Building a Turbulence-Transport workflow incorporating uncertainty quantification for predicting core profiles in a tokamak plasma

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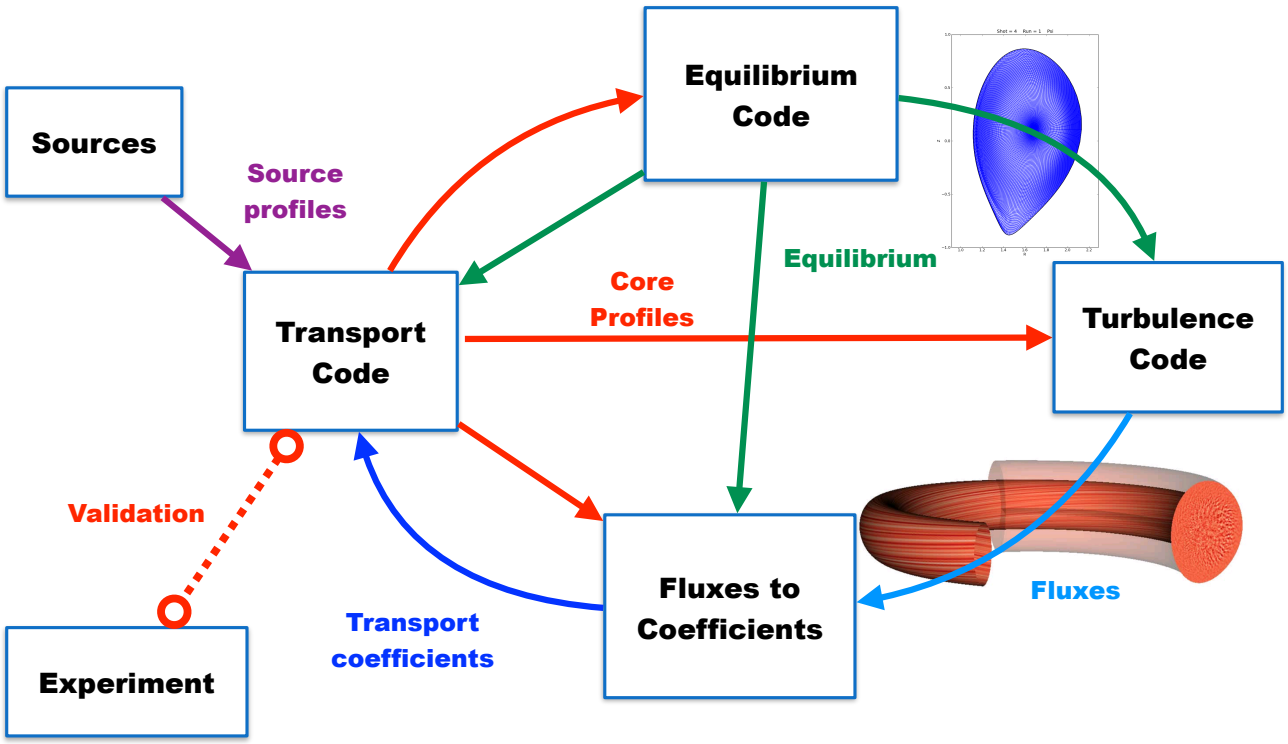
Turbulence-Transport Workflow

Turbulence is thought to be the main source of transport in the core of tokamak plasmas.

Have built a multi-scale (in time and space) workflow incorporating

- ETS (transport code)
- CHEASE (equilibrium code)
- GEM (turbulence code)

Coupled via MUSCLE2 (moving to MUSCLE3)

