Modelling and optimization of SOLEIL II survey and uncertainty assessment of the measurement process using Monte Carlo approach

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ABSTRACT

SOLEIL synchrotron is preparing a major upgrade that will lead to the commissioning of a new and more powerful machine by 2030. Questions naturally arise about the technical solutions that will be chosen to align the components of the future machine and meet the tight alignment tolerances. To identify the best alignment strategy (implantation of the geodetic networks, fiducialization of magnets, mechanical alignment of the components, survey, smoothing etc.), the development of a model has been initiated. The aim is to simulate the measurement process, to estimate the alignment uncertainties of the machine components and test various measurement configurations. This contribution focuses on the approach used to develop the model and presents some preliminary results.

ALIGNMENT TOLERANCES

Tolerance interval = *interval of permissible value of a property* [1]

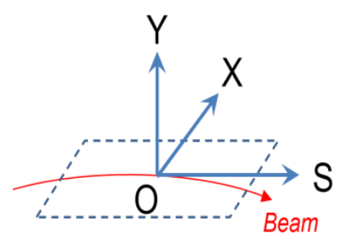
Conformity assessment measurements for alignment:

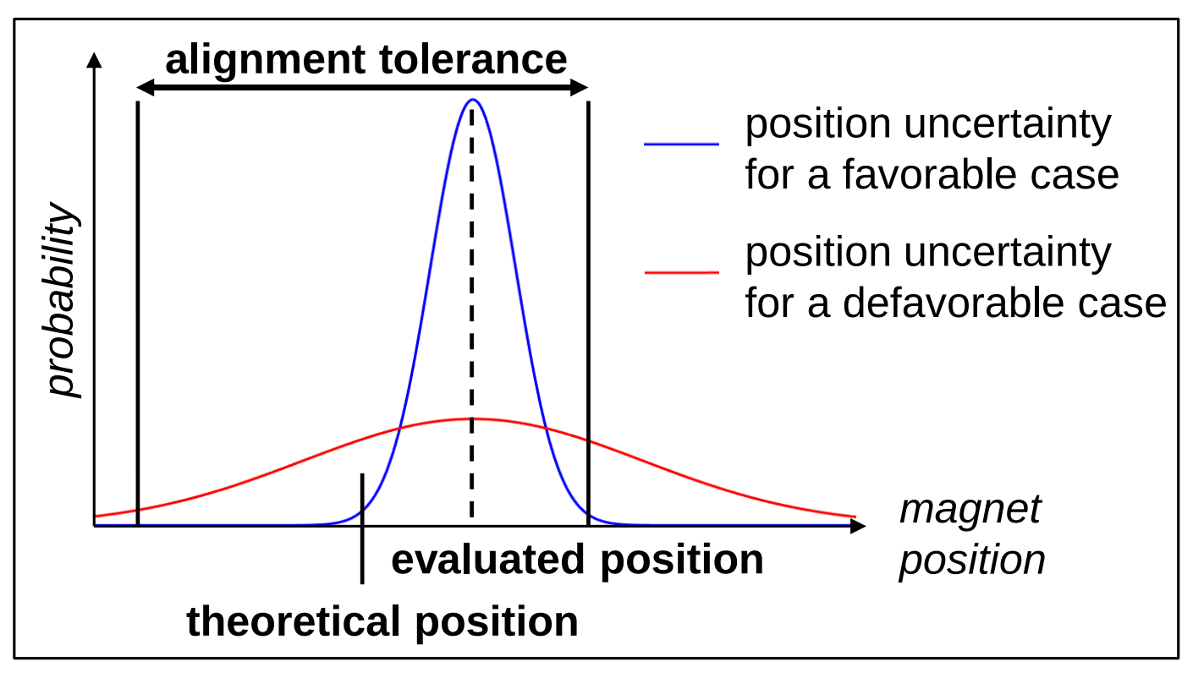
- measure the positions of magnetic centre magnets
- compare the deviations of these positions with the tolerances set by physicists
- decide if a realignment is necessary

Due to measurement uncertainty, there is always a risk when deciding whether or not a magnet position is within the required alignment tolerances. Incorrect decisions are of two types:

- consider that the magnet is aligned when it is not (false positives)
- consider that the magnet is not aligned when it is (false negatives)

