Potential for Treatment Planning of Radiopharmaceutical Therapeutics Based on Pb-212

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Precision Medicine for
Radiopharmaceutical Therapy

Disclosure

Michael Ghaly is a co-founder of Radiopharmaceutical Imaging and Dosimetry (RAPID), LLC and currently devotes 51% effort to this company. This company was founded to provide quantitative imaging and dosimetry service to developers of radiopharmaceutical therapy agents.

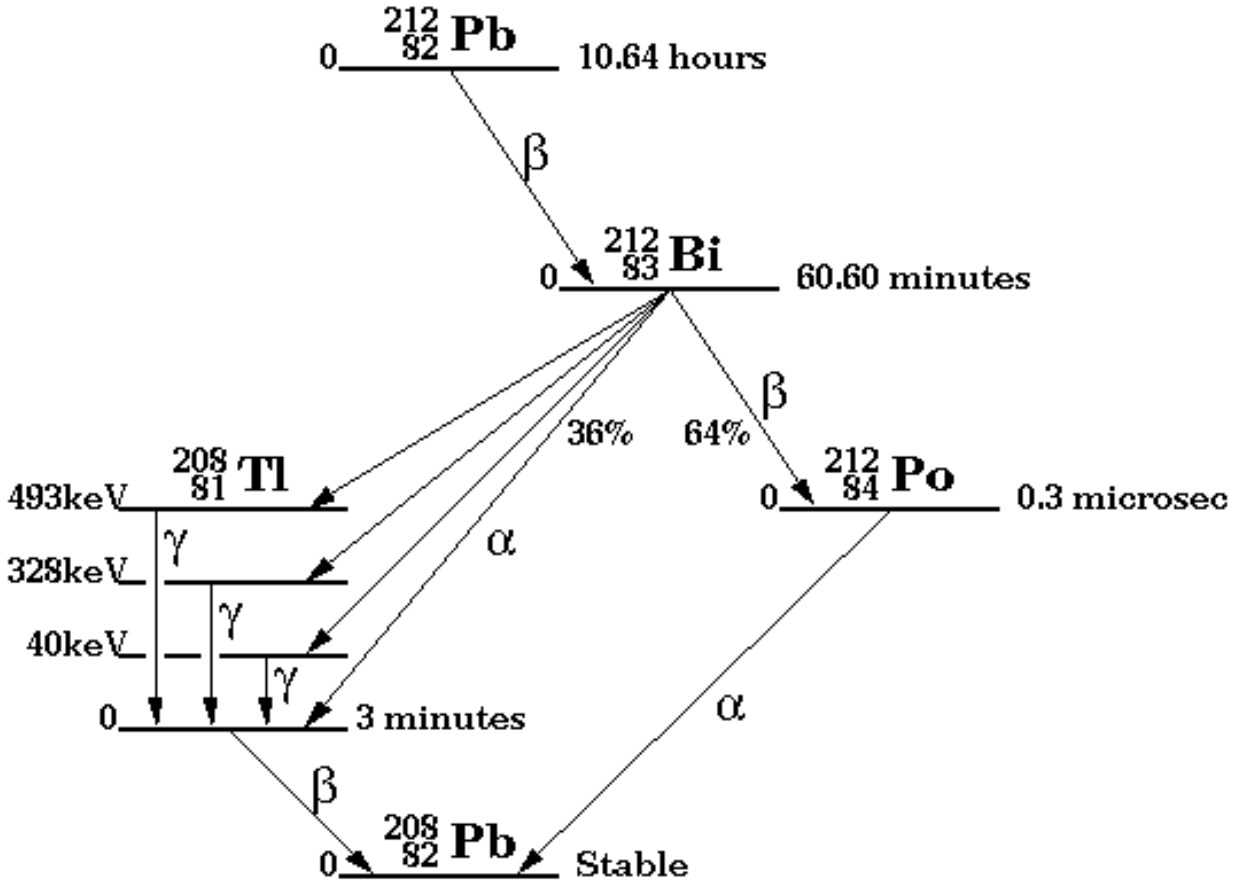
Johns Hopkins University Licenses an iterative reconstruction code for SPECT to GE Healthcare. Eric Frey, a co-author, is entitled to a share of royalty received on sales by GE Healthcare of this reconstruction code. Portions of that code were used to generate many of the examples used in this presentation. Eric Frey is also a co-founder of RAPID and devotes 25% effort to the company.

These interests have been disclosed and are being managed by the Johns Hopkins University in accordance with its conflict of interest policies.

Introduction:
Imaging of Pb-212

Quantitative SPECT imaging of Pb-212 challenging because of:

- Complicated decay scheme
- Complicated emission spectrum
- Small injected activities

