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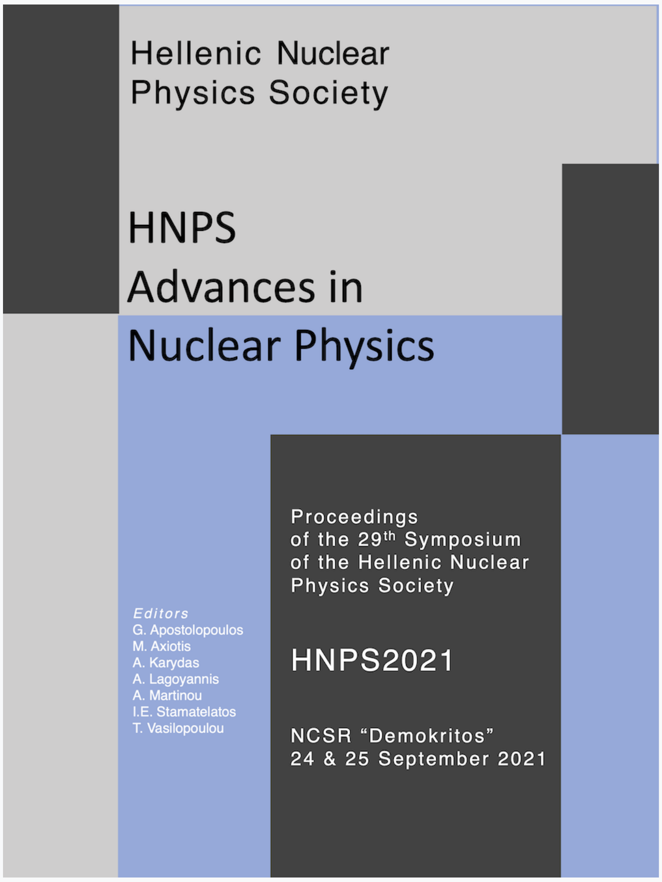

A Technique for Metallic Waste Characterization and Segregation in Management Routes

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A Technique for Metallic Waste Characterization and Segregation in Management Routes

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Abstract Adequate radiological characterization is important for optimization of metallic waste management. For decommissioning planning, the objective is to obtain a radiological understanding of the involved installation. The characterization at this stage could be carried out by means of: 1) neutron activation calculations based on reactor design and neutron flux; 2) dose rate measurements; 3) in-situ gamma spectrometry; 4) sampling for determination of the scaling factors in activated and contaminated components. During dismantling, in-situ characterization is carried out to classify and package the generated waste. Then, the packages are monitored for assessment of activity and determination of the management route. The selection of cutting and decontamination techniques should be based on accurate determination of the radionuclides inside the material and/ or on the surface contamination. . It is important to decide in which cases the decontamination will be efficient as well as to select the appropriate decontamination techniques based on whether the waste is slightly activated or contaminated or both. A Semi-empirical technique for optimization of determination of contamination and activation of components and metallic waste is under development based on combination of gamma spectrometry measurements and MCNPX Monte Carlo simulations. Firstly, the technique aims at reduction of the uncertainties related to the density and activity distribution. The specific activities inside and on the surface of the materials could be determined by using the measurement results of the proposed non-destructive technique in combination with the use of the scaling factors for activation and/ or contamination.

Keywords gamma spectrometry, MCNPX simulation, radiological characterization

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INTRODUCTION

After dismantling, in-situ characterization is carried out to classify and package of the generated waste [1]. This is usually achieved by using portable devices to measure dose rate or total counts. Then, the packages that are usually of 1-2 m^3 are monitored by non-destructive gamma spectrometry or plastic scintillators for assessment of the activity and determination of the management route. The measurement uncertainties in this case is high, some times higher than 90%. The uncertainty is mainly due to the density inhomogeneity as well as the geometry (that encompasses the geometry of the measurement package and the positioning of the sources). For localization of the sources and better estimation of radioactivity in waste packages, technique based on gamma camera [2] or system of plastic scintillation detectors [3] are examined.

The objective of the present work is to propose a new measurement layout for the non-destructive gamma spectrometry which will be used for classification of metallic waste into LLW to be managed as radioactive waste, VLLW to be decontaminated, EW for release. Furthermore, the parameters of the measurement to determine with higher accuracy the activity, regarding the

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activation as well as the surface contamination of the metallic waste are determined for more effective classification.

