



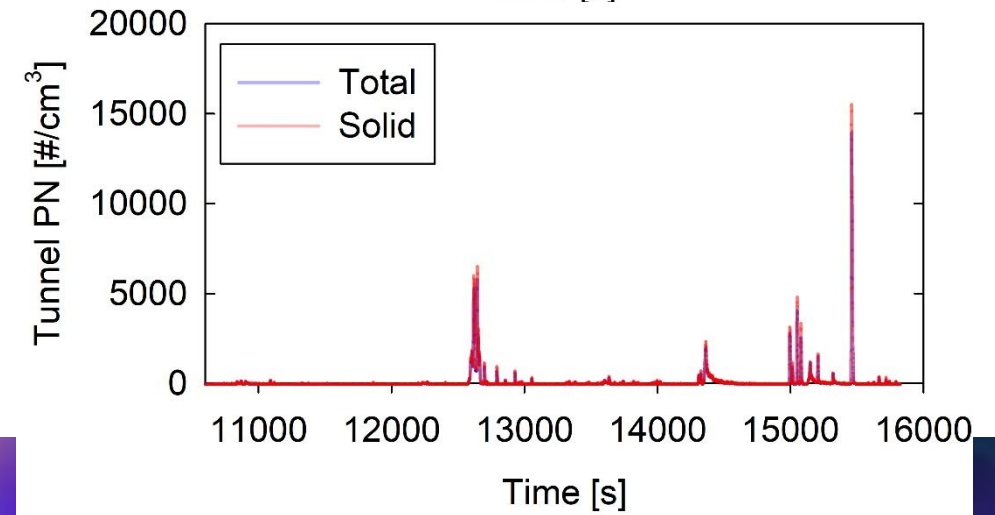
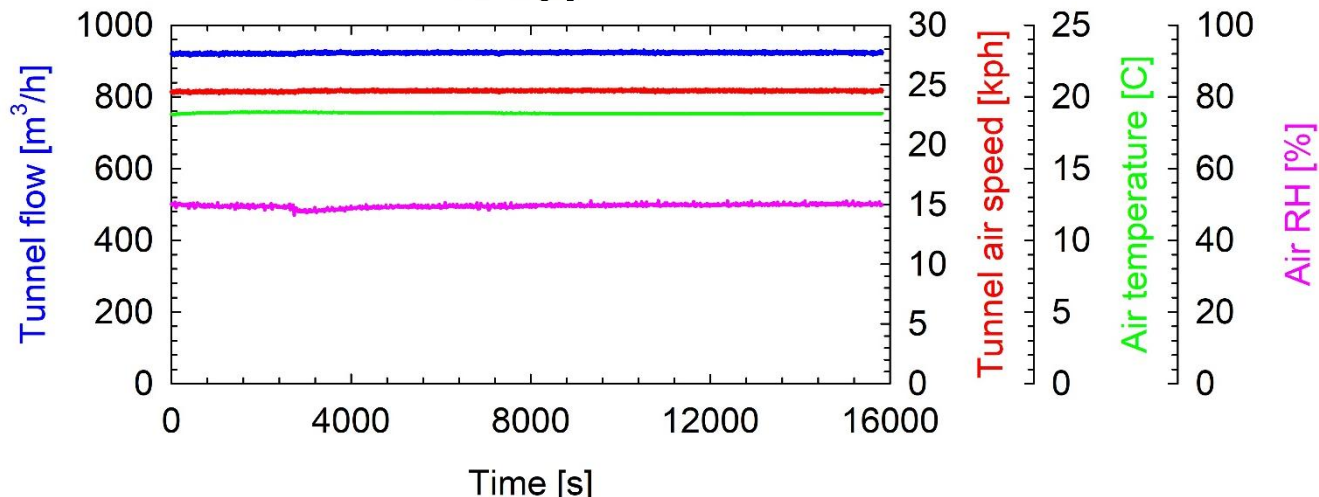
