XGC1 at NSTX T&T TSG Theory/Experiment Meeting

September 27, 2013

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and the EPSI Team

More contents related to edge/SOL phyiscs will be presented at the Edge/SOL TSG Theory/Experiment Meetings

XGC1 plan for NSTX: S. Ku, R. Hager, J. Lang, D. Stotler and C.S. Chang

(Suggested by S. Kaye, Y. Ren, W. Guttenfelder, A. Diallo, July 8, 2013 at B252)

Near term plan (FY2014): L-mode limiter plasma

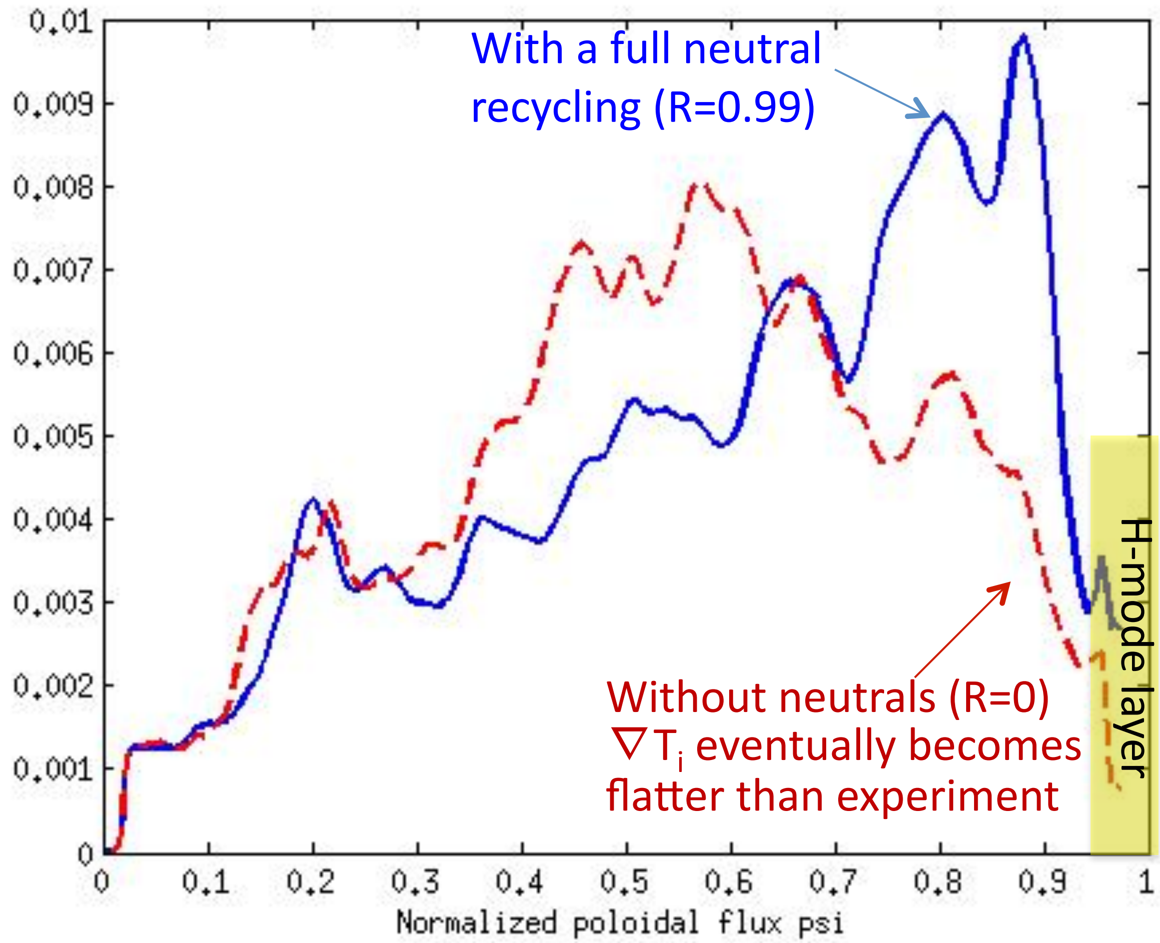
- Profile data to be provided by Y. Ren.
- Low β, no micro-tearing: easily utilizing the current production version of XGC1
- Limiter plasma: Set the outer boundary of simulation ψ=~0.95 to reduce the complications from divertor geometry. ψ=0.95 is close enough to edge to resolve interesting and useful L-mode physics, such as:
    - Quantitative impact of non-local effects/turbulence-spreading on thermal transport
    - Profile-shearing contributions to momentum transport
    - Possibly compare with BES measurements
    - Is there an L-mode shortfall in NSTX, if so where?
    - Code-code comparison with GTS and GYRO (both can't do magnetic axis)

