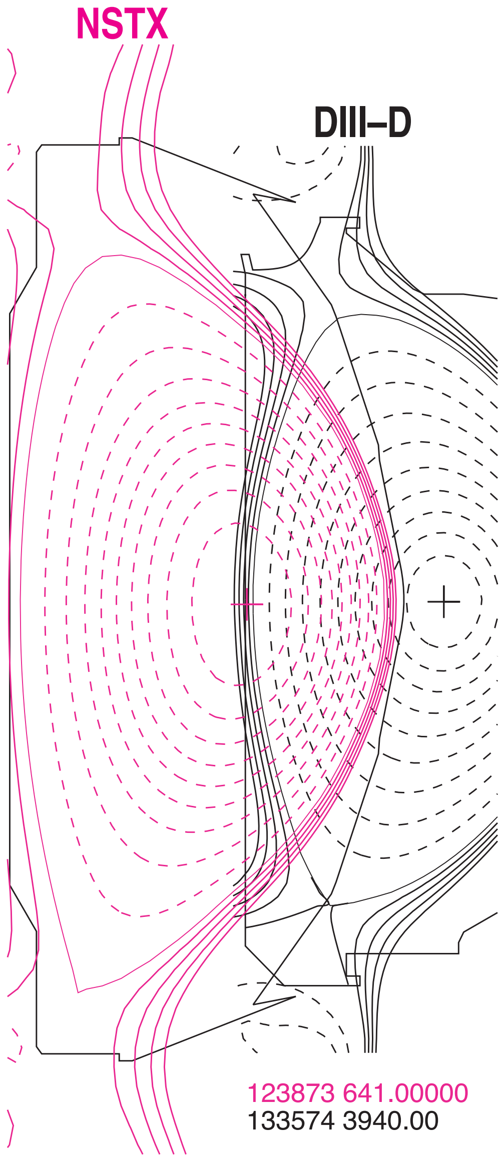
# XP914: NSTX and DIII–D Aspect Ratio Comparison of NTM Physics

**R.J. La Haye, General Atomics**
**R.J. Buttery, UKAEA Culham**
**S. Gerhardt, PPPL**

- **ELMing H-mode**
  - ★ with sawteeth
- **Cross-section similar**
- **Match $q_{95} \approx 7$**
- **Planned in 2009...**
  - ★ 0.75D in NSTX (2009)
    - – correlated with 0.75D in XP915
  - ★ 0.50D in DIII–D (2009)




NATIONAL FUSION FACILITY

017-09/RJL/jy

# $\Delta'$ and $w_{mar}$ are Key Parameters for NTMs

$$\frac{\tau_R}{r^2}\frac{dw}{dt} = \Delta' + \varepsilon^{1/2}\frac{L_q}{L_{pe}}\beta_{\theta e}\left[\frac{w}{w^2+w_d^2} - \frac{w_{pol}^2}{w^3}\right]$$

classical tearing index ($\Delta'$)

$\varepsilon = r/R$

$L_q \equiv q/(dq/dR)$

$L_{pe} \equiv -p_e/(dp_e/dR)$

$\beta_{\theta e} = \frac{2\mu_o p_e}{B_\theta^2}$

transport threshold ($w_d$)

polarization threshold ($w_{pol}$)

with curvature effects (GGJ) lumped into $\Delta'$ and $w_{marg}^2 \equiv 3(w_d^2 + w_{pol}^2)$

- **Transport threshold (R. Fitzpatrick 1995)**
  - ★ **transport along $\vec{B}$ in island is fast compared to perpendicular**
    - helical pressure perturbation washed out if perpendicular transport dominates

$$w_d \approx \left(\frac{L_s^2}{k_\theta^2}\frac{\chi_\perp}{\chi_{||}}\right)^{1/4}$$

