Presenting the Omnistar

E. Engelhardt, E. Fiedler, W. Aeschbach

Institute of Environmental Physics, University of Heidelberg, Germany

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

INSTITUT FÜR UMWELTPHYSIK

Why the Omnistar?

INSTITUT FÜR UMWELTPHYSIK

Environmental Science & Technology

Article

pubs.acs.org/est

Membrane Inlet Mass Spectrometer for the Quasi-Continuous On-Site Analysis of Dissolved Gases in Groundwater

Lars Mächler,*[,†,‡] Matthias S. Brennwald,[†] and Rolf Kipfer[†,§]

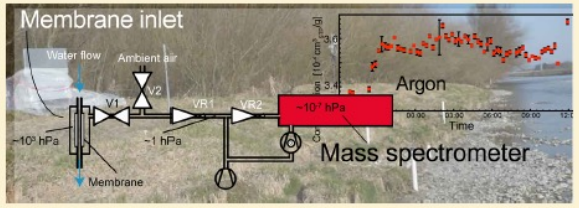
[†]Department of Water Resources and Drinking Water, Eawag, Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland

[‡]Institute of Biogeochemistry and Pollutant Dynamics, ETH Zürich, Zürich, Switzerland

[§]Institute of Geochemistry and Petrology, ETH Zürich, Zürich, Switzerland

Supporting Information

ABSTRACT: We developed a stand-alone system based on a membrane inlet mass spectrometer (MIMS) for measuring dissolved gas concentrations in groundwater under field conditions. The system permits the concentrations of dissolved gases (He, Ar, Kr, N_2, and O_2) in groundwater to be determined quasi-continuously (every 12 min) with a precision of better than 4% for He and Kr, and with a precision of 1% for Ar, N_2, and O_2 in air-saturated water. The detection limits are below 3×10^{-9} cm^3_{STP}/g for the noble gases and below 400×10^{-9} cm^3_{STP}/g for N_2 and O_2. The results of a first deployment of the system in the field indicate that changes in the concentration of Ar that result from diel fluctuations of 3 °C in the river water temperature were still able to be resolved in groundwater, although the corresponding temperature signal almost vanished.



2012

Why the Omnistar?

INSTITUT FÜR UMWELTPHYSIK

ENVIRONMENTAL Science & Technology

Article

pubs.acs.org/est

Membrane Inlet Mass Spectrometer for the Quasi-Continuous On-Site Analysis of Dissolved Gases in Groundwater

Lars Mächler,*[,†,‡] Matthias S. Brennwald,[†] and Rolf Kipfer[†,§]

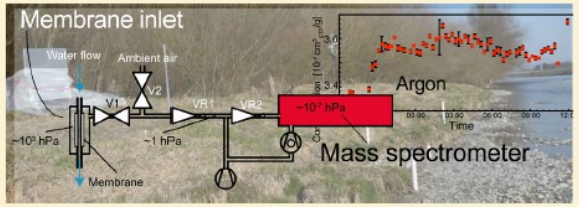
[†]Department of Water Resources and Drinking Water, Eawag, Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland

[‡]Institute of Biogeochemistry and Pollutant Dynamics, ETH Zürich, Zürich, Switzerland

[§]Institute of Geochemistry and Petrology, ETH Zürich, Zürich, Switzerland

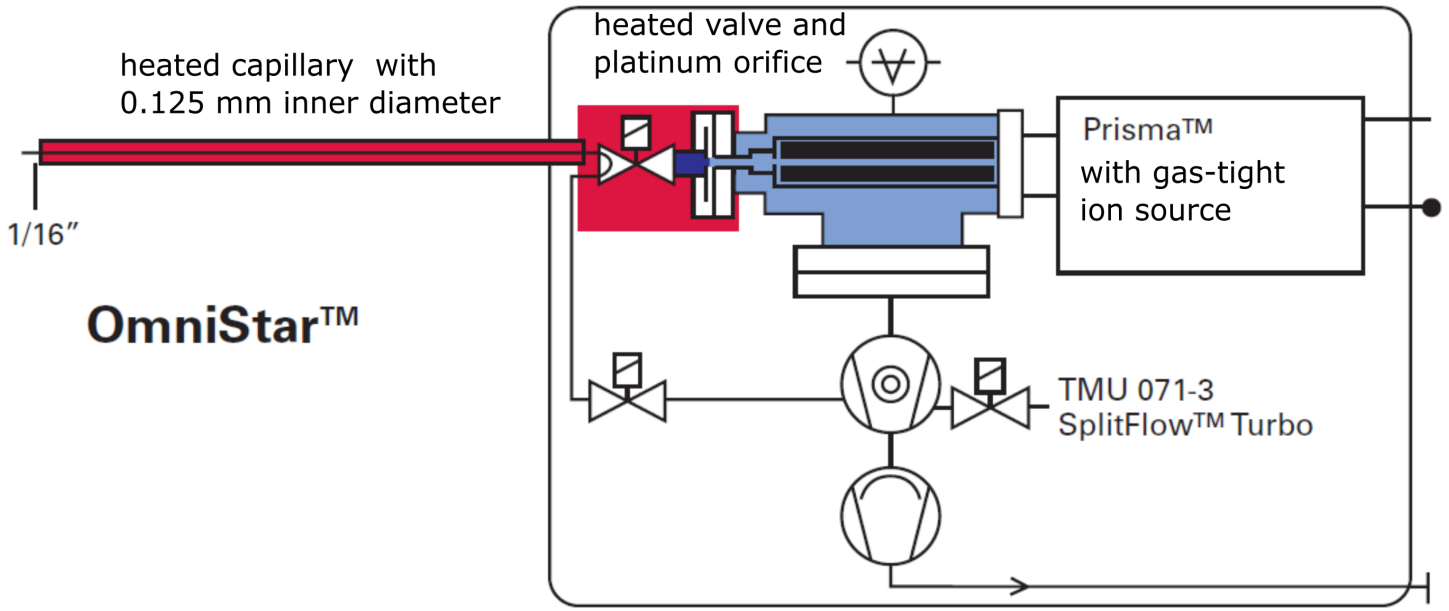
Supporting Information

ABSTRACT: We developed a stand-alone system based on a membrane inlet mass spectrometer (MIMS) for measuring dissolved gas concentrations in groundwater under field conditions. The system permits the concentrations of dissolved gases (He, Ar, Kr, N_2, and O_2) in groundwater to be determined quasi-continuously (every 12 min) with a precision of better than 4% for He and Kr, and with a precision of 1% for Ar, N_2, and O_2 in air-saturated water. The detection limits are below 3×10^{-9} cm^3_{STP}/g for the noble gases and below 400×10^{-9} cm^3_{STP}/g for N_2 and O_2. The results of a first deployment of the system in the field indicate that changes in the concentration of Ar that result from diel fluctuations of 3 °C in the river water temperature were still able to be resolved in groundwater, although the corresponding temperature signal almost vanished.



2012

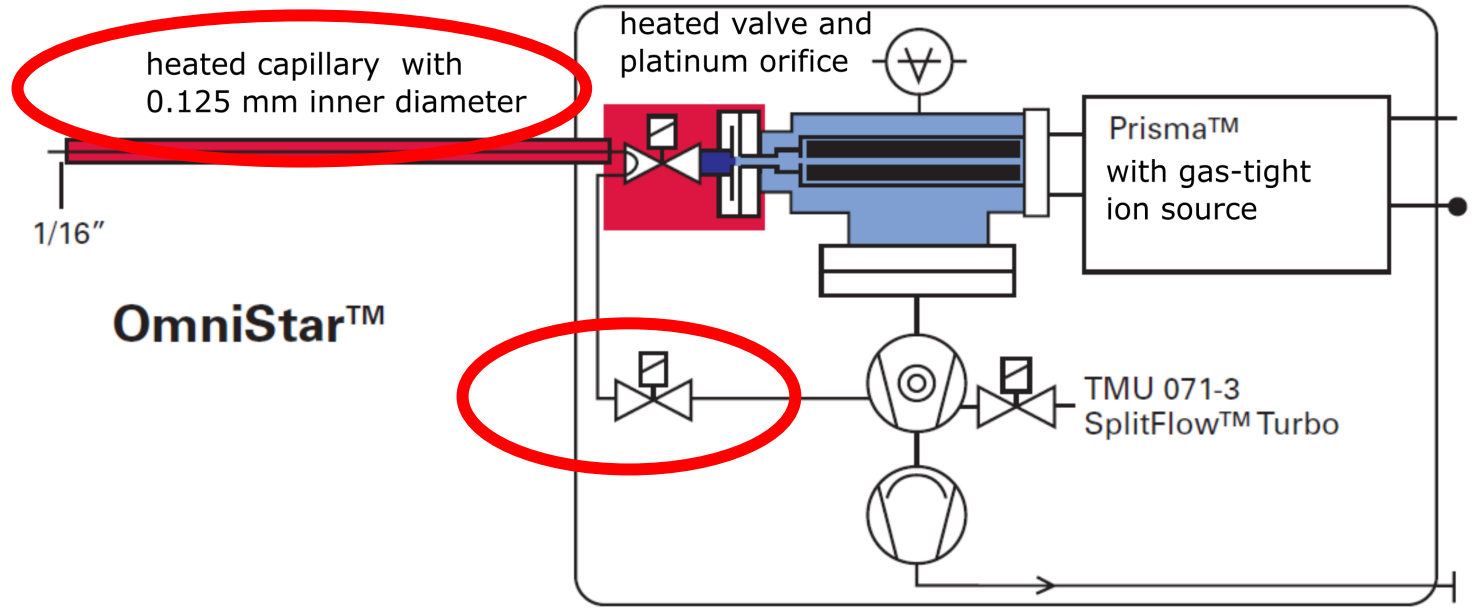
Omnistar set-up



Adapted from: *Pfeiffer Vacuum GmbH: Massenspektrometer 050607, Produktkatalog, 2005*

