Brief summary of FY'05 supersonic gas jet fueling experiments

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FY'05 technical progress

- XMP-36 "SGI commissioning for FY05" completed

- Max SGI injection rate of 60 Torr l / s is limited by max plenum pressure of 1800 - 2000 Torr - considering the possibility of rising it to a higher value

- SGI drive motion rate was found to be too slow - about 4 min one way (from R=1.98 m to R=1.56 m) - problem for a shot cycle turnaround.

Now testing a faster rate (x 10)

- New converging and conical nozzles have been fabricated and will be evaluated in a lab test facility at PPPL (L-111)

nstx.pppl.gov/sgi

FY'05 physics progress

- XP-516 "Plasma fueling with supersonic gas jet" started - ohmic plasma part completed, H-mode plasma part started
- Obtained a lot of data for gas jet penetration and fueling model development - profiles, fast camera movies, probe data
- Did a scan of SGI-LCFS distance in ohmic plasmas, and a crude scan in H-mode plasmas
  - Gas jet effect on plasma is small - no significant T_e drop, no significant neutral pressure increase
  - See small density inflection at closest distance
  - Compatibility with H-mode confirmed
  - In NBI heated plasmas can not insert SGI beyond RF limiter (R=155 cm) for safety reasons due to interaction with energetic ions (probably bad orbit loss ions)
  - At Γ=50 Torr l / s SGI delivers (η x 5) Torr l into a 10-12 Torr l plasma
  - Fueling efficiency analysis in progress

FY'05 work to be done

- Complete XP-516

  - H-mode part (flat-top fueling, center stack gas injector replacement)

  - Start-up fueling

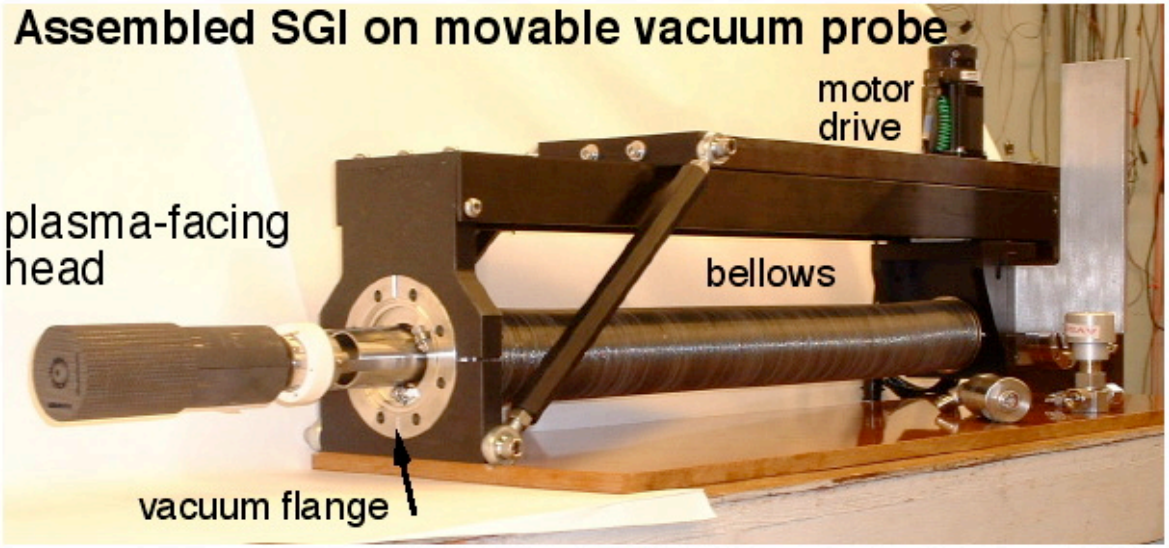
- If plenum pressure limit raised, will want to revisit some parts of XP-516

