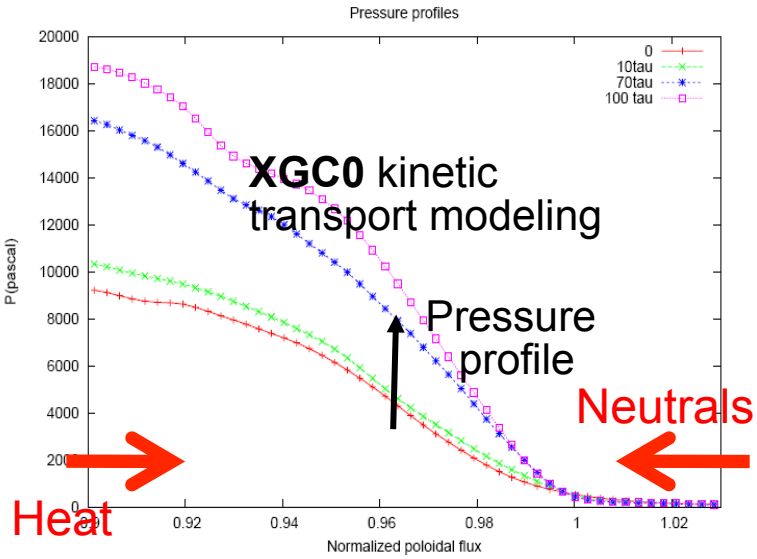
Boundary physics in the full-f GK code XGC1 (Chang, et al)

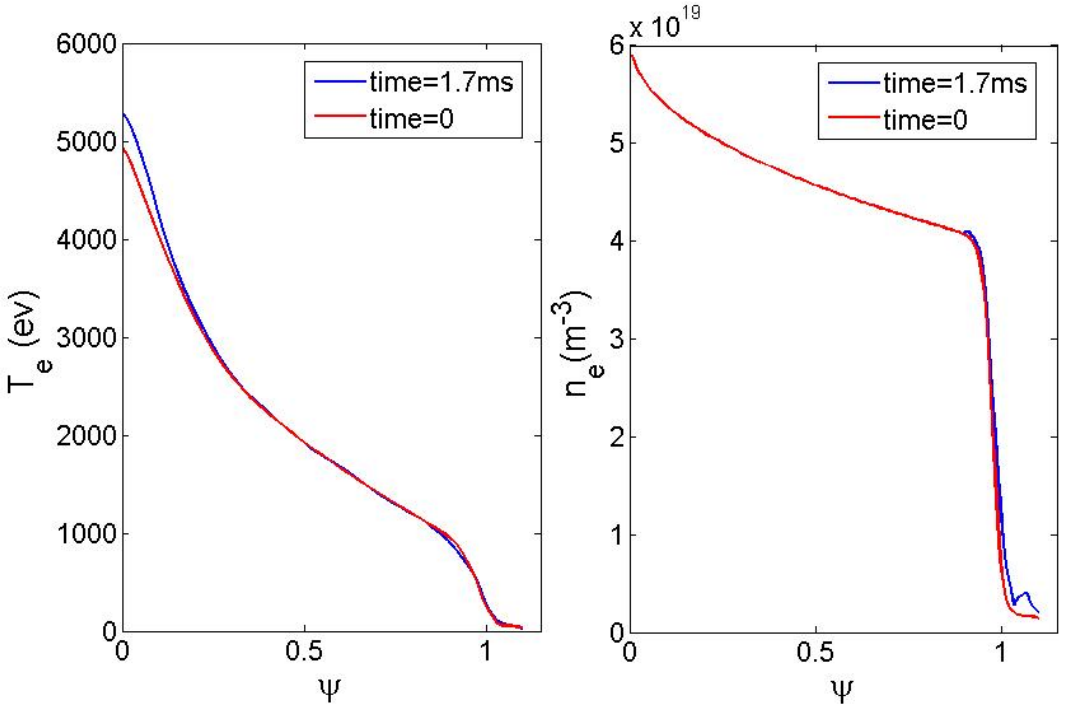
- **Simulation: non-local first principles approach in diverted geometry**
  - **Pedestal and SOL, consistently with core physics and wall boundary (recycling, sputtering and electric grounding)**
  - **Multi-physics: Neoclassical, turbulence, impurities, neutrals, atomic physics, wall interaction (data)**
    - Turbulence will include all the important electromagnetic modes (ETG will be handled on localized adaptive grids)
  - **Heat and particle sources, heat sink from atomic processes in the pedestal**
  - **Study topics**
    - Pedestal physics: formation, height and width
    - Scrape-off layer width, turbulence and transport
    - Divertor wall load
    - Li transport and effect
- **Diagnostics**
  - **Radially distributed turbulence property: δn, δT, k, ω, V'_{ExB}, correlations**
  - **Neutral density and temperature profiles, radiative loss measurement**
- **Code development**
  - **Present capability:**
    - ITG + neoclassical + neutral in diverted geometry
    - E&M turbulence in non-diverted geometry
  - **Near Future (≤1 year)**: E&M turbulence + neoclassical + neutrals + impurities
  - **Longer Term: ETG, NBI**

