Yale-NUIST Center on Atmospheric Environment

A discussion on the paper "Particle Loss Calculator – a new software tool for the assessment of the performance of aerosol inlet systems"

By S.-L. von der Weiden et al.

Atmospheric Measurement Techniques

IF: 3.206

Liu Xiaoyan
2014-09-19

Outline

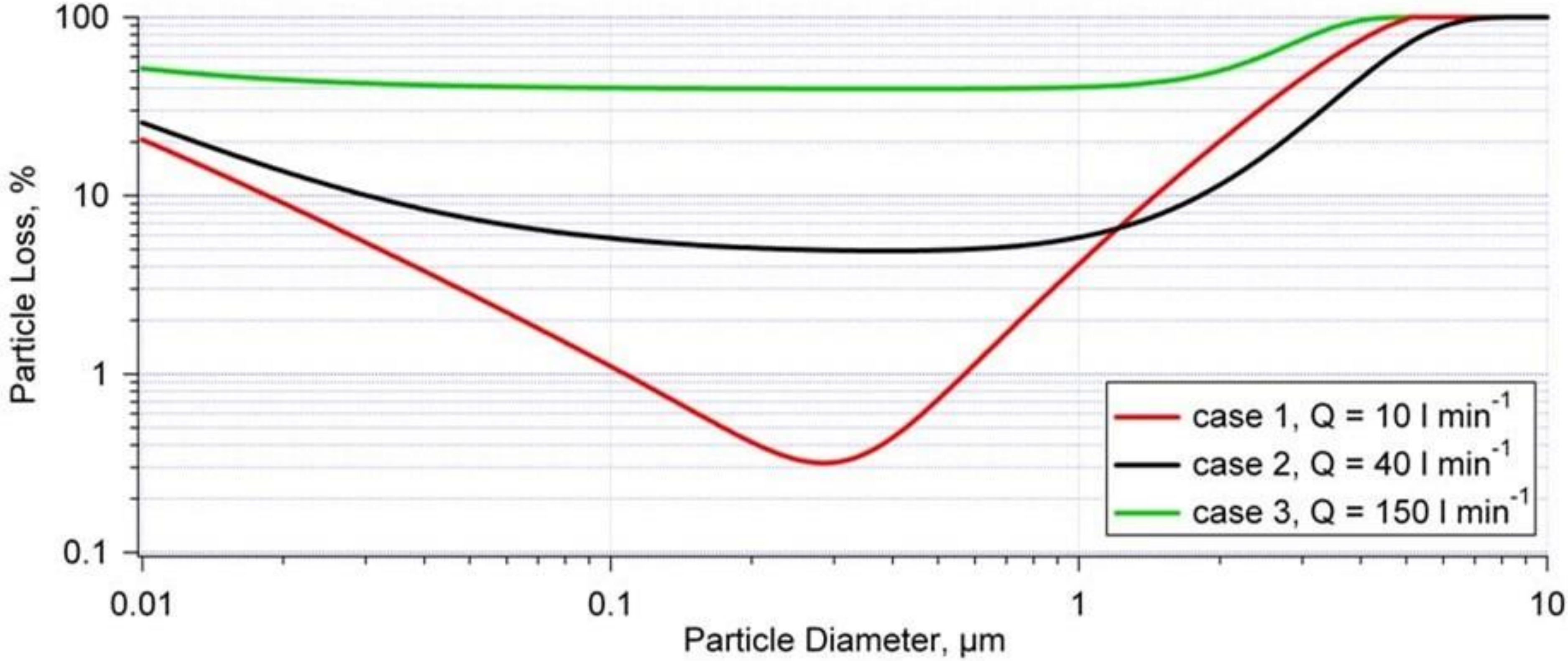
- Introduction
- Theory and method
- Operation
- Validation measurements
- Applications
- Summary

Introduction

- For aerosol measurement instruments, there's always an inlet system to transport aerosols from a sampling location to the analysor through some length of tubing, where aerosol particle loss due to a number of mechanisms exists.

- The inlet system with better performance is the one with less particle loss and higher sampling efficiency.

- Particle Loss Calculator(PLC) is a software which produces graphs showing particle loss on Y-axis and particle size on X-axis after inputting parameters of the inlet system.



