AIR LAB
AEROSOL INTRUMENTATION RESEARCH

Clarkson UNIVERSITY defy convention

Low-cost optical sensors:
Laboratory and field performance evaluation

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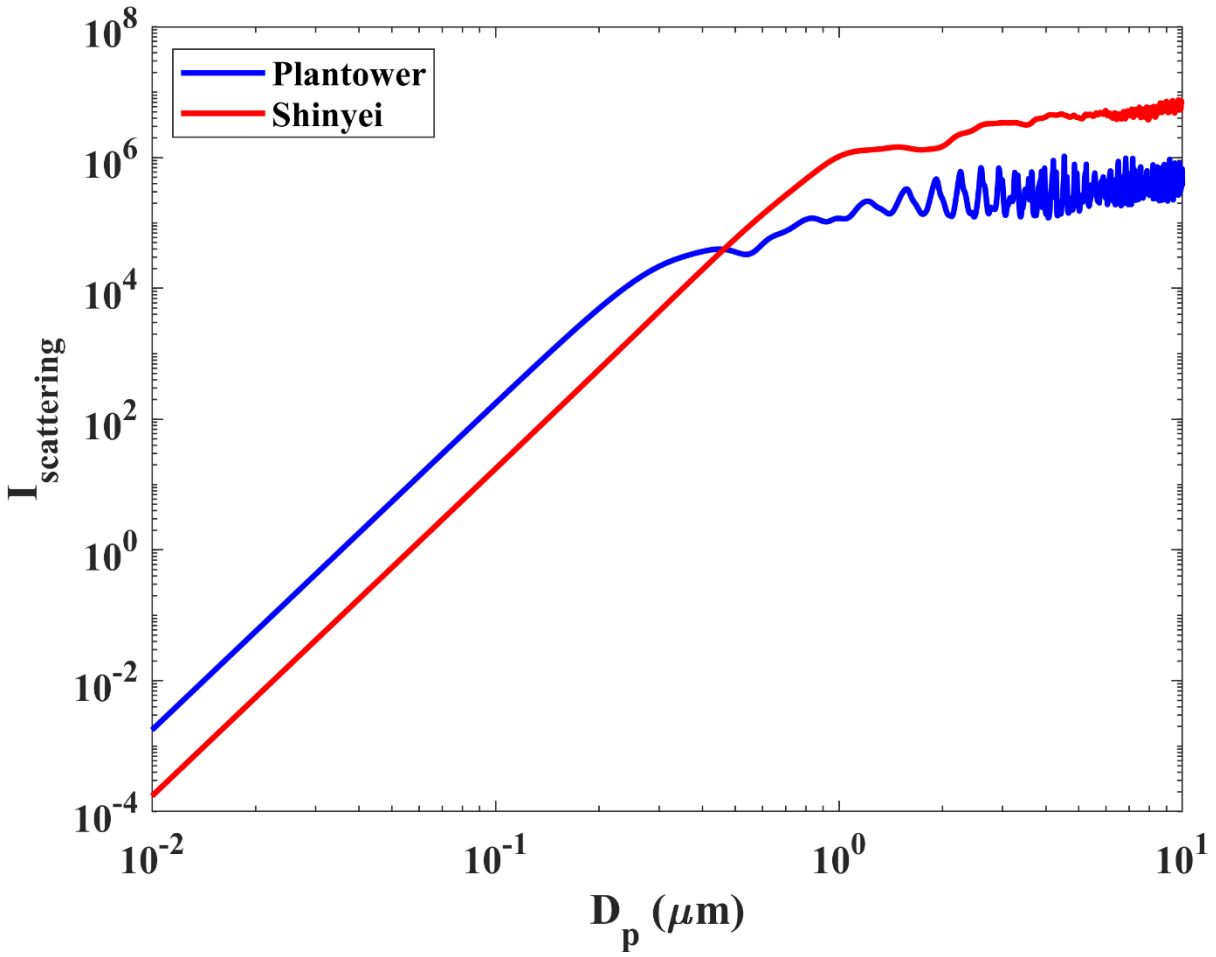
Motivation

- Can we measure ambient PM2.5 using low-cost sensors without field-based calibration
- Approach
  - Lab calibration using monodisperse aerosol
    - Different composition and concentration
  - Build calibration model
    - Machine learning
  - Field testing

Single particle scattering



PLANTOWER
90 degree
Red laser

Shinyei
65 degree
Infrared

Low-cost sensor unit

- Multi-sensor measurements
  - 4 optical sensors
- Weather-proof NEMA box
- Meteorology sensors (wind speed, RH, Temperature)
- Battery-powered

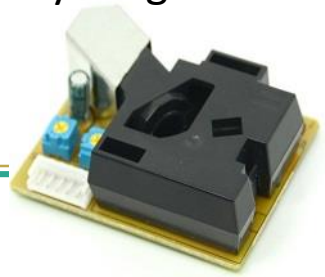
A smart mobile platform for air quality monitoring

Plantower (6 size channels)

