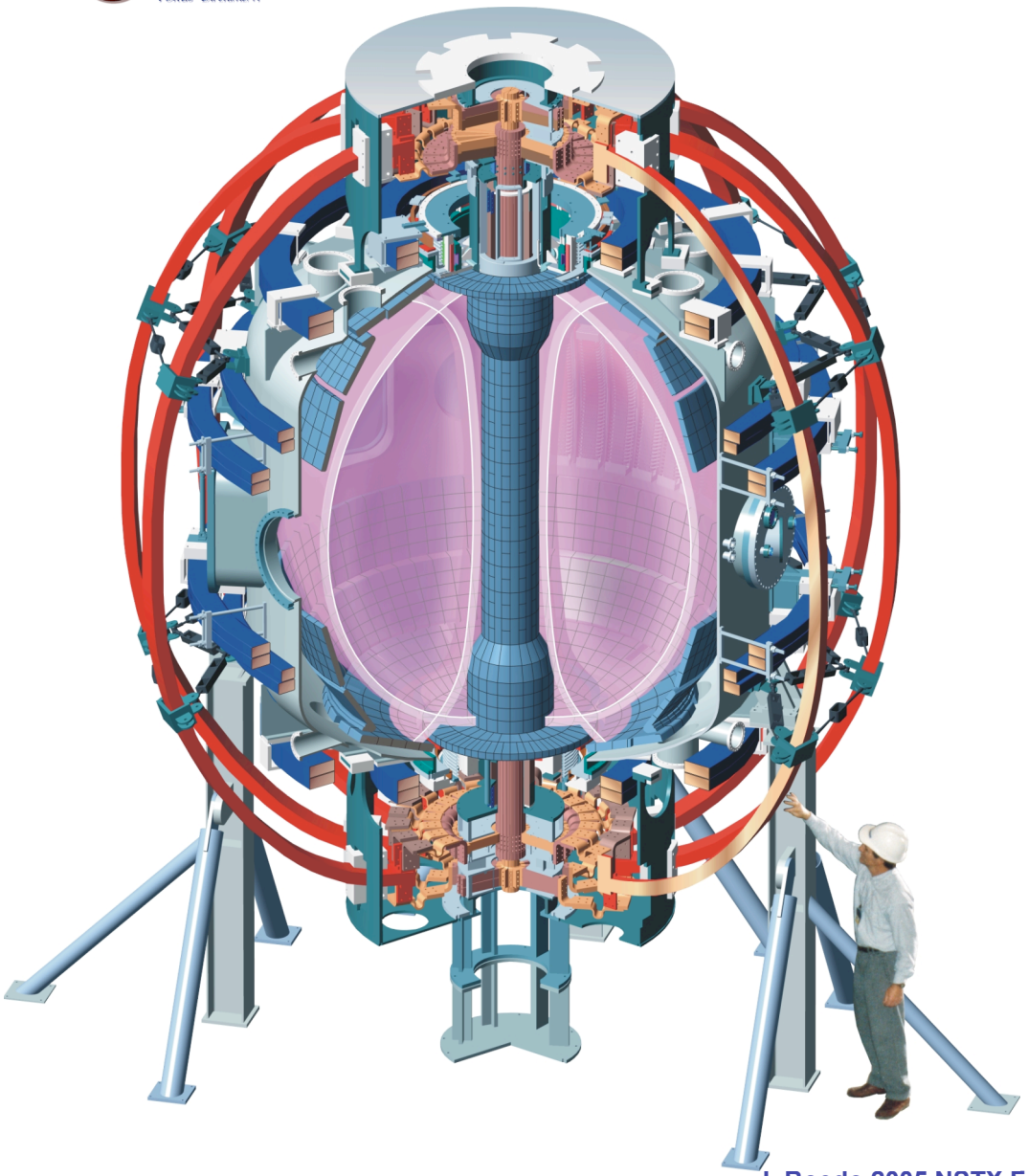
NSTX Edge Characterization Using Probes

J. Boedo
for
The UCSD and NSTX Teams



Goals

- These XPs are to provide:
  - Input on boundary parameters
    - Add to general NSTX knowledge
    - Provide information for discharge development/design
  - High spatial resolution edge/SOL profiles for modeling
    - Required for optimal UEDGE, BOUT modeling
    - Developing NSTX boundary understanding/interpretation
  - Boundary crucial for ITER, little predictive capability
    - Recent “discoveries”: Intermittency, blobs, ExB flows, Parallel flows, ELM dynamics, ELM wall fluxes, etc etc. Lots to know
  - In ST concept, wall loads may be even more limiting. Crucial topic

Two XPs were run

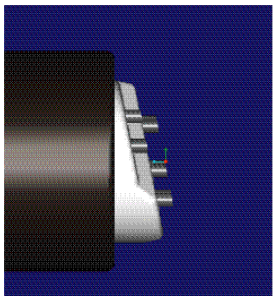
- Edge Characterization (XP437)
  - Ran for several half-days
  - Probe on for a fraction of these. Probe incompatibility.
  - Partial data

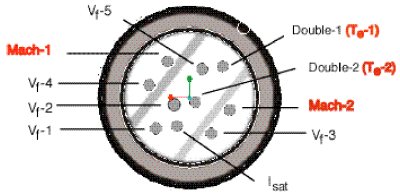
- Edge/SOL and Turbulence Characterization (XP523). Probe dedicated
  - July 13th 2004 Low Bt Discharge development failed (2 days)
  - May 5th-6th 2005 campaign very successful
    - Basic discharge 1 MW NBI, L-mode, LSN
    - Density scan
    - 2MW (1 OH, 1 NBI) low side gas puff
    - L-mode and some H-mode
    - Shape scan (1 shot) DN
    - Power scan (2 shots)

