New Approaches to Differential Mobility Analysis for Airborne Measurements

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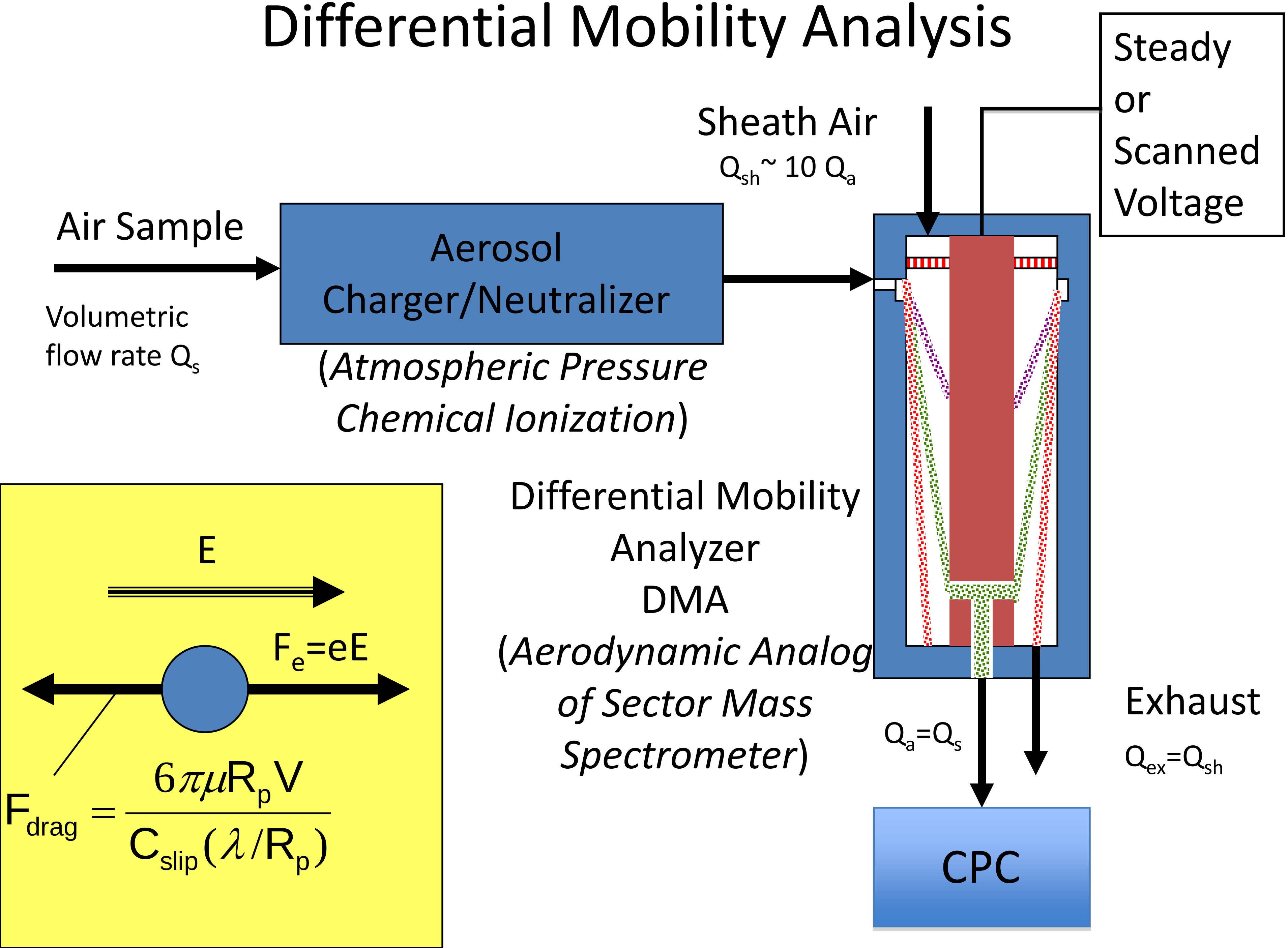
Support: NSF, ONR, Davidow Foundation

Differential Mobility Analysis



Migration Velocity

$$v_E = Z_p E$$

- **Mobility**

$$Z_p = \frac{n_p e}{k_B T} D$$

- **Peclet number for migration**

$$Pe_{mig} = \frac{electrophoretic\ migration}{diffusive\ transport} = \frac{b v_E}{D} = \frac{b n_p e E}{k_B T}$$

Singly Charged Particles

- **Radial DMA**

$$E = \frac{V}{b}$$

$$Pe = \frac{eV}{k_B T}$$

- **Cylindrical DMA**

$$E = \frac{V}{r \ln \frac{R_2}{R_1}}$$

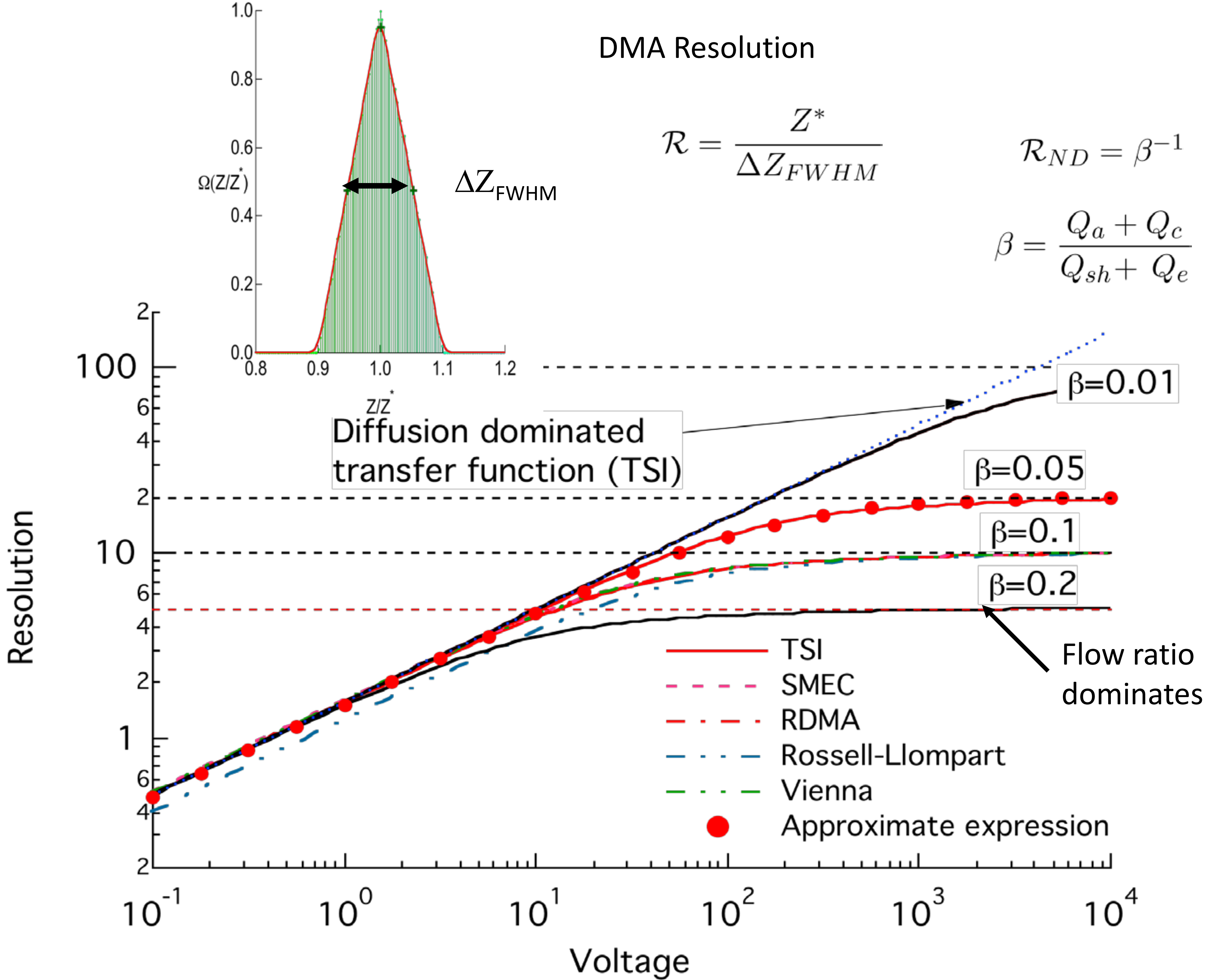
$$Pe = \frac{eV}{k_B T} \frac{1 - \frac{R_2}{R_1}}{\ln \frac{R_2}{R_1}}$$

