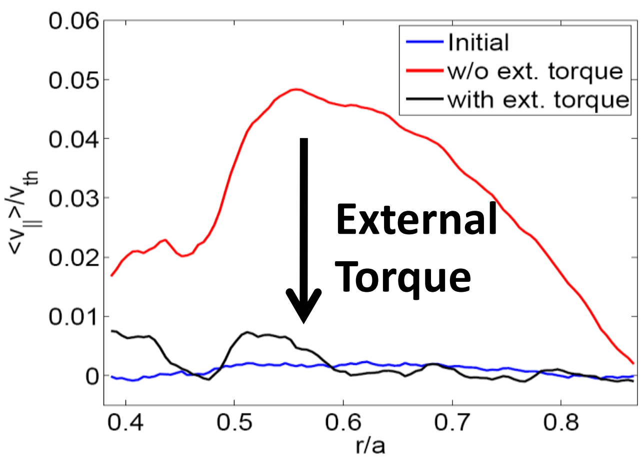
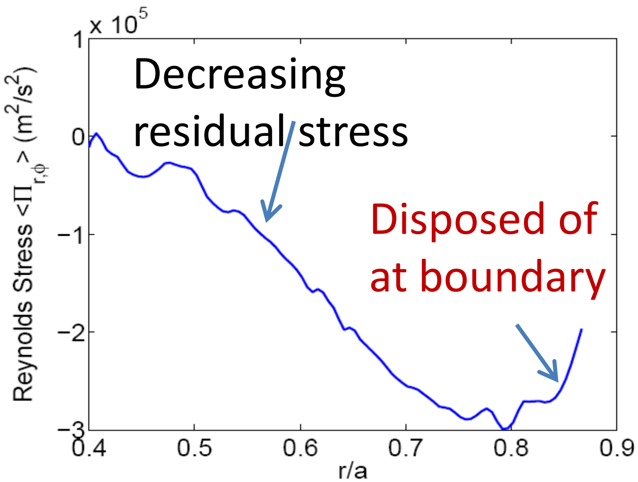
Intrinsic momentum generation

