



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

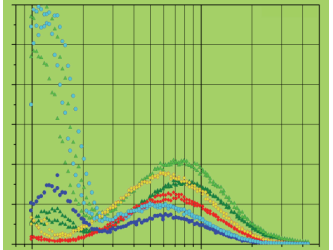
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**NEX-EL**

27<sup>th</sup> ETH-Nanoparticles Conference (NPC-24)

Including the Workplace and Indoor Aerosols Conference (Aerosols-24)

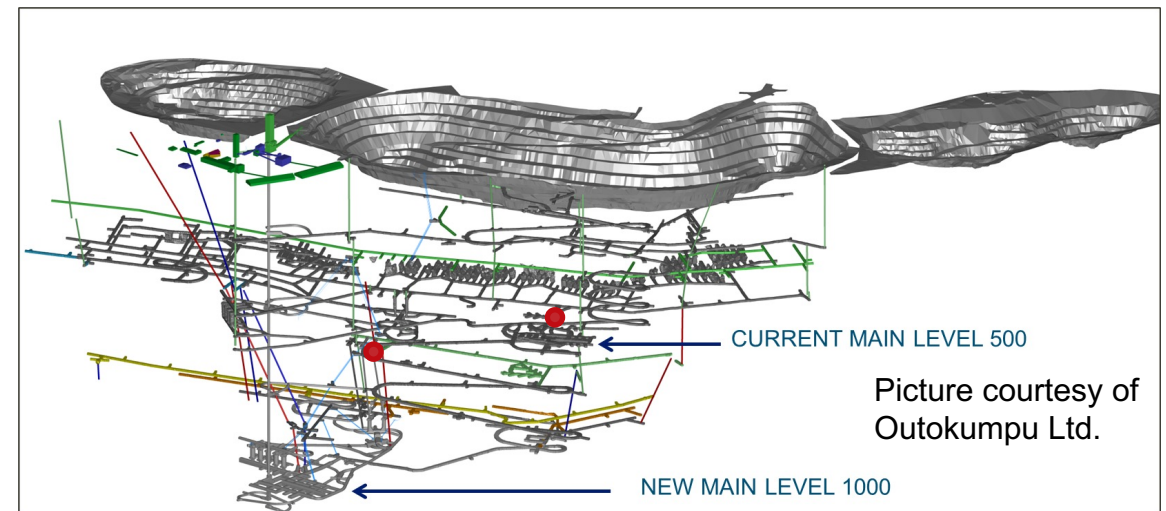
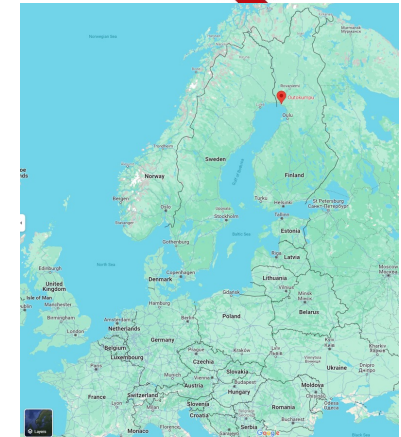


# Project and measurement site

- 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 ( $\text{FeCr}_2\text{O}_4$ ) 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



A screenshot of the NEX-EL project website. The header includes the NEX-EL logo and navigation links: About, Work plan, Partners, News and publications, and Contact. The main content area is titled "About project" and "Objectives: Mining and urban environment". It lists research topics: "How much emissions reduce along with electrification?", "Harmfulness of non-exhaust emissions, source-identification, air quality model?", and "Prevention possibilities? Materials, filters, operations, etc.". Below this, there are two sections: "Mining" and "Urban environment". The "Mining" section lists: Mining activities and resulting non-exhaust (real environment measurements), Air filtration of cabin (simulation), Effect of electrification (real environment), and Air quality instrumentation and sensors (laboratory + real environment). The "Urban environment" section lists: Brake dust and affecting factors (laboratory) and Tire wear (laboratory measurement). To the right of the text is a photograph of a mining worker in an orange safety suit and helmet, standing in a dark tunnel. Various emission sources are labeled with callouts: Exhaust emissions, Cabin air quality, Emissions from operation, Outdoor/workplace air quality, Tyre emissions, Brake emissions, Ground surface emissions, and Citizen/worker exposure.



