Testing of Cracow phoswich scintillator detector for PARIS project

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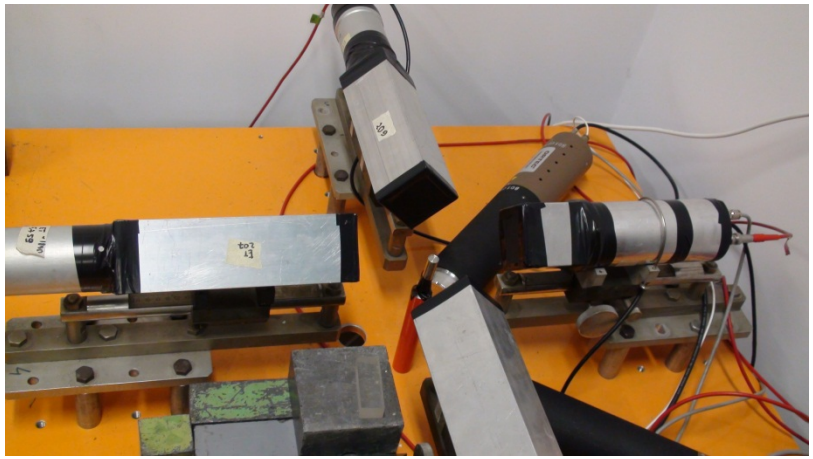
Test bench for 2”x2”x2” LaBr3 – 2”x2”x6” NaI(Tl) phoswiches

* Three phoswiches produced by Saint Gobain company were tested.
* As a reference we used 2”x2”x2”LaBr3(Ce) scintillator (BrilLanCe ™ 380) and two BaF2 detectors.
* We tested three different kind of PMT with different kind of voltage divider.
* Our test have concerned phoswiches S/N A207 , A209, A302.
* Phoswiches A207 and A209 were coupled with advaTech ET Enterprises 9815B PMT/C638B voltage divider,
* Phoswich A302 - Hamamatsu R7723-100 PMT/ E5859-15
* BrilLanCe ™ 380 - Photonis XP 3292/B PMT.
* Referenced for time resolution BaF2 were equipped with Philips XP2020Q PMT.
* All phoswiches were tested also with XP 3292/B PMT



The electronic setup

We used NIM and VME electronics.

The voltage divider for ET Enterprises 9815B PMT was designed for positive polarity high voltage power supply.

In case of XP3292B PMT we used negative polarity of the high voltage power supply.

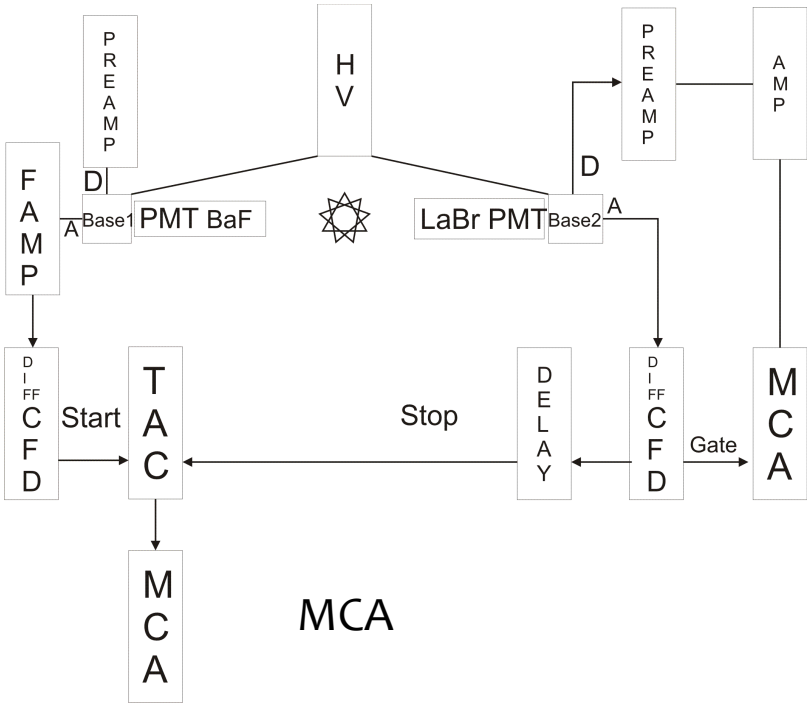
The energy gate for time resolution measurement was chosen by proper setup of the upper and lower level of the Differential CFD.

For the time resolution tests we used the ^{60}Co:
gating E >200 keV,
gating 1 MeV>E >1.5 MeV
and the ^{22}Na gamma sources :
gating on E >200 keV,
gating on E ~ 511 keV

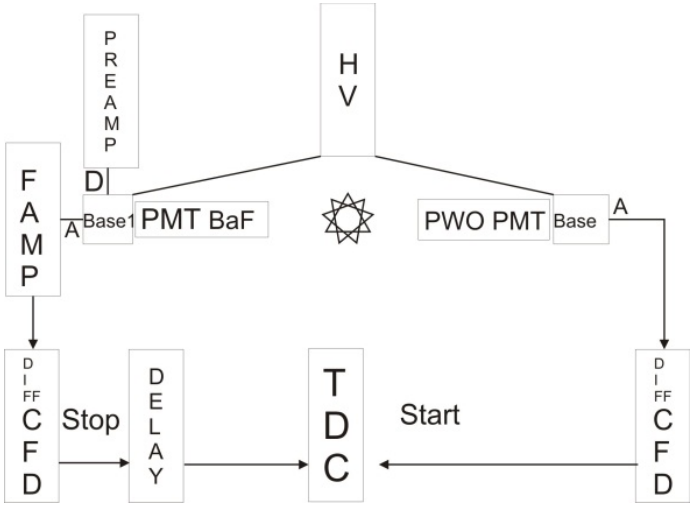
Abbrevation used in block diagrams

PMT BaF - cylindrical 2" x 2" BaF2 scintillator with Philips XP 2020Q PMT
Base1 - ORTEC 269 Base and ORTEC 130 Preamplifier
LABr PMT - cubic 2"x2"x2" LaBr3 scintillator with Photonis XP 3292B PMT
Base2 - IPJ Świerk voltage divider network and CR113 preamplifier
Base - Hamamatsu or AdvaTech voltage divider network
Diff. CFD - ORTEC 583 Constan Fraction Differential Discriminator
Delay - POLON 1506 Delay lines
TAC – ORTEC 566 Time to Amplitude Converter
HV - CAEN N471 HV power Supply
F AMP - ORTEC 535 Quad Fast Amp.
AMP - ORTEC 671 Amplifier
MCA - Amptek 8000A multichannel analyzer
TDC - CAEN V775 Time to Digital Converter
BaFP - Milano BaF processor
785 - V785 CAEN ADC
812 - V812 CAEN CFD
QDC - CAEN V792
BUFF - Milano 4 chn. buffer

Block diagram for time measurement



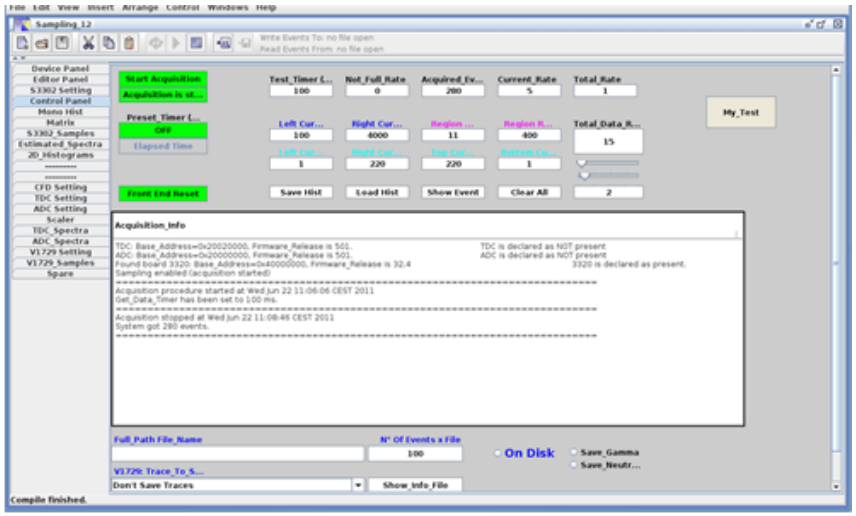
MCA



VME1

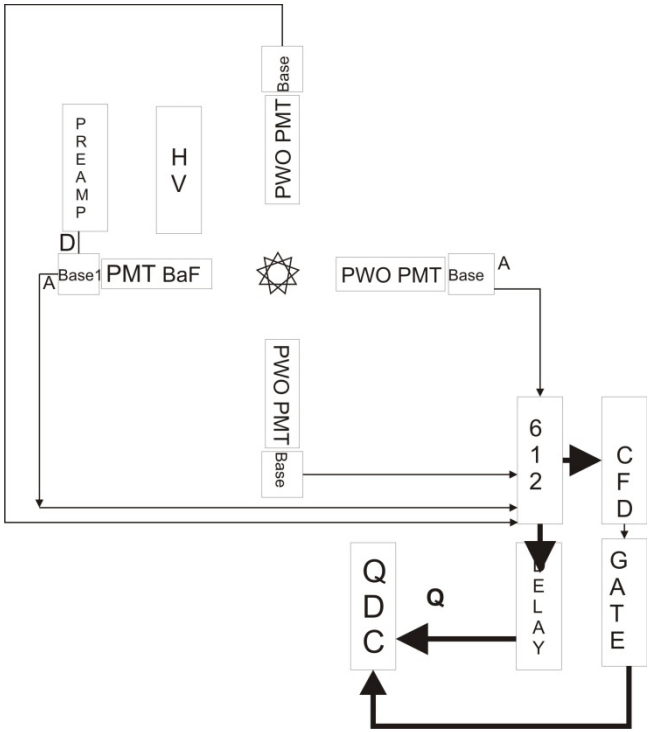
VME setup

* VME DAQ for time and energy resolution measurements consist three systems based on Kmax environment
* First with CAEN TDC 775,
* Second with additional CAEN QDC V792, V965
* Last based on CAEN V875 ADC and INFN Milano BaF processor

