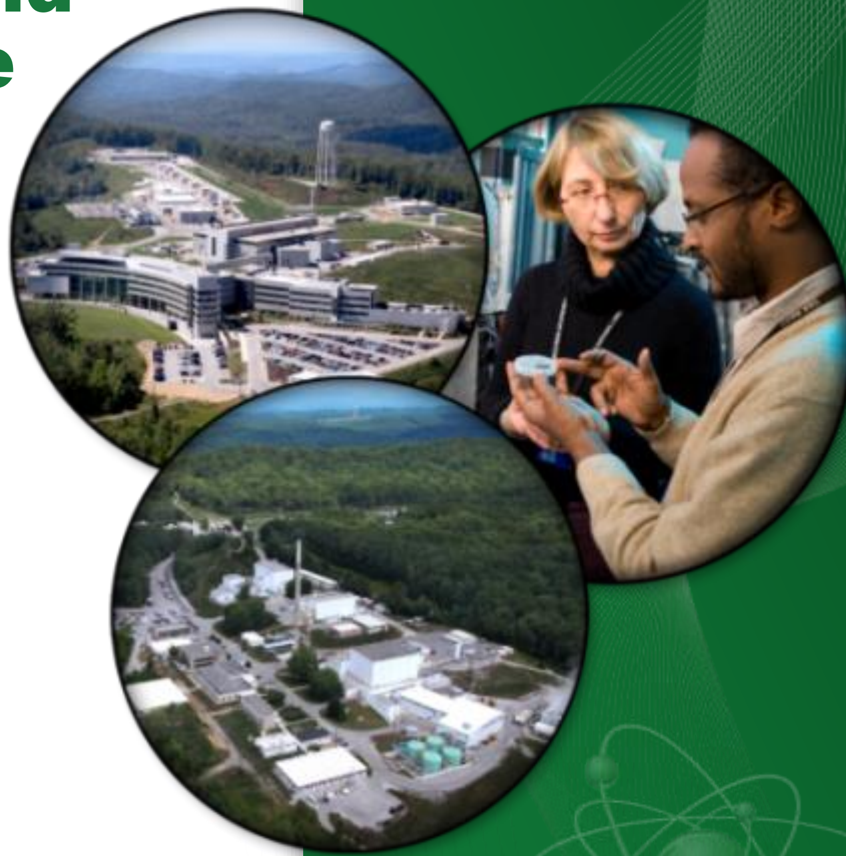
Effect of Discriminator (Positive Threshold) and Pulse Integration Time (Sample 2) on ARCS Detector Performance

Tests After 2018 Electronics Upgrade



May 21, 2018

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Part 1

Tests to better understand source of low amplitude events in pulse height spectrum

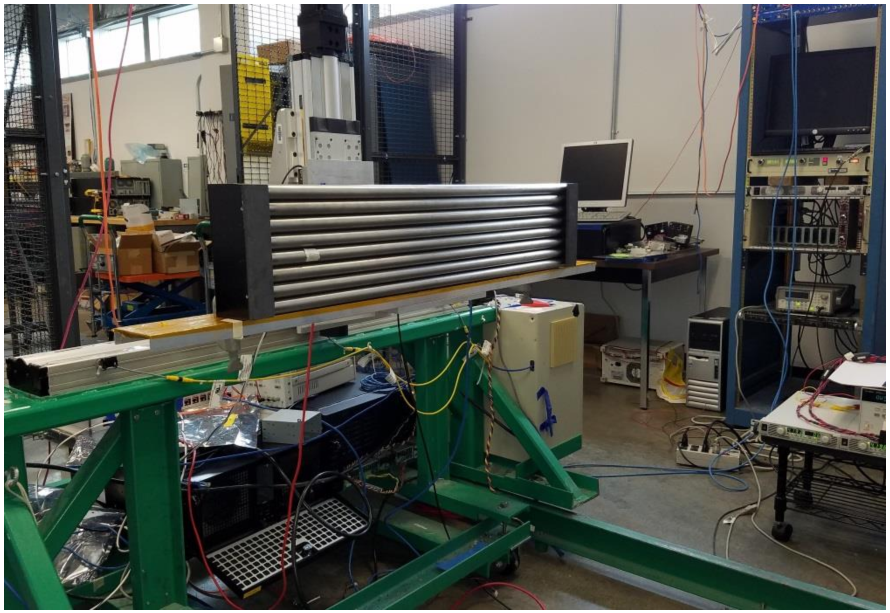
Part 2

Tests to determine effect of discriminator setting on pulse height spectrum

Part 3

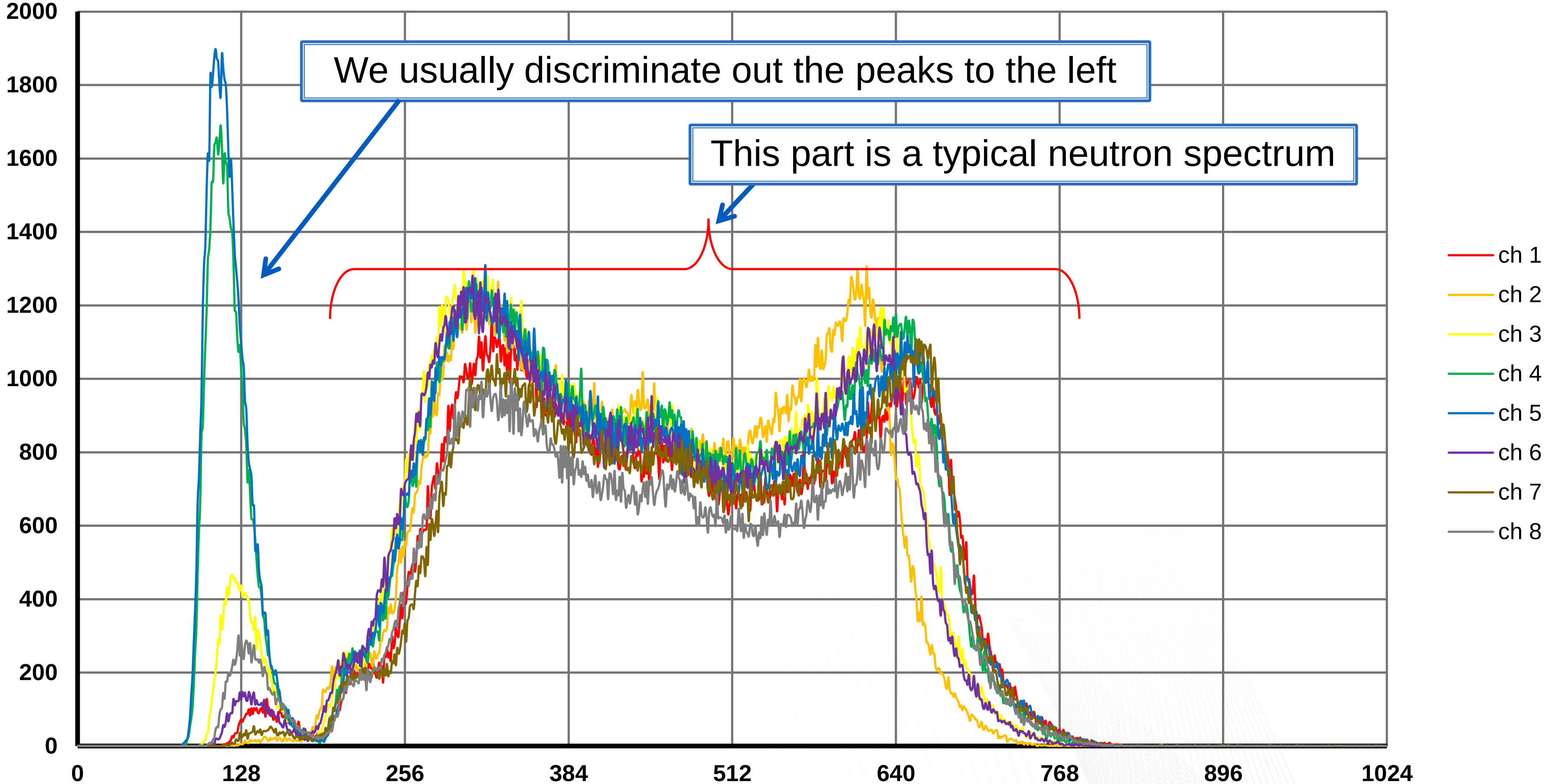
Tests to determine effect of integration time and MinADC on pulse height spectrum