For the proposed non-destructive gamma spectrometry layout, the efficiencies of the measurement for several source geometries (i.e. straight & convex pipes, sheet metals and slightly convex surfaces, screws and bolts, flanges and filters, etc.) are estimated and the results are compared with the results of simplified geometries (e. g., pipes of specific diameter and thickness, metallic slabs, homogeneous density distribution etc.). Sensitivity analysis against the parameters that influence the measurement efficiency are carried out (e.g. diameter of pipes, thickness of metallic slabs etc.). Furthermore, the bias due to activity inhomogeneity for each source geometry (real or simplified) is determined [4].

The aim of this work is the determination of the optimum parameters of the measurement to achieve significant reduction of the uncertainty in the determination of the activities while the sensitivity for key radionuclides (Co-60, Cs-137 and in some cases Am-241 but could be also others) is sufficient for acceptable measuring time.

EXPERIMENTAL DETAILS

- *Methodology*

In Table 1 the sources of uncertainty in non-destructive gamma spectrometry measurements for metallic waste characterization, as well as the way to cope with them are shown.

Table 1. *The cause of uncertainty in non – destructive gamma spectrometry measurements and the way to cope with them*

Causes of Uncertainty	Way
a. Density in-homogeneity	Segregation based on the geometries of the metallic segments
b. Activity in-homogeneity (1): different measurement efficiencies for different distances of the source from the detector	Reduction of the range of the distances/ removal of the detector away from the source
c. Activity in-homogeneity (2): different measurement efficiencies for different angles of the source to the detector	Reduction of the solid angle of detection/ removal of the detector away from the source
d. Activity in-homogeneity (3): different attenuation of radiation	Reduction of the source thickness
e. Statistic of the measurement	Sufficient measurement efficiency in acceptable measuring time to achieve MDA $\leq$ 10 times lower than the clearance criterion

The steps of this work are the following:

a) Selection of the measurement layout and the preliminary parameters of the measurement: segregation of the metallic segments based on their geometries; small amount of metallic waste/ thin source; sufficient amount of metallic waste to be measured/ about 100 kg; removal of the detector away from the source while ensuring that the MDA ≤ 10 times lower than the clearance criterion for acceptable measuring time.

b) Estimation of the efficiencies for several geometries of the metallic segments (i.e. pipes, metallic slab, convex surfaces, screws and bolts, flanges etc.). The efficiencies should allow sufficient statistic for 1-2 min measuring time.
c) Determination of bias for several geometries of the segments.
d) Study of the simplified geometries which represent well each real geometry.
e) Carry out sensitivity analysis against the parameters that influence the efficiency of the measurement.
f) Drawing of the layout for the non-destructive gamma spectrometry measurement and determination of the parameters of the measurement.

MATERIALS AND METHODS

- *Measurement layout*

There are two option for source-detector configuration (see Fig. 1.):

a) The segments are put on a square shallow box 1.2m x 1.2m. The measurement is performed by one detector above the box, at the middle.
b) The segments are put on a square shallow box 1.2m x 1.2m. The box is divided in four squares and four detectors are above each square at the middle.

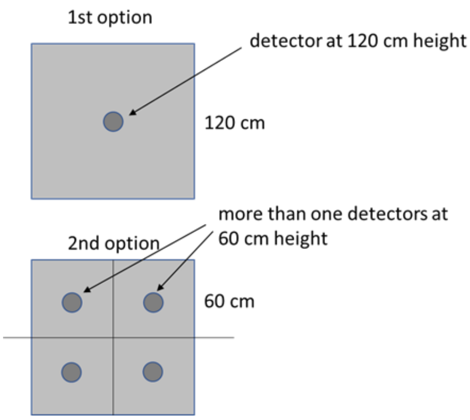

Fig. 1 *The two options foe source detector/ detectors configuration*

- *Monte Carlo simulations*

For description of the source-detector geometry, Monte Carlo simulations are carried out by using the MCNPX code. Several geometries of metallic segments like pipes, slabs etc., activated or contaminated, inside a square shallow boxes of 1.2m x 1.2m and 0.6m x 0.6m are simulated. The 3x3 NaI (Tl) detector was modeled as a cylinder of sodium iodide of 3 inches in diameter and 3 inches in length. The models are validated by volume sources of nominal activity or by the ISOCS software.

