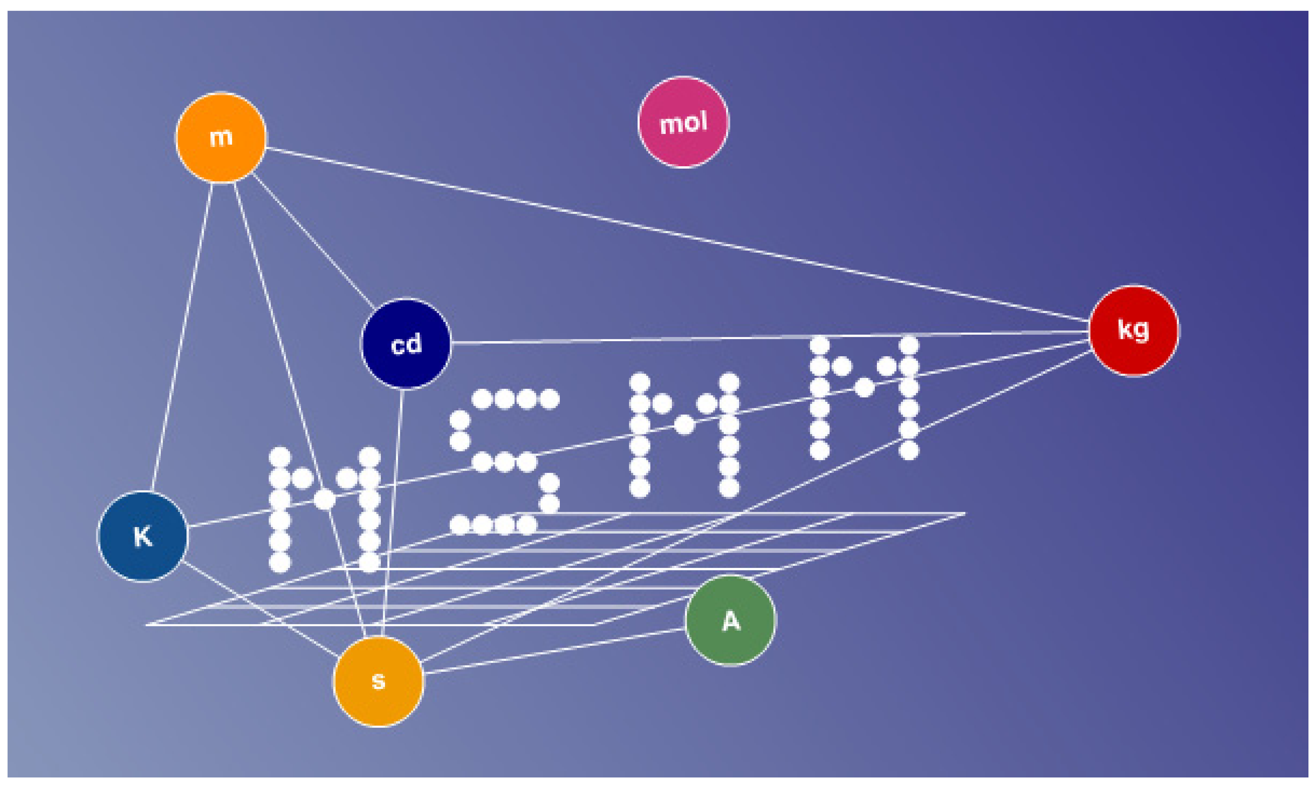

Ensuring the validity of measurement results through the use of triangulation rules

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Measurement results are critical in various industries, including healthcare, aerospace, and manufacturing. Inaccurate measurements can lead to severe consequences, such as faulty medical diagnoses, airplane crashes, and defective products. Therefore, it is essential to ensure the validity of measurement results to maintain the integrity and reliability of measurements.

To comply with the ISO/IEC 17025 standard, laboratories must demonstrate the validity of their measurement results [1]. They can achieve this by using the triangulation rules, which involves using multiple methods or instruments to measure the same quantity. By comparing the results of multiple measurements, laboratories can identify any discrepancies.

Poster presentation at MSMM 2023 Workshop.

