Hybrid Scatter Correction (HSC) for Diagnostic CT and for Flat Detector CT

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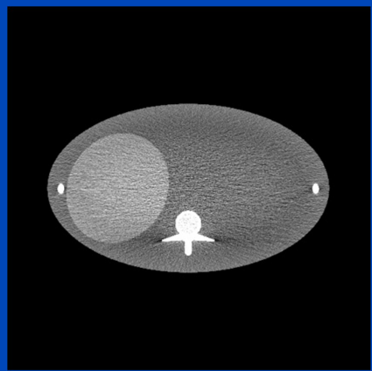
DEUTSCHES KREBSFORSCHUNGSZENTRUM IN DER HELMHOLTZ-GEMEINSCHAFT

Aim

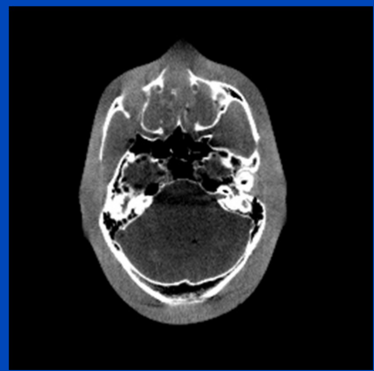
Develop a fast, physics-based, patient-specific and object-dependent scatter correction algorithm for CT imaging.

Simulation

Simulation



Measurement

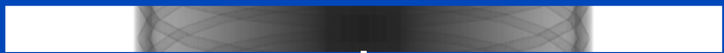


Typical scatter artifacts: Cupping and streaks

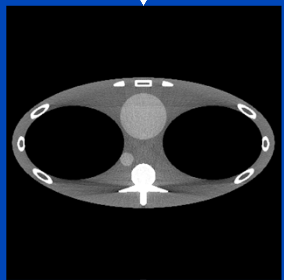
Scatter Estimation

Monte Carlo-based

Measured intensities (primary plus scatter)



Reconstruction



Simulation of physical photon paths based on density and material distribution

Physical effects:
Photo effect
Compton scattering
Rayleigh scattering

Monte Carlo-based scatter estimate

Patient-specific, many computations

Convolution-based

Measured intensities (primary plus scatter)

$$\hat{I}_{\mathrm{s}}^{\mathrm{CB}}(\boldsymbol{c}_1, \boldsymbol{c}_2) = \Phi\big(I_{\mathrm{ps}}, \boldsymbol{c}_1\big) * K\big(\boldsymbol{c}_2\big)$$

Convolution of the scatter potential Φ with scatter kernel K

I_{ps}: Primary plus scatter intensity

c_1 and c_2 (vectors): Open coefficients

We used the convolution-based method of Ohnesorge et al.*

Convolution-based scatter estimate

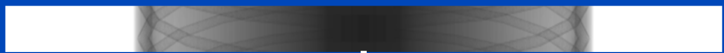
Not patient-specific, few computations

* Ohnesorge et al., *Efficient scatter correction algorithm for third and fourth generation CT scanners*, Eur. Radiol., 9, 563-569 (1999).

Scatter Estimation

Monte Carlo-based

Measured intensities (primary plus scatter)



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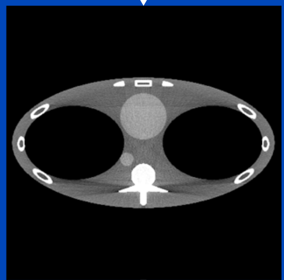

