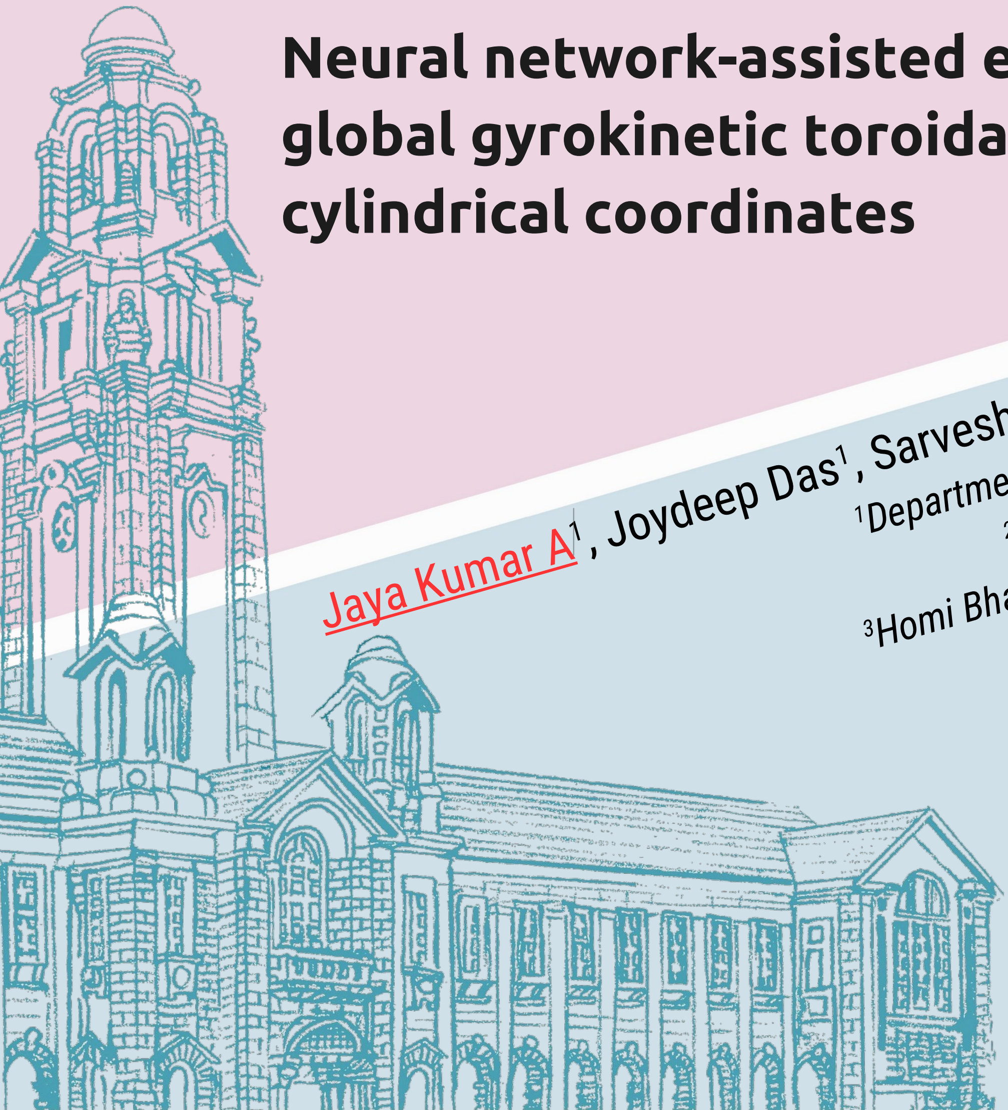
G2C3

Global **G**yrokinetic
Code using **C**ylindrical **C**oordinates



Neural network-assisted electrostatic global gyrokinetic toroidal code using cylindrical coordinates

Jaya Kumar A[1], Joydeep Das[1], Sarveshwar Sharma[2], Abhijit Sen[2,3], Animesh Kuley[1]

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PTG@IISc

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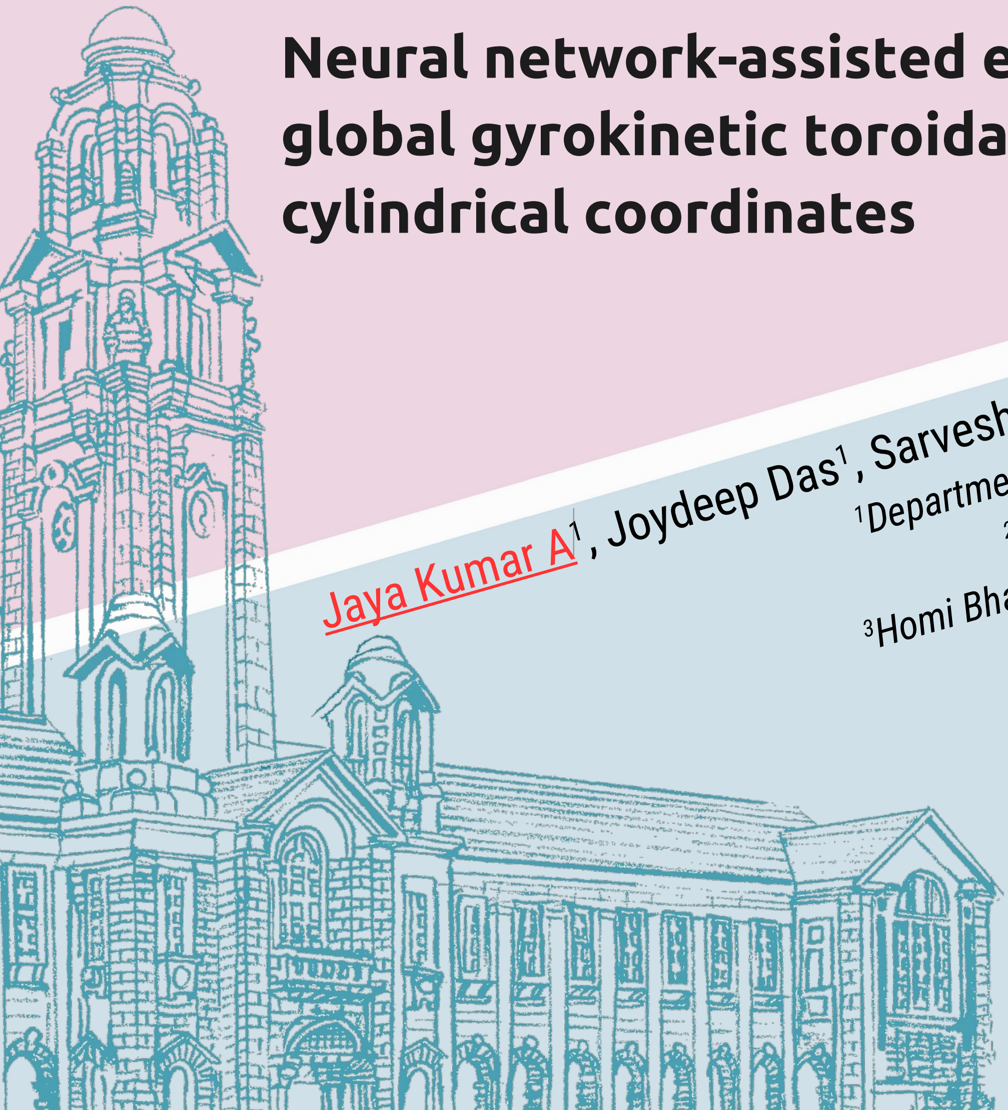

