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ELMs and the H-mode Pedestal in NSTX

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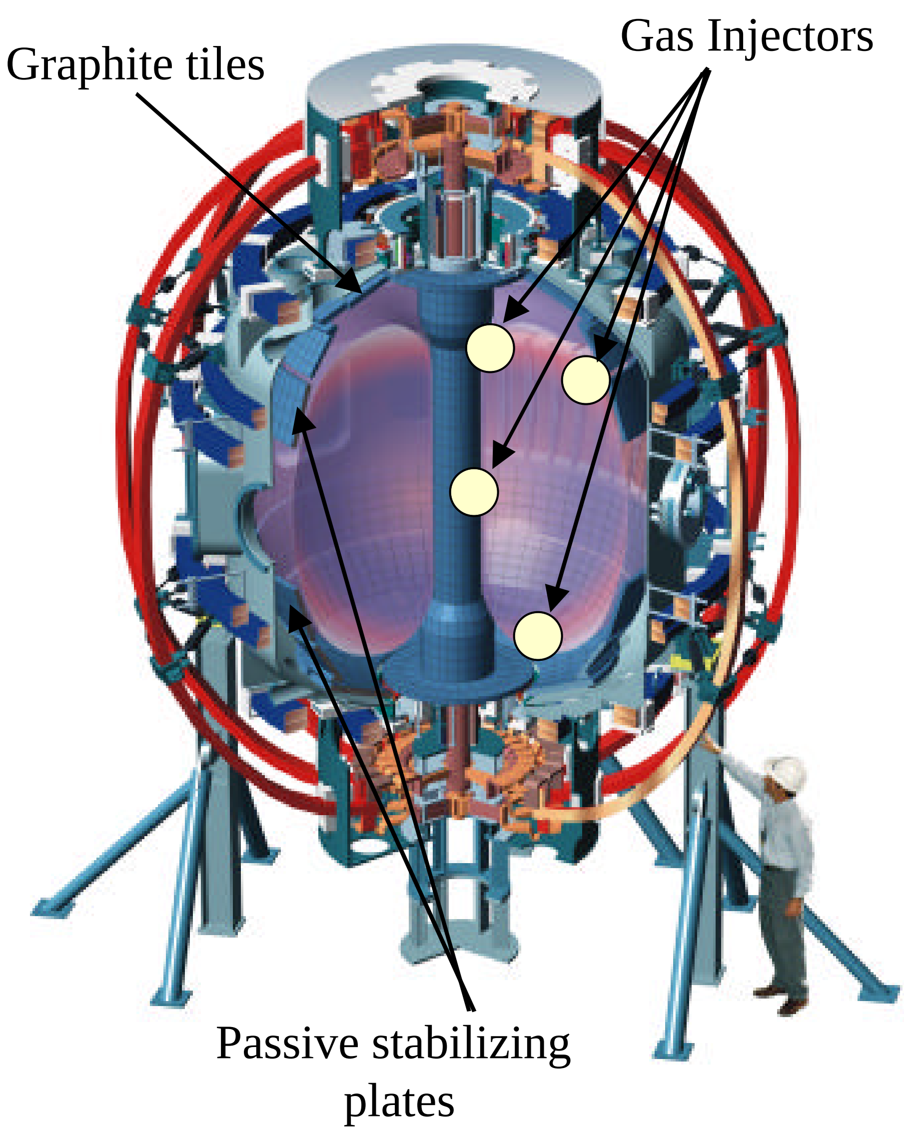
Abstract

Edge localized modes (ELMs) are routinely observed during H-mode operation in NSTX. A systematic experiment to explore the dependence of ELM characteristics on density/fueling, number of X-points, NBI power, magnetic balance, and plasma-wall gaps was performed. We find that single-nulls have either small ELM-like oscillations or very large events which can eject up to 70% of the pedestal stored energy. We also find that the ELMs in double-nulls have characteristics similar to ones from conventional aspect ratio, with a pedestal energy loss fraction typically less than 10%, and frequency in the 100-200 Hz range. A modified hyperbolic tangent fitting function is applied to Thomson scattering profiles to obtain the pedestal stored energy. These fits show that the NSTX pedestal contains typically 0.25 - 0.33 of the total stored energy.

NSTX Explores Low Aspect Ratio (A=R/a) physics regime



Parameters	Design	Achieved
Major Radius	0.85m	$A \geq 1.27$
Minor Radius	0.67m	
Plasma Current	1MA	1.5MA
Toroidal Field	0.6T	0.6T
Heating and Current Drive		
NBI (100keV)	5MW	7 MW
RF (30MHz)	6MW	6 MW

Wall Conditioning:

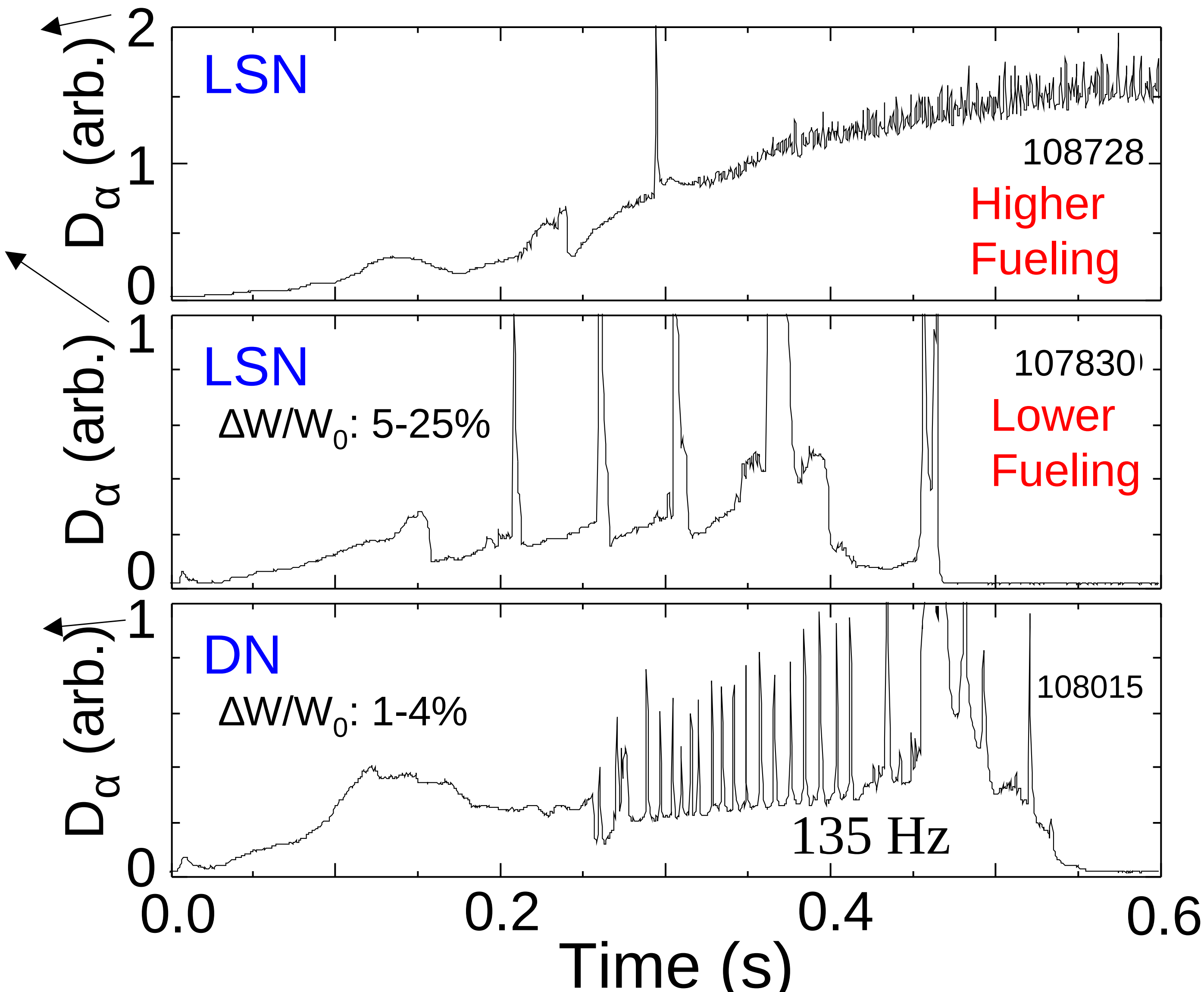
350 deg. bakeout of graphite tiles

Regular boronization (~3 weeks)