$$d_a = d_{phys}\left(\frac{\rho_p}{\rho_0}\right)^{1/2}$$

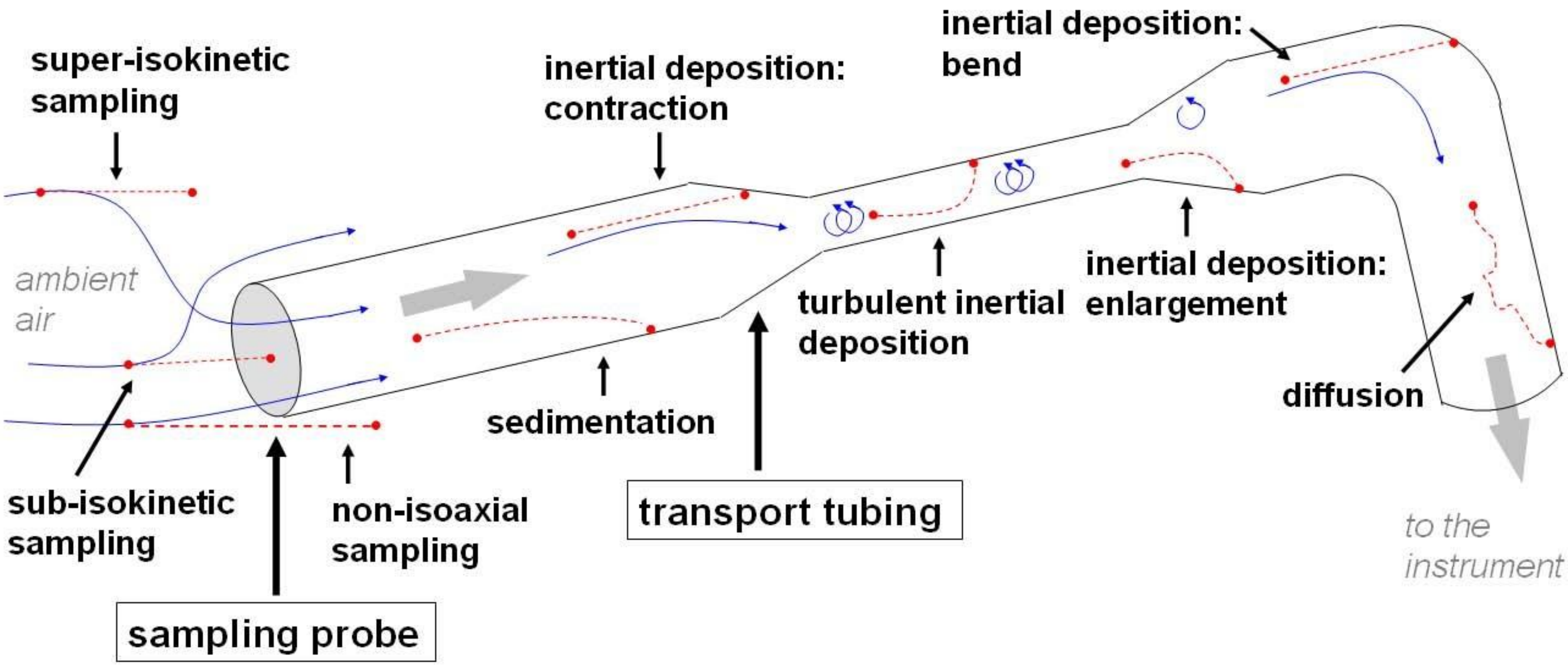
d_{phys} physical diameter

ρ_p density of the particles

ρ_0 standard density of $1 g/cm^3$ *(Willeke and Baron,2005)*

Theory and method

- Particle loss mechanisms



Also include electrostatic deposition, thermophoreses, diffusiophoresis, interception and coagulation.

Theory and method

- Overall efficiency η_{inlet}

The ratio of the number concentration of particles behind the tube and the number concentration of particles in front of it.

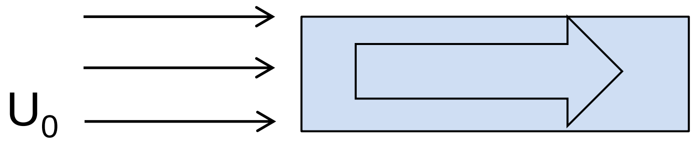
$$\eta_{inlet}(d_a) = \eta_{sampling}(d_a) \cdot \eta_{transport}(d_a)$$

(Willeke and Baron,2005)

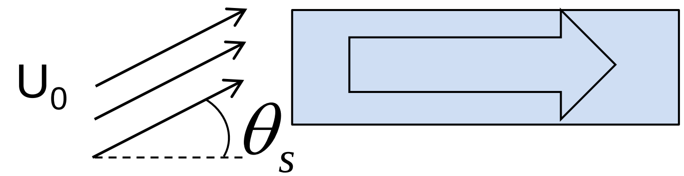
Theory and method

- Sampling situations:

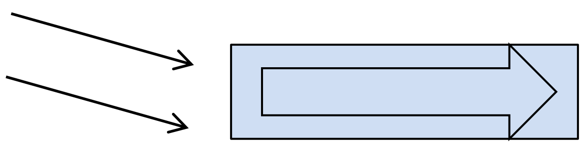
- Isoaxial sampling

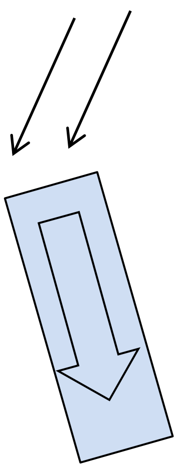


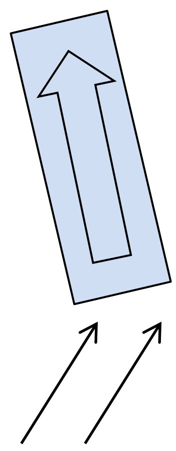
Non-isoaxial sampling



- Non-isaxial sampling







I_w : Horrizontal sampling   Downward sampling   Upward sampling

Theory and method

- Sampling situations:
  - Non-isokinetic

    $R=U_0/U$

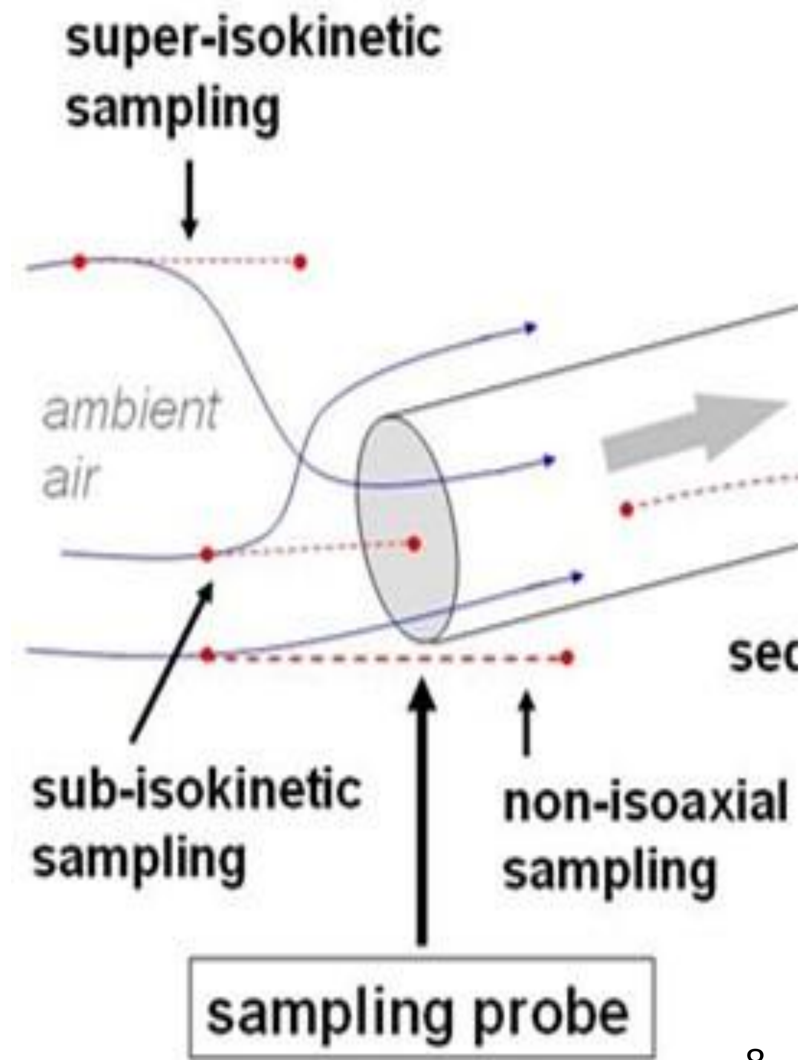
    U_0:local wind speed

    U:flow velocity in the sampling probe

    R>1,sub-isokinetic sampling

    R<1,super-isokinetic sampling

- Isokinetic sampling(R=1)



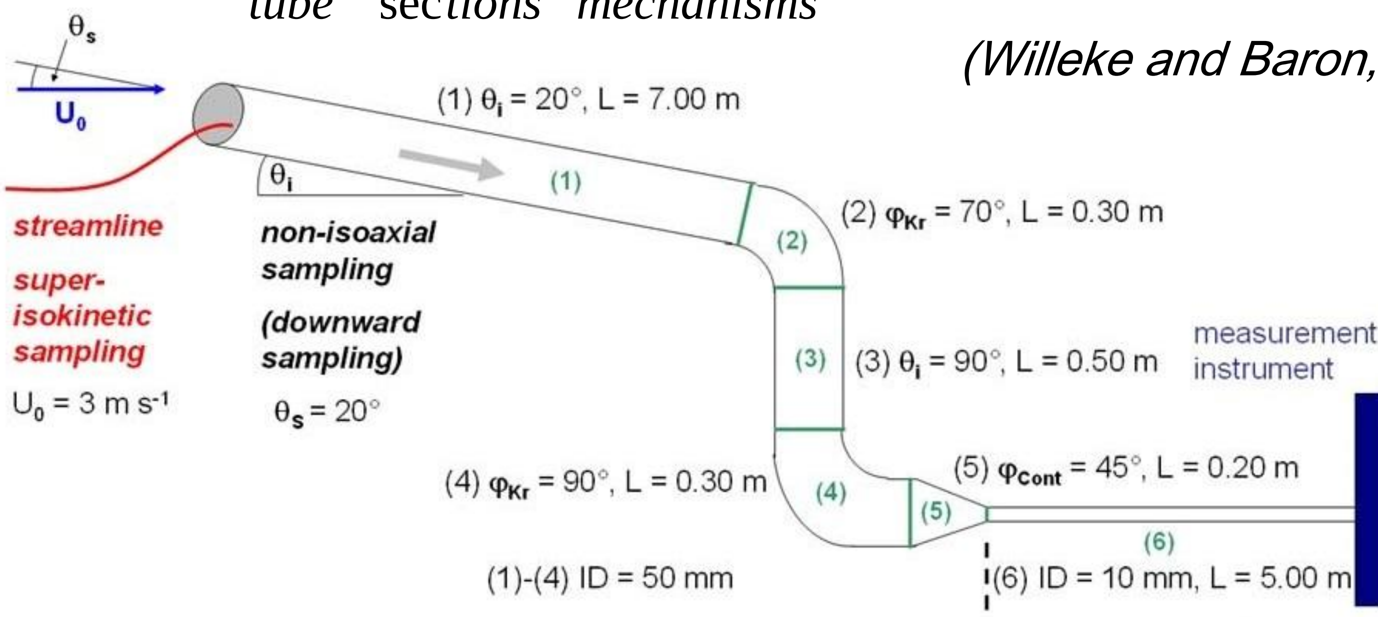
Theory and method

- Transport efficiency $\eta_{transport}$

The ratio of number concentration of aerosol particles leaving the transport tubing to that of those entering it.

