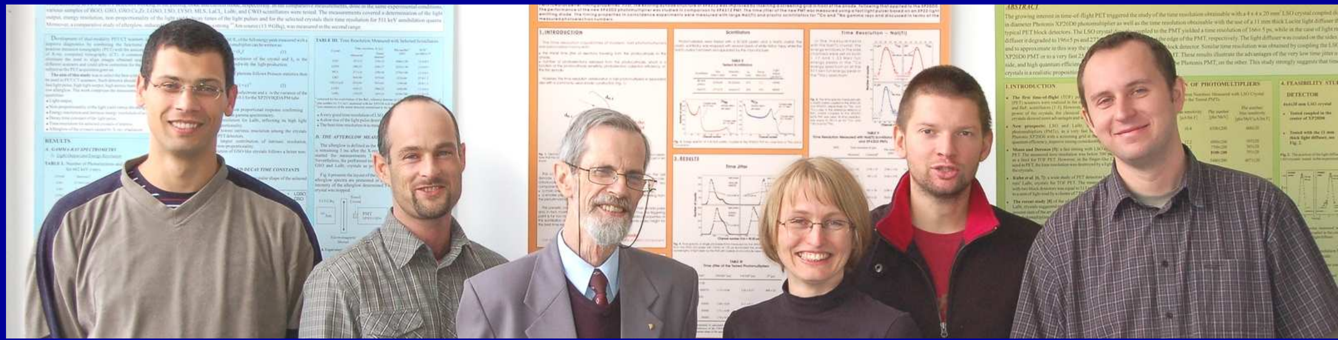
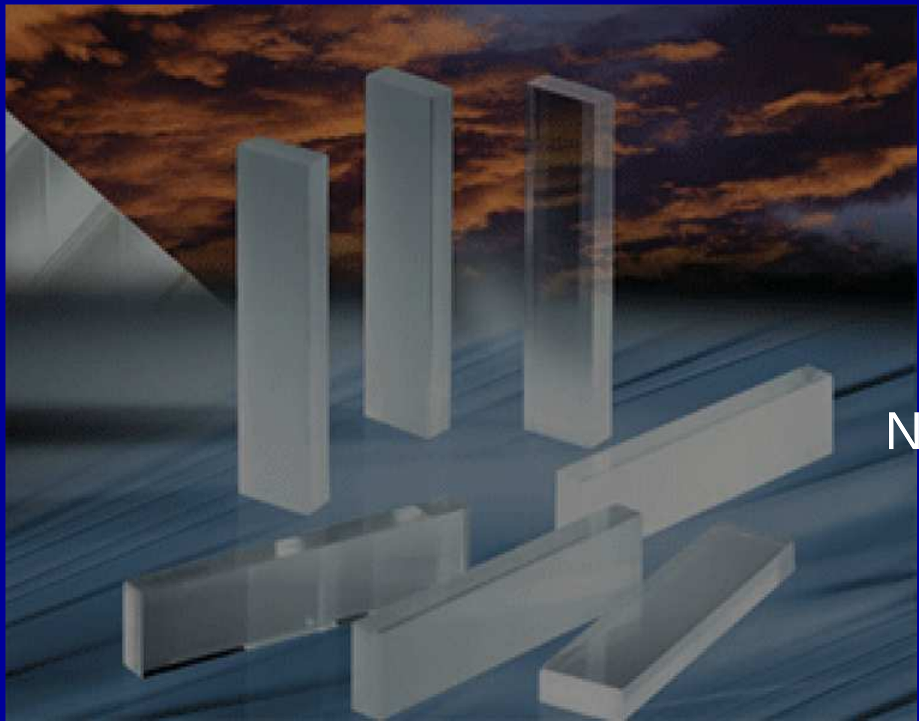




Scientific activity in scintillation research at NCBJ Świerk, Poland

M.Moszyński
National Centre for Nuclear Research
Świerk-Otwock, Poland

Program

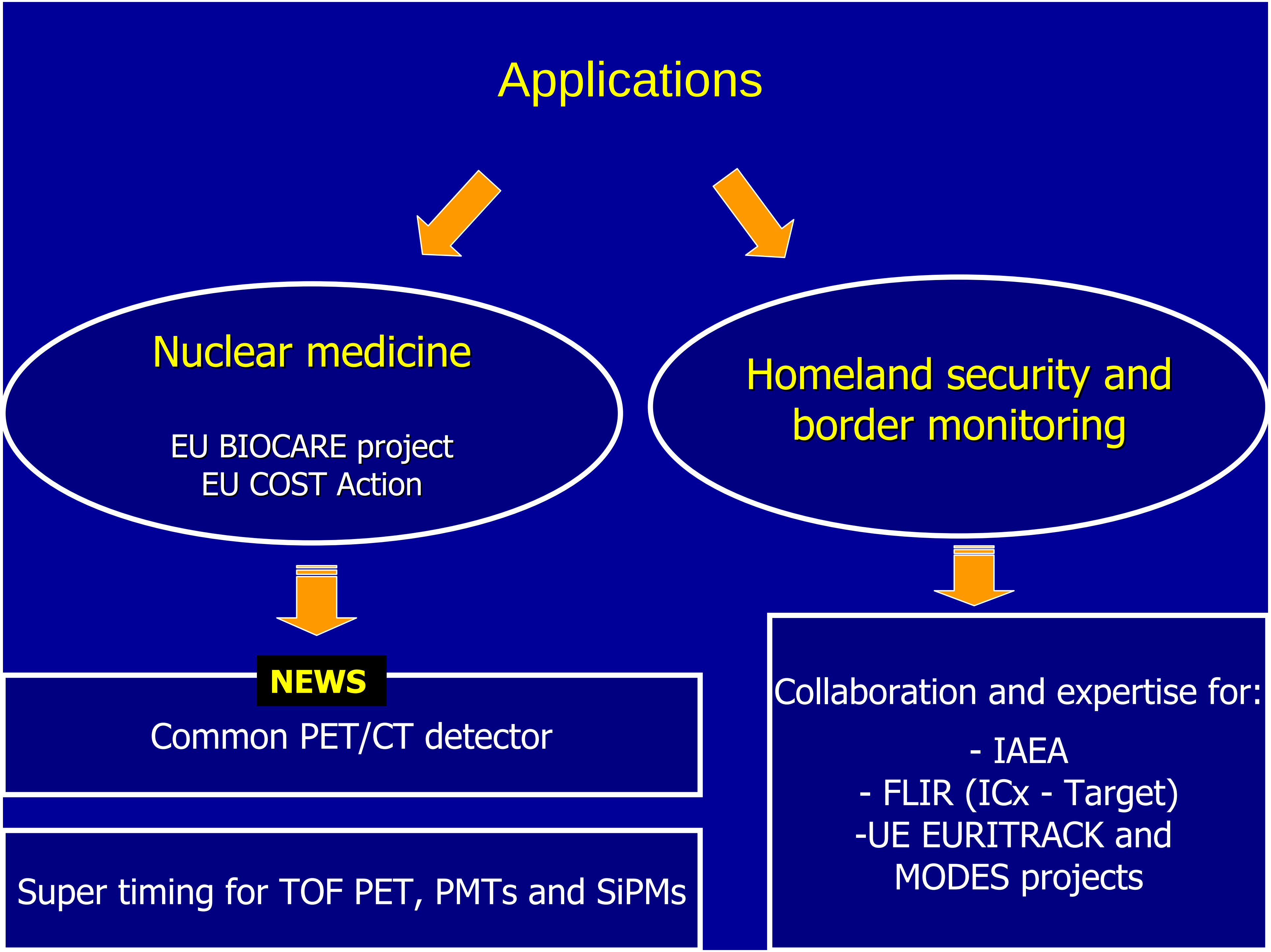
New scintillation detectors

$CeBr_3$, GAGG, LSO:Ce:Ca, LuAG:Pr,
LuAG:Ce, undoped NaI,
codoped CsI(Tl)

