WPJET4 Gamma Camera Upgrade (GCU)

D14	*Detector response function calculations*

Replacing the existing gamma-ray detectors of the Gamma Camera at JET for improving the energy resolution and count rate capability is needed for operation in the DT campaign. Target values are an energy resolution of 5% at 1.1 MeV and a count rate capability exceeding 500 kHz.

For the upgraded Gamma Camera new $LaBr_3$:Ce-based detectors are used coupled to MPPC with a passive RC system.

Necessary scintillators and electronic elements were ordered and delivered to the National Centre for Nuclear Research (NCBJ) in 2016:

- 25.4×16.9 (diameter) mm $LaBr_3$:Ce scintillators from St Gobain – 19 scintillators,
- MPPC type S13361-3050NE-04 from Hamamatsu,
- aluminum capsules,
- printed circuit boards for FilterBoxes@NCBJ production,
- printed circuit boards for MPPC temperature compensation device MTCD@NCBJ production.

In Fig. 1 a schematic view of a capsule is shown.

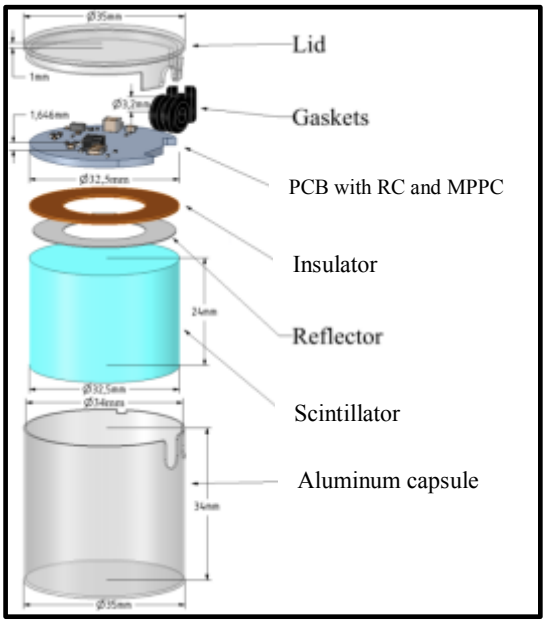

Fig. 1. Schematic view of a capsule.

The detector performance in laboratory conditions was described in the D20 deliverable report on M25: *Detector assembly and laboratory tests with radioactive source and C&M* (2017). Data sheets in the D20 report contain, e.g., FWHM as a function of energy for each detector, and they are included in this report.

Detector response function is used to determine an output of detectors when they are exposed to radiation sources, e.g., gamma-rays or neutrons. Such a function is needed to get a response of a detector to a known radiation source or to perform a spectrum analysis to find a type and quantity of a source irradiated a detector. In case if it is possible, experimentally determined response functions should be used but Monte Carlo simulated distributions could be used as well.

We performed Monte Carlo simulations to evaluate a detector response to gamma radiation which allows to reconstruct spectra measured with a Φ25.4x16.9 mm $LaBr_3$:Ce scintillator, installed at the upgraded Gamma-ray Camera. For all simulations, we used the Geant4 code due to its well-defined physics, flexibility and good reliability. A point-like gamma-ray source was put at a fixed distance from the face of the detector.

We compared measured and simulated gamma-ray spectra registered with a $LaBr_3$:Ce scintillator. Measurements were done with PuBe and PuC sources, emitting 4.4 MeV and 6.1 MeV gamma-rays, respectively. The geometry used in simulations was the same as in measurements. For both sources a distance from the scintillator face to the source was 40 mm.

In Fig. 1 a comparison of measured and simulated gamma-ray spectra is shown: in the upper part for the PuBe and in the lower part for PuC source. A total energy deposited in the scintillator is presented in all spectra. Simulated spectra were normalized to experimental ones. FWHM equal to 3% was assumed in simulations.

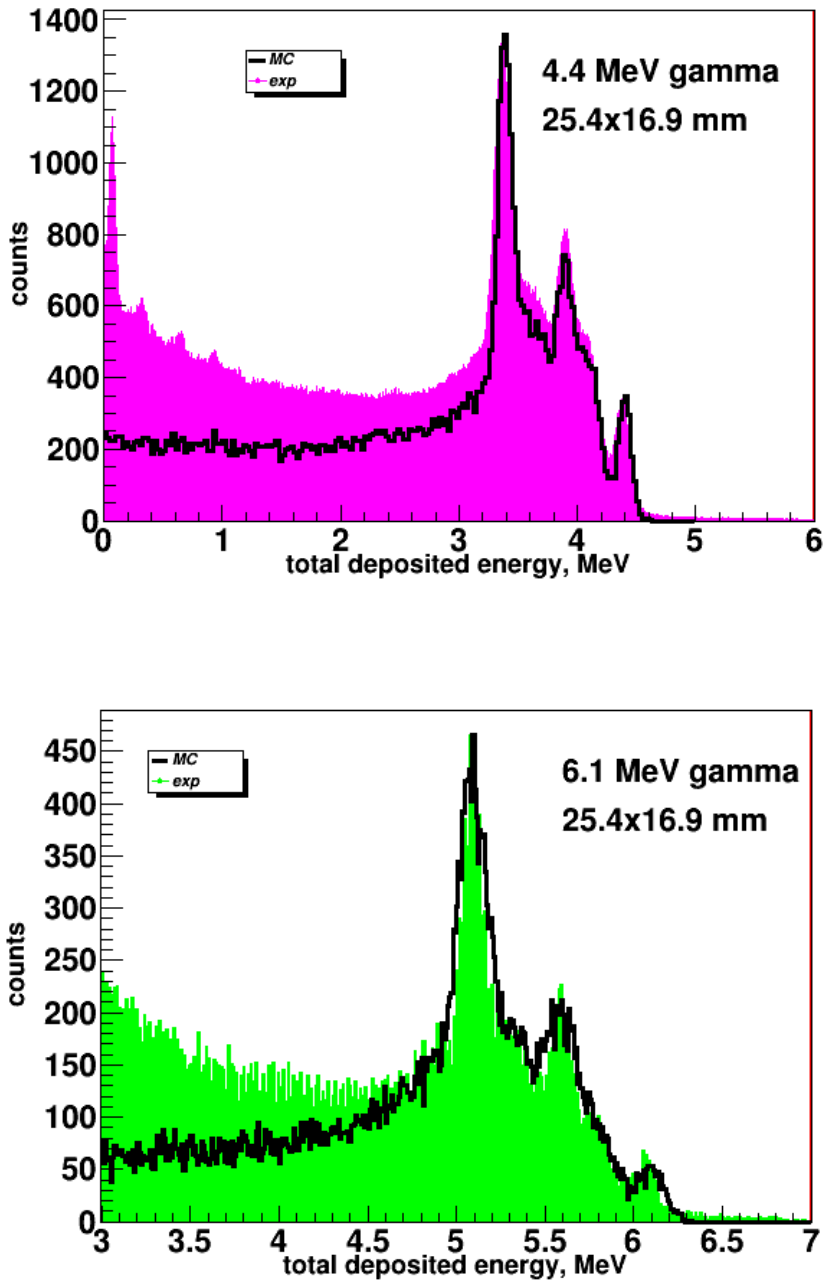

Fig. 1. Measured (non black) and simulated (black) gamma-ray spectra for PuBe (upper) and PuC (lower) sources.

No significant difference is seen in the energy range above 3 MeV and 4.5 MeV for PuBe and PuC sources, respectively. For lower energies, a difference in measured and simulated spectra is observed because in Monte Carlo simulations any additional gamma-ray sources, e.g., from long-lived naturally occurring ^{138}La isotopes or natural background, were not included [SOFT_2016_GCU]. Since natural background depends on an installation place, it should be measured and analyzed for each new place to see an influence on registered spectra.

In Fig. 2, results of Monte Carlo simulations for gamma-ray energies 4.4, 6.1 and 8.0 MeV. and a 25.4x16.9 mm $LaBr_3$:Ce scintillator are shown. All spectra are normalized to 10^6 events on the input.

