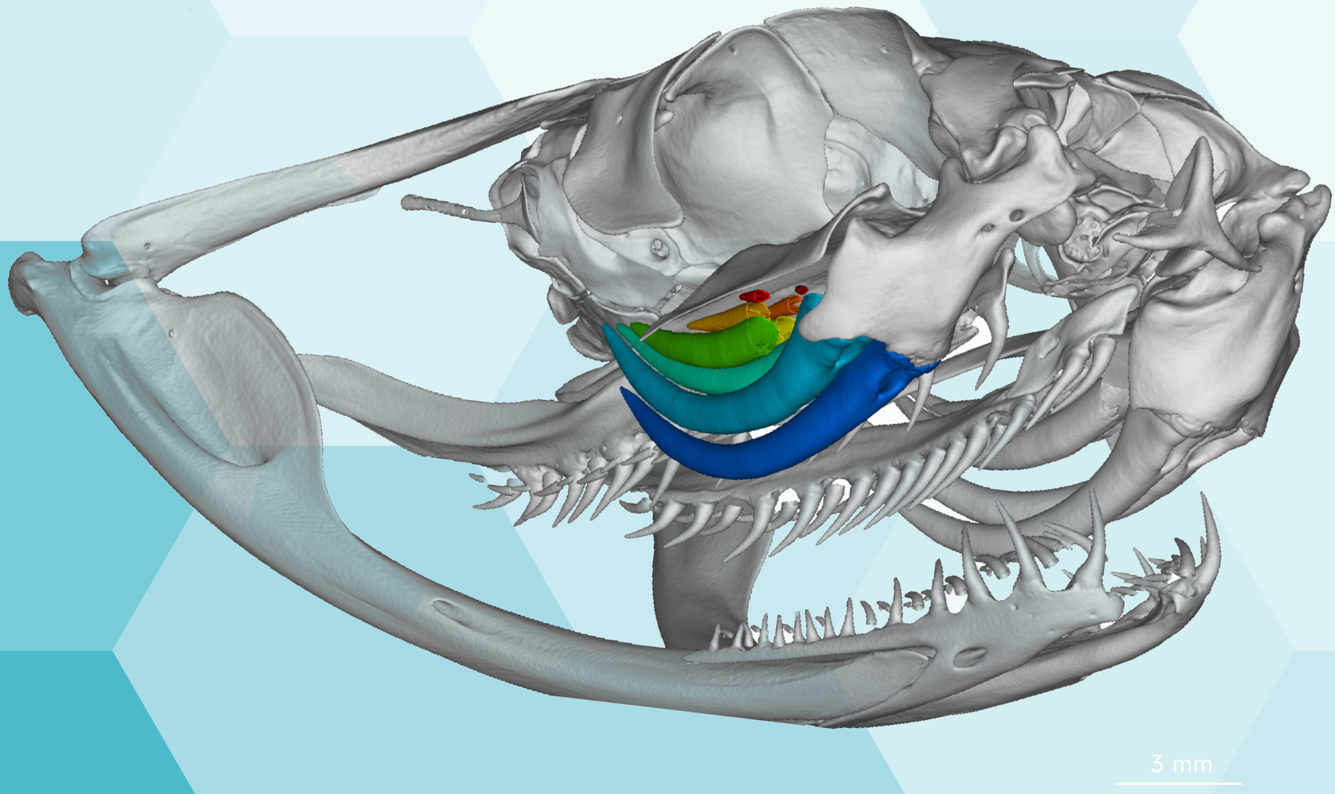


Gaboon viper fang analysis on page 3.

# NEWSLETTER AUTUMN 2021

**Dear Readers,**

It is a pleasure for me to introduce to you a new issue of the autumn newsletter of our ‚CEITEC BUT Laboratory of X-ray Micro- and Nano-Computed Tomography'. You can read about some of our recent analyses, including a Gaboon viper fang analysis and additive manufacturing correction. We will describe a metal artefact reduction, determination of bone and teeth density and share some of the latest news.

Enjoy reading!

