

Comparison of Proton Stopping Power Measurements of Animal Tissues From Proton CT and X-Ray CT Systems

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INTRODUCTION

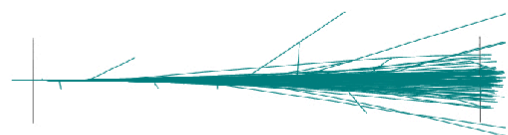
Proton Imaging can help reduce range uncertainties by directly measuring proton stopping power

We aim to:

1. Develop a proton imaging system based on well-established fast scintillator technology.
→ High-performance, low-cost measurements
2. Achieve lower dose to the patient relative to equivalent x-ray images.
3. Produce spatially sharp images.
4. Images free of artifacts from high-Z implants.

Multidisciplinary team of detector physicists, medical physicists, computer scientists, and radiation oncologists:

METHOD

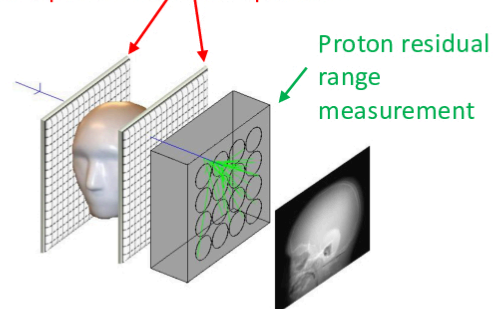


Multiple Coulomb Scattering spreads protons ~4mm after 20 cm water

Detector measures individual protons.

Turn down beam intensity. Proton rate ~ few MHz
Use of individual proton trajectories produces spatially sharp images

Tracking to measure proton transverse position

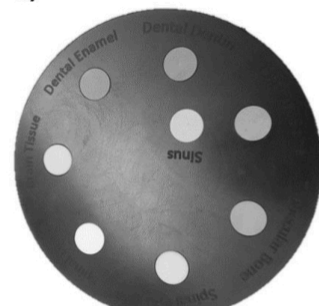


System uses pencil beam scanning proton beams.

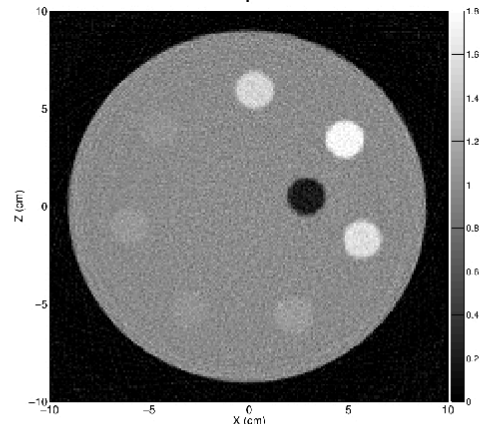
We acquire pCT images with the system operating with a scanning pencil beam at the Northwestern Medicine Chicago Proton Center. Compare with relative stopping power (RSP) maps derived from x-ray CT images using stoichiometric calibration.