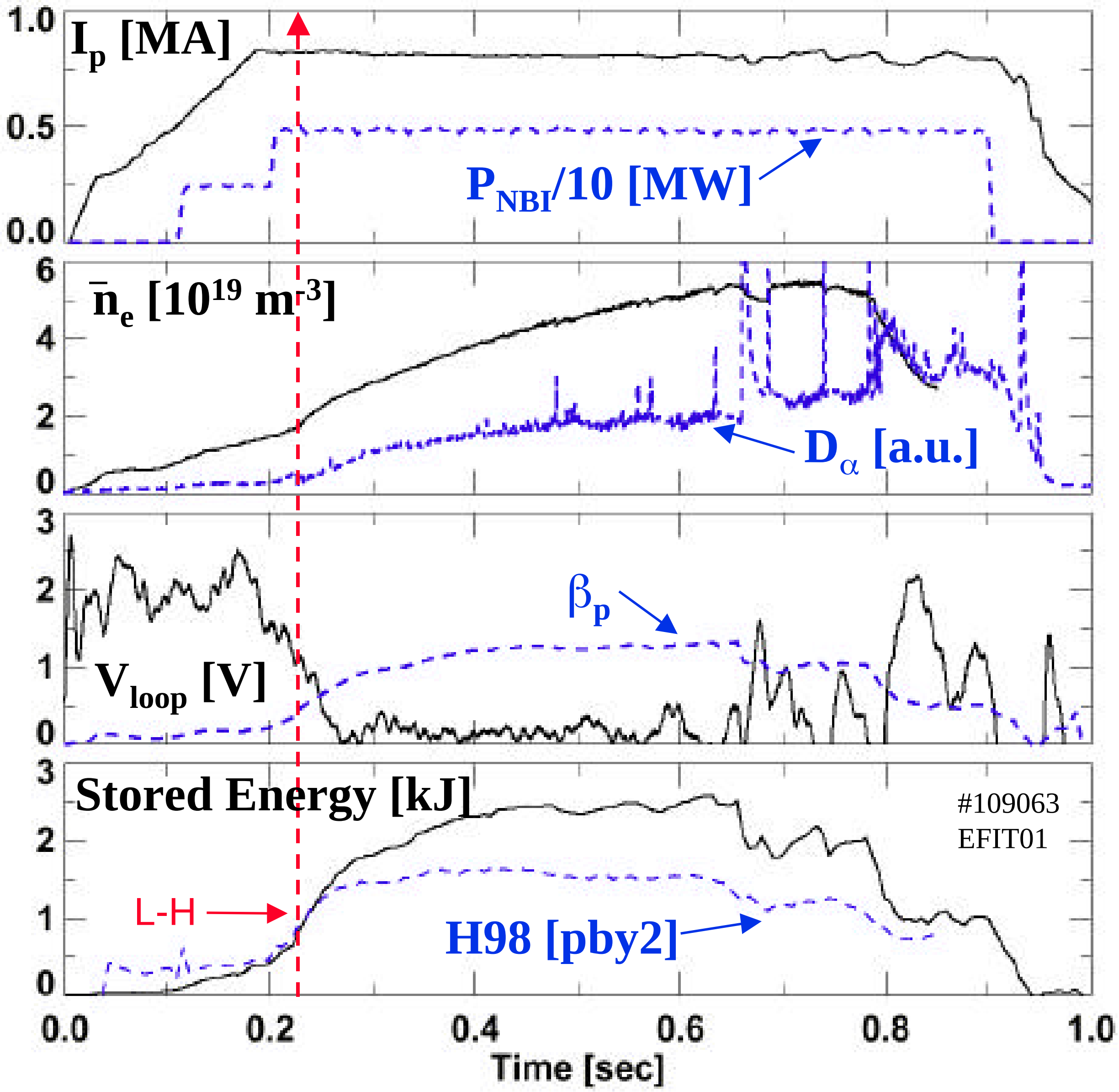
Helium Glow between discharges

Center stack gas injection

Wide variety of ELMS observed in NSTX



Long pulse H-modes are mostly ELM-free and have D_α like FDR H-mode in PDX and EDA H-mode in C-MOD



Dedicated ELM characterization experiments just begun

- Dedicated scans
  - ✱ Density (fueling rate) - DN, LSN
  - ✱ NBI power scan - DN
  - ✱ Magnetic balance scan (drsep from EFIT) - DN
  - ✱ Inner gap scan - LSN

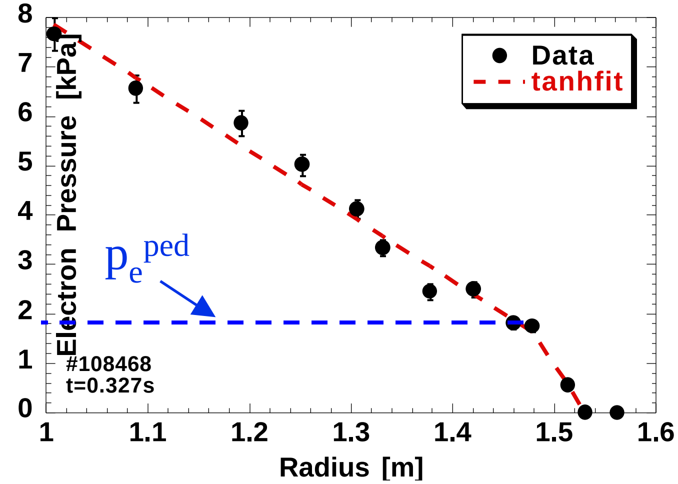
- **Marked differences in lower single-null and double-nulls**

ELM analysis uses data from multiple diagnostics

- ELM times from time derivative of D_α
- ELM frequency from period between ELM times (from D_α)
- ELM energy loss from fast EFIT analysis (1ms resolution, using magnetics data only)
- Pedestal energy from modified tanhfit to Thomson pressure profile (20 points spatial, 60 Hz)

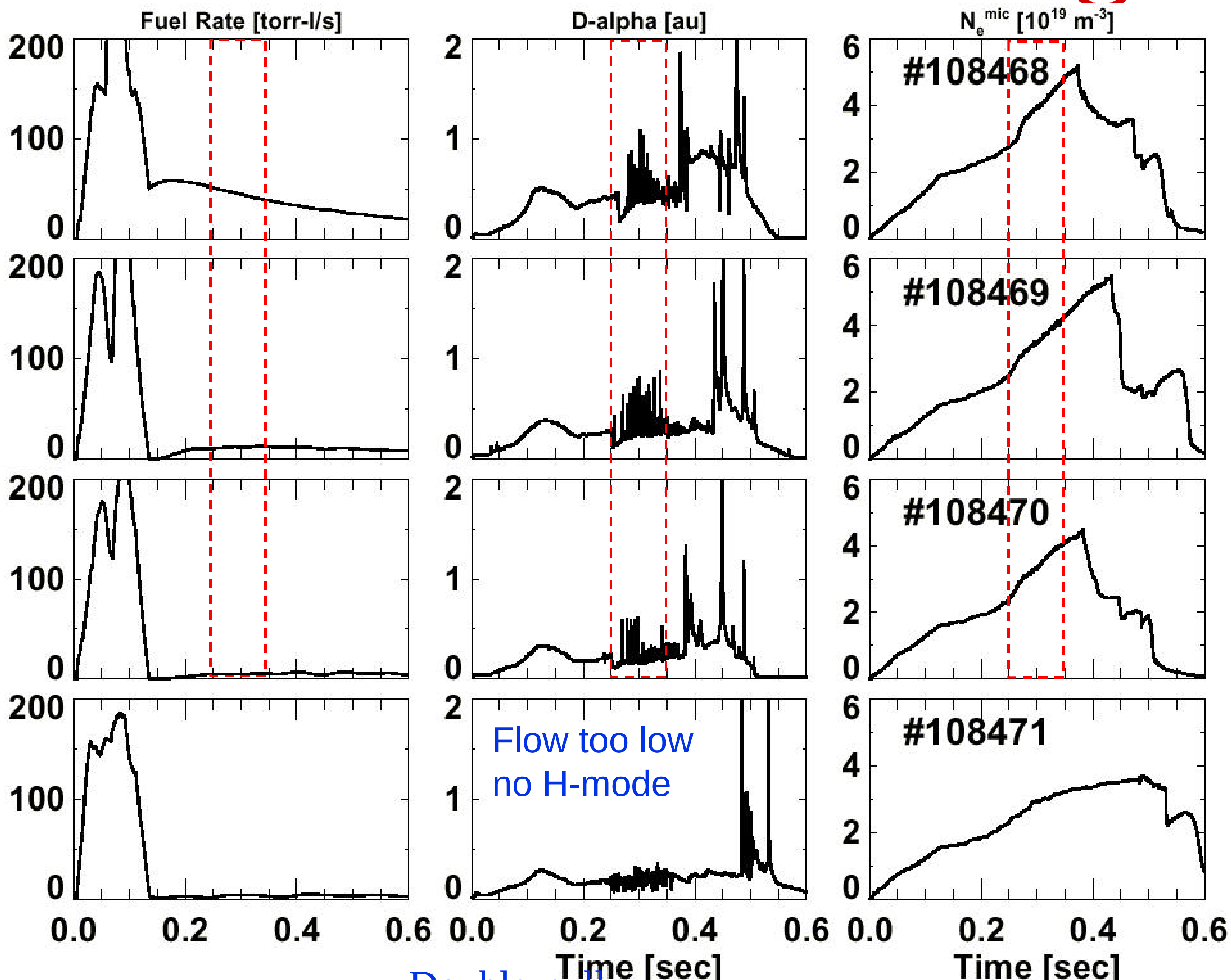
$$W_{ped}=0.92*\mathrm{volume}_{EFIT}*\ p_e^{ped}*3.0$$

