Advanced GPI Diagnostic for NSTX-U

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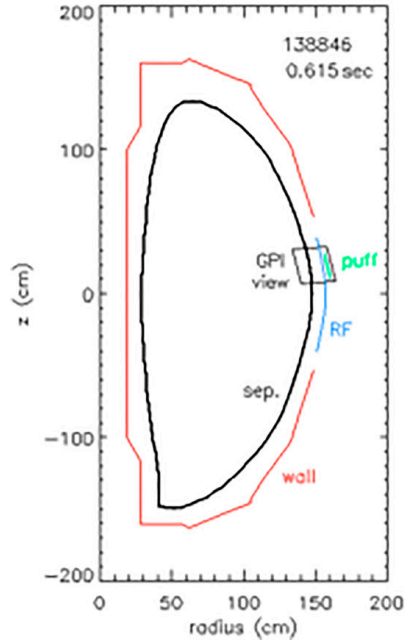
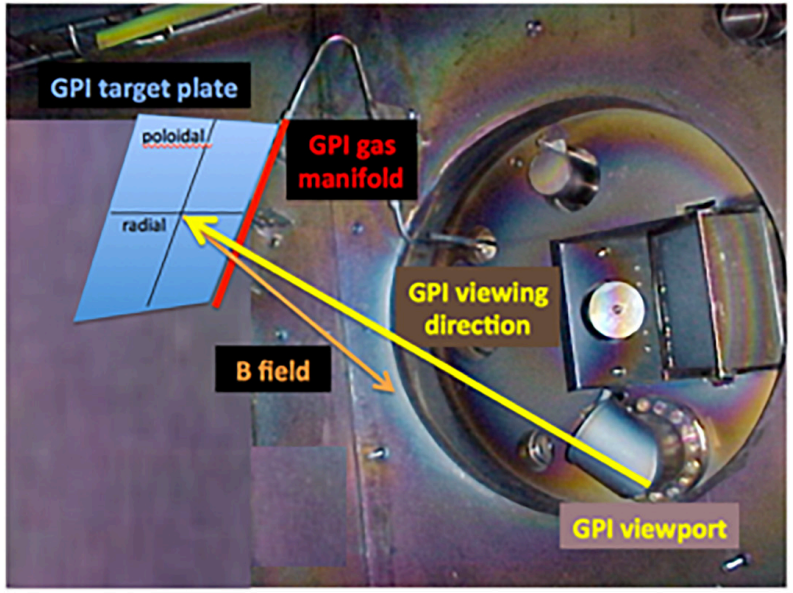
Existing Gas Puff Imaging Diagnostic on NSTX (2001-2010):

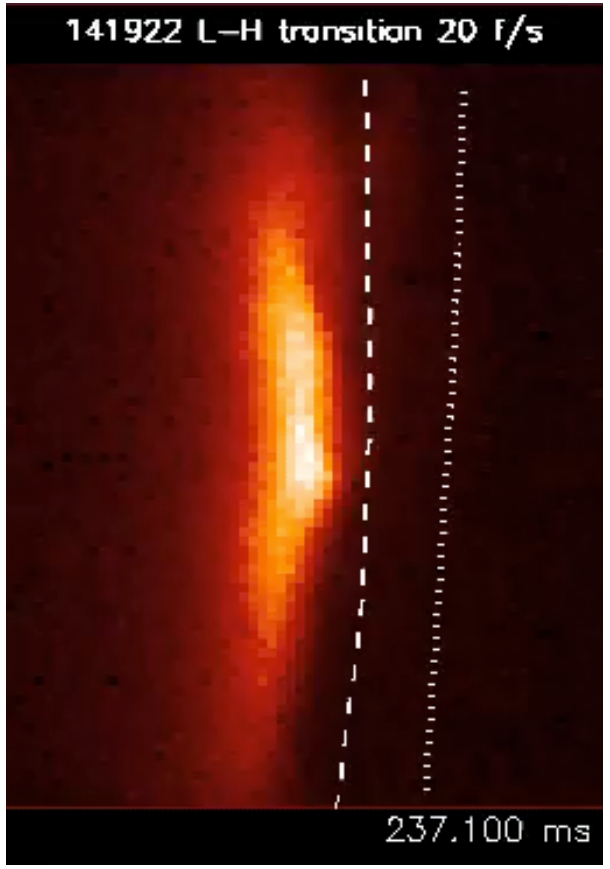
- measures edge and SOL turbulence just above outer midplane
- physics of L-H transition, blobs, divertor disconnection, SOL width
- ongoing validation of edge turbulence codes such as SOLT, XGC1





Example of GPI Data at L-H Transition (2010)

