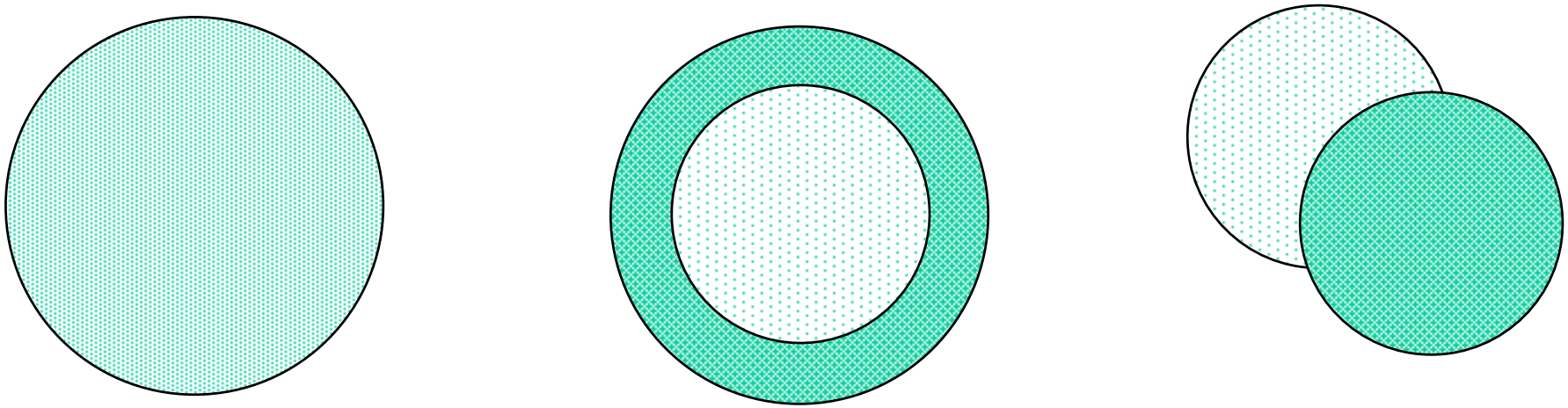
# SANS from aerosols

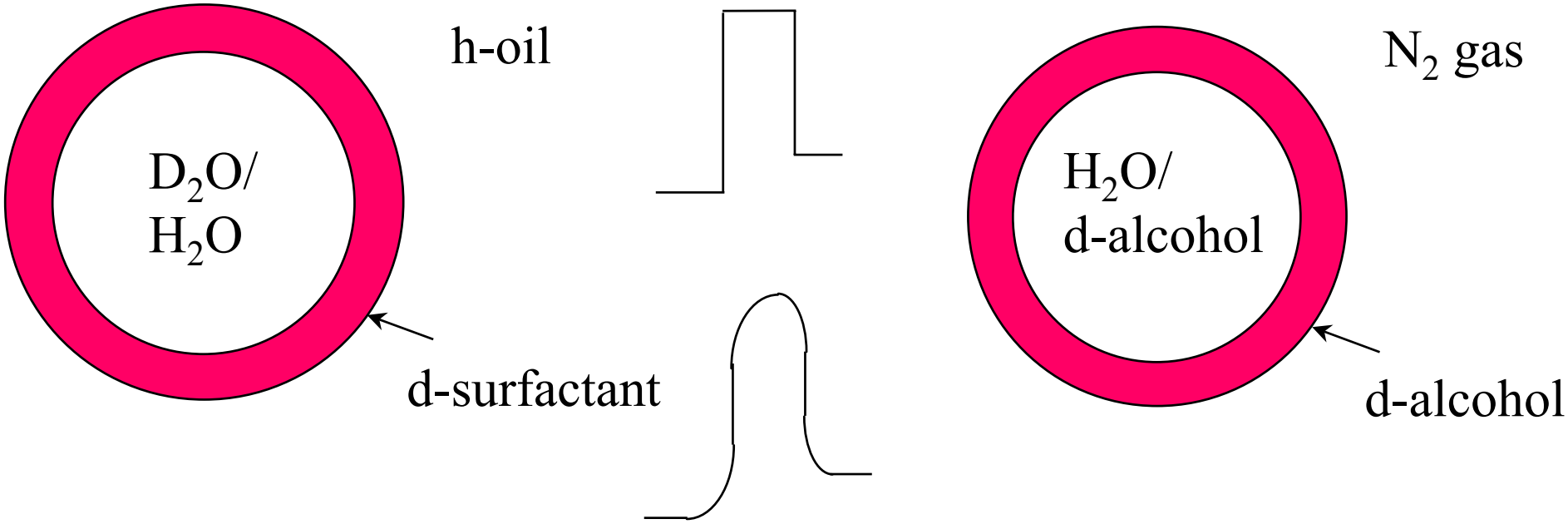
Barbara Wyslouzil,WPI,Worcester MA
Gerald Wilemski, U. Missouri-Rolla, Rolla MO
Reinhard Strey, Univerität zu Köln, Köln, Germany

# Do droplets with 1<r<10 nm exhibit microstructure?



- $D_2O$ $D_2O$ – butanol
- $D_2O$ – $H_2O$ $H_2O$ – d-butanol
- $D_2O$ – ethanol

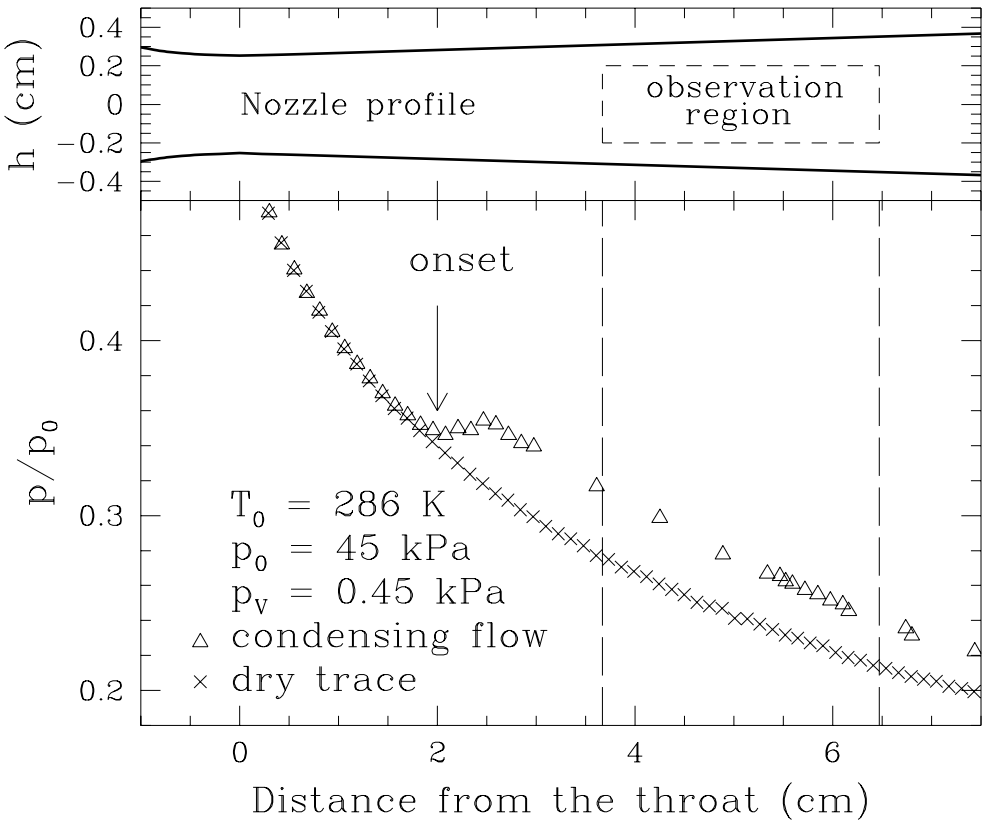
# SANS for microemulsions
# $\Rightarrow$ SANS for aerosols?



