Role of ExB Shear/Zonal Flow and Rational *q* in ITB Formation

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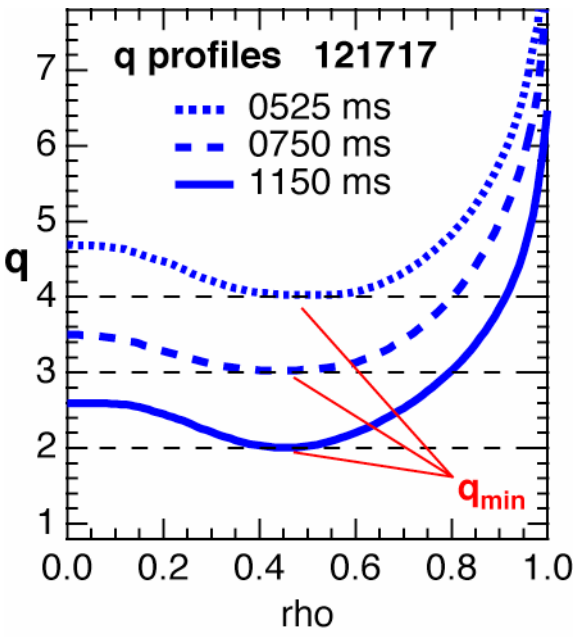
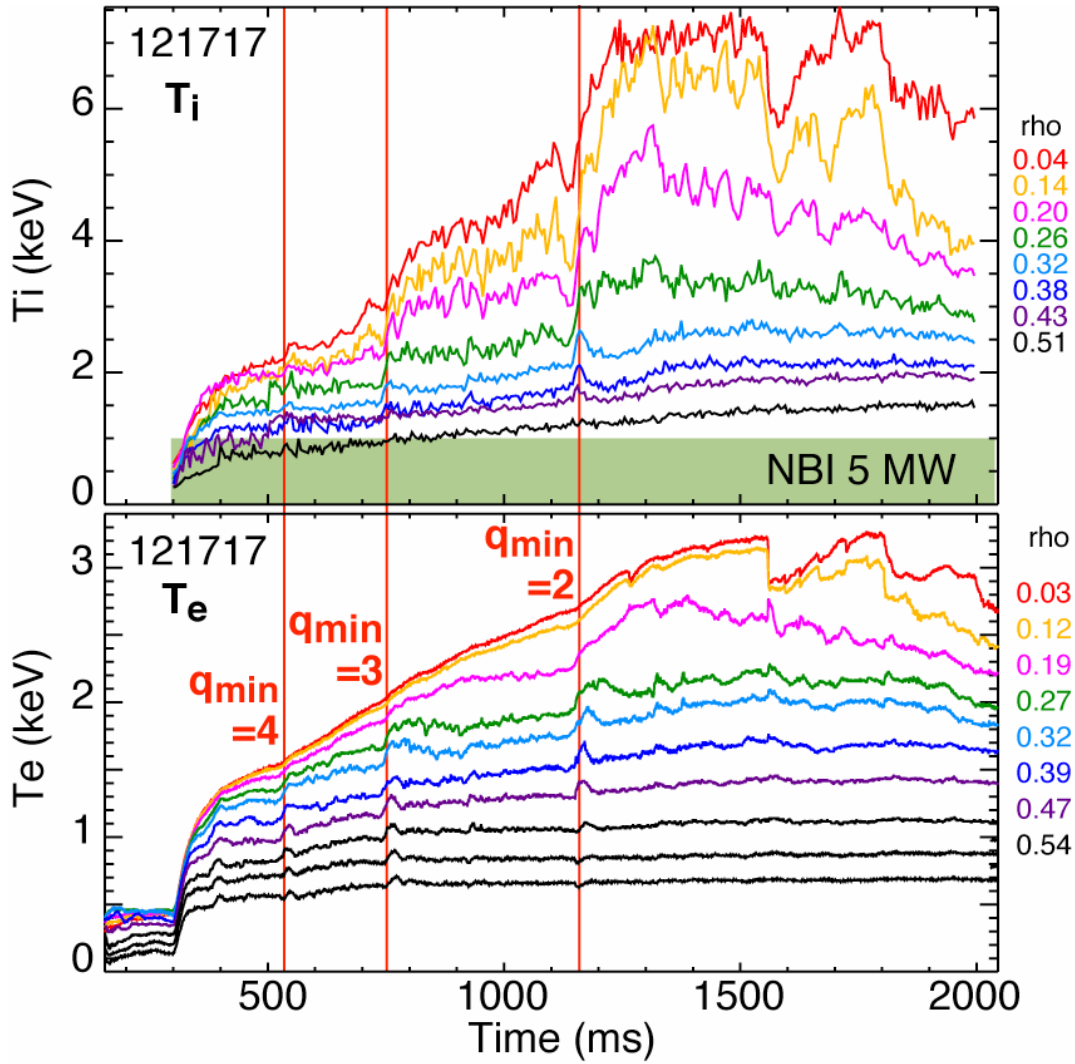
Changes in transport seen in DIII-D as q_{min} traverses integer values in low-n_e L-mode NCS discharges

