Visible Imaging of Edge Turbulence in NSTX

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TTF Meeting, Apr. 00

Goal: Understand physics of edge turbulence as a basis for understanding:

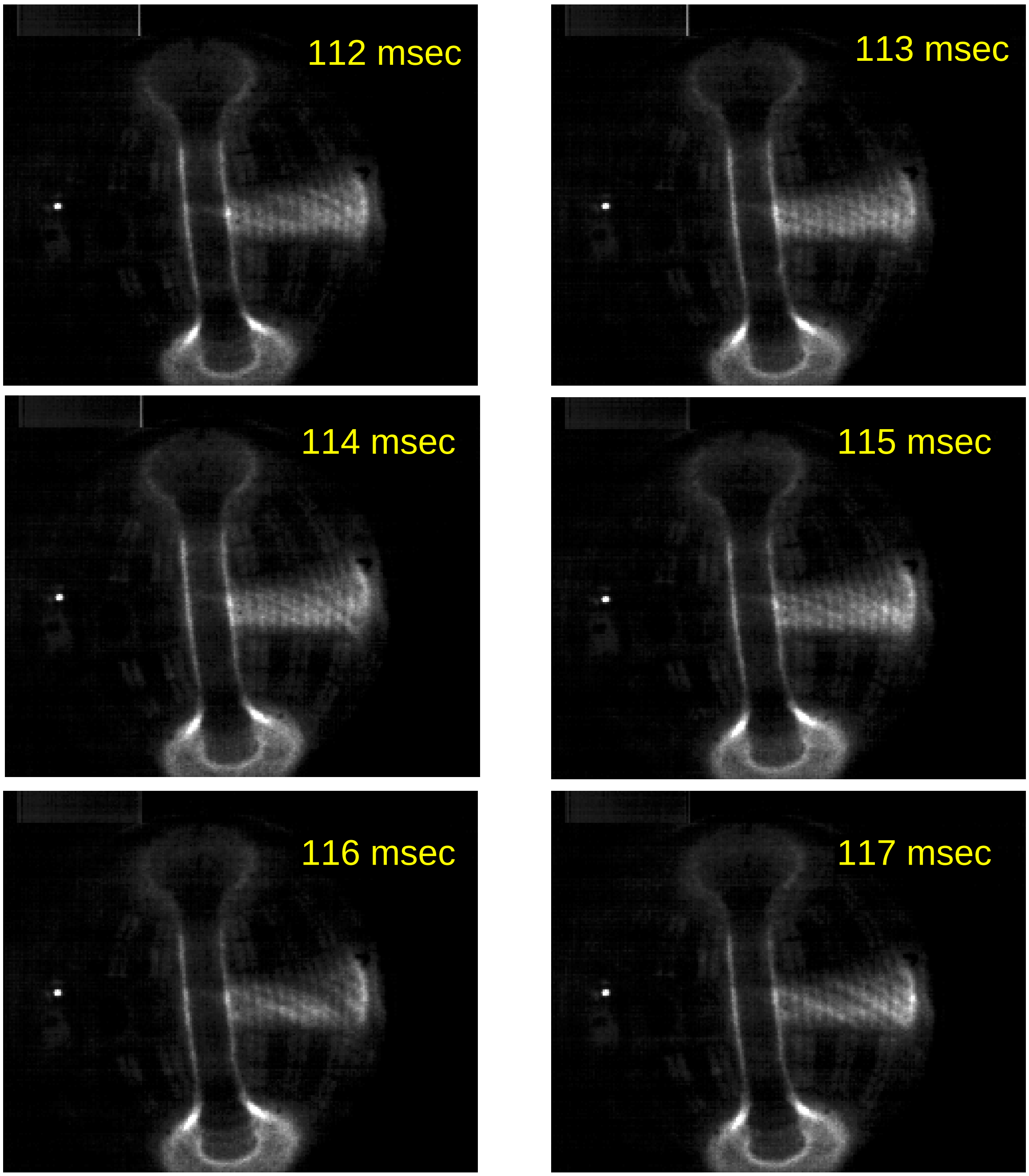
- H-mode transition
- power and particle flow across SOL
- CHI current penetration (?)
- ICRH wave coupling (?)

