WPJET4 Gamma Camera Upgrade (GCU)

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

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.

C&M - Control and Monitoring system: CANCELLED not designed and installed.

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

- $LaBr_3$:Ce scintillators from St Gobain,
- 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.

The passive bases used in capsule swere delivered by our Italian collaborators.

1. Printed circuit board (PCB) for MTCD@NCBJ

- communication between MTCD@NCBJ and FilterBox@NCBJ, 10 channel power supply for MPPC detectors,
- input and output synchronization of the whole system.

2. FilterBox@NCBJ

- high voltage power supply filters,
- power supplies for active elements placed inside each detector capsule,
- temperature readout from a temperature sensor to be sent to MTCD@NCBJ.

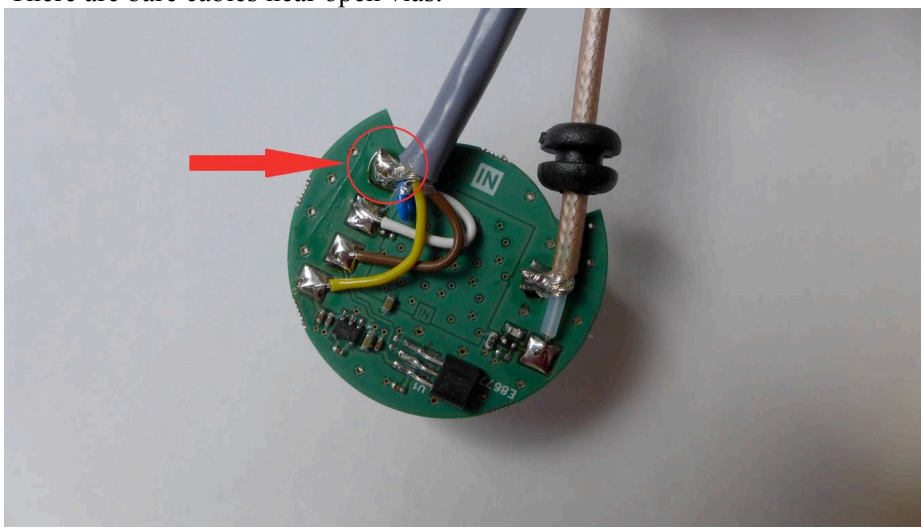
3. REMARKS

Our remarks concerning passive bases delivered by Milan to be installed in a final capsule:

1. from 3 "old" passive bases one was left by Milan at NCBJ on January 19, 2017 - we have sent questions/comments concerning this base, checked only "by eye" and making a photo.
   We are concerned about a quality of this base as well as length of cables, see photo.
   We have asked to put some attention to a relative position of MPPC and a temperature sensor:
   To measure a temperature in a proper way, the thermometer should be placed centrally over the MPPC.

A thermal paste, easy available in any shop, should be applied between the thermometer and the PCB to ensure a thermal contact between MPPC and thermometer.
Already at NCBJ in January an intervention was required for the 1st passive base set to remove a capacitor. The 2nd set of passive bases was delivered without this capacitor.

2. Two "old" passive bases were brought to NCBJ by the Milan team on February 14, 2017.
   - no changes were made into these 2 "old" bases by the Milan team between visits in January and February. The necessary resoldering had to be made at NCBJ, see below.
3. 7 new passive bases were delivered to NCBJ with the same position of a temperature sensor but with a better soldering. The 2nd set of passive bases has the same position of a temperature sensor.
4. After a discussion with Marco Tardocchi, Stefan Korolczuk has started to work with "old" passive bases. Stefan has removed a capacitor and made a resoldering of cables.
   - 4.1. It was observed that loose tin drops were left on a passive base.
   - 4.2. It was removed too much bare cable (without isolation) from cables what can cause a short circuit during mounting a base in a capsule.
   - 4.3. There are bare cables near open vias.



   As a conclusion, we are concerned about a performance of these 3 "old" passive bases at JET. In our opinion, these 3 bases should be made in the same way as 7 new one, as it was declared by Marco in his email (7.02.2017): *"The bases and cables are identical to the one which we have left you. "*
5. Longer cables were soldered to all 10 passive bases, about 40 cm. The already installed at JET two prototypes were equipped with cables of length ~20 cm. The length of cables in prototypes were obtained from measurements done with CsI-based capsules and technical drawing. We decided to cut cables to the length ~20 cm.
6. Capsules with U-opening were chosen for a final capsule.
7. No thermal paste is used in a final capsule.
8. Different BNC types: in the 2nd part of passive bases different BNC connectors have been found - see photo. New BNC connectors of the same type were brought to JET in May 2017 and replaced by Stefan.

9. We had a question regarding LEMO cables.
   Now the shielding is connected to the ground (GND), but previously, in the 1st part of passive bases, it was not used on the detector side - it was simply cut. Which standard should we use now? This information is necessary before we start a detector testing. Answer from Milan: *"We think that you can go on with the bases with the shielding connected to the ground. We guess that there will be no differences in terms of performance. Let us know if you don't agree."*

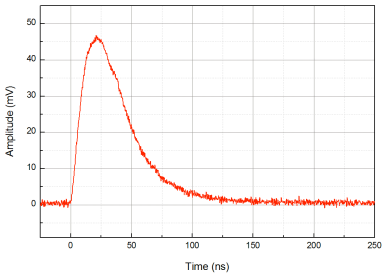
DATA SHEETS

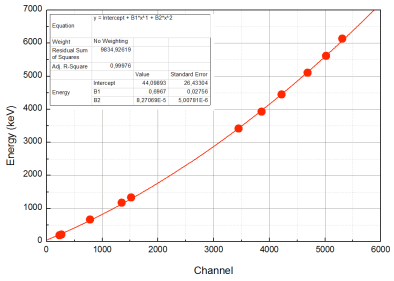
Below there are 19 data sheets for capsules installed at JET, as measured at NCBJ.
One data sheet is missing for the detector No 1, now installed in the channel 6 of the Horizontal Camera - the detector was taken to Milan before complete measurements at NCBJ.
All measurements were performed according to a plan from Marco Tardocchi.

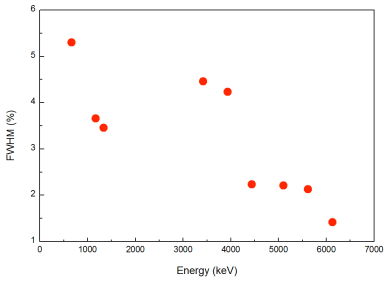
Measurements
at NCBJ 2017

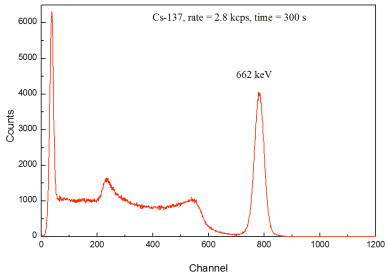
Detector: #2
Scintillator: #11574
MPPC: #1165
Cables: #1165
Voltage: 54.6 V

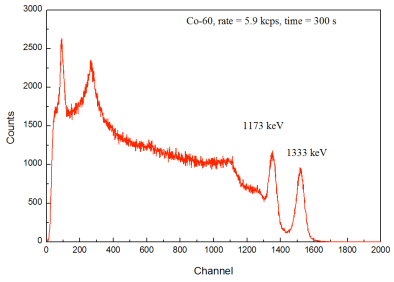
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
238	184	-	26748
268	212	-	35585
782	662	5,3	171808
1354	1173	3,66	44190
1520	1333	3,46	45040
3448	3421	4,46	266488
3861	3932	4,23	115142
4222	4443	2,23	31337
4692	5106	2,21	6125
5017	5617	2,13	2295
5310	6128	1,42	541