Pedestal buildup in XGC0 (~10 ms)

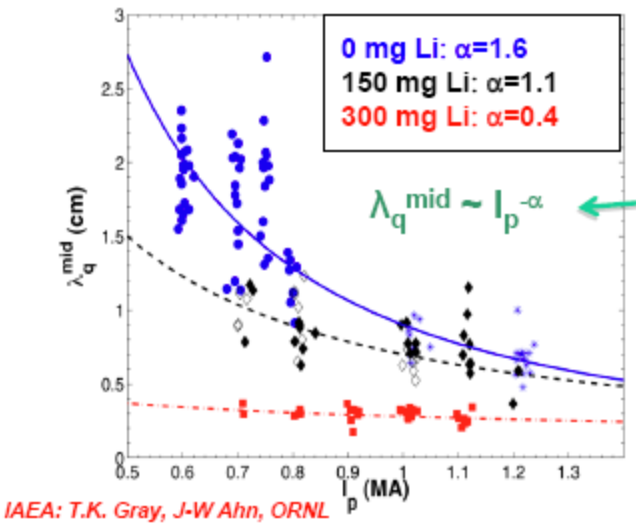


ψ_N

Pedestal buildup in XGC1 (1.7 ms)



XGC0 shows that neoclassical physics sets the basis for the $1/I_p^{\alpha}$ heat flux width behavior (2010 JRT)

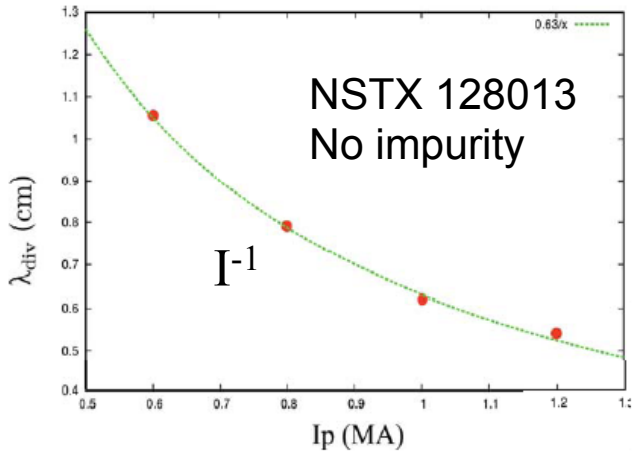


IAEA: T.K. Gray, J-W Ahn, ORNL

Joint Research Target (3 U.S. Facilities)

- Divertor heat flux width decreases with increased plasma current I_P
  - Potentially major implications for ITER
  - NSTX: λ_q^{mid} further decreases with Li

→ NSTX Upgrade with conventional divertor (LSN, flux expansion of 10-15) projects to very high peak heat flux up to 30-45MW/m^2



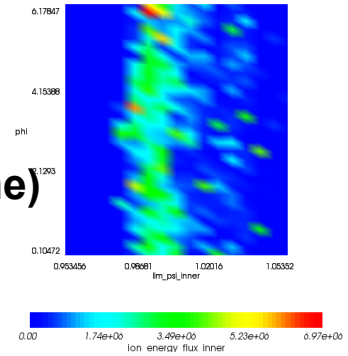
Neoclassical orbit broadening/squeezing physics:
XGC0 shows $\lambda_q^{mid} \propto I_P^{-\alpha}$, where α is function of collisionality, with some broadening by radial anomalous transport.

