DUAL ASYMMETRIC AND HIGH RESOLUTION DETECTION HEADS OF A NOVEL COMPACT MOLECULAR BREAST IMAGING SYSTEM FOR EARLY BREAST CANCER DIAGNOSIS

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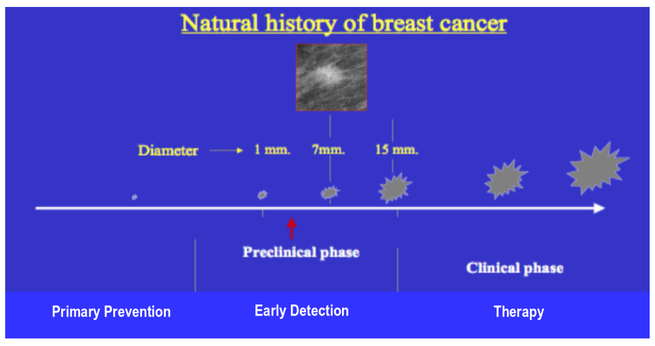
Abstract

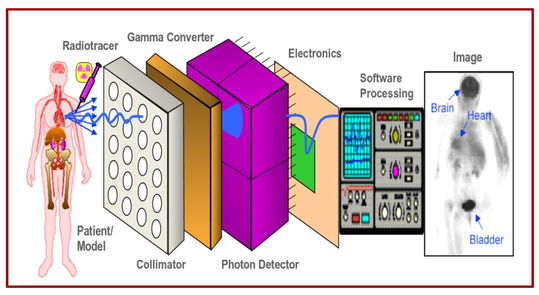
Early cancer diagnosis increases therapy success probability. Molecular Breast Imaging (MBI) by dedicated gamma camera represents one of the most promising technique of early cancer detection. A new MBI device, recently designed, with two peculiar asymmetric detectors facing each other, for spot compression, and Limited-Angle Tomography. The complementary sensors offer substantial opportunities to improve the tumor detectability and its characterization but requires dedicated algorithms and data analysis tools; some of them are illustrated here.

Breast Imaging Of Small-Size Cancer

- Breast cancer is the most common cancer in women, and its treatment is linked to the early diagnosis expecially for small-size cancers ($\leq$ 5 mm). The cancer detection makes possible the therapy before metastasis formation.
- Currently, the most used imaging tecnique is the *mammography*, mainly used for screening thanks to its high sensitivity and relatively small costs.
  - it provides good morphological images
  - it has high sensitivity
  - it has low specificity, and therefore it induces to false-positive and relative overdiagnosis
- Molecular Breast Imaging (MBI) with radionuclides (example ^{99m}**Tc**) has a central role:
  - it provides functional & specific informations, and it works well with dense breast
  - MBI aims: localization, identification and quantification of the lesion inside breast
  - key parameters: spatial & energy resolution, Signal-to-Noise Ratio (SNR)



Molecular Breast Imaging System



Anger Camera scheme: single-head components

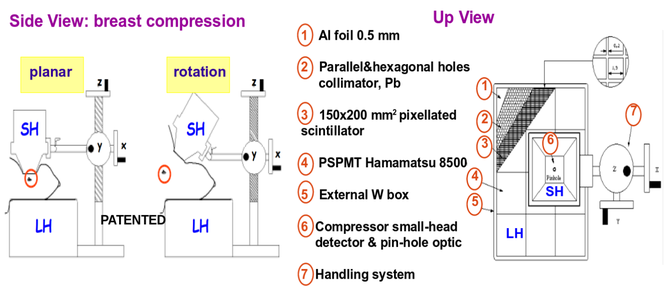
- **Radiotracer**: injected into Patient, "follows" the biological process & emits single γ-rays (99mTc)
- **Collimator**: projects γ-rays on γ-converter
- **Scintillator**: convert γ-rays into visible light
- **Sensor**: converts light into electrical signals
- **Readout Electronics**: amplifies and digitizes electrical signals (raw data)
- **Software**: back-reconstruct radionuclide image from raw data

