Pedestal Width Physics

by
A.W. Leonard

Presented to
DIII–D Program
Advisory Committee

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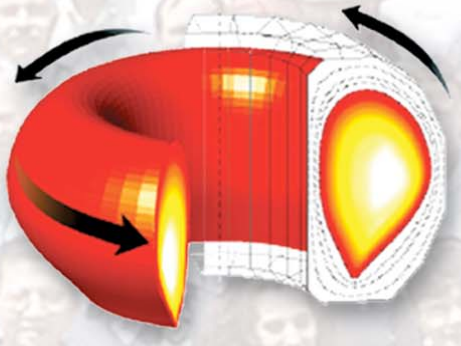
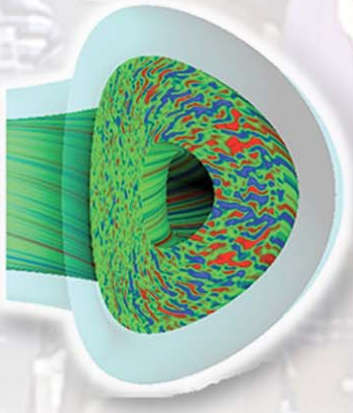
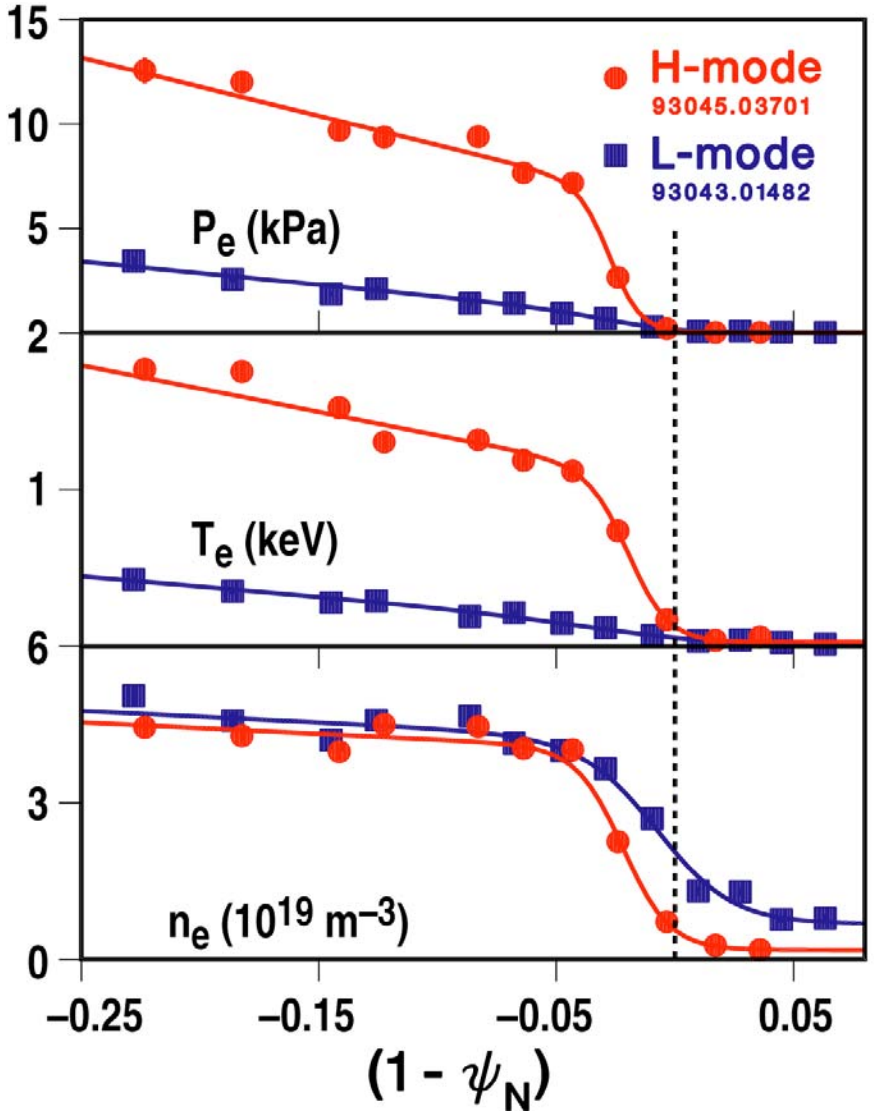
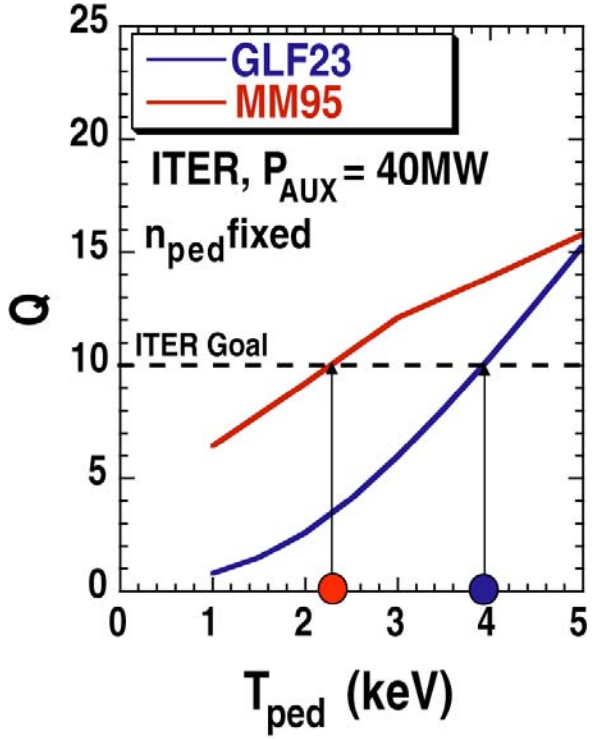




