Attività scintillatori/Nuovi materiali/Politecnico : F. Camera

High-efficiency and fast-timing scintillators

Convener: Enrique Nácher (IEM-CSIC, Madrid, Spain)

Franco Camera (University of Milano and INFN, Italy):

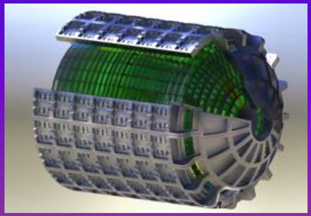
Response of a large LaBr3:Ce detector to 6-38 MeV gamma rays

Jose Manuel Udias (Univ. Complutense de Madrid, Spain):

Digital strategies for time and energy measurement for ultra-fast scintillators

Joakim Cederkal (University of Lund, Sweden):

Innovative solutions for the CALIFA forward endcap



Response of a large $LaBr_3$:Ce detector to 6-38 MeV γ-rays and new scintillator crystals

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Nuspin 2017

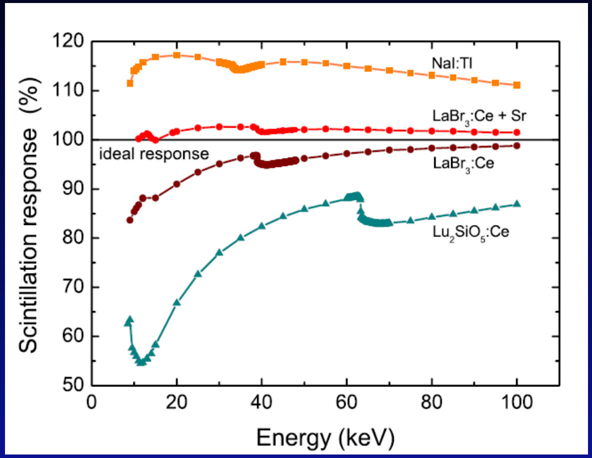
Response of a large $LaBr_3$:Ce detector to 6-38 MeV γ-rays and new scintillator crystals

Outline:

- The problem $\Rightarrow$ measure the detector response at high energy γ-rays
- SPring8
- Experimental Setup
  - Two identical $LaBr_3$:Ce crystals 3.5” x 8”
  - Two identical PMT (R10233 S/N -55 and -59) + Voltage Divider
- Calibration and Measurements
- Geant 4 Simulations
- Response Function
- New scintillators (CLLBC, CLYC, co-doped $LaBr_3$:Ce)
- Conclusions and Perspective

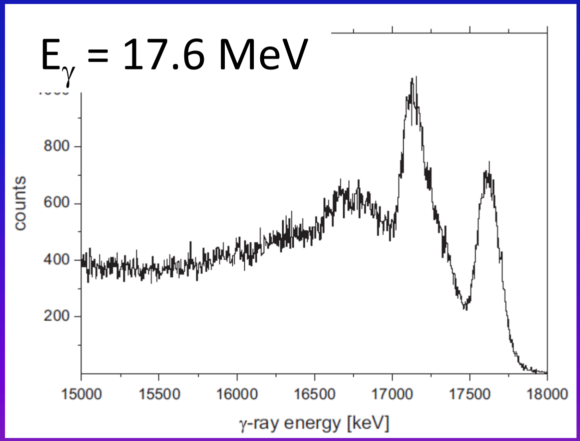
Starting Point

- Very low energy γ or x rays (E < 100 keV)
  - Some non-linearity (< 15%) intrinsic of the crystal
    - see Alekhin et al App. Ph. Lett. 102,161915 (2013)



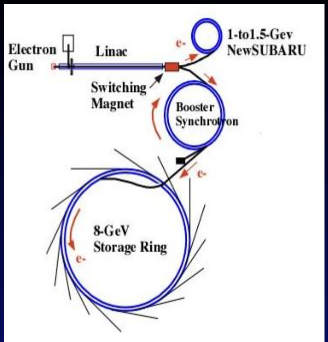
- Low Energy γ-rays (Standard sources: 0.1 < E < 9 MeV)
  - The crystal has a linear behavior
  - Non linear effect mainly due to the PMT-VD
    - see A.Giaz et al. NIM A 729 (2013) 910–921
    - see A.Favalli et. al. App. Rad. and Iso. 68 (2010) 901–904
    - I. Mazumdar et al (NIM A 705 (2013) 85–92)
      - reports a «decrease in pulse height of not more than 0.6%"

- High energy γ-rays E > 10 MeV
  - An accelerator and a nuclear reaction is necessary
  - A possible alternative
    - Laser Compton Scattering (NewSubaru – Hiγs)
      - Future – ELI-NP -> FWHM 0.3 %