- **Polarization threshold (H.R. Wilson et al., 1996)**
  - ★ **inertial effects are important in frame of E×B equilibrium flow**
    - polarization currents induced by island propagation are stabilizing for $\omega(\omega_{*i} - \omega) > 0$

$$w_{pol} \approx (L_q/L_p)^{1/2}\varepsilon^{1/2}\rho_{\theta i}$$

**... small compared to saturated islands typically observed**

# m/n = 2/1 Rampdown Results in 2007/8 Obtained One Good Shot Each in NSTX and DIII-D

- **NSTX 2007**
  - ★ **2/1 locked first**
    - fix is to add n = 3 EFC to "better" n = 1 EFC

- **NSTX 2008**
  - ★ **no 2/1 excited with Li**
    - fix is pre-Li
    - change shape, get frequent ELMs . . . but stay in H on rampdown

- **DIII-D 2008**
  - ★ **took 7 shots to develop target that worked**
    - moved on to low $q_{95}$ JET

# Appraising Saturated Marginal Island Width and Δ´ in NSTX for m/n = 2/1 Neclassical Tearing Modes

- **Helically perturbed bootstrap current balanced by negative Δ´ in MRE**

★ $\Delta' r \approx -\varepsilon_B^{1/2} (L_q/L_{pe}) (r/w_{sat}) \beta_{\theta e}$

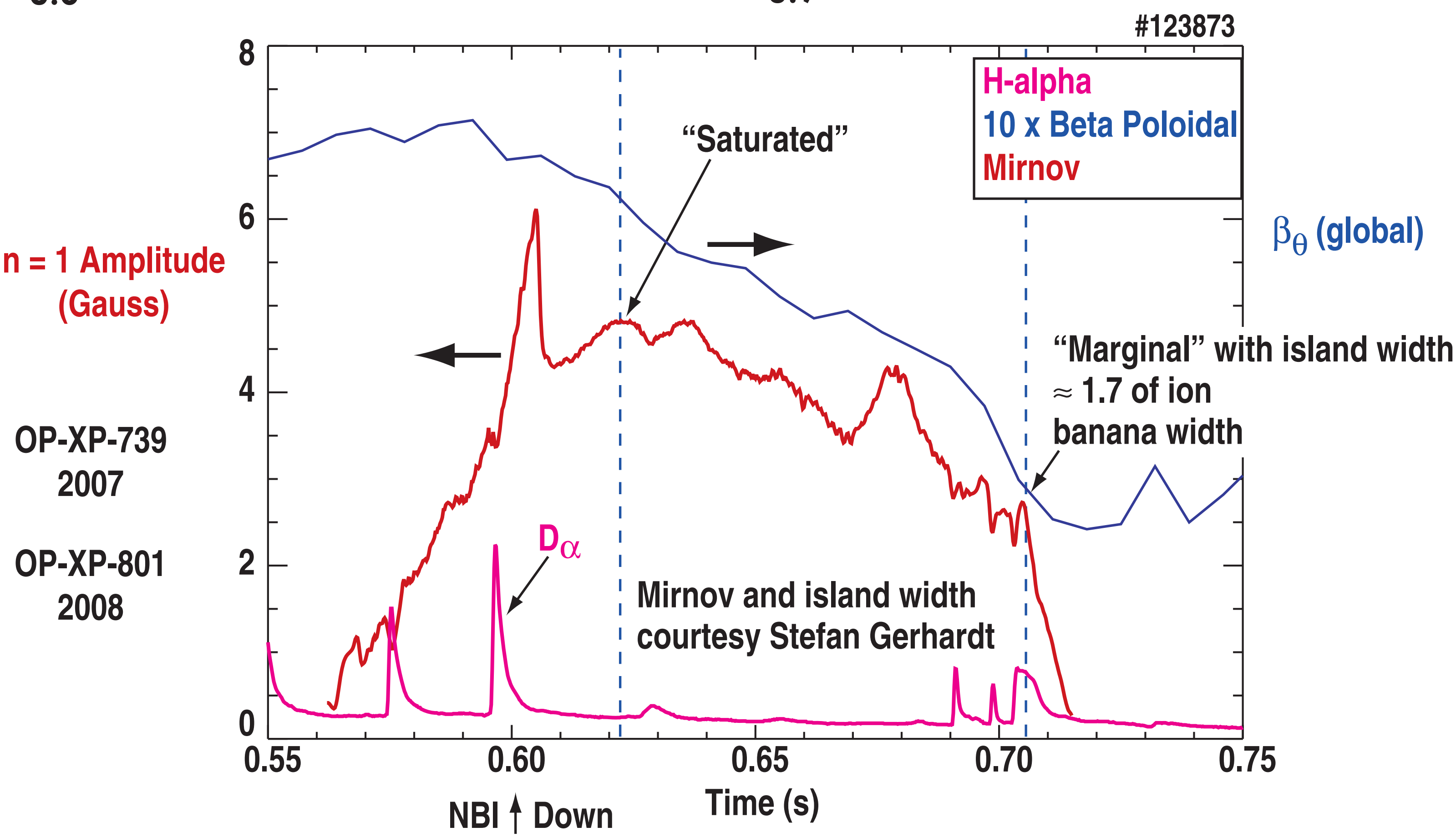
$\approx -0.65\ (0.083/0.158)\ (0.447/0.060)\ 0.22$