DMA Resolution

$$\mathcal{R} = \frac{Z^*}{\Delta Z_{FWHM}}$$

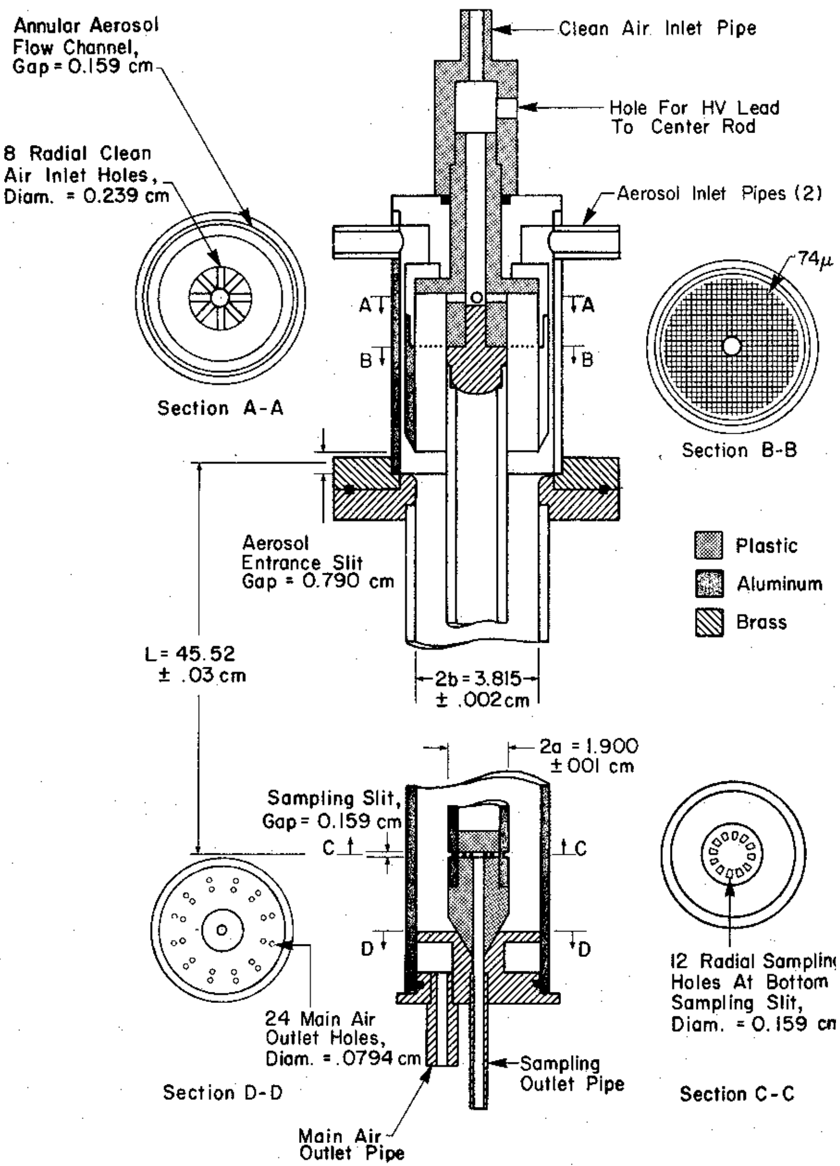
$$\mathcal{R}_{ND} = \beta^{-1}$$

$$\beta = \frac{Q_a + Q_c}{Q_{sh} + Q_e}$$



Differential Mobility Analyzer

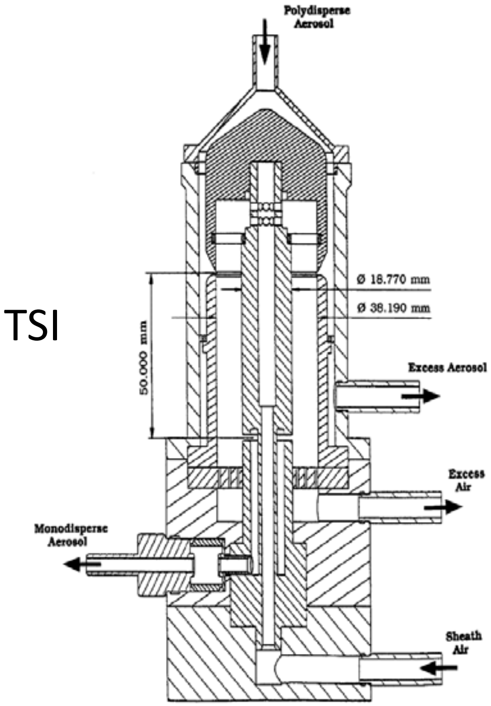
Knutson and Whitby (1975) &TSI 10-1000nm