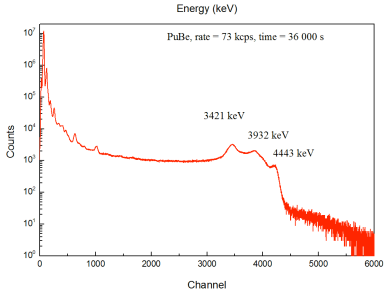


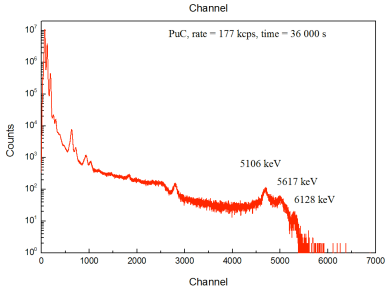








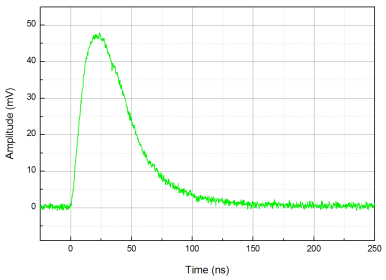


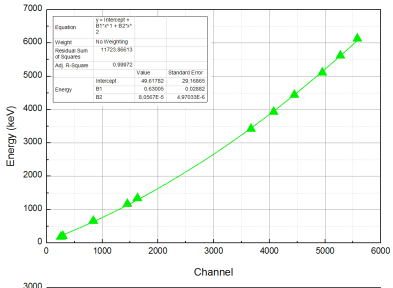


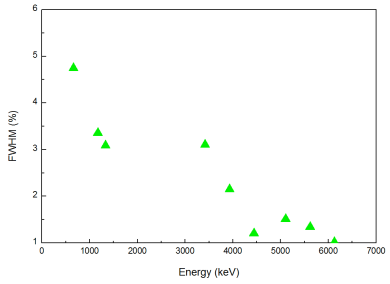
Measurements
at NCBJ 2017

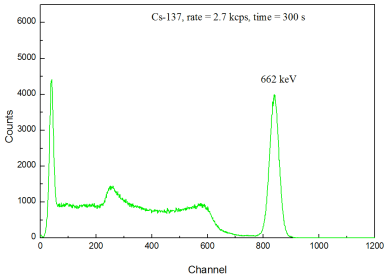
Detector: #3
Scintillator: #11572
MPPC: #1162
Cables: #1162
Voltage: 54.6 V

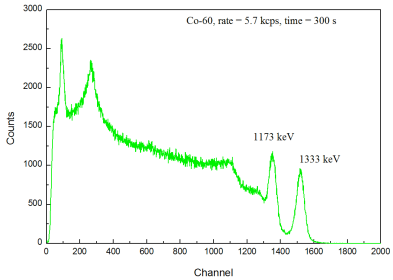
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
258	184	--	29159
290	212	--	29171
840	662	4,75	162267
1453	1173	3,36	48882
1630	1333	3,09	48376
3671	3421	3,11	36311
4079	3932	2,15	79349
4451	4443	1,2	62167
4951	5106	1,51	5642
5276	5617	1,34	2031
5580	6128	1,02	615

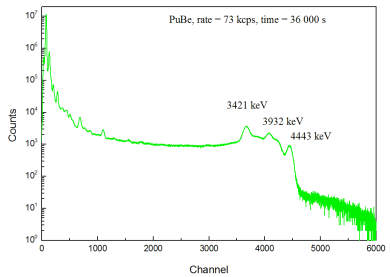


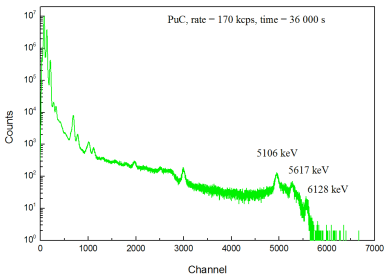








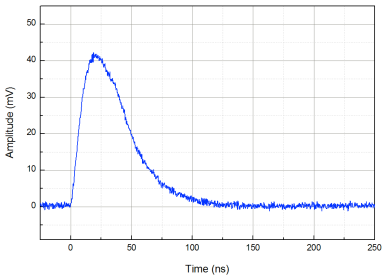


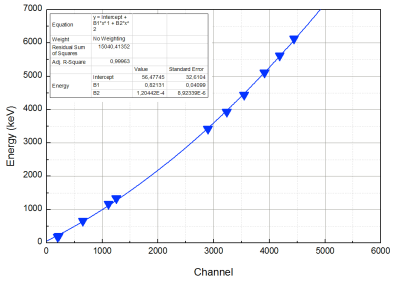


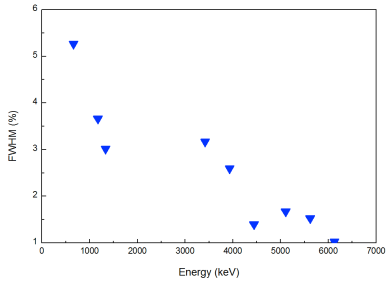
Measurements
at NCBJ 2017

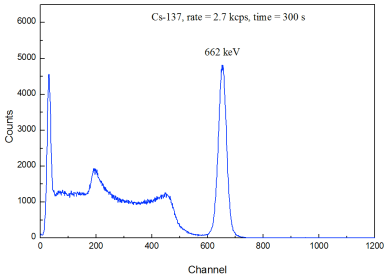
Detector: #4
Scintillator: #11576
MPPC: #001
Cables: #001
Voltage: 53.4 V

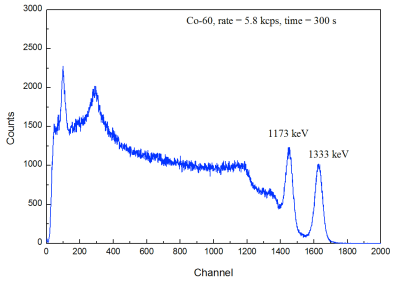
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
198	184	-	27014
219	212	--	33965
654	662	5,26	168179
1115	1173	3,66	46122
1252	1333	3,02	45999
2898	3421	3,17	238296
3235	3932	2,59	78432
3545	4443	1,4	61070
3911	5106	1,67	4918
4187	5617	1,53	1685
4443	6128	1,03	484

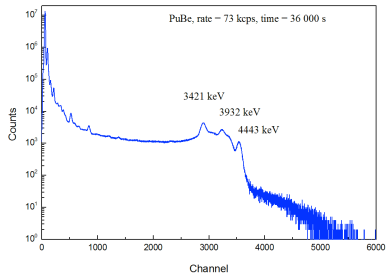


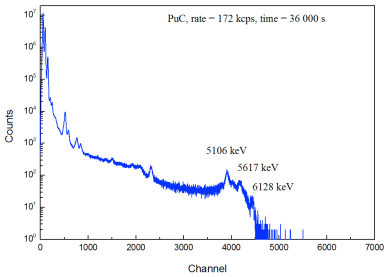








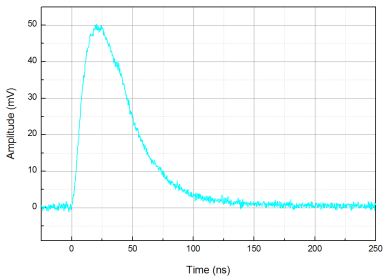


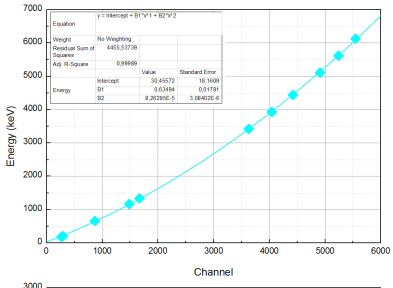


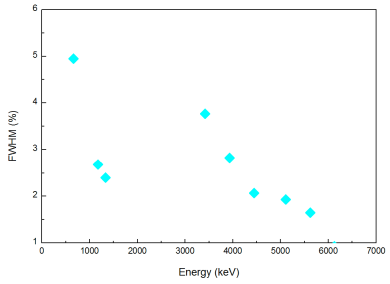
Measurements
at NCBJ 2017

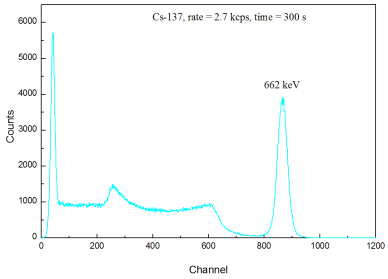
Detector: #5
Scintillator: #11575
MPPC: #1166
Cables: #1166
Voltage: 54.6 V

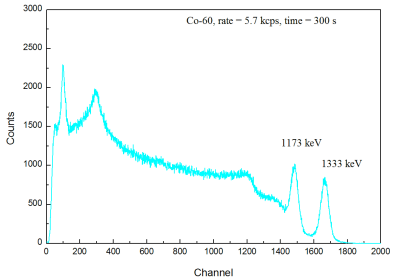
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
263	184	--	31567
296	212	--	30983
865	662	4,95	169775
1485	1173	2,68	40465
1666	1333	2,4	40810
3627	3421	3,77	193632
4043	3932	2,82	54840
4420	4443	2,07	28687
4907	5106	1,93	5441
5239	5617	1,65	1841
5542	6128	0,93	565