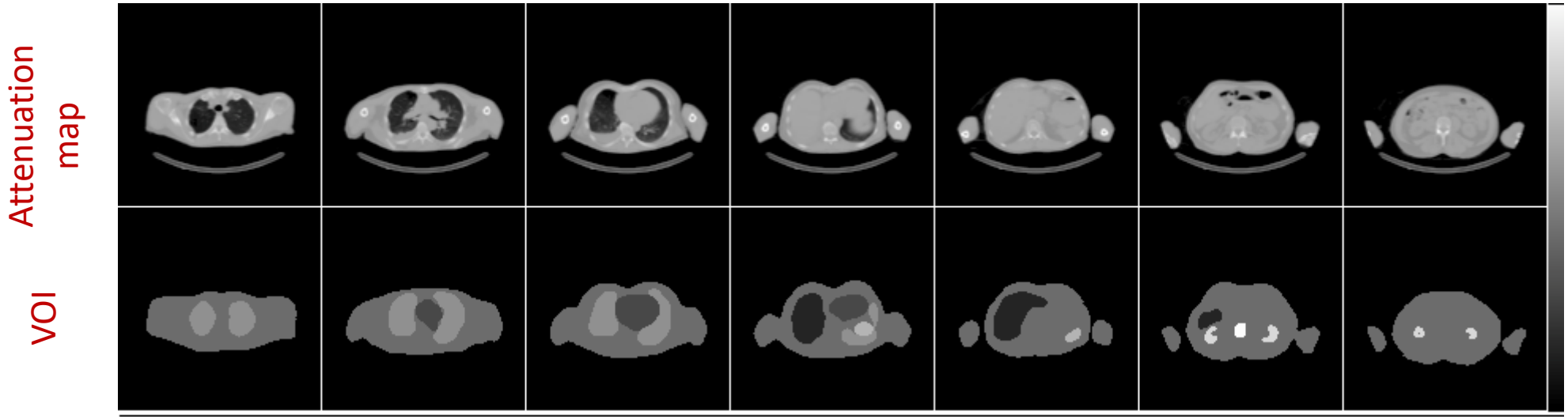


Goal of study

Demonstrate the feasibility of quantitative Pb-212 SPECT imaging to provide accurate estimates of absorbed doses in the different organs.

Methods – Phantom

- Based on a patient that underwent a Pb-203 study
- Modeled an administered activity of 2.1 mCi of Pb-2
- Values for the fraction of the injected activity (FIA) i
  based on distributions obtained from 6 Pb-203 clinic
  - Accounted for the different half-lives for Pb-203 (51.87 hr) and
- Simulated acquisition at 1, 24 and 48 hours post inje



Methods – Experiment 1

Goal: To determine the optimal acquisition energy window and collimator

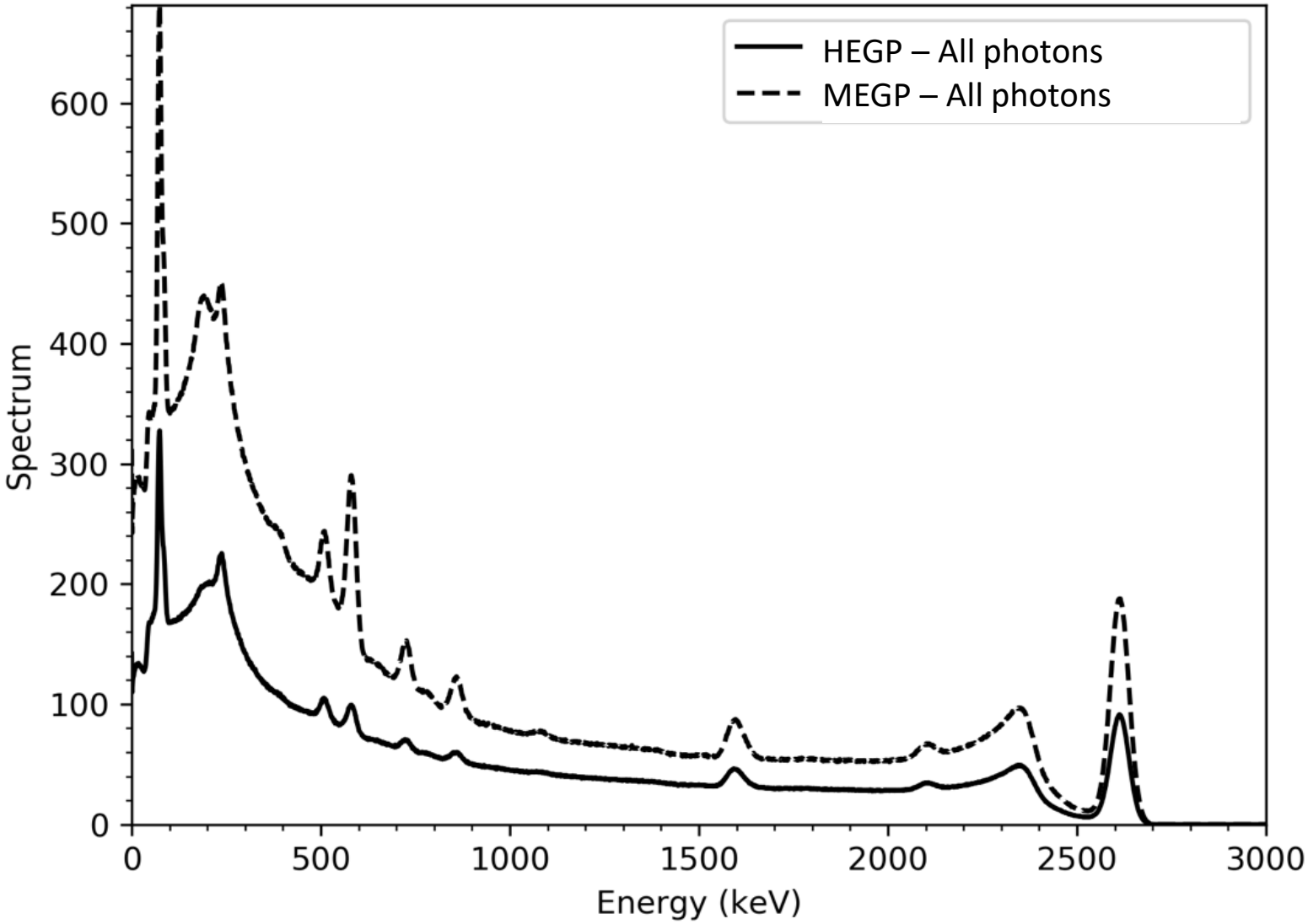
- Generated projections using the SIMIND Monte Carlo (MC) simulation program

