What have we learned on LaBr3 and LaBr3 based Phoswich Detectors at IPN Orsay ?

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1. Introduction
2. Energy resolution measurements
3. Time resolution measurements
4. (Simulations)

Material

Gamma sources

Standard Laboratory Sources:
- 137 Cs (reference)
- 60 Co
- 22 Na

Reaction induced gammas:
- TANDEM 15 MV (Emin = 2 MeV for p)

All the tests done at IPN are with standard sources

Crystals (traveled between Strasbourg and Orsay)

Pure LaBr3(Ce) crystals:
- 1”x1”
- **1”x1”x2”**
- 2”x2”x4”

Phoswich:
- **1”x1”x2”** LaBr3(Ce) + 1”x1”x6” CsI(Na)
- **1”x1”x2”** LaBr3(Ce) + 1”x1”x6” NaI(Tl)
- (packed and provided by Saint Gobain)

Photomultipliers

Photonis (closed!):
- XP 5300B (3” diameter)
- XP 20D0 (2” diameter)
- XP 2282 (2” diameter)

Hamamatsu:
- R 2083 (2” diameter)
- R 7899-01 (1” diameter)
- R 6236-01 (2”x2”)

It is very important when citing an energy/time resolution value to specify the material used for the measurement !

Detector readout

PMT signal samples

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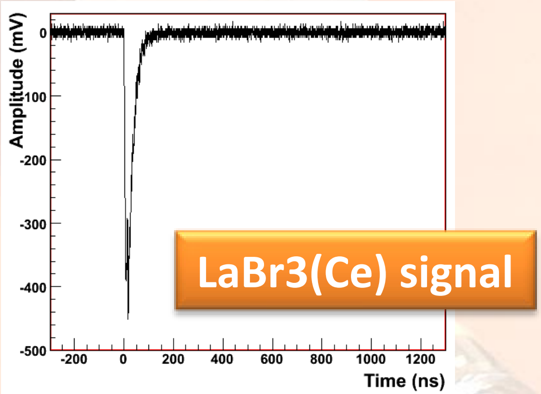
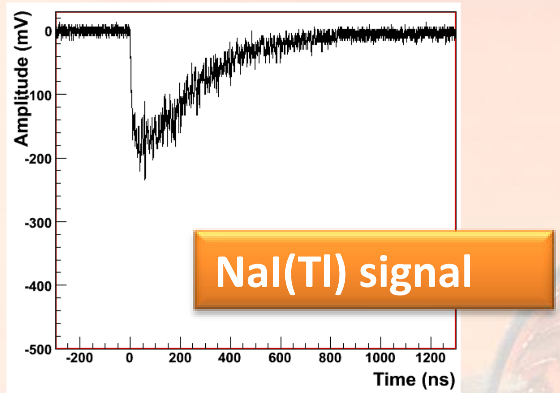
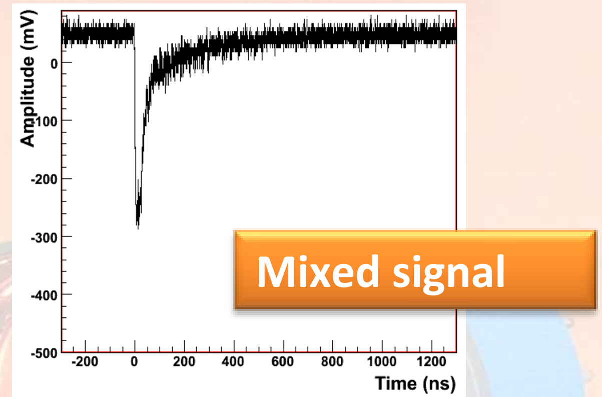
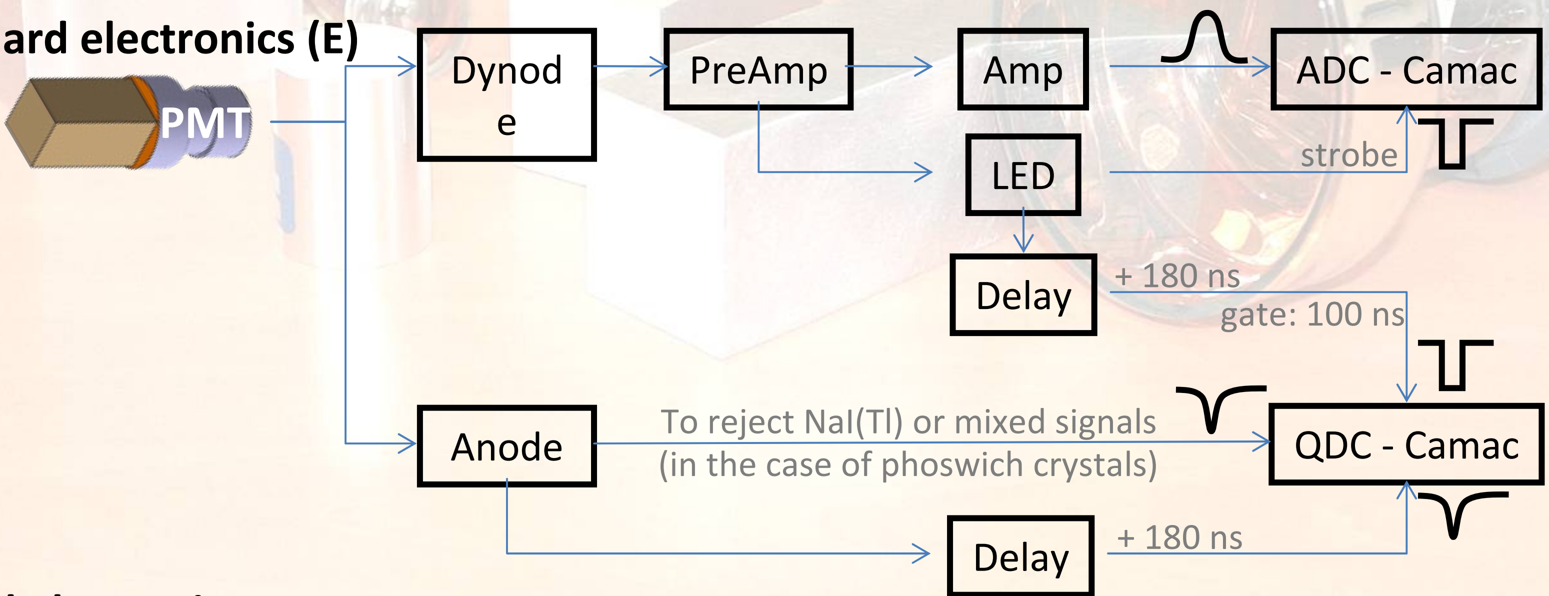






