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Peak search and fitting techniques for analysis of the radioxenon beta-gamma coincidence spectra

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Introduction

IMS beta-gamma coincidence Noble Gas samples are analysed at the IDC using the so called net count calculation method (NCC) based on a number of Regions of Interest (ROI) in the coincidence spectrum. In order to enhance the reliability of analysis results, an alternative method - briefly called peak search and fitting method (PSF) - is being developed to be used in parallel with the NCC method. This applies peak analysis techniques on beta and gamma projections of the coincidence spectrum. The idea is to reduce the rate of false positives by using distinct peak structures of xenon isotopes, especially coincidence beta peaks of the metastable Xe-131m and Xe-133m if the number of counts per channel is allowing for this approach. This poster presents the analysis method and a few preliminary results for spike samples as well as for low level noble gas samples.

Analysis Method

- The peak search and fitting are based on beta and gamma projections of the coincidence spectrum separately.
  - The gamma projection is gated on the full beta range.
  - The beta projection is gated only on the 30 keV x-ray peak region.
- The peak analysis is based on the concept of Currie detection limits and Single Channel Analyser(SCA), Lc and baseline curves, which is the same as the spectra analysis method in the AutoSaint for particulate and HPGe noble gas samples (De Geer, 2004).
  - Regarding the low resolution of NaI and plastic scintillation detectors, the parameters of the baseline definition are optimized for beta and gamma projections, respectively.
  - Peak detectability is determined with the SCA, Lc and baseline curves.
  - Net peak areas are calculated with respect to the baseline curve.
- Energy lines are only searched for CTBT relevant xenon isotopes.
  - 30, 81 and 250 keV in the gamma projection for Xe-133 and Xe-135.
  - 129 and 199 keV in the beta projection for Xe-131m and Xe-133m.
  - 352 keV as well as 295 and 242 keV in the gamma projection for radon background.
  - Energy lines for non-traditional radioxenon isotopes could be added to the search.

Table 1. Comparison of peak areas of 81 keV gamma and 129 keV beta between the PSF and Genie2k for spike samples with high concentrations

	Collect_stop	Counts (cts)				Deviation (%)	
		G2k		2Df		2Df to G2k	
		81 keV gamma	129 keV beta	81 keV gamma	129 keV beta	81 keV gamma	129 keV beta
AUX04_004	30/05/2016 06:47	7.45E+05		7.41E+05		-0.46	
JPX38_004	03/06/2016 18:51	2.17E+05		2.11E+05		-2.90	
NZX46_003	22/06/2016 13:25	1.66E+04		1.59E+04		-4.17	
SEX63_003	31/05/2016 00:30	5.25E+05		5.15E+05		-1.97	
USX75_006	05/05/2016 22:41	8.50E+04		8.76E+04		3.04	
AUX04_003	23/02/2015 18:44	6.54E+03	1.25E+04	6.36E+03	1.17E+04	-2.64	-6.11
AUX04_003	25/02/2015 18:44	1.74E+04	2.45E+04	1.72E+04	2.26E+04	-1.01	-7.64
AUX04_004	24/02/2015 06:44	1.54E+04	3.13E+04	1.58E+04	3.09E+04	2.95	-1.20
AUX04_004	27/02/2015 06:44	3.33E+03	6.14E+03	3.46E+03	6.09E+03	3.84	-0.90
Number						9	4
Average						-0.37	-3.96
STD						2.94	3.42

Spike samples

A few spike samples in 2015 (with both Xe-131m and Xe-133) and 2016 (only with Xe-133) were analysed and compared with the NCC method as well as the Genie2k.

- Spike samples with high concentrations
  - With respect to the Genie2k, the peak areas match by (-0.4±2.9)% for 81 keV gamma and (-4.0±3.4)% for beta 129 keV, see Table 1.
  - With respect to the NCC method, the differences between peak areas and net counts are within (-5.7±3.8)% for 81 keV gamma and (-0.1±2.3)% for 129 keV beta. (The data are not shown.)
  - The baselines can be defined properly for the spike samples with high concentrations, therefore the peak areas of gamma and beta projections can be calculated accurately.
- Spike samples with low level Xe-131m and Xe-133
  - Proper baseline definitions can also be achieved for both beta and gamma projections even when the counts are only a few counts per channel, for example a sample from USX75, see Figure 1.

