1st Annual ARDENT Workshop: ESR Presentation by Kevin Loo

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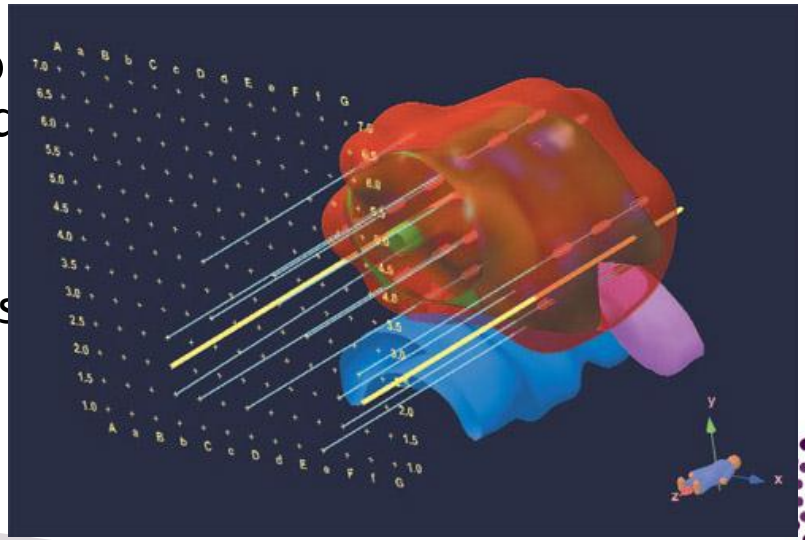
Kevin Loo

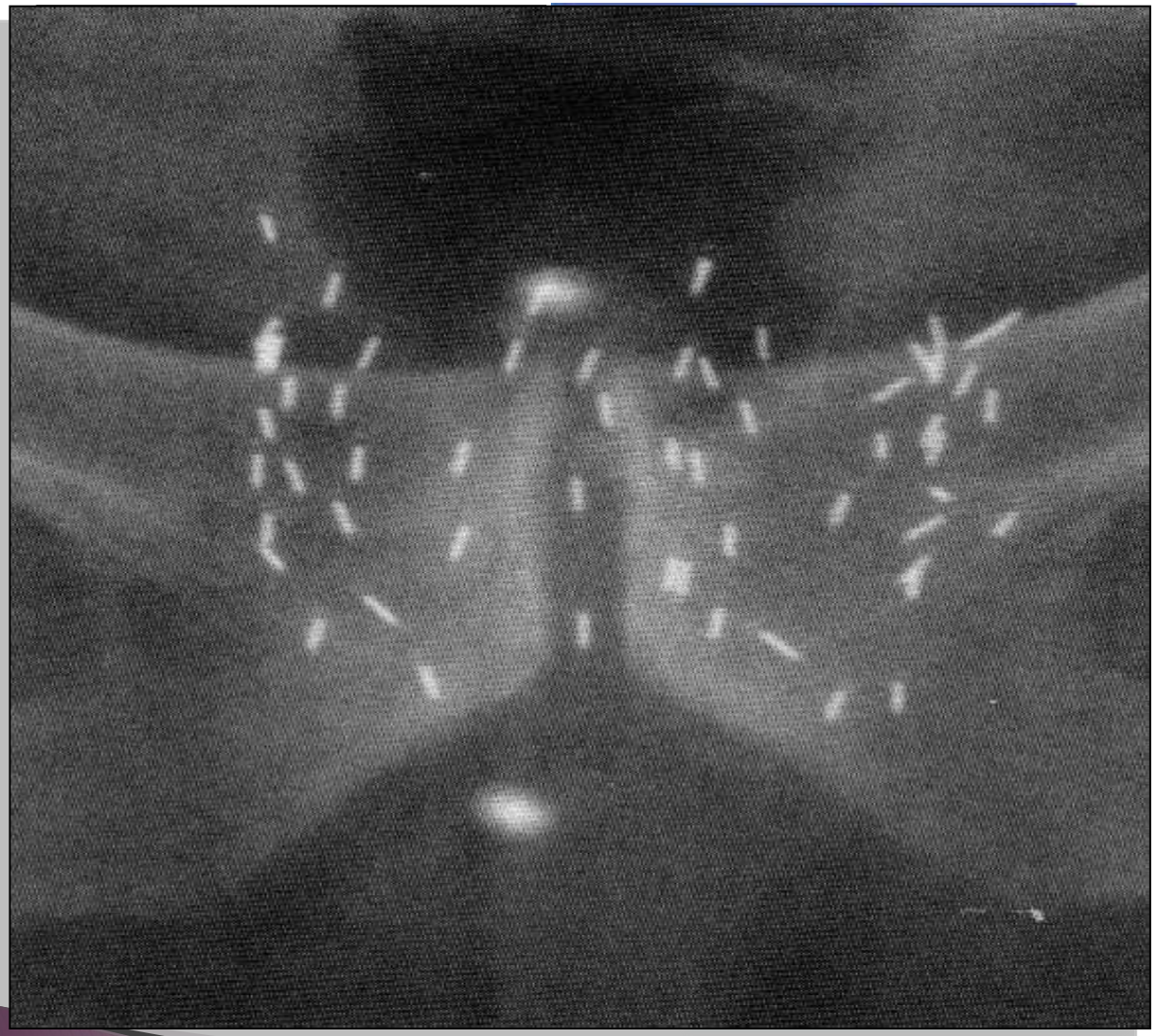
- Centre for Medical Radiation Physics- University of Wollongong, Australia, 2006-present
- Bachelor of Medical Radiation Physics (Adv Hon): graduated first class honours in 2009
  - Topic: *High spatial resolution surface dosimetry for episcleral eye plaque radiation therapy using MOSkin*
- Commenced PhD studies 2010:
  - Topic: *BrachyView: A novel intra-operative system for prostate brachytherapy*
  - Supported by National Health and Medical Research Council and Australian Rotary Health

BrachyView Concept

- Brachytherapy implant localisation uncertainty causes dosimetric complications
  - Prostate mobility
  - Seed twisting
  - Brachy needle placement errors
- Intraoperative dynamic dose planning
  - Fuse with existing ultrasound technology
- New in-body ultra-functional probe:
  - Ultrasound, radiation source and CT imaging captured real-time
  - Possibility to introduce fast, o
    using seeds themselves as rad
- Applications:
  - Seed positioning in tumour
  - Real-time CT imaging of implants



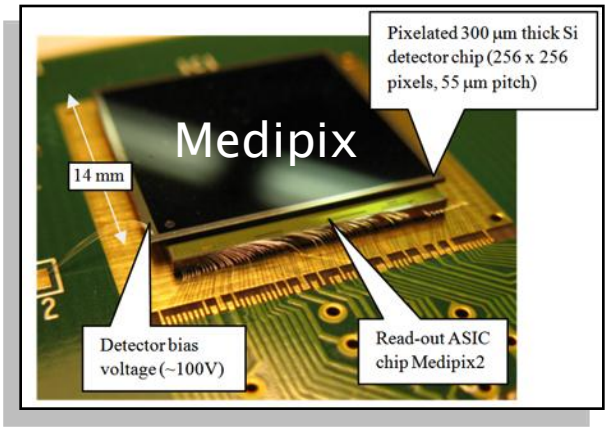
Current Technology – TRUS



Result

- Seed misplacement errors
- Urethral and rectal toxicity: 40% cases
- No real-time planning option available
- Disadvantage: not true 'real-time', planar image only (no anatomy), cumbersome and expensive equipment

Application 1: Seed Positioning



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TRUS

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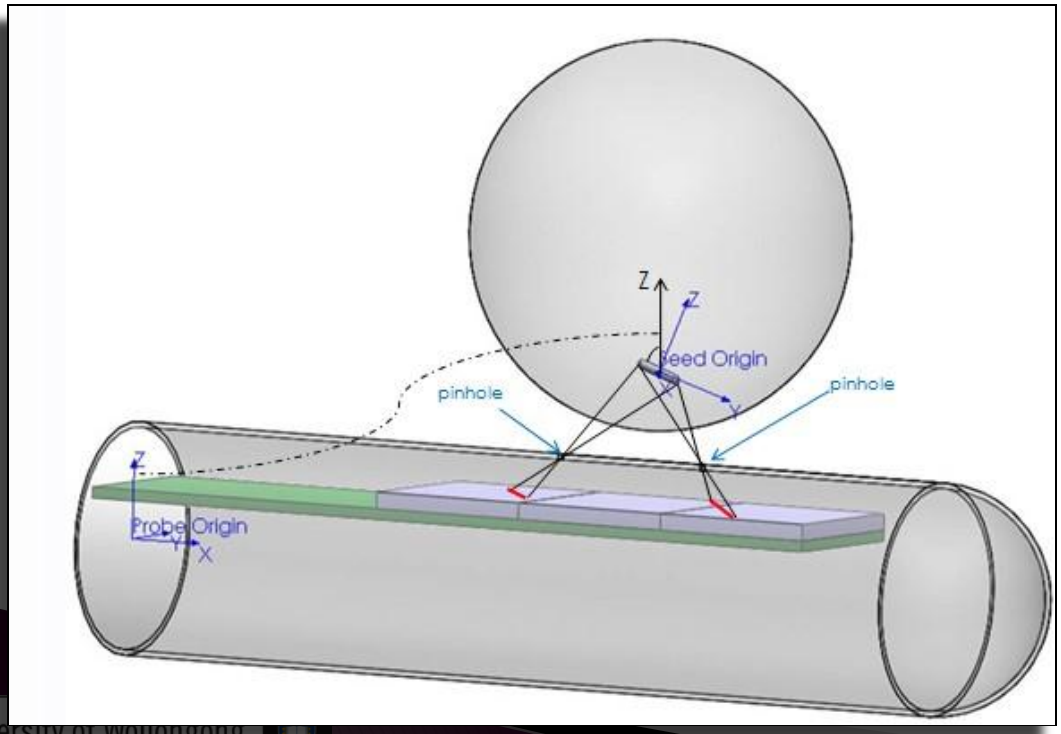
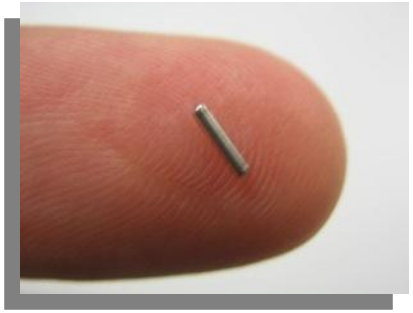
Gamma Camera >US$ 700,000