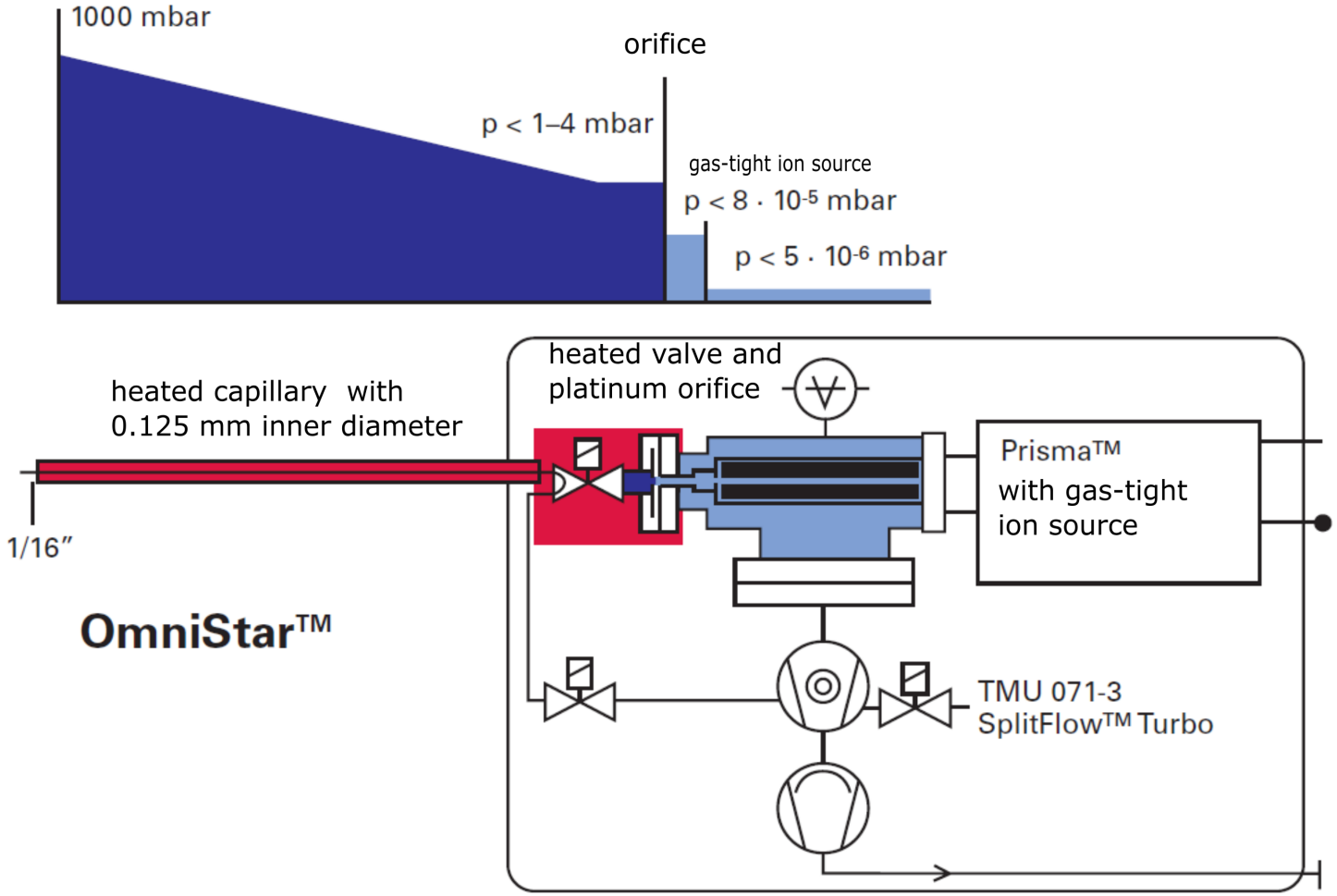
Omnistar set-up

miniRuedi: 0.01 mm ID



Adapted from: *Pfeiffer Vacuum GmbH: Massenspektrometer 050607, Produktkatalog, 2005*

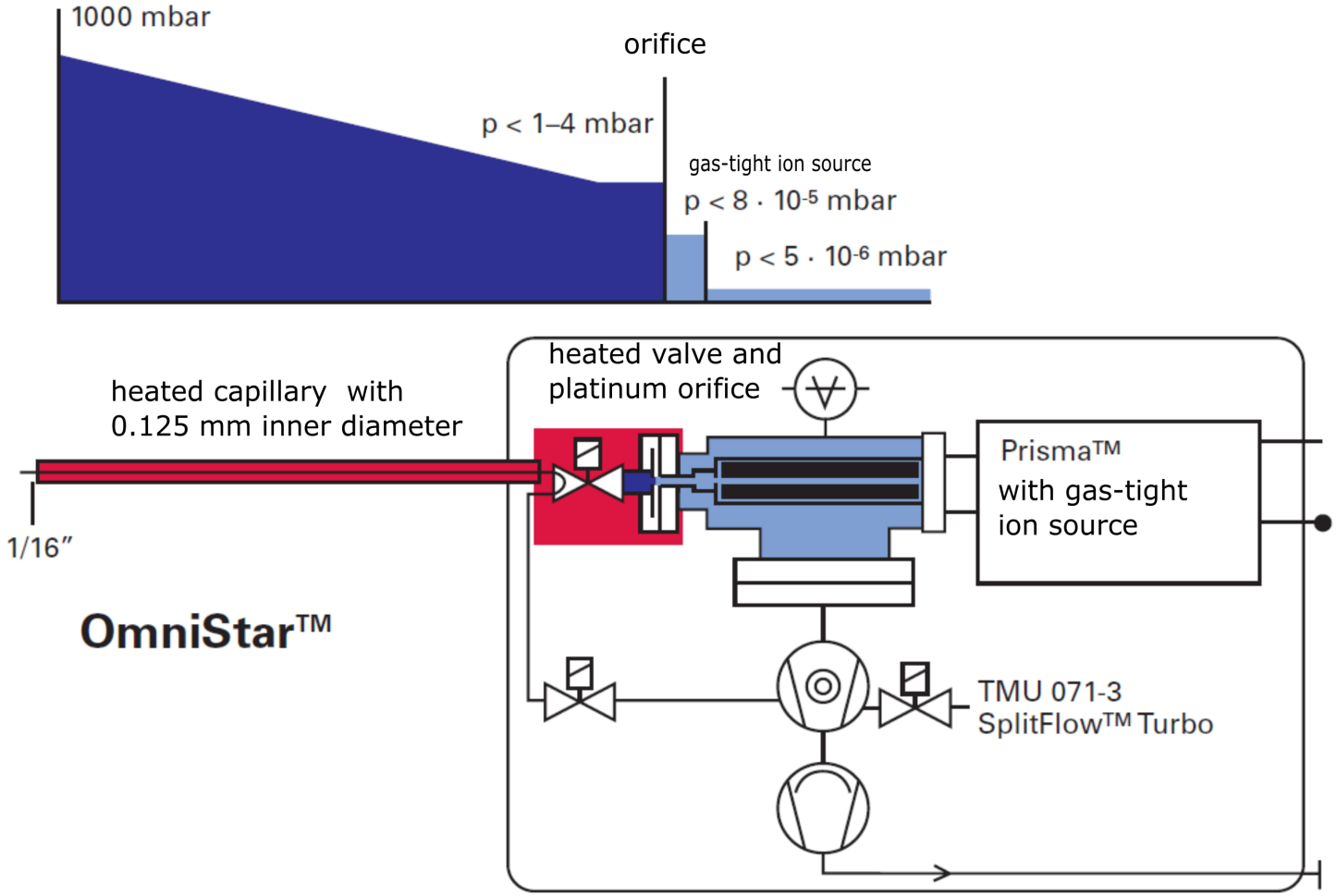
Omnistar set-up



Adapted from: *Pfeiffer Vacuum GmbH: Massenspektrometer 050607, Produktkatalog, 2005*

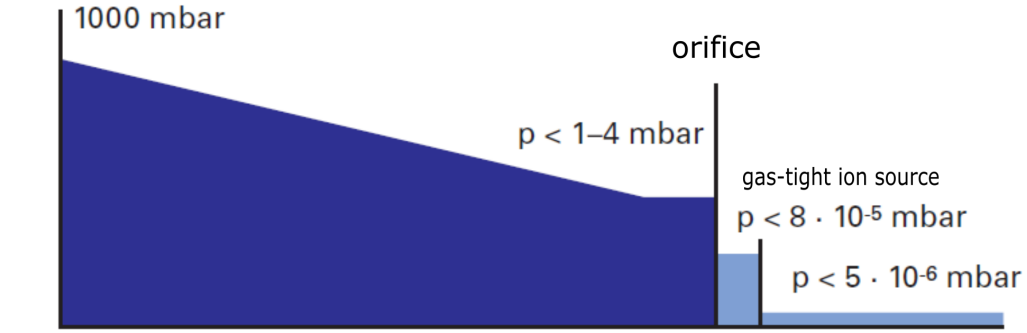
Omnistar set-up

Gas consumption: 0.7 ml/min



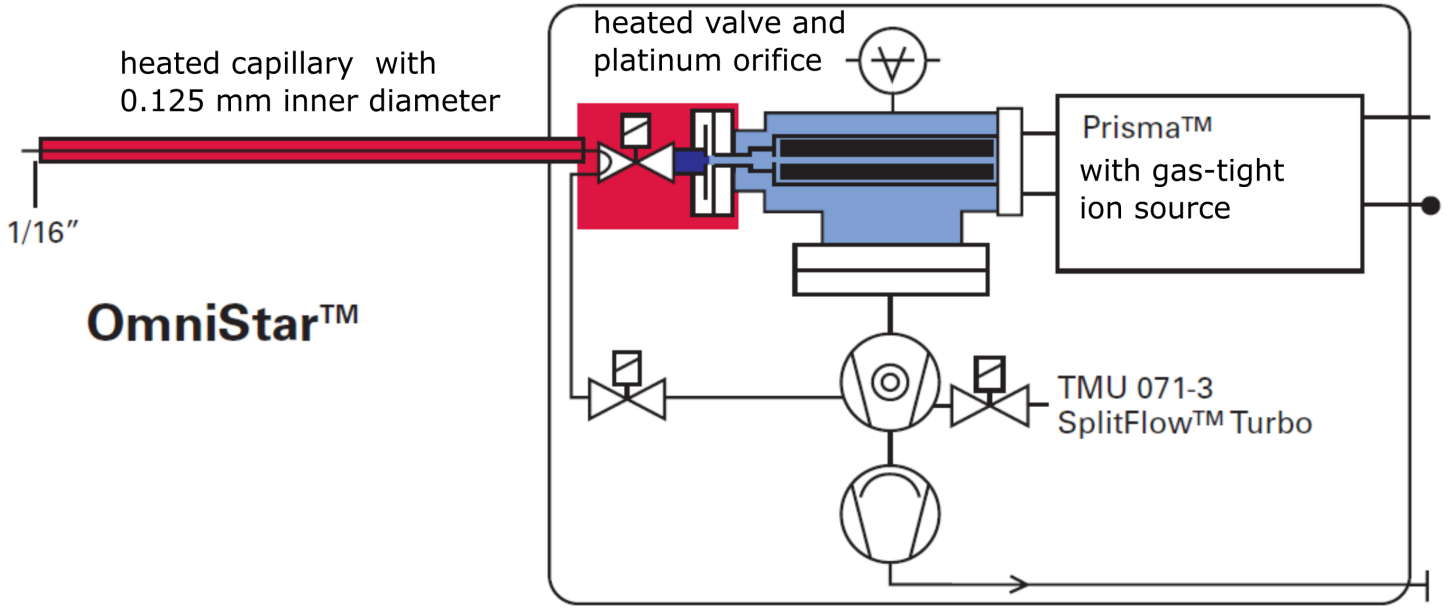
Adapted from: *Pfeiffer Vacuum GmbH: Massenspektrometer 050607, Produktkatalog, 2005*

