Sampling, Analysis, and Properties of Primary PM-2.5: Application to Coal-Fired Boilers

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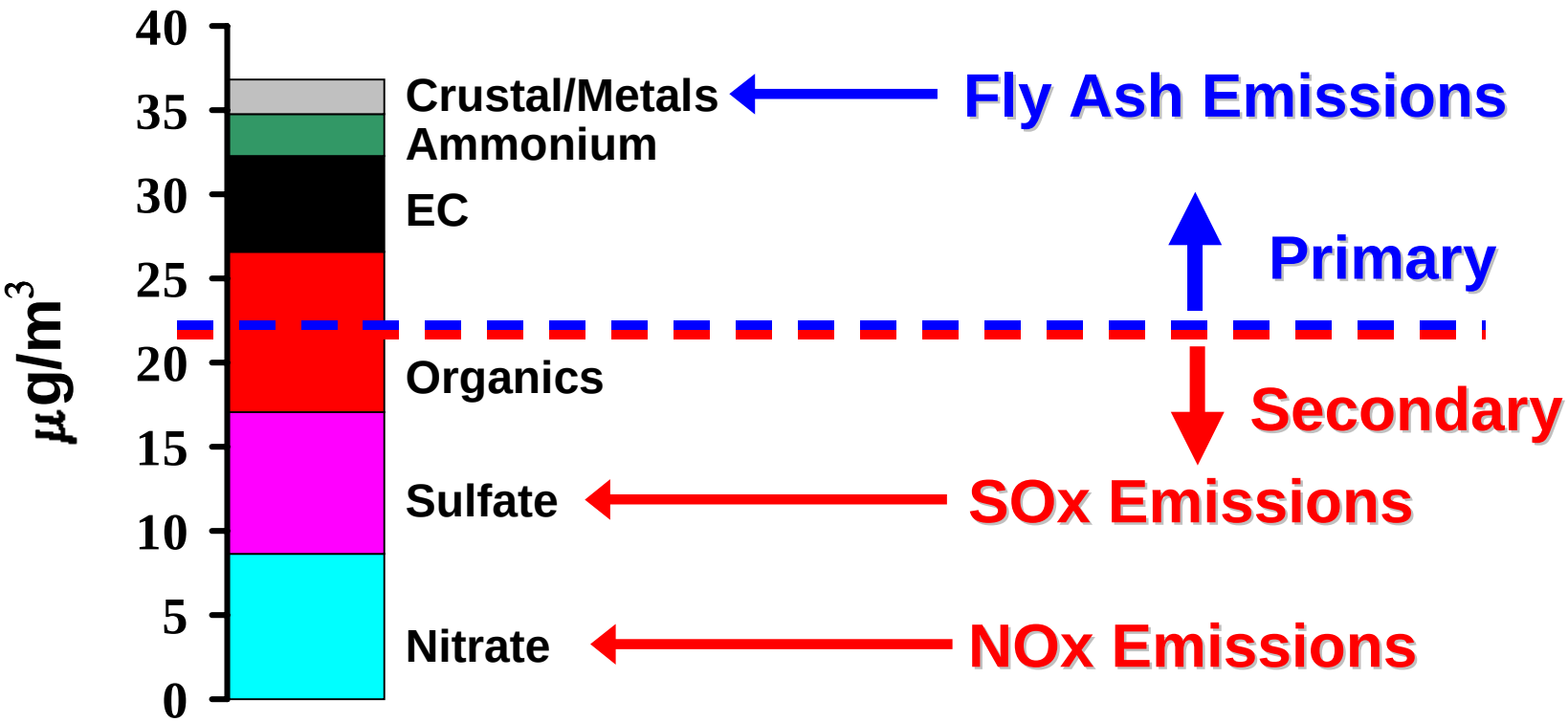
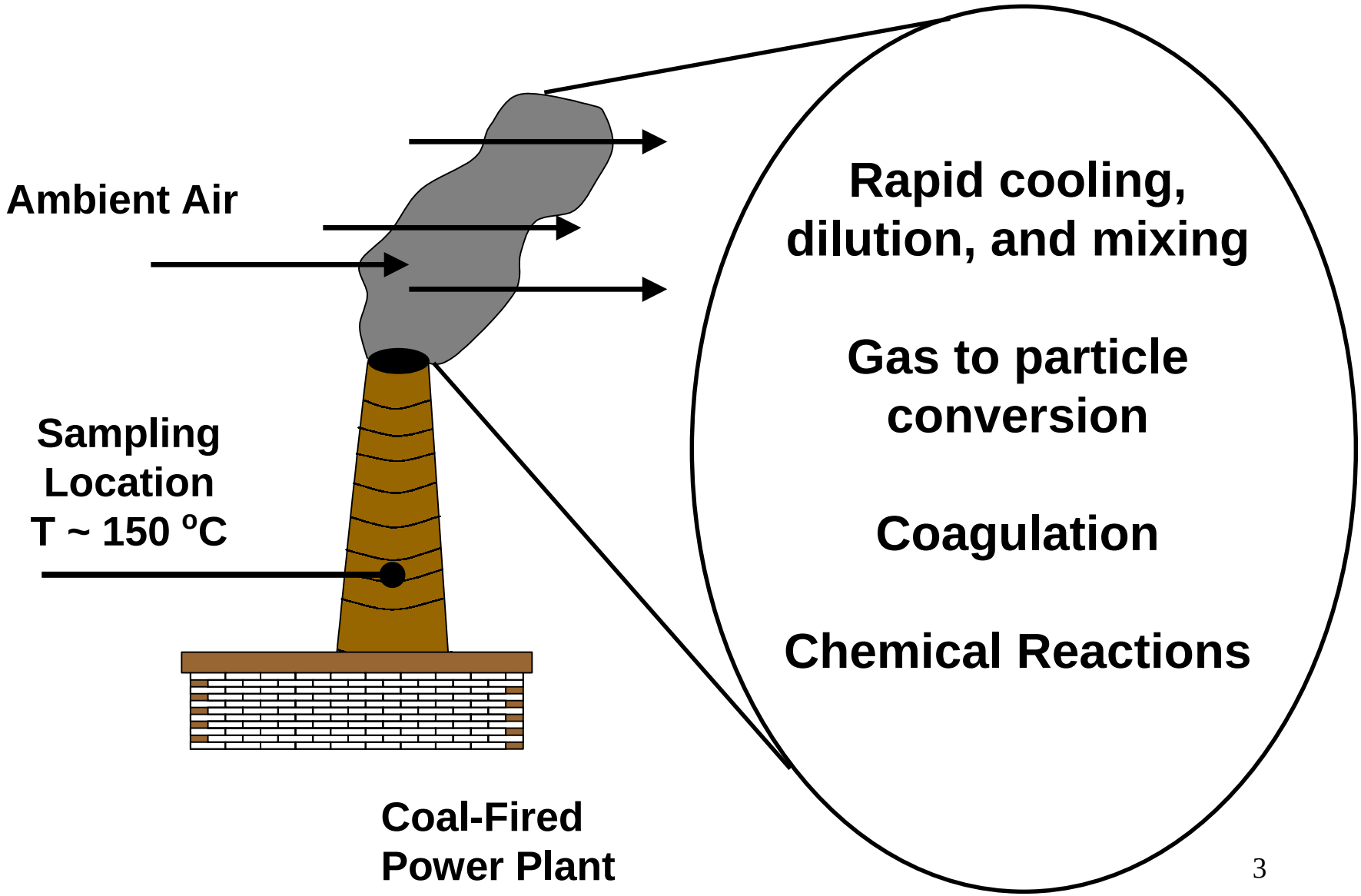
PM-2.5 and Coal-Fired Power Plants