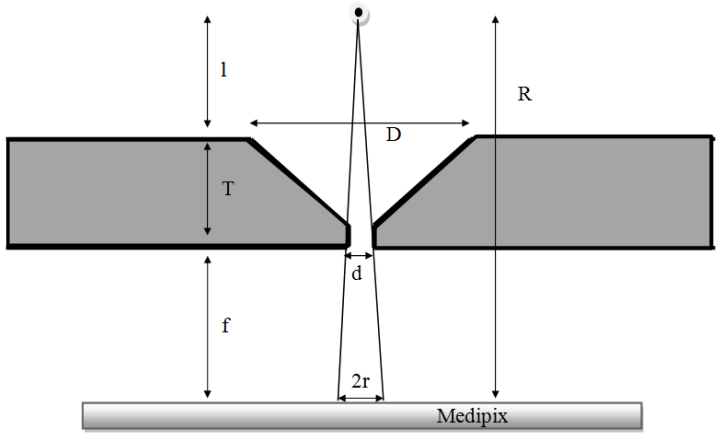


- Gamma camera lacks anatomical information, which is provided by proposed medipix dataset fusion with ultrasound images
- Multiple medipix detectors in TRUS probe for multiple views and therefore, seed triangulation

Pinhole Gamma Camera Concept

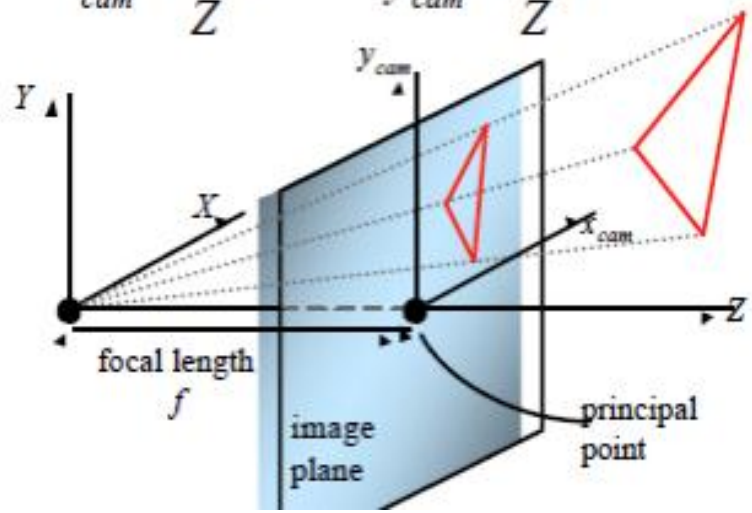


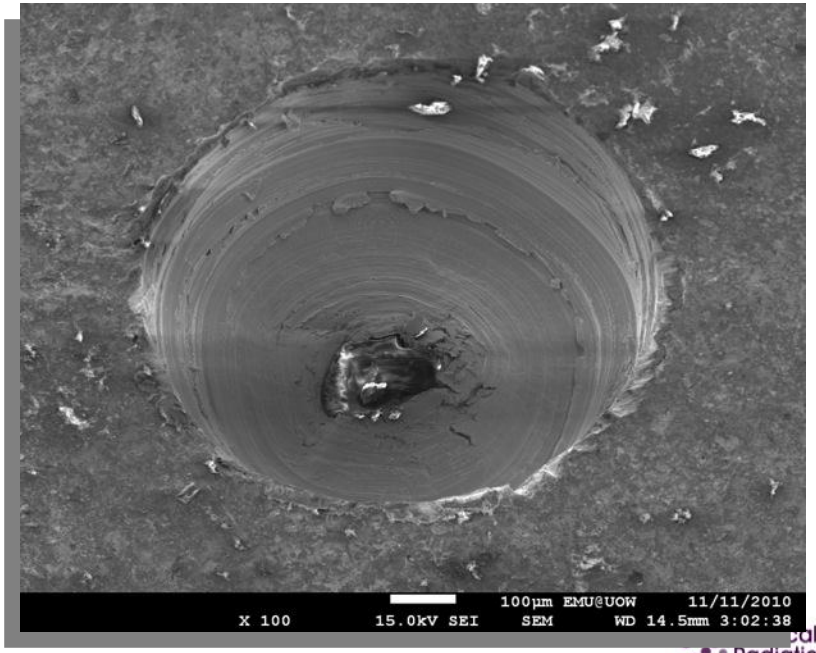
ONCURA I-125 Seed:
- Shell dimensions: 4.5x0.8mm
- Radioactive core: 2.8x0.5mm



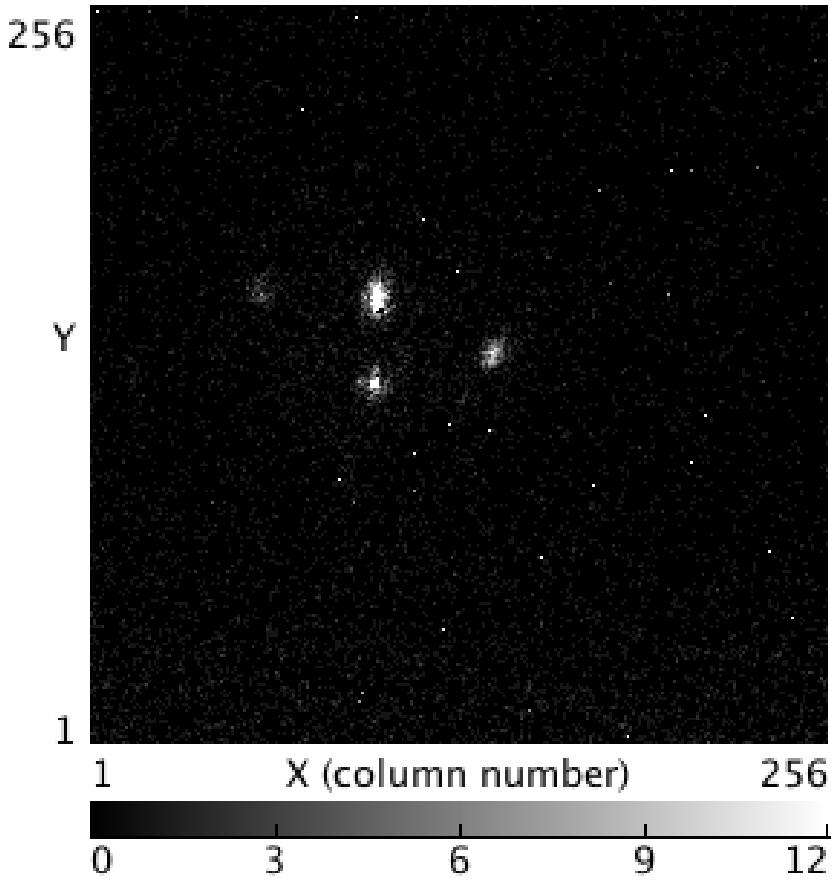
3D point (X,Y,Z) is projected onto the image plane at (x_{cam}, y_{cam})

