LINK'S BRAKE EMISSION SYSTEM 'M6330'

PN and PSD Subsystem

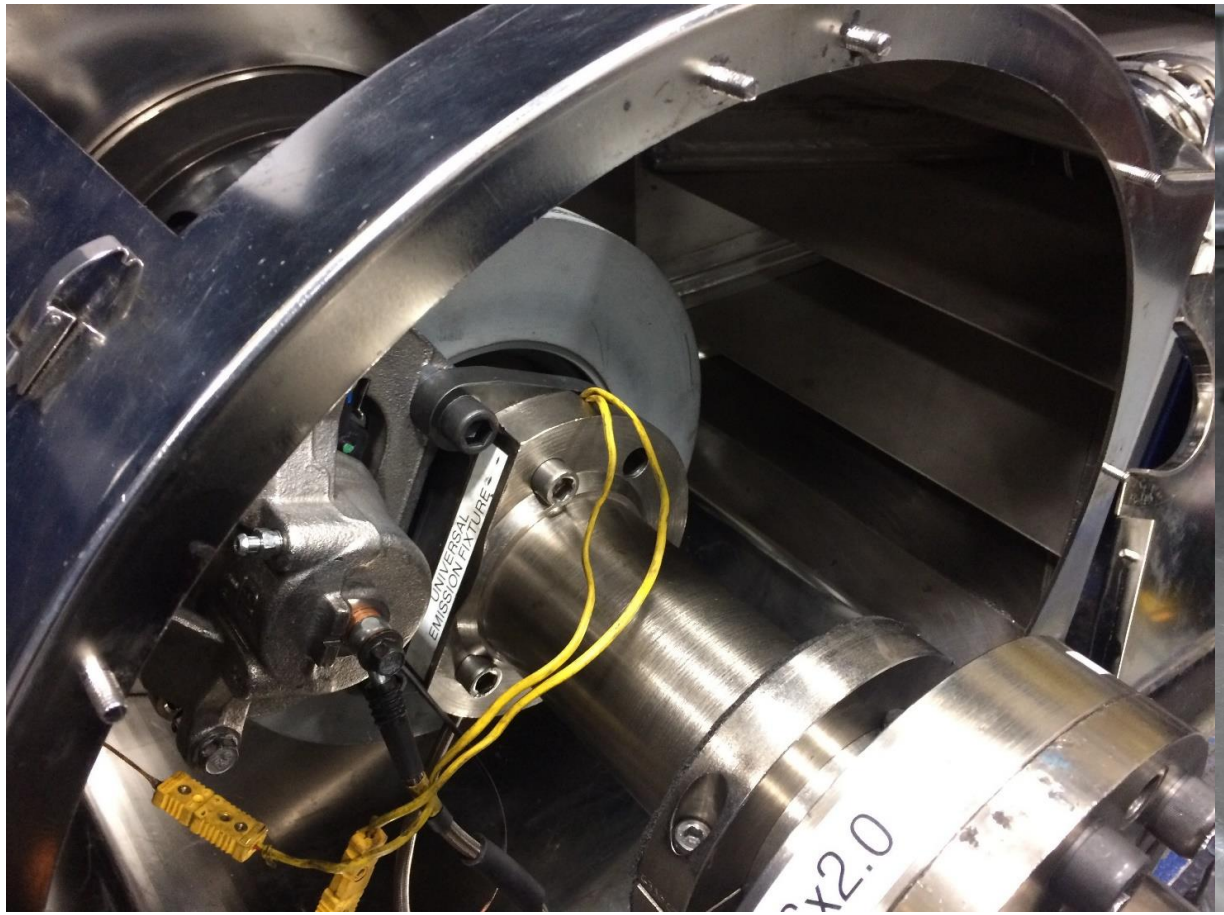
Presented to PMP TF2

June 3rd 2021

Link Engineering Company

Testing services accredited to ISO 17025:2017

Engineering and lab processes, isokinetics, and fully-integrated test reports

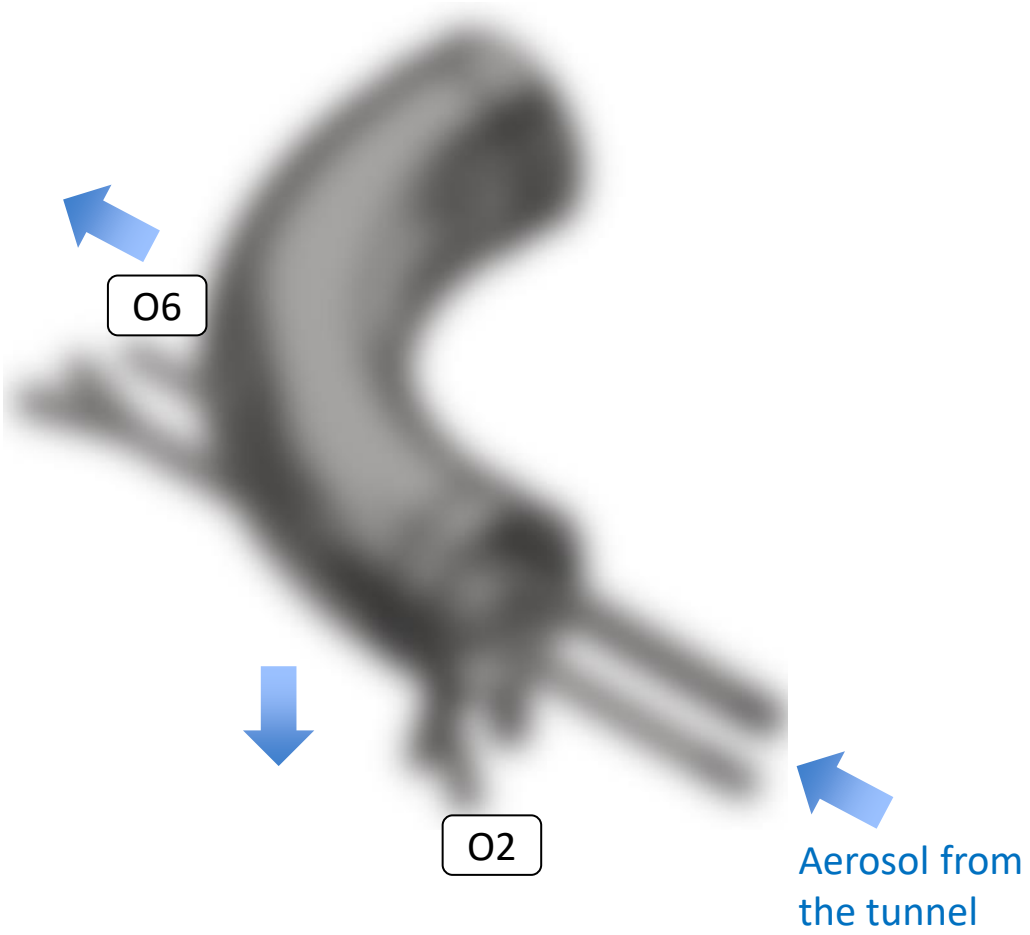


Dedicated dynamometers

Isokinetic sampling

Particulate sampling elbow

Multiple inlets and outlets

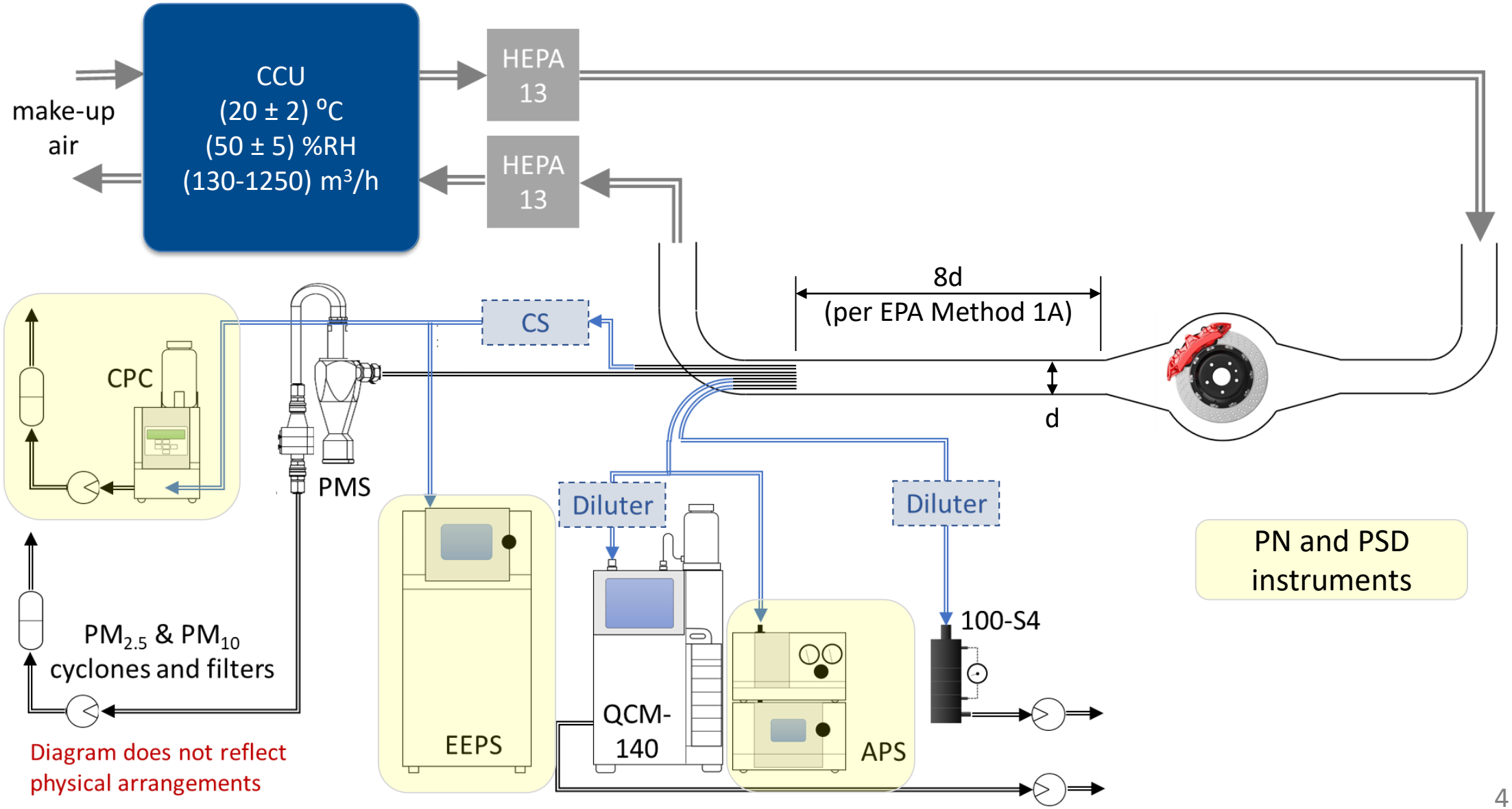


Filled blocks represent outlets for PM sampling

Outlet	Instrument Model	Instrument Supplier	Flow (L/min)	Measurand
O1	MOUDI 100S4	TSI (MSP model)	30.0	PM
O2	APS 3321 + 20:1 Diluter	TSI	5.0	PSD
O3	MOUDI QCM 140	TSI (MSP model)	10.0	Time-based PM
O4	PM filter holder 2000-30FVT PM_{10} cyclone 2000-30EI	URG	16.7	PM
O5	PM filter holder 2000-30FVT $PM_{2.5}$ cyclone 2000-30EHS	URG	16.7	PM
O6A*	EEPS 3090 + I/L cyclone	TSI	10.0	PSD
O6B*	CPC 3790A-10 + I/L cyclone	TSI	1.0	PN
** O6 is connected to a flow splitter leading to multiple outlets*				