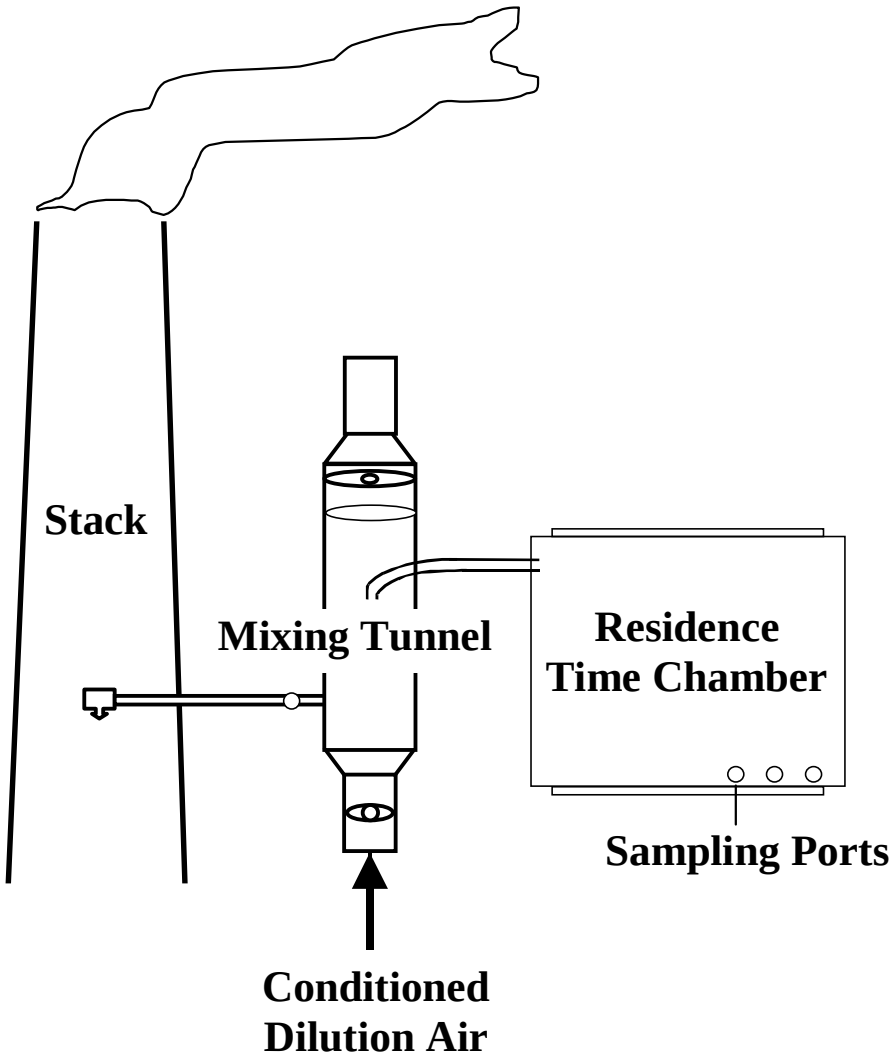


PM-2.5 Composition during the Winter of 1999 in Philadelphia

Plume Processes Effect PM Emissions



Dilution Sampling

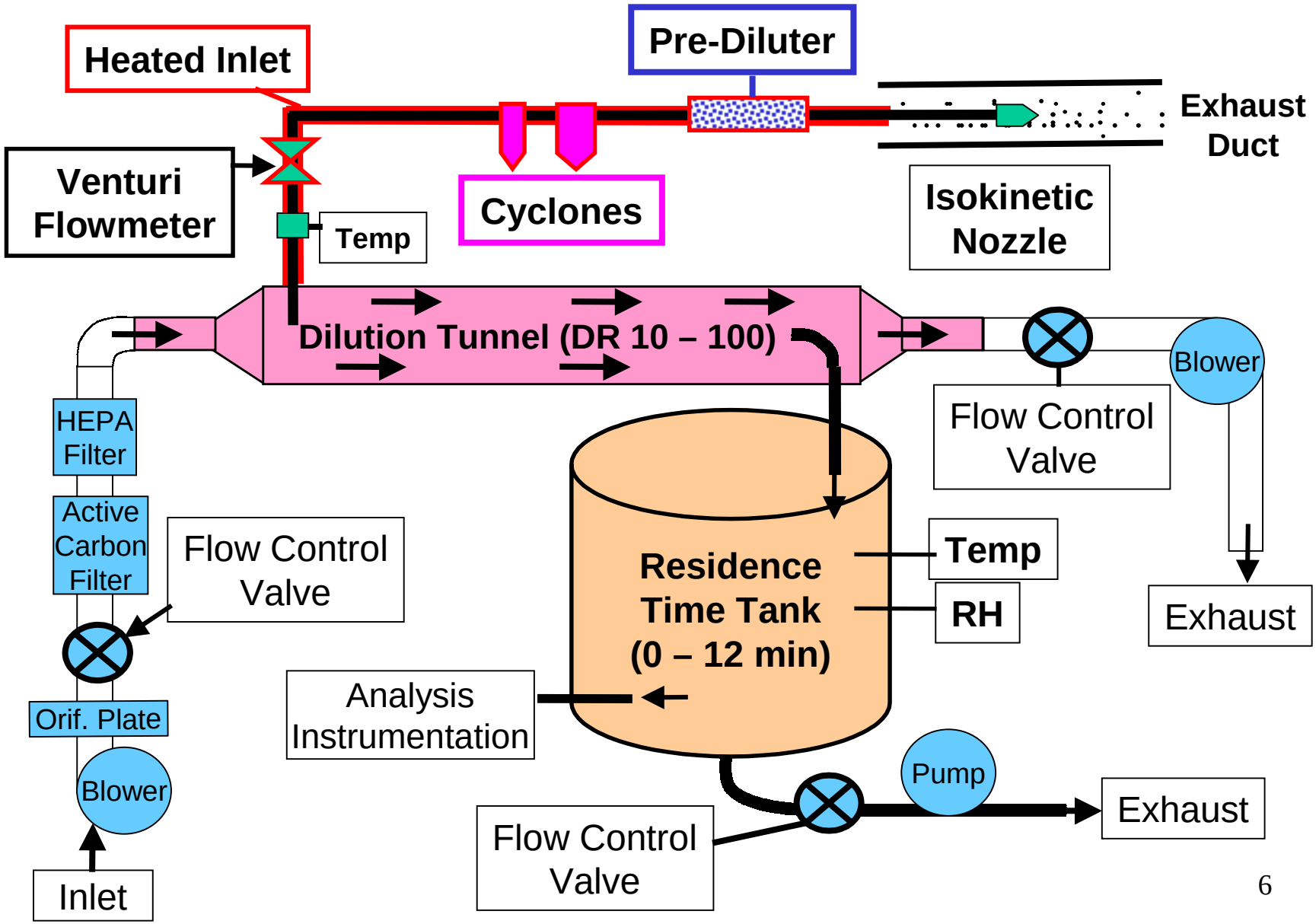


- Simulates plume processes
  - Semi volatile species (Organics, Metals)
  - Size Distribution
- Advanced instrumentation
- Limited data for coal emissions
- Complex

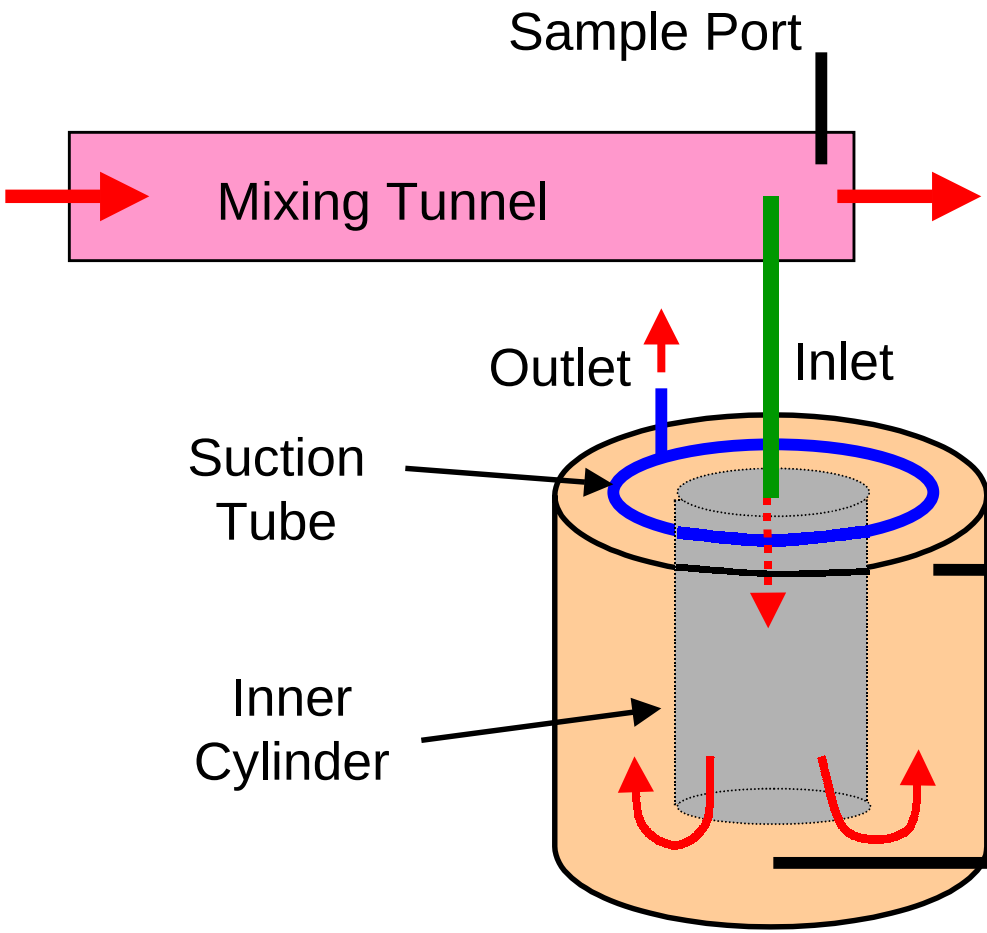
Project Objectives

- **Design, construction and evaluation of a portable state-of-the-art dilution sampler**
- **Characterize PM-2.5 emissions from a pilot-scale pulverized coal combustor.**
- **Examine effect of dilution sampling on PM-2.5 emissions:**
  - **Particle size distribution**
  - **Particle chemical composition**
  - **Particle properties**
- **Develop dilution sampling methodology for coal-fired power plants**