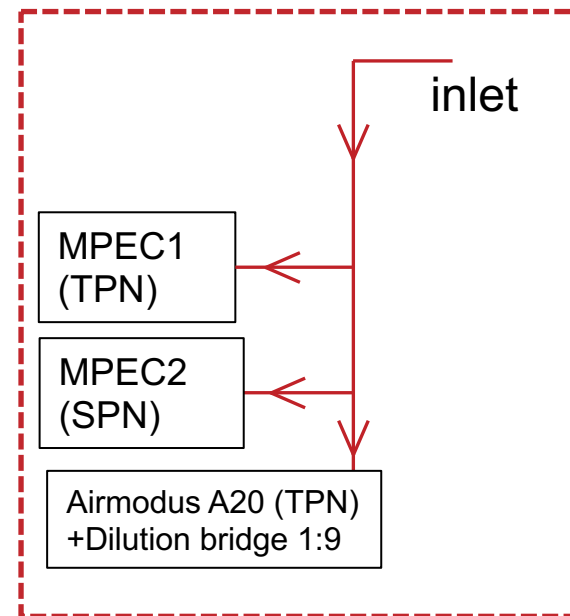
Picture courtesy of Outokumpu Ltd.

# Instrumentation

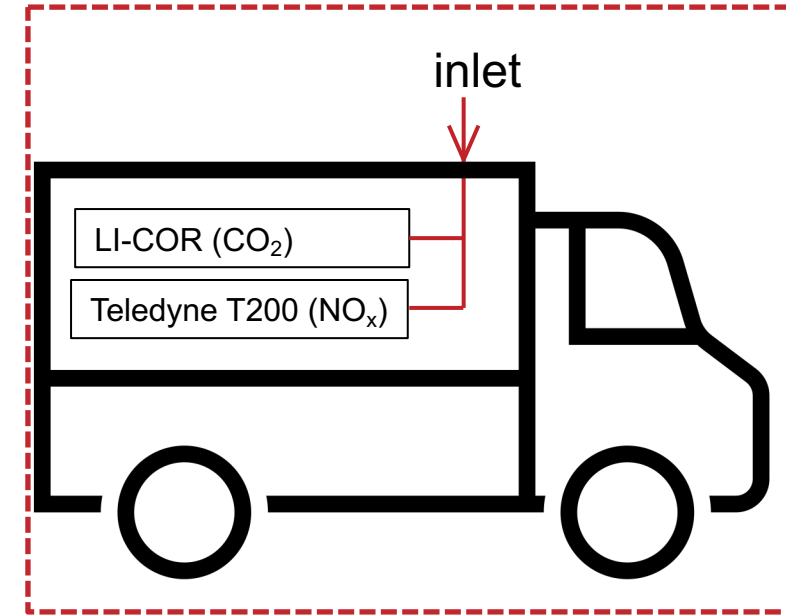
- Main instruments were two standalone PN PEMS devices (MPEC+)
  - MPEC standalone instrument that complies with RDE EU directive EU 2017/1154 and upcoming UNECE GTR n:o 15
  - Measuring total PN a new application → MPEC (105) was modified to measure the total PN
  - MPEC (104) used to measure the solid PN
- Gas measurements
  - Monitors inside the ATMO-Lab
  - LI-COR → CO, CO<sub>2</sub>
  - Teledyne T200 inside the mobile lab
  - located most of the time nearby the stationary site