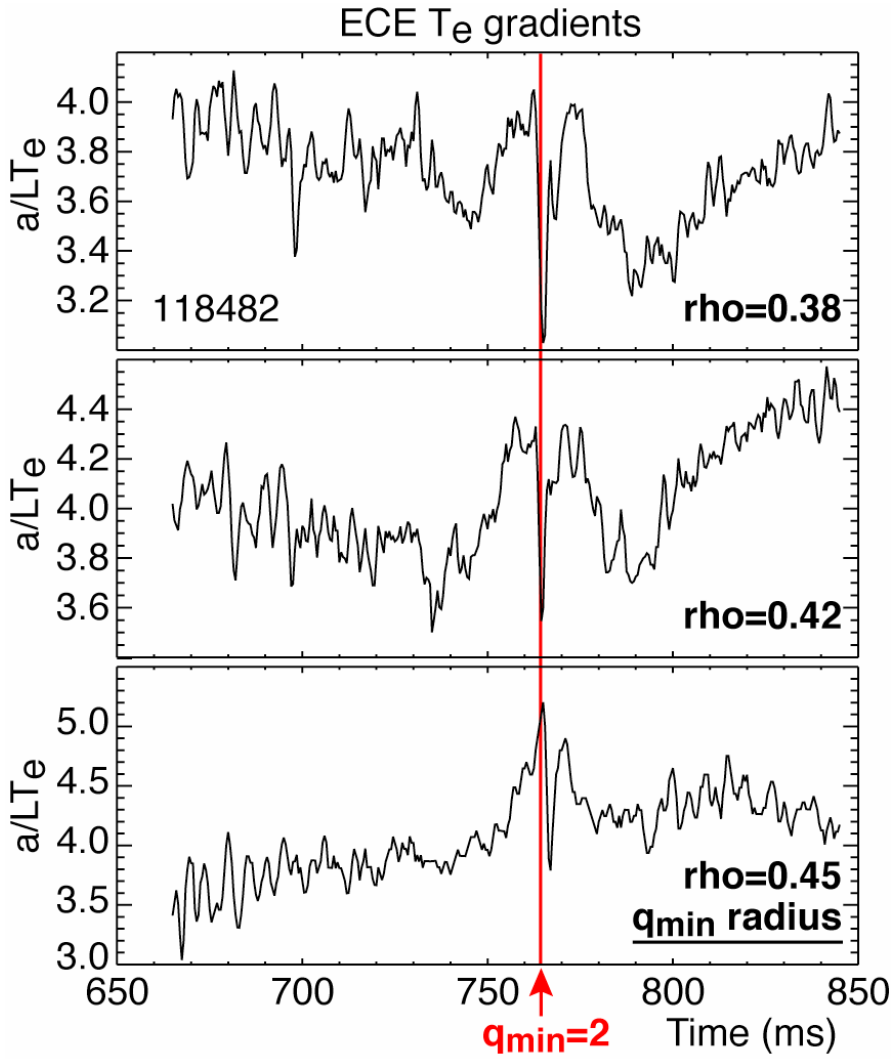
- Persistent core barrier forms in T_i after 1200 ms, triggered at q_{min}=2 crossing





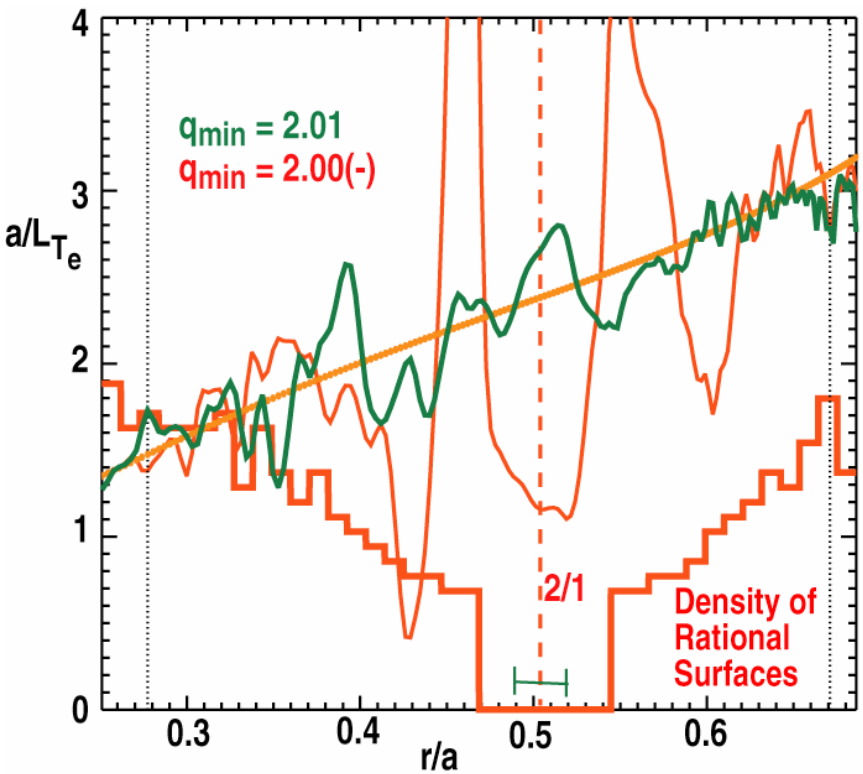
A key signature of the transport changes is seen in the T_e gradient data

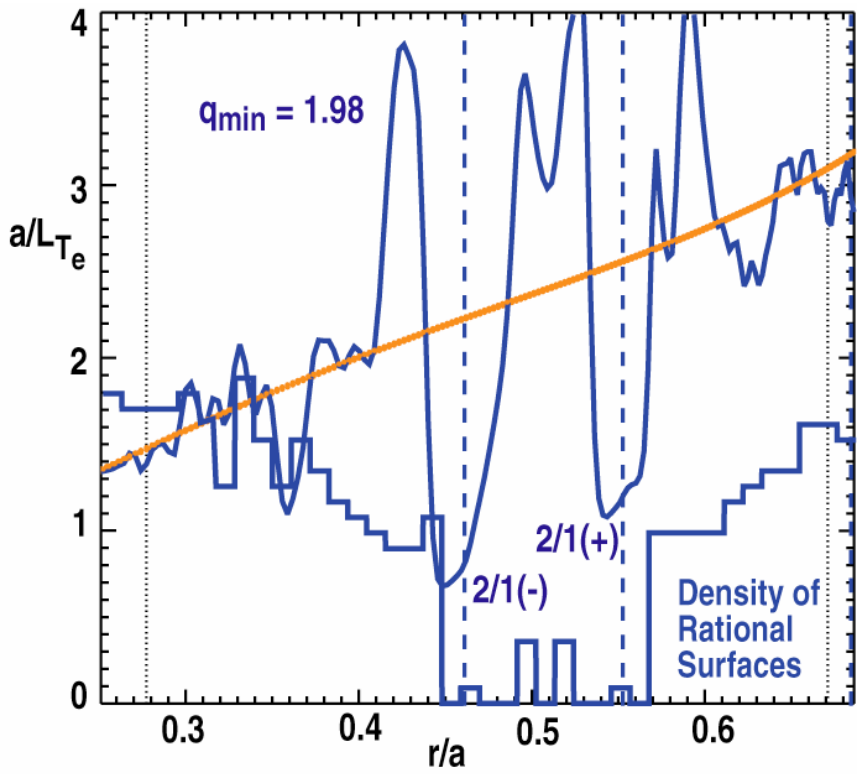
- T_e gradient steepens before and after q_{min}=2, dips at q_{min}=2
- Alfvén cascades are used to pinpoint the integer q_{min} times