Omnistar set-up



Gas consumption: 0.7 ml/min

miniRuedi: 0.06 ml/min



#unpaid_promotion

Adapted from: *Pfeiffer Vacuum GmbH: Massenspektrometer 050607, Produktkatalog, 2005*

Omnistar calibration

INSTITUT FÜR UMWELTPHYSIK

Internal calibration matrix with side peaks

		Mass							
Component	Concentratio	Mass 28	Mass 16	Mass 44	Mass 32	Mass 14	Mass 40	Mass 20	Mass 22
N2	78,051%	☑	☐	☐	☐	☑	☐	☐	☐
CO2	3,013%	☐	☐	☑	☐	☐	☐	☐	☑
O2	17,97%	☐	☑	☐	☑	☐	☐	☐	☐
Ar	0,966%	☐	☐	☐	☐	☐	☑	☑	☐

Omnistar calibration

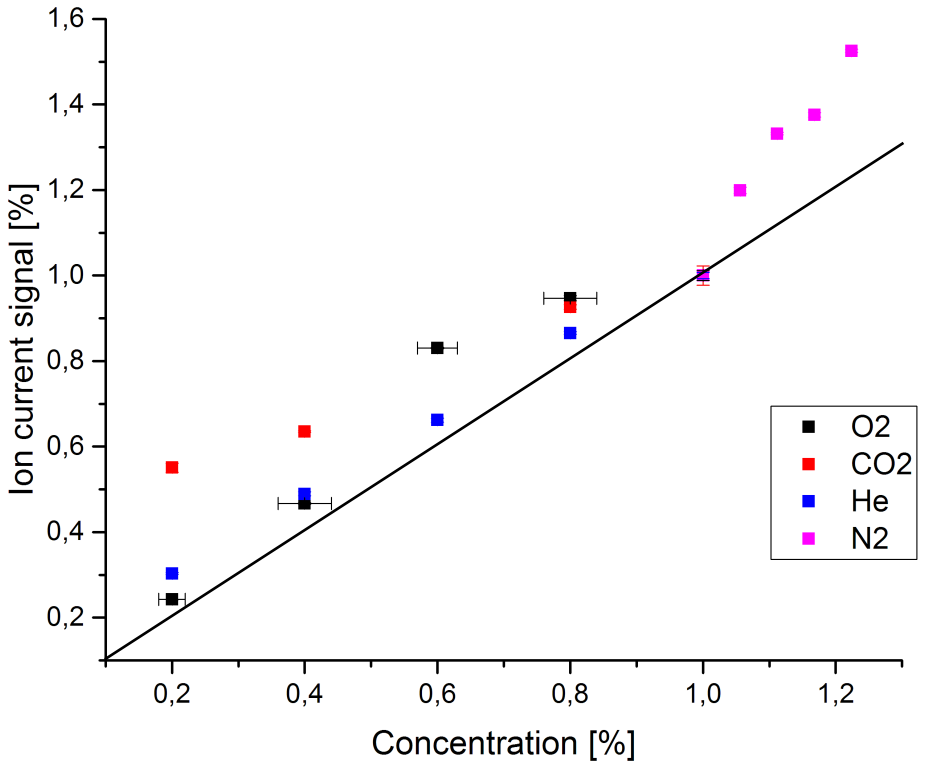
INSTITUT FÜR UMWELTPHYSIK

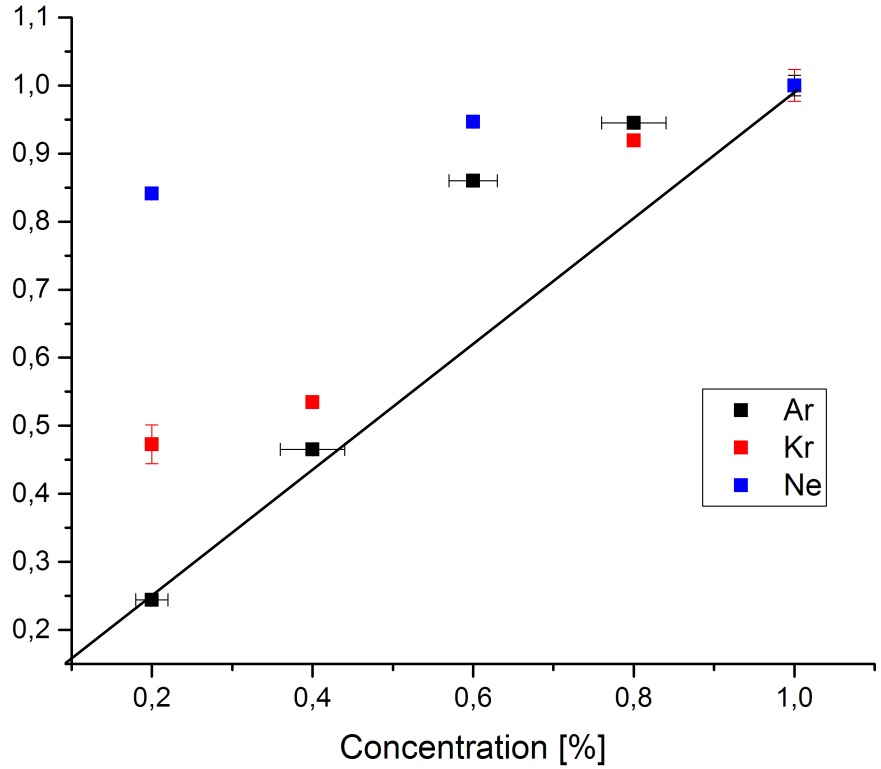
Internal calibration matrix with side peaks

		Mass							
Component	Concentratio	Mass 28	Mass 16	Mass 44	Mass 32	Mass 14	Mass 40	Mass 20	Mass 22
N2	78,051%	☑	☐	☐	☐	☑	☐	☐	☐
CO2	3,013%	☐	☐	☑	☐	☐	☐	☐	☑
O2	17,97%	☐	☑	☐	☑	☐	☐	☐	☐
Ar	0,966%	☐	☐	☐	☐	☐	☑	☑	☐

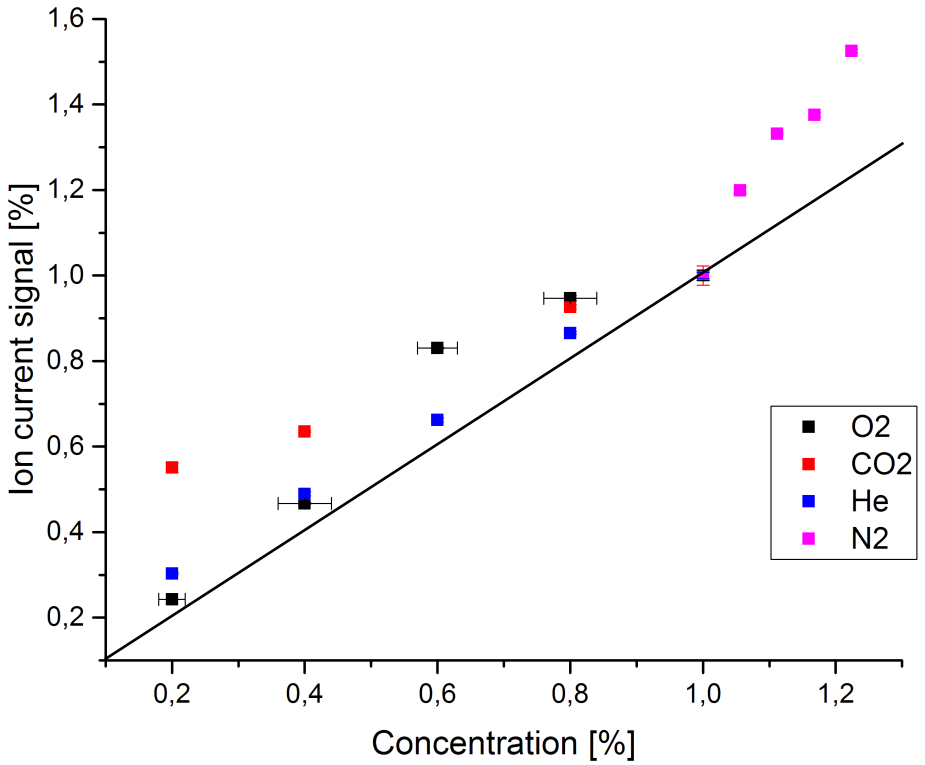
		28	32	40	44	20	14	16
▶	N2	6,915E-01	0,000E00	0,000E00	0,000E00	0,000E00	5,078E-02	0,000E00
	CO2	0,000E00	0,000E00	0,000E00	7,003E-01	0,000E00	0,000E00	0,000E00
	Ar	0,000E00	0,000E00	1,000E00	0,000E00	1,239E-02	0,000E00	0,000E00
	O2	0,000E00	5,318E-01	0,000E00	0,000E00	0,000E00	0,000E00	7,570E-0

