EP-SAW for Measurement of Atmospheric Particulate Matter

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Overview

1. Atmospheric Science
    - Analytical and Sensor Applications
2. Atmospheric Particulates
    - Principles
    - Properties and Approaches
3. EP-SAW
    - Electrostatic Precipitation
    - Combining EP with SAWs
    - Preliminary Data
4. Summary

Research in Atmospheric Science

- Chemical Ionisation Mass Spectrometry (CJP)

  Direct detection of radical species[1]

- Development of Sensors

  Real time, lightweight, low power, high spatial coverage

  → *MIP recognition elements + Acoustic waves*

- Current Projects

  MIPs for selective detection of terpenes[2] (linked to ozone)

  Recognition element for polyaromatic hydrocarbons[3] (PAHs)

  Electrostatic Precipitator- SAW for particulate monitoring[4]

[1]Bardwell *et al*., (2002) submitted to *J. Phys. Chem.* A

[2]Percival *et al*, Anal. Chem. (2001) 73 4225-4228.

[3]Percival *et al*., (2002) submitted to *Anal. Chem*

[4]Newton *et al.*, *UK patent no. 0101248.3 (2001)*

Aims

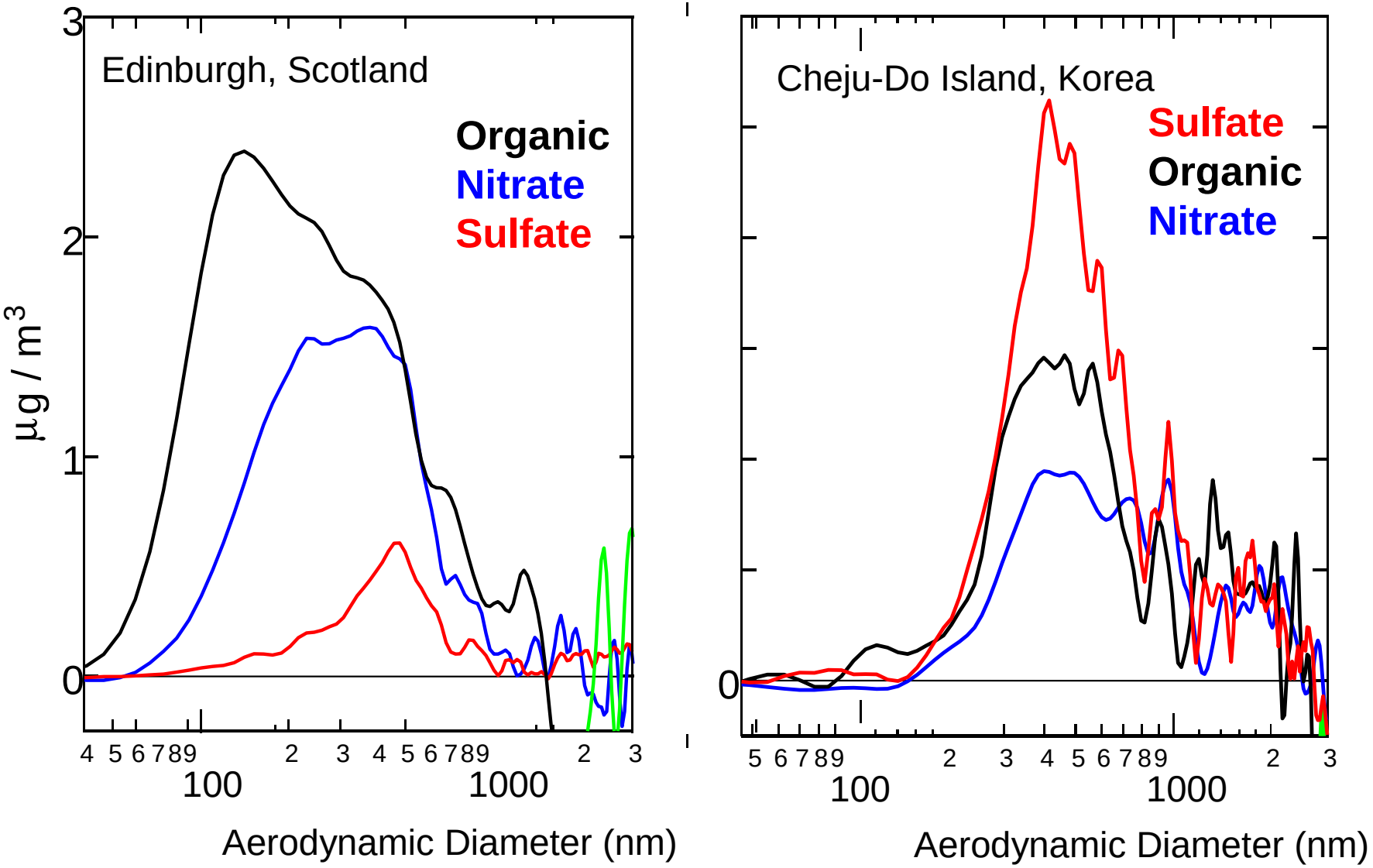
- Atmospheric Particulate Monitoring
  - Real time
  - Spatially resolved
  - Low cost
  - Lightweight
  - Low power instrument
- Combine Proven Technologies
  - Electrostatic precipitators
  - Surface acoustic wave (SAW) “mass” (*surface*) loading sensor
    - *Electrostatic Precipitator-SAW (EP-SAW)*