GYRO results show profile corrugations that are locked to integer *q* surface

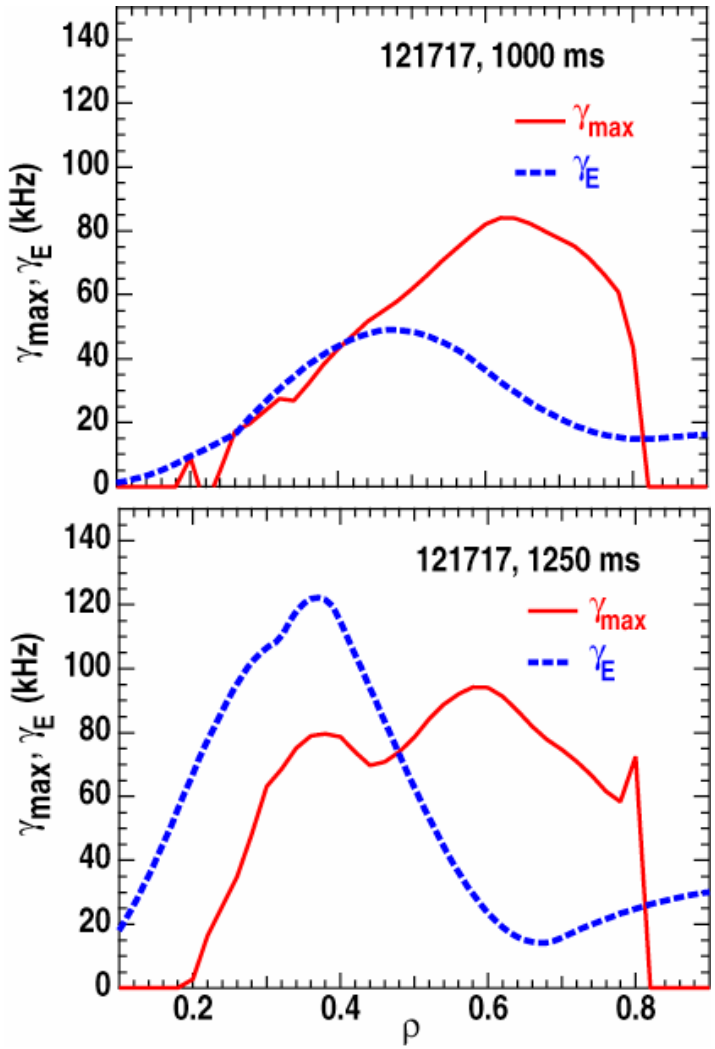
- Match $|\nabla T_e|$ measurements observed in exp. => temperature component of the zonal flow
- $|\nabla T_e|$ highest where dens. of rational magnetic surfaces changes most rapidly
- Increased $|\nabla T_e|$ starts when q_{min} is slightly above 2





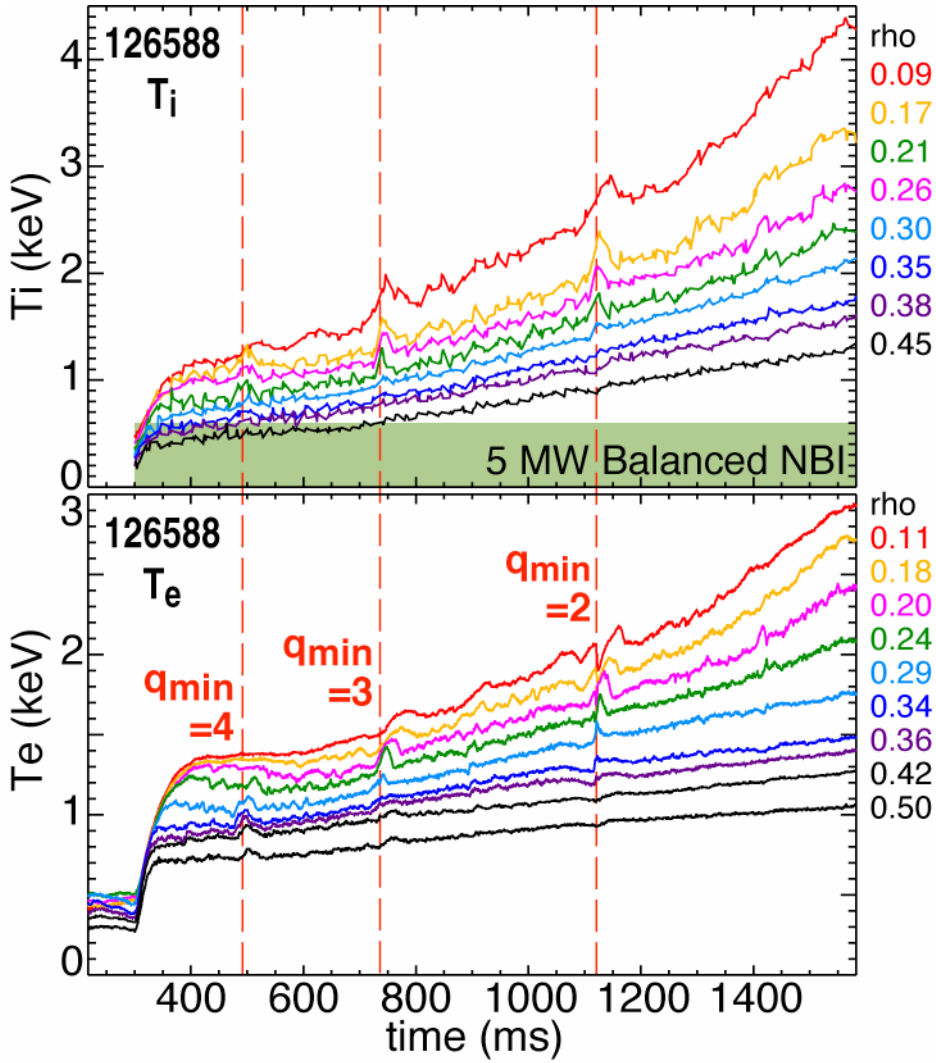
A model for core transport barrier formation near integer values of q_{min}

- Early in the discharge the plasma is marginal for barrier formation
- Before transition, shearing rate is insufficient for ITG suppression
- Near q_{min}=integer the addition of zonal-flow-induced ExB shear to the equilibrium ExB shear pushes the plasma into an improved confinement state



