

Structure and statistics of turbulently generated structures in LAPD

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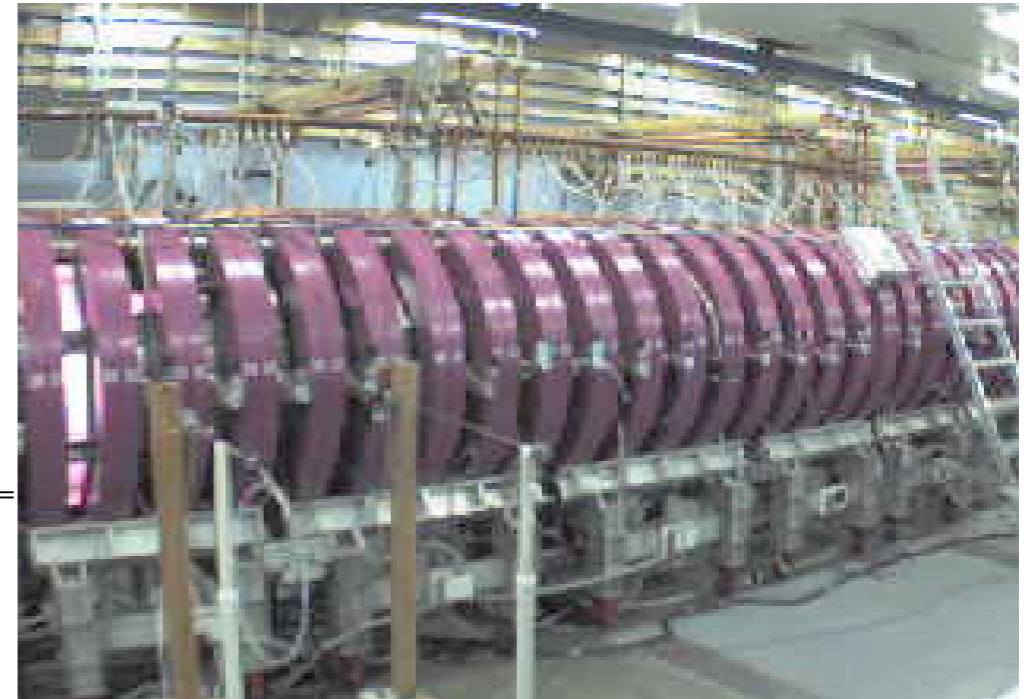
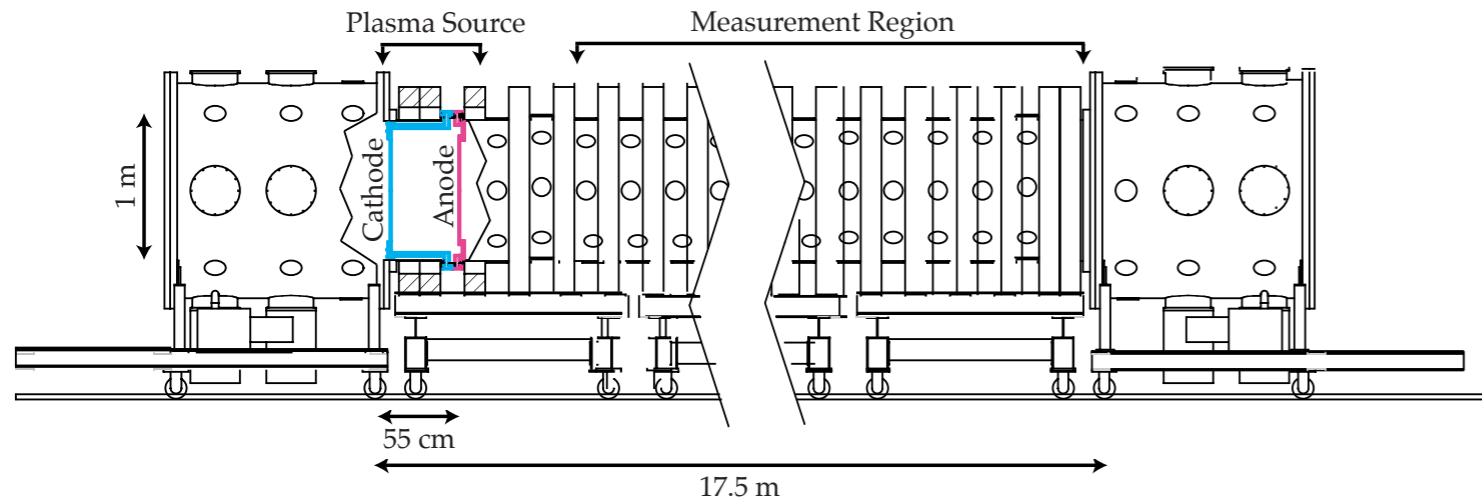
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Summary/Outline

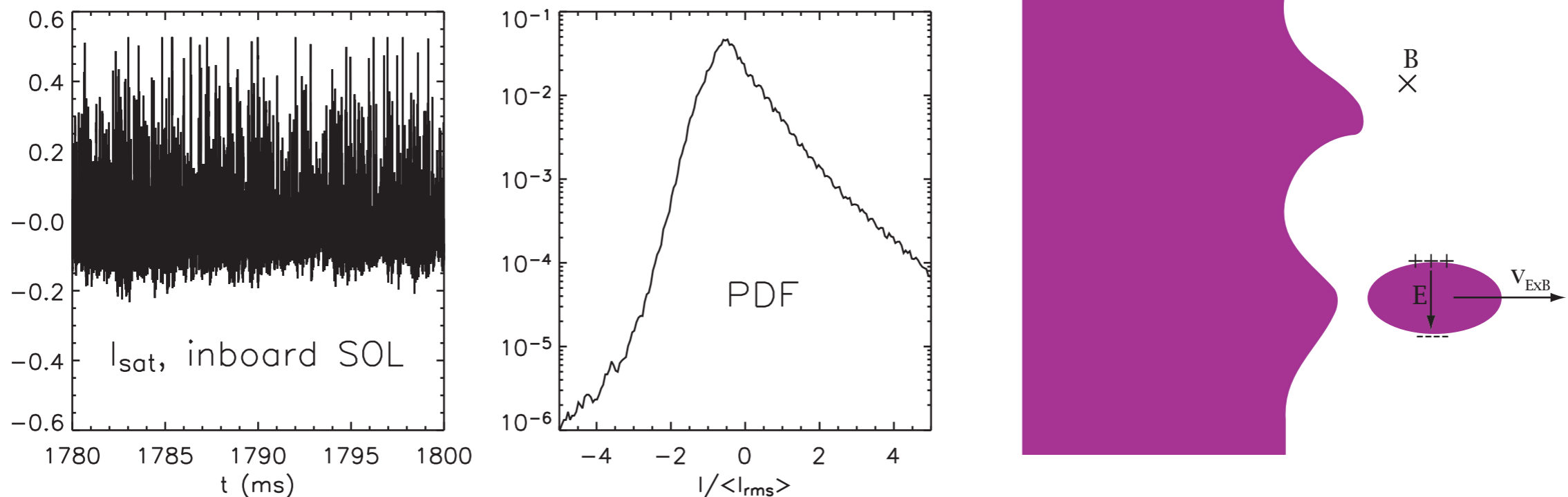
- Strongly intermittent turbulence observed in limiter shadow of LAPD [T. Carter, Phys. Plasmas 13, 010701 (2006)]
 - Both “blobs” and “holes” observed.
 - 2D imaging shows blobs are detached filamentary structures with dipolar potential; holes do not appear to be isolated structures
 - Blob velocity scales with sound speed, blob size with sound gyroradius
 - Preliminary measurements of joint PDF of blob velocity and density, magnetic signature of blobs

