ARDENT ESR 8:
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BrachyView – RT for prostate cancer

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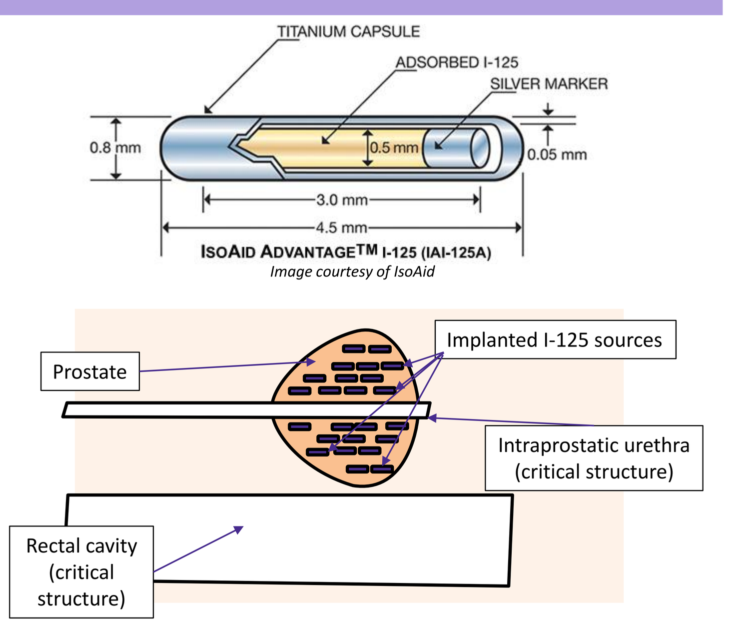
Introduction

Prostate cancer affects 1 in 3 men over the age of 55. Treatment has high success rates when detected early. Patients choose either surgical or radiation therapy options.

LDR brachytherapy is the process of inserting radioactive material directly into the prostate. These are in the form of multiple I-125 sources (25-32 keV).

BrachyView is a state-of-the-art technique aiming to address issues of source localisation by introducing Timepix detectors into the brachytherapy hardware.



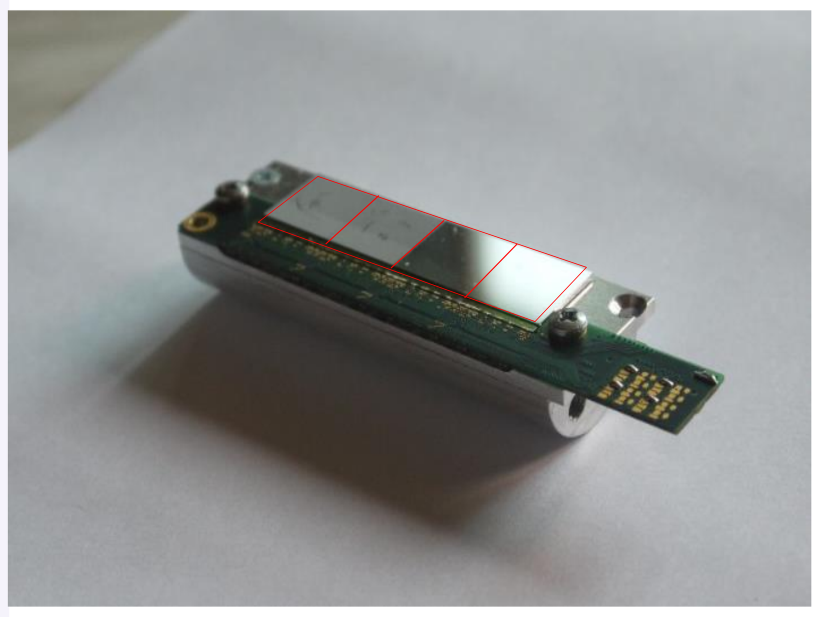
Timepix

Timepix is the latest generation of the Medipix detector family.