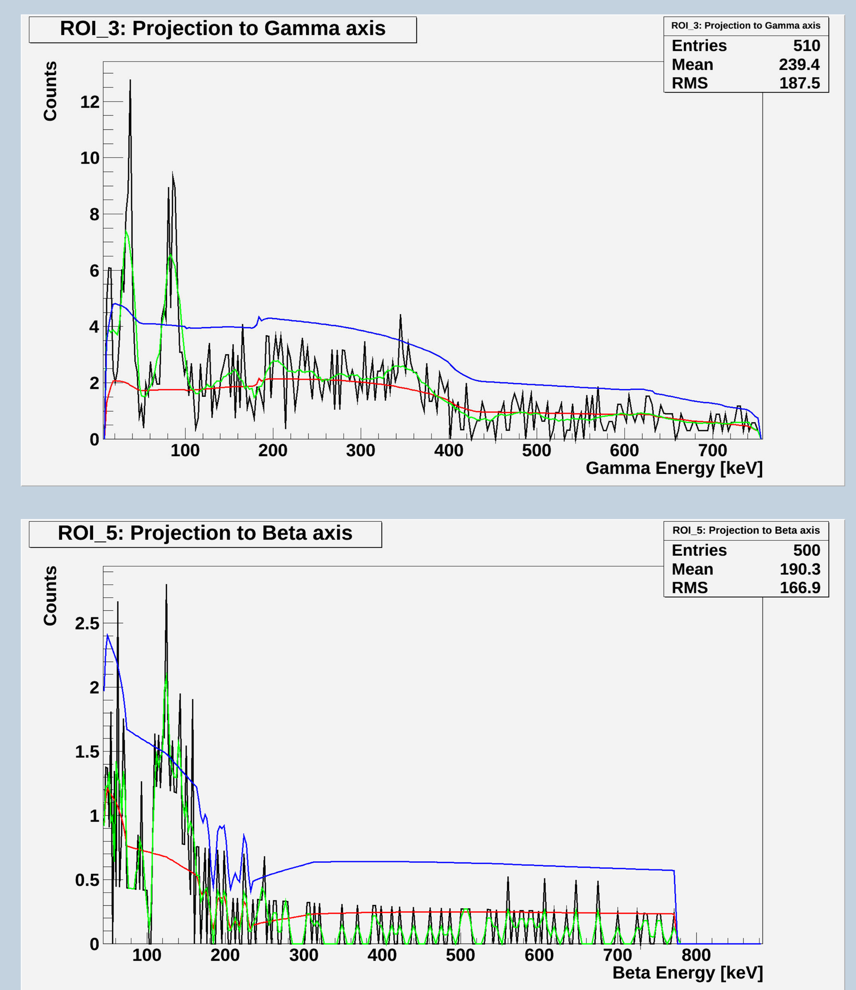

Figure 1. Gamma (top) and beta (bottom) projections of a spike sample with low level Xe-133 and Xe-131m concentrations from USX75 (C-stop: 20150916-10:36)

Samples at Lc to abnormal level

A few typical samples from JPX38 were analysed with respect to Lc, MDC and abnormal threshold levels of the NCC method in CTBTO ops.

- Xe-131m
  - It is hard to fit peaks for samples at the Lc level and it is still a case by case at the MDC and abnormal threshold levels, for instance, 5 samples of the Level C from JPX38 (see Table 2).
    - No peak detected at the level abnormal threshold (Figure 2 top)
    - Poor peak structure at the double abnormal threshold (Figure 2 middle)
    - Clear peak structure at the triple abnormal threshold (Figure 3 bottom)
  - It seems that the peak structure at 129 keV beta is still very weak at the abnormal level (see Figure 2 top). That might mean that the rate of false positive by the NCC method probably be high.