Honeywell

Shinyei

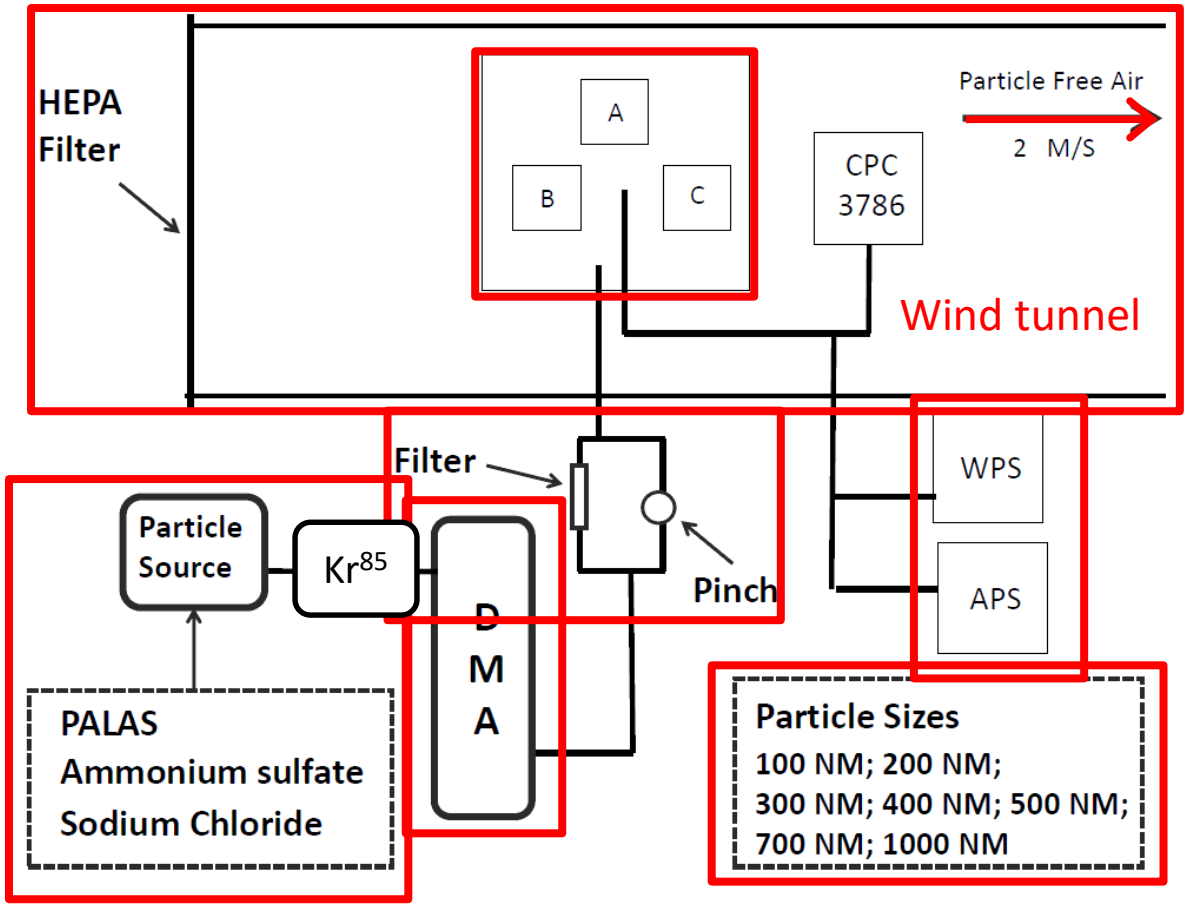
Samyoung



Wind tunnel testing setup

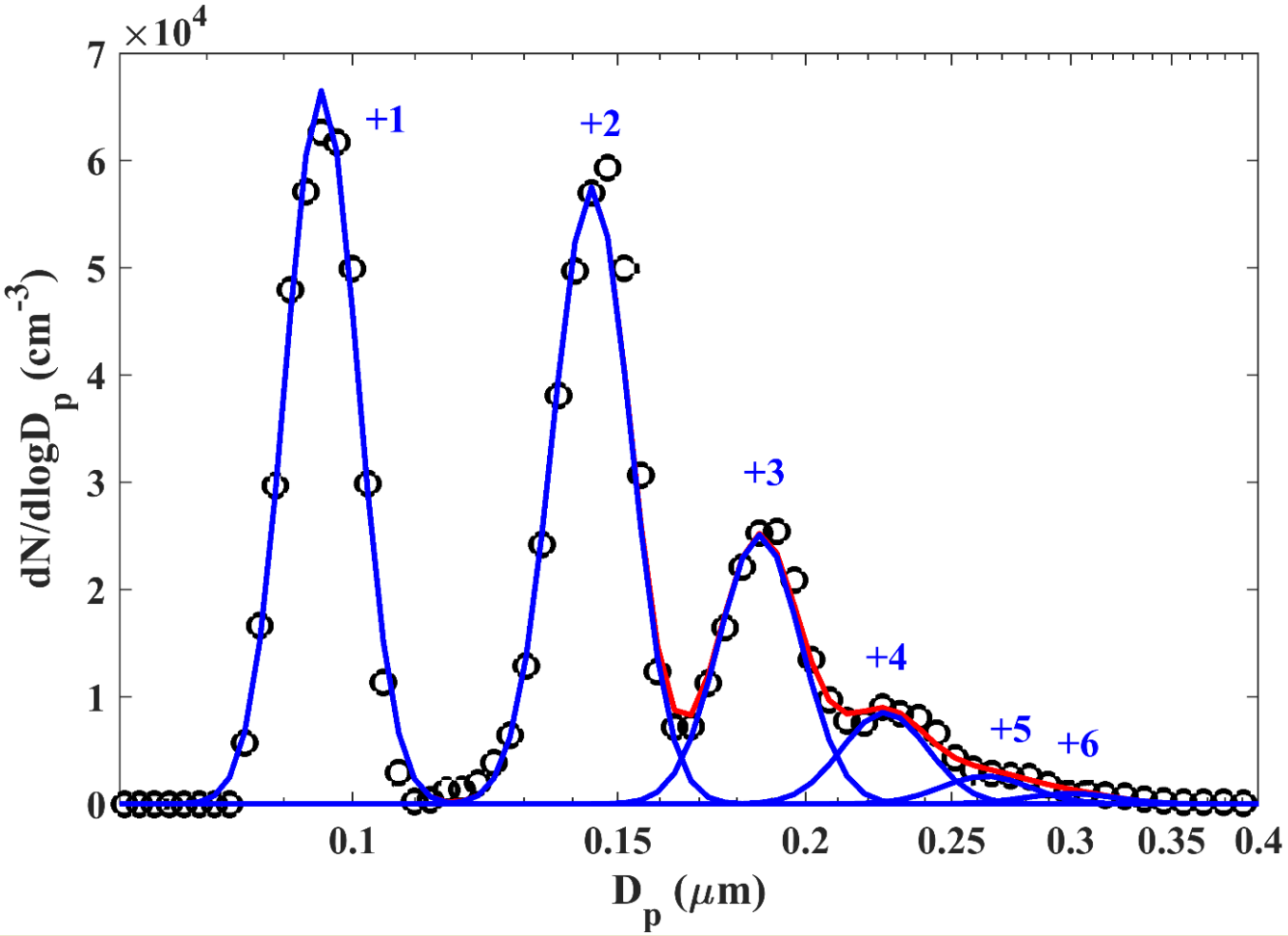
- Test with monodisperse particles
- Particle size, concentration, and composition are varied during the testing.

