POLITECNICO DI MILANO
DIIAR Environmental Section

Summer School: Biological and Thermal Treatment of Municipal Solid Waste

EMISSION OF ULTRAFINE AND NANOPARTICLES FROM WASTE TO ENERGY PLANTS

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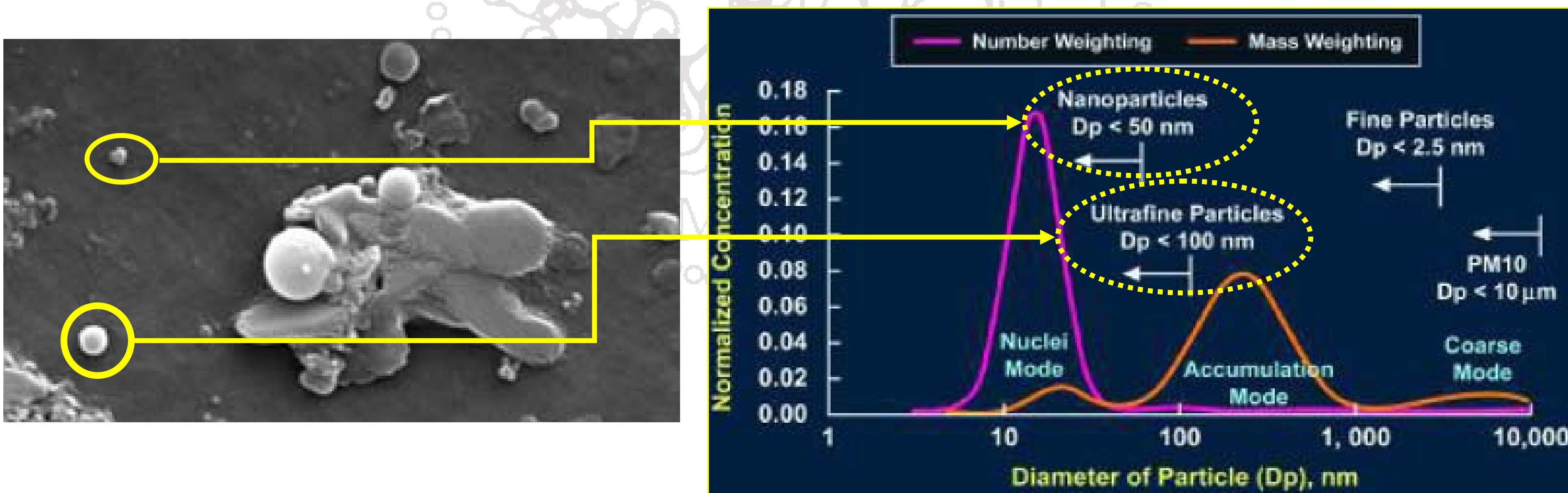
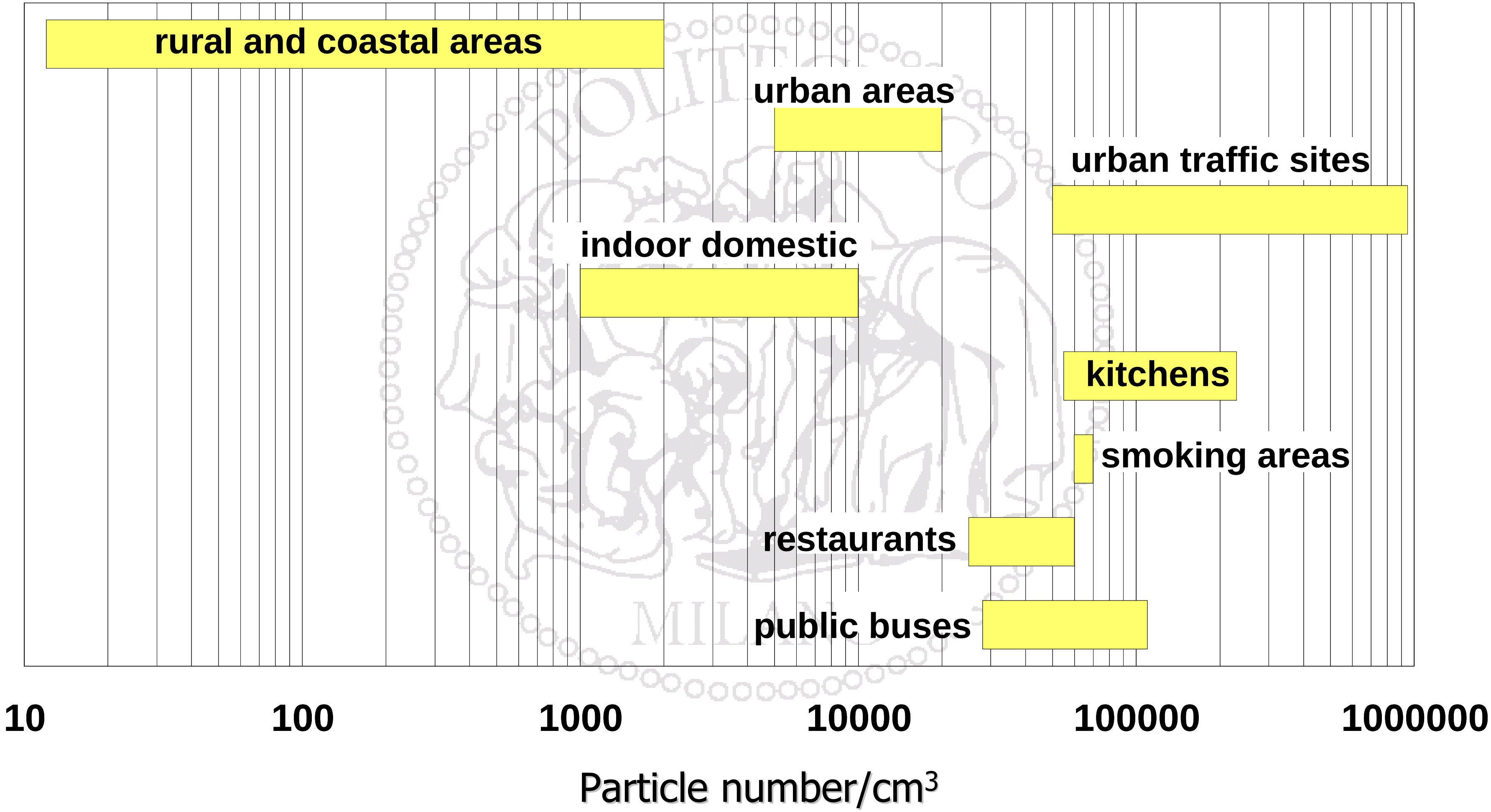
Background

Ultrafine (UP) and nanoparticles (NP)

- Dimensions < 0,1 µm (UP) - 0,05 µm (NP)
- **Main environmental** concerns → nanotechnologies, nanomaterials, indoor exposures
- Recent attention to **combustion emissions**
  - most data available for vehicle exhaust
  - limited investigations for stationary sources
  - **few studies for WTE plants**



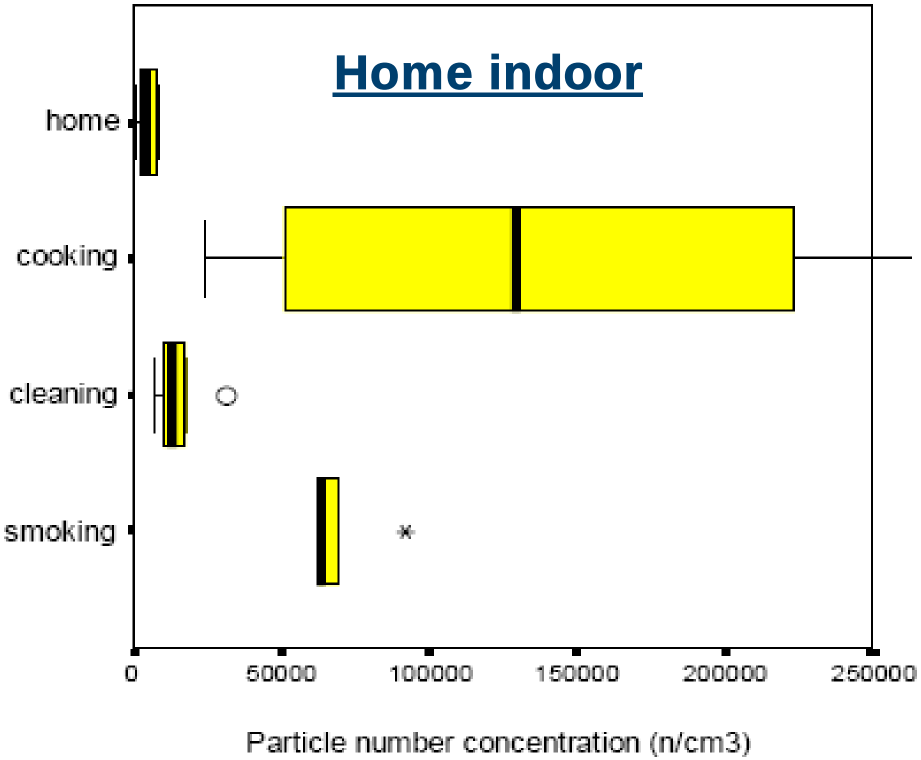
PU concentrations in selected environments

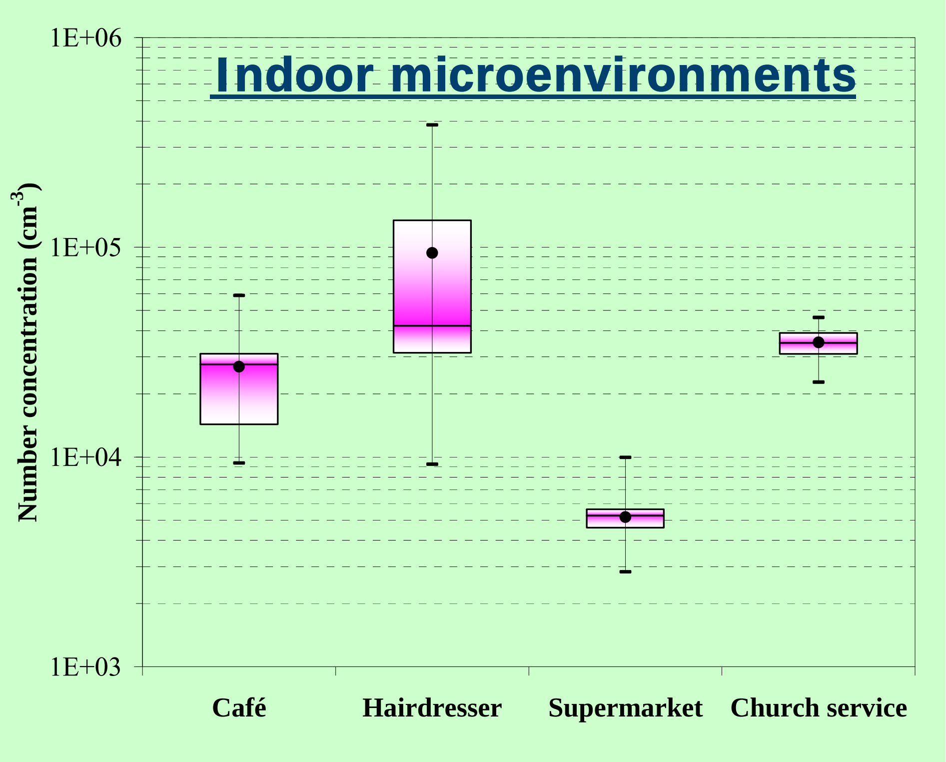


Background - industrial levels

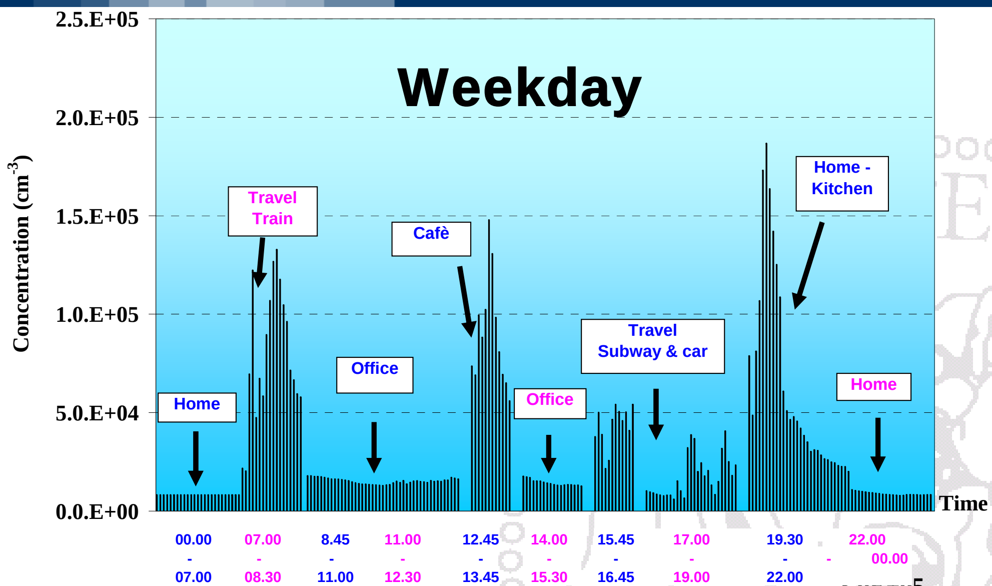
Process	Concentration within 14 - 673 nm size range (particles/cm³)	Typical size range (nm)
Background, indoor	≥ 10 000	
Silica fusion	≥ 100 000	280-520
Metal grinding	≥ 130 000	17-170
Metal soldering	≥ 400 000	36-64
Plasma cutting	≥ 500 000	120-180
Bread baking oven	≥ 640 000	32-109
Airport landing runway	≥ 700 000	< 45
Electrode welding	54 000 - 3 500 000	33-126
Steel welding	100 000 - 40 000 000	40-600

