Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

Combining three independent traceability chains for high-pressure gas flow in Germany

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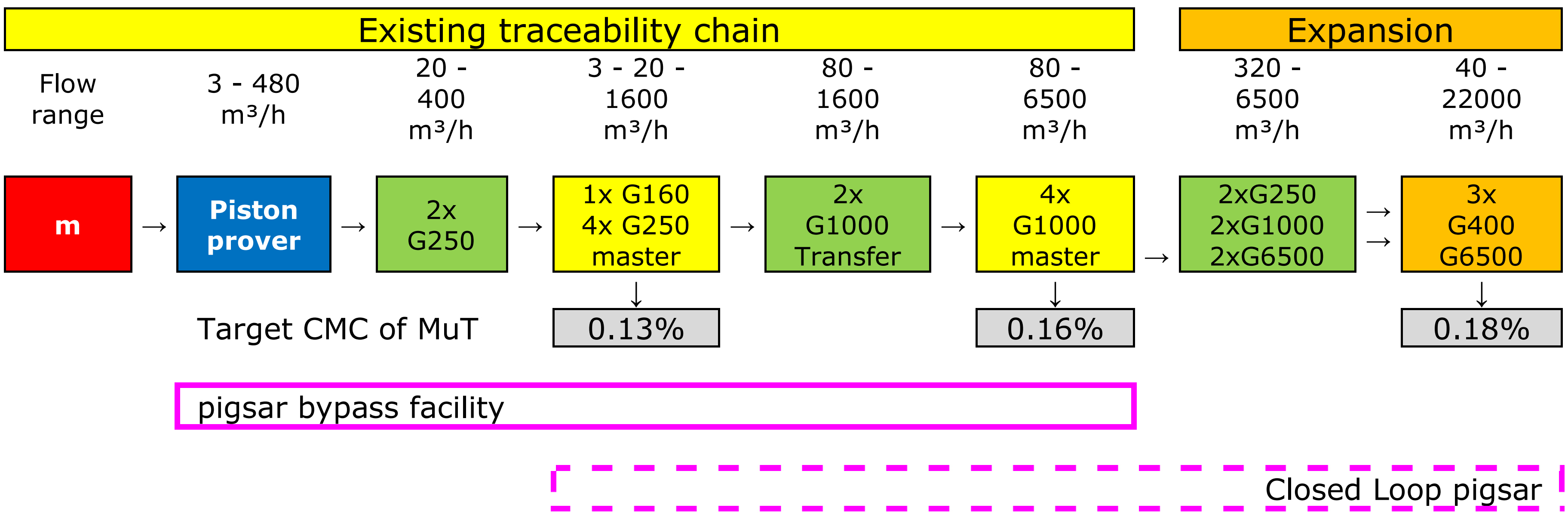
Introduction