System	Siemens Symbia dual-head SPECT
Detector	3/8” NaI crystal
Intrinsic spatial resolution	3.8 mm
Projection bin size	4.8 mm
Collimator	Medium energy and High energy
Radius of rotation	Body contouring

Methods – Experiment 1

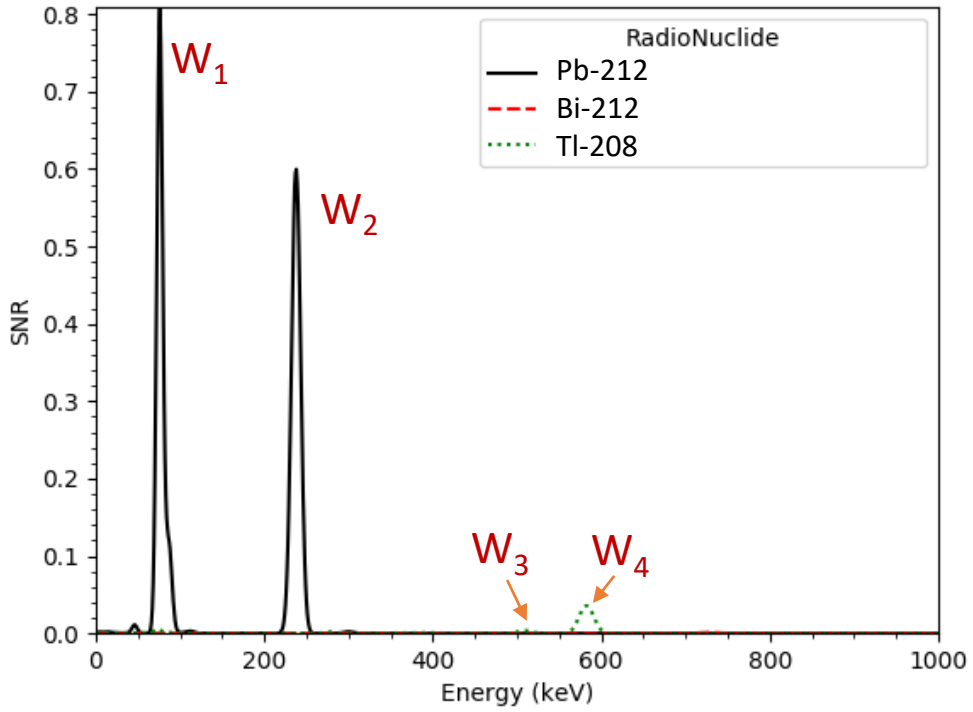
- Generated energy spectra at 4 projection views separated by 90 degrees over the energy range 50 to 3000 keV
- Generated separate spectra for:
  - All photons and
  - Primary geometric photons
- Used a projection-domain signal-to-noise ratio (SNR) as the metric for optimization
  - SNR: square of geometrically-collimated primary-photon counts divided by total photon counts

Results – Experiment 1



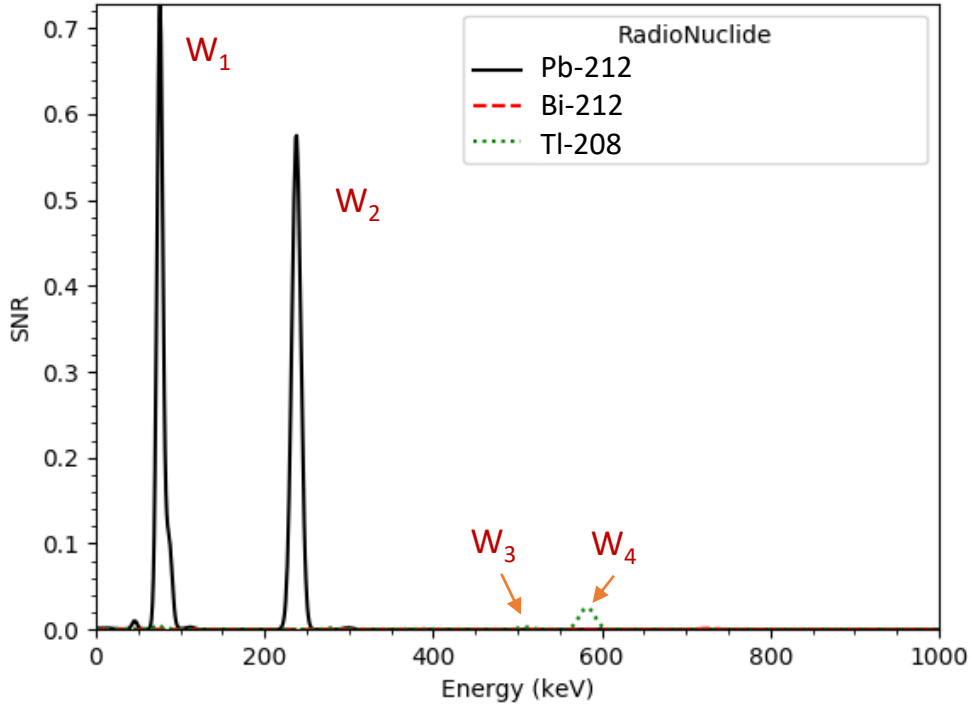
Results – Experiment 1

HEGP Collimator



Radionuclide	Collimator	Energy Window	SNR
Pb-212	HEGP	W_1=67-91 keV	7.0689
Pb-212	HEGP	W_2=220-257 keV	5.7314
Tl-208	HEGP	W_3=484-538 keV	0.05253
Tl-208	HEGP	W_4=556-613 keV	0.5863

