

# **Electrostatic Enhanced Compact Aerosol Concentrator Development**

**Presented at the 2003 Joint Service Scientific  
Conference on Chemical & Biological Defense  
Research**

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Sarnoff Corporation

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# Report Documentation Page

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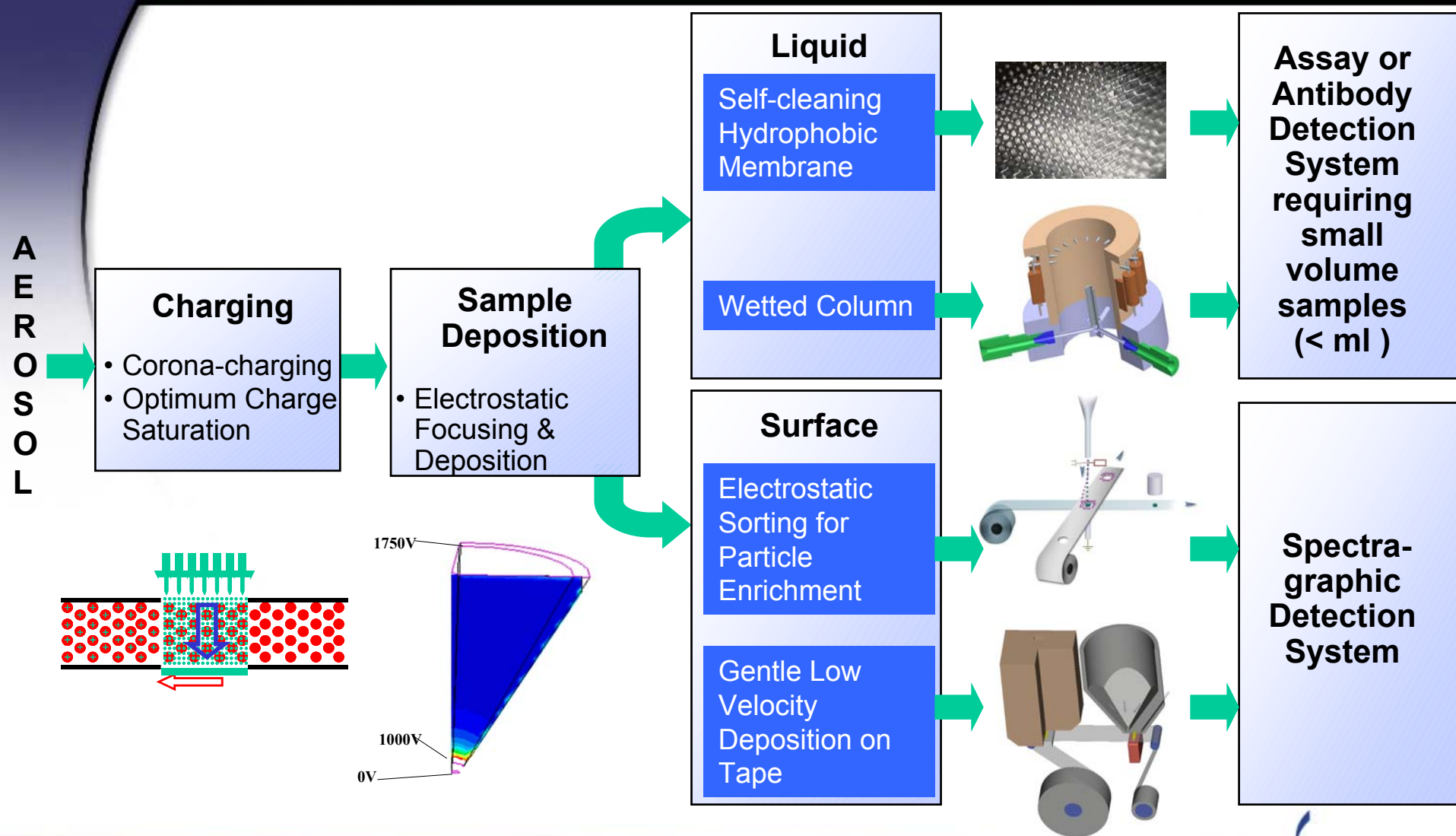
# Electrostatic Collection Technology

## Acknowledgements

- **The Electrostatic Enhanced Compact Aerosol Concentrator Development Program is part of the Technology Transfer Program being funded by DTRA / SBCCOM, under the technical direction of the Edgewood Chemical Biological Center**
- **Technical Point of contact Dr. J. Bottiger, Dr. E Steubing**

# Electrostatic Collection Technology

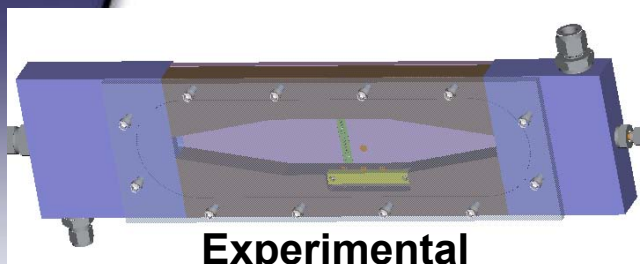
...versatile technology capable of interfacing to many detection modalities...



# Electrostatic Enhanced Compact Aerosol Concentrator Development

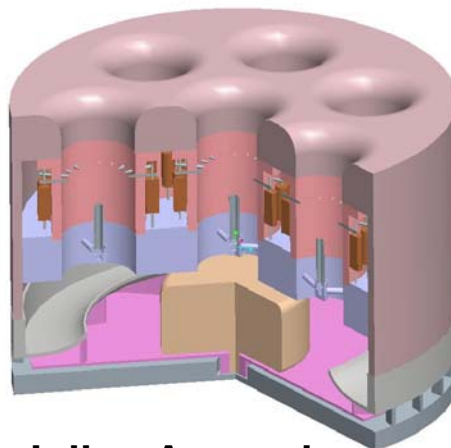
...Roadmap...

**FY 03**



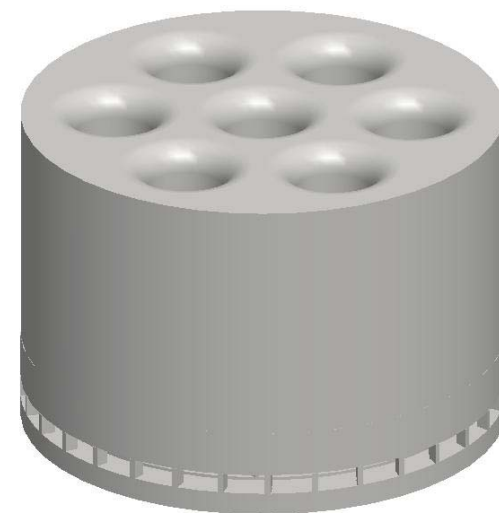
**Experimental  
Electrostatic Capture  
Module**

