Update: Pravda project - imaging update

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On behalf of the

PRaVDA

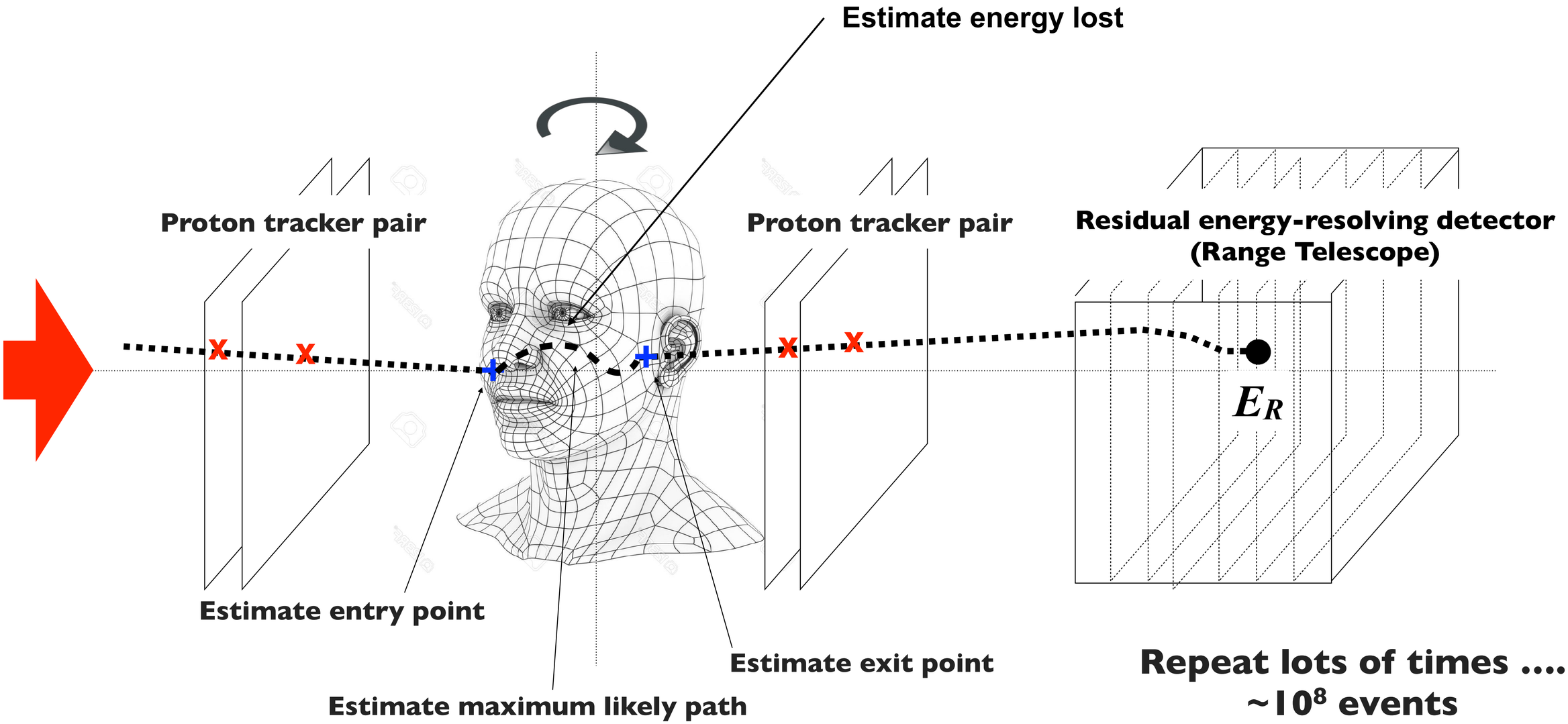
Proton Radiotherapy Verification and Dosimetry Applications Consortium