The H-mode Pedestal Provides the Boundary Condition for Core and Edge Plasmas

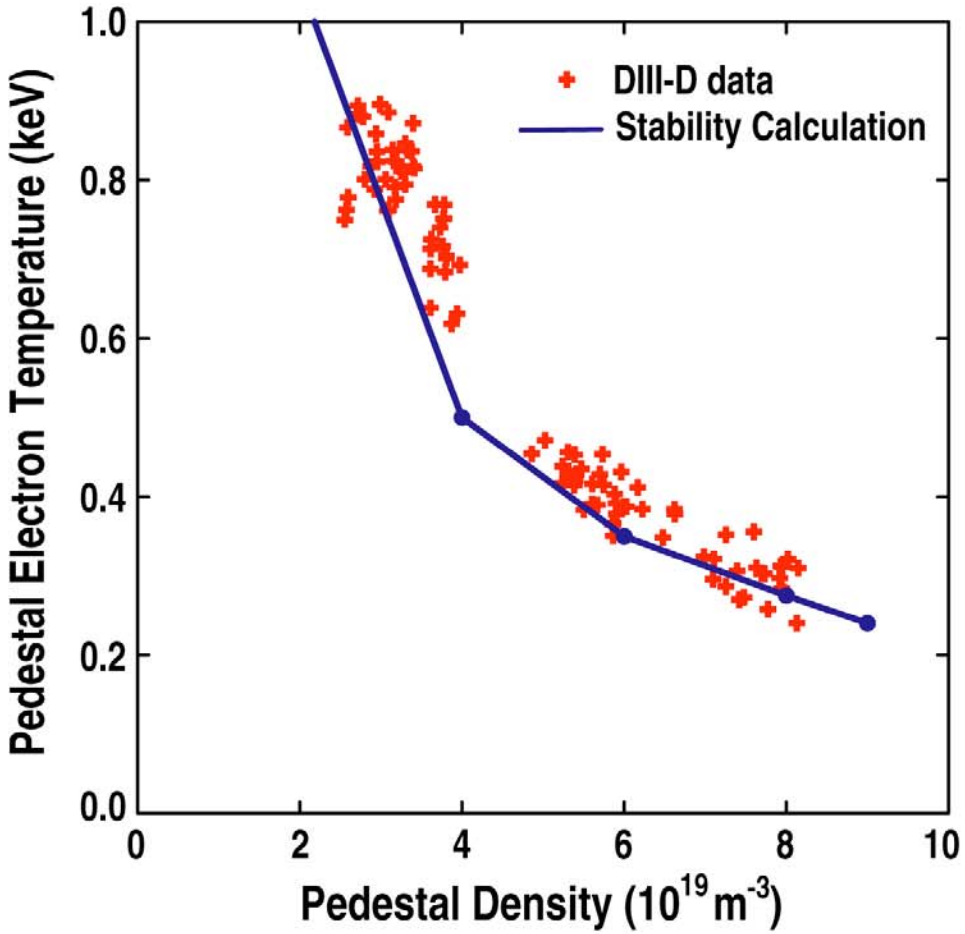


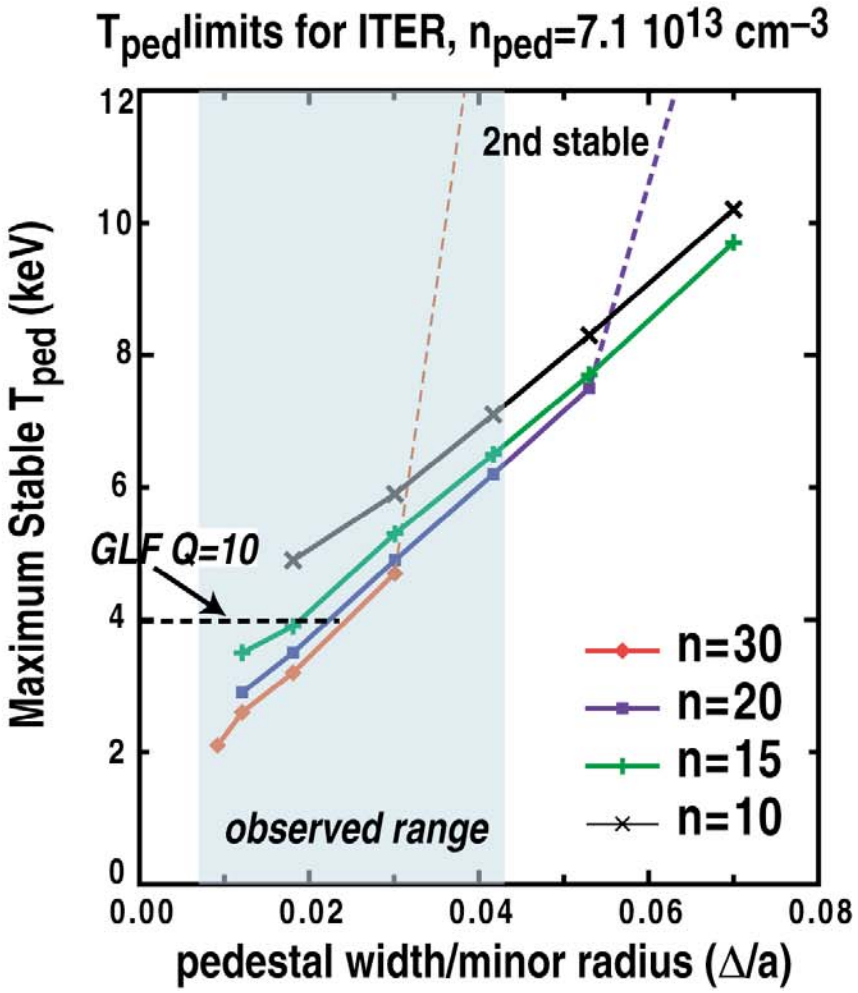


- **Pedestal Pressure is major uncertainty in modeling core confinement**
- **If pedestal width is known the stability limit can be calculated**
- **A pedestal model is also necessary to simulate the SOL and divertor plasmas**