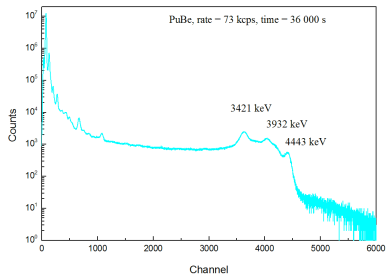


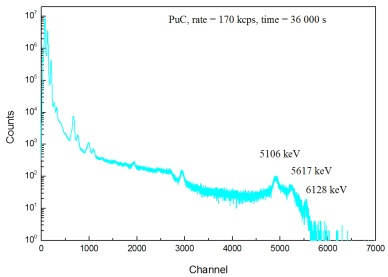








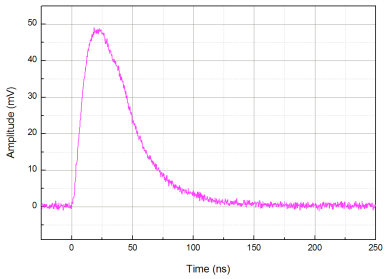


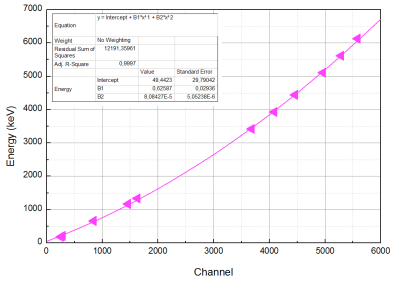


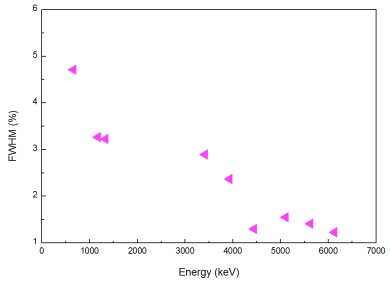
Measurements
at NCBJ 2017

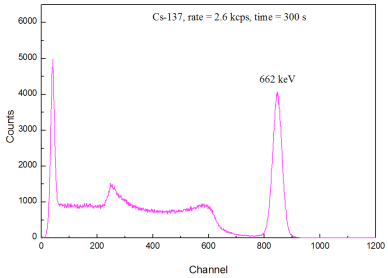
Detector: #6
Scintillator: #11573
MPPC: #1161
Cables: #1161
Voltage: 54.6 V

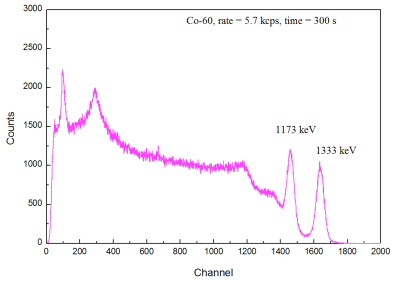
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
258	184	--	26772
292	212	--	30399
847	662	4,71	164654
1462	1173	3,27	46154
1634	1333	3,23	50970
3681	3421	2,9	237311
4088	3932	2,37	83590
4460	4443	1,3	65915
4962	5106	1,55	5449
5289	5617	1,41	2283
5587	6128	1,23	801

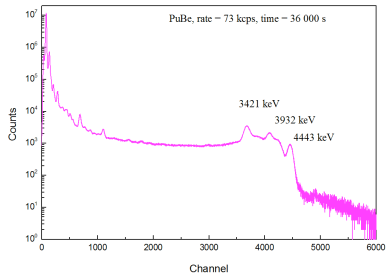


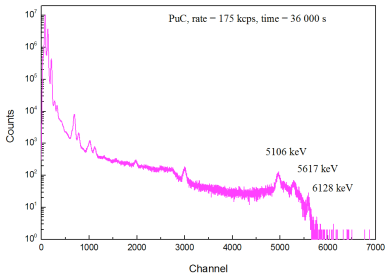








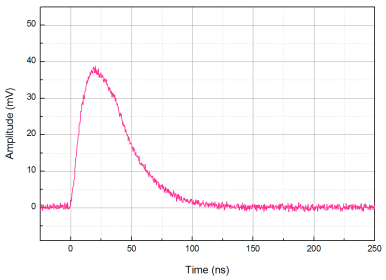


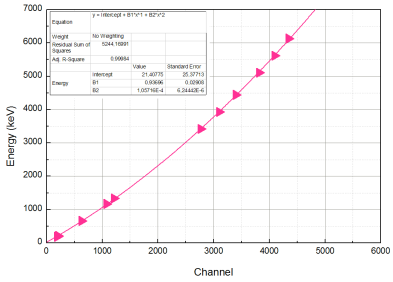


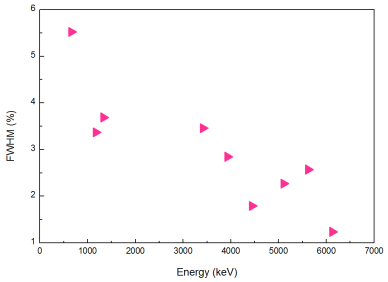
Measurements
at NCBJ 2017

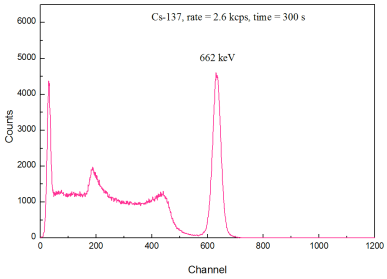
Detector: #7
Scintillator: #11584
MPPC: #002
Cables: #002
Voltage: 53.4 V

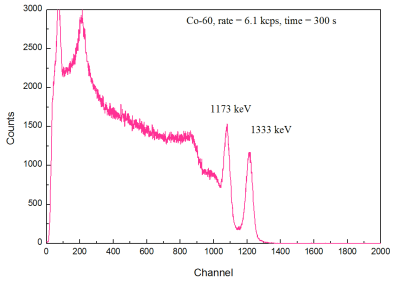
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
192	184	--	26936
212	212	--	43197
633	662	5,52	162588
1081	1173	3,37	46083
1215	1333	3,69	47750
2773	3421	3,46	237396
3099	3932	2,85	79572
3396	4443	1,79	56064
3821	5106	2,27	5643
4098	5617	2,57	2305
4344	6128	1,24	409

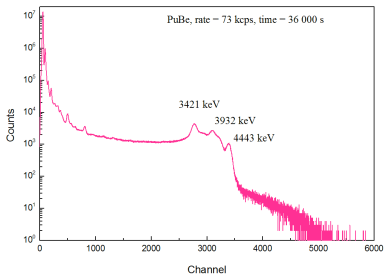


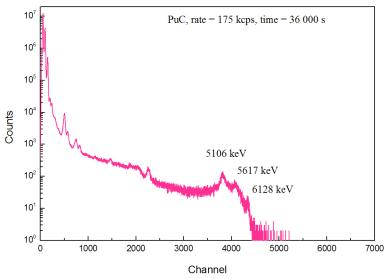








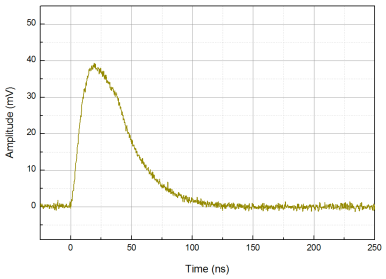


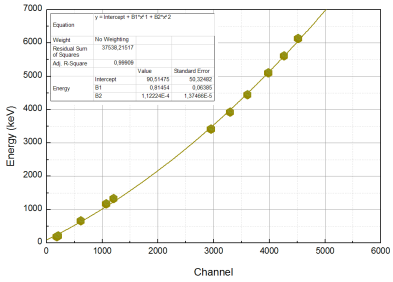


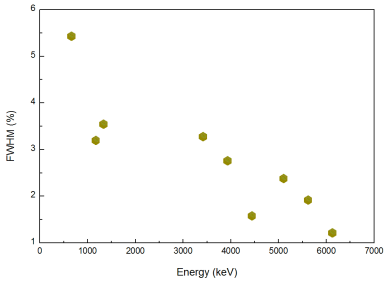
Measurements
at NCBJ 2017

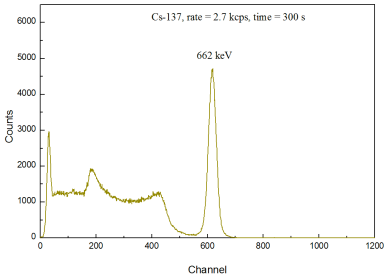
Detector: #8
Scintillator: #11580
MPPC: #003
Cables: #1167
Voltage: 53.4 V

