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FOSDEM 2025

A Pantheon of The Gods

Open Source Multiphysics Software for Analysis of Fusion Power Plant Systems

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Dr. Aleksander Dubas

Overview

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What Is Fusion Energy?

What Are The Challenges?

Finding A Solution

The Pantheon

Learnings

Fusion Reaction

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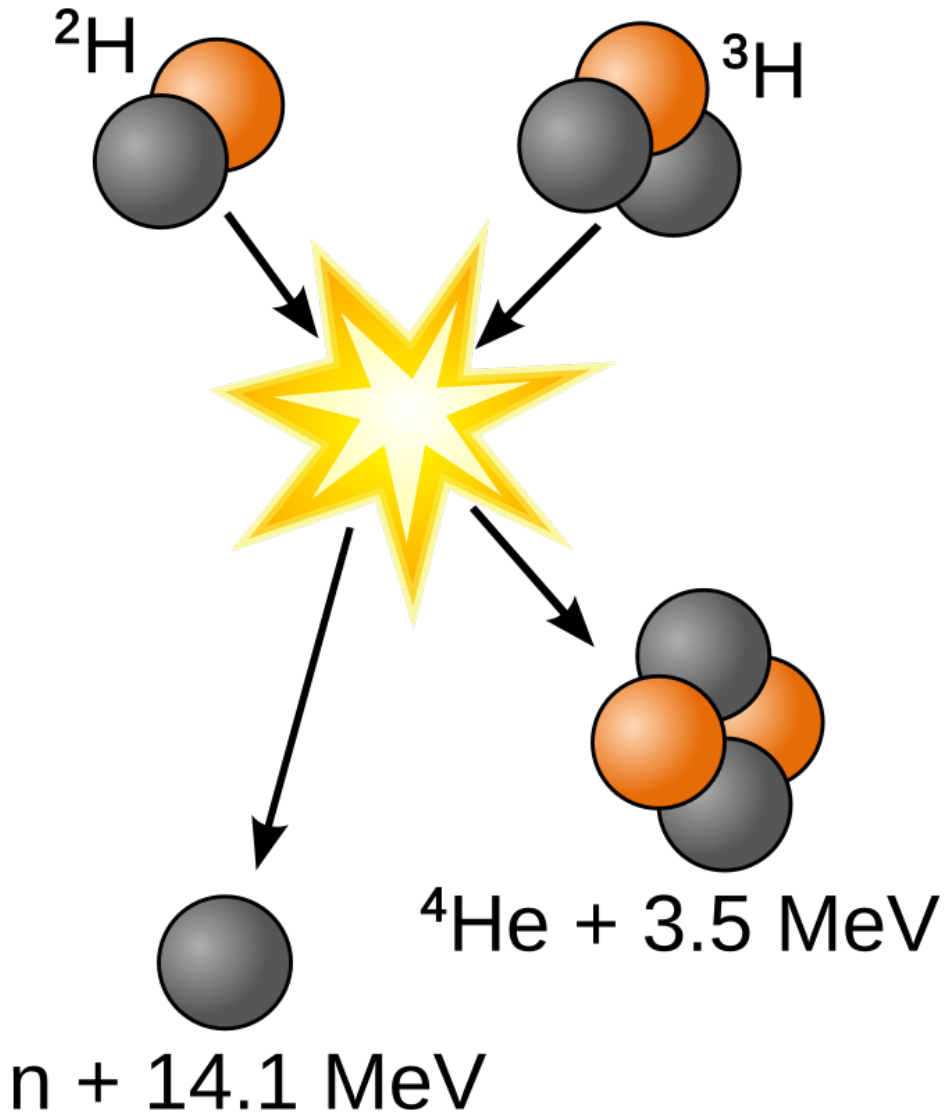

