Deep Learning-based Iterative Reconstruction for Field of View Extension in Dual-Source Dual-Energy CT

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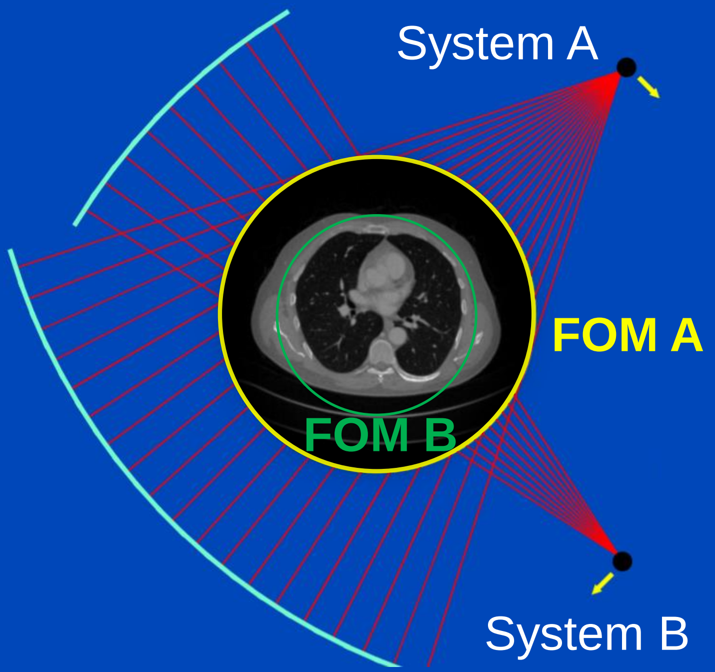
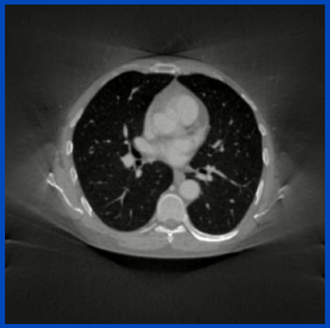
KREBSFORSCHUNGSZENTRUM
IN DER HELMHOLTZ-GEMEINSCHAFT

Motivation



Reconstruction A

Reconstruction B*



- **In dual-source CT, the field of measurement (FOM) of the second source-detector pair is often limited by technical constraints.**
- **Dual-energy information is only available within the small FOM.**
- **Deep learning-based iterative reconstruction to recover missing information.**

*Note: The reconstruction was performed using a custom reconstruction software. The vendor's reconstruction software would clip the reconstruction to the small FOM.

