LTX Status

Presented by Dick Majeski

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PFC meeting
3-5 May 2004
University of Illinois - Urbana

Next step for lithium walls- the Lithium Tokamak eXperiment (LTX)

CDX-U

LTX

- LTX will be the first tokamak dedicated to PFC issues since ISX
- Completely rebuild CDX-U for larger, longer duration, higher current plasmas
  - R=40 cm, a=26 cm, □=1.55 (ISX-B!), B_T=4 kG, I_p <400 kA (>50 msec flattop)
- Lithium wall technology: thin films
  - Recoated between discharges
  - Plasma-aligned, heated, replaceable first wall
  - Multiple wall materials planned
- Poloidal field, control system upgraded
- Core fueling
  - Multiple (8) pellet injector
  - □ □ Supersonic gas injector
  - Upgraded ohmic system, toroidal field to permit pellet sustainment

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LTX will use a conformal, heated, lithium coated wall

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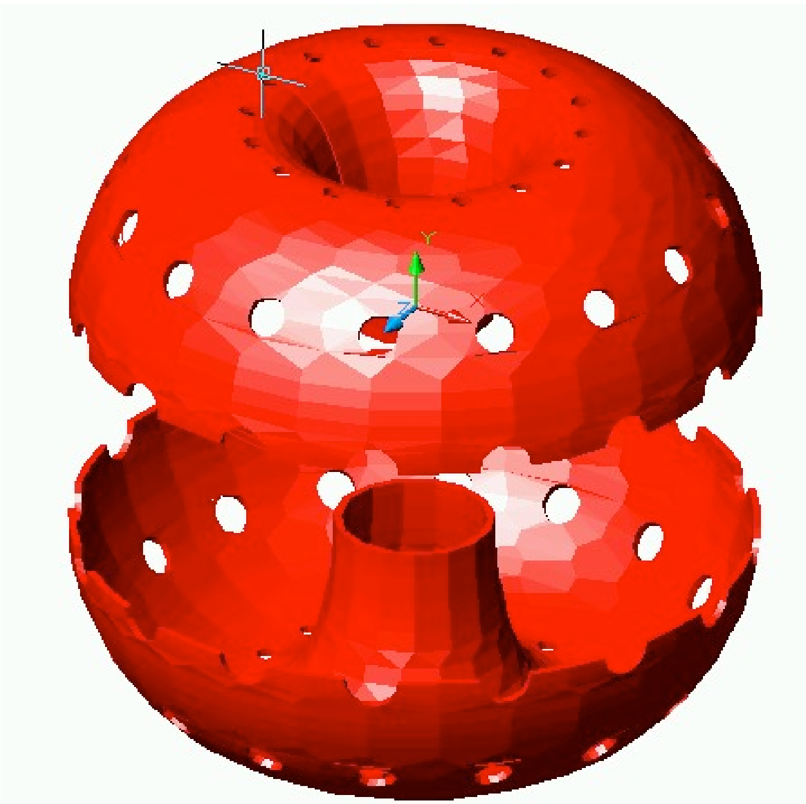
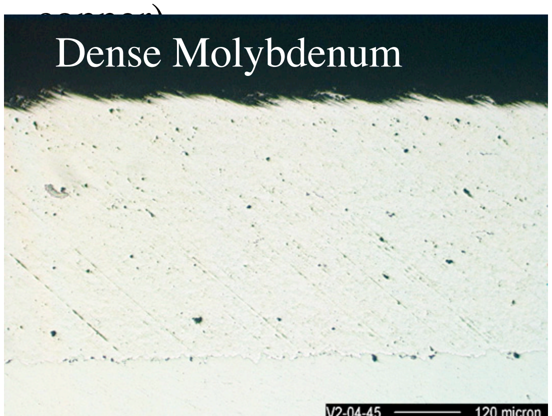


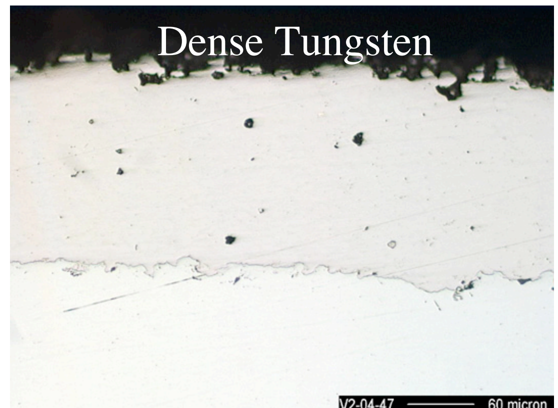
- Considering explosively bonded laminate of barrier material and copper
- Have located a firm capable of spinning the shell
  - Considerable cost reduction over casting
- First barrier material considered: tantalum
  - Tantalum-faced copper commercially available
  - But: concerned with tantalum embrittlement by hydrogen
- Appreciate feedback and data on hydrogen embrittlement of tantalum over 20 - 300C range
- First shell lead concept: stainless steel explosively bonded to copper
  - Contact with CDX-U lithium-on-stainless experience
  - Subsequent shells will be plasma sprayed with moly or tungsten

