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H-mode access with supersonic gas jet fueling (XP 626, Part 2)

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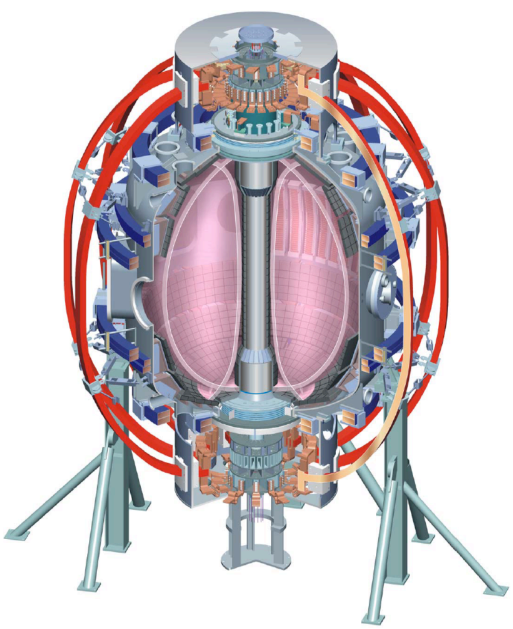
and NSTX Team



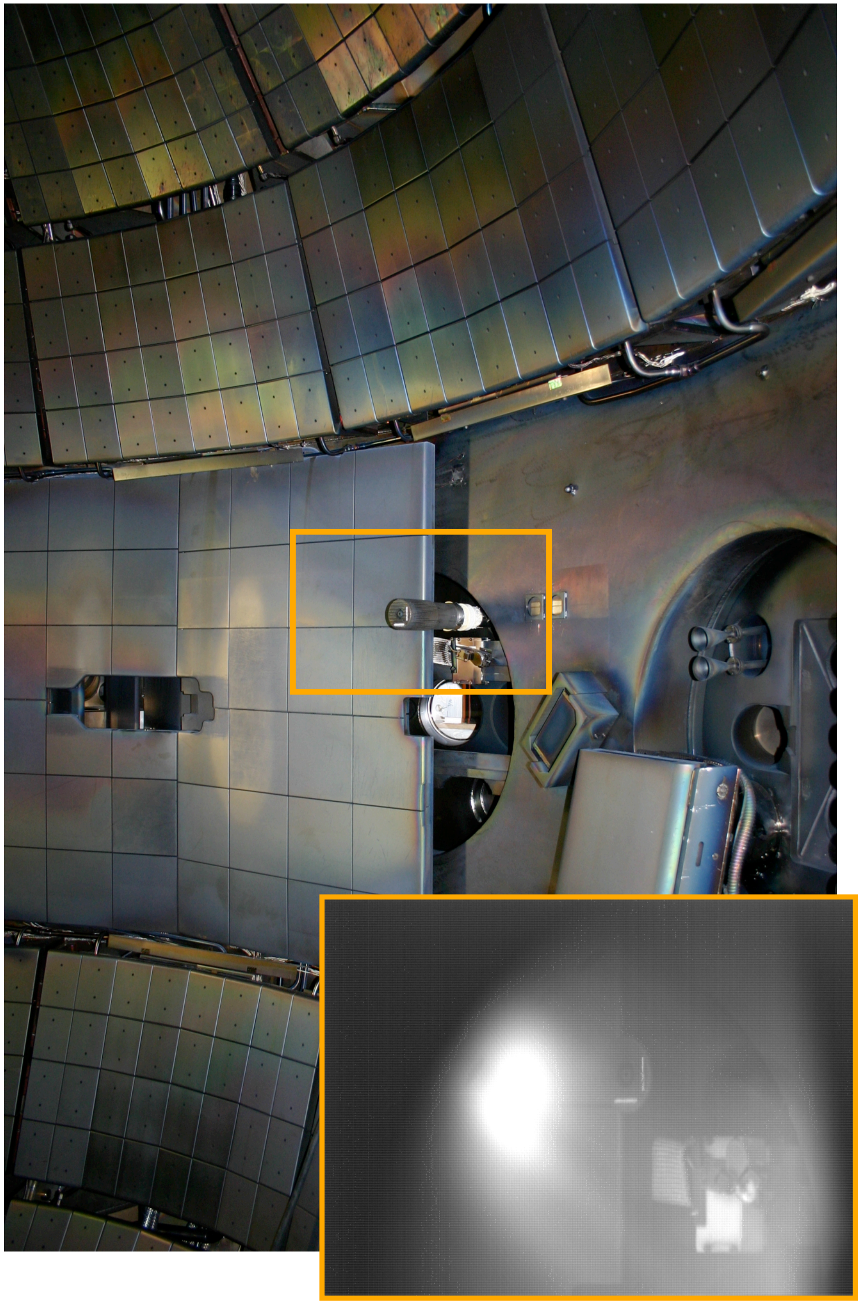
NSTX Monday Physics Meeting
Princeton Plasma Physics Laboratory
Princeton, NJ