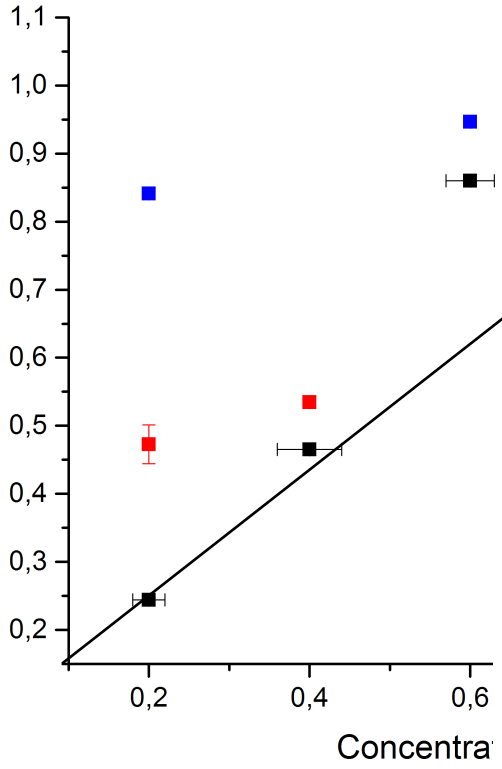
Linearity


Ion current signal [%]
Concentration [%]
O2
CO2
He
N2

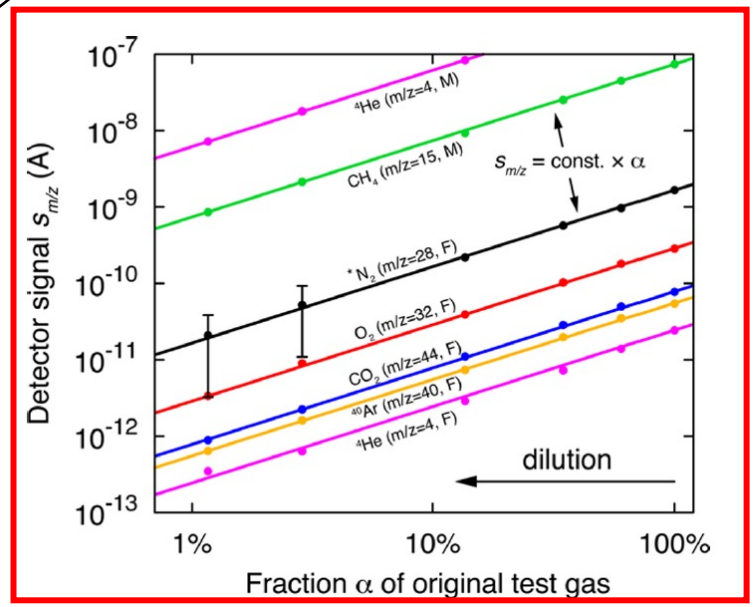

Concentration [%]
Ar
Kr
Ne

Linearity



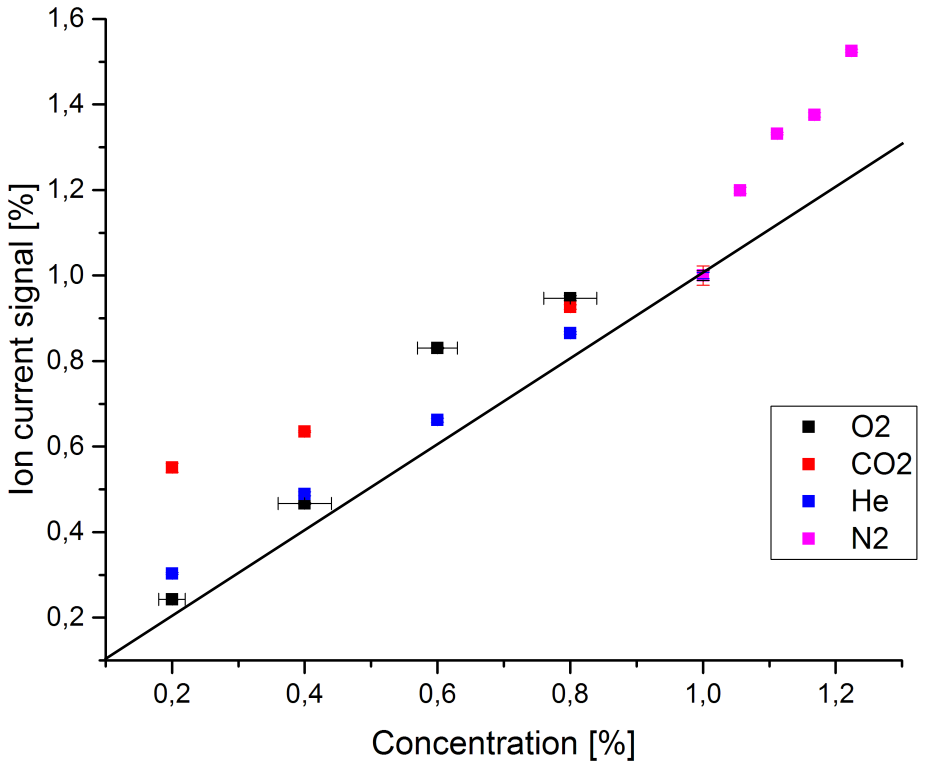


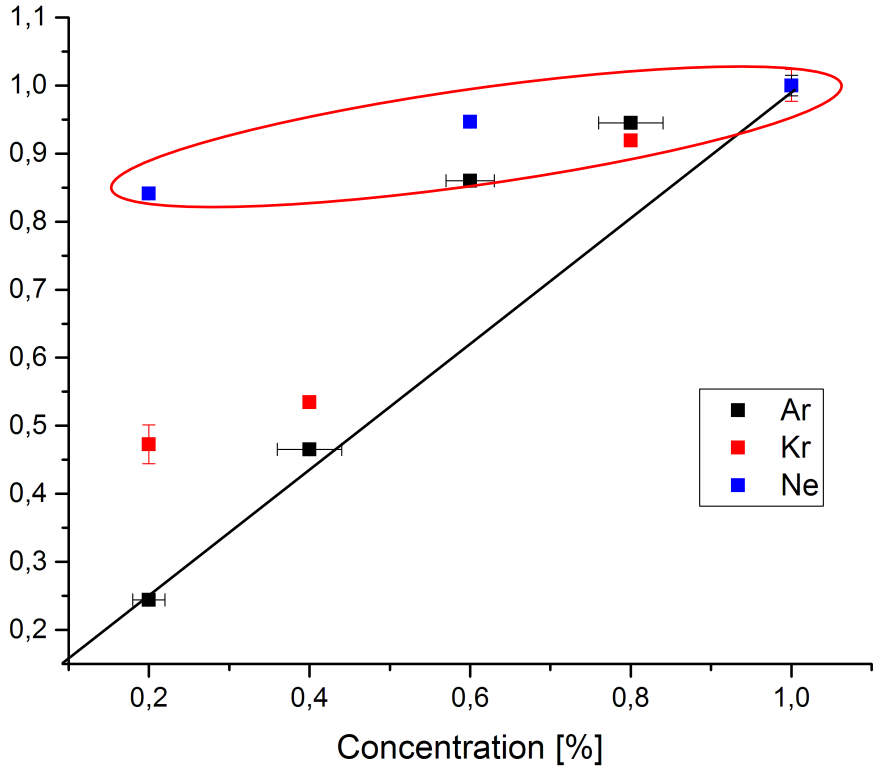
miniRuedi



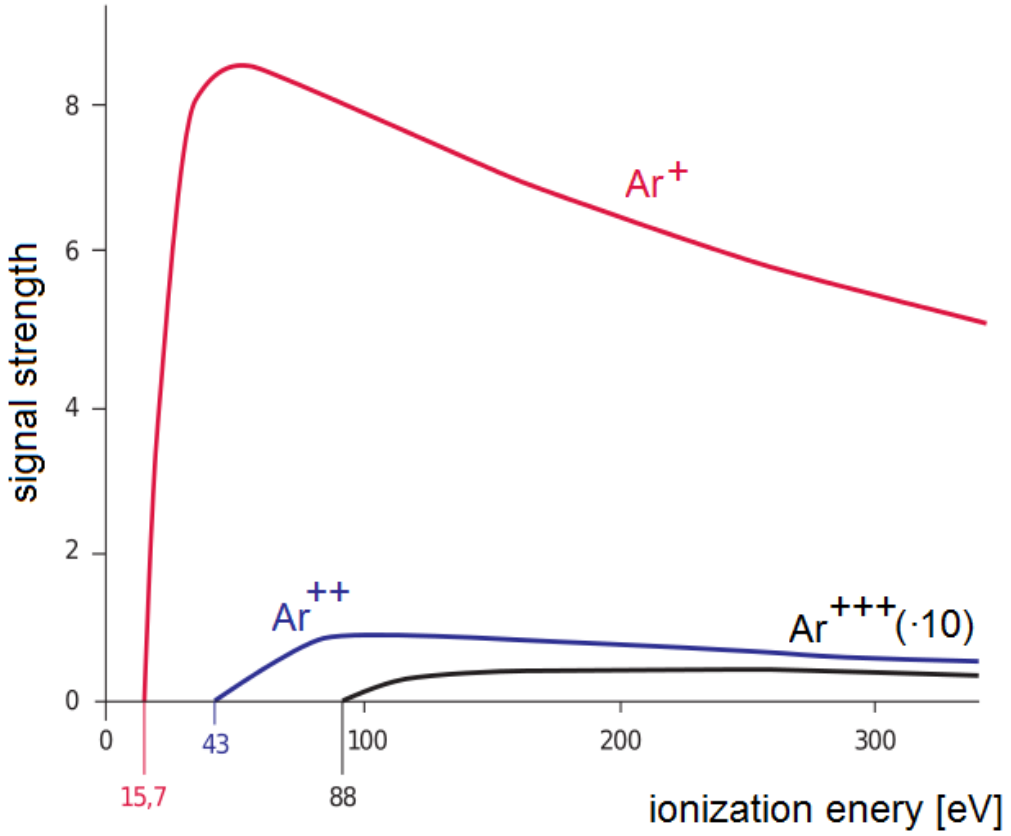
Brennwald et al., A Portable and Autonomous Mass Spectrometric System for On-Site Environmental Gas Analysis, 2016