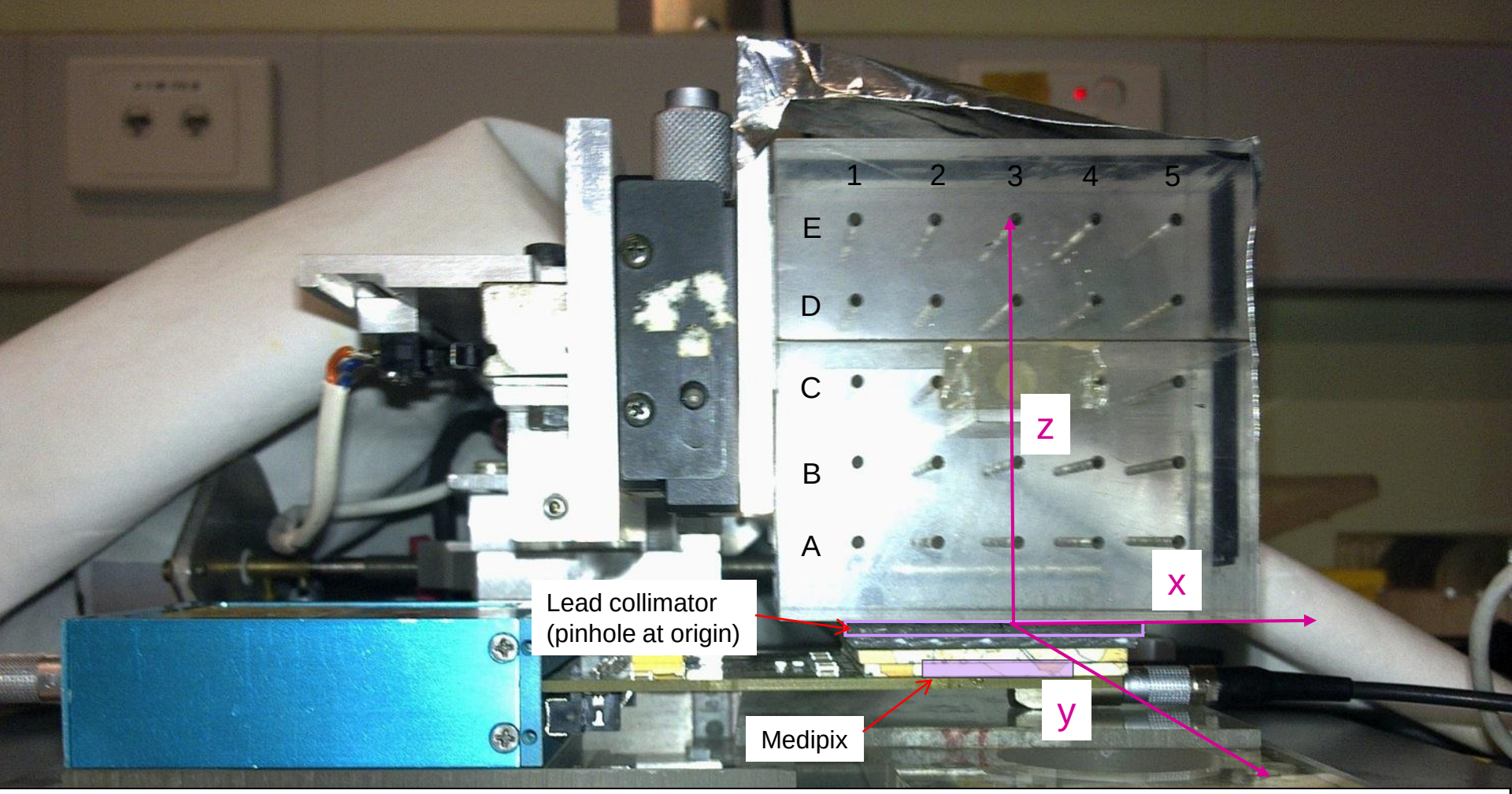
$$x_{cam} = \frac{f}{Z}X \qquad y_{cam} = \frac{f}{Z}Y$$





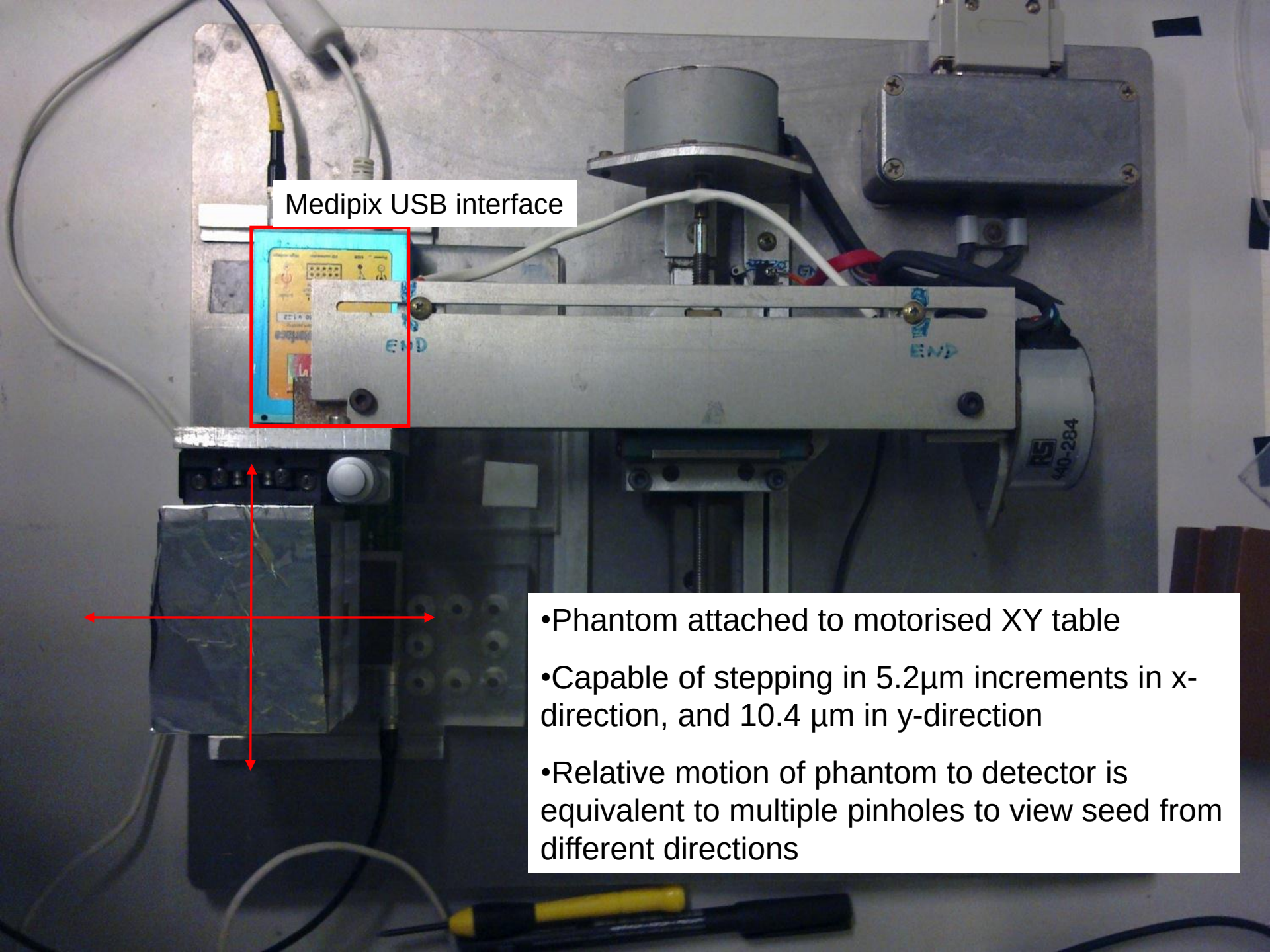
- Based on multiple views from medipix, seed position can be triangulated from projected rays through pinhole
- Note: for seeds ‘behind’ other seeds, multiple views are essential (see figure; seeds B3 and D3)
- Determine possibility of seed coordinates





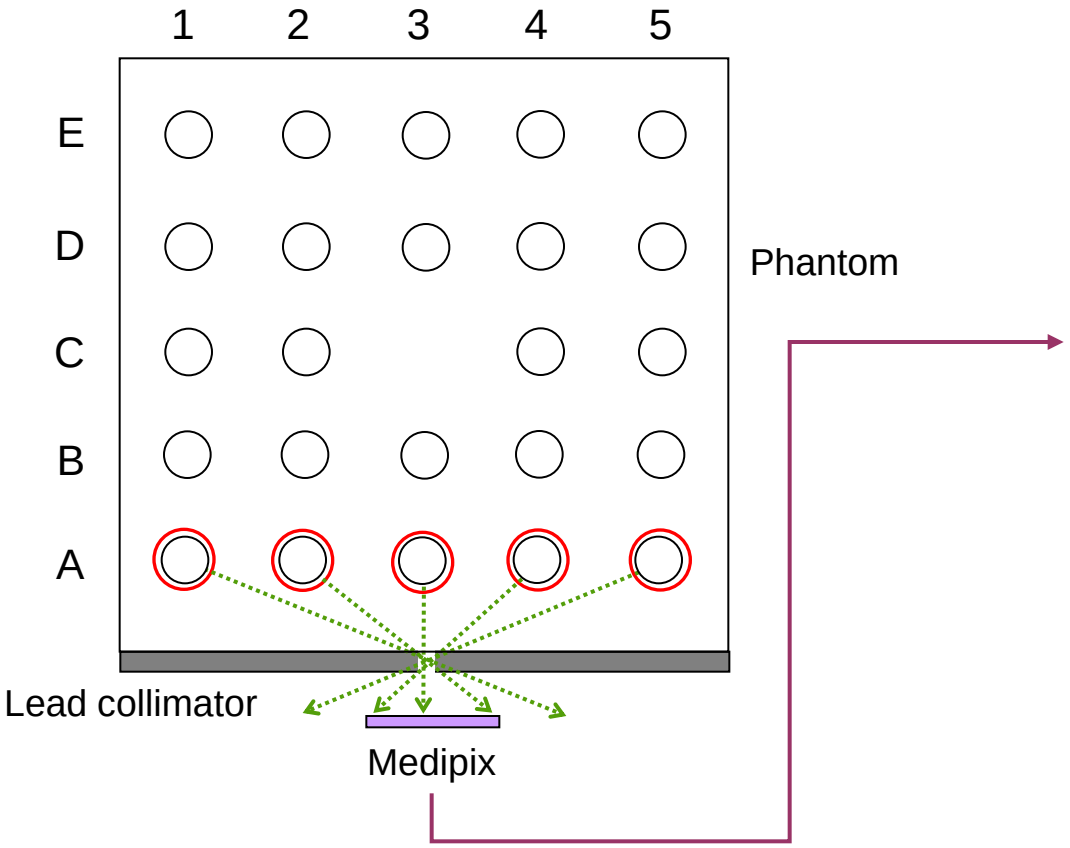
- PMMA phantom 60x60x60mm
- Grid (rows A-E, columns 1-5) to simulate template in TRUS brachy implant procedure

