

INNOVATION AT WORK

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How to Interpret High Uncertainty Peaks Using Apex-InVivo™ Software

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The Question

• Here at the ACME nuclear plant, if a peak has an uncertainty of 30% or greater, we consider it a false positive and ignore it — do you agree with this practice?



The Question Restated:

Is there a percent uncertainty for a net peak area above which I can assume there is no activity present...

We have a parameter for this... the Critical Level (L_C)

So, the question becomes, can we associate net peak area uncertainty with Critical Level, and make decisions based on this?



Summary

Quick Summary Table:

Concept	Symbol	Purpose	Controls	Typical k-value
Critical Level	L_C	Threshold to say "detected"	α (false positive)	1.645 (for α=0.05)
Detection Limit	L_D	Minimum signal you expect to detect	β (false negative)	1.645 (for β=0.05)



Critical Level (L_C)

The number of counts that can be detected above background with a 5% chance of false positive. (95% $L_{\rm C}$)

- Counts above L_c indicates radioactivity present
- L_C converted to activity commonly referred to as Decision Level (DL).

$$L_C = k_\alpha \sqrt{2B}$$

Where:

- L_C = critical level, in net counts
- B =background counts (measured over the same interval as the net signal)
- $\sqrt{2B}$ = standard deviation of the background (at least 2 components in gamma spectroscopy)
- k_{α} = critical value from the standard normal distribution for the desired false positive rate (e.g., 1.645 for α = 0.05) 95% Confidence level



Detection Limit (L_D)

The number of counts that can be quantified above background with a 5% chance of false negative. (95% Conf Level)

- Counts above L_C indicates radioactivity present
- L_D converted to activity commonly referred to as Minimum Detectable Activity (MDA).

$$L_D = k^2 + 2k\sqrt{2B}$$

$$L_D = k^2 + 2L_C$$

$$L_D = 2.71 + 4.65\sqrt{B}$$

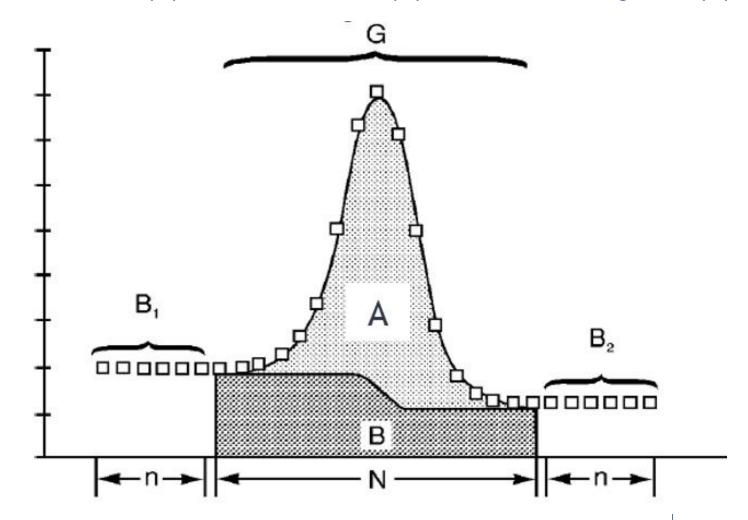
Where:

- $k=k_{lpha}=k_{eta}$, often both taken as 1.645 for 5% error rates
- ullet B is the background count
- $\sqrt{2B}$ = standard deviation of the background



Peak Model

Net Peak Area (A) = Gross Peak ROI (G) – Estimated Background (B)





Net Peak Uncertainty σ_A (simplified case)

Net Peak Area (A) = Gross Peak ROI (G) - Estimated Background (B)

$$A = G - B$$

- Peak Uncertainty is the uncertainty of the Gross Peak ROI, and the estimated background propagated in quadrature.
- Simple case