A Novel MBI System

- Unique features:
  - asymmetrical detectors (Small and Big Heads)
  - complementary optics (pin and parallel holes)
  - optimized spot compression by SH pinhole
    - close to lesion increases efficiency and resolution
- Electronics
  - Front End MAROC3 ASICS, FPGA based, 4096 indip. chs
- NaI(Tl) Scintillators
  - Thickness/Pixel Size: 0.5/1.3$\pm$0.2 mm
- Detectors
  - PSPMT H8500, 64 indip. chs
  - Anode Size/Pitch: 5.8$\times$5.8/6.1 mm

Outlook: SiPM Detectors

Two Asymmetrical Heads



Components & Features

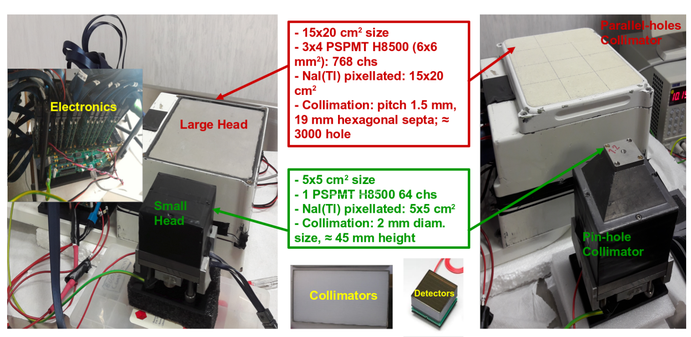


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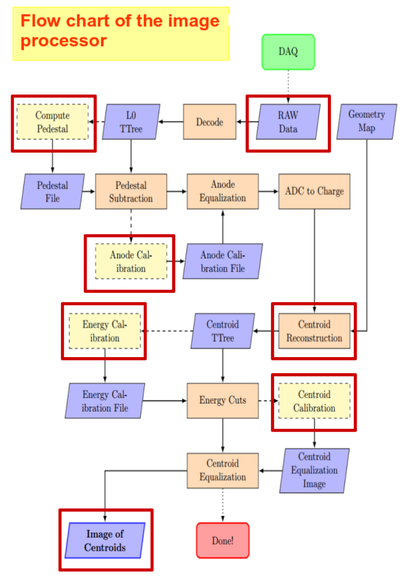
Image Processing & Reconstruction

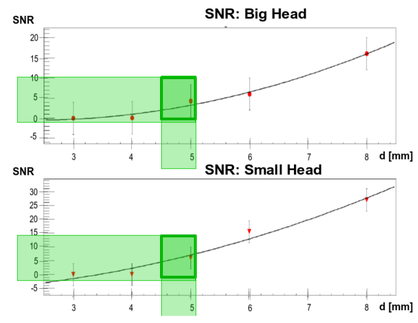
- The reconstruction software (ROOT Framework) generates the final image from the raw data:
  - it includes the *calibrations methods*
- The independent channel readout offers a large flexibility in image reconstruction optimization;
- *Final Image* is the image of the number of centroids in each pixel.



Tumor Detectability: SNR versus Lesion Size

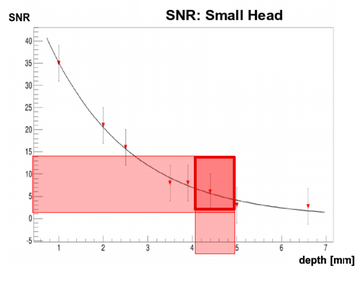
- Uptake 10
- Parallel Hole collimator for both heads
- Fixed lesion distances of 1 cm from the Big Head and 1 cm from the Small Head