- *Preparation of the volume sources*

Standard source representing metallic segments of pipes with Cs-137 contamination were prepared. A filter paper is subdivided into squares of 9 cm2 each. In the center of each square, 0.05 ml (uncertainty in volume determination 10%) of Cs-137 acid solution (2 M HNO_3,) of (240 ± 24) Bq/ml is dispensed, using a 0.5 ml pipette. The mean surface activity of the contaminated paper, eventually equalling the surface contamination of the volume source, is 1.30 ± 0.13 Bq/cm^2. The paper is positioned between two plastic sheets and cover the internal surface of pipes.

RESULTS AND DISCUSSION

1. Internally contaminated pipes in shallow box – first measurement option

The geometrical centre of the 3x3 NaI detector is placed at 1.2m above the bottom of the square shallow box of 1.2m x 1.2m. Three cases of 0.003m thickness pipe (diameter of 0.1m, 0.2m and 0.3m) are put in the box, in one layer. Each pipe is divided into 3 segments. The efficiency of each segment and the total efficiency for homogeneous activity distribution on the pipes are shown in the Fig. 2, 3 and 4.

The total efficiency for the pipes: a) of diameter 0.3m is 1.24*10^{-4} and the maximum positive and negative bias for the contaminated segments is of the order of +16 % and -14 % respectively; b) of diameter 0.2m is 1.14*10^{-4} and the maximum positive and negative bias for the contaminated segments is of the order of +16% and -18% respectively; c) of diameter 0.1m is 1.1*10^{-4} and the maximum positive and negative bias for the contaminated segments is of the order of +14% and -15% respectively.

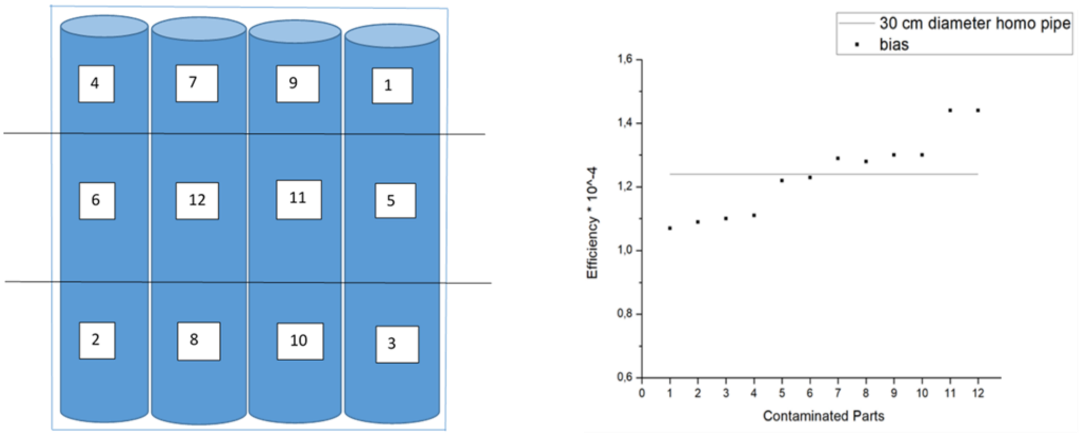

Fig. 2. *On the left is the configuration of the 30 cm diameter pipes in the 1.2m x 1.2m shallow box where the segments of the pipes are also shown. On the right the total efficiency for homogeneous activity distribution on the pipes (line) as well as the efficiency of each segment (points) are presented.*