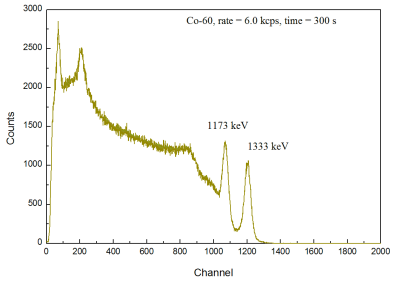
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
187	184	--	31051
209	212	--	22844
617	662	5,43	159410
1072	1173	3,2	37951
1204	1333	3,55	38191
2955	3421	3,28	251955
3295	3932	2,76	88066
3606	4443	1,58	59176
3983	5106	2,38	5880
4264	5617	1,92	1536
4517	6128	1,22	303

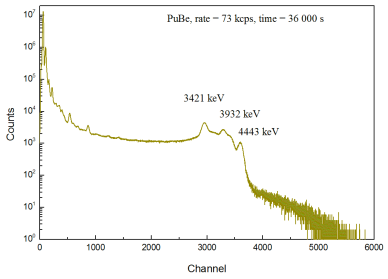


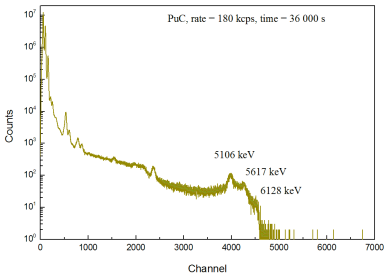








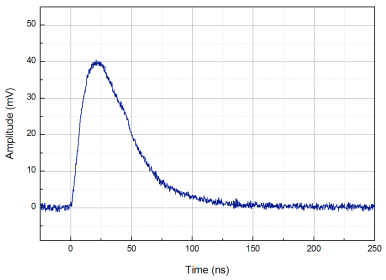


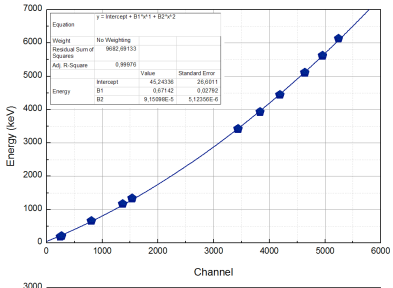


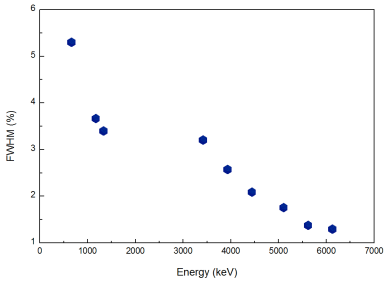
Measurements
at NCBJ 2017

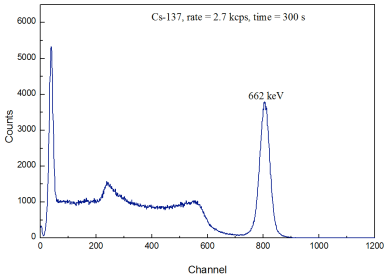
Detector: #9
Scintillator: #11568
MPPC: #1167
Cables: #003
Voltage: 54.6 V

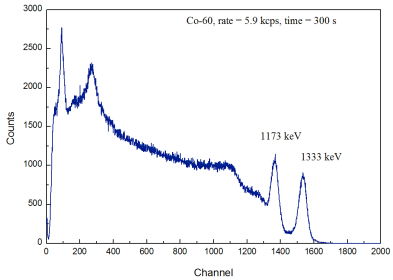
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
246	184	--	24915
271	212	--	30312
805	662	5,3	161769
1367	1173	3,67	43066
1535	1333	3,4	41947
3439	3421	3,21	237936
3835	3932	2,57	79091
4190	4443	2,09	55712
4637	5106	1,76	10389
4954	5617	1,38	3105
5242	6128	1,3	1232

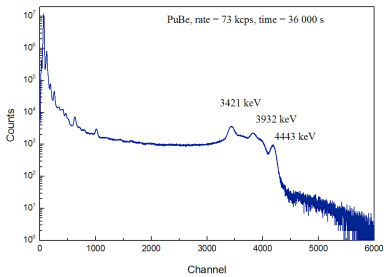


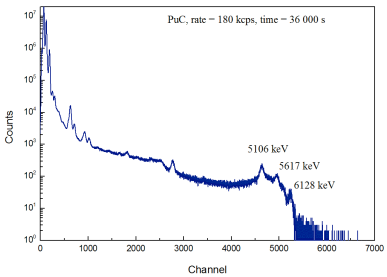








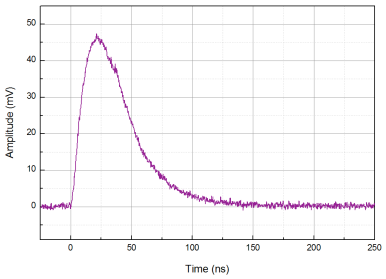


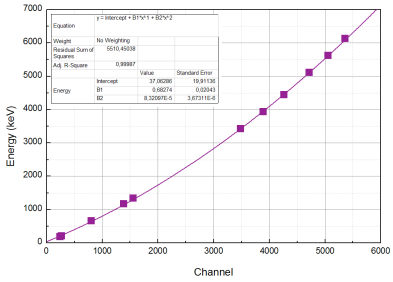


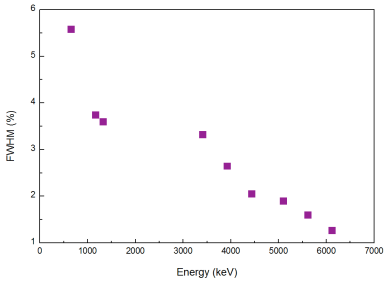
Measurements
at NCBJ 2017

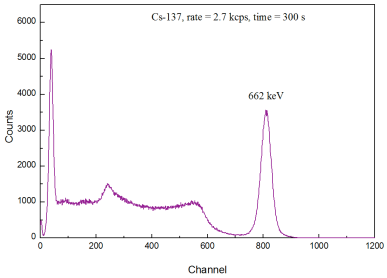
Detector: #10
Scintillator: #11570
MPPC: #1163
Cables: #1163
Voltage: 54.7 V

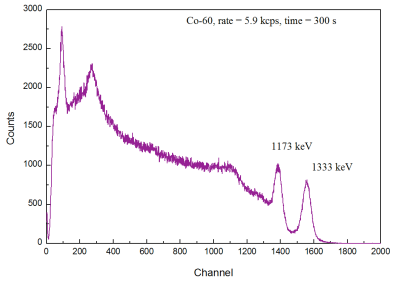
Channel	Energy (keV)	FWHM/E (%) += 0,07	Peak Area +- 5%
245	184	--	21251
273	212	--	29365
810	662	5,57	158615
1388	1173	3,74	37903
1558	1333	3,59	39777
3487	3421	3,32	269523
3895	3932	2,64	85672
4267	4443	2,04	56049
4721	5106	1,89	9958
5057	5617	1,59	3487
5364	6128	1,26	1038