M6330 comprehensive configuration for PM, PN, and PSD

Conditioned air, aerodynamic enclosure, isokinetics, 6 nm-20 µm range

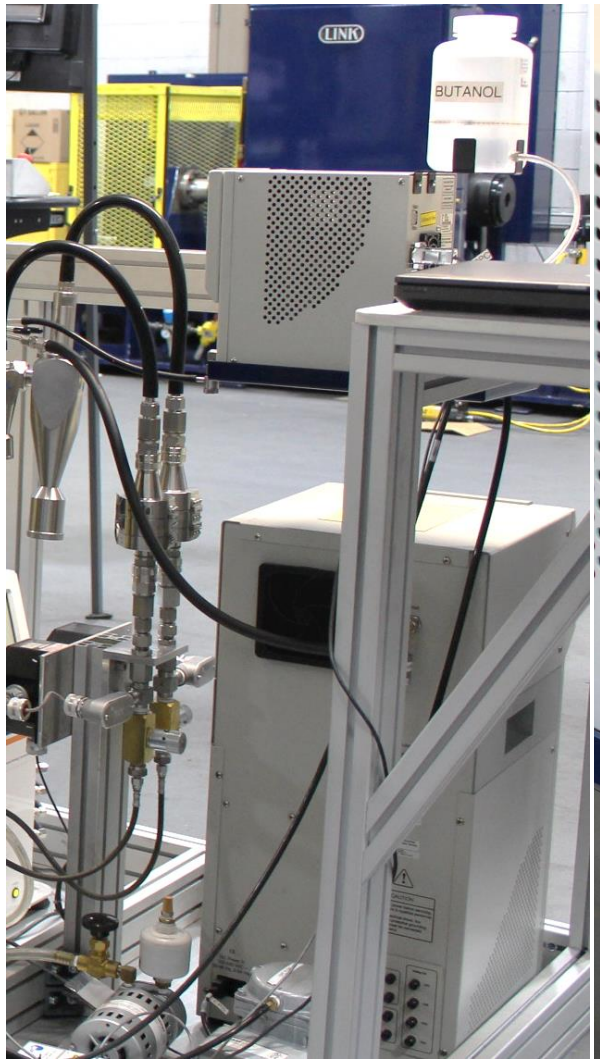


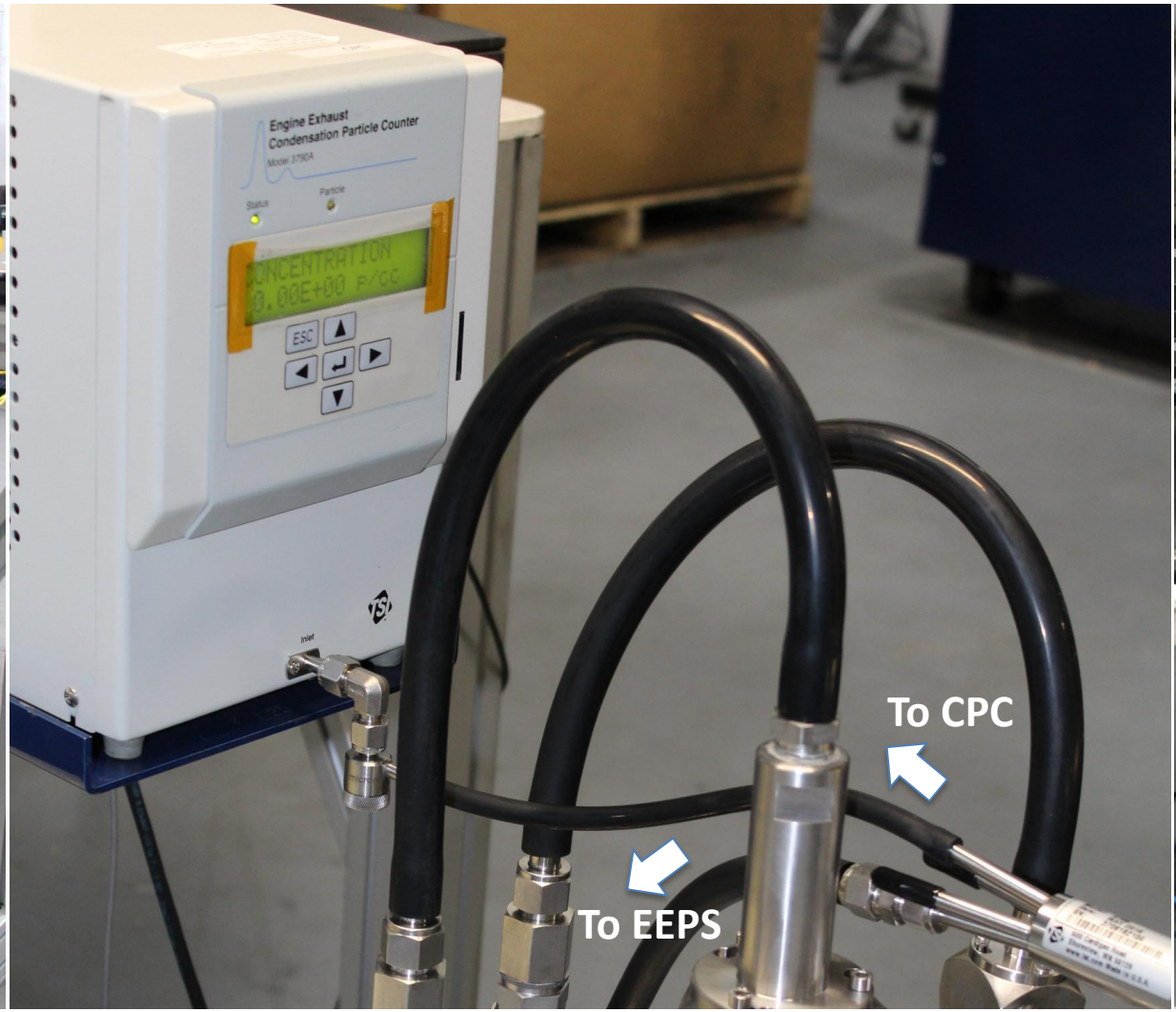
Instrumentation cluster

PM, PN, and PSD

PN and PSD instruments

Connections using flexible hoses with gradual bend





Particulate measurement range

PM, PN, and PSD

Bubbles along the lines are cutpoint diameters

Particle Mass

PMS_{10} – Cyclone + 47-mm filters

$PMS_{2.5}$ – Cyclone + 47-mm filters

100S4 – Low-pressure impactor

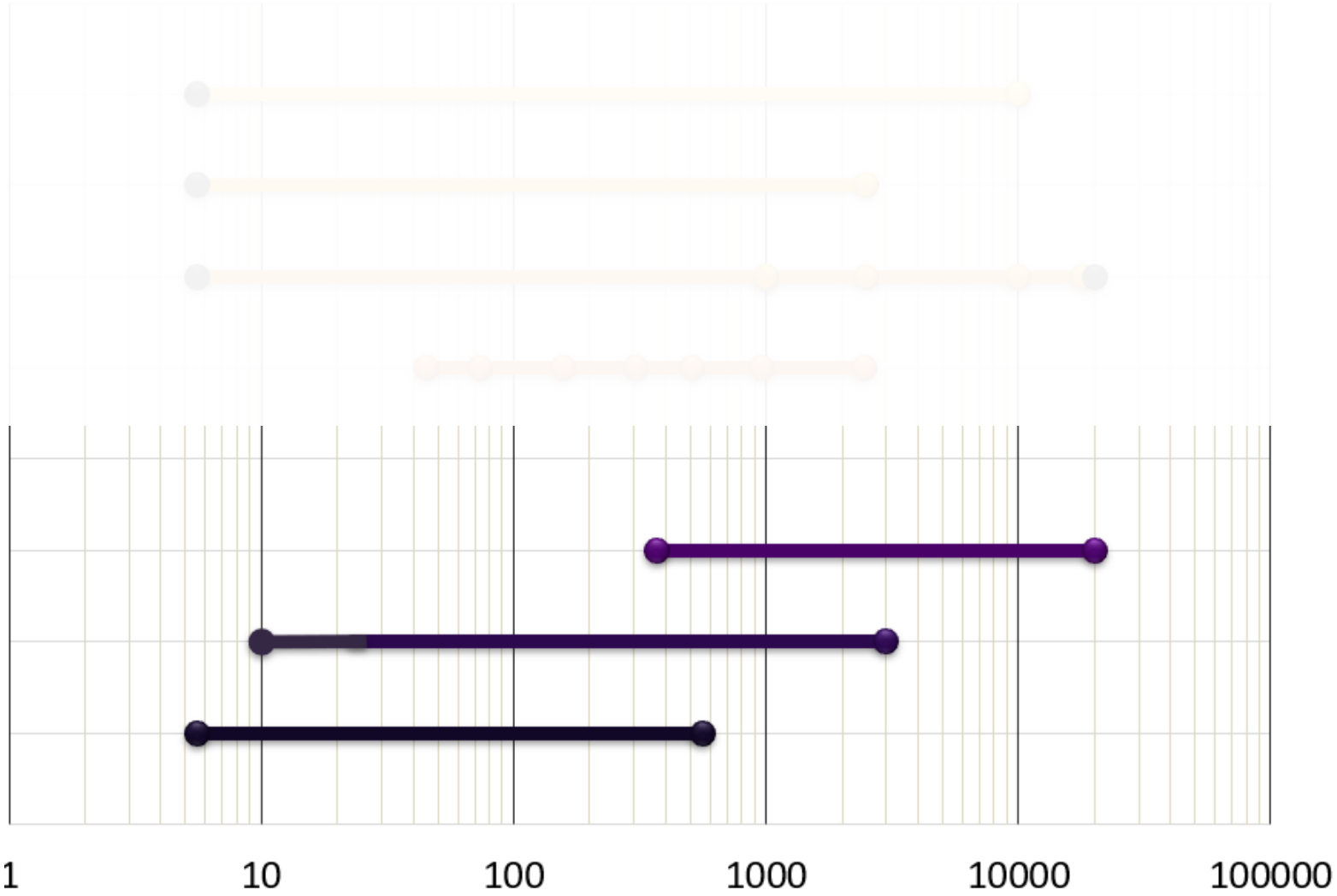
QCM – Quartz-crystal microbalance

Particle Count

APS – Aerodynamic Particle Spec.