# Experimental challenges

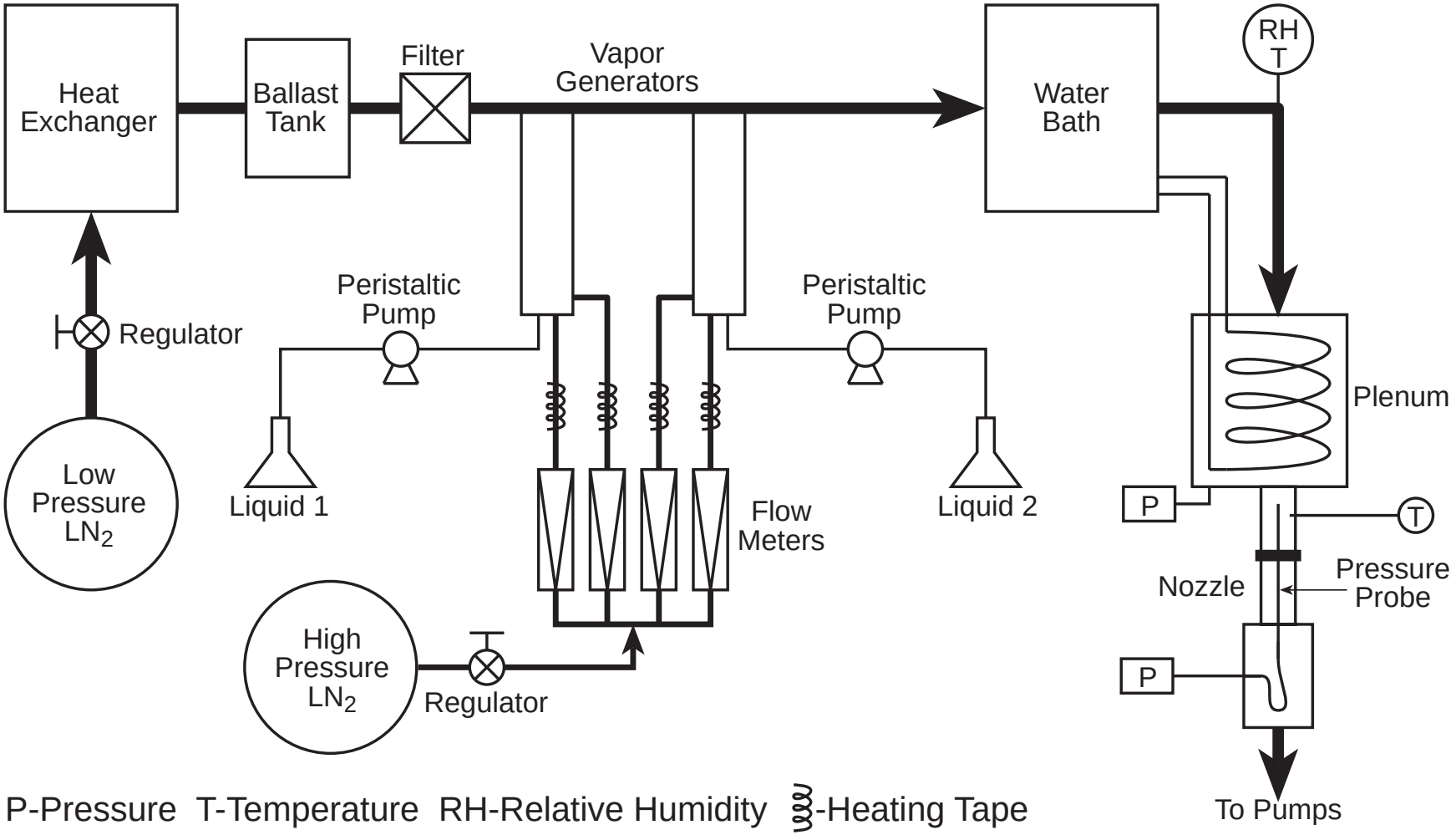
| | Microemulsion | Aerosol |
|---|---|---|
| $\langle r \rangle$ | 1 - 10 nm | 1 - 10 nm |
| $N$ | $10^{16}$ cm$^{-3}$ | $<10^{14}$ cm$^{-3}$ |
| $\phi$ | 0.01 - 0.9 | $< 10^{-5}$ |
| state | stable | unstable |
| background | low | ?? |
| scattering | isotropic | anisotropic |

# We make the nanodroplets in supersonic nozzle expansions.

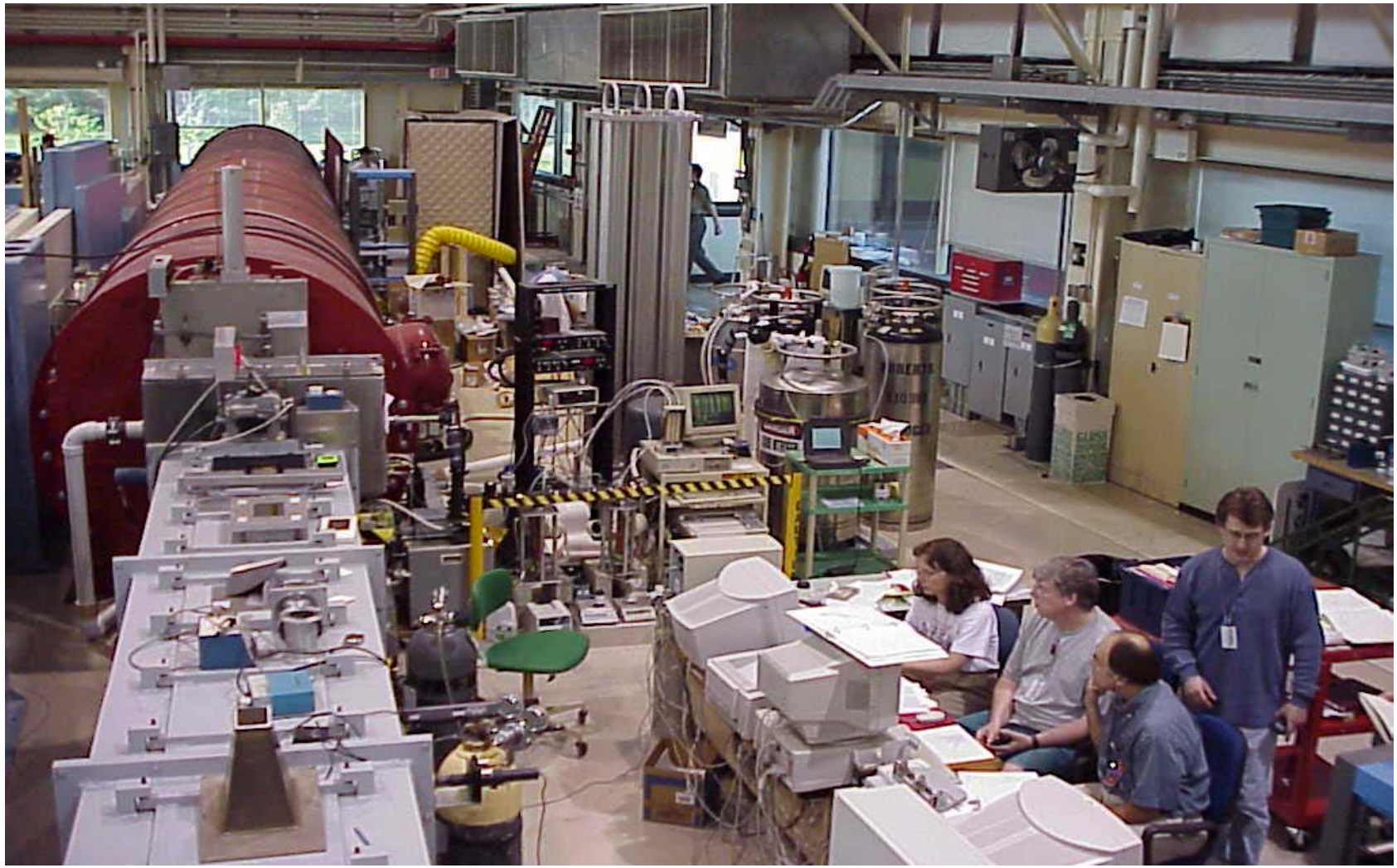



- $p \downarrow$
- $T \downarrow$
- $S = p/p^e(T) \uparrow$
- Droplets form and grow
- Heat is released
- Vapor depletion quenches nucleation

