Role of Pedestal in Hybrid Discharges in DIII-D

by

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with

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DIII-D NATIONAL FUSION FACILITY

GENERAL ATOMICS

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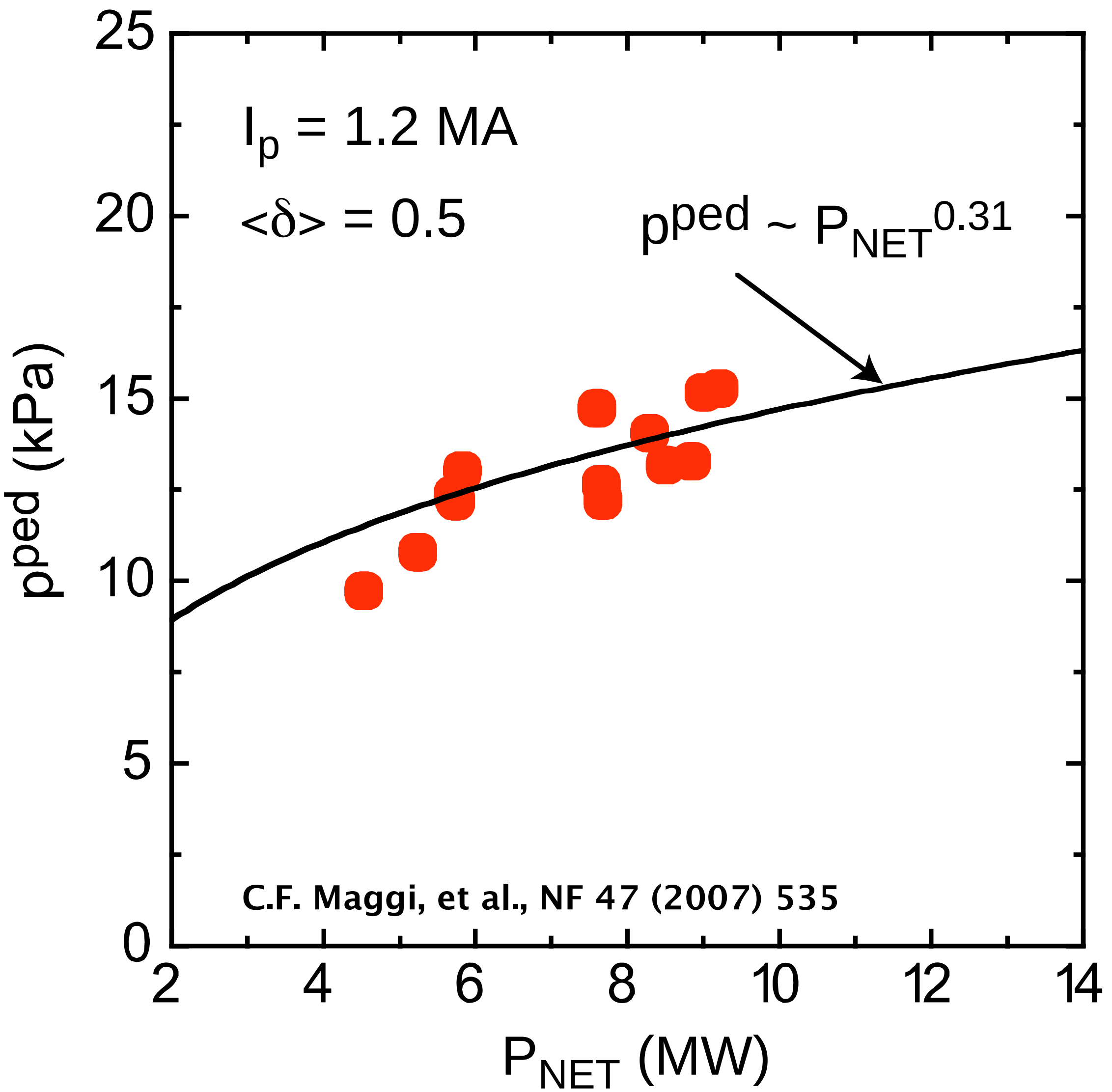
Does the H-mode Pedestal Play an Important Role in the Physics of the Hybrid Discharge?

