The Impact of Using Dual-Energy CT for Determining Proton Stopping Powers of Real Tissues

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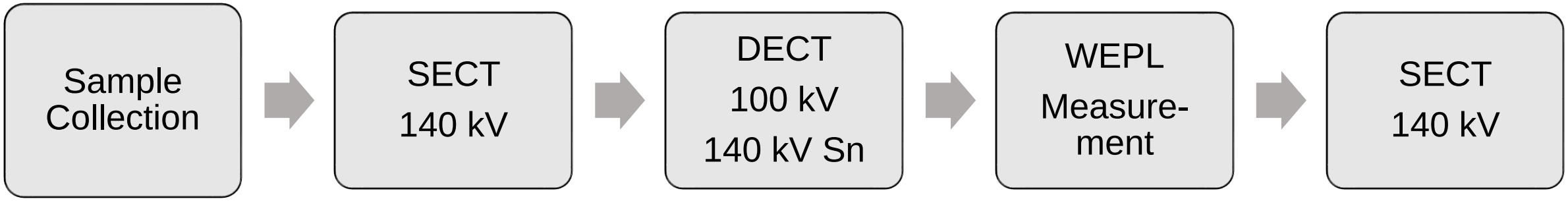
Motivation: Reducing Range Uncertainties in Proton Therapy

- Dose calculation in particle therapy is based on the Stopping Power Ratio (SPR) of tissues
- Clinically: SPR values are obtained using single energy Computed Tomography (SECT)
- Uncertainties in SPR of up to 2% for variations in human tissues (Yang *et al.* (2010))
- In clinical practice, range margins of 3.5% or more are used to ensure target coverage, but risking damages to organs nearby
- Potential solution to improve SPR prediction: Dual energy CT (DECT)
- Proposed formalisms to convert DECT to SPR need experimental validation
- Aim of this work: Validate DECT determined SPR with tissue substitutes and animal tissue samples