Standard electronics (E)



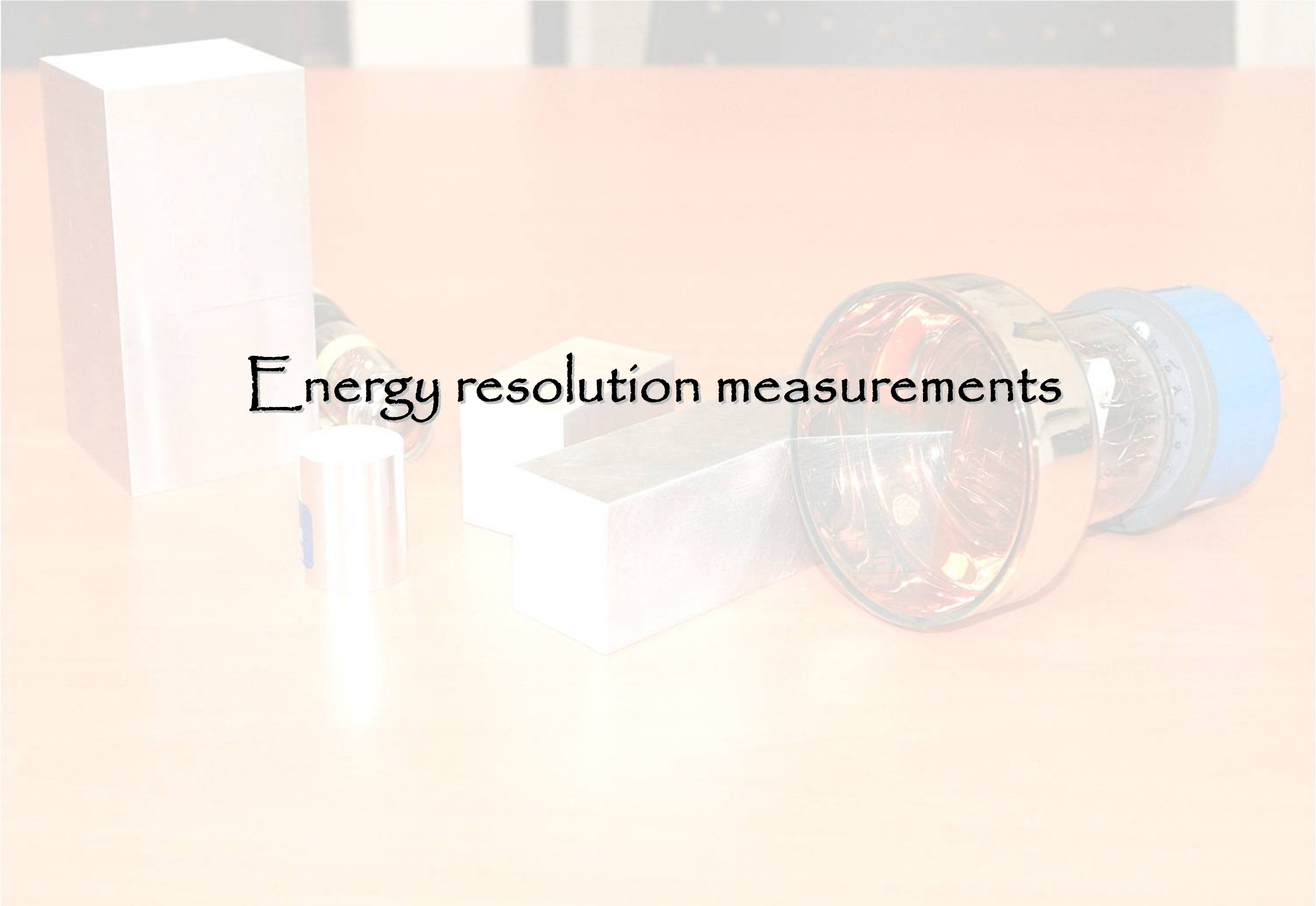
Digital electronic

Digitizer:

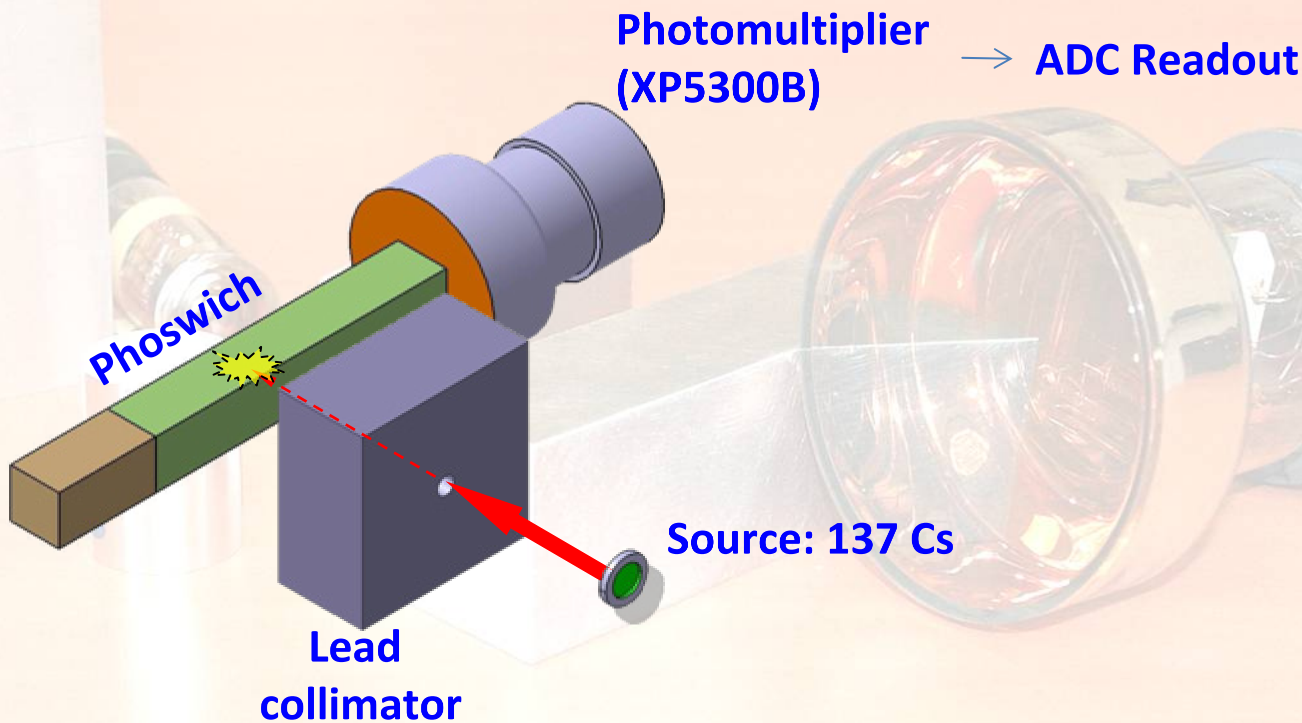
Prototype of V1751 – VME

Oscilloscope (solution dropped)

