Characterisation and first measurements of a fully-automated mini-AMS on a passenger aircraft (IAGOS-CARIBIC)

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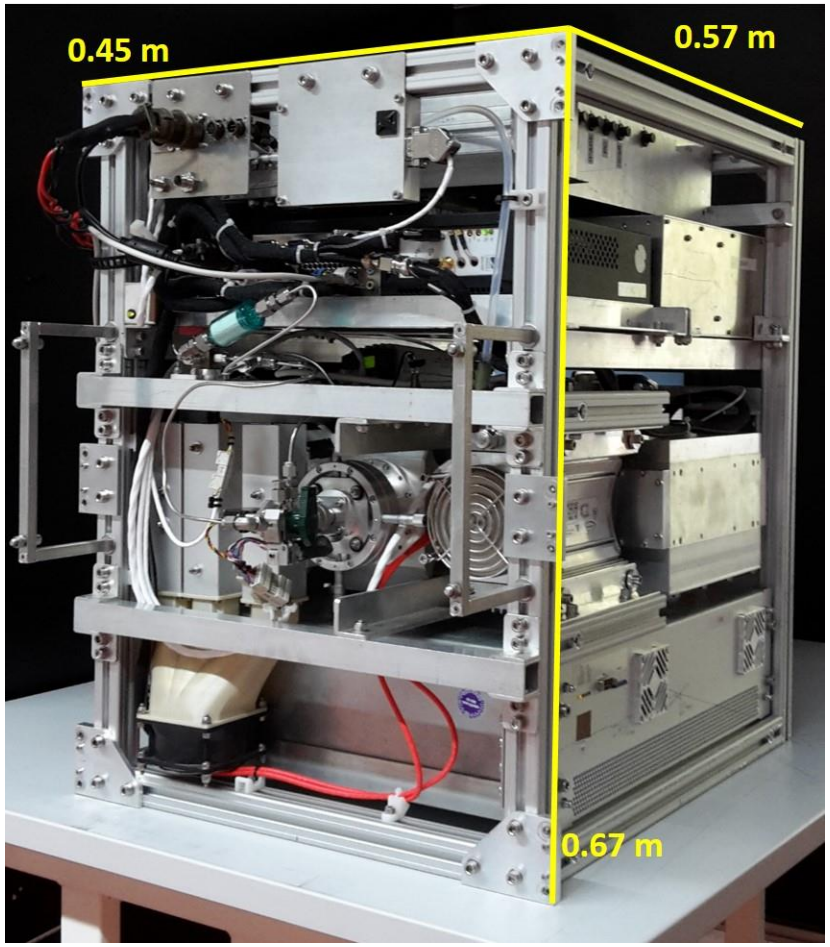
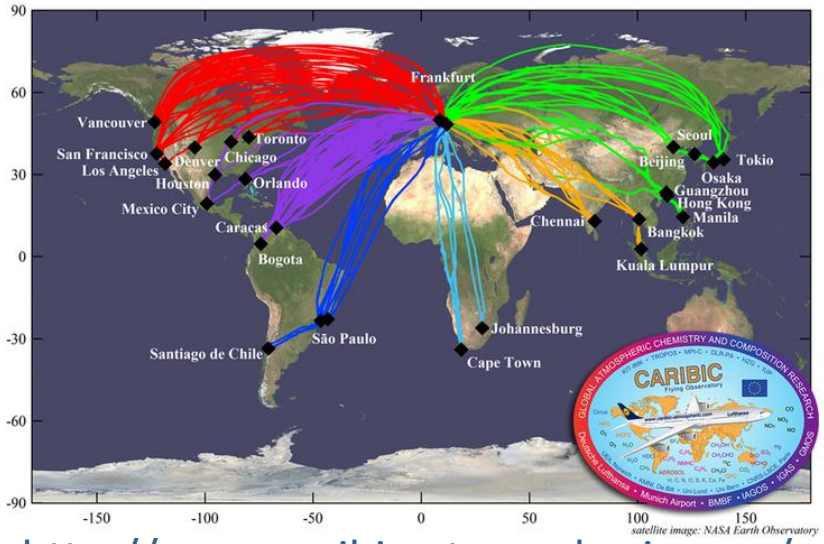
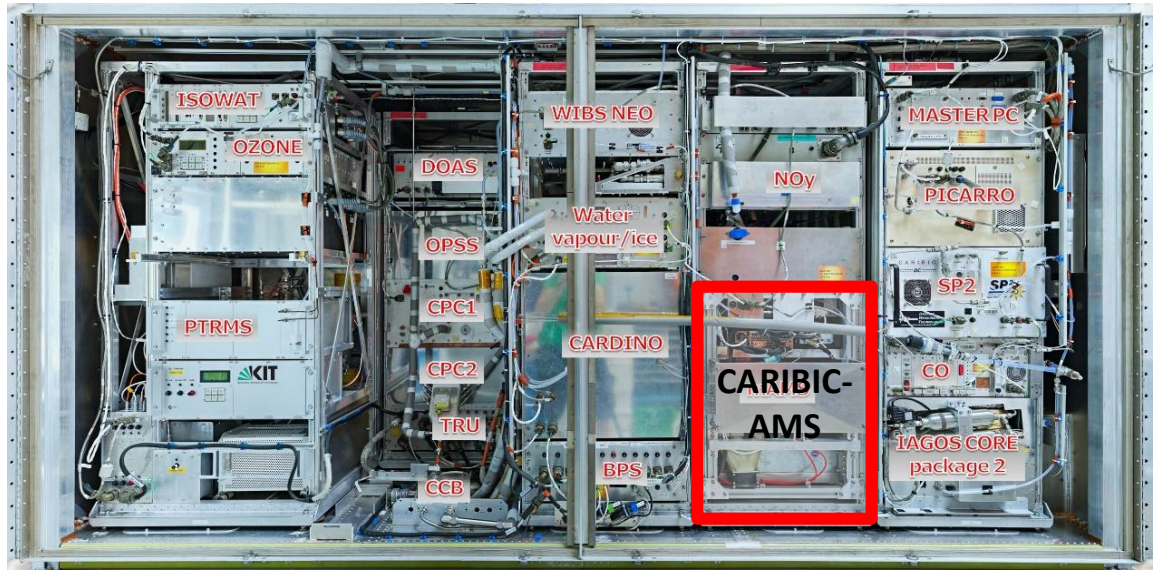


IAGOS-CARIBIC infrastructure

- IAGOS = In-service Aircraft for a Global Observing System
- European Research Infrastructure
- Part: IAGOS-CARIBIC
  - CARIBIC = Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container
  - Passenger aircraft with scientific measurement container
  - In-depth and complex investigation of UT/LS on regular basis



http://www.caribic-atmospheric.com/



Petzold, A., *et al.* (2015)

CARIBIC-AMS Timeline

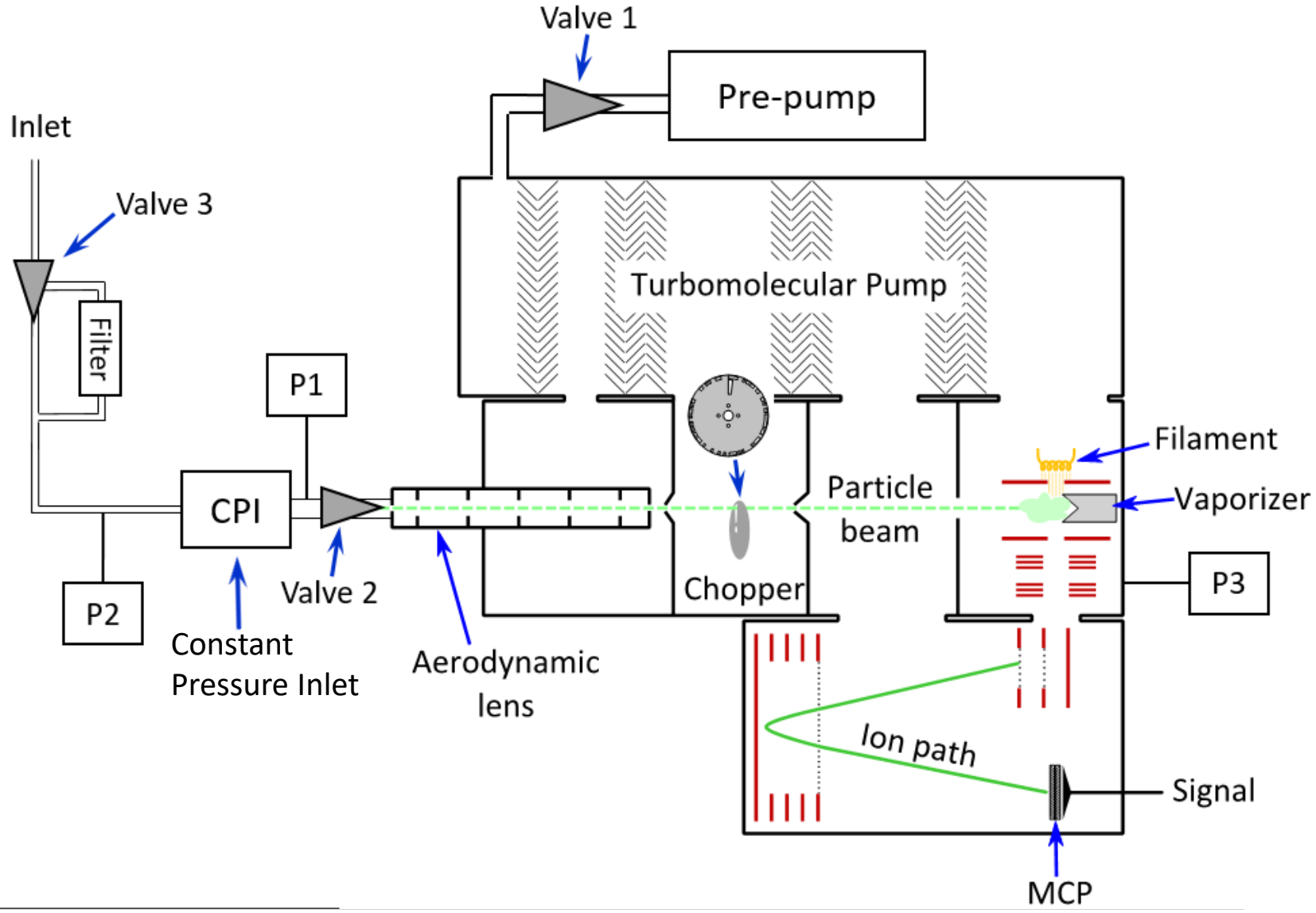
When	What
October 2012	DFG proposal (TROPOS, MPIC, JGU Mainz)
January 2014	Delivery of miniAMS
2014-2016	Reconfiguration, automatic operation, certification → Florian Rubach
January 2017	First EMI-test at Lufthansa
March 2017	New DFG proposal (TROPOS)
February 2018	First flight – no data
October 2018	First flight with recorded data
November 2018	Laboratory characterisation and comparison with HR-ToF-AMS at TROPOS → Anna Ludwig, Laurent Poulain
October 2018 – March 2020	38 flights, 14 successful with available data
March 2020	Last IAGOS-CARIBIC flight so far
Ongoing until Dec 2021	Modification and new certification for Lufthansa A350

Technical challenges for full automation

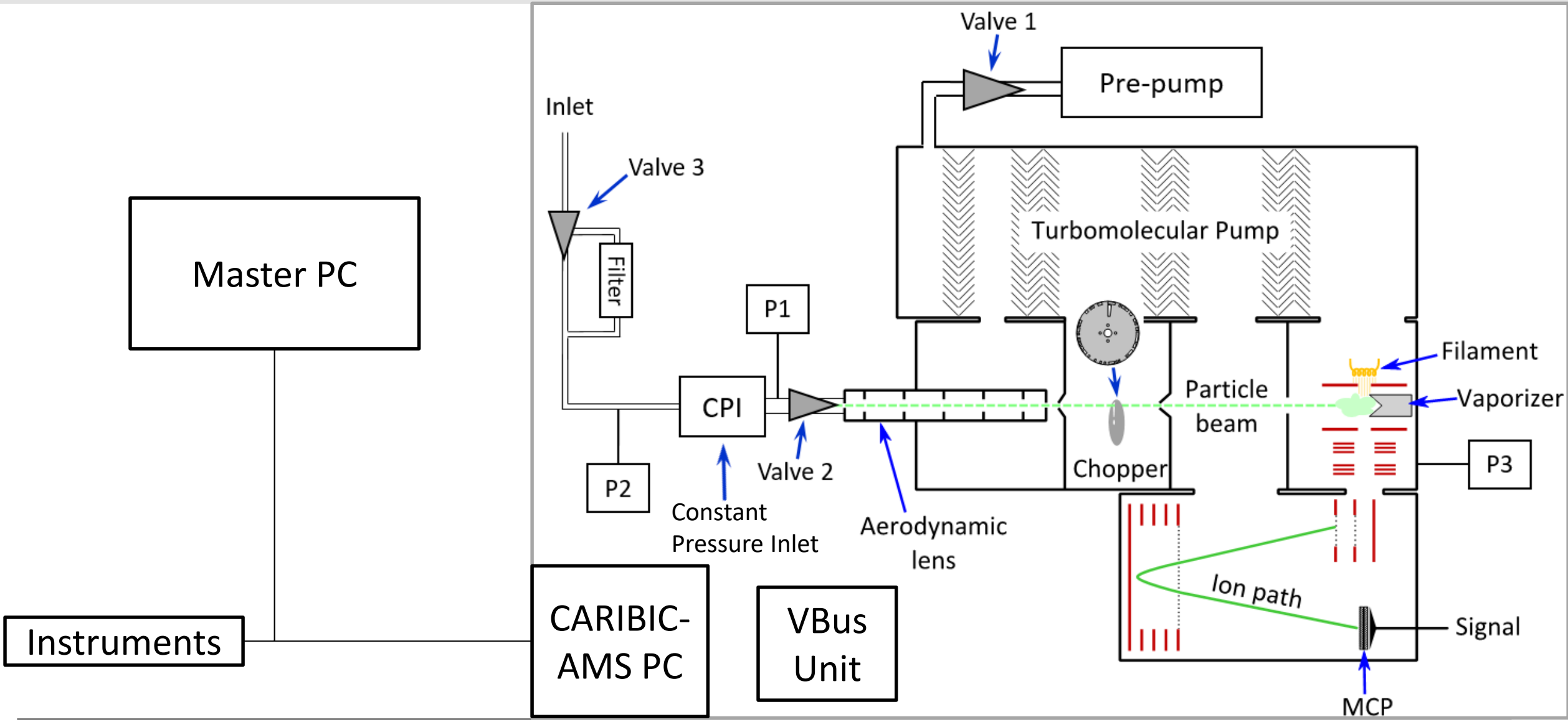
- No operator on board
- No connection to instrument
- 1 flight series = 4 flights

→ Full automation needed!

