PET/MR Headphone Attenuation Estimation using xMLAA

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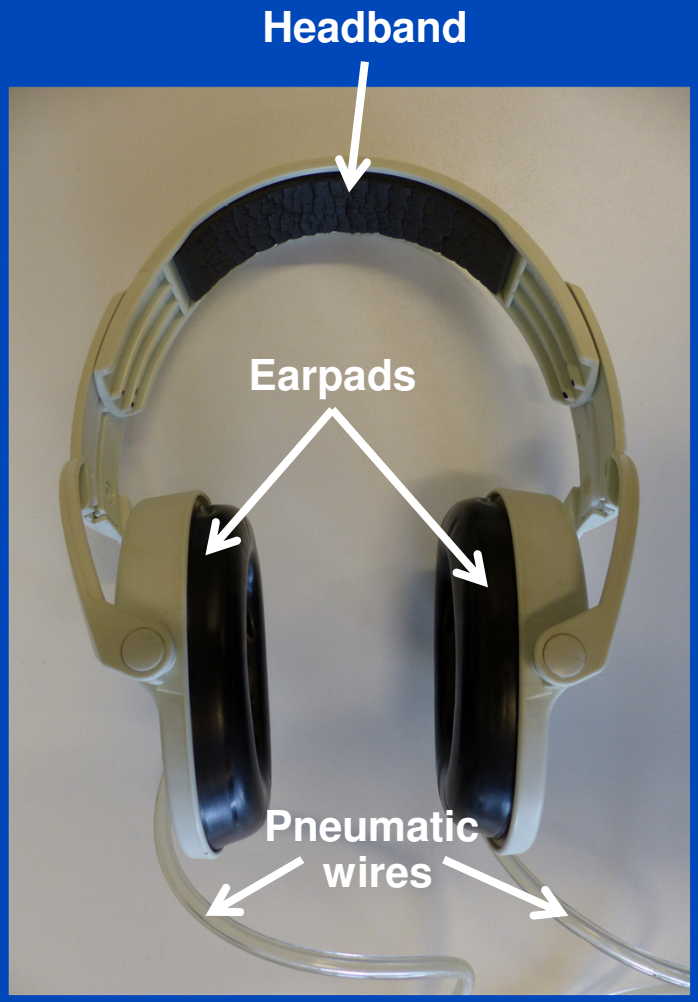
MR-safe Pneumatic Headphones

- In MR imaging, patients routinely wear headphones
  - as hearing protection
  - to receive instructions from the technical staff (e.g., breathing instructions)
  - to listen to music (study time up to 2 h)