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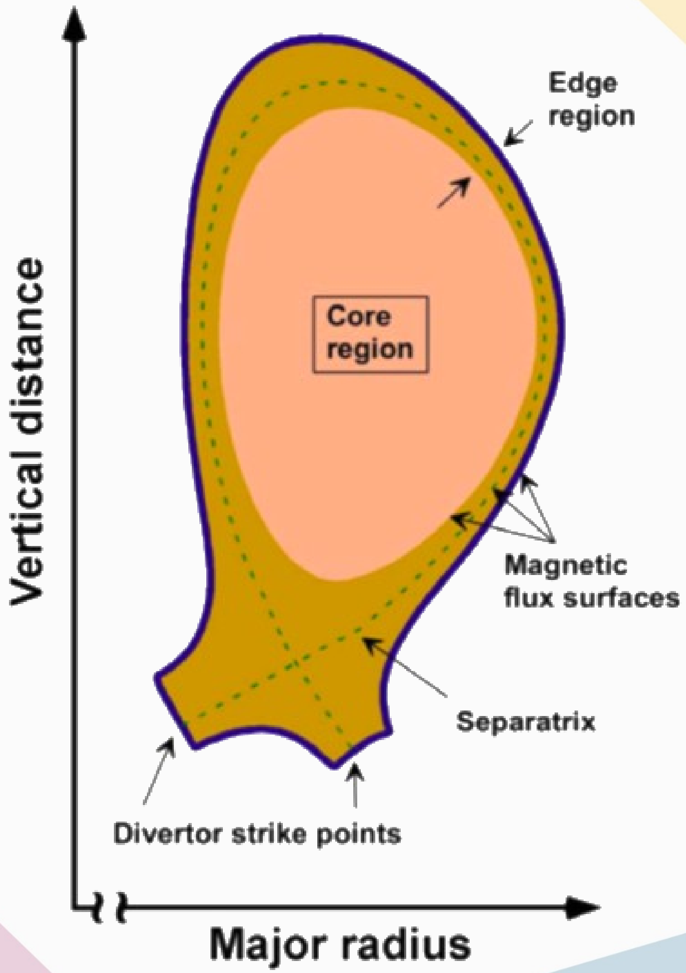
Importance and objective

- ❑ Drawback of the mostly available simulation codes, such as GTC, GENE, ORB5……
  - ➢ They are based on flux coordinates, which fails near the X point and separatrix surface.
  - ➢ Therefore, combing core and edge region is not possible…..

- ❑ Solution: Development of a simulation code, independent of flux coordinates
  - ➢ *Global Gyrokinetic Code using Cylindrical Coordinates.* (G2C3)



Codes available:

XGCs' (PPPL, USA), GENE-X, TRIMEG (Max-Planck, Germany)

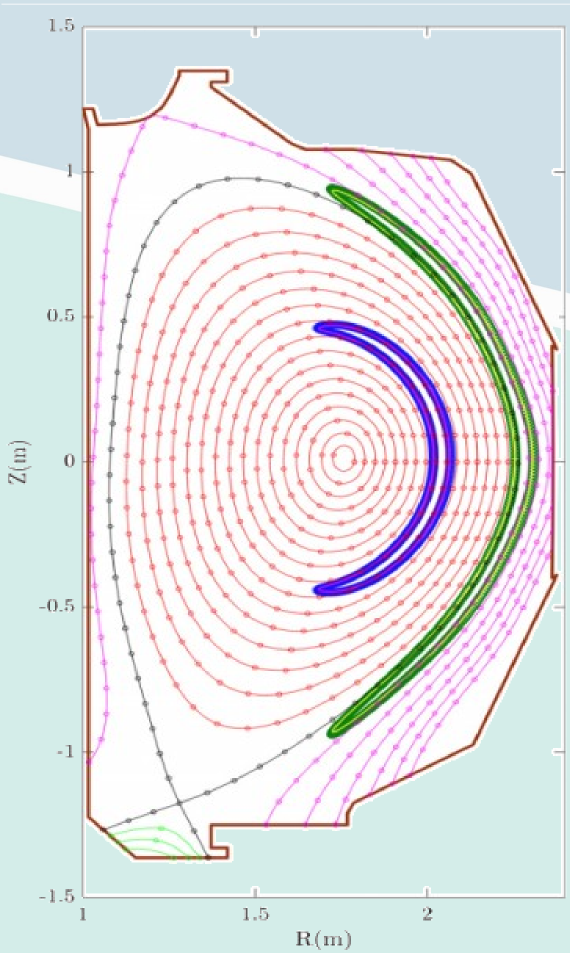
G2C3

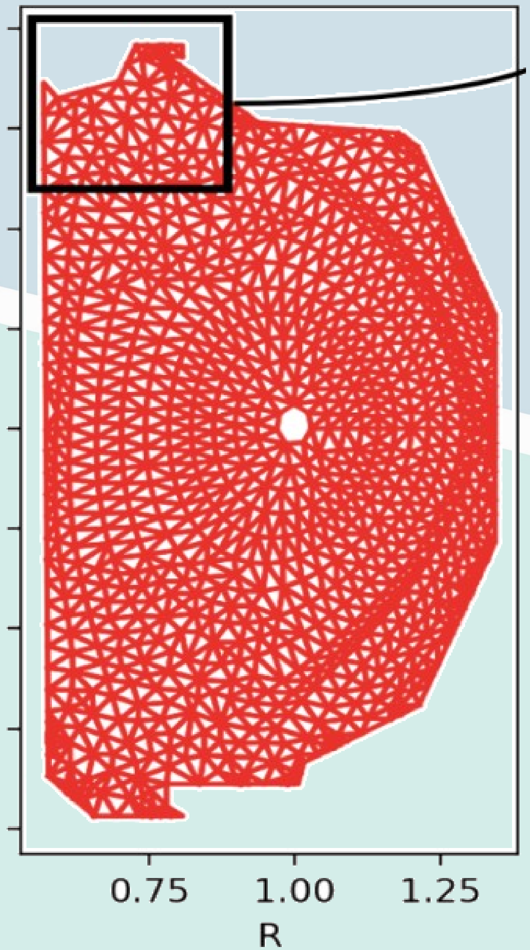
Capabilities of G2C3

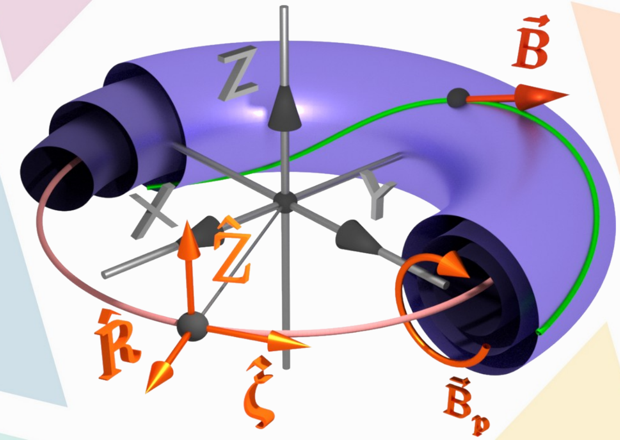
❑ G2C3 is a global code currently under development at IISc Bangalore.
The G2C3 code has the following features:

- ❖ G2C3 is a first principle particle-in-cell (PIC) code based on cylindrical coordinates
- ❖ Global approach for plasma and background magnetic geometry, obtained from axisymmetric ideal MHD equilibria computed with EFIT and IPREQ code.
- ❖ Both gyrokinetic (5D for low-frequency micro-turbulence) and fully kinetic (6D for high-frequency modes) particle integrators.
- ❖ Field-aligned particle grid interpolation for axisymmetric mesh in cylindrical coordinates.
- ❖ G2C3 has MPI parallelization with particle decomposition.
- ❖ Poisson solver using PETSc library.
- ❖ Neural Network for particle locating, gathering scattering operation
- ❖ Microturbulence: Gyrokinetic thermal ion and adiabatic electron.