Magnetic Confinement

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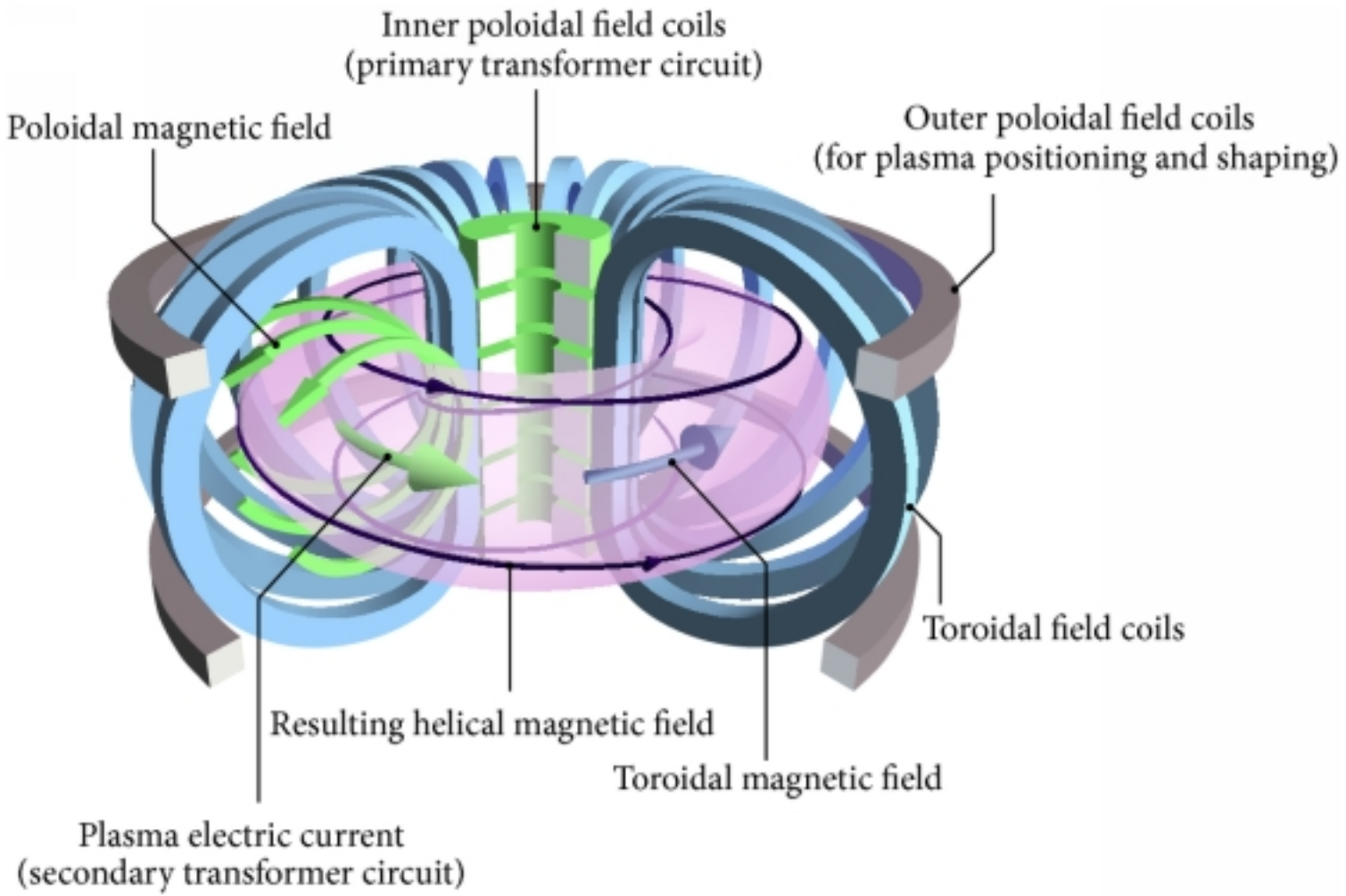

