Real-time measurement of total and solid particle fraction in underground mining environment with DC based sensors (MPEC+)

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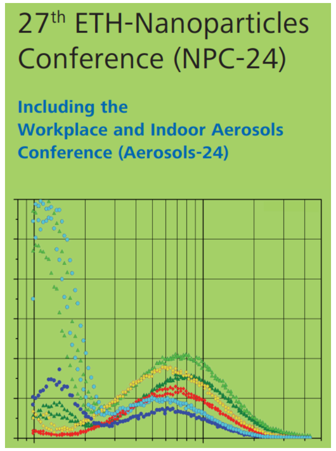
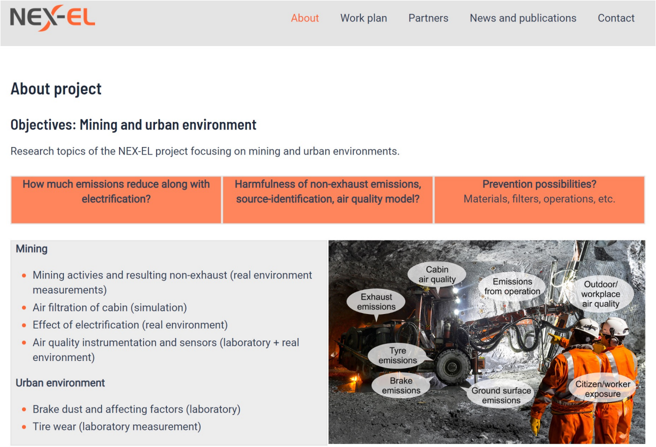
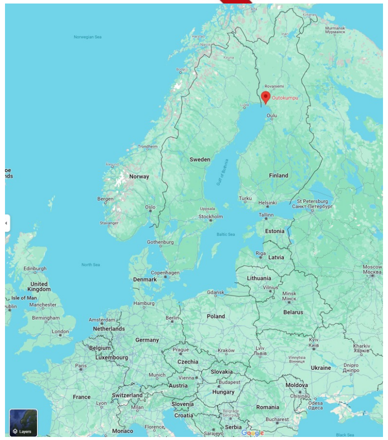
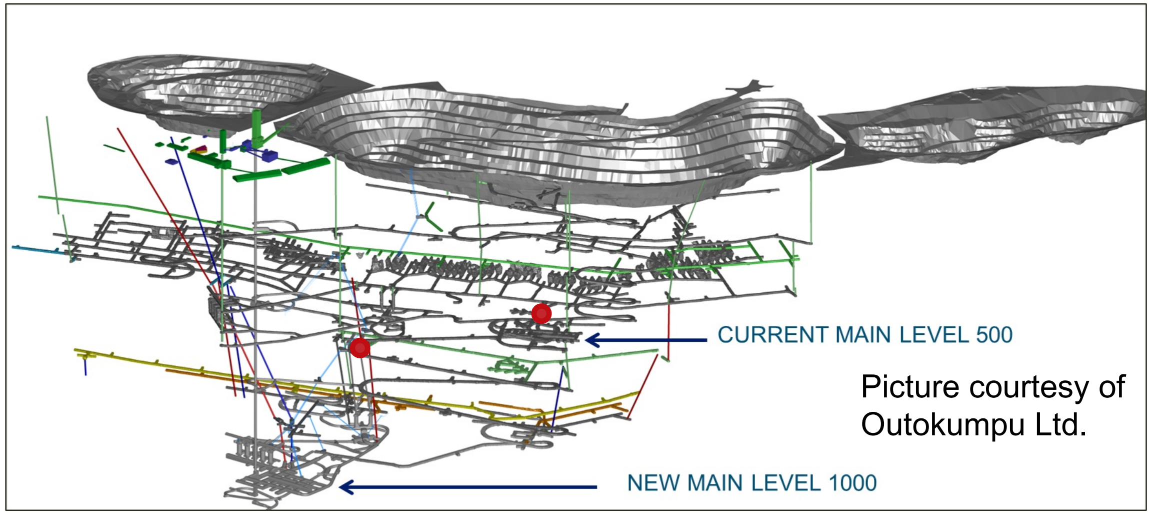


Project and measurement site

- Measurement campaign of NEX-EL project
- Measurements were conducted in an underground mine, located in Kemi, northern Finland
- Outokumpu Ltd.'s Kemi mine produces chromite (FeCr2O4) concentrate
- Already two previous studies (Saarikoski et al. 2017 and 2019) about the PM composition, some PN too
- Solid particle fraction a new parameter
- The measurement sites
  - 500 m maintenance area (parking area,restaurant, meeting rooms, storages etc.) mostly vehicles emissions
  - 650 m tunnel site, closer to mining activities
- Particle sources include diesel operated vehicles, heavy-duty working machines, mining activities (ore processing, blasting), and ventilation air from the ground level

