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Utilization of X-ray tomography data for process improvement in additive manufacturing through cross-correlation with real time monitoring data

Jitendra Singh Rathore¹, Setoain Imanol¹, Philippe Brédif¹, Vincent Bergeaud¹, Adrien Stolidi¹, Marius Costin¹

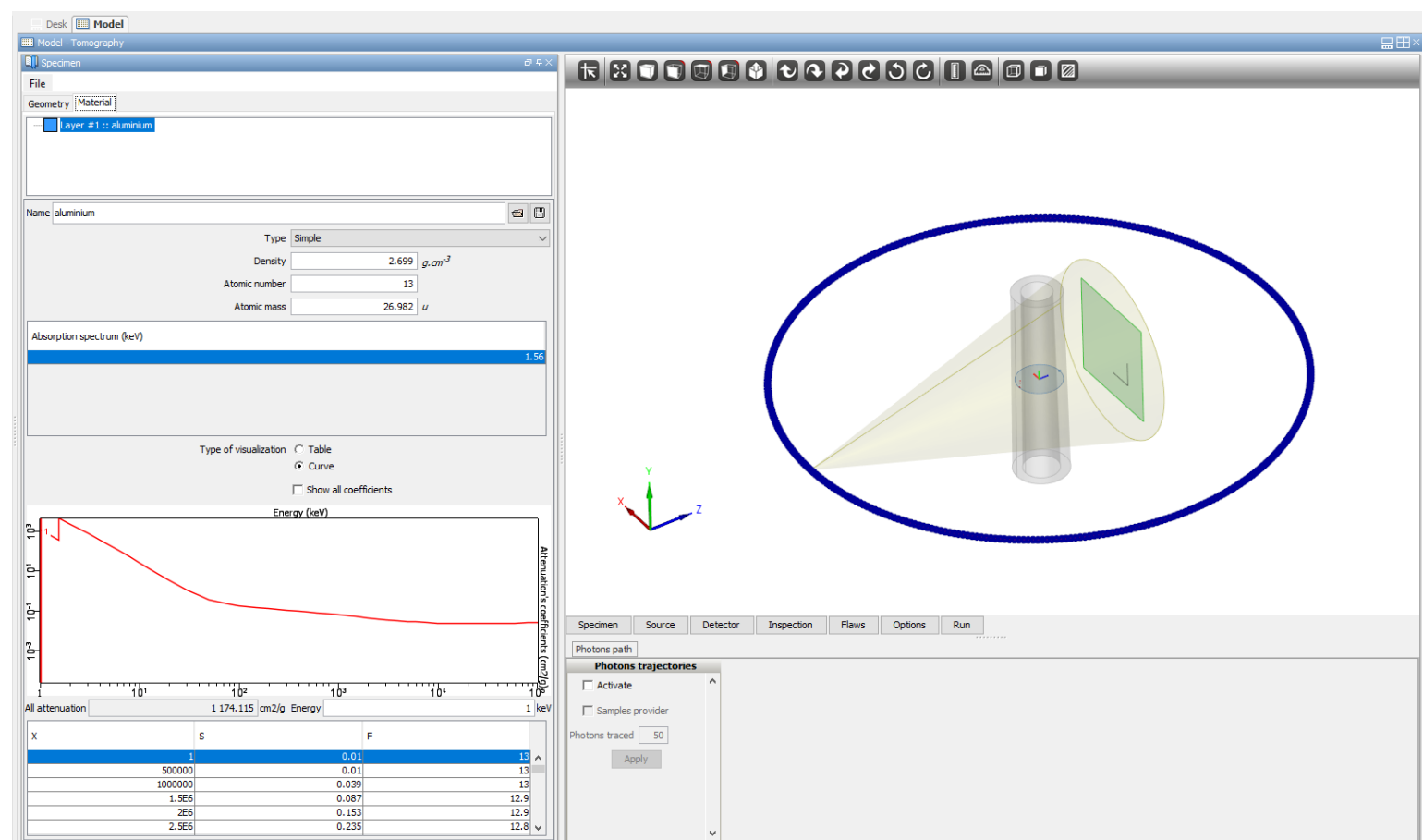
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Introduction

- Additive Manufacturing (AM) parts are often subject to defects which are induced from one or more undesirable variations in the process parameters.
- The process monitoring data are available from the machines but there is a lack of strategies about how this can be used in a meaningful way.
- CIVA is a software consisting of several model related to different NDT techniques
- The "RT" model consists of a number of capabilities