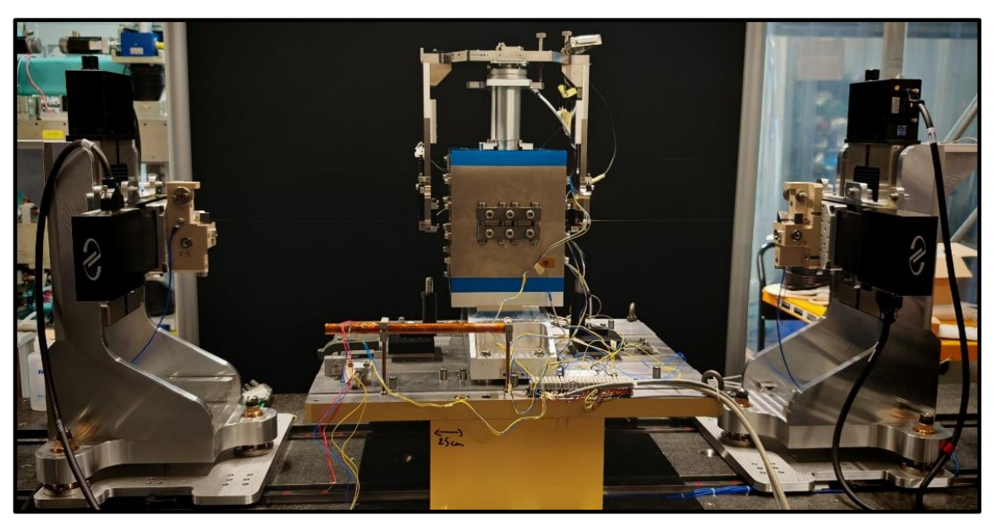
Points to check	Simulation inputs for Accelerator Physics	Tolerances
Alignment of magnets on a girder	$\sigma_{T_X} = \sigma_{T_Y} = 25\ \mu m$ $\sigma_{T_S} = 50\ \mu m$ $\sigma_{R_S} = \sigma_{R_X} = \sigma_{R_Y} = 100\ \mu rad$	$-50\ \mu m < T_X,T_Y < 50\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$ $-200\ \mu rad < R_S,R_X,R_Y < 200\ \mu rad$
Alignment of magnets on section matching girders	$\sigma_{T_X} = \sigma_{T_Y} = 10\ \mu m$ $\sigma_{T_S} = 50\ \mu m$ $\sigma_{R_S} = \sigma_{R_X} = \sigma_{R_Y} = 100\ \mu rad$	$-20\ \mu m < T_X,T_Y < 20\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$ $-200\ \mu rad < R_S,R_X,R_Y < 200\ \mu rad$
Alignment of girders with respect to each other (close or on both sides of a straight section)	$\sigma_{T_X} = \sigma_{T_Y} = 25\ \mu m$ $\sigma_{T_S} = 50\ \mu m$ $\sigma_{R_X} = \sigma_{R_Y} = 10\ \mu rad$ $\sigma_{R_S} = 60\ \mu rad$	$-50\ \mu m < T_X,T_Y < 50\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$ $-20\ \mu rad < R_X,R_Y < 20\ \mu rad$ $-120\ \mu rad < R_S < 120\ \mu rad$
Control of the circumference	$\sigma_C = 1$ mm	-2 mm < C < 2 mm