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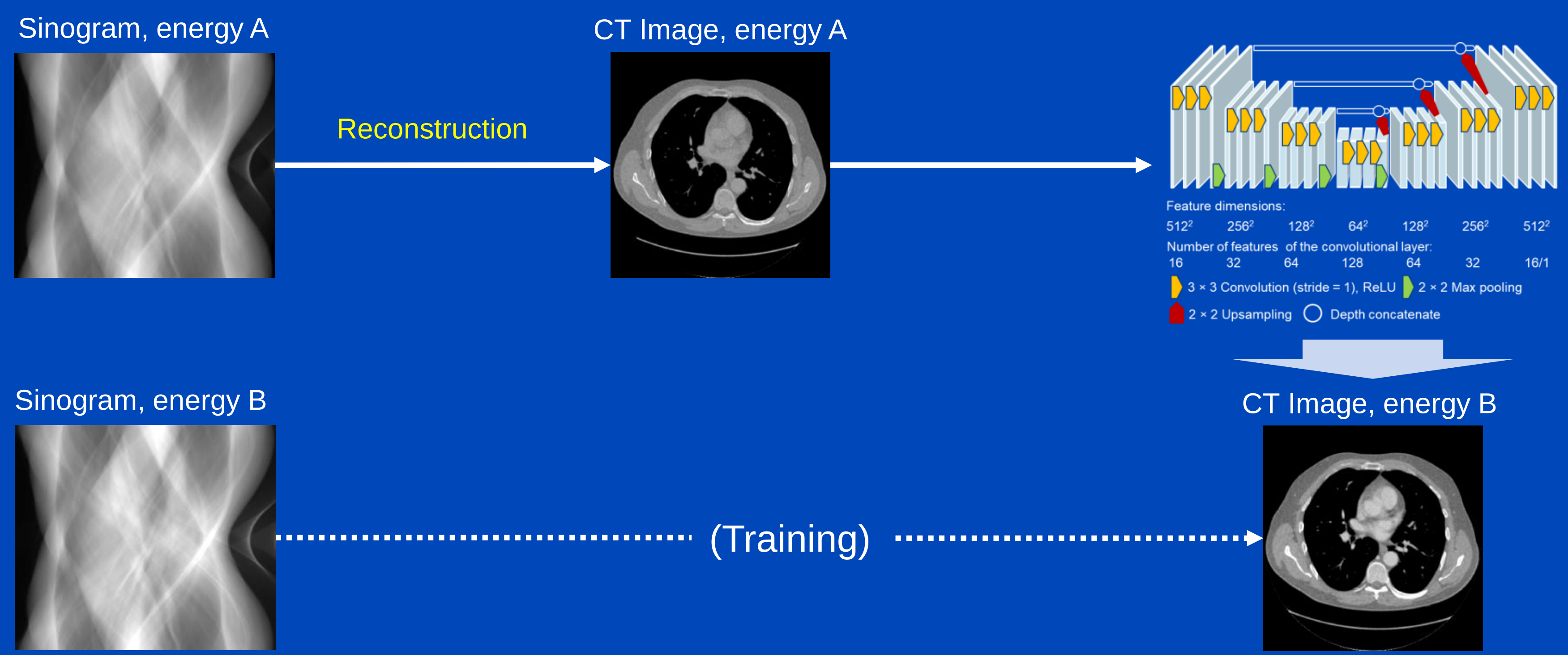
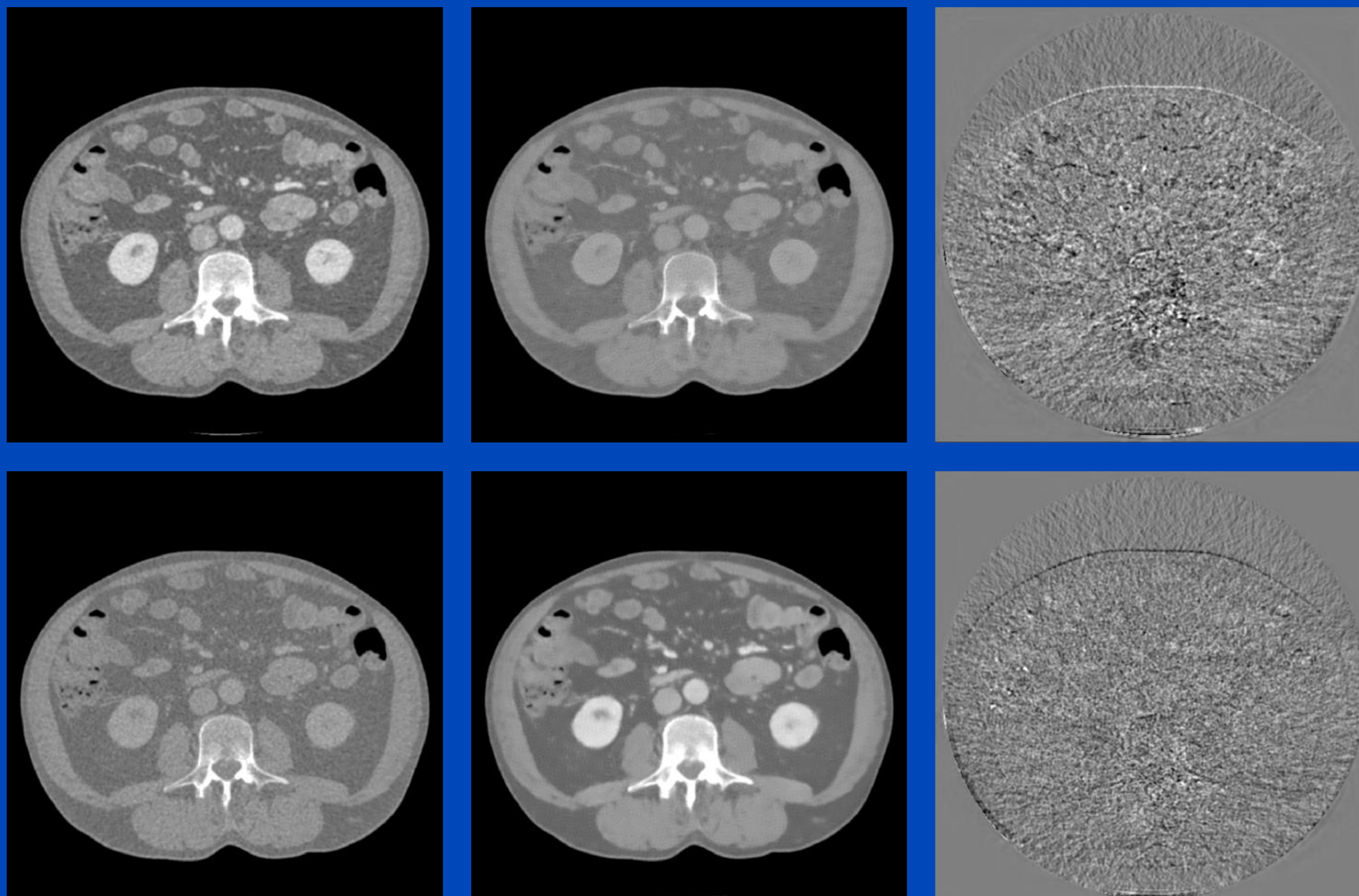
Prior Work



[1] D. Lee et al., “Development of a deep neural network for generating synthetic dual-energy chest x-ray images with single x-ray exposure”, *Phys. Med. Biol.*, 2019.
[2] Y. Liao et al., “Pseudo dual energy CT imaging using deep learning-based framework: basic material estimation”, *SPIE*, 2018.
[3] W. Zhao et al., “A deep learning approach for dual-energy CT imaging using a single-energy CT data”, *Fully 3D*, 2019.
[4] C. K. Liu, C. C. Liu, C. H. Yang, H. M. Huang, “Generation of brain dual-energy CT from single-energy CT using deep learning”, *J. Digit. Imaging,* 2021.
[5] T. Lyu et al., “Estimating dual-energy CT imaging from single-energy CT data with material decomposition convolutional neural network”, *Med. Img. Anal.*, 2021.
[6] Y. Li et al., “Deep-En-Chroma: mining the spectral fingerprints in single-kV CT acquisitions using energy integration detectors”, *SPIE, 2022.*
[7] D. P. Clark et al., “Deep learning based spectral extrapolation for dual-source, dual-energy x-ray computed tomography”, *Med. Phys.*, 2020.
[9] L. Yao et al., “Leveraging deep generative model for direct energy-resolving CT imaging via existing energy-integrating CT images”, *SPIE*, 2020.