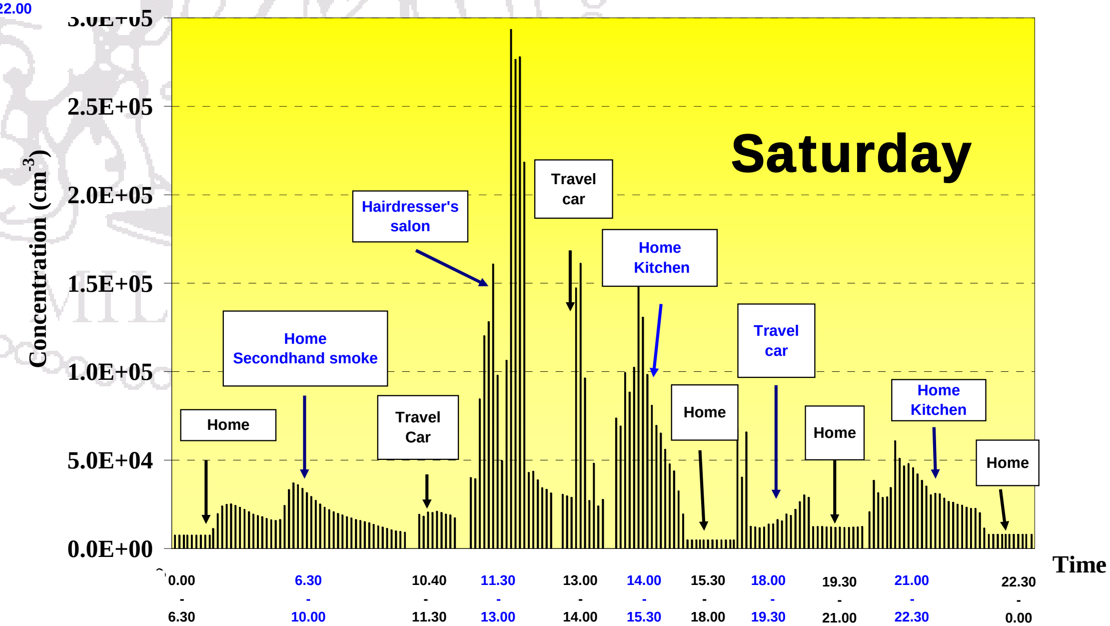
Background - domestic levels





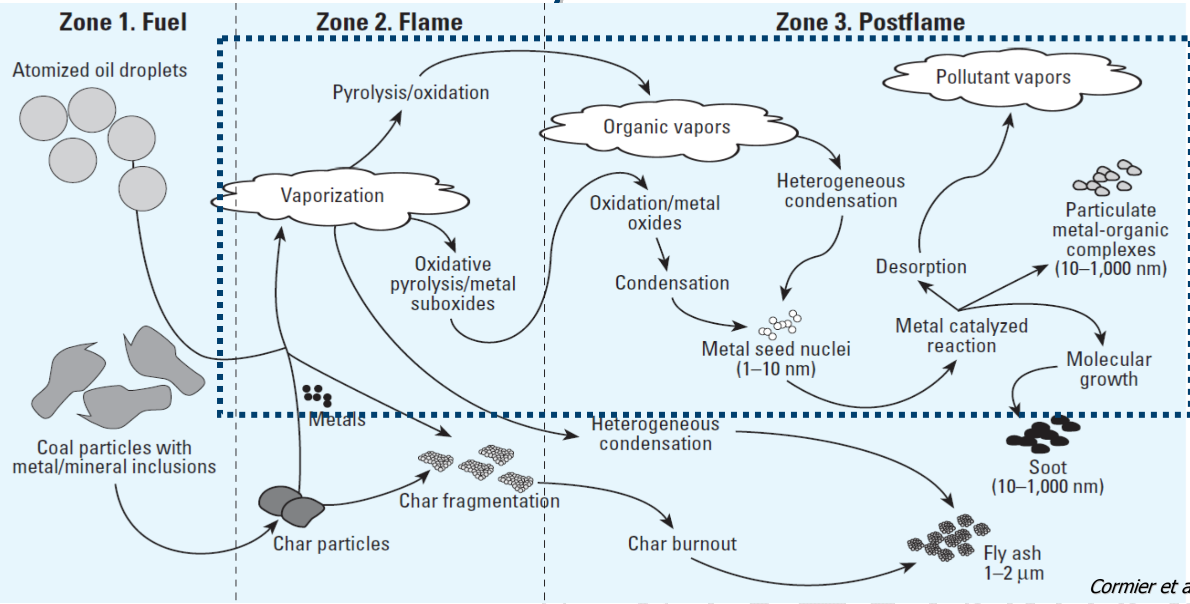
Background - personal exposures





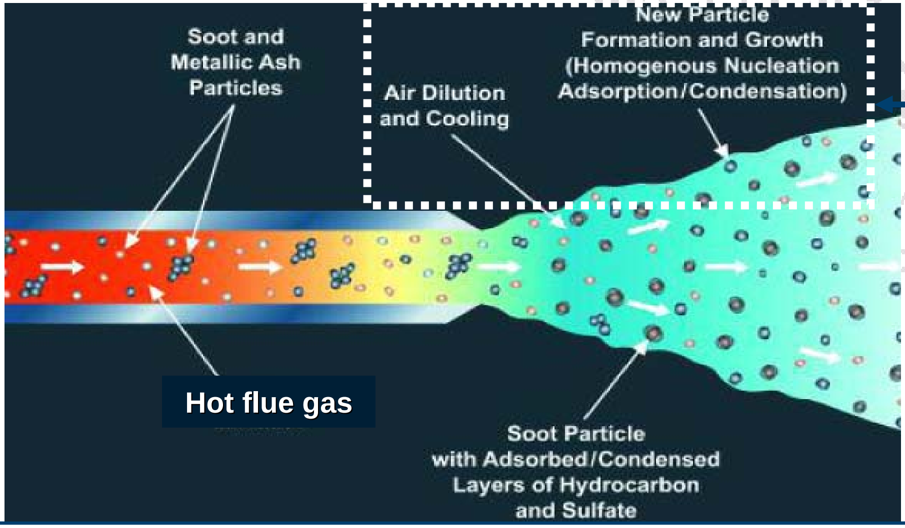
Background

UP/NP emissions from combustion



Cormier et al., Env. Health Persp. 2006

Primary particles



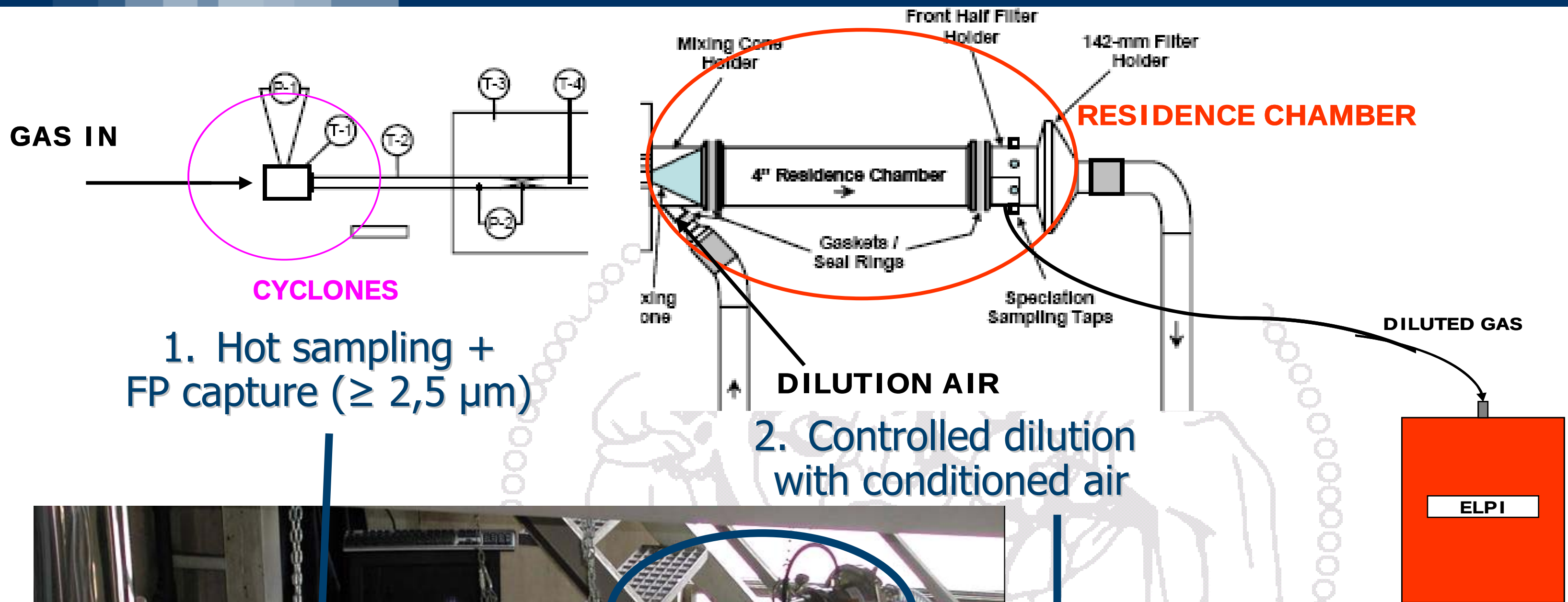
Condensable particles
(semivolatiles nucleation
driven by atmospheric gas dilution)

Research contents

ULTRAPART project

- Characterization of ultrafine and nanoparticle emissions from stationary combustion sources
  - **waste to energy plants**
  - residential boilers fuelled with biomass, light fuel oil and natural gas
- Particle number **concentration** and **size distribution**
- Evaluation of the **condensation effects** by **diluting** and **cooling** the exhaust gas prior to measurements
- **Measurement issues**
  - no standard protocol
  - significance in terms of **number** rather than mass
  - contribution of **condensable fraction** from semivolatiles driven by atmospheric gas dilution