**FY 04**



**Inline Aerosol  
Concentrator**

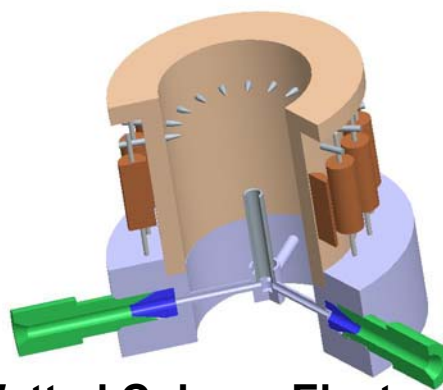
**FY 05**



**Compact Electrostatic  
Aerosol Concentrator  
Prototype**



**Hydrophobic Membrane**



**Wetted Column Electrostatic  
Capture Module**

# Electrostatic Enhanced Compact Aerosol Concentrator Development

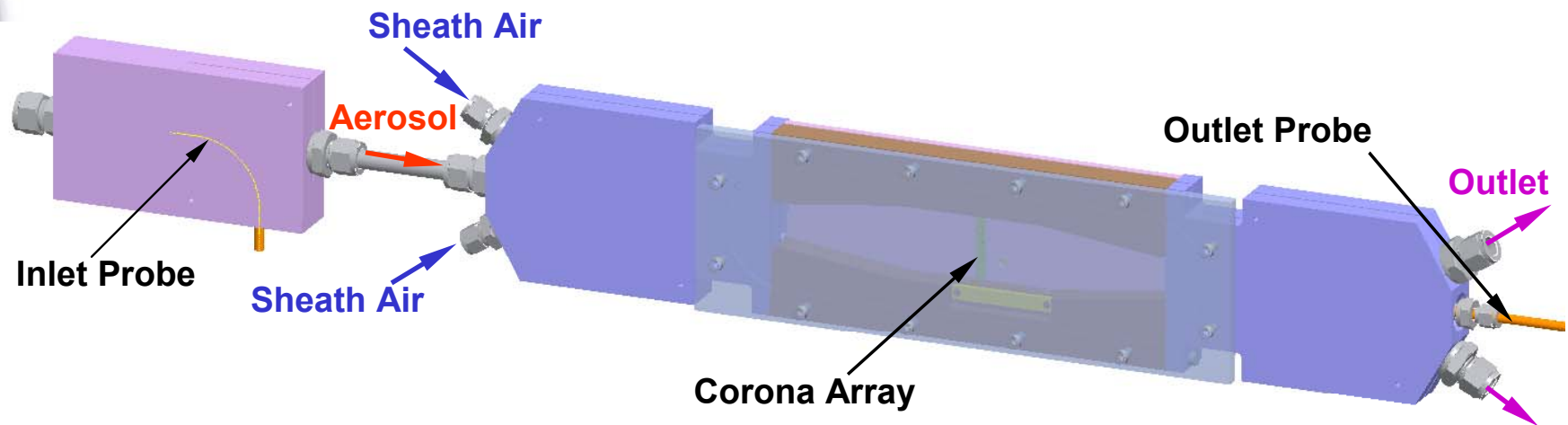
*...Description of Current Effort...*

- **Moderately concentrated aerosol drawn through experimental capture duct**
  - **simulates the output of a cyclone concentrator**
  - **monodispersed aerosol consisting of fluorescent beads**
  - **sheath air employed to confine aerosol stream**
- **Electrostatically charged by corona array**
- **Particles electrostatically focused directly into small liquid volume**
  - **beads deposited on solid surface in initial experiments**
- **Component configuration modified to optimize collection efficiency**
- **Performance determined by fluorescent imaging techniques**

# Electrostatic Enhanced Compact Aerosol Concentrator Development

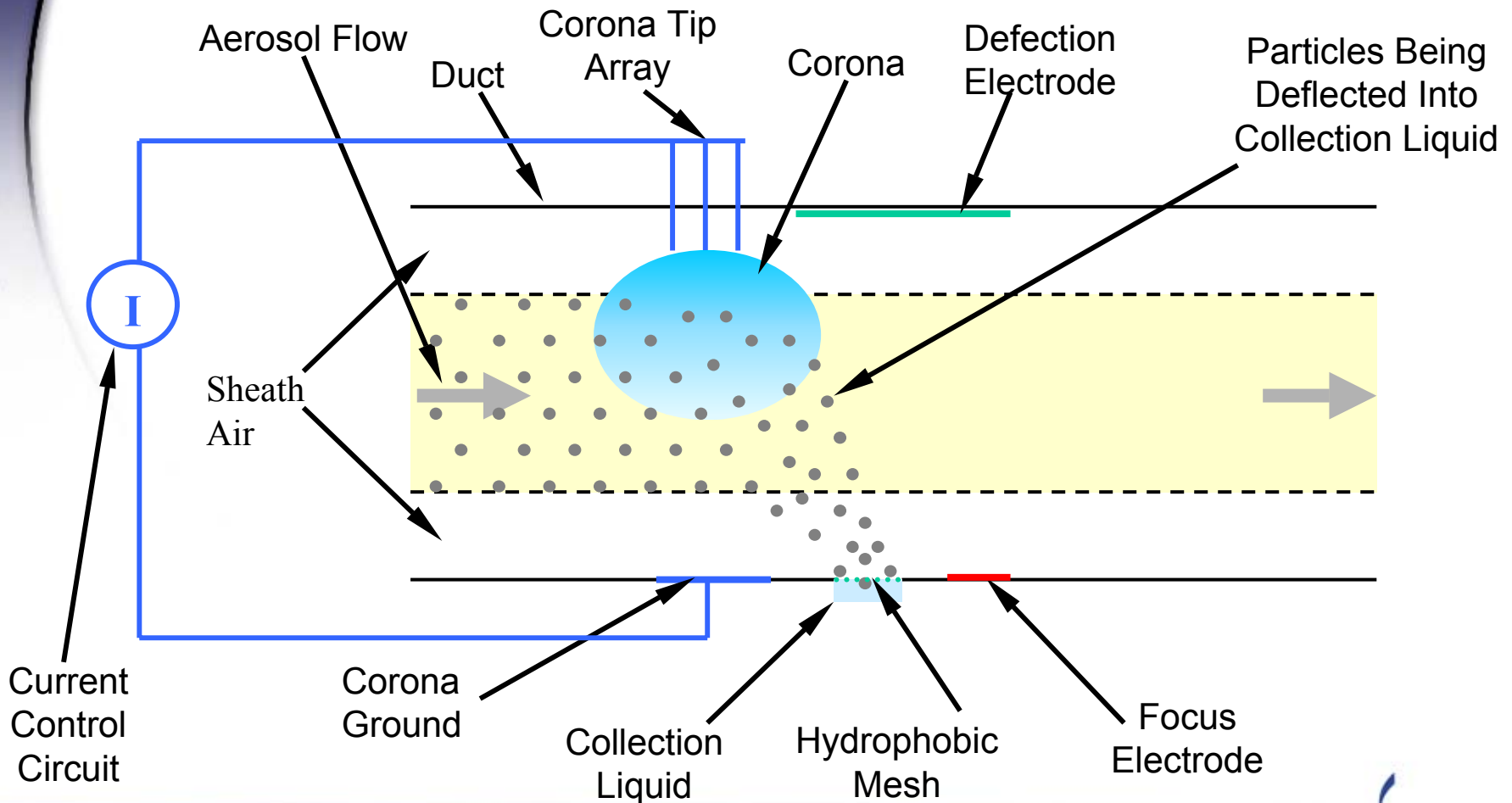
*...experimental set-up for optimizing electrostatic capture configuration...*