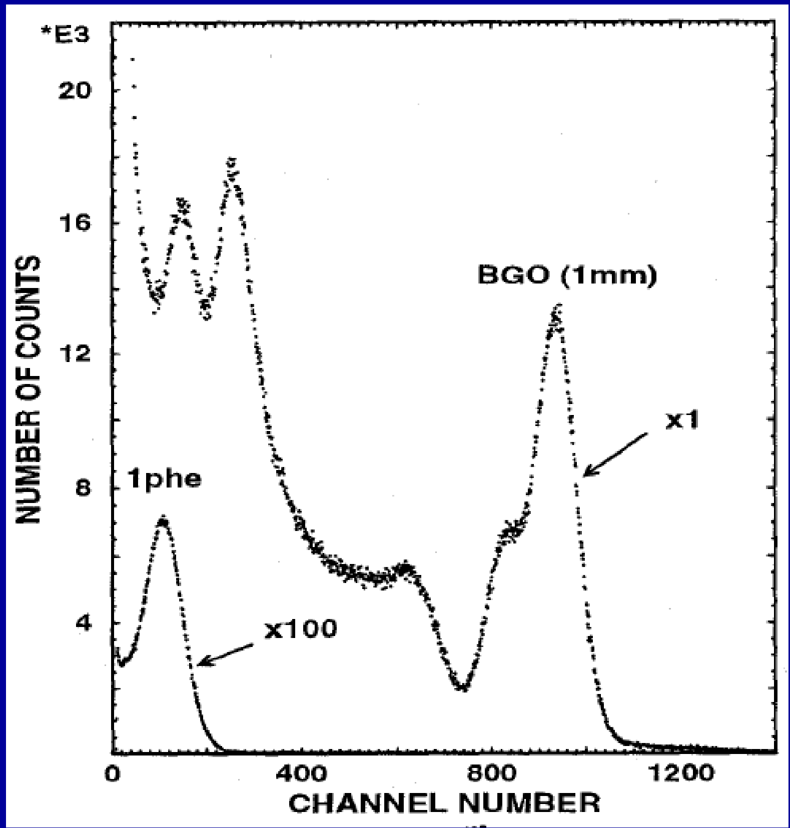
New photodetectors

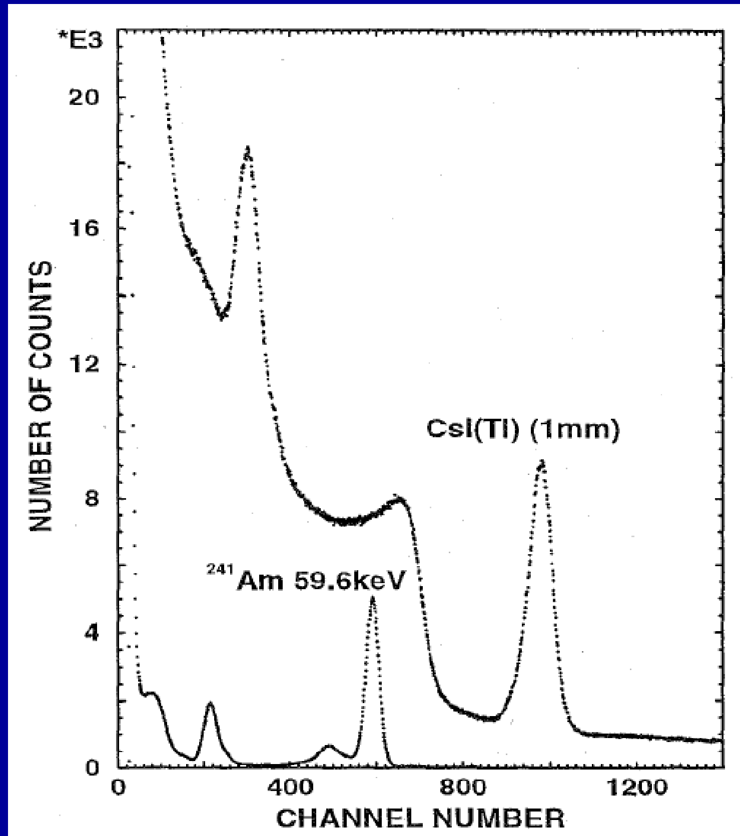
PMTs for fast timing and gamma spectrometry
Silicon Drift Detector
SiPM

A new look at the energy resolution
and the nonproportional response of scintillators


Applications
Nuclear medicine
EU BIOCARE project
EU COST Action
Homeland security and border monitoring
NEWS
Common PET/CT detector
Super timing for TOF PET, PMTs and SiPMs
Collaboration and expertise for:
- IAEA
- FLIR (ICx - Target)
-UE EURITRACK and MODES projects

Principle of the light output measurements





The light output of scintillators is determined correcting the measured number of photoelectrons (phe) or electron – hole (e-h) pairs produced by a scintillation light for the integral quantum efficiency of a photodetector.

The present work….

The study was triggered by a comparative test of the light output of LSO and BGO crystals done in **2006** by Chuck Melcher at the Tennessee University and by us at Świerk, in Poland. Three calibrated PMTs were used **R2059 (TU), XP2020Q and R6231 (Świerk).**

Light output [ph/MeV]

Crystal	Size [mm]	Świerk		Knoxville
		XP2020Q	R6231MOD	R2059
BGO	10x10x1	**7700±400**	9300±600	9600±500
LSO	10x10x2	**33600±1700**	38800±1900	39500±2000

BGO – light output measured with different photodetectors

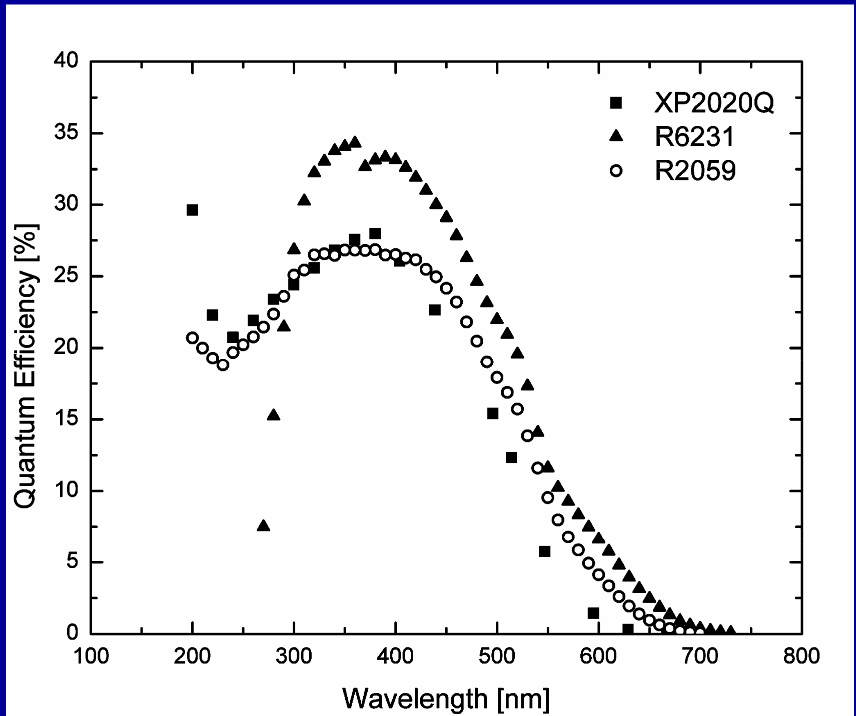
Crystal	Holl, et al. 1988	M.M., et al. 1997		Świerk 2009			Knoxville 2009	
Type	Si PD	XP2020	Si PD	XP2020	Si PD S3590-18	R6231	XP2020	R2059
BGO	**8200±350 ±400**	**8300 ±160**	**8020 ±160**	**7900 ±300**	**8000 ±300**	9350 ±400	**8600 ±400**	9900 ±500