Single-Energy Mappings



C = 0 HU, *W* = 1000 HU

C = 0 HU, *W* = 300 HU

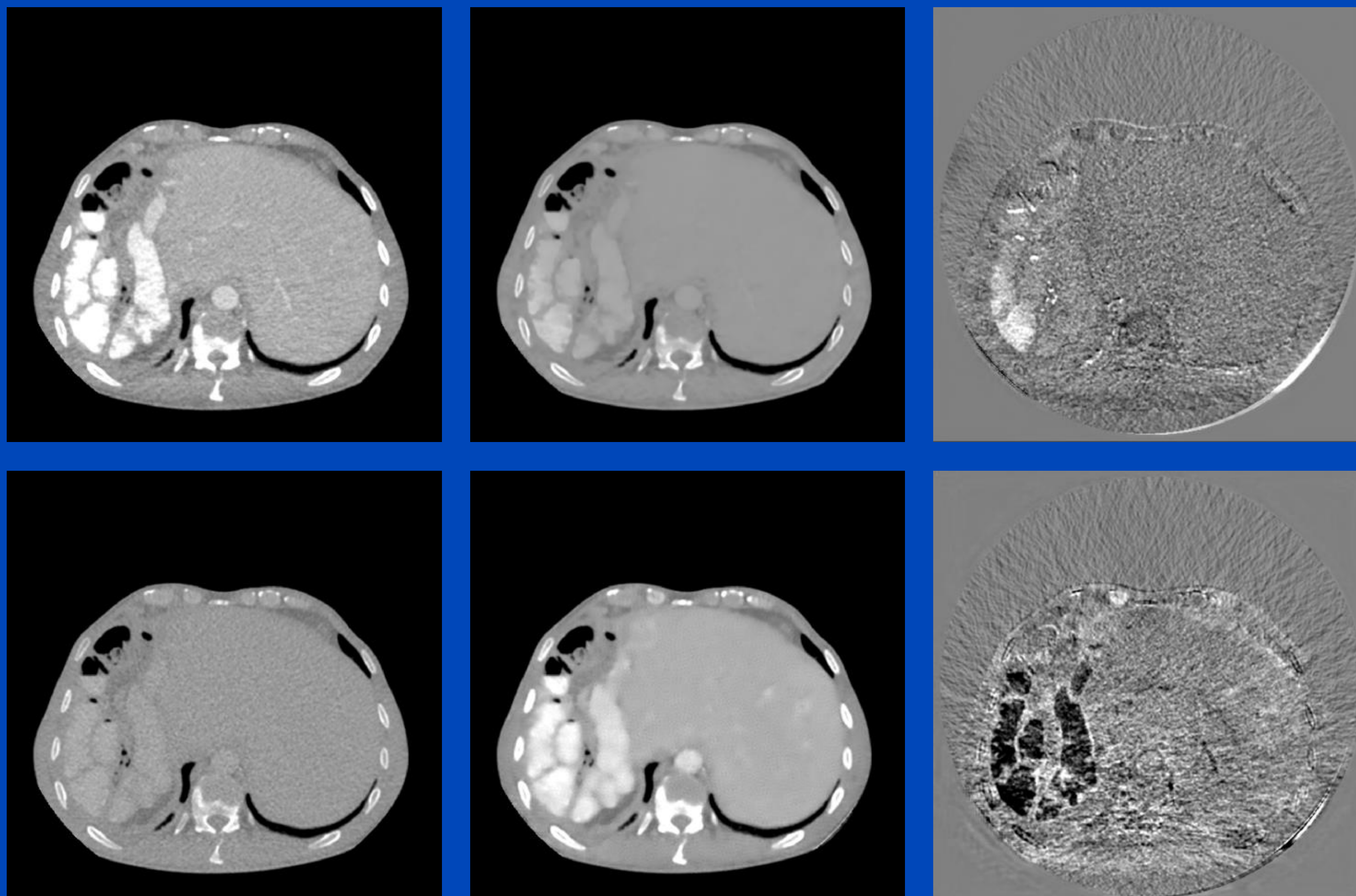
Single-Energy Mappings

Out-of-distribution samples

Input to network | Prediction | Error w.r.t. ground truth

70 kV to 150 kV mapping

150 kV to 70 kV mapping

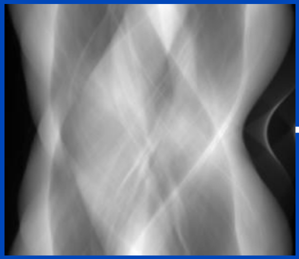


C = 0 HU, W = 1000 HU

C = 0 HU, W = 300 HU

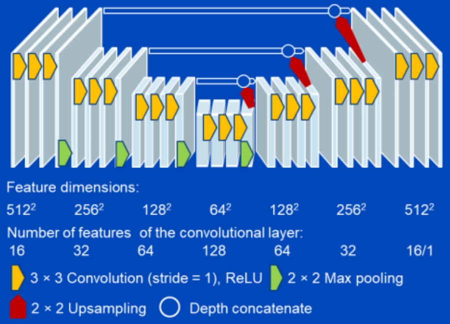
