Update on giant sawtooth calculations
CEMM, Savannah, GA

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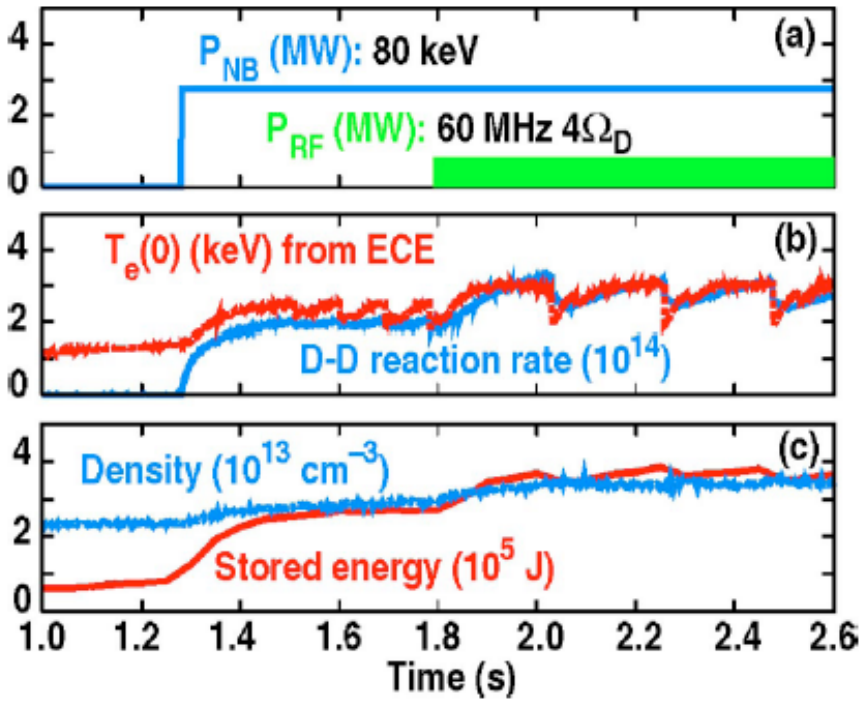
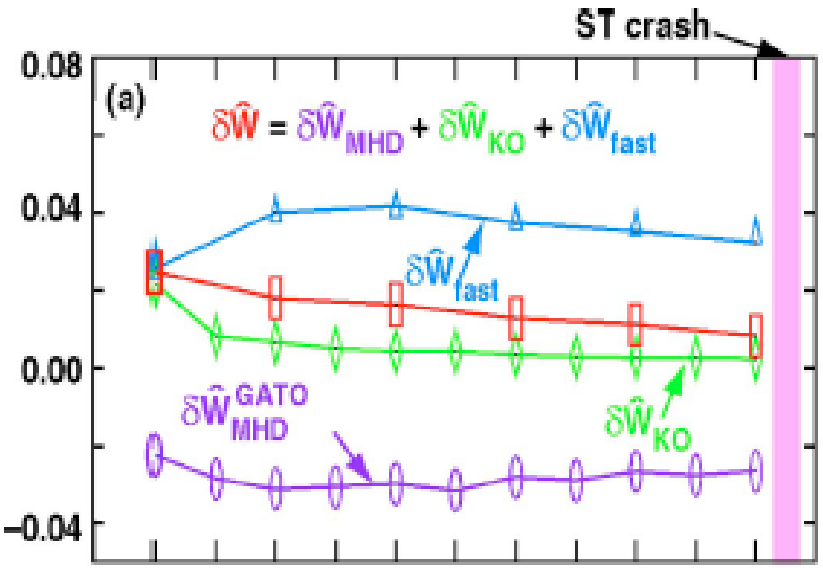
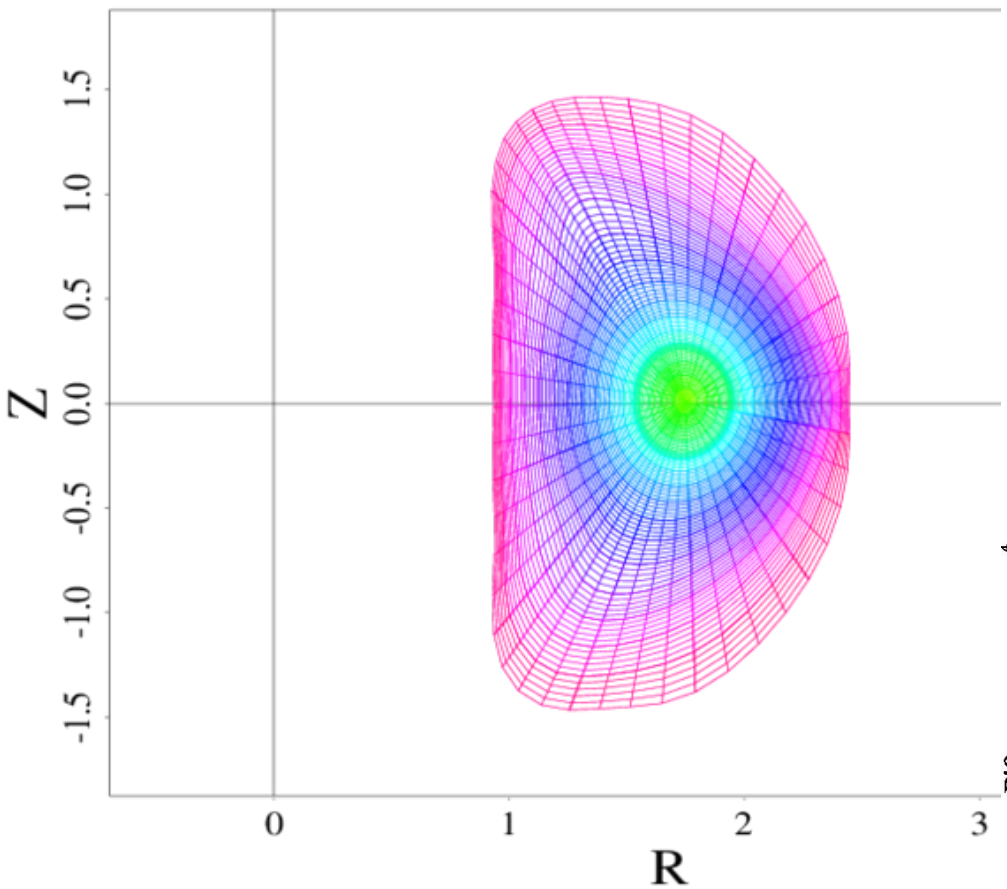
Beam ions affect sawteeth in DIII-D shot #96043.

