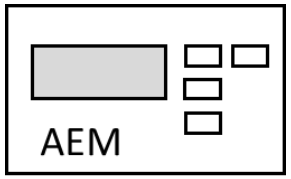
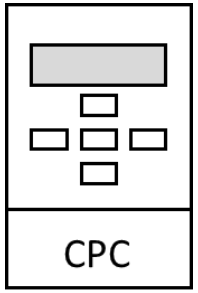
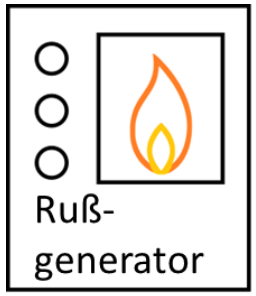
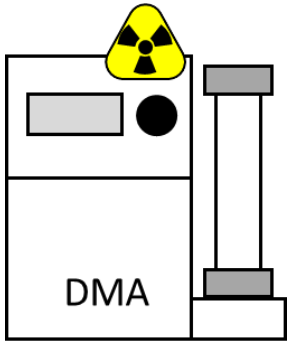
System calibration for exhaust PN counters

51st PMP Meeting
2019-10-29
Alexander Terres

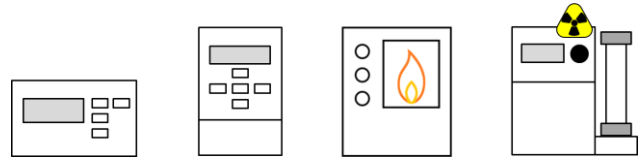


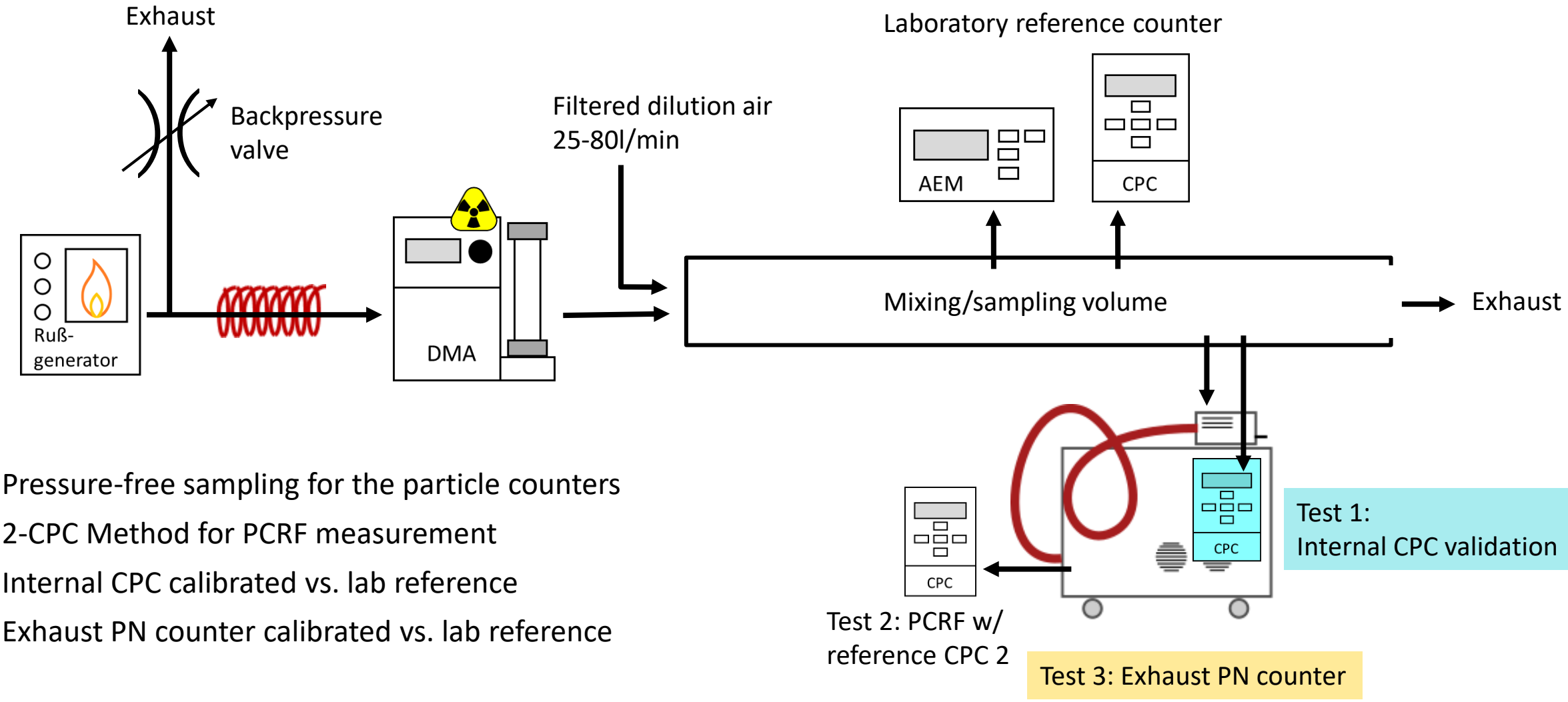






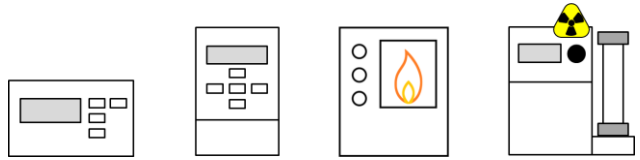
CALIBRATION SETUP





- Pressure-free sampling for the particle counters