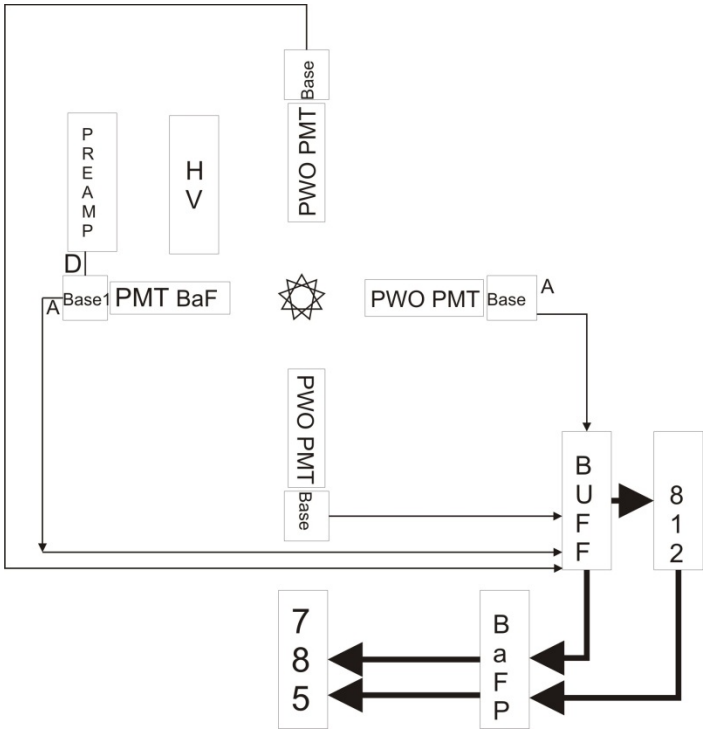


Block diagram for energy measurement

VME2



VME3



Time measurement procedure

The time resolution for LaBr3 counter was measured using as a reference measured time resolution of BaF2 counter (FWHM = $2\sqrt{2\ln 2}\ \sigma$).

The intrinsic time resolution of BaF2 counter was obtained from the measurement done for two similar 2"x2" BaF2 counters ($\sigma_{iBaF_2} = \sigma/\sqrt{2}$).

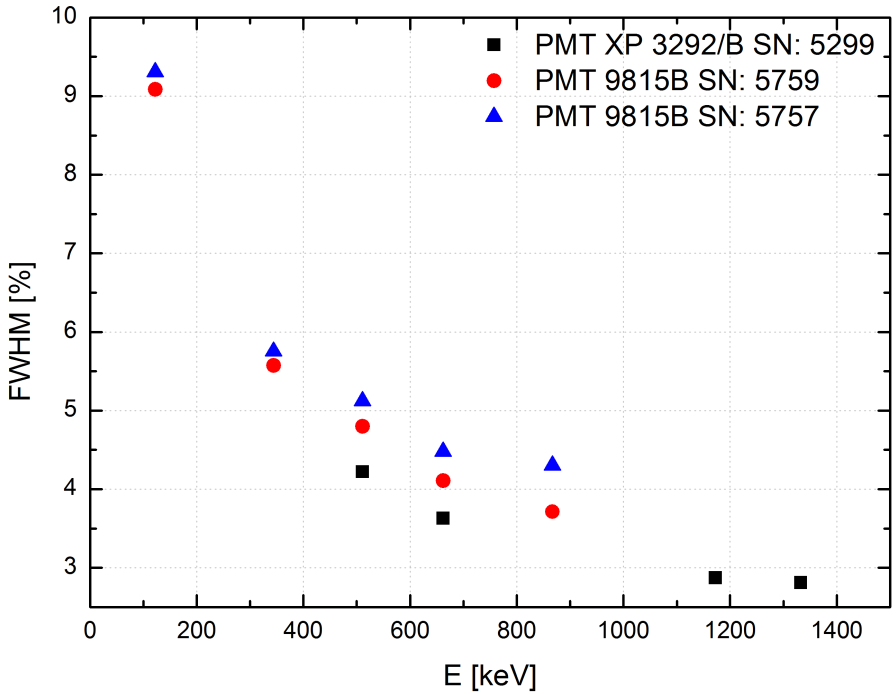
Comparison of the time resolution measured for different detectors

FWHM [ns]	A209 @ XP3292/B	A207@ XP3292/B	LaBr3@ XP3292/B	LaBr3@ ET S/N5757	LaBr3@ ET S/N5759
^{60}Co > 200 keV	0.60	0.58	0,54	0,35	0,38
^{60}Co gate 1 – 1.5 MeV	0.58	0.53	0,37	0,31	0,3
^{22}Na > 200 keV	0.87	0.83	0,56	0,42	0,51
^{22}Na gate 511 keV	0.77	0.71	0,52	0,38	0,42

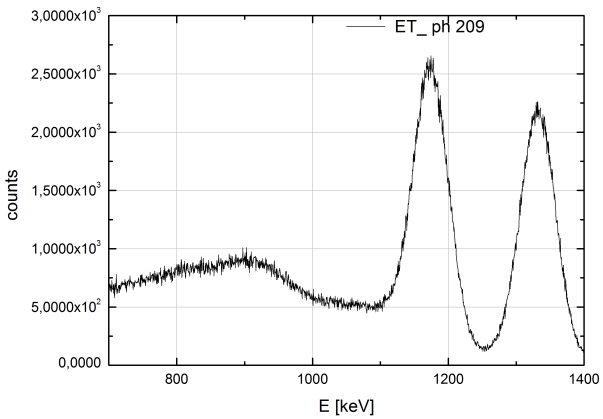
Time resolution comparison for different phoswiches

Gate on energy	A209 FWHM [ns] @ ET 5757	A209 FWHM [ns] @XP3292/B	A207 FWHM [ns] @XP3292/B	A207 FWHM [ns] @ET 5759	A302 FWHM [ns] @R7723	LaBr3 FWHM [ns] @XP3292/B
^{60}Co > 200keV	0,61	0,72	0,70	0,70	0,50	0,66
^{60}Co 1-1.5 MeV	0,40	0,64	0,60	0,36	0,59	0,46
^{22}Na> 200 keV	0,84	1,0	0,96	0,82	0,76	0,73
^{22}Na ~ 511 keV	0,70	0,89	0,84	0,61	0,71	0,67

LaBr3 scintillator energy resolution for different energy



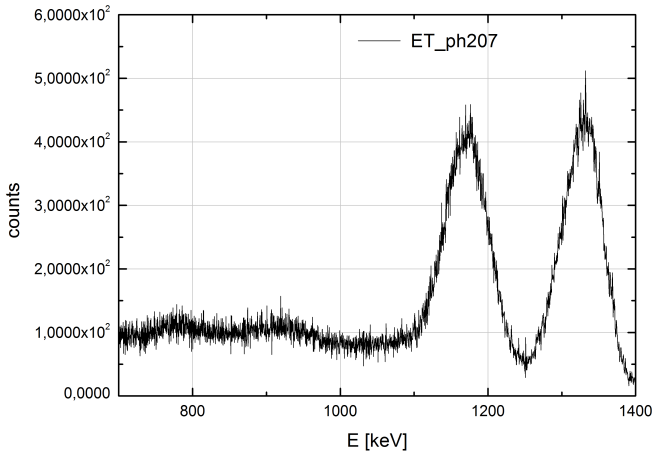
A209 energy resolution



Energy	FWHM/E [%] @ ET5757	FWHM/E [%] @ XP 3292
511	9,7	
662	6,8	4,0
1172	5,4	
1272	7,3	
1332	4,6	3,0

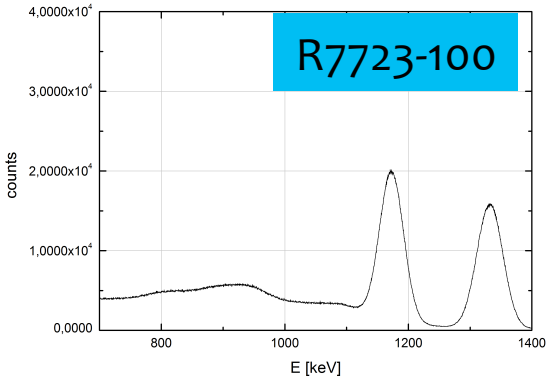
A207 energy resolution

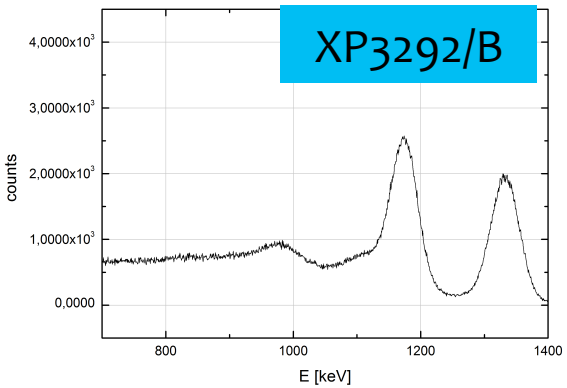
Energy [keV]	FWHM/E [%]@ ET S/N 5759	FWHM/E [%] @ XP3292B
511	7,1	
662	6,1	4,0
1172	5,0	
1272	5,3	
1332	4,4	2,9
6130	3.1	



Phoswich 302

Energy	Phoswich @ R7723-100	Phoswich @ R7723-100/dig.	Phoswich @ XP3292/B	LaBr3@ XP3292/B
511	5,9%			
662	5,7%	4,61%		
1172	4,4%	3,55%	3,9%	
1332	4,0%	4,1%	3,8%	
6130	2,5%|fast(LaBR3) 4,2%|slow(NaI)			1,2%