Funded by wellcome trust

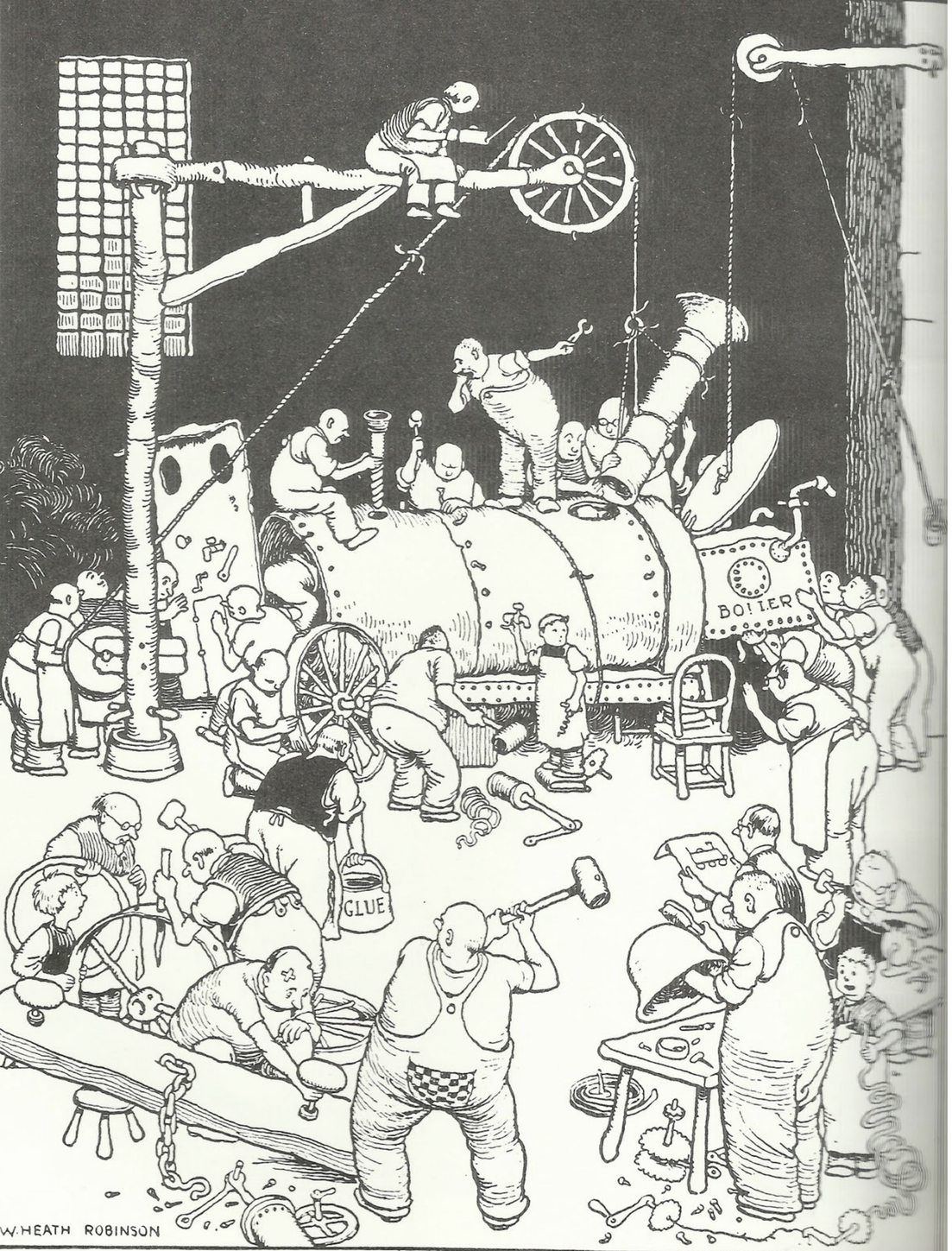
PPRG

1-2 December 2016

Proton CT principles



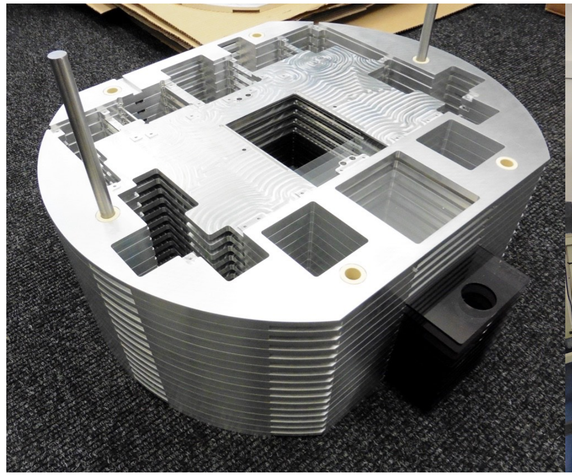
Repeat lots of times ....
~10^8 events

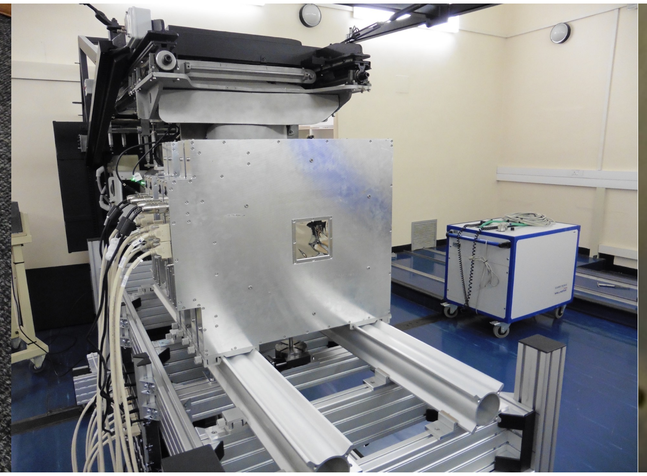


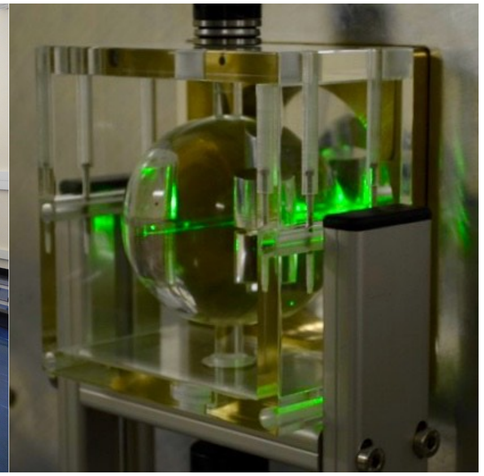
Three and a half years later

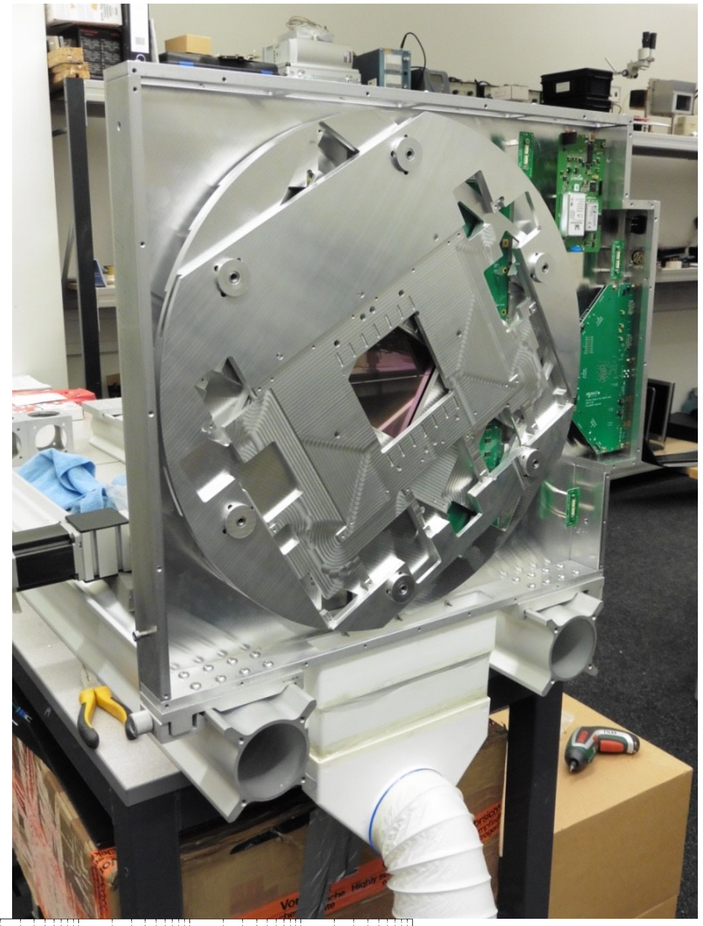
Well, we made it!

