

Critical gradient and predictive models validations for EP profiles on NSTX

presented by N.N. Gorelenkov, PPPL
for PPPL SFG

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Crit. grad. (CGM); stiff transport; hybrid - theory/NOVA/ORBIT

Stiff transport - GA, UCSD

- *Mostly local computations by GYRO*
- *Validation for a drive and dominant dampings needed*
 - *Participation in ITPA? APS 2013 talk by E.Bass.*

Crit. grad. model - PPPL, IFS

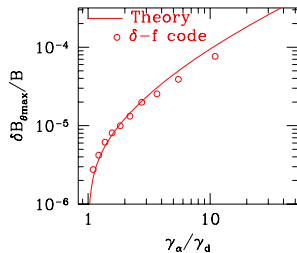
- *Full eigenmode computations*
- *V&V within ITPA? further needed.*
 - *Some dampings are perturbative: radiative, continuum (BP?)*
 - *Are they important for predictive modeling? pessimistic?*

Hybrid: TAEs/theory/guiding center orbits (NOVA/ORBIT) = LIGKA+HAGIS

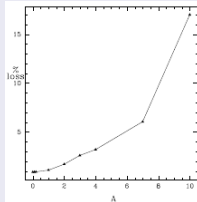
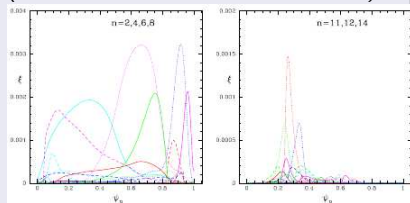
- *use NOVA and*
- *compute AE amplitudes using B&B theory*
 - *employ ORBIT to estimate losses, relaxation*
 - *multiple modes could be a problem*

Theory predicted *AE amplitudes can be used by HAGIS, ORBIT..

Verifications with B&B model (Berk, Breizman, Pekker, PPR'97) and ORBIT (Y.Chen, R.White, PoP'97) exist.



Made use to predict EP in ITER redistribution - consistent with CGM;
(N.Gorelenkov, R. White, PPCF'13)

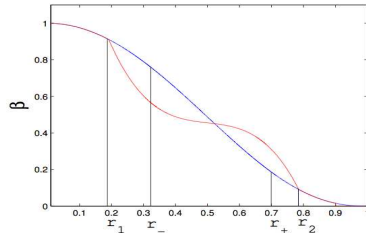
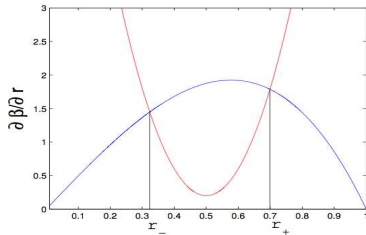


~ 1% loss

EP critical gradient from *AE instabilities

$$\frac{\partial \beta_{EPcr}}{\partial r} = -\frac{\gamma_{iL} + \gamma_{ecoll} + \gamma_{rad}}{\gamma_{EP}}, \quad \gamma_{EP} = \gamma_{EP}/(\partial \beta_{EP}/\partial r)$$

Three damping mechanisms are often dominant in DIII-D, ITER...:
ion Landau, electron collisional, radiative \rightarrow essentially nonlocal!! \Rightarrow 1.5D, 2D
should rely on global codes stability analysis.



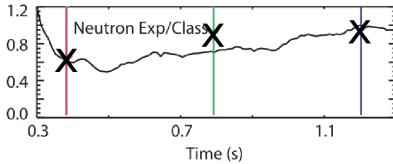
Use particle conservation law $\int_0^a r(\beta_{EP} - \beta_{EPrelax}) dr = 0$ to
compute **profile broadening** and EP losses.

limit $|\beta'_{EP}| \leq |\beta'_{EPcrit}|$ result in the relaxed EP profile $r_{\pm} \rightarrow r_{1,2}$

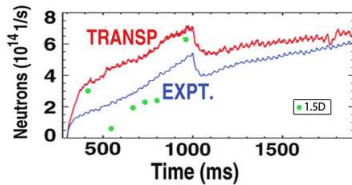
1.5D (CGM); 2D model; hybrid; how should we reduce the problem?