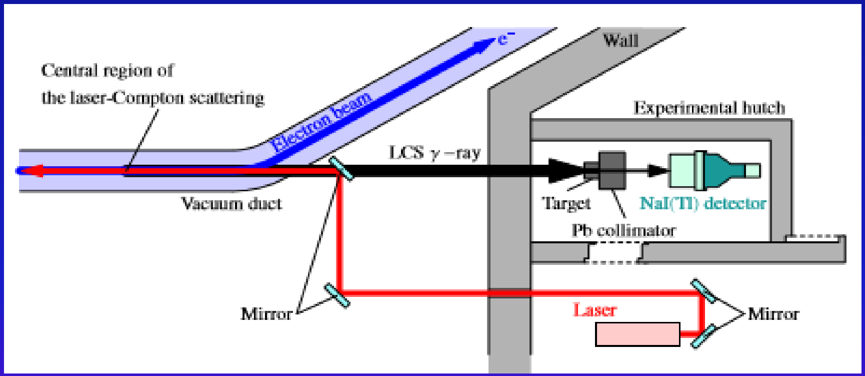
Spring-8

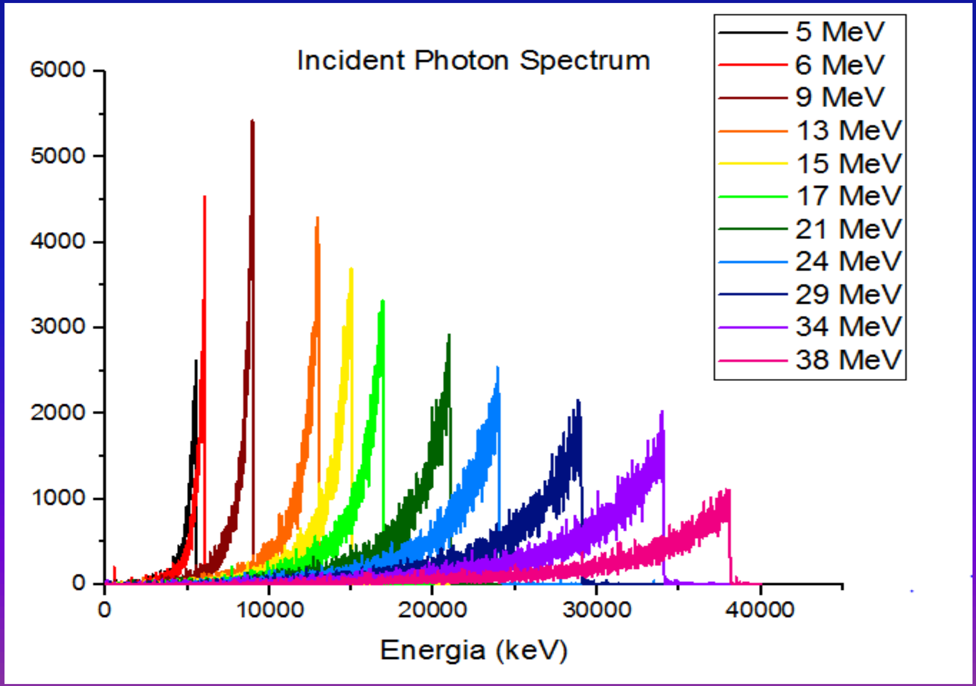
- Linac (1 GeV)
- Sincrotrone (8 GeV)
- Electron Storage Ring (8 GeV)
- Electron Storage Ring (1-1,5 GeV)
- SACLA



NewSUBARU :

- laser Compton scattering (LCS)
- E_{e-} = 0.5 - 1.5 GeV.
- Laser Nd(w): YVO_4 with wavelength 1064 nm
- 'Almost'-monocromatic gamma-rays





$LaBr_3(Ce)$:

- Light Yield 6300 ph/keV
- Decay time 16 ns
- Densiy 5,08 g/cm^3
- Energy resolution 3.1 % ^{137}Cs
- Time Resolution ~ 1 ns

Two crystals + two PMT+VD

Crystal S/N L824 and K604

PMT R10233 S/N -55 and -59

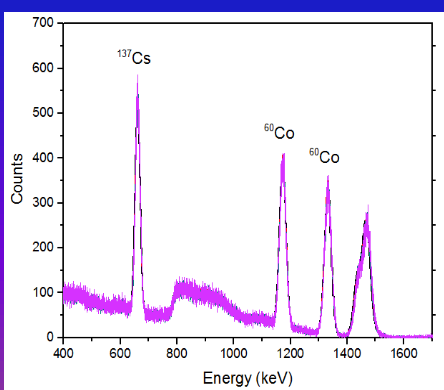
Misura 1	RF - CW	
E(γ) MeV	E (e-) MeV	Laser Power
5,53	550	10%
6,04	575	3%
9,00	704	2%
13,00	849	3%
14,99	914	2%
16,93	974	2%
20,99	1087	1%
24,02	1162	1%
29,02	1273	2%
34,03	1380	2%
38,00	1460	2%

