BETA-COLLAPSE EVENTS IN AT REGIME ON DIII–D

by

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Beta-Collapse Events in AT Regime on DIII-D[1] M. GRYAZNEVICH, UKAEA Fusion, E.J. STRAIT, K.H. BURRELL, R.J. LA HAYE, J.T. SCOVILLE, A.D. TURNBULL, General Atomics, E.D. FREDRICKSON, M. OKABAYASHI, Princeton Plasma Physics Laboratory, A.M. GAROFALO, G.A. NAVRATIL, Columbia University, E.A. LAZARUS, Oak Ridge National Laboratory — Beta-collapse and rollover events have been observed in negative central shear AT regimes on DIII–D. These events are associated with a growth of a slow rotating resistive wall mode (RWM), which can stop the plasma rotation and cause fast β-collapse after the mode amplitude reaches critical value. The duration of the mode growth and the critical amplitude increase with the $\beta_{\rm N}$ value at the RWM onset. This increase is correlated with the increase in the toroidal rotation in the high velocity shear region between $q_{\rm min}$ and $q = 2$. Increase in the heating power and application of an active feedback compensation of the $n = 1$ field at the wall help to sustain rotation and can prevent β-collapse, which suggests a strong influence of the velocity shear on the RWM evolution.

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☐ Prefer Oral Session
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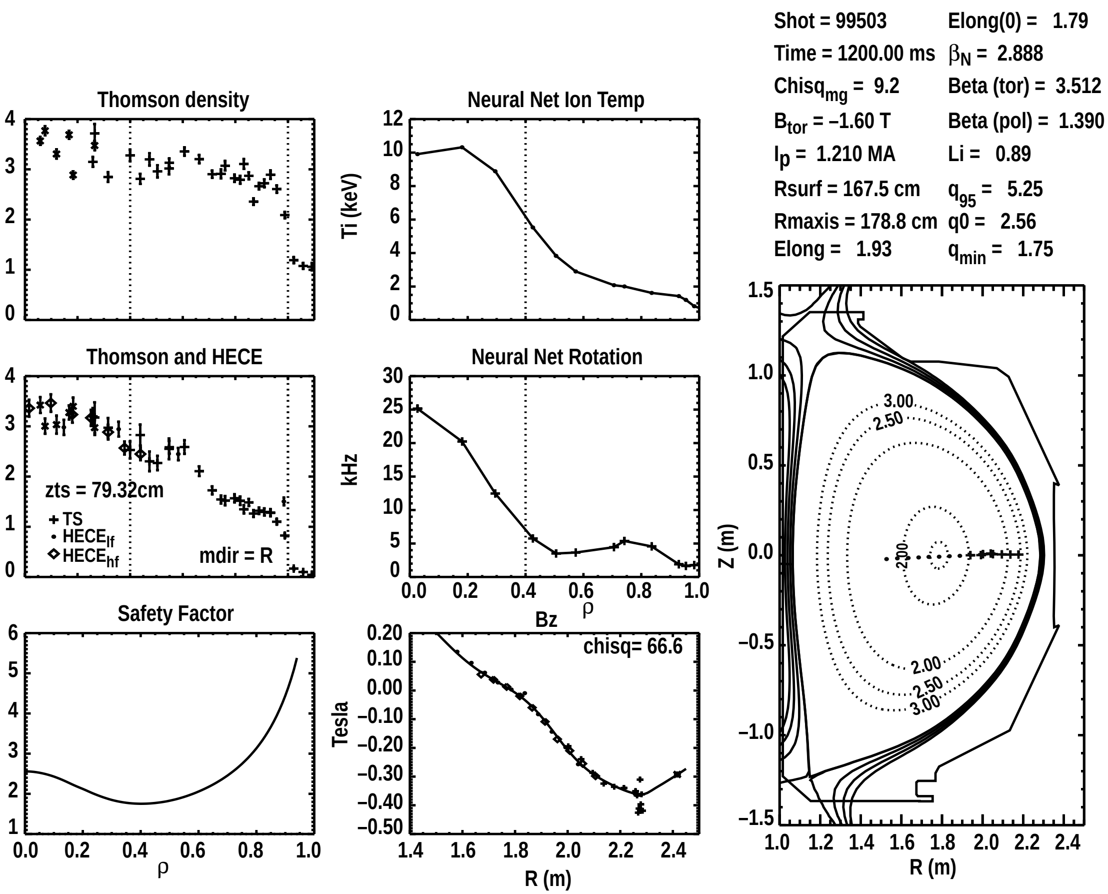
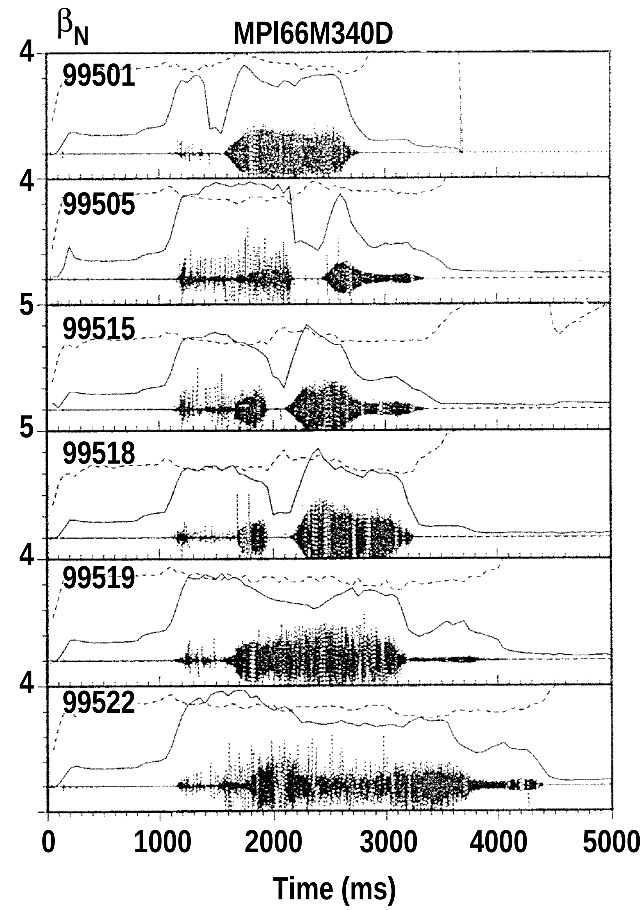
ABSTRACT

