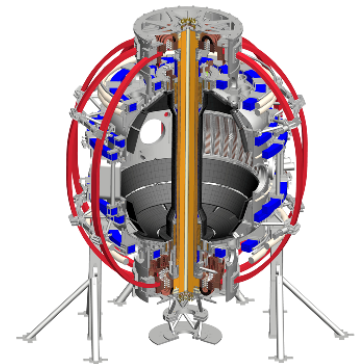# Gas Injection System (GIS)
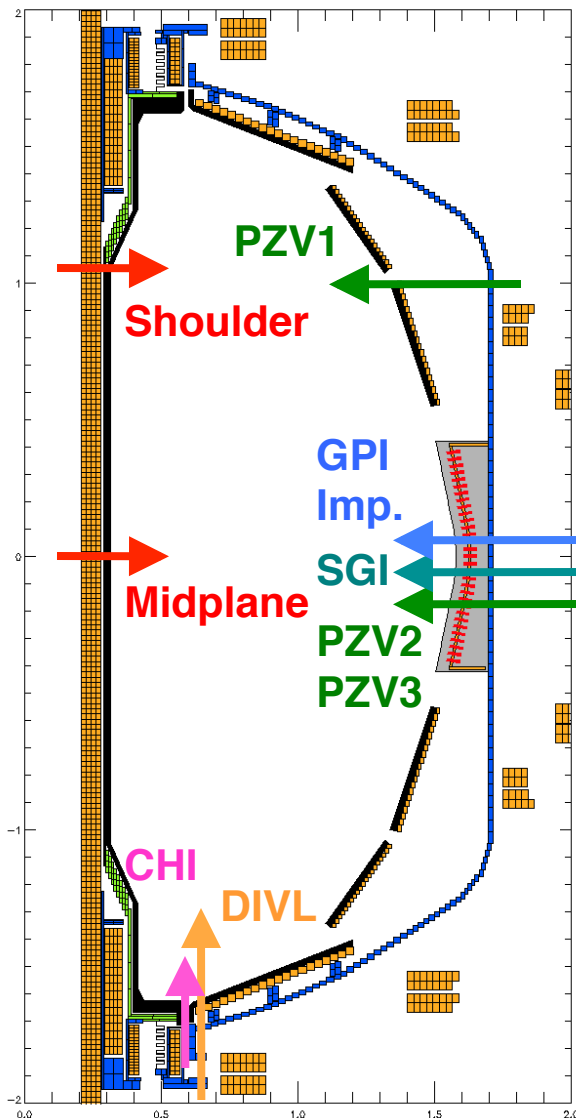
Devon Battaglia,
Keith Erickson, Dennis Mueller, Stefan Gerhardt,
Roger Raman, Vlad Soukhanovskii

Gas Injection Systems on NSTX-U for FY16

- Piezoelectric (P10) valves
  - Fast on/off using piezoelectric crystal that bends in response to voltage
  - PZV: Main LFS injection valves
  - SGI: Supersonic gas injector
    - Advanced nozzel on moveable probe
  - GPI and Impurity: Diagnostic gas
  - DIVL: Two valves (Bay I and Bay C)
    - Two upper divertor systems (DIVU) in the future

- Pneumatic (puff) valves
  - Empty plenum into vessel when triggered
  - HFS: 2 at midplane, 2 at shoulder
    - Each location has 2 varieties of tube diameter
  - CHI: 2 systems used for CHI
    - See Rogers talk