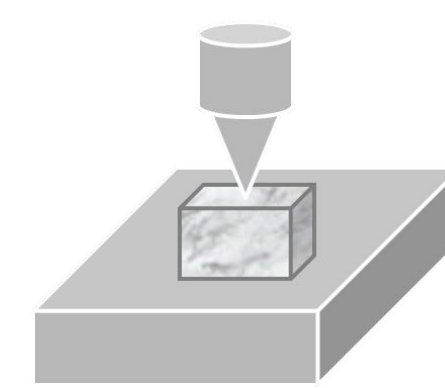
- RT/CT simulation
- RT Linear scan
- RT/CT import
- Parametric study
- POD Study
- Batch Manager



Methodology

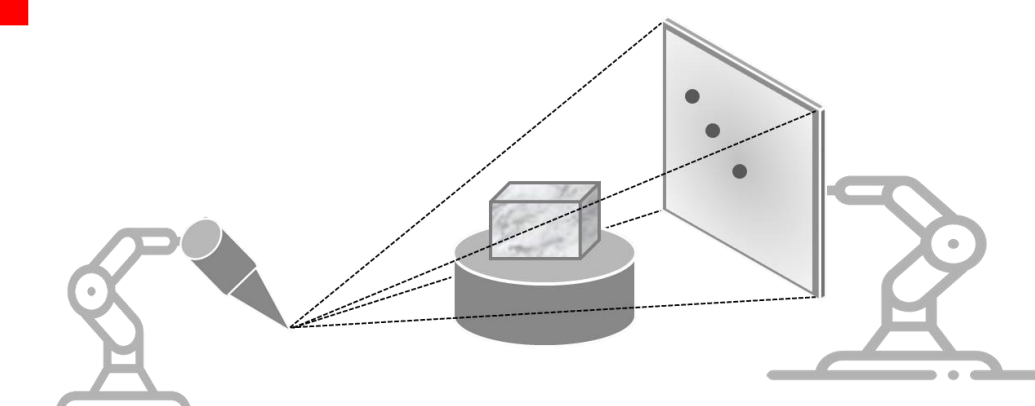
MANUFACTURING

- Additive manufacturing samples are produced with intentional variations in the process parameters
- The process data is recorded on the time scale
- A file containing monitoring data in a standardized Hierarchical Data Format (HDF5)



X-RAY CHARACTERIZATION

- The tomography acquisition are performed with an in-house robotic CT system
- A tomography file reconstructed file in the raw format
- The indication table (defect analysis) as CSV file



CIVA DEVELOPMENT

- Registration of the different files in a common frame
- Annotation of the monitoring files to specify the time ranges corresponding to the different AM layers
- Analysis of the monitoring files via inter-layer comparison
- Analysis of the monitoring files via comparison with tomographic data



