

# CPC CALIBRATION MATERIAL INTER-LABORATORY COMPARISON.

R&D Powertrain | 2017-06-22

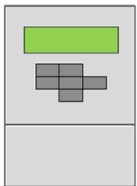


# MOTIVATION.



**Harmonized calibration material** in automotive applications for:

- CPC (Condensation Particle Counter).
- VPR (volatile particle remover).
- PN-PEMS.



Device under test:  
PMP compliant CPC  $D_{50} = 23\text{nm}$ .  
For engine exhaust measurements.



– **Material influence** on CPC calibration.



– Variation of calibration among 7 laboratories.



– Variation among 7 in-house reference devices and setups.



Aerosol generators:

- APG miniCAST (circulated)
- miniCAST
- Palas DNP
- Silver
- Emery Oil

# PARTICIPANTS.

Time	Laboratory	Type
2/16	TSI Germany	Instrument Manufacturer
3/16	JRC	Research Institute
4/16	AVL Austria	Instrument Manufacturer
6/16	PTB	National Metrological Institute
7/16	BMW	Vehicle Manufacturer
9/16	Ricardo E&E	Calibration Service
11/16	VW	Vehicle Manufacturer
12/16	TSI Germany	Instrument Manufacturer

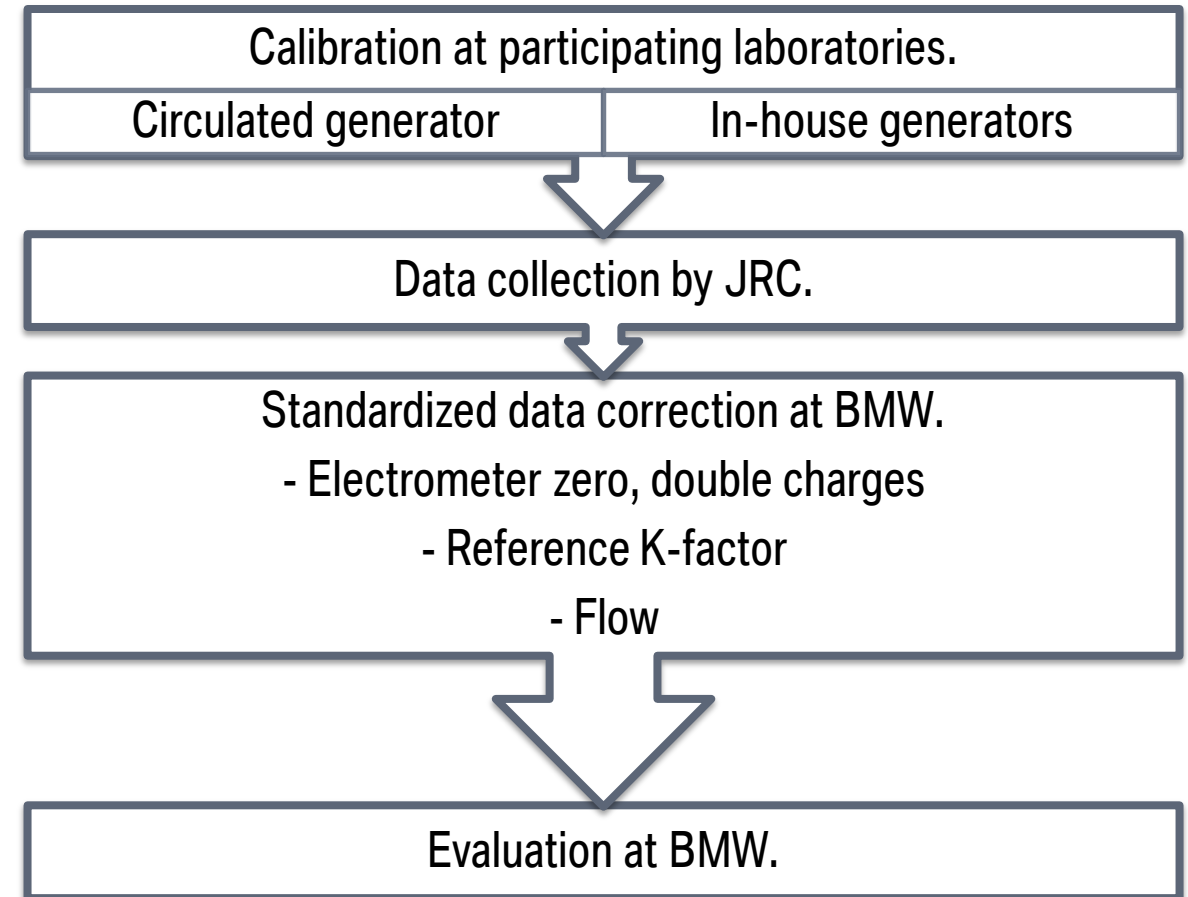


## PROCEDURE.

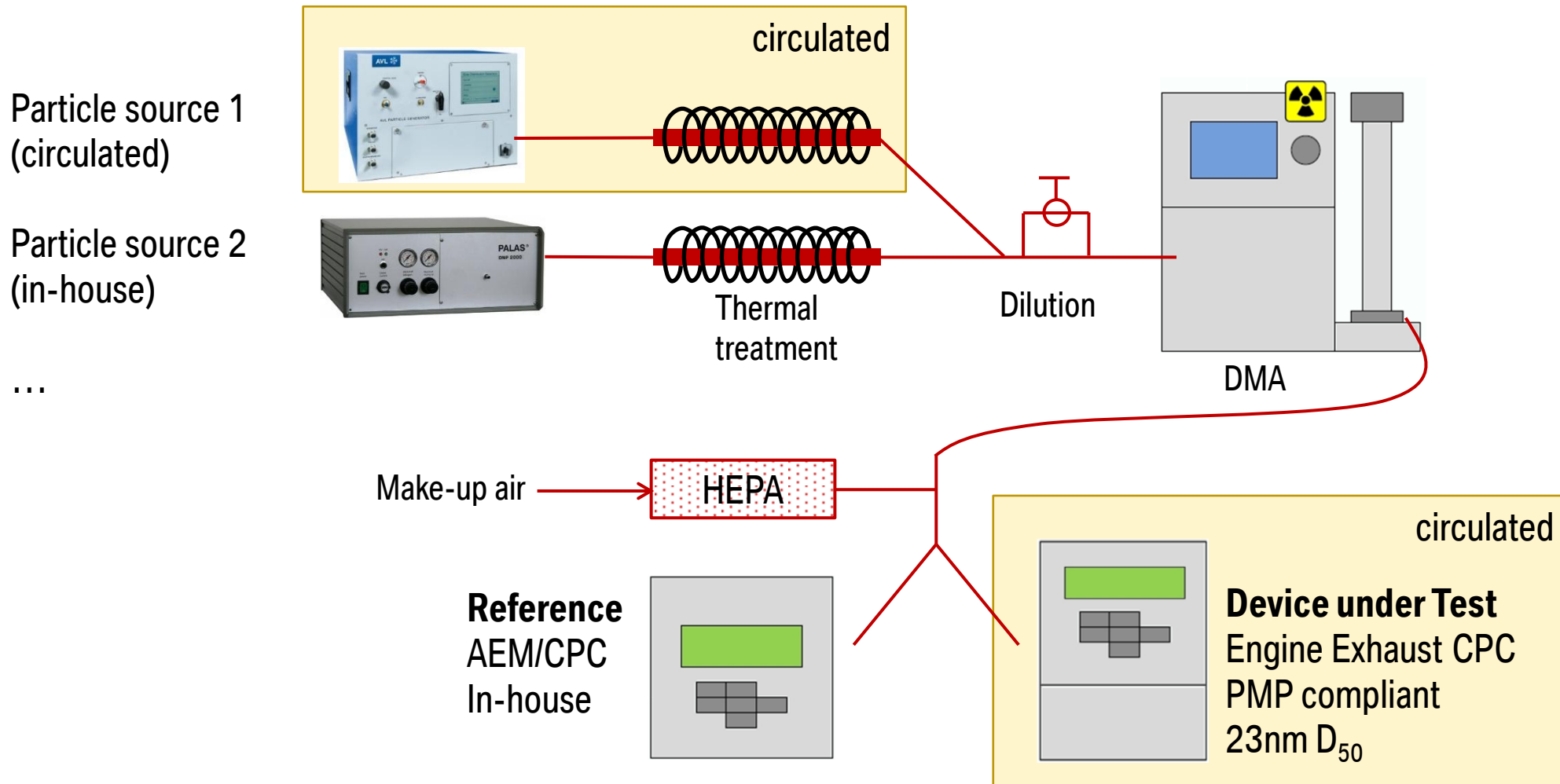
## Circulated instruments.