MEGP Collimator



Radionuclide	Collimator	Energy Window	SNR
Pb-212	MEGP	W1=67-91 keV	6.3824
Pb212	MEGP	W2=220-257 keV	5.3771
Tl-208	MEGP	W3=484-538 keV	0.04803
Tl-208	MEGP	W4=556-613 keV	0.4807

Conclusions – Experiment 1

- The HEGP collimator is moderately more appropriate than the MEGP collimator.
  - SNR is higher by ~10% and 7% in window W_1 (67-91 keV) and W_2 (220-257 keV), respectively.
- Acquisition energy windows W_1 and W_2 contain approximately equal information.
- It is recommended to acquire the data in separate energy windows since the attenuation, scatter, etc., are different for these two energy ranges.

Methods – Experiment 2

Goal: To evaluate the quantitative precision when using the acquisition parameters identified in experiment 1

A. SIMIND simulations:

System	Siemens Symbia dual-head SPECT
Detector	3/8” NaI crystal
Intrinsic spatial resolution	3.8 mm
Number of projections	64 over 360°
Projection bin size	4.8 mm
Collimator	Medium energy and High energy
Radius of rotation	Body contouring
Acquisition Energy Window	W_1: 67 -91 keV, W_2: 220-257 keV
Total acquisition time	~20 minutes

Methods – Experiment 2

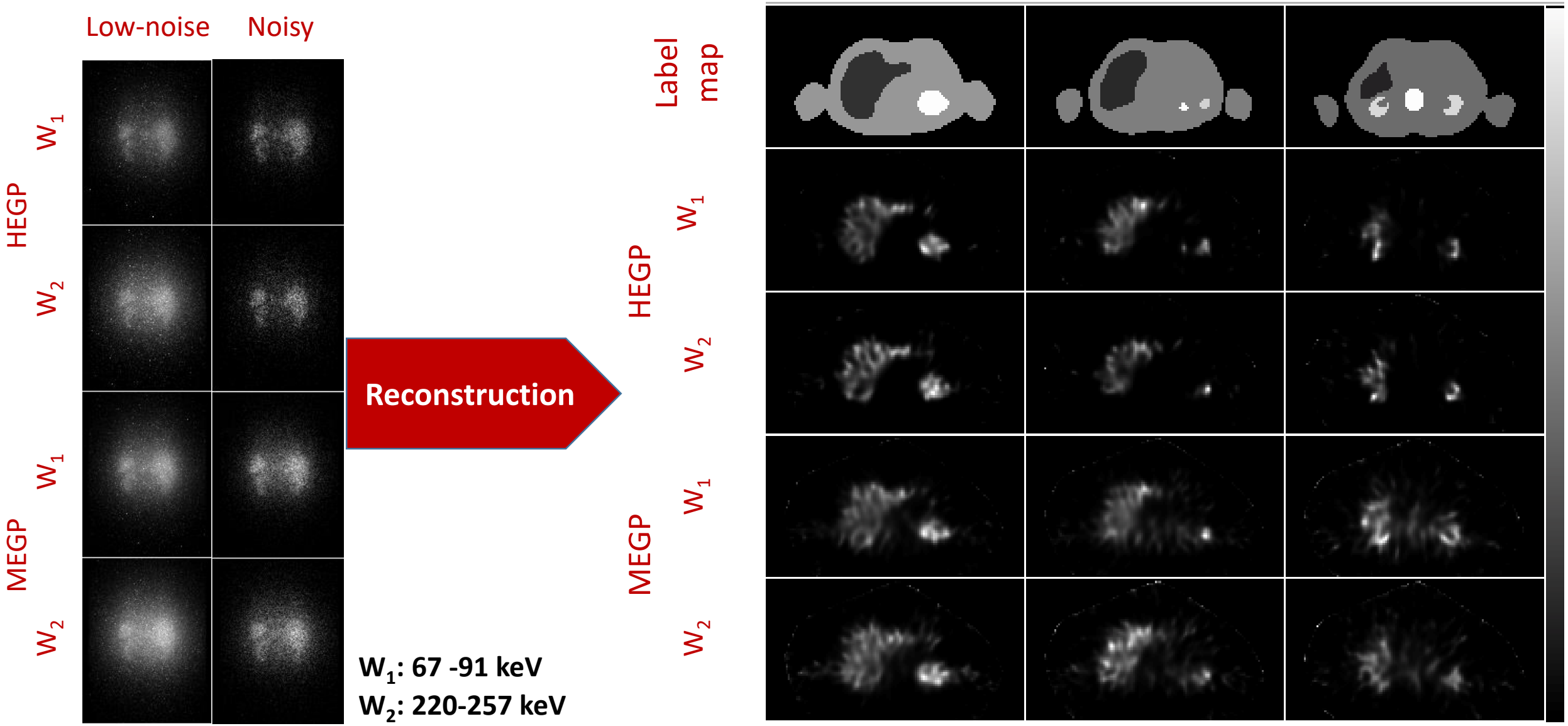
- For each collimator and energy window, we generated separate projections for:
  - All photons – i.e. model all possible effects
  - Scattered photons – used to perform ideal scatter compensation
- Separately simulated projections of the heart, lungs, liver, kidneys, spleen and marrow.
- Generated 25 noise realizations for each combination of collimator and energy window