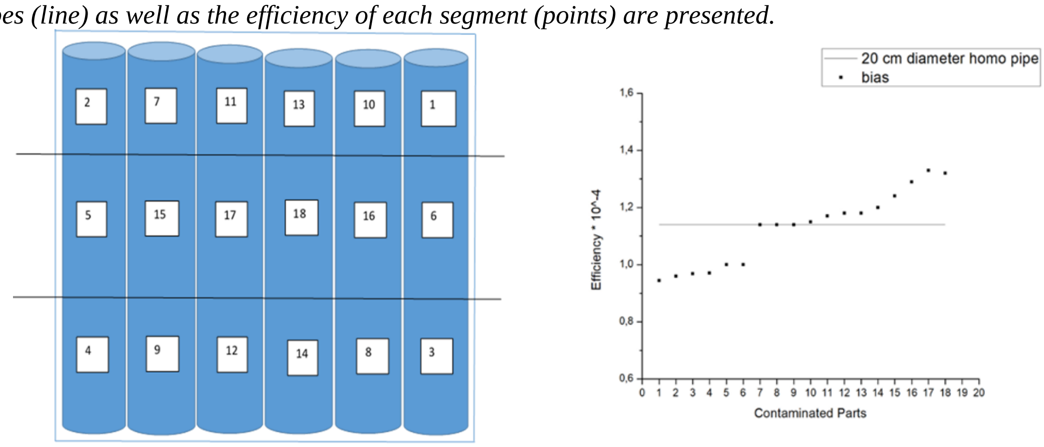

Fig. 3. *On the left is the configuration of the 20 cm diameter pipes in the 1.2m x 1.2m shallow box, where the segments of the pipes are also shown. On the right the total efficiency for homogeneous activity distribution on the pipes (line) as well as the efficiency of each segment (points) are presented.*

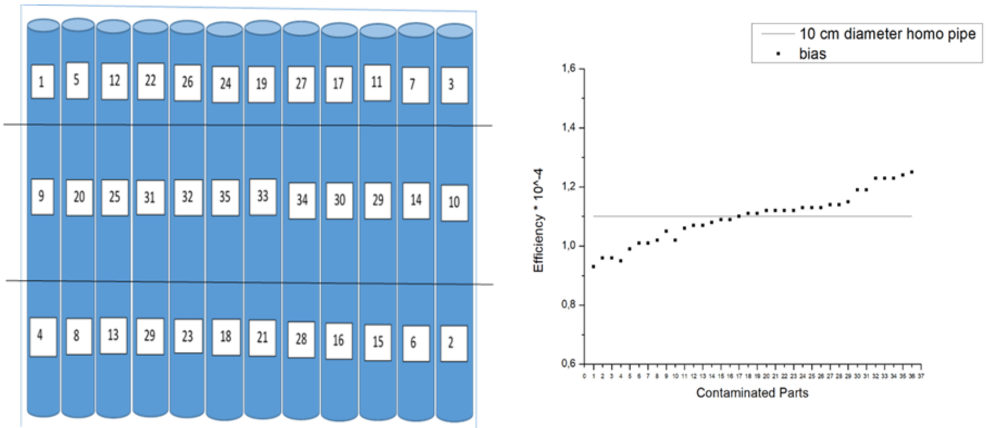

Fig. 4. *On the left is the configuration of the 10 cm diameter pipes in the 1.2m x 1.2m shallow box where the segments of the pipes are also shown. On the right the total efficiency for homogeneous activity distribution on the pipes (line) as well as the efficiency of each segment (points) are presented.*

2. Internally contaminated pipes in shallow box – second measurement option

The geometrical centre of the 3x3 NaI(Tl) detector is placed at 0.6m above the bottom of the shallow box 0.6m x 0.6m. Three cases of 0.003m thickness pipe (diameter of 0.1m, 0.2m and 0.3m) are put in the box, in one layer. Each pipe is divided into 3 segments. The total efficiency for homogeneous activity distribution on the pipes as well as the bias in case all the activity is on the closest and the most remote segments to the detector are shown in the Table 2.

Table 2. *Total Efficiency for homogeneous activity distribution and bias*

Diameter (m)	Efficiency	Max positive bias	Min negative bias
0.1	$4.80 * 10^{-4}$	+16	-14
0.2	$5.74 * 10^{-4}$	+19	-9
0.3	$7.10 * 10^{-4}$	+14	-5

3. Activated metallic slab-second measurement option

The geometrical centre of the 3x3 NaI(Tl) detector is placed at 80cm above the bottom of the shallow box 0.6m x 0.6m. An activated metallic slab 0.6m x 0.6m and 0.005m thickness is put in the box. The metallic slab is divided into 9 segments. The efficiency of each segment and the total efficiency for homogeneous activity distribution inside the slab are shown in the Fig. 5.

