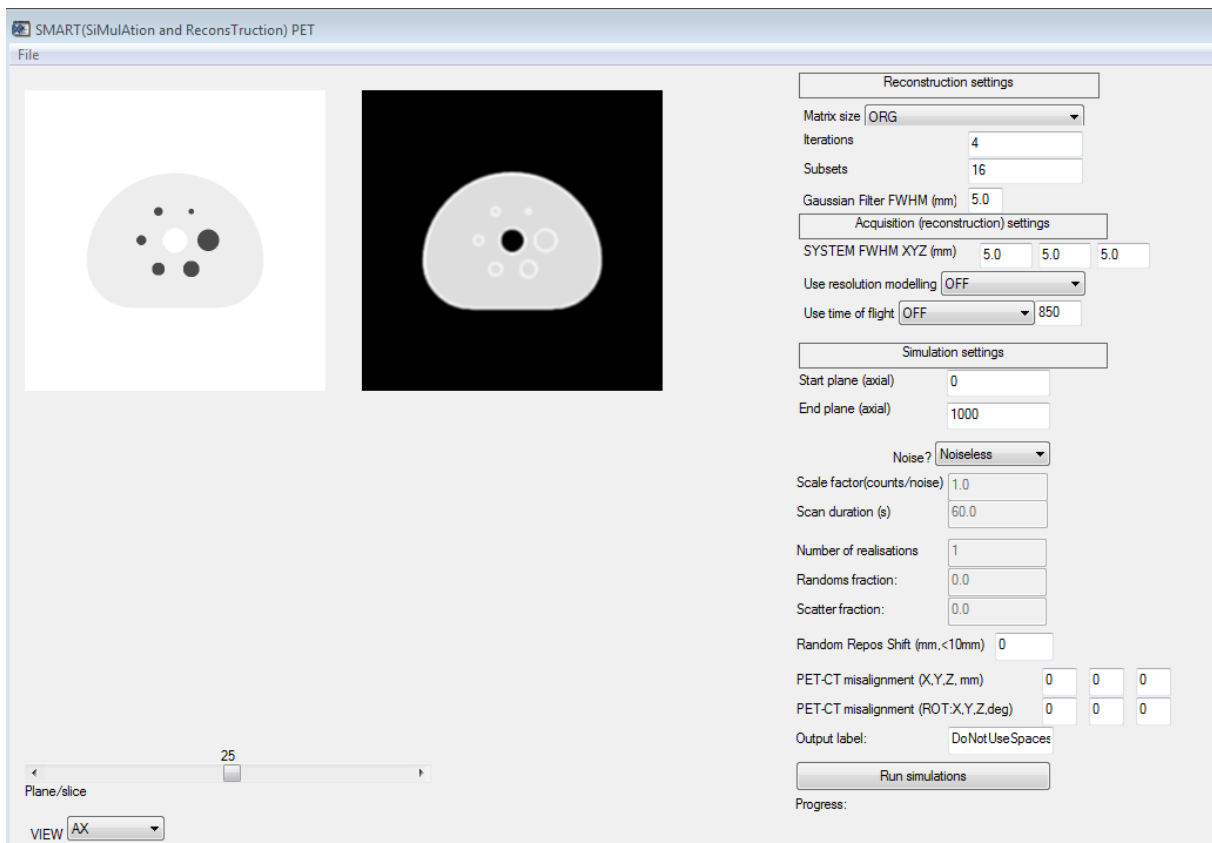# Manual SMART-PET

SMART-PET is a tool for the reconstruction and simulation of realistic PET-images. It is written in IDL (version 8.3, 64 bit; Harris Geospatial solutions, Broomfield, CO, USA).

SMART-PET can be adapted to any PET/CT system by changing some parameters for the simulation and reconstruction process via a Graphical User Interface:

By changing the parameters of SMART-PET, SMART-PET can be adjusted to every PET-CT system. For this purpose, the following steps are necessary:

- acquire a scan of a standard phantom (e.g. the NEMA image quality phantom) and reconstruct it using different reconstruction settings and with different scan durations/scan statistics
- Generate two mathematical Digital Reference Object (DRO) of the same object (one simulating the CT-image/attenuation map and one the PET image) (DROs of the NEMA phantom are provided with this toolbox)
- Match the activity distribution in the DROs to the ones observed in the physical phantom data (To achieve this, a separate tool (IQ_DRO_modifier) is available with this software.

This tool allows the user to adjust the activity distribution of the spheres and the background compartment of the DROs. A manual how to use this tool is also provided)

- Generate simulations with the same reconstruction settings as the physical phantom data
- Calibrate SMART-PET to your system. In order to calibrate SMART-PET to the desired PET/CT-system the simulated images should be compared to the physical phantom data, regarding the following measurements:
  - The coefficient of variation (COV) in the background compartment of the phantom is a measure for image noise. The parameters of SMART-PET should be set so that this values correspond for simulated and real PET-images with the same reconstruction settings,
  - The recovery coefficients of the spheres should be compared between physical phantom and simulated data

To use SMART-PET, follow the following steps:

I.   Upload DROs as input images

SMART-PET requires as input a noise free and high resolution PET- and a corresponding CT-image/attenuation map: Upload the DROs of the CT-image/attenuation map and the corresponding PET-image

II.   Adjust Reconstruction settings

In the Reconstruction part, the following changes can be made:

1) Matrix size: The matrix size of the simulated image can be set:
   a. ORG – original size
   b. Matrix size of 128 x 128, resulting in a voxel-size of 4 x 4 mm

c. Matrix size of 170 x 170, resulting in a voxel-size of 3 x 3 mm

d. Matrix size of 256 x 256, resulting in a voxel-size of 2 x 2 mm

e. Matrix size of 400 x 400, resulting in a voxel-size of 1.3 x 1.3 mm

For comparison the voxel size of scan and simulation should correspond

2) The iterations and subsets of the OSEM reconstruction can be changed in order to match the noise texture of scan and simulation

3) The Gaussian Filter can be set

For comparison, the Gaussian Filter should be set to the same value as in the physical phantom data

4) The system Full-Width-at-Half-Maximum (FWHM, in mm) can be set for each direction separately: To match the FWHM of simulation and physical phantom data, the RCs should be compared. The FWHM showing the best correspondence should be chosen for all simulations.

5) The user can switch the use of resolution modelling (PSF) ON/OFF

6) The user can switch the use of TOF ON/OFF. If TOF is set ON, the user can set the TOF setting to any value.

III. Adjust Simulation settings

In the Simulation part, the following parameters can be set:

1) Start and end plane of the simulation
2) Switch between Noisy and Noiseless image;

   If Noisy is selected, the following parameters can be changed as well:
   a. Scale factor: This factor is a noise factor which has to be matched with the noise observed in the physical phantom data . It can be any value from 0 – inf The Coefficient of Variation values in the background compartment should be compared for different scale factors between simulated and real PET images. The scale factor showing the best correspondence should be used for all simulations
   b. Scan duration: Use same scan duration as in the acquired scans
   c. Number of realisations
   d. Randoms and scatter fractions: a value between 0-1: To match the Randoms and scatter fractions, also compare the COV values in the background compartment of the phantom (see point 3)
3) Random Repos Shift to simulate patient repositioning
4) PET-CT misalignment: Values to simulate patient movement during the scan: A translational movement (in mm) can be simulated as well as a rotation (in degrees)
5) The output label of the simulated images can be set.