A more comprehensive plan items for NSTX-U, including the above near-term plan

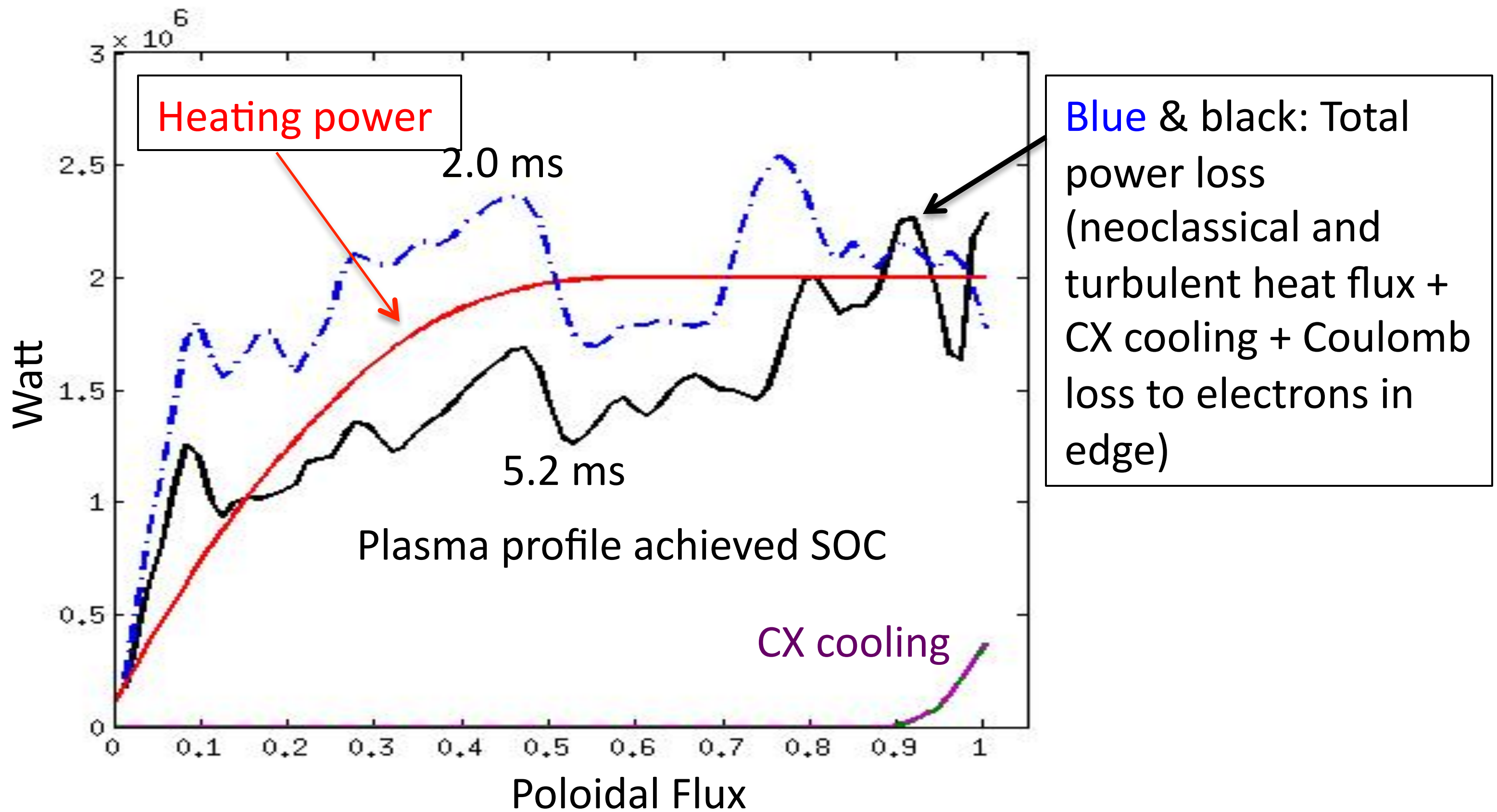
- L-mode (Low β, no micro-tearing): as described above
- Divertor heat load, including snow flake
- Understand H-mode (E&M) pedestal and core-edge interaction: turbulence and transport, including neutral particles, Lithium and atomic physics
- Tearing modes, KBMs, ITG, trapped electron modes, KAMs, resistive wall modes
- Scrape-off layer physics and impurity transport
- Effect of Lithium wall on plasma confinement

XGC1 shows that Nonlinear ITG is sensitive to edge neutrals

(Natural BD condition at wall, full-f, driven by heat-flux)