## Orthogonal Collection Approach



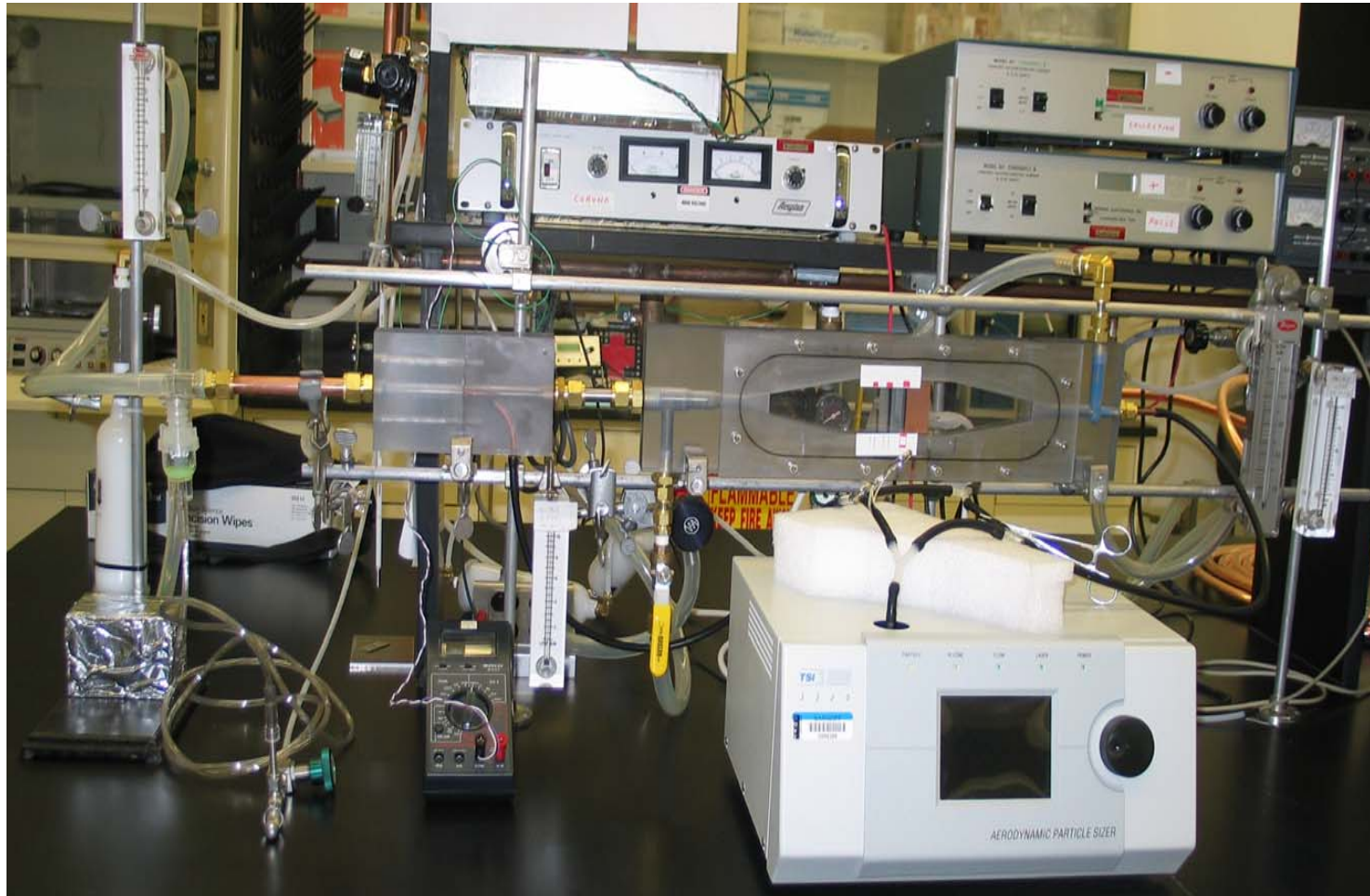
# Electrostatic Focusing of Particles Into a Liquid Using Corona Charging & Transport

## Operation Schematic for Orthogonal Collection Approach



# Electrostatic Enhanced Compact Aerosol Concentrator Development

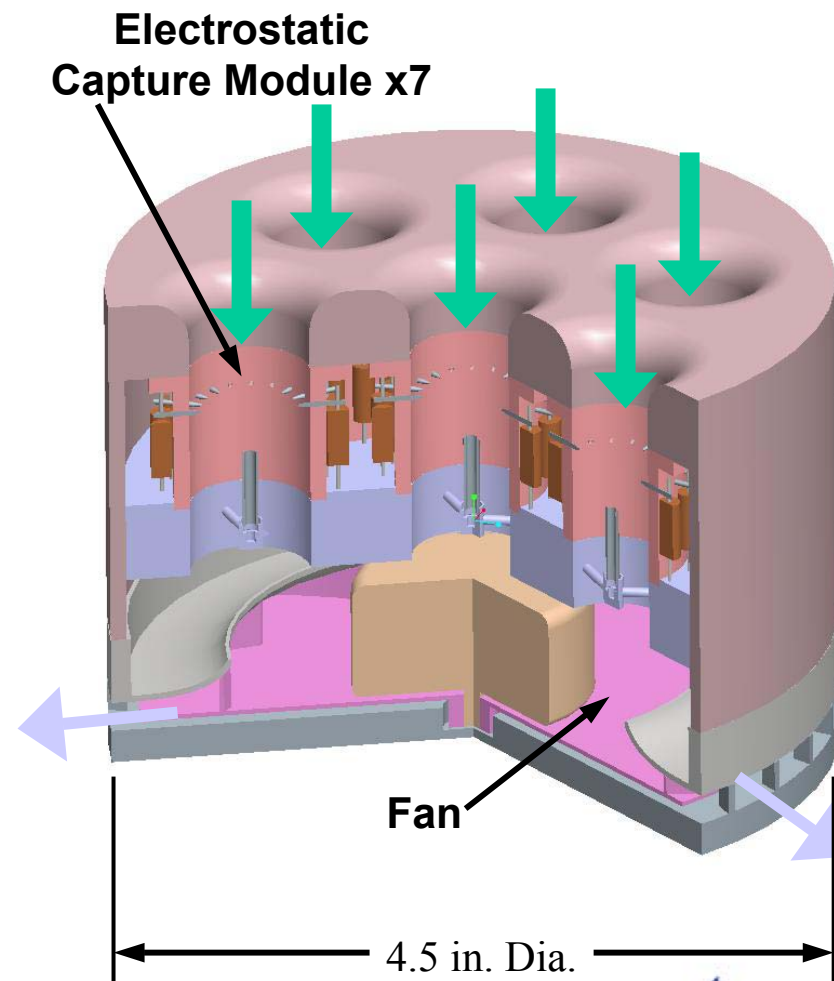
*...experimental set-up for optimizing electrostatic capture configuration...*