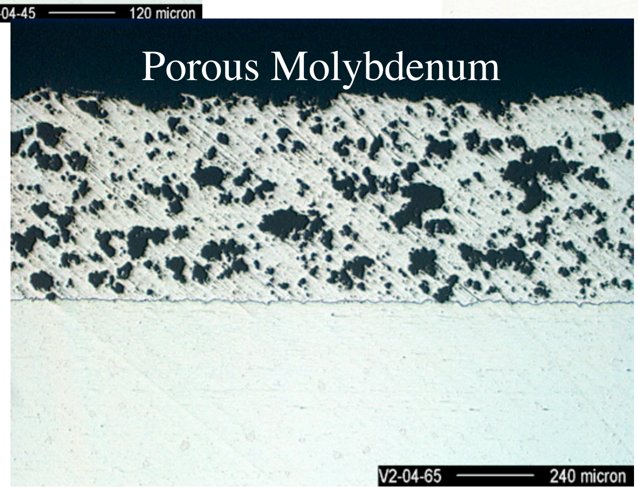
Substrates to be tested

CDX-U

- Explosively bonded stainless (tantalum?) on copper
  - 0.75 - 1 mm layer on 0.75 - 1 cm copper
- Plasma sprayed molybdenum, tungsten surfaces (Plasma Processes, Inc.)
  - Cam be applied over laminate or chromium-plated copper
  - Have 6 sprayed samples from PPI for testing now (sprayed on chromium plated copper)







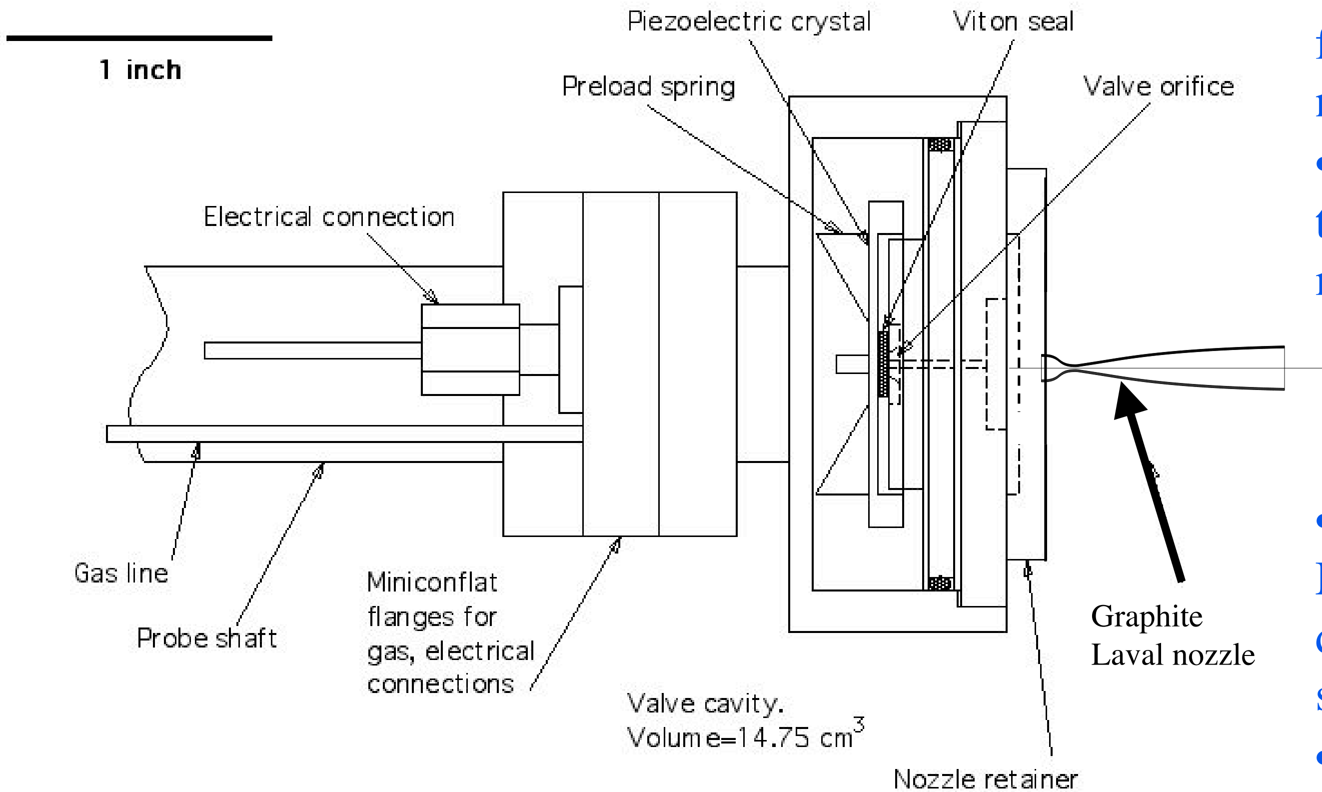
Micrographs courtesy of
Scott O'Dell, PPI

