Treating brain cancer with heat therapy using a novel noninvasive microwave applicator

COMSOL 2020 North America • October 7-8 • Online Event

Dario Rodrigues, Assistant Professor
University of Maryland School of Medicine, Baltimore

Mark Mishra
Jason Molitoris
Zeljko Vujaskovic

Martin Wadepohl
Günter Futschik

Paul Turner
Jason Ellsworth

University of Maryland School of Medicine
Maryland Proton Treatment Center
Affiliated with University of Maryland Marlene and Stewart Greenebaum Comprehensive Cancer Center
Dr. Sennewald medizintechnik gmbh
Pyrexar Medical

Disclosures

- Dr. Dario Rodrigues – grant recipient of a Sponsored Research Agreement (SRA) with Pyrexar Medical, Salt Lake City, UT

Clinical benefit of radiation (RT) ± hyperthermia (HT) in glioblastoma (GBM)

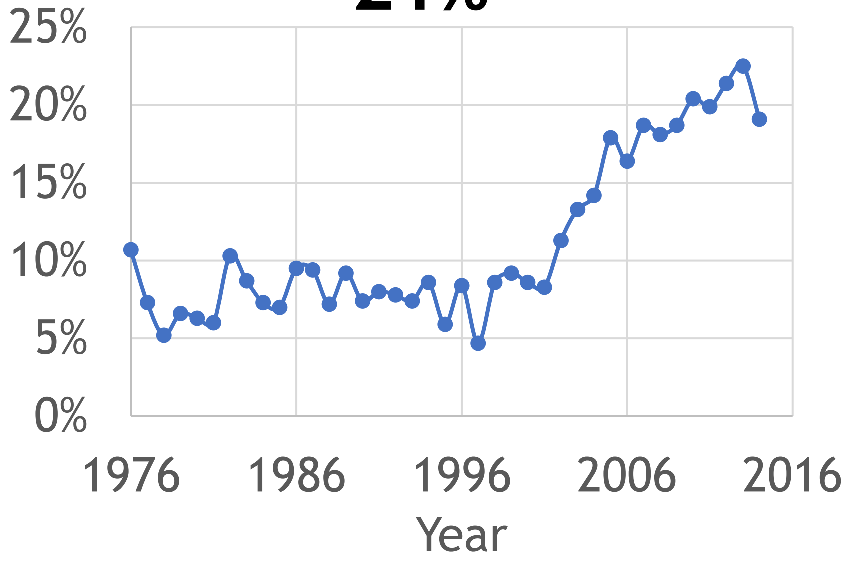
UNIVERSITY of MARYLAND BALTIMORE

GBM 2-year survival

Current Standard of Care

SEER Registry 2010-2014

21%



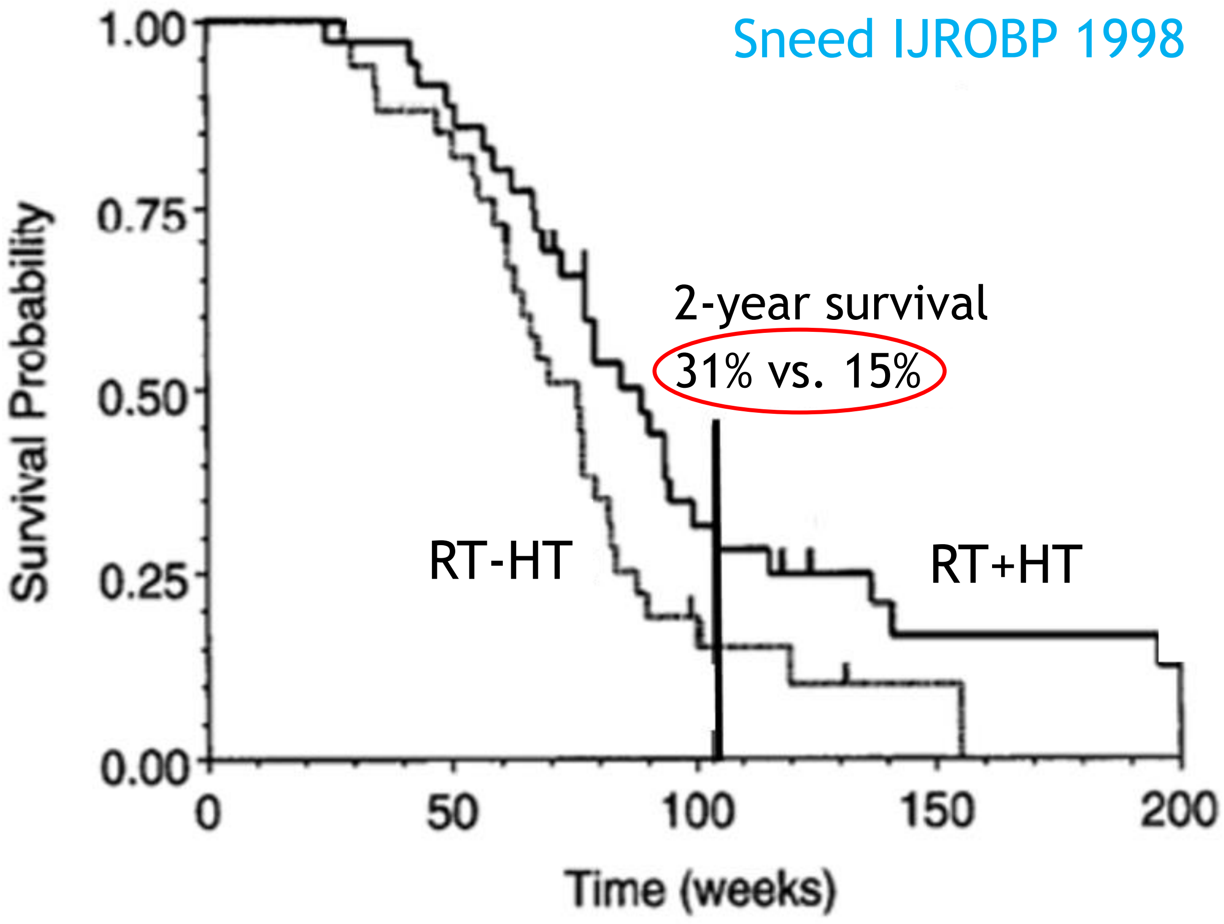
Temozolomide + RT

Stupp et al. 2008, Lancet

(EORTC-NCIC rand phase III)

27%

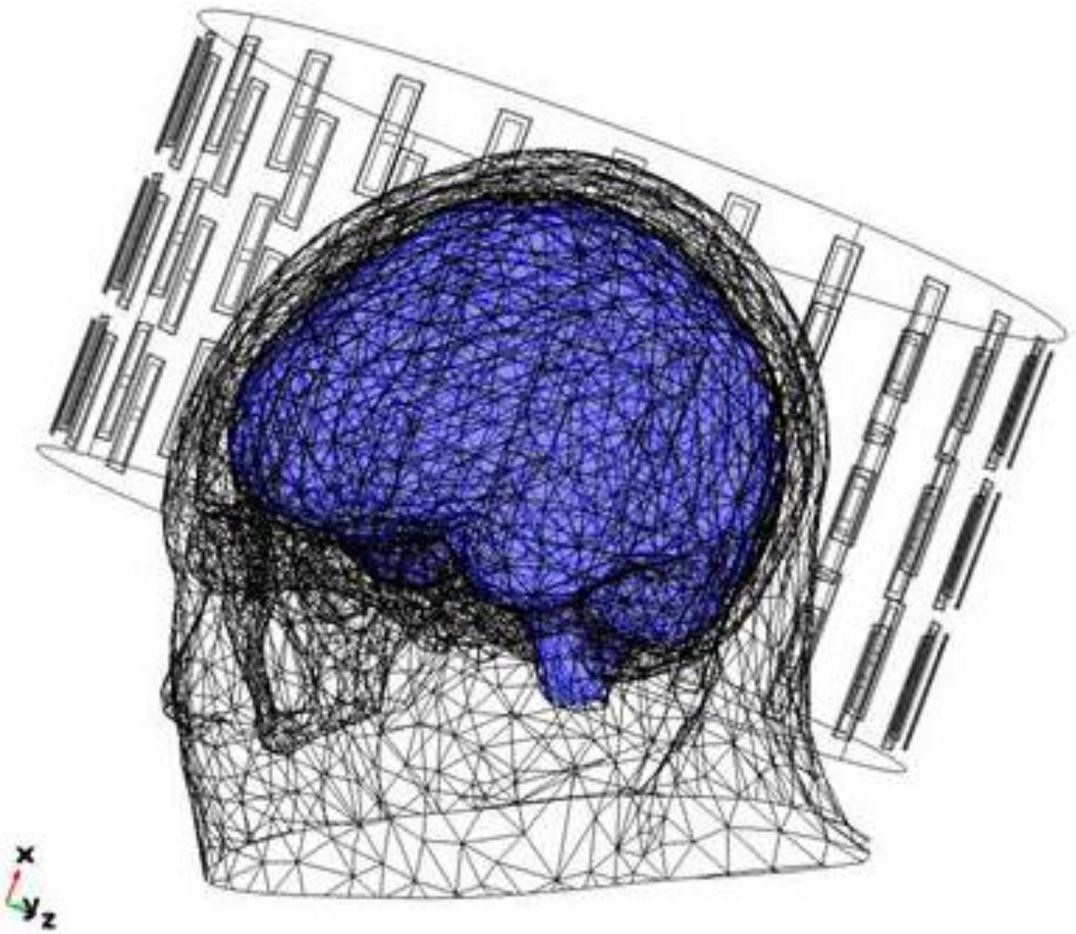
Randomized Trial in Primary GBM
(Conventional RT + brachy boost ± interstitial HT)

