# Investigating the use of Ultra High-Field MRI as a Theranostic Thermal Therapy Platform

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RSL RADIOLOGICAL SCIENCES LABORATORY STANFORD MEDICINE

SCIT STANFORD CANCER IMAGING TRAINEESHIP

# Brain Mets: Motivation and Challenges

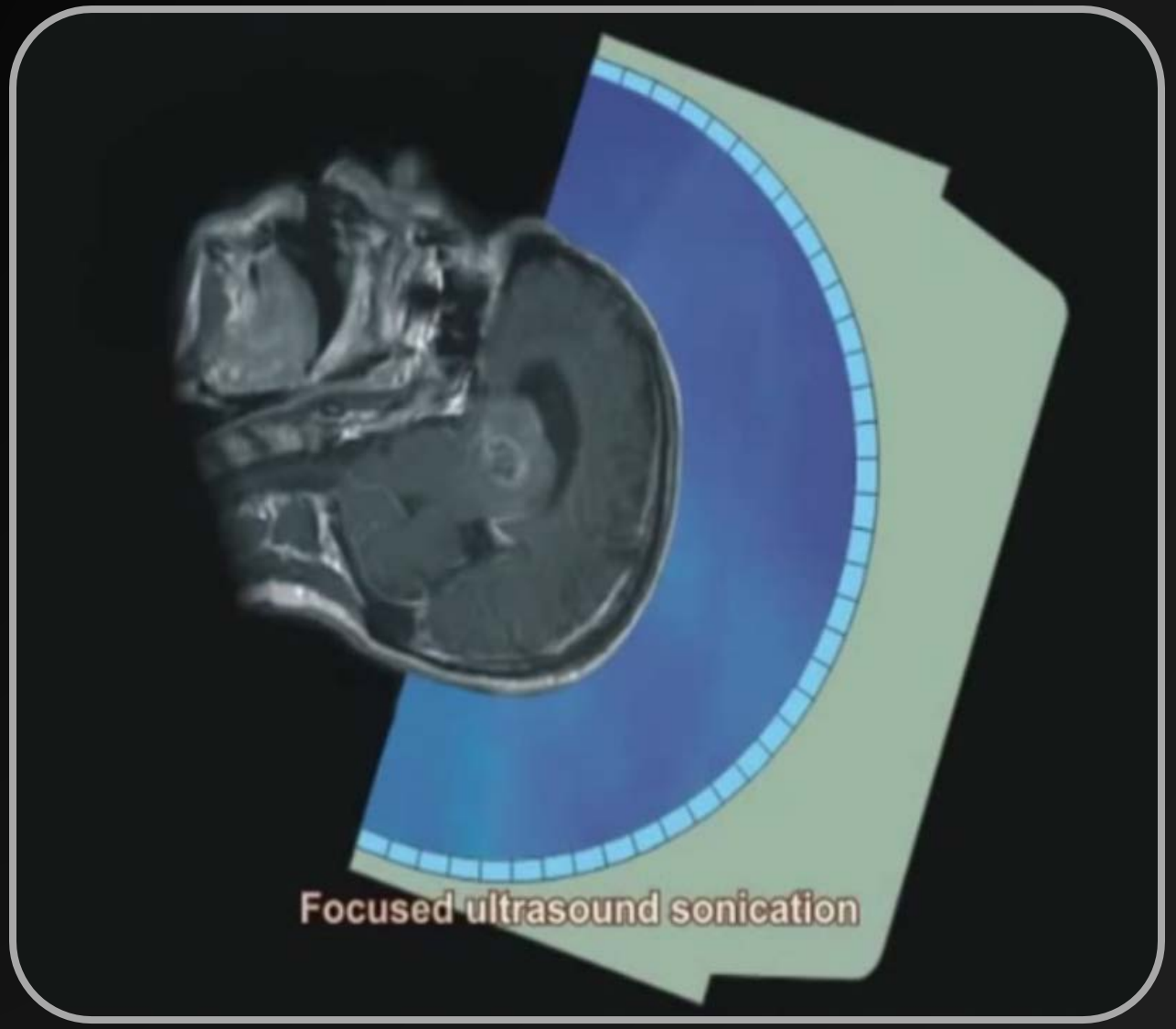
- Most common type of brain tumors
  - ~200,000 cases per year (USA)
  - > all intracranial tumors
  - Primary cancers: Lung, Breast, Melanoma

- Treatment options
  - Surgical resection
  - Whole-brain radiation therapy (WBRT)
  - Corticosteroids
  - Stereotactic Radiosurgery  (SRS)

- Median overall survival:
  - Untreated: 1 month
  - With treatment: 3-11 months