ARCS Module # 69
- after electronics upgrade
- high voltage 1.87 kV



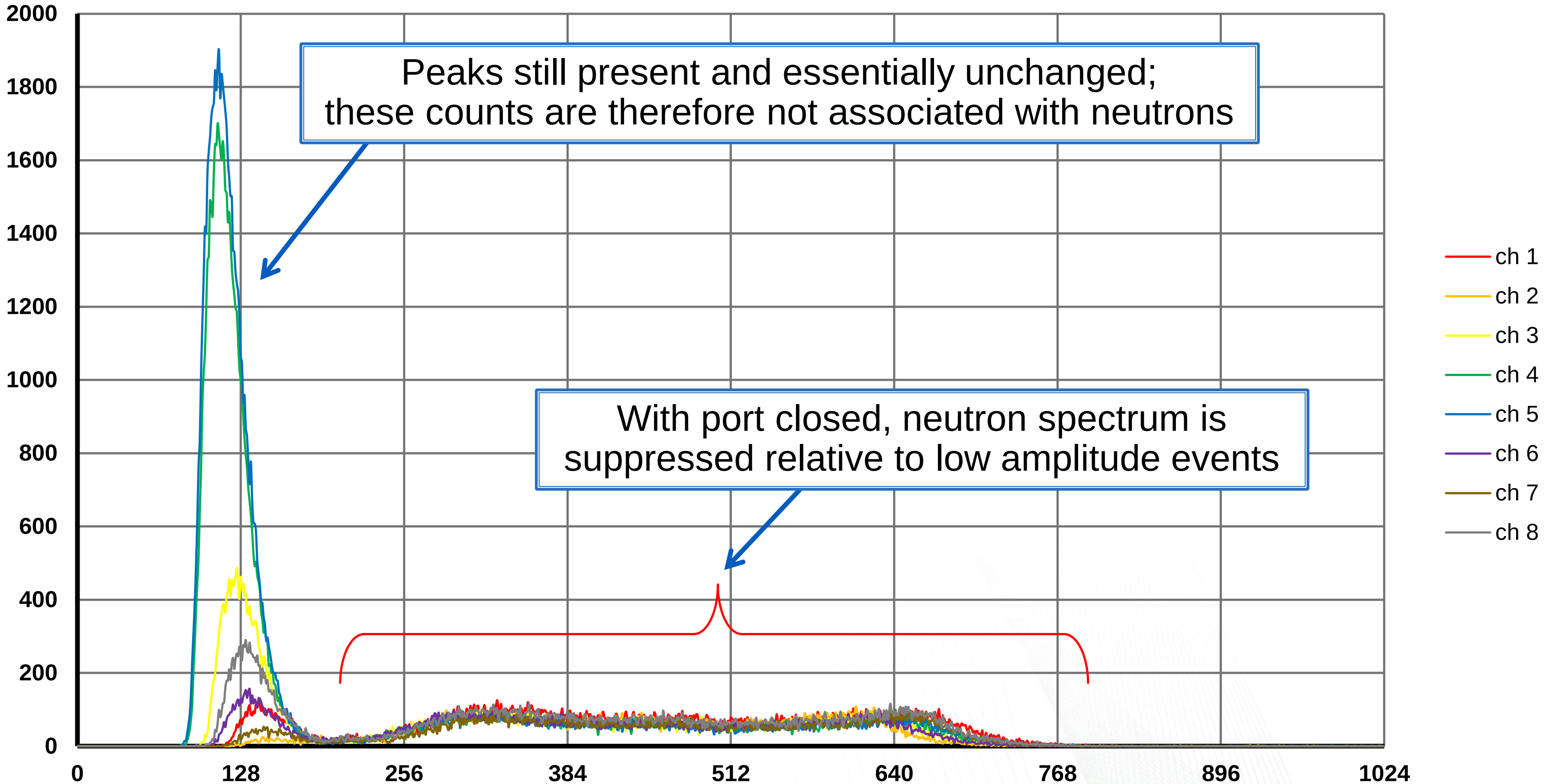
ARCS detector module on test station in Detector Lab
Centered in front of Cf-252 source

Discriminator at 0, neutron port open
- only gammas are those associated with Cf-252 source



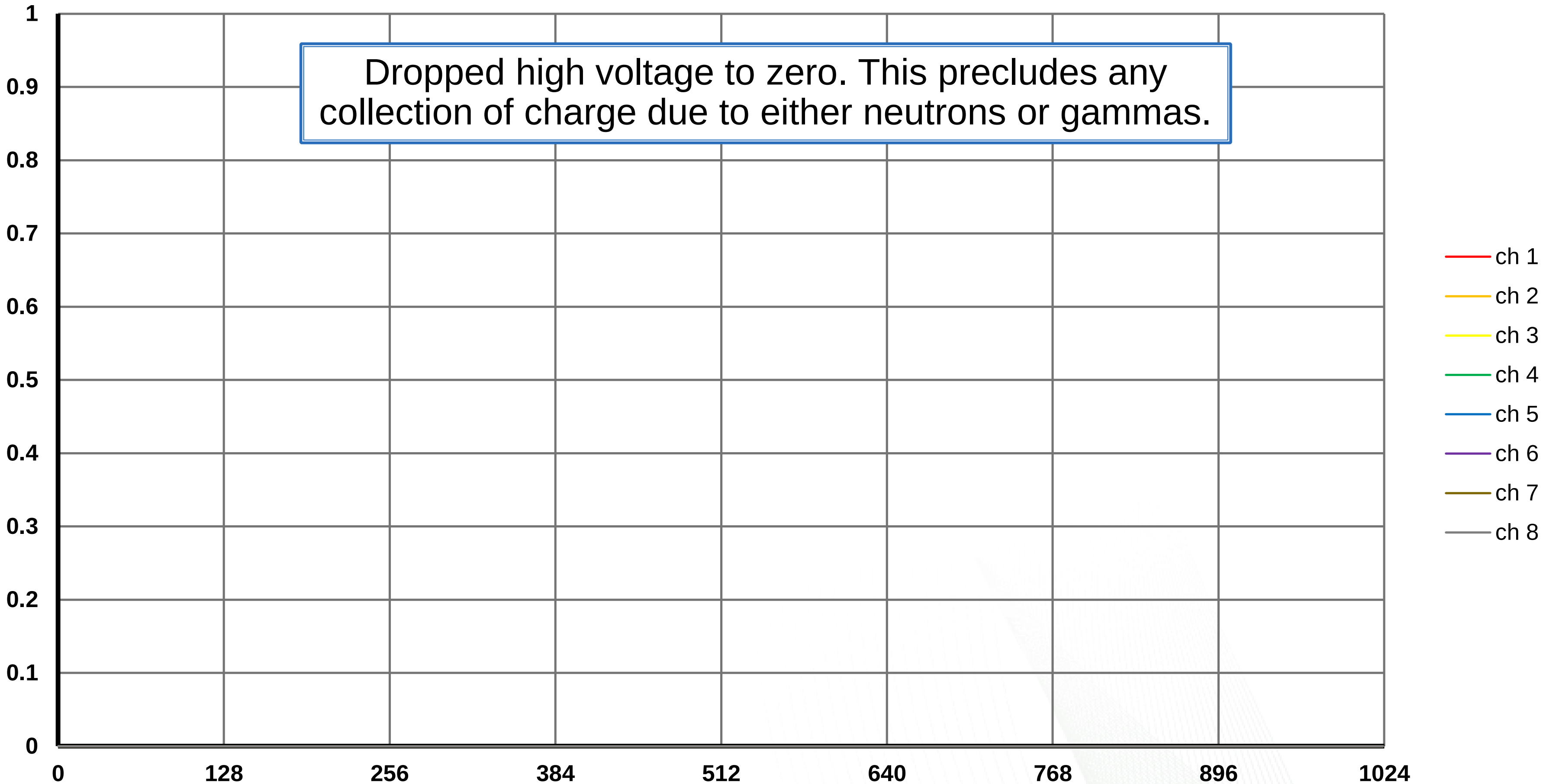
Even though discriminator is set the same for all, some channels
(4 and 5 in particular) allow more low amplitude events through than others.

Discriminator at 0, neutron port closed
- only gammas are those associated with Cf-252 source



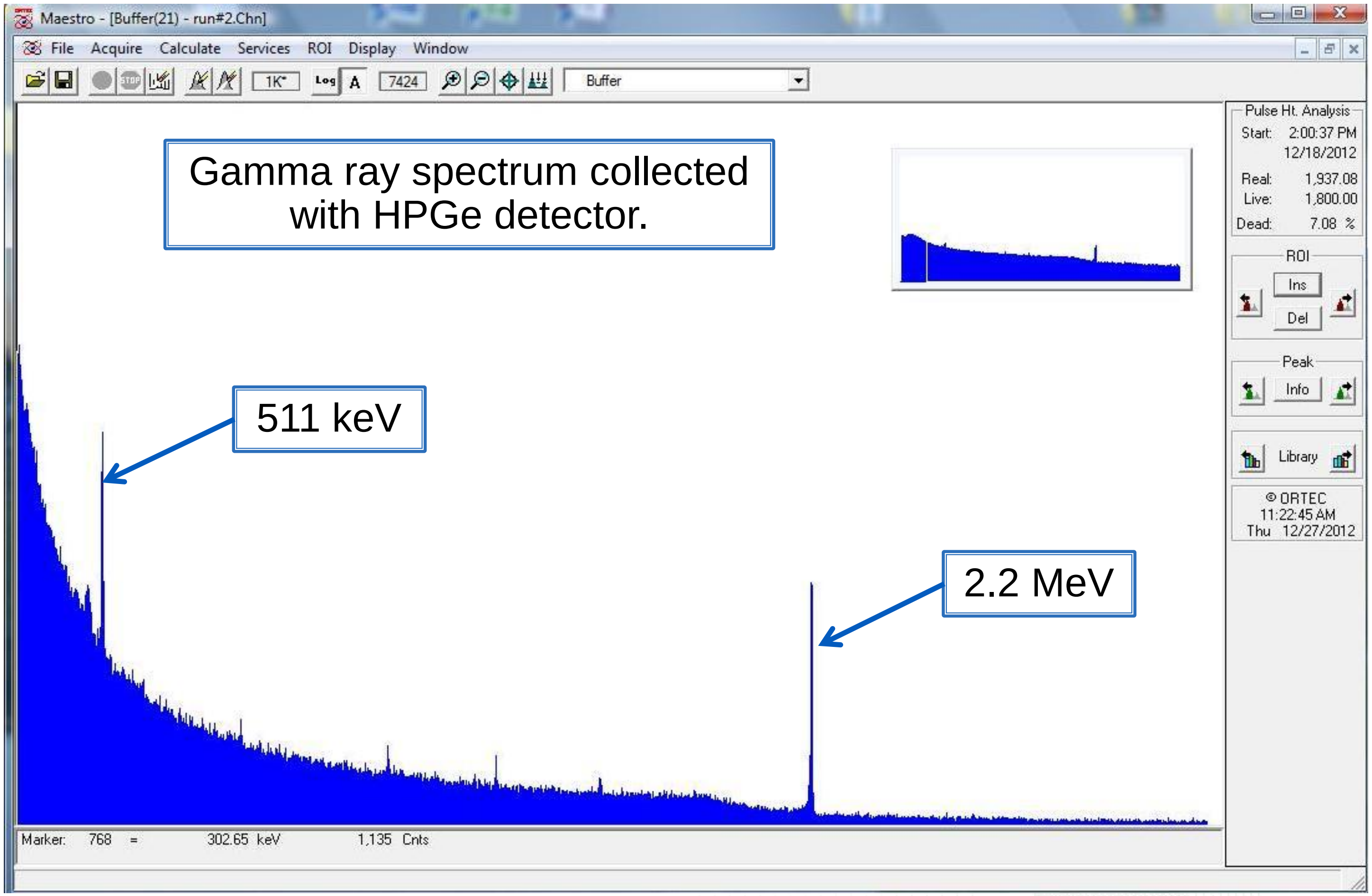
The low amplitude events are not due to neutrons. Two other possibilities these are generally attributed to are gamma rays or electronic noise.