Numerical "Solomon Exp." : Cancelation of rotation → Residual stress

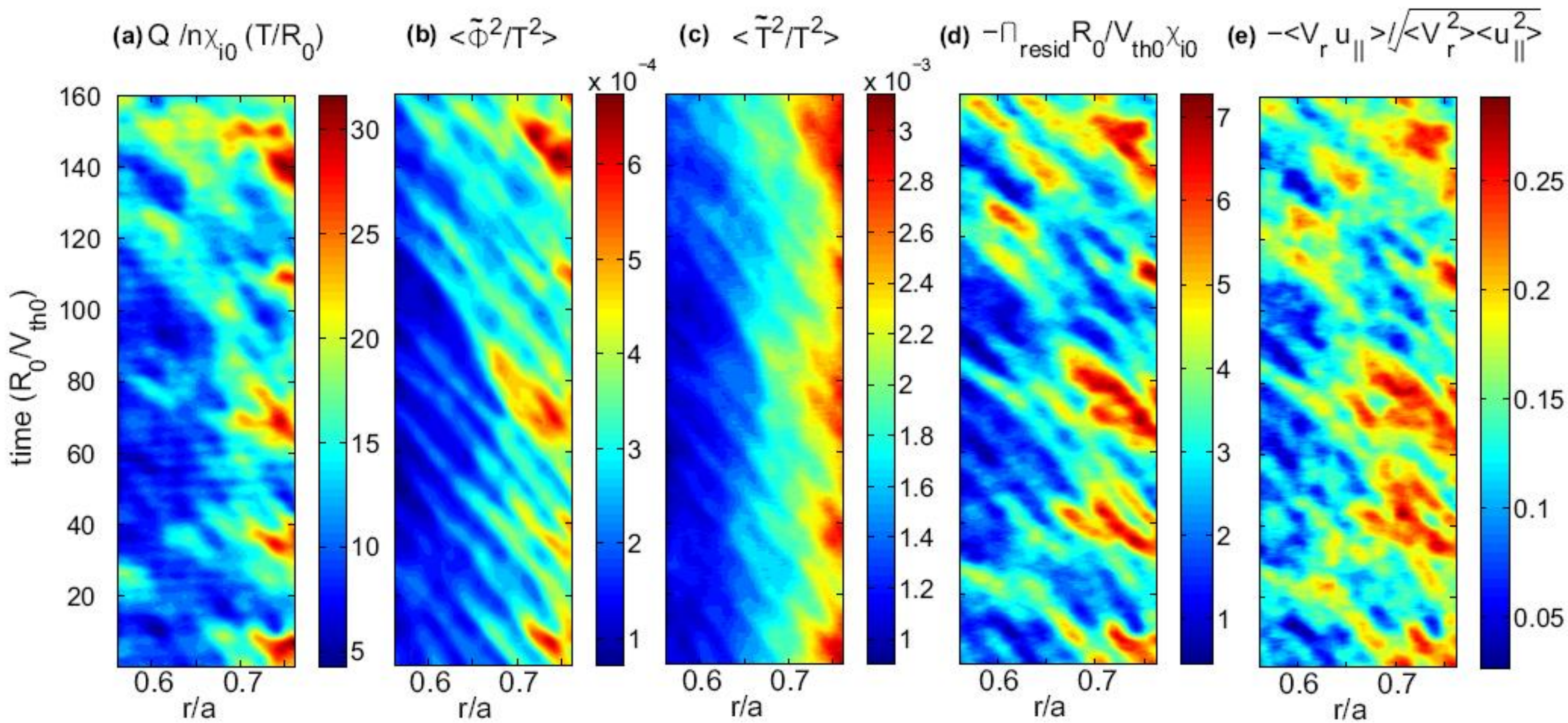




- ITG simulation with no-slip boundary condition for simple modeling of "external world."
- Significant net intrinsic rotation (co-current, $M_T \cong 0.05$ → 5% of thermal velocity) develops from zero initial flow after 7 ms, still increasing.
- Peak flow is still increasing and moving toward core from the edge.
- External counter-current torque was then applied to null out intrinsic rotation.
- Residual stress is inward and decreasing towards to edge (r/a<0.8)

  → Co-current intrinsic torque (= $-\nabla\cdot\Pi$)
- **Counter-current torque r/a>0.8 is disposed of by no-slip boundary condition.**