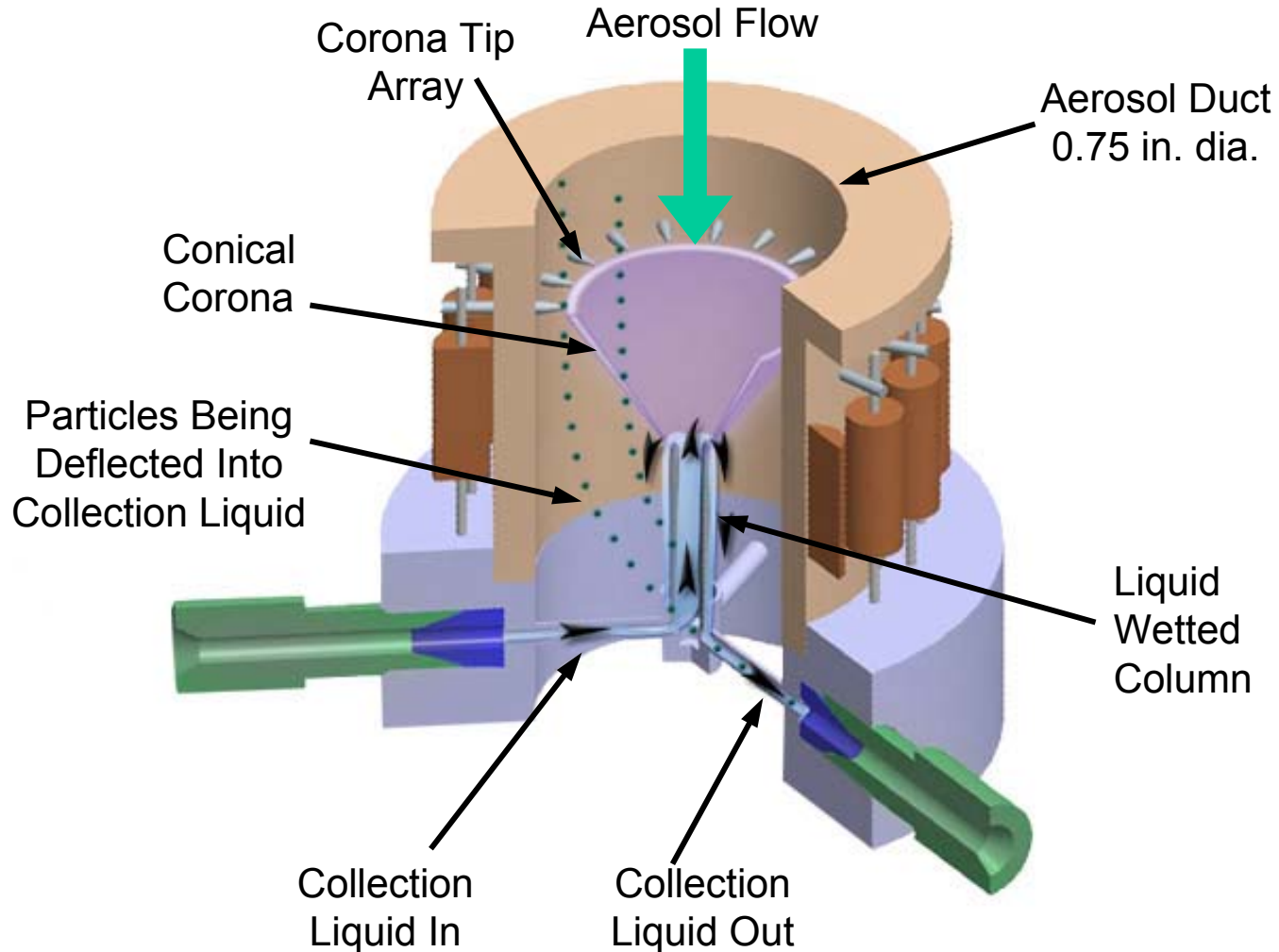
# Compact Electrostatic Aerosol Concentrator

*...compact, low power, high flow rate...*

- **Direct aerosol concentration without energy consumptive inertial separation process upstream**
  - Pressure drop orders of magnitude lower than inertial separation collector
  - 7 unit array samples 210 LPM with 1 watt fan
- **Particles charged by radial array of corona tips**
- **Particles deposited onto small liquid wetted column located on the axis of the aerosol duct**