Discriminator at 0, neutron port closed
- only gammas are those associated with Cf-252 source



Collected zero counts. Conclusion is that the source of the low amplitude events is not electronic noise, therefore most likely must be gamma rays.

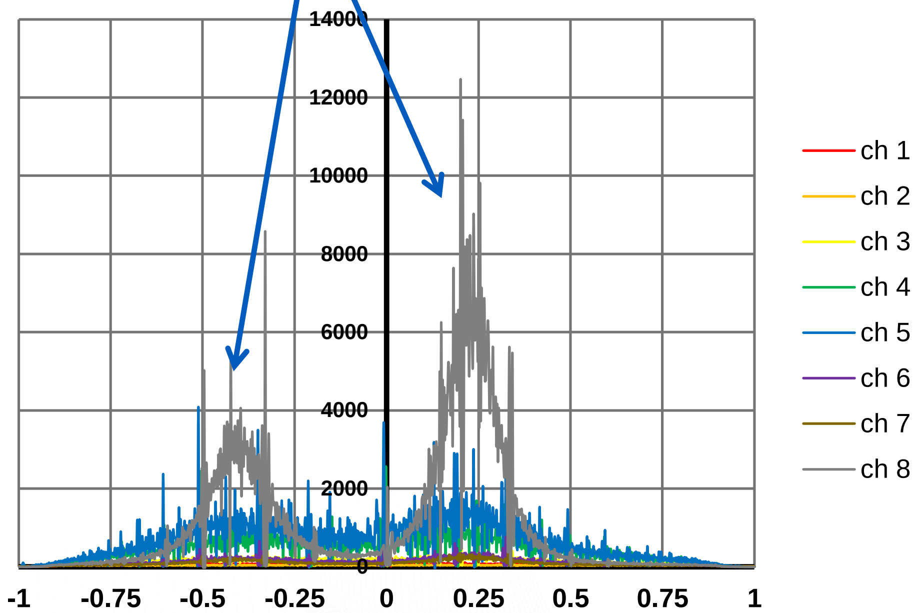
Gamma spectrum from Cf-252 source at approximate location of ARCS module



Gamma rays are associated with spontaneous fission of Cf-252 (same decay mode which yields neutrons). Continuous spectrum up to at least 7 MeV

Discriminator at 0, neutron port closed
- added two 10 µCi Co60 sources near tube 8

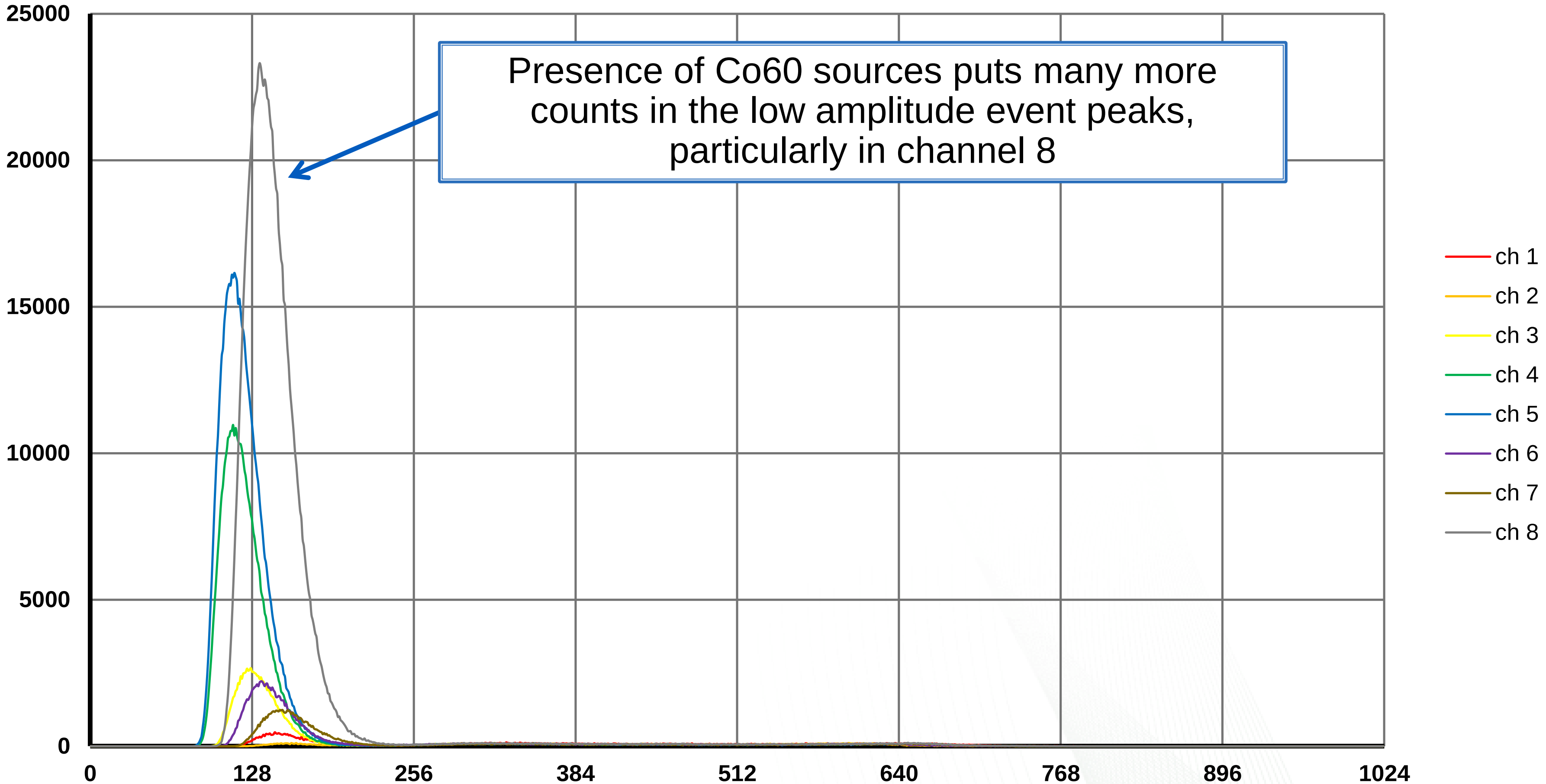
Two Co60 sources located on top of tube 8. They are also quite visible in the position spectrum.



Co60 is a pure gamma source with emission energies 1173 keV and 1332 keV

Discriminator at 0, neutron port closed

- with two Co60 sources near tube 8



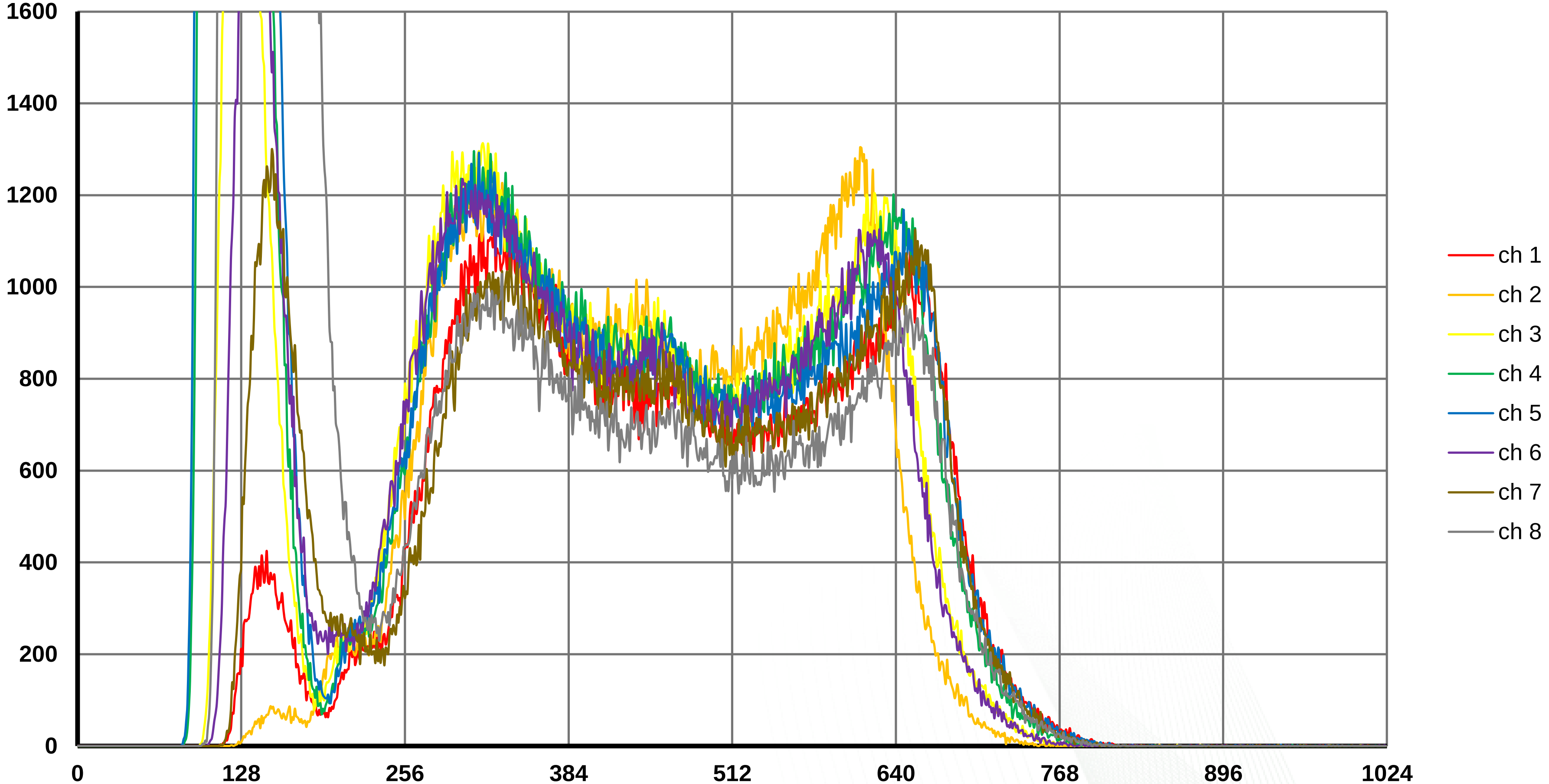
Conclusion is that the low amplitude events are due to gamma rays, and would need to be discriminated out during acquisition.