Kinetic-MHD coupled simulation for pedestal-ELM cycle in automated EFFIS framework

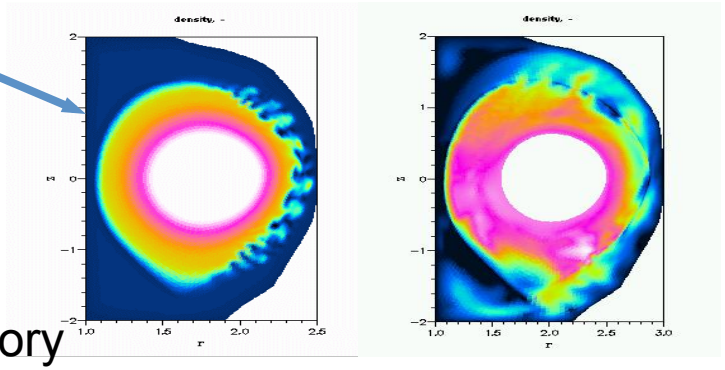
Linear stability check (Binary **Elite**)

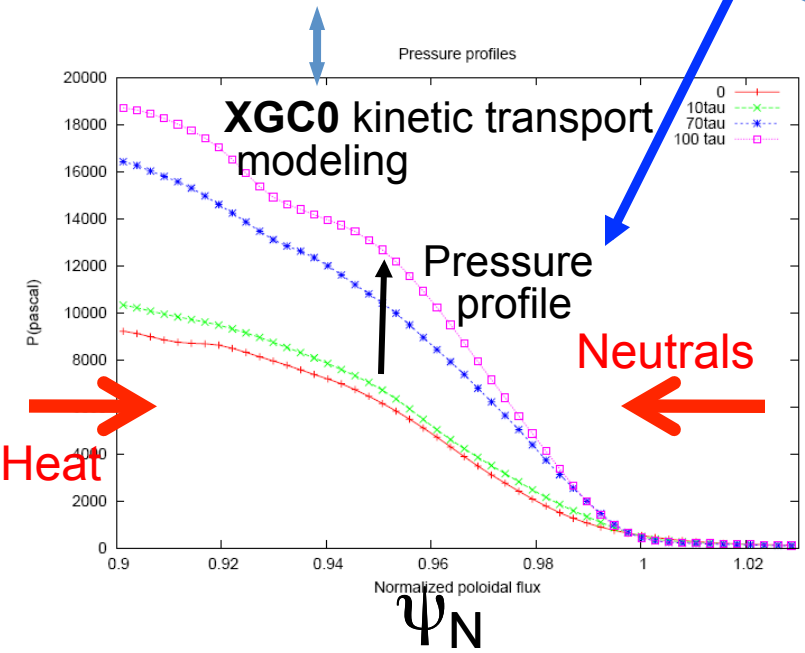
B-reconstruction and mesh interpolation by **M3D-OMP**

Divertor Heat Load
(2010 OFES Milestone)



ELM crash in extended **M3D-MPP**





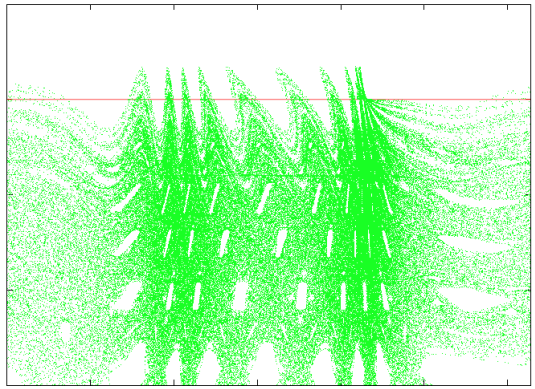
mxn Memory coupling of MHD turbulence

T=76
saturation

T = 496
relaxation

Field line puncture plots, starting from ψ_N=0.96, show stronger connection between pedestal and wall in the ELM suppression window