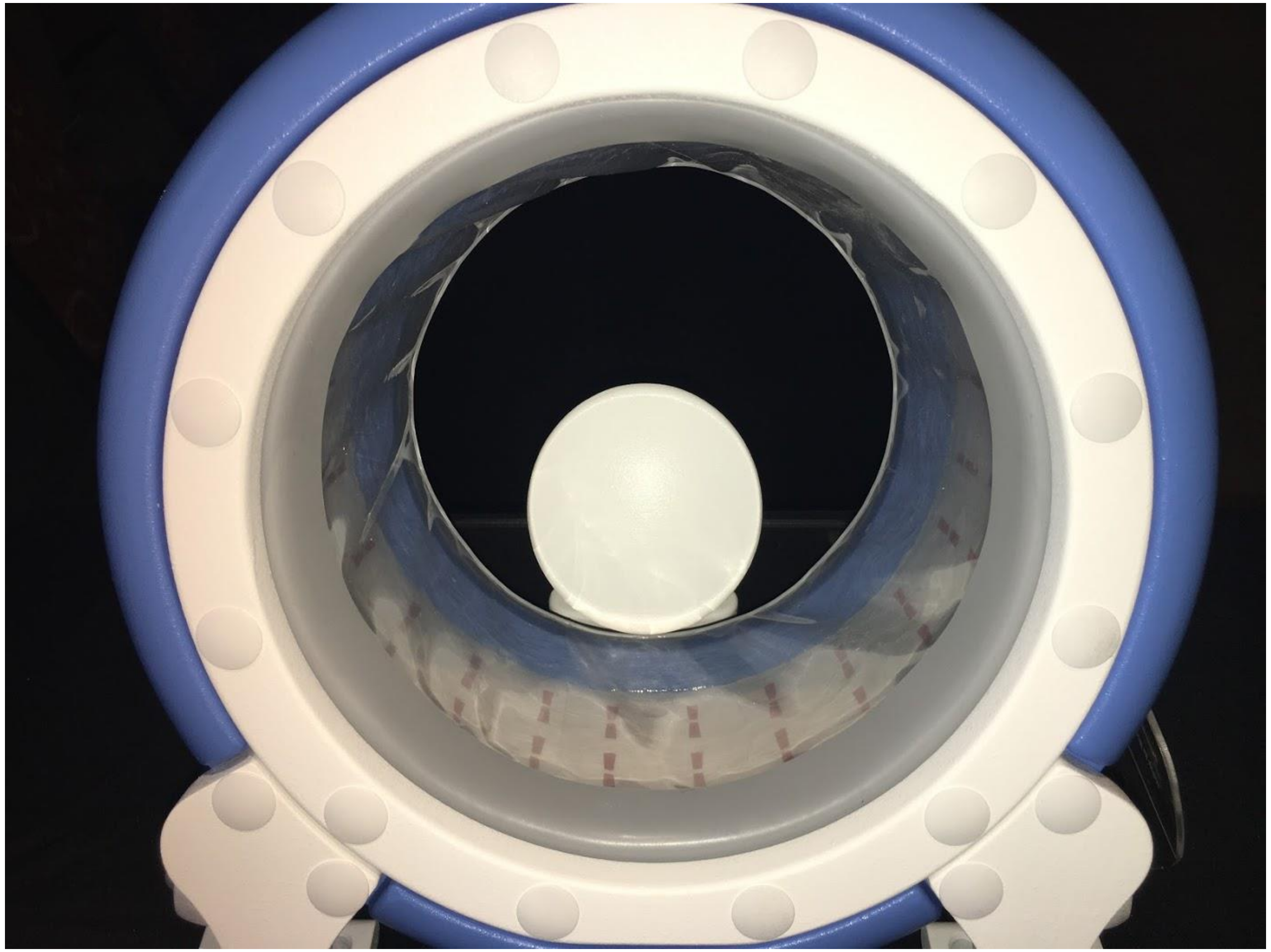


HT (40-45˚C) doubled 2-year survival!

Noninvasive applicator configuration

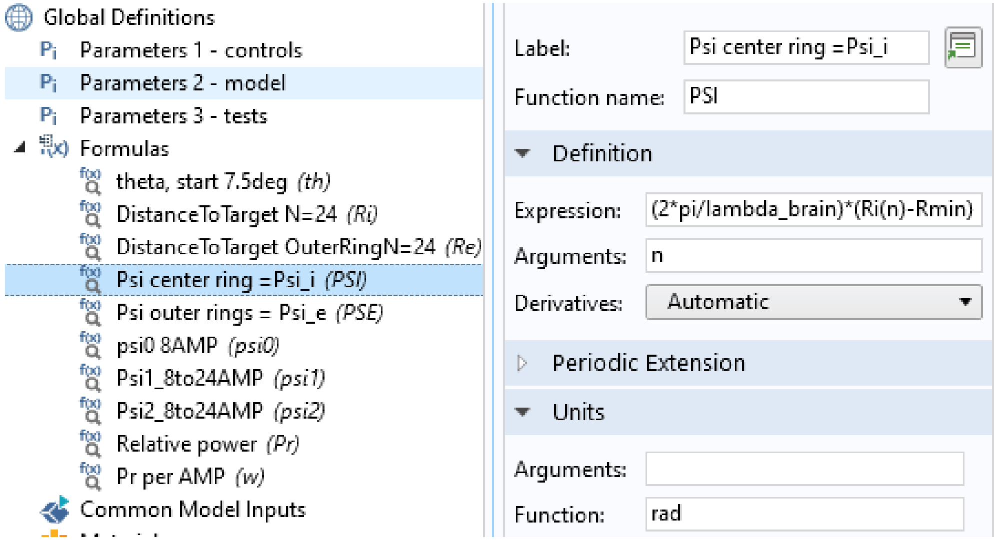
- Operating frequency: 915 MHz
- Array: 3 rings of 24 antennas (dipole size 9×24 mm)
- Cylindrical frame: 13 cm length, 26 cm dia. (~4cm water bolus)