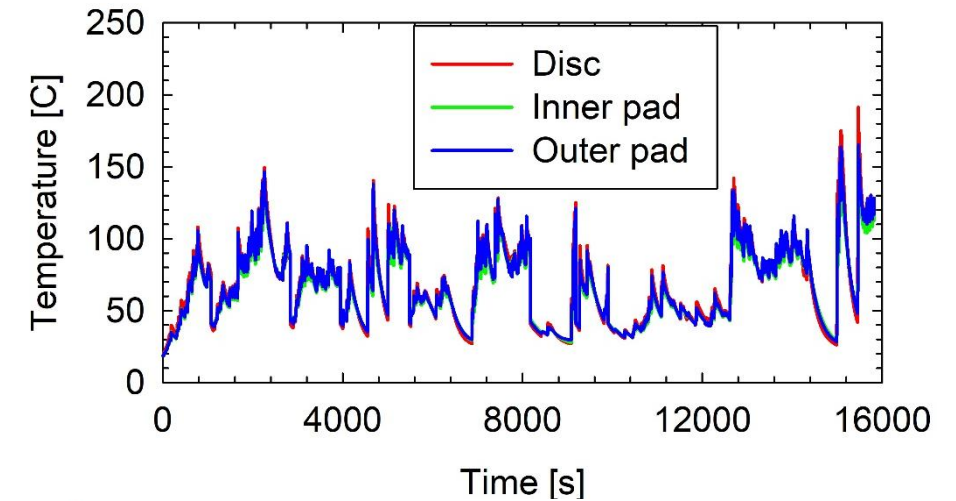
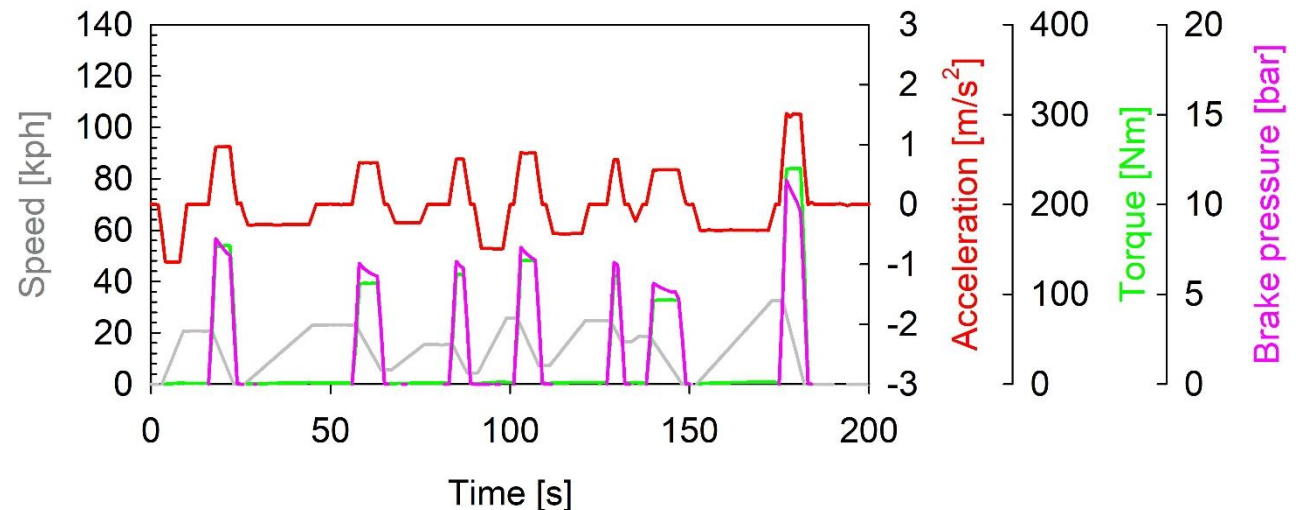
Time-Based Files