The Large Plasma Device (LAPD) at UCLA



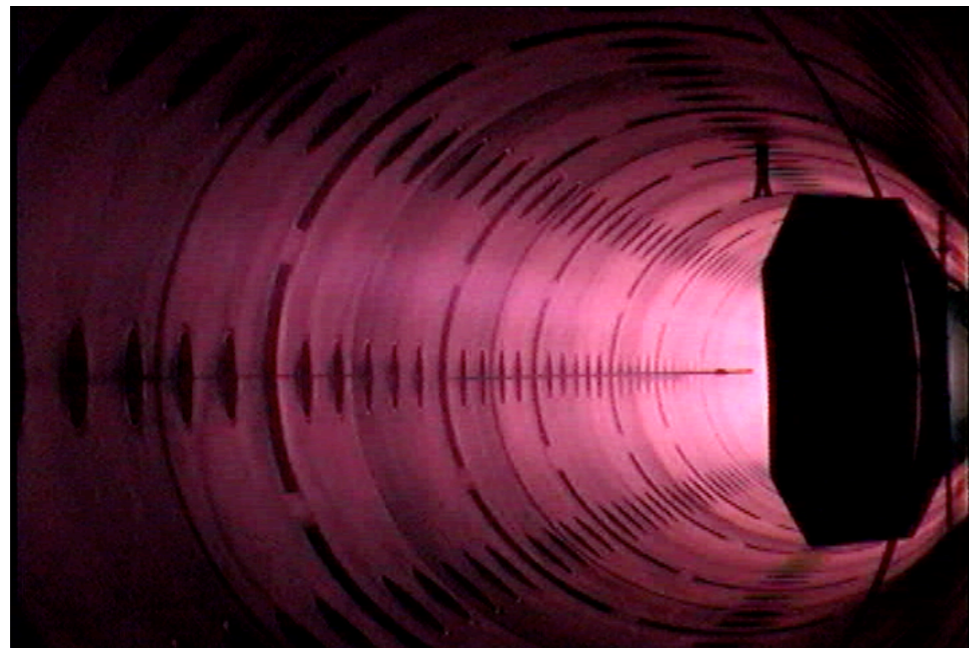
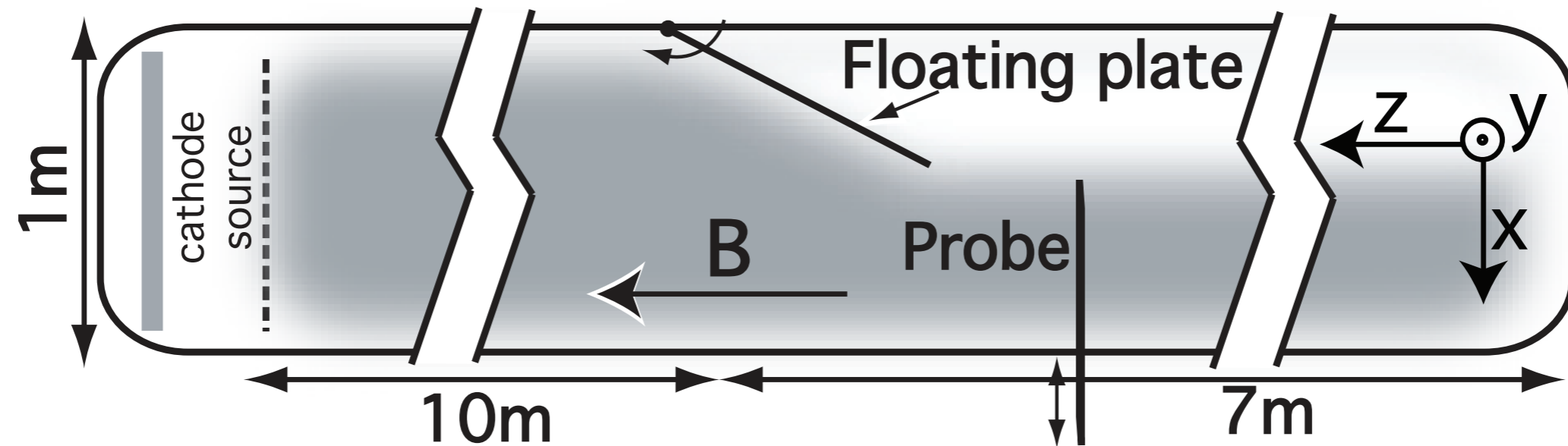
- Barium Oxide cathode source (50V, 10kA)
- $0.5 < B < 2$ kG, $n_e \sim 10^{12} \text{ cm}^{-3}$, $T_e \sim 5 \text{ eV}$, $T_i \sim 1 \text{ eV}$
- 1 m diameter, 20 m long chamber
- He, Ne, Ar, H plasmas
- 1 Hz rep rate, 10 ms pulse length
- International user facility (<http://plasma.physics.ucla.edu/bapsf>)

What is intermittent turbulence?