- **Hybrid discharges in DIII-D provide better performance than conventional ELMing H-mode discharges**
  - H89 factors typically greater than 2
  - β_N values typically in range of 2 - 3.5
- **Hybrid is obtained by careful tailoring of q profile early in discharge**
  - Thus, q-profile may control some of the physics
- **It is also plausible that pedestal physics plays a role**
- **Pedestal characteristics in hybrids have been examined**
  - Does pedestal pressure height increase as heating power is increased?
  - Alternatively, does pedestal beta increase as core beta increases?
  - What is effect of plasma shape (triangularity) on pedestal and on core?

Initial Survey Showed That There Is a Trend for Pedestal Pressure to Increase With Heating Power

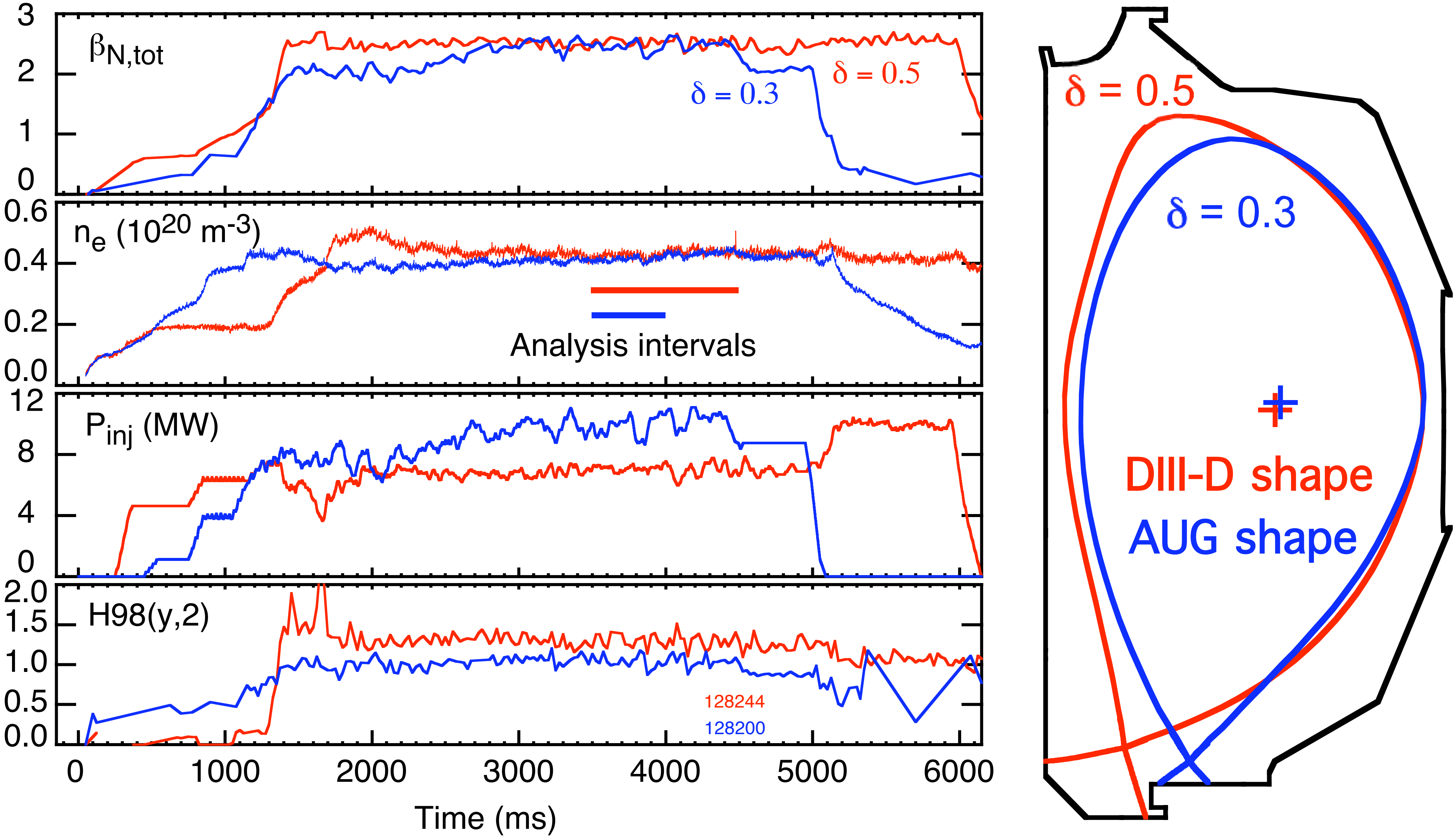


- Plasmas had same shape, current, field and density
- Pedestal pressure (p^{ped}) includes ions, electrons and carbon
- Pedestal pressure roughly follows power dependence of IPB98(y,2) scaling
- Improved core confinement also observed at high power
- Dataset assembled from data-mining; discharges span several years

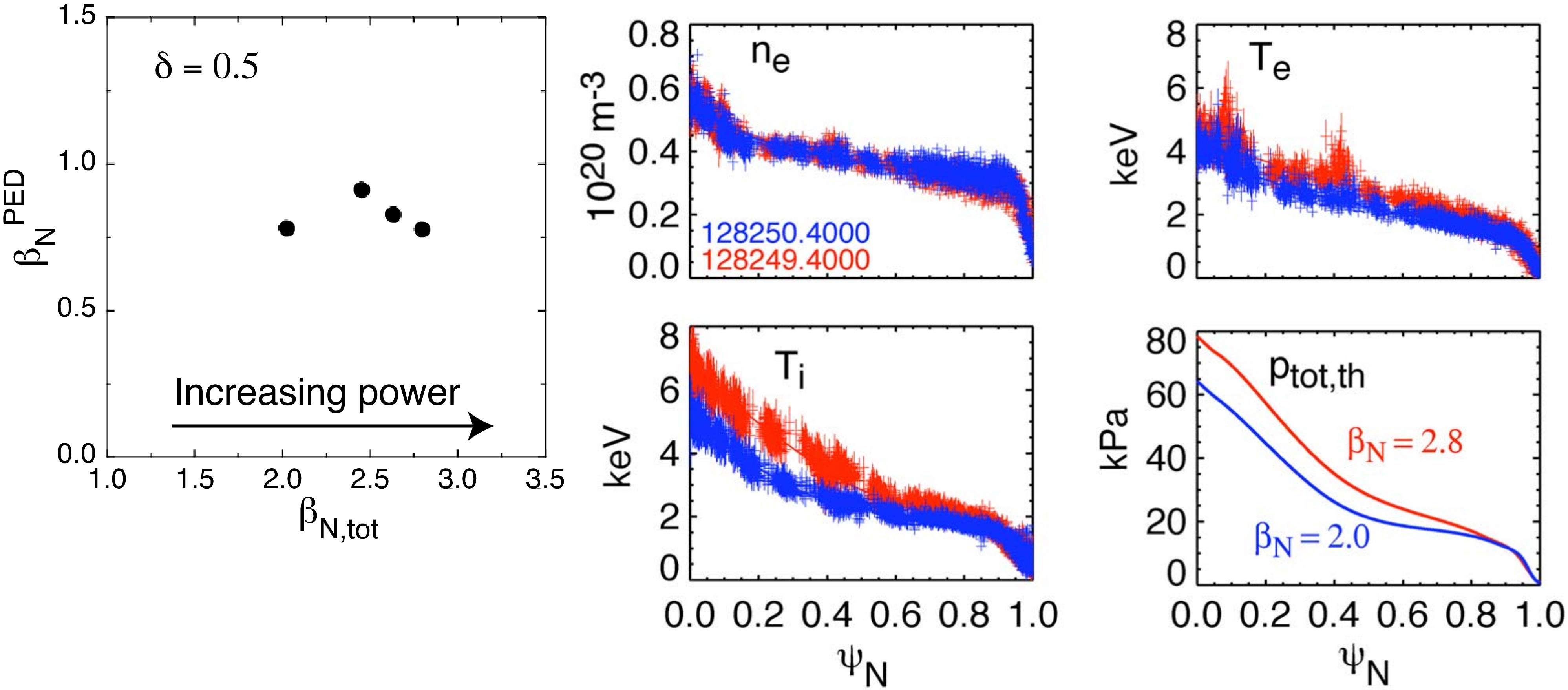
New Data Have Been Obtained for Power Scans in Hybrids in 2 Shapes – Moderate and High Triangularity

