First results from NSTX supersonic gas jet fueling experiments

V. A. Soukhanovskii

Lawrence Livermore National Laboratory

H. W. Kugel, R. Kaita, A. L. Roquemore

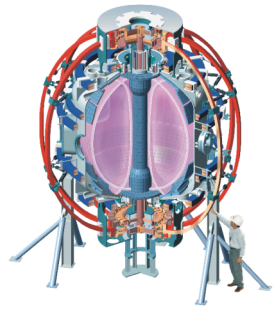
Princeton Plasma Physics Laboratory

NSTX Research Team

NSTX FY'04 Results Review

20-21 September 2004

Princeton, NJ

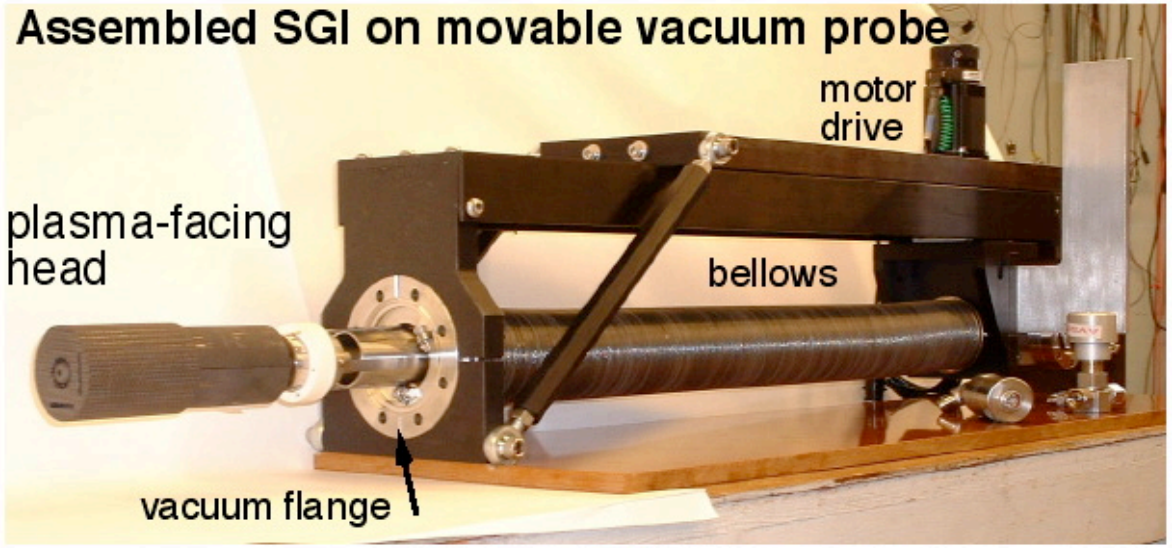


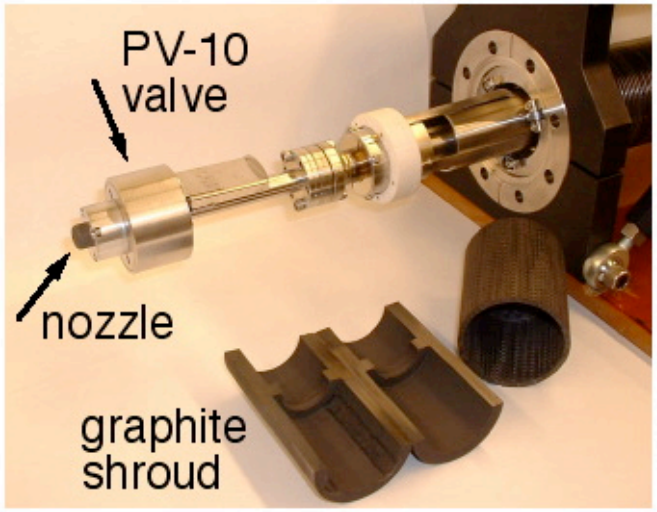
Acknowledgements

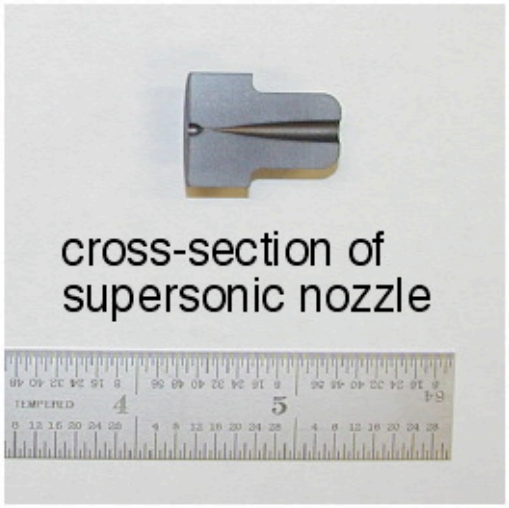
- R. Bell, T. Biewer, W. Blanchard, D. Gates, R. Gernhardt, G. Gettelfinger, T. Gray, L. Guttadora, D. LaBrie, R. Majeski, M. Ono, T. Provost, P. Sichta, D. Stotler, J. Taylor, J. Timberlake (PPPL)
- A. J. Smits and S. Zaidi (Princeton University)
- N. Nishino (Hiroshima University, Japan)
- R. Raman (University of Washington)
- M. Frost (Kent State University)

