Controlling the onset of Type-I Elms by rigid-body toroidal rotation via ExB flow shear

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Summary

- ExB shear flow calculated from force-balance equation with increasing toroidal rotation as an additional control
  - stabilizes the high-n peeling-ballooning modes with only a few low-n modes unstable
    - the highest unstable mode number n is inversely proportional to the toroidal rotation speed
  - increases the fluctuation levels
  - reduces size of pedestal collapses
- The overall characteristics is consistent with observation of quiescent H-Mode discharges in DIII-D with edge rotation ranging from strong counter to strong co-rotation

The basic set of equations for the MHD peeling-ballooning modes

$$\frac{\partial \varpi}{\partial t} + \left(v_E + V_{||0}\right)\cdot \nabla \varpi = B_0^2 \nabla_{||}\left(\frac{j_{||}}{B_0}\right) + 2b_0 \times \kappa \cdot \nabla P,$$

$$\frac{\partial P}{\partial t} + \left(v_E + V_{||0}\right)\cdot \nabla P = 0,$$

$$\frac{\partial A_{||}}{\partial t} = -\frac{1}{B_0}\nabla_{||}\phi + \eta \frac{B_0}{\mu_0}\nabla_{\perp}^2 A_{||},$$

$$\varpi = \frac{n_0 M_i}{B_0}\left(\nabla_{\perp}^2 \phi + \nabla_{\perp}^2 P\right),$$

$$j_{||} = J_{||0} - \frac{1}{\mu_0} B_0 \nabla_{\perp}^2 A_{||}, v_E = \frac{1}{B_0} b_0 \times \nabla(\phi + \Phi_0)$$

Non-ideal physics

✓Using resistive MHD term, resistivity can renormalized as Lundquist Number

$\sigma_{lund}=(hB_0/m_0)(t_A/R_0^2)$

✓After gyroviscous cancellation, the diamagnetic drift modifies the vorticity and additional nonlinear terms

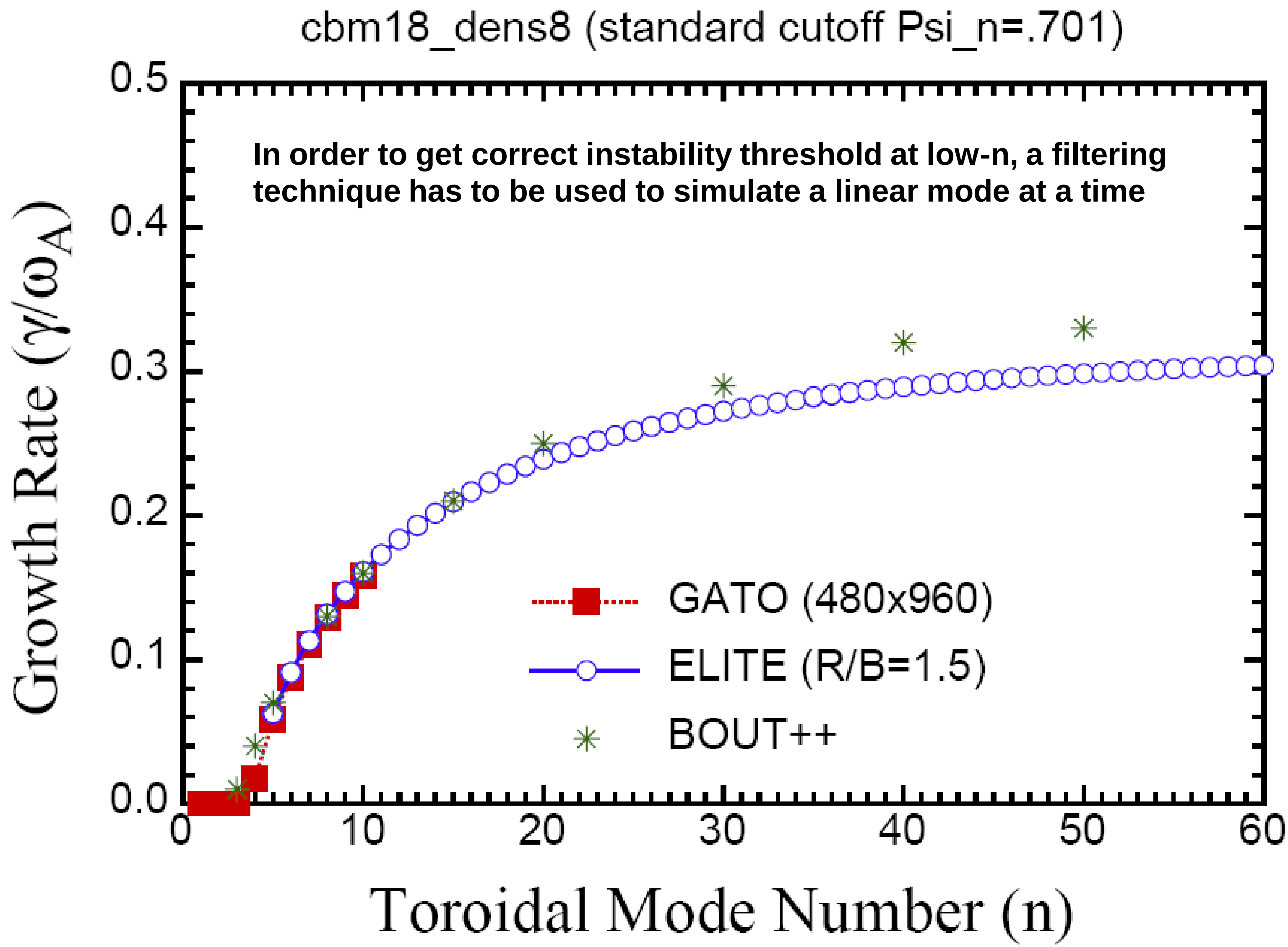
✓Using force balance and toroidal rotation as a control knob