20 March 2006

SGI on NSTX

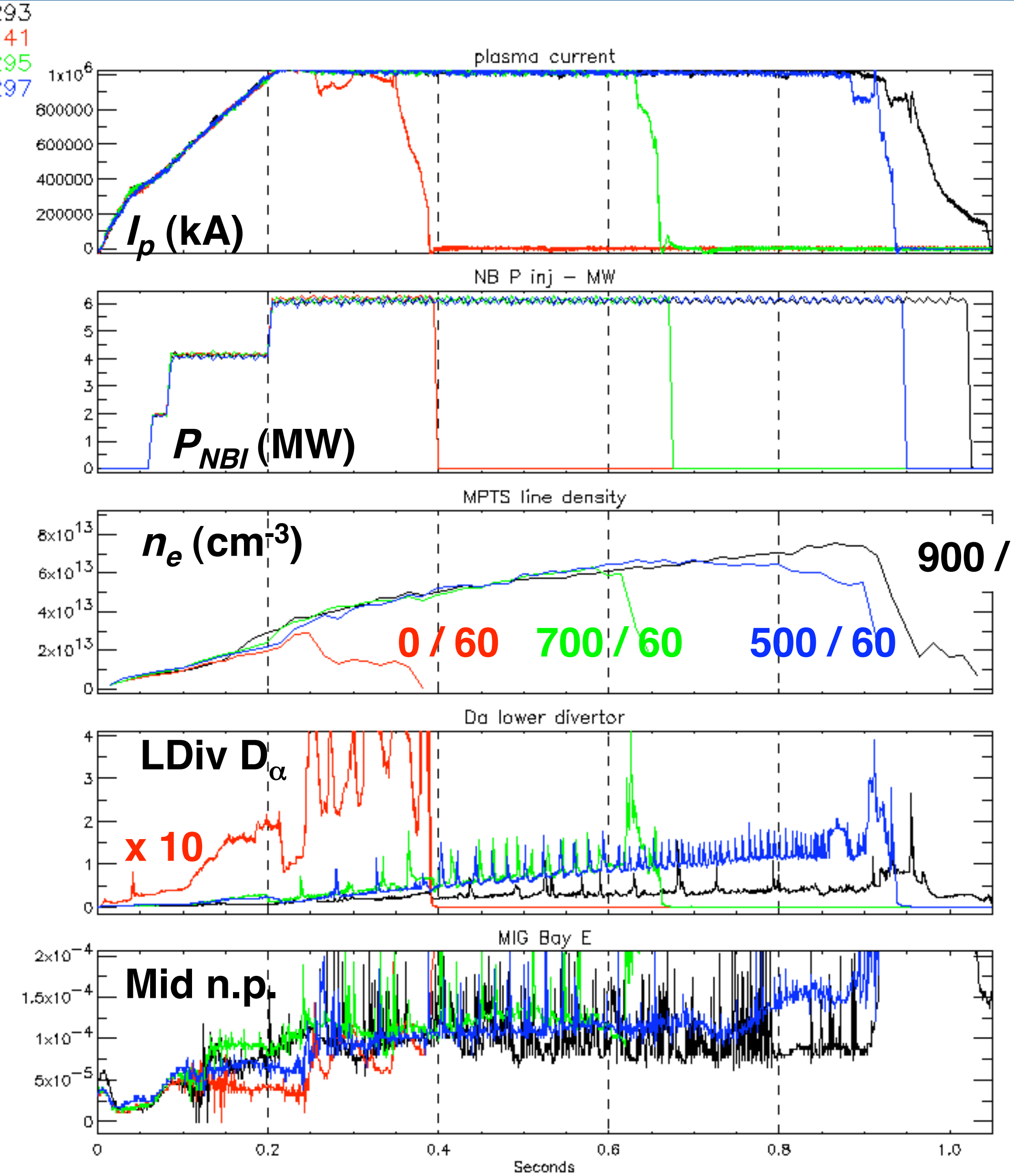
- XP 605 includes four parts - study supersonic gas (SG) jet fueling
  - Comparison of SG fueling efficiency with LFS gas injectors
  - H-mode access and density control with SG jet fueling
  - Front end fueling with SG jet
  - SG jet penetration through SOL in limited and divertor configurations