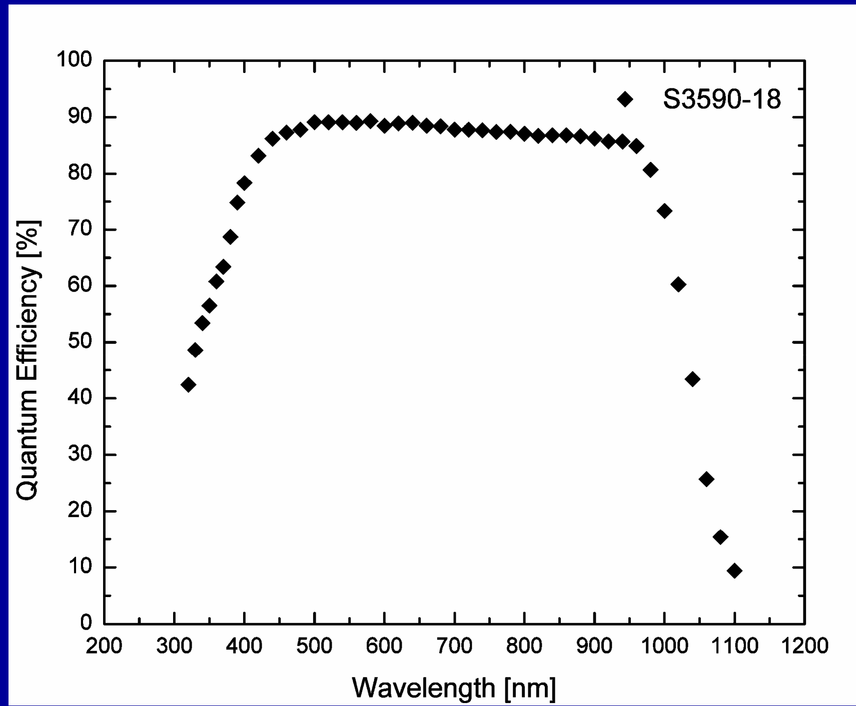
A good agreement of the measured light output with the XP2020Q and S3590-18 photodiode to those of the earlier measurements.

Evident excess of the light output measured with the new Hamamatsu PMTs.

What is the origin of the observed effect?

Photodetectors





Photomultipliers

Si photodiode

S3590-18 BGO: QE=86%

LSO: QE=82.7

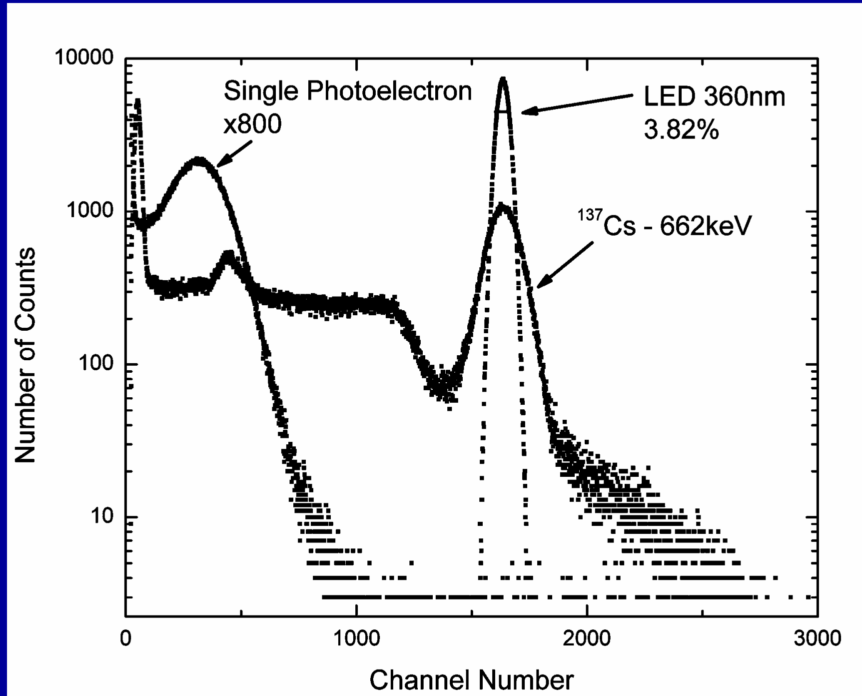
Study of the PMT response

- Phe number by pulse height resolution method:

$\delta_{st} = 2.355 \times 1/N^{1/2} \times (ENF)^{1/2}$

ENF calculated from the pulse height resolution of the single phe peak:

$\delta_{spe} = 2.355 \times \sqrt{(ENF - 1)}$



LSO at XP2020Q,

$\mathbf{N_{sphe}}$ **= 6150±150 phe/MeV**

PHR = 3.82%, ENF = 1.09

$\mathbf{N_{phr}}$ **= 6300±200 phe/MeV**

First experiments in 2006

Crystal	Size [mm]	Świerk		Knoxville
		XP2020Q	R6231MOD	R2059
BGO	10x10x1	**7700±400**	9300±600	9600±500
LSO	10x10x2	**33600±1700**	38800±1900	39500±2000

Final experiments in 2009

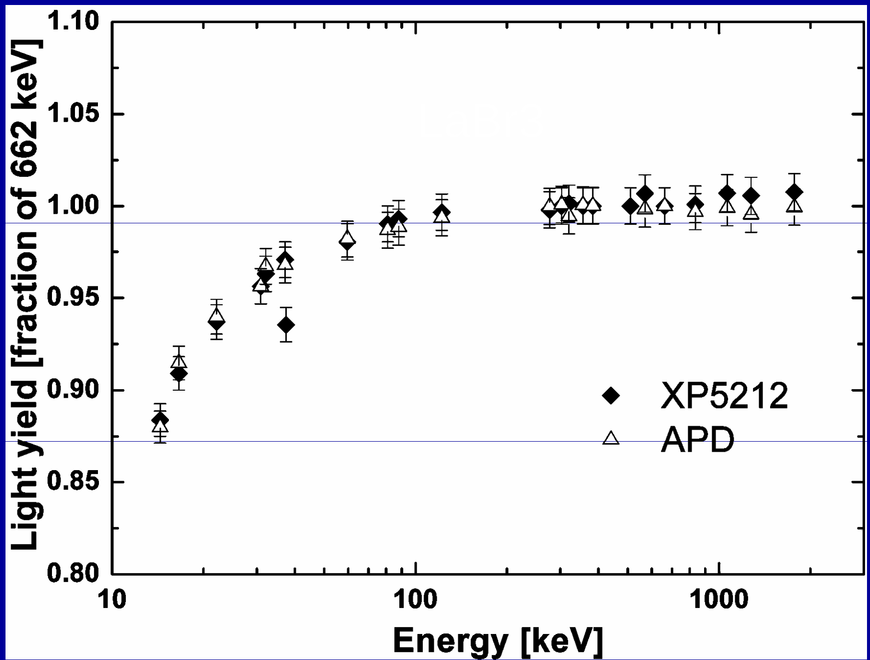
Light output of LSO (10x10x5 mm3):

XP2020Q:	28800 ±1500 ph/MeV	
R6231:	**29200±1500 ph/MeV**	**by PHR method!!**
	36900±1800 ph/MeV	by single PHE method

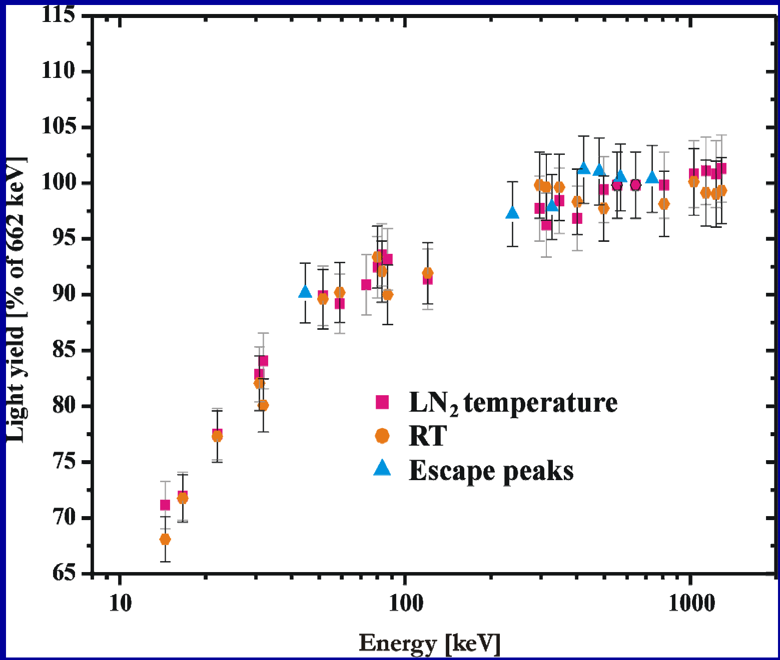
Energy resolution, Non-proportionality

Intrinsic resolution of scintillators

Non-proportionality is a fundamental limitation of energy resolution!