- Massive gas injector (MGI)
  - See Roger's talk

Piezo valves on NSTX-U
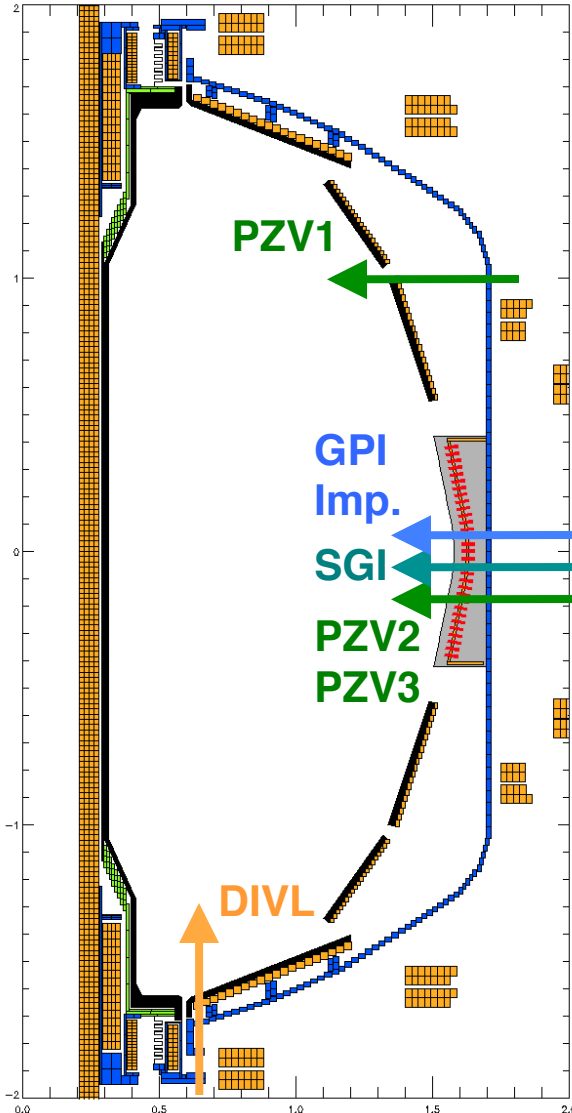
- **Piezoelectric (P10) valves**
  - PZV, SGI used for prefill, plasma fueling, GDC
  - GPI, DIV, Impurity used for specific experiments
  - Each valve supplies gas from a plenum
  - Typical maximum flow rates ~ 150 Torr-liters/second

- **Flow-rate control using pulse-width modulation**
  - Valves cycle between fully-opened and closed to achieve, on average, the desired flow rate
    - Algorithm considers min on/off time, evolving plenum pressure to compute open/close times
  - Why not control flow by partially opening valve?
    - Drifting voltage response of piezo crystal requires frequent tuning, irreproducible results

Prefill control for plasma startup

- Gas injected prior to breakdown
  - Pumped away by turbo (vessel) and cyro (beam) pumps
  - Prefill algorithm does active feedback on vessel pressure

- Vessel pressure gauges have a slow response
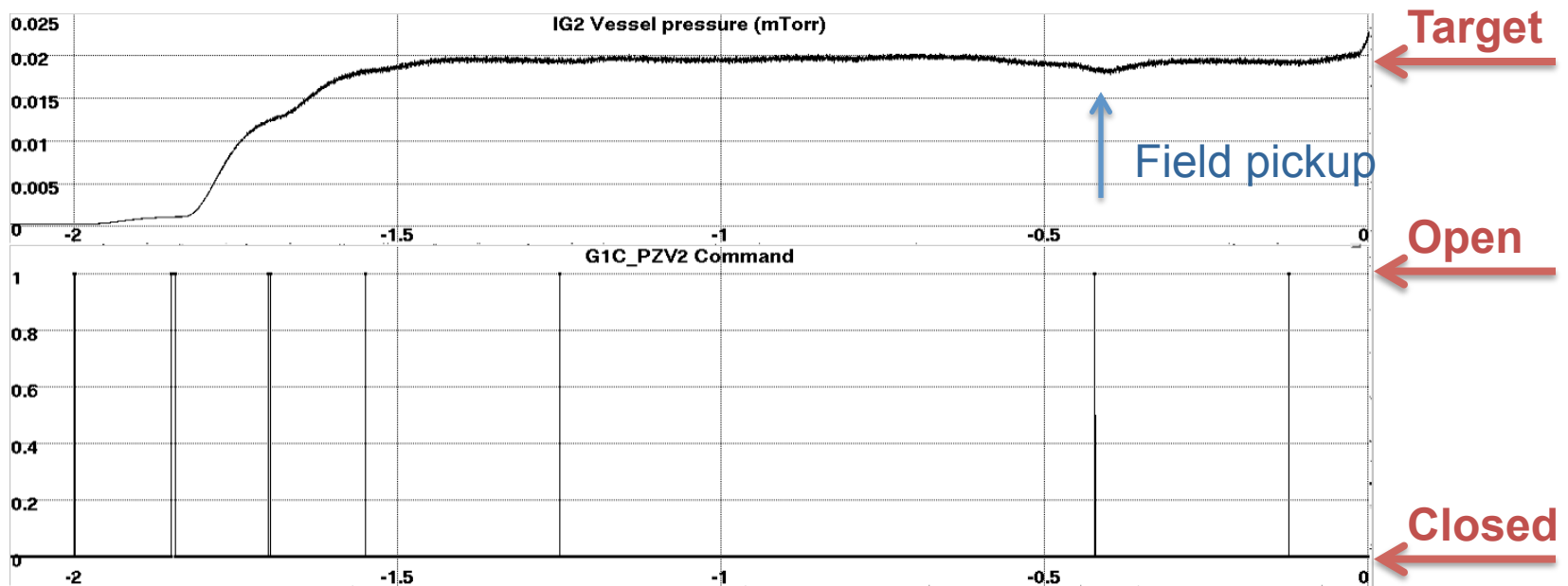
Prefill is mostly left alone, except …