Beta-collapse and rollover events have been observed in negative central shear AT regimes on DIII–D. These events are associated with a growth of a slow rotating resistive wall mode (RWM), which can stop the plasma rotation and cause fast beta-collapse after the mode amplitude reaches critical value. The duration of the mode growth and the critical amplitude increase with the β_N value at the RWM onset. This increase is correlated with the increase in the toroidal rotation in the high velocity shear region between q_{min} and q=2. Increase in the heating power and application of an active feedback compensation of the n=1 field at the wall help to sustain rotation and can prevent β-collapse, which suggests a strong influence of the velocity shear on the RWM evolution

BETA SATURATION AND BETA COLLAPSE ON DIII–D





- Typical AT negative central shear shot on DIII–D

- Different types of beta-collapses:
  ##99501, 99505 – fast collapse
  ##99515, 99518 – slow collapse
  ##99519, 99522 – roll-over

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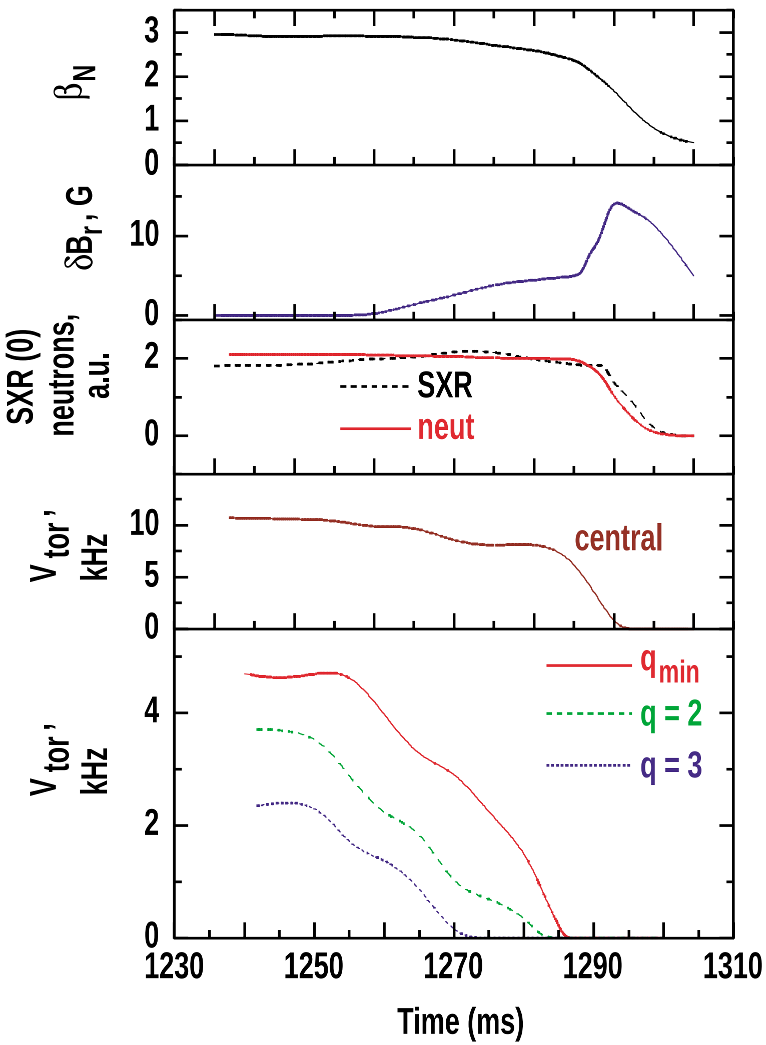
RWM INSTABILITY BEGINS WITH SLOW MODE GROWTH AND DECREASES PLASMA ROTATION



- Beta-collapse and rollover events are associated with a growth of a slow rotating resistive wall mode (RWM), which can stop the plasma rotation and cause fast β-collapse

- The plasma rotation in the outer, positive shear region decreases first as the mode grows slowly

- The plasma rotation in the central negative shear region is less affected by the RWM, until rotation in the positive shear region reduces and the mode amplitude reaches critical amplitude