Efficient fueling is essential to LTX operation - Supersonic gas injector development

CDX-U

LTX

Assembly drawing - modified PV-10 piezoelectric valve with mount and Laval nozzle



- Core fueling is essential for operation of a nonrecycling tokamak
- Primary core fueling technique for LTX is multiple pellet injection
  - -Not really steady state; will only fuel for ~8
- Also developing high Mach number, high density jets for high field side fueling
- Applicable to both present fusion experiments and ITER

Nozzle design scaled from working Mach 8 wind tunnel at Gaseous Dynamics Laboratory, Princeton University (A. Smits, M. Baumgartner)

 Used with 20kW 14 GHz high-field side ECH for startup

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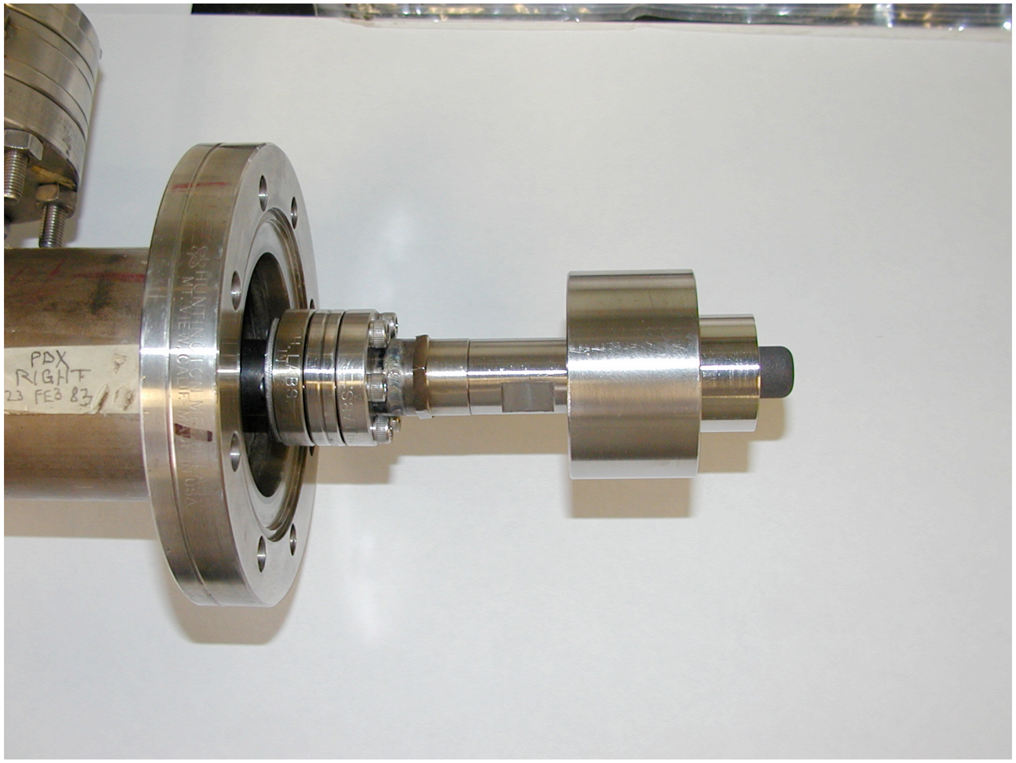
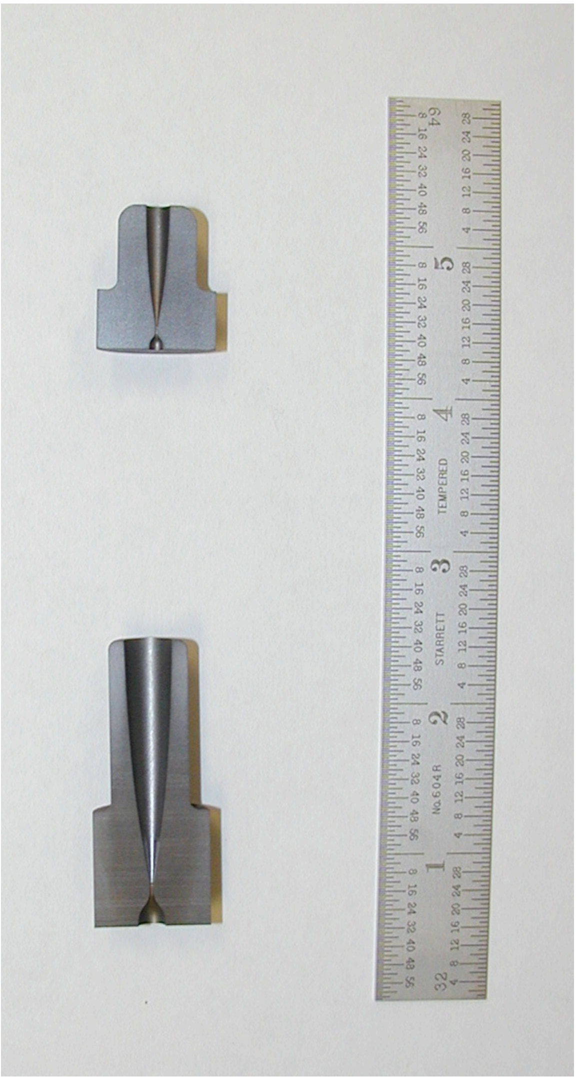
Supersonic Gas Injector prototype