We want to reject the low amplitude gamma events but allow neutrons to be counted.

What is an appropriate value to set the discriminator ?

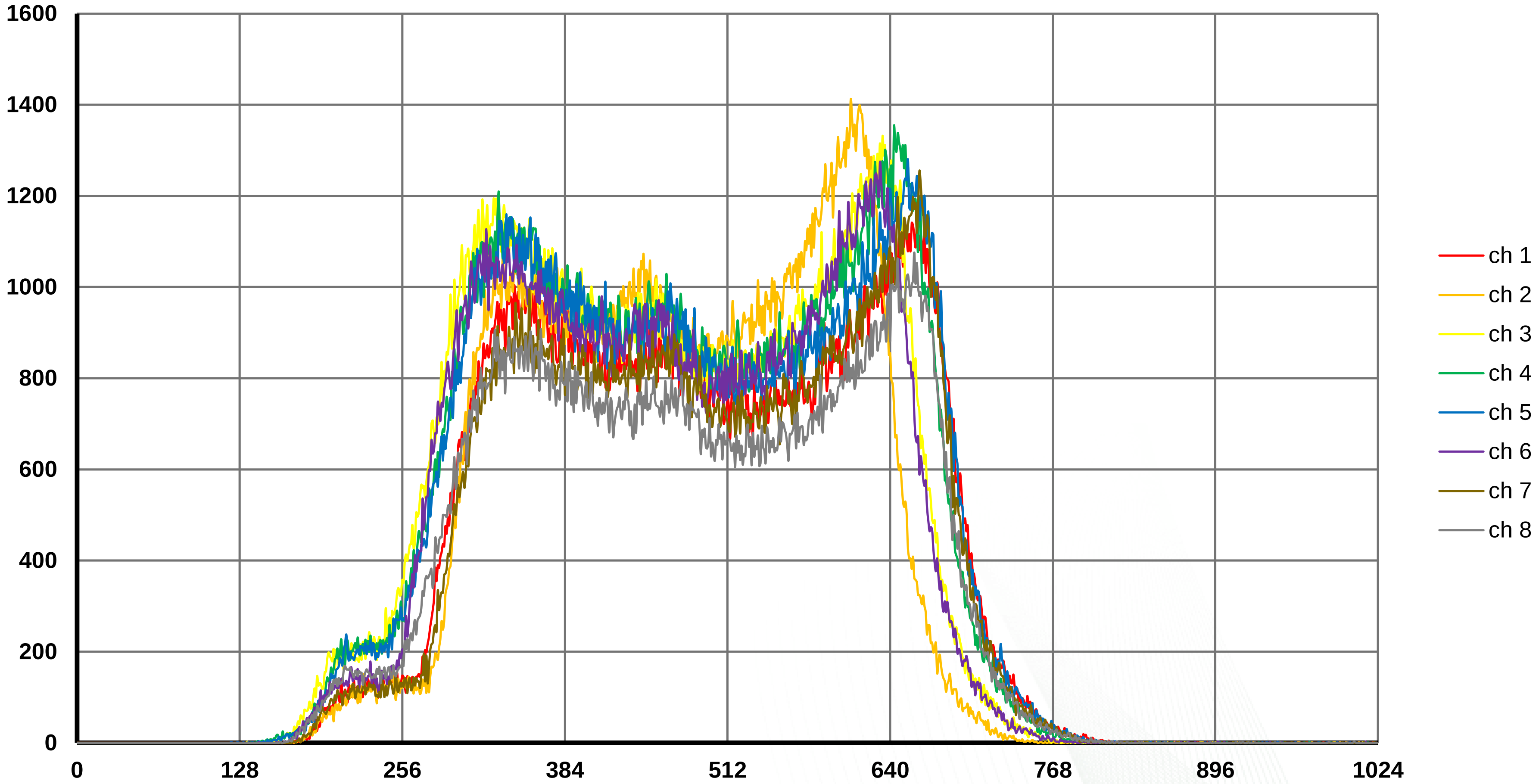
The next 5 slides show pulse height spectra for discriminator set to 0, 100, 200, 300, 400

