Dedicated Metal Artifact Reduction for Photon Counting CT

Achim Byl[1,2], Jennifer Hardt[1,2], Laura Klein[1,2], Eckhard Wehrse[1,2], Heinz-Peter Schlemmer[1,2], Sarah Heinze[2], Monika Uhrig[1,2], Stefan Sawall[1,2], and Marc Kachelrieß[1,2]

[1]German Cancer Research Center (DKFZ), Heidelberg, Germany

[2]Ruprecht-Karls-University of Heidelberg, Germany

DEUTSCHES KREBSFORSCHUNGSZENTRUM IN DER HELMHOLTZ-GEMEINSCHAFT

Introduction

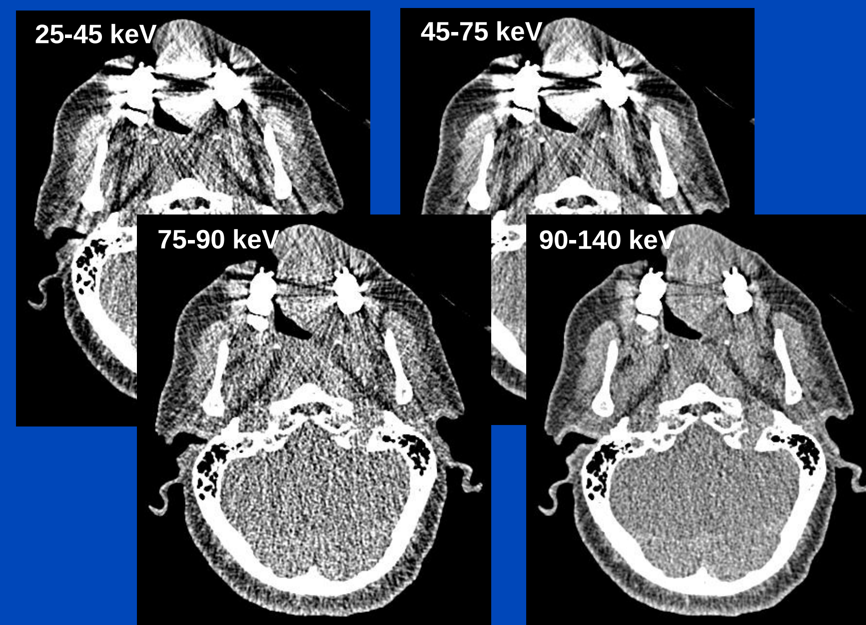
- Metal artifacts strongly reduce the diagnostic value of CT images
- Metal artifacts are caused by a combination of scatter, beam hardening, and photon starvation
- Even frequency split normalized metal artifact reduction (FSNMAR), the gold standard, cannot fully remove artifacts