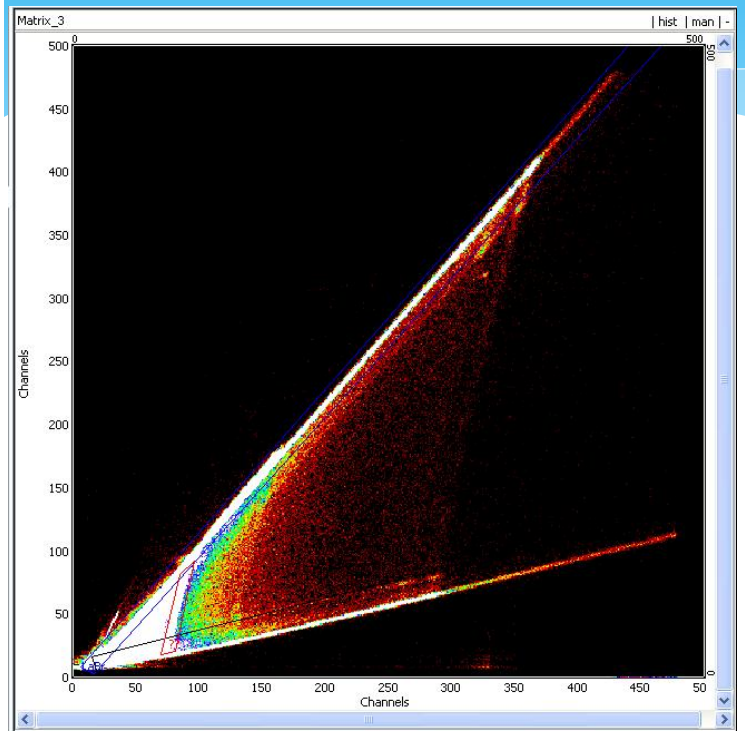




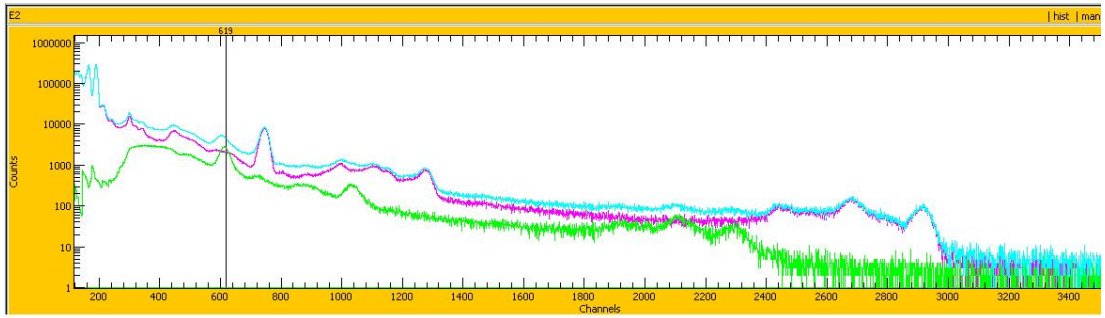
Summary of energy resolution

Energy	A209 FWHM/E [%] @ET S/N5757	Labr3 FWHM/E [%] @ XP 3292/B	A302 FWHM/E [%] @R7723-100	A207 FWHM/E[%] @ET S/N 5759	A302 FWHM/E [%] @R7723-dig.
511	9,7	4,2	5,9	7,1	
662	6,8	3,6	5,7	6,1	4,6
1172	5,4	2,9	4,4	5,0	3,6
1272	7,3			5,3	
1332	4,6	2,8	4,0	4,4	4,1
6130		1,2	$2,5\|_{fast(LaBr3)}$ $4,2\|_{slow(NaI)}$	3.1	

Measurement with 6MeV source

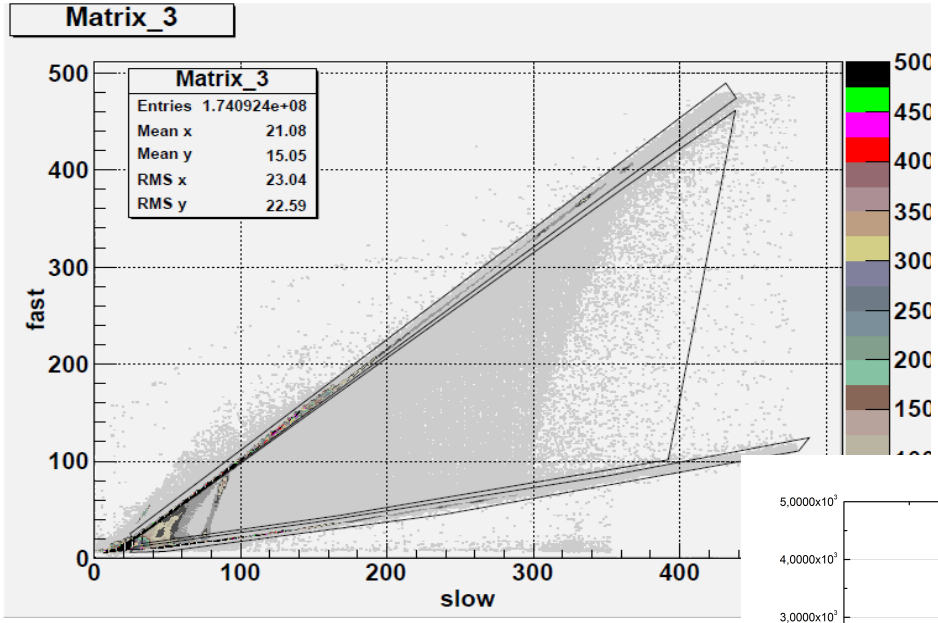


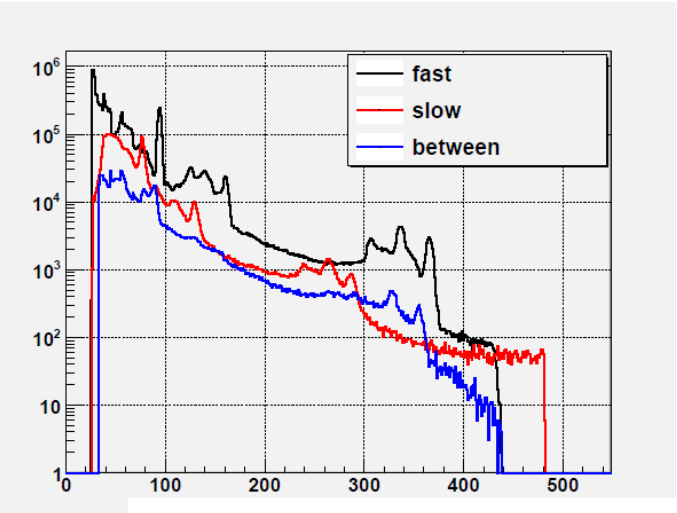
Cm/C 6 MeV gamma source was used to measure phoswich energy resolution in higher energy range.
Using Milano BaF processor was possible to distinguish slow and fast part of phoswich response for gamma from source

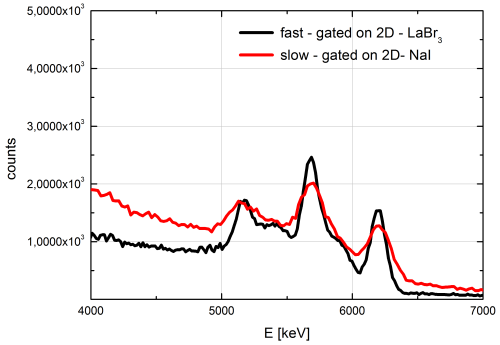


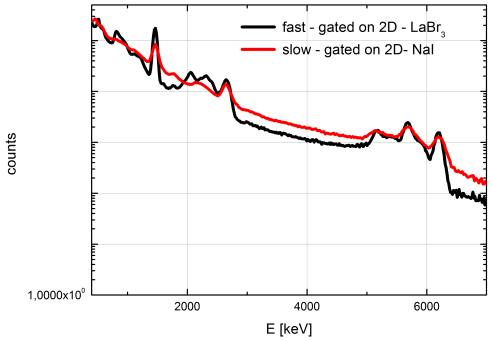
A302 with 6MeV source using BaF processor