**Tomáš Zikmund**
**Head of the laboratory**

CTLAB
X-ray Computed Tomography

CEITEC
Central European Institute of Technology
BRNO | CZECH REPUBLIC

## ADDITIVE MANUFACTURING CORRECTION

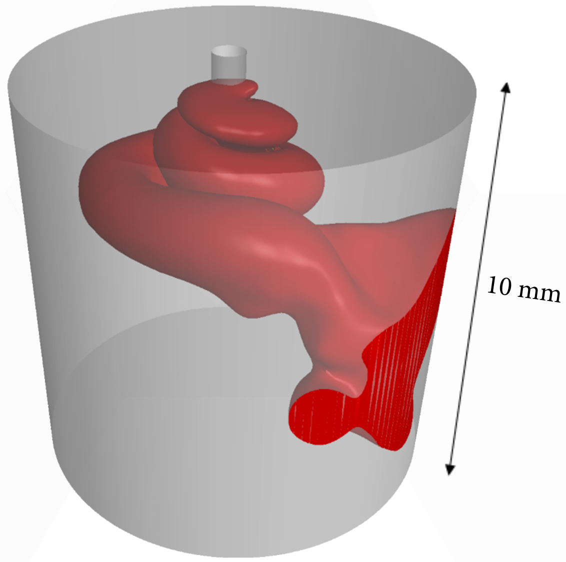


Figure 1: 3D visualization of STL cochlear chamber model.

During cochlear implant insertion, the mechanical trauma causes a loss of residual hearing in up to 50% of implantations. Creating highly accurate and optically clear 3D printed cochlea at a realistic scale can help to test factors which cause the mechanical trauma. This highly accurate 3D printing is complicated because of the small dimensions and its shape. The deviations against the nominal model appear through all printing technologies.

The mesh compensation (Volume Graphics software tool) can help with these devitations. Based on the CT data, a new 3D model design (STL file) is created. This design guarantees the correct shape when it is printed again. We have perfomed this method on 3D printed cochlea and we obtained the correct shape of cochlea.

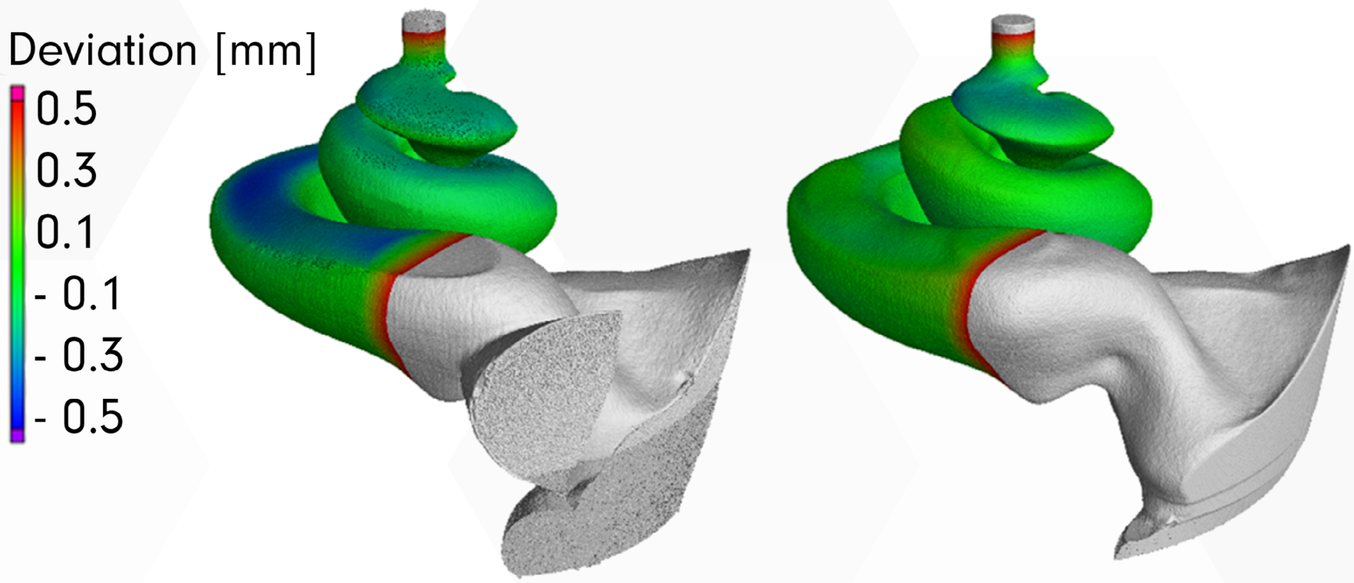


Figure 2: Left – first print with deviations; Right – second print with compensation.