The total efficiency for homogeneous activity distribution when: a) the slab is placed at the bottom of the shallow box is $2.87*10^{-4}$ and the maximum positive and negative bias for the segments is of the order of +6 % and -3 % respectively, b) the slab is placed at 0.1m from the bottom of the shallow box is $3.71*10^{-4}$ and the maximum positive and negative bias for the contaminated segments is of the order of +9% and -4% respectively, c) the slab is placed at 0.2m from the bottom of the shallow box is $4.94*10^{-4}$ and the maximum positive and negative bias for the contaminated segments is of the order of +13% and -6% respectively, d) the slab is placed at 0.3m from the bottom of the

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shallow box is $6.8*10^{-4}$ and the maximum positive and negative bias for the contaminated segments is of the order of +17% and -6%, respectively.

4. Simplified geometries for pipes in shallow box

The 3x3 NaI(Tl) detector is placed at 0.6 m and at 0.8m above the bottom of the shallow box 0.6m x 0.6m. Three cases of 0.003m thickness pipe (diameter of 0.1m, 0.2m and 0.3m) are put in the box, in one layer. The total efficiency in case of homogeneous activity distribution on the pipes for each diameter is shown in the Fig. 5. and compared by the simplified geometries: a) 0.2m thickness slab positioned in the box, b) 0.2m diameter pipes positioned in the box.

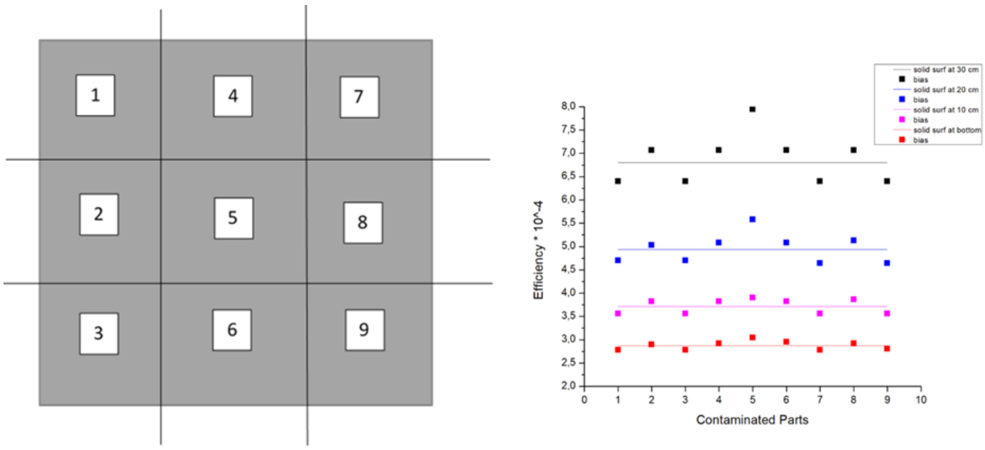

Fig. 5. *On the left is the metallic slab 0.6m x 0.6m x 0.005m divided into 9 segments. On the right the total efficiency for homogeneous activity distribution inside the slab (lines) as well as the efficiency of each segment (points) are presented*

– Simplified by pipe of 0.2m

The efficiency of homogeneous activity distribution on the pipes of 0.2m diameter when the detector is at 0.6m is $5.74*10^{-4}$ while for the pipes of diameter of 0.1m and 0.3m the deviation is of the order of -16% and +24% respectively. The efficiency of homogeneous activity distribution on the pipes of 0.2m diameter when the detector is at 0.8m is $3.10*10^{-4}$ while for the pipes of diameter of 0.1m and 0.3m the deviation is of the order of -10% and +18% respectively (see fig. 6).

– Simplified by 0.2m thickness slab

The efficiency of homogeneous activity distribution inside the slab of 0.2m thickness when the detector is at 0.6m is $6.17*10^{-4}$ while for the pipes of diameter 0.1m, 0.2m and 0.3m the deviation is of the order of -29%, -8% and +15% respectively. The efficiency of homogeneous activity distribution inside the slab of 0.2m thickness when the detector is at 0.8m is $3.34*10^{-4}$ while for the pipes of diameter 0.1m, 0.2m and 0.3m the deviation is of the order of -17%, -7% and +10%, respectively (see fig.6).