And Many Other Systems

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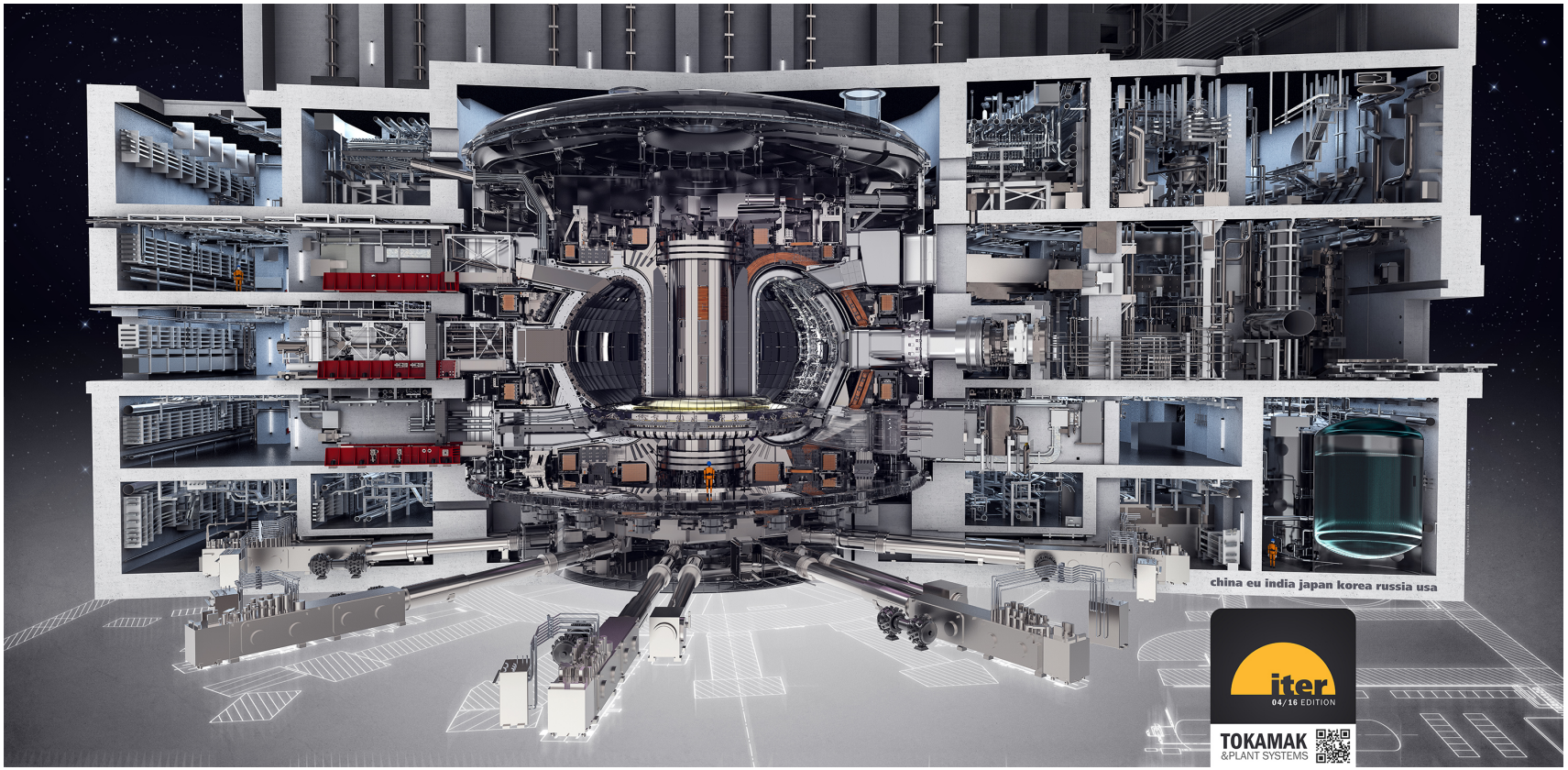

