Energy-based scatter correction for the Walk-Through PET system

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WT PET THE FAST LANE

www.wt-pet.org

Background

Walk-Through PET (WT-PET)

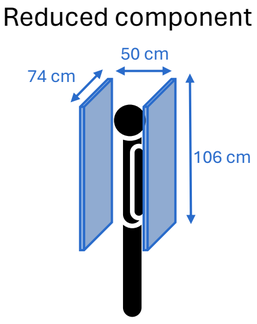
A cost-efficient, high-resolution, high-throughput total-body PET system[1]

Flat panel geometry

Detectors are placed closer to the patient

Similar sensitivity is achieved with fewer detectors (+/- 50%)

→ Reduced component costs

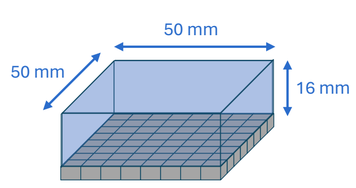


Monolithic detectors

Superior detector resolution (1 – 1.5 mm FWHM)

Depth-of-interaction (DOI) capable

→ High, near uniform resolution



Standing patient design

Simplified patient positioning procedure

→ Increased patient throughput

Scatter correction methods

Single scatter simulation (SSS)

Based on physical model for photon scattering
→ ignores multiple scattering

Uses relative detector efficiencies
→ requires tail fitting

Requires activity estimate
→ ignores out-of-FOV scatter

Requires attenuation estimate
→ CT scan is needed

Energy-based scatter correction[2,3]

Based on coincidence energy histograms
→ includes multiple scattering

Uses energy information per coincidence
→ requires listmode data

No activity estimate required
→ includes out-of-FOV scatter

No attenuation estimate required
→ No CT needed

STUDY AIM

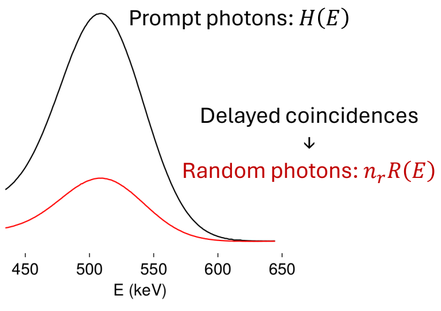
Implement and evaluate energy-based scatter correction for the Walk-Through PET

Methods

Energy-based scatter correction

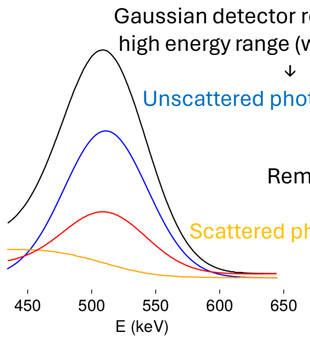
Single energy histograms (global)

$$H(E) = n_u U(E) + n_s S(E) + n_r R(E)$$



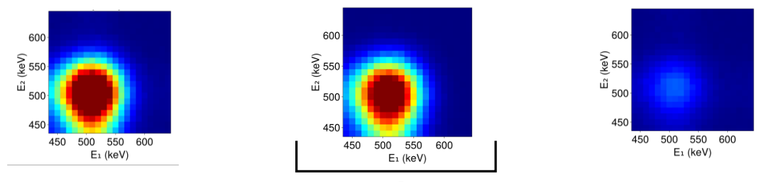
Gaussian detector resolution + fit to high energy range (where $S(E) \approx 0$)
↓
Unscattered photons: $n_u U(E)$

Remainder
↓
Scattered photons: $n_s S(E)$

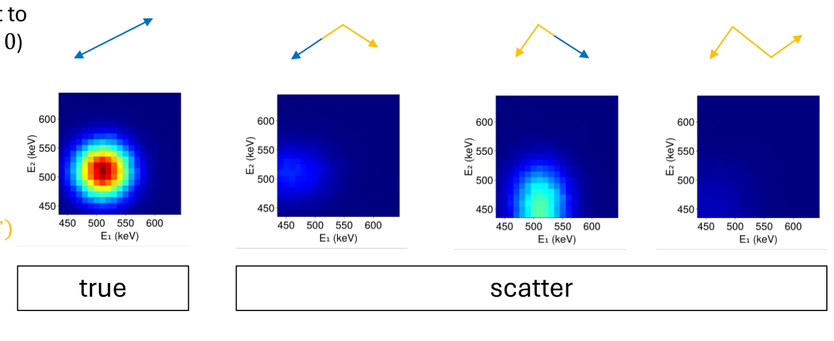


Dual energy histograms (per sinogram bin)

$$H_C(E_1, E_2) = H_{T+S}(E_1, E_2) + H_R(E_1, E_2)$$



$$n_{uu} U(E_1)U(E_2) + n_{us} U(E_1)S(E_2) + n_{su} S(E_1)U(E_2) + n_{ss} S(E_1)S(E_2)$$