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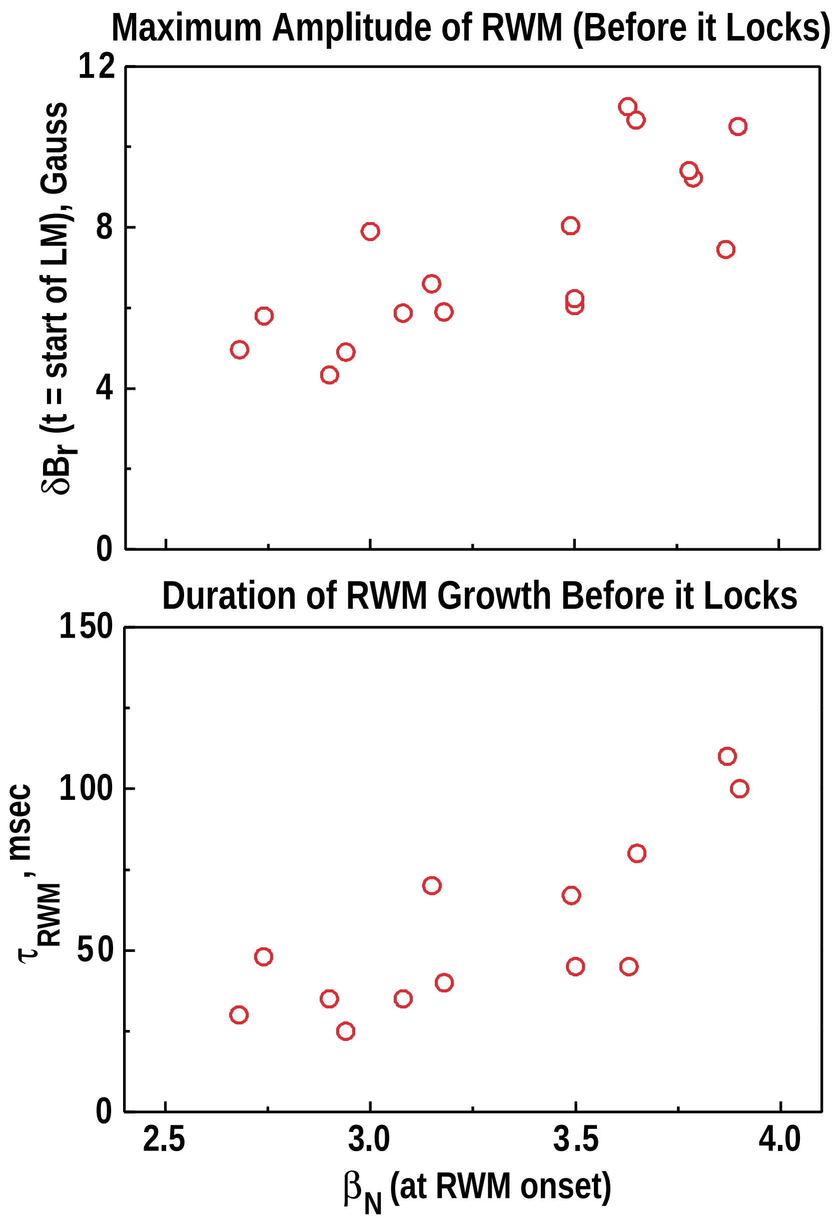