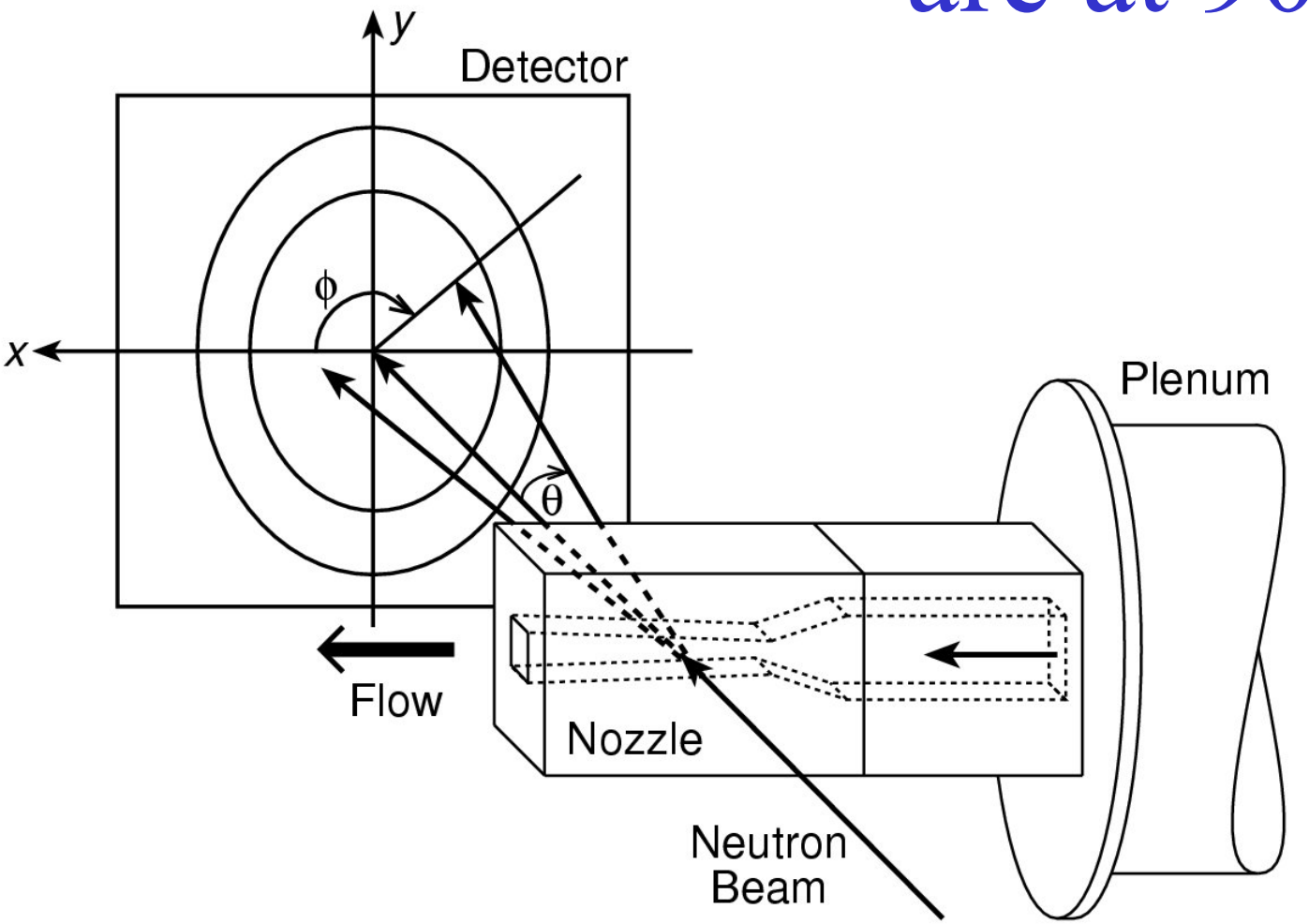
# +2000 lbs of equipment



# + a national facility...



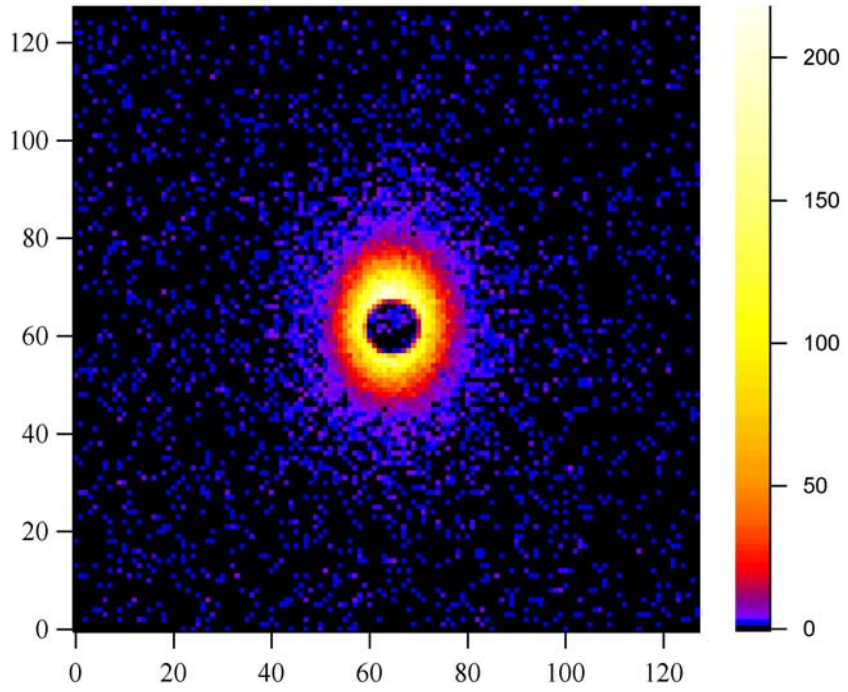
# The particles and neutron beam are at 90°.

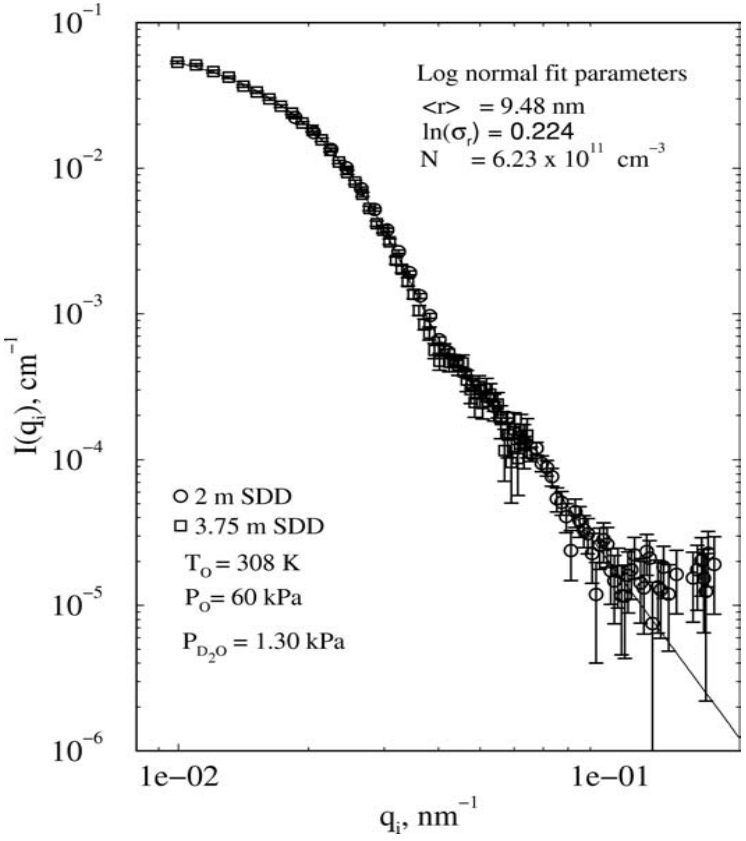


# Nozzle operating conditions

| | Source | Observation region |
|---|---|---|
| $T$ (K) | 273 - 315 | 190 - 240 |
| $p_{N2}$ (kPa) | 44 - 67 | 10 - 20 |
| $p_c$ (kPa) | 0.1 - 1.5 | 0.02 - 0.45 |
| $v$ (m/s) | ~ 0 | 430 - 450 |

# Good SANS spectra are possible!



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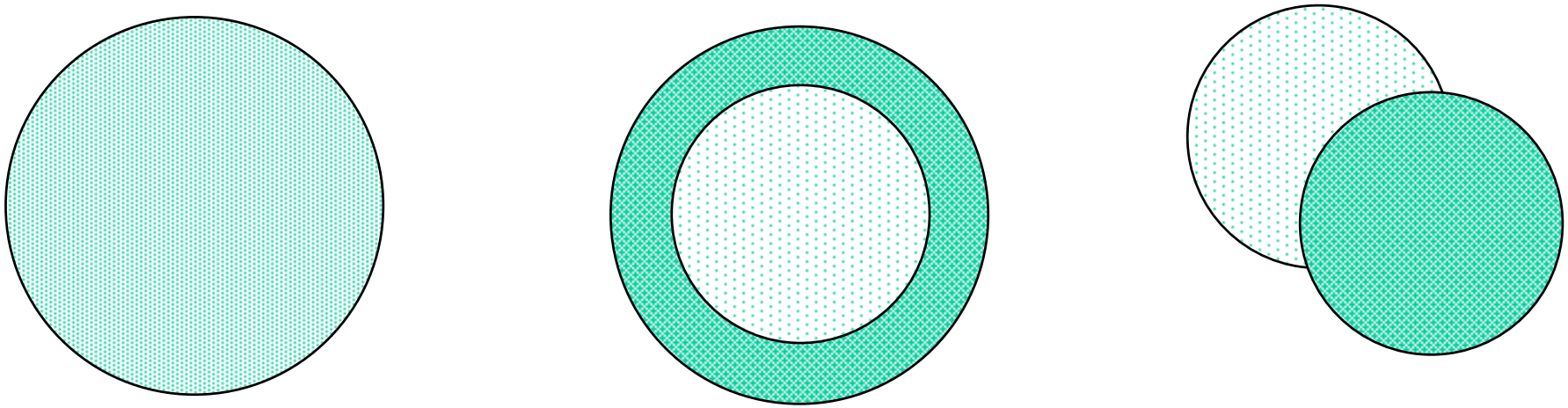

- $D_2O$ $D_2O$ – butanol
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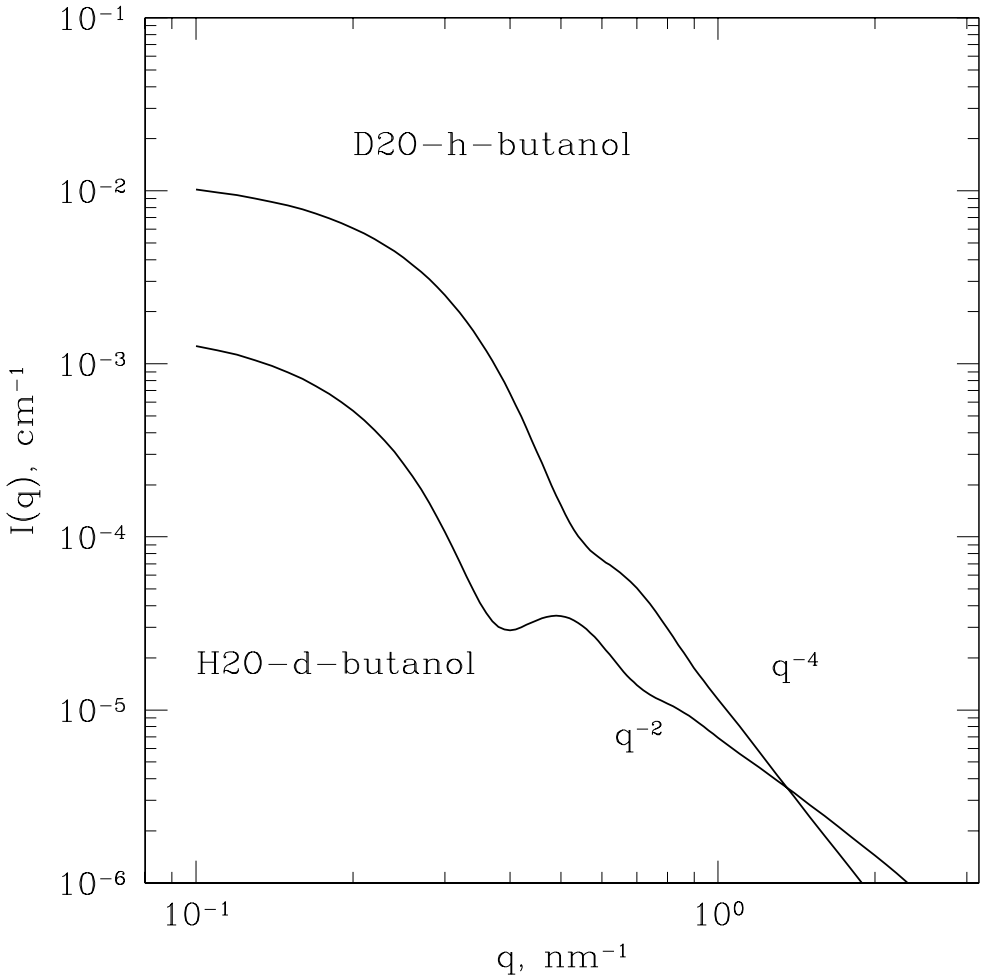
# Core vs. Shell scattering