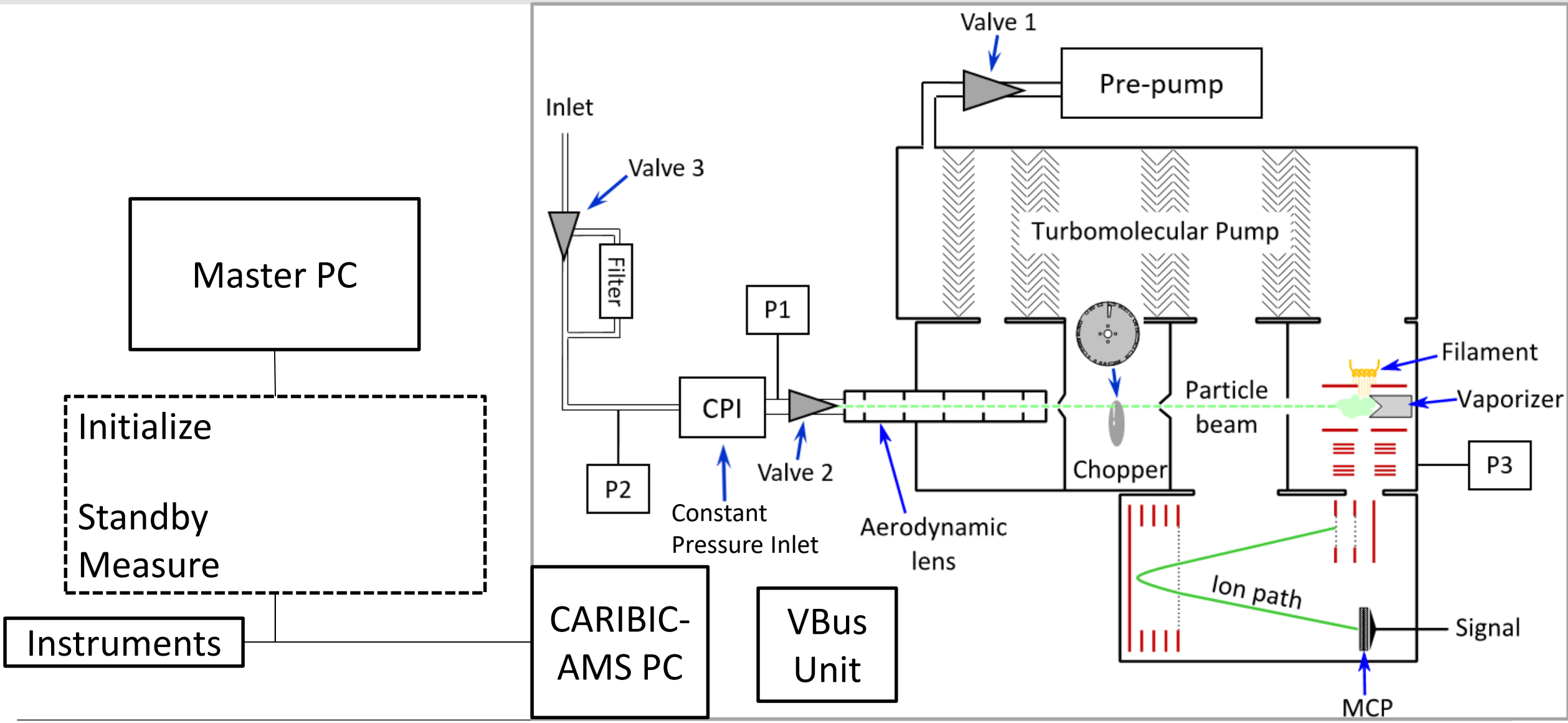
Schneider et al., in prep. for AMT



Technical challenges for full automation



Technical challenges for full automation



Technical challenges for full automation

Initialize:

- VBus unit and PC on
- CARIBIC-MAN software starts
- Everything handled by CARIBIC-MAN and VBus unit

Master PC

Initialize minimal power consumption

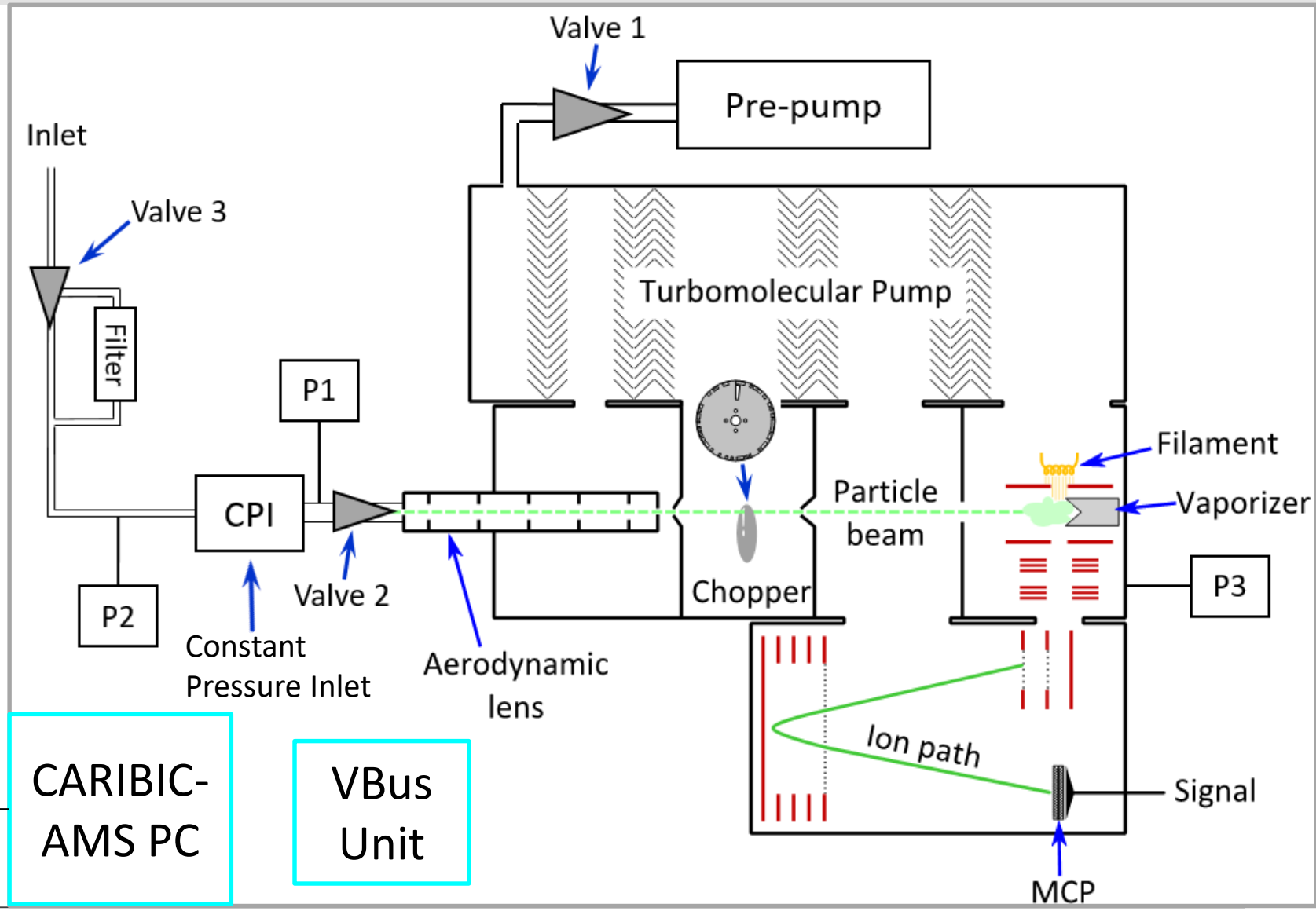
Standby

Measure

Instruments

CARIBIC-AMS PC

VBus Unit



Technical challenges for full automation

Standby:

- Pre-pump on, valve 1 open

Master PC

Initialize minimal power consumption

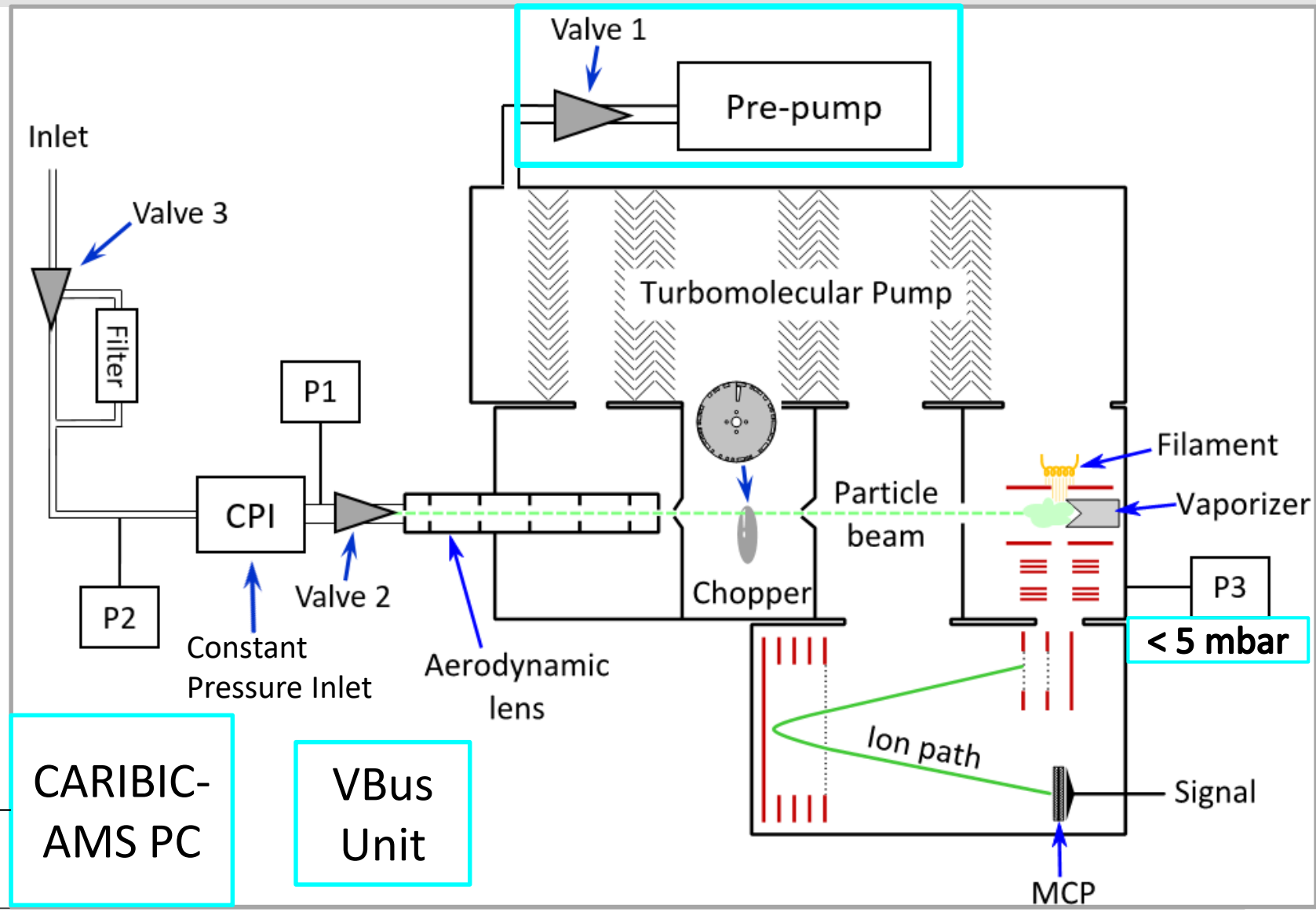
Standby p_{amb} > 800 mbar

Measure

Instruments

CARIBIC-AMS PC

VBus Unit



Technical challenges for full automation

Standby:

- Pre-pump on, valve 1 open
- Turbopump on

Master PC

Initialize minimal power consumption

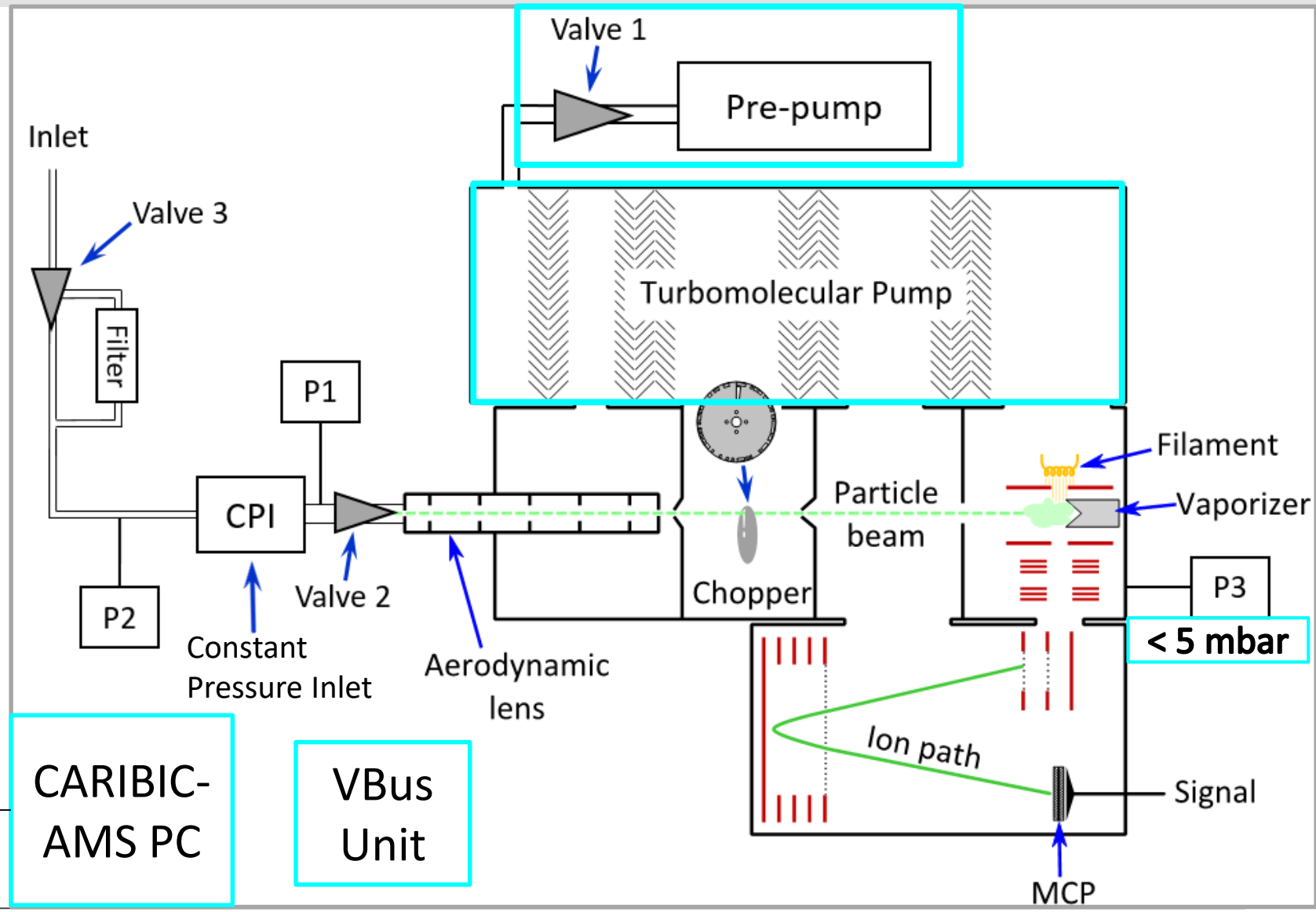
Standby p_{amb} > 800 mbar

Measure

Instruments

CARIBIC-AMS PC

VBus Unit



Technical challenges for full automation

Standby:

- Pre-pump on, valve 1 open
- Turbopump on
- TPS on, DAQ starts

Master PC

Initialize minimal power consumption

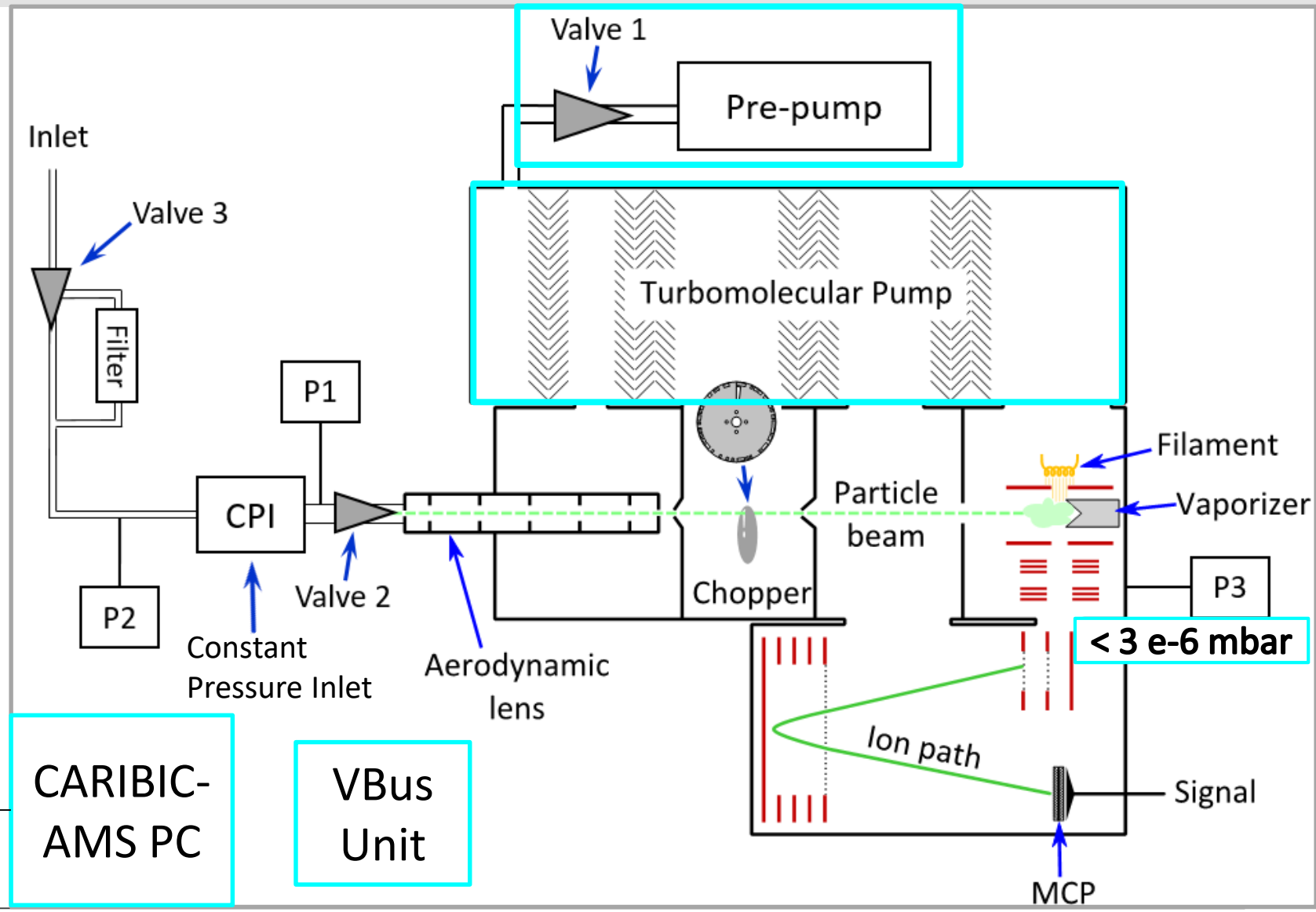
Standby p_{amb} > 800 mbar

Measure

Instruments

CARIBIC-AMS PC

VBus Unit



Technical challenges for full automation

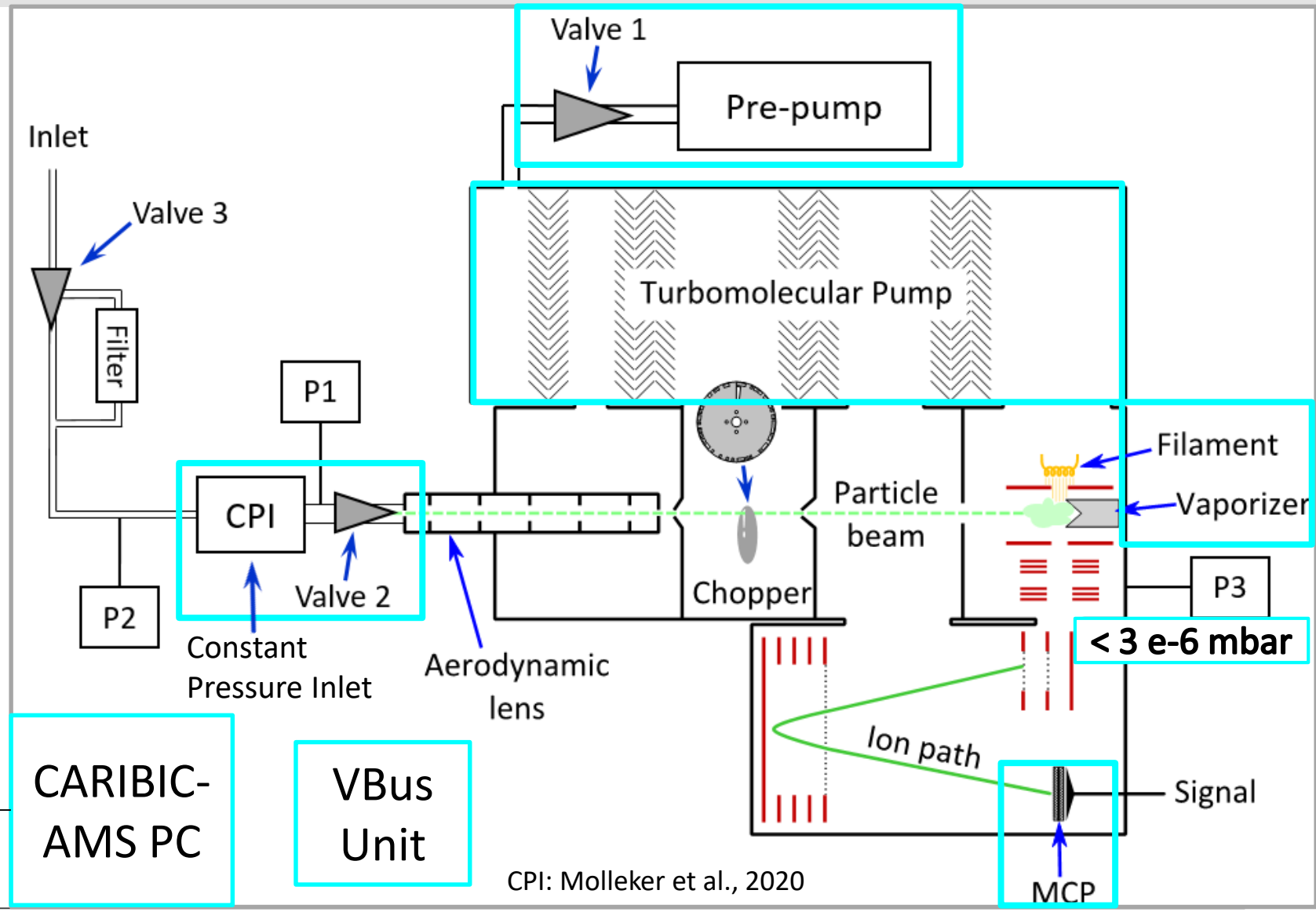
Measure:

- Valve 2 (inlet) open, CPI on
- Filament, vaporizer, MCP on

Master PC

Initialize	minimal power consumption
Standby	p_{amb} > 800 mbar
Measure	p_{amb} < 800 mbar