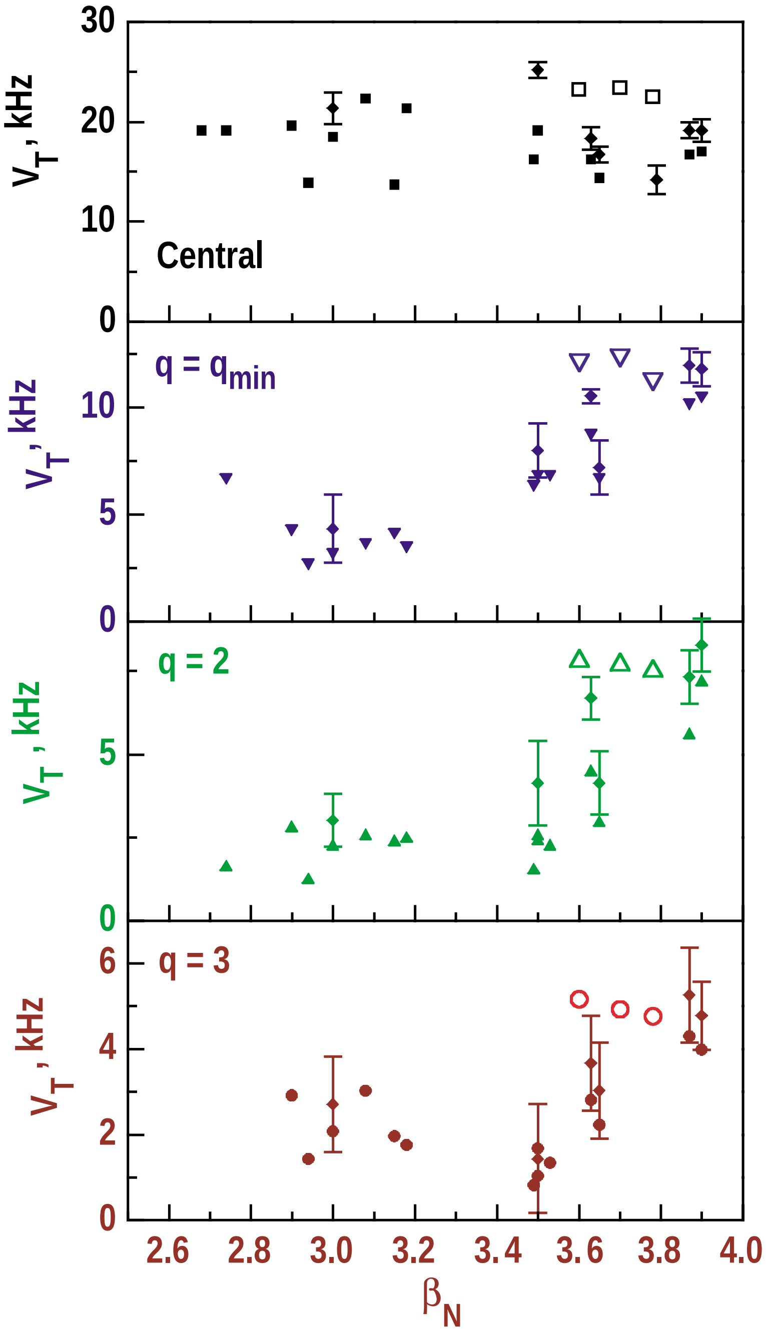
AMPLITUDE AND DURATION OF SLOW GROWTH INCREASE WITH BETA