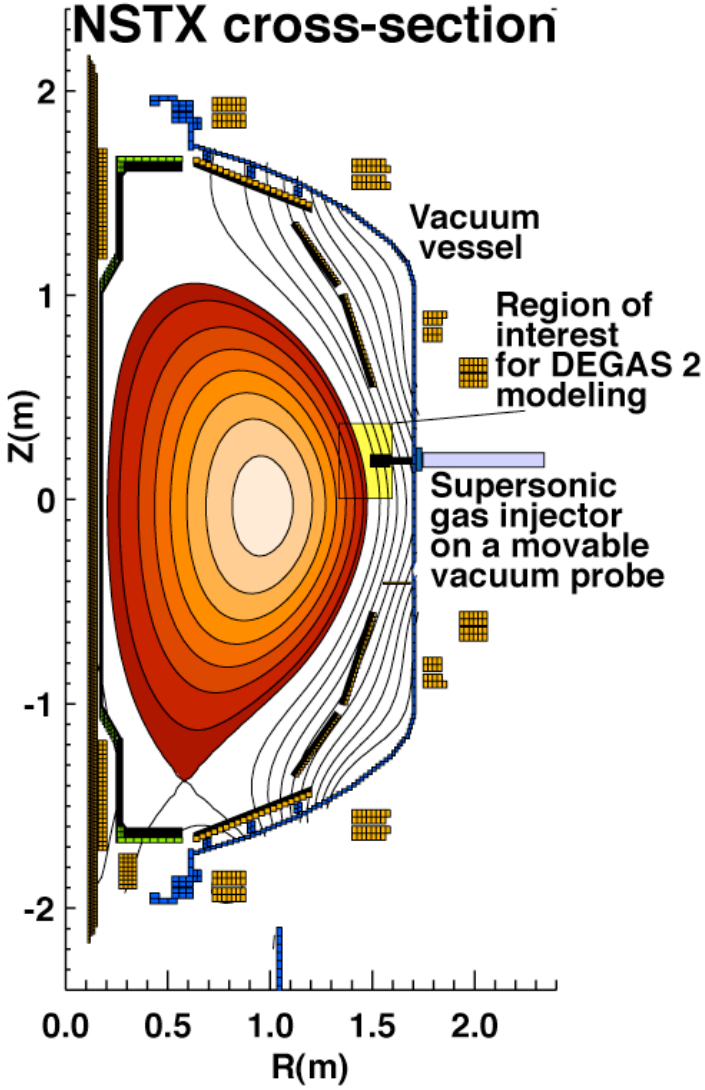
This research is supported by the U.S. Department of Energy under contracts No. W-7405-Eng-48 at LLNL and DE-AC02-76CH03073 at PPPL.