Atmospheric Particulates

- Radiative Forcing
  - Direct cooling by reflection from atmosphere
  - Indirect cooling by making clouds/reducing flux at surface
- Health Effects
  - PM<10 are breathed in
  - Increased conc's <PM10 suspected to increase mortality
- Atmospheric Budgets
  - Gases adsorb on particulates — Sinks
  - Then act as catalysts for other gases — Sources

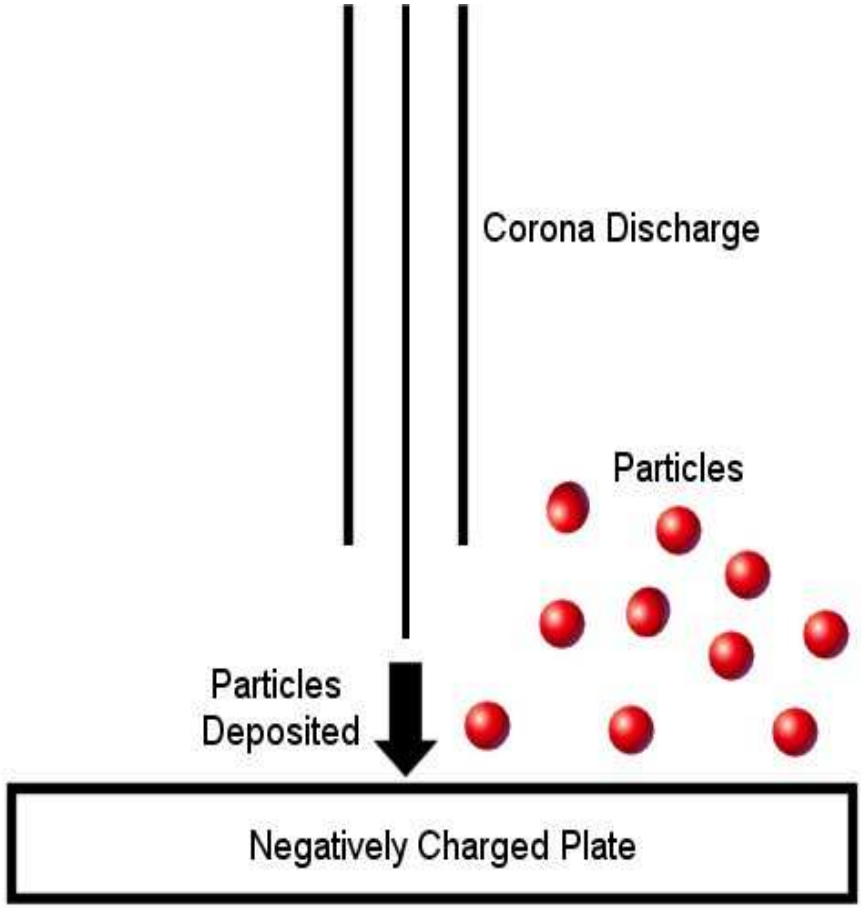
Require *Time and space resolved measurements of particles*

Why Spatially Resolved Data?



Electrostatic Precipitation

- Principle
  - Charged particles deposited
  - onto collector plate
- Existing Successes
  - Fog droplets - Tenberken and Bachman, 1998
  - Atmospherically borne microorganisms - Mainelis *et al.*, 1999
- Mainelis's Work
  - High efficiency 99-100%
  - Particle size 0.05 – 5 μm



EP-SAW

- System Design[1]