- 1 aerosol generator **propane flame**.  
APG (miniCAST + thermal treatment)
- 1 reference CPC  **$D_{50} = 10\text{nm}$** .  
~~TSI 3792E~~
- 2 engine exhaust CPC  **$D_{50} = 23\text{nm}$** .  
TSI 3791  
AVL CPC (pre-production)

## Data Handling.



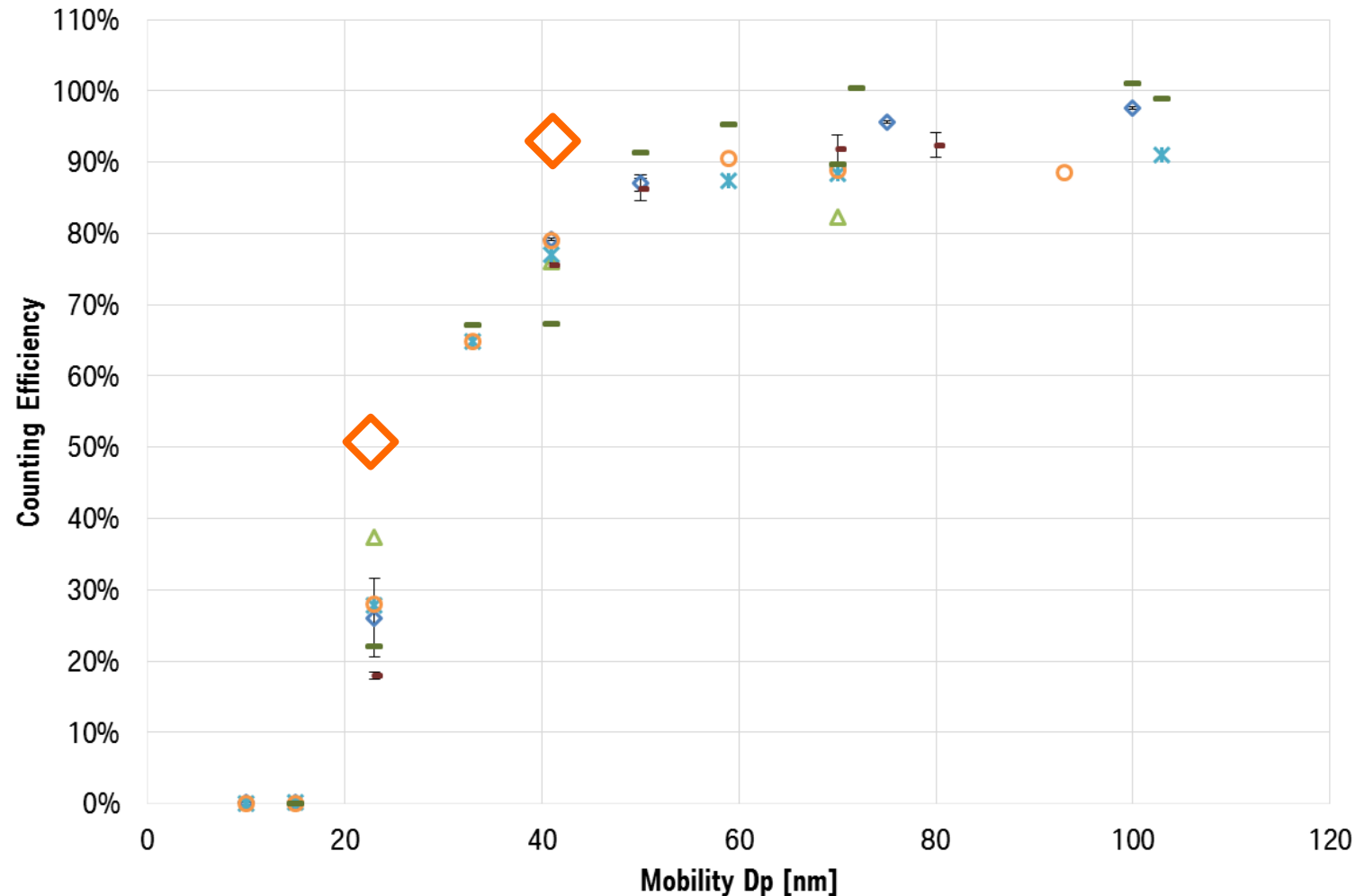
# CALIBRATION SETUP.



Note: not all labs use an ISO 27891 compliant setup (2-way splitter).