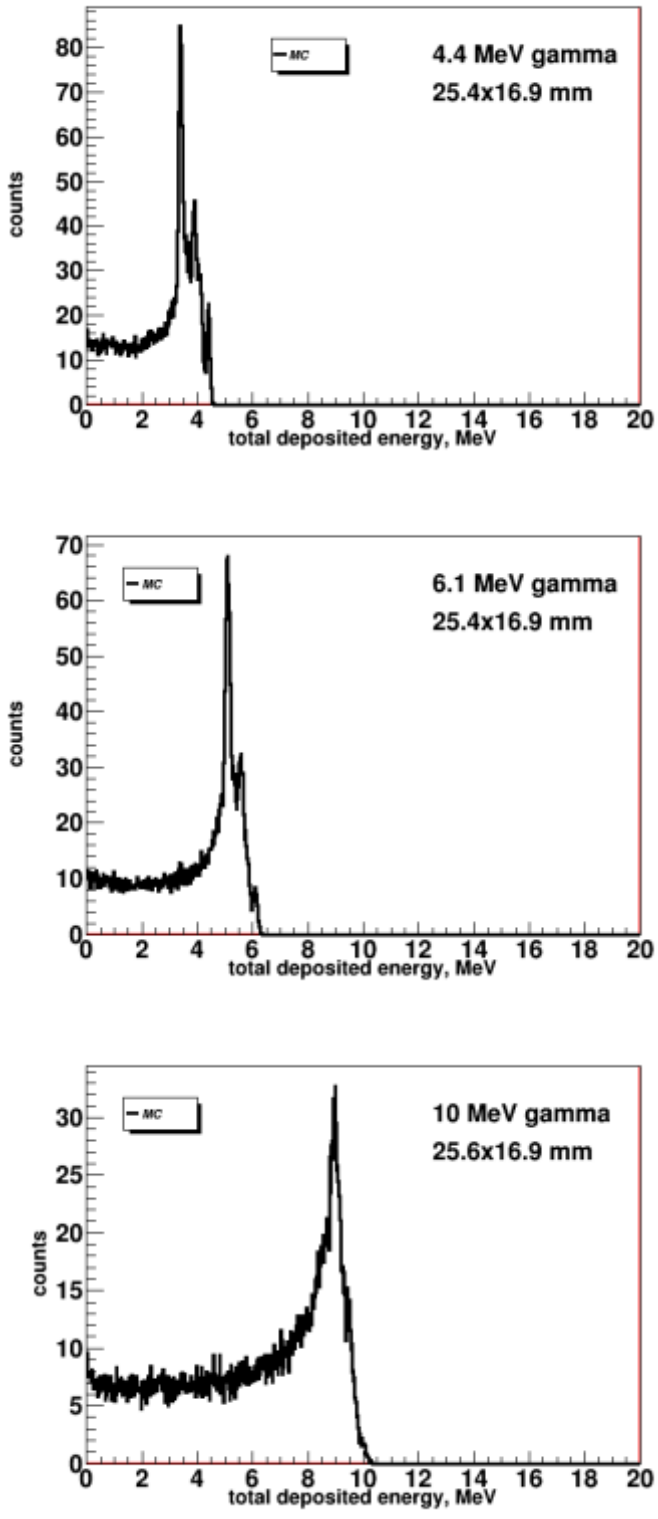

Fig. 2. Monte Carlo simulated spectra for 25.4x26.9 mm $LaBr_3$:Ce scintillator.

A good agreement between measured and Monte Carlo simulated spectra shows a usefulness of such simulations for calculating a scintillator-based detector response in a wide energy range of gamma-rays.

The report was prepared by the NCBJ team
Andrzej Brosławski, Arkadiusz Urban and Izabella Zychor.

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WPJET4 Gamma Camera Upgrade (GCU)

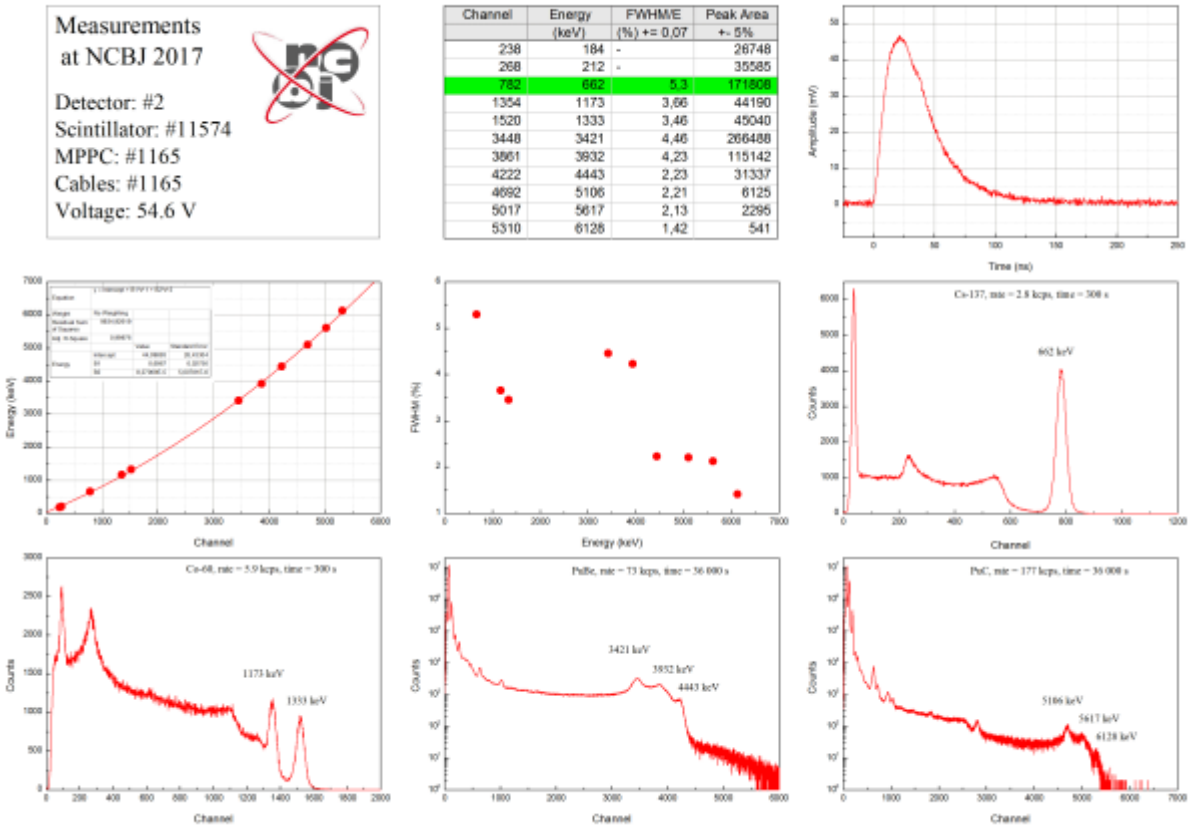
D20	Part of Report on M25: *Detector assembly and laboratory tests with radioactive source and C&M*

DATA SHEETS

Below there are 19 data sheets for capsules installed at JET, as measured at NCBJ.

One data sheet is missing for the detector No 1, now installed in the channel 6 of the Horizontal Camera - the detector was taken to Milan before complete measurements at NCBJ.

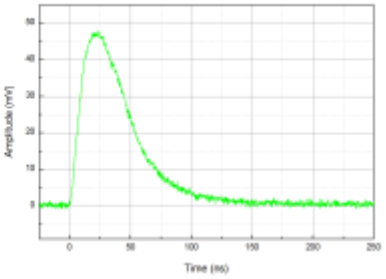
All measurements were performed according to a plan from Marco Tardocchi.

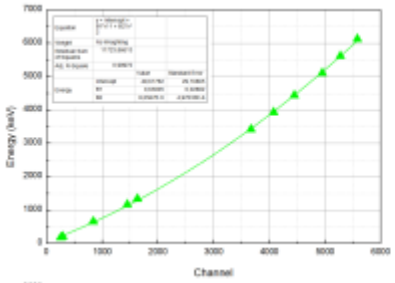


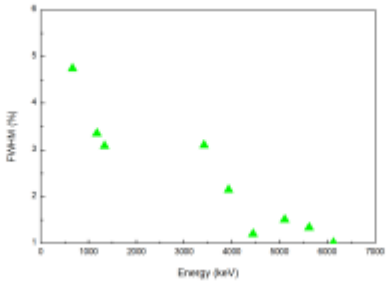
Measurements
at NCBJ 2017

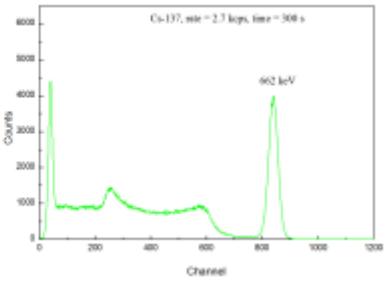
Detector: #3
Scintillator: #11572
MPPC: #1162
Cables: #1162
Voltage: 54.6 V

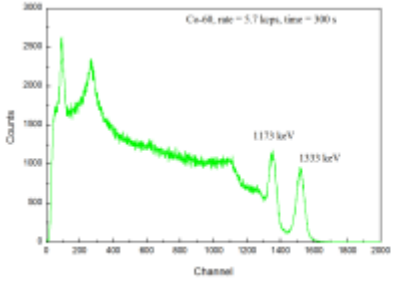
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
258	184	--	29159
290	212	--	29171
840	662	4,75	162267
1453	1173	3,36	48882
1630	1333	3,09	48378
3671	3421	3,11	38311
4079	3932	2,15	79349
4451	4443	1,2	62187
4951	5106	1,51	5642
5276	5617	1,34	2031
5580	6128	1,02	615

