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H-mode fuelling optimization using supersonic gas jet - XP 742 summary

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Acknowledgements:

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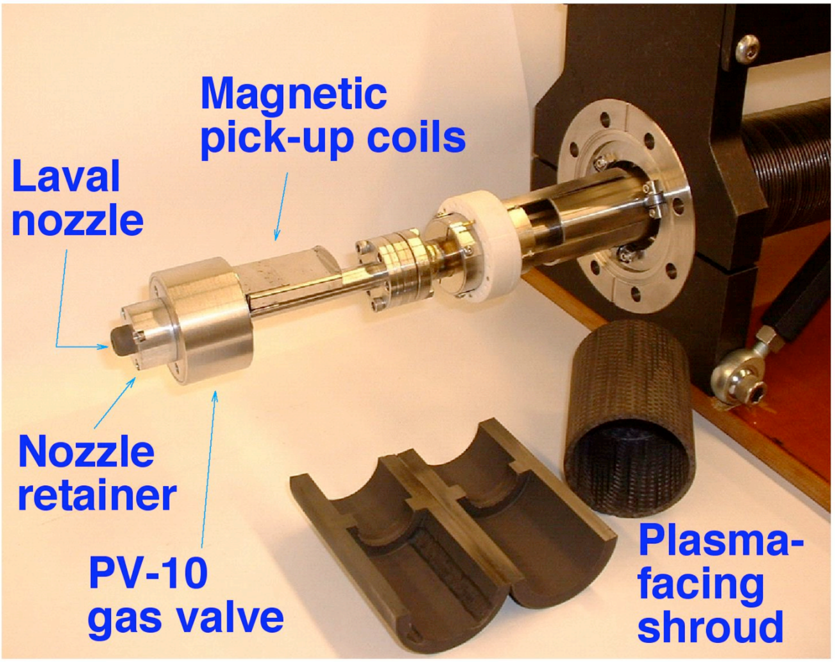
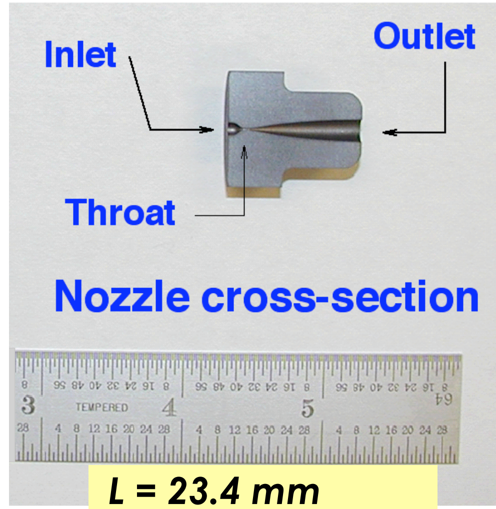
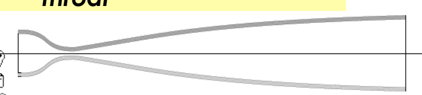
H-mode fueling optimization and density control are studied on NSTX using supersonic gas jet





