Continuous-Flow Plasma Target for LWFA:
Concept Towards High Repetition Rates

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CFEL SCIENCE

LAOLA. is a collaboration of UH DESY

LUX Junior Research group

Junior Research group at CFEL and Hamburg University

commission & operate 200 TW ANGUS laser system

build and operate the LUX beamline for laser-plasma driven undulator radiation

lux.cfel.de

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Outline

- Motivation
  - High repetition rates for Laser Plasma Acceleration
  - Combine high power laser with continuous flow target
  - Increase efficiency and data acquisition
- Differential Pumping
  - Concept at LUX
  - Pressure reduction of 7 orders of magnitude in 1,5m
- Additional Benefits of Continuous Flow
  - Direct high precision pressure measurement, absolute values

Motivation: Continuous Gas Flow Operation

> Setup

> ANGUS: 200TW @ 5 Hz

> Target pressure: ~50 mbar

> Laser Beam Line pressure: x10^-6 mbar

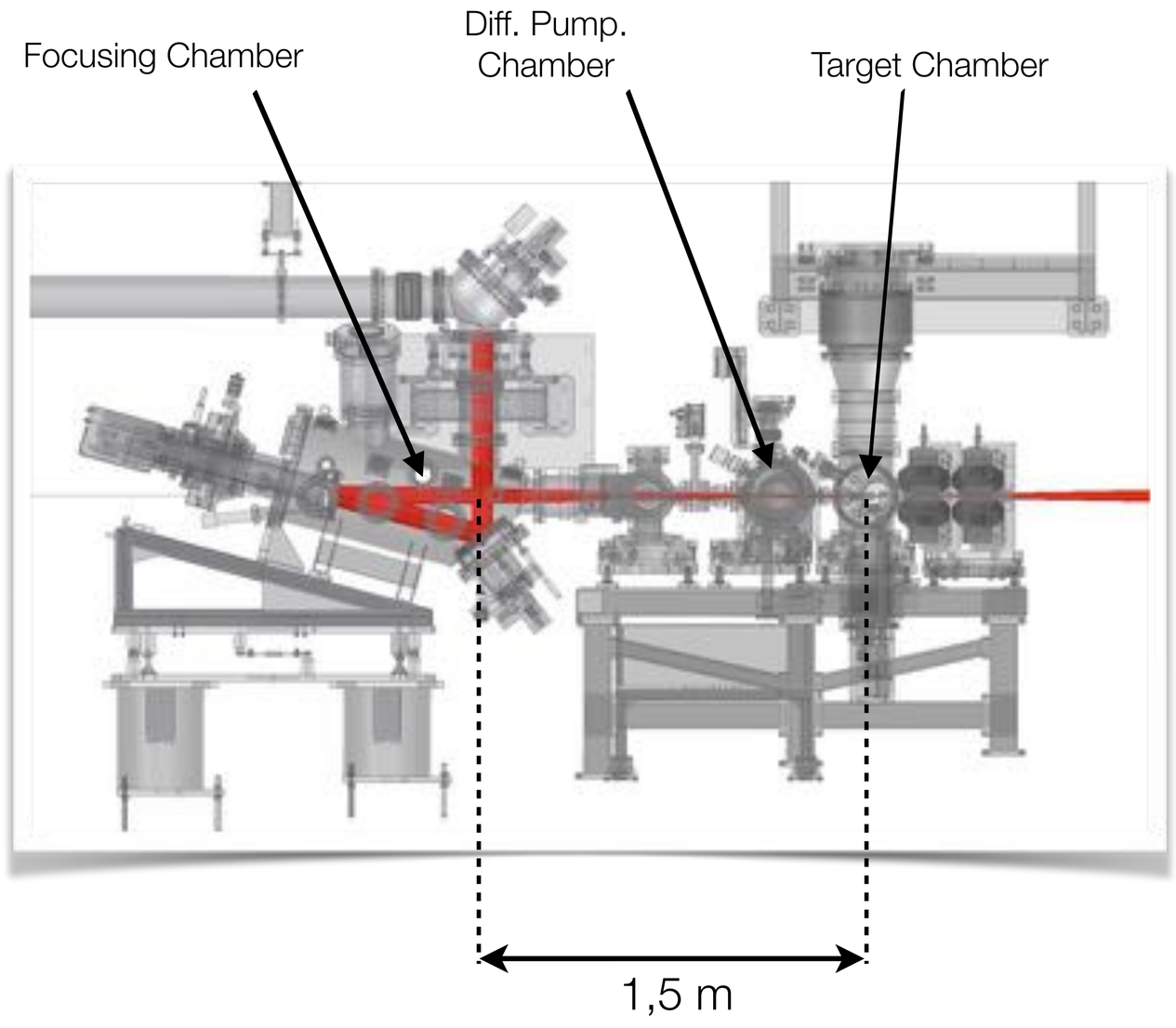
> Gas from target contaminates vacuum

> Previous Experiments:

> pulsed gas operation due to high gas load

> shoot with fraction of laser repetition rate

> slow data acquisition

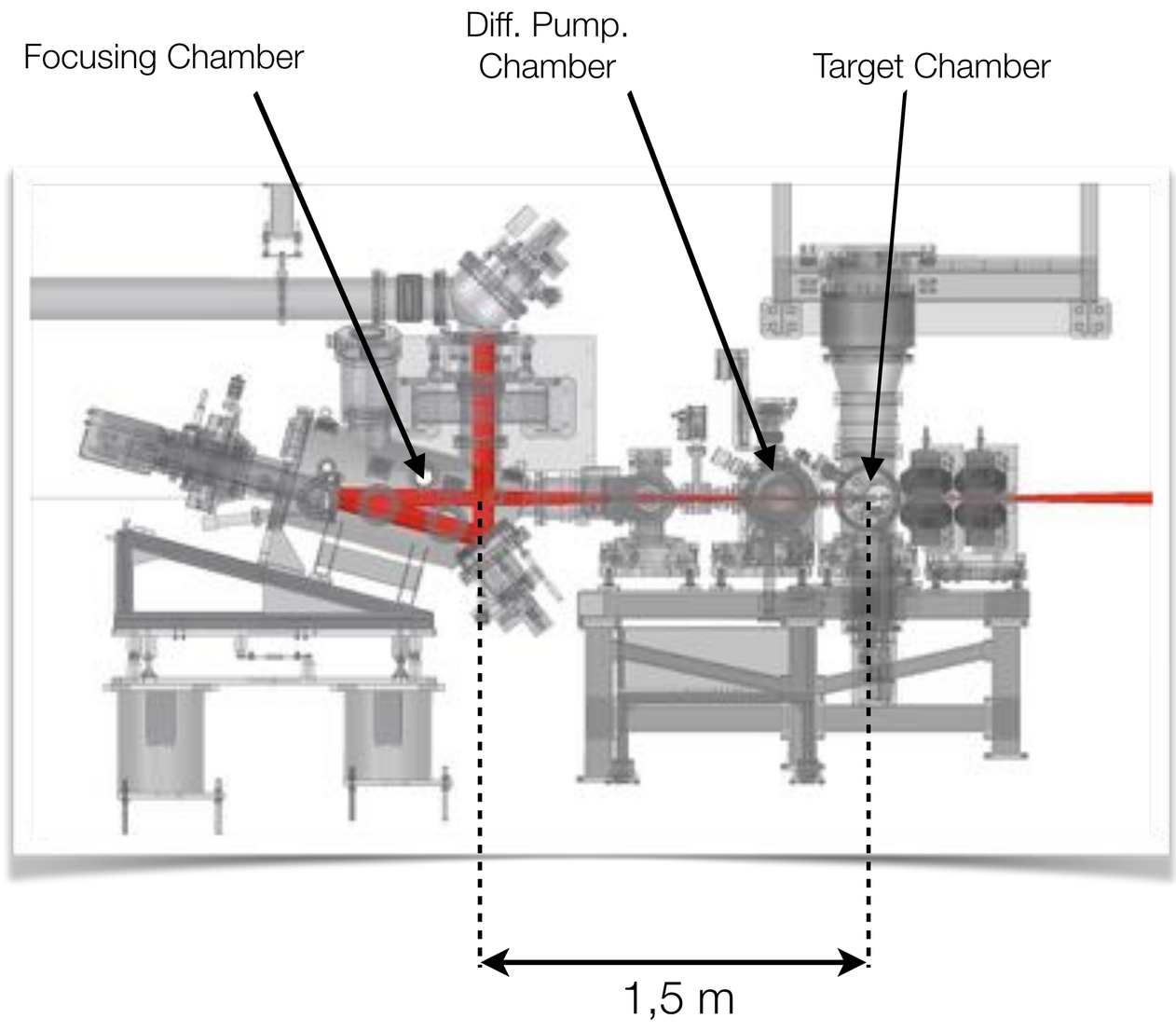


Motivation: Continuous Gas Flow Operation

> Goal

  > Use full repetition rate of laser

  > Decrease pressure fluctuations caused by valve dynamics



Motivation: Continuous Gas Flow Operation

> Goal

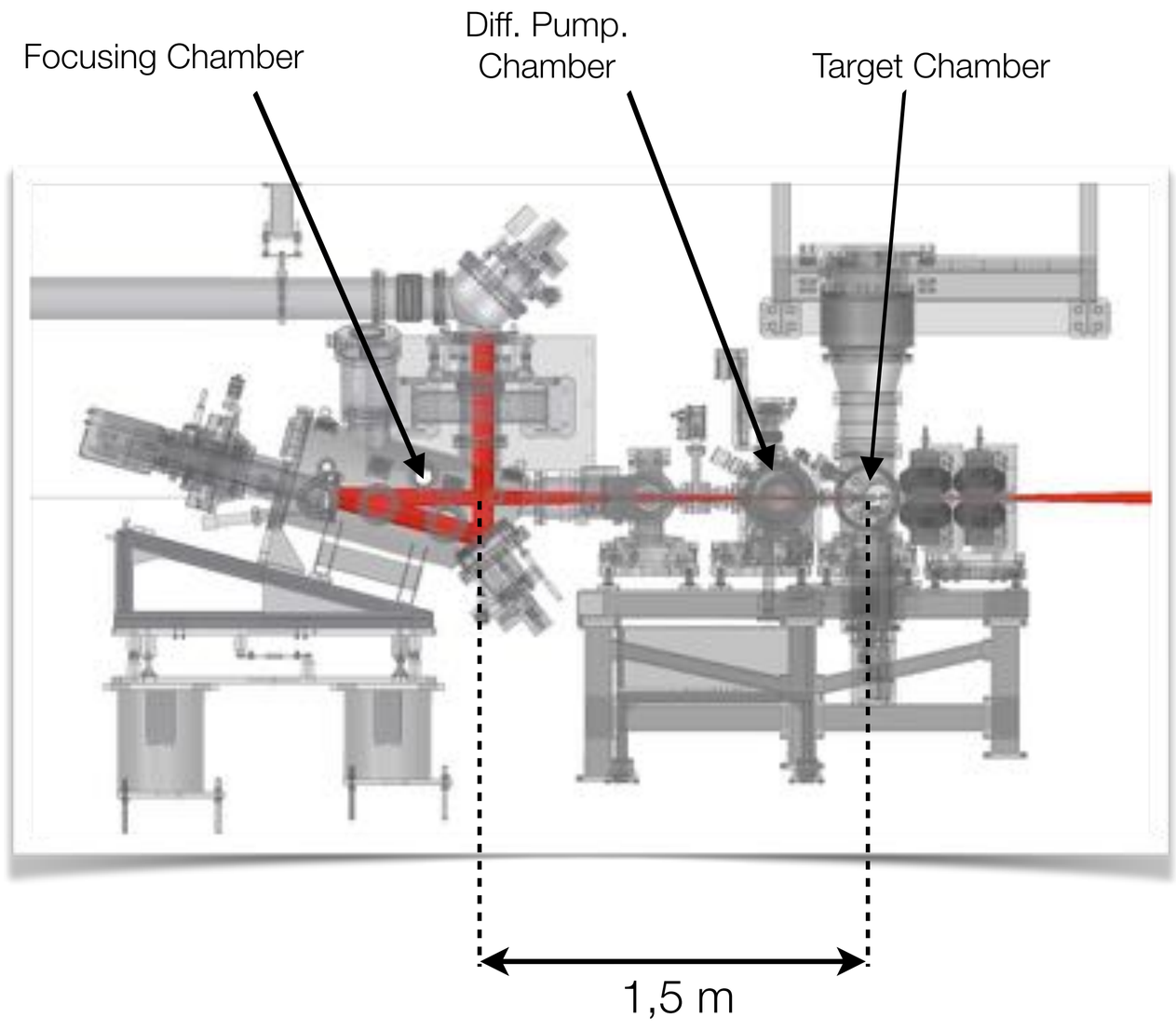
> Use full repetition rate of laser

> Decrease pressure fluctuations caused by valve dynamics

> Required

> Pressure drop: 7 orders of magnitude under continuous flow

> Differential pumping scheme within 1,5m



Differential Pumping

Design Basics: Flow in Vacuum

> Flow inside a vacuum system:

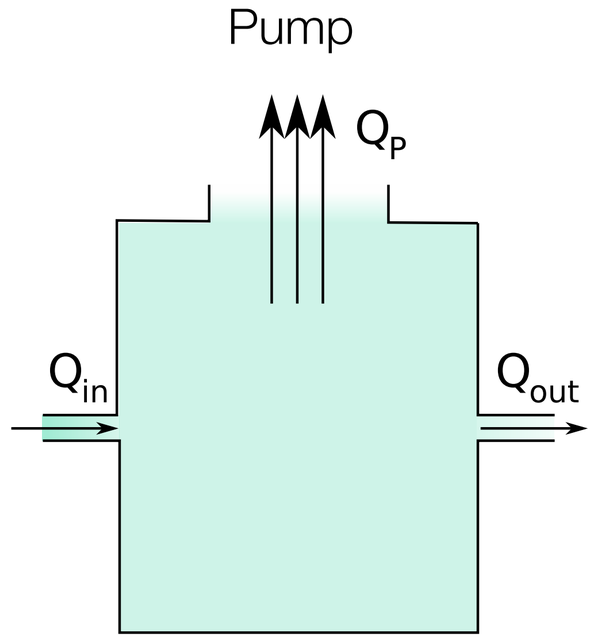
$$Q = C \cdot \Delta P$$

> Conductance in series:

$$\frac{1}{C_{\text{total}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ...$$

> Conductance, parallel:

$$C_{\text{total}} = C_1 + C_2 + C_3 + ...$$

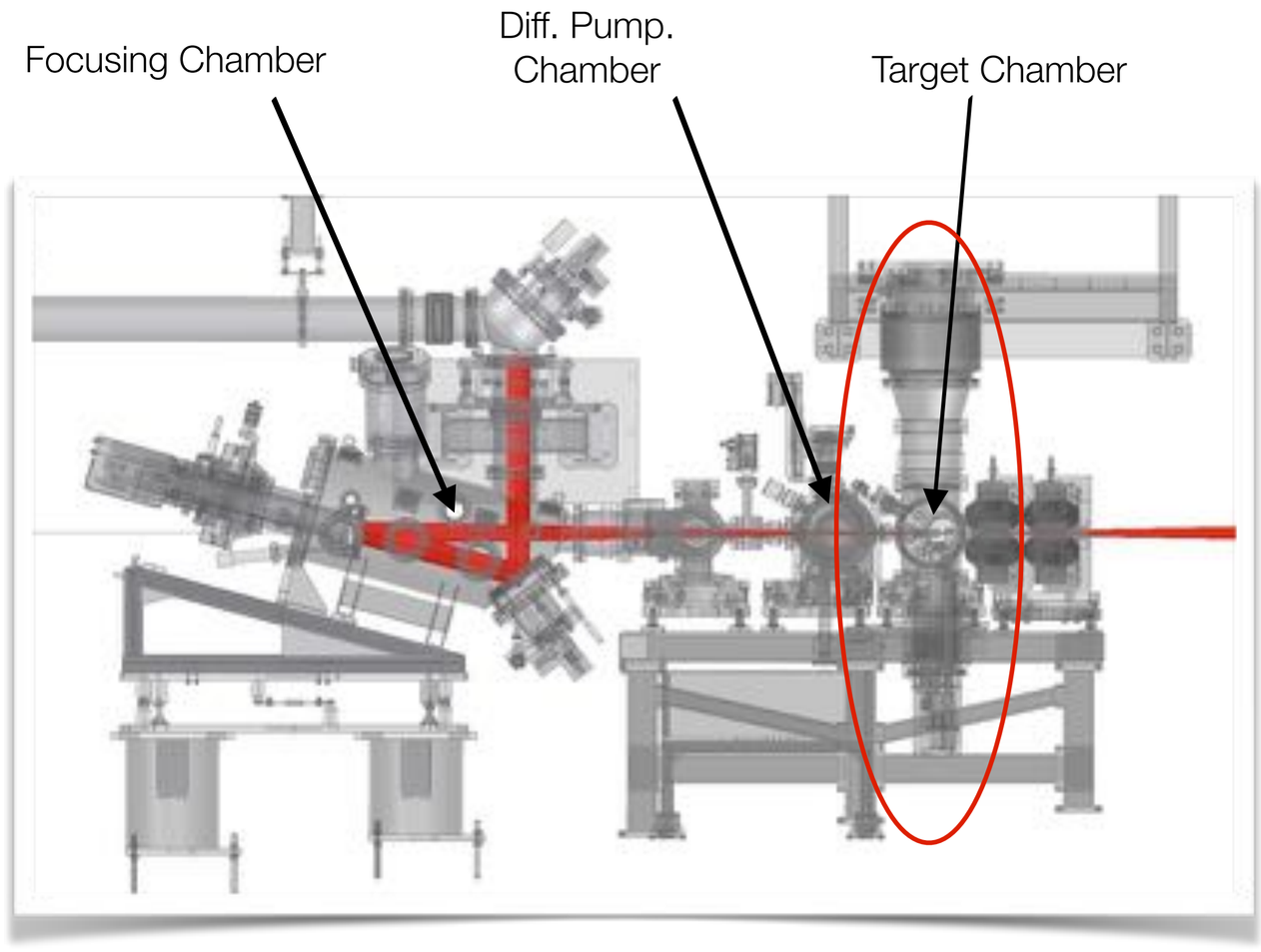


Differential Pumping

> I. Target Chamber Pumping Concept

> II. Differential Pumping Chamber

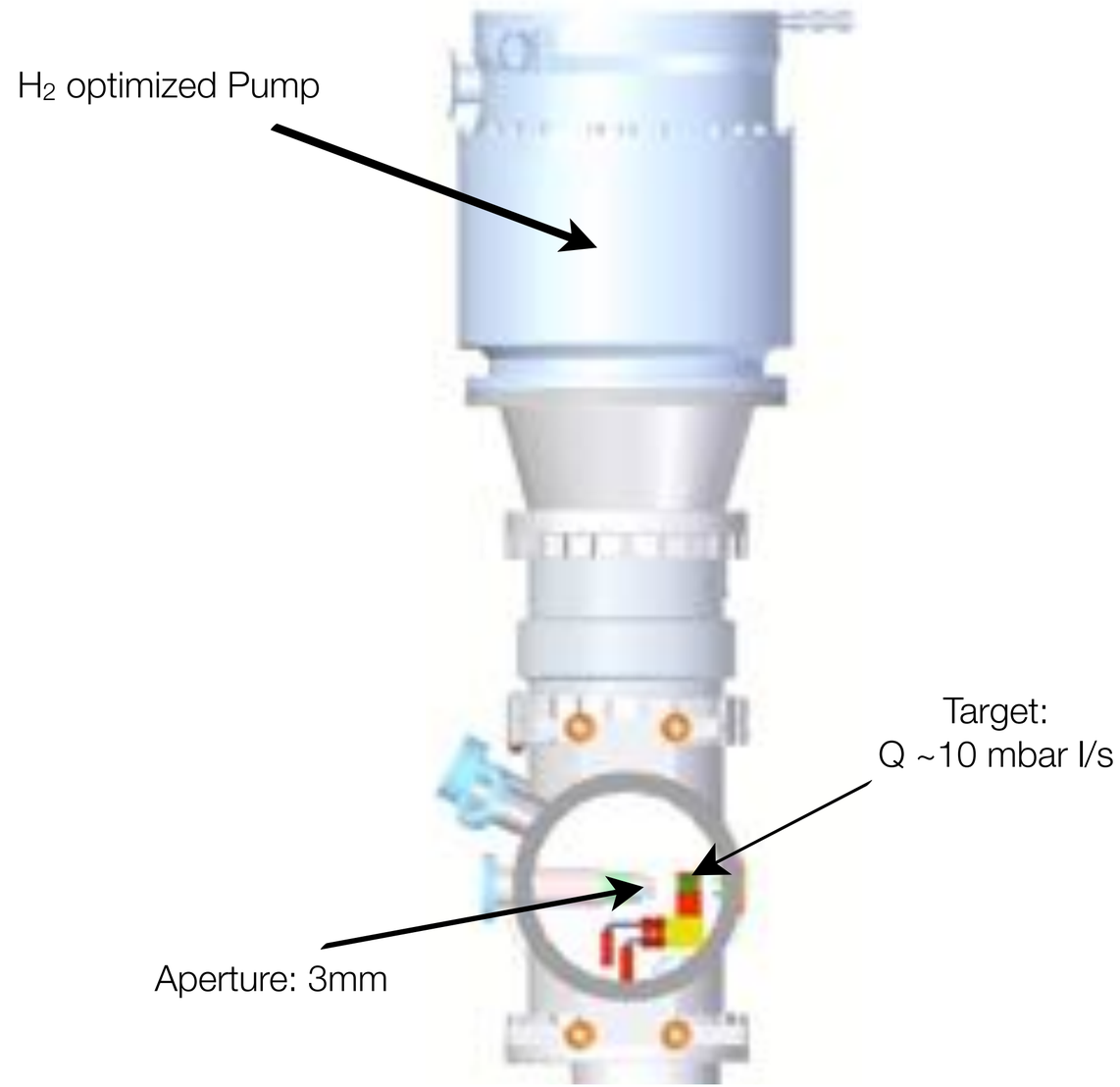
> III. Overall Vacuum Simulation



I. Target Chamber

Parameters:

> Incoming flow: Q ~ 10 mbar l/s (H2)
> Target Pressure: ~ 50 mbar
> Narrow apertures: d = 3mm



> Compact

> Reduces outgoing flow to < 0.2 % of incoming flow

> End pressure in chamber: p ~ 1e-2 mbar

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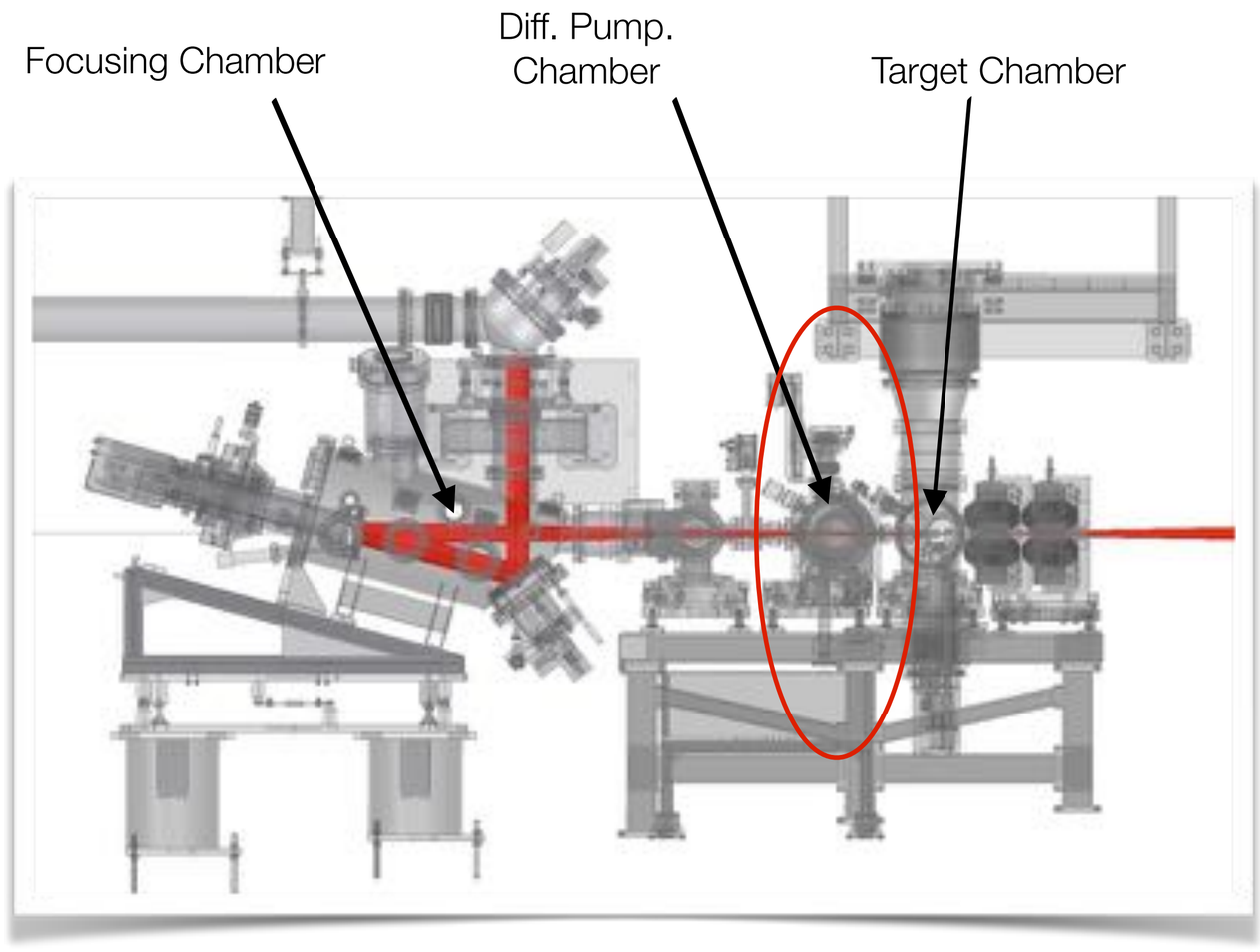
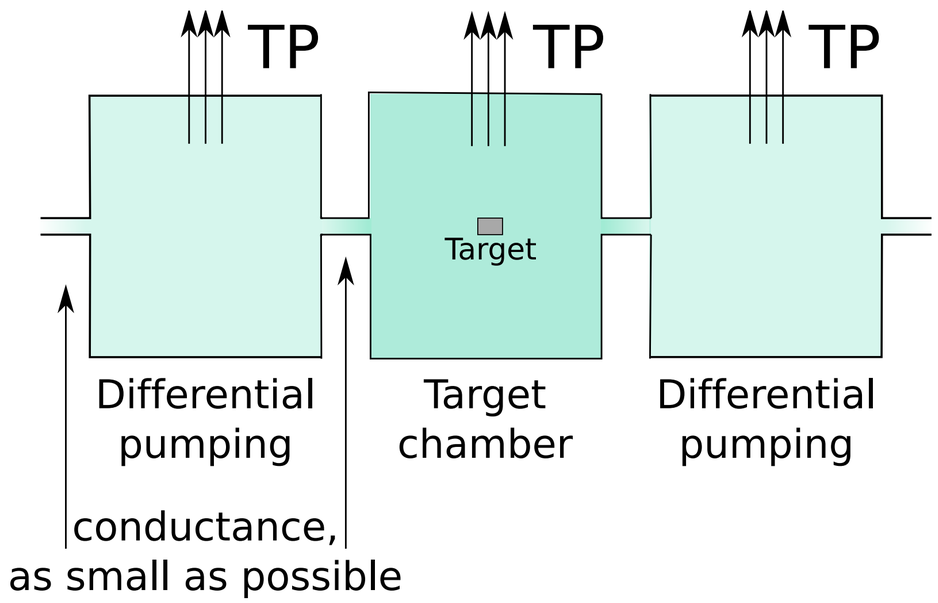


