Atmospheric Sampling of Aerosols and Cloud Droplets

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Science questions

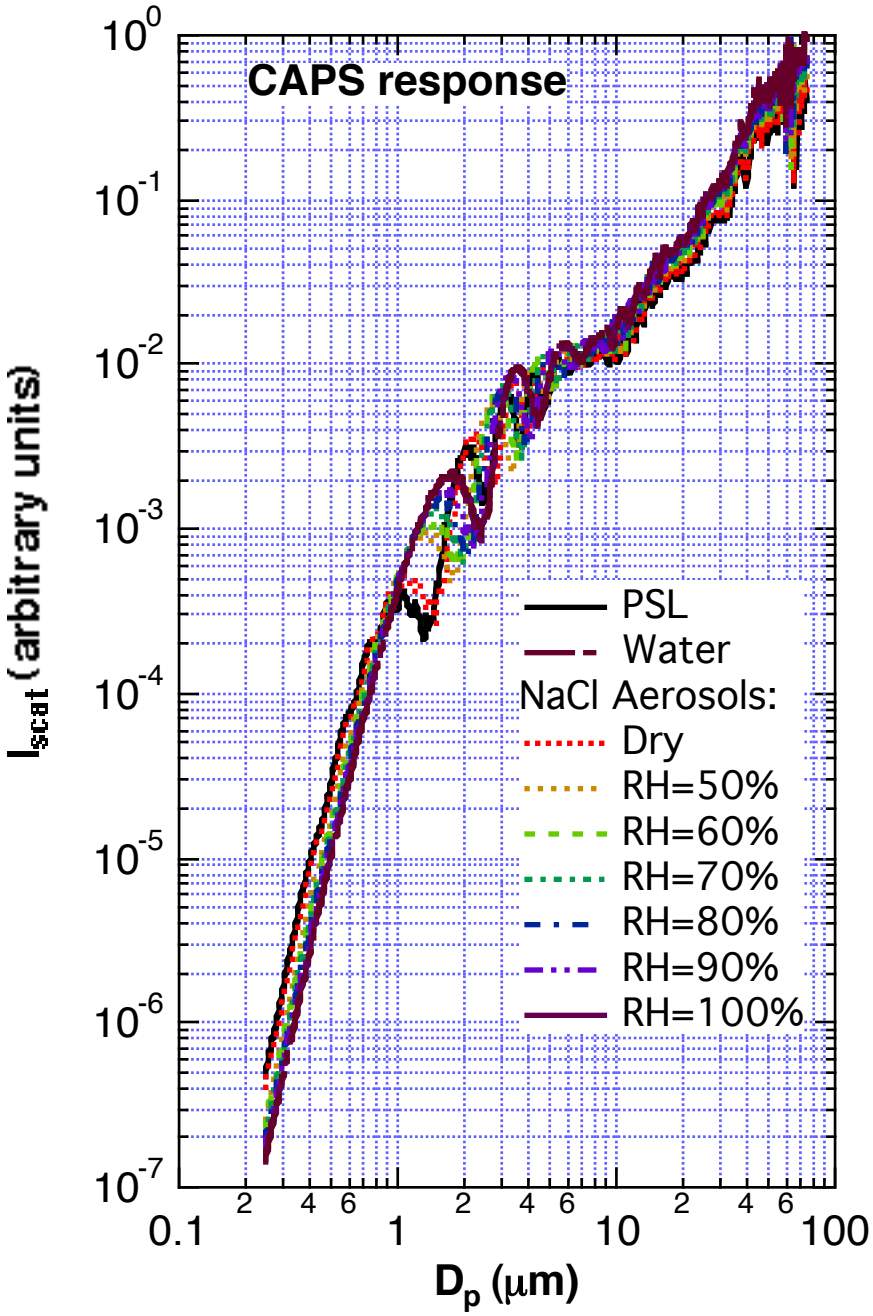
- What is Titan's climate?
- What governs the hydrologic cycle on Titan
- What is the nature of the hydrologic cycle and what are the material fluxes?
- What controls the energy budget to different regions of the atmosphere?
- Microphysics
  - Nucleate aerosols
  - Growth by condensation and reaction
  - Activation to form cloud droplets/particles
  - Multiple condensate materials --- multiple types of clouds
  - Mixed solution clouds
  - Complex phase behavior
  - Relevant particle sizes may differ substantially from water clouds on earth
    - Terminal settling velocity
    - Activation behavior – Kohler model for cloud droplet activation of organic vapors
    - Optical properties

Focus on microphysical characterization

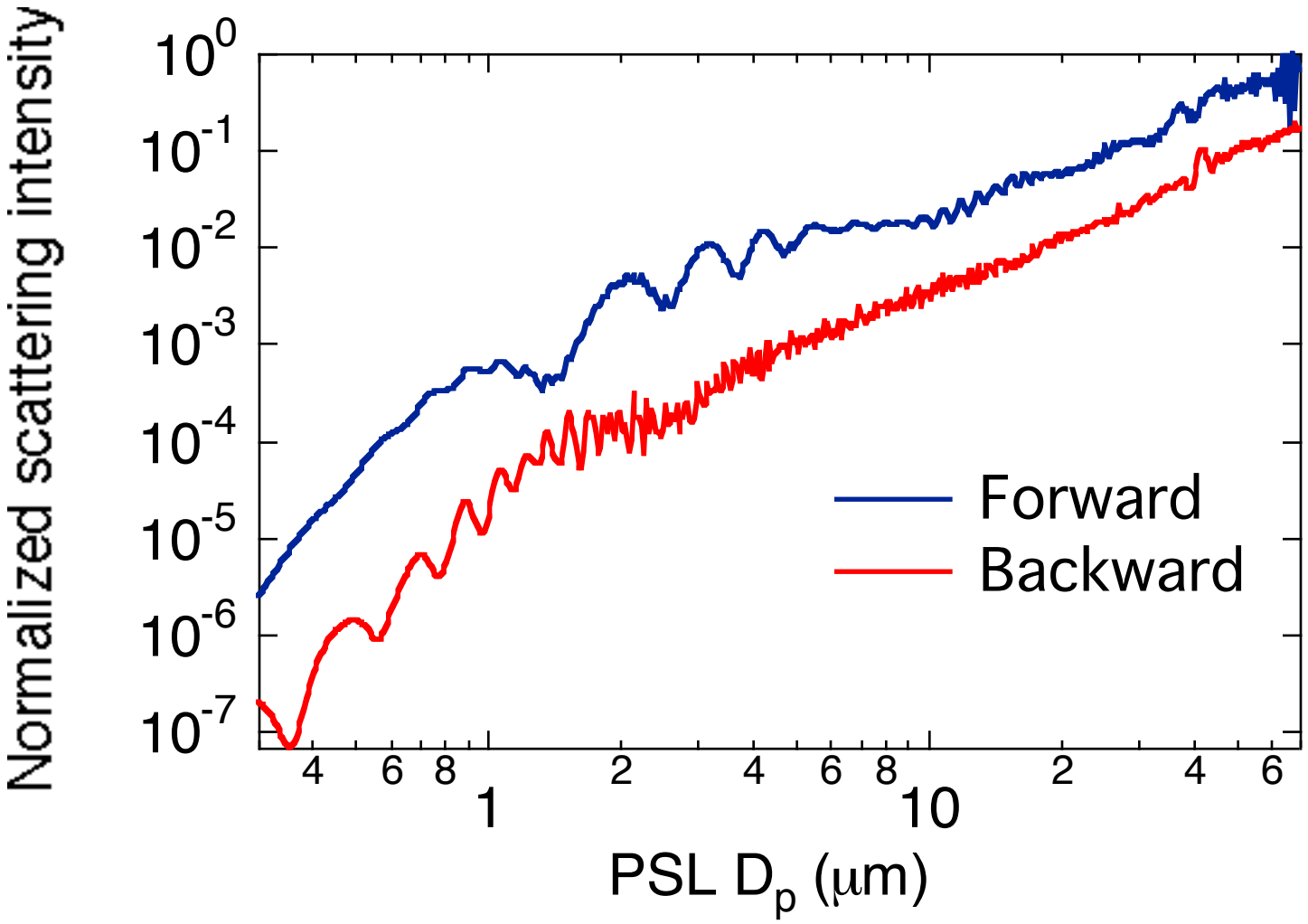
- Aerosols
  - Size distribution
  - Number concentration
  - Activation behavior
- Cloud microphysics