$\approx -0.6$

★ $\Delta' r \approx -(2/3)\ \varepsilon_B^{1/2} (L_q/L_{pe}) (r/w_{marg}) \beta_{\theta e}$

$\approx -0.667{*}0.65\ (0.128/0.081)(0.436/0.045)0.135$

$\approx -0.9$




017-09/RJL/jy

NSTX

# Appraising Saturated and Marginal Island Width and $\Delta'$ in DIII–D for m/n = 2/1 Neclassical Tearing Modes

- **Helically perturbed bootstrap current balanced by negative $\Delta'$ in MRE**

★ $\Delta' r \approx -\varepsilon^{1/2} (L_q/L_{pe}) (r/w_{sat}) \beta_{\theta e}$

$\approx -0.42\ (0.116/0.323)\ (0.308/0.074)\ 0.92$

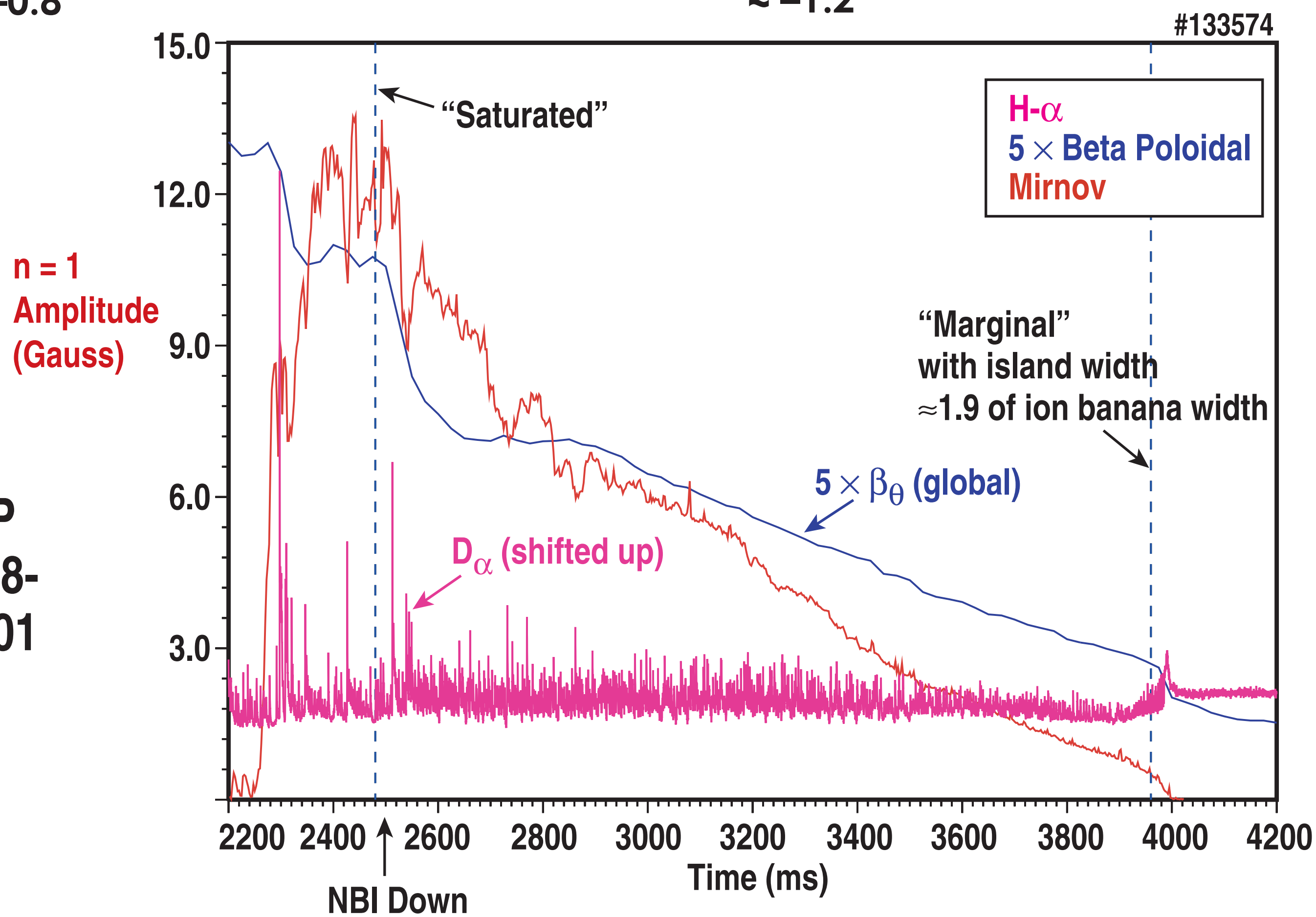
$\approx -0.8$

★ $\Delta' r \approx -(2/3)\, \varepsilon^{1/2} (L_q/L_{pe}) (r/w_{marg}) \beta_{\theta e}$