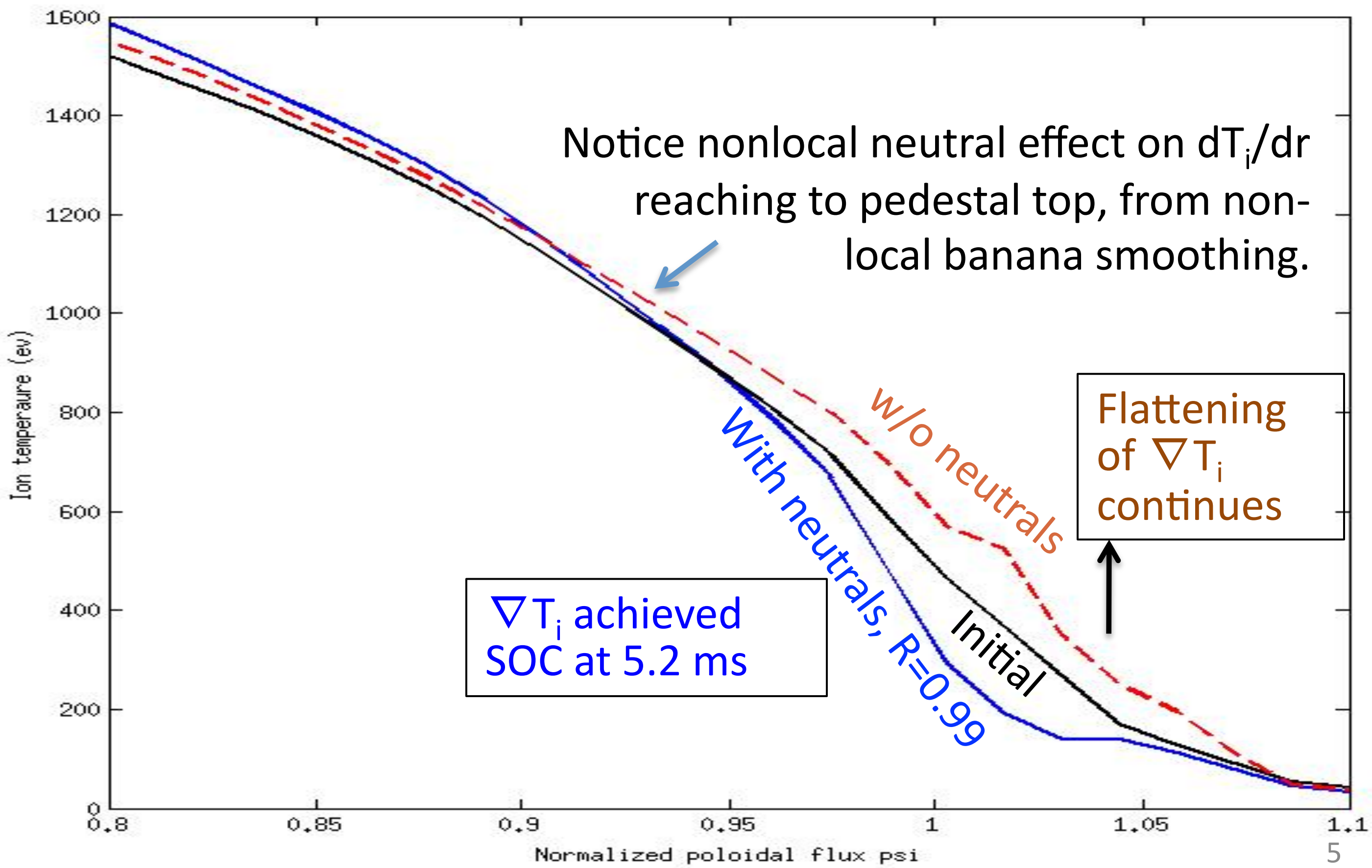


SOC ITG turbulence satisfies radial power balance (it is a ms-type dynamic balance!)



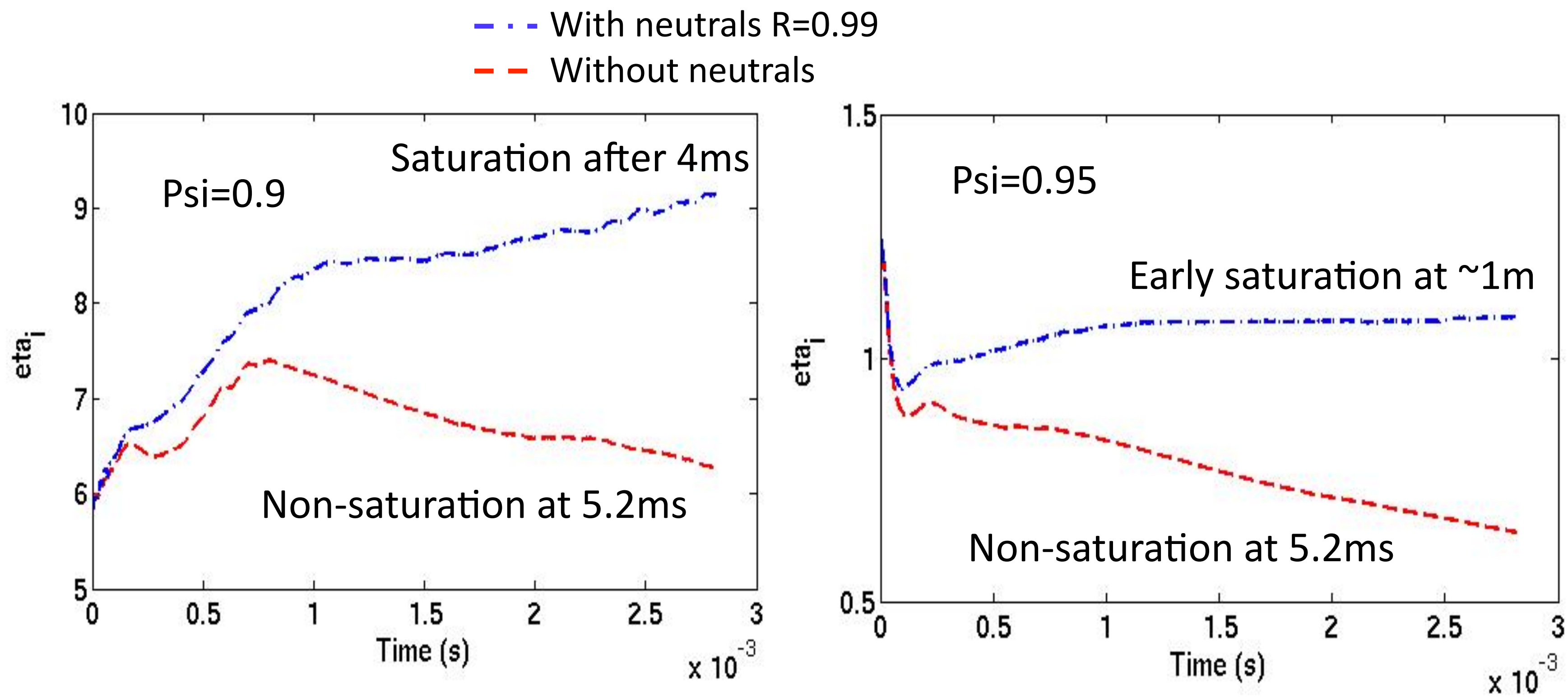
Red: Total heating power
Black: Total power loss at 5.2 ms (heat flux + CX cooling + loss to electrons)
Blue dashed: Total power loss at 2.0 ms, showing large bursty time variation
Purple: CX cooling at 2.0 ms
Green: CX cooling at 5.2 ms: shows a quick saturation of CX loss

