Transient events ≡ sudden changes of the plasma state

Matthias Hoelzl for the TSVV 8 Team

Lead 37 refereed publications
+ contributed strongly to 36

> 30 contributors, some
without funding

Trained 7 PhDs
+ 8 ongoing

Developed kinetic/hybrid methods in TRIMEG incl. fully implicit PiC scheme, non-linear collisions & el-mag GK model

(gyro-)kinetic models for ITG and TEM

Fluid-kinetic

A full description of JOREK and recent progress is given in **[1-3]**

Numerics & Code

AI for enhancing efficiency
Much broader user base
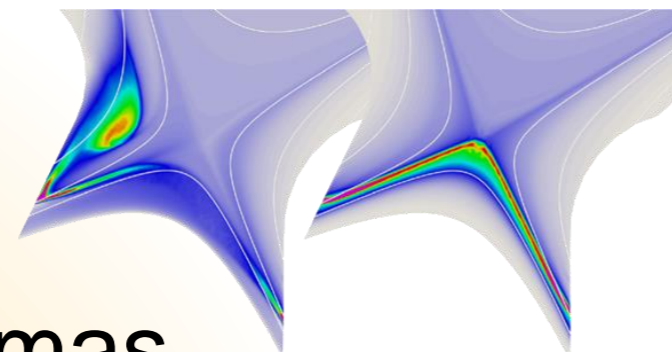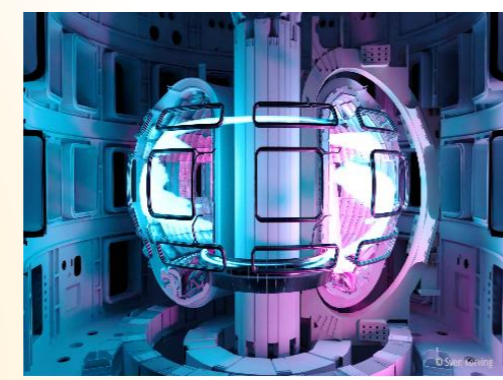Progress with IMAP adaptations
Progress with kinetic & fluid on GPUs
Precond. for highly non-linear scenarios

3D SOL/div models incl. kin. neutrals & impurities

Tungsten transport in RMP plasmas

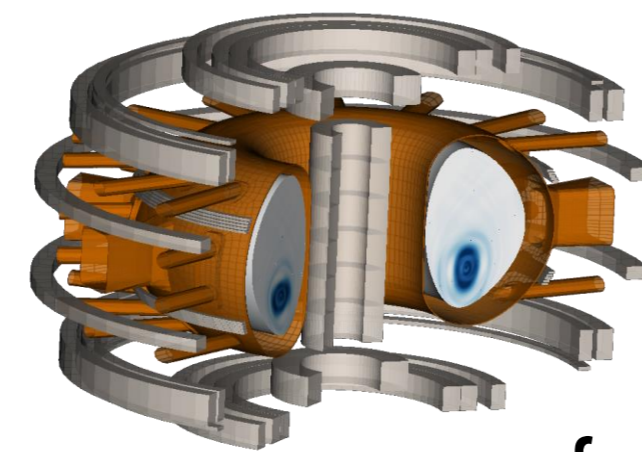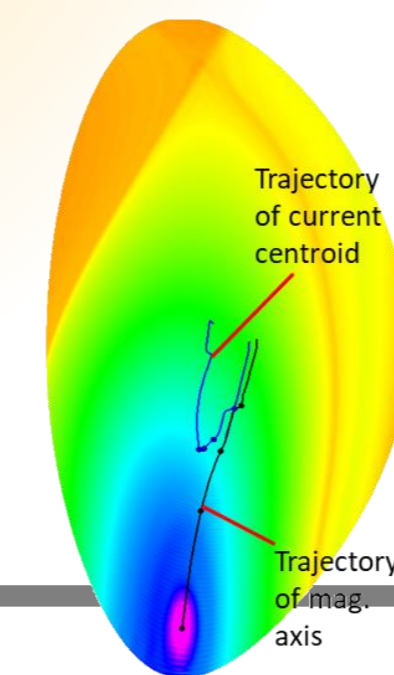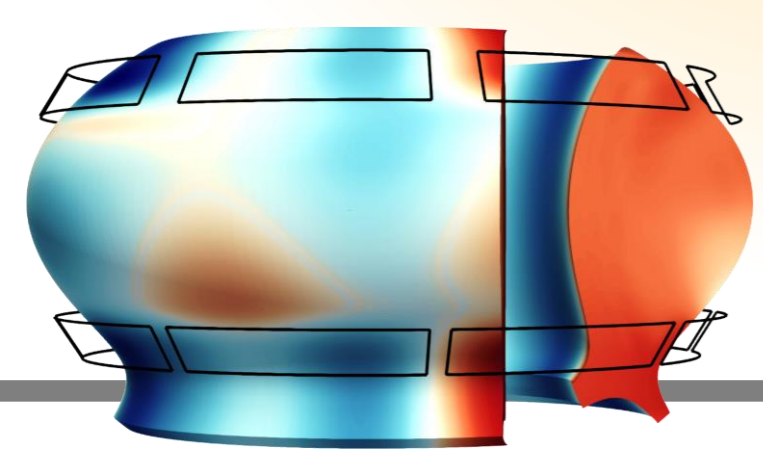Time resolved X-point radiator incl. formation, loss, transition to MARFE

