BNL-101484-2013-CP

Modeling of a Slanted-Hole Collimator in a Compact Endocavity Gamma Camera

Mark Kamuda[1,3], Yonggang Cui[1], Terry Lall[2], Jim Ionson[2], Giuseppe Camarda[1], Anwar Hossain[1], G. Yang[1] and R. B. James[1]

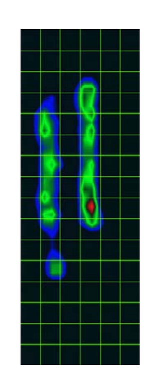
1. Brookhaven National Laboratory, Upton, NY, USA
2. Hybridyne Imaging Technologies, Inc., Toronto, ON, Canada
3. University of Illinois, Urbana, Illinois, USA

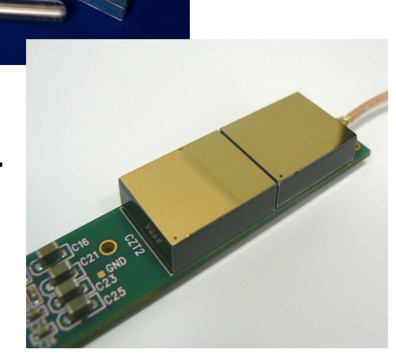
Introduction

With its improved material properties and detector performance, Cadmium Zinc Telluride (CdZnTe or CZT) radiation detectors are attractive in medical imaging applications. The detector modules can be very compact when fabricated in advanced pixilation and hybridization processes, and are finding applications in endo-cavity measurements. However, such applications have very limited space for probe operation; the traditional detector and collimator design and arrangement are not suitable, especially in 3D imaging applications. Here we present a feasibility study of a slant-hole collimator that can be employed with planar pixilated detectors to produce 3D images. We modeled the slanted-hole collimator with the gamma camera using Monte-Carlo simulations, and investigated the detectors' response to the radioactive sources in the field of view. Then, we modified a Maximum Likelihood Estimation Method (ML-EM) and used the code to reconstruct 3D images of shaped radioactive sources. In this presentation, we talk about the collimator and detector setup and report the Monte-Carlo simulation results.

Motivation of the Work

- Recently we developed a compact trans-rectal gamma camera, ProxiScan™, for prostate cancer imaging based on CZT pixilated detectors.
  - The camera employed matched parallel hole collimator to generate 2D projection images.
  - The camera has gone through phase I clinical trials in 2011-2012 successfully and generated promising images indicating focused high uptake regions in the prostate glands.

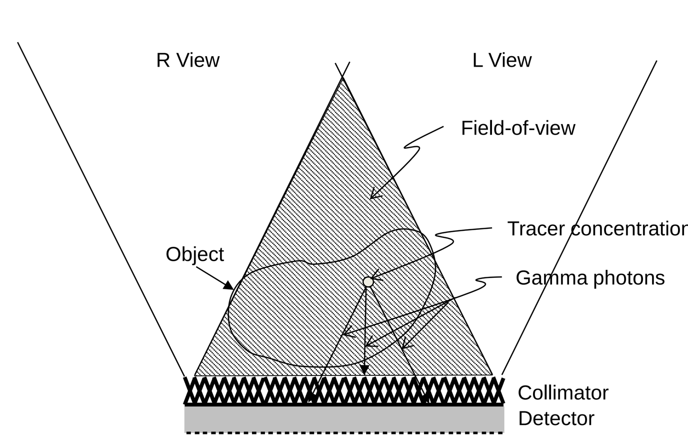




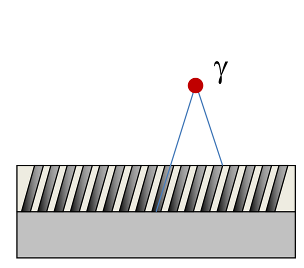
- 3D imaging capability is needed to provide depth information for the foci.
  - Individual scans using a parallel hole collimator can only generate 2D images.
  - Rotating parallel hole collimator can generate 3D images. However it has:
    - Very limited focusing length (depth of field of view)
    - Long image acquisition time as more projections are needed for image reconstruction
- Slanted-hole collimator could be useful in this specific application.
  - The collimator can produce images at angles other than the parallel-hole collimators.
  - By changing collimators with different slanted-angle, multiple projections can be acquired.
  - The image acquisition process can be facilitated if adaptive collimators are used.