# ENGINE EXHAUST CPC CALIBRATION: RAW DATA.

## Calibration Curve: APG generator, Reference 23nm CPC, all laboratories.



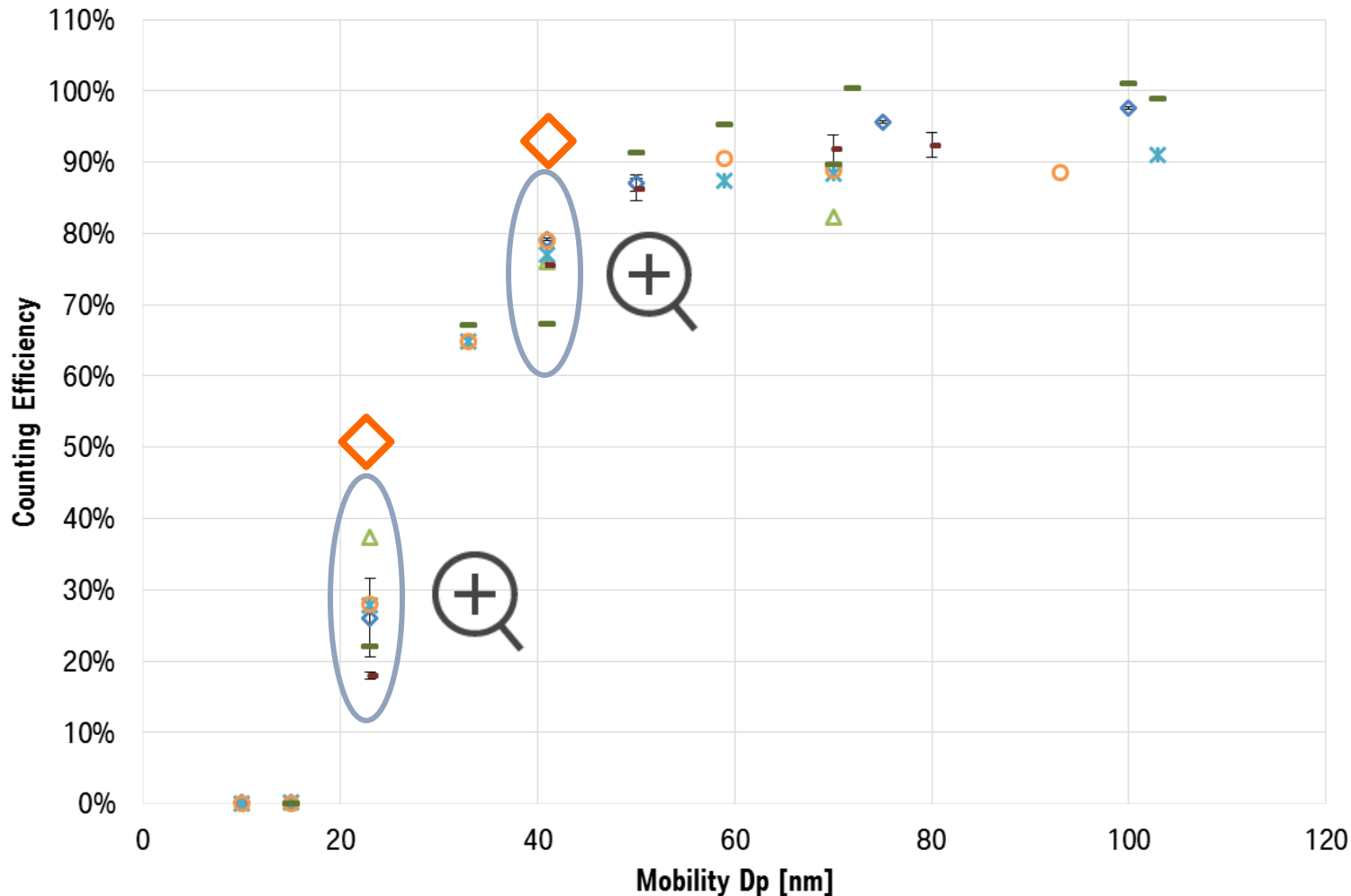
- Error bar: multiple measurements from one lab.

- Standardized correction applied.

 Calibration certificate value

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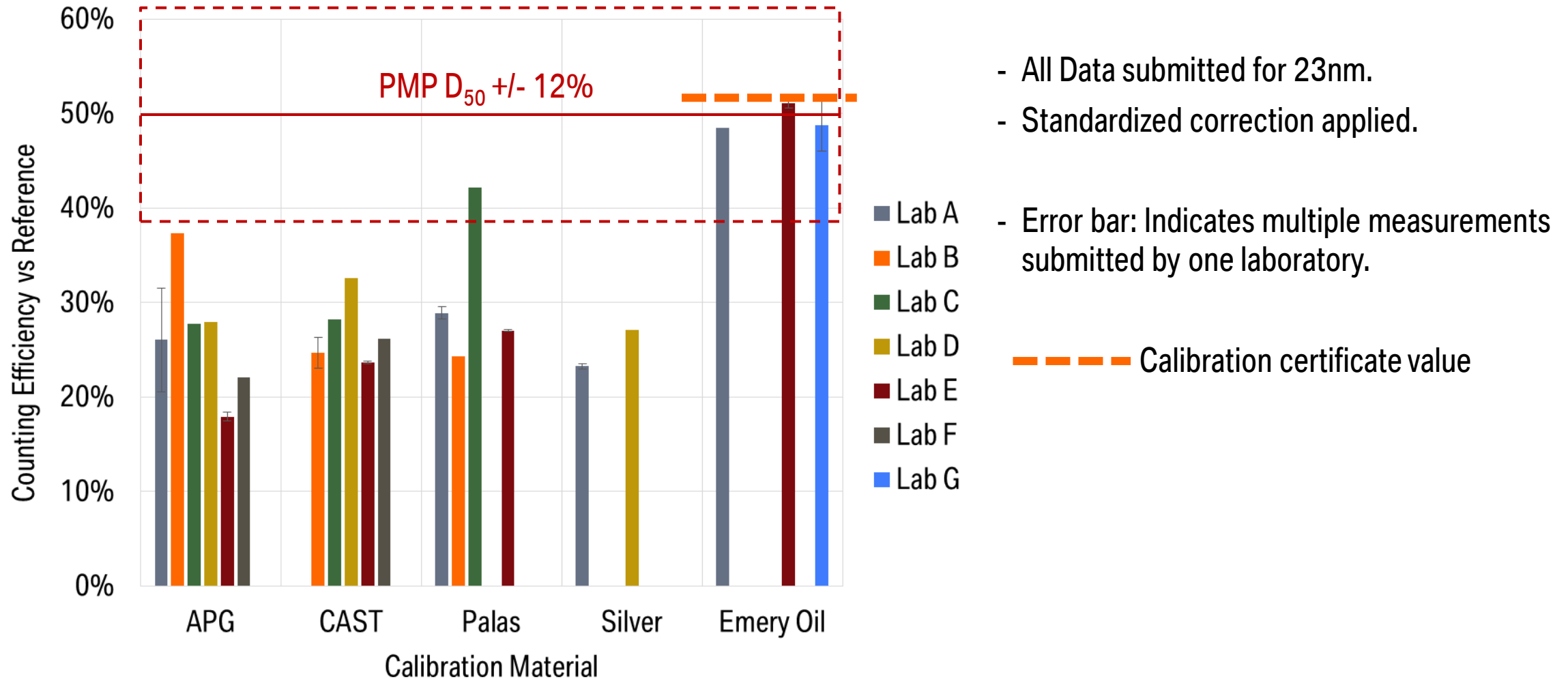
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◇ Calibration certificate value