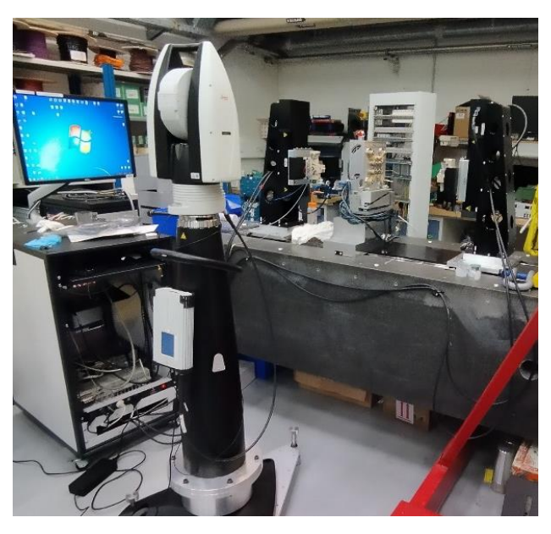


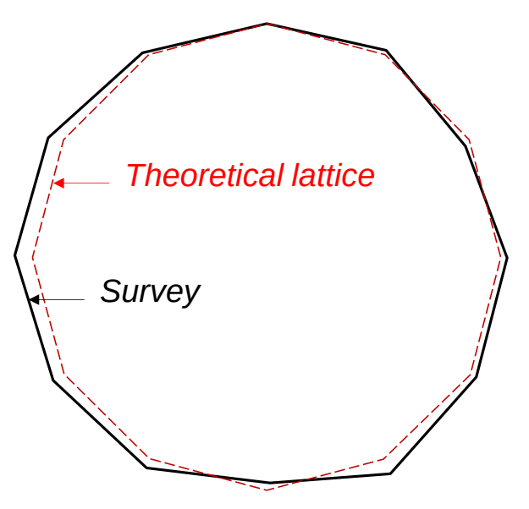


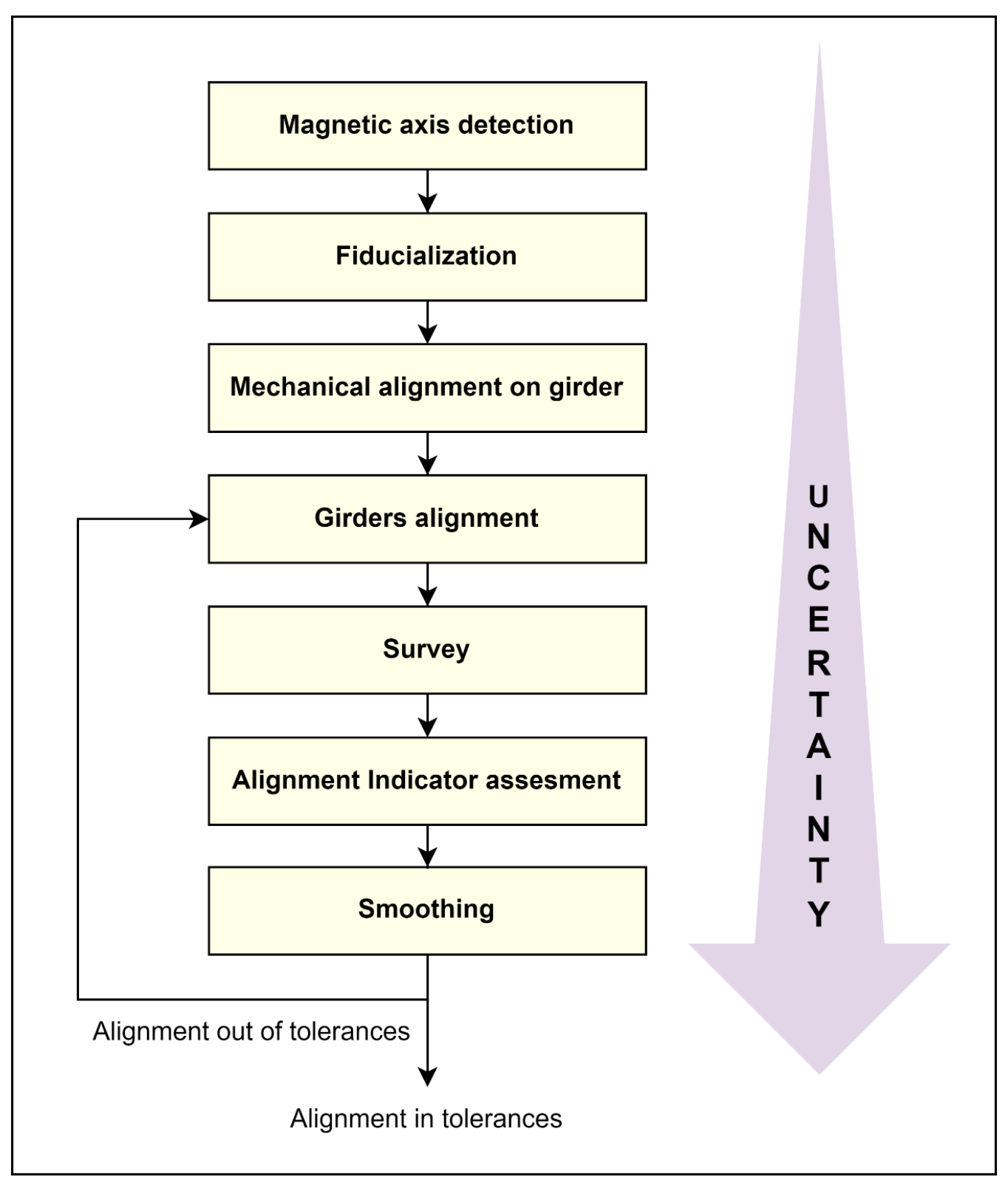
MEASUREMENT PROCESS

Each step of the measurement process contributes to the final uncertainty of the component alignment. The challenge is to control this uncertainty so that the alignment tolerances are respected.