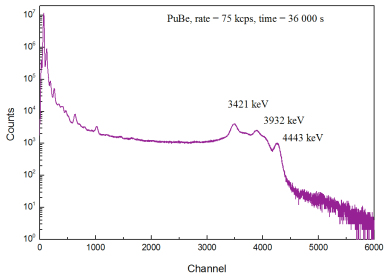


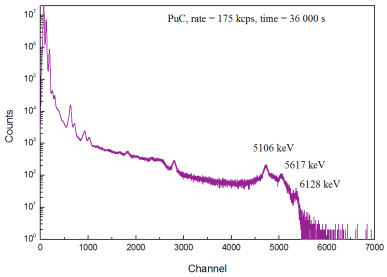








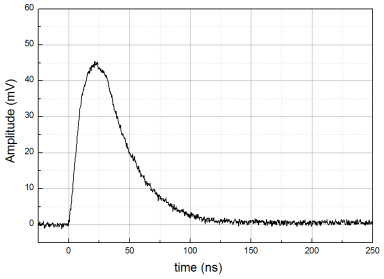


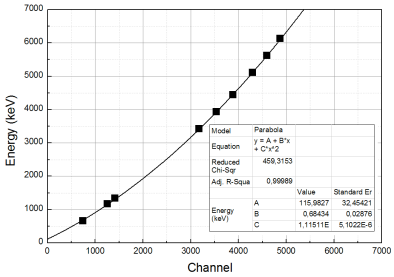


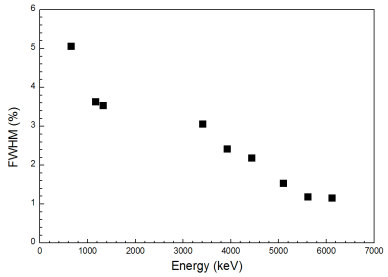
Measurement at NCBJ 2017

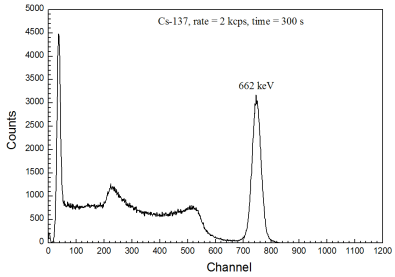
Detector: #11
Scintillator: #11578
MPPC: #1171
Cables: #1171
Voltage: #54.6V

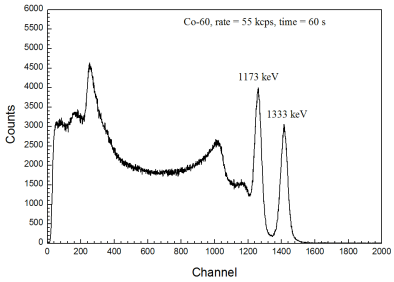
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
748	662	5,05	116494
1261	1173	3,62	152401
1417	1333	3,53	145443
3177	3421	3,05	278299
3543	3932	2,41	89505
3884	4443	2,18	71436
4300	5107	1,52	3868
4601	5618	1,18	1269
4876	6129	1,15	427

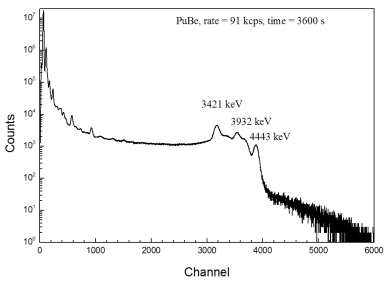


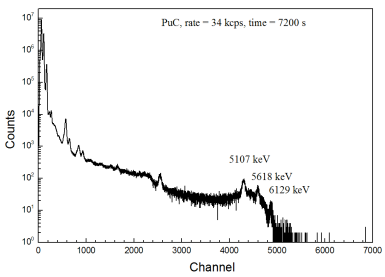








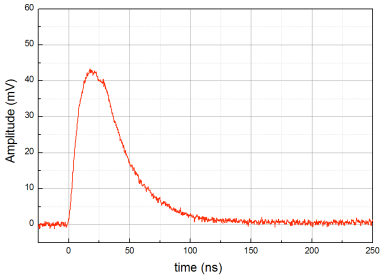


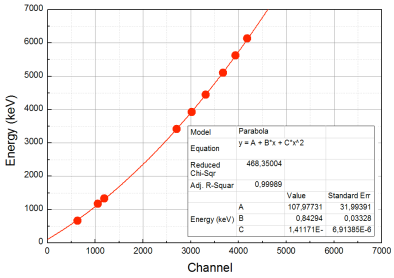


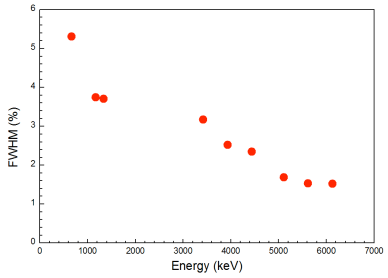
Measurement at NCBJ 2017

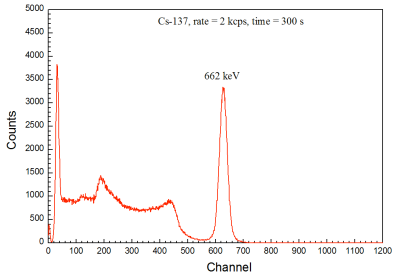
Detector: #12
Scintillator: #11586
MPPC: #1178
Cables: #1178
Voltage: #54.6V

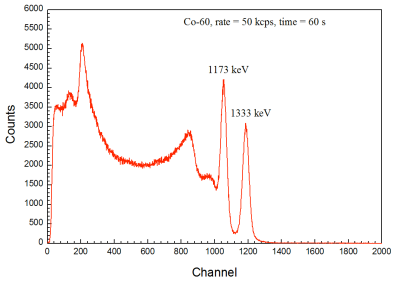
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
628	662	5,3	111941
1055	1173	3,74	135043
1187	1333	3,71	130790
2703	3421	3,17	276336
3021	3932	2,52	89344
3315	4443	2,35	73065
3679	5107	1,68	3509
3940	5618	1,53	1173
4185	6129	1,52	388

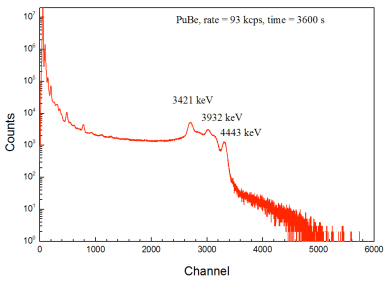


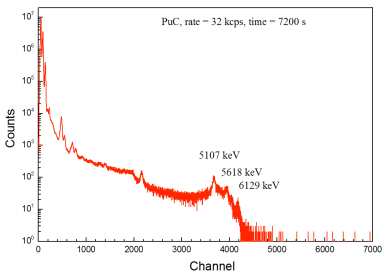








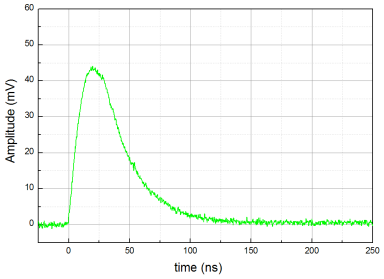


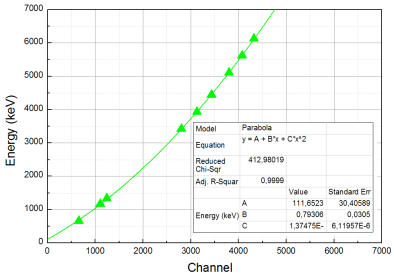


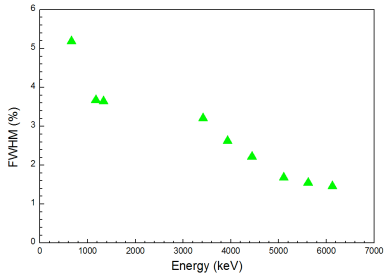
Measurement at NCBJ 2017

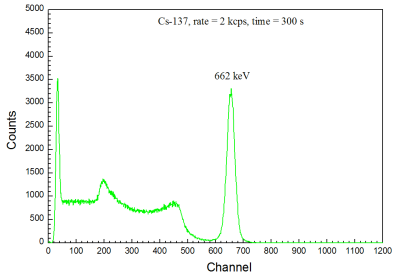
Detector: #13
Scintillator: #11565
MPPC: #1169
Cables: #1169
Voltage: #54.6V

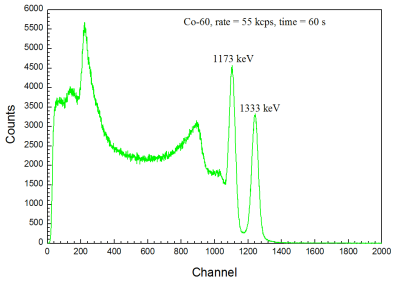
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
655	662	5,18	112629
1106	1173	3,67	156027
1242	1333	3,64	148745
2805	3421	3,21	266997
3131	3932	2,62	93533
3433	4443	2,22	66868
3802	5107	1,68	3651
4075	5618	1,54	1147
4322	6129	1,46	505