Table 2. Analysis results of the NCC method in the CTBTO ops for five Level C samples based on Xe-131m concentrations from JPX38

SAMPLE_ID	DETECTOR_CODE	COLLECT_STOP	XE_VOLUME	CATEGORY	NID_FLAG_131M	CONC_131M	UNCERT_131M	LC_131M	MDC_131M	ABN_XE131M	NET_COUNT_131M	NET_COUNT_ERR_131M	129 keV
3595099	JPX38_001	06-MAY-16	9.29E-01	3	detected	0.21	0.12	0.19	0.4	0.18	27.44	16.41	no
3169829	JPX38_001	13-JUN-15	9.19E-01	3	detected	0.21	0.12	0.18	0.39	0.18	27.95	15.66	no peak but higher background
2900148	JPX38_001	05-NOV-14	1.12E+00	3	detected	0.66	0.39	0.63	1.27	0.2	106.2	62.42	clear peak structure
2886657	JPX38_001	25-OCT-14	7.56E-01	3	detected	0.36	0.14	0.21	0.44	0.19	38.69	15.03	yes
3627669	JPX38_003	31-MAY-16	1.07E+00	3	detected	0.35	0.08	0.11	0.23	0.19	59.12	13.54	yes but looks not a real peak

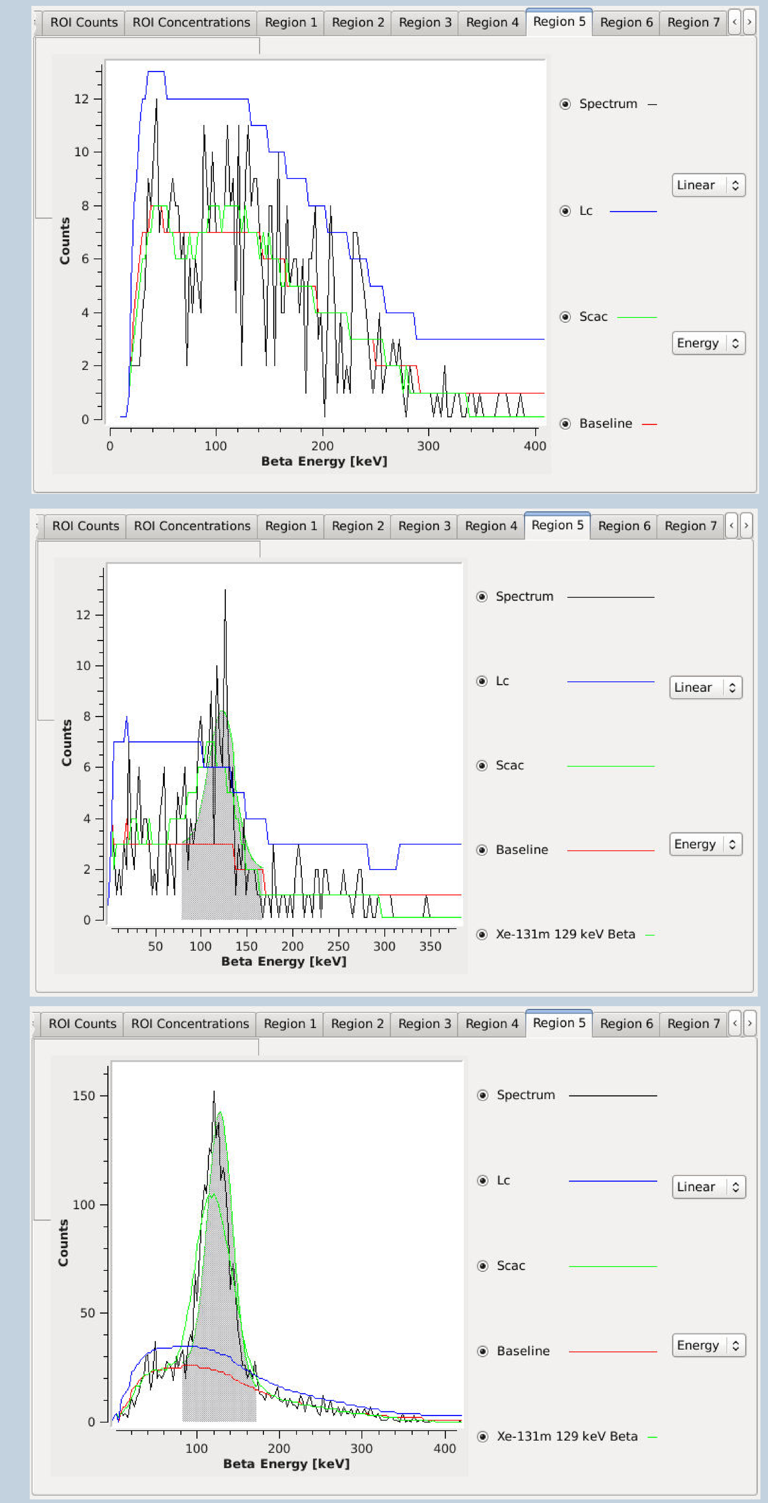

Figure 2. Beta projections of samples with the Xe-131m concentration at the Level C from JPX38 (see Table 2)

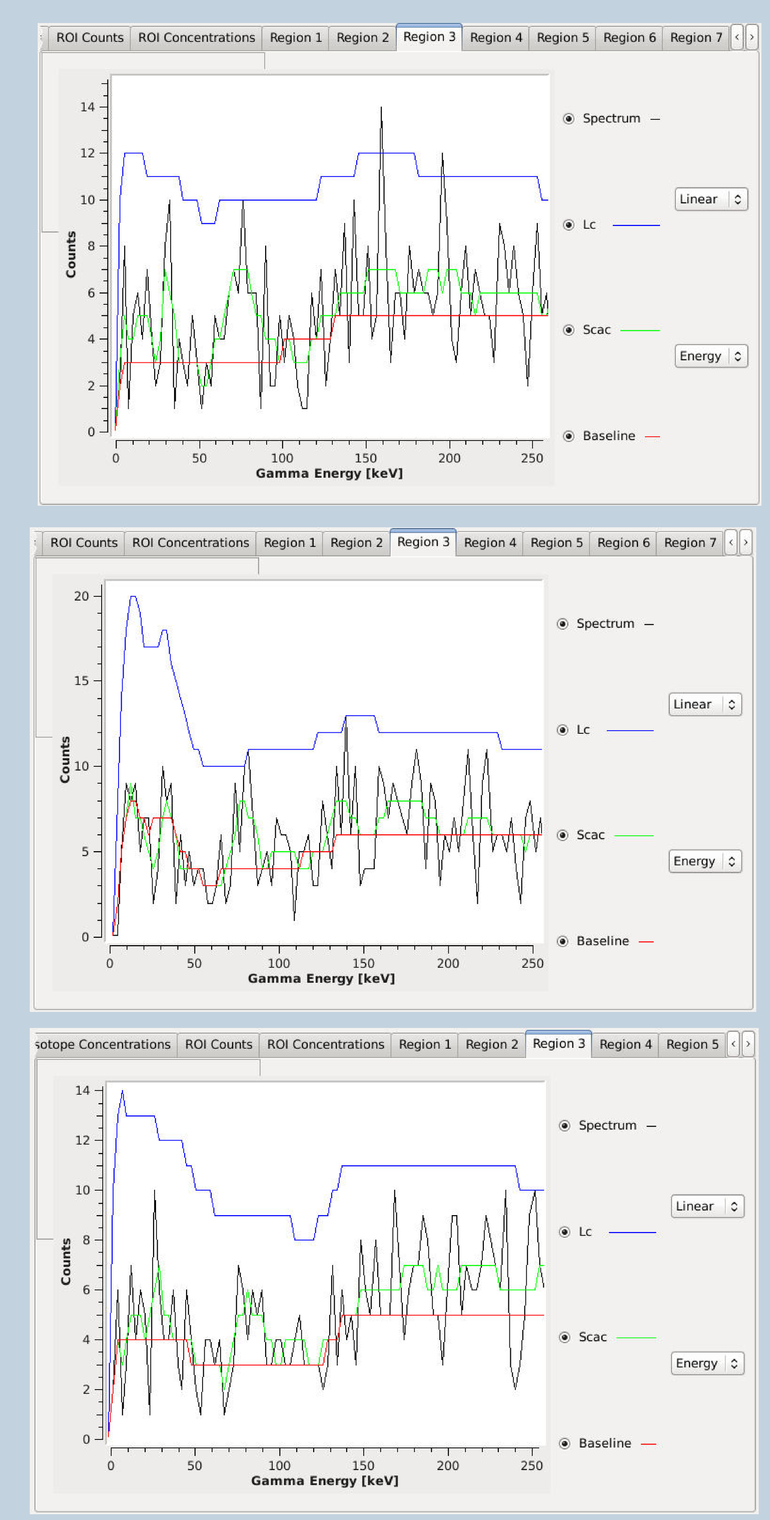

Figure 3. Gamma projections of samples with the Xe-133 concentration at the MDC level from detector JPX38_001 (top), -003 (middle) and -004 (bottom)