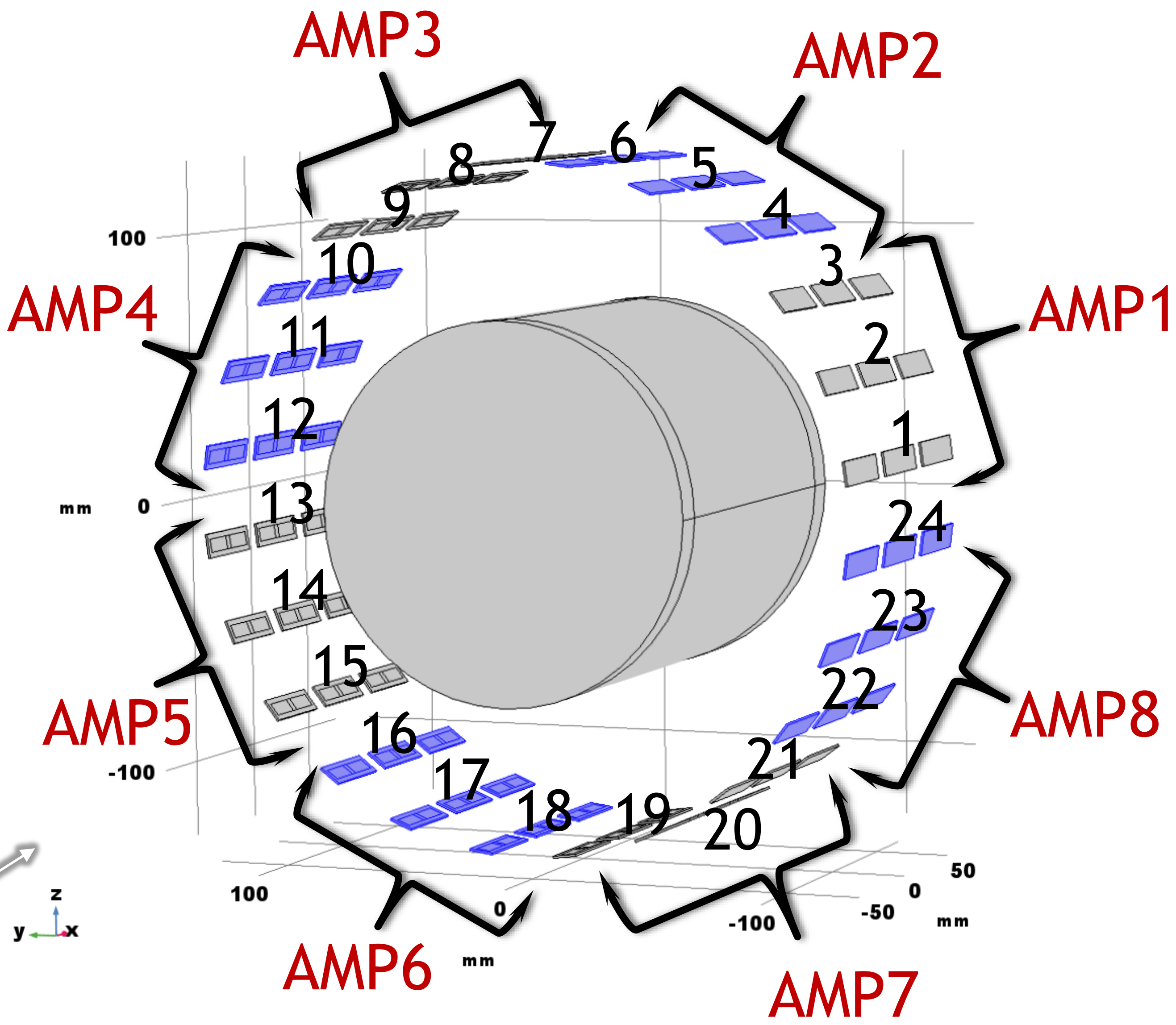


Antenna port parametrization

- Fully parametrized port phase and input power for all 72 antennas using 72, 24, or 8 amplifier controls



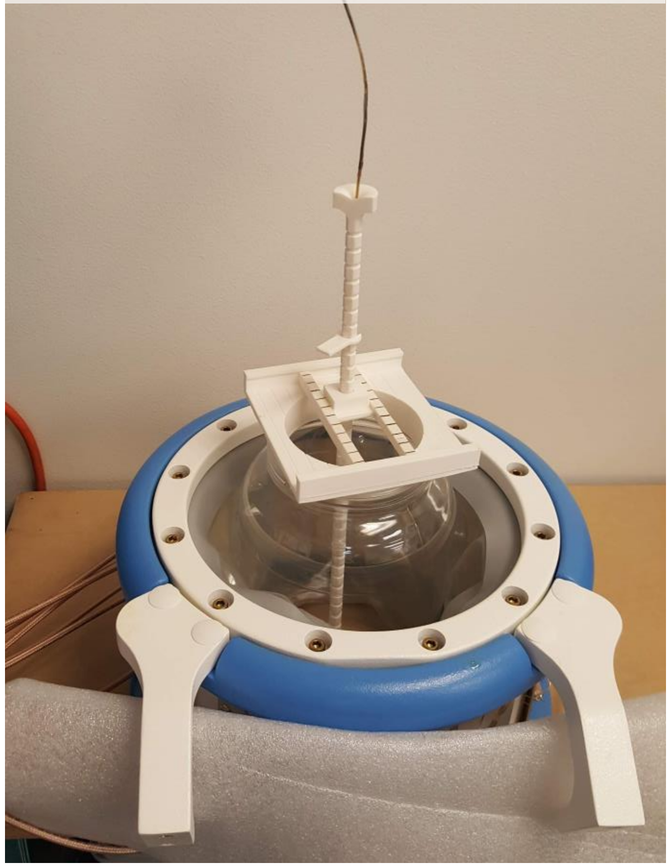
Practical applicator design involves using 8 amplifiers controlling 9 antennas each



Experimental phantom measurements

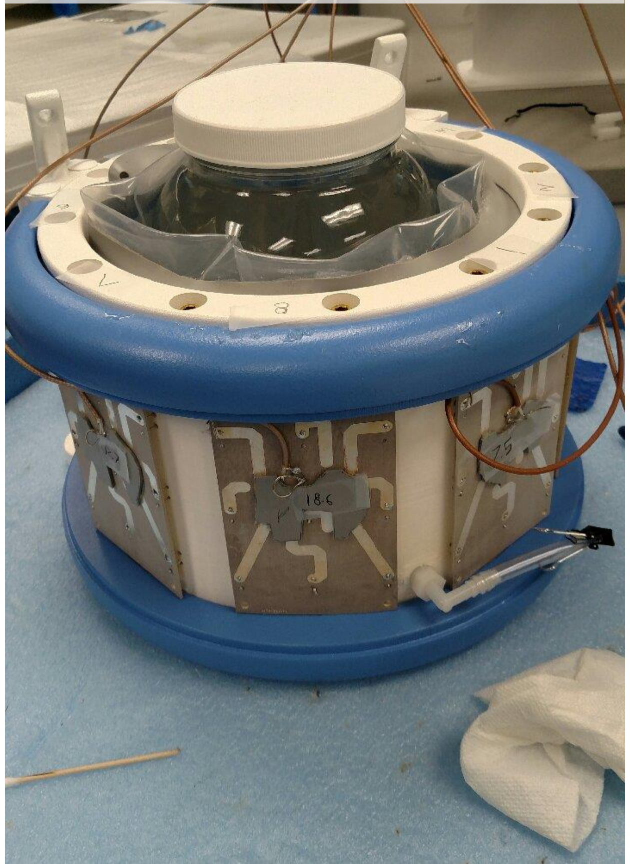
UNIVERSITY of MARYLAND BALTIMORE

Setup for E-field measurements



E-field sensor – miniature dipole 12mm long

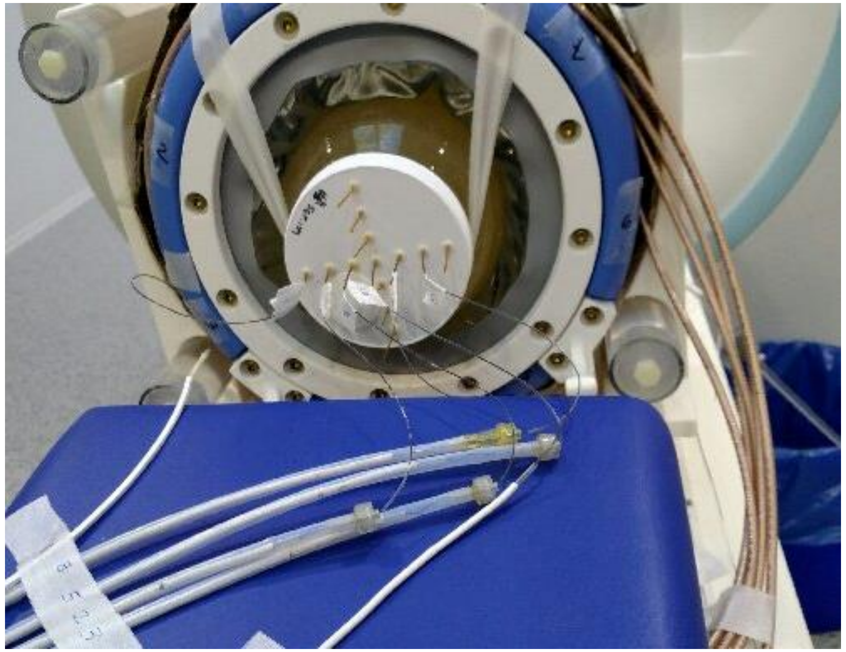
Phantom Heating measurements



BSD-500 915MHz
8 channel generator

Setup for Thermometry

3D MR, SigmaVision Advanced
& 1D RF-insensitive thermistors



1.5T MRI system
(Magnetom Symphony)

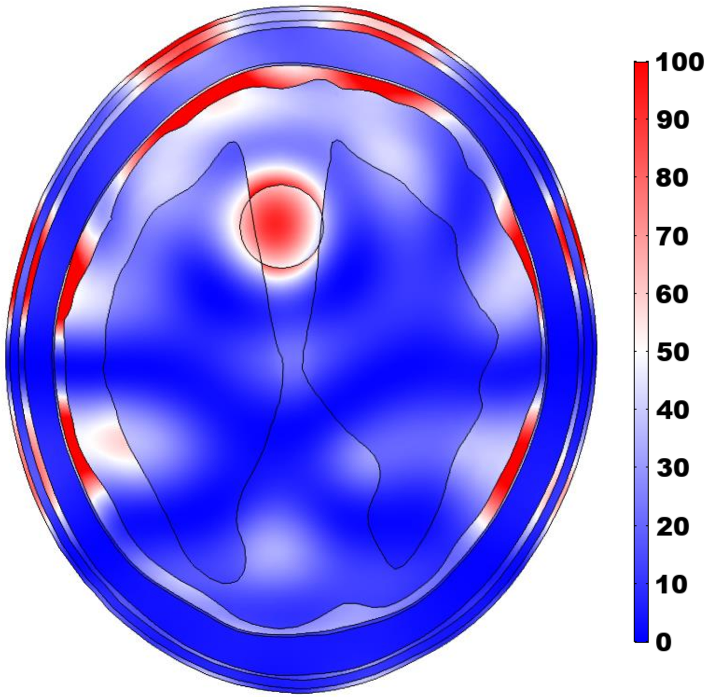
Computational modeling methods: RF→HT↔FF