* FWHM projection - 2,77%
* Gate on fast 2,5%
* Gate on slow 4,21%

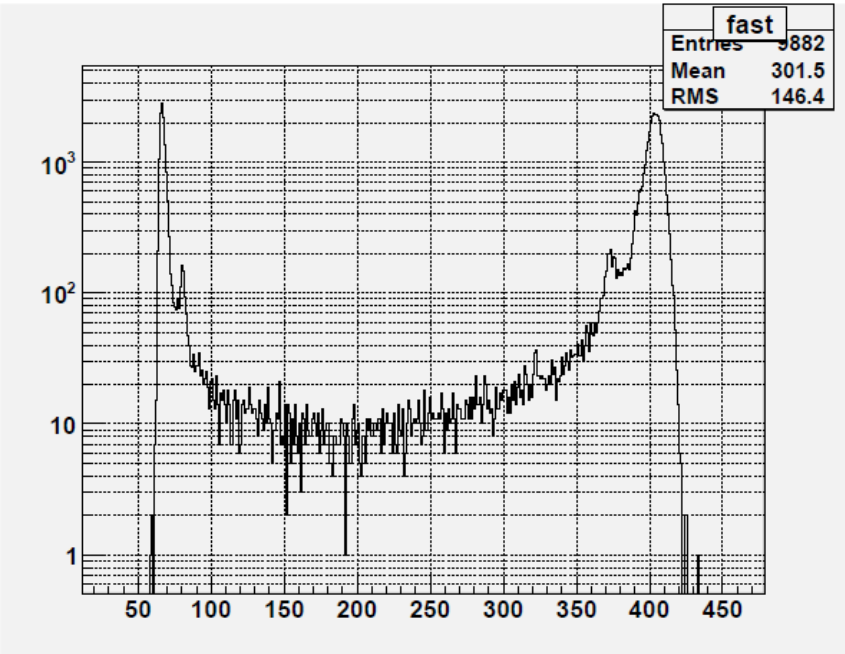




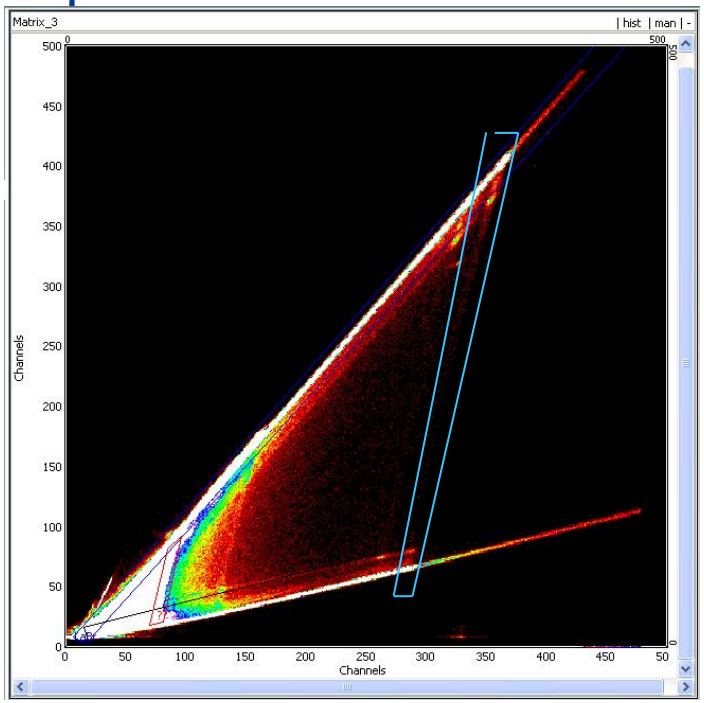




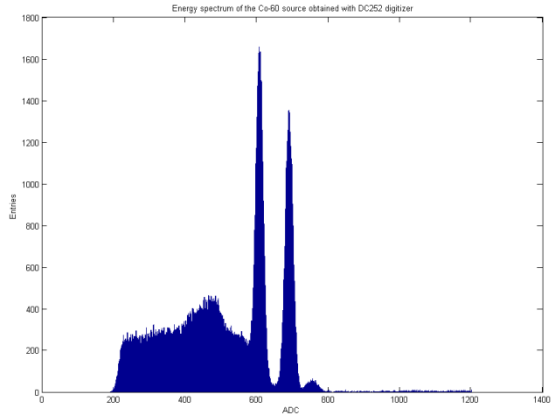
A302 with 6 MeV source

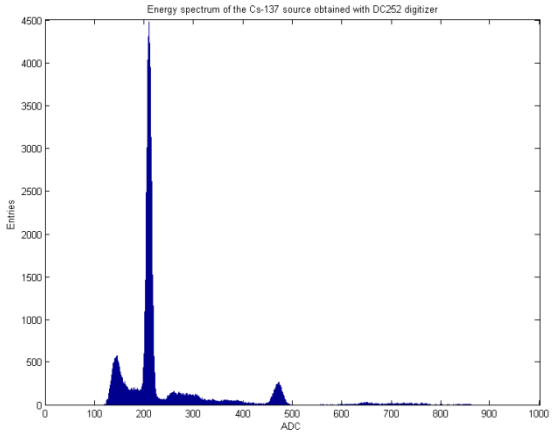


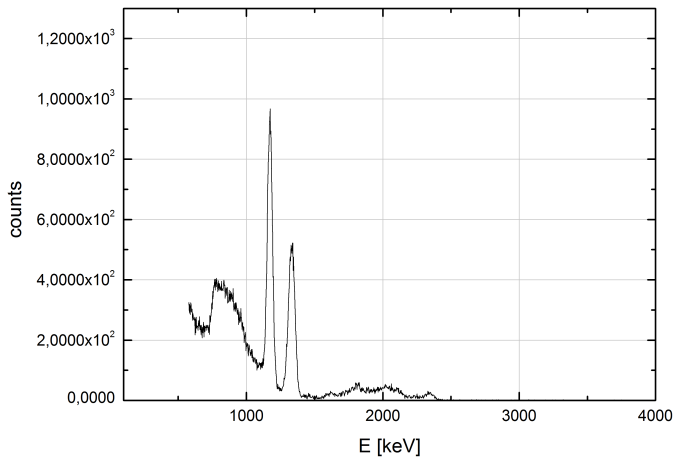
* Gate on slow and fast part of matrix at 6 MeV



Spectra obtained from Acqiris DC 252 digitizer

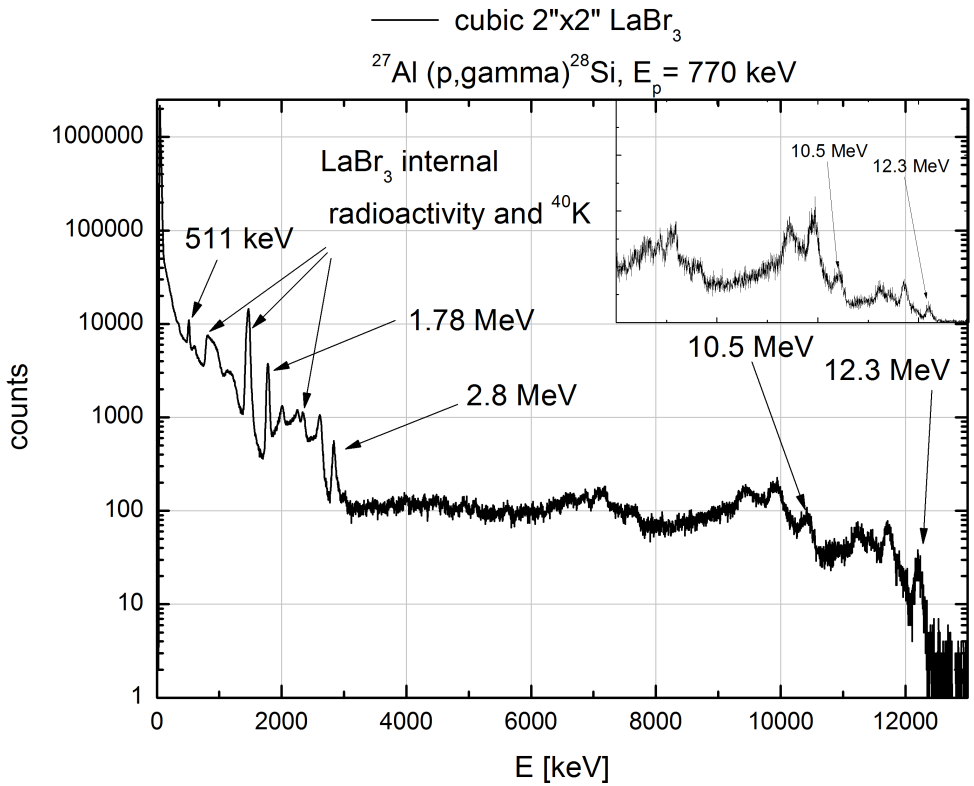






4GS/s digitizer obtained data during 6 MeV source test. Presented data concern A302 phoswich

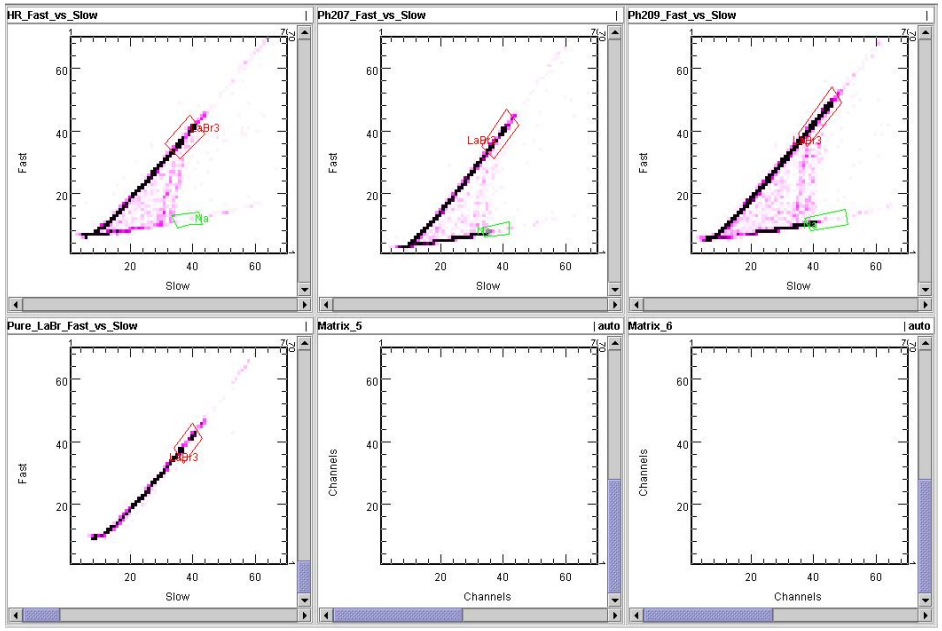
Test with $^{27}Al(p,\gamma)^{28}Si$ at the Cracow 2MeV Van de Graaff

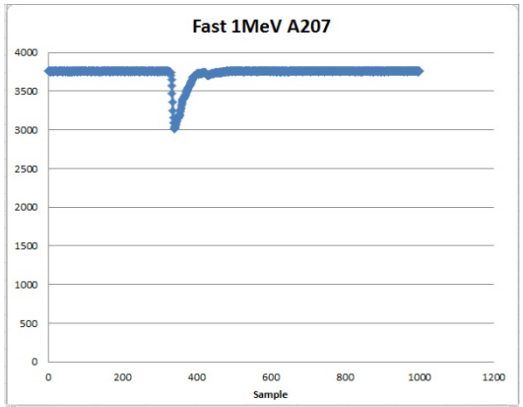


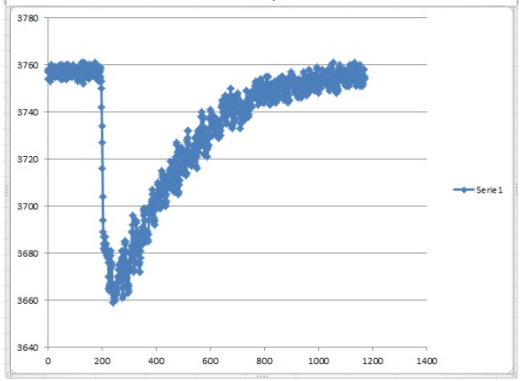
* Experiment carried out at Cracow VdG Only data from 2”x2” Labr3 measured with MCA are reasonable.