New "AM" module

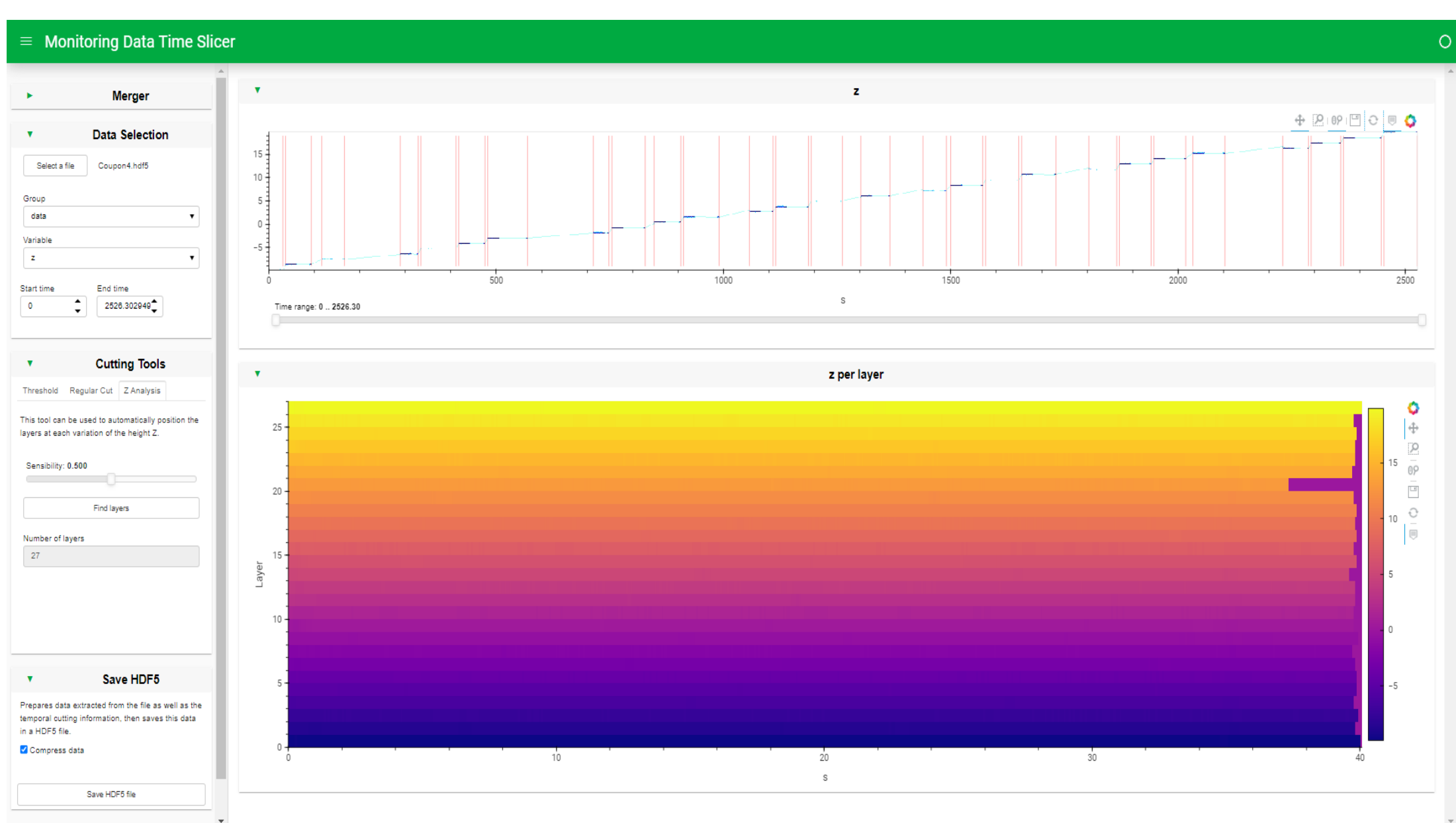
- The first version of the module is developed containing different tools
- Several validations are being performed