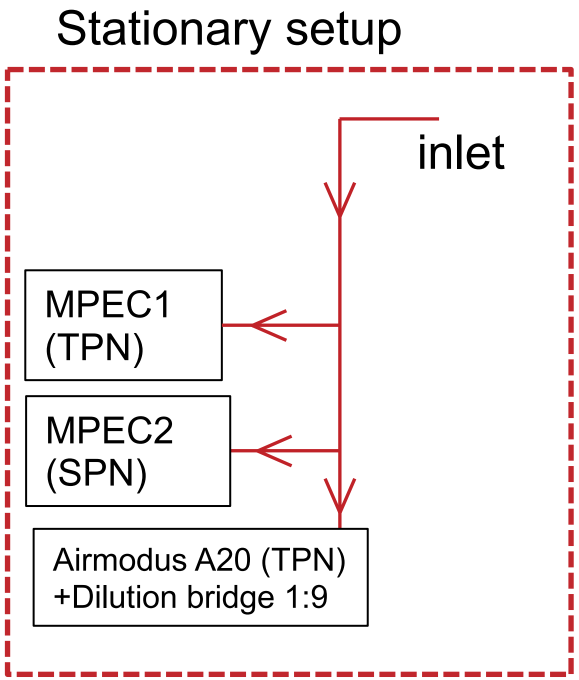


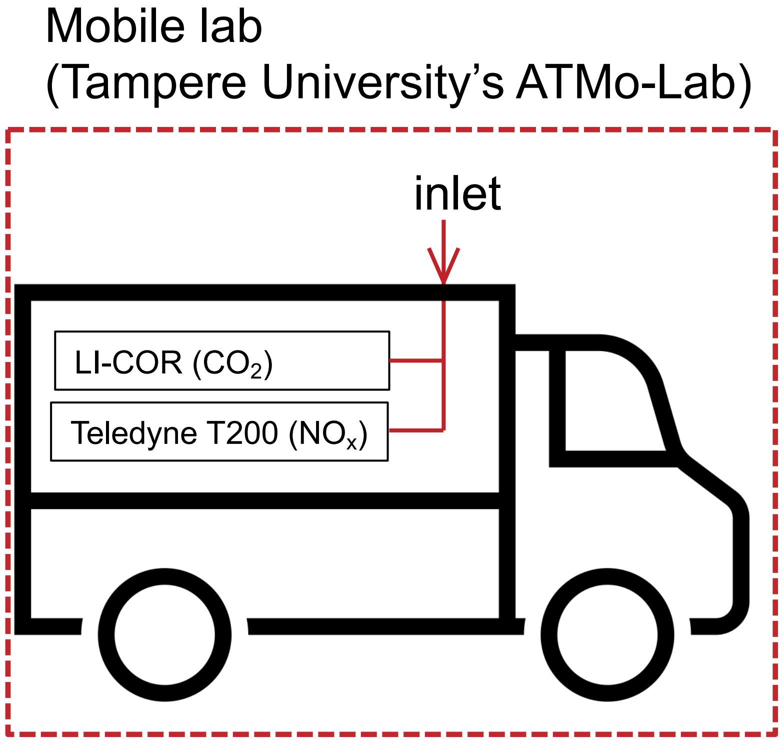




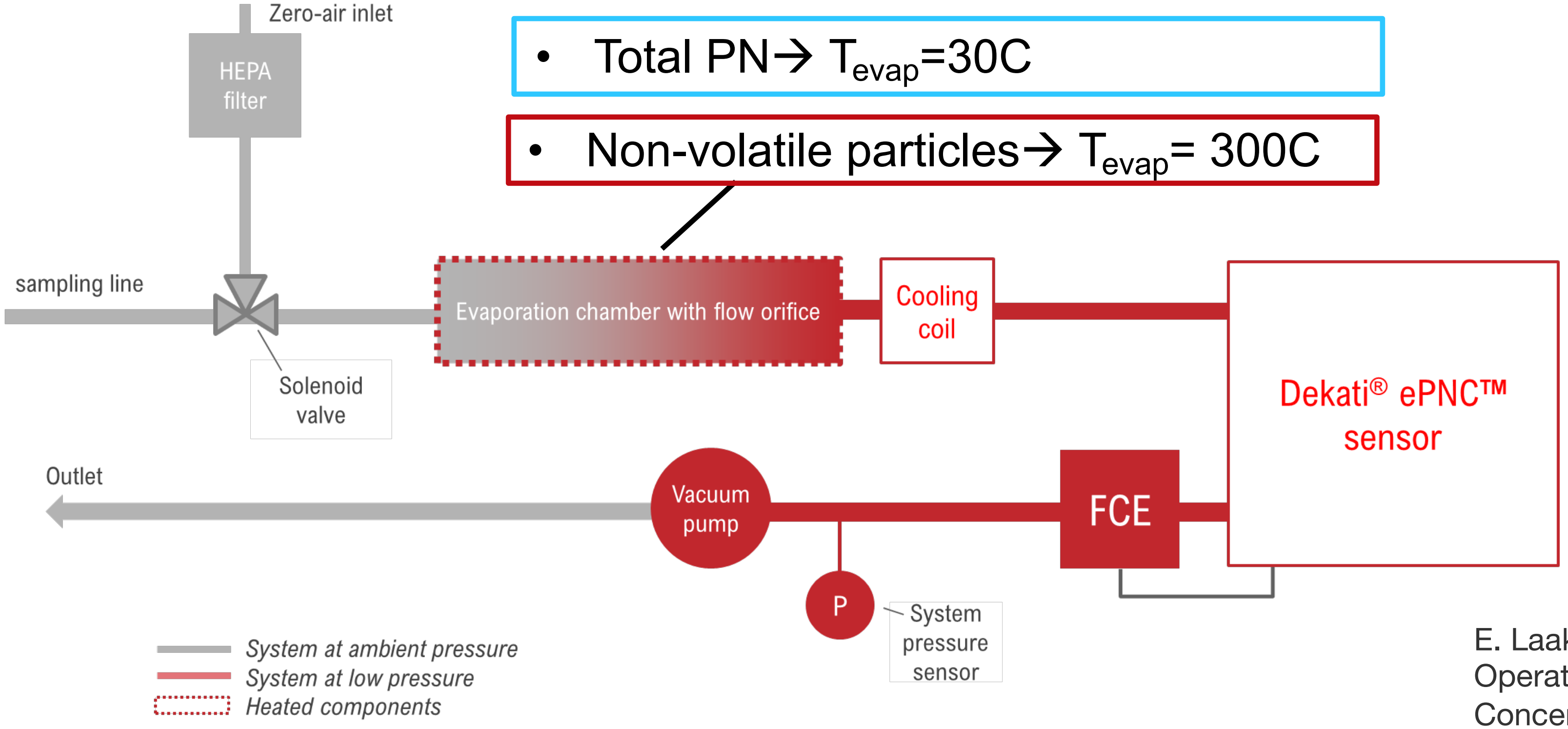
Instrumentation

- Main instruments were two standalone PN PEMS devices (MPEC+)
  - MPEC standalone instrument that complies with RDE EU directive EU 2017/1154 and upcoming UNECE GTR n:o 15
  - Measuring total PN a new application→MPEC (105) was modified to measure the total PN
  - MPEC (104) used to measure the solid PN
- Gas measurements
  - Monitors inside the ATMO-Lab
  - LI-COR → CO, CO_2
  - Teledyne T200 inside the mobile lab
  - located most of the time nearby the stationary site