Methods and Materials: Workflow



Fresh animal samples at room temperature from different butchers

Siemens Somatom Definition Flash

Siemens Somatom Definition Flash

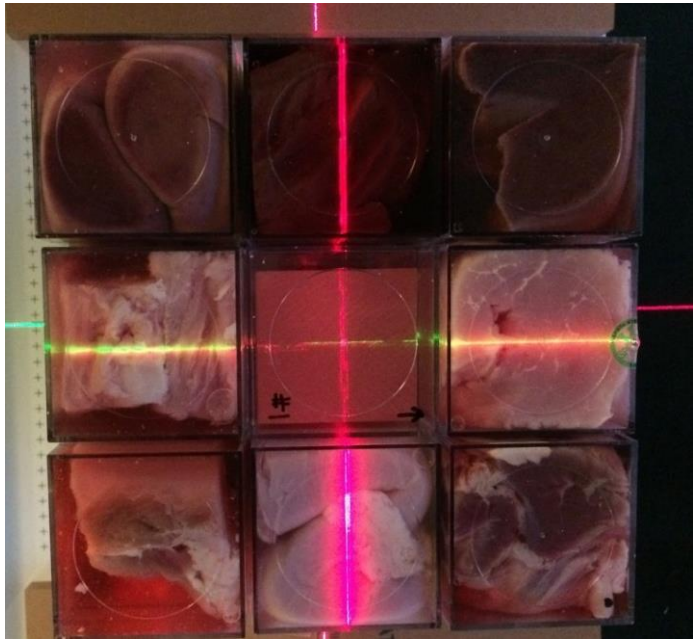
Dose extinction

Check for tissue movement and deformation

Methods and Materials: Samples

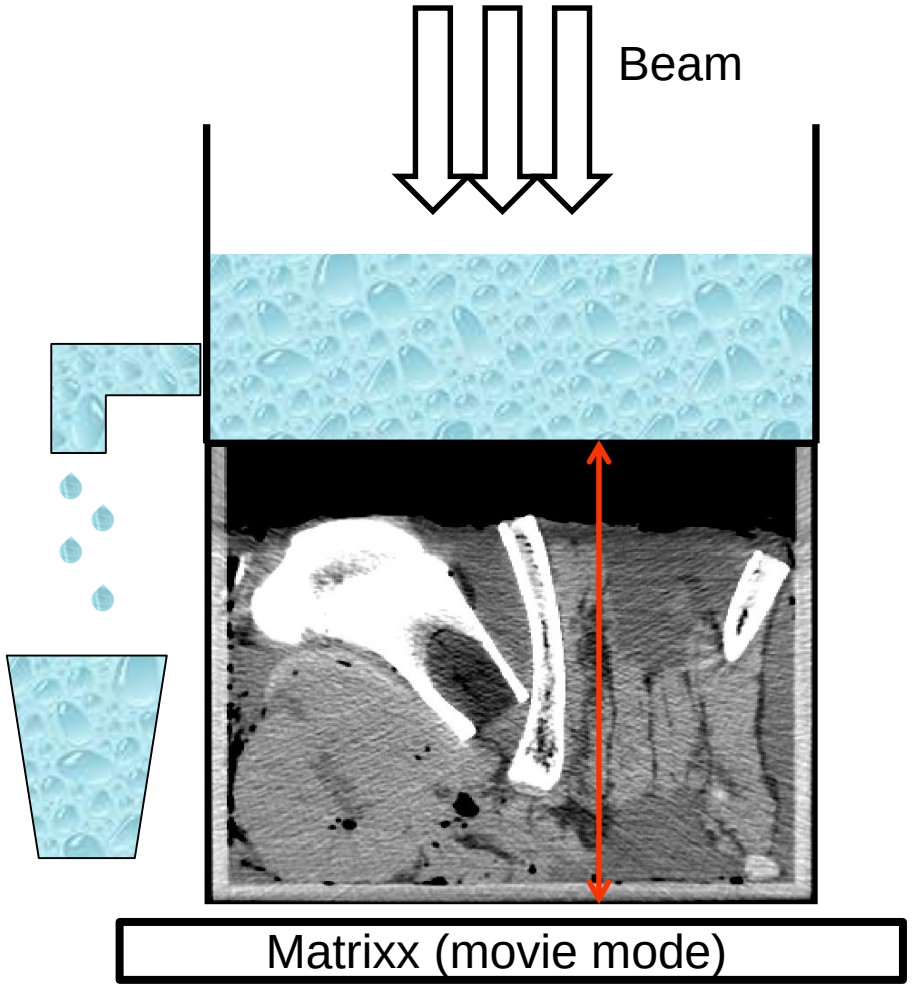
Tissue substitutes

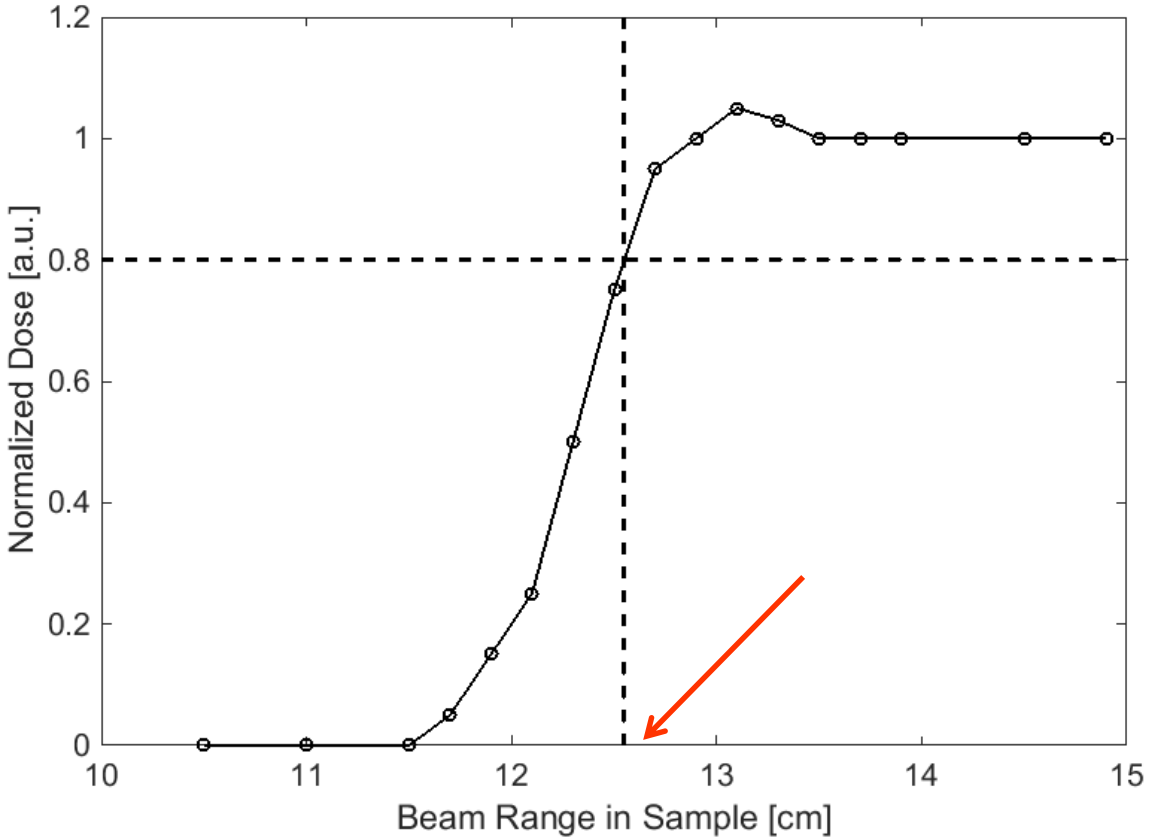
Animal tissues



No.	Tissue
1	Pig Stomach
2	Pig Blood
3	Pig Muscle
4	Cow Muscle
5	Pig Kidney
6	Veal Brain
7	Pig Liver
8	Pig Rib
9	Pig Leg
10	Cow Tailbone
11	Pig Vertebra
12	Pig Scapula