Annotation of monitoring data

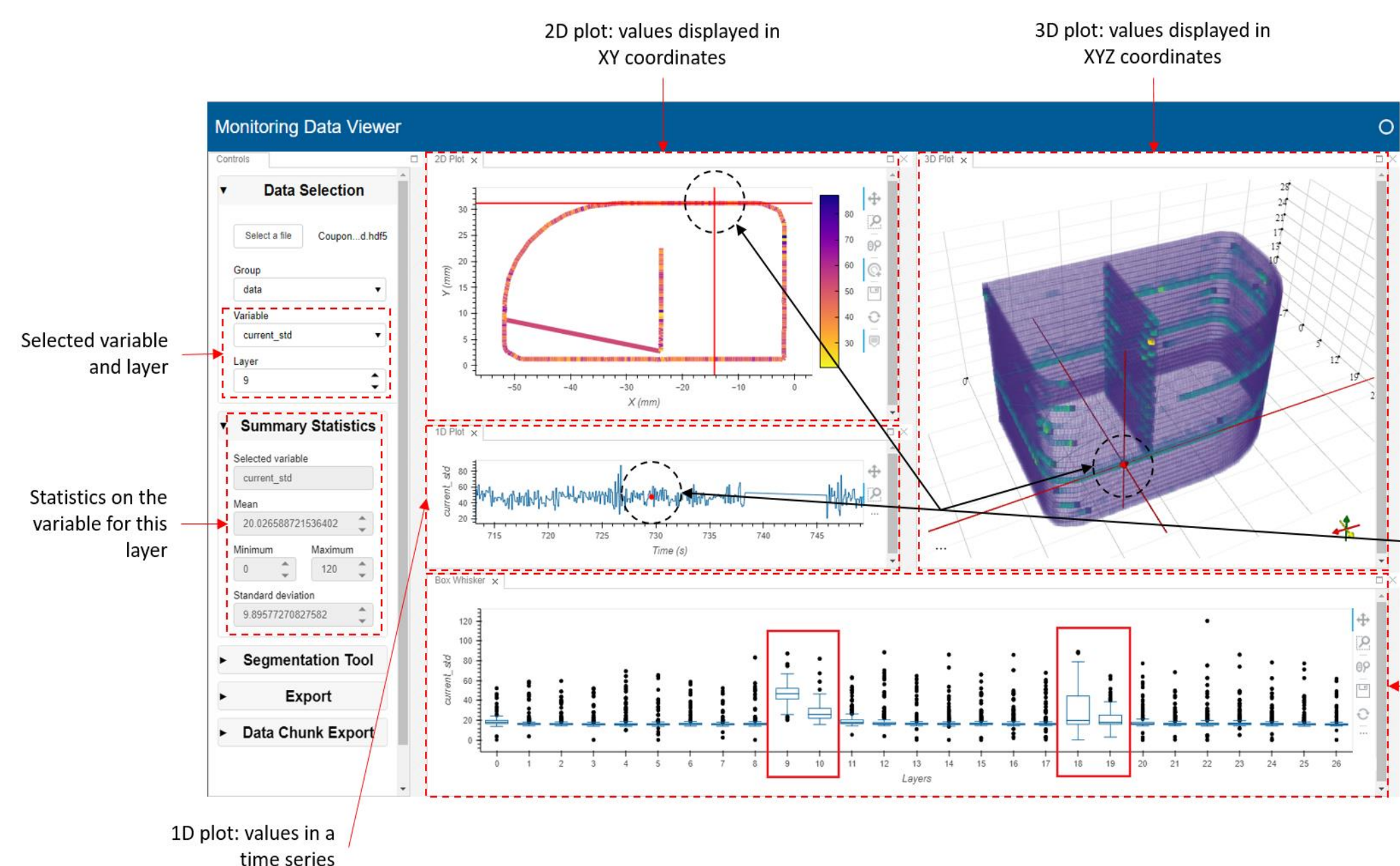
To be able to adapt to a majority of cases, this module has three tools to perform the temporal cutting of the data:

- Regular Cut aims at positioning the layers by taking a regular hypothesis (identical manufacturing time for each layer)
- Z Analysis allows layers to be positioned automatically with each variation in the Z-height signal
- Threshold allows the layers to be positioned semi-automatically each time a given threshold is crossed



Inter-layer comparisons

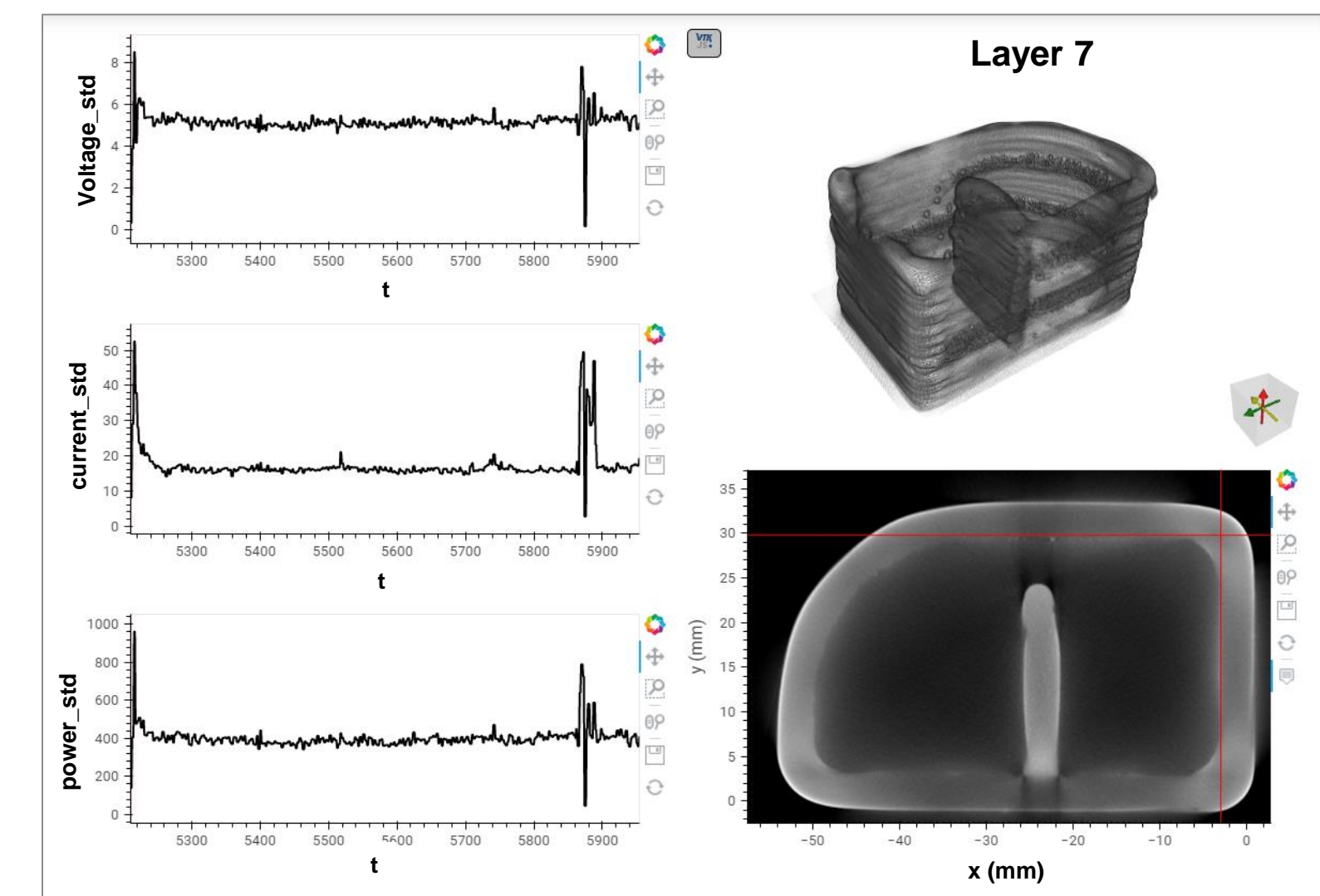