- Challenges
  - So far has been a “filler” XP - got two 1.5-2 hour run time segments
  - Neither an ITPA nor a milestone topic
  - Results to be presented at the 33d EPS meeting



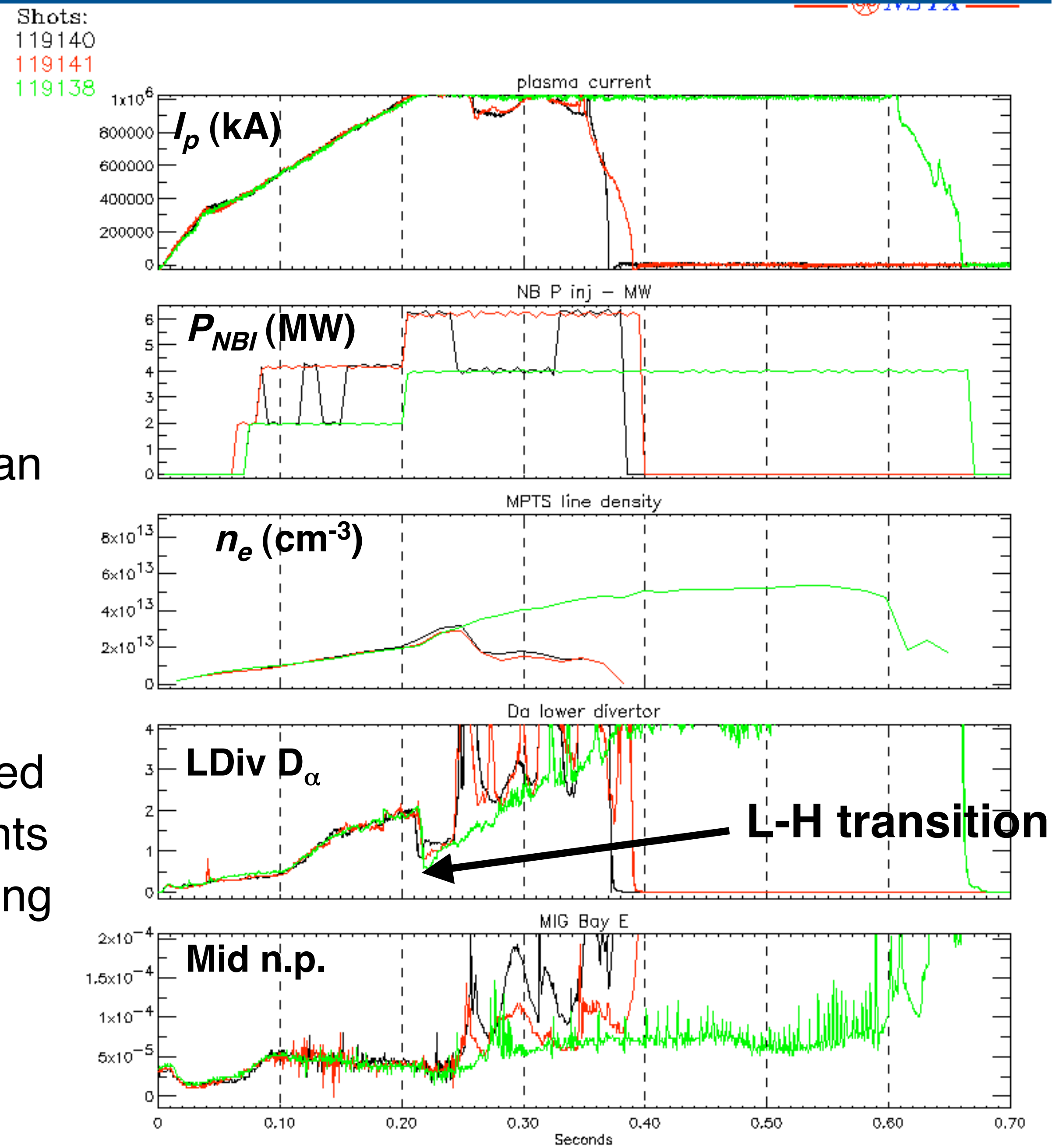
SG jet can control density in long-pulse H-mode discharges

