Empirical Scatter Correction (ESC): A Universal CBCT Scatter Reduction Method without Prior Knowledge

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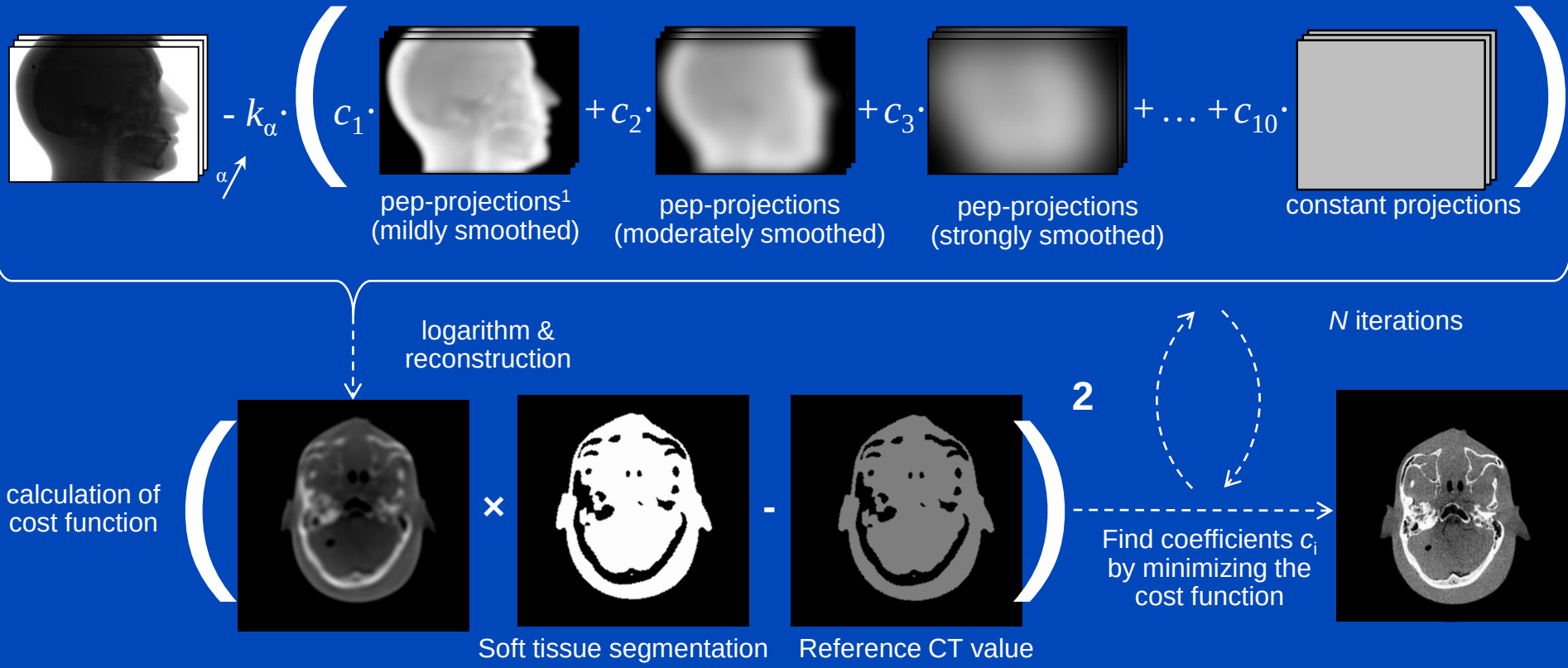
Motivation & Aim

- **Scatter is one of the most prominent sources of artifacts in cone-beam CT (CBCT).**
- **Software-based correction methods (kernel-based, Monte Carlo, Boltzmann, DSE, …)* rely on precise prior information about the object and the CT system.**
- **This prior knowledge may not always be available.**

- **Aim:**
  To provide a scatter correction algorithm that works without prior knowledge.