Schematic of Dilution Sampler



Residence Tank Design



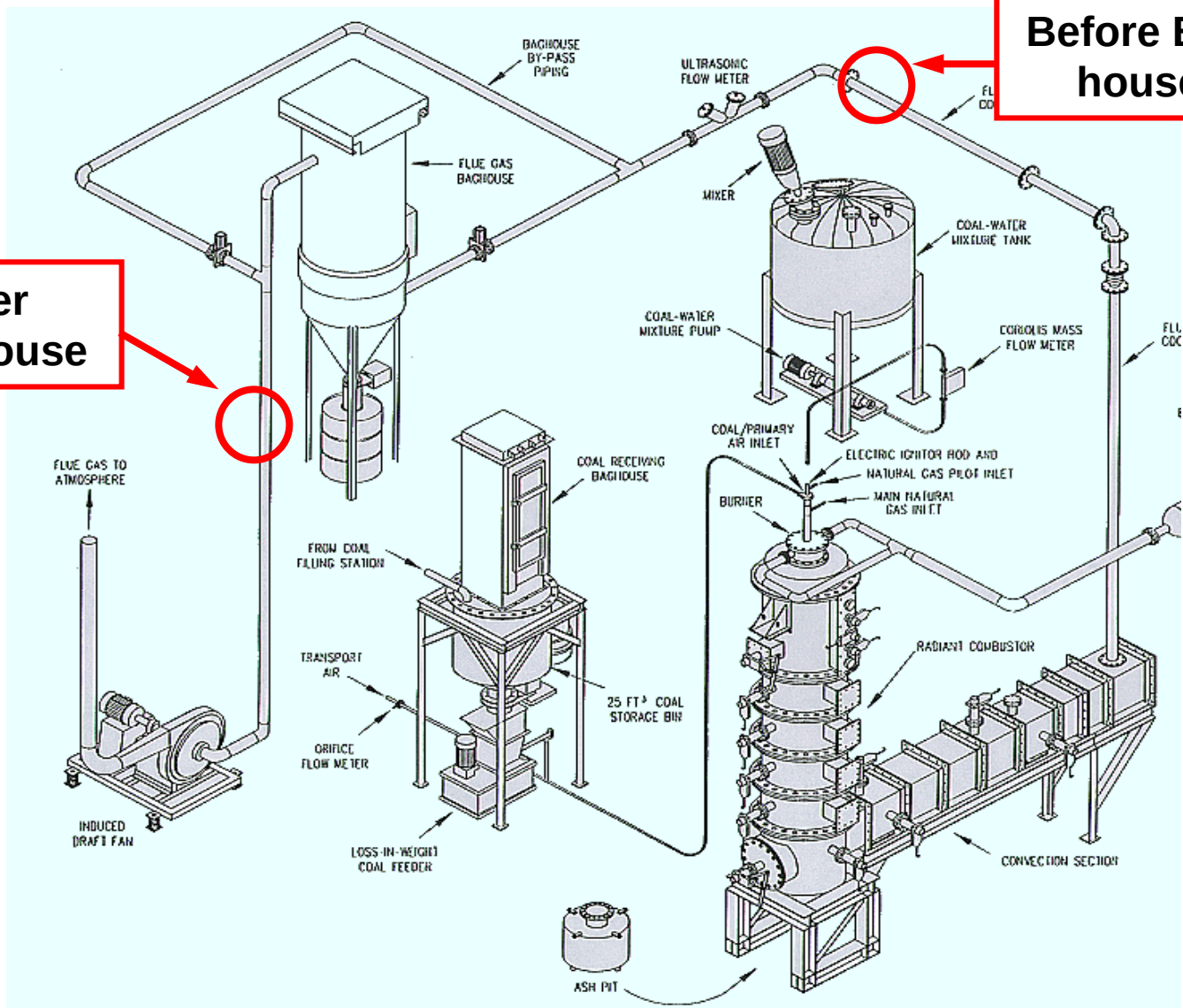
Allows simultaneous collection of samples at 3 residence times

Pilot-Scale Coal Combustor (CERF)

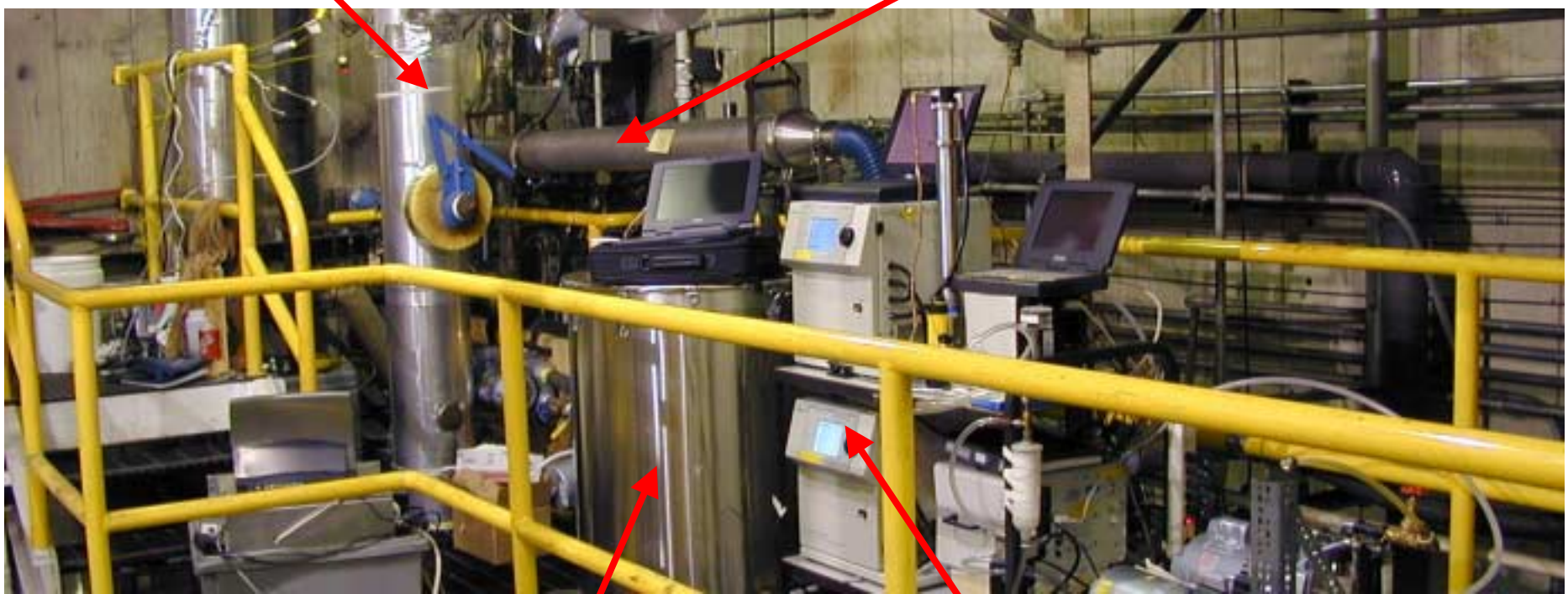
- Pilot-scale: 50 lbs/hr
  (~500,000 Btu/hr)
- Simulates:
  - Gas temperature
  - Gas composition
  - Residence time

  of a Utility Boiler
- Eastern Bituminous Coal
  (low ash, low S)