MPEC+ construction and modifications



ePNC™

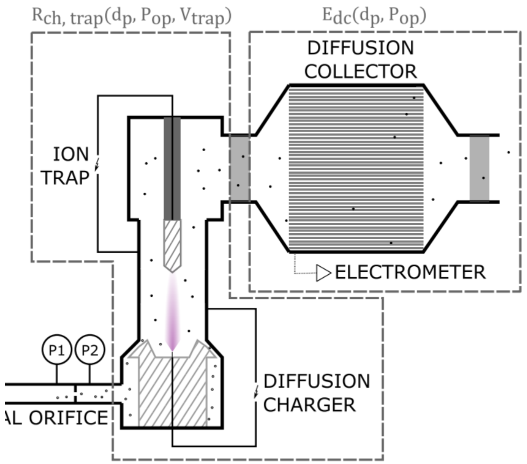
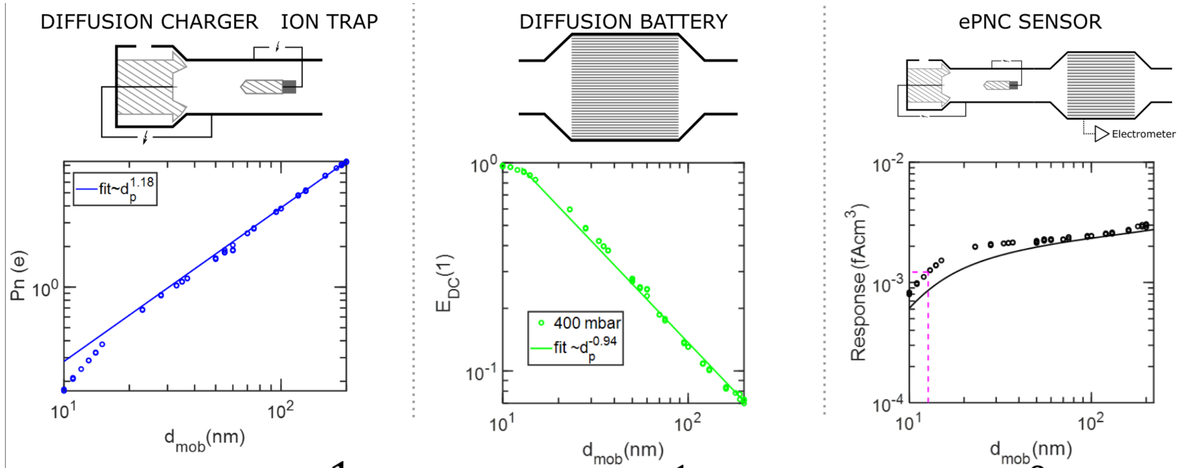


Fig. 1. Schematic view of the ePNC sensor.

E. Laakkonen, A. Arffman, A. Rostedt and J. Keskinen, "Effect of Operation Pressure on the Response of ePNC Particle Number Concentration Sensor," in *IEEE Sensors Journal*, vol. 24, no. 1, pp. 798-805, 1 Jan.1, 2024

- Flow rate increases slightly when running evap. tube in room temperature, this was compensated in through response function
- Delay times in the software also tuned to account the higher flow rate

MPEC+ / ePNC size response

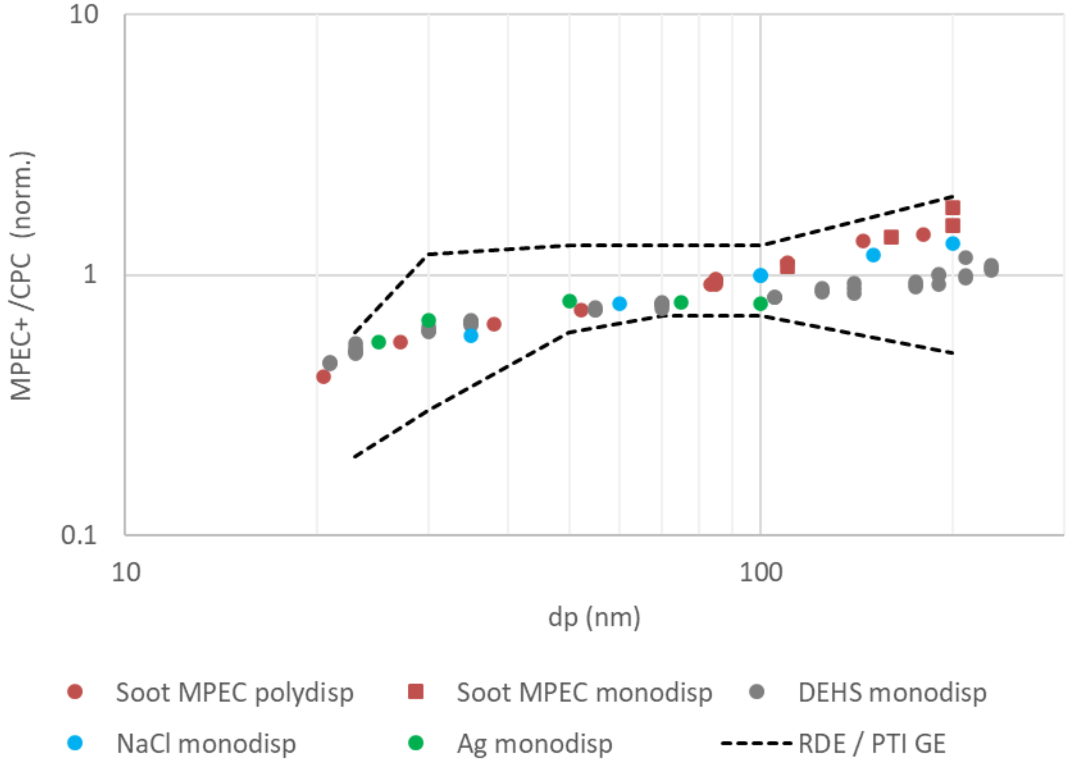


$$I \approx N * d_p^{\approx 1} \times d_p^{\approx -1} \approx N * d_p^{0} = N$$