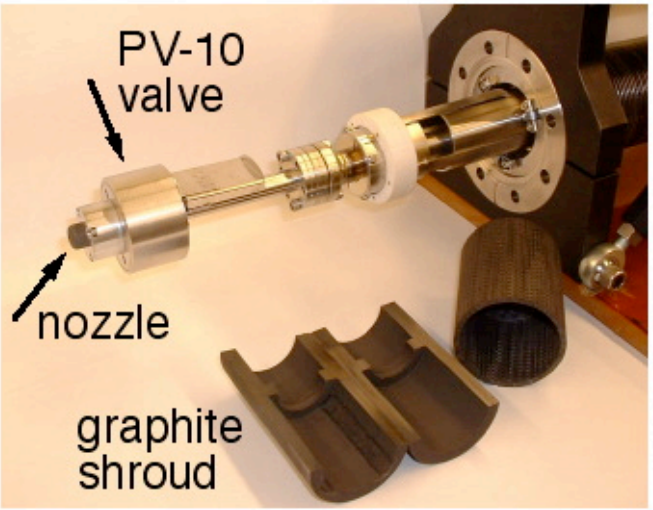
- Develop a fueling scenario for high performance long H-mode plasmas (can work with XP-507 and XP-508)

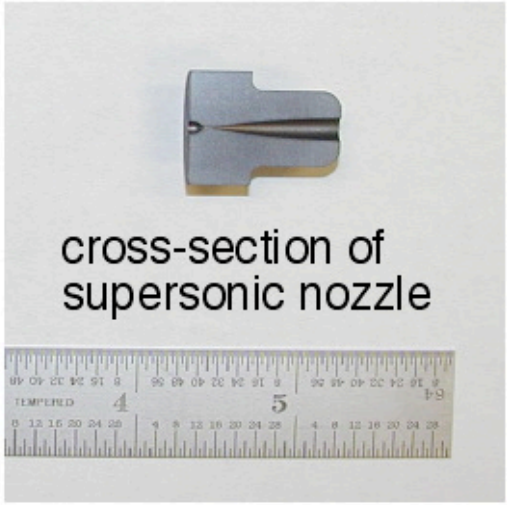
- Defer ELM pacing attempts to SGI with higher plenum pressure