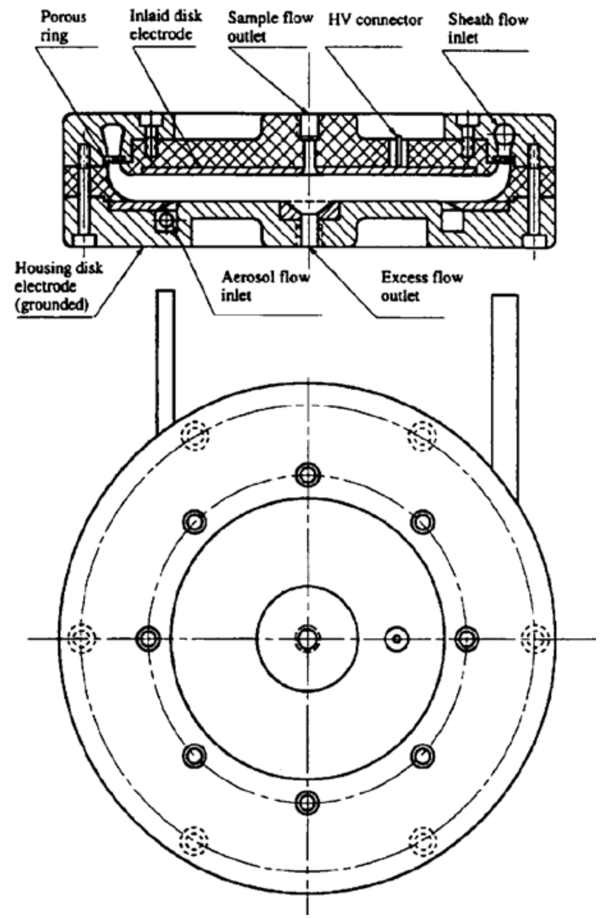


Nano DMA

Chen and Pui (1998) & TSI

6-150 nm



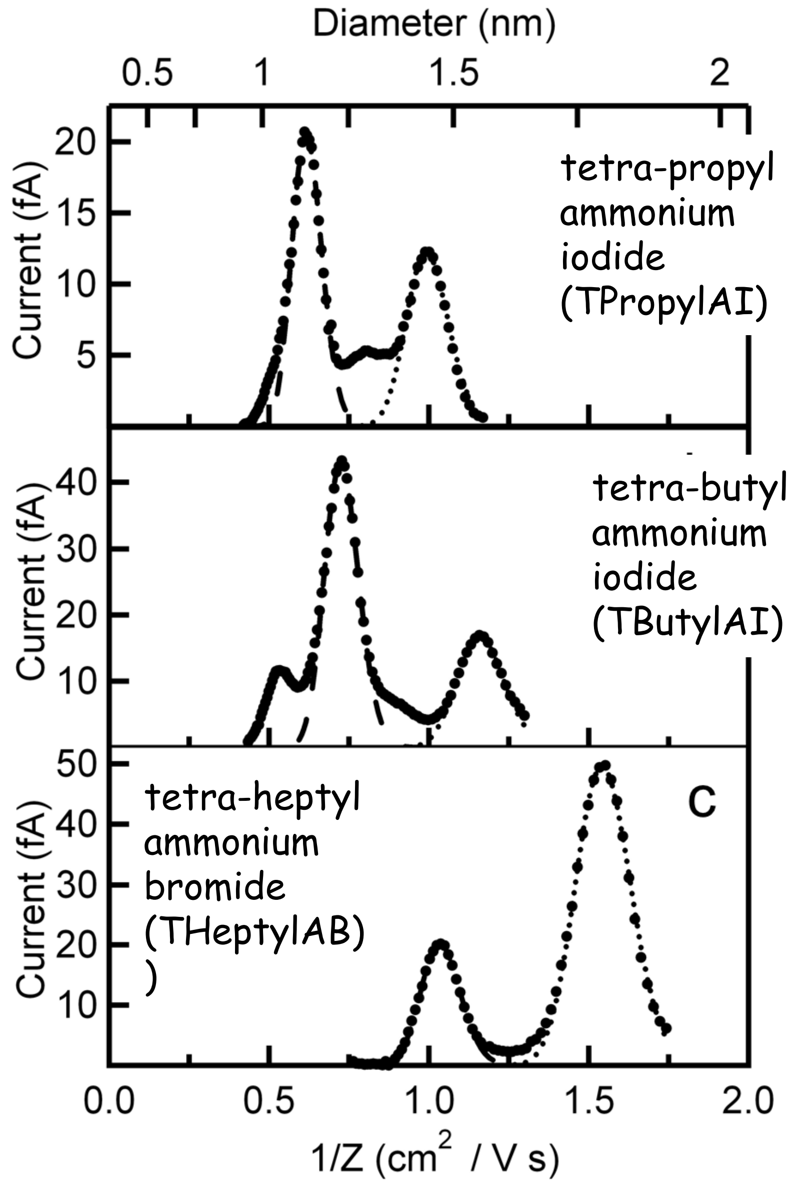


Radial DMA

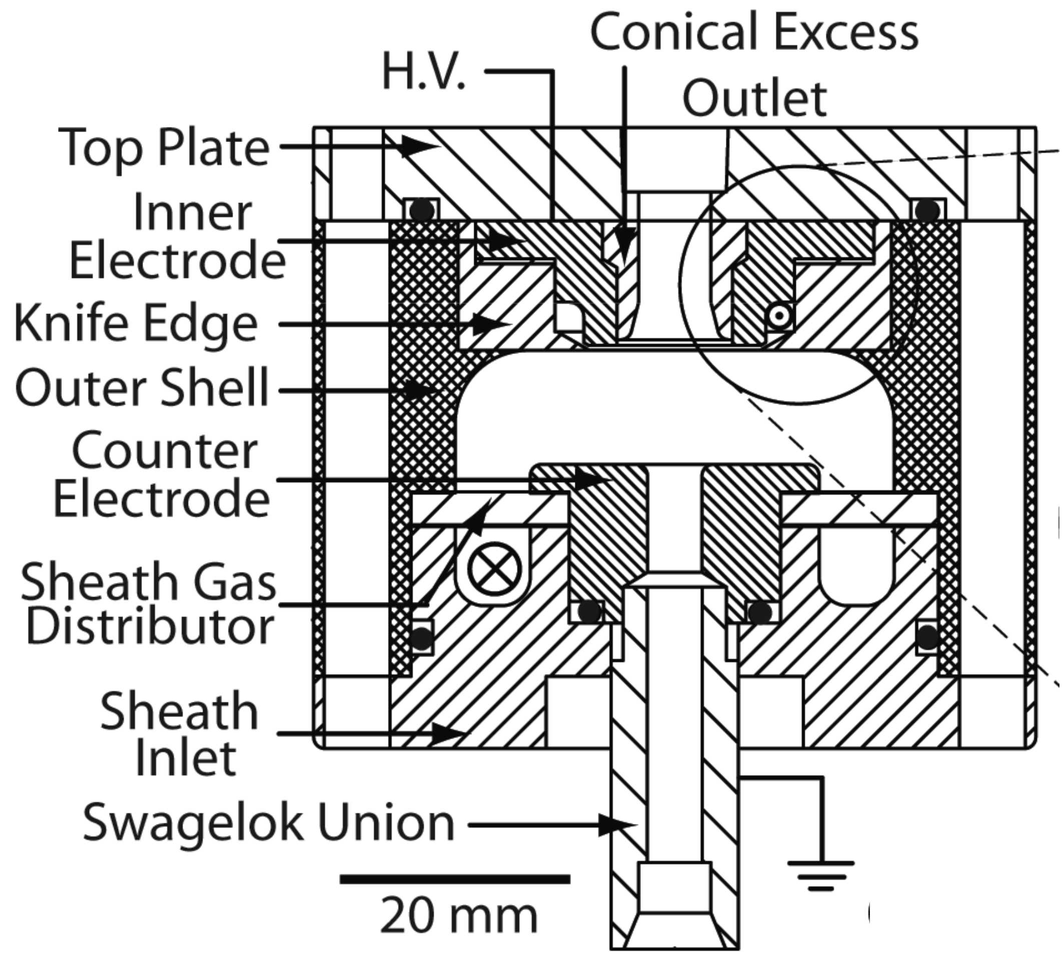
Zhang et al. (1995)