Multiphysics

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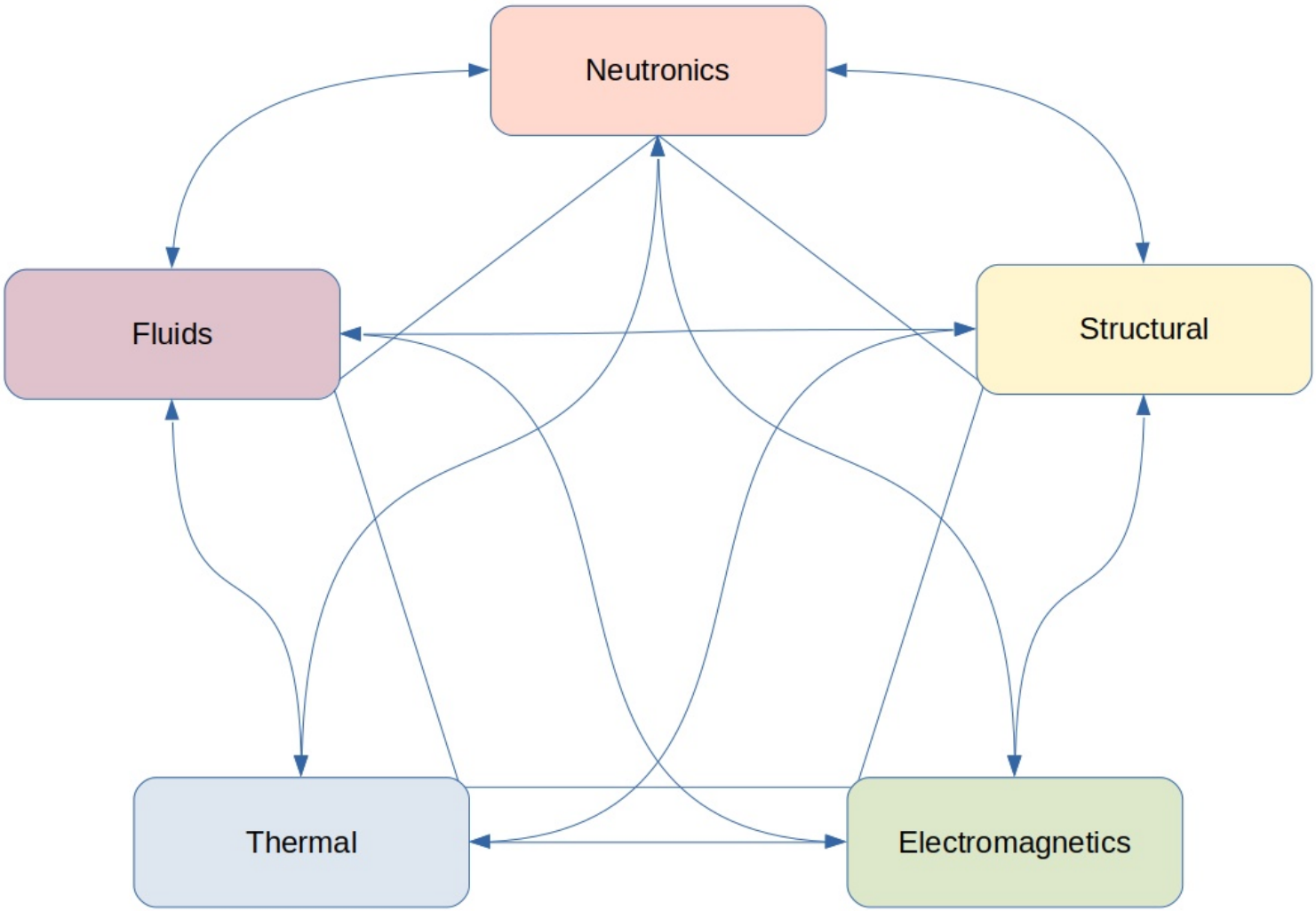