Conventional vs. Photon Counting CT

Conventional CT

- 1 image to correct
- No additional information

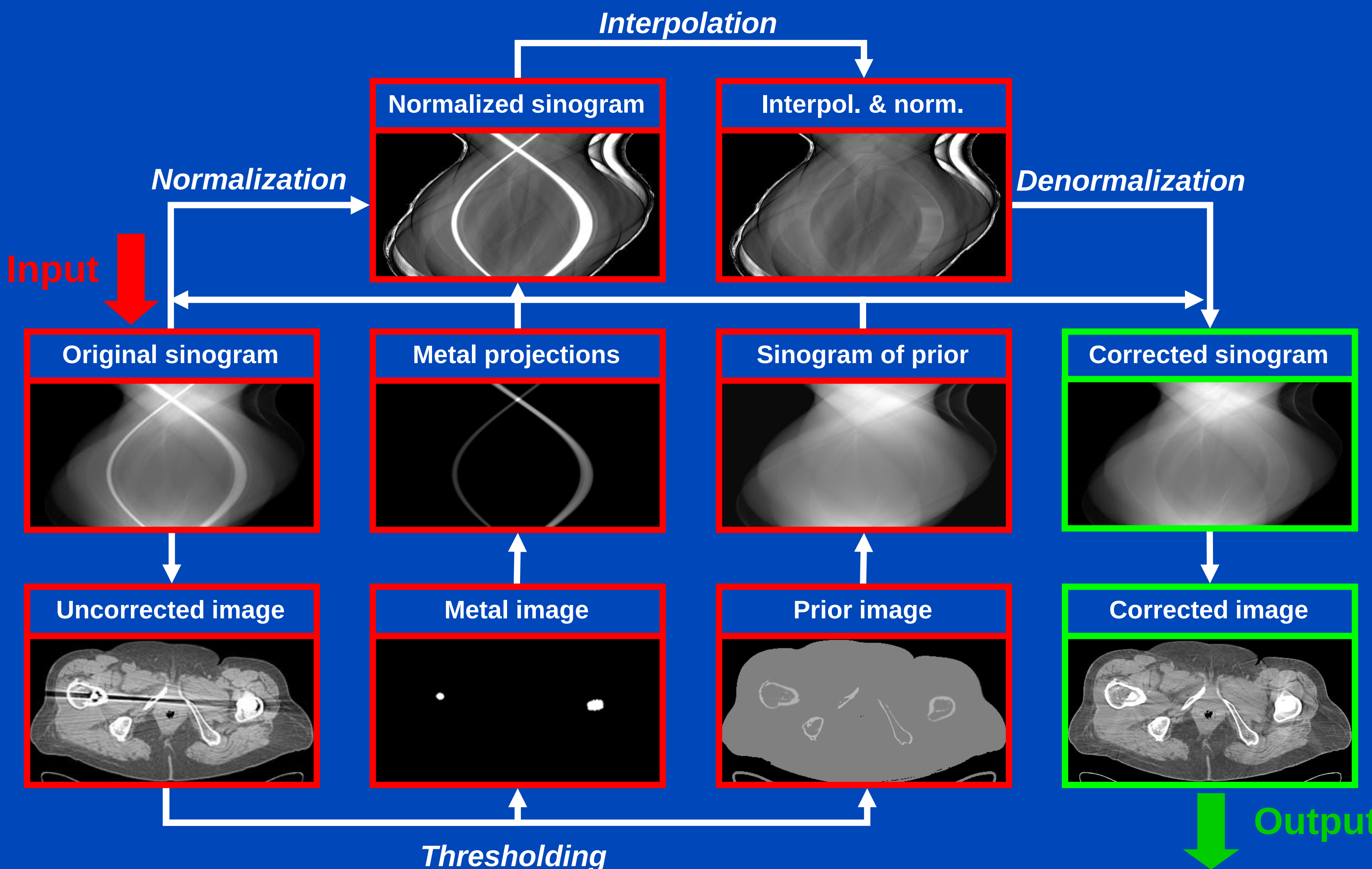
Photon Counting CT (PCCT)