Shape for different energy region

Signal shape was measure with V1729 2GS/s digitizer

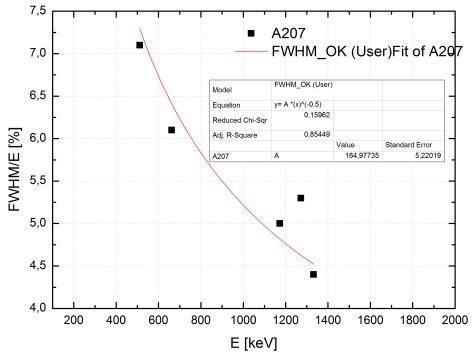


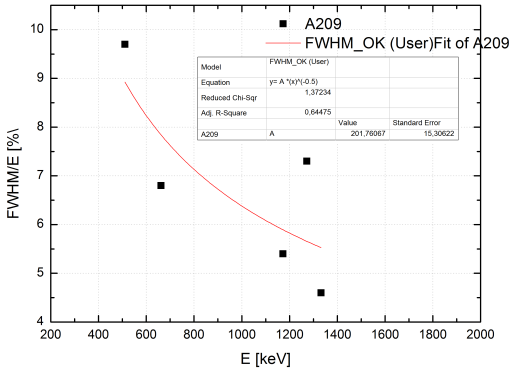


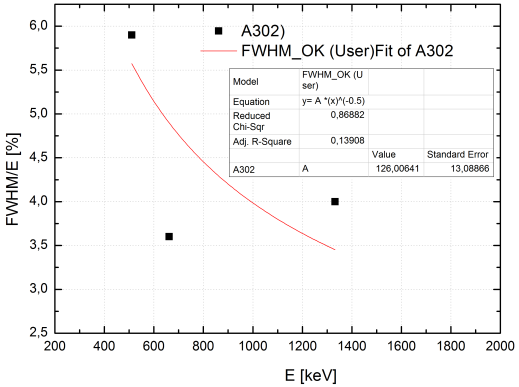


Thank you for your attention

Phoswich Energy Resolution versus Energy







Phoswich A302 (former A208)

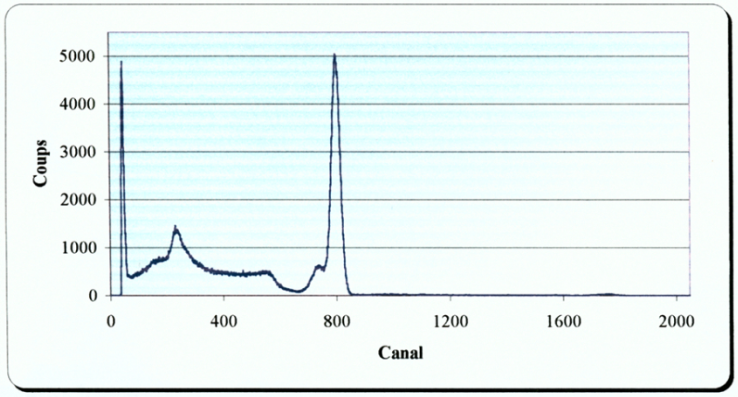
S/N : A0302CsB **INP**

Informations / *Informations*

Désignation SGCD : N53X53X51W152_B380
SGCD Designation
N° de commande : 165710
Order Number
Code produit : 22300137
Product Code
N° de plan : 1-4-7515
Drawing Number

Désignation PMT : R6231
PMT Designation
N° de série PMT : ZE0742
PMT Serial Number
Isotope : 137Cs_662keV2048
Isotope
N° de source : 50414
Source Number

Spectre / *Spectrum*



Mesures nucléaires / *Nuclear measurements*

Haute Tension *High Voltage*	Résolution -	Résolution -	Pic / Vallée *Peak To Valley*	Intégrale *Integral*	Efficacité 125I *125I Efficiency*
645 V	-	-	-	-	-

Commentaires / *Comments*

Résolution @662KeV: 4.3 %

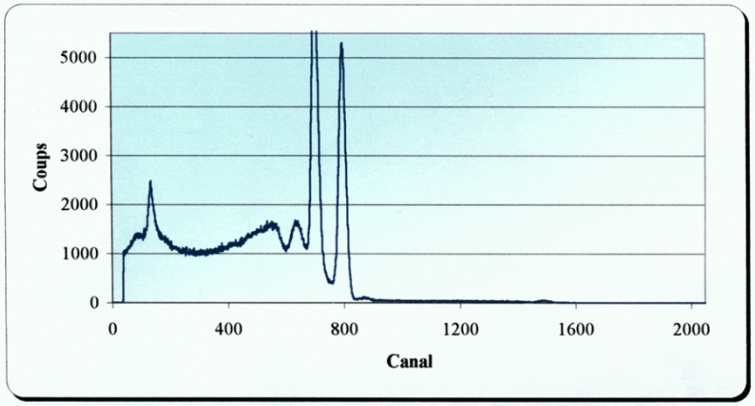
S/N : A0302CoB **INP**

Informations / *Informations*

Désignation SGCD : N53X53X51W152_B380
SGCD Designation
N° de commande : 165710
Order Number
Code produit : 22300137
Product Code
N° de plan : 1-4-7515
Drawing Number

Désignation PMT : R6231
PMT Designation
N° de série PMT : ZE0742
PMT Serial Number
Isotope : 60Co_1332keV2048
Isotope
N° de source : 50113
Source Number

Spectre / *Spectrum*



Mesures nucléaires / *Nuclear measurements*

Haute Tension *High Voltage*	Résolution -	Résolution -	Pic / Vallée *Peak To Valley*	Intégrale *Integral*	Efficacité 125I *125I Efficiency*
575 V	-	-	-	-	-

Commentaires / *Comments*

Résolution @1332KeV: 3.3 %

FINAL TES

TYPE : R7

CUSTOMER : HPF/IN2P3_ORSAY

Serial Number	(1) Cathode Luminous Sens. µA/lm	(2) Anode Luminous Sens. A/lm	(3) Anode Dark Current nA	(4) Cathode Blue Sens. Index
ZK5752	119.0	14.5	1.90	15.10
ZK5753	145.0	47.0	0.99	15.80

Phoswich A207

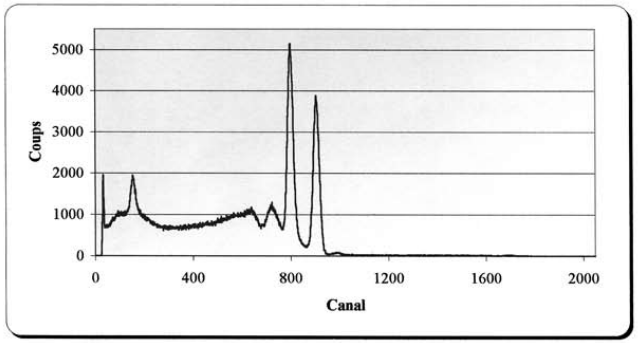
S/N : A0207CoB **INP POLOGNE**

Informations / *Informations*

Désignation SGCD : N53X53X51W152_B380_NAI
SGCD Designation
N° de commande : 165597
Order Number
Code produit : 22300137
Product Code
N° de plan : 1-4-7515
Drawing Number

Désignation PMT : R6231
PMT Designation
N° de série PMT : ZE0742
PMT Serial Number
Isotope : 60Co_1173keV2048
Isotope
N° de source : 50113
Source Number

Spectre / *Spectrum*



Mesures nucléaires / *Nuclear measurements*

Haute Tension *High Voltage*	Résolution -	Résolution -	Pic / Vallée *Peak To Valley*	Intégrale *Integral*	Efficacité 125I *125I Efficiency*
574 V	-	-	-	-	-

Commentaires / *Comments*

Résolution @1332KeV: 3.0 %

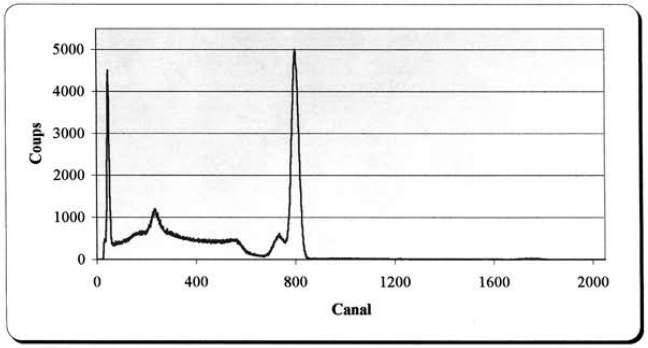
S/N : A0207CsB **INP POLOGNE**

Informations / *Informations*

Désignation SGCD : N53X53X51W152_B380_NAI
SGCD Designation
N° de commande : 165597
Order Number
Code produit : 22300137
Product Code
N° de plan : 1-4-7515
Drawing Number

Désignation PMT : R6231
PMT Designation
N° de série PMT : ZE0742
PMT Serial Number
Isotope : 137Cs_662keV2048
Isotope
N° de source : 50414
Source Number

Spectre / *Spectrum*



Mesures nucléaires / *Nuclear measurements*

Haute Tension *High Voltage*	Résolution -	Résolution -	Pic / Vallée *Peak To Valley*	Intégrale *Integral*	Efficacité 125I *125I Efficiency*
630 V	-	-	-	-	-

Commentaires / *Comments*

Résolution @662KeV: 4.1 %

Phoswich A209

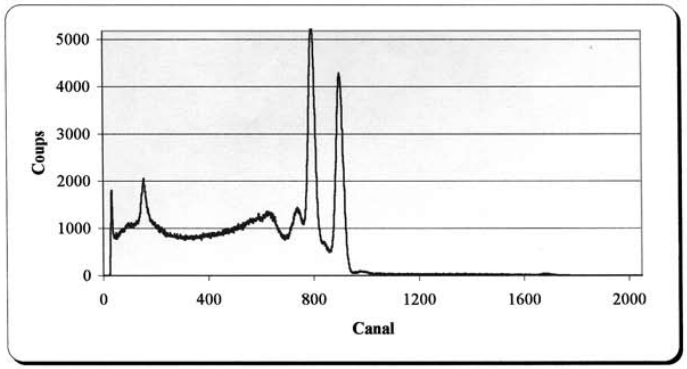
S/N : A0209CoB **INP POLOGNE**

Informations / *Informations*

Désignation SGCD : N53X53X51W152_B380_NAI
SGCD Designation
N° de commande : 165597
Order Number
Code produit : 22300137
Product Code
N° de plan : 1-4-7515
Drawing Number