Global geometry using cylindrical coordinates







Jacobian

$$J^{-1} = \nabla R \cdot (\nabla \zeta \times \nabla Z)$$

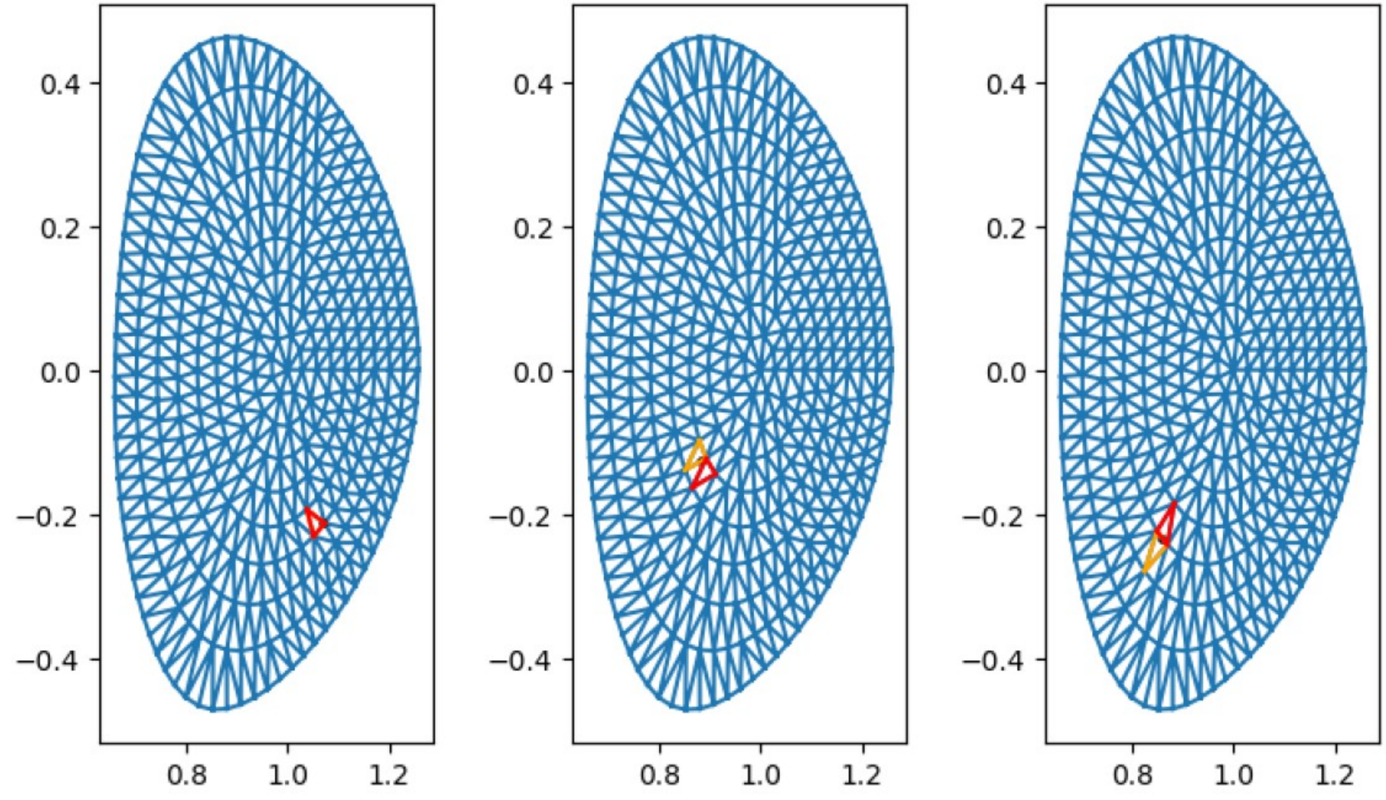
Magnetic field

$$\vec{B} = \nabla \psi(R,Z) \times \nabla \zeta + g(R,Z) \nabla \zeta$$

$$B_R = \frac{1}{R}\frac{\partial \psi}{\partial Z} \qquad B_Z = -\frac{1}{R}\frac{\partial \psi}{\partial R}$$

G2C3

Particle locator using Neural Network

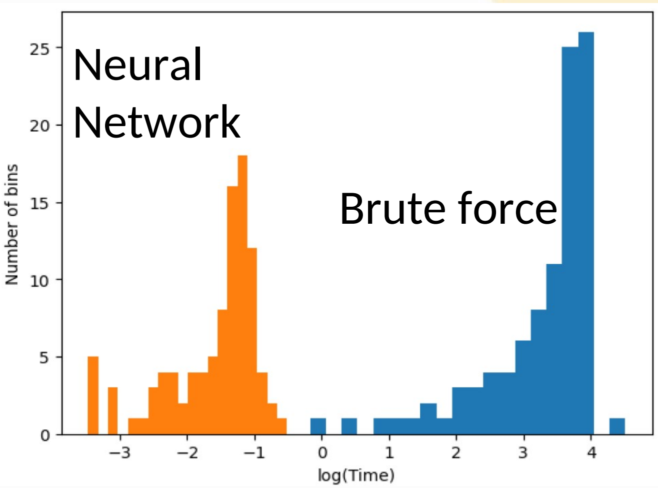


(a) Prediction matches exactly and overlaps

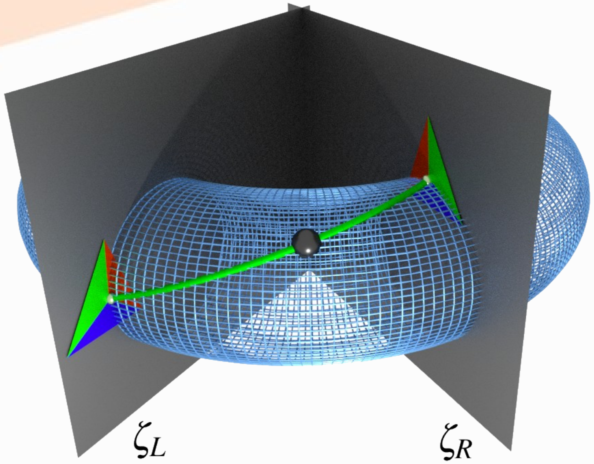
(b) Prediction is close and lies on the same flux surface