Sampling Locations



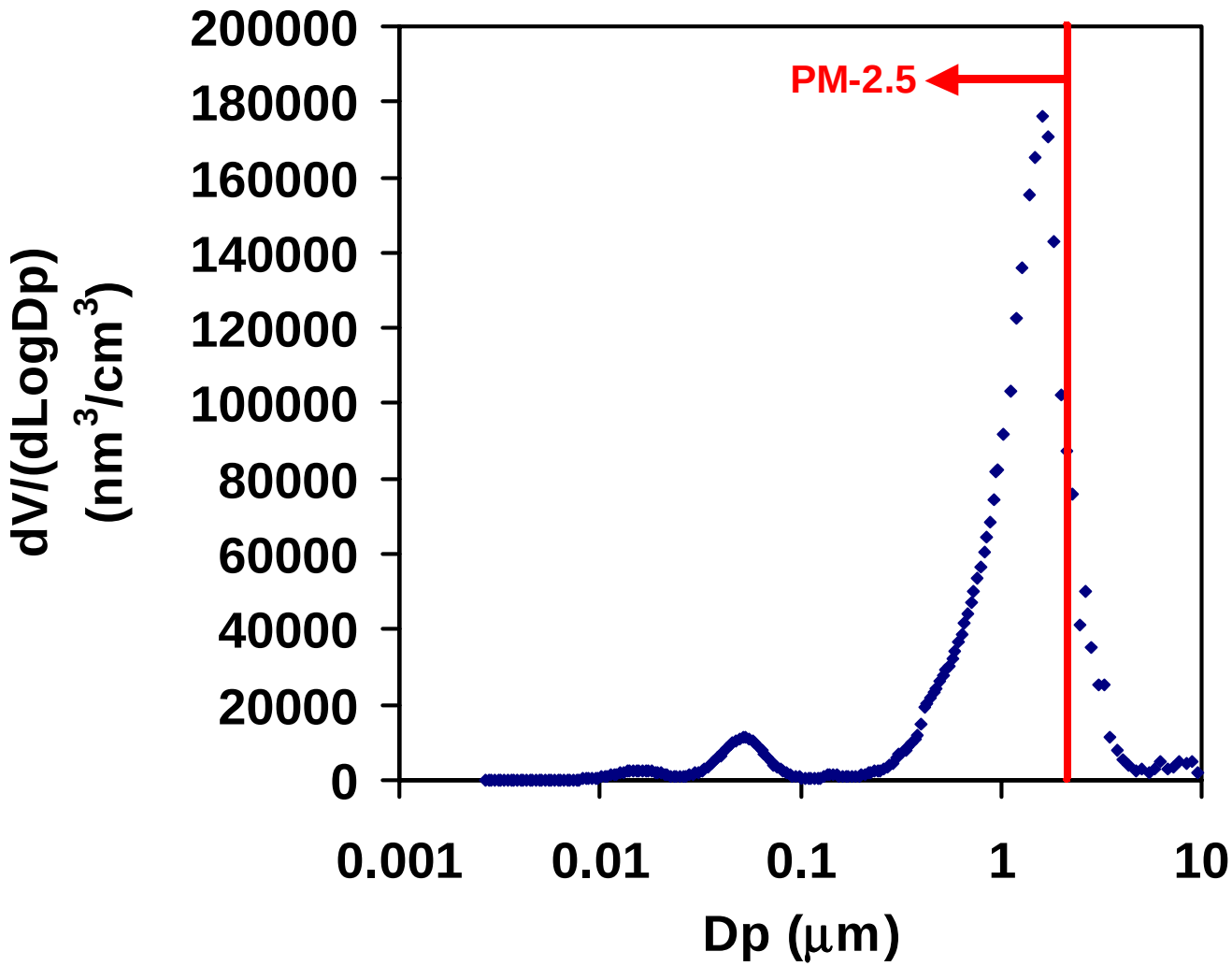
Picture of Experimental Set-Up



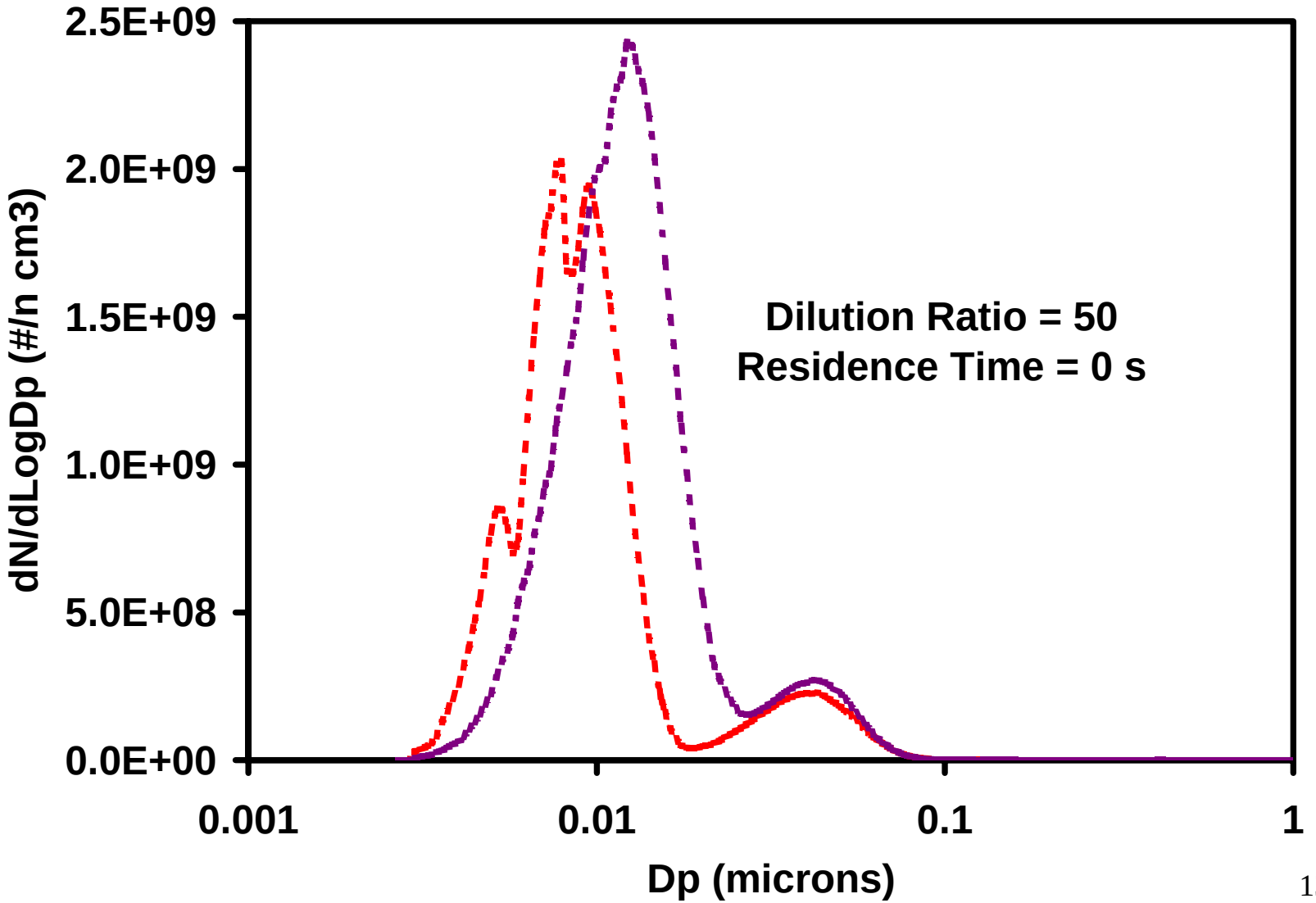
What is the effect of dilution sampling on PM emissions?