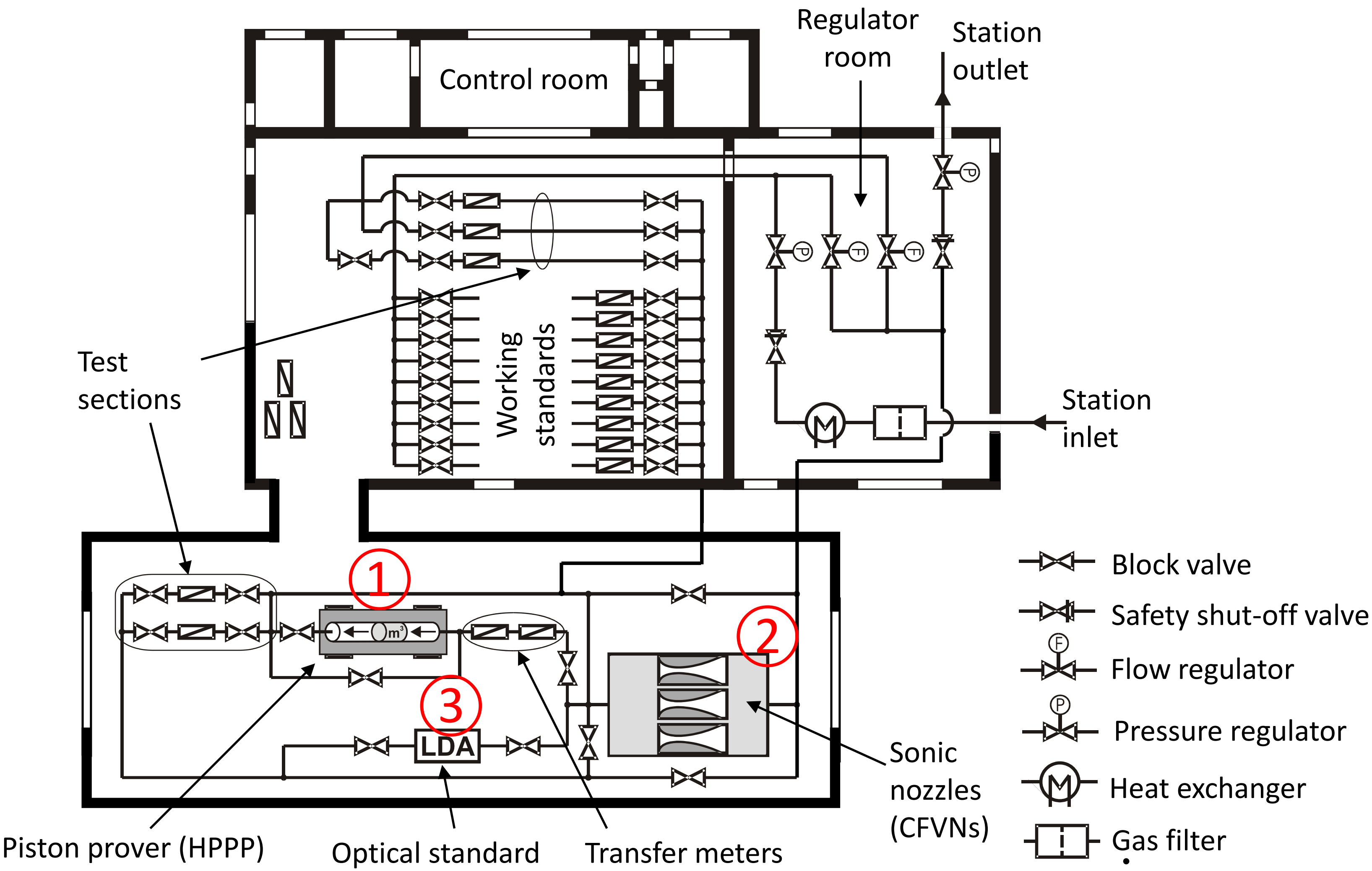
- High-pressure natural gas flow measurement
- 20 years harmonized cubic metre
  - Reduction of the measurement uncertainty
  - Reduction of differences between laboratories
- Uncertainty reduction possible by using more independent traceability chains [1]
- PTB / pigsar has three standards that can be made independently traceable
- Study to see how much the uncertainty can be improved using the method of the harmonized m³

Introduction

- Current traceability chain and future expansion



Three Primary Standards



Three Primary Standards

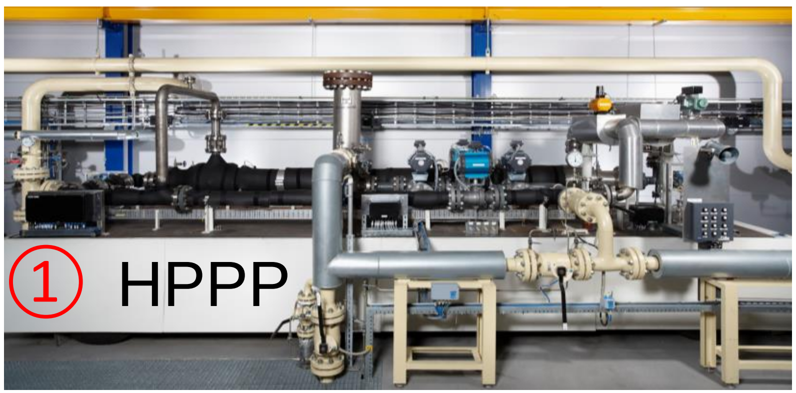
- High-Pressure Piston Prover: HPPP
- Sonic Nozzles or Critical Flow Venturi Nozzles: CFVN
- Optical standard Laser Doppler Anemometry: LDA