RF Module

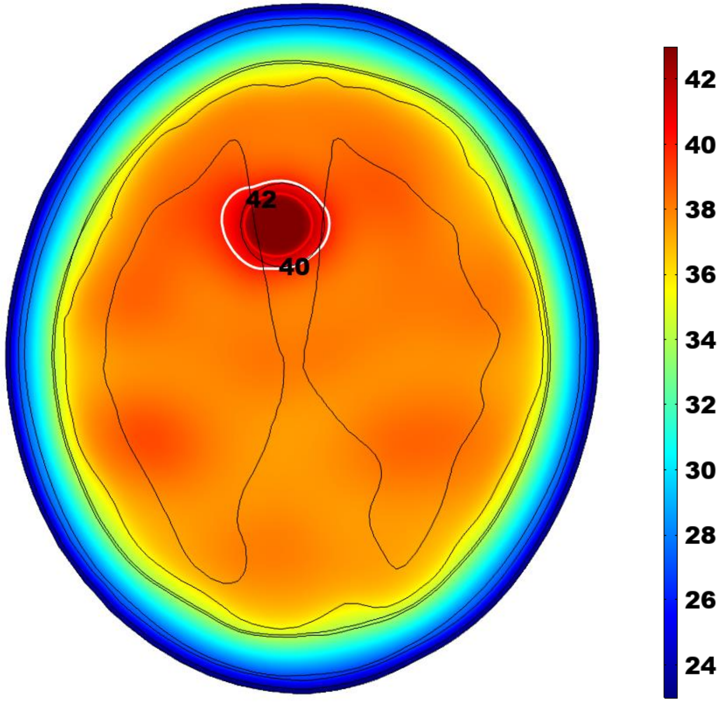
Heat Transfer Module

CFD Module

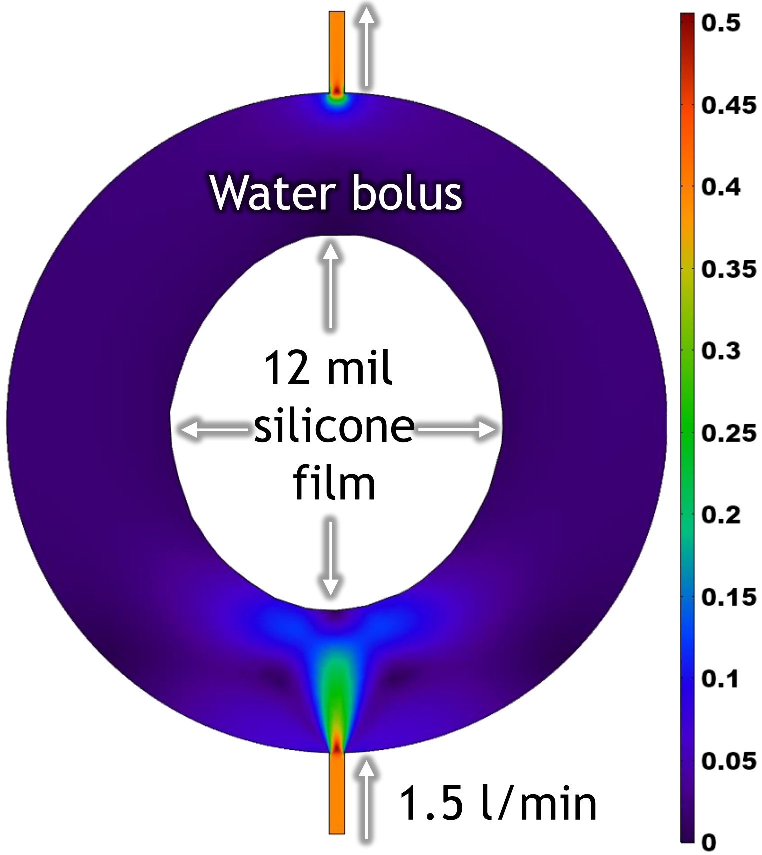
Specific absorption rate, SAR (%)



Temperature (°C)



Velocity (cm/s)