Uncertainty

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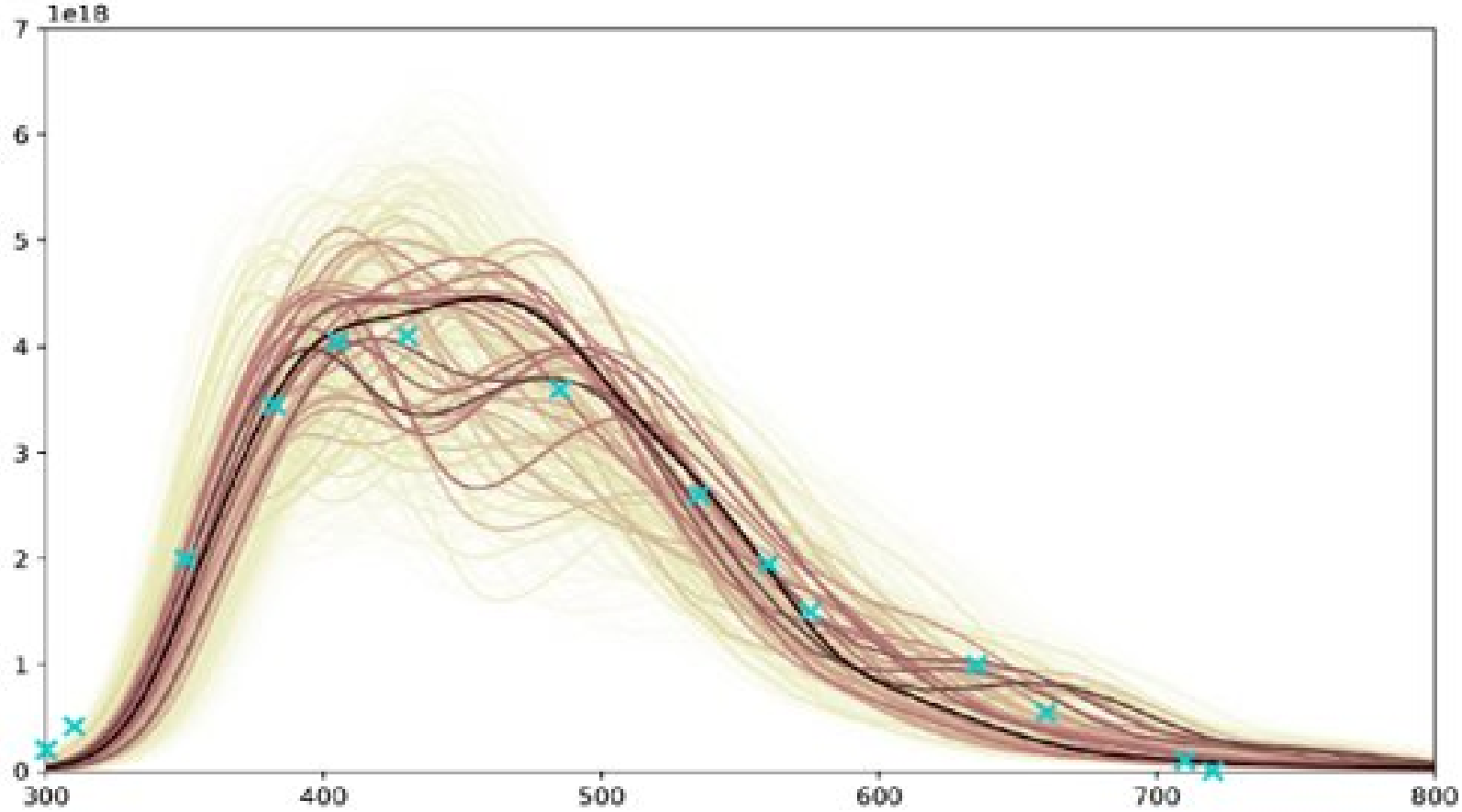