(Cordey IAEA 2002)



- Pedestal energy fraction from $(\Delta W/W_0)*(W_0/W_{ped})$, where W_{ped} from nearest time point with good tanhfit

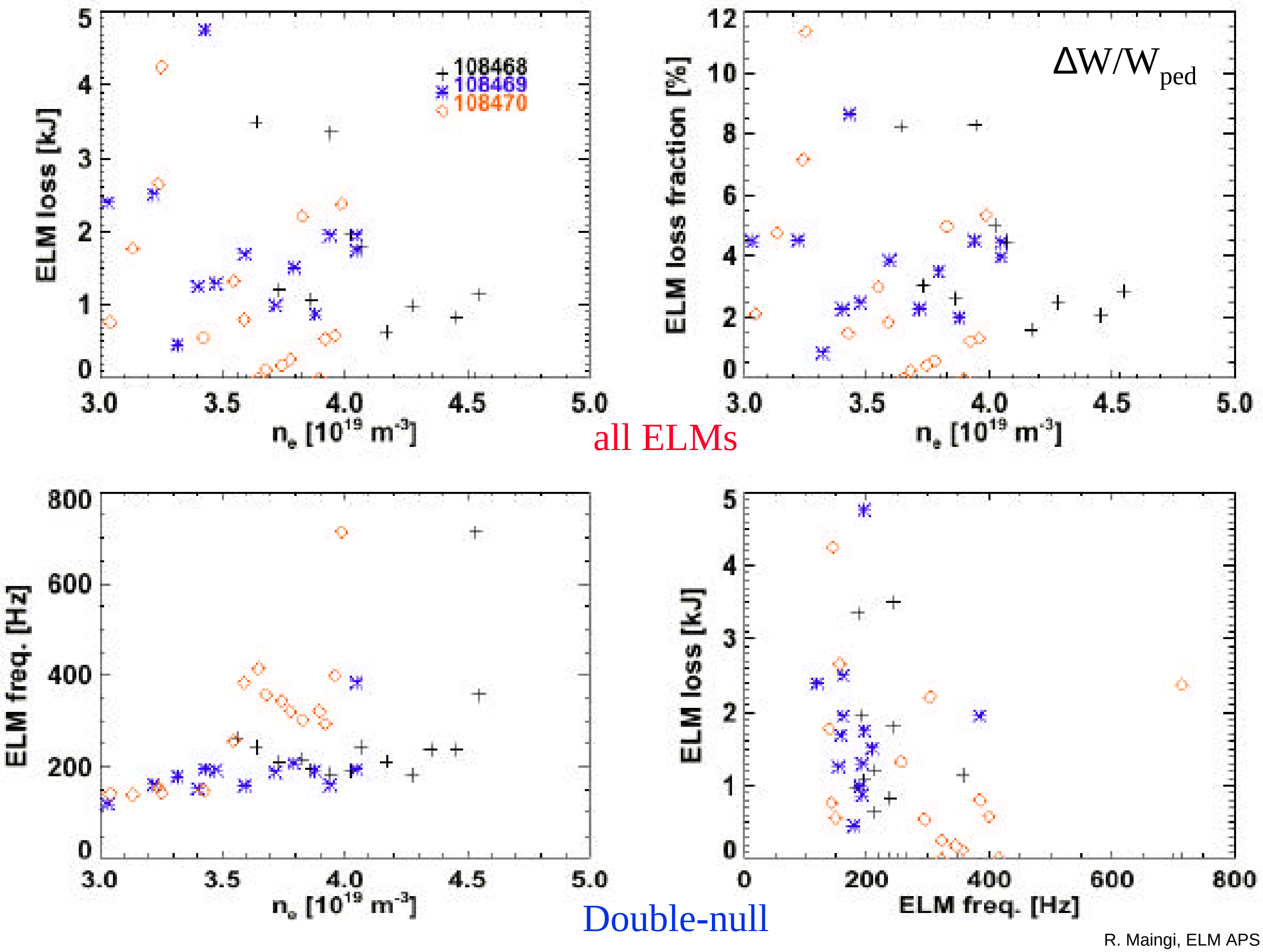
Density ramps throughout discharge and affects ELMs modestly



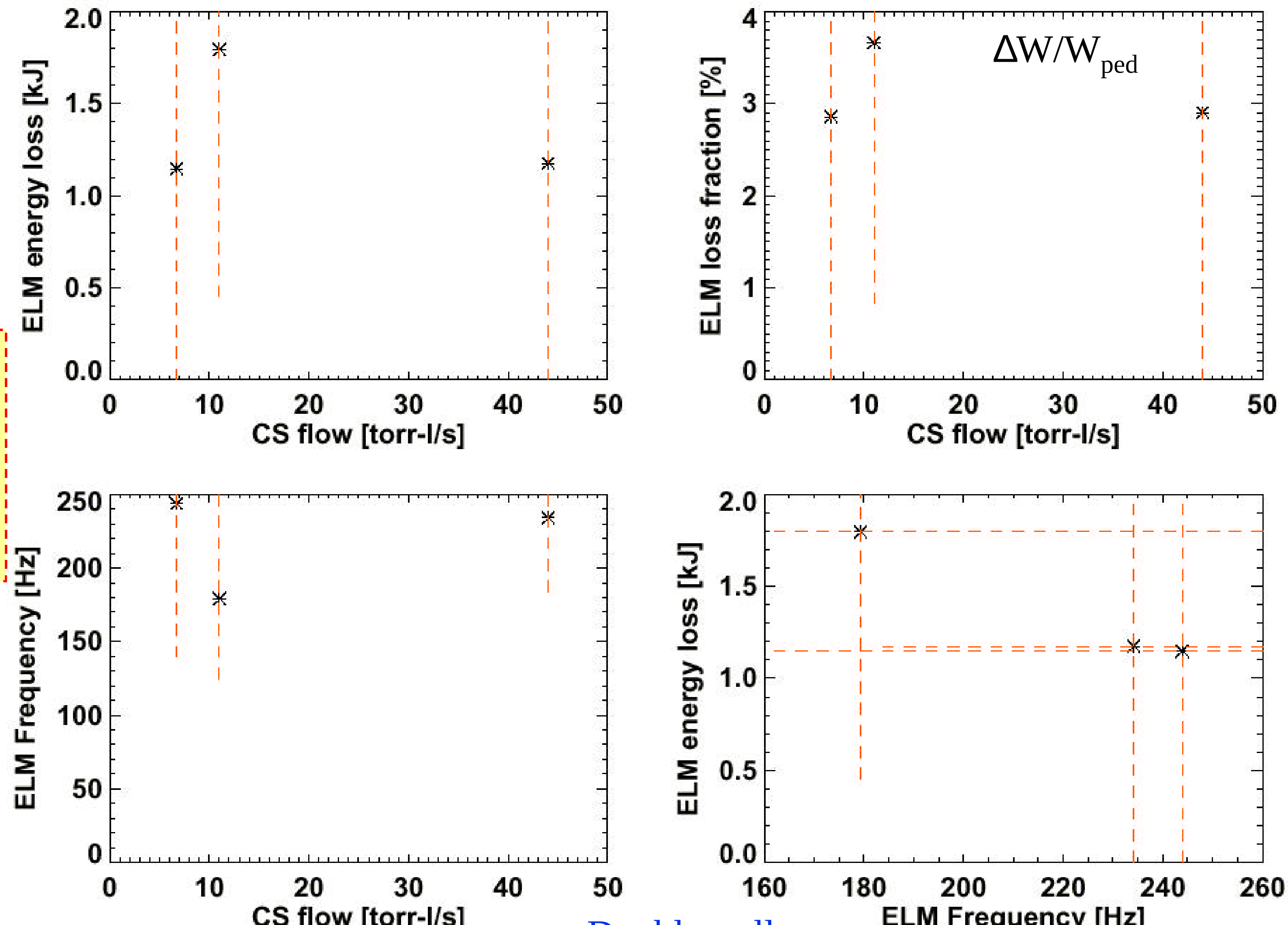
Time of constant NBI power with no locked mode signature