Saturated T_i profile is different without neutrals in XGC1



Neutrals increase η_i at density pedestal top

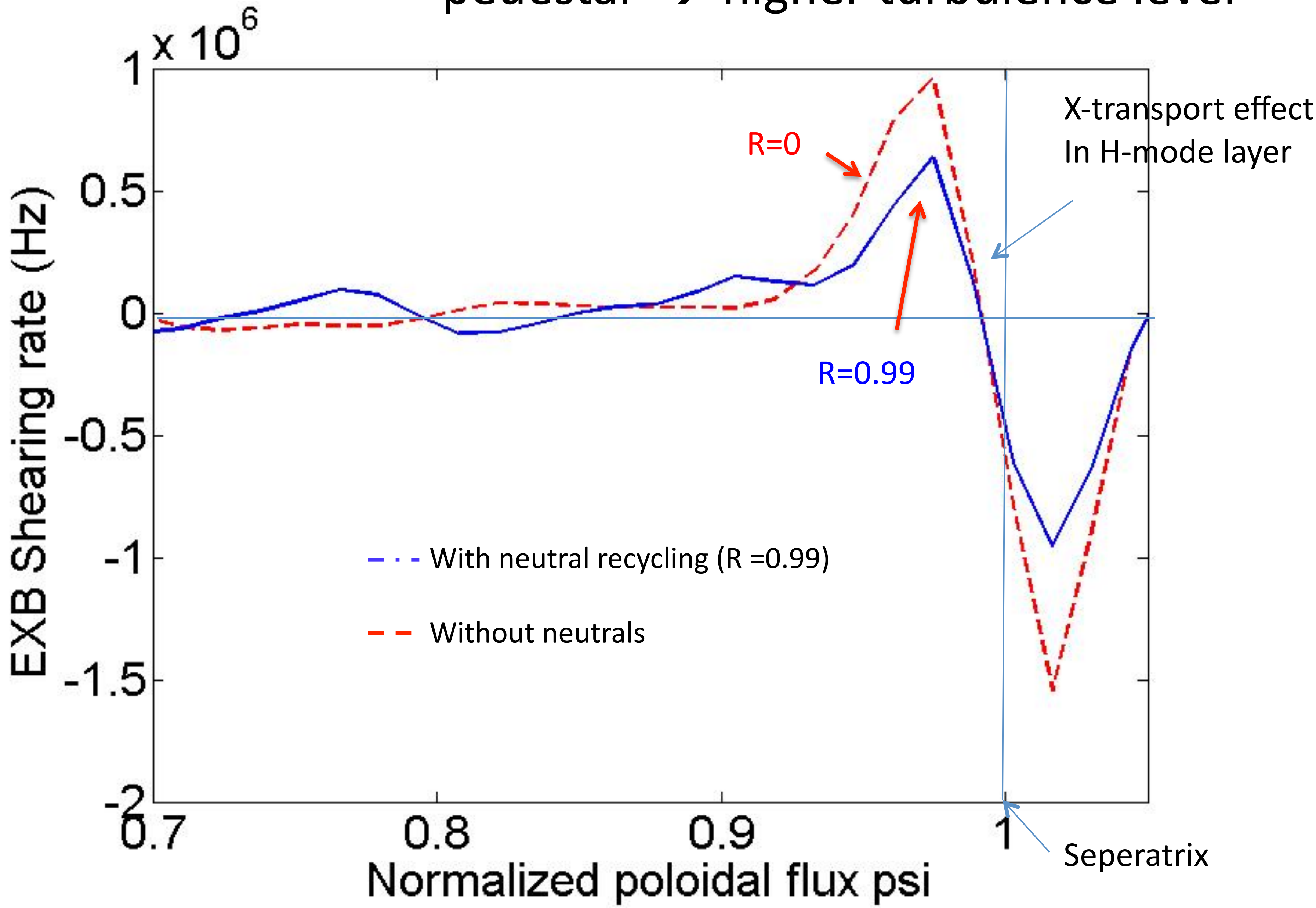
In steep H-mode gradient region, η_i stays low ~1



→ Neutrals produce stronger T_i pedestal

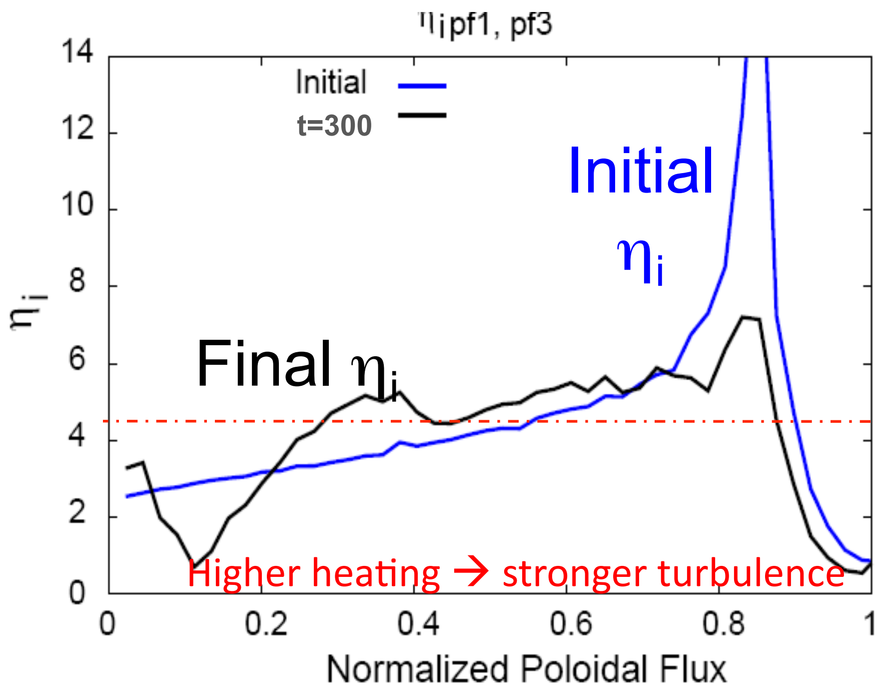
→ Stronger turbulence source at density pedestal top Psi~0.9

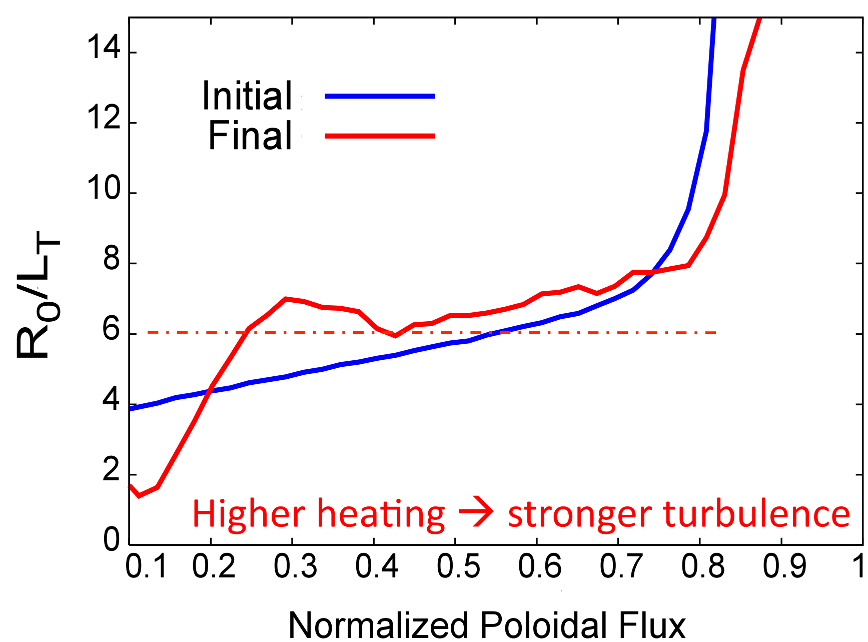
EXB shearing rate is weaker with neutrals in the edge pedestal → higher turbulence level

