# Evaluation of the Varian AcurosPT Monte-Carlo dose calculation algorithm

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PPRIG
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# Dose calculation algorithms at the Christie

- **Eclipse:**
  - Proton-Convolution-Superposition (PCS) 16.0.2: Analytical
  - Acuros 16.1.0: Monte-Carlo

- **AutoMC [1]:**
  - GATE 8.1 / GEANT4 10.3.3: Monte-Carlo

[1] Aitkenhead et al. Automated Monte-Carlo re-calculation of proton therapy plans using Geant4/Gate: implementation and comparison to plan-specific quality assurance measurements. (BJR 2020) https://doi.org/10.1259/bjr.20200228


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**(>1000 patients to date)**

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# Dose calculation algorithms at the Christie

- **Eclipse:**
  - Proton-Convolution-Superposition (PCS) 16.0.2: Analytical ← **Primary dose calc.**
  - Acuros 16.1.0: Monte-Carlo ← **Aim: To evaluate Acuros, comparing against PCS and Gate**
- **AutoMC [1] :**
  - GATE 8.1 / GEANT4 10.3.3: Monte-Carlo ← **Indep. secondary calc.**

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# Evaluation approach

1. **Box fields – in water**

2. **Box fields – in homogeneous biological media**

3. **Clinical plans – 21 in total**
   - Brain
   - Base-of-skull
   - Mediastinal
   - Lung
   - Oesophagus
   - Pelvis
   - Thymoma
   - Lymphoma


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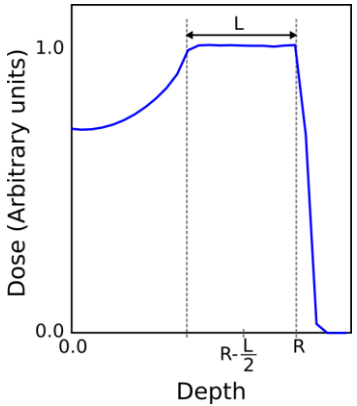
# 1. Box fields in water

1. Material set to water.

2. Fields created to deliver a series of 27 SOBPs:
   - R = overall range (10 to 35 cm)
   - L = SOBP length (3 to 30 cm)

3. Evaluated in terms of:
   - R80
   - Dose



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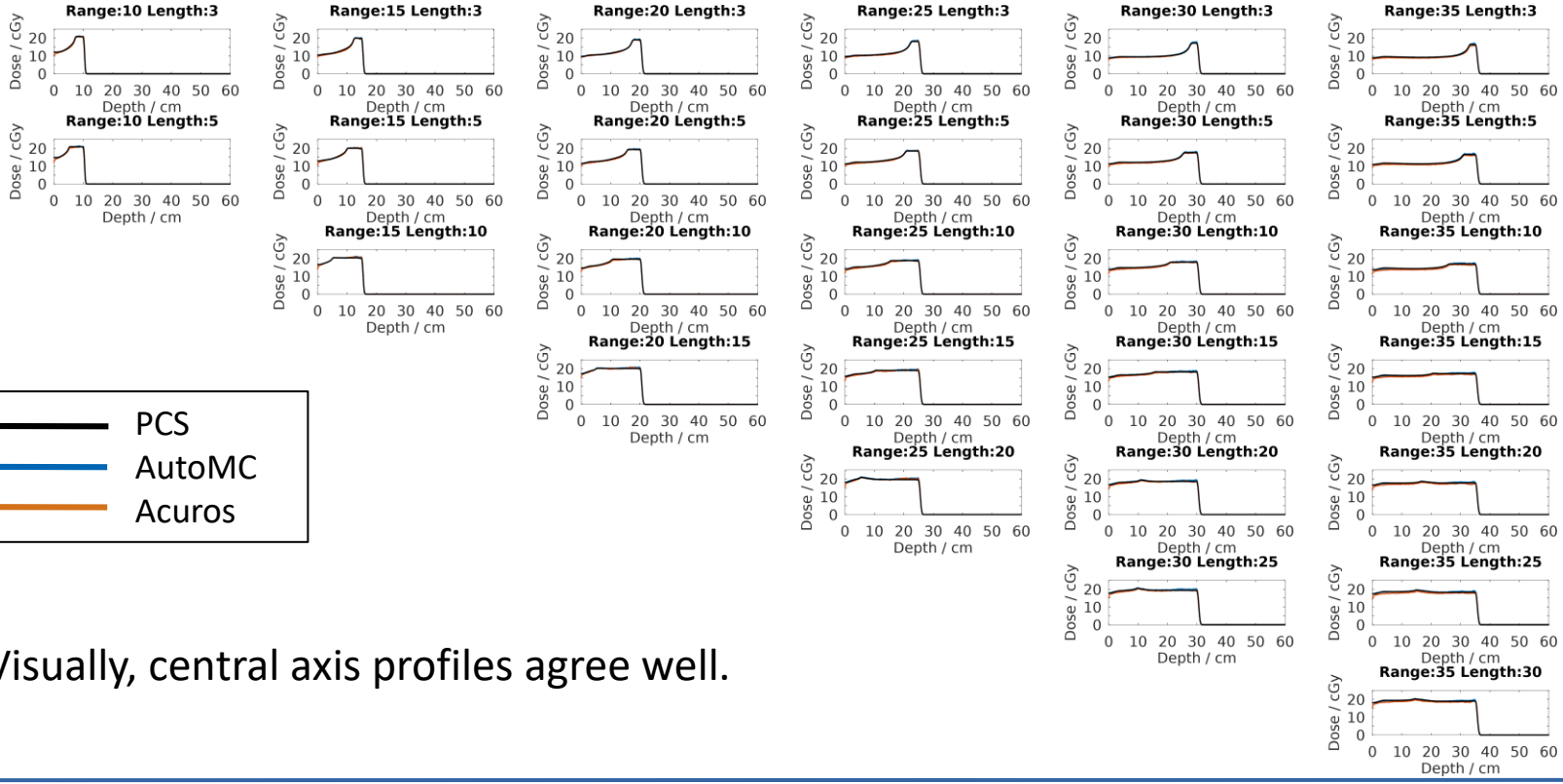
# 1. Box fields in water