$\approx -0.667*0.41\ (0.165/0.169)(0.282/0.019)0.30$

$\approx -1.2$

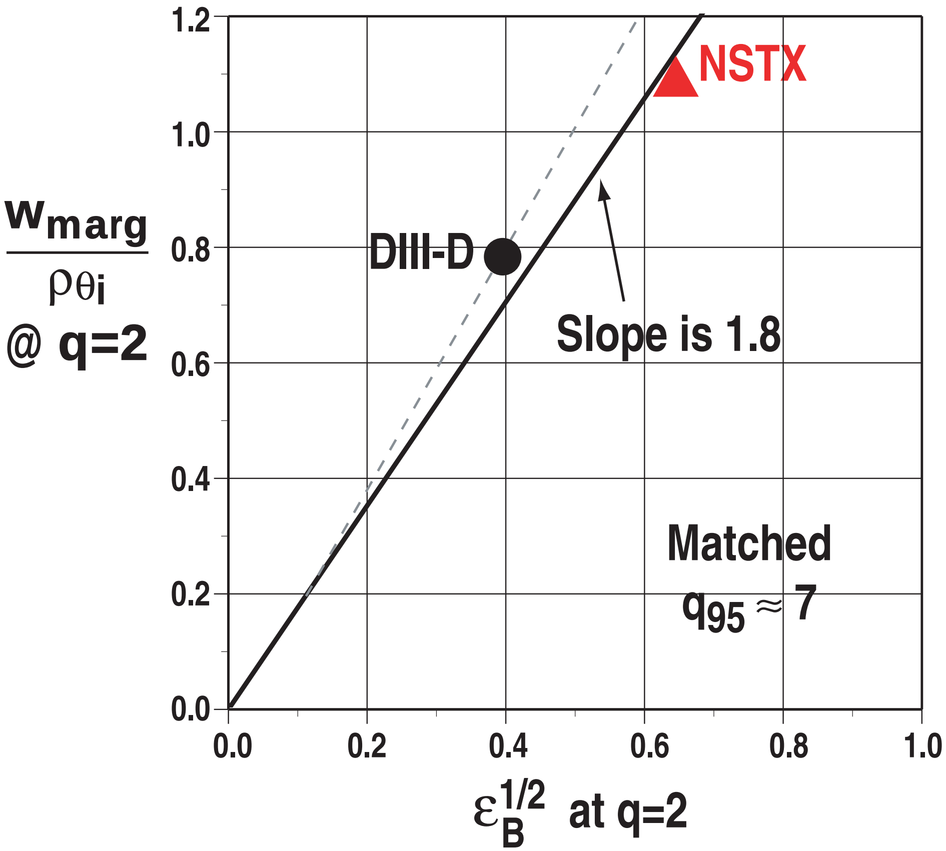
MP 2008-54-01




$q_{95} \approx 7$ for comparison to NSTX

# Preliminary Results on DIII–D and NSTX m/n = 2/1 NTM Island Marginal Stability Show Consistency

- Marginal island width a few times the ion banana width at q = 2
- $\Delta'(w_{marg})r \approx -1$ noting that w, flow shear and $\beta$ are all "small"




- Followup Experiments Need
  - ★ more cases for reproducibility
  - ★ vary rotation at onset (also n=1 EFC)
    - ... and saturation?
    - ... probably need full co-rot at marginal point
      - to avoid locking
  - ★ input for ITPA 2009
    - ... MDC-4 aspect ratio
    - ... MDC-14 rot effects

# XP914 Deliverables (with DIII–D Results)

- **Scaling of marginal island width with aspect ratio**
  - ★ **comparison to $w_d$ and $w_{pol}$ models**

- **Effective $\Delta'$ ($w_{marg}$) $r_s$ including $D_R$ effect if any**
  - ★ **comparison of marginal case to saturated case**
    - – effect of rotation (& it's shear) on saturated case

# For Slowly Evolving "Saturated" Magnetic Islands, the LHS of the MRE is Zero

- **Helically perturbed bootstrap current balanced by negative $\Delta'$**
  - ★ **for islands sustained beyond threshold island width**