Methods – Experiment 2

B. Image Reconstruction:
- Ordered Subsets-Expectation Maximization (OS-EM)
  - Iterations: 1, 2, 5, 10, 20, and 40
  - Subsets: 16
  - Compensations: Attenuation, scatter and spatially varying geometric collimator-detector response modelling

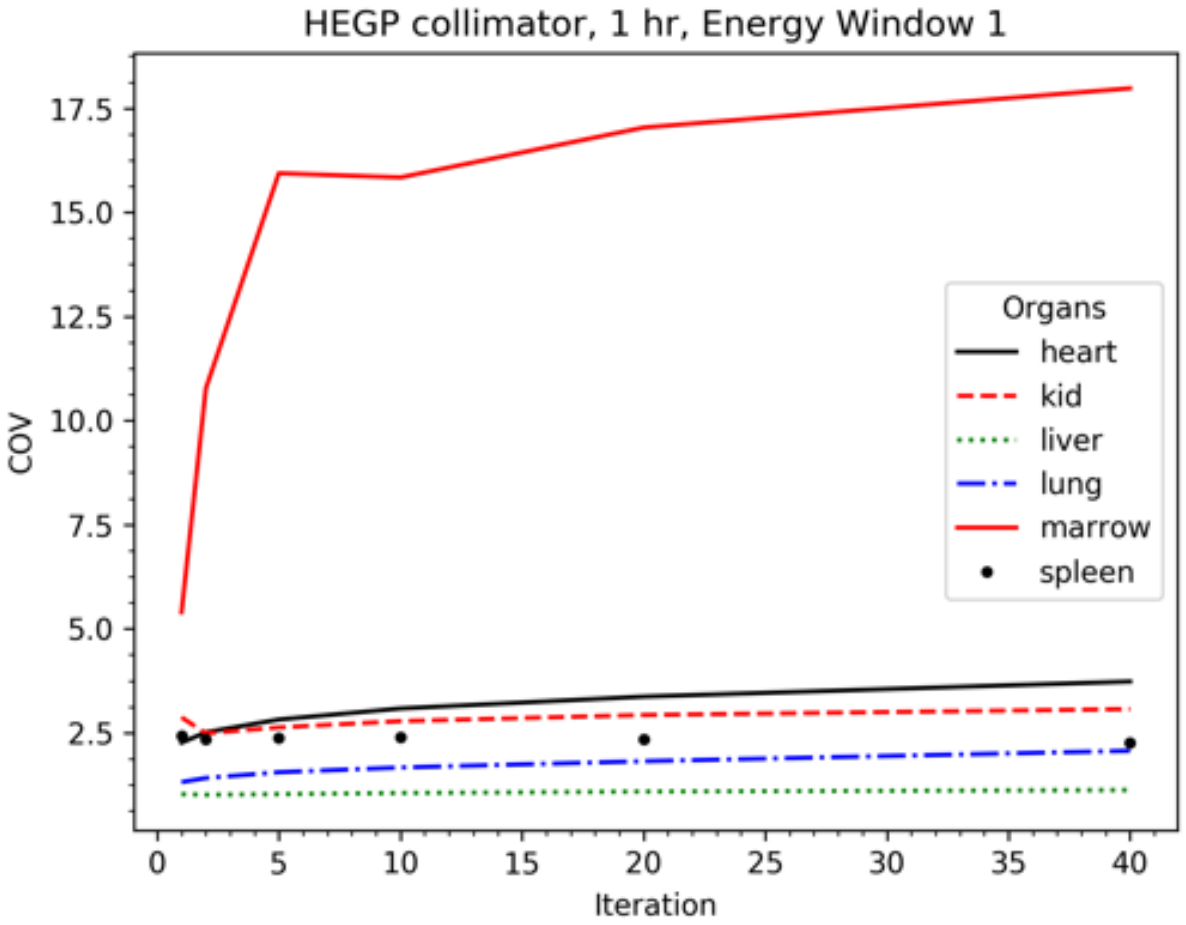
C. Precision and Accuracy Analysis:
- Precision: Calculated the Coefficient of Variation (COV) for each organ and time point over 25 noise realizations
- Accuracy: Plotted the counts in each organ and each time point averaged over all noise realizations versus the true organ activity