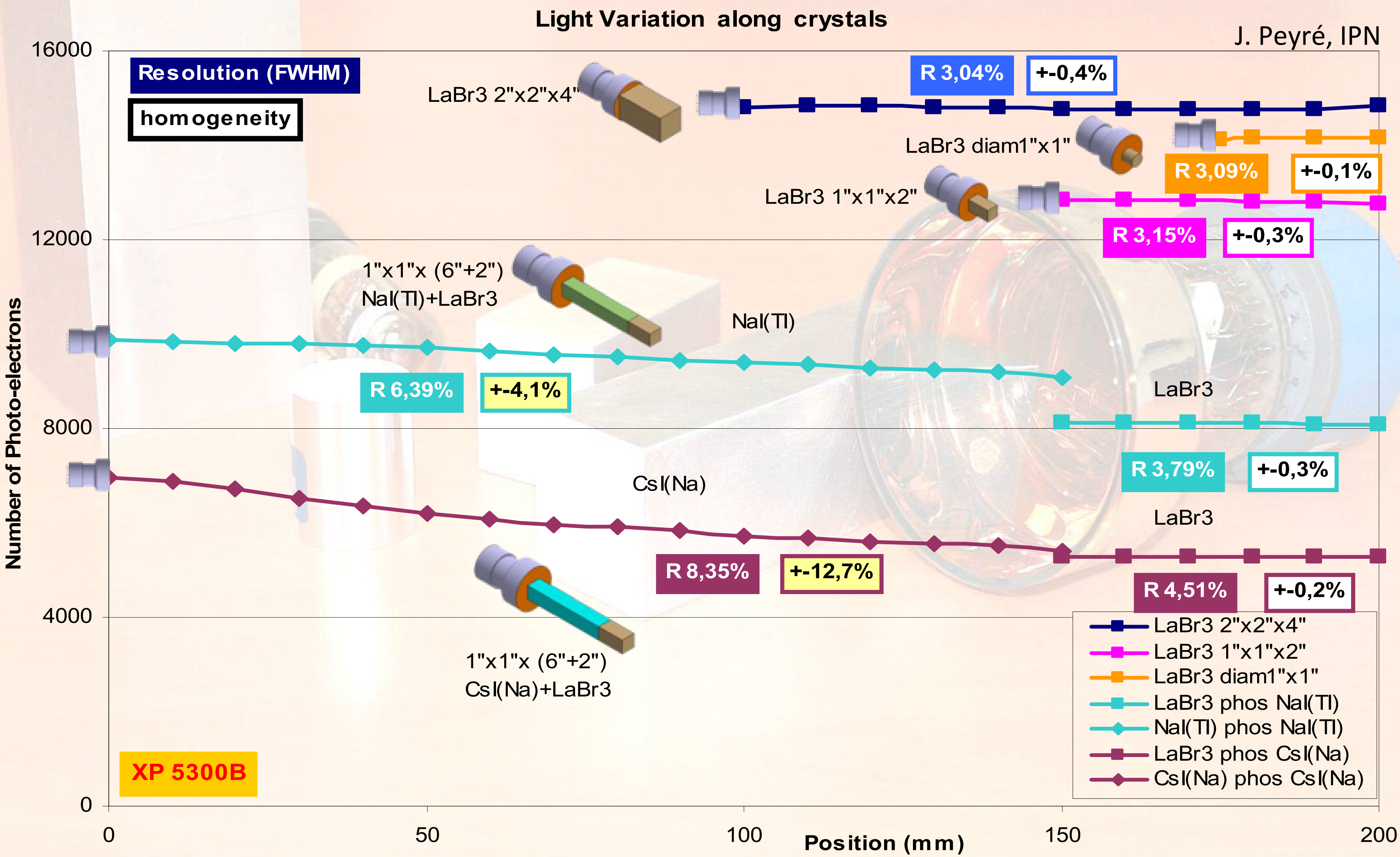
Energy resolution measurements



a. Crystal homogeneity : Setup



a. Crystal homogeneity : Results



a. Crystal homogeneity : Conclusions

A. The homogeneity of single LaBr3(Ce) crystals is better than 1%

B. The NaI(Tl) crystal in the phoswich has 8% in-homogeneity in the energy response

C. The CsI(Na) crystal in the phoswich has 20% in-homogeneity in the energy response

b. Crystal + PMT energy resolution: Results

J. Peyré, IPN

PMT ↓ / $LaBr_3$ →	Diam1"x1"	2"x2"x4"	1"x1"x2"	1"x1"x2" + 1"x1"x6"	1"x1"x2" + 1"x1"x6"	mA/lmF-b QE
XP5300B Ø3"	3,09% $LaBr_3$	3,04% $LaBr_3$	3,15% $LaBr_3$	NaI(Tl) 6,39% +-4,1%; 3,79% $LaBr_3$	CsI(Na) 8,35% +-12,7%; 4,51% $LaBr_3$	14,6 36,3%
XP2282 Ø2"	3,95% $LaBr_3$	4,98% $LaBr_3$	4,07% $LaBr_3$	NaI(Tl) 7,02%; 5,10% $LaBr_3$	CsI(Na) 8,92%; 6,19% $LaBr_3$	<< 9 << 20%
R2083 Ø2"	3,37% $LaBr_3$	4,03% $LaBr_3$	3,49% $LaBr_3$	NaI(Tl) 6,59%; 4,21% $LaBr_3$	CsI(Na) 8,52%; 4,91% $LaBr_3$	10,5 26,1%
R7899-01 Ø1"	3,38% $LaBr_3$	N.R.* $LaBr_3$	3,79% $LaBr_3$	NaI(Tl) 7,63%; 5,45% $LaBr_3$	CsI(Na) 10,17%; 7,19% $LaBr_3$	10,2 25,4%
R6236-01 1"x1"		2.9%				

N.R.*: Value 6,89% non relevant due to the difference of size between PMt and crystal

