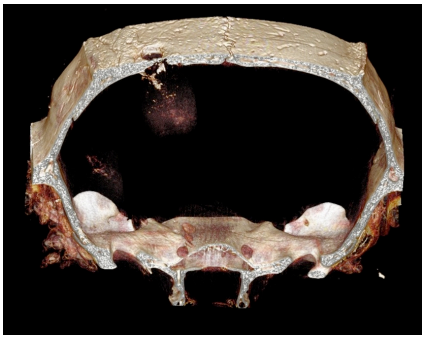
Basics on radiation probing and imaging using x-ray detectors



It lies in human nature to advance as far as possible into the microscopic world and to investigate the underlying principles of nature. At present almost the entire electromagnet spectrum is utilized to probe the morphology of matter and the function in chemical or biological systems. Probing methods discussed in this course are based on the interaction of x-rays with matter. X-rays generated by synchrotron source will be of special interest since research using synchrotron radiation has emerged to be one of the most powerful tools in almost every field of science, especially in advanced imaging technologies. The course will be subdivide into three parts which are:

- Image formation
    - After a brief compendium of the main characteristics of Poisson statistics including its time structure and interaction of x-rays with matter, the concept of Signal to Noise Ratio (SNR) in (digital) images will the discussed in depth. Due to its importance in biomedical imaging the dependence of the radiation dose with respect to the SNR, the image contrast and the spatial resolution will be deduced from the scratch. It will be shown that both radiation dose and SNR are strongly coupled to a detector benchmark referred as to the "detective quantum efficiency (DQE)" which will be discussed in depth in the next part of the course.
- Basics on imaging detectors
    - By means of a generic energy converting radiation detector the underlying principles of charge generation and charge collection will be discussed in depth but utilizing rather basic models. The impact of the range of photoelectrons, fluorescence, drift and diffusion on the spatial resolution and on the charge collection will be emphasized. Single event energy resolution and Fano factor will be discussed. With the help of different readout schemes the commons and the differences between integrating, counting and spectroscopic detectors will be derived. Together with the quantum efficiency, noise and dead time considerations the DQE will be deduced for the two former types of detectors. Owning these tools pros and contras of utilizing hybrid pixel detectors, CCDs and CMOS imagers in x-ray imaging /CT applications will be discussed. Some remedies of detector generated artifacts for instance in CT will be shown.
- Imaging applications with synchrotron radiation.
    - In the remaining time applications of integrating, counting and spectroscopic detectors in synchrotron radiation based biomedical imaging on different length scales from the molecule to the patient level will be demonstrated. Besides spectral absorption imaging, which reveals morphology and function at a time, different approaches of x-ray phase contrast imaging will be demonstrated which represent a workaround to overcome the inherent limitations of absorption imaging discussed in the first part of the course.