RESULTS

Check with custom cylindrical phantom with various inserts



1 mm thick pCT slice

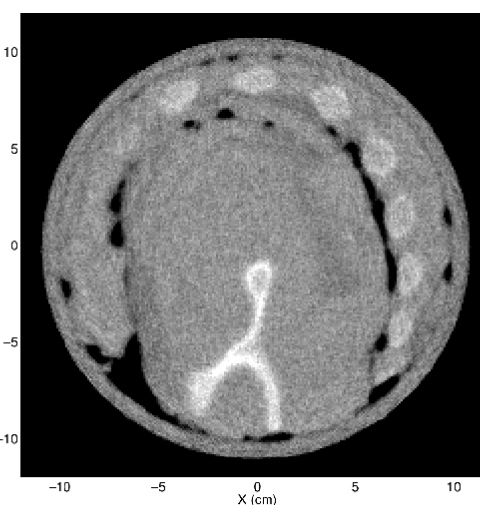


Insert	RSP	RSP from pCT image In ROI for each insert (Statistical uncertainty only)	Difference (pCT - Nominal)
Sinus	0.200	0.192 ± 0.002	-0.008
Enamel	1.755	1.768 ± 0.002	0.013
Dentin	1.495	1.504 ± 0.002	0.009
Brain	1.040	1.043 ± 0.002	0.003
Spinal Cord	1.040	1.046 ± 0.002	0.006
Spinal Disc	1.070	1.079 ± 0.002	0.009
Trabecular Bone	1.100	1.106 ± 0.002	0.006
Cortical Bone	1.555	1.570 ± 0.002	0.015