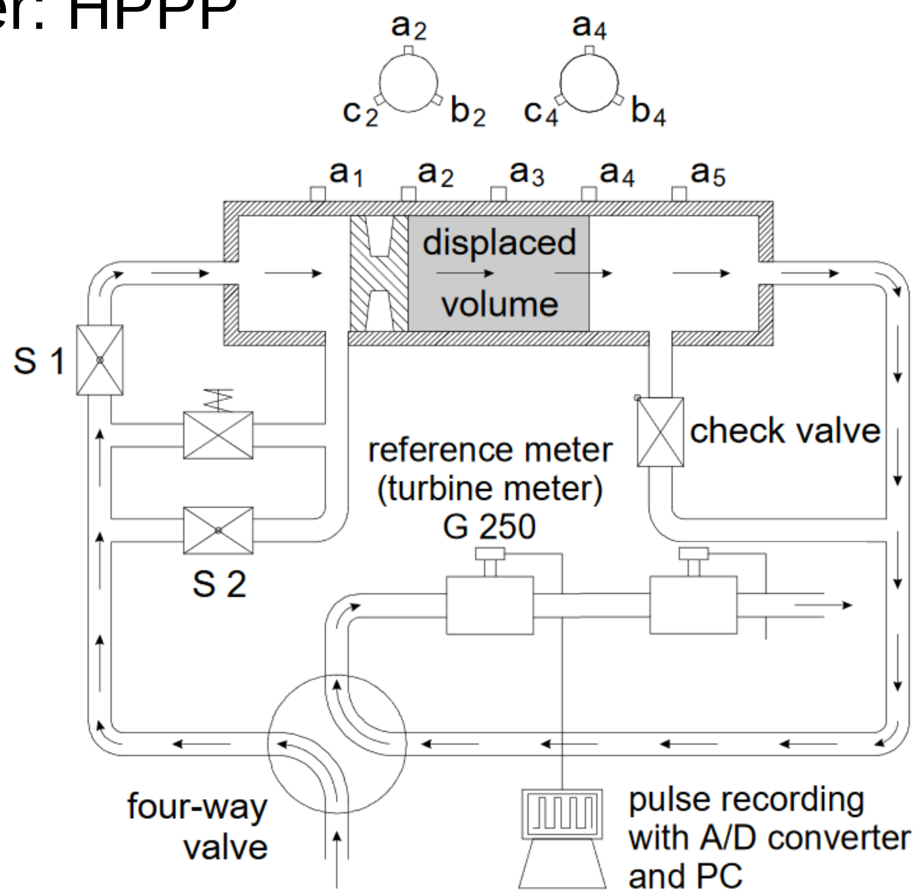
	1 HPPP	2 CFVN	3 LDA
Pressure [bar]	8 – 50	8 – 50	8 – 50
Flowrate [m³/h]	3 – 480	3 – 1600	3 – 1600
CMC	0.065%	0.15%	0.21%