b. Crystal + PMT energy resolution: Comments

A. The resolution for single squared LaBr3(Ce) crystals is comparable with the cylindrical shaped crystals

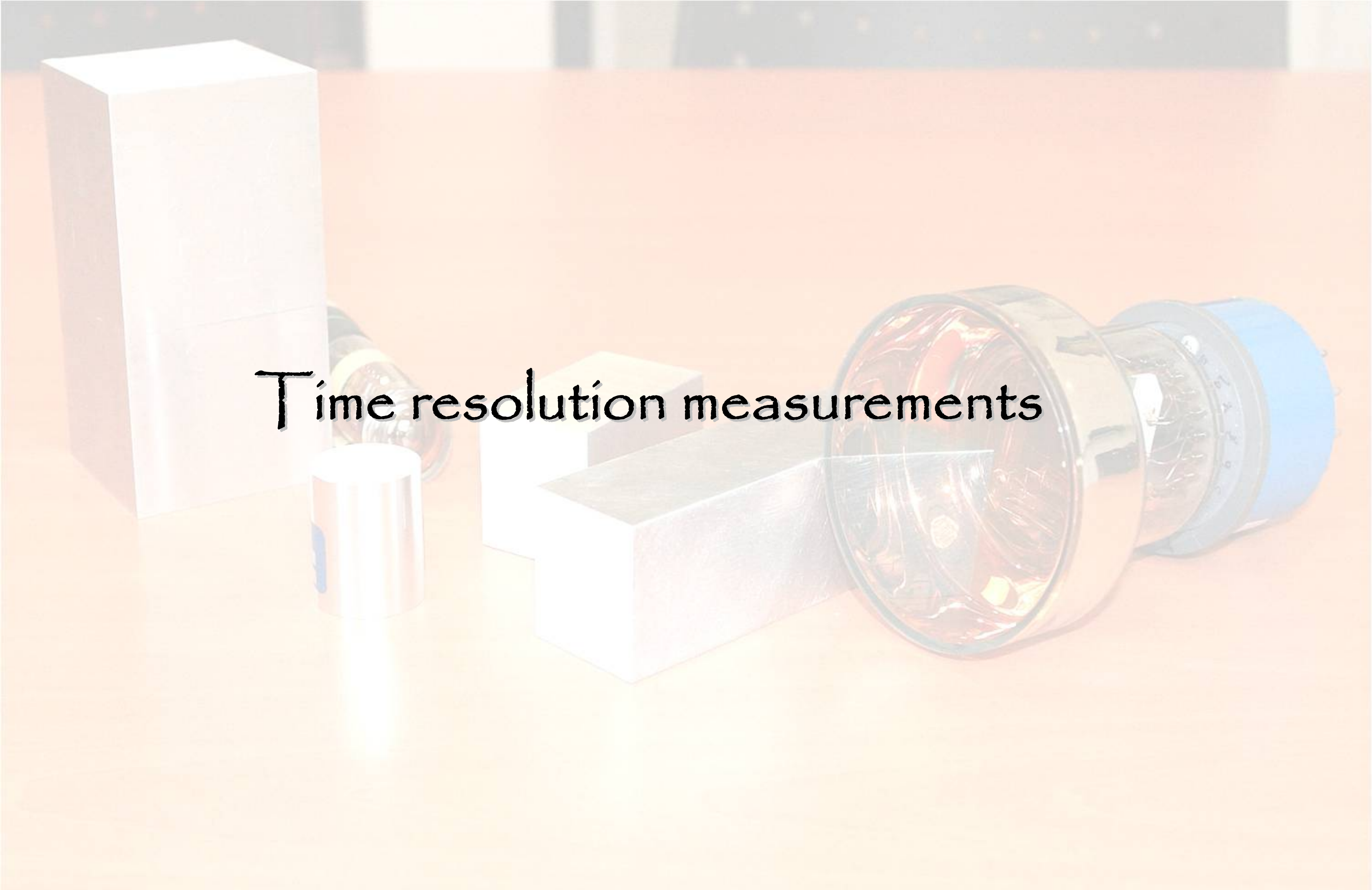
B. The NaI(Tl) crystal in the phoswich degrades by 20% the LaBr3(Ce) crystal energy resolution

C. The CsI(Na) crystal in the phoswich degrades by 43% the LaBr3(Ce) crystal energy resolution (homogeneity …)

Triggered the choice of the LaBr3(Ce) + NaI(Tl) phoswich as option for PARIS prototype/demonstrator