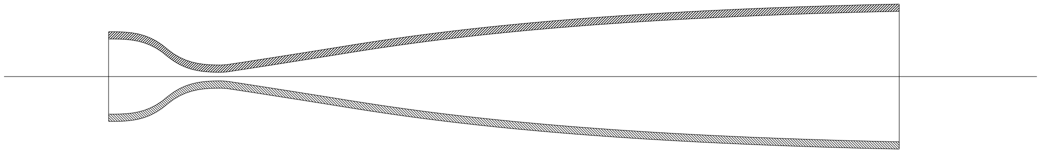
CDX-U



- Modified Veeco PV-10 piezoelectric valve (□< 2 ms)
- Mounted on movable feedthrough

Laval nozzle





• Graphite nozzle L = 23.4 mm

• 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!

Apparatus for pressure measurements

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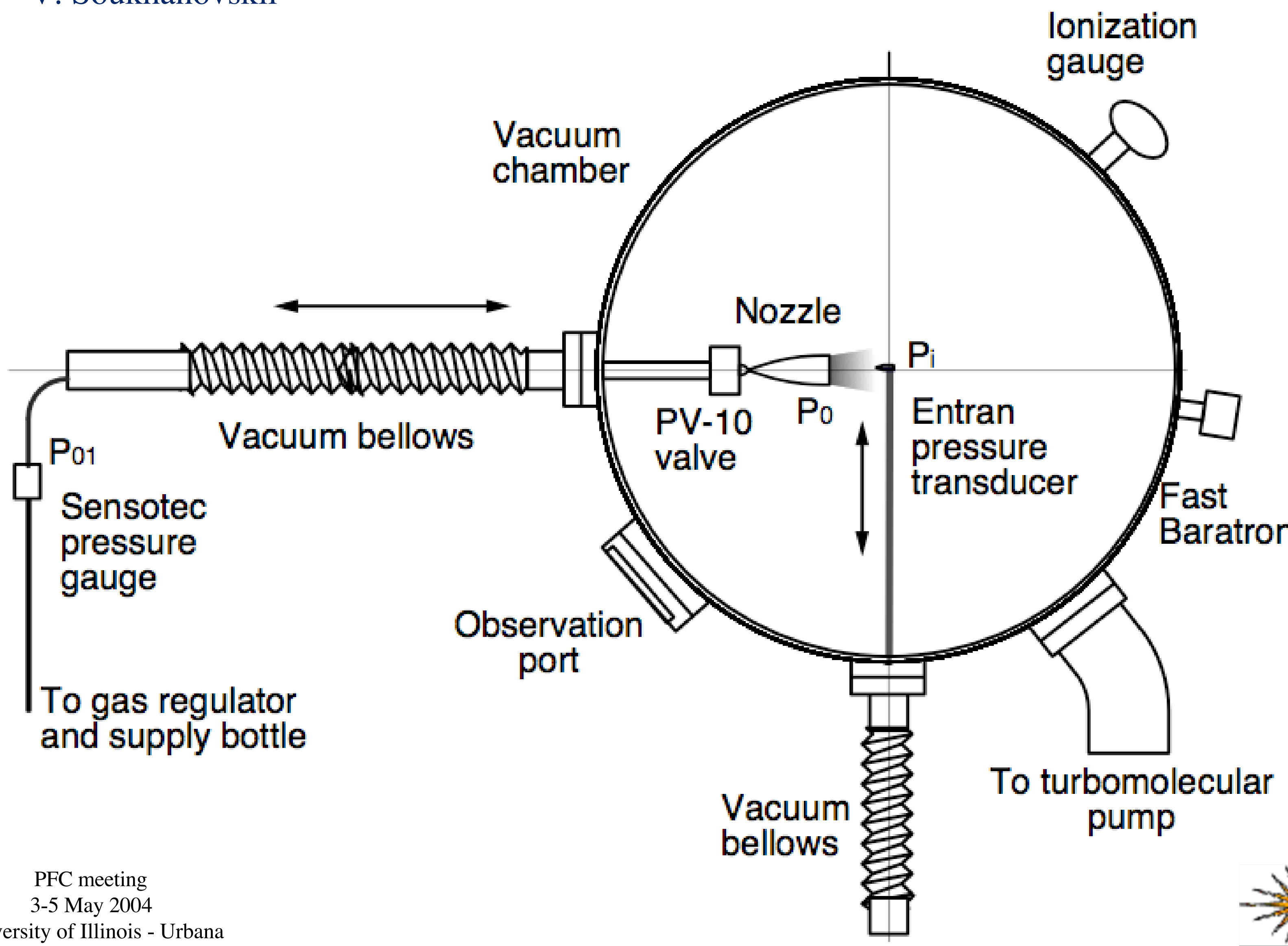

Impact pressure measurements in pulsed regime

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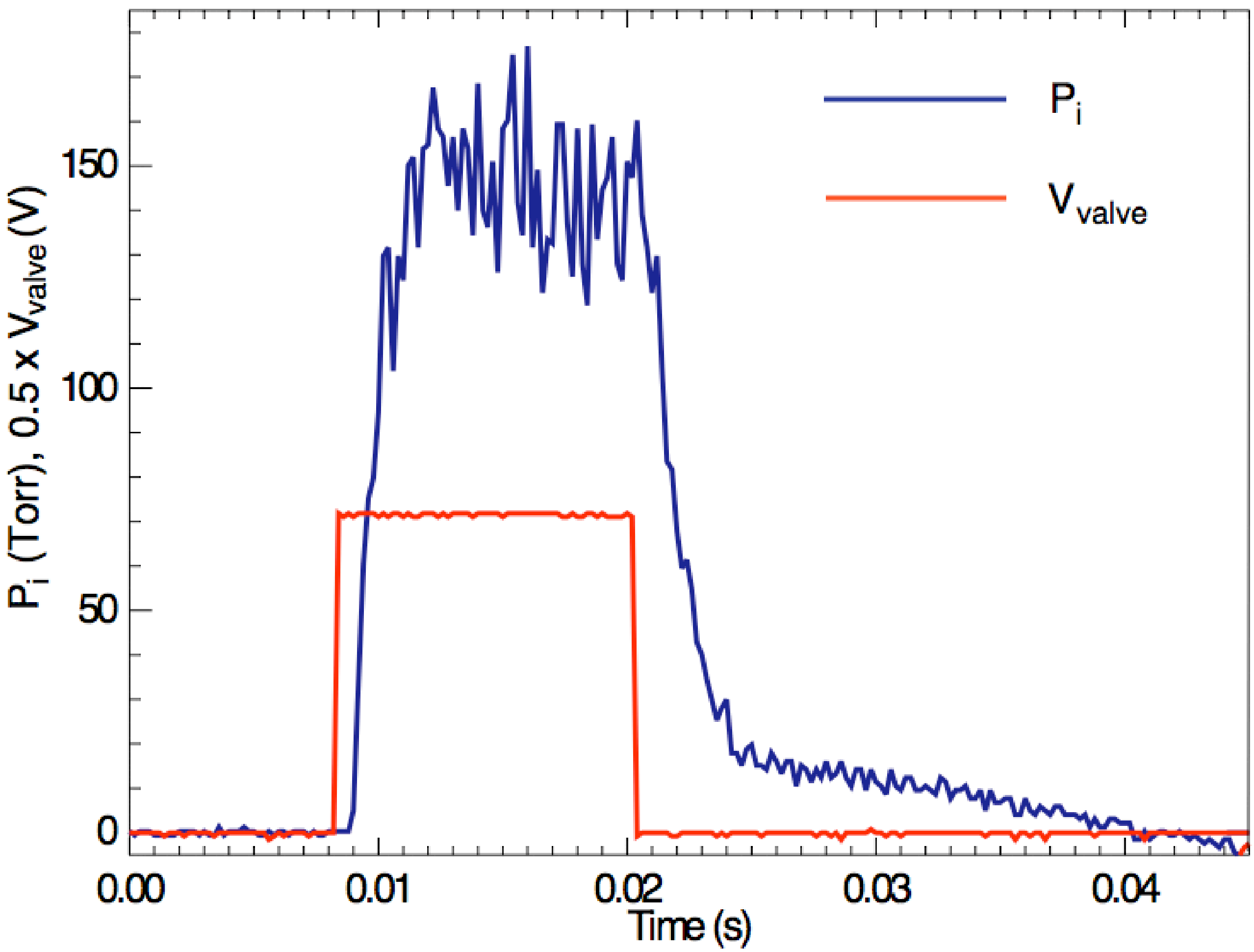