The proposed tool is indicated, for example, for measurements involving ratios, such as the calibration of high standard resistors using a **commercial dual sources high resistance bridge based on a modified Wheatstone bridge** [2, 3, 4]. To evaluate the equation limit (1a, 1b) we performed Monte Carlo simulations (MCs), by GUM Workbench software in the student version OMCE V: 1.2.14, in the following scenarios of equation (2) using data [3, 4]:

MCs1: Error 0, meaning there are no differences between the traceability paths, and approximately 90% of the values obtained from the MCs are below the equation's limit.

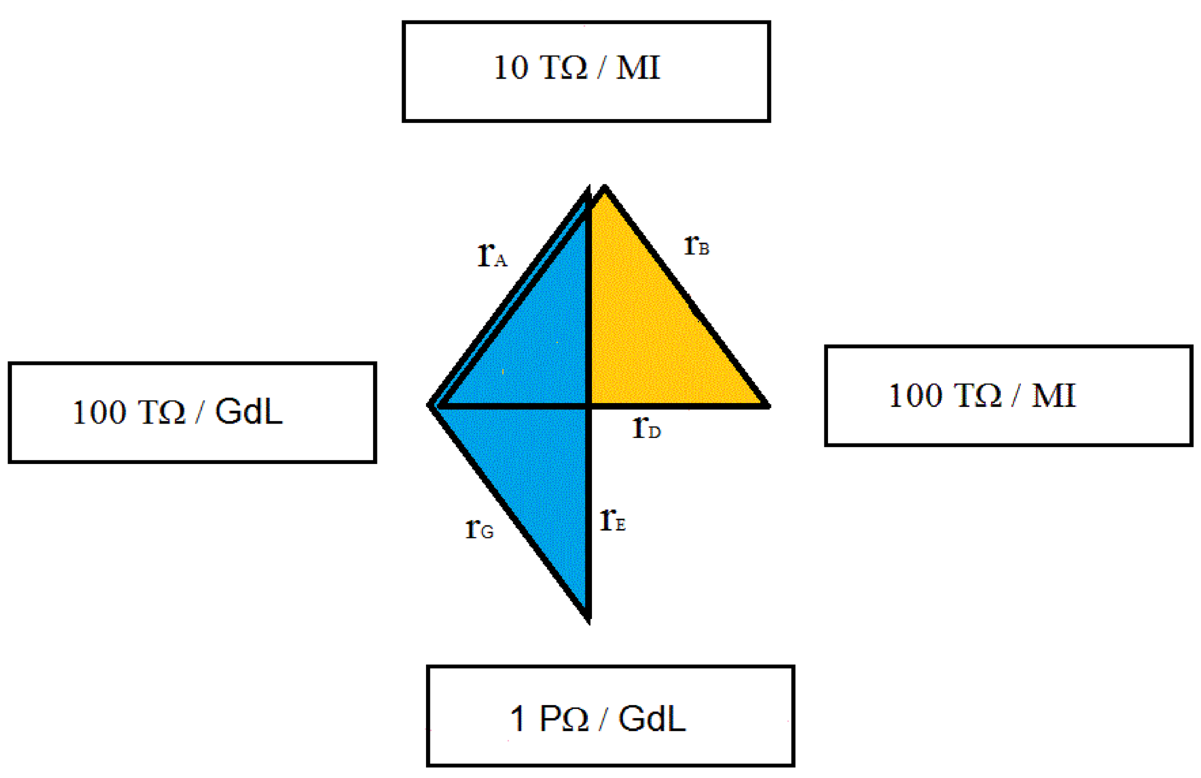
MCs2: Error equal to the equation's limit (sum of the uncertainties of the ratios), meaning the difference between the traceability paths is equal to the error limit, and about 50% of the values obtained from the MCs are below the equation's limit.