*Colijn et al., PMB 2004, Jarry et al., MedPhys 2006, Maslowski et al., MedPhys 2018, Wang et al., MedPhys 2018, Ohnesorge et al., EurRad 1999, Sun et al., PMB 2010, Nomura et al., MedPhys 2019, and Maier, Kachelrieß et al., MedPhys 2019

Method



- **To reduce computation times: use subsampled projection data and reconstructions on a smaller voxel grid!**
- $$k_\alpha = \begin{cases} \min \frac{I(u,v,\alpha)}{\sum_i c_i \cdot B_i(u,v,\alpha)} (1-\delta) & \text{if } \min\left(I(u,v,\alpha) - \sum_i c_i \cdot B_i(u,v,\alpha)\right) < 0 \\ 1 & \text{else} \end{cases}$$

[1]Ohnesorge, Flohr and Klingenbeck-Regn: *Efficient object scatter correction algorithm…*, European Radiology (1999), Vol. 9, Nr. 3, S. 563-569

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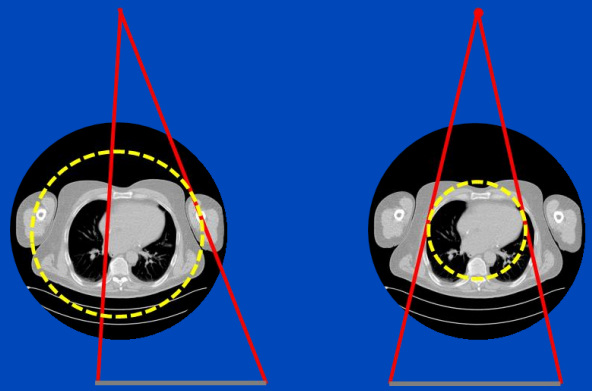
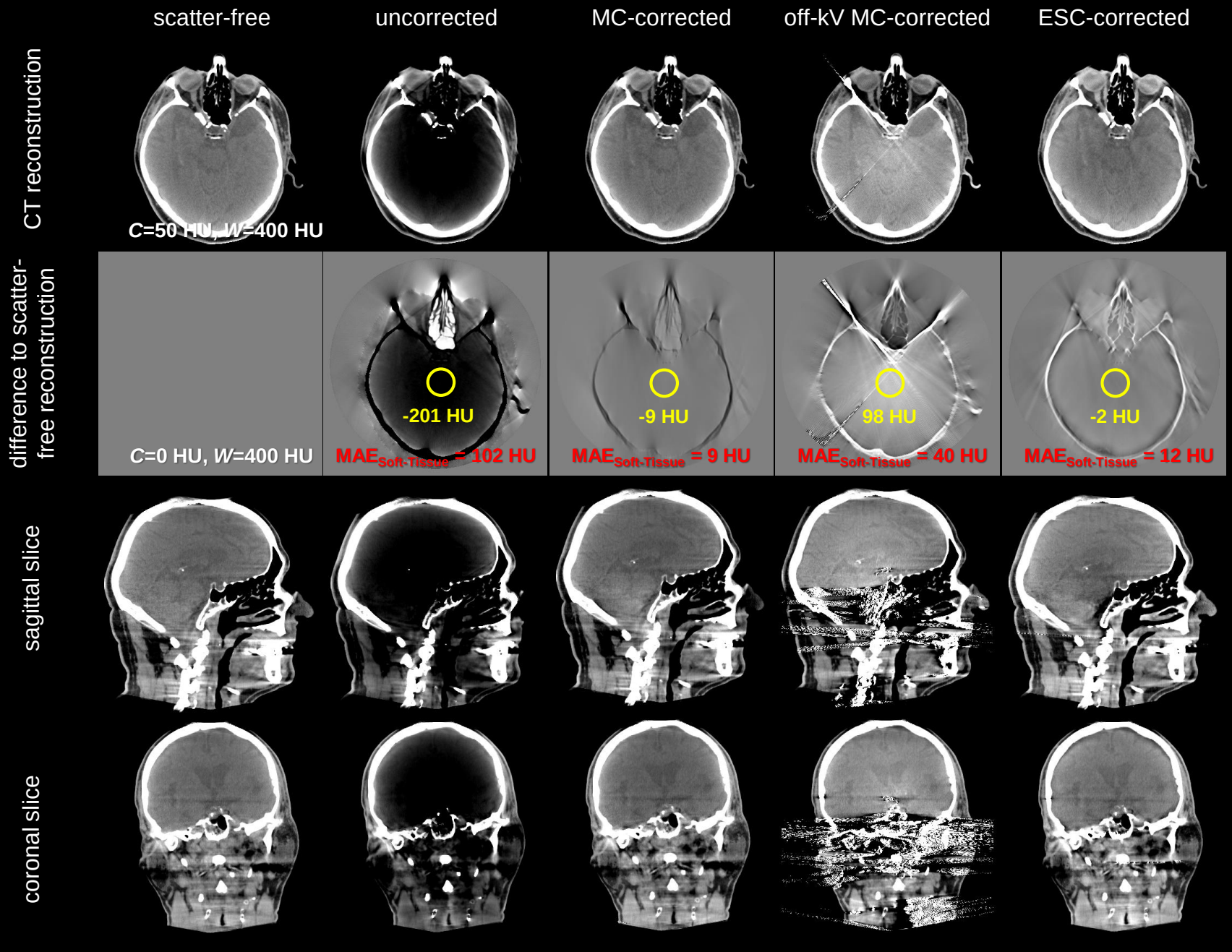
Simulation Study