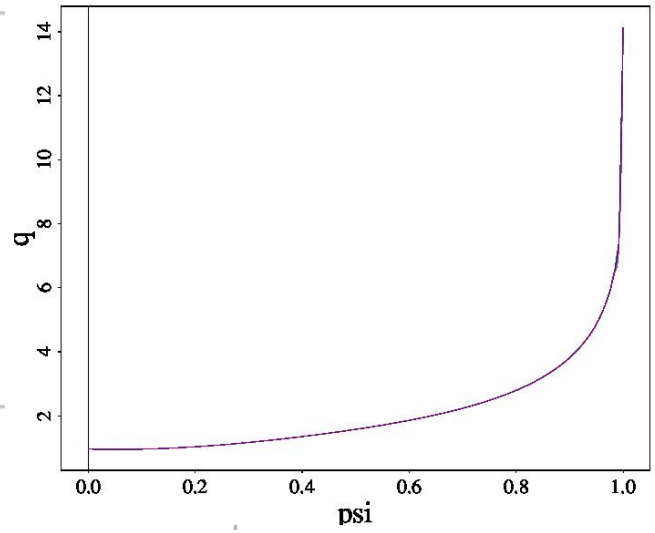
- Toroidal precession of high-energy tail stabilizes small sawteeth but results in giant sawteeth (Choi et al. POP, 2007).

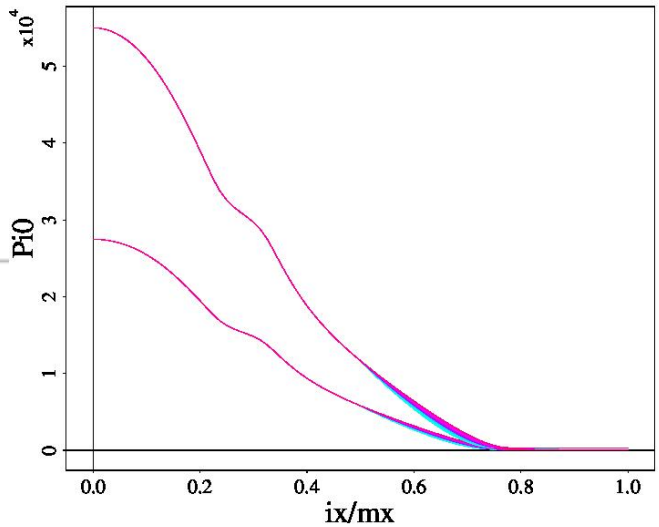




NIMROD's spatial grid; q and pressure profiles at $t = 1.9$ s.

