

User's guide

dPETSTEP simulation GUI

This document shows the usage of the dPETSTEP GUI for PET image simulation, and explains the different inputs to the GUI.

The GUI can be run by typing in the MATLAB command prompt:

```
>> dPETSTEPgui_sim
```

This command opens the full window seen below. All fields have tool tips to guide you.

The screenshot shows the dPETSTEP simulation GUI window. The window is titled "dPETSTEP simulation" and contains several panels for configuring the simulation. The panels include:

- Input data**:
 - Data**: Radio button for "From WS" (selected), text field for "Name".
 - Time frame**: Radio button for "From WS" (selected), text field for "Name" with "(sec)" label.
- Scanner settings**:
 - Sinogram radial size**: Radio button for "Radial bins" (selected), text field for "# Radial bins" with "(near)" label, text field for "Ring diameter" with "mm" label.
 - Angular bins**: Text field for "# Angular bins".
 - System PSF**: Text field for "System PSF" with "mm" label.
 - Maximum ring diff**: Text field.
 - System sensitivity**: Text field for "System sensitivity" with "cnts per kBq/cc" label.
- Acquisition settings**:
 - # Replicates**: Text field.
 - Counts scale factor**: Text field.
 - Scatter fraction**: Text field.
 - Random fraction**: Text field.
 - Nuclide half-life**: Text field with "sec" label, checkbox for "No decay" (checked).
- Kinetic modelling**:
 - Input function**: Radio button for "From WS" (selected), text field for "Name" with "(Bq/cc)" label, text field for "Scale factor".
 - Model**: Radio button for "1-Tissue" (selected), radio button for "2-Tissue", radio button for "FRTM", radio button for "SRTM", radio button for "SumExp", text field for "# exp".
 - Interpolation**: Radio button for "Linear" (selected), radio button for "Nearest", radio button for "PCHIP", radio button for "Spline", text field for "Time step" with "sec" label.
 - Biologic variability**: Radio button for "None" (selected), radio button for "Scale", text field.
- Reconstruction settings**:
 - Image matrix size**: Text field.
 - FOV**: Text field with "mm" label.
 - Method**: Checkboxes for "FBP", "OSEM", "OSEM w/ PSF".
 - # iterations**: Text field.
 - # Subsets**: Text field.
 - PSF correction**: Text field with "mm" label.
 - Postfiltering**:
 - XY**: Checkboxes for "XY", "FWHM", text field with "mm" label.
 - Z**: Radio button for "From WS" (selected), radio button for "From file", text field for "Name".
- Output data names**: Checkboxes for "Data", "Counts", "Counts noisy", "Prompts sino", "Trues sino", "Scatters sino", "Randoms sino", "WCC", "FBP", "OSEM", "OSEM w/ PSF", each with a text field.

At the bottom right, there are buttons for "Save", "Load", "Reset", and a large "Run" button.

Created by Ida Häggström, 2017.07.07

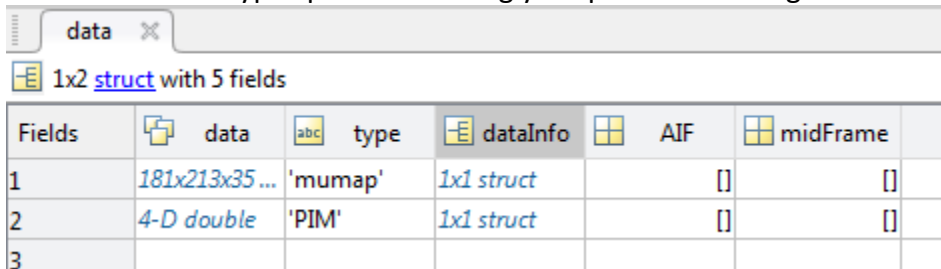
1. Run test example

1.1 *data_ex_dPETSTEP_kineticModelling*

This is for choosing “Parametric image input”, i.e. starting with a parametric image, which simulates a pristine 4D PET image, and finally a realistic PET acquisition (noisy) of that image. Download the test example data found on Github at

https://github.com/CRossSchmidtlein/dPETSTEP/blob/master/example_kineticModelling.