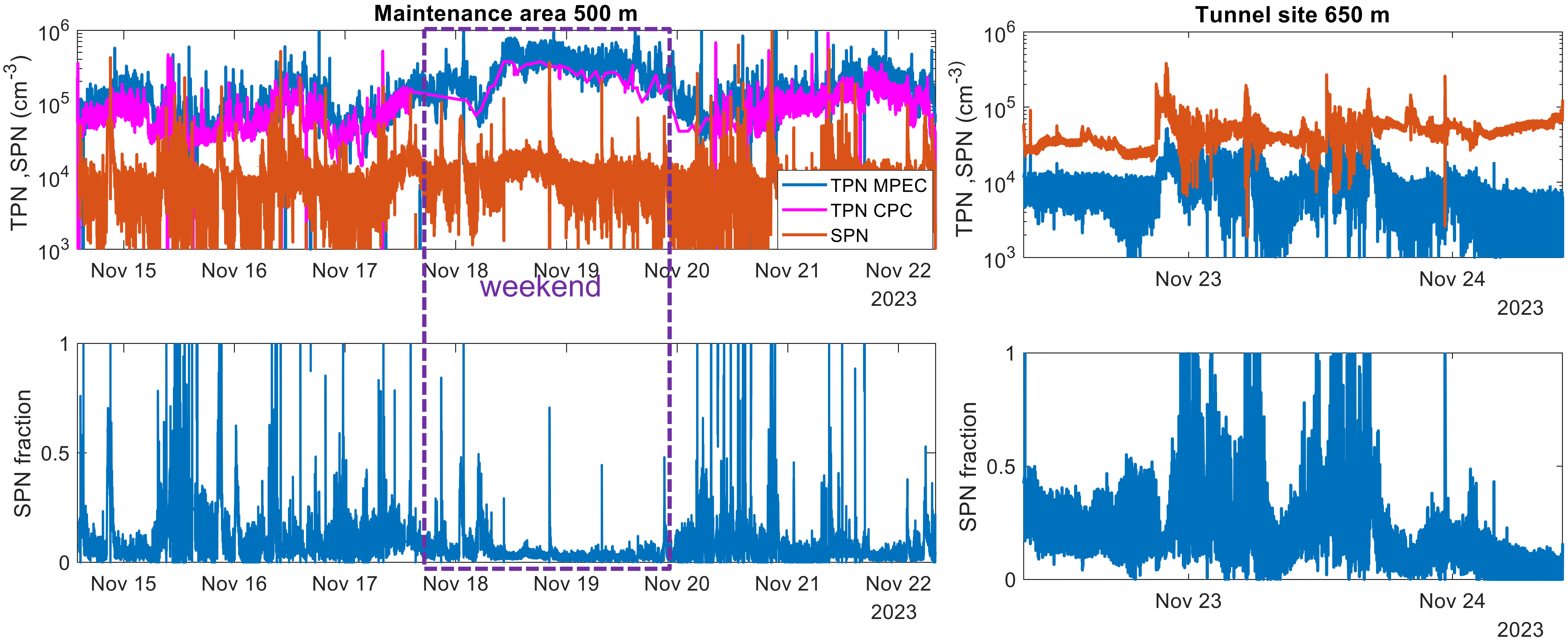
Adapted from: E. Laakkonen, A. Arffman, A. Rostedt and J. Keskinen, "Effect of Operation Pressure on the Response of ePNC Particle Number Concentration Sensor," in *IEEE Sensors Journal*, vol. 24, no. 1, pp. 798-805, 1 Jan.1, 2024

- Decreased operation pressure (400 mbar)
  - to modify the sensor response close to number concentration
  - prevents condensation