Single-Energy Mapping

Sinogram, energy A

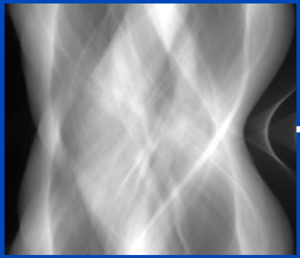


Reconstruction

CT Image, energy A



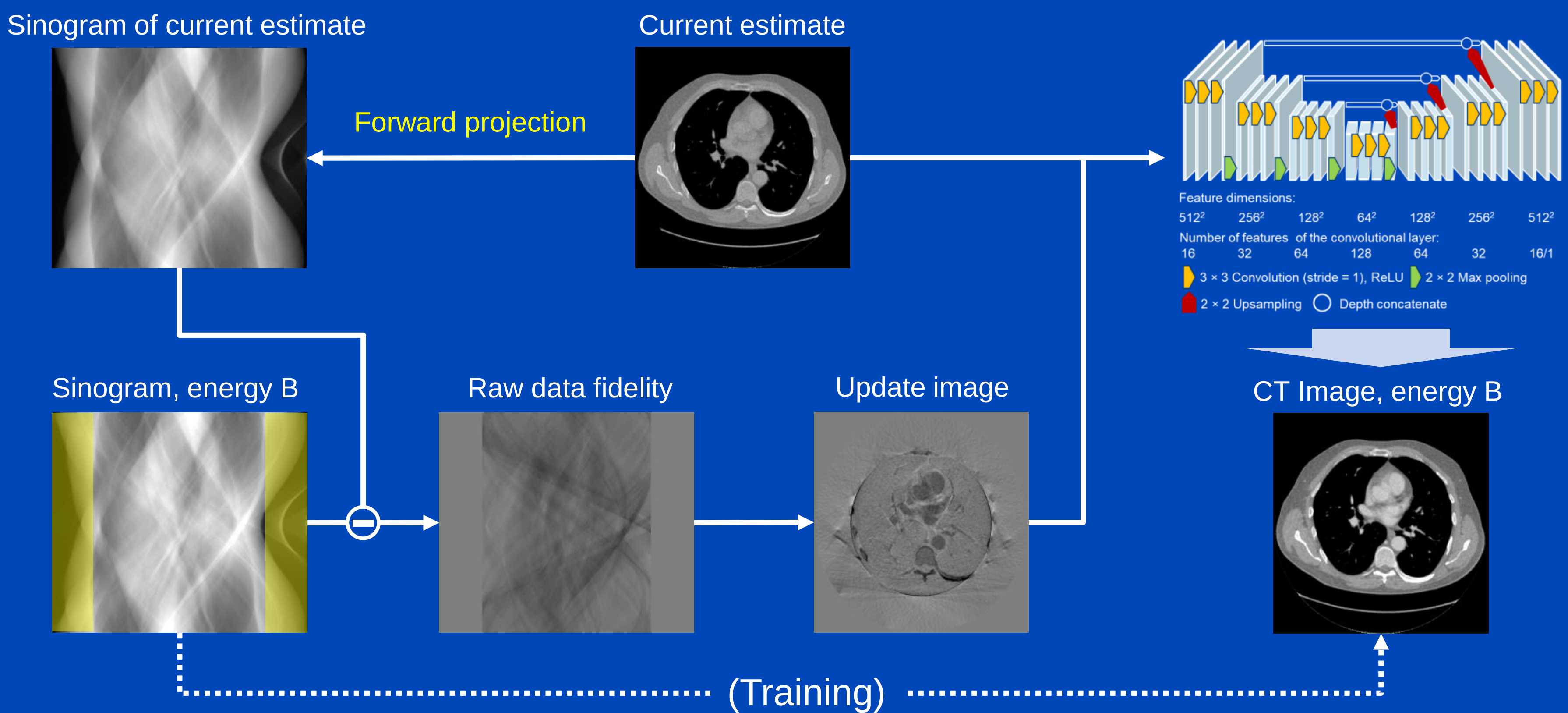
Sinogram, energy B



(Training)

CT Image, energy B

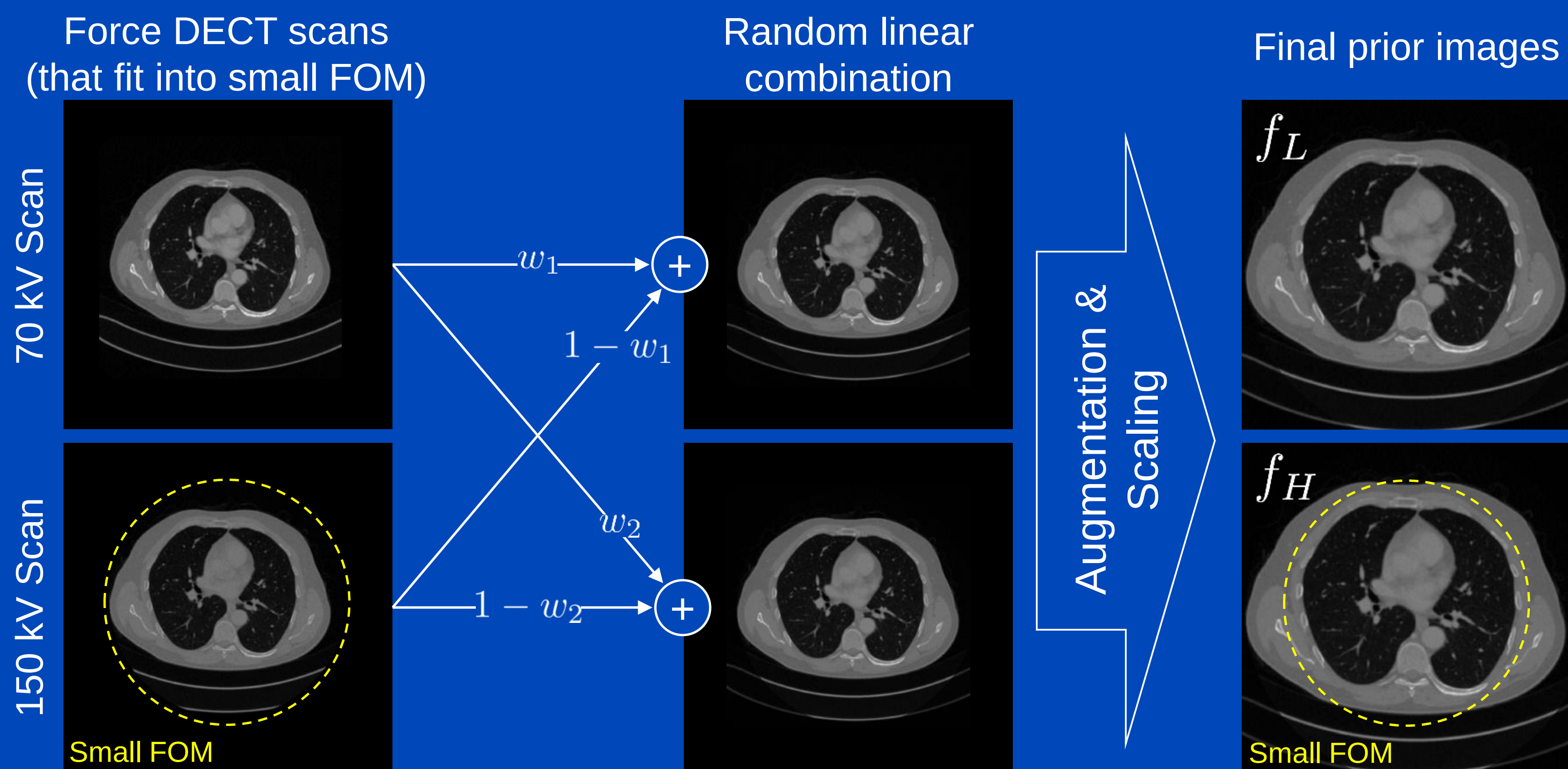
Proposed Approach



Make use of limited angle information outside small FOM to learn a more reliable mapping.