Single particle light scattering for determination of particle size

- Measure scattered light from individual particles
- Strong influence of refractive index
- Strong influence of particles morphology



CAPS
Intensity based estimation of particle size



Differential Mobility Analysis

Steady or Scanned Voltage

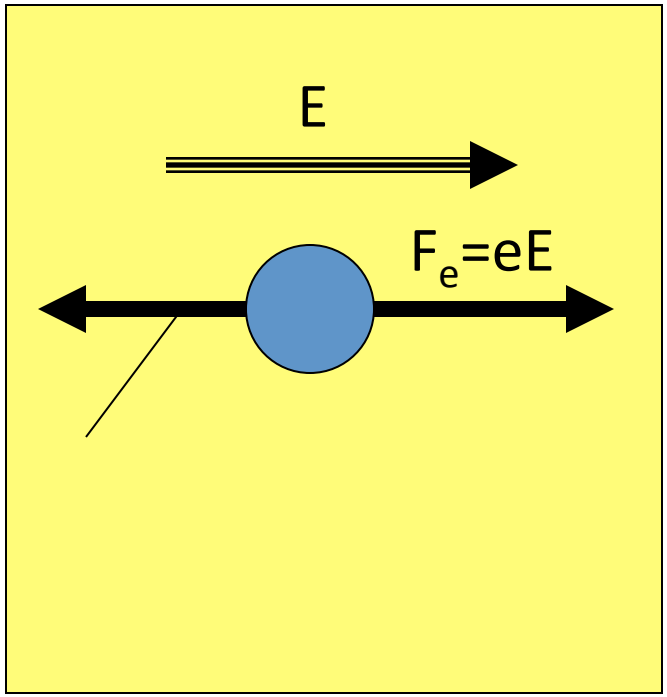
Sheath Air
Q_{sh}~ 10 Q_a

Air Sample

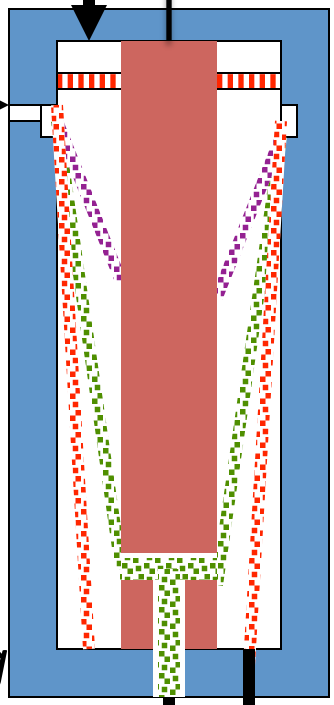
Volumetric flow rate Q_s

Aerosol Charger/ Neutralizer

(*Atmospheric Pressure Chemical Ionization*)