- **Approximate vessel volume must be chosen**
  - NBI beam line volume similar to NSTX-U volume
  - Planned: consistency check with beam TIV status in EPICs
    - Until then, be aware of opening and closing NBI TIVs
  - Not fatal, but could result in missing prefill target

Gas injection category →
  Prefill Subset →
    Prefill Data …

25000 liters: No beam TIVs open
50000 liters: One beam TIV open
75000 liters: Both beam TIVs open

Prefill Data Editor

25000 Liters	Volume of NSTX vessel and beams
0.0	Gain
0.1	Time (s) after which pre-fill control request to the flow should not be calculated
0.0	interval (s) of checking for increments to the total flow
IG1	Which Ion Gauge
Deuterium	Gas in Prefill
0.0	Low pass filter time constant (s)

load defaults | unchanged | cancel | apply | NEXT SHOT | Close

Prefill is mostly left alone, except …

- Approximate vessel volume must be chosen
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- All other changes or problems …
  - Fail to break down, gas injector or pressure gauge breaks, not getting prefill target, changing prefill gas type …
  - Call Devon or Dennis

If you want gas, you must ...

- Enable valve in PCS
  - Gas Injection → Enable and Status → Injector enable ...

- Tell the vacuum PLC operator
  - They also need to know the plenum pressure

- Make sure Piezo gas type is correct in PCS at the start of XP
  - Gas Injection → Enable and Status → Gas type ...
  - Daily checklist would have this in it
  - Future: check consistency with EPICS

