MONTE CARLO TECHNIQUES FOR MODELLING X-RAY DETECTOR SYSTEMS

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[1] S.H Chou et al., Digital Tomosynthesis of the Chest: Current and Emerging Applications. Radiographics, 2014

Background

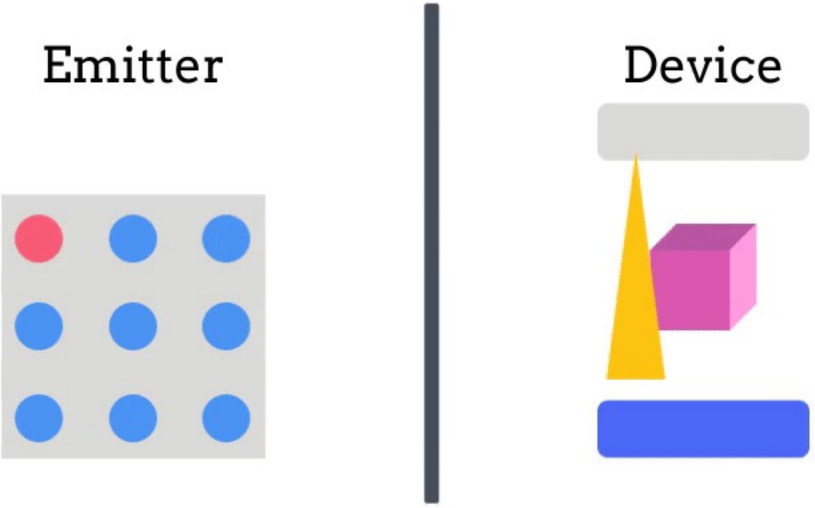
DIGITAL TOMOSYNTHESIS

- **Digital Tomosynthesis (DT)** is a mode of **3D imaging** [1]
- Varying **positions** of an x-ray source creates different **projections** ('slices') that can be **reconstructed** into a **3D image** of the **object**
- **Conventional DT** does this by rotating an **x-ray tube** 30° – 60° over the object

[2] S Wells et al.. Modelling the Use of Stationary, Rectangular Arrays of X-Ray Emitters for Digital Breast Tomosynthesis. In Medical Imaging 2020: Physics of Medical Imaging, SPIE, 2020
[3] Adaptix Ltd, www.adaptix.com

Background

ADAPTIX DIGITAL TOMOSYNTHESIS



- to conventional DT

ube

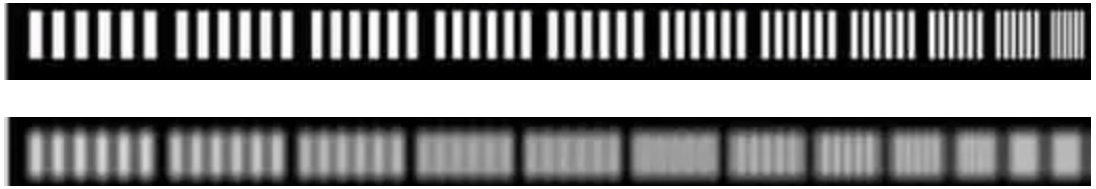
[4] T. Hatsui and H. Graafsma, "X-ray Imaging Detectors for Synchrotron and XFEL sources", IUCrJ, vol. 2, no. 3, pp. 371 2015
[5] E. Samei and M. Flynn, "A method for measuring the presampled MTF of digital radiographic systems using an edge test device," Med. Phys., 1998

Background

X-RAY DETECTORS

Accepted Parameters [5]:

- Modulation Transfer Function (MTF)
- Noise Power Spectrum (NPS)
- Detector Quantum Efficiency (DQE)



- **Modern x-ray detectors** are **flat-panel digital detectors** (medical and accelerator) [4]
  - Indirect vs direct
  - Electronic readout (fast, no intermediate step required)
  - Good for **mobility**
  - Geometry characteristic to system and purpose