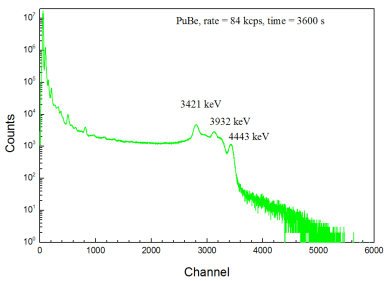


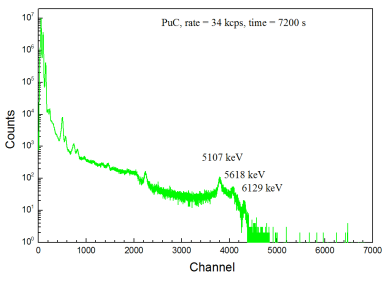








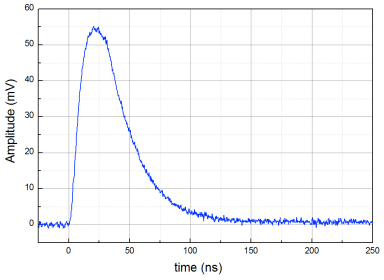


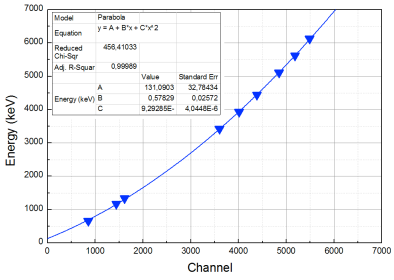


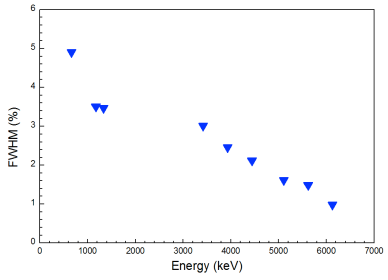
Measurement at NCBJ 2017

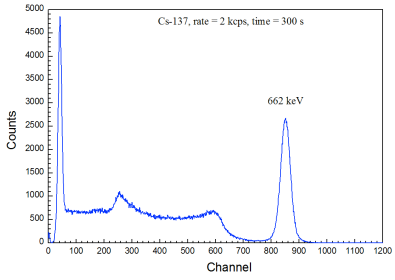
Detector: #14
Scintillator: #11587
MPPC: #1172
Cables: #1172
Voltage: #54.6V

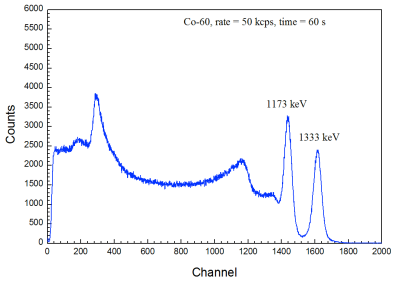
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
851	662	4,9	114846
1440	1173	3,51	138081
1616	1333	3,47	131495
3599	3421	3,01	285217
4010	3932	2,46	99859
4385	4443	2,12	76301
4848	5107	1,61	3952
5183	5618	1,49	1255
5489	6129	0,98	416

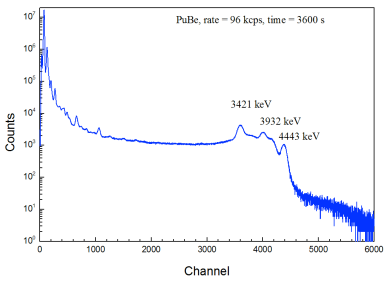


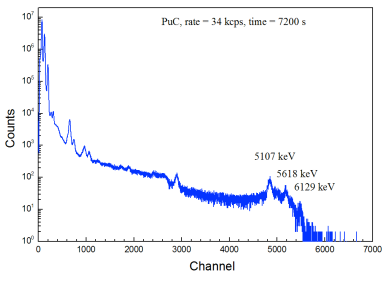










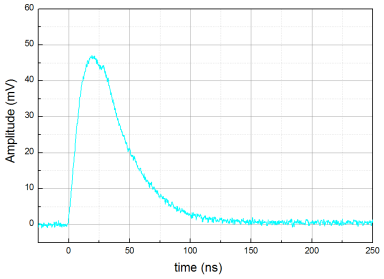


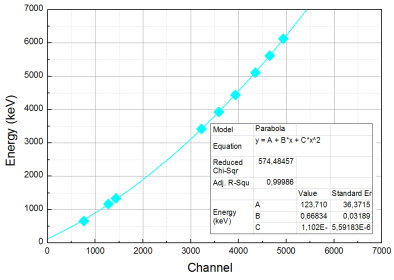
Measurement
at NCBJ 2017

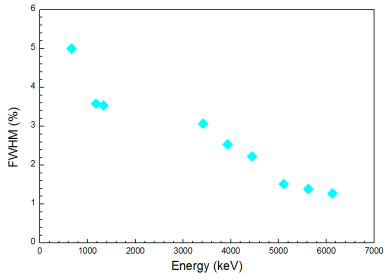
NCBJ ŚWIERK

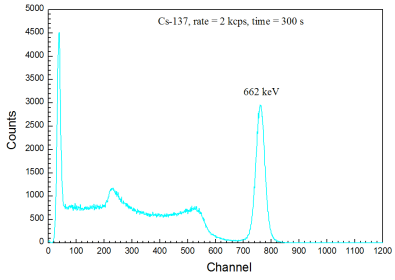
Detector: #15
Scintillator: #11582
MPPC: #1173
Cables: #1173
Voltage: #54.6V

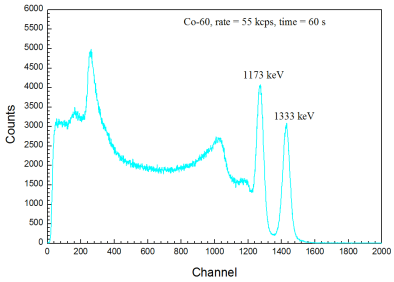
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
761	662	5	115922
1273	1173	3,58	162437
1429	1333	3,54	151136
3220	3421	3,07	252298
3590	3932	2,54	86950
3933	4443	2,23	67486
4352	5107	1,51	3674
4654	5618	1,39	1192
4935	6129	1,27	494

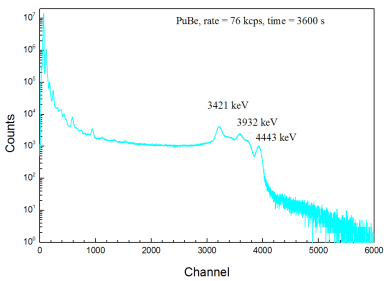


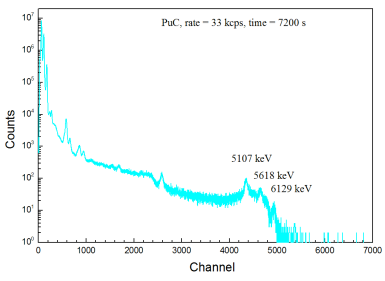










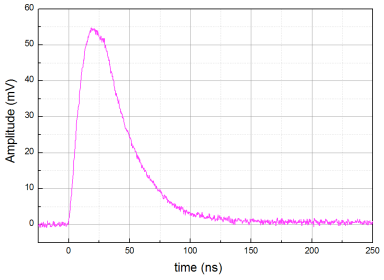


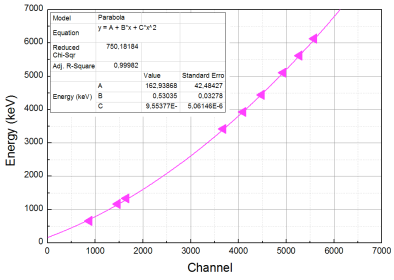
Measurement
at NCBJ 2017

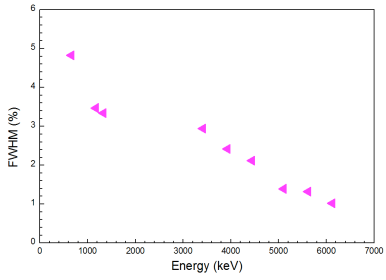
NCBJ ŚWIERK

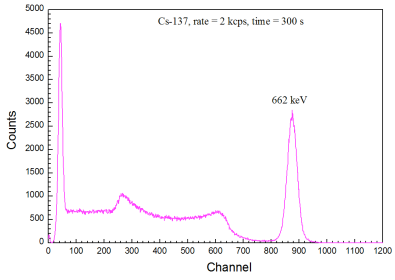
Detector: #16
Scintillator: #11569
MPPC: #1174
Cables: #1174
Voltage: #54.6V

