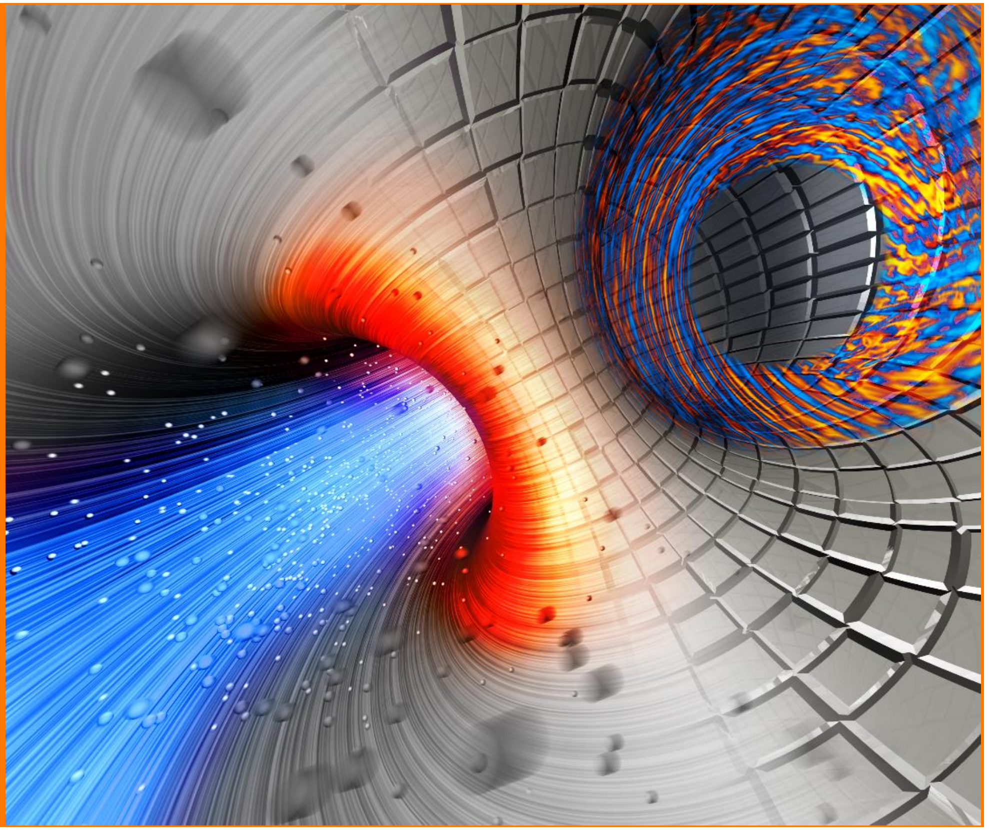
ASCOT for JT-60SA

Taina Kurki-Suonio & Antti Snicker
Aalto University



ASCOT4: part of the IMAS/JINTRAC workflows

ASCOT5: tailored for fast ion physics studies

(J. Varje et al., Submitted to CPC)

- Designed for modern CPUs, e.g., inbuilt vectorization (originally Xeon Phi)
- Better implementation of the modularity
- With Python integration for pre- and post-processing
- GPU-version in 2021?

ASCOT for JT-60SA: -2020

What has been done so far:

- ★ Simulations of fast-ion distribution function (for various purposes)
- ★ Synthetic FILD studies
  - – Moving detector head radially, estimating the sensitivity of losses (and velocity space coverage)
  - – ‘Worst-case –scenario’ simulations to estimate maximal (NBI) power loads to probe head
- ★ Work to account for 3D perturbations due to external coils (in progress)

Including MARS-F fields in ASCOT simulations

- ★ For low-fidelity simulations
  - Generate full field using MARS-F, interpolate it in rectilinear *(R,phi,z)* grid
  - No need for TF ripple, no need for additional superimposition
  - Has been used for AUG
- ★ High fidelity simulations with several 3D components
  - Create a vacuum 3D field using existing tools (BIOSAW etc.)
  - Communicate the full field with MARS-F, compute plasma response for n1, n2, n3…
  - FFT the original 3D field, replace n1+n2+n3… (but leave all the rest!)
  - Back transform the 3D field including plasma response
  - Improved quality together with more realistic description of the total field
  - The process has been successfully used for ITER