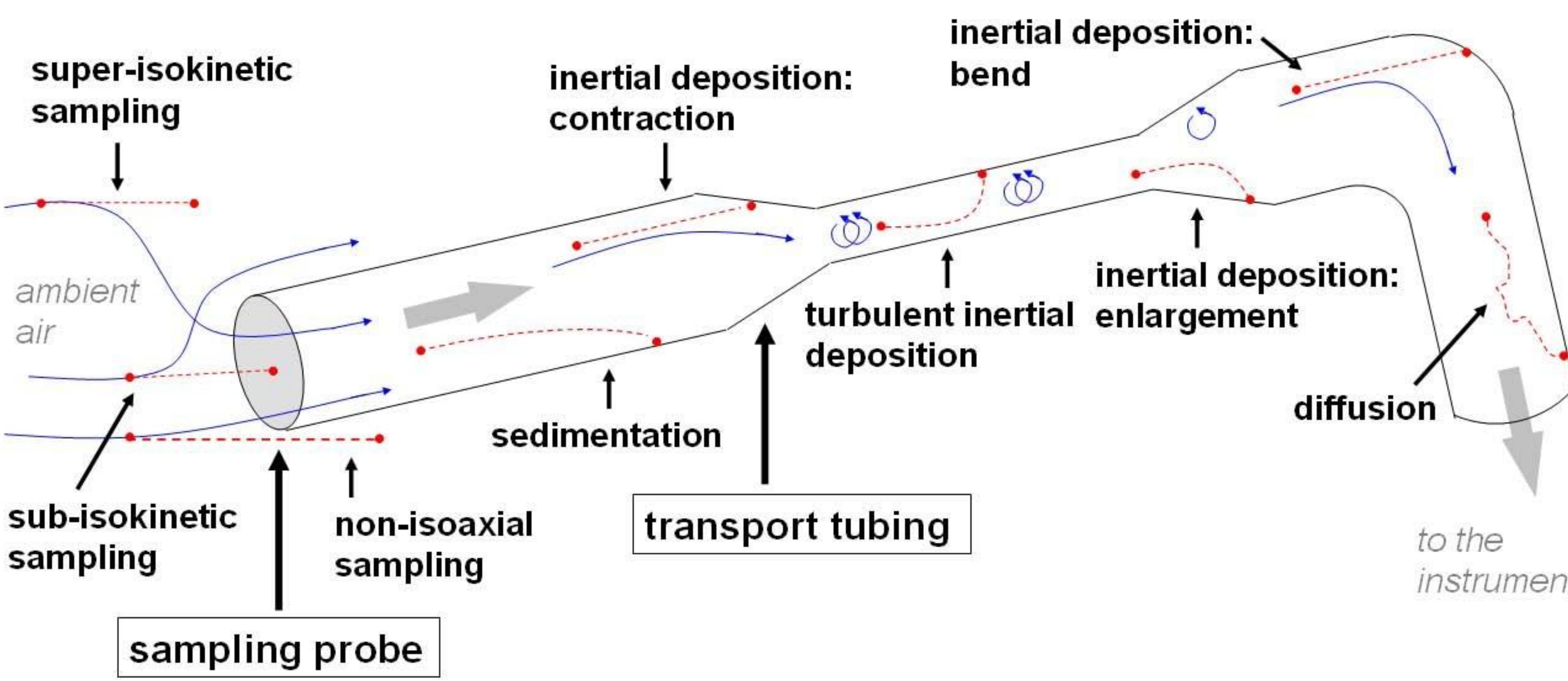
$$\eta_{transport}(d_a) = \prod_{tube\ \ sections} \left(\prod_{mechanisms} \eta_{tube\ \ section,mechanism}(d_a) \right)$$

(Willeke and Baron,2005)

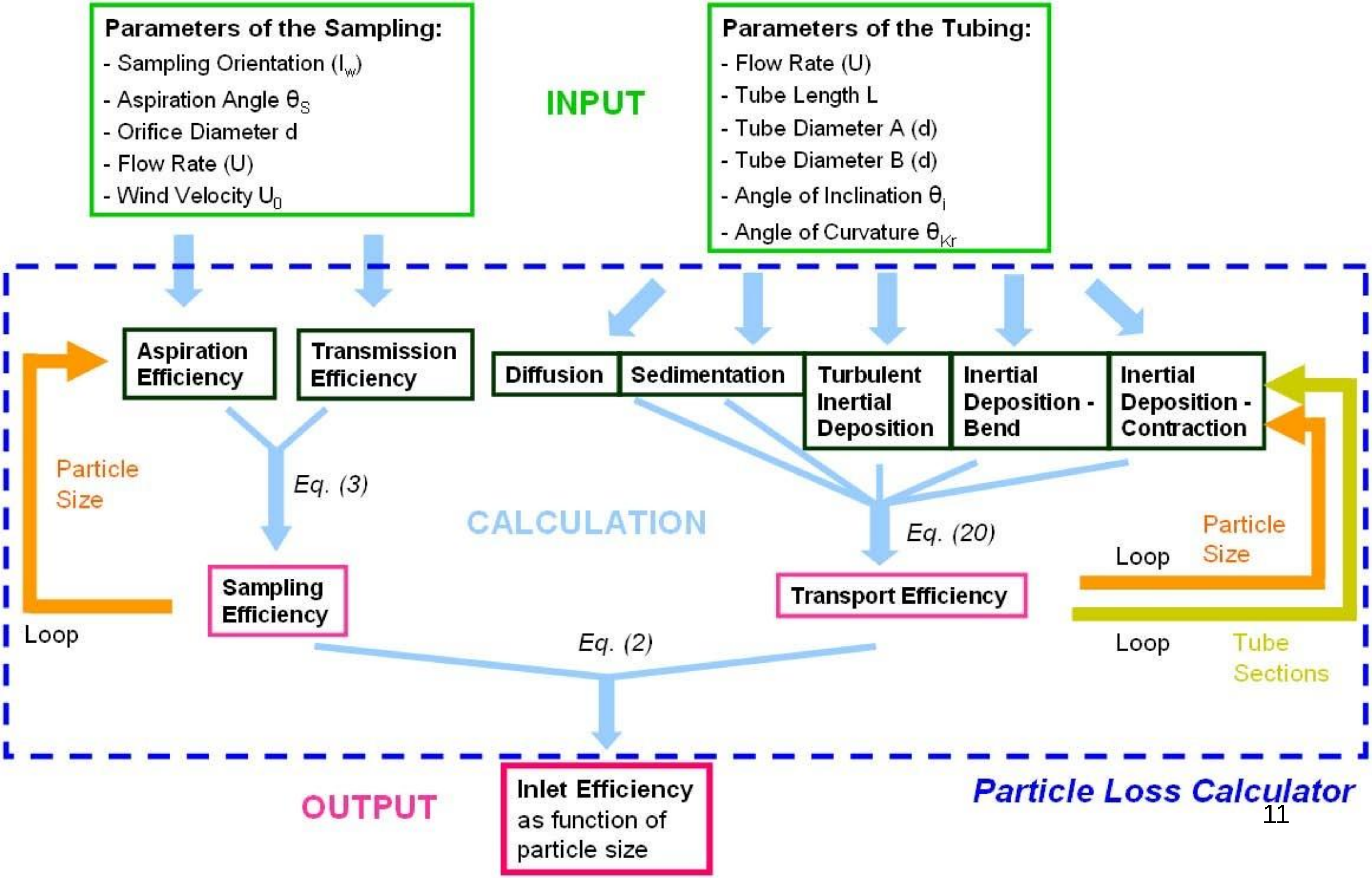


Theory and method

- Transport efficiency $\eta_{transport}$
  - Diffusion efficiency η_{diff}
  - Sedimentation η_{grav}
  - Inertial deposition $\eta_{turb \quad inert}$ $\eta_{bend,inert}$ $\eta_{cont,inert}$