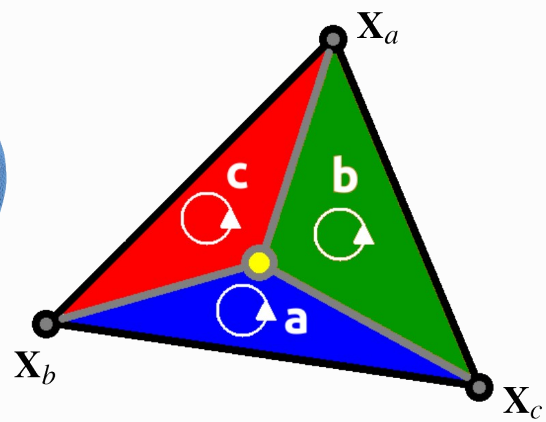
(c) Prediction is close and lies on different flux surfaces

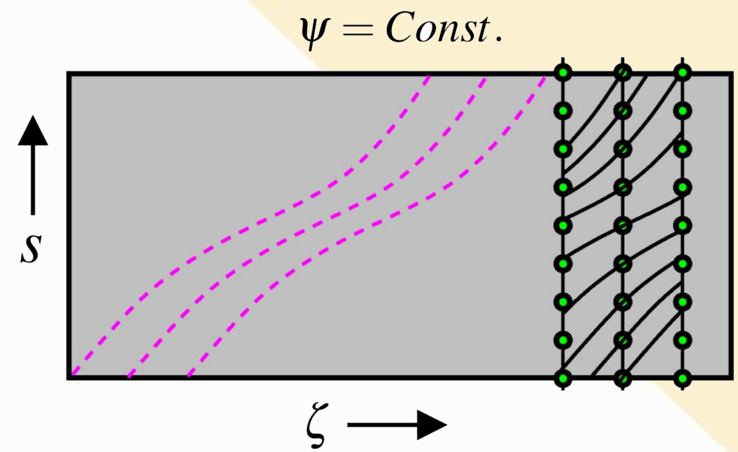
Histogram

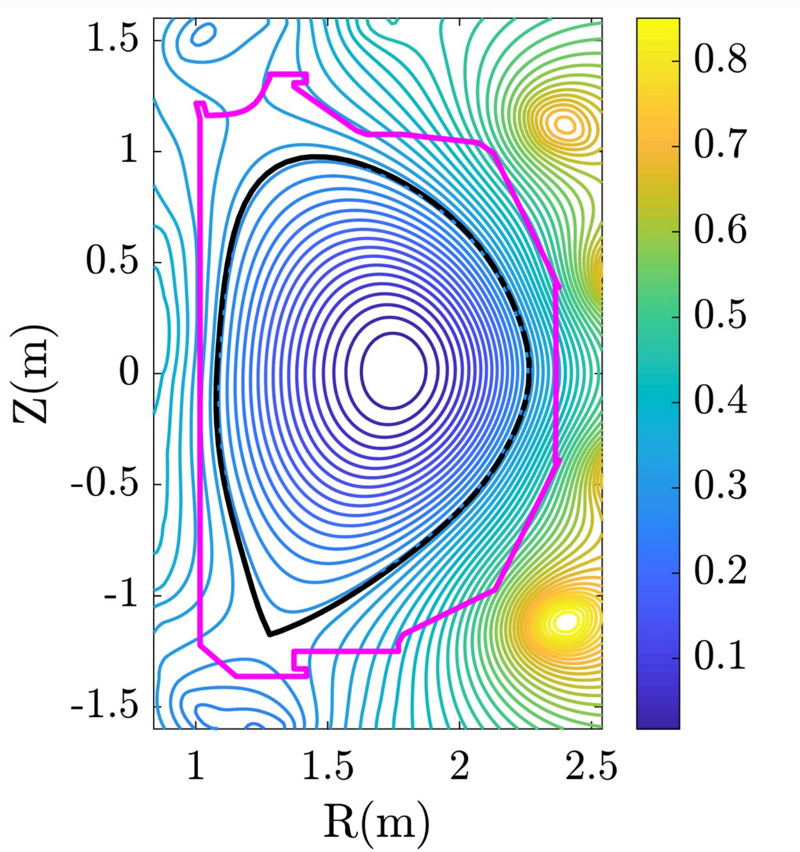


Gather-Scatter operations for field and charges

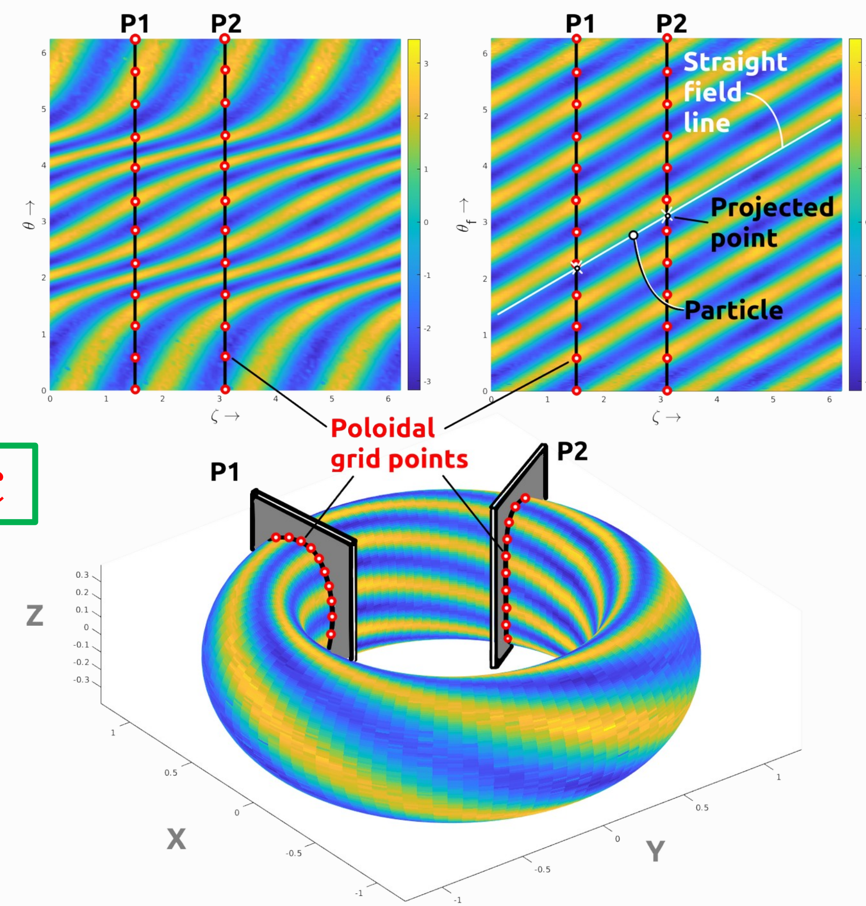




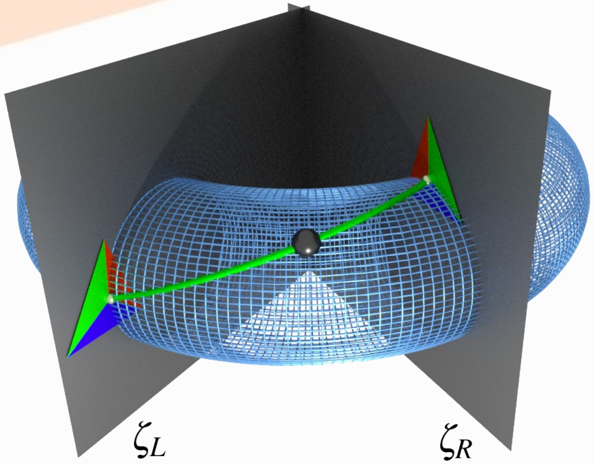


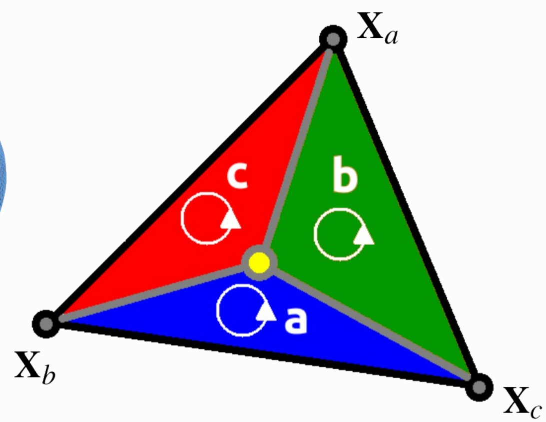


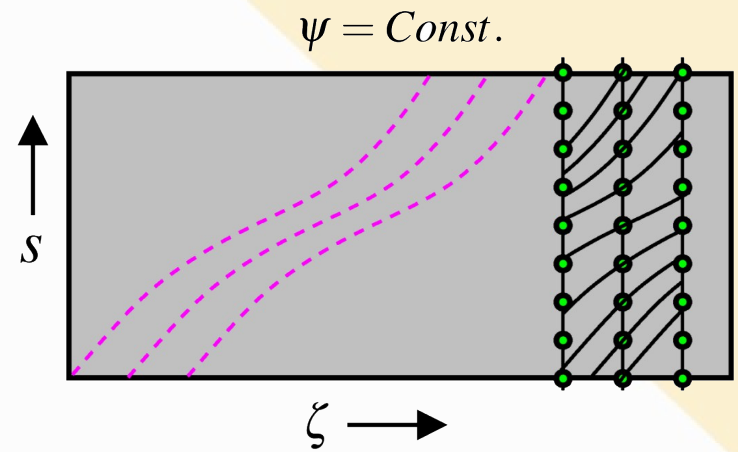
GTC