II. Differential Pumping Chamber

> Without Laser:

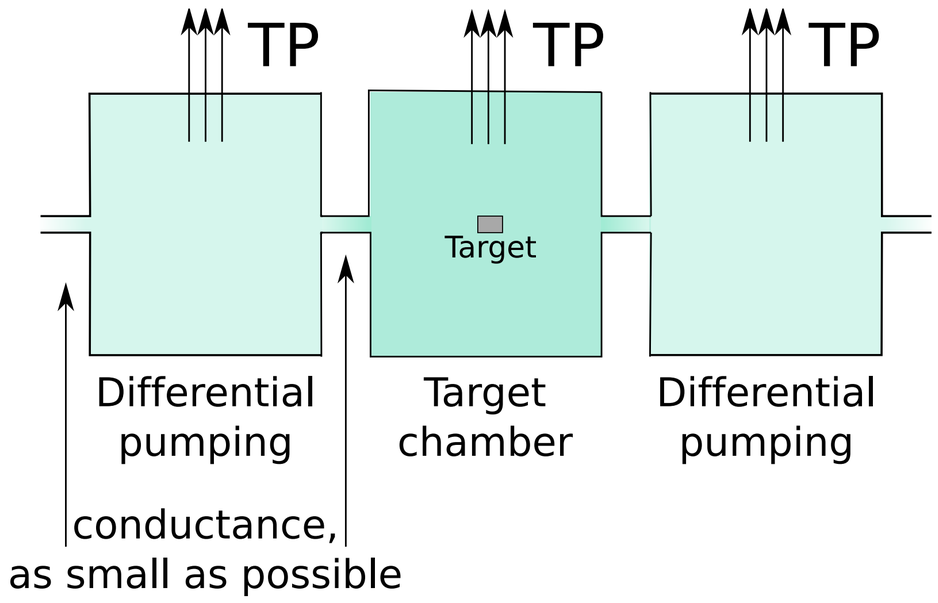
$$Q = C \cdot \Delta P$$



Pump speed limited by number of attachable pumps, Space consuming

II. Differential Pumping Chamber

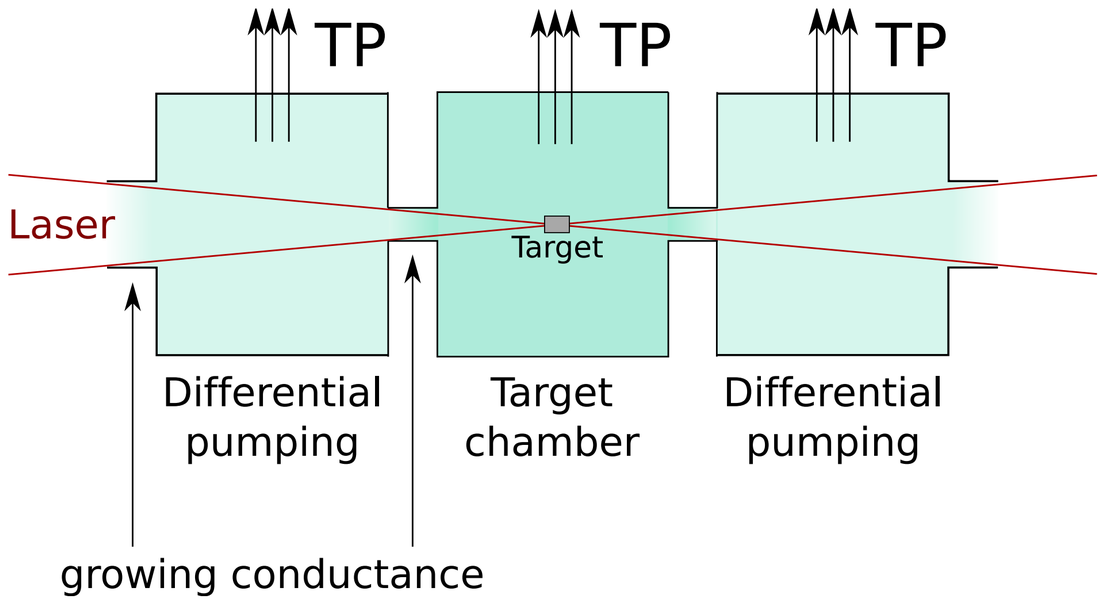
> Without Laser:



Pump speed limited by number of attachable pumps, Space consuming

> With Laser:

$$Q = C \cdot \Delta P$$

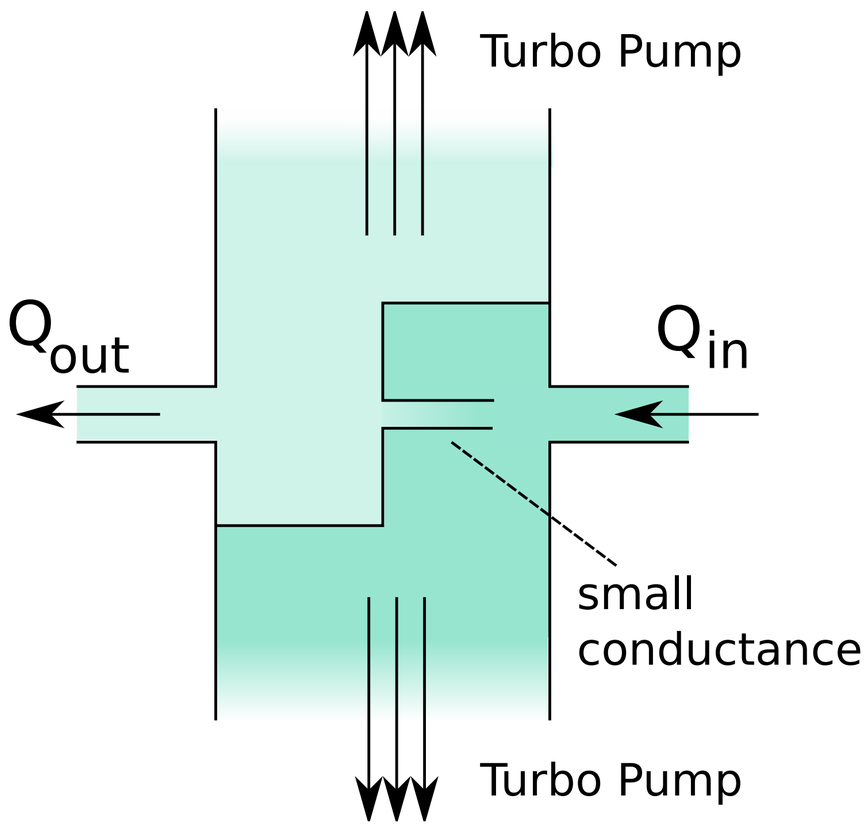


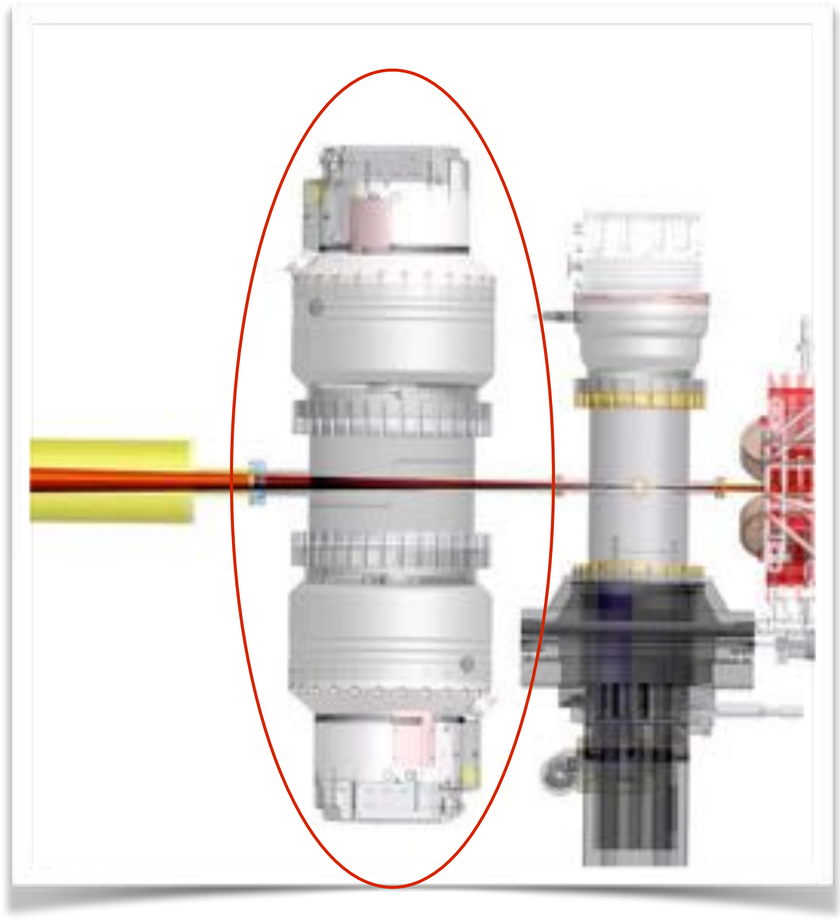
Space consuming + inefficient

II. Differential Pumping Chamber

Close to focus: Two separate Volumes in one chamber

$$Q = C \cdot \Delta P$$





II. Differential Pumping Chamber

Experimental Test

> Comparison:

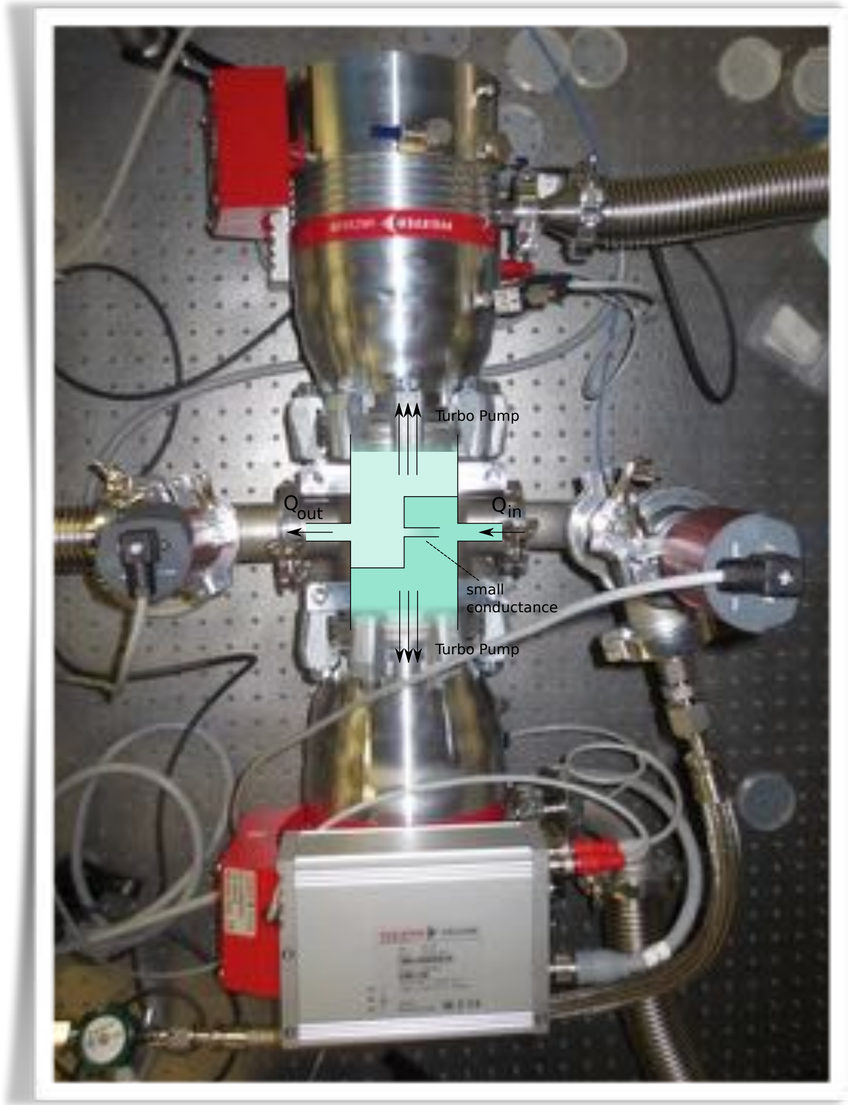
> with separation

> without separation

> Gas: N2

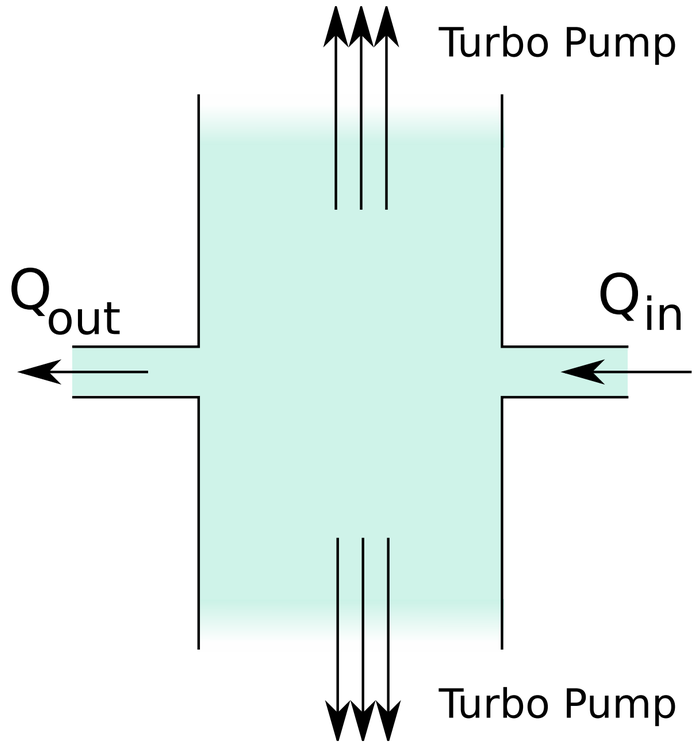
> Pumps: 2 x 255 l/s

> Measure incoming flow and resulting pressure in different sections

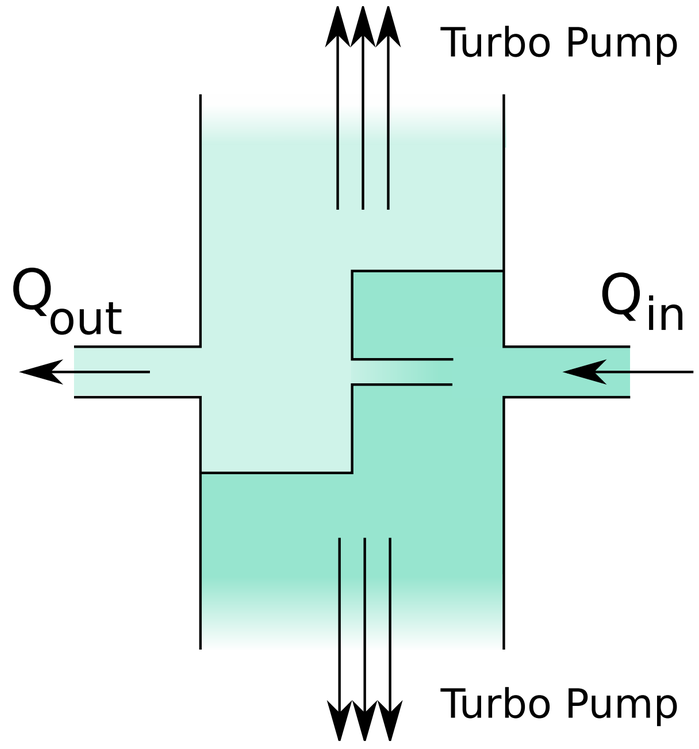


II. Differential Pumping Chamber

Measurement: Normal Chamber



Measurement: Diff. Pump. with same pumps



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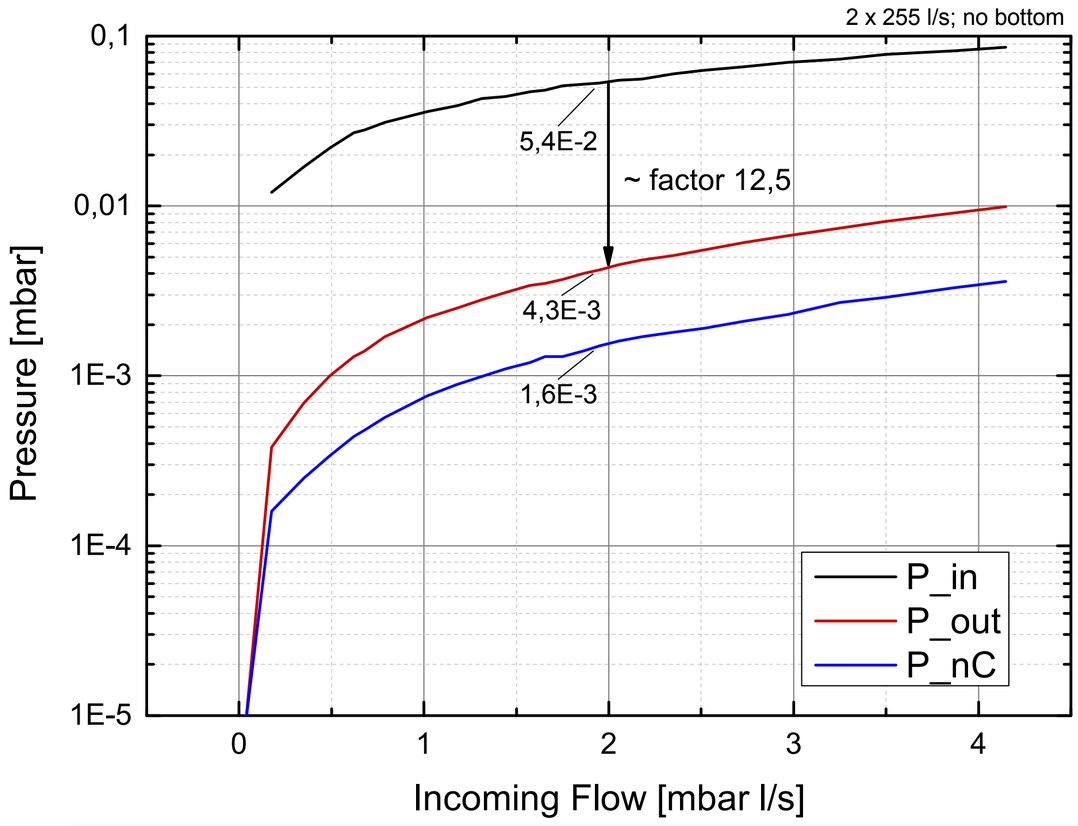
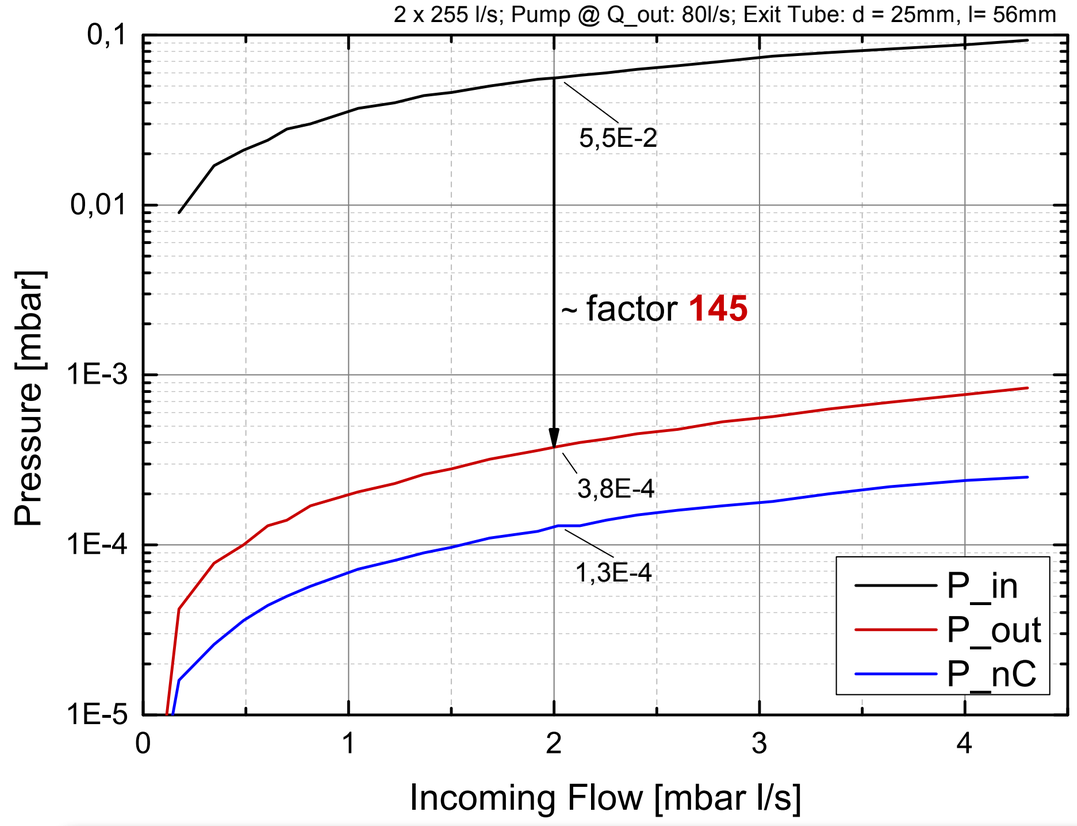


Pressure Reduction by factor 12,5

Measurement: Diff. Pump. with same pumps



*Pressure Reduction by factor **145***

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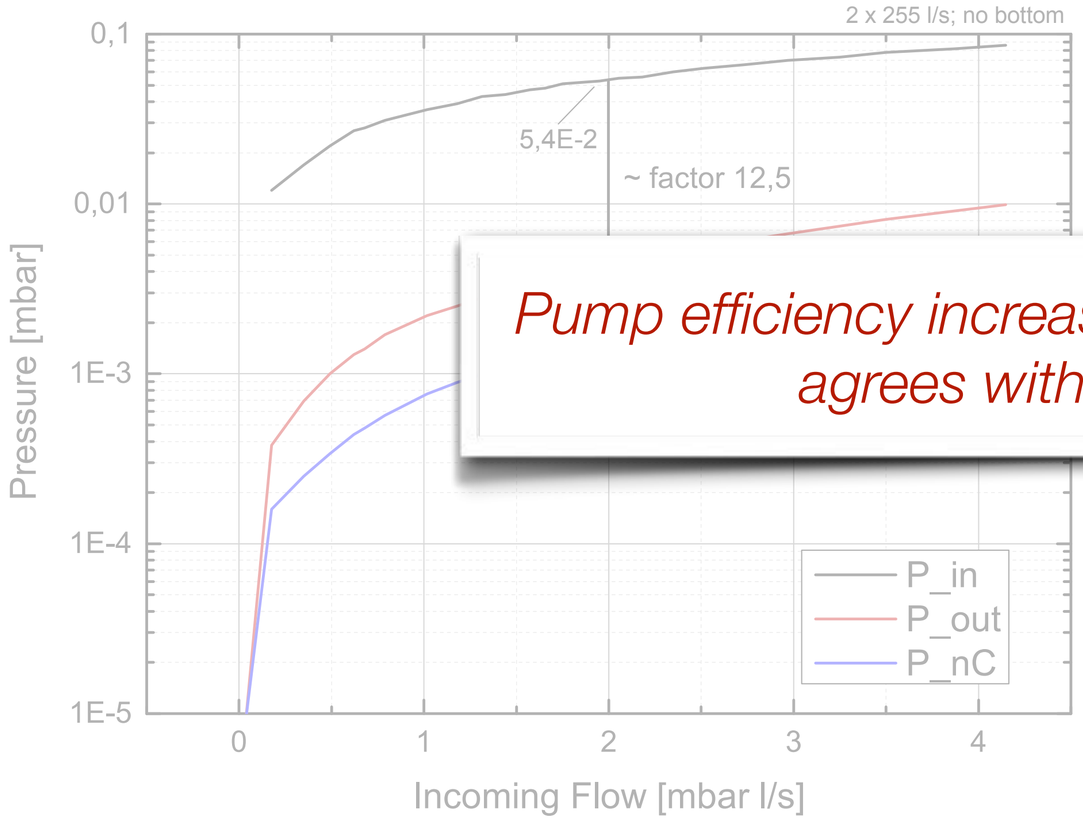