- views neutral Dα line emitted from local gas puff
- aligned as closely as possible along B-field line
- 24 cm radially x 30 cm poloidally (64 x 80 pixels)
- speed up to 400,000 frames/sec (2.5 µsec/frame)
- single gas puff gives ~ 50 msec imaging duration



R. Maqueda et al, Rev. Sci. Inst. 72, 931 (2001)
S.J. Zweben et al, Rev. Sci. Inst. 88,041101 (2017)
(presently about 10 GPI systems worldwide)

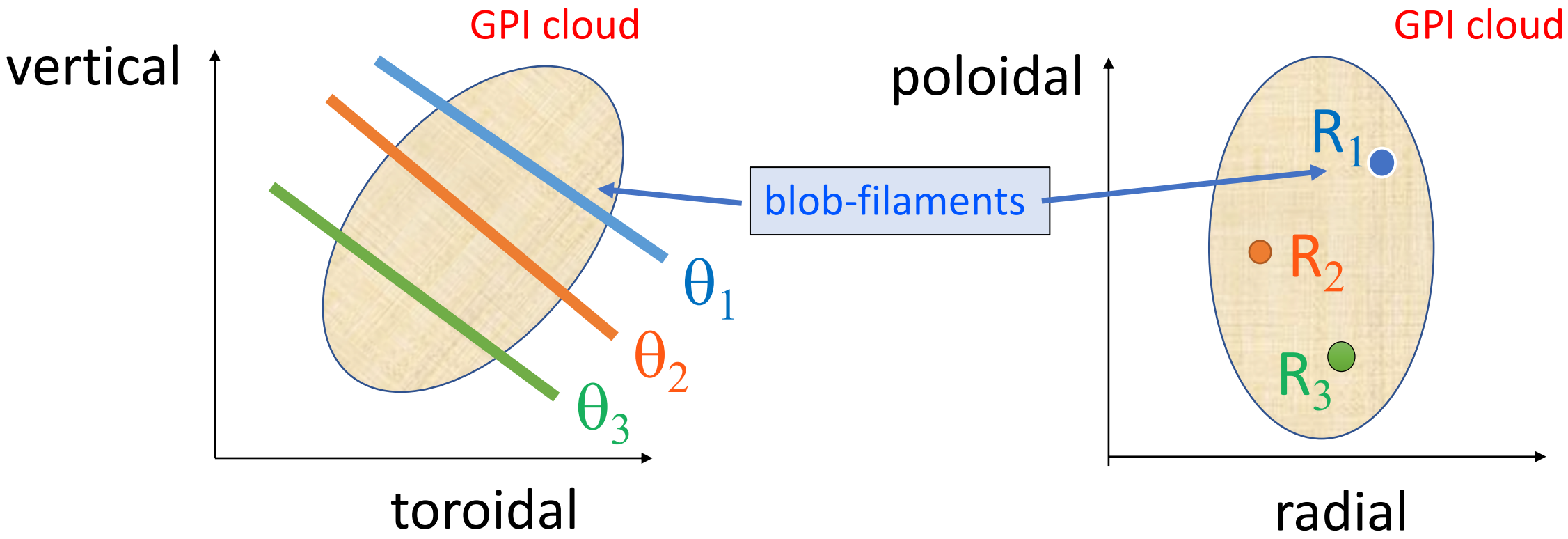
Interesting GPI Upgrades for NSTX-U

1) Measurement of edge B field line angle with a 2nd camera
2) Imaging measurement of n_e and T_e with helium line ratios
3) Improved spatial resolution for sub-ion scale turbulence
4) Measurement of 3-D structure of edge turbulence
5) Measurement of neutral density in GPI gas cloud