$L = 23.4$ mm
$d_{throat} = 0.254$ mm

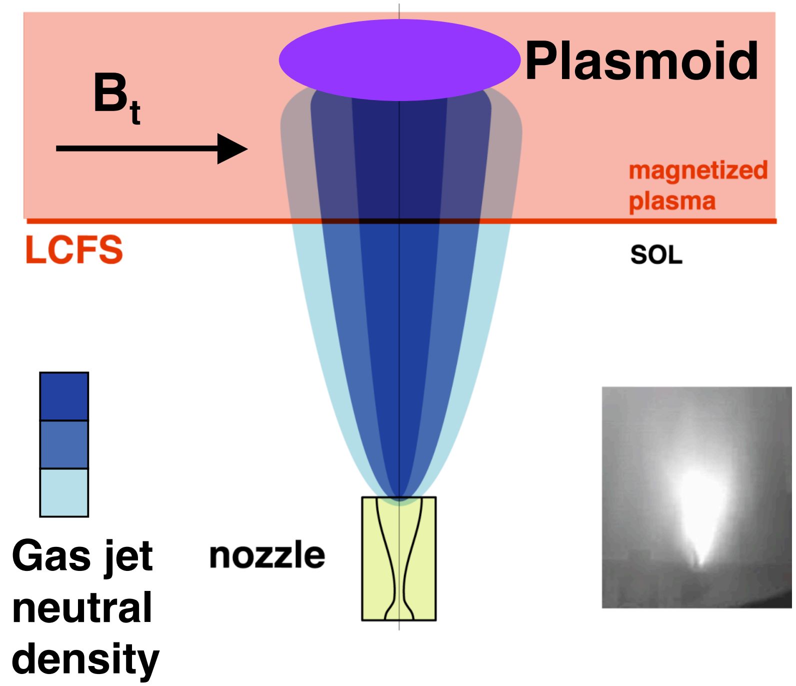


Supersonic gas injector installed on NSTX in 2004, experiments conducted in 2005-2006

- NSTX SGI is operated at flow rates 20-65 Torr l /s ($1.5 - 4.5 \times 10^{21}$ s^{-1}) - unique fueling tool
- Supersonic deuterium jet:
  - ✓ Jet divergence half-angle: 6° - 25° (measured)
  - ✓ Mach number $M = 4$ (measured)
  - ✓ Estimated: T ~ 60 - 160 K, $n < 5 \times 10^{23}$ m^{-3}, $Re = 6000$, $v_{flow} = 2400$ m/s , $v_{therm} \sim 1100$ m/s

Supersonic gas jet penetration mechanism is different than that of conventional gas injection

- Unlike conventional gas injection, penetration depth of supersonic gas jet cannot be described by single neutral particle ionization / charge exchange penetration model
- Supersonic gas jet is a low divergence high pressure, high density gas stream with low ionization degree - bulk edge/SOL electrons do not fully penetrate gas jet
- High density plasmoid blocks jet from deep penetration into magnetized plasma
- Depth of penetration is ultimately determined by jet pressure and plasma kinetic and magnetic pressure
- Desirable for fueling are molecular clustering and/or droplet formation in jet achieved at very high pressure and cryogenic temperatures



References: Rozhansky et al. NF 46 (2006) 367
Lang et. al. PPCF 47 (2005) 1495

FY 2007 SGI Upgrades are motivated by fueling results obtained with SGI in 2004-2006

- Results from 2005-2006 experiments:
  - ✓ Reliable H-mode access and low power threshold (< 2 MW NBI) in SGI-fueled H-mode discharges
  - ✓ Progress has been made in development of SGI-fueled H-mode scenario with reduced (up to 20) high field side fueling rate
  - ✓ SGI-fueled double-null H-mode plasmas demonstrate different ELM character (type III ELMs vs small and type I ELMs)
  - ✓ SGI flow rate < 65 Torr l / s
  - ✓ Measured fueling efficiency 0.1 - 0.4