  Air sampled via filter

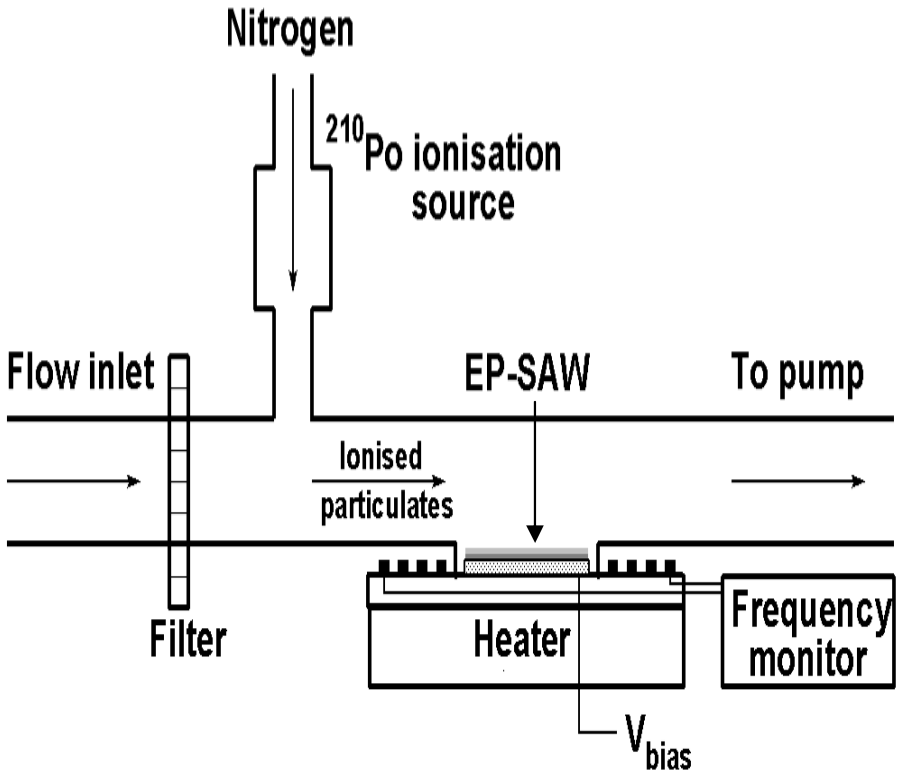
  Particles ionised by N_2^+

  Particles collected onto path of biased metallised SAW

- SAW

  Indicates surface loading

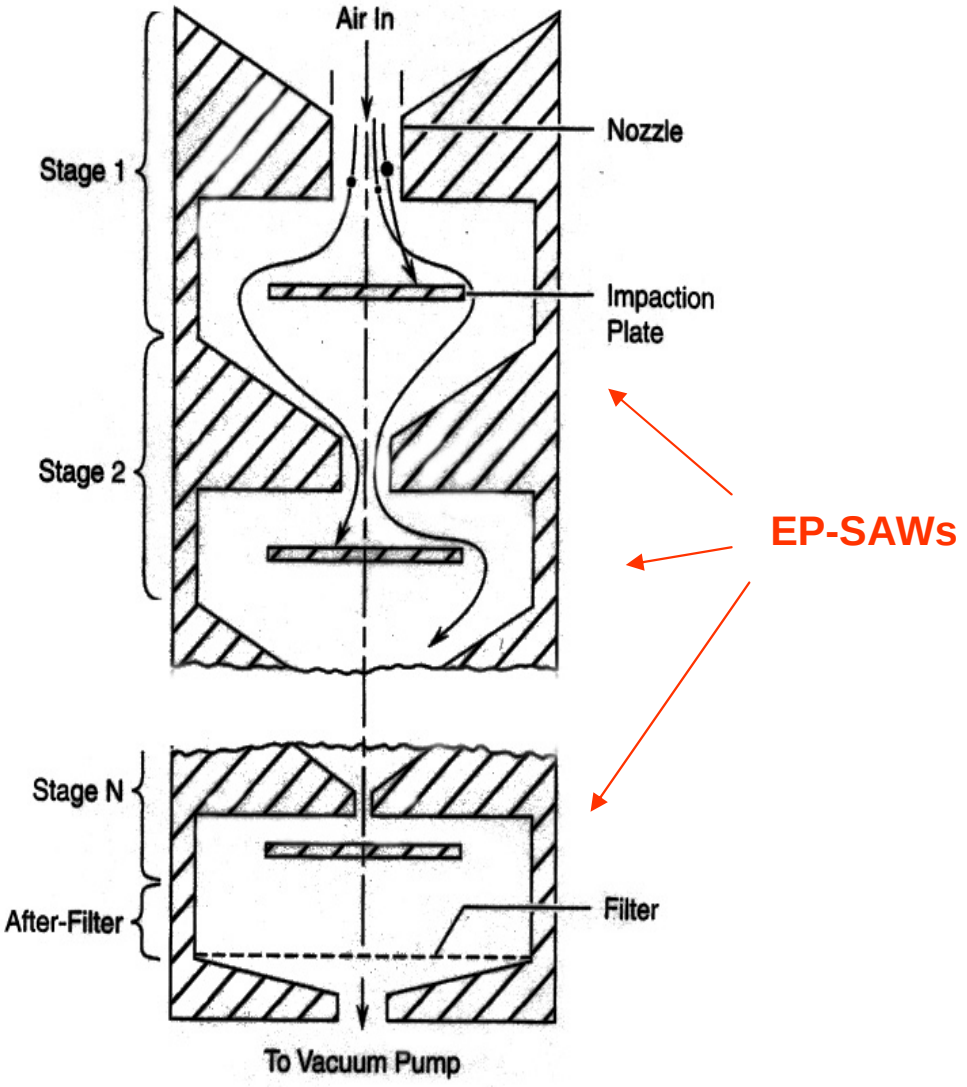