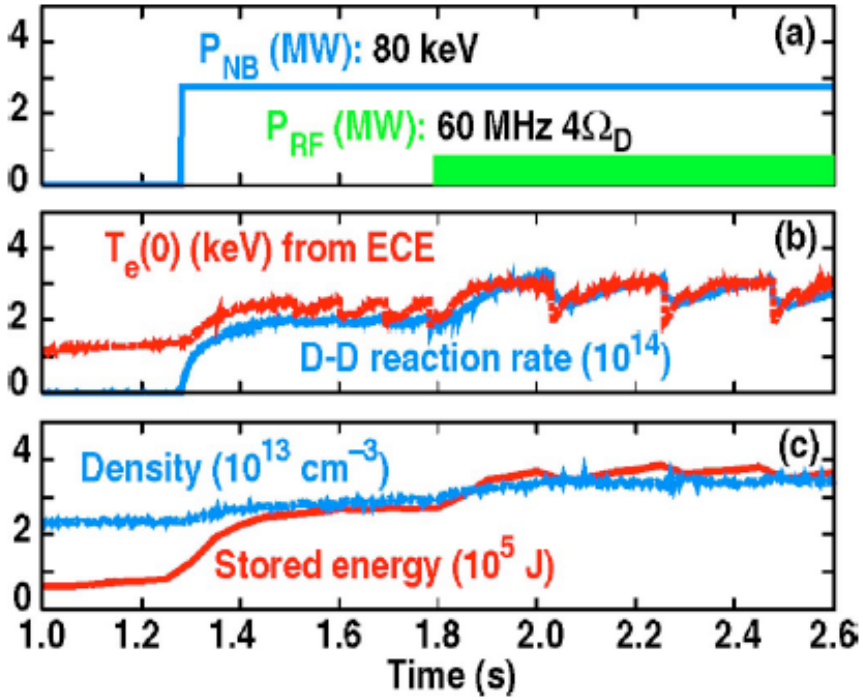


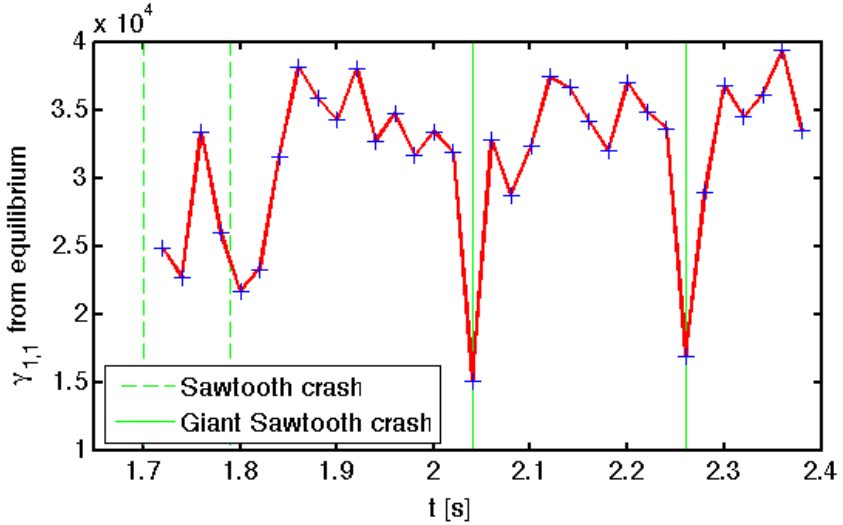




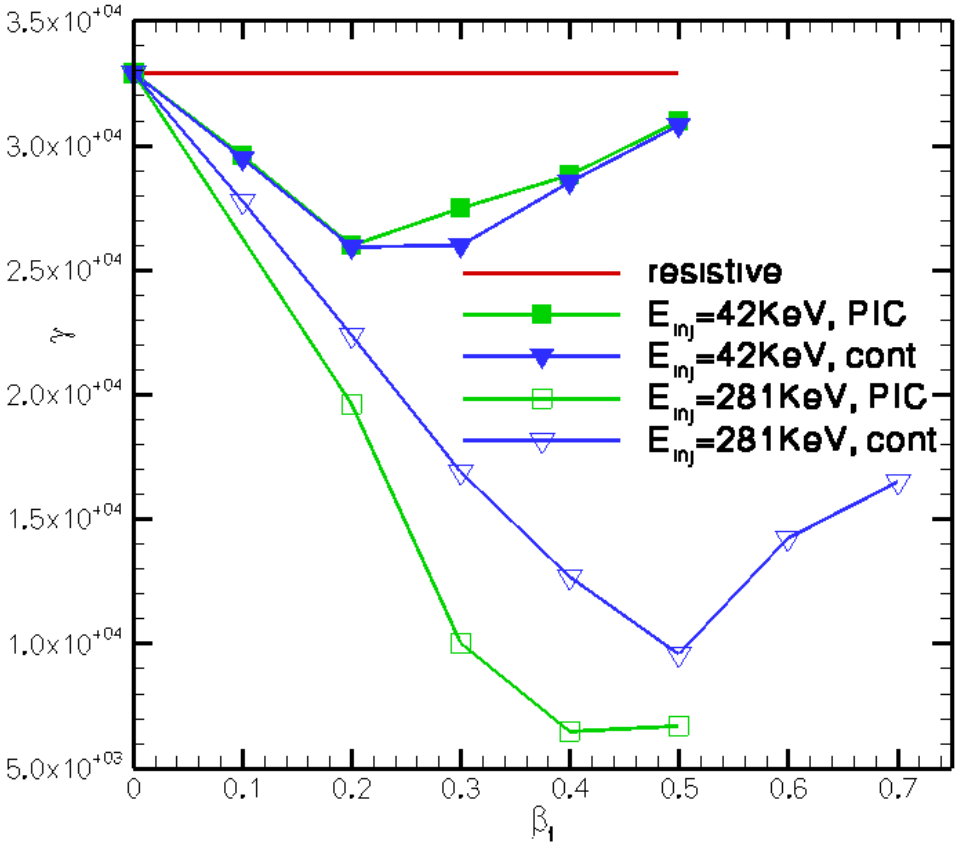
- NIMROD resolves Grad-Shafranov equation which significantly improves equilibria.