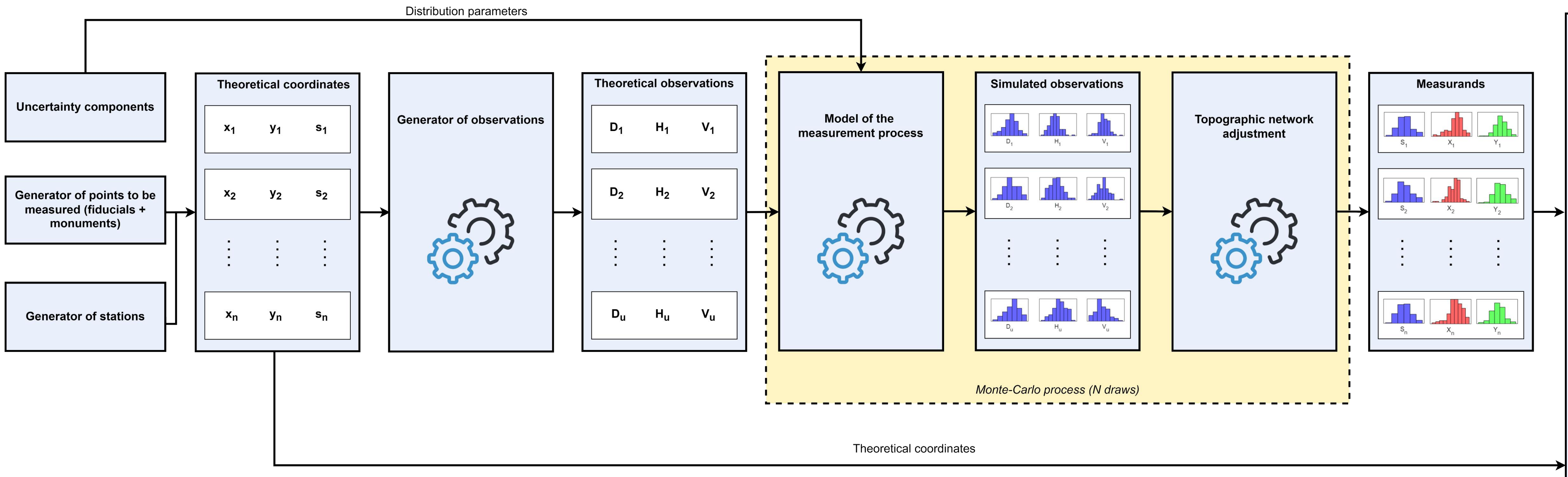


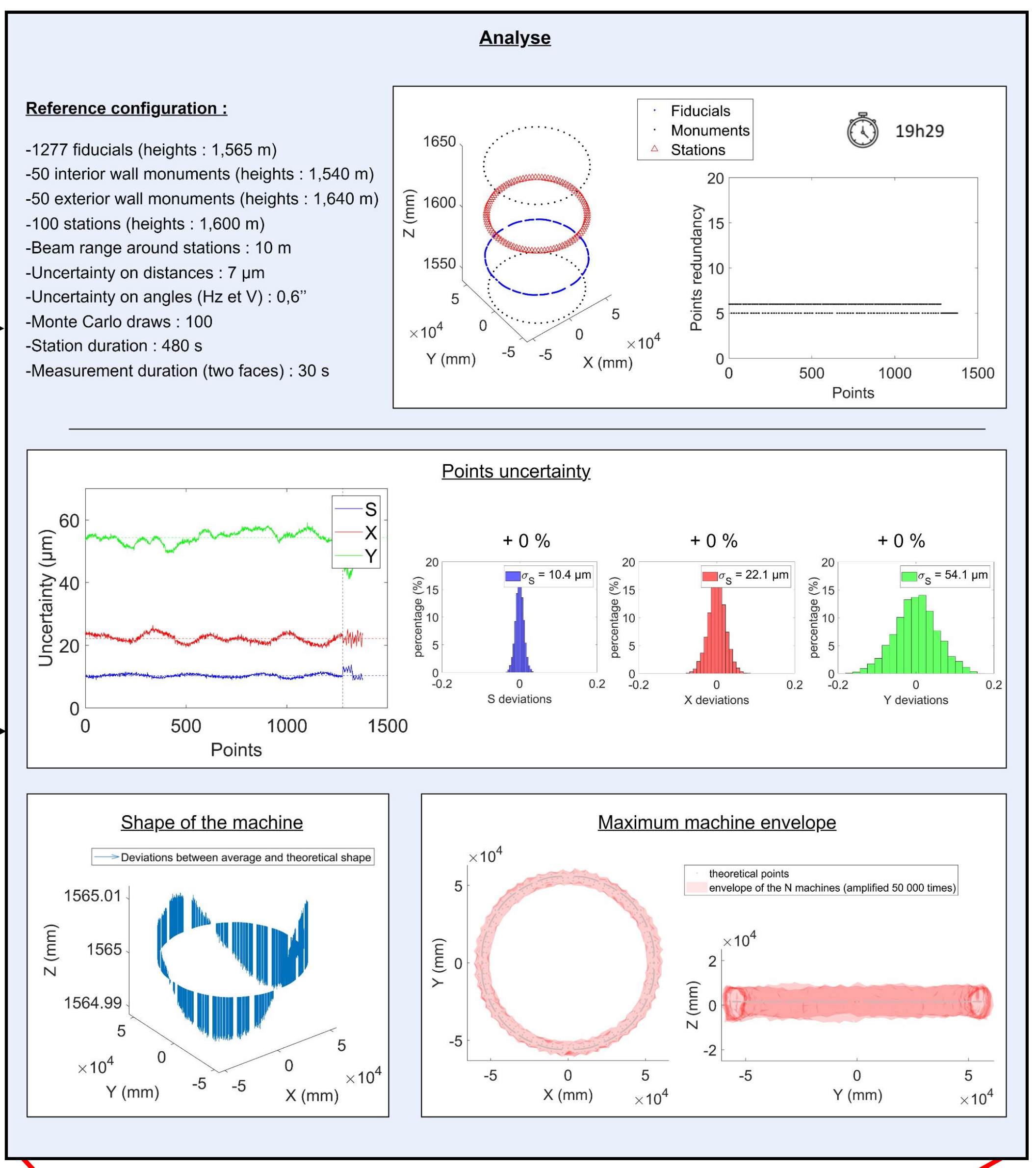






SIMULATION SCHEME





Reference configuration :

- -1277 fiducials (heights : 1,565 m)
- -50 interior wall monuments (heights : 1,540 m)
- -50 exterior wall monuments (heights : 1,640 m)
- -100 stations (heights : 1,600 m)
- -Beam range around stations : 10 m
- -Uncertainty on distances : 7 µm
- -Uncertainty on angles (Hz et V) : 0,6''
- -Monte Carlo draws : 100
- -Station duration : 480 s
- -Measurement duration (two faces) : 30 s

Uncertainties applied to the model:

Currently applied to the model:

Observation	PDF law	Standard deviation / Mean value
Distance	Gaussian	$\sigma = 7\ \mu m$ $\overline{m} = D$
Horizontal angle	Gaussian	$\sigma = 3\ \mu rad$ $\overline{m} = Hz$
Vertical angle	Gaussian	$\sigma = 3\ \mu rad$ $\overline{m} = V$