$$0 \approx \Delta' + \varepsilon^{1/2} \frac{L_q}{L_{pe}} \frac{\beta_{\theta e}}{w}$$

**(Note $\Delta'$ includes $D_R$ term)**

- **The classical tearing stability index $\Delta'$ can be or have...**
  - ★ **linear function of island width (R. White, 1976)**
  - ★ **linear function of flow shear (R. Buttery, 2008)**
  - ★ **"pole" at ideal kink beta limit (D.P. Brennan, 2007)**

$$\Delta' r \approx C_o - C_w w + C_2 \left(\frac{-d\omega_\phi}{dr}\right) L_s \tau_A + C_3 \left[1 - \left(\frac{\pi\beta}{\beta_{kink}}\right) \cot\left(\frac{\pi\beta}{\beta_{kink}}\right)\right]$$

# For "Marginal" Magnetic Islands, the LHS of the MRE is Also Zero

- **Helically perturbed bootstrap current balanced by negative $\Delta'$**
  - ★ for islands at the "marginal" width, $\dot{w} \leq 0$ for all w

$$0 \approx \Delta' + \varepsilon^{1/2} \frac{L_q}{L_{pe}} \frac{\beta_{\theta e}}{w_{marg}} \left[ \frac{w_{marg}^2}{w_{marg}^2 + w_d^2} - \frac{w_{pol}^2}{w_{marg}^2} \right]$$

$$\cdots\ 0 \approx \Delta' + \frac{1}{2} \varepsilon^{1/2} \frac{L_q}{L_{pe}} \frac{\beta_{\theta e}}{w_{marg}} \quad \text{for } w_{pol}^2 \ll w_d^2$$

– $w_{marg} = w_d$

$$\cdots\ 0 \approx \Delta' + \frac{2}{3} \varepsilon^{1/2} \frac{L_q}{L_{pe}} \frac{\beta_{\theta e}}{w_{marg}} \quad \text{for } w_d^2 \ll w_{pol}^2$$

– $w_{marg} = \sqrt{3}\, w_{pol}$