- Used 1 MA / 0.45 T / 6 MW NBI-heated long pulse DN shots
- SGI injected at ~ 60 Torr.l/s from 90 ms to 1000 ms
- Compare 4 shots with HFS/SGI fueling (Torr / Torr.l/s): **900 / 0**, **700 / 60**, **500 / 60**, **0 / 60**
- In 119297 SGI injected from 200 ms to 1000 ms
- Change in fueling changed ELM regime from small+Type I ELMs to Type III ELMs
- With HFS+SGI put more gas - recycling and midplane neutral pressure *slightly* higher



H-mode can be obtained with SG jet + wall fueling

- Used 1 MA / 0.45 T / 6 MW NBI-heated long pulse DN shots
- SGI injected at ~ 60 Torr.l/s from 90 ms to 1000 ms
- All three shots - no other than SGI flattop gas fueling
- Got delayed L-H transition
- In 119138 apparently had strong wall fueling
- In 119140, 119141 got locked modes and large MHD events - apparently due to low fueling



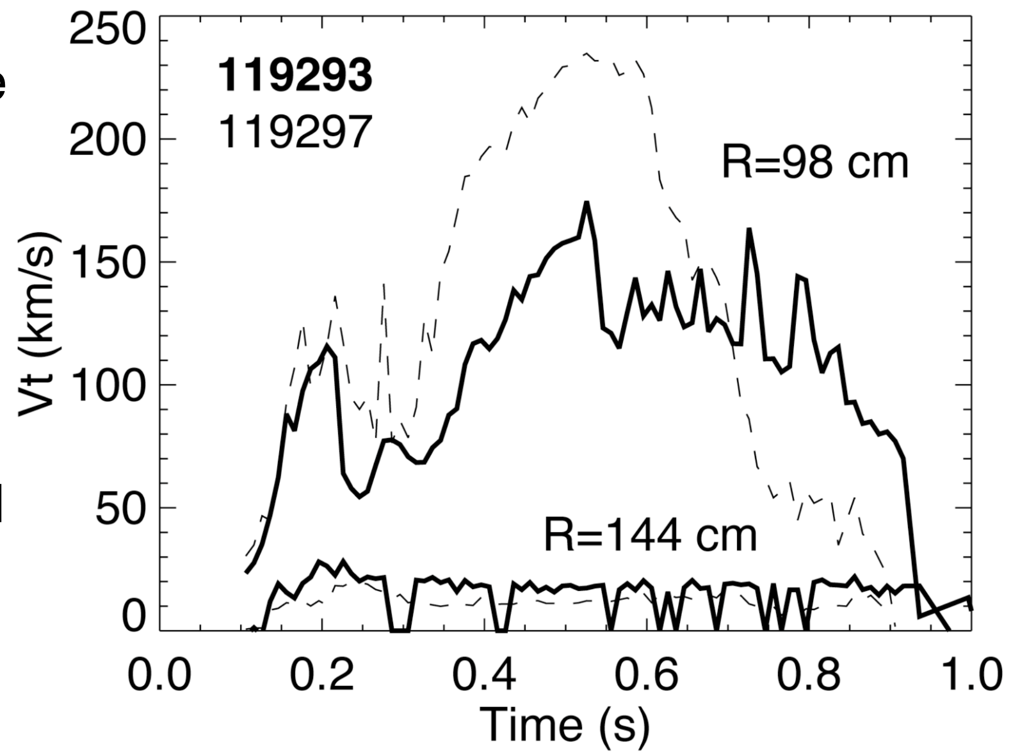
Various H-mode SG jet fueled scenarios are possible

