Employing a Novel Analysis Method in the field of Tomographic Image Reconstruction for Single Photon Emission Computed Tomography (SPECT)

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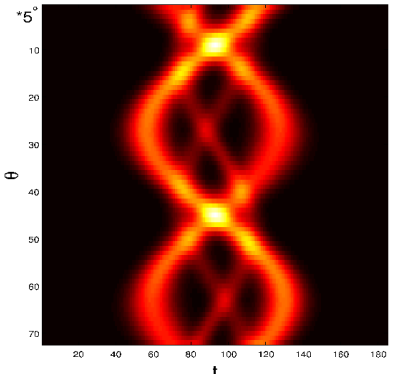
Outline

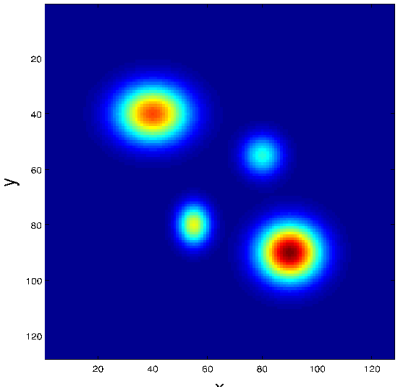
- Introduction:
  - SPECT and Challenges in Emission Tomography.
- Implementation of AMIAS in SPECT Image Reconstruction.
- Validation with Software Phantoms.
- Experimentation with ^{99m}Tc Phantoms and Reconstruction.
- Concluding Remarks.

Introduction: SPECT – Image Reconstruction

Set of Multiple Projections



Tomographic Image



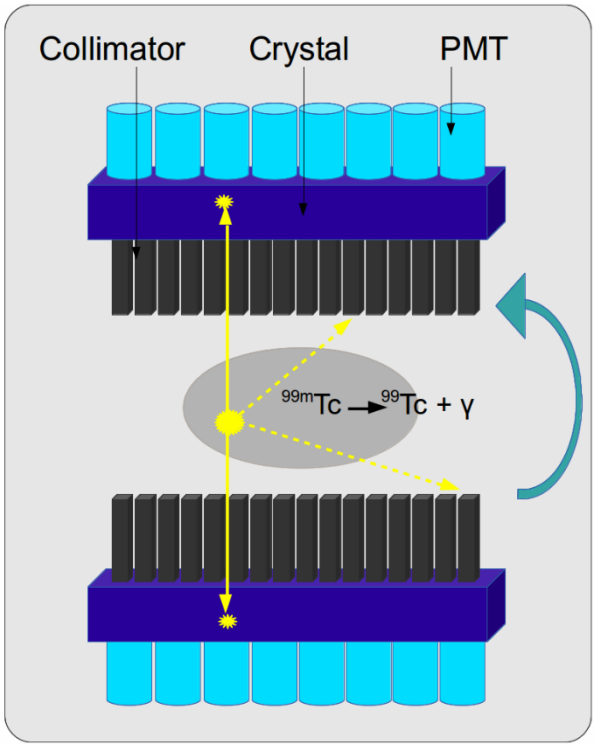


Image Reconstruction is involved to solve the inverse problem of defining the image of the radioactive distribution from the dataset of measured projections.

Introduction: SPECT Image Reconstruction

Analytic techniques

- **Filtered Back - Projection (FBP)**

*Based on the **Radon** Transform (First Inversion Formula for the Tomographic Problem).*
Fast.
Limited by the angular sampling frequency and noise.

Iterative Techniques

- **Algebraic Reconstruction Technique (ART)**

Suitable for limited number of projections/not equidistantly obtained.
Sensitive to noise.

- **Maximum Likelihood Expectation Maximization (MLEM)**

Suitable for limited number of projections/not equidistantly obtained.
Taking into account the statistics of photon emission.
Low Convergence.

Factors Affecting the Reconstruction Process

- Projection measurements suffer from statistical uncertainties due to the Poisson statistics of photon emission.
- Background from regions around the target impedes the detectability of the lesion.
- Scatter/Attenuation.
- Number of Projections.
- Radiation dose.

The Challenge in SPECT Image Reconstruction

Methods able to reconstruct projection datasets characterized by:

- Limited Number of Projections
- Low scintillation counts (large uncertainty).
- Background Radioactivity.

Without scarifying the diagnostic accuracy of the image.

Reduction of Radiation dose

Implementation of the AMIAS method in SPECT Image Reconstruction

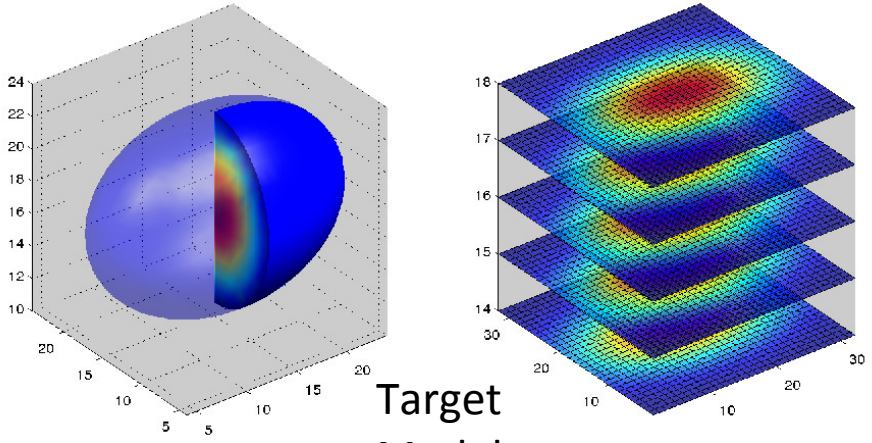
Target Modeling - Physical Parameters :

- Intensity.