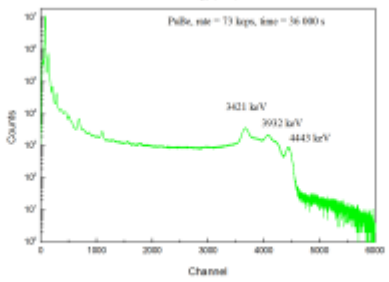


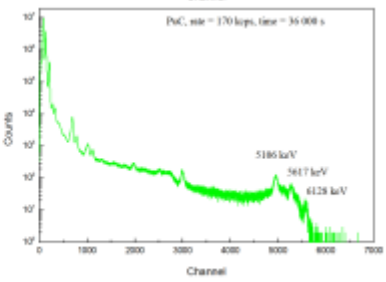








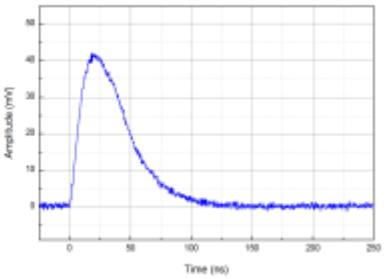


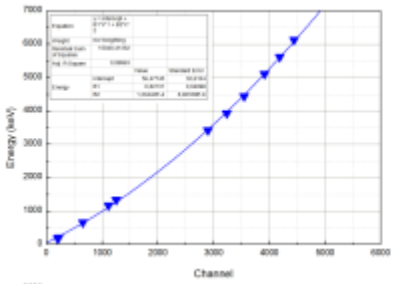


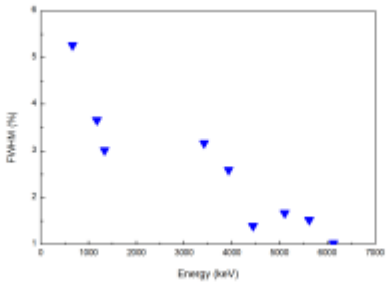
Measurements
at NCBJ 2017

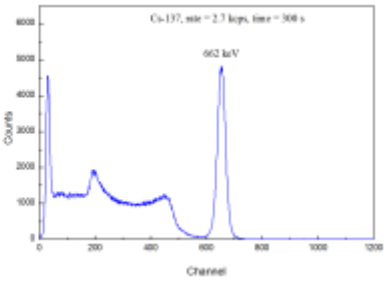
Detector: #4
Scintillator: #11576
MPPC: #001
Cables: #001
Voltage: 53.4 V

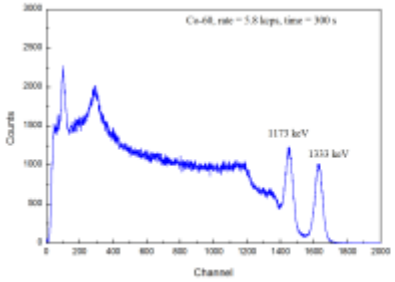
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
198	184	-	27014
219	212	--	33965
654	662	5,26	168179
1115	1173	3,68	46122
1252	1333	3,02	45999
2898	3421	3,17	238296
3235	3932	2,59	78432
3545	4443	1,4	61070
3911	5106	1,67	4918
4187	5617	1,53	1685
4443	6128	1,03	484

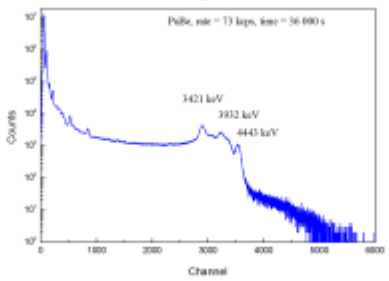


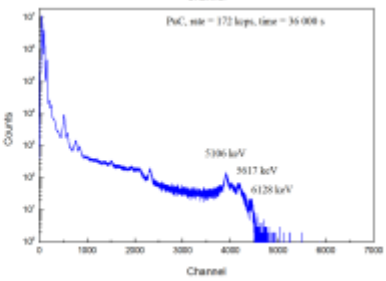








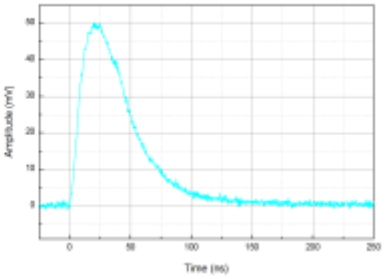


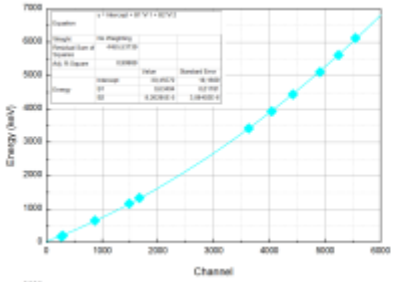


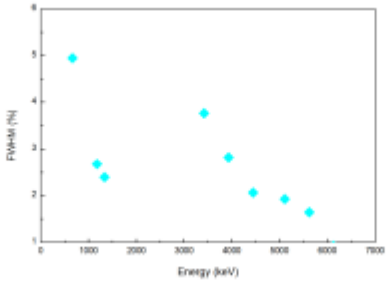
Measurements
at NCBJ 2017

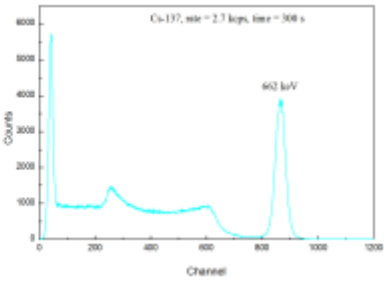
Detector: #5
Scintillator: #11575
MPPC: #1166
Cables: #1166
Voltage: 54.6 V

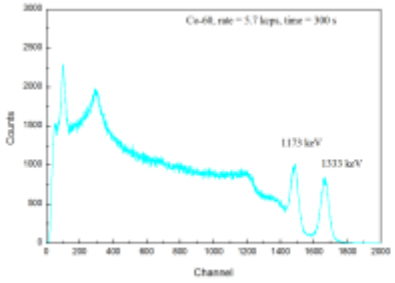
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
263	184	--	31567
296	212	--	30983
865	662	4,95	169775
1485	1173	2,68	40465
1868	1333	2,4	40810
3627	3421	3,77	193632
4043	3932	2,82	54840
4420	4443	2,07	28687
4907	5106	1,93	5441
5239	5617	1,65	1841
5542	6128	0,93	565

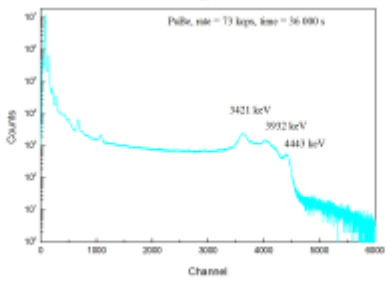


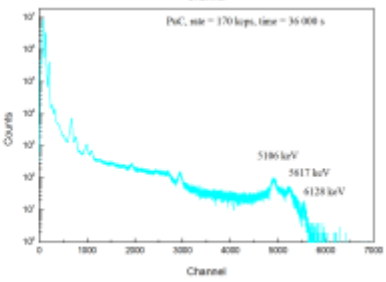








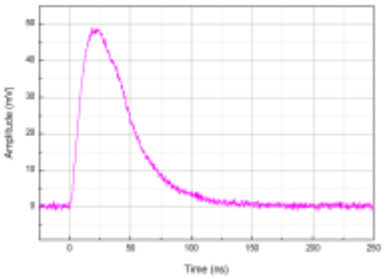


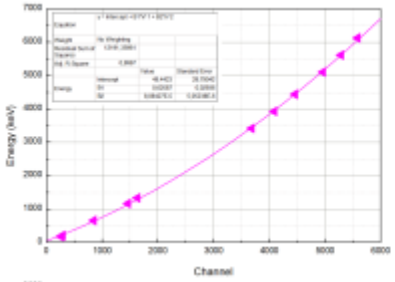


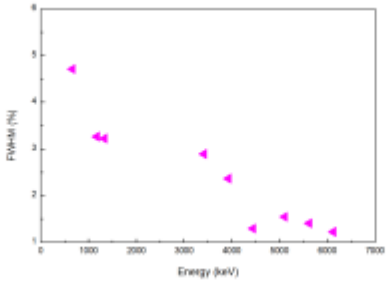
Measurements
at NCBJ 2017

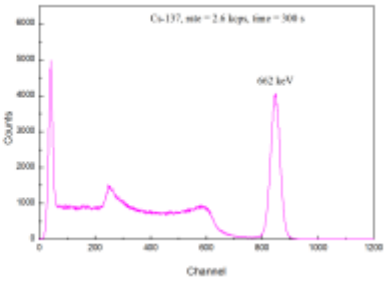
Detector: #6
Scintillator: #11573
MPPC: #1161
Cables: #1161
Voltage: 54.6 V