Increasing R →




Increasing L →

- Visually, central axis profiles agree well.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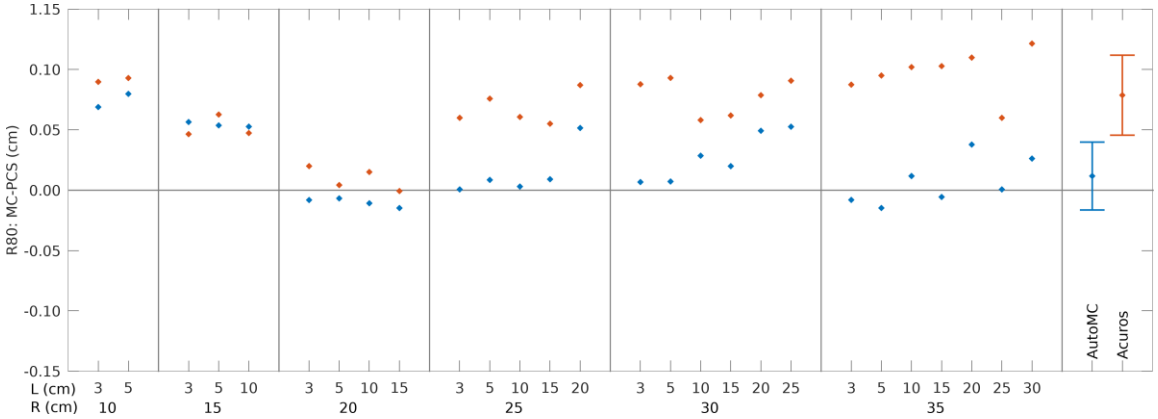
# 1. Box fields in water

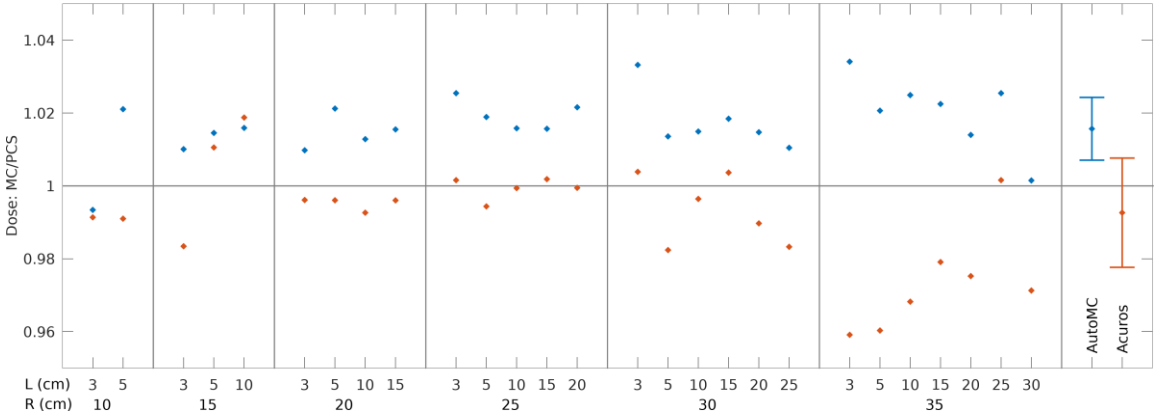
## Range differences vs. PCS:

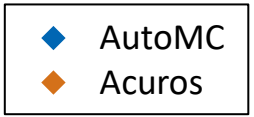
- **AutoMC**: Within ~0.5 mm.
- **Acuros**: Within ~1 mm.




## Dose differences vs. PCS:

- Within ~2%.
- Note: Direction of the difference differs for AutoMC and Acuros.





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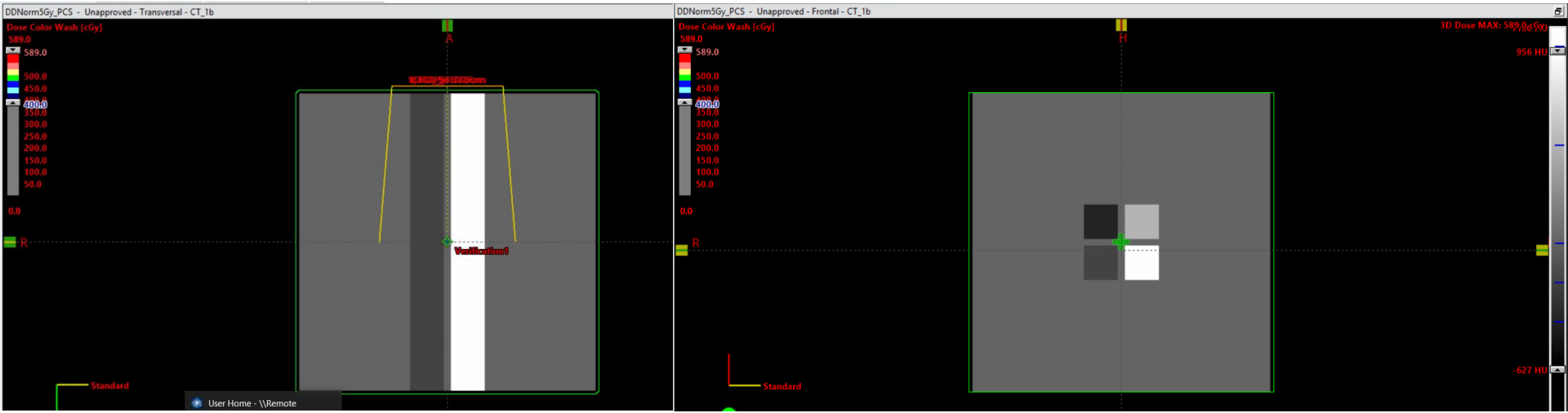
# 2. Box fields in homogeneous biological media

- Phantom with homogeneous regions of -400, -200, 0, 500, 1000 HU.
- CT calibration:
  - HU mapped to material composition and mass density.
  - The HU-to-mass density table matched the table used for PCS.