Slanted-hole Collimator

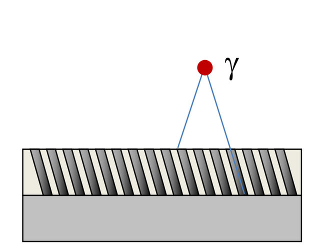
- Collimator has parallel holes to match the pixels of the CZT detectors on the bottom
- Imaging process
  - Two projection images of an object are taken sequentially with the collimator at different positions.
  - From Position A to Position B, the collimator is rotated by 180° about the axis of the field of view (FOV).



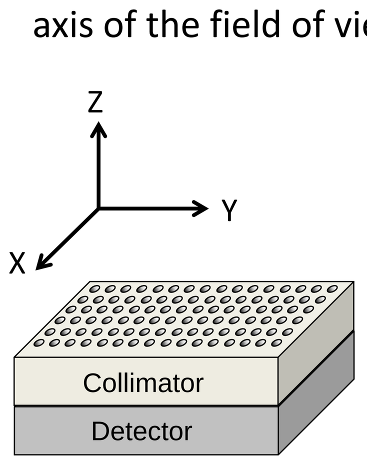
FOV of Imaging System Using Slanted-hole Collimator



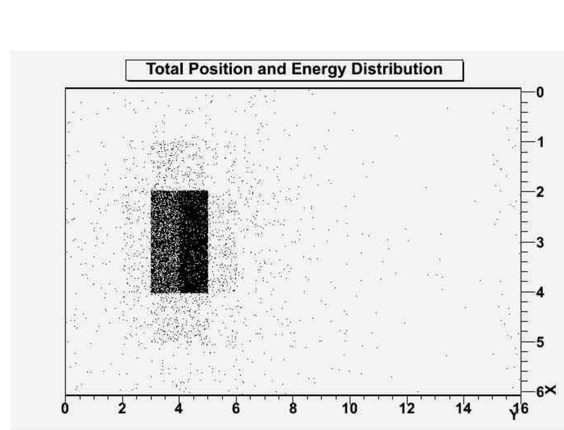
Collimator at Position A



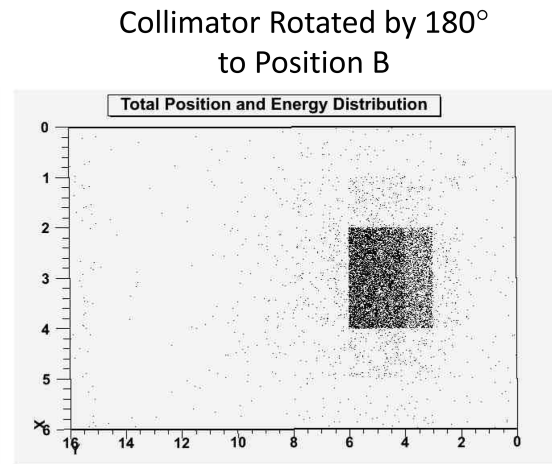
Collimator Rotated by 180° to Position B