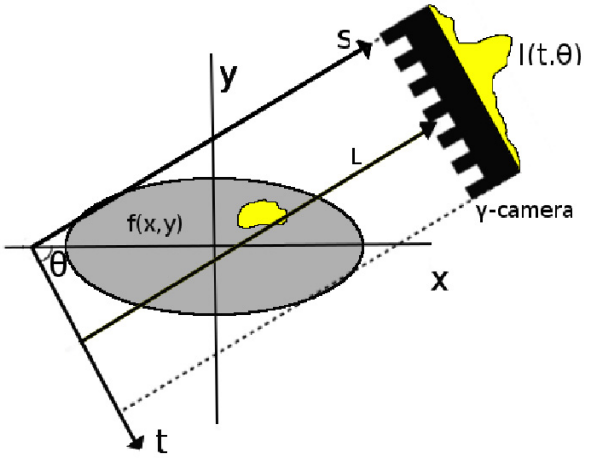
  (A_i - number of emitted photons from the center of tumor).
- Location.

  Coordinates (x_i, y_i, z_i).
- Size.

  Orthogonal Axis (a_i, b_i, c_i).



Target Model



Projec
Mode

Determination of Target Parameters in the AMIAS framework.

Implementation of the AMIAS method in SPECT Image Reconstruction

Random Sampling of Parameters in a predefined range.

↓

Construction of the Image by using the sampled values of parameters and a defined model.

↓

Transformation of the constructed image into the Projection Space (Radon).

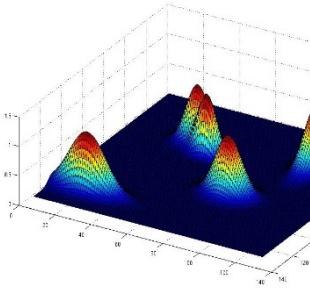
↓

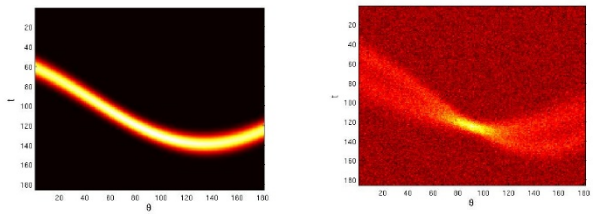
Calculation of the χ^2 (Estimated Sinogram – Measured Sinogram).

↓

Extract PDFs/ Correlation Plots.

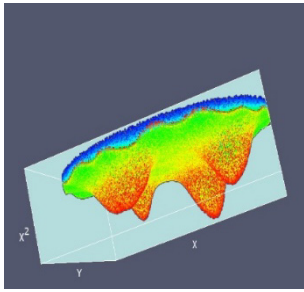
Model Parameters Image Construction





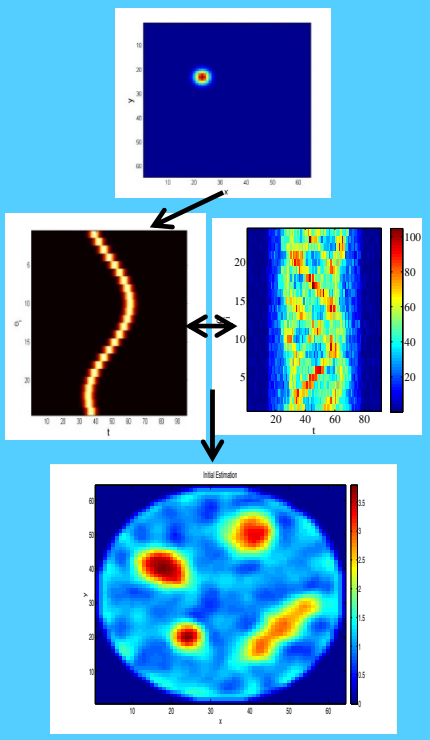
$$\chi^2 = \sum \frac{(y_m - y_o)^2}{\sigma^2}$$

Ensemble of Solutions

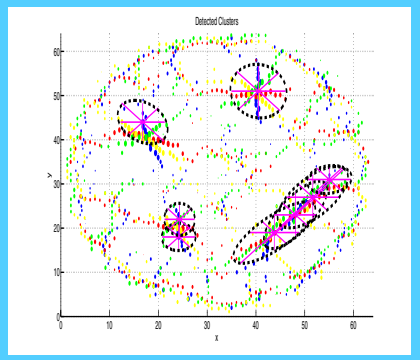


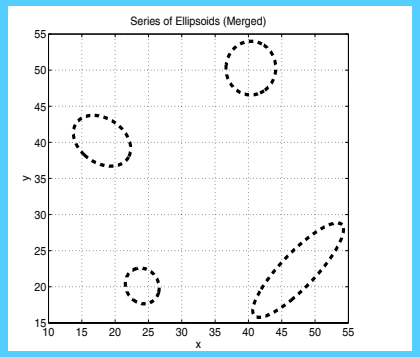
Implementation of the AMIAS method in SPECT Image Reconstruction