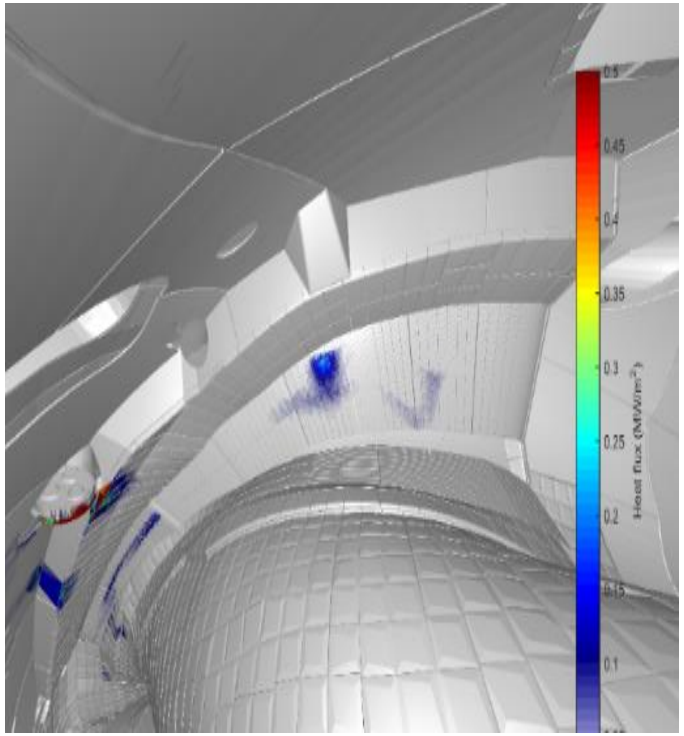
ASCOT for JT-60SA: 2021->

What would be the best ways to complement the work carried out by our Japanese colleagues:

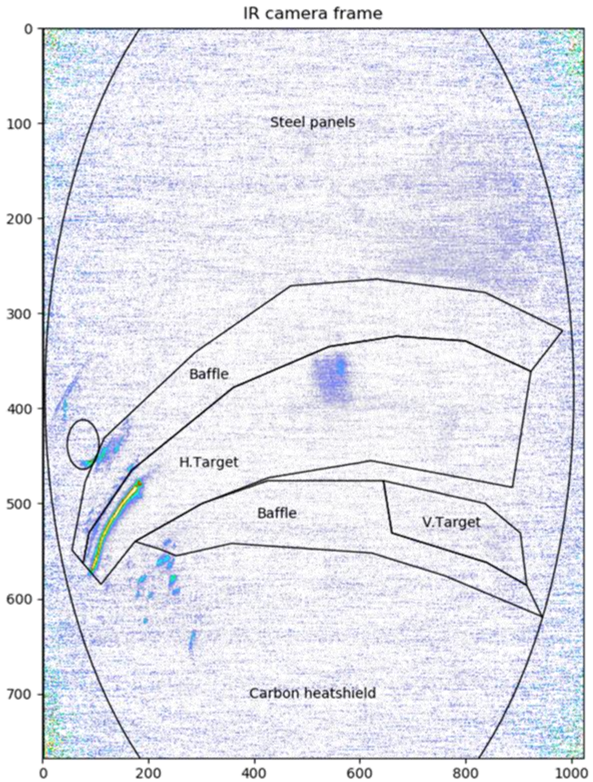
- ★ Effect of non-axisymmetric magnetic field and/or various MHD modes on fast ion dynamics
- ★ Evaluation of NBCD and/or rotational drive?
- ★ Power load simulations including identification of possible hot spots?
- ★ Evaluation of neutron fluxes?
- ★ Synthetic diagnostics (IR, FILD, neutron & gamma diagnostics)?
- ★ Estimation of shine-through losses with high energy NBI?

Disclaimer: the extent of VTT activities in 2021 will be in part limited by national funding decisions.

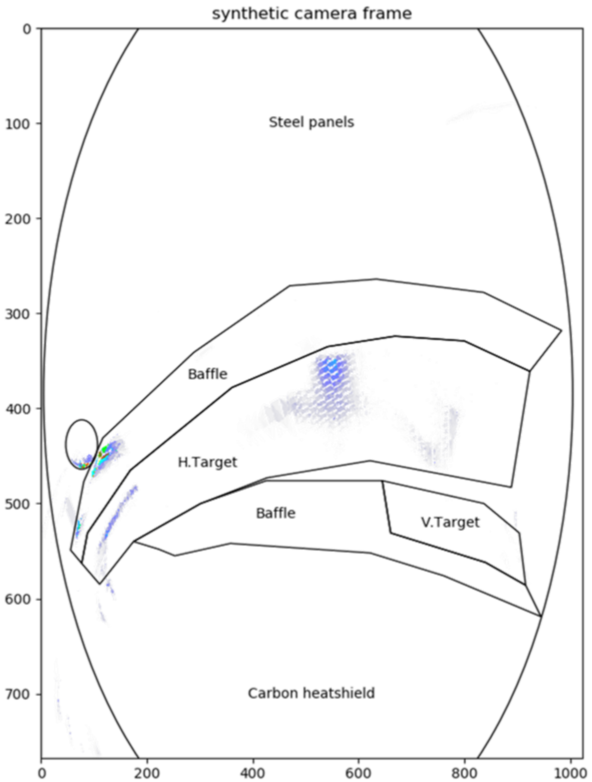
Synthetic IR studies with ASCOT (in W7-X)