Strategy: Quantitative and detailed comparisons of experiment with theory

- use "Gas Puff Imaging" to measure 2-D structure of edge density turbulence
- compare numerical simulations for NSTX (e.g from Maryland, LLNL, Garching...)

Imaging of Turbulence at ICRF Antenna

all Shot 101125, 20 µsec exposure time

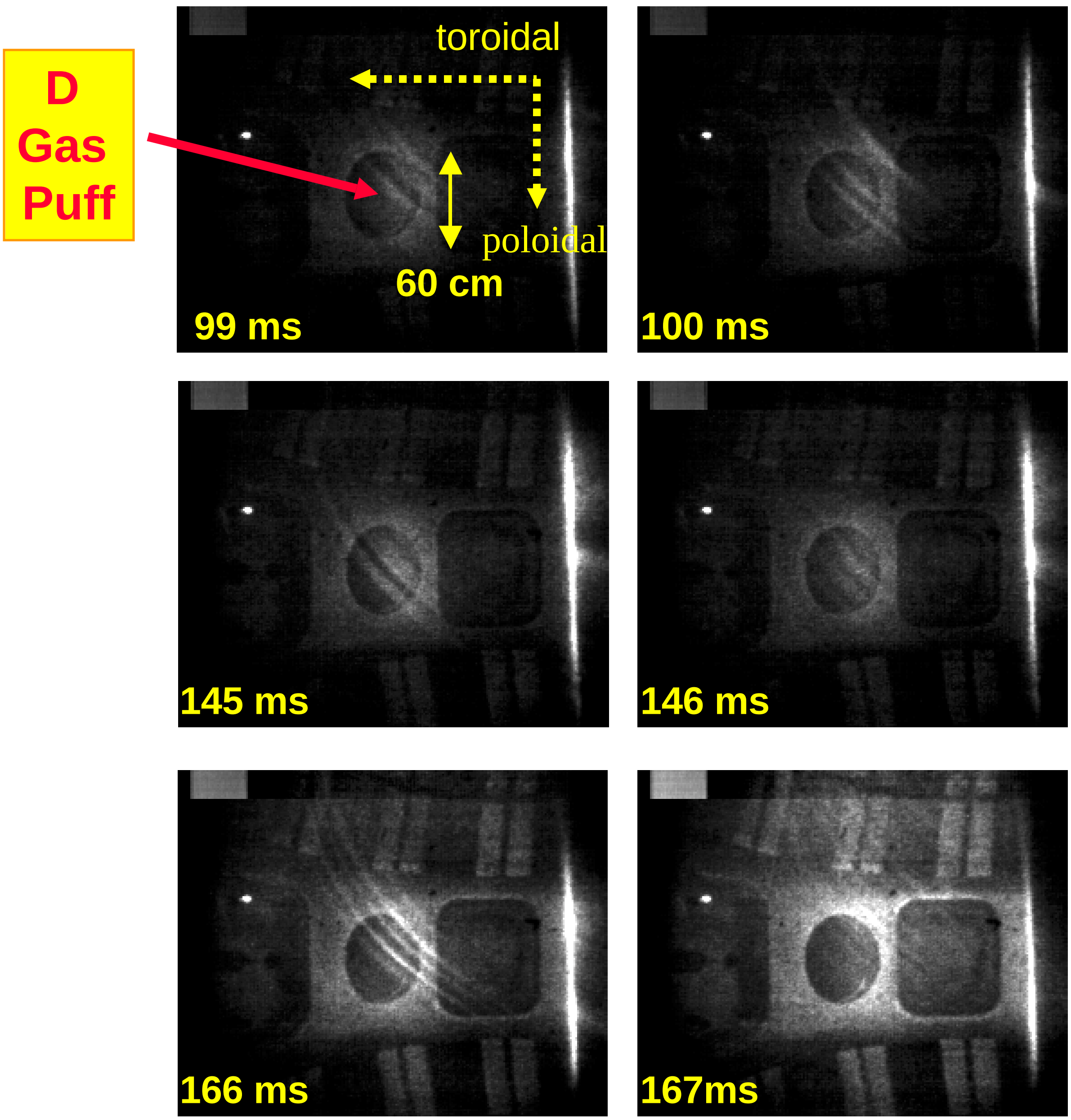