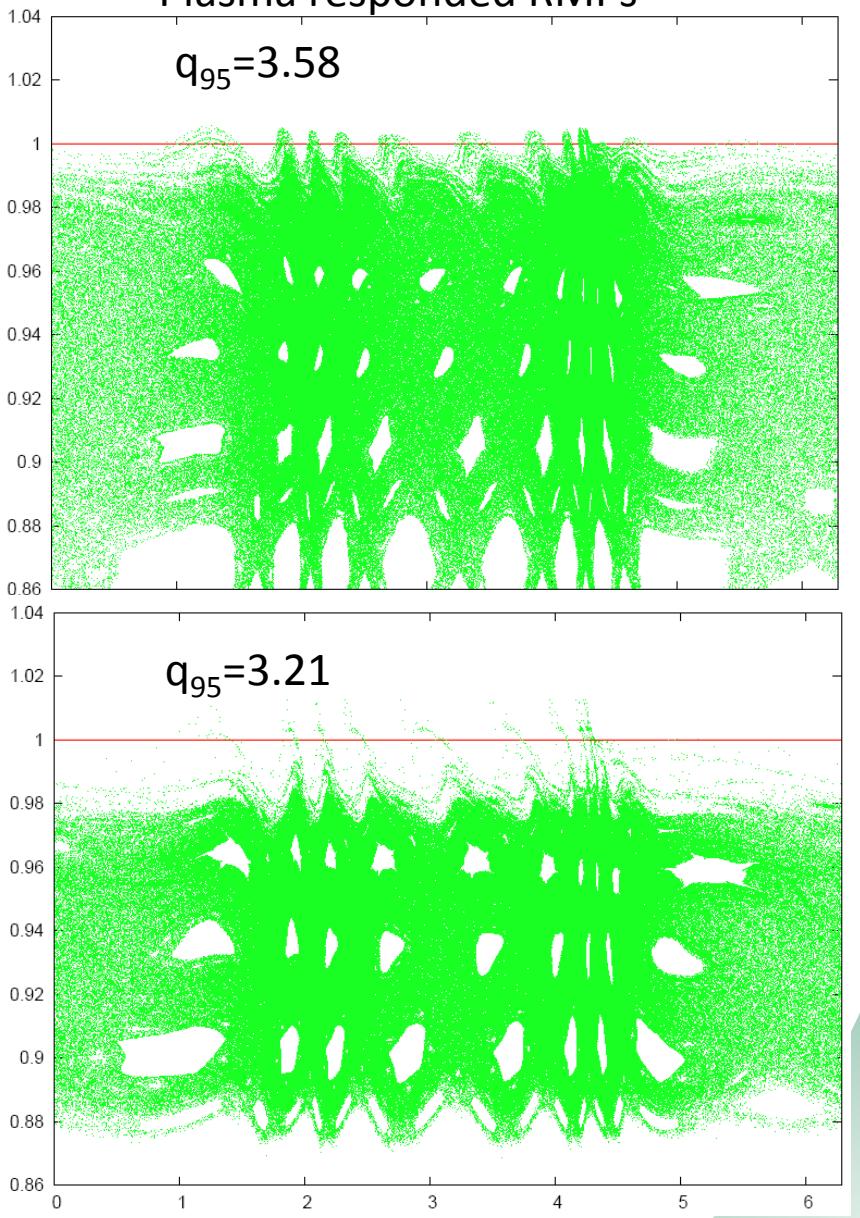
Inside the window: Field connection between plasma and wall is stronger



Vacuum RMPs with
B_T =1X $B_{T,EQDSK}$, q_{95}=3.69

Out-of-window: Field connection between plasma and wall is weak
→Stronger ∇p at new barrier