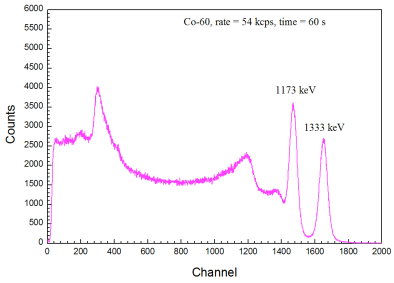
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
875	662	4,82	118839
1472	1173	3,47	158109
1652	1333	3,34	146195
3685	3421	2,94	286265
4104	3932	2,42	102806
4489	4443	2,12	80717
4938	5107	1,39	3650
5273	5618	1,32	1380
5587	6129	1,02	438

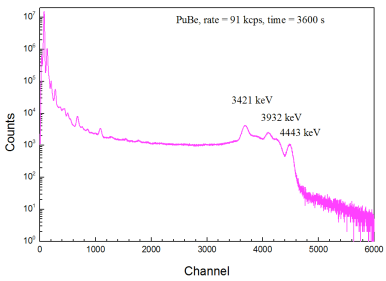


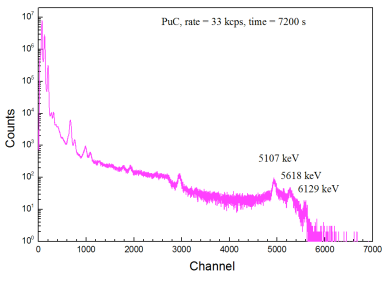










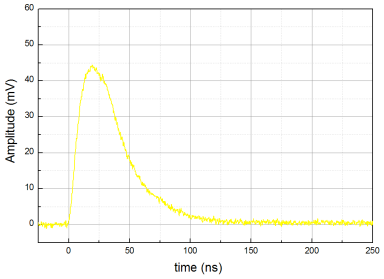


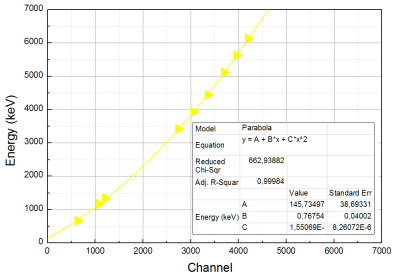
Measurement
at NCBJ 2017

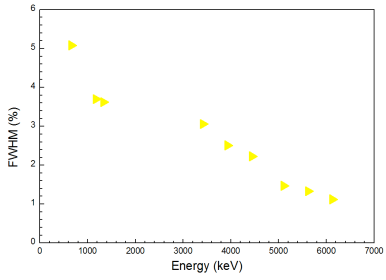
NCBJ ŚWIERK

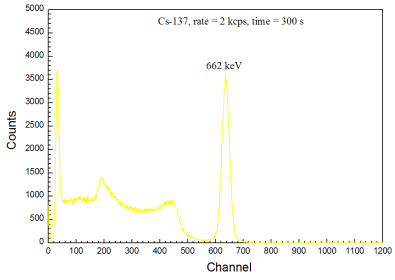
Detector: #17
Scintillator: #11563
MPPC: #1175
Cables: #1175
Voltage: #54.6V

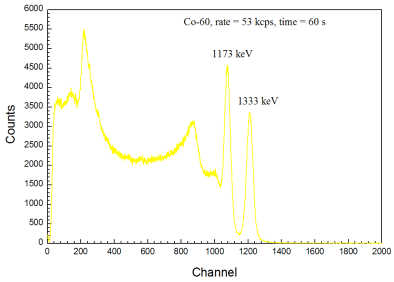
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
637	662	5,08	113917
1077	1173	3,7	156020
1211	1333	3,62	146770
2740	3421	3,06	270279
3061	3932	2,51	93765
3356	4443	2,23	74708
3700	5107	1,47	3724
3961	5618	1,33	1311
4202	6129	1,12	428

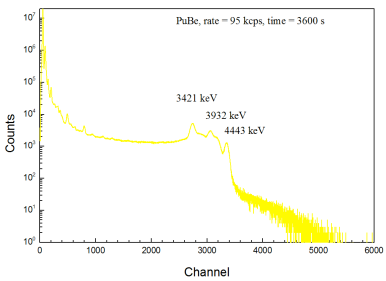


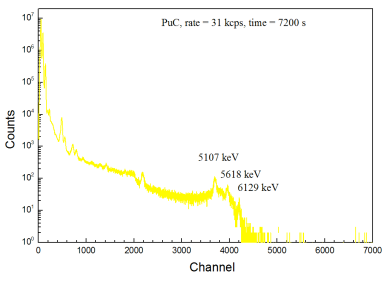










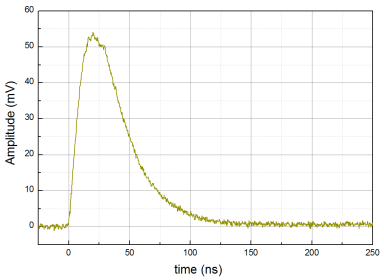


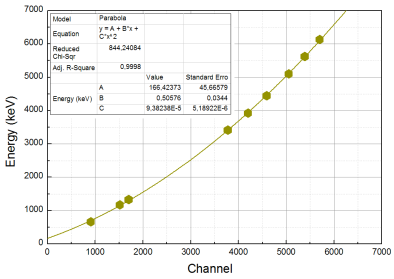
Measurement
at NCBJ 2017

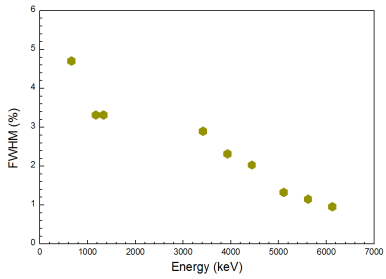
NCBJ ŚWIERK

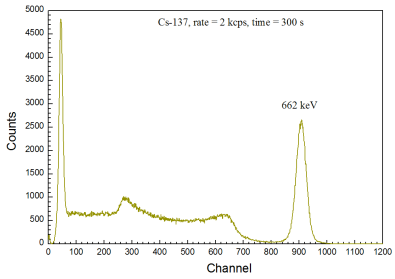
Detector: #18
Scintillator: #11566
MPPC: #1177
Cables: #1177
Voltage: #54.6V

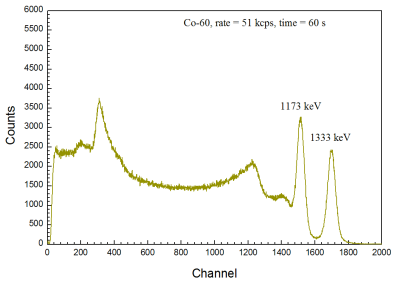
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
908	662	4,7	114705
1516	1173	3,32	143222
1700	1333	3,32	134571
3779	3421	2,9	278127
4201	3932	2,32	100023
4590	4443	2,03	74776
5053	5107	1,33	3507
5391	5618	1,15	1398
5703	6129	0,96	513