Energetic particle model, TAEs & fishbones (↔ TSVV 10)

Core

Flux pumping for sawtooth control (↔ WP DES)
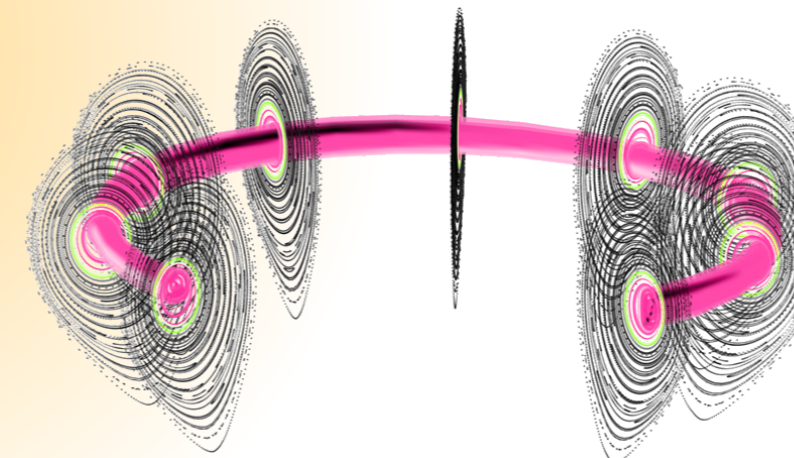
Supported stellarator extension

Pedestal, edge & SOL

Realistic QH-mode & small ELM studies

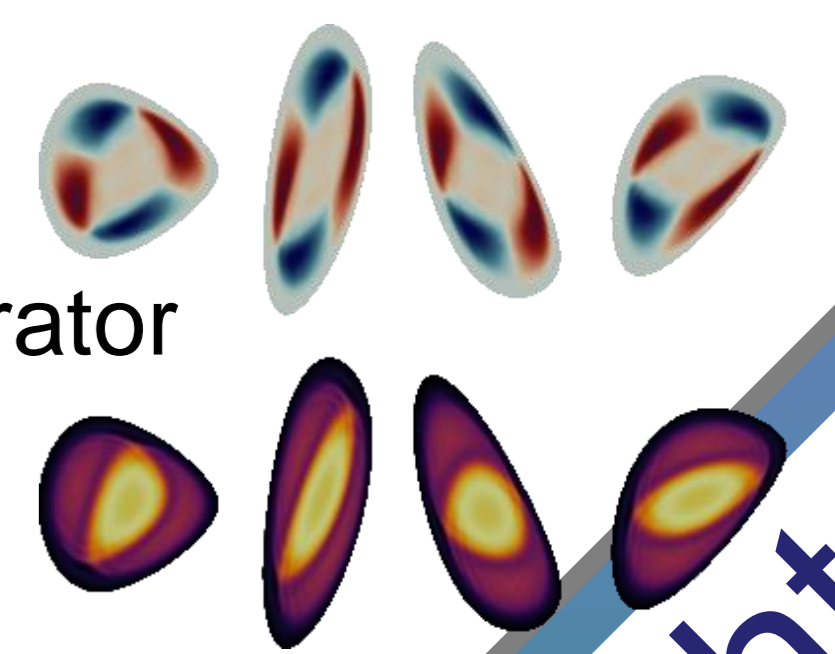Free boundary RMP model & island penetration at pedestal top