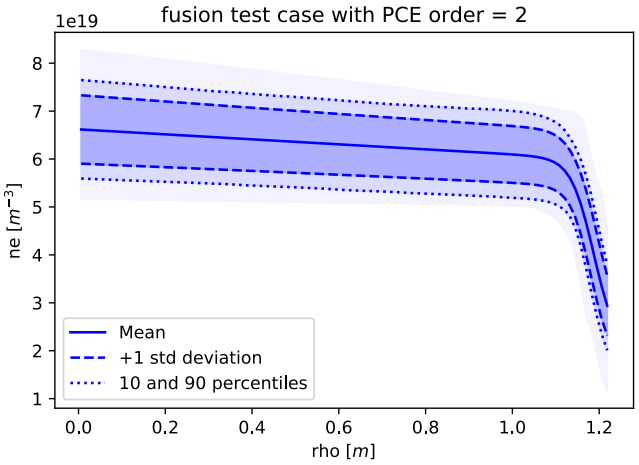


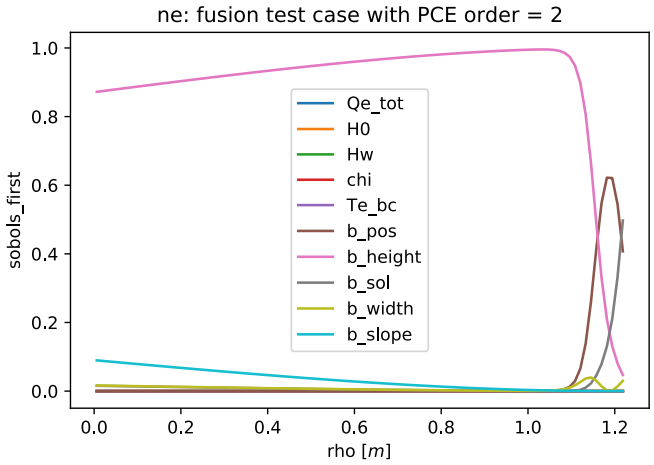
VVUQ for core profile prediction

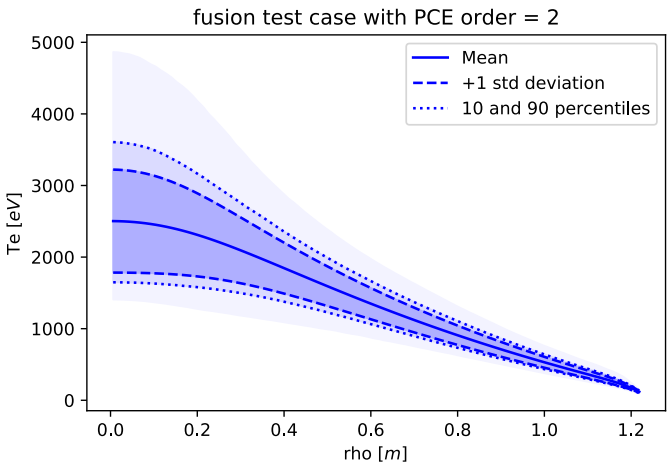
- Want to produce verified and validated temperature and density profiles in tokamaks with quantified uncertainty
- Pursuing a number of paths
  - Simple heat transport in a cylinder to explore UQ techniques and as a tutorial
    - 20 ms on 1 core for a steady state solution
    - Can afford to explore a large number of simulations
  - Turbulence-Transport Workflow with a cheap proxy for the GEM turbulence code (GEM0)
    - 30 seconds on 1 core for a steady state solution
    - Can afford to explore ideas that will be used for the full workflow
  - Full Turbulence-Transport Workflow
    - Takes multiples of 19 hours on 1024 cores

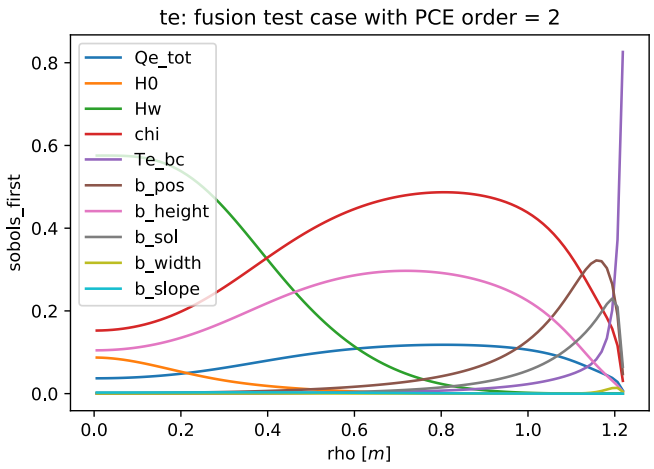
UQ for simple cylindrical model

- Use Polynomial Chaos Expansion (PCE) to look at the uncertainty in the profiles as well as the Sobol indices explaining the source of the uncertainty
- 10 uncertain parameters, PCE order 2, 59049 cases