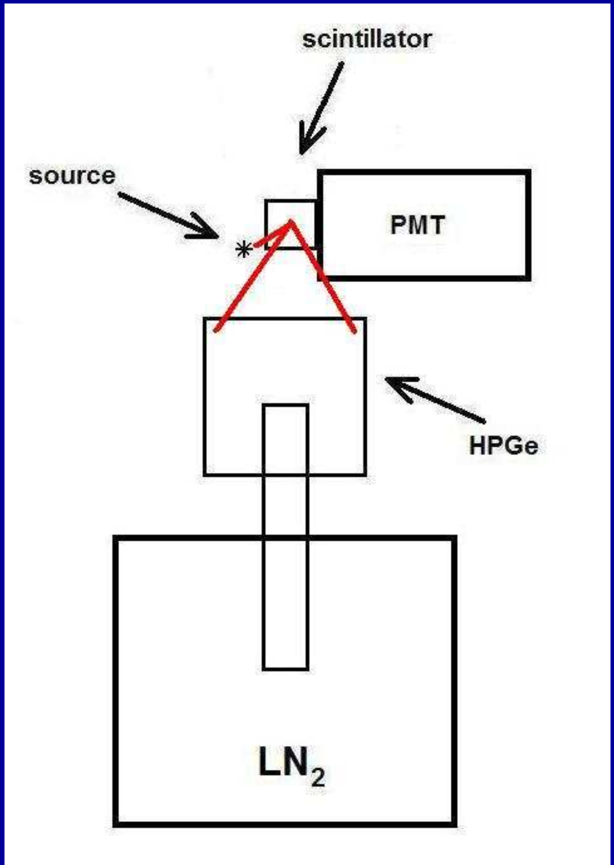
$LaBr_3$



BGO

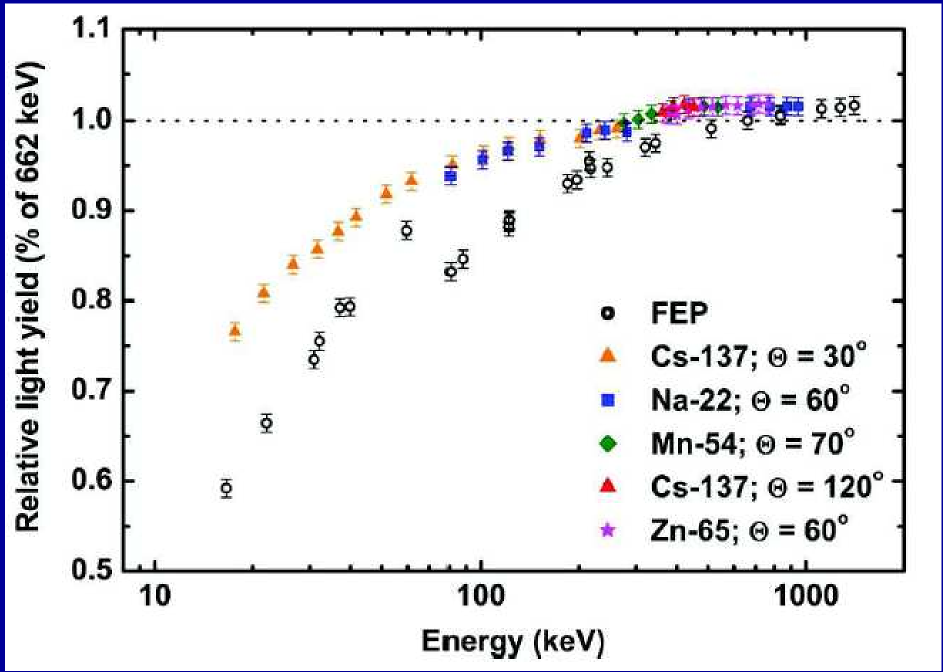
Non-proportionality measured with γ-rays

Nonproportionality of Compton electrons



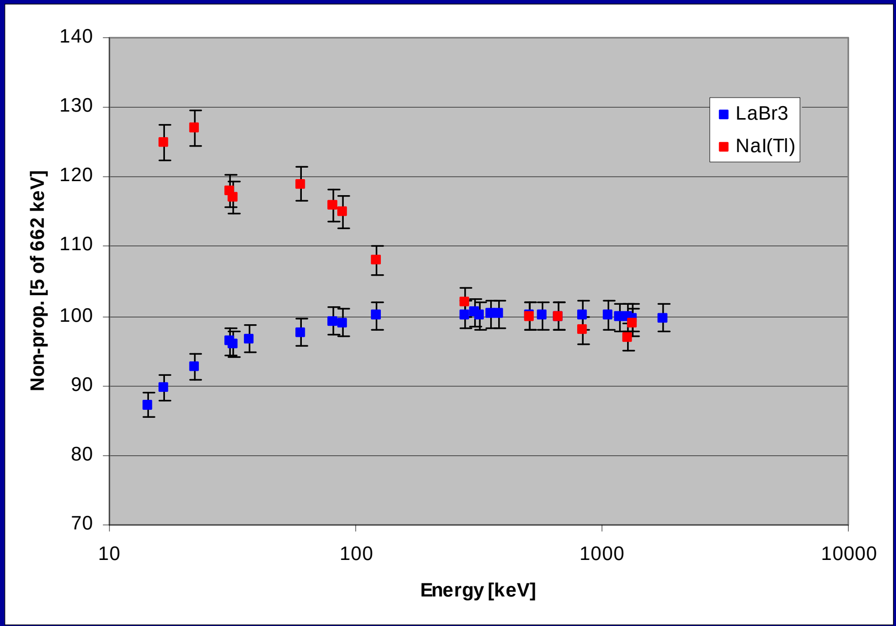
close geometry: ~ 1- 6 cm
large solid angle: ≤ 90º
weak sources: ~ 10 - 30 µCi

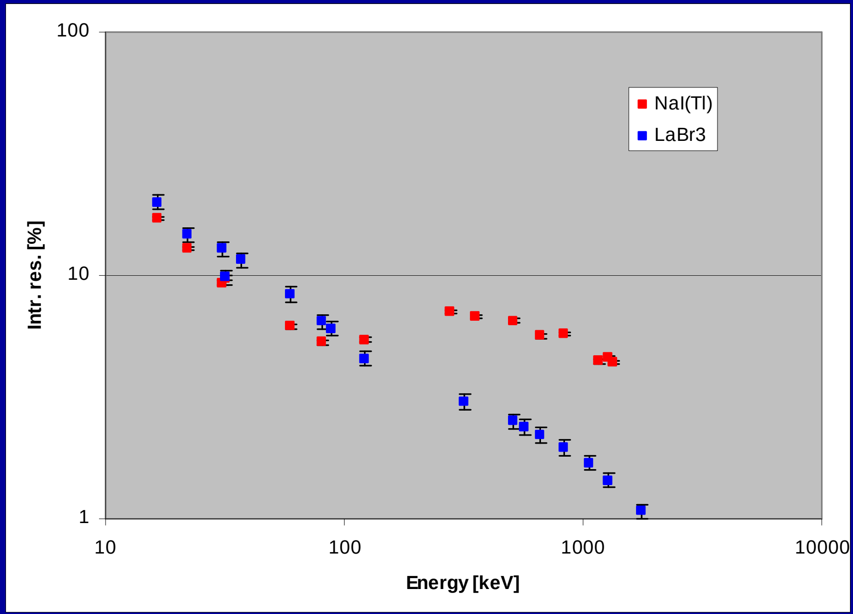
LYSO – 2 x 2 x 2 cm^3



Nonproportionality of Compton electrons and full energy peaks. Curves are normalized to 662 keV full energy peak of Cs-137.