Double-null

Larger ELMs observed at lower density



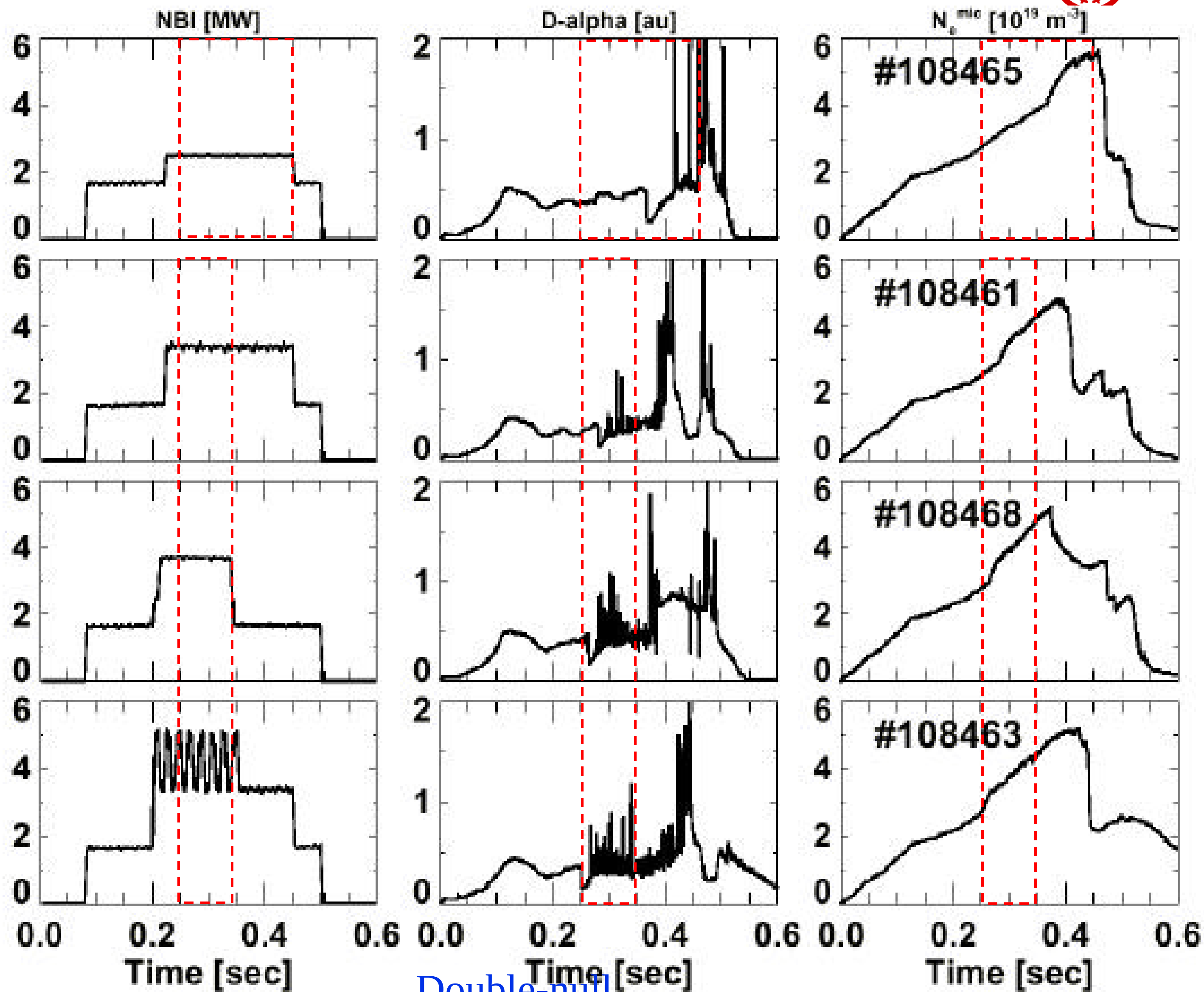
Average ELM size and frequency independent of gas flow rate