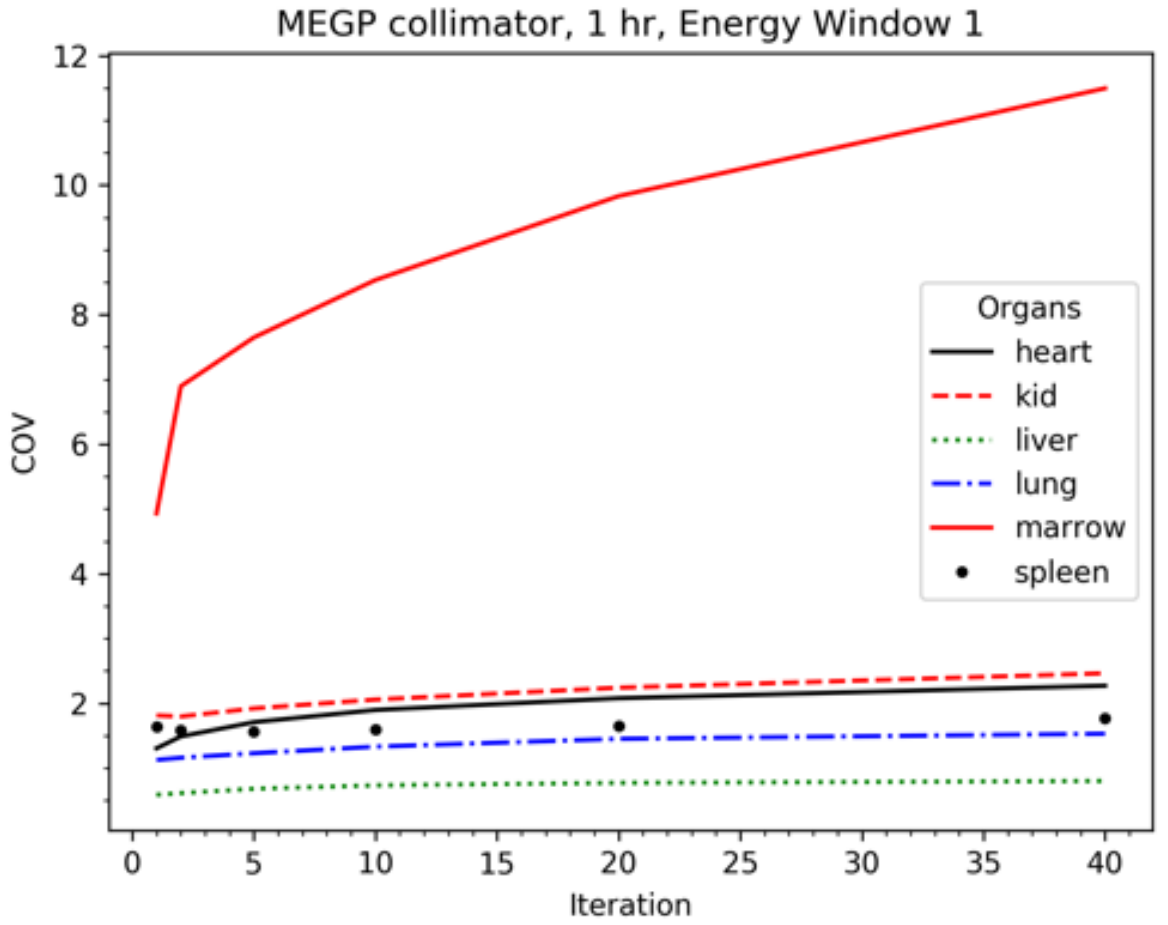
Results – Experiment 2



Results – Experiment 2

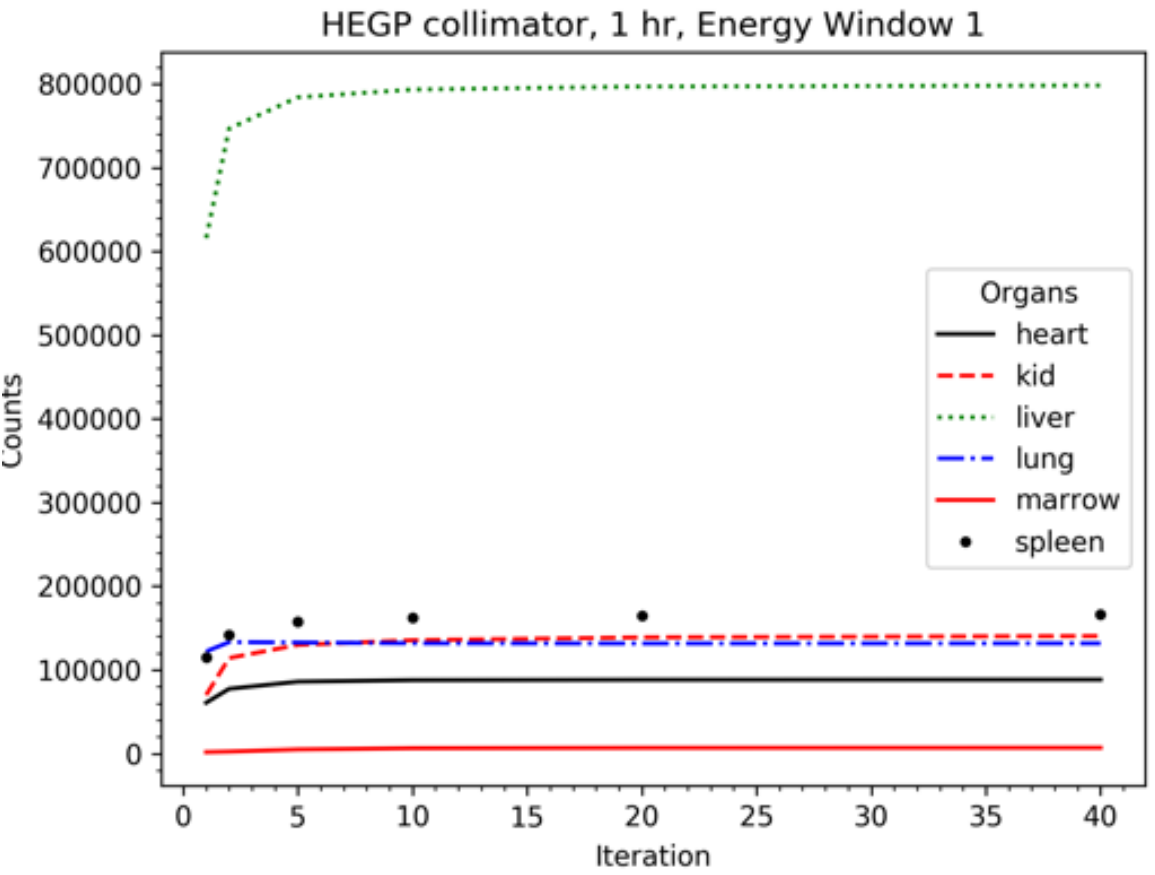
Precision – COV

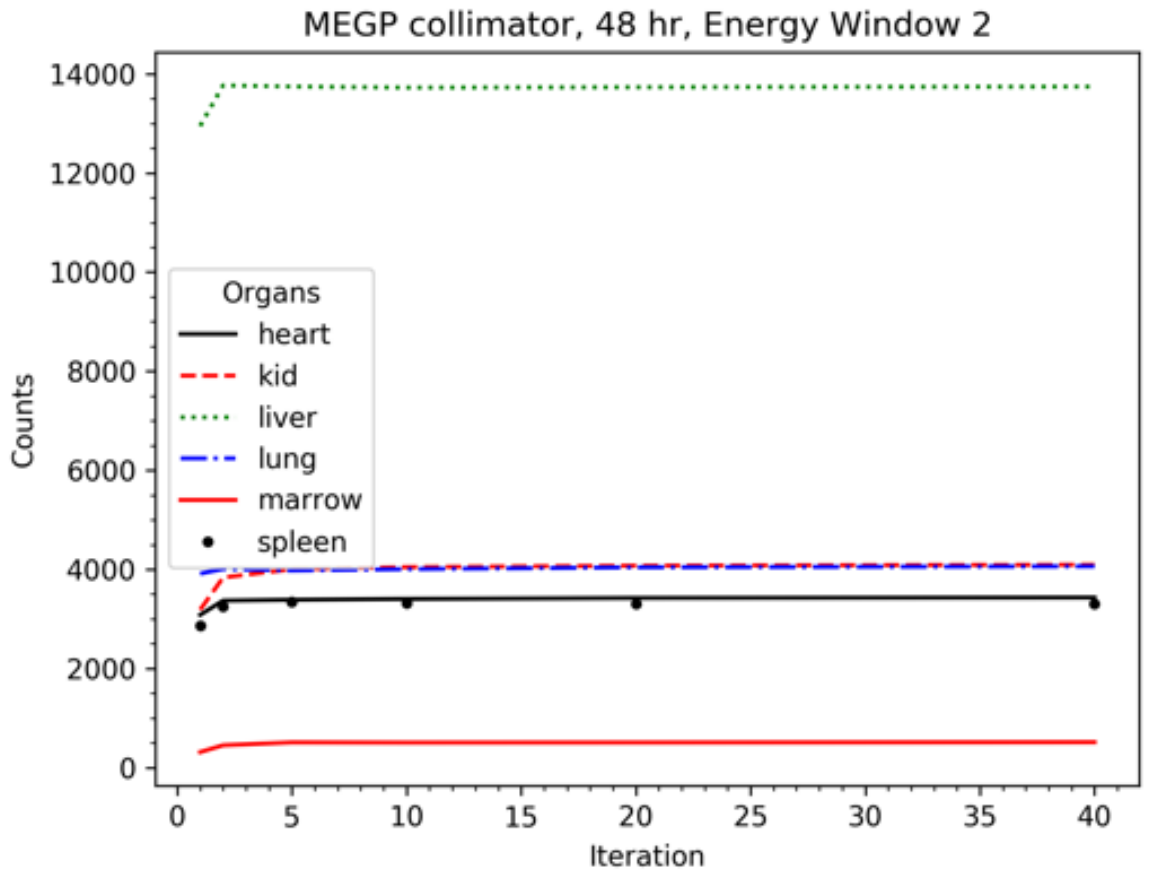