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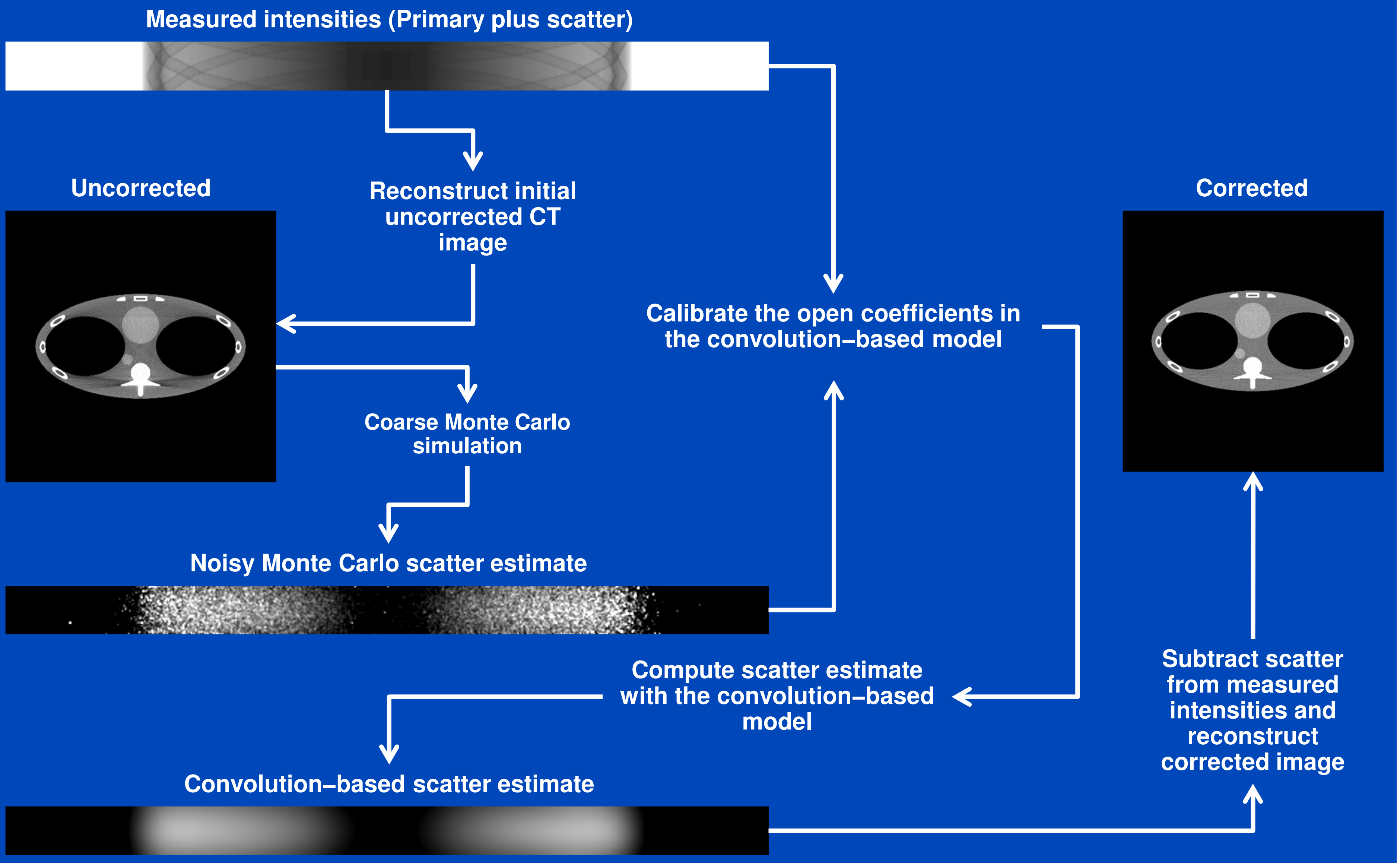
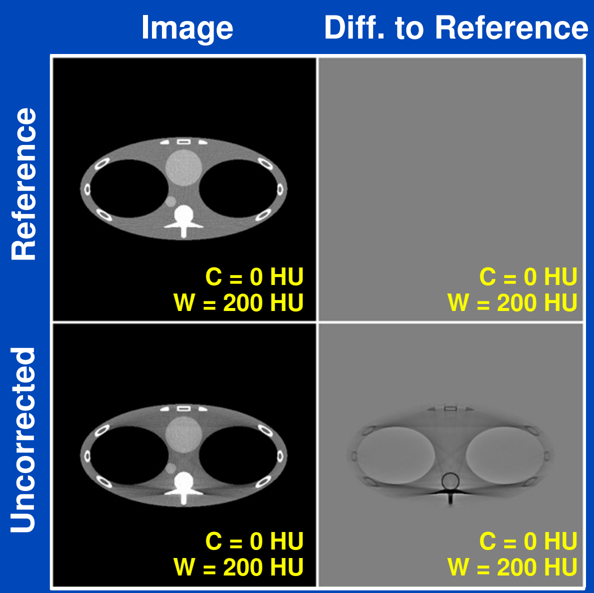
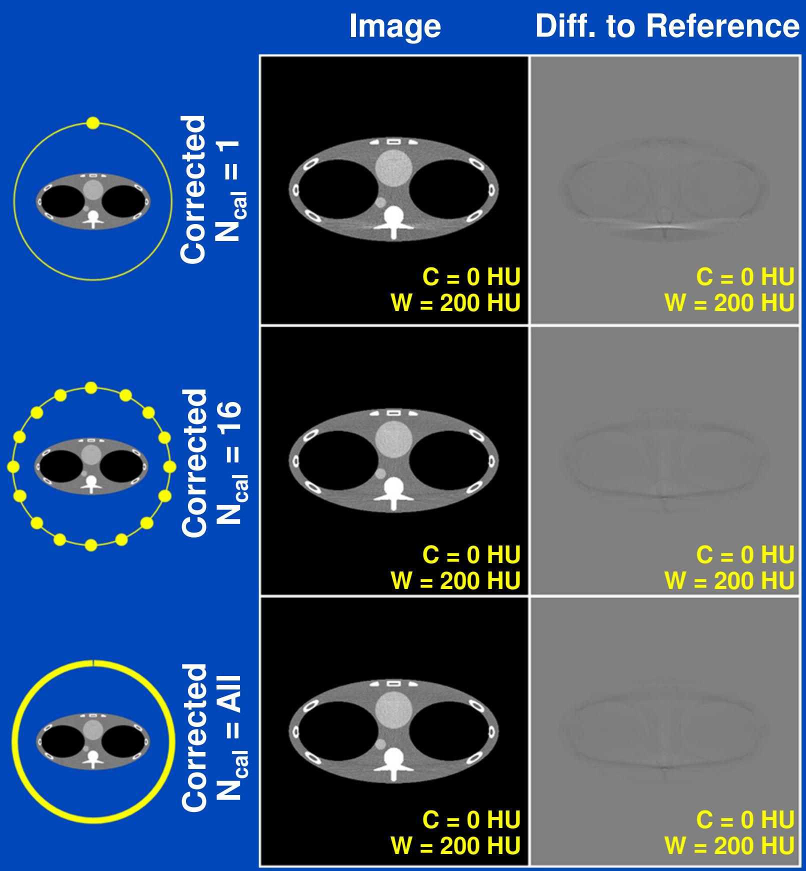
Hybrid Scatter Correction