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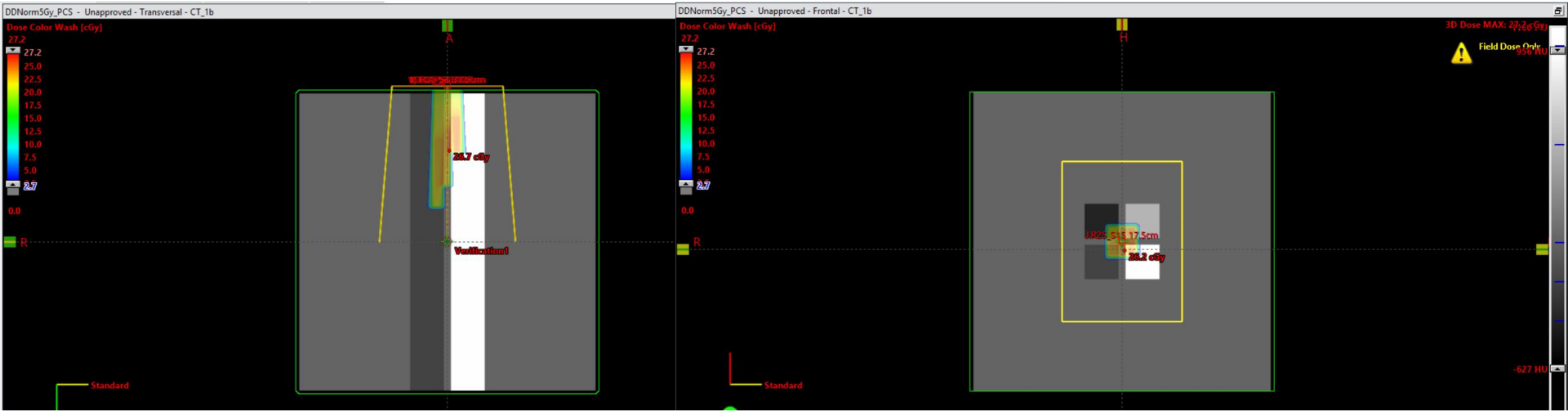



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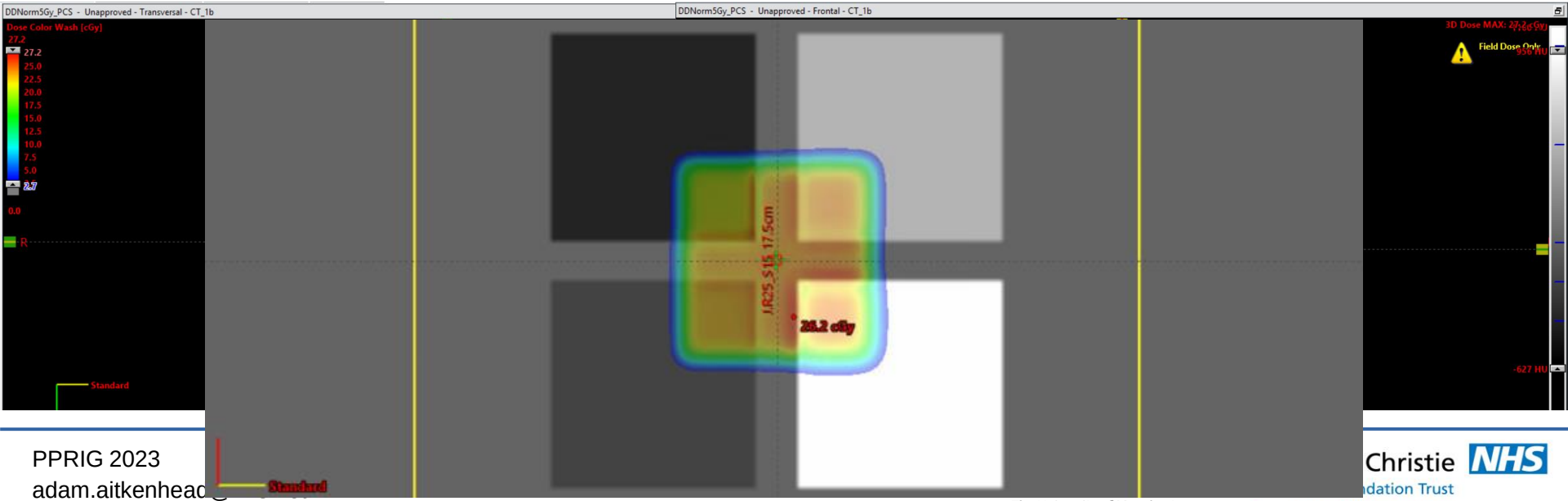

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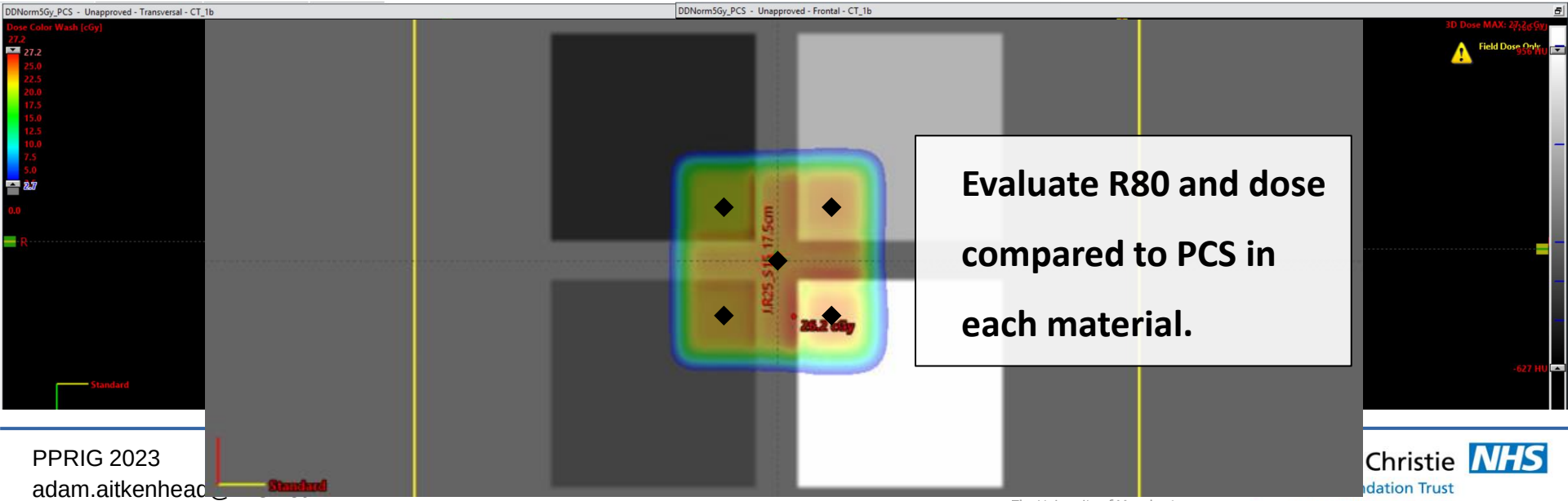