Probe Introduction

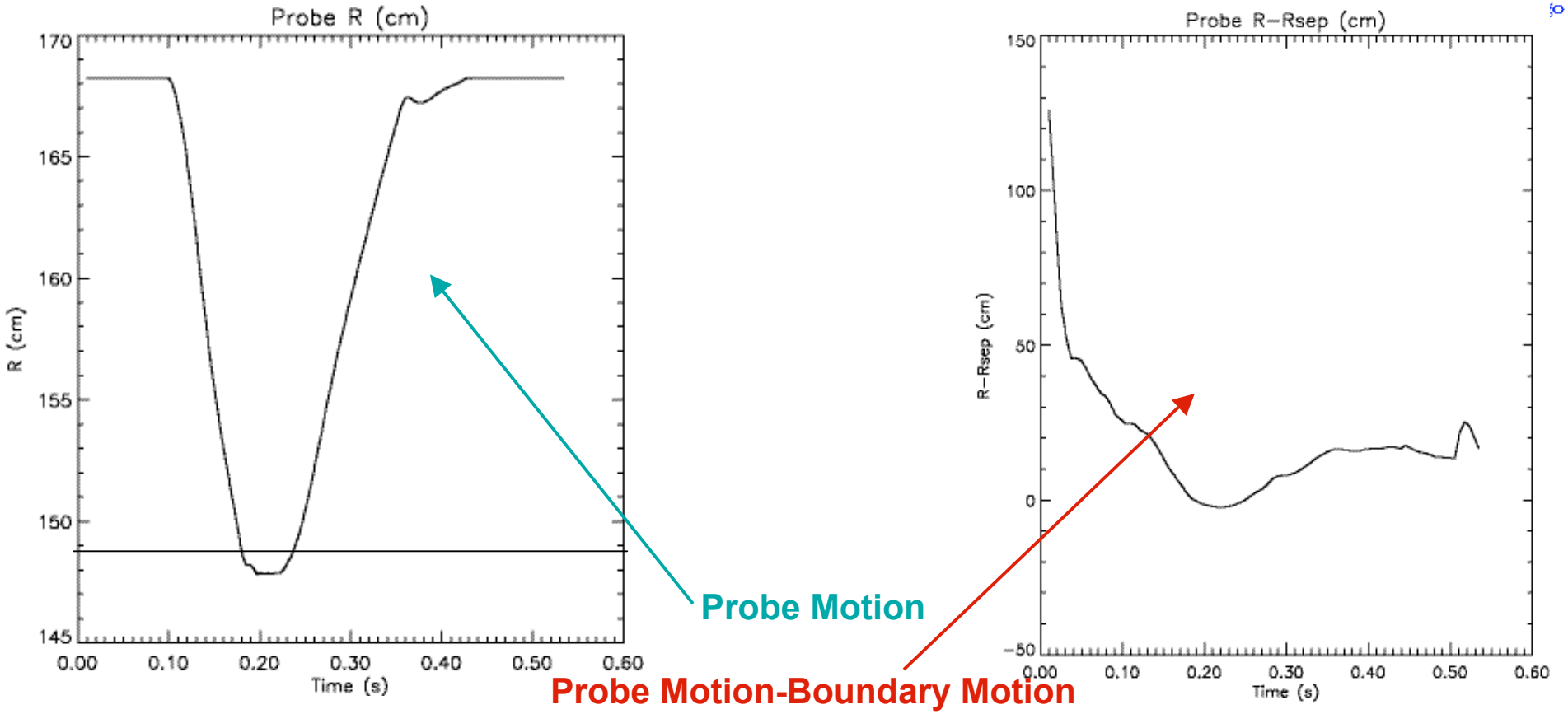
- General Information:
  - Located ~7” below midplane
  - 10 tips (1xIsat, 2xDP, 2xImach, 4xVf (Er, E_θ)
  - Measures: Te, Ne (~3 ms), Isat, 2xE_r, 2x E_θ, Mach #, V_{par} , Γ_r, V_r, etc)
  - Yet to be implemented (Fast Te, Ne, Bfluct)
  - Bandwidth ~ 4 MHz
  - DAQ Sampling 1MS/s
  - In/out time ~ 80 ms

- Recent Improvements:
  - New electronics (better S/N, shielded)
  - New shaft (lighter, better shielded)
  - Simpler connector
  - Rotatable flange > Ip, Bt adaptable
  - > Faster probe





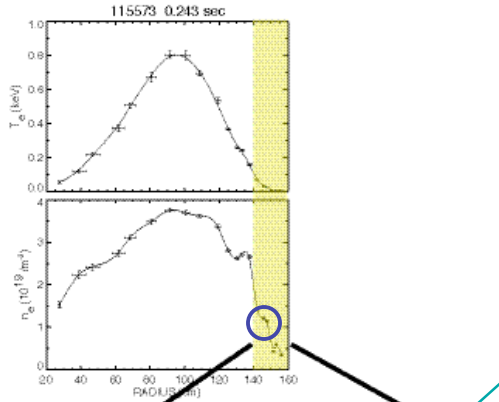
Many other improvements

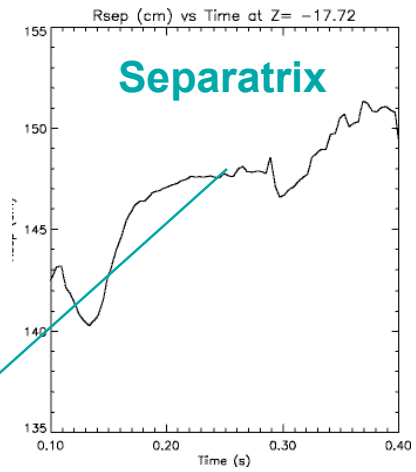


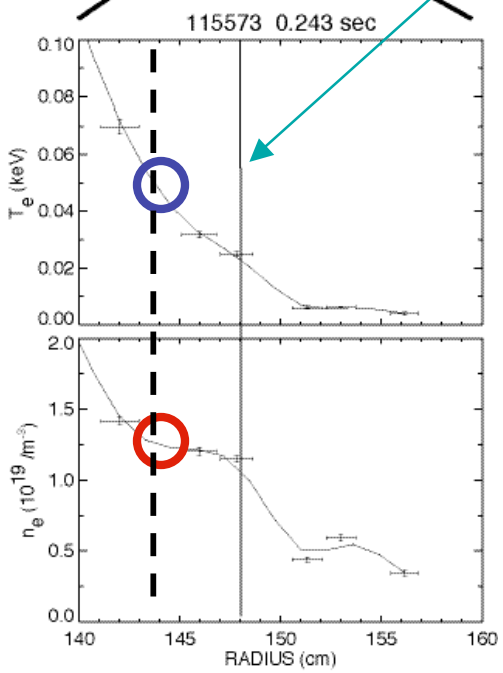
- Detailed FARO arm probe position calibration (0.005”)

- Software compensation for plasma boundary motion > Much reduced data scattering