LaBr-PRO Amplifier

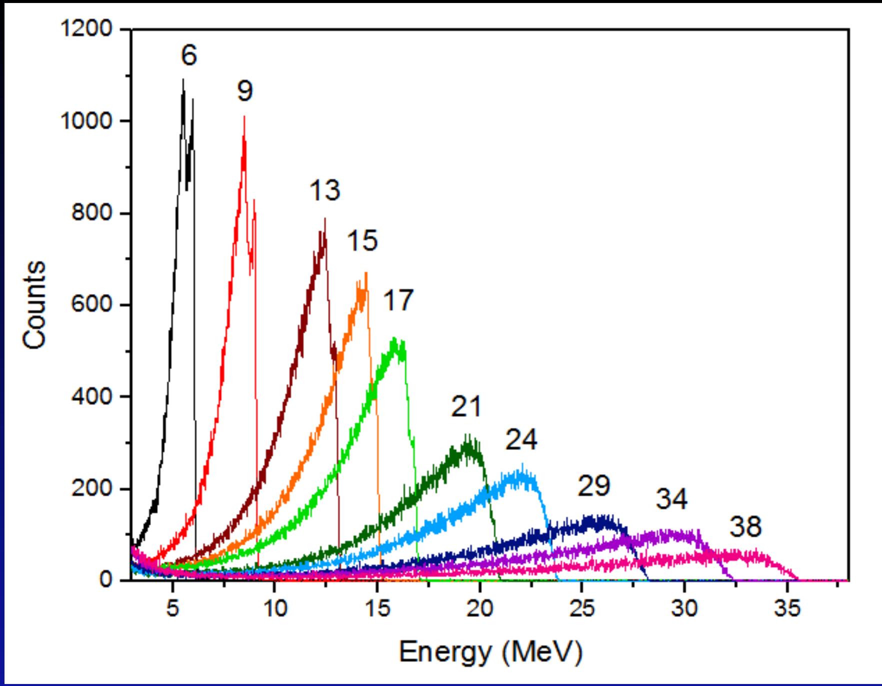
Two ADCs Amptek MCA8000D

- off beam - on beam spectra

Electronic non linearity up to 5.5 V ⇒ 0.3% %



Signal Amplitude [mV]	ΔE (keV) C1	ΔE (keV) C2
≈ 157	20.5	20.7
≈ 519	19.7	20.2
≈ 2048	19.8	20.1
≈ 3357	19.4	19.8



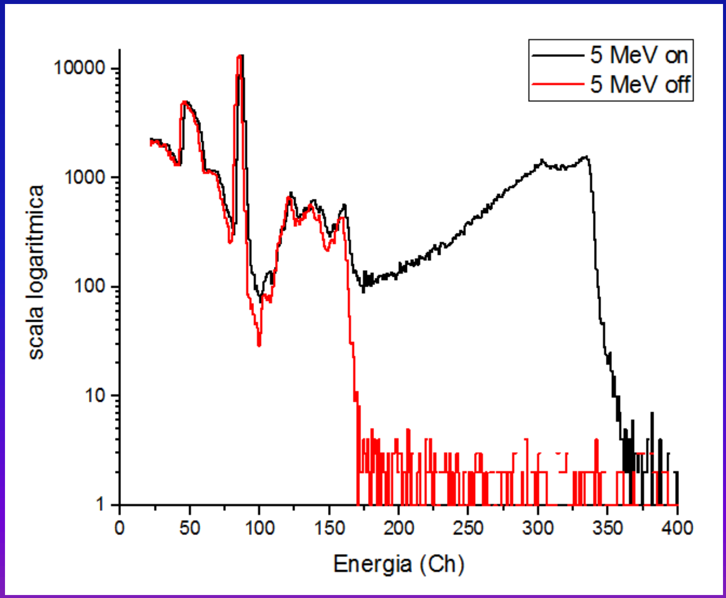
2 Crystals + 2 PMT+VD

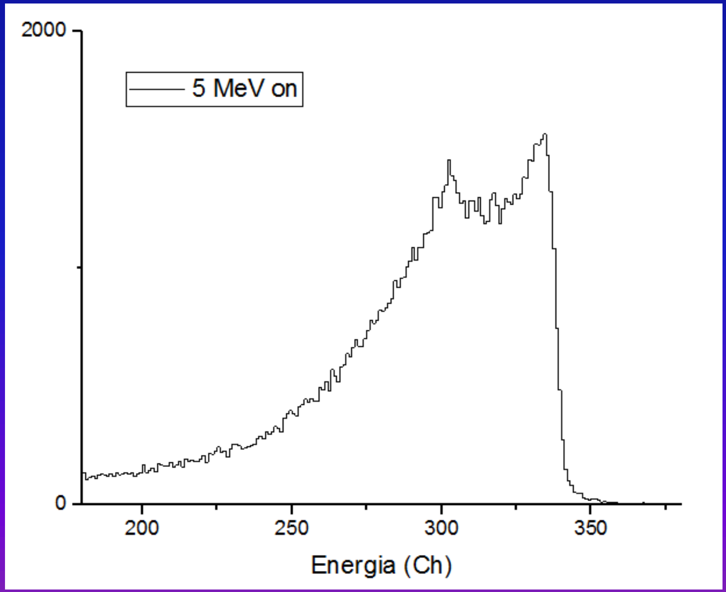
- Test two crystals with same PMT
- Test two PMTs with same crystal