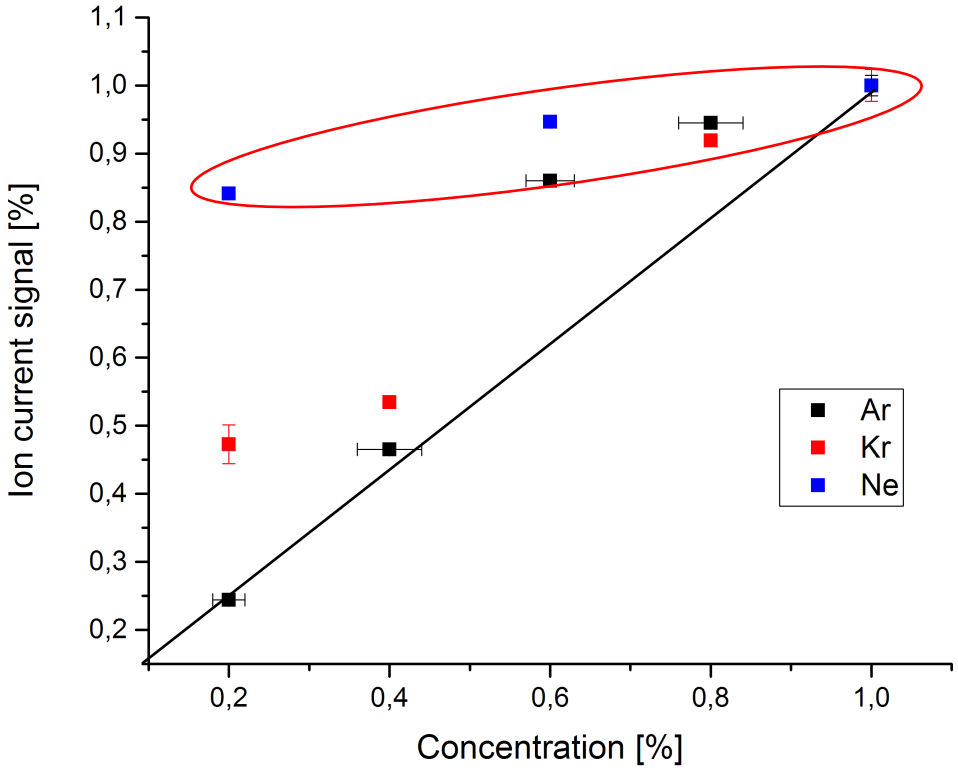
Linearity


Ion current signal [%]
Concentration [%]
O2
CO2
He
N2

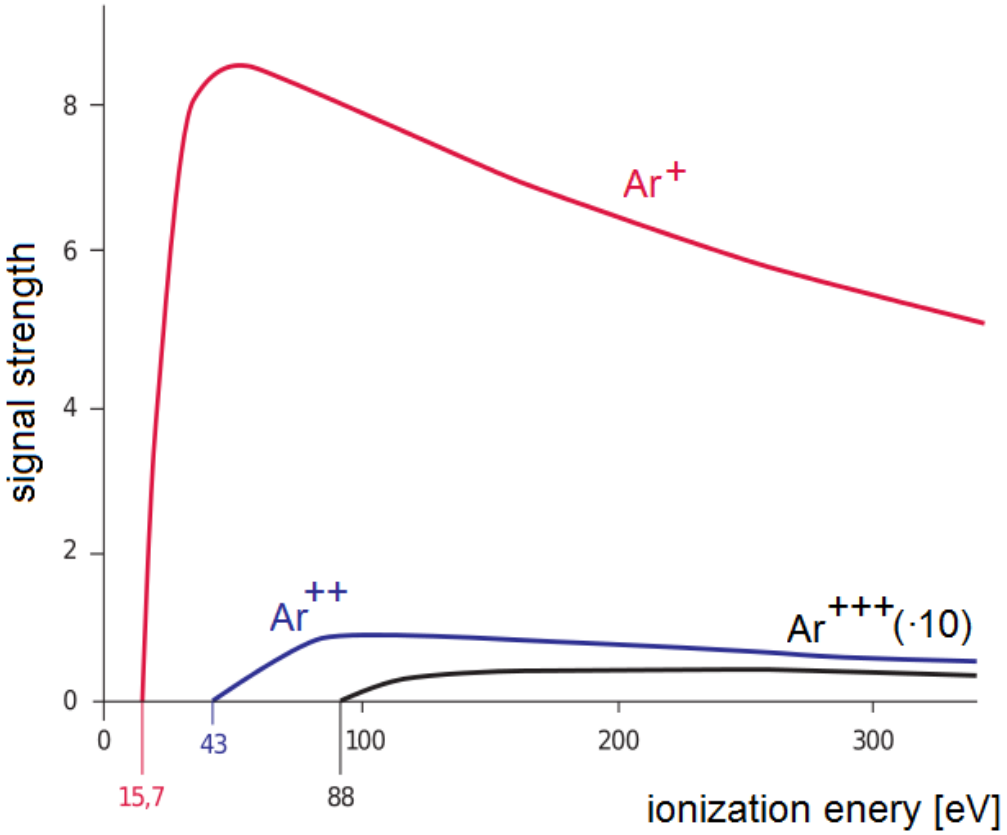

Concentration [%]
Ar
Kr
Ne

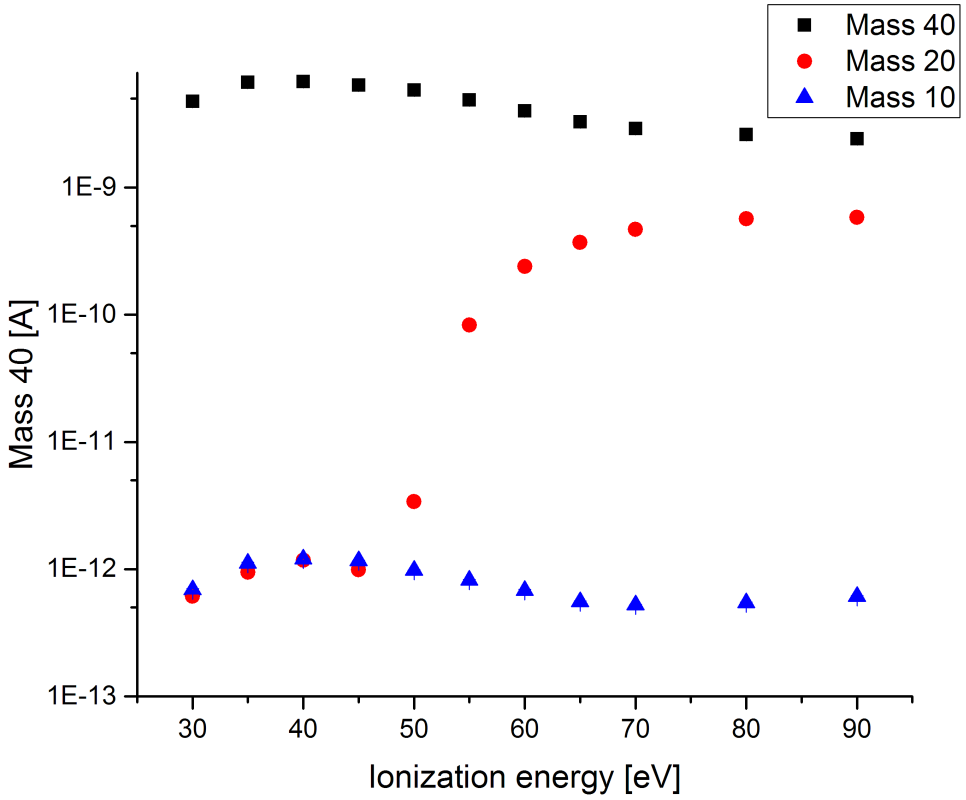
Linearity


signal strength
ionization enery [eV]
Ar+
Ar++
Ar+++(·10)
15,7
43
88
0
2
4
6
8
0
100
200
300

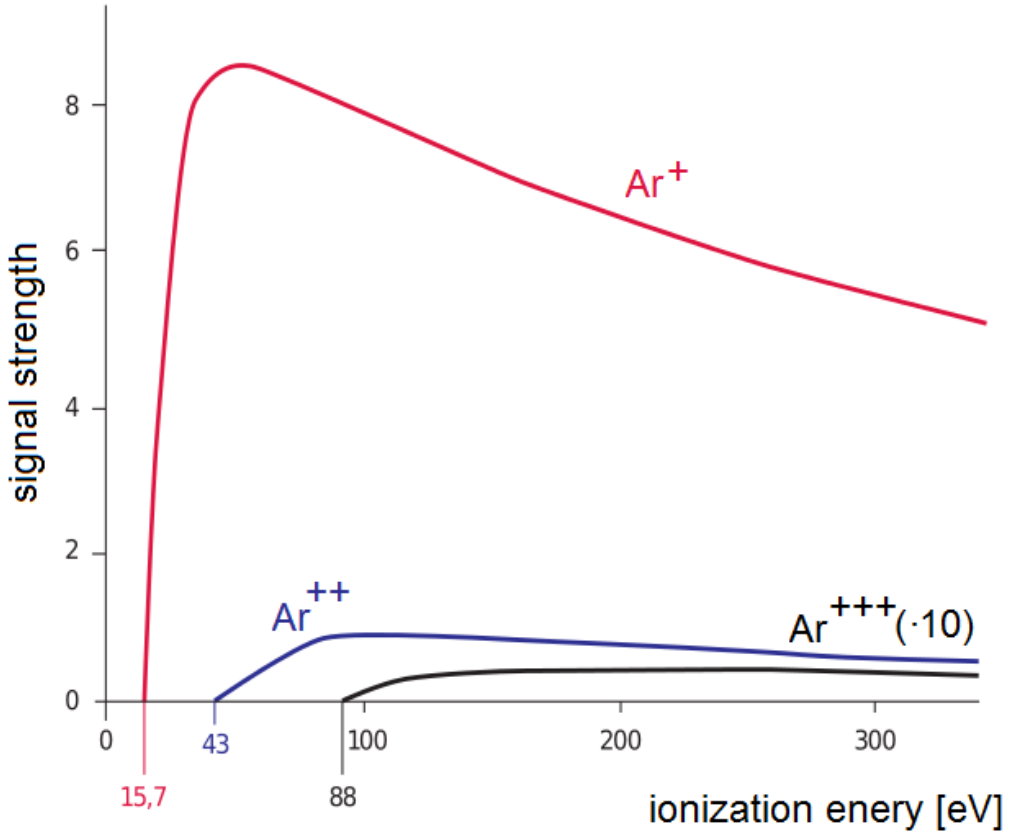

Ion current signal [%]
Concentration [%]
Ar
Kr
Ne
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1,0
1,1
0,2
0,4
0,6
0,8
1,0