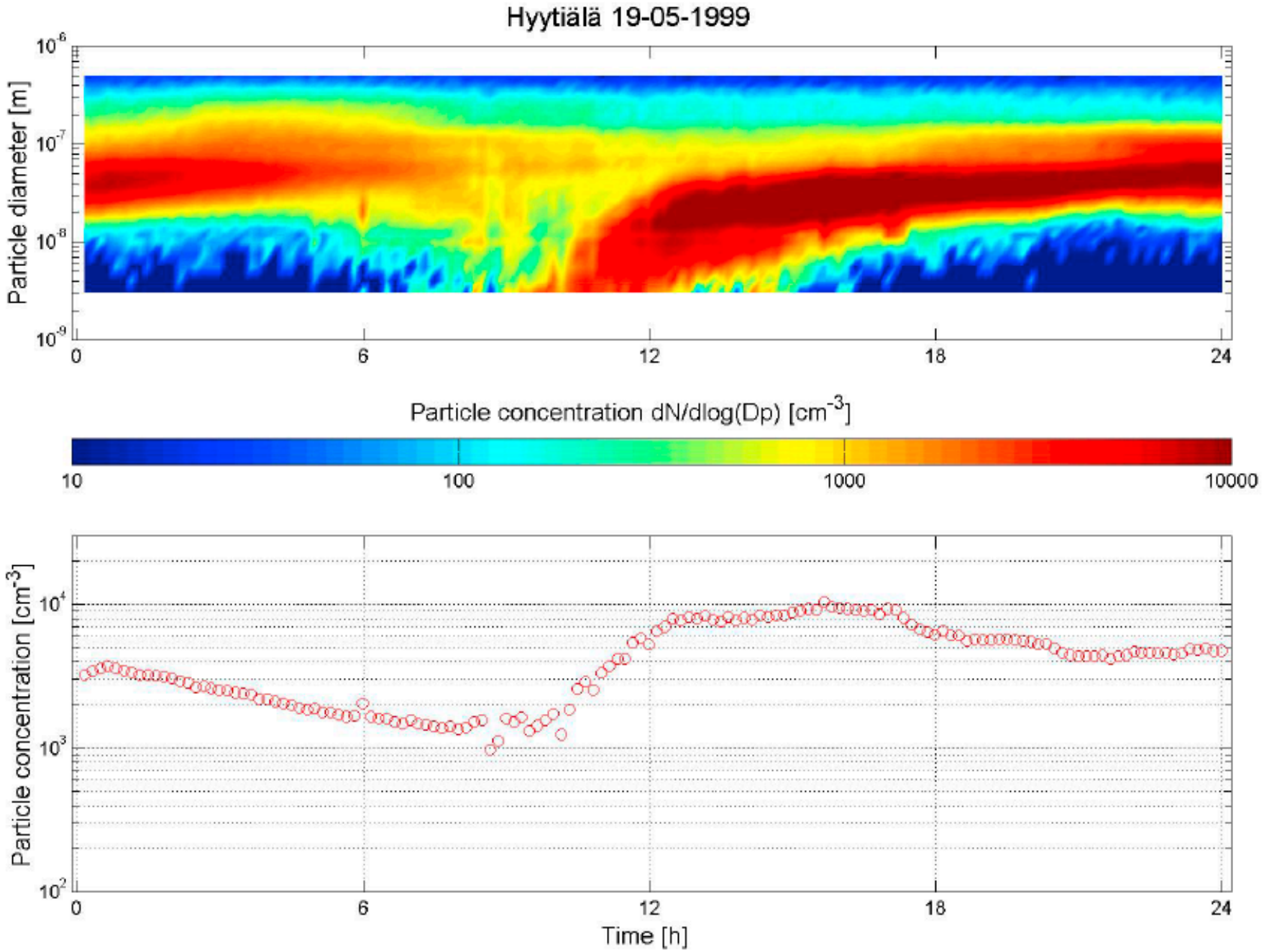
Differential Mobility Analyzer
DMA
(*Aerodynamic Analog of Sector Mass Spectrometer*)



Q_a=Q_s

Exhaust
Q_{ex}=Q_{sh}