- **Experiments:**
  1. **Constant residence time vary dilution ratio**
  2. **Constant dilution ratio vary residence time**
  3. **Hot filter samples (EPA method 5)**
- **Measurements:**
  - **Particle size distribution from 5 nm to 5 microns (TSI nano-SMPS, SMPS, APS)**
  - **Mass and composition (Filter packs)**

Typical Particle Volume/Mass Size Distribution



Typical Particle Number Size Distributions



Analysis of Particle Distribution Data

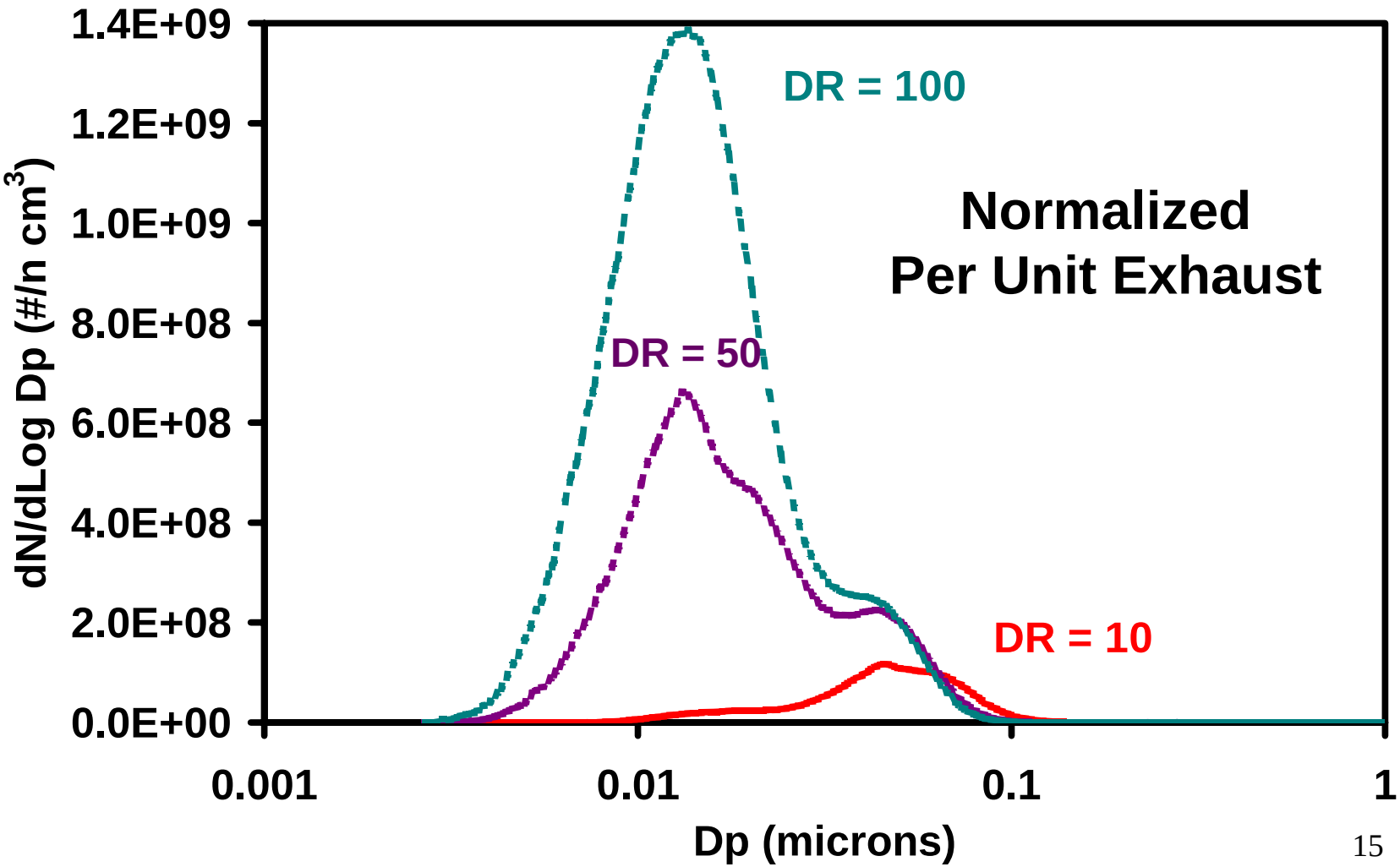
- **Normalize to an exhaust basis**
  - $PM_{norm} = PM_{measured}$ X (DR + 1)

- **Coagulation simulations**

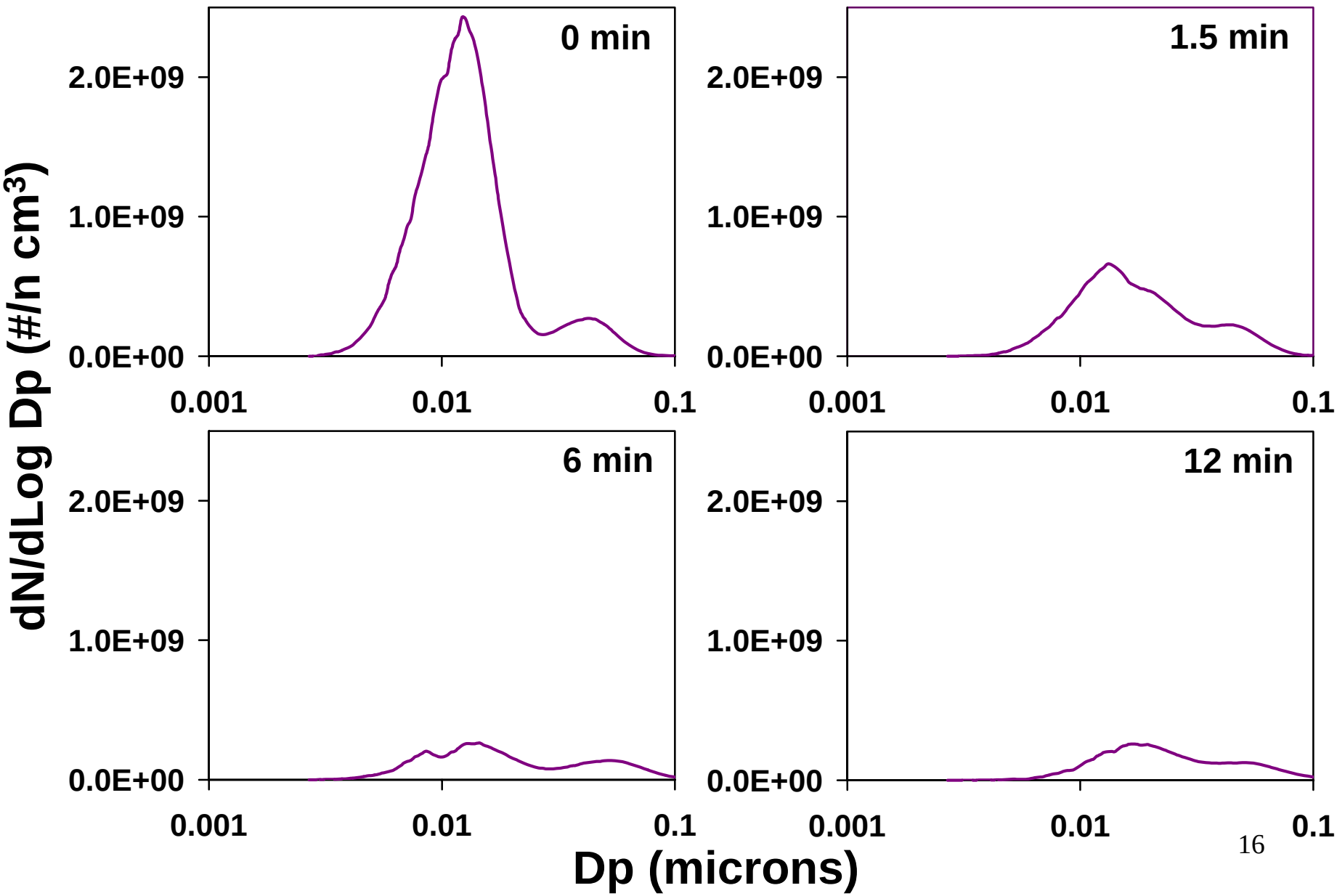
$$\frac{dN(D_i)}{dt} = N(D_i) - R_{coag}$$