- Xe-133
  - At Lc level: There is no peak structure detected.
  - At MDC level: The typical spectra of three detectors at JPX38 are shown in Figure 3. It is hard to detect a peak at the MDC level. Peak structures look clear but below Lc curves. The parameters of the Lc curve need to be optimized further so that the small peak structures at 81 keV could be detected.
  - At Level C level: The abnormal thresholds are around triple MDCs. Clear peak structures of both 30 and 81 keV can be detected, see one typical gamma projection in Figure 4.

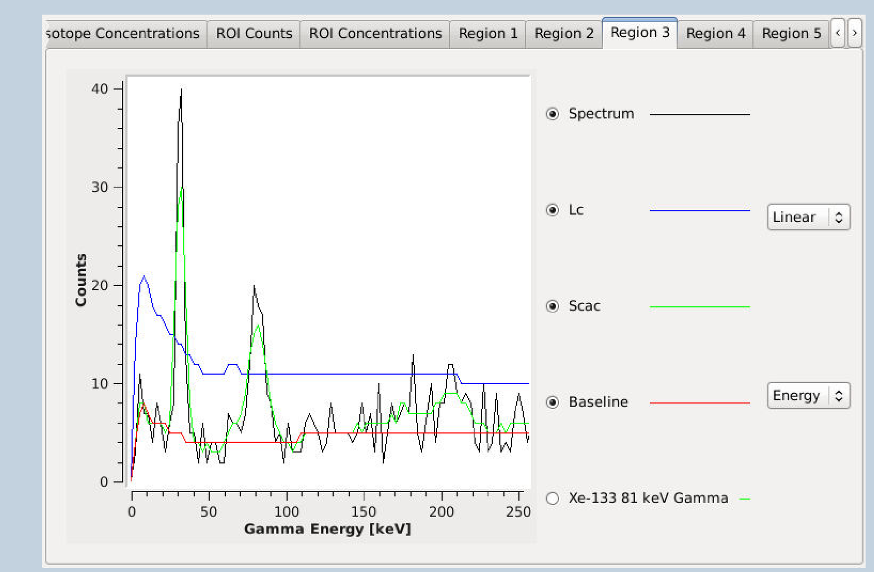

Figure 4. A typical gamma projection of samples with the Xe-133 concentration at the abnormal threshold level from JPX38

Summary

- The PSF methods based on the SCA-LC curves works well for the low resolution spectra of beta-gamma coincidence samples.
- The baselines can be defined properly above the MDCs for gamma and beta projections both. But it is hard to define a proper baseline and Lc curves at the level from Lc to MDC.

Further investigations

- Peak fitting
  - More investigations are needed on how to define proper baseline and Lc curves for both beta and gamma projections for low level samples.
    - The spectrum might be only a few counts per channel, probably low to 0 or 1 outside the peak region, especially for the beta projection.
    - Optimize the baseline of the Xe-131m beta projection under the Xe-133 beta continuum Kurie plot.
- Calibration
  - The same energy and resolution calibration with the NCC method can be used directly. However, a different efficiency and interfere corrections should be developed based on the peak analysis approach itself.
- Algorithm
  - Activity concentrations should be determined based on the key peak for each xenon isotope.
  - The counts of the x-ray peak 30 keV could be used for deconvolution to contributions from all four xenon isotopes like for SPALX samples.
- High-resolution beta-gamma spectra
  - For next generation noble gas systems with high-resolution beta-gamma coincidence spectra, the PSF method might get more advantage over the NCC method.

References

De Geer, L.-E. (2004). Currie detection limits in gamma-ray spectroscopy. Applied Radiation and Isotopes 61(2-3) 151-160.