Supersonic gas injector has become operational in FY'04

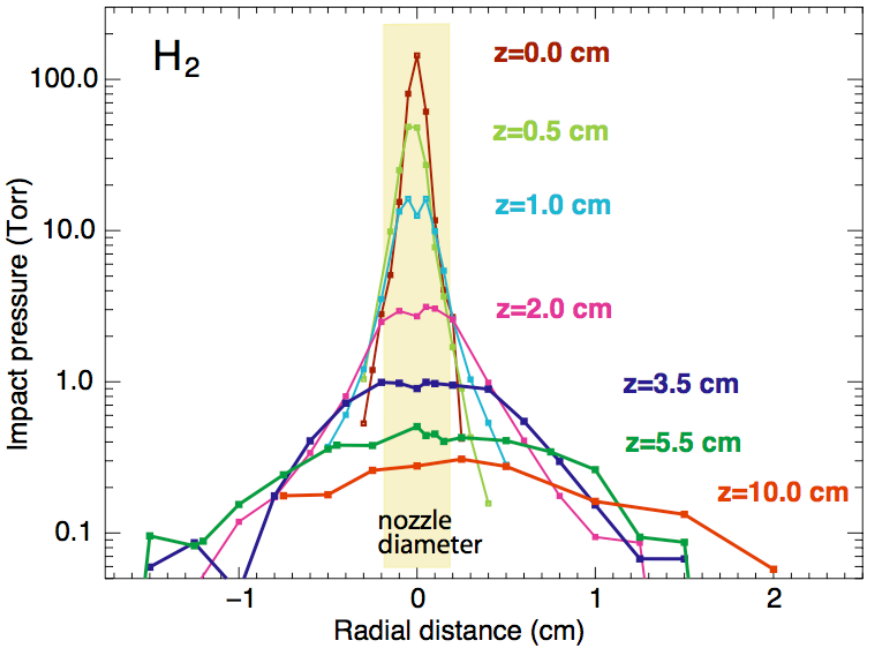


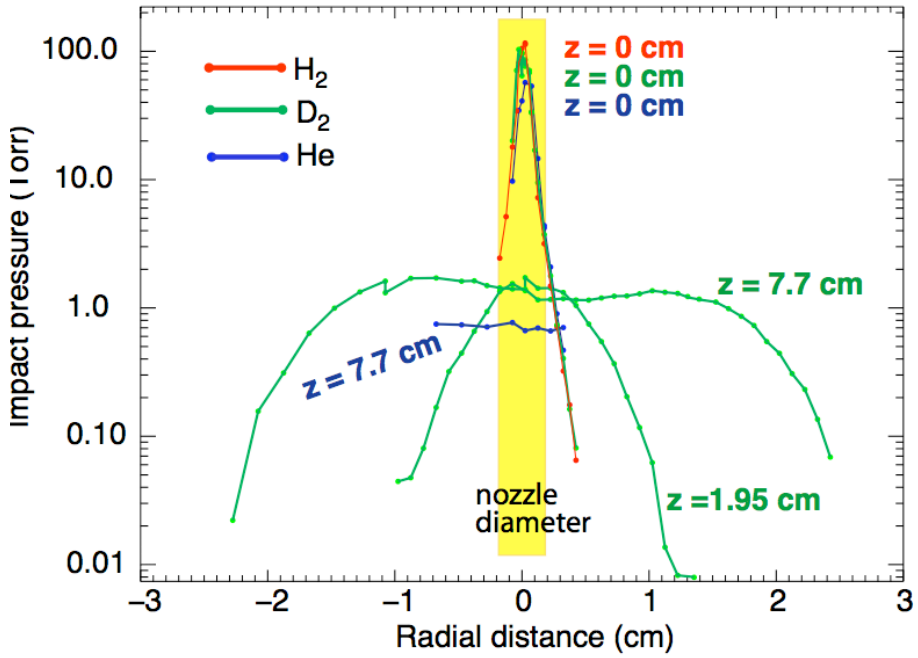






Off-line pressure measurements confirm high Mach number and highly collimated gas jet shape