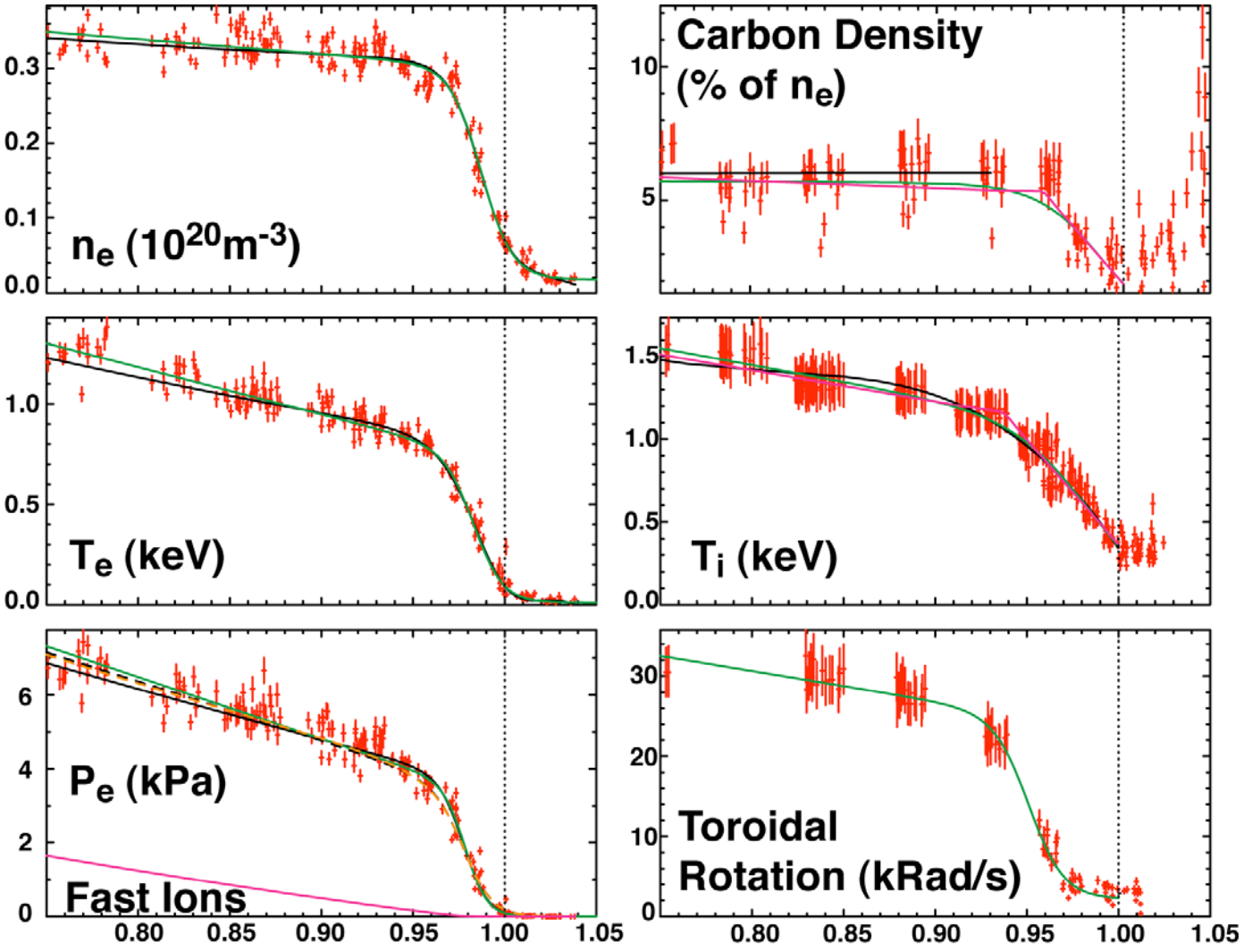
Pedestal Width is Key Uncertainty in Predicting ITER Performance