Instruments



CPI: Molleker et al., 2020

Technical challenges for full automation

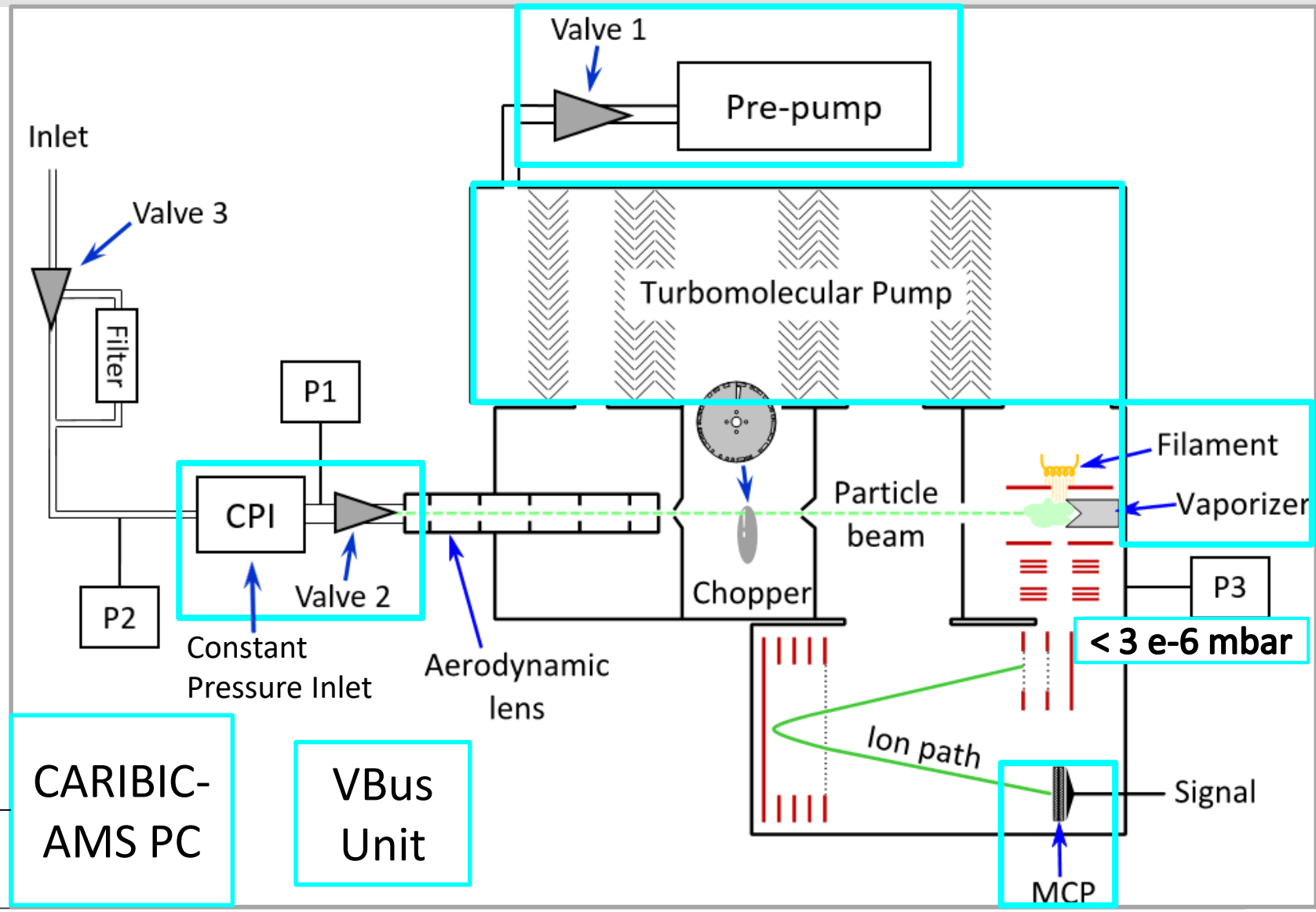
Measure:

- Valve 2 (inlet) open, CPI on
- Filament, vaporizer, MCP on
- m/z & SI calibration
- Data acquisition (ambient & filter)

Master PC

Initialize	minimal power consumption
Standby	p_{amb} > 800 mbar
Measure	p_{amb} < 800 mbar

Instruments



CARIBIC-AMS PC

VBus Unit

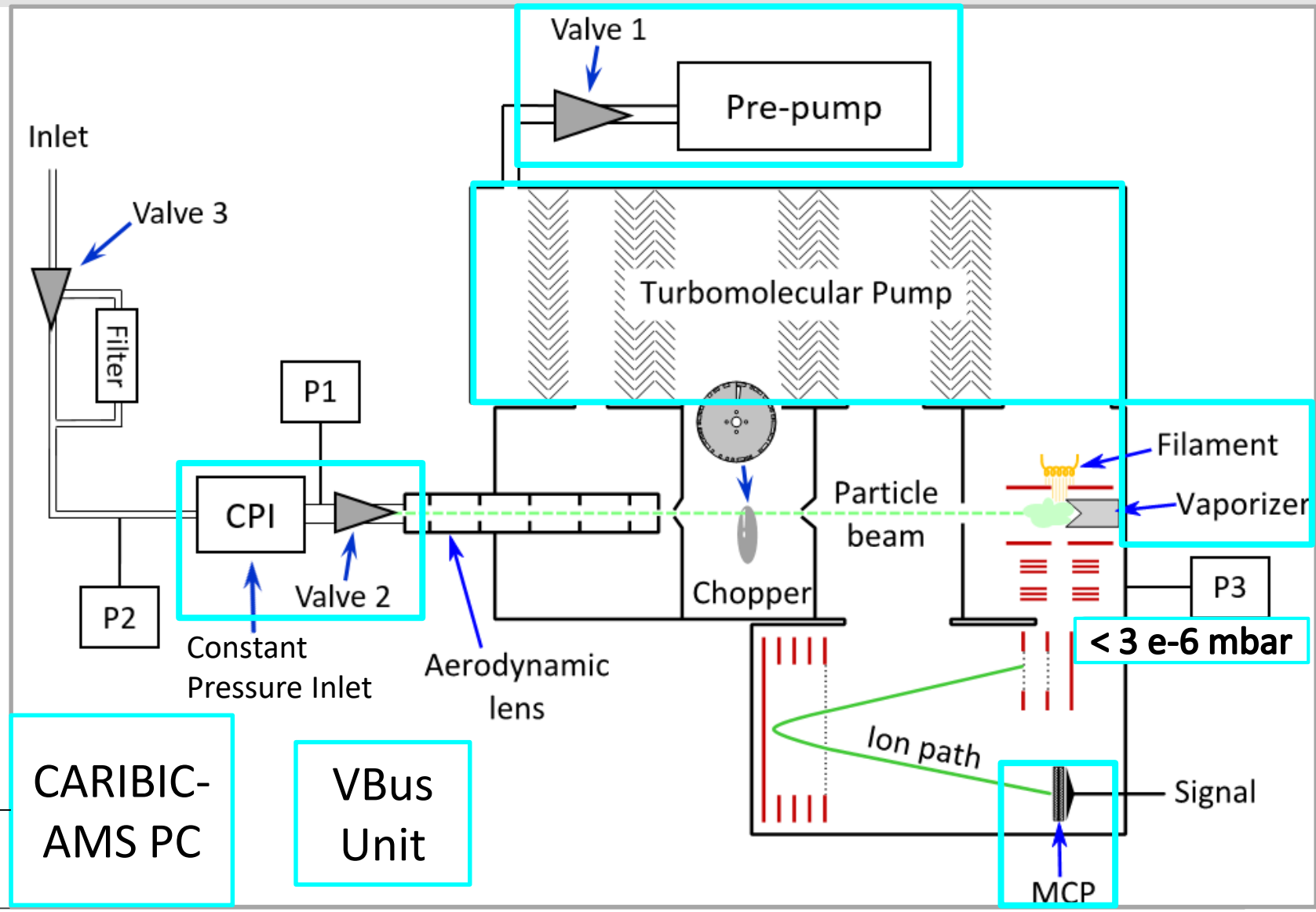
Technical challenges for full automation

Standby:
- Valve 2 (inlet) closed
- DAQ stops
- Voltages off

Master PC

Initialize	minimal power consumption
Standby	p_{amb} > 800 mbar
Measure	p_{amb} < 800 mbar

Instruments



CARIBIC-AMS PC

VBus Unit

Technical challenges for full automation

Power off

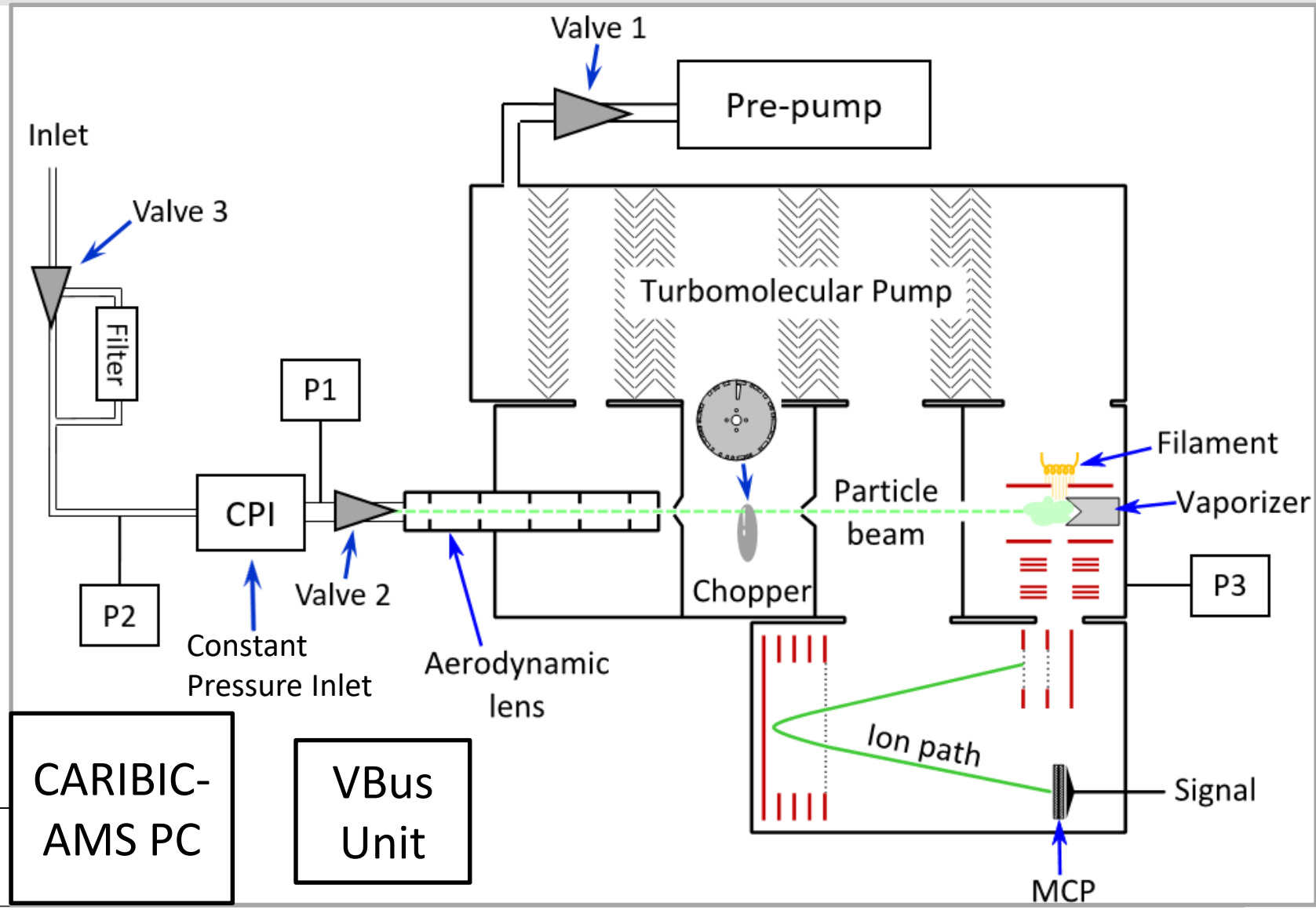
Master PC

Initialize	minimal power consumption
Standby	p_{amb} > 800 mbar
Measure	p_{amb} < 800 mbar