Detector
CPC or electrometer



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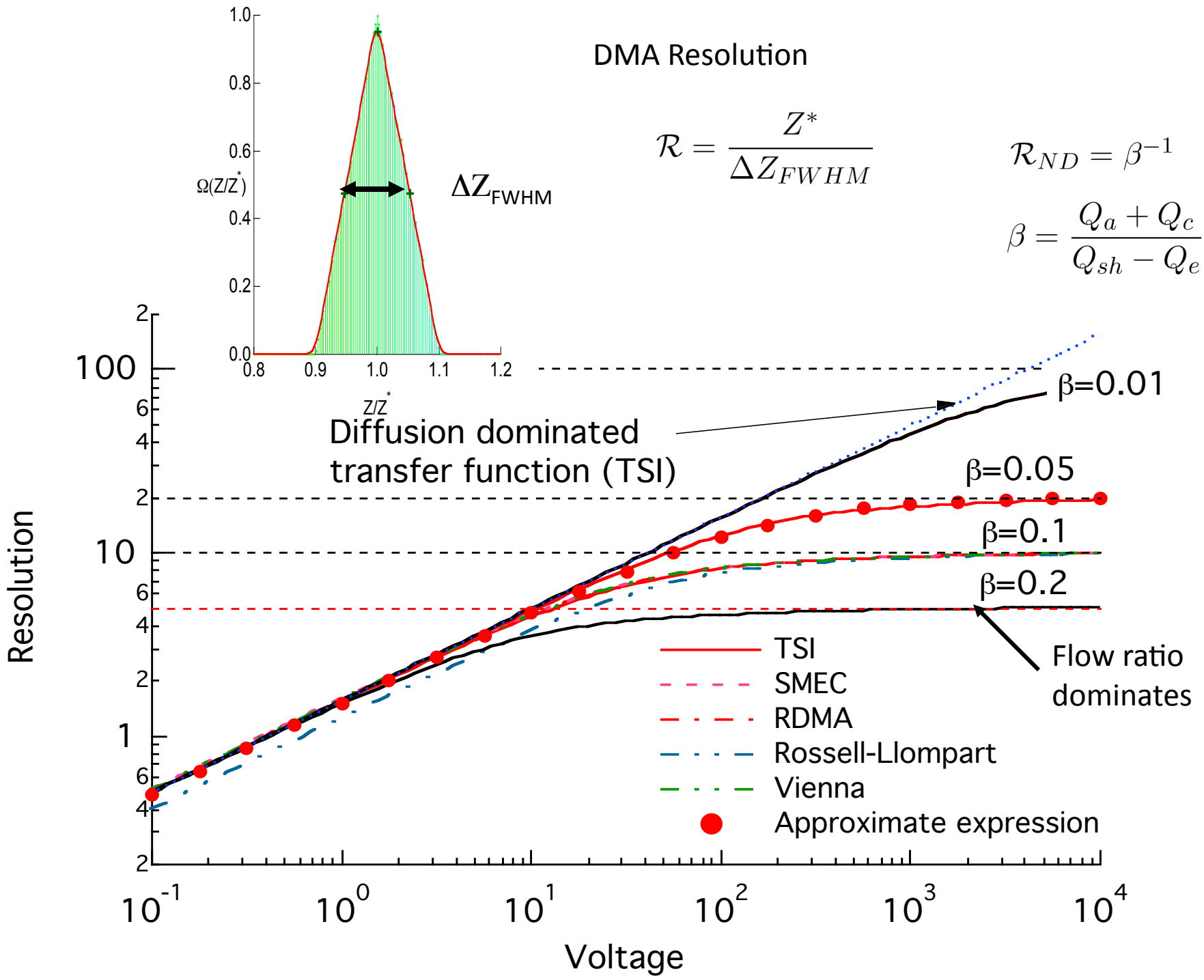
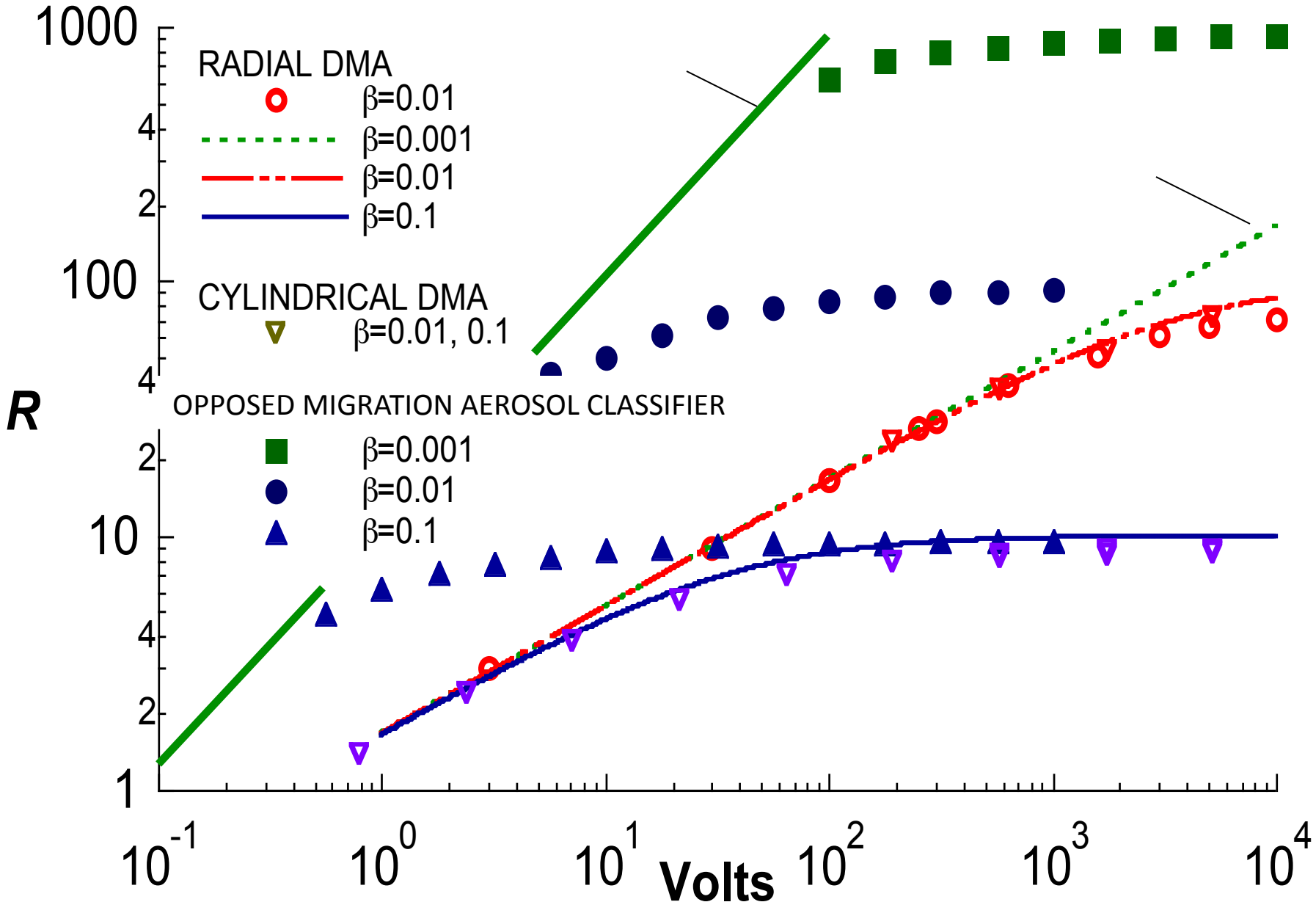