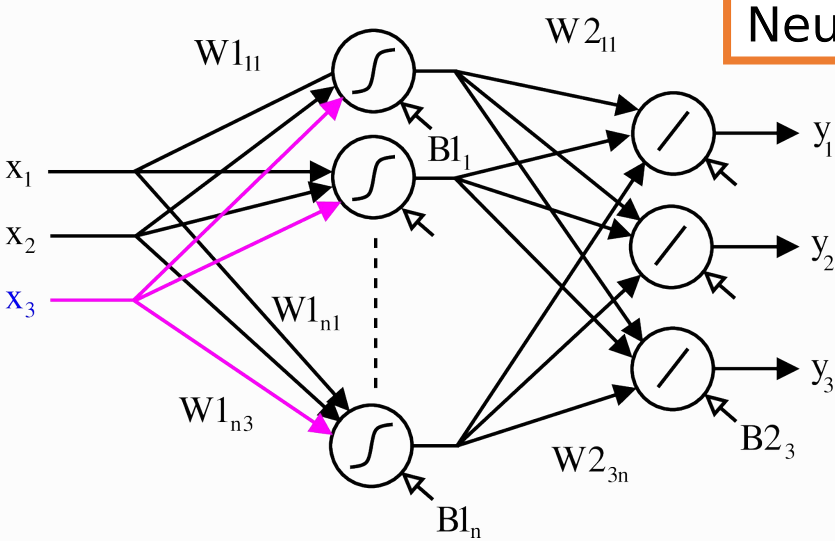
Gather-Scatter operations for field and charges



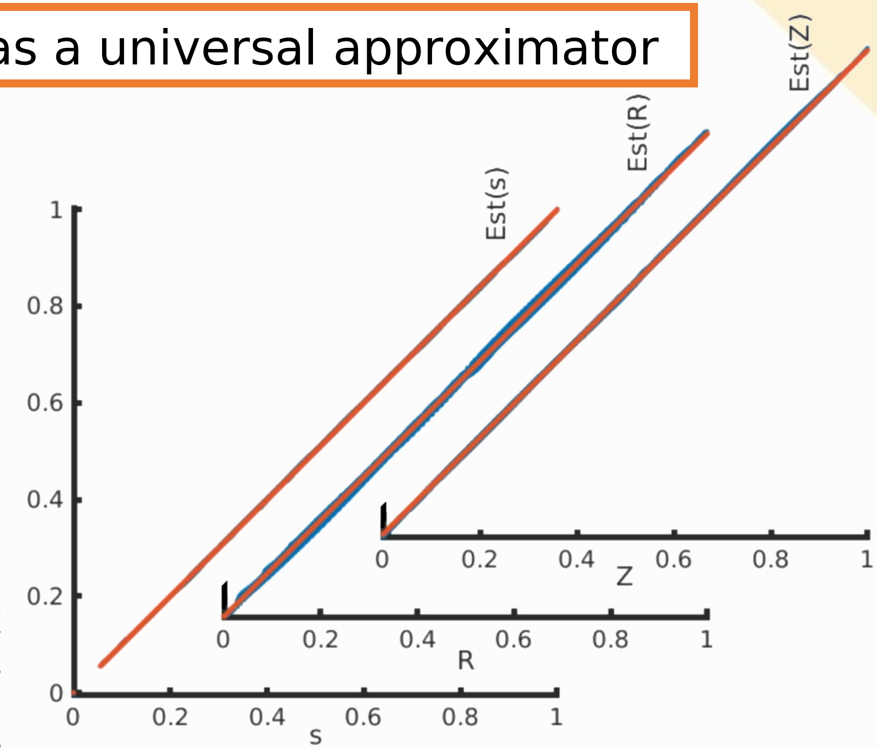




Neural network as a universal approximator



G2C3



Comparison of the trained neural network output against the target values. Left lower panel shows the relation for δ*s*, center panel for δ*R*, and the right panel shows δ*Z*. Notice that a error free map corresponds to a 45^0 straight line.