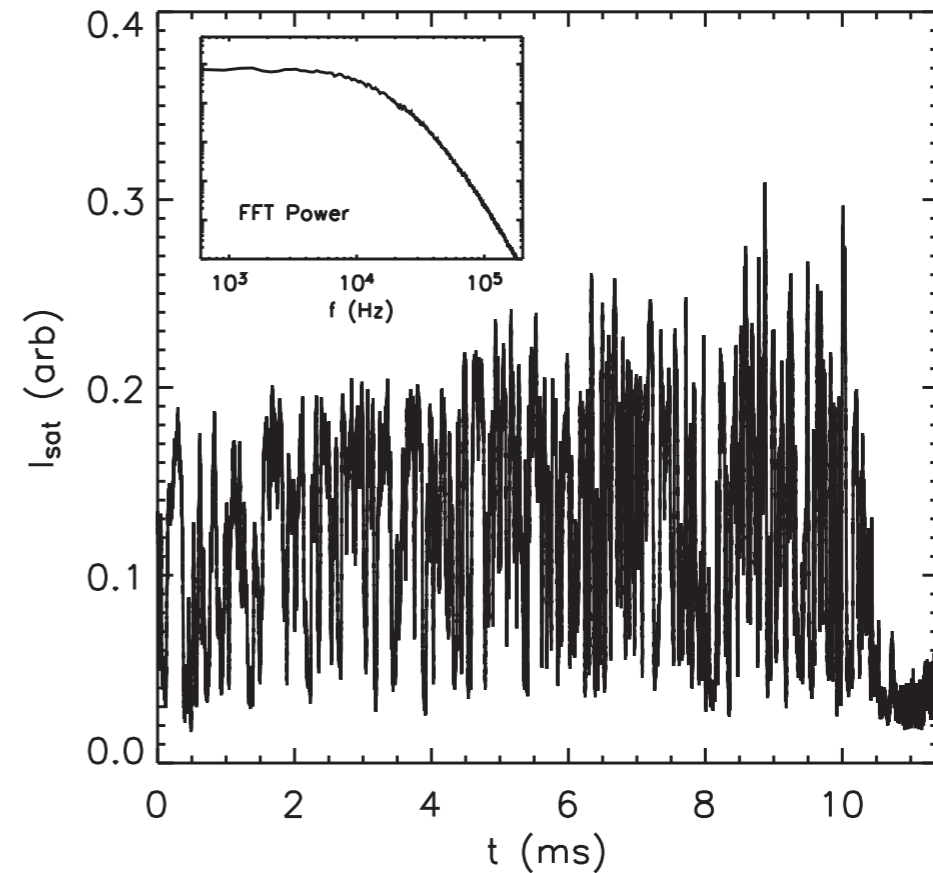
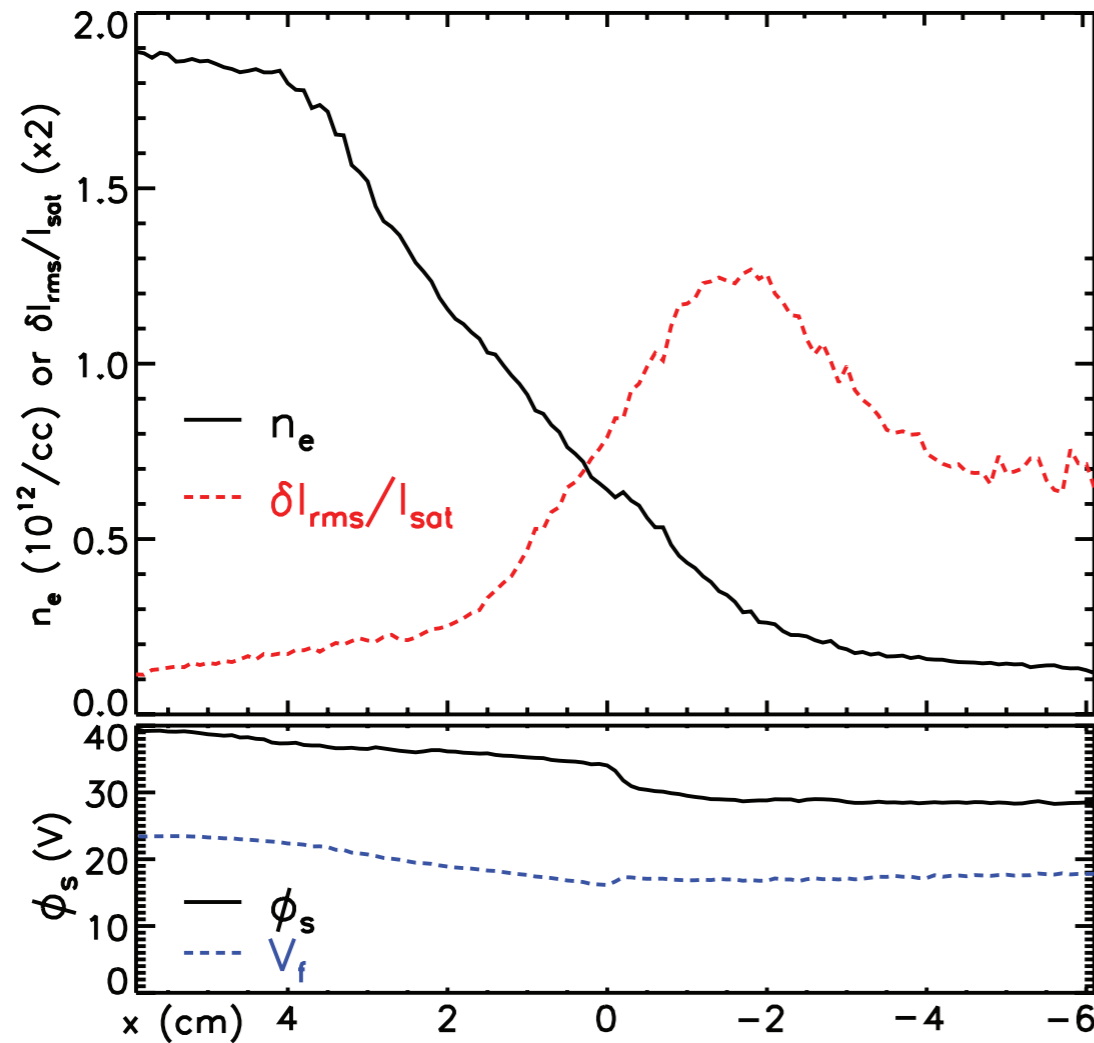
- Patchy in space or bursty in time, non-Gaussian amplitude PDF
- In edge magnetic confinement devices, explained by presence and propagation of structures (seen in nearly all such devices [Antar])
- Propagation of structures tied to polarization by drift-charging [Krasheninnikov] (need interchange force)
- Transport by intermittent convection very important in edge of confinement devices, and may be linked to density limit [Greenwald]

Limiter-produced density gradients in LAPD



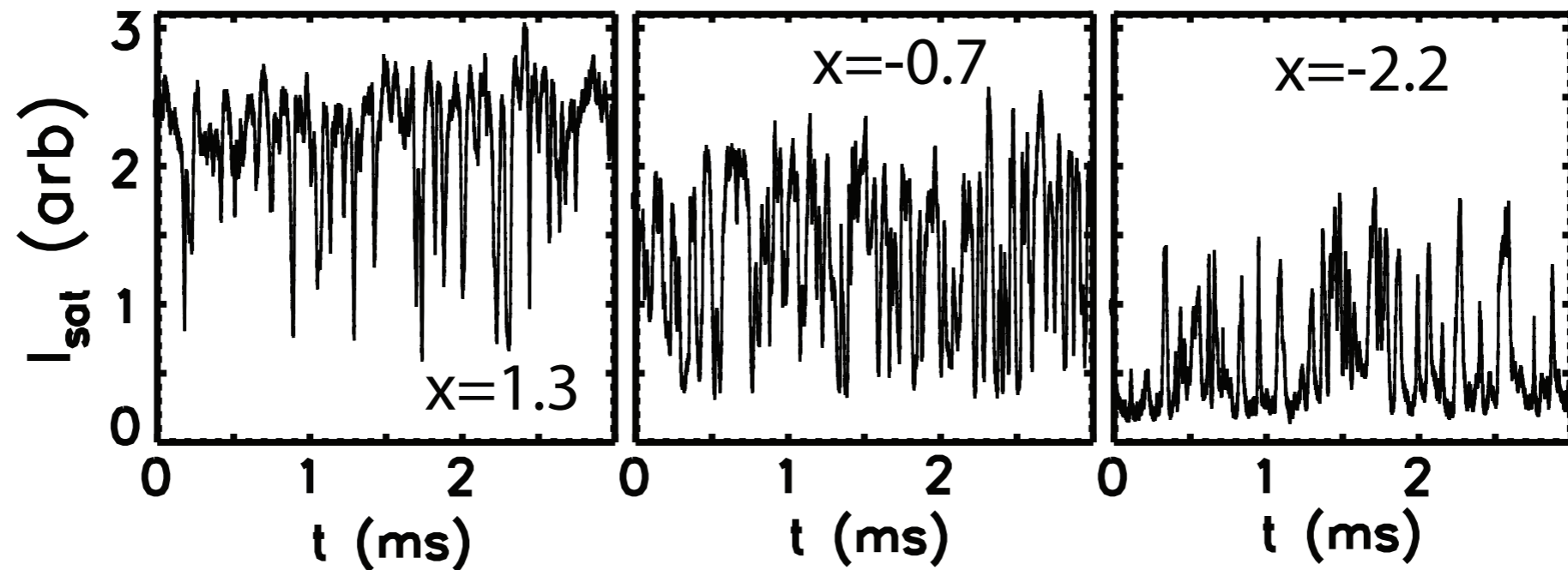
- Floating plate (10m from source) partially closed
- Steep density gradient behind limiter
- Vertical limiter edge - flows, but not rotation