- **Experiment led by C. Maggi of IPP-Garching and performed as joint ITPA experiment**
- **Observed unexpected trend - pedestal pressure did not increase with power in high triangularity shape**
  - This result is atypical and not understood
  - However, core pressure did increase - plasma was not perfectly stiff
  - Thus, core physics must be invoked to explain the results - possibly increased ExB shear or Ti/Te
- **Higher triangularity provided a wider and higher pressure pedestal**
- **Higher triangularity discharges had higher H98(y,2) confinement enhancement factor**
  - Partly a pedestal effect; possibly some core effect also
- **Higher triangularity discharges had ELMs with longer periods and pedestals which recovered more fully from ELM crashes**

Long Steady-state Discharges Were Produced in Two Shapes



Power (Beta) Scan at High Triangularity Shows That Profiles Are Not Perfectly "Stiff"



- Core pressure increases with power even though pedestal pressure does not
- Core effect - perhaps increased rotation (ExB) shear or T_i/T_e ratio allow core pressure to increase without change of pedestal pressure

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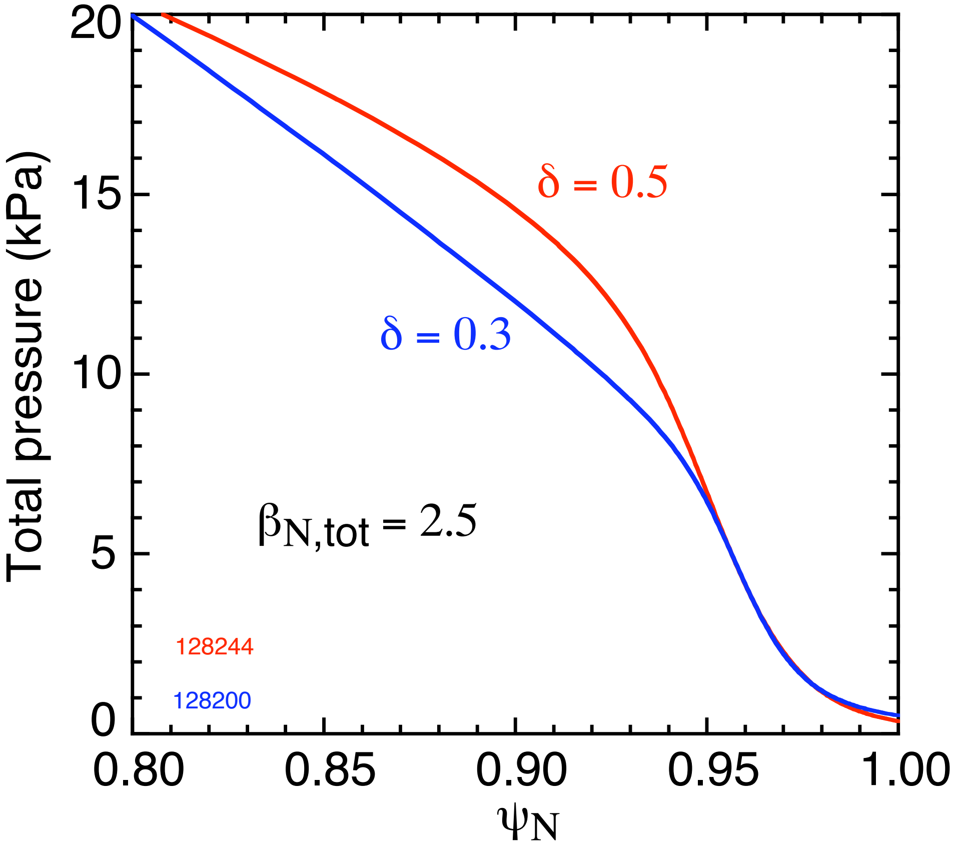
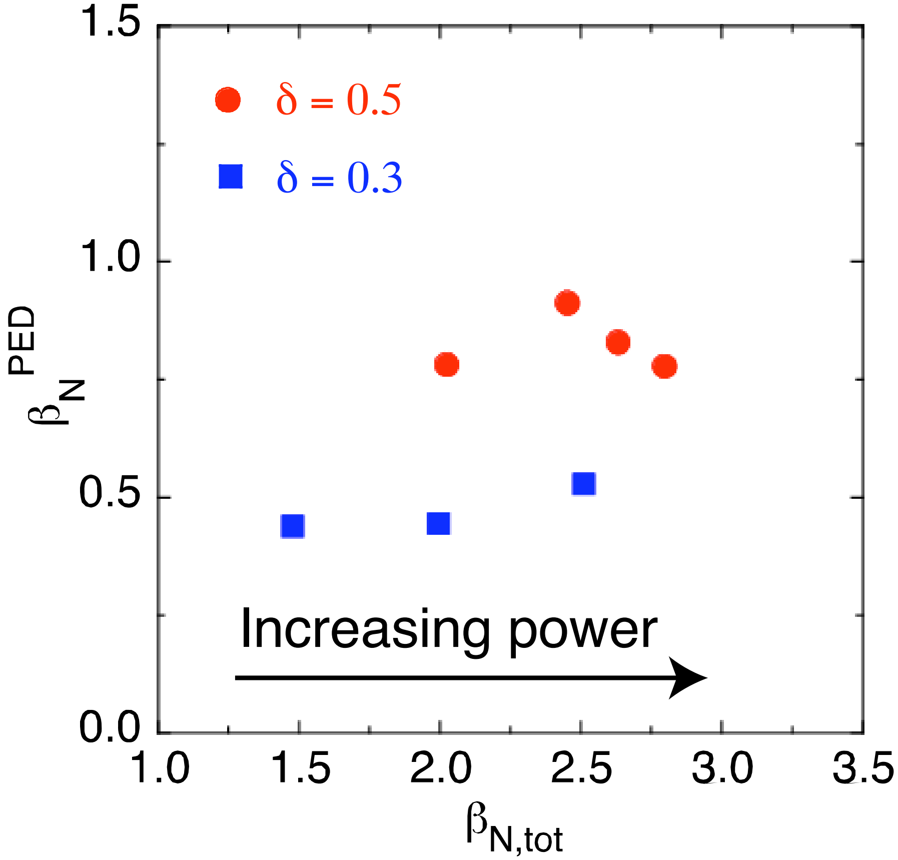
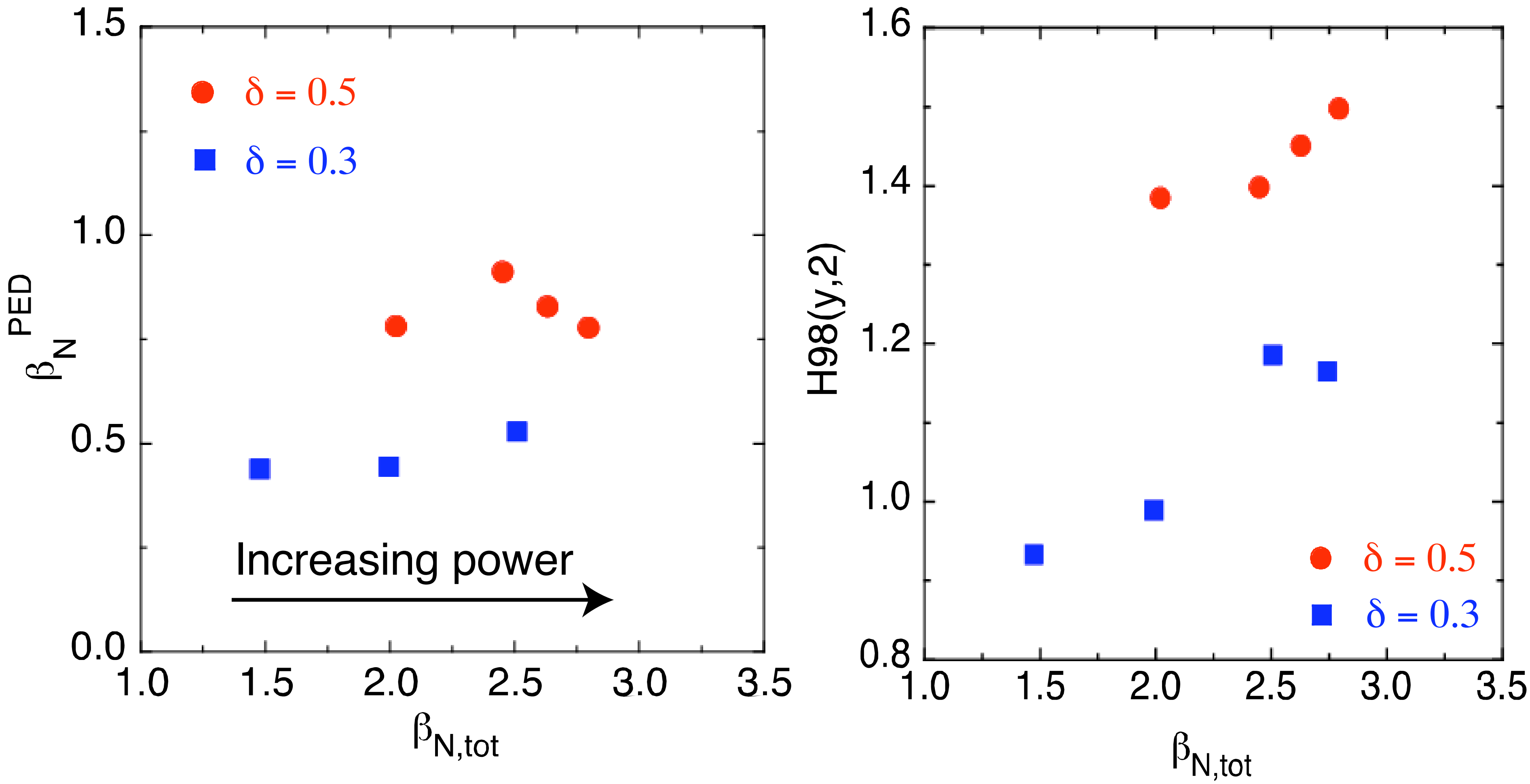
Higher δ Shape Has Wider and Higher Pressure Pedestal for a Given $\beta_{N,tot}$