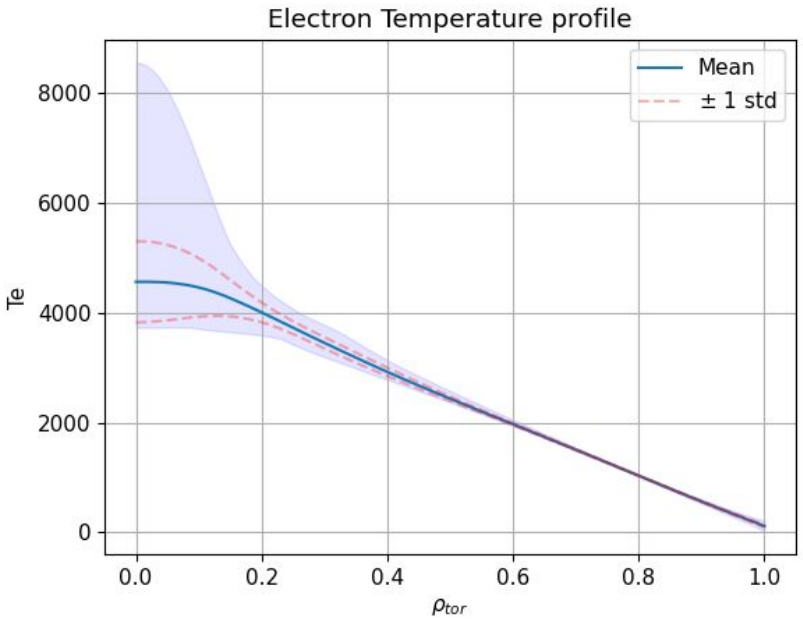


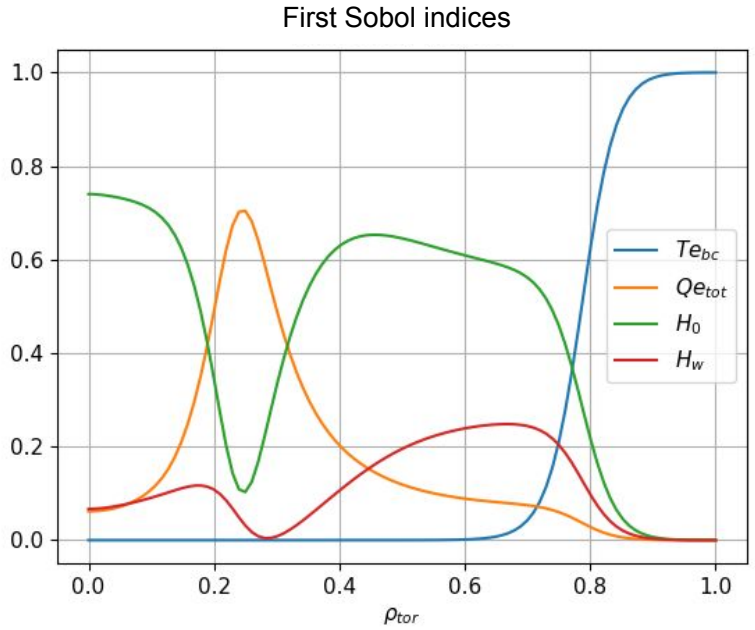




UQ for light version of workflow

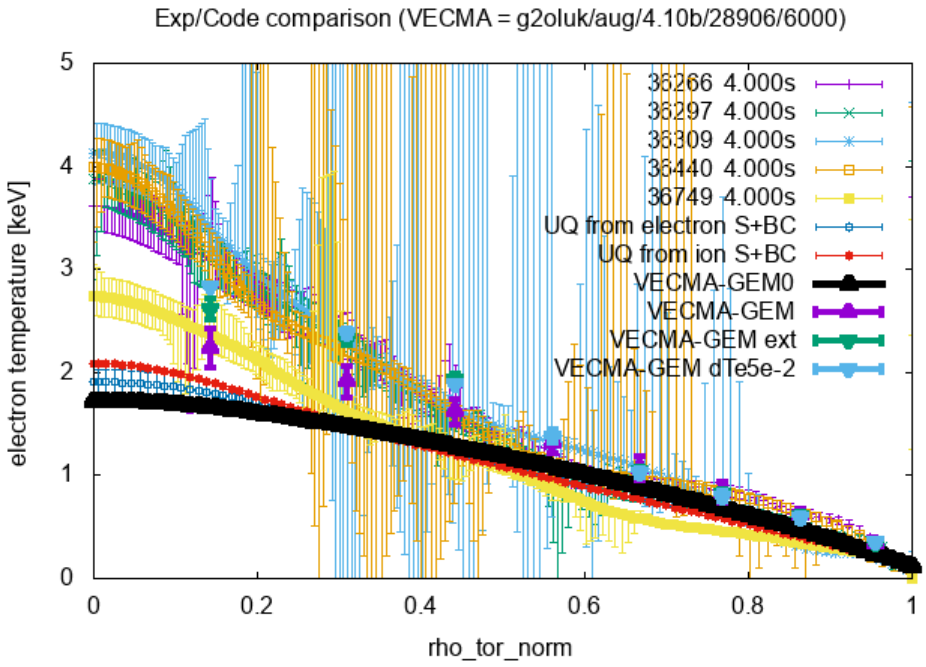
- Performed PCE with the workflow (with GEM0 replacing GEM)