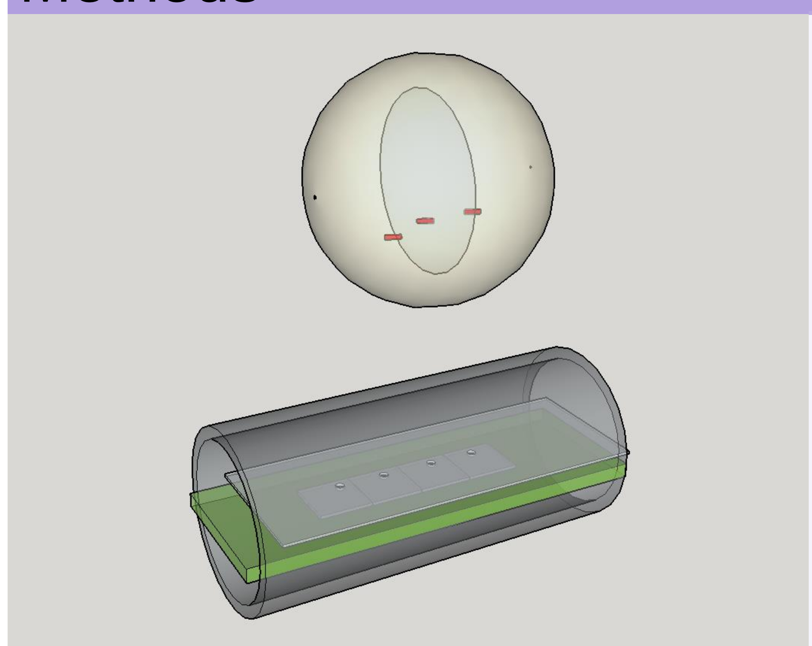
It is a semiconductor detector with several important characteristics:

- High-resolution (55 um pixels, 14 mm² surface area)
- Real-time readout
- Spectroscopic information

While mainly used in high energy phyrics for particle detection and identification, BrachyView proposes a new application by combining Timepix's imaging capabilities with pinhole imaging.