Results – Experiment 2

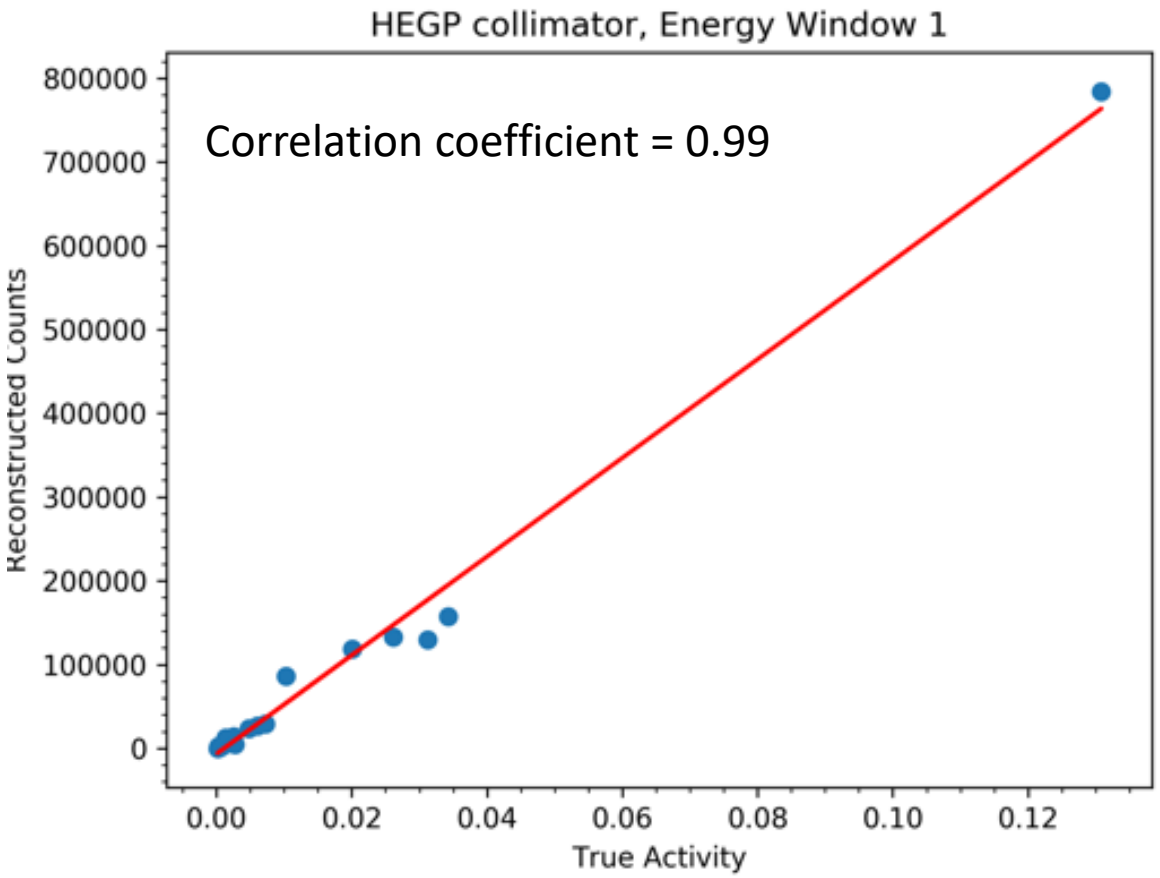
Accuracy

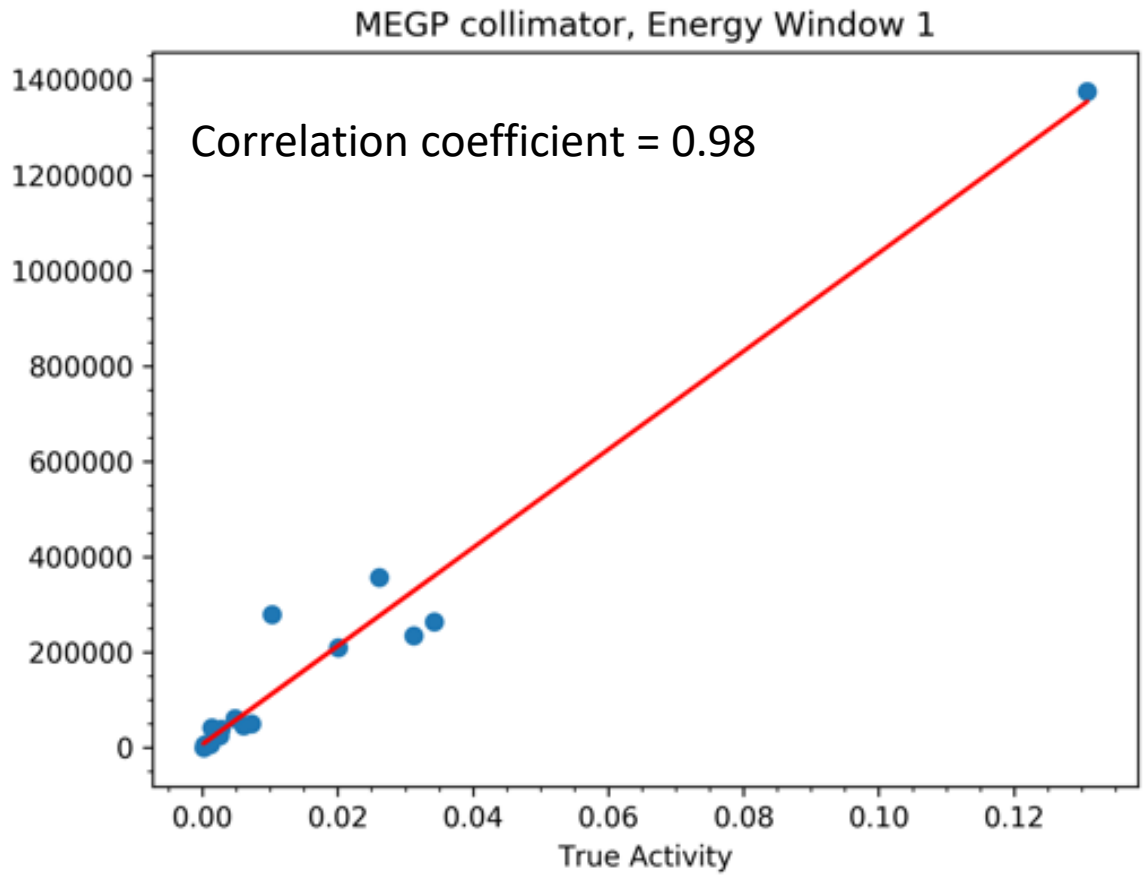




Results – Experiment 2

Accuracy





Conclusions – Experiment 2

- Quantitative Pb-212 imaging with reasonable precision is feasible
- The precisions decrease with time and are better for organs with larger activities.

Thank you

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