- 4 images to correct
- Additional spectral information

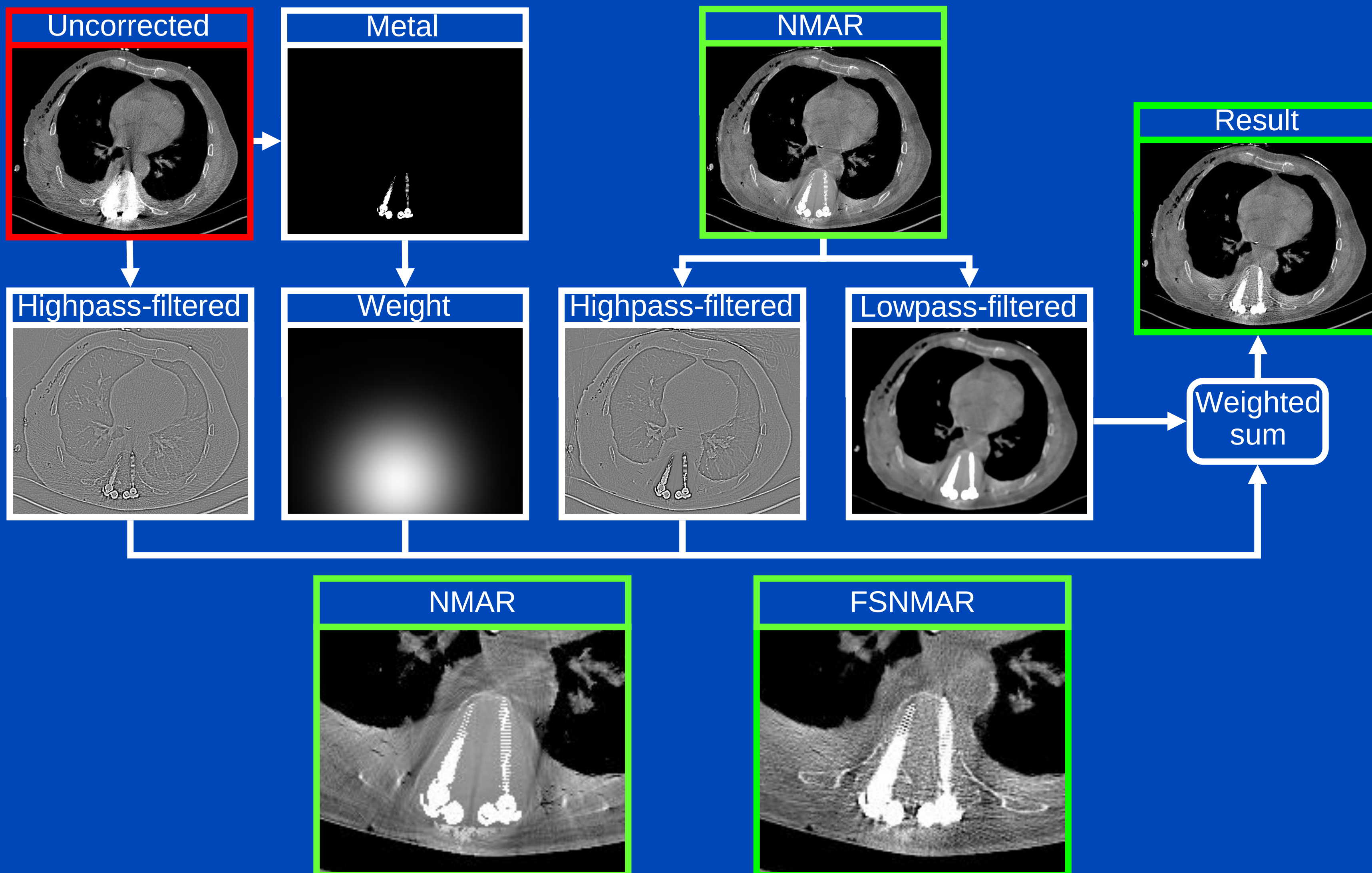
C = 50 HU, *W* = 700 HU

Normalized MAR (NMAR)