$LaBr_3$ in comparison to NaI(Tl) crystals

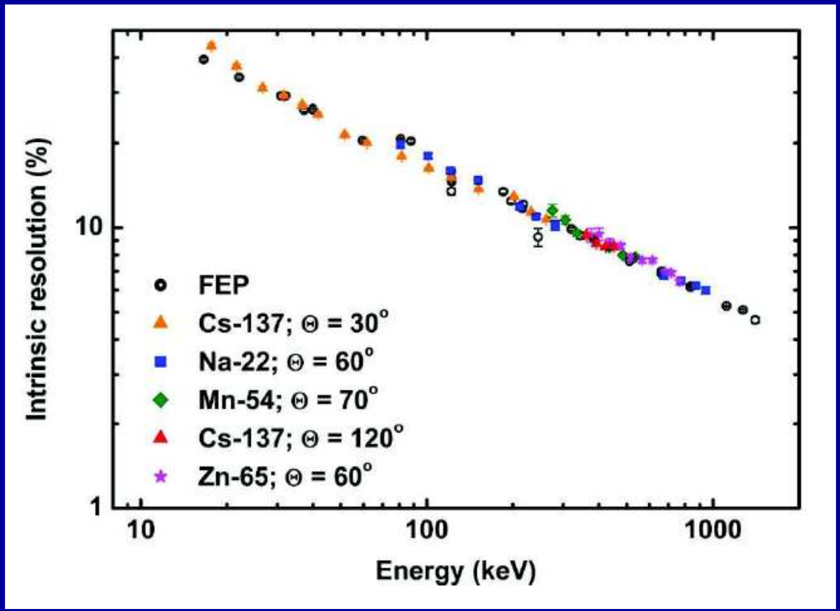




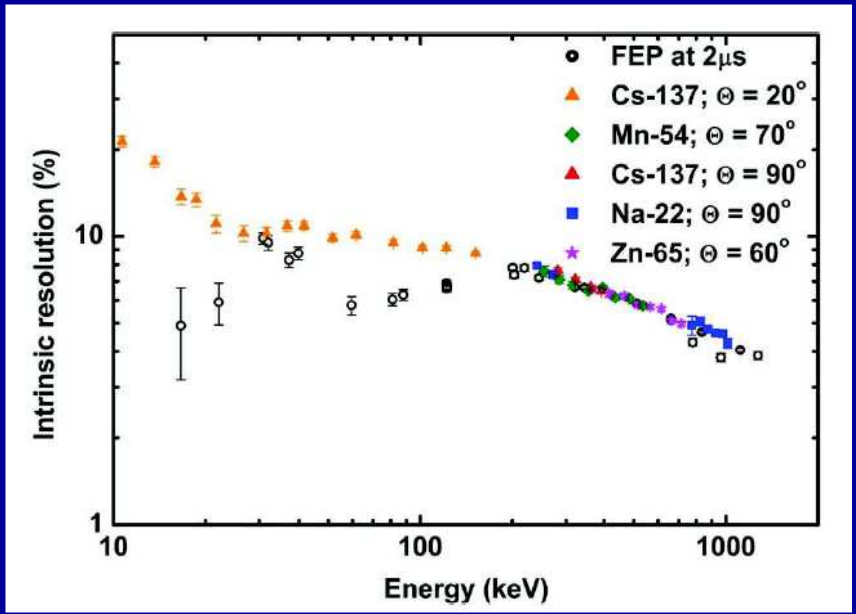
Non-proportionality of $LaBr_3$ and NaI(Tl)

Intrinsic resolution of $LaBr_3$ and NaI(Tl)

Intrinsic resolution of scintillators



LYSO – 2 x 2 x 2 cm^3

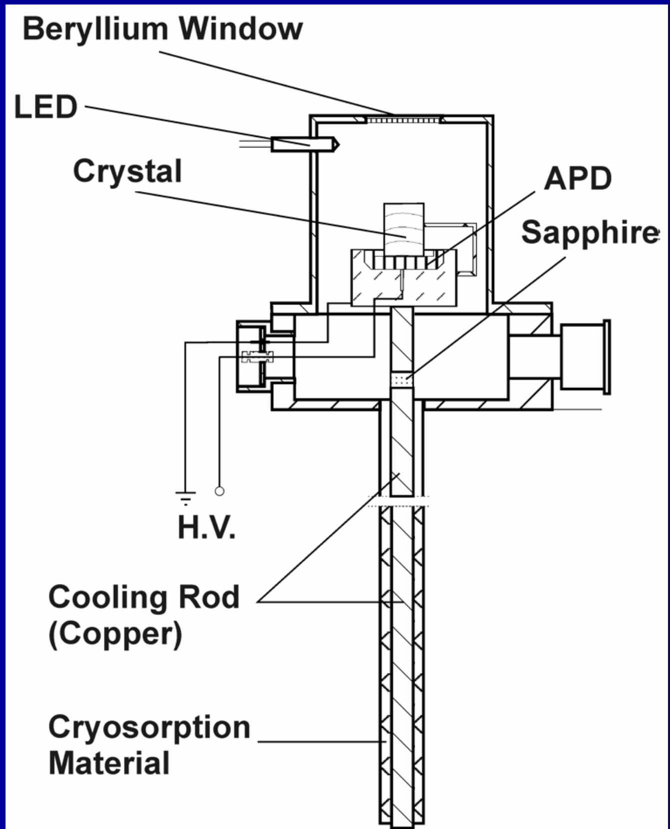


CsI(Tl) – Ø1” x 1”

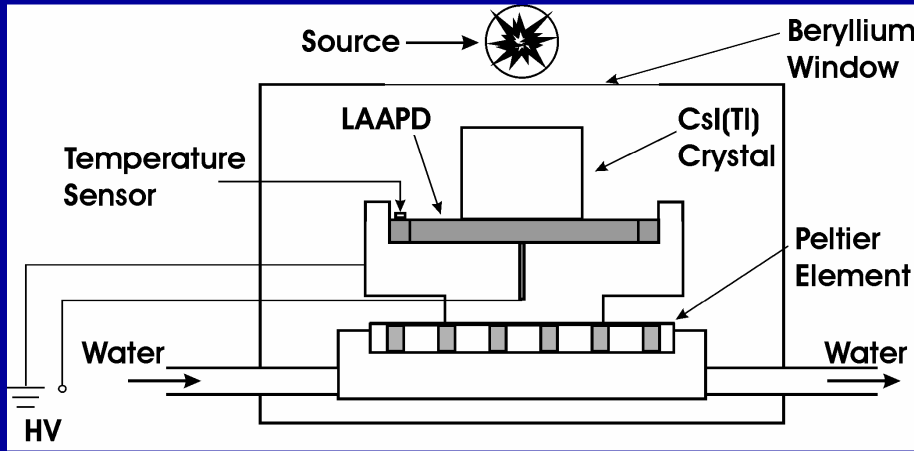
Mesured energy resolution corrected for the photoelectron statistic.