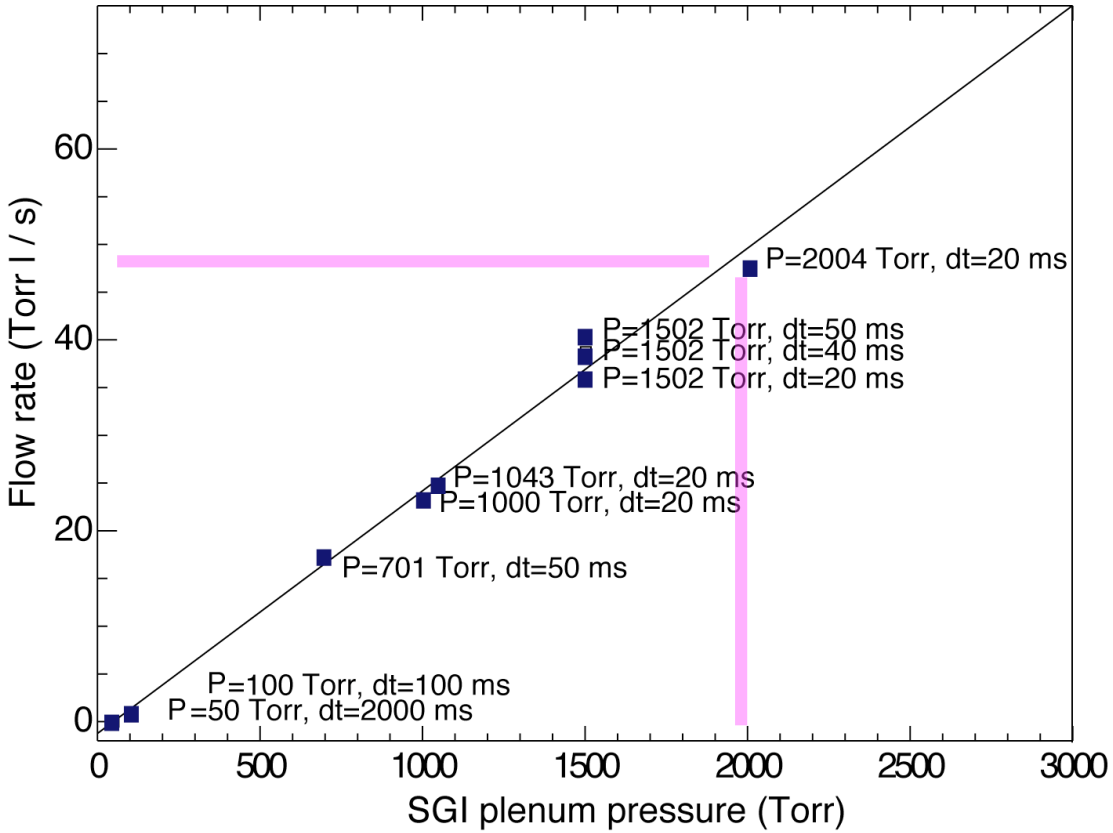
Jet divergence half-angle: 6° - 25°

D_2: *M = 4, T ~ 60 - 160 K, ρ ~ 5 x 10^{17} cm^{-3}, Re = 6000*

D_2: v_{therm} ~ 1100 m/s, v_{flow} = 2400 m/s

$$u_{max} = \sqrt{\frac{2\gamma}{\gamma-1}\frac{kT_0}{m}}.$$

Flow rate is measured *in situ* on NSTX



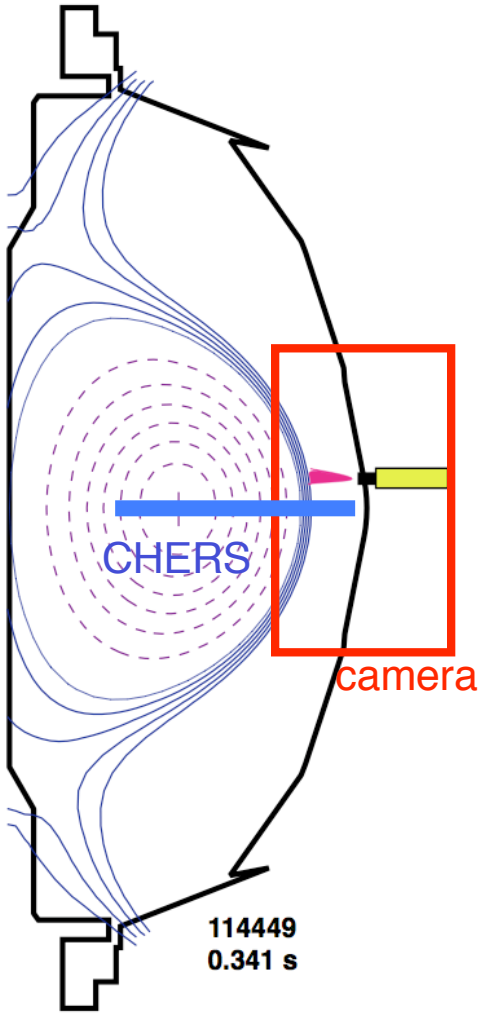
NSTX gas injector flow rates:
HFS: 10 - 50 Torr l /s
LFS: 20 - 150 Torr l /s

- Flow rate (Torr l / s): $\Gamma = V_{NSTX}\, \Delta P / \Delta t$
- Future SGI may require $P_{plenum} > 2000$ Torr

Experiments on NSTX

- XMP-35 “SGI commissioning” completed
- No exp. time was allocated for an XP
- Preliminary results are encouraging: higher fueling efficiency, high gas jet collimation (expect higher wall saturation limit), good SOL penetration, compatibility with H-mode edge
- Future work will aim at optimizing nozzles and studying the physics of supersonic gas jet fueling