Hierarchy of 3D runaway electron models coupled to MHD (↔ **TSVV 9**)
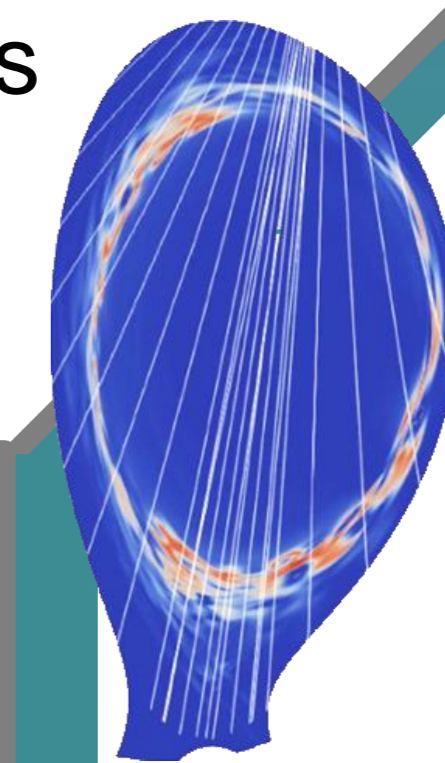
JOREK-CARIDDI coupling for electromagnetic wall forces

SPI in various devices

Mechanism of vertical force mitigation by massive impurity injection

Disruptions

Highlights

- Complete **halo current coupling** with CARIDDI for horizontal forces
- Complete **predictive simulations** for ITER, DEMO, JT60-SA, DTT

- Complete **IMAS** coupling as joint activity with ITER
- Complete **GPU porting** of hybrid fluid-kinetic simulations
- Advance **usability** by development coordination and documentation
- Develop detailed **project plan for 2026+**

2025

2026+

- **Include CASTOR3D, INDEX and Carma0NL** in TSVV 8: Establish a hierarchy of non-linear & linear 3D, 2D & 1D models for disruptions, pedestal, flux pumping, soft beta limits, core crashes, etc.
- **Include kinetic effects for MHD instabilities** wherever needed via hybrid models & kinetic MHD with full flexibility regarding fluid / kinetic treatment of each particle species
- **Advance exhaust models in interplay with 3D MHD** by including all relevant atomic and molecular physics
  - **Include stellarator MHD** in the TSVV 8 activity and transfer extended MHD and hybrid fluid-kinetic capabilities from the tokamak to the stellarator models
    - **Advance pellet ablation & assimilation models** with additional expertise
    - **Optimize for large fusion devices** by new iterative solver algorithms, porting to accelerators etc. with additional expertise
      - **ACH need:** primarily 2x HPC experts & 1-2x code engineers in full time
      - **Investigate disruption, core, edge and exhaust physics** relevant in existing and future devices
        - **Derive surrogate models** for flight simulators and transport codes.

ACHs, TSVV 9/10, PrIO, ITER, DES, DTT, SA, TE (various RTs)

White paper

SCAN ME
https://datashare.mpcdf.mpg.de/s/vT5cTMr1S8gyRyx
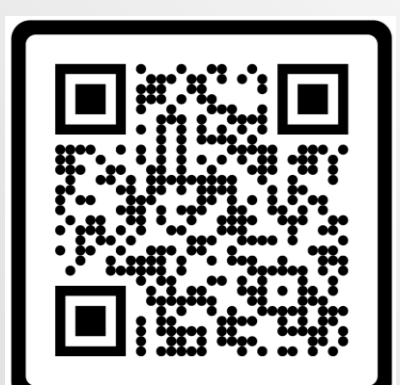
[1] Huysmans GTA and Czarny O. Nuclear Fusion 47, 659 (2007)
[2] Hoelzl M, Huijsmans GTA, Pamela SJP, Becoulet M, Nardon E, Artola FJ, Nkonga B et al. Nuclear Fusion 61, 065001 (2021)
[3] Hoelzl M, Huijsmans GTA, Artola FJ, Nardon E, Becoulet M, Schwarz N, Cathey A, Pamela SJP et al. Nuclear Fusion 64, 112016 (2024)