•
$$A = G - B$$

$$\sigma_G = \sqrt{G}, \quad \sigma_B = \sqrt{B}$$

$$\sigma_A = \sqrt{\sigma_G^2 + \sigma_B^2}$$

$$u_{ ext{rel}}(A) = rac{\sigma_A}{A}$$

$$u_\%(A) = rac{\sigma_A}{A} imes 100$$

where $oldsymbol{u}$ is uncertainty



Relationship between L_c and Net Peak Area Uncertainty

$$L_C = k_\alpha \sqrt{2B}$$

~ proportional to background uncertainty

$$\sigma_A = \sqrt{\sigma_G^2 + \sigma_B^2}$$

$$u_{
m rel}(A) = rac{\sigma_A}{A}$$

~ ratio A to
$$\sqrt{\sigma_G^2 + \sigma_B^2}$$

Uncertainty at L_C

Background (Counts) [B]	L _C (Counts) [A]	Gross ROI [G]	σ_A	$u_{\%}(A)$
1	2.33	3.33	2.08	89%
10	7.36	17.36	5.23	71%
50	16.45	66.45	10.79	66%
100	23.26	123.26	14.94	64%
500	52.01	552.01	32.43	62%
1000	73.56	1073.56	45.54	62%
5000	164.48	5164.48	100.82	61%
10000	232.60	10232.60	142.24	61%
50000	520.12	50520.12	317.05	61%
100000	735.56	100735.56	448.04	61%
500000	1644.75	501644.75	1000.82	61%
1000000	2326.03	1002326.03	1415.04	61%
5000000	5201.16	5005201.16	3163.10	61%
1.00E+07	7355.55	10007355.55	4472.96	61%
5.00E+07	16447.52	50016447.52	10000.82	61%
1.00E+08	23260.30	100023260.30	14142.96	61%
5.00E+08	52011.61	500052011.61	31623.60	61%
1.00E+09	73555.53	1000073555.53	44722.18	61%
5.00E+09	164475.16	5000164475.16	100000.82	61%
1.00E+10	232603.00	10000232603.00	141422.18	61%
5.00E+10	520116.12	50000520116.12	316228.59	61%
1.00E+11	735555.27	100000735555.27	447214.42	61%
5.00E+11	1644751.59	500001644751.59	1000000.82	61%



Uncertainty at L_D

Background (Counts) [B]	L _D (Counts) [A]	Gross ROI [G]	σ_A	$u_\%(A)$
1	7.36	8.36	3.06	42%
10	17.42	27.42	6.12	35%
50	35.61	85.61	11.64	33%
100	49.23	149.23	15.79	32%
500	106.73	606.73	33.27	31%
1000	149.82	1149.82	46.37	31%
5000	331.66	5331.66	101.64	31%
10000	467.92	10467.92	143.07	31%
50000	1042.94	51042.94	317.87	30%
100000	1473.82	101473.82	448.86	30%
500000	3292.21	503292.21	1001.64	30%
1000000	4654.77	1004654.77	1415.86	30%
5000000	10405.03	5010405.03	3163.92	30%
1.00E+07	14713.82	10014713.82	4473.78	30%
5.00E+07	32897.74	50032897.74	10001.64	30%
1.00E+08	46523.31	100046523.31	14143.78	30%
5.00E+08	104025.93	500104025.93	31624.42	30%
1.00E+09	147113.76	1000147113.76	44723.00	30%
5.00E+09	328953.03	5000328953.03	100001.64	30%
1.00E+10	465208.71	10000465208.71	141423.00	30%
5.00E+10	1040234.95	50001040234.95	316229.41	30%
1.00E+11	1471113.25	100001471113.25	447215.24	30%
5.00E+11	3289505.88	500003289505.88	1000001.64	30%



Conclusion

Here at the ACME nuclear plant, if a peak has an uncertainty of 30% or greater, we consider it a false positive and ignore it — do you agree with this practice?



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1.00E+10	232603.00	10000232603.00	141422.18	61%
	l6.12	50000520116.12	316228.59	61%
	55.27	100000735555.27	447214.42	61%
	51.59	500001644751.59	1000000.82	61%

Interpretation	Int	erp	ret	ati	on
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Counts equal to or below L _C	Counts greater than L_{C} but below L_{D}	Counts above L _D
No Activity Present	Gray Area	Reliably Detectable Activity Present
	Activity present but not reliably detectable	
L_{ϵ}	$_{C}$ L	D



Thank you