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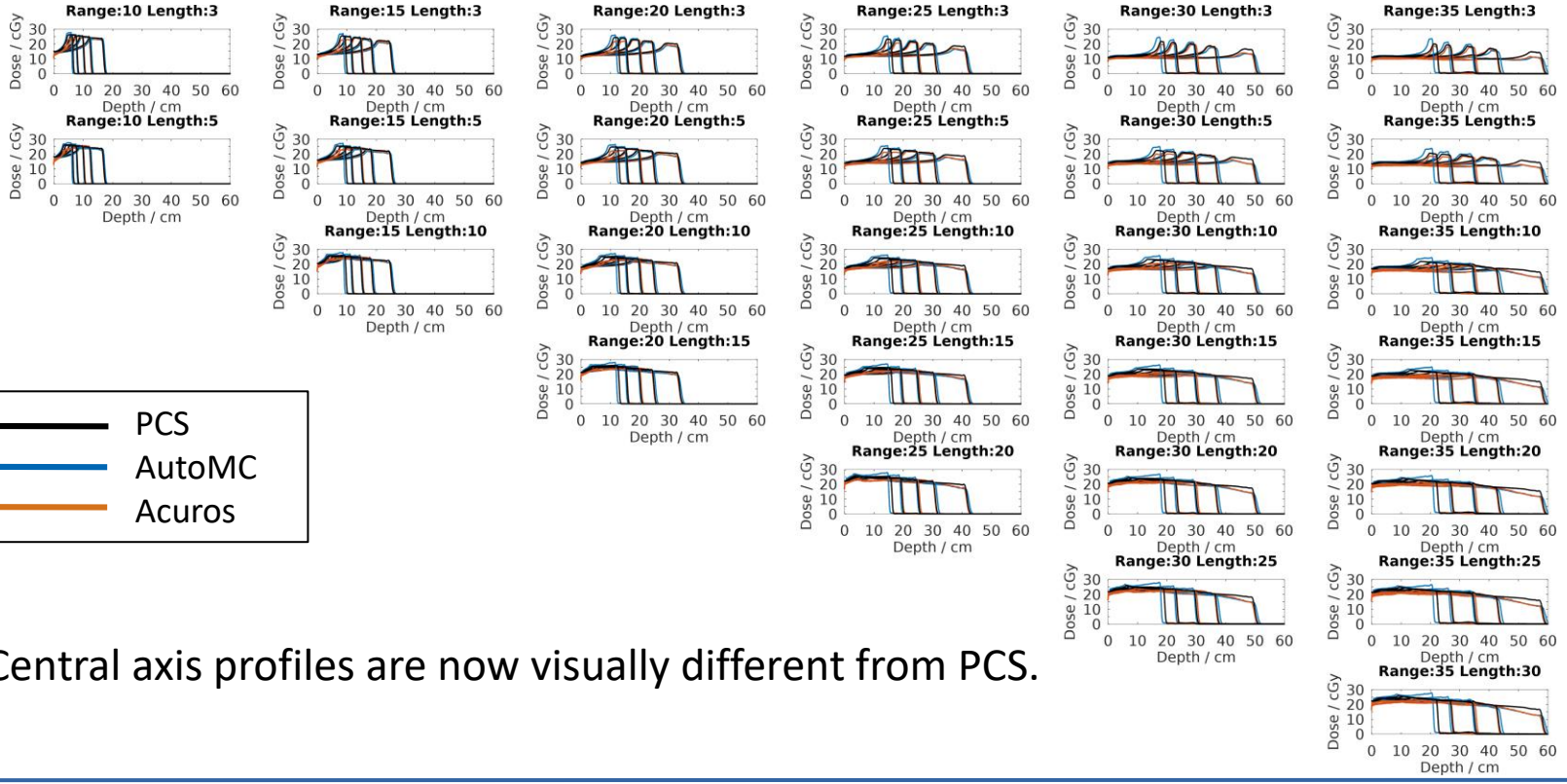
Increasing R →




- Central axis profiles are now visually different from PCS.