1. Estimation of the Radioactivity Distribution by using the model of the target.

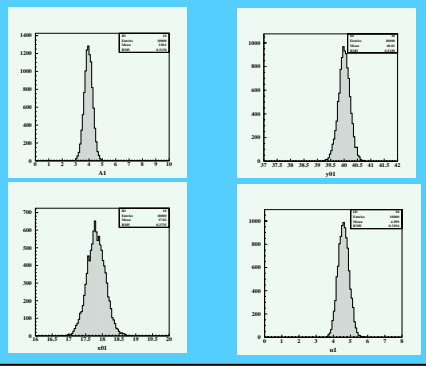


2. Detection of the Target and Initial Estimation of its Parameters

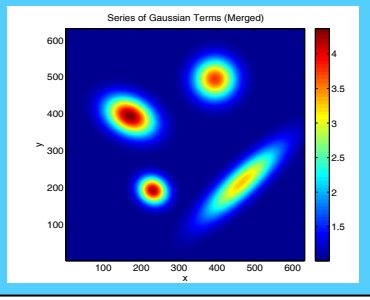




3. Precise Determination of Physical Parameters



4. Visualization of the Target



Validation with Software Phantoms

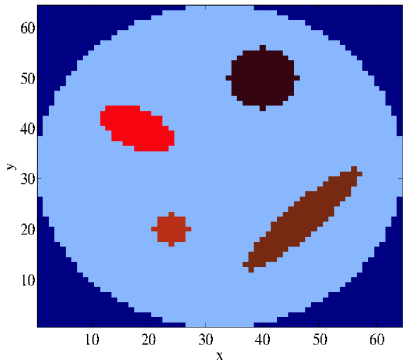
Objective:

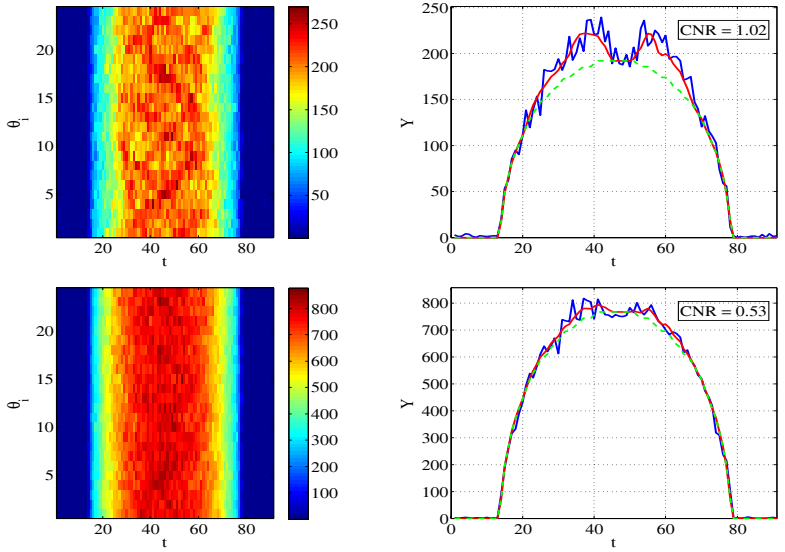
Evaluation of the AMIAS method at low CNR (Contrast-to-Noise) values.

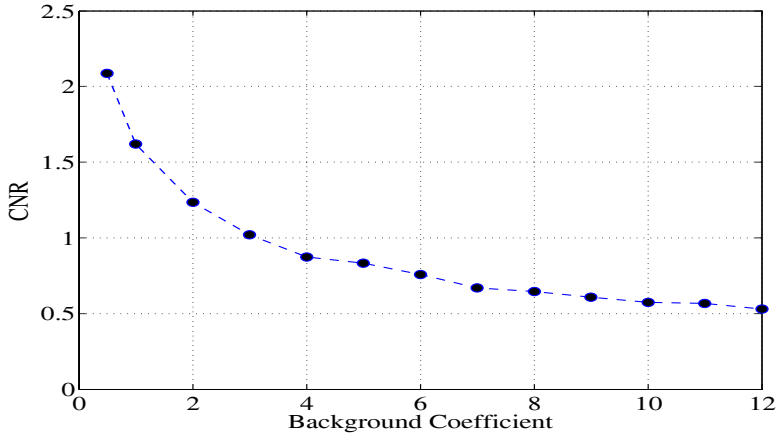
$$CNR = \frac{X_{Signal} - X_{Background}}{\sigma}$$

Phantom Characteristics:

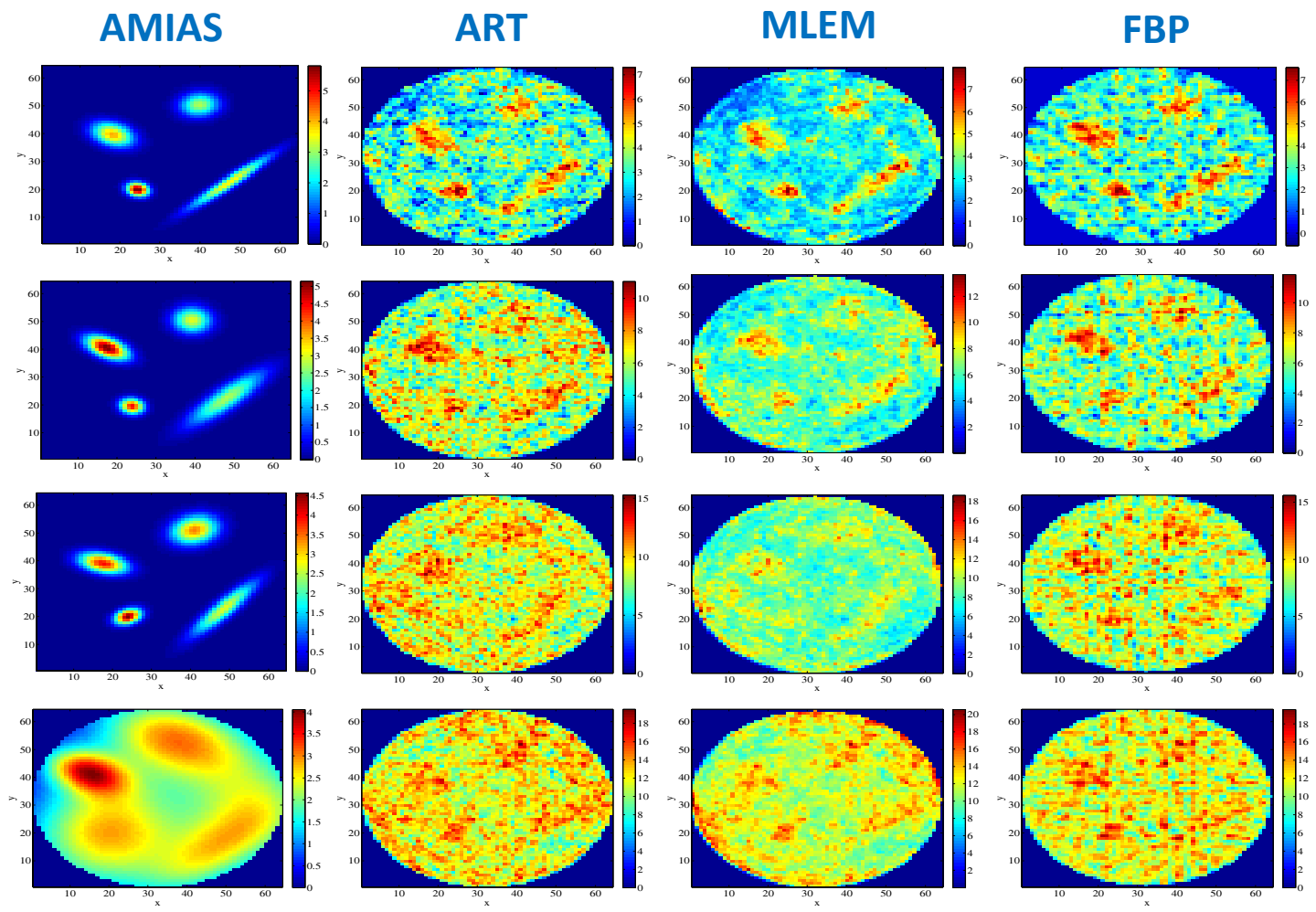
1. Ellipsoid Shaped Objects at different orientations.
2. Background : 14 datasets of projections at different levels of background`0.25% - 92%.
3. Number of Projections: 24 (angular step = 15°)