ASCOT'S view of W7-X intestines



InfraRed (IR) camera frame of the same place

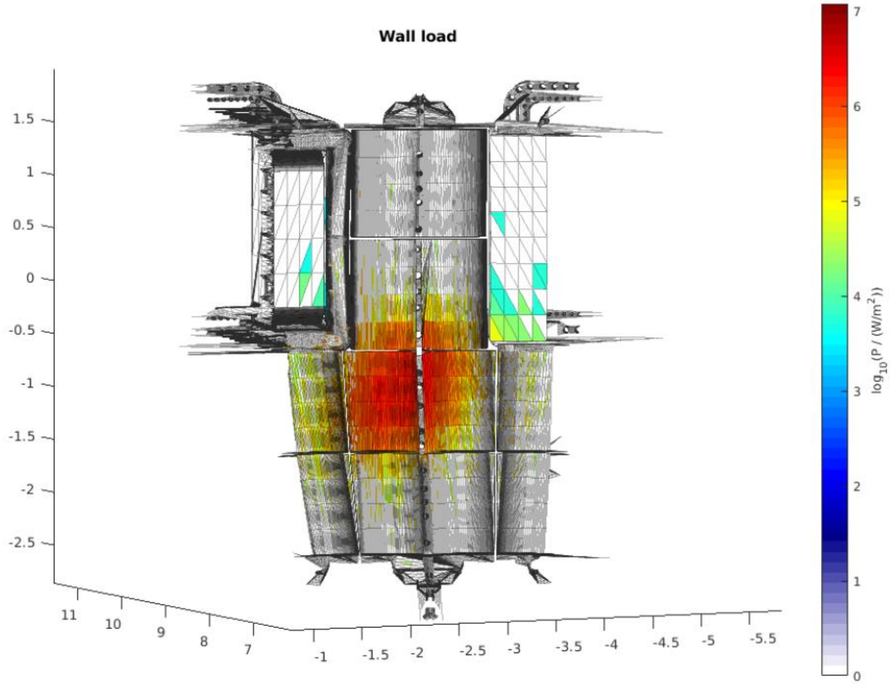


ASCOT's synthetic IR camera frame

ASCOT/BBNBI for shine-through losses

"Required R&D in existing fusion facilities to support the ITER Research Plan (XAKZLK ITER IDM)"

- ★ *Ref B11.2:*
  - *"Validation of shine-through loads with high energy NBI"*
  - *"Perform experiments with high energy NBI (E~500 keV) to validate models for evaluation of shine-through loads in ITER"*
  - *"Required to accurately determine the Hydrogen H-mode operational space which is limited (in the low density side) by ST loads"*
  - *"New activity, only JT60-SA"*
- ★ *ASCOT/BBNBI to predict shine-through/design experiments (see below for ITER He PFPO-2)?*



Thank you

ASCOT5 inside out

- ★ Magnetic background:
  - External field from experimental data bases, 2D or 3D (newest new: ***4D*** for ELMs)
  - interpolation using 3D splines (4D also implemented for ELMs)
  - numerical model for δB (and δE) due to various MHD modes (NTM, TAE)
- ★ Plasma background:
  - Kinetic profiles imported from experimental data bases, mainly 1D
  - Neutral backgrounds 1D to 2D to 3D. Work on-going
- ★ Orbit-following in *cylindrical coordinates*: (R,φ,z) ➔ all the way to wall
  - GC: 4-5th order Runge-Kutta using Cash-Karp
  - GO: modified Boris method
  - hybrid