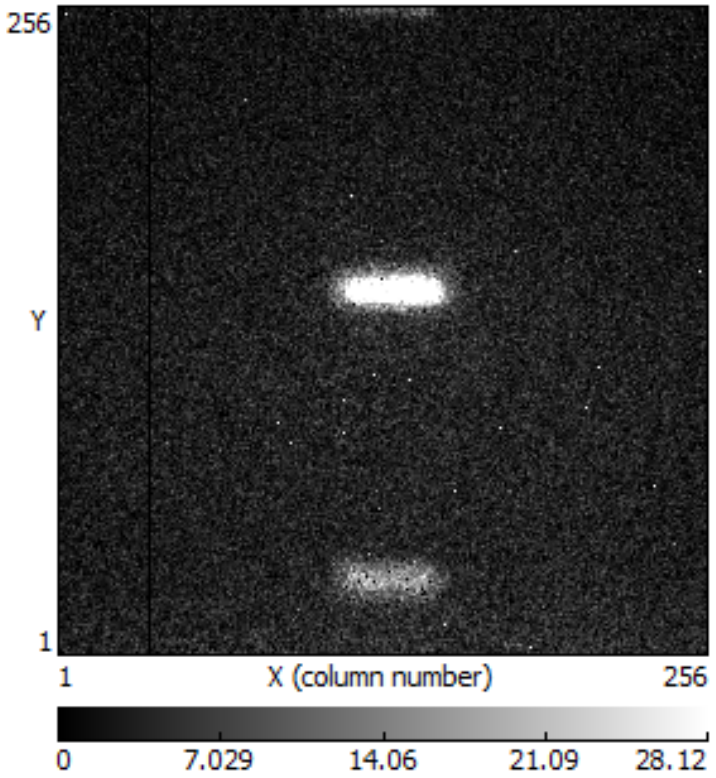
- Single chip used in experiment
- Phantom is moved relative to detector and collimator to obtain multiple views
  - Model of multipinhole collimator using single pinhole and detector



- Phantom attached to motorised XY table
- Capable of stepping in 5.2µm increments in x-direction, and 10.4 µm in y-direction
- Relative motion of phantom to detector is equivalent to multiple pinholes to view seed from different directions