Discriminator at 0, neutron port open
- two Co60 sources near tube 8



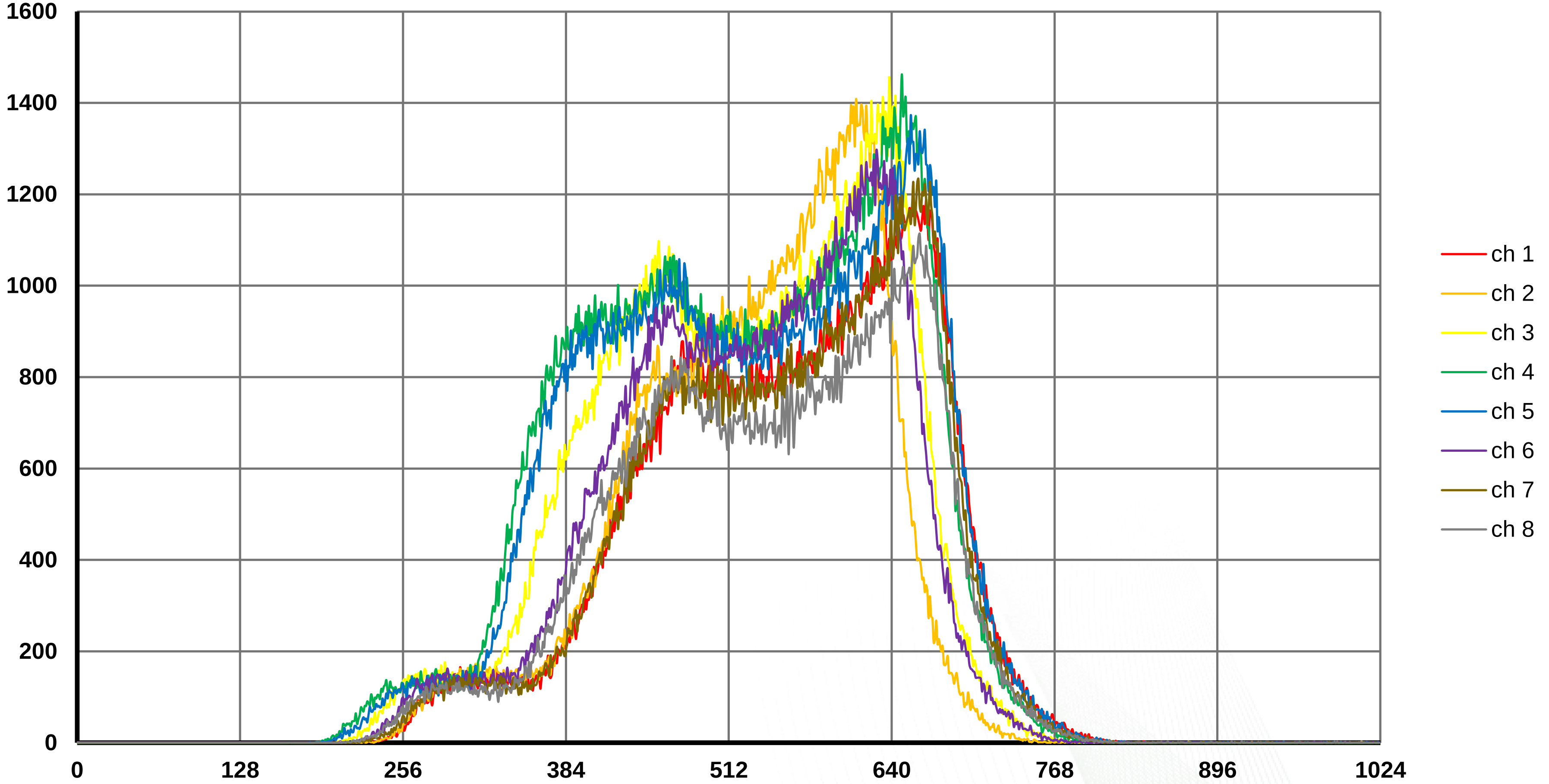
Discriminator at 100, neutron port open

- two Co60 sources near tube 8



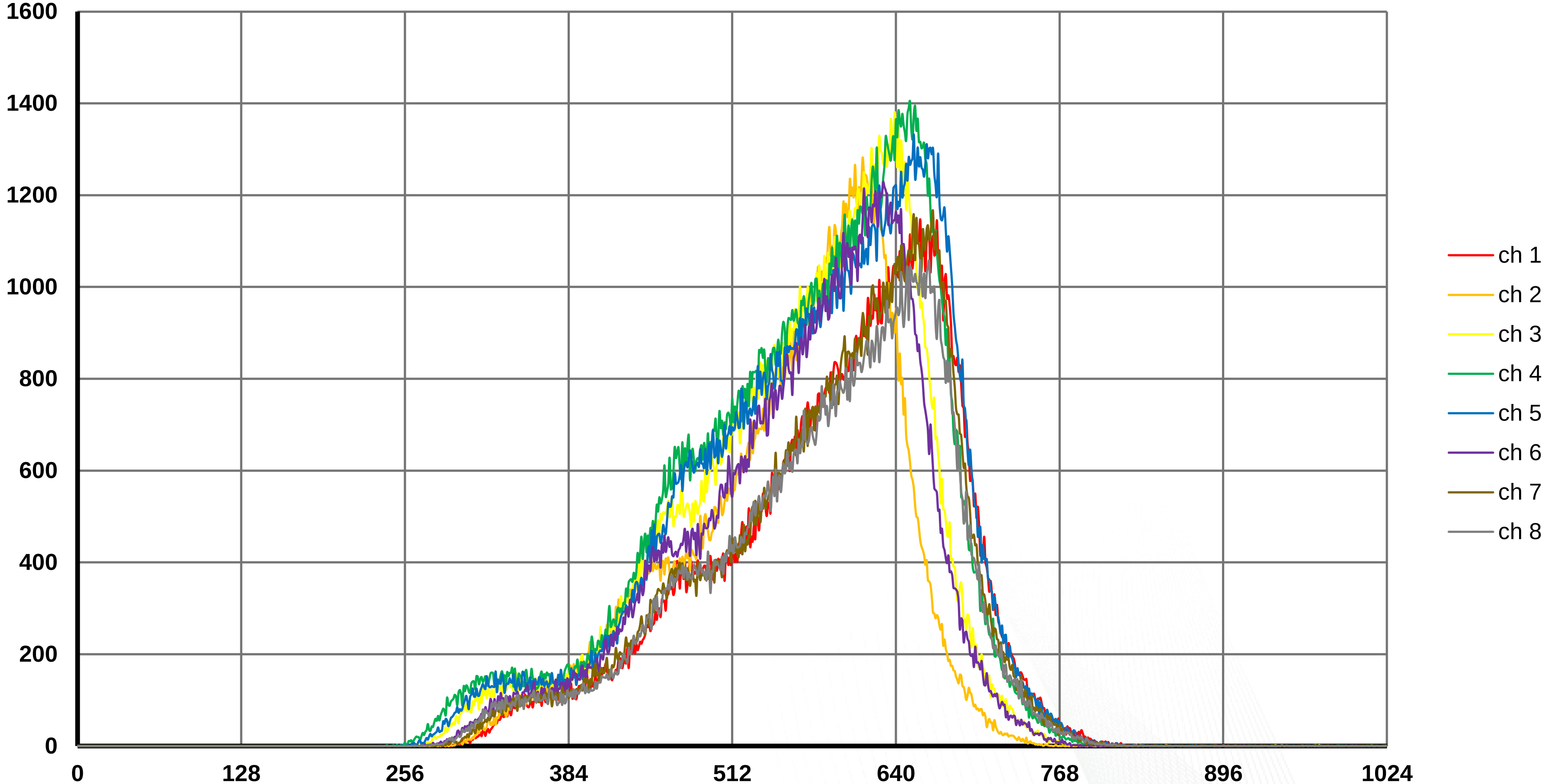
Discriminator at 200, neutron port open

- two Co60 sources near tube 8



Discriminator at 300, neutron port open

- two Co60 sources near tube 8



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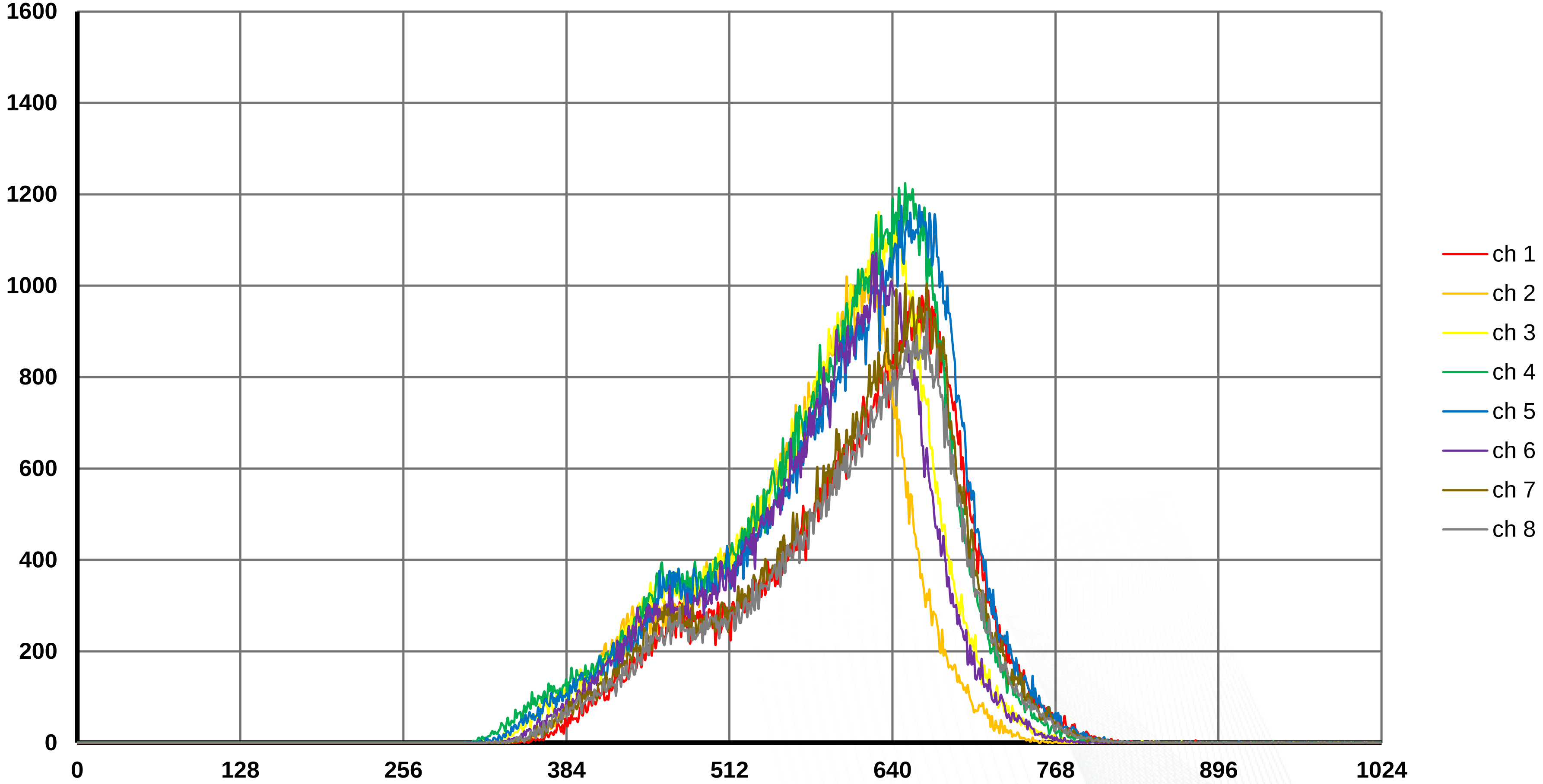
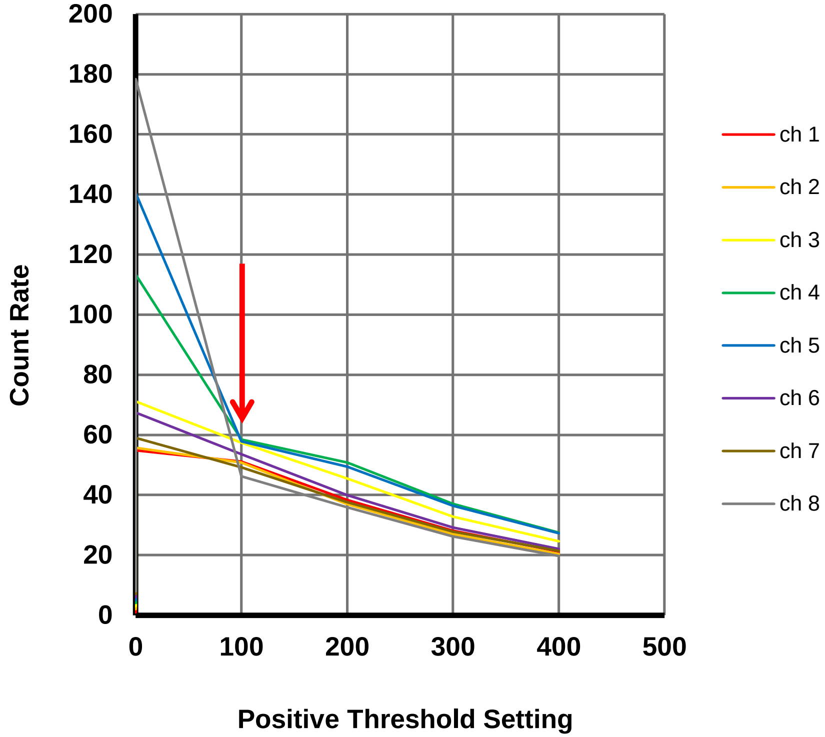
Discriminator at 400, neutron port open