2-200 nm

NanoRDMA

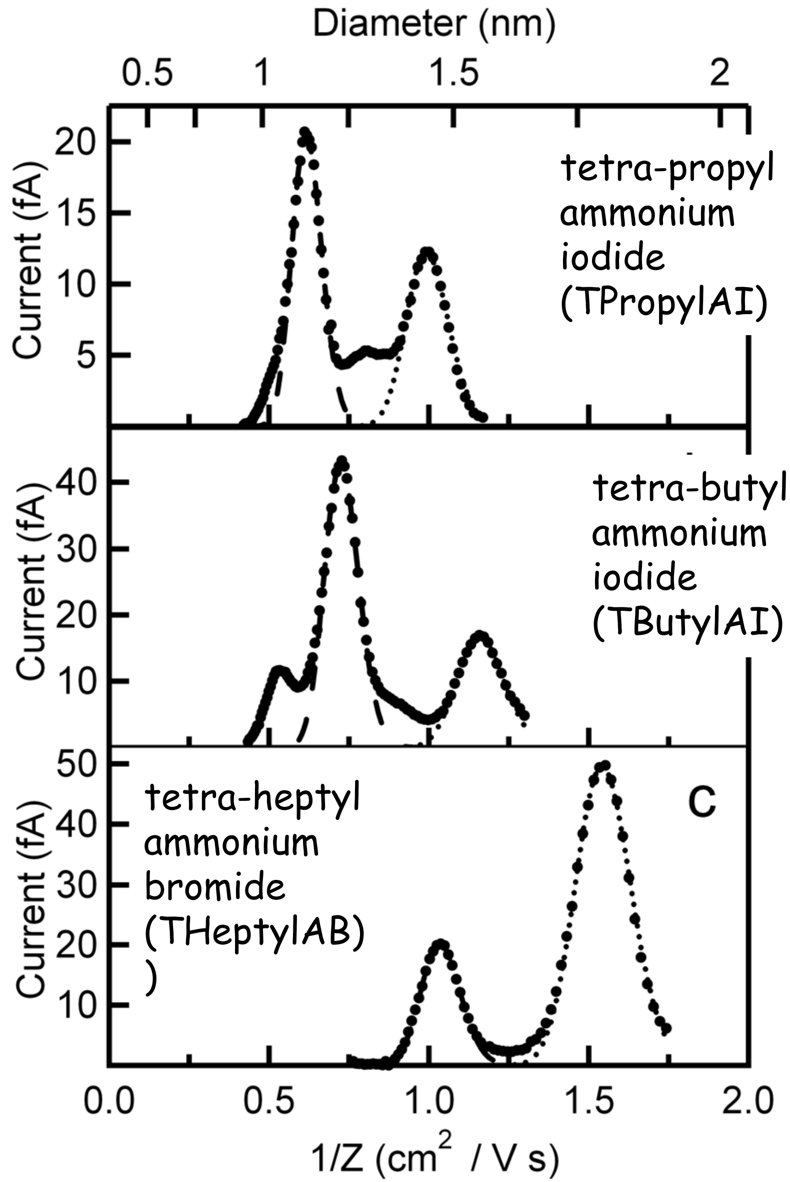


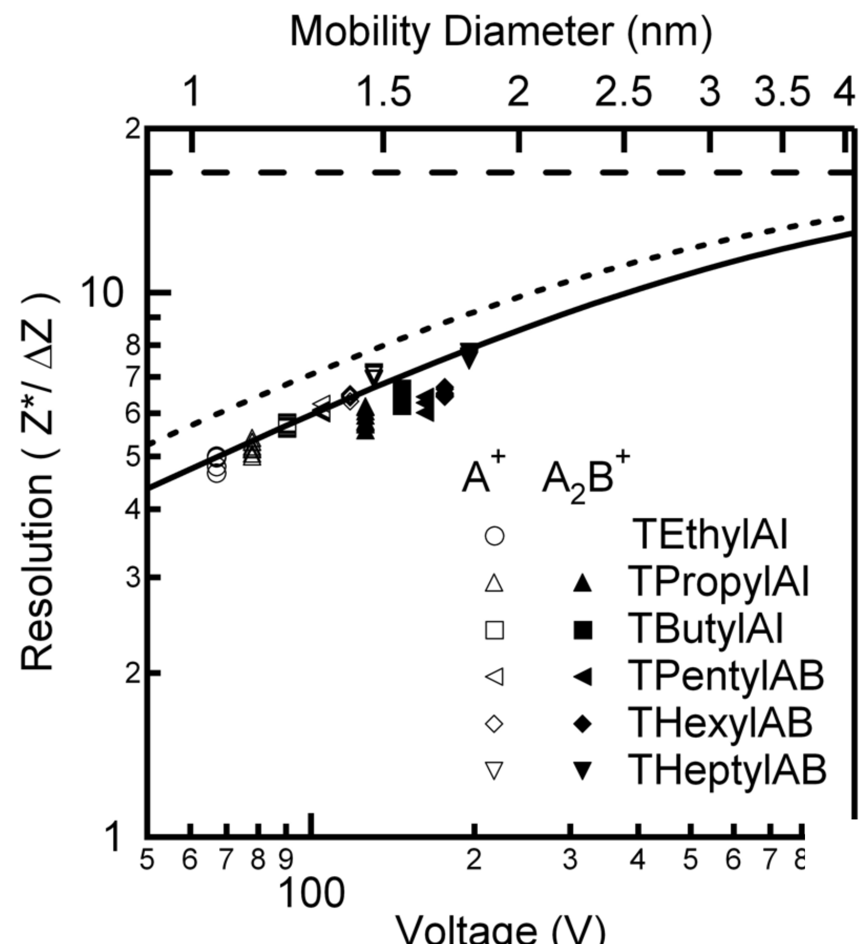
Diameter (nm)
0.5
1
1.5
2
Current (fA)
tetra-propyl ammonium iodide (TPropylAI)
tetra-butyl ammonium iodide (TButylAI)
tetra-heptyl ammonium bromide (THeptylAB))
c
0.0
0.5
1.0
1.5
2.0
1/Z (cm^2 / V s)



H.V.
Conical Excess Outlet
Top Plate
Inner Electrode
Knife Edge
Outer Shell
Counter Electrode
Sheath Gas Distributor
Sheath Inlet
Swagelok Union
20 mm

NanoRDMA

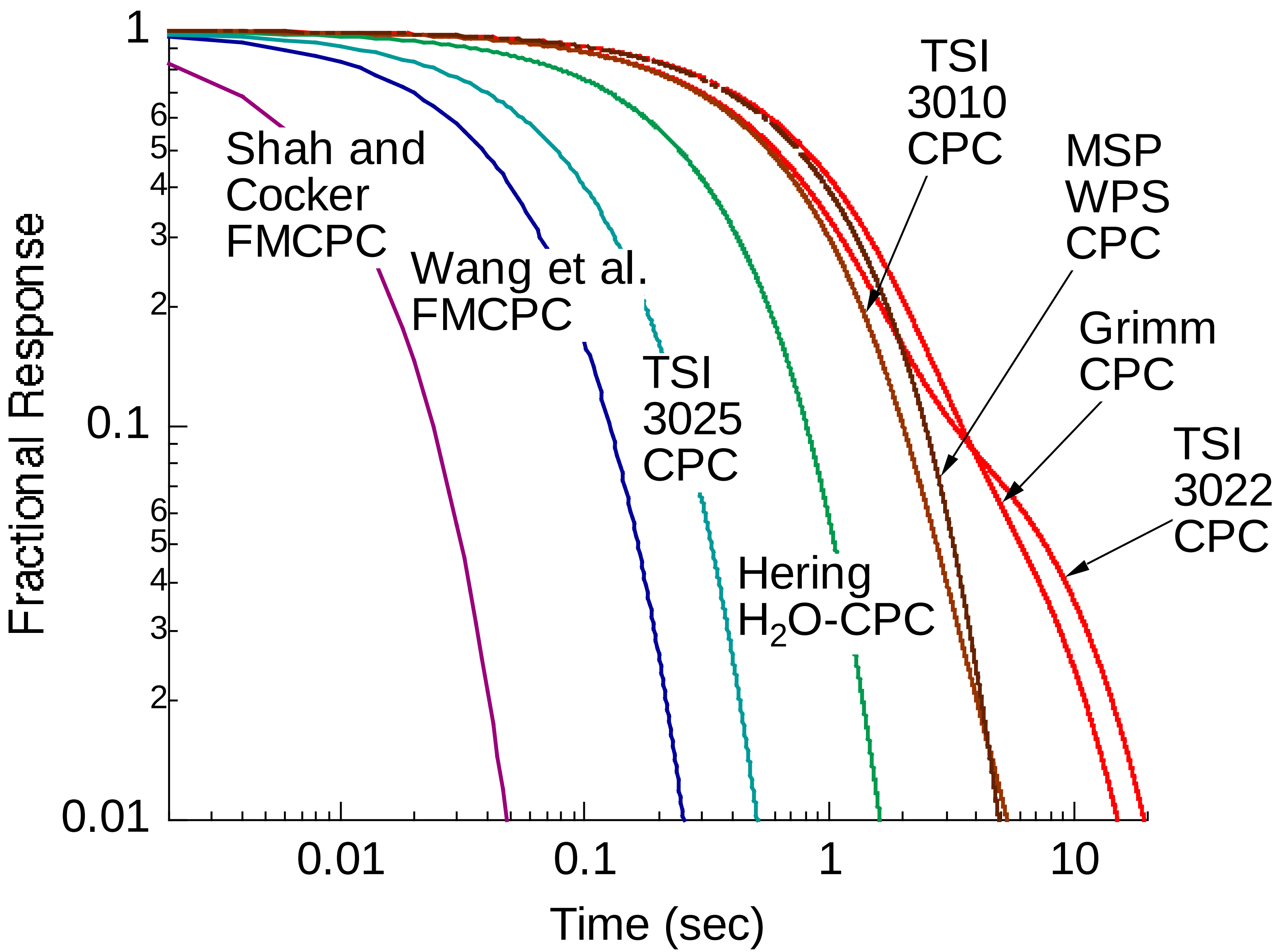

Diameter (nm)
0.5
1
1.5
2
Current (fA)
tetra-propyl
ammonium
iodide
(TPropylAI)
tetra-butyl
ammonium
iodide
(TButylAI)
tetra-heptyl
ammonium
bromide
(THeptylAB)
)
C
0.0
0.5
1.0
1.5
2.0
1/Z (cm2 / V s)


Mobility Diameter (nm)
1
1.5
2
2.5
3
3.5
4
Resolution (Z*/ ΔZ)
10
1
A+
A2B+
TEthylAI
TPropylAI
TButylAI
TPentylAB
THexylAB
THeptylAB
100
Voltage (V)