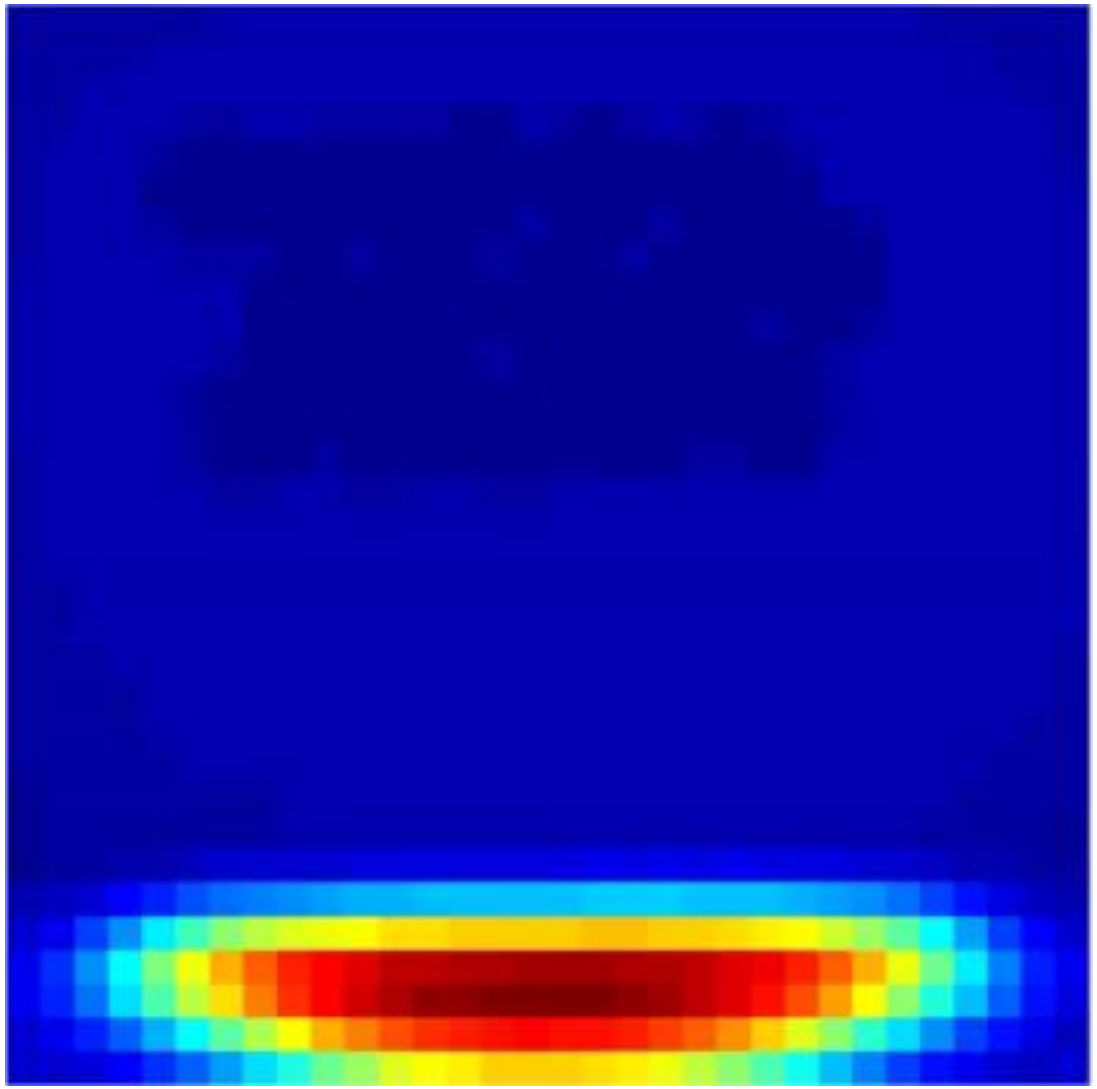
Dose Extinction: Measurement of the WEPL





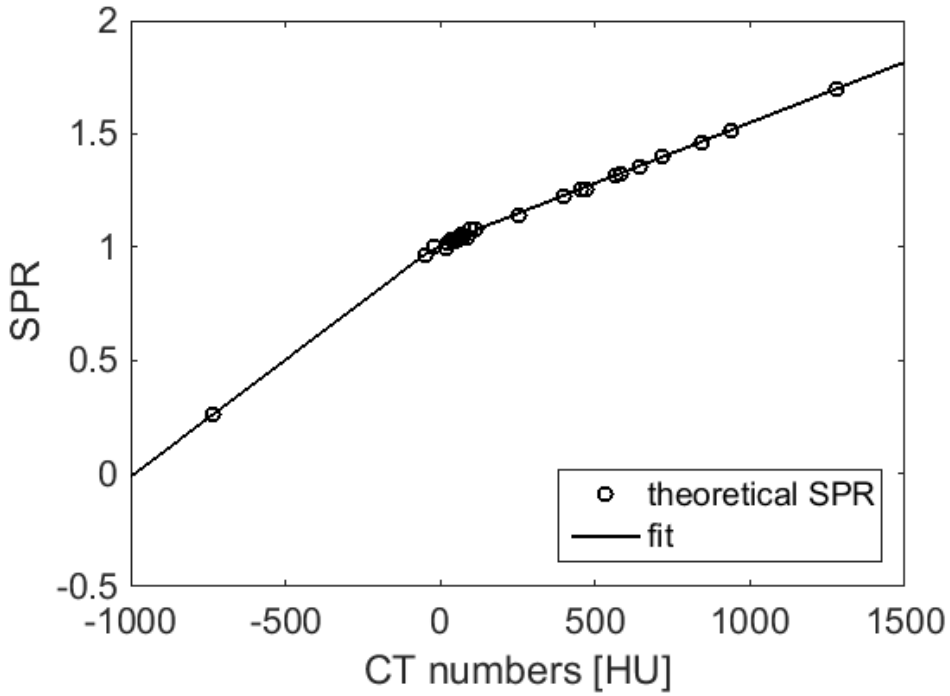
Measurement time: 3-5 min
Produces 1000+ WEPL values