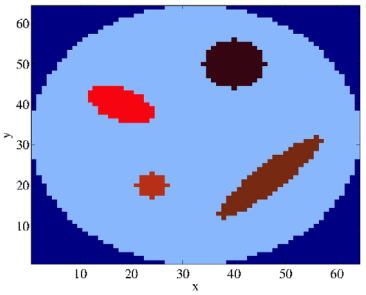




Application of AMIAS on Software Phantoms

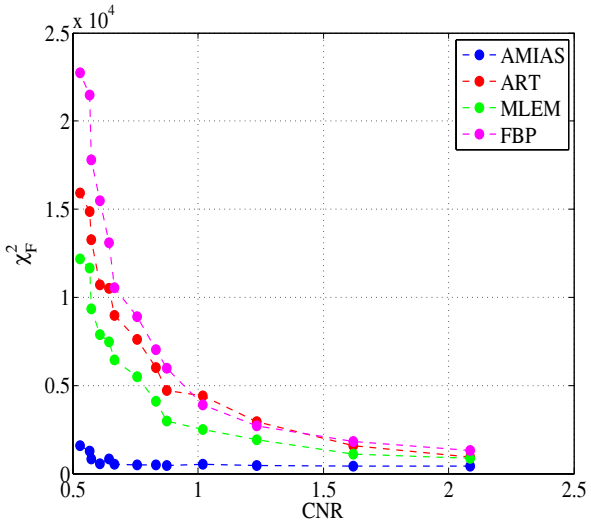


PHANTOM

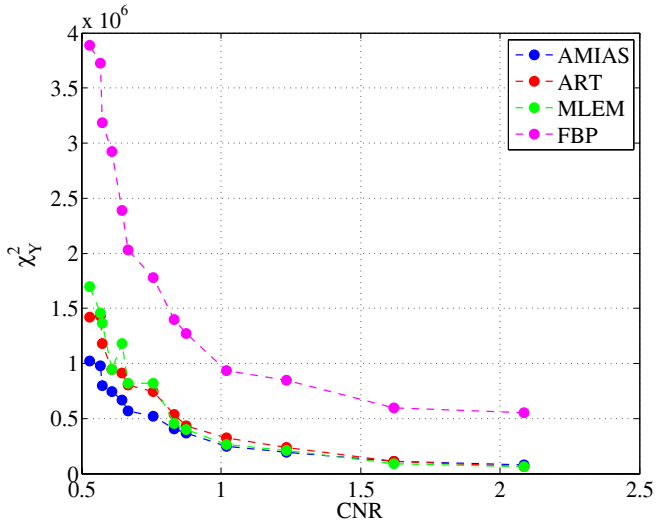


Application of AMIAS on Software Phantoms

Comparison of Reconstructed Images



Comparison of Reconstructed Sinograms

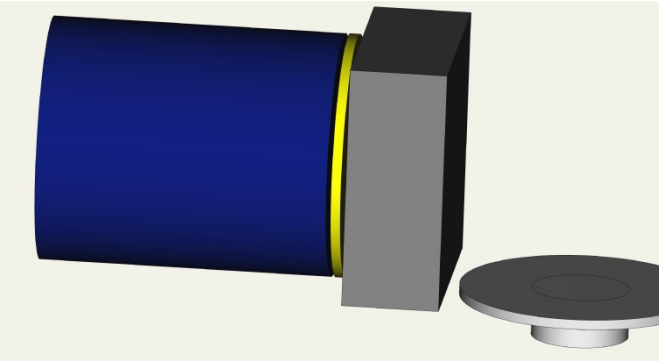


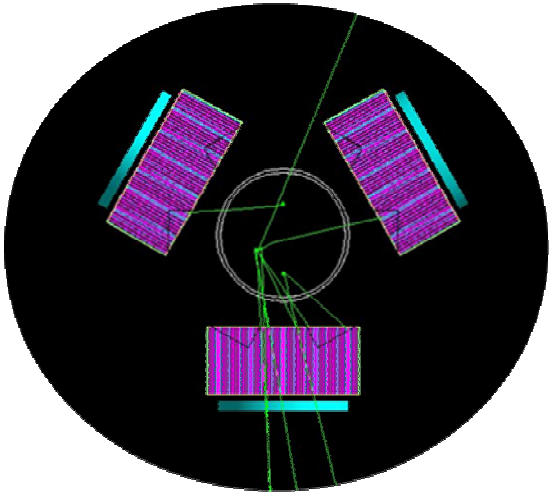
- The quality of the reconstructed images are almost at the same level at CNR ~= 2.0.
- As the CNR value is decreasing bellow the value of 1.5, the AMIAS method produces images of better quality.
- AMIAS reconstruction stability at the range 0.5<CNR is an important observation from this analysis.

Experimentation with ^{99m}Tc Phantoms

Small Field of View (FOV) γ-camera system

- Position Sensitive Photomultiplier Tube (PSPMT).
- CsI(TI) scintillation crystal
  - Thickness = 4mm.
- Hexagonal Hole Collimator
  - Thickness = 26.8mm.
  - Hole Diameter = 1.364 mm
- Spatial Resolution ~= 1mm.



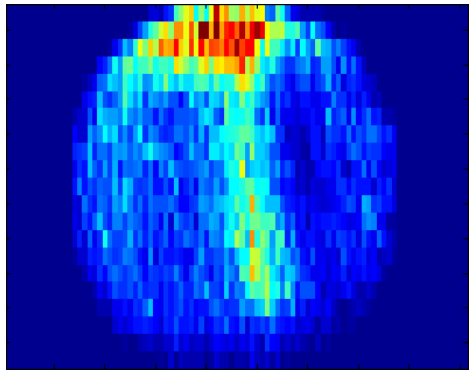


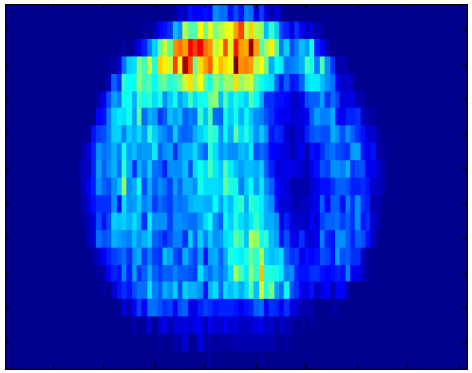
Phantom – Background from the Radioactive Environment