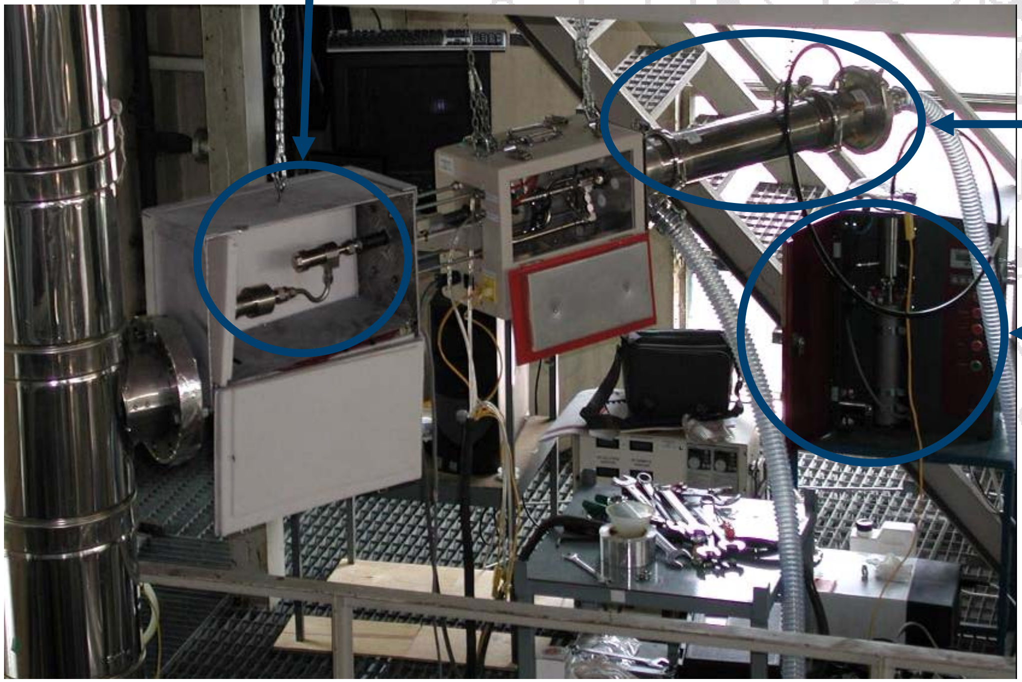
Sampling / measurement train



1. Hot sampling + FP capture (≥ 2,5 μm)

2. Controlled dilution with conditioned air

3. Particle counting (0.007 μm - 10 μm in 12 classes) Inertial impactor ELPI™



Materials and methods

Sources investigated

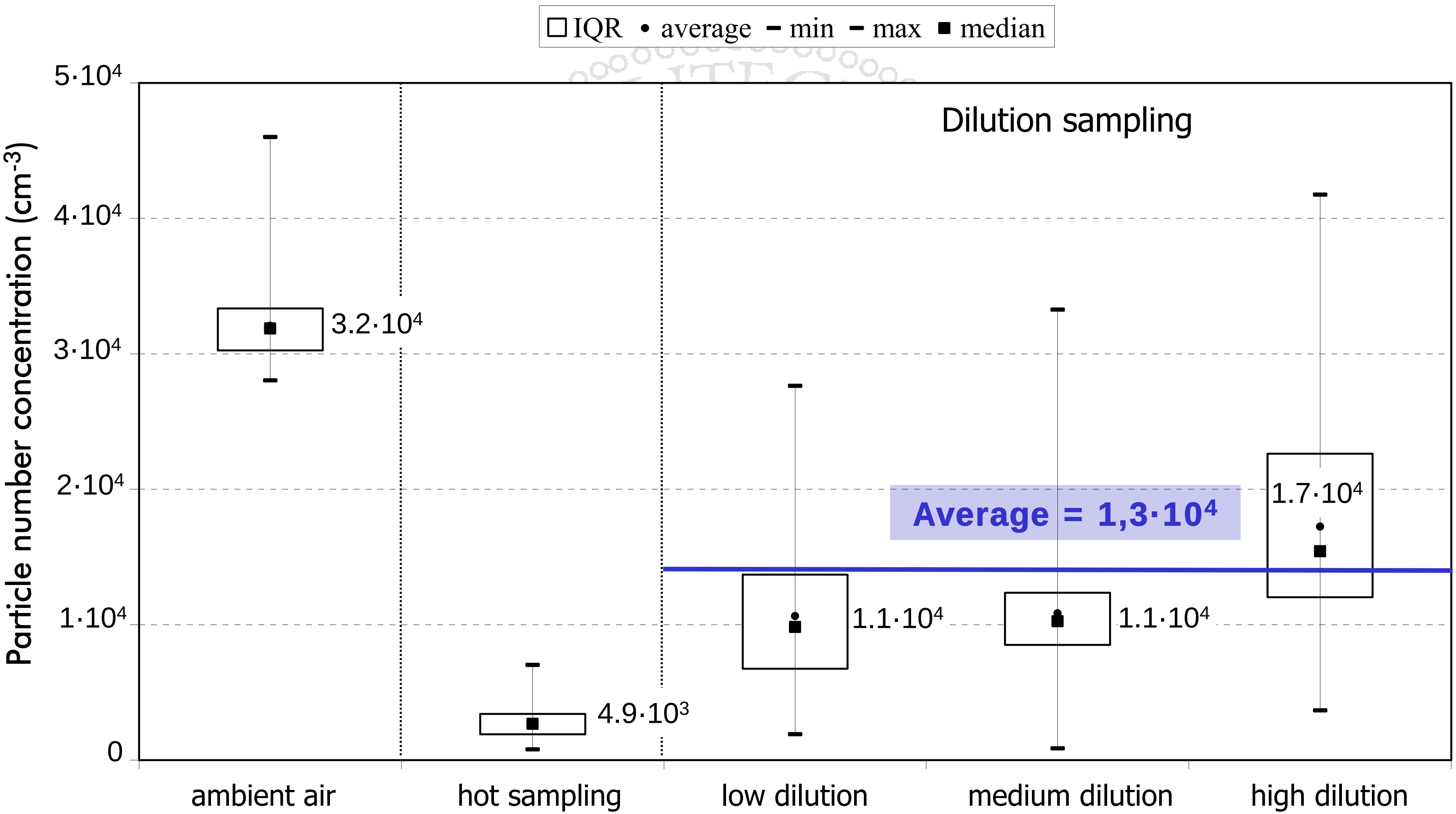
- Urban and commercial waste
- 4 plants, capacity 600 - 1200 tpd
- BAT design for flue gas treatment
  - dry removal + SCR (2 plants)
  - dry/wet removal + SCR (1 plant)
  - dry/wet removal + SNCR (1 plant)

Measurement campaigns

- Hot sampling
- Dilution sampling
  - low: DR =15 → 20
  - medium: DR = 25 → 35
  - high: DR = 40 → 60
- Ambient air

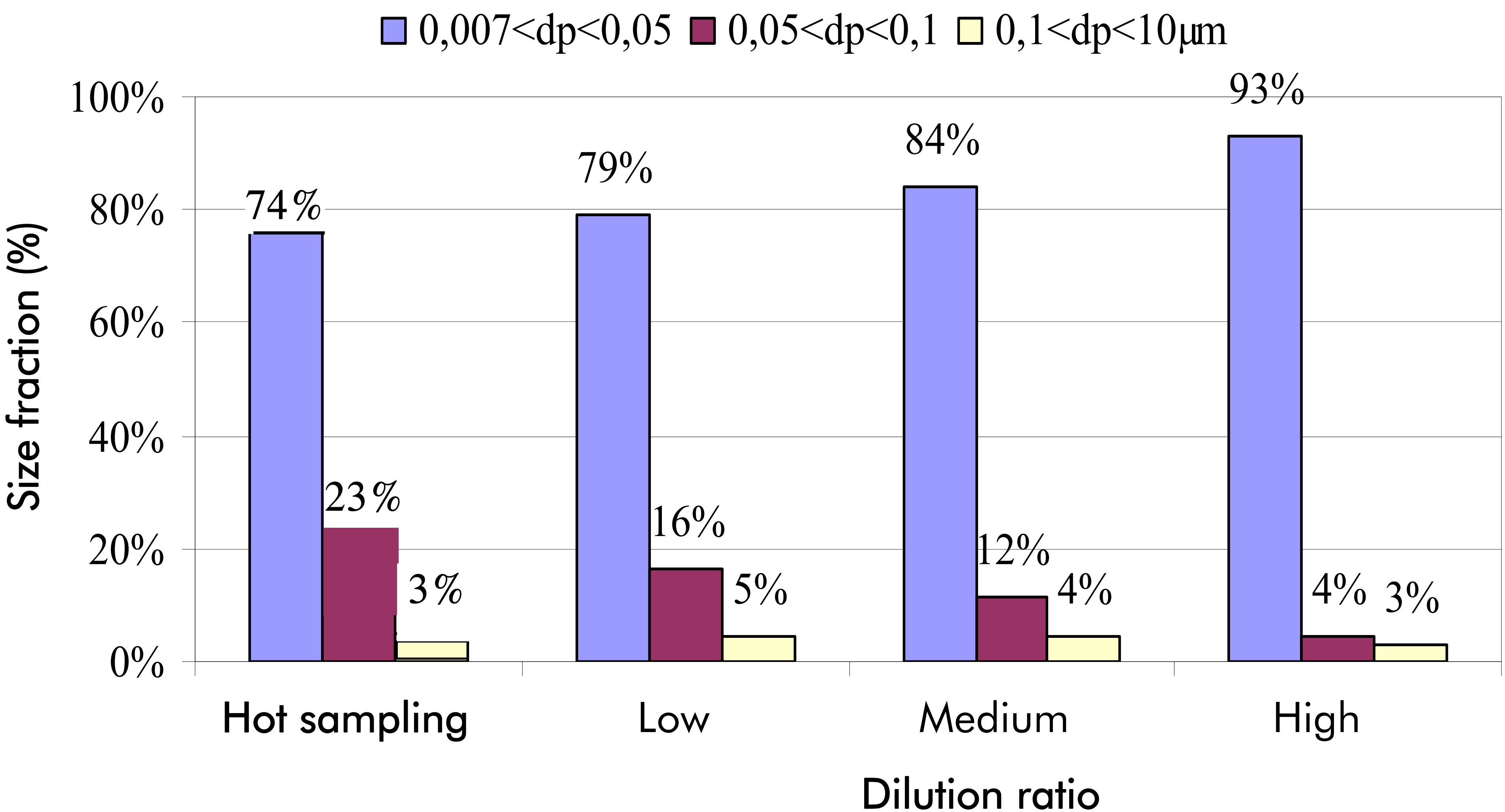
WTE 1 - Dry, FF at 170°C

Number concentration (particles cm^{-3})