- 2-CPC Method for PCRF measurement
- Internal CPC calibrated vs. lab reference
- Exhaust PN counter calibrated vs. lab reference

CALIBRATION SETUP



System calibration

– Newly serviced exhaust PN counter

– Particle generator: Palas DNP 3000 digital

– Comparison reference counter: TSI CPC 3772 (10nm)

– 2 runs each with 2 exhaust particle counters

Evaluation:

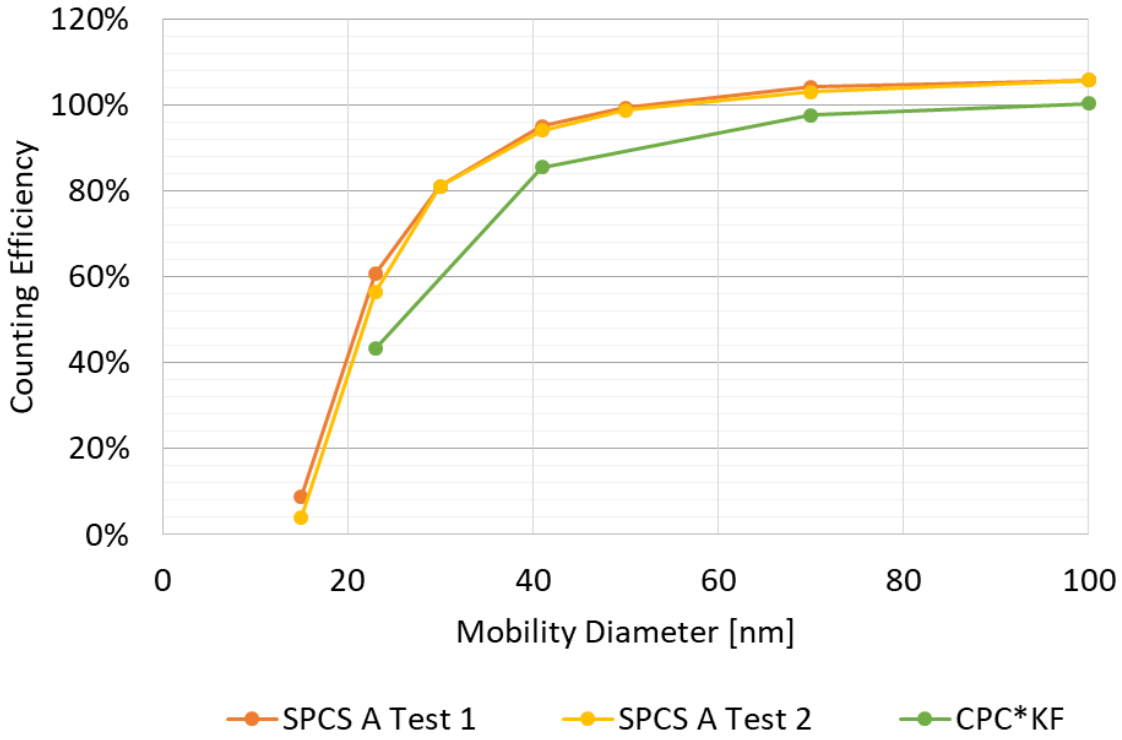
– Exhaust PN counter tested for system performance