# GABOON VIPER FANG ANALYSIS

The Gaboon viper (Bitis gabonica) is the largest member of the viper family, it is found in the rainforests and savannas of sub-Saharan Africa and like all vipers is venomous. Among all the vertebrates, snakes possess the most sophisticated venom delivery system. The Gaboon viper has the longest fangs of any venomous snake - up to 5 cm in length.

Morphological studies are often restricted to describing external characteristics, in many cases due to the rarity of analysed species and specimens. X-ray micro-CT has become a highly useful imaging method for taxonomy and morphological analysis. Here we present the analysis of the venomous fangs of the Gaboon viper. Since the snakes regularly replace their teeth, including the fangs, there is always a number of replacement fangs posterior to the functional one. Micro-CT imaging enabled detection of 9 present generations of venomous fangs and allowed futher analysis.

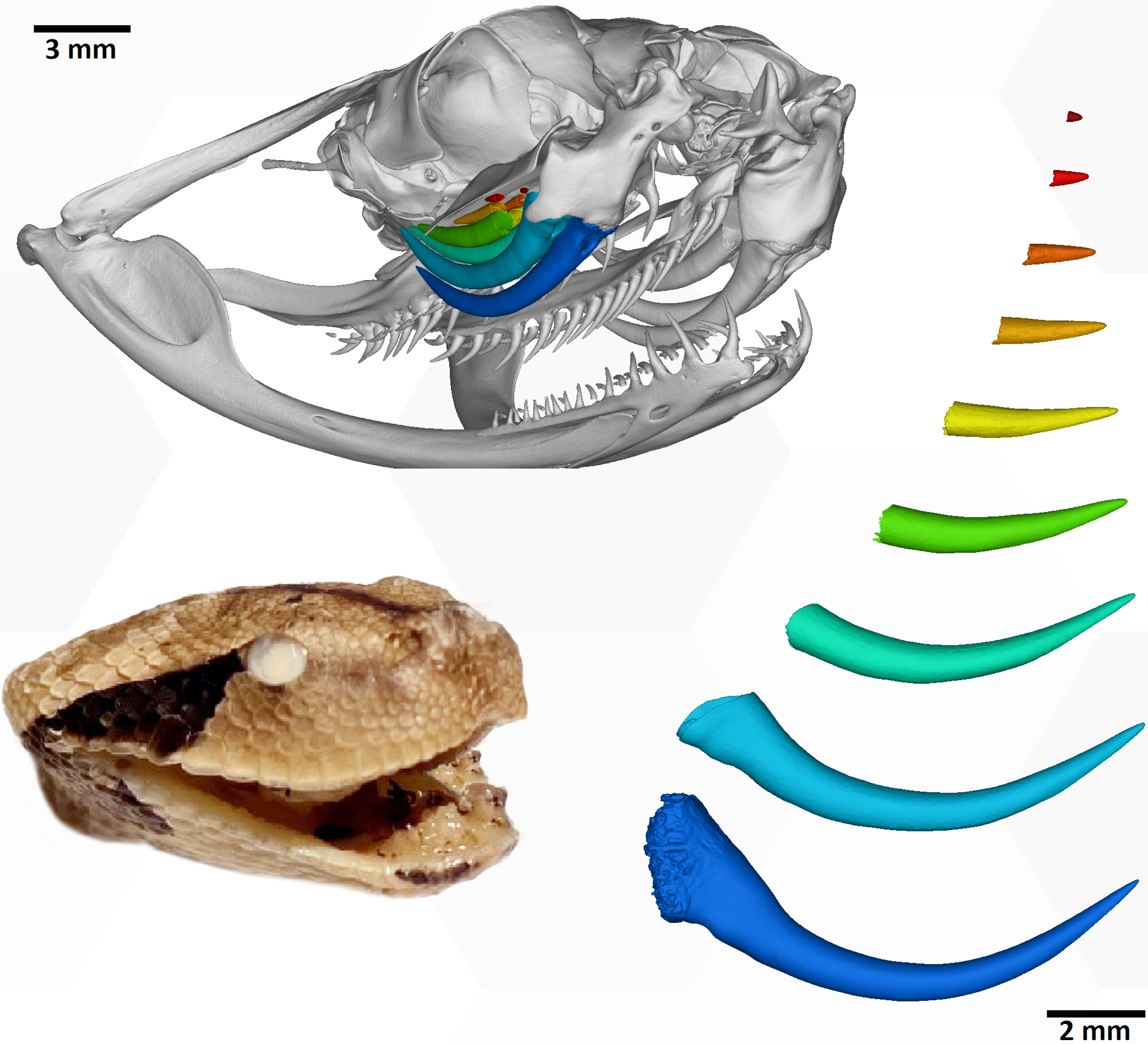