Piezo valve control from the PCS

- Piezo valve control waveform

  – Valve is closed, open or in flow rate (PWM) control

  – In the future, could have option for density, div radiation …

- Piezo flow rate waveform
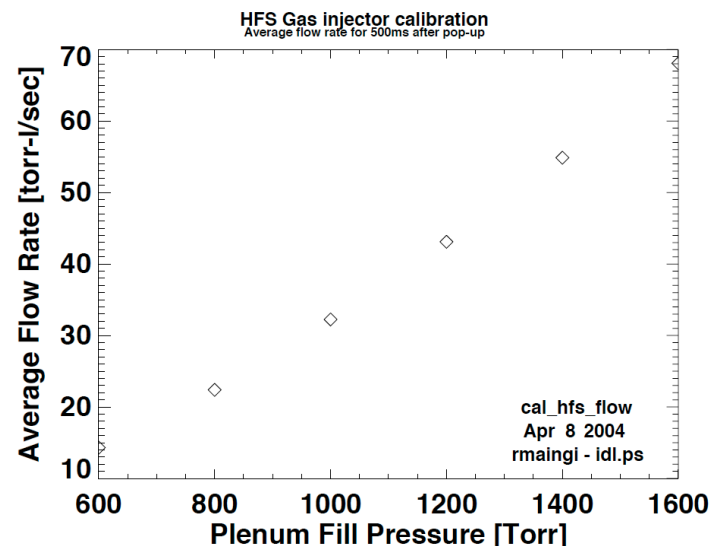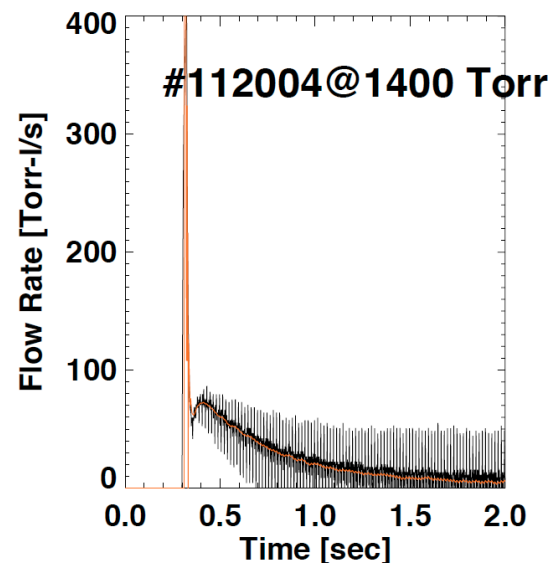
  – Set target flow rate for when valve control = flow