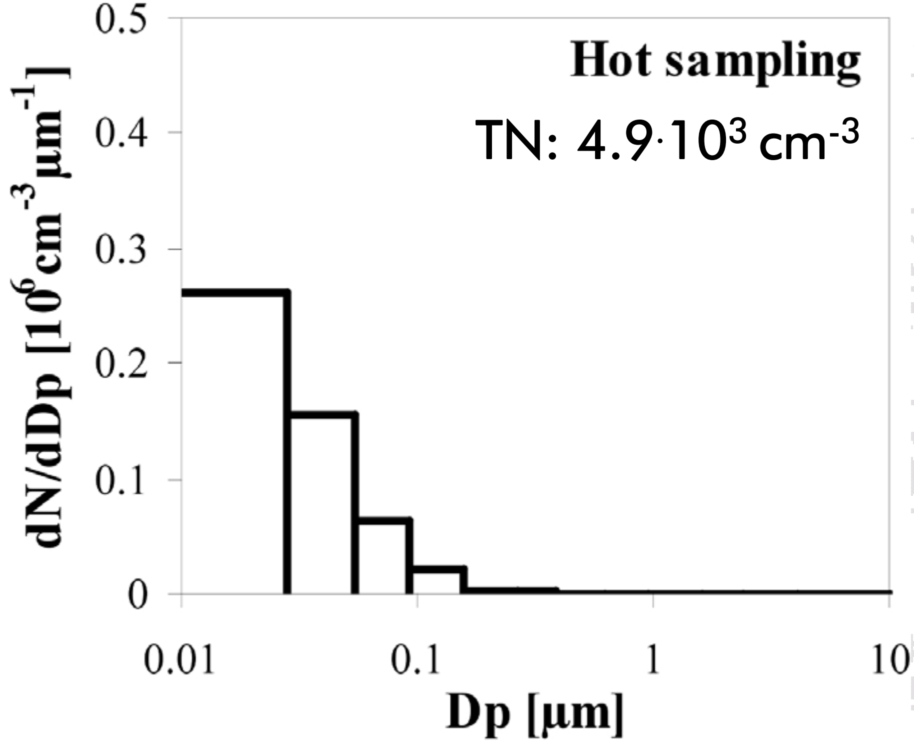
WTE 1 - Dry, FF at 170°C

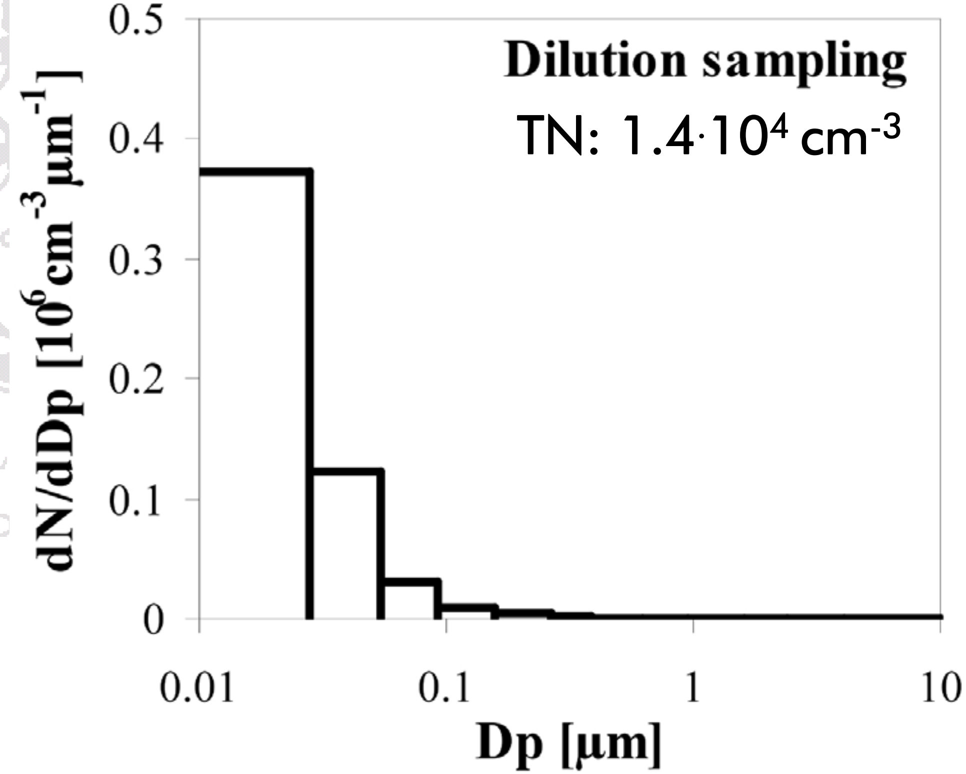
Size fractions



WTE 1 - Dry, FF at 170°C

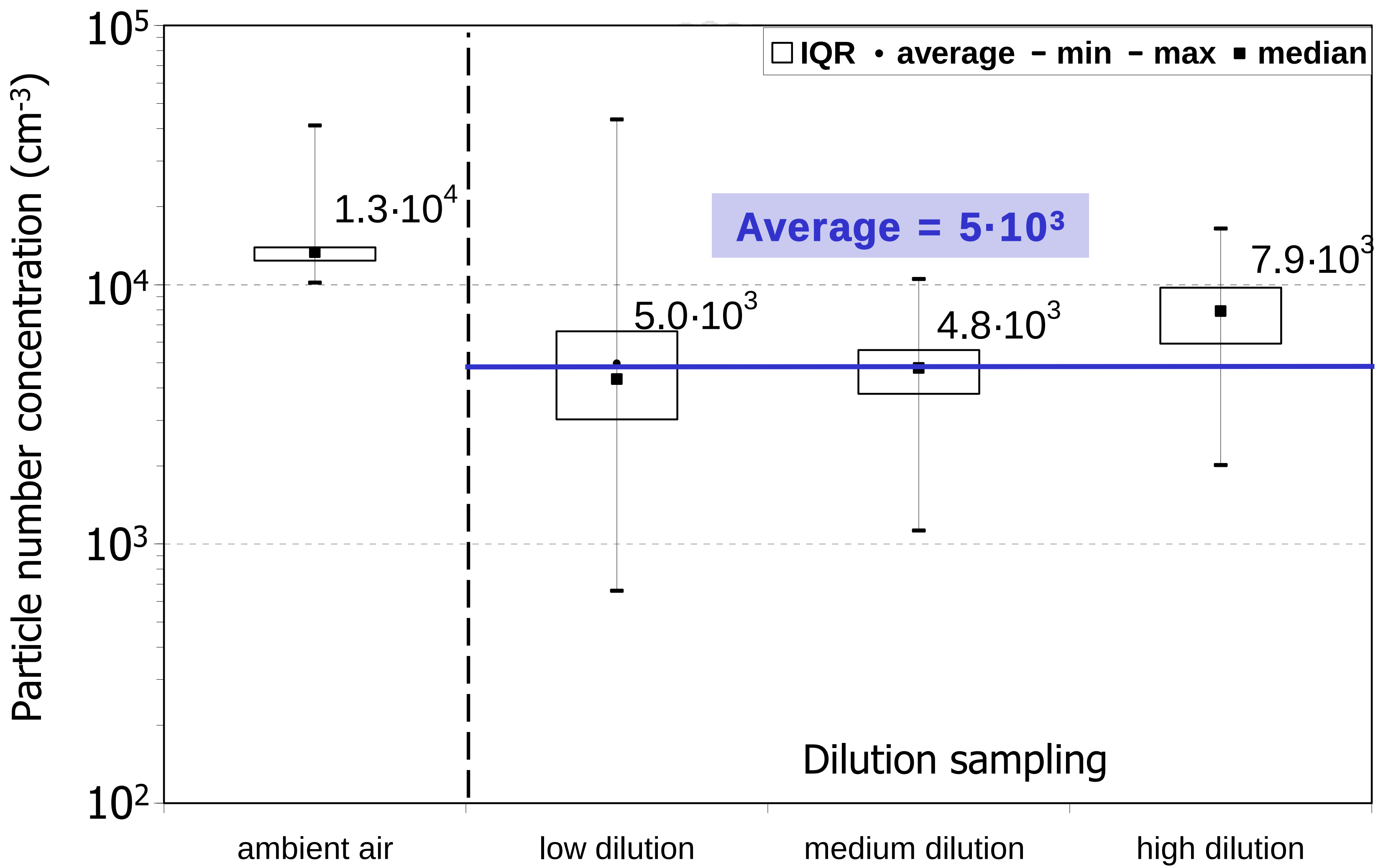
Size distributions





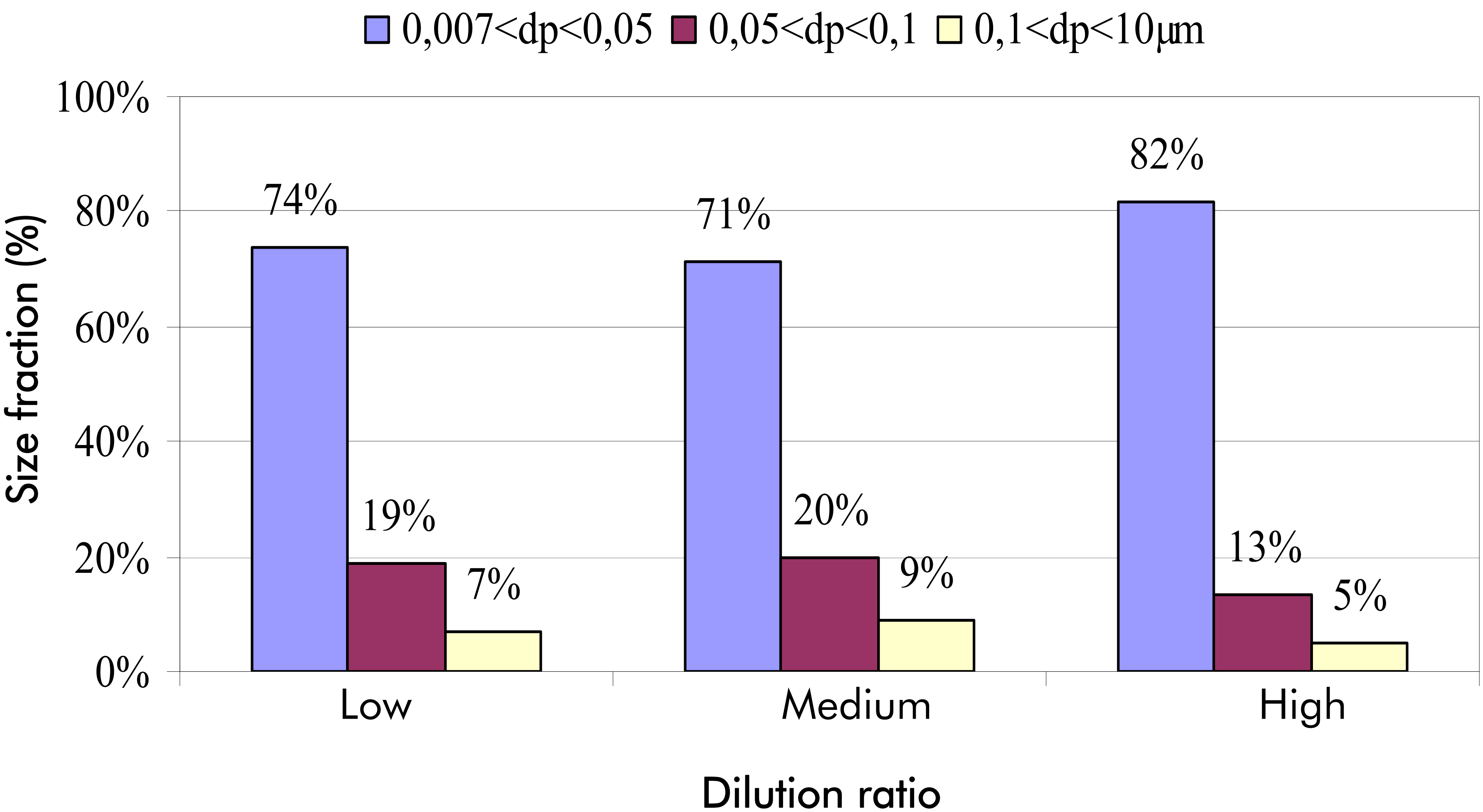
WTE 2 - Dry, FF at 130°C

Number concentration (particles cm^{-3})