Stability limit calculated by ELITE matches DIII–D data when width is measured



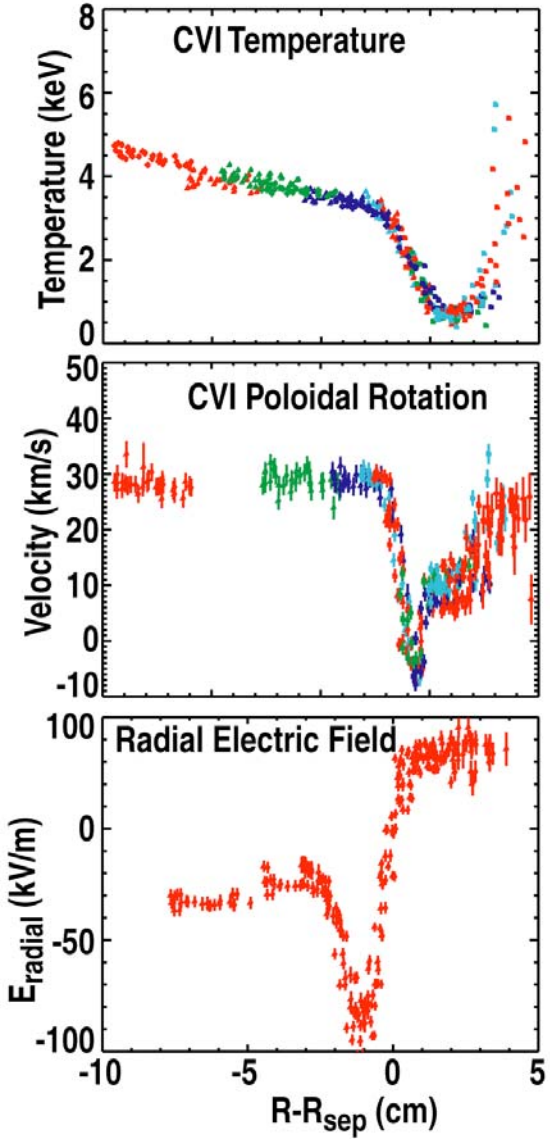


DIII-D Diagnostics Measure All Relevant Profiles for Pedestal Characterization

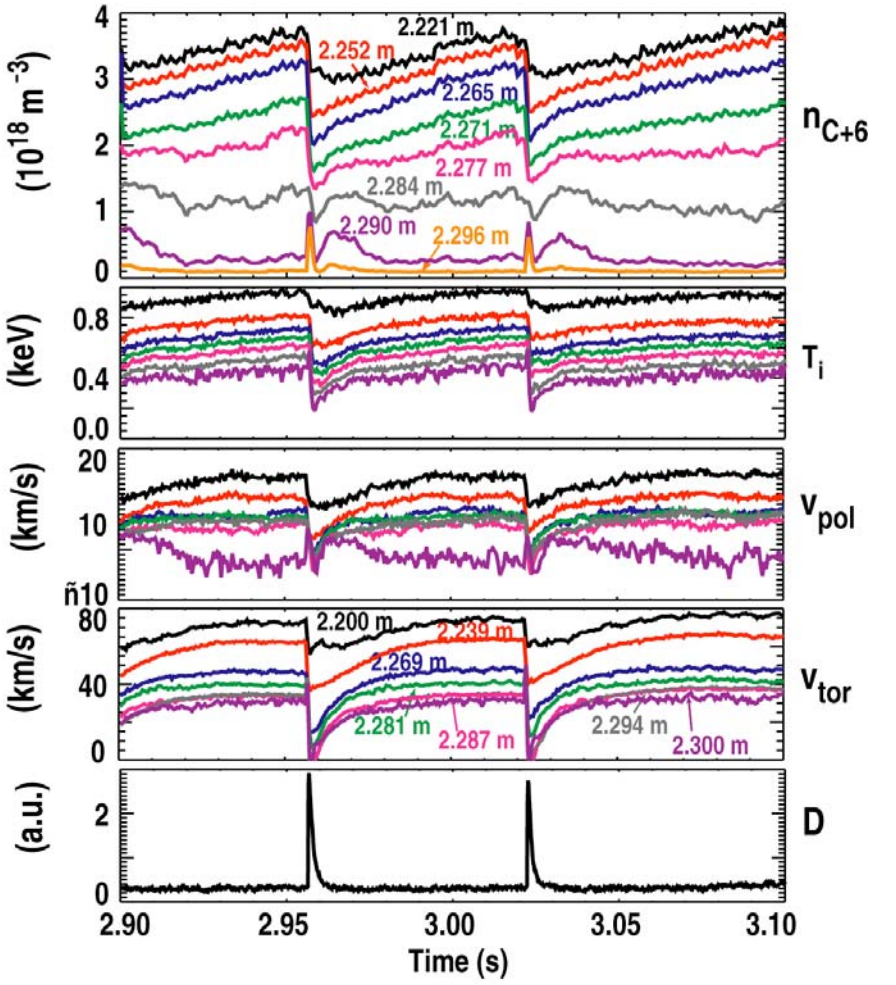


- **Electrons:**
  - Thomson
  - Reflectometry
- **Ions:**
  - CER
- **Rotation and E_r:**
  - CER
- **Magnetic Shear**
  - Li Beam
  - MSE
- **Fluctuations**
  - BES
  - Reflectometry

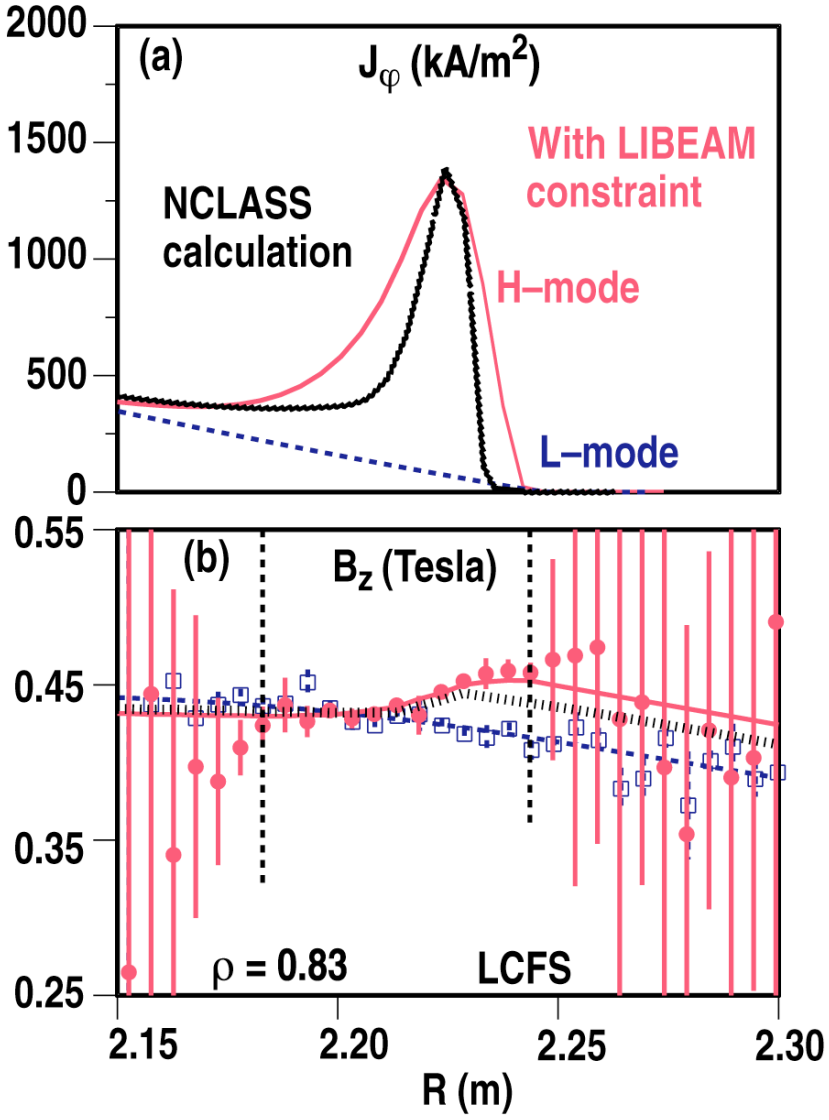
CER Provides High Spatial and Temporal Resolution of the Pedestal