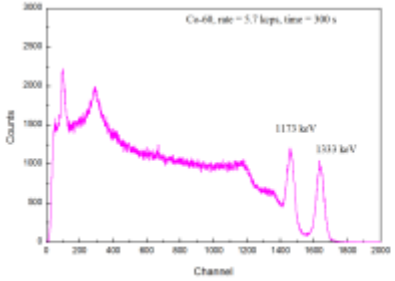
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
258	184	--	26772
292	212	--	30399
847	662	4,71	164654
1462	1173	3,27	46154
1634	1333	3,23	50970
3681	3421	2,9	237311
4088	3932	2,37	83590
4460	4443	1,3	65915
4962	5106	1,55	5449
5289	5617	1,41	2283
5587	6128	1,23	801

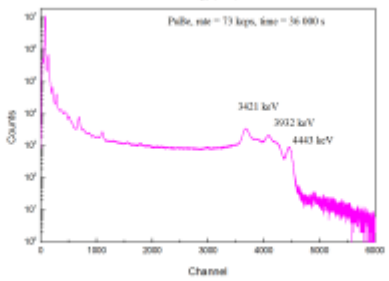


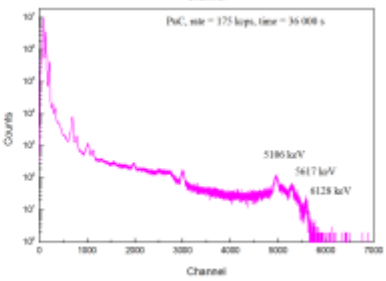








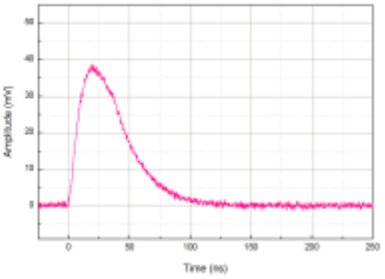


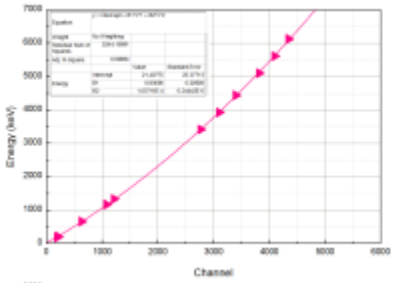


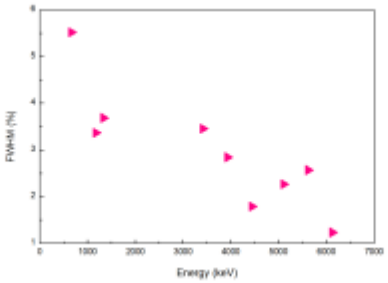
Measurements
at NCBJ 2017

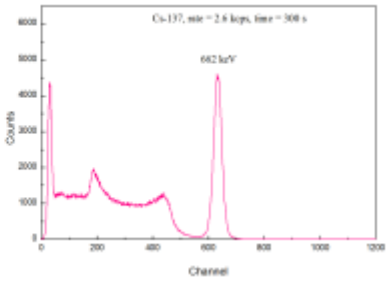
Detector: #7
Scintillator: #11584
MPPC: #002
Cables: #002
Voltage: 53.4 V

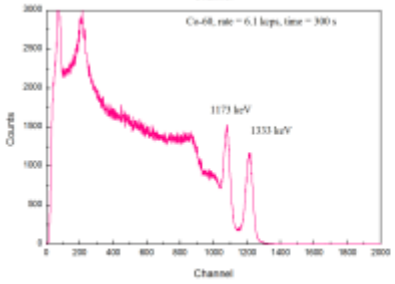
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
192	184	--	28936
212	212	--	43197
633	662	5,52	162588
1081	1173	3,37	48083
1215	1333	3,69	47750
2773	3421	3,46	237396
3099	3932	2,85	79572
3398	4443	1,79	58084
3821	5106	2,27	5643
4098	5617	2,57	2305
4344	6128	1,24	409

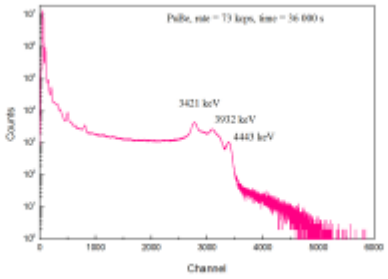


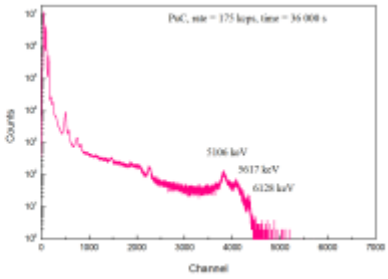








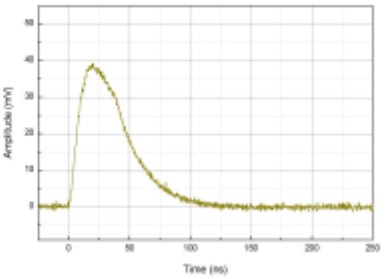


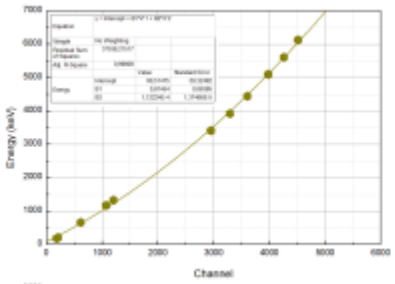


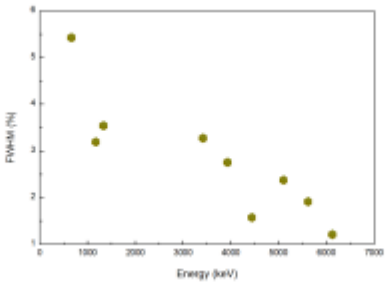
Measurements
at NCBJ 2017

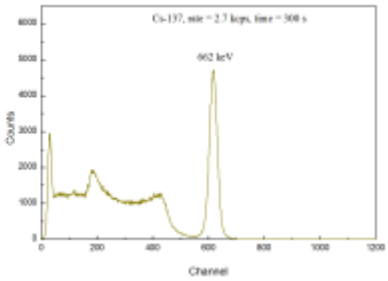
Detector: #8
Scintillator: #11580
MPPC: #003
Cables: #1167
Voltage: 53.4 V

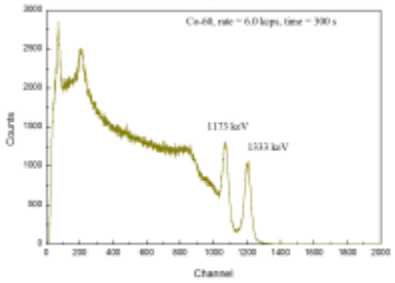
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
187	184	--	31051
209	212	--	22844
617	662	5,43	159410
1072	1173	3,2	37951
1204	1333	3,55	38191
2955	3421	3,28	251955
3295	3932	2,76	88066
3606	4443	1,58	59176
3983	5106	2,38	5880
4264	5617	1,92	1536
4517	6128	1,22	303