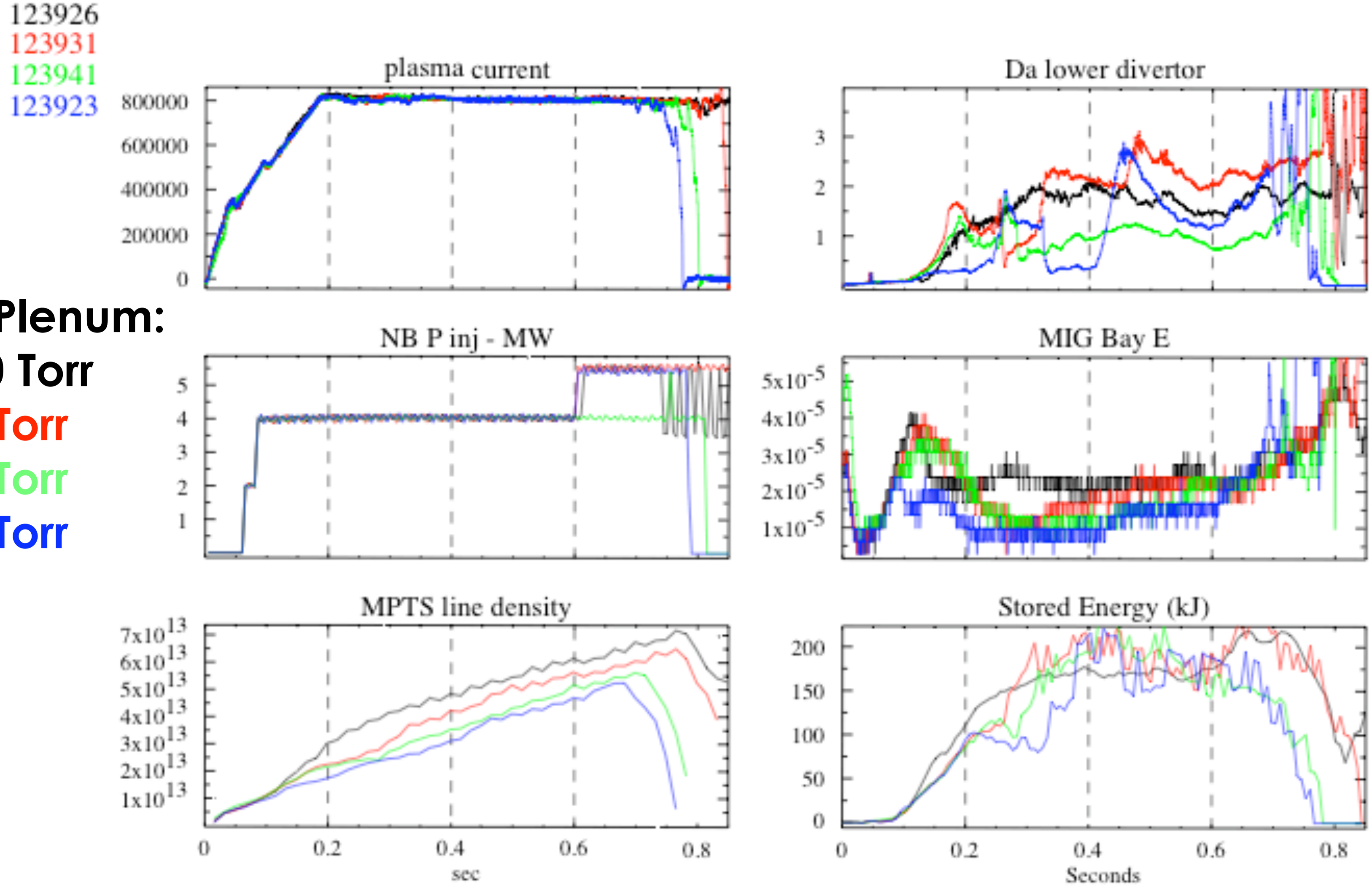
- SGI Upgrade program includes:
  - ✓ Independent gas handling system (D_2, other gases, e.g. He, CD_4)
  - ✓ Increase SGI plenum pressure from 2500 to 5000 Torr
  - ✓ Multi-pulse capability
  - » Density feedback with SGI using Plasma Control System

In blue: ready in FY 2007

XP 742 focused on H-mode fueling optimization with high-pressure SGI

- Operational notes:
  - ✓ Ran XP in rt-EFIT-controlled high κ, δ shape
  - ✓ Ran XP on Monday, after extensive LITER-ing in preceeding week
  - ✓ Ran with 2 NBI sources (4 MW)
  - ✓ Throughout the day, observed late H-mode transitions, suppressed ELMs, impurity accumulation, different MHD (low m,n modes)
  - ✓ Used SGI with 5000 Torr plenum pressure (= flow rate ~ 120 Torr l /s) and multi-pulse SGI capability
  - ✓ Reduced HFS fueling from 1100 Torr in plenum to 500 Torr and then to 300 Torr in plenum (x 3.8 reduction in flow rate)
  - ✓ Obtained comparison of SGI fueling efficiency with LFS injector
  - ✓ Demonstrated superior fueling capability of SGI-Upgrade

Reduced density H-mode plasmas obtained



HFS Plenum:

1100 Torr

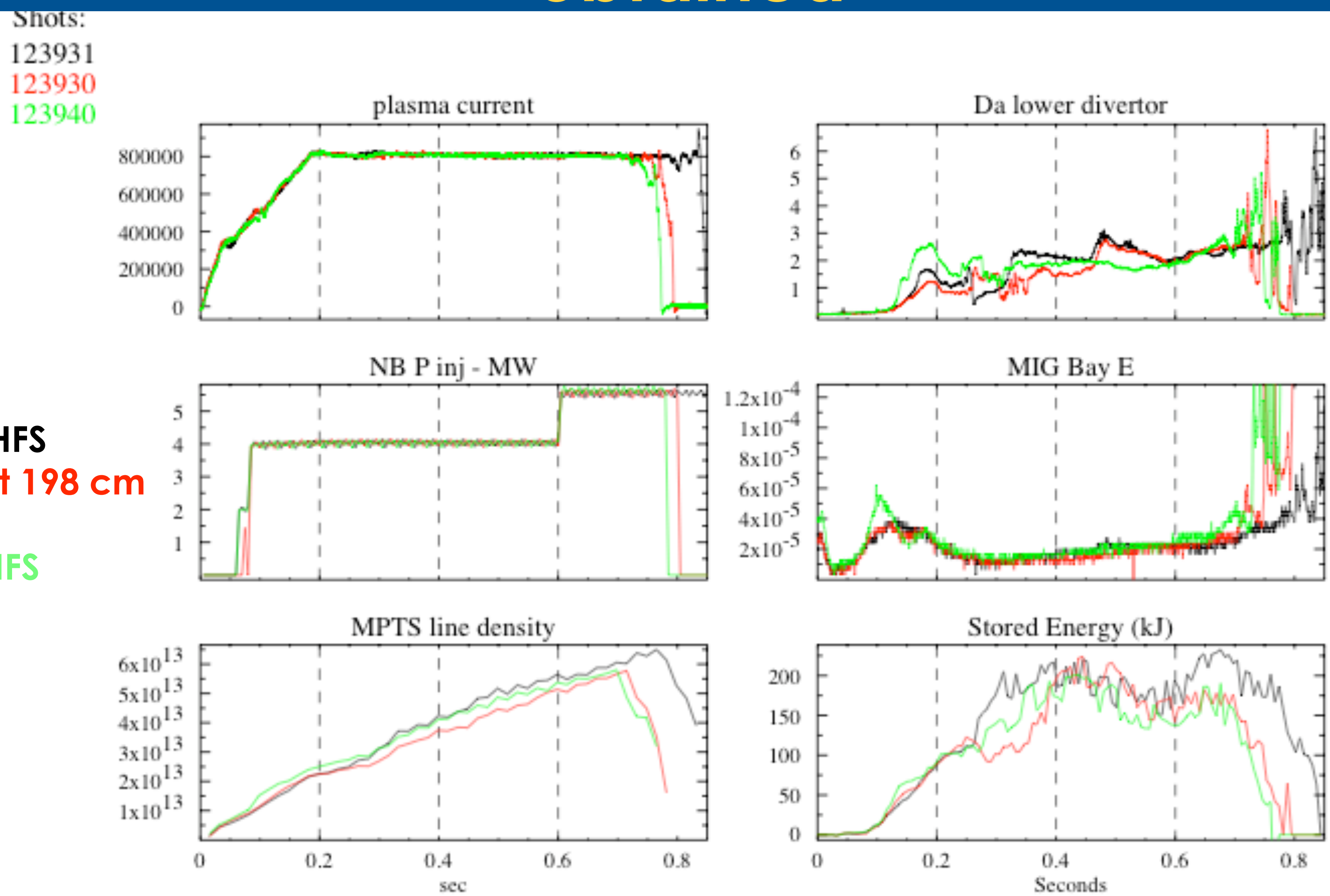
500 Torr

400 Torr

300 Torr

- ✓ Reduced H-mode density x 2-2.5
- ✓ Peak T_e increased from 800 eV to 1-1.4 keV
- ✓ Midplane neutral pressure decreased