Talk outline

- Gas puff Imaging (GPI) diagnostic
- GPI Implementation on NSTX
- 2-D Images (w/ video)
- Data Analysis
- Comparison with theory
- Plans for NSTX and C-Mod

Gas Puff Imaging - Poloidal vs. Toroidal

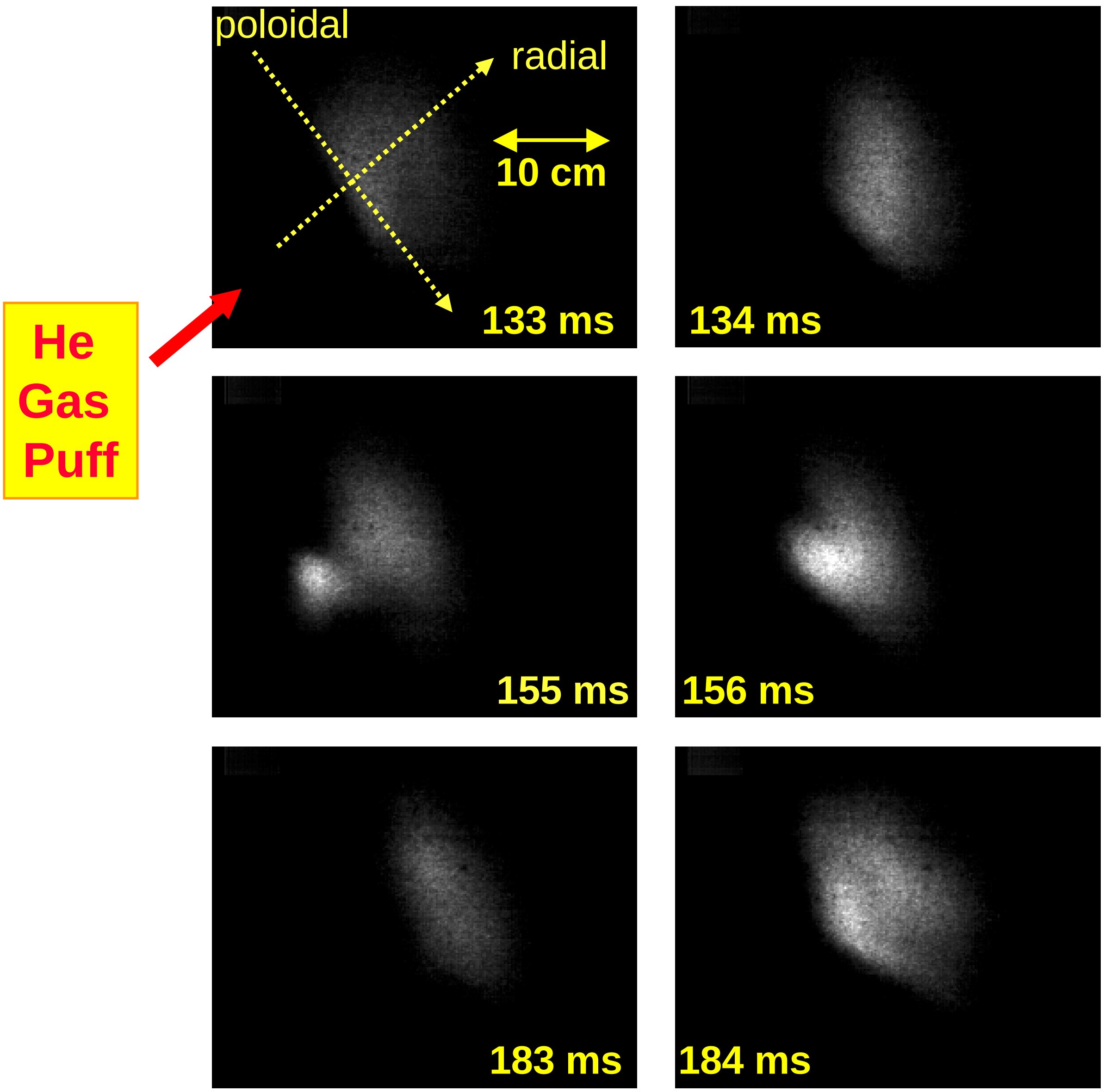
Deuterium gas puff with no filter
10 μs exposure @ 1000 frames/sec