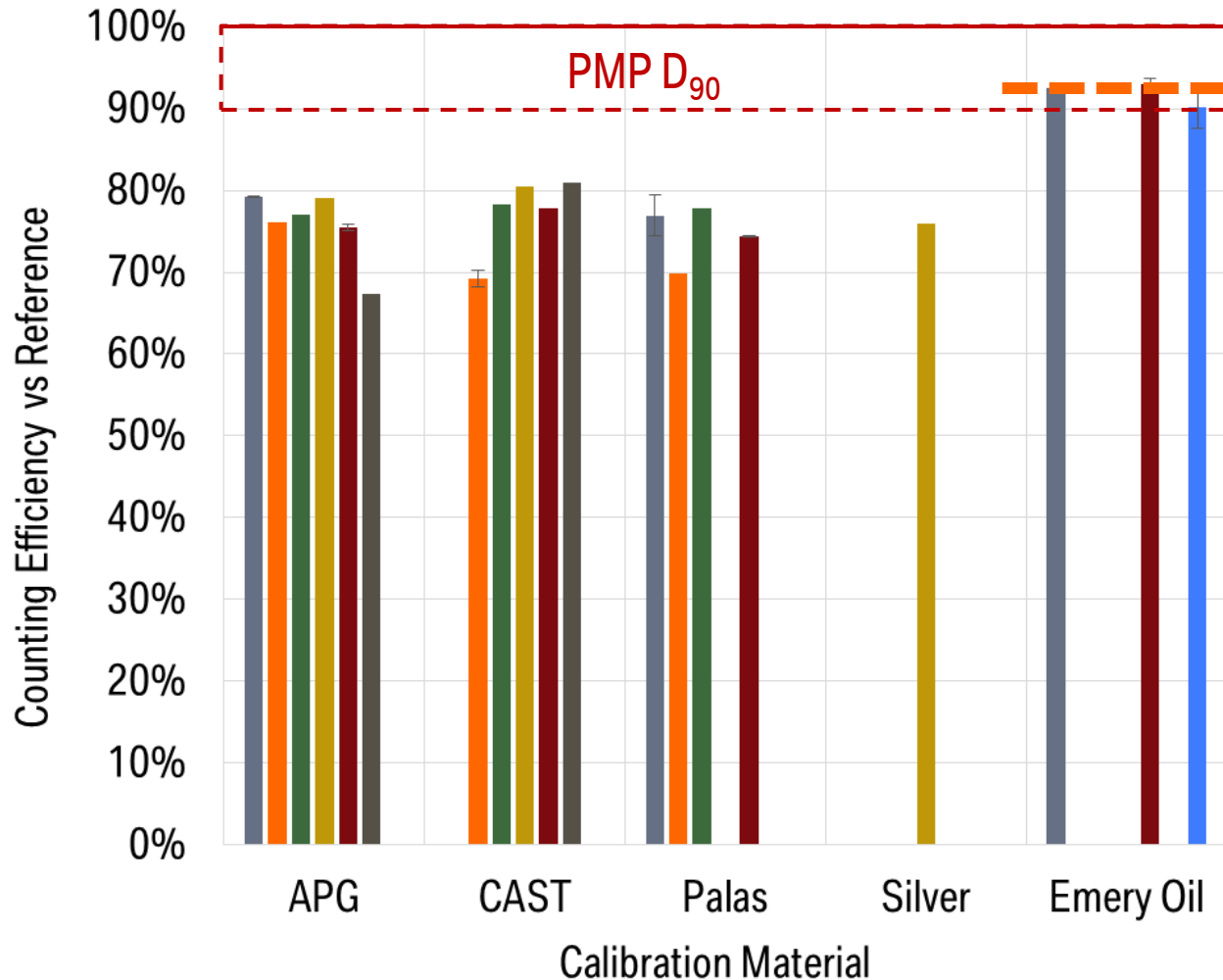
# ENGINE EXHAUST CPC CALIBRATION: MATERIAL.

All data at 23nm.



# ENGINE EXHAUST CPC CALIBRATION: MATERIAL.

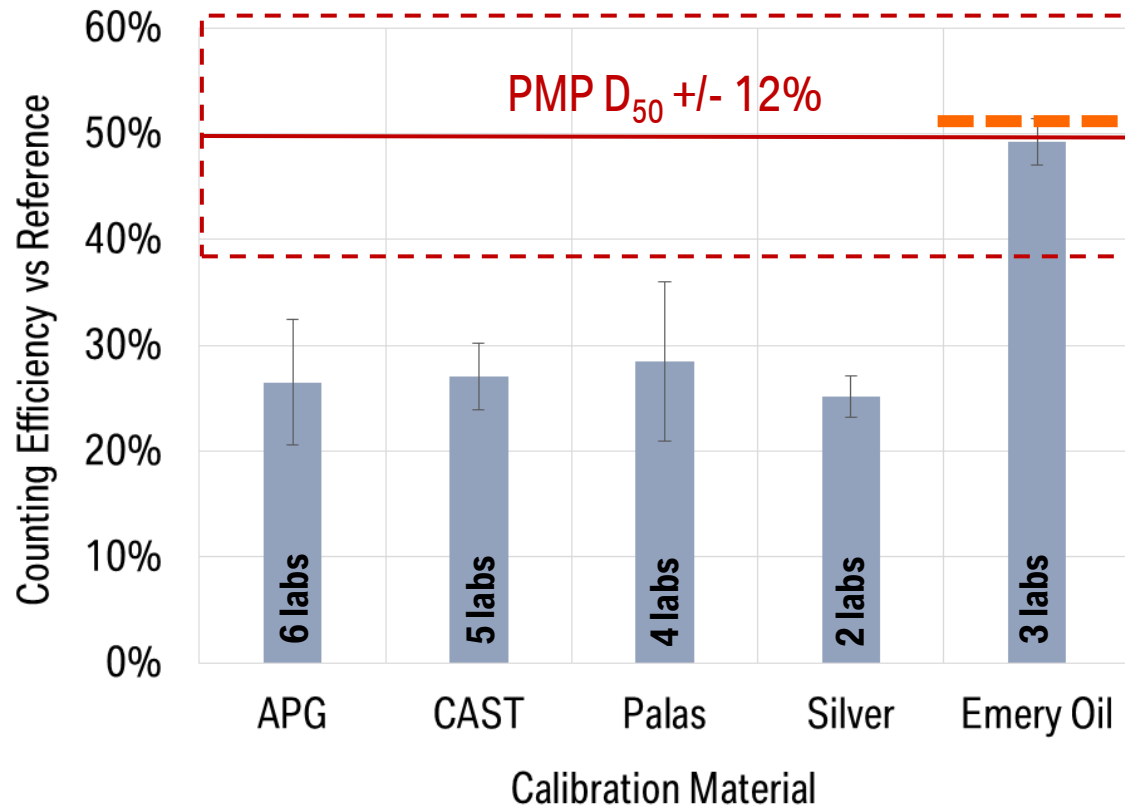
All data at 41nm.



- All Data submitted for 41nm.
- Standardized correction applied.
- Error bar: Indicates multiple measurements submitted by one laboratory.
- Calibration certificate value