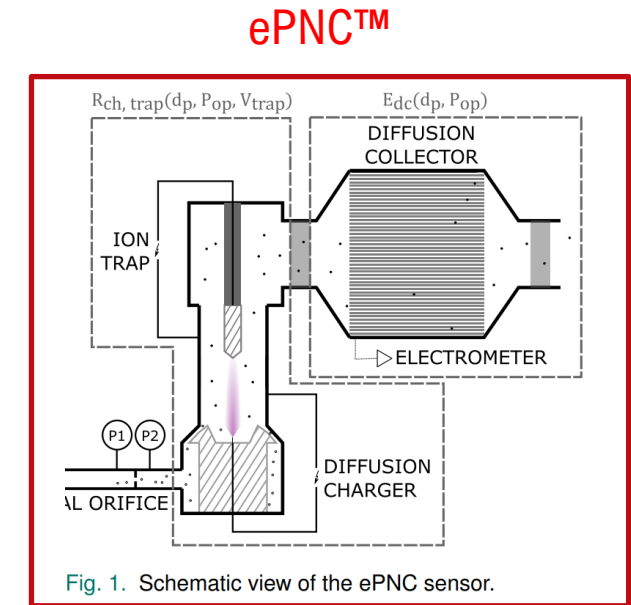
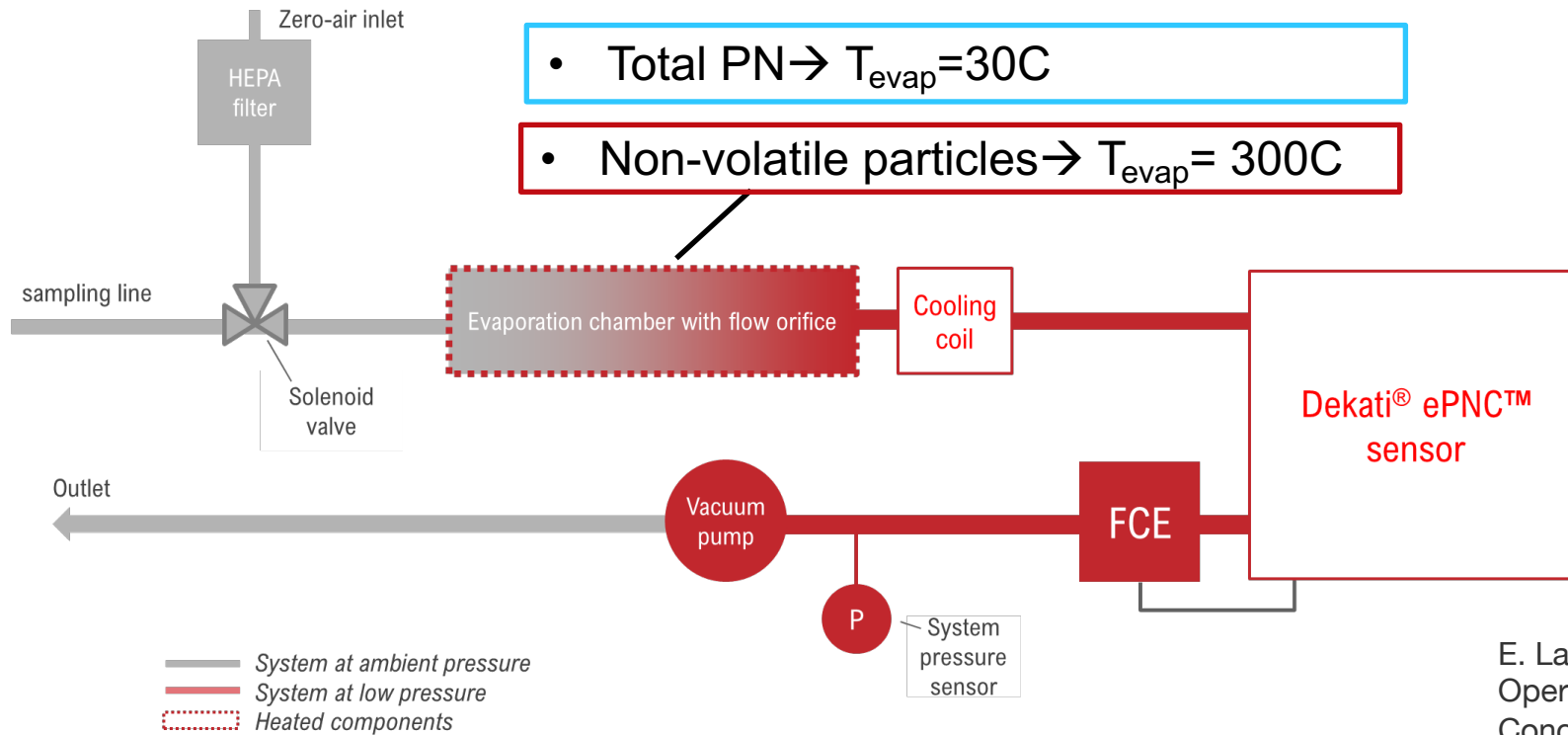
Stationary setup



Mobile lab  
(Tampere University's ATMO-Lab)