$$R_{coag} = \sum_{j}^{150} K_{coag}(D_i, D_j) \bullet N(D_i) \bullet N(D_j)$$

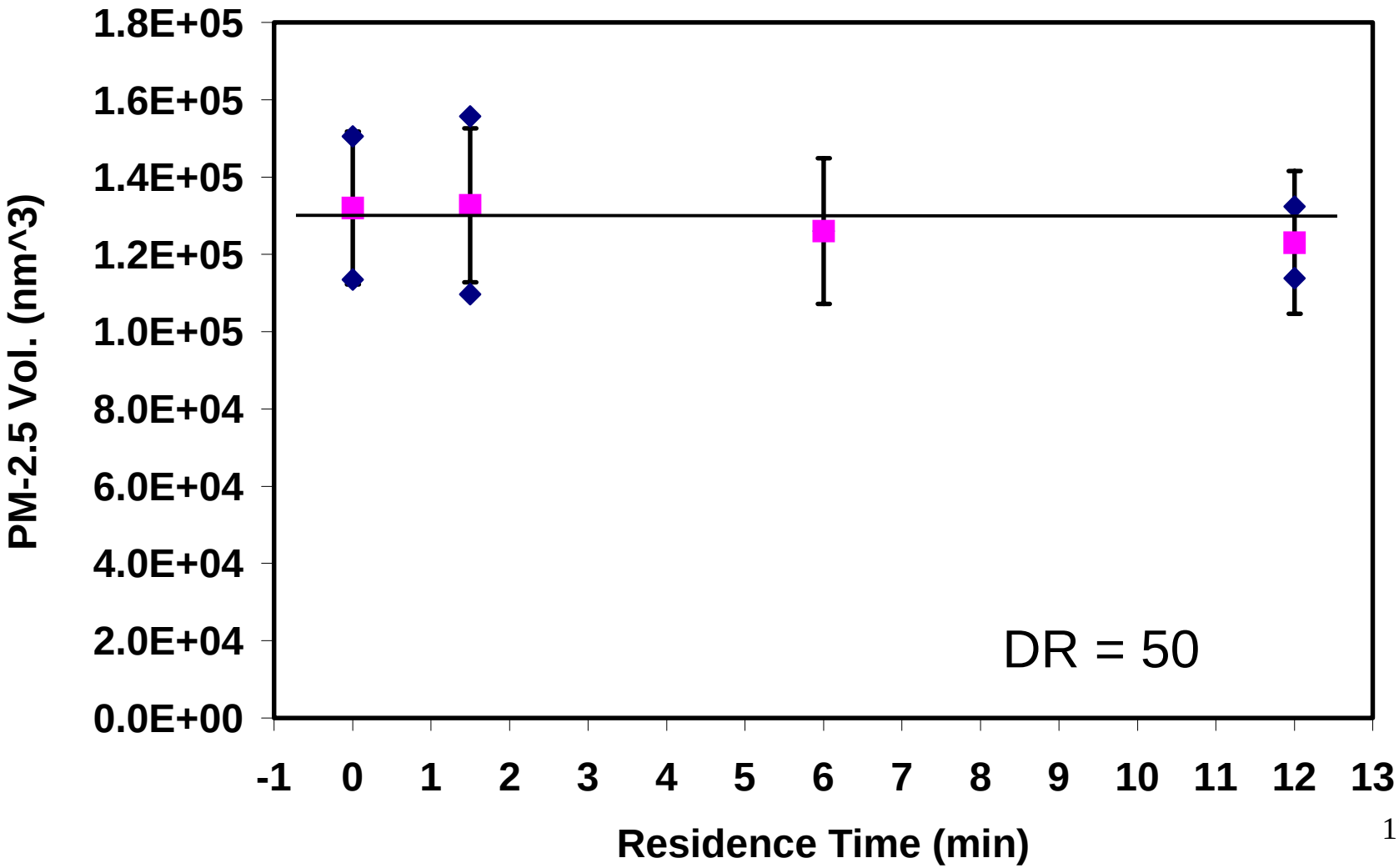
Effect of Dilution Ratio on Size Distribution



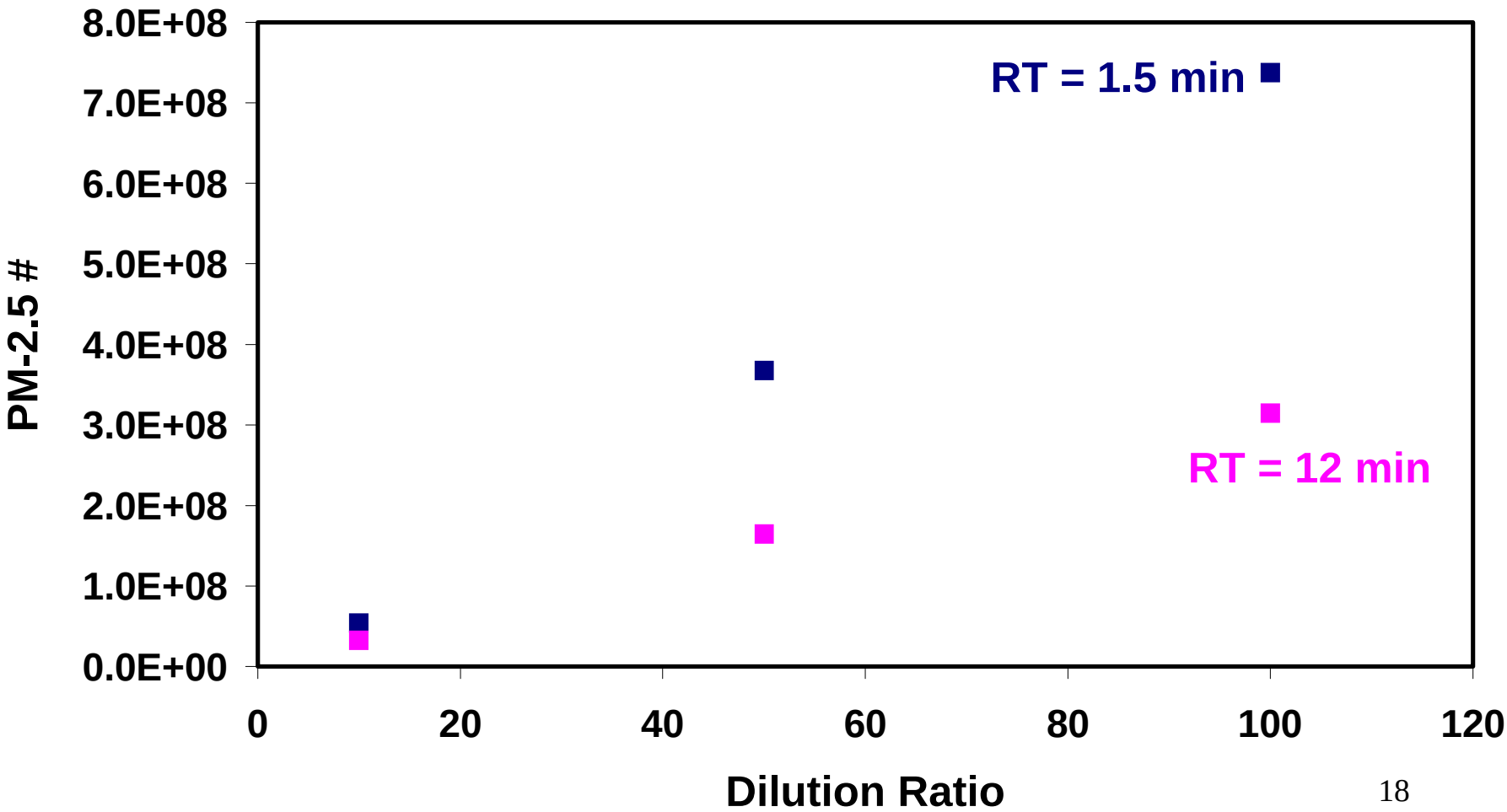
Effect of Residence Time



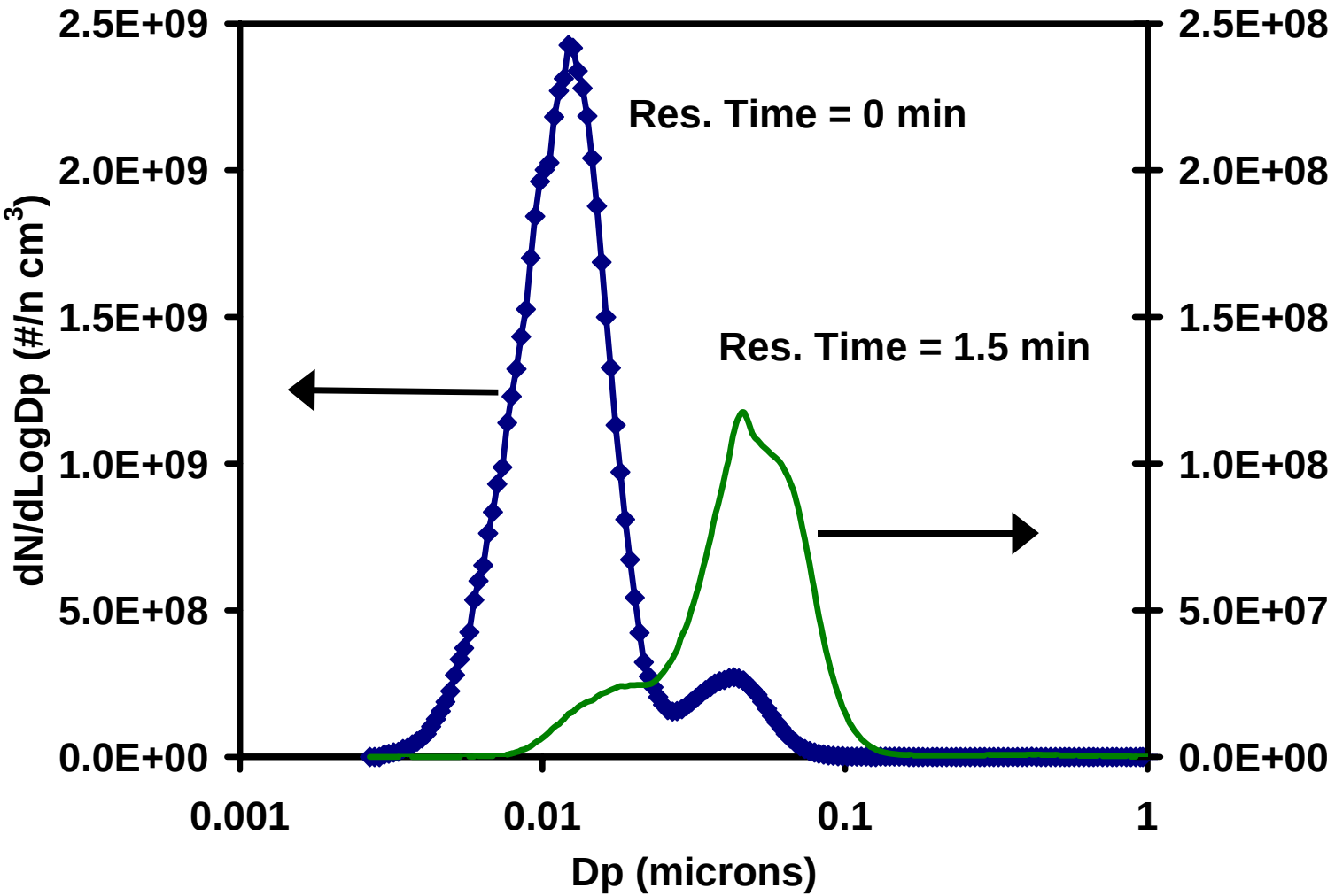
Mass Emission Remain Constant With Residence Time