Training Data Generation

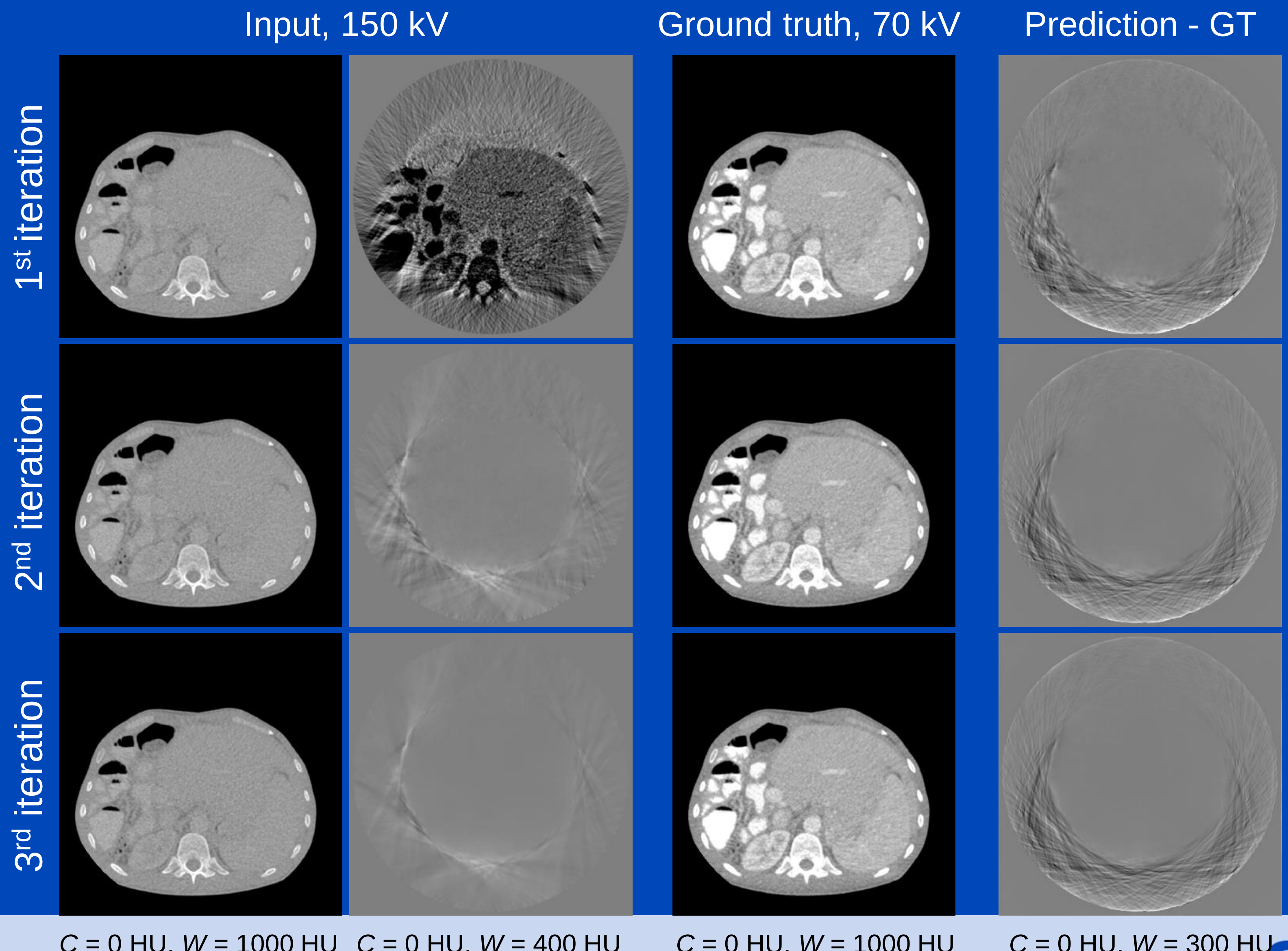
Prior images



→ Forward projection of prior images to generate synthetic raw data.