  Real-time measurements



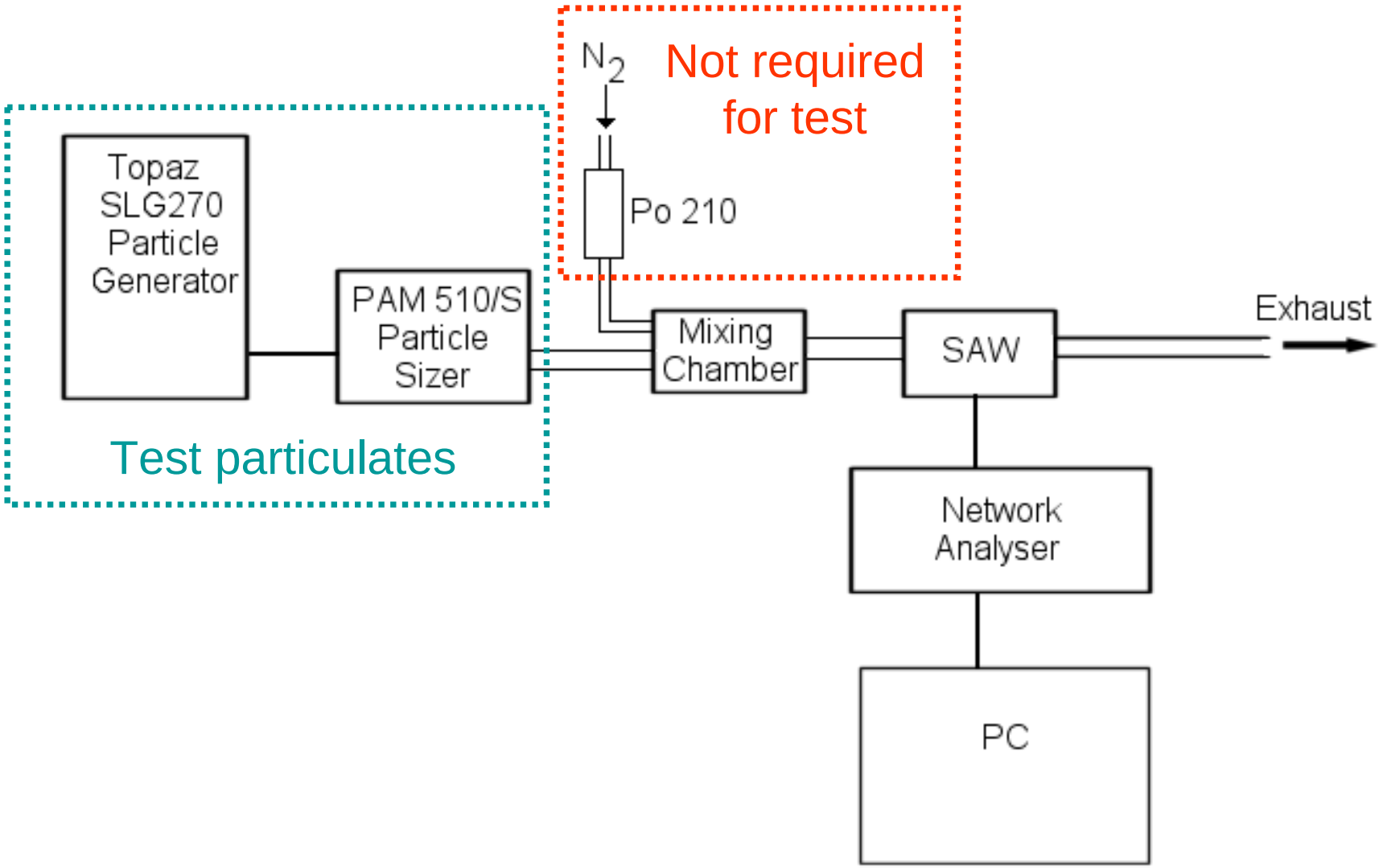
[1] Newton *et al.*, *UK patent no. 0101248.3 (2001)*

Multi Bin Analysis

- Use Multiple EP-SAWs
- Compatible with
  - Filters
  - Cyclone impactors
  - Cascade impactors