Load into Matlab the data “data_ex_dPETSTEP_kineticModelling.mat”. There should be a field in that data structure of type “pim” containing your parametric image:

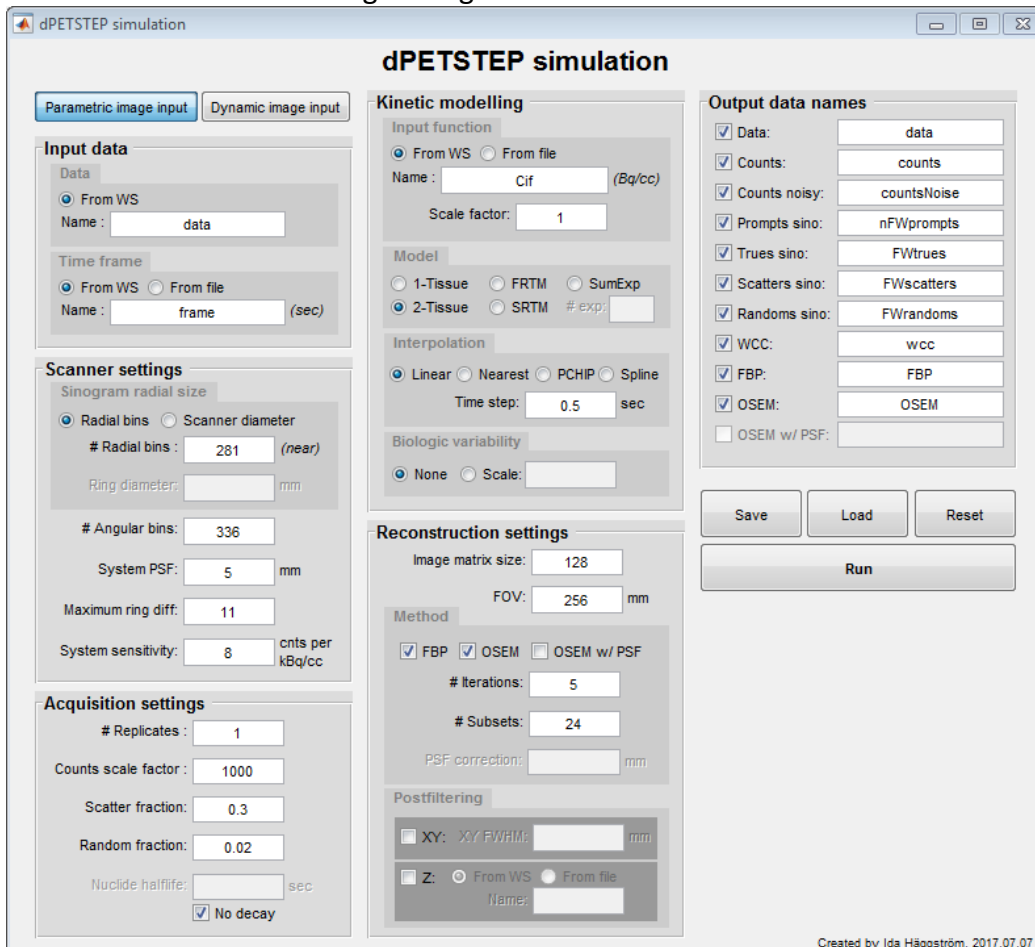


data

1x2 struct with 5 fields

Fields	data	type	dataInfo	AIF	midFrame
1	181x213x35 ...	'mumap'	1x1 struct	[]	[]
2	4-D double	'PIM'	1x1 struct	[]	[]
3					

Example settings can be found in “settings_dPETSTEPgui_simulation_kineticModelling.xls”, and loaded via the GUI. Resulting settings seen below:



dPETSTEP simulation

Parametric image input | **Dynamic image input**

Input data

Data

☒ From WS ☐ From file

Name: data

Time frame

☒ From WS ☐ From file

Name: frame (sec)

Scanner settings

Sinogram radial size

☒ Radial bins ☐ Scanner diameter

Radial bins: 281 (near)

Ring diameter: mm

Angular bins: 336

System PSF: 5 mm

Maximum ring diff: 11

System sensitivity: 8 cnts per kBq/cc

Acquisition settings

Replicates: 1

Counts scale factor: 1000

Scatter fraction: 0.3

Random fraction: 0.02

Nuclide half-life: sec

☒ No decay

Kinetic modelling

Input function

☒ From WS ☐ From file

Name: Cif (Bq/cc)

Scale factor: 1

Model

☐ 1-Tissue ☐ FRTM ☐ SumExp

☒ 2-Tissue ☐ SRTM # exp:

Interpolation

☒ Linear ☐ Nearest ☐ PCHIP ☐ Spline

Time step: 0.5 sec

Biologic variability

☒ None ☐ Scale:

Output data names

☒ Data: data

☒ Counts: counts

☒ Counts noisy: countsNoise

☒ Prompts sino: nFWprompts

☒ Trues sino: FWtrues

☒ Scatters sino: FWscatters

☒ Randoms sino: FWrandoms

☒ WCC: wcc

☒ FBP: FBP

☒ OSEM: OSEM

☐ OSEM w/ PSF:

Reconstruction settings

Image matrix size: 128

FOV: 256 mm

Method

☒ FBP ☒ OSEM ☐ OSEM w/ PSF

Iterations: 5

Subsets: 24

PSF correction: mm

Postfiltering

☐ XY: XY FWHM: mm

☐ Z: ☐ From WS ☐ From file

Name:

Save Load Reset

Run

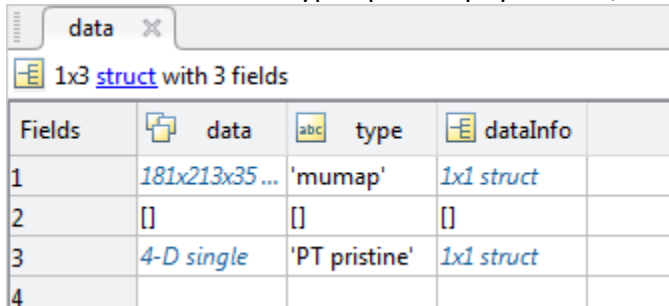
Created by Ida Häggström, 2017.07.07

1.2 data_ex_dPETSTEP_dynamicImage

This is for “Dynamic image input”, simulating a realistic PET acquisition (noisy) of an input dynamic PET image. Download the test example data found on GitHub at

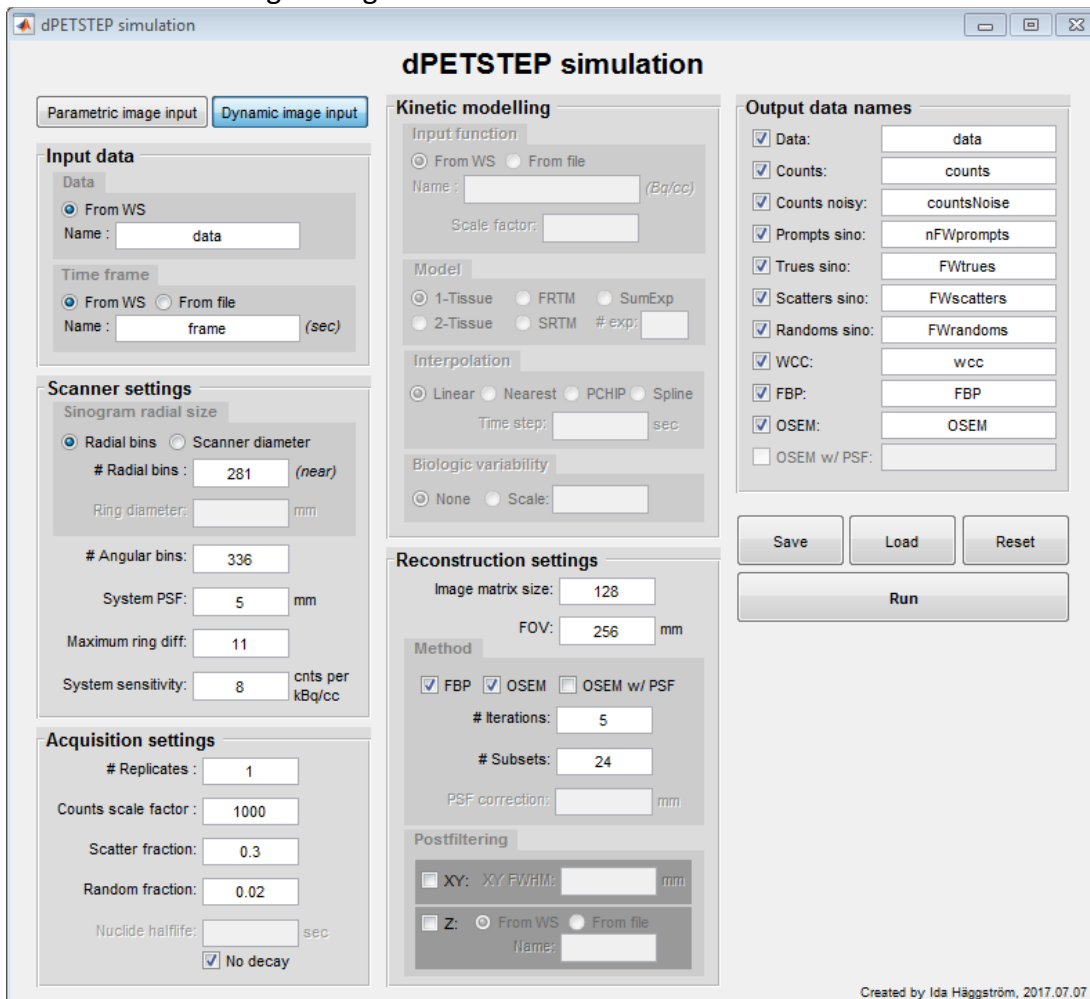
https://github.com/CRossSchmidtlein/dPETSTEP/blob/master/example_dynamicImage.