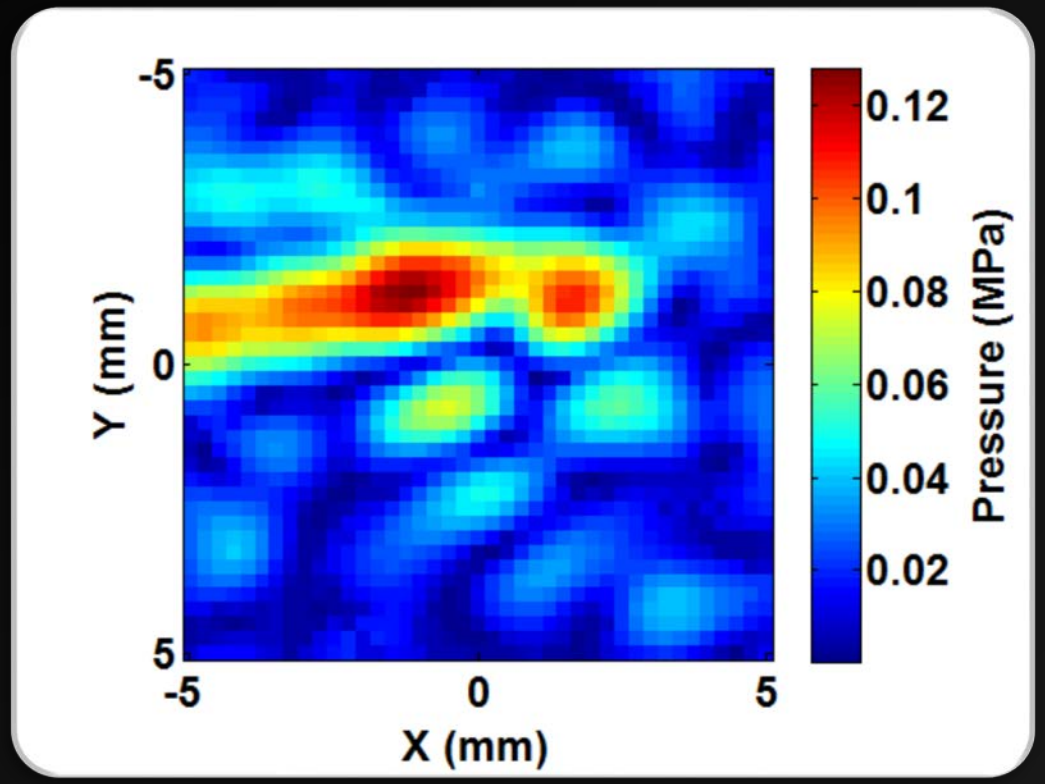
T1w - Gd

# One Solution: MR Guided Focused Ultrasound (FUS)

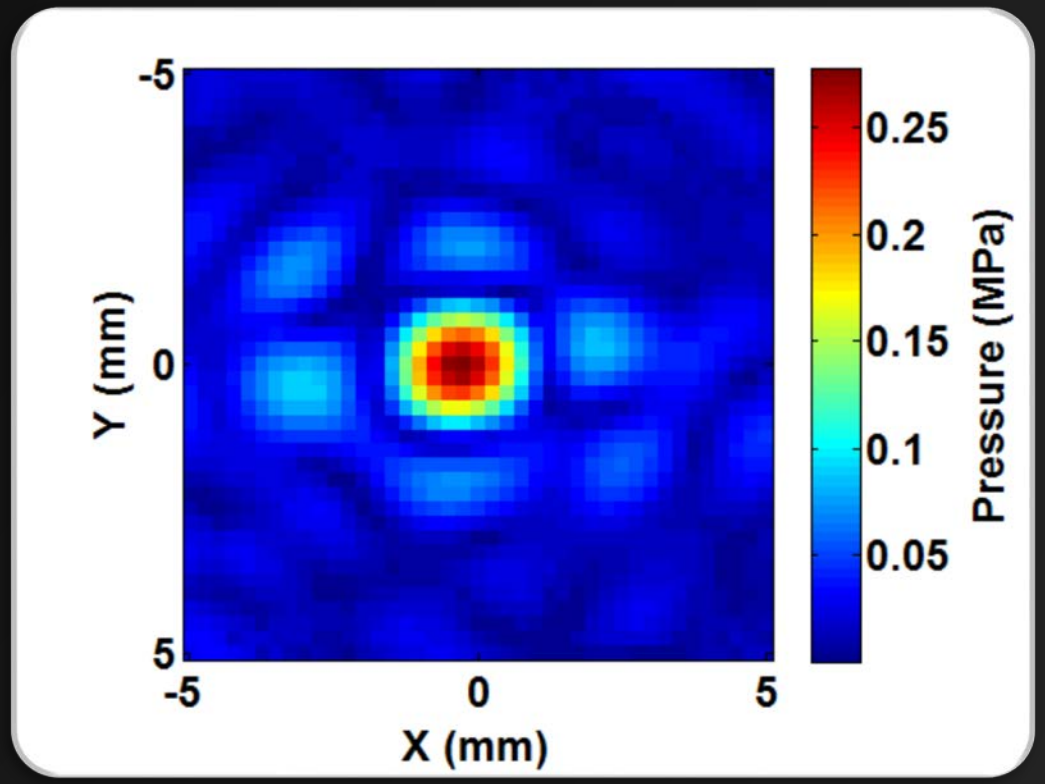


# FUS Through Skull Flap

**No Correction**

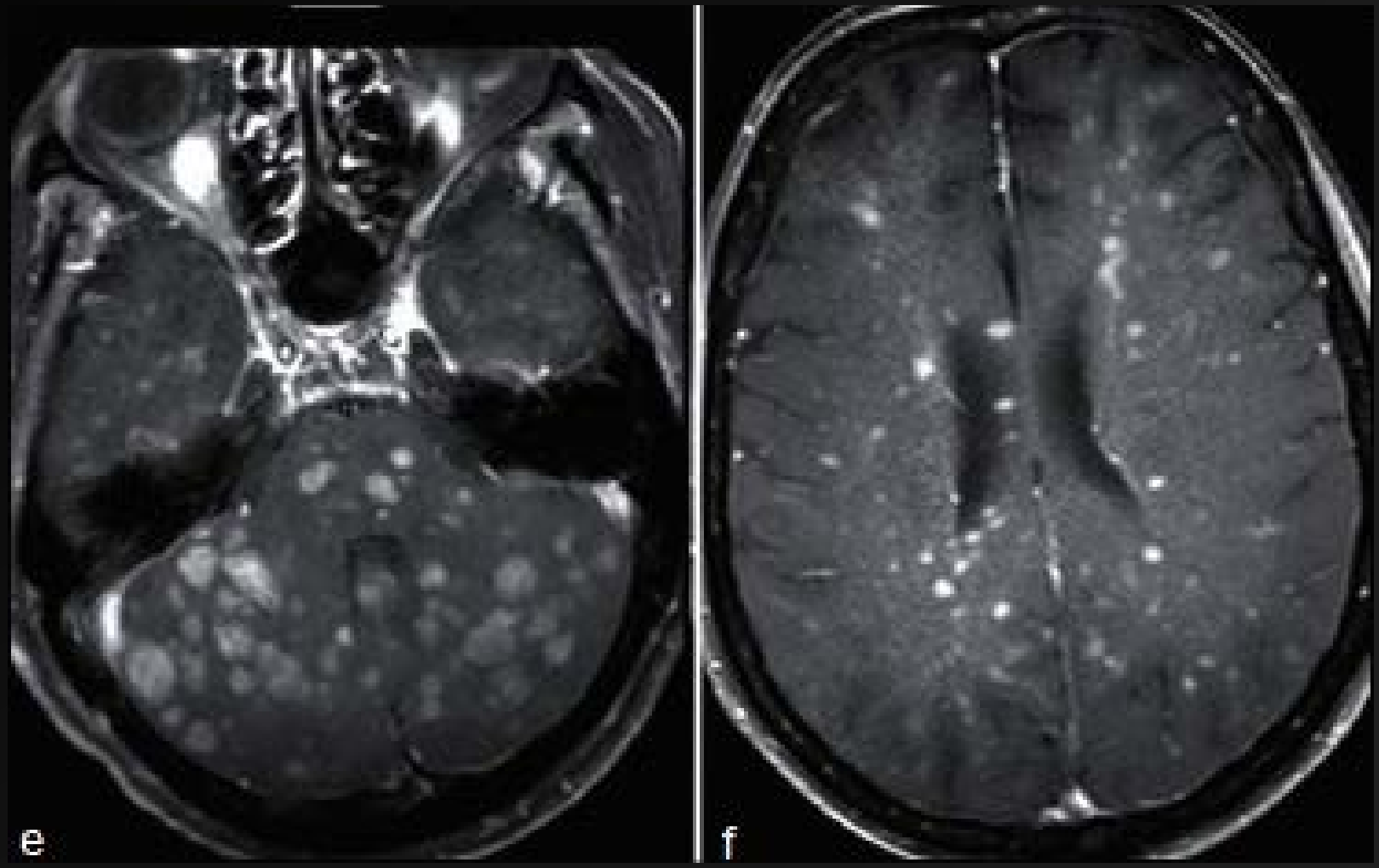



**After Phase Correction**




Courtesy of Scott Almquist – Univ. Of Utah

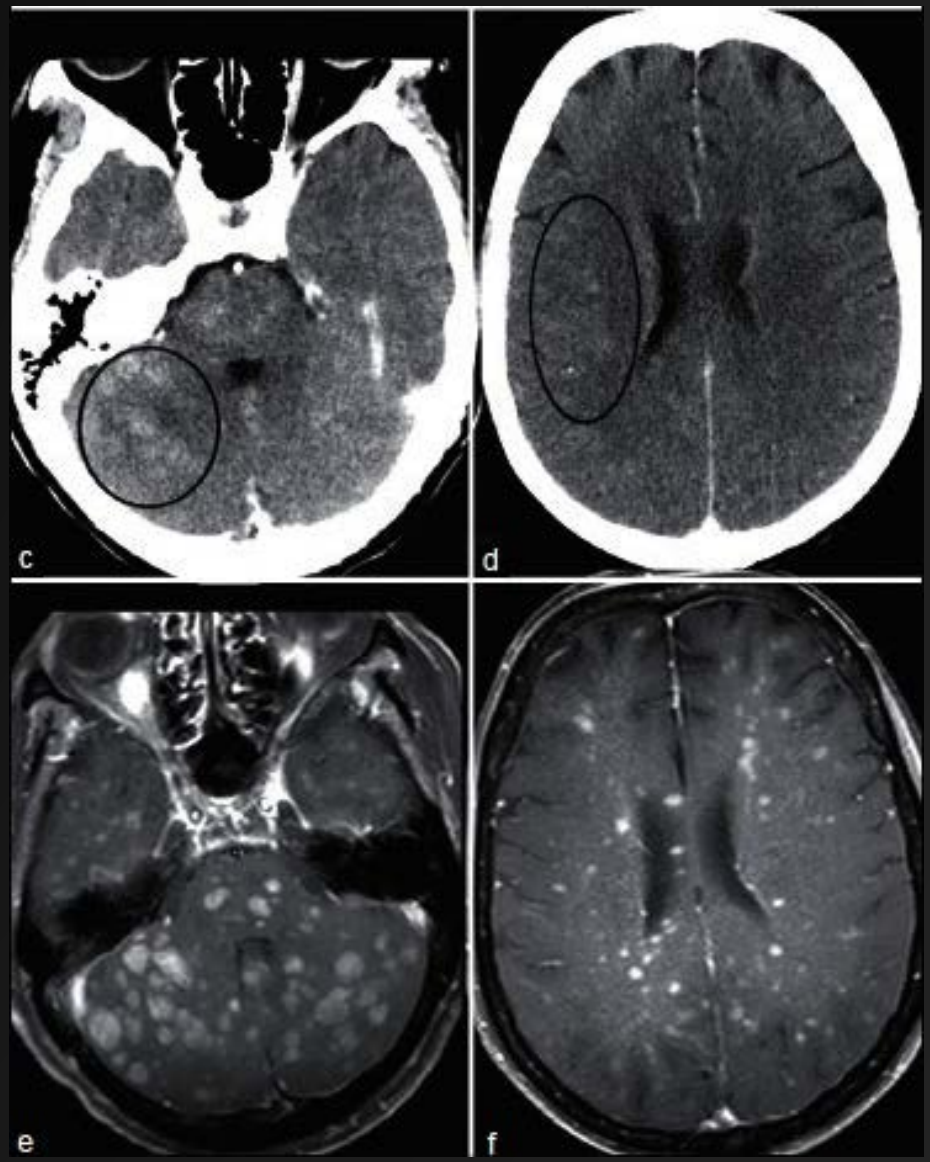
# Multiple Brain Metastases




Fink, *SNI,* 2013

# Ultra High-Field MRI

- MRI w Gd leads in BM detection
- 66-75% of patients who present with a single lesion on CT actually have multiple lesions
- Higher Field = More Signal
- Increase: Resolution, speed, etc




**CECT**

**MRI w Gd**

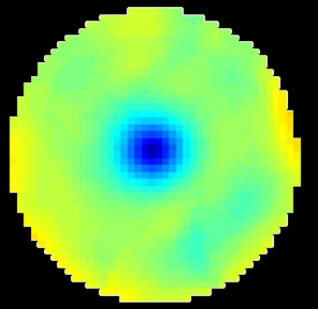
Fink *et al*, *SNI,* 2013

# Ultra High-Field MRI: Challenges

## BIRDCAGE MODE

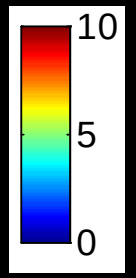
**SPGR**
**TR=4000ms**
**FA = 30°**

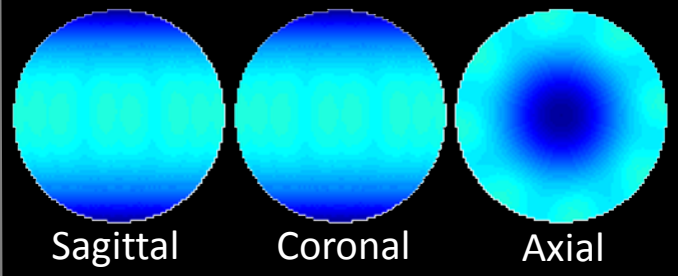
**FA error (%)**






**Local SAR MIP (W/kg)**




Courtesy of: Mehir Pendse, ISMRM 2015 #573

# Ultra High-Field MRI: Challenges

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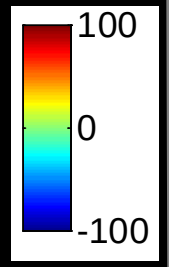