$E_{r0}=(1/N_iZ_ieB)\nabla_{\perp}P_0-v_{\theta 0}B\varphi-v\varphi 0B_\theta$

✓Parallel velocity

$V_{||0}=v_\theta B_\theta/B+v_\varphi B_\varphi/B$

Linear growth rate of BOUT++ and ELITE



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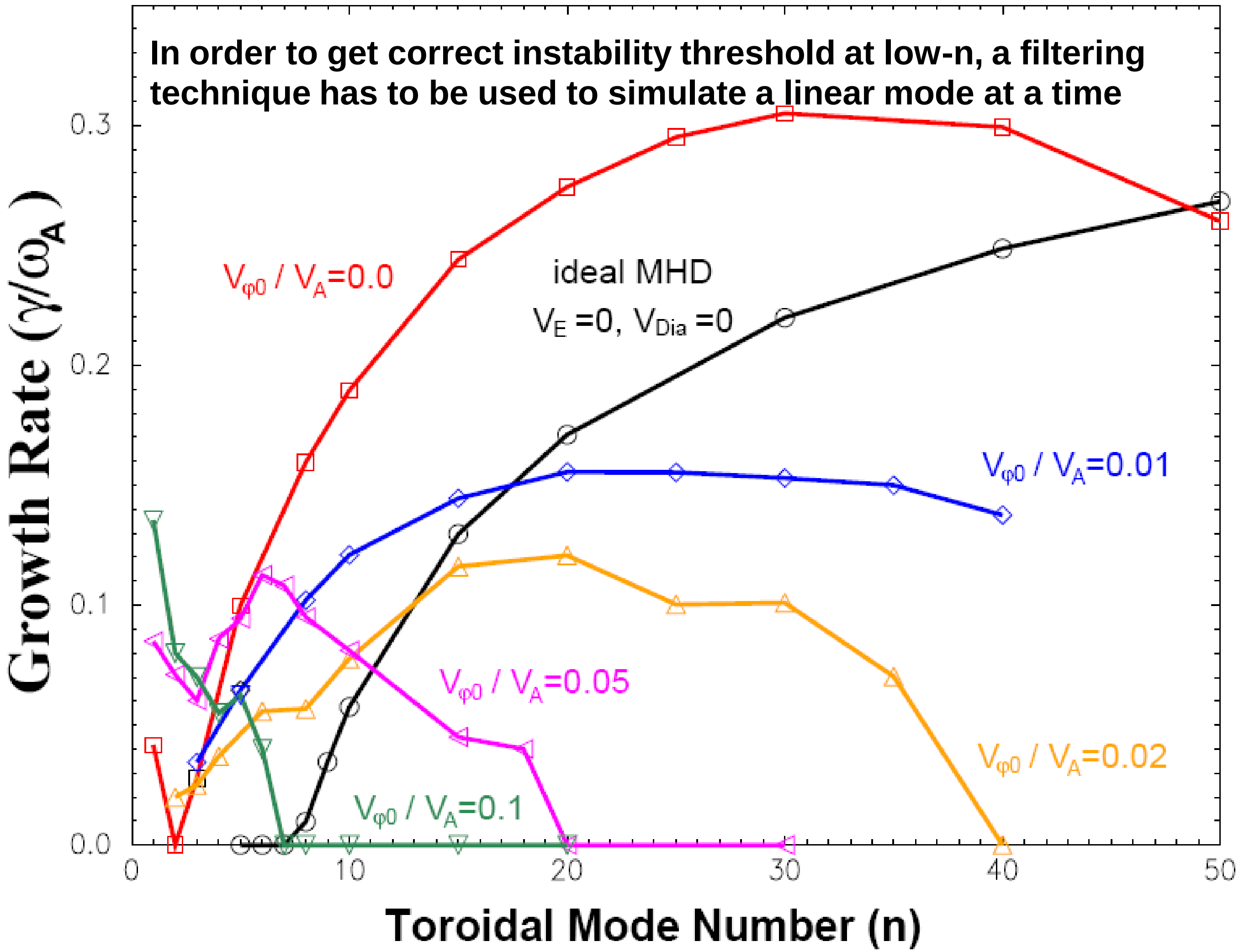
ExB shear flow calculated from force-balance equation with increasing toroidal rotation stabilizes the high-n peeling-ballooning modes ($P_i = P_e = 0.5P$), cbm18_dens6