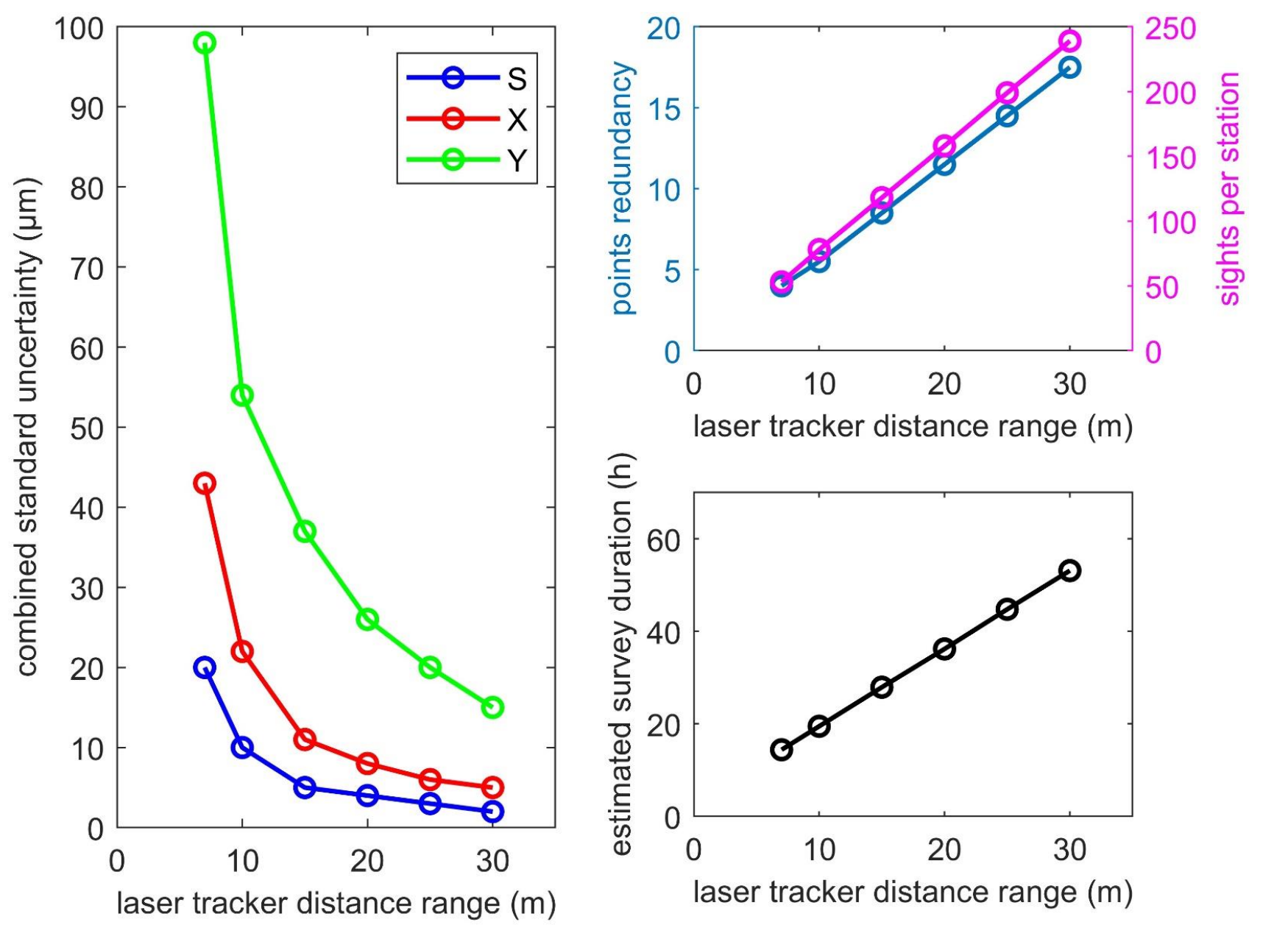
To be added to the model:

- uncertainty on the tracker inclinometer ;
- uncertainties related to environmental sensors ;
- uncertainties related to tracker geometry ;
- uncertainties related to machine movement ;
- uncertainties related to tracker ADM ;
- uncertainties related to tracker IFM ;
- uncertainties related to the reflector ;
- etc.