A smart mobile platform for air quality monitoring



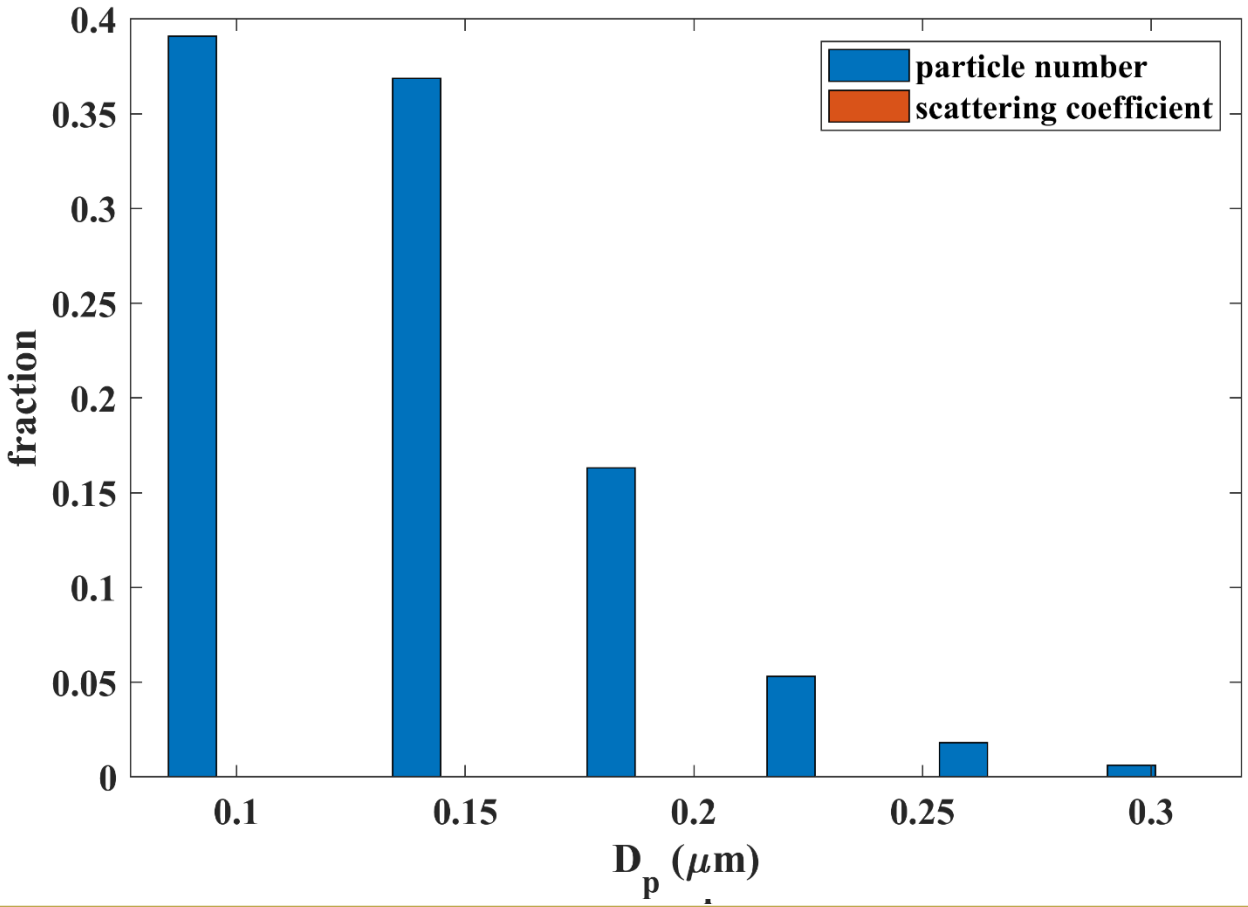
Particle size distribution for wind tunnel testing

- Significant contribution from multiply charged larger size particles.