$E_{r0}=(1/N_iZ_ieB)\nabla_\perp P_0 - v_{\varphi 0}B_\theta$

$v_{\theta 0}=0$,

$v_{\|0}= v_{\varphi 0}B\varphi/B \sim v_{\varphi 0}$,

Doppler shift for $v_{\varphi 0}$=const.

The highest unstable mode number n is inversely proportional to the toroidal rotation speed

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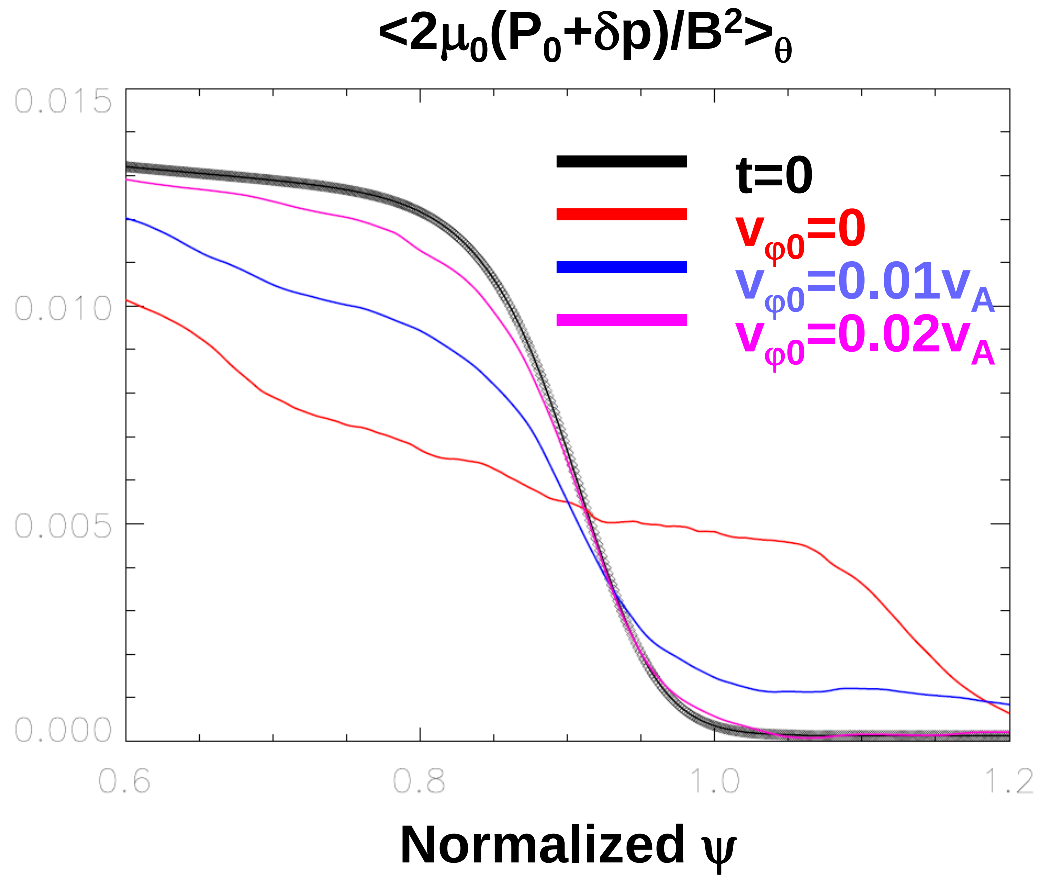
ExB shear flow calculated from force-balance equation with increasing toroidal rotation