30 mV anode signal at ^{137}Cs

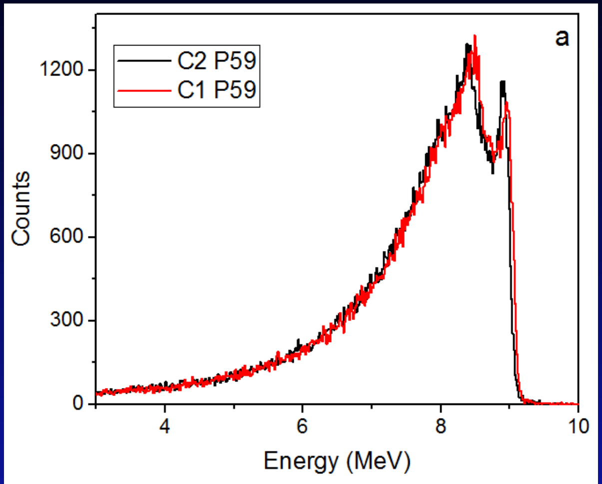
HV = - 810 V and - 950 V

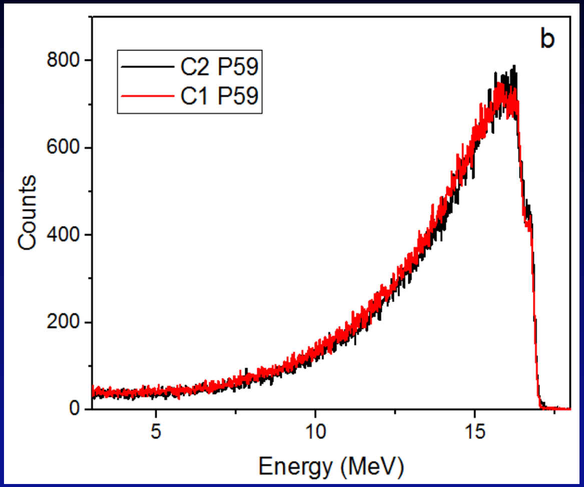
- Simulation LCS + GEANT4

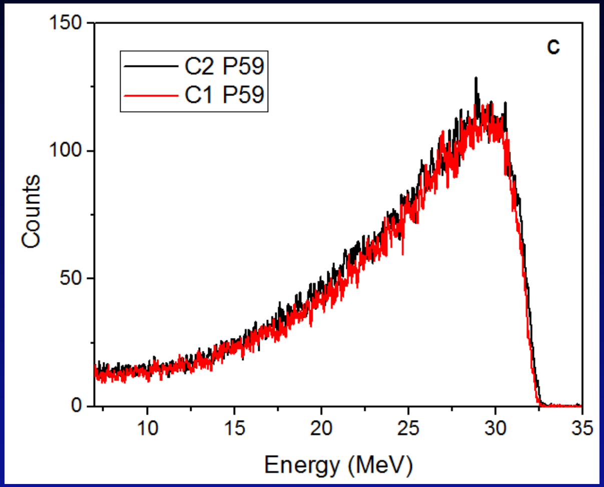


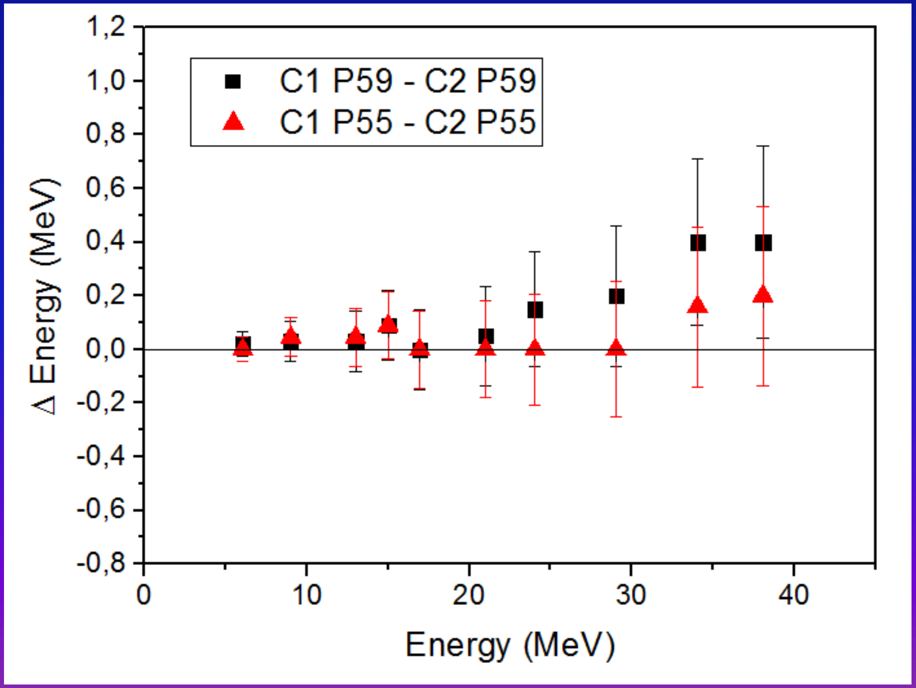


Two crystals - One PMT



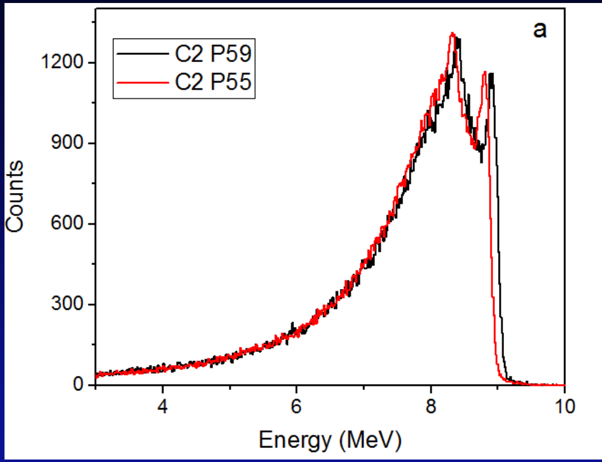


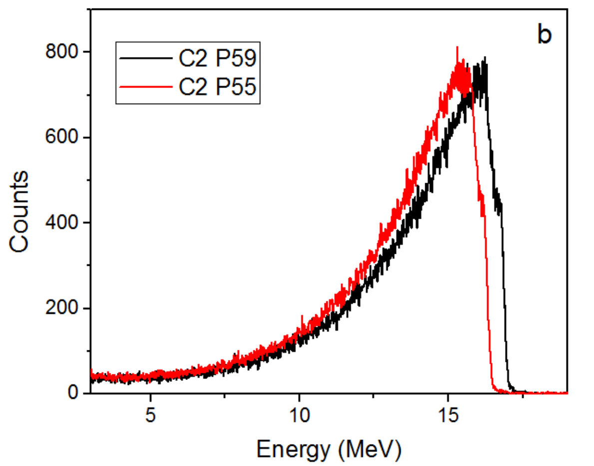


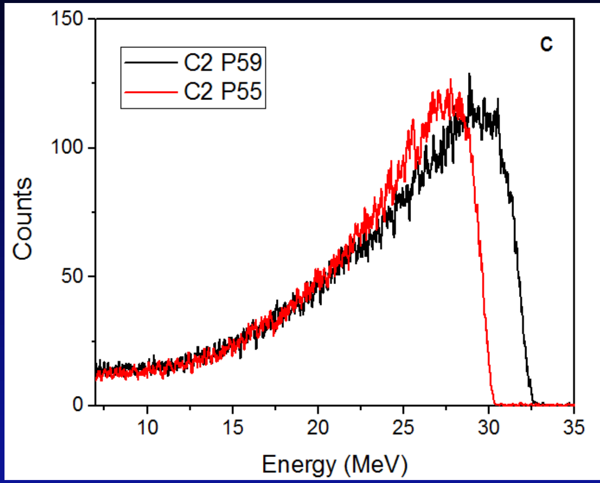


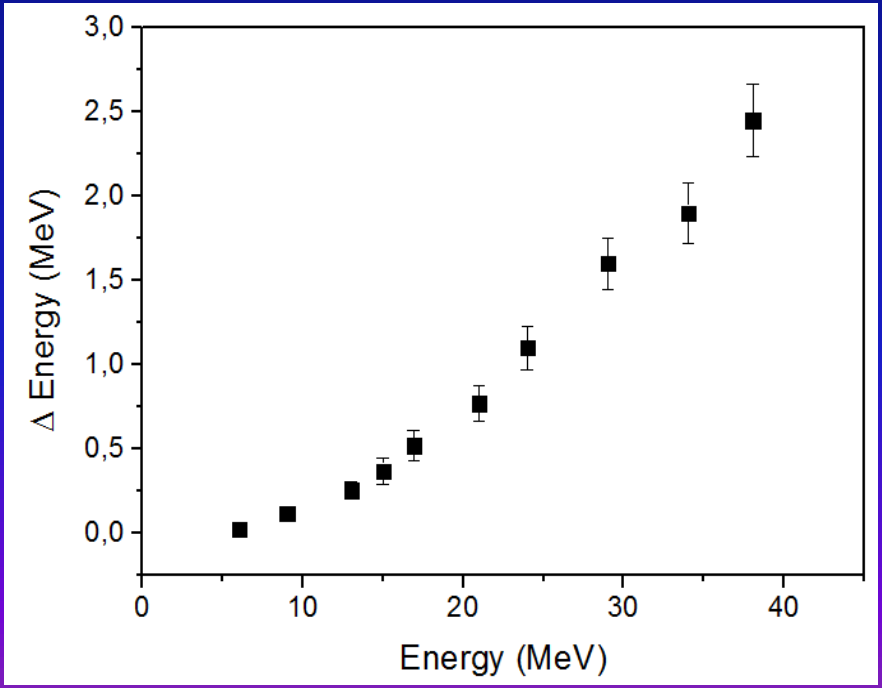
The two crystals have the same response (within the error bars) for high energy γ-rays

One crystal - Two PMTs



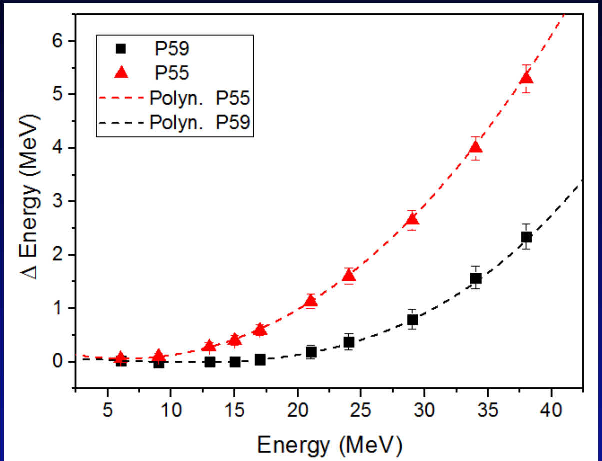






- The difference increases with γ-rays energy
- The difference starts at 6 MeV
- From 21 to 38 MeV the spectral line-shape changes
- The two PMTs have a very different response - even though they are of the same model, they are from the same production run and have been delivered in the same moment -