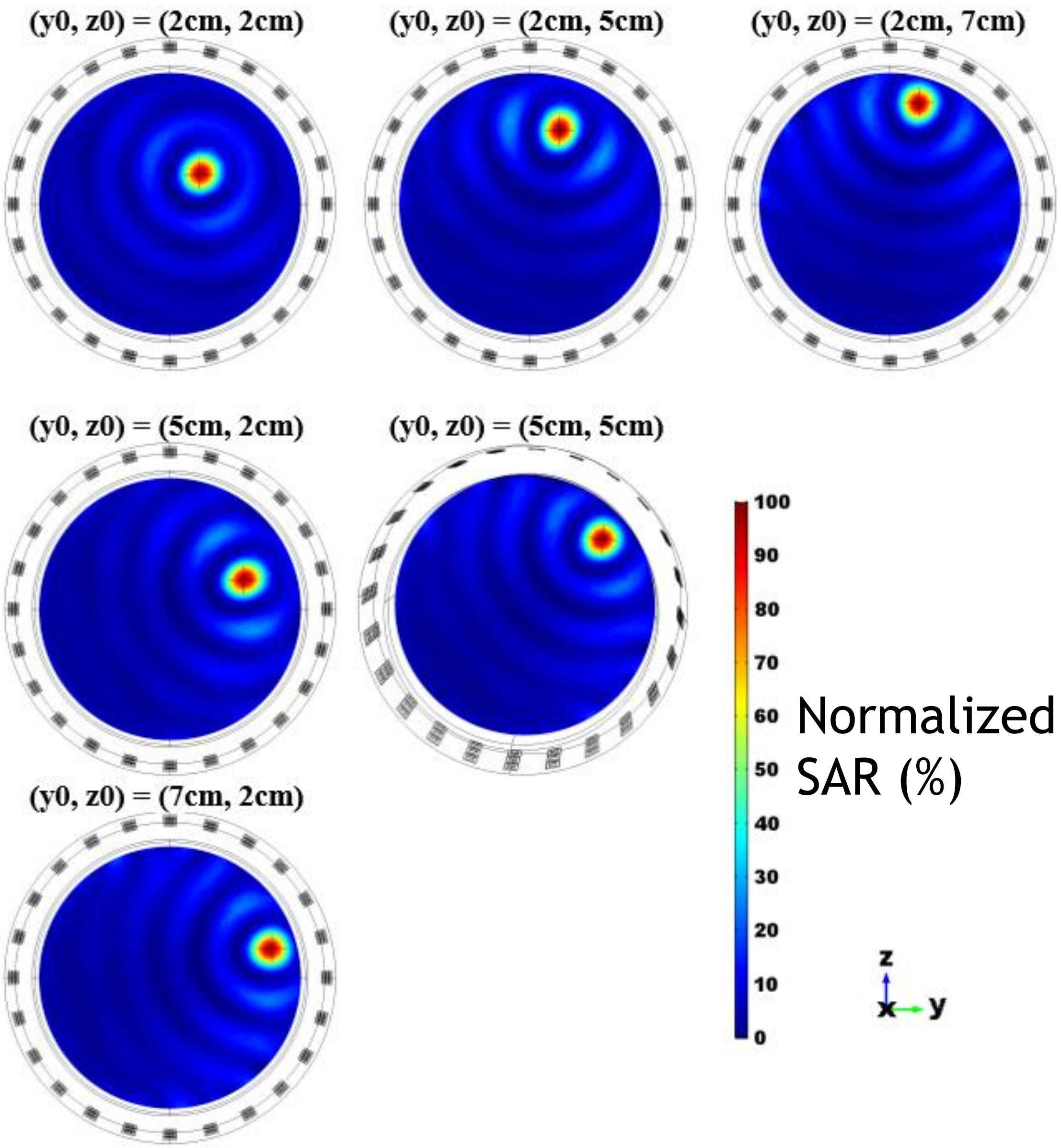
CAD Import Module

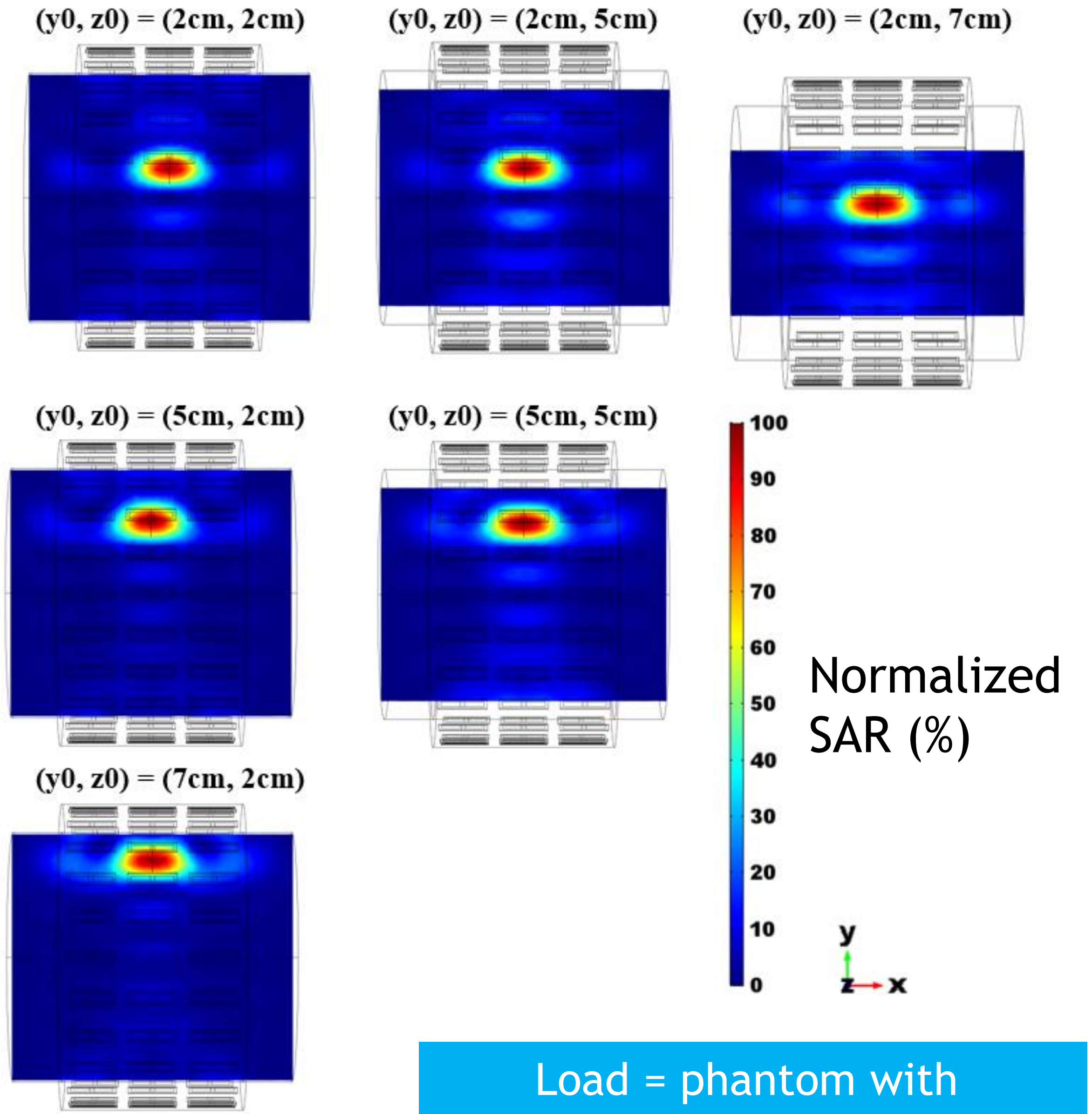
Material Library

Optimization Module

Fluid flow embedded in a boundary condition in HT using average h_{bolus} = 50 W/m²/K and T_{bolus} = 23°C

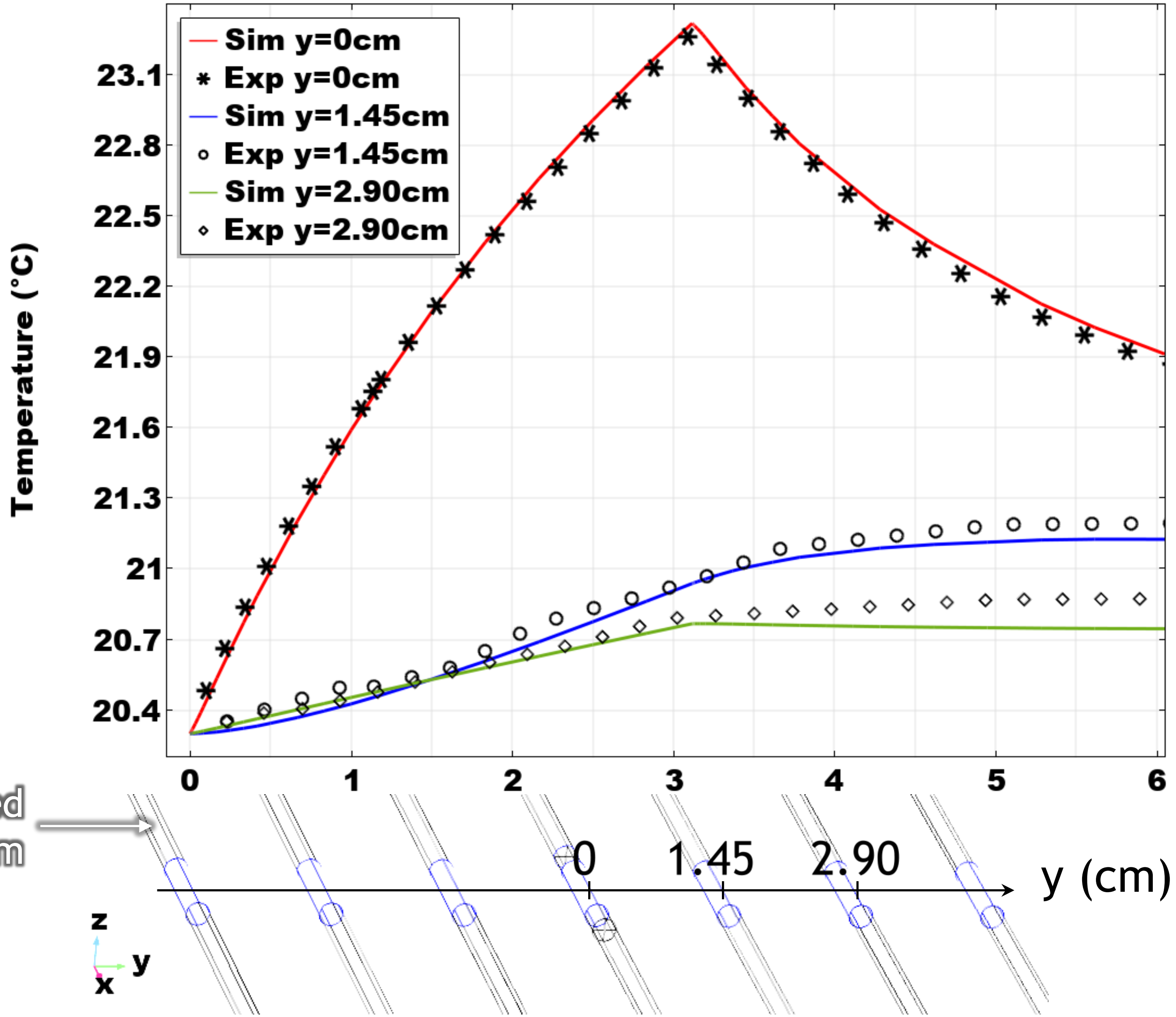
Steering with 72 amplifiers in a phantom