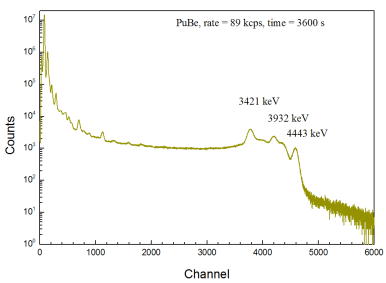


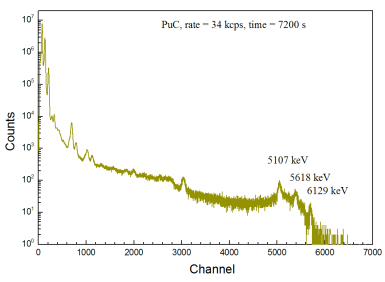








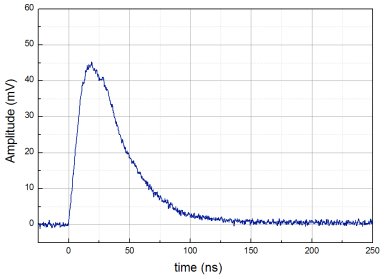


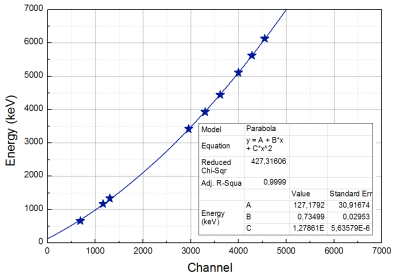


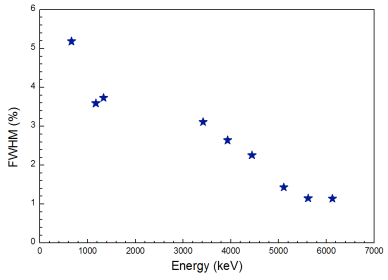
Measurement
at NCBJ 2017

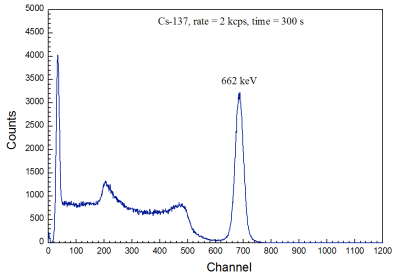
Detector: #19
Scintillator: #11577
MPPC: #1179
Cables: #1179
Voltage: #54.6V

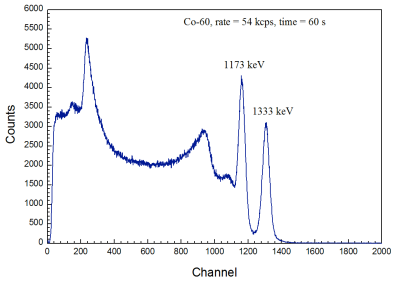
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
686	662	5,18	115961
1164	1173	3,59	150823
1308	1333	3,73	145836
2956	3421	3,11	262269
3299	3932	2,64	91066
3618	4443	2,26	70656
4000	5107	1,43	3448
4281	5618	1,15	1239
4547	6129	1,14	436

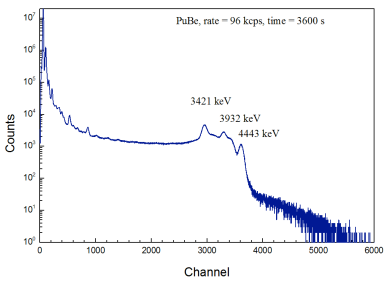


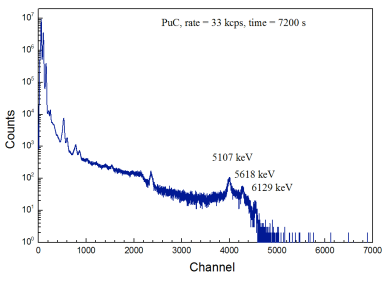








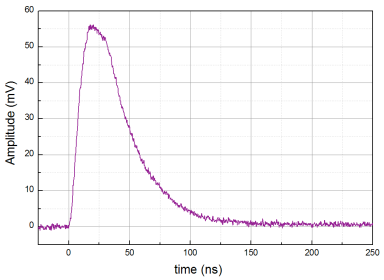


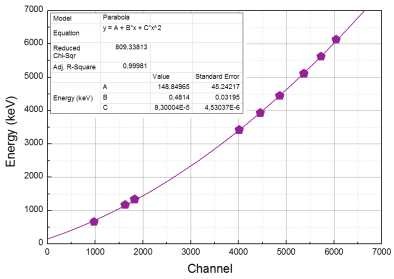


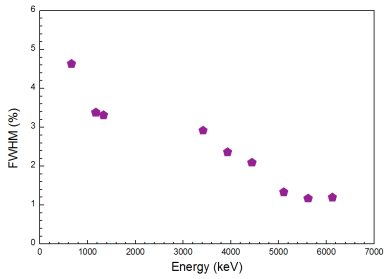
Measurement
at NCBJ 2017

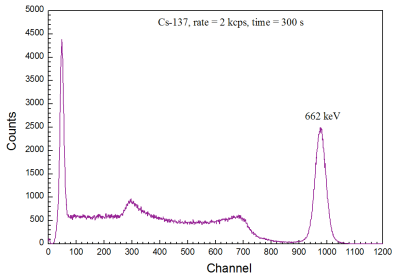
Detector: #20
Scintillator: #11567
MPPC: #1180
Cables: #1180
Voltage: #54.6V

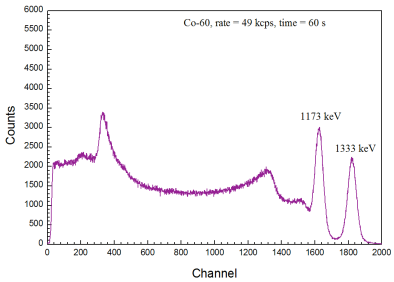
Channel	Energy (keV)	FWHM/E (%) +- 0,07	Peak Area +- 5%
977	662	4,63	114927
1626	1173	3,38	143489
1823	1333	3,31	132206
4014	3421	2,92	275015
4456	3932	2,36	91167
4864	4443	2,09	71419
5371	5107	1,33	3916
5728	5618	1,17	1251
6046	6129	1,19	394

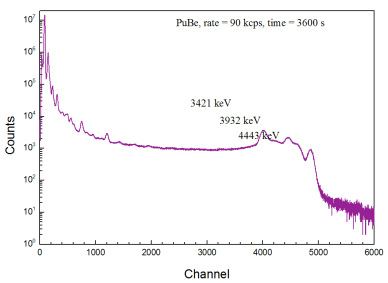


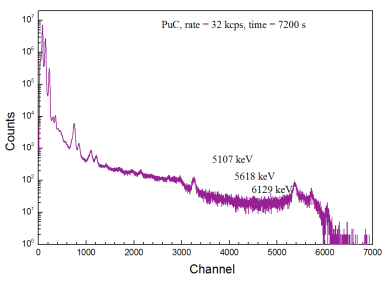












Detector no.	Scintillator no.	MPPC no.	Cables no.	Comments Δ FWHM = 0,07%
# 1	11571	1164	1164	FWHM (Cs) = 4,90 % OK (TAKEN TO MILAN)
# 2	11574	1165	1165	FWHM (Cs) = 5,30 % OK
# 3	11572	1162	1162	FWHM (Cs) = 4,75 % OK
# 4	11576	001	001	FWHM (Cs) = 5,26 % OK
# 5	11575	1166	1166	FWHM (Cs) = 4,95 % OK
# 6	11573	1161	1161	FWHM (Cs) = 4,71 % OK
# 7	11584	002	002	FWHM (Cs) = 5,52 % OK
# 8	11580	003	1167	FWHM (Cs) = 5,43 % OK
# 9	11568	1167	003	FWHM (Cs) = 5,30 % OK
# 10	11570	1163	1163	FWHM (Cs) = 5,57 % OK

Detector no.	Scintillator no.	MPPC no.	Cables no.	Comments Δ FWHM = 0,07%
# 11	11578	1171	1171	FWHM (Cs) = 5,05 % OK
# 12	11586	1178	1178	FWHM (Cs) = 5,30 % OK
# 13	11565	1169	1169	FWHM (Cs) = 5,18 % OK
# 14	11587	1172	1172	FWHM (Cs) = 4,90 % OK
# 15	11582	1173	1173	FWHM (Cs) = 5,00 % OK
# 16	11569	1174	1174	FWHM (Cs) = 4,82 % OK
# 17	11563	1175	1175	FWHM (Cs) = 5,08 % OK
# 18	11566	1177	1177	FWHM (Cs) = 4,70 % OK
# 19	11577	1179	1179	FWHM (Cs) = 5,18 % OK
# 20	11567	1180	1180	FWHM (Cs) = 4,63 % OK

During installation at JET in May 2017, it was found that the Vertical Camera has a different shape than the Horizontal Camera. Additional cables shortening (by approx. 5 cm) were performed during installation on JET.

A new report on data obtained in March and May 2017 at JET, will be prepared after analysis is finished, by the end of June 2017.

The detector No 12 was given to Ana and Rita for their tests at home lab.

The report was prepared by the NCBJ team

Grzegorz Bołtruczyk, Andrzej Brosławski, Marcin Gosk, Stefan Korolczuk,
Arkadiusz Urban, Izabella Zychor.