ADAPTIX DETECTOR FOCUS

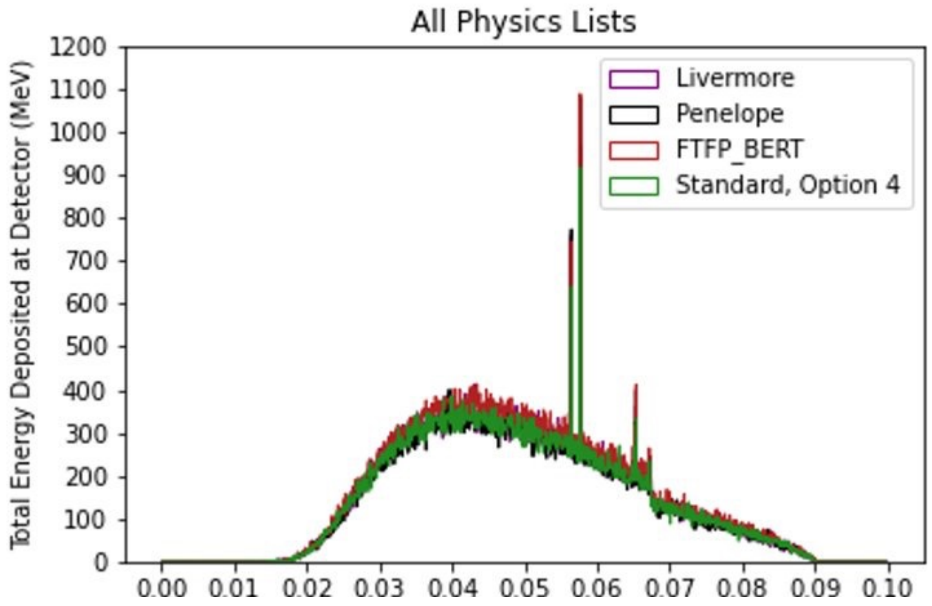
- While flat-panel source is designed in-house, **flat-panel detector** is **commercially sourced**
- Creates questions:
  - If this detector was designed in-house, what would the optimal design look like?
  - How to parameterise the suitability of the detector?
  - What are the **key characteristics** of a 'good' detector?
    - Inform 'most suitable' commercially available option

[6] S. Agostinelli et al., "Geant4—a simulation toolkit", Nuclear Instruments and methods in physics research section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 2003

Method

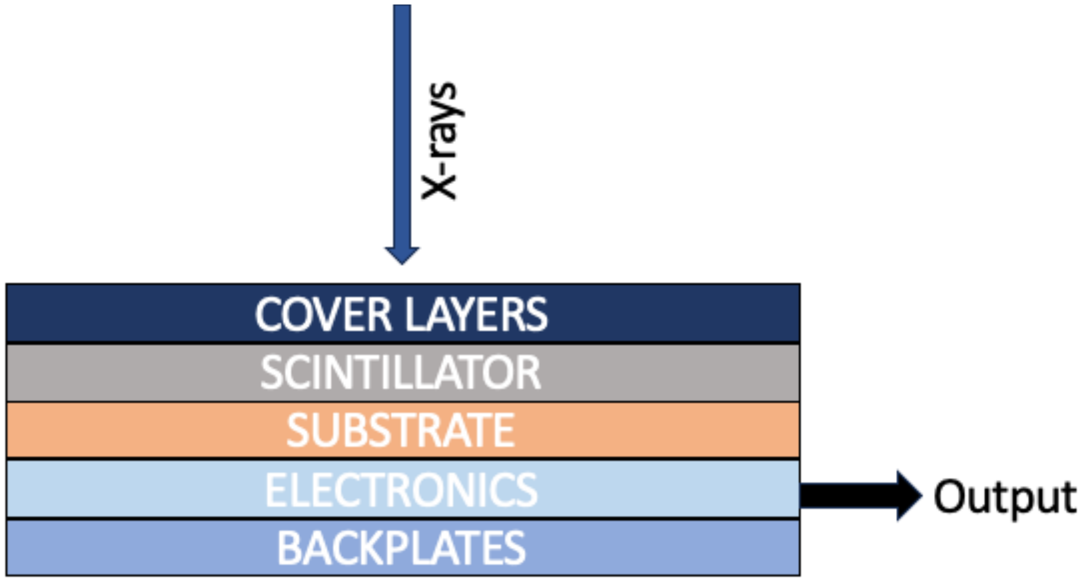
MONTE CARLO TECHNIQUES : GEANT4

- This work uses **Geant4** [6]
- Tested a range of electromagnetic physics lists and settings
  - Used **Livermore** (within error, faster runtime)
  - 5 um **range cut**
  - **Energies** in range of **60 keV – 150 keV** of interest
  - Between **1 x 10^4 and 2 x 10^9 primary particles** simulated
  - **Sensitive detector** creates CSV readout