DMA Resolution
$\mathcal{R} = \frac{Z^*}{\Delta Z_{FWHM}}$
$\mathcal{R}_{ND} = \beta^{-1}$
$\beta = \frac{Q_a + Q_c}{Q_{sh} - Q_e}$
ΔZ_FWHM
Ω(Z/Z*)
Z/Z*
Diffusion dominated
transfer function (TSI)
β=0.01
β=0.05
β=0.1
β=0.2
Flow ratio
dominates
TSI
SMEC
RDMA
Rossell-Llompart
Vienna
Approximate expression
Resolution
Voltage



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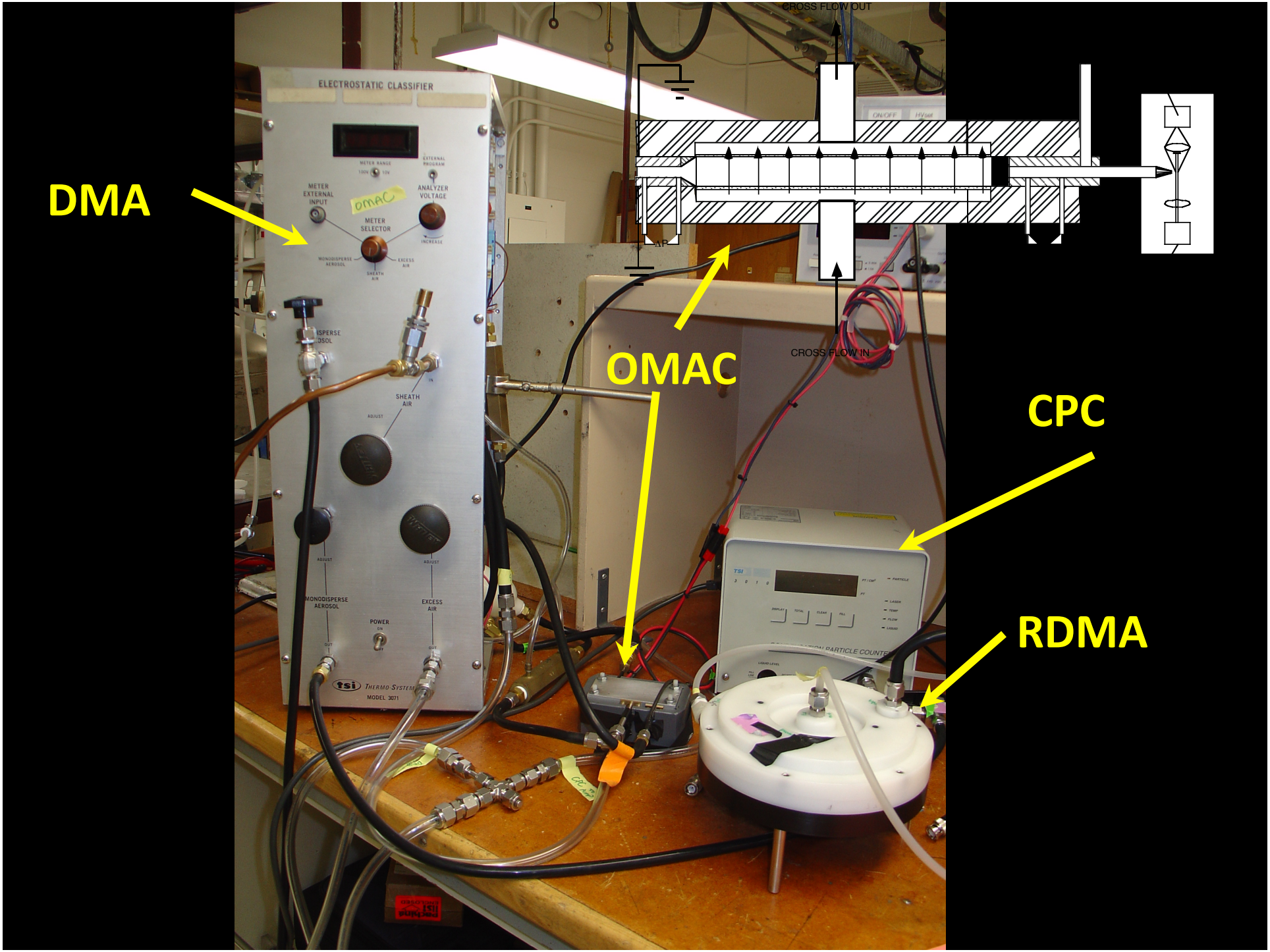
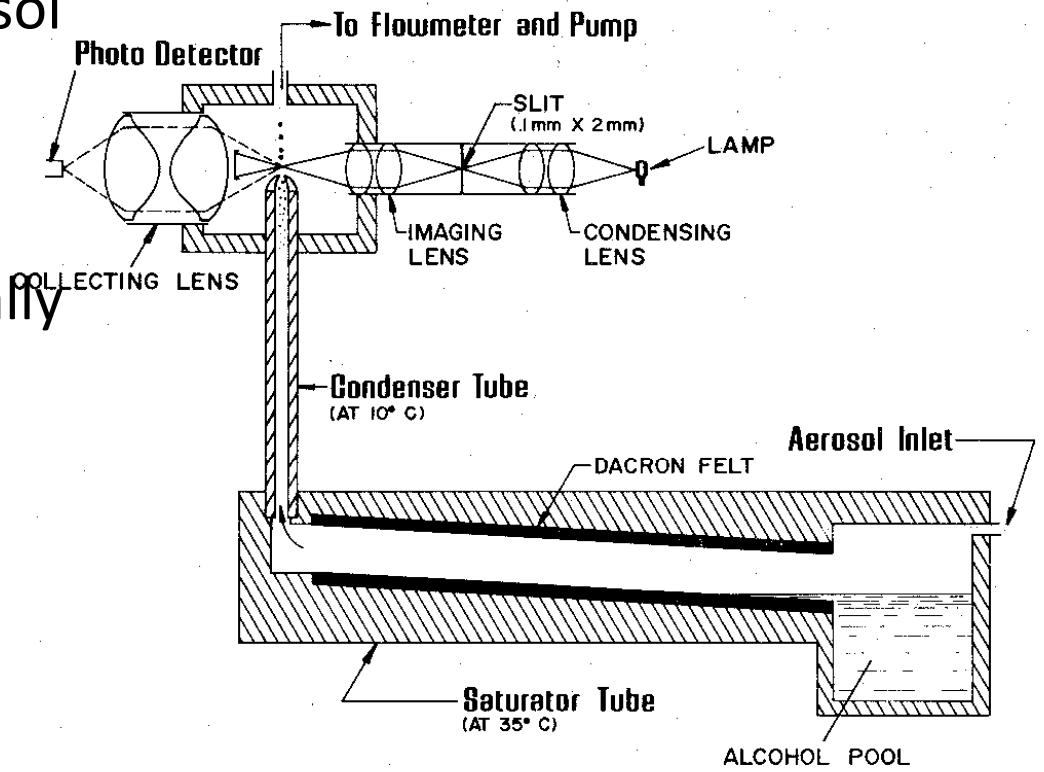

DMA
OMAC
CPC
RDMA
ELECTROSTATIC CLASSIFIER
CROSS FLOW OUT
CROSS FLOW IN
ΔP
METER EXTERNAL INPUT
METER SELECTOR
ANALYZER VOLTAGE
SHEATH AIR
MONODISPERSE AEROSOL
EXCESS AIR
POWER
MODEL 3071