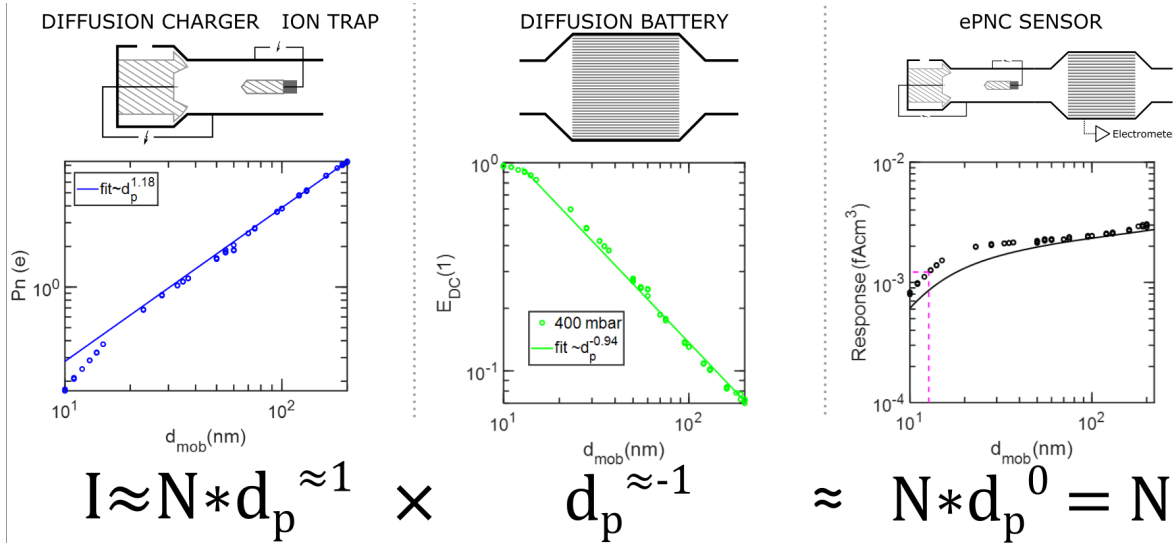
# MPEC+ construction and modifications



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

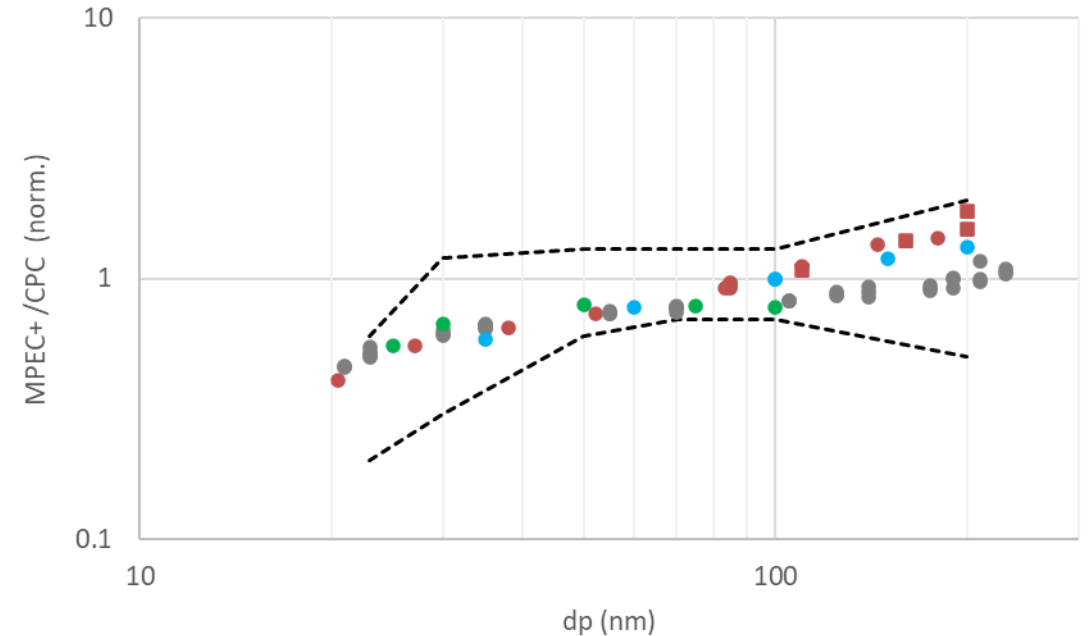
# MPEC+ / ePNC size response



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