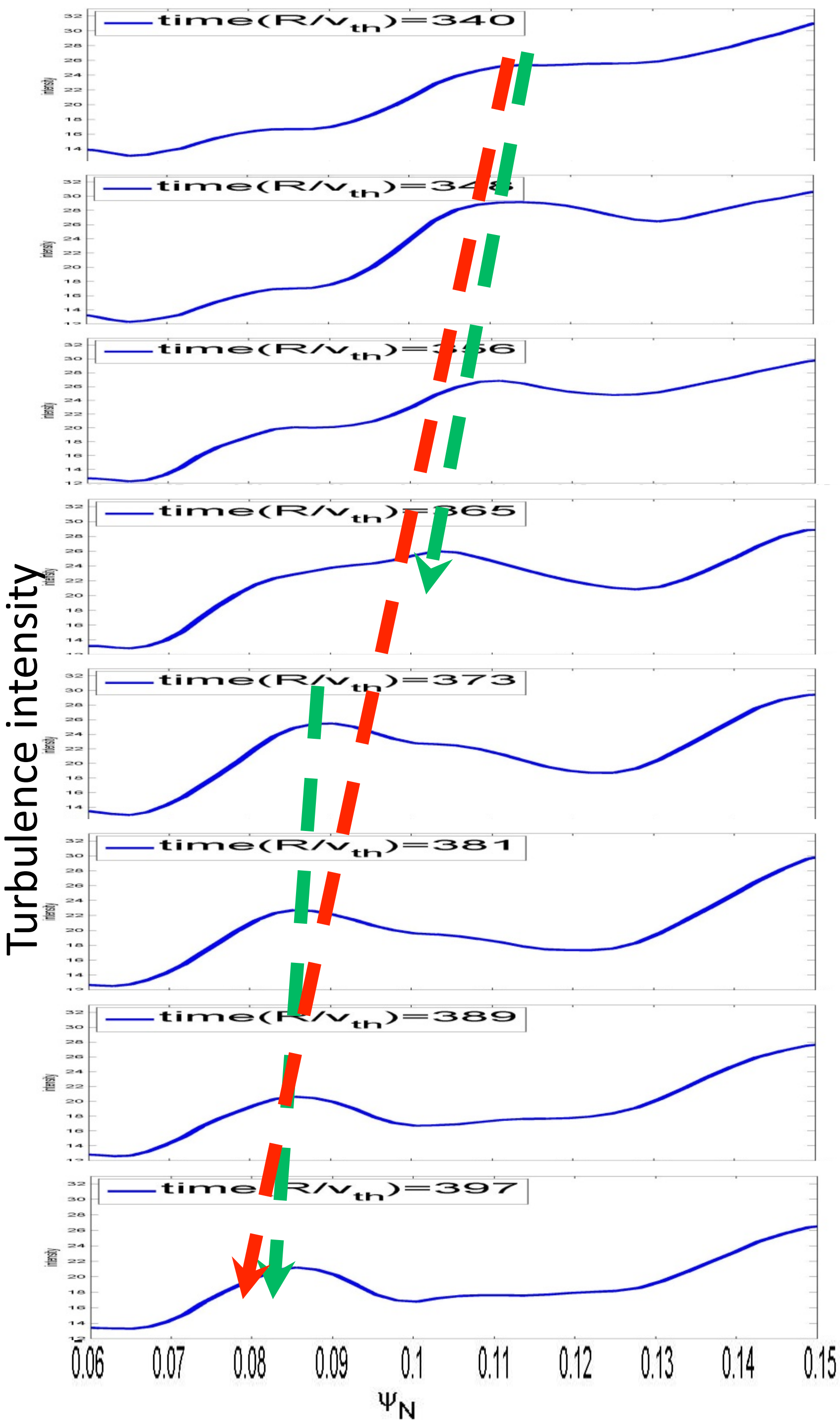


T_i advances to stiff self-organized criticality

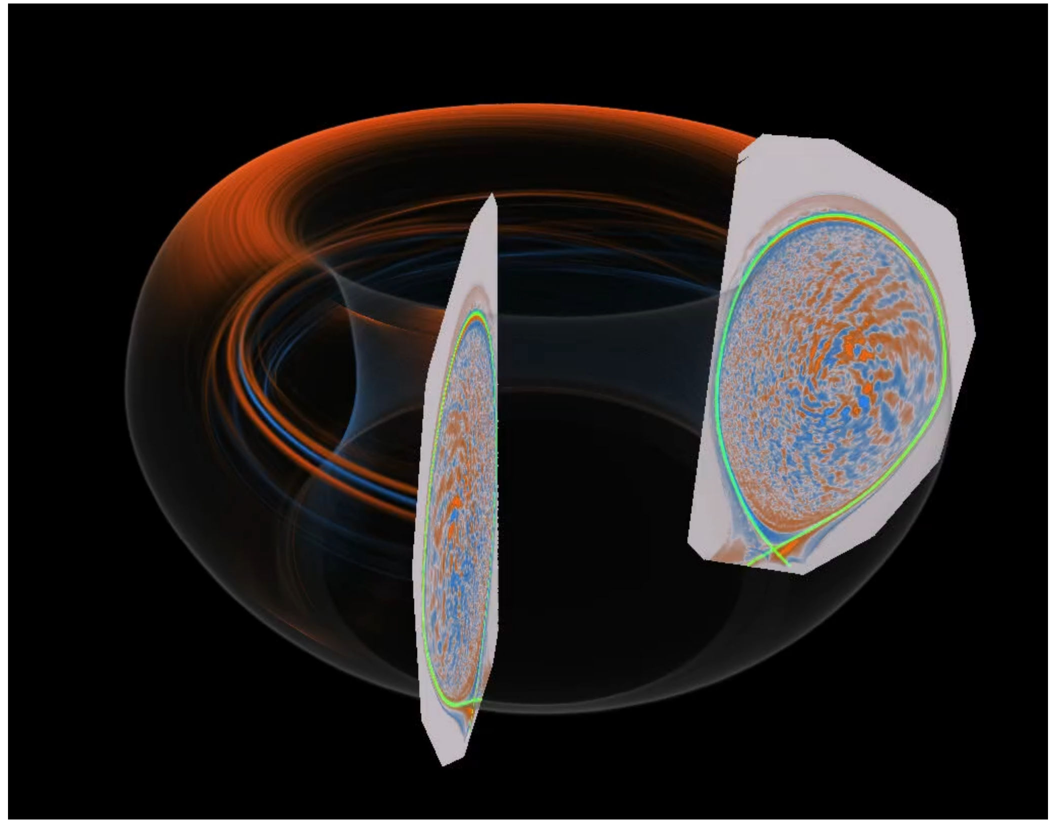
- TRIGINITY, TGYRO, etc: "Scale separation assumption. Turbulence simulation in small regions of the space-time grid, embedded in a coarse grid on which fluid transport equations are evolved" [M. Barns et al, PoP2010]