high $q$ region

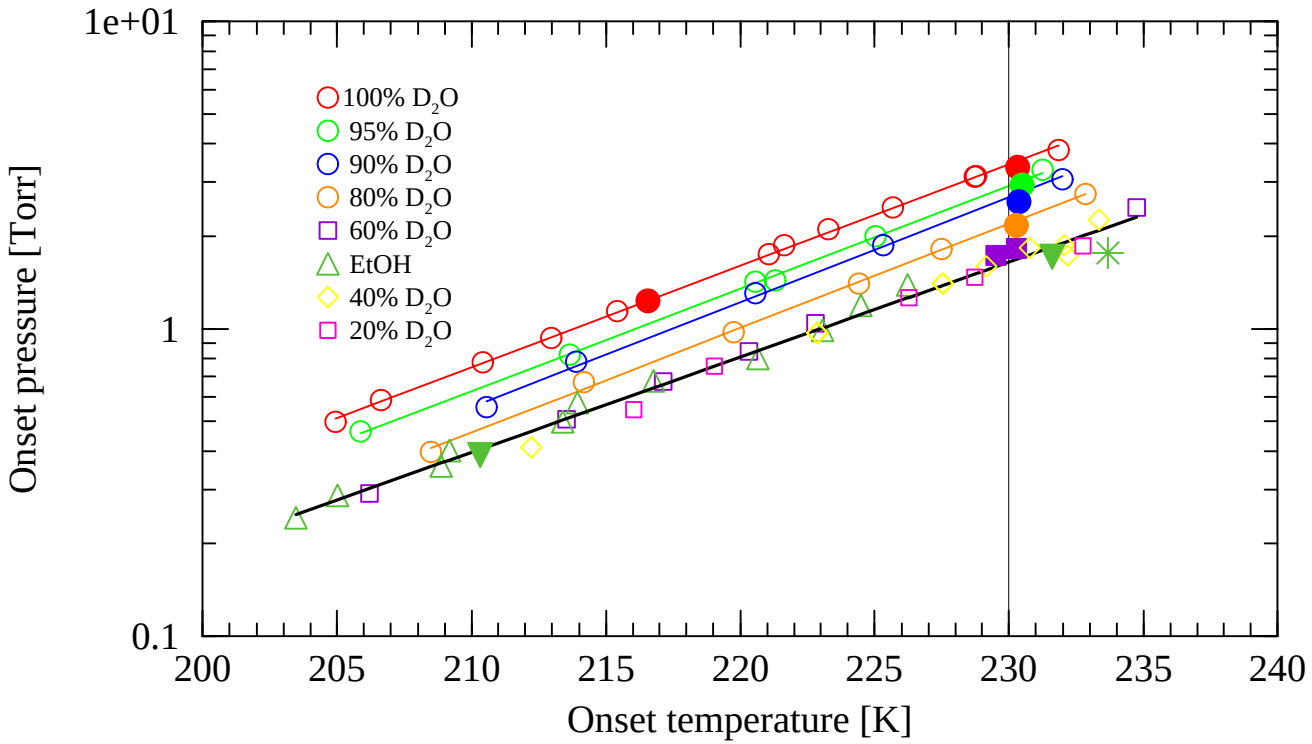
sphere

$I \propto q^{-4}$

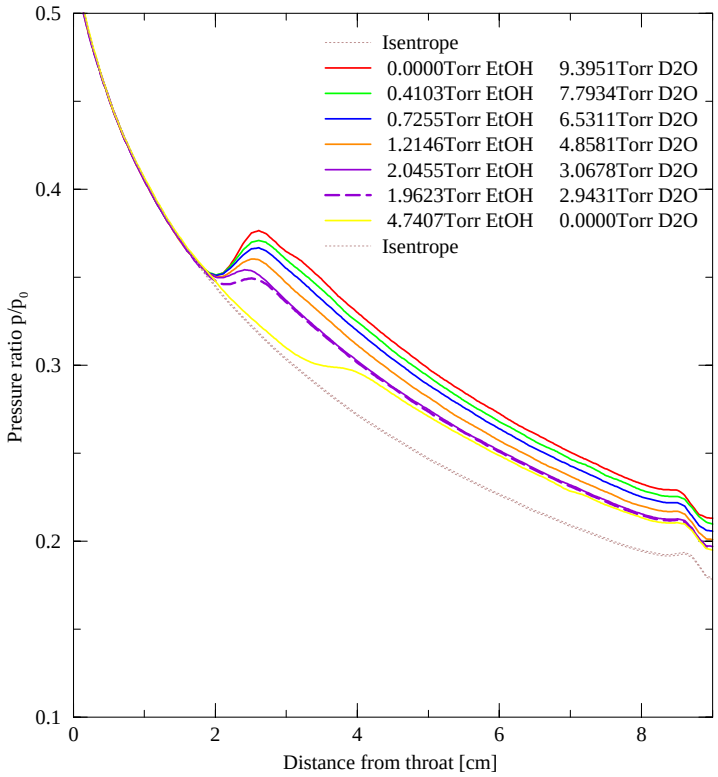
shell structure

$I \propto q^{-2}$

# How should we compare aerosols with different compositions?

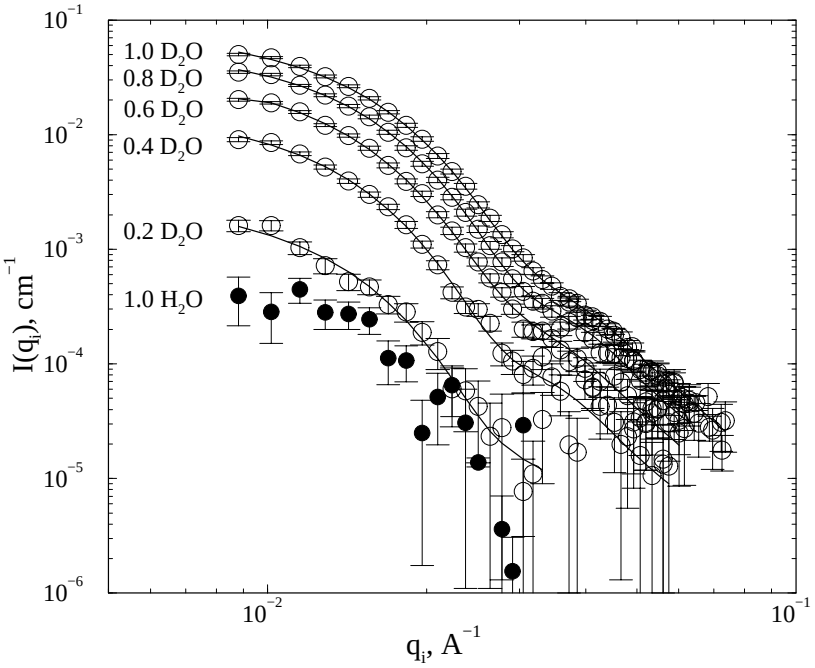


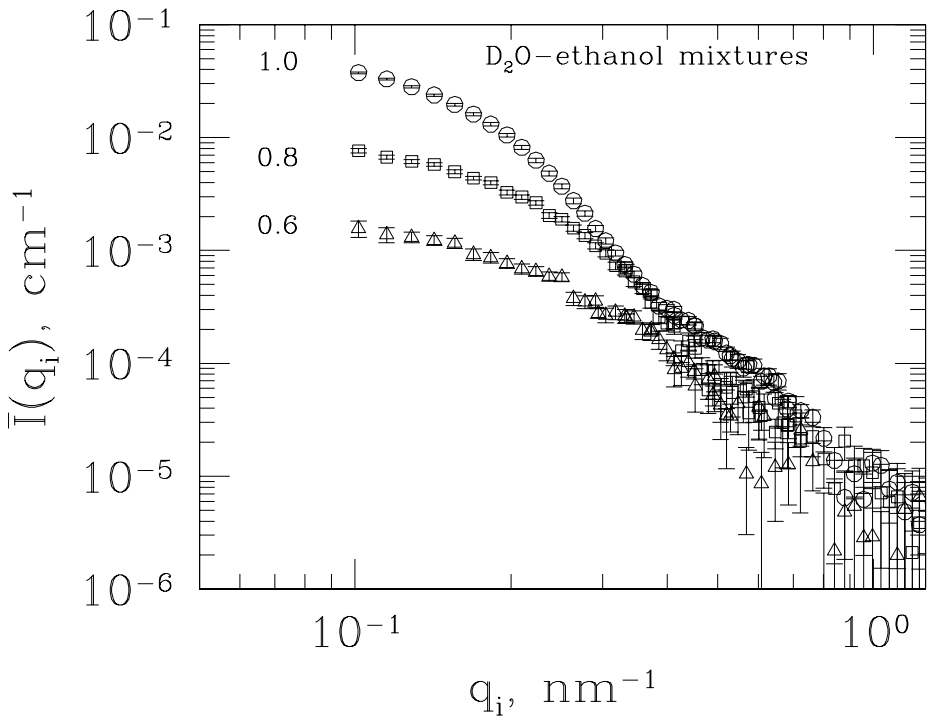
# Maintain “identical” formation conditions