- If a critical mode amplitude (4 – 11 G) is reached, then the mode locks the plasma rotation and grows in non-linear phase with the growth time comparable or faster than the wall's magnetic field penetration time τ_W
- However, if this critical amplitude is not reached, then the mode may saturate or disappear with little loss of energy
- The duration of the mode growth before it locks and the critical amplitude increase with the β_N value at the RWM onset

AMPLITUDE AND DURATION OF SLOW GROWTH INCREASE WITH ROTATION FREQUENCY AT q ~ 2–3



- This increase is correlated with the increase in the toroidal rotation in the region between q_{min} and q = 2 at higher β_N
- There is no apparent dependence on the rotation in the negative shear region or on the plasma edge rotation at RWM onset (at least at low β_N)
- These observations suggest a strong influence of shear on the mode stability, and also suggest that feedback stabilization must keep the mode below this critical amplitude in order to be successful

Plasma toroidal rotation at RWM onset. Neural Net data. Points with error bars-cerquick data. Open points-no RWM

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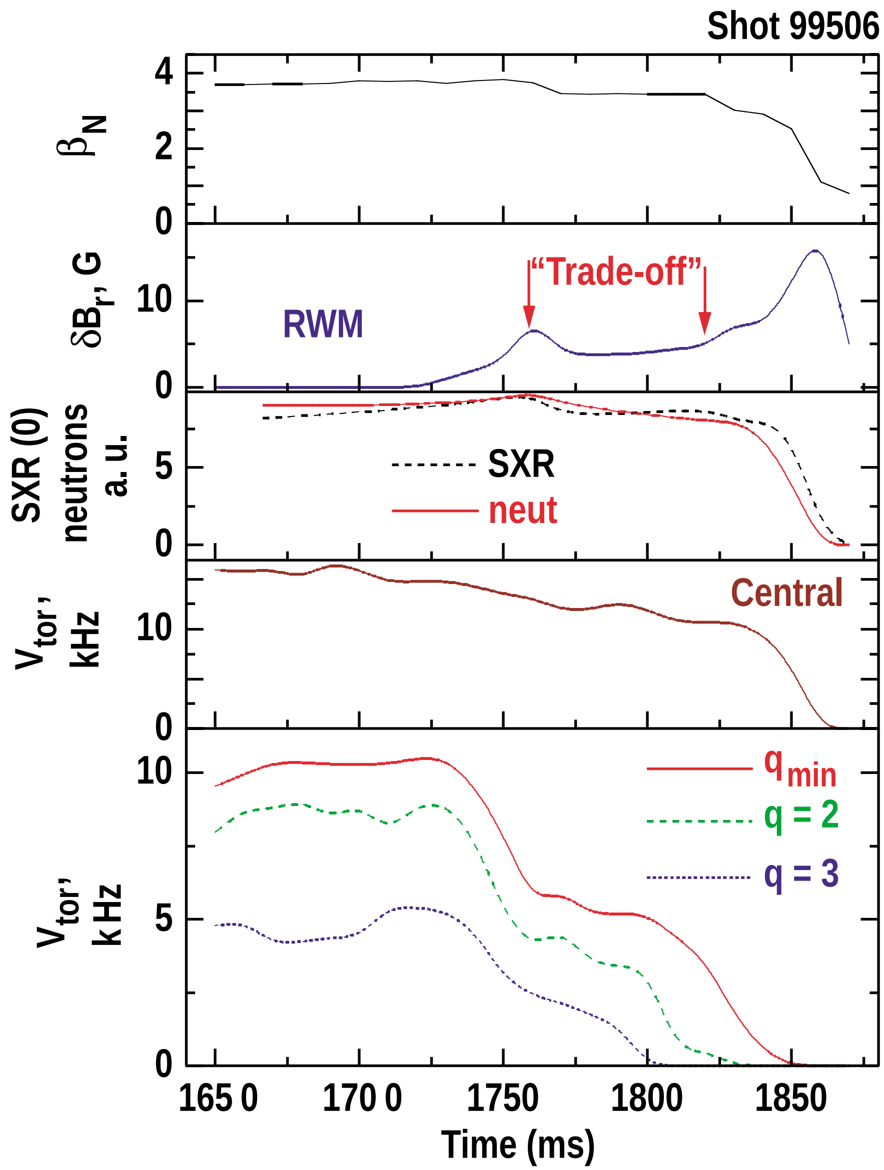
IMPLICATIONS FOR RWM STABILIZATION