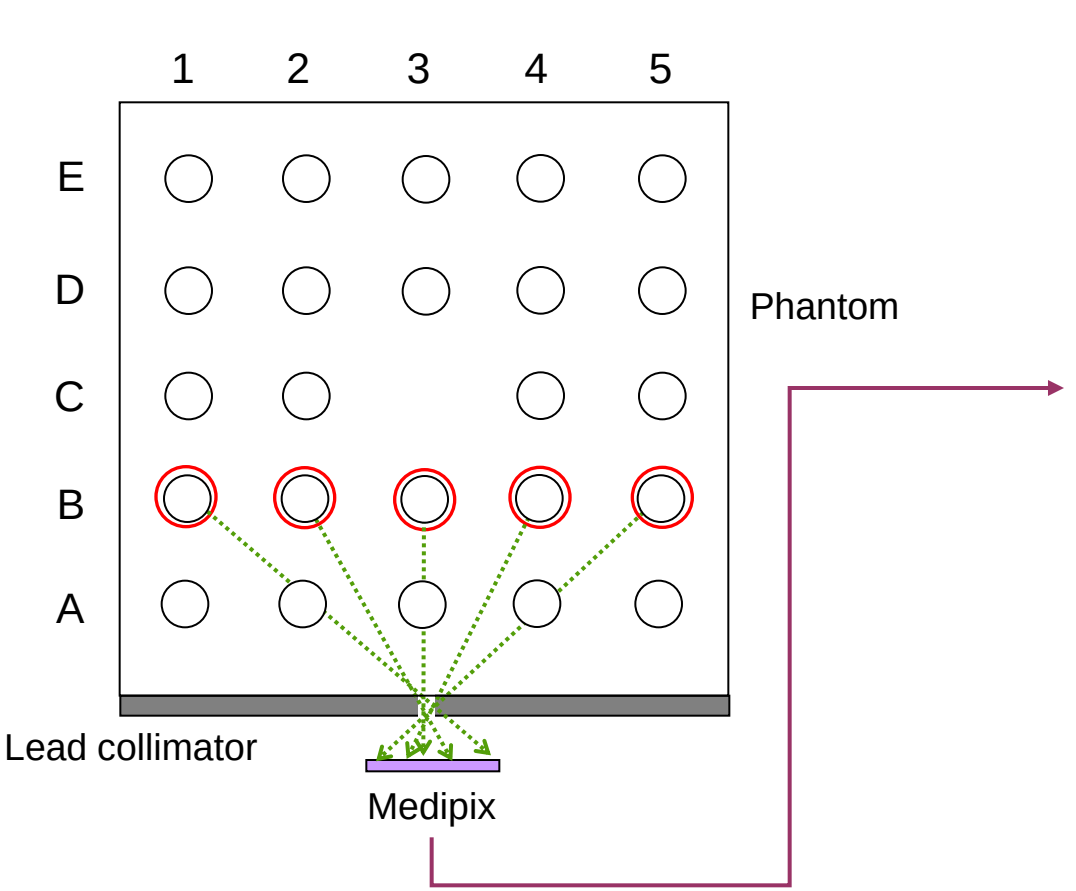
Seed Images

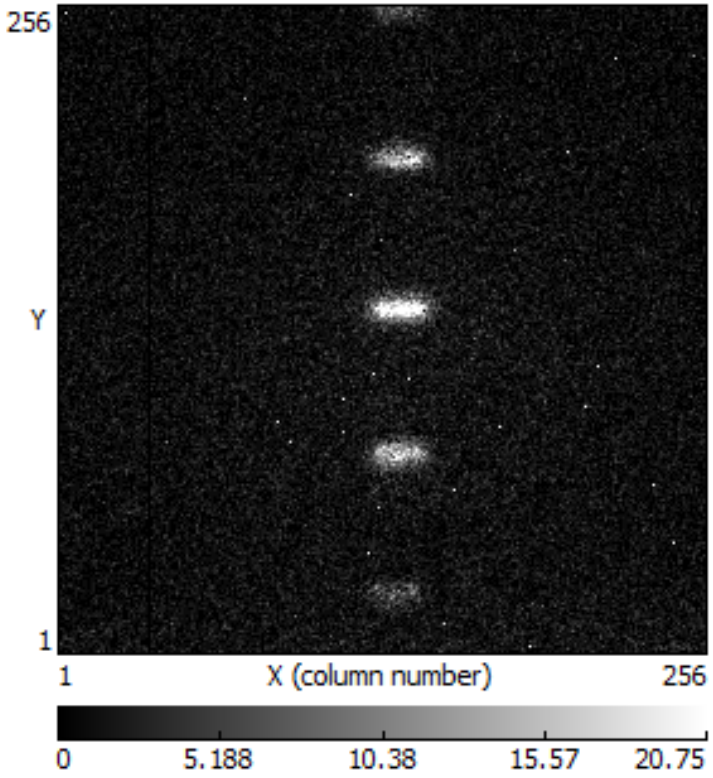




Row A- 5 seeds, single acquisition,
Note that only 3 seeds are in field of view

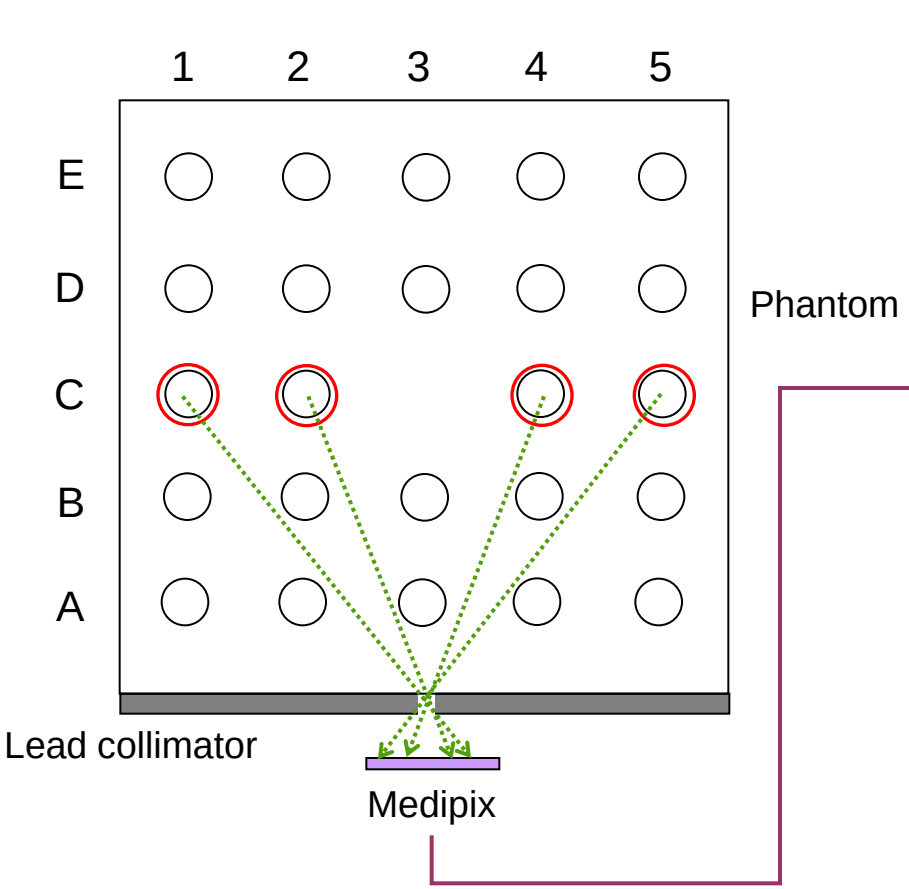
Seed Images

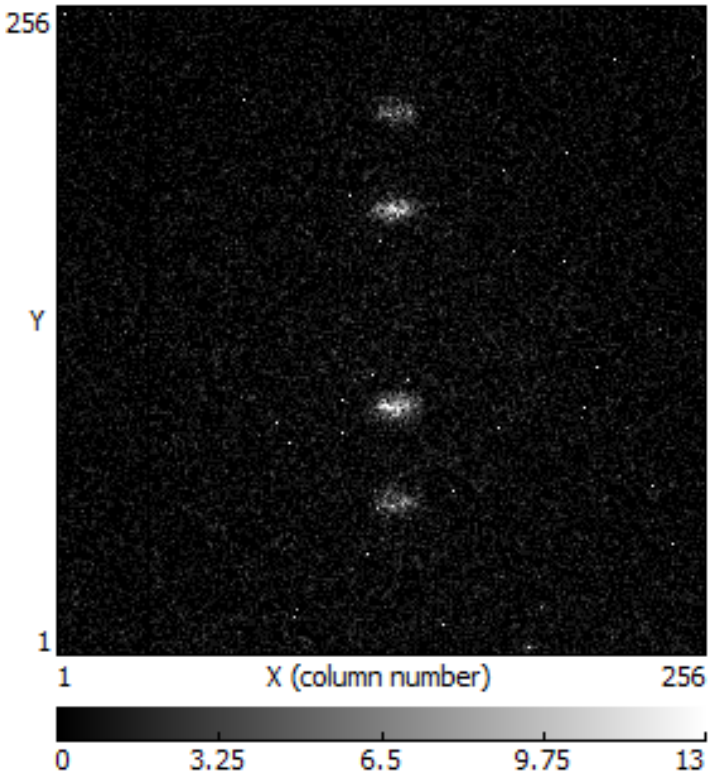




Row B- 5 seeds, single acquisition,

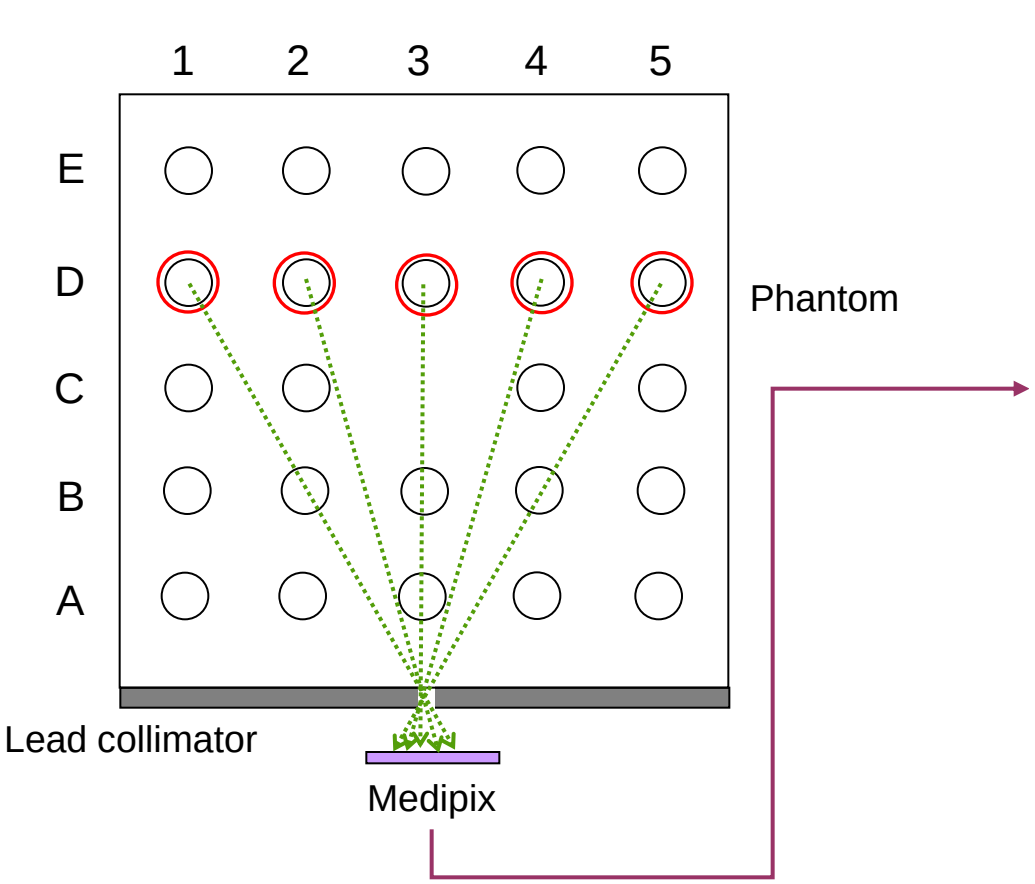
Seed Images

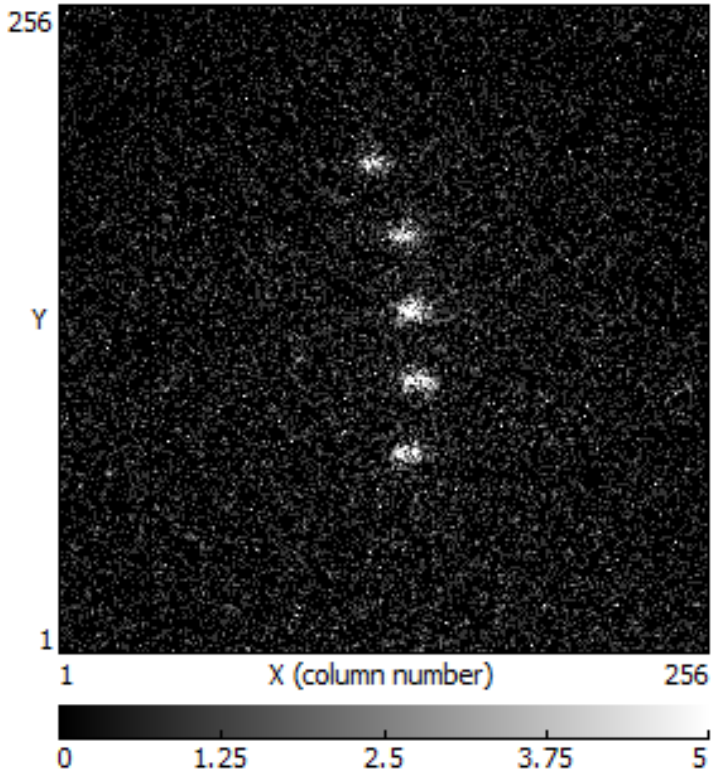




Row C- 5 seeds, single acquisition,