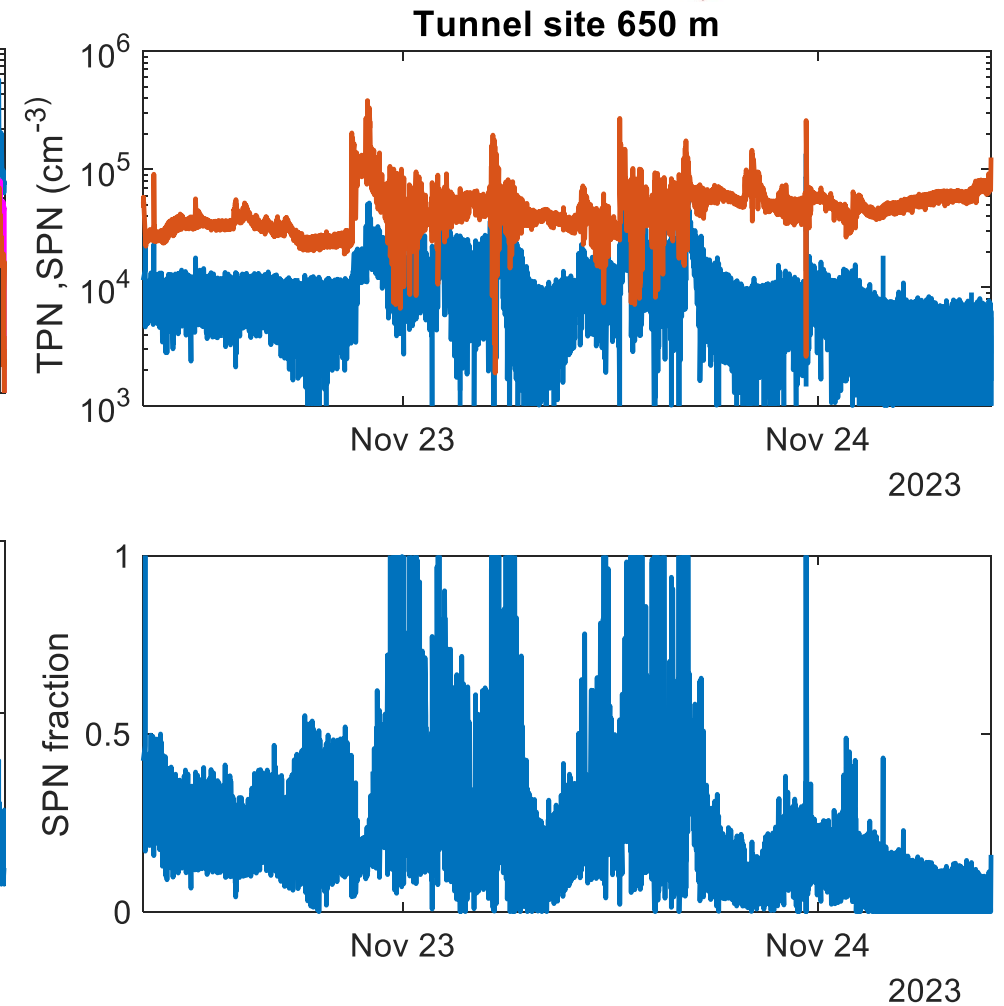
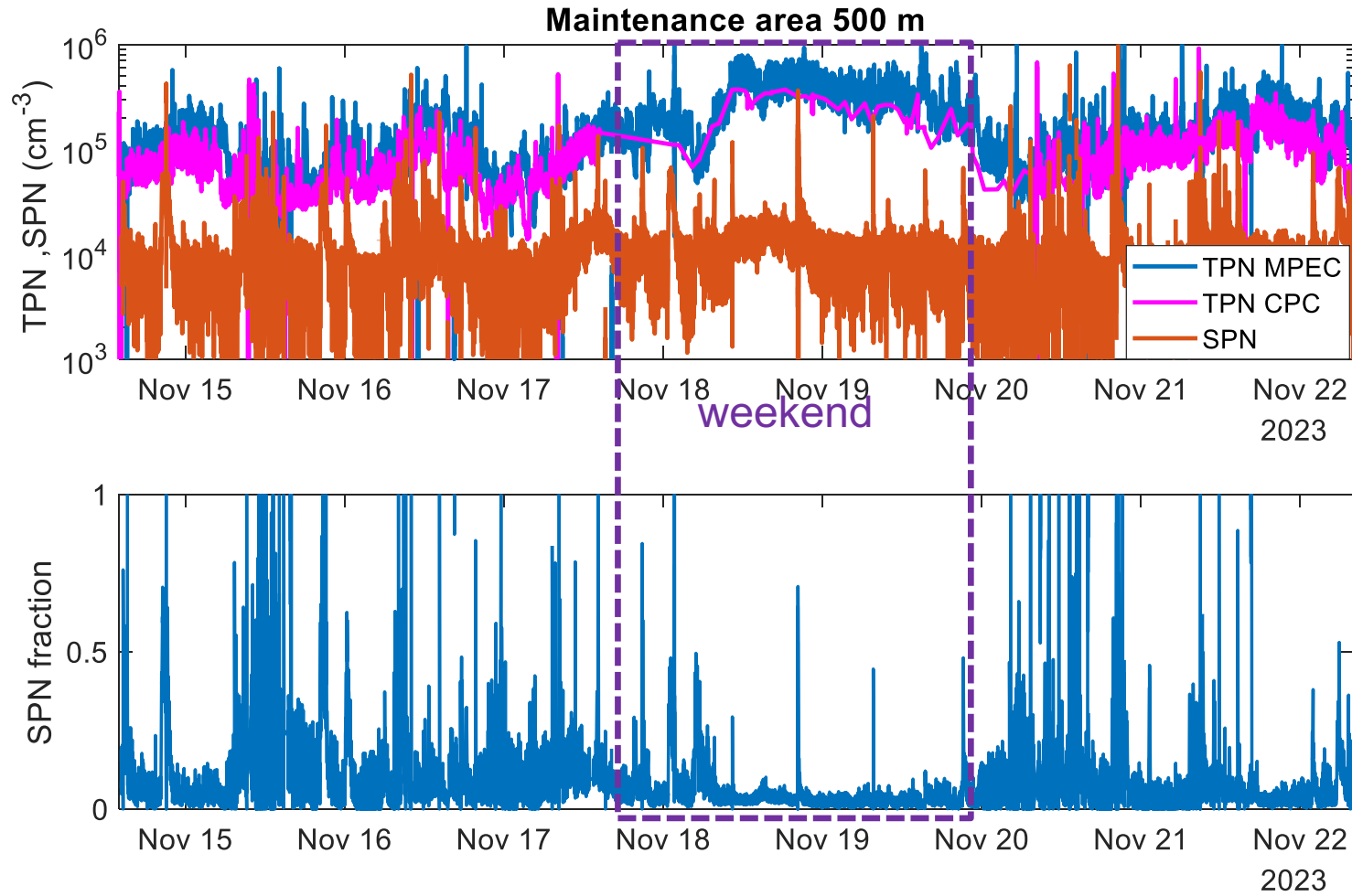
- Decreased operation pressure (400 mbar)
  - to modify the sensor response close to number concentration
  - prevents condensation