Slanted-hole Collimator



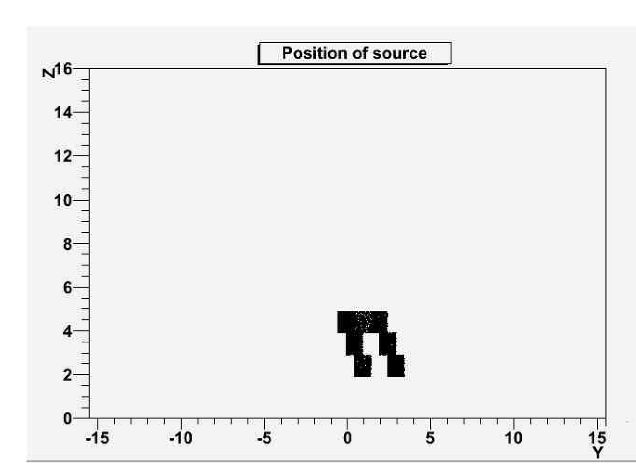
Projection Image at Position A



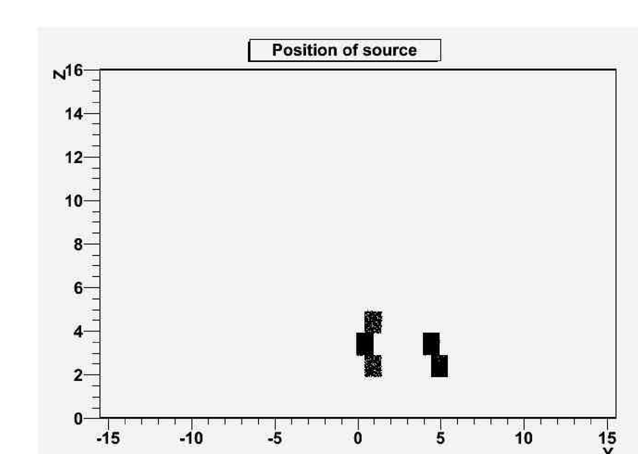
Projection Image at Position B

Monte-Carlo Simulation Settings

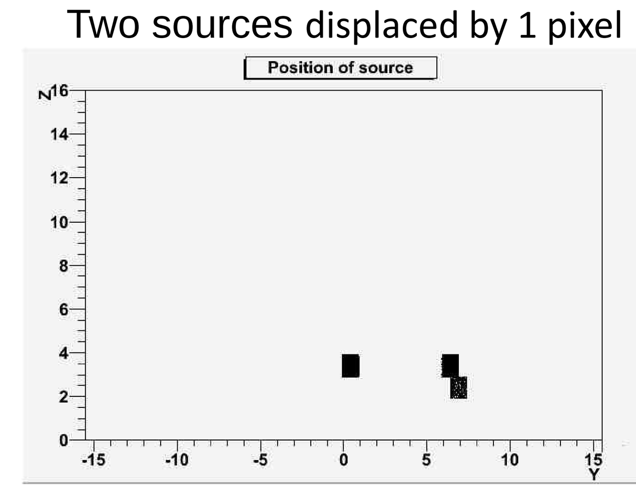
- Software package: Geant4 running on a 256-node cluster computer
- Collimator
  - Match the detector pixel array
  - 6.4-mm thick tungsten plate
  - 1.0-mm diameter holes with 60° slanted angles
- Detector
  - 16x48 pixel CZT detector
  - 5-mm thick
  - 2.46-mm pixel pitch
- Radiation source
  - Energy: Tc-99m (140.5-keV γ-ray)
  - Size: 0.5-mm-diameter sphere
  - We simulated the detector response to the source in each voxel within the FOV of the collimator
- Spatial resolution along y and z axis
  - The resolution is determined from images of two separated point sources
  - y axis: the resolution is 3 detector pixels as shown in the figures below
  - z axis: the resolution depends on the slanted angle of the collimator and the relative position of two point sources on the y axis