Expansion history determines shape of the size distribution

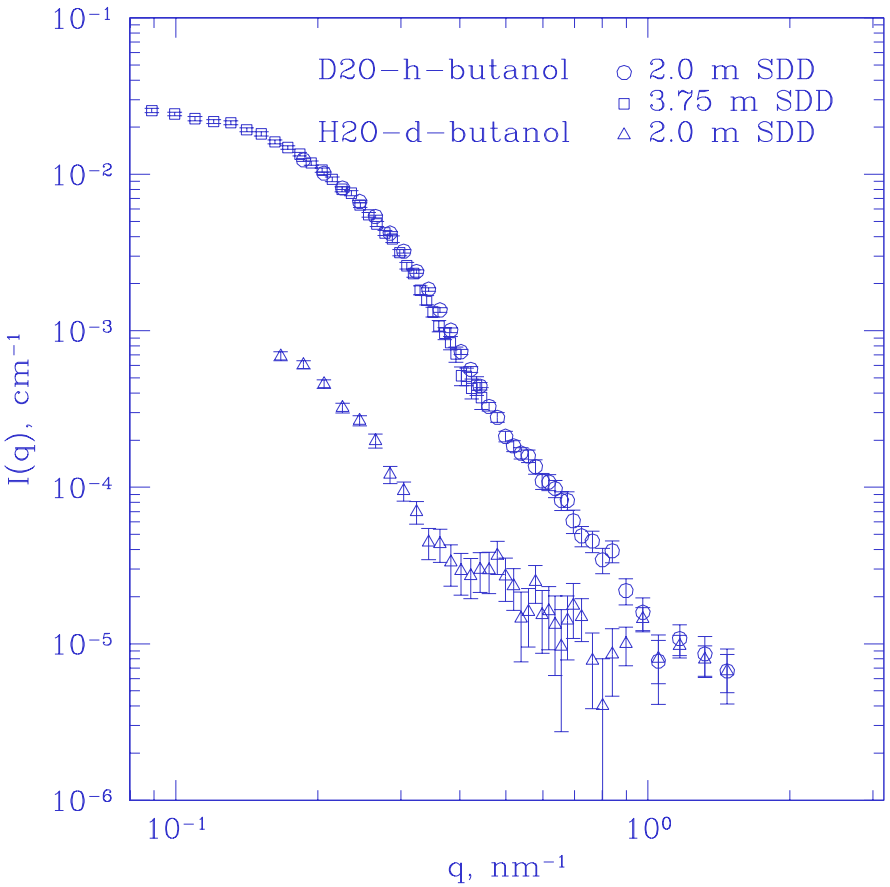
# Scattering intensity decreases with mixture composition.

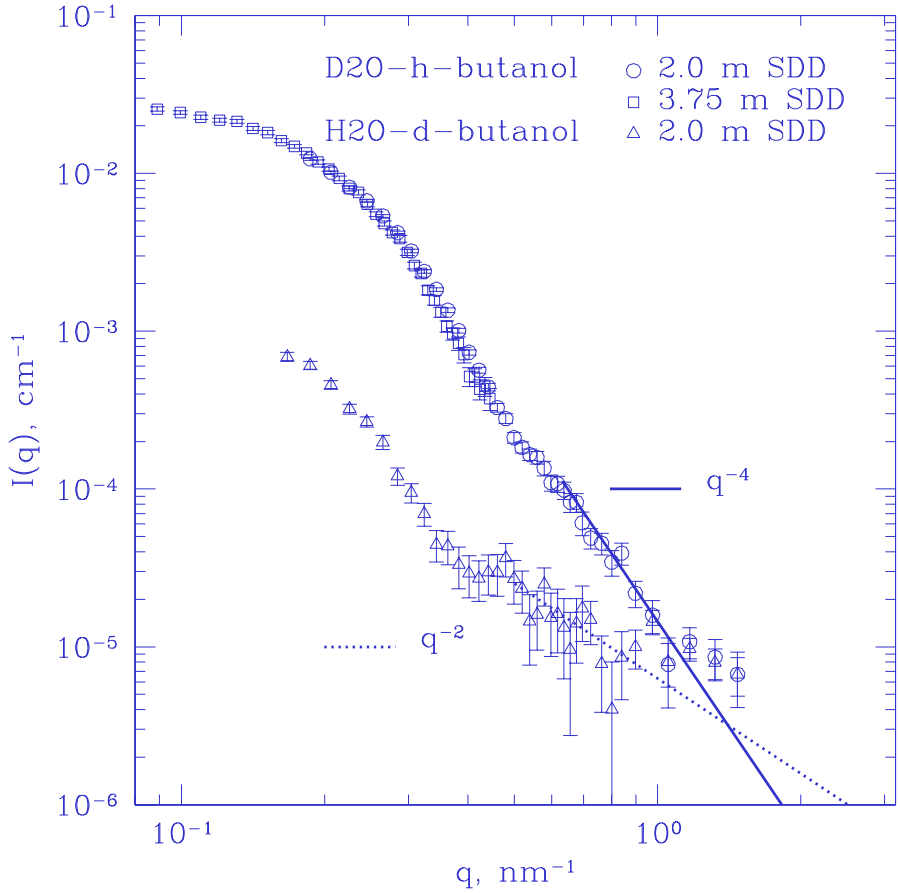



$$I_0 \propto N\langle r^6\rangle(\Delta\rho)^2$$

# Evidence for shell scattering



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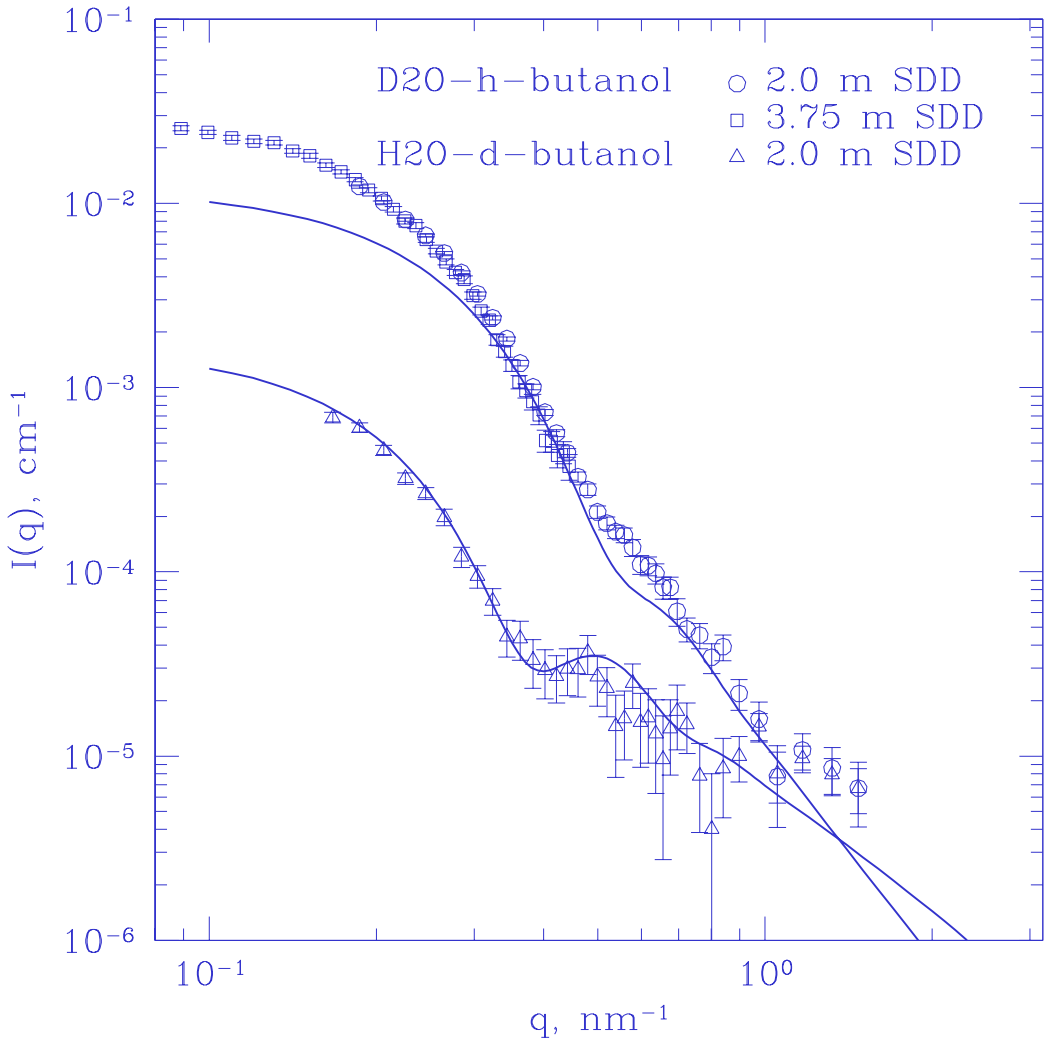


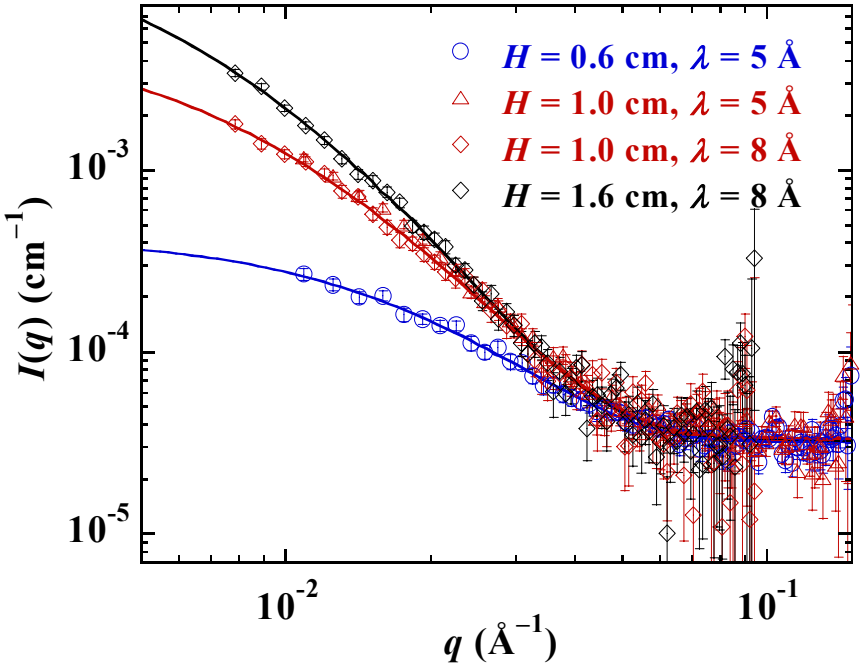
# What Next?