- High spatial resolution provided by sweeping separatrix
- Shortest integration time, ~250 μs

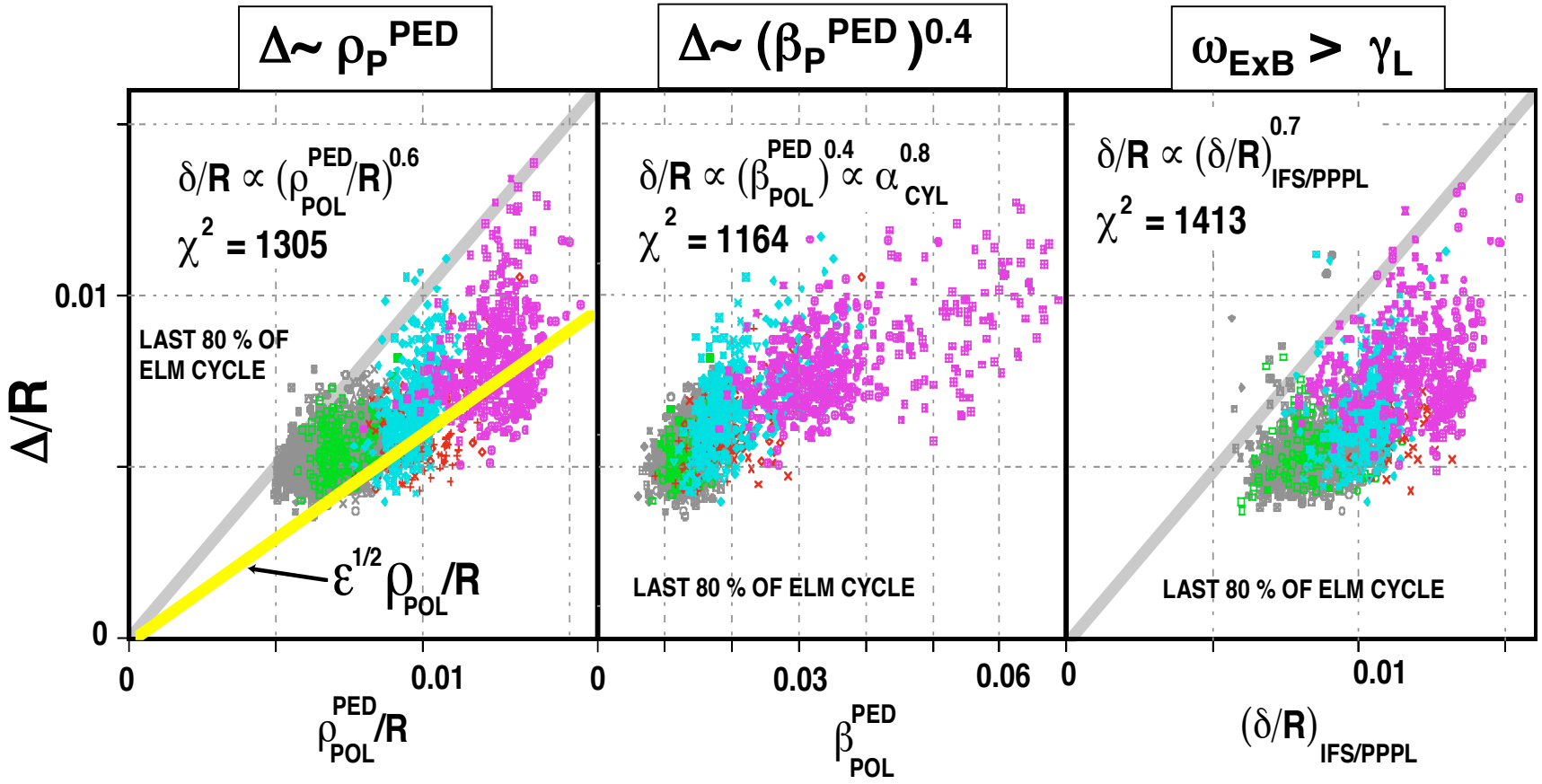


Diagnostic Improvements will Provide Additional Pedestal Measurements



- **Magnetic Shear**
  - Improvements in Li beam polarimetry and additional edge MSE channels should improve temporal resolution
- **Fluctuations**
  - Reflectometry: profile of radial correlation lengths of pedestal fluctuations
  - BES: expanded spatial coverage with sensitive detectors