Dashed Bands Show Data Range

Double-null

ELM size and frequency affected by NBI heating power



Time of constant NBI power with no locked mode signature

Double-null

Average ELM size largest at low NBI power, and varies inversely with frequency

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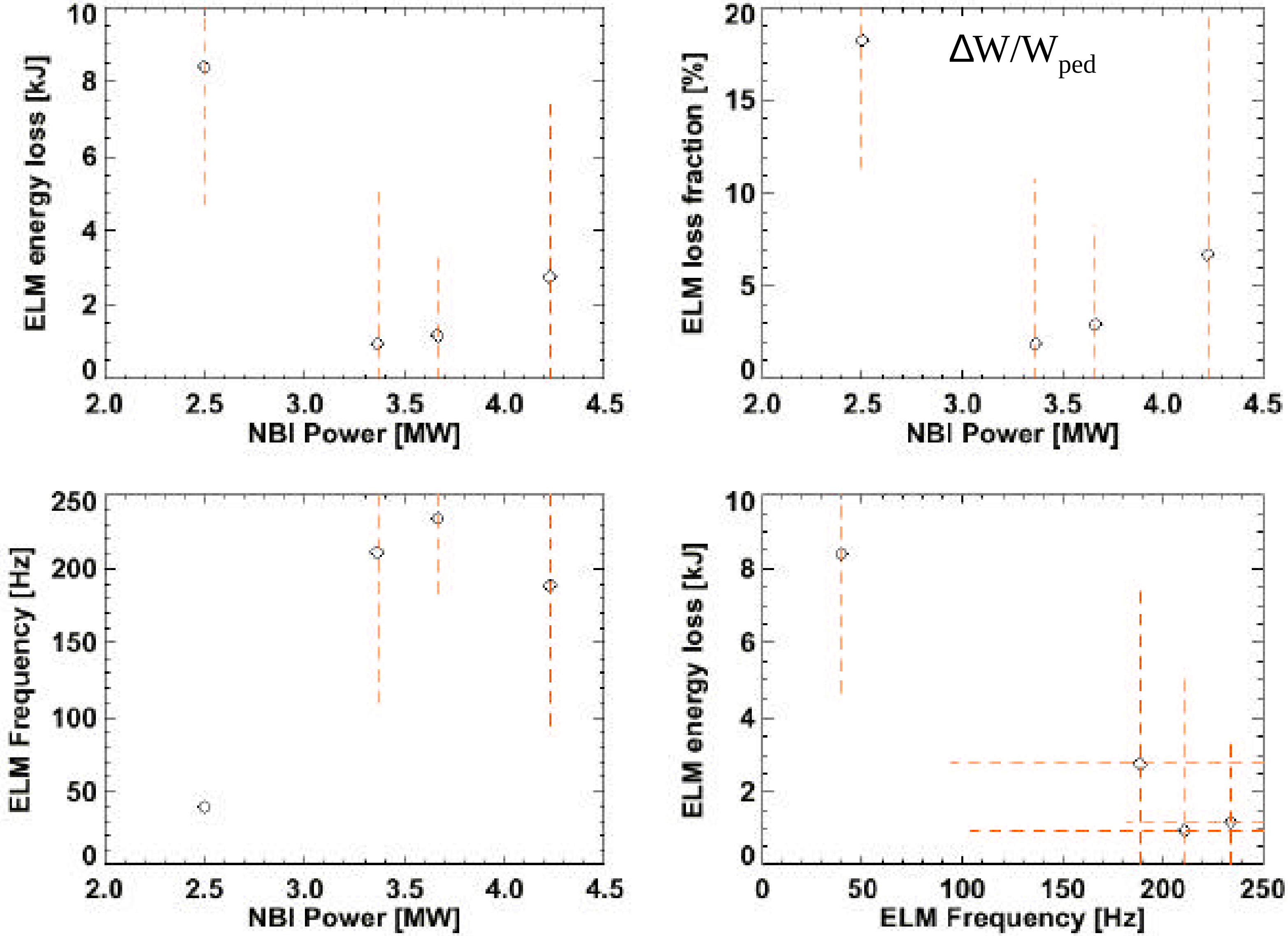
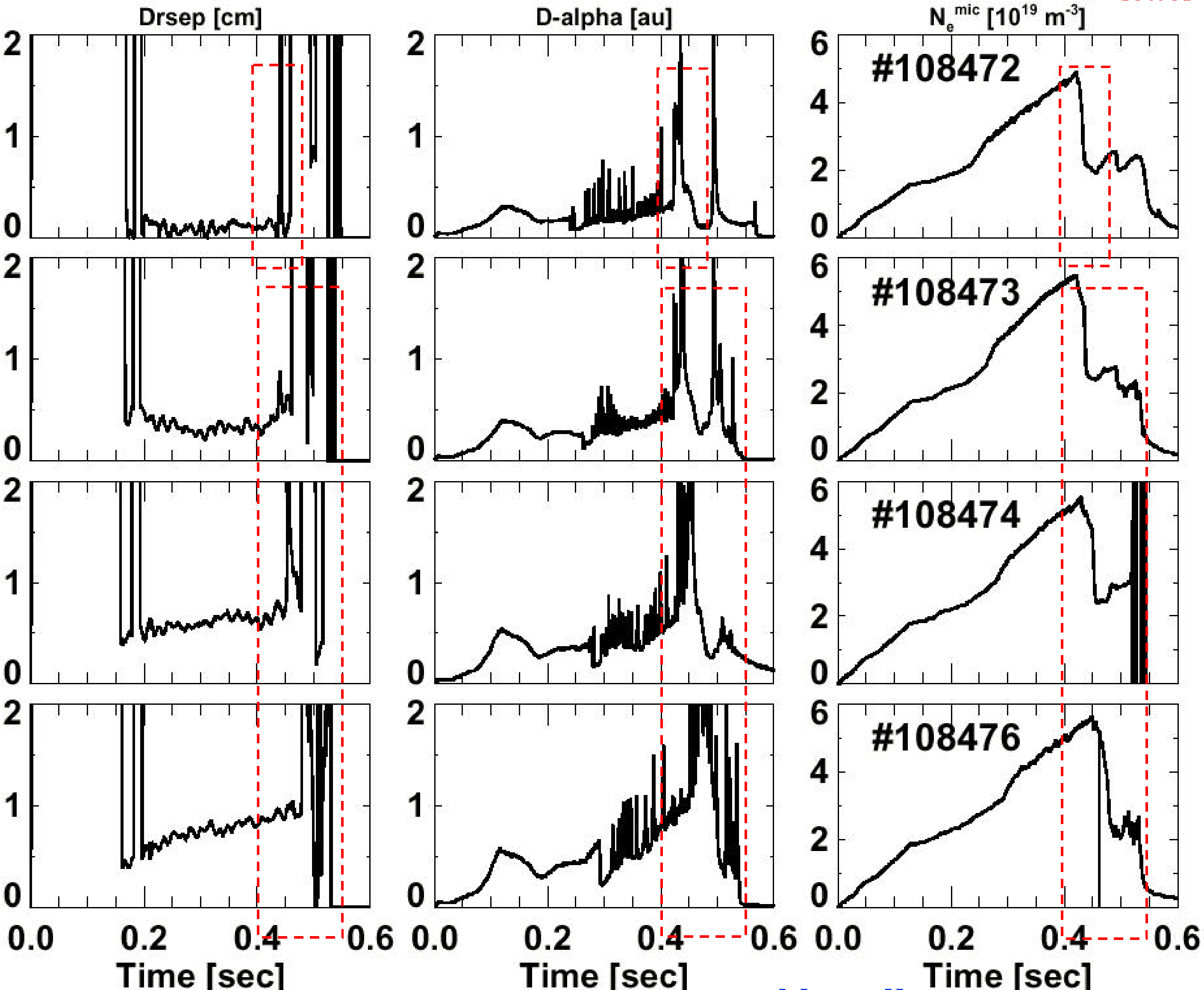


Double-null

ELM characteristics weakly dependent on magnetic up/down balance?