PN emissions analysis

Mamakos, Athanasios

EED files format

- EED files contain 1 Hz of aligned data from essential dyno (speed, brake pressure and torque, acceleration, friction coefficient), tunnel (flowrate, airspeed, temperature, RH, pressure), brake temperature (disc, pads), PN (concentration, PCRF for total and optionally solid), PM samplers (flows)

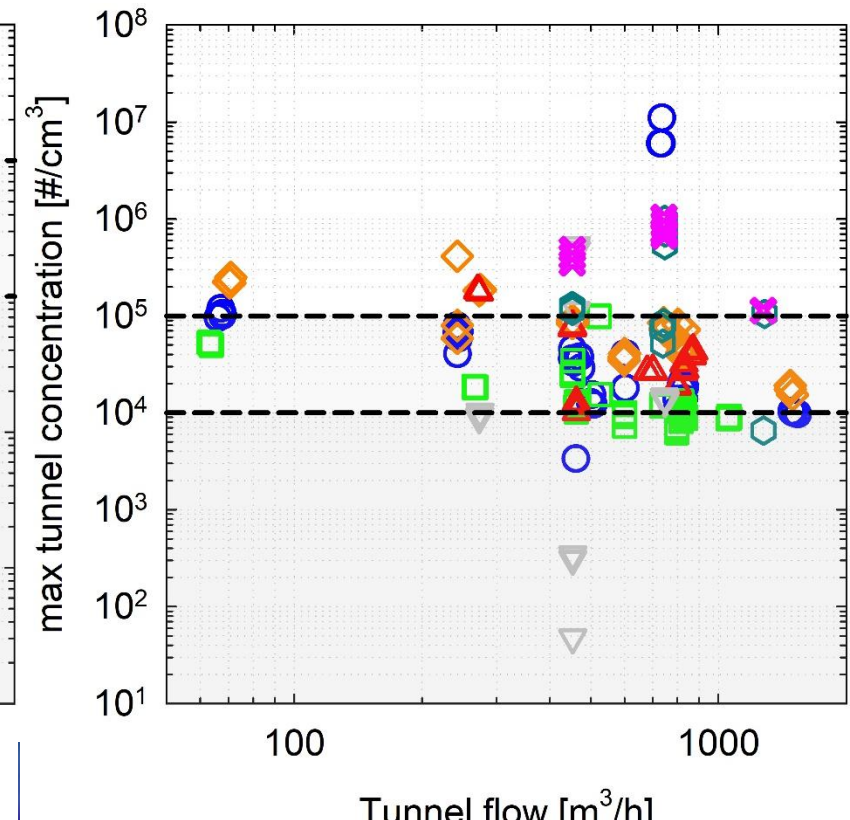
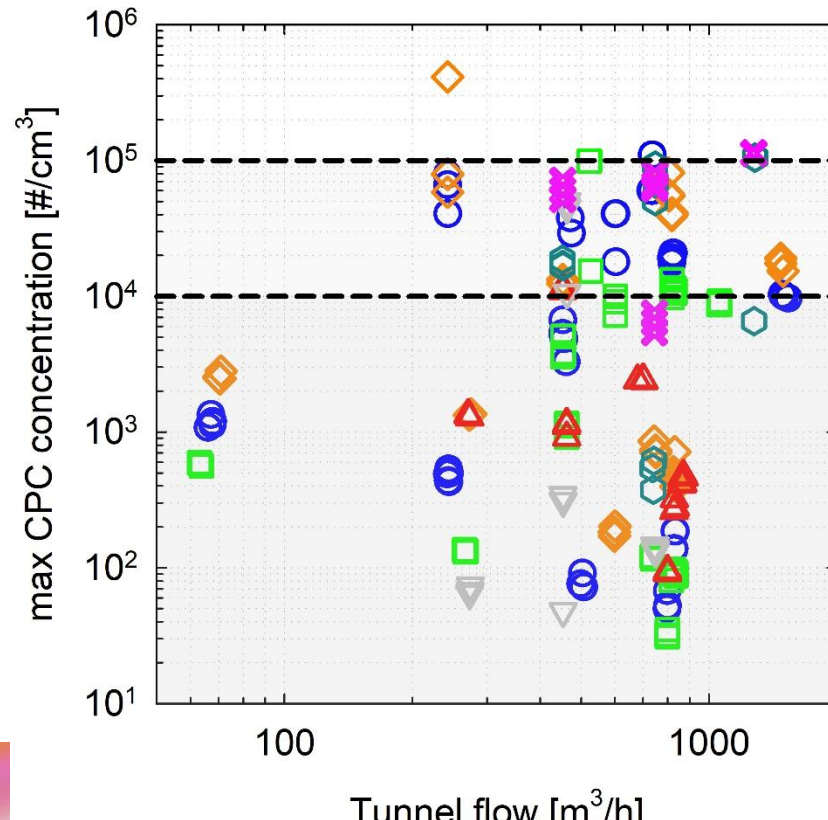
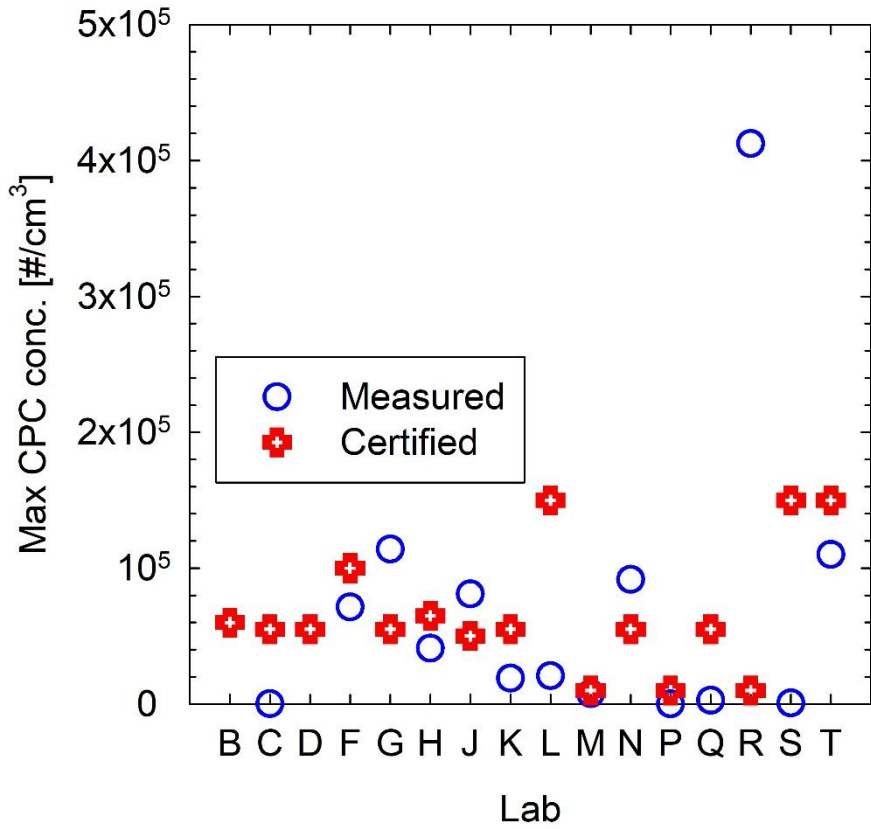
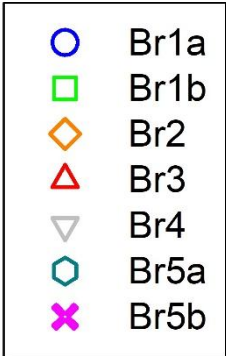