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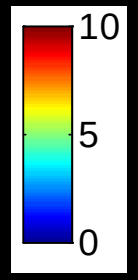


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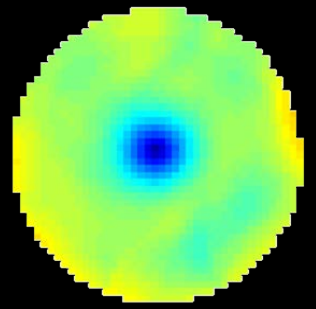
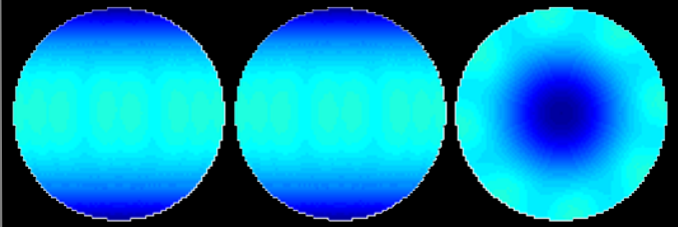
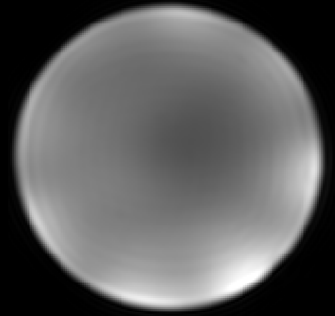
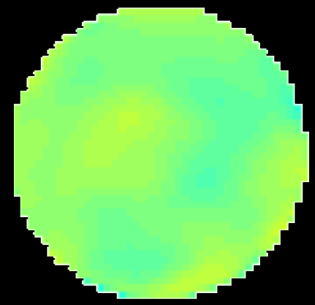
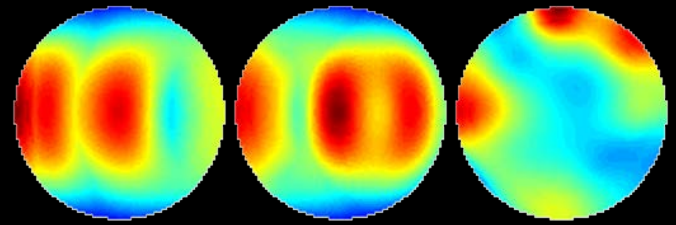





## SAR UNAWARE[1]



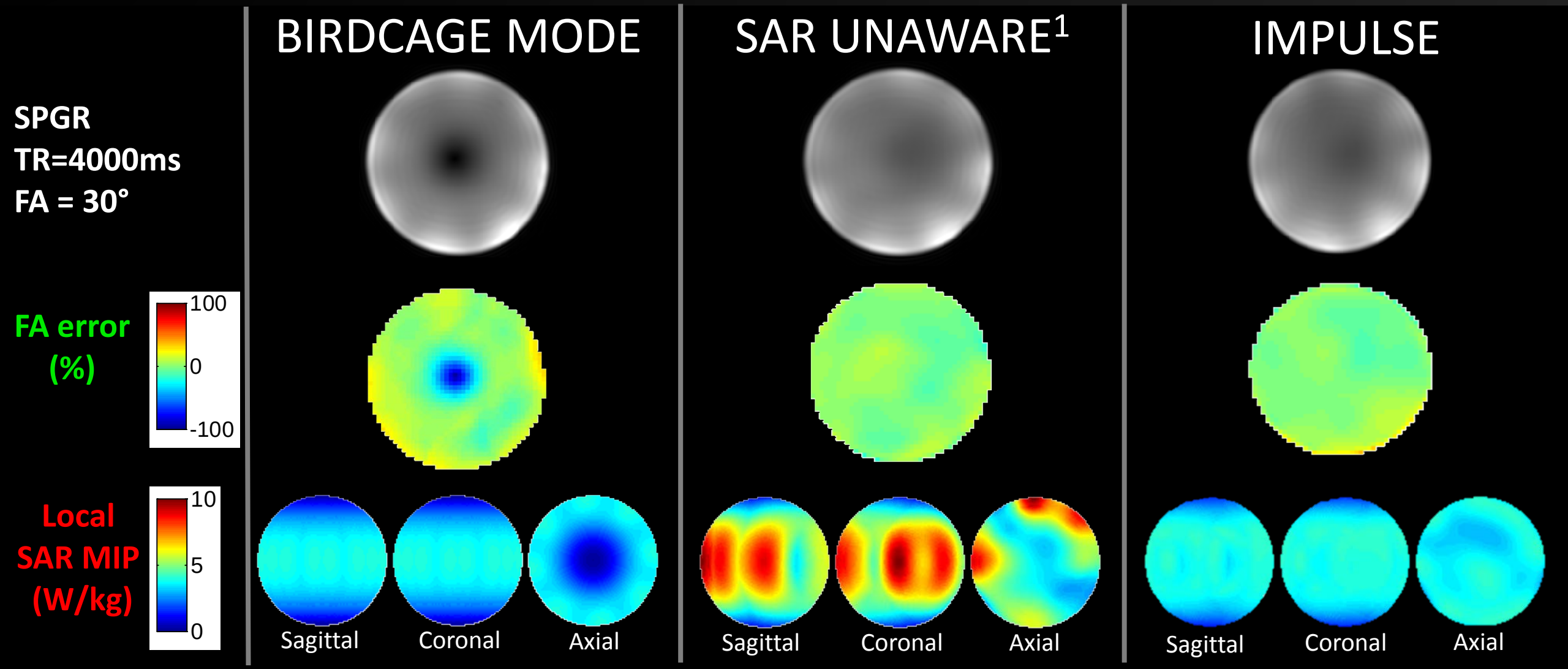





Courtesy of: Mehir Pendse, ISMRM 2015 #573

[1]Grissom, MRM 2012;68:1553–1562

# Ultra High-Field MRI: Challenges

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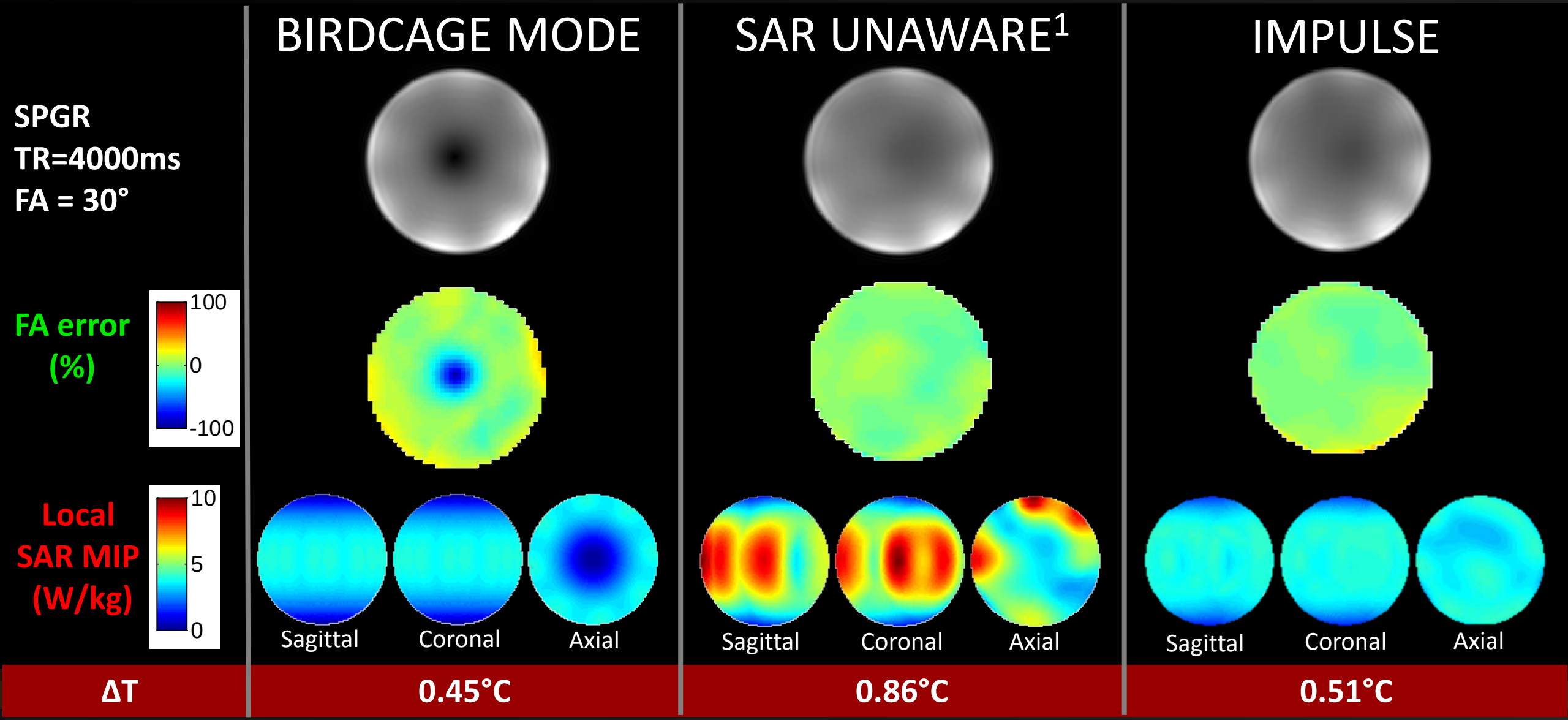