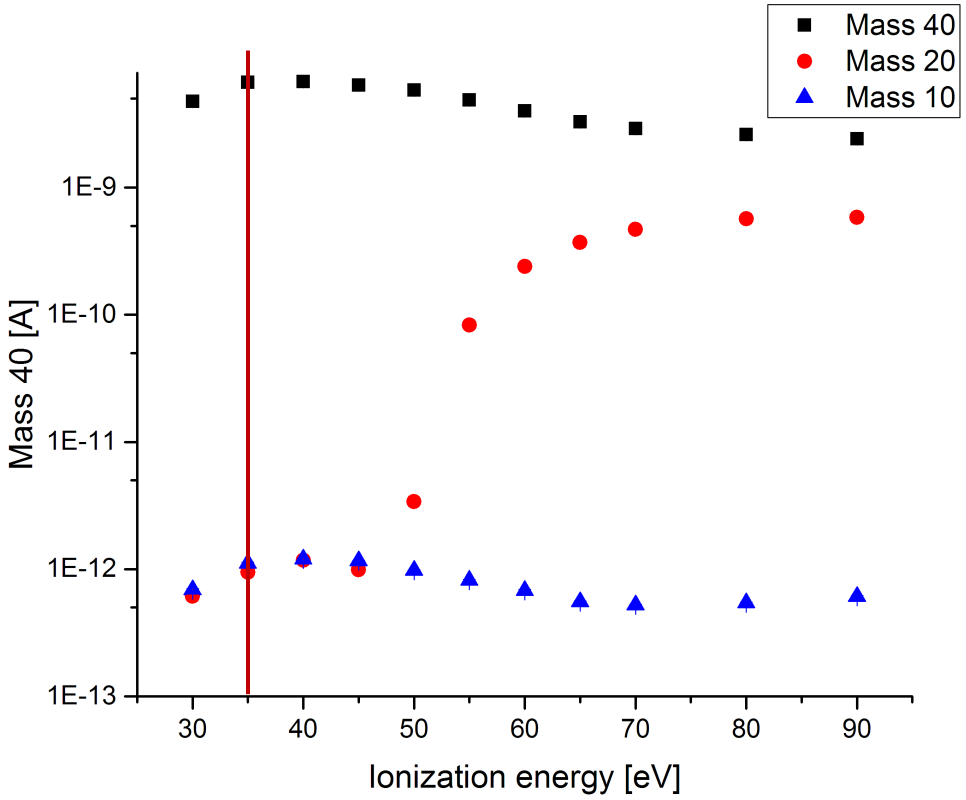
Overlaps


signal strength
ionization enery [eV]
Ar+
Ar++
Ar+++(·10)
15,7
43
88
0
2
4
6
8
0
100
200
300

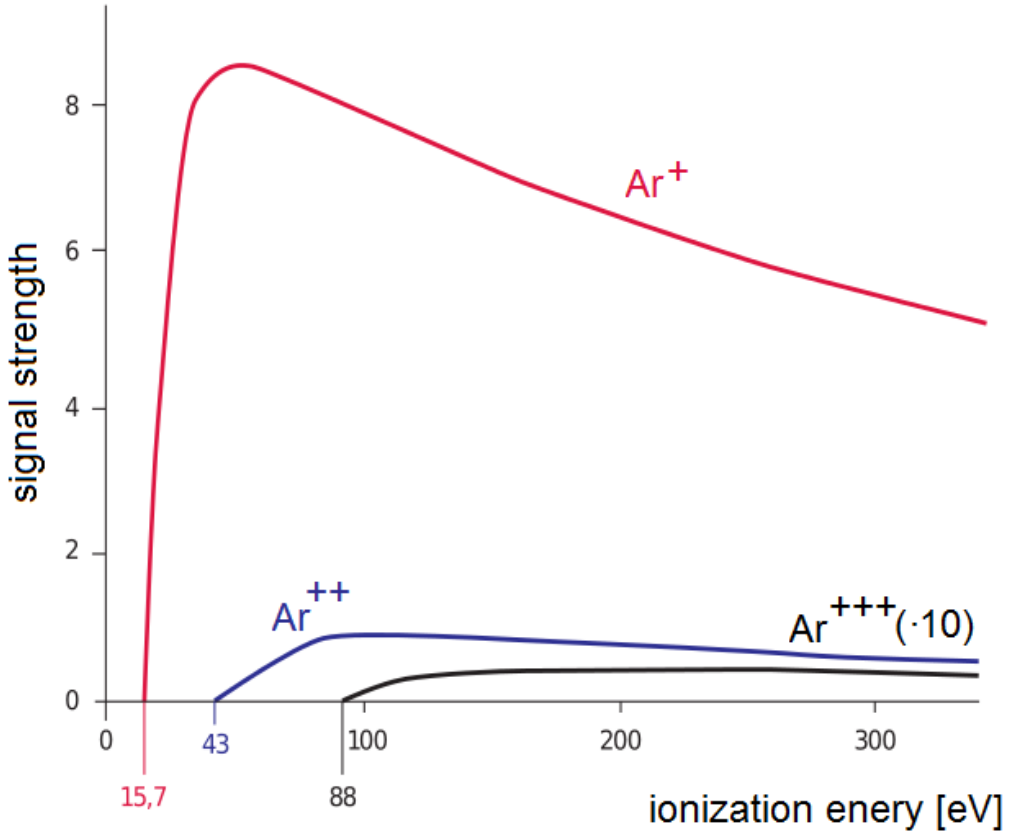

Mass 40
Mass 20
Mass 10
Mass 40 [A]
Ionization energy [eV]
1E-9
1E-10
1E-11
1E-12
1E-13
30
40
50
60
70
80
90

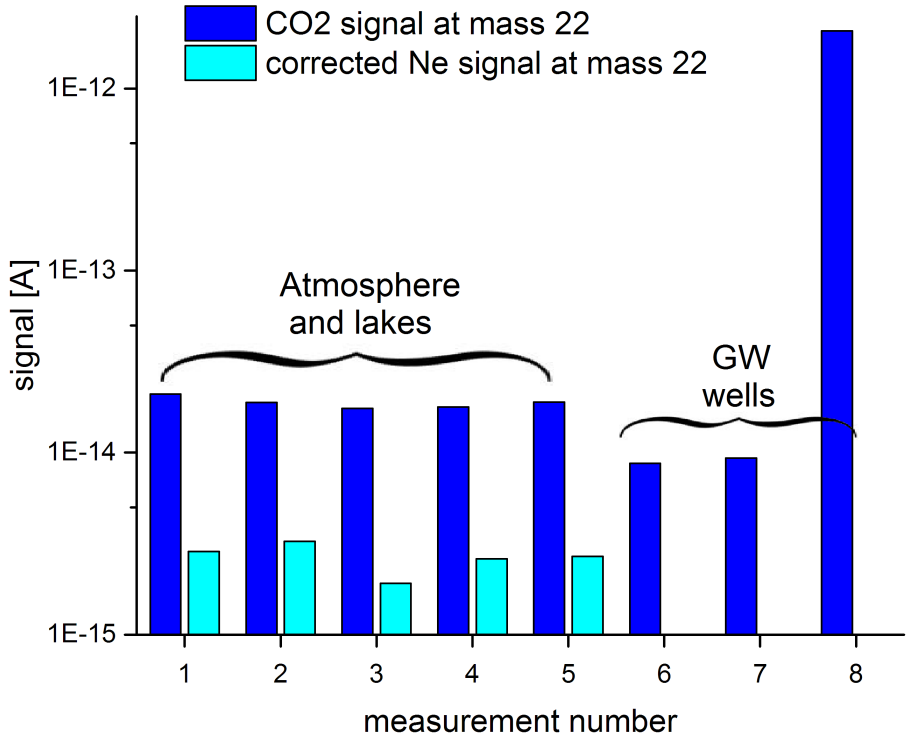
Overlaps


signal strength
ionization enery [eV]
Ar+
Ar++
Ar+++(·10)
15,7
43
88
0
2
4
6
8
0
100
200
300