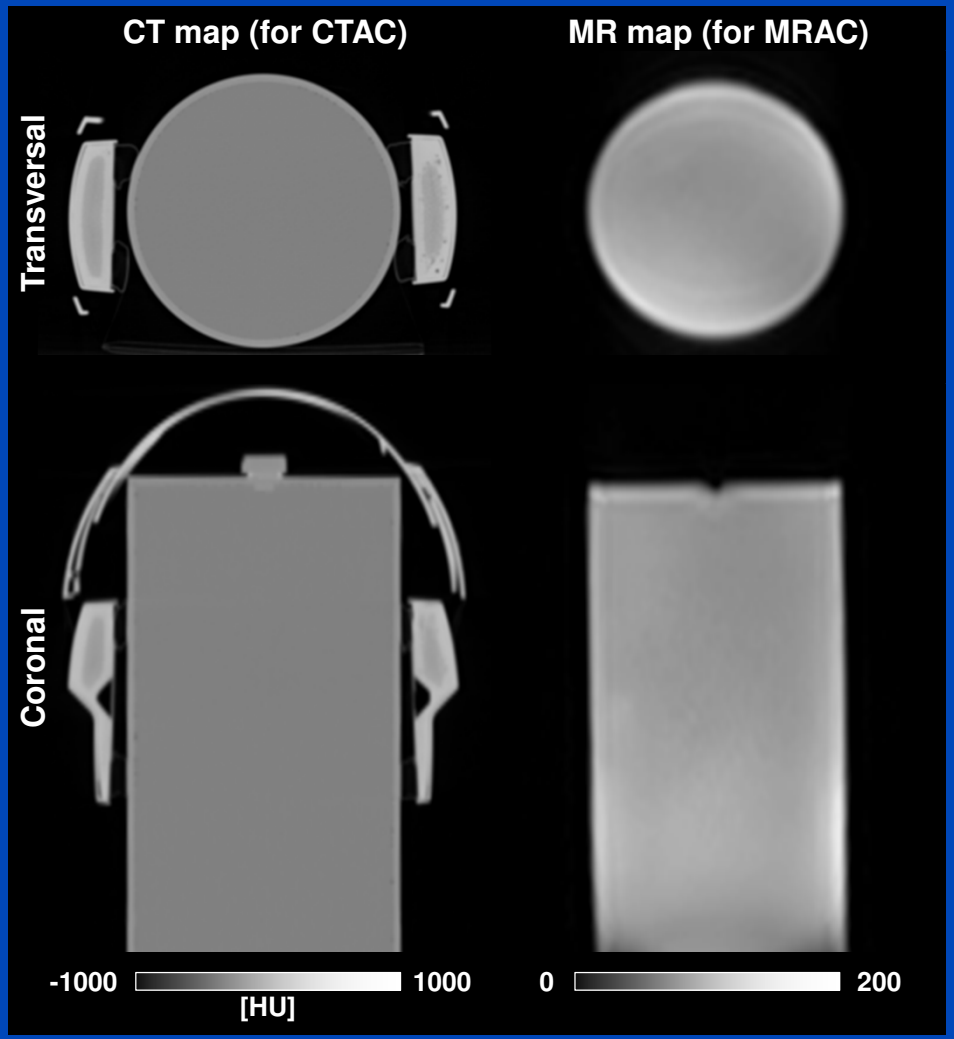
Motivation

- **Headphones are not visible in MR images**

  ⇒**MR-based attenuation correction (MRAC) neglects headphone attenuation**

  ⇒**Activity is underestimated by up to 16%[1,2]**

  ⇒**Vendors recommend not to use headphones for quantitative PET studies of the brain.**
  This, however, is uncomfortable to the patient and it may cause damage to the ears.



[1] Ferguson A, McConathy J, Su Y, Hewing D, Laforest R. Attenuation Effects of MR Headphones During Brain PET/MR Studies. *JNMTechnology* 42(2):93–100, (2014).
[2] Büther F, Vrachimis A, Becker A, Stegger L. Impact of MR-safe headphones on PET attenuation in combined PET/MRI scans. *EJNMMI Research*. 6:20, (2016).