- These standards are or can be made independently traceable

Three Primary Standards

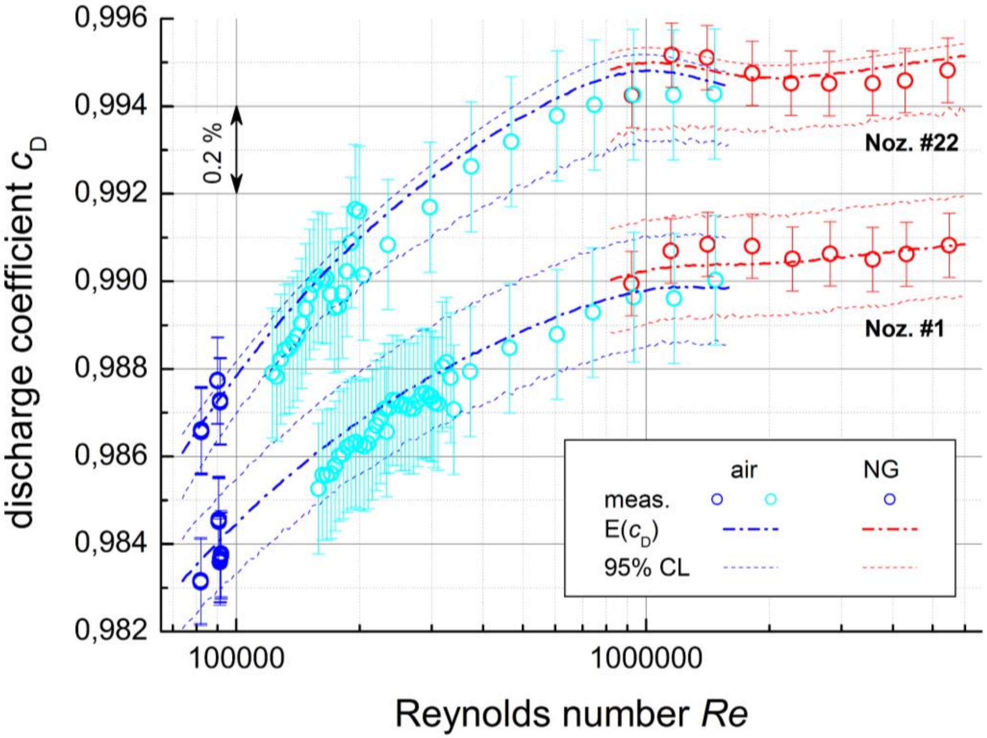
- High-Pressure Piston Prover: HPPP
- Calibration
  - Diameter: length tester
  - Length: interferometric