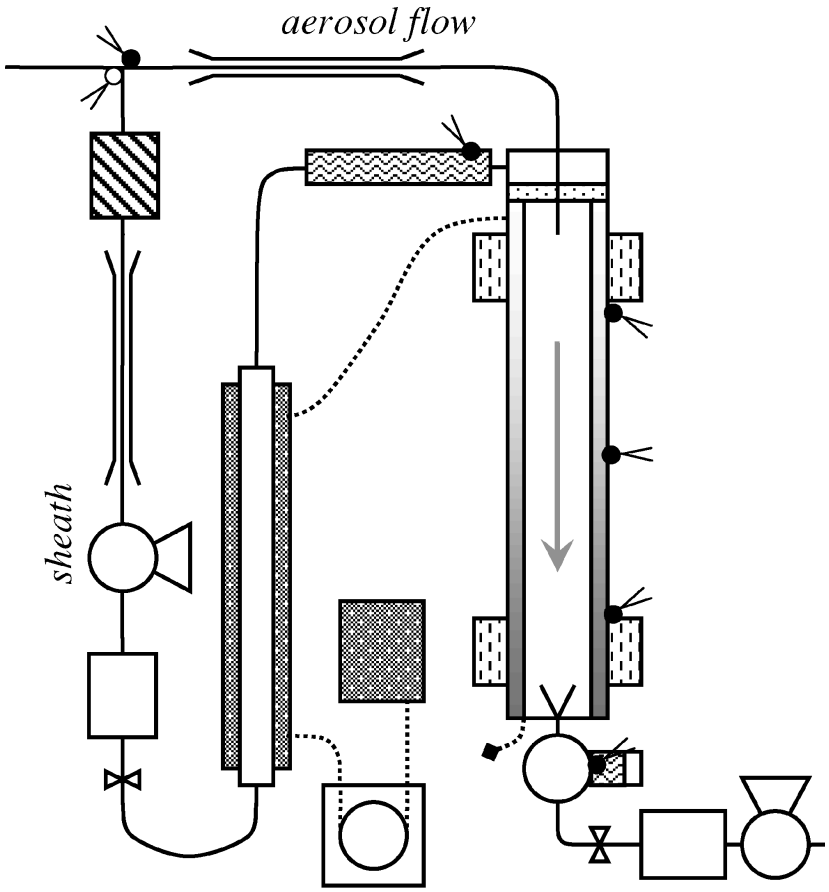
Detection

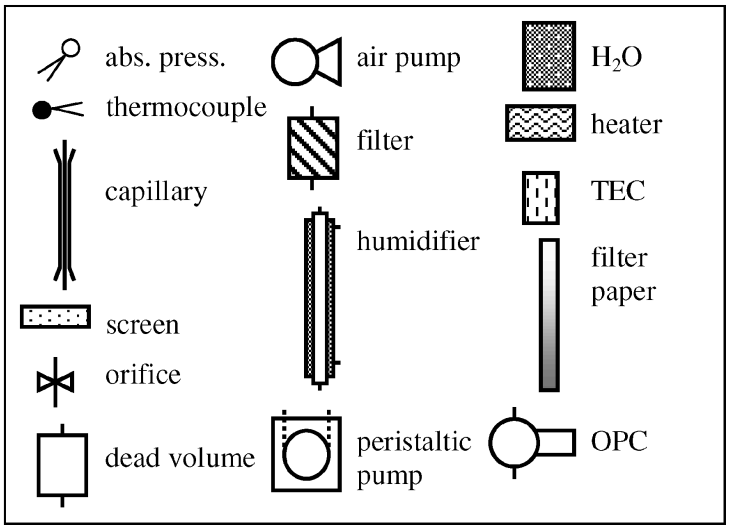
- Electrometer
  - Femtoamp to attoamp sensitivity required without use of electron multipliers
- Condensation particle counter
  - Introduce vapor into aerosol sample to produce supersaturation
  - Condense vapor onto particles to grow to optically detectable size (>1µm)
  - Count optically
  - Commercial detectors see particles with D_p>2.5μm



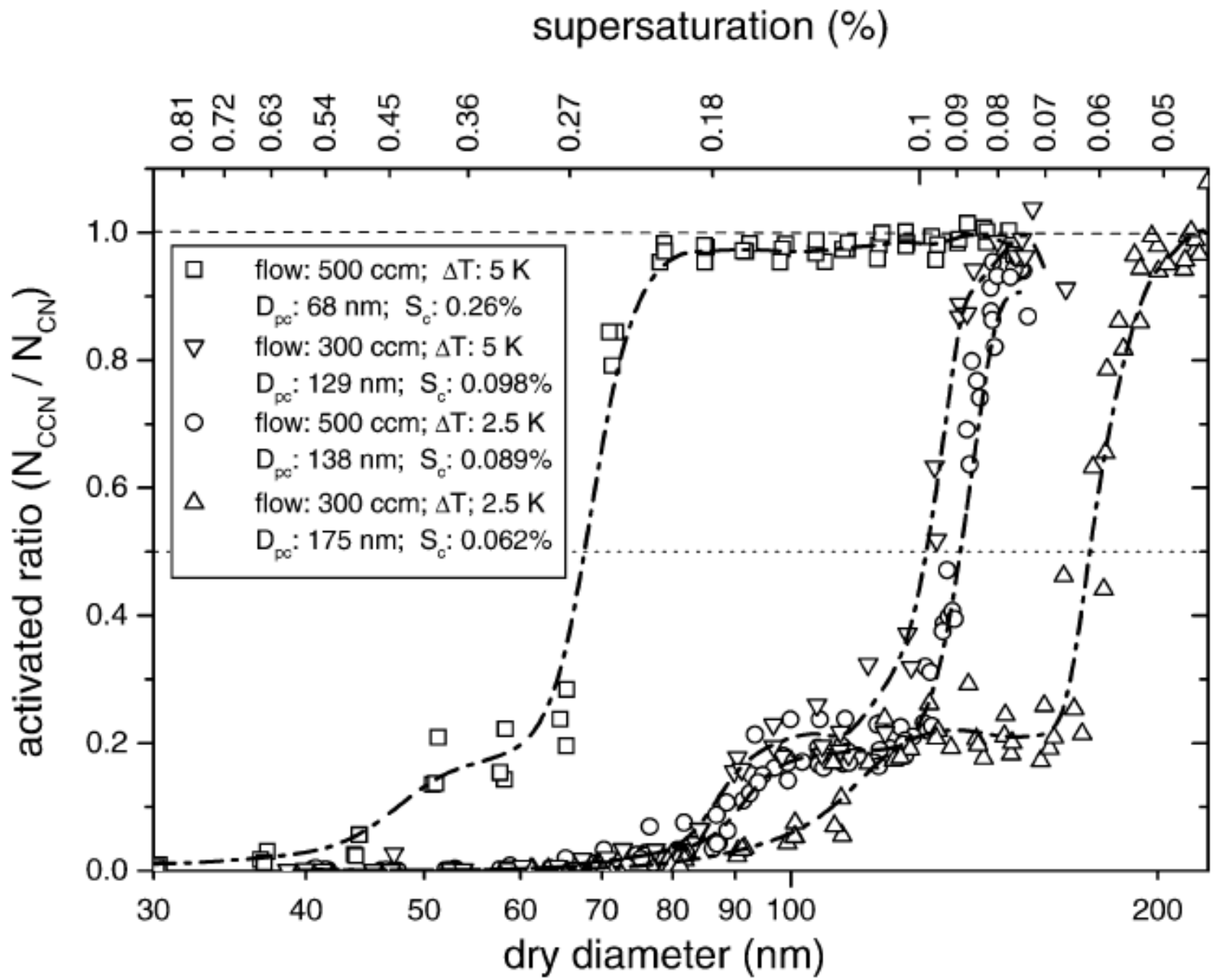
Streamwise gradient cloud condensation nucleus counter/spectrometer

- Water vapor diffuses faster in air than heat
- Wet wall condenser with temperature increasing along length produces supersaturation
- Same approach should work for methane
- Extract working fluid from atmosphere