Edge B Field Line Angle with 2nd GPI Camera

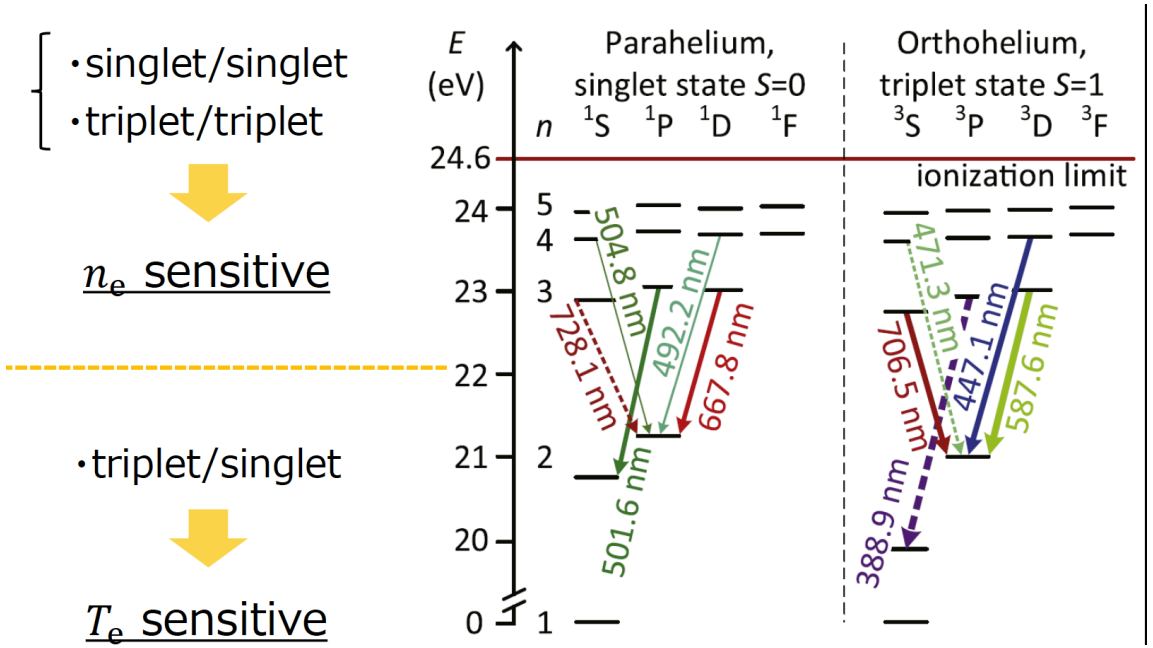
- Assume edge blob-filaments follow local B field line (to within $\lambda_{perp}/\lambda_{II}$~1%)
- Measure angle of each filament in 2nd camera view (vertical vs toroidal)
- Measure radius of each filament in normal GPI view (poloidal vs radial)

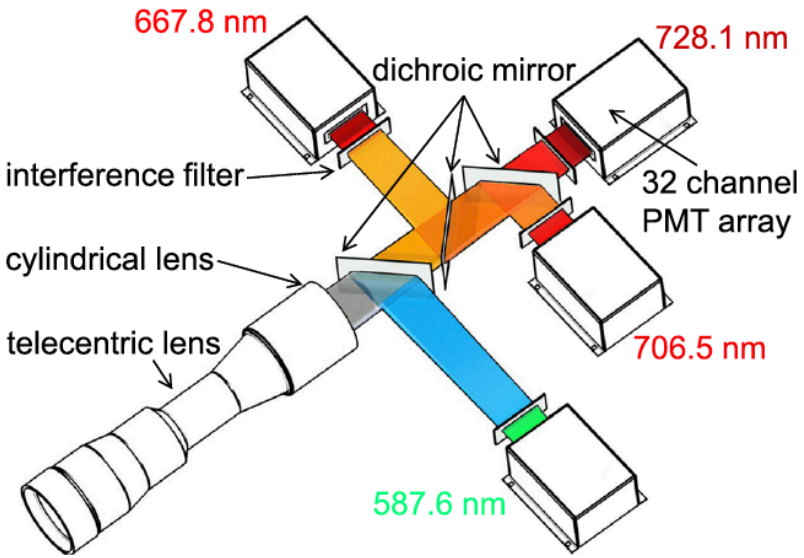
  => infer filament (B-field line) angle vs. radius within GPI cloud



Imaging of n_e and T_e with Helium Line Ratios

- Need to measure three visible HeI lines: 667.8 nm, 706.5 nm, and 728.1 nm
- Feasibility of fast "THB" diagnostic evaluated for NSTX (Burgos et al PoP '16)
- THB diagnostic proposed for NSTX by RFX-Mod group using PM tubes (2015)
- Fast imaging of two of these lines done on TJ-II (de la Cal, Nucl. Fusion 2016)



