Algorithms Implemented in the Livermore Tomography Tools (LTT) Software Package

Center for Advanced Signal
and Image Sciences (CASIS)

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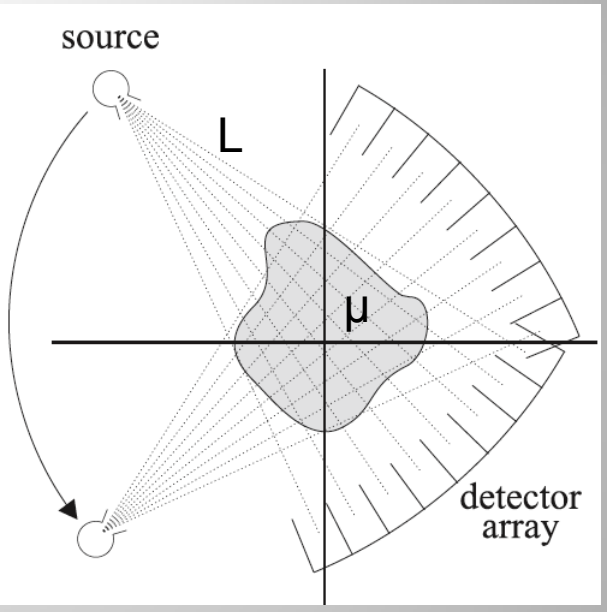
Computed Tomography (CT)

μ = linear attenuation coefficient (units: cm^{-1})



Beer-Lambart Law

$$I_{\det ector} = I_{source} e^{-\int_L \mu(x)\,dx}$$

Goal: reconstruct μ, given: b = Aμ

A = system matrix (forward model)

b = measured data

LLNL Needs

- Knowable, documented algorithms
- Quantitatively accurate
- Can process data from a large array of scanners

Commercial CT Software Packages

- Algorithms are “black boxes”
- Results in arbitrary units
- Do not employ the latest algorithms
- Sophisticated GUIs

Types of Algorithms Implemented

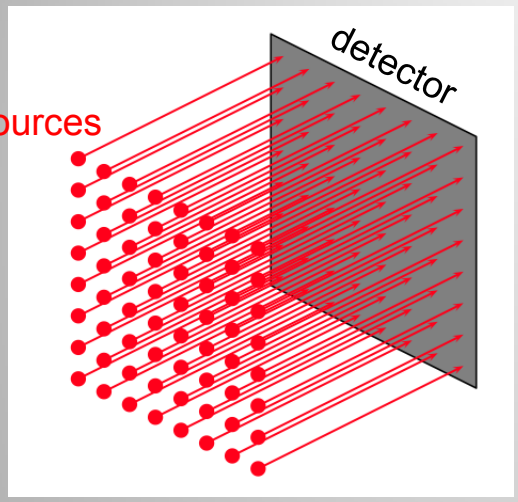
1) **Simulation & Physics Models**
   a) Based on EPDL97
   b) Spectra modeled with Finkelshtein method
   c) Data simulated with analytic ray tracing methods
2) **Corrections, Calibrations, and Pre-corrections**
   a) Detector Deblur
   b) Beam Hardening Correction
   c) Scatter Correction
3) **Image Reconstruction**
   a) Filtered Backprojection (FBP; fast)
   b) Statistical Iterative Reconstruction (accurate, but slow)
4) **Post-Processing**

LTT Algorithm Implementation Features

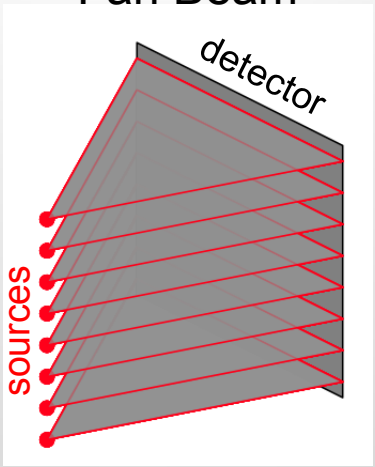
- Implemented in C/C++
- Cross-Platform (Windows, Mac, Linux, Unix)
  - only requires FFTW, OpenMP, and OpenCL libraries
- Large data sets are processed in chunks when RAM is limited
- Implements state-of-the-art algorithms

All Standard Scanner Geometries Supported

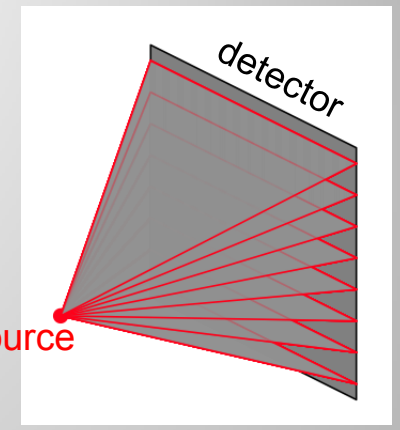
Parallel Beam



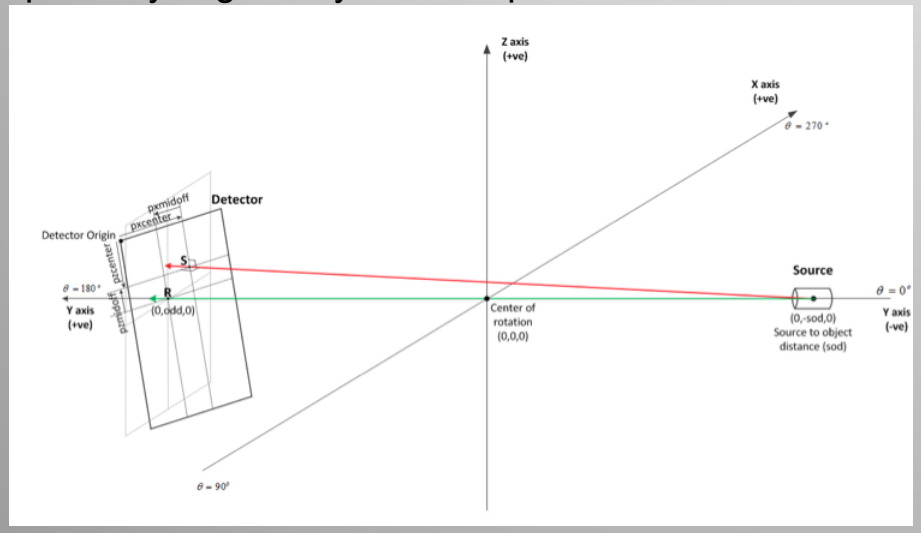
Fan Beam



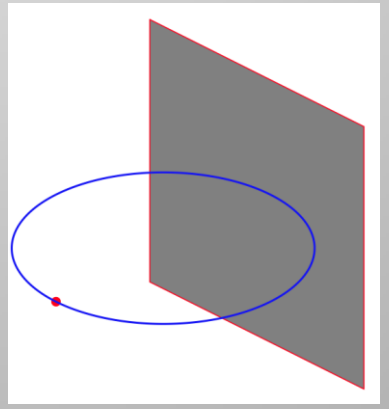
Cone Beam



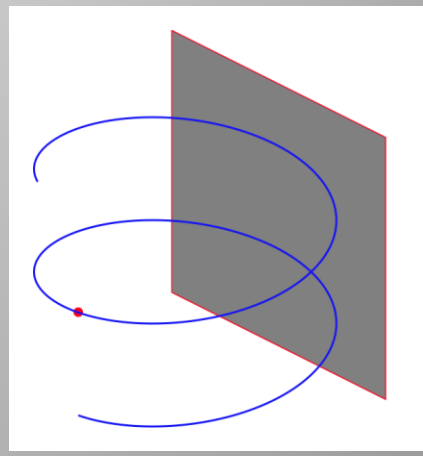
Imperfectly Aligned System/ Displaced Center of Rotation



Circular Source Trajectory



Helical Source Trajectory



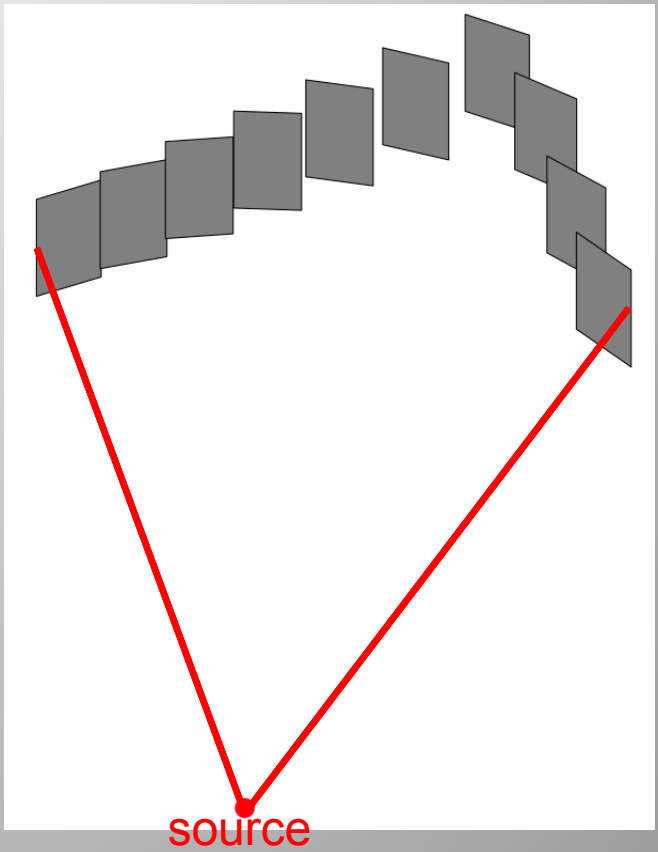
Modular Beam Data Set- for those geometries that aren't in a standard format

Human-readable geometry file specifies location of every source and detector pair and detector module orientation

{sourcePosition = (314.325000, 513.842000, 0.000000);
 moduleCenter = (280.289000, -306.832000, 0.000000);
 colVector = (-0.999141, 0.041438, 0.000000);
 rowVector = (0.000000, 0.000000, 1.000000)}

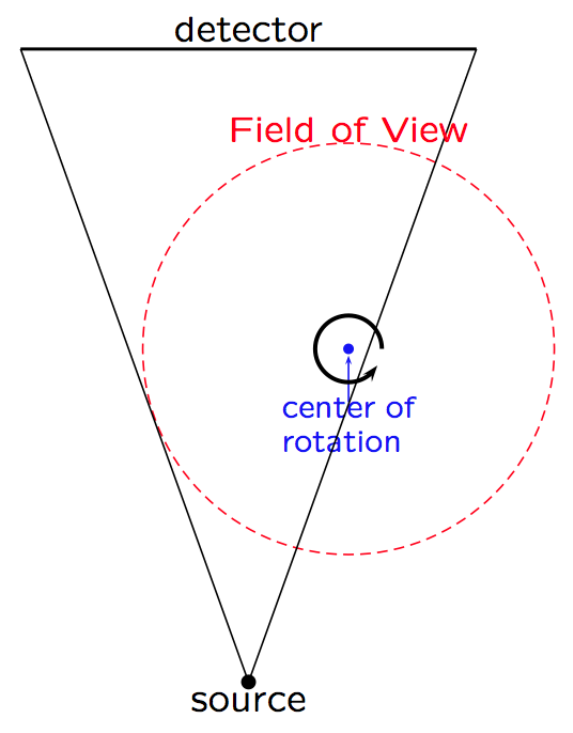
{sourcePosition = (314.325000, 513.842000, 0.000000);
 moduleCenter = (181.991000, -309.372000, 0.000000);
 colVector = (-0.987324, 0.158715, 0.000000);
 rowVector = (0.000000, 0.000000, 1.000000)}
…

10 Detectors Modules



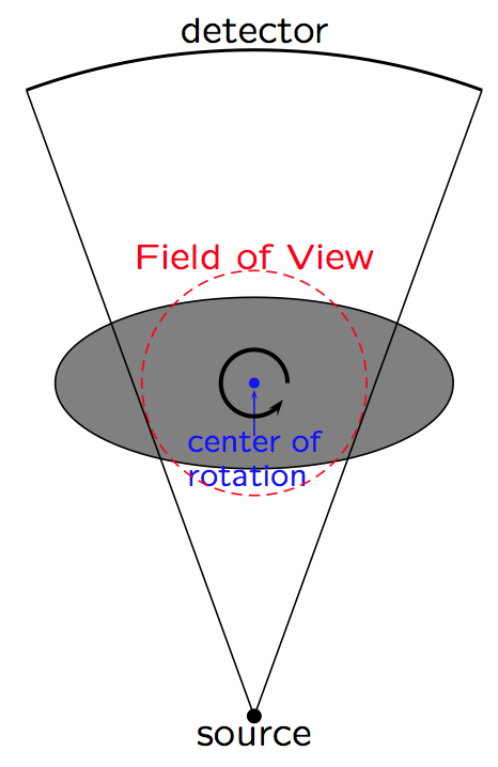
Analytic Reconstruction with Truncated Data

Increase field of view by displacing center of rotation



Reconstruct with standard FBP using an asymmetric weighting function

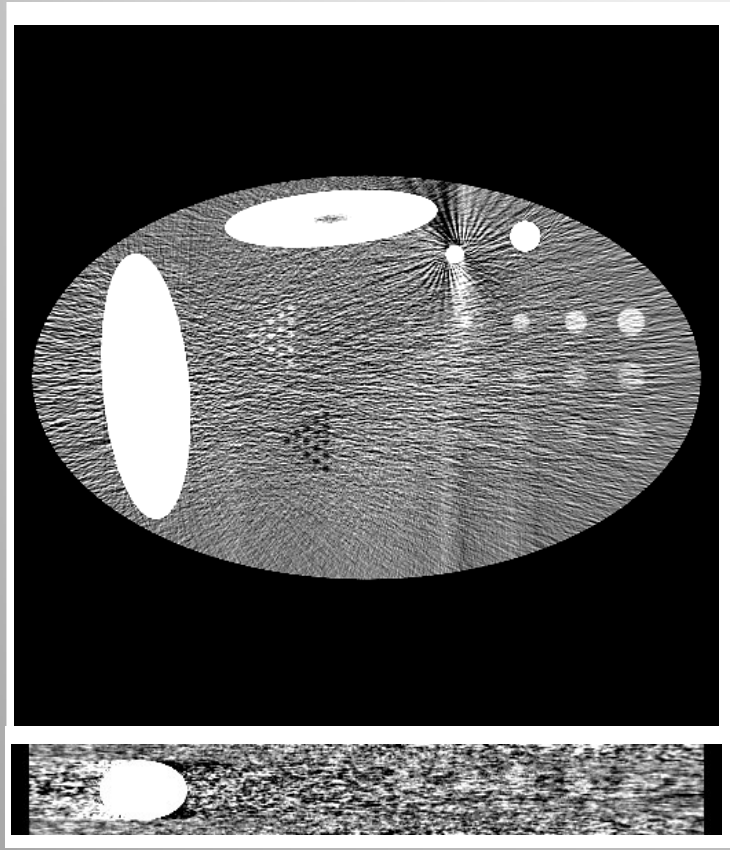
When data is truncated on both sides, cannot reconstruct with FBP



Can reconstruction with Derivative Backprojection (DBP)

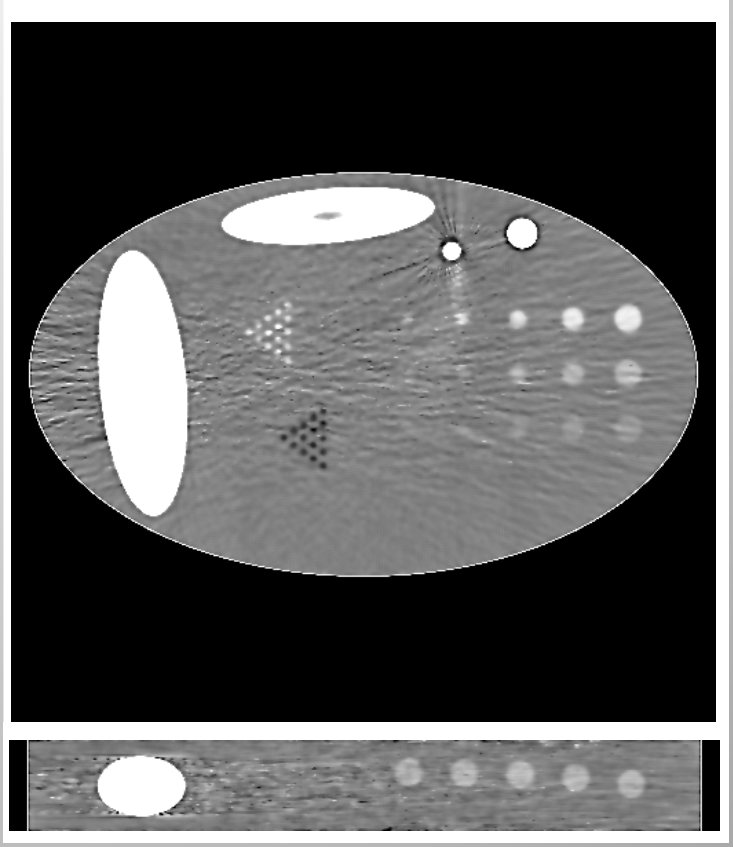
Remove Noise and Artifacts with Regularized Weighted Least Squares (RWLS)

FBP Reconstruction



small spheres barely visible

RWLS Reconstruction

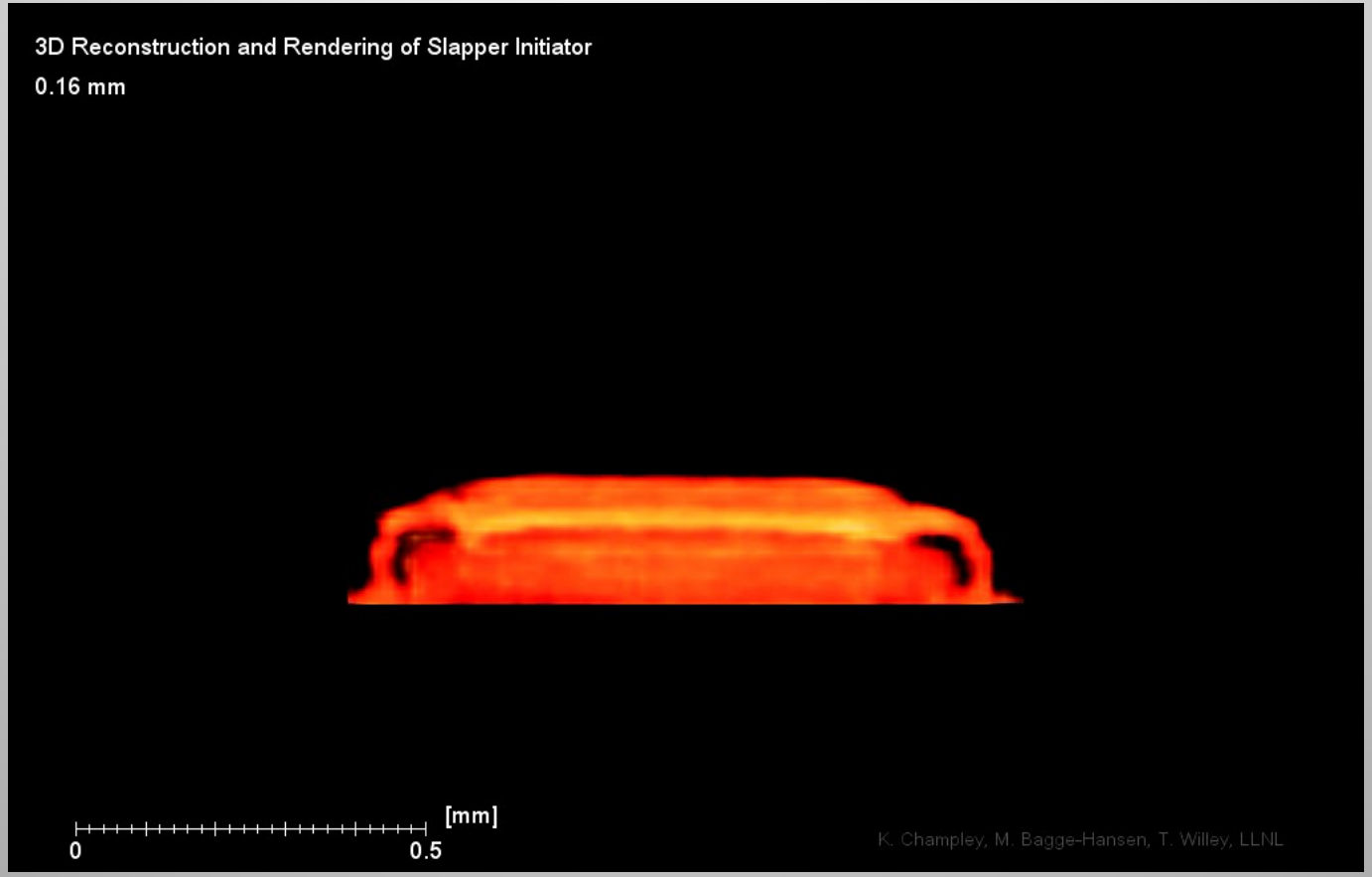


small spheres clearly visible

Reconstruct with Sparsely (< 200) Sampled Angles

7-view reconstruction of in-flight (2.5 km/sec) slapper initiator

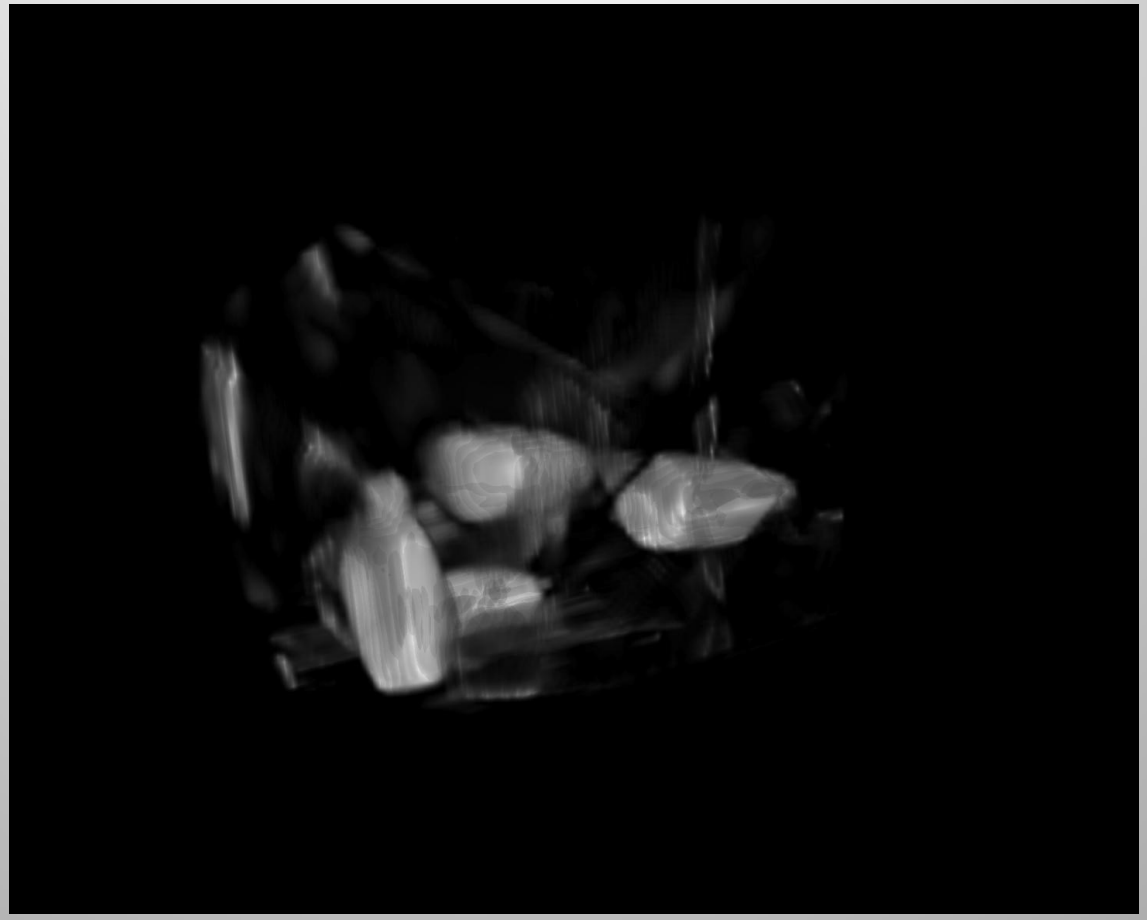
Willey, Champley, Hodgin, Lauderbach, Bagge-Hansen, May, Sanchez, Jensen, Iverson, van Buuren



Reconstruct with Sparsely Sampled Angles

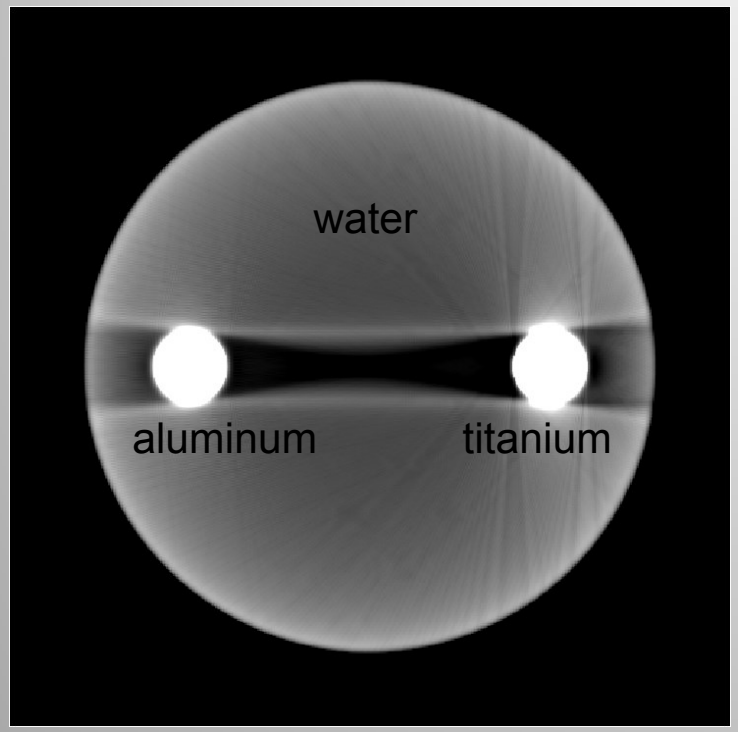
4-view reconstruction of liquid containers in carry-on luggage scanner

Champley, Smith, Kallman, Bond, and Top

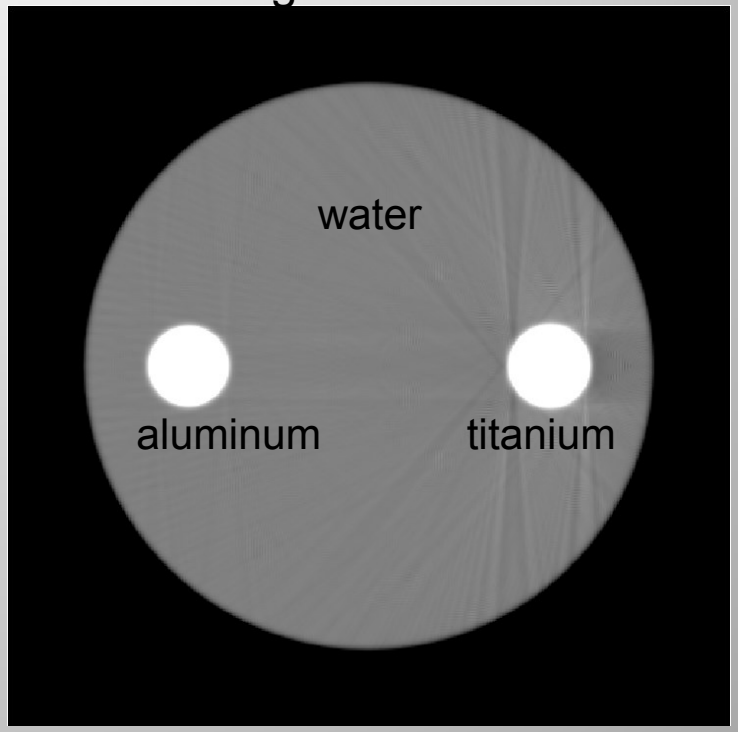


Physics-Based Iterative Beam Hardening Correction

Standard Reconstruction

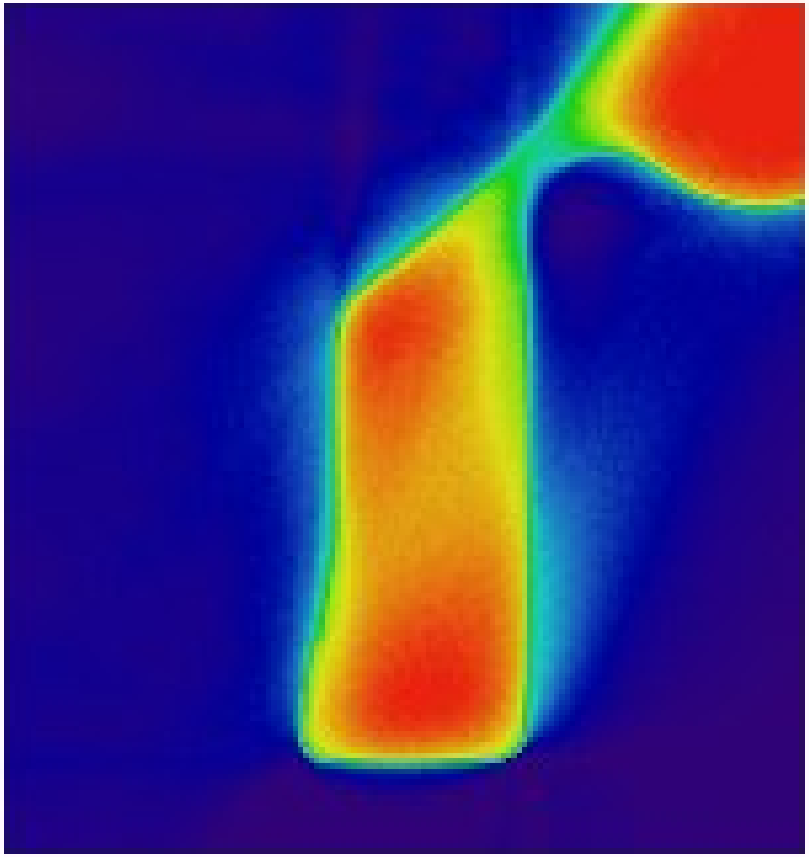


Reconstruction with Beam Hardening Correction

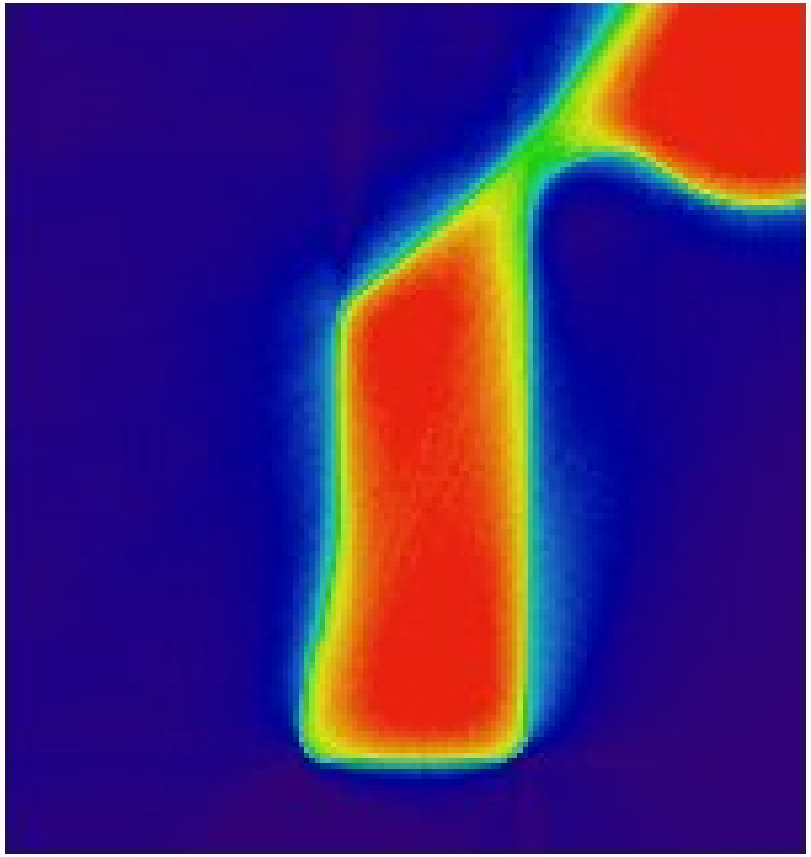


Physics-Based Scatter Correction

Standard Reconstruction



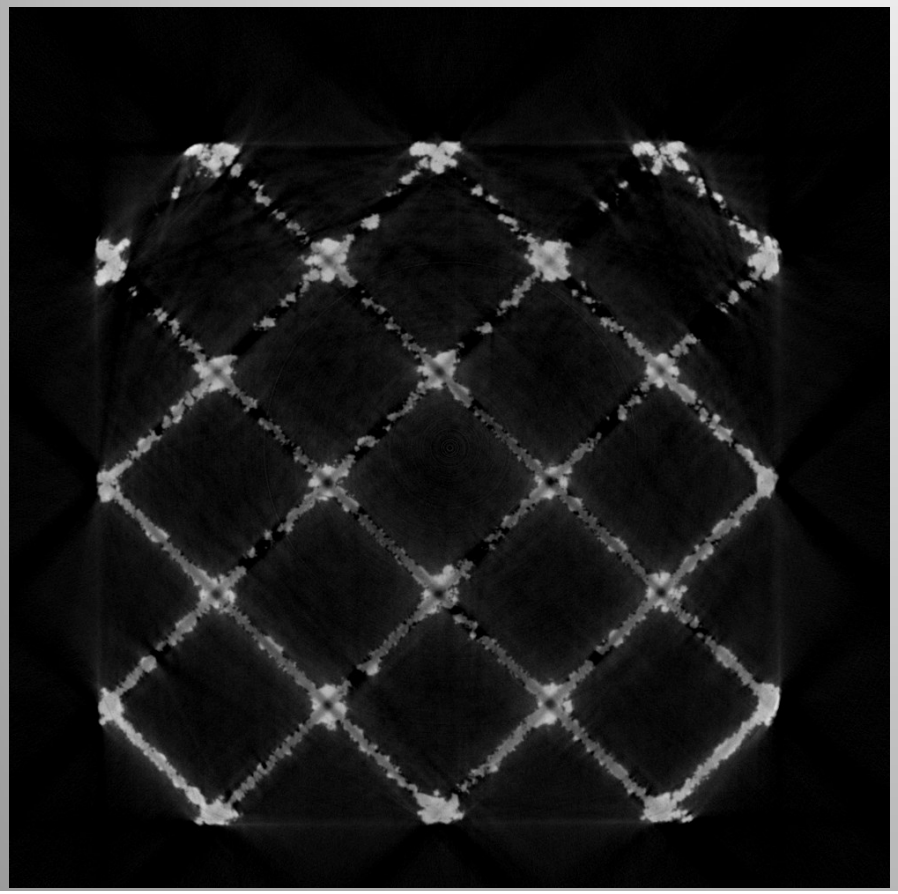
Reconstruction with Scatter Correction



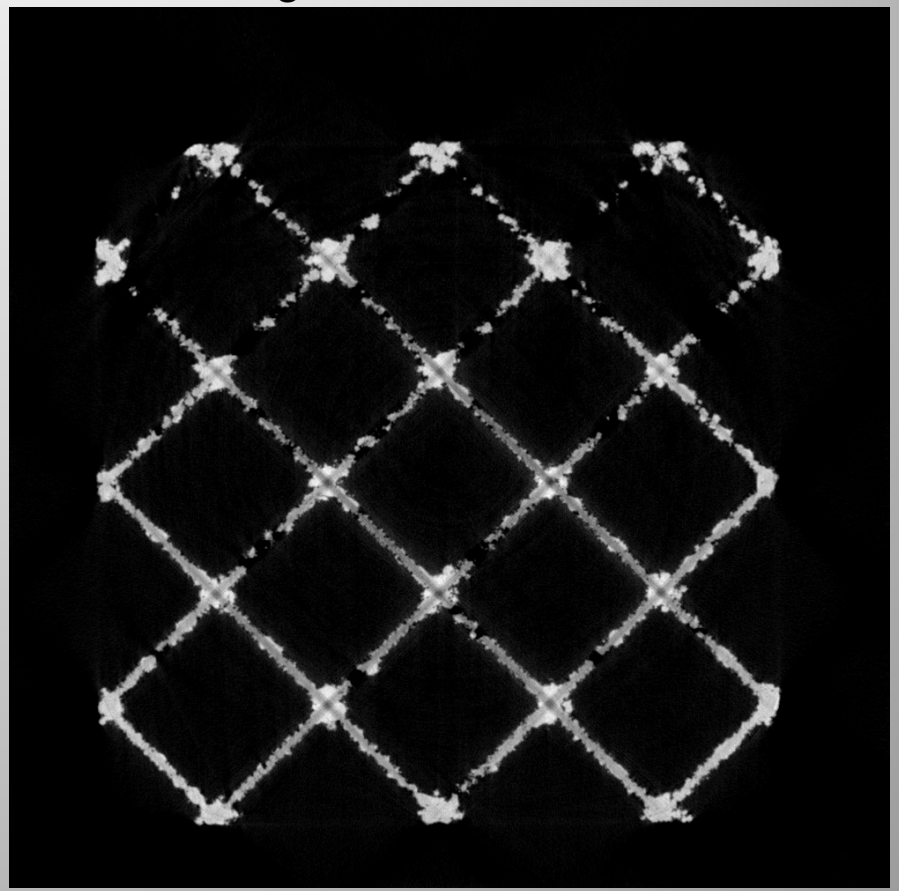
Industrial metal part scanned with 9MeV source

Reconstruction of Stainless Steel Truss built with Additive Manufacturing

Standard Reconstruction



Iterative Reconstruction
with detector blur, scatter & beam hardening corrections



Thank You!

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