Jet pressure gradient extends up to 10 cm

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LTX

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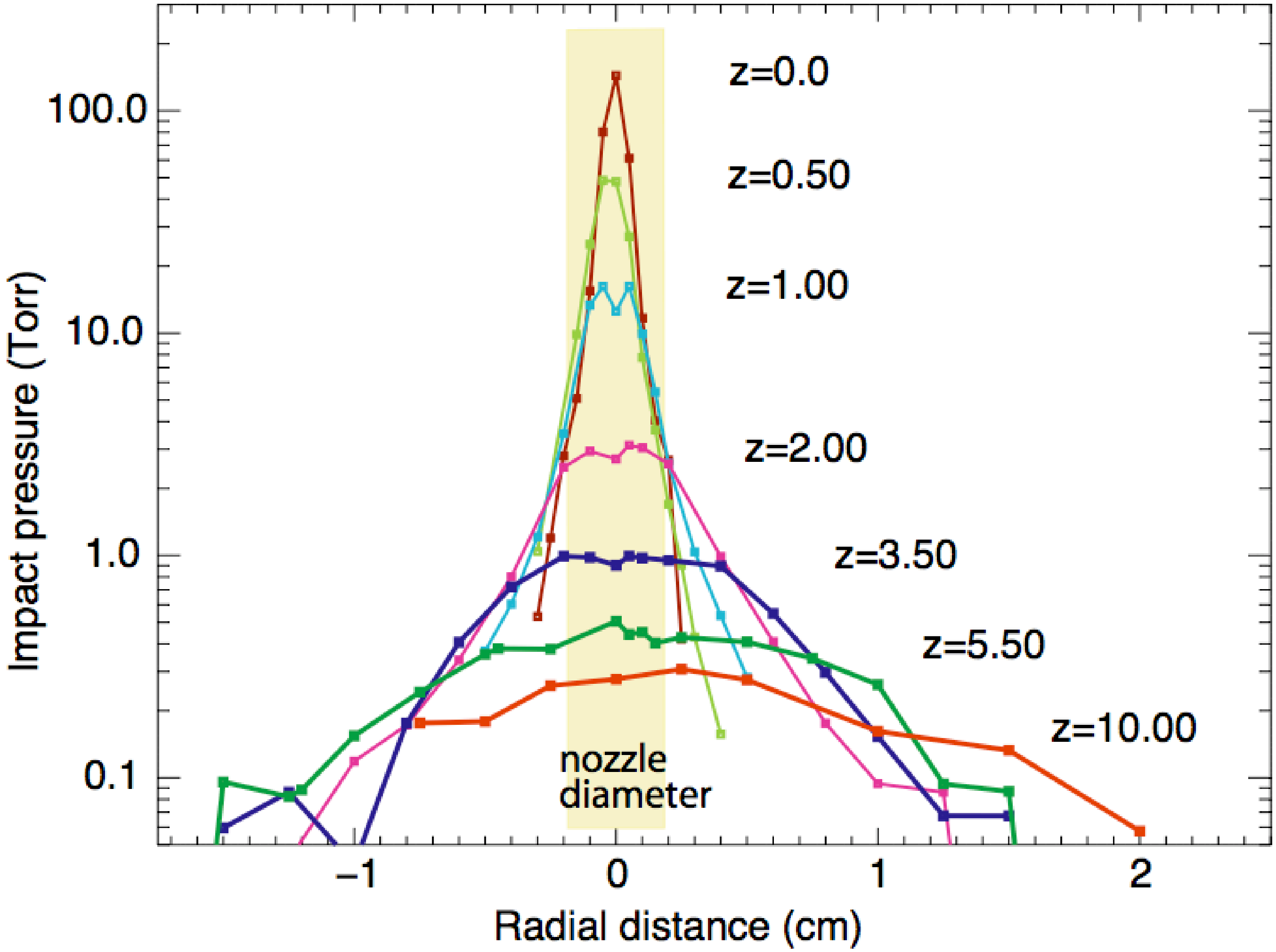