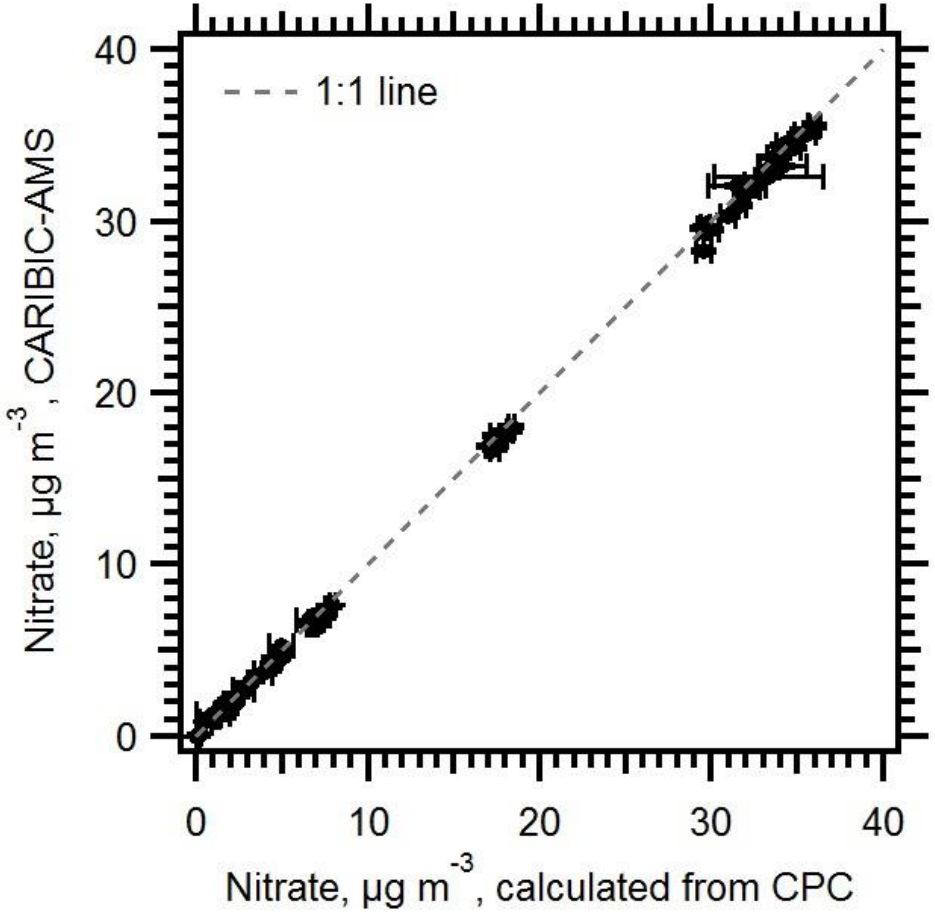
Instruments

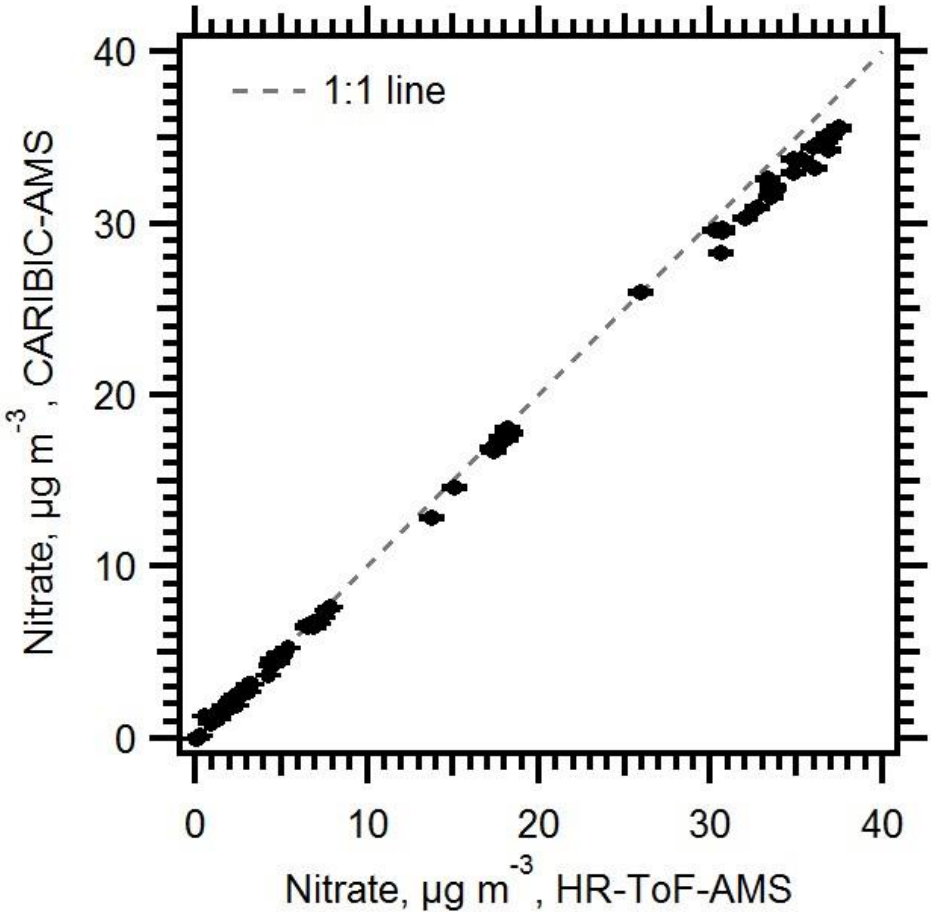
CARIBIC-AMS PC

VBus Unit



Comparison measurements

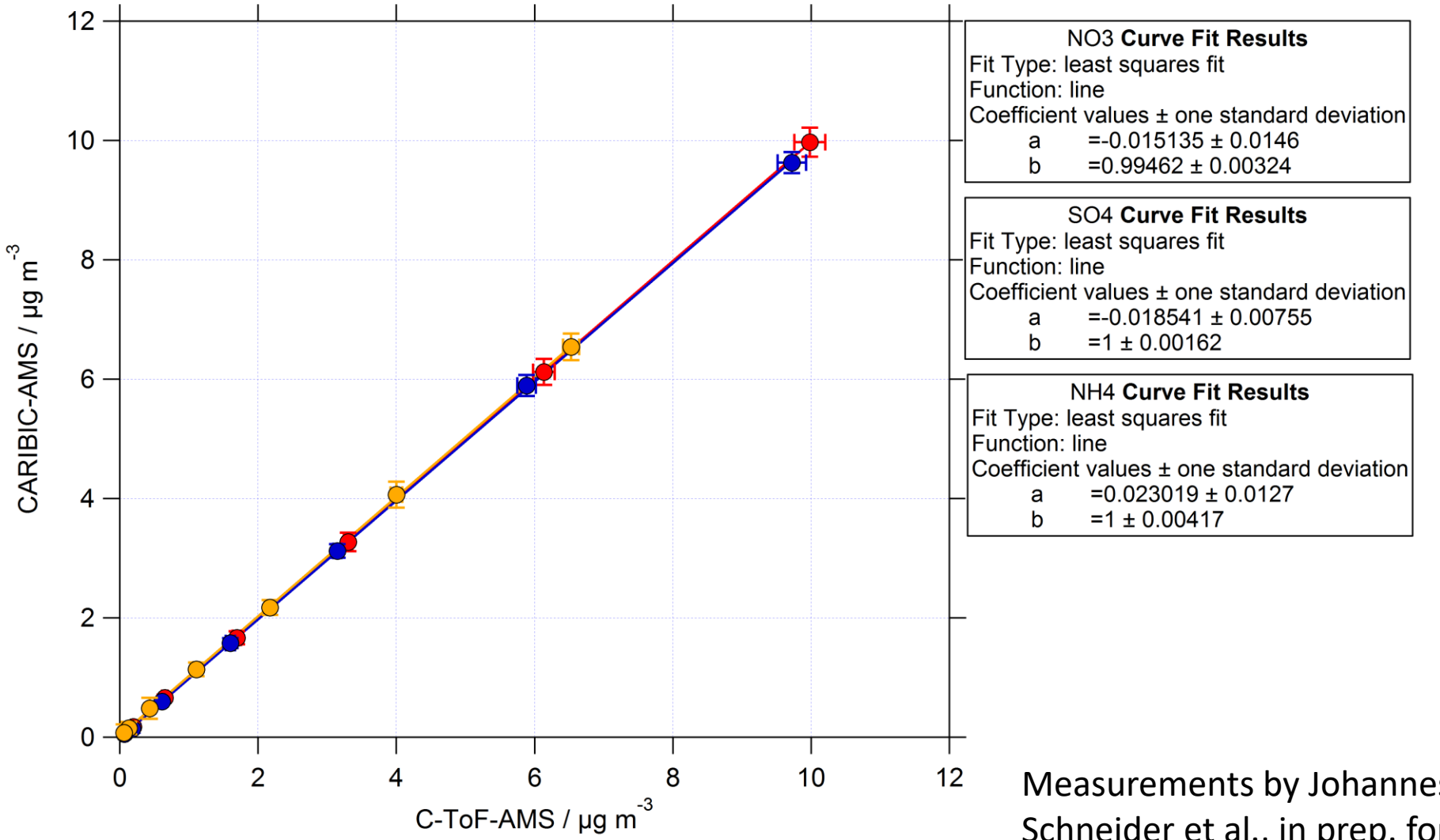




- AMS calibrated with CPC
- Comparison with HR-ToF-AMS
  - Very good agreement between CARIBIC-AMS and HR-ToF-AMS

Measurements by Anna Ludwig and Laurent Poulain
Schneider et al., in prep. for AMT

Comparison measurements



- Comparison with C-ToF-AMS
  - Very good agreement for different species

Measurements by Johannes Schneider and Christiane Schulz
Schneider et al., in prep. for AMT

ePToF-Chopper

- MPIC-internal developed automation
  → Electronics workshop, Christian Gurk
- Sequence length: 127
- Oversample: 6; standard value is 2? (https://sites.google.com/site/tofamsdaq/manual-v5/menu-window/configuring-eptof)

ePToF-Chopper

- MPIC-internal developed automation
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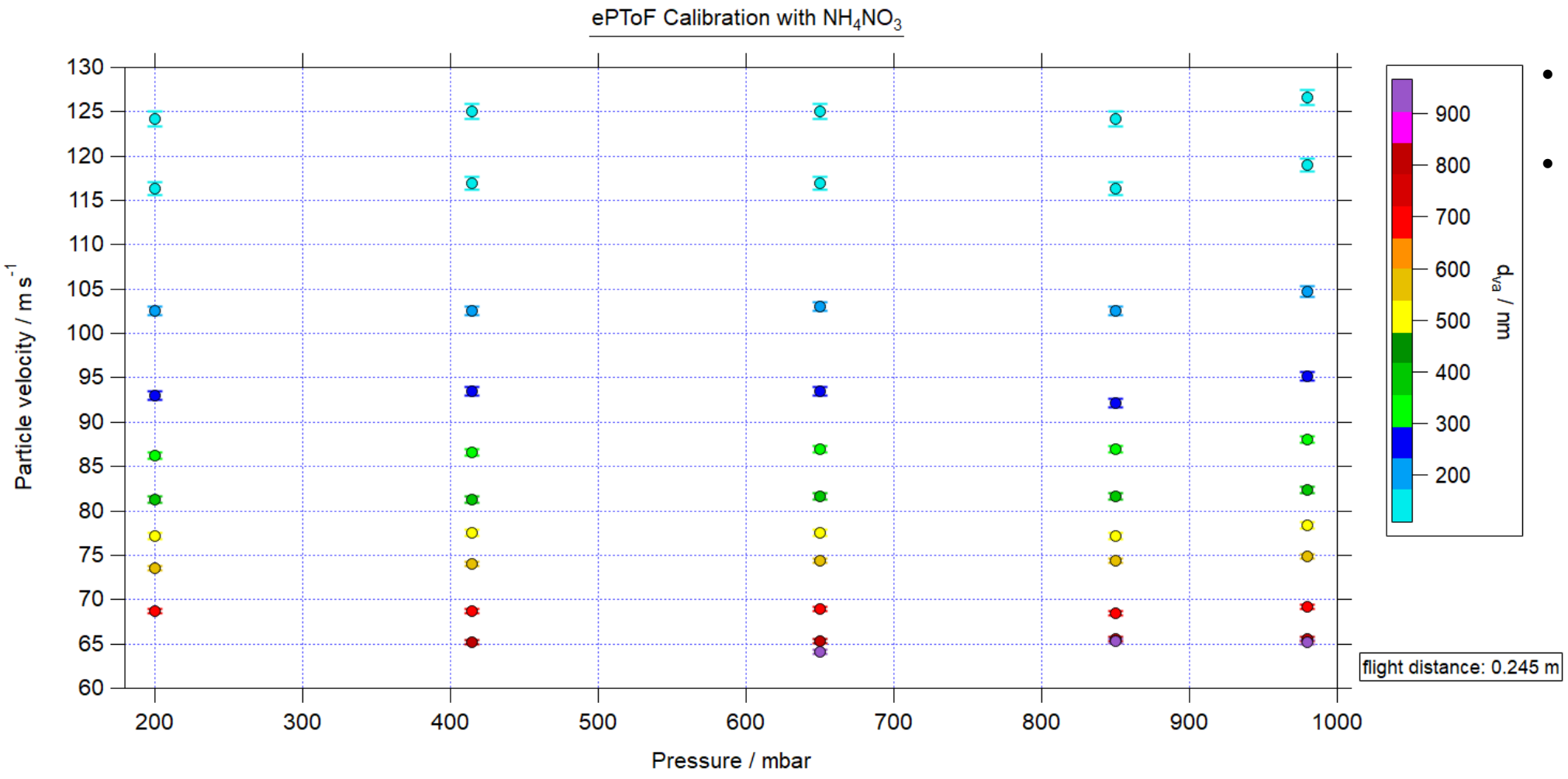
- Sequence length: 127
- Oversample: 6; standard value is 2? (https://sites.google.com/site/tofamsdaq/manual-v5/menu-window/configuring-eptof)
- Microprocessor with frequency and phase automated rotating field
- Feedback of microprocessor via optical scanning of rotation
- Microprocessor gets pulse from chopper once per rotation
- Microprocessor generates a virtual „slit"-signal which is in phase with extraction pulses generated from MS (every 762 = 127 * 6) → triggering of data aquisition; efficiency > 95%
  - Issue: if the virtual slit signal is not in phase with extraction pulse, some complete chopper rotations will not be used for measurements → efficiency below 50%
- Real phase of chopper adjusted relative to virtual slit pulses
- Besides: maintenance checks if chopper wheel does not hit the wall, servo is not consuming to much power