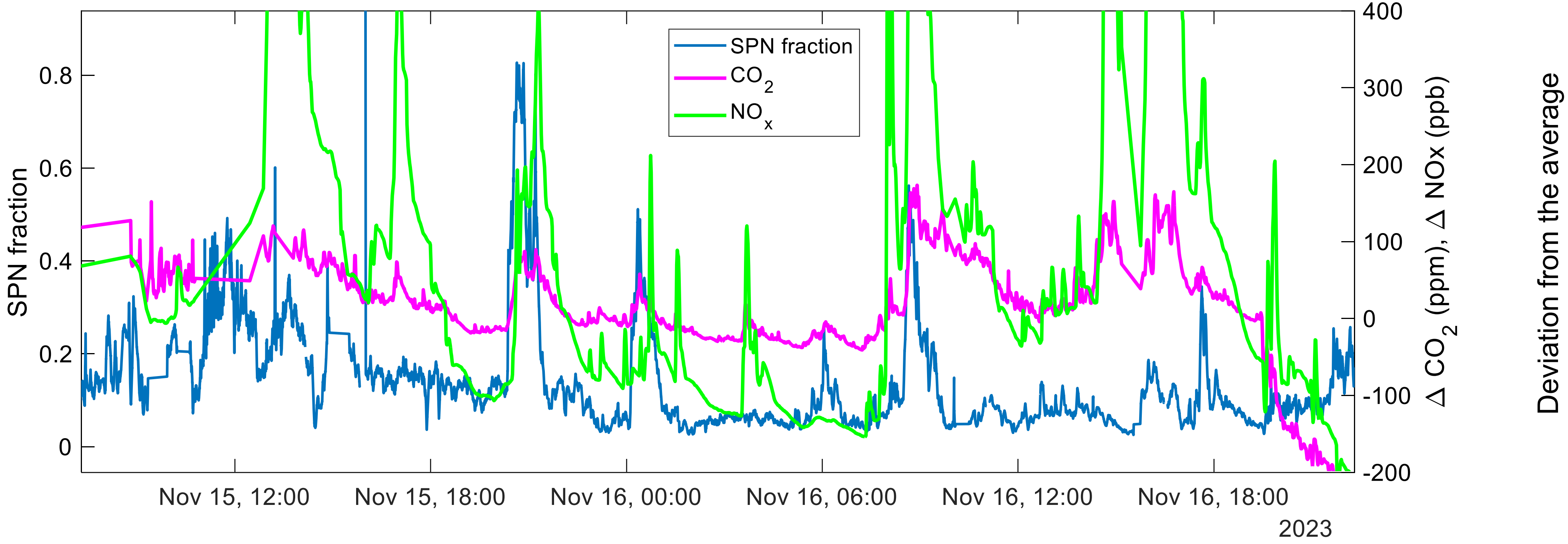
- Cut-off (response 50%) ~ 20 nm
- Concentration range ~1000 – 1x10^{8}cm^{-3}