Sawtooth behavior reflected in NIMROD's linear, ideal-MHD growth rates.



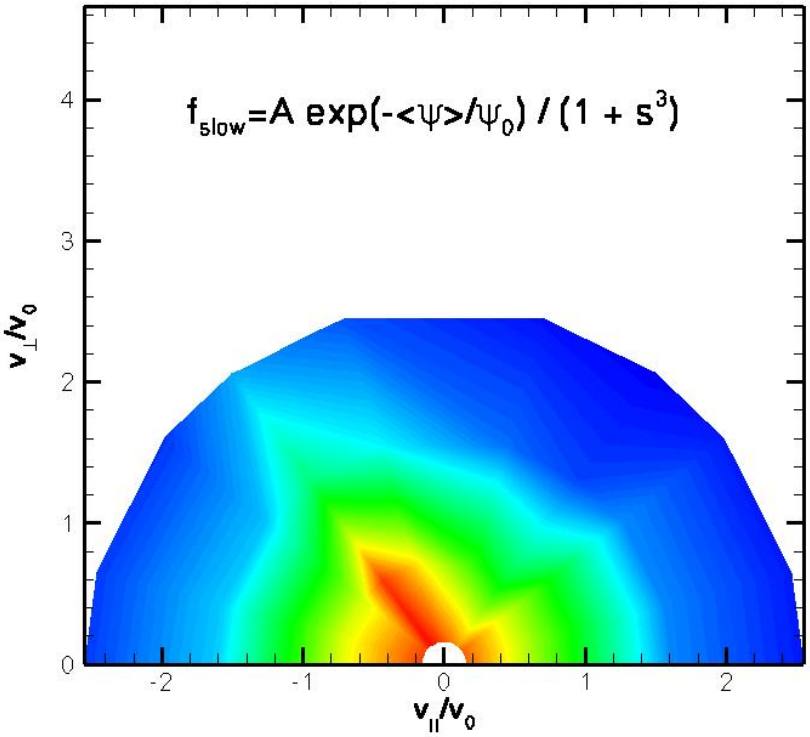


Plot shows prior results with hot particles.



- Anisotropic stress tensor for hot particles couples to NIMROD's momentum equation.
- With improved equilibria
  - revisit NIMROD's continuum and δf-PIC predictions for slowing-down f_0 only.
  - add RF driven-tail to see if that fully stabilizes the ideal kink.
  - add anisotropic stress closure for thermal ions and two-fluid effects in more complete simulations.

Examples of f_{slow}.