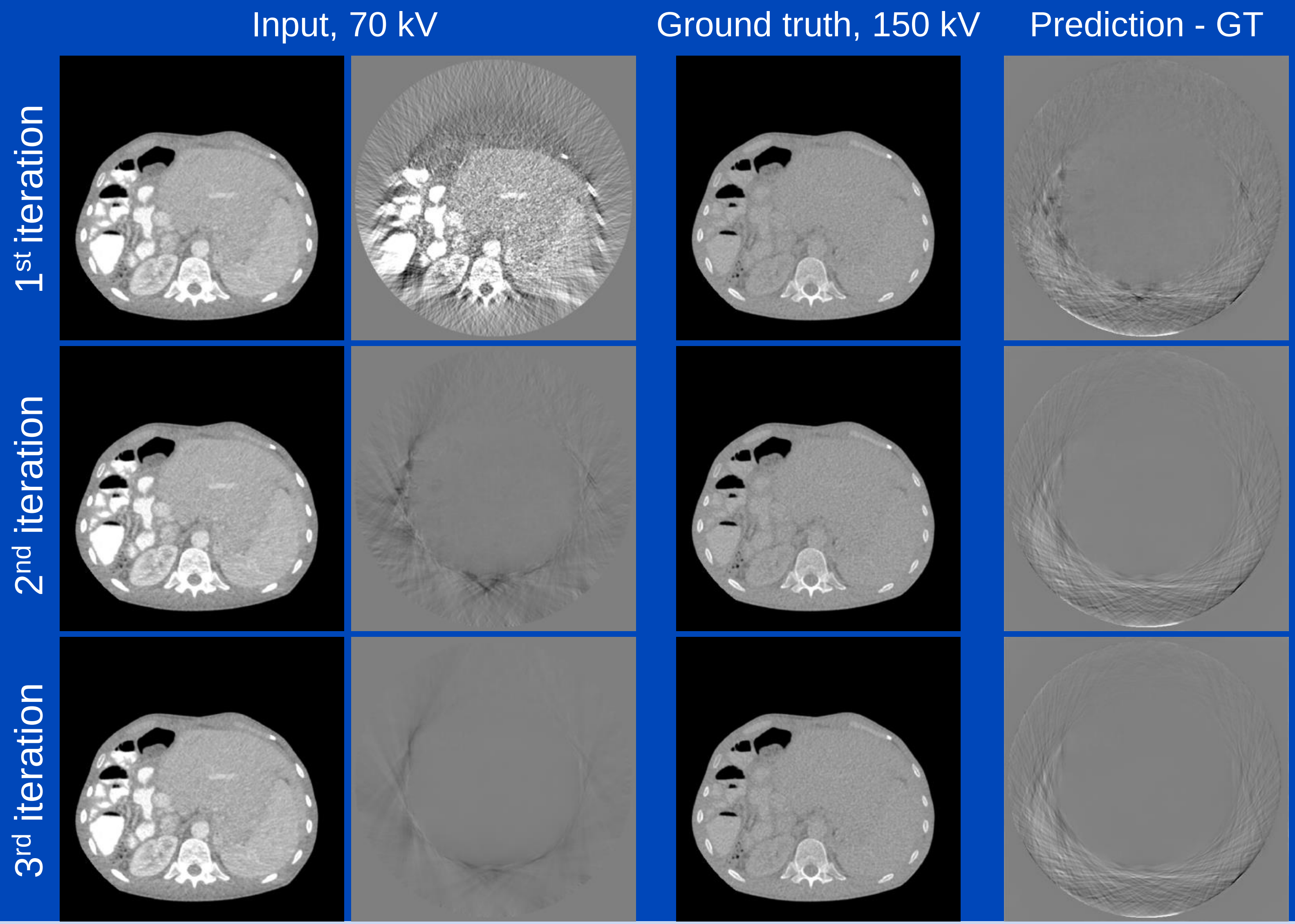
Results

Simulated data



Results

Simulated data



C = 0 HU, *W* = 1000 HU *C* = 0 HU, *W* = 400 HU *C* = 0 HU, *W* = 1000 HU *C* = 0 HU, *W* = 300 HU

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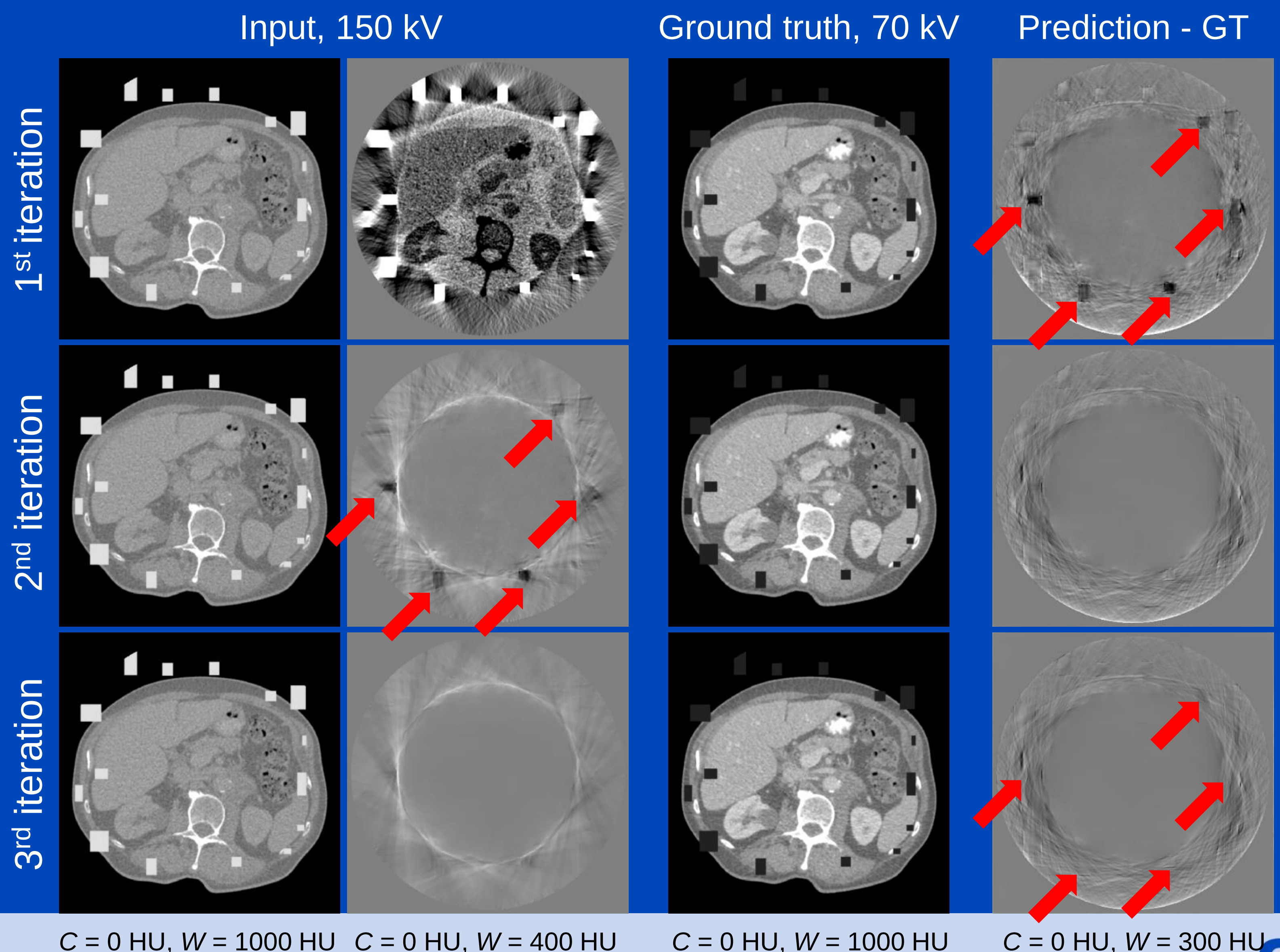
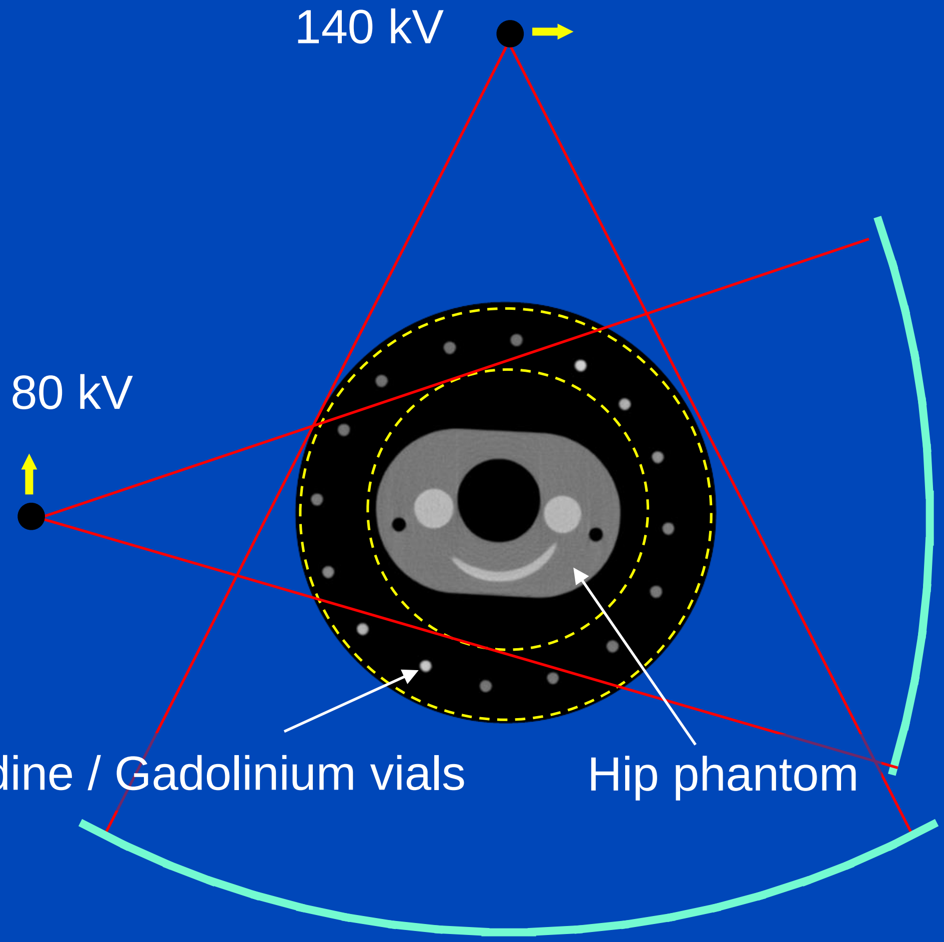
Results