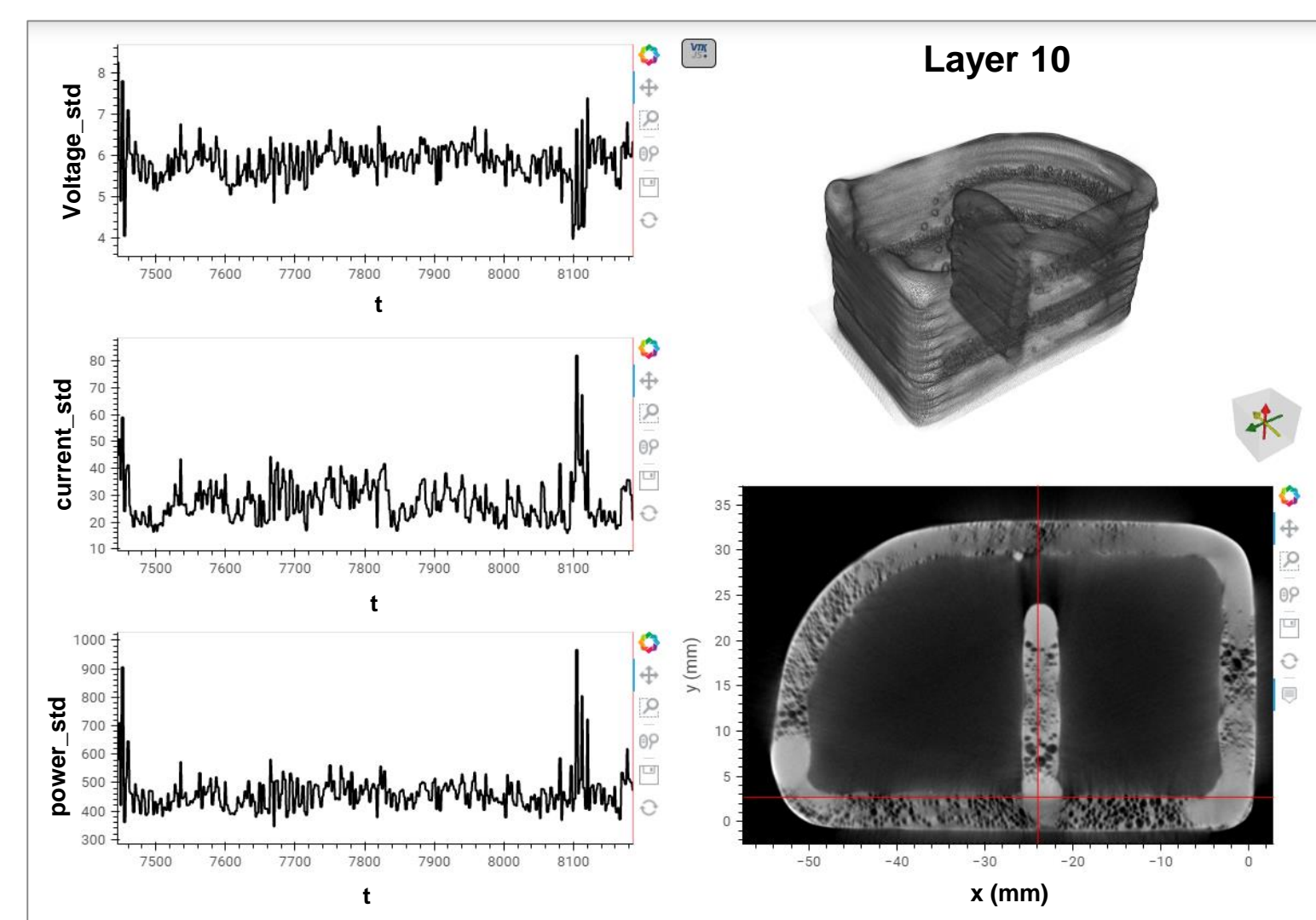
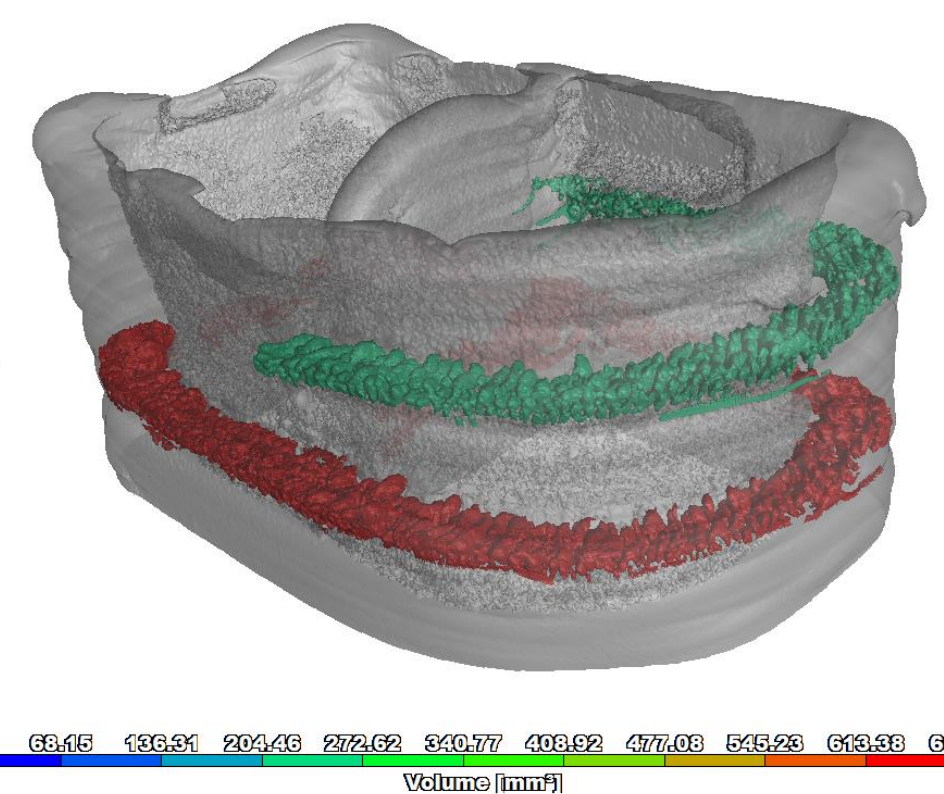
- 3D representation with a colour map in order to spot the outlying values observed during the process
- 2D representation in order to focus on a given layer
- Statistical analysis for each layer in order to compare the layers and identify the layers containing abnormal values