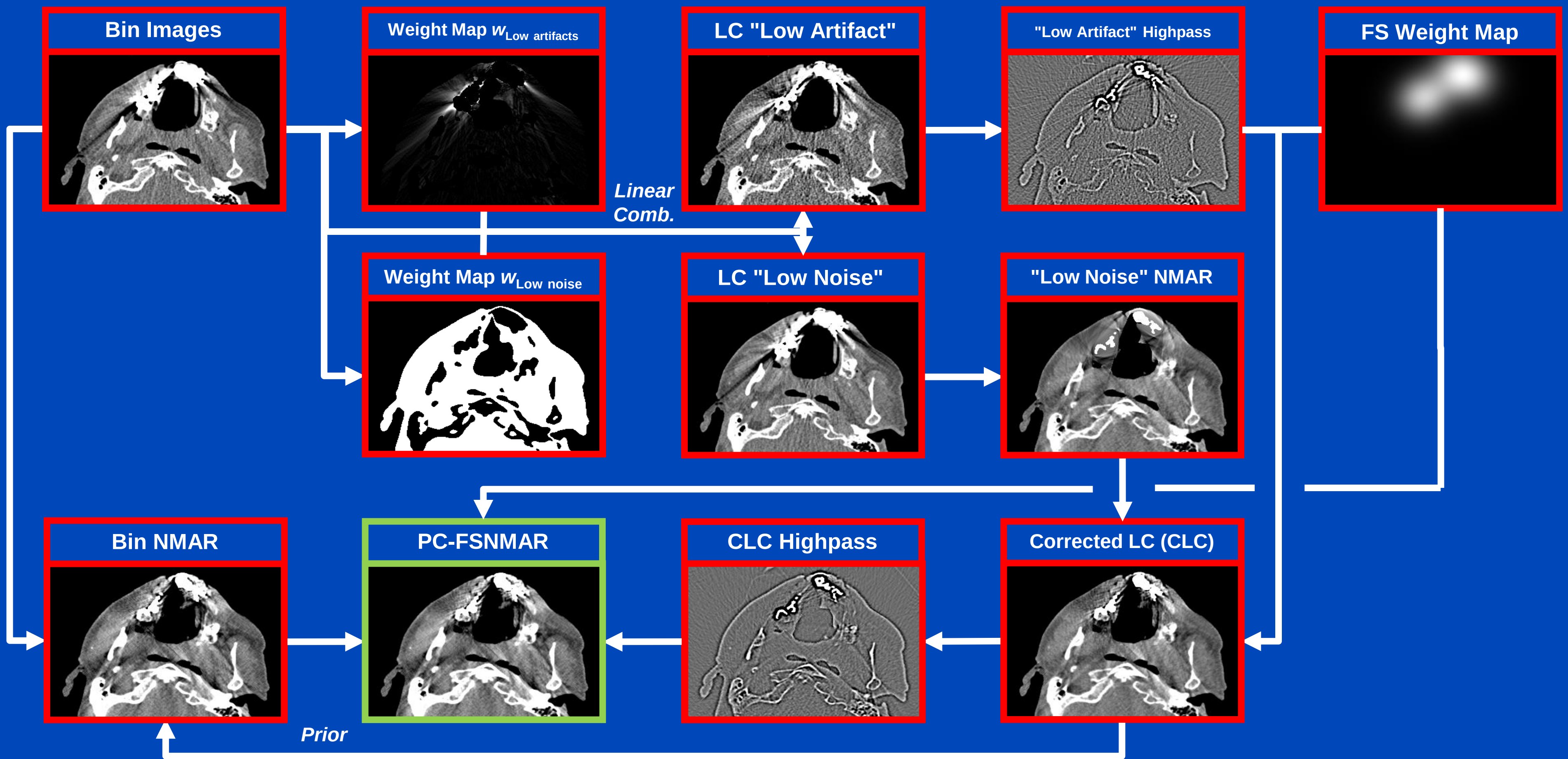
Meyer, Raupach, Lell, Schmidt, and Kachelrieß, "Normalized metal artifact reduction (NMAR) in computed tomography", Med. Phys. 37(10):5482-5493, 2010.

Frequency Split NMAR (FSNMAR)



Meyer, Raupach, Lell, Schmidt, and Kachelrieß, "Frequency split metal artifact reduction (FSMAR) in computed tomography", Med. Phys. 39(4):1904-1916, 2012.

PC-FSNMAR Scheme



Optimization

- The optimization uses a Nelder-Mead algorithm that minimizes a cost function *C* with respect to the linear combination *LC.*
- $C(LC, w) = L(LC, w) + \lambda TV(LC, w)$
- $L(LC, w) = \sum_{i,j} w(i, j) LC^2(i, j)$
- The weight map *w*(i,j) is non-zero only for soft tissue
- *TV*(*LC,w*): reduces streaks and smooths the image
- *L*(*LC,w*): penalizes large homogeneous Artifacts
- Choice of *w* and *λ* determine the properties of the *LC*

$w_{\text{Low noise}}$

$w_{\text{Low artifacts}}$

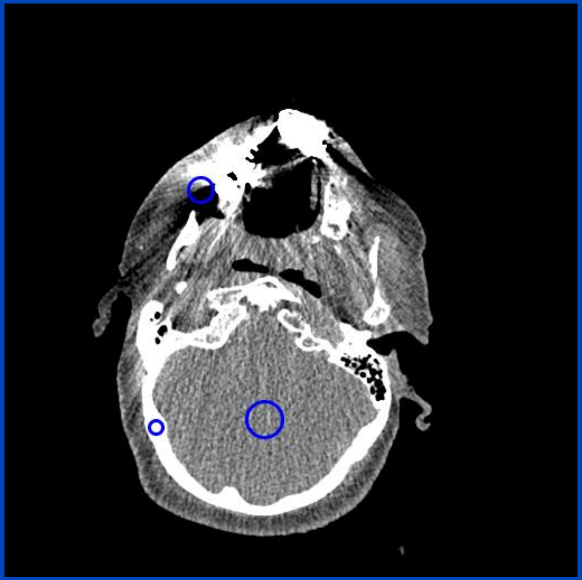
Measurements

CT data of forensic specimen (approval by ethics board S-388/2014) were obtained from a Siemens SOMATOM CounT with