D. 2 x R 7723-01 PMTs at IPN (just received) …

Time resolution measurements

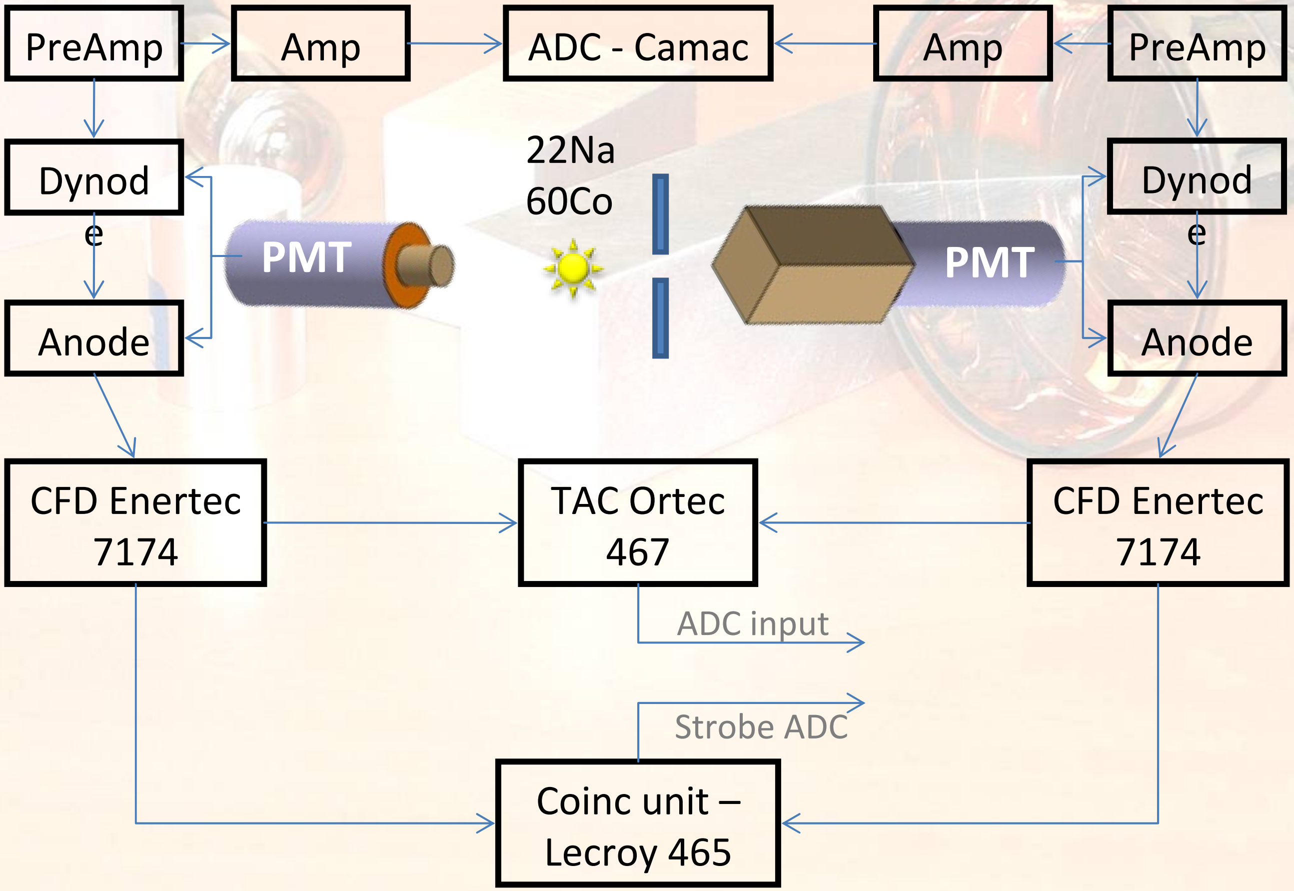


Time resolution : Material and Setup

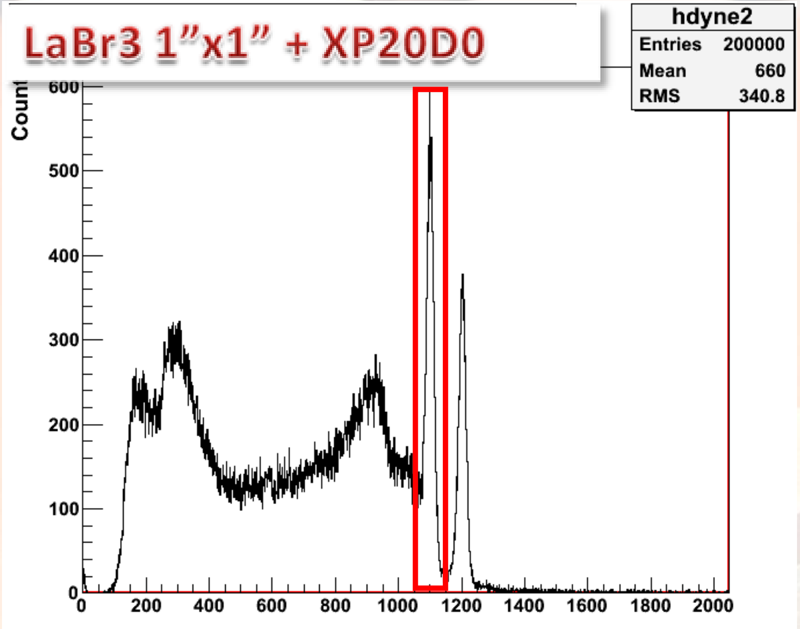
Crystals + PMTs :

LaBr3(Ce) 1”x1” + XP 20D0

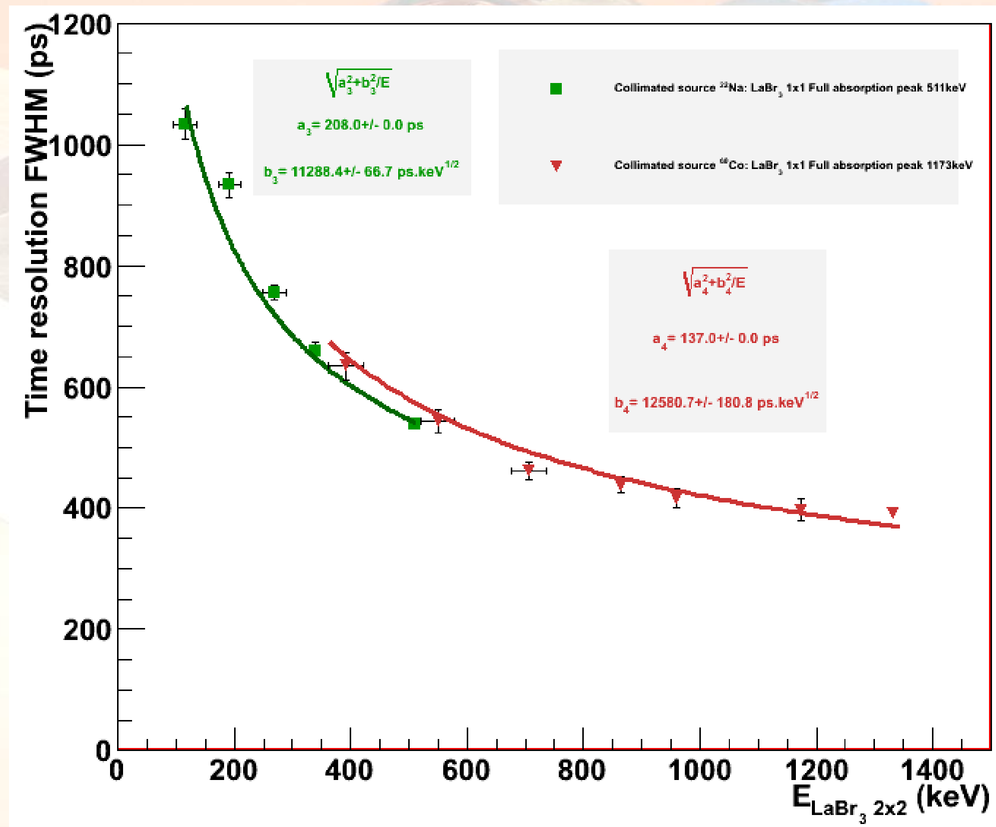
LaBr3(Ce) 2”x2”x4” + XP 2282 (round) or R 6236-01 (square)