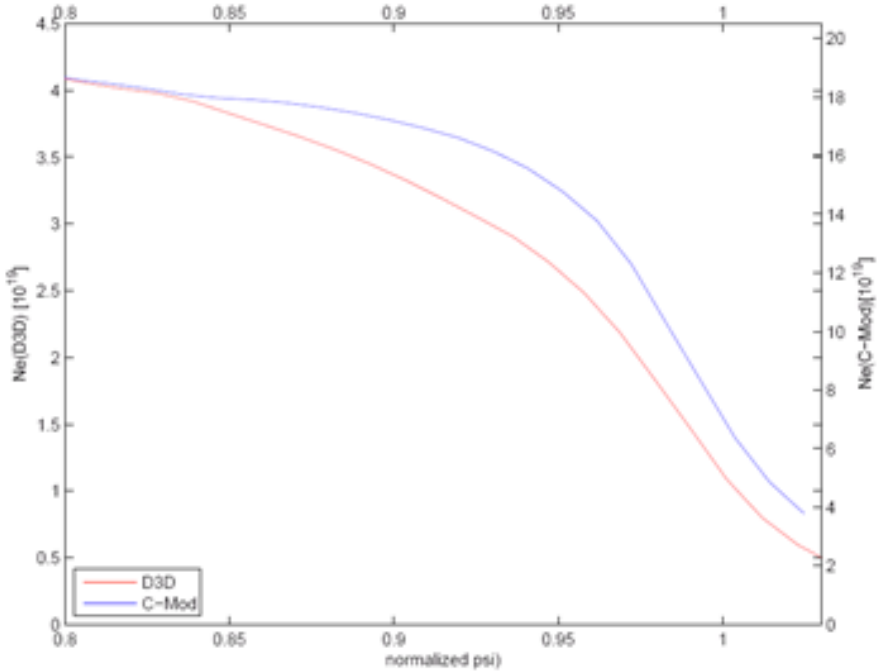
Plasma responded RMPs

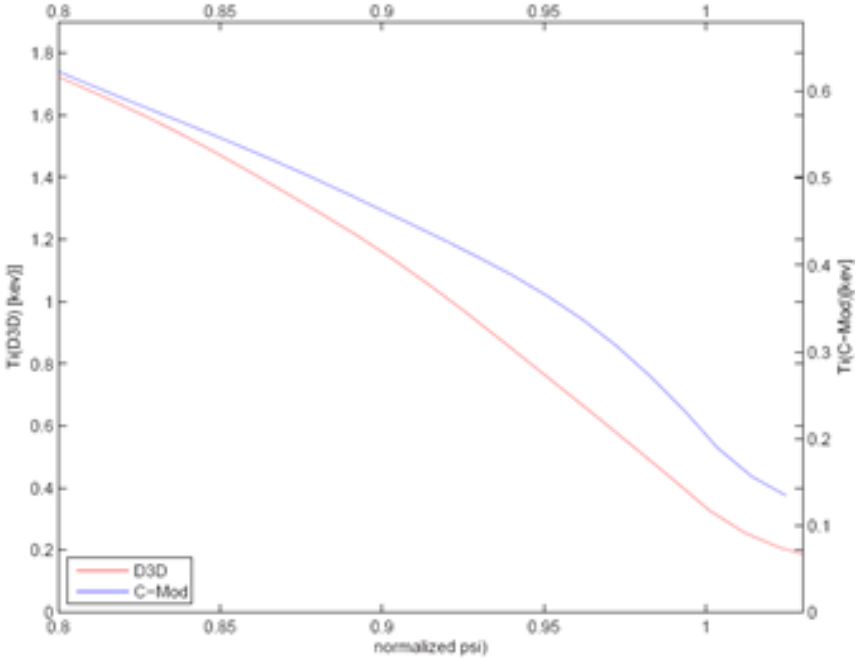


ψ_N

Poloidal angle

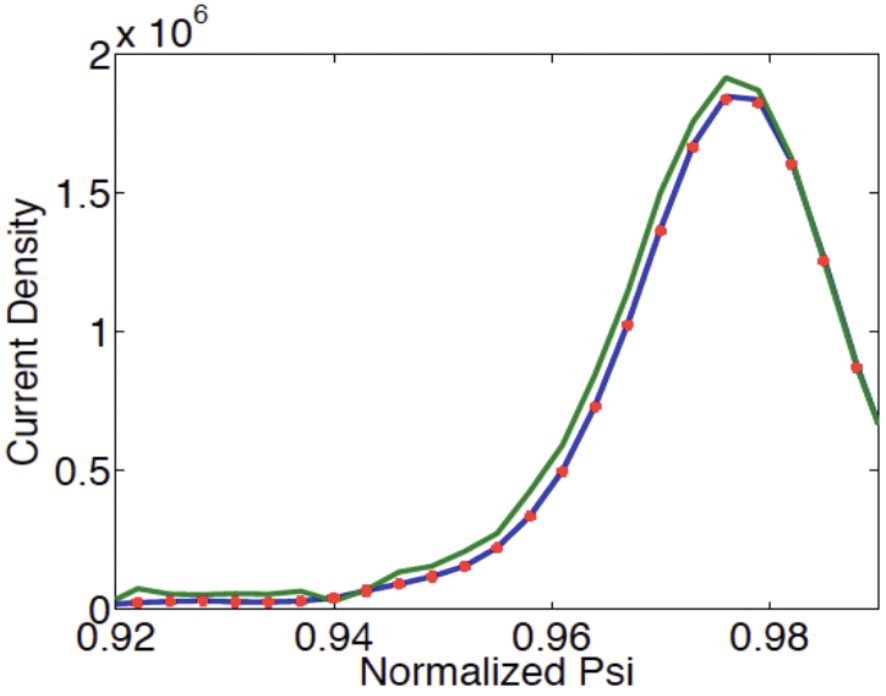
XGC0 simulation shows that density pedestal in C-Mod is shifted outward relative to DIII-D [DOE JRT2011]