Simulated data

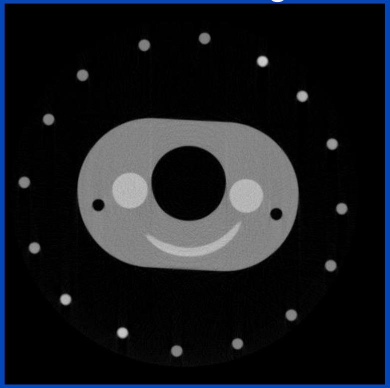


Measurements

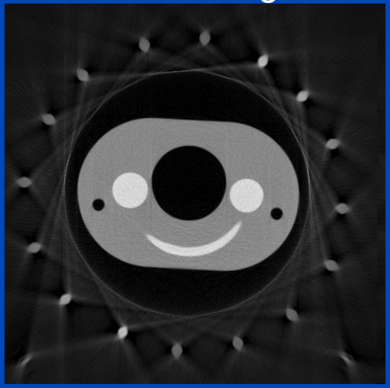
Siemens SOMATOM Definition Flash



140 kV Image

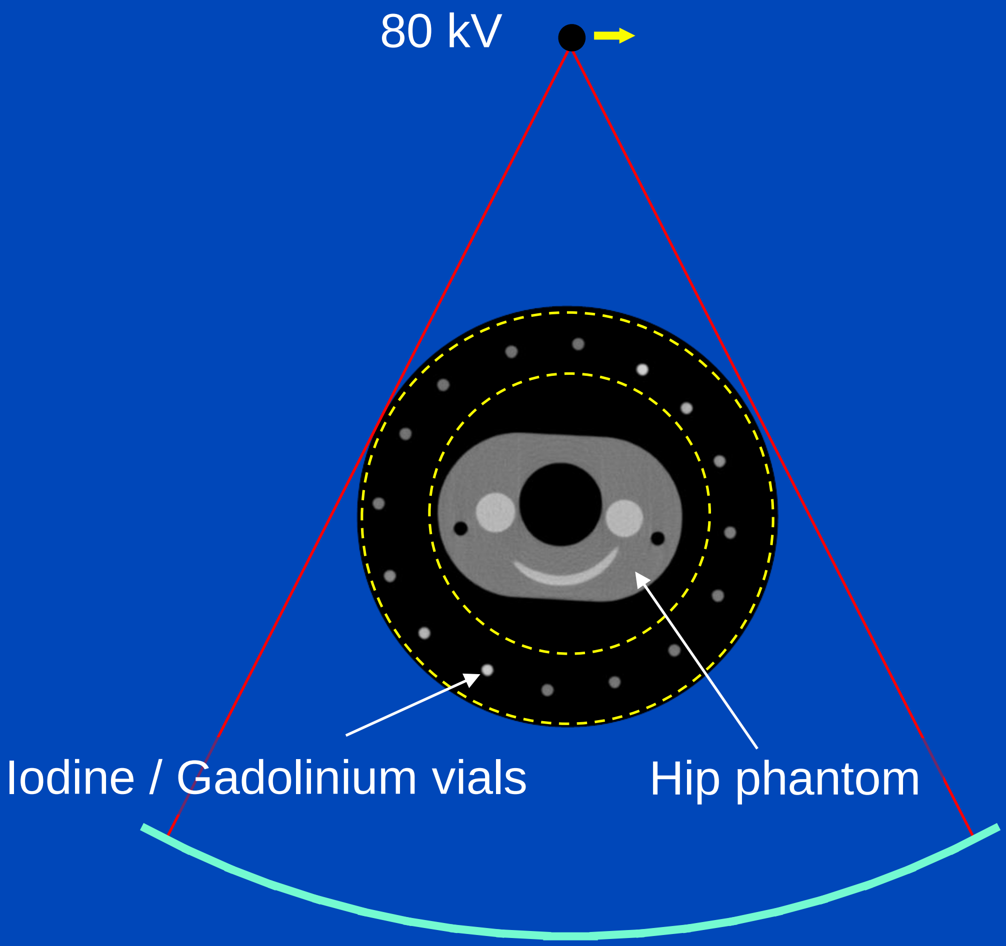


80 kV Image

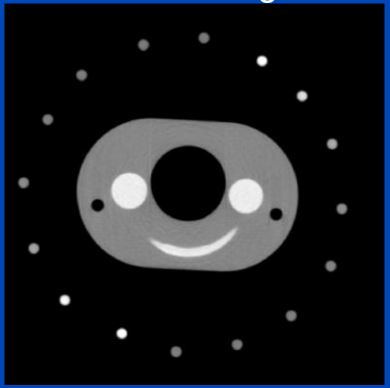


Measurements

Siemens SOMATOM Definition Flash: Reference measurement



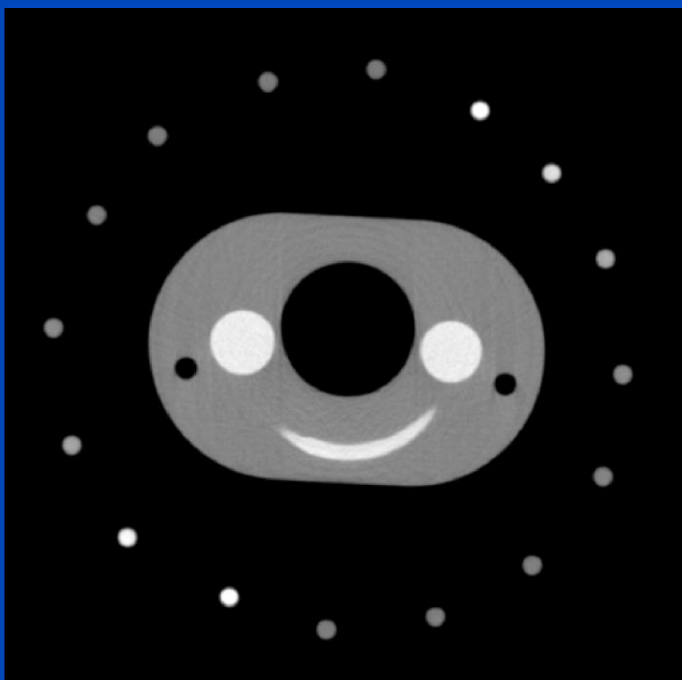
80 kV Image



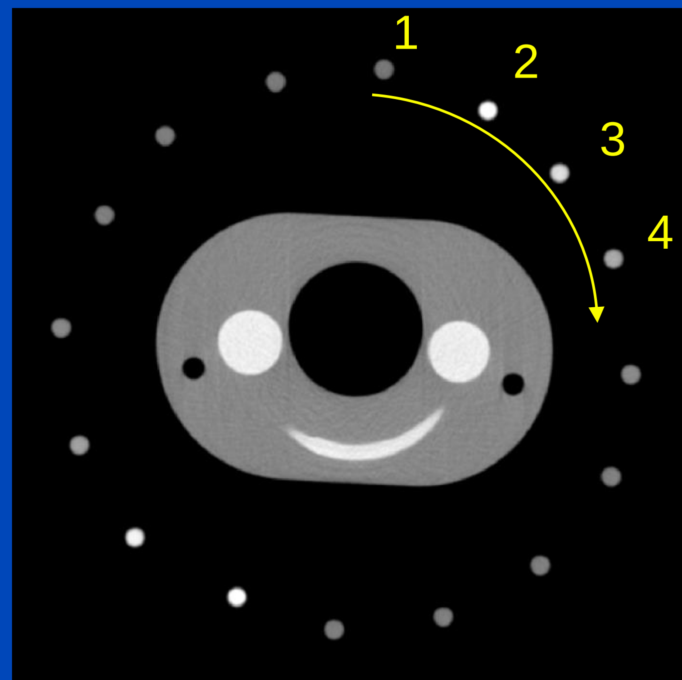
Results

Siemens SOMATOM Definition Flash

80 kV reference



Prediction



C = 0 HU, *W* = 1400 HU

ROI	CT #	Error
1	-43 HU	-9 HU
2	853 HU	3 HU
3	559 HU	10 HU
4	252 HU	-2 HU
5	72 HU	-12 HU
6	10 HU	-12 HU
7	-2 HU	-3 HU
8	12 HU	13 HU
9	-5 HU	7 HU
10	977 HU	11 HU
11	684 HU	20 HU
12	198 HU	-15 HU
13	61 HU	-4 HU
14	4 HU	-3 HU
15	-3 HU	6 HU
16	-27 HU	-1 HU

Conclusions

- Proposed approach is able to provide accurate dual-energy information for the entire FOM.
- The current training strategy allows to have one network for any tube voltage combination.
- Iterative application of the proposed approach may improve the quality of the prediction, especially for out-of-distribution samples.

Thank You!

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

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).

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