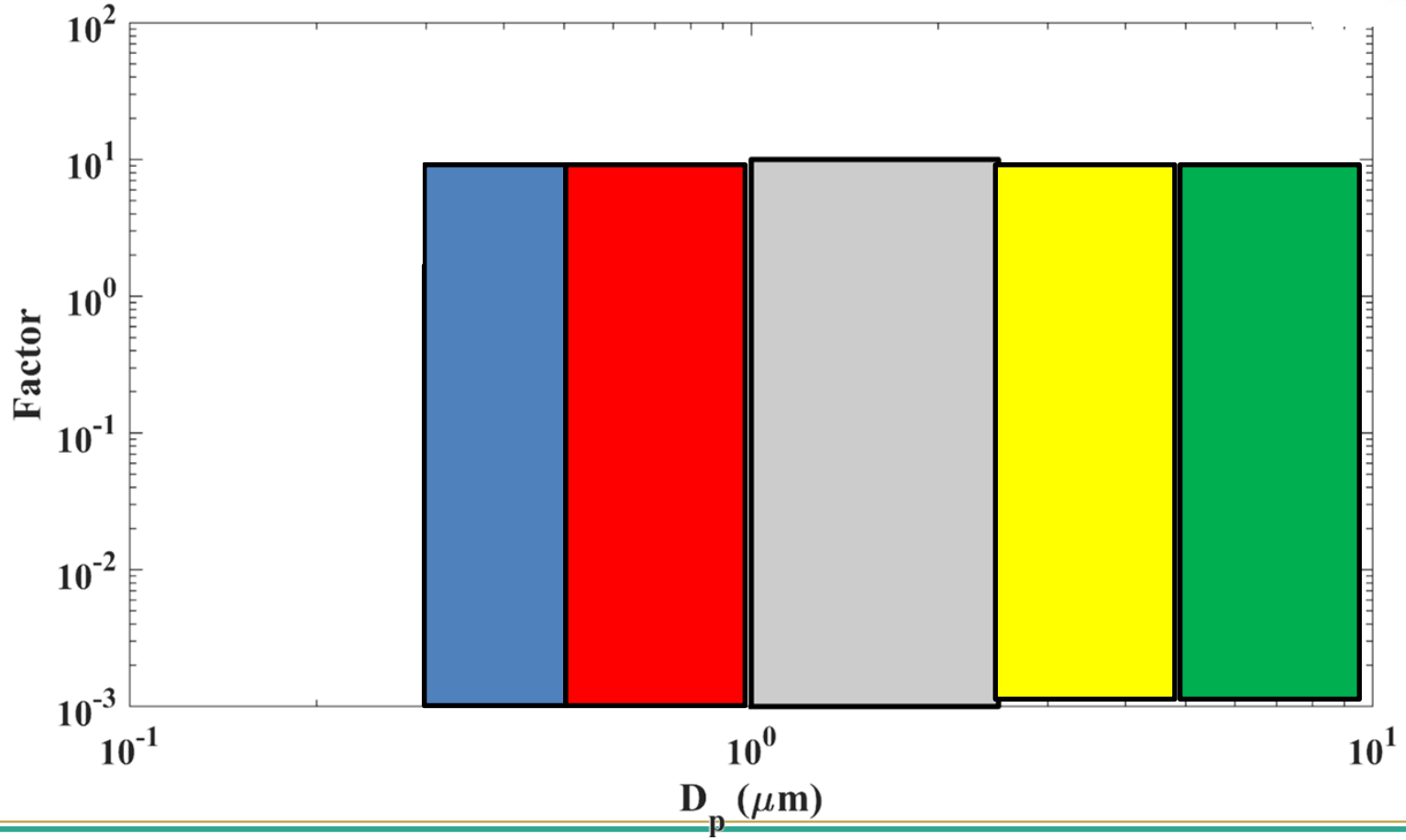
Fraction of different size particles

- Small number fraction, multiply charged particles dominate the light scattering signal.