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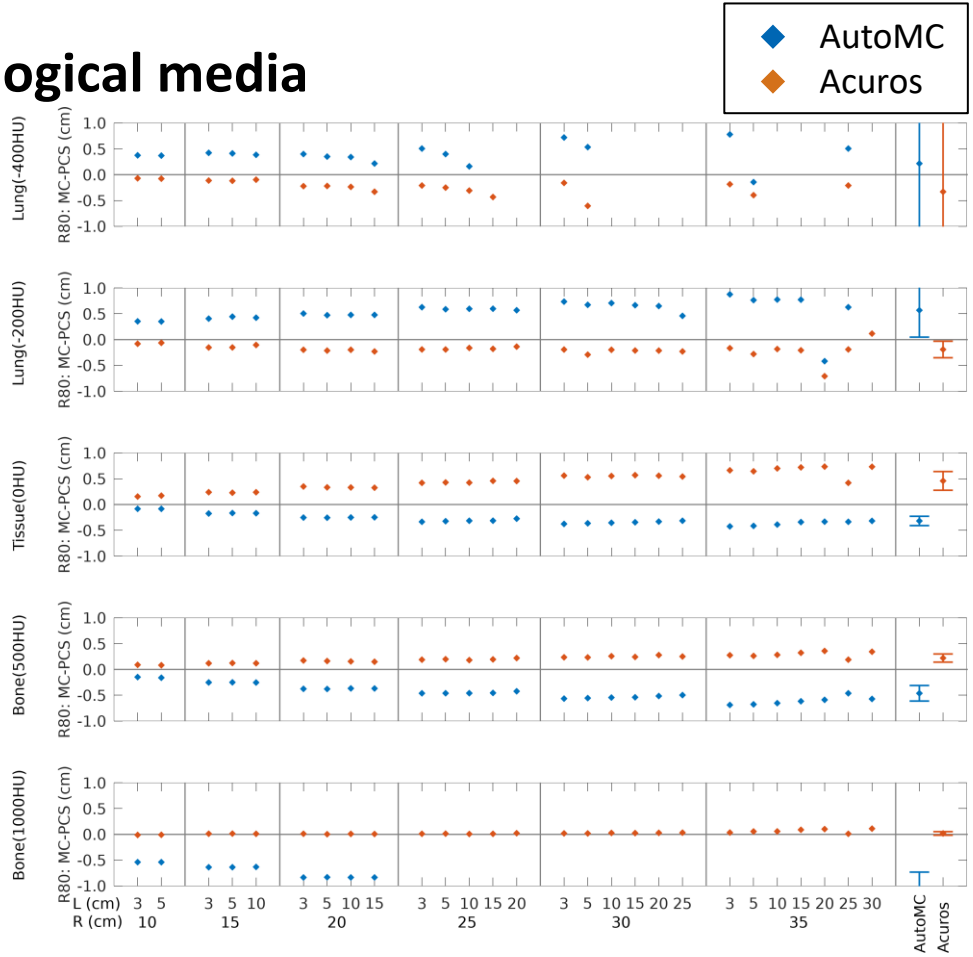
# 2. Box fields in homogeneous biological media

## Range differences vs. PCS:

- **Acuros**: Typically within 2%.
- **AutoMC**:
  - Lung: Within 2-3%
  - Soft-tissue: Within 1%
  - Bone: Up to 7%

- Two Monte-Carlo systems give different results.
- No measurement data to determine which is most accurate or tune the systems.





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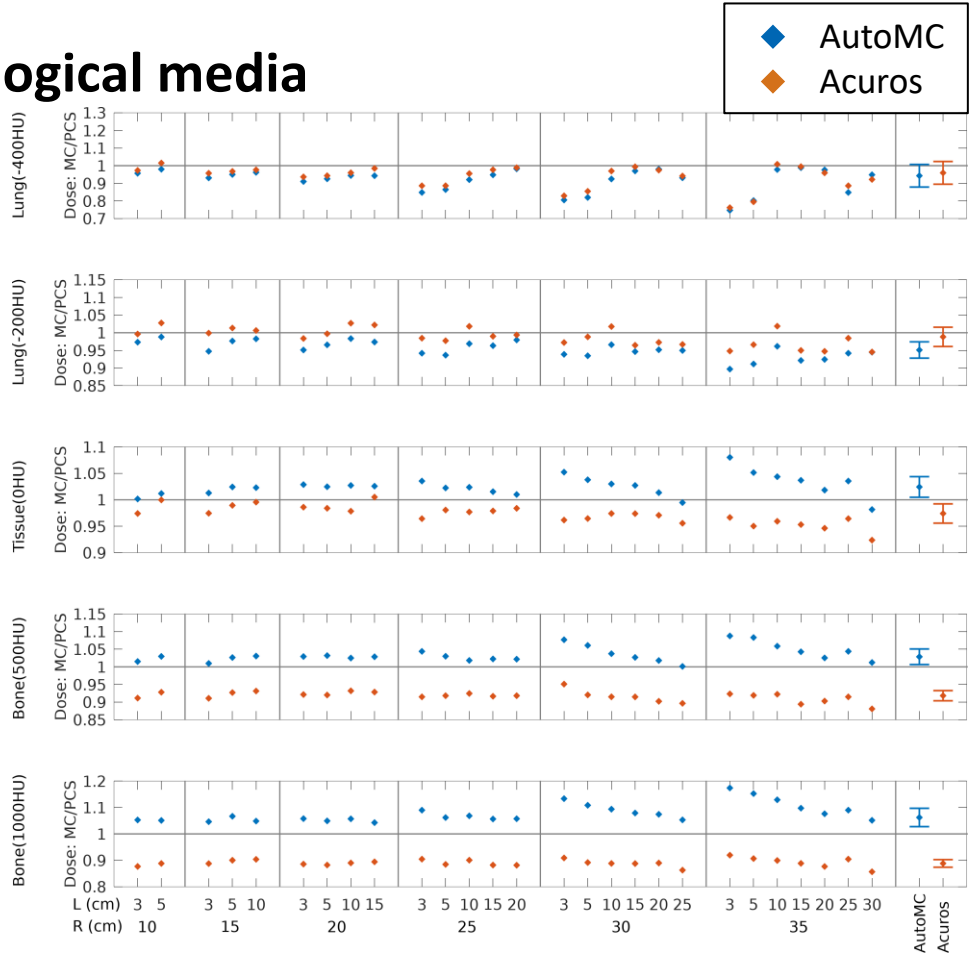
# 2. Box fields in homogeneous biological media

## Dose differences vs. PCS:

- **Acuros**:
  - Lung: Within 5%
  - Soft-tissue: Within 2%
  - Bone: Within 10%
- **AutoMC**:
  - Lung: Within 5%
  - Soft-tissue: Within 2%
  - Bone: Within 10%

- Best agreement with PCS in soft tissue.
- Direction of the difference differs for AutoMC and Acuros.