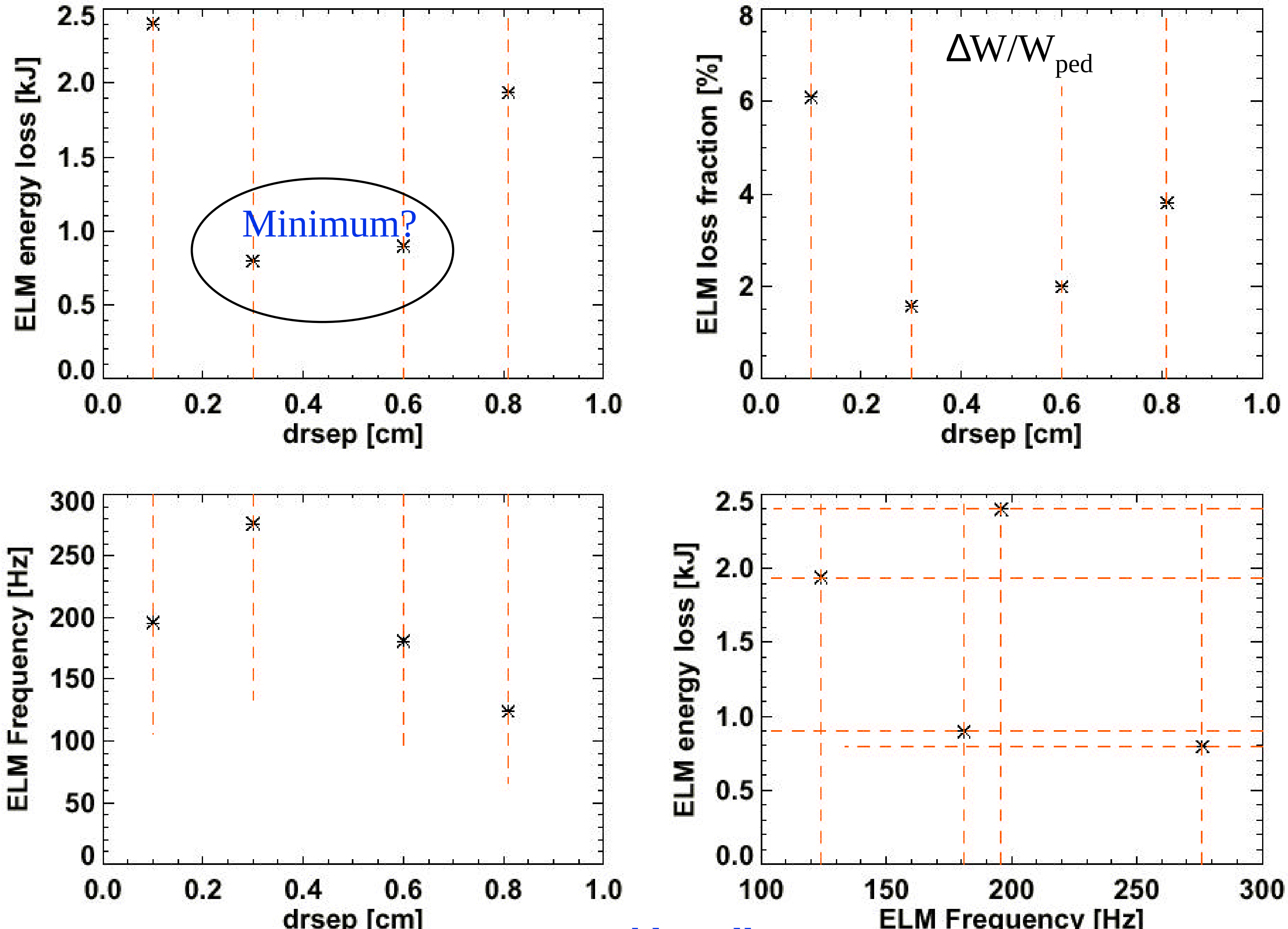


Double-null

Drsep = distance between lower and upper X-point mapped to outer midplane (EFIT)

Time of constant NBI power with no locked mode signature

Average ELM characteristics weakly dependent on magnetic up/down balance?

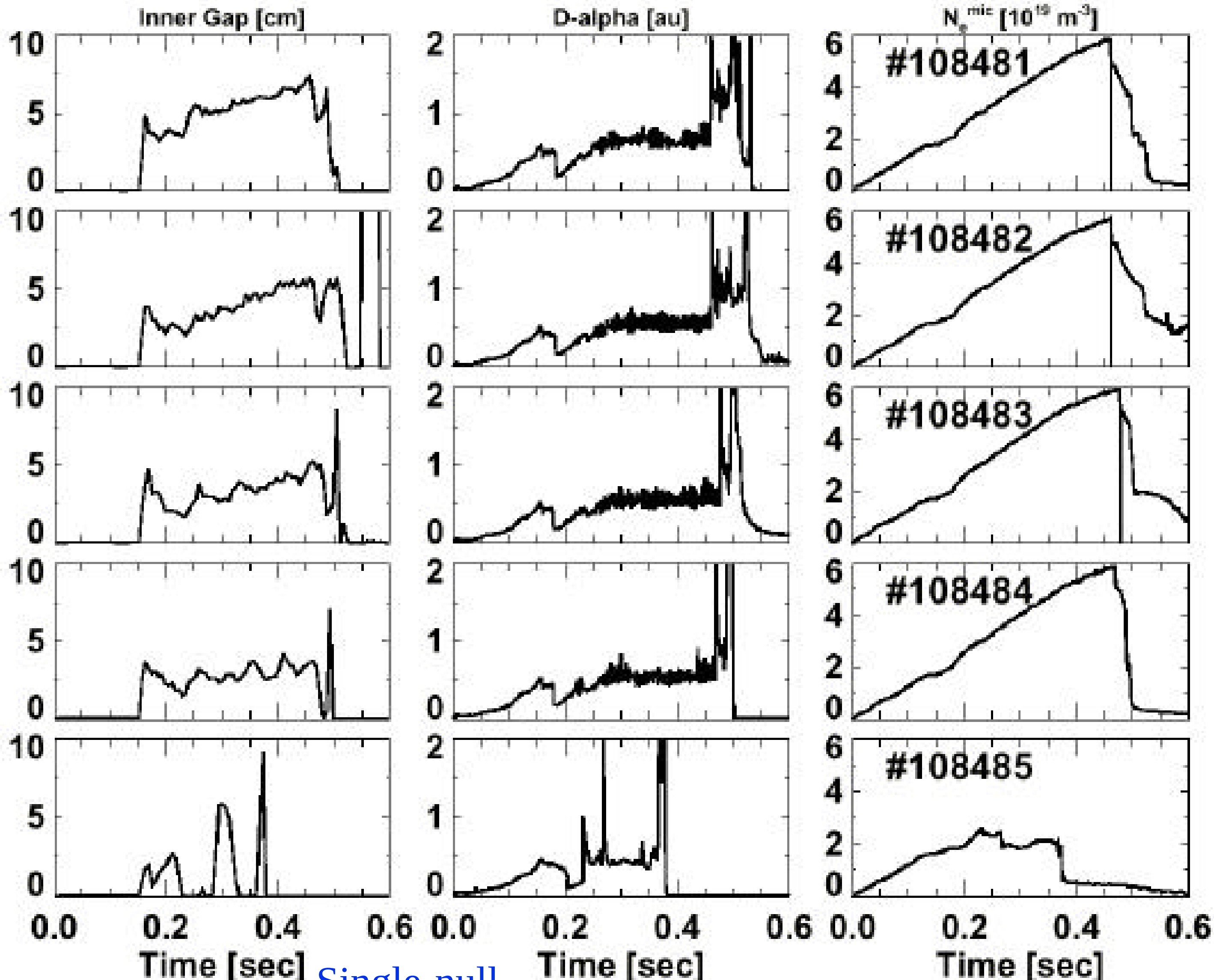


Dashed Bands Show Data Range

Double-null

ELM characteristics independent of inner-wall gap unless plasma becomes inner-wall limited