Built lots of hardware … Wrote lots of software …

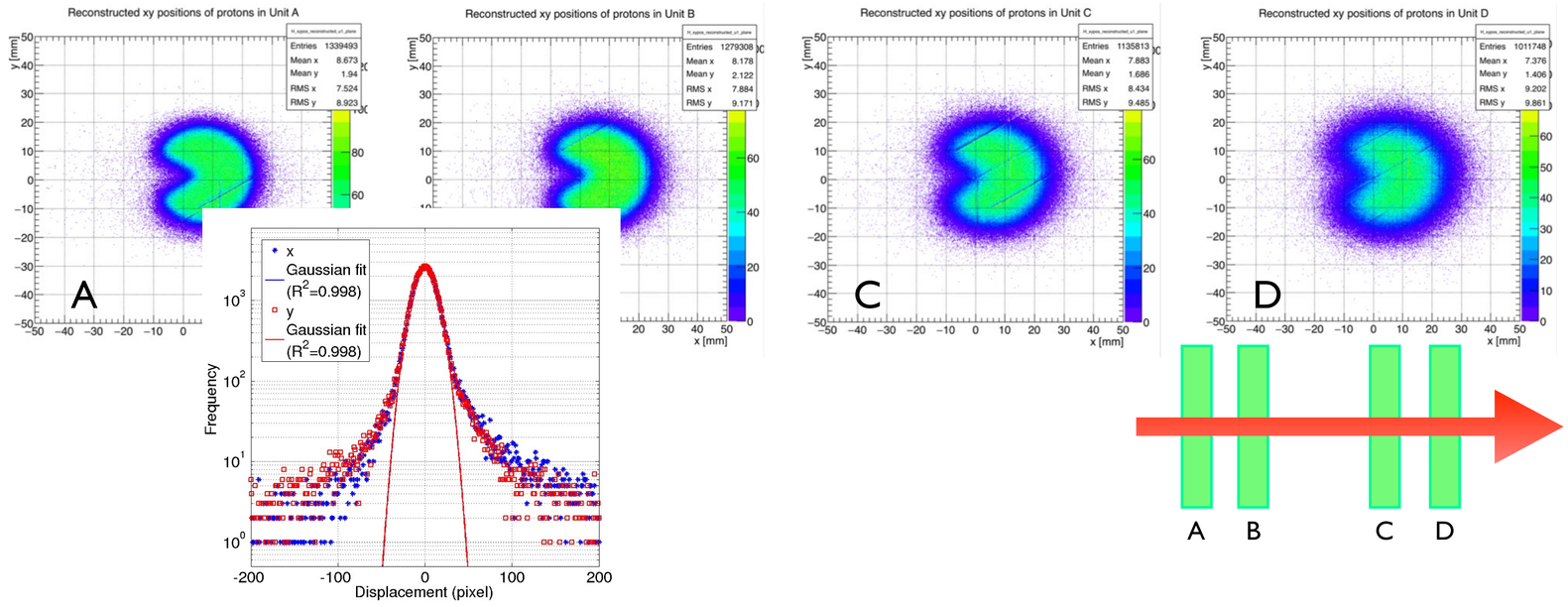


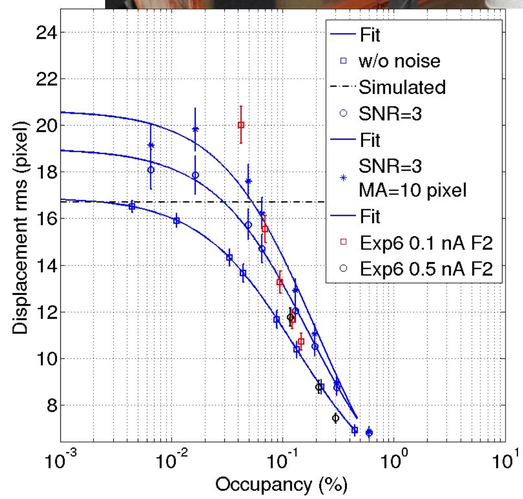






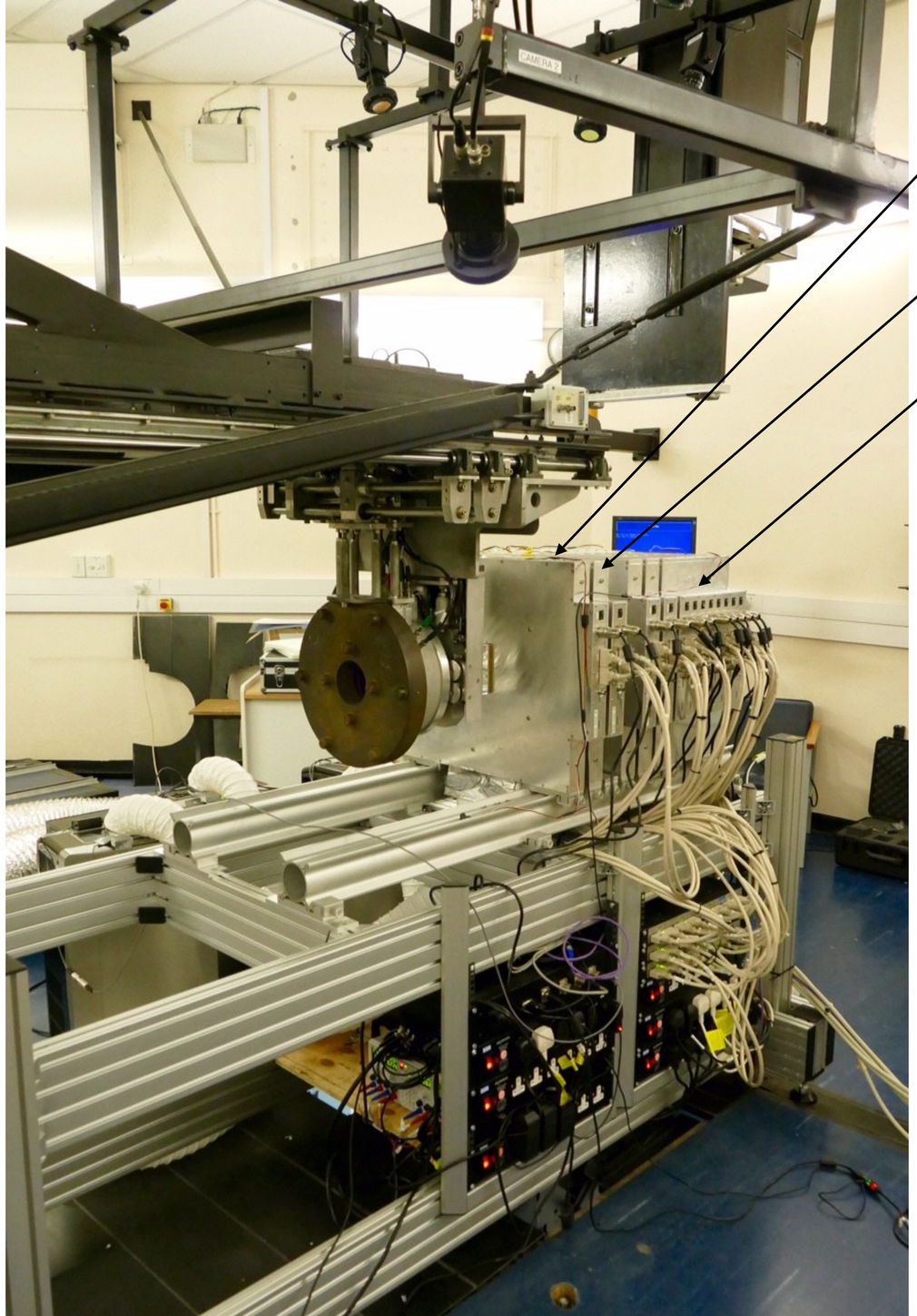
Took lots of measurements …





Had lots of discussions

Shed a few tears



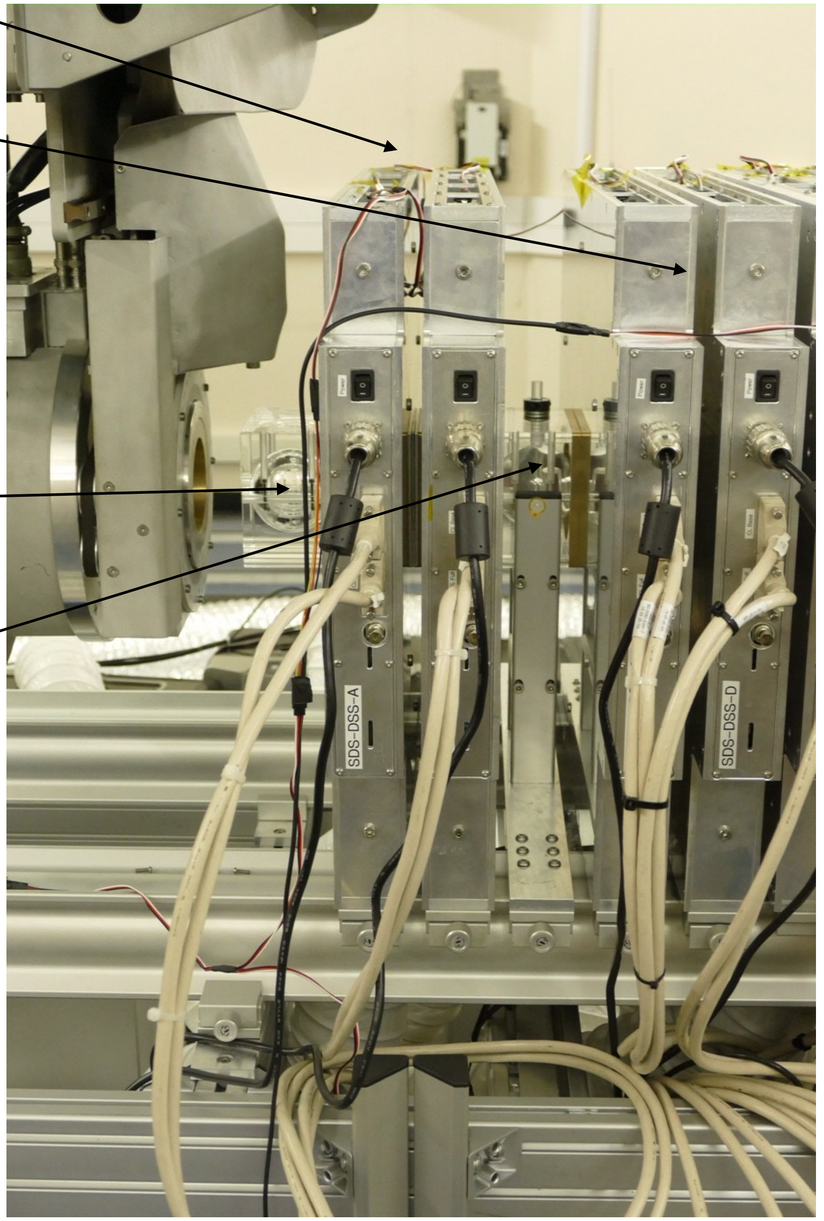
Proximal trackers

Distal trackers

Range telescope