RESULTS

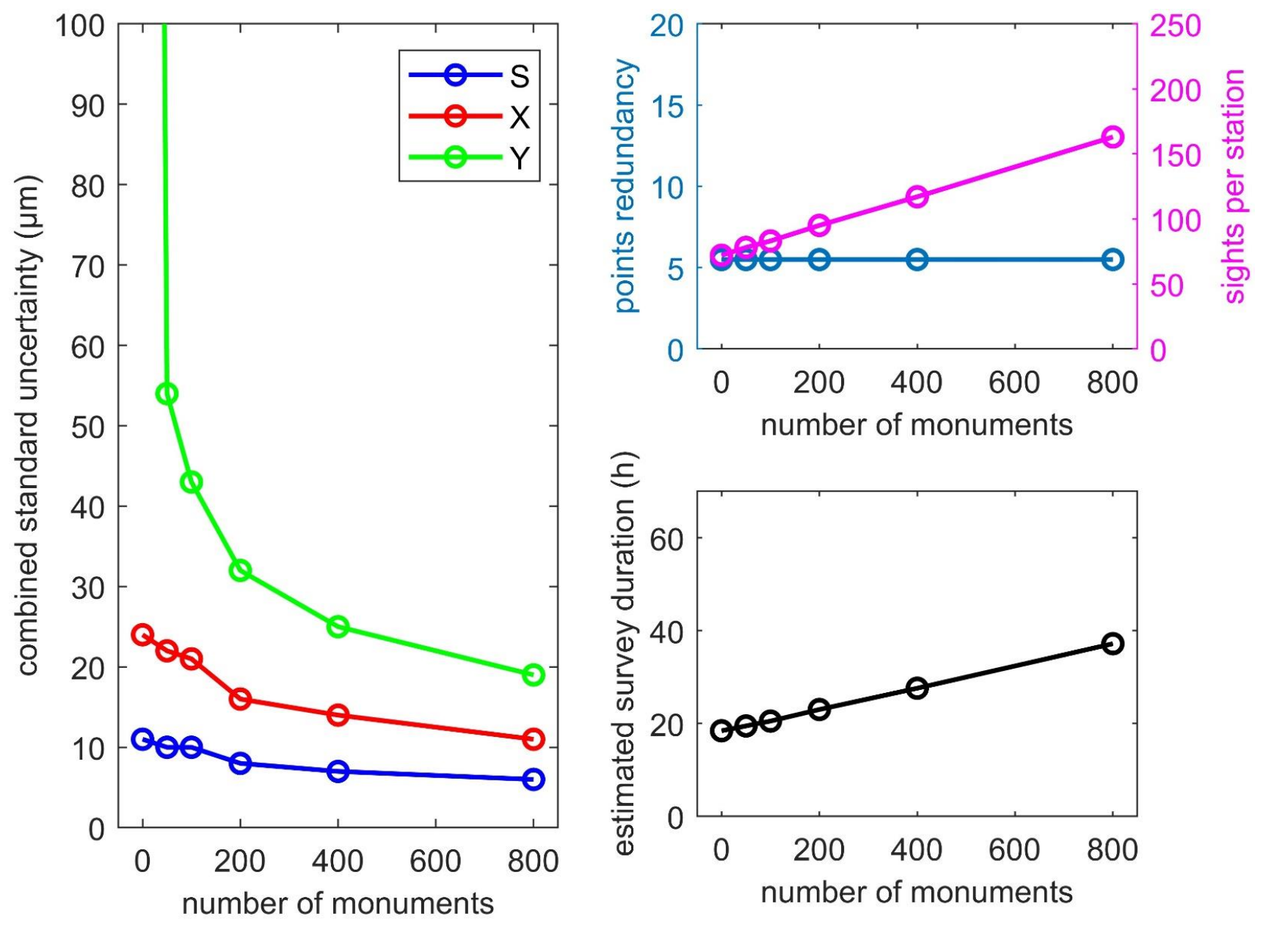
Several simulations of survey configurations were carried out. The idea is to vary the model's input variables to find those that contribute the most to the final uncertainty. In order to analyse the influence of certain parameters, a reference machine configuration was first defined. Each tested configuration can then be compared with this reference configuration.

The same procedure was used for each configuration tested. 100 sets of compensated coordinates were obtained, and a Helmert transformation was performed for each set of coordinates. The aim is to analyse the dispersion of the set of compensated points around the theoretical points by calculating the standard deviation of the 100 measurement scenarios. The combined standard uncertainty obtained for each configuration and the estimated duration of the survey will be the main parameters to compare the relevance of one configuration with respect to another.