Gamma spectrometry at low temperatures

LN_2 temperature

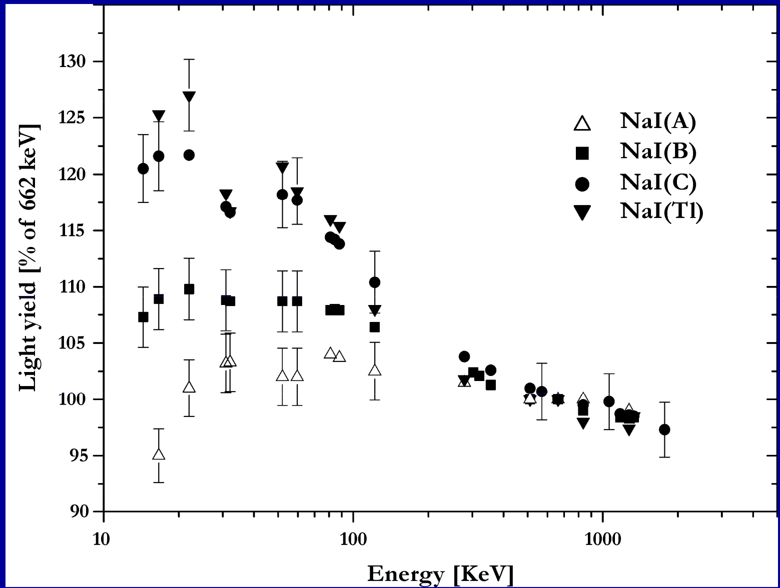


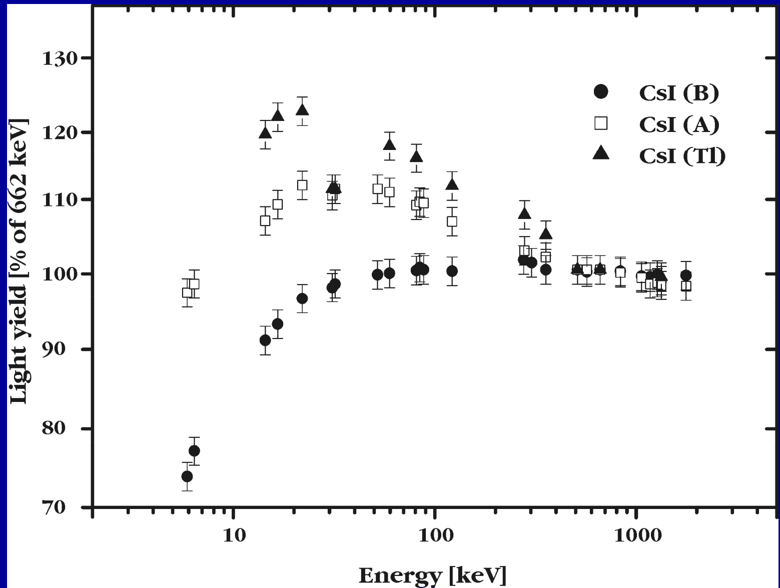
Cryostat with NaI coupled to LAAPD



Temperatures down to – 40 ◦C

Non-proportionality of undoped NaI and CsI at liquid nitrogen temperature

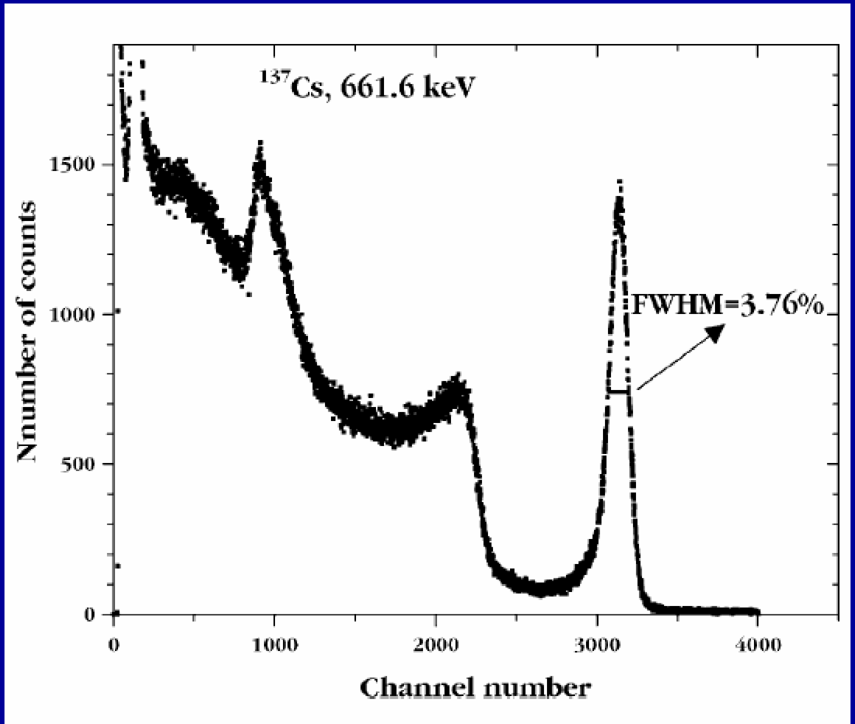


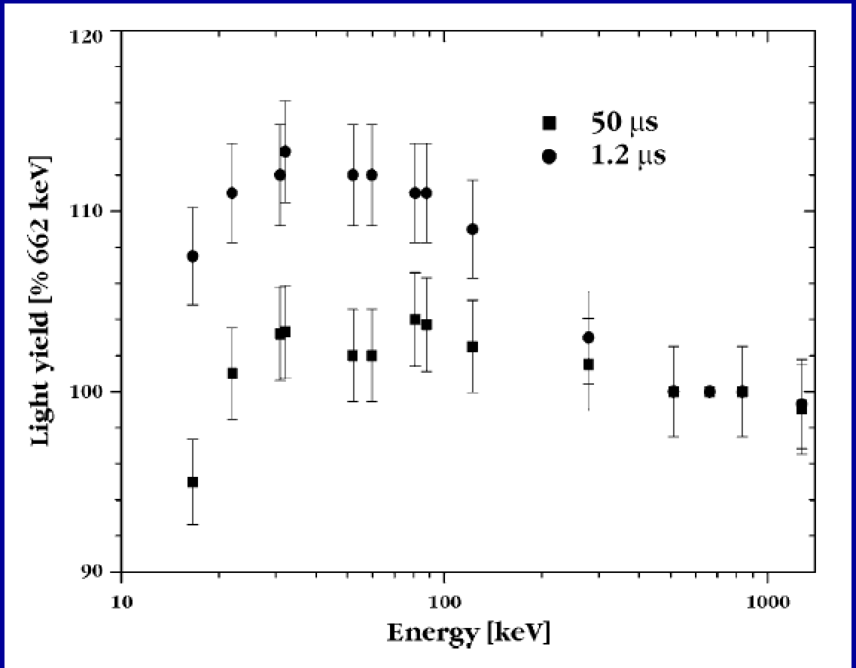


Undoped NaI and standard NaI(Tl)

Undoped CsI and standard CsI(Tl)