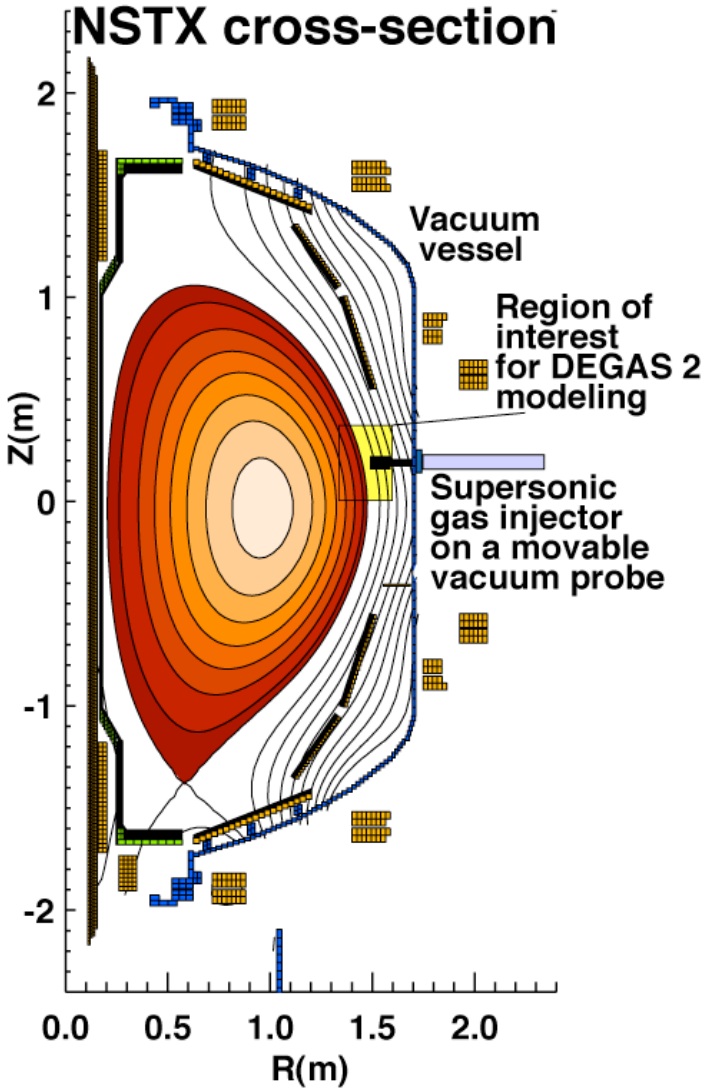
Backup

Supersonic gas injector is operational in FY'05

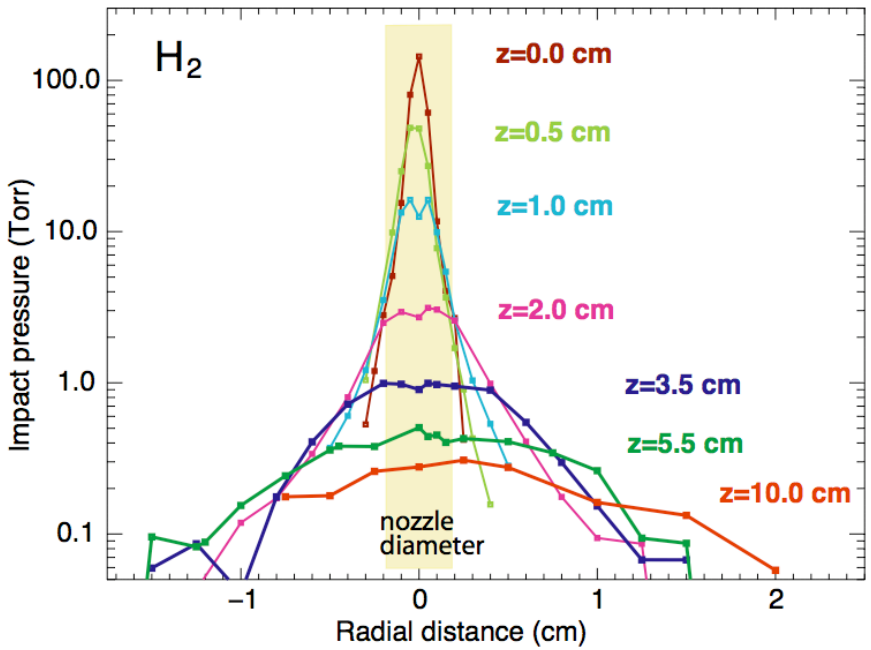


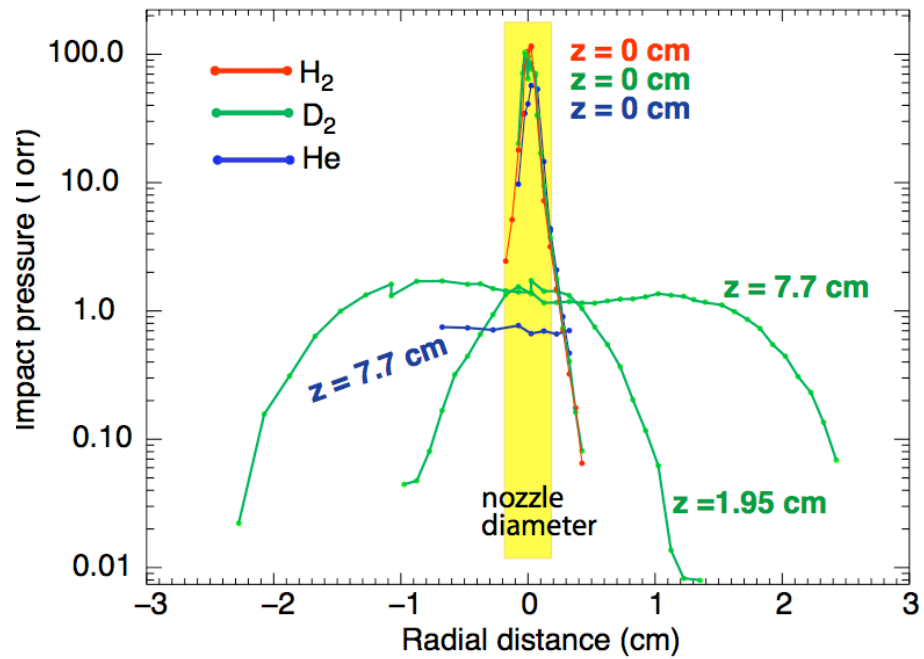






Off-line pressure measurements confirm high Mach number and low divergence of gas jet