Désignation PMT : R6231
PMT Designation
N° de série PMT : ZE0742
PMT Serial Number
Isotope : 60Co_1173keV2048
Isotope
N° de source : 50113
Source Number

Spectre / *Spectrum*



Mesures nucléaires / *Nuclear measurements*

Haute Tension *High Voltage*	Résolution -	Résolution -	Pic / Vallée *Peak To Valley*	Intégrale *Integral*	Efficacité 125I *125I Efficiency*
590 V	-	-	-	-	-

Commentaires / *Comments*

Résolution @1332KeV: 3.3 %

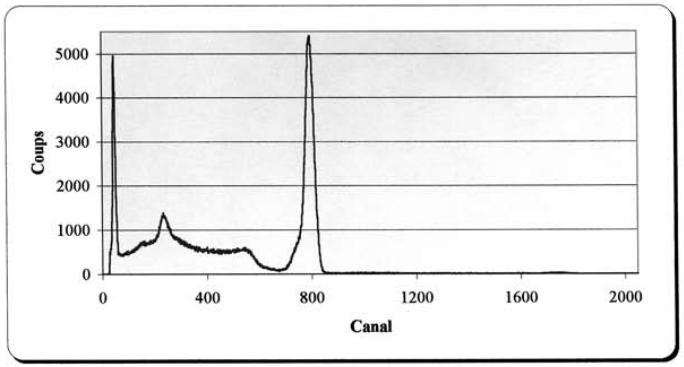
S/N : A0209CsB **INP POLOGNE**

Informations / *Informations*

Désignation SGCD : N53X53X51W152_B380_NAI
SGCD Designation
N° de commande : 165597
Order Number
Code produit : 22300137
Product Code
N° de plan : 1-4-7515
Drawing Number

Désignation PMT : R6231
PMT Designation
N° de série PMT : ZE0742
PMT Serial Number
Isotope : 137Cs_662keV2048
Isotope
N° de source : 50414
Source Number

Spectre / *Spectrum*



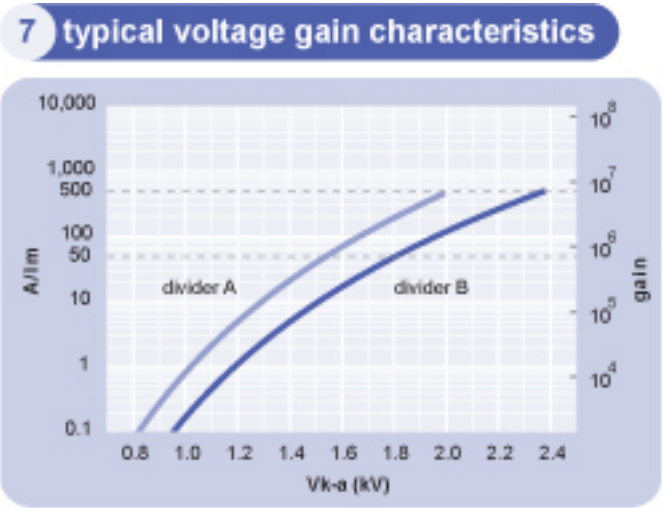
Mesures nucléaires / *Nuclear measurements*

Haute Tension *High Voltage*	Résolution -	Résolution -	Pic / Vallée *Peak To Valley*	Intégrale *Integral*	Efficacité 125I *125I Efficiency*
646 V	-	-	-	-	-

Commentaires / *Comments*

Résolution @662KeV: 4.3 %

ET Enterprise 9815B



	unit	min	typ	max
photocathode: bialkali				
active diameter	mm		46	
quantum efficiency at peak	%		30	
luminous sensitivity	µA/lm		70	
with CB filter		8	11.5	
with CR filter			2	
dynodes: 10LFBeCu				
anode sensitivity in divider B:				
nominal anode sensitivity	A/lm		50	
max. rated anode sensitivity	A/lm		5000	
overall V for nominal A/lm	V		1800	2300
overall V for max. rated A/lm	V		2400	
gain at nominal A/lm	x 10^6		7	
dark current at 20 °C:				
dc at nominal A/lm	nA		0.3	10
dc at max. rated A/lm	nA		3	
dark count	s^{-1}		300	
pulsed linearity (-5% deviation):				
divider A	mA		50	
divider B	mA		150	
pulse height resolution:				
single electron peak to valley	ratio		2	
rate effect (I_a for $\Delta g/g$=1%):	µA		1	
magnetic field sensitivity:				
the field for which the output decreases by 50 %				
most sensitive direction	T x 10^{-4}		2	
temperature coefficient:	% $°C^{-1}$		± 0.5	
timing:				
single electron rise time	ns		2	
single electron fwhm	ns		3	
single electron jitter (fwhm)	ns		2.2	
transit time	ns		40	
weight:	g		150	
maximum ratings:				
anode current	µA			100
cathode current	nA			100
gain	x 10^6			7
sensitivity	A/lm			500
temperature	°C	-30		60
V (k-a)[1]	V			2500
V (k-d1)	V			500
V (d-d)[2]	V			450
ambient pressure (absolute)	kPa			202

(1) (2)

Photonis XP3292B

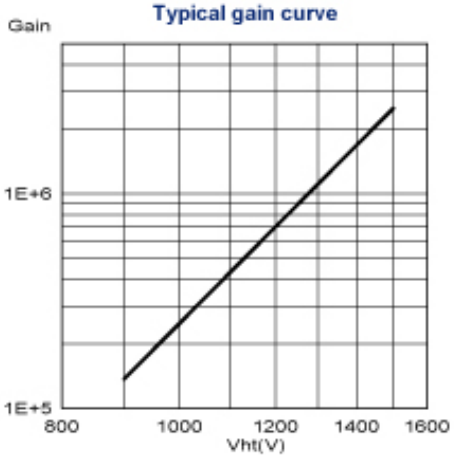
Description	
Window material	Lime glass
Photocathode	Bi-alkali
Refr. Index at 420nm	1.54
Multiplier structure	Linear focused

Photocathode characteristics	Min	Typ	Max	Unit
Spectral range :		270-650		nm
Maximum sensitivity at :		420		nm
Sensitivity :				
Luminous :		95		µA/lm
Blue * :	11	12		µA/lmf
Radiant, at 420nm		95		mA/W
Characteristics with voltage divider A	**Min**	**Typ**	**Max**	**Unit**
Gain slope (vs supp. Volt., log/log)		5.8		
For an anode blue sensitivity of		3		A/lmf
Supply voltage *	800	1000	1200	V
Gain		2.3×10^6		
Anode dark current *		1	20	nA
Pulse height resolution ^{57}Co :		8.6	9.1	%
Pulse height resolution ^{137}Cs :		7		%
Mean anode sensitivity deviation :				
Long term (16h) :		1		%
After change of count rate :		1		%
Vs temperature between 0 and +40°C at 420 nm		-0.3		%/K
For a supply voltage of : 1000V	**Min**	**Typ**	**Max**	**Unit**
Linearity (2%) of anode current up to :		10		mA
Anode pulse :				
Rise time :		4		ns
Duration at half height :		8		ns
Transit Time :		38		ns

Recommended Voltage Divider

Type A for maximum gain

K	D1	D2	D3	D4	D5	D6	D7	D8	A	
2	1.5	1.5	1.5	1	1	1	1	0.5		(total : 11)



Hamamatsu R7723-100

CHARACTERISTICS (at 25 °C)

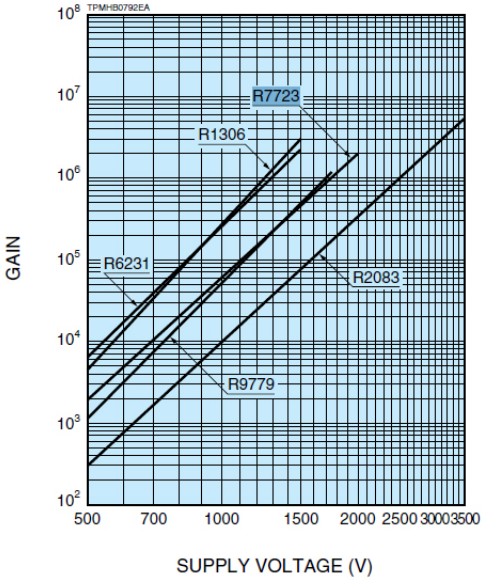
Parameter		R7723			R7724		
		Min.	Typ.	Max.	Min.	Typ.	Max.
Cathode Sensitivity	Luminous (2856 K)	60	90	—	60	90	—
	Quantum Efficiency at 420 nm	—	26	—	—	26	—
	Blue Sensitivity Index (CS 5-58)	—	10.5	—	—	10.5	—
Anode Sensitivity	Luminous (2856 K)	10	90	—	30	300	—
Gain		—	1.0×10^6	—	—	3.3×10^6	—
Anode Dark Current (after 30 min storage in darkness)		—	3	20	—	6	40
Time Response	Anode Pulse Rise Time	—	1.7	—	—	2.1	—
	Electron Transit Time	—	23	—	—	29	—
	Transit Time Spread (T.T.S.)	—	1.1	—	—	1.2	—
Pulse Linearity	±2 % Deviation	—	80	—	—	60	—
	±5 % Deviation	—	100	—	—	90	—

NOTE: Anode characteristics are measured with voltage distribution ratios shown below:

VOLTAGE DISTRIBUTION RATIO AND SUPPLY VOLTAGE

R7723

Electrodes	K	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	P
Ratio	4	1	2	1	1	1	1	2	1	



PMTs data sheet comparison

ET Enterprises electron tubes

Ref No. 11E

Order No. 42853

IMPORTANT–This test ticket must be returned with tube if making a guarantee claim