– CPC corrected with KF

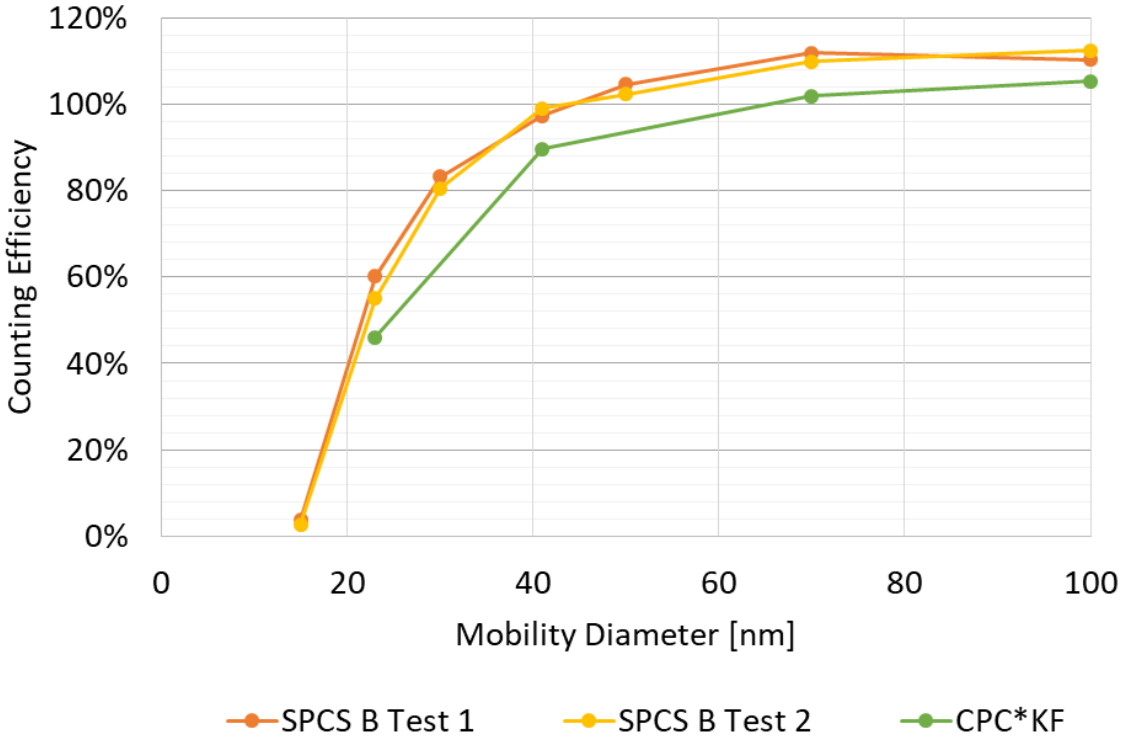
– All instruments at standard conditions (0°C, 1013kPa)

MEASUREMENTS

Integrated CPC compared to full system, PALAS DNP3000

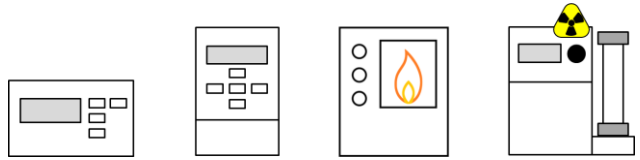


PCRF	30vs100nm	50vs100nm
216	1,03	0,99



PCRF	30vs100nm	50vs100nm
186	1,05	1,00

MEASUREMENTS



System calibration findings

– Good repeatability of system calibration

– No limitations with regard to aerosol concentration or reference instrument range

– Easy and fast procedure compared to PMP legislation *without loss of accuracy*

– At plateau: system 5-6% above CPC alone. Possible reason: PCRF

– At 23nm: system 25-35% above CPC, reason unclear (aerosol changes?)

– At 41nm: system 9-11% above CPC

– Same test with 10nm-CPC: no such change in counting efficiency at 23/41nm!