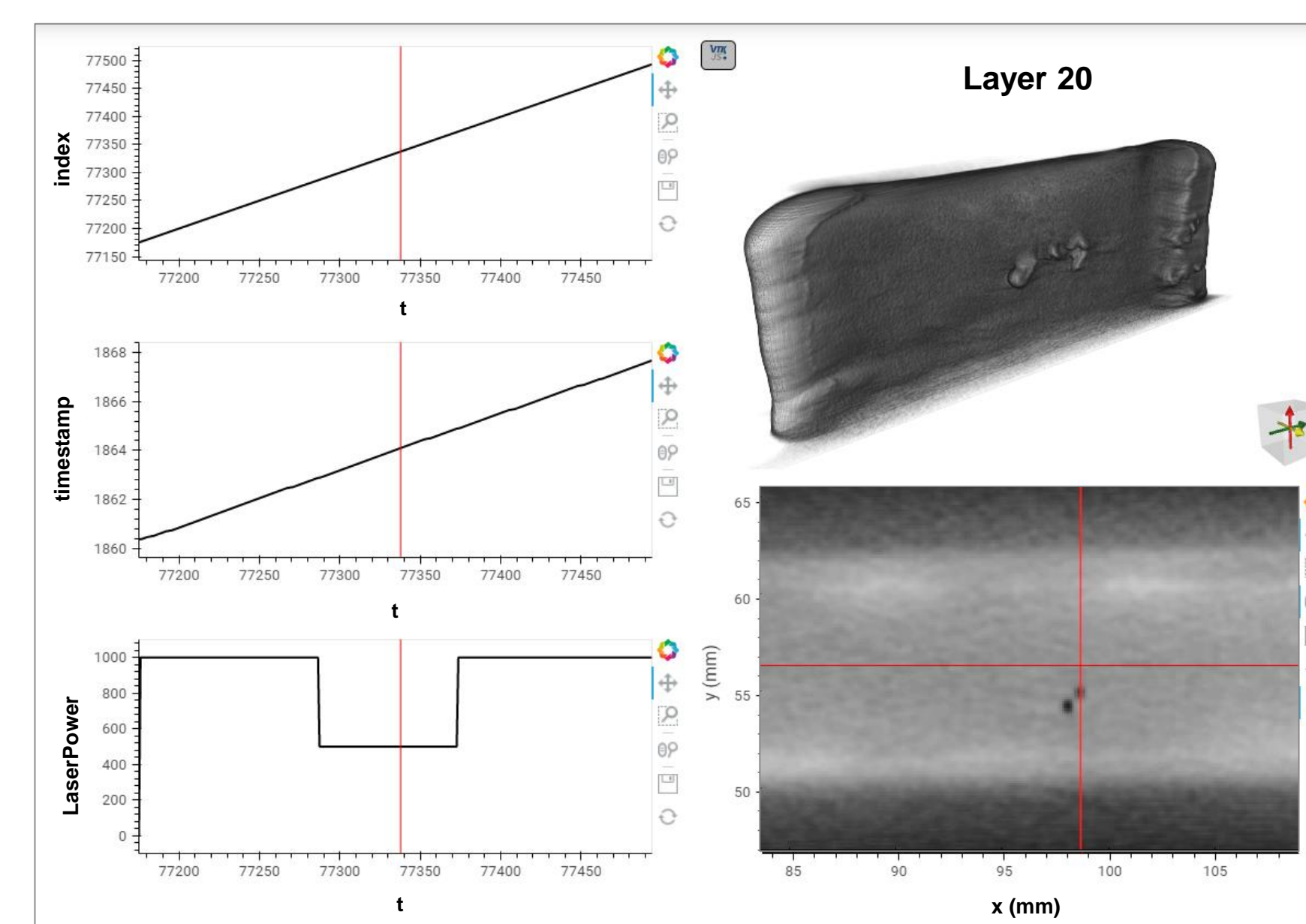
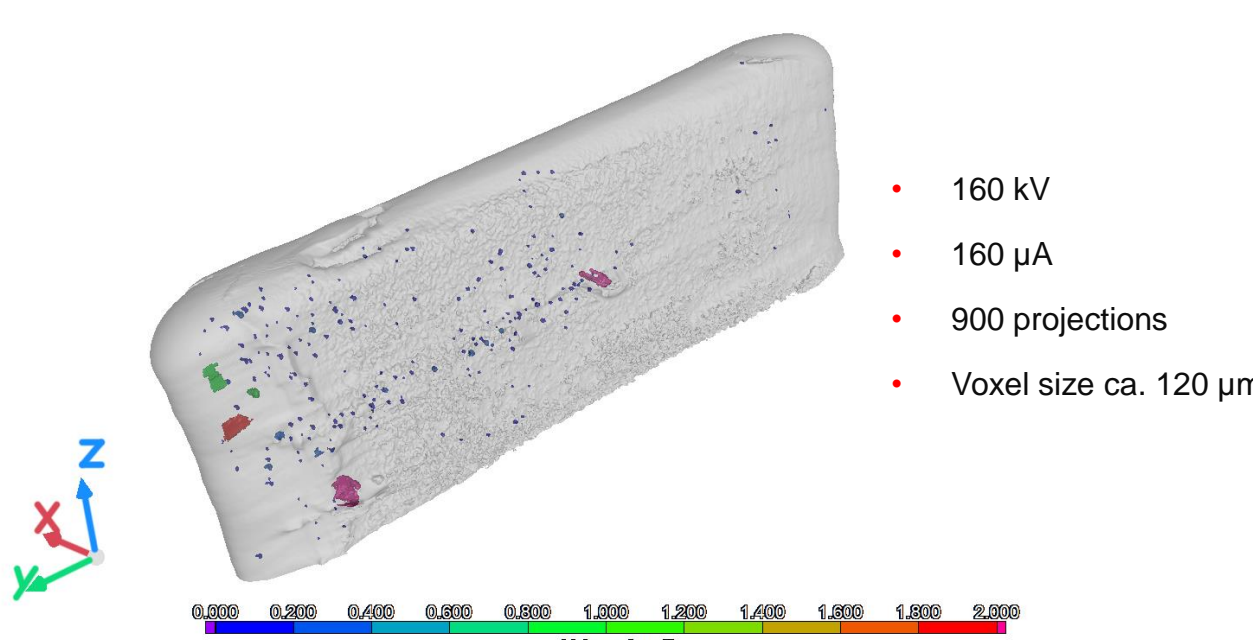
First results on metallic AM