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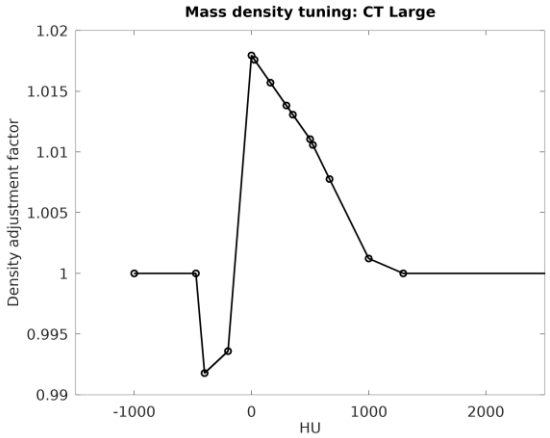
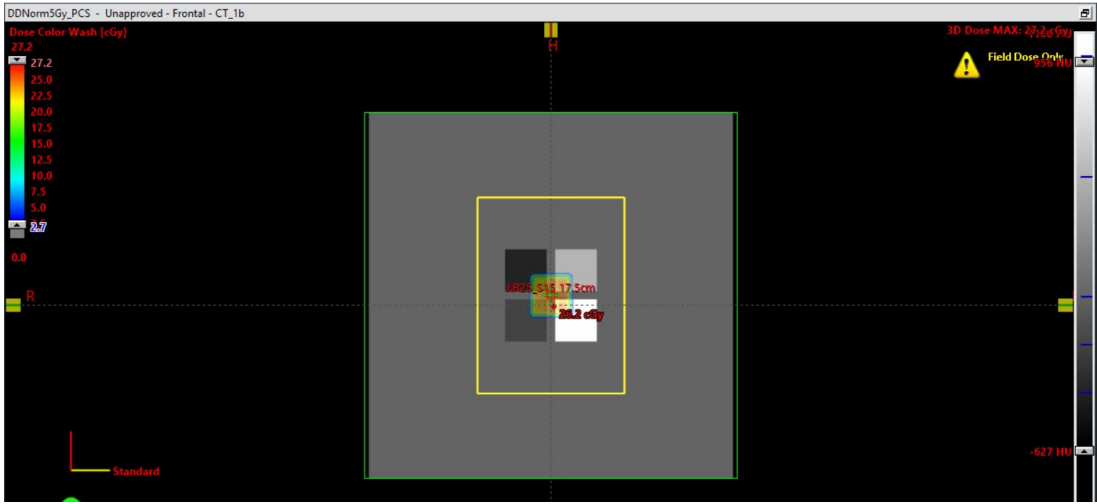
# 2. Box fields in homogeneous biological media – with tuned CT

- Phantom with homogeneous regions of -400, -200, 0, 500, 1000 HU.
- CT calibration:
  - HU mapped to material composition and mass density.
  - The HU-to-mass density table **tuned to match the range in PCS**.





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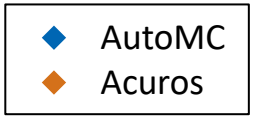


**Range differences vs. PCS:**

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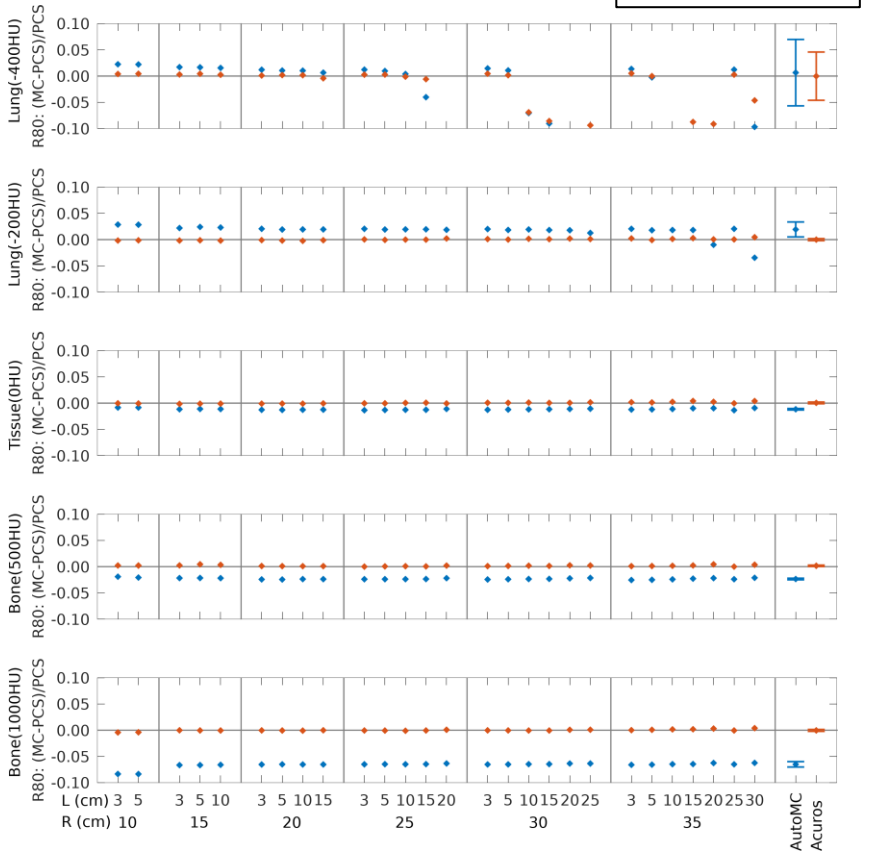