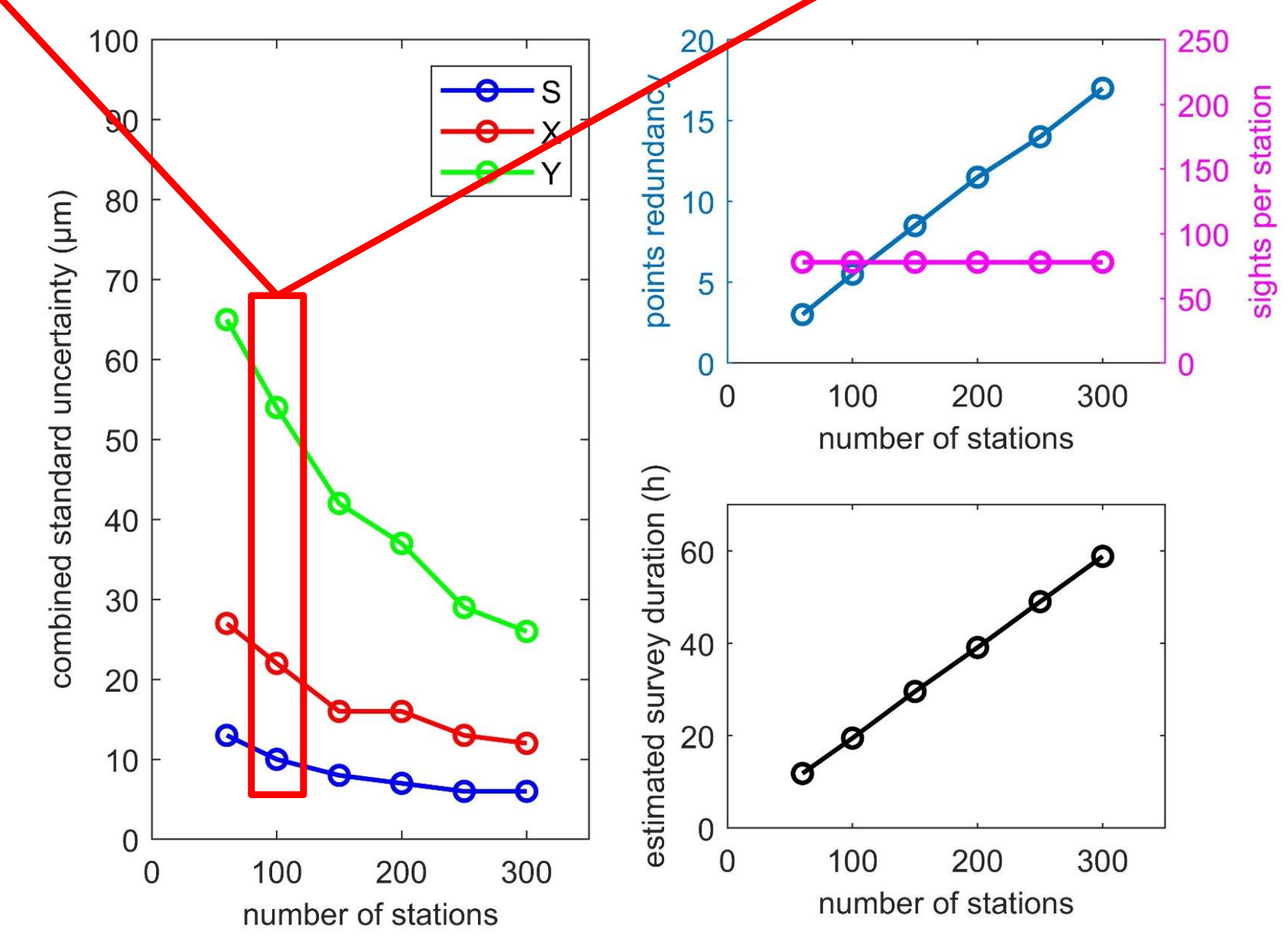
Laser tracker distance range influence:

-Increase point redundancy and sights per stations
-Doubling laser tracker distance range = duration **x 1.8**



Number of monuments influence:

-Increase only the sights per stations
-Doubling number of monuments = duration **x 1.3**



Number of station influence:

-Increase only the points redundancy
-Doubling number of stations = duration **x 2.0**

CONCLUSION

The model of the measurement process currently under development is very important for determining the best alignment strategy for SOLEIL II. The aim of this work is to ensure that each component of the machine can be aligned within the tolerances set by the physicists. For the moment, the work has focused on modelling the machine survey. This is the step with the largest number of parameters to optimize (number of stations, number of monuments, location of monuments, laser tracker distance range, etc.). The model will need to be updated with new input parameters to make it more realistic. Next, the aim will be to implement optimization algorithms to consider all the input parameters simultaneously and find the best possible configuration.

Reference: [1] JCGM 106:2012 Evaluation of measurement data - The role of measurement uncertainty in conformity assessment