Jet divergence half-angle: 6°

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M = 2-5 is obtained from Rayleigh-Pitot law

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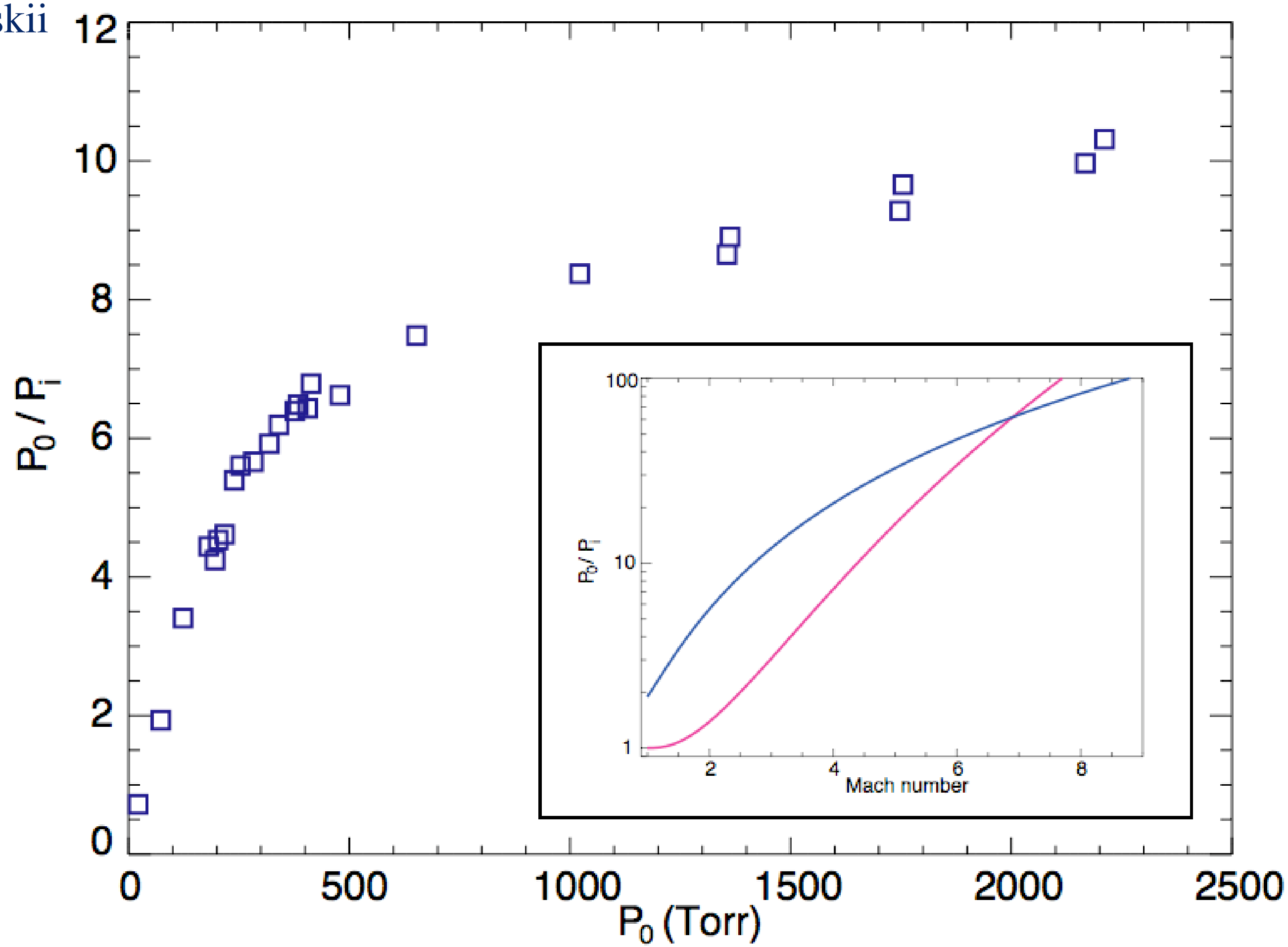