Results – time series overview

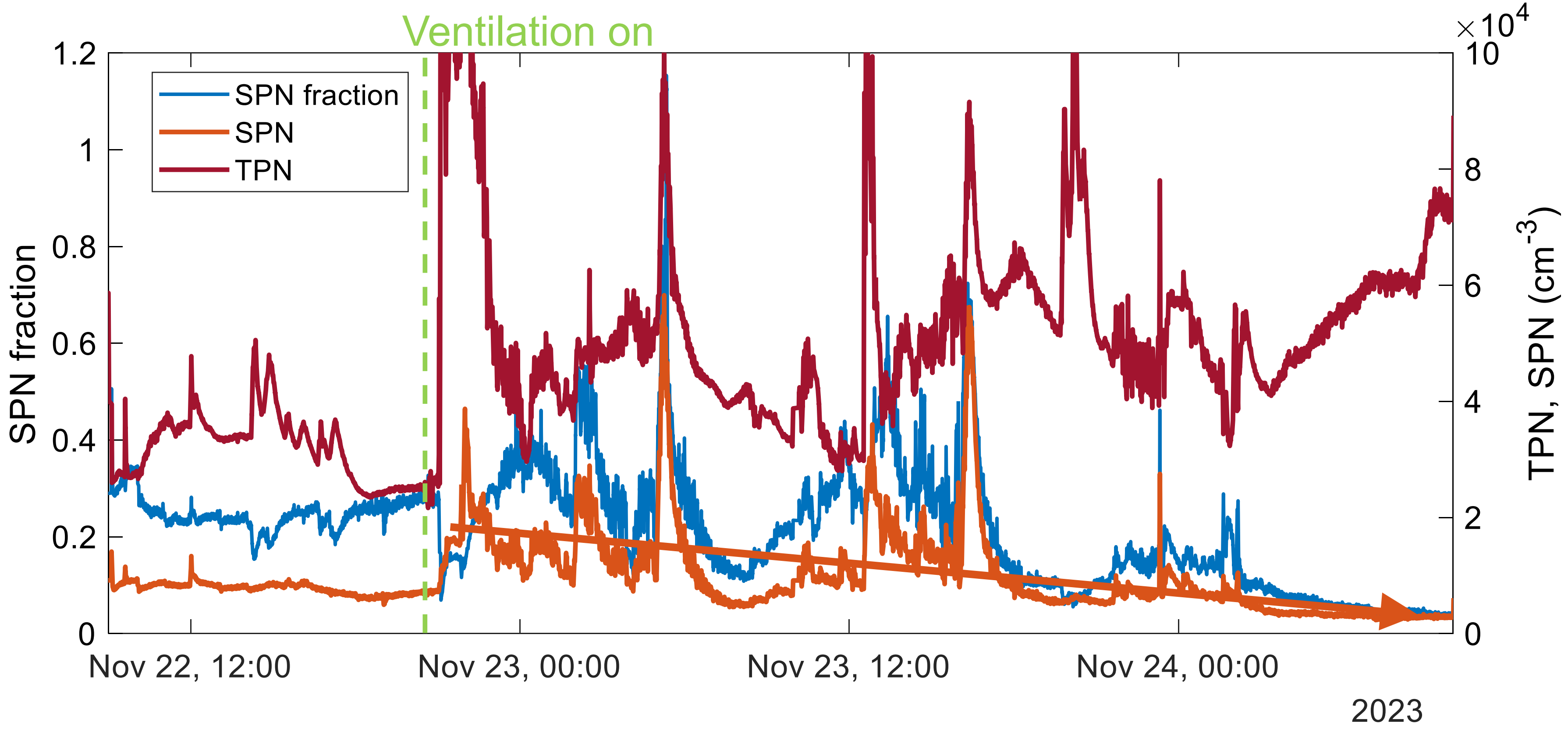


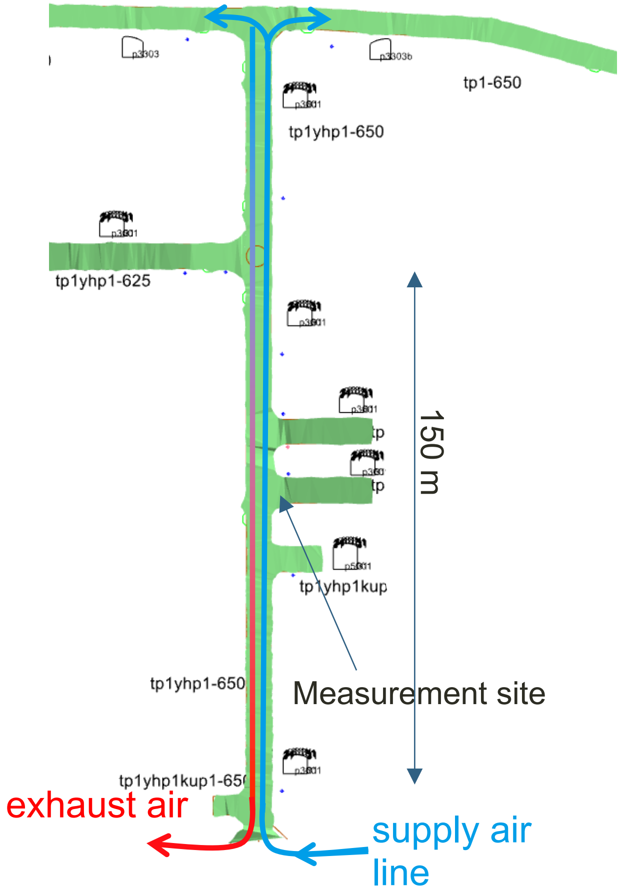
Results – time series of SPN fraction at maintenance area



- SPN fraction correlates in many cases with the CO_2 and NO_x →soot bursts by bypassing vehicles and working machines, maybe some DPF's not fully working or older vehicles
- After particle bursts solids removed / diluted by the ventilation ~30 minute time scale