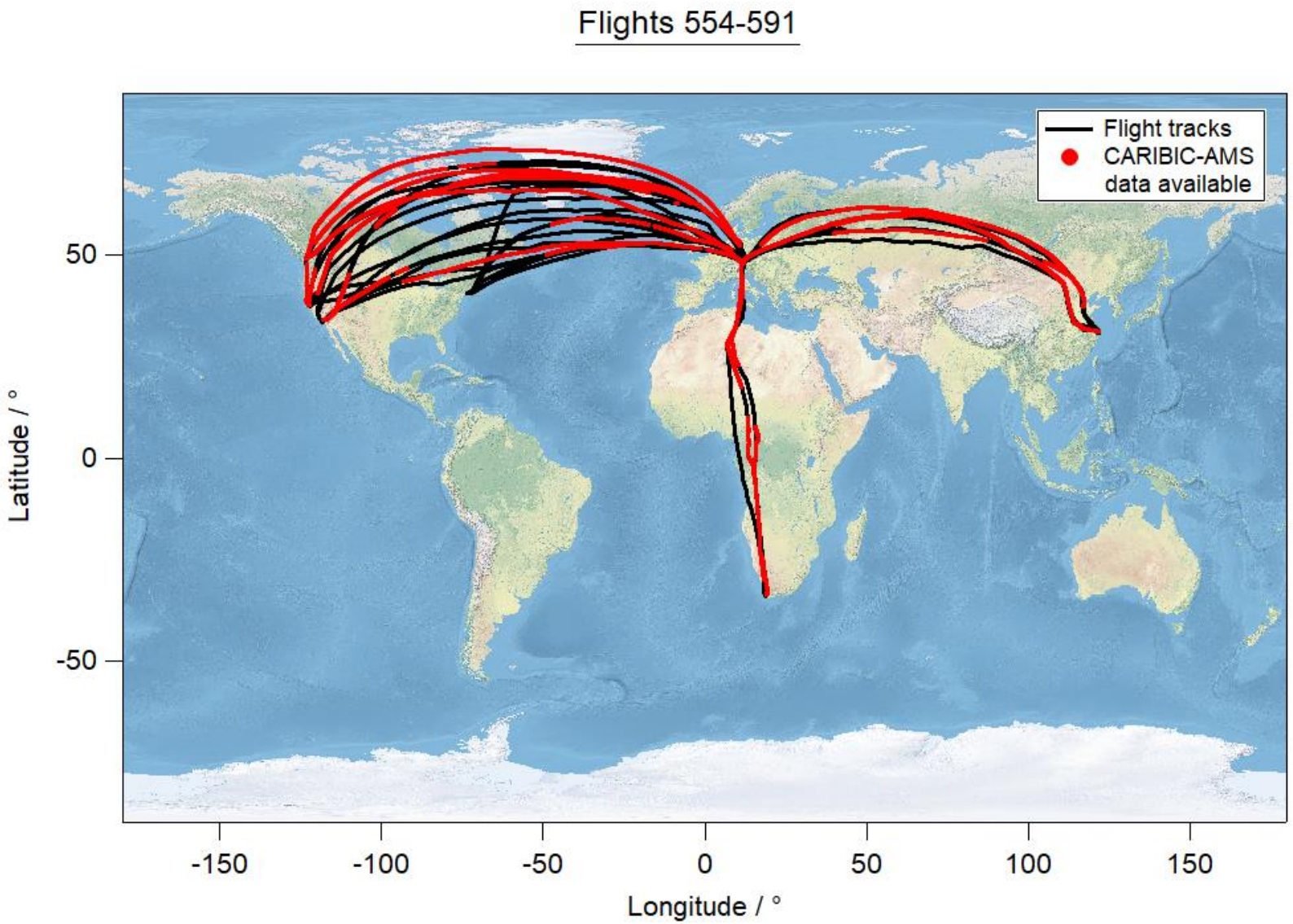
ePToF



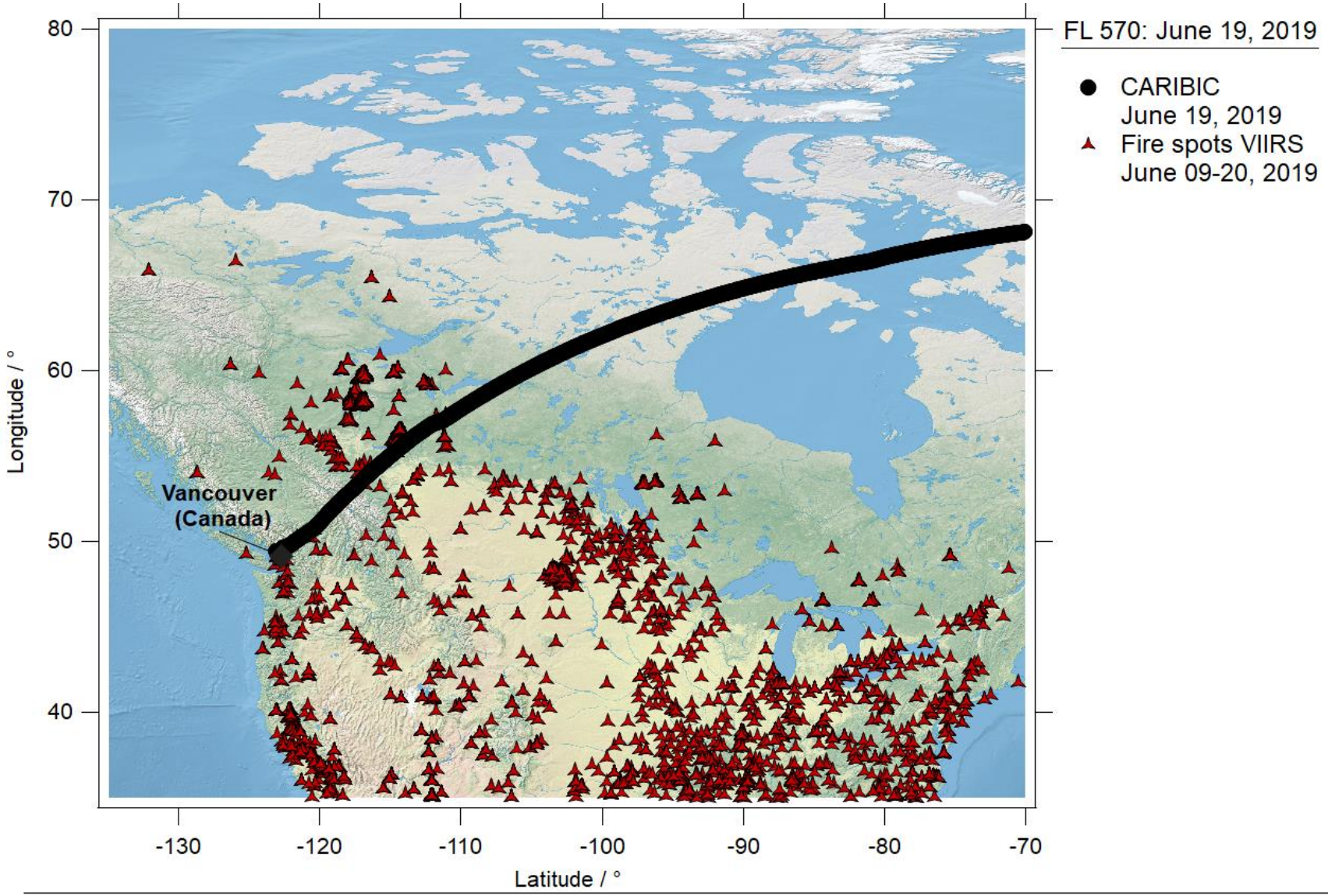
- No pressure dependence
- CPI provides constant mass flow and pressure in aerodynamic lens

Data availability

- October 2018 – March 2020 → 38 flights
- 14 successful with (partly) available data



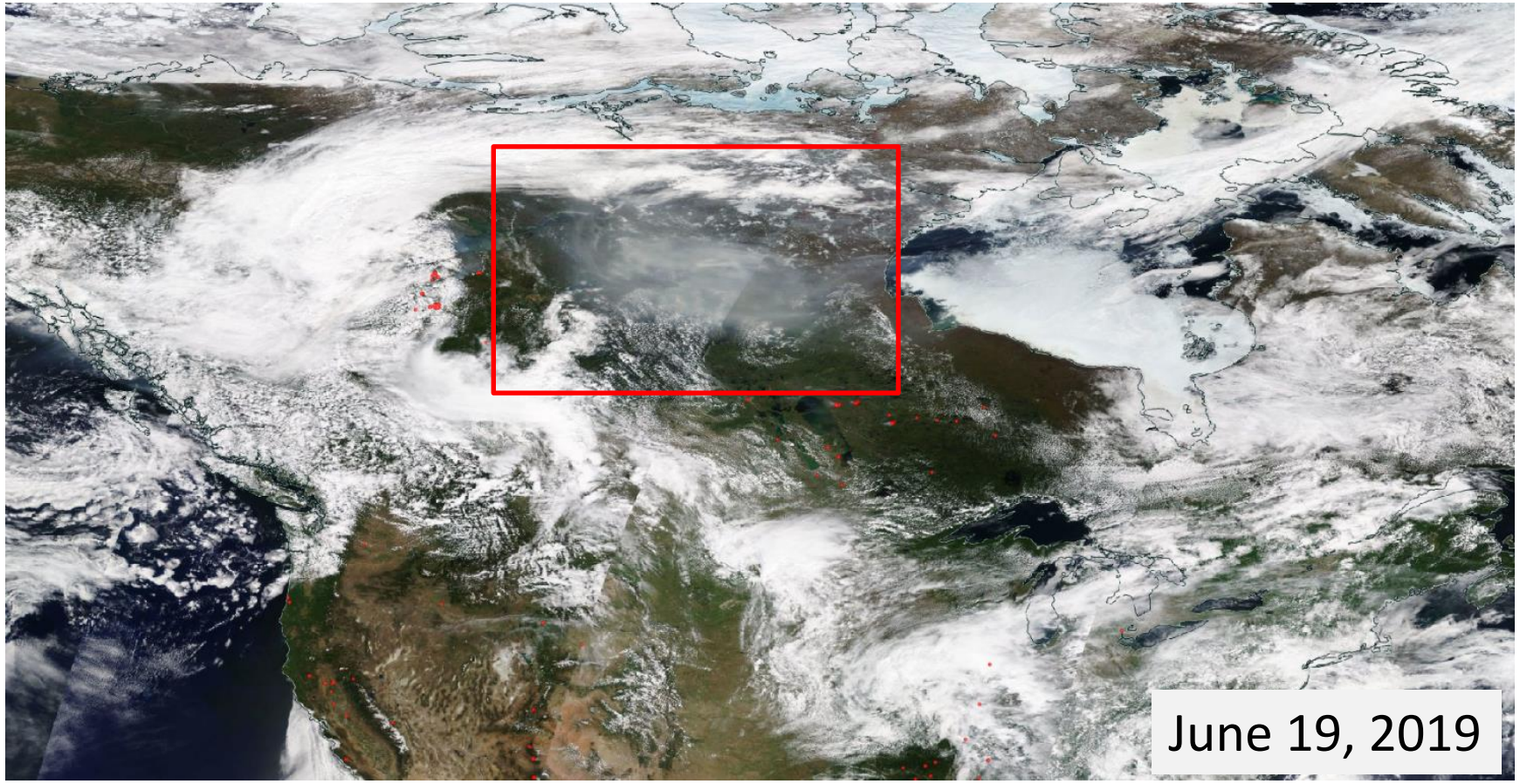
Case Study: Alberta forest fire plume, June 2019



- FL570: Munich – Vancouver
- June 2019: forest fires in Canada for several days
- Plume visible by satellite