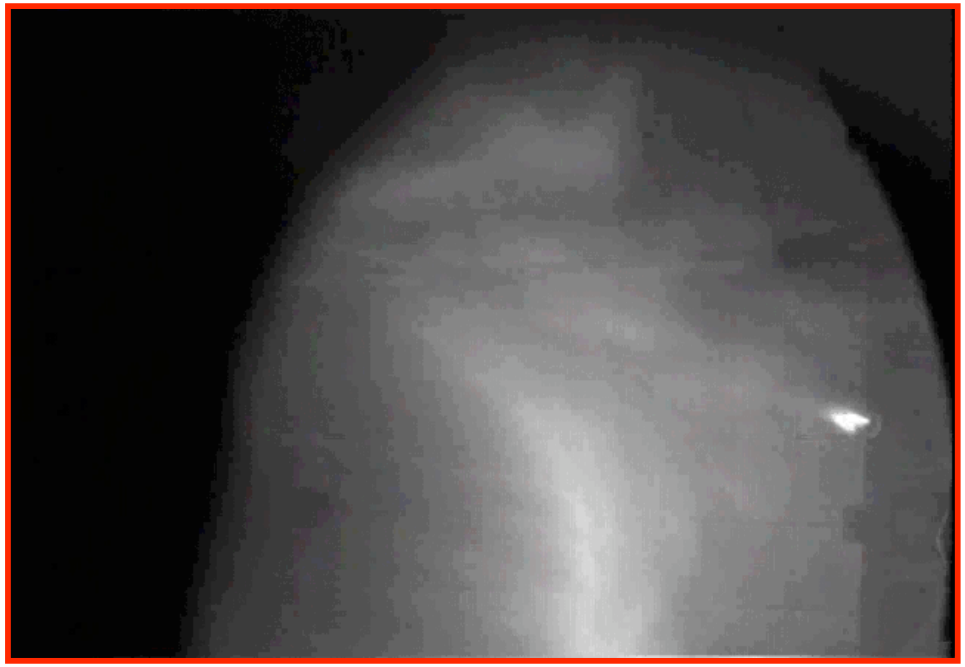
Supersonic gas jet penetrates well through a thick scrape-off layer



Injection in the end of discharge into a 25 cm SOL with $T_e < 5$ eV, $n_e < 5 \times 10^{12}$ cm^{-3} plasma

PPPL PRINCETON PLASMA PHYSICS LABORATORY

D_2 injections in 4-6 MW NBI heated plasmas (movies)



Shot 114473:

6 MW **high** β plasmas, injection at t=180 ms

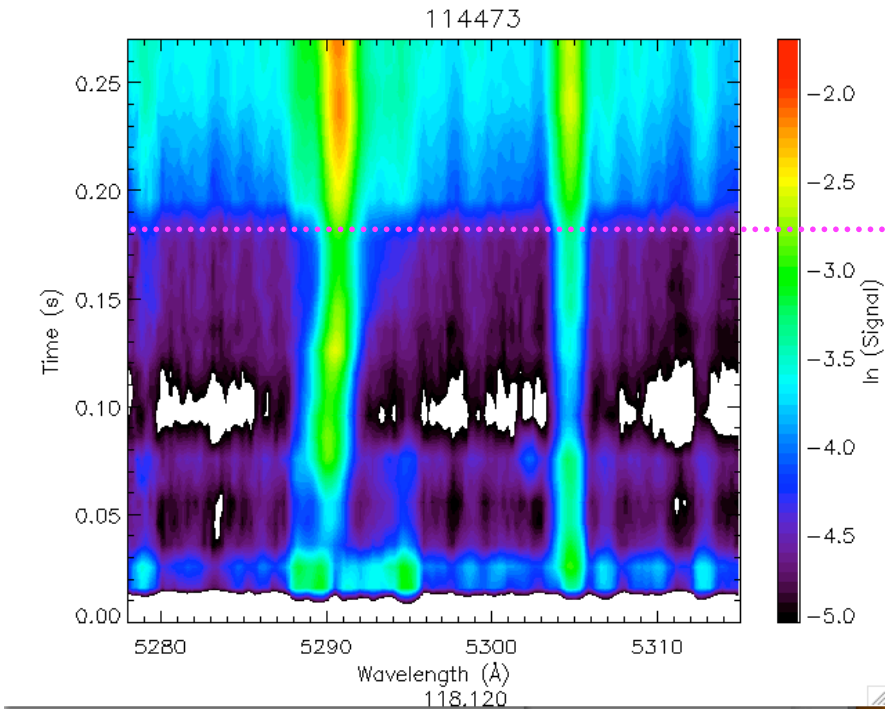
R_{SGI}=1.604 m, Z_{SGI}=0.198 m
R_{sep}=1.49-1.52 m

