SnT 2021

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Improving the sensitivity for radioxenon beta-gamma measurements by optimizing the ROI limits for each sample

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T3.5-377

POSTER

Improving the sensitivity for radioxenon beta-gamma measurements by optimizing the ROI limits for each sample

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INTRODUCTION

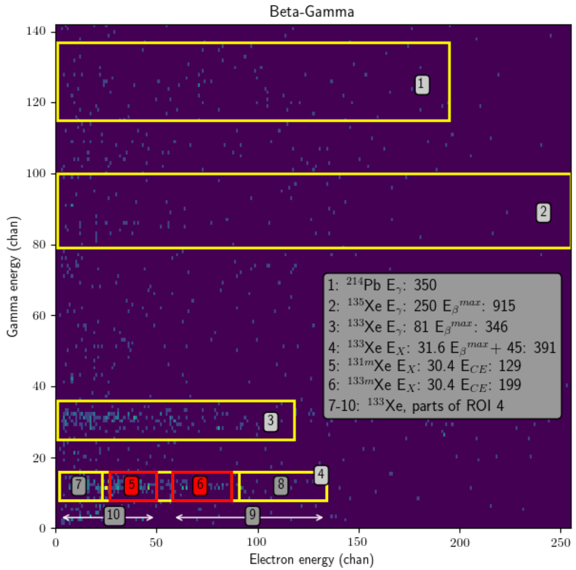
- The measurement sensitivity (MDA) for a particular ROI in a radioxenon measurement depends on:

  1) The background in the ROI.
  2) The detection efficiency of the ROI
  3) The measurement protocol

- The background comes from *ambient* (constant) background and *interfering isotopes*, and varies for each sample.

- Thus, an optimum ROI- setting exists for each sample. But currently, the same ROIs are used for all samples.

Goal: Develop a method to optimize the ROI -settings for individual samples in order to increase the measurement sensitivity.



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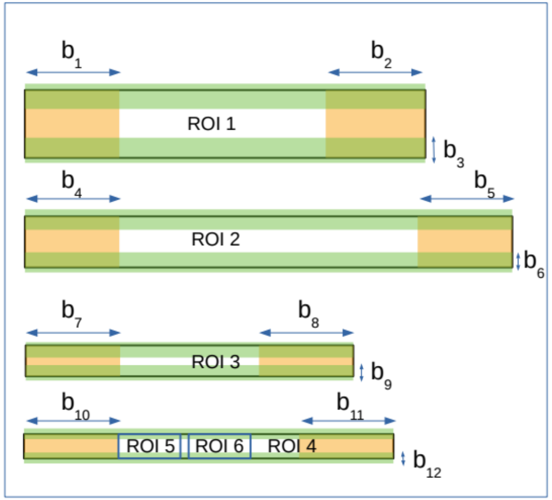
METHOD

- Create an ***objective function*** returning the MDA.
- The objective function depends on efficiency calibration, analyzed sample, isotope, original ROI-settings, and a set of parameters **b** that adjust the original ROI-settings.
- The parameters **b** are allowed to vary inside selected bounds.
- The objective function calculates a new efficiency calibration for every new ROI-setting.
- For each radioxenon isotope, minimize the objective function using ***differential evolution****, a minimization technique for multidimensional real-valued functions, not requiring the function to be differentiable.



* R. Storn and K. Price, *Journ. of Global Optimization 11:341–359, 1997*

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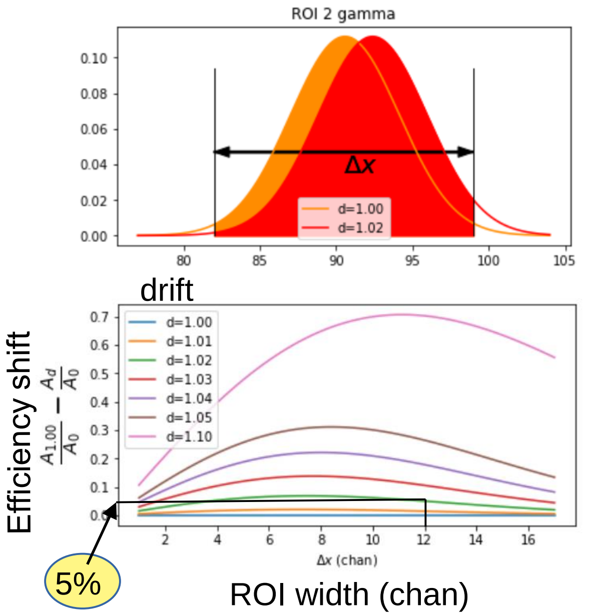
METHOD