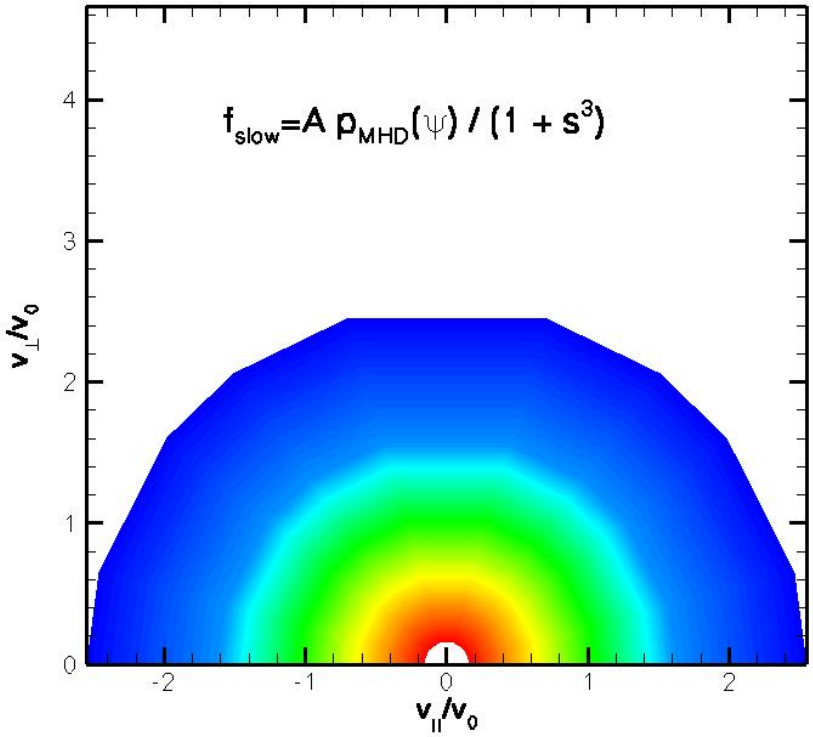


$f_0 = A\exp(-\langle\psi\rangle/\psi_0)/(1+s^3)$

$\langle\psi\rangle = P_\zeta/e - \frac{m}{e}\langle v_{||} R \frac{B_\phi}{B}\rangle \approx P_\zeta/e$, trapped

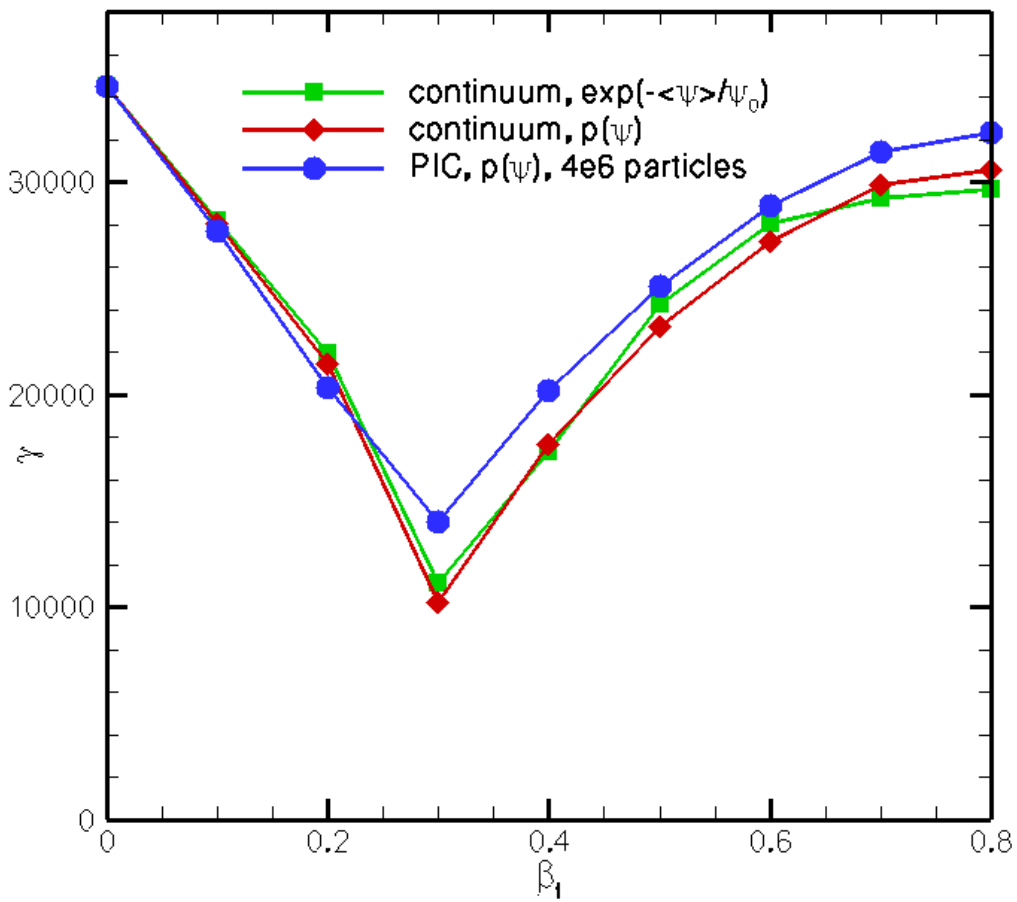
$\langle\psi\rangle \approx P_\zeta/e - vR_0 sign(\frac{v_{||}}{v})\sqrt{1-\mu B_0/E}$,

passing.