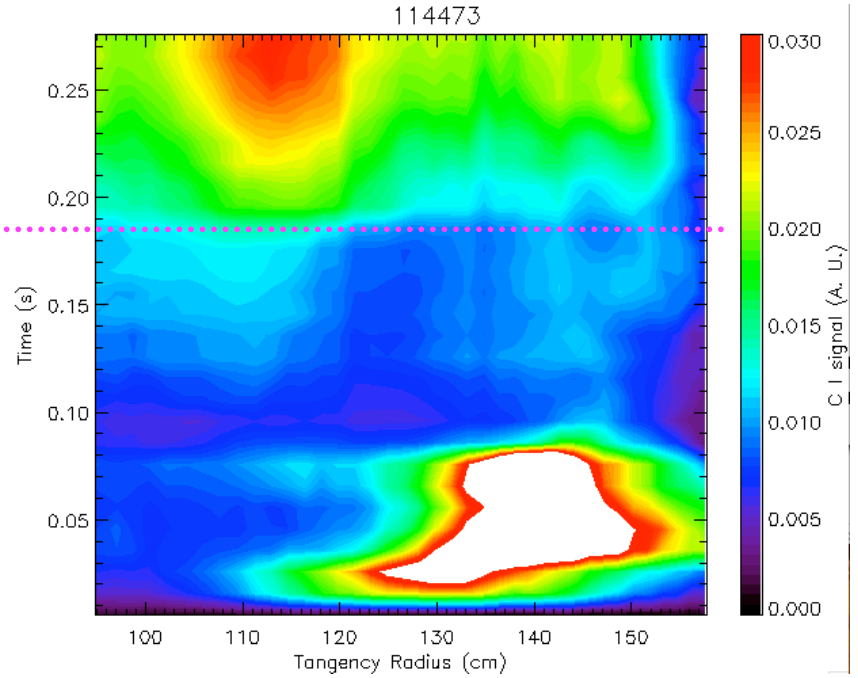
Shot 114475:

4 MW **H-mode** with type 1 ELMs, injection at t=300 ms

R_{SGI}=1.604 m, Z_{SGI}=0.198 m
R_{sep}=1.50-1.52 m

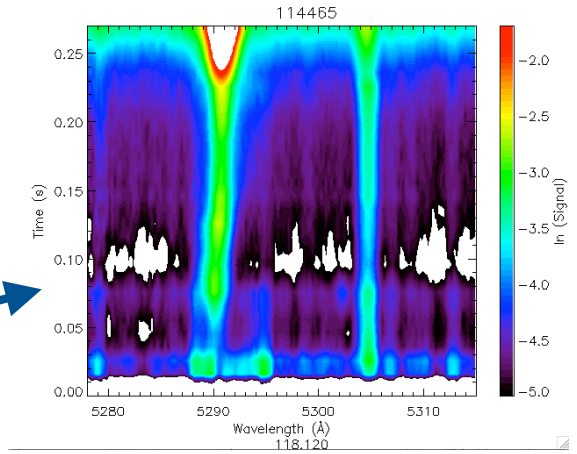
Localized cooling is evident from C I spectroscopy