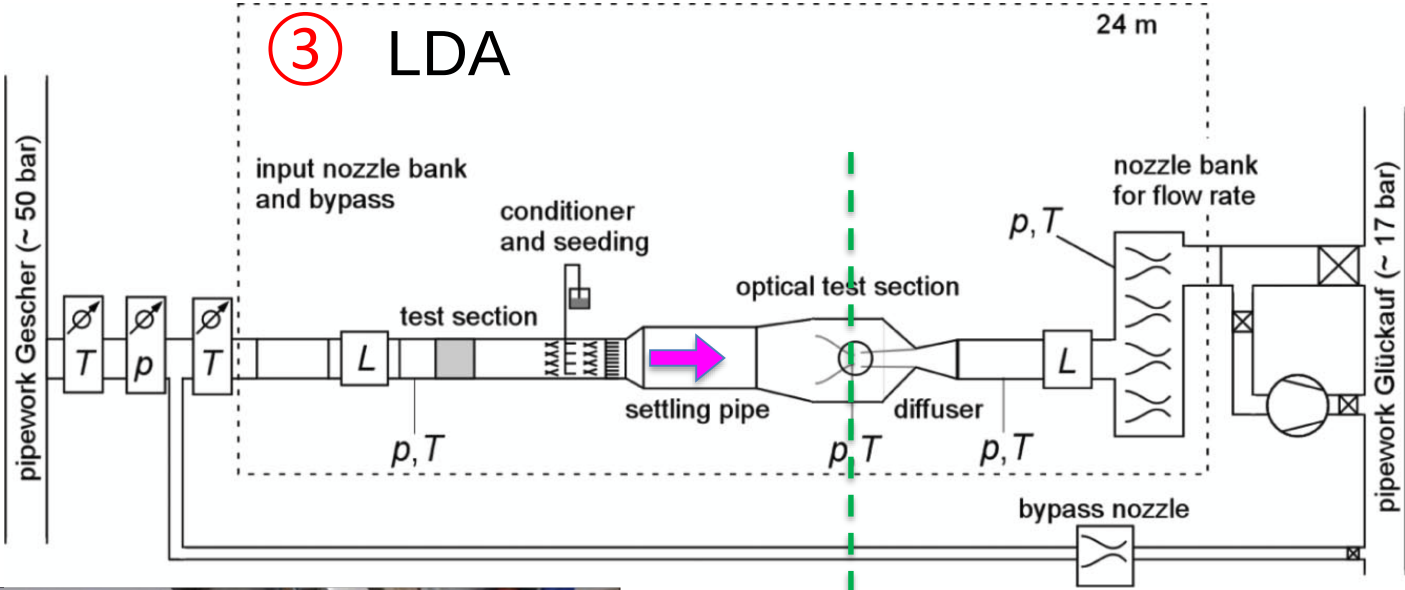


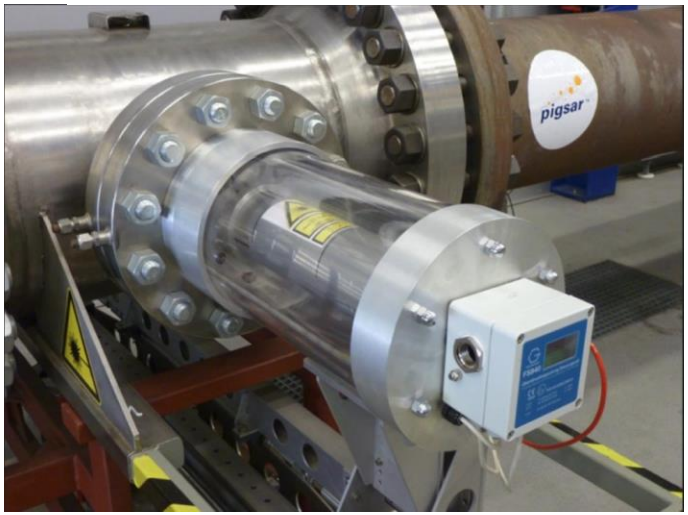
Three Primary Standards

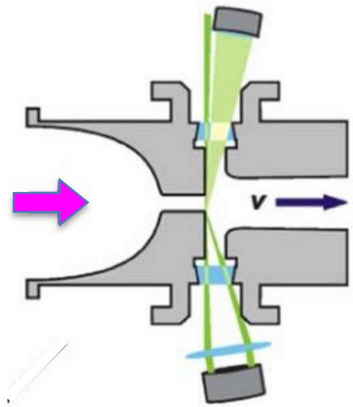
- Sonic Nozzles or Critical Flow Venturi Nozzles: CFVN