- Voltage: $U = 140$ kV
- Tube current: $I_{\mathrm{eff}} = 300$ mAs
- Eff. slice thickness: $S_{\mathrm{eff}} = 0.6$ mm
- Pixel size: $\Delta x = \Delta y = 0.5$ mm
- Energy thresholds: 25/45/75/90 keV
- Reconstruction kernel: B40f

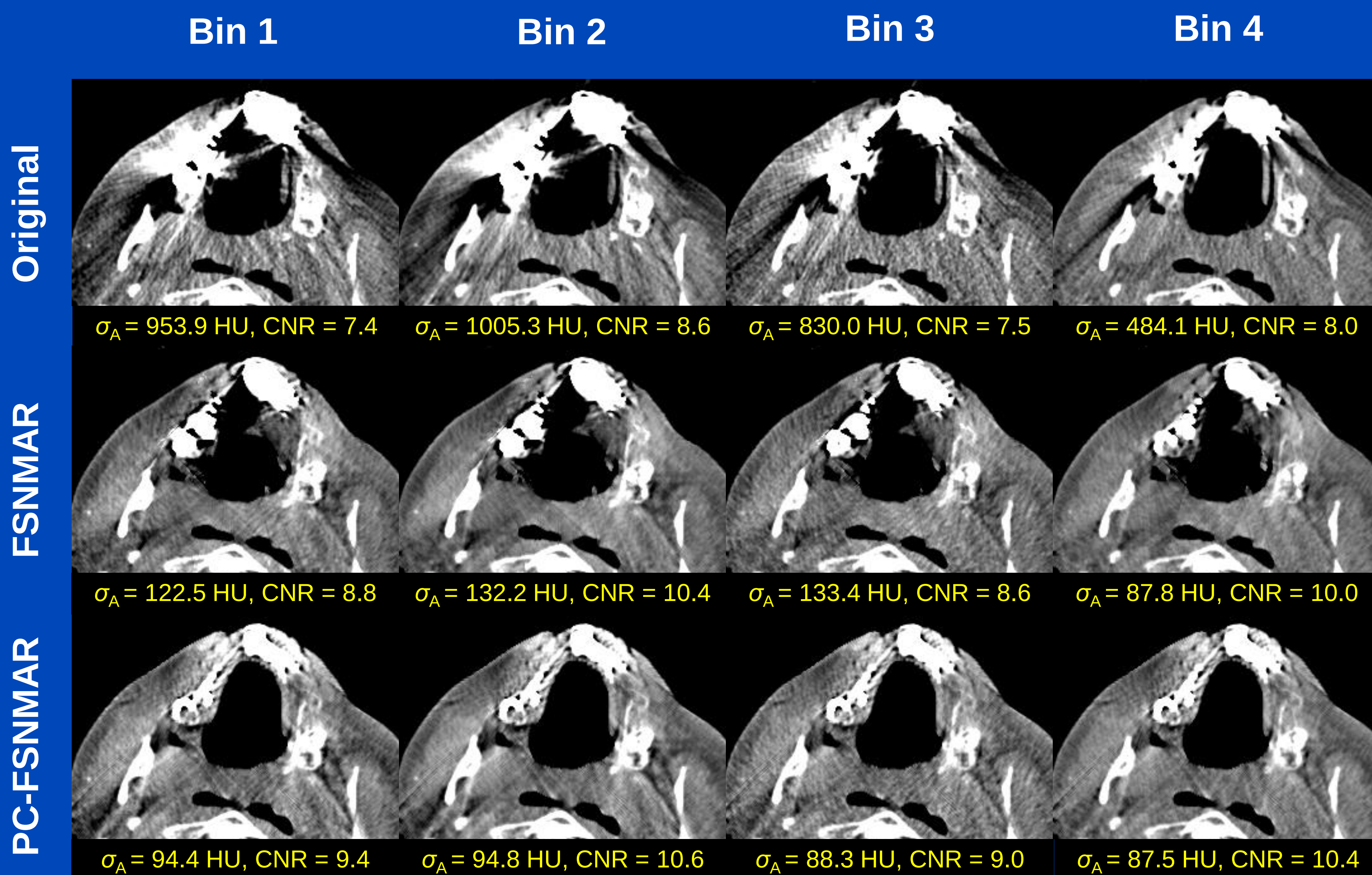
Analysis

- To quantify image quality, we employ these measurements:
  - Artifact content: standard deviation of an ROI with metal artifacts
  - Image quality: contrast-to-noise ratio of soft tissue and bone; one ROI in each tissue



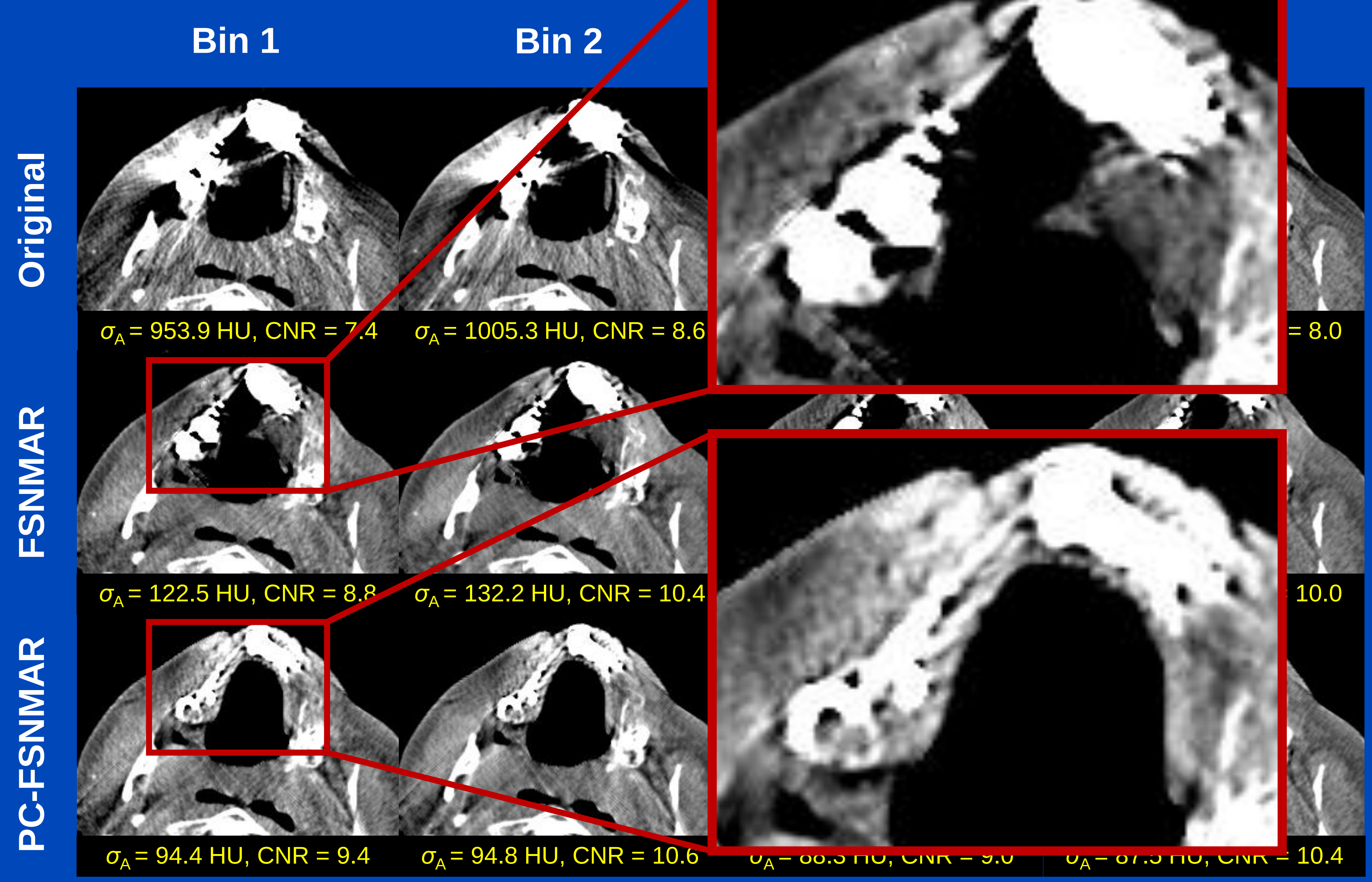
C = 50 HU, *W* = 700 HU

Results



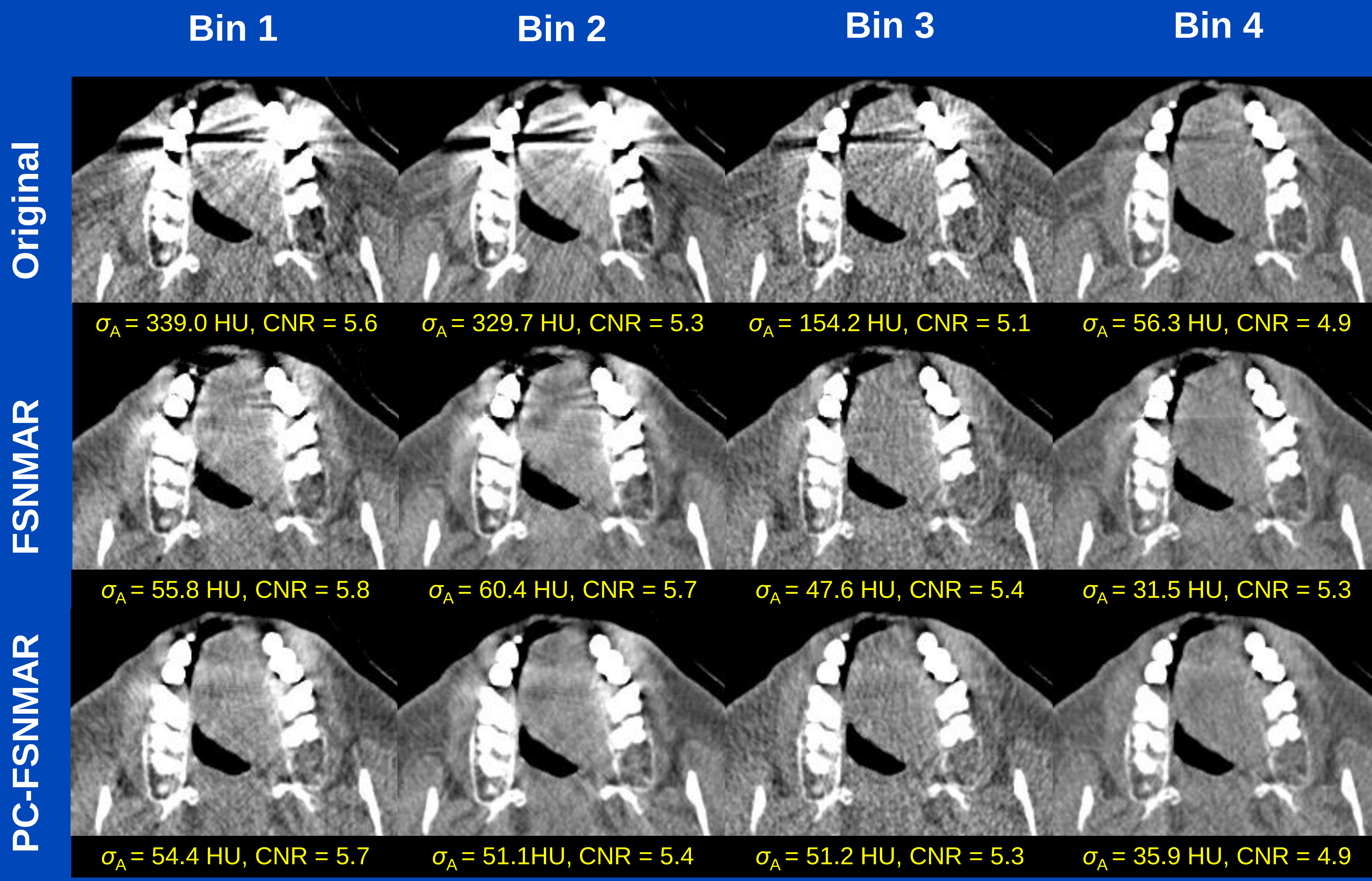
C = 50 HU, W = 700 HU

Results



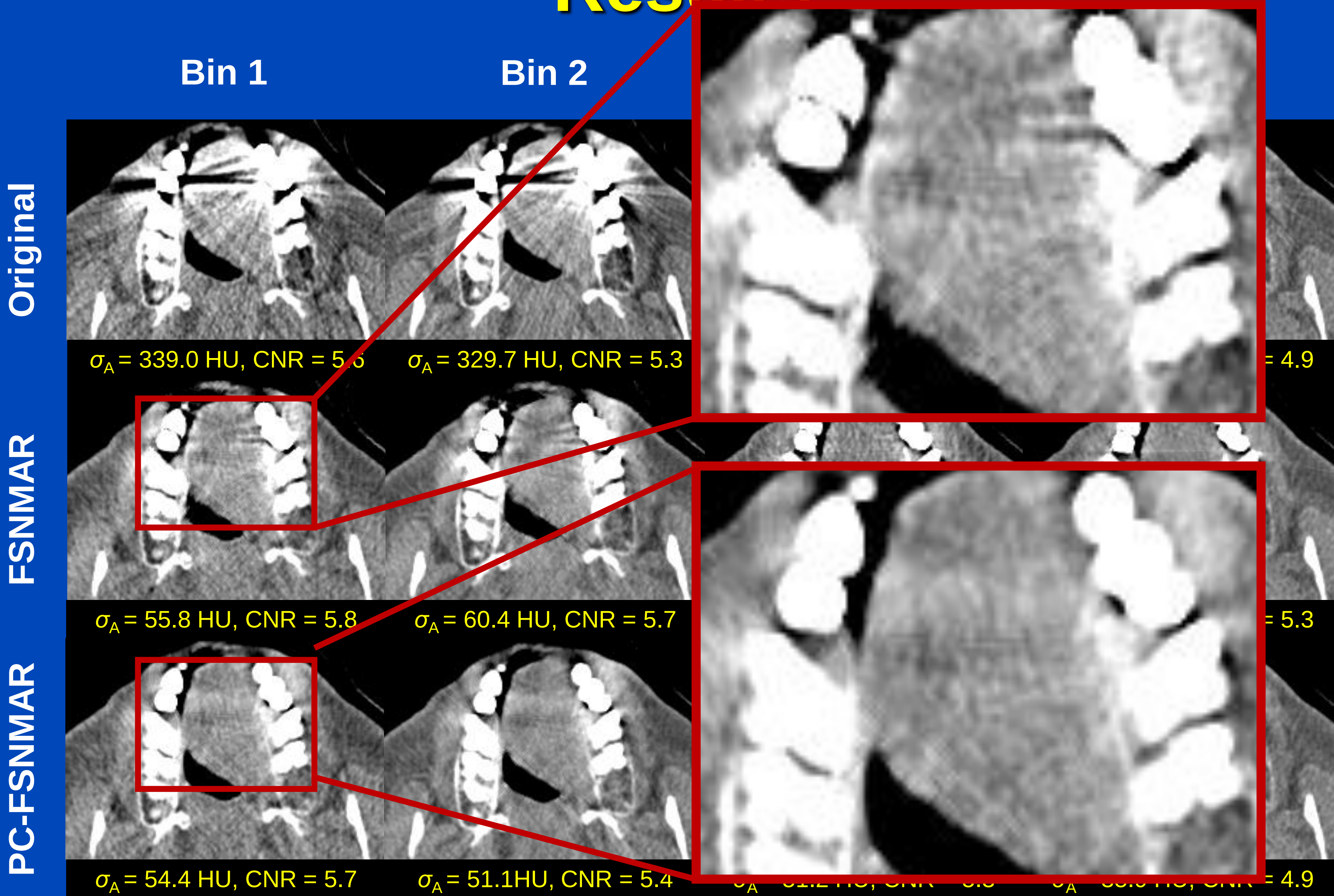
C = 50 HU, *W* = 700 HU

Results



C = 50 HU, W = 700 HU

Results



C = 50 HU, W = 700 HU

Conclusion

- PC-FSNMAR significantly improves image quality compared to conventional bin-wise FSNMAR
- Regions close to the metal show more details
- Artifacts are reduced without sacrificing CNR
- Some artifacts remain

Thank You!

This presentation will soon be available at www.dkfz.de/ct.
Job opportunities through DKFZ's international Fellowship programs (marc.kachelriess@dkfz.de).
Parts of the reconstruction software were provided by RayConStruct® GmbH, Nürnberg, Germany.