Schulz et al., EAC, 2020

Case Study: Alberta forest fire plume, June 2019



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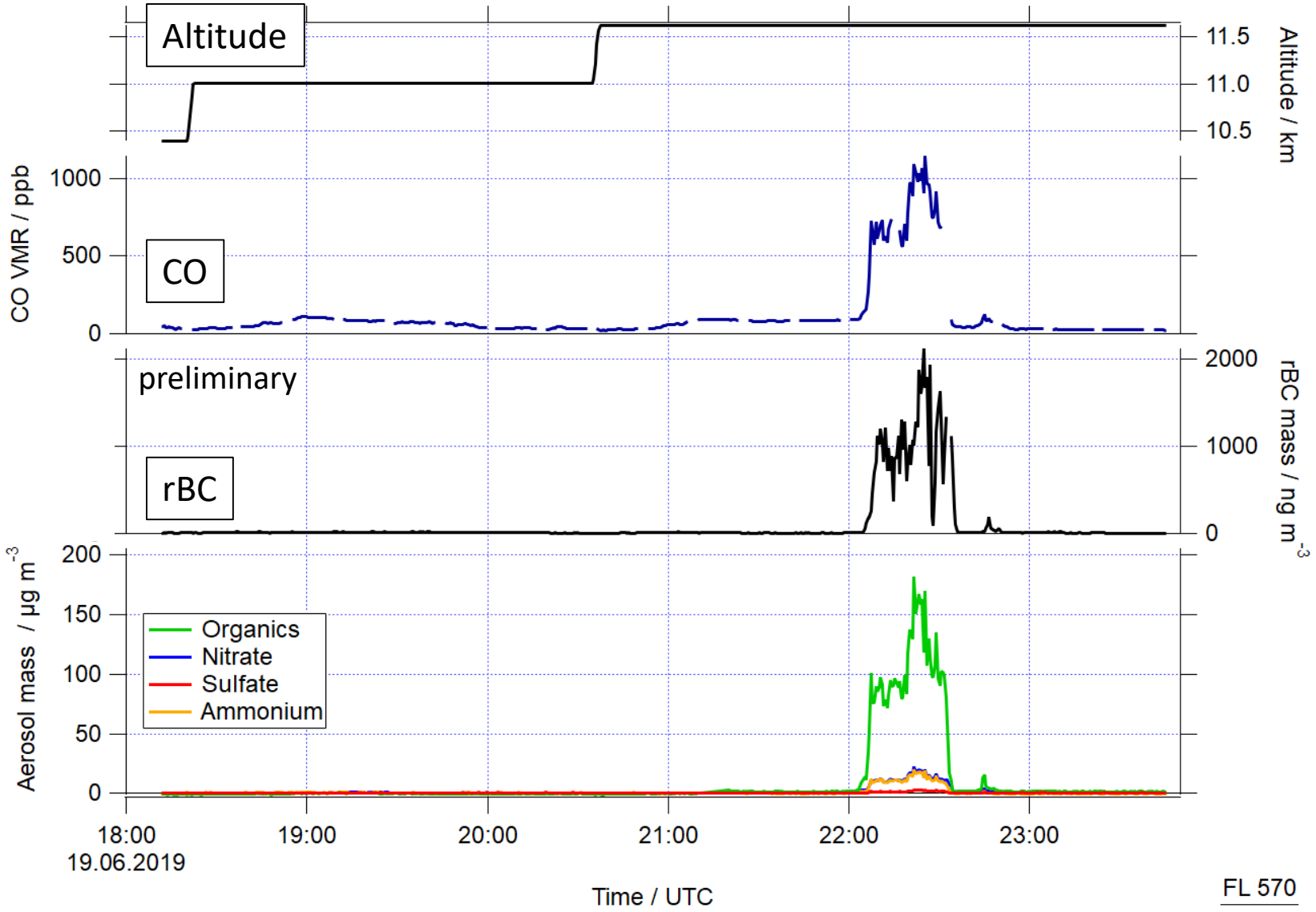
https://wvs.earthdata.nasa.gov/api/v1/snapshot?REQUEST=GetSnapshot&TIME=2019-06-19T00:00:00Z&BBOX=34.9734375,-138.0375,73.153125,-63.857812499999994&CRS=EPSG:4326&LAYERS=MODIS_Terra_CorrectedReflectance_TrueColor,Coastlines,MODIS_Combined_Thermal_Anomalies_All&WRAP=day,x,none&FORMAT=image/png&WIDTH=1688&HEIGHT=869&ts=1597405116941

Schulz et al., EAC, 2020

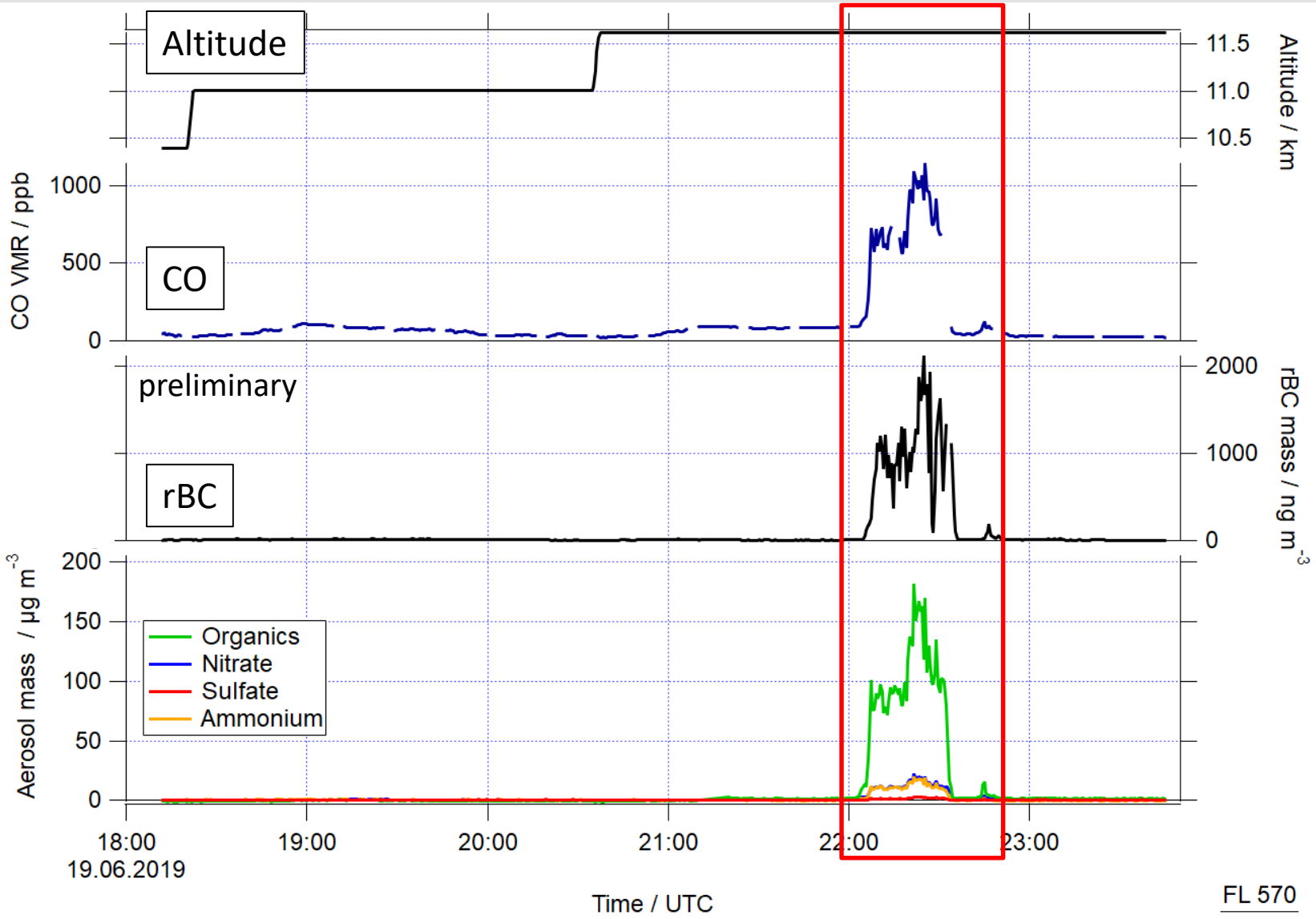
Case Study: Alberta forest fire plume, June 2019



- Low values for most part of the flight
- One massive plume event

Schulz et al., EAC, 2020

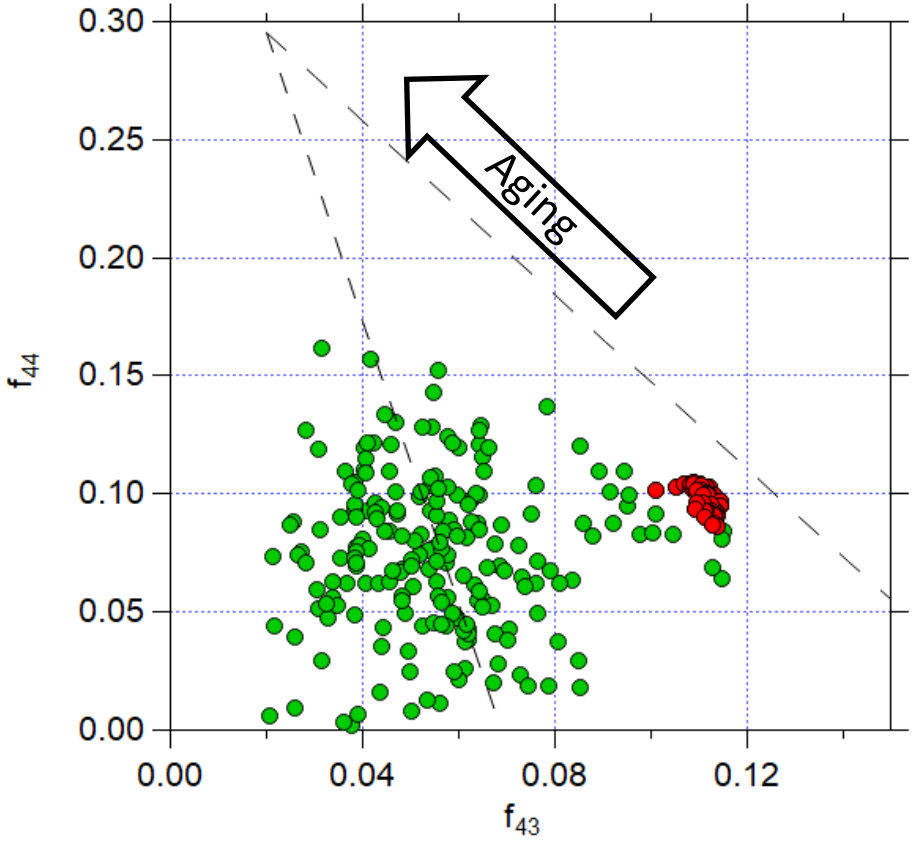
Case Study: Alberta forest fire plume, June 2019

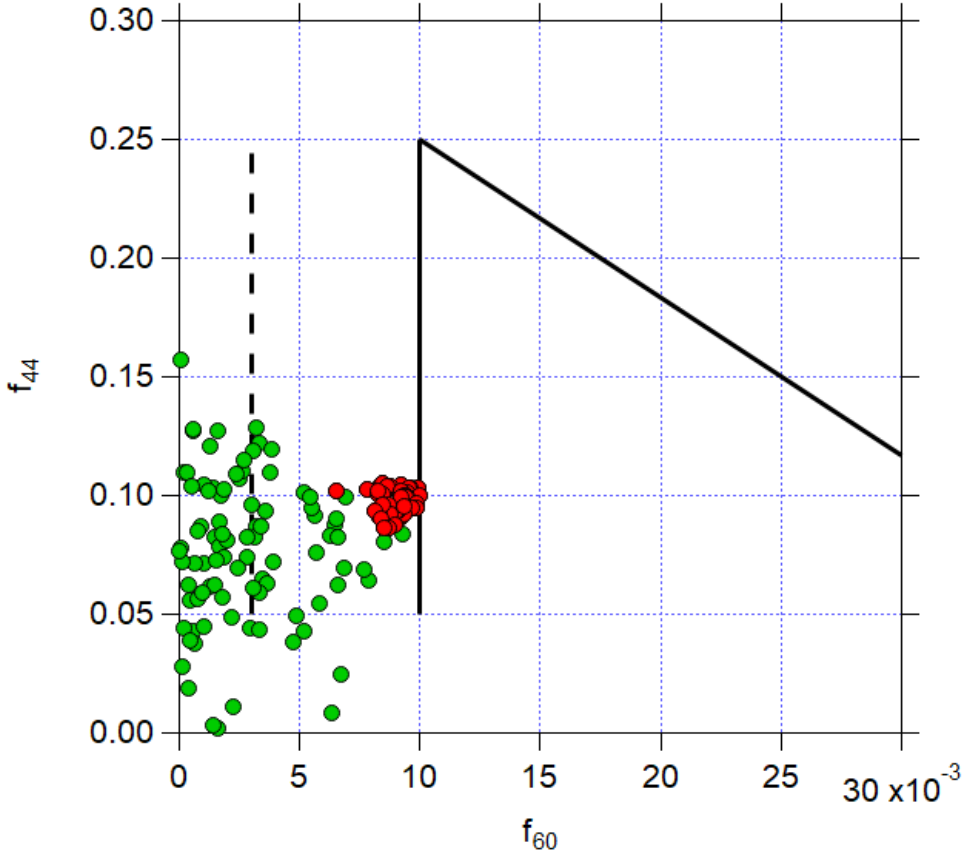


- Low values for most part of the flight
- One massive plume event
- CO -> 1200 ppb
- rBC -> 2 µg m^{-3}
- Org, NO_3, NH_4 ↑
- Aerosol mass conc. (sum) -> 220 µg m^{-3}