Example profiles: large amplitude, broadband fluctuations in limiter shadow



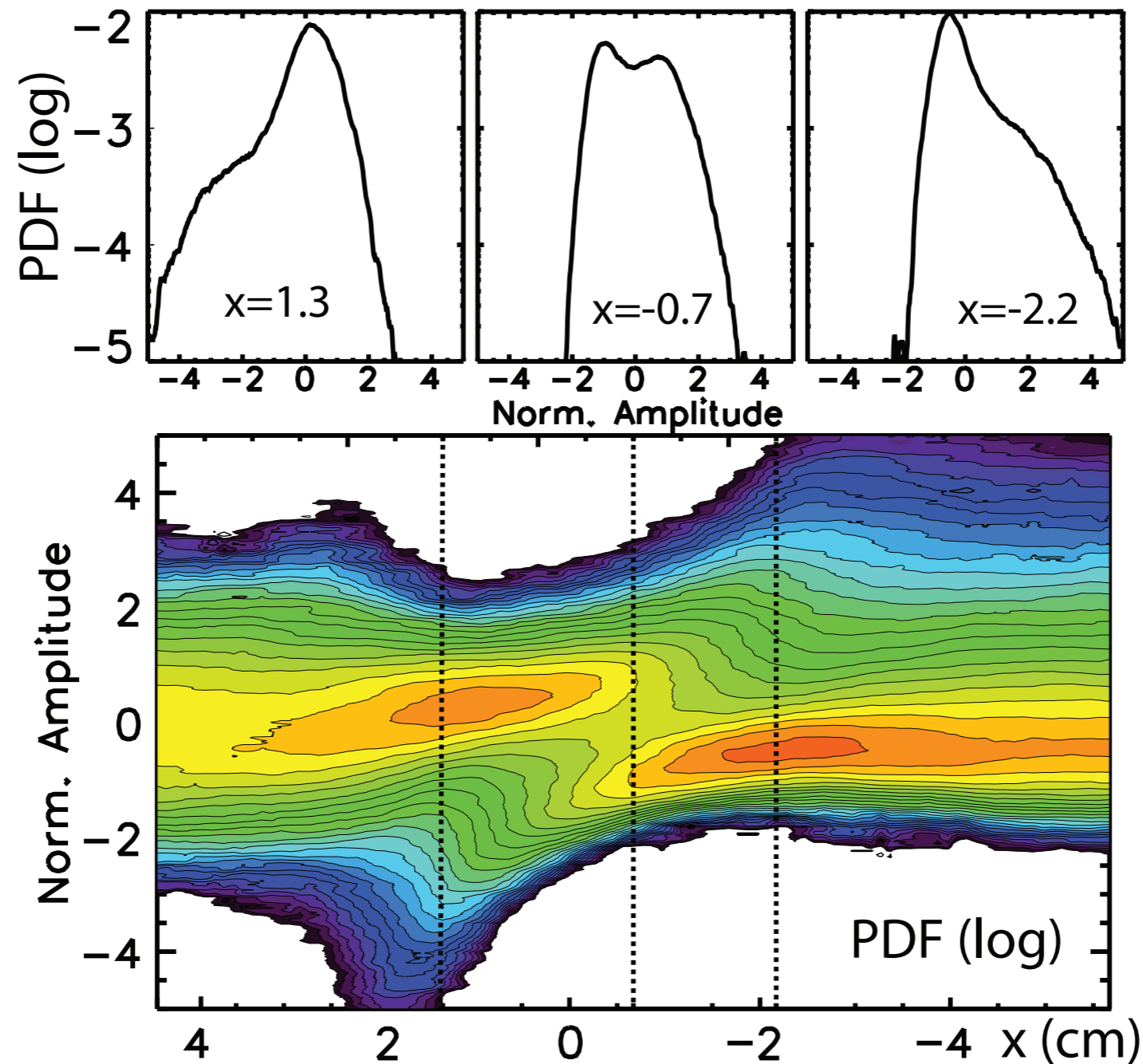
- $L_n \sim 2 - 4$ cm ($10 - 20\rho_s$) , $\delta n/n \sim 1$
- Broadband frequency spectrum (no coherent modes)
- Substantial density behind plate (no parallel source)

Strong intermittency and observation of both “blobs” and “holes”



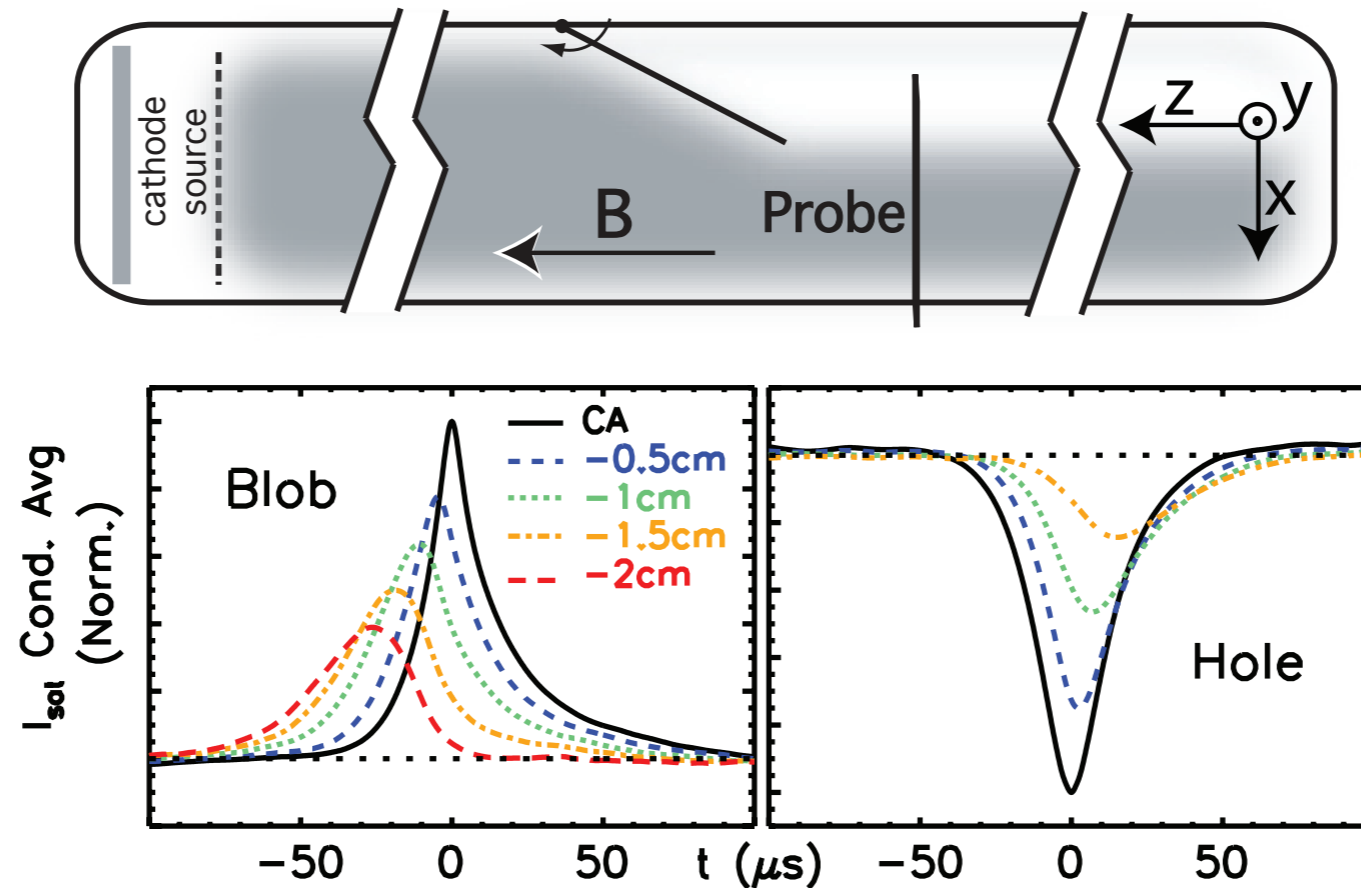
- Density depletion events (or “holes”) dominant on core side of gradient, density enhancement events (or “blobs”) dominant in limiter shadow
- Consistent with interchange-like drive? (but what is the interchange force?)
- Holes not typically seen on other devices (only DIII-D [Boedo])