Preliminary Experimental Arrangement



Test Particulates

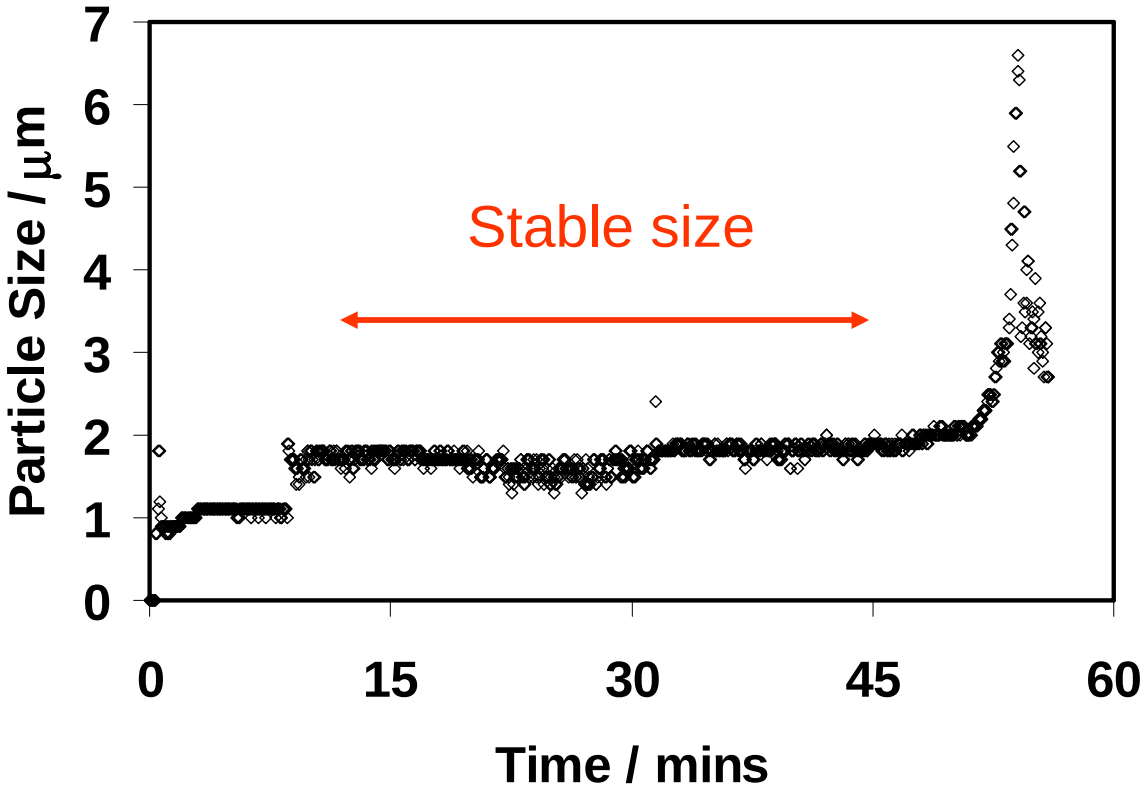
- Test Particulates/Aerosol
  - Mono-disperse ~ 2 μm particles
  - at 298 K and 760 Torr
  - Controllable number concentration
- Production via Nebulisor (Controlled Condensation)
  - Heterogeneous nucleation using NaCl
    - Gas bubbled through saturated NaCl.
    - Dried to get solid (small) NaCl.
    - Passed thro' heated chamber with Bis(2 ethyl hexyl)sebacate.
    - Supersaturated BIS cooled to condense small NaCl particles.

Test Particulate Size Stability

- Test Particulates/Aerosol

  Mono-disperse ~ (2.0±0.1) μm particles

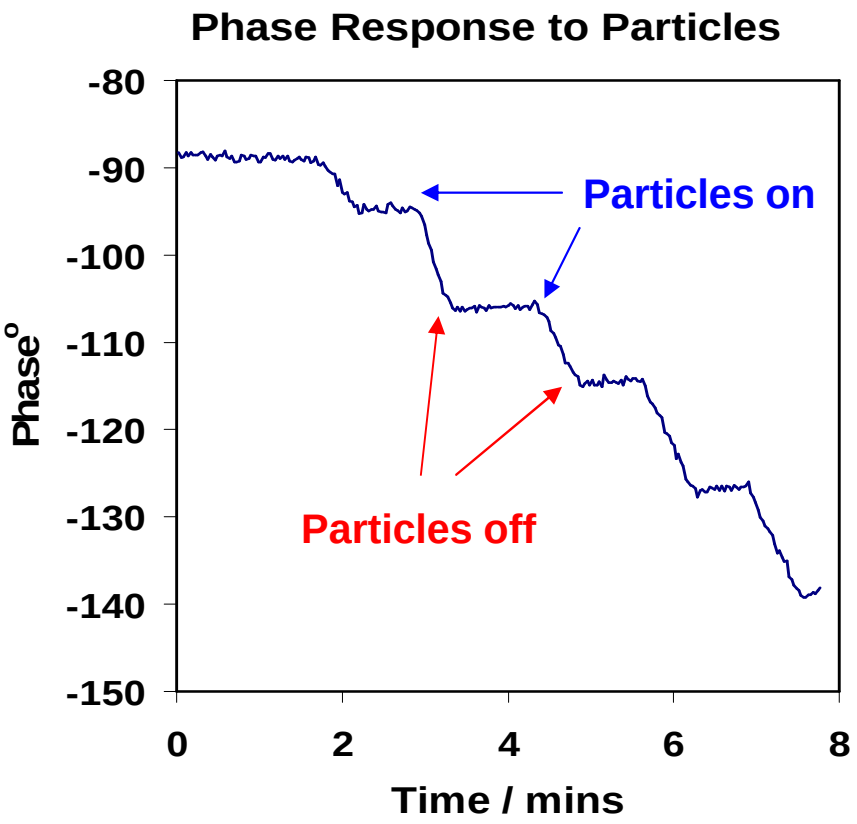
  Number concentration in preliminary tests ~ 10^6