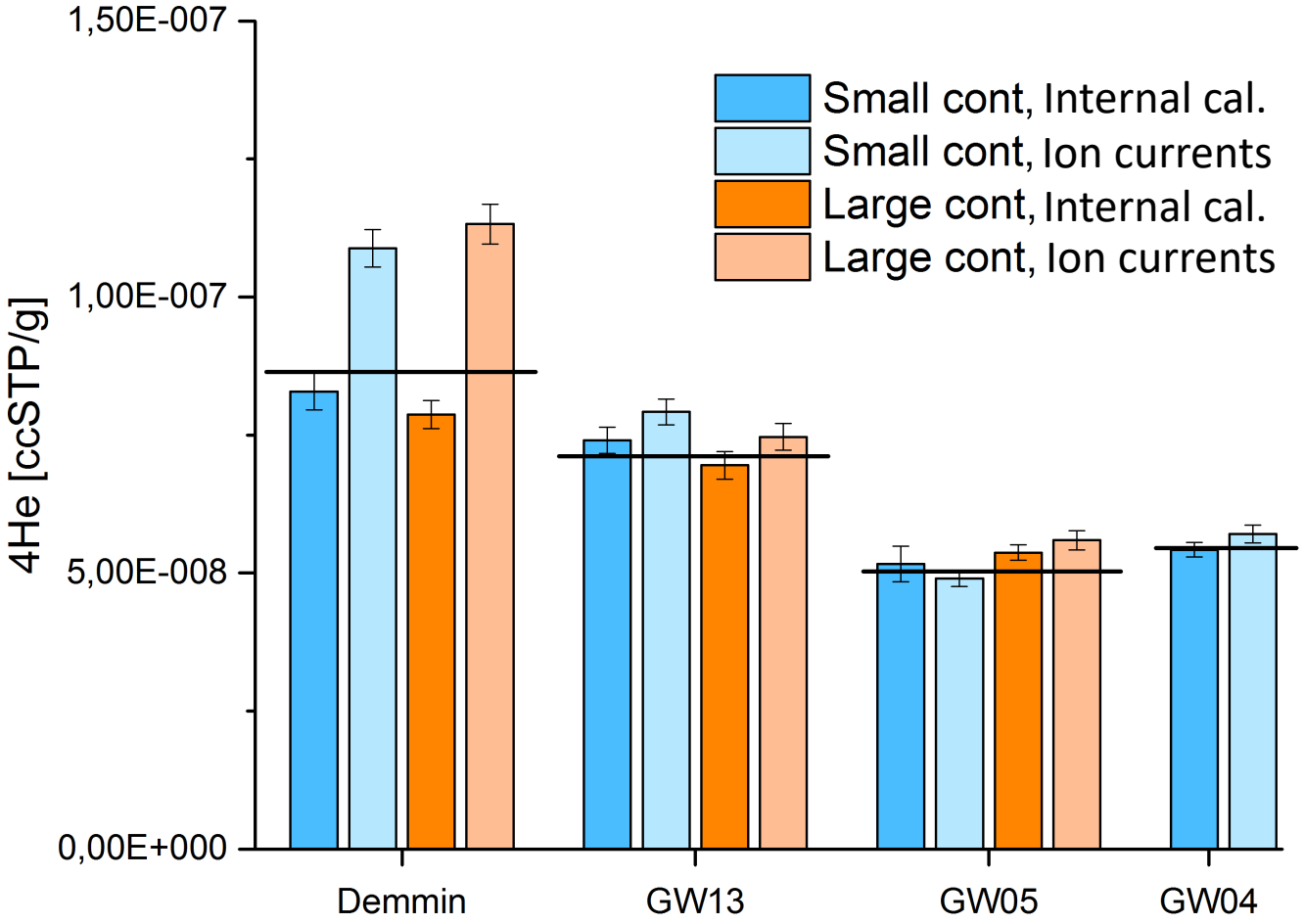

Mass 40
Mass 20
Mass 10
Mass 40 [A]
Ionization energy [eV]
1E-9
1E-10
1E-11
1E-12
1E-13
30
40
50
60
70
80
90

Overlaps

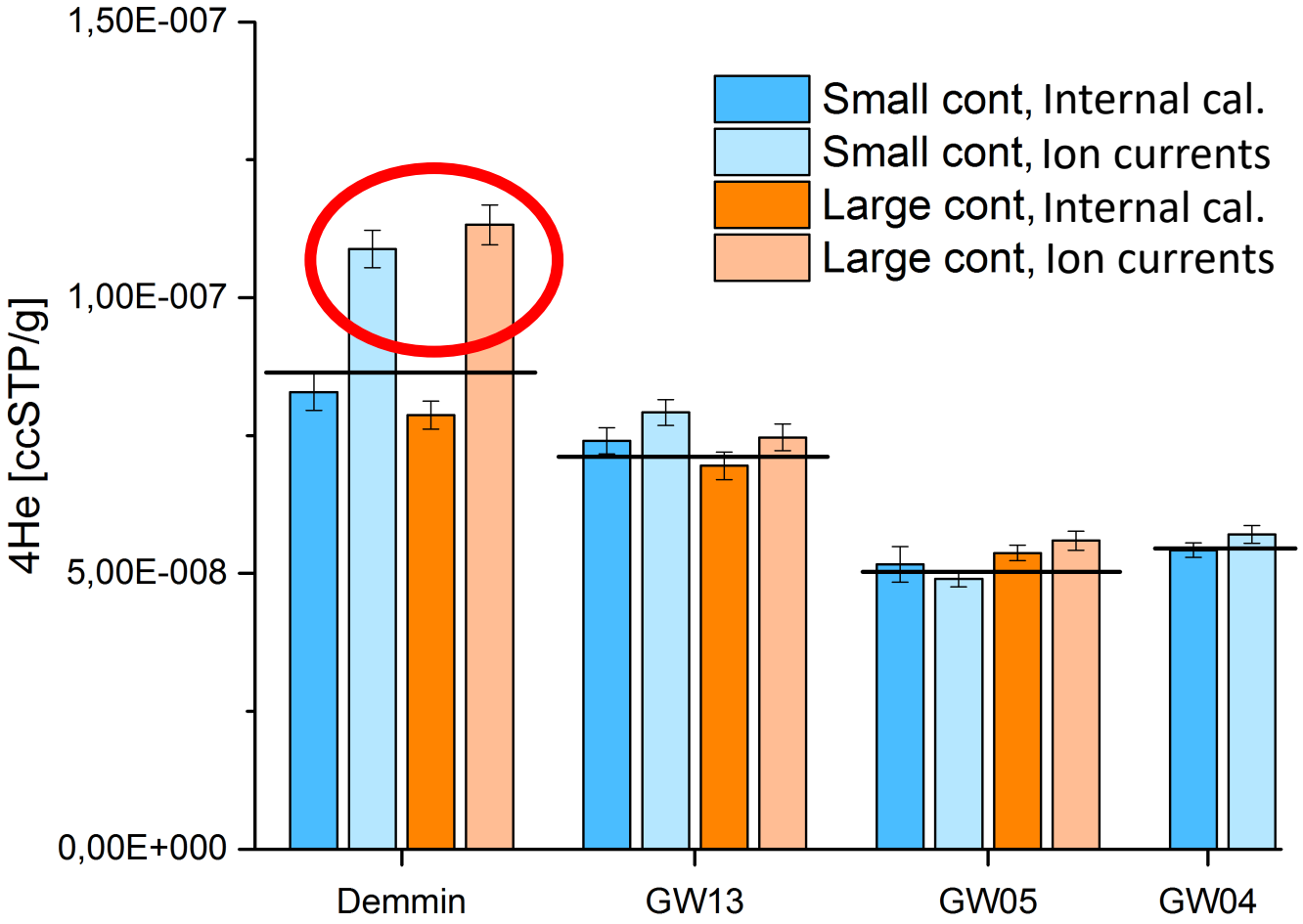

signal strength
ionization enery [eV]
Ar+
Ar++
Ar+++(·10)
15,7
43
88
0
2
4
6
8
0
100
200
300


CO2 signal at mass 22
corrected Ne signal at mass 22
signal [A]
1E-12
1E-13
1E-14
1E-15
Atmosphere
and lakes
GW
wells
1
2
3
4
5
6
7
8
measurement number