  - 4 uncertain parameters, PCE order 3, 256 cases

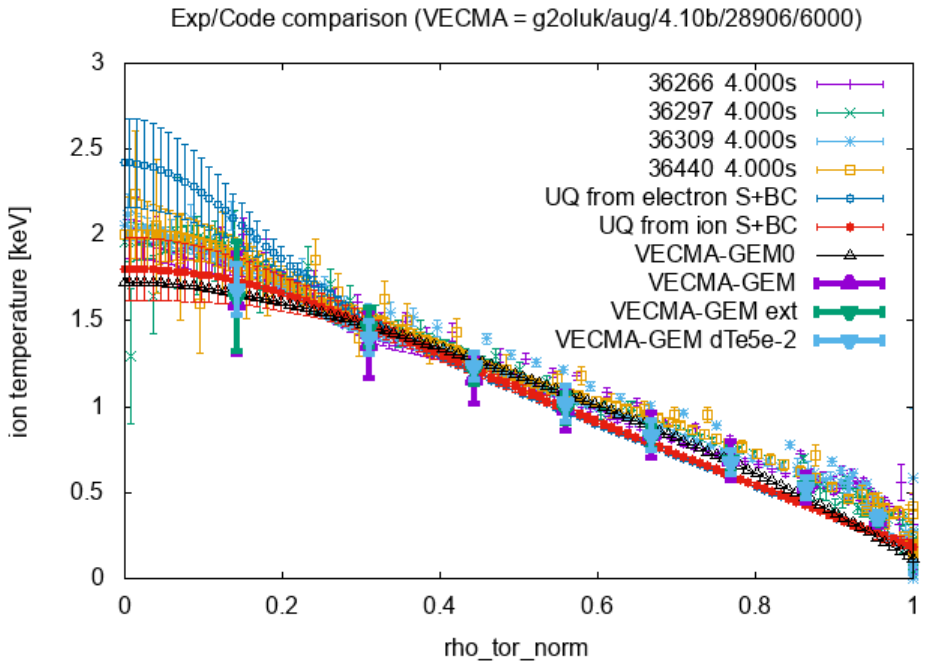




Full workflow simulations

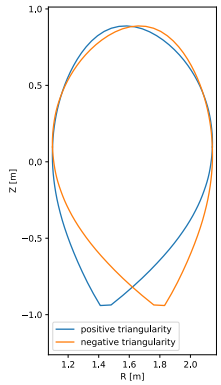
- Comparison between full workflow to a few AUG standard H-Mode discharges