Simulations (LCS + Collimation + Geant)

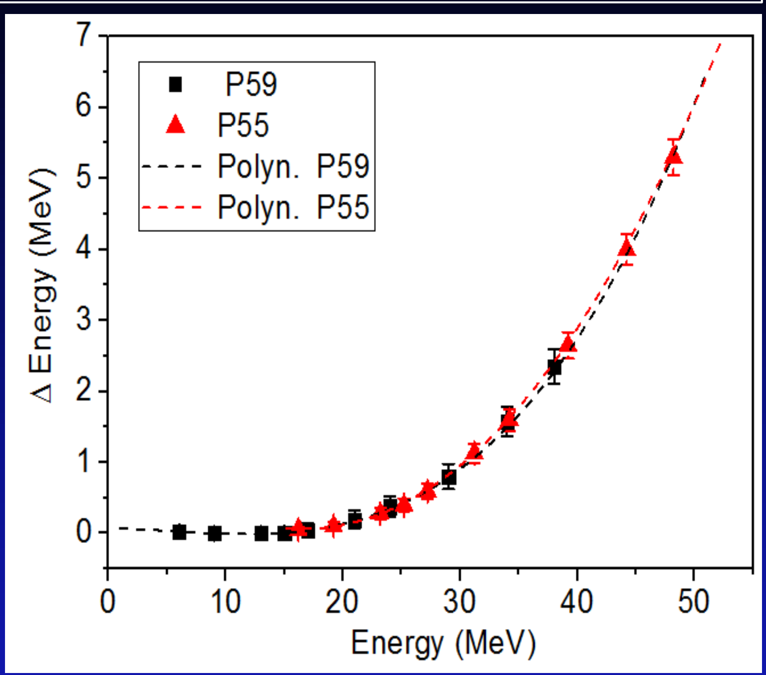


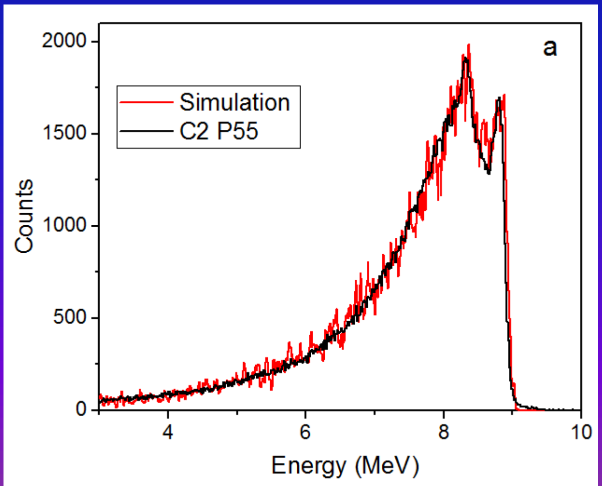
	P59	P55
a	0.00007	0.00002
b	-0.001	0.0043
c	-0.0053	-0.057
d	0.078	0.2455

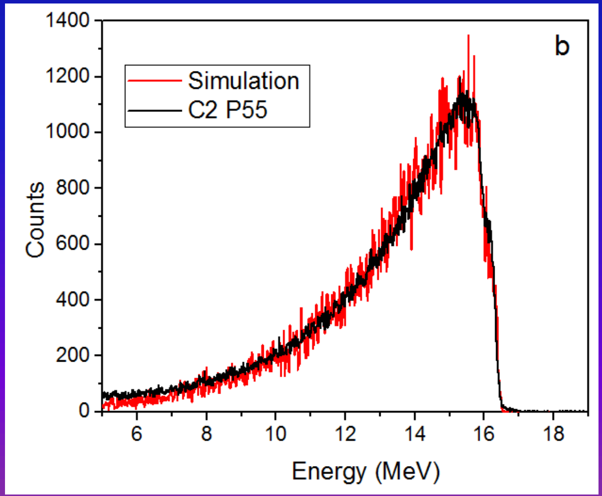
Crystals have the same response

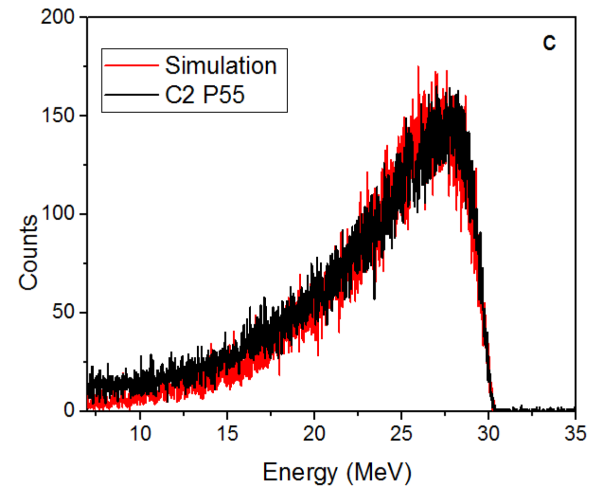
PMTs have different responses. A shift of 10.2 MeV makes the two NON- linearity curves overlap