Nenes et al. (2005) Aerosol Sci. Technol. 39: 206-221



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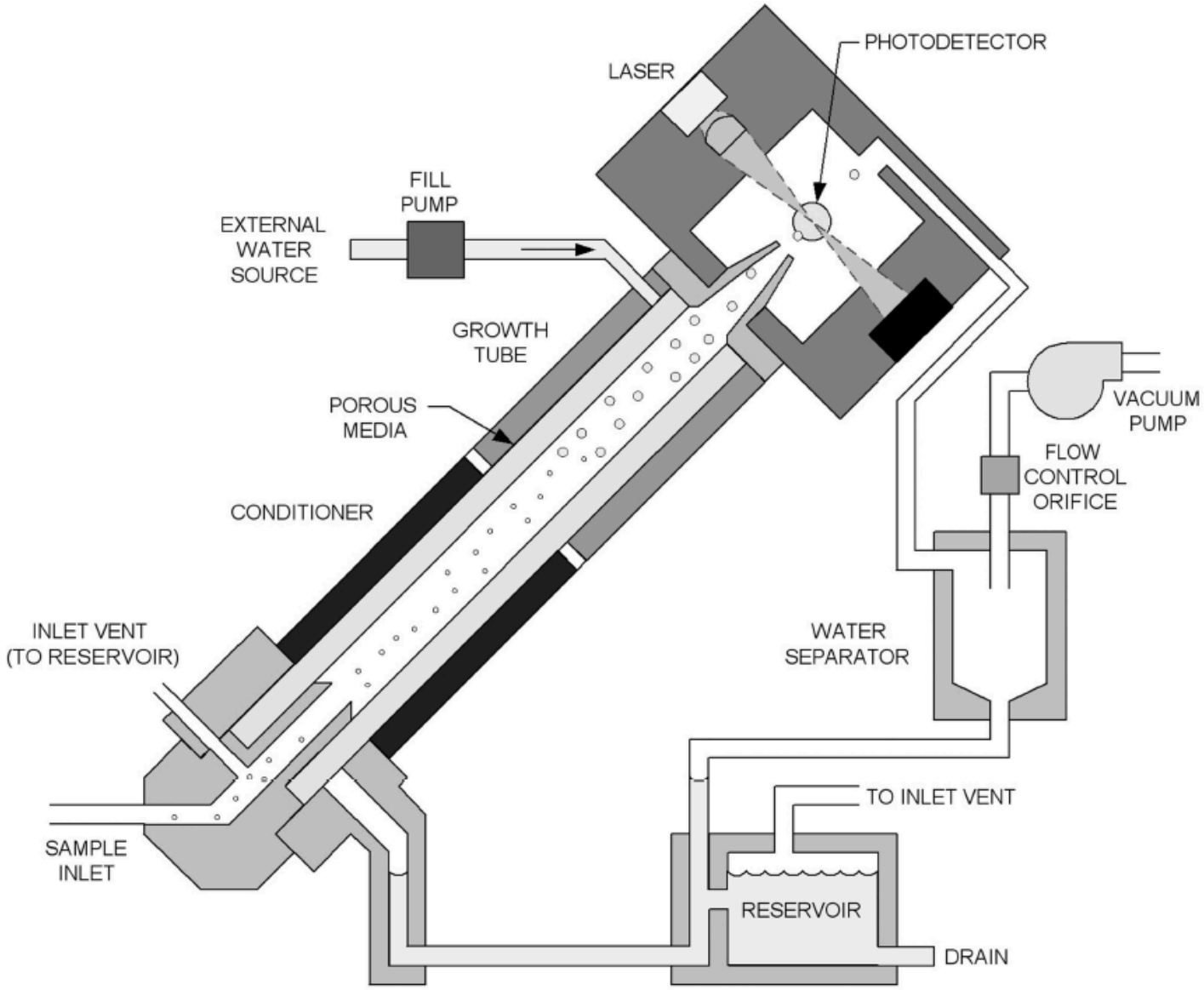
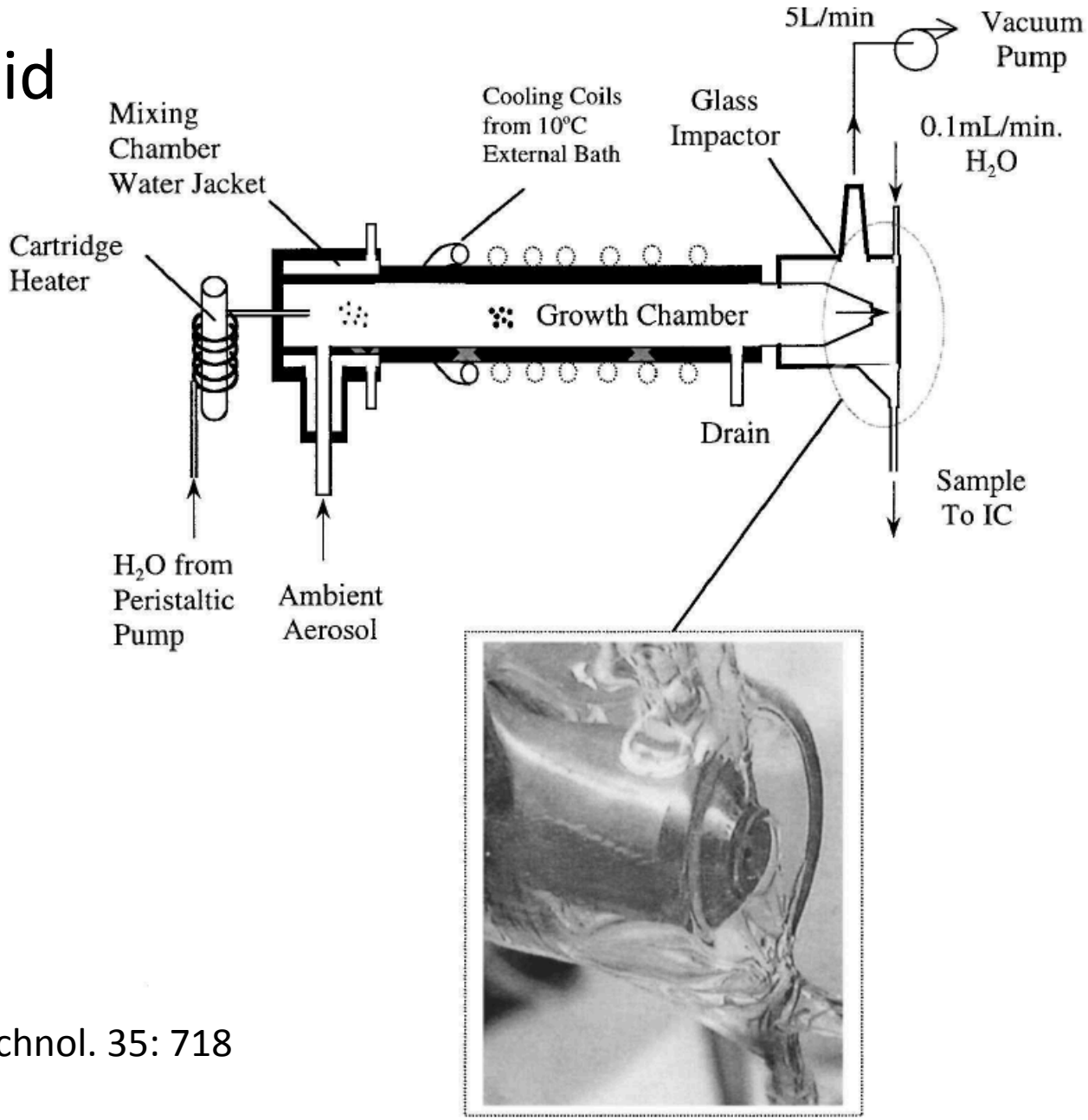


Hering et al. (2005) Aerosol Sci. Technol. 39:695-672.

