In [479…
```python
from sirf.STIR import (ImageData, AcquisitionData,
                       SPECTUBMatrix, AcquisitionModelUsingMatrix,
                       make_Poisson_loglikelihood, OSMAPOSLReconstructor,
                       SeparableGaussianImageFilter, MessageRedirector,
                       FBP2DReconstructor,
)
from simind import *
import pandas as pd
import matplotlib.pyplot as plt
```

In [134…
```python
current_directory = os.getcwd()
current_directory
```

Out[134]:
```
'/home/sam/working/STIR_users_MIC2023'
```

In [78]:
```python
msg = MessageRedirector()
AcquisitionData.set_storage_scheme('memory')
```

In [47]:
```python
# SIMIND parameters
total_activity = 258.423 # MBq
time_per_projection = 43 # seconds
photon_multiplier = 0.01
photopeak_energy = 208 # keV
window_lower = 187.56 # keV
window_upper = 229.24 # keV
source_type = "lu177"
collimator = 'ma-megp'
kev_per_channel = 1
num_energy_spectra_channels = 300

# OSEM parameters
iterations = 5
subsets = 12
```

In [154…
```python
template_image = ImageData(os.path.join(os.getcwd(), "data/Lu177/SPECT_NEMA_Lu177_template.hv"))
mu_map = ImageData(os.path.join(os.getcwd(), "data/Lu177/registered_CTAC.hv"))

measured_data = AcquisitionData(os.path.join(os.getcwd(), "data/Lu177/SPECTCT_NEMA_128_EM001_DS_en_1_Lu177_EM.
```

In [49]:
```python
mu_map_stir = mu_map.clone()
mu_map_stir.fill(np.flip(mu_map_stir.as_array(), axis=2))
```

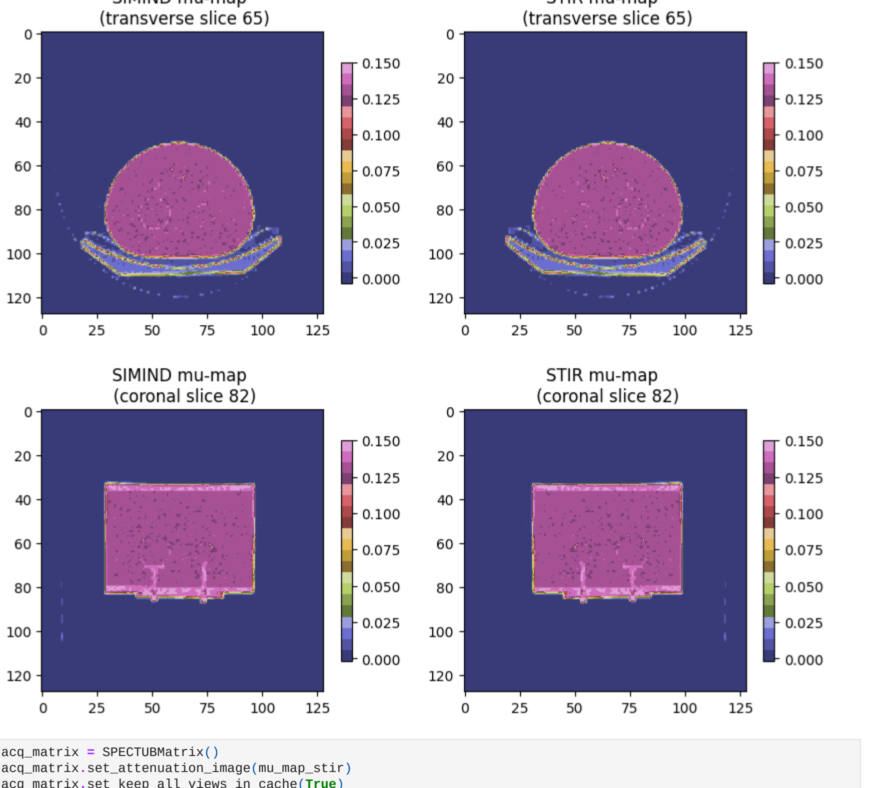
Out[49]:
```
<sirf.STIR.ImageData at 0x7f8972eef850>
```

In [50]:
```python
axial_slice = 65
coronal_slice = 82

vmax = 0.15

fig, ax = plt.subplots(2, 2, figsize=(10, 9))
ax0 = ax[0,0].imshow(mu_map.as_array()[axial_slice, :, :], cmap='tab20b', vmax=vmax)
ax[0,0].set_title(f"SIMIND mu-map \n (transverse slice {axial_slice})")
fig.colorbar(ax0, ax=ax[0,0], shrink=0.7)
ax1 = ax[0,1].imshow(mu_map_stir.as_array()[axial_slice, :, :], cmap='tab20b', vmax=vmax)
ax[0,1].set_title(f"STIR mu-map \n (transverse slice {axial_slice})")
fig.colorbar(ax1, ax=ax[0,1], shrink=0.7)
ax2 = ax[1,0].imshow(mu_map.as_array()[:, coronal_slice, :], cmap='tab20b', vmax=vmax)
ax[1,0].set_title(f"SIMIND mu-map \n (coronal slice {coronal_slice})")
fig.colorbar(ax2, ax=ax[1,0], shrink=0.7)
ax3 = ax[1,1].imshow(mu_map_stir.as_array()[:, coronal_slice, :], cmap='tab20b', vmax=vmax)
ax[1,1].set_title(f"STIR mu-map \n (coronal slice {coronal_slice})")
fig.colorbar(ax3, ax=ax[1,1], shrink=0.7)
```

Out[50]:
```
<matplotlib.colorbar.Colorbar at 0x7f8972cbad40>
```



In [155…
```python
acq_matrix = SPECTUBMatrix()
acq_matrix.set_attenuation_image(mu_map_stir)
acq_matrix.set_keep_all_views_in_cache(True)
acq_matrix.set_resolution_model(1.81534, 0.02148, False)
acq_model = AcquisitionModelUsingMatrix(acq_matrix)
acq_model.set_up(measured_data, template_image)
```

In [156…
```python
def divide(a,b, eps=1e-8):
    return (a+eps)/(b+eps)

def osem_step(acq_model, acq_data, current_image, sensitivity_image, scatter):
    fp = acq_model.forward(current_image) + scatter
    bpr = acq_model.backward(divide(acq_data, fp))
    return divide(current_image * bpr, sensitivity_image)

def run_osem(acq_model, acq_data, initial_image, iterations, subsets, scatter = 0):
    current_image = initial_image.clone()
    sensitivity_images = []
    one_sino = acq_data.get_uniform_copy(1)
    for i in range(iterations):
        for s in range(subsets):
            acq_model.subset_num = s
            if len(sensitivity_images) < subsets:
                sensitivity_images.append(acq_model.backward(one_sino))
            current_image = osem_step(acq_model, acq_data, current_image, sensitivity_images[s], scatter)
            print(f"Completed iteration {i+1} of {iterations}, subset {s+1} of {subsets}")
    return current_image
```

In [157…
```python
acq_model.num_subsets = subsets

osem_reconstruction = run_osem(acq_model, measured_data, template_image.get_uniform_copy(1), iterations, subse
```

```
backprojecting...ok
no additive term added
no unnormalisation applied
no background term added
backprojecting...ok
Completed iteration 1 of 5, subset 1 of 12
backprojecting...ok
no additive term added
no unnormalisation applied
no background term added
backprojecting...ok
Completed iteration 1 of 5, subset 2 of 12
backprojecting...ok
no additive term added
no unnormalisation applied
no background term added
backprojecting...ok
Completed iteration 1 of 5, subset 3 of 12
backprojecting...ok
no additive term added
no unnormalisation applied
no background term added
backprojecting...ok
Completed iteration 1 of 5, subset 4 of 12
backprojecting...ok
no additive term added
no unnormalisation applied
no background term added
backprojecting...ok
Completed iteration 1 of 5, subset 5 of 12
backprojecting...ok
no additive term added
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backprojecting...ok
Completed iteration 1 of 5, subset 6 of 12
backprojecting...ok
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backprojecting...ok
Completed iteration 1 of 5, subset 7 of 12
backprojecting...ok
no additive term added
no unnormalisation applied
no background term added
backprojecting...ok
Completed iteration 1 of 5, subset 8 of 12
backprojecting...ok
no additive term added
no unnormalisation applied
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backprojecting...ok
Completed iteration 1 of 5, subset 9 of 12
backprojecting...ok
no additive term added
no unnormalisation applied
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backprojecting...ok
Completed iteration 1 of 5, subset 10 of 12
backprojecting...ok
no additive term added
no unnormalisation applied
no background term added
backprojecting...ok
Completed iteration 1 of 5, subset 11 of 12
backprojecting...ok
no additive term added
no unnormalisation applied
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Completed iteration 1 of 5, subset 12 of 12
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no unnormalisation applied
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backprojecting...ok
Completed iteration 2 of 5, subset 1 of 12
no additive term added
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Completed iteration 2 of 5, subset 2 of 12
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Completed iteration 2 of 5, subset 3 of 12
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Completed iteration 2 of 5, subset 4 of 12
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Completed iteration 2 of 5, subset 5 of 12
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Completed iteration 2 of 5, subset 8 of 12
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backprojecting...ok
Completed iteration 2 of 5, subset 9 of 12
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Completed iteration 2 of 5, subset 10 of 12
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backprojecting...ok
Completed iteration 2 of 5, subset 11 of 12
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backprojecting...ok
Completed iteration 2 of 5, subset 12 of 12
no additive term added
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backprojecting...ok
Completed iteration 3 of 5, subset 1 of 12
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Completed iteration 3 of 5, subset 2 of 12
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Completed iteration 3 of 5, subset 3 of 12
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Completed iteration 3 of 5, subset 9 of 12
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Completed iteration 3 of 5, subset 10 of 12
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Completed iteration 3 of 5, subset 11 of 12
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Completed iteration 3 of 5, subset 12 of 12
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Completed iteration 4 of 5, subset 1 of 12
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Completed iteration 4 of 5, subset 2 of 12
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Completed iteration 4 of 5, subset 6 of 12
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Completed iteration 4 of 5, subset 7 of 12
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Completed iteration 4 of 5, subset 8 of 12
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Completed iteration 4 of 5, subset 9 of 12
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Completed iteration 4 of 5, subset 10 of 12
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Completed iteration 4 of 5, subset 11 of 12
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Completed iteration 4 of 5, subset 12 of 12
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backprojecting...ok
Completed iteration 5 of 5, subset 1 of 12
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Completed iteration 5 of 5, subset 2 of 12
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Completed iteration 5 of 5, subset 3 of 12
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Completed iteration 5 of 5, subset 4 of 12
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Completed iteration 5 of 5, subset 5 of 12
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Completed iteration 5 of 5, subset 6 of 12
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Completed iteration 5 of 5, subset 7 of 12
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backprojecting...ok
Completed iteration 5 of 5, subset 10 of 12
no additive term added
no unnormalisation applied
no background term added
backprojecting...ok
Completed iteration 5 of 5, subset 11 of 12
no additive term added
no unnormalisation applied
no background term added
backprojecting...ok
Completed iteration 5 of 5, subset 12 of 12
```
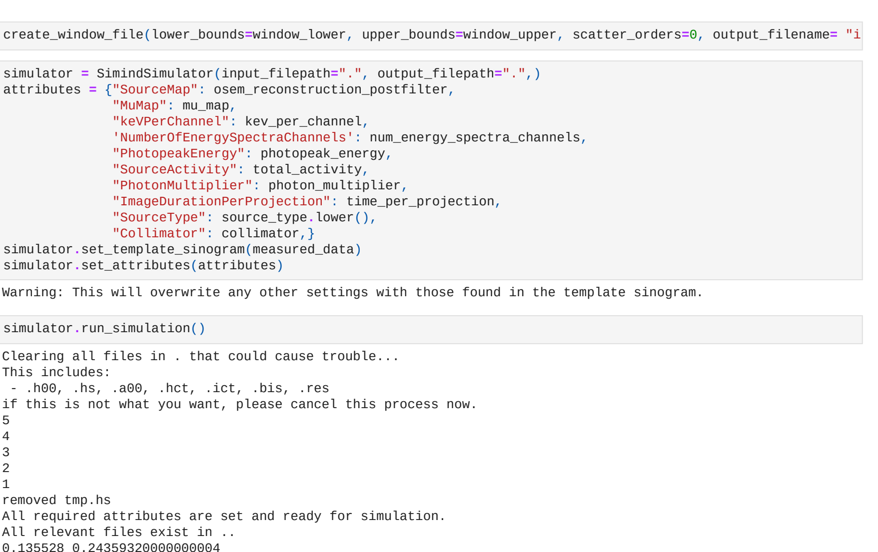

In [158…
```python
osem_reconstruction_postfilter = osem_reconstruction.clone()

gaussian_filter = SeparableGaussianImageFilter()
gaussian_filter.set_fwhms((5, 5, 5))
gaussian_filter.apply(osem_reconstruction_postfilter)

osem_reconstruction_postfilter_array = osem_reconstruction_postfilter.as_array()
osem_reconstruction_postfilter_array[osem_reconstruction_postfilter_array < 0.1 * osem_reconstruction_postfilt
osem_reconstruction_postfilter.fill(osem_reconstruction_postfilter_array)
```

Out[158]:
```
<sirf.STIR.ImageData at 0x7f89710b7a60>
```

In [159…
```python
fig, ax = plt.subplots(1, 2, figsize=(10, 5))
ax0 = ax[0].imshow(osem_reconstruction.as_array()[axial_slice, :, :])
ax[0].set_title(f"OSEM reconstruction \n (transverse slice {axial_slice})")
fig.colorbar(ax0, ax=ax[0], shrink=0.7)
ax1 = ax[1].imshow(osem_reconstruction_postfilter.as_array()[axial_slice, :, :])
ax[1].set_title(f"OSEM reconstruction postfiltered \n and thresholder \n (transverse slice {axial_slice})")
fig.colorbar(ax1, ax=ax[1], shrink=0.7)
```

Out[159]:
```
<matplotlib.colorbar.Colorbar at 0x7f8971249f60>
```



In [60]:
```python
create_window_file(lower_bounds=window_lower, upper_bounds=window_upper, scatter_orders=0, output_filename= "i
```

In [61]:
```python
simulator = SimindSimulator(input_filepath=".", output_filepath=".",)
attributes = {"SourceMap": osem_reconstruction_postfilter,
              "MuMap": mu_map,
              "keVPerChannel": kev_per_channel,
              'NumberOfEnergySpectraChannels': num_energy_spectra_channels,
              "PhotopeakEnergy": photopeak_energy,
              "SourceActivity": total_activity,
              "PhotonMultiplier": photon_multiplier,
              "ImageDurationPerProjection": time_per_projection,
              "SourceType": source_type.lower(),
              "Collimator": collimator,}
simulator.set_template_sinogram(measured_data)
simulator.set_attributes(attributes)
```

```
Warning: This will overwrite any other settings with those found in the template sinogram.
```

In [62]:
```python
simulator.run_simulation()
```

```
Clearing all files in . that could cause trouble...
This includes:
 - .h00, .hs, .a00, .hct, .ict, .bis, .res
if this is not what you want, please cancel this process now.
5
4
3
2
1
removed tmp.hs
All required attributes are set and ready for simulation.
All relevant files exist in ..
0.135528 0.24359320000000004
symlink already exists
symlink already exists
symlink already exists
symlink already exists
symlink already exists
symlink already exists
symlink already exists
symlink already exists
symlink already exists


              SIMIND Monte Carlo Simulation Program    V7.0.3
------------------------------------------------------------------------------
 Phantom(S): h2o       Crystal...: nai       InputFile.: symlink_input
 Phantom(B): bone      BackScatt.: pmt       OutputFile: output
 Collimator: pb_sb2    SourceRout: smap      SourceFile: tmp_source
 Cover.....: al        ScoreRout.: scattwin  DensityMap: tmp_density
------------------------------------------------------------------------------
 PhotonEnergy.......: 140          lu177     PhotonsPerProj....: 701513
 EnergyResolution...: 8.8          ma-megp   Activity..........: 1
 MaxScatterOrder....: 5            SPECT     DetectorLenght....: 25
 DetectorWidth......: 0            BScatt    DetectorHeight....: 0.953
 UpperEneWindowTresh: 154          Random    Distance to det...: 19.1125
 LowerEneWindowTresh: 126          Phantom   ShiftSource X.....: 0
 PixelSize  I.......: 0.44197      Resolut   ShiftSource Y.....: 0
 PixelSize  J.......: 0.44197      Header    ShiftSource Z.....: 0
 HalfLength S.......: 28.28634               HalfLength P......: 28.28634
 HalfWidth  S.......: 28.28634               HalfWidth  P......: 28.28634
 HalfHeight S.......: 28.28634               HalfHeight P......: 28.28634
 SourceType.........: Integer2Map            PhantomType.......: Integer2Map
------------------------------------------------------------------------------
          Projection          Hits       Scatt/Tot    Progress



 GENERAL DATA
 keV/channel........: 1                      CutoffEnergy......: 0
 Photons/Bq.........: 0.22749                StartingAngle.....: 360
 CameraOffset X.....: 0                      CoverThickness....: 0
 CameraOffset Y.....: 0                      BackscatterThickn.: 10
 MatrixSize I.......: 128                    IntrinsicResolut..: 0.34
 MatrixSize J.......: 128                    AcceptanceAngle...: 4.71508
 Emission type......: 2                      Initial Weight....: 0.32428
 NN ScalingFactor...: 0.01                   Energy Channels...: 300
------------------------------------------------------------------------------
 SPECT DATA
 RotationMode.......: 360                    Nr of Projections.: 120
 RotationAngle......: 3                      Projection.[start]: 1
 Orbital fraction...: 1                      Projection...[end]: 120
------------------------------------------------------------------------------
 COLLIMATOR DATA FOR ROUTINE: Analytical
 CollimatorCode.....: ma-megp                CollimatorType....: Parallel
 HoleSize X.........: 0.25                   Distance X........: 0.12
 HoleSize Y.........: 0.28868                Distance Y........: 0.24826
 CenterShift X......: 0.185                  X-Ray flag........: F
 CenterShift Y......: 0.32043                CollimThickness...: 3.5
 HoleShape..........: Hexagonal              Space Coll2Det....: 0
 CollDepValue [57]..: 0                      CollDepValue [58].: 0
 CollDepValue [59]..: 0                      CollDepValue [60].: 0
------------------------------------------------------------------------------
 IMAGE-BASED PHANTOM DATA
 RotationCentre.....:  65, 65                Bone definition...: 1170
 CT-Pixel size......: 0.44197                Slice thickness...: 0.44197
 StartImage.........: 1                      No of CT-Images...: 128
 MatrixSize I.......: 128                    CTmapOrientation..: 0
 MatrixSize J.......: 128                    StepSize..........: 0.1
 CenterPoint I......: 65                     ShiftPhantom X....: 0
 CenterPoint J......: 65                     ShiftPhantom Y....: 0
 CenterPoint K......: 65                     ShiftPhantom Z....: 0
------------------------------------------------------------------------------
  Photon energy       Abundance
     54.612 keV       0.1590E-01
     55.791 keV       0.2780E-01
     63.294 keV       0.9170E-02
     65.130 keV       0.2450E-02
     71.642 keV       0.1726E-02
    112.950 keV       0.6200E-01
    136.725 keV       0.4700E-03
    208.366 keV       0.1038
    249.674 keV       0.2012E-02
    321.316 keV       0.2160E-02
------------------------------------------------------------------------------
  Scattwin results: Window file: symlink_input.win

  Win  WinAdded  Range(keV)   ScaleFactor
   1       0    187.6 - 229.2    1.00
   2       1    187.6 - 229.2    1.00

  Win    Total    Scatter   Primary  S/P-Ratio S/T Ratio  Cps/MBq
   1   0.338E+03 0.108E+03 0.230E+03 0.471E+00 0.320E+00 0.282E+01
   2   0.338E+03 0.108E+03 0.230E+03 0.471E+00 0.320E+00 0.282E+01

  Win  Geo(Air)  Pen(Air)  Sca(Air)  Geo(Tot)  Pen(Tot)  Sca(Tot)
   1   100.00%     0.00%     0.00%   100.00%     0.00%     0.00%
   2   100.00%     0.00%     0.00%   100.00%     0.00%     0.00%

  Win   SC 1  SC 2  SC 3  SC 4  SC 5
   1   86.4% 12.3%  1.2%  0.1%  0.0%
   2   86.4% 12.3%  1.2%  0.1%  0.0%
------------------------------------------------------------------------------
 INTERACTIONS IN THE CRYSTAL
 MaxValue spectrum..: 32.45
 MaxValue projection: 0.3113E-02
 CountRate spectrum.: 22.53
 CountRate E-Window.: 1.753
------------------------------------------------------------------------------
 SCATTER IN ENERGY WINDOW
 Scatter/Primary....: 11.60741
 Scatter/Total......: 0.92068
 Scatter order 1....: 35.70 %
 Scatter order 2....: 39.72 %
 Scatter order 3....: 18.48 %
 Scatter order 4....: 5.10 %
 Scatter order 5....: 1.00 %
------------------------------------------------------------------------------
 CALCULATED DETECTOR PARAMETERS
 Efficiency E-window: 0.0715
 Efficiency spectrum: 0.9192
 Sensitivity Cps/MBq: 1.7529
 Sensitivity Cpm/uCi: 3.8914
------------------------------------------------------------------------------
 Simulation started.: 2023:10:26 14:51:10
 Simulation stopped.: 2023:10:26 15:02:16
 Elapsed time.......: 0 h, 11 m and 6 s
 DetectorHits.......: 2420744
 DetectorHits/CPUsec: 3681
------------------------------------------------------------------------------
 SIMIND built 2023:02:22 with intel Linux  compiler
 Random number generator: ranmar
 Comment:EMISSION
 Energy resolution as function of 1/sqrt(E)
 Header file: output.h00
 Linear angle sampling within acceptance angle
 Inifile: simind.ini
 Command: symlink_input output /NN:0.01/FS:tmp_source/FD:tmp_density/FW:symlink_input/PX:0.44197402000427244/T
H:0.44197402000427244/28:0.44197402000427244/31:0.44197402000427244/fi:lu177/cc:ma-megp/02:28.286337280273436/
05:28.286337280273436/03:28.286337280273436/04:28.286337280273436/06:28.286337280273436/07:28.286337280273436/
14:-1/15:-1/29:120/34:128/76:128/77:128/78:128/79:128/81:0/82:0/84:1/30:2/41:360.0/12:19.1125/80:300/27:1/25:
1/tr:04/tr:05/tr:11/tr:14
removed symlink @ ./symlink_input.smc
removed symlink @ ./symlink_input.win
```

In [119…
```python
simind_total = simulator.get_output_total()
simind_scatter = simulator.get_output_scatter()
```

```
Output in ./output_air_w1.hs

WARNING: No Time_Zone info in DICOM DT. Using local time-zone without DST (+0 secs)
Output in ./output_tot_w1.hs

WARNING: No Time_Zone info in DICOM DT. Using local time-zone without DST (+0 secs)
Output in ./output_sca_w1.hs

WARNING: No Time_Zone info in DICOM DT. Using local time-zone without DST (+0 secs)
Output in ./output_sca_w2.hs

WARNING: No Time_Zone info in DICOM DT. Using local time-zone without DST (+0 secs)

WARNING: No Time_Zone info in DICOM DT. Using local time-zone without DST (+0 secs)

WARNING: No Time_Zone info in DICOM DT. Using local time-zone without DST (+0 secs)

WARNING: No Time_Zone info in DICOM DT. Using local time-zone without DST (+0 secs)

WARNING: No Time_Zone info in DICOM DT. Using local time-zone without DST (+0 secs)

WARNING: No Time_Zone info in DICOM DT. Using local time-zone without DST (+0 secs)

WARNING: No Time_Zone info in DICOM DT. Using local time-zone without DST (+0 secs)
```

In [167…
```python
stir_projection = measured_data.get_uniform_copy(0)
for i in range(subsets):
    acq_model.subset_num = i
    stir_projection+=acq_model.forward(osem_reconstruction_postfilter)
```

```
no additive term added
no unnormalisation applied
no background term added
no additive term added
no unnormalisation applied
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no additive term added
no unnormalisation applied
no background term added
no additive term added
no unnormalisation applied
no background term added
no additive term added
no unnormalisation applied
no background term added
```
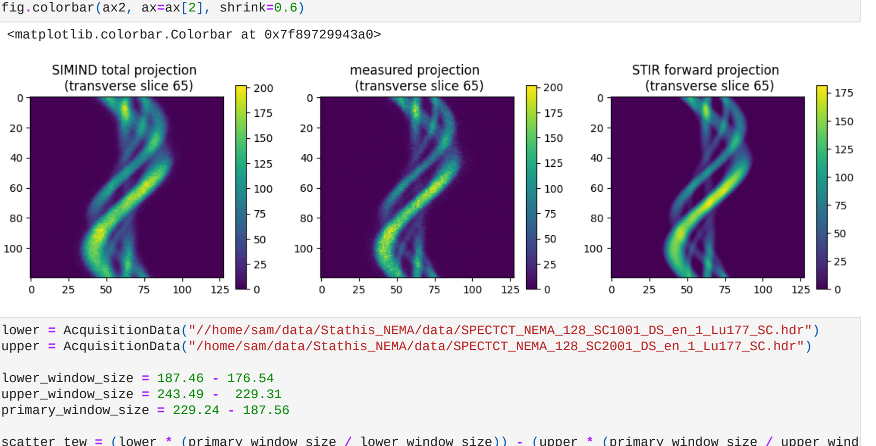

In [168…
```python
fig, ax = plt.subplots(1, 3, figsize=(14, 5))
ax0 = ax[0].imshow(simind_total.as_array()[0,axial_slice, :, :])
ax[0].set_title(f"SIMIND total projection \n (transverse slice {axial_slice})")
fig.colorbar(ax0, ax=ax[0], shrink=0.6)
ax1 = ax[1].imshow(measured_data.as_array()[0,axial_slice, :, :])
ax[1].set_title(f"measured projection \n (transverse slice {axial_slice})")
fig.colorbar(ax1, ax=ax[1], shrink=0.6)
ax2 = ax[2].imshow(stir_projection.as_array()[0,axial_slice, :, :])
ax[2].set_title(f"STIR forward projection \n (transverse slice {axial_slice})")
fig.colorbar(ax2, ax=ax[2], shrink=0.6)
```

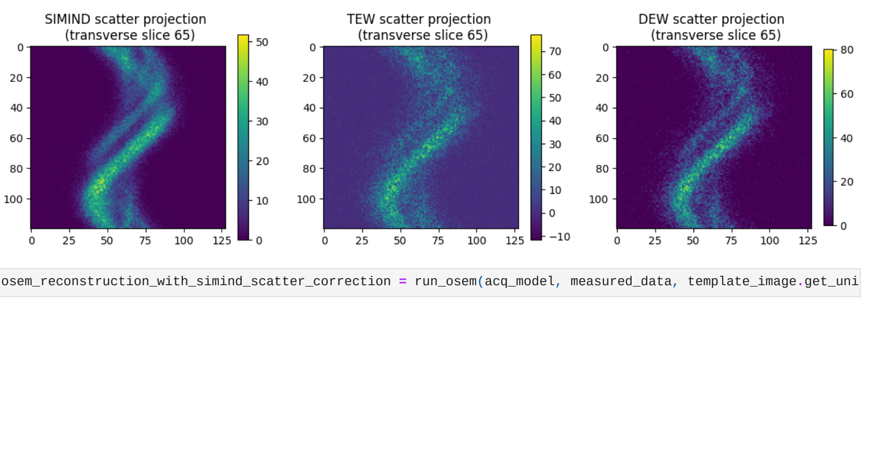
Out[168]:
```
<matplotlib.colorbar.Colorbar at 0x7f89729943a0>
```



In [508…
```python
lower = AcquisitionData("//home/sam/data/Stathis_NEMA/data/SPECTCT_NEMA_128_SC1001_DS_en_1_Lu177_SC.hdr")
upper = AcquisitionData("/home/sam/data/Stathis_NEMA/data/SPECTCT_NEMA_128_SC2001_DS_en_1_Lu177_SC.hdr")

lower_window_size = 187.46 - 176.54
upper_window_size = 243.49 -  229.31
primary_window_size = 229.24 - 187.56

scatter_tew = (lower * (primary_window_size / lower_window_size)) - (upper * (primary_window_size / upper_wind
scatter_dew = (lower * (primary_window_size / lower_window_size))
corrected_tew = measured_data - scatter_tew
corrected_dew = measured_data - scatter_dew
```

In [509…
```python
fig, ax = plt.subplots(1, 3, figsize=(14, 5))
ax0 = ax[0].imshow(simind_scatter.as_array()[0,axial_slice, :, :])
ax[0].set_title(f"SIMIND scatter projection \n (transverse slice {axial_slice})")
fig.colorbar(ax0, ax=ax[0], shrink=0.7)
ax1 = ax[1].imshow(scatter_tew.as_array()[0,axial_slice, :, :])
ax[1].set_title(f"TEW scatter projection \n (transverse slice {axial_slice})")
fig.colorbar(ax1, ax=ax[1], shrink=0.7)
ax2 = ax[2].imshow(scatter_dew.as_array()[0,axial_slice, :, :])
ax[2].set_title(f"DEW scatter projection \n (transverse slice {axial_slice})")
fig.colorbar(ax2, ax=ax[2], shrink=0.6)
```

Out[509]:
```
<matplotlib.colorbar.Colorbar at 0x7f89721dd8a0>
```



In [172…
```python
osem_reconstruction_with_simind_scatter_correction = run_osem(acq_model, measured_data, template_image.get_uni
```

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```

In [173…

```
[illegible]
```

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```
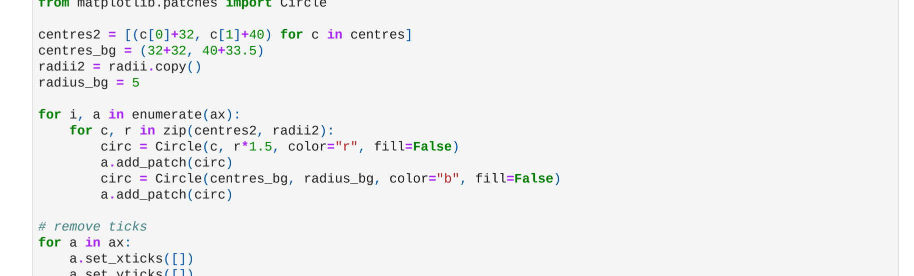
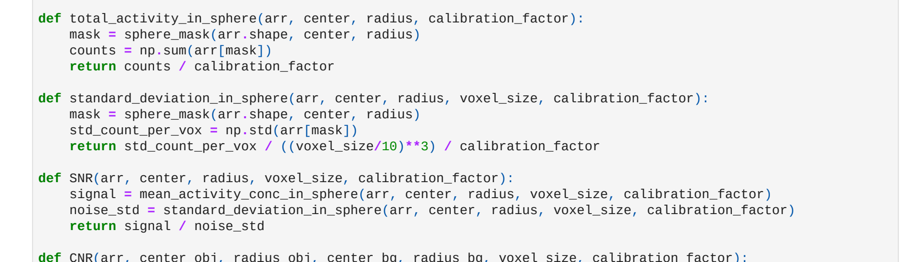

In [341…

```python
from matplotlib.colors import LogNorm

# round osem_max up to the nearest power of 10
osem_max = 10 ** np.ceil(np.log10(osem_reconstruction.max()))

# Lu177 [65, 40:104, 32:96]

slice = 66
vmin = 0.1

# same as above but highlight lower values with inverse log scale
fig, ax = plt.subplots(1, 3, figsize=(12, 5))
ax0 = ax[0].imshow(osem_reconstruction.as_array()[slice, 40:104, 32:96], norm=LogNorm(vmin=vmin, vmax=osem_max
ax[0].set_title("OSEM - no scatter correction")
ax1 = ax[1].imshow(osem_reconstruction_with_simind_scatter_correction.as_array()[slice, 40:104, 32:96], norm=L
ax[1].set_title("OSEM - simind scatter correction")
ax3 = ax[2].imshow(osem_reconstruction_with_tew_scatter_correction.as_array()[slice, 40:104, 32:96], norm=LogN
ax[2].set_title("OSEM - TEW scatter correction")
fig.colorbar(ax0, ax=ax[0], shrink=0.6)
fig.colorbar(ax1, ax=ax[1], shrink=0.6)
fig.colorbar(ax3, ax=ax[2], shrink=0.6)


# draw spheres on images to show where the spheres are
# sphere diams are 60, 37, 28, 22, 17, 13 mm
from matplotlib.patches import Circle

# sphere centres in pixels - Lu177
centres = [(19.5, 42), (42.5, 41.5), (31, 22), (42.5, 28.5), (20, 28.5), (31, 48)]
# sphere radii in pixels
pixel_size = template_image.voxel_sizes()[0] # assume isotropic voxels (which we know they are)
diams = [60, 37, 28, 22, 17, 13]
radii = [d / pixel_size /2 for d in diams]

for i, a in enumerate(ax):
    for c, r in zip(centres, radii):
        circ = Circle(c, r, color="r", fill=False)
        a.add_patch(circ)

# remove ticks
for a in ax:
    a.set_xticks([])
    a.set_yticks([])
```



In [506…

```python
# round osem_max up to the nearest power of 10
osem_max = 10 ** np.ceil(np.log10(osem_reconstruction.max()))

slice = 66
vmin = 0.1

# same as above but highlight lower values with inverse log scale
fig, ax = plt.subplots(1, 3, figsize=(12, 5))
ax0 = ax[0].imshow(osem_reconstruction.as_array()[slice])
ax[0].set_title("OSEM - no scatter correction")
ax1 = ax[1].imshow(osem_reconstruction_with_simind_scatter_correction.as_array()[slice])
ax[1].set_title("OSEM - simind scatter correction")
ax3 = ax[2].imshow(osem_reconstruction_with_tew_scatter_correction.as_array()[slice])
ax[2].set_title("OSEM - TEW scatter correction")
fig.colorbar(ax0, ax=ax[0], shrink=0.6)
fig.colorbar(ax1, ax=ax[1], shrink=0.6)
fig.colorbar(ax3, ax=ax[2], shrink=0.6)


# draw spheres on images to show where the spheres are
# sphere diams are 60, 37, 28, 22, 17, 13 mm
from matplotlib.patches import Circle

centres2 = [(c[0]+32, c[1]+40) for c in centres]
centres_bg = (32+32, 40+33.5)
radii2 = radii.copy()
radius_bg = 5

for i, a in enumerate(ax):
    for c, r in zip(centres2, radii2):
        circ = Circle(c, r*1.5, color="r", fill=False)
        a.add_patch(circ)
        circ = Circle(centres_bg, radius_bg, color="b", fill=False)
        a.add_patch(circ)

# remove ticks
for a in ax:
    a.set_xticks([])
    a.set_yticks([])
```



In [474…

```python
# some functions for calculating metrics

def sphere_mask(arr_shape, center, radius):
    z, y, x = np.ogrid[:arr_shape[0], :arr_shape[1], :arr_shape[2]]
    dist_sq = (x - center[2])**2 + (y - center[1])**2 + (z - center[0])**2
    return dist_sq <= radius**2

def mean_activity_conc_in_sphere(arr, center, radius, voxel_size, calibration_factor):
    mask = sphere_mask(arr.shape, center, radius)
    mean_count_per_vox = np.mean(arr[mask])
    return mean_count_per_vox / ((voxel_size/10)**3) / calibration_factor

def total_activity_in_sphere(arr, center, radius, calibration_factor):
    mask = sphere_mask(arr.shape, center, radius)
    counts = np.sum(arr[mask])
    return counts / calibration_factor

def standard_deviation_in_sphere(arr, center, radius, voxel_size, calibration_factor):
    mask = sphere_mask(arr.shape, center, radius)
    std_count_per_vox = np.std(arr[mask])
    return std_count_per_vox / ((voxel_size/10)**3) / calibration_factor

def SNR(arr, center, radius, voxel_size, calibration_factor):
    signal = mean_activity_conc_in_sphere(arr, center, radius, voxel_size, calibration_factor)
    noise_std = standard_deviation_in_sphere(arr, center, radius, voxel_size, calibration_factor)
    return signal / noise_std

def CNR(arr, center_obj, radius_obj, center_bg, radius_bg, voxel_size, calibration_factor):
    signal_obj = mean_activity_conc_in_sphere(arr, center_obj, radius_obj, voxel_size, calibration_factor)
    signal_bg = mean_activity_conc_in_sphere(arr, center_bg, radius_bg, voxel_size, calibration_factor)
    noise_std_bg = standard_deviation_in_sphere(arr, center_bg, radius_bg, voxel_size, calibration_factor)
    return (signal_obj - signal_bg) / noise_std_bg

calibration_factor = 0.0472 # Counts per second per MBq = counts / acquisition time / activity
calibration_factor*= (time_per_projection * measured_data.dimensions()[2]) # counts per MBq
activity_concentration = 1.611 # MBq/ml
activity_concentraion_voxel = activity_concentration * template_image.voxel_sizes()[0] * template_image.voxel_

radii_150percent = [r * 1.5 for r in radii] # to include spillout
radii_75percent = [r * 0.75 for r in radii]
radii_50percent = [r * 0.5 for r in radii]

centres_3d = [(slice, c[1]+40, c[0]+32) for c in centres] # centres for full 3D array
centre_bg_3d = (slice, 40+33.5, 32+32) # centre for full 3D

expected_sphere_activity = [activity_concentration * 4/3 * np.pi * (d/2/10)**3 for d in diams]
```

In [477…

```python
def calculate_metrics(arr, center, radius, voxel_sizes, calibration_factor, bg_center, bg_radius):
    voxel_volume = voxel_sizes[0] * voxel_sizes[1] * voxel_sizes[2] # ml
    voxel_size_mm = np.mean(voxel_sizes) # assuming voxels are approximately cubic

    total_activity = total_activity_in_sphere(arr, center, radius, calibration_factor)
    activity_conc = mean_activity_conc_in_sphere(arr, center, radius, voxel_size_mm, calibration_factor)
    snr = SNR(arr, center, radius, voxel_size_mm, calibration_factor)
    cnr = CNR(arr, center, radius, bg_center, bg_radius, voxel_size_mm, calibration_factor)

    return total_activity, activity_conc, snr, cnr
```

```
/tmp/ipykernel_2692758/3259244206.py:26: RuntimeWarning: divide by zero encountered in scalar divide
  return signal / noise_std
Expected sphere activity (MBq):
[182.19980753759364, 42.7266983851932, 18.51689895863544, 8.981775697501378, 4.144202103852766, 1.853208227593
0244]
Metrics
Total Activity, Activity Concentration, SNR, CNR
Metrics for original radii (Total Activity, Activity Concentration, SNR, CNR):
[(167.4420400982131, 1.5175514485234456, 3.1183226343138486, 62.640410208084134), (32.32931223042205, 1.185002
1635110923, 2.931927589231681, 58.89755837225202), (13.109940170630914, 1.0329829116853884, 2.516712709792174
4, 54.62815029322612), (4.59491186927612, 0.9503836281134654, 3.0940103852904977, 55.86743607511406), (1.66702
03243381418, 0.6895926867039215, 2.7851259743175405, 51.75123473045673), (0.19112251666666347, 0.1165112933692
3038, 1.4102690331489969, 7.155715306403805)]

Metrics for 75% radii:
[(88.9489045203899, 1.8596902585425321, 6.808645979465786, 92.2705337678933), (17.58498153115146, 1.4976584316
232797, 5.089325693899291, 79.86258018364941), (6.774722409928116, 1.3766591406808, 4.684776960997856, 81.6800
560466513), (1.9961091350935838, 1.1567606136728274, 4.434033893611073, 88.11805098406576), (0.742041317552950
8, 0.8594841506652287, 3.9008789013249703, 63.63867326247697), (0.10479314930882878, 0.17339822194659288, 1.68
39510221232468, 10.239116195021072)]

Metrics for 50% radii:
[(29.564937300350646, 1.9680561181363976, 8.480382515540768, 105.16299702418276), (5.2758887098866465, 1.69747
30995592768, 7.210497853533188, 96.24384029761102), (2.2273295124732092, 1.6016614827621152, 5.86473292762013
4, 133.07390032479958), (1.267303478825877, 1.2232329087535103, 6.911991143014937, 91.29191201530118), (0.1737
11836251898, 1.0060259675457803, 15.591988595705677, 73.31193178164139), (0.025578002753638043, 0.296262310310
31647, inf, 19.546257385718047)]

Total Activity for 150% radii:
[242.69146706686342, 49.79970348349634, 20.179522991368373, 8.919775650451443, 3.613333275433737, 0.27537872155
06885]
```

In [501…

```python
reconstructions = {
    'OSEM': osem_reconstruction.as_array(),
    'OSEM with Simind Scatter': osem_reconstruction_with_simind_scatter_correction.as_array(),
    'OSEM with TEW Scatter': osem_reconstruction_with_tew_scatter_correction.as_array()
}

# Lists of metrics and radii
radii_list = [radii, radii_75percent, radii_50percent, radii_150percent]
radii_names = ["Original", "75%", "50%", "150%"]

# Initialize empty list for storing dataframes
dfs = []

# Iterate for each radii
for rad, rad_name in zip(radii_list, radii_names):

    # Create a temporary dictionary to build dataframe
    data = {}

    for recon_name, recon_data in reconstructions.items():

        # Check if rad_name is 150% for special case (only Total Activity)
        if rad_name == "150%":
            activity_list = [total_activity_in_sphere(recon_data, c, r, calibration_factor) for c, r in zip(ce
            data[recon_name] = activity_list
        else:
            activity_concentration_list = []
            snr_list = []
            cnr_list = []

            for c, r in zip(centres_3d, rad):
                activity_concentration = mean_activity_conc_in_sphere(recon_data, c, r, template_image.voxel_s
                snr = activity_concentration / standard_deviation_in_sphere(recon_data, c, r, template_image.v

                bg_std = standard_deviation_in_sphere(recon_data, centre_bg_3d, r, template_image.voxel_sizes(
                cnr = (activity_concentration - mean_activity_conc_in_sphere(recon_data, centre_bg_3d, r, temp

                activity_concentration_list.append(activity_concentration)
                snr_list.append(snr)
                cnr_list.append(cnr)

            # We store each metric as a separate column in the dictionary
            data[f"{recon_name} - Activity Concentration"] = activity_concentration_list
            data[f"{recon_name} - SNR"] = snr_list
            data[f"{recon_name} - CNR"] = cnr_list

    # Convert dictionary to DataFrame with sphere diameters as the index and append to list
    df = pd.DataFrame(data, index=diams)  # Set sphere diameters as the index
    df.index.name = "NEMA sphere diameter"  # Set the index title
    dfs.append(df)

# At this point, dfs contains the four DataFrames. You can access each one by indexing the list.
original_df, seventy_five_df, fifty_df, one_fifty_df = dfs
```

```
/tmp/ipykernel_2692758/3375048664.py:35: RuntimeWarning: divide by zero encountered in scalar divide
  snr = activity_concentration / standard_deviation_in_sphere(recon_data, c, r, template_image.voxel_sizes()
[0], calibration_factor)
```

In [503…

```python
one_fifty_df
```

Out[503]:

NEMA sphere diameter	OSEM	OSEM with Simind Scatter	OSEM with TEW Scatter
60	242.691467	175.641681	200.189378
37	49.799703	37.372329	43.167686
28	20.179523	15.984001	17.881021
22	8.919776	7.073645	7.999460
17	3.613333	2.491531	3.040209
13	0.275379	0.135469	0.170369

In [502…

```
original_df
```

Out[502]:

NEMA sphere diameter	OSEM - Activity Concentration	OSEM - SNR	OSEM - CNR	OSEM with Simind Scatter - Activity Concentration	OSEM with Simind Scatter - SNR	OSEM with Simind Scatter - CNR	OSEM with TEW Scatter - Activity Concentration	OSEM with TEW Scatter - SNR	OSEM with TEW Scatter - CNR
60	1.517551	3.118323	62.640410	1.247191	2.707297	287.085257	1.330680	2.914540	115.867997
37	1.185002	2.931928	58.897558	1.004254	2.582313	855.213126	1.075202	2.792764	153.171514
28	1.032983	2.516713	54.628150	0.900085	2.267638	761.574056	0.954974	2.422586	144.914152
22	0.950384	3.094010	55.867436	0.849574	2.783032	601.932388	0.892051	2.967017	160.470624
17	0.689593	2.785126	51.751235	0.567389	1.966738	312.119226	0.632058	2.552387	148.933649
13	0.116511	1.410269	7.155715	0.061081	0.861318	44.548969	0.079185	1.023473	19.979077

In [504…

```
seventy_five_df
```

Out[504]:

NEMA sphere diameter	OSEM - Activity Concentration	OSEM - SNR	OSEM - CNR	OSEM with Simind Scatter - Activity Concentration	OSEM with Simind Scatter - SNR	OSEM with Simind Scatter - CNR	OSEM with TEW Scatter - Activity Concentration	OSEM with TEW Scatter - SNR	OSEM with TEW Scatter - CNR
60	1.859690	6.808646	92.270534	1.562564	5.751009	1079.620464	1.639753	6.110158	242.318050
37	1.497658	5.089326	79.862580	1.302519	4.608647	1102.498270	1.366953	4.802178	207.713416
28	1.376659	4.684777	81.680056	1.227521	4.384244	870.115249	1.286546	4.538594	231.795008
22	1.156017	4.434034	88.118051	1.049813	4.109932	578.262517	1.087210	4.214877	256.821606
17	0.859484	3.900879	63.638673	0.734412	2.843879	545.908800	0.793706	3.665015	207.338718
13	0.173398	1.683951	10.239116	0.111626	1.185797	107.119389	0.130204	1.382025	23.483998

In [505…

```
fifty_df
```

Out[505]:

NEMA sphere diameter	OSEM - Activity Concentration	OSEM - SNR	OSEM - CNR	OSEM with Simind Scatter - Activity Concentration	OSEM with Simind Scatter - SNR	OSEM with Simind Scatter - CNR	OSEM with TEW Scatter - Activity Concentration	OSEM with TEW Scatter - SNR	OSEM with TEW Scatter - CNR
60	1.968056	8.480383	105.162997	1.665876	7.197411	1433.575653	1.727400	7.271773	264.502421
37	1.697473	7.210498	96.243840	1.499663	6.443198	961.380652	1.544167	6.619438	280.798782
28	1.601661	5.864733	133.073900	1.410632	5.195220	736.619666	1.504947	5.535437	350.824155
22	1.223233	6.911991	91.291912	1.087273	7.330899	808.646878	1.147791	6.314268	300.185761
17	1.006026	15.591989	73.311932	0.986193	17.852331	957.900355	0.937909	14.350916	178.067026
13	0.296262	inf	19.546257	0.250763	inf	242.472378	0.252186	inf	46.829638