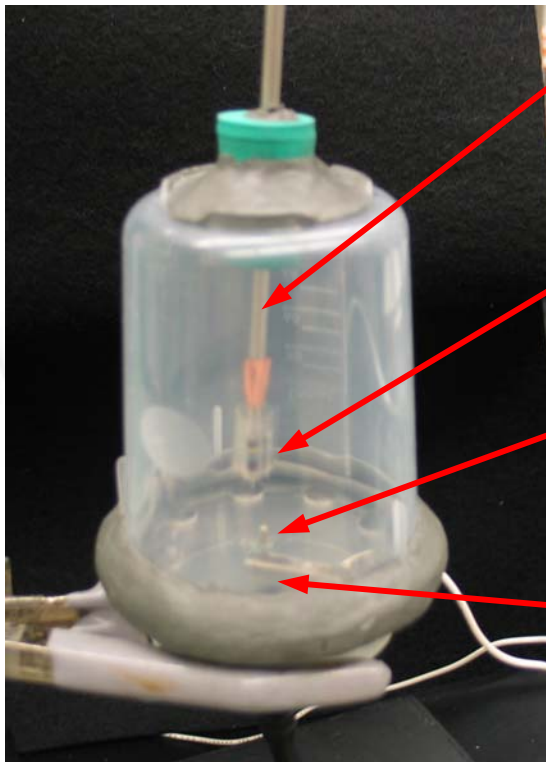


# Electrostatic Focusing of Particles Onto Liquid Wetted Column Concept



# Electrostatic Focusing of Particles Onto Column Experiments

## Test Setup

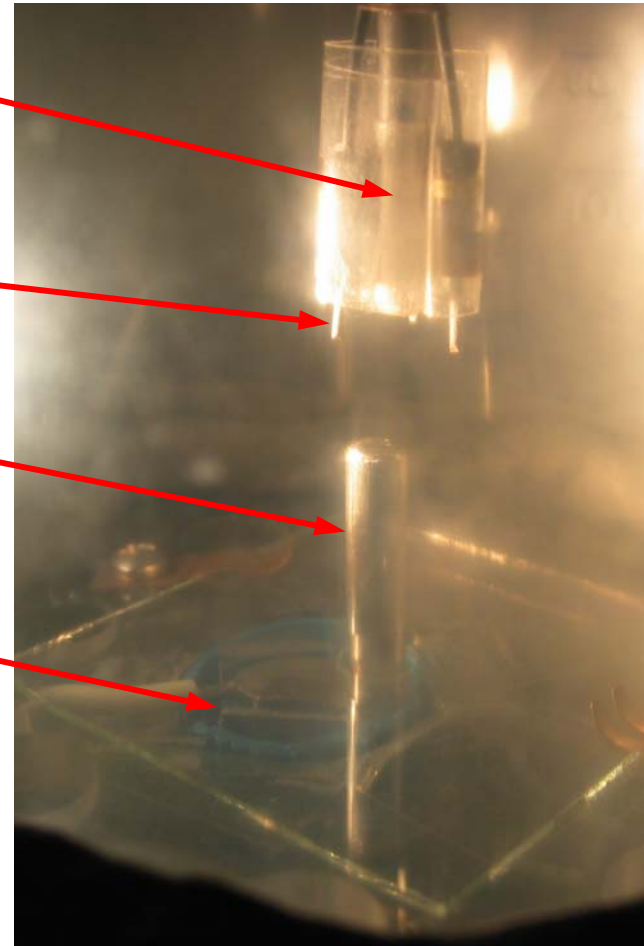


2.5 mm diameter nozzle

Corona Array

1.5 mm dia. dry column

ITO coated glass focus electrode

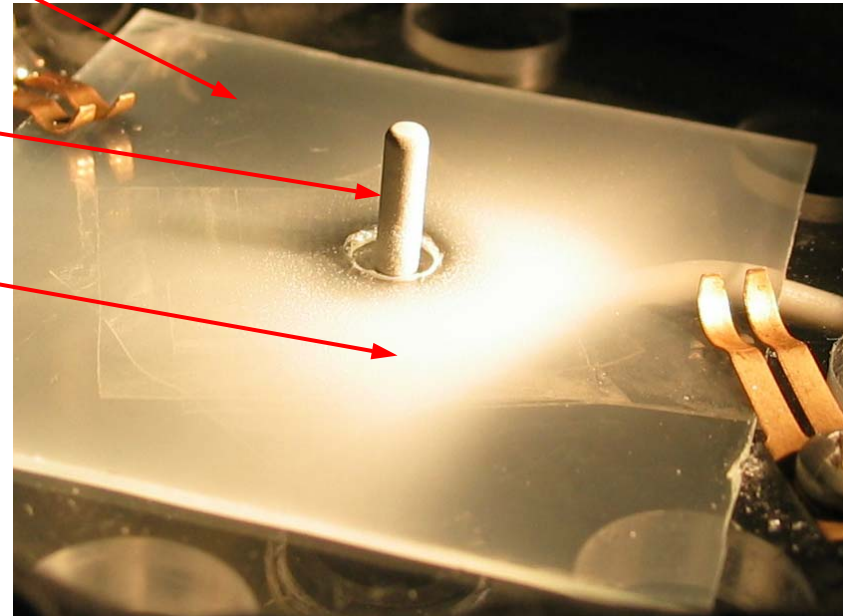


# Electrostatic Focusing of Particles Onto a Column Experiments

**Electrostatic deposition of smoke onto a 1.5 mm diameter dry column @ 1 liter per minute aerosol flow rate through 2.5 mm diameter nozzle**

ITO coated glass  
focus electrode

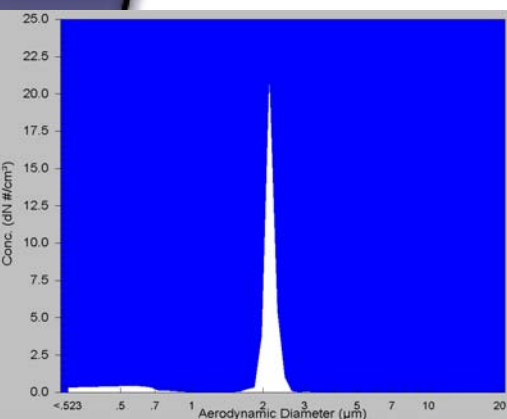
1.5 mm diameter dry column  
ground electrode



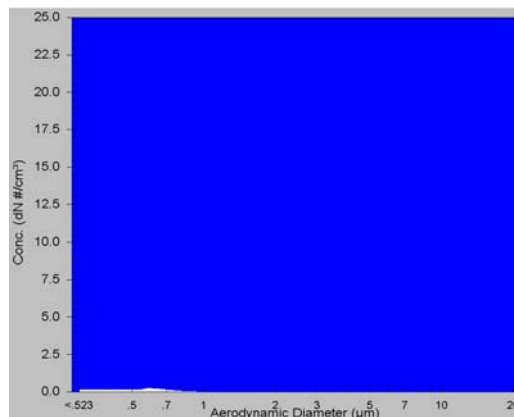
- Excess deposition beyond column occurs when deposited particles form insulating layer preventing newly arriving particles from discharging to the column ground
- The particles then repel each other causing them to be deposited on the surrounding surface.
- This will not occur in the actual implementation of the technology where the aerosol density is orders of magnitude lower than that of the smoke used to visualize the aerodynamic characteristics of the collector.

# Electrostatic Focusing of Particles Onto Column Experiments – AEROSOL DATA

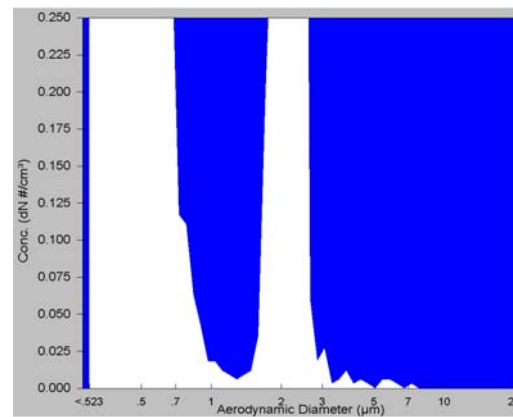
Electrostatic deposition of 2.3  $\mu$  beads onto a 2 mm diameter dry column with 3 mm diameter nozzle @ 1 liter per minute aerosol flow rate



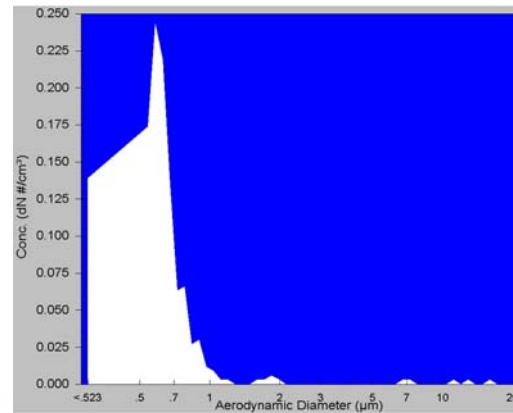
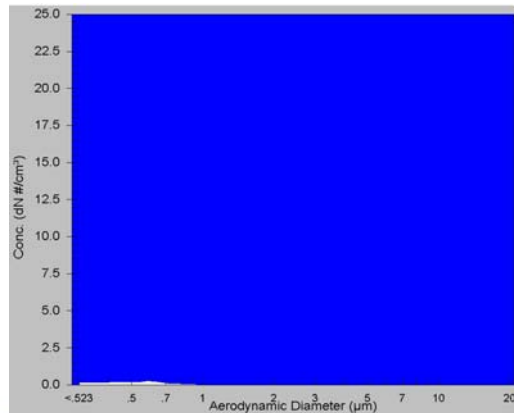
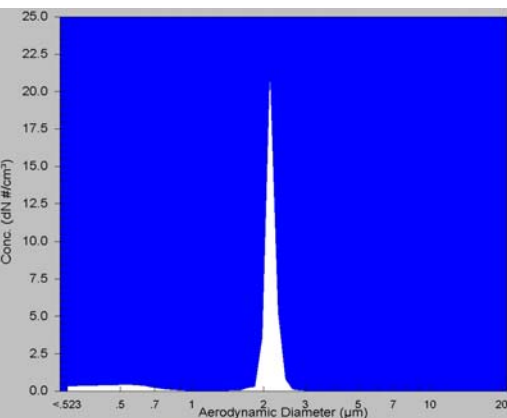
Electrostatics Off



Electrostatics On



Electrostatics Off 10X  
Electrostatics On 10X

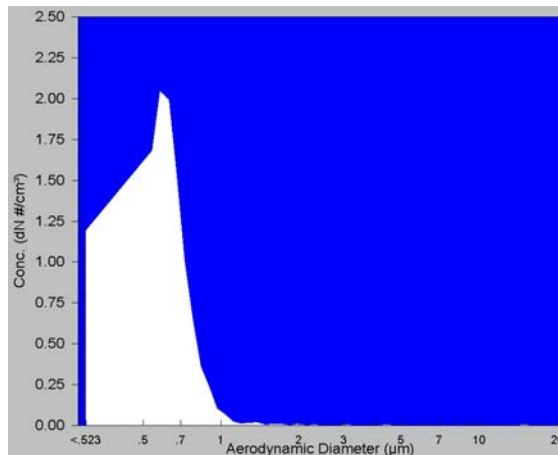


> 99% of 2.3  $\mu$  Particles Removed From Aerosol by Electrostatic Collection

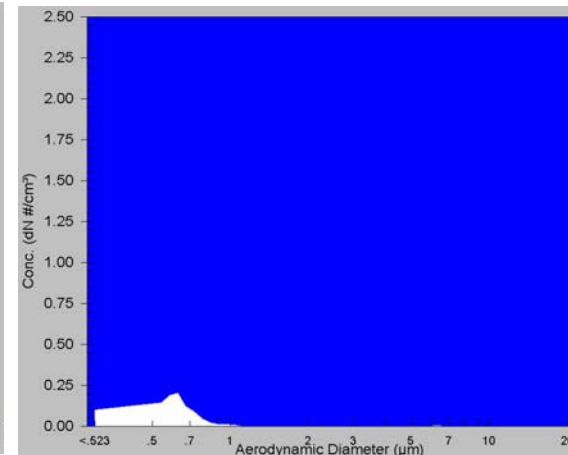
# Electrostatic Focusing of Particles Onto Column Experiments – AEROSOL DATA

Electrostatic deposition of room air onto a 2 mm diameter dry column with 3 mm diameter nozzle @ 1 liter per minute aerosol flow rate

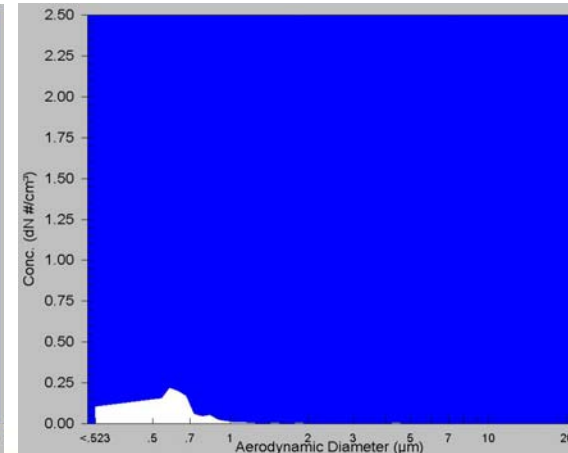
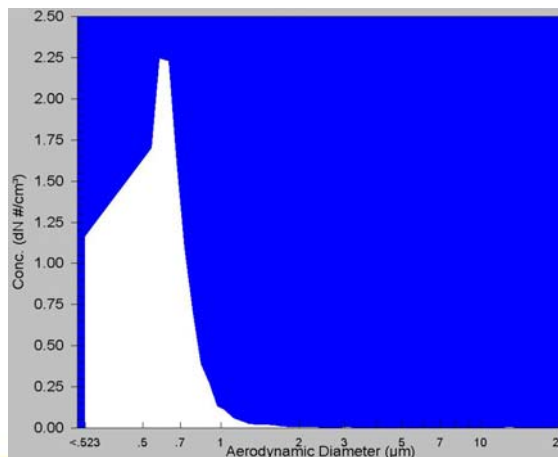
**> 90% of 0.5  $\mu$ m Particles removed from Aerosol by Electrostatic collection**



**Electrostatics Off**

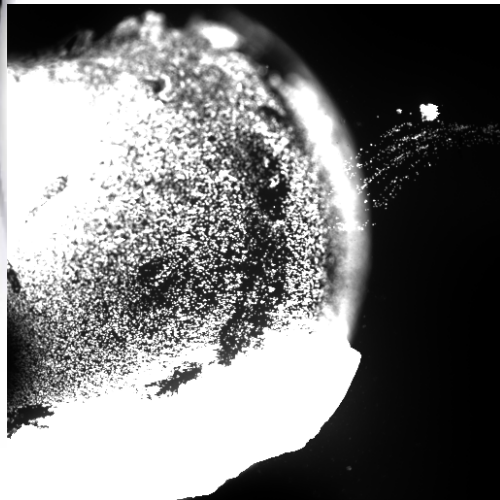


**Electrostatics On**



# Electrostatic Focusing of Particles Onto Column Experiments – DEPOSITION DATA

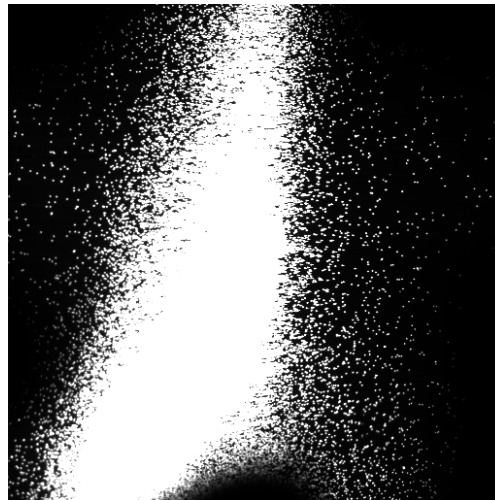
**Electrostatic deposition of 2.3  $\mu$  fluorescent beads onto a 2 mm diameter dry column with 3 mm diameter nozzle @ 1 liter per minute aerosol flow rate**



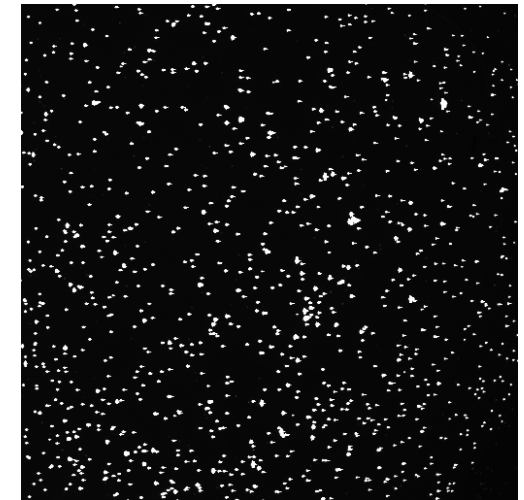
Top of Column

Deposition predominantly on column collection surfaces

Small amount on the focusing electrode surface



Side of Column



Focus Electrode

Half this density of particles observed on focusing electrode surface with the electrostatics turned off.

# Corona Charging Technology

*...developed on independent program involving electrostatic deposition of pharmaceuticals ...*

## ■ Corona charging advancements

- Developed new corona charging technique superior to currently available technology
- High efficiency (demonstrated >99%) uni-polar charging
- Current controlled corona eliminates ion density variation due to tip erosion
- Array of Corona tips generates uniform corona

## ■ Corona wind management

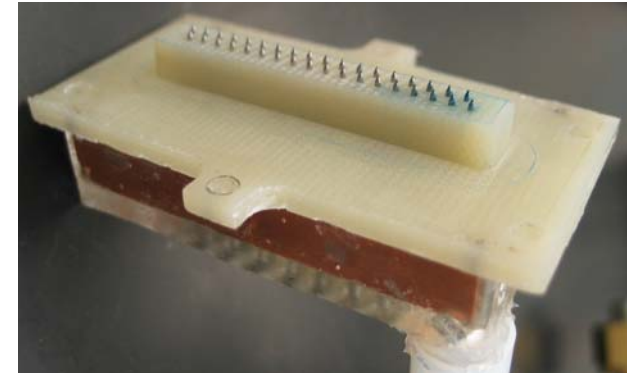
- “wind” blows particles toward collection port
- controlled by tip array

### Charging

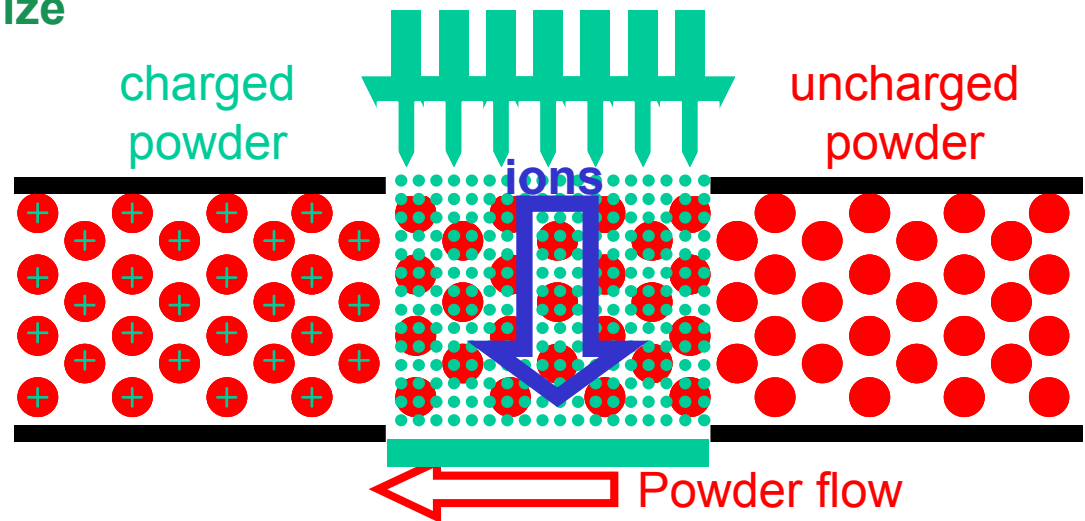
- Corona-charging
- Optimum Charge Saturation

# Corona Charging Technology

- **Advantages of corona charging**
  - Predictable particle charging
  - Charging obeys Pauthenier equation
  - Field charger
  - Uses maximum E-Field for capture
  - Designed for theoretical efficiency for respirable particle size



Corona Tip Array



Unipolar Charging

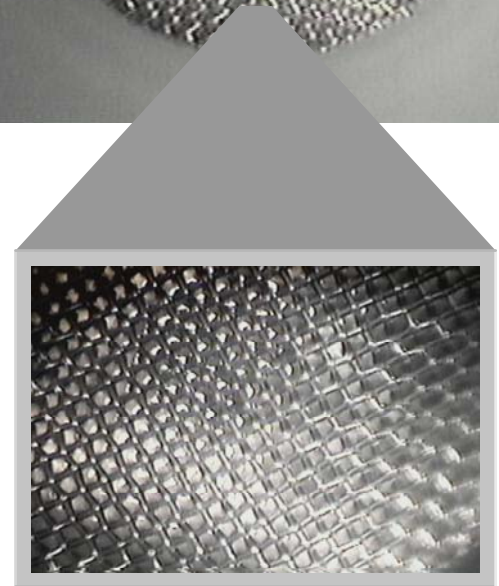
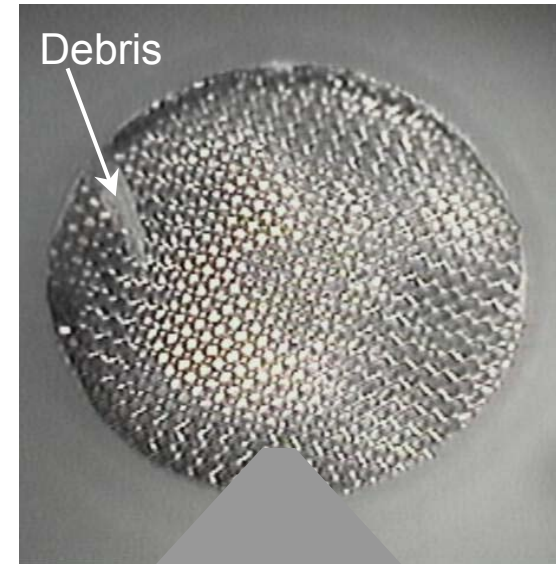
## Charging

- Corona-charging
- Optimum Charge Saturation

# Self Cleaning Liquid-Air Interface

...withstand differential pressure with efficient particle transport...

- **Teflon treated nylon mesh retains liquid in collection channel**
  - Debris tolerant
  - 40% open area
  - Low cost - standard Teflon fabric treatment
  - thermal imbedment assembly
  
- **Self Cleaning**
  - over pressurize channel to purge liquid past mesh to rinse contaminants off surface
  - liquid seal re-established when pressure is reduced



*Results in clog-free,  
low-maintenance  
continuous operation*

**Liquid**

- Self-cleaning Hydrophobic Membrane

# Electrostatic Surface Deposition

## *...Benefits ...*

- **Superior to impaction methods**
  - **Better control of deposition parameters**
    - Smaller size sample
    - Potential to deposit mono layer
  - **Less likely to damage pathogen**
    - Gentle Low Velocity Deposition
  - **Lower pressure drop**
    - Lower power
    - Quieter aerosol collection fan
  
- **Tape transport from collector to detector**
  - **Rapid, automated, precise location**
  - **Tape configuration:**
    - Disposable - reel to reel
    - Reusable - loop
    - Materials - polymer, ceramic, metal

### Surface

- Low Velocity Deposition

# Electrostatic Sorting

...sample enrichment by electrostatic deflection of selected particles...

## ■ Description of operation

- Stream of particles electrostatically charged by corona created at the exit of nozzle
- Particles interrogated by UV laser
- resulting laser induced fluorescence used to determine particles of biological origin
- Selected particles focused onto small diameter target
- rejected particles deflected to annular surface surrounding target

## ■ Features

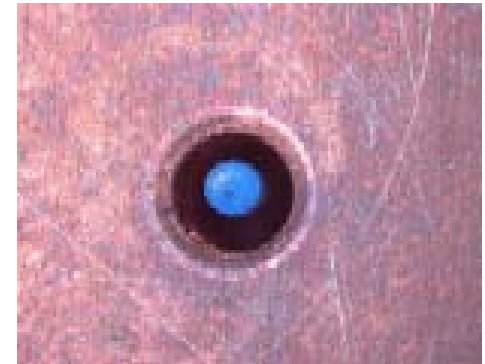
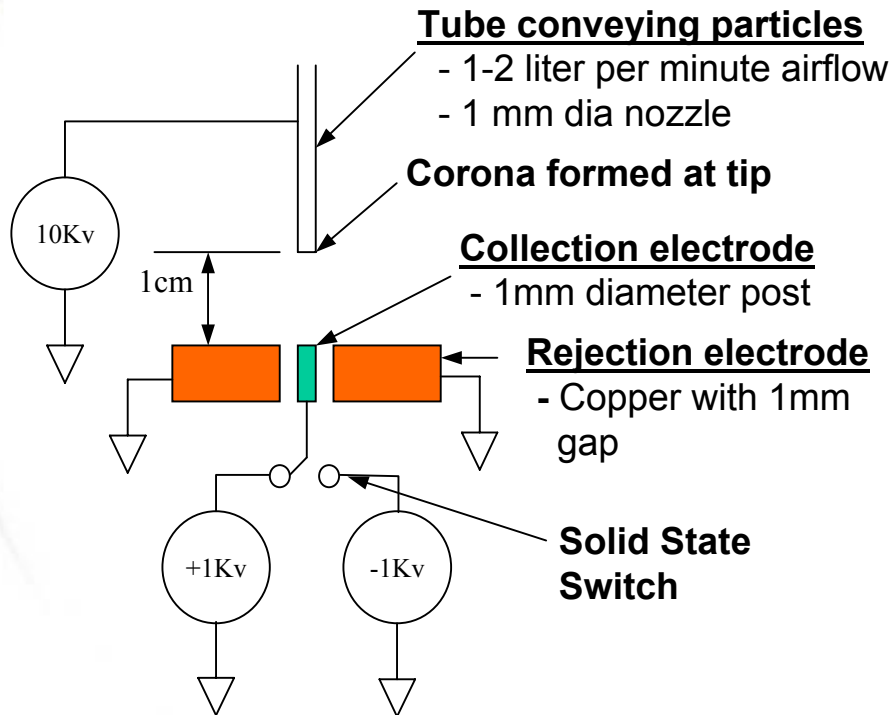
- High S/N ~ 50,000:1
- High switching speeds > 10Khz
- High efficiency (>99% @ 2um)

Surface

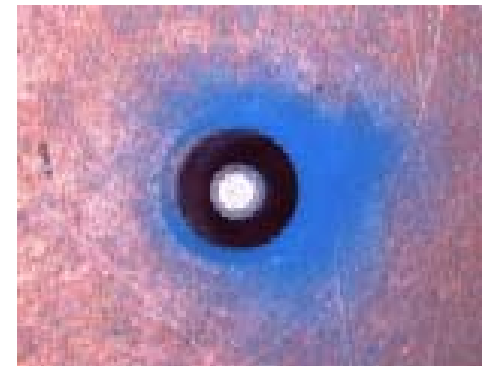
Sorting

# Electrostatic Sorting

...feasibility experiment...



Experimental result showing deposition of HP cyan toner (3um-9um) particles onto collection electrode



Experimental result showing deposition of HP cyan toner (3um-9um) particles onto rejection electrode

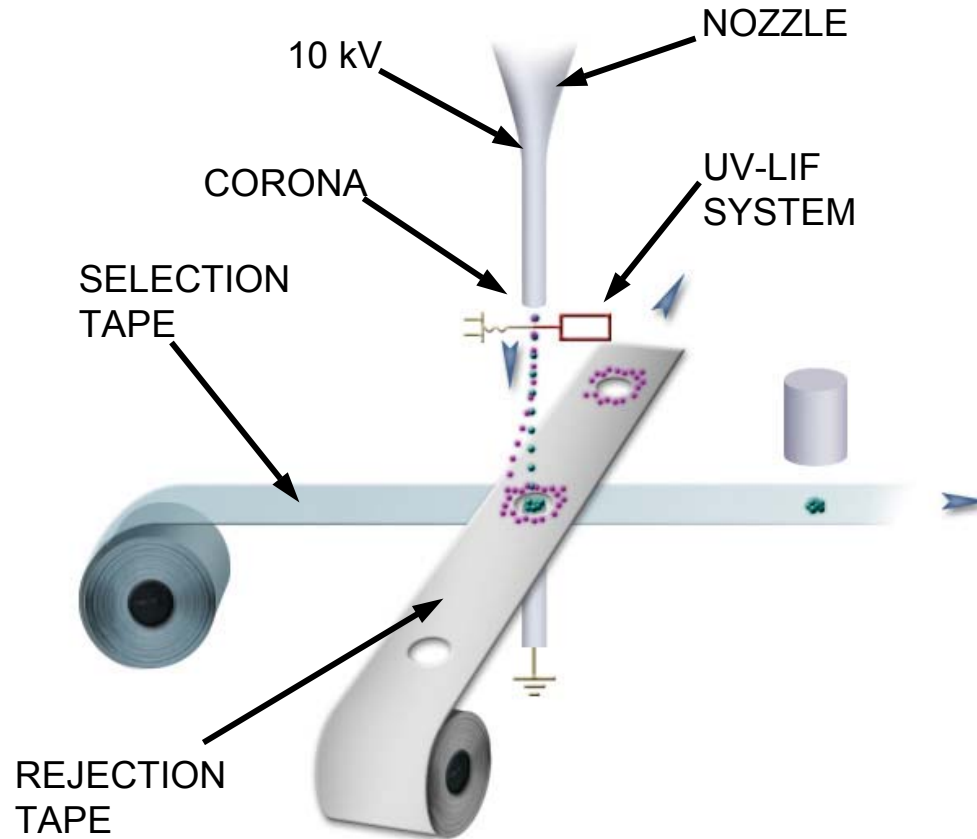
## Experimental electrostatic sorting mechanism

Surface

Sorting

# Electrostatic Sorting

...deposition onto tape concept ...



Surface

Sorting

# Benefits of Electrostatic Collection

- **Affords plug and play detector integration for standardized air sampling module**
  - Deposition into liquid for assay and antibody based detection
  - Solid surface deposition for spectrographic detection
  - Electrostatically focused aerosol stream for advanced particle sorting techniques
- **Electrostatically focus particles into  $\mu\text{l}$  liquid volumes**
  - Interfaces to advanced detection technologies
  - Clog free hydrophobic membrane
  - Capable of low temperature operation
- **Electrostatic surface deposition superior to impaction methods**
  - Better control of deposition parameters
  - Less likely to damage pathogen
  - Lower pressure drop reduces fan power & noise