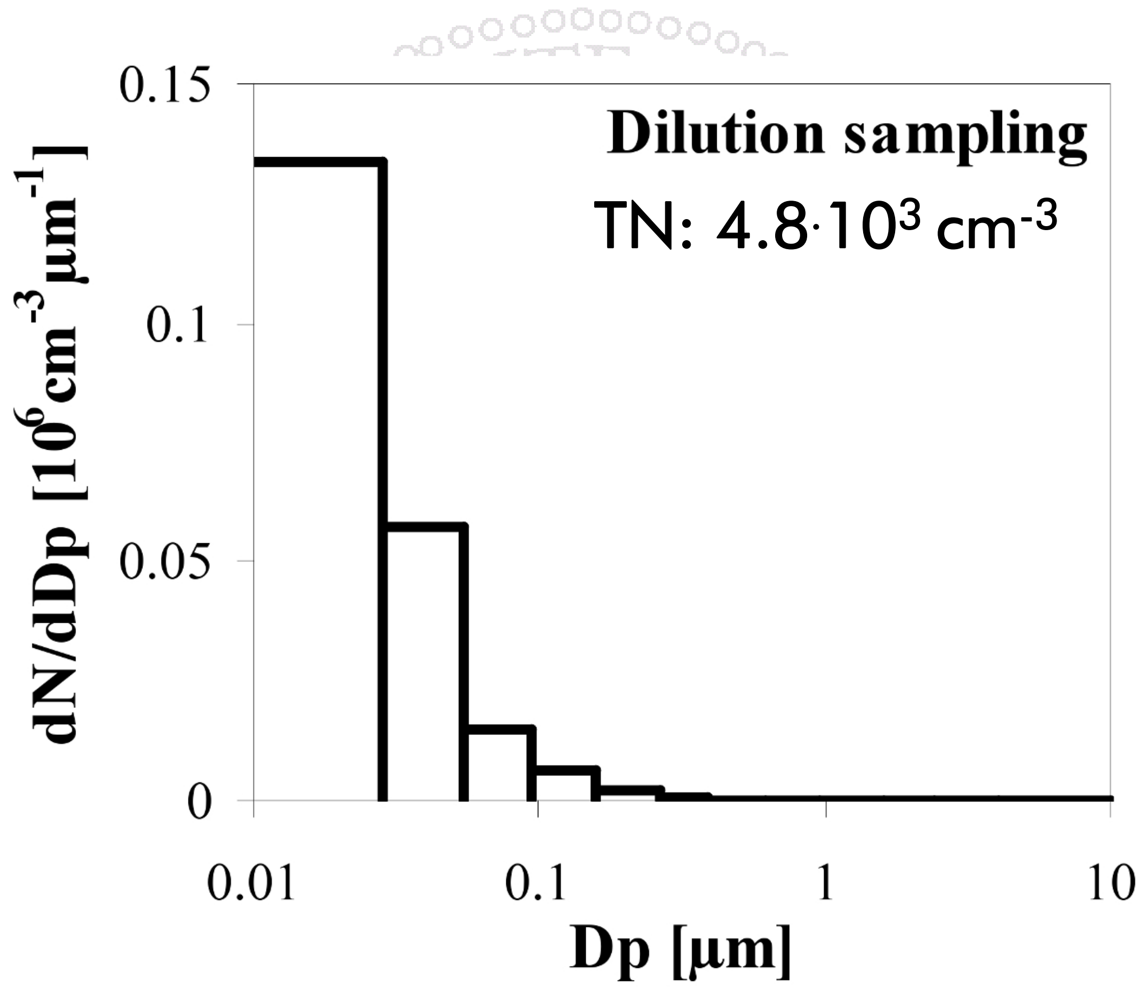
WTE 2 - Dry, FF at 130°C

Size fractions



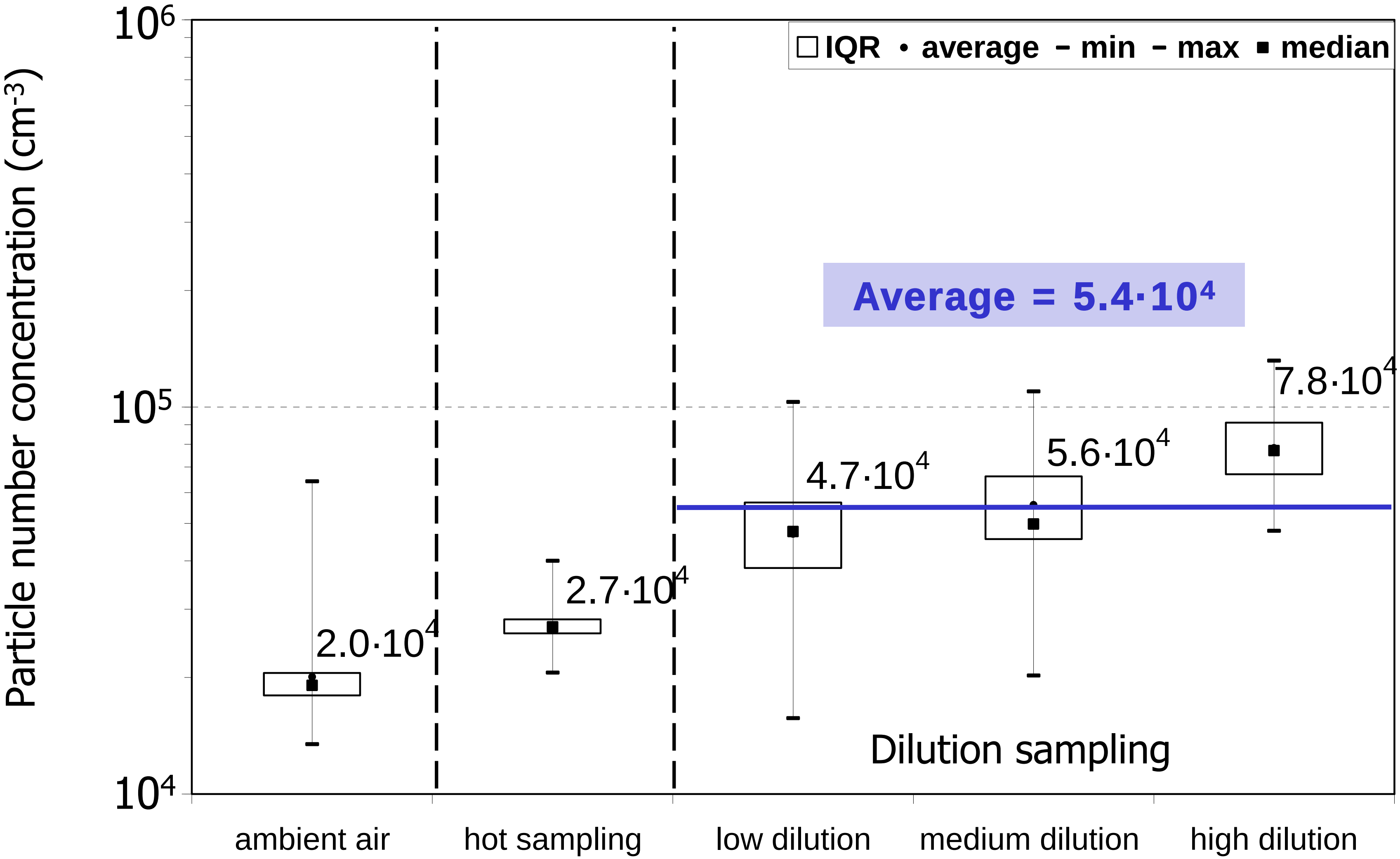
WTE 2 - Dry, FF at 130°C

Size distribution

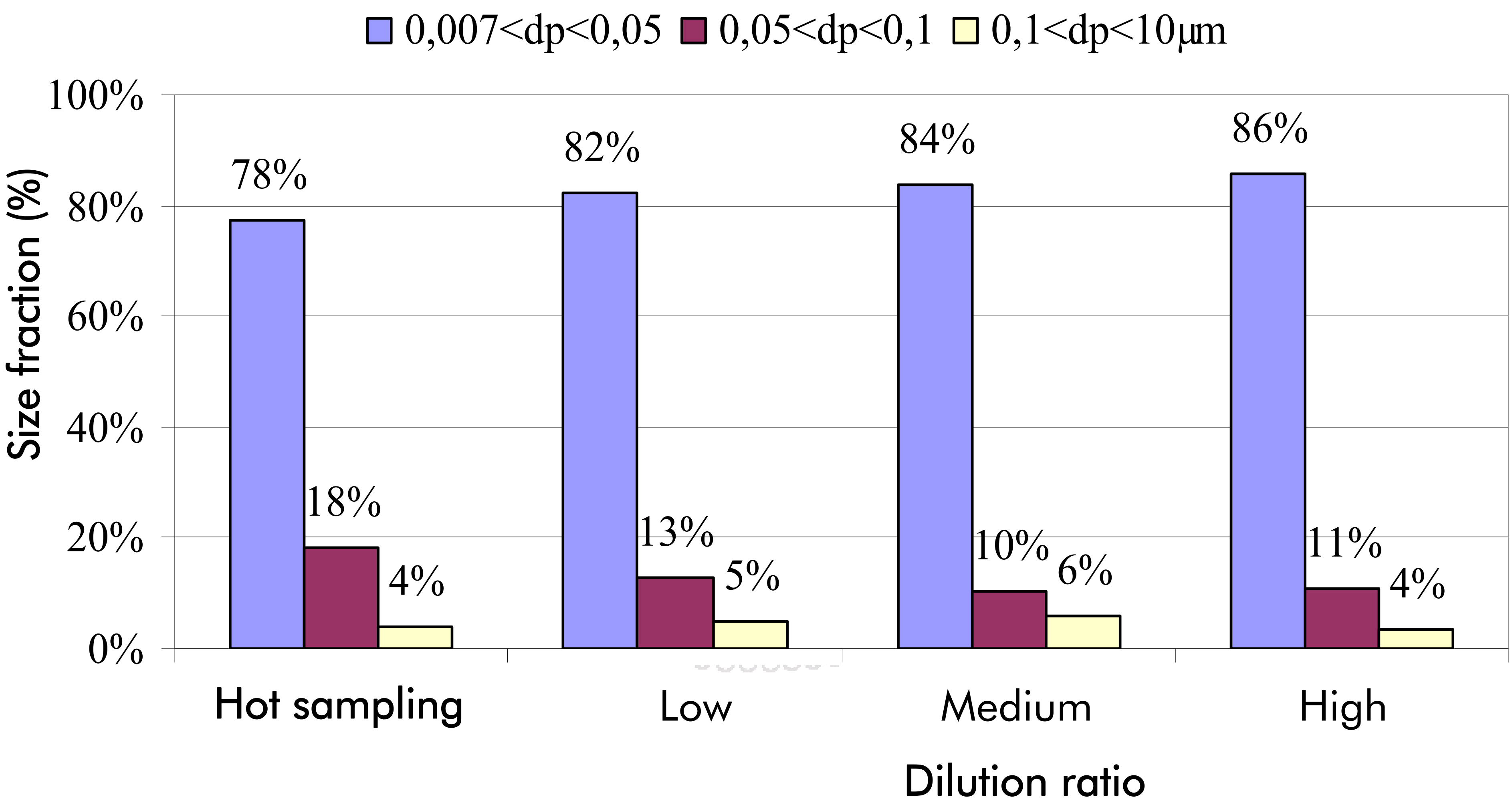


WTE 3 - Wet/dry

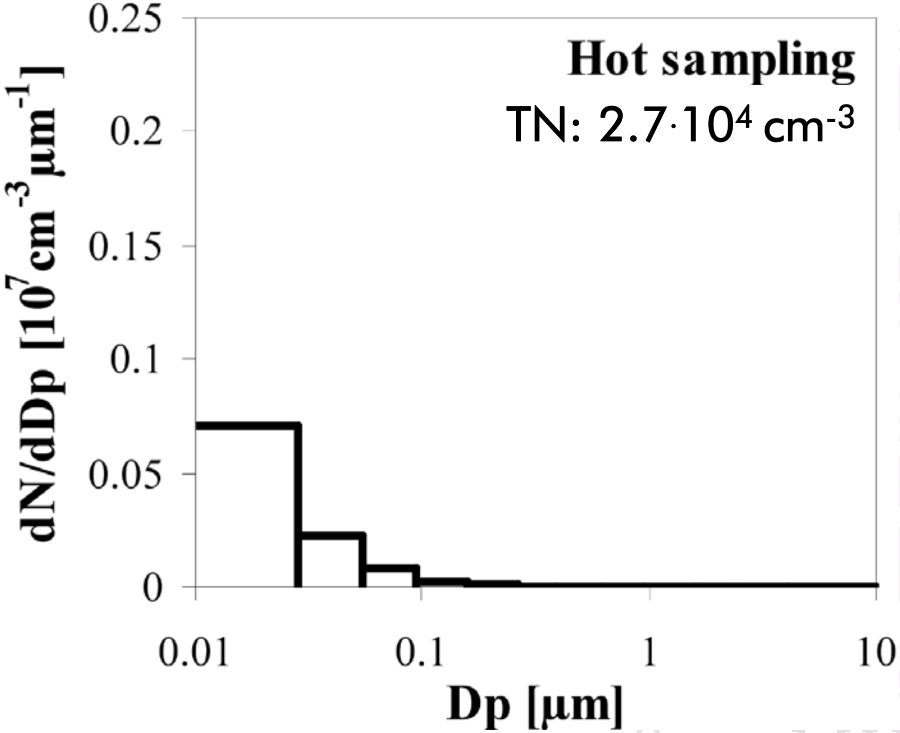
Number concentration (particles cm^{-3})