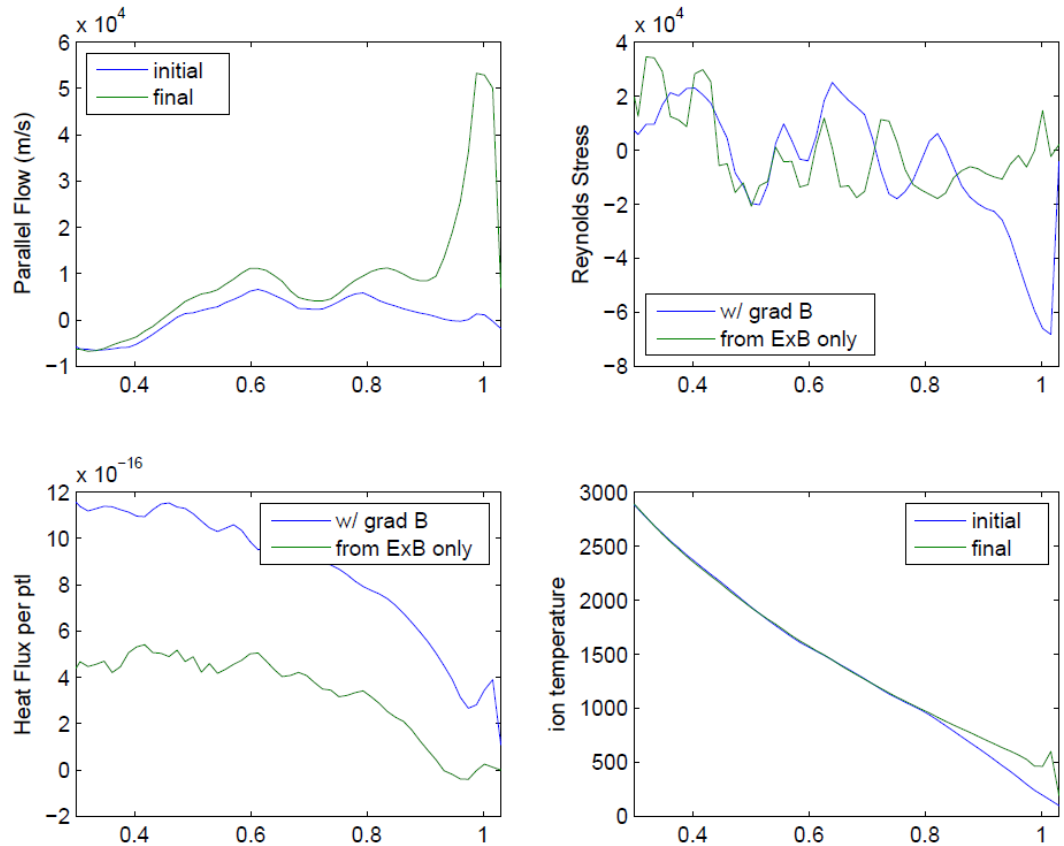
Intensity pulse drives residual stress



- Turbulence arises near the outside boundary and propagates inward.
- Inward intensity pulse drives residual stress as well as heat flux.
- Non-local transport phenomena for momentum transport

Intrinsic rotation during I-mode transition (preliminary results)

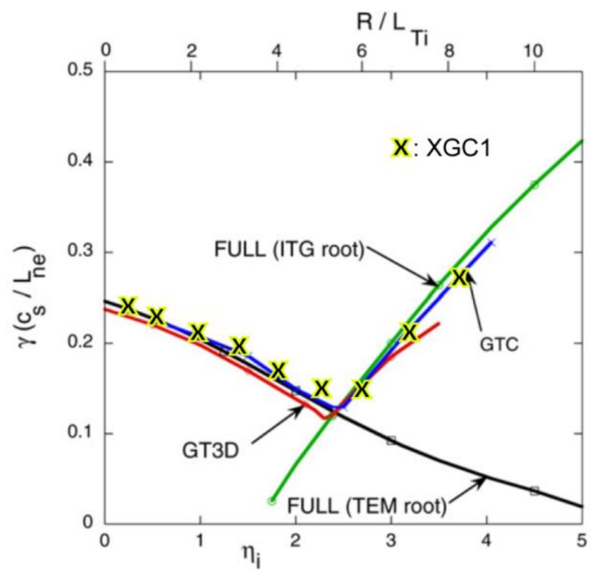
- ITG turbulence simulation with adiabatic electron response
- Realistic geometry with separatrix and x-point
- Co-current rotation is building up at the separatrix and propagates inward.
- Momentum generation from X-transport seems to be dominant near the separatrix.



Edge electron turbulence calculation with XGC1

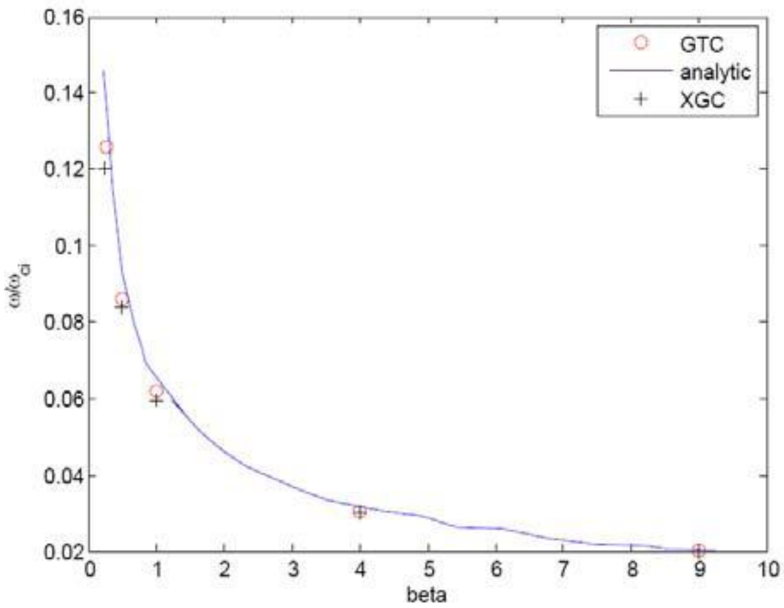
Edge electron turbulence calculation with XGC1

- Current capabilities:
  - Full-f electrostatic ITG-TEM turbulence
  - Full-f kinetic electrons working at core only
  - Delta-f electromagnetic turbulence in core only
- Edge electron turbulence calculation (present)
- Electromagnetic turbulence capability (~ 1 years)
  - Fluid–particle hybrid scheme (no tearing)
  - Split-weight scheme (yes tearing, but low-n?)
- ETG simulation is expected to be possible in a few years (availability of 100PFlop machine)