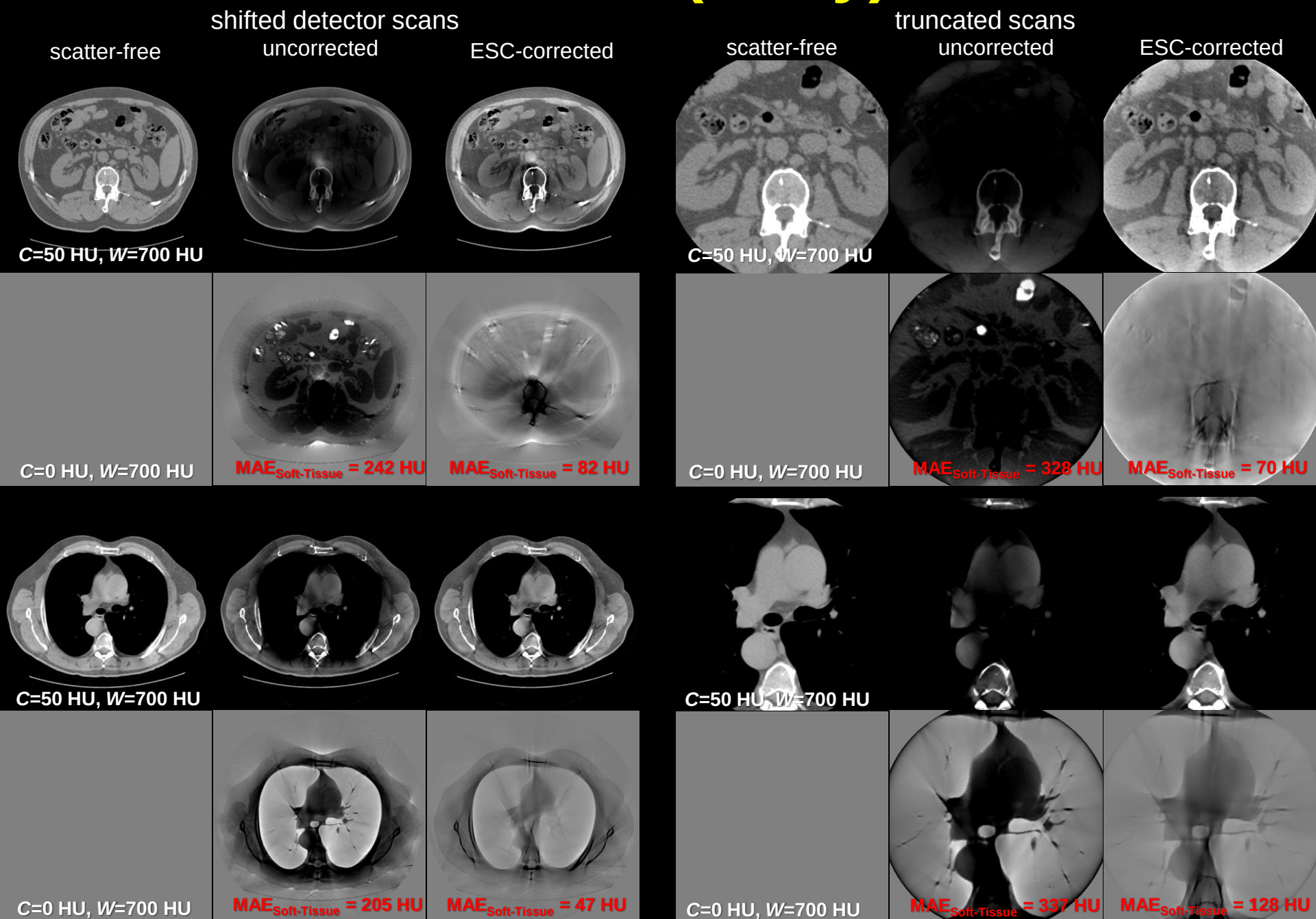
- Forward project diagnostic head, thorax, and abdomen CT scans into CBCT geometry.
- Add Monte Carlo-simulated scatter intensities.
- Simulate no ASG in order to obtain high SPRs.
- Geometries
  - Conventional cone-beam
  - Shifted-detector cone-beam
  - Truncated cone-beam (small detector)
- Compare with
  - MC-based scatter correction
  - Off-kV MC-based scatter correction (20 kV off)