⇒The system has slightly higher counting efficiency than the CPC at the plateau

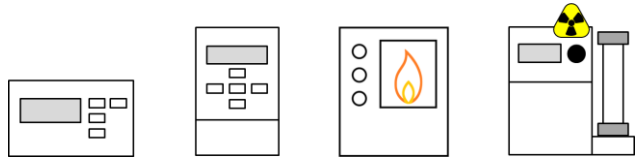
⇒This could be a question of PCRF

⇒The system has noticeably higher counting efficiency at 23/41nm

⇒This could be a question of the aerosol (but spark discharge soot is considered “stable”)

⇒Is this more representative of actual exhaust measurements? (!)

CONCLUSION/QUESTIONS



System calibration

– Possible, has lower complexity as previous approach and presumably same accuracy

– Yields slightly different (but coherent) results

PCRF:

– PCRF influences system “offset” (but not curve shape)

– Is the PCRF also material dependent? (yes)

Aerosol:

– Is the aerosol (spark discharge) completely stable?

– What is the consequence of swapping evaporation tube for catalytic stripper?

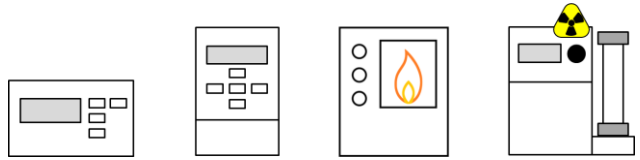
Calibration goal:

– Which scenario is correctly representing vehicle exhaust?

– Do we go for a standard that is detached from vehicle exhaust?

– PEMS must be subject to the presented effect

CONCLUSION/NEXT STEPS



- Definition of what is a suitable standard (what is thermally stable, engine-like)
- Derivation of a standard aerosol for traceability and accreditation
- Consequence of evaporation tube vs. catalytic stripper for PCRF/system calibration

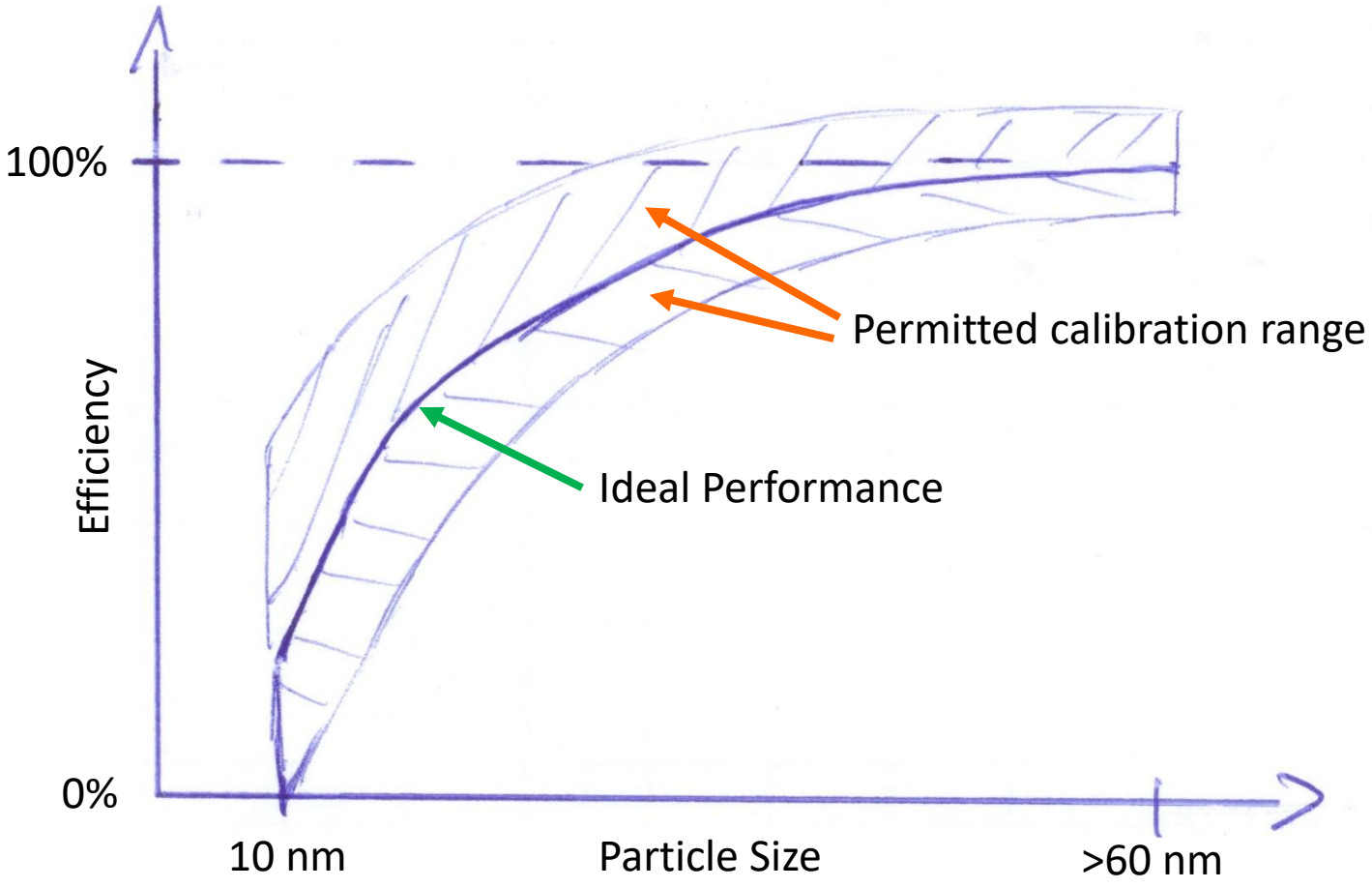
- 10nm system/PCRF might be impossible, 15nm stable aerosol should be practical

