Optical Beam Diagnostics

Introduction and Status Report for the Year 2017

R.Hampf[1], A. Himpsl[1], R.Mühling[2] A. Ulrich[1], J. Wieser[2]

[1]Physik-Department E12/E15, Technische Universität München, James Franck Str.1, 85748 Garching, Germany
[2]Excitech GmbH, Branterei 33, 26419 Schortens, Germany

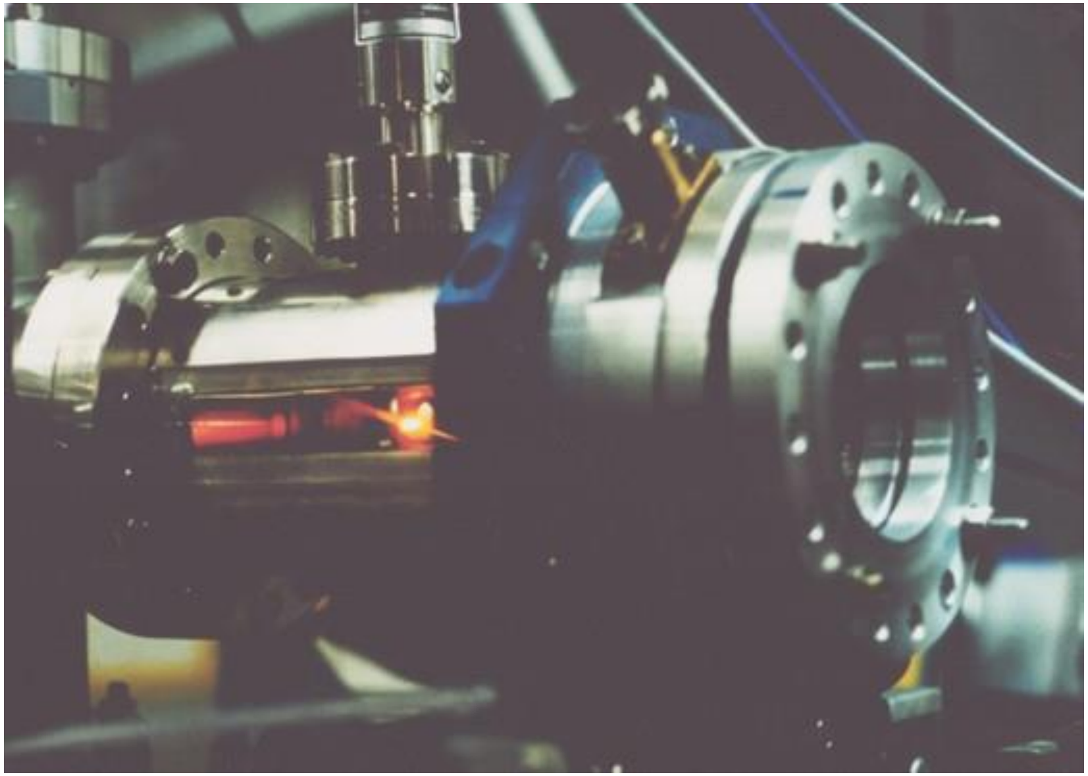
Layout

- Introduction/Motivation
  - „History“ - nuclear/heavy ion beam pumping
  - Excitech GmbH
- Experimental setup
- Experimental results
  - Spectroscopy
  - Beam profile measurements

Introduction/Motivation

"Our history": heavy ion beam pumping

Heavy ion beam pumped visible laser
A. Ulrich, J. Wieser, A. Brunnhuber, and W. Krötz
Appl. Phys. Lett. **64**, 1902 (1994)