NSTX

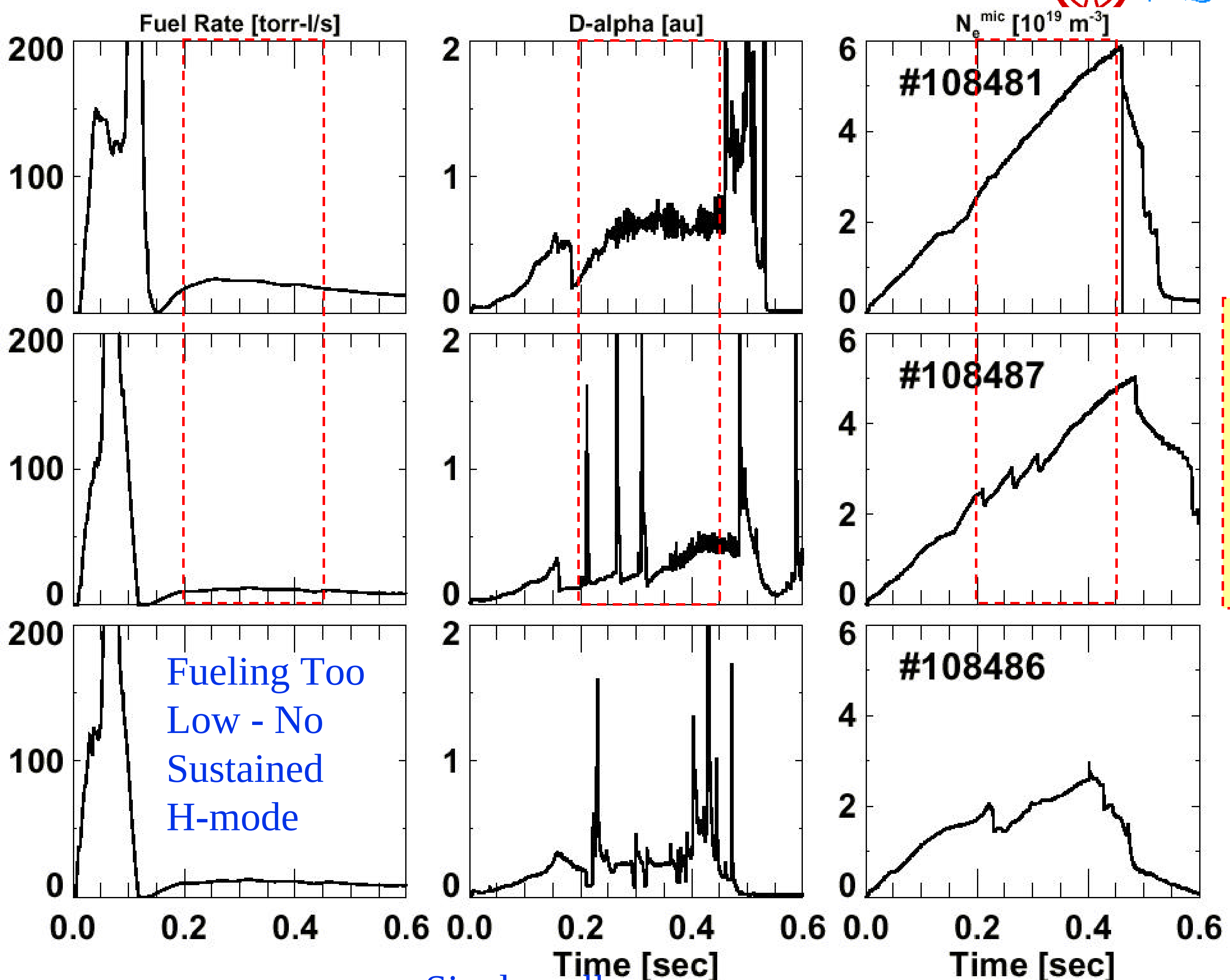


Single-null

ornl

Fueling (density) strongly affects ELMs in single-null

NSTX

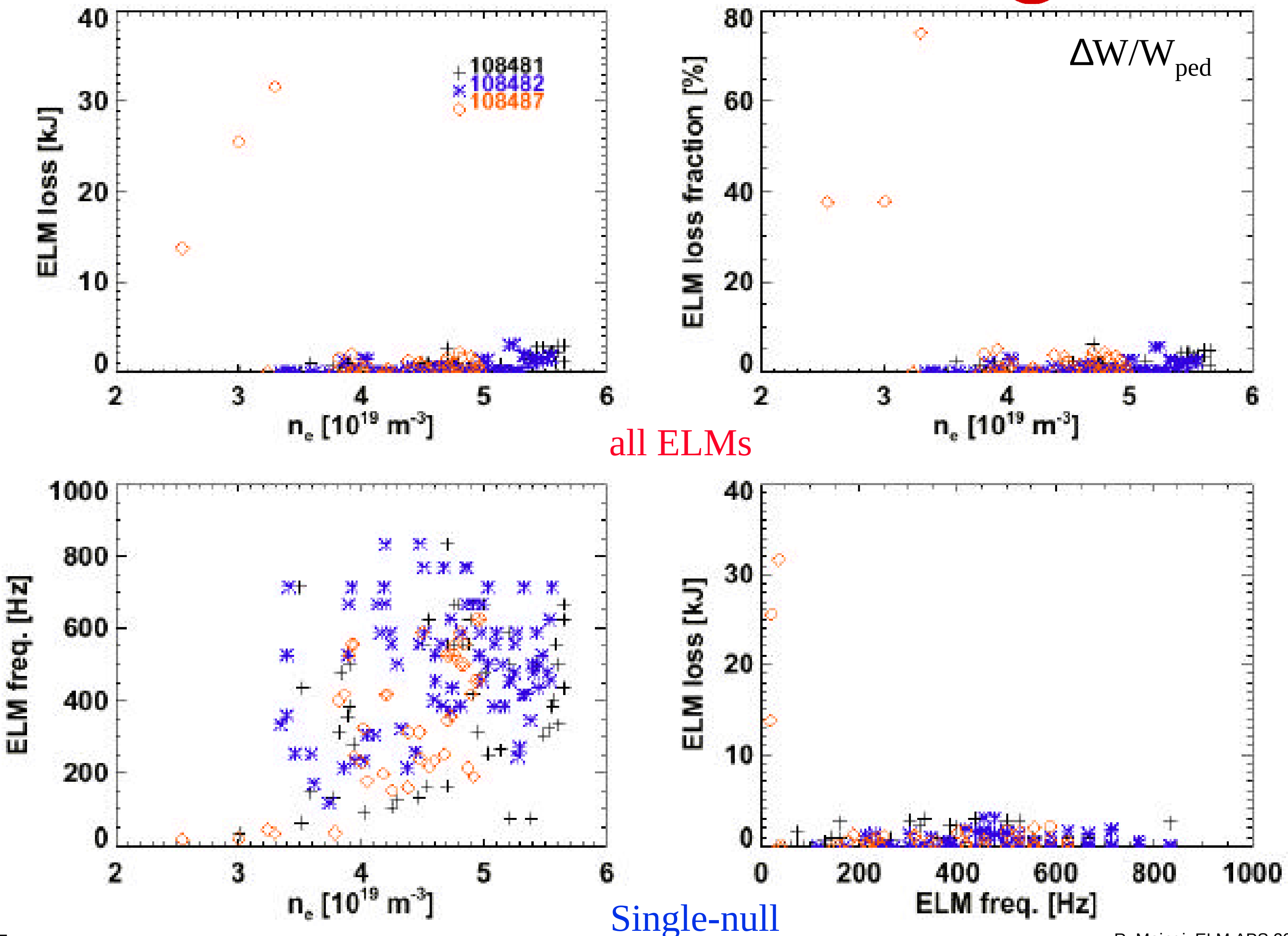


Time of constant NBI power with no locked mode signature

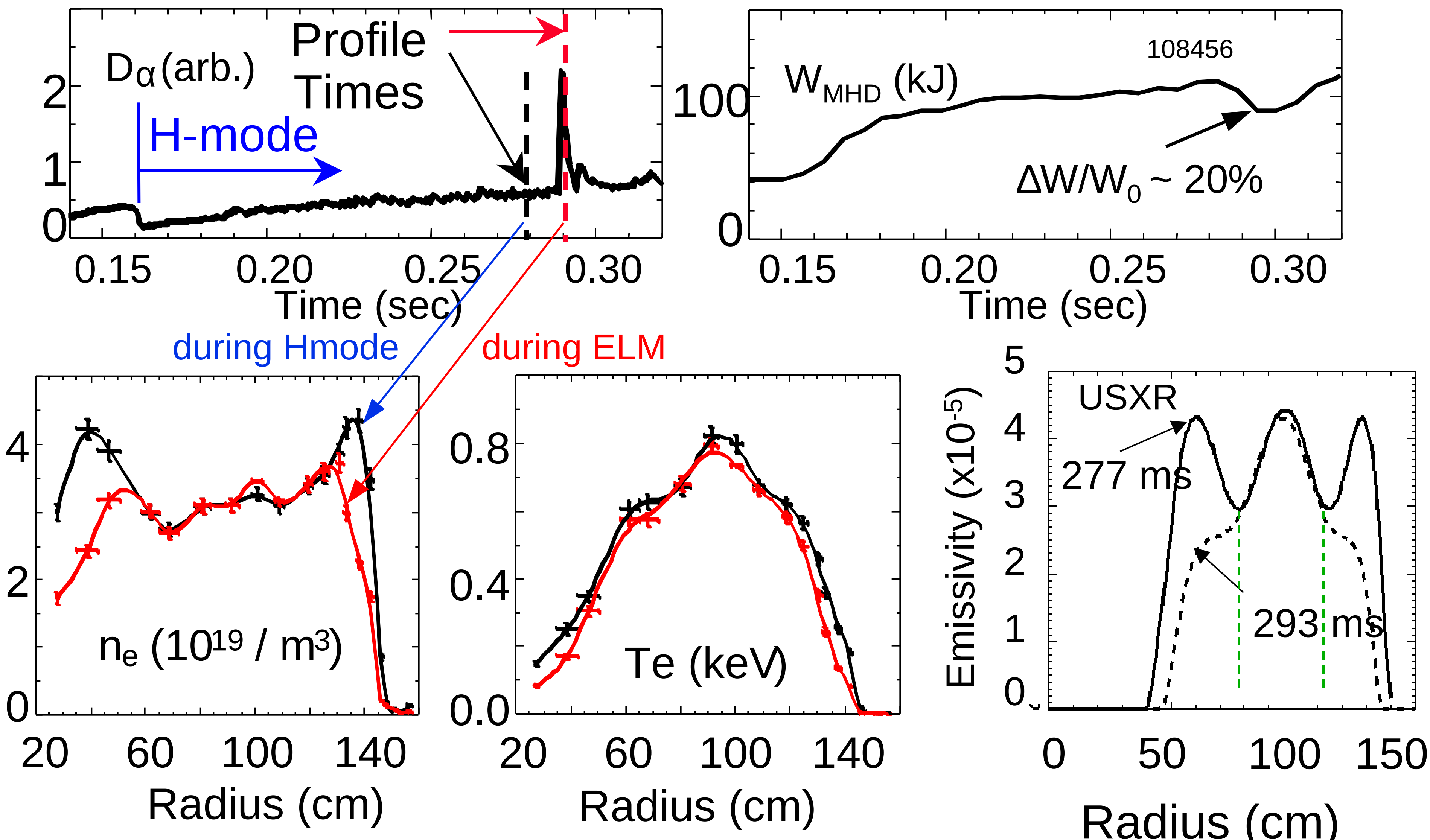
Single-null

ornl

Giant ELMs observed at lowest density, but beyond those few ELMs unaffected explicitly by density



