Design and Characterization of the Pyxis™ Photon-Counting CT Detection Platform

A White Paper on Detector Architecture, Calibration Methods, and Experimental Performance

Varex Imaging White Paper | June 2026

Authors: Josh Star-Lack, PhD; and Varex Imaging Photon Counting CT Development Team

Executive Summary

Photon-counting CT (PCCT) enables energy-resolved acquisition, higher spatial resolution, and the potential for greater dose efficiency than conventional energy-integrating detector CT [1]–[4]. Delivering these advantages at CT-relevant flux levels requires detector systems that maintain high count-rate capability, strong linearity, stable threshold response, and controlled spectral distortion [1]–[4]. The Pyxis™ platform combines direct-conversion detector hardware with a calibrated correction pipeline designed to address pulse pile-up, threshold variation, charge sharing, tile-edge discontinuities, bad pixels, and defect-related artifacts in CdTe-based PCCT acquisition [3]–[5]. In a four-module development configuration, the platform was characterized using MTF/DQE, linearity, spectral-resolution, and cone-beam CT phantom studies, with results showing DQE(0) above 80%, post-correction linearity within 99.5% for water- and aluminum-like attenuation conditions, and spectral resolution approaching 10 keV when charge-sharing correction is enabled [5]–[8].

Detector Architecture

The Pyxis platform is built around modular photon-counting detector units based on four-side-buttable ASIC hybrids bump-bonded to direct-conversion sensor material, with the current implementation focused on CdTe [3]–[5]. The experimental system used four detector modules with a total active area of 76.6 × 76.6 mm^2, a 150 µm pixel pitch, a 1.6 mm CdTe thickness, and energy thresholds set at 25, 40, 60, and 85 keV under a -800 V bias condition [5]. The ASIC architecture supports 128 × 128 pixels per hybrid, optional 1×1 and 2×2 binning, up to six independent energy channels, frame rates of up to 10,000 frames/s, minimum dead times of 20–50 ns, and integrated charge-sharing correction [5]. Modules can be tiled to form curved CT detector assemblies, while the same modular architecture also supports benchtop characterization and staged system scaling [3]–[5].

Signal Processing and ASIC-Level Performance

At the detector level, the ASIC and associated acquisition chain are designed to operate across the count-rate regime required for CT [1]–[5]. With charge-sharing correction enabled, spectral resolution approaches 10 keV, while maximum count rate reaches approximately 80 × 10^6 photons/mm^2/s; with charge-sharing correction disabled, the maximum count rate increases to approximately 700 × 10^6 photons/mm^2/s, although lower-energy spectral information becomes degraded [5]. This trade-off highlights a central challenge in PCCT system design: preserving spectral fidelity while maintaining throughput at clinically relevant flux levels [1]–[4]. In the reported measurements, pile-up correction restored the expected response trend across energy bins, and post-correction detector linearity remained within 99.5% for both water- and aluminum-equivalent attenuation conditions [5], [7].

Software Correction Pipeline (PCST)

A key scientific contribution of the Pyxis platform is its structured calibration-and-correction workflow, implemented in Varex software tools [5]–[7]. Calibration pipelines are executed sequentially to generate correction tables that are stored in a reusable CalBundle, after which a real-time correction pipeline applies the relevant parameters during acquisition [5]. The reported correction stages include multi-material pile-up and multi-point gain correction using flood-field scans of water- and bone-like slabs; a dedicated “vein” correction targeting localized electric-field perturbations associated with CdTe defects through matched-filter methods; tile-edge correction for bias-field-related discontinuities near detector boundaries; and bad-pixel calibration with 2-D inpainting [5], [7]. Together, these steps move the platform beyond detector hardware alone by embedding detector-physics compensation into a reproducible preprocessing chain [5]–[7].

Experimental Methods

Experimental characterization was performed using a four-module Pyxis development configuration based on CdTe detector technology. The system had a total active area of 76.6 × 76.6 mm^2, a 150 μm pixel pitch, a 1.6 mm sensor thickness, and a detector bias of -800 V. Measurements were acquired using energy thresholds of 25, 40, 60, and 85 keV. The detector architecture incorporated 128 × 128 pixel ASIC hybrids, optional 1×1 and 2×2 binning, and integrated charge-sharing correction. Linearity testing was carried out at 120 kV using PMMA slabs of 0, 10, 30, 50, and 100 mm and aluminum slabs of 4, 8, 17, and 30 mm, with beam currents ranging from 31 to 469 CT-equivalent mA at a frame rate of 1440 Hz [5], [7].

Detector performance was further evaluated through IEC 62220 DQE measurements under an RQA9 spectrum at 14.5, 145, and 436 CT-equivalent mA, corresponding to input doses of 0.05, 0.53, and 1.6 μGy/frame, all acquired at 1440 Hz [5], [8]. Spectral-resolution characterization was performed using an Am-241 source with threshold sweeps from 0 to

100 keV in 1 keV increments [5]. Cone-beam CT imaging was assessed using a mini-spine phantom in a half-fan geometry with a 29 mm detector offset, a 760 mm source-to-imager distance, a 560 mm source-to-axis distance, 2000 frames per rotation, and a reconstruction voxel size of 0.1 mm. For calibration of the multi-point gain correction, PMMA slabs of 0, 25, 50, and 100 mm were used. Projection preprocessing and reconstruction analysis were then used to assess image homogeneity, ring-artifact suppression, and histogram-based tissue separation [5], [6], [9].

Detector Performance

The platform was evaluated through IEC 62220 DQE measurements, attenuation-based linearity testing, energy-resolution measurements using an Am-241 source, and cone-beam CT imaging of a mini-spine phantom [5], [8]. The DQE study, performed under an RQA9 spectrum at 1440 Hz, demonstrated DQE(0) above 80%, with MTF and DQE reported to be relatively insensitive to input flux rate and temperature [5], [8]. In the phantom study, preprocessing reduced background noise by approximately 28%, removed structured projection-domain artifacts, and substantially suppressed ring artifacts in reconstructed images [5], [6], [9]. Histogram analysis further indicated improved separation and more accurate mean values for soft-tissue and bone peaks after correction [5]. Together, these findings show that preprocessing materially improves both quantitative and structural image quality in PCCT projection and reconstruction workflows [5]–[9].

Scalability and System Integration

The Pyxis platform is designed for scalable detector assembly, enabling configurations that range from limited field-of-view systems to full-body CT. FPGA-based control allows dynamic adjustment of acquisition parameters, including frame rate, pixel binning, and energy-bin configuration. The API-driven software architecture supports integration into OEM reconstruction pipelines on Linux or Windows environments with minimal customization.

Technical Differentiation

From a technical standpoint, the differentiation of the Pyxis platform lies in the co-design of detector hardware, calibration methodology, and correction software rather than in any single component [3]–[6]. The platform combines four-side-buttable ASIC architecture, direct-conversion sensing, integrated charge-sharing correction, modular detector assembly, and a calibration framework tailored to known physical error sources in photon-counting detectors, including pile-up, threshold nonuniformity, crystalline defects, and electric-field variation near tile boundaries [3]–[5], [7]. This systems approach is scientifically important because it treats detector non-idealities as measurable and correctable phenomena, enabling performance closer to diagnostic PCCT requirements under realistic acquisition conditions [1]–[5].

Conclusion

In summary, the Pyxis™ platform demonstrates that a modular CdTe-based photon-counting detector architecture, when combined with a calibrated correction pipeline, can achieve the performance characteristics required for advanced PCCT. The reported results show high DQE, strong post-correction linearity, clinically relevant count-rate capability, and improved reconstructed image quality through targeted compensation of detector non-idealities [1]–[9]. These findings support the suitability of the platform as a foundation for scalable next-generation photon-counting CT systems.

References

[1] C. H. McCollough *et al.*, "The technical development of photon-counting detector CT," *European Radiology*, vol. 33, no. 8, pp. 5321-5330, 2023.

[2] T. Flohr, M. Petersilka, A. Henning, S. Ulzheimer, J. Ferda, and B. Schmidt, "Photon-counting CT review," *Physica Medica*, vol. 79, pp. 126-136, 2020.

[3] R. Ballabriga *et al.*, "Photon counting detectors for X-ray imaging with emphasis on CT," *IEEE Transactions on Radiation and Plasma Medical Sciences*, vol. 5, no. 4, pp. 422-440, 2020.

[4] M. Danielsson, M. Persson, and M. Sjölin, "Photon-counting X-ray detectors for CT," *Physics in Medicine & Biology*, vol. 66, no. 3, Art. no. 03TR01, 2021.

[5] C. Ullberg *et al.*, "Measurements on a novel 4-side buttable photon counting ASIC with integrating charge sharing correction," in *Medical Imaging 2022: Physics of Medical Imaging*, vol. 12031, 2022.

[6] K. Holt *et al.*, "Design and optimization of 3D VSHARP scatter correction for industrial CBCT using the Linear Boltzmann Transport Equation," in *7th International Conference on Image Formation in X-Ray Computed Tomography*, vol. 12304, 2022.

[7] S. Veijola *et al.*, "Material-Aware Pulse Pile-Up and Pixel Gain Correction for Spectral Photon Counting Detectors (PCDs)," submitted to the 2026 CT Meeting, Salt Lake City, Utah.

[8] IEC 62220-1:2003, "Medical electrical equipment - Characteristics of digital X-ray imaging devices - Part 1: Determination of the detective quantum efficiency."

[9] J. Star-Lack *et al.*, "SU-FF-I-04: a fast variable-intensity ring suppression algorithm," *Medical Physics*, vol. 33, no. 6, pt. 2, p. 1997, 2006.