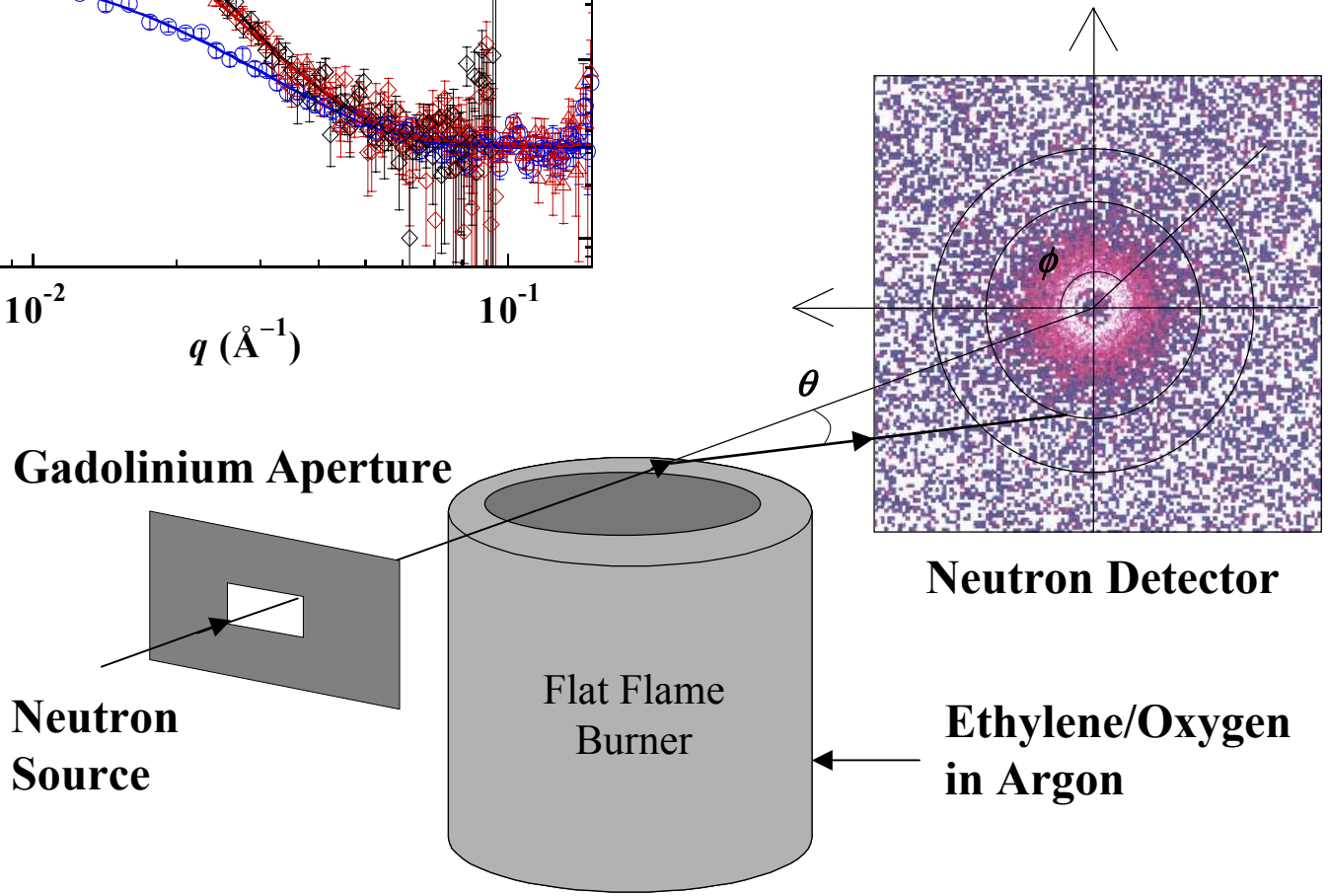
- Data analysis:
  - integrate pressure trace and scattering data
- Additional experiments:
  - gas phase composition measurements

# Summary and Conclusions

- Aerosol SANS works!
- first direct measurement of particle size in a supersonic nozzle expansion
- evidence for microstructure
- first direct measurements of nucleation rates in nozzles
- the Doppler shift provides particle velocity

# SANS in Flames



# Acknowledgements


- People

- Dr. Janice Cheung
- Dr. Chris Heath
- Dr. Kiril Streletzky
- Dr. Judith Wölk
- Dr. Melissa Lunden
- Dr. Hai Wang
- Dr. John Barker
- Dr. Charlie Glinka
- Dr. Paul Butler
- Kevin Petrini
- Monaca McNall
- Carlo Cioffi

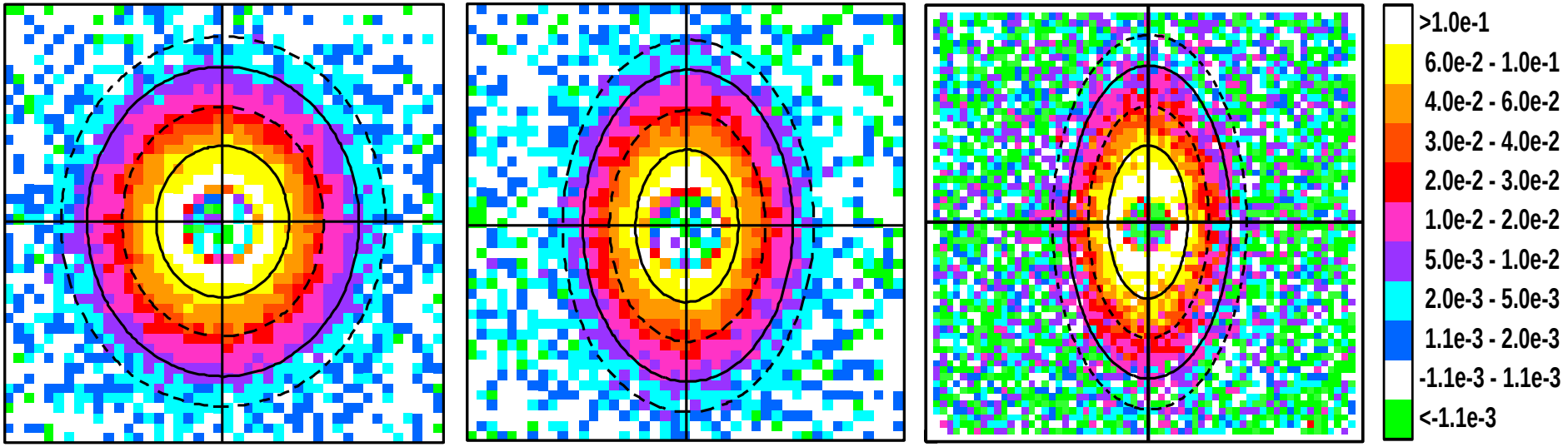
- Funding
- This work has been supported in part by the National Science Foundation, the Donors of the American Petroleum Research Fund, the U.S. Department of Energy and NATO.

# Small Angle Scattering

$$d \cong \lambda$$

| | $\lambda$ |
|---|---|
| light | ~ 500 nm |
| x-ray | ~ .1 nm |
| electrons | ~ 0.1 nm |
| neutrons | ~ 0.5 - 2 nm |