EED data analysis

- Parameters extracted from the EED files allowed for investigation of defined specifications:
 - Speed violations
 - Speed RMSE
 - Cooling air humidity violations
 - Cooling air temperature violations
 - Cooling airflow violations
 - Cooling air average temperature
 - Cooling air flow & air speed average
 - Average and maximum disc temperature
- Perhaps more importantly, allowed for analysis of PN emissions, which will be the focus of the presentation.

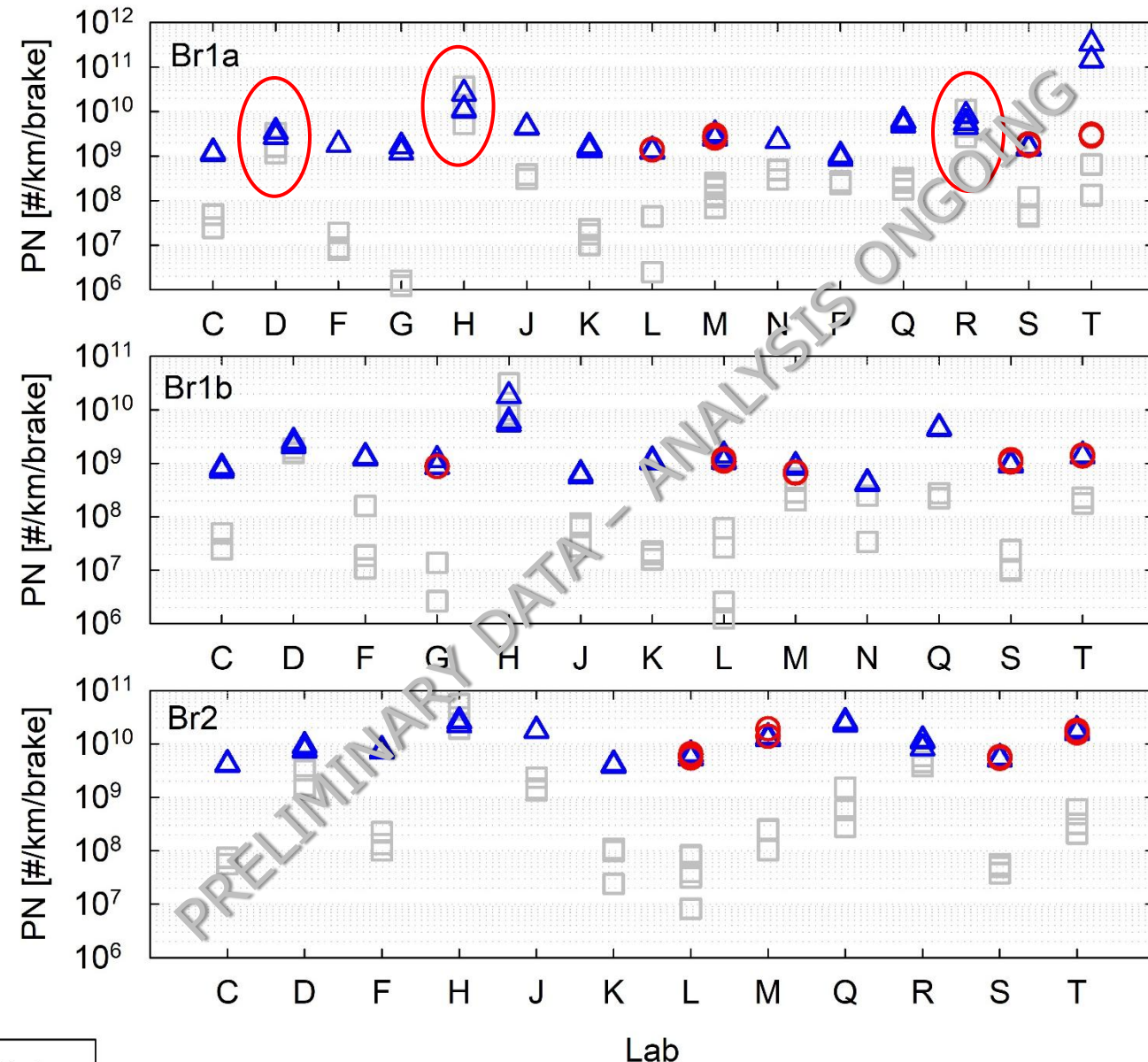
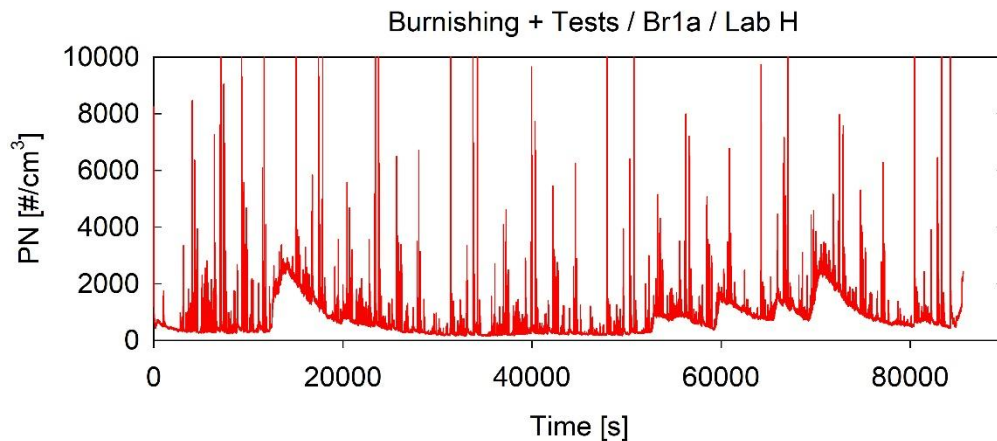
Maximum tunnel PN concentration

- Maximum total PN tunnel concentrations ranged between 3.5×10^3 and 1.1×10^7 $\#/\text{cm}^3$
 - Labs G, J N and R measured concentrations higher than the certified range of the employed CPCs illustrated with dashed lines.
- ➔ A dilution of 10:1 to 100:1 is necessary to ensure proper PN measurements