- **β-collapse on DIII–D, like on other tokamaks, usually has two stages: slow, W loss ~ 10 %–20 %, and fast, W loss up to 80 %. Timescale of thermal quench on DIII–D in the absence of RWM is in agreement with ITER scaling, however, growth of RWM is 10 –100 times slower. In the presence of RWM the collapse event also has two stages, the second, fast stage, has timescale comparable with (or below) the wall's magnetic field penetration time**

- **Energy loss timescale and mode structure analysis, and non-linear resistive 3-D MHD simulations of high-β disruptions (Hayashi *et al*, NIFS, IAEA Yokohama, IAEA-CN-69/TH3/3) suggest that the fast W loss during the second stage is a result of a non-linear coupling (and reconnection) of internal and external modes. <u>When mode development reaches this non-linear stage, feedback can't prevent energy loss</u>: the reconnection has already happened, and the energy loss has a fast parallel transport timescale. The mode structure is complicated which makes feedback difficult to apply**

- **There has been much theoretical speculation that plasma rotation can stabilise the RWM. The theories presented to date have demonstrated the *principle* of RWM stabilisation by rotation *[Gimblett and Hastie, Ph.Pl. 1999, to appear]*, but often require parameters (plasma rotation rates, dissipation mechanisms, equilibrium profiles etc.) that do not appear to conform to the experimental data. One interesting proposal to stabilise the RWM is that of a secondary rotating shell *[Gimblett, PPCF 31 1989].* Essentially, the RWM cannot lock to both a stationary and rotating wall and is stabilised at "slow" (i.e. inverse wall time scale) rotation. This scheme mimics, in some case, a <u>sheared rotation</u> and thus may be another indicator of it's importance**

VELOCITY SHEAR MAY HELP TO MAINTAIN STABILITY



- The internal part of the mode holds the main magnetic energy, however, it does not necessarily set a disruptive limit: it "trades off" with the velocity shear connected with the ITB. The increase in the heating power, or any other means of ITB and velocity shear control may therefore stabilize the mode from the "inside"

- The external part of the mode (and edge localized) is responsible for collapse events, that create a "hole" from the outside towards the core due to parallel transport caused by magnetic reconnection during the non-linear coupling stage. There is an amplitude threshold (4 – 12 G in DIII–D) for this reconnection to happen. This part of the global mode sets the stability limit, which can be increased by the wall