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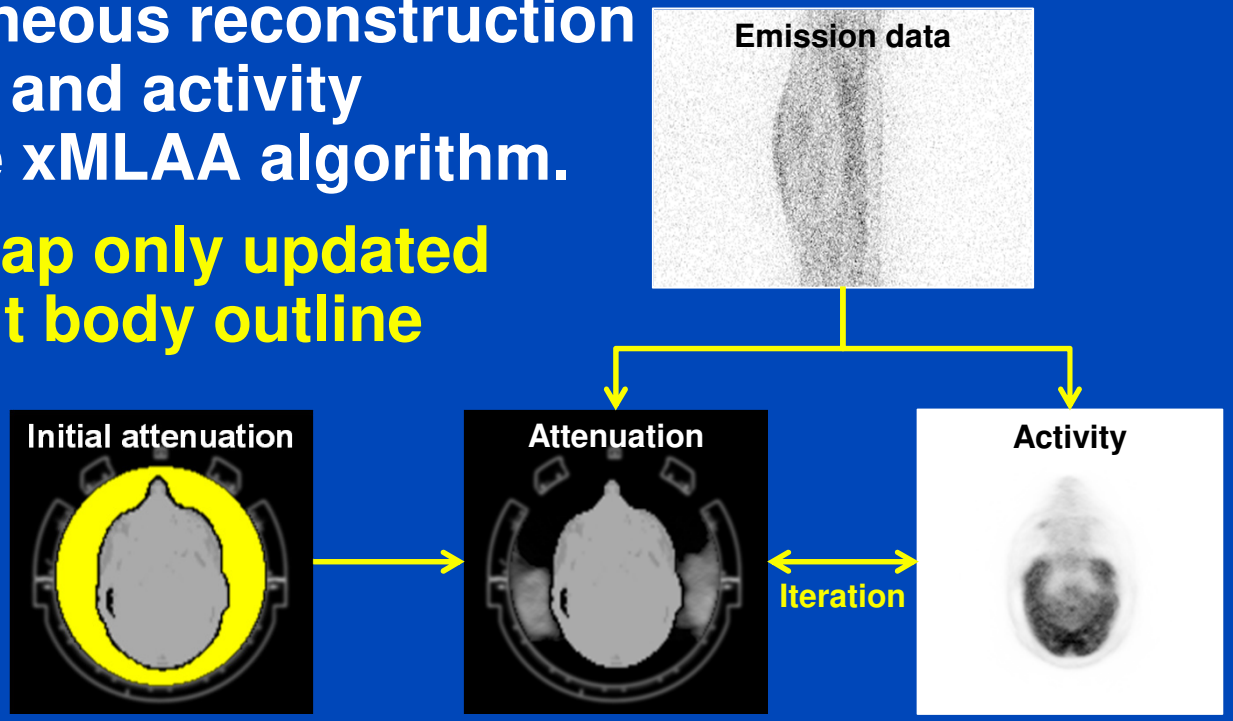
Aim

- Enable the use of MR-safe headphones (and other hardware) for quantitative PET studies of the brain

Algorithm

- Generalize the MLAA[1] algorithm to update patient external voxels rather than internal voxels: xMLAA.
- Estimate headphone attenuation using simultaneous reconstruction of attenuation and activity employing the xMLAA algorithm.
- **Attenuation map only updated outside patient body outline**



[1] J. Nuyts, P. Dupont, S. Stroobants, R. Benninck, L. Mortelmans, and P. Suetens. Simultaneous maximum a posteriori reconstruction of attenuation and activity distributions from emission sinograms. IEEE Trans. Med. Imaging 18(5), 393–403 (1999).