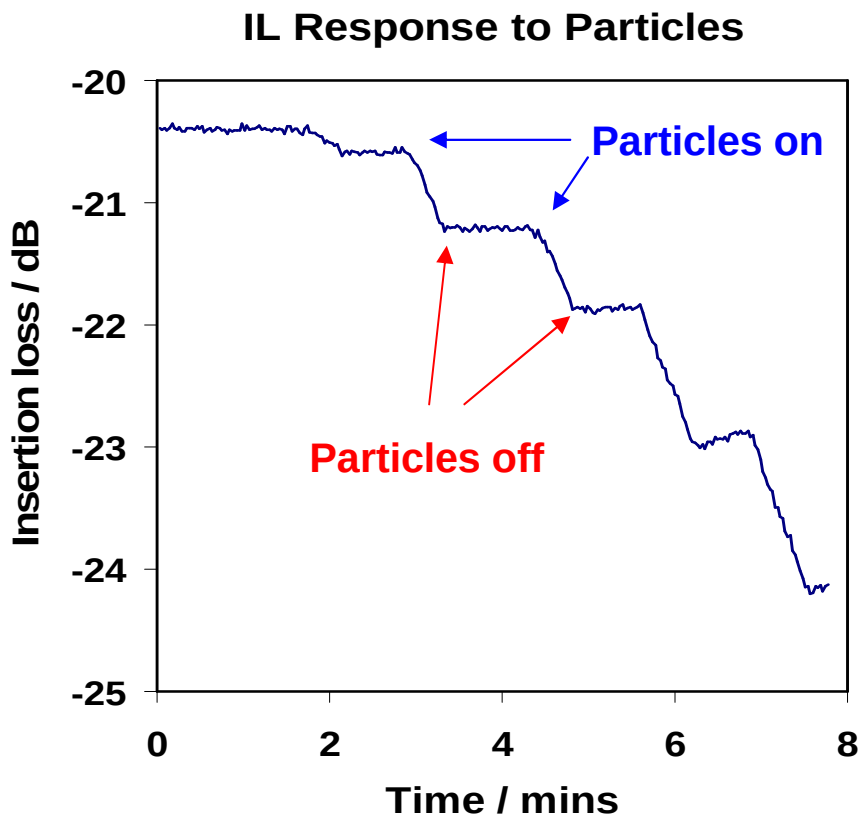


Settling of Particulates

- SAW Device *No Bias Voltage*

$LiNbO_3$ - Rayleigh-SAW, $\lambda \sim 45$ μm, 86 MHz + 253 MHz



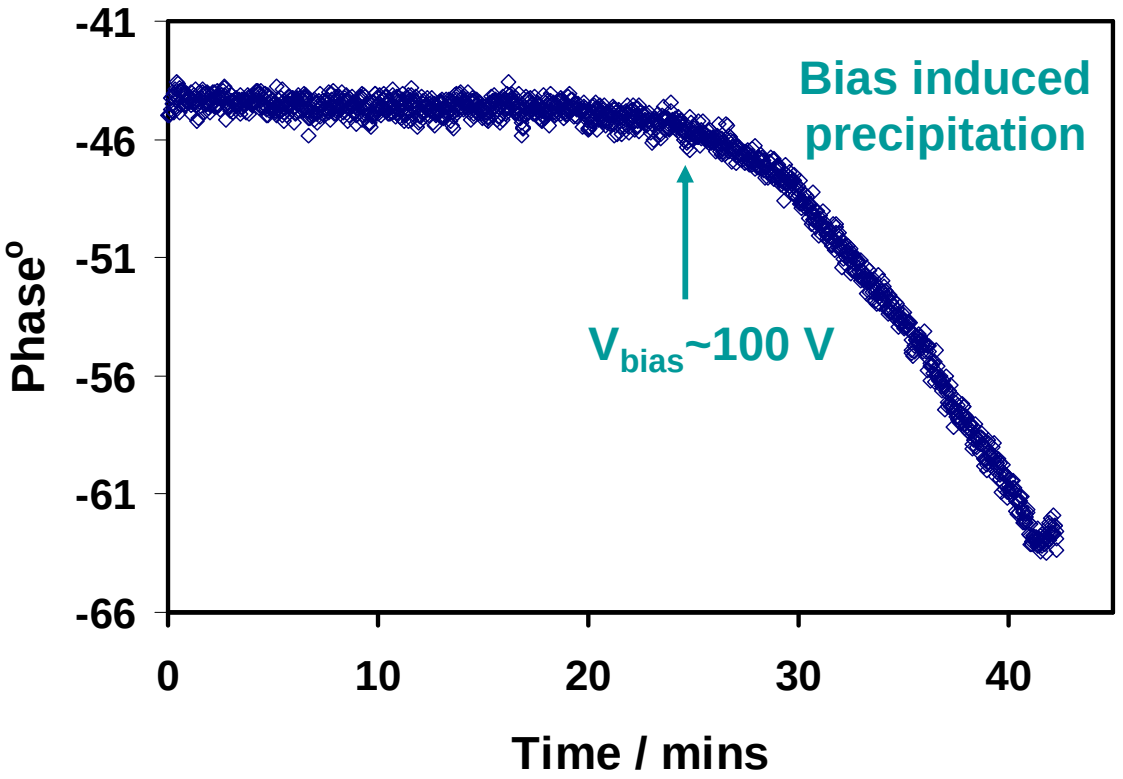


Reverse orientation ⇒ No response

Particulate Response with Bias

- Voltage of plate increased to > 120 V in 20 V steps

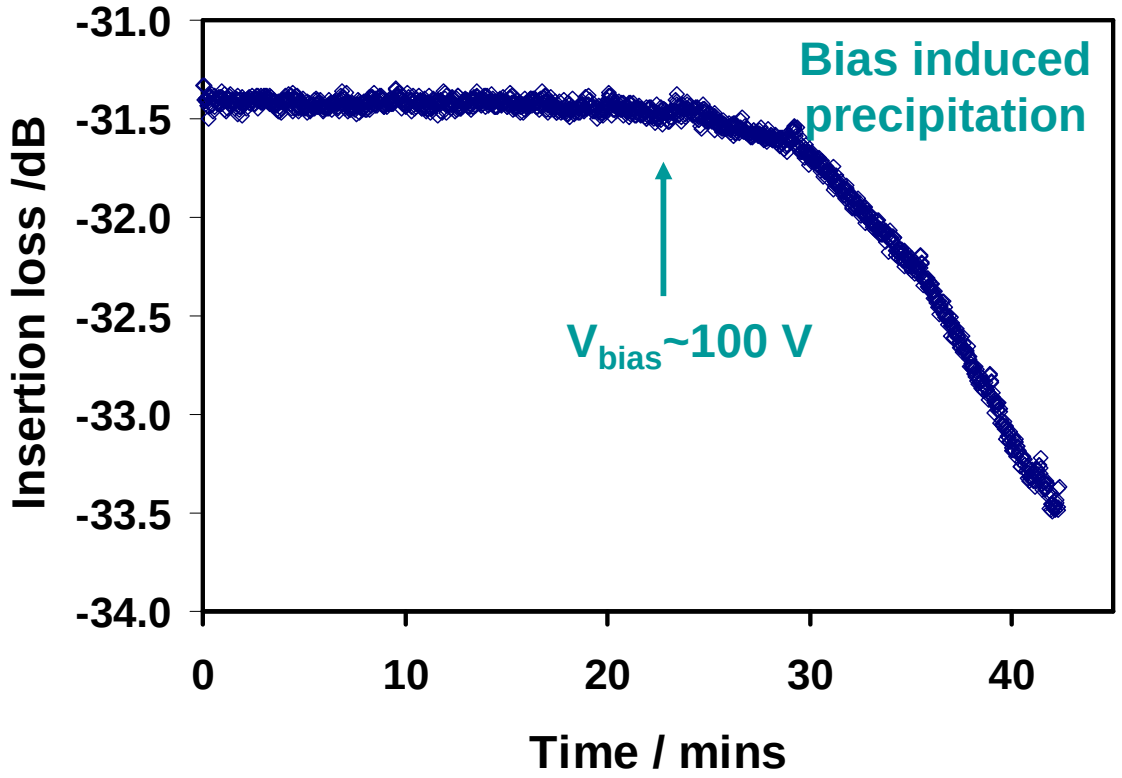