Compensator

Phantom



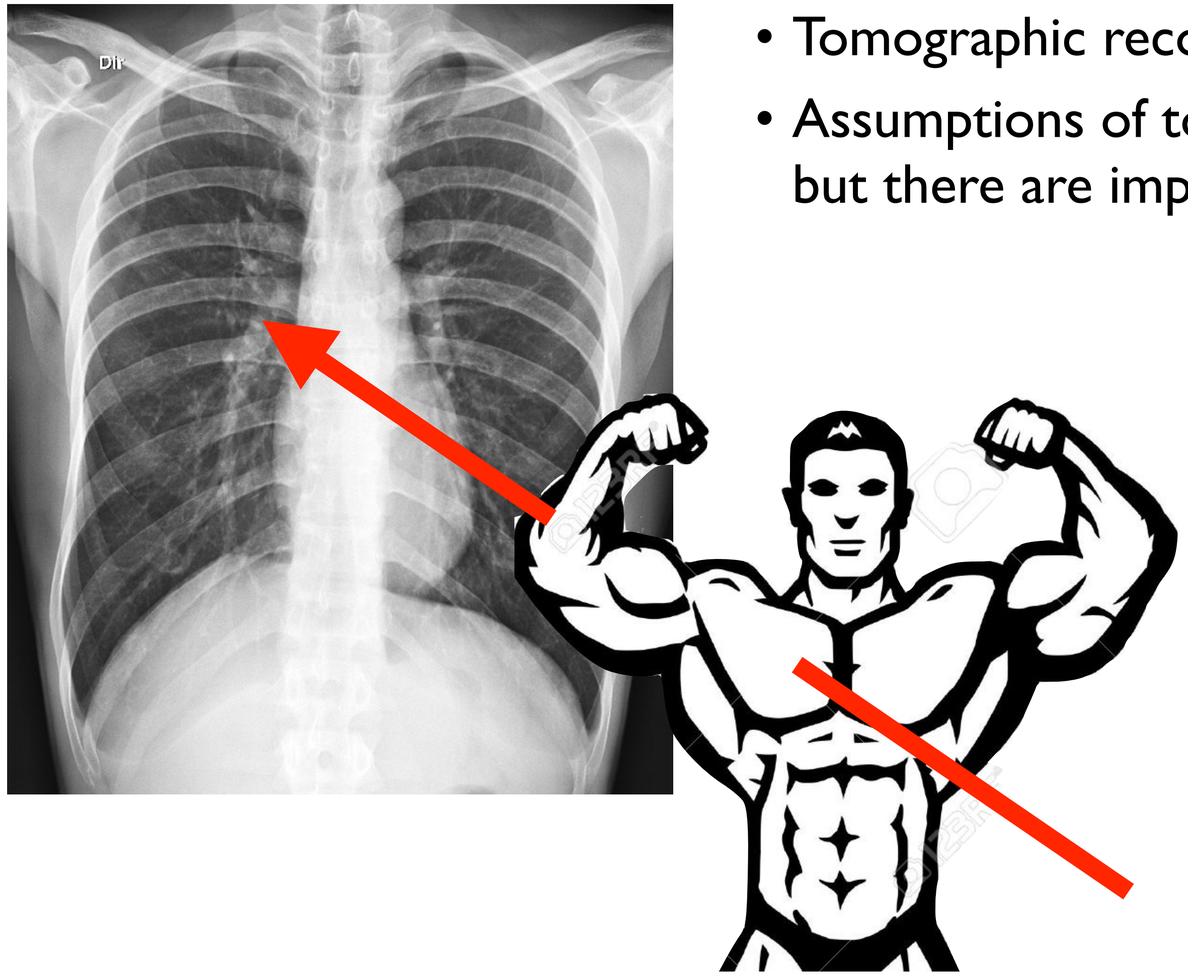
PRaVDA

@

NRF National Research Foundation

iThemba LABS Laboratory for Accelerator Based Sciences

Proton CT reconstruction: getting the data is only half the problem



- Tomographic reconstruction relies on straight rays
- Assumptions of tomography are only weakly violated but there are important consequences

$$RSP(x,y) = i(x,y) **k(x,y)$$

Relative Stopping Power

Backprojected image (blurred image)

2D deblurring kernel

G Poludniowski, N M Allinson and P M Evans, Proton computed tomography reconstruction using a backprojection-then-filtering approach, Physics in Medicine and Biology Journal link tile ends, **59**, (2014)