Figure 3: An image of the actual scanned sample of a Gaboon viper and the 3D render of the skull and the teeth. All of the detected fang generations are shown on the right.

## METAL ARTEFACT REDUCTION

Samples made of light and dense materials like plastics and metals are common in industrial computed tomography. They are also notoriously difficult to handle because the presence of metals causes severe errors in the resulting image, and mainly in the plastic parts. These so-called metal artefacts usually take the form of strong bright and dark streaks between metal pieces. For example, in the scan of a power plug (Figure 4), we see streaks between and around the prongs. These streaks are a serious obstacle in reconstructing the true shape of the plastic parts.

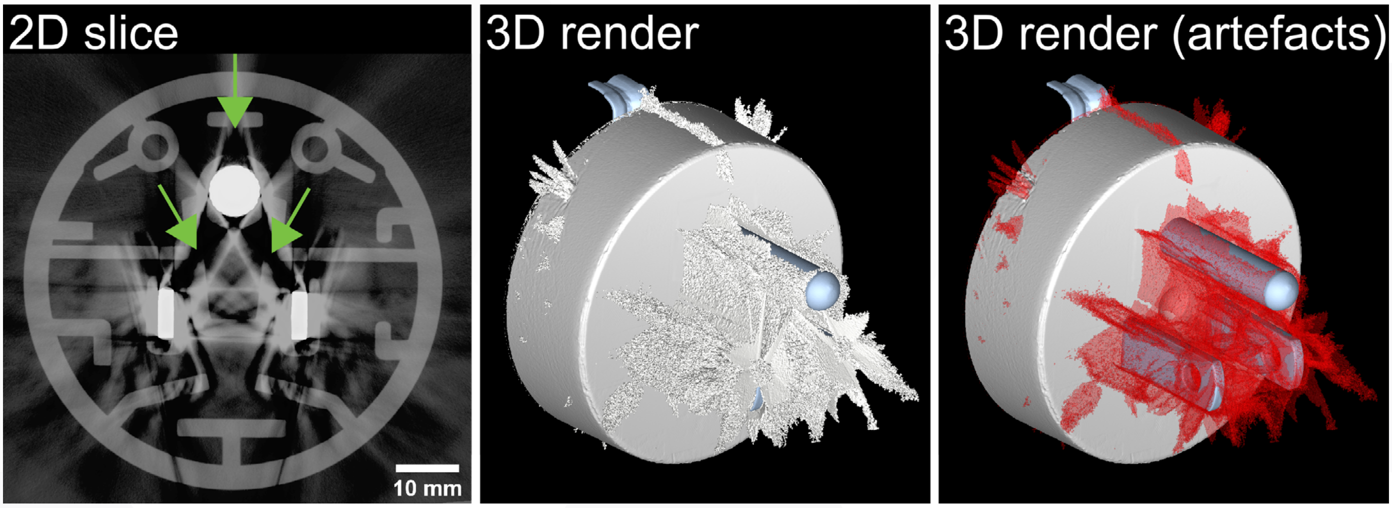


Figure 4: Metal artefacts in a power plug. The artifacts are visible as streaks in the slice on the left (green arrows), and as false plastic structures (white) around metals (light blue) in the 3D render in the middle. The image on the right shows the metal artifacts separated in red.