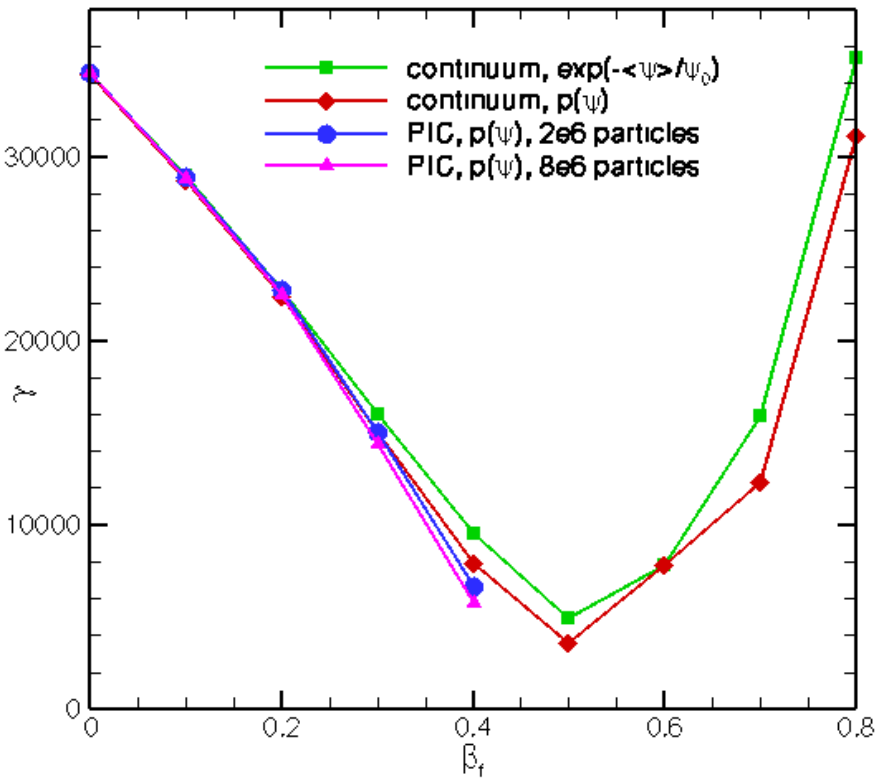
$f_0(\psi, s) = Ap_{\mathrm{MHD}}(\psi)/(1+s^3)$

Results from $E_{crit} = 50$ keV and $E_{inj} = 80$ keV calculations.



- Growth rates relatively insensitive to pitch-angle anisotropy.
- Results in Choi *et al.* use $\delta \hat{W}_{\mathrm{fast}} = C_f \varepsilon_1^{3/2} \beta_{\mathrm{ph}} / s_1$ where β_{ph} is isotropic, poloidal beta inside the q=1 surface.

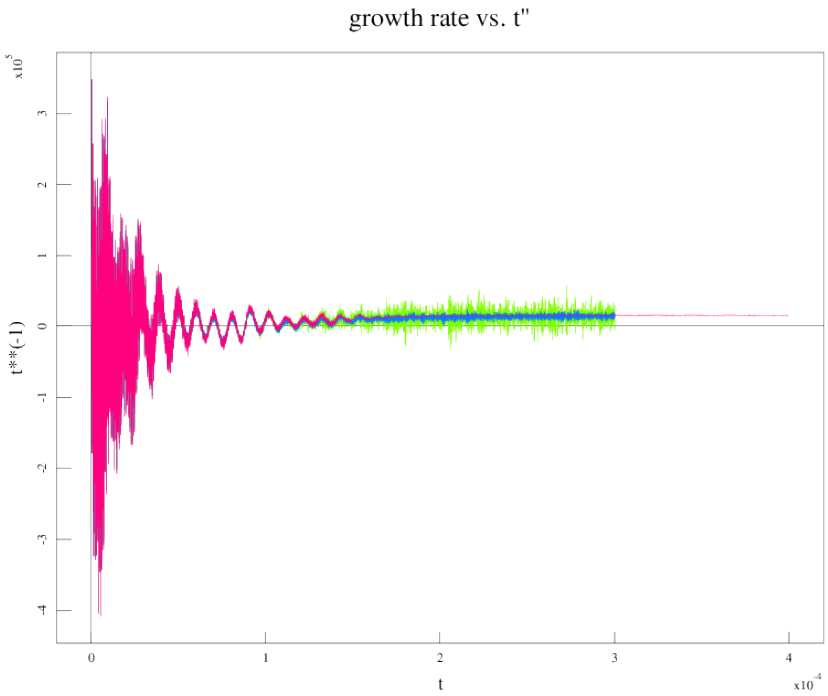
Results from $E_{crit} = 28$ keV and $E_{inj} = 227$ keV calculations.