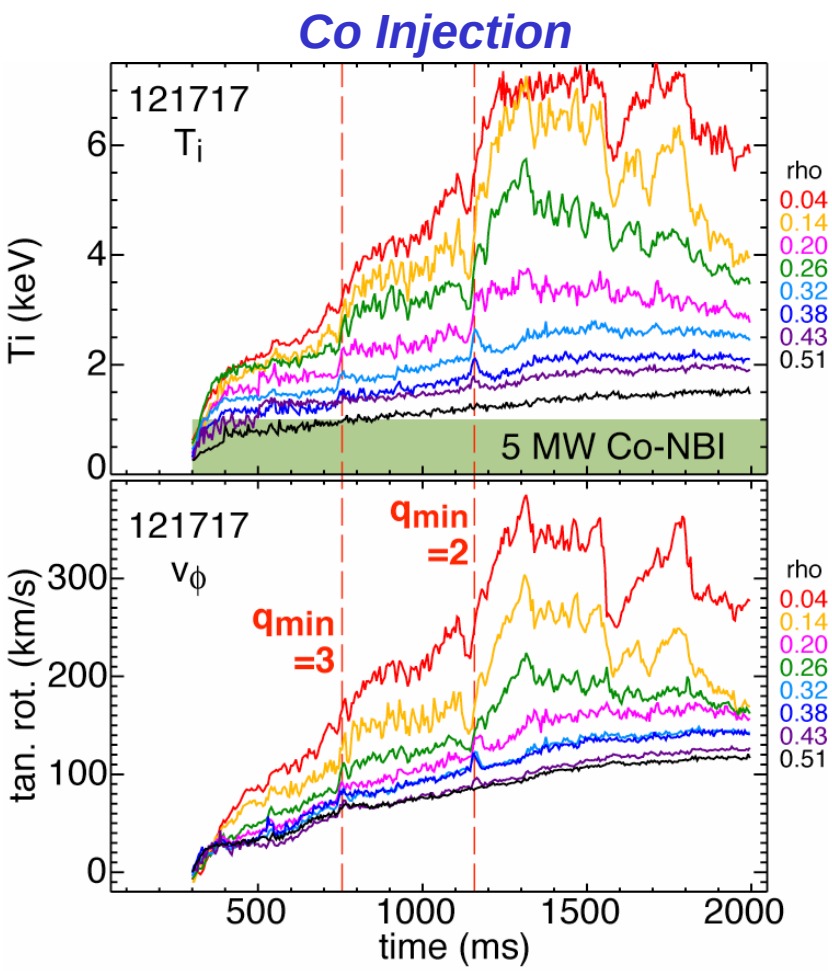
New capability for balanced NBI in DIII-D allows a test of the model

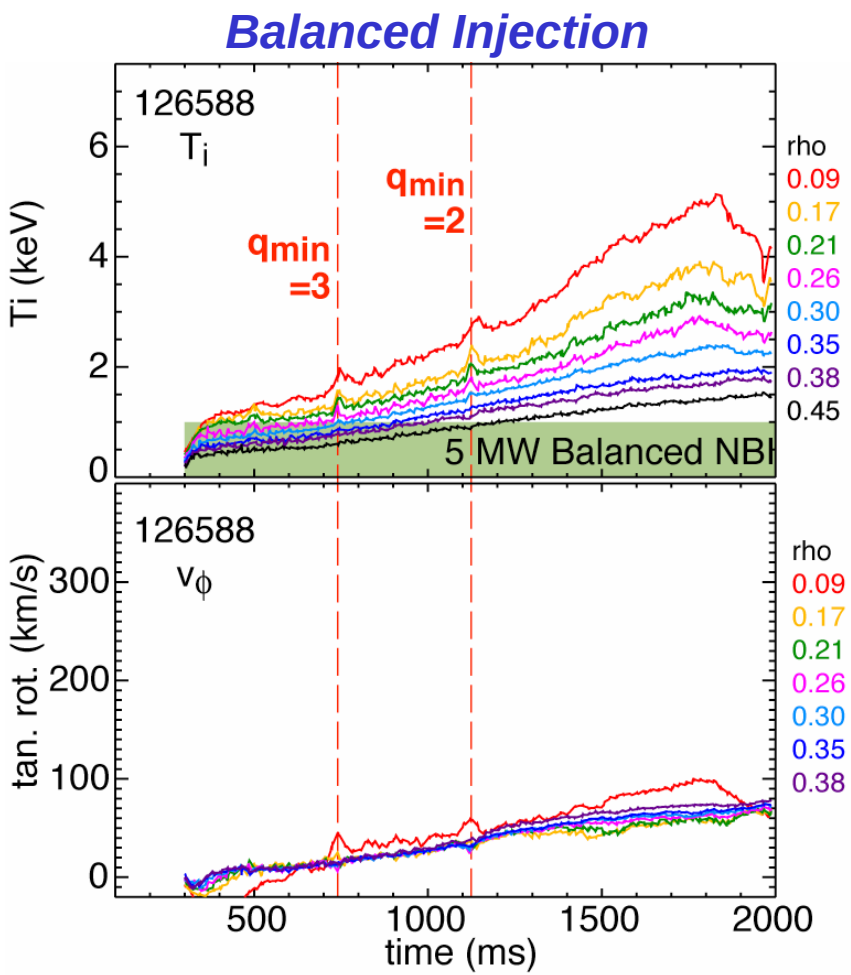
- Results from recent experiment using new counter injection beamline
- Balanced NBI case shows only transient confinement improvement near integer q_{min}, no core barrier formation