Particle into liquid sampler (PILS)

- Condense vapor onto particles to grow to inertially collectable size



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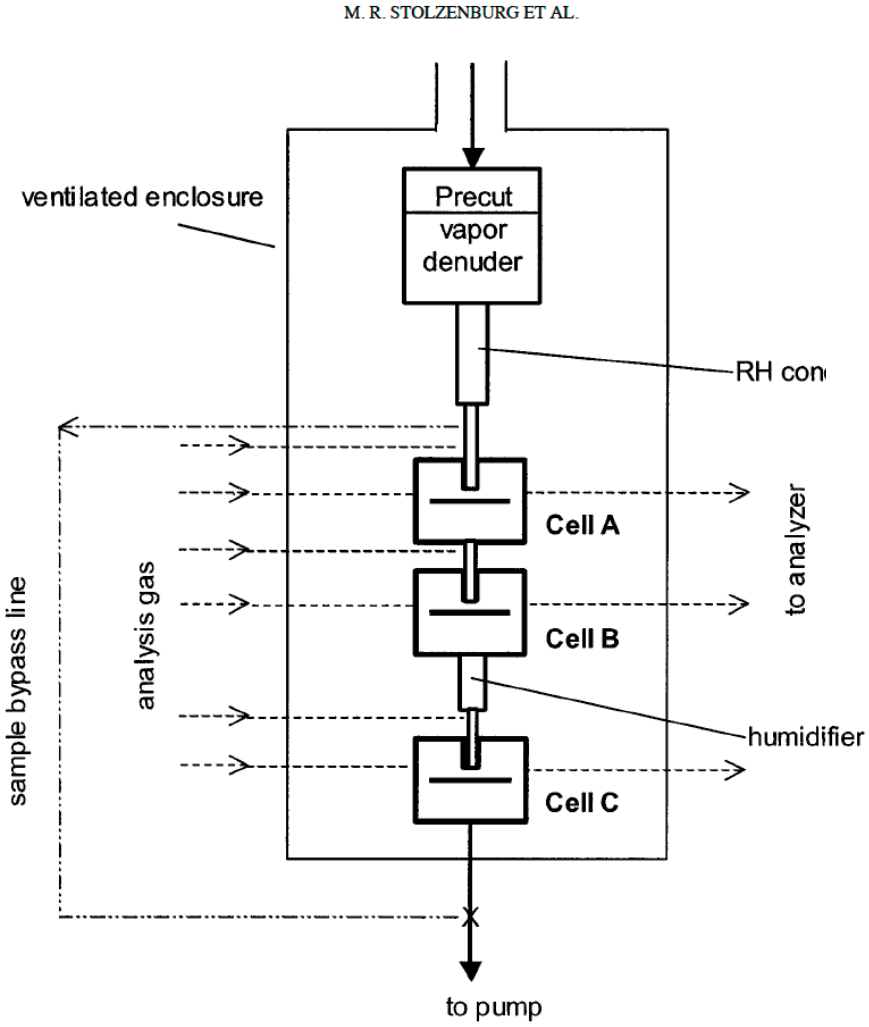
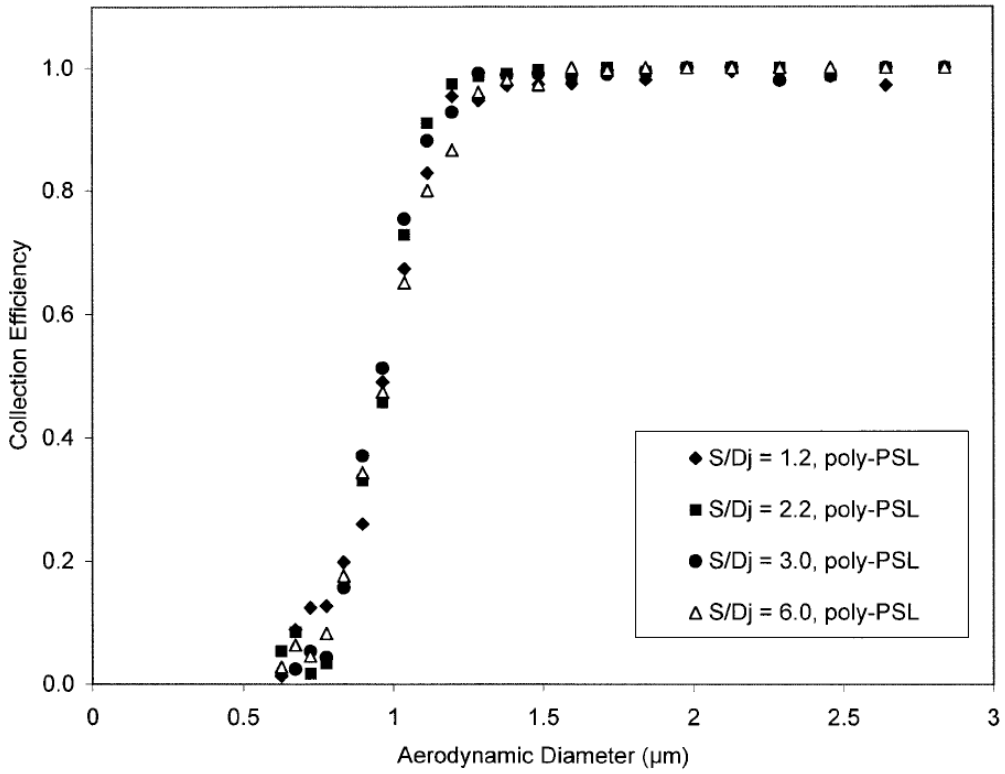
Condensation Activation for On-Line Size-Resolved Analysis





- Dry collection of aerodynamically sized large particles
- Thermal desorption for on-line analysis
- Grow smallest particles by condensation to facilitate collection and analysis

Stolzenburg et al. (2003) Aerosol Sci. Technol. 37:537-546,