Load = phantom with
18 cm diameter × 20 cm length

Simulation vs Experimental probe thermometry

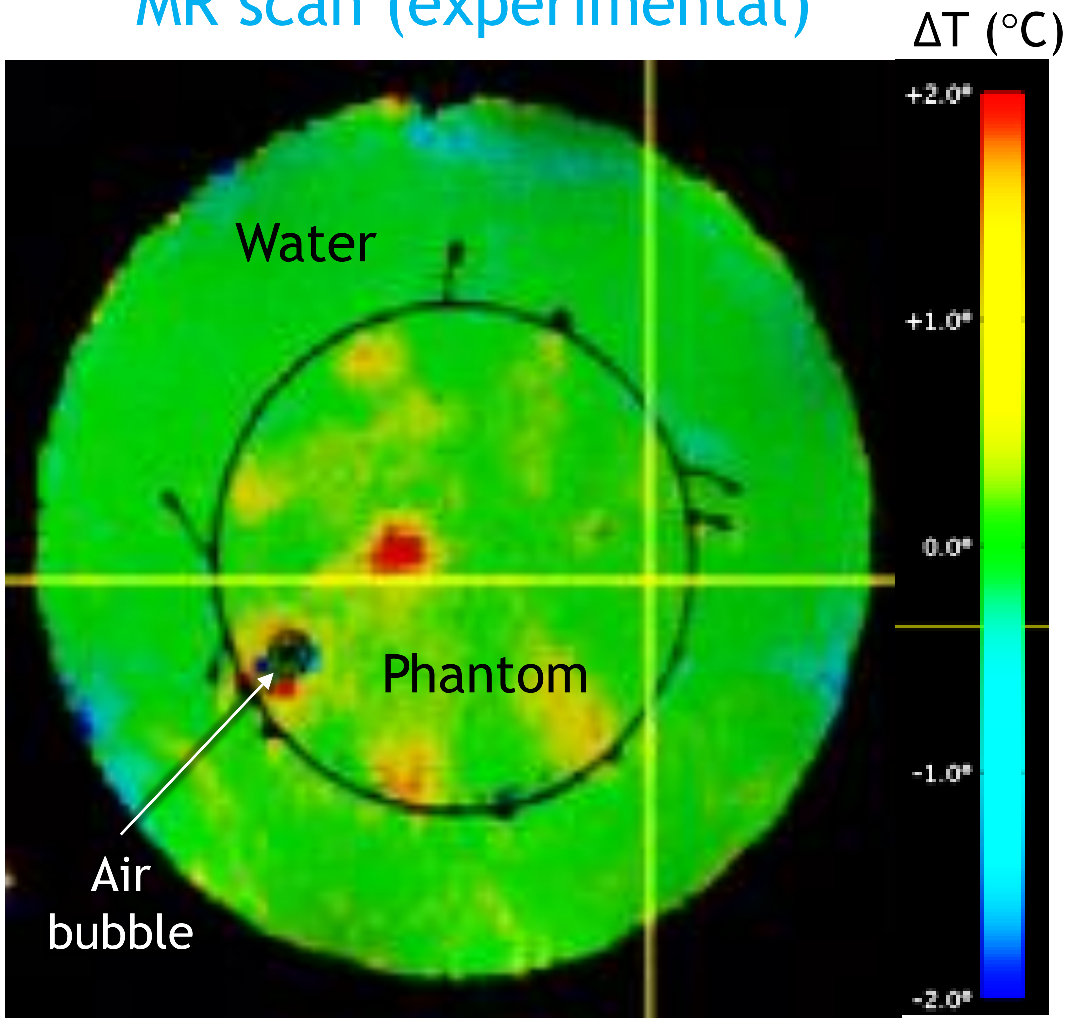


Target = phantom center (0,0,0) cm

Catheters embedded in phantom

Simulation vs Experimental MR thermometry

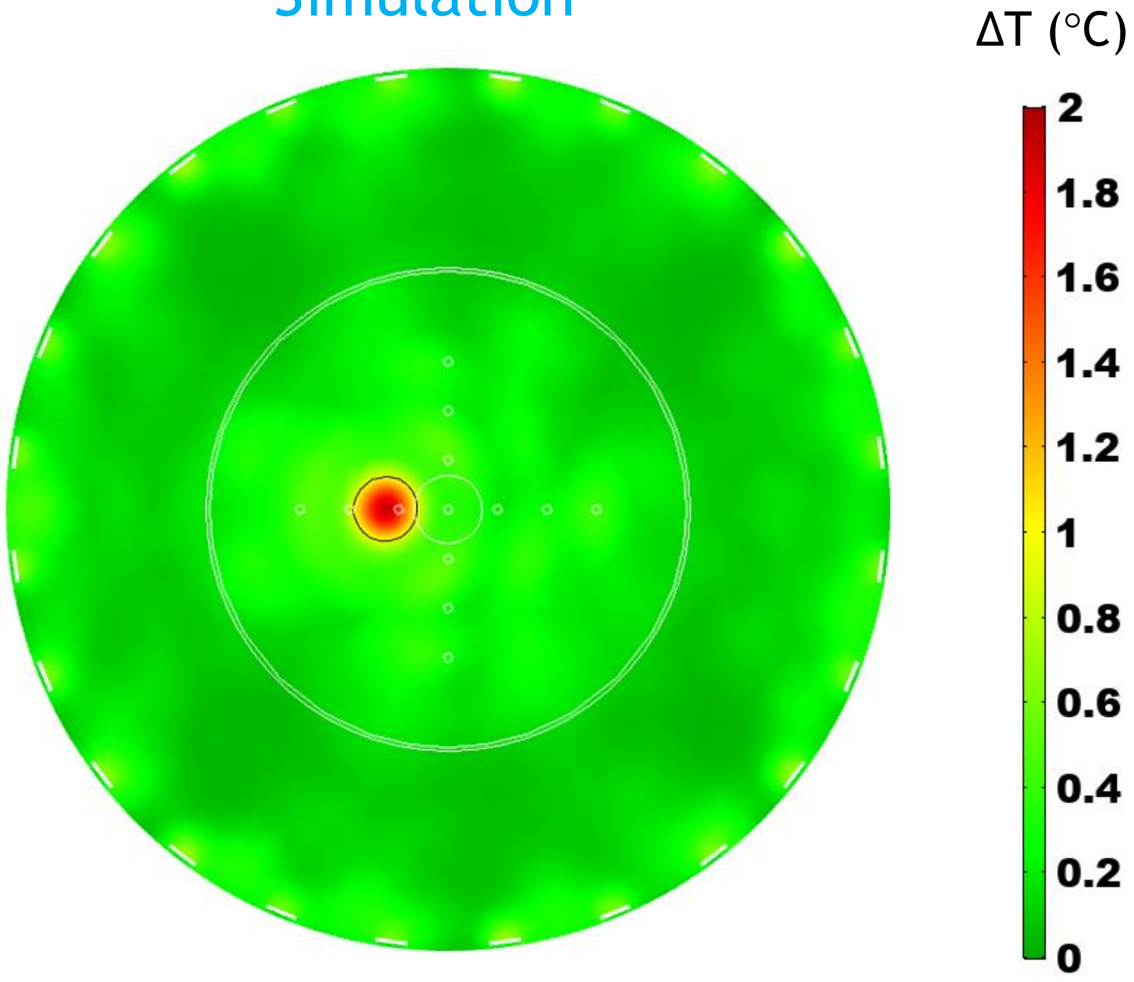
MR scan (experimental)