Results (Head)

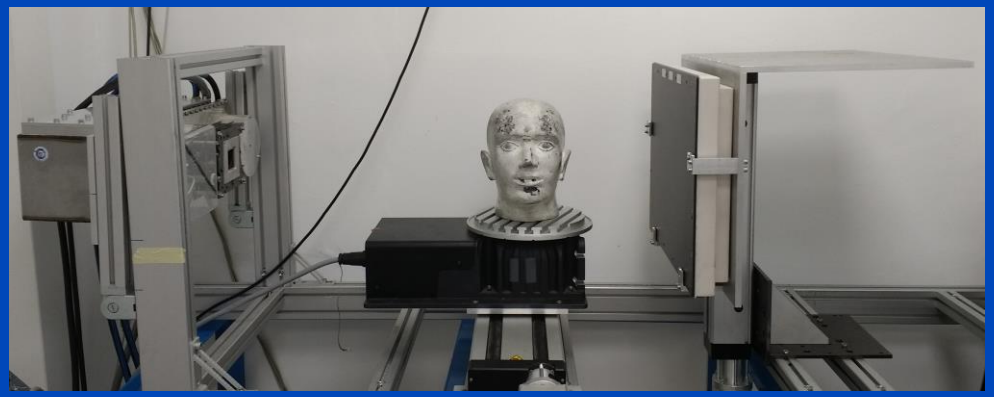


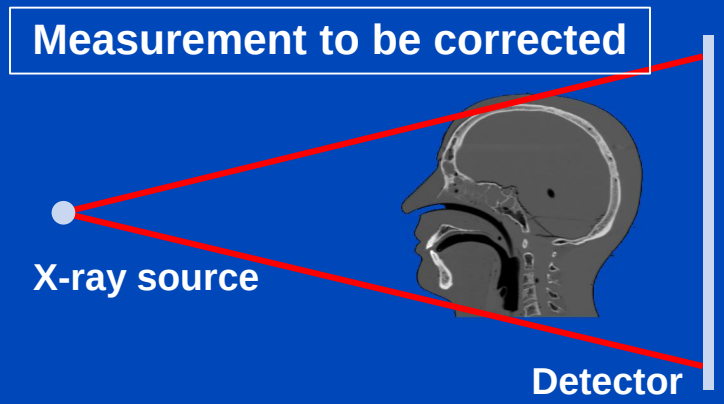
Results (Body)