Data generation

Monte Carlo Simulation

GATE software

30 s acquisitions of IQ & XCAT

XCAT: BMI = 22.47, ~ 3 MBq/kg

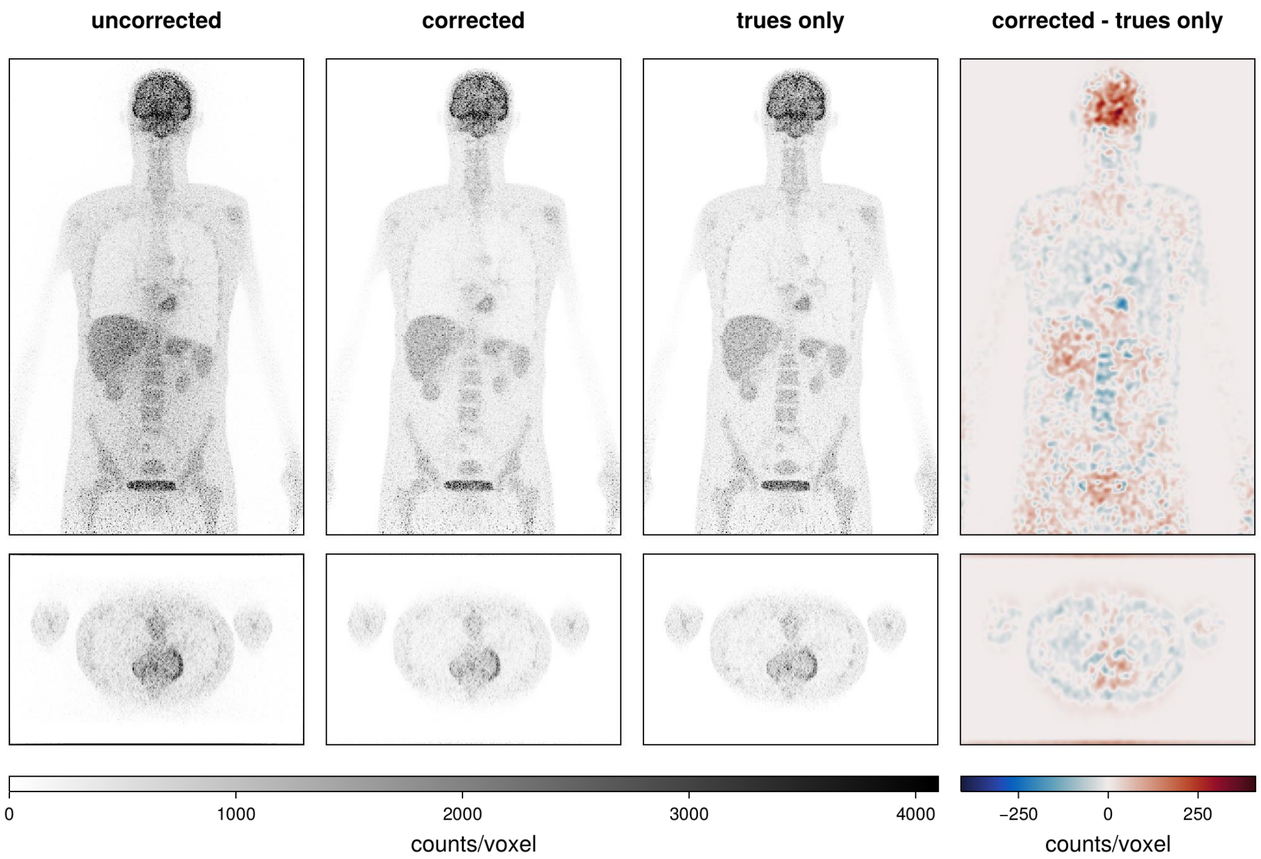
Image reconstruction

Iterative listmode MLEM

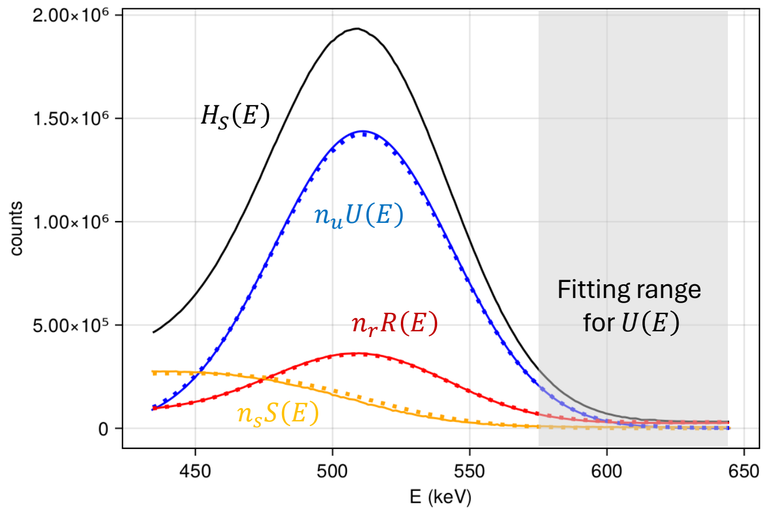
400 ps TOF

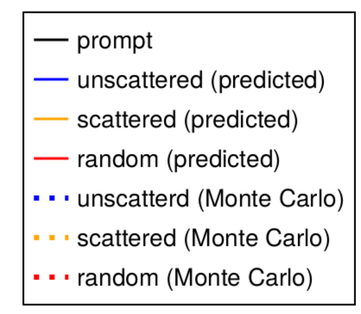
10 iterations with no subsets

Results: XCAT

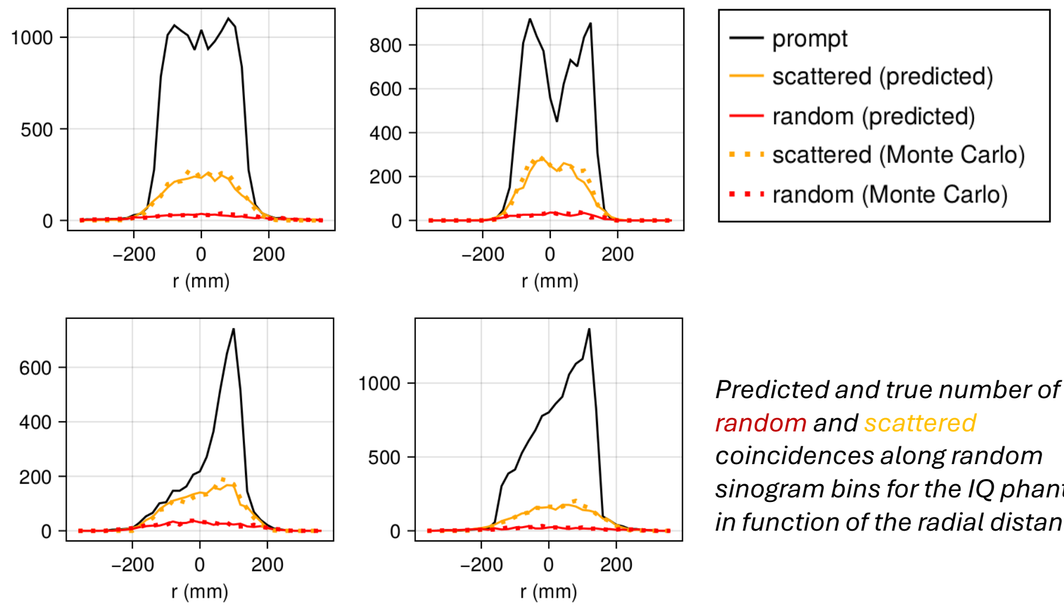


Results: IQ

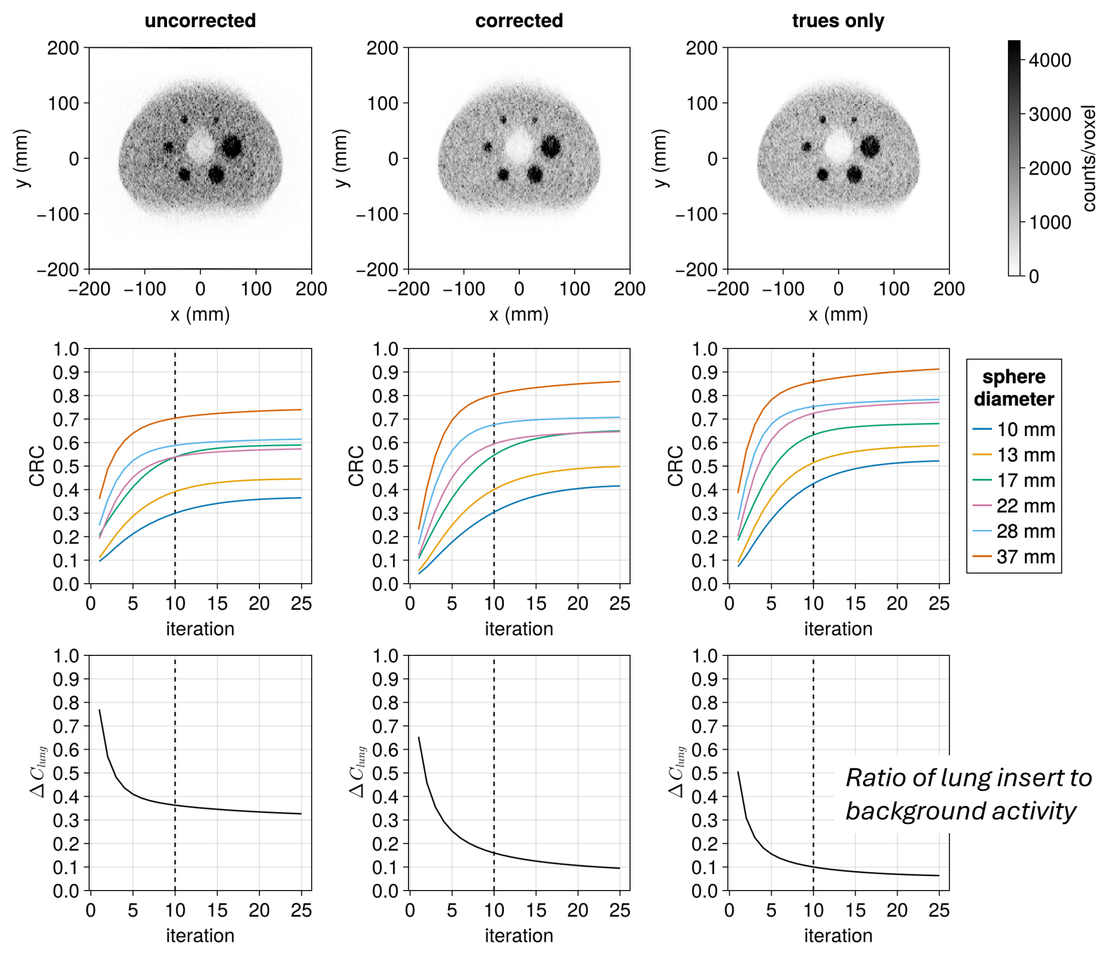




Predicted energy distributions $U(E)$ and $S(E)$ for the IQ phantom.



Predicted and true number of random and scattered coincidences along random sinogram bins for the IQ phantom, in function of the radial distance r.



Ratio of lung insert to background activity

Conclusion

Energy based scatter correction works well for the WT-PET, but some loss of detail compared to trues only reconstruction

Offers several advantages compared to SSS, and is computationally fast (takes only a few minutes)

Could be problematic for low count scans, since energy distributions are derived from the acquisition data itself

[1]Walk through flat panel total-body PET: A patient-centered design for high throughput imaging at lower cost using DOI-capable high resolution monolithic detectors
[2]L. M. Popescu, R. M. Lewitt, S. Matej, and J. S. Karp, "PET energy-based scatter estimation and image reconstruction with energy-dependent corrections", Physics in Medicine & Biology, vol. 51, no. 11, p. 2919, May 2006, issn: 0031-9155.
[3]N. Efthimiou, J. S. Karp, and S. Surti, "Data-driven, energy based method for estimation of scattered events in positron emis sion tomography", Physics in Medicine & Biology, vol. 67, no. 9, p. 095010, Apr. 2022, issn: 0031-9155.

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