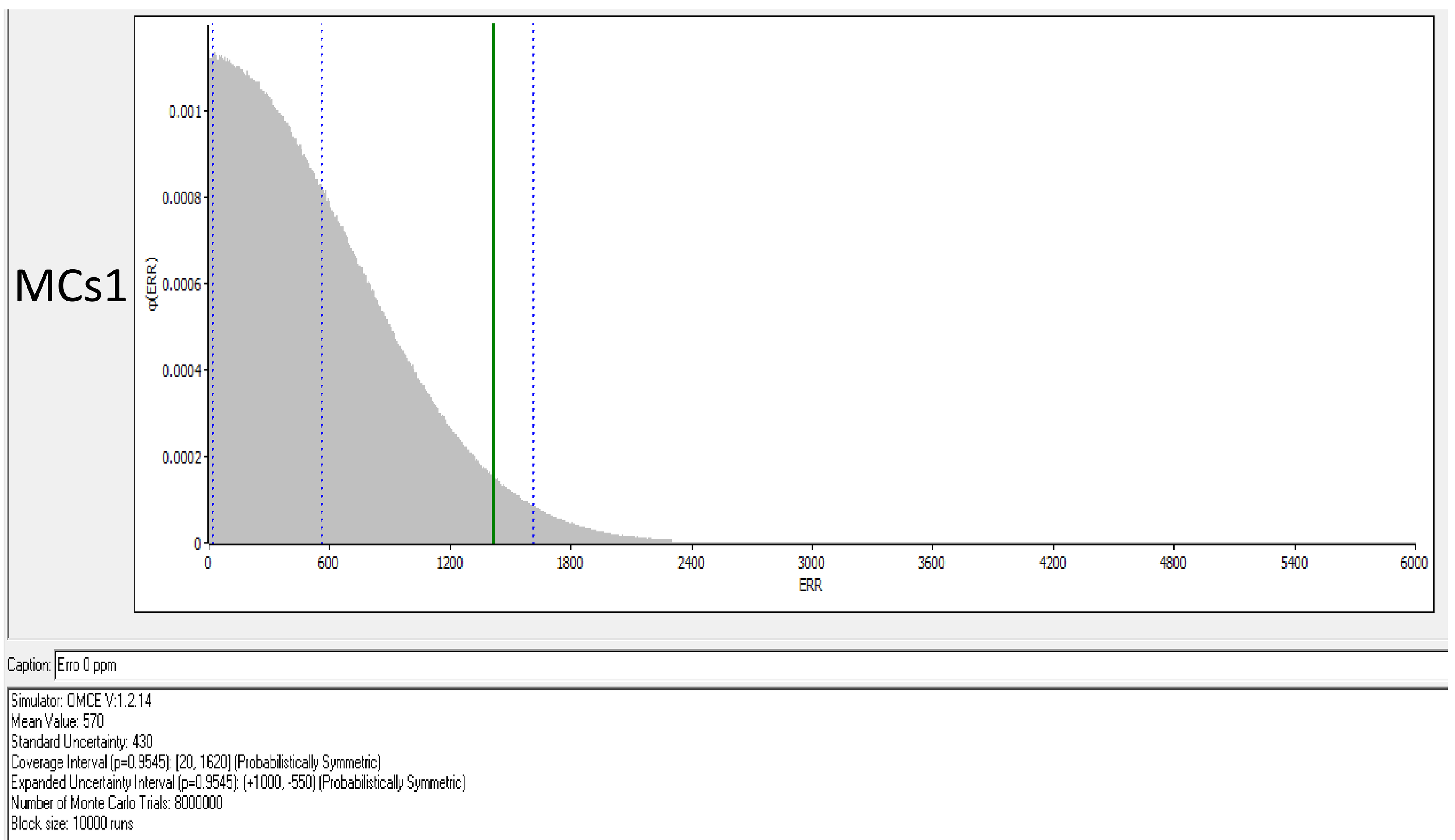
MCs3: Error equal to twice the equation's limit (sum of the uncertainties of the ratios), meaning the difference between the traceability paths is double the error limit, and only about 10% of the values obtained from the MCs are below the equation's limit.