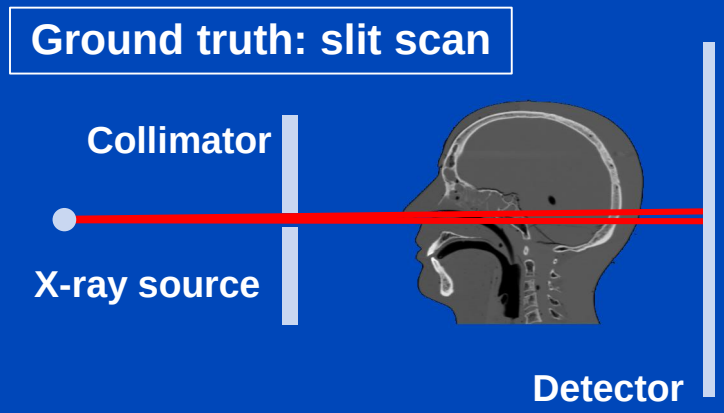
Phantom Measurement

DKFZ table-top CT

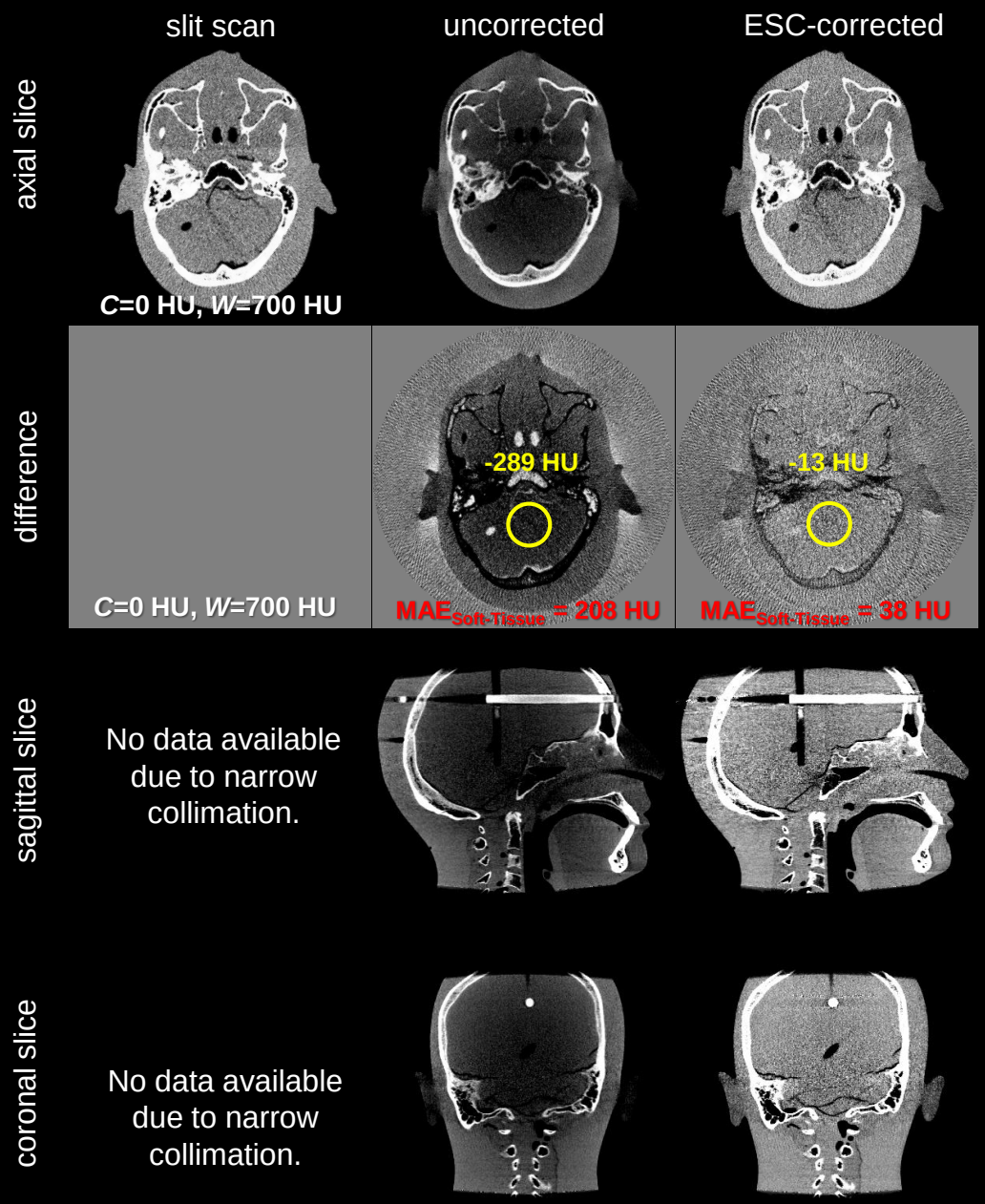




- Measurement of a head phantom at our in-house table-top CT.
- Slit scan measurement serves as ground truth.
- Scan parameters:
  - U = 120 kV (9 mm Al)
  - P = 360 W



Results (Measured Phantom)



Conclusions

- ESC is able to improve image quality in CBCT simulations and measurements without specific prior knowledge.
- In some cases the remaining artifacts may be higher than with optimized solutions that use prior knowledge.
- The computation time of ESC is in the order of one to two minutes. Optimizations may include a Taylor expansion from intensity to log domain.

Thank You!

This presentation is available at www.dkfz.de/ct

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Job opportunities through DKFZ's international PhD or Postdoctoral Fellowship programs (www.dkfz.de), or directly through Prof. Dr. Marc Kachelrieß (marc.kachelriess@dkfz.de).

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