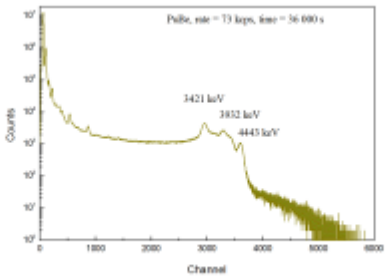


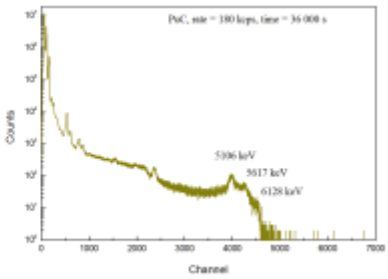








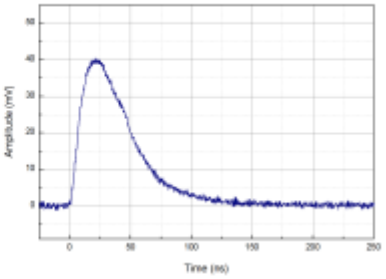


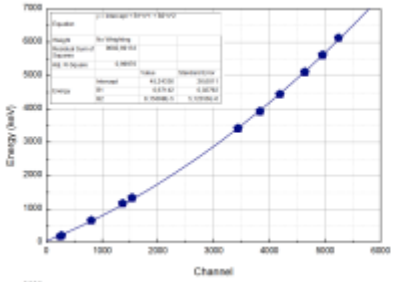


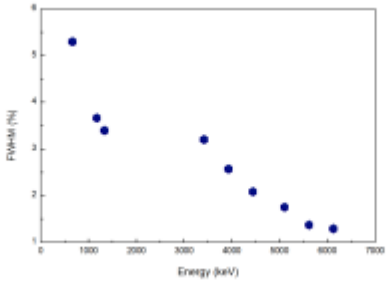
Measurements
at NCBJ 2017

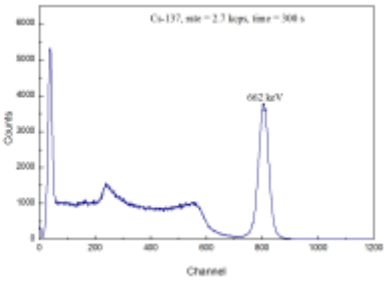
Detector: #9
Scintillator: #11568
MPPC: #1167
Cables: #003
Voltage: 54.6 V

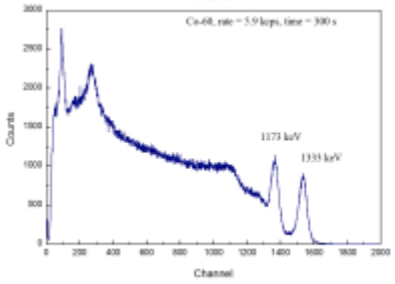
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
246	184	--	24915
271	212	--	30312
805	662	5,3	161789
1367	1173	3,67	43066
1535	1333	3,4	41947
3439	3421	3,21	237936
3835	3932	2,57	79091
4190	4443	2,09	55712
4637	5106	1,76	10389
4954	5617	1,38	3105
5242	6128	1,3	1232

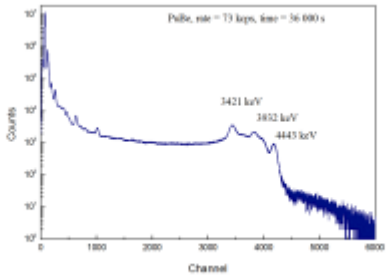


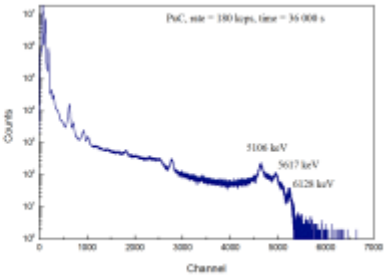








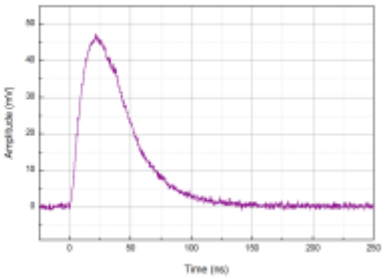


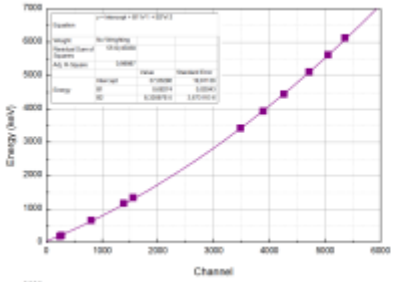


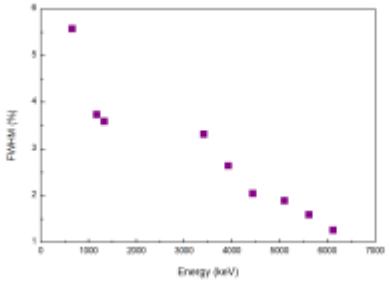
Measurements
at NCBJ 2017

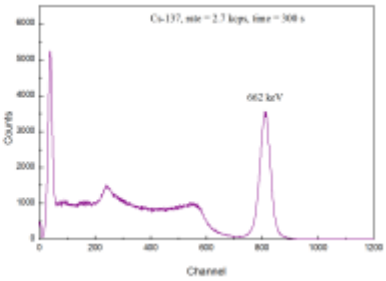
Detector: #10
Scintillator: #11570
MPPC: #1163
Cables: #1163
Voltage: 54.7 V

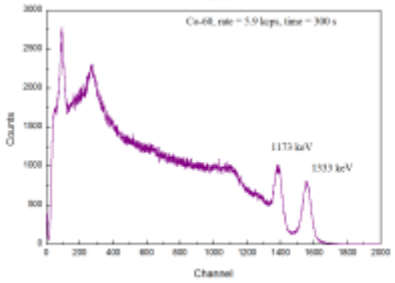
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
245	184	--	21251
273	212	--	29365
810	662	5,57	158615
1388	1173	3,74	37903
1558	1333	3,59	39777
3487	3421	3,32	269523
3895	3932	2,64	85672
4267	4443	2,04	58049
4721	5106	1,89	9958
5057	5617	1,59	3487
5364	6128	1,26	1038

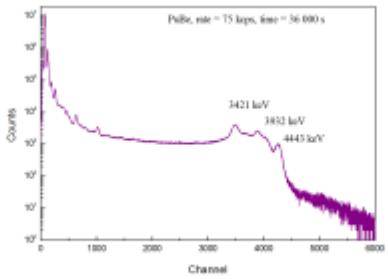


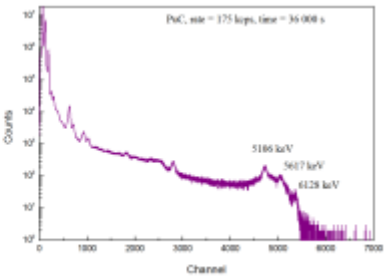










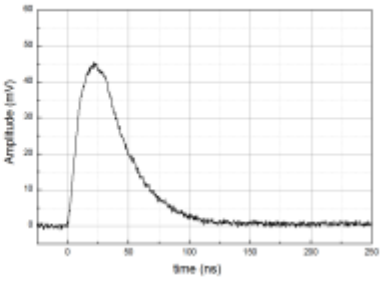


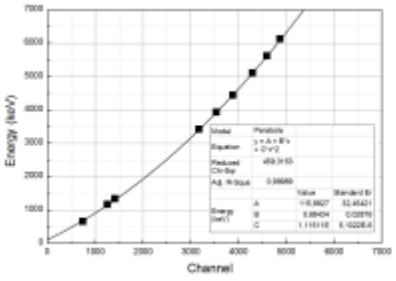
Measurement
at NCBJ 2017

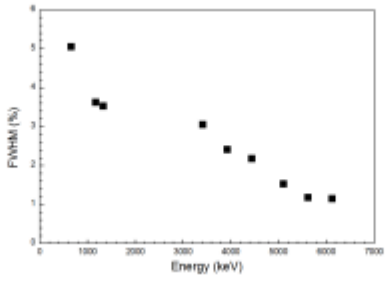
NCBJ ŚWIERK

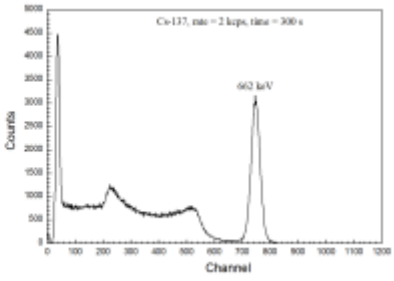
Detector: #11
Scintillator: #11578
MPPC: #1171
Cables: #1171
Voltage: #54.6V

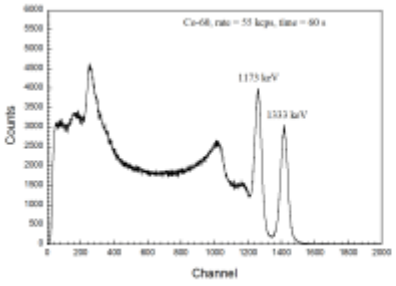
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
748	662	5,05	116494
1261	1173	3,82	152401
1417	1333	3,53	145443
3177	3421	3,05	278299
3543	3932	2,41	89505
3884	4443	2,18	71436
4300	5107	1,52	3868
4601	5618	1,18	1269
4876	6129	1,15	427