- SGI in combination with HFS fueling can be used to obtain dN/dt~0

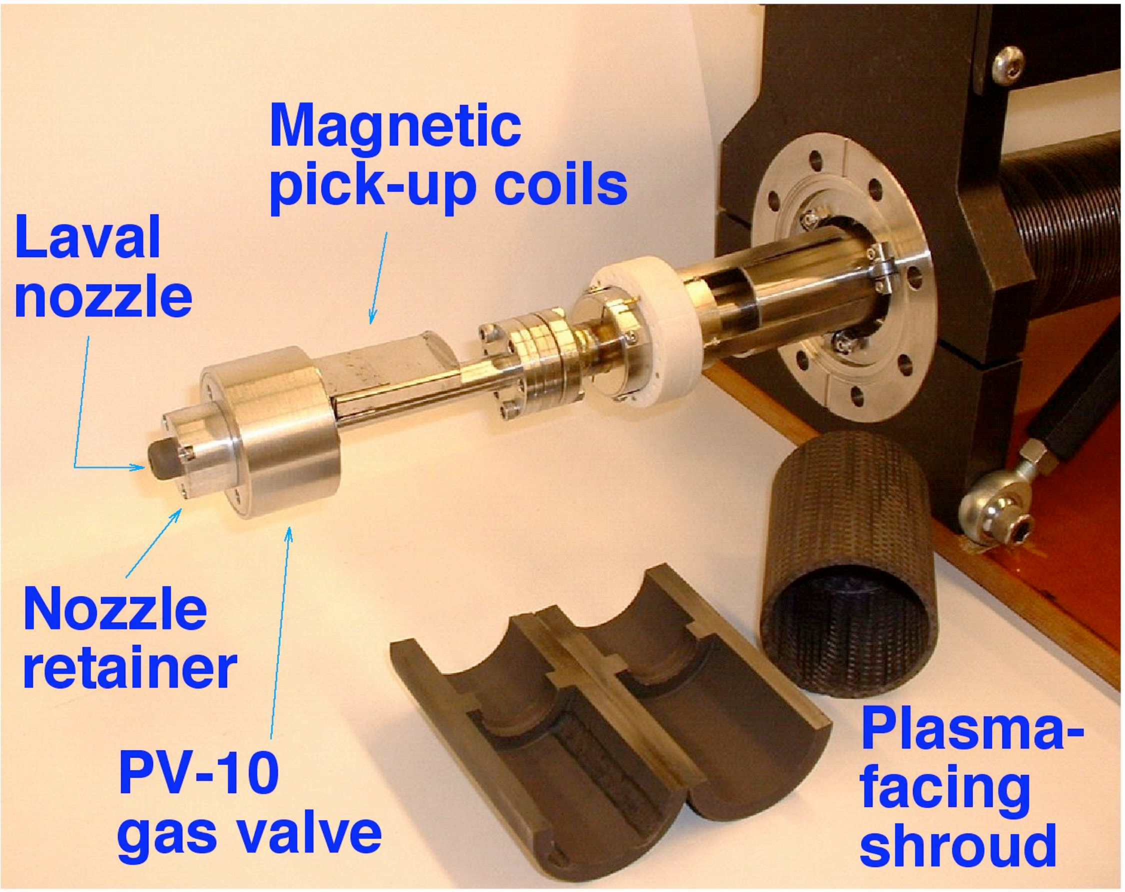
- Considering two scenarios: 1/ Use low-level HFS fueling for H-mode initiation and add SGI for density control and sustainment 2/ Use SGI from t=0 for H-mode initiation and add low-level HFS fueling to avoid locked modes and MHD events