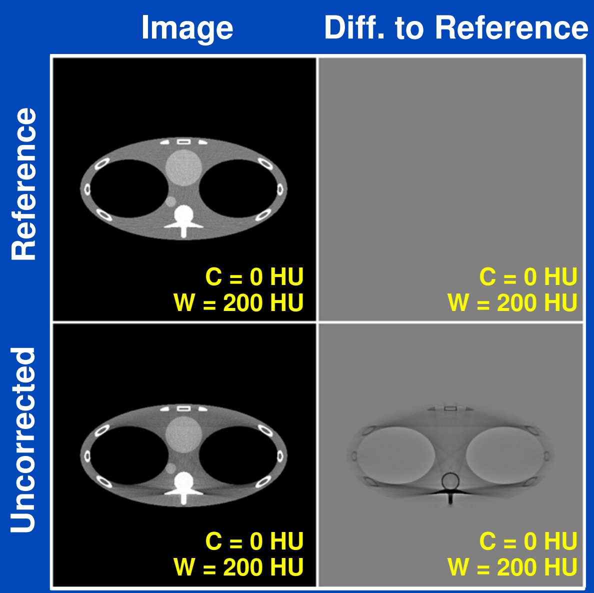
Number of Calibration Steps





Monochromatic simulation study in clinical CT geometry
Scatter simulation by Monte Carlo