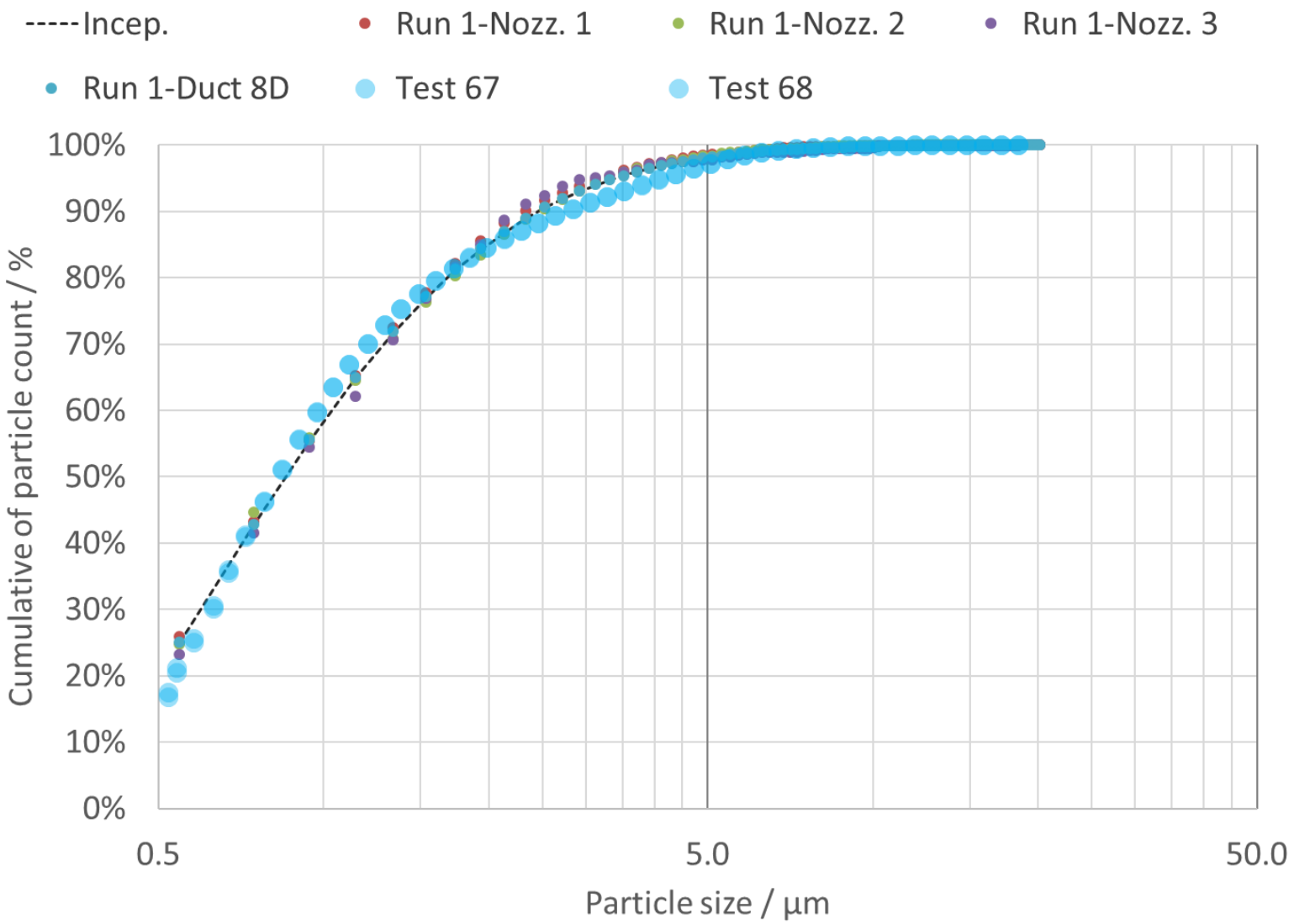
CPC – Condensation Particle Counter

EEPS – Engine Exhaust Particle Spec.