- XGC1: f contains all scale turbulence and transport physics without scale separation, together with heat/torque source and neutral particles
- Plasma profile in XGC1 evolves while maintaining "stiff" self-organized criticality: **Edge T_i determines core T_i.**







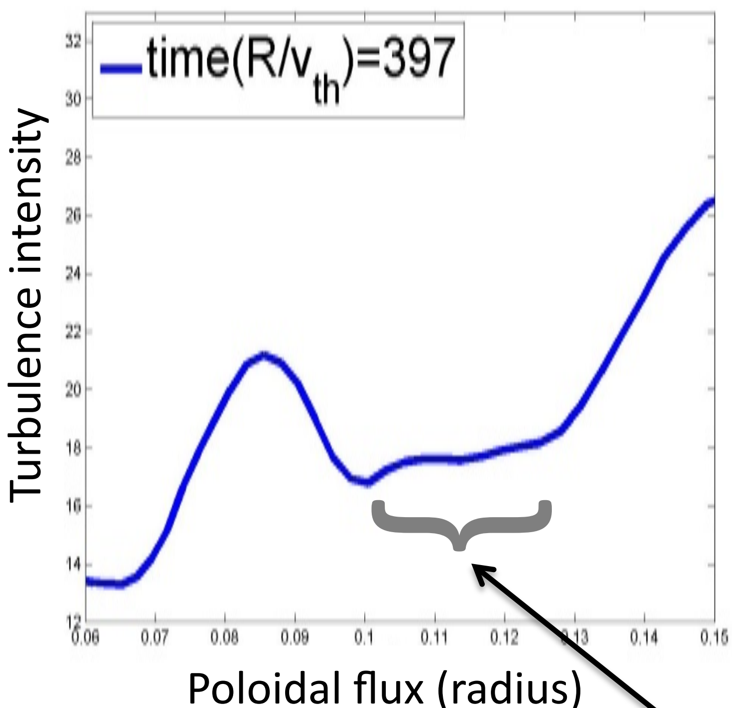
Turbulence exists in central core where the turbulence drive is subcritical.



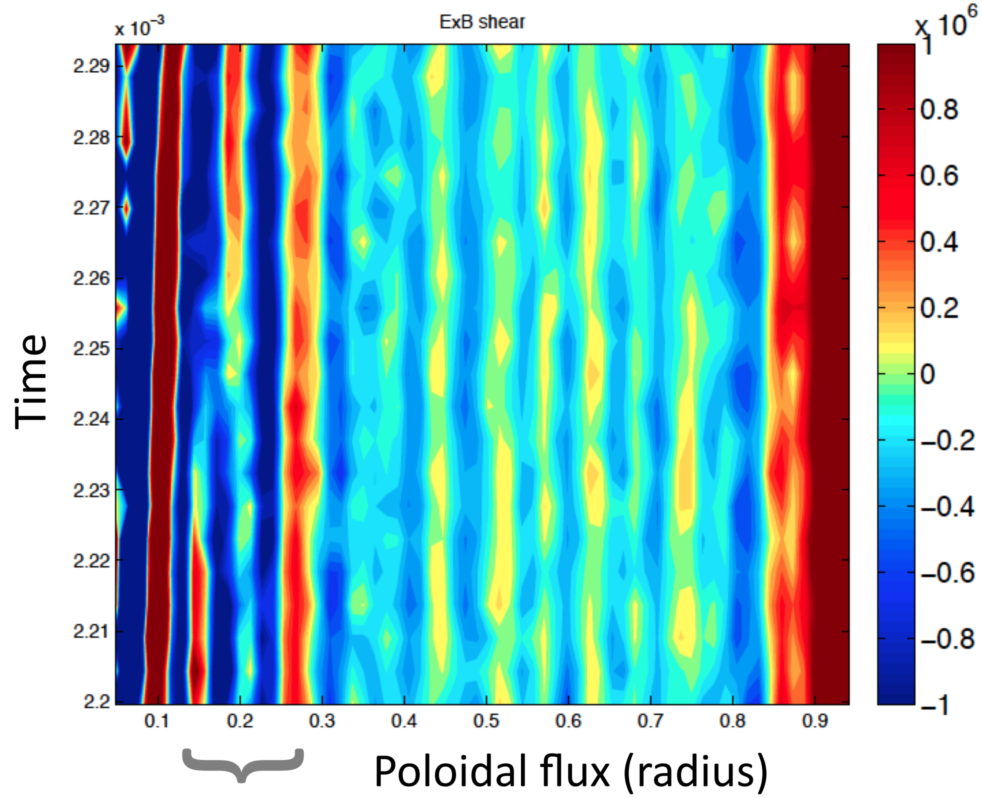
Inward spreading from turbulent region.

