# Accuracy of a helium-beam radiography system based on thin silicon pixel detectors

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#### Idea of our detection system

Many systems measure residual energy / range [1]



Our idea:

#### Thin detector

- Very small and light
- Measuring energy deposition
   in the steep rising edge of Bragg peak





#### Detector



[2

Timepix [3], a semiconducting detector:

- Sensor layer: 300 µm silicon
- Pixelated (256x256, 55 µm pixel size)
- Single particle detection
- Each of the 65k pixels operable in 2 modes:
  - Time of Arrival
  - Energy deposition
- Background-free













10/27/2024 Slide 5 [4] Amato et al., 2020, Med.phys. 47(5)

<sup>4</sup><sub>2</sub>He<sup>2+</sup>

Synchronization:

- Search for temporal coincidences
- Cubic Spline path [5,6]

[6] Krah et al. 2019





Energy degrader



10/27/2024 Slide 7 [4] Amato et al., 2020, Med.phys. 47(5)









#### $\rightarrow$ combination of several energies

10/27/2024 Slide 9 [7] Metzner et al. *PMB* 69.5 (2024): 055002.

# **Energy painting** [7]





ΔE1 ΔE2



10/27/2024 Slide 10 [7] Metzner et al. PMB 69.5 (2024): 055002.

# **Energy painting** [7]







**Energy painting: Experimental results** [7]

 $\rightarrow$  factor 2.5 improvement of single-ion WET precision [7]

 $\rightarrow$  mean SIWP of around 2% competitive with US pCT system (Dickmann et al. 2019 [8]))



#### **Imaging of anthropomorphic phantom** [9]





Region at the skull base: [9]

- Clinically relevant
- Heterogeneous
- Severe anatomical changes can occur



#### **Imaging of anthropomorphic phantom** [9]



Comparison to projections of:

- Single-energy CT scan (converted to RSP with clinical protocol)
- Dual-energy CT scan (converted to RSP with clinical protocol)
- Similar to Dedes et al. [10], Volz et al. [11] and Bär et al. [12] For **our detection system**, determining **WET accuracy** in an **anthropomorphic phantom**
- Reference data set of Wohlfahrt et al. [13] :
  - RSP measurement of all 9 materials
     present in head phantom
  - Segmentations of high resolution Xray CT scan (0.5mm)<sup>3</sup>
  - Assignment of RSP values to all segmented volumes



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[10] Dedes et al., *PMB* 64.16 (2019): 165002.
[11] Volz, et al., *PMB* 66.23 (2021): 235010.

[12] Bär et al., *Medical physics* 49.1 (2022): 474-487.[13] Wohlfahrt et al. *IJROBP* 100.1 (2018): 244-253.

#### Imaging of anthropomorphic phantom: Results [9]





RMSE [9]:

- αRad: 1.43%
- DECT: 1.19%
- SECT: 1.30%
- (SECT with simpler HLUT: ~1.5%)
- (RMSE of reference scan ~1.0%)



[9] Metzner et al. Submitted to: *Medical Physics* [13] Wohlfahrt et al. *JROBP* 100.1 (2018): 244-253.

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#### **Imaging of anthropomorphic phantom: Results** [9]



#### Where do deviations from Reference stem from?







[9] Metzner et al. Submitted to: Medical Physics

# Imaging of anthropomorphic phantom: Results [9]



 $\rightarrow$  Results for SECT and DECT agree with findings in Wohlfahrt et al. [13]



0%: no correlation 100%: maximum correlation -100%: maximum anticorrelation



# **Summary**

- Energy painting overcomes the limitation in WET range of thin detectors
- Also in anthropomorphic phantoms we reached accurate WET values (RMSE ~1.4% compared to 1.0% of reference)
- **Competitive** with X-ray CT modalities in terms of WET accuracy