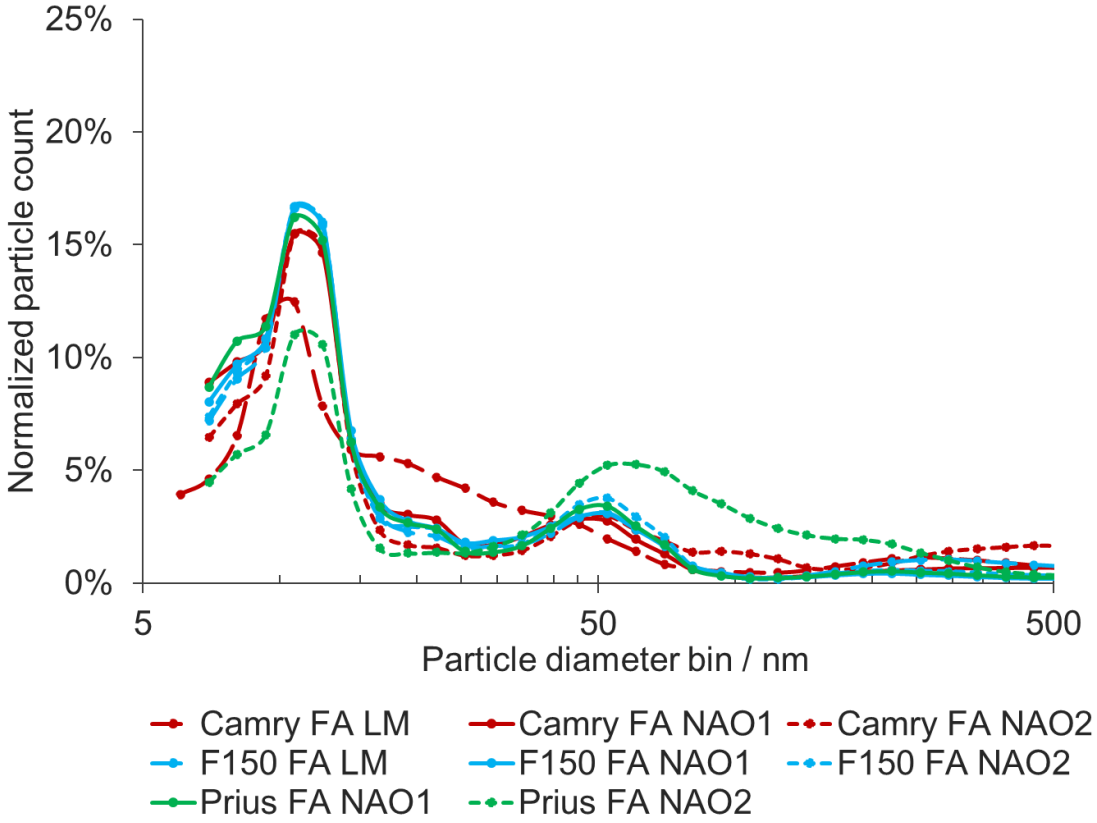
PN sampling along duct cross section

Cumulative PN is consistent among inception, sampling plane, and model v. actual

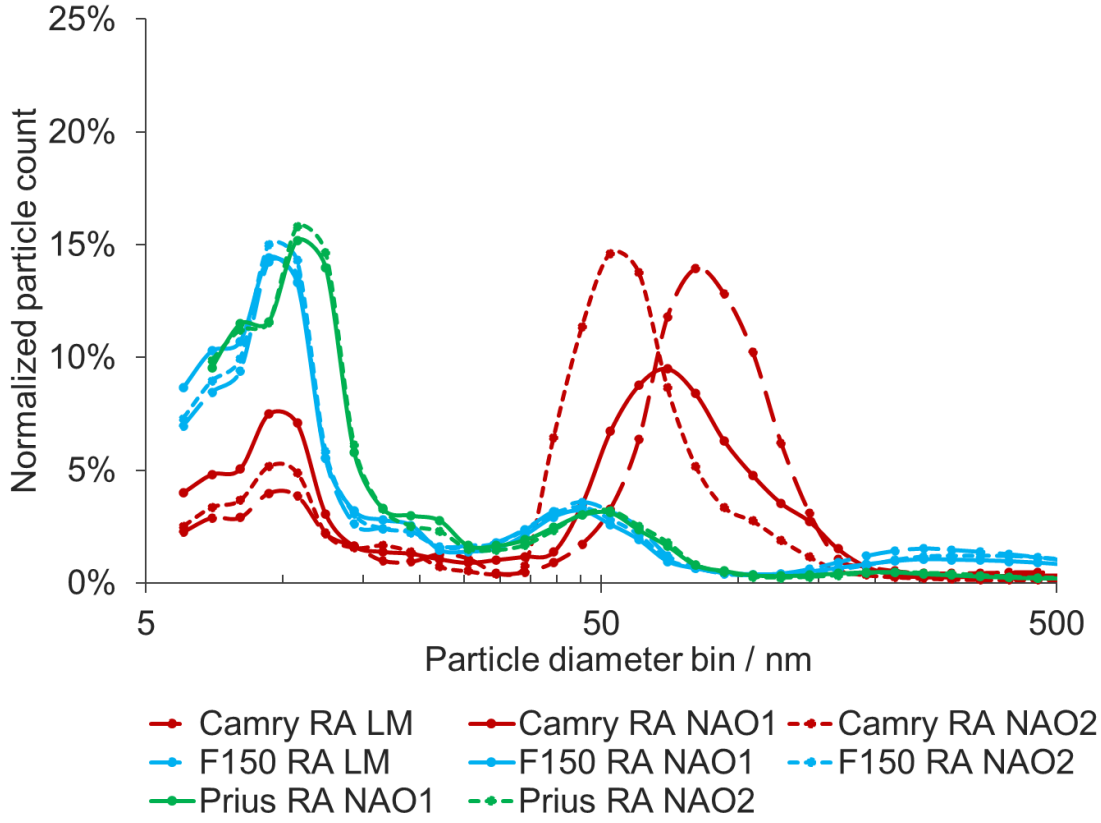


Particle size distribution 5 nm – 500 nm

All materials exhibited multimodal response, with significant differences among them