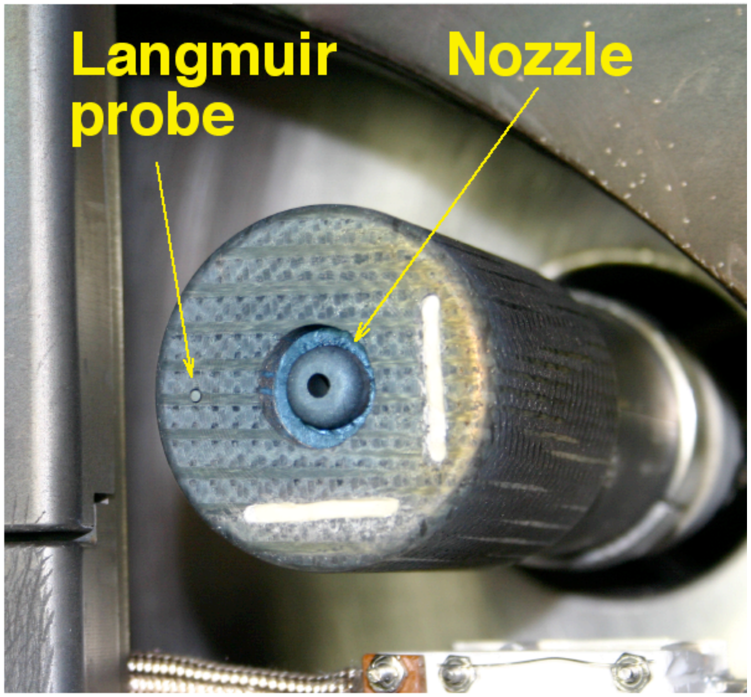
- May need to increase SGI plenum pressure to obtain higher fueling rate

- In all SGI shots central toroidal rotation 70 % higher, but edge rotation always lower than in HFS fueling only shot. These results can further test the theory of edge E_r and L-H transition dependence on edge neutral particle source location