Δy = 16 mm
Heat focus = 4×1.5×1.5 cm^3

$$Heat\ focus = \frac{\Delta T_{max}}{2}$$

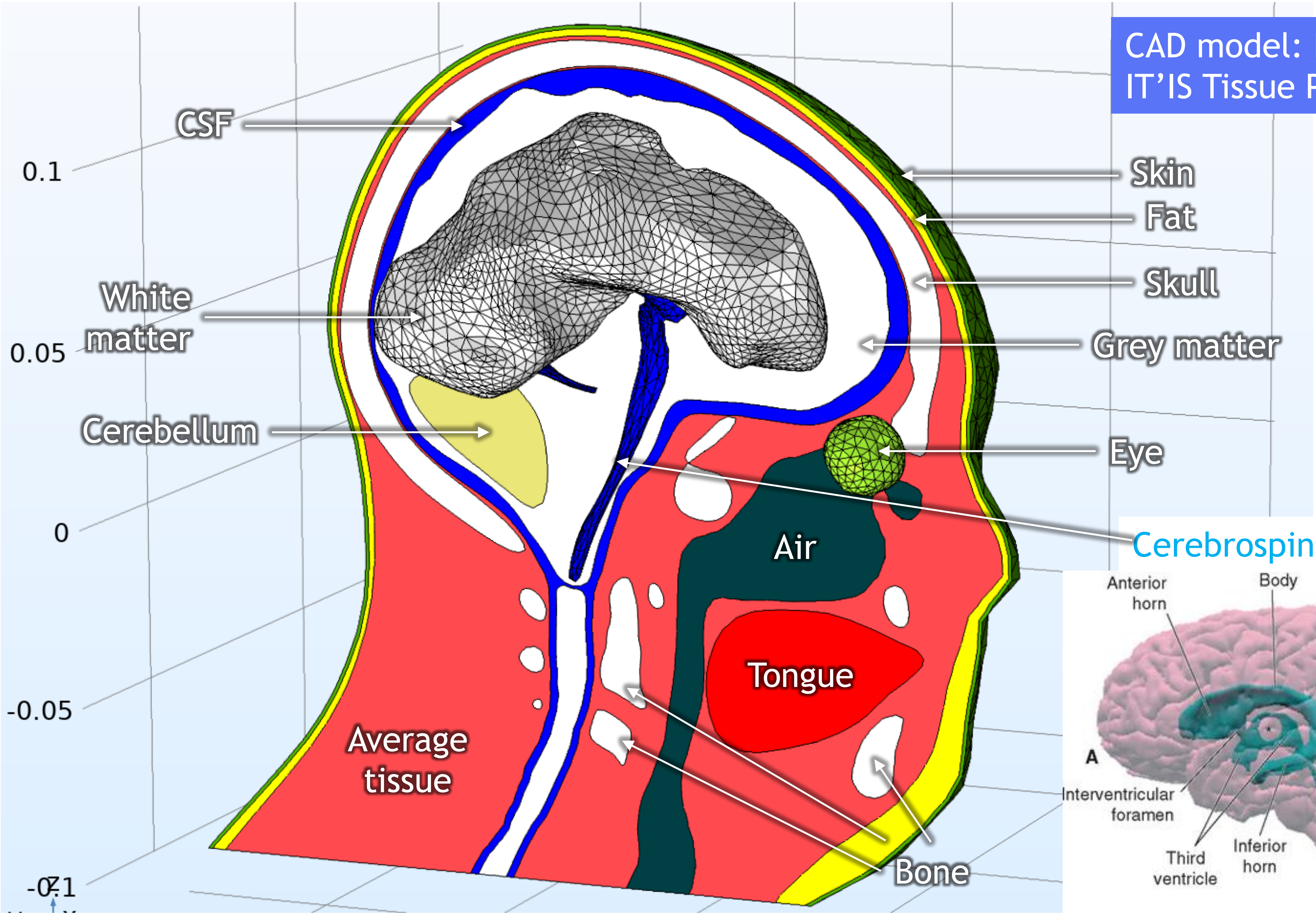
Simulation



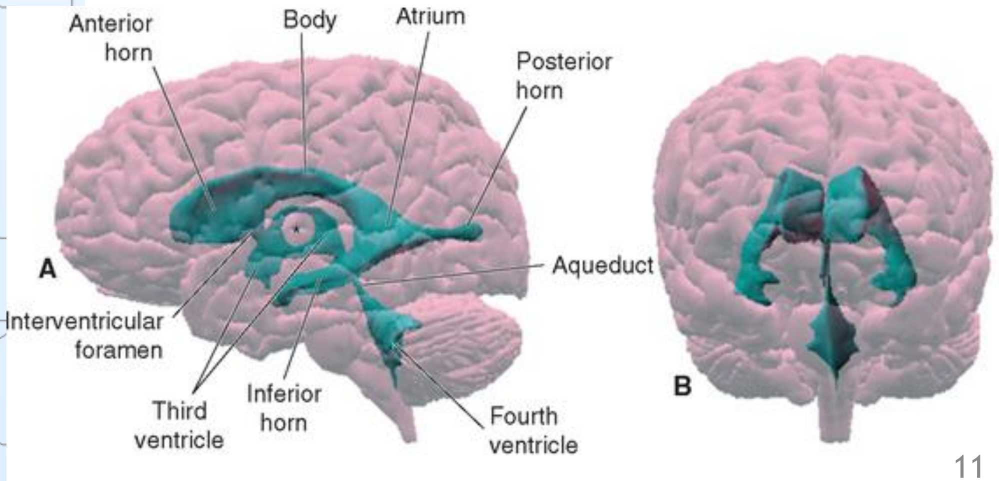
Δy = 18 mm
Heat focus = 3.4×1.4×1.5 cm^3

Anatomical model

CAD model: Neva Electromagnetics v3.0
IT'IS Tissue Property database v4.0

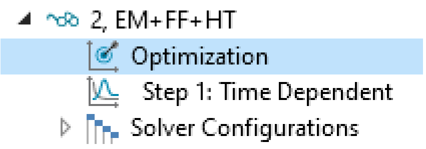


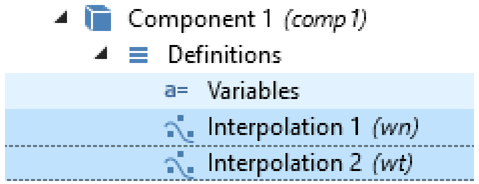
Cerebrospinal fluid (CSF) ventricles



Computational methods

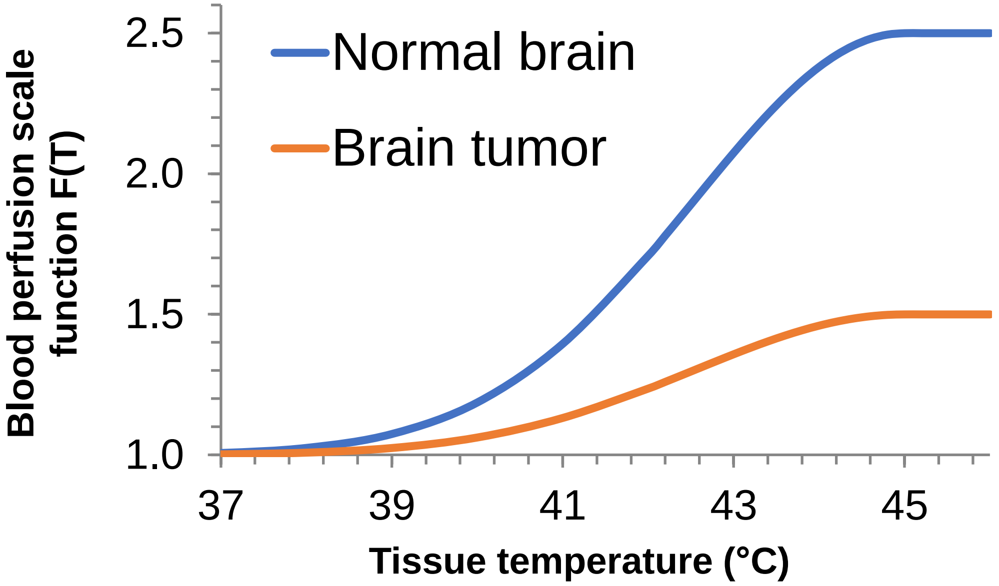
- Power optimized based on T_{tumor} = 40-44°C, T_{normal} <42°C
- Necrotic core (2 cm) with 10% of white matter blood perfusion
- Water bolus convective cooling: T_{bolus}= 23°C, h_{bolus} = 50 W/m²/K
- Bioheat equation with temperature dependent blood perfusion:





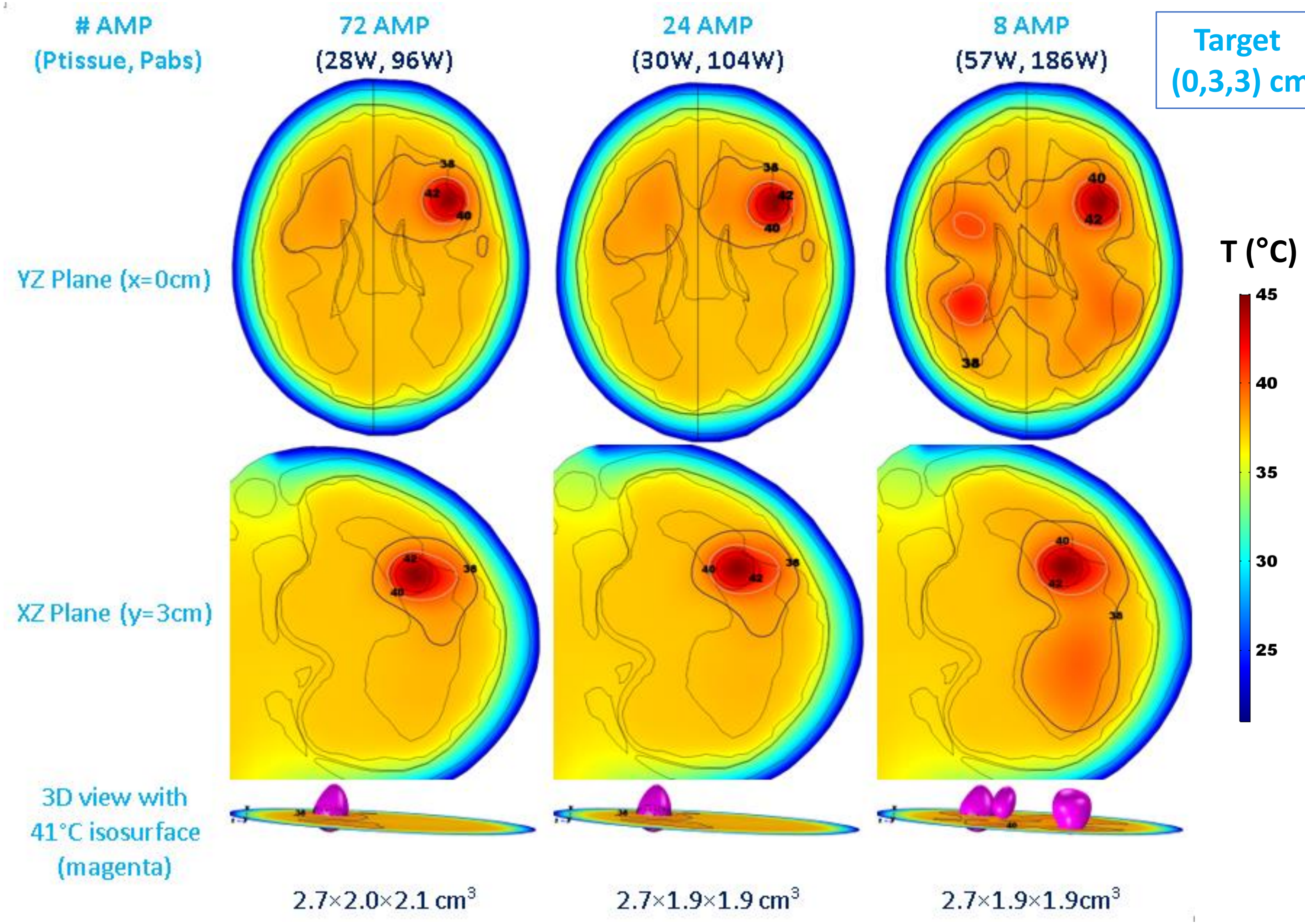
$$\omega_B(T) = \omega_b \times F(T)$$

Basal blood perfusion



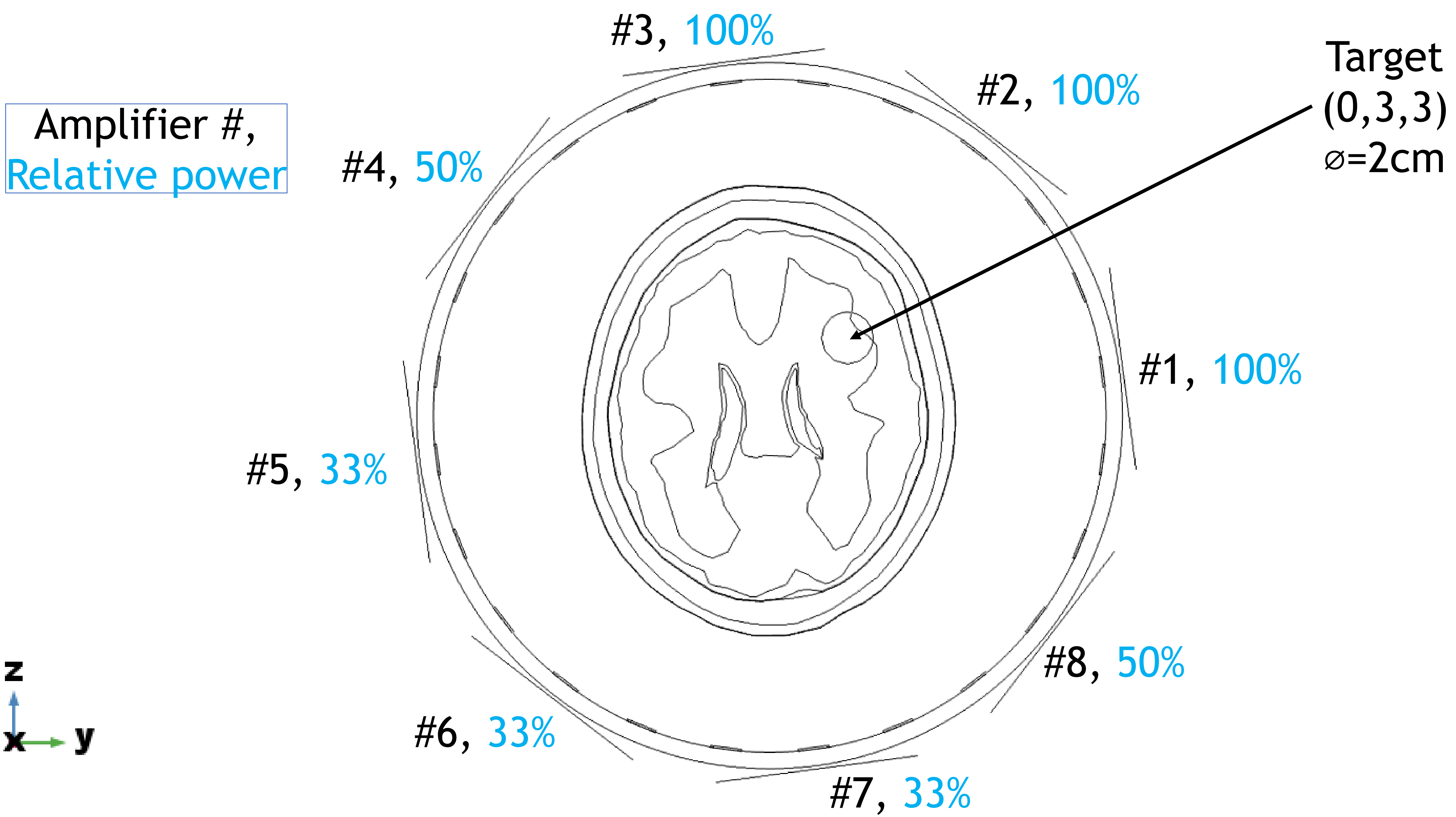
Steering with 72→8 amplifiers

Target
(0,3,3) cm

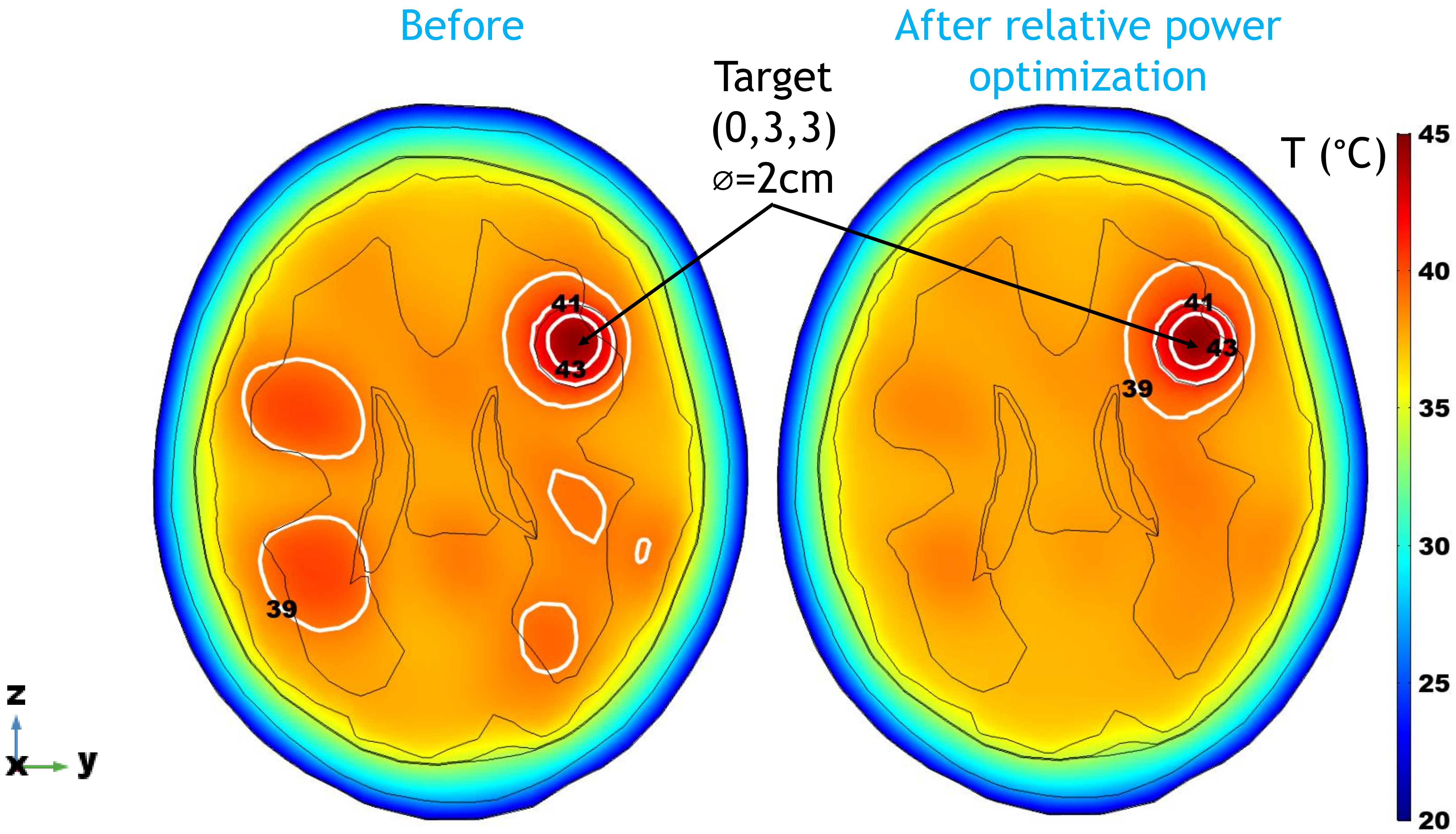


Relative power optimization 1/2

Amplifier #, Relative power



Relative power optimization 2/2



Conclusions

- 3D MR and 1D thermometry validated COMSOL numerical simulations
- The feasibility of heating small targets in a head phantom using a novel microwave brain applicator is demonstrated with experiments and numerical simulations
- Phantoms confirm reliable and predictable focus steering
- 8 channels may have phase control limitations, but using improves thermal dose in target while reducing hot spots in healthy tissue
- By providing a dedicated noninvasive HT brain applicator, focused heating will likely significantly increase clinical outcomes of GBM cancer treatments using radiation and/or chemotherapy, as it has in many other clinical trials that used adjuvant HT

Thank you! Dario Rodrigues (drodrigues@som.umaryland.edu)