- Small energy drifts may cause systematic shifts in efficiency.
- The minimum allowed ROI width was determined assuming a max gamma drift of 2%, and a max beta drift of 5%, and accepting an efficiency shift of 5%.
- The metastable ROIs (5&6) was allowed to vary only in gamma direction.
- The lower bounds in gamma direction was set to 3 channels.
- Xe-133, 131m, 133m: ROI2 not included in minimization.
- Xe-135: ROI 3 & 4 not included in minimization.
- Samples analyzed using the BGM-method*



Determination of minimum gamma ROI with for ROI2, allowing a systematic efficiency shift of 5%.

*A. Ringbom and A. Axelsson, "*A new method for analysis of beta-gamma radioxenon spectra*", Appl. Radiat. Isot. , 2020, Feb; 156.

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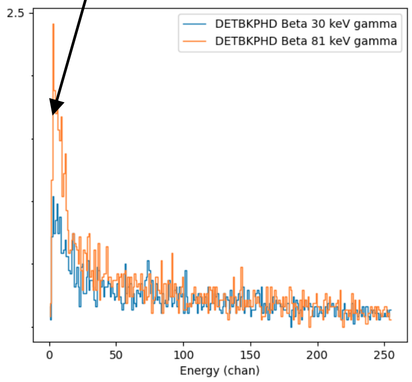
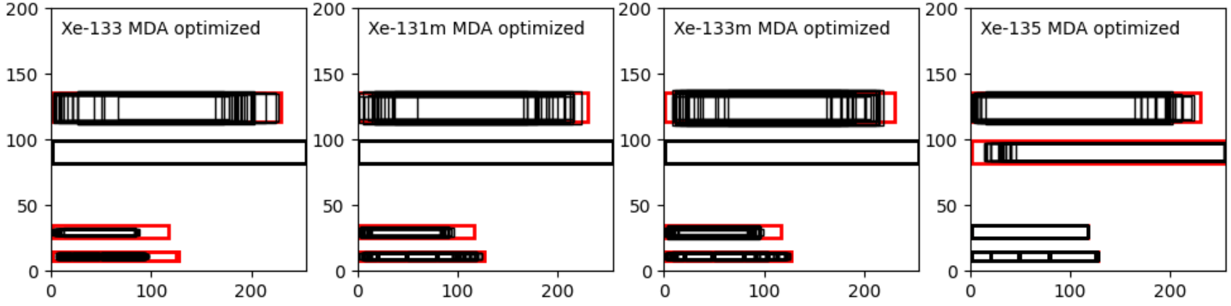
RESULTS - ROIs

- Test set with 22 SAUNA-CUBE samples*
- Every sample and isotope optimized individually.
- Average runtime/sample (with 4 isotopes) using 10 Intel Xeon 2.60GHz cores was 10 min

- General ROI settings depends on isotope
- Xe-133: ROI 3 and 4 considerable smaller in gamma direction.
- The beta ROI widths decreased. Lower side moved up due to higher background at low channels.





Resulting ROIs for 22 test samples. Original ROIs in red.