- two Co60 sources near tube 8

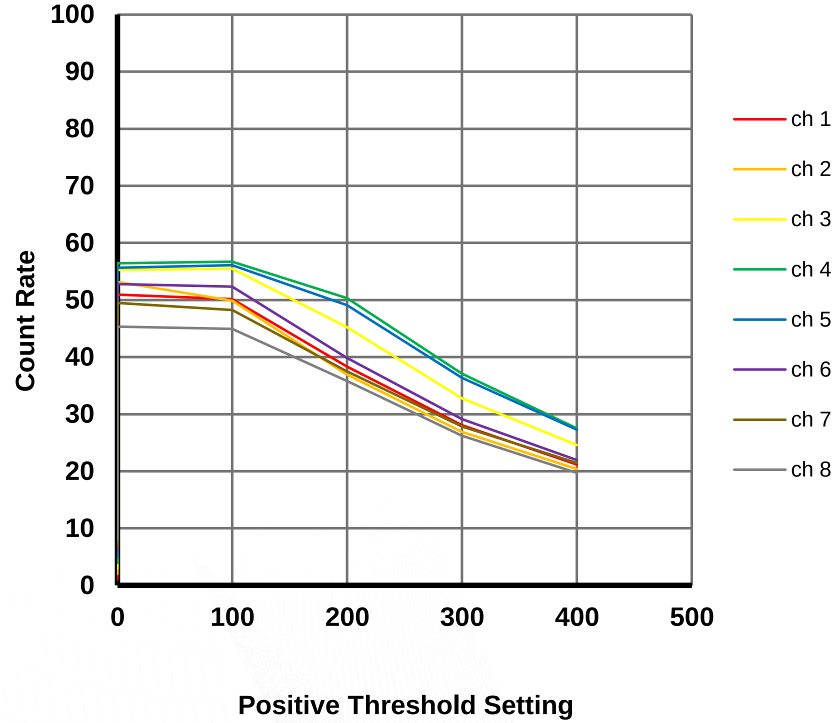


Count Rate vs Discriminator
- with and without low amplitude events included

All events included

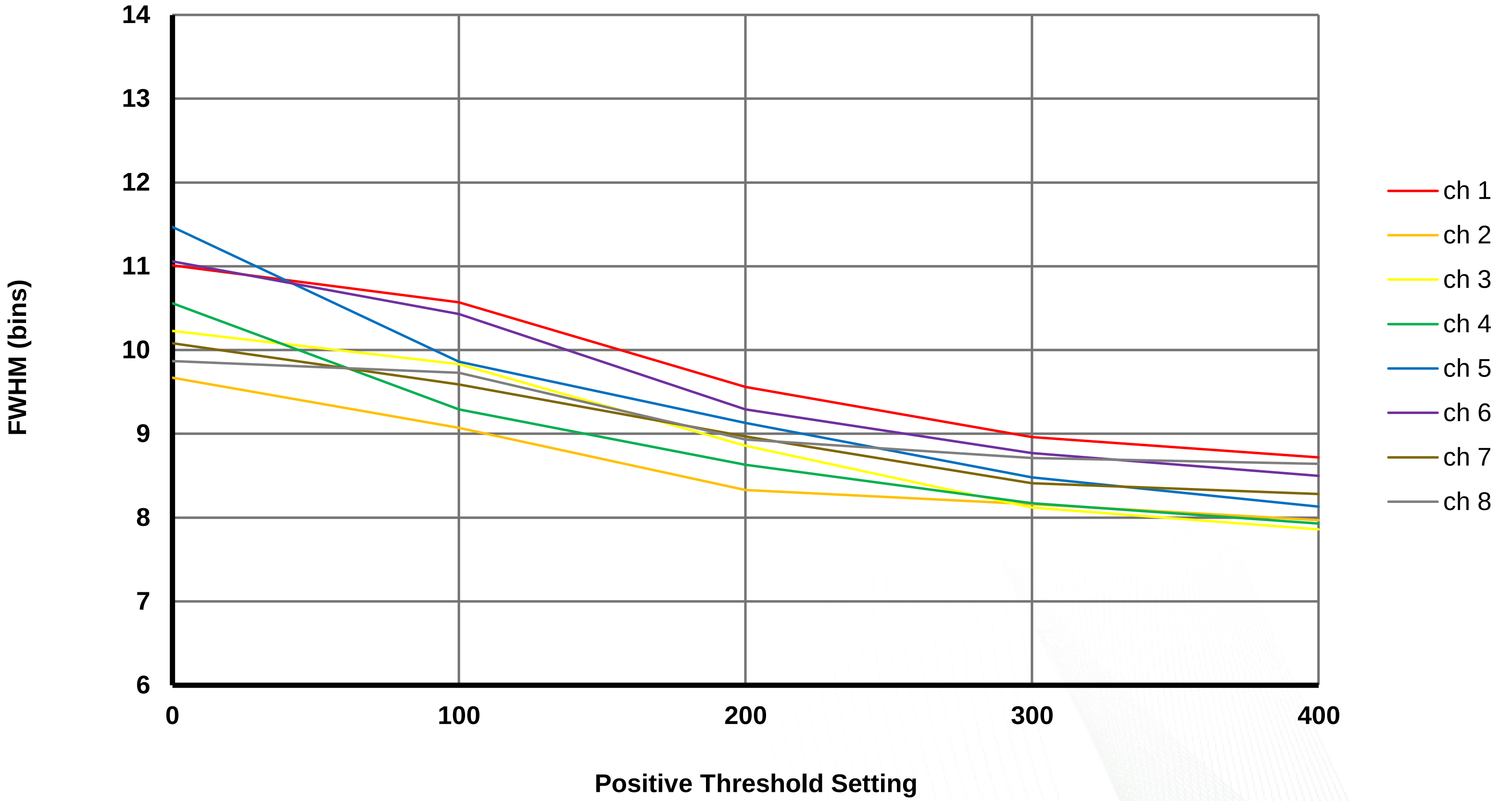


Reject all events < channel 250



Based on the above plots, a positive threshold of 100 appears to be a reasonable setting to maximize neutron throughput and minimize non-neutron events. Further refinement would require analyzing pulse height spectra on a channel by channel basis.

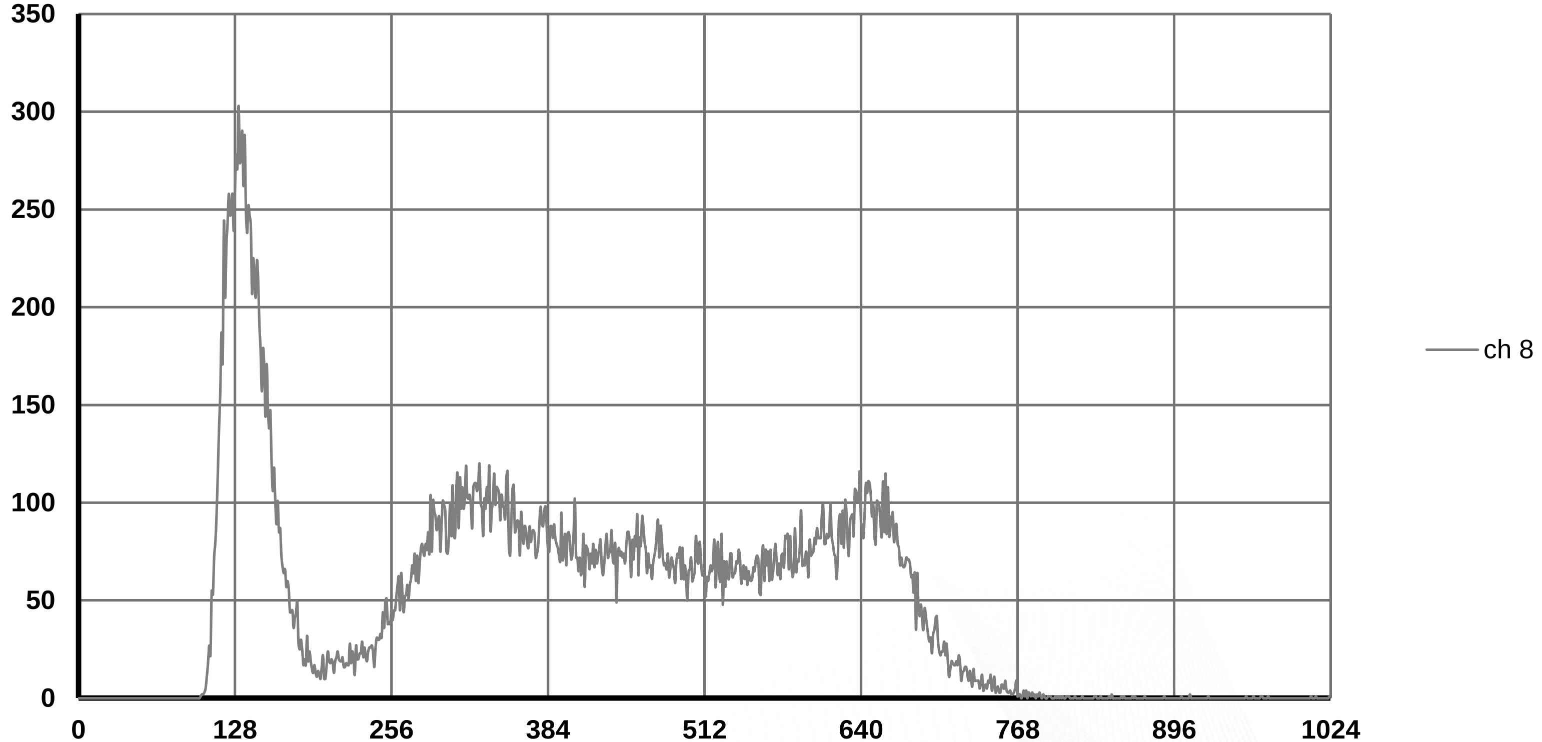
FWHM vs Discriminator



Discriminator setting also affects spatial resolution, thus there is a tradeoff between throughput and resolution.