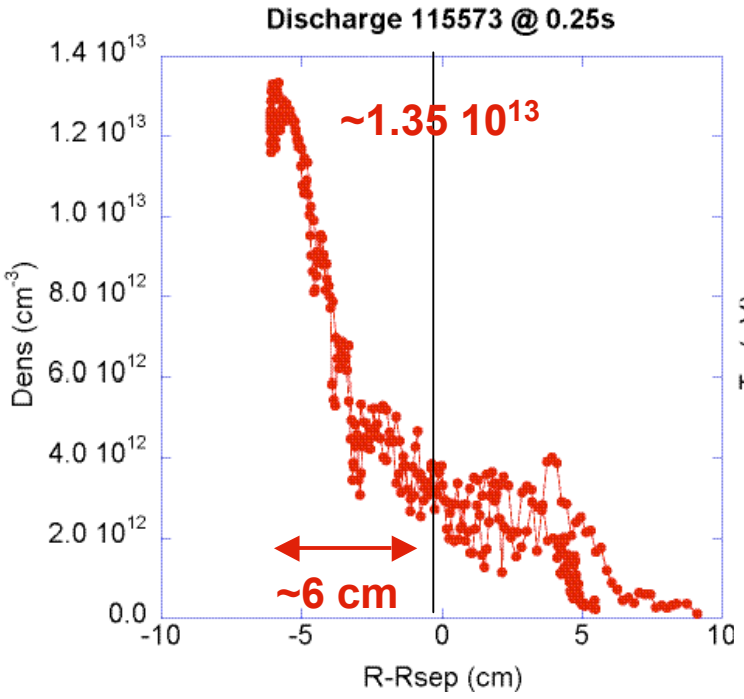
Results: Probe Can Reach Mid-Pedestal

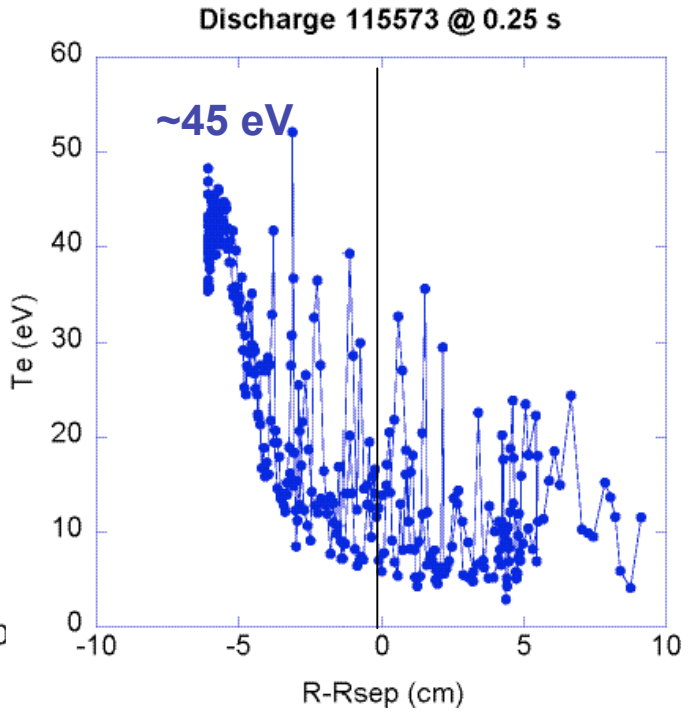






- Pedestal physics can be addressed with super-dense diagnostic
- Clearly Ne has pedestal, Te does not. Heat and particles transport different.
- ELM growth, L-H transition, Er well formation, zonal flows, etc





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SOL Characterization

•Goal: Profiles for UEDGE benchmarking, upgrading and fundamental SOL understanding (recent: inermittency, asymmetries, flows)

•Goal: Heat and particle loads to divertor and walls can be estimated when changing plasma parameters

•Method: Measure profiles, describe them by 2-3 parameters. SOL profiles can be fitted by an analytical expression and a scaling derived. LCFS position crucial

•Plasma parameters scanned:

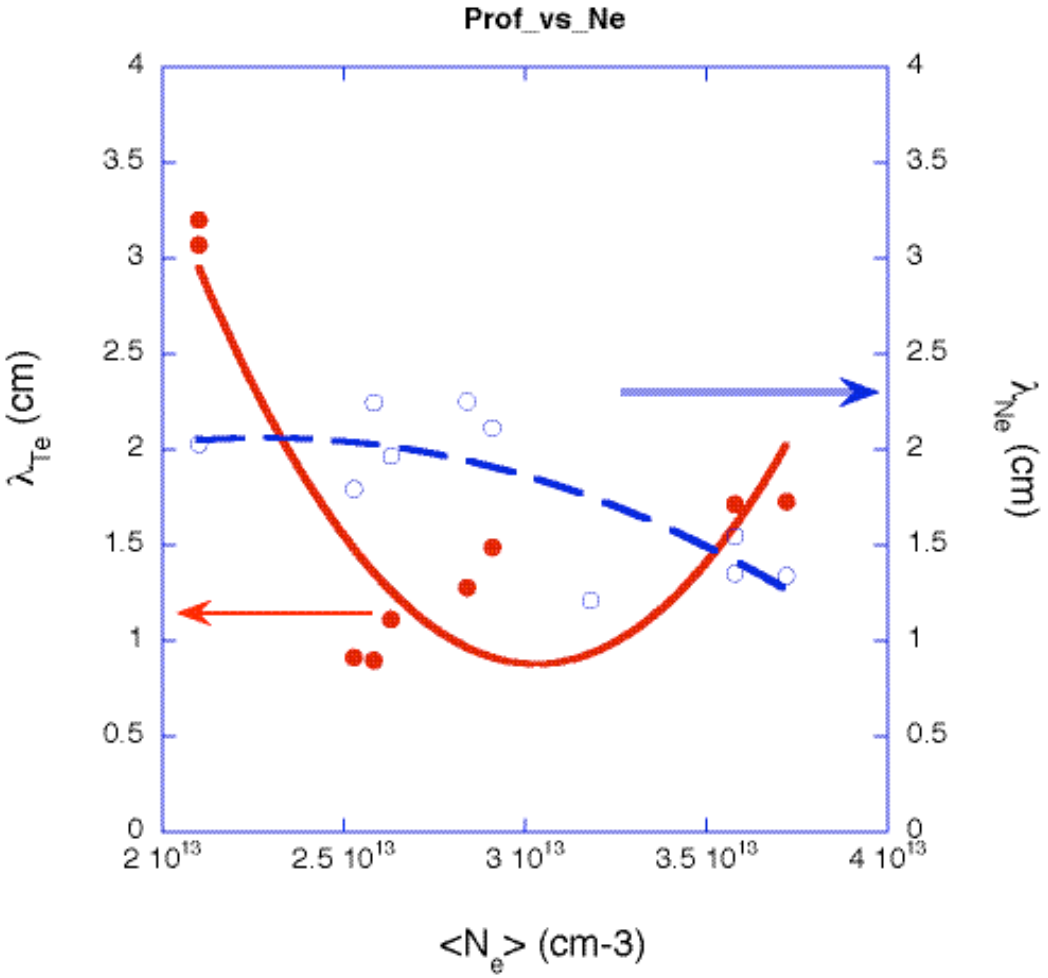
- –Ne > Intermittent transport increases
- –Magnetic geometry SN vs DN > shorter connection length
- –Pin > More power for SOL (still pending)

Result: SOL Decay Length Scaling L-Mode

- Take profiles measured with ~1.5 mm resolution (every ~1 ms)
- Fit offset exponentials
- Analytical expressions used:

$$n_e = n_{e0} + n_{e1} e^{-(r - r_{sep})/\lambda_n}$$

$$T_e = T_{e0} + T_{e1} e^{-(r - r_{sep})/\lambda_T}$$

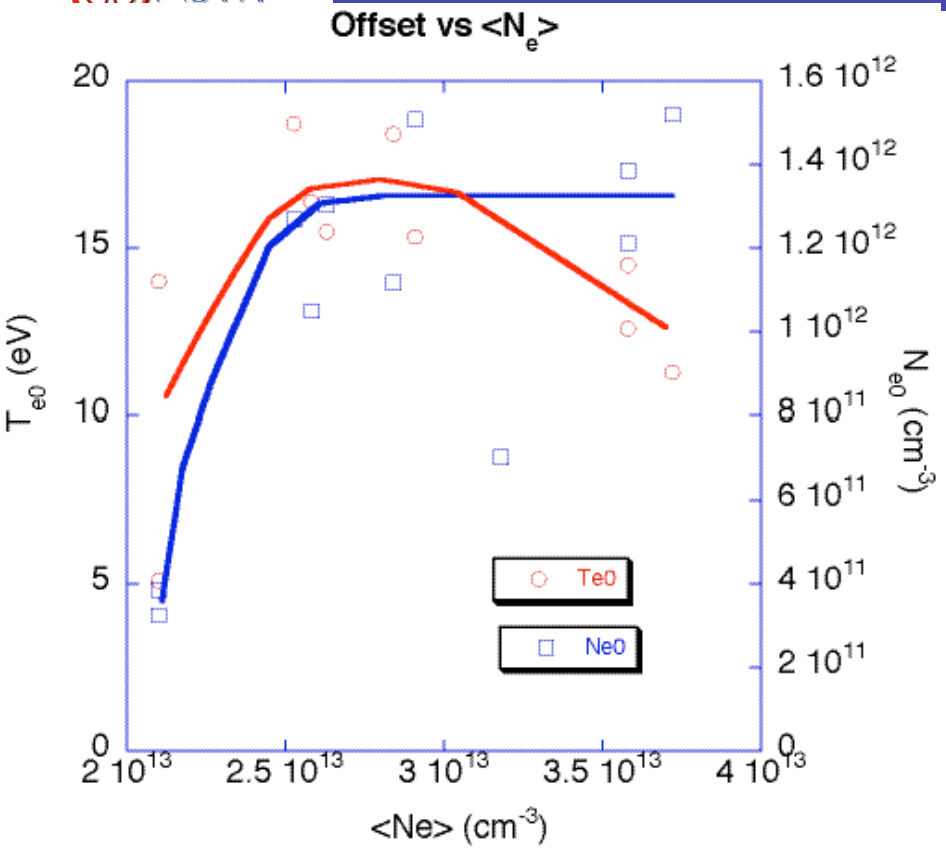


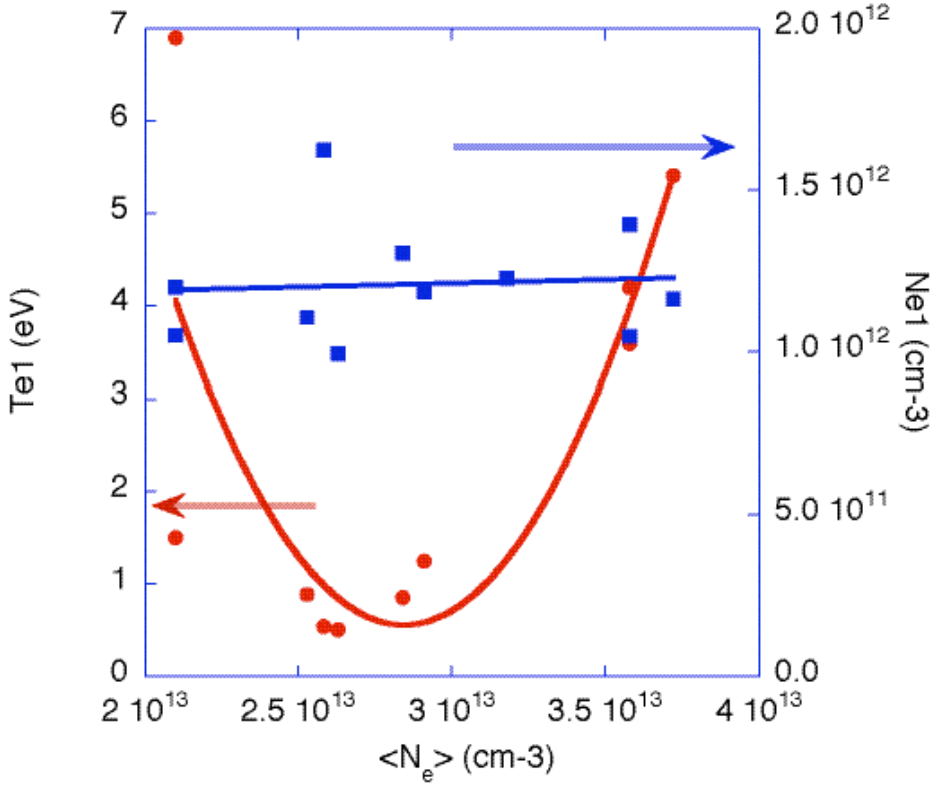
- Density decay length is ~2-1.5 cm
- Drops slightly with density

- Temperature decay length is ~1.0-2.0 cm. Except a low density.

- H-mode scaling experiments to be completed
- Power scanning experiments to be completed

Result: Fit parameters sensitive to <ne>





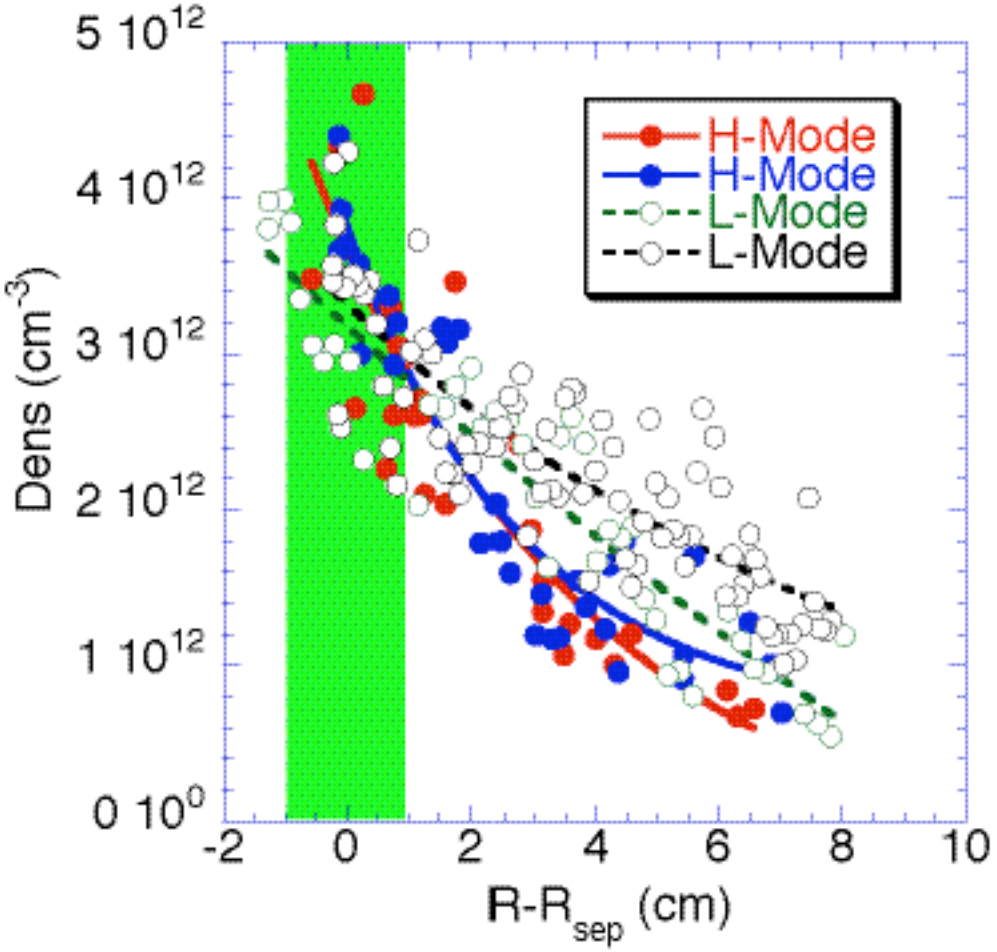
- Ne0, Te0 mostly insensitive to <ne> except at low density