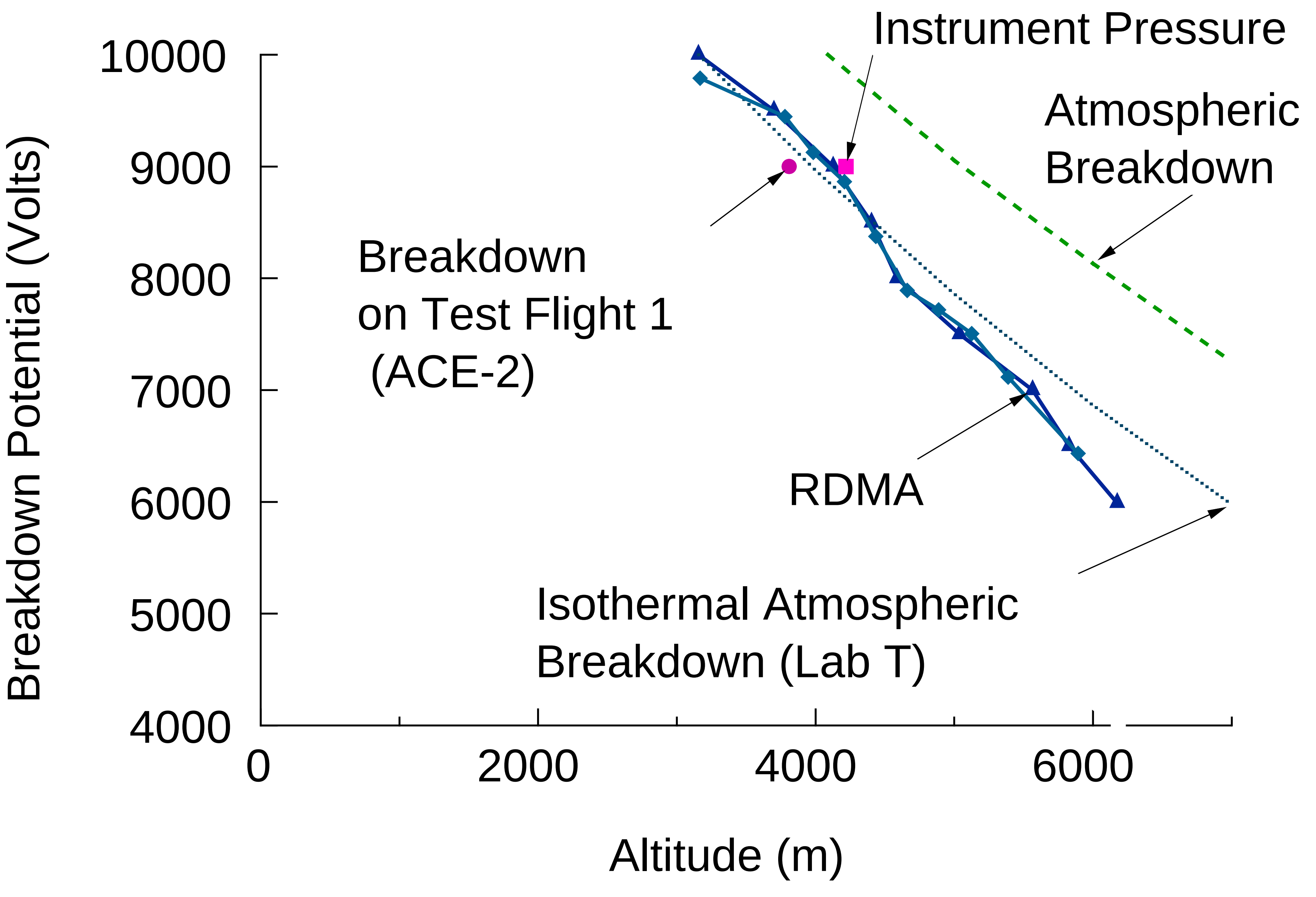
Issues in Airborne Operation

- Time response
  - Scanning
  - Parallel measurements
- Pressure effects
  - Charging Probability
    - Concentration calibration standard???
  - Electrostatic Breakdown
  - Flow control
- Dynamic range

CPC time response



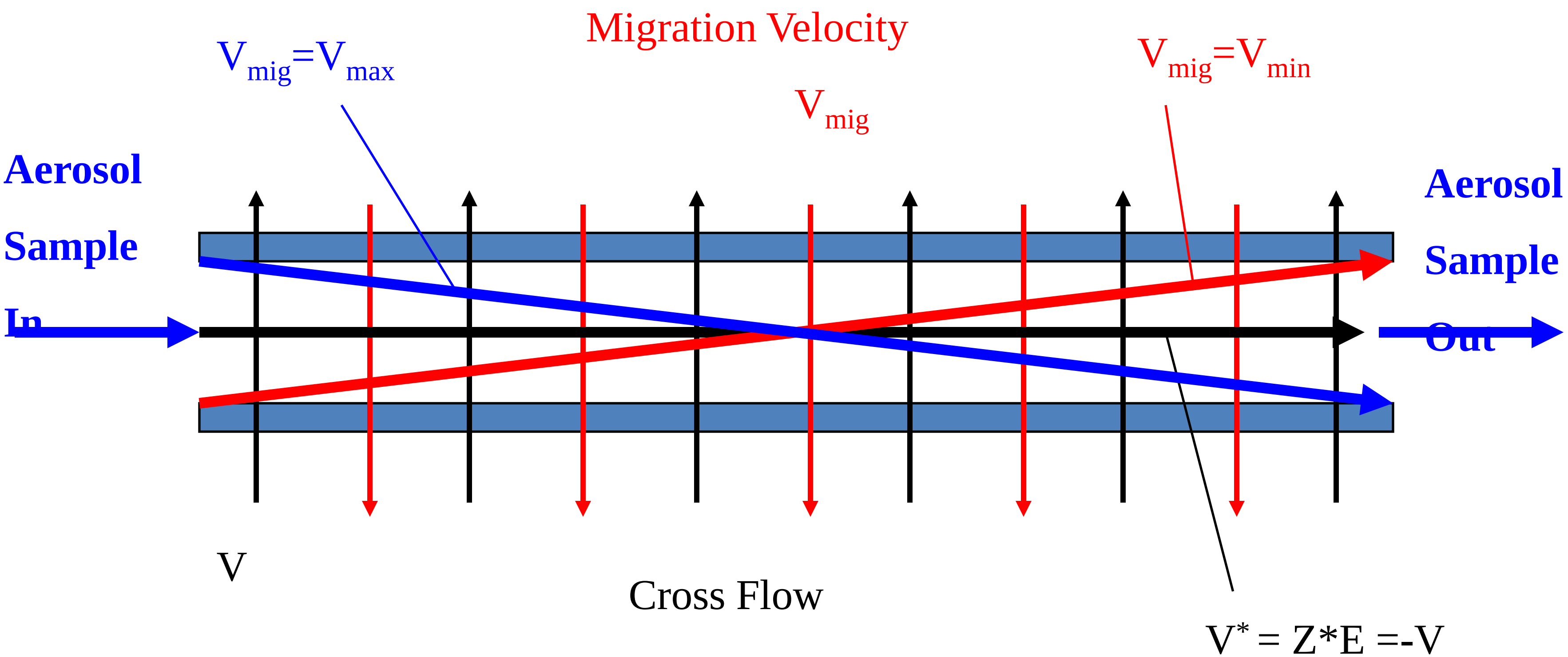
Arcing limits in RDMA (1 cm gap)