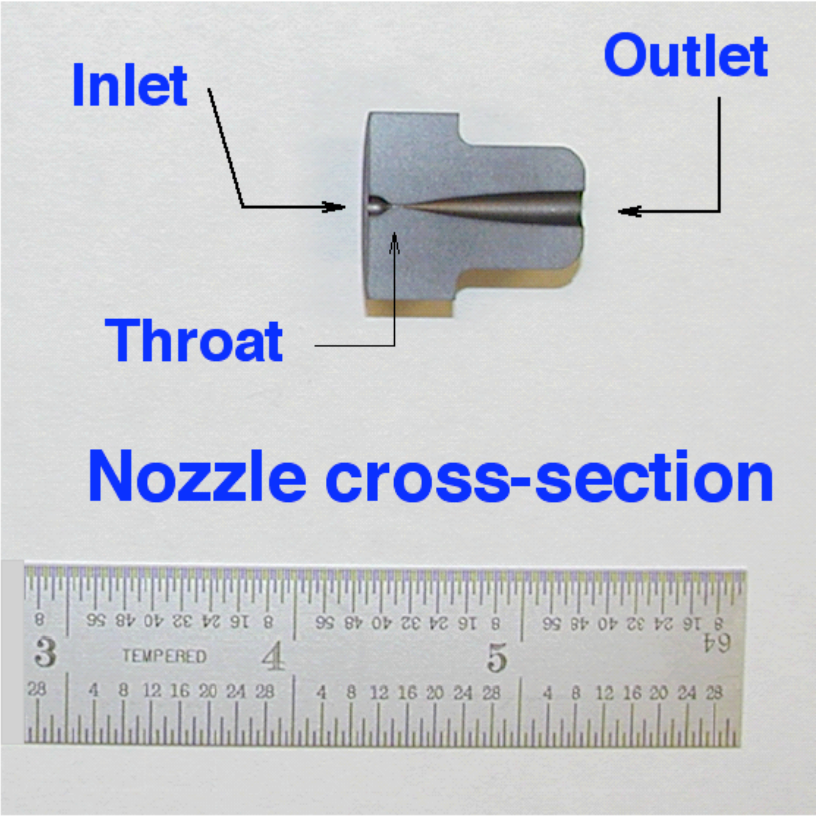
SGI head is a densely packed apparatus



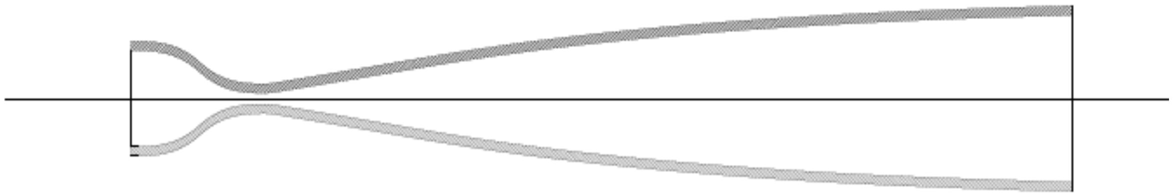


- Veeco PV-10 gas valve: d_{throat}=0.02”, typical opening time 1-2 ms, driving voltage150 V
- Thermocouples in shroud and in gas valve
- Two magnetic pick-up coils on shroud front surface for B_z, B_t measurements
- Three magnetic pick-up coils in shielded box inside shroud for B_z , B_r and magnetic fluctuations measurement
- Langmuir probe: flush-mounted design, d_{tip}= 1.75 mm, *I-V* recorded at 5 kHz, $-50 < V < 50$
- Shroud: CFC and ATJ graphite