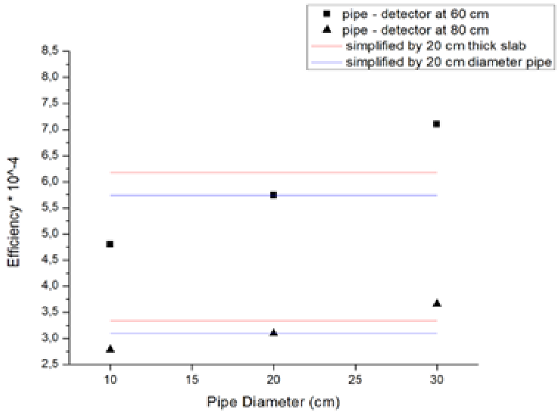

Fig. 6. *Efficiencies of pipes and simplified geometries*

5. Slab simplified geometry for 0.2m diameter pipes with different thickness in the shallow box

The geometrical centre of 3x3 NaI detector is placed at 0.6m and at 0.8m above the bottom of a shallow box 0.6m x 0.6m. In the shallow box, 3 pipes of 0.2m diameter are put in one layer. The thickness of the pipes is changing from 0.001m to 0.096m thickness. This geometry is compared by a slab of 0.6m x 0.6m x 0.2m simplified geometry positioned in the box. The efficiency against the thickness of the pipes wall is shown in the Fig. 7.

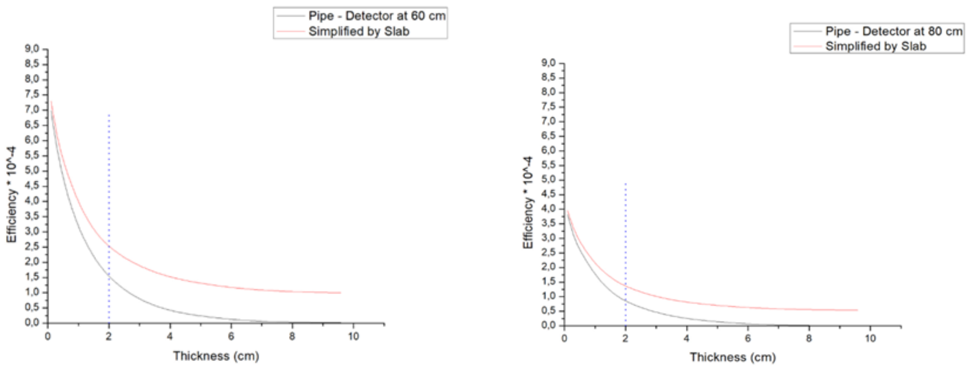

Fig. 7. *Efficiencies comparison of the real geometry of 0.2m diameter pipes put in a shallow box of 0.6m x 0.6m in one layer, with the simplified geometry of a 0.6m x 0.6m x 0.2m slab, against the thickness of the pipes wall.*

CONCLUSIONS AND FUTURE WORK

The preliminary results of this study showed that by the proposed source-detector/ detectors layout, crucial reduction of the measurement uncertainty can be achieved, while the sensitivity is sufficient for acceptable measuring time. The activities of the metallic waste, inside the material and on the surface of the material, will be determined with higher accuracy and therefore a more effective classification and sorting of metallic waste will be achieved. Furthermore, the use of simplified geometries could replace the real geometries of the source, making the non-destructive gamma spectrometry measurements more user friendly. In case of pipes of different wall thickness a preliminary result is that the efficiencies of the real and the simplified geometry are getting closer while the wall thickness is reducing. From the work done in this study we can extract two preliminary conclusions: a) the measurement efficiency decreases when the detector - source distance increases, while the accuracy is getting better, b) the accordance between real and simplified geometries doesn't get better when the distance between detectors and sources increases.

The future work will focus on the investigation of more items geometries (i.e. rods, convex pipes, convex surfaces, grids etc.) as well as of other simplified geometries. Moreover, sensitivity analysis against the parameters which influence the measurement efficiency will be carried out.

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