Discriminator at 0, neutron port closed

- only gammas are those associated with Cf-252 source



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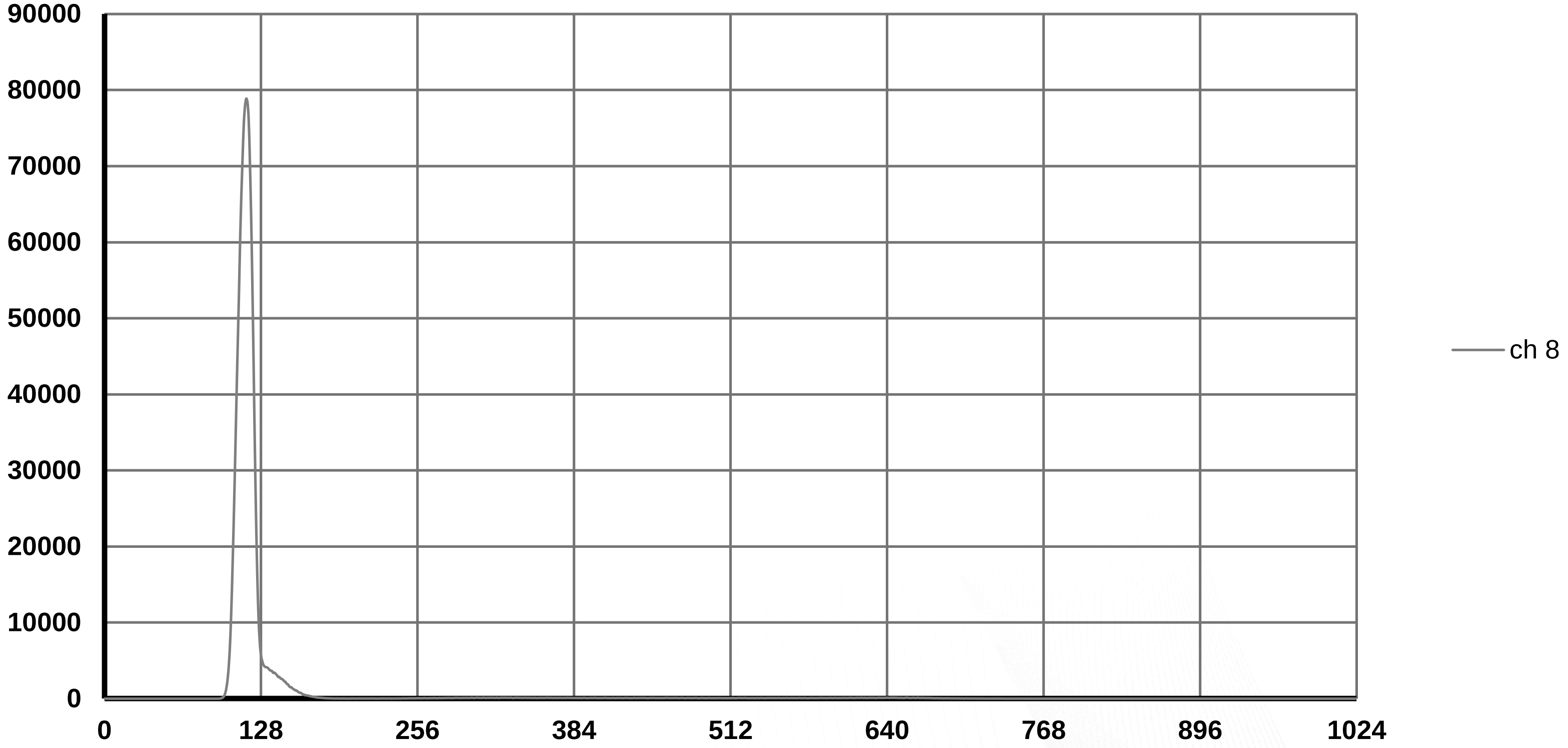
Discriminator at 0, neutron port closed

Am241 source superimposed on gamma spectrum from Cf252



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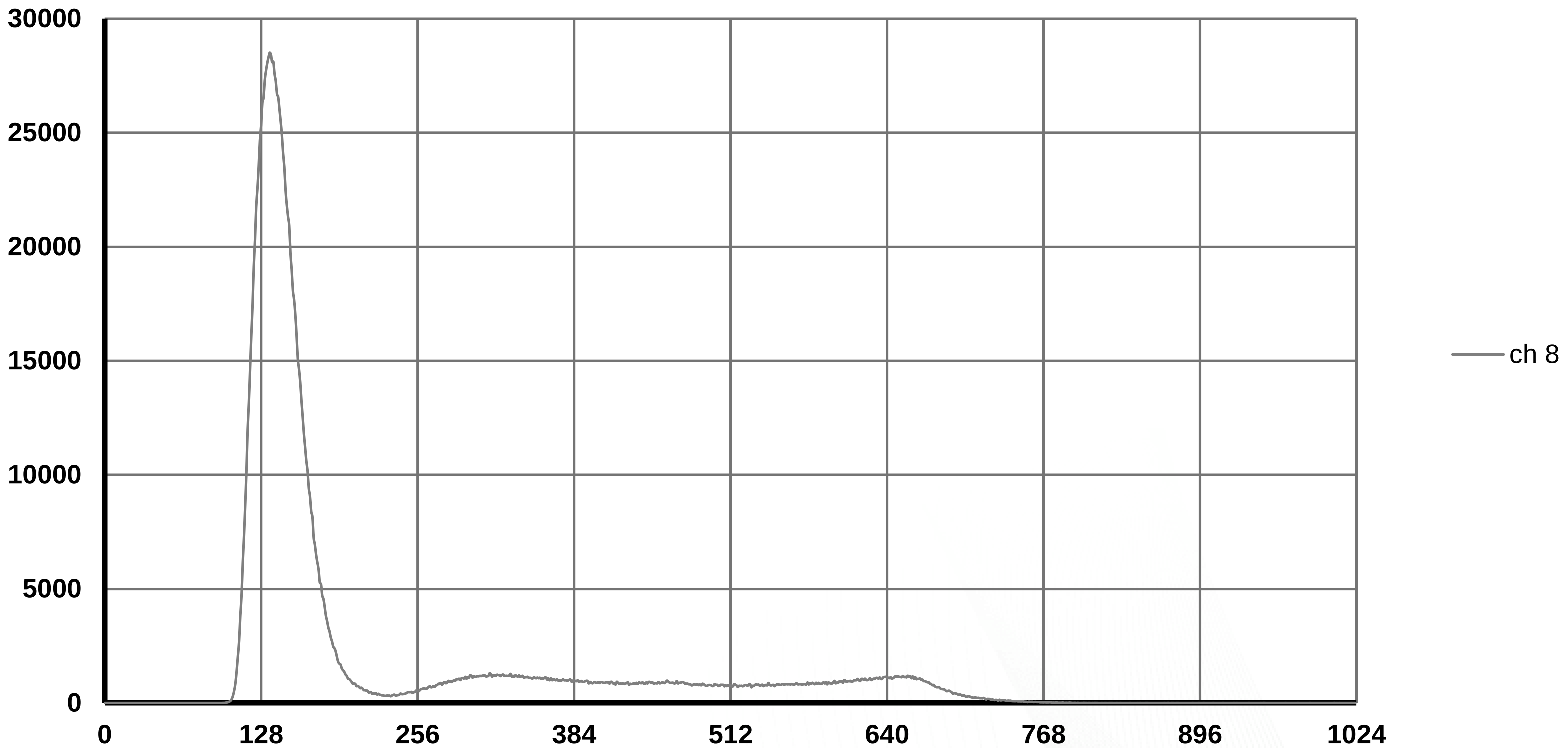
Discriminator at 0, neutron port closed

Co60 source superimposed on gamma spectrum from Cf252



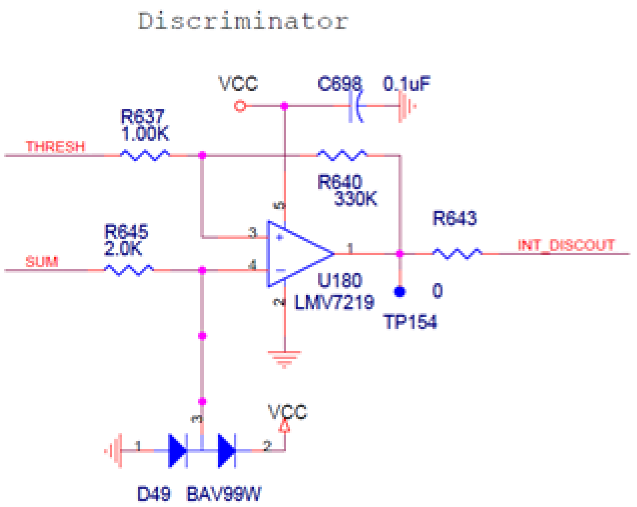
Some Comments on Discriminator
- why do channels respond differently to discriminator settings

Discriminator circuit allows pulses to pass when voltage at Sum is greater than voltage at Thresh.

Measured values are tabulated below.

As can be seen, changing discriminator (PT) in steps of 100 changes measured voltage by increments of ~ 50 mV.

Ideally, Thresh (when PT = 0) and Sum should be at 0 reference voltage. However, measurable offset voltages (circled in red) are present in both.