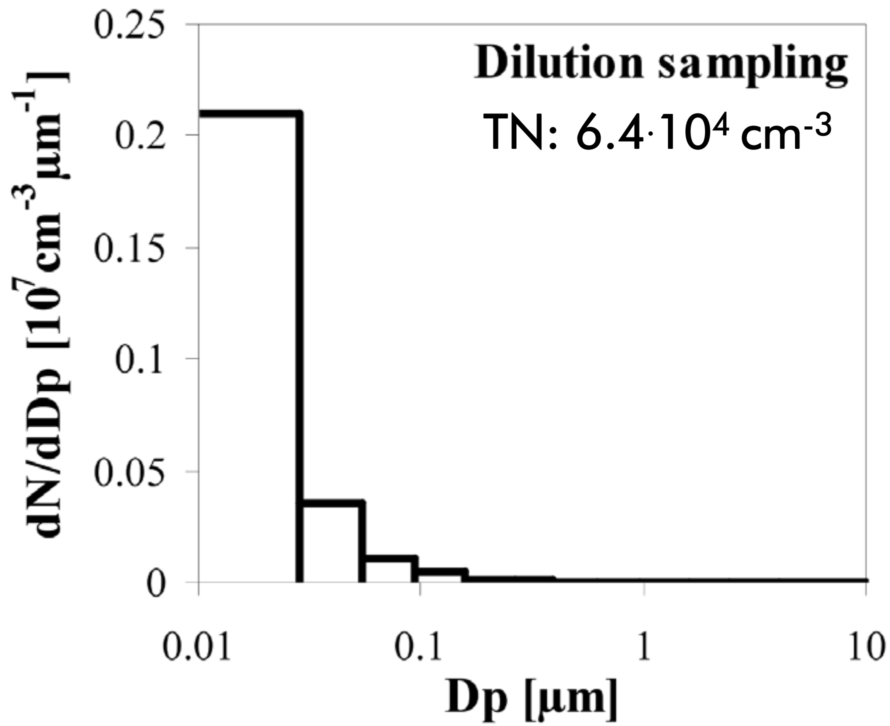


Size fractions



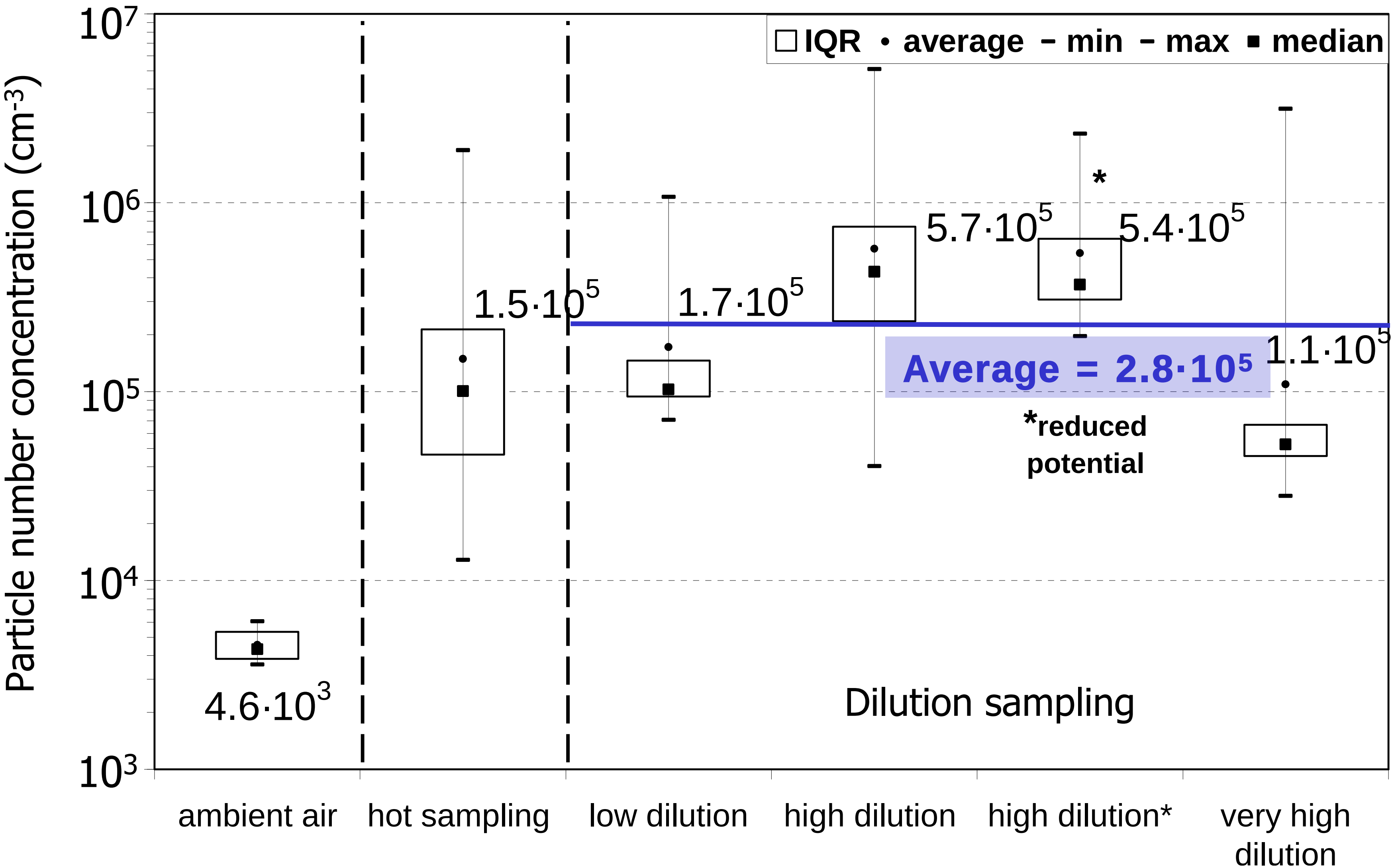
Size distribution



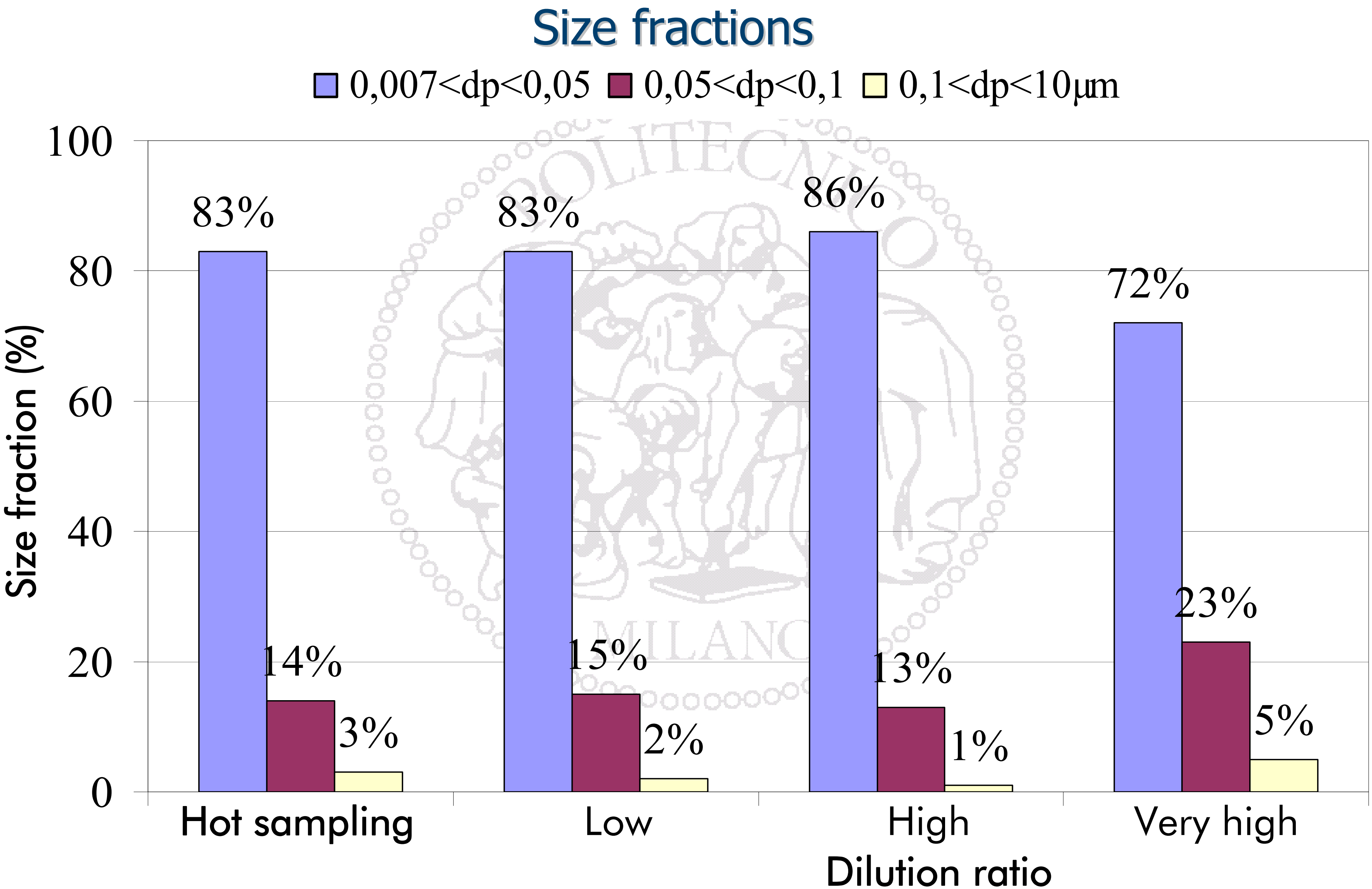


WTE 4 - Wet/dry

Number concentration (particles cm^{-3})