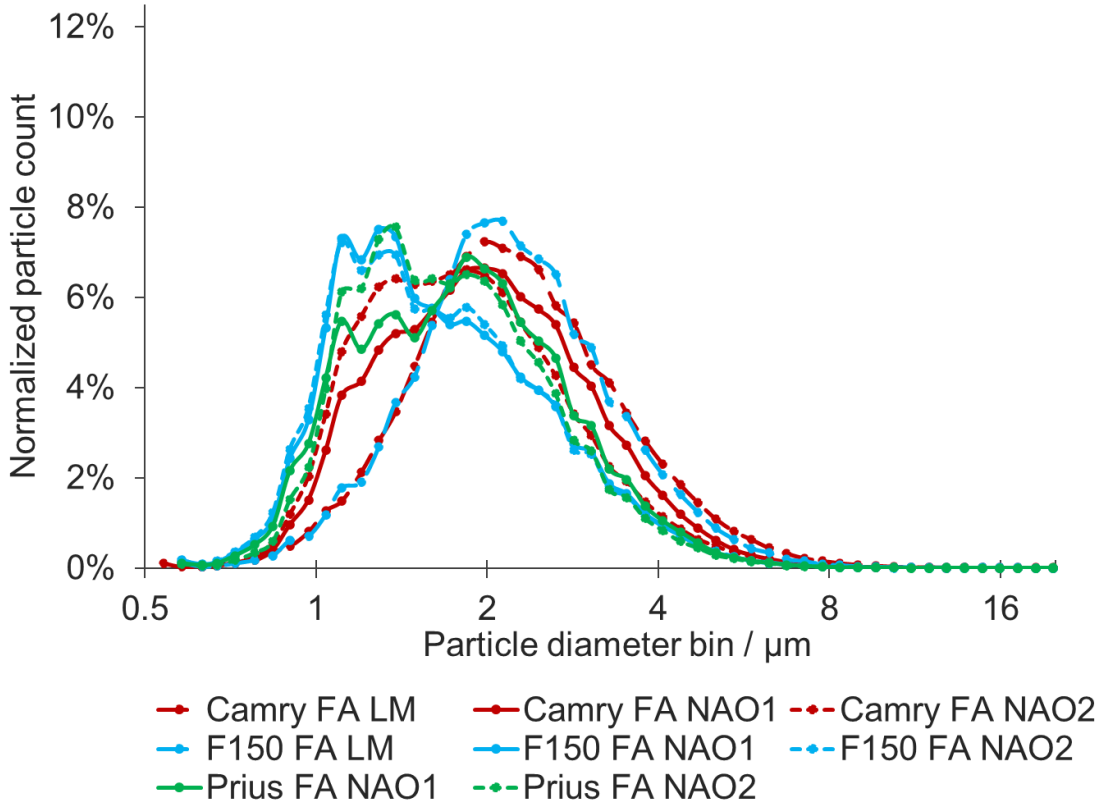
front



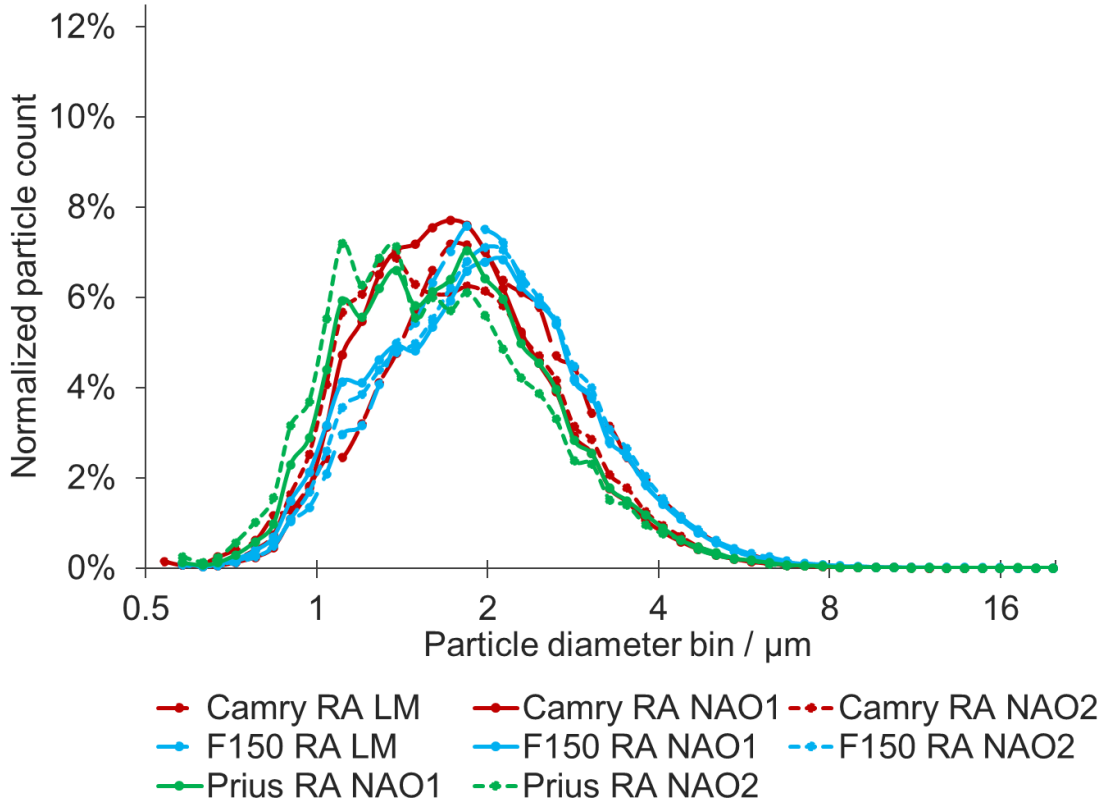
rear

Particle size distribution 500 nm – 18 µm

NAOs tend to give a bimodal response, while LM were predominantly unimodal



front



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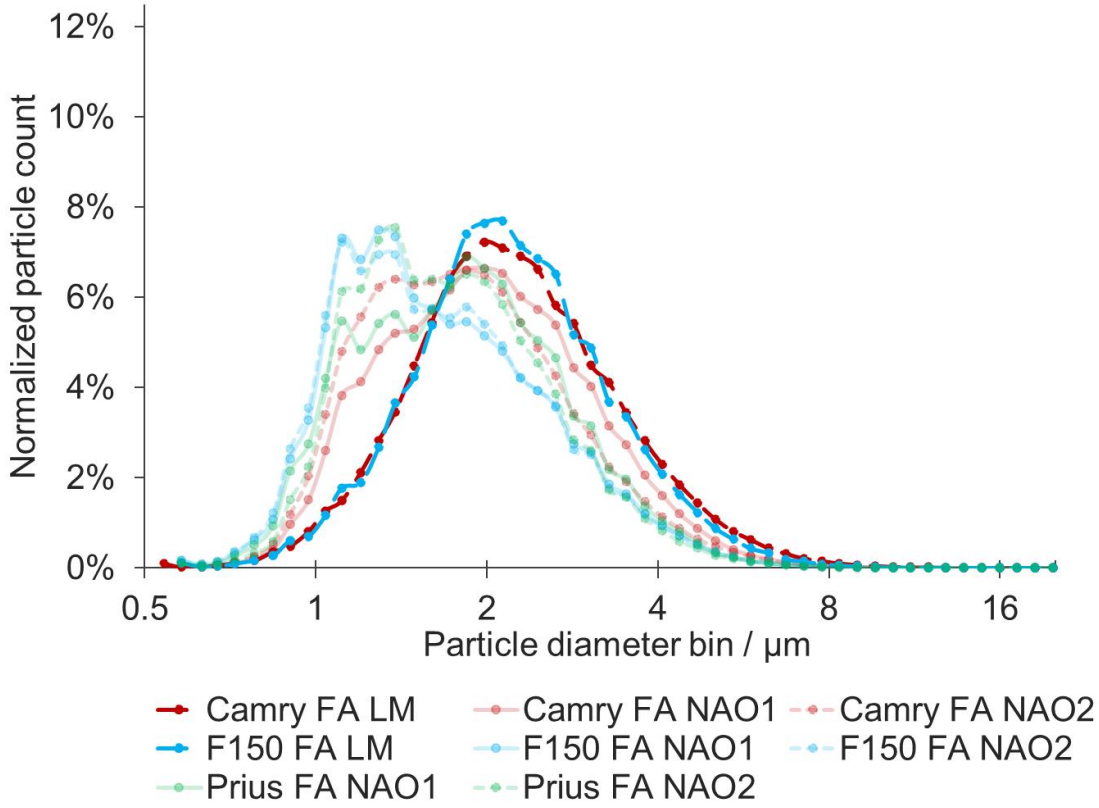
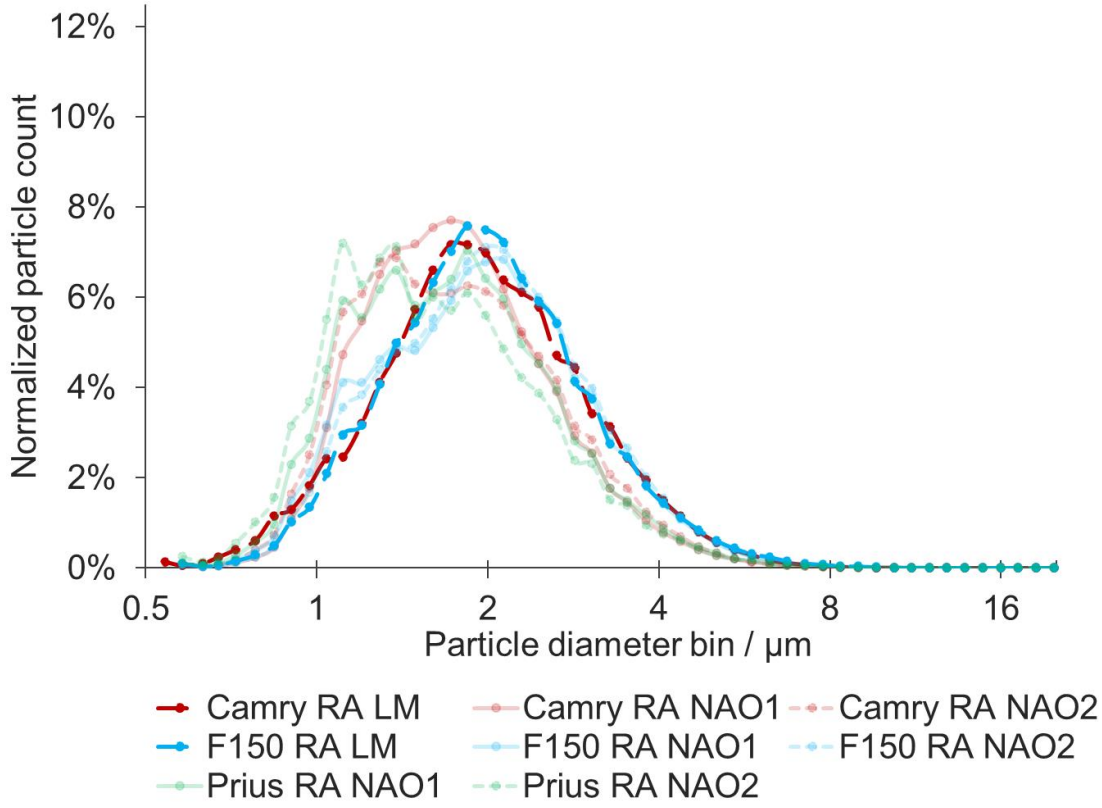