- Ne1 insensitive to <ne>, Te1 very sensitive

$$n_e = n_{e0} + n_{e1} e^{-(r - r_{sep})/\lambda_n}$$

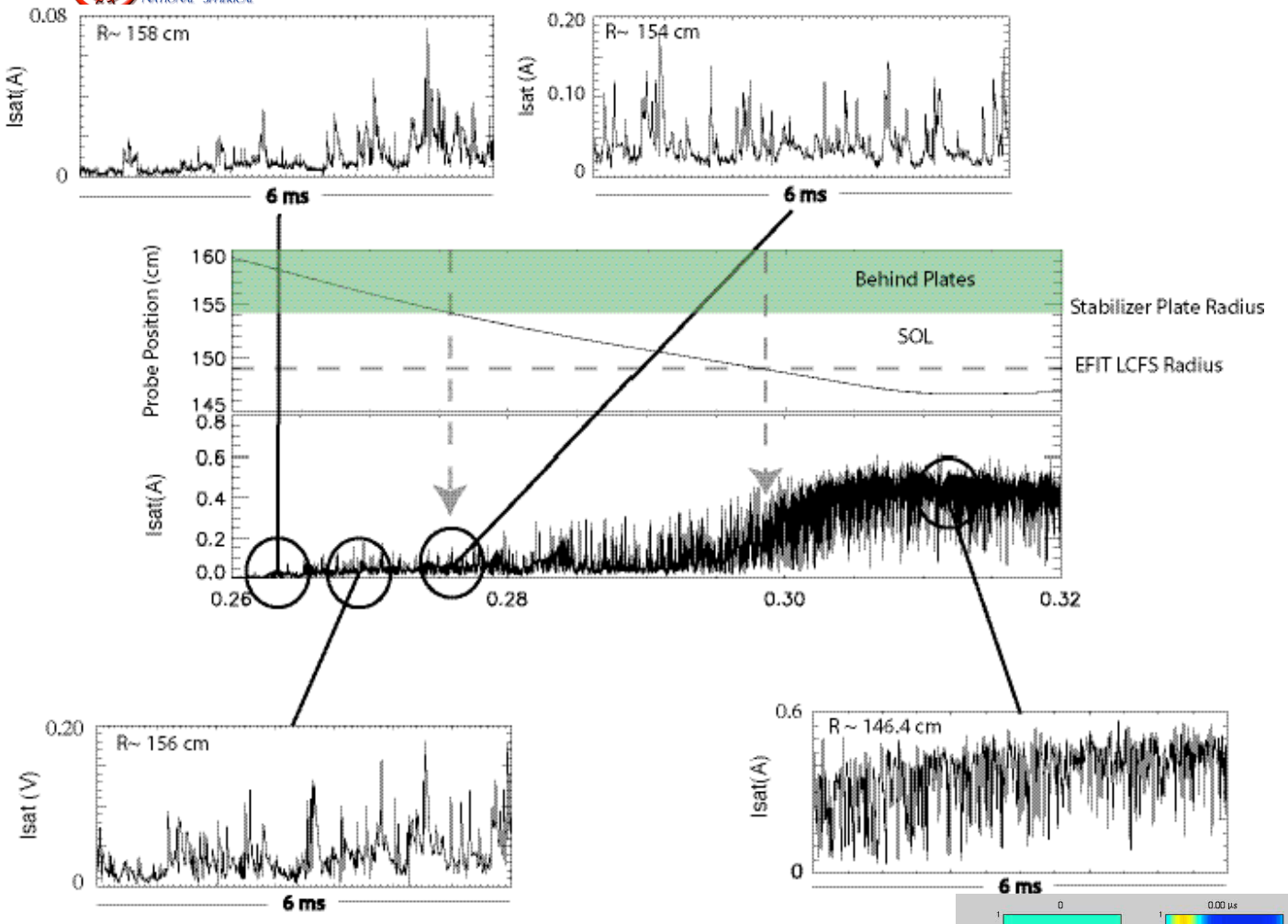
$$T_e = T_{e0} + T_{e1} e^{-(r - r_{sep})/\lambda_T}$$

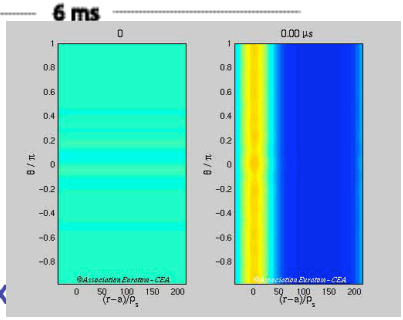
Result: Decay Length shortens with Pin



- Density SOL decay length is reduced by factors of ~2-3 by increased Pin.
- Scaling experiment incomplete, to be proposed this year.

Intermittency Characterization





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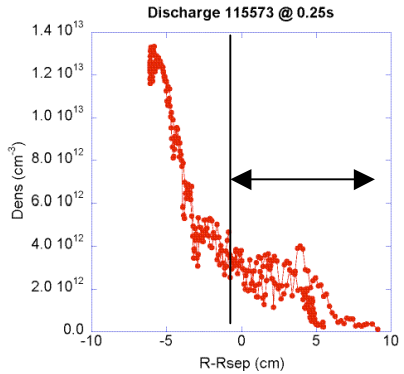
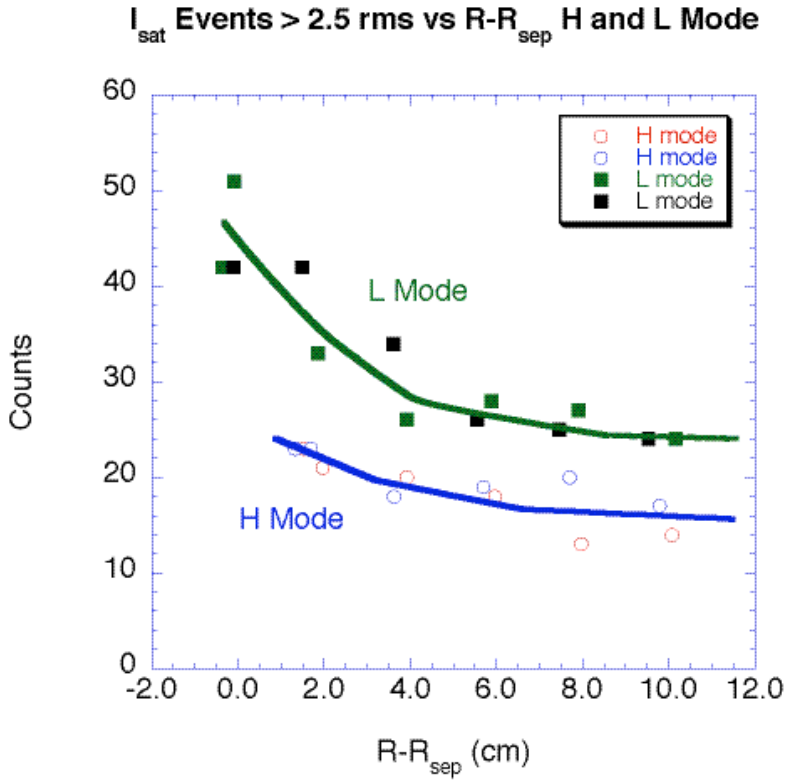
Intermittency strong in NSTX > Universal SOL feature