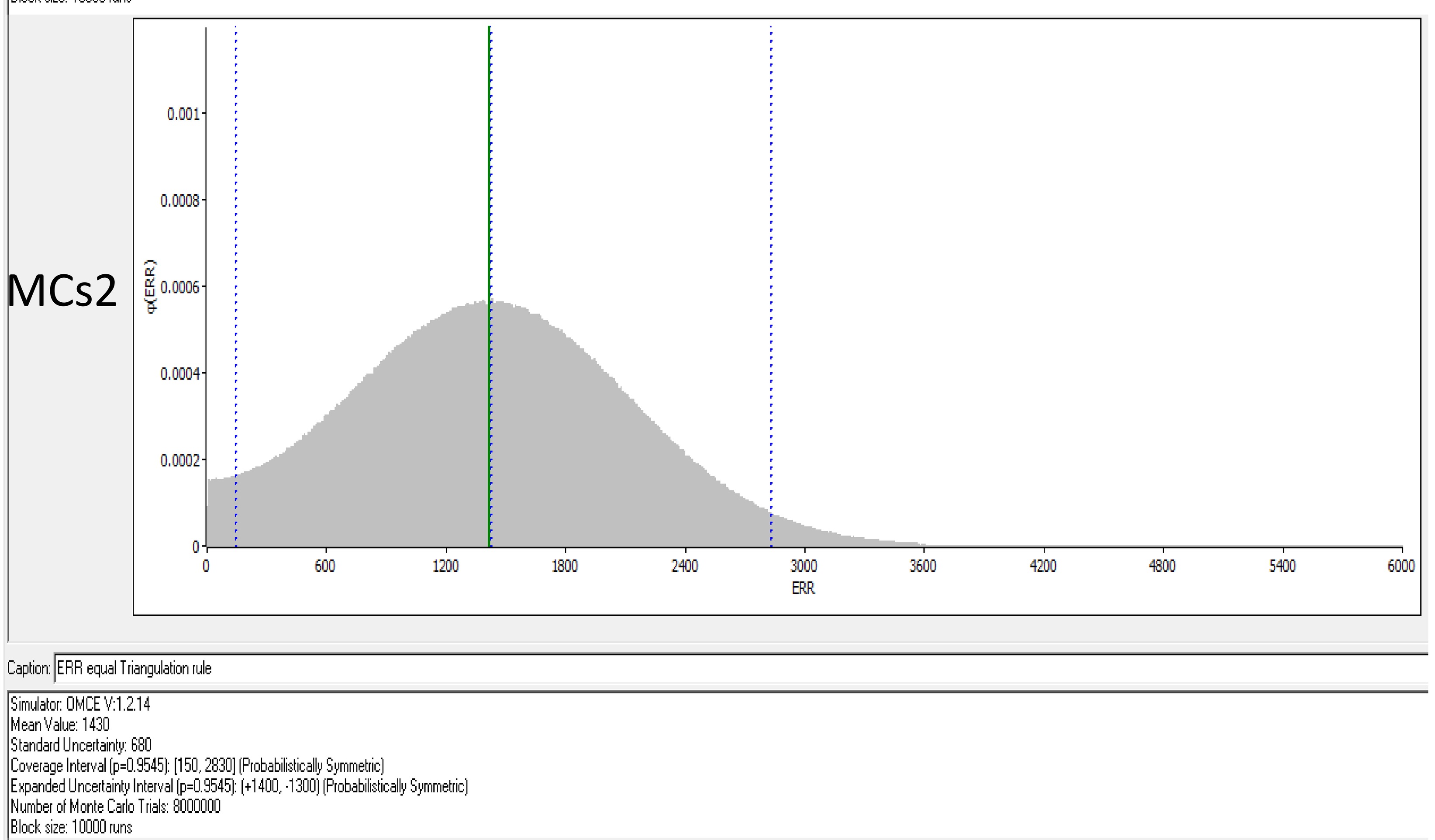
$$\bar{r}_A \cdot \bar{r}_G \cong \bar{r}_E \quad \text{(1a)} \quad \Rightarrow \quad \left(1 - \frac{\bar{r}_A \cdot \bar{r}_G}{\bar{r}_E}\right) \cdot 10^6 \cong 0 \quad \text{(ppm) (1b)}$$