Beam:
42µA, ^{35}Cl, 120MeV
(3e13/s, $500W_{inst}$)
2…50µs, 50Hz

Target:
He-Ne-Ar, 800mb, 92:6:2

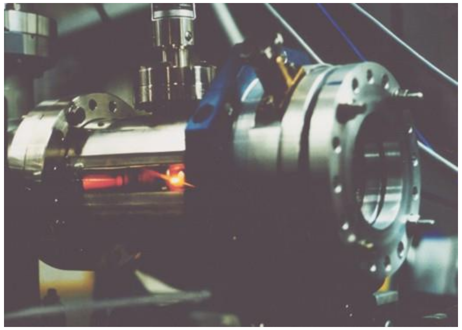
Generally: non-thermal excitation of high-pressure targets

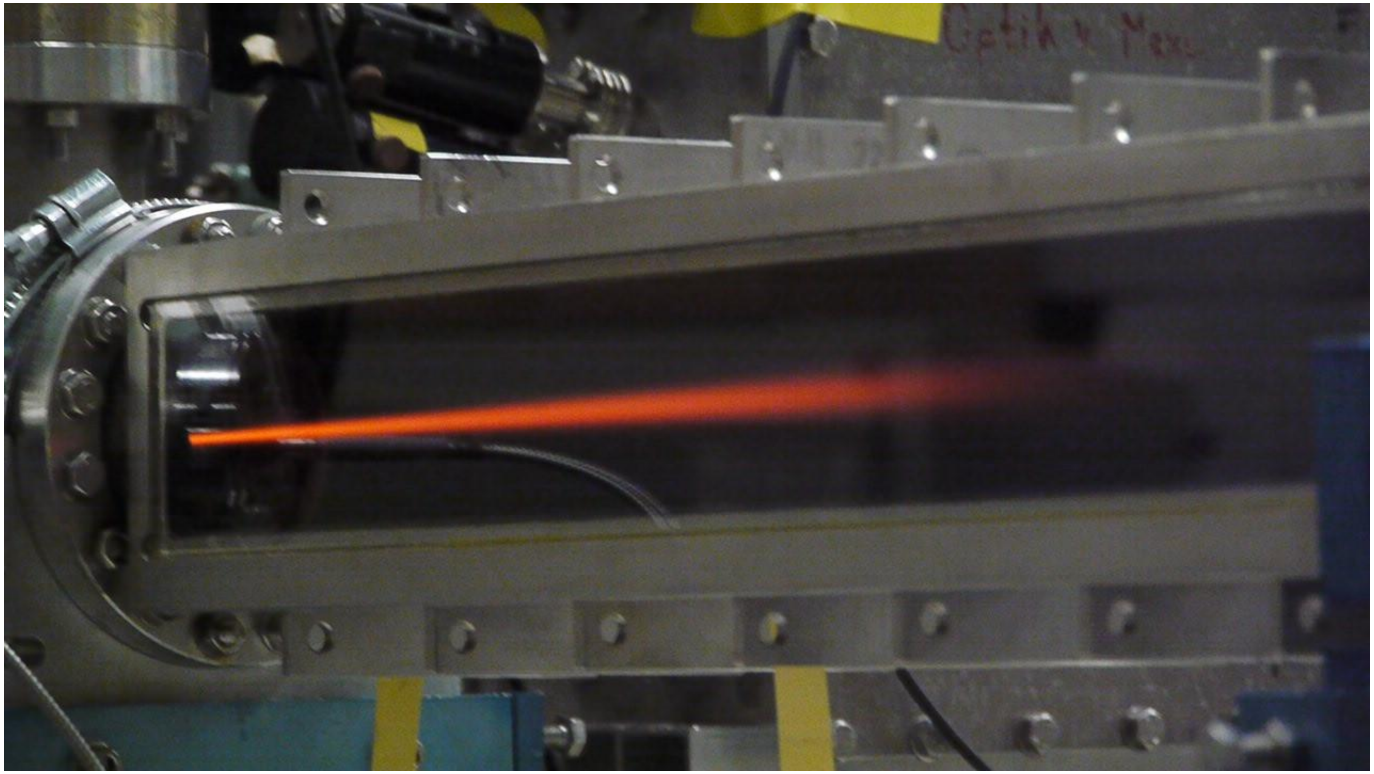
excitech

Introduction/Motivation

Heavy ion beam pumping:

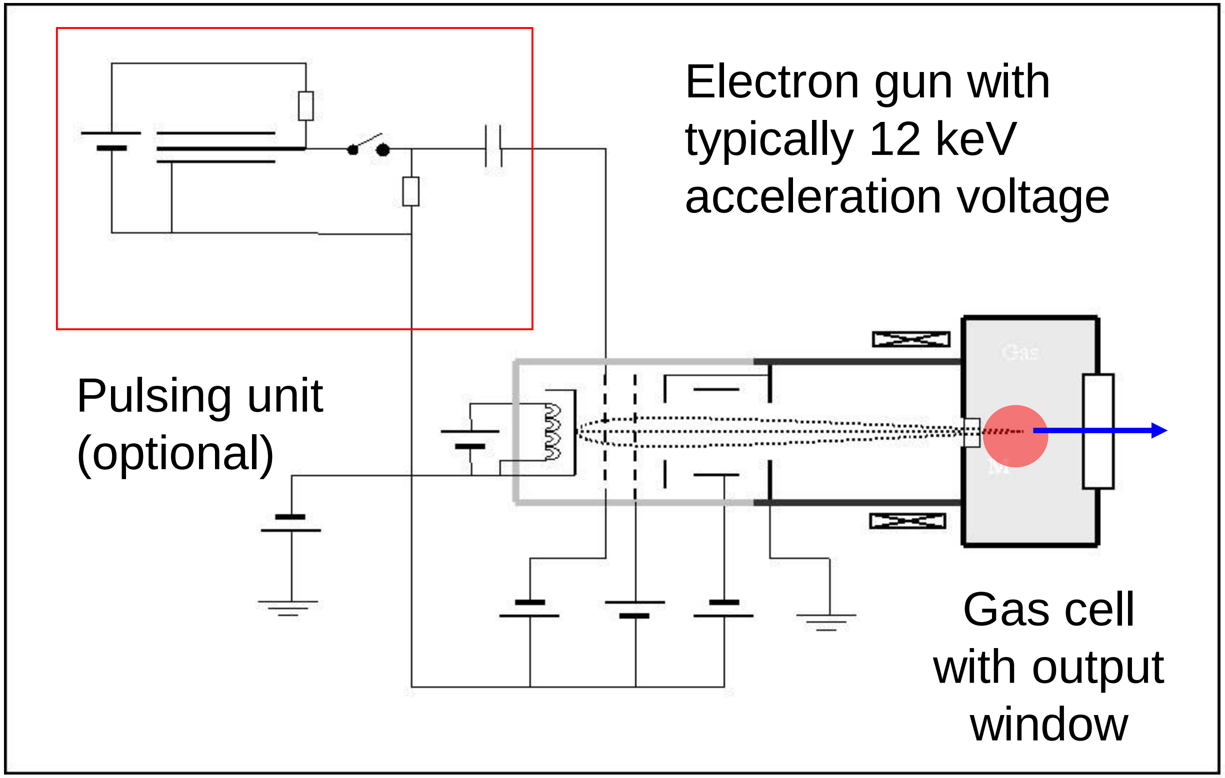
- Gas kinetic studies
- Laser
- VUV Light Sources E-Lux