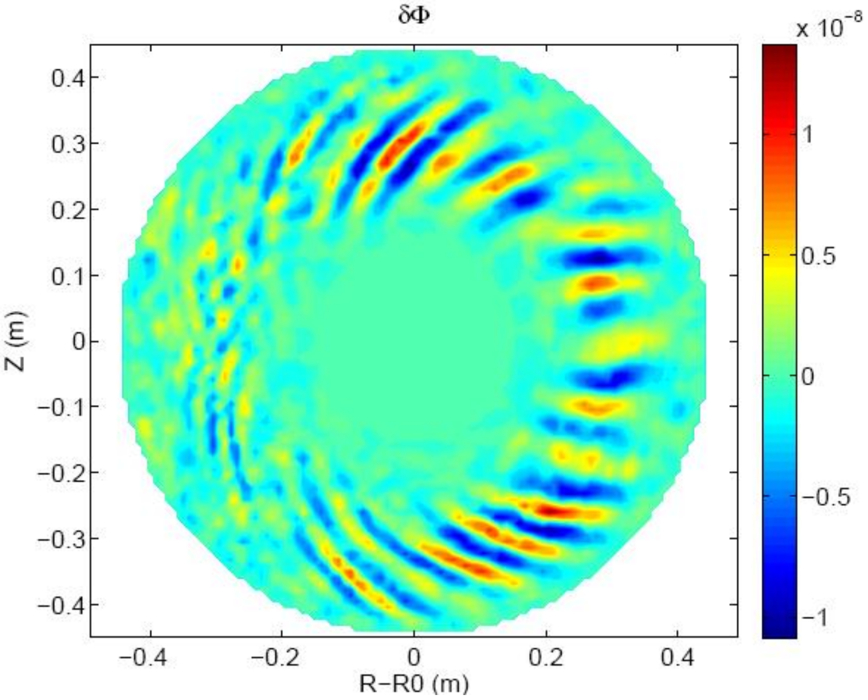
Moving Forward into Electromagnetic edge turbulence: delta-f → full-f

Fluid-kinetic hybrid electron technology, imported from GTC



XGC1 verification of Shear Alfven wave. The line is from an analytic calculation, the “o” data points are from GTC and the “+” data points are from XGC1.

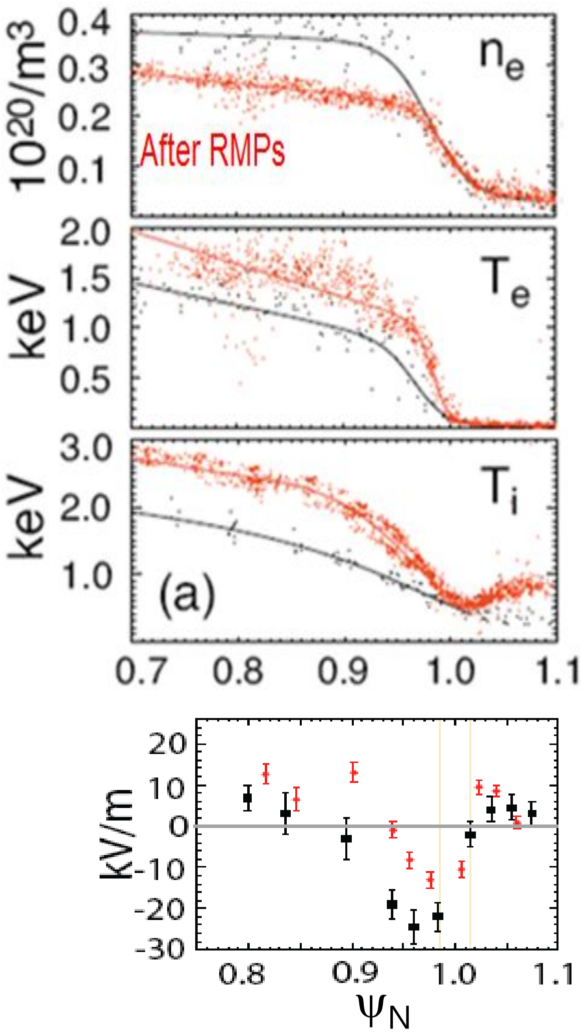
Split-weight kinetic electron technology, imported from GEM