Options for Measurement at Altitude

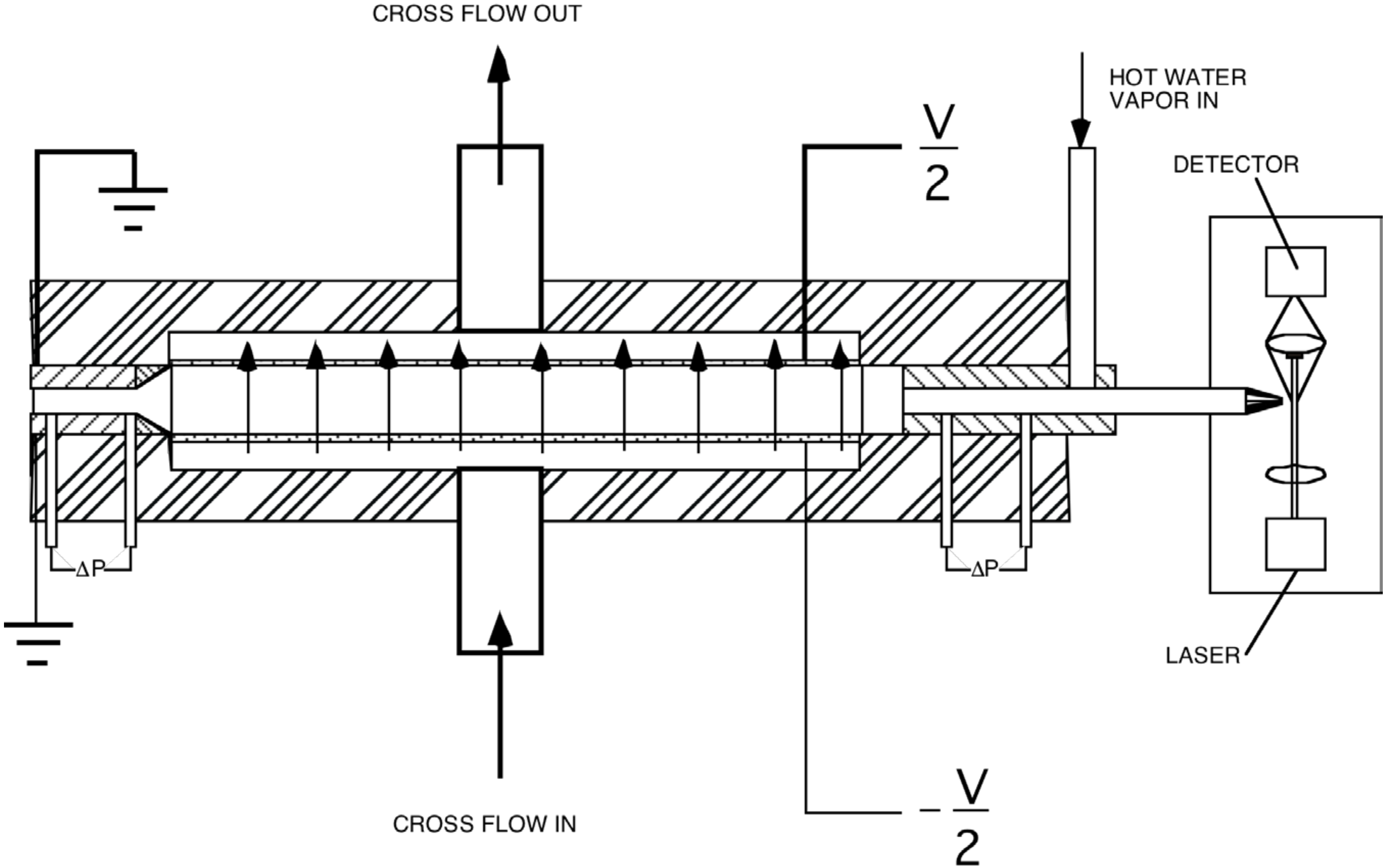
- Limit voltage range as altitude increases
  - Limits dynamic range
- Find a way to reduce diffusional effects at low voltage
- Use multiple mobility analyzers
- Compress sample
  - Compression heating
  - Dilution if use ejector pump