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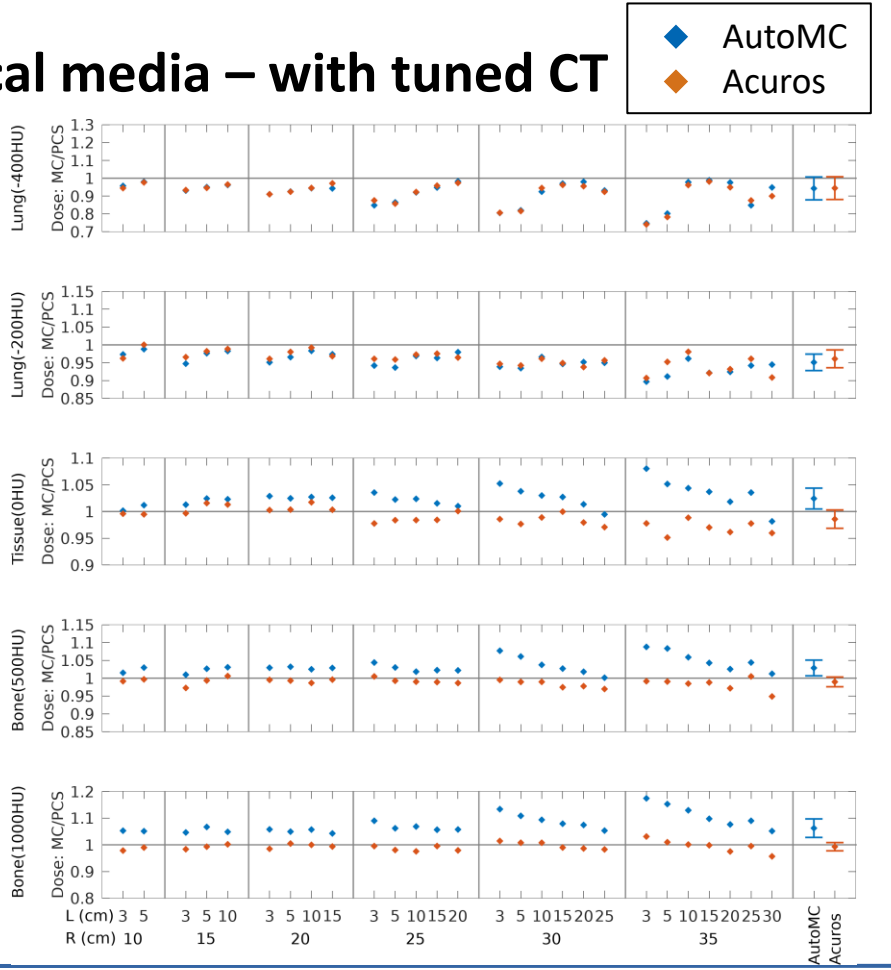


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# 3. Clinical cases

- Clinical cases compared for the three dose calc. methods:
  - PCS
  - Acuros
  - AutoMC

- Evaluation done in terms of:
  - Gamma analysis vs. PCS
  - Dose vs. PCS

- 21 patients (75 fields) evaluated with a mix of:
  - Range-shifter: 0, 2, 3, 5 cm
  - CT calibration: Cranial, Small, Large
  - Clinical site: Brain, Base-of-skull, Mediastinal, Lung, Oesophagus, Pelvis, Thymoma, Lymphoma


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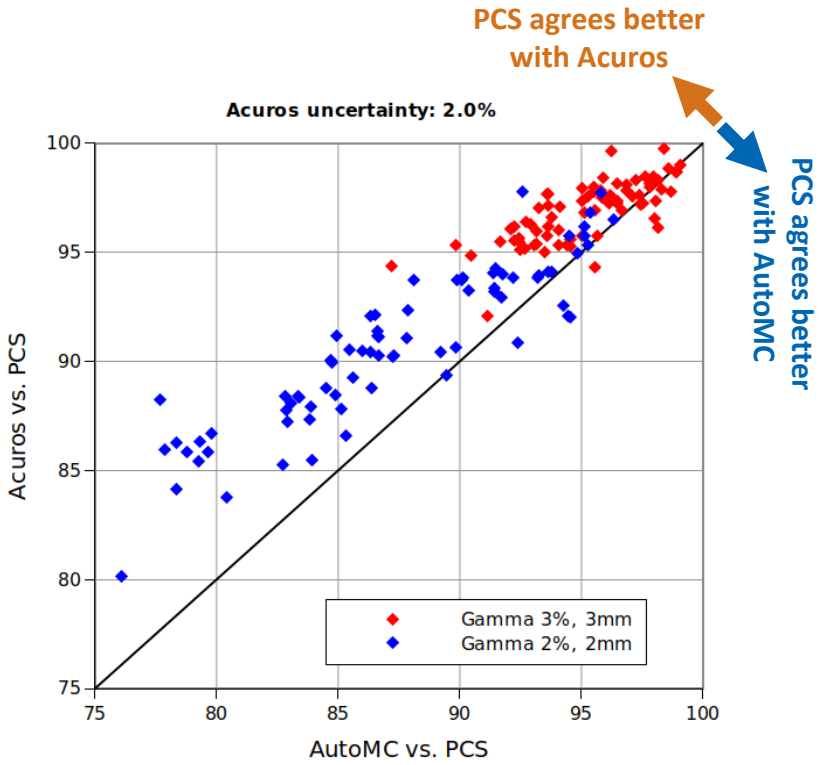
# 3. Clinical cases

**Gamma analysis:**

- Dose distributions are normalised, so the gamma analyses are a test of dose distribution shape only.

- **Acuros vs. PCS** shows better agreement than **AutoMC vs. PCS**.





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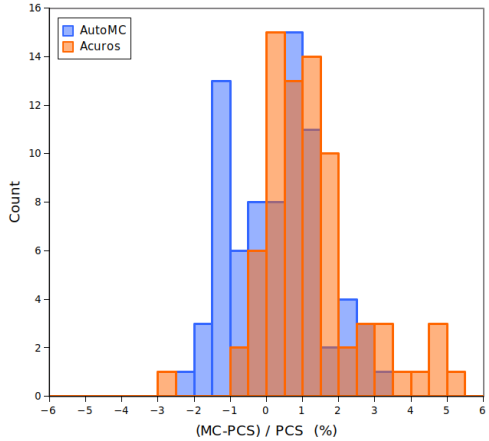
# 3. Clinical cases

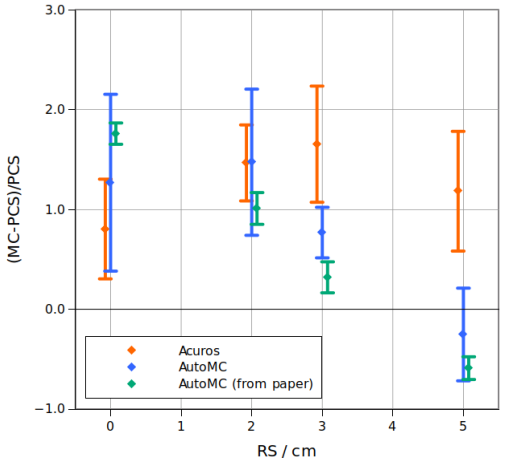
**Dose:**

- Dose differences relative to PCS are calculated from the gamma analysis normalisation factors.