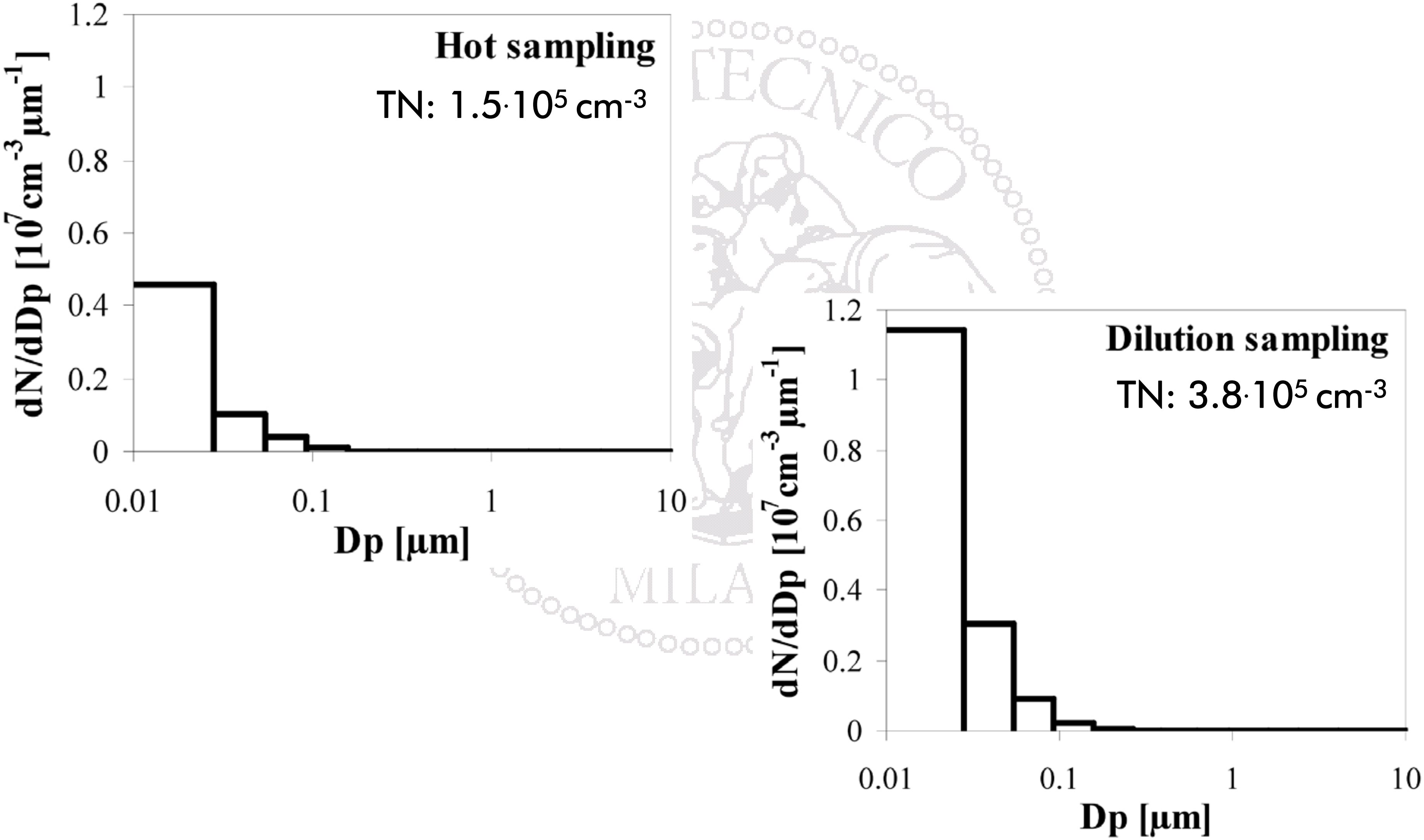
WTE 4 - Wet/dry



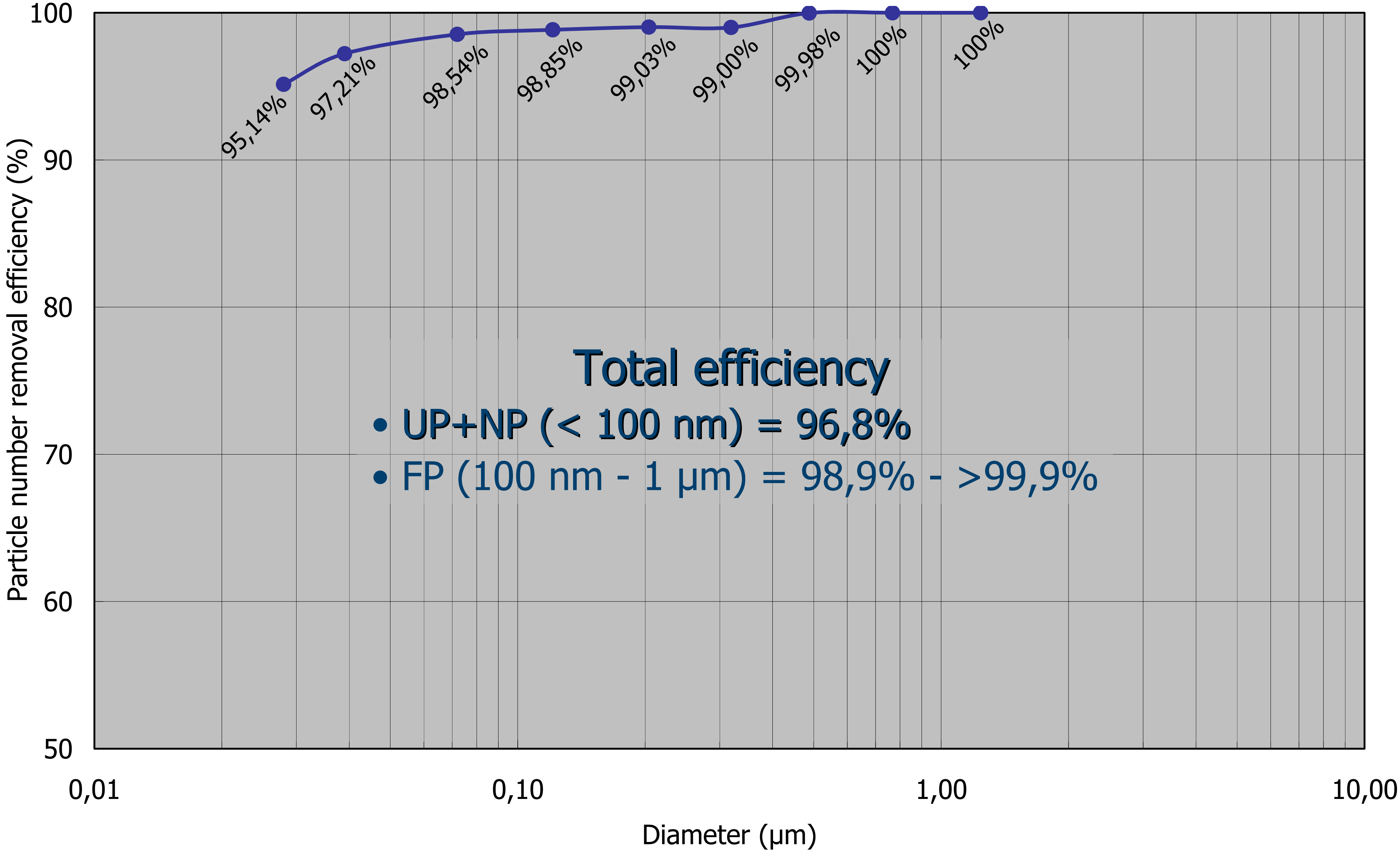
Size fractions
0,007<dp<0,05
0,05<dp<0,1
0,1<dp<10µm
Size fraction (%)
100
80
60
40
20
0
83%
14%
3%
83%
15%
2%
86%
13%
1%
72%
23%
5%
Hot sampling
Low
High
Very high
Dilution ratio

WTE 4 - Wet / dry

Size distribution

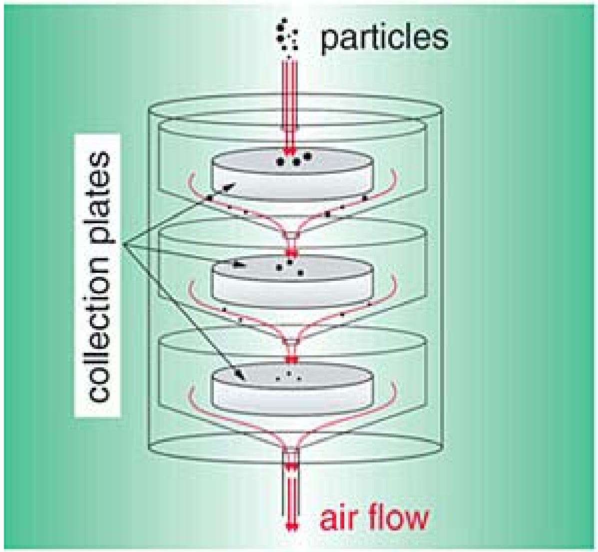


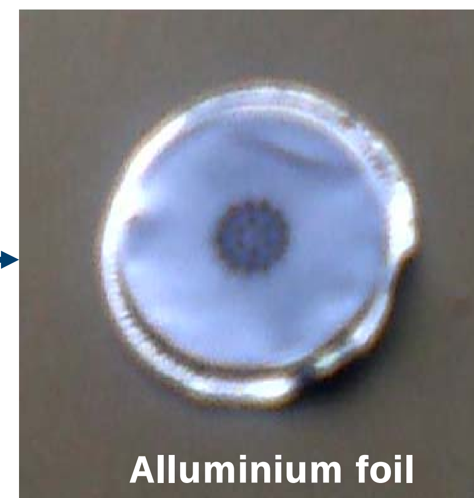
FF - removal efficiency



UP / NP chemical characterization

Samping techniques





UP/NP chemical characterization

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ANALYTICAL TECHNIQUES

- **IONS** (nitrates, sulphates, ammonium)
  - Anions → **Ion chromatography**
  - Ammonium → **UV-Visible Spectrophotometry**

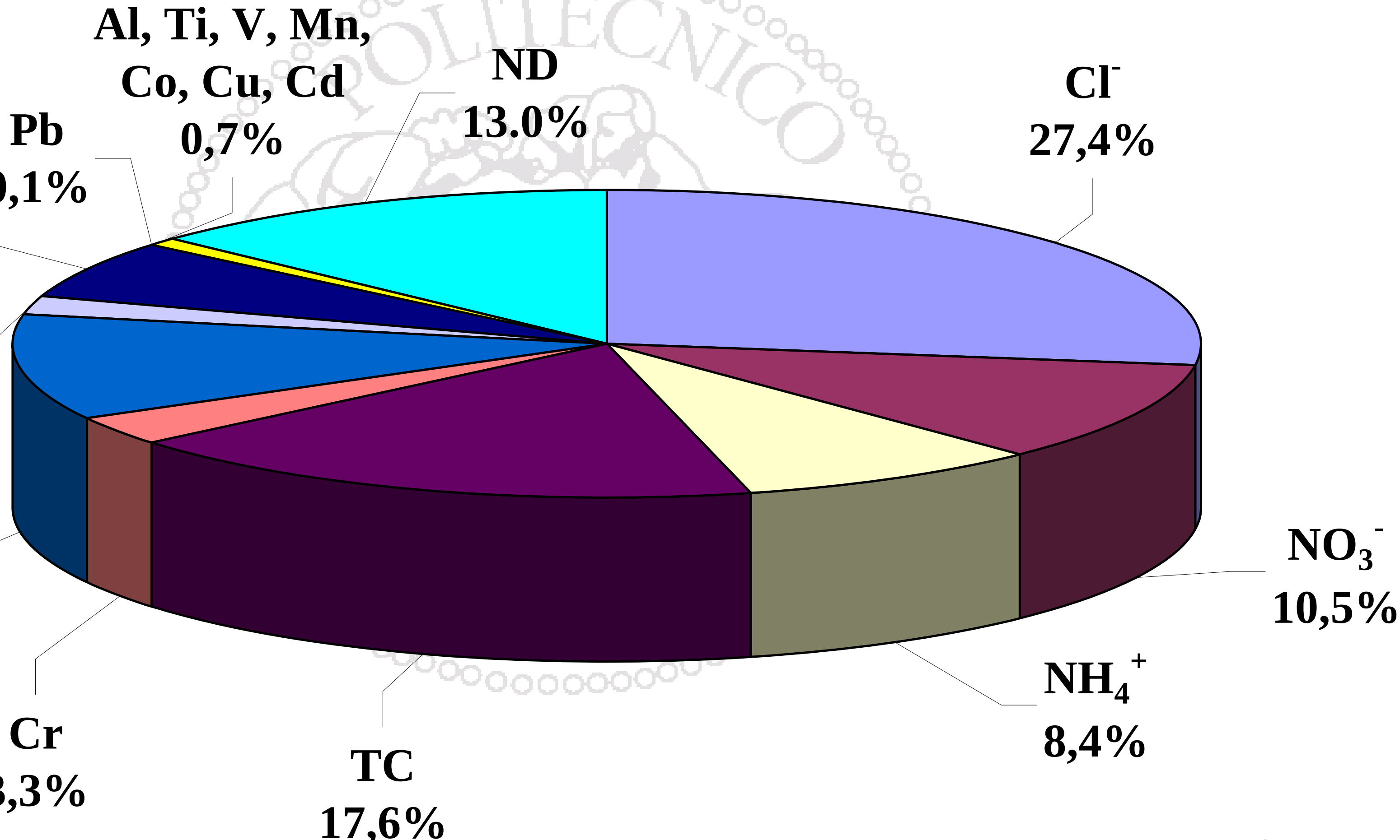
- **METALLIC ELEMENTS** (Al, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Sb, Hg, Tl, Pb)
  - **ICP-MS** (inductively coupled plasma-mass spectroscopy)

- **TOTAL CARBON**
  - **EGA** (Evolved Gas Analysis) - 630° C in oxidising atmosphere with NDIR CO_2 detection

- **MASS**
  - **Gravimetric** (microbalance)

UP chemical characterization

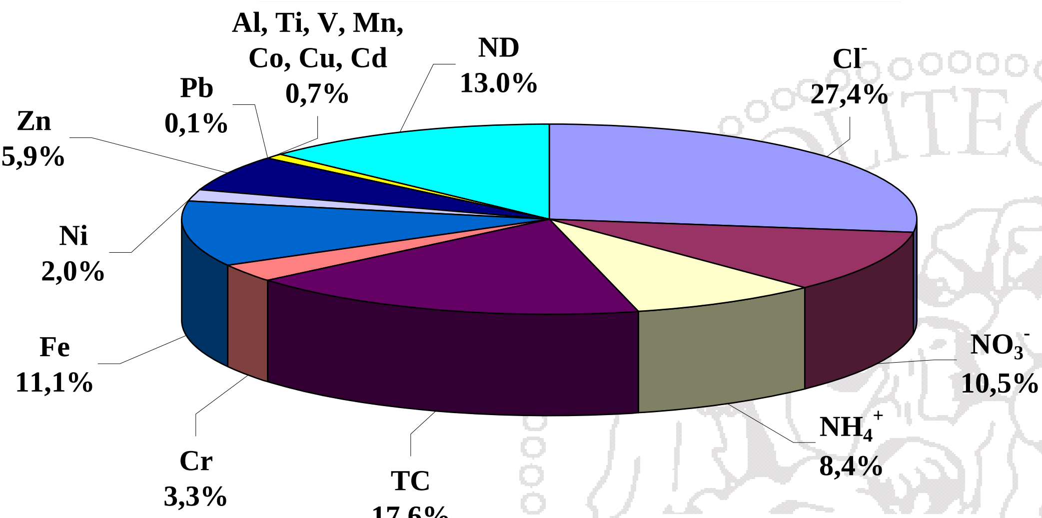
WTE ultrafine size fraction chemical composition