model	diffus.mechanism	accuracy	Valid.	readiness
crit. gradient	crit.thresh.	approx.	+ (-)	+
GYRO stiff transp.	crit.thresh.?	approx.	-	+/-
2D QL complete	QL diffusion	good	-	-
hybrid: theory/ORBIT	diffusion	good	+/-	+
initial value codes	diffusion	good	+/-	-

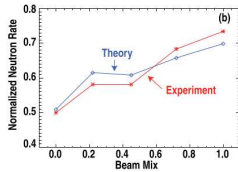
Approximate agreement can be claimed



(K. Ghantous et al. Phys. Plasmas'12)



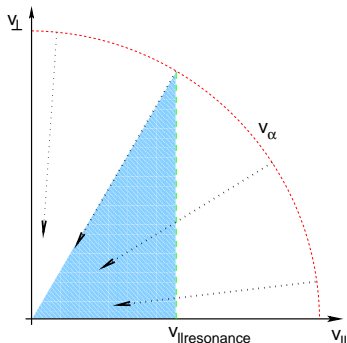
(K. Ghantous et al. Phys. Plasmas'12)



(W.W. Heidbrink et al. Nucl. Fusion'13)

- 1.5D critical gradient model is ready for applications on NSTX(-U)
 - offers rather limited accuracy
 - N.N. Gorelenkov, M. Podesta and graduate student 1st year Jeff Lestz for CGM validations.
- Hybrid models can be used for predictions.
- ORBIT+ NOVA don't have multimode WPI consistent model?
LIGKA + HAGIS do.

How much EP/alphas are affected?



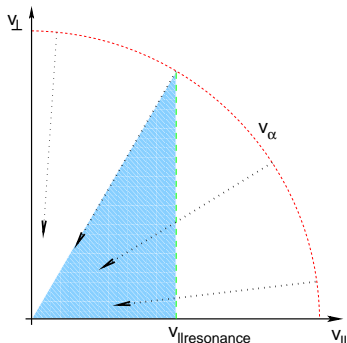
Ya. I. Kolesnichenko, NF'80

- expected max effect from instabilities with $v_{\parallel} = v_A \sim$ shaded area
- \Rightarrow address EP transport in a regime when *AE modes are not virulent
- fraction of effected alpha power

$$P_{\alpha res} = P_{\alpha} (v_{\alpha 0} - v_{\parallel}) v_{\parallel} / v_{\alpha 0}^2 \leq 25\%$$
- 0.5D part of the QL model

too optimistic? sideband resonances ignored: $v_{\parallel} = v_A / (1 \pm 2/\dots)$!!!
 need to look at in validations?

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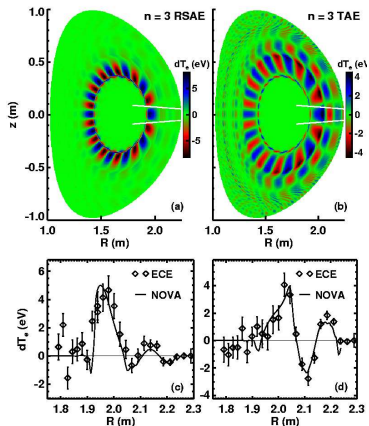
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Linear *AE theory is well developed

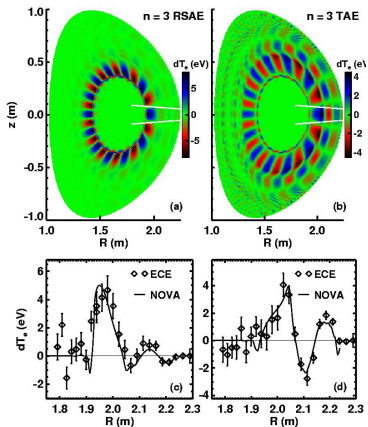


M. Van Zeeland, et.al.PRL06

DIII-D *AE validation XP:

- TAE/RSAEs computations are validated
- growth/damping rates are consistent
 - predictions (NSTX, TFTR - TAEs, ITER)
- \Rightarrow address EP transport in a regime when *AE modes are not virulent [S. Sharapov, IAEA12]

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