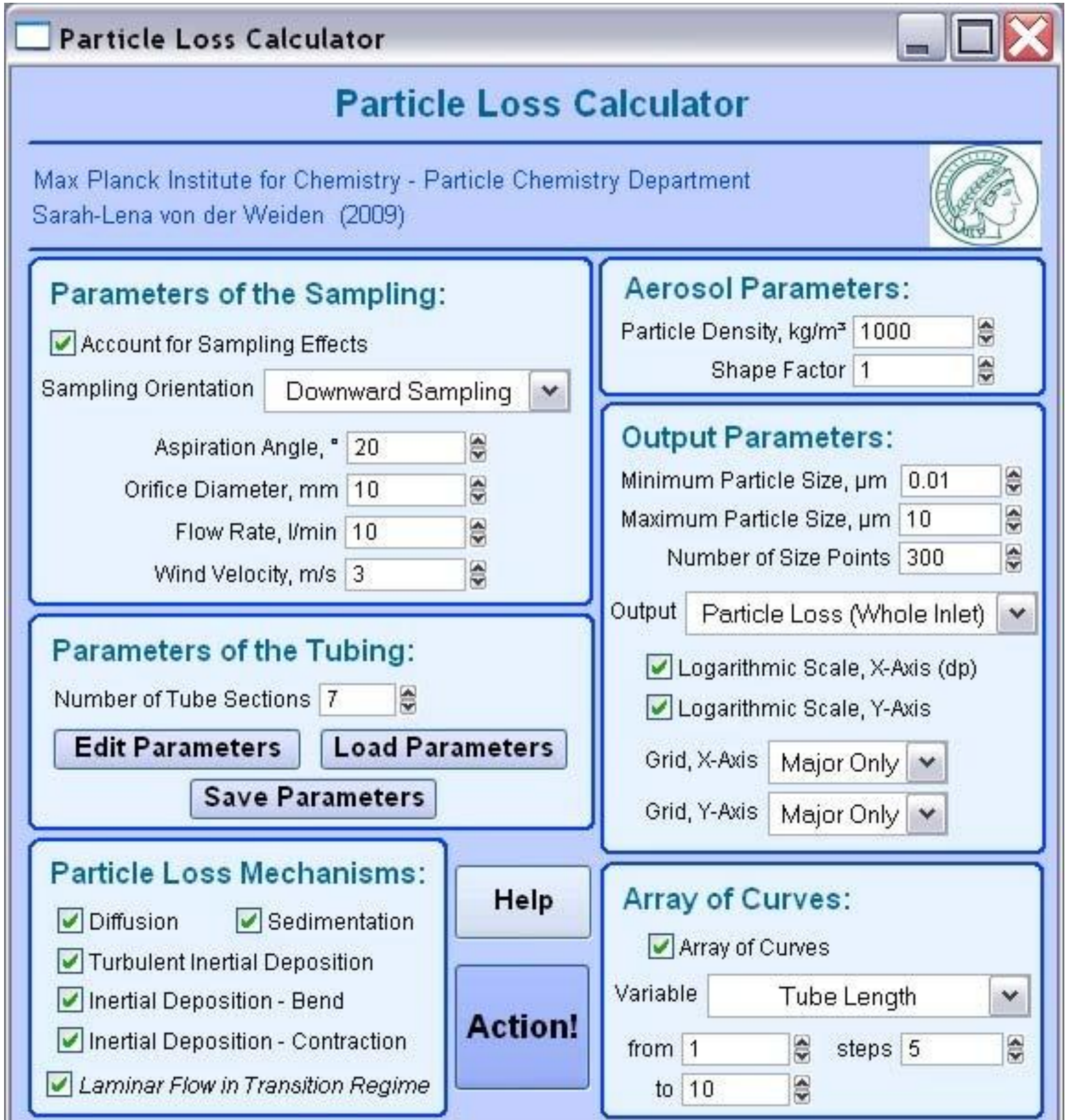


Operation



Parameters of the Sampling:
- Sampling Orientation (I_w)
- Aspiration Angle θ_S
- Orifice Diameter d
- Flow Rate (U)
- Wind Velocity U_0
INPUT
Parameters of the Tubing:
- Flow Rate (U)
- Tube Length L
- Tube Diameter A (d)
- Tube Diameter B (d)
- Angle of Inclination θ_i
- Angle of Curvature θ_{Kr}
Aspiration Efficiency
Transmission Efficiency
Diffusion
Sedimentation
Turbulent Inertial Deposition
Inertial Deposition - Bend
Inertial Deposition - Contraction
Particle Size
Eq. (3)
CALCULATION
Eq. (20)
Loop
Particle Size
Sampling Efficiency
Transport Efficiency
Loop
Eq. (2)
Loop
Tube Sections
OUTPUT
Inlet Efficiency as function of particle size
Particle Loss Calculator

Operation



Particle Loss Calculator
Particle Loss Calculator
Max Planck Institute for Chemistry - Particle Chemistry Department
Sarah-Lena von der Weiden (2009)
Parameters of the Sampling:
Account for Sampling Effects
Sampling Orientation
Downward Sampling
Aspiration Angle, °
20
Orifice Diameter, mm
10
Flow Rate, l/min
10
Wind Velocity, m/s
3
Parameters of the Tubing:
Number of Tube Sections
7
Edit Parameters
Load Parameters
Save Parameters
Particle Loss Mechanisms:
Diffusion
Sedimentation
Turbulent Inertial Deposition
Inertial Deposition - Bend
Inertial Deposition - Contraction
Laminar Flow in Transition Regime
Help
Action!
Aerosol Parameters:
Particle Density, kg/m³
1000
Shape Factor
1
Output Parameters:
Minimum Particle Size, µm
0.01
Maximum Particle Size, µm
10
Number of Size Points
300
Output
Particle Loss (Whole Inlet)
Logarithmic Scale, X-Axis (dp)
Logarithmic Scale, Y-Axis
Grid, X-Axis
Major Only
Grid, Y-Axis
Major Only
Array of Curves:
Array of Curves
Variable
Tube Length
from
1
steps
5
to
10

Operation

Table0:No,flowrate,tubelength,...