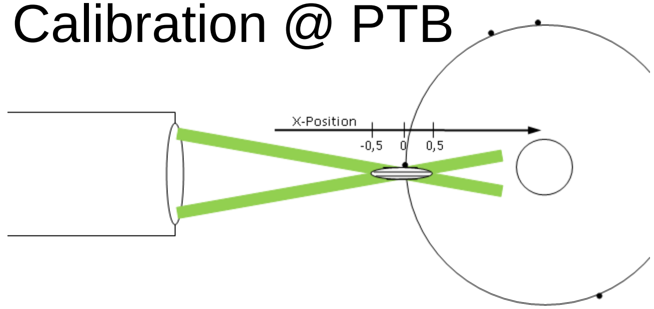
Three Primary Standards







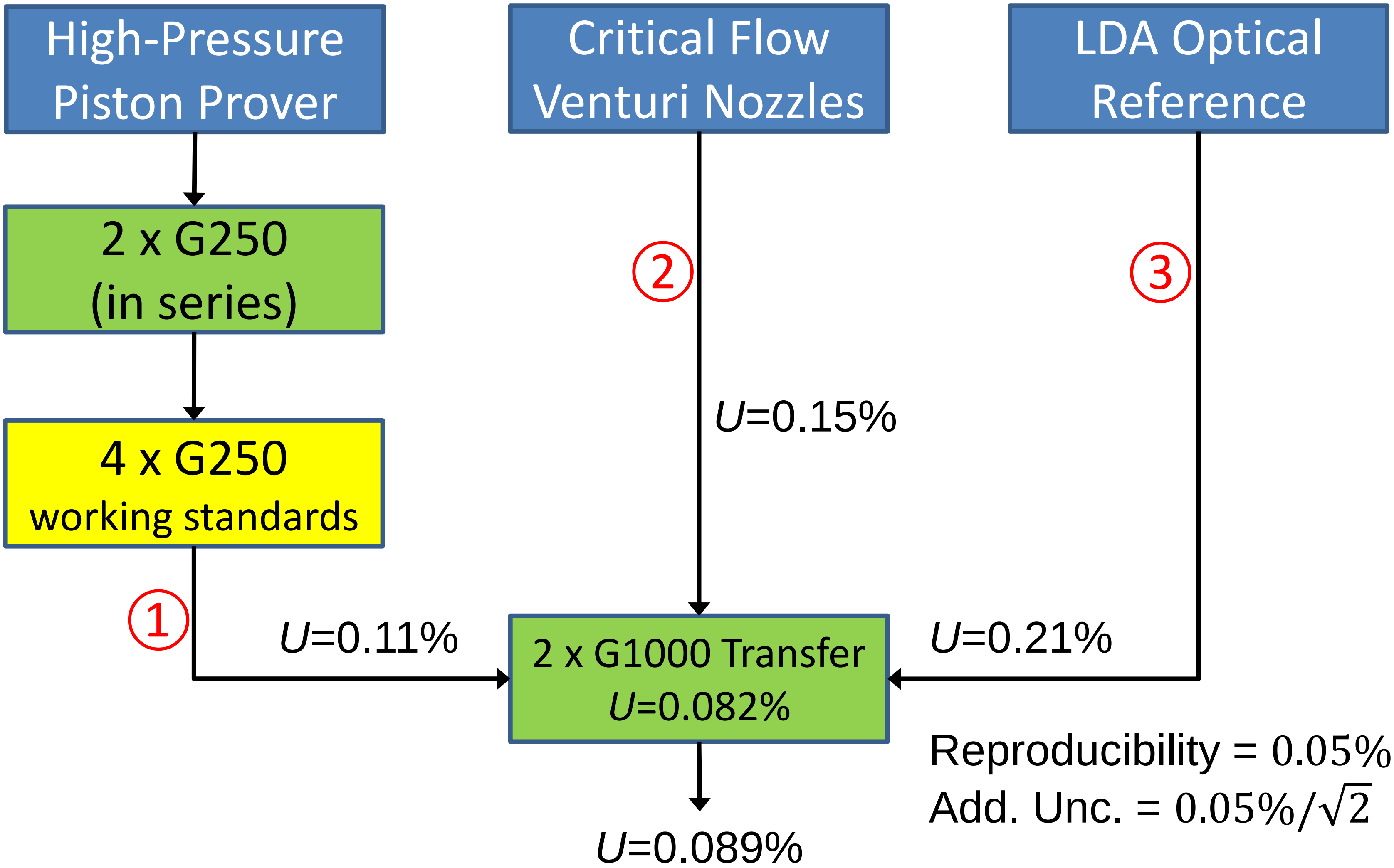
Calibration @ PTB



Combining traceability chains

- Data processing identical to a key comparison
- Uncertainty: $$\frac{1}{U_{TRM}^2} = \frac{1}{U_1^2} + \frac{1}{U_2^2} + \frac{1}{U_3^2}$$
- Optimum is if all three have identical uncertainties
- In that case $U_{combined} = U/\sqrt{3}$