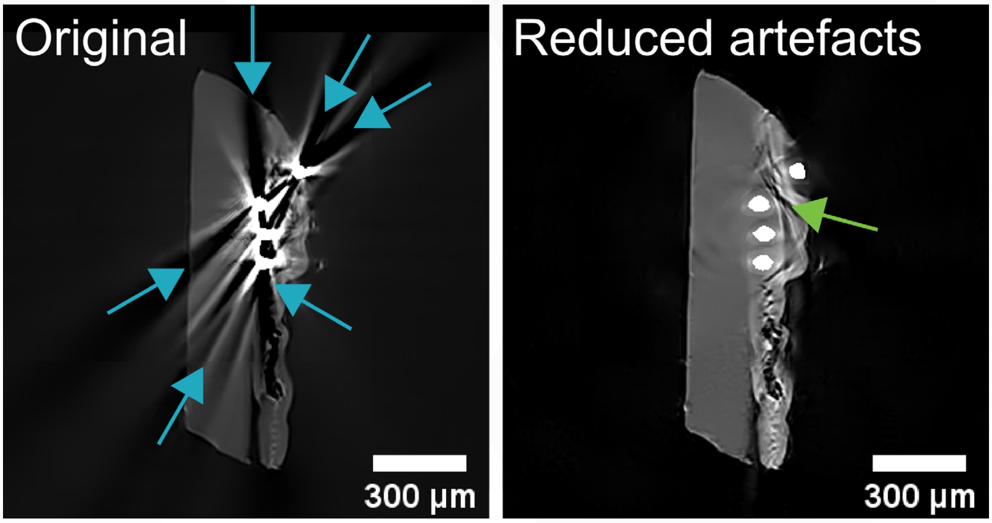


Figure 5: Metal artefacts forming around tungsten wires (blue arrows) were eliminated by replacing projections of metals by synthetic data. The image is much improved, although some residual streaks can remain (green arrow).

Metal artefacts are caused by the physical properties of heavier elements in terms of x-ray absorption; these properties make the data inconsistent with the mathematics used for conventional tomographic reconstruction. Reduction or removal of these artifacts is challenging, but desirable; existing reduction approaches include special scan protocols, dual-energy CT, processing of projections or CT slices, specialized tomo-graphic reconstruction algorithms, and more. For example, a common projection processing strategy is to completely remove the metals from the raw data and replace them with synthetic values, which do not cause as much trouble during reconstruction. Such an algorithm was used on data of a plastic sample with tungsten wires shown Figure 5, greatly improving the quality of the resulting CT slice and removing the disturbing streaks.

# DETERMINATION OF BONE AND TEETH DENSITY USING MICRO-CT IMAGES

Non-destructive inspection of mineral density is nowadays a desirable type of bone and teeth analysis. The utilisation of such analysis can be found in various comparative studies, i.e., developmental biology, drug therapies response investigation, implantology, etc. Thanks to the resolution of a micro-CT scan in the order of micrometres, cortical and trabecular density can be distinguished in the bone, as well as dentin and enamel density in case of teeth. Moreover, the utilisation of microCT for density analysis is beneficial thanks to its' nondestructivity, speed, and analysis of the whole sample in 3D. Because bones and teeth are composed mainly of hydroxyapatite (HA), mineral density analysis is aimed directly at determining the concentration of HA. A low HA concentration within the tissue causes its' fragility. Based on the HA concentration knowledge, the overall tissue density can be quantitatively estimated. The usual concentration range is in the hundreds (bone) or thousands (teeth) of milligrams of hydroxyapatite per cubic centimetre.