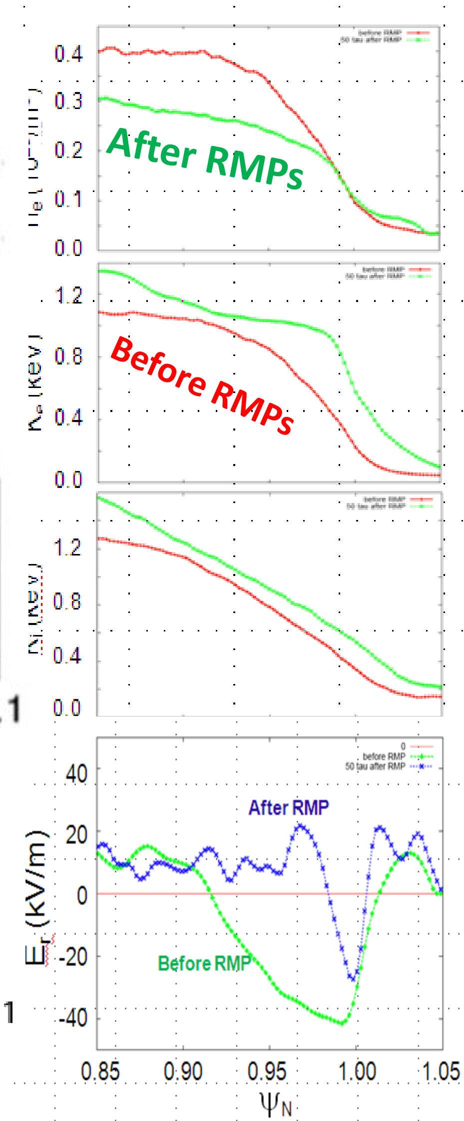
Split-weight-electron simulation of electromagnetic turbulence in XGC1 at low electron beta.

Effects of RMP with edge turbulence

- Currently, XGC0 has RMP capability with ampere solver.
- RMP capability is being moved to XGC1 (J. Lang)
  - First, study RMP effect on ITG-TEM turbulence, and transport, on XGC0 calculated 3D field
  - Next, add RMP Ampere law solver to XGC1 for self-consistent magnetic perturbation



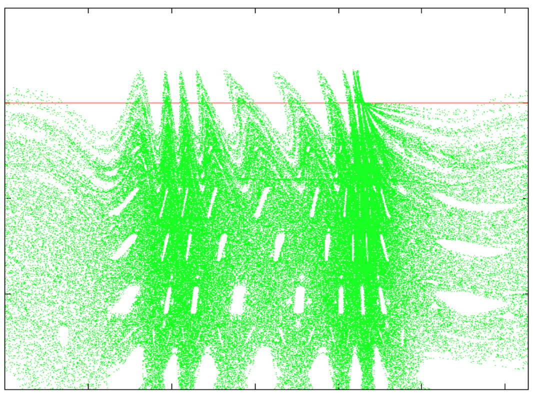
XGC0: Black is before and red is ~100ms after the RMP turn-on.



XGC0: Red is before and green is 4ms after the RMP turn-on.