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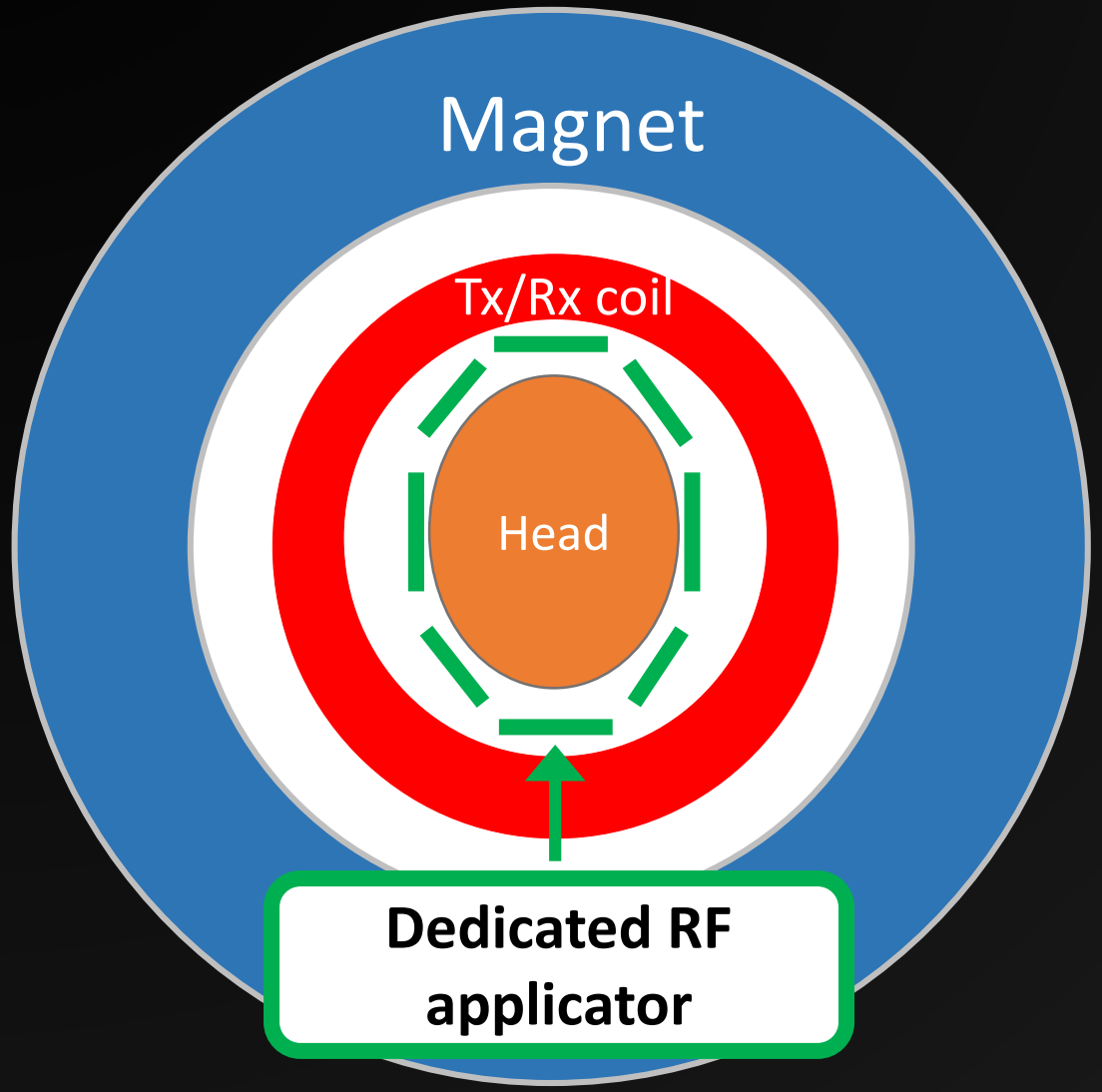
**Q**: Can this undesired heating been turned into something positive?

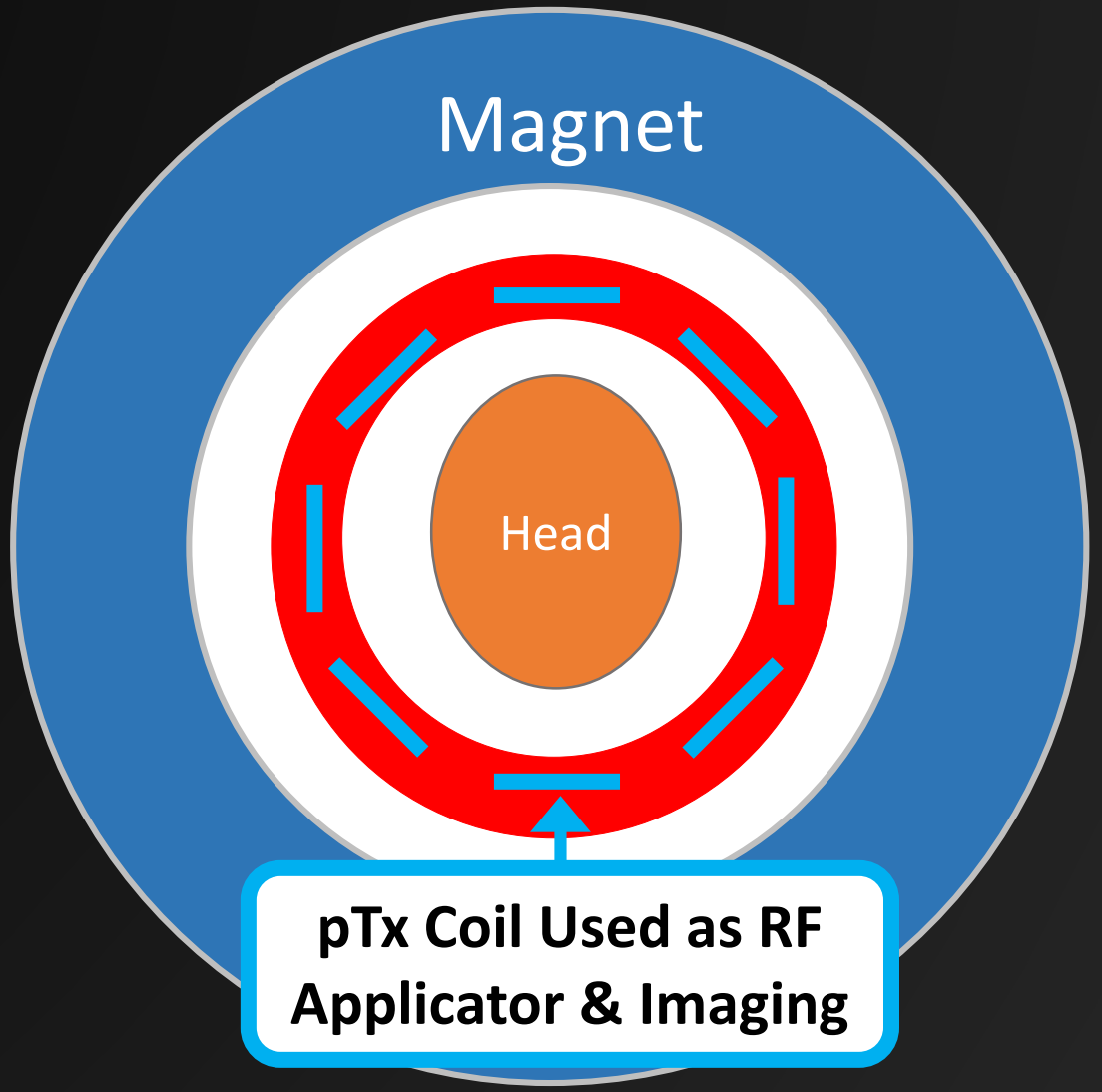
# Focused RF (FRF)