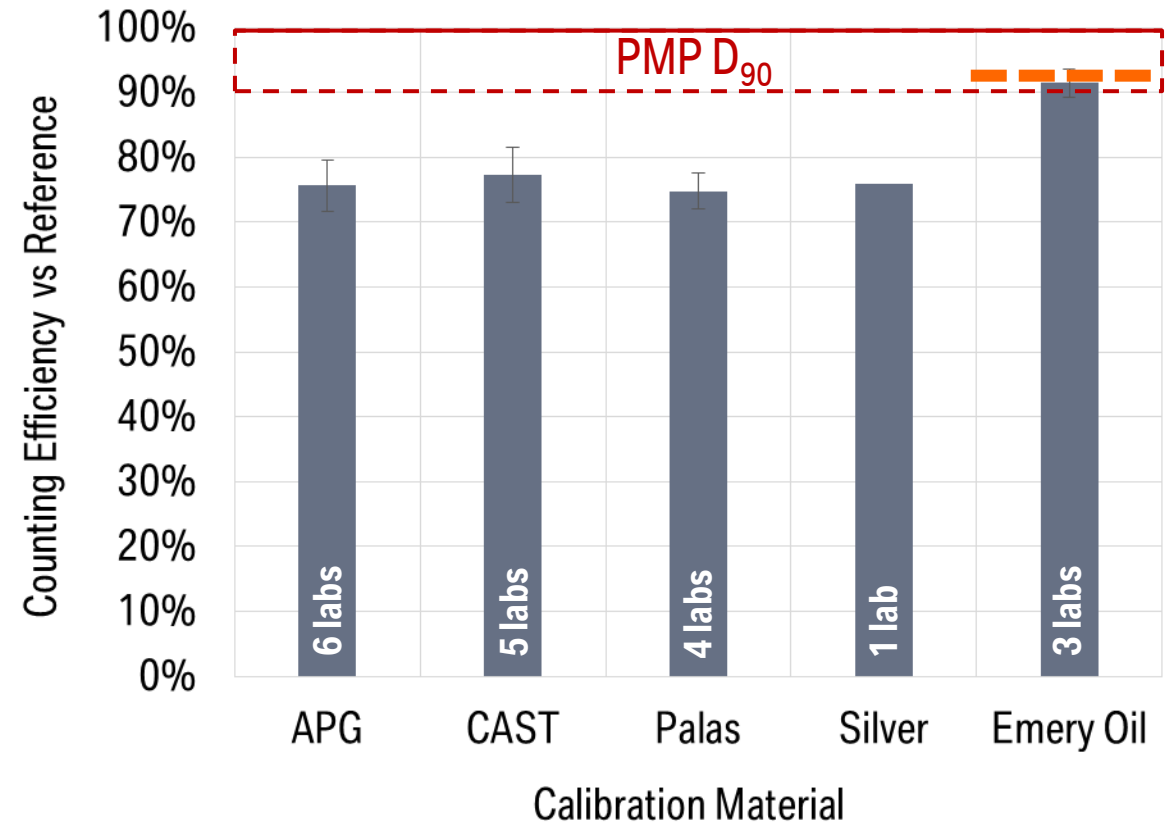
# ENGINE EXHAUST CPC CALIBRATION: MATERIAL.

## Average data at 23nm.



- Soot-like aerosols APG, CAST, Palas very similar.
- Emery Oil shows significant difference.

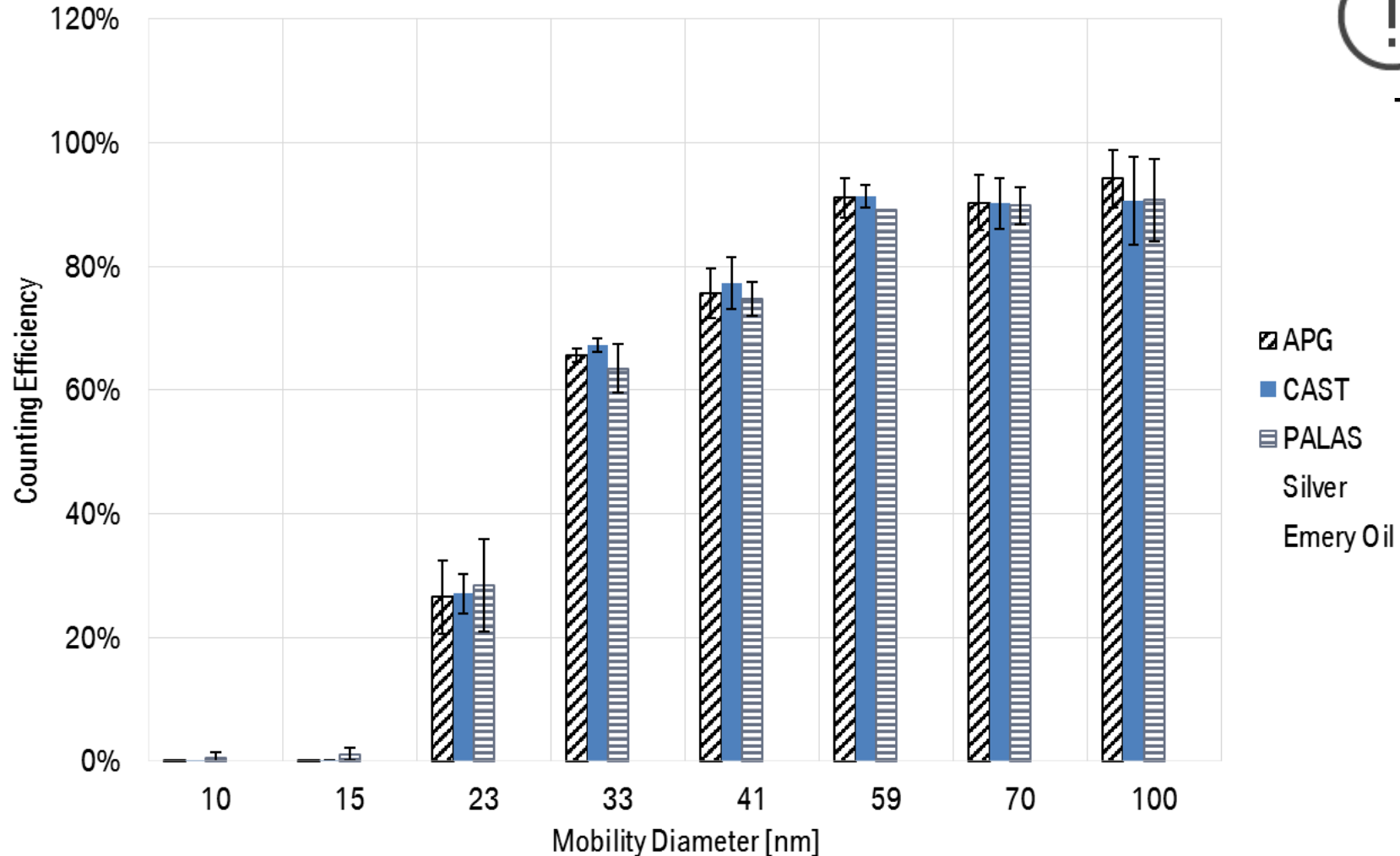
## Average data at 41nm.



- Smaller difference between soot-like and emery oil.
- Smaller standard deviation as for 23nm.