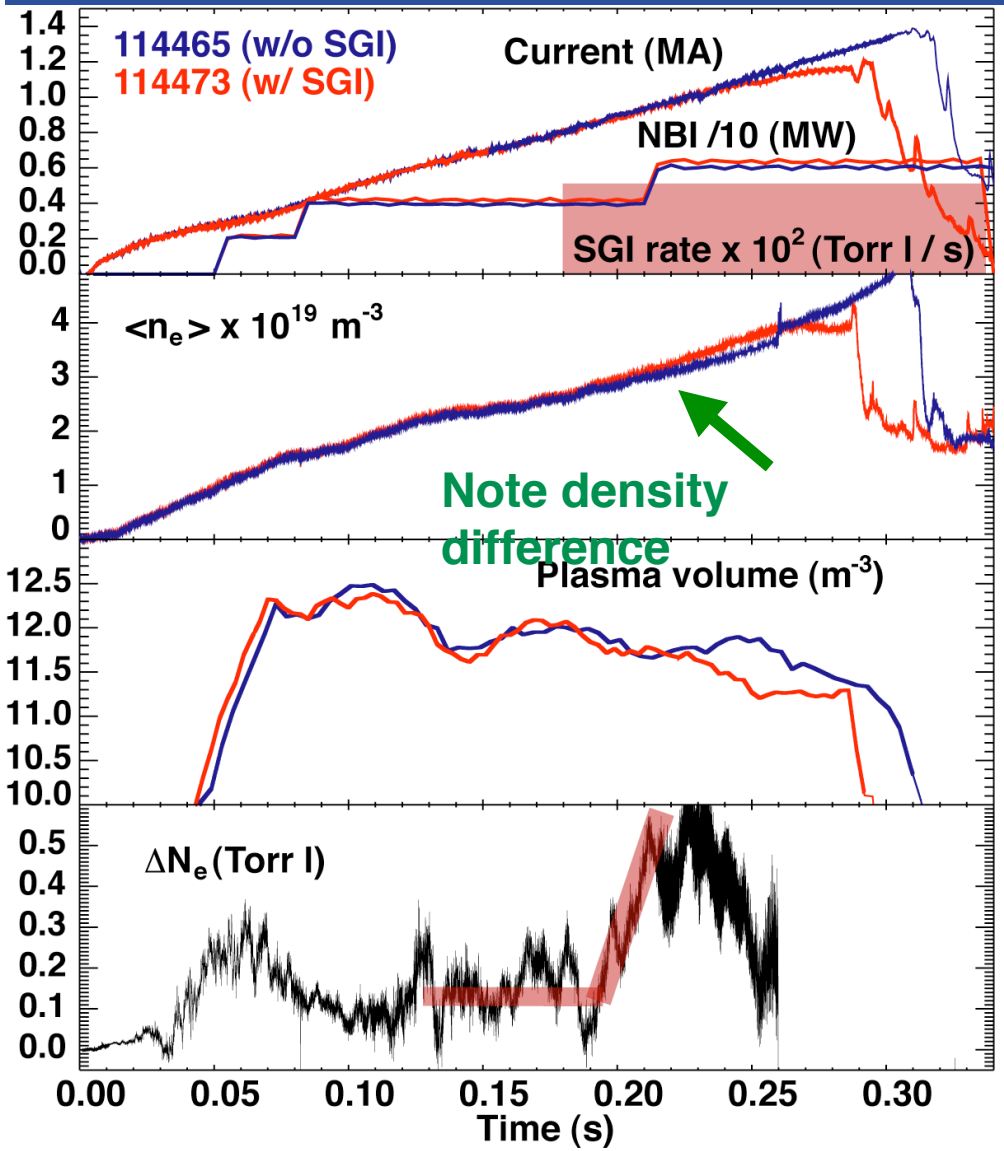
Start of injection

- In SGI-fueled plasma bg-CHERS array measures localized C I emission characteristic of cool plasma edge
- Do not see in reference plasma



Background CHERS - R. Bell

Supersonic gas jet fueling efficiency η is 3-4 times higher than η of a conventional gas puff



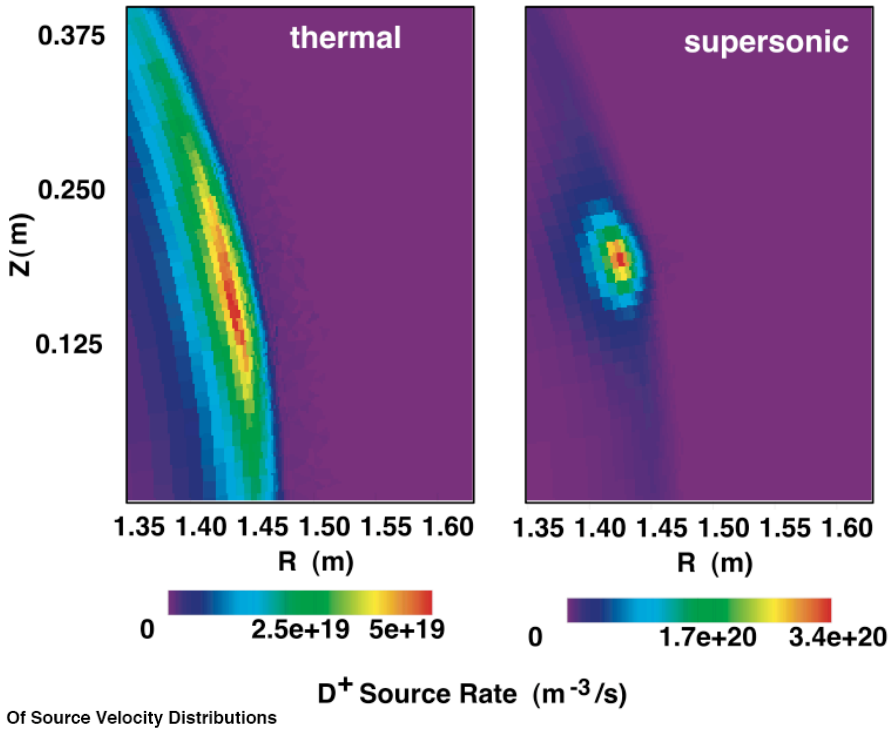
- Compare two 6 MW NBI high-β pulses with and without supersonic gas injection
- Fueling efficiency