Type: 9815B

Serial: 5757

TEST RESULT DATA

CB 10.6 CR 1.1 D1 8.9

VOLTS @ 50A/lm 1842.000 V

D/C @ 50A/lm 3.400 nA

VOLTS @ 500A/lm 2597.000 V

ET Enterprises electron tubes

Ref No. 11E

Order No. 42853

IMPORTANT–This test ticket must be returned with tube if making a guarantee claim

Type: 9815B

Serial: 5759

TEST RESULT DATA

CB 10.5 CR 0.8 D1 9.2

VOLTS @ 50A/lm 1838.000 V

D/C @ 50A/lm 9.800 nA

VOLTS @ 500A/lm 2582.000 V

HAMAMATSU FINAL TEST SHEET

PHOTOMULTIPLIER TUBE TYPE : R7723-100

CUSTOMER : HPF/IN2P3 ORSAY

Serial Number	(1) Cathode Luminous Sens. μ A/lm	(2) Anode Luminous Sens. A/lm	(3) Anode Dark Current nA	(4) Cathode Blue Sens. Index	
ZK5752	119.0	14.5	1.90	15.10	
ZK5753	145.0	47.0	0.99	15.80	

Date : 29-Jan-09

Type : XP3292/B

Serial Nr : 05299

PHOTONIS

Cathode Blue sensitivity : 12.3 μA/lmF

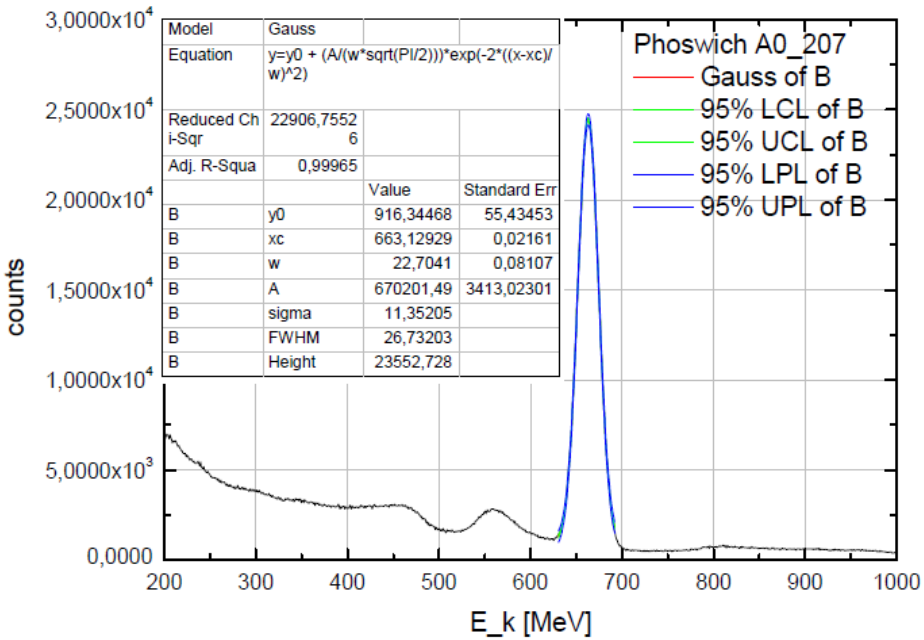
For a anode blue sensitivity: 3 A/lmF

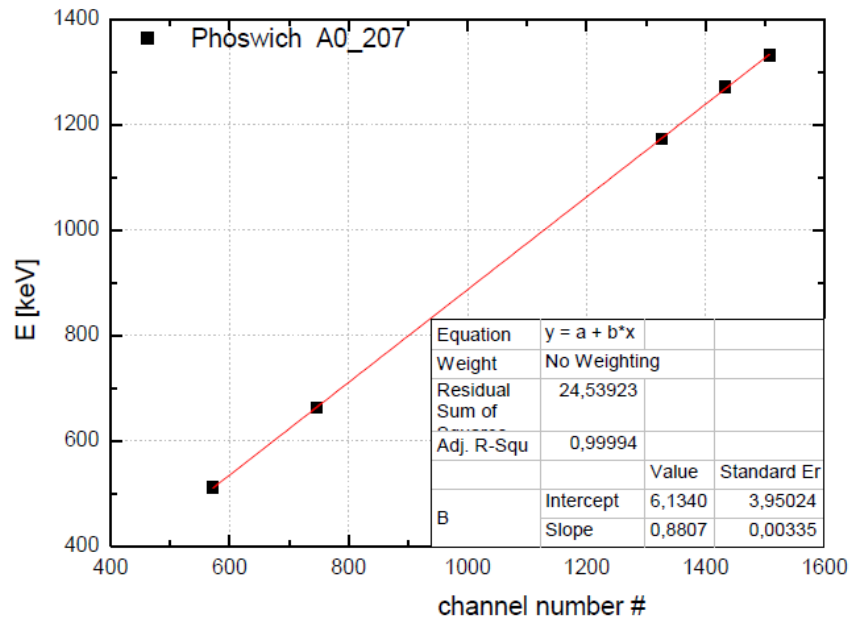
Supply voltage : 959 V

Dark current : 1.0 nA

PHR for Co57 : 8.6 %

A207 with XP 3292/B





Energy resolution A0209 irradiated from different sides

Phoswich 209@	Photonis XP 3292B		ET S/N 5757	
662,00	**4,00%**	irradiated LaBr3		
1332,00	**2,80%**	irradiated LaBr3		
662,00	**4,10%**	source in front of phos		
1332,00	**3,00%**	source in front of phos		
662,00	**9,20%**	irradiated NaI part, not colimated	8,90%	irradiated NaI part, collimated
1332,00	**7,20%**	irradiated NaI part, not colimated	5,60%	irradiated NaI part, collimated

A207 irradiated with different sides

Phoswich 207	Photonis XP 32	
662,00	3,90%	irradiated LaBr3
1332,00	2,80%	irradiated LaBr3
662,00	4,00%	source in front of phos
1332,00	2,90%	source in front of phos
662,00	11,50%	irradiated NaI part, colimated
1332,00	6,00%	irradiated NaI part, colimated

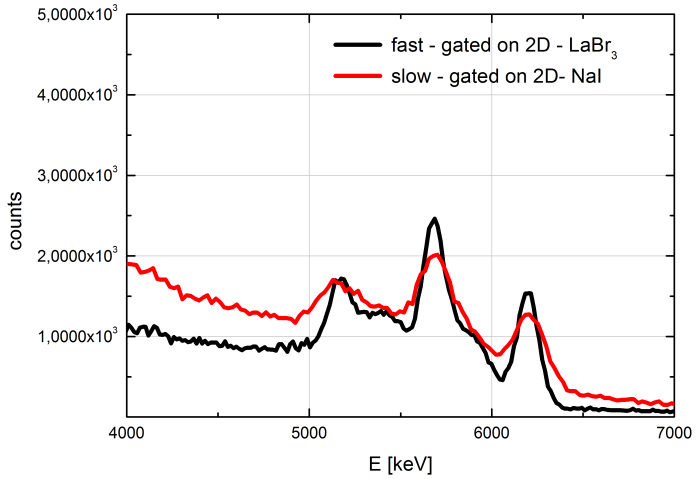
Test advaTech ET Enterprises PMTs

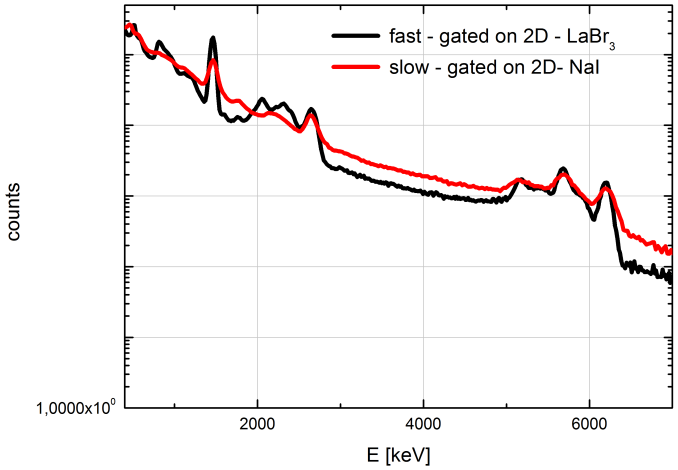
* There are presented time resolutions obtained for LaBr3 detector and also , FWHM and BaF2 as reference.
* The time resolution of the LaBr3 detector with a ET Enterprises PMTs is better than obtained for the detector with Photonis XP3292B photomultiplier.

Time resolution of LaBr3 scintillator coupled with differnet PMTs

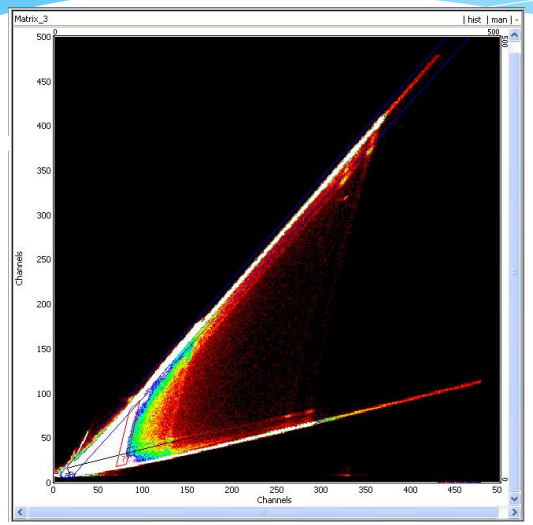
Detector type	Source of γ-rays	[illegible]	FWHM[ps]	[illegible]iBaF$_2$[ps]	FWHM[ps]
BaF$_2$ PMT:XP2020Q HV 2200V					
BaF2-BaF2	^{22}Na, gate E >200 keV	290	670	200	480
	^{22}Na gamma E = 511 keV	260	620	190	440
	^{60}Co gate E >200 keV	230	550	170	390
BaF2-BaF2	^{60}Co gate 1 MeV>E >1.5 MeV	160	380	110	270
LaBr3 PMT:XP3292/B S/N: 5299HV=- 960V					
LaBr3-BaF2	^{22}Na, gate E >200 keV	310	730	240	560
	^{22}Na gamma E~511 keV	290	670	220	520
	^{60}Co gate E >200 keV	280	660	230	540
LaBr3-BaF2	^{60}Co gate 1 MeV>E >1.5 MeV	200	460	160	370
LaBr3 PMT: 9815B S/N: 5759, HV=+1850 V					
LaBr3-BaF2	^{22}Na, gate E >200 keV	270	640	180	420
	^{22}Na gamma E~511 keV	250	580	160	380
	^{60}Co gate E >200 keV	220	520	150	350
LaBr3-BaF2	^{60}Co gate 1 MeV>E >1.5 MeV	170	410	130	
LaBr3 PMT: 9815B S/N: 5757, HV=+1850 V					
LaBr3-BaF2	^{22}Na, gate E >200 keV	300	700	220	510
	^{22}Na gamma E~511 keV	260	600	180	420
	^{60}Co gate E >200 keV	230	540	160	380
	^{60}Co gate 1 MeV>E >1.5 MeV	170	400	130	300
LaBr3 PMT: 9815B S/N: 5757, HV=-1850 V					
LaBr3-BaF2	^{22}Na, gate E >200 keV	320	750	250	590
	^{22}Na gamma E~511 keV	290	670	220	510
	^{60}Co gate E >200 keV	270	640	220	510
	^{60}Co gate 1 MeV>E >1.5 MeV	190	440	150	350