Results from field measurements

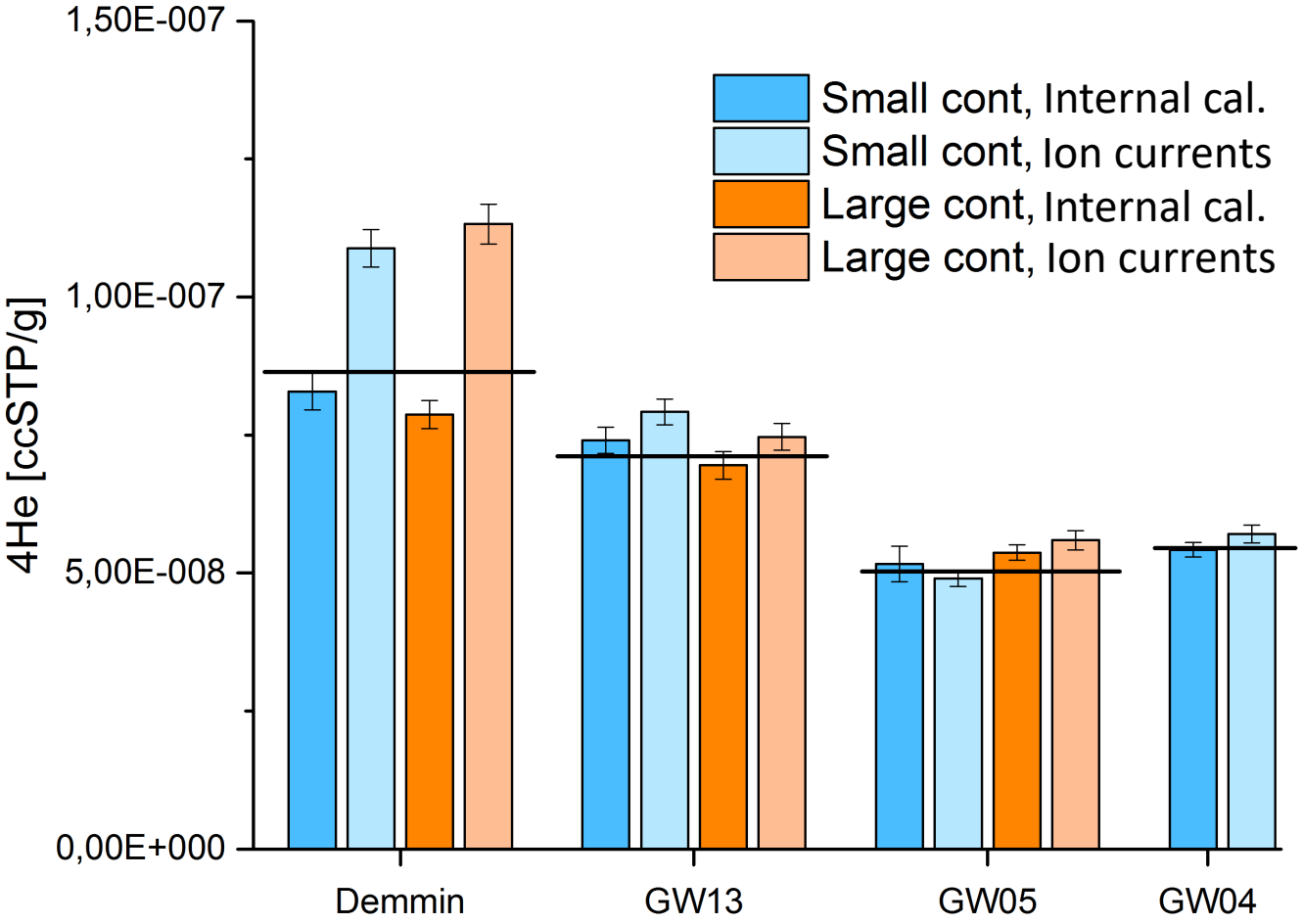


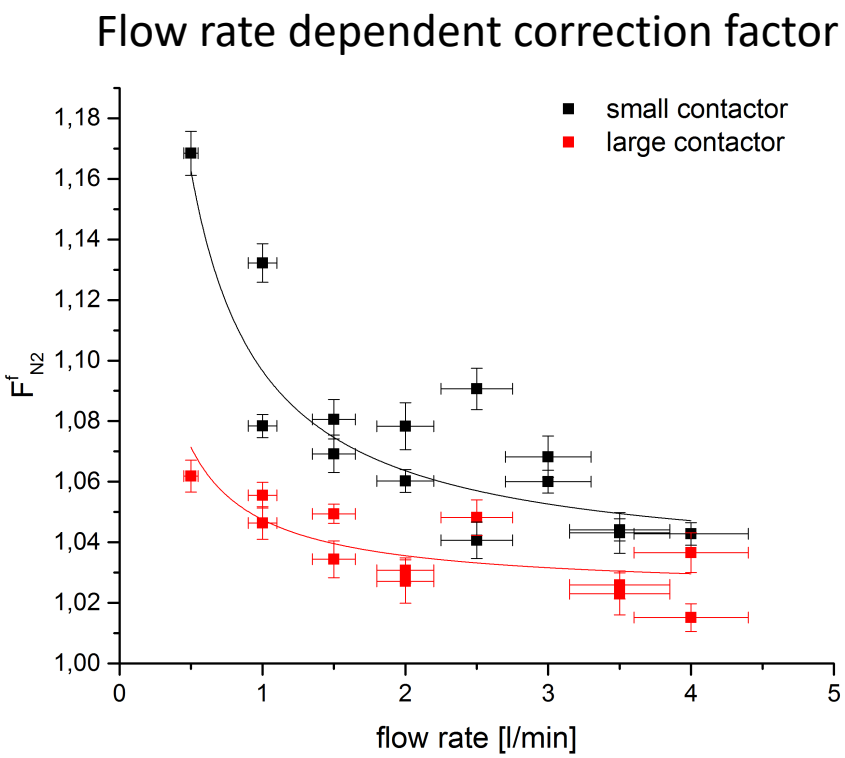
Results from field measurements



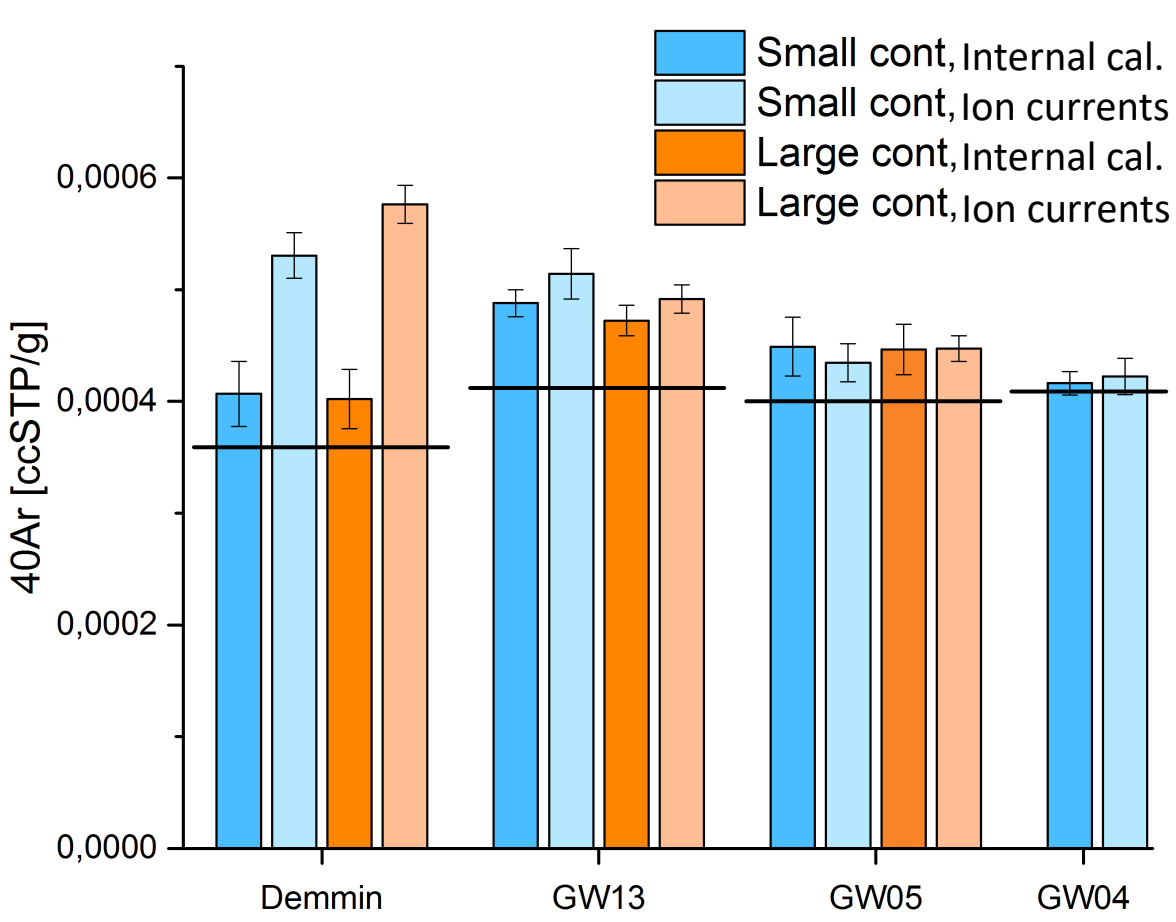
Internal calibration works better?

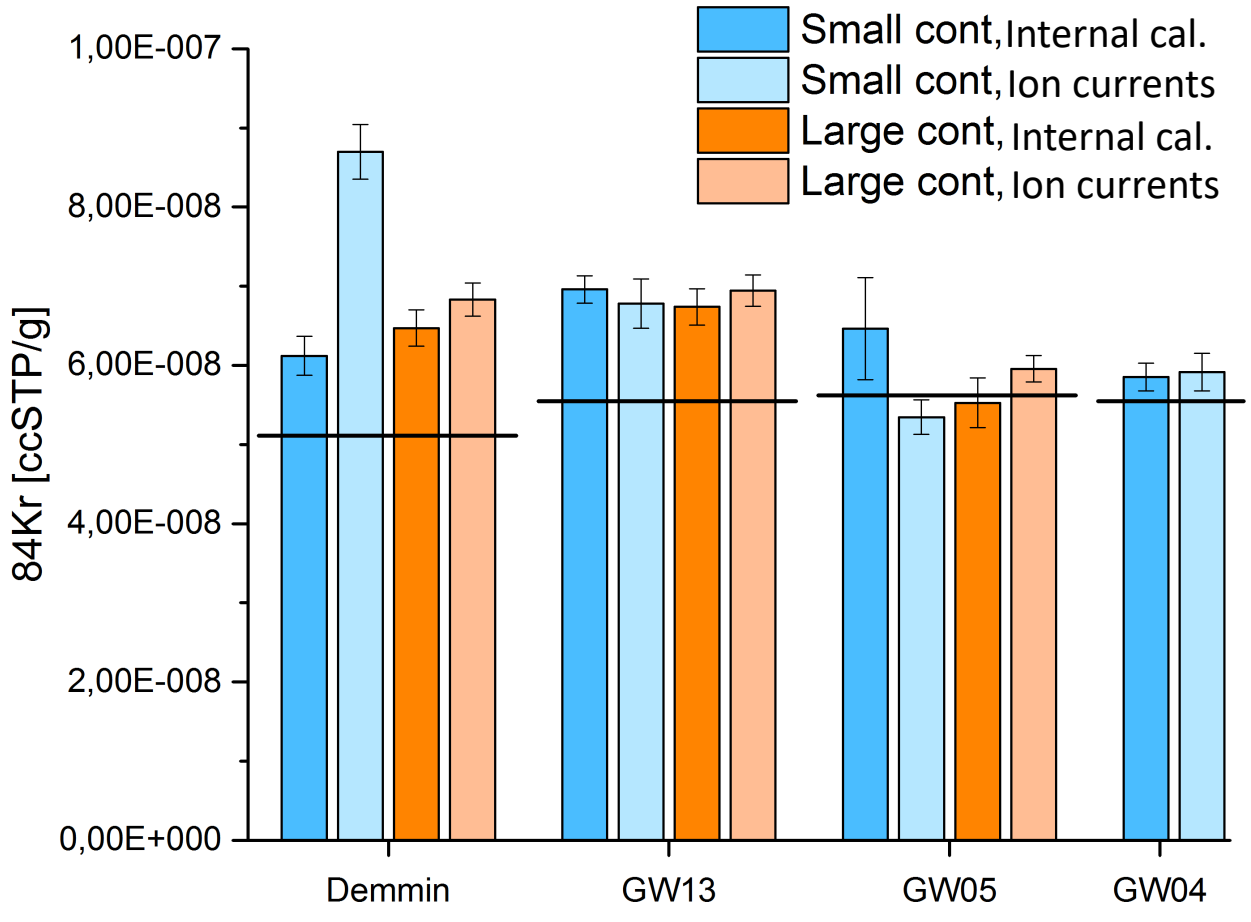
Results from field measurements





Results from field measurements





Steps towards a „miniRuedi-like“ system…

Future plans…

INSTITUT FÜR UMWELTPHYSIK

- Compare different capillaries
- Re-investigate linearity, long-term stability
- Calibration modes with new set-up?
- Field measurement ⟷ copper tubes