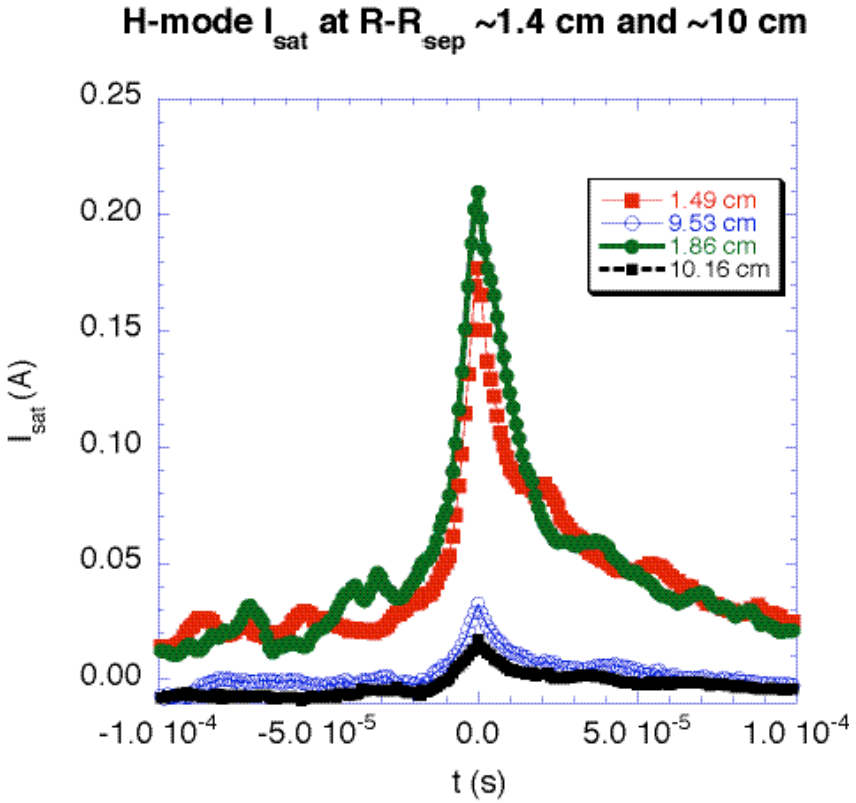
Peaks in SOL, Holes inside LCFS > Signature of Interchange Instability (Benkhada, Gendrih)



Results: Intermittency Radial Decay

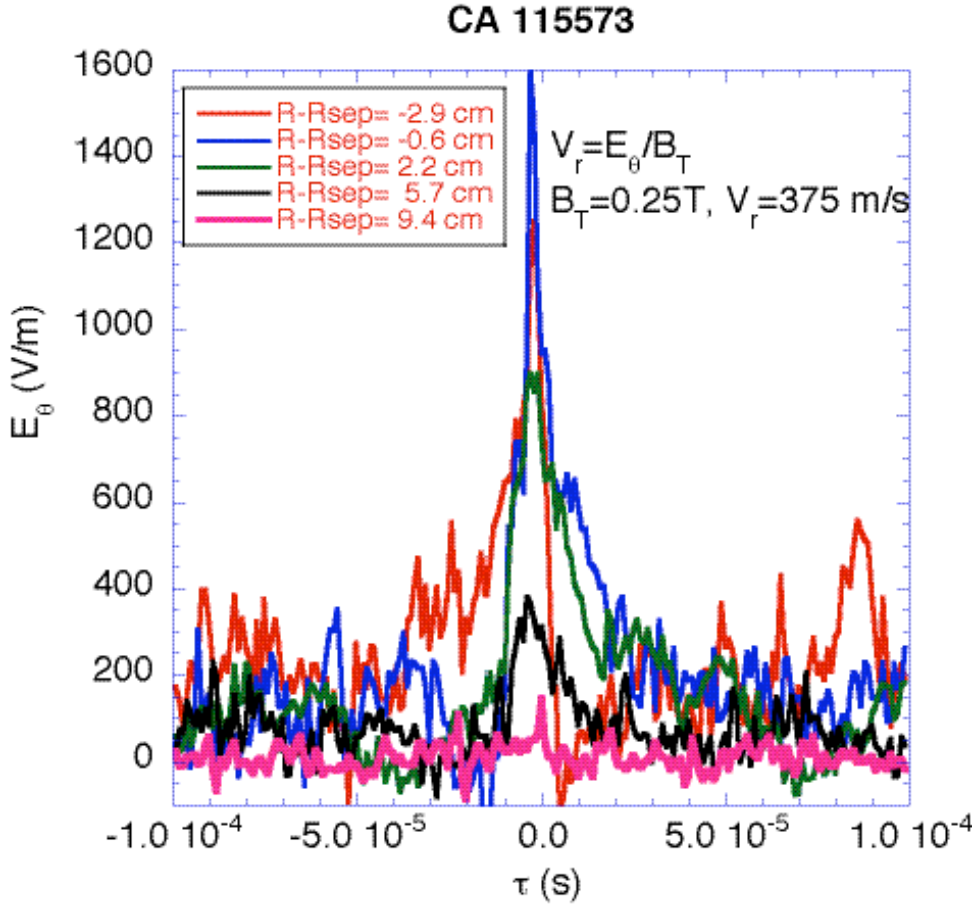


- Intermittent plasma objects decay radially in two ways:
  - Amplitude
  - Number of events per time