Schulz et al., EAC, 2020

Case Study: Alberta forest fire plume, June 2019





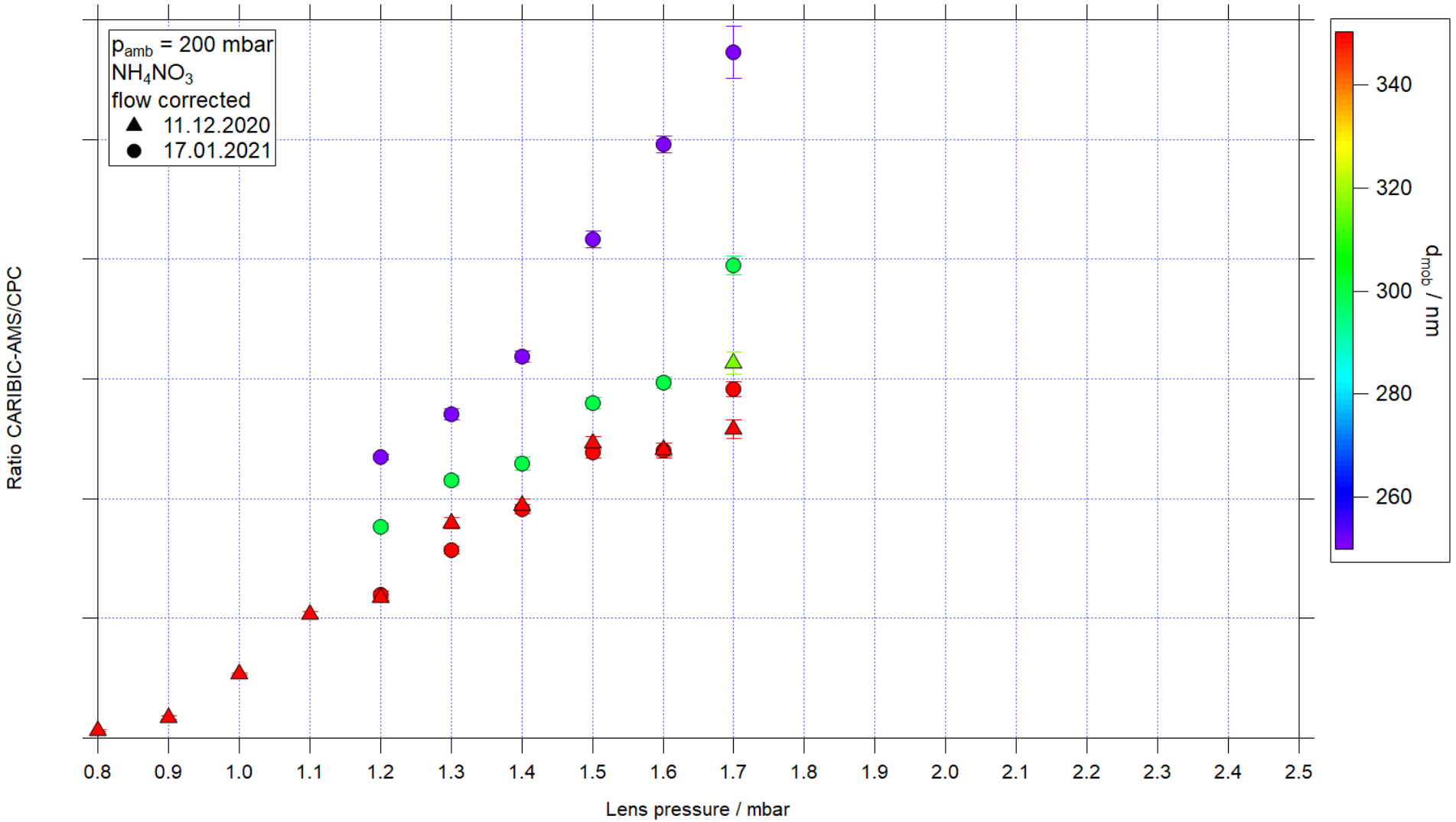
Ng et al., 2010

Cubison et al., 2011

Organic aerosol from forest fires not strongly oxidized, but partly processed

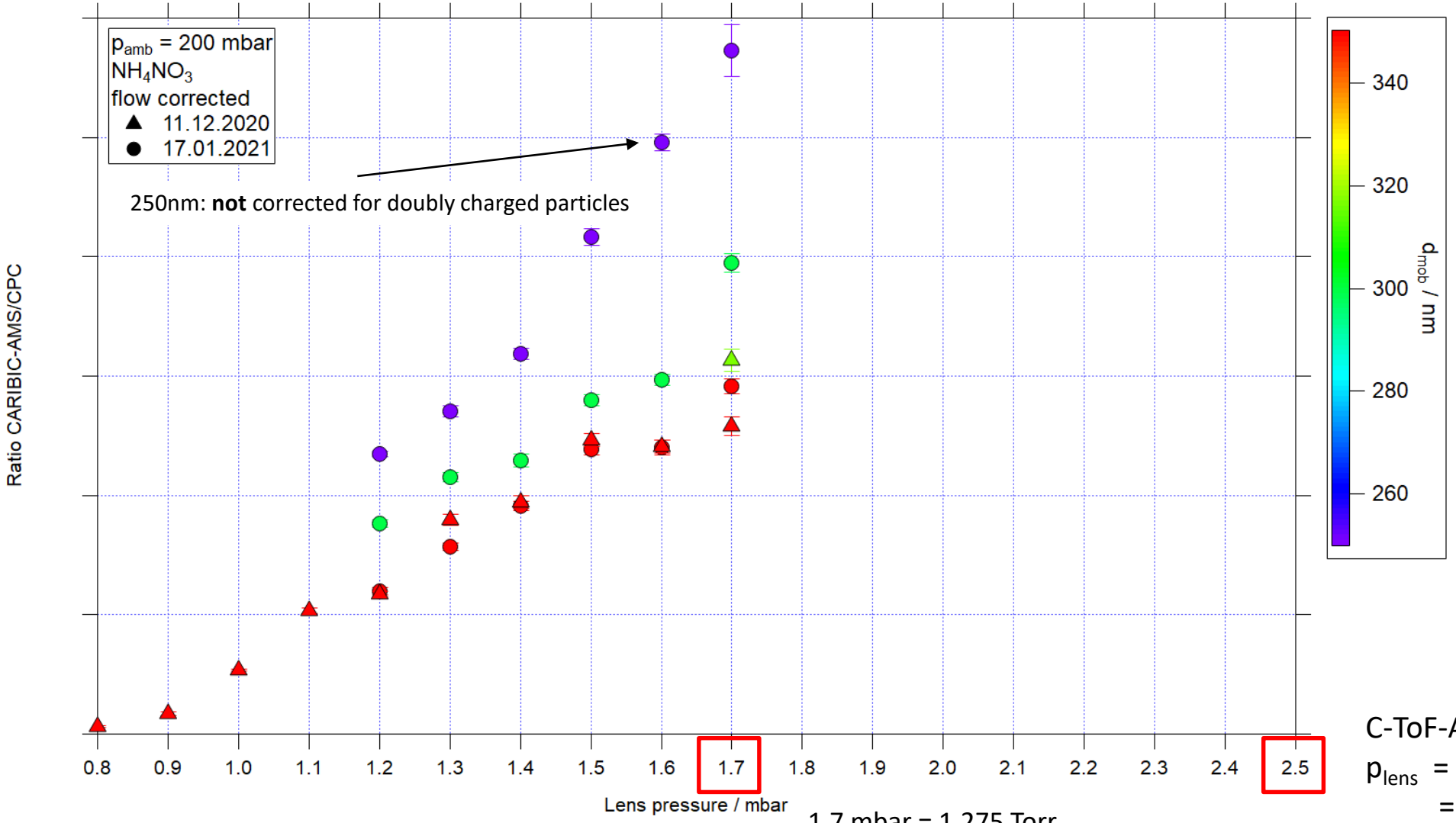
Schulz et al., EAC, 2020

Lens pressure measurements



- Ongoing laboratory measurements
- Lens transmission not ideal
- Idea: lens pressure too low

Lens pressure measurements



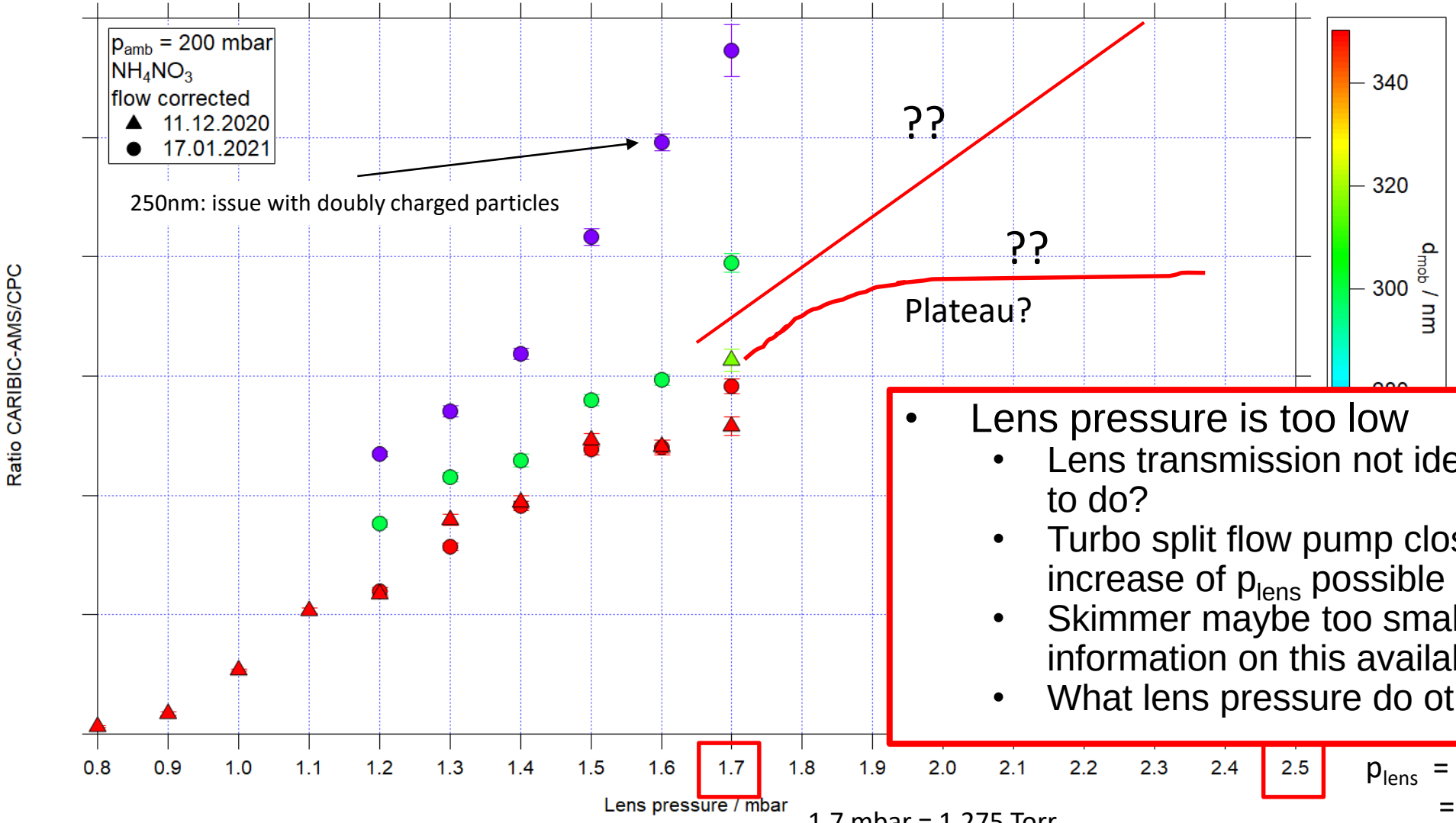
- Ongoing laboratory measurements
- Lens transmission not ideal
- Idea: lens pressure too low

- Issue: increasing p_{lens} not possible → turbo pump power consumption close to maxiumum

1.7 mbar = 1.275 Torr

C-ToF-AMS:
p_{lens} = 2.5 mbar
= 1.9 Torr

Lens pressure measurements



- Ongoing laboratory measurements
- Lens transmission not ideal
- Idea: lens pressure too low

- Issue: increasing p_{lens} not possible → turbo pump power consumption close

- Lens pressure is too low
  - Lens transmission not ideal at the moment → what to do?
  - Turbo split flow pump close to maximum → no increase of p_{lens} possible
  - Skimmer maybe too small → need to check, any information on this available?
  - What lens pressure do other miniAMS-users have?

1.7 mbar = 1.275 Torr

p_{lens} = 2.5 mbar
= 1.9 Torr

Thank you for your attention!

<u>Acknowledgements:</u>

IAGOS-CARIBIC Team
DFG
BMBF
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NASA Earthdata