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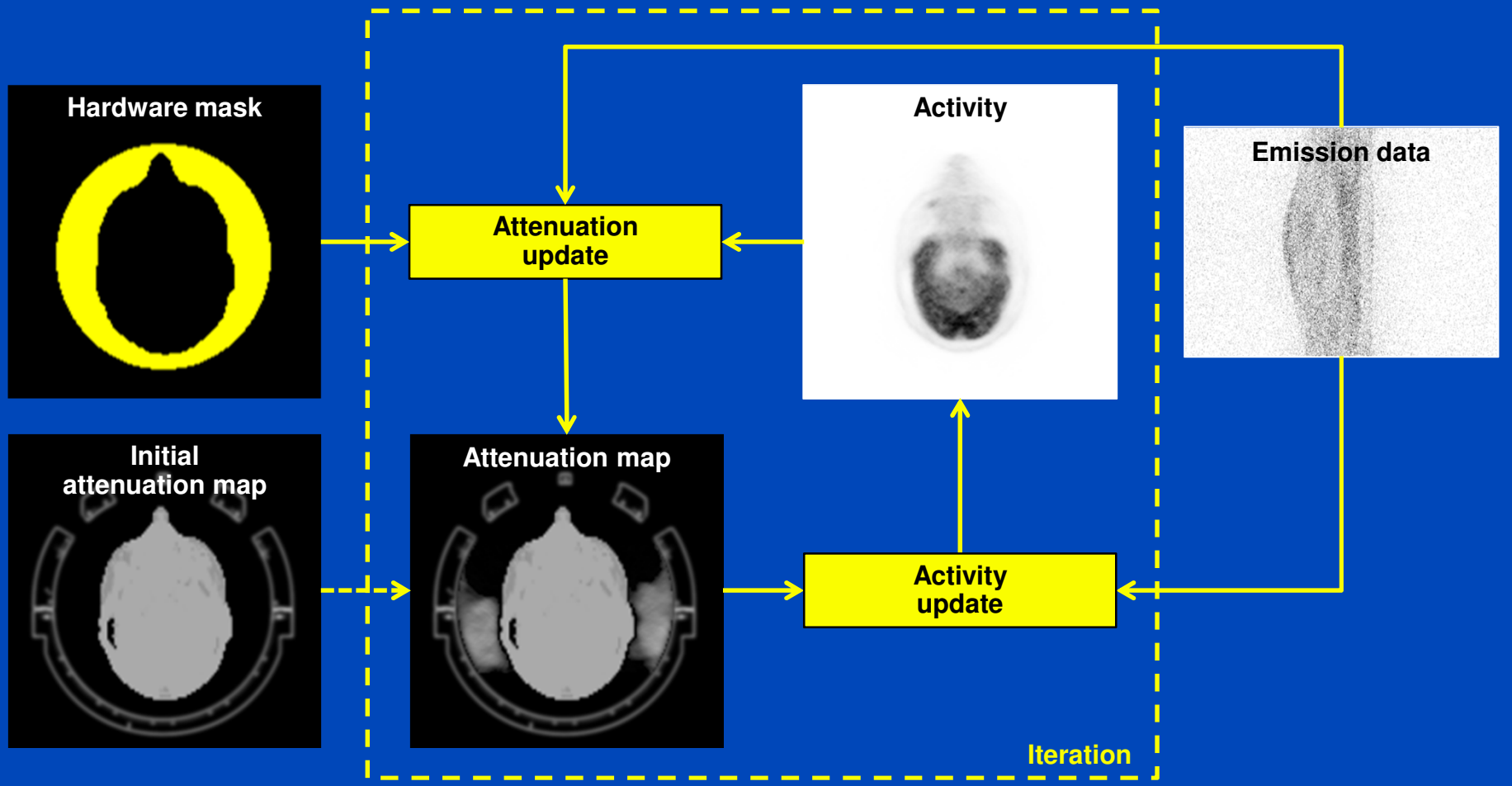
xMLAA Workflow



$$C(\boldsymbol{\lambda}, \boldsymbol{\mu}) = \underbrace{L(\boldsymbol{\lambda}, \boldsymbol{\mu})}_{\text{Log-likelihood}} + \underbrace{L_{\mathrm{S}}(\boldsymbol{\mu}) + L_{\mathrm{I}}(\boldsymbol{\mu})}_{\text{Prior terms}}$$

50 xMLAA iterations were used for this presentation.

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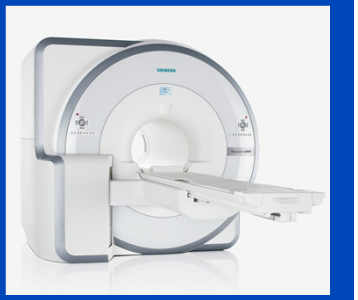
Phantom and Patient Data