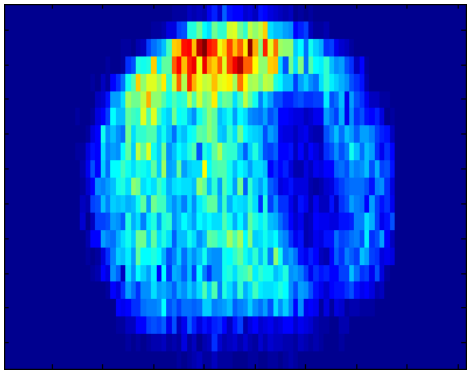
Background = 0.25 %

Background = 0.5 %

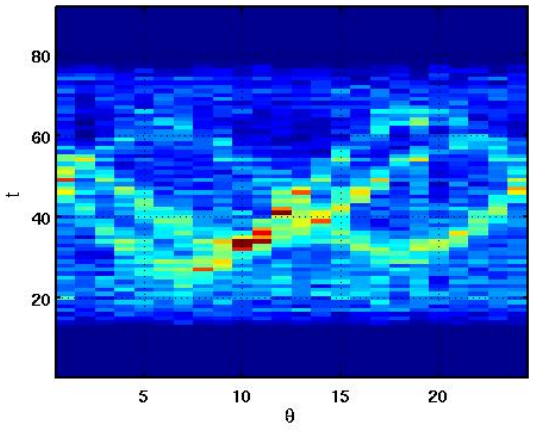
Background = 1.0 %

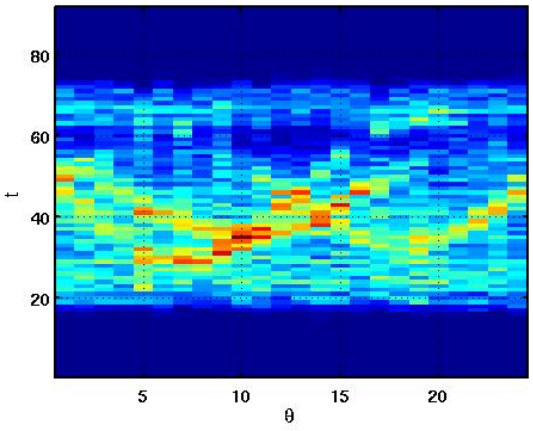


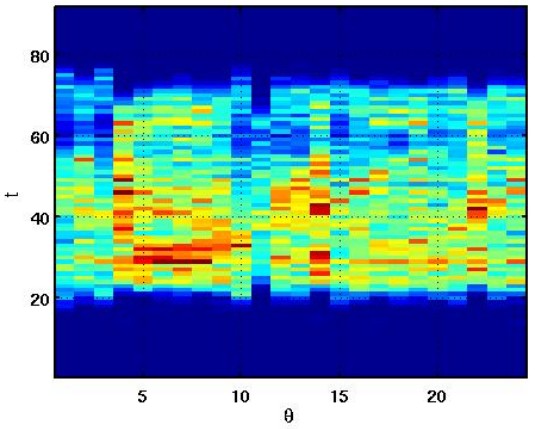




Set of Planar Projections







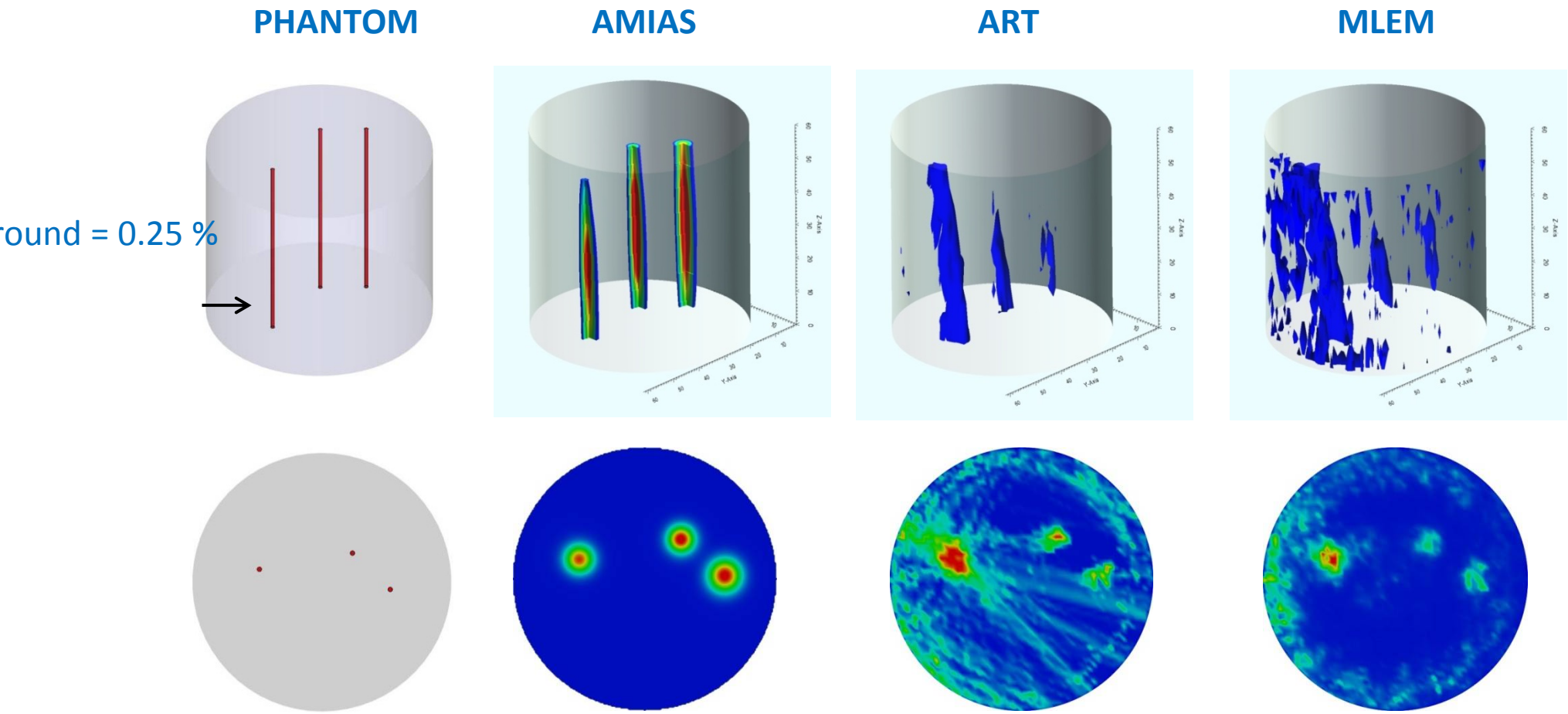
Sinograms

CNR = 0.96

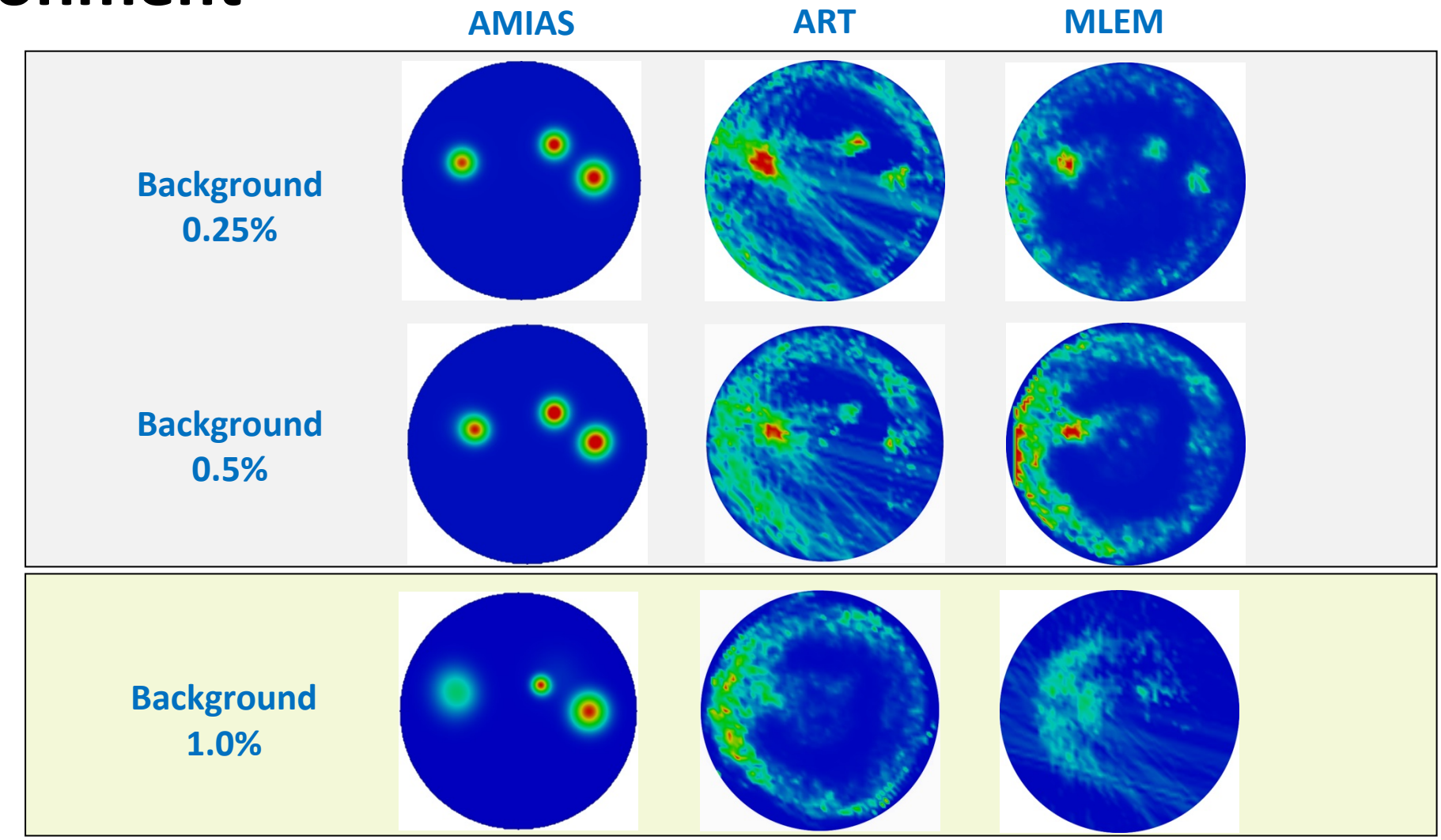
CNR = 0.78

CNR = 0.56

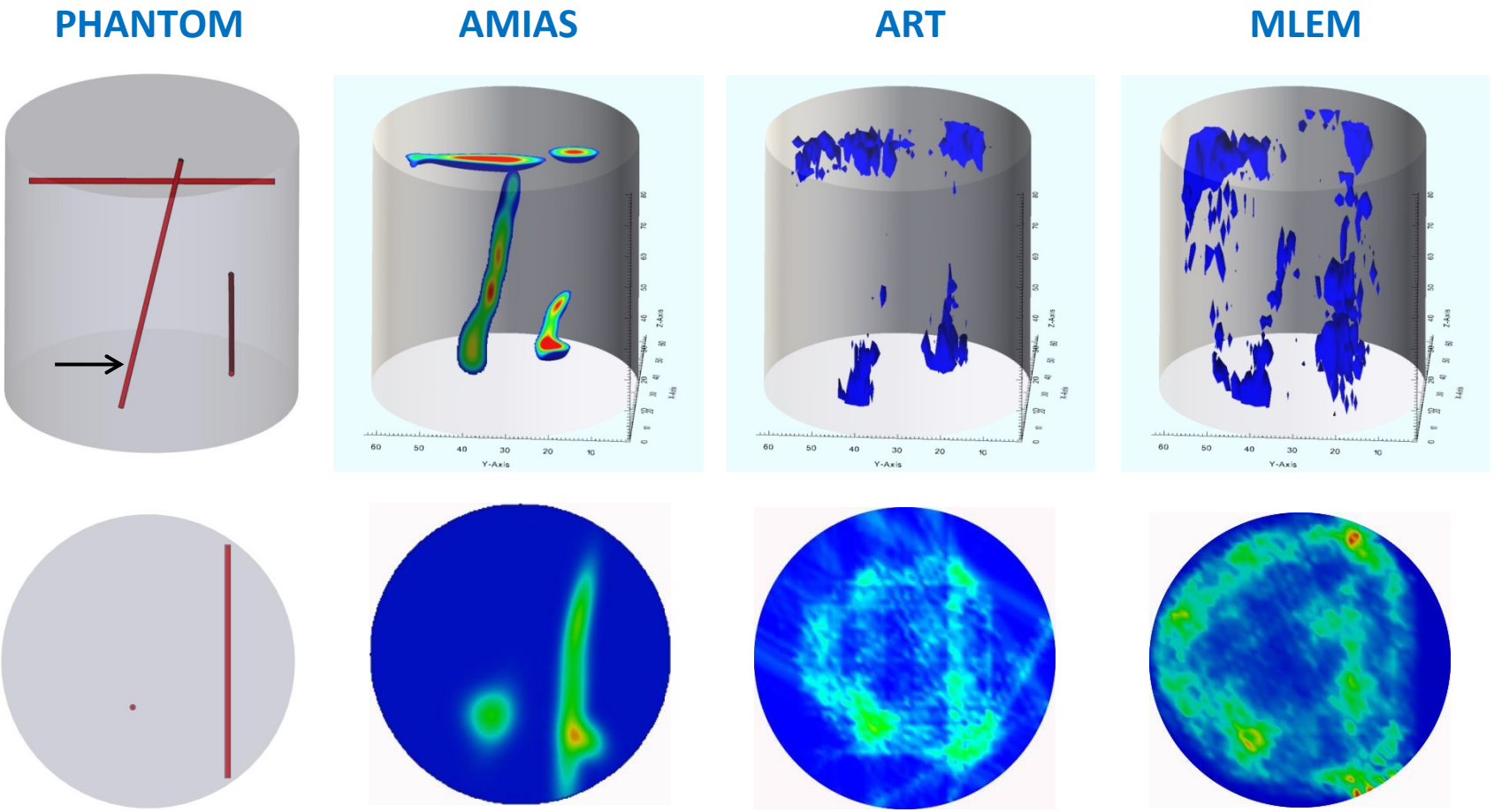
Phantom – Background from the Radioactive Environment



Phantom – Background from the Radioactive Environment



Phantom - Imaging with limited number of projections



Concluding Remarks

1. The evaluation of the AMIAS reconstruction process on the Computerized Phantom has shown that the method was able to extract robust and accurate numerical results from datasets characterized by low CNR (bellow the critical value of 1.0).

2. By exploiting
   - the incorporation of a model to represent the characteristics of the tumour,
   - the ability of AMIAS to explore the whole phase-space of the problem,

   the method was able to extract information in cases where the traditional reconstruction techniques produced noisy tomographic images

3. Based on the results, the AMIAS method can be involved to:
   - reduce the duration of a SPECT scan,
   - Reduce the radiation dose,
   - extract information from low Lesion-to-Background datasets.

Thank you