# Hardware Configurations

## #1: Dedicated RF Applicator

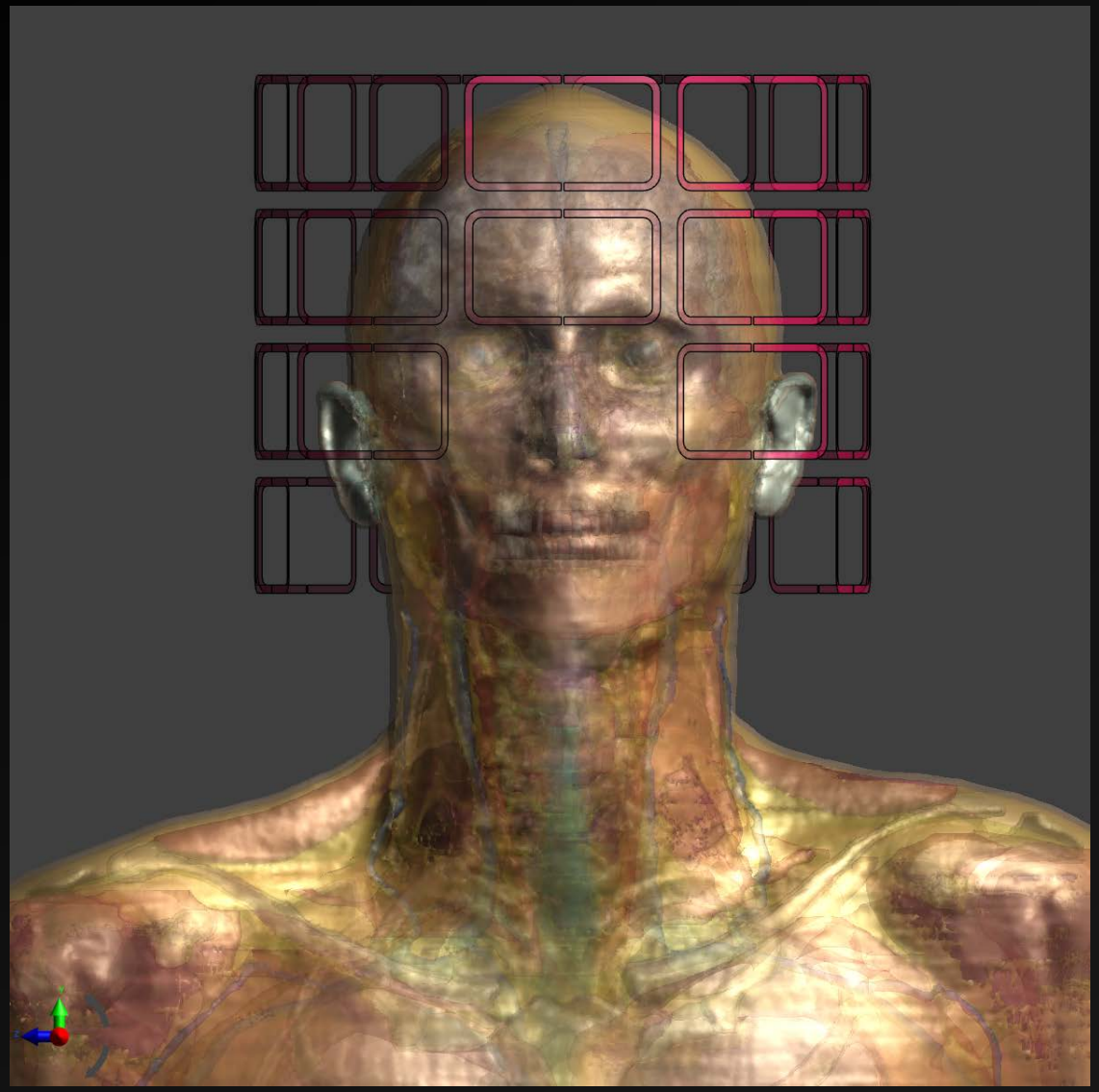



## #2: All-In-One



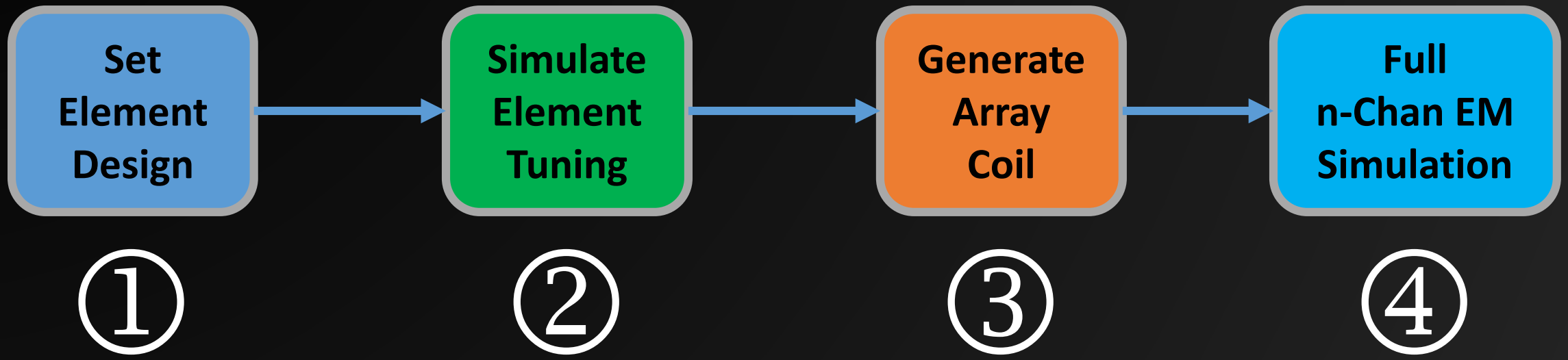
# FRF Design Study

# SPEAG Sim4Life



- FDTD Electromagnetic simulations
- Virtual Family – Realistic body models
- Working with SPEAG on accelerating simulations

# FRF Coil Design Study



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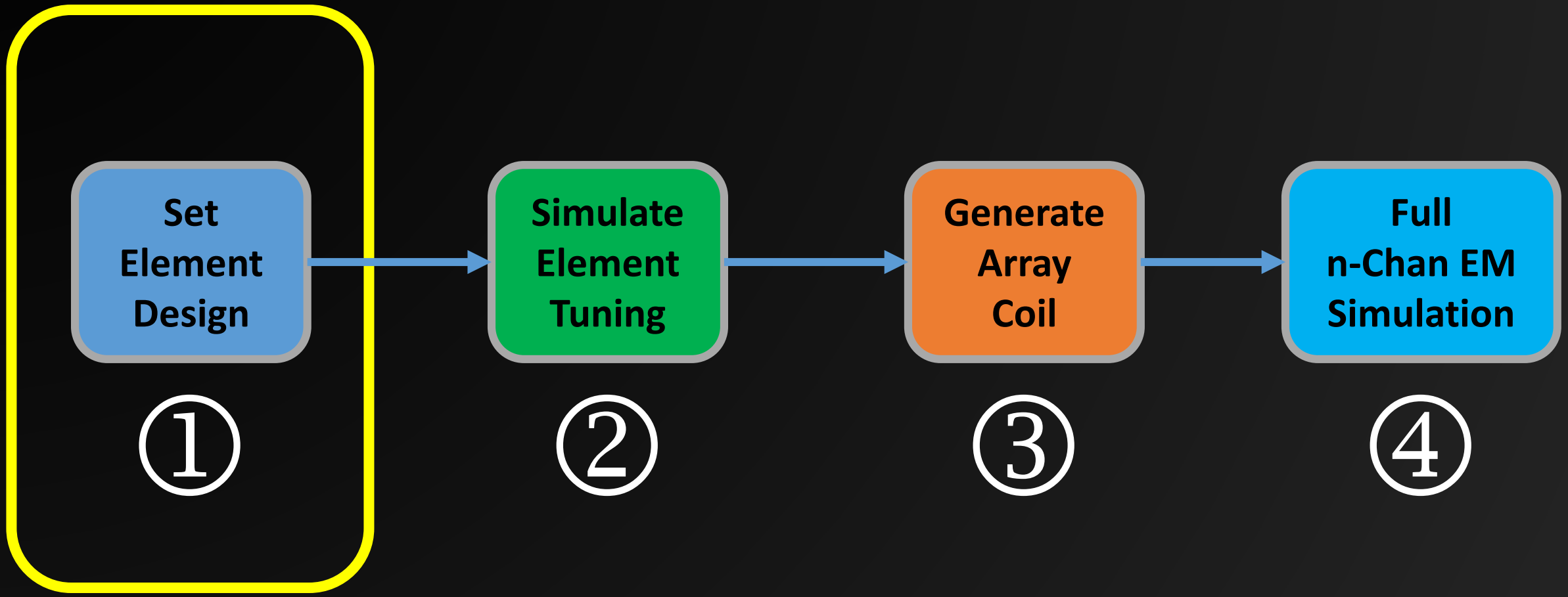
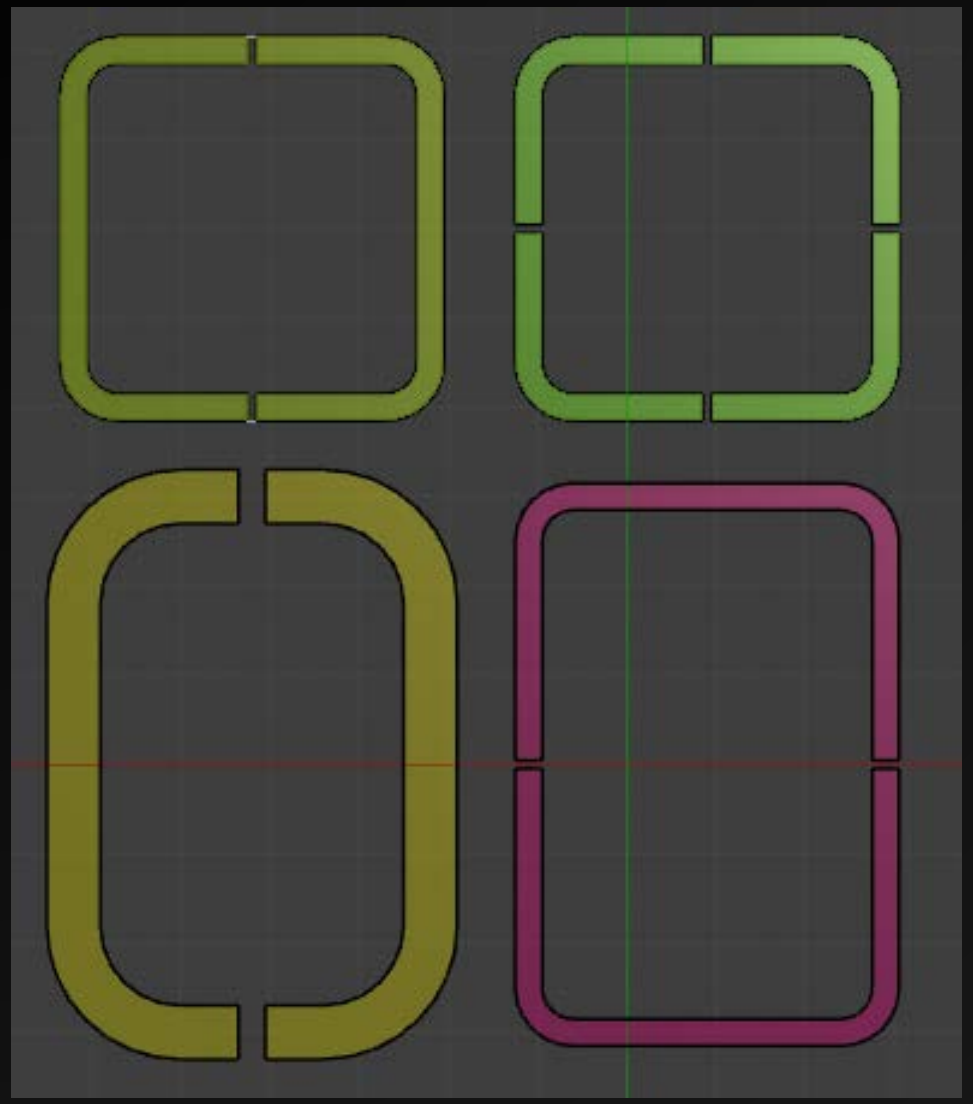
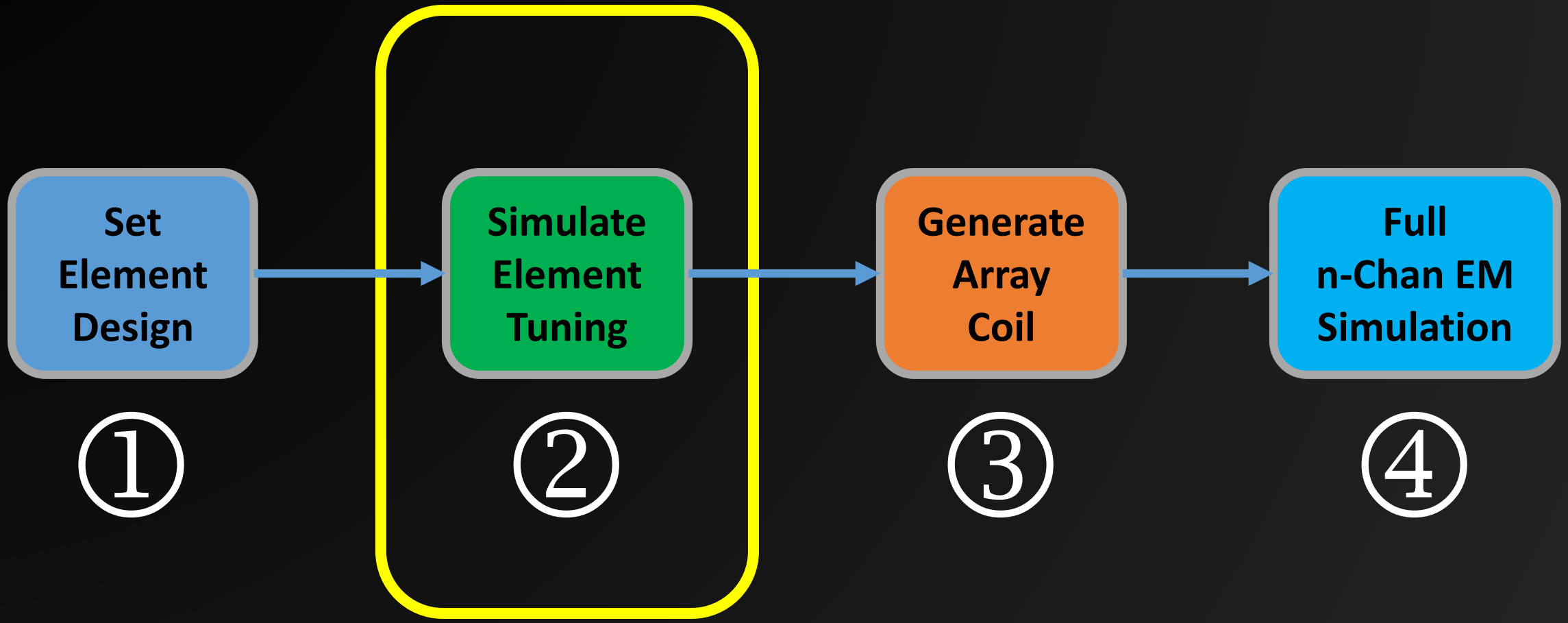