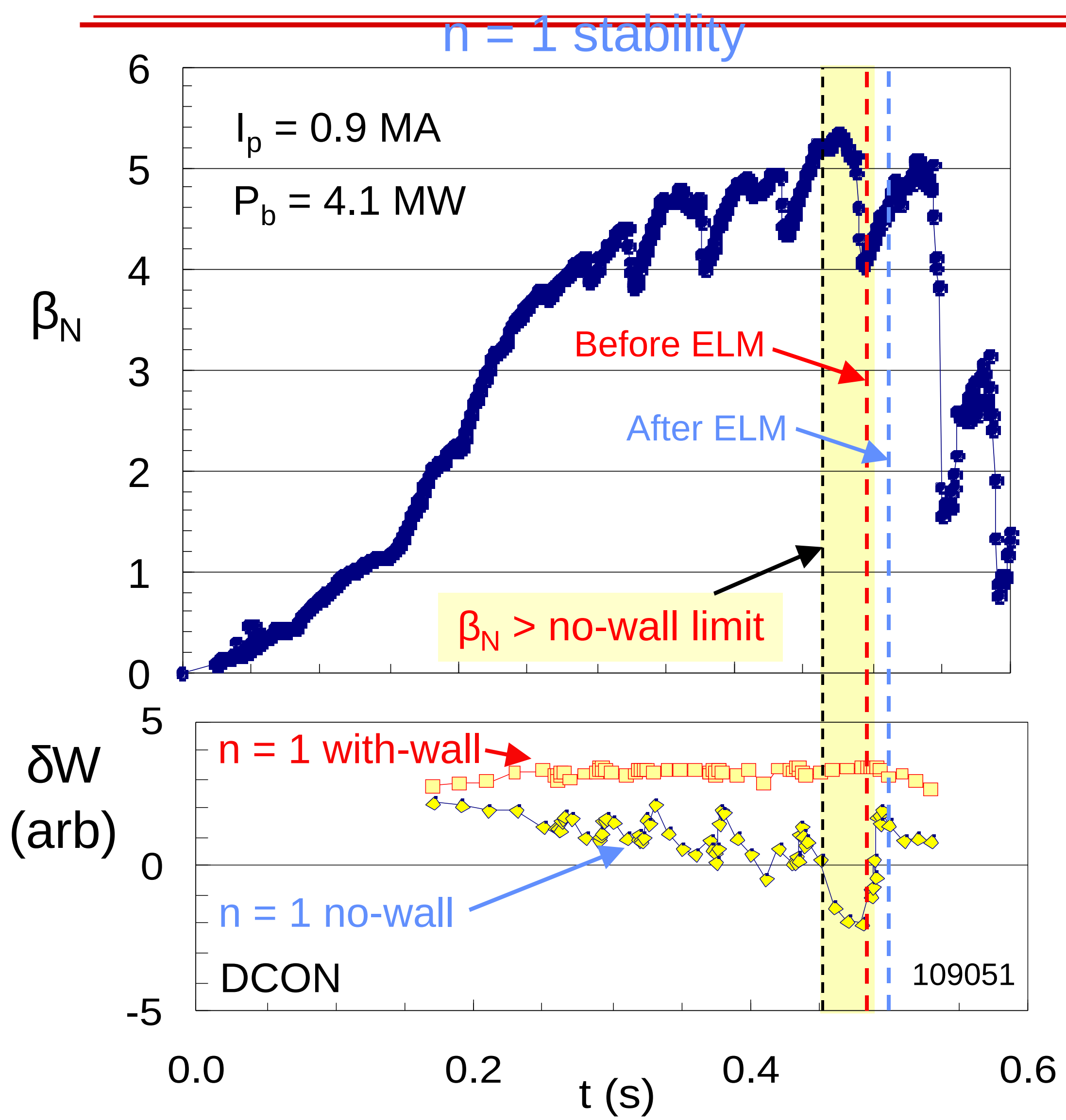
Large ELMs penetrate deep into the plasma

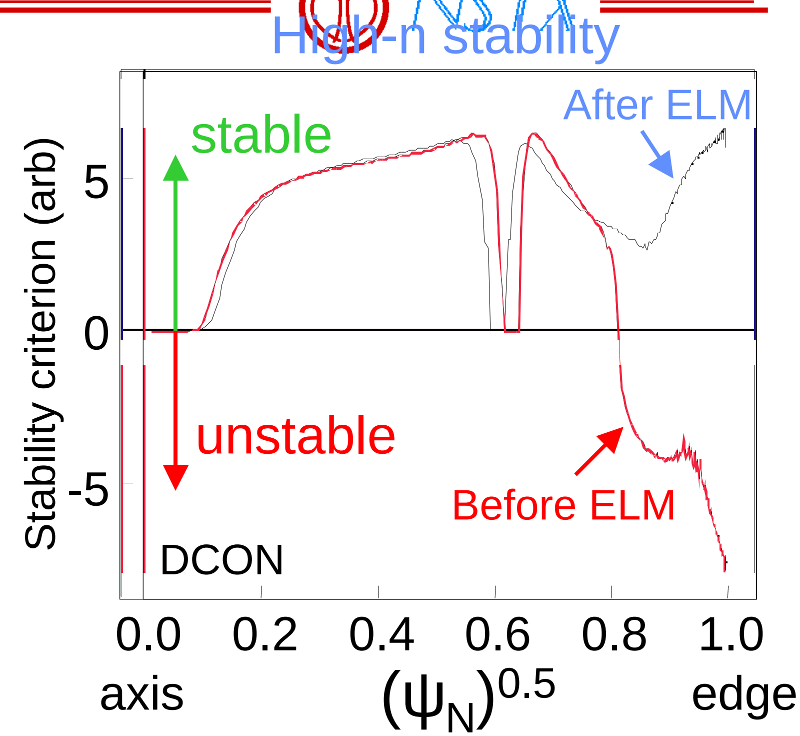


Bush, LeBlanc, Stutman

Single-null

Ideal High-*n* Ballooning Unstable before giant ELM and stabilized after ELM





- Computed as high-n stable after ELM
- n = 1 stabilized by wall
  - No-wall β_N limit exceeded before last ELM

Single-null

Sabbagh, Glasser, Bush

Double-null ELMs have similarities to Type I ELMS
Single Nulls are either gigantic or very small

- ELMs in double-nulls have typically ~ $\Delta W/W_{ped} < 10\%$
  - ✱ Increase in size and decrease in frequency near power threshold
  - ✱ No clear frequency increase with higher NBI power
  - ✱ Size not directly correlated with fueling rate, but largest ELMs at low density
  - ✱ Average size weakly depends on magnetic balance(?)
- ELMs in Lower single-null are either very small or gigantic
  - ✱ Size not directly correlated with fueling rate, but gigantic ELMs observed reproducibly at low density/fueling
  - ✱ Independent of inner-wall gap if gap > 0

Questions and future plans

- Why do ELMs appear different in LSN vs. DN, but have not a strong dependence on magnetic balance (drsep)?
  - Does drsep need to be >> 1 cm for comparison?
  - Is observed difference related to triangularity? (probably not, based on other observations)
- Are the rapid ELMs in SN type III? (frequency not affected by P_{NBI})
  - MAST sees type III routinely, but have less P_{NBI}
- Availability of 50 channel T_i from CHERS in FY04 will allow measurement of ion pedestal energy; more accurate than 3*electron pedestal energy
- NSTX/MAST/DIII-D experiment planned to quantify effect of aspect ratio on pedestal parameters and ELMs

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