Reduced tor. rotation and lack of barrier formation in accordance with model

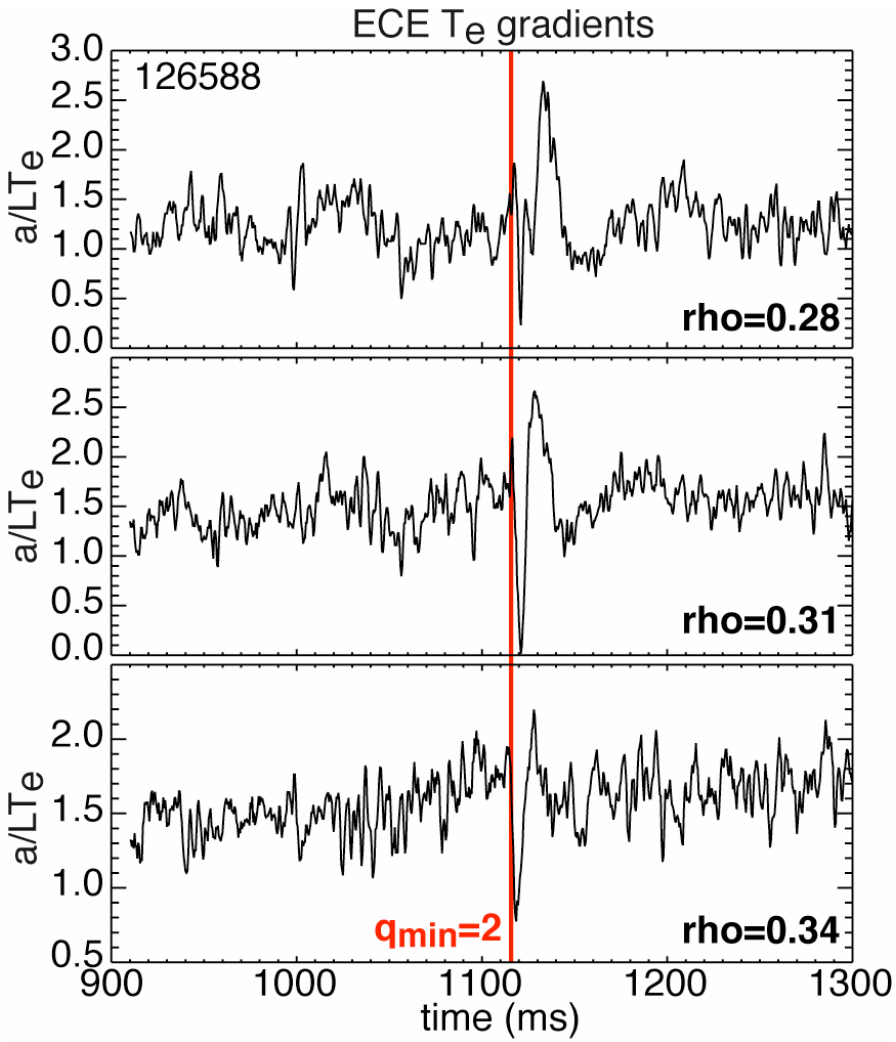
- Balanced injection case confirms that sufficient background ExB shear is required for barrier formation





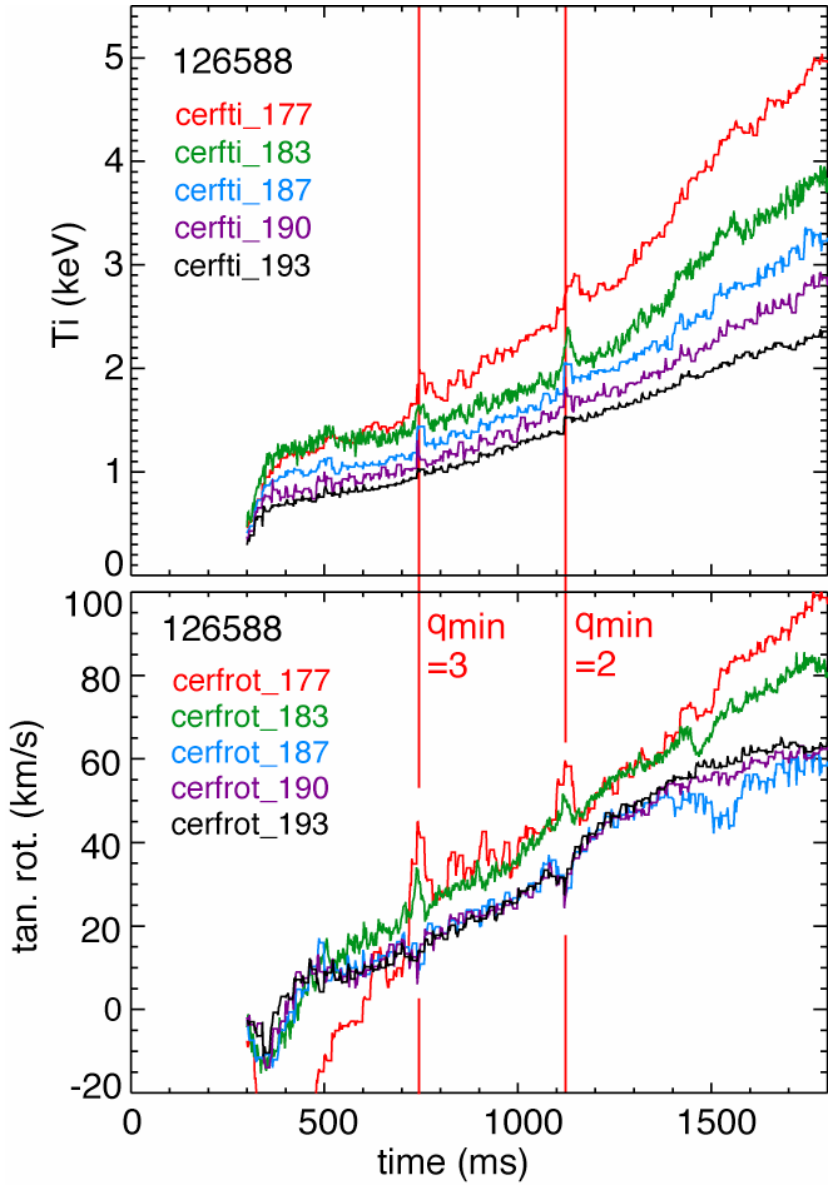
T_e exhibits similar zonal flow signature in balanced injection discharges as in co