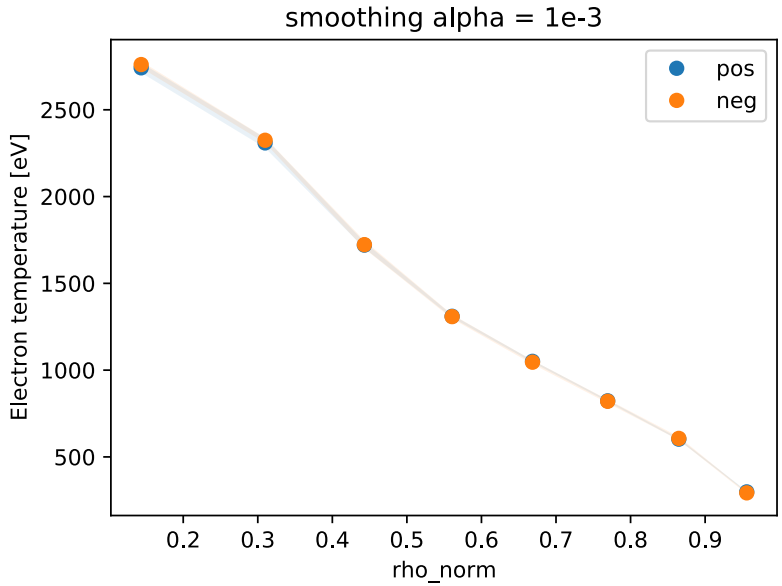


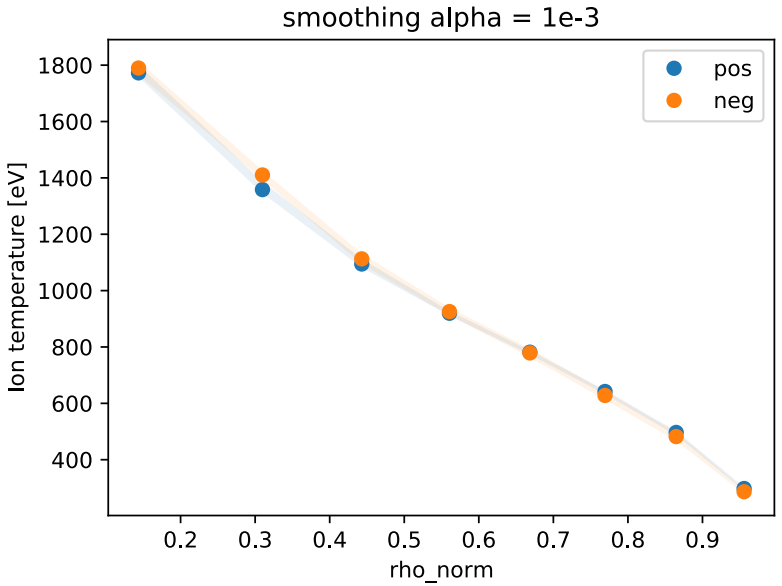


Full Workflow to + and - triangularity

- Flipped the outer boundary around the geometric centre of the surface
- Ran the full work flow
- Disappointingly, the plasma profiles are very similar!







Next step: Workflow with distributions

ECMA

- Aim to move to a workflow where, instead of profiles, distributions are passed around
  - Each code is run a number of times
    - with input profiles sampled from its input distribution,
    - and a distribution calculated from its outputs
- Pieces have been developed
- Hope will be faster than doing black-box UQ around the whole workflow