Boundary conditions and physics models

- ★ First wall and divertor:
  - – Imported from experimental data bases, 2D contour or full 3D
  - – Formed of a large number of triangles
    - AUG: ~160k, W7-X: ~**10M**, ITER: ~300k, DEMO: ~80k, only one sector
- ★ Particle sources:
  - – Beam ions: BBNBI [*O. Asunta et al., CPC **188** (2015) 33*]
  - – Fusion alphas and neutrons: AFSI [*P. Siren et al., NF **58.1** (2017) 016023*]
  - – ICRH-generated ions: RFOF (T. Johnson, KTH)
- ★ Interaction with background plasma:
  - – Coulomb scattering: advanced model, w/ adaptive GC time-stepping
  - – CX model for neutralization/re-ionization of fast ions
- ★ Additional physics: MHD models as external actuators

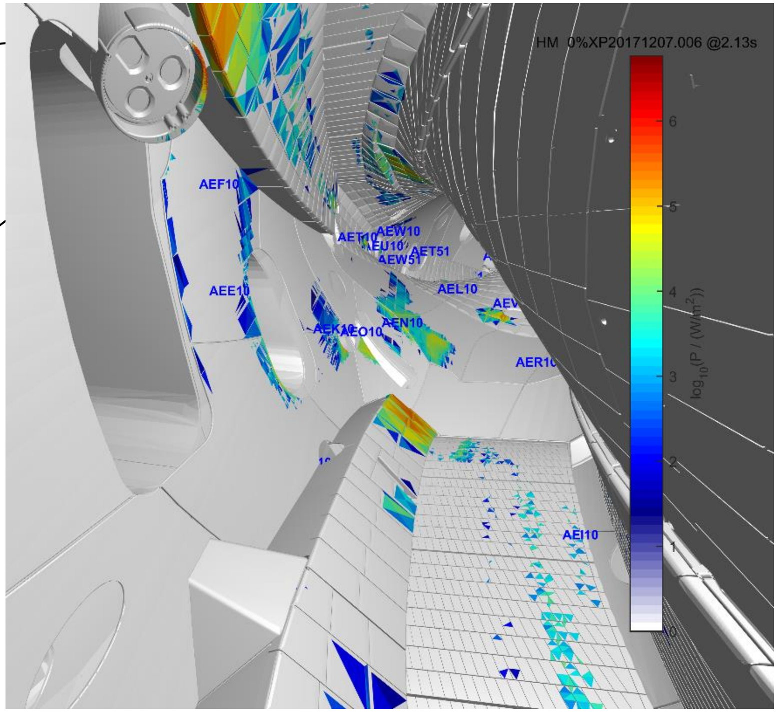
Validating ASCOT in 3D geometry (W7-X)

Thank you, Simppa Äkäslompolo!

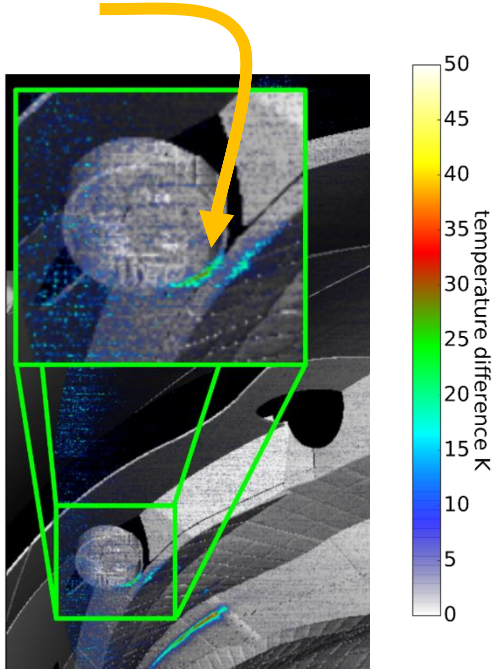
Wall design improved thanks to ASCOT simulations !

Fragile (sapphire) vacuum windows

ASCOT predicted
excessive NBI power loads
➔
Protective collar installed
before starting the beams



Wendelstein 7-X á l'ASCOT



power loads in excess
of 1.5MW/m^2 measured

International ASCOT community

- ASDEX Upgrade, IPP-Garching
- CCFE (JET & MAST/-U)
- Chalmers Technical University, Göteborg, Sweden
- DIII-D, General Atomics, California
- Ioffe Institute, St. Petersburg, Russia
- TJ-II, CIEMAT, Madrid, Spain
- TCV-EPFL, Lausanne, Switzerland
- IPP-CAS, Praha, Czech Republic
- MIT (SPARC), USA
- National Center for Scientific Research “Demokritos” , Athens, Greece
- Tokamak Energy, Ltd, UK
- University of California: Irvine and Los Angeles
- University Milano-Bicocca, Italy
- University of Padova, Italy
- University of Sevilla, Spain
- Wendelstein 7-X, IPP-Greifswald