backprojection-then-filtering

Total analytic solution

Cope with non-linear paths

Correction for finite reconstruction volume

Incorporate differing most likely path algorithms

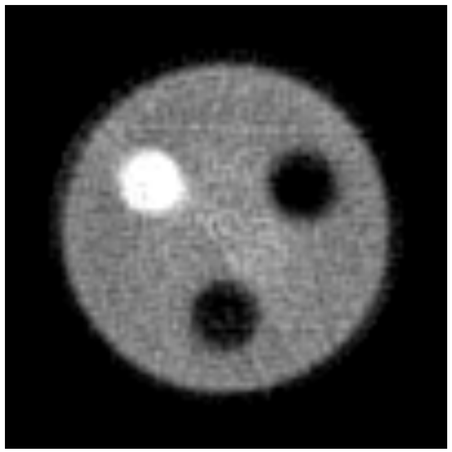
Computationally efficient

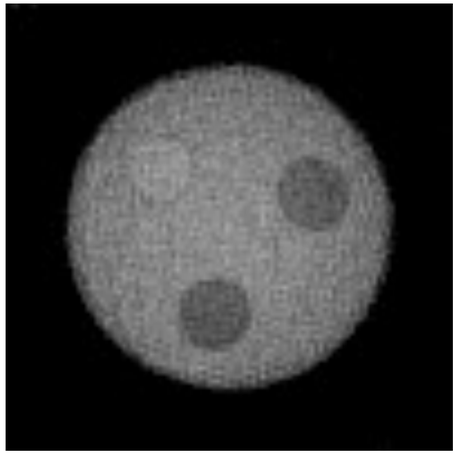
Relative stopping-power pCT

high contrast

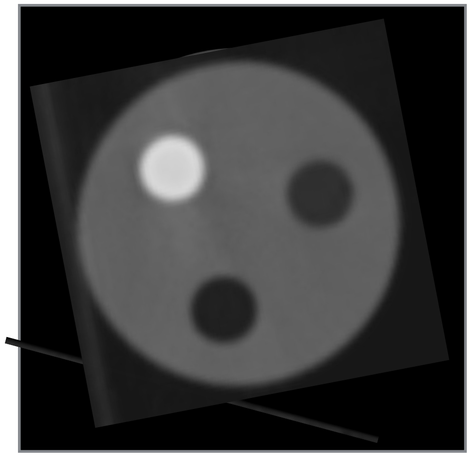
low contrast

pCT





cone-beam CT

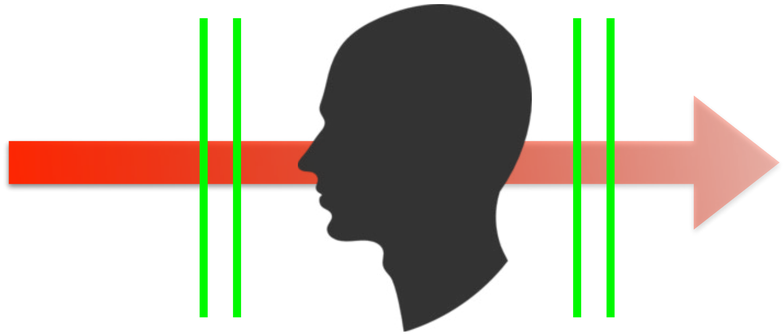


125 MeV beam with compensator

180 projections at 1° steps

~1M protons tracked per projection

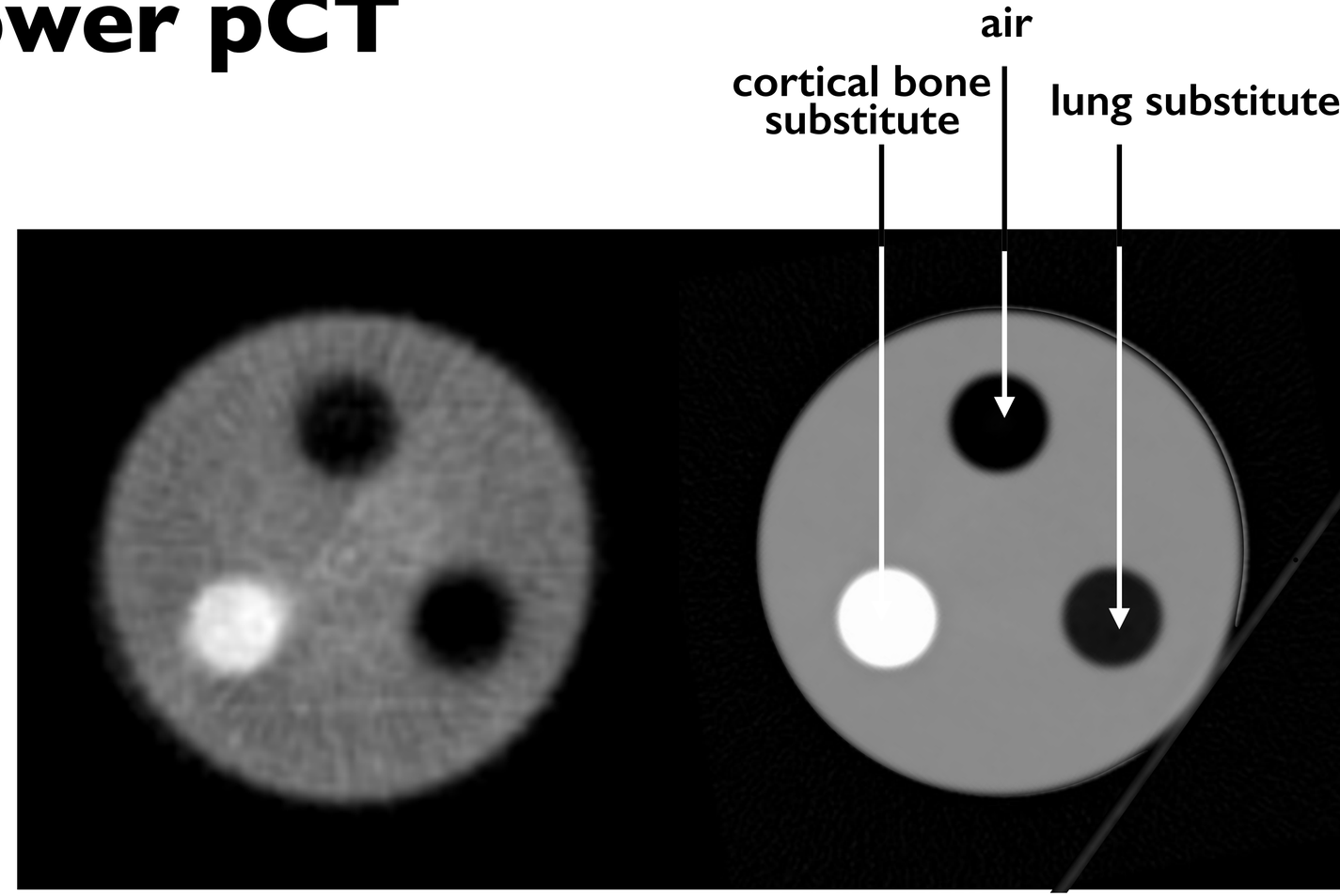
Relative scattering-power pCT