# ENGINE EXHAUST CPC CALIBRATION: MATERIAL.

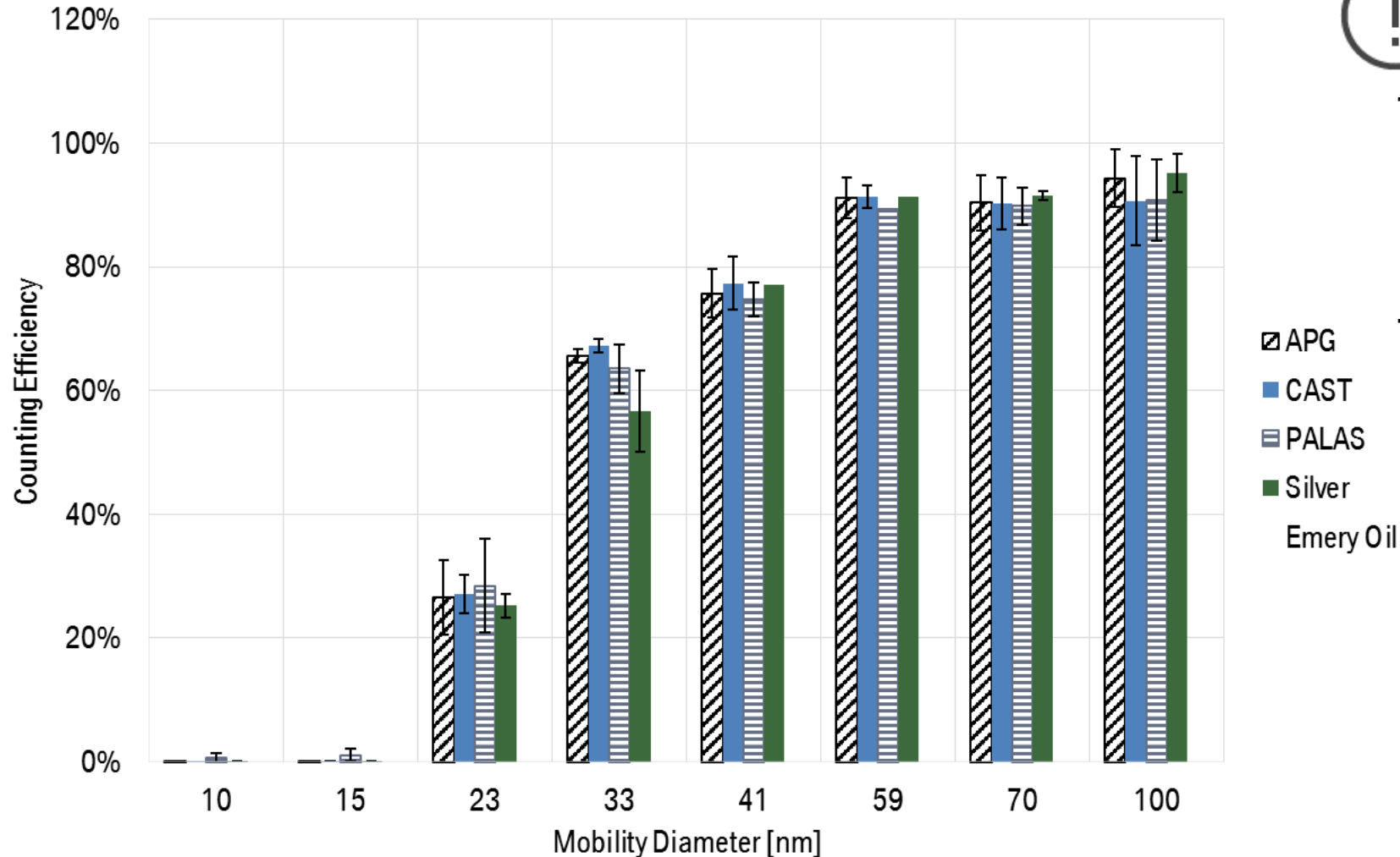
## Calibration Curve: Material Comparison.



- In-house CAST: Small error bars even for 5 different devices and setups. Advantage of a well-known setup.

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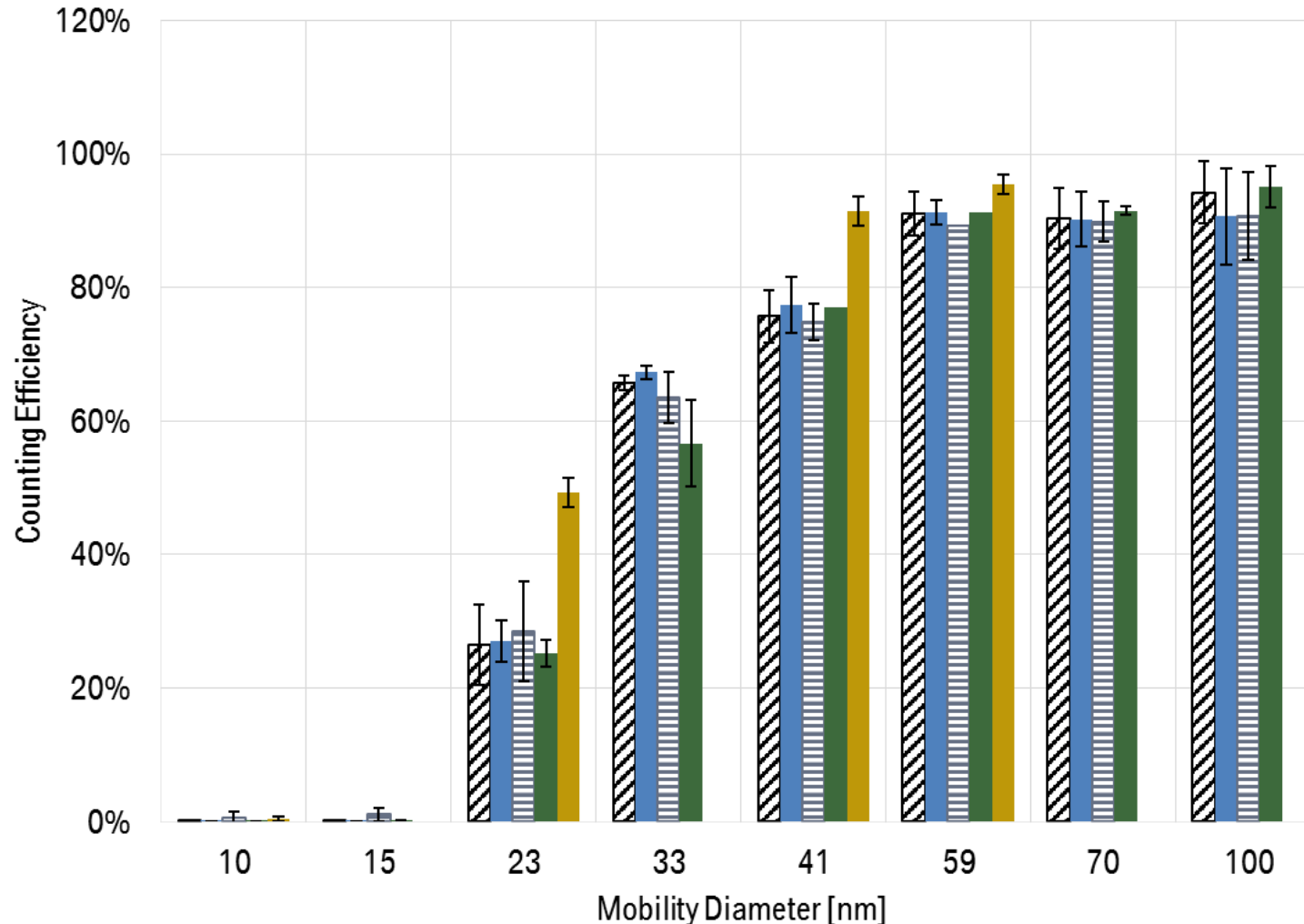
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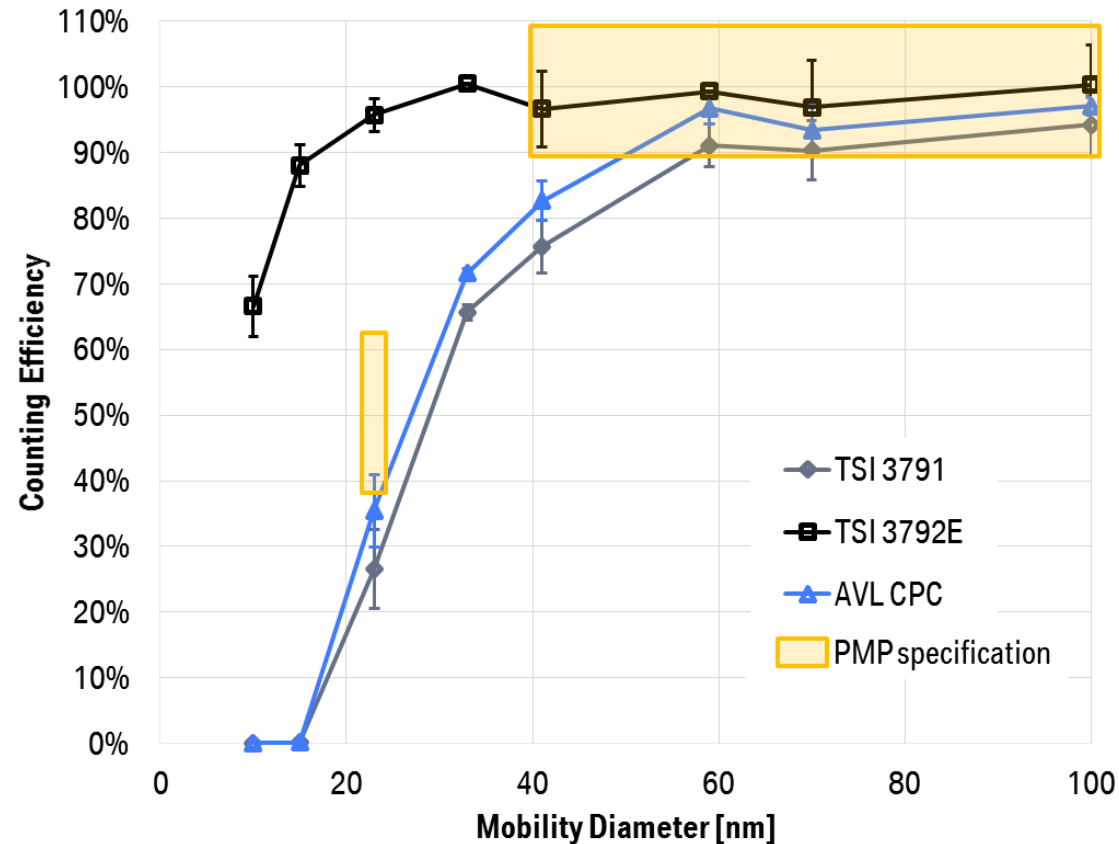
## Calibration Curve: Material Comparison.