Dose Extinction: Measurement of the WEPL



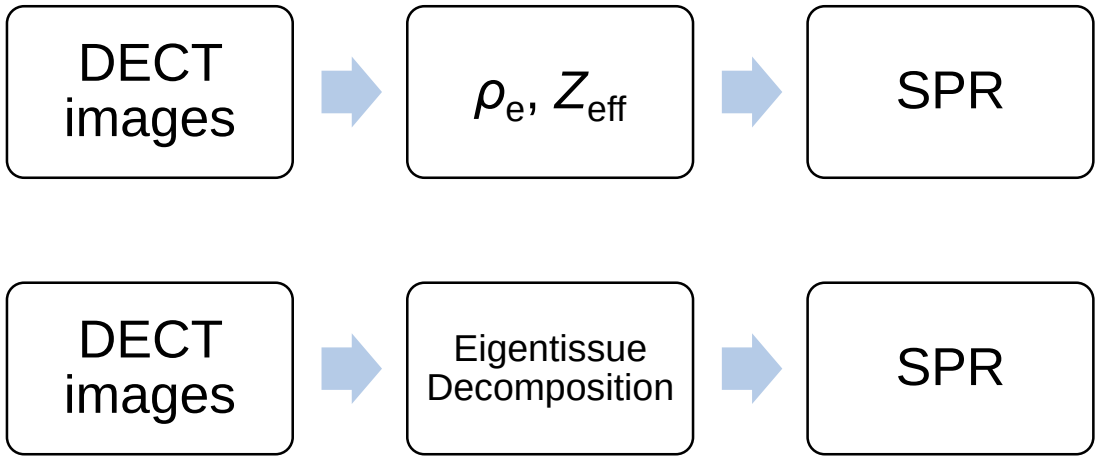
CT Scan and Conversion to SPR

SECT



- Stoichiometric calibration, Schneider *et al.* (1996)