	PT = 0	PT = 100	PT = 200	PT = 300	PT = 400	Sum (mV)
Channels	Thresh (mV)					
ch 1	17	67	118	168	217	-16
ch 2	23	72	122	172	222	-21
ch 3	1	47	97	147	197	-22
ch 4	1	45	95	145	195	-13
ch 5	1	51	101	151	201	-11
ch 6	11	60	110	159	209	-20
ch 7	20	69	118	168	217	-20
ch 8	13	63	114	164	215	-14

Some Comments on Discriminator
- accounting for Thresh and Sum Offsets

- Thresh - Sum (column 4) is the difference between these measured offsets.
- These are sorted low to high (column 6) and the corresponding channels are reordered (column 5).
- Channels with small offset difference (5, 4) are more likely to pass low amplitude pulses, e.g. gammas.
- This reordering of channels based on offset difference correlates exactly with the intensity of gamma counts (left side of plot) on slide 4.
- **This very likely explains the difference in discriminator response.**

Channel	Thresh (mV)	Sum (mV)	Thresh - Sum (mV)
ch 1	17	-16	33
ch 2	23	-21	44
ch 3	1	-22	23
ch 4	1	-13	14
ch 5	1	-11	12
ch 6	11	-20	31
ch 7	20	-20	40
ch 8	13	-14	27

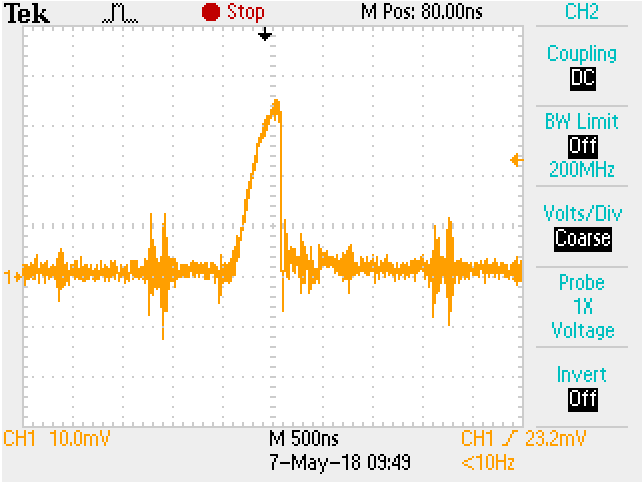
Reordered	Low to High
ch 5	12
ch 4	14
ch 3	23
ch 8	27
ch 6	31
ch 1	33
ch 7	40
ch 2	44

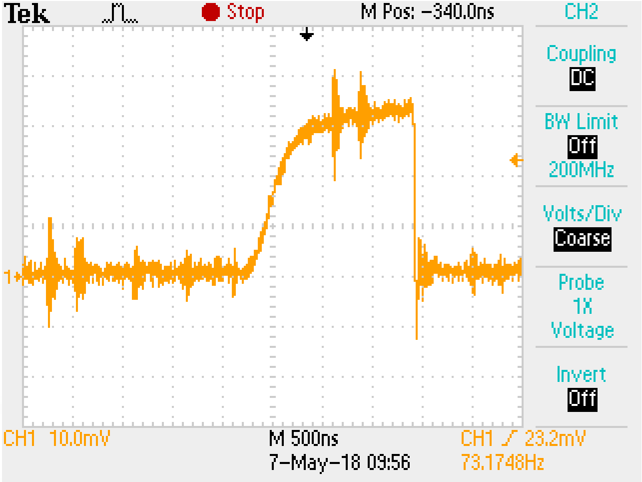
Integration Time (aka Sample 2, or S2)

Pulses of sufficient amplitude to pass through the discriminator are then integrated to determine the charge in the pulse.

The parameter which determines integration time is called Sample 2.

Sample 2 is in time units of 50 ns after discrimination.



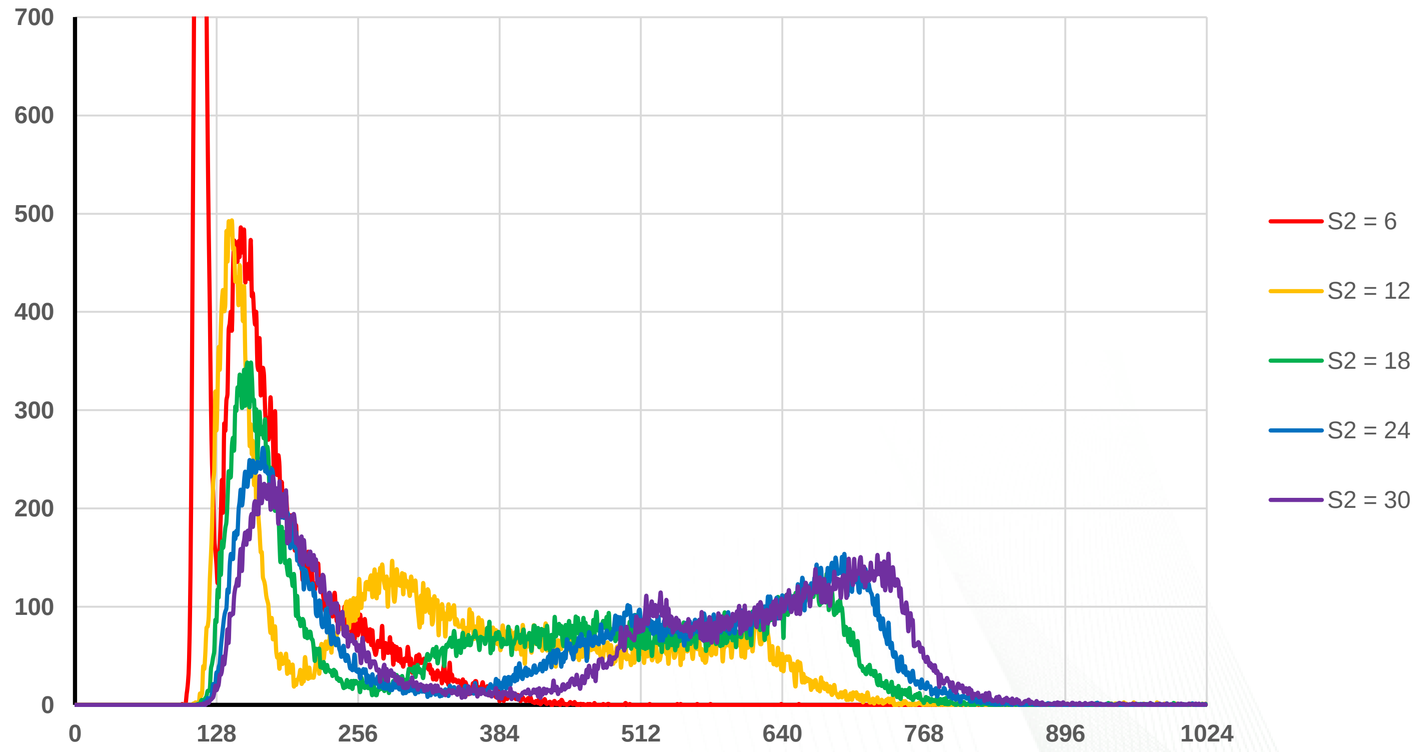


S2 = 6 (300 ns)

S2 = 30 (1500 ns)

Longer integration times lead to more charge per pulse

i.e. pulse height distribution shifts to the right

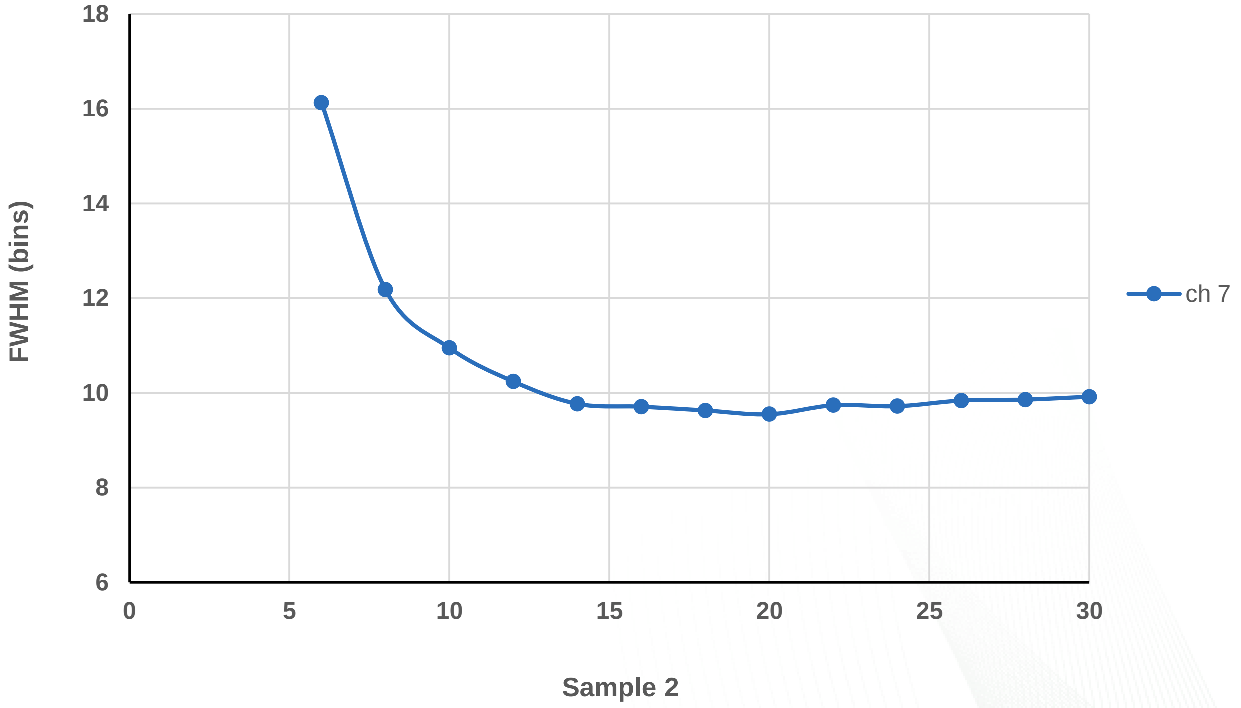


ch 7 pulse height spectrum vs. S2

Note no observable effect on count rate however

Longer integration times also give improved signal to noise

Spatial Resolution vs. Sample 2



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Effect of changing MinADC

Rejects all counts in pulse height spectrum below MinADC value