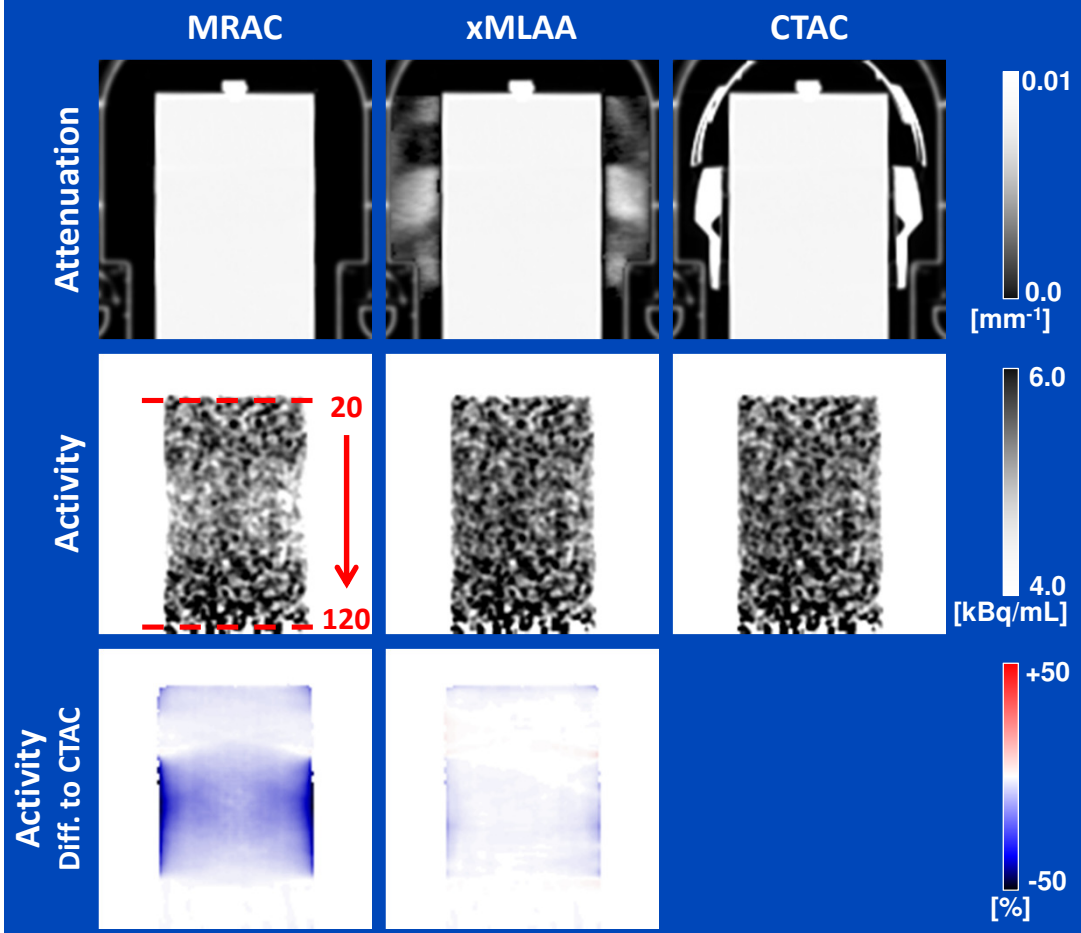
Acquired with Siemens Biograph mMR

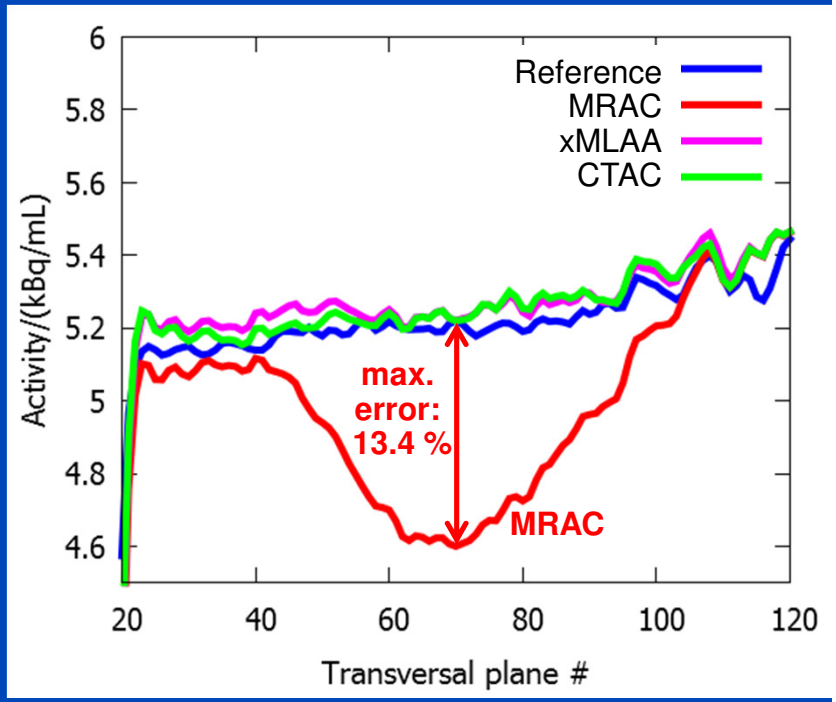


- **Phantom**
  - 15 cm diameter water-filled cylinder (volume ≈ 5 L)
  - Filled with 48 MBq ^{68}Ga
  - Acquired counts: 59 × 10^6 (≈ 2 min data acquisition)
  - Without Headphones
    - Reference
  - With Headphones
    - MRAC (= uncorrected)
    - xMLAA
    - CTAC

- **Patients**
