2023 Helmholtz – OCPC – Programme

for the involvement of postdocs in bilateral collaboration projects

PART A

Title of the project:

Probabilistic inclusion of inter crystal scatter in PET image reconstruction

Helmholtz Centre and/or institute:

Forschungszentrum Jülich GmbH

Project leader:

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Description of the project (max. 1 page)**:**

Positron emission tomography (PET) is the most sensitive imaging tool for neuroscientific imaging in humans. Compared to MRI, PET has a million-fold higher detection sensitivity. This allows imaging of physiologically active compounds, tagged with positron-emitting radionuclides, which are administered to the patient or volunteer in tracer amounts (e.g., in nanomolar or picomolar quantities). PET has contributed significantly to the understanding of cerebrovascular diseases, dementia, movement disorders, epilepsy, schizophrenia, addictive disorders, depression, anxiety disorders, brain tumors and the healthy brain.

PET allows imaging due to the following underlying physical principle: The previously injected radioactive nuclide tagged to the metabolic target emits a positron which annihilates into two back-to-back γ-rays of the same energy (511keV) independent of the radiotracer or its surrounding. The PET scanner measures the energy and detection position of these rays. As the emission of the annihilation radiation is isotropic, PET systems normally consist of annular arrangements of many scintillation detectors building an entire ring. Typical scintillation detectors for PET are usually built from an array of small scintillation pixels optically bond to a photodetector. An incoming annihilation photon is stopped by the scintillator and converted into scintillation photons and those are subsequently converted by the photodetector into electronic signals. In order to calculate the position of a scintillation event from the measured electronic signals, in most cases, the computation of the weighted mean, which is also known as Anger logic, is used. The determined position is subject to statistical and systematic errors, combined in the Point Spread Function (PSF) of the detector. Further, the incoming annihilation photon can be scattered in the imaged object (object scatter) or inside the scintillation detector (inter crystal scatter - ICS). In both cases, at least one of both annihilation photons forming a line of response (LOR) is deviated, and an erroneous LOR will be used for the image reconstruction. The probability of ICS in current PET systems is relatively high and therefore ICS leads to degradation of the spatial resolution and the contrast of the PET images.

For the high-spatial-resolution detector blocks of the BrainPET-7T (in in-house developed Ultra-high field MR compatible PET insert for head imaging), a more advanced technique for crystal identification, i.e. determination of the photo-conversion position will be employed, namely the Maximum-Likelihood (ML) estimation, which can provide additional information as confidence information. This additional probability information can be used during image reconstruction with ML Expectation Maximisation (ML-EM) to appropriately handle the scintillation detectors PSF and also ICS.

In this research project, the feasibility of this approach shall be evaluated. In detail, the established ML positioning formalism shall be extended to provide reliable information on the probability values of the scintillation crystal pixels where the photoconversion steps potentially took place. In this way, a unified approach for PSF and ICS can be provided. As part of this evaluation, a robust method for pattern recognition (for identifying the number of photo conversion steps, i.e. one, two, or more scintillation centres) should be developed based on statistical, analytical or machine learning techniques. For the correct treatment of ICS, Compton Kinetics and probabilistic considerations should be taken into account. The event-by-event computed detection probabilities of the single-crystal interactions will be passed to the in-house developed PET image reconstruction software PRESTO. The method shall be evaluated by Monte Carlo (MC) simulation and measurement data.

Description of existing or sought Chinese collaboration partner institute (max. half page)**:**

Still not decided

Required qualification of the postdoc:

- PhD in Nuclear Physics, Computational Science, Particle Physics or related fields, ideally with expertise in PET
- Experience in Monte Carlo simulation and typical libraries as GEANT-4 or similar
- Additional skills in programming languages (C++, Mathematica, MATLAB, Phyton …) and Linux
- English language skills that allow for professional discussions on the topic and independent writing of scientific publications