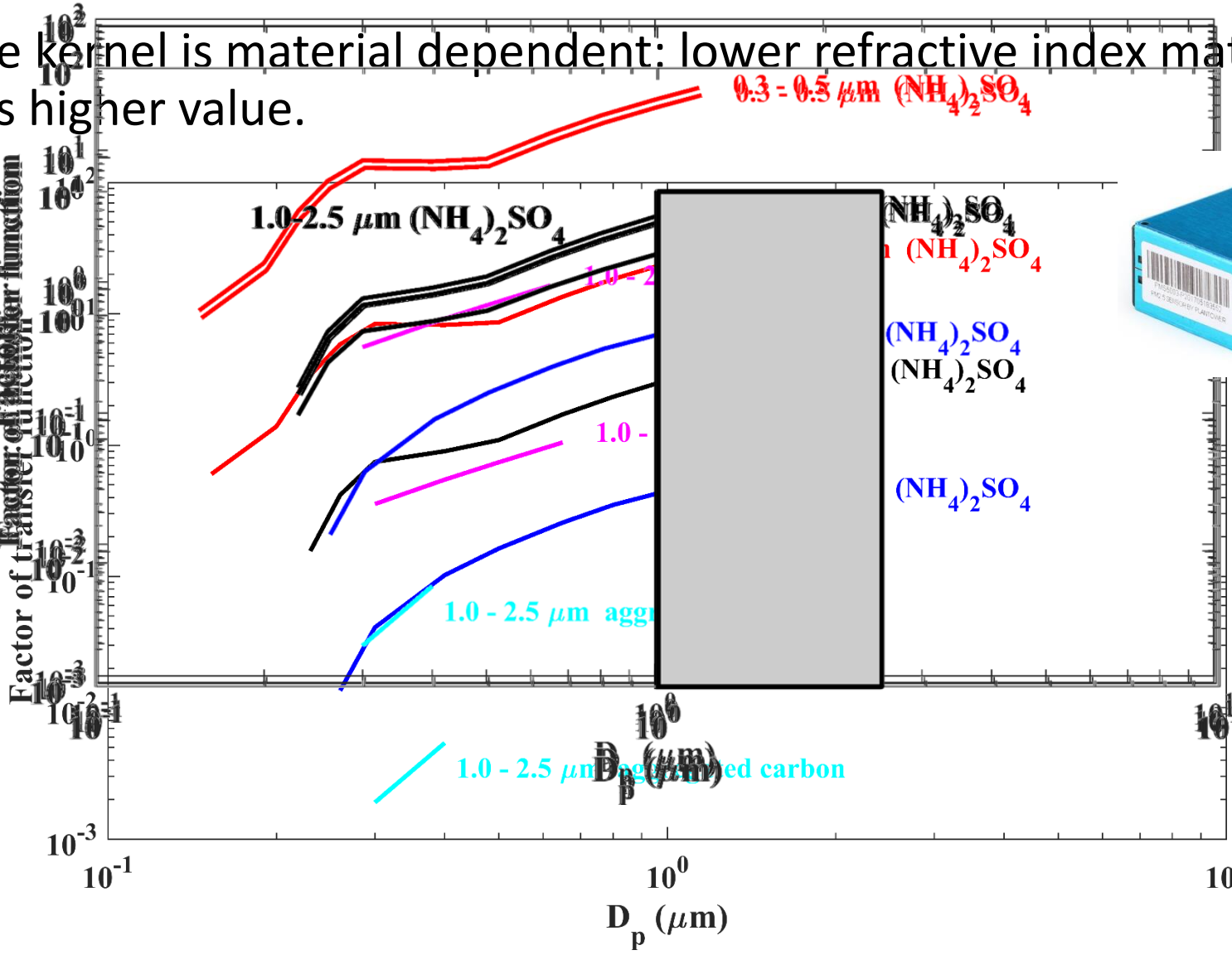
PLANTOWER

Plantower channel response



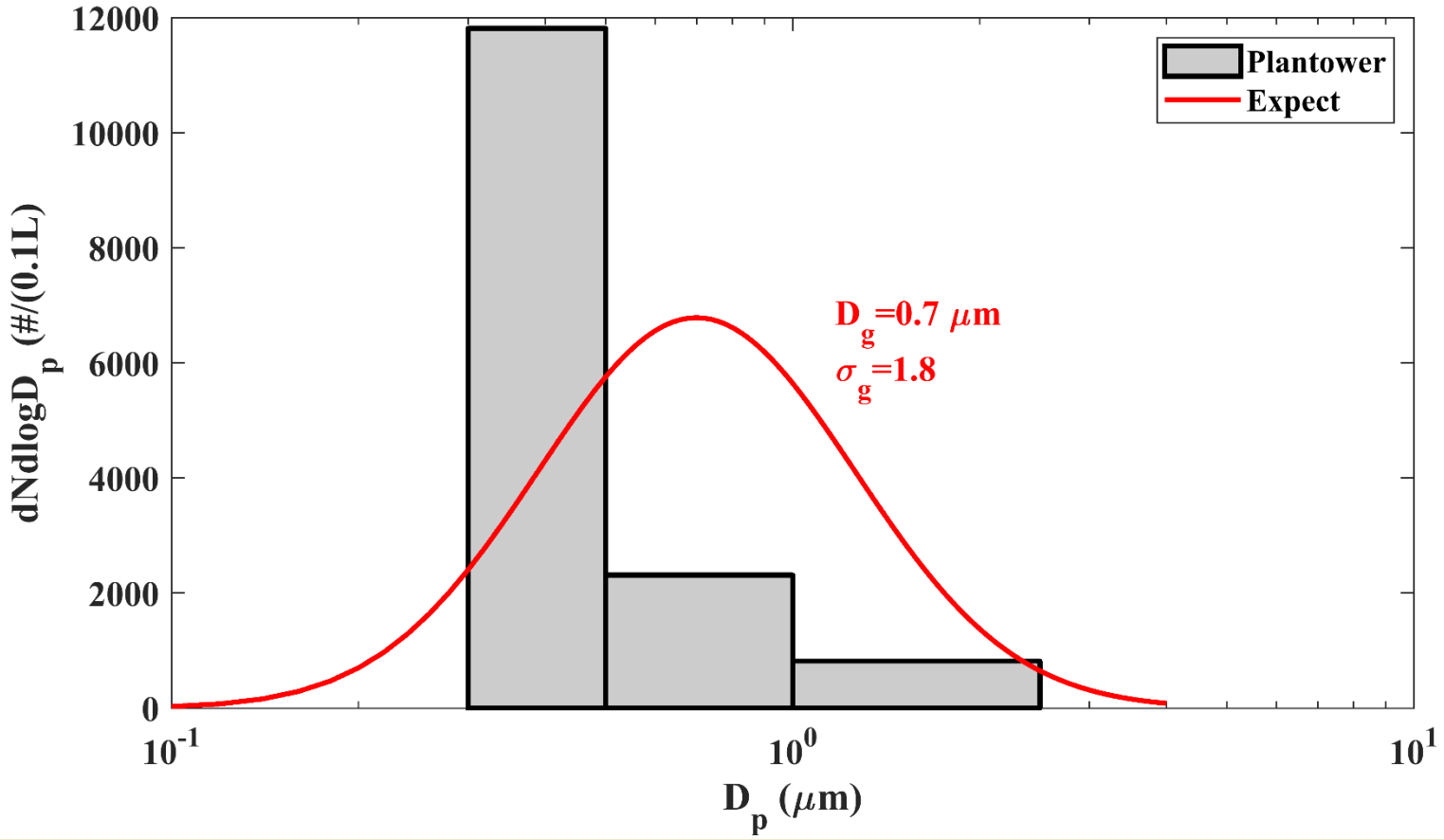
Plantower channel response

- Larger signal is contributed by larger size particles.
- The kernel is material dependent: lower refractive index material has higher value.