# The scattering patterns become more elliptical as $v_p/v_n$ increases.

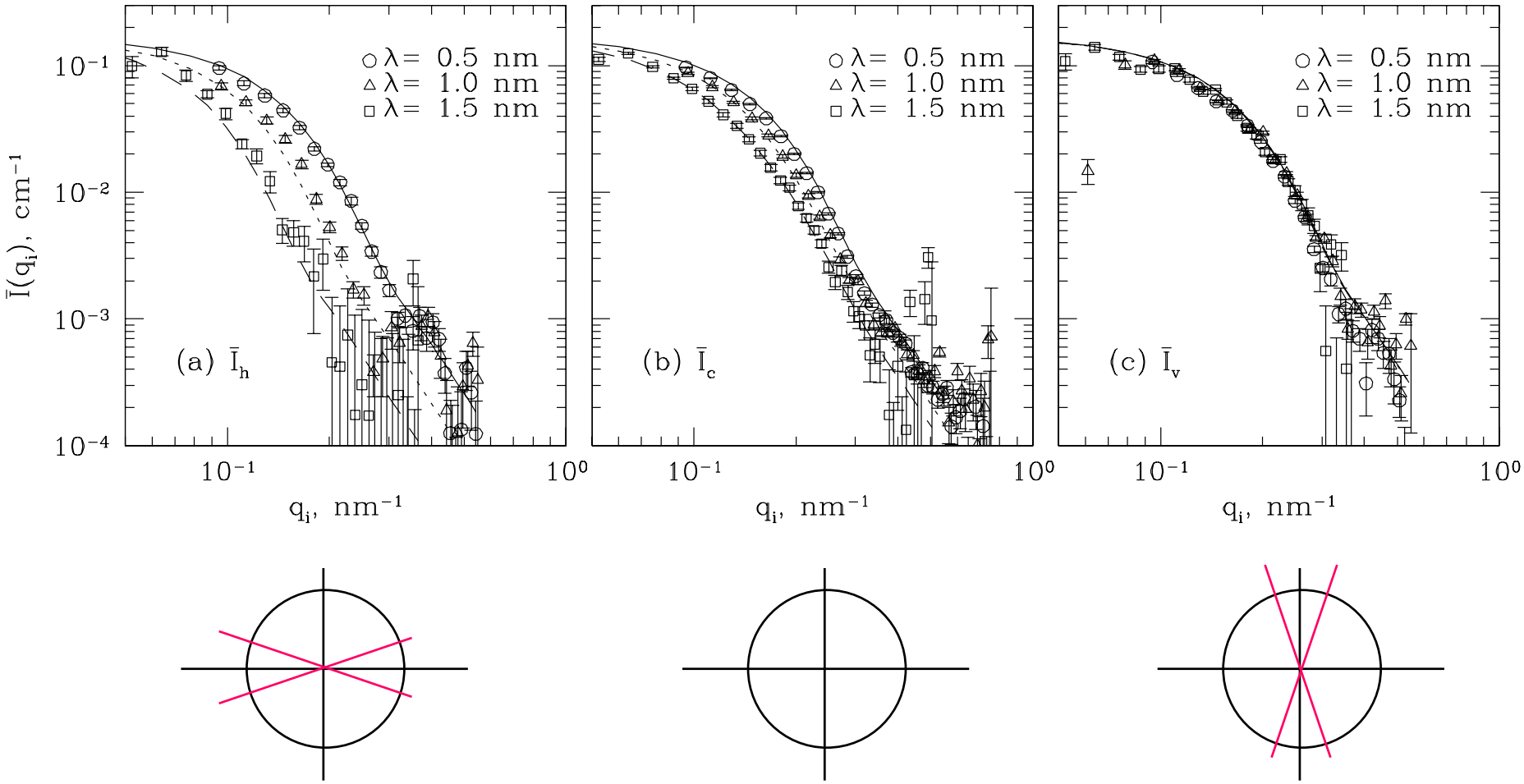



$\lambda = 0.5$, SDD = 7.3 m

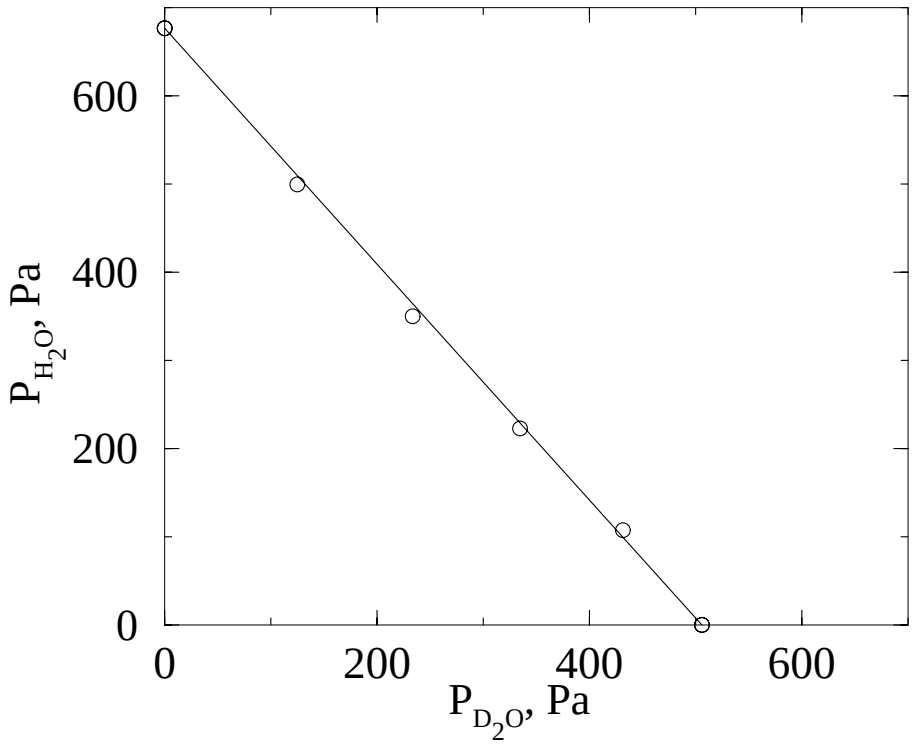
$\lambda = 1.0$, SDD = 3.6 m

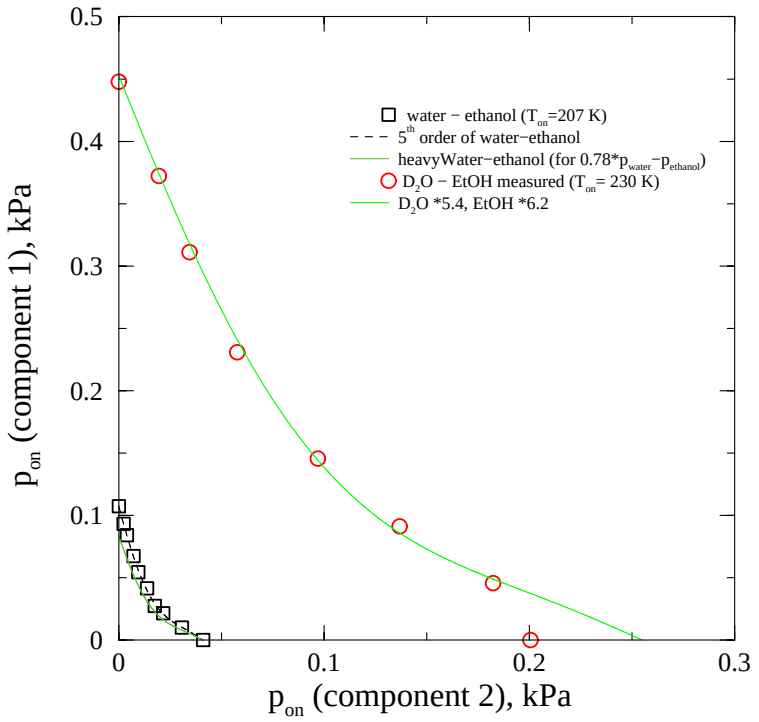
$\lambda = 1.5$, SDD = 3.6 m

# If $v_p = 0$, the scattering patterns overlap.



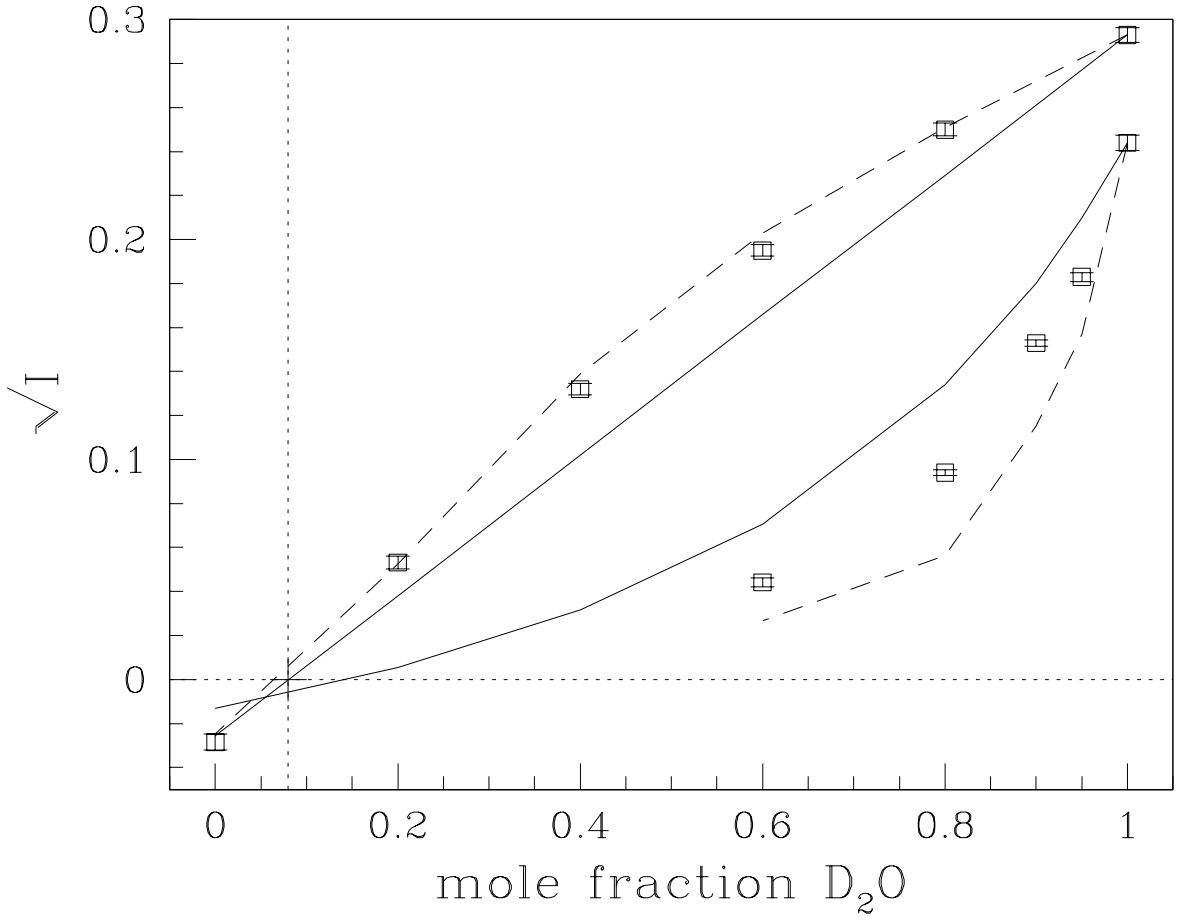
# The pressure at constant onset varies between the pure species



# Droplet composition

$$I_0 \propto N \langle r^6 \rangle (\Delta\rho_{\mathrm{mix}})^2$$




assume:

$N \sim$ constant

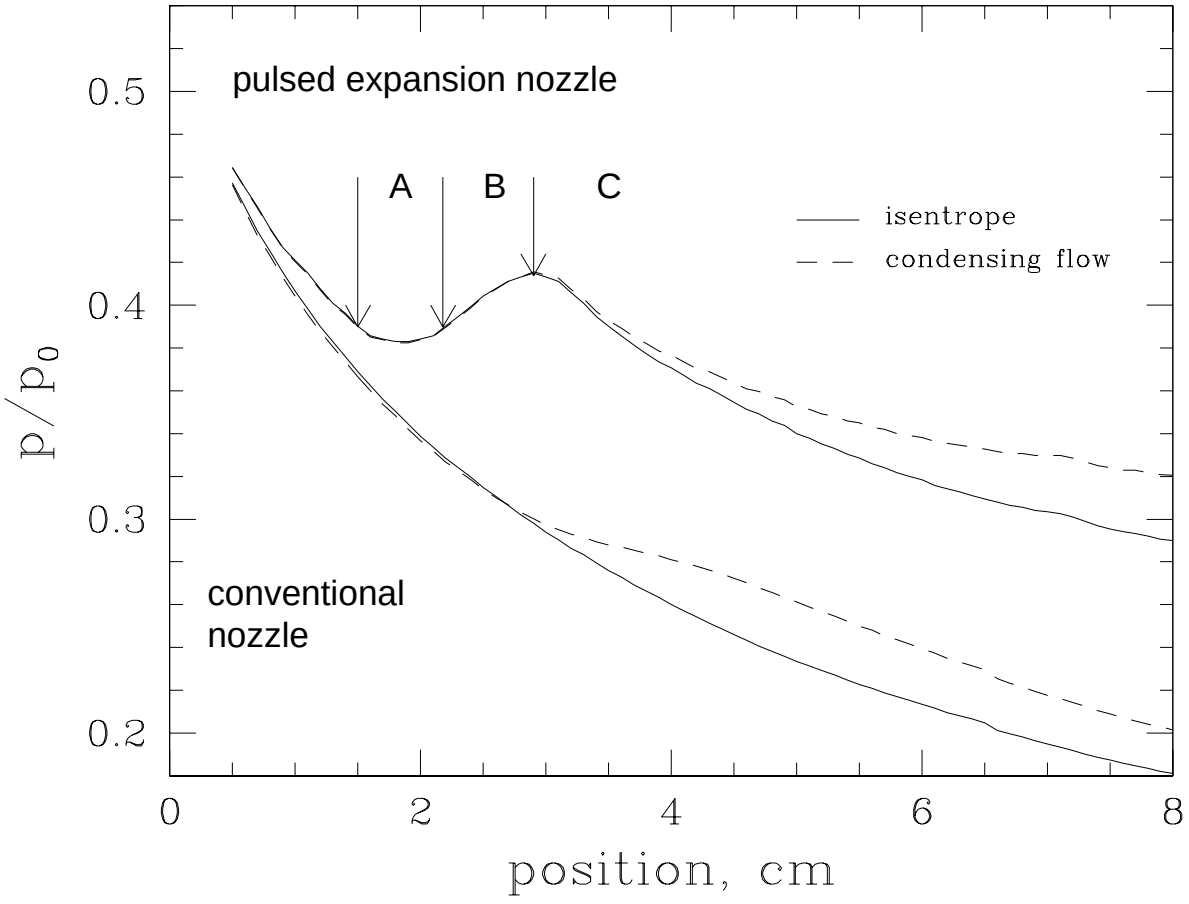
$x$ droplet

$= x$ gas phase

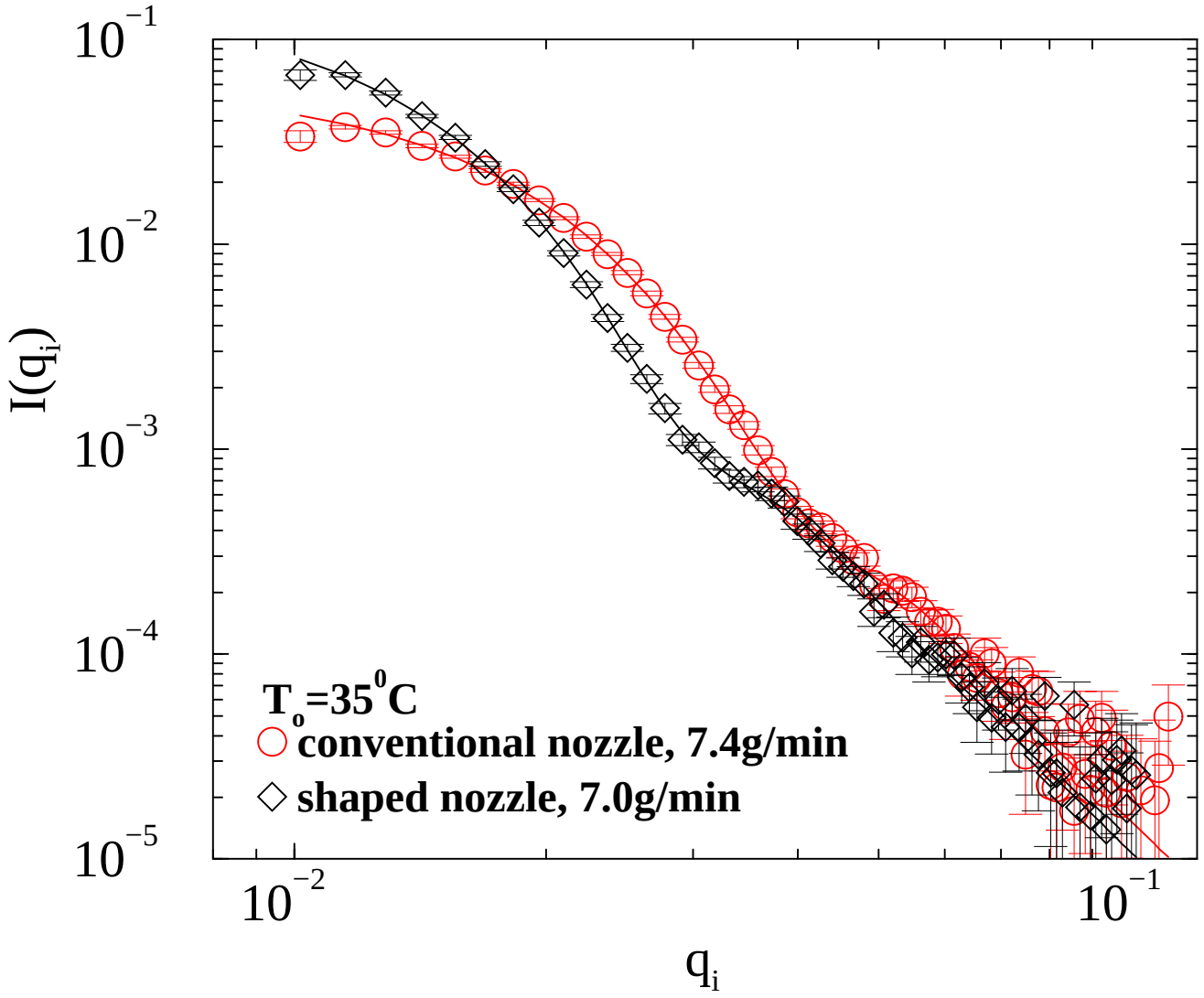
$\sigma/r \sim$ constant

correct for $r$

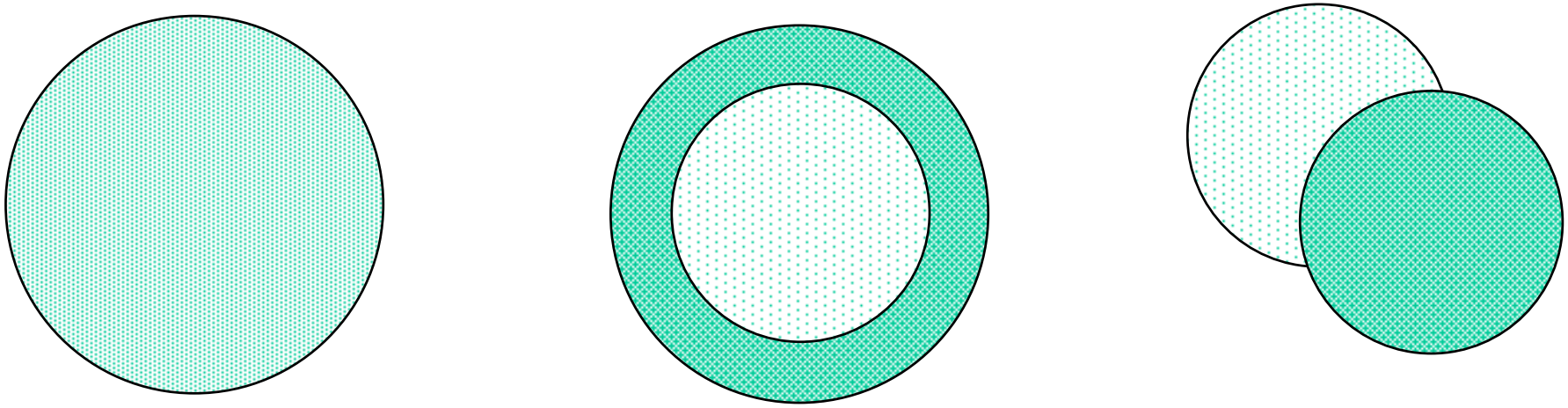
# Measuring *J*: Shaped nozzles



# SANS signal


$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
$I(q_i)$
$10^{-2}$
$10^{-1}$
$q_i$
$T_o=35^0C$
conventional nozzle, 7.4g/min
shaped nozzle, 7.0g/min

# Do droplets with 1<r<10 nm exhibit microstructure?



# Outline

- Motivation
- Development
- Applications
  - Binary condensation in supersonic nozzles
  - Nucleation rate measurements in nozzles
  - What is next?
- Summary

# Future directions

- Modeling
- Isothermal nucleation rate measurements in supersonic nozzles.
- Probe structure/phase of high pressure, supercooled liquids in the absence of contamination.
- Other systems …. soot formation