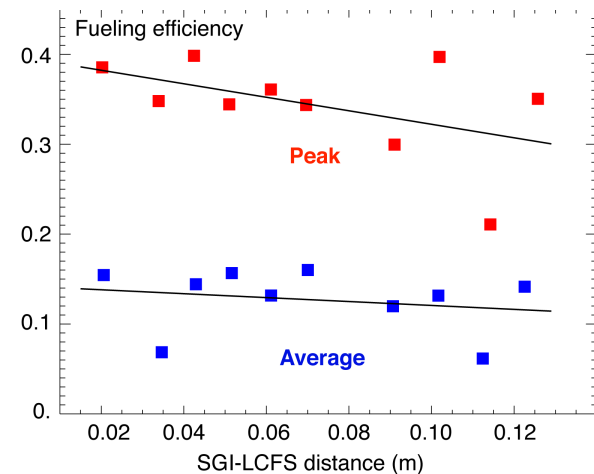
PZV2 Voltage 141182
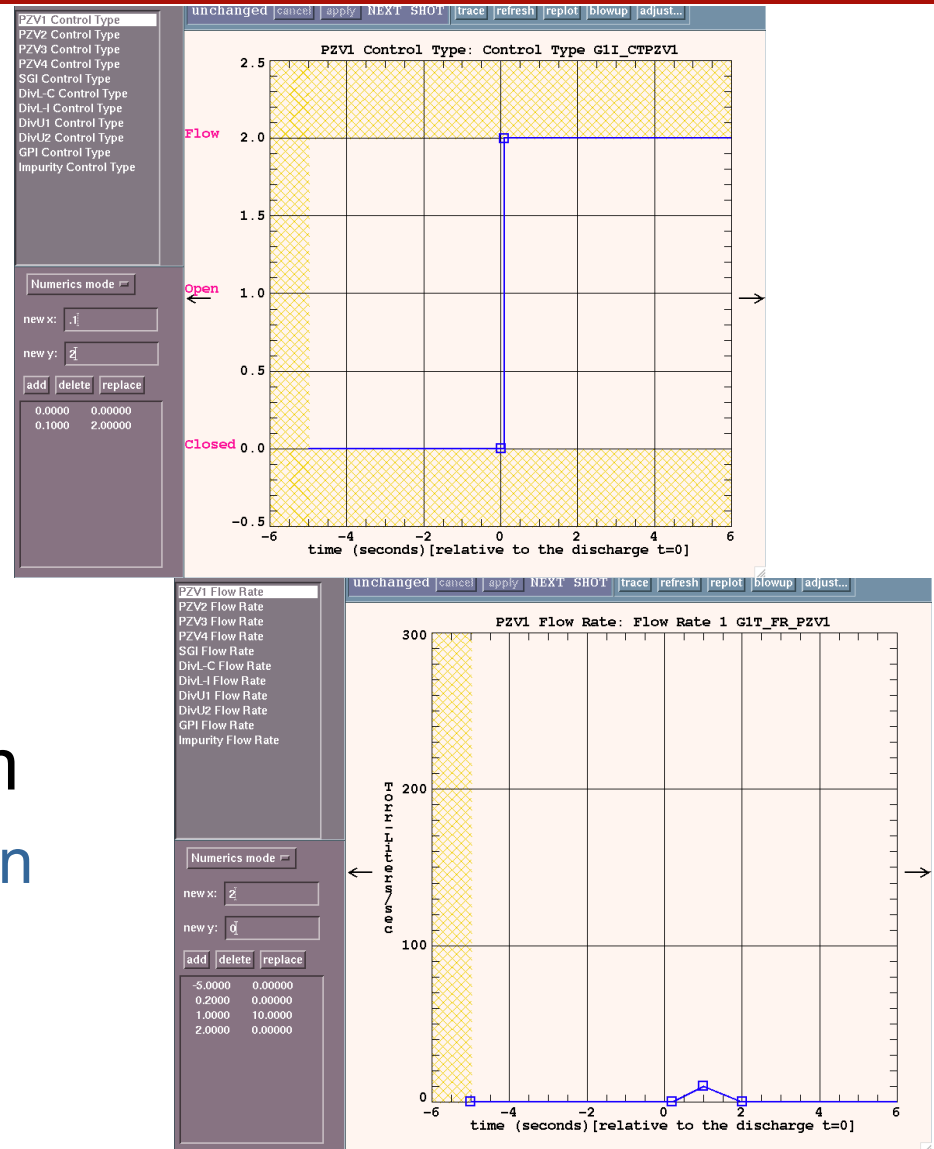
Time (s)
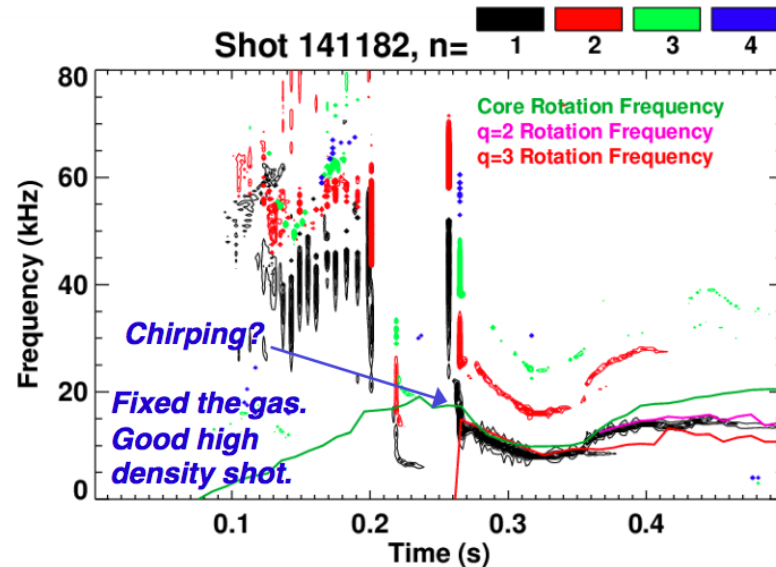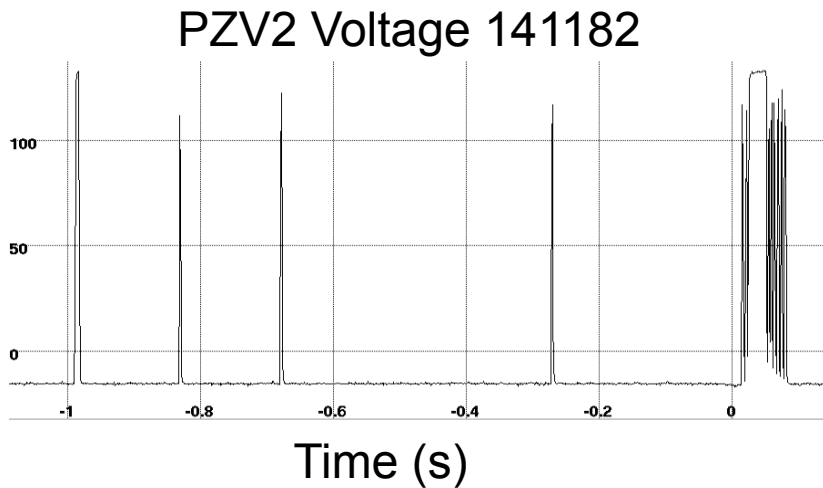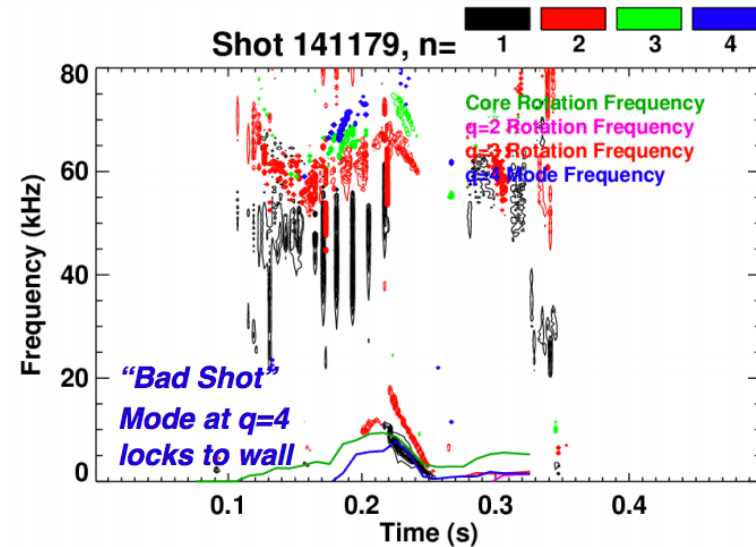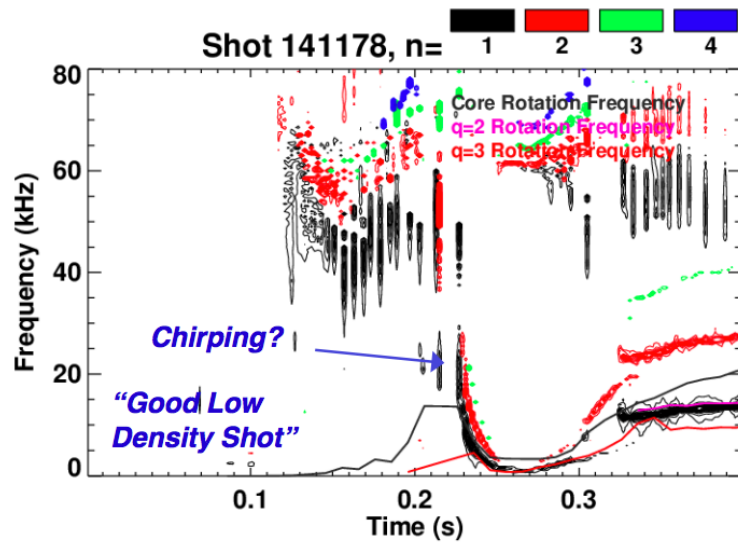
HFS gas important for H-mode access