Fluctuation amplitude PDF is highly non-Gaussian



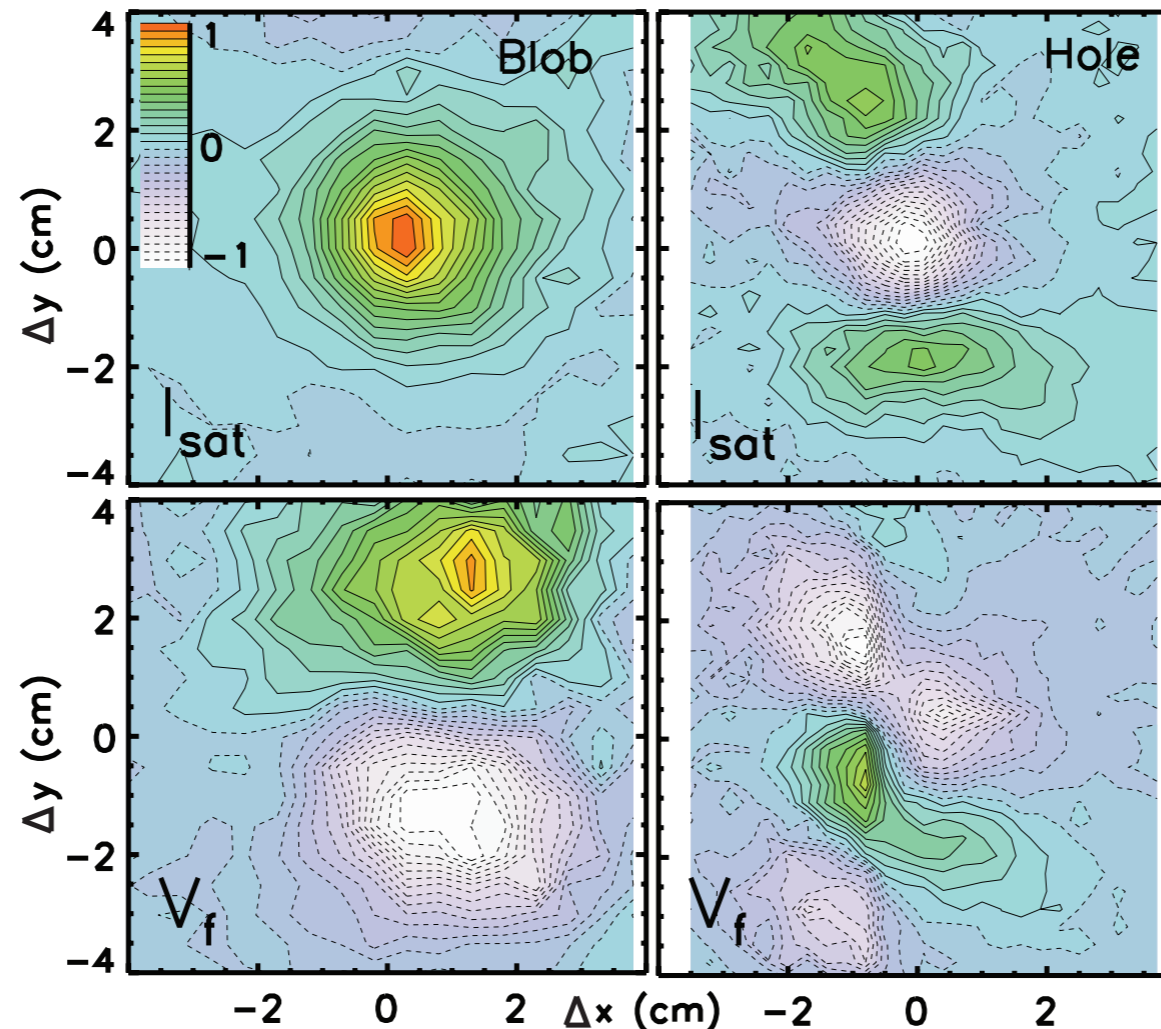
- Hole signature spatially localized, blob-dominated PDF extends into low density region