Image Credit: Stephen Dixon, UKAEA

We’re going to need a bigger computer

And some scalable software to run on it

Criteria For A Scalable Library/Framework

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- Parallel First.
  A code designed to scale well on parallel HPC from the outset.
- Permissively Licensed.
  Able to run anywhere on any number of processes, with extension and modification permitted.
- Portable.
  Able to run on any exascale hardware.
- Extensible.
  Open to external contribution and follow good software engineering practices.
- Supported.
  User community, forums, mailing lists, documentation.
- Compiled Language.
- Stable API, Actively Developed.

The Selection

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- All things considered, there is no clear winner
- Trade off between performance and development effort
- Selected MOOSE due to large amount of pre-implemented physics
- A snapshot in time, so doing the same process now may yield different results
- For more details: `https://archive.fosdem.org/2020/schedule/event/exascale_fusion_sim/`

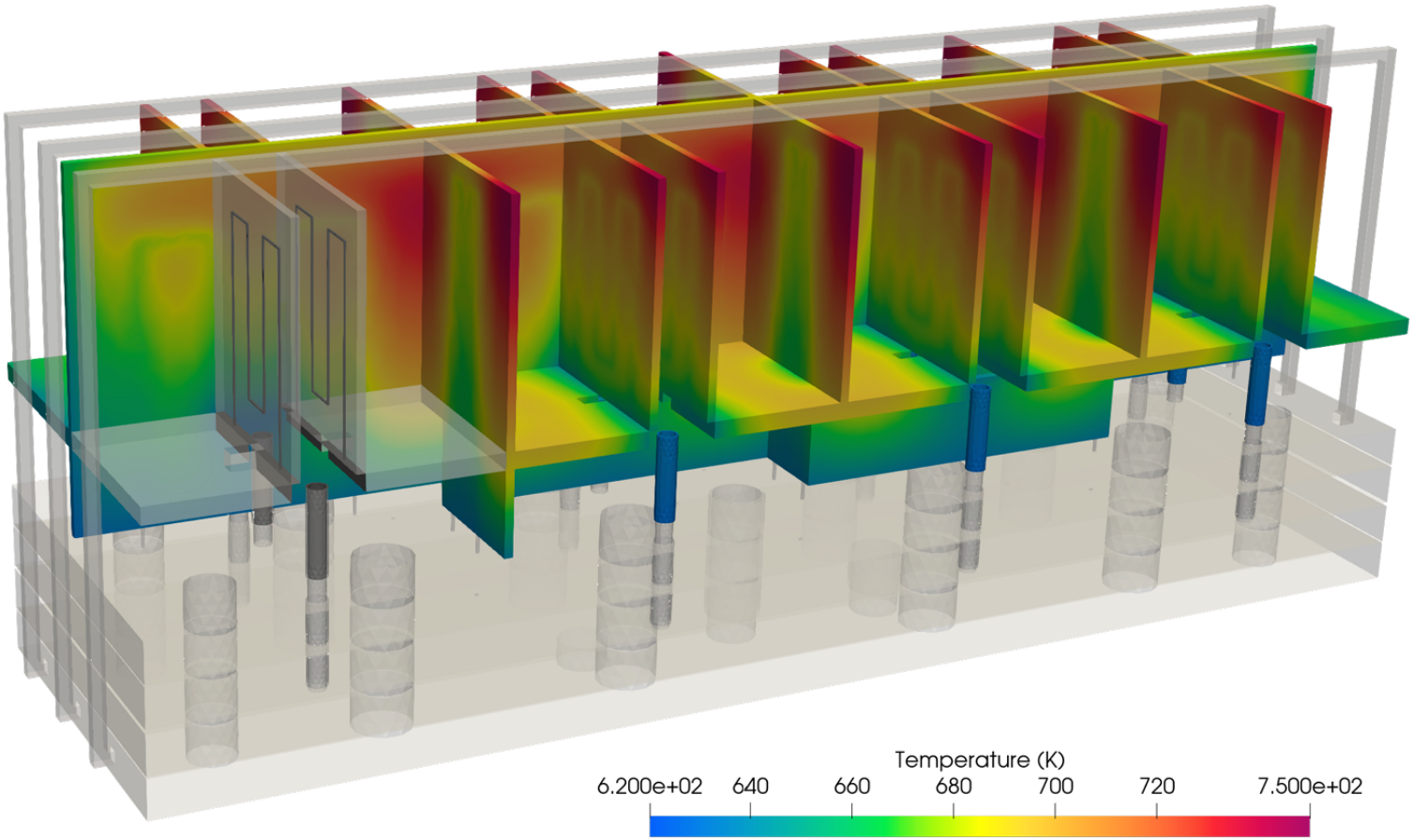

Image Credit: Helen Brooks, UKAEA

Apollo/Hephaestus

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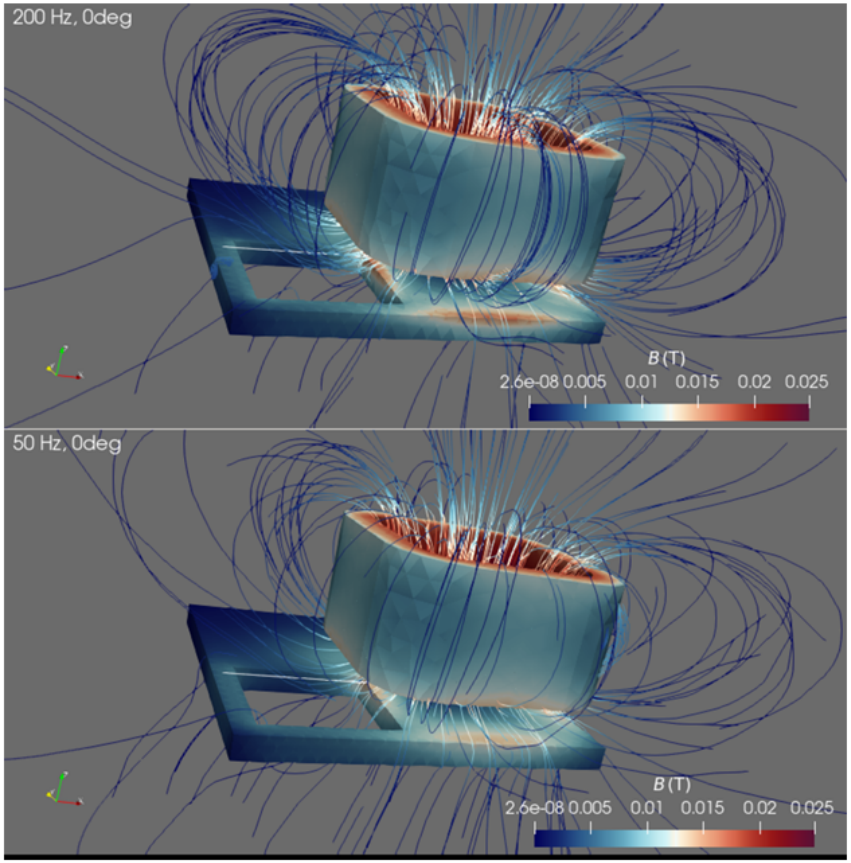