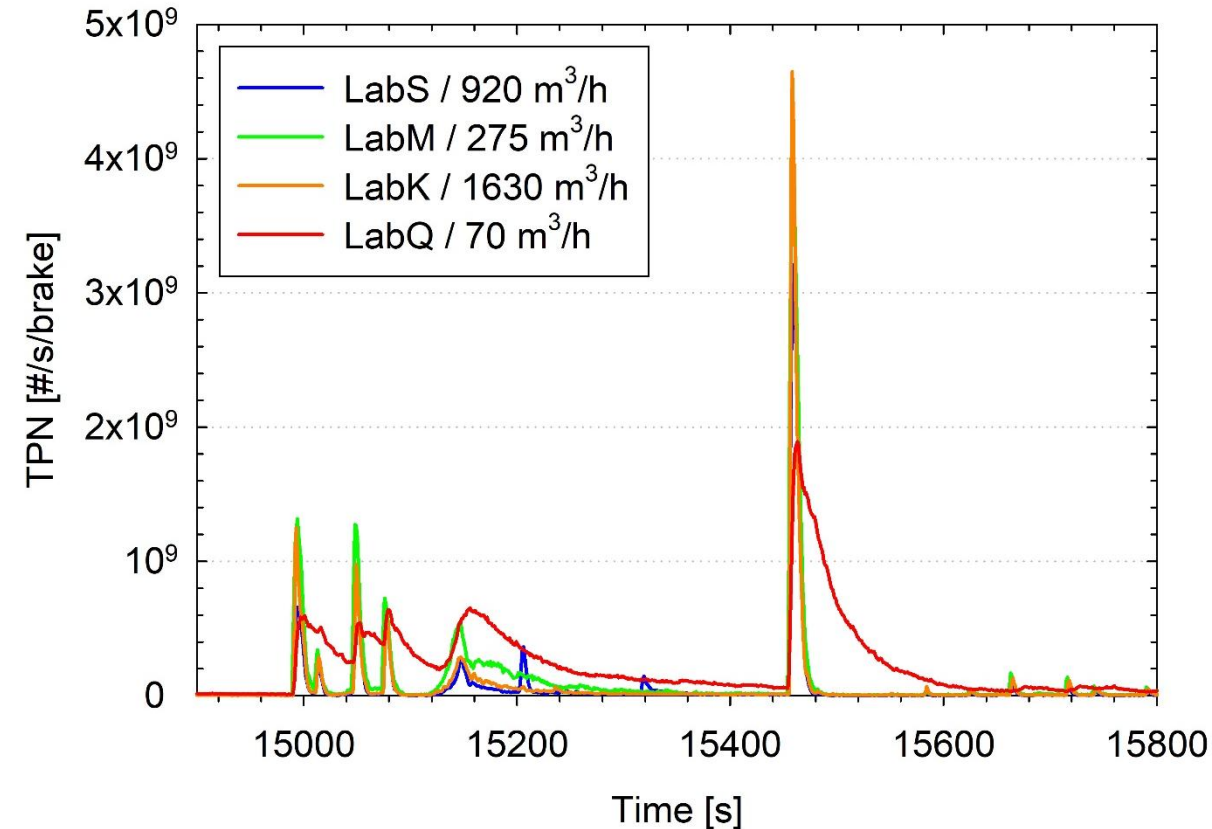
Background PN levels

- In general, background PN concentrations in the tunnel were at least one order of magnitude below the cycle-average tunnel concentrations.
- However, three labs (D, H & R) had background levels similar to measured emission levels ($1000\text{--}2000 \text{ \#/cm}^3$) → PN results from these specific labs are unreliable.