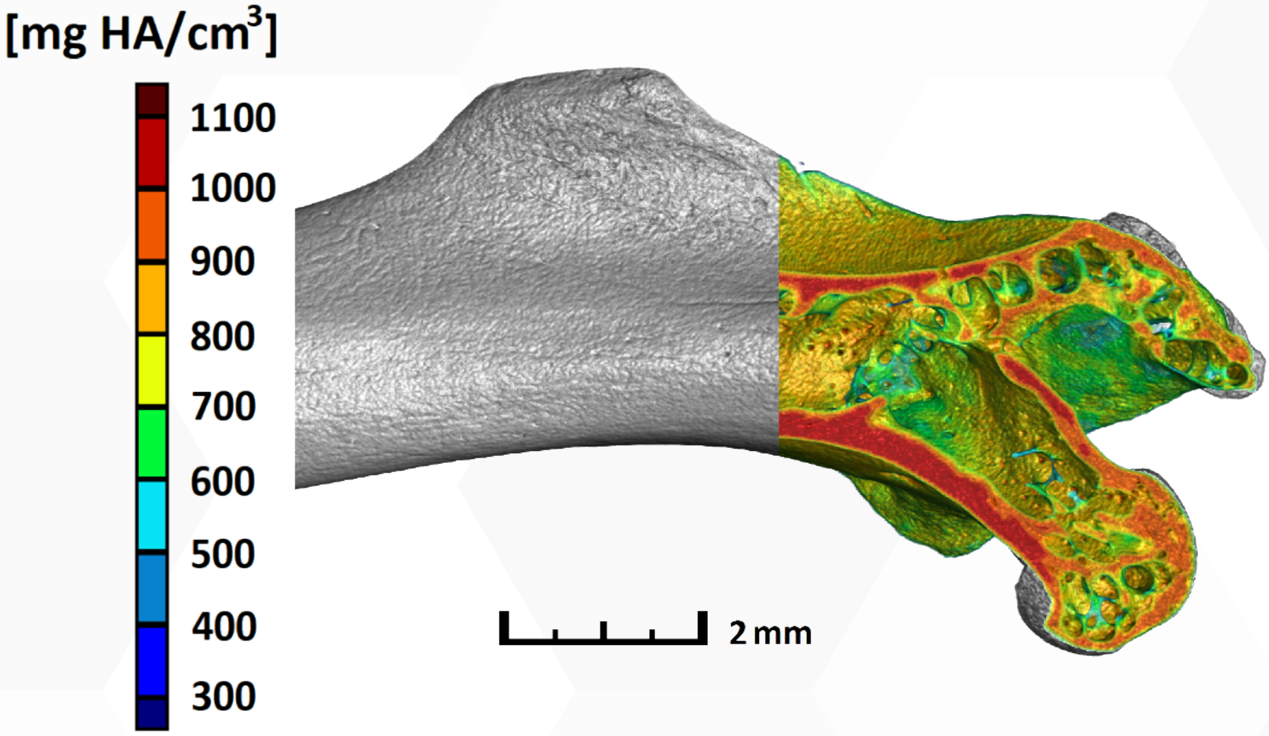


Figure 6: 3D render of the murine proximal part of the femur. The cross-section on the right part is colorized according to the bone density (hydroxyapatite concentration).

The practical measurement consists in calibrating the CT machine to HA units. The calibration is performed by the scanning of the appropriate calibration phantom. The principle is to extract attenuation values from individual inserts in the phantom, which contains five materials with different HA concentrations. Based on the knowledge of the difference between the extracted values from the sample, and the reference values of HA concentration in the phantom, the individual voxel values can be transformed into mineral density by linear transfer function. We integrated this algorithm into commercial CT systems and started to offer this type of analysis to biologists (Figure 6).

# LATEST NEWS

## SOFTWARE UPDATE

We keep our laboratory up to date! We have upgraded our computer stations to the latest VGStudio MAX 3.5 in order to perform the best possible analyses. We currently have 6 licences for analysis processing. We simultaneously increased our computing power in order to process a large amount of data. Such as multiple scans, since the demands for hardware are still increasing. For example, our new 4K flat panel detector (4000 px × 4000 px) generates eight times more CT data (i.e. up to 120 GB)  than its predecessor (2000 px × 2000 px).

## MARIE SKLODOWSKA-CURIE INNOVATIVE TRAINING NETWORKS PROJECT XCTING

One of our PhD students was awarded a prestigious grant under the Marie Skłodowska-Curie Innovative Training Networks project xCTing. This project is a pan-European industrial-academic initiative committed to train a new generation of researchers in the field of industrial X-ray comuted tomography. The student will work at Waygate Technologies in Wunstorf, Germany.  It is one of the leading companies in the developement and manufacturing of industrial CT machines.

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