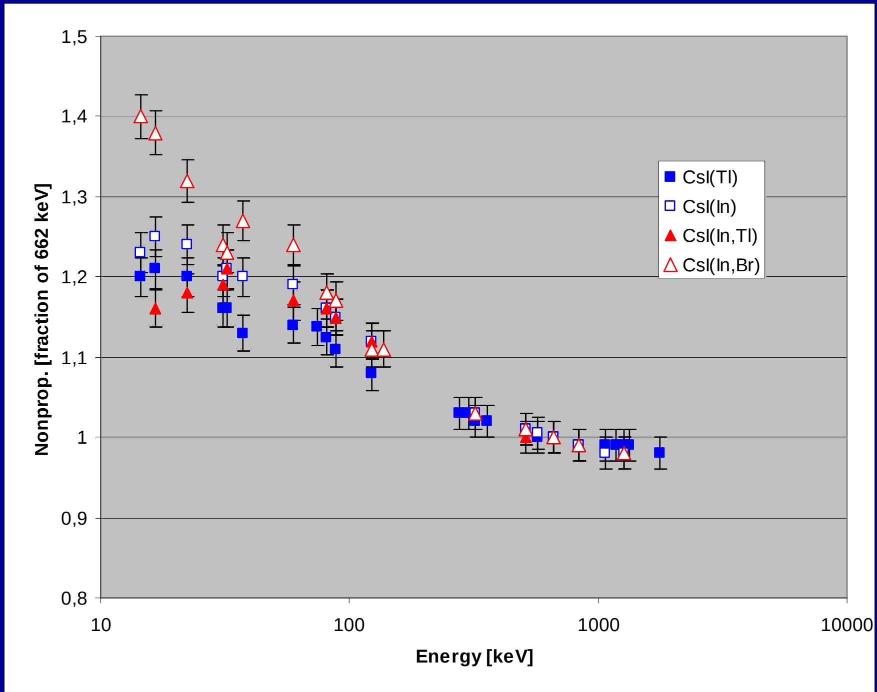
Udoped NaI at LN_2 temperature

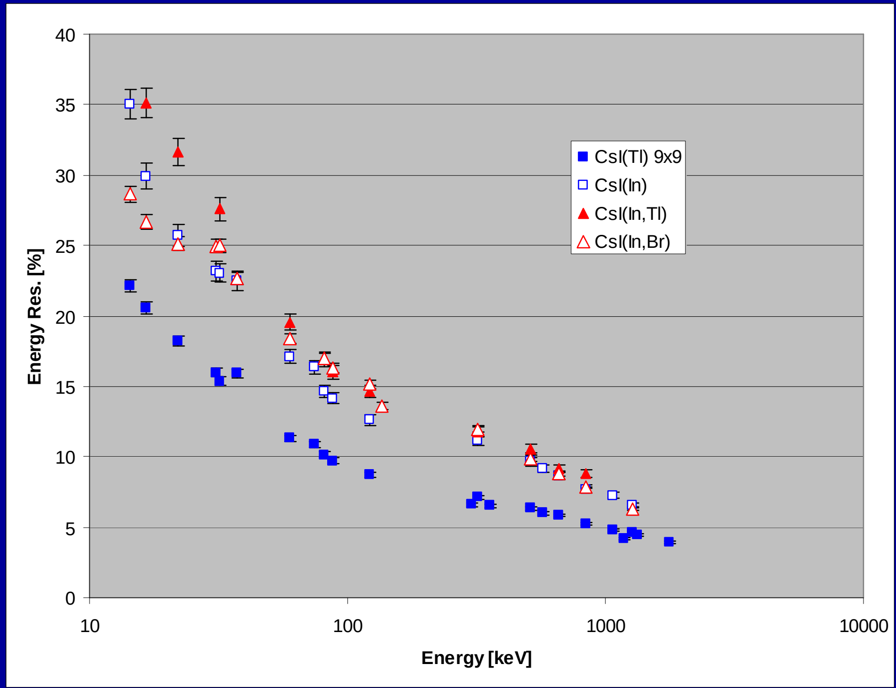




Exceptional sample of undoped NaI. Integration of the slow component up to 50 μs improves dramatically energy resolution, see non-proportionality characteristics.

Modified CsI crystals from Alex Gektin

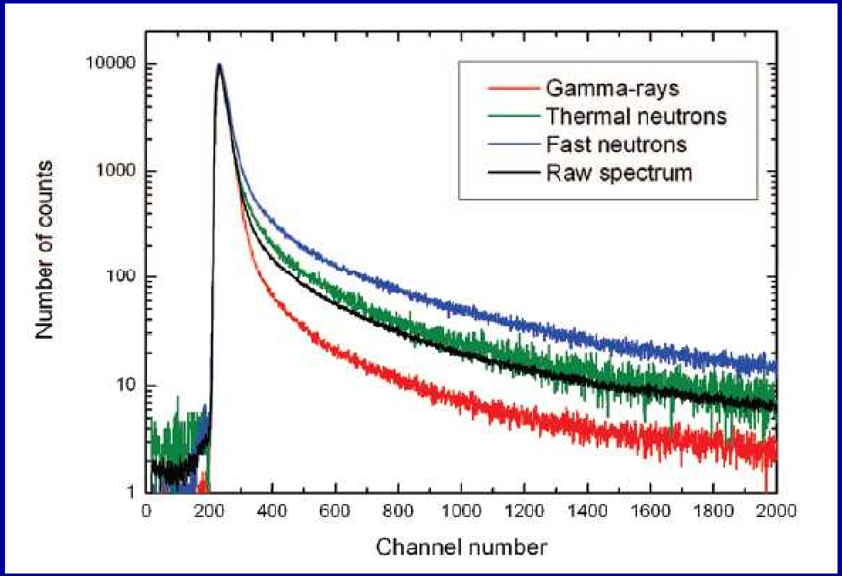




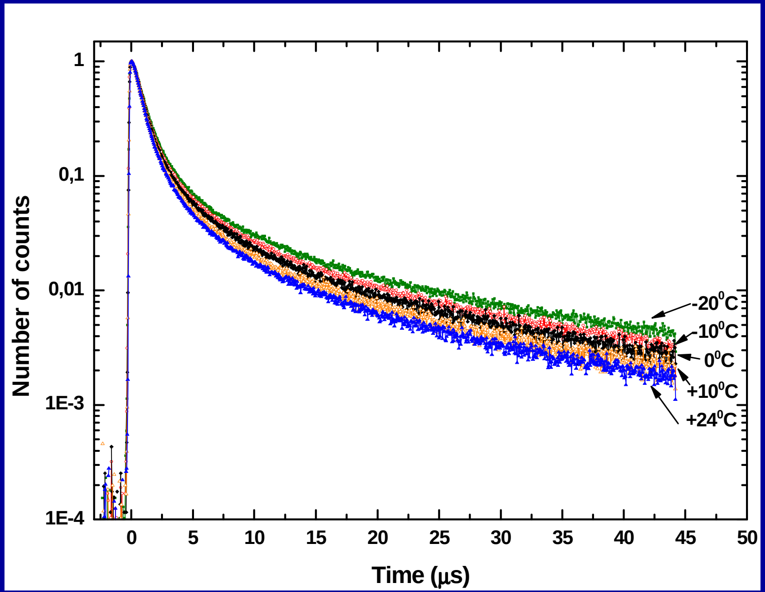
Note an influence of doping agents or codoping on the non-proportionality characteristics

Light pulse shape of scntillators

Single photon method



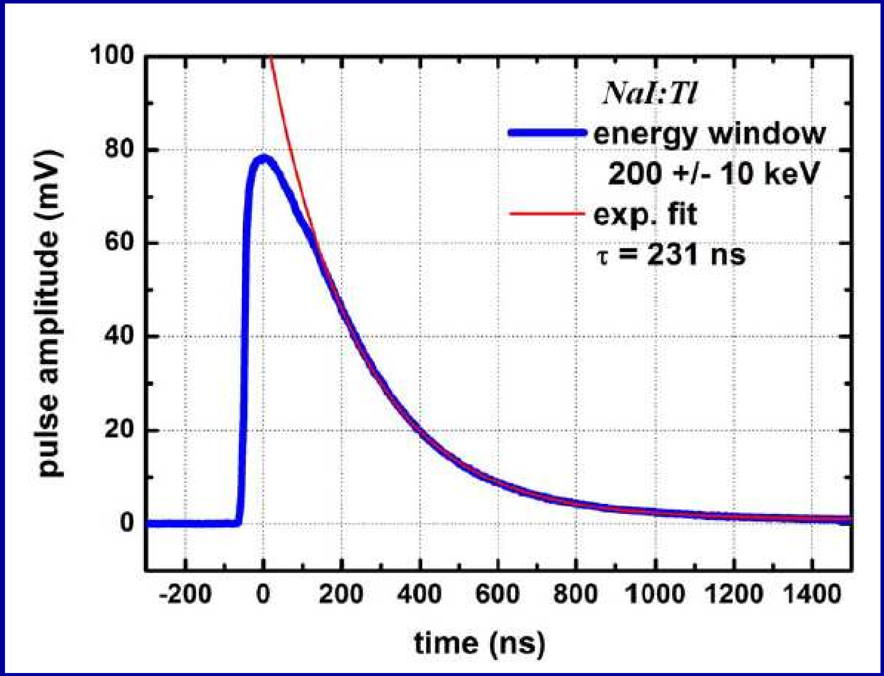
Light pulse shape of BC523A liquid scintillators due to γ-rays, thermal nad fast neutrons.