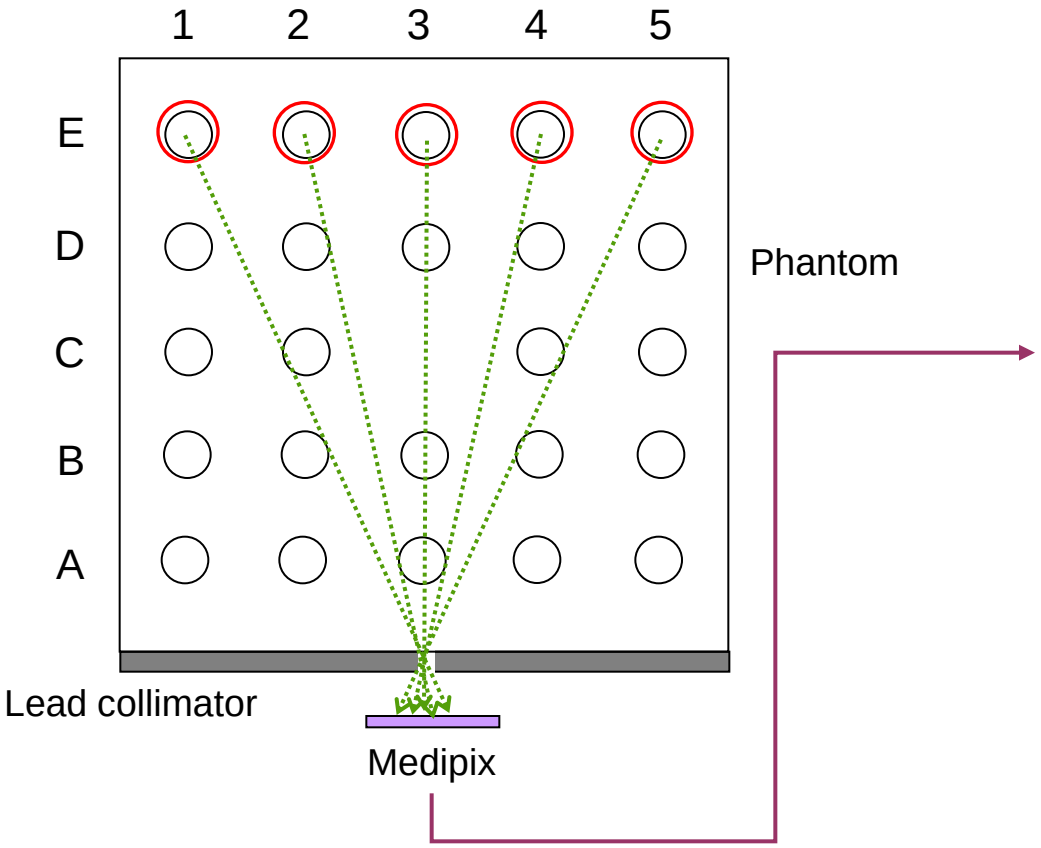
Seed Images

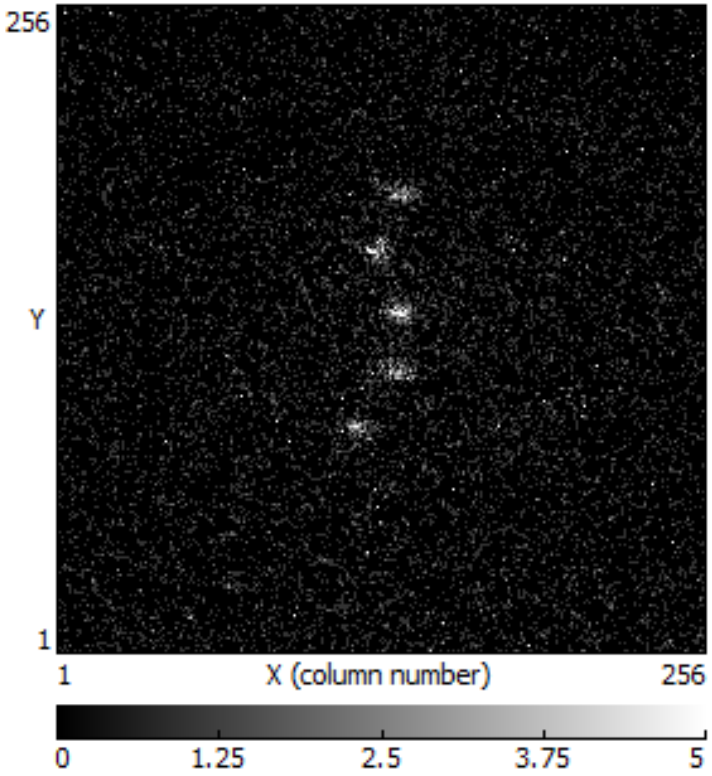




Row D- 5 seeds, single acquisition,

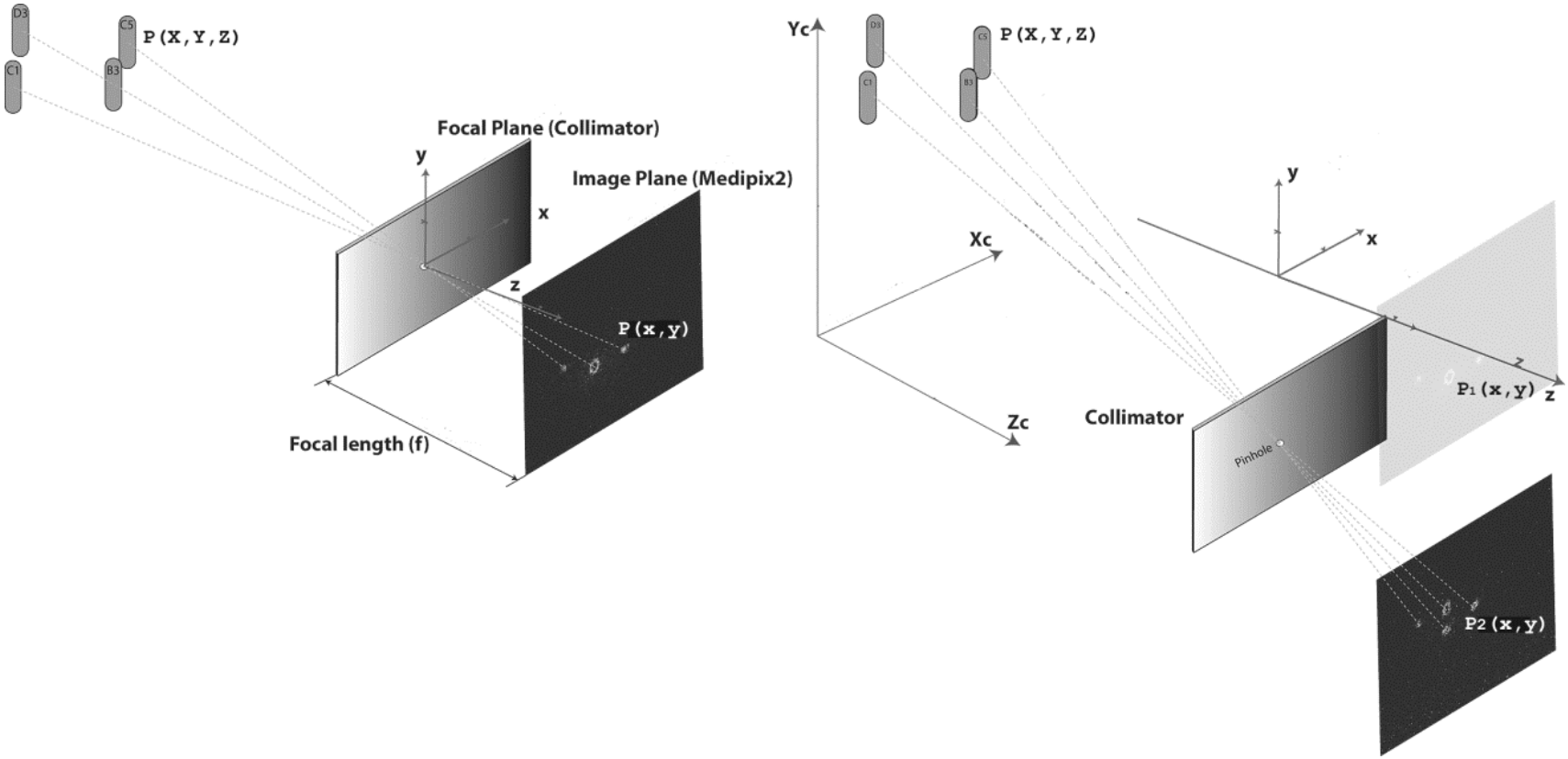
Seed Images





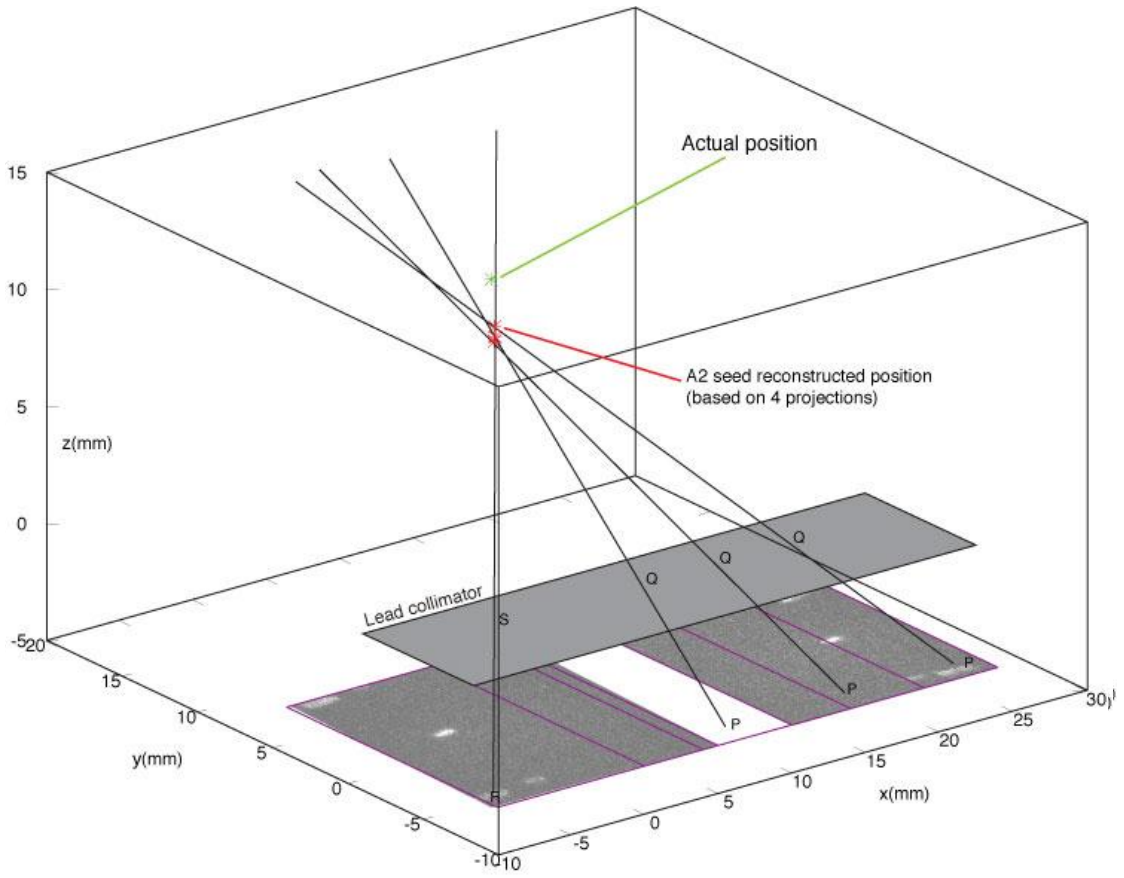
Row E- 5 seeds, single acquisition,

Reconstruction process

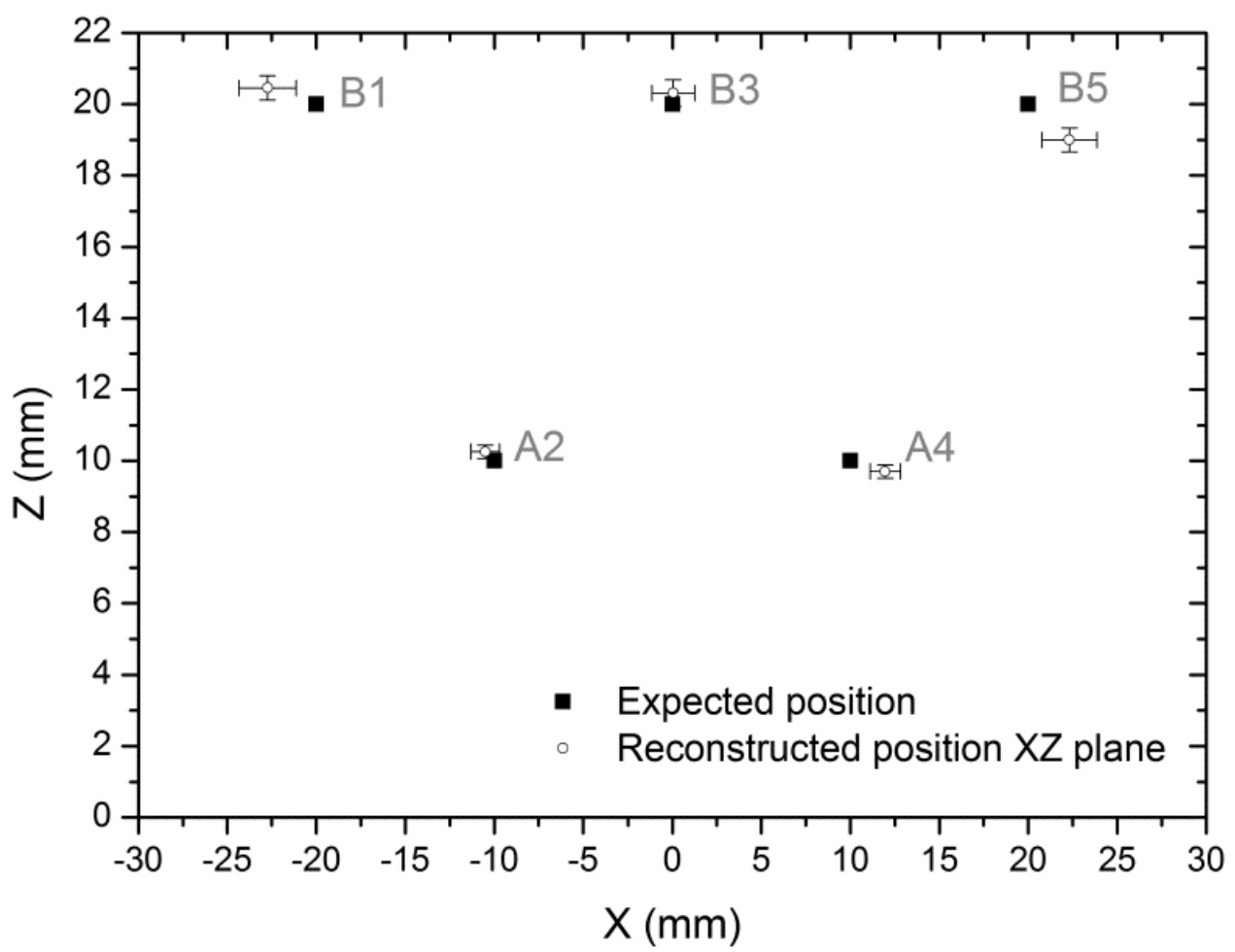


Experimental results

- Using linear algebra, the point of intersection of rays through pinhole is used to reconstruct seed coordinate (centre-of-mass)