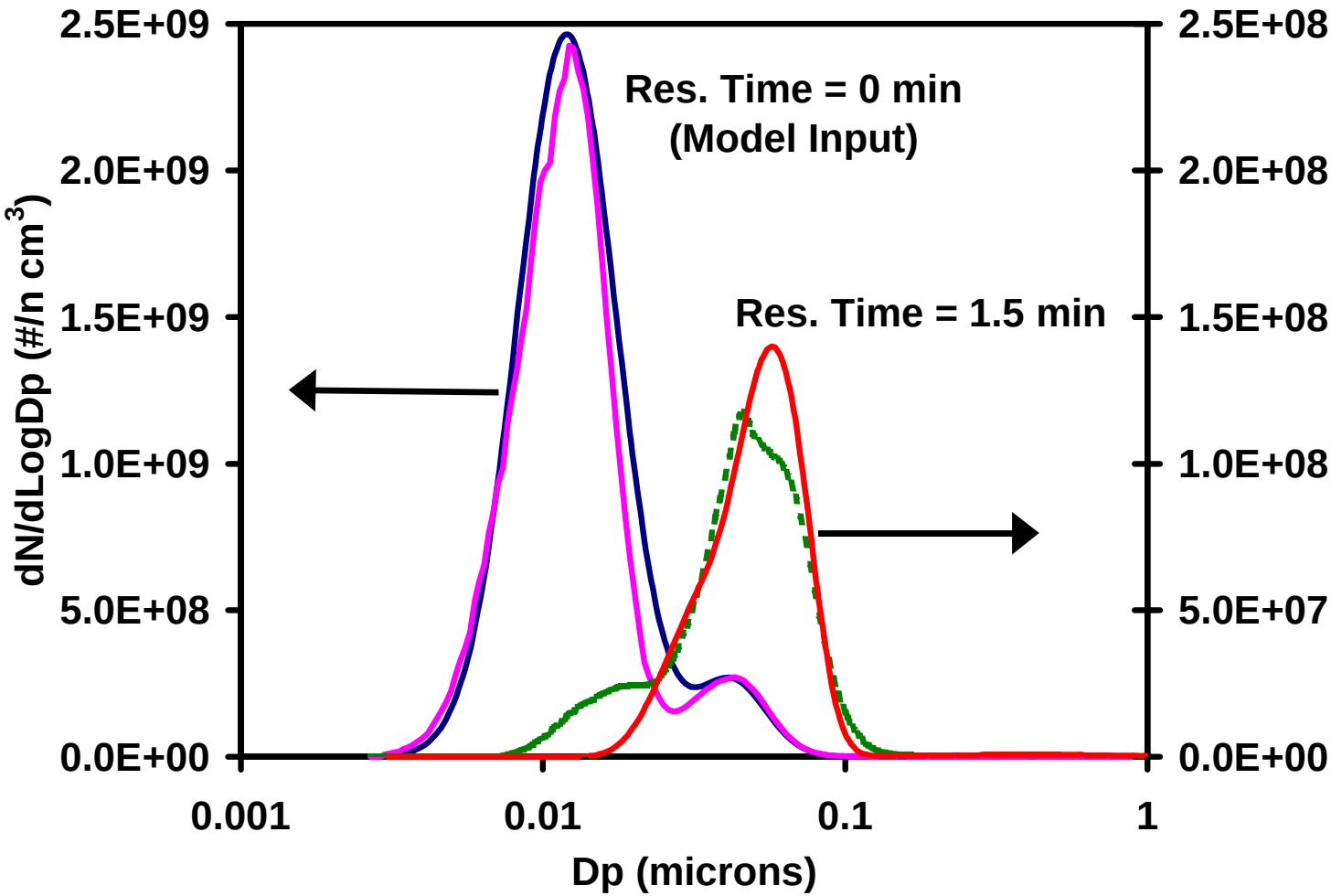
Increasing dilution ratio increases particle number