- Cut-off (response 50%) ~ 20 nm
- Concentration range ~1000 – 1x10<sup>8</sup>cm<sup>-3</sup>



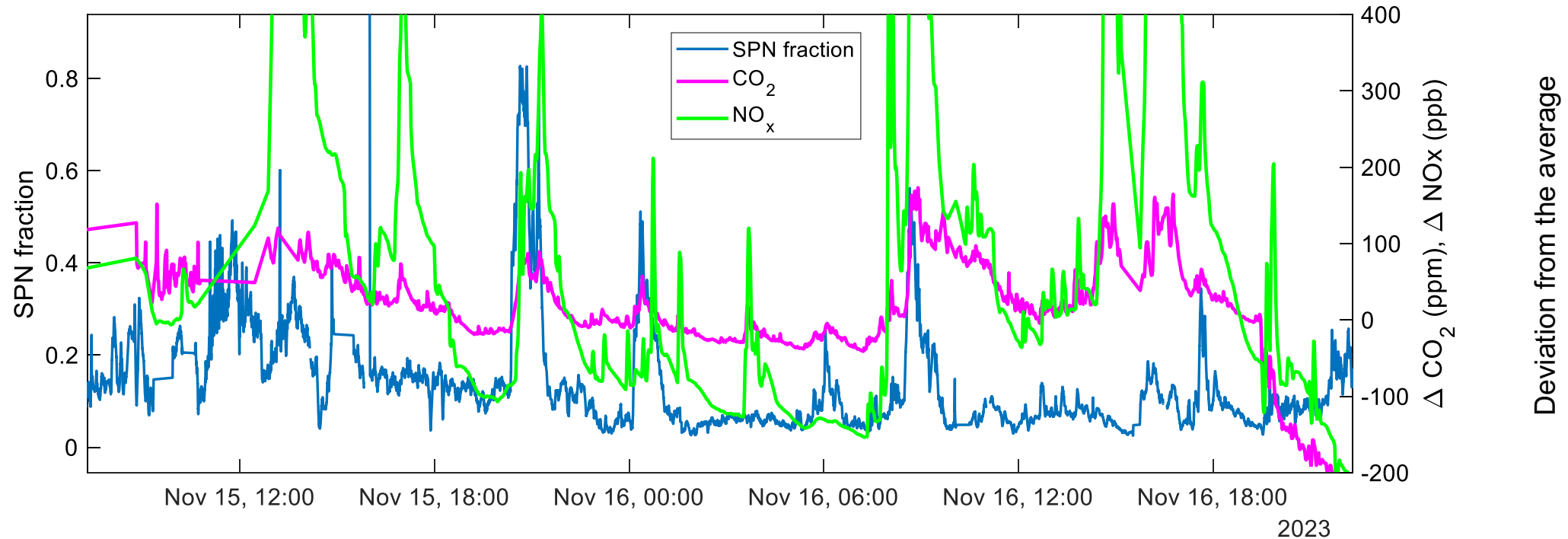
- Soot MPEC polydisp (red circle)
- Soot MPEC monodisp (red square)
- DEHS monodisp (grey circle)
- NaCl monodisp (blue circle)
- Ag monodisp (green circle)
- RDE / PTI GE (dashed line)