No Clear Scaling of Pedestal Width from DIII-D Database

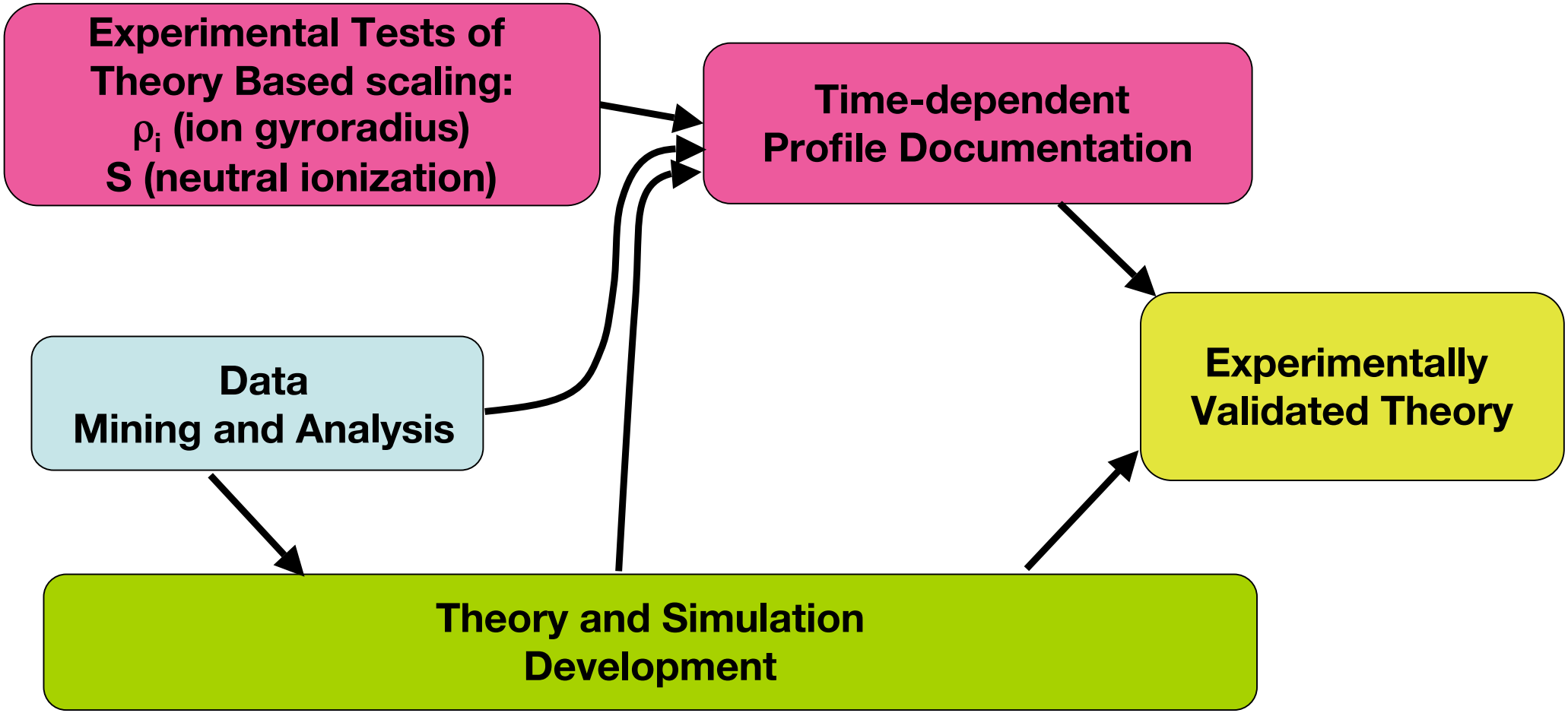


- Several scaling parameters, or models, fit width data equally well
- Correlated dependent parameters are hard to isolate
- ITPA pedestal database has similar issues

Pedestal Simulation Soon Ready for Testing

- **ExB flow shear stabilization suggests poloidal ion gyro-radius scaling, but:**
  - ExB shear enhanced by edge density source
  - Trapped particles, shape, shear and other effects could mask simple scaling
- **Drift wave theory based transport model TGLF expected in June 06**
  - Uses gyro-fluid drift wave linear eigenmodes with a saturation rule parameterized to fit GYRO nonlinear simulations
  - Full set of instabilities; TIM, ITG, TEM, ETG, KBM
  - Realistic geometry out to separatrix, trapped particles, collisions, ...
  - Fully theory based, no experimental calibration required
- **Other theoretical ideas should also be tested**
  - Neoclassical, Paleoclassical,...
- **Longer term; two new edge simulation programs have been initiated**
  - CPES (NYU) and ESL (LLNL) will simulate transport in pedestal, SOL and divertor
  - Will include drift wave turbulence, kinetics, neoclassical transport, neutrals, impurities and SOL plasma out to material limiters

Pedestal Width Thrust Combines Efforts in Experiment, Data Analysis, and Theory



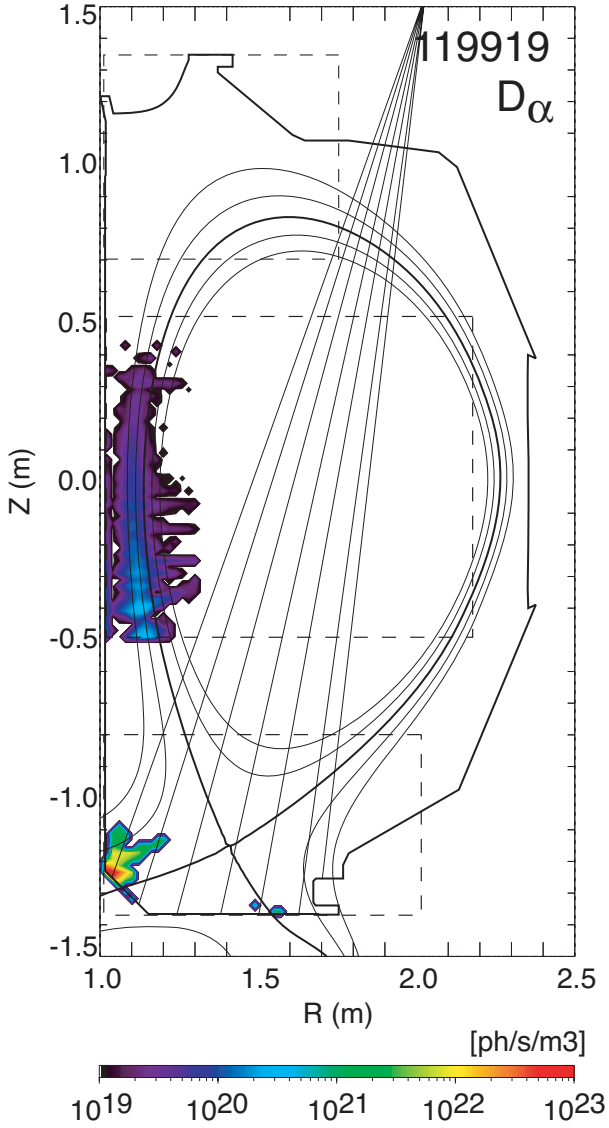
Pedestal Width Thrust Plan

- **Near Term Goals (2006-2007):**
  - Identify physics processes controlling the pedestal width
  - Examine existing data for pedestal dependencies
  - Test transport simulation codes
- **Longer Term Goals:**
  - Construct time-dependent profile database with variations in relevant parameters for testing theory
  - Poloidal distribution of particle and energy transport across separatrix for SOL models
  - Test integrated edge (pedestal and SOL) simulation models now under development (CPES and ESL)
  - Integrate the above with ELM cycle