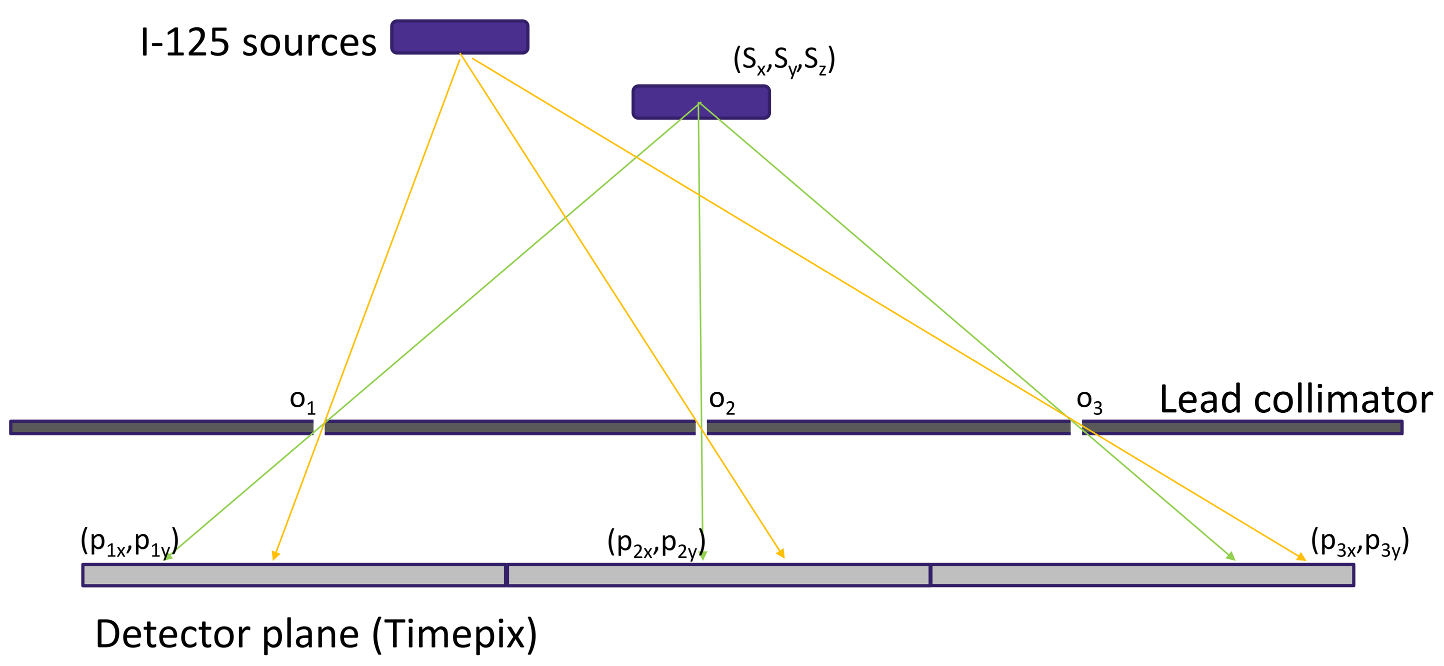
Methods



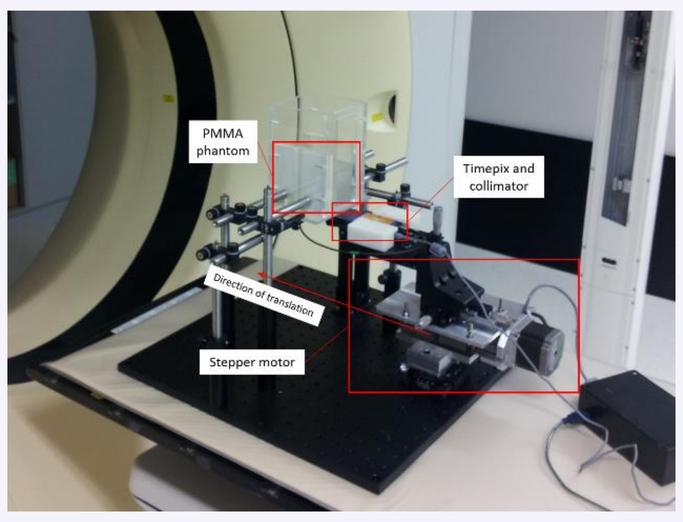
Install lead collimator with Timepix detectors inside TRUS probe.

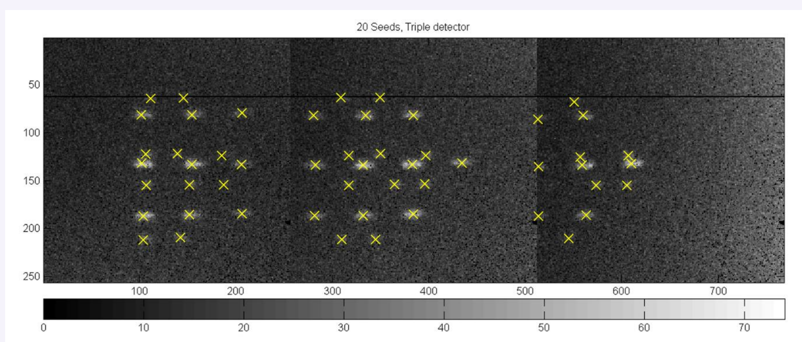
Use pinholes to determine location of real I-125 sources implanted in prostate phantom in real-time.

Early prototypes utilise 3 or 4 pinholes coupled with 3 or 4 individual imaging planes, but future designs may incorporate a larger number of pinholes for more views, and therefore higher accuracy in localising implanted sources.



Latest experimental work involved comparing BrachyView results against those obtained from a full clinical CT scan (using a slice width of 0.8 mm). The results show that real active sources can be localised within 1-2 mm of expected position, within the tolerable range.