Many interesting physics to be studied, including internal transport barrier.

A sign of internal transport barrier formation at the boundary between the subcritical and SOC regions!



ExB shearing rate the final time window

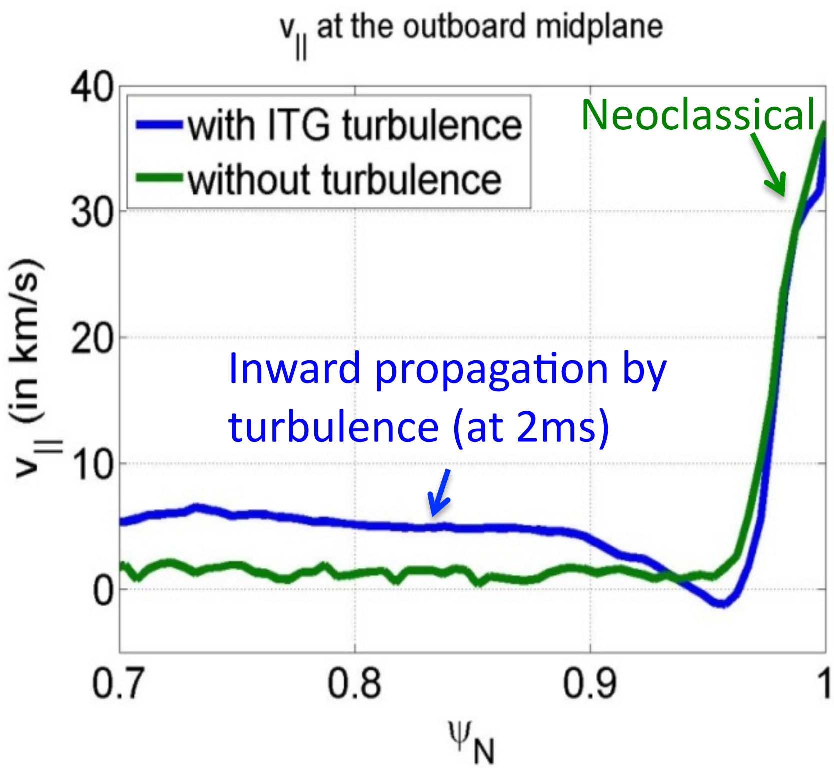


Drop in turbulence intensity

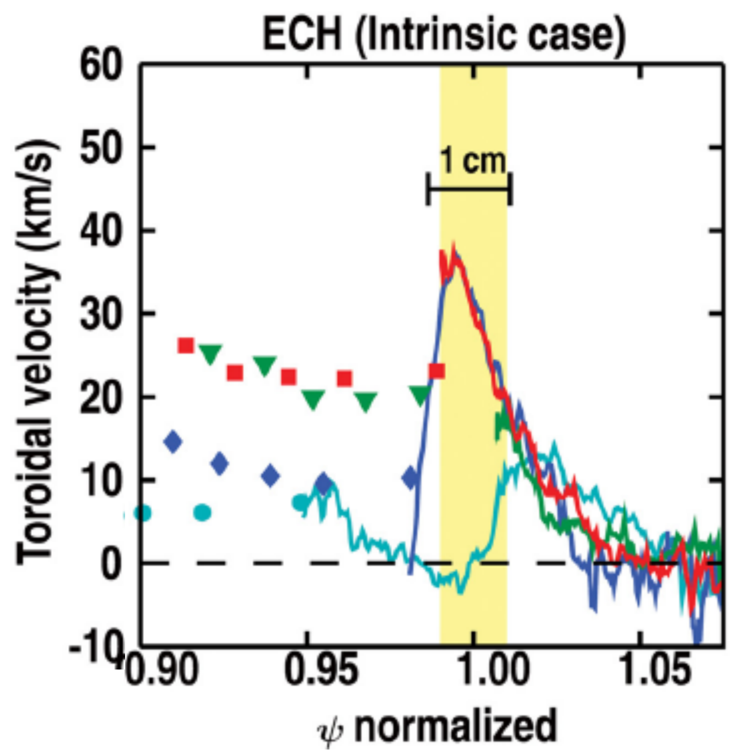
Strongly sheared ExB layer

Rotation is generated at edge and pinched inward in XGC1 (& in experiments: Rice et al)

- **Strong neoclassical co-rotation at edge: Pfirsch-Schulter and orbit loss**
- **Turbulent residual-stress driven inward pinch of edge rotation (by holes)**