*See poster 3.1-375

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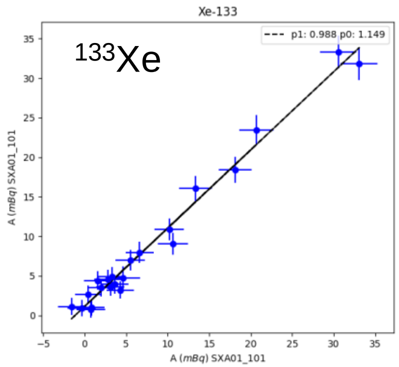
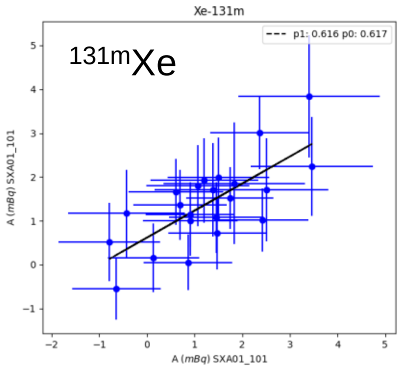
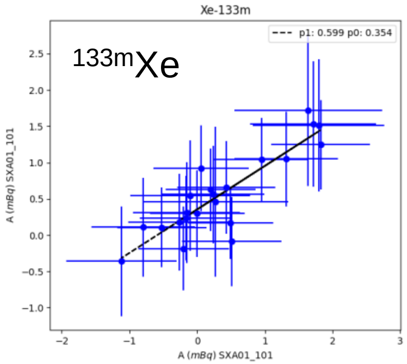
RESULTS - activities

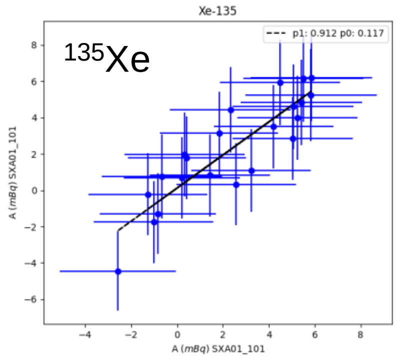
Consistent with original analysis*

Activities after MDA optimization (mBq)









Original activities (mBq)

No detections were found for ^{131m}Xe, ^{133m}Xe, and ^{135}Xe => 1:1 correlation not expected.

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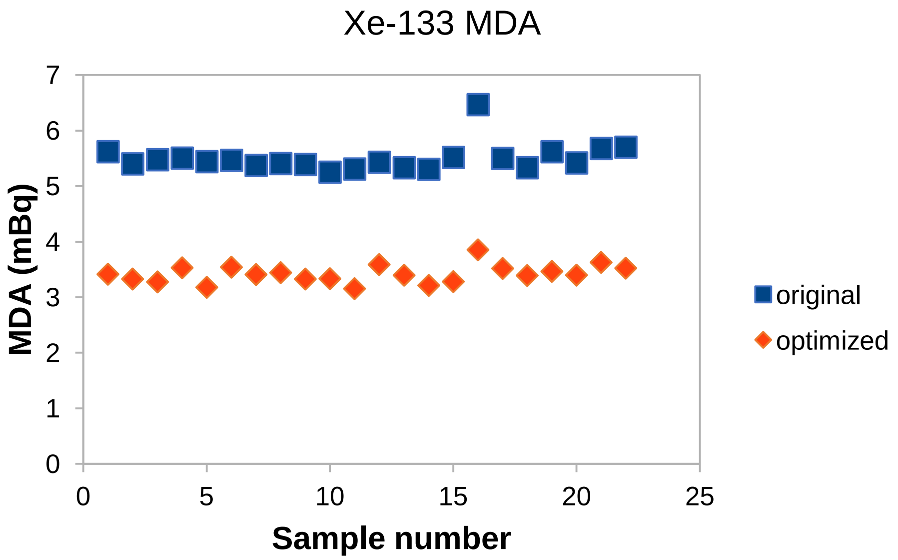
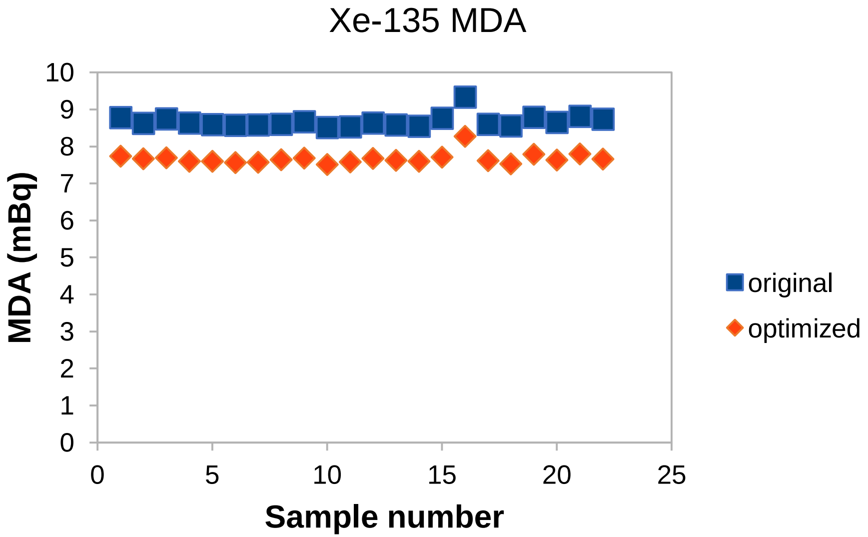
RESULTS - MDA