excitech: Electron Beam Excited Light Sources „E-Lux“

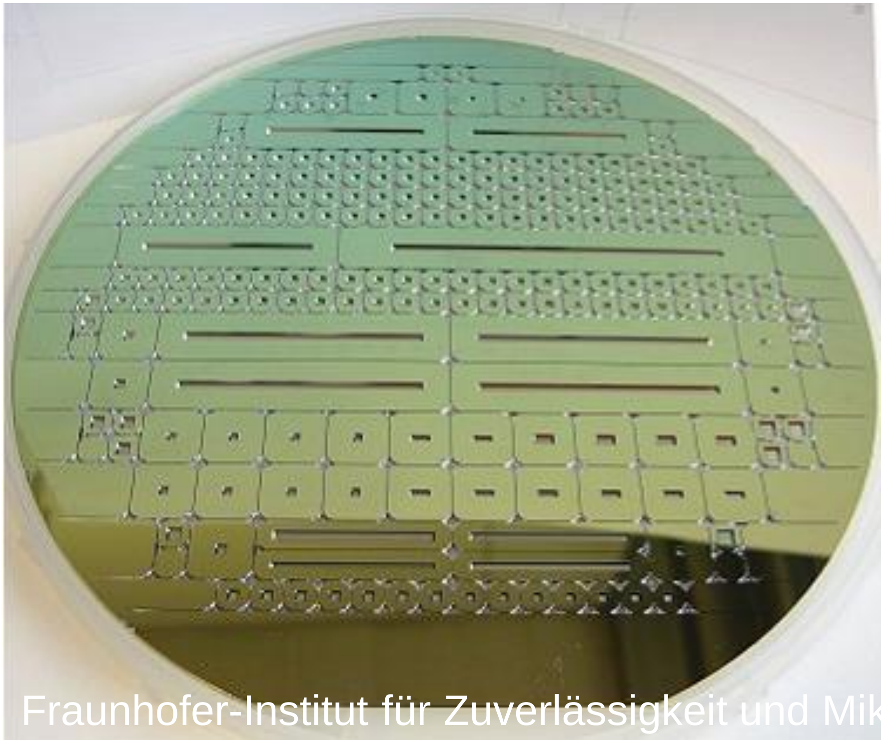
„Our“ traditional setup: 12keV Electron beam excitation

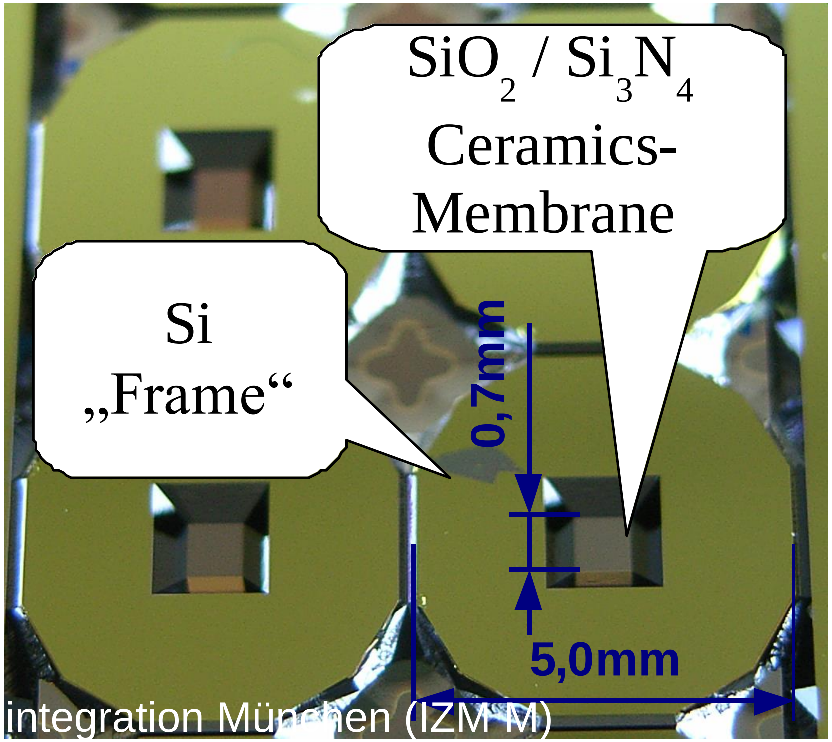


The Technology:

The key for the technology lies in the entrance foil for the electrons: Here