Total deflection-angle squared determined for each proton based on measurements of spatial position in each of the four tracker units. Total mean-square angular deflection can be approximated as:

$$\vartheta^2 = (\Omega_{x,\text{in}} - \Omega_{x,\text{out}})^2 + (\Omega_{y,\text{in}} - \Omega_{y,\text{out}})^2,$$

Direction cosines of proton in *x* and y directions, orthogonal to beam direction. Subscripts in and out refer to first and second pairs of detectors



proton scattering-power CT

x-ray CT

J. T. Taylor et al., An experimental demonstration of a new type of proton computed tomography using a novel silicon tracking detector, Med. Phys. **43**, 6129 (2016)

Proton CT modalities

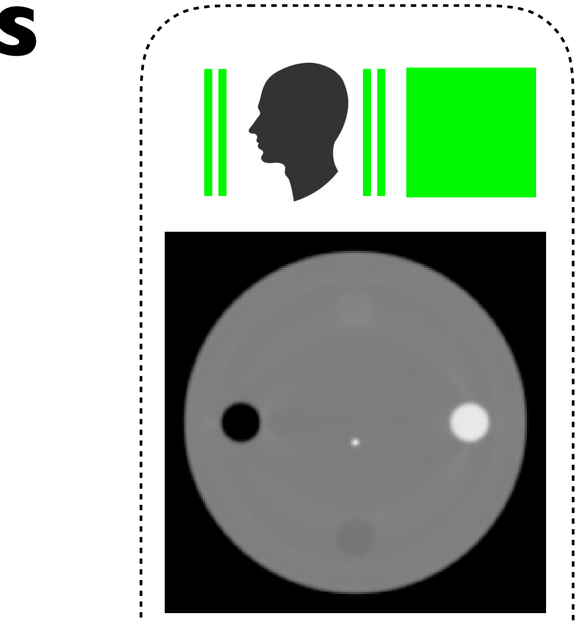
Stopping-power – most crucial quantity for PT planning