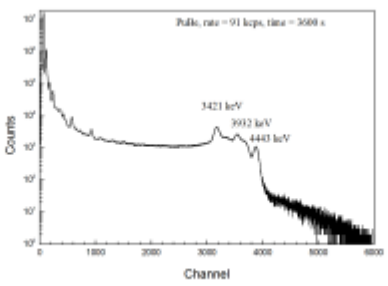


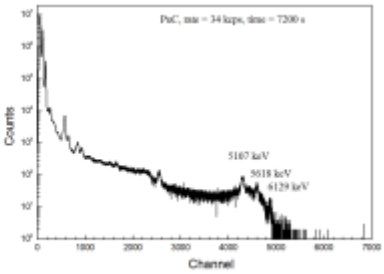










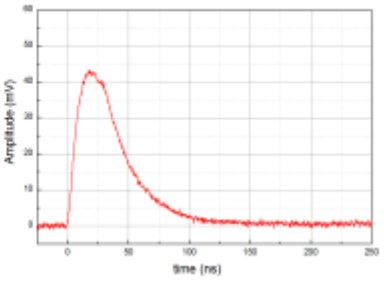


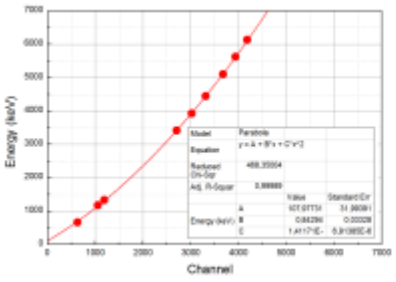
Measurement
at NCBJ 2017

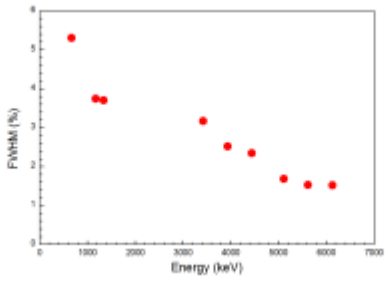
NCBJ ŚWIERK

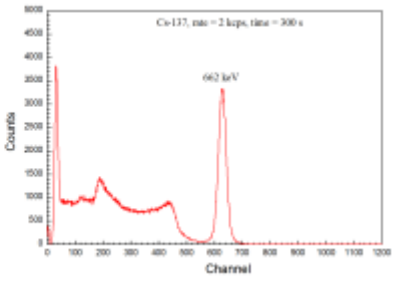
Detector: #12
Scintillator: #11586
MPPC: #1178
Cables: #1178
Voltage: #54.6V

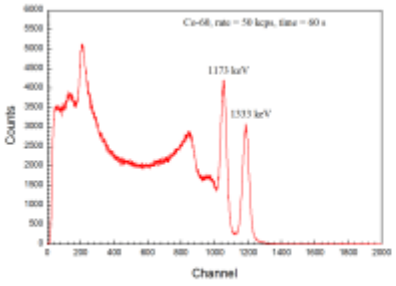
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
628	662	5,3	111941
1055	1173	3,74	135043
1187	1333	3,71	130790
2703	3421	3,17	276336
3021	3932	2,52	89344
3315	4443	2,35	73065
3679	5107	1,68	3509
3940	5618	1,53	1173
4185	6129	1,52	388

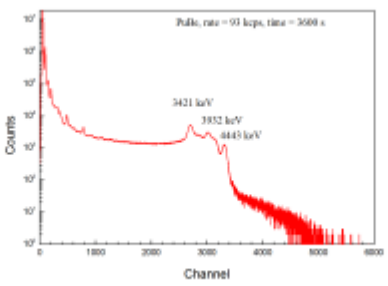


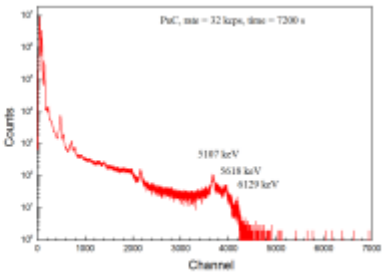










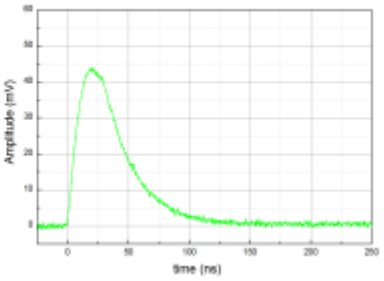


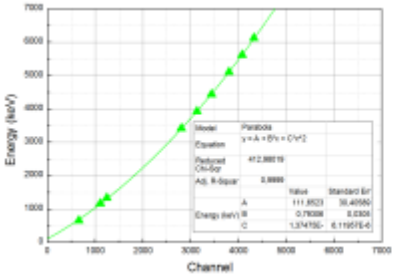
Measurement at NCBJ 2017

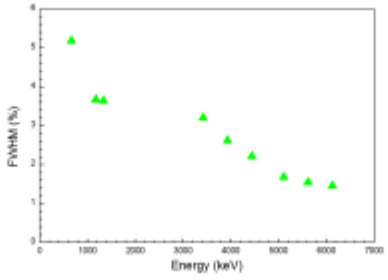
NCBJ ŚWIERK

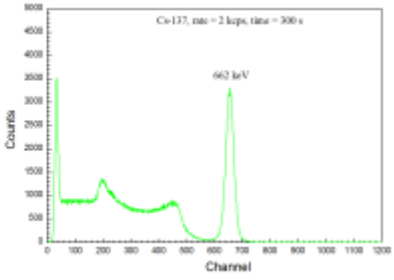
Detector: #13
Scintillator: #11565
MPPC: #1169
Cables: #1169
Voltage: #54.6V

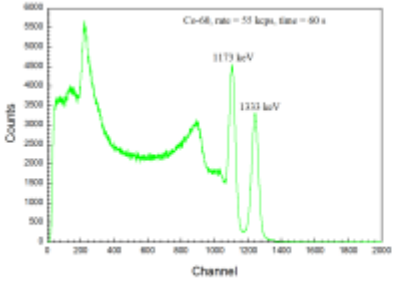
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
655	662	5,18	112629
1106	1173	3,87	156027
1242	1333	3,64	148745
2805	3421	3,21	266997
3131	3932	2,62	93533
3433	4443	2,22	66868
3802	5107	1,88	3851
4075	5618	1,54	1147
4322	6129	1,46	505

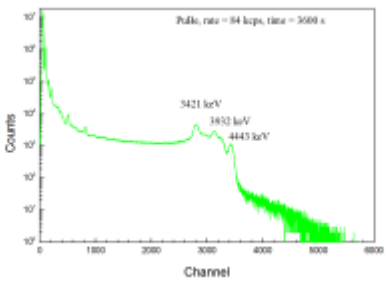


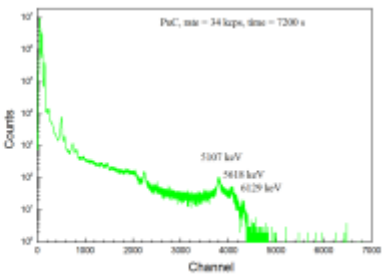










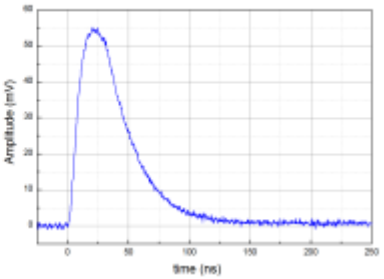


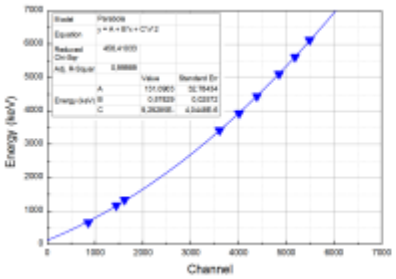
Measurement at NCBJ 2017

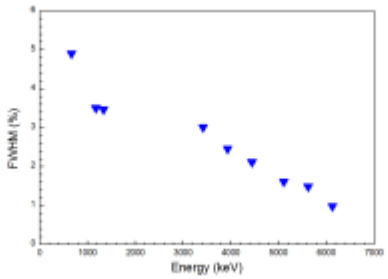
NCBJ ŚWIERK

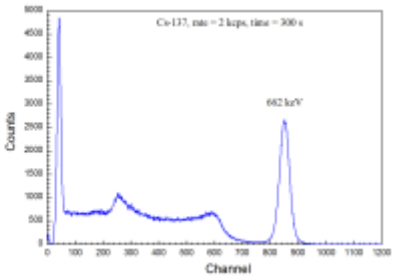
Detector: #14
Scintillator: #11587
MPPC: #1172
Cables: #1172
Voltage: #54.6V

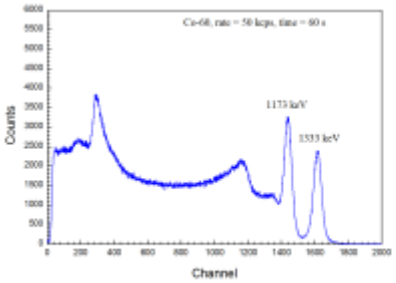
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
851	662	4,9	114848
1440	1173	3,51	138081
1616	1333	3,47	131495
3599	3421	3,01	285217
4010	3932	2,46	99859
4385	4443	2,12	76301
4848	5107	1,81	3952
5183	5618	1,49	1255
5489	6129	0,98	416