- **Acuros:** No dependence on range-shifter.
  Systematically hotter than PCS by 1.0-1.5%.

- **AutoMC**: Dependent on range-shifter.
  0 cm RS: 1.5% hotter than PCS.
  5 cm RS: 0.5% cooler than PCS.





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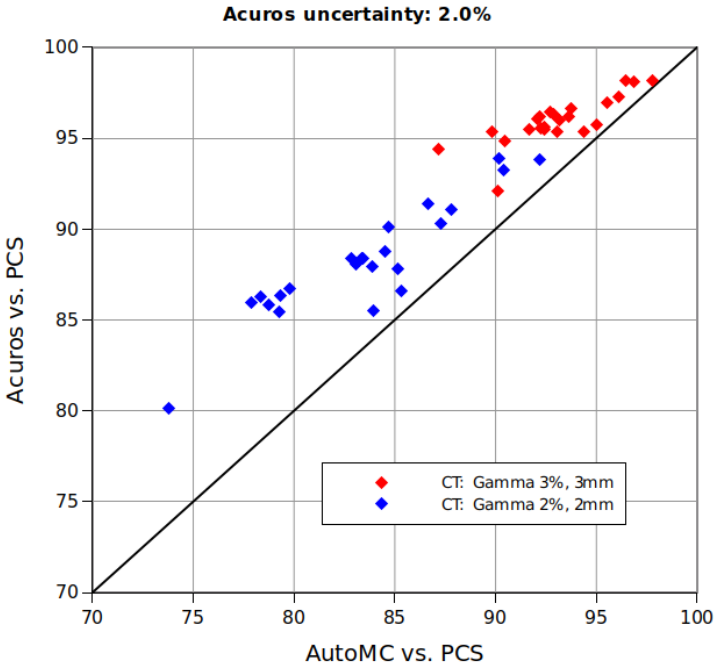
# 3. Clinical cases – with tuned CT calibration

**Reminder:**

- The Acuros CT calibration can be tuned by adjusting the HU-to-mass density table to match range in homogeneous lung, soft-tissue and bone.





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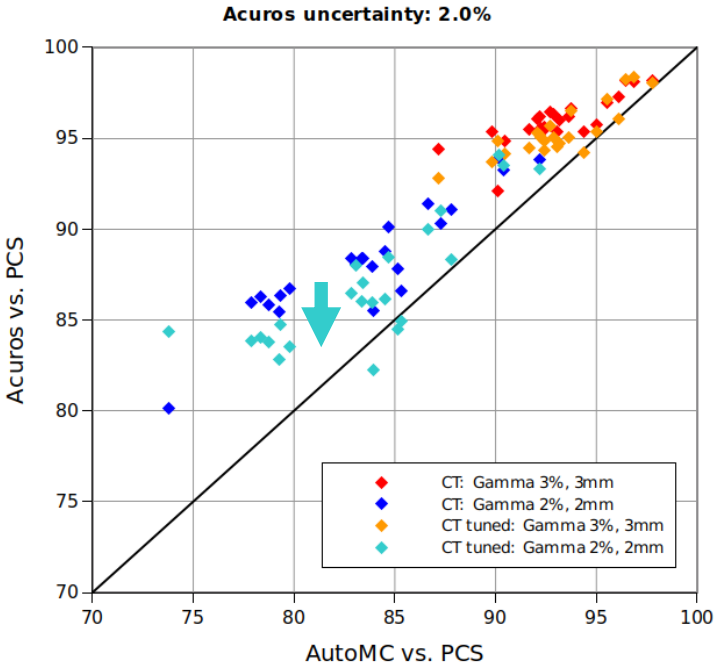
**Gamma analysis:**

- Tuning the Acuros CT calibration led to generally poorer agreement between Acuros and PCS.
- *However*, it was a small effect. Agreement was still better than between AutoMC and PCS.





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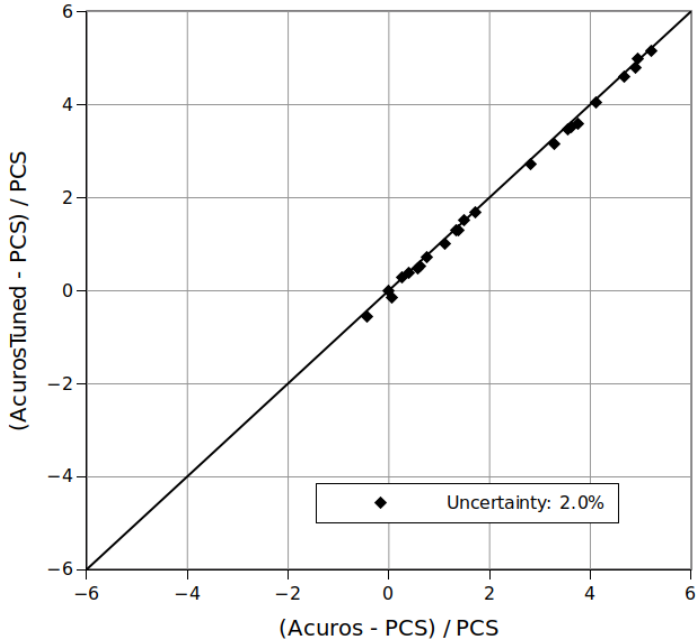
- *However*, it was a small effect. Agreement was still better than between AutoMC and PCS.

**Dose:**

- Tuning the Acuros CT calibration had no impact on the magnitude of the dose calculated by Acuros.





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# Summary

## In water:

- Acuros and AutoMC agree well with PCS

## In homogeneous biological tissues:

- Acuros and AutoMC both differ from PCS in terms of range and absolute dose.
- Acuros and PCS agree more closely than AutoMC and PCS.

## For clinical cases:

- Acuros and PCS agree better than AutoMC and PCS.

## Tuning the CT calibration:

- Improves agreement between Acuros and PCS in homogeneous biological media.
- Worsens agreement between Acuros and PCS in patient CT.


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