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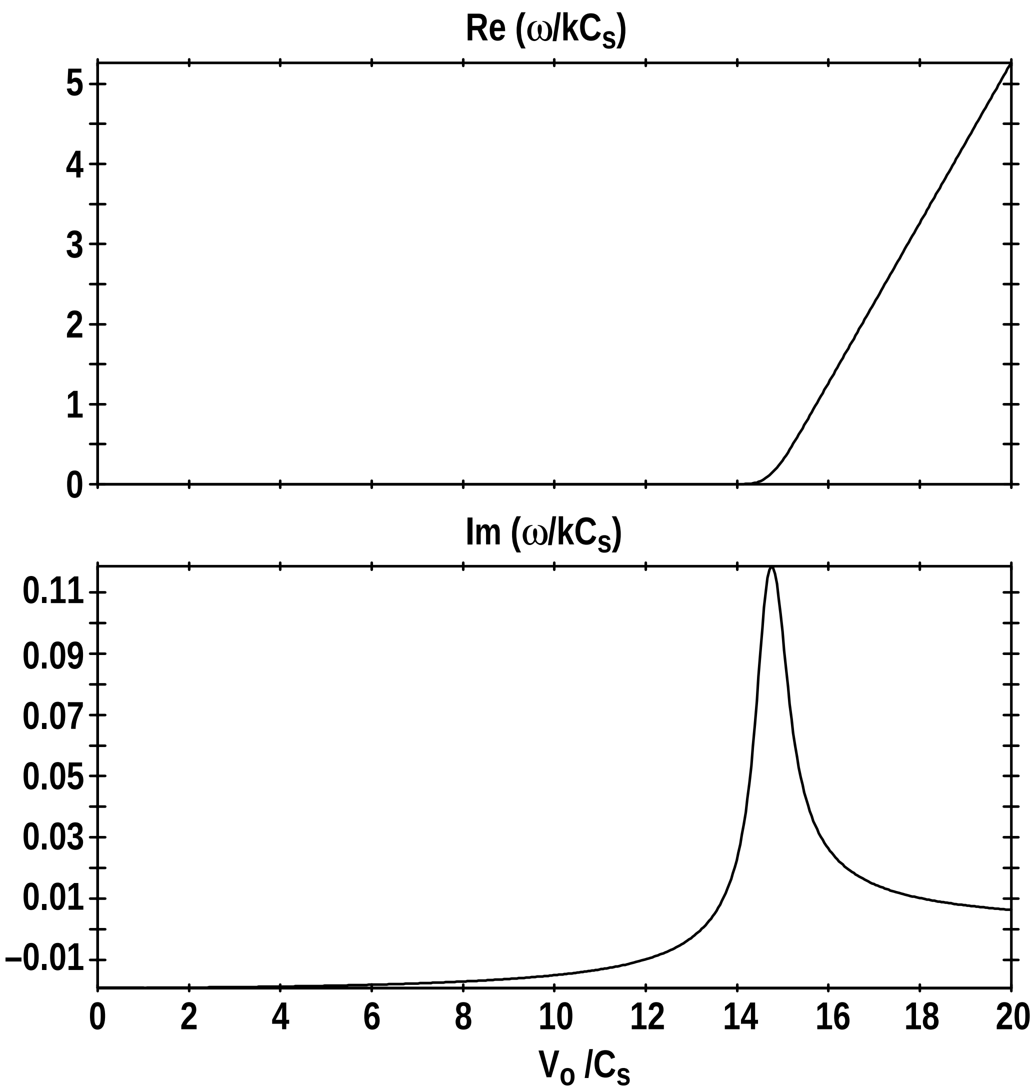
MAXIMUM GROWTH RATE IS PREDICTED WHEN $\Omega_{rot} \approx \Omega_{mode}$



- The maximum growth rates occur when the zero frequency wall mode couples to the zero frequency internal mode. Under these circumstances the behaviour is similar to the ideal MHD instability rather than resistive. Although the example shown corresponds to Alfvén frequency range, a similar effect has been observed for slow sound waves [Lashmore-Davies, Wesson and Gimblett, Ph.Pl, 6, 1999, 3990]

- This is consistent with experimentally observed sudden increase in the mode growth when the rotation in the positive shear region vanishes.

SUMMARY

- **Beta-collapse and rollover events have been observed in negative central shear AT regimes on DIII–D. These events are associated with a growth of a slow rotating resistive wall mode (RWM), which can stop the plasma rotation and cause fast beta-collapse after the mode amplitude reaches critical value**

- **Analysis of beta-collapse events caused by RWM shows that the plasma rotation in the outer, positive shear region decreases first as the mode grows slowly. If a critical mode amplitude (or a critical rotation in the outer region) is reached, then the rotation in the inner, negative shear region decreases, accompanied by rapid mode growth (comparable to or faster than the wall time) and a thermal quench**

- **The duration of the mode growth and the critical amplitude increase with the β_N value at the RWM onset. This increase is correlated with the increase in the toroidal rotation in the high velocity shear region between q_{min} and $q = 2$ at higher β_N**

- **Increase in the heating power and application of an active feedback compensation of the n=1 field at the wall help to sustain rotation and can prevent β-collapse**

- **These observations suggest a strong influence of velocity and velocity shear on stability in the AT regime, and also suggest that feedback stabilization must keep the mode below critical amplitude and help to sustain high toroidal rotation in a positive shear region in order to be successful**