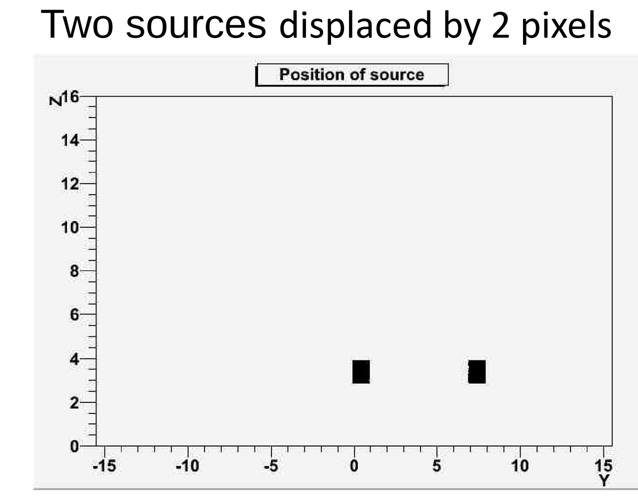
Two sources displaced by 1 pixel



Two sources displaced by 2 pixels



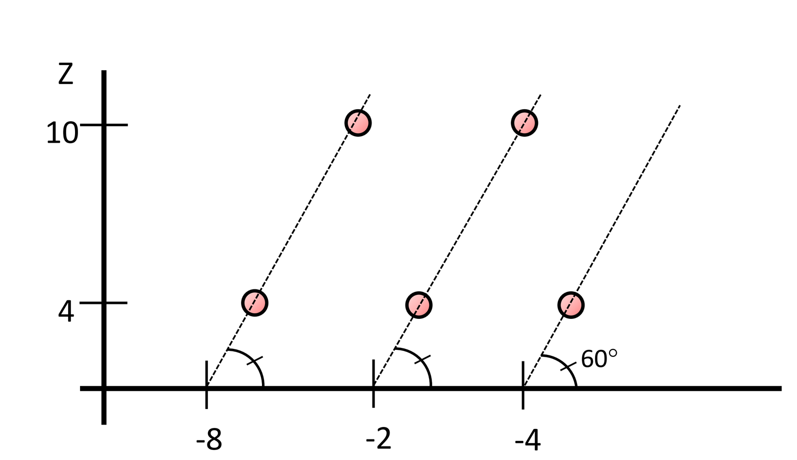
Two sources displaced by 3 pixels



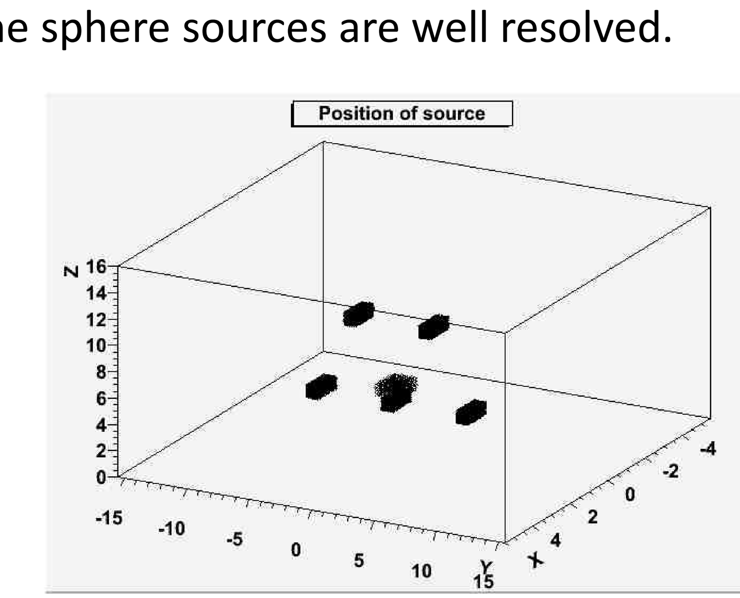
Two sources displaced by 3.5 pixels

Reconstructed 3D Image Using ML-EM Algorithm

- Phantom used for this study
  - Five sphere sources distributed in a trapezoidal shape
  - Each sphere source has a diameter of 0.5 mm
  - Each sphere has the same radioactivity
- ML-EM algorithm was developed for the 3D reconstruction
- In the reconstructed image as shown below, all the sphere sources are well resolved.



Multiple-sphere Phantom



Reconstructed 3D Image of the Multiple-sphere Phantom

Conclusions

- We simulated the response of a slanted-hole collimator to gamma ray radiation and developed ML-EM algorithm for 3D image reconstruction.
- The Monte-Carlo simulation results demonstrated the 3D imaging capability of the slanted-hole collimator in endo-cavity imaging applications.
- A bench-top test system is being set up in the laboratory. More experimental results will be reported later.

BROOKHAVEN NATIONAL LABORATORY

Notice: This poster has been authored by employees of Brookhaven Science Associates, LLC under Contract No. DE-AC02-98CH10886 with the U.S. Department of Energy. The publisher by accepting the poster for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this poster, or allow others to do so, for United States Government purposes.

For more information, please contact ycui@bnl.gov or 631-344-5351.

Hybridyne IMAGING TECHNOLOGIES, INC.