Combining traceability chains



Traceability benefits

1 2 3

								Long-term stability	
								0.075%	
								↓	
U_{TRMs}	TRM	2 x	8" G1000 TM				0.089%		
			|			↙			*0.110%*
	Process		|			0.056%			
			↓		↙				
	References	4 x //	8" G1000 TM		0.01%	-->	0.106%		
			|			↙			
	Process		|			0.056%			
			↓	↓	↙			↓	
CMC_{WS2}	TRM / MuT	2 x	16" G6500 TM	MuT	0.01%	-->	0.120%	-->	**0.141%**
			|			↙			*0.156%*
	Process		|			0.056%			
			↓		↙				
CLP *	References CLP	3 x //	20" G6500 TM		0.01%	-->	0.133%		
			|			↙			
	Process		|			0.056%			
			↓	↓	↙			↓	
CMC_{WS3}	TRM / MuT		Transfer	MuT	0.01%	-->	0.144%	-->	**0.163%**
									0.175%

OIML Class 0.5

* CLP = new Closed Loop pigsar facility (under construction)

Discussion

- Great differences between the uncertainties of the three traceability chains: 0.11% – 0.15% – 0.21%
- What would happen if we leave out one chain?
- What would happen if we introduce a new standard?

Discussion

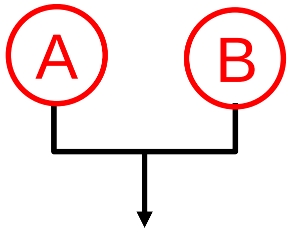
Traceability combination	U(2x G1000) ≤ 1600 m³/h	CMC WS2 ≤ 6500 m³/h	CMC WS3 ≤ 21000 m³/h
1 – – –	0.110%	0.156%	0.175%
1 2 – –	0.095%	0.146%	0.166%
1 2 3 –	0.089%	0.142%	0.163%
1 – – 4	0.082%	0.137%	0.159%
1 2 – 4	0.075%	0.133%	0.156%
1 2 3 4	0.072%	0.132%	0.154%

4 New HPPP, 8 – 65 bar, 20 – 1600 m³/h, U = 0.10%

Discussion

- So far, traceability chains are combined at 1600 m³/h
- What will happen if we combine 2 chains at 6500 m³/h?
  - Assuming both chains **A** and **B** have the same uncertainty
  - $U_{2xG6500}$ = 0.137% for each meter [6]
  - Reproducibility 0.05% for each meter
- U_{TRM} = 0.103%

Discussion



	TRM / MuT	2 x	16" G6500 TM	MuT	0.01%	-->	0.103%		*0.137%*
						↙			
	Process					0.056%			
			↓		↙				
CLP	References CLP	3 x //	20" G6500 TM		0.01%	-->	0.118%		
						↙			
	Process					0.056%			
			↓	↓	↙			↓	
CMC_{WS3}	TRM / MuT		Transfer	MuT	0.01%	-->	0.131%	-->	**0.151%**
									0.175%

- Result smaller than any value of the previous table
- So it makes sense to combine chains at the flow level where needed
- Difference with HPPP, CFVN and New HPPP is 0.005%