DECT

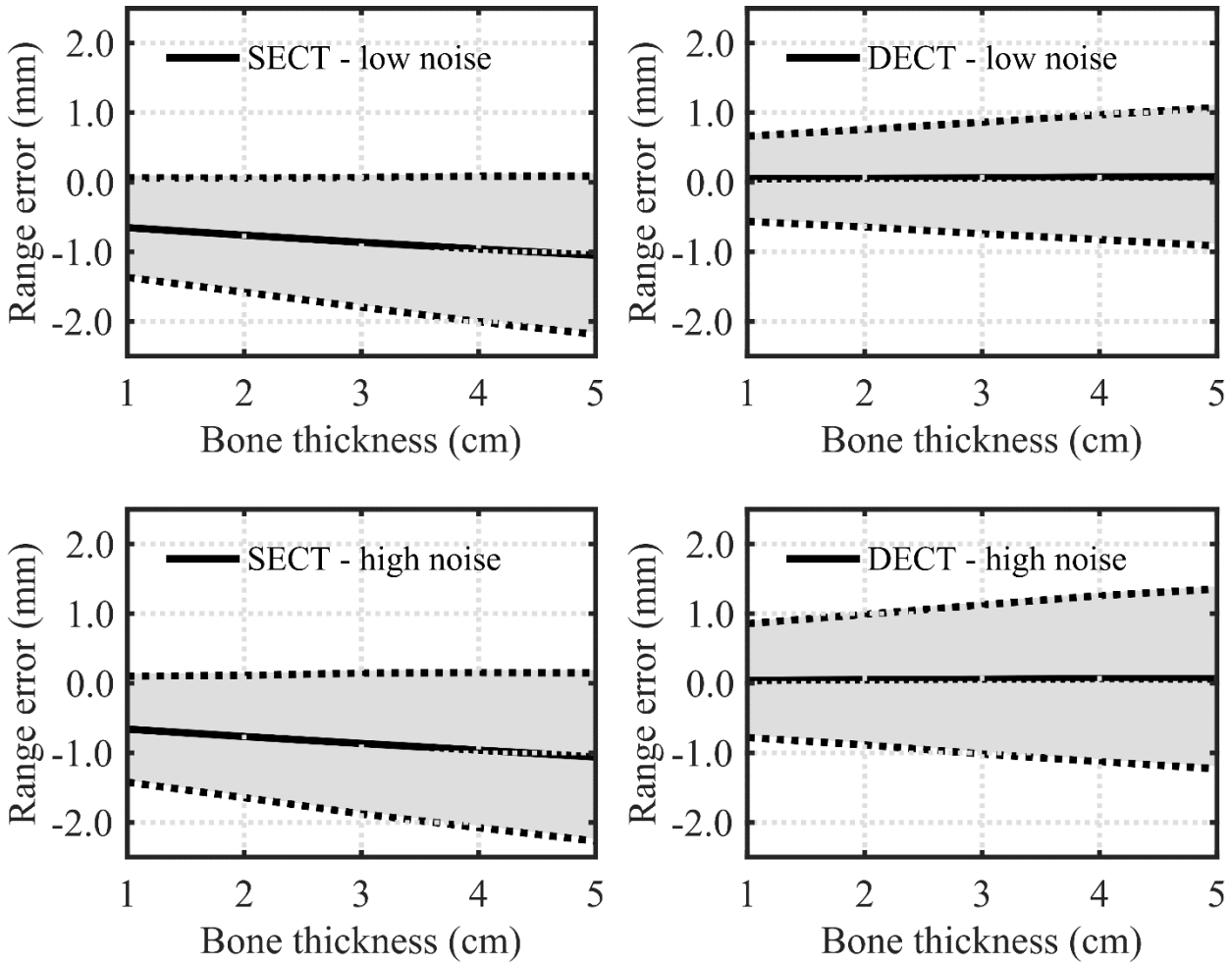


- Bourque *et al.* (2014)
- Lalonde and Bouchard 2016

On the performance of dual-energy CT for determining proton stopping powers

- Simulate SECT and DECT images without noise using the *ImaSim* [1] software
- Apply CT-to-SPR conversions
- Calculate PDFs of SPR errors for soft tissues and bones
- Calculate the range of a proton beam in water using randomly sampled SPR errors from cumulative PDFs
- Repeatedly sample the range error by comparing to range without SPR error
- Repeat with different noise levels

→ See our poster!