Example of 3 Timepix tiled projection images

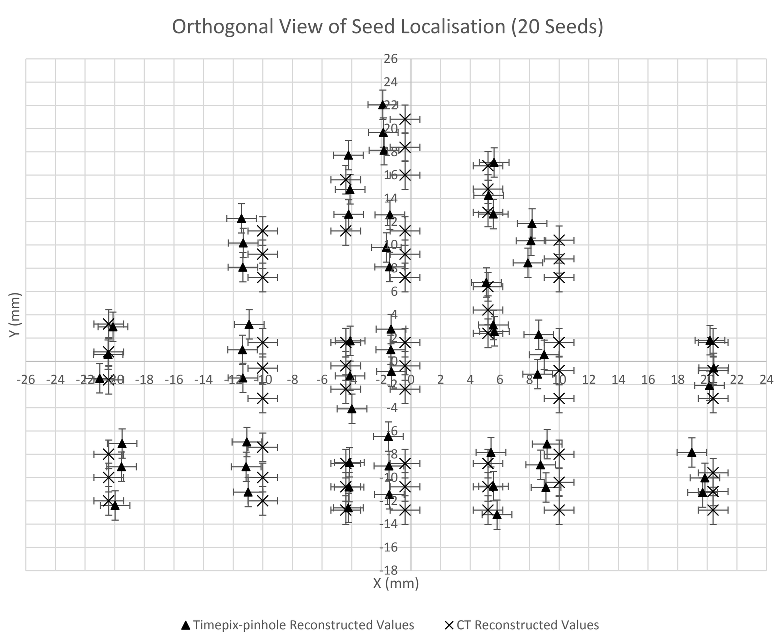
Results

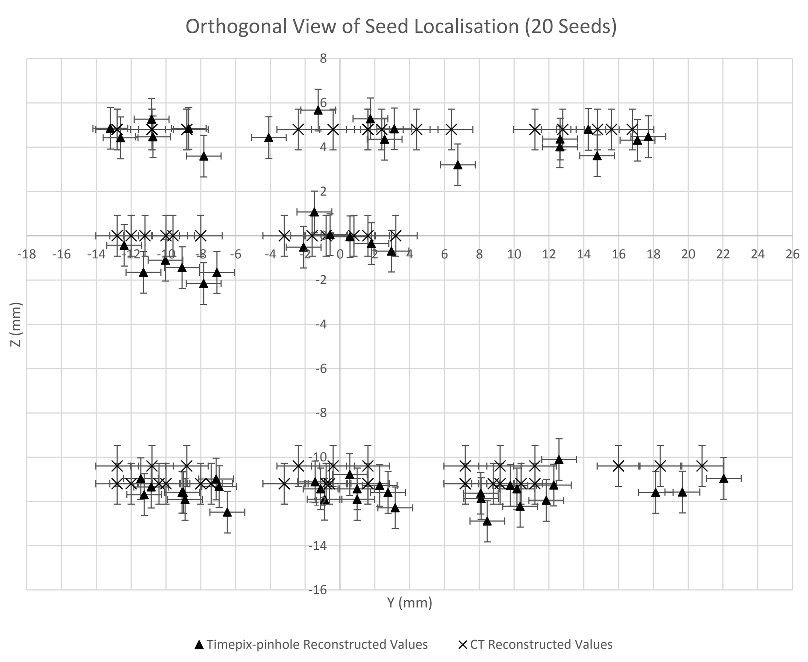
As mentioned previous, the results obtained from linear algebra methods in BrachyView were compared with those obtained with a clinical CT scanner. The centre of mass, as well as the endpoint of each seed projection image was determined manually, and calculations performed in MATLAB to obtain the coordinates in 3D.

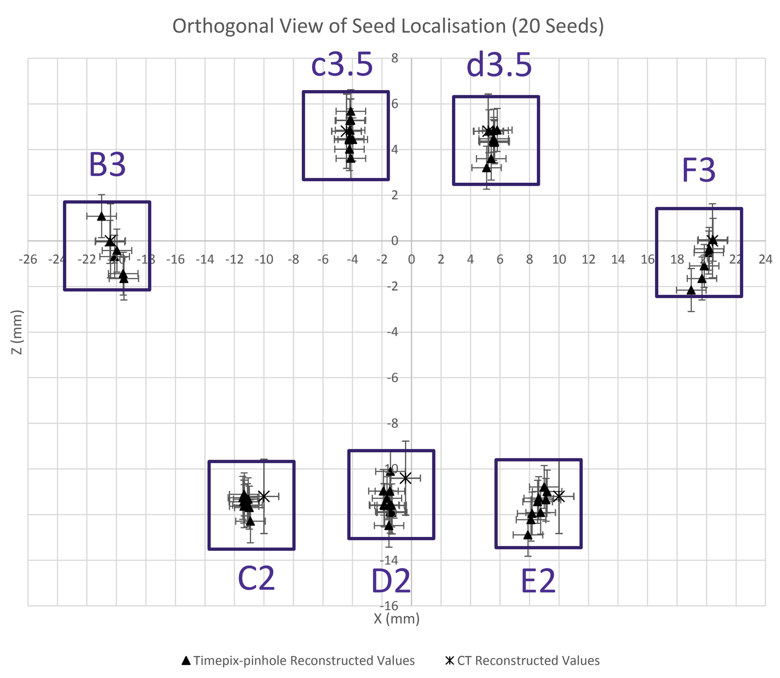
For co-registration of the two datasets, a fiducial-based rigid registration method was used whereby the average of the two outermost coordinates are used to obtain a 'shared origin'. In a similar fashion, the ultrasound dataset may also be co-registered to these dataets.