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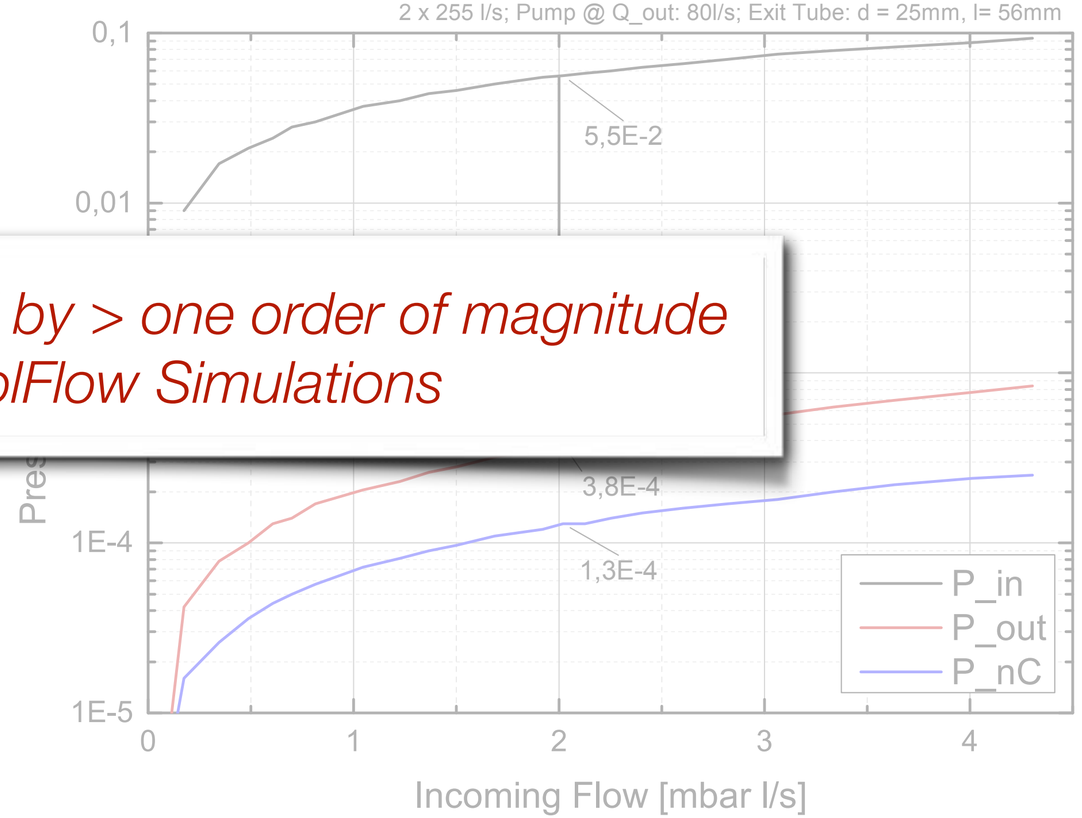

*Pressure Reduction by factor **145***

Pump efficiency increased by > one order of magnitude agrees with MolFlow Simulations

Differential Pumping

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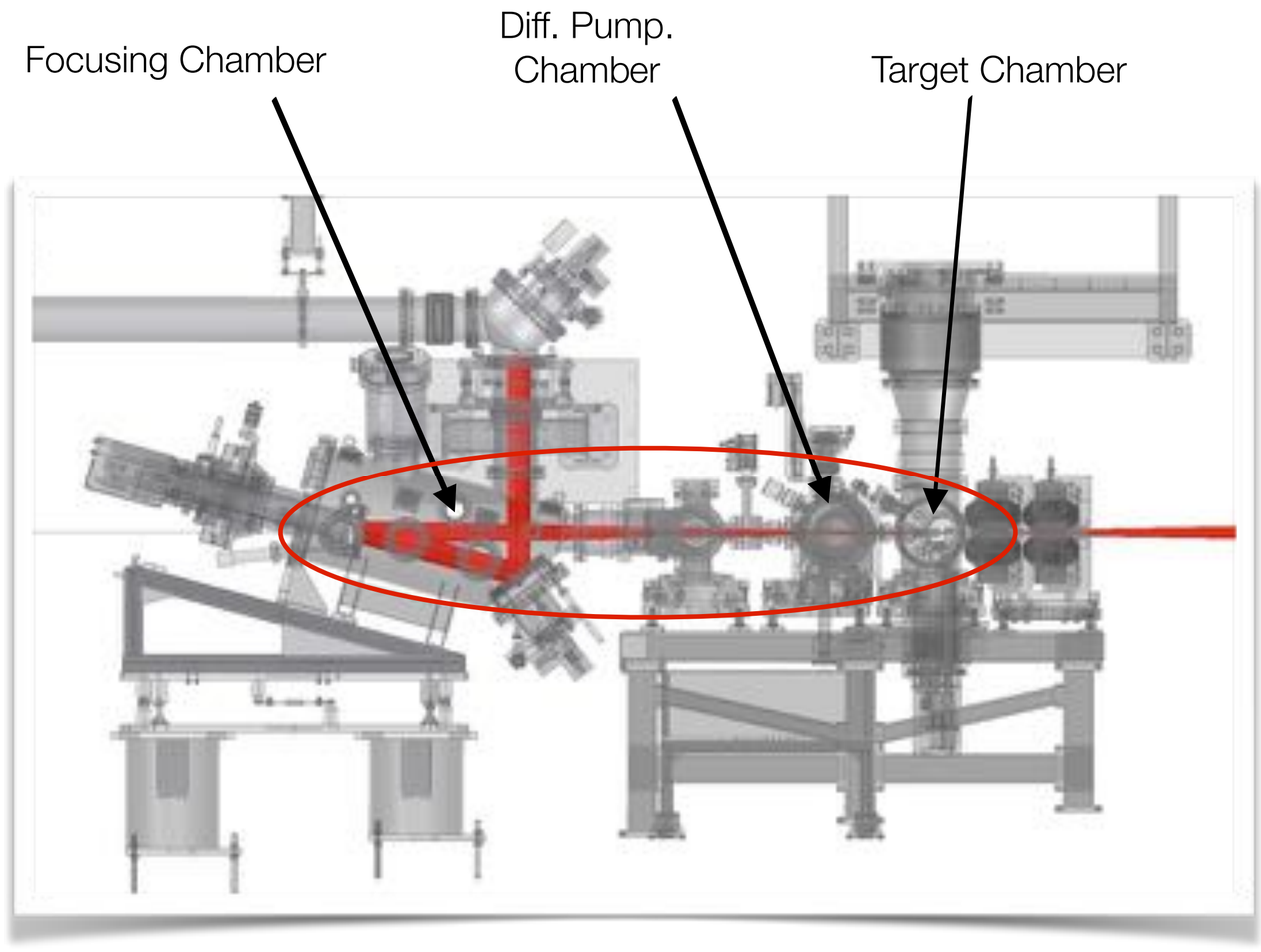
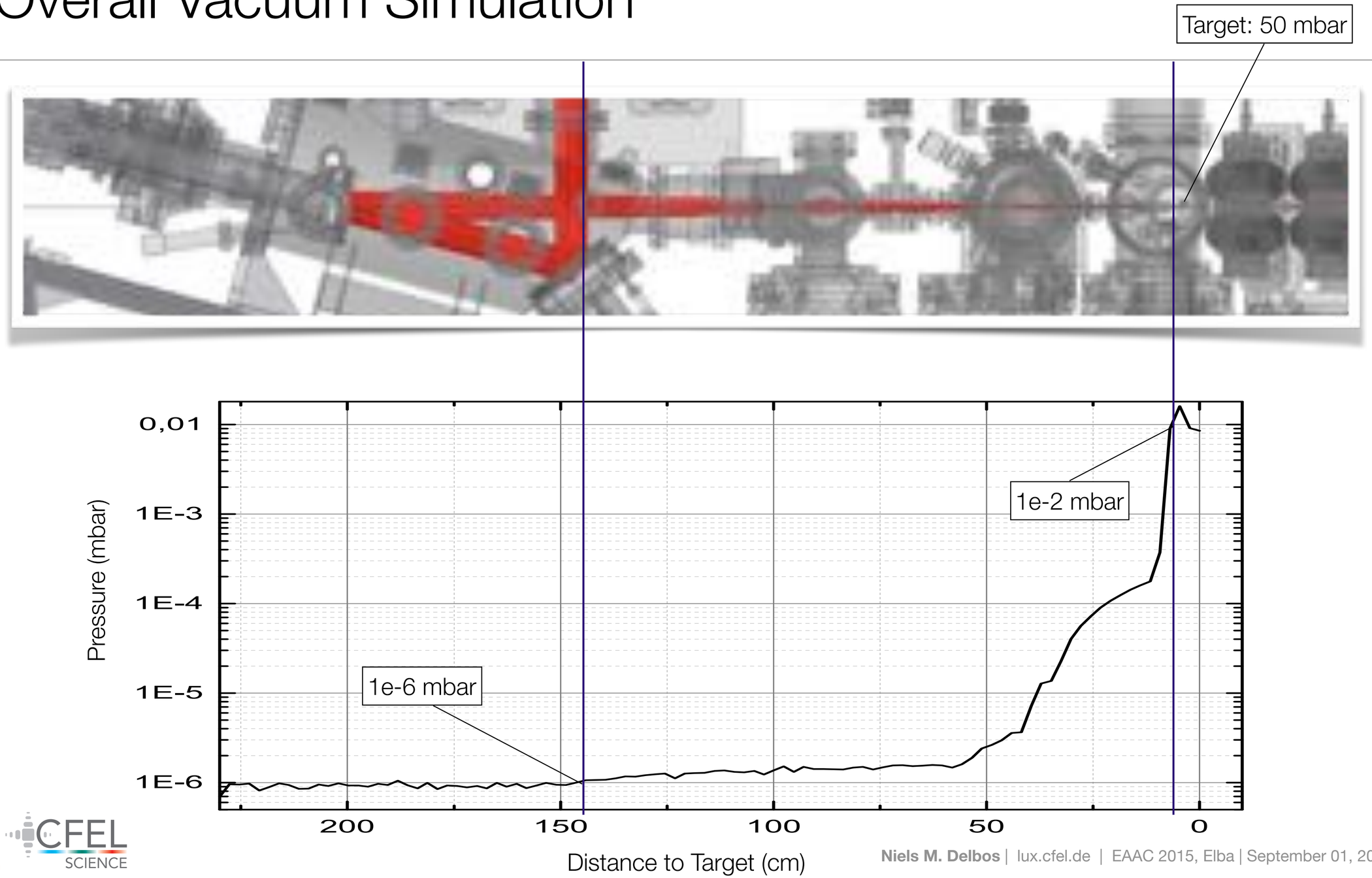