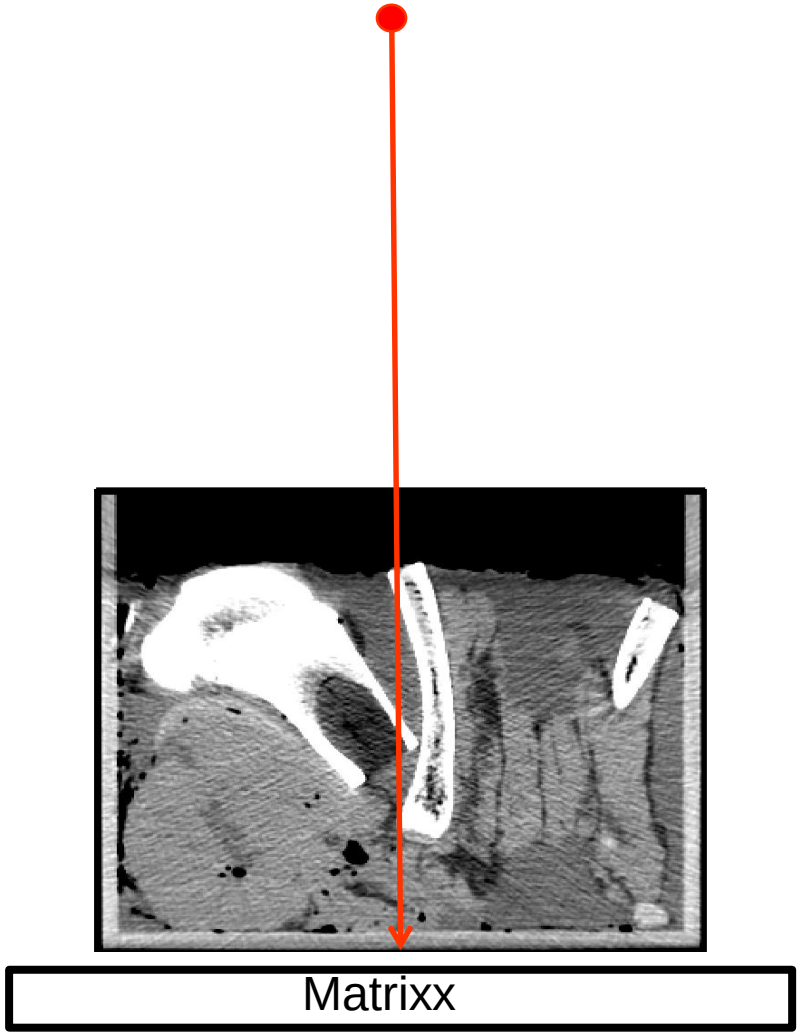


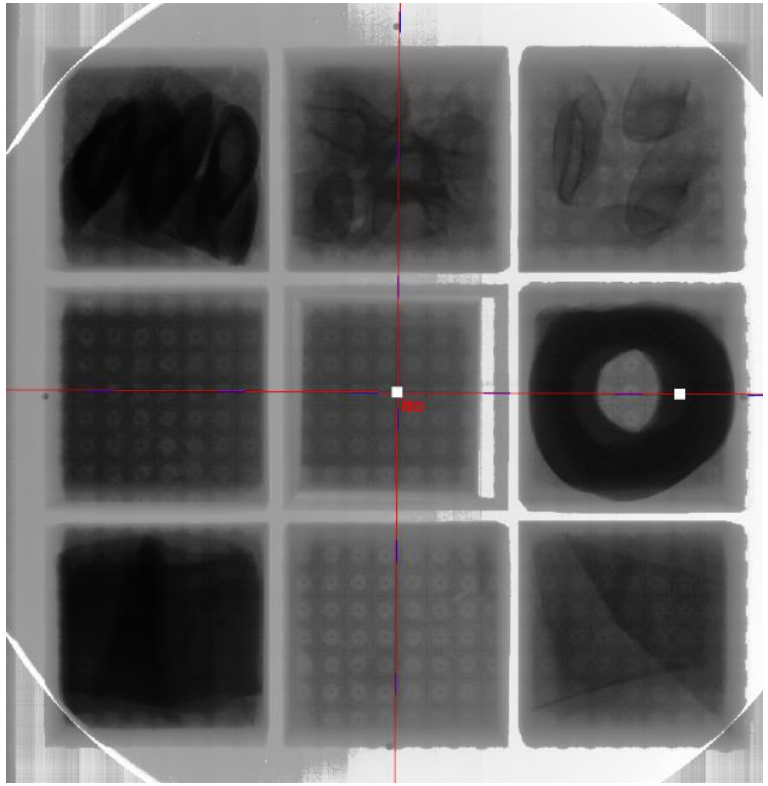
Calculation of WEPL from SECT and DECT

Ray tracing

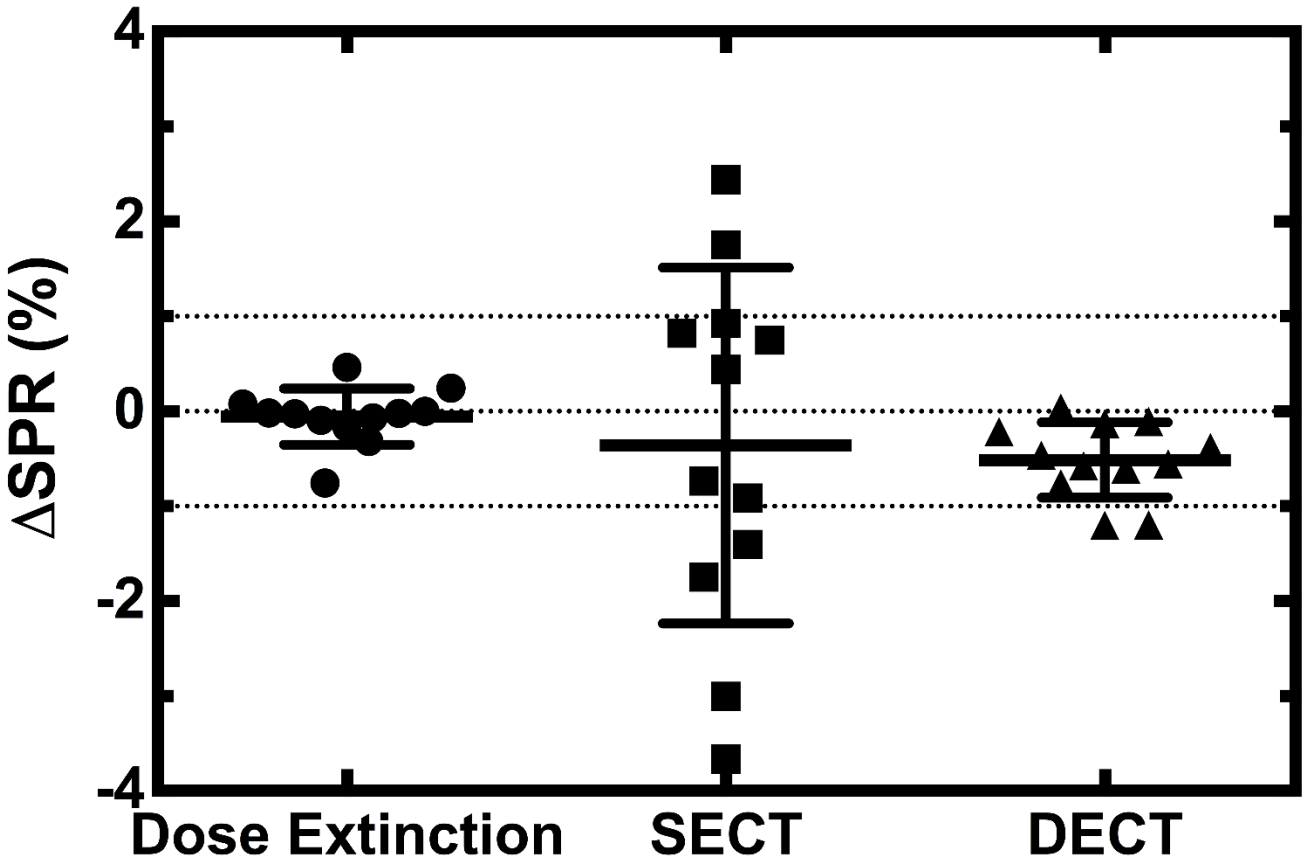
SPR map (from SECT/DECT)