Shot 101533

Gas Puff Imaging - Radial vs. Poloidal

Helium gas puff with HeI filter (587.6 nm)
10 μs exposures @ 1000 frames/sec



Shot 101989

Summary of NSTX GPI Analysis

- Strong (>10%) turbulence in visible light emission from D or He gas puffs or recycling at edge
- Poloidal / toroidal structure is similar to previous experiments (B field-aligned with $\lambda_{pol} \approx$ 10-15 cm, $k_{pol}\,\rho_s \approx$ 0.1-0.2, assuming $T_e \approx$25 eV at edge
- Radial / poloidal structure as viewed by He gas puff shows strong turbulent variation vs. time
- Frequencies spectrum is broadband 1-100 kHz, power law exponent 2±1 above ≈ 1 kHz

Yet to do:

- Cross-correlation analysis of time series
- Search for coherent spatial structure
- Variation with plasma edge conditions
- Effects of ICRH or CHI on turbulence

Implementation of GPI on NSTX

- Use LANL fast camera for 2-D imaging
  - typically use 10 μsec exposure time
  - 1000 frames/sec @ approx. 200x200 pixels
  - use with either D or He gas & line filters

- View gas puff either:
  - across machine (toroidal vs. poloidal view)
  - along B field line (radial vs. poloidal view)
  - also look at recycling from ICRF antenna

- Supplement with 3-channel time series
  - fiberoptic views 5 cm diameter at wall
  - light detected by photomultiplier tube
  - frequency response to ≈ 200 kHz

Plans for GPI on NSTX and C-Mod

- Clarify relationship between visible light fluctuations and density fluctuations
  - atomic physics
  - effect of neutrals on turbulence ?

- Improve 2-D imaging along B field
  - linear gas manifold in NSTX
  - re-entrant bellows on C-Mod
  - million frame/sec camera ?

- Increase radial extent of imaging
  - high speed gas nozzle ?
  - USX imaging w/µchannel plate ?