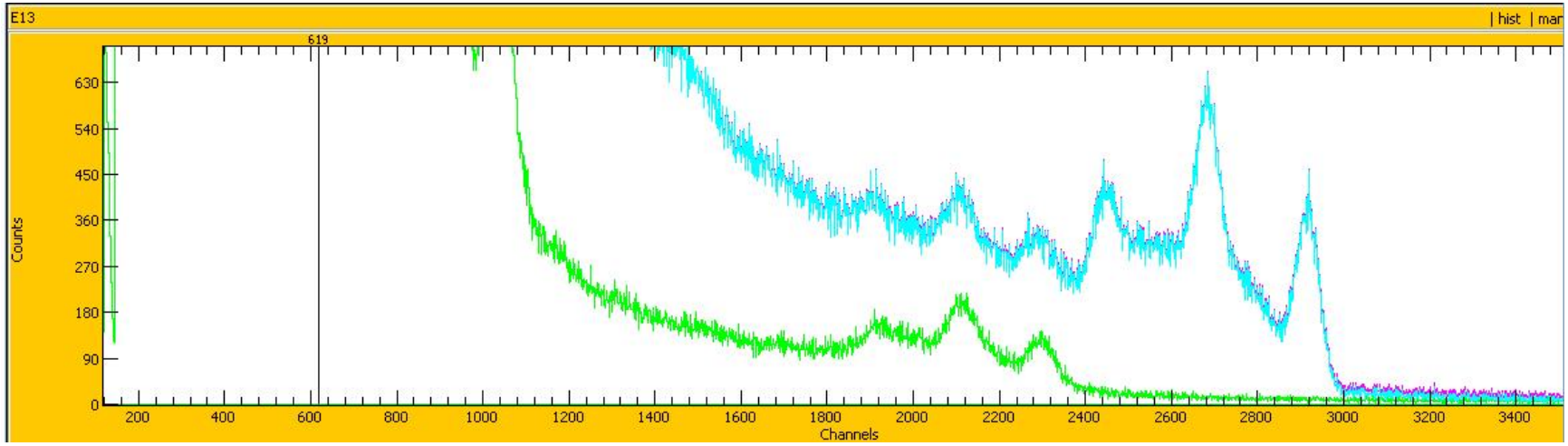
PWO 302 under 6MeV





A302 with 6 MeV source

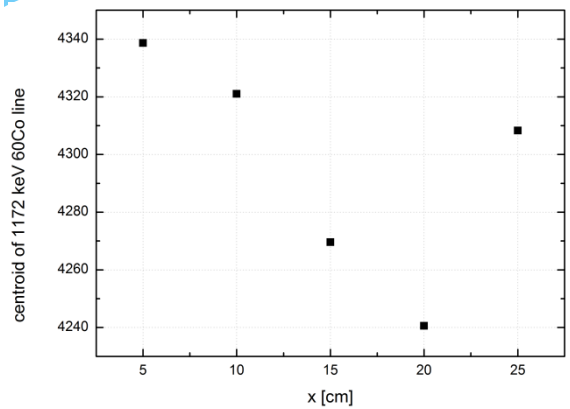


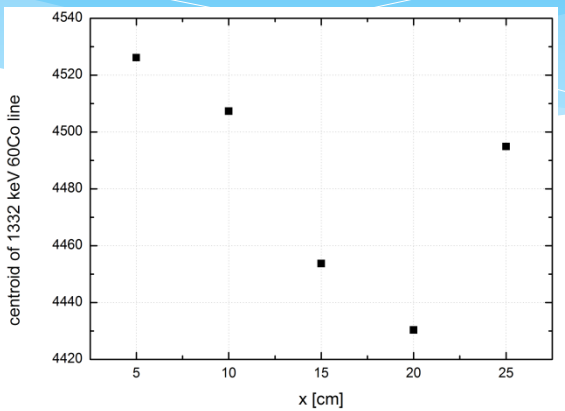


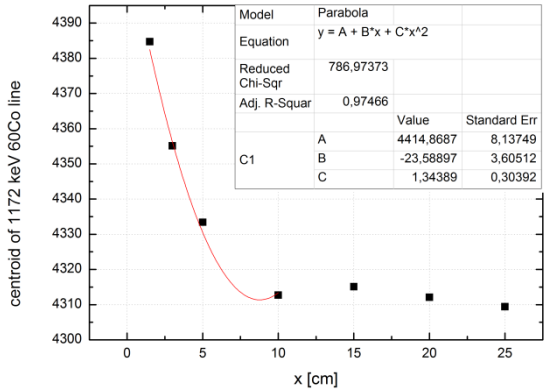
A302 with R7723-100 PMT time resolution

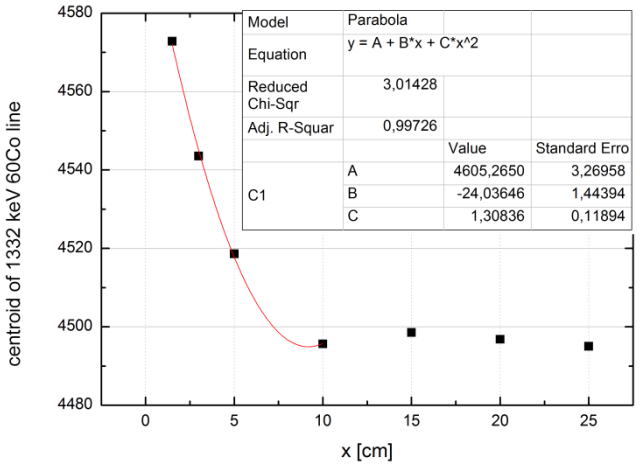
Gate on energy	FWHM [ns]	
^{60}Co 1-1.5 MeV	0,590	
^{60}Co > 200 keV	0,500	
^{22}Na gate 511 keV	0,710	
^{22}Na> 200 keV	0,760	

Nonlinearity









Energy resolution for Labr3 counter

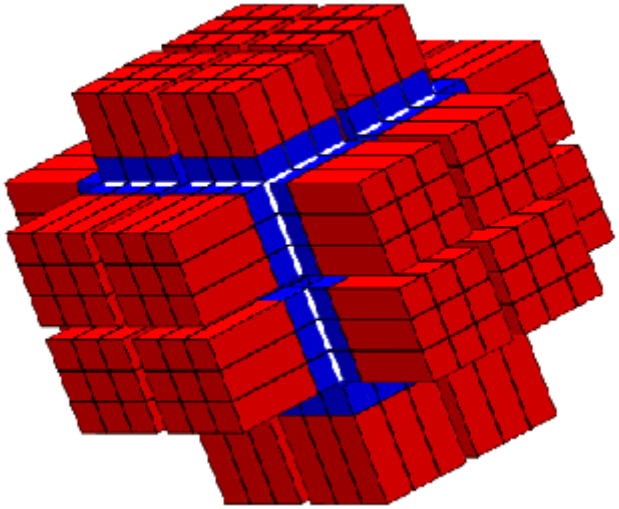
$LaBr_3$ 2"x 2"x 2"

PMT type	**Photonis XP 3292/B**	**ET S/N 5759**	**ET S/N 5757**
	FWHM %	FWHM %	FWHM %
662,00	**3,63**	**4,11**	**4,48**
1172,50	**2,87**		
1332,50	**2,81**		
511,00	**4,22**	**4,80**	**5,12**
122,50		**9,09**	**9,31**
867,00		**3,71**	**4,30**
344,30		**5,57**	**5,75**

PARIS

PHOTON ARRAY FOR STUDIES WITH RADIOACTIVE ION AND STABLE BEAMS

* PARIS –is intended for SPIRAL2 as two shells detector holds a phoswiches with LaBr3(Ce) and NaI(Tl)scintillators coupled with common PMT.



Phoswich A207

Phoswich with XP 3292B

Condition	FWHM (ns) Phos-BaF2	FWHM (ns) LaBr3-BaF2	FWHM [ns] Phos@ET 5759
^{60}Co without gates	0,70	0,66	0,700
^{60}Co gate 1.1 – 1.4 MeV	0,60	0,46	0,360
^{22}Na without gates	0,96	0,73	0,82
^{22}Na energy gate on 511	0,84	0,67	0,610

PWO with ET 5759 in VME1

sigm	FWHM	
0,150	0,360	Co60_1-1.5MeV
0,300	0,700	Co60 > 200keV
0,260	0,610	Na22 only 511 keV
0,350	0,820	Na22> 200keV

PWO with XP in MCA

LaBr3 energy resolution for ^{137}Cs

* The better result was obtained for counter with XP 3292B - Photonis photomultiplier.

Name of PMT	HV	FWHM @ 662 keV [keV]	FWHM E @ 662 keV [%]
XP3292/B SN: 5299	-960	24	3.6
9815B SN: 5759	1850	27	4.1
9815B SN: 5757	1850	30	4.5