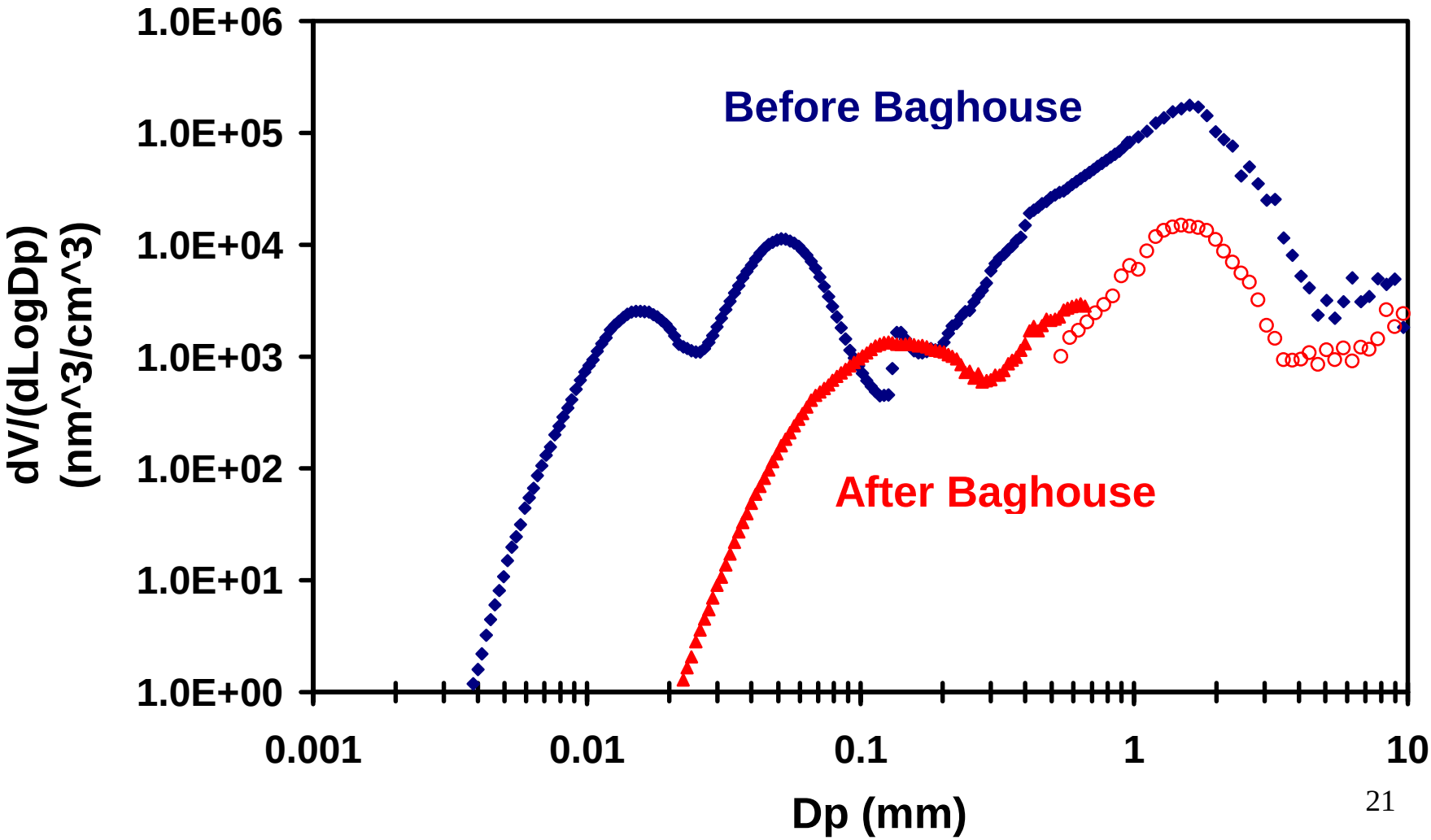
Changes with increased residence time



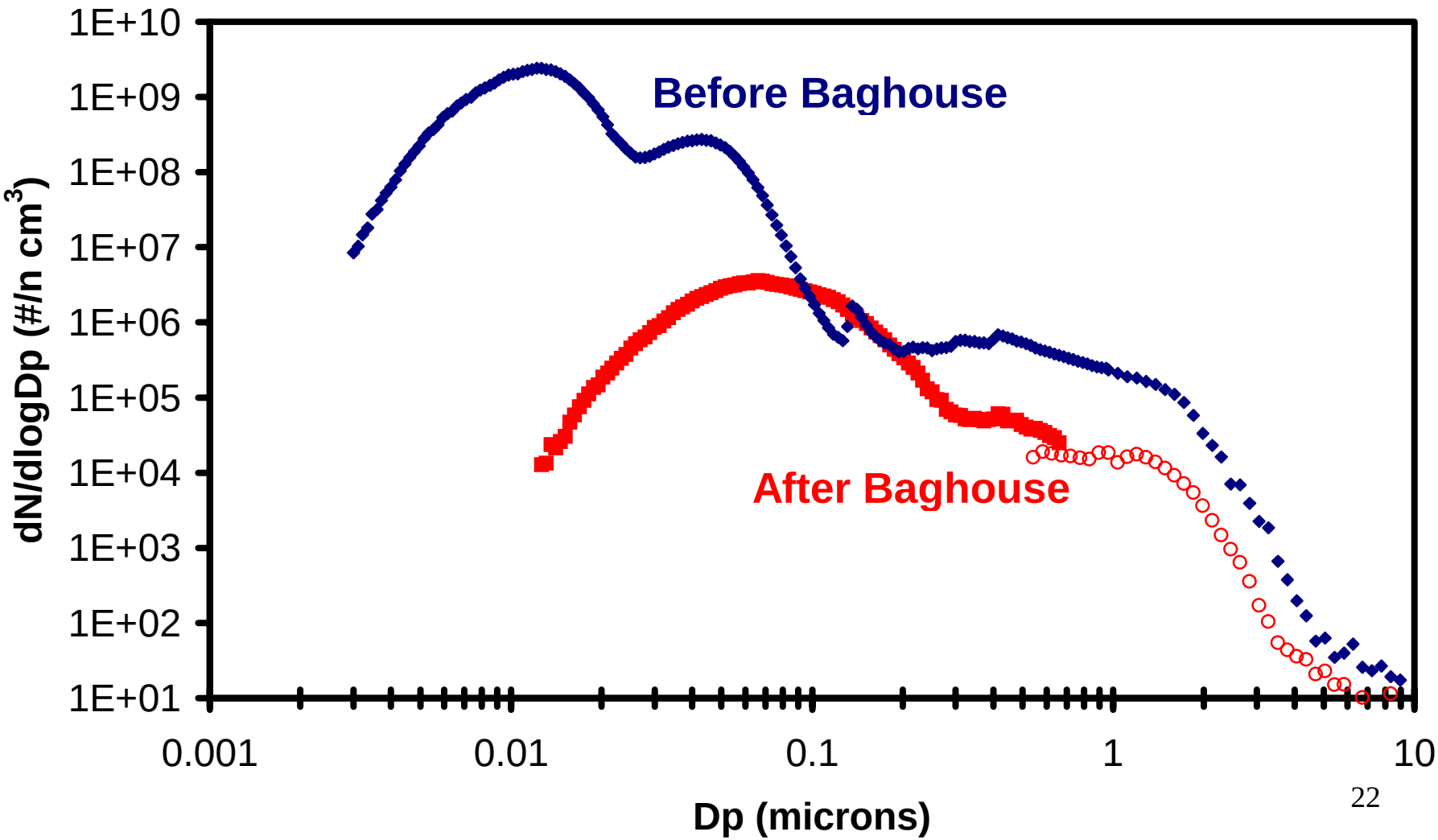
Changes in size distribution are primarily due to coagulation



Effect of Bag House on Mass Emissions



Bag house removes nucleation mode



Conclusions for Particle Size Distributions

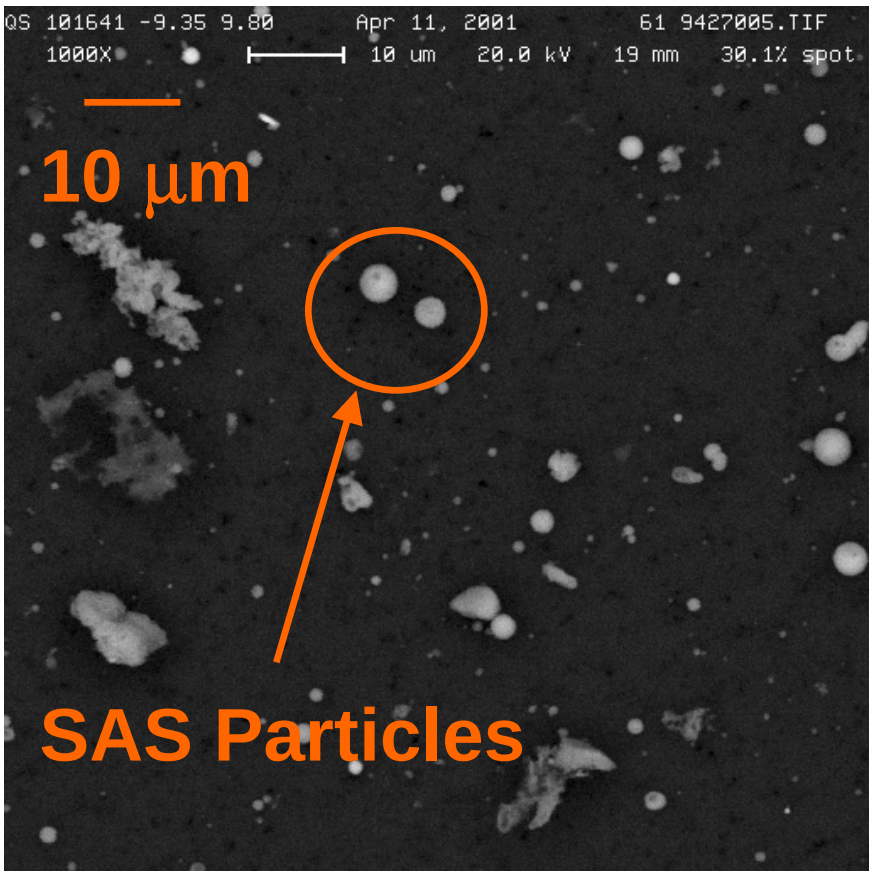
- **Effects of dilution ratio and residence time can largely be explained by coagulation**
  - **Higher dilution ratio lowers the coagulation rate**
  - **Longer residence time more coagulation**
- **Bag house removes 10 nm mode**
- **Dilution sampling has little effect on mass emission rates**

Chemical Composition

- **What are the effects of dilution sampling, coal quality, and operating parameters on PM chemical composition?**

- **Tracers for coal combustion**
  - **Ratio Se, As to SOx**
  - **Spherical Aluminum Silicate Particles**

SEM analysis for Spherical Aluminum Silicate (SAS) Particles



SAS particles are unique fingerprint for coal combustion

Examine effects of coal quality and load on SAS emissions

Future Work

- **Chemical composition:**
  - **Focus on semi-volatile metals Se and As used as fingerprints for coal combustion**
- **Single particle measurements:**
  - **Particle classes for source apportionment**
  - **Single particle mass spectrometer; laser induced breakdown spectroscopy**
- **Smog chamber experiments to examine interaction of coal boiler exhaust with urban or biogenic plume**
- **Effect of coal quality and operating conditions on emissions**