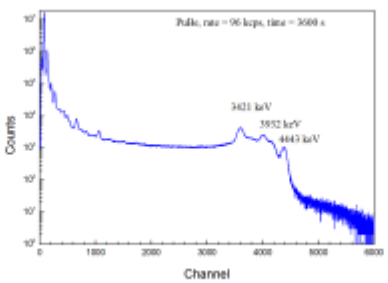


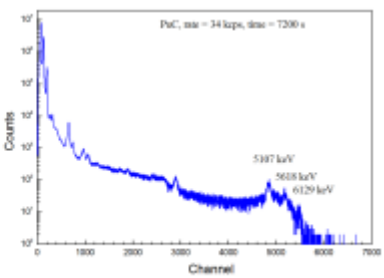










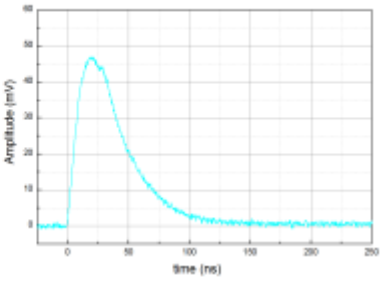


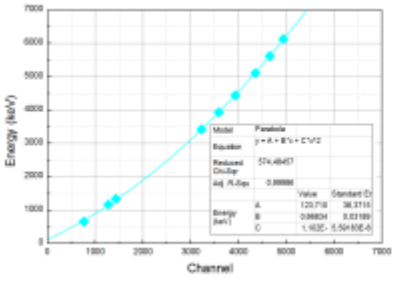
Measurement
at NCBJ 2017

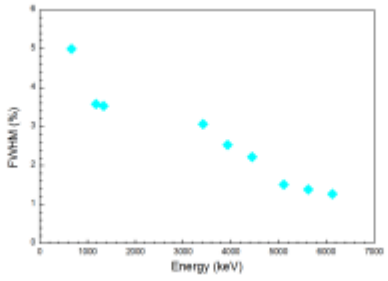
NCBJ ŚWIERK

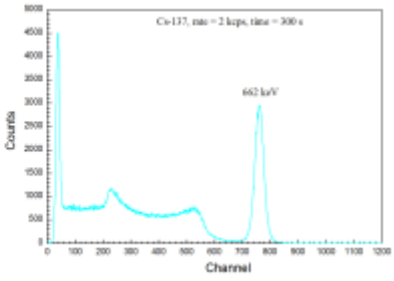
Detector: #15
Scintillator: #11582
MPPC: #1173
Cables: #1173
Voltage: #54.6V

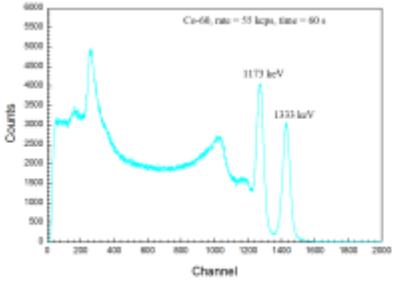
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
761	662	5	115922
1273	1173	3,58	162437
1429	1333	3,54	151136
3220	3421	3,07	252298
3590	3932	2,54	86950
3933	4443	2,23	67486
4352	5107	1,51	3874
4654	5618	1,39	1192
4935	6129	1,27	494

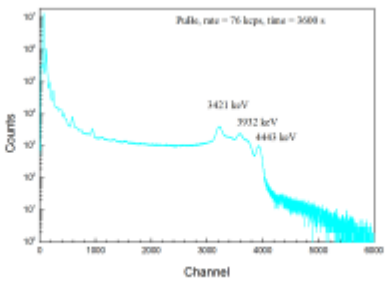


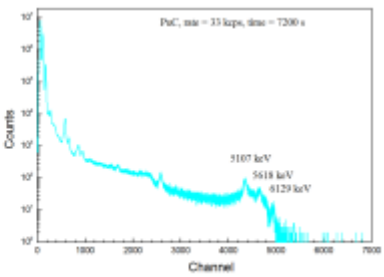










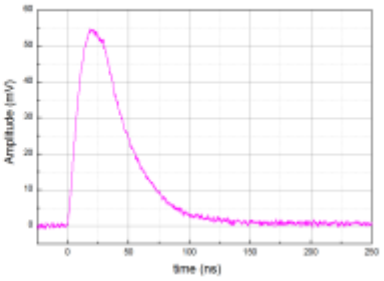


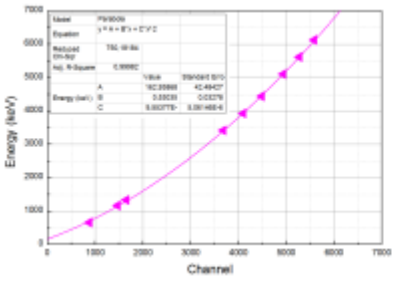
Measurement
at NCBJ 2017

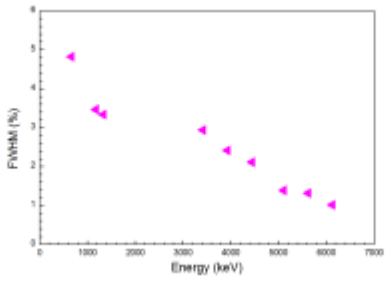
NCBJ ŚWIERK

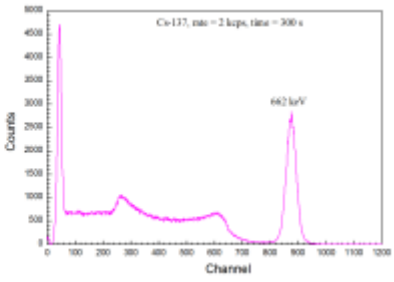
Detector: #16
Scintillator: #11569
MPPC: #1174
Cables: #1174
Voltage: #54.6V

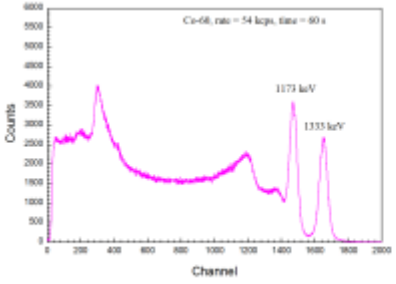
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
875	662	4,82	118839
1472	1173	3,47	158109
1652	1333	3,34	146195
3685	3421	2,94	286265
4104	3932	2,42	102806
4489	4443	2,12	80717
4938	5107	1,39	3850
5273	5618	1,32	1380
5587	6129	1,02	438

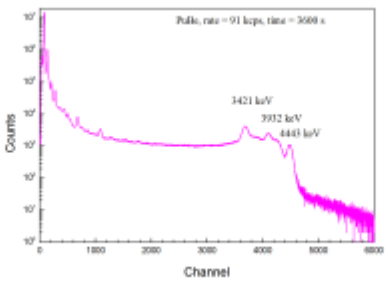


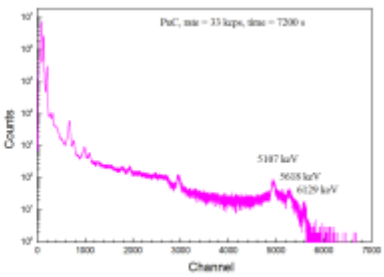










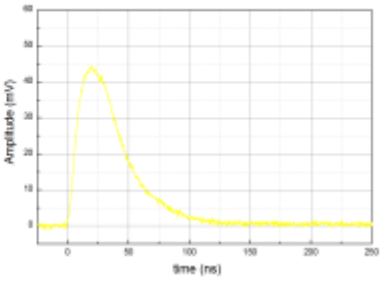


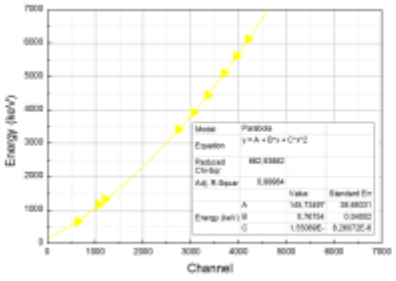
Measurement at NCBJ 2017

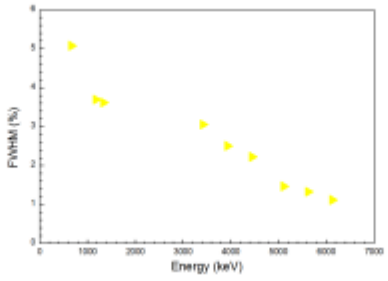
NCBJ ŚWIERK

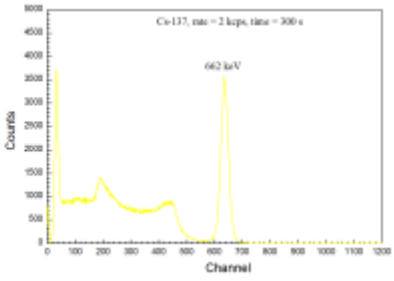
Detector: #17
Scintillator: #11563
MPPC: #1175
Cables: #1175
Voltage: #54.6V