- L-mode almost 2x H-mode frequency
- Amplitude neat LCFS 5x that near wall

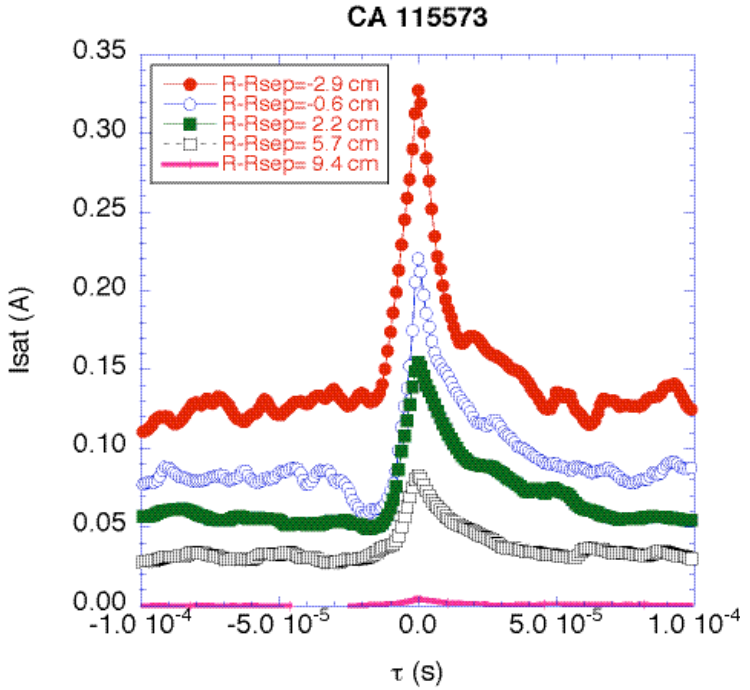
Result: Blob speed at LCFS ~ 400 m/s



Intermittent plasma object velocity **directly** measured by probe

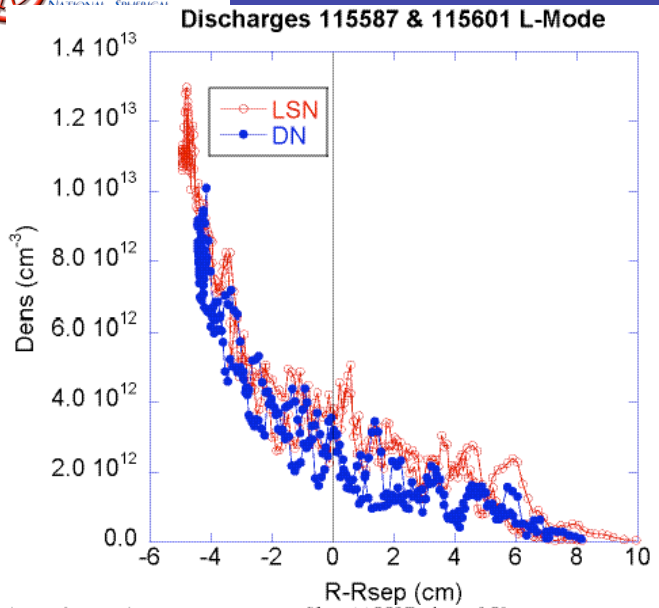
Velocity at LCFS ~ 400 m/s.
Decays to ~100 m/s at ~6cm

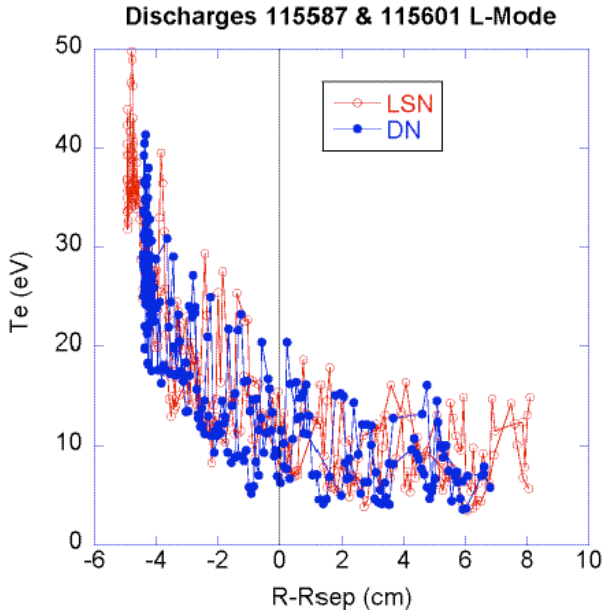
Measurement possible with improved S/N



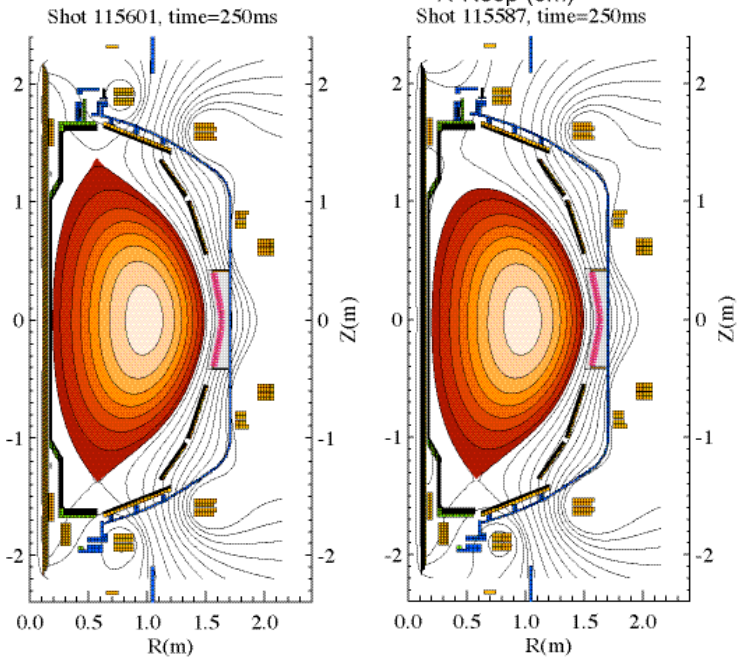
Heat flux (I.e.Te) can not yet be measured. Plans to add fast Te next year (06-07).

Result: SOL Dependence on Shape



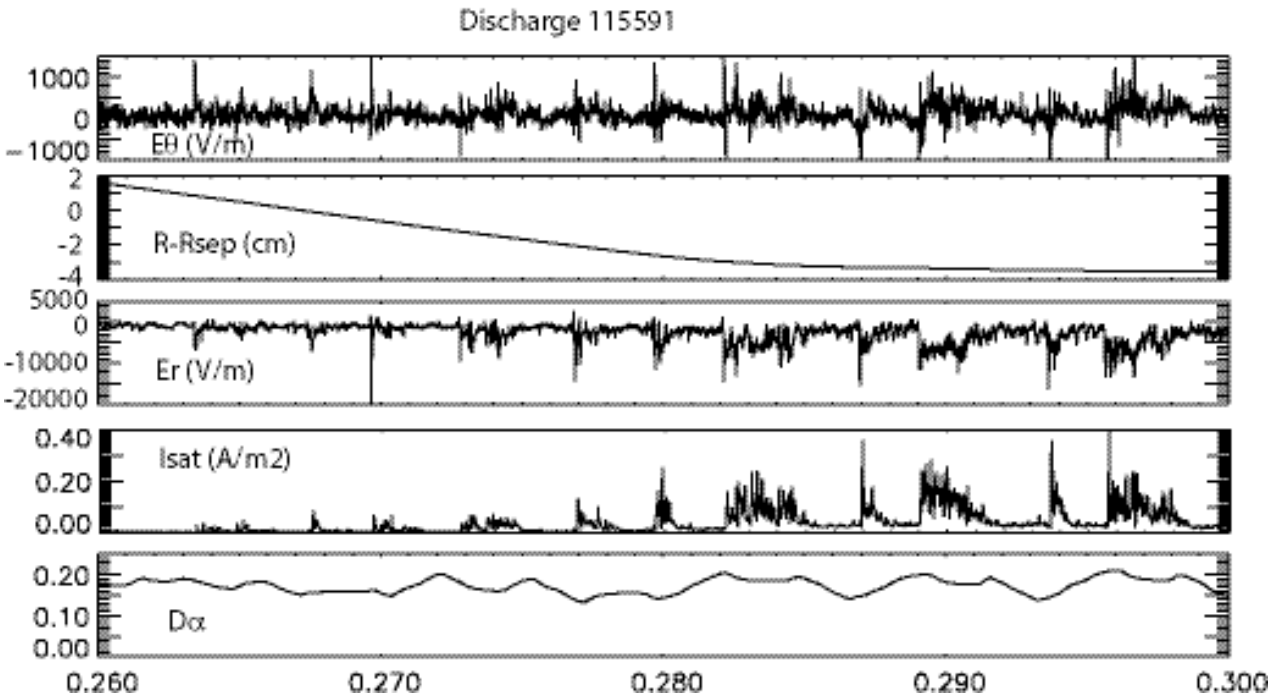


L-Mode LSN and DN, 800 kA, 1.2 MW NBI, 2 MW Pin, ne~2.2 10^{13} cm^{-3}



- Goal 1: What does the SOL look like? Expecting shorter SOL due to decreased connection length. >> Answer: Particles, somewhat, heat, not much
- Goal2: BOUT predicts second X-point will increase turbulence. Two discharges only. Proposal to continue