R8 | 0

No	Flow Rate, l/min	Tube Length, m	Tube Diameter A, mm	Tube Diameter B, mm	Angle of Inclination, °	Angle of Curvature, °
1	4	0.05	10	10	0	0
2	4	0.1	10	20	45	0
3	4	0.1	20	5	0	0
4	1.2	0.083	5	10	0	0
5	1.2	0.05	10	10	90	45
6	1.2	0.033	10	3	90	0
7	3	1.2	3	3	0	90

Validation

- Experimentally determined particle losses:

$$particle \quad loss(\%) = \left(1 - \frac{number \quad conc. \quad of \quad particles \quad at \quad tube \quad exit}{number \quad conc. \quad of \quad particles \quad at \quad tube \quad entrance}\right) \cdot 100\%$$

- Experiment instrument:

instrument	size range	correction factor
Condensation Particle Counter (CPC,TSI,model 3007)	10nm-250nm	1.0094
Optical Particle Counter (OPC,Trimm,model 1.109)	300nm-32μm	concerning size

Table 1.Correction factor applied to one of the OPCs during the outdoor validation measurements

Particle Size (μm)								
	0.265	0.290	0.325	0.375	0.425	0.475	0.54	0.615
	0.675	0.750	0.900	1.150	1.450	1.800	2.250	2.750
	3.250	4.500	5.750	7.000	8.000	9.250	11.250	13.750
	16.250	18.750	22.500	27.500	31.000			
Correction Factor								
	0.841	0.998	1.015	0.968	0.840	0.609	1.028	0.870
	0.920	1.101	0.816	1.125	0.930	0.903	0.963	0.925
	0.881	0.912	0.833	0.985	0.868	1	1	1
	1	1	1	1	1			

Validation

- Small particles (diffusion)
- Devices:

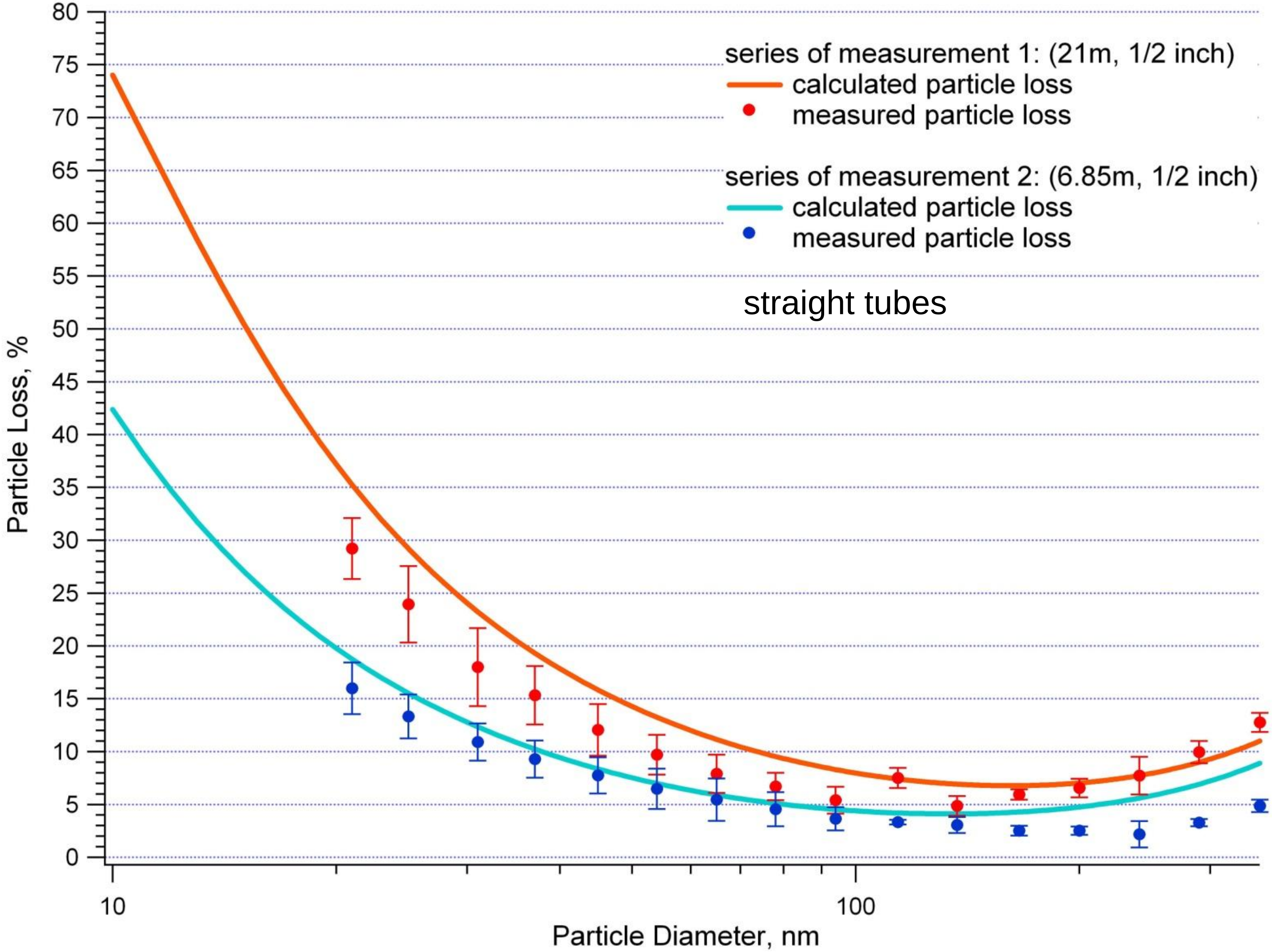
ID	1/4 inch
lengths	20.80m,10m,3m
geometry	coiled in several turns(up to 10)

- Results:

a. There're similar trends between particle the losses measured and those calculated.
b. There're differences in the size range from about 20nm to 200nm,which depend on the angle of curvature.
c. Particle loss due to inertial effects is not negligible for small particles in a laminar flow in the range tested.