- A metallic mock-up produced from wire arc additive manufacturing process
- Several parts were produced with intentional process variation inducing defects
- There are always high variations observed in the process parameters at the start and end of a layer
- An example of an defective layer and a health layer is shown

- 165 kV
- 180 μ A
- 900 projections
- Voxel size ca. 70 μ m

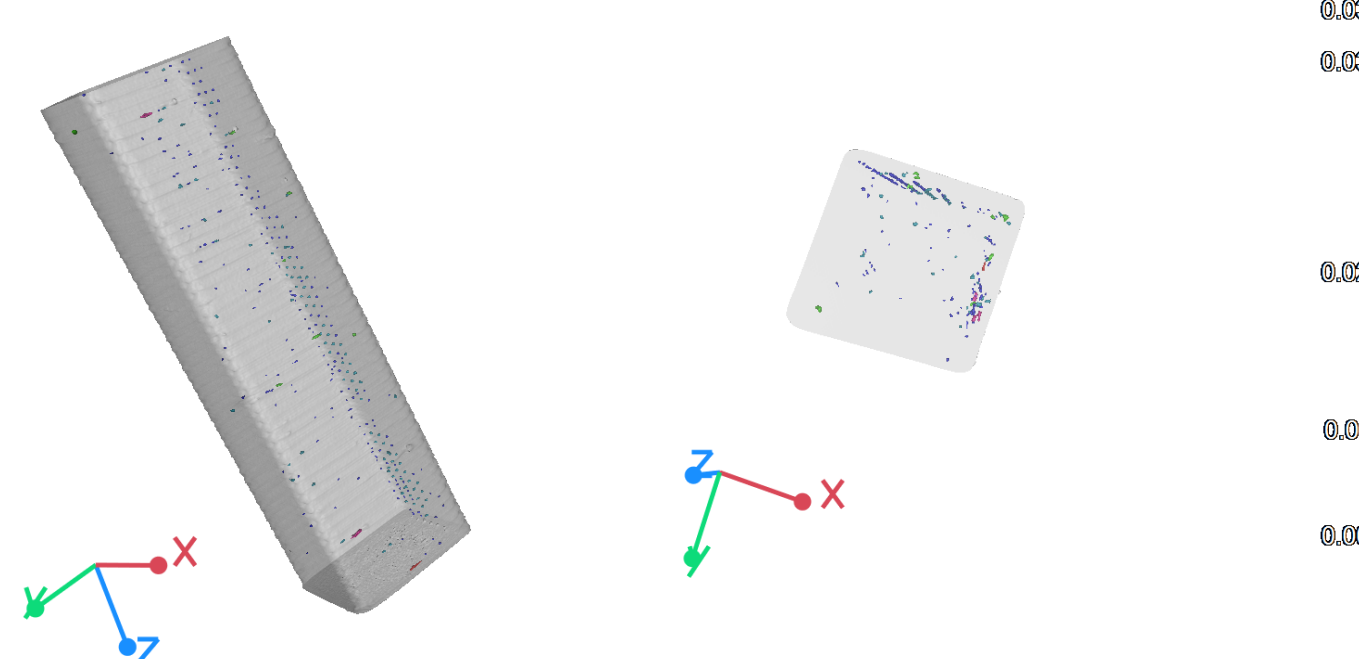


- A metallic wall shaped part is produced from WAAM process
- The defects are well characterized with tomography
- The process data is however nominal here
- There is a good correspondence between local process variations and defects



Future work

- A new experimental campaign is ongoing for nanocomposites produced through FDM (Fused Deposition Modelling) AM process
- The first tomography results revealed that the defects are indeed layer-wise distributed



CONCLUSIONS

- The work is an attempt towards the development of software module for AM process enhancement within CIVA framework
- It has been demonstrated that there are correspondence between the real time micro process variations and the defects
- This is an important step towards AM process improvement
- The module is being validated on several applications