Much Existing Data Yet to be Fully Analyzed

- **A number of issues can be examined in existing data**
  - Pedestal width time dependence between ELMs
  - Difference between ion and electron temperature width
  - Pedestal fueling, GradB drift direction, ...
- **Existing data could indicate most productive parameter scans for theory-experiment comparison**
  - Initial study indicates strongest width correlation is plasma current
- **Use existing pedestal characterization for initial TGLF comparison**
- **Profile database development will aid theory-experiment comparison and outside collaborations**
  - Promote joint analysis of cross machine comparisons
  - First application; edge modeling of pedestal neutral sources

Analysis of Pedestal Fueling Important for Transport Analysis

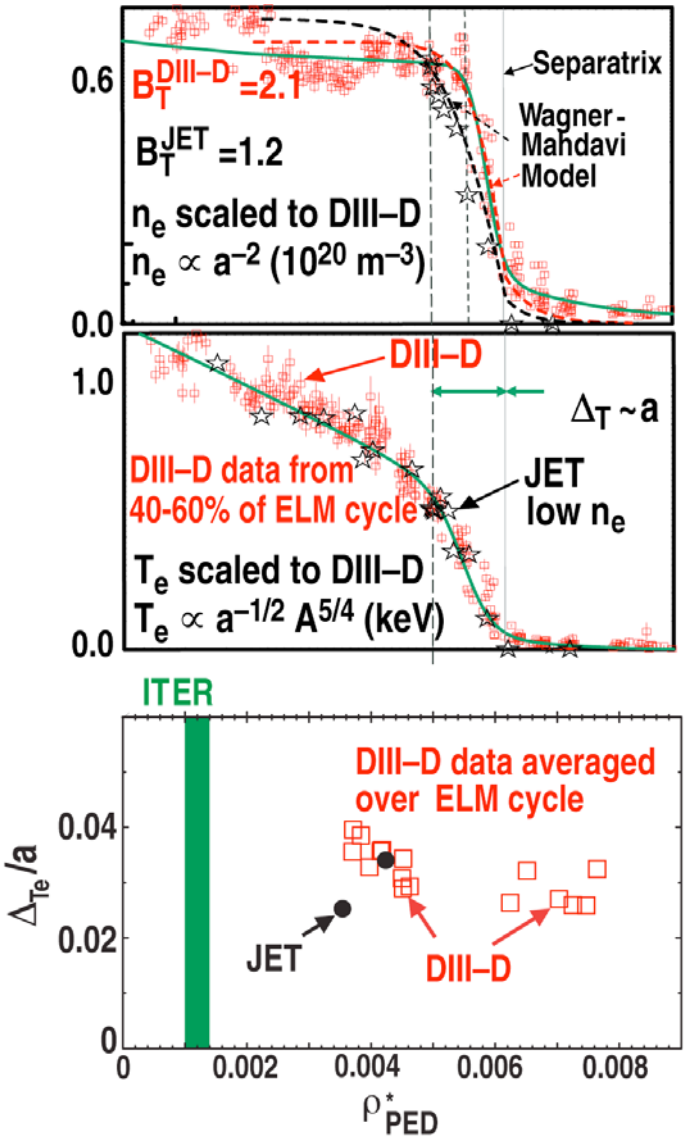


- **DIII-D/C-MOD exhibited similar density width, though different expected neutral penetration. Poloidal distribution? Kinetic effects?**
- **How does fueling affect width of the transport barrier? The transport barrier on density profile?**
- **To assess role of fueling on density profile several efforts are underway**
  - Analytic and 1-d model comparison with data
  - Monte Carlo 2-d modeling of neutral ionization
  - Development of profile database to aid cross machine comparisons

Staged Experimental Plan to Examine Pedestal Width

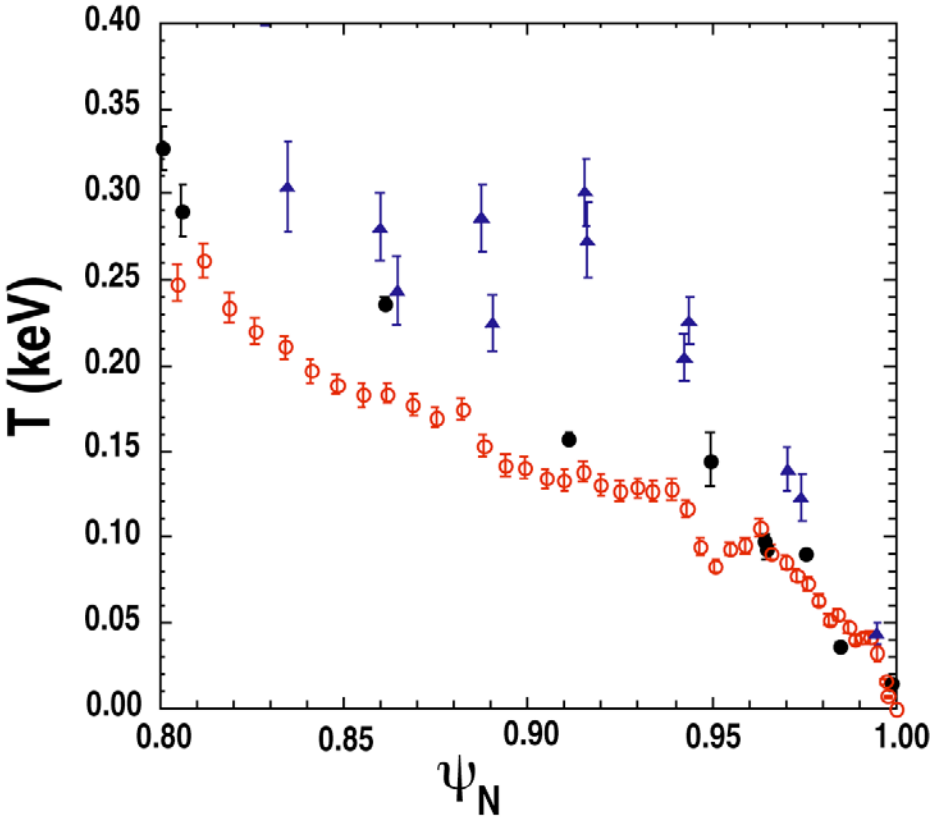
- **Initial experiments to test scaling and mechanisms controlling pedestal width**
  - JET/DIII-D; gyro-radius dependence
  - NSTX/MAST/DIII-D; aspect ratio scaling
  - Pellet fueling and pumping; neutral source dependence
- **Later detailed pedestal characterization for tests of theory**
  - Time dependent profiles with optimized diagnostics, including fluctuations
  - Initial TGLF tests and data mining to indicate most useful parameter variations