# Results – time series overview



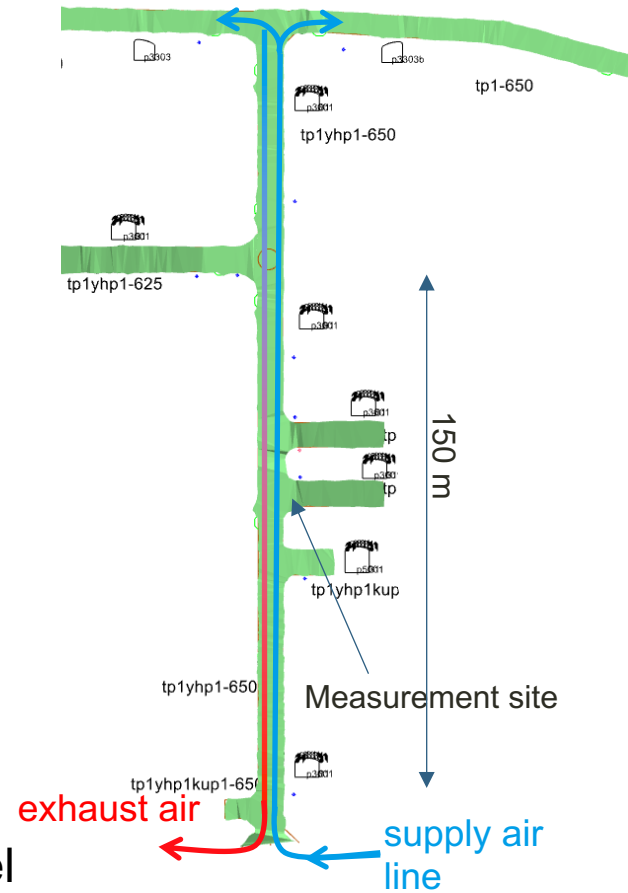
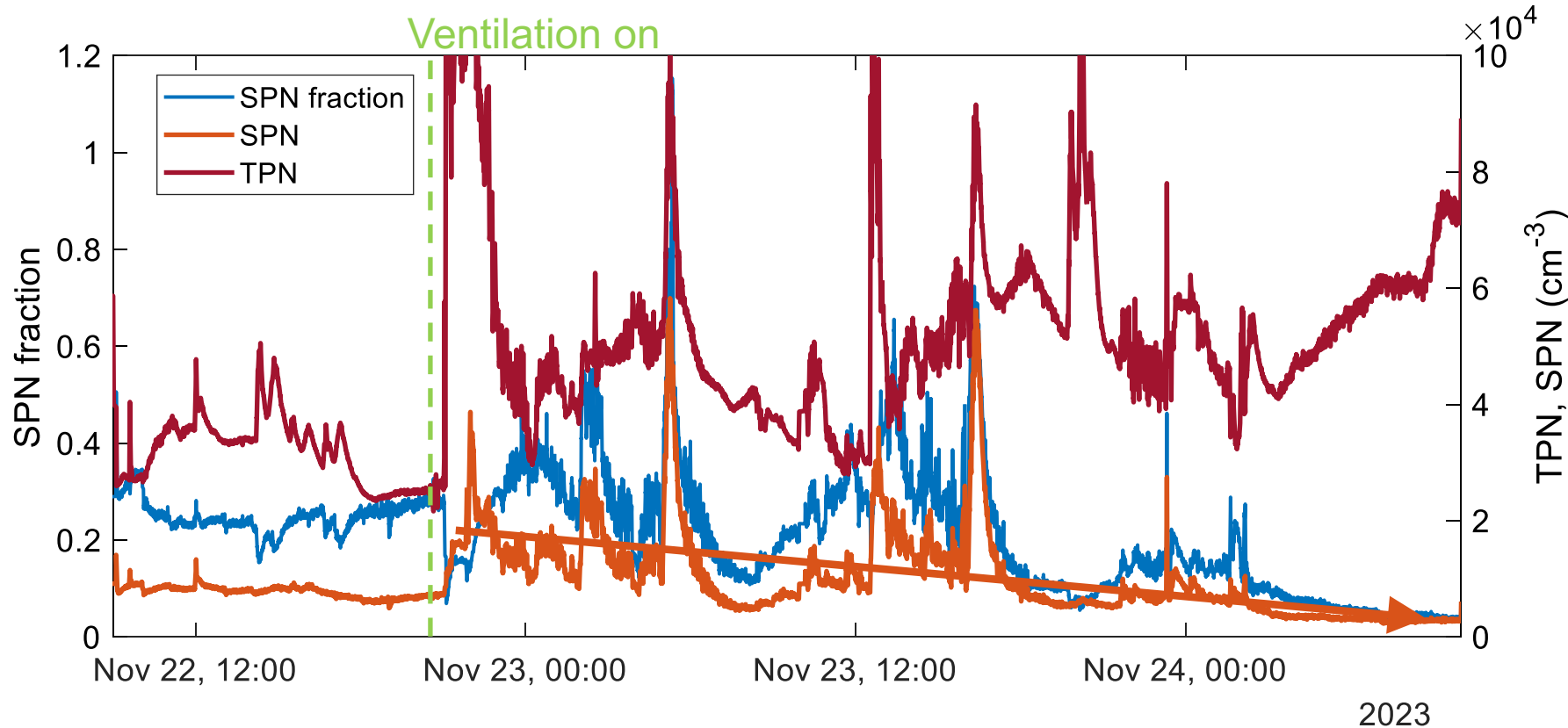