III. Overall Vacuum Simulation



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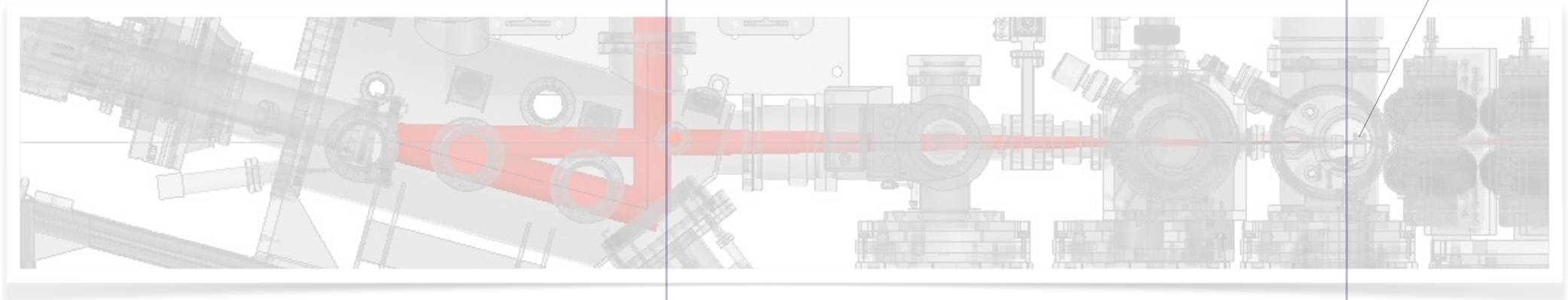
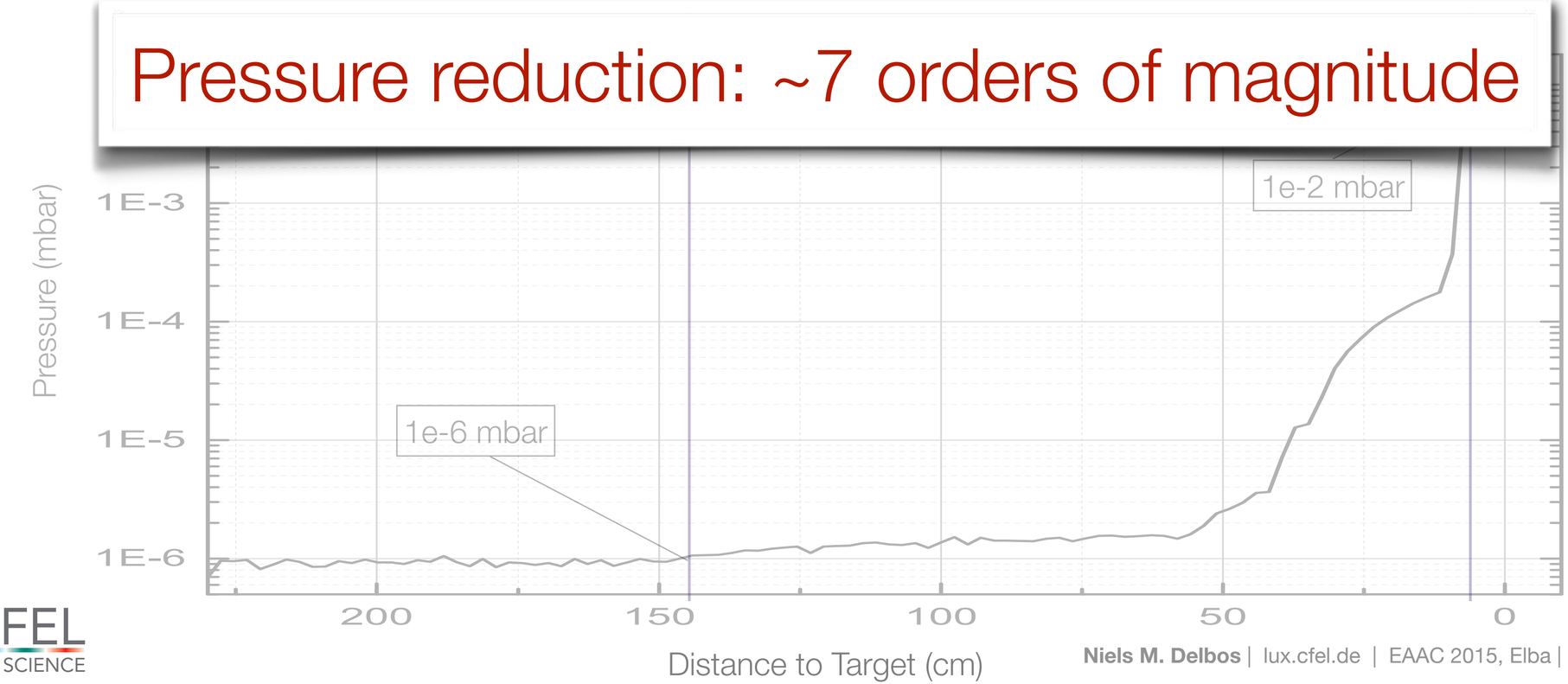


Pressure reduction: ~7 orders of magnitude



Additional Benefits of Continuous Flow Operation

Direct pressure measurement

Additional Benefits of Continuous Flow Operation

Direct pressure measurement

Pros

> Continuos flow enables direct measurement

> Absolutely calibrated

> High accuracy ± 0.2%

> Online diagnostics during experiment

> Robust

> Able to measure gas densities $< 10^{16} cm^{-3}$

Cons

> Low spatial resolution

Summary and Outlook

- Continuous flow allows for
  - High repetition rates
  - Direct pressure measurement, online with sub-% accuracy
  - Stable flow into target
- Target area installation and first tests Q1 2016
- Cross-calibration of direct pressure measurement with Raman scattering*

* in Cooperation with DESY FLA, Group J. Osterhoff

Thank you for your attention

funding

project HHH20

partners

DESY - M

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group Georg Korn

group Johannes Bahrdt

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