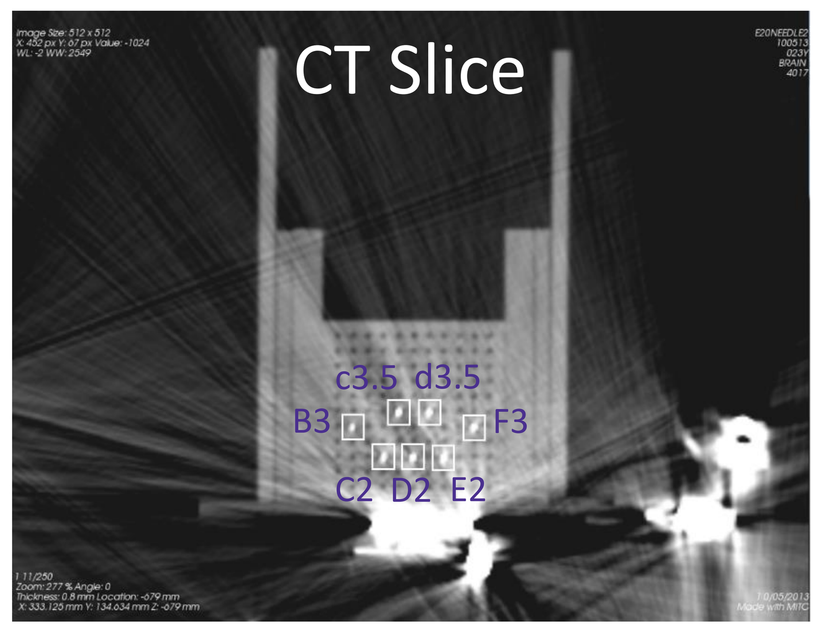
As expected, the results show that seed position can be reconstructed within 1-2 mm of expected positions.

The figures below show 2D orthogonal views of the 3D source position reconstruction.

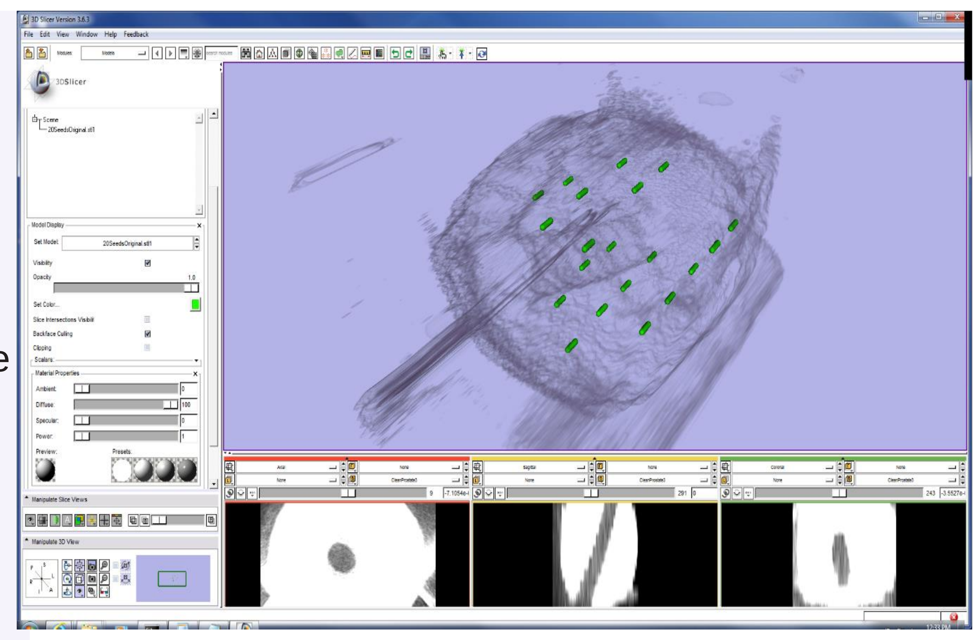








Finally, an intuitive software system is proposed for use of BrachyView in a real clinical situation. This software would provide real-time information of the Timepix dataset co-registered with anatomically relevant information provided by ultrasound data. An example of what this could look like is shown in the figure using data taken from a tissue-equivalent phantom (CIRS Medical Phantoms).



Conclusions

In order to avoid errors in brachytherapy treatment, which would lead to a) unwanted toxicity, or b) suboptimal dose distribution within the affected organ, intraoperative treatment planning methods have been proposed. To date, no robust, cost-effective system exists for prostate LDR intraoperative planning. A novel application of semiconductor hybrid pixel detectors such as Timepix can be a solution. BrachyView utilises multiple Timepix assemblies and has been developed and passed feasibility studies showing source localisation within 1-2 mm of expected positions. Furthermore, for fresh clinical sources, it is predicted that the required statistics for such measurements would occur in less than 5-10 s, allowing a real-time analysis of source distribution in the prostate. This would therefore account for real-time adjustments and lead to a novel dynamic dose planning system, allowing for maximal treatment outcomes.

Future Work

Development of multiple detector prototype for implementation into TRUS probe. Pinhole characterisation and optimisation could also lead to higher accuracy in localisation.

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