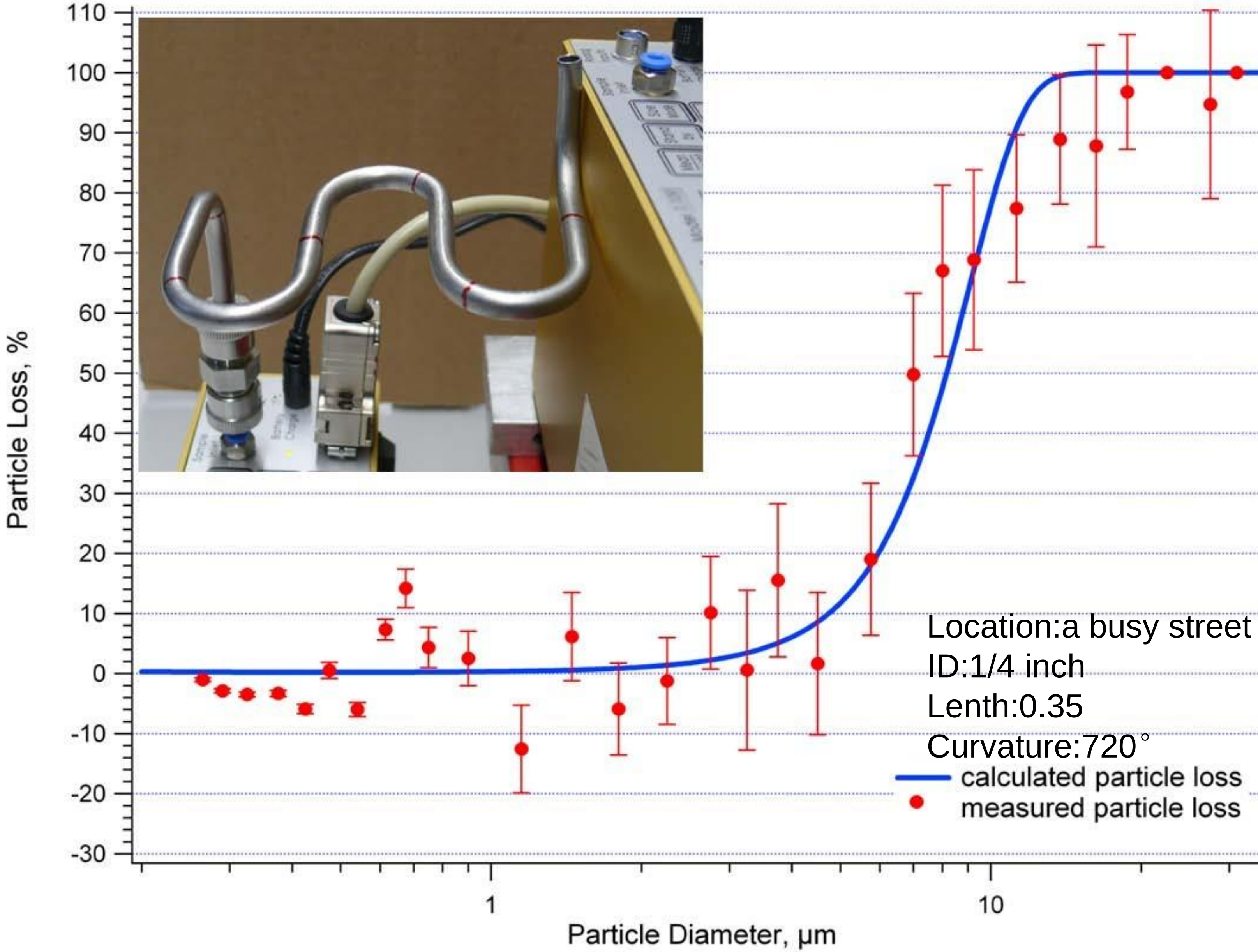
Validation

- Small particles(diffusion)