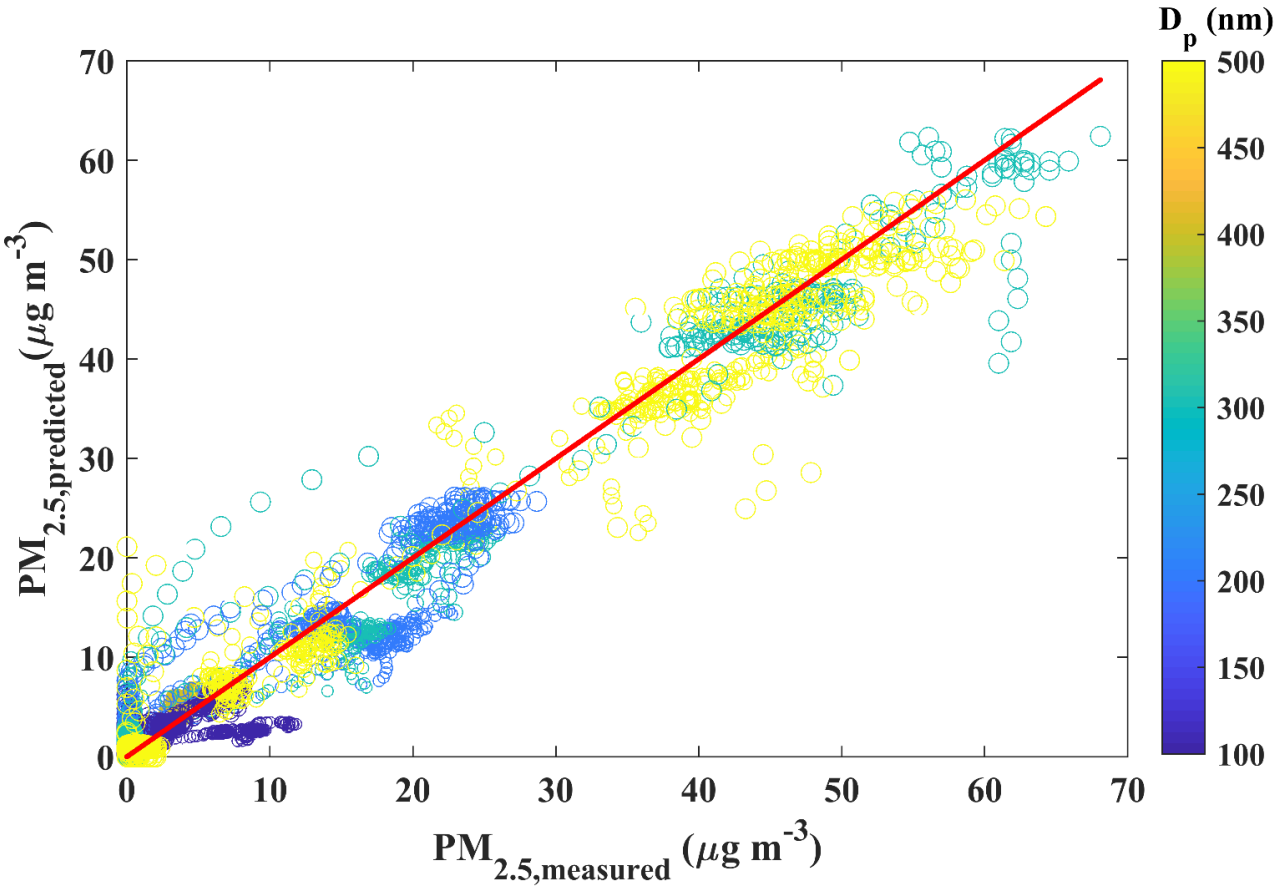
Plantower signal prediction

- The signal matches with the expected distribution for general ambient sampling, not for the scenarios with large mode size.