→ **The smallest visible lesion is 5 mm diameter!**

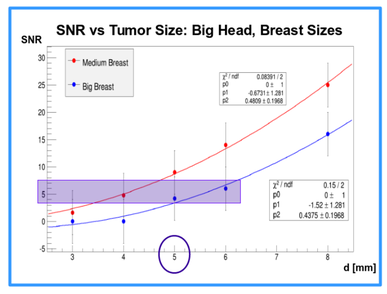


- Uptake 10
- Pinhole (reduced FOV) has been centered on 6 mm tumor

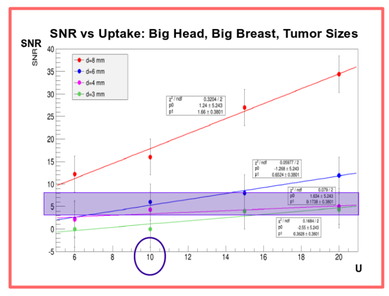
→ **With the Pinhole SNR is higher then with parallel hole (fixed diameter and depth), but it decreases more rapidly**



- Uptake 10
- Fixed 1 cm from the Big Head
- The SNR increases of about 5, for medium tumors, moving from the full size breast phantom to half size breast

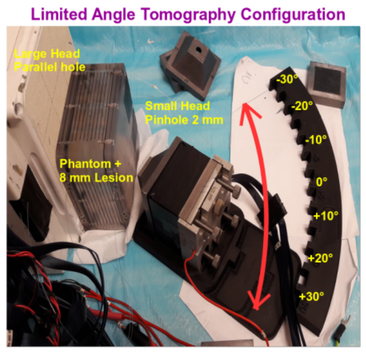


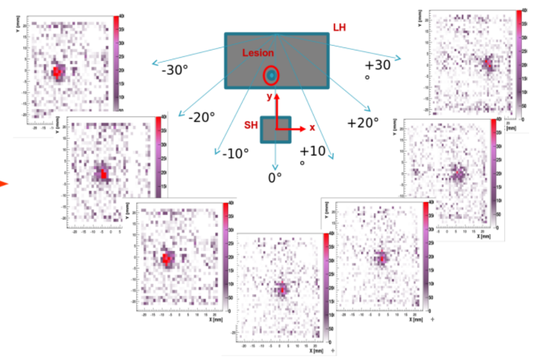
- Fixed 1 cm from the Big Head
- Smallest tumor (3 mm diameter) becomes visibile for uptake U=15
- At U=10, the SNR=5 for all the tumor sizes less than for 3 mm tumor size



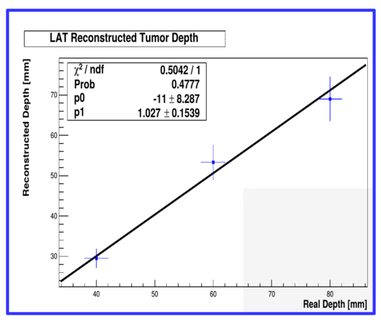
Lesion Depth Reconstruction

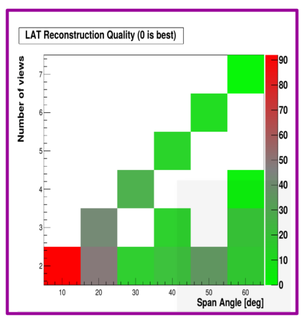
Limited Angle Tomography Configuration





- Reconstructed versus Real Depth: span angle 60° and 7 measures for each depth (40, 60, 80 mm)
- **Result**: LAT maximum reconstruction accuracy of deep lesion ↔ **fit slope = 1!**
- Number Of Views versus Span Angle: 7 experimental views and 60° span angle
- **Result**: LAT reconstruction quality of lesion grows with N_{VIEWS} **& Span Angle**





Conclusions & Outlooks

- First results on lesion detectability shows 5 mm diameter as lower limit
- Preliminary Limited Angle Tomography results show good correspondence of reconstructed and real tumor depth: reconstruction improves with larger span angle and number of views
- Analysis will soon be integrated by Monte Carlo simulations
- Images Fusion & Co-Registration in 2D/3D using Deep Learning Approaches could be beneficial and will be explored