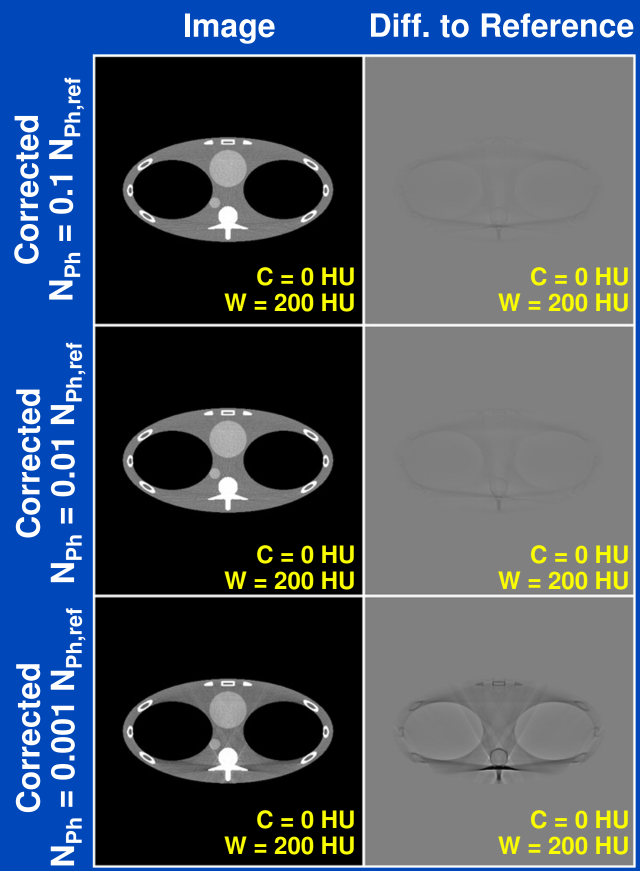
Number of Photons



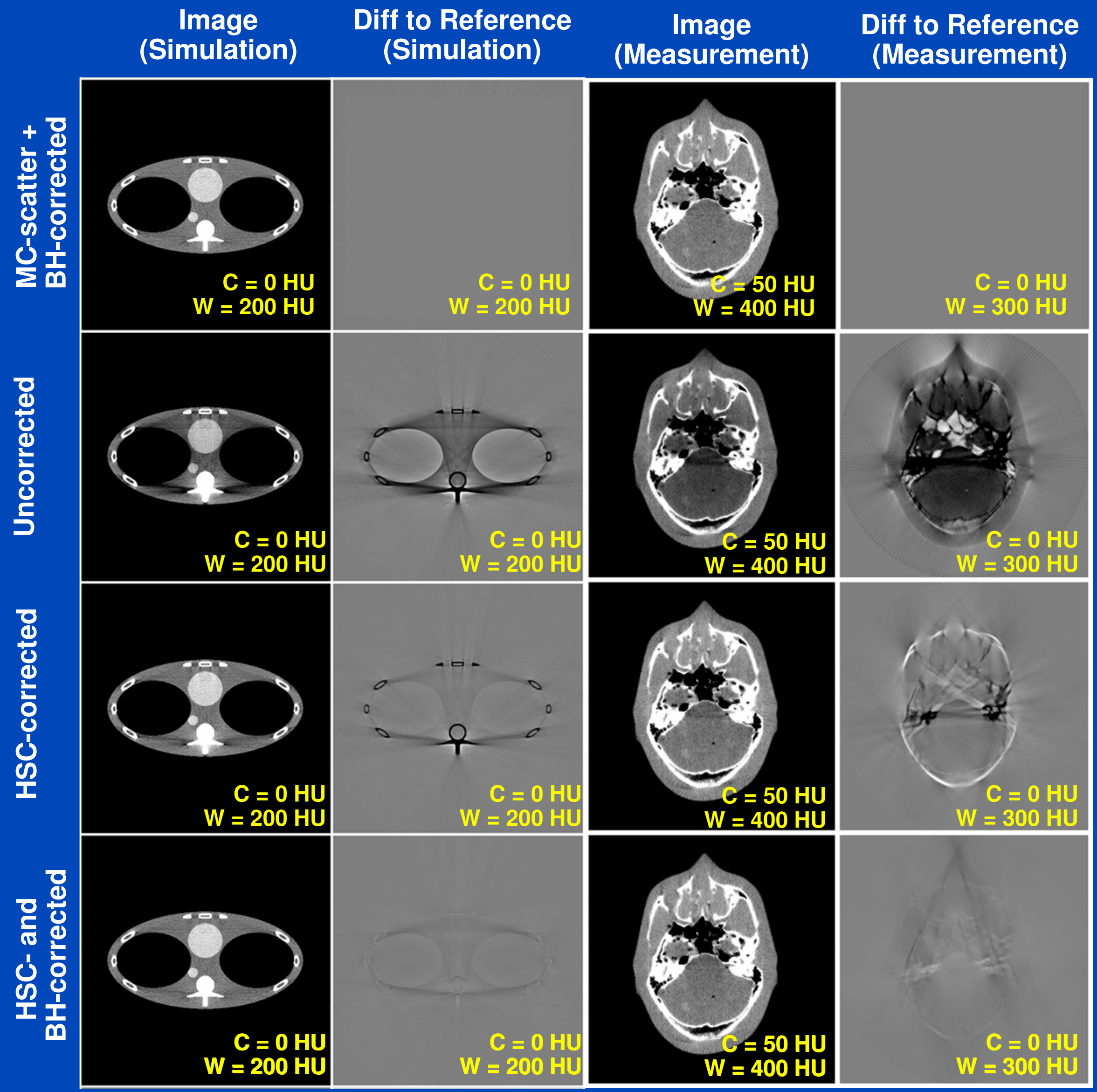
Monochromatic simulation study in clinical CT geometry
Scatter simulation by Monte Carlo

$N_{Ph,ref}$: Photon number for the low noise reference Monte Carlo simulation used for the uncorrected image

N_{cal} = 16



Scatter Correction Results



Polychromatic simulation study in clinical CT geometry and measurements in cone beam CT geometry

Hybrid scatter correction (HSC): Monte Carlo simulation for only 16 projections and 100 times less photons than in the pure Monte Carlo correction.

Additionally the empirical beam hardening correction (EBHC*) method was applied to correct for beam hardening artifacts.

Reference = MC-scatter + BH-corrected

*Kyriakou, Y.; Meyer, E.; Prell, D.; Kachelrieß, M.; *Empirical Beam Hardening Correction (EBHC) for CT*, Med. Phys. 37, 5179-87 (2010).

Summary and Conclusion

- With the hybrid scatter correction we propose a patient-specific, physics-based, and object-dependent scatter correction algorithm based on a Monte Carlo simulation of scatter intensities
- To reduce computational needs the Monte Carlo simulation is regularized with a convolution-based scatter estimation
  - The number of simulated Monte Carlo photons can be reduced
  - Monte Carlo scatter estimates are computed for only a fraction of all projections
- Using the hybrid scatter correction resulted in a speed up of a about a factor of 100 as compared to a full Monte Carlo scatter correction for the cases investigated
  - Both the Monte Carlo software and the hybrid scatter correction algorithm were not fully optimized for speed

Thank You!

This project was supported by a grant from the Intel Corporation.

Parts of the reconstruction software were provided by RayConStruct® GmbH, Nürnberg, Germany.

This presentation will be soon available at www.dkfz.de/ct.