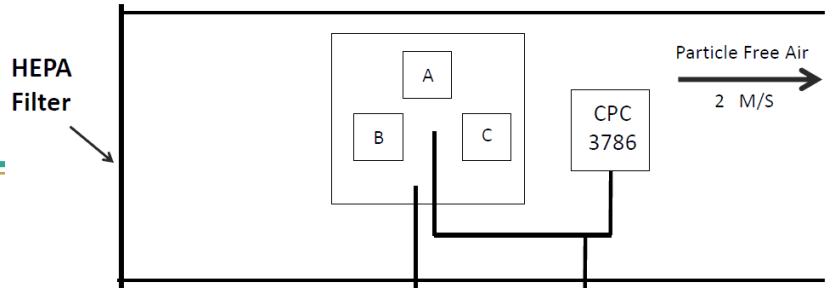


Model establishment

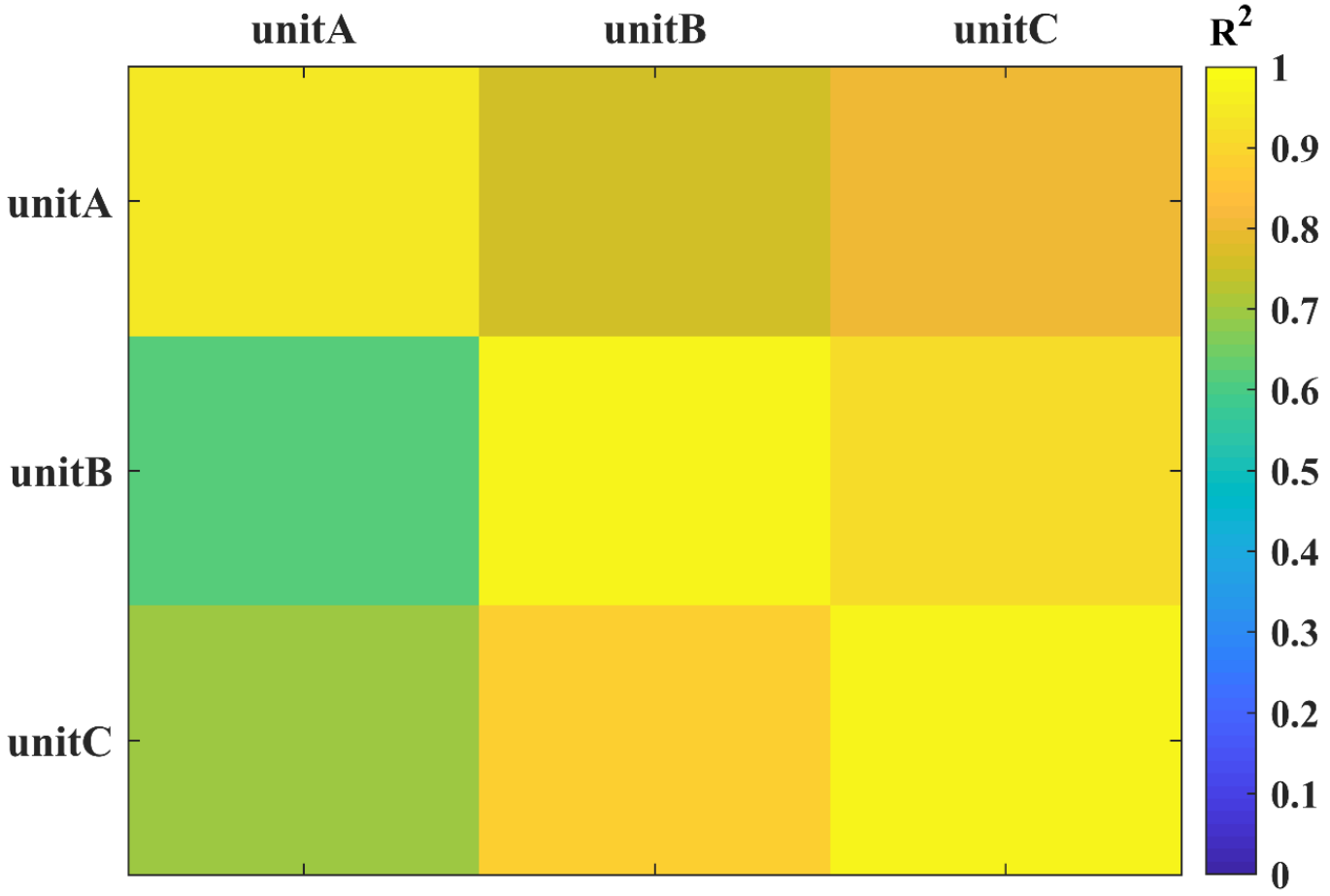
- The machine learning models (random forest, SVR) used for $PM_{2.5}$ model generation.
  - Used ridge regularization with SVR to prevent overfitting
  - 5-fold cross-validation