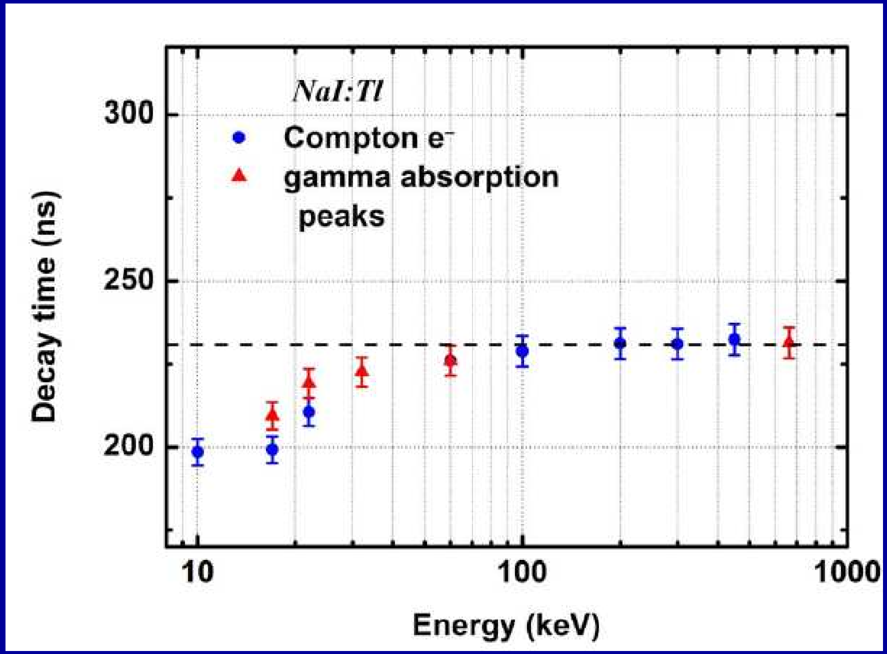


Light pulse shape of CsI(Tl) at different temperatures down to – 20 ℃.

Light pulse shape of scntillators

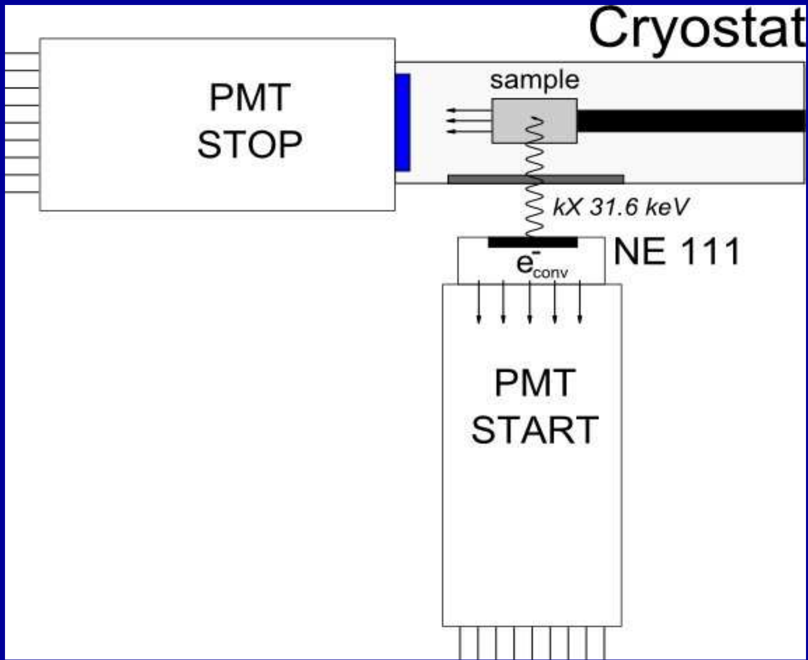
Digital scope method

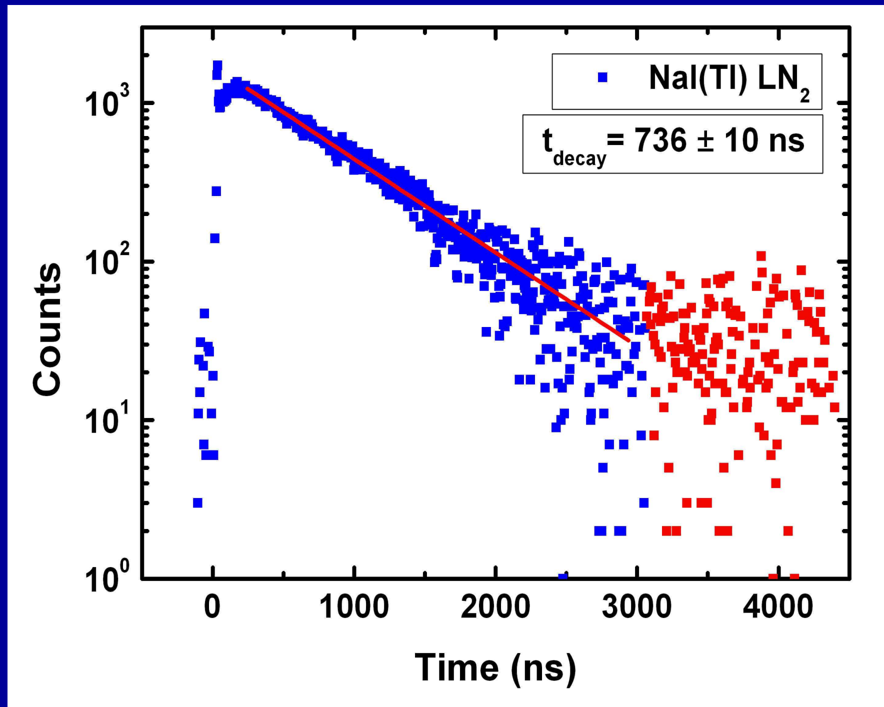




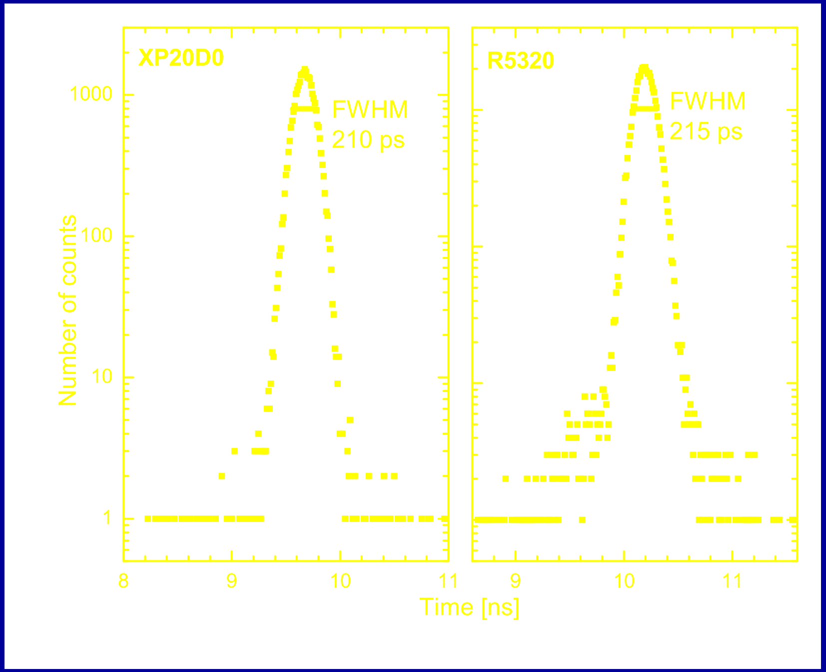
Decay times measured by digital scope gated by full energy peaks and Compton electrons of different energies.

Light pulse shape at LN_2 temperature





Fast timing


XP20D0
FWHM
210 ps
R5320
FWHM
215 ps
Number of counts
1000
100
10
1
8
9
10
11
9
10
11
Time [ns]

ERROR: undefined
OFFENDING COMMAND: II*

STACK: