2024 IEEE NSS MIC RTSD
26 OCT – 2 NOV 2024
TAMPA , FLORIDA, USA

NPL
National Physical Laboratory
UCL

Enhancing SIMIND-SIRF integration for improved SPECT modelling and reconstruction using residual correction principles

Sam Porter[1,2], Daniel Deidda[2], Kris Thielemans[1] & Rebecca Gillen[1,3]

1 Institute of Nuclear Medicine, University College London
2 National Physical Laboratory
3 NHS Greater Glasgow and Clyde

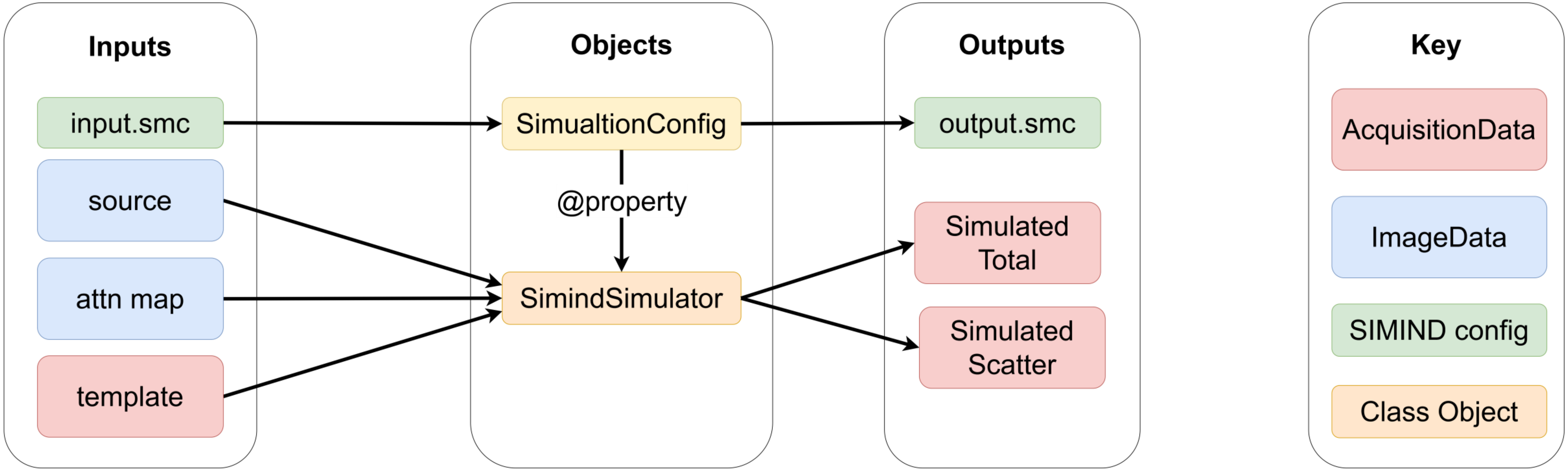
Enhancing SIMIND-STIR connection

- Basic Structure of connection code
- Preliminary results
  - Lutetium-177
  - Yttrium-90

Reconstruction with residual correction

- Basic idea behind residual correction method
- Preliminary results
  - Yttrium-90 feasibility study
  - Lutetium-177 simulations
  - Yttrium-90 simulations

Basic Connection Principles



Basic Connection Principles

1. Read in SIMIND config file & define SIRF data objects

```
simulator = SimindSimulator(config_filepath, output_dir, output_prefix, source, mu_map, template_sinogram)
```

```
self.config = SimulationConfig(config_filepath)
```

2. Edit indexes, flags and add runtime switches

```
simulator.config.set_comment("Comment to label output files")

simulator.config.set_value("index name", index_value)
simulator.config.set_value(index_number, index_value)

simulator.config.set_flag("flag name", flag_value)
simulator.config.set_flag(flag_number, flag_value)

simulator.config.set_text_variable("text variable name", "text variable value")
simulator.config.set_text_variable(text_variable_number, "text variable value")

simulator.set_windows(window_lower, window_upper, scatter_order)

simulator.add_runtime_switch("RuntimeAcronym", runtime_value)
```

```
simulator.config.print_config()
```

Basic Connection Principles

3. Run simulation

```
simulator.run_simulation()
```

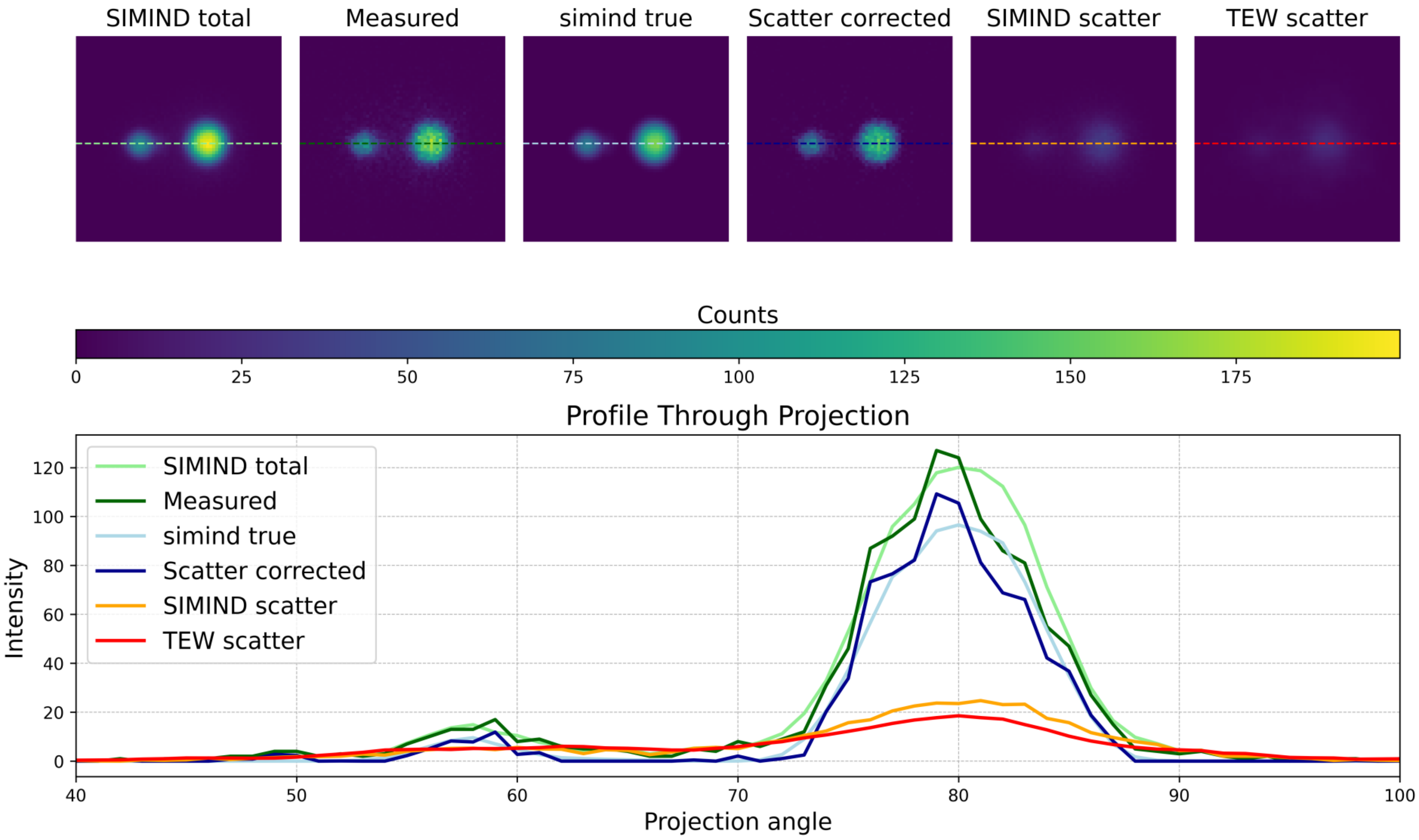
```
self.config.save_file(os.path.join(self.output_dir, self.output_prefix + ".smc"))
```

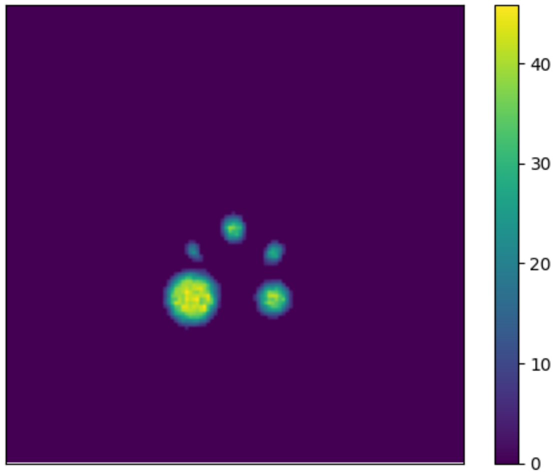
4. Get the output files as SIRF objects

```
simind_total = simulator.get_output_total(window_number)
simind_scatter = simulator.get_output_scatter(window_number)
simind_true = simind_total - simind_scatter
```

Results – Lu177

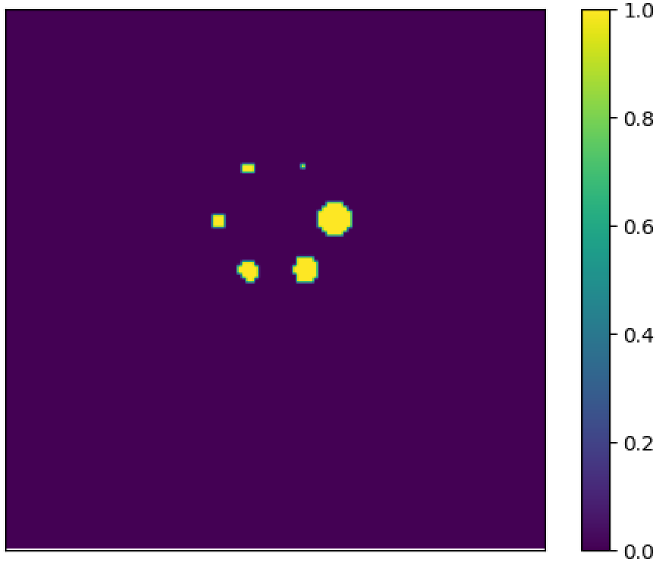
- Smoothed OSEM reconstruction as source
- No septal penetration modelled
- Simulation took 36 minutes

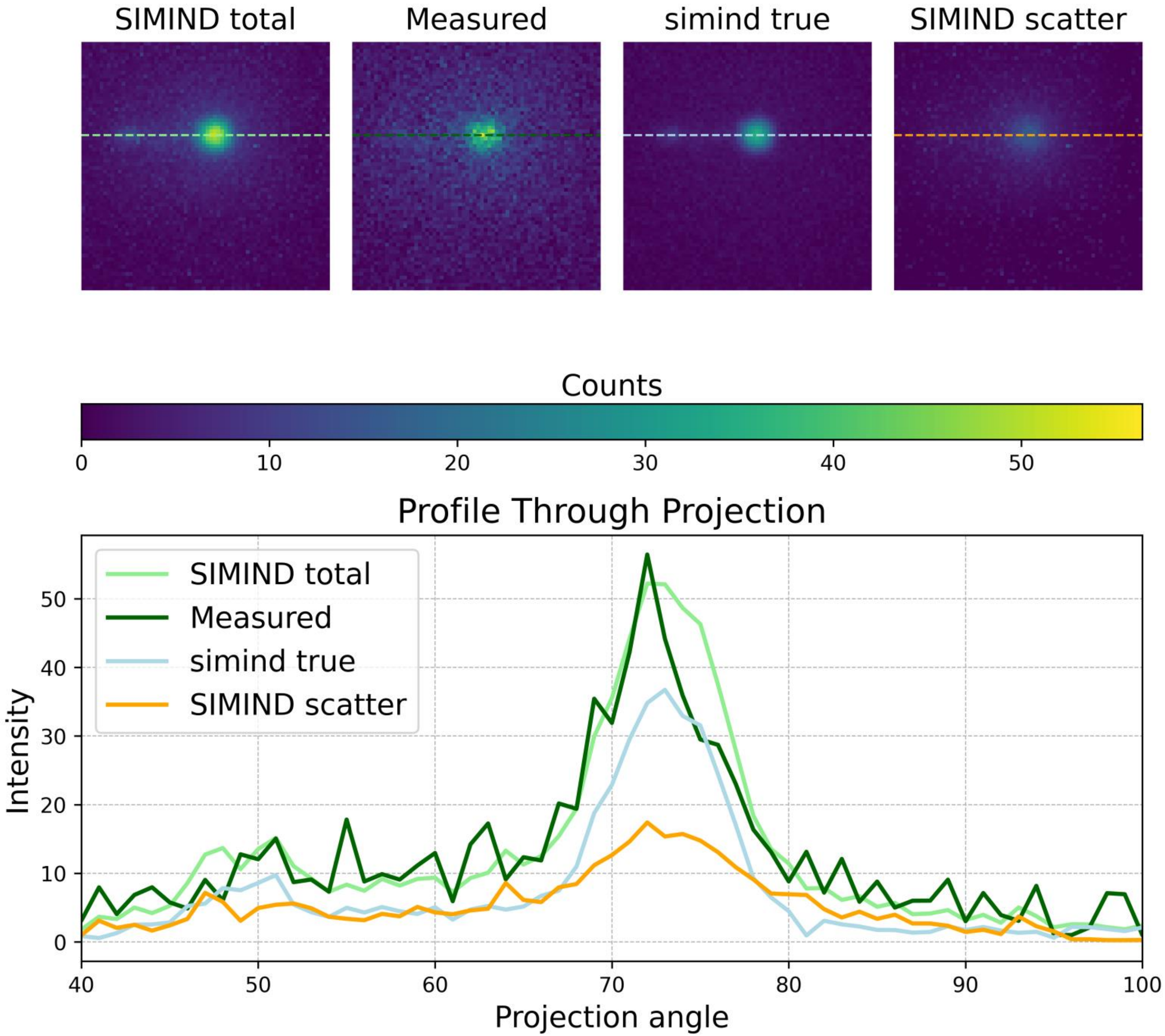




Results – Y90

- Ideal NEMA phantom image as source
- Septal penetration modelled
- Simulation took 7 hours





Fast and more accurate reconstruction

Following the technique set out in this paper:
A residual correction method for high-resolution PET reconstruction with application to on-the-fly Monte Carlo based model of positron range (https://doi.org/10.1118/1.3284980)

$$\hat{x}^{(0)} = \hat{x}\ , \qquad \hat{x}^{(n+1)} = \underset{x \geq 0}{\arg\max}\ \Psi_{\text{approx}}\left(x \middle| y, r + (\Delta P)\hat{x}^{(n)}\right)$$

But apply to SPECT imaging.

“Fast” forward models many not account for more complex features of SPECT acquisition:

- Septal penetration
- Collimator shape
- Accurate 3D resolution modelling

Previously SIMIND has been used as a forward projector:
Monte Carlo-based SPECT reconstruction within the SIMIND framework (https://doi.org/10.1088/1361-6560/aaf0f1)

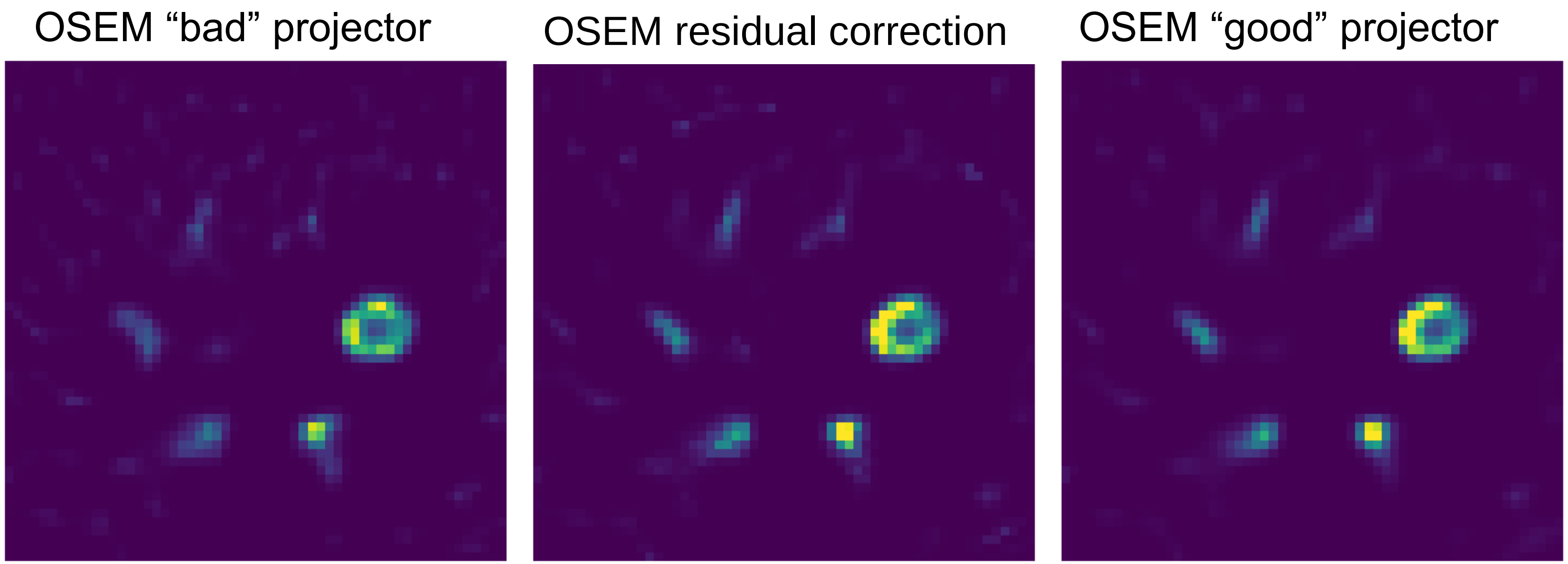
But slow!

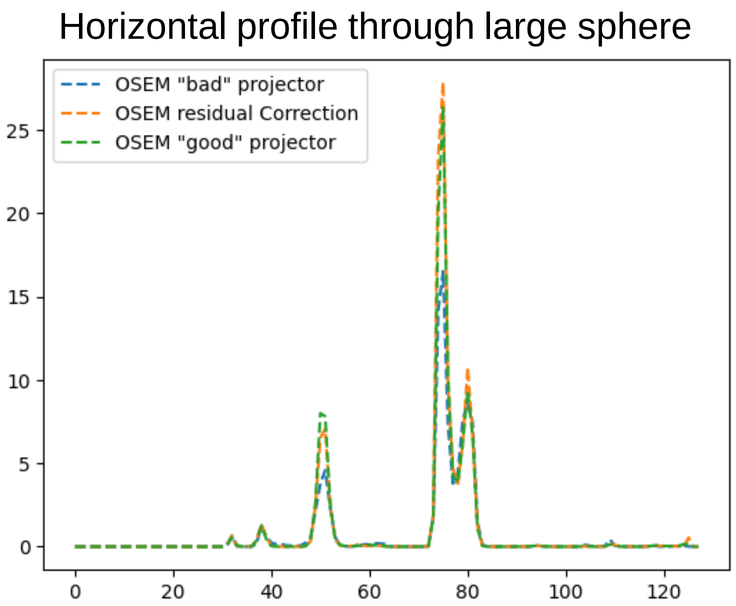
Results - Feasibility

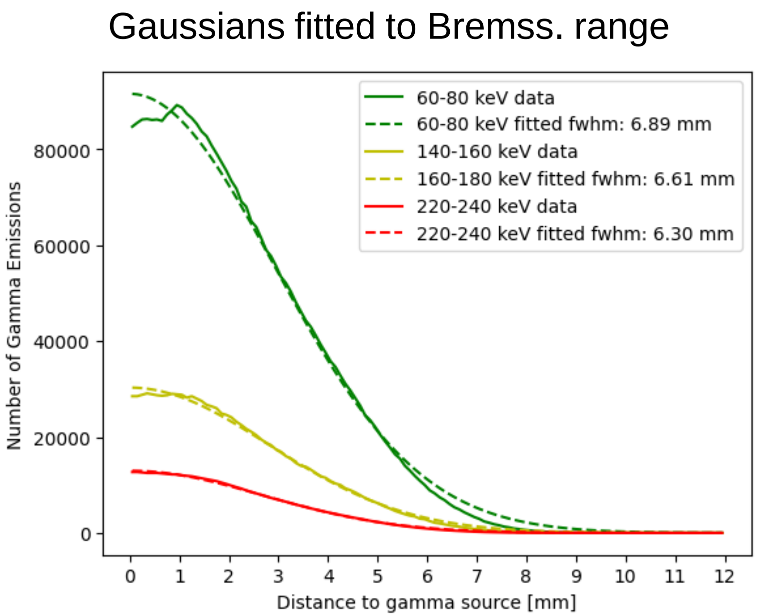
Test feasibility for residual correction with SPECT

Yttrium-90 NEMA data
- “bad” projector:
  - Lu-177 res. model
- “good” projector
  - Lu-177 res. Model
  - + gaussian blurring based on functions fitted to GATE bremsstrahlung data

Run residual projection routine:
- 12 subsets, 15 epochs
- Update correction every 5 epochs



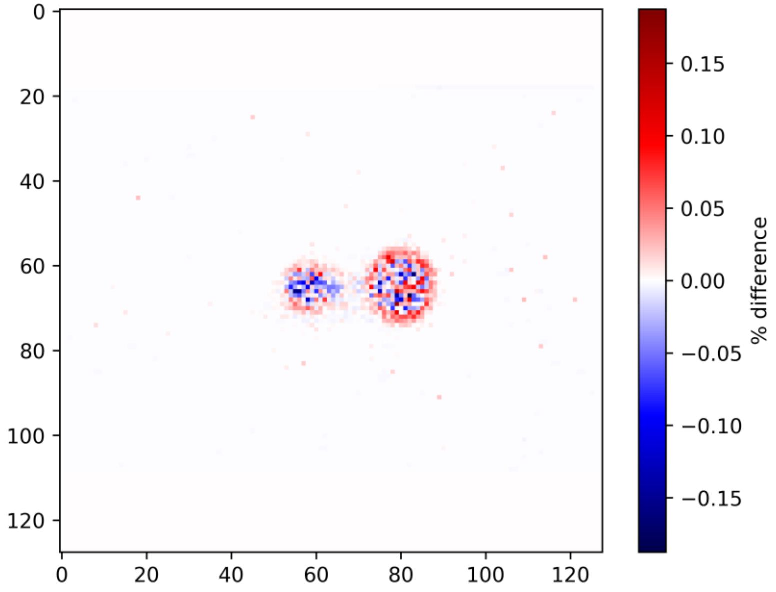


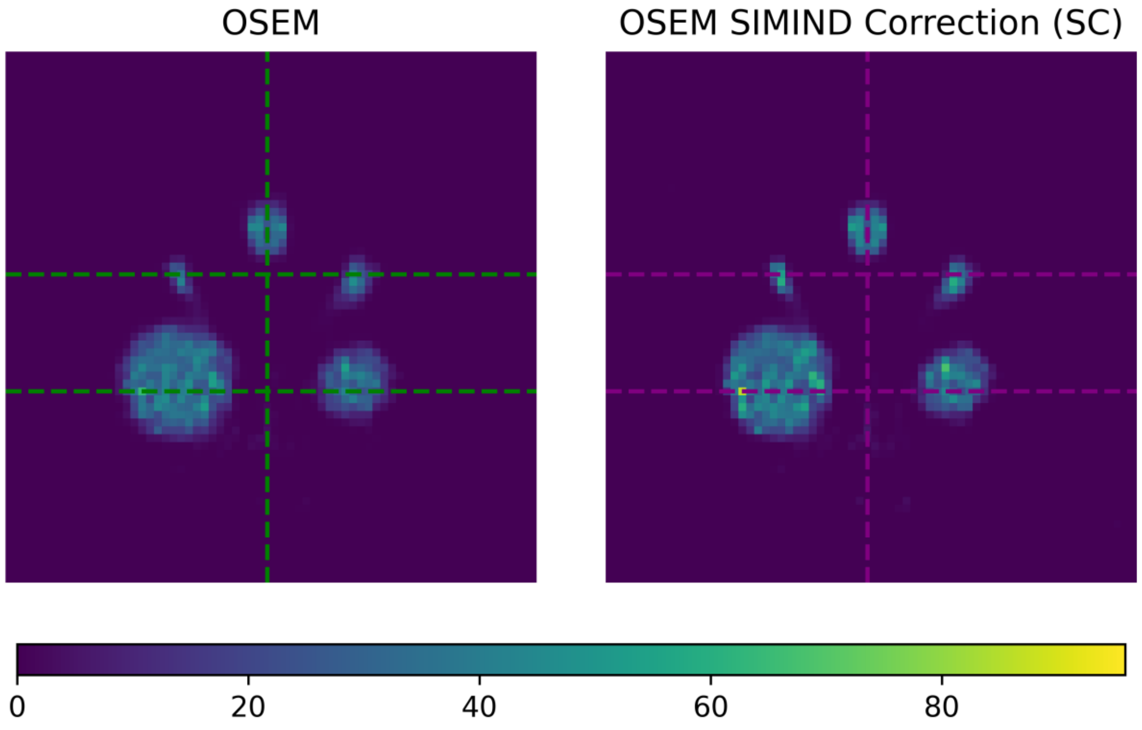


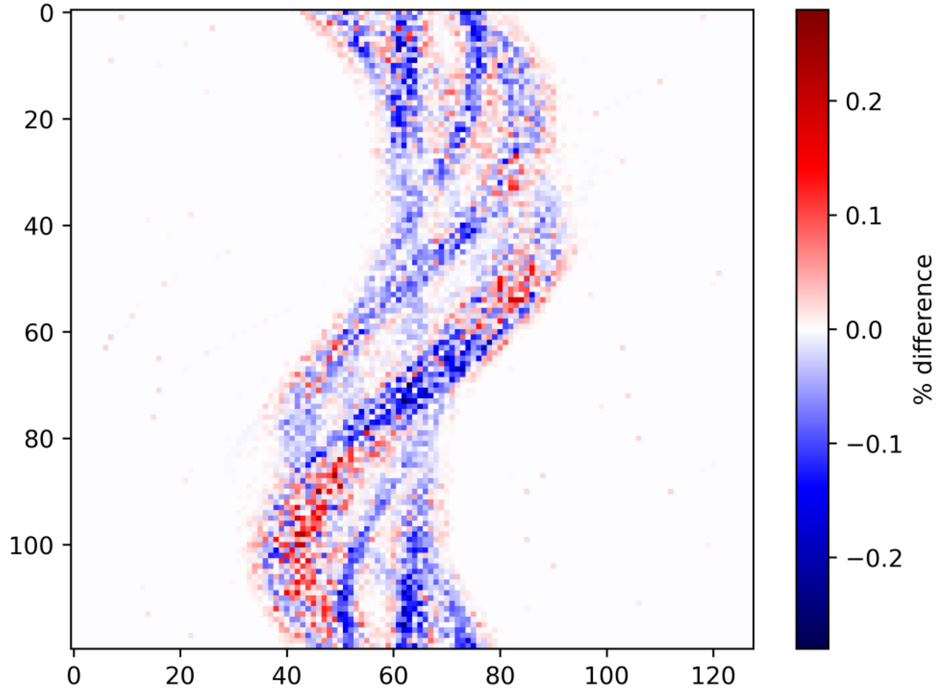
Results

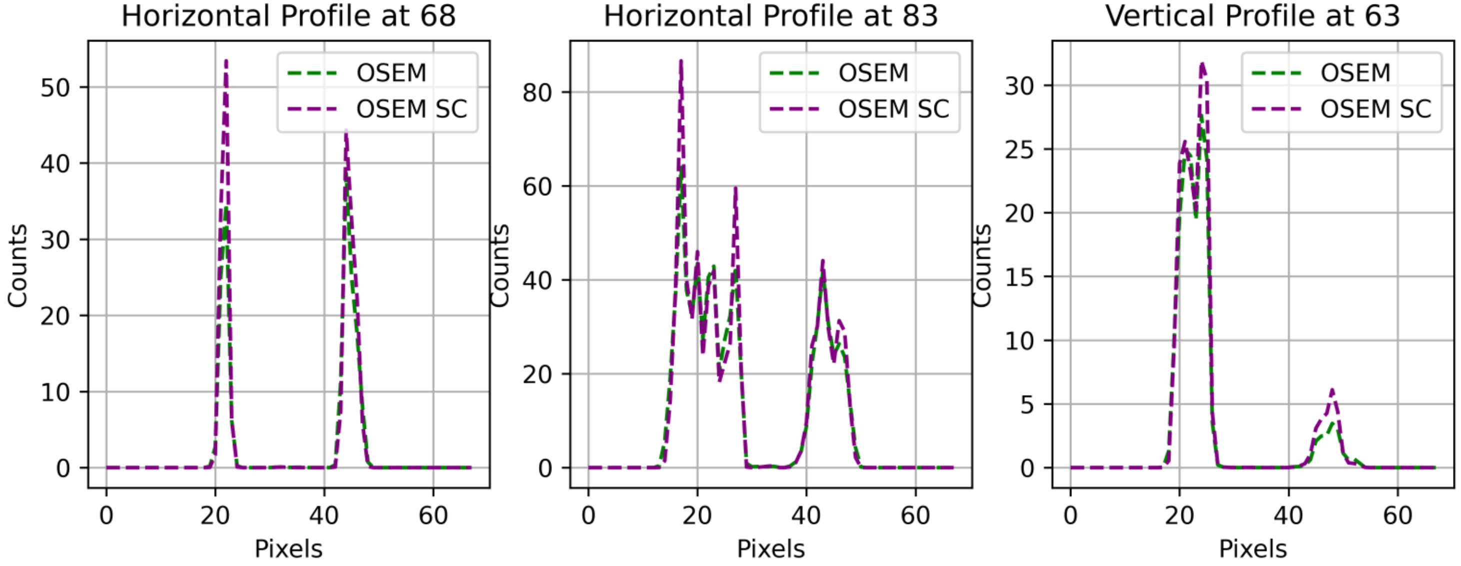
Lu177

- 16 subsets, 15 epochs
- Update correction every 5 epochs





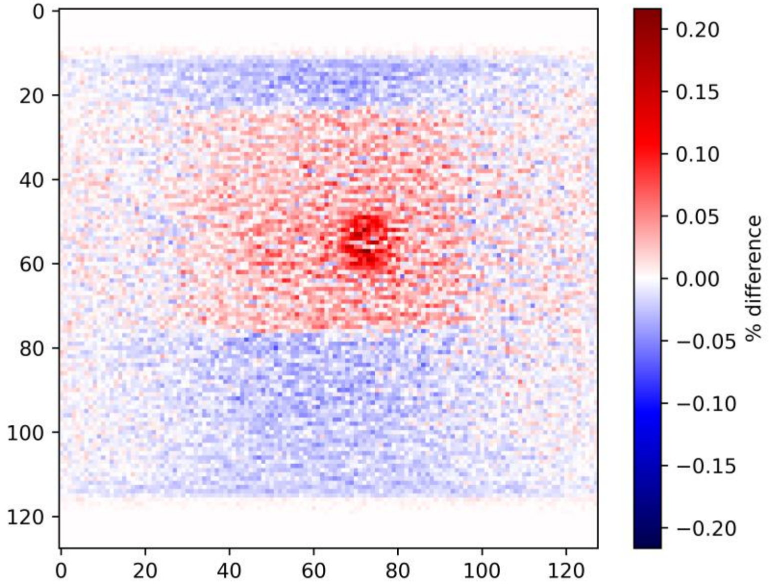


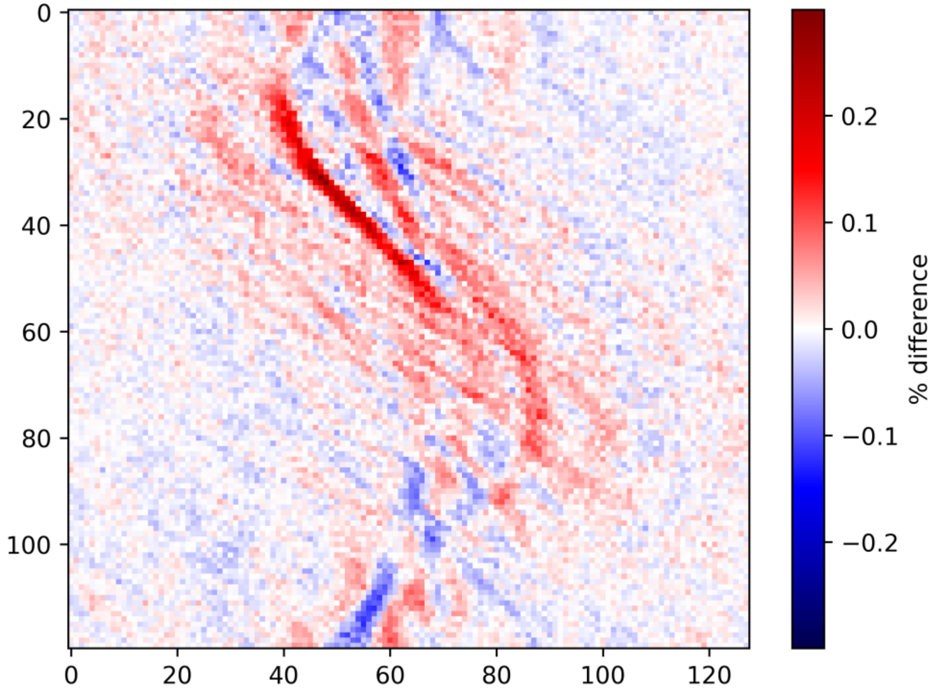


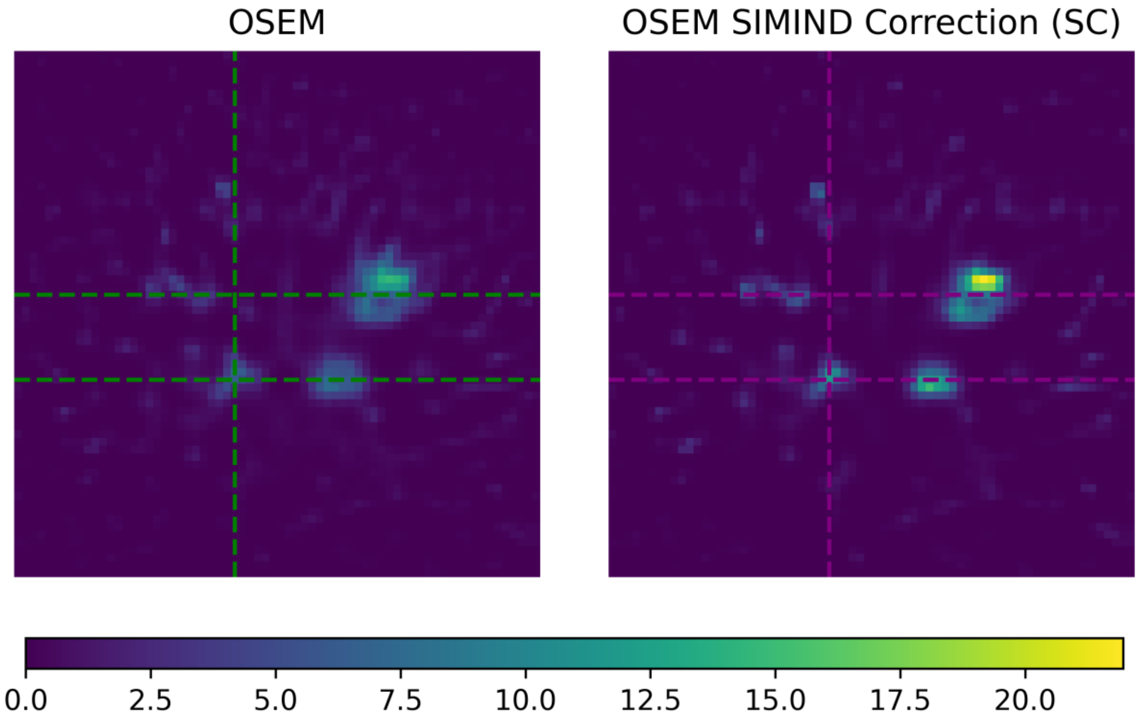
Results

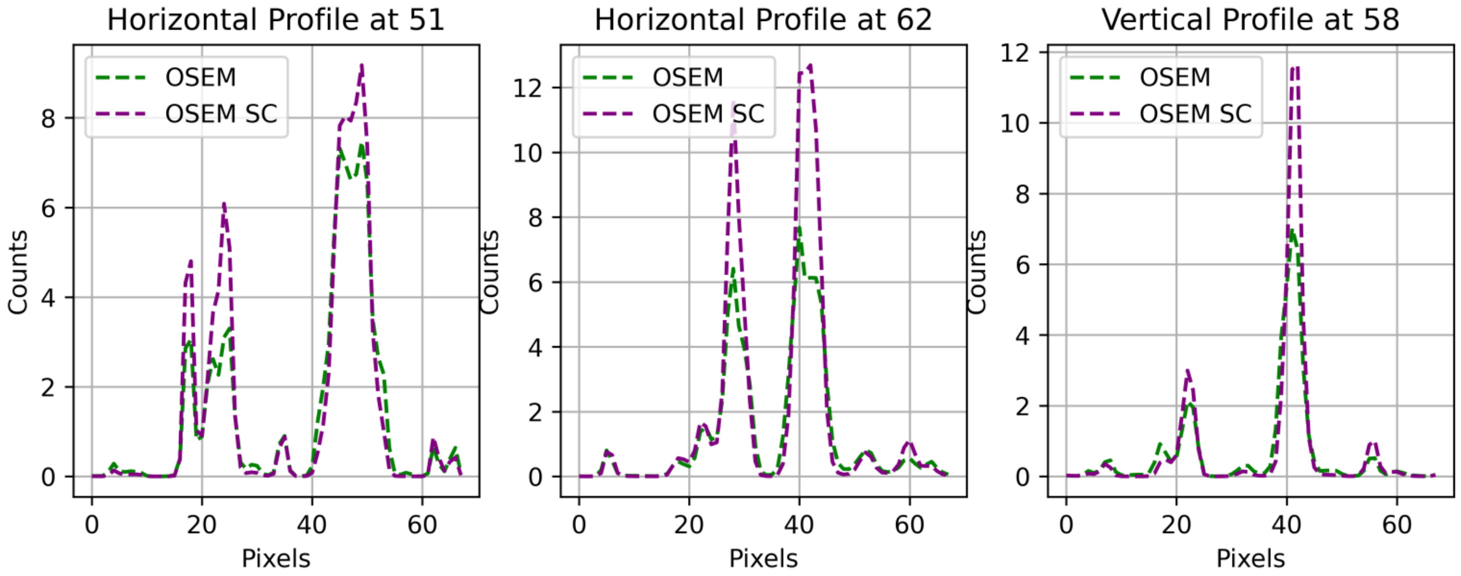
Y90

- 12 subsets, 15 epochs
- Update correction every 5 epochs









In Summary:

- Improved SIRF-SIMIND connection
  - Fully python API for SIMIND
  - Simple and easy to input and output SIRF data objects

- Demonstrated use of connection with residual connection
  - Shown that the residual correction can well approximate accurate projector reconstruction
  - Demonstrated using two real sets of data

However, difficult to judge whether the residual correction is accurate or beneficial without a ground truth.

Need to test further on simulations

Thanks for listening!

Any Questions?

sam.porter.18@ucl.ac.uk