Simulation nicely reproduces measured spectra

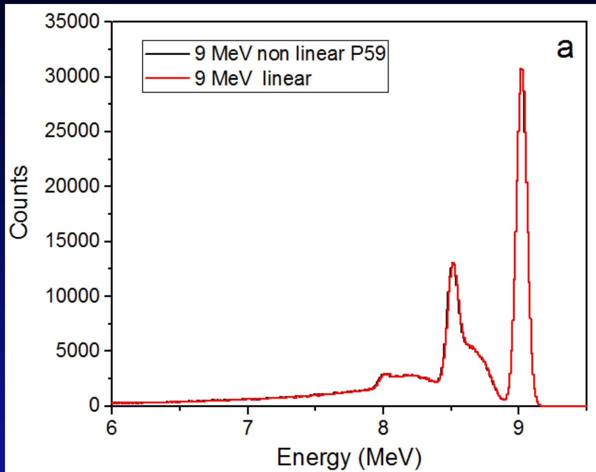


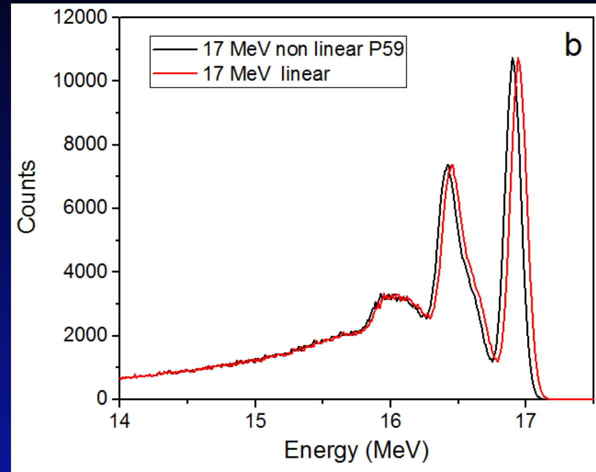


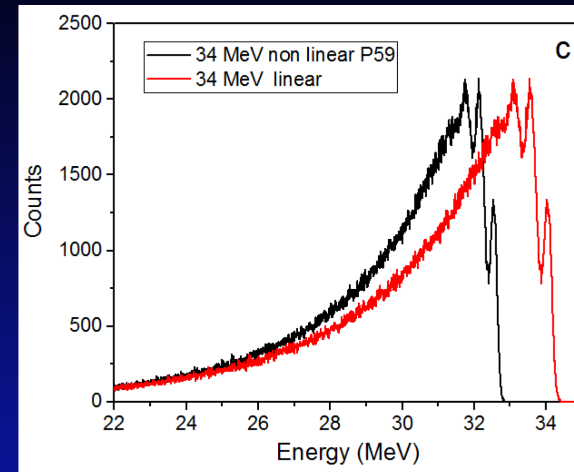


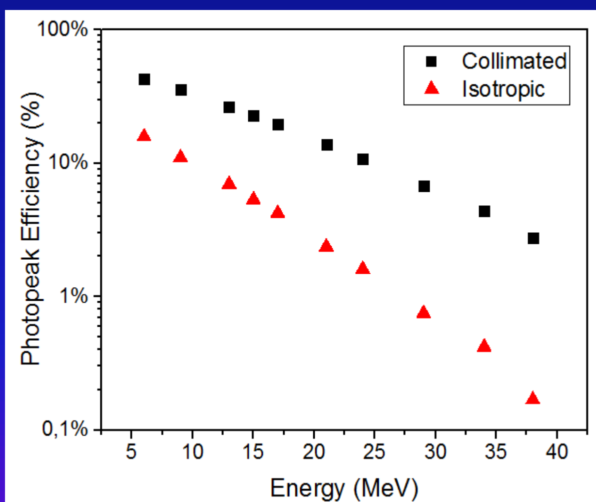


Response Function



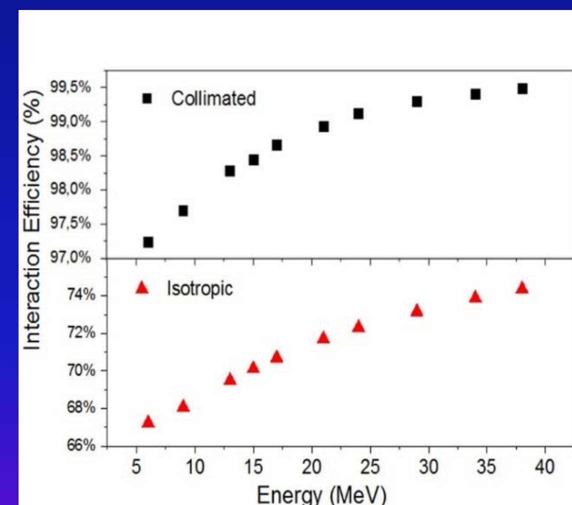






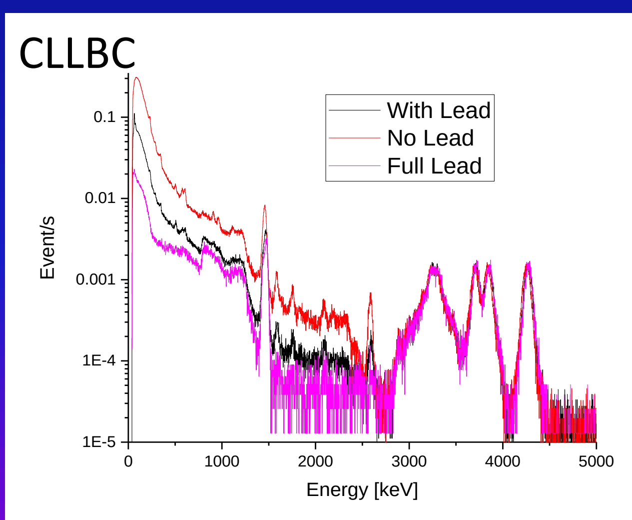
Simulations work on measured data.

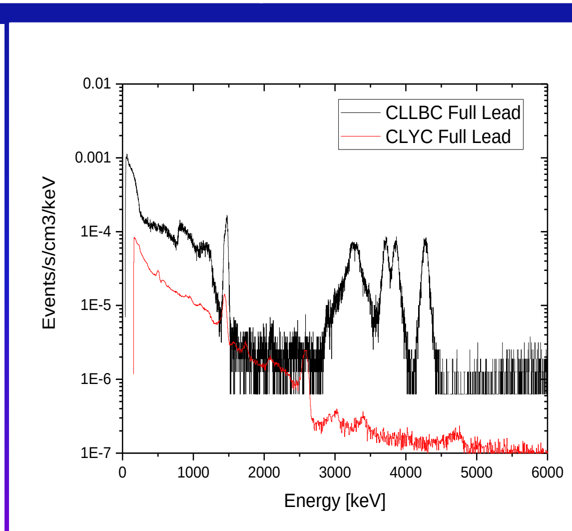
We performed simulations with monocromatic high energy gamma rays

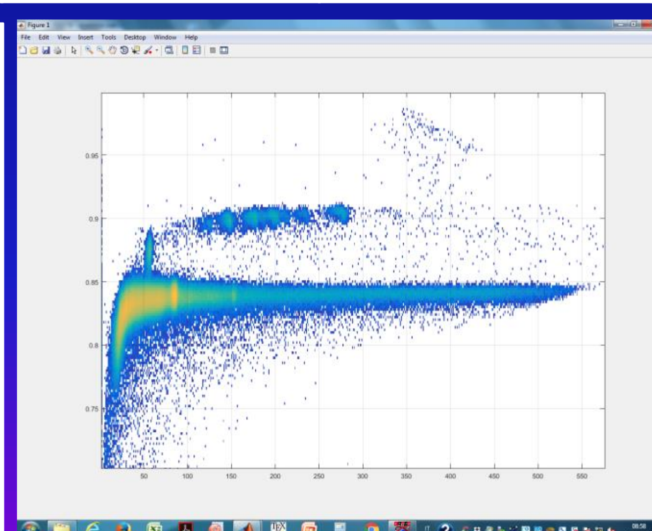


New materials

Material	Light Yield [ph/MeV]	Emission λ_{max} [nm]	En. Res. at 662 keV [%]	Density [g/cm^2]	Principal decay time [ns]
NaI:Tl	38000	415	6-7	3.7	230
CsI:Tl	52000	540	6-7	4.5	1000
$LaBr_3$:Ce	63000	360	3	5.1	17
SrI_2:Eu	80000	480	3-4	4.6	1500
$CeBr_3$	45000	370	~4	5.2	17
GYGAG	40000	540	<5	5.8	250
CLYC:Ce	20000	390	4	3.3	1 CVL 50, ~1000
CLLBC	**45000**	**Blue**	**3**	**4.1**	







$LaBr_3$:Ce Co-Doped are now available from St.Gobain – 17 keV at 661.7 keV

Conclusions and Perspective

Conclusions:

- The response function of two large volume LaB_3:Ce crystals + two PMTs+VD was measured
- Within the error bars the crystals behave in an identical way
- The two PMTs behave in a different way
  - They are of the same model and from the same production run
- Using simulations we have extracted the non linearity curve of the two PMTs
- Simulations reproduce measured data

- There are new and very interesting scintillators (i.e. CLYC, CLLB, CLLBC, Co-Doped, $LaBr_3$:Ce, …) with excellent performances

- ## Perspectives

- Is the NON-Linerity curve ‘universal’ ? Probably not. May be it is specific for that particular model of PMT. We will perform other NON-Linearity measurements to verify this
- Non linearity curves will be applied to measured spectra

Thanks to

<u>G. Gosta</u>, N. Blasi, B. Million, A. Giaz, O. Wieland, F. M. Rossi - From Milano
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D. Filipescu, I. Gheorghe - From ELI-NP