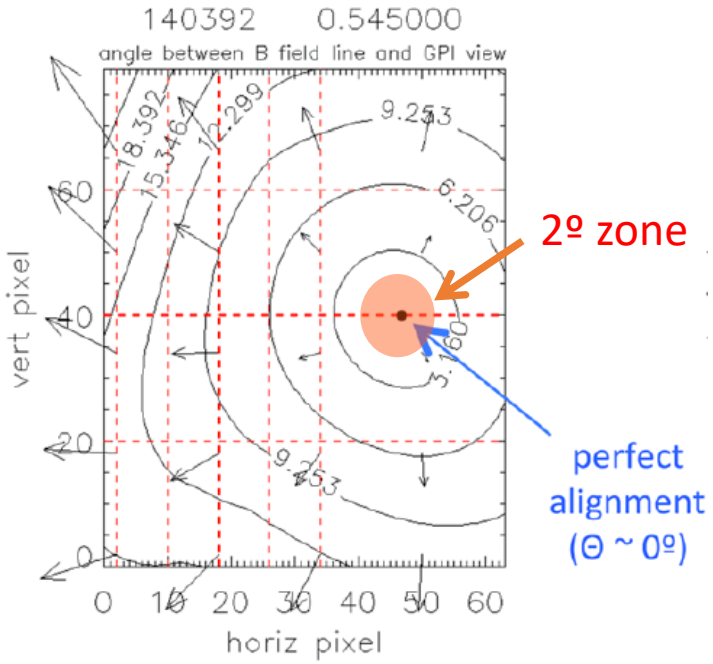


Greiner et al., Rev. Sci. Instrum. 89, 10D102 (2018)

GPI Resolution of Sub-ion Scale Turbulence

- Zoom lenses installed on NSTX GPI to improve *optical* resolution from 5 mm -> 1 mm at plane of GPI gas cloud (N. Mandell 1st year project, 2015)

- Geometrical "smearing" to finite toroidal extent of GPI gas of $\Delta \sim L_{||} \tan \Theta$, where $L_{||}$ is length along cloud and Θ is angle with respect to local B field (Zweben et al PoP '17)



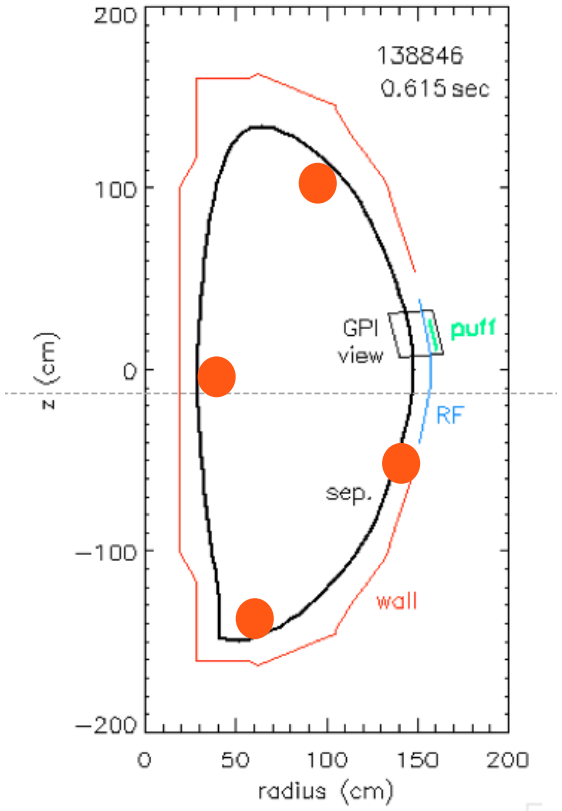
- For $L_{||} \sim 12$ cm, $\Delta \sim 1$ mm at $\Theta \sim 0.5º$, implying zone of 1 mm imaging will be about 1 cm diameter

- With a low divergence gas nozzle* to make $L_{||} \sim 3$ cm, imaging zone is $\Theta \sim 2º$ or ~5 cm diameter, inside of which resolution could be ~0.1 cm

* Shesterikov et al, RSI '13

Measurement of 3-D Structure of Edge Turbulence

- Physics of edge turbulence involves rarely measured quantities such as the parallel wavelength (drift waves vs. interchange modes), turbulence dependence on poloidal angle, flux tube shearing near X-point, divertor disconnection



- Additional GPI views can be installed at several locations shown in orange (proposed by T. Munsat in 2012)
- Gas puffs can be provided using thin capillary tubes and optical access using in-vessel quartz fiber bundles (both previously used on C-Mod GPI)
- A new fast camera will be needed for each new GPI view

Measurement of Neutral Density in the GPI Gas Cloud

- The largest uncertainty in the interpretation of GPI is the possible fluctuations in local neutral density due to the surrounding turbulence itself

- This “shadowing effect” was first seen in Degas 2 simulations of GPI (Stotler JNM ‘03) and recently in turbulence simulations of GPI (e.g. Wersal et al Nucl. Fusion ‘18), and to some extent in an XGC1 simulation of C-Mod (Stotler et al, in progress)

- It would be interesting to measure directly the neutral density *inside the GPI gas cloud* in NSTX-U, perhaps using LIF or other advanced spectroscopic techniques

- This should be relatively easy compared with other neutral density measurements in NSTX-U, since the local density is at least 10x higher than without the puff