DIII-D/JET Comparison to Test Ion Gyro-radius Scaling



- **DIII-D/JET comparison has high priority**
  - Ion gyroradius dependence inherent in many theories
  - Previous DIII-D/JET experiment compromised by poor JET pedestal diagnostics.
  - IEA/ITPA sponsored experiment
- **<u>Goal:</u> Start with similarity comparison;**
  - JET-> high field, low ρ^*; DIII-D-> low field, high ρ^*; factor of 4 variation targeted
  - Triangularity variation
- **Other physics goals are also targeted**
  - Scaling of ELM loss
  - Neutral fueling modeling
- **Scheduling constraints**
  - JET experiment scheduled for mid June 06
  - DIII-D experiment to follow JET, late 06

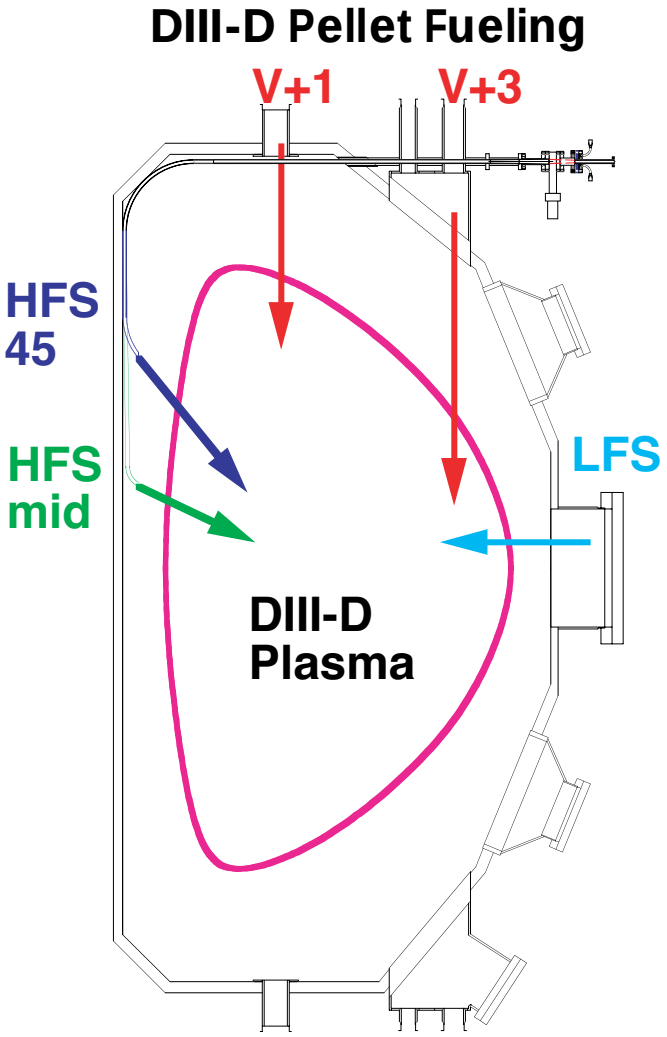
NSTX/MAST/DIII–D Examine Aspect Ratio Dependence



NSTX (black),
MAST (red), and DIII–D (blue).

- JT-60U/DIII-D exhibited $\Delta \sim \varepsilon^{0.5}$
- NSTX/MAST/DIII-D will test this scaling
- DIII-D completed experiment last year in 05
- NSTX and MAST will complete their parts in FY06
- Additional DIII-D data (1/2 day) may be required, depending on further NSTX/MAST data analysis

Pellet Fueling with Pumping Could Remove Sources from Pedestal



Maximum Injection: 30 torr-ℓ/s

- **Pellet fueling and pumping can offer:**
  - Opportunity to change pedestal particle source and affect pedestal profiles
  - In ITER, bulk of pedestal flux expected from pellet fueling. No device has tested this regime
  - Removal of particle source from transport analysis
- **Experimental plan:**
  - Continuous inner wall pellet injection, ~30 torr-ℓ/s with maximum pumping
  - Compare profiles with and without pellet fueling at same pedestal density
  - Dedicated experiment if available, piggyback where possible

Experiment-Theory Comparison Requires Additional Experimental Time in FY07

- **Goal: Detailed time-dependent profiles to test TGLF and other theories**

- **Measure profile evolution and turbulence in several regimes:**
  - L-mode for measuring transport before H-mode suppression
  - Long ELM free period for time evolution of pedestal
  - Regular well spaced ELMs for characterization of ELM cycle

- **Parameter scans:**
  - Existing data and TGLF simulations to indicate best configuration and scans
  - Parameter scans may include: Density (collisionality), ρ^*, q, shape, magnetic shear (current ramps),...

- **Expect at least 4 days of parameter and diagnostic scans**

- **Diagnostic improvements to: MSE, Li Beam, fluctuation reflectometry**

- **Result: Profile evolution with high temporal and spatial resolution to serve as database for testing a number of theories and simulation codes**

Bulk of Experimental Plan Scheduled for FY07

- **Plan for 12 weeks; 1 day**
  - DIII-D/JET in late 06
  - Pellet fueling piggyback, if possible
- **Plan for 32 weeks; 6 days**
  - DIII-D/JET in late 06
  - Pellet fueling in 06
  - Pedestal time-dependent profiles in 07