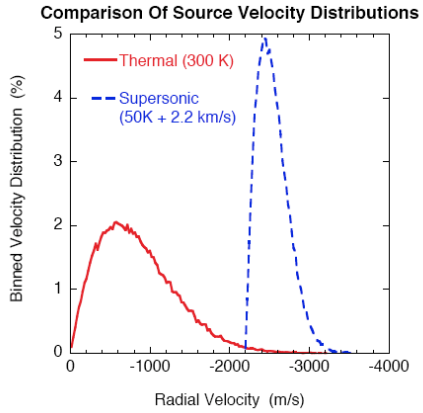
$$\eta = \frac{dN_i/dt}{\Gamma_{gas}}$$

- Γ_{gas}~ 50 Torr l / s
- dN_e/dt = 0.4 / 0.025 = 16 T l / s
- η = 0.3-0.4
- **Preliminary result - based on one shot**

DEGAS 2 neutral transport modeling consistent with general features of supersonic gas injection

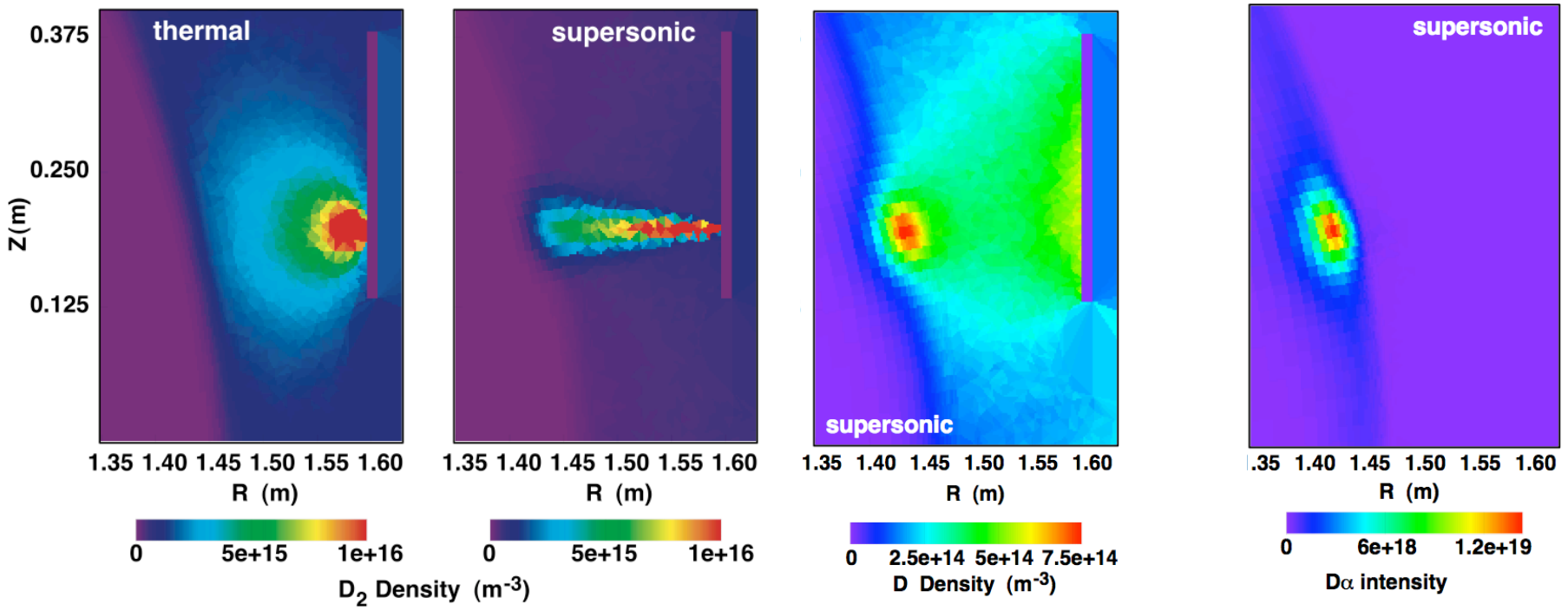
- DEGAS 2 neutral transport model
- Conventional D_2 injection: *T = 300 K*
- Supersonic D_2 injector: *T= 50 K, v_{flow} = 2200 m/s*
- Not self-consistent: fixed T_e, n_e, are used
- D_2 injected from a 5 mm nozzle
- **Good starting point for experiment interpretation**





DEGAS 2
D. P. Stotler

DEGAS 2 neutral transport modeling consistent with observed features of supersonic gas injection



Molecular density Atomic density D_α intensity

DEGAS 2
D. P. Stotler

Summary

- Supersonic gas injector proposed at FY'02 NSTX Research Forum (November 2001)
- First results reported at FY'04 Results Review
- **Preliminary** results are encouraging: higher fueling efficiency, high gas jet collimation (expect higher wall saturation limit), good SOL penetration, compatibility with H-mode edge
- **Future work** will aim at optimizing SGI and studying the physics of supersonic gas jet fueling, H-mode access and ELM control with SGI
- Potential for **collaborations** (MAST, others?)