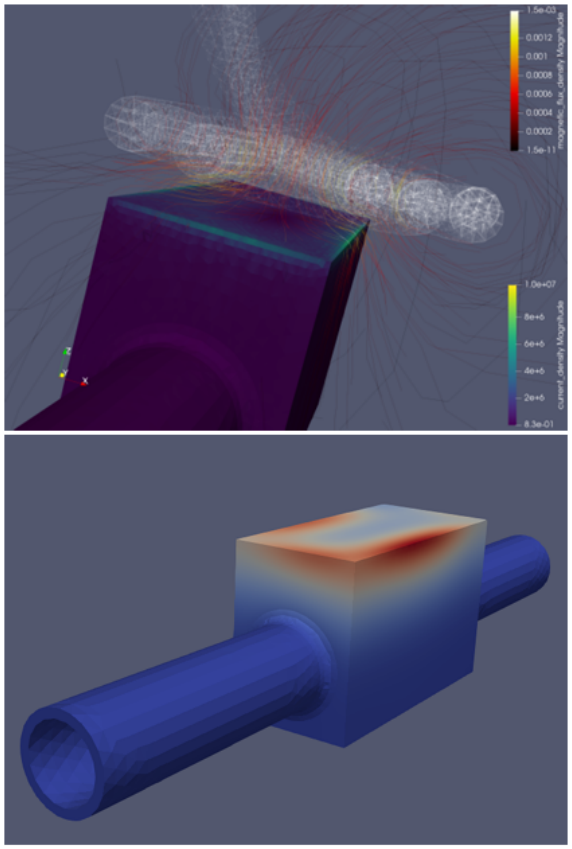

Image Credit: Alex Blair, UKAEA

Achlys

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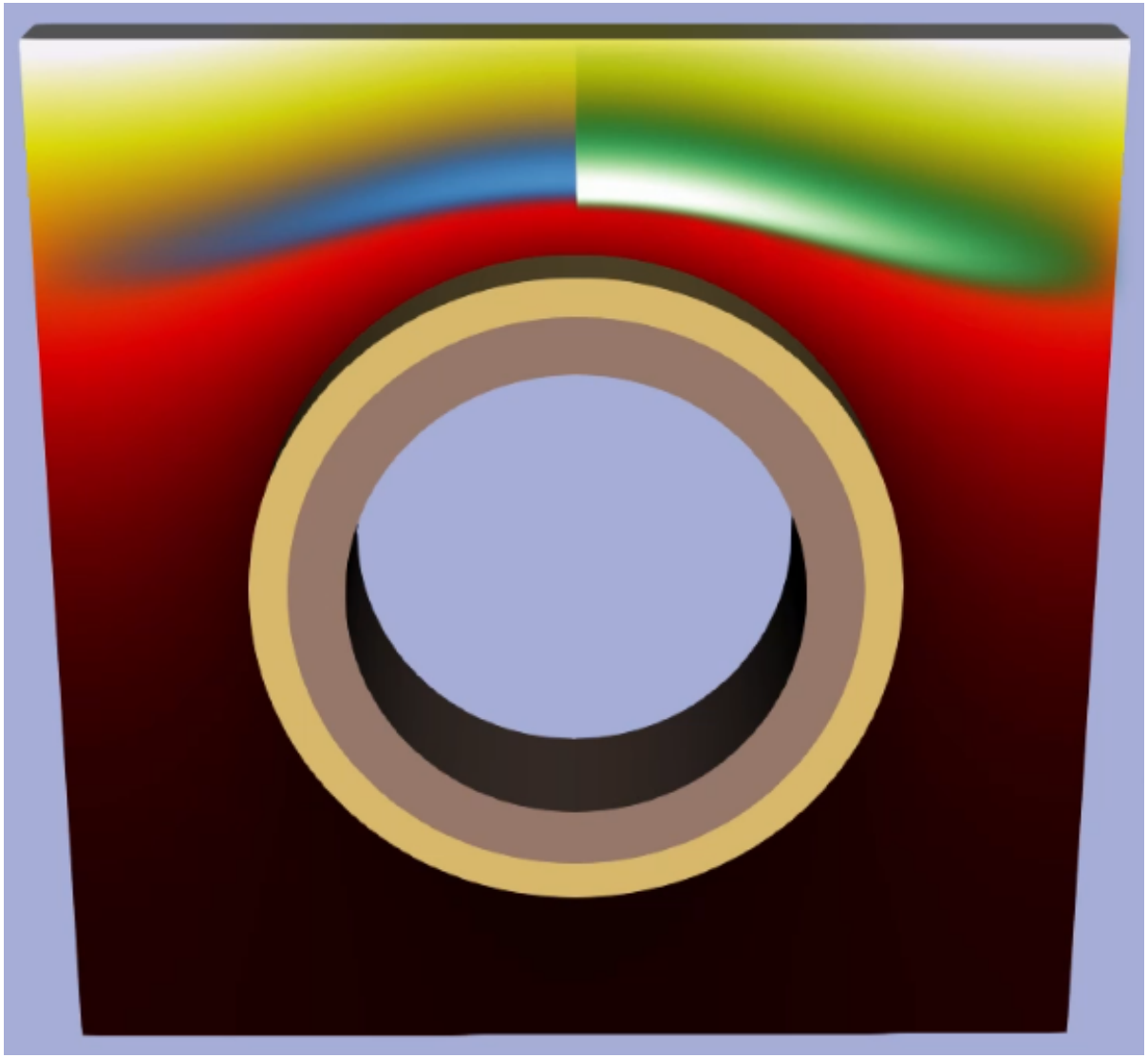