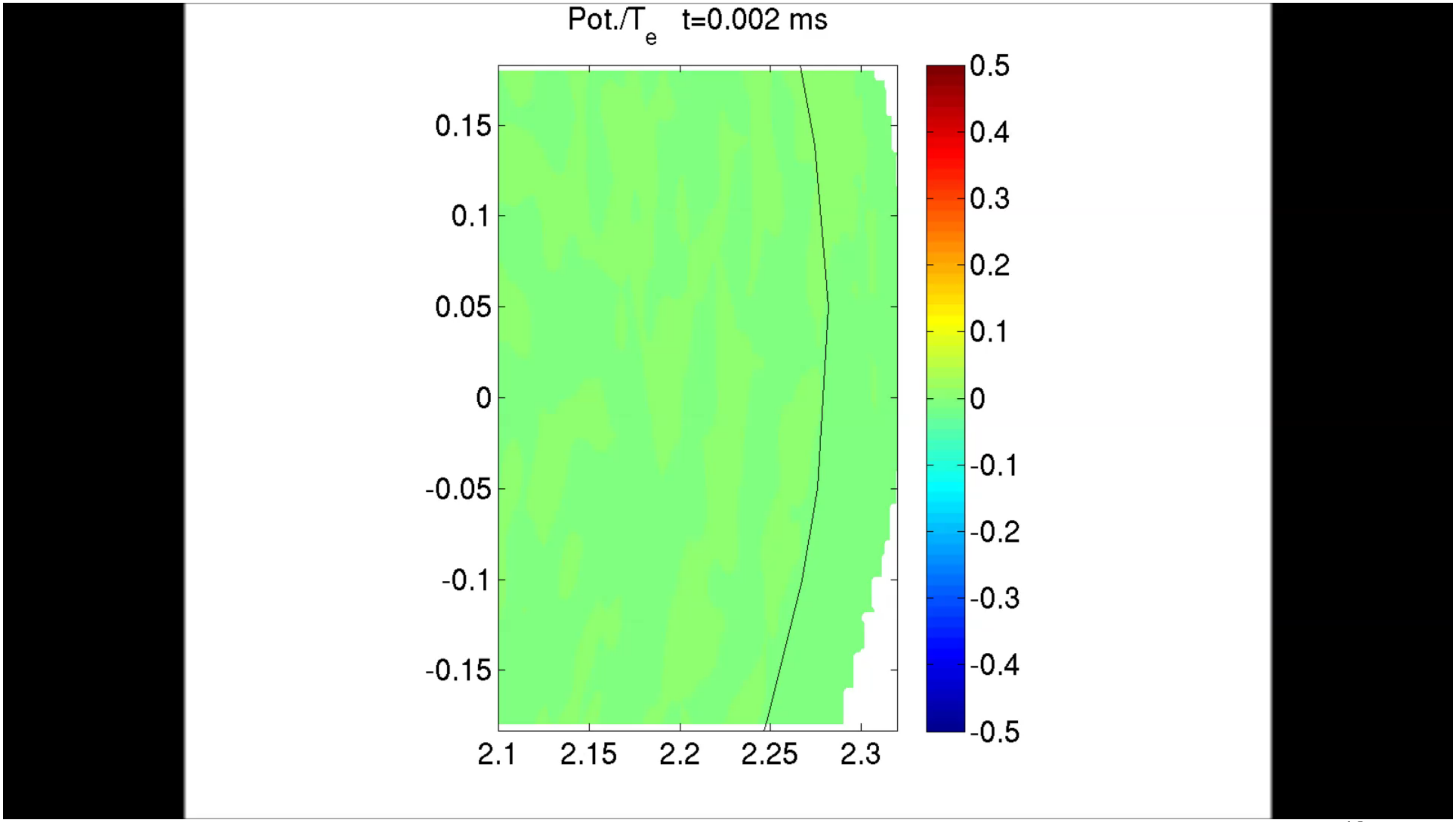
S. Muler et al, PoP 2011, L-H transition



Holes carry the co-rotation inward

Gyrokinetic dynamics of nonlinear coherent potential structures ("blobs") across separatrix at outside midplane.

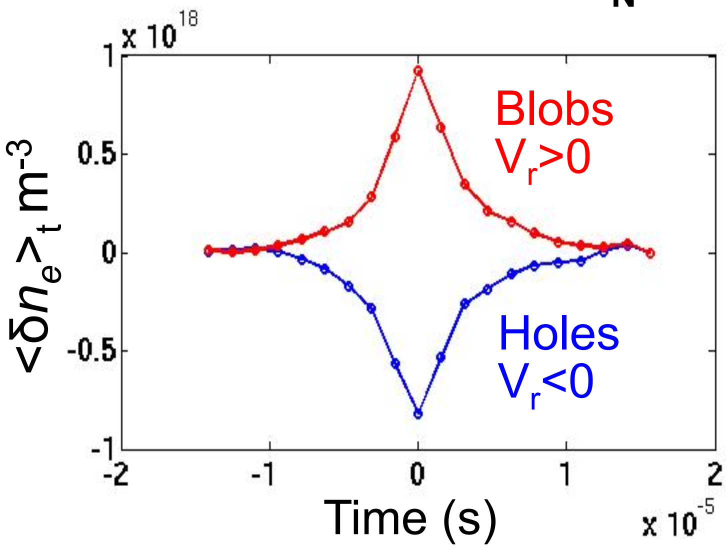
Notice that the blob amplitude is ~50%

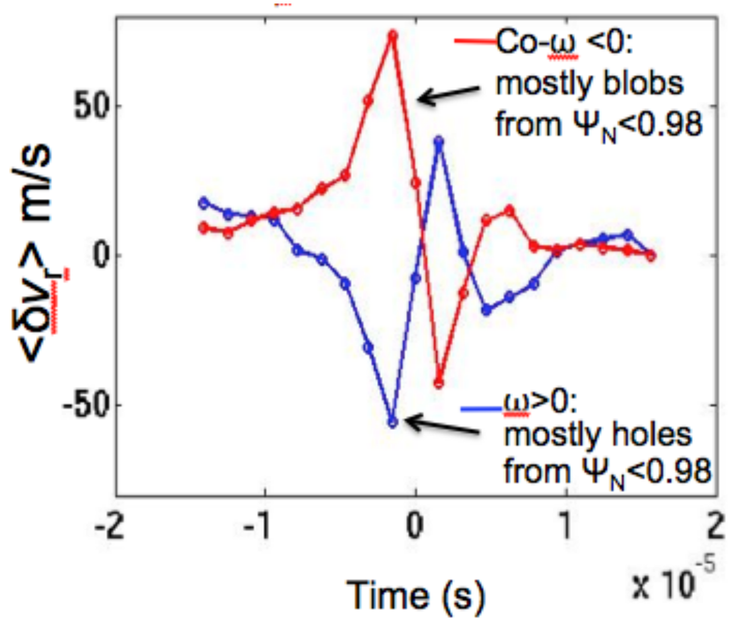


The nonlinear coherent structures are composed of blobs and holes

- **Blobs** move radially **outward** and **holes** move **inward**
- Similar to observations from HL-2A experiment
  - M. Xu et. al., IAEA 2012
- Blobs and holes **carry physics information** with them
  - **mass, heat, and momentum**

Measured at 0.96<Ψ_N<1





Inward cold-particle pinch at Ψ>0.8: It increases with neutral particles: Holes are colder. (Figures are from ITG turbulence)