Estimation Error

Benchmark of Finite element solver using PETSc

Weak form of Poisson equation for gradient calculation

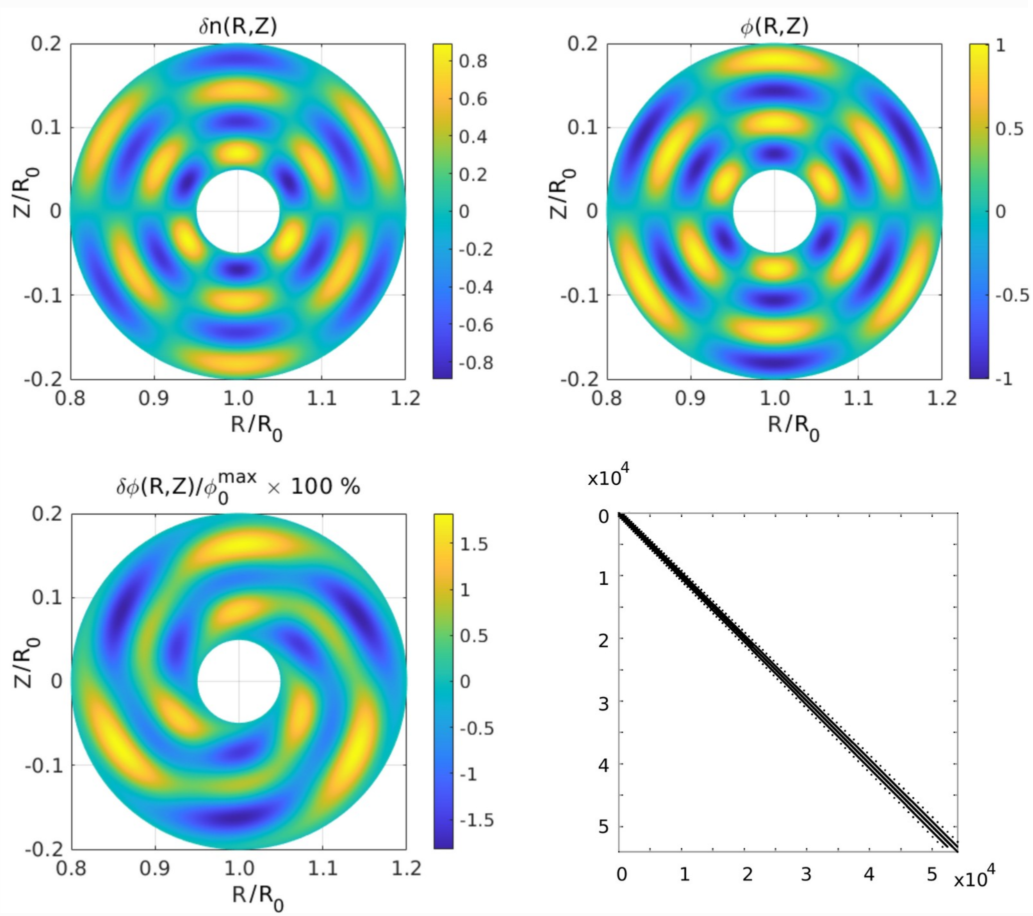
Poisson Eq. in weak form

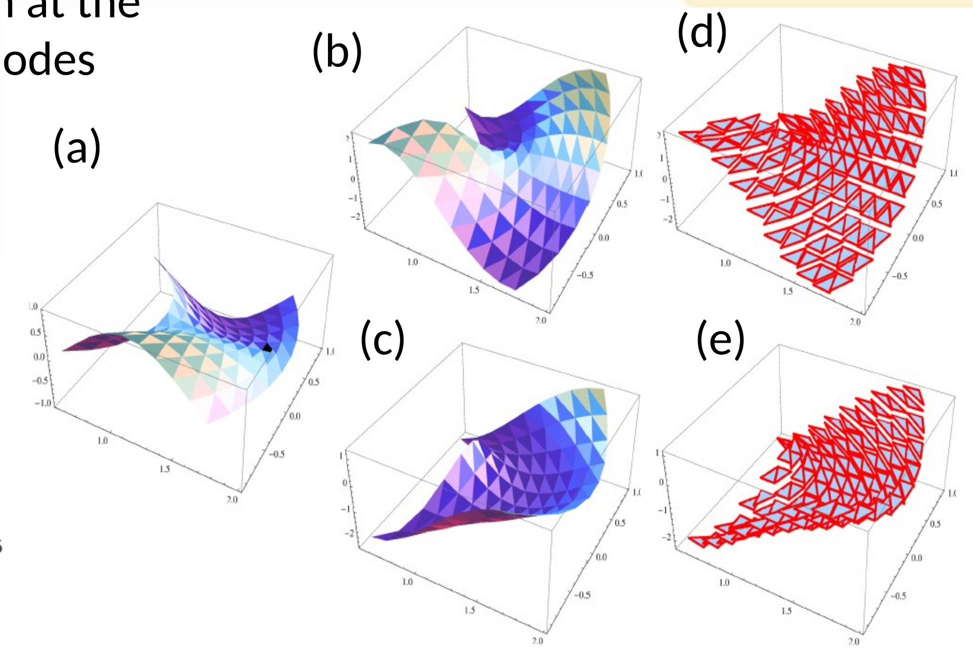
$$K_{ij}\ \phi_j = d_i$$

Source term at the triangular nodes

Sparse matrix

Potential at the nodes



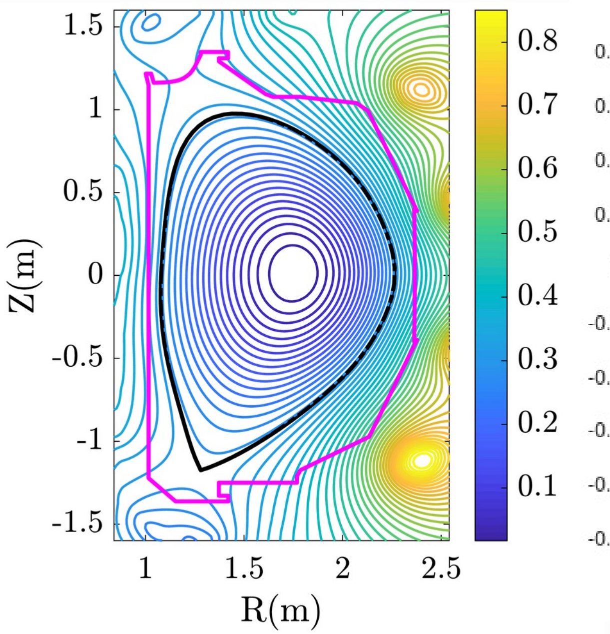


(a) Potential , (b) and (c) gradient of obtained using weak form (continuous)

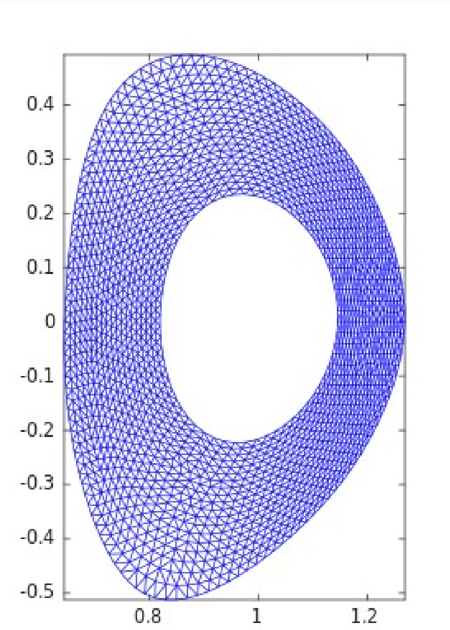
(d) and (e) obtained from 1st order FEM (show discontinuity)

Benchmarking ITG mode in DIII-D [*Shot # 158103*]:
(Linear-, Adiabatic electron-, gyrokinetic ion-, Electrostatic- case)