Averaging over detector size

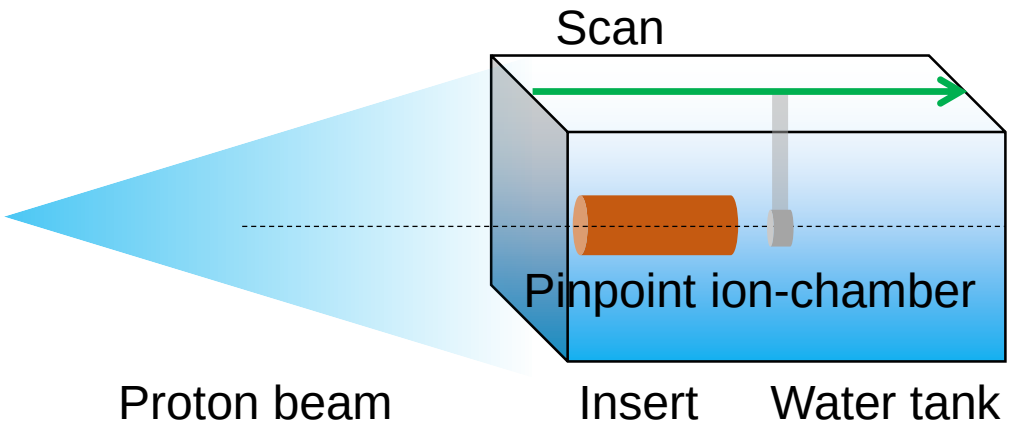


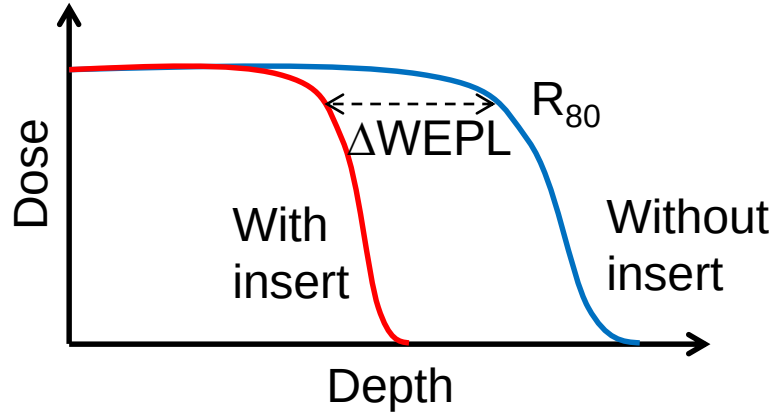


Validation with Tissue Substitutes

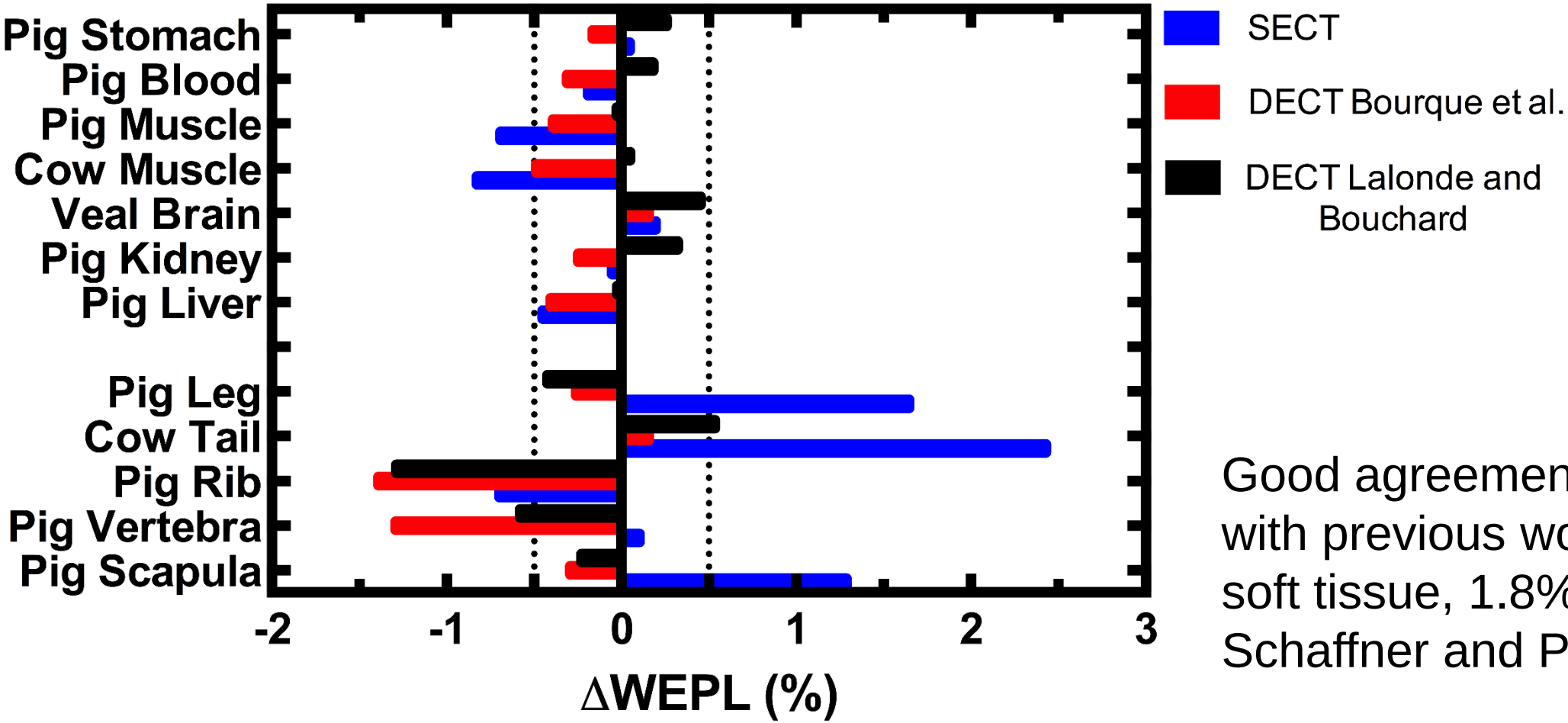


Reference SPR:



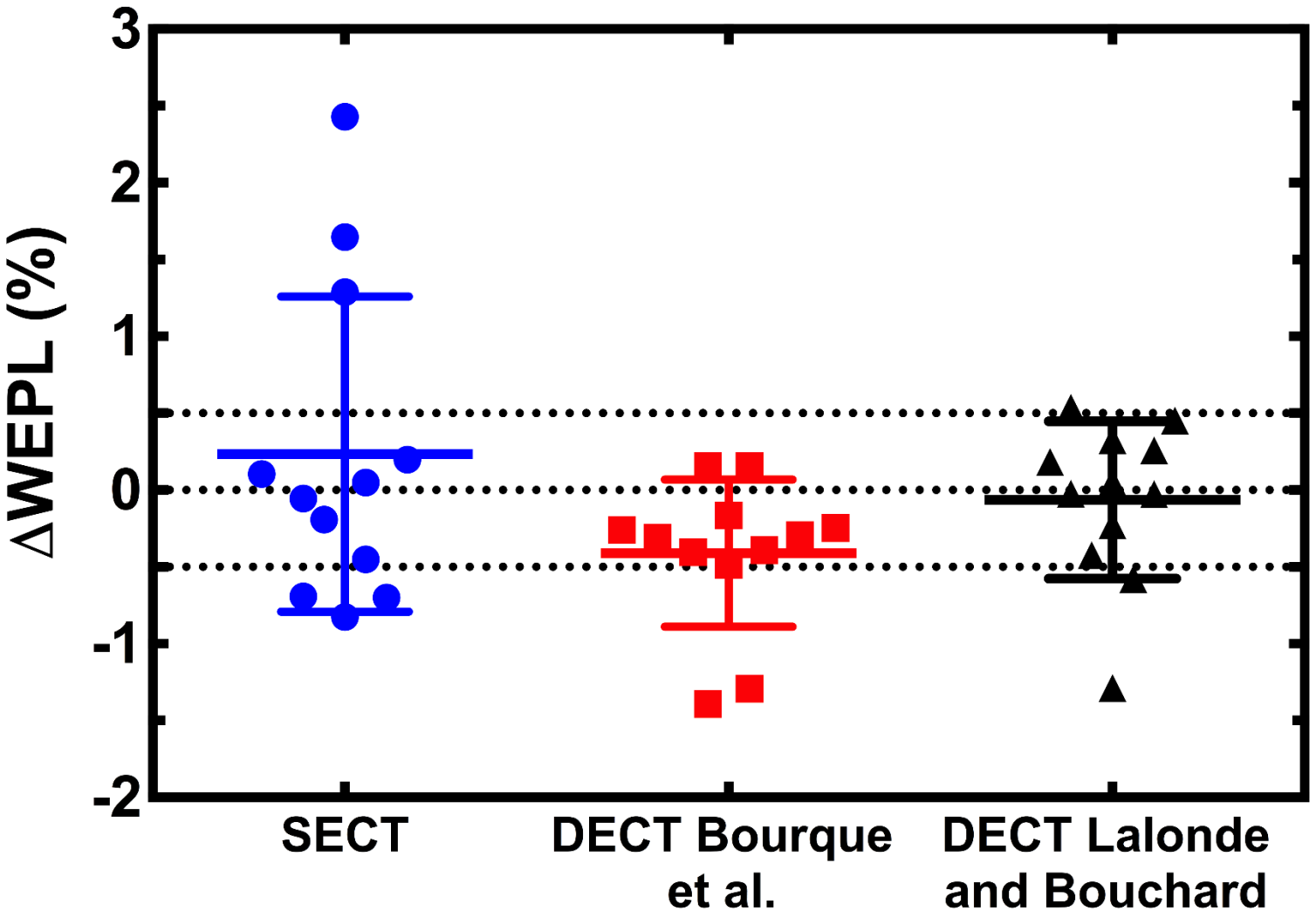


Animal Samples



Good agreement of SECT with previous work: 1.1% in soft tissue, 1.8% in bone; Schaffner and Pedroni 1998

Animal Samples



	ΔWEPL (%) (Mean ± Std)
SECT	0.23 ± 1.03
DECT Bourque et al.	-0.41 ± 0.48
DECT Lalonde and Bouchard	-0.06 ± 0.51

Discussion

- Our WEPL measurement technique has successfully been validated on tissue substitutes
- We show an improvement in WEPL estimation with DECT determined SPR values in both, tissue substitutes and animal samples
- Our results indicate possible improvement in range prediction by the use of DECT

Acknowledgements

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