Regression

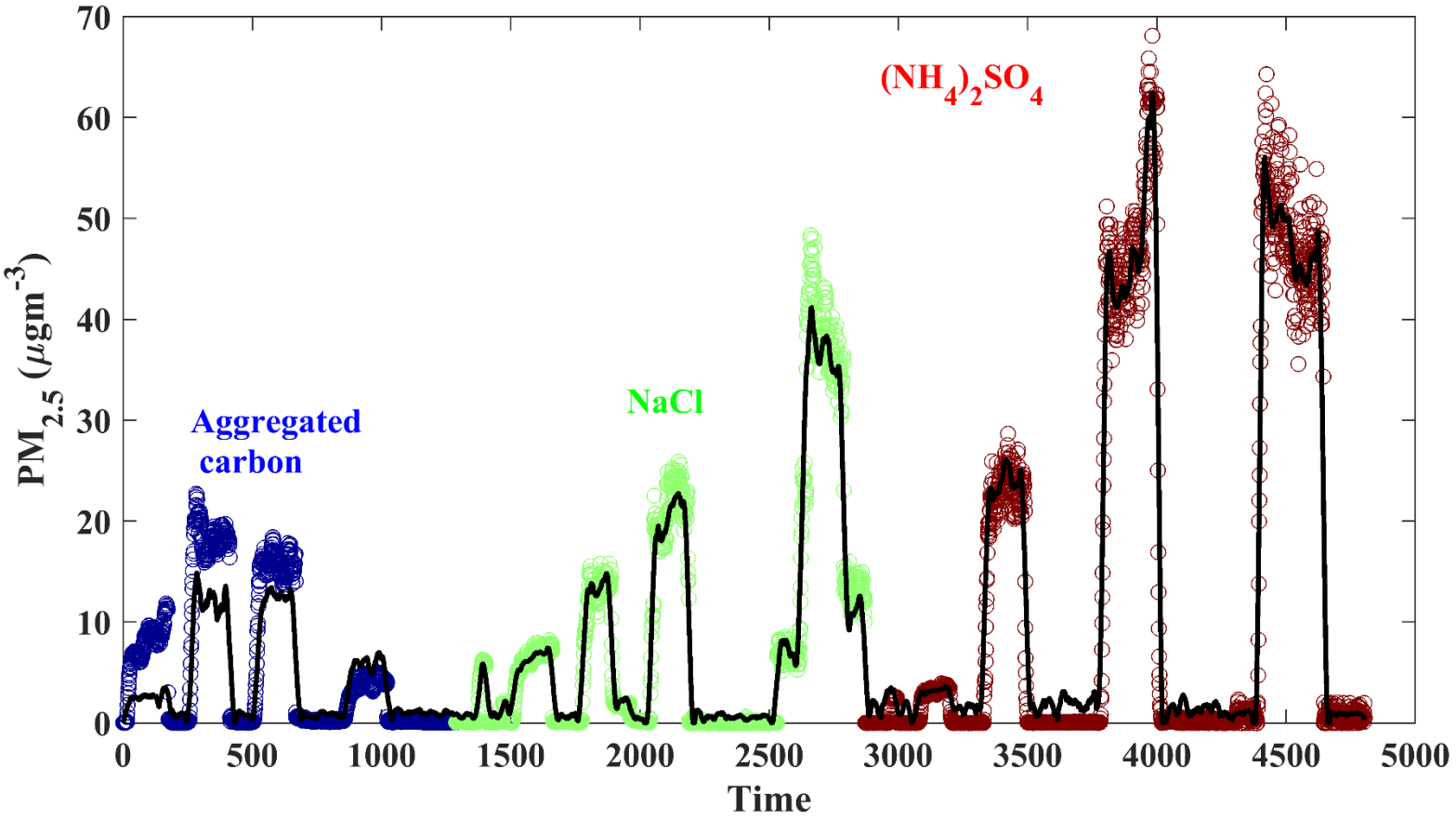


- High precision of the sensors.



Time Series

- The model prediction matches the measurement under wind tunnel test for three material particles with different sizes.

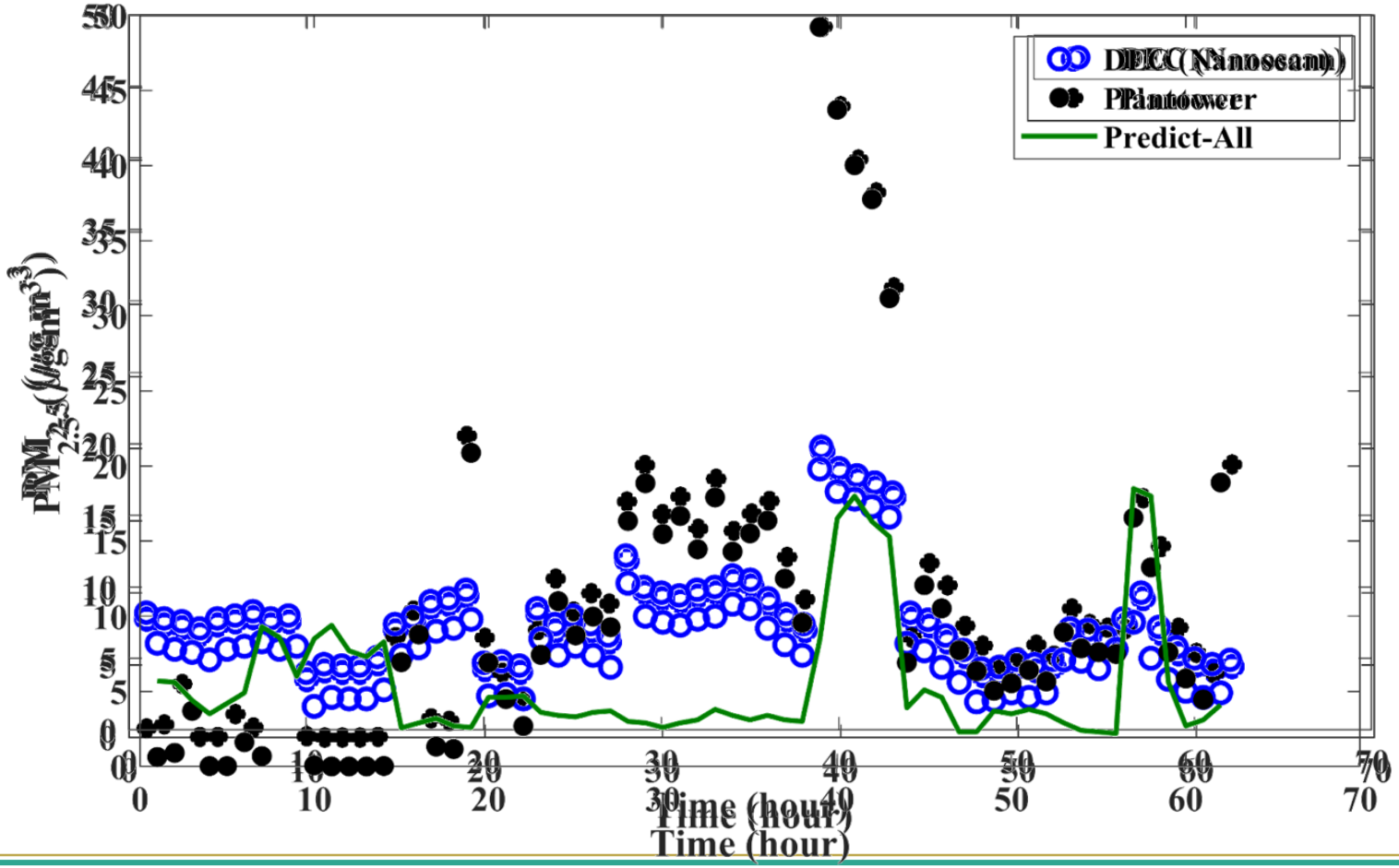


Field Measurement Site

- The low-cost sensors are deployed in Albany, NY near the port during the last 3 months.

Field $PM_{2.5}$

- More information (e.g. size distribution) is required to improve the model prediction accuracy.



Conclusions & Future work

- Preliminary results with a multi-sensor system shows that lab-based calibration improves field performance of the sensor compared to factory calibration

- Optical sensors size channel information is complicated
  - Optical response is a strong function of size distribution of test aerosol
  - For best model development, need more data from test aerosol in large model size

- Future work
  - Further calibration in the lab and field testing
  - Can we use the size response curves of each channel to improve model predictions?

Acknowledgements

- Funding support from NYSERDA