- Radius of q_{min} is smaller for balanced NBI discharges



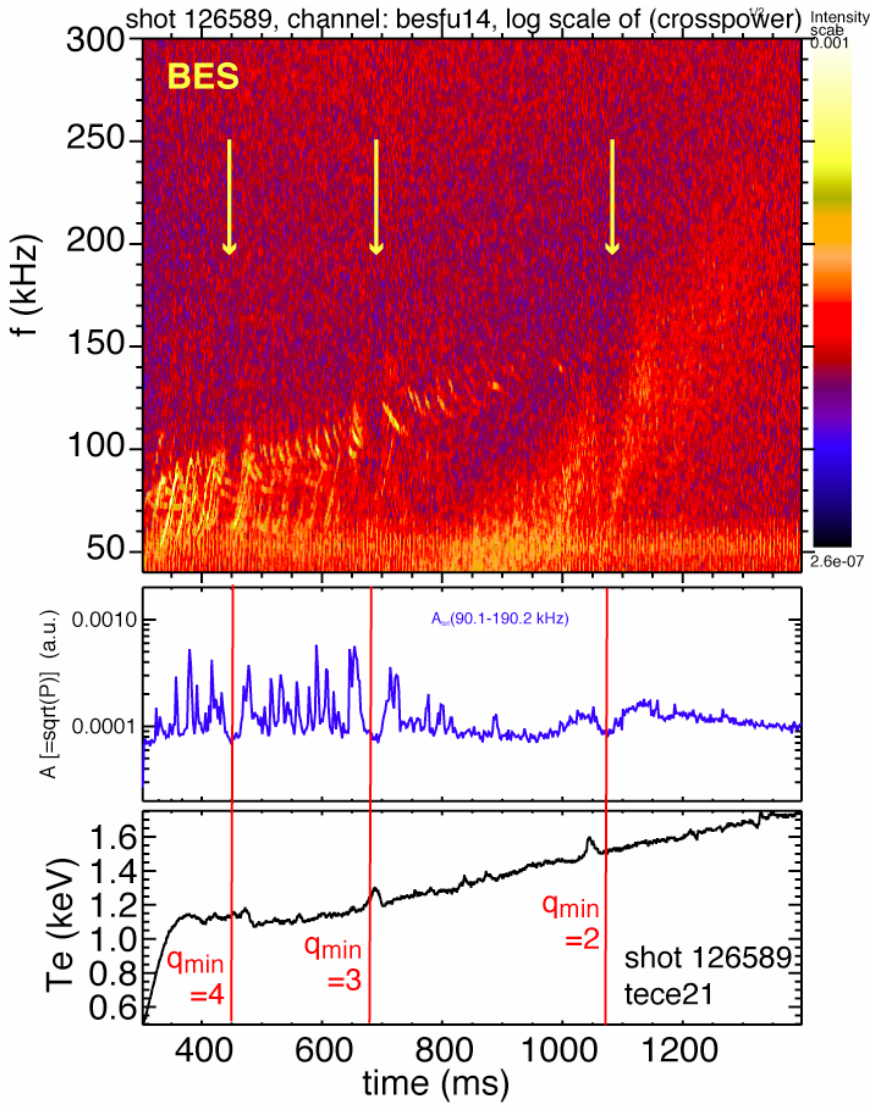
Toroidal rotation in balanced NBI exhibits zonal flow characteristics

- Large increase in tor velocity shear between R=187-190 cm near integer q_{min} times
- From ECE, the radius of q_{min} is between 192-194 cm



Fluctuation reductions seen near integer q_{min} in balanced NBI case

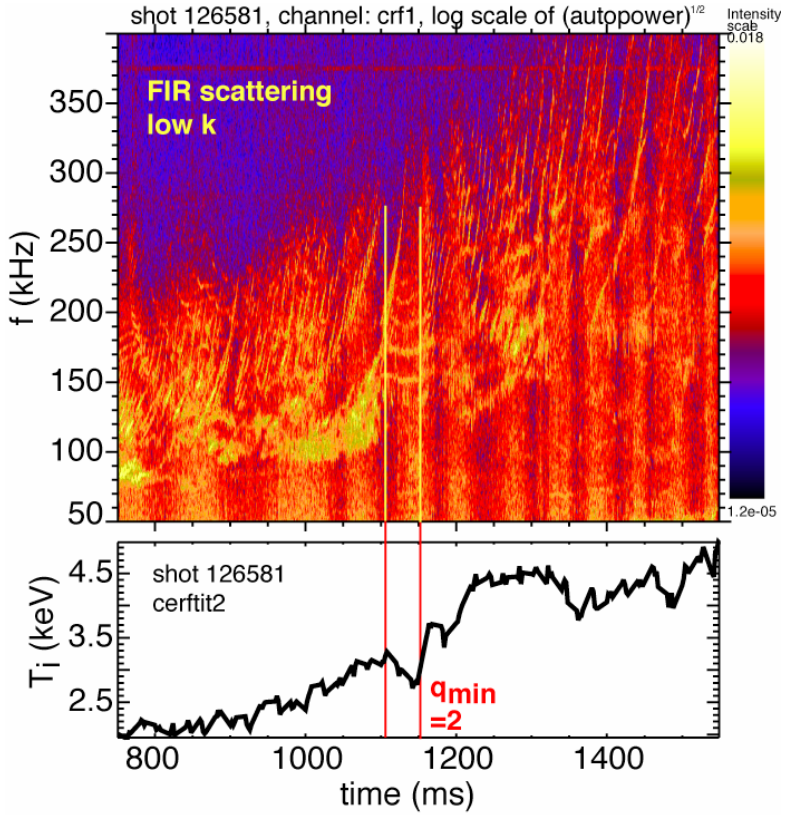
- BES location is near/outside of q_{min} radius



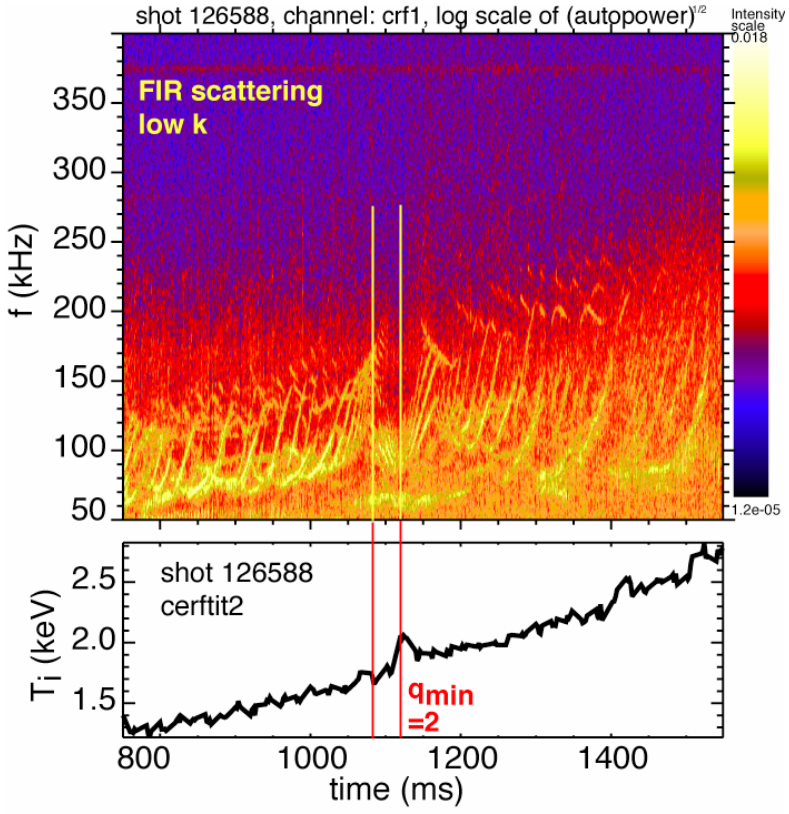
Strong TAE modes and drop in core ion temperature are absent in balanced NBI case

