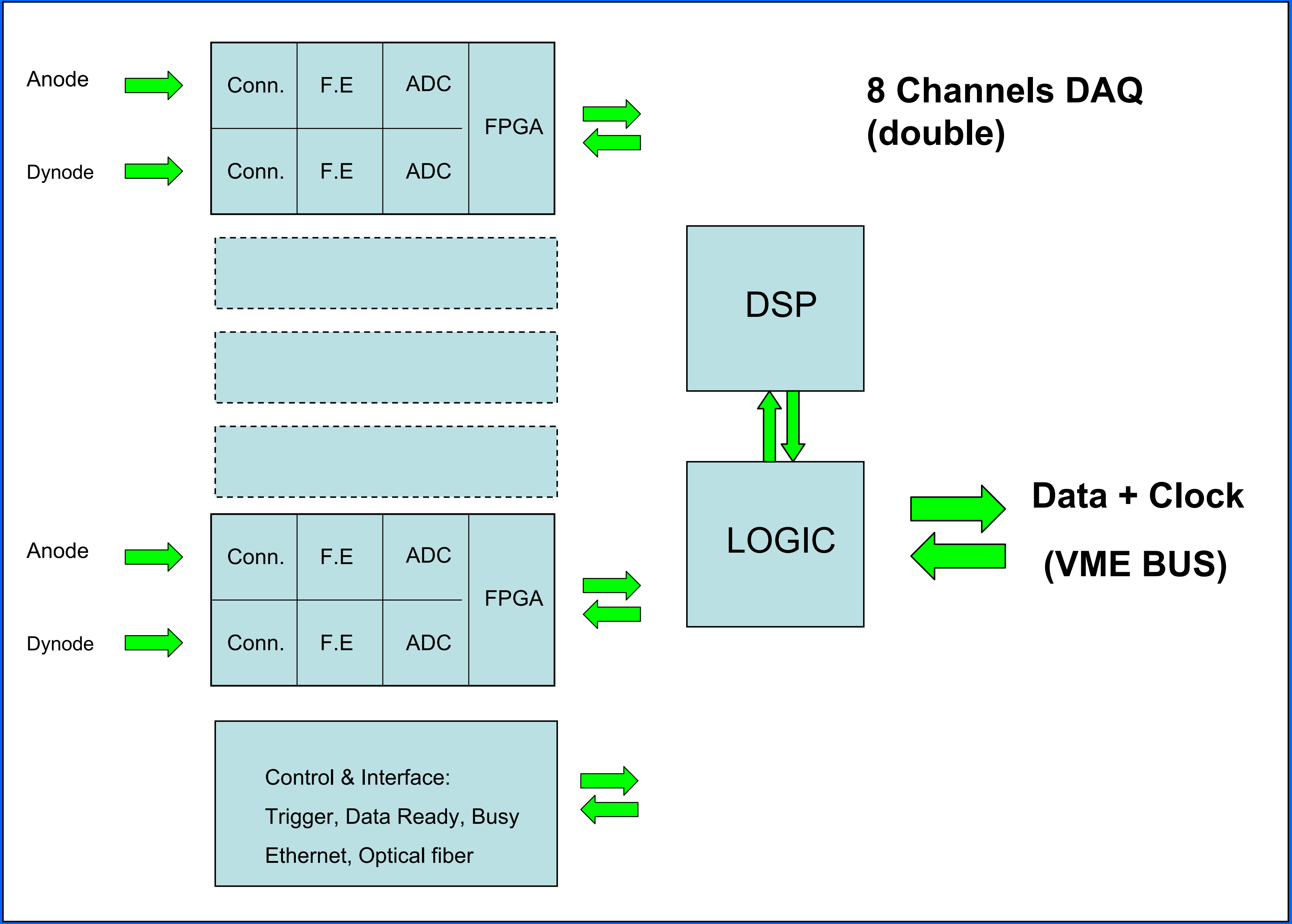
Timing 1"x1" and 3"x3" LaBr3 (^{60}Co**) (**Thr. 150KeV**)**

16 set of coefficients	660 ps

Base cell for the new board



New VME board



Thank you!