  ⇒ Phase changes



Particulate Response with Bias

- Voltage of plate increased to > 120 V in 20 V steps

  ⇒ Insertion loss changes



Particulate Response with Bias

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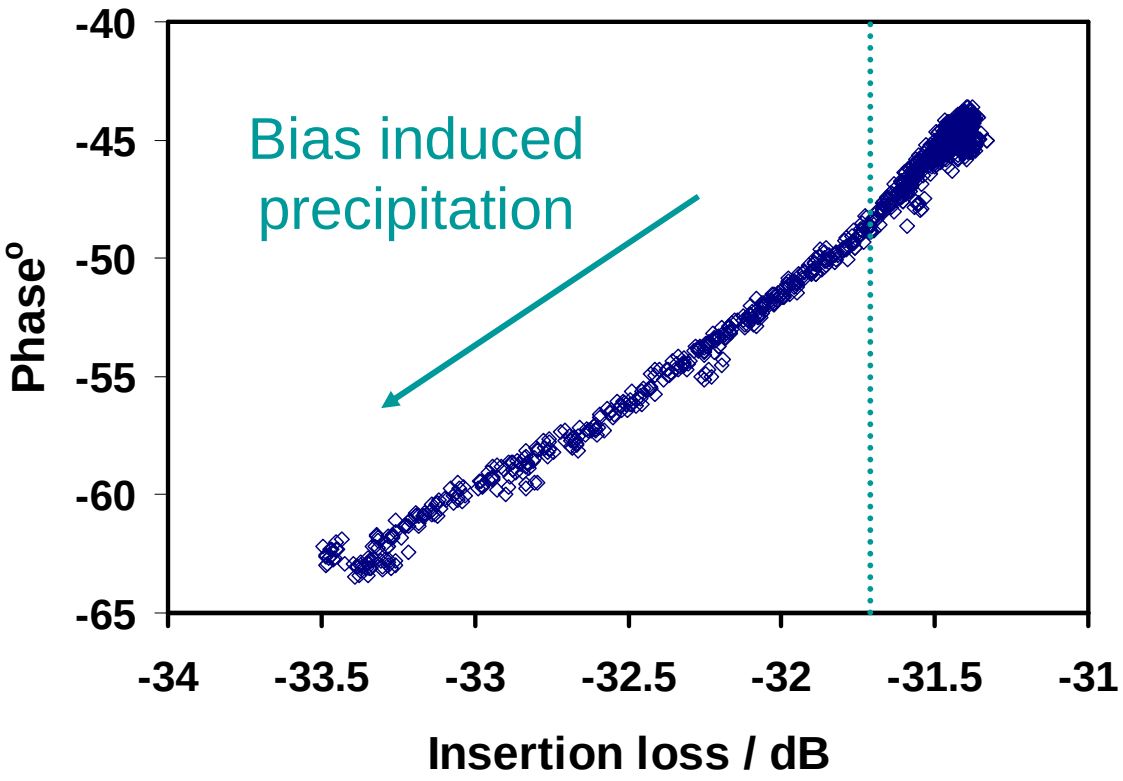
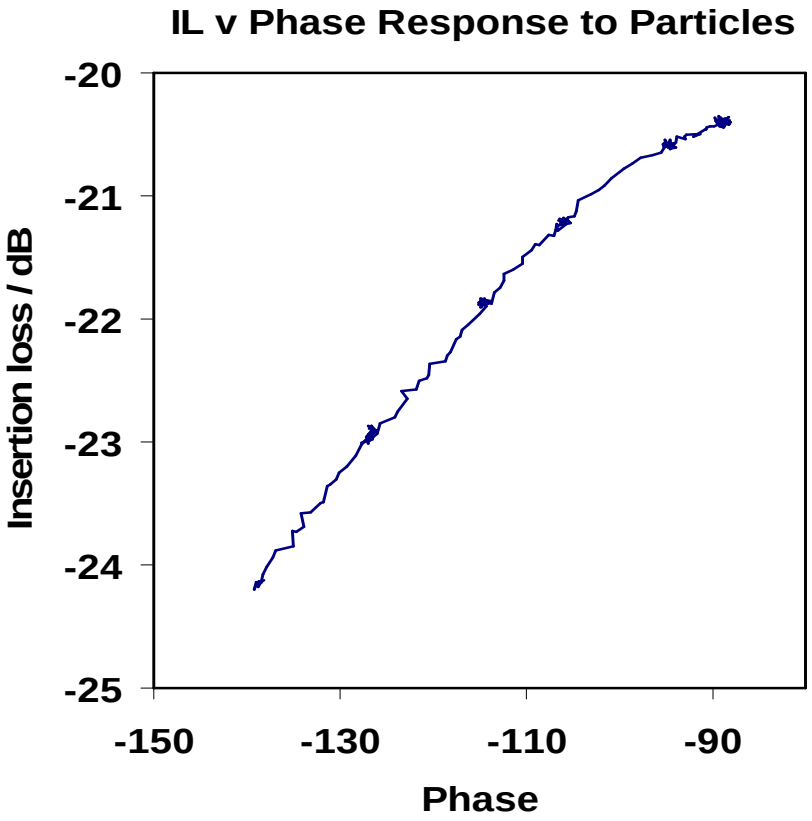
Phase v Insertion loss



Summary

- Feasibility of EP-SAW Principle ✓
- Basic Work Still Needed
  - Complete experimental rig
  - Size/concentration/constituents experiments
  - Interpretation of SAW response
- Future Aims
  - Extend towards field instrument
  - Develop high throughput measurements

The End


IL v Phase Response to Particles
-20
-21
-22
-23
-24
-25
Insertion loss / dB
-150
-130
-110
-90
Phase