# ① : Element Design

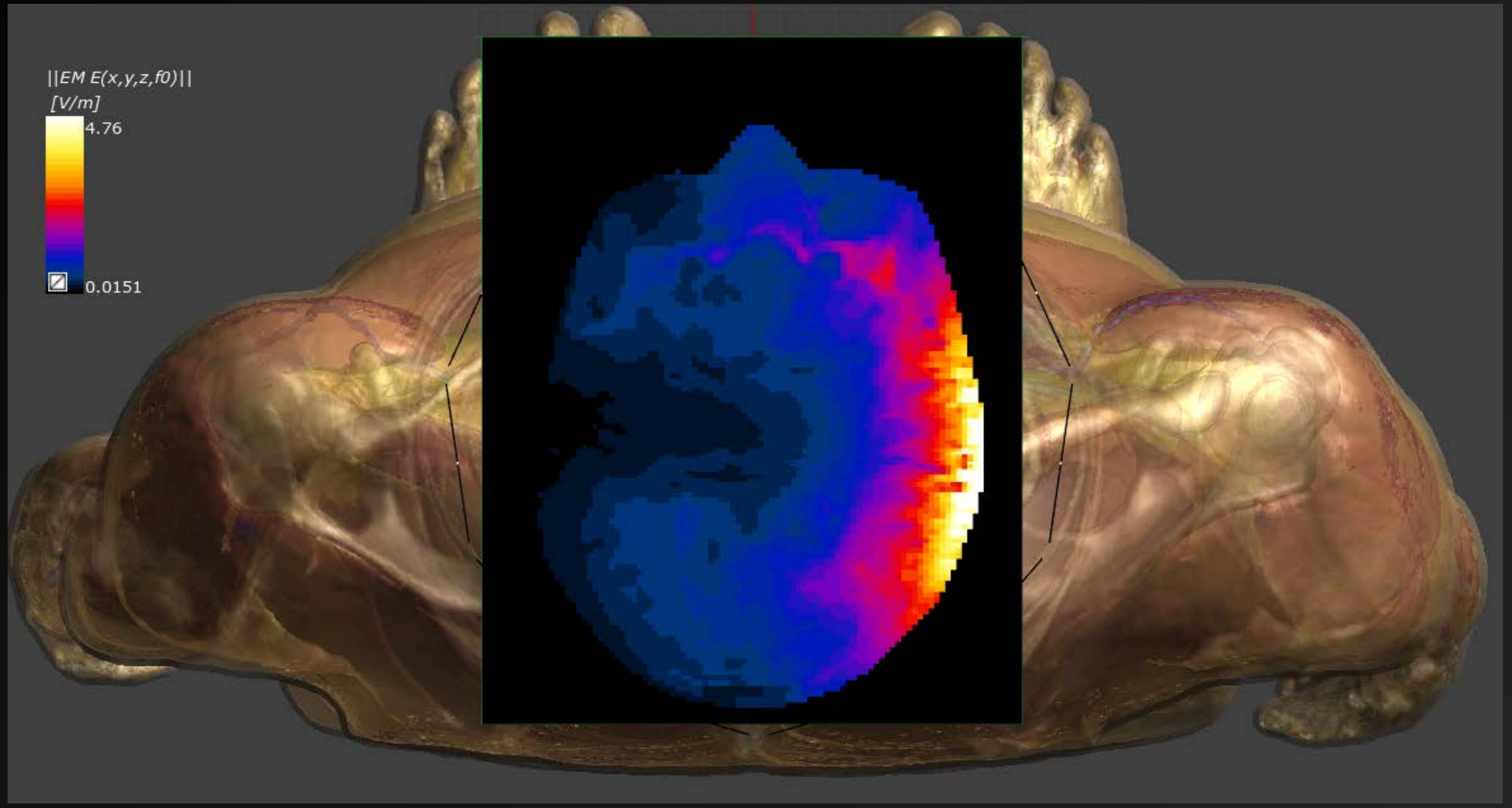


- Can vary multiple parameters:
  - Width
  - Height
  - Conductor width
  - Radius of corner curvature
  - Cuts on horizontal rungs
  - Cuts on vertical rungs
  - Cut width

# FRF Coil Design Study



# ② Element Tuning Simulation



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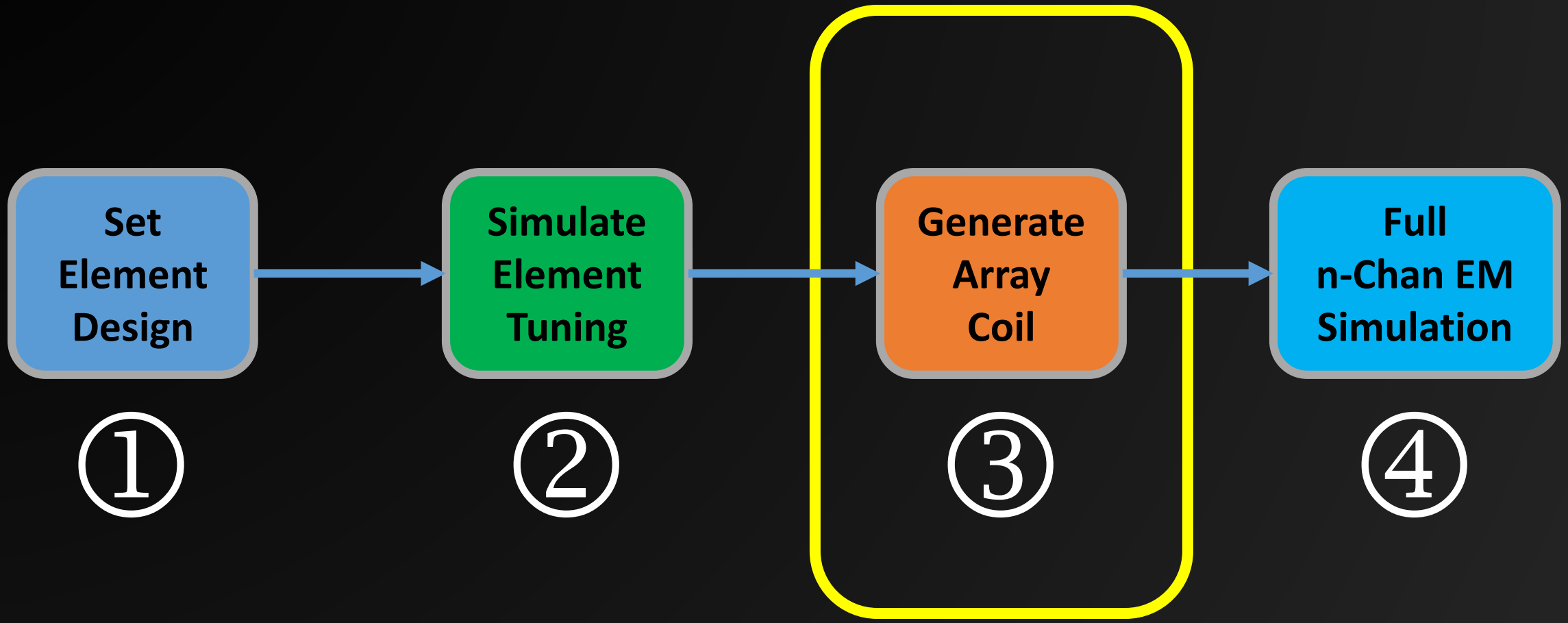