Cross-conditional averaging shows blobs propagate out of plasma, holes back in



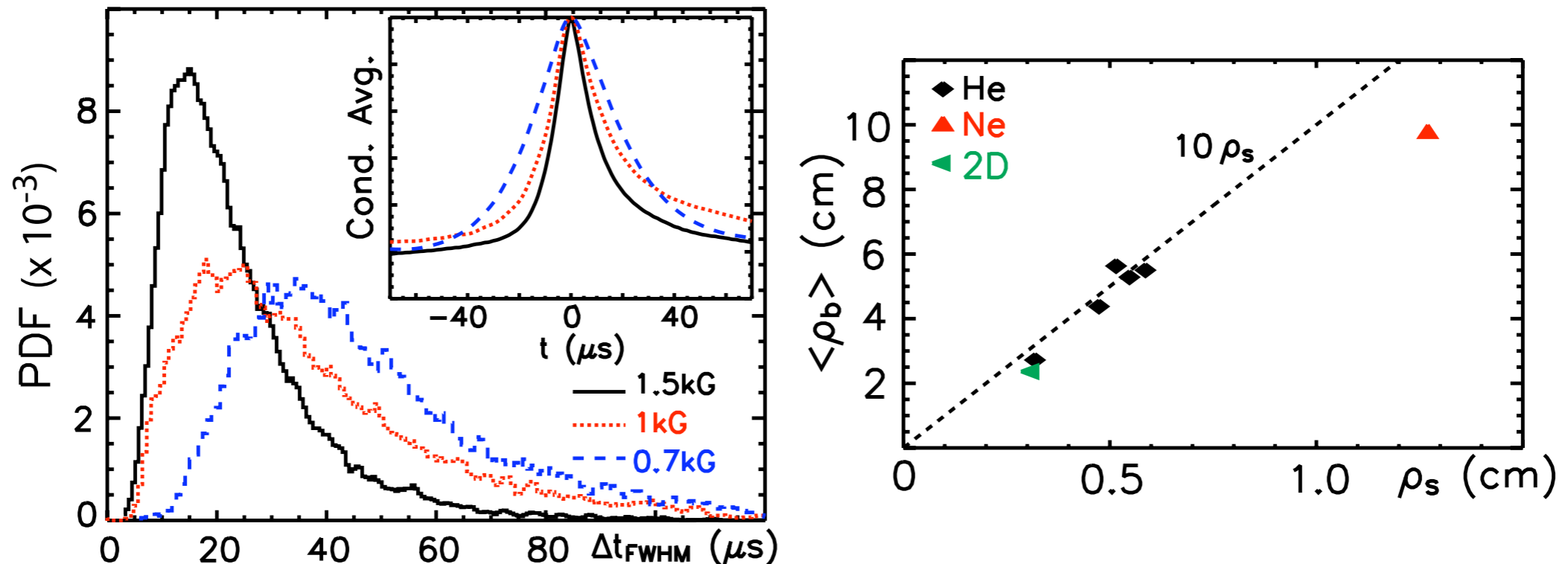
- Linear array of Langmuir tips, arranged on the x -axis
- $V_{blob} \approx 940 \text{ m/s} \sim \frac{C_s}{10}$
- However - need to know 2D structure to interpret 1D velocity measurement (e.g. could be vertical propagation of tilted structure)

2D structure measurement: blobs are polarized filaments, holes are not isolated structures



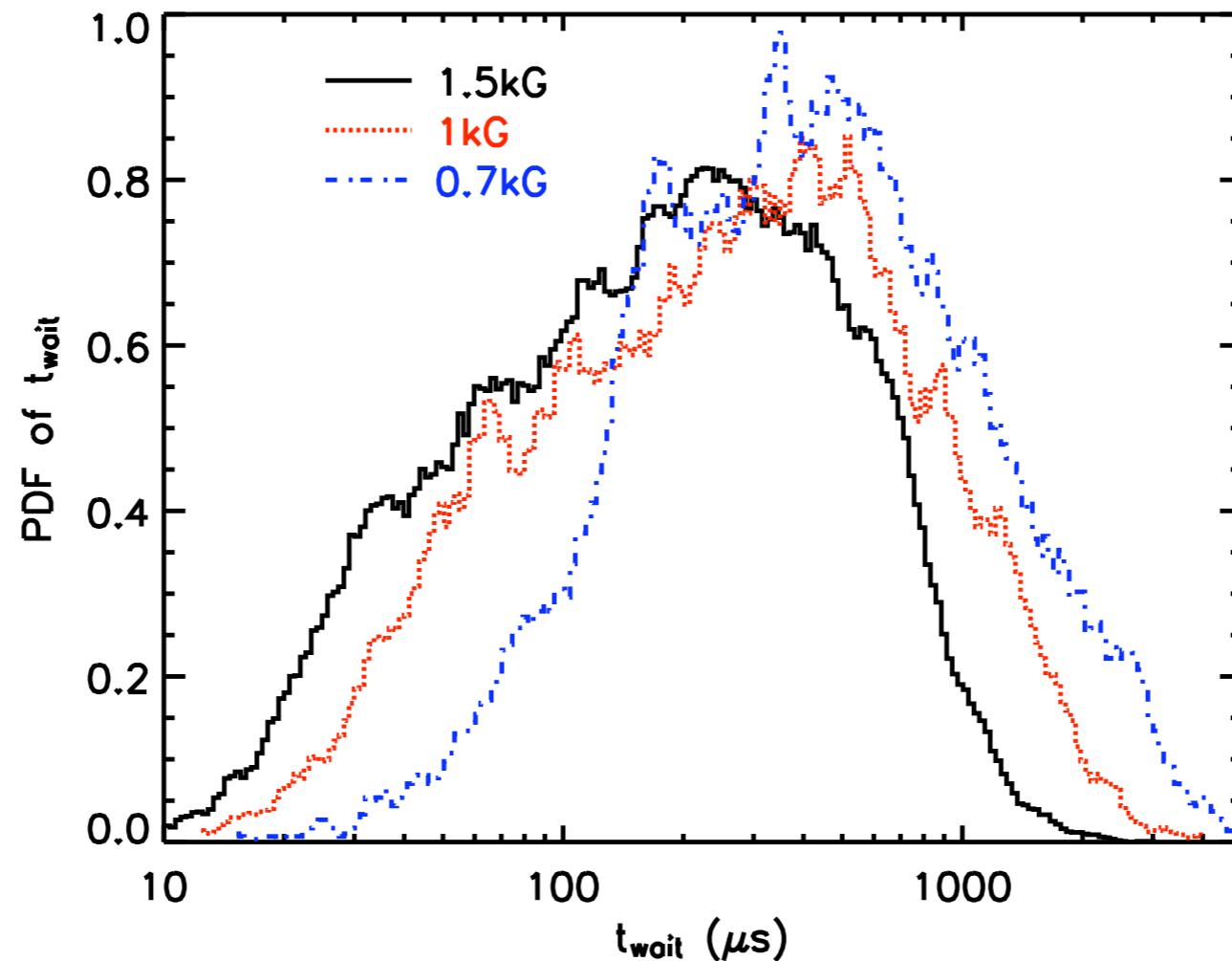
- 2D cross-conditional average, using two triple Langmuir probes (separated by 60cm along the field)
- Derived blob velocity consistent with linear array, $V_{ExB} \approx 980$ m/s
- Hole structures do not appear to be detached - instead are likely part of extended nonlinear drift wave structure

Blob size scales with sound gyroradius



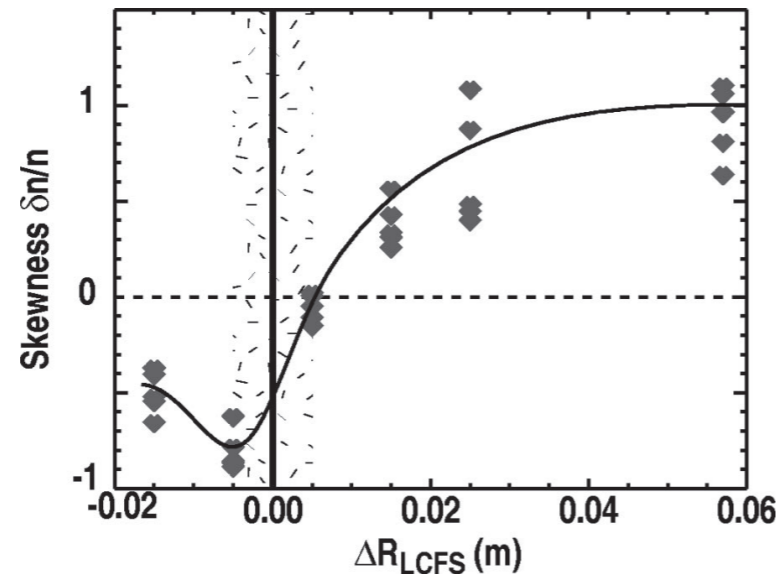
- PDF of event time width: time width of blob events increases with decreasing field
- Average blob size, computed using time width and linear array measured velocity: $\langle \rho_b \rangle \sim 10\rho_s$
- Gyroradius scaling predicted theoretically [D'Ippolito]
- However, note that average blob size is comparable to gradient scale length (indirect scaling?)