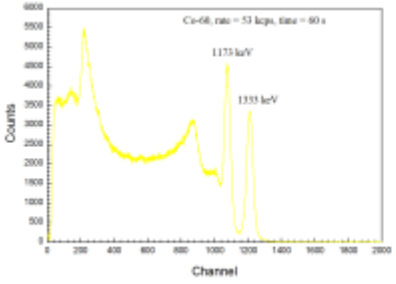
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
637	662	5,08	113917
1077	1173	3,7	156020
1211	1333	3,62	146770
2740	3421	3,06	270279
3061	3932	2,51	93765
3356	4443	2,23	74708
3700	5107	1,47	3724
3961	5618	1,33	1311
4202	6129	1,12	428

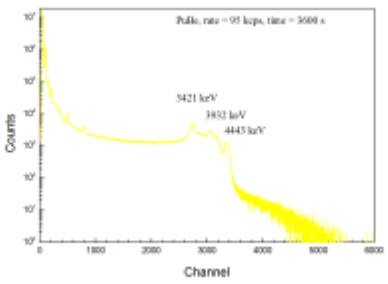


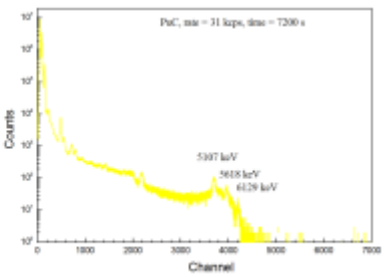










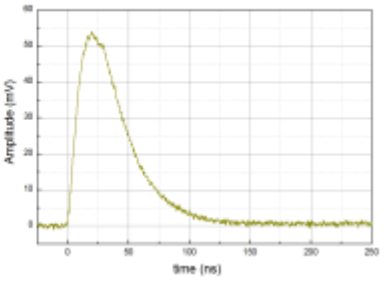


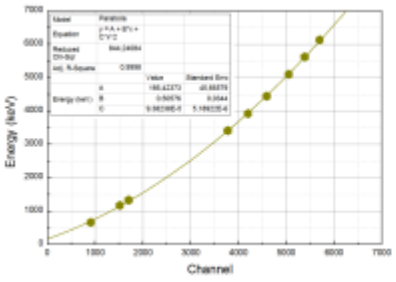
Measurement at NCBJ 2017

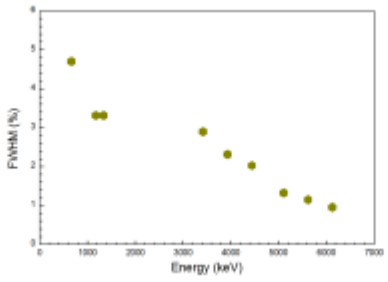
NCBJ ŚWIERK

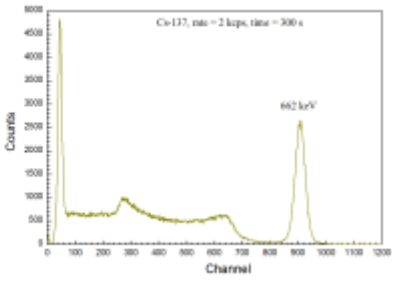
Detector: #18
Scintillator: #11566
MPPC: #1177
Cables: #1177
Voltage: #54.6V

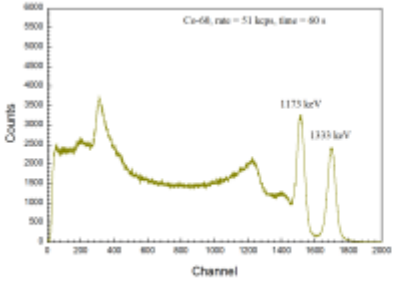
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
908	662	4,7	114705
1516	1173	3,32	143222
1700	1333	3,32	134571
3779	3421	2,9	278127
4201	3932	2,32	100023
4590	4443	2,03	74776
5053	5107	1,33	3507
5391	5618	1,15	1398
5703	6129	0,96	513

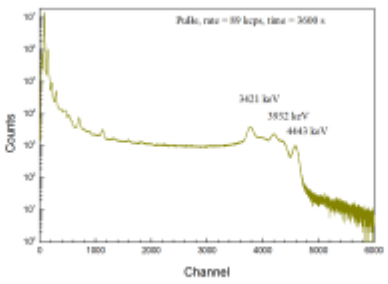


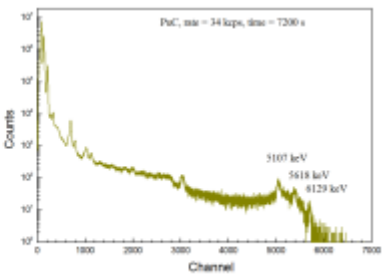










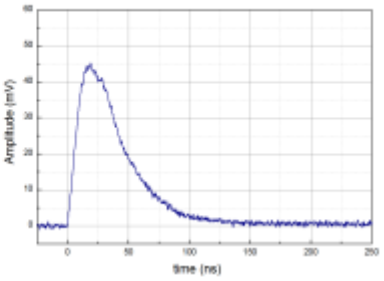


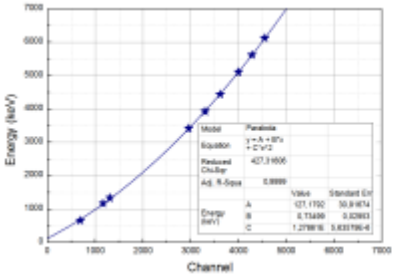
Measurement at NCBJ 2017

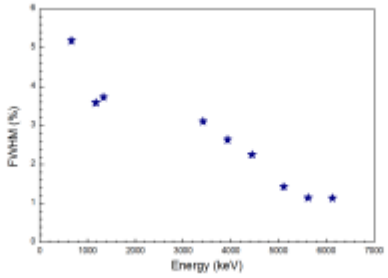
NCBJ ŚWIERK

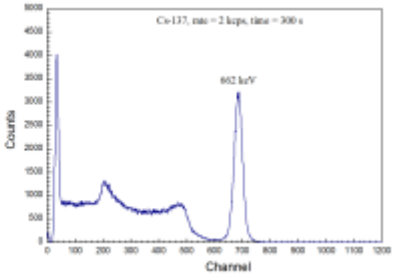
Detector: #19
Scintillator: #11577
MPPC: #1179
Cables: #1179
Voltage: #54.6V

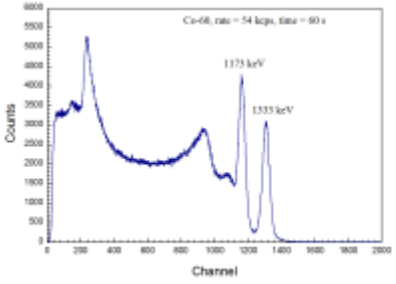
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
686	662	5,18	115961
1164	1173	3,59	150823
1308	1333	3,73	145836
2956	3421	3,11	262269
3299	3932	2,64	91066
3618	4443	2,26	70656
4000	5107	1,43	3448
4281	5618	1,15	1239
4547	6129	1,14	436

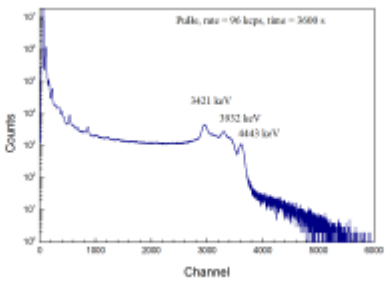


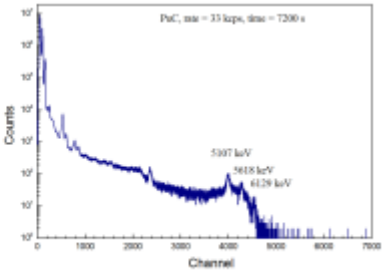












Measurement at NCBJ 2017

NCBJ ŚWIERK

Detector: #20
Scintillator: #11567
MPPC: #1180
Cables: #1180
Voltage: #54.6V

Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
977	662	4,63	114927
1626	1173	3,38	143489
1823	1333	3,31	132206
4014	3421	2,92	275015
4456	3932	2,36	91167
4864	4443	2,09	71419
5371	5107	1,33	3916
5728	5618	1,17	1251
6046	6129	1,19	394