- In-house CAST: Small error bars even for 5 different devices and setups. Advantage of a well-known setup.
- Silver efficiency curve shows good correlation with soot.
- Emery Oil has much steeper cut-off.
- Small error bars for silver/emery oil: (!) low number of labs.

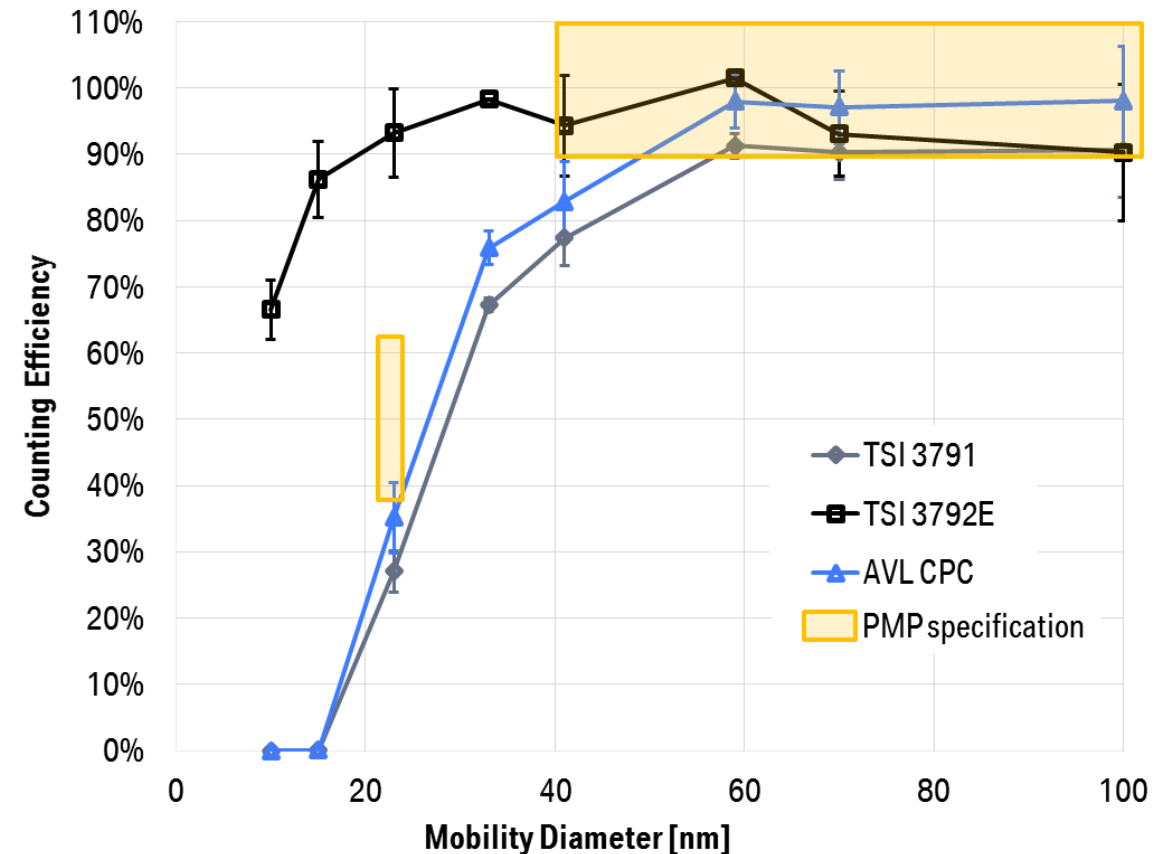
# LESSONS LEARNED: CPC COMPARISON.

## Circulated APG miniCAST.



- Only Electrometer and sub-10nm CPC as reference for 3792E.
- **Instabilities:** larger error bars for 3792E.