ELM Characterization and Dynamics

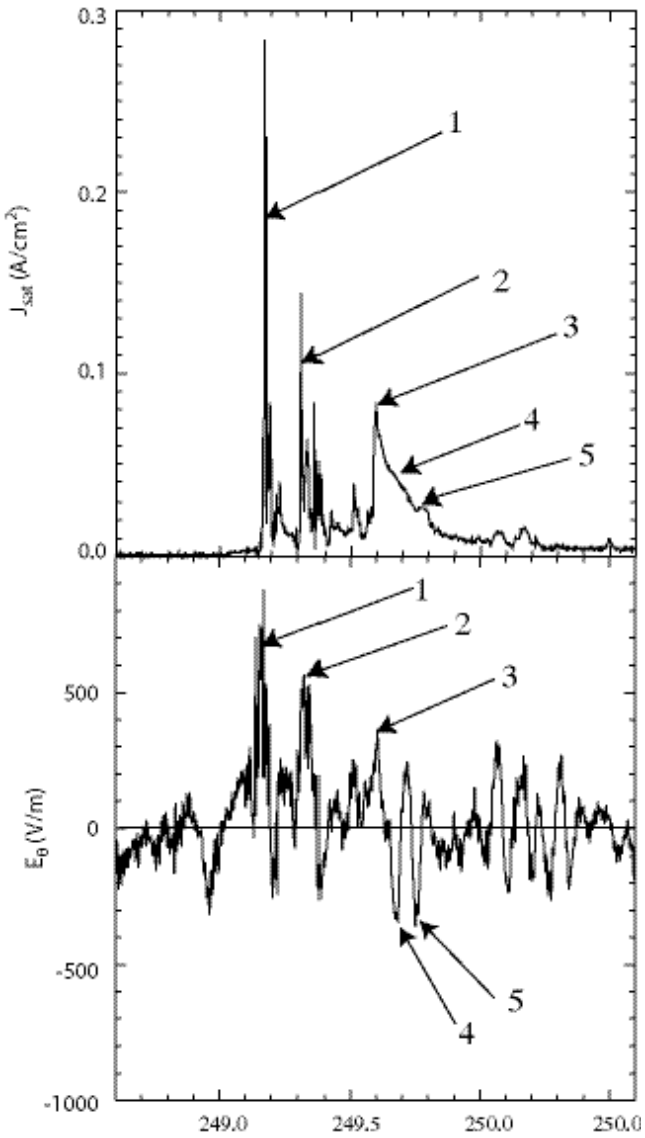


Probes measure ELM plasma parameters with high (1 MS/s) time resolution.

ELM velocity, electric fields, velocity and particle flux can be measured > SOL dynamics

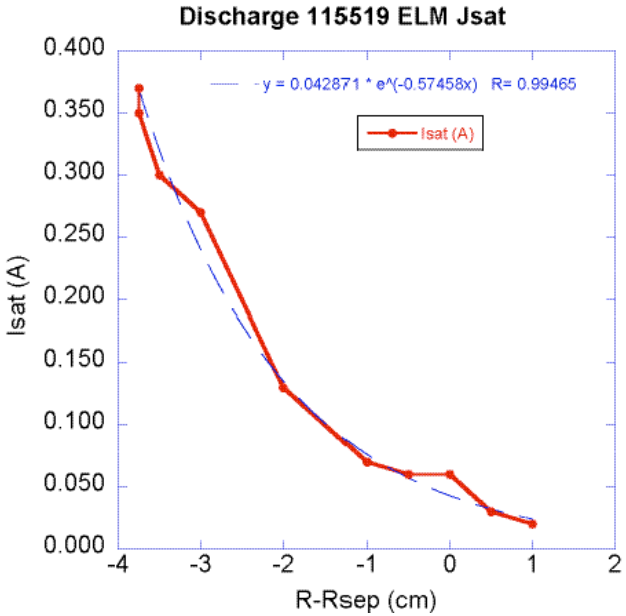
- Study ELM pedestal physics > Fundamental

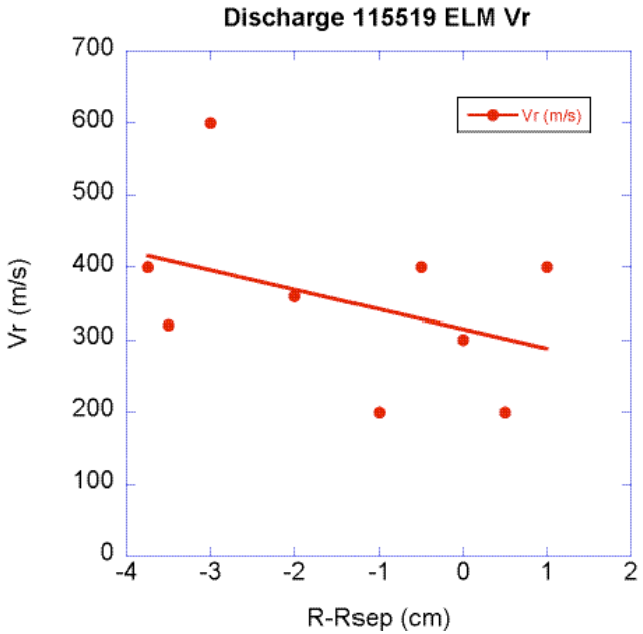
Result: ELM Dynamics in SOL



- ELM is comprised of various short (~10 μs) bursts in rapid succession (~20-50 μs)
- ELM radial velocity can be high ~ 500 m/s near LCFS and slows down (~200 m/s) in the SOL.
- Near wall, negative Vr (4,5) is seen in some ELM components (reflected plasma?)

Result: ELM spatial decay and speed





- ELM plasma content decays exponentially away from pedestal
- ELMs convective speed (~400 m/s) decays only slightly > wall impact quite unmitigated

Goals: Future Work

- Compare high-res SOL profiles to modeling (UEGDE)
- Turbulence scaling (ne, X-pointness) Compare BOUT
  - Finish SOL scaling with power
  - Variability with shape (LSN, USN, DN)
- Blob dynamics comparison with BOUT and other models (Myra, etc). Explore regimes. Need fast Te
- ELM origin, growth and SOL dynamics study in various regimes. Need fast Te
- Magnetic turbulence at high beta
- Reynolds Stress > L-H mode transition physics
- Poloidal asymmetries > Need divertor probe
- Flows in SOL

Result: Er Well Characterization

- Check radial conductivity theory