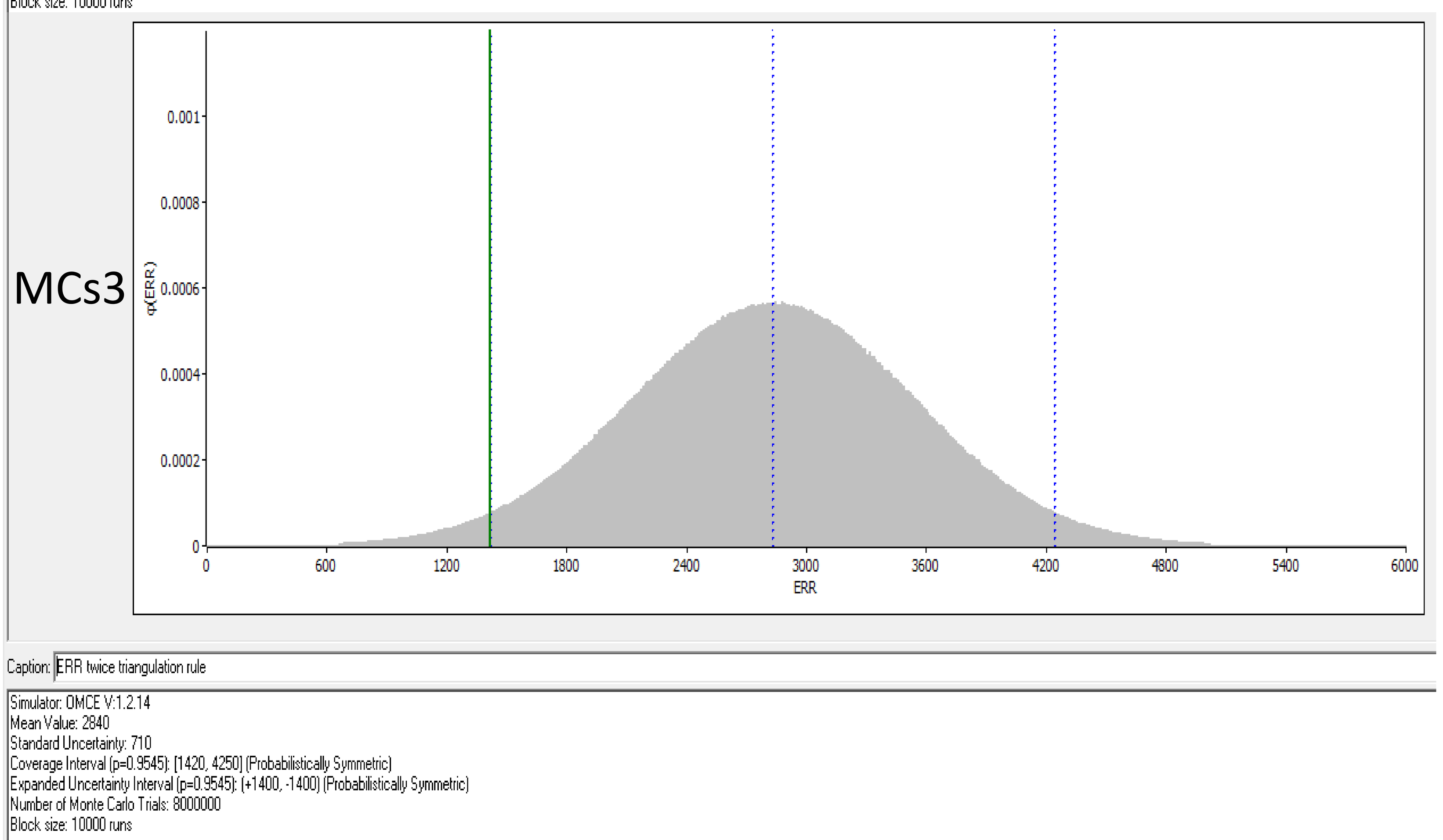
$$abs\left(1 - \frac{\bar{r}_A \cdot \bar{r}_G}{\bar{r}_E}\right) \cdot 10^6 < \sqrt[2]{u_{rA}^2 + u_{rE}^2 + u_{rG}^2} \quad \text{(ppm)} \quad (2)$$

Comparisons	Ratio	Mean ratio $\bar{r}$	Relative standard deviation (of the mean), u_r	Measurement distribution
A. 10 TΩ / MI : 100 TΩ / GdL	1 : 10	$\bar{r}_A$	u_{rA}	Normal
E. 10 TΩ / GdL : 1 PΩ / GdL	1 : 100	$\bar{r}_E$	u_{rE}	Normal
G. 100 TΩ / GdL : 1 PΩ / GdL	1 : 10	$\bar{r}_G$	u_{rG}	Normal









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