- NOTE: lines do not necessarily intersect in 3D, and so use the midpoint of shortest chords between skew lines
- Accuracy within 0.5-1mm of expected positions

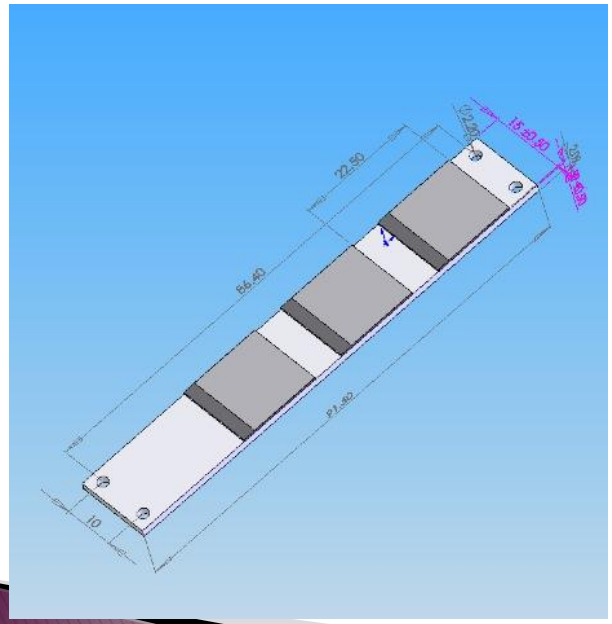


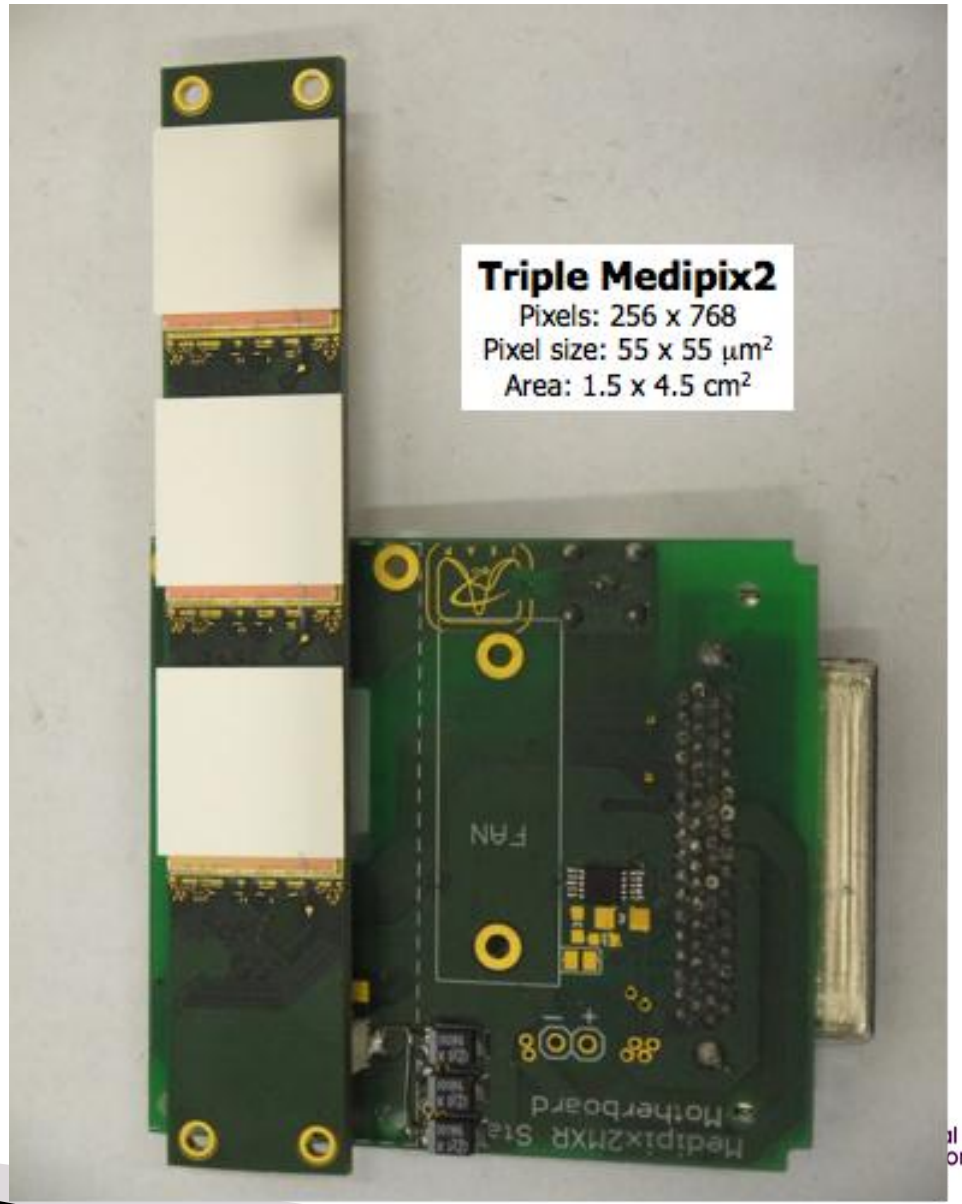
Experimental Results



Detector Design

- Multiple views from novel 3 chip/multi-pinhole design
- Integrate with existing TRUS probe design