Average decrease 38%



Average decrease 12%

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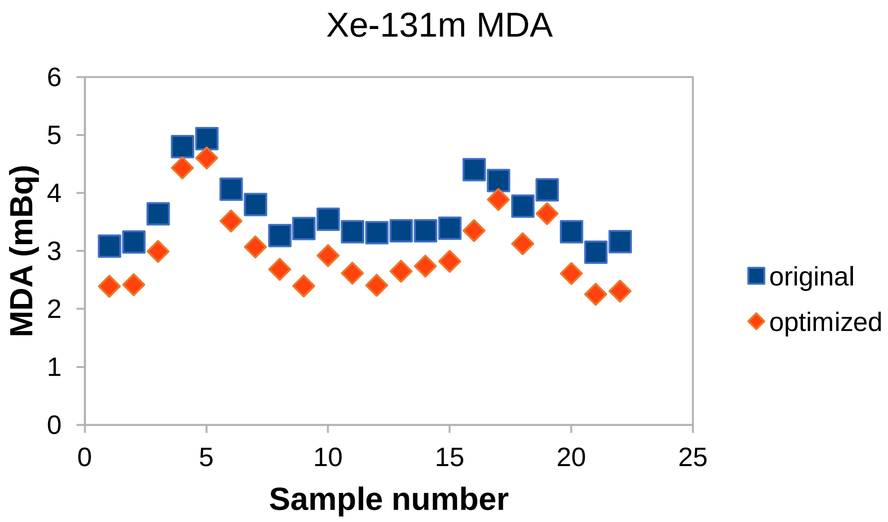
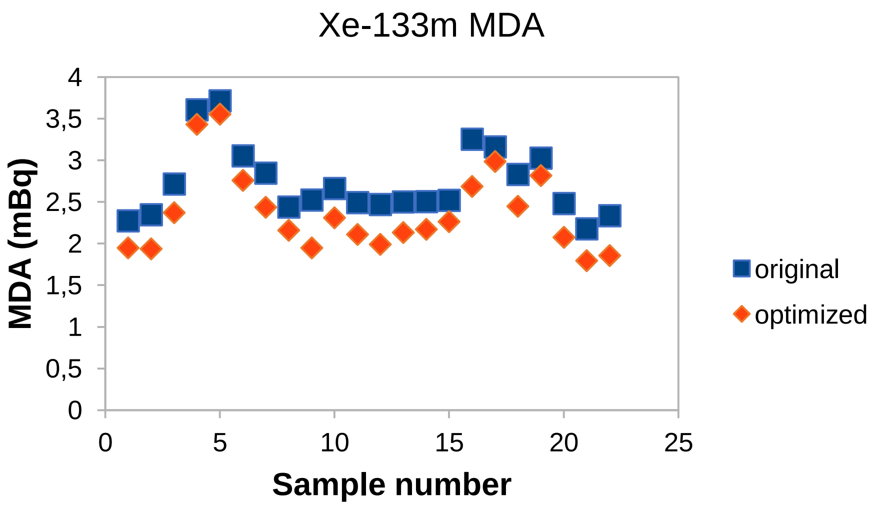
RESULTS – MDA



Average decrease 9%



Average decrease 13%

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CONCLUSIONS

- By using an objective function that includes the beta-gamma efficiency calibration, it is possible to use differential evolution to optimize the ROI settings for individual samples.
- The method requires systems with automatic energy drift correction.
- For a test set from a SAUNA-CUBE system – the Xe-133 MDA was reduced about 40%, and around 10% for the other isotopes.
- The method may also be used to improve the currently used system calibration.
- The size of the MDA improvement is expected to depend on detector background shape and size.
- The technique will be further studied using other system types and data sets with various isotopic composition.