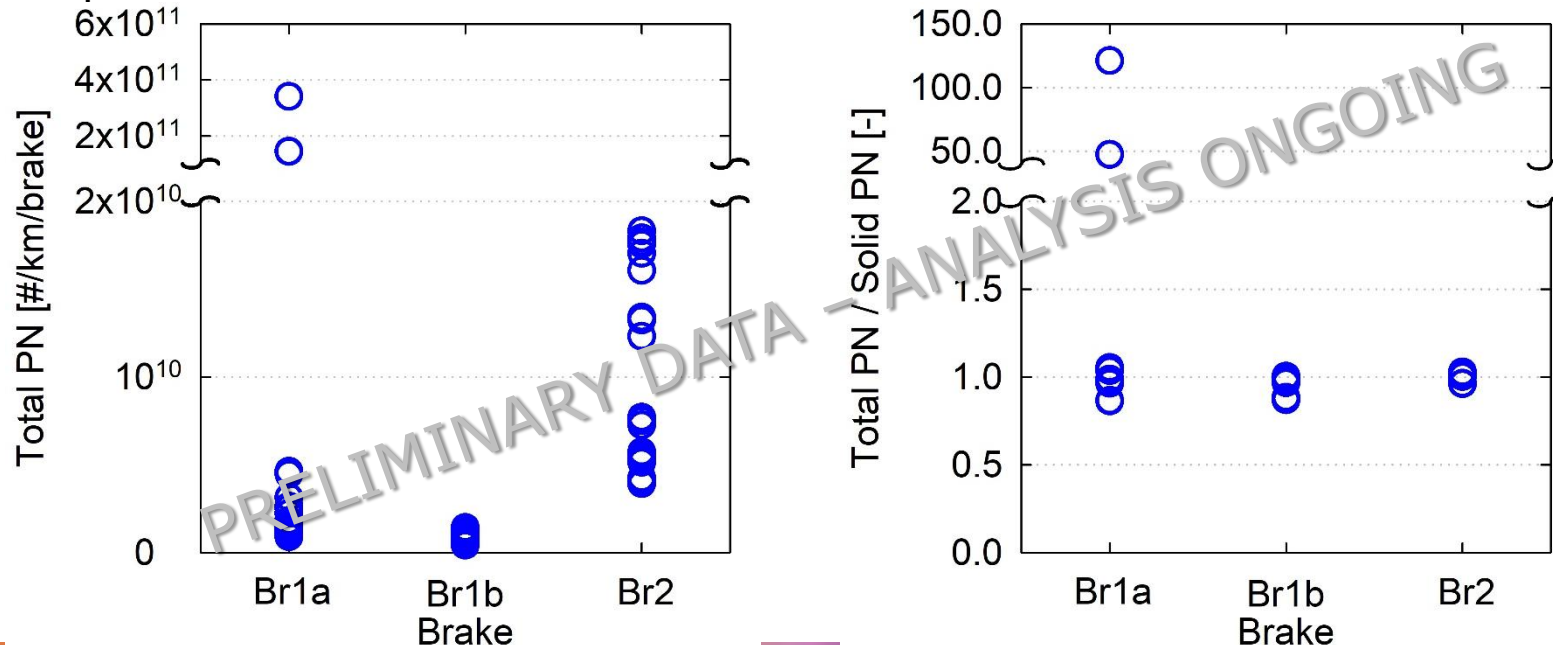
Evacuation times

- The real time traces of one lab (Q) exhibited excessively slow response times (>2 min).
 - LabQ employed a very low tunnel flow ($70 \text{ m}^3/\text{h}$) leading to duct velocities of $\sim 1 \text{ m/s}$ and even lower average speeds inside the enclosure.
 - Still response times do not scale with the flows in other labs that could also differ by ~ 1 order of magnitude (275 to $1630 \text{ m}^3/\text{h}$).
- ➔ Strong indications of recirculating patterns inside the enclosure.



PN results overview

- The three labs with high background (D, H, R) and LabQ with excessive evacuations times were excluded from this first analysis.
- Left-hand graphs below shows the lab average total PN emissions from all mandatory brakes. Total PN emissions ranged between 0.9 and 4.6×10^9 #/km/brake for Br1a (with the exception of one lab which measured $> 2 \times 10^{11}$ #/km/brake), 0.4 to 1.4×10^9 #/km/brake for Br1b and between 3.9 to 18×10^9 #/km/brake for Br2.
- The ratio of total to solid PN (right-hand panel) revealed that the very high emission at Br1a was due to release of volatile particles.



Summary

- Tunnel concentrations can exceed 10^7 $\text{\#}/\text{cm}^3$ but nearly all labs applied the necessary dilution (10:1 to 100:1) to properly measure PN.
- High PN background levels were measured at 3 labs (1000-2000 $\text{\#}/\text{cm}^3$) which made the quantification of the true PN emissions impossible.
- Excessive evacuation times (>2 min) were observed in one lab that employed a very low tunnel flow (70 m^3/h).
- Volatile particles were observed in one lab for Br1a leading to ~ 2 orders of magnitude higher PN from the other labs and from the solid PN (measured in parallel at this lab).

Thank you



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