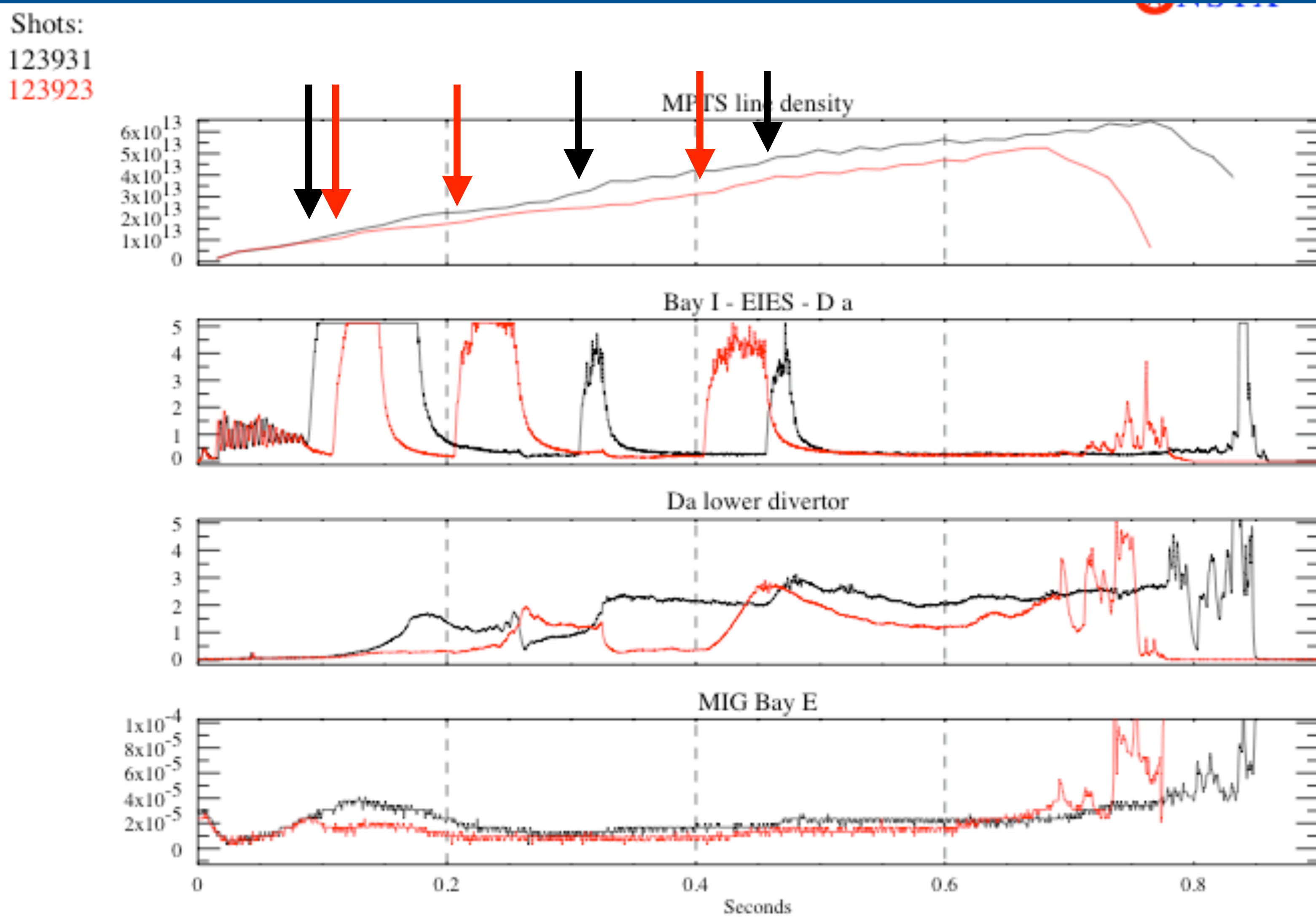
Favorable comparison of SGI and LFS injector obtained



SGI+HFS
SGI at 198 cm +HFS
LFS+HFS

- ✓ SGI-fueled shots have higher "flattop" density
- ✓ However, during gas flow density is higher for LFS gas injector
- ✓ SGI-deposited particles penetrate deeper? Higher containement time?

Fueling efficiency is high with high-pressure SGI



- ✓ Bay I Da shows SGI injection pulses
- ✓ Clear *dN/dt* increase during SGI pulses
- ✓ Weak midplane n. pressure increase, but increase in divertor recycling

Conclusions and future work

- SGI-Upgrade commissioned for plasma operations
  - ✓ High-pressure SGI pulses yield efficient fueling
  - ✓ High-pressure SGI pulses do not lead to H-L transitions
  - ✓ Most productive is probably use of many short pulses
- SGI-fueled reduced density H-mode scenario obtained
  - ✓ Reduced HFS gas flow rate by up to x 3.8 (to ~ 10 Torr l / s (?))
  - ✓ Density decreased by x 2
  - ✓ H-mode access with SGI demonstrated at 4 MW NBI
  - ✓ SGI-fueled H-mode density can be increased to match HFS-fueled reference shot
  - ✓ However, at low HFS fueling and pulsed SGI, *dN/dt* is still not zero
- Hope to use SGI in ISD experiments in FY 2007
- SGI needs refurbishment before FY 2008 run to address leaky valve problem