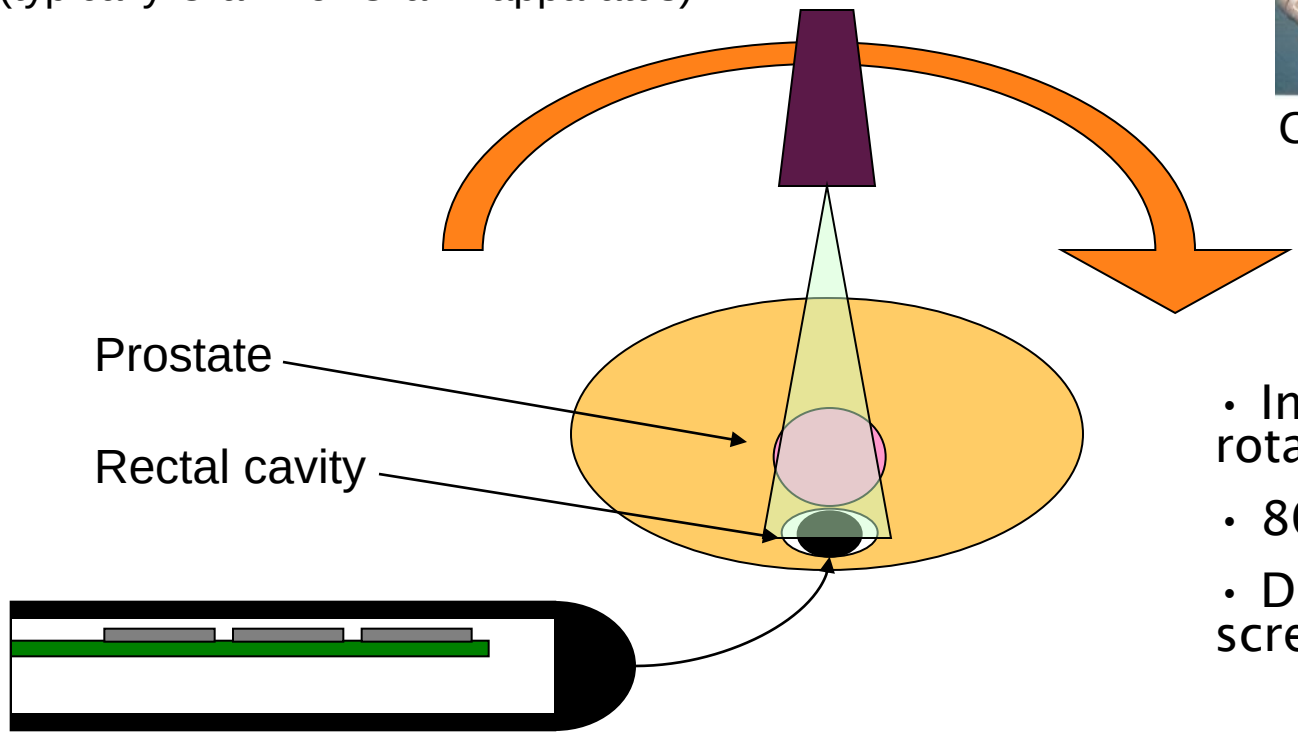




BrachyView and CT

External x-ray source
(typically C-arm or O-arm apparatus)

CT scanner >US $800,000



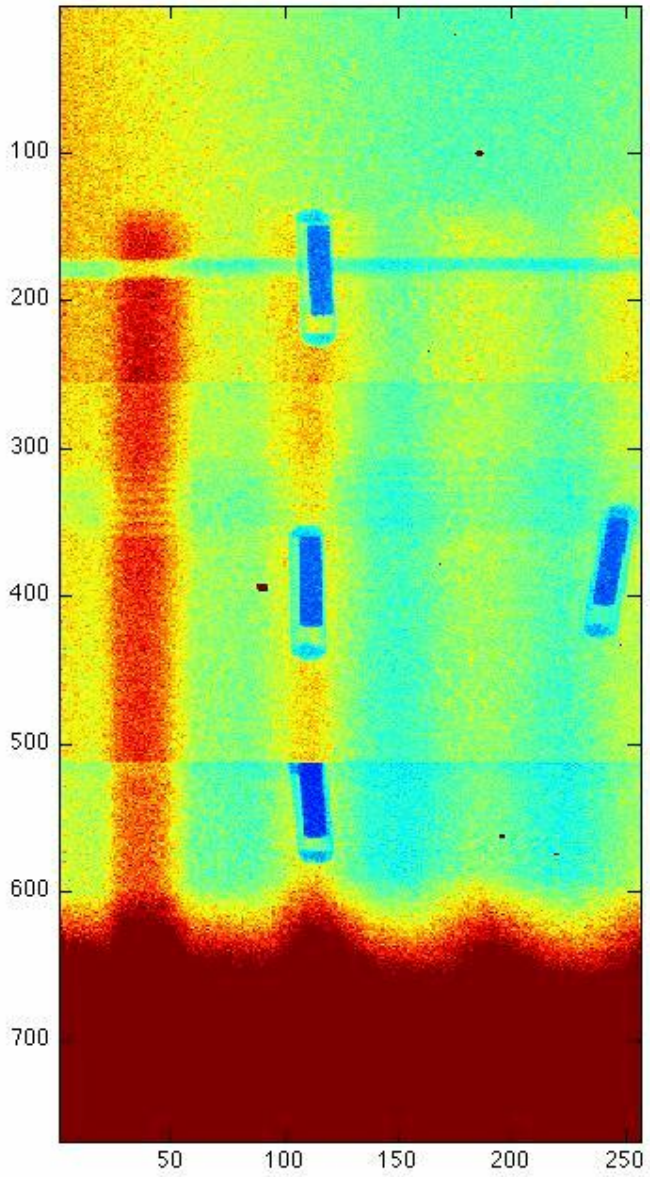
TRUS Probe w/ Medipix

Not to scale

- In-body CT with rotating x-ray tube
- 80 times less dose
- Diagnostic and screening capability

Results

- Obtain 180 projection images to simulate realistic clinical scenario
- Using iterative reconstruction method (OSEM), limited angles are no problem
- Note: presence of ‘dead zones’ due to spacing on detector plane
- First steps taken in developing reconstruction algorithms



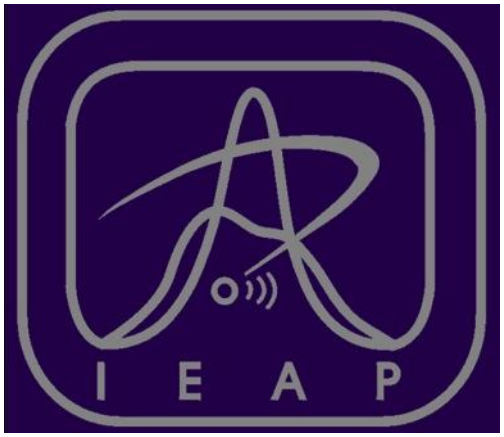
Conclusions

- Brachytherapy procedures benefit from knowledge of exact seed coordinates *during* implant
- Experimental proof-of-concept studies completed with promising results
- Image reconstruction algorithm for CT slices has been developed and is currently being tested for use in limited angle reconstruction (limited FOV)
- Perform dosimetry on reconstructed seed positions to determine best treatment outcomes
- Enhance/introduce ability for ***intraoperative dynamic dose planning*** developed at MSKCC
  - Real-time adjustment of seed and needle placement based on *actual* implants, not preplanned arrangements
  - Streamline entire procedure to include post-implant dosimetry and CT imaging into single procedure: so-called 'one-stop-shop'

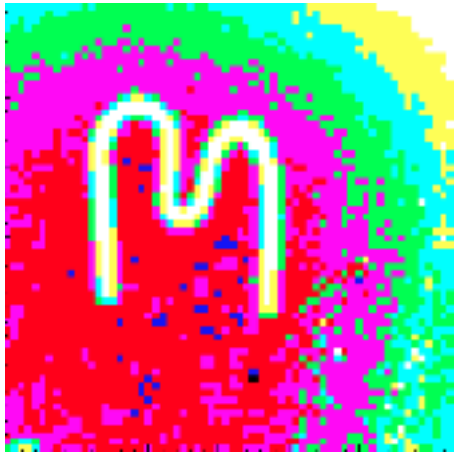
My research and ARDENT

- Familiarity with Medipix technology, and have received training in fundamentals surrounding Medipix operation
- Unique clinical application of Medipix has great potential
- Further my expertise in this powerful device for medical imaging but also in developing dosimetry techniques for mixed radiation fields

Acknowledgments



Prostate Cancer Institute



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