TC: total carbon; ND: unidentified

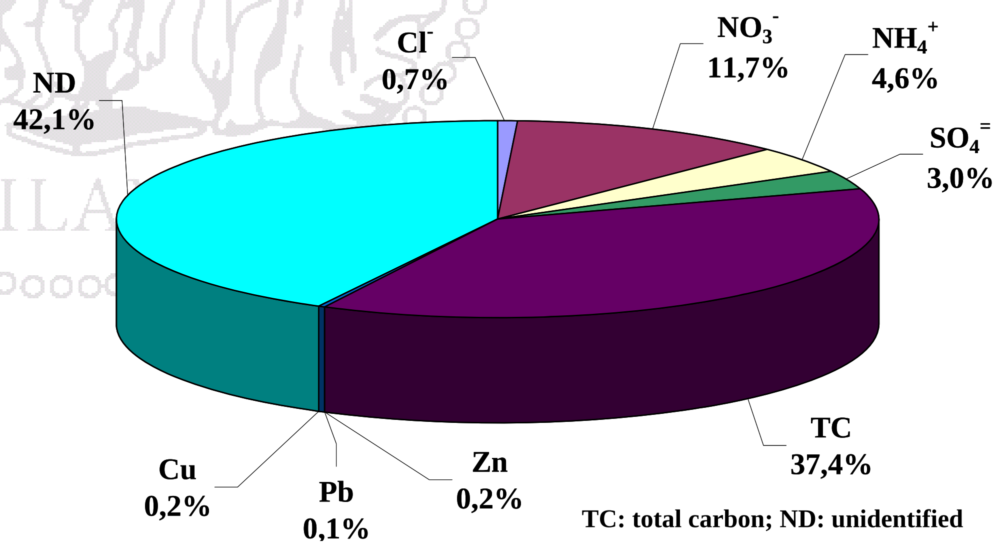
UP chemical characterization

WTE ultrafine fraction chemical composition



TC: total carbon; ND: unidentified

Background air
Ultrafine fraction chemical composition



TC: total carbon; ND: unidentified

NP chemical characterization

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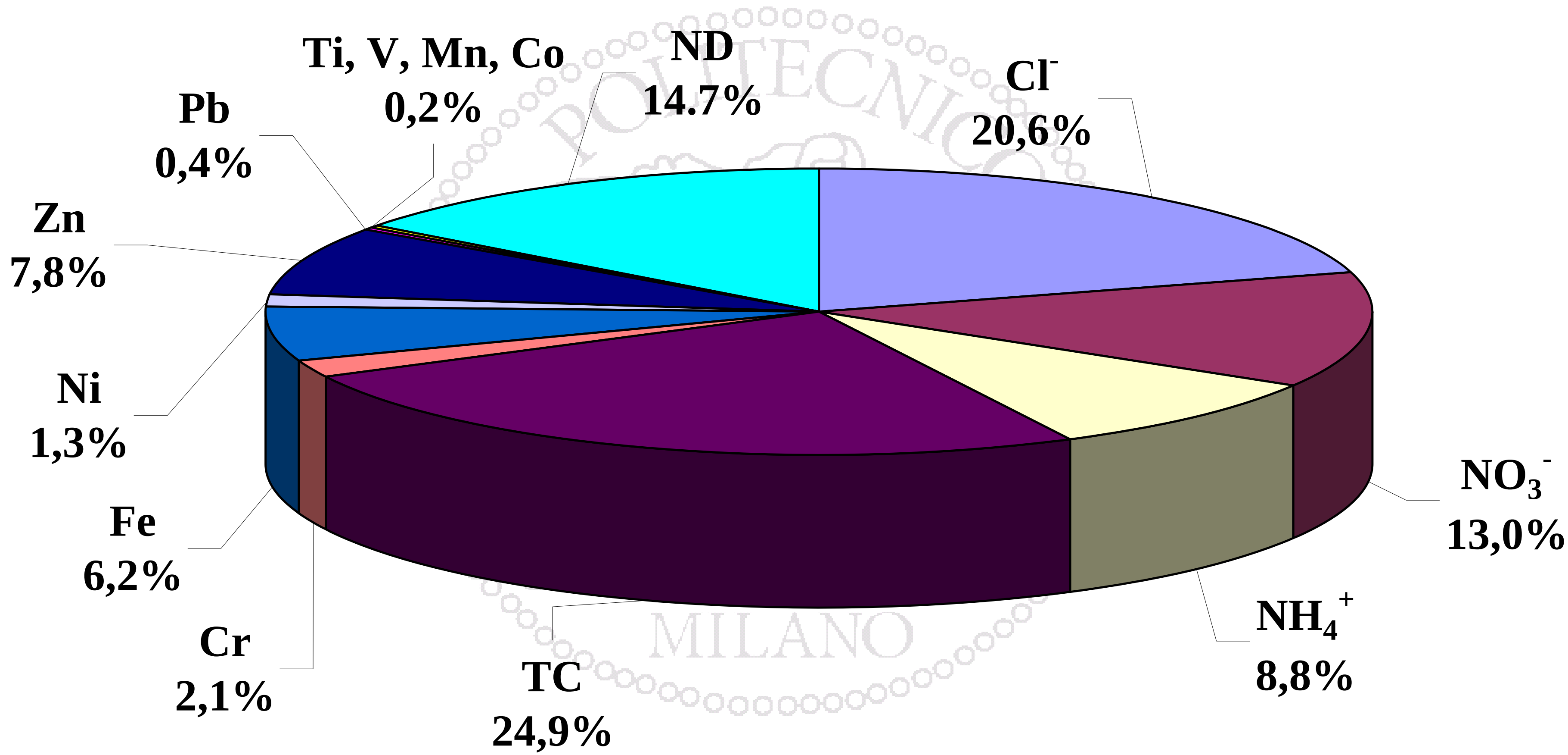
WTE nanoparticle size fraction chemical composition



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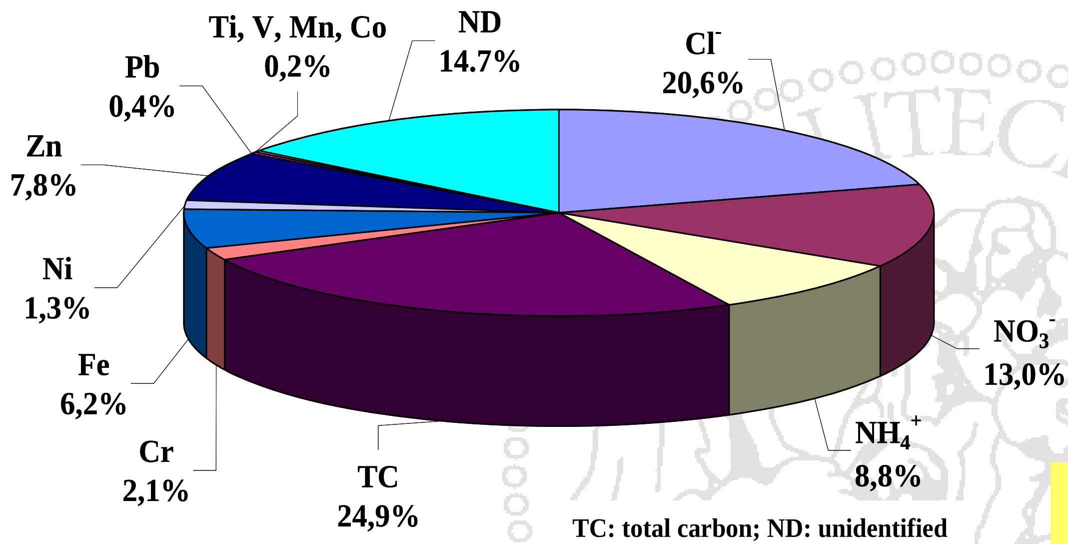
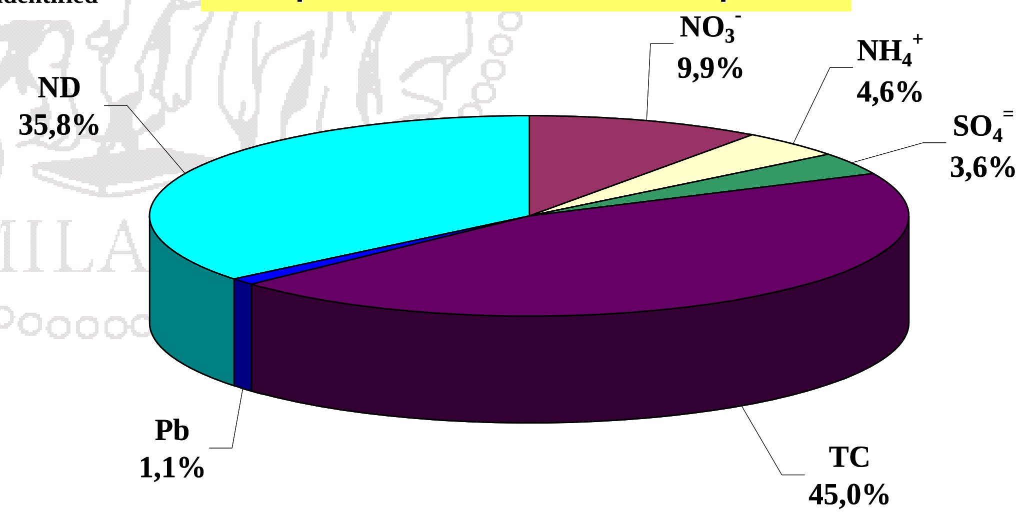
NP chemical characterization

WTE nanoparticle fraction chemical composition



TC: total carbon; ND: unidentified

Background air
Nanoparticle fraction chemical composition



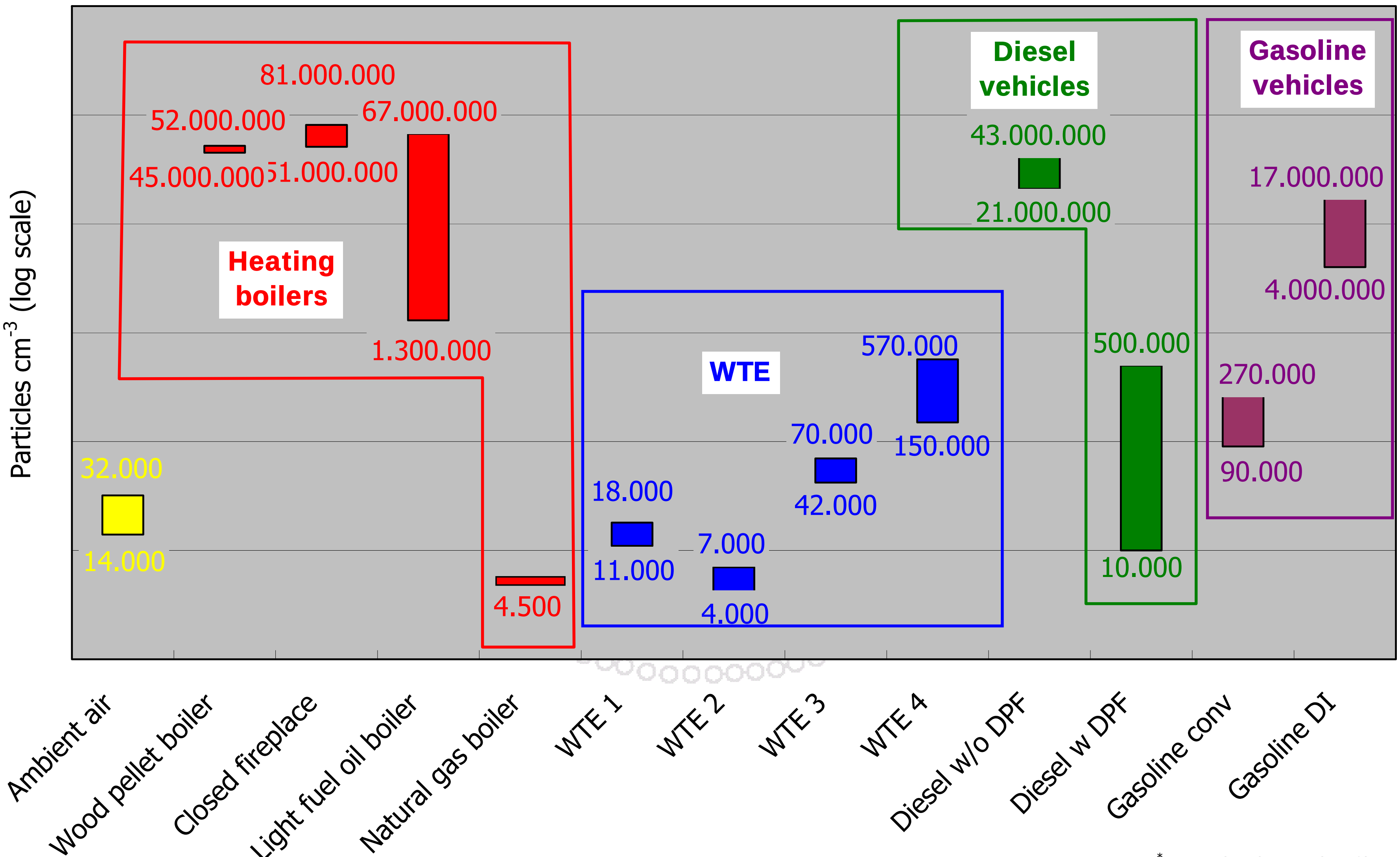
TC: total carbon; ND: unidentified

Conclusions

- Measured number concentrations
  - influence of flue gas treatment process configuration (scrubber, T baghouse)
  - generally comparable or slightly higher than ambient air
  - very high capture efficiency for FF: ≈ 97% for NP+UP, 98-99,9% for FP (0,1 - 1 μm), both for primary than for condensible particles
- Effects on concentration levels arising from fractions of condensable origin
- UP and NP fractions largely prevailing in size distributions for all sampling conditions
- Chemical characterization
  - in accordance with waste composition and combustion process influence (presence of chlorides, Fe, Zn, Cr)

Conclusions

Comparative assessment



*DPF = diesel particulate filter

Acknowledgements

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- ULTRAPART research team
  - Politecnico di Milano: S; Cernuschi, M. Giugliano, S. Consonni, R. Tardivo, S. Ozgen
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