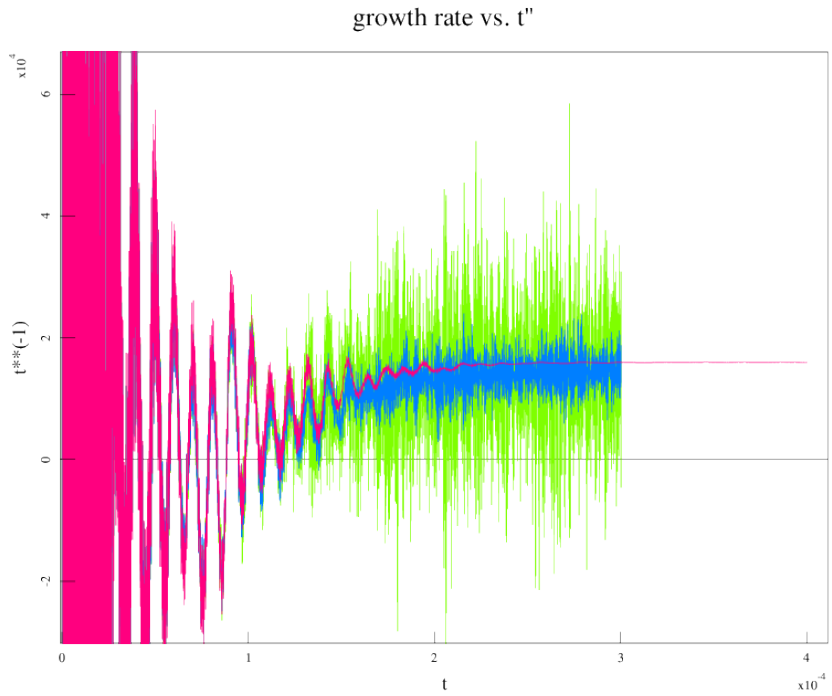


- Higher-energy particles = stronger stabilization.
- Difficult to ascertain γ's from PIC calculations.
- Improve fidelity by addressing high-energy RF tail.

Comparison of growth rates for continuum and PIC.

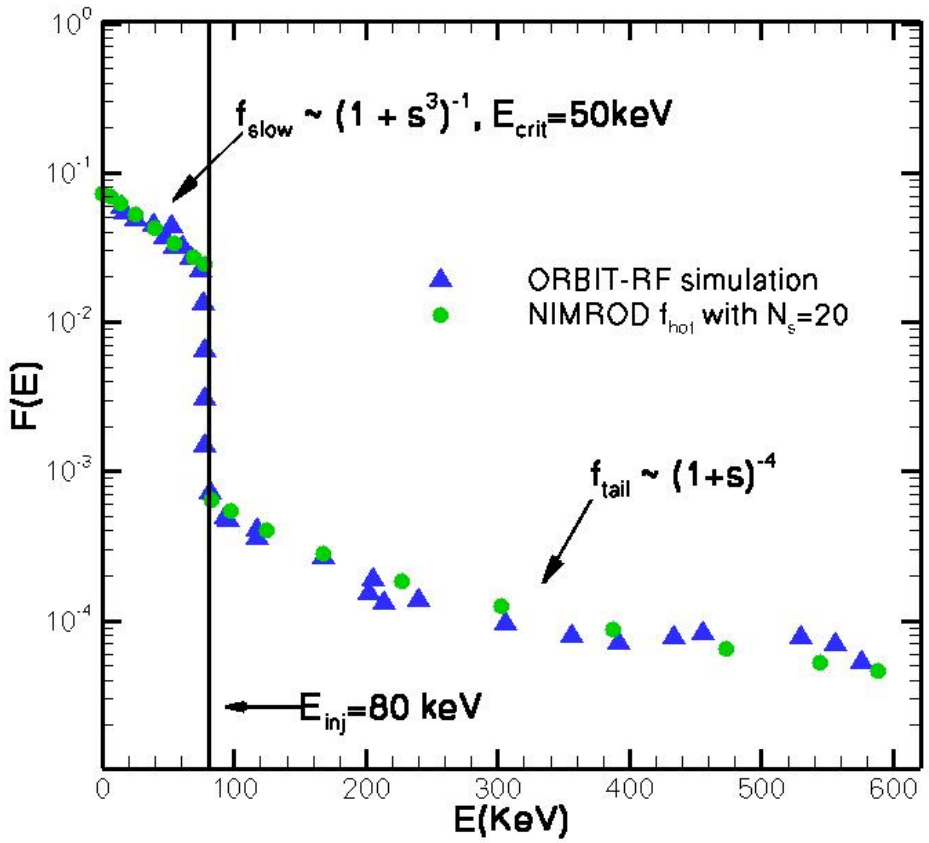
- Compare $\beta_f = 0.3$ cases from previous slide: continuum(pink), 2e6 particles(green), 8e6 particles(blue).