Image Credit: Stephen Dixon, Daniel Mason, Nitesh Bhatia, UKAEA

Proteus

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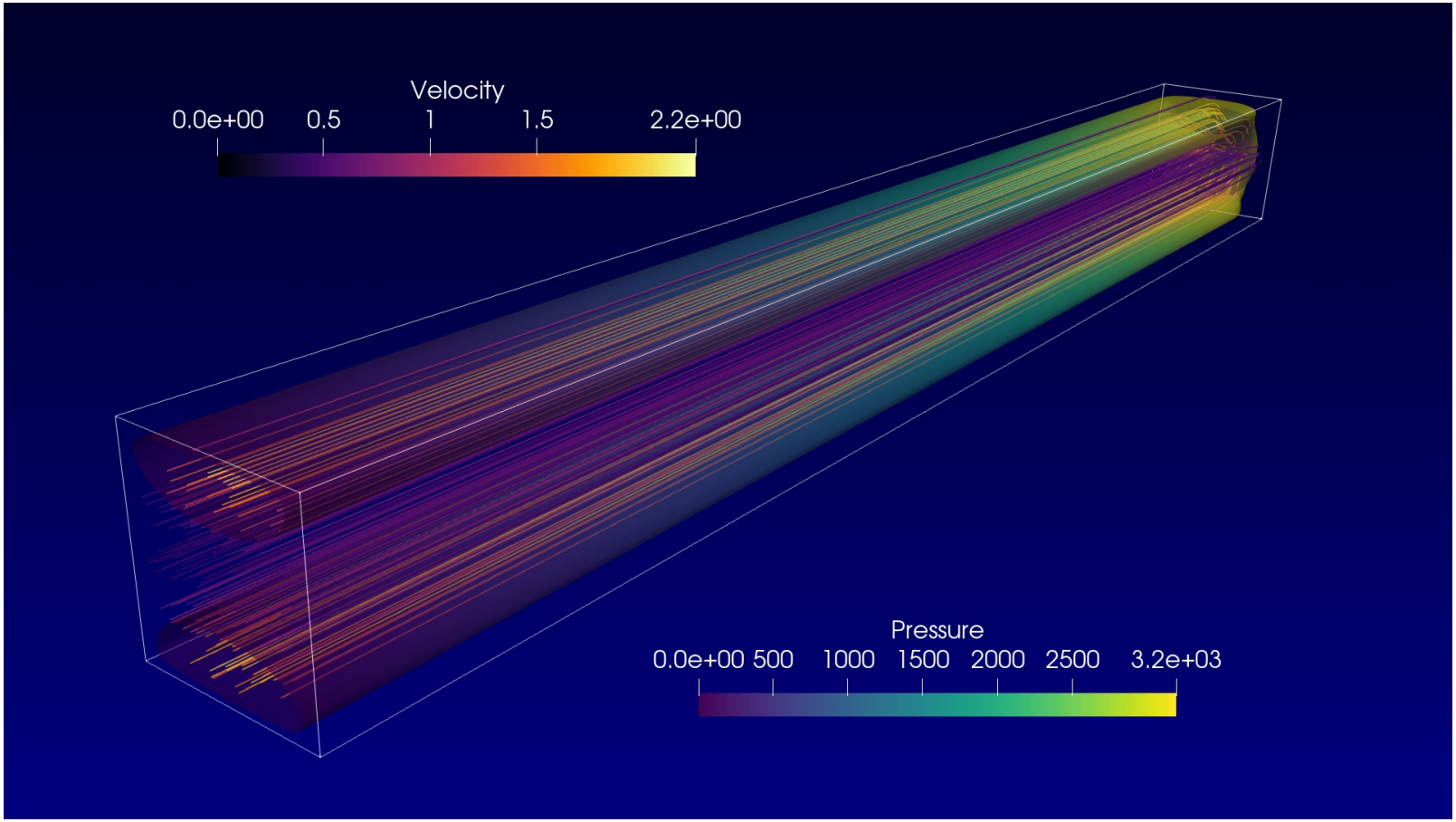

Image Credit: Aleksander Dubas, Rupert Eardley-Brunt, UKAEA

Et Cetera

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`https://github.com/aurora-multiphysics`

- Aegis
  Charged particle tracking for heat deposition.
- Hippo
  Thermal hydraulics through coupling to OpenFOAM.
- Phaeton
  Fast ion heat flux through coupling to ASCOT5.
- Platypus
  Enabling MOOSE simulations using MFEM FE library.

Learnings

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- Portable?
  Able to run on any exascale hardware.
  This means GPU.
  Platypus (see previous slide) or
  Cardinal: `https://cardinal.cels.anl.gov/`
- Compiled Language?
  Easier to find Python developers.
  Most users aren't running at the scale where it matters.
- Finite Element Types?
  Allows better formulations.
  These are now available in MOOSE.

Thank You For Your Attention

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Any Questions?

Reach out: aleksander.dubas@ukaea.uk

Give it a try: `https://github.com/aurora-multiphysics`

With thanks to:
Andrew Davis, Helen Brooks, Alexander Blair, Stephen Dixon, Daniel Mason, Nitesh Bhatia, Rupert Eardley-Brunt, Waqar Butt, Harry Saunders, Seimon Powell, Matthew Bluteau, Luke Humphrey, Alexander Whittle and everyone else who has contributed to Aurora Multiphysics.