- **Reliable and lower power H-mode access observed on STs with HFS fueling**
  - HFS geometry limits injectors to solenoid valves with long tubes
  - P.O. sets trigger to open in PCS

- **Gas "leaks" in after some delay**
  - Flow rate and gas load set by plenum pressure and tube diameter
  - Two poloidal locations: midplane and shoulder
  - NSTX-U: two tube diameters at each location to choose from

#112004@1400 Torr

HFS Gas injector calibration
Average flow rate for 500ms after pop-up

cal_hfs_flow
Apr 8 2004
rmaingi - idl.ps

Supersonic gas injector (SGI) provides increased fueling efficiency

- ## SGI is a standard piezo valve fitted with a nozzle
  - Mounted on a moveable, shielded probe at the midplane
    - Probe position request made to vacuum PLC operator
  - Gas injected at Mach 4 speeds

- ## NSTX experiments demonstrated SGI can replace HFS fueling for H-mode access
  - Also shown to increase fueling efficiency for early LFS gas

Langmuir probe   Nozzle

Inlet   Outlet   Throat

Nozzle cross-section

Vlad Soukhanovskii SOFE07

Fueling efficiency

Peak

Average

SGI-LCFS distance (m)
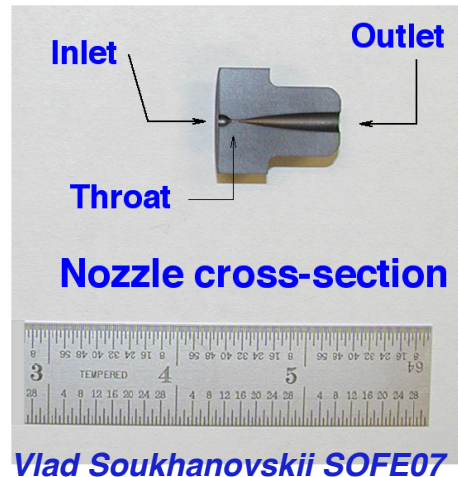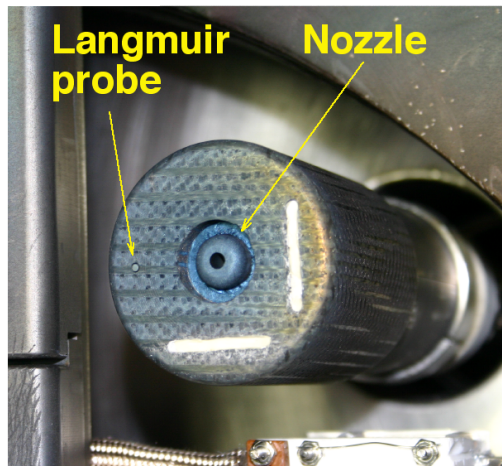
Summary of NSTX-U gas injection system

- LFS Piezo valves
  - Prefill with vessel pressure feedback
  - Early fueling with flow-rate feedback
  - Glow-discharge cleaning (GDC)
  - Diagnostics (GPI), trace impurities or divertor fueling
- Puff valves
  - HFS for H-mode access
  - CHI startup
- Supersonic Gas Injector
  - Tool for improving fueling efficiency