Conclusions

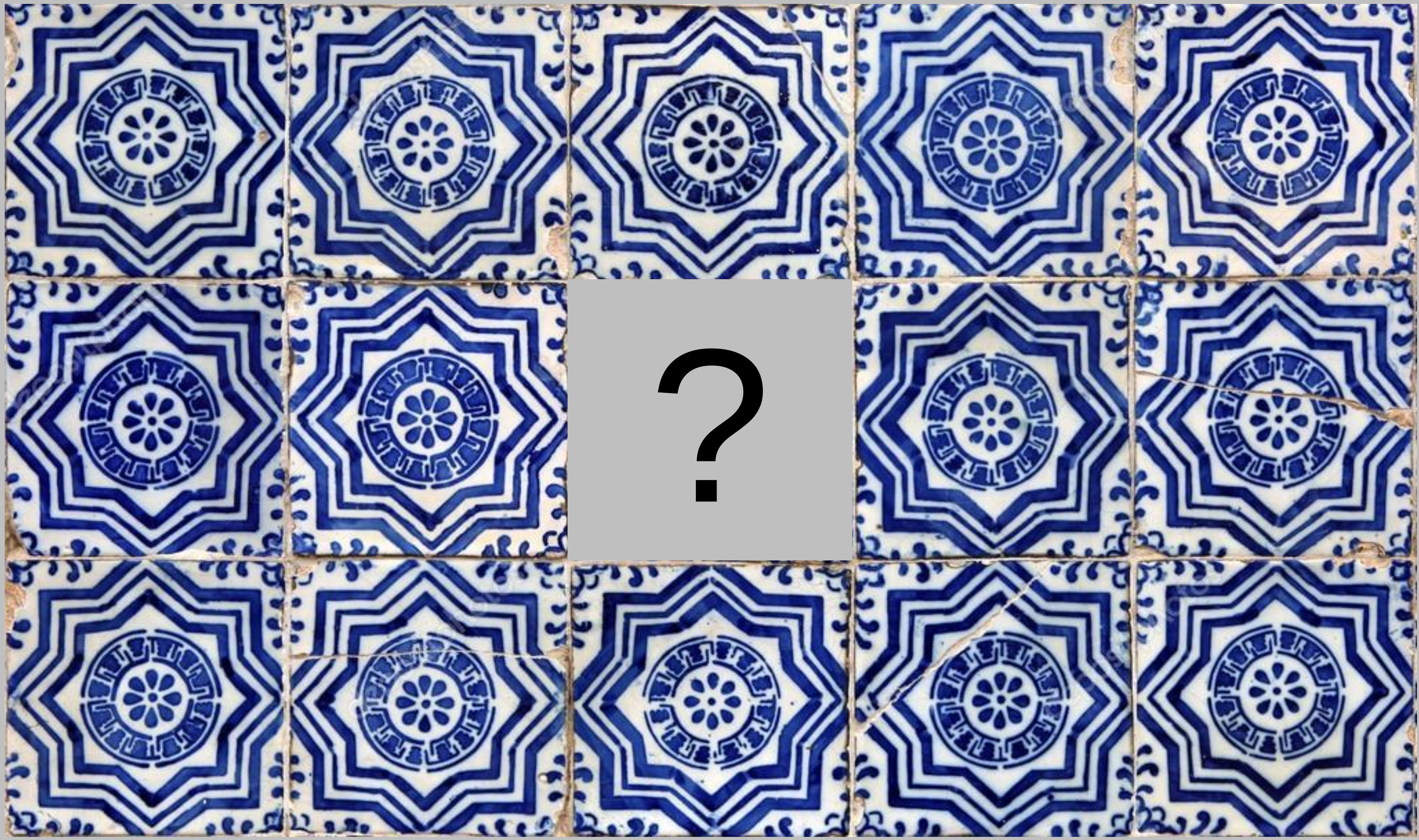
Compared to the present single traceability chain …

1. Three parallel traceability chains result in better CMCs
   - G1000 TRMs $U_{1\ 2\ 3}$ / U_1 = 0.81
   - Working standards' $\mathrm{CMC}_{1\ 2\ 3}$ / CMC_1 = 0.91 resp. 0.93

2. When omitting the LDA the two remaining chains
   - Working standards' $\mathrm{CMC}_{1\ 2}$ / CMC_1 = 0.94 resp. 0.95

3. Replace LDA with new standard with 0.10% uncertainty
   - G1000 TRMs $U_{1\ 2\ 4}$ / U_1 = 0.75
   - Working standards' $\mathrm{CMC}_{1\ 2\ 4}$ / CMC_1 = 0.85 resp. 0.89

Thank you !



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