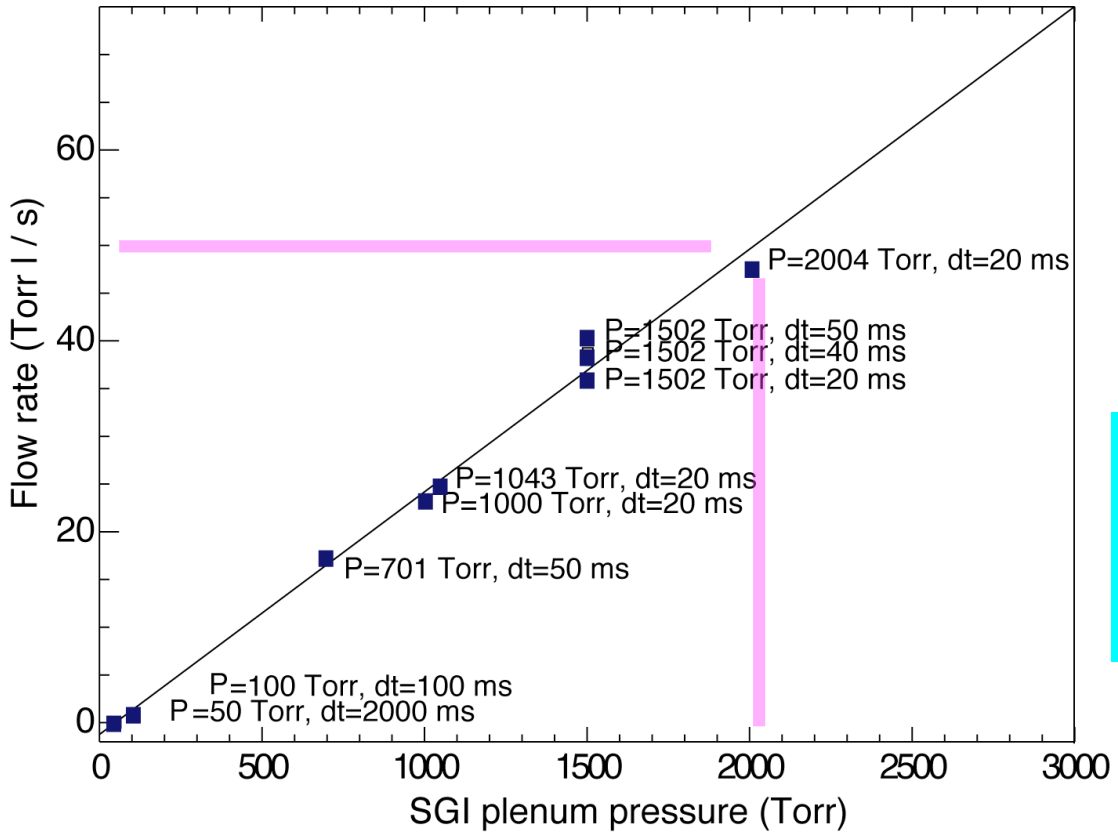
Jet divergence half-angle: 6° - 25°

D_2: $M = 4$, $T \sim 60 - 160$ K, $\rho \sim 5 \times 10^{17}$ cm^{-3}, $Re = 6000$