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

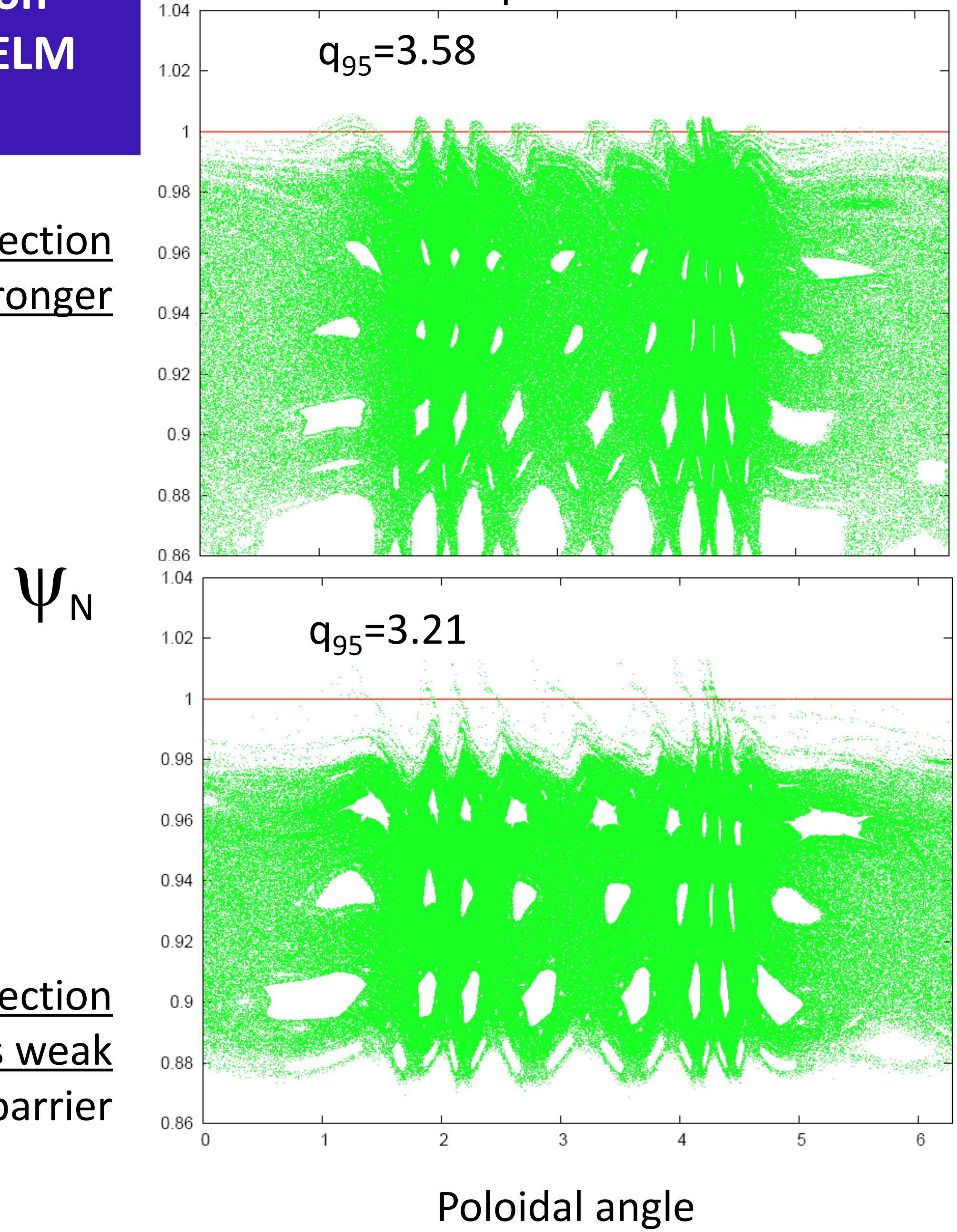
<u>Inside the window:</u> <u>Field connection between plasma and wall is stronger</u>



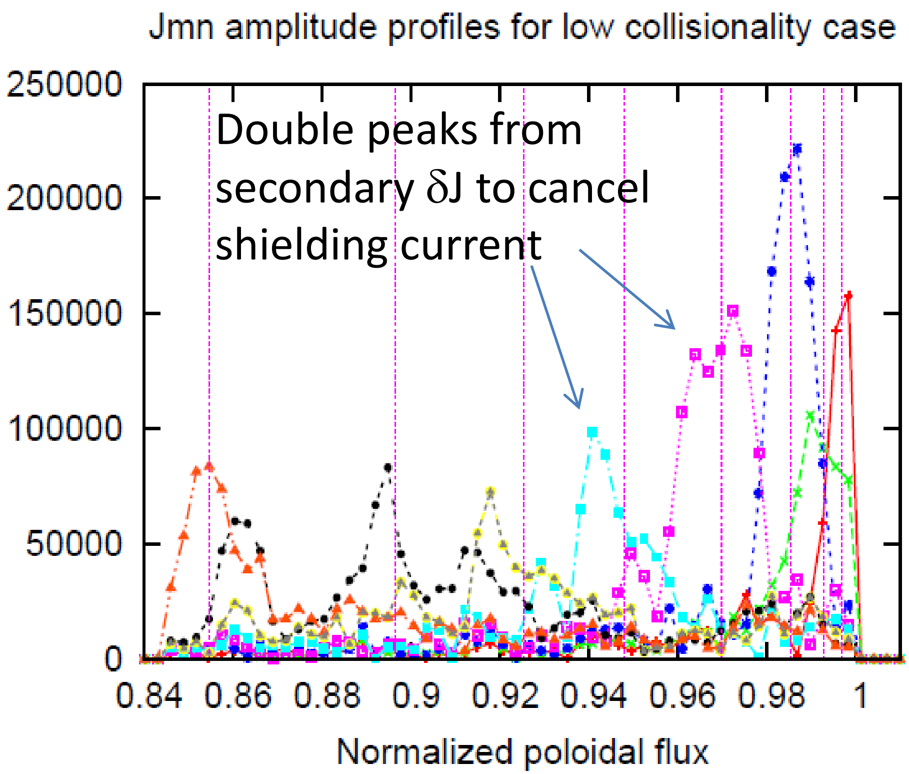
Vacuum RMPs with
B_T =1X $B_{T,EQDSK}$, q_{95}=3.69