Waiting time PDF: blob creation is broadband

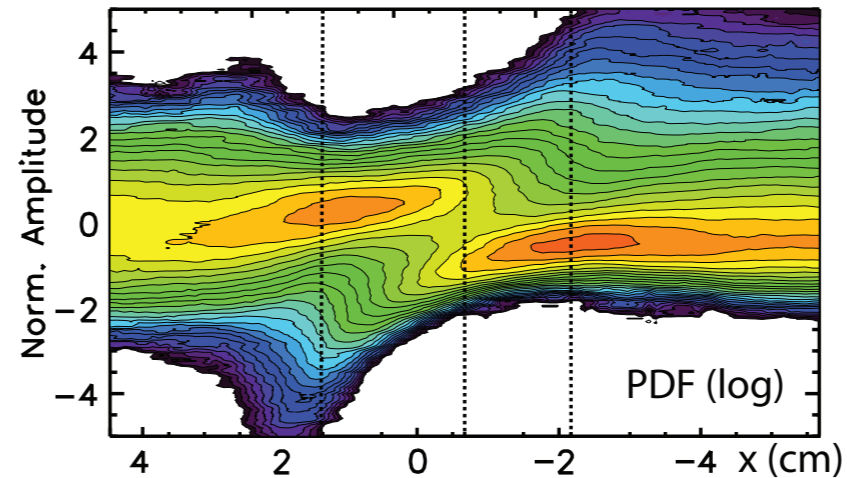


- Waiting time: time between consecutive blob events
- Waiting time is broadband (consistent with power spectrum of turbulence in gradient region)
- Waiting time increases with decreasing field, some signs of increased coherency

LAPD data very similar to tokamak data, in the absence of typical interchange forces

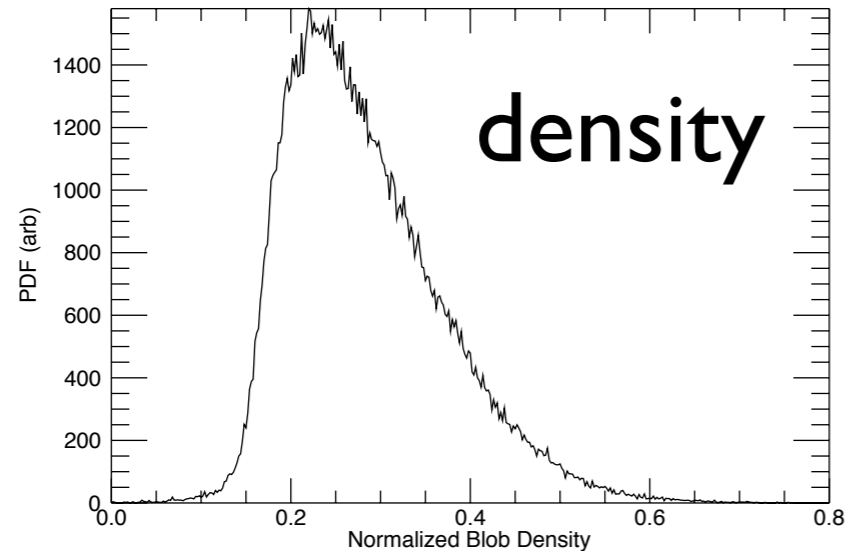
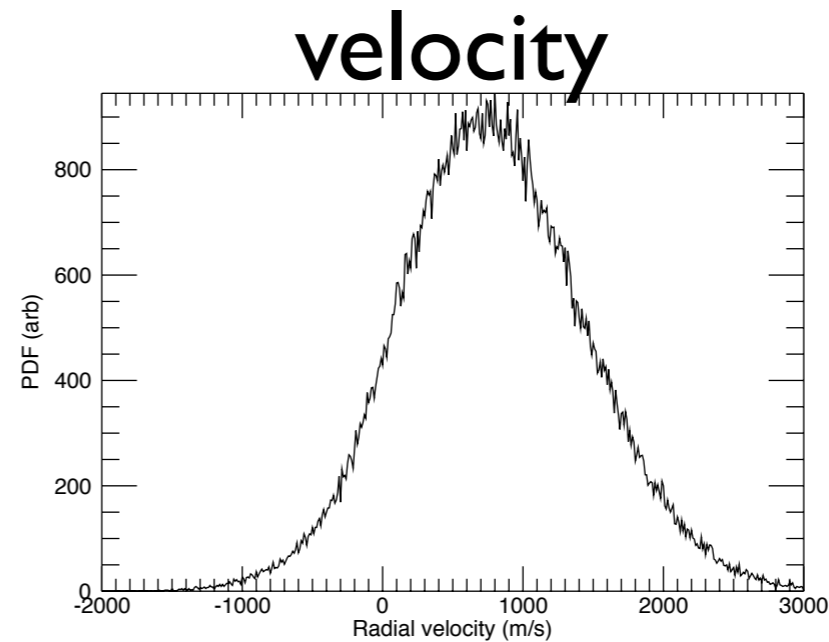
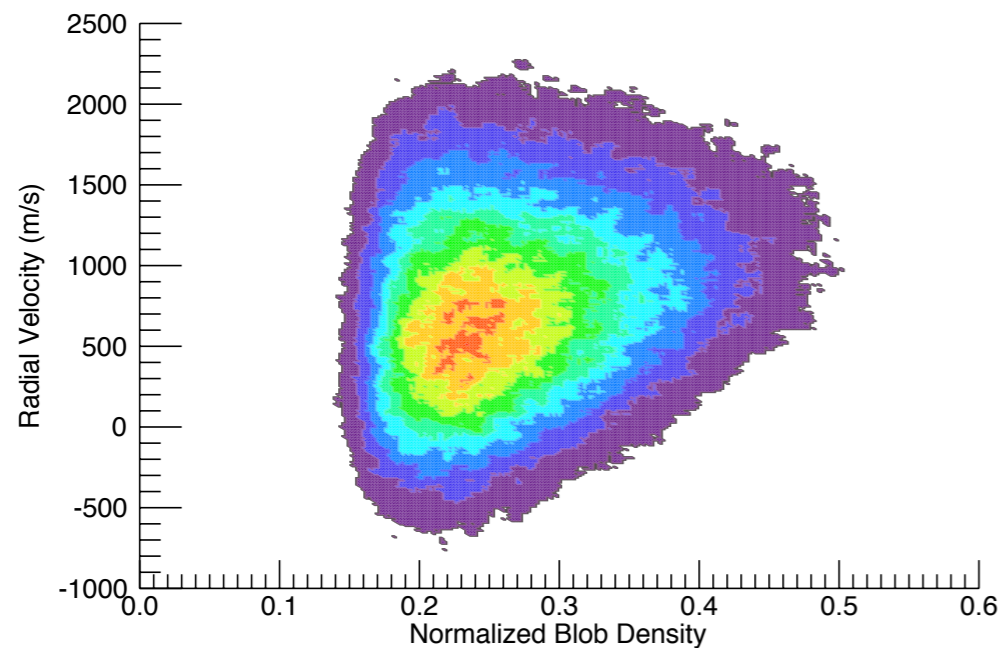