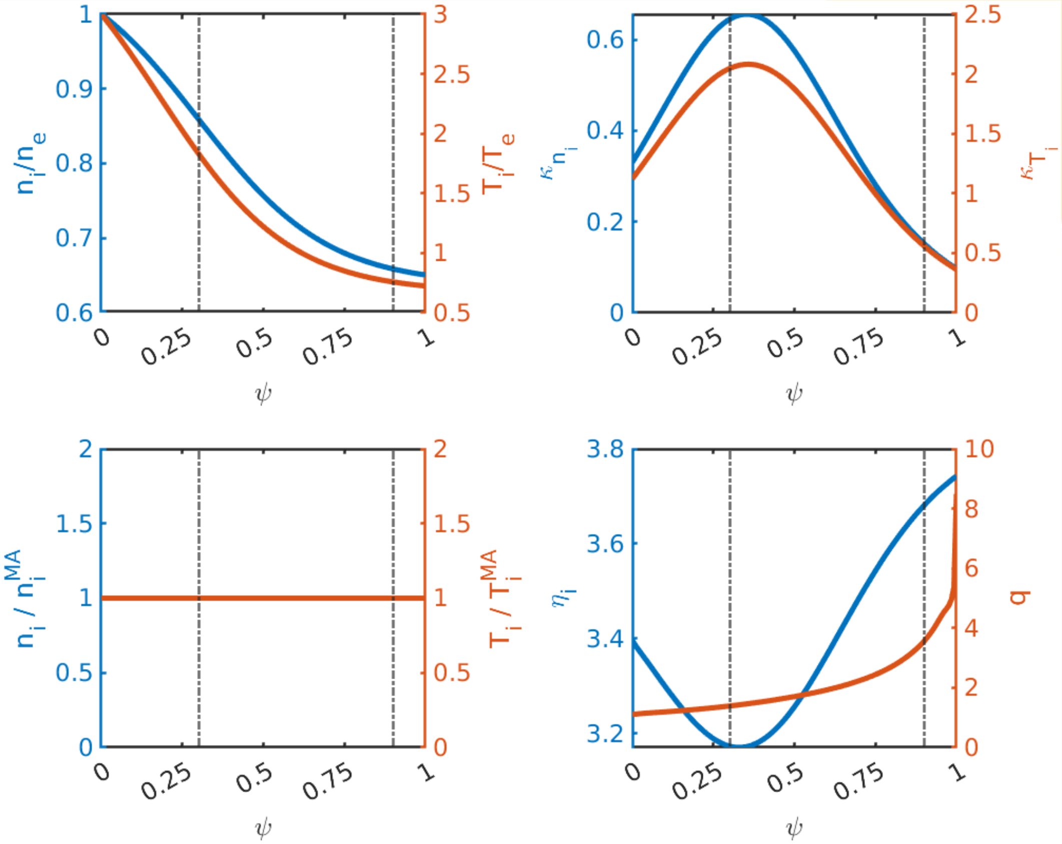
Flux function



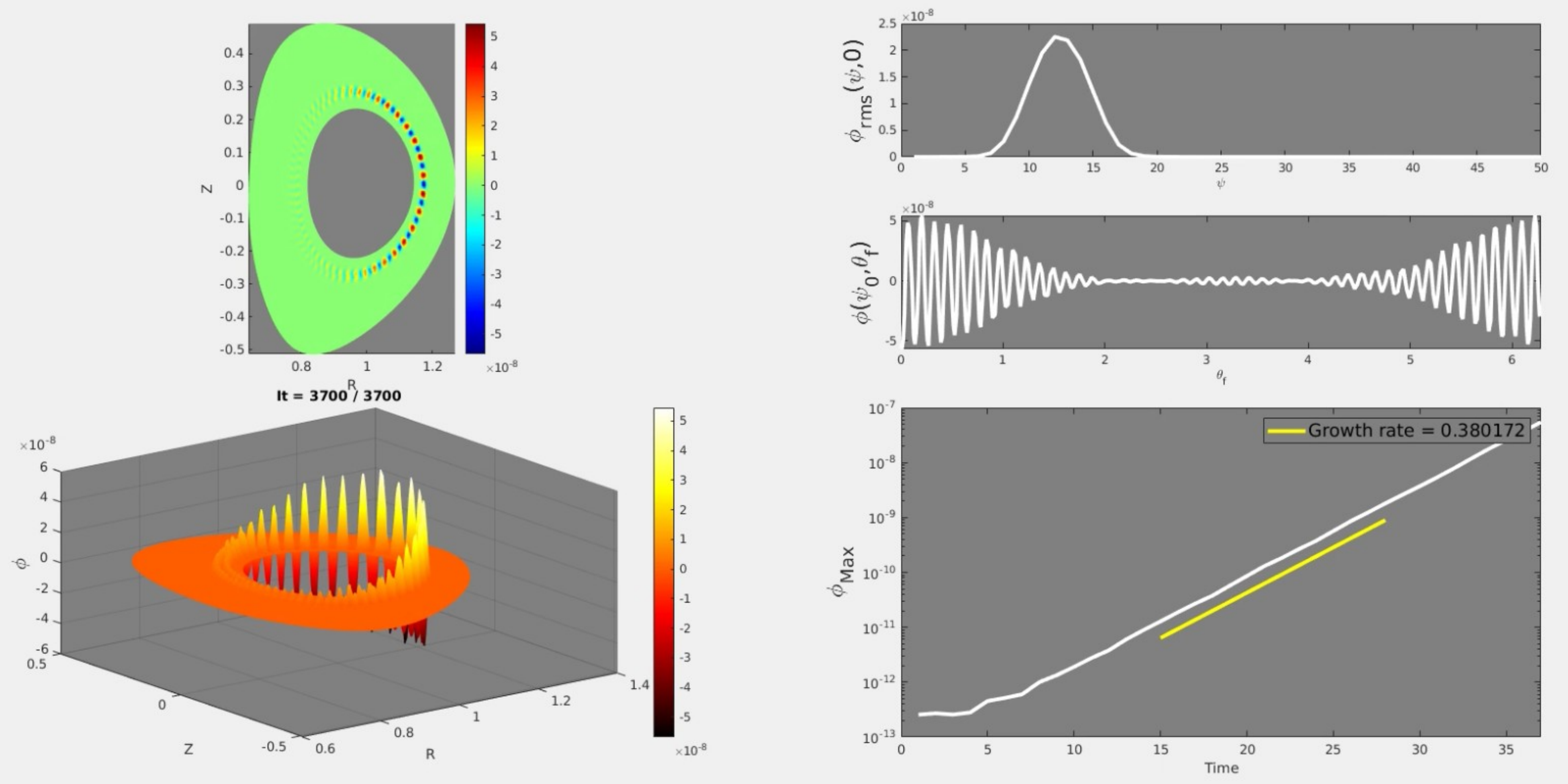
Simulation grid



Temperature and density (cyclone) profiles:



Verification of Linear ITG mode in the core region of DIII-D tokamak



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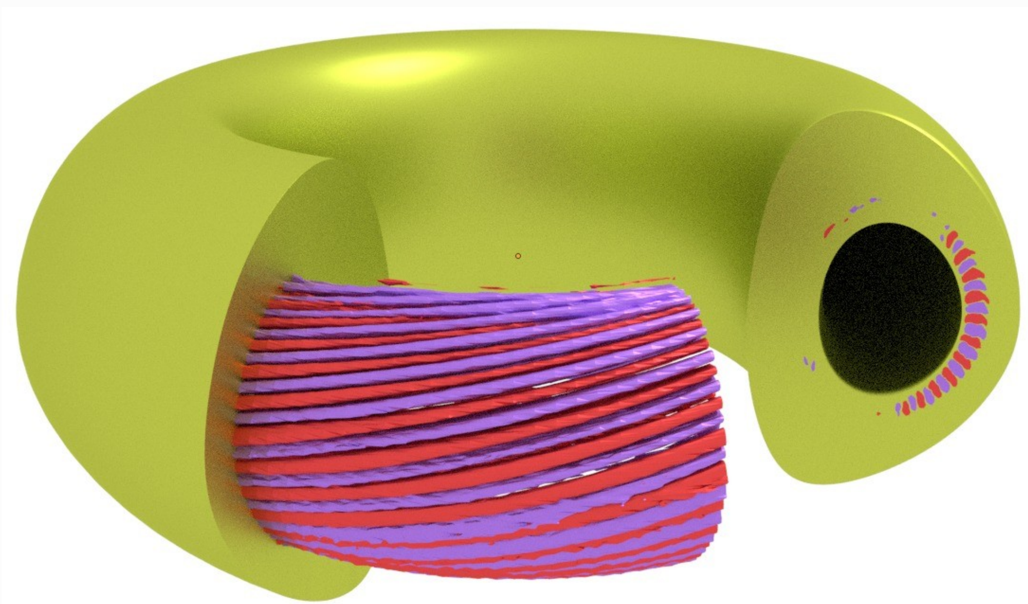
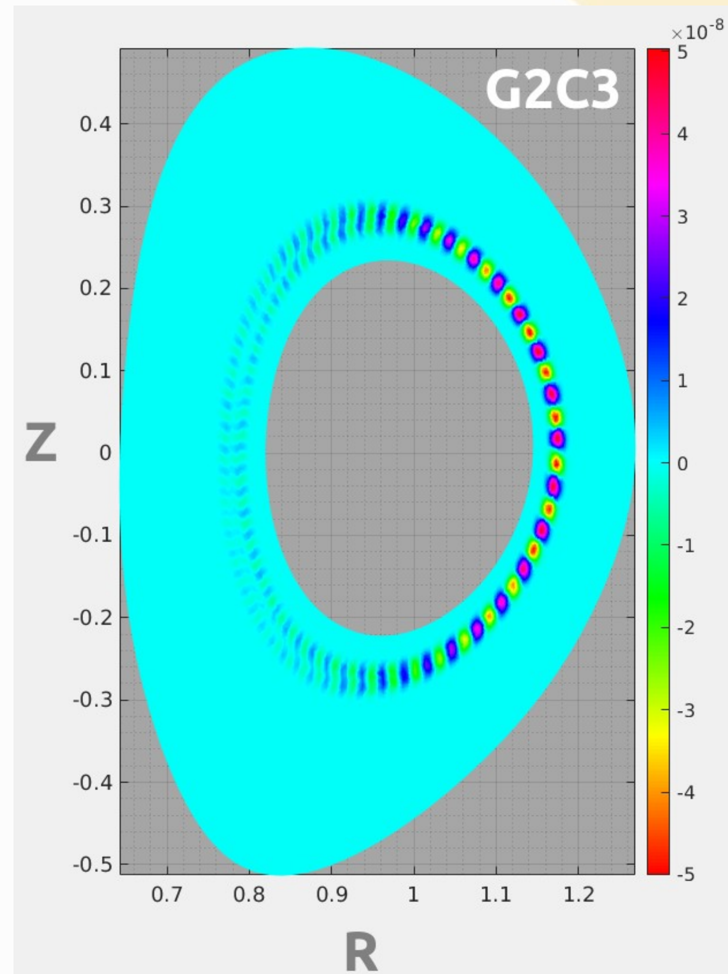
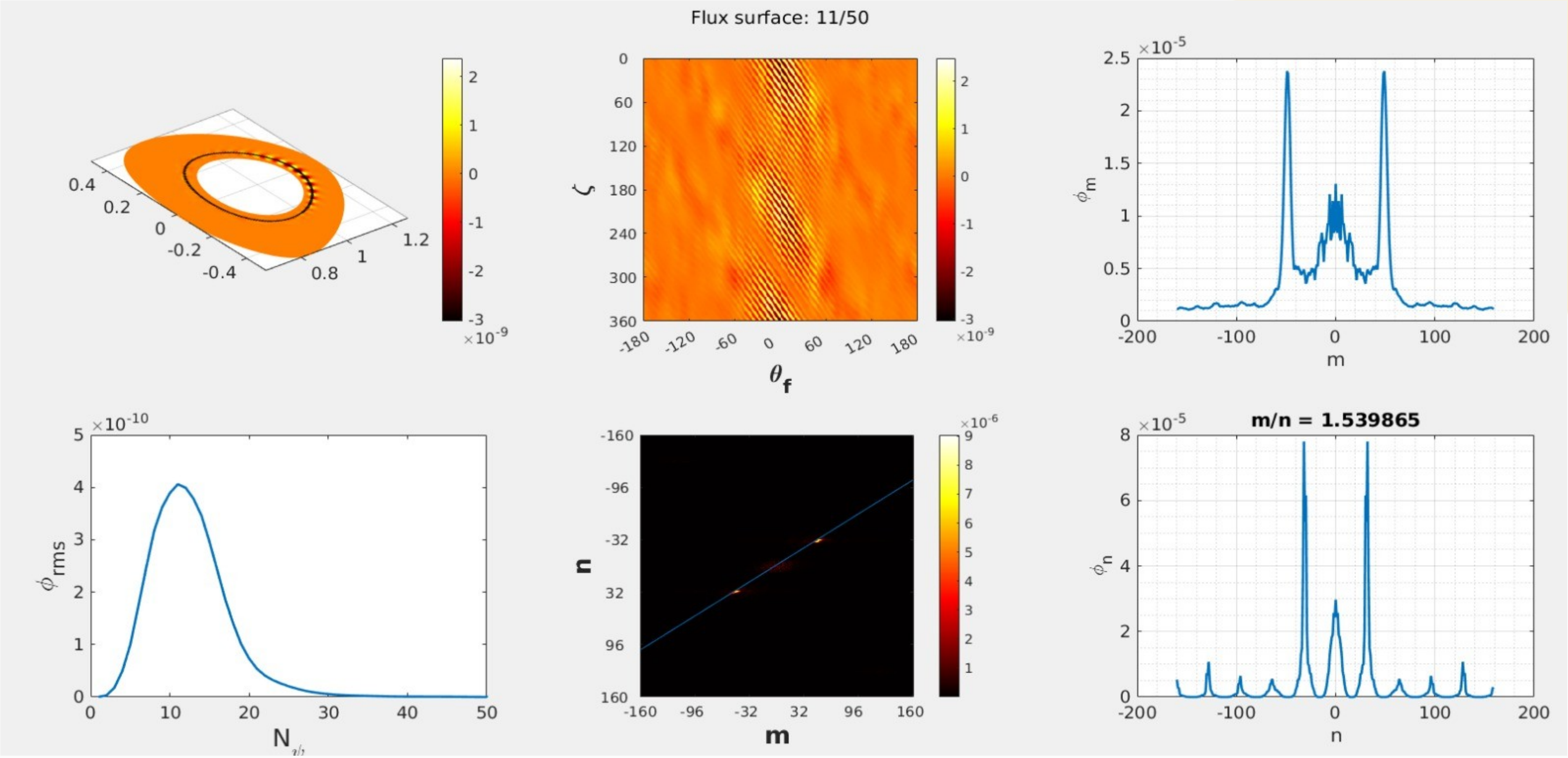
2D View

3D View





Mode Analysis



Thank you for your attention.