  - Three ^{18}F-FDG patients
  - Administered activity: 230 ± 12 MBq
  - Only bed position corresponding to head region is investigated
  - Acquired counts: (62 ± 26) × 10^6 (5 min data acquisition)
  - With Headphones
    - MRAC (= uncorrected)
    - xMLAA

Phantom Results





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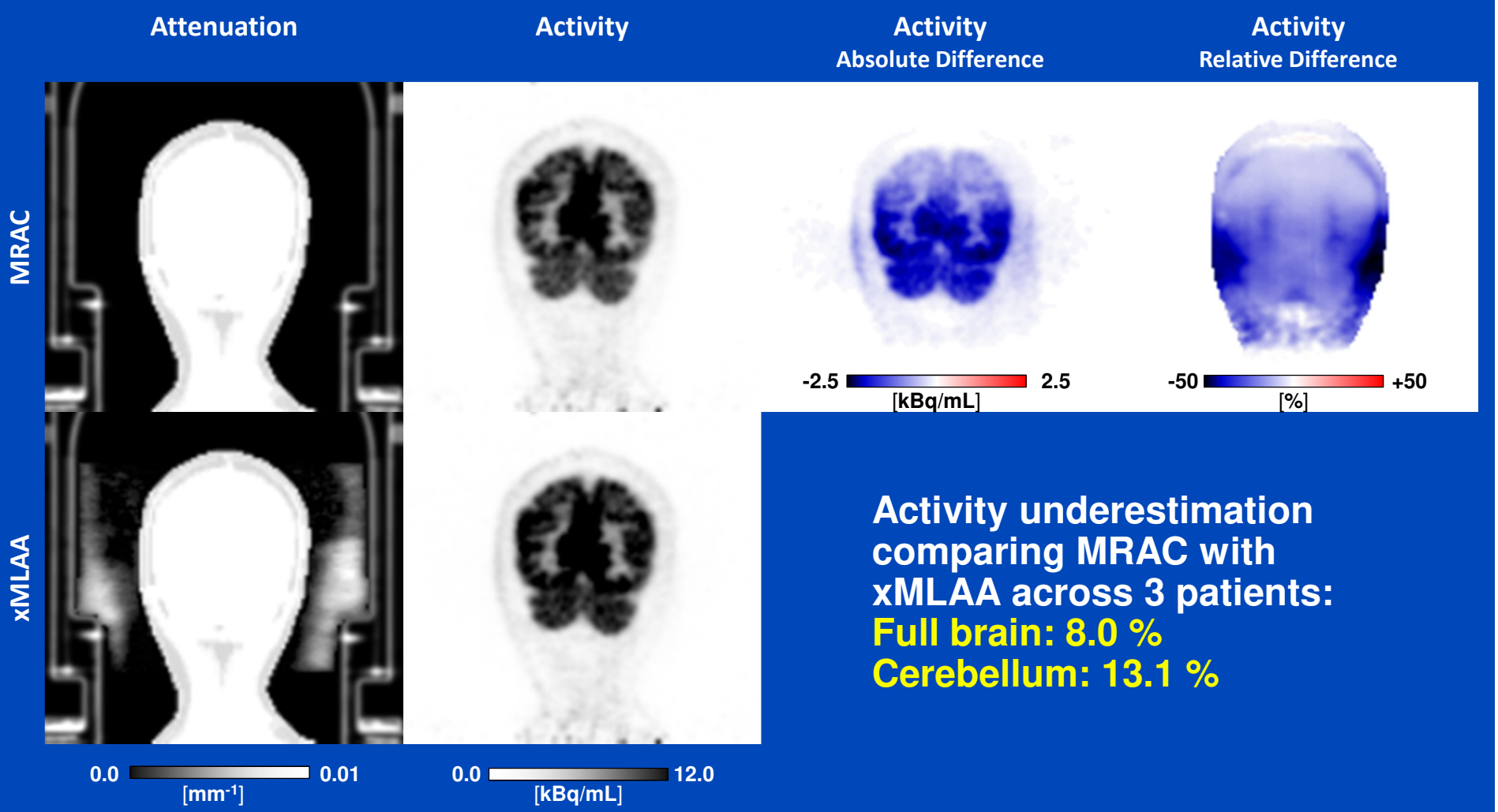
Patient Results