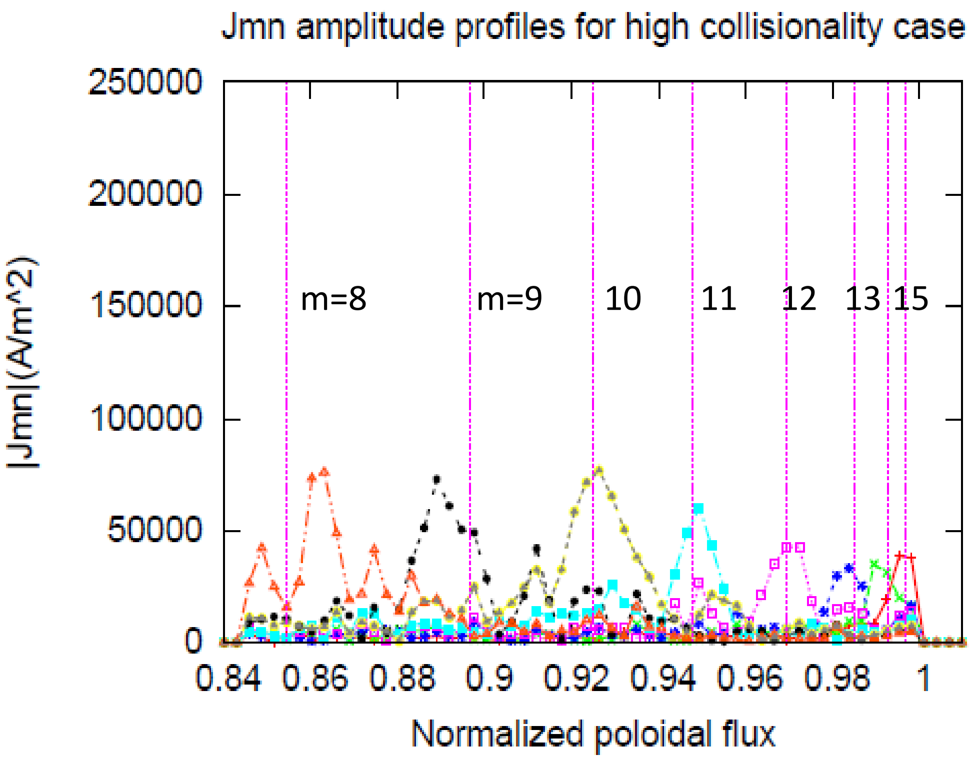
<u>Out-of-window:</u> <u>Field connection between plasma and wall is weak</u>
→Stronger ∇p at new barrier

Plasma responded RMPs



Fourier current amplitudes in the stochastic region shows double peak, with the secondary current pushed inward while the primary current is pulled outward.





Low collisionality

Strong shielding currents at m≥13 suppresses local RMPs and stochasticity as soon as the RMPs meet the pedestal.

Secondary currents tend to cancel the primary shielding currents at m≤12, leading to the recovery of RMPs and stochasticity at inner radii.

High collisionality

Primary shielding currents are weak and does not generate strong secondary currents.

Primary shielding currents accumulate toward inner radii and shields RMPs and stochasticity.

Vacuum Chirikov is similar, but the plasma-responded Chirikov is a sensitive function of q_{95} around 3.58.

Near q_{95} =3.58, Chirikov >1 everywhere. Otherwise, Chirikov<1 just inside the separatrix surface.

→ "Vacuum Chirikov>1 is only a necessary condition."