- Implies TAE are responsible for drop in core T_i, v_ϕ, but not linked to transient confinement improvement

5 MW Co Injection



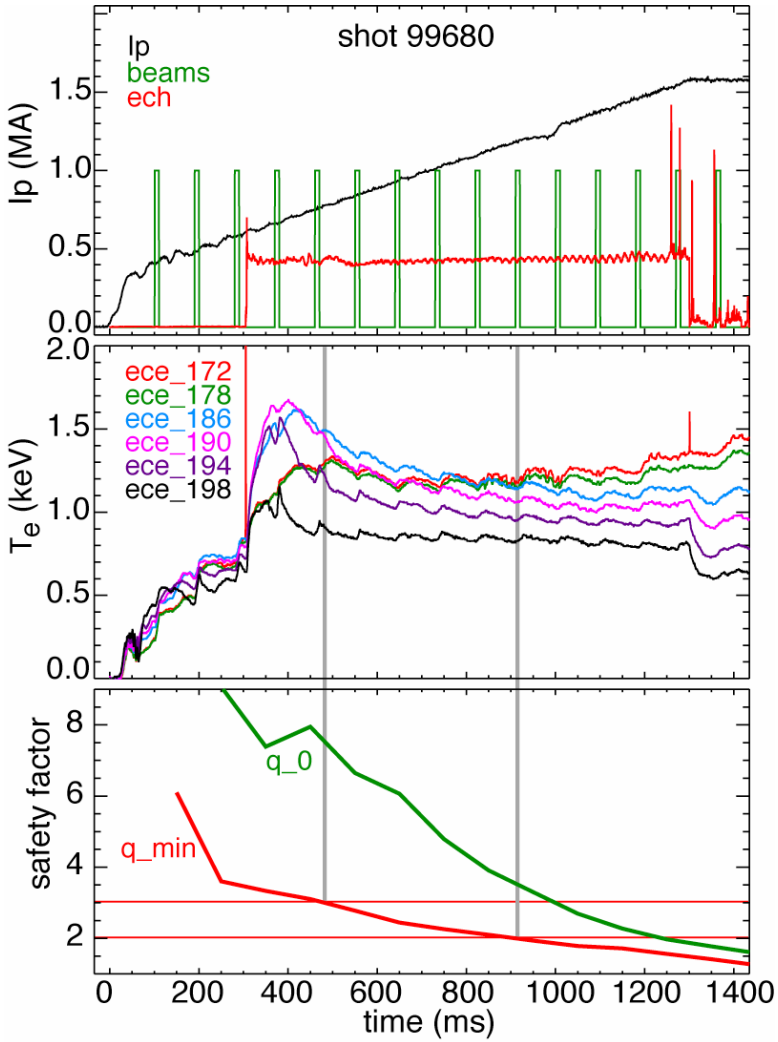
5 MW Balanced Injection



Key question: Why are zonal flow signatures only seen in low-n_e, L-mode NCS discharges?

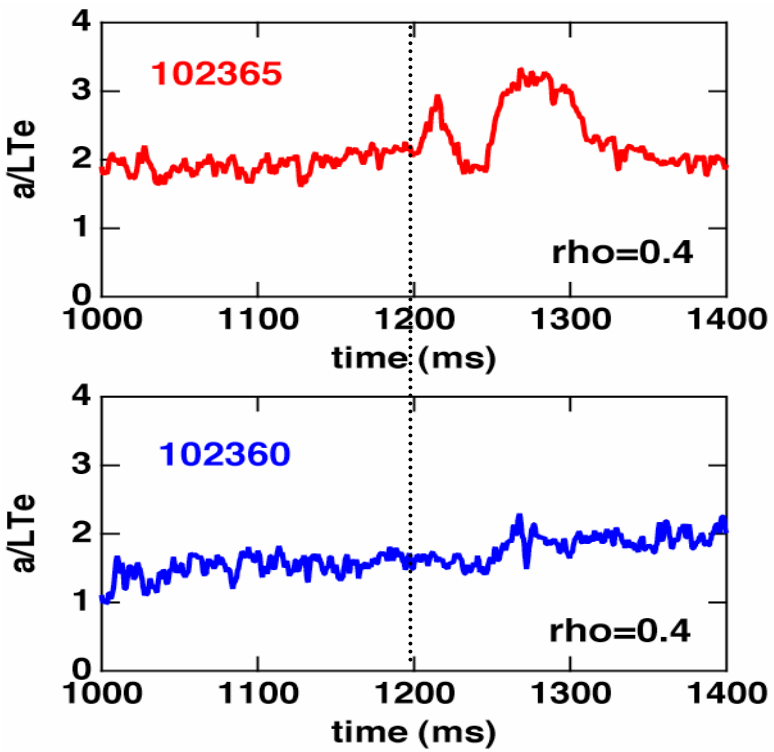
- Neg. central shear occurs in a variety of DIII-D discharge types
  - Temperature jumps diminish as n_e is increased in L-mode NCS –collisionality?
  - Not visible in H-mode NCS –low turbulence levels?
  - Not apparent in ECH-generated NCS discharges –$T_e \geq T_i$?