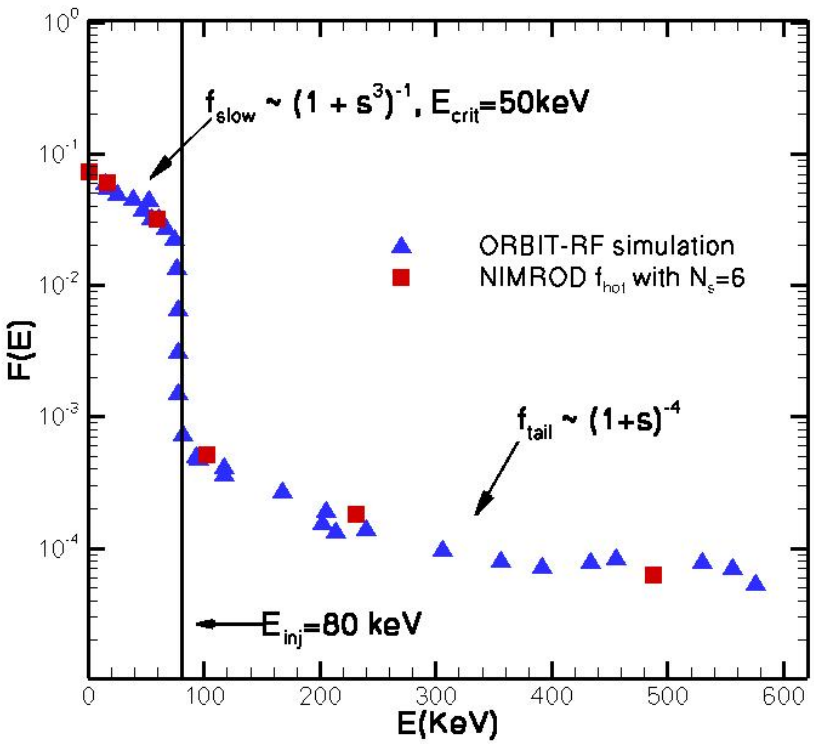
Improve fidelity by incorporating RF tail in continuum calculations.

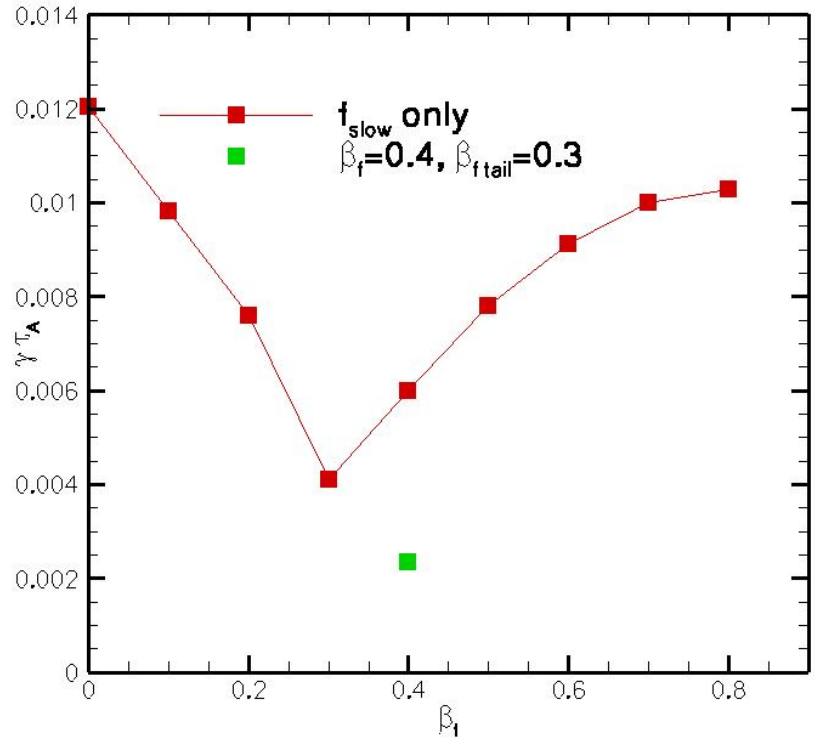
- Match energy dependence of ORBIT-RF simulations.
- Lowest-order energetic particle distribution $f_0 = f_{slow} + f_{tail}$.



Result from one low s resolution case.

- Continuing with higher resolution cases on Edison and Mira.





Conclusions

- Slowing-down-only growth rates insensitive to pitch-angle anisotropy in f_0.
- Continuum and PIC growth rates agree.
- Continuum simulations with RF tail underway for 6 equilibria in first giant sawtooth cycle.
- Remains to be seen if full stabilization requires anisotropic stress closure for thermal ions and/or two-fluid effects.