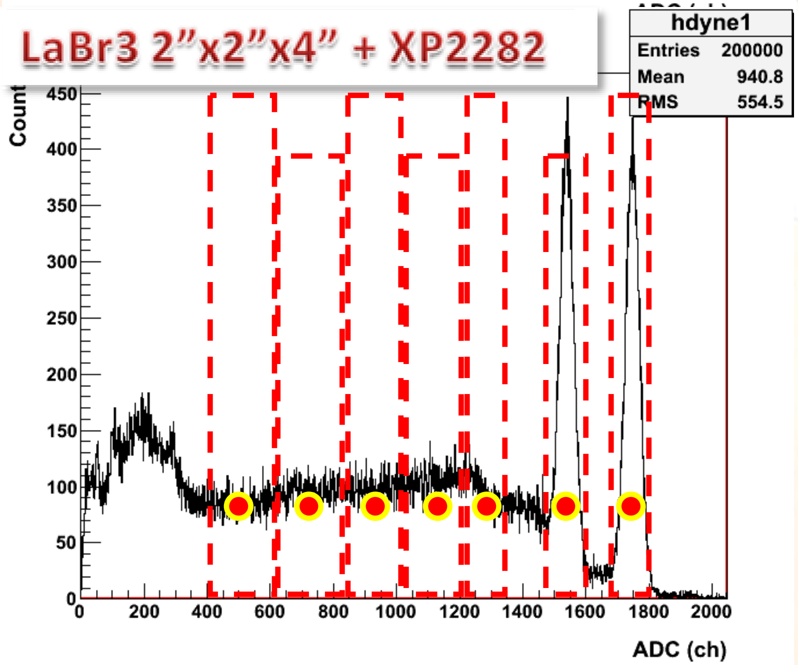


Time resolution : Method



Fit function: $f(E)=\sqrt{a+\frac{b}{E}}$ **Intrinsic time resolution**





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Time resolution : Results

Crystal + PMT	FWHM @511 keV	FWHM @1332 keV	b coef (ps $keV^{1/2}$)
LaBr3(Ce) 1"x1" + XP 20D0	208(9) ps	129(5) ps	4700(200)
LaBr3(Ce) 2"x2"x4" + XP 2282	499(35) ps	309(22) ps	11269(800)
LaBr3(Ce) 2"x2"x4" + R 6236-01	938(23) ps	581(10) ps	21213(400)

A. Good intrinsic time resolution of single crystals when used with proper PMTs

B. Squared PMTs have a poor time resolution (but a very good energy resolution, depending on the PK)

Simulations (a glance …)

Energy deposit **GEANT 4 simulations**

T. Zerguerras, IPN

+

Light collection **LITRANI simulations**

B. Genolini, IPN

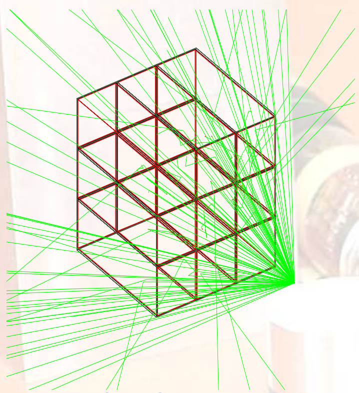
= **Scintillators + light guides + PMT answer**

Simulations: GEANT4

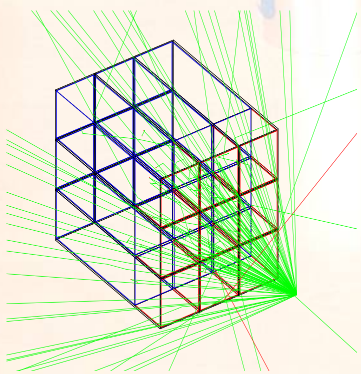
Use:

Efficiency estimations

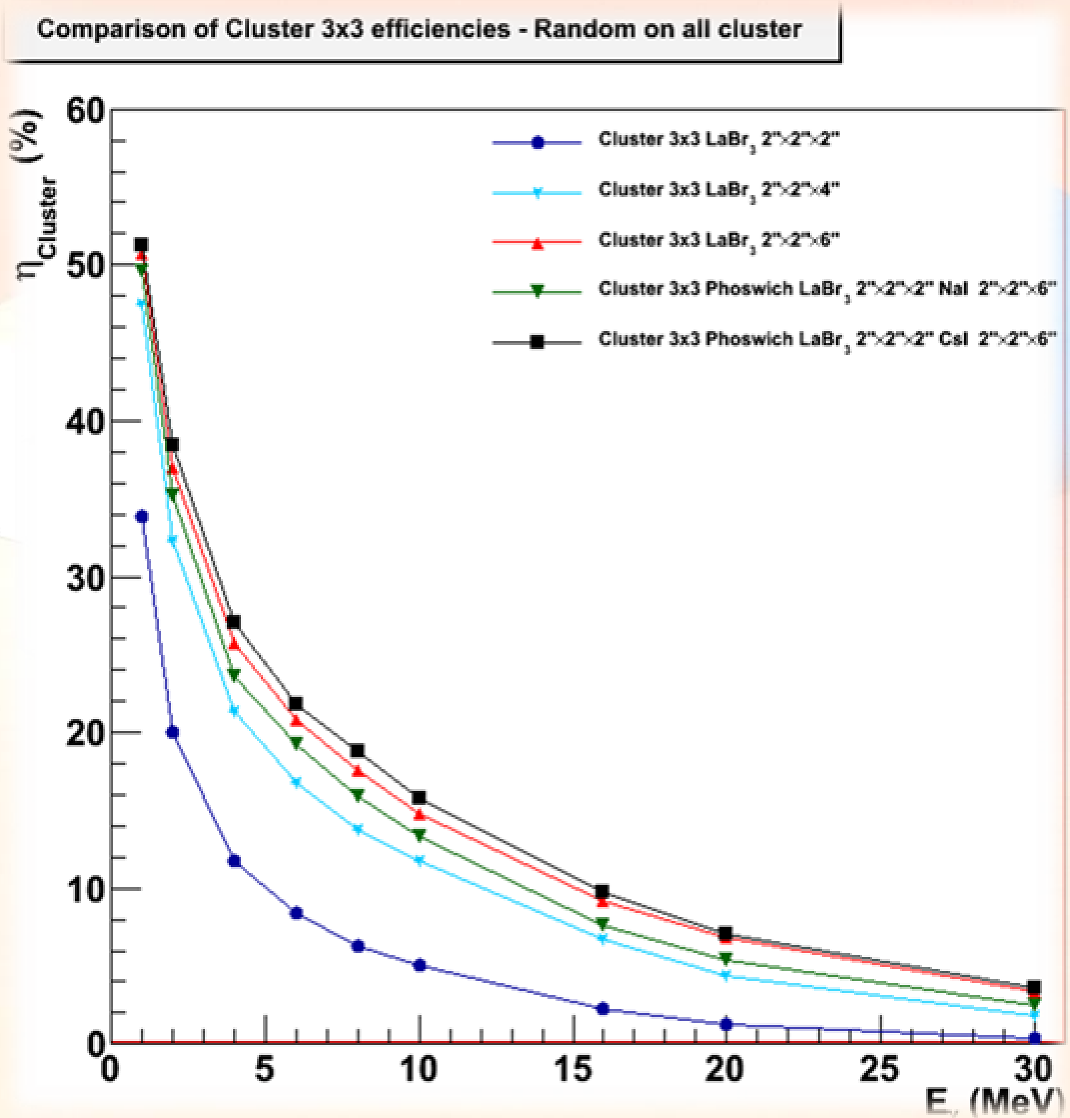
<u>Input for LITRANI</u>



LaBr3(Ce) Cluster



Phoswich $LaBr_3$ – CsI/NaI Cluster



Simulations: LITRANI

(**LI**ght **T**ransmision in **ANI**sotropic media)

- General purpose Monte-Carlo program to simulate the propagation of optical photons
- ROOT library
- Developped at CEA, Saclay, France for GLAST and the CMS calorimeter
  (http://gentit.home.cern.ch/gentit/litrani)
- Classes and data library from measured materials :
  – Scintillators: $PbWO_4$, CsI(Tl)
  – Revetments: Aluminum,Tyvek, VM2000
  – Detectors: PMT (XP2020), APD
  – Surface state: depolished, thin slice of air
- Extendable library (Photocathode sensitivity, scintillator emission spectrum, etc.)

Interest of the LITRANI simulations:
- Understand where the losses occur
- Localization / light guides

Important for the prototype design

Simulations: LITRANI

- **Model of the LaBr3 scintillator**
  - Determine the emission peaks from Gaussian fits
  - Decay time: defined according to the data sheet
  - Absorption Length: not found – took 5 m
  - Wrapped with aluminum
  - Light yield: 63 photons / keV (Saint-Gobain data)

- **Photocathode:**
  - Quantum efficiency: data from Photonis XP3292 (30 % QE at max)
  - segmentation: 5×5 subfaces
  - N.B.: photons not transformed are lost. The photons reflected by the aluminum and the first dynode of the PMT input are also lost.

- **Event generation**
  - Gamma interaction simulated by T. Zerguerras with Geant 4
  - Light emission: isotropic emission generated with the specified decay, from the calculated energy deposit. The possible crystal non linearity is introduced at this step.

- **Run Litrani**
  - Run on a reduced set of events (250 to 1000 to get the resolution and the histogram, 25 to estimate the number of photoelectrons)
  - Automated reports: information where the losses occur.
  - The program tracks the photons: get the information on subfaces of the photocathode.

Results:
-Lower number of phe wr experiment
- poor capacity to localize
- very sensitive to wrapping

Source measurements :

First step in detector (scintillator + PMT) testing

Need to optimize the light collection at the crystal/PMT interface

(the choice goes to cylindrical PMT on square crystals …)

but

cover only a very small part of the energy range requested for PARIS

One needs high energy gammas and PARIS prototype in order to have a full picture on the detector response

What about monitoring the linearity of the detectors and its evolution in time ?

Implement leds on each crystal ? Mechanics + detector WG …