# Results – time series of SPN fraction at maintenance area



- SPN fraction correlates in many cases with the CO<sub>2</sub> and NO<sub>x</sub> → 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

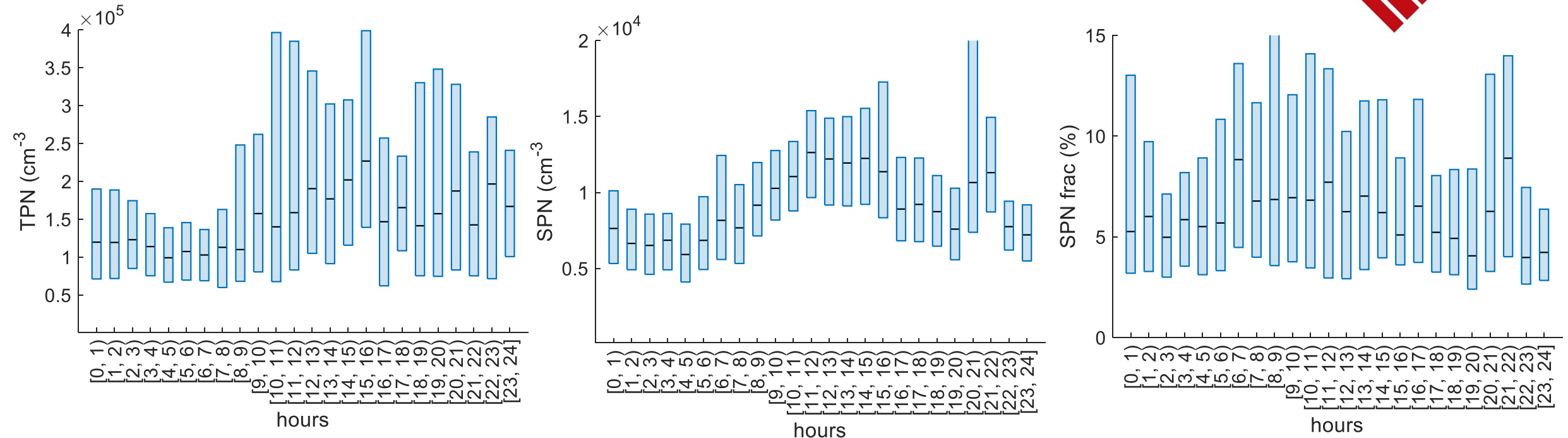
# Results – time series of PN at tunnel site 650m



- 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 O<sub>3</sub> and NO<sub>x</sub> 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



<b>This study</b>	<b>TPN±std (x10<sup>5</sup>cm<sup>-3</sup>)</b>	<b>SPN(x10<sup>4</sup>cm<sup>-3</sup>)</b>	<b>SPN fraction (%)</b>
<b>Maintenance area</b>			
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
<b>Tunnel site</b>			
Workdays	0.52±0.13	0.87±0.75	16.8±14.6
<b>Comparison</b>			
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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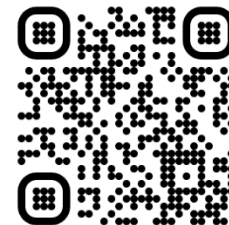
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# Contents



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