(from Boedo, et. al., PoP 10, 1670 (2003))



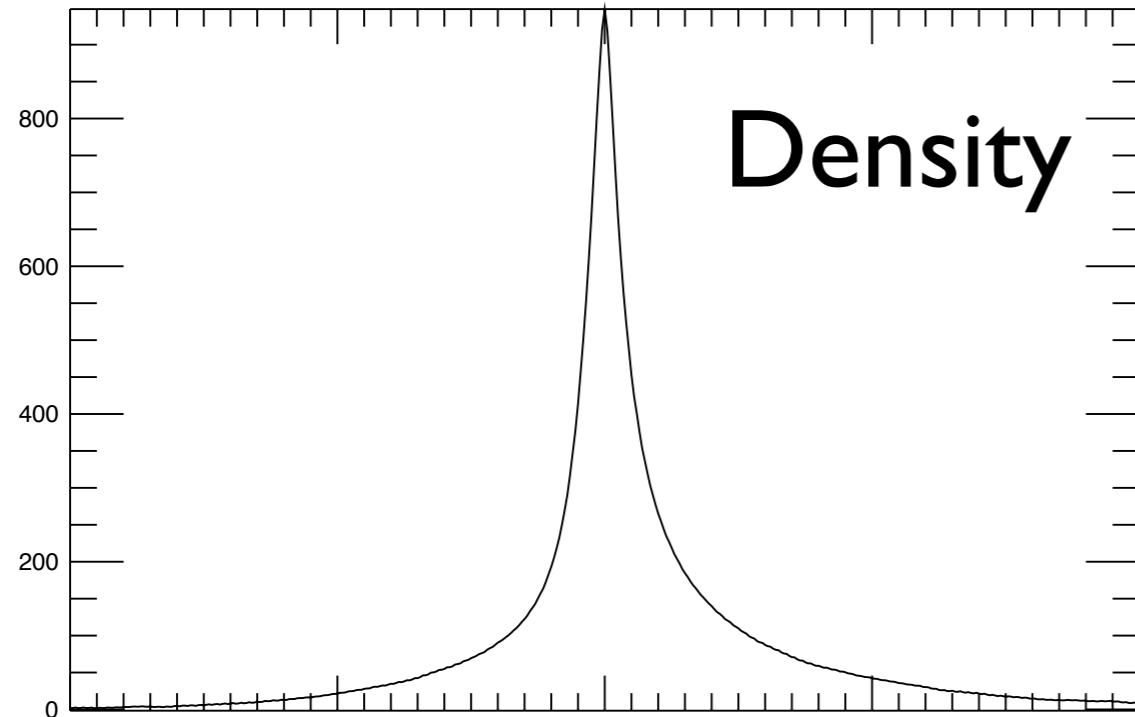
- BES observations in DIII-D exhibit trends in PDF strikingly similar to LAPD observations (blob and hole production)
- However, no magnetic curvature or rotation in LAPD (what creates and polarizes blobs?)
- Basic physics of structure generation independent of interchange force? (importance of detailed studies on LAPD)
- “Neutral wind” may serve as interchange force in these experiments [Krasheninnikov], predicts consistent blob speed

PDF of velocity and blob density

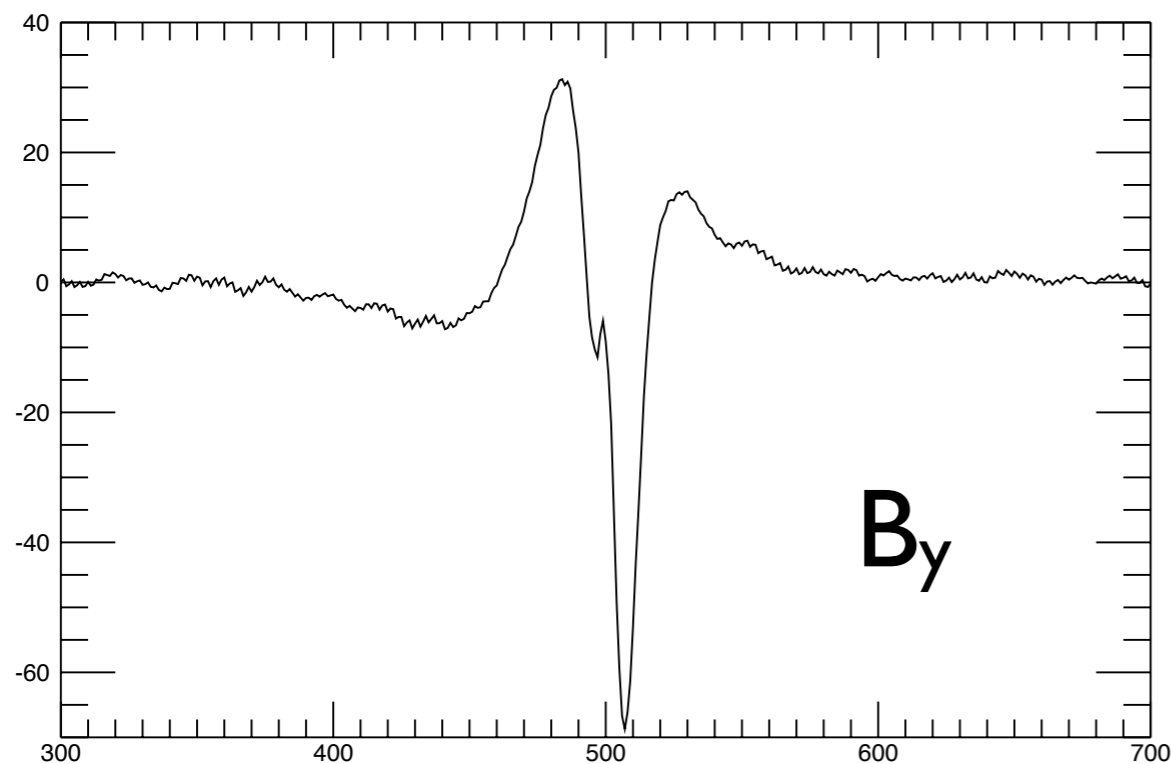


- Velocity estimated using vertically separated floating potential measurements
- Preferred peak density for blobs? (role of conditional cutoff?)
- Faster (at least narrower velocity spread) at high blob density?

Magnetic signature of blob



- Conditional average magnetic pick-up loop signal
- Preliminary structure measurement indicates single current channel in filament
- Relevance to formation mechanism (drift-Alfven turbulence)?
- Dynamics of charging (direct measurement of loss current?)



Summary/Speculation/Future work

- (1) blobs and holes observed in absence of typical interchange drive, (2) 2D measurements show blob is polarized filament, hole is not an isolated structure, (3) Blob size scaling with gyroradius observed [T. Carter, Phys. Plasmas 13, 010701 (2006)]
- What is mechanism of blob and hole generation? Are these structures solitary drift waves/vortices [Horton]? (Observation of drift-Alfven vortices in magnetosphere [Sundkvist, Nature (2006)])
- Common denominators in all experiments: drift wave turbulence and sheared flows at boundary. Future work: study intermittency and structure generation under driven sheared flow in LAPD. [with M. Gilmore, UNM]
- What polarizes blobs in LAPD? Future work: look at scaling with neutral pressure, dynamics of blob charging