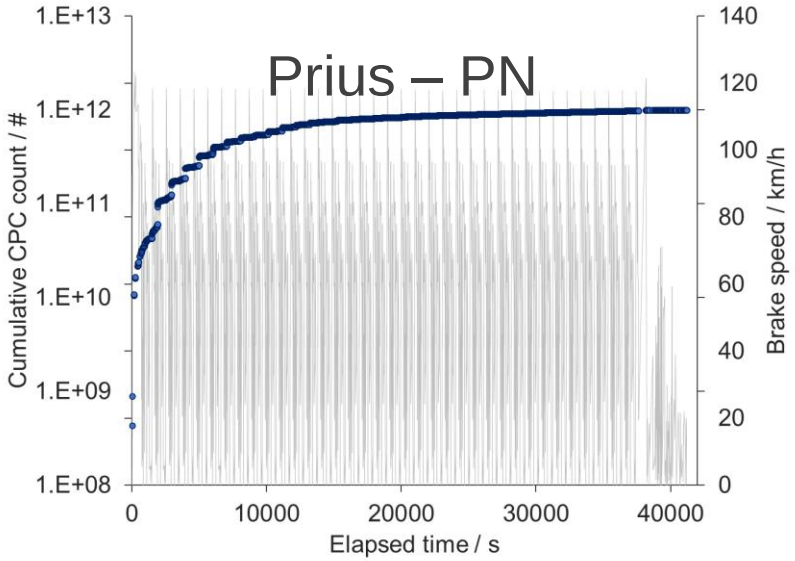
front

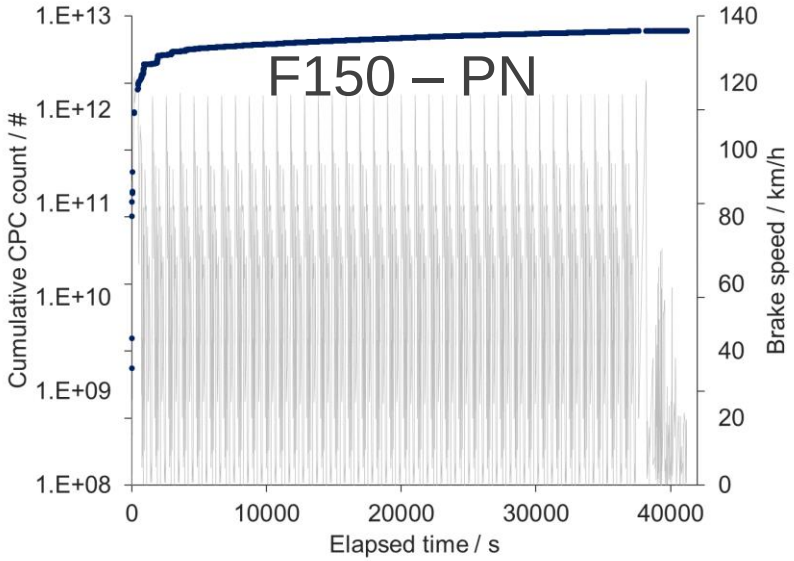


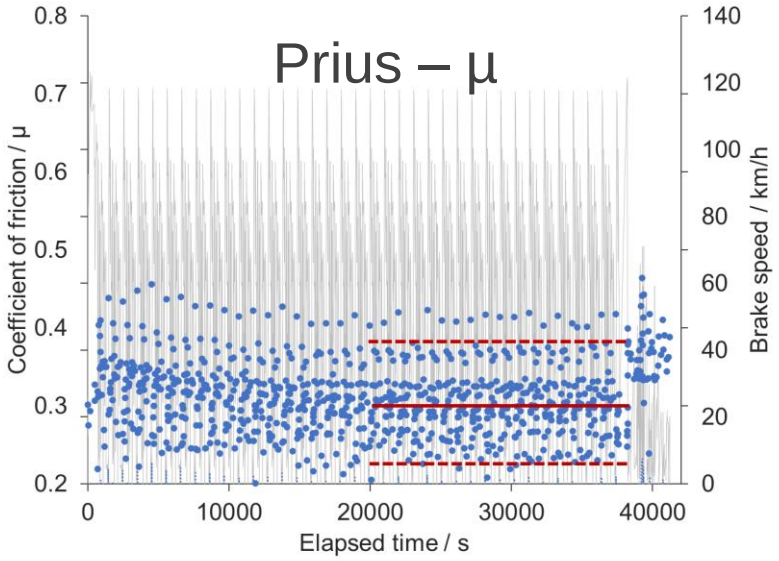
rear

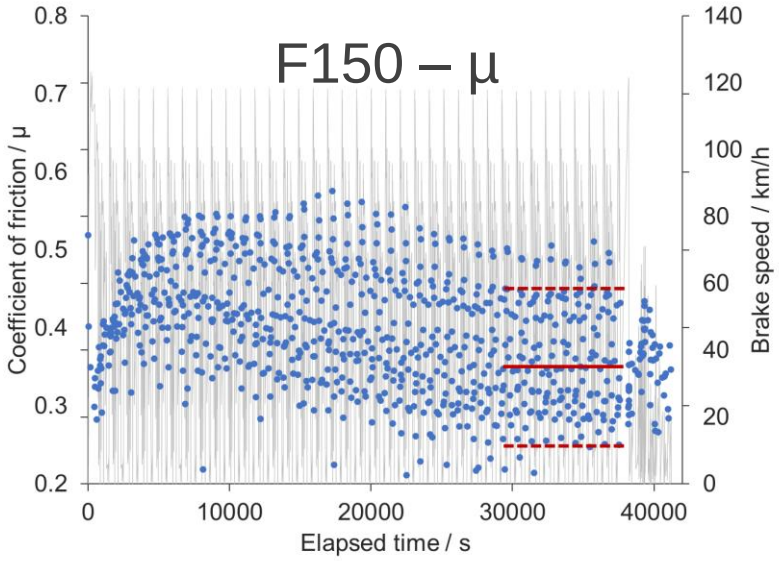
2-parameter burnish behavior – examples

Stable particle generation rates need a stable friction layer



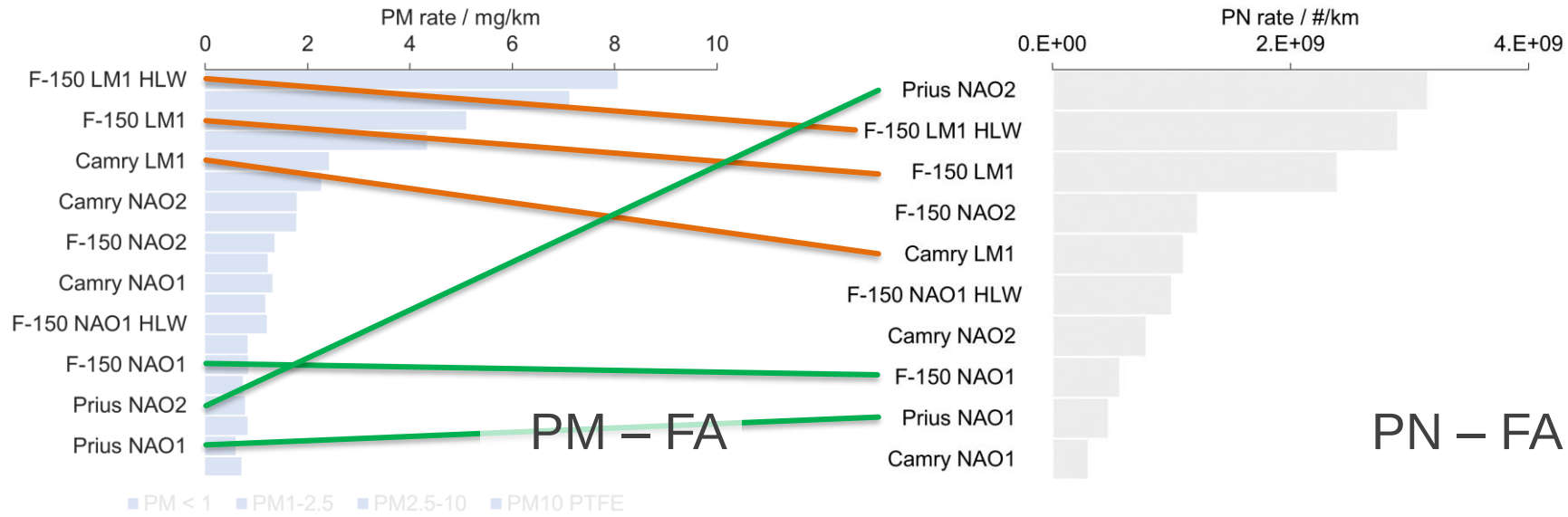


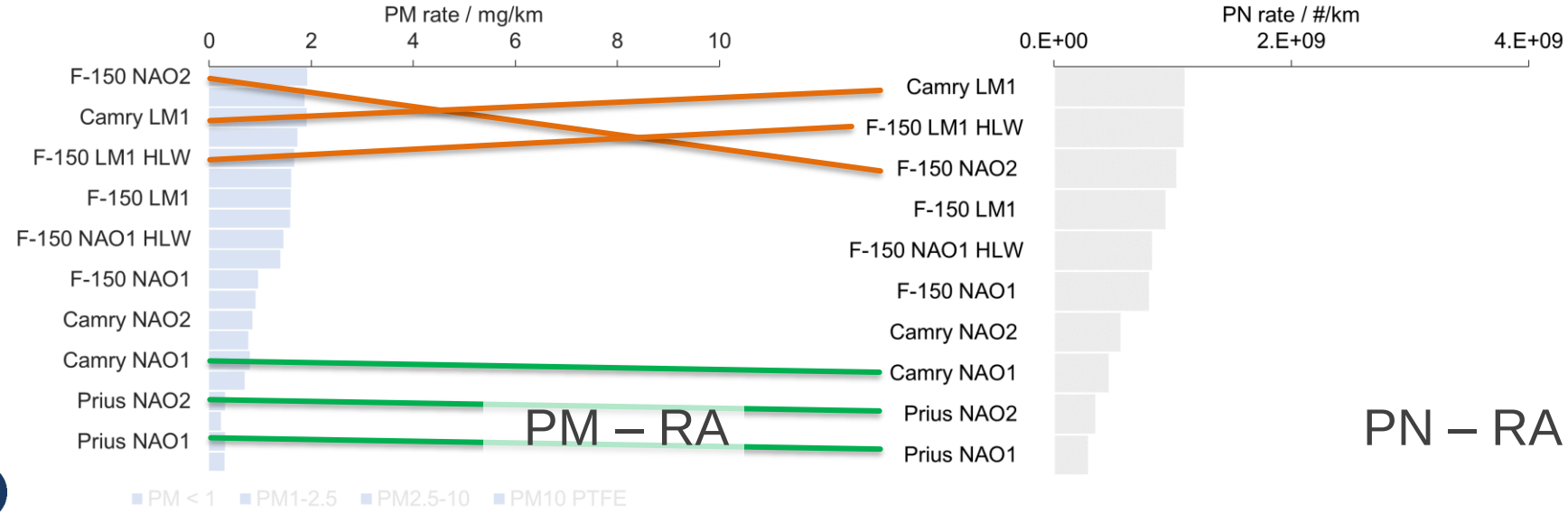




PM v. PN ranking by vehicle, axle, test mass and friction couple

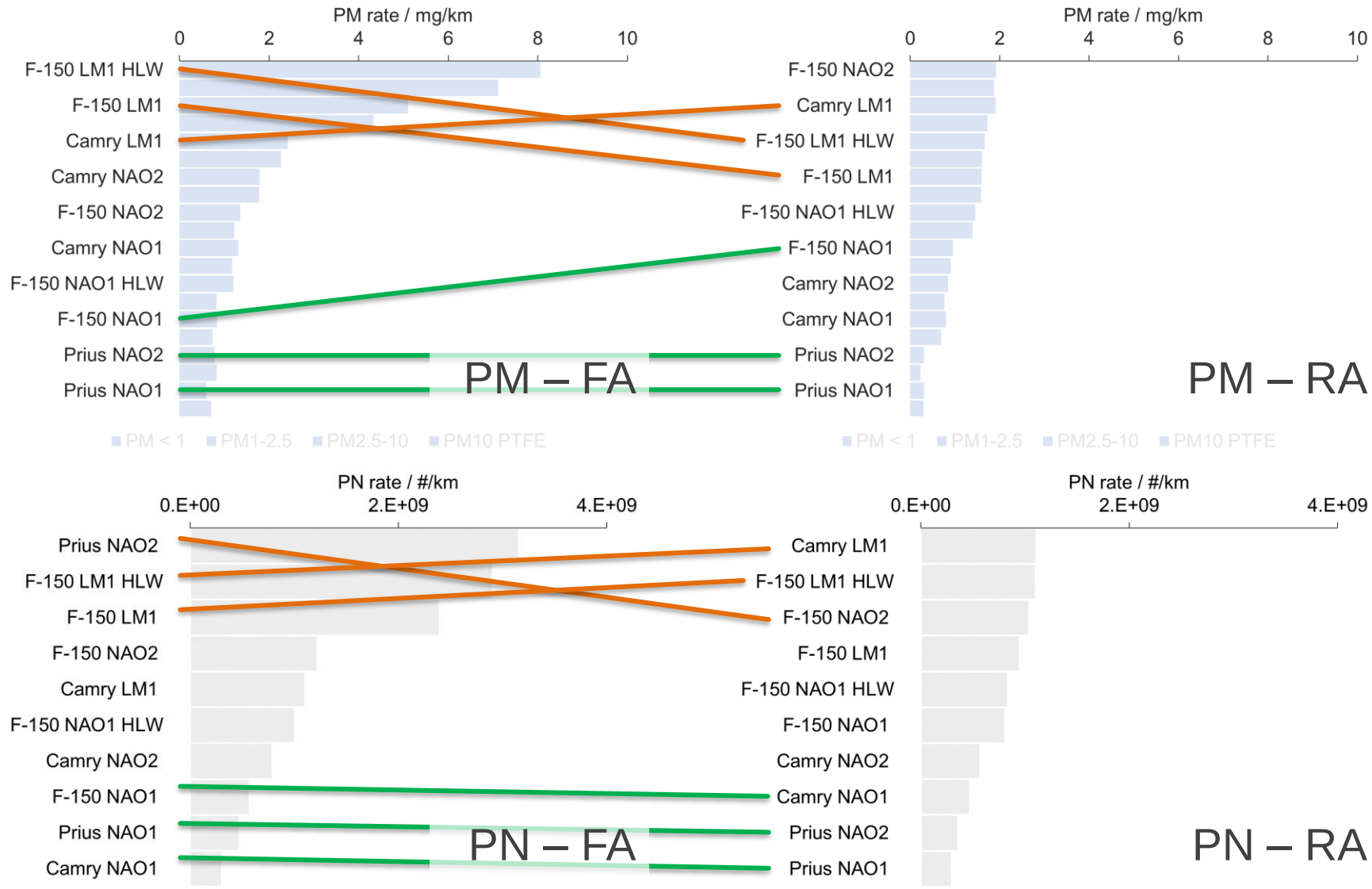
The translation and ranking from PM to PN is not a 1:1 relationship





front v. rear axle ranking by vehicle, test mass and friction couple

the axle position can make a difference when ranking front v. rear brakes



PN Recommendations

- Total PN seems more relevant for brake emissions as implemented during projects with US EPA, CARB, Caltrans, and several OEMs
- CPC PN is recommended along with brake effectiveness to evaluate friction stabilization during bedding procedure
- No bends or gradual bends are suggested in the sampling train, especially for particles larger than 1 micron. No specific bend limits assigned for smaller particles (e.g. EEPS)
- Flowsplitter with a flow transition angle of less than 20 degrees is allowed
- Sampling plane located 8D-length downstream of the enclosure exit resulted in uniform particle-air mixture

- More data is invited from eligible groups to assess the necessity of measuring solid PN separately for brake emissions

THANK YOU

OEMs

Tier 1 & 2