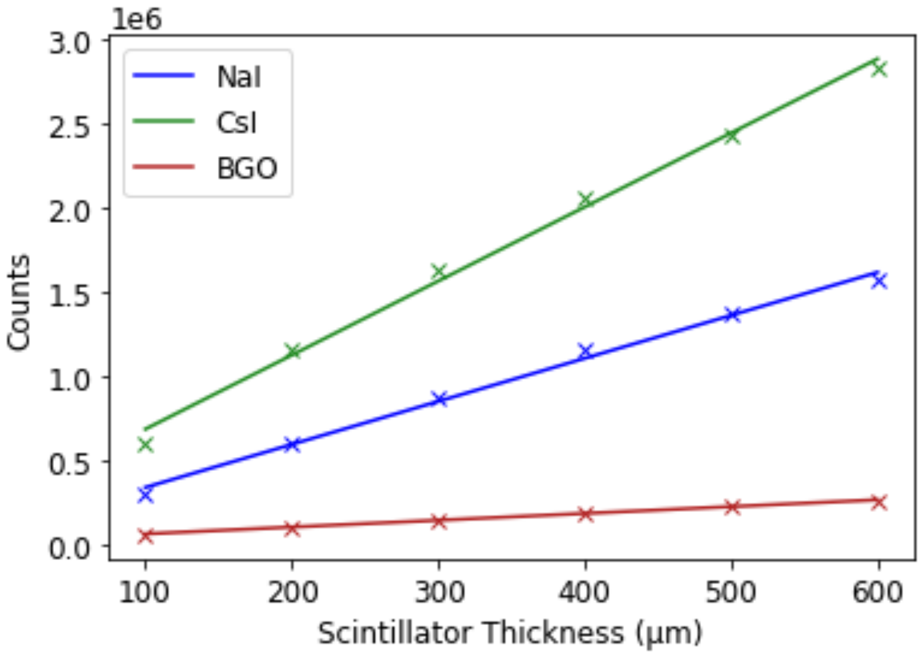


BUILDING A DETECTOR IN GEANT4

- Key elements of simulation are the **target, filters** and the **phantom**
- Implementation of **optics**
  - Numerical handling; sourced from literature
- Recreation of detector layers from actual detector used
- Change geometrical choices in the environment (e.g. scintillator material)

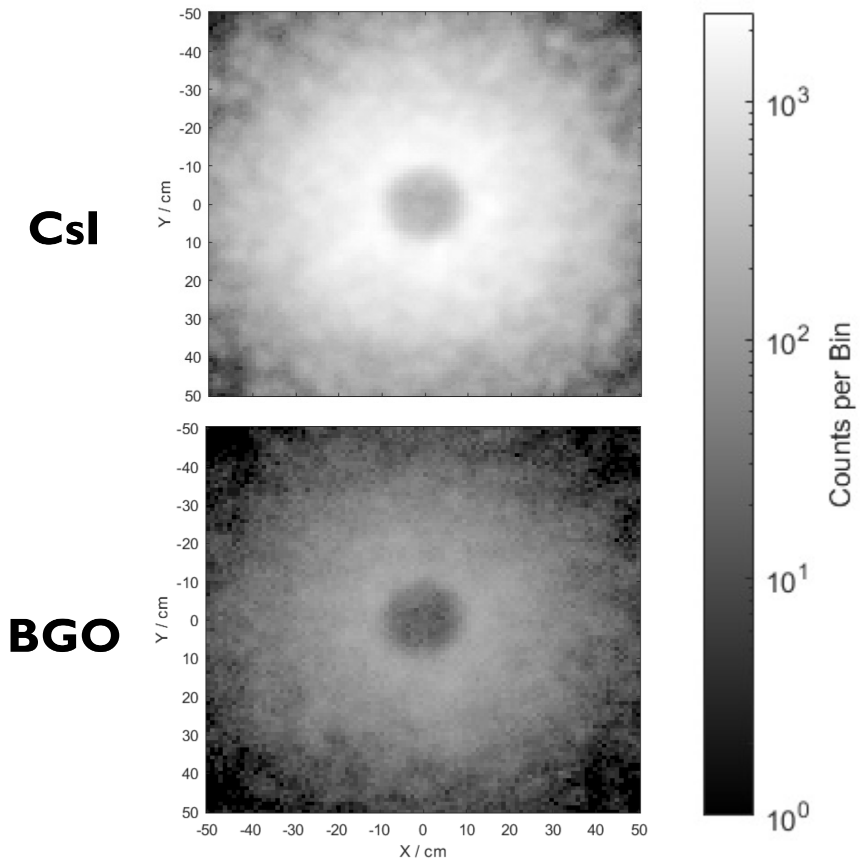


PRELIMINARY TESTS



- **Varying scintillator material** and **thickness** to **validate optical behaviour**
  - Bismuth Germanate (BGO), CsI (Caesium Iodide), NaI (Sodium Iodide) as most commonly used crystal scintillators
- Expect **linearity**
  - Due to numerical handling already discussed
- Different gradient corresponds to differing photon yield

PRELIMINARY TESTS



- A **key capability** of any **x-ray** detector is the ability to **produce analysable images**
- By applying a **binning grid** over the **detecting layer,** analogous readout to pixel-by-pixel binning can be achieved
- The images read **optical photon count** per bin
  - The images shown show the shadow cast by a **cylindrical steel phantom**
  - **Attenuation differentials** key for **reconstruction**

FINDINGS & FUTURE WORK

- The **scintillating layers** showed the **expected linearity in photon yield**
- The **images created** reflect the necessary **attenuation** and **pixel detail** that make it comparable to **real-life detector systems**
- The next steps are to **quantify known parameters** (MTF, NPS, DQE) and **benchmark simulation to experimental data**
- This will allow **change of geometry and simulation conditions** to answer the questions

References
[1] S.H Chou et al., Digital Tomosynthesis of the Chest: Current and Emerging Applications. Radiographics, 2014
[2] S. Wells et al.. Modelling the Use of Stationary, Rectangular Arrays of X-Ray Emitters for Digital Breast Tomosynthesis. In Medical Imaging 2020: Physics of Medical Imaging, SPIE, 2020
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THANK YOU FOR LISTENING!

ANY QUESTIONS?

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