D_2: $v_{therm} \sim 1100$ 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

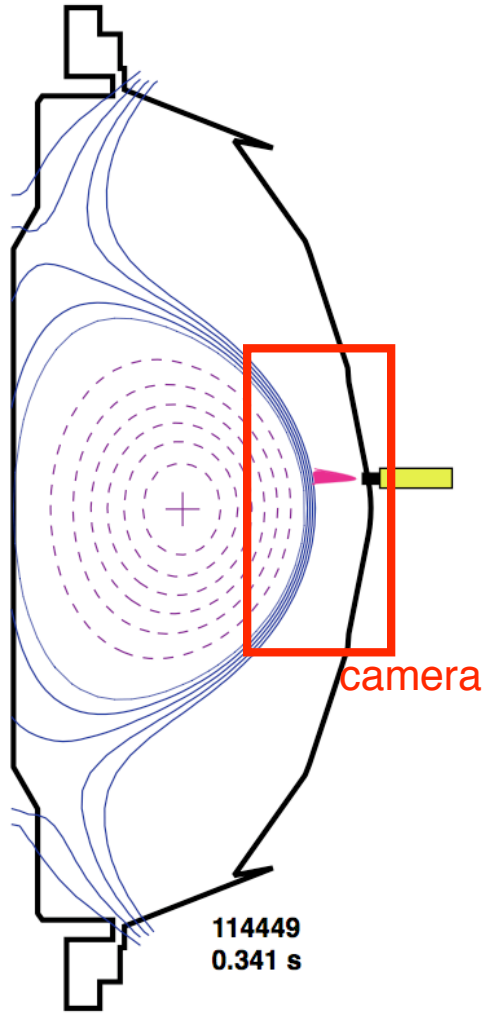


NSTX gas injector flow rates:
HFS: 10 - 50 Torr l /s
LFS: 20 - 150 Torr l /s

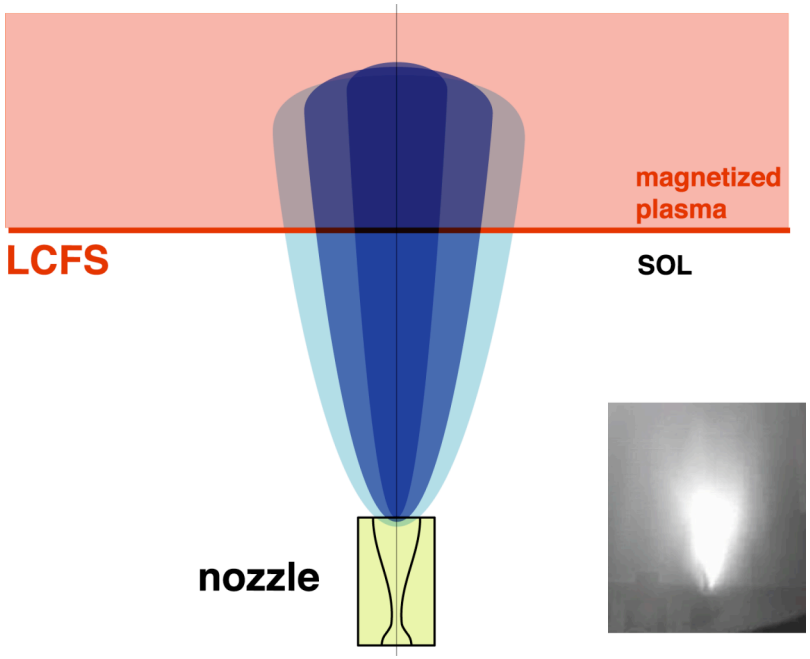
NSTX SGI will be operated at 50 Torr l /s (= 3.5 x 10^{21} molecules/s)

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

Supersonic gas jet penetrates well through a wide 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

Gas jet penetration mechanism

- Single particle model is inapplicable
- Gas jet retains shape due to compressible flow considerations
- Gas jet eventually ionizes and creates a plasmoid
- Gas jet retains cluster-molecular-atomic-ion structure
- SOL/edge electrons with low T_e do not fully penetrate gas jet
- Plasmoid can not penetrate into the magnetized plasma due to insufficient velocity and high plasma kinetic and magnetic pressure
- Modeling must include particle, momentum, energy balance (Braginskii) equations with detailed reaction rates and neutral transport (UEDGE+DEGAS 2)