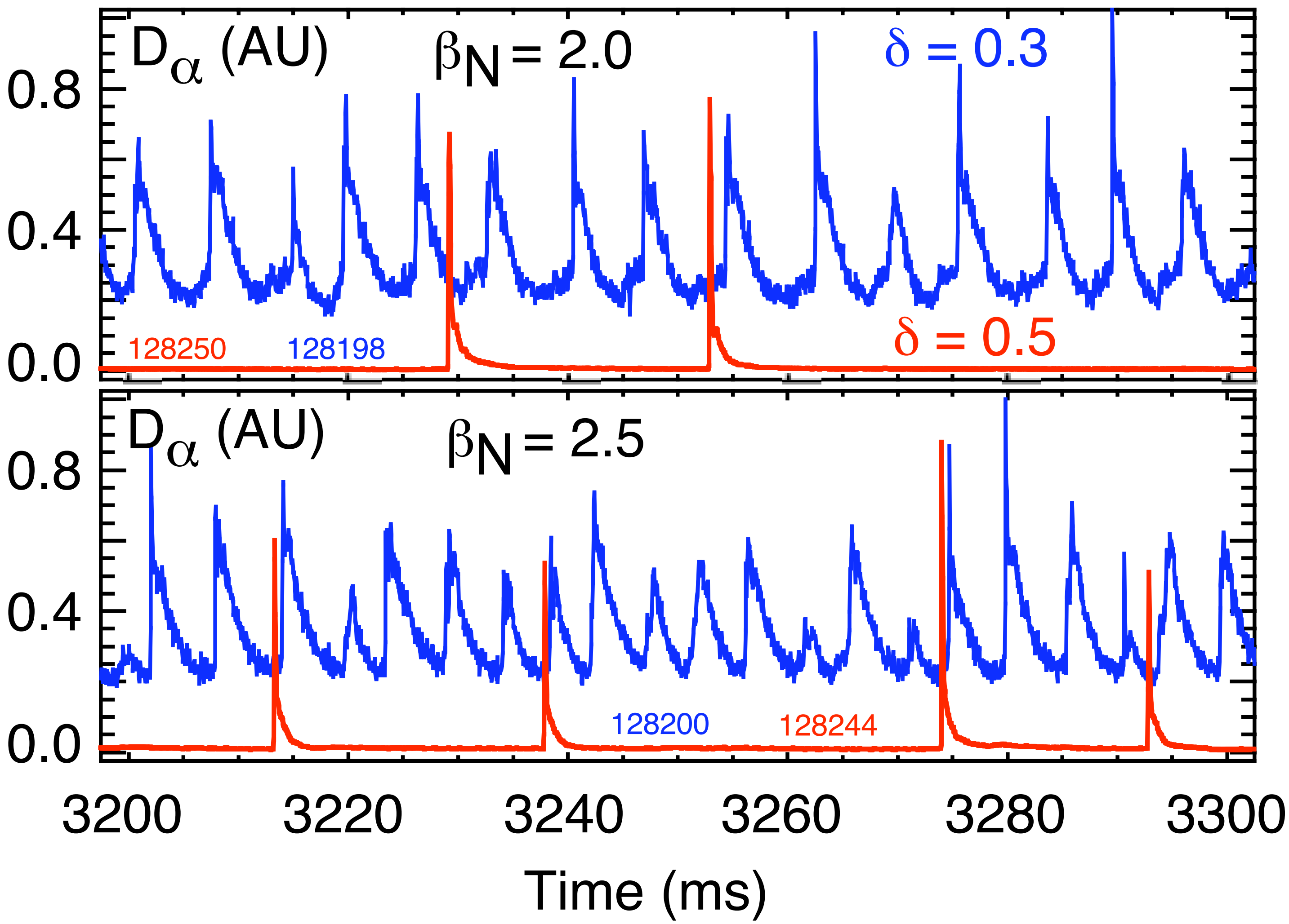
- **These results also imply that lower triangularity shape has higher fraction of energy in core**
  - Another indication that core physics is playing a role in performance