Opposed Migration Aerosol Classifier

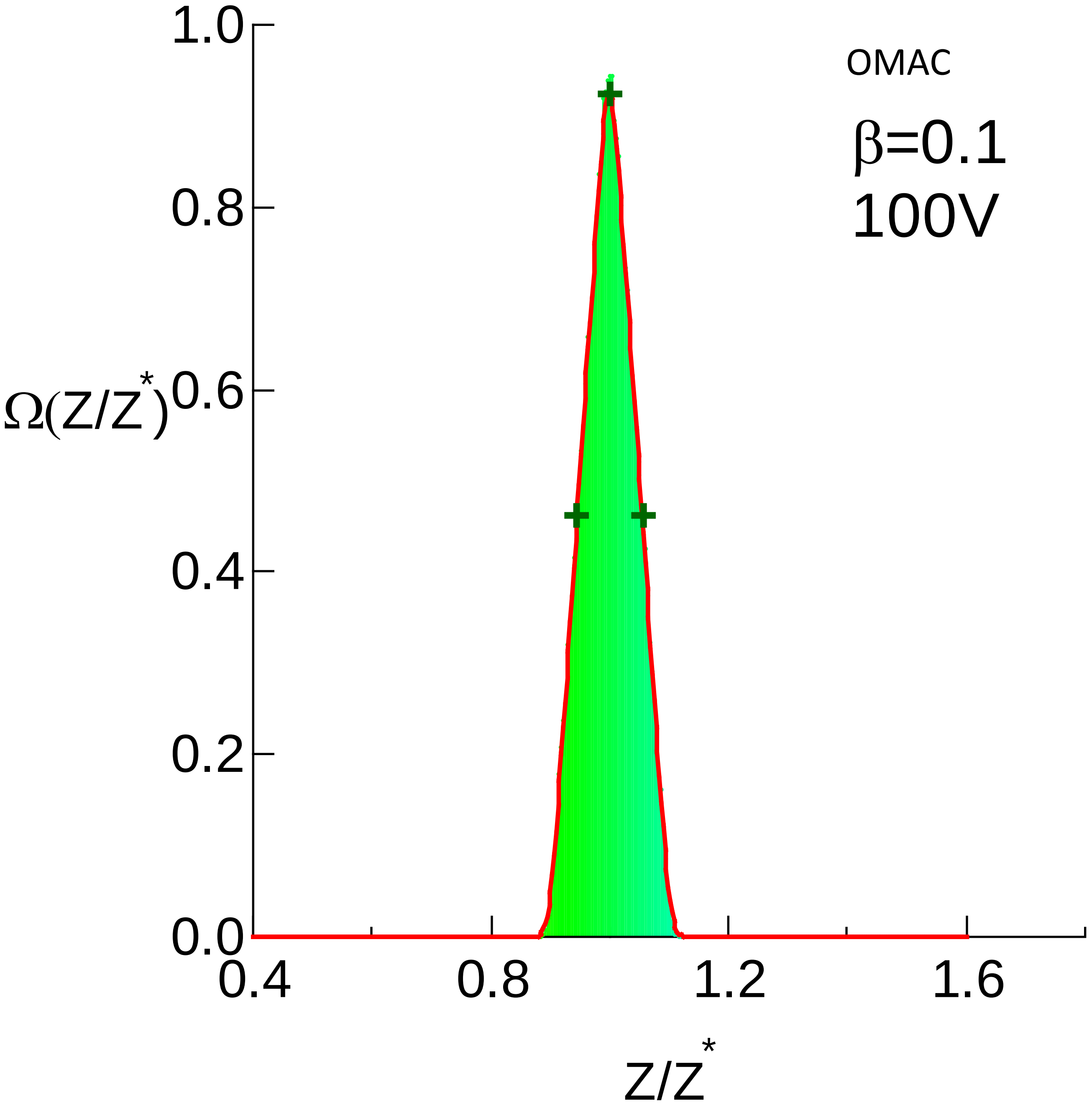


Flagan, *Aerosol Science and Technology*, **38**:890–899, 2004

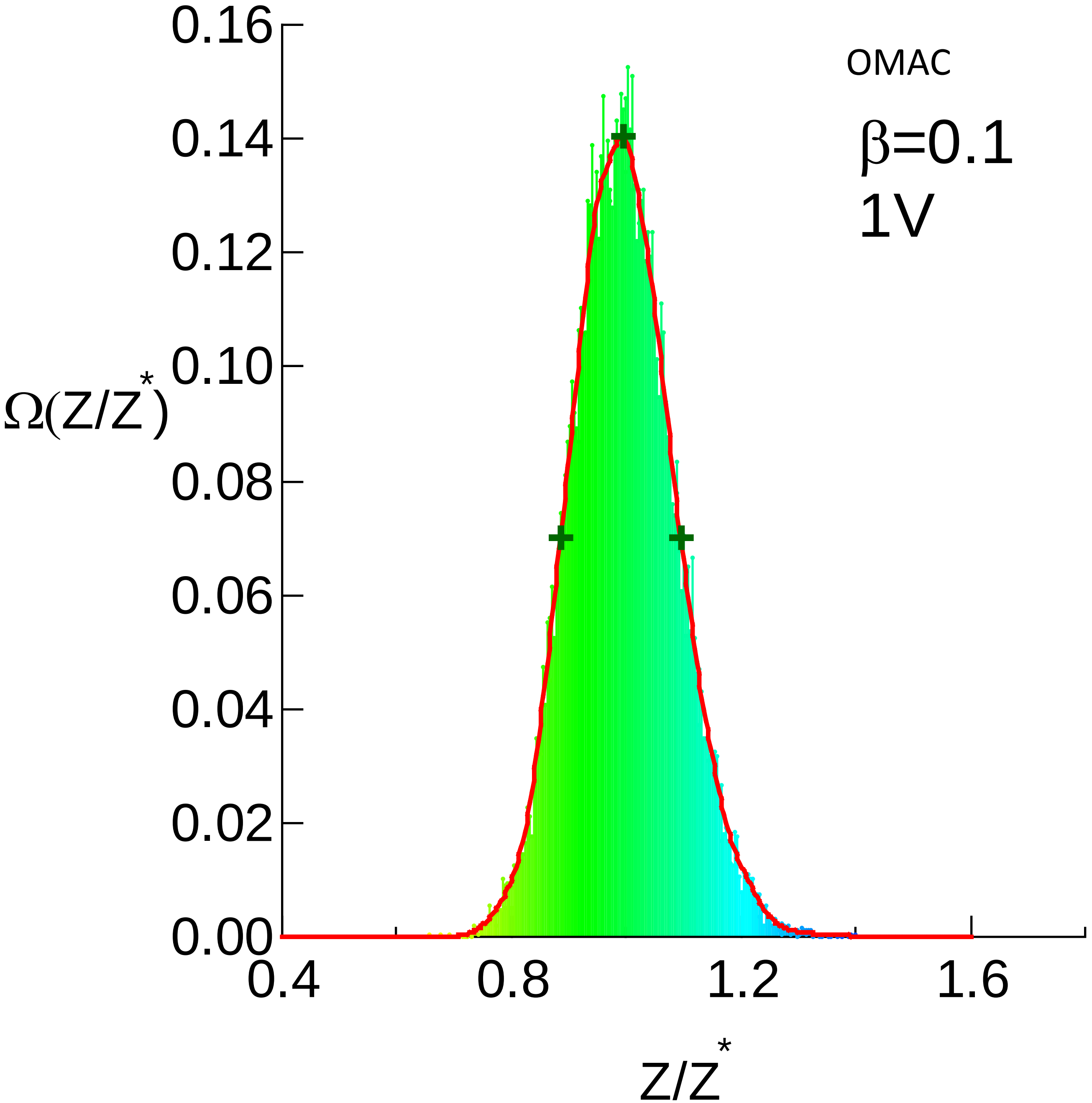
Nano Opposed Migration Aerosol Classier



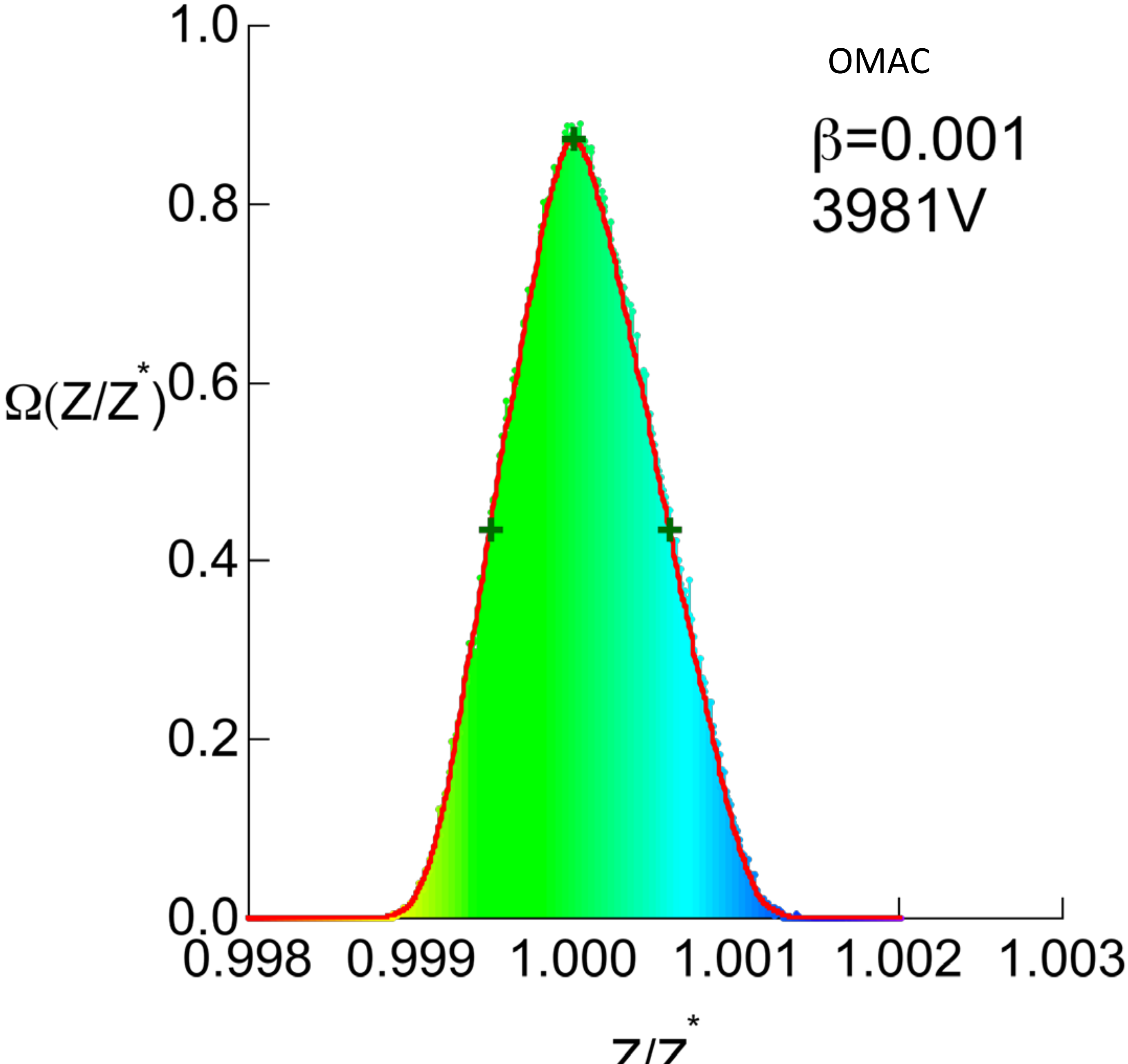
Flagan, *Aerosol Science and Technology*, **38**:890–899, 2004

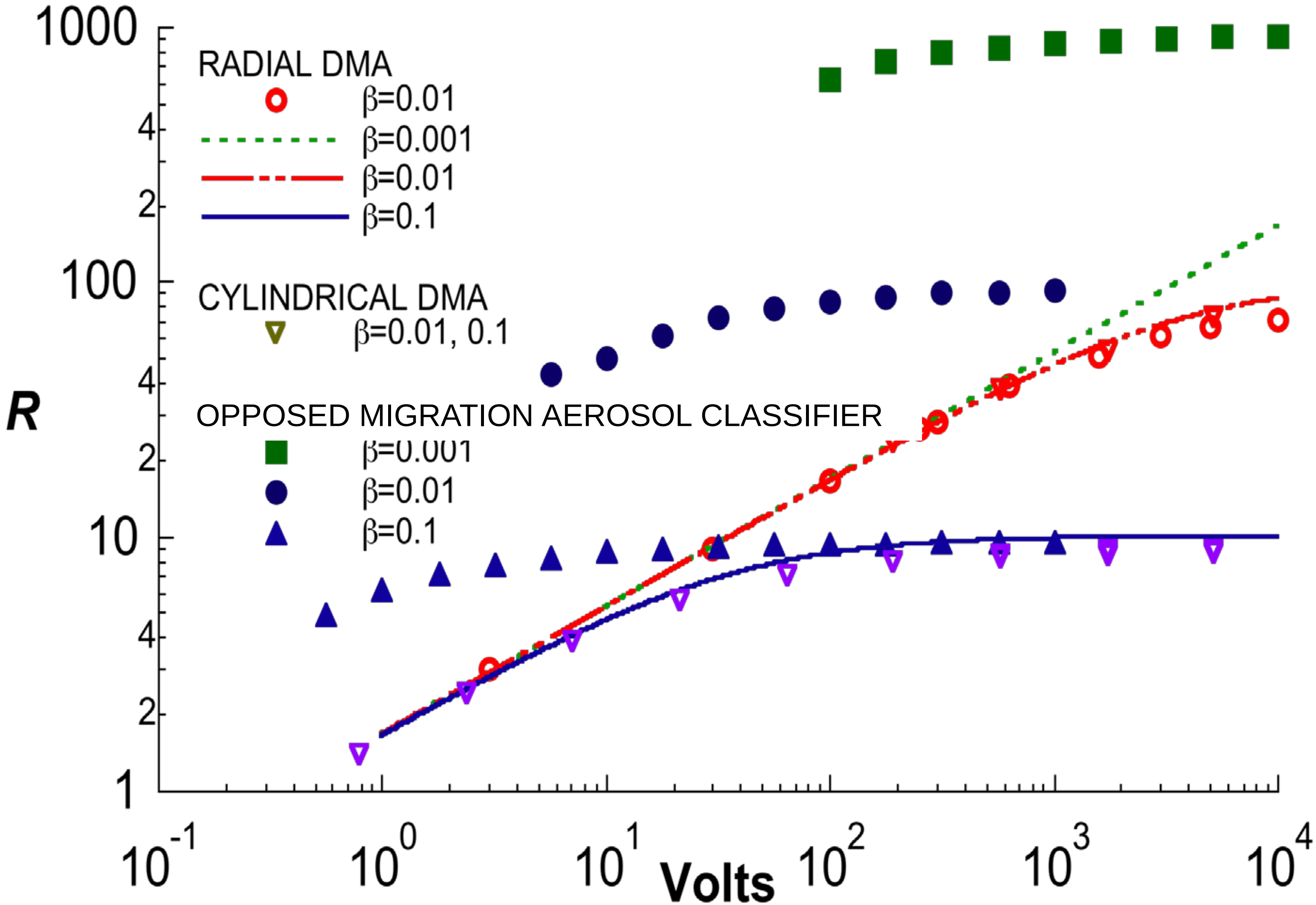


OMAC
β=0.1
100V
Ω(Z/Z*)
1.0
0.8
0.6
0.4
0.2
0.0
0.4
0.8
1.2
1.6
Z/Z*



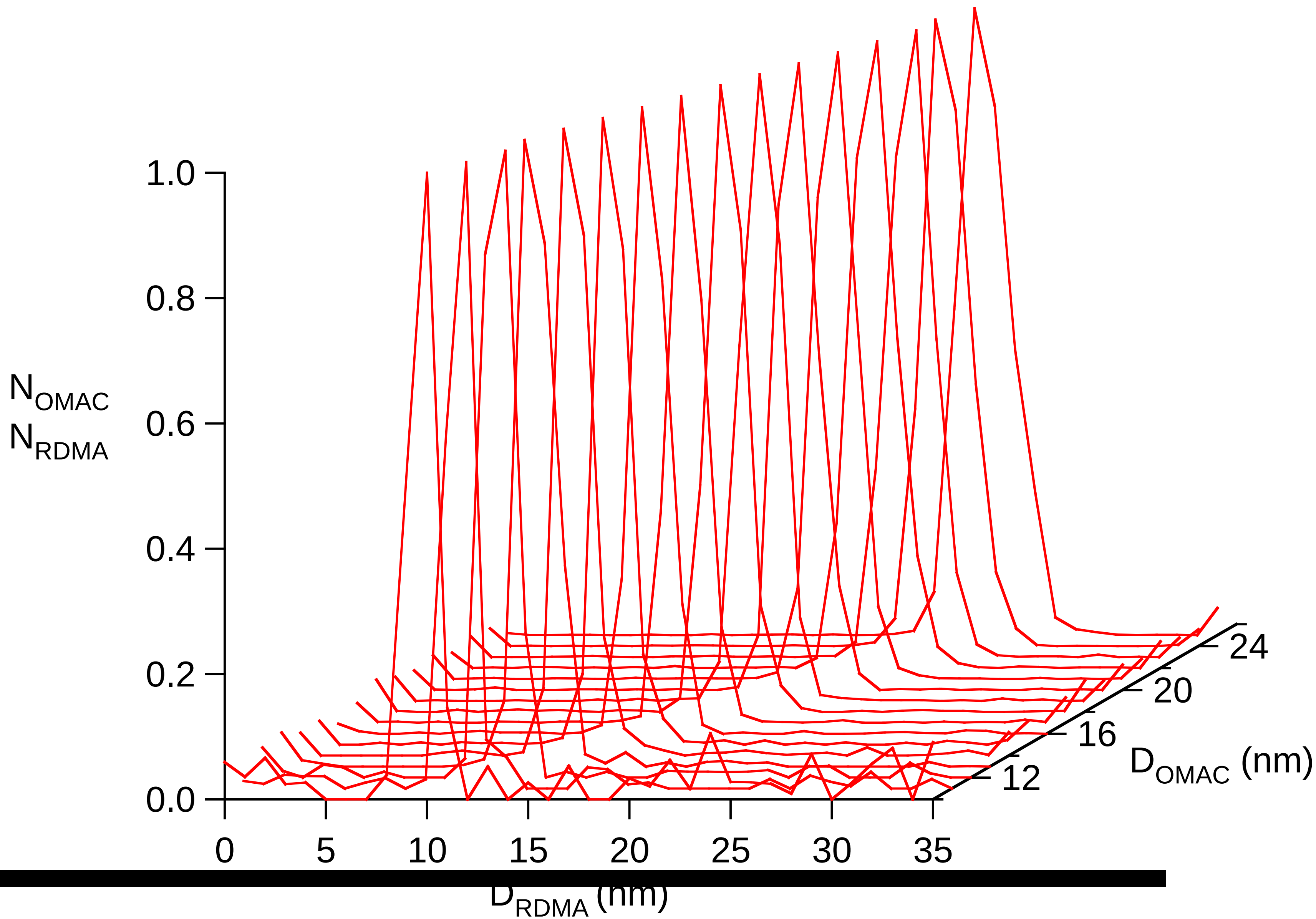
OMAC
β=0.1
1V
Ω(Z/Z*)
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.4
0.8
1.2
1.6
Z/Z*


OMAC
β=0.001
3981V
Ω(Z/Z*)
1.0
0.8
0.6
0.4
0.2
0.0
0.998
0.999
1.000
1.001
1.002
1.003
Z/Z*



Flagan, RC. 2004. Opposed Migration Aerosol Classifier (OMAC). AEROSOL SCIENCE AND TECHNOLOGY 38 (9): 890-899.

OMAC calibration



Mobility Analysis

- Differential Mobility Analyzer (DMA)
  - Proven technology
  - Sequential or parallel measurements now possible
    - Detector time response remains an issue
  - Electrostatic breakdown limits altitude range
  - Need concentration standard
- Opposed migration aerosol classifier (OMAC)
  - Reduces voltage at which diffusion degrades resolution
  - Allows same dynamic range as DMA at lower voltage
    - Reduce size and weight
    - Enable wide dynamic range operation at reduced pressure