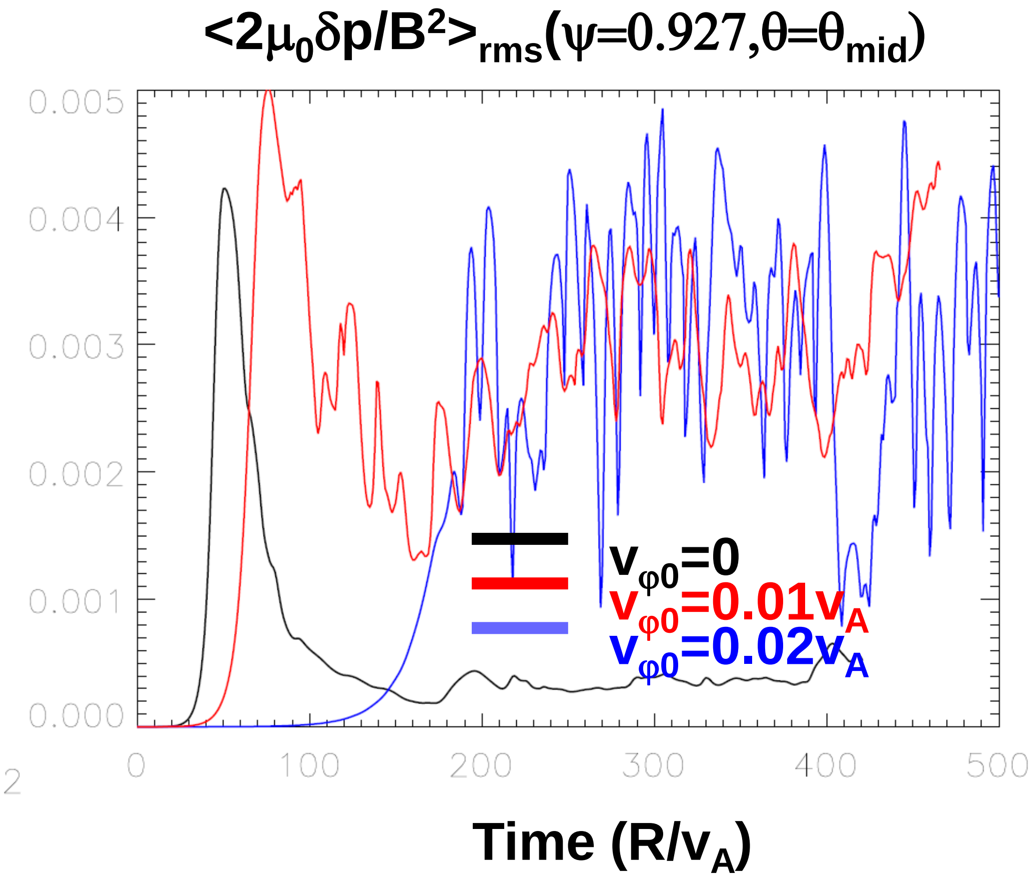
reduces

size of pedestal collapses and maintains high fluctuation level

($P_i = P_e = 0.5P$), cbm18_dens6

Lundquist Number $\sigma = 1\times10^5$





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