For Fixed $\beta_{N,tot}$, Higher δ Shape Has Higher Normalized Confinement



- **Higher pedestal at higher triangularity may lead to higher H-factor due to stiffness of profiles**

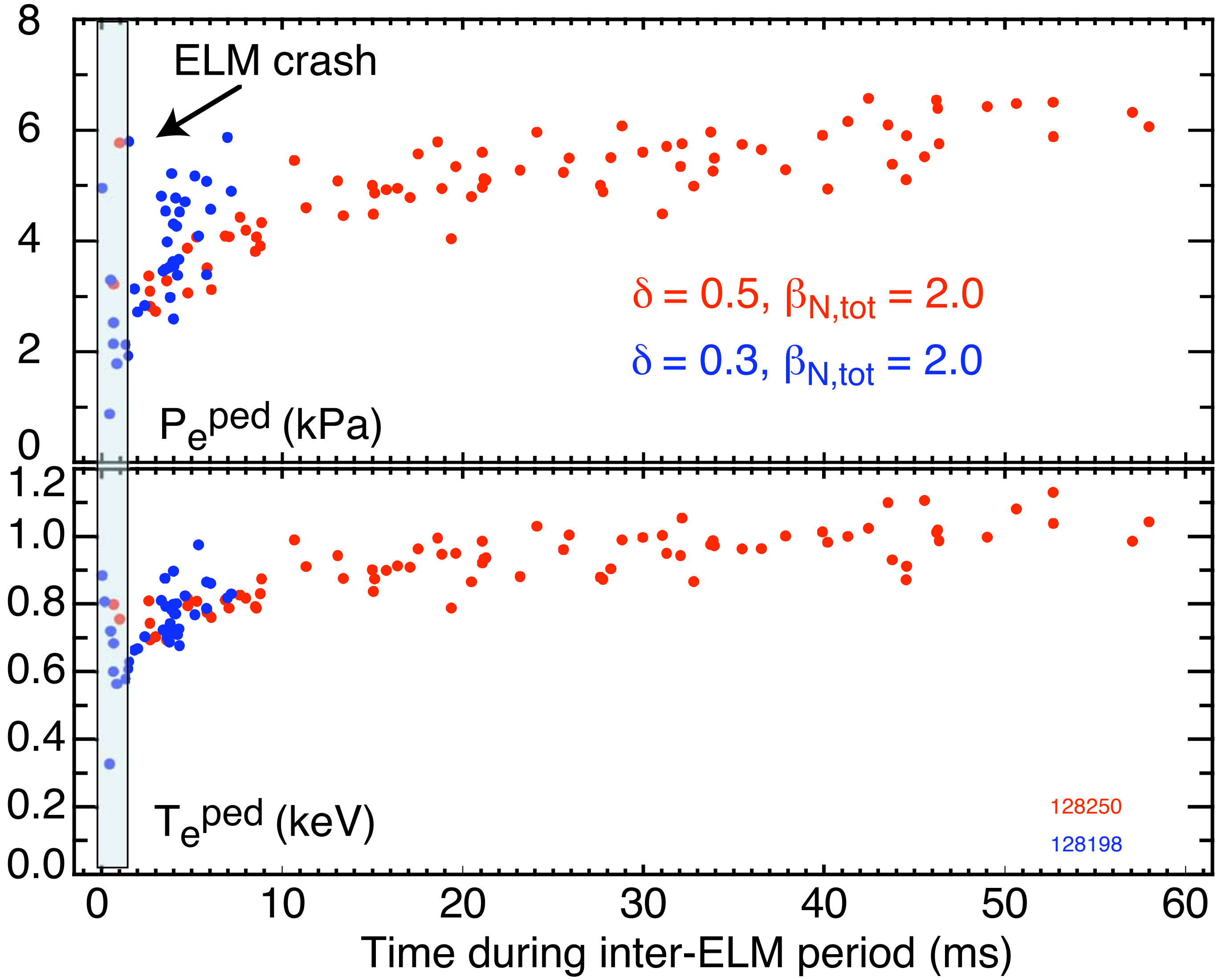
ELM Frequency Is Much Lower for Higher Triangularity Discharges



Average ped height is higher for lower frequency, larger ELMs - as seen in other studies

For sufficiently stiff core profiles, we expect higher stored energy for higher average pedestal - also seen in other studies

For Lower Frequency ELMs, Pedestal Height Recovers More Completely After ELM Crash



Data assembled from many ELM cycles to show pedestal evolution between ELMs

Higher δ plasma has higher time-averaged pedestal

If core is "stiff" to some degree, higher average pedestal would provide higher H-factor

Role of Pedestal in DIII-D Hybrid Performance

- **Plasma shape can be used to improve hybrid performance through pedestal effects**
  - Higher triangularity helps provide higher pedestal pressure
  - May confer a benefit in confinement quality (H-factor) and thus reduce power requirement to achieve a given global β
- **Higher pedestals are correlated with lower ELM frequencies**
  - Lower ELM frequency may allow more complete recovery of pedestal after an ELM and thus higher time-averaged pedestal pressure
  - Physics relation between high δ and low ELM frequency not clear
- **Hybrids exhibit some confinement enhancements which cannot be attributed to pedestal**
  - Core stored energy can increase even when pedestal pressure does not increase with increased power
  - Thus, some of the performance is due to core physics
  - GLF23 analysis has shown ExB shear is important in hybrids