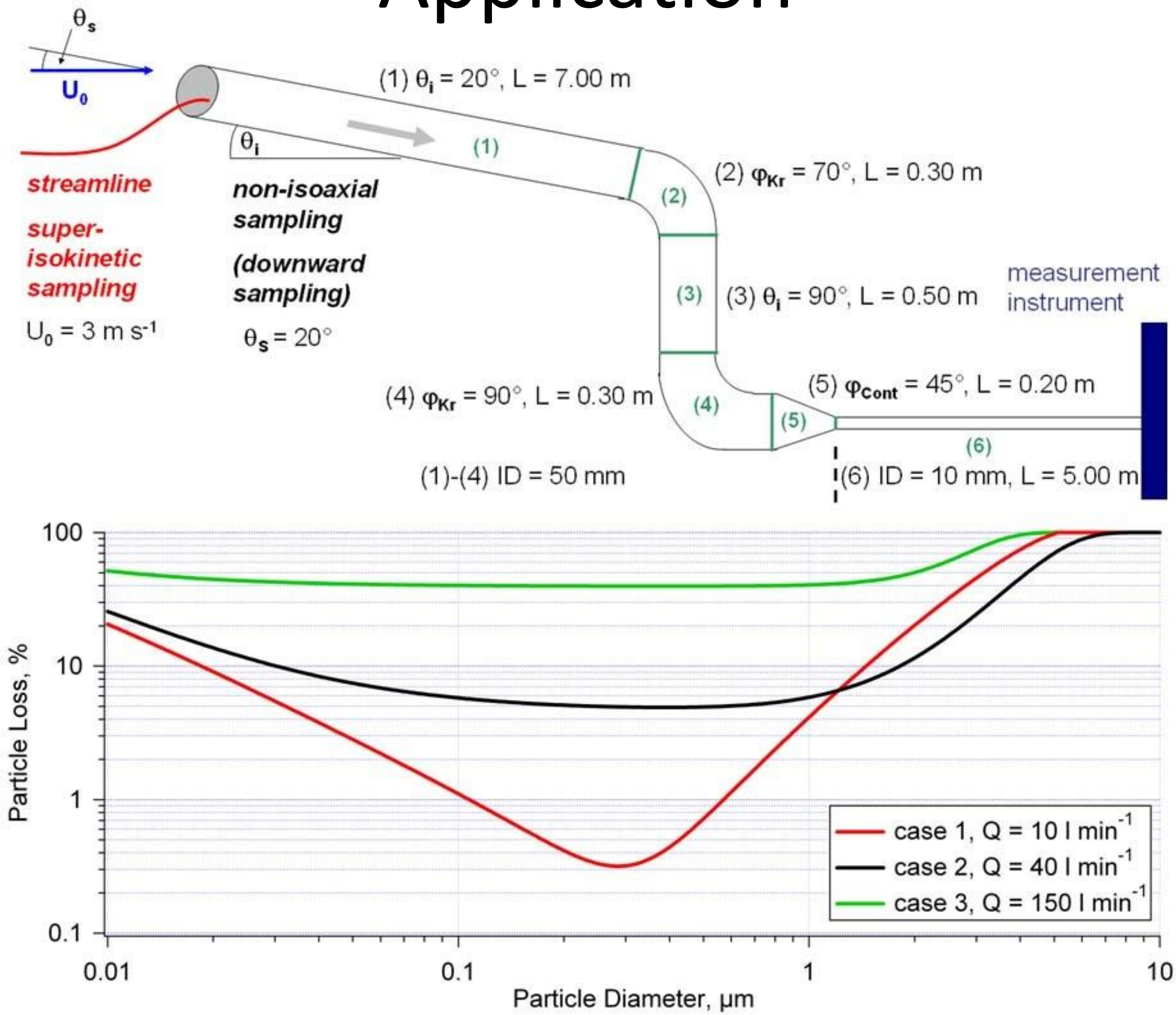


Validation

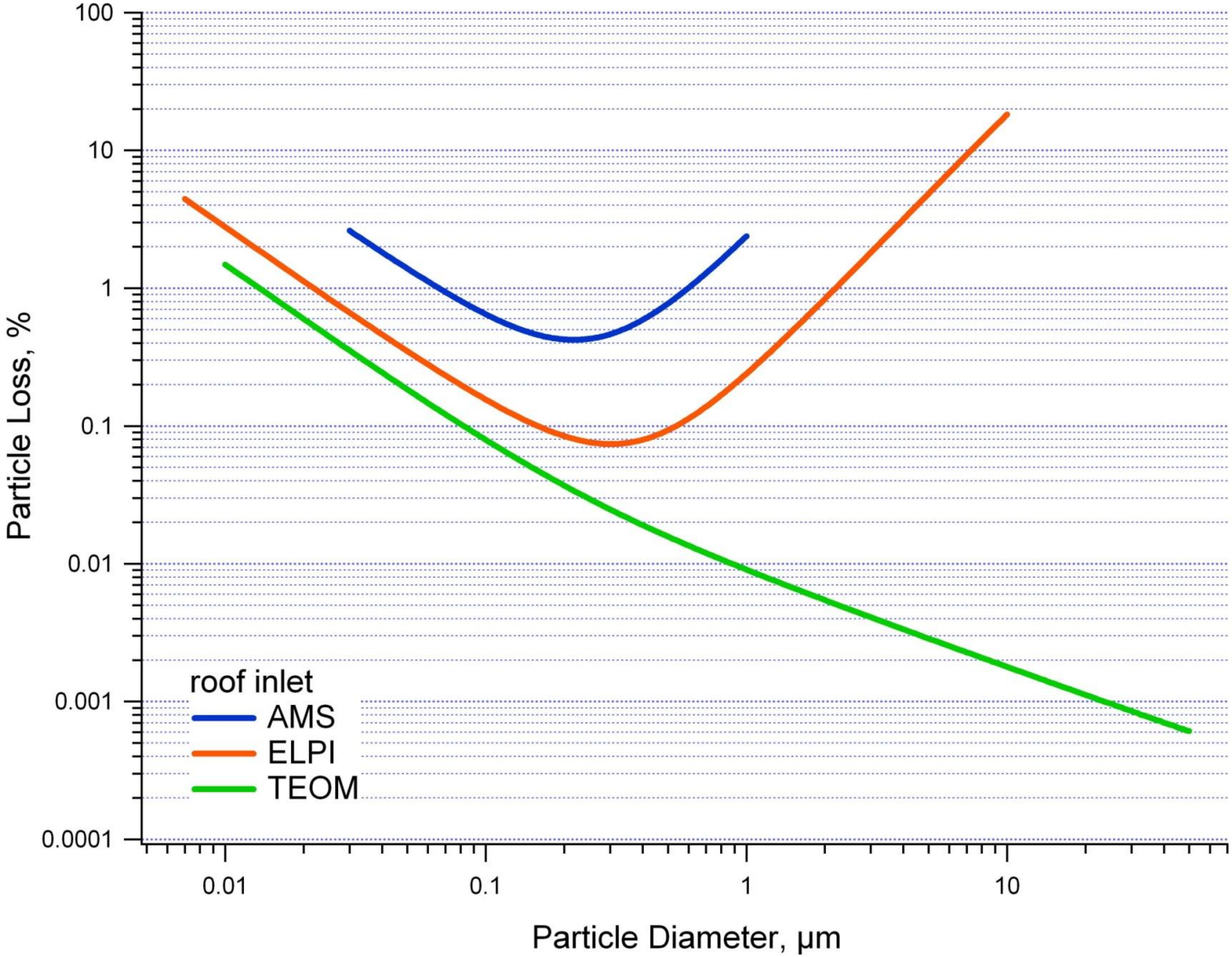
- Larger particles(impaction losses in bends)



Application



Application



Summary

- Calculations from PLC agree well with those from experiment for less extreme geometries.

- The software PLC based on both empirically and theoretically derived relations can quickly assess aerosol sampling efficiencies and particle transport losses for arbitrary tubing system.

THANK YOU