Activity underestimation comparing MRAC with xMLAA across 3 patients:
Full brain: 8.0 %
Cerebellum: 13.1 %

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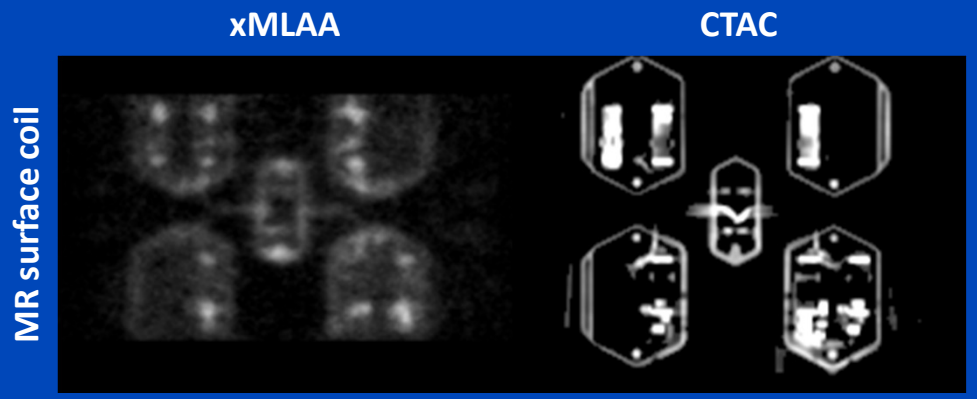
Conclusions on xMLAA

- **Phantom experiments**
  - MRAC: -13.4 % max error compared to reference
  - xMLAA: +1.7 % max error compared to reference
- **Patient data**
  - MRAC underestimates the average activity distribution by 13.1 % in the cerebellum compared to xMLAA.
- **The xMLAA algorithm can be employed to enable the use of MR-safe headphones for quantitative PET studies of the brain.**
- **The xMLAA method is applicable to other hardware components present in the PET FOV[1].**



[1]T. Heußer, C. Rank, Y. Berker, M. Freitag, and M. Kachelrieß. MLAA–Based Attenuation Correction of Hardware Components in Hybrid PET/MR Imaging. Submitted to EJNMMI Physics.

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Thank You!

Job opportunities through DKFZ's international PhD or Postdoctoral Fellowship programs (www.dkfz.de), or directly through Marc Kachelrieß (marc.kachelriess@dkfz.de).

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