- Direct comparisons with simulations
  - LLNL BOUT code
  - Rogers/Drake code

Comparison with Theory

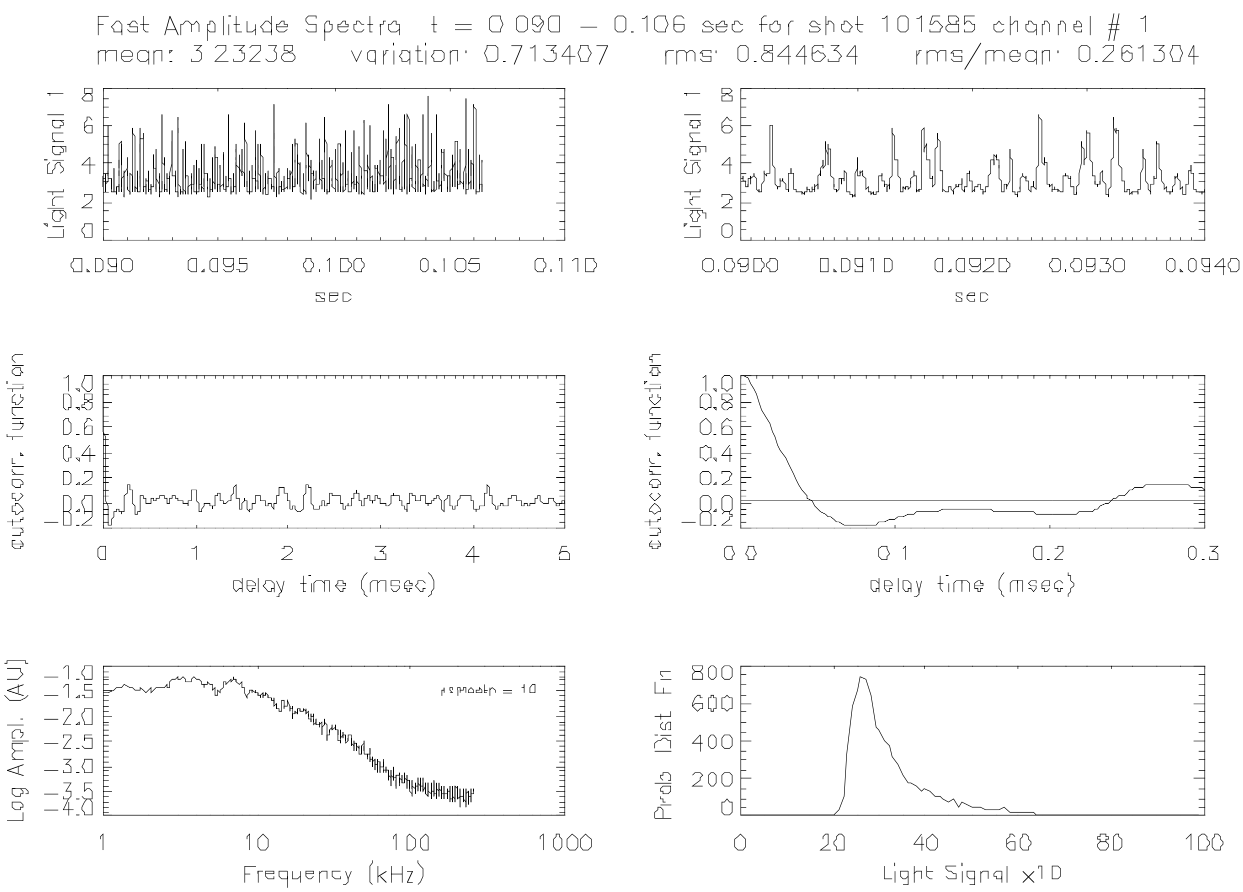
- First results from BOUT code show edge structures ≈ 2 cm in NSTX

- Not much else done yet:
  - edge parameters not well measured
  - codes not quite ready for NSTX

- Eventually want to compare:
  - radial and poloidal correlation lengths
  - zonal flows and coherent structures
  - changes with H-mode transition
  - variations with j(r), p(r), β(r), ν(r), etc.

Time Series Analysis (1 Channel)

- Looking at gas puff near midplane in Dα light
- Diameter of view ≈ 5 cm at wall
- Digitized at 500 kHz for 8 msec



- rms/mean ≈ 25%
- τ(auto) ≈ 30 μsec
- power law f(-2±1)
- no long-time correlations
- tail on probability dist. f'n
- often seems like "bursts"

GPI Gas Flow Rate in NSTX

- For He puff case in "end-on" image, total gas input ≈ 4×10^{19} atoms into chamber in ≈ 1 sec
- This is much less than the total neutral influx due to recycling, ≈ 10^{22} atoms/sec
- Local neutral density at He puff ≈ 10^{12} atoms/cm^3 similar to normal edge neutral density (?)
- Local particle source rate ≈ 10^{16} ions/cm^2-sec
- Local ion flow without puff ≈ 10^{19} ions/cm^2-sec, i.e. much larger than gas puff source
- Local cooling rate @ 50 eV/atom ≈ 0.1 W/cm^3
- Local cooling without puff ≈ 1 W/cm^3 (?)

==>> seems like local puff should not perturb edge plasma significantly at this level