- Aerosol suitable for CPC, VPR and **PN-PEMS**

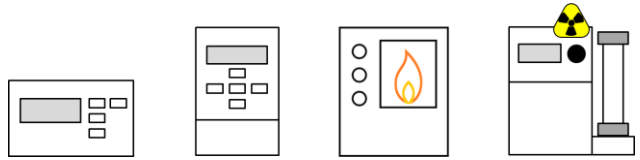
- **Aligning with sub-23nm PEMS drafting (from 2020)** should save us time & trouble and lead to a better understanding and calibration!
- **PN-PEMS performance** will be the limiting factor for the upcoming legislation. Requirements for counting efficiency, particle penetration etc. must be compatible!

Backup

CALIBRATION CONCEPT



EXHAUST PN COUNTER INSTRUMENT DEFINITION



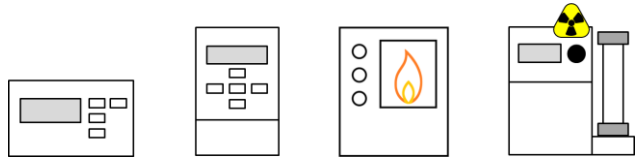
Define the full instrument performance curve, similar to PN-PEMS

to be discussed

Size [nm]	(10)	15	23	41	60-80	(100)
System efficiency (23nm)	0	<5%	47±12%	>90	102%	102%
Imaginable efficiency (10nm)	<50%	40-80%	60-90%	80-100%	90-110%	90-110%

- Numbers **highly dependent** on the available VPR (CS/ET) technology → **benchmarking** required!
- Direct visual representation of the actual device performance (unlike separated KF+CPC+PCRF curve)
- 10nm point could be omitted, since performance directly related to 15nm (mostly diffusion losses) and calibration error is largest at 10nm!
- A point at 60-80nm could be used instead of 100nm for easier calibration: very similar performance to 100nm, but higher concentration and use of shorter DMA possible
- *No pointless discussion, what an arbitrary "new PCRF" would look like*

CALIBRATION CONCEPT



Calibration is closely linked to instrument definition.

You cannot decide on one without the other.

Proposal: 2-part calibration

- CPC linearity: calibration of CPC linearity from 1.000-25.000 #/cm³ (tbd)
  - Measured at >20nm (plateau)
  - Error definition: residual errors <5%
- Whole System counting efficiency at 15nm, 23nm, 41nm, 60-80nm
  - incorporates both VPR penetration and CPC counting efficiency
  - single normalization factor at 60-80nm to adjust curve to “100%”
  - a certain minimal penetration through the VPR should be required
  - CPC counting efficiency **does not** need to be calibrated, since lower cutoff is determined by VPR penetration while CPC plateau efficiency is stable
  - High dilution factors (up to 1:3000) not needed anymore with current engines