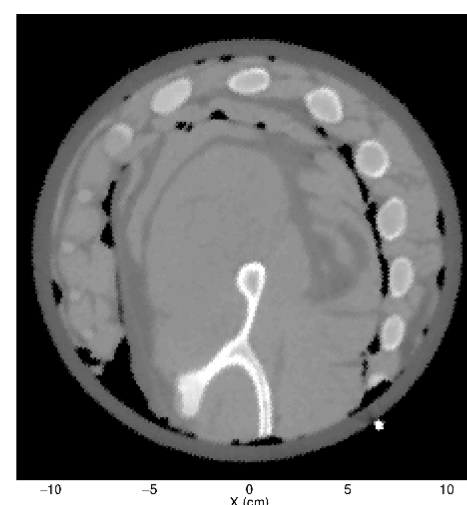
Pork shoulder and ribs



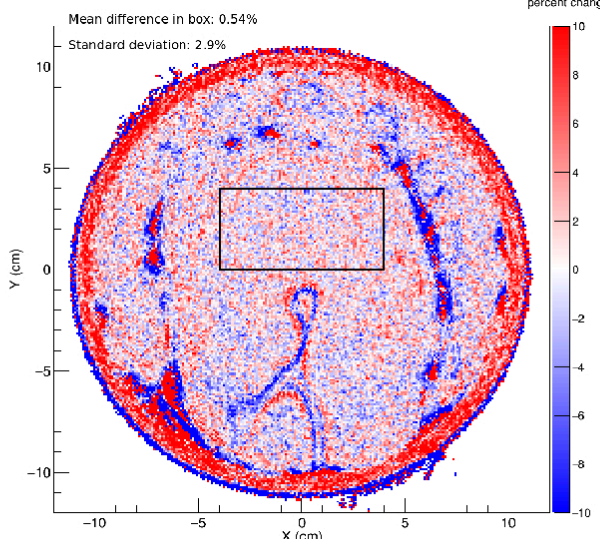
1 mm thick pCT slice



Slice derived from x-ray CT



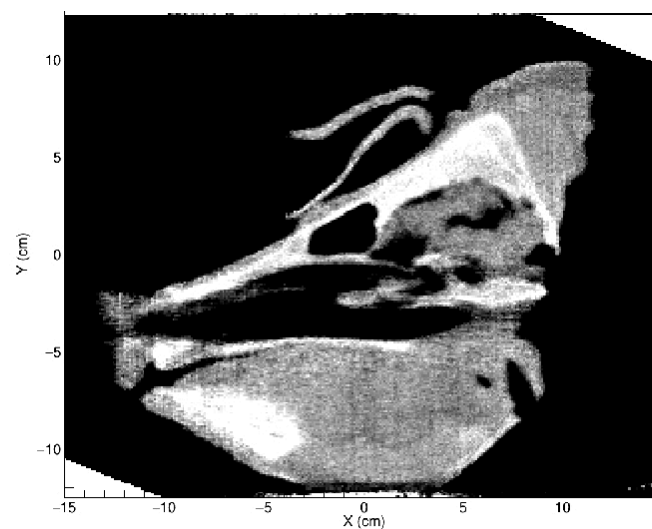
pCT - x-ray CT difference image



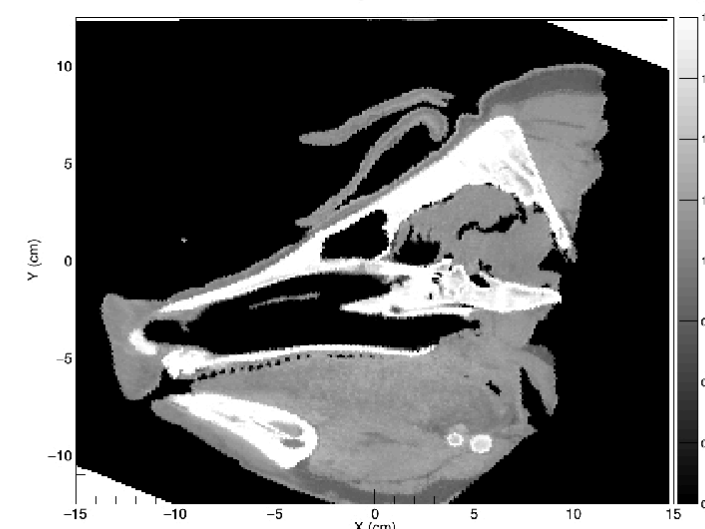
Pig's head



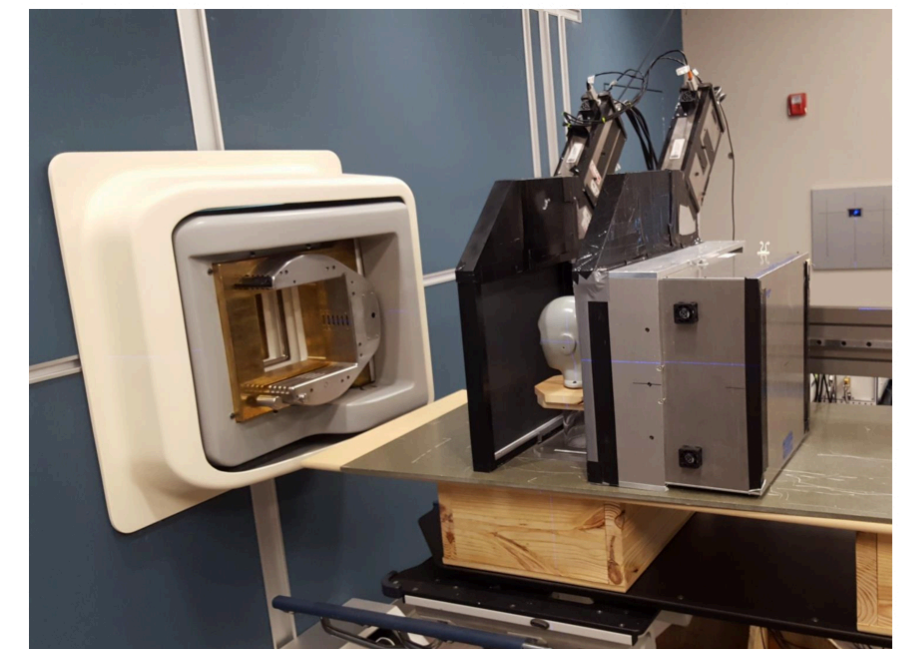
1 mm thick pCT slice



Slice derived from x-ray CT



CONCLUSIONS



We have characterized the first pCT images of complex animal tissue samples mimicking human patients in size and composition. In comparison, x-ray CT images using stoichiometric calibration produce good agreement in these samples.

In a 1 mm thick pCT slice of a sample of pork shoulder and ribs, the average agreement is better than 1% in uniform regions of muscle, fat and bone. Local discrepancies occur in regions with high density variation. Noise in the pCT slice could be improved by using more protons, and with algorithm improvements in progress.

Further comparisons with complex samples are in progress. An image of a pig's head demonstrates the capability of imaging complex structures. A careful 3D alignment is in progress for the comparison with x-ray CT.

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*Our partners for
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