Example of NCS created with early ECH

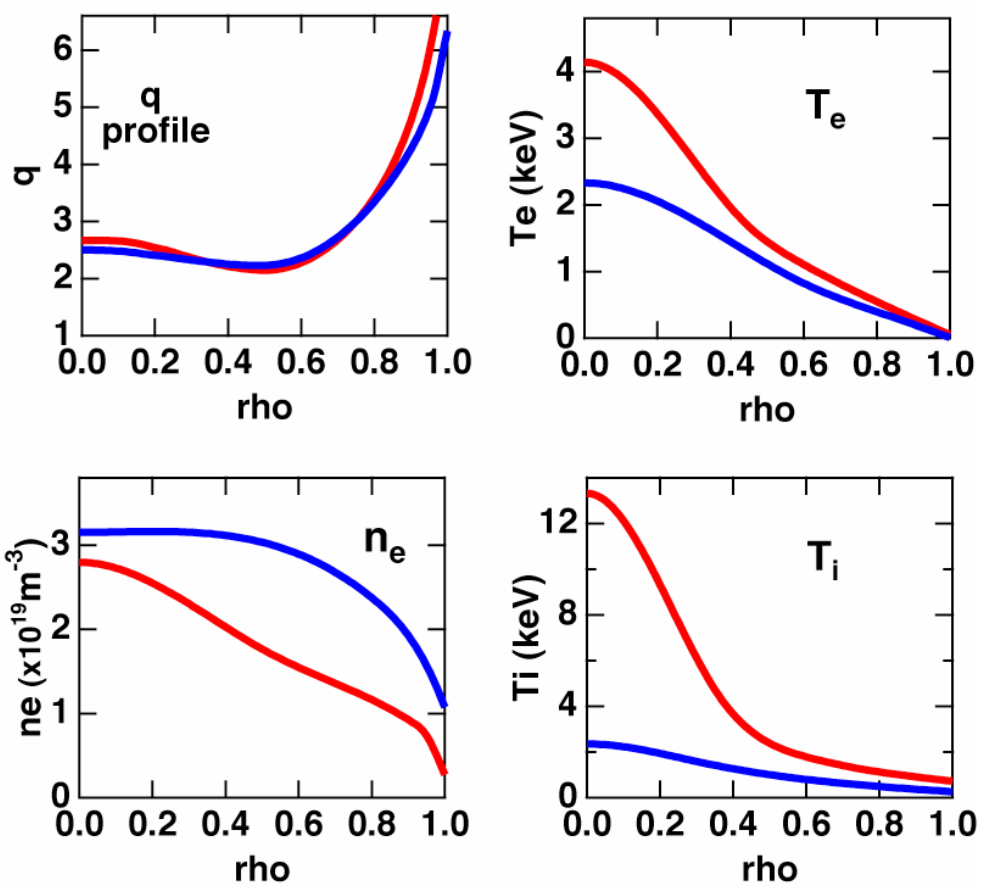


Gradients, collisionality vary as density changes in core barrier discharges

- Two shots from an experiment with a density scan, one with large ΔT, one with small

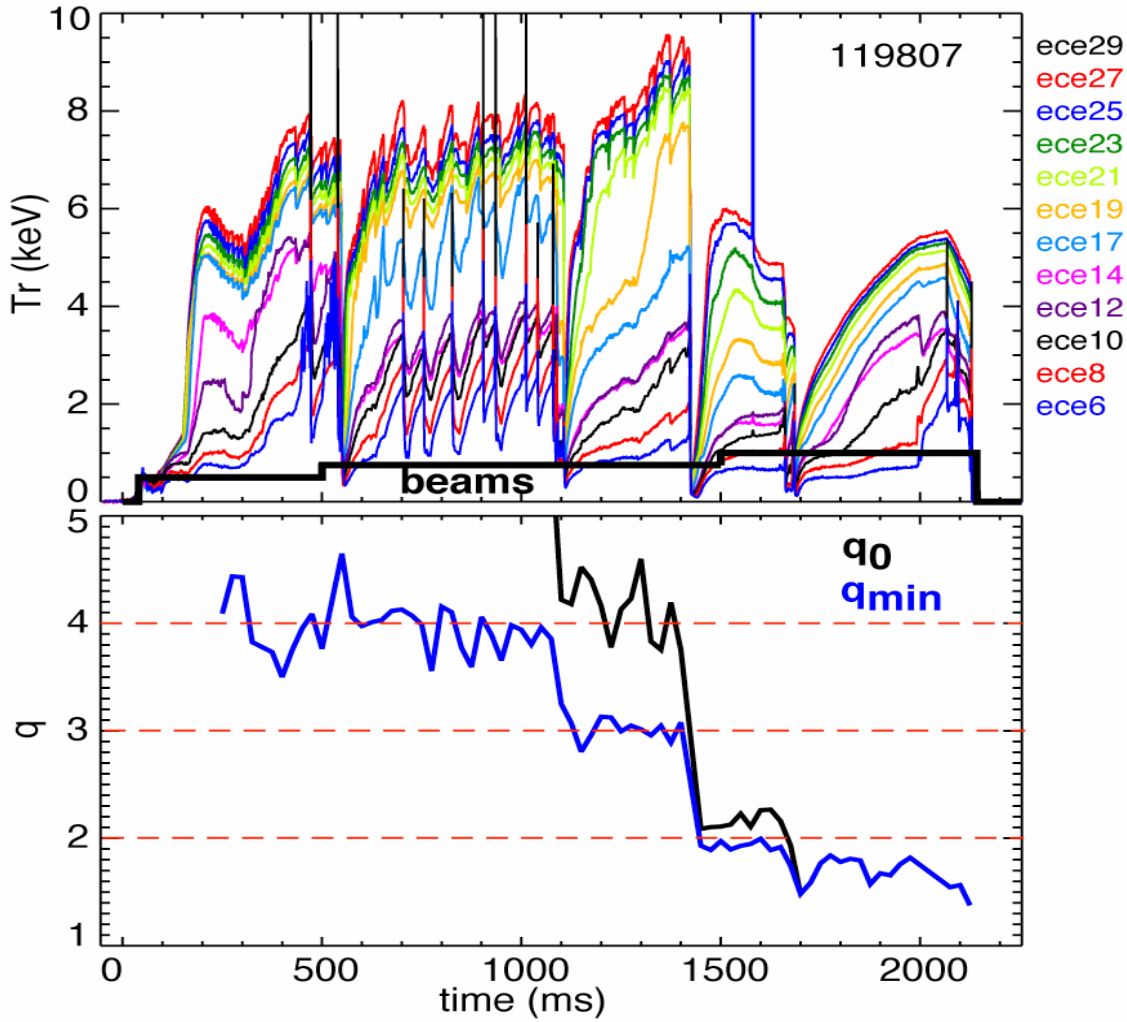


Profiles at 1200 ms



Current diffusion barriers at rational q_{min}?

- Current hole experiment on DIII-D
- Very early NBI plus ECH create and sustain extreme reverse shear/hollow current profiles
- In several discharges, q_{min} transitions between integer values at X-events



Summary

- Database of rational-*q* induced transport changes and ITB formation continues to grow
- A model for ITB formation in L-mode NCS was tested in experiments with mixed co and counter injection; more evidence of zonal flows was seen
- Differences in AE activity in co and balanced injected discharges rule out its contribution to barrier formation
- Operating regime required for observing rational *q* effects on transport is not understood

Corrugations related to density of rational surfaces

- The flattened T_e-corrugations and enhanced ExB shear rates result from low density of rational surfaces and results in slightly reduced flow at the low order surfaces
- Electrostatic GYRO reruns show nearly same level of corrugations hence not a magnetic island effect