Laval contoured nozzle is used in NSTX SGI

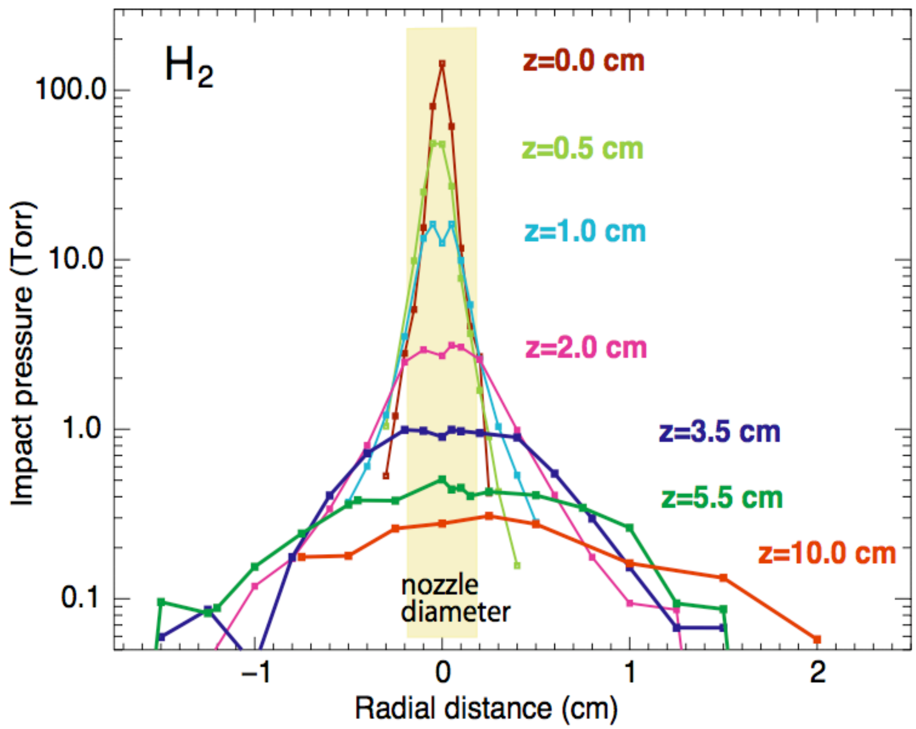


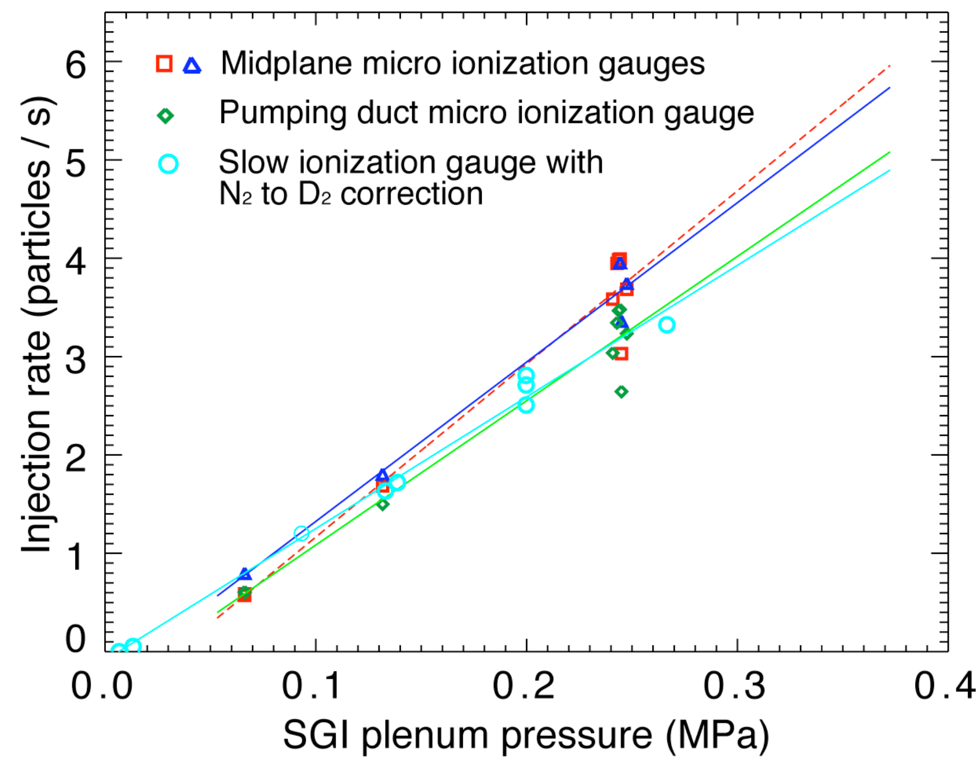
- Graphite nozzle L = 23.4 mm
- True Laval geometry calculated for air at P=1 atm, designed for M = 8, linearly scaled down to obtain d_{throat} = 0.01" (throughput requirement)
- Compressible fluid theory: isentropic core and boundary layer scale differently!
- Nozzle is made by mechanical machining using special tool with tolerance +- 0.0025"
- Nozzle attached to valve with a retainer using Viton O-ring



Nozzle design courtesy of Drs A. J. Smits, S. Zaidi (Princeton Univ.)

SGI parameters characterized off-line and *in situ*





- NSTX SGI is operated at 45-60 Torr l /s (~ (3.2 - 5) x 10^{21} mol/s)
- NSTX gas injector rates: HFS: 10 - 50 Torr l /s, LFS: 20 - 120 Torr l /s
- Jet divergence half-angle: 6^o - 25^o
- Hydrogen / Deuterium: $M = 4$, $T \sim 60 - 160$ K, $\rho \sim 5 \times 10^{17}$ cm^{-3},

  $Re = 6000$, $v_{therm} \sim 1100$ m/s, $v_{flow} = 2400$ m/s