Load into Matlab the test data “data_ex_dPETSTEP_dynamicImage.mat”. There should be a field in that data structure of type “pt” or “pt pristine”, containing your 4D image.



Fields	data	type	dataInfo
1	181x213x35...	'mumap'	1x1 struct
2	[]	[]	[]
3	4-D single	'PT pristine'	1x1 struct
4			

Example settings can be found in “settings_dPETSTEPgui_simulation_dynamicImage.xls”, and loaded via the GUI. Resulting settings seen below:



dPETSTEP simulation

Parametric image input | **Dynamic image input**

Input data

Data

☒ From WS ☐ From file

Name: data

Time frame

☒ From WS ☐ From file

Name: frame (sec)

Scanner settings

Sinogram radial size

☒ Radial bins ☐ Scanner diameter

Radial bins: 281 (near)

Ring diameter: mm

Angular bins: 336

System PSF: 5 mm

Maximum ring diff: 11

System sensitivity: 8 cnts per kBq/cc

Acquisition settings

Replicates: 1

Counts scale factor: 1000

Scatter fraction: 0.3

Random fraction: 0.02

Nuclide half-life: sec

☒ No decay

Kinetic modelling

Input function

☒ From WS ☐ From file

Name: (Bq/cc)

Scale factor:

Model

☒ 1-Tissue ☐ FRTM ☐ SumExp

☐ 2-Tissue ☐ SRTM # exp:

Interpolation

☒ Linear ☐ Nearest ☐ PCHIP ☐ Spline

Time step: sec

Biologic variability

☒ None ☐ Scale:

Reconstruction settings

Image matrix size: 128

FOV: 256 mm

Method

☒ FBP ☒ OSEM ☐ OSEM w/ PSF

Iterations: 5

Subsets: 24

PSF correction: mm

Postfiltering

☐ XY: XY FWHM: mm

☐ Z: ☒ From WS ☐ From file

Name:

Output data names

☒ Data: data

☒ Counts: counts

☒ Counts noisy: countsNoise

☒ Prompts sino: nFWprompts

☒ Trues sino: FWtrues

☒ Scatters sino: FWscatters

☒ Randoms sino: FWrandoms

☒ WCC: wcc

☒ FBP: FBP

☒ OSEM: OSEM

☐ OSEM w/ PSF:

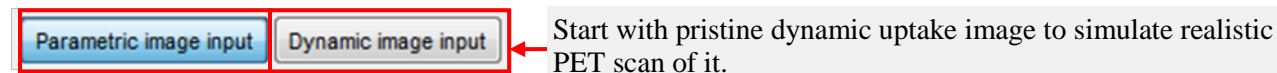
Save Load Reset

Run

Created by Ida Häggström, 2017.07

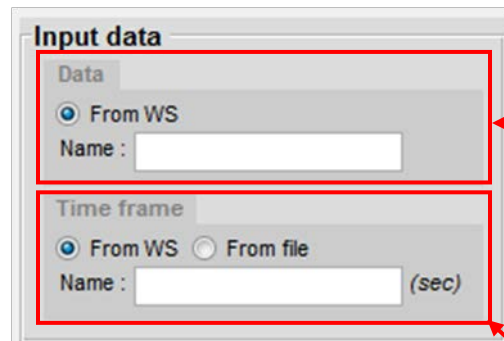
2. GUI field explanations

Buttons for type of simulation



Start with parametric image, which calculates to a pristine dynamic uptake image which is used to simulate realistic PET scan.

Input data



Read data structure (containing attenuation data, and parametric image or dynamic image) either from workspace (WS), or from *.mat-file. Enter the name (string) of the WS variable/file. The *.mat-file has to contain ONLY the data structure, no other data.

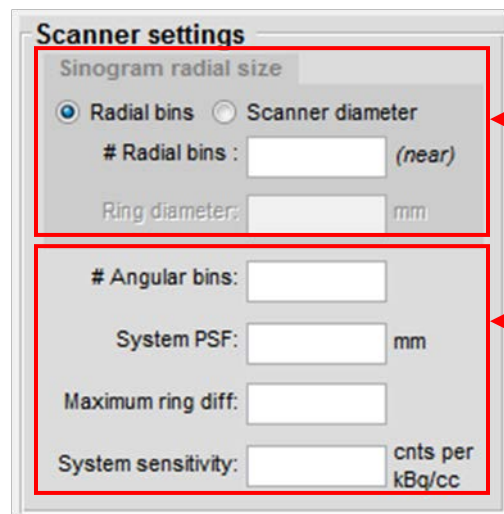
For parametric image input, the structure should contain parametric image.

For dynamic image input, the structure should contain dynamic uptake image.

Read frame time points either from workspace (WS), or from *.mat, *.txt, or *.xls file. Enter the name (string) of the WS variable/file. The data file has to contain ONLY the frame vector, no other data.

The frame data vector [nt+1,1] should be in unit (sec).

Scanner settings



Choose if you want to set the number of radial bins directly, or have it calculated indirectly via the scanner diameter.

Number of radial bins is an integer number, and the program will get to the desired number as closely as possible (uneven number).

The ring diameter is a number in unit (mm).

The number of angular bins is an integer number.

The system PSF is the blurring point spread function FWHM of the imaging system in unit (mm).

The maximum ring difference is an integer number with max separation between scanner rings allowed for coincidences.

The system sensitivity is the number of counts per kBq/cc for the particular scanner.

Acquisition settings

Acquisition settings

Replicates :

Counts scale factor :

Scatter fraction:

Random fraction:

Nuclide half-life: sec

☒ No decay

Number of replicates is an integer with number of desired noise realizations of the simulation.

Counts scale factor is a factor that scales the dynamic image activity, in turn number of counts (noise level).

Scatter fraction is a unitless number, $SF=S/(T+S)$.

Random fraction is a unitless number $RF=R/(T+S+R)$.

Uncheck if you want to simulate physical decay, and specify nuclide half-life in unit (sec).

Kinetic modeling

Kinetic modelling

Input function

☒ From WS ☐ From file

Name : (Bq/cc)

Scale factor:

Model

☒ 1-Tissue ☐ FRTM ☐ SumExp

☐ 2-Tissue ☐ SRTM # exp:

Interpolation

☒ Linear ☐ Nearest ☐ PCHIP ☐ Spline

Time step: sec

Biologic variability

☒ None ☐ Scale:

Read input/reference function vector either from workspace (WS), or from *.mat, *.txt or *.xls-file. Enter the name (string) of the WS variable/file. The data file has to contain ONLY the input/ref function vector, no other data.

The input/ref function vector [nt,1] should be in units (Bq/cc).

The unitless scale factor is a multiplicative scalar that scales the amplitude of the input function. Set to 1 for no scaling.

Choose which kinetic model to simulate. For general sum of exponentials model (SumExp), also specify number of exponentials (integer number).

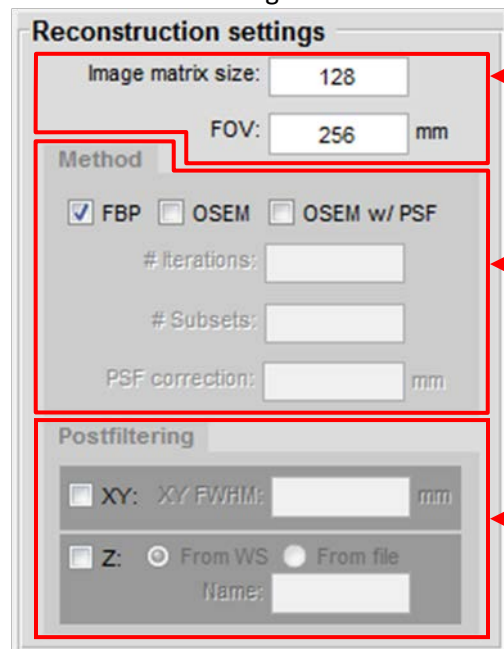
If uneven time sampling, the data will be interpolated to even sampling (for convolution) during fitting. Choose interpolation method, and time step for the interpolation.

The time step is a number in units (sec).

Chose if you want to simulate biologic variability by setting the scale to a unitless number.

Scale of added varaibility: variance of Gaussian noise = image value/scale.

Reconstruction settings



The 'Reconstruction settings' window contains three main sections: 'Image matrix size' with fields for '128' and 'FOV: 256 mm'; 'Method' with checkboxes for 'FBP' (checked), 'OSEM', and 'OSEM w/ PSF', and input fields for '# iterations:', '# Subsets:', and 'PSF correction: mm'; and 'Postfiltering' with checkboxes for 'XY' and 'Z', and input fields for 'XY FWHM: mm' and 'Z' (radio buttons for 'From WS' and 'From file', and a 'Name:' field).

Set desired simulated image matrix XY-size (integer number).

Set image XY field of view (FOV) in (mm). Pixel size will be FOV/matrix size.

Check which type of reconstructed images you want to simulate; filtered back projection (FBP), ordered subset expectation maximization (OSEM), and/or OSEM with point spread function (PSF) correction.

For OSEM and OSEM+PSF, specify number of iterations (integer) and number of subsets (integer).

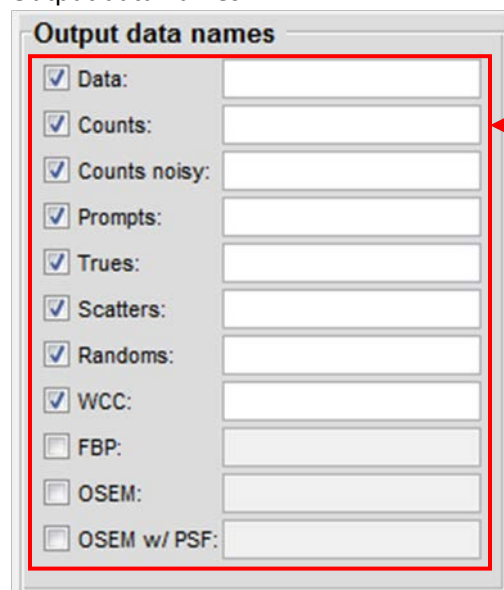
For OSEM+PSF, specify the correction PSF FWHM in (mm).

Check boxes if you want to perform XY and/or Z postfiltering.

Set the XY-postfilter Gaussian FWHM in (mm).

Read the Z-filter either from workspace (WS), or from *.mat, *.txt or *.xls-file. Enter the name (string) of the WS variable/file.

Output data names



The 'Output data names' window features a list of checkboxes on the left and corresponding text input fields on the right. The checked items are 'Data:', 'Counts:', 'Counts noisy:', 'Prompts:', 'Trues:', 'Scatters:', 'Randoms:', and 'WCC:'. The unchecked items are 'FBP:', 'OSEM:', and 'OSEM w/ PSF:'.

Choose what data you want as output from the simulation, and set the name (string) of that data. Will end up in your WS after run.

Data is the structure used as input, with (for parametric image input) a field of the pristine dynamic uptake image added.

Counts is the noiseless sinogram counts of prompts, trues, scatters and randoms.

Counts noisy is the noisy sinogram counts of prompts, trues, scatters and randoms.

Prompts is the prompts sinogram matrix.

Trues is the trues sinogram matrix.

Scatters is the scatters sinogram matrix.

Randoms is the randoms sinogram matrix.

WCC is the well counter calibration factor to calibrate reconstructed image to (Bq/cc).

FBP is the reconstructed 4D FBP image.

OSEM is the reconstructed 4D OSEM image. Each iteration is saved.

OSEM w/ PSF is the reconstructed 4D OSEM w/ PSF correction image. Each iteration is saved.

Buttons



Load settings from chosen *.xls-file.

Reset all settings.

Executes the simulation main program.

Save all current settings to *.xls-file.