For biological materials: stopping-power, scattering-power and attenuating-power can be related to electron density (Kanematsu *et al*., Medical Physics **39**, 1016, 2012)

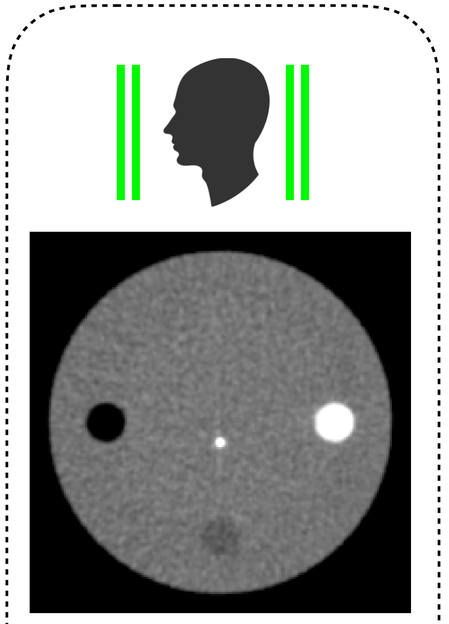
Scattering and attenuation power only require trackers – lower system complexity

Possible to combine two or more modalities to yield improved quality pCT

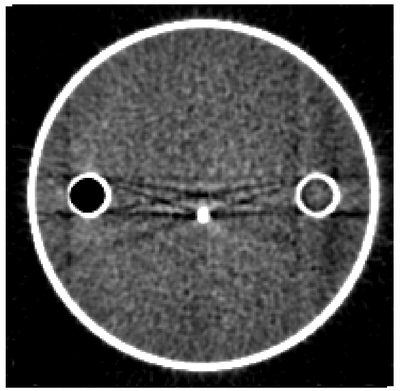
UK Patent pending



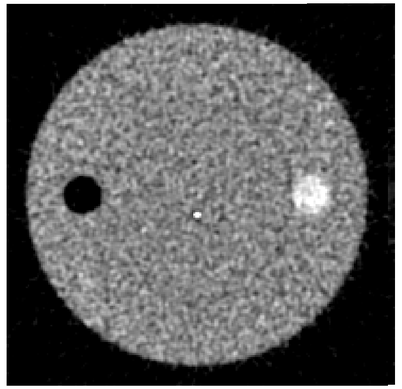
relative stopping-power



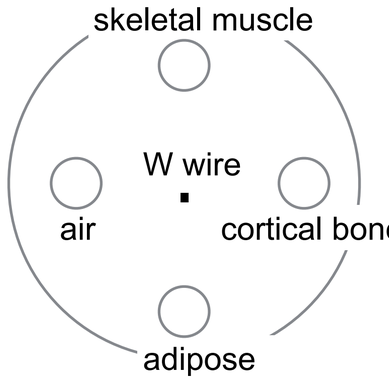
relative scattering-power



relative straggling-power



relative attenuating-power



Simulated

Just returned
from 2 weeks at:

iThemba
LABS

With over 10 TB of data!

Most of the iThemba Team

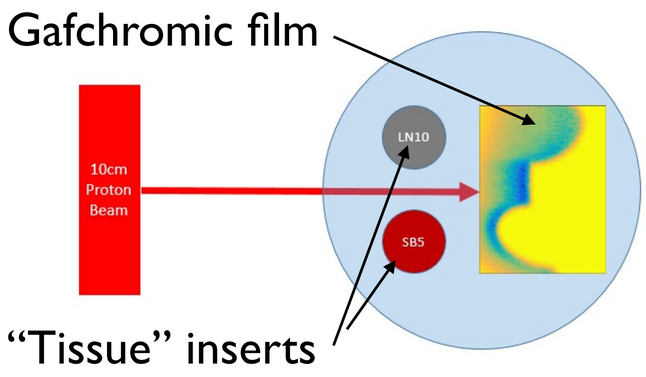
6-insert phantom relative stopping-power pCTs (good stats)

(*scattering and attenuation pCTs come free*)

2 new phantoms

Biological (*meat*) phantom

Direct proton range measurement phantom



+ 1.5 TB of calibration data!

Summary

Proton imaging is challenging but proven! Certainly for broad beam delivery.

Treating and imaging with the same radiation – "use the same ruler"

Imagery will be of clinical quality – certainly better than cone-beam!

PRaVDA concept is integrated instrument for entire PT workflow

PRaVDA is fully solid-state

Need to optimise sensors and supporting engineering

Need to explore different pCT modalities and fusion with other imagery

Need to integrate with current and future delivery systems (pencil beam)

Need to integrate into robust, effective and efficient workflow

Need to undergo trials

Need to commercialise

Need to clinically use!

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