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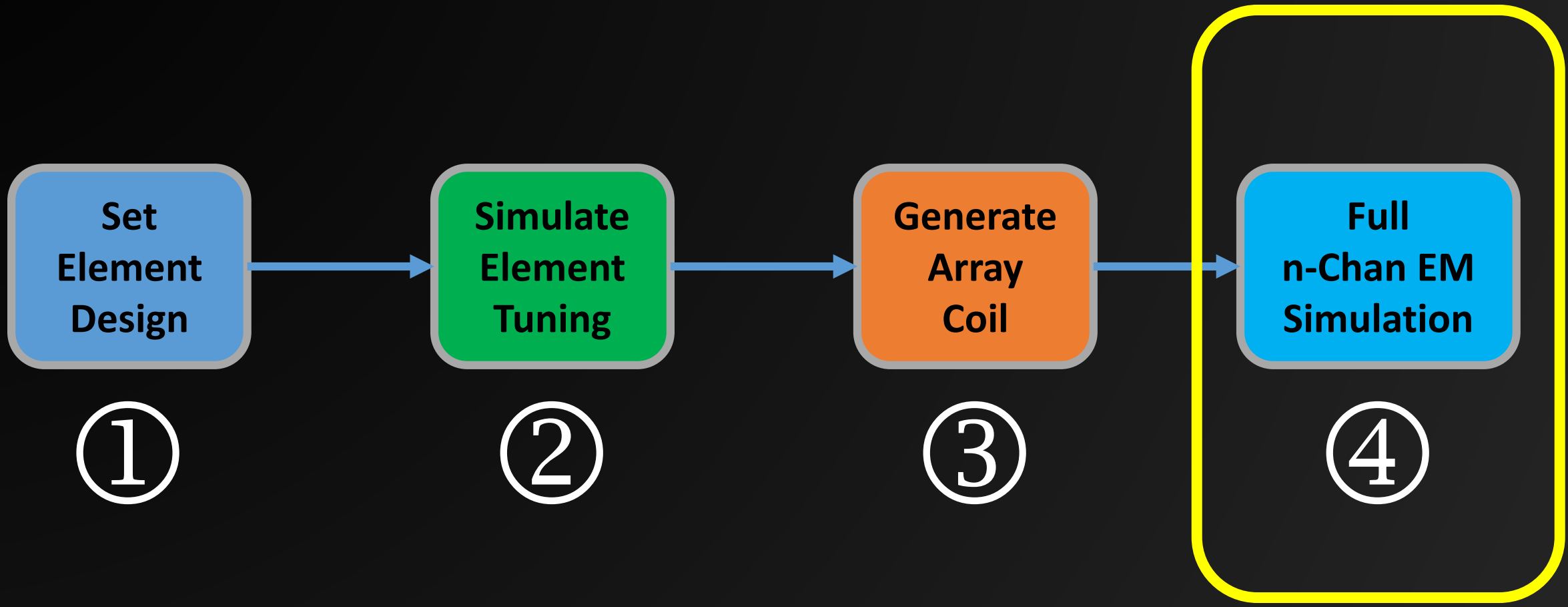
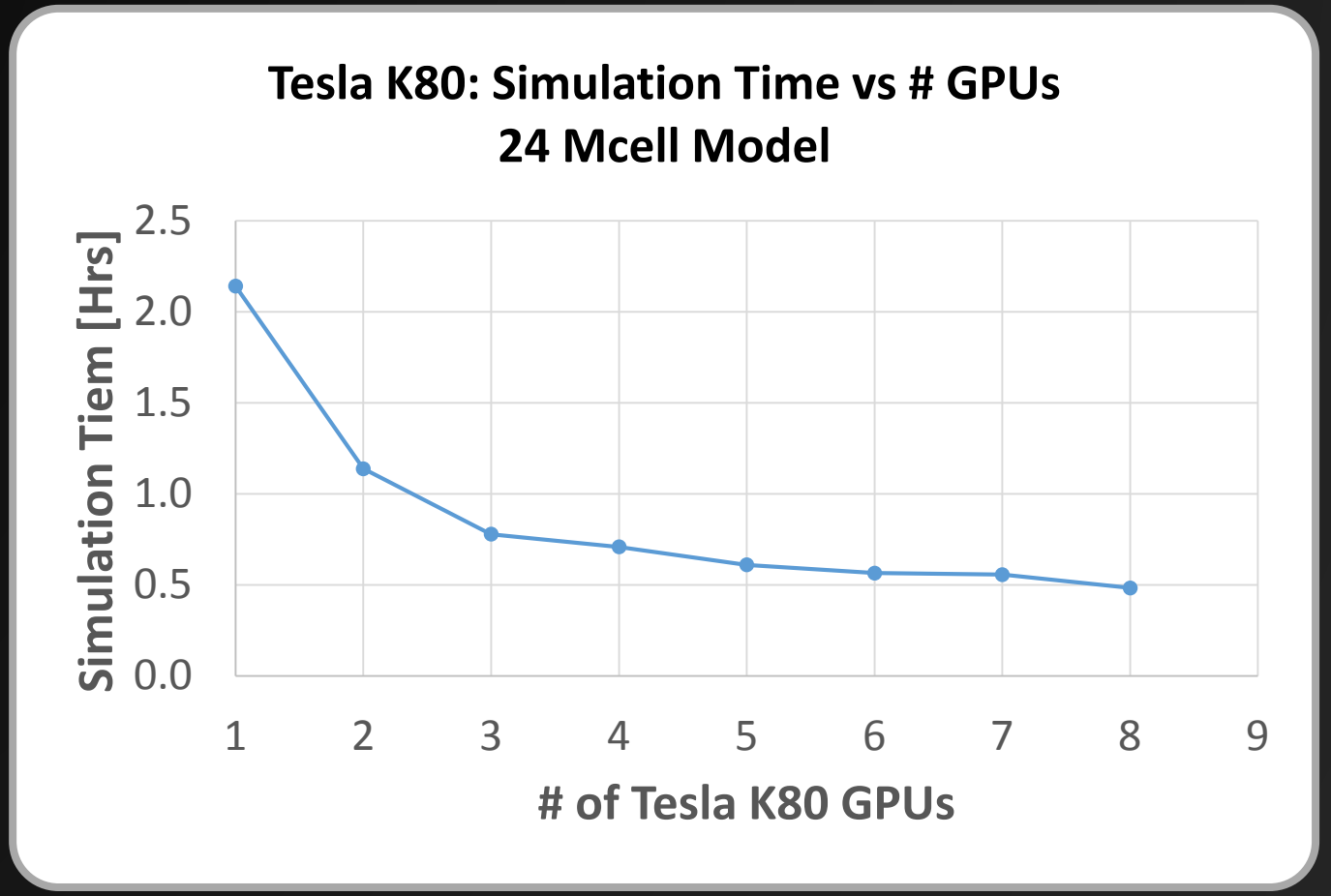


# Simulation Time

| Hardware | Sim. Time Per Chan. [Hours] | 8 Chan Sim. Time [Hours] | 32 Chan Sim. Time [Hours] |
|---|---|---|---|
| CPU | 26.6 | 212 (8.8 days) | 851 (35 days) |
| GTX 670 | 4.08 | 32.7 | 130.6 (5.4 days) |
| Titan Black x2 | 1.23 | 9.8 | 39.4 (1.6 days) |

# Sherlock Computing Cluster

- Sherlock – 48 GPUs
  - 2 * 8x Tesla 20X
  - 3 * 8x Titan Black
  - 1 * 8x K80
- Collaborating with SPEAG S4L
- Granted us a special multi-GPU license



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| Sherlock: K80 x8 | 0.48 | 3.8 | 15.4 |