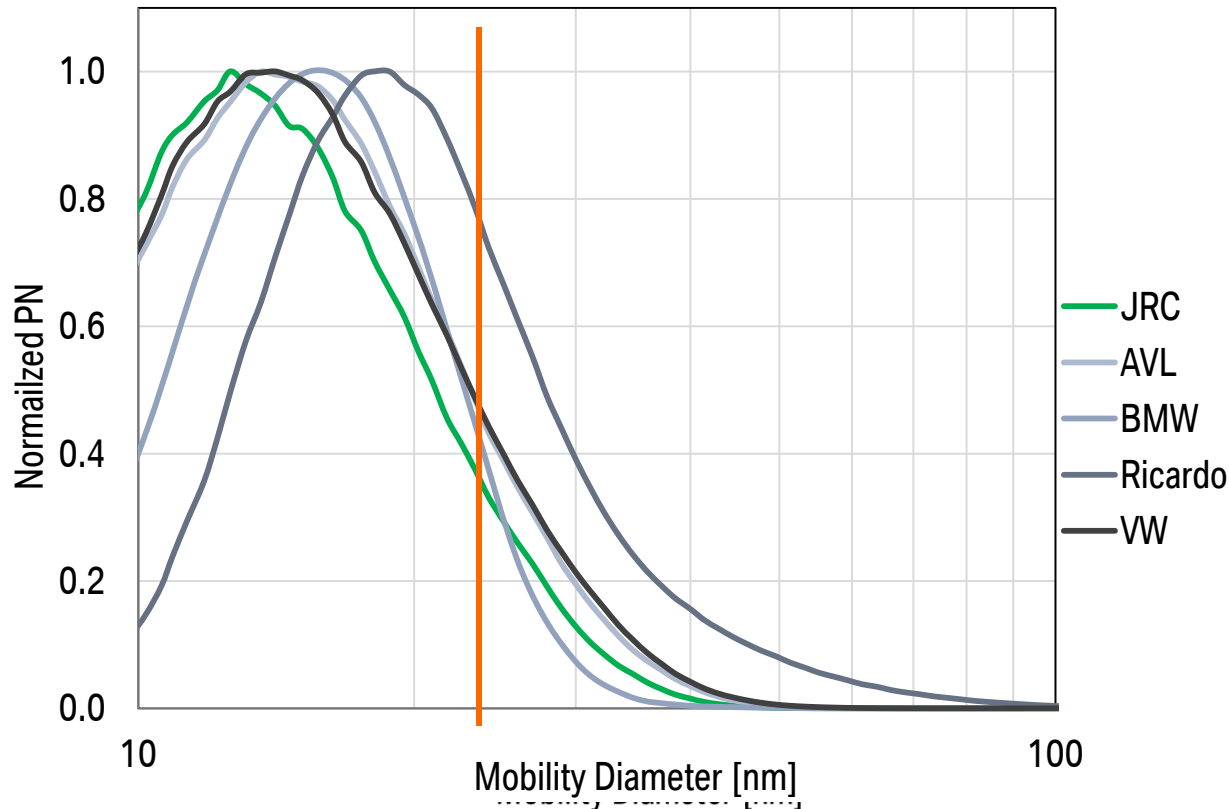
## In-house miniCAST.



- Similar performance of TSI and AVL engine exhaust CPC.

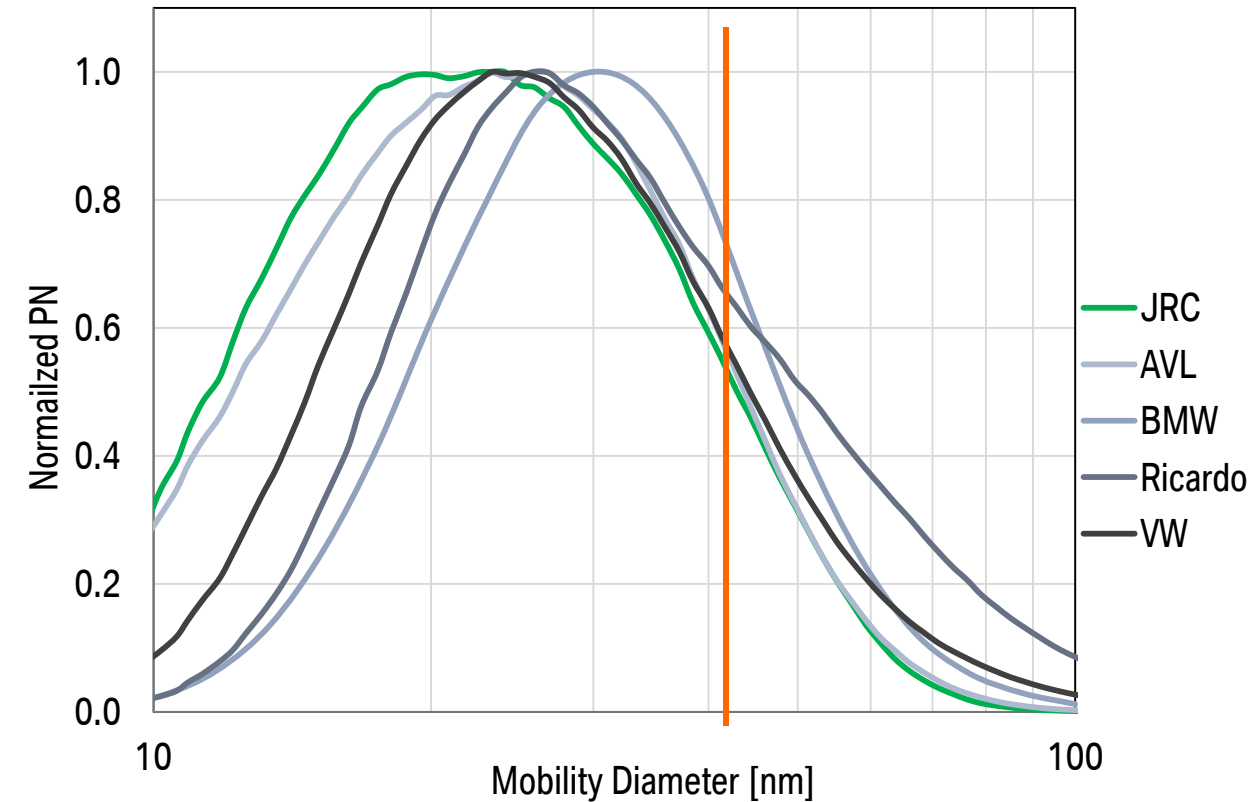
# LESSONS LEARNED: GENERATOR SIZE DRIFT.

APG generator operating point “B” for 23nm.




- Mode range: 13nm – 18.1nm.
- **Contamination:** generator cleaned at VW (after Ricardo).

APG generator operating point “C” for 41nm.




- Mode range: 21nm – 30.4nm.

# CONCLUSION.

- **Comprehensive comparison** of aerosol sources and setups.
- Soot identified as candidate aerosol for **harmonization of calibration in automotive exhaust applications**. 
- Good correlation of in-house soot generators **in spite of different burners and aerosol after-treatment**.
- Significant differences between emery oil and soot-like at small particle sizes (important for automotive testing).

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## Open questions:

- What is the **quantitative uncertainty** of soot calibration?
- What is the **influence of the laboratory setup**?



**PMP Sub-Group**  
**“PNC Calibration” led by PTB**  
**2<sup>nd</sup> stage of the Comparison Exercise**

# ACKNOWLEDGEMENTS.



**Thank you to all the participants of the Round Robin for their effort, advice and support.**

JRC: Barouch Giechaskiel  
PTB: Volker Ebert, Andreas Nowak, Johannes Rosahl  
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VW: Sebastian Usarek, Manuel Kaatz  
TSI: Hans-Georg Horn  
BMW: Heinz Bacher

**And many other contributors!**