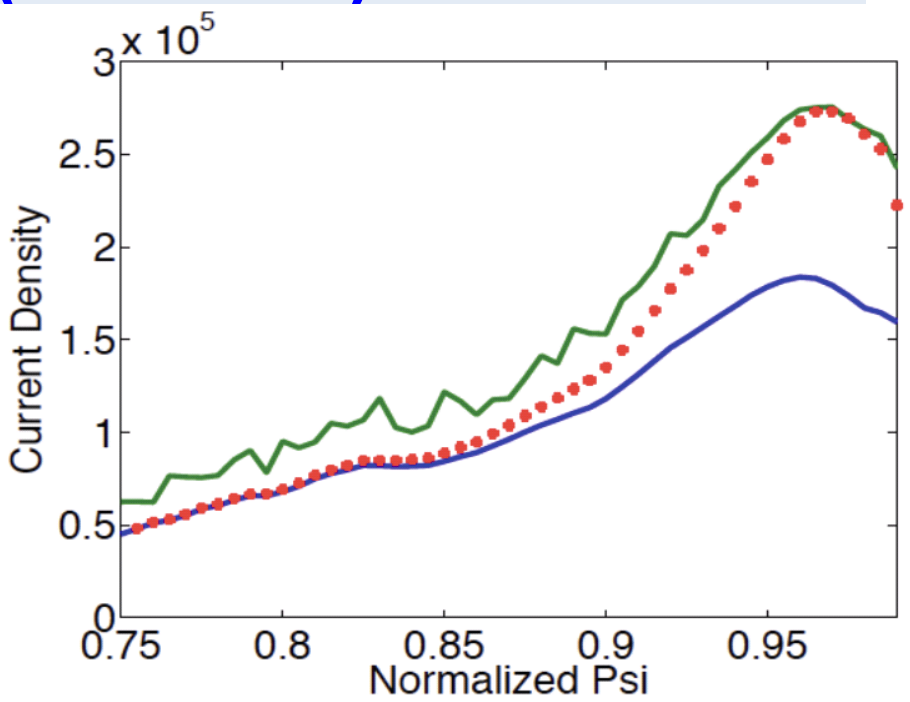




- Maximal gradient point is closer to separatrix in C-Mod
- This effect persists regardless of anomalous transport level or collisionality
- More pronounced outward shift at lower anomalous transport level
- It is found that the shift is originated from the competition between the ion orbit width ($\propto E_r$ width from X-transport, hence density pedestal width) and the neutral mean free path (radial smoothing)
- Higher B yields more outward shift (the T_i effect cancels out): higher neutral opacity
- Implication to ELM stability and particle fueling in ITER.

Bootstrap current is an output from XGC. A new formula has been established and implemented in kinetic EFIT (T. Osborne).





In the weakly collisional regime, Sauter formula is surprisingly good in steep edge pedestal all the way to the separatrix. DIII-D case is shown here. C-Mod shows similar agreement. NSTX shows somewhat worse agreement, but acceptable.

However, in the collisional regime, Sauter formula shows deviation from XGC0. In the NSTX case shown here, XGC0 bootstrap current is about 40% higher than Sauter.

[Sehoon Koh, part of PhD thesis].