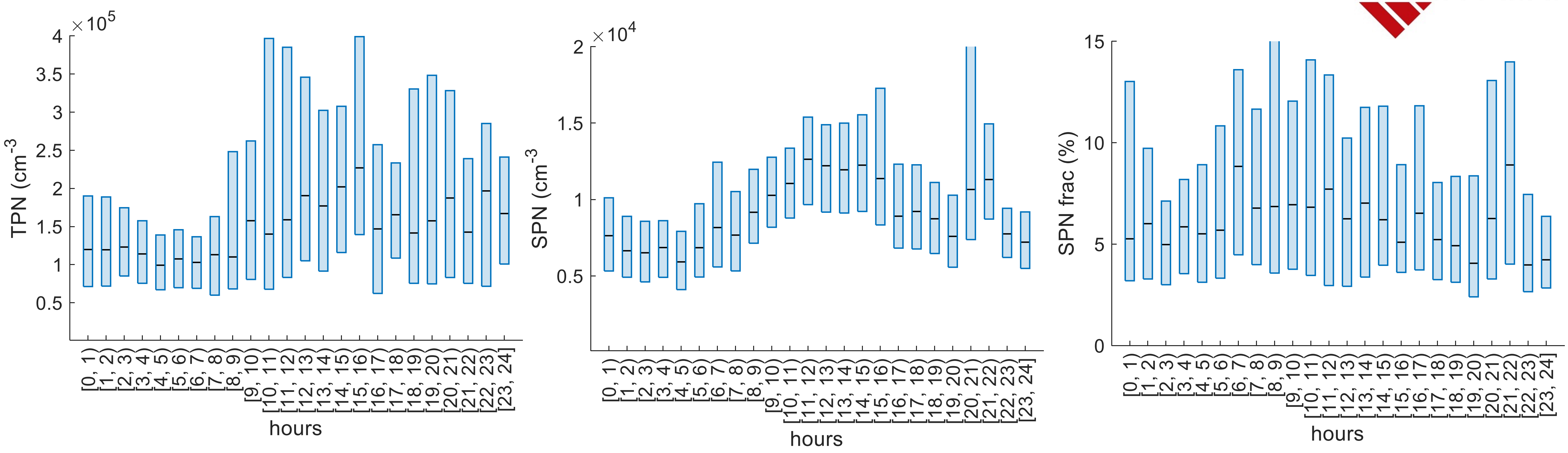
Results – time series of PN at tunnel site 650m





- After the ventilation switched on the SPN slowly decays (large fluctuations)
- TPN increases→ volatile particle forming when supply air mixes with air in tunnel or supply air brings particles within
- No photochemical aging in underground, maybe O3 and NOx initiated particle formation?

Results – diurnal variation at maintenance area



- Diurnal trends can be observed following the traffic intensity changes (restaurant lunch time 11-13)
- TPN: high hourly scattering, the level is rising after 9
- SPN: clearer patterns daytime peak (11-15) and evening peak (20-22), less scattered than TPN
- SPN fraction has two narrow peaks (6-7) and (21-22)
- Maybe solids arrive more directly from tailpipe to instruments and volatile particles after a delay

Results – average SPN and TPN

This study	TPN±std (x10⁵cm-3)	SPN(x10⁴cm-3)	SPN fraction (%)
Maintenance area			
Workdays	1.89±1.5	1.04±0.84	5.5±4.4
Weekend	3.28±1.8	1.15±0.79	3.5±2.4
Tunnel site			
Workdays	0.52±0.13	0.87±0.75	16.8±14.6
Comparison			
Saarikoski et al. (2017) Kemi mine (average whole campaign)	0.23±0.14		
Saarikoski et al.(2019) (maintenance area)	0.31		
Busy park road pavement in Helsinki, 7 days measurement, spring 2024	0.14±0.03	0.43±0.32	30±23.4

Saarikoski, S., Teinilä, K., Timonen, H., Aurela, M., Laaksovirta, T., Reyes, F., … Hillamo, R. (2017). Particulate matter characteristics, dynamics, and sources in an underground mine. Aerosol Science and Technology, 52(1), 114–122. https://doi.org/10.1080/02786826.2017.1384788

Saarikoski, S.; Salo, L.; Bloss, M.; Alanen, J.; Teinilä, K.; Reyes, F.; Timonen, H. Sources and characteristics of particulate matter at five locations in an underground mine. Aerosol Air Qual. Res. 2019, 19, 2613–2624.

Conclusions & discussion

- Two MPEC+ PEMS with different evaporation tube temperatures were used to measure the solid particle fraction in an underground mine
- SPN number concentration found at same level in different locations most of the time
- SPN fraction peaks reflected the bypassing traffic intensity (only diesel vehicles used)
- TPN was more complex, highly variable, unclear where volatiles coming from
- TPN concentrations were higher than has been found in the previous study from the same mine
    - this study in November previous studies in March, April
- The SPN fraction was low (5.5% - 16%) compared to for example what was found in the city center of Helsinki near a busy park road(~30%)
- From the occupational safety point of view, the workers spend most of the time in the vehicle cabins →I/O ratio important!

Thank you for listening!

Questions or comments?

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