M = 2 - 5, T = 60 - 160 K, □ = 3 x 10^{17} cm^{-3}, Re = 6000

Gas injector studies for LTX

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- Present nozzle was not designed for deuterium
  - Probable reason for operation at reduced Mach number
    - » Designed for Mach 8, runs at <5.
- Working with a group at Princeton University to produce a design for a Mach 10 nozzle
  - Intent is to produce a dense, thin jet with a high fraction of condensed gas (clusters).
  - Design may incorporate a right-angle bend
- Parks (APS-DPP03, submitted for publication; Sherwood Conference, last week) has indicated that thin, dense gas jets will provide good core fueling when injected from the HFS midplane)
  - Parks' modeling performed for ITER
- A nonrecycling tokamak with a *combination* of edge puffing and core fueling with a jet would provide full control over the electron temperature profile *through fueling*

Condensation and clustering

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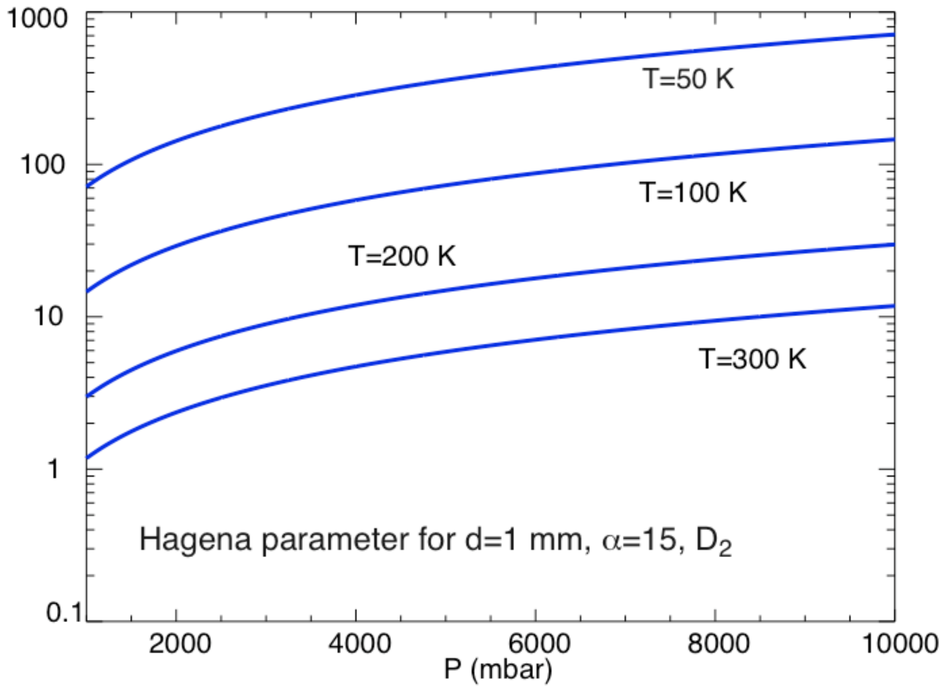

- Molecular clustering increases jet density by order(s) of magnitude
- Condensation / droplet formation in jet is attractive for fueling
- Degree of clustering in jet is estimated through Hagena parameter

$$\Gamma^* = k \frac{(d/\tan\alpha)^{0.85}}{T_0^{2.29}} P_0 = 100 \div 300$$

D - nozzle diameter, α - nozzle half angle, T_0 and P_0 are stagnation temperature and pressure. Cluster bond formation constant k=181 for D_2, k=185 for Ne. Number of molecules in cluster $N_c \sim \Gamma^{2-2.5}$

Summary

CDX-U

- New material, fabrication technique identified for LTX shell
  - Explosively bonded, spun stainless steel - copper laminate will provide contact with CDX data on lithium-covered stainless steel
- Planning for multiple shells
  - Plasma-sprayed molybdenum coating (with Plasma Processes)
  - Porous coatings in molybdenum or tungsten
  - "Thick film" shell
- Investigating two evaporation techniques
  - Commercial resistive source
  - Modified e-beam source
- Actively investigating dense gas jet fueling
  - ITER-relevant technology
  - Very desirable for low recycling regimes
- Development needed in: shell materials & coatings, evaporative sources, fast gas valves, high Mach number nozzles (condensing if possible)