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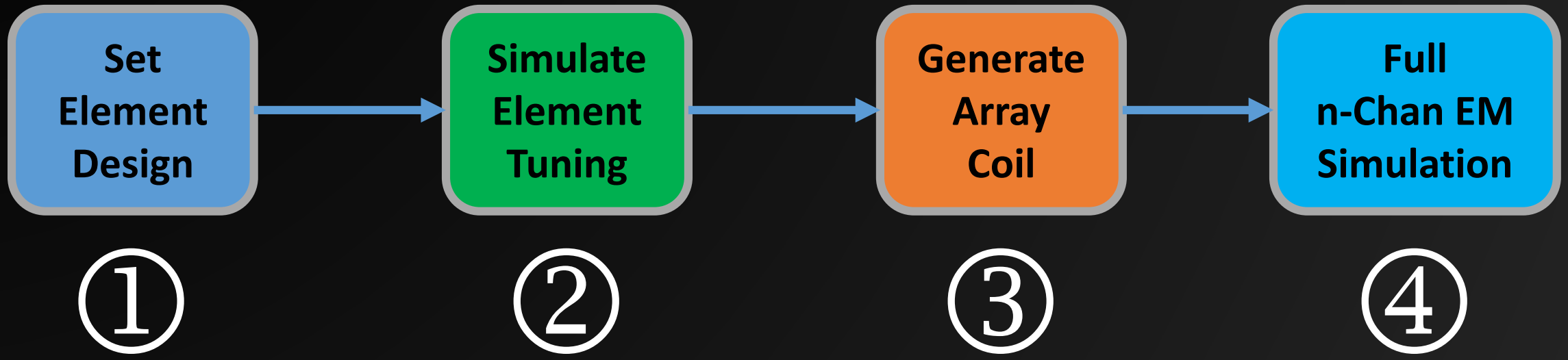

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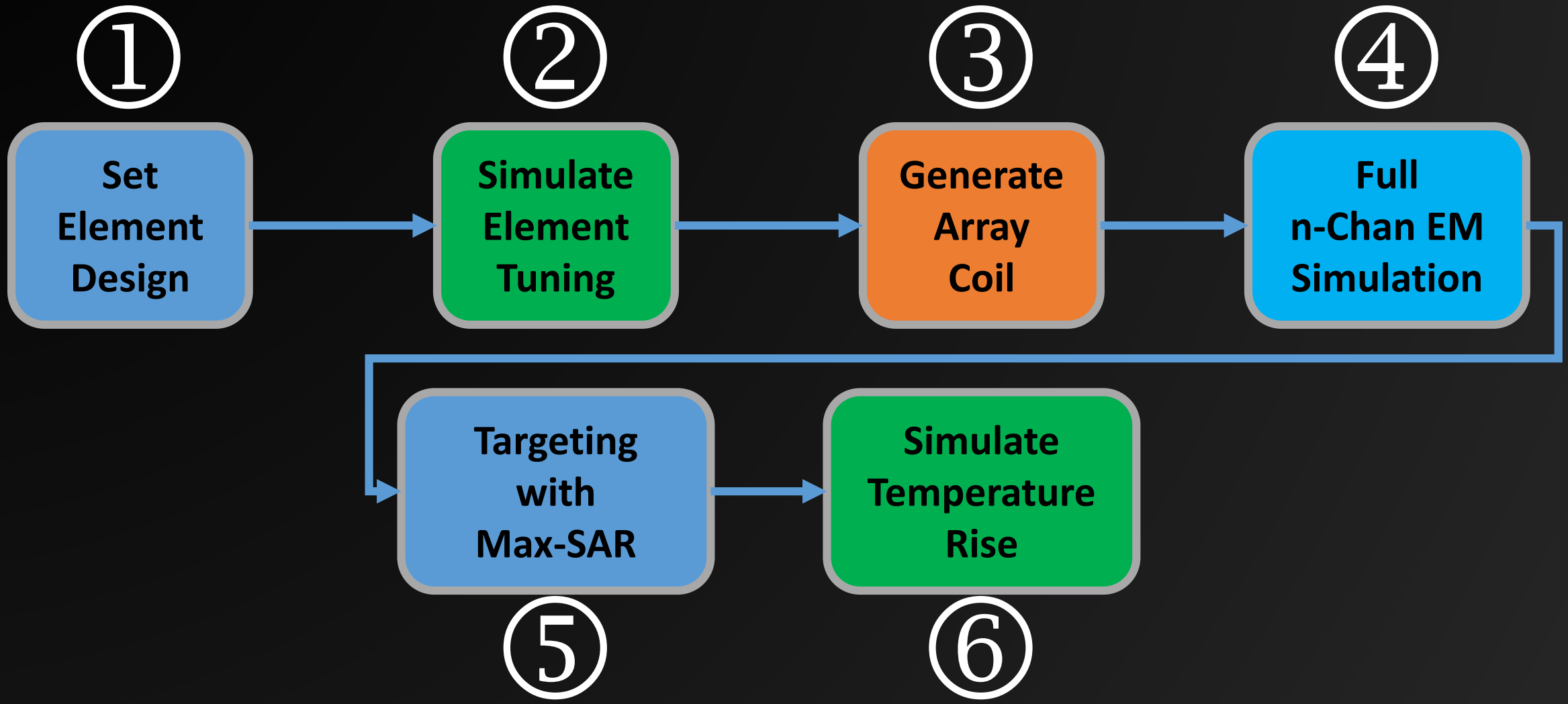

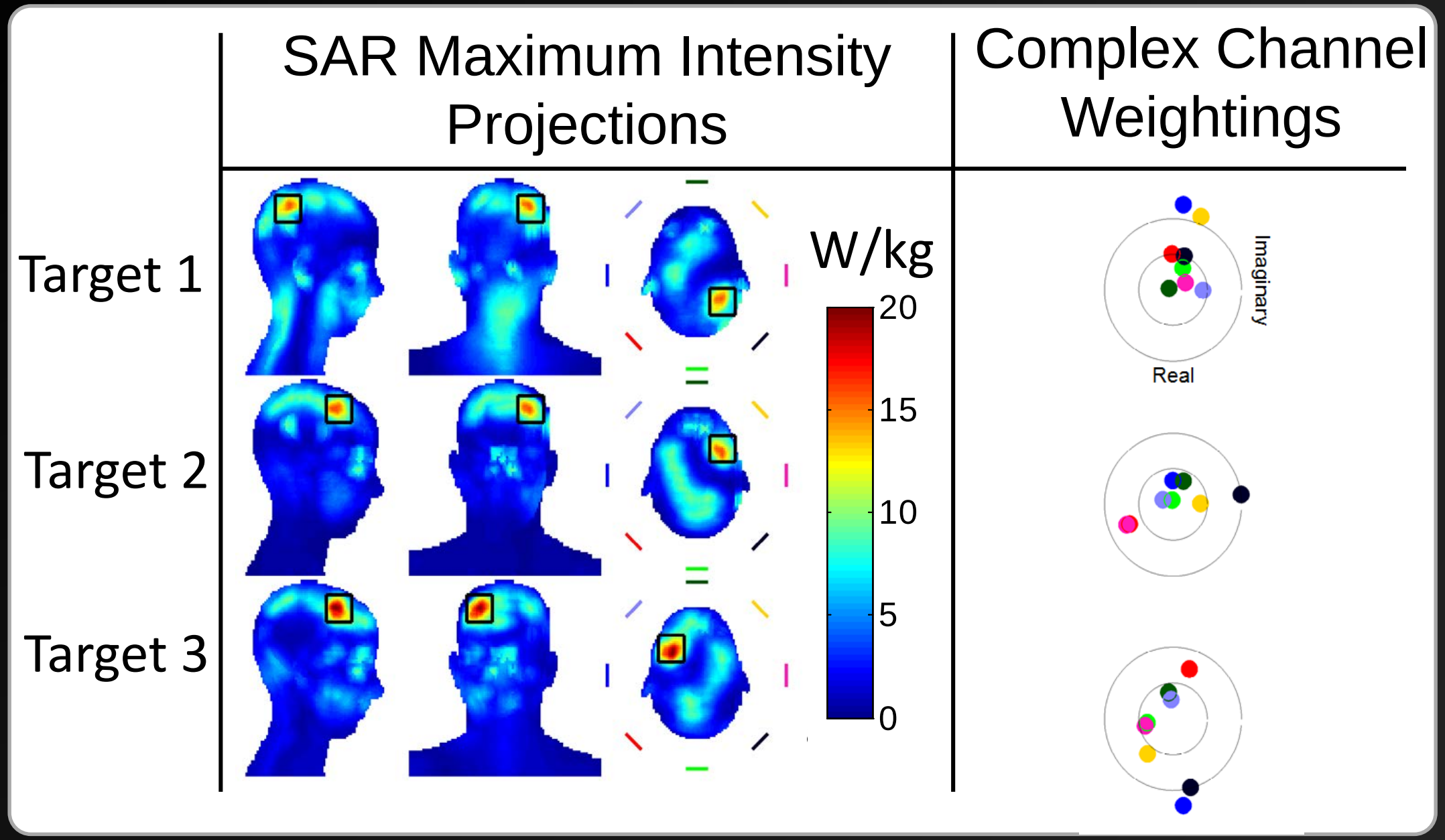
SAR Maximum Intensity Projections
Complex Channel Weightings
Target 1
Target 2
Target 3
W/kg
20
15
10
5
0
Imaginary
Real

# Potential

- FRF has all the positives of MRgFUS
  - Non-invasive, monitoring, free of ionizing radiation, etc.
- Hyperthermia
  - Can improve outcomes of radiation and chemotherapy
  - Treat multiple metastases
- Ablation - Direct cell death
  - May not be possible
- BBB Opening

# Conclusion & Next Steps

- Design study of FRF coils using S4L
  - Realistic body models
  - Built automated tools for generating arrays
- Simulations working on Sherlock GPU Cluster
  - Design study would be very difficult otherwise
  - Has application to real-time Min-SAR pTx pulses
- Experimentally verify simulations in simple phantom

# Acknowledgements


- **Stanford SCIT (NCI)**
  - Prof. Brian Rutt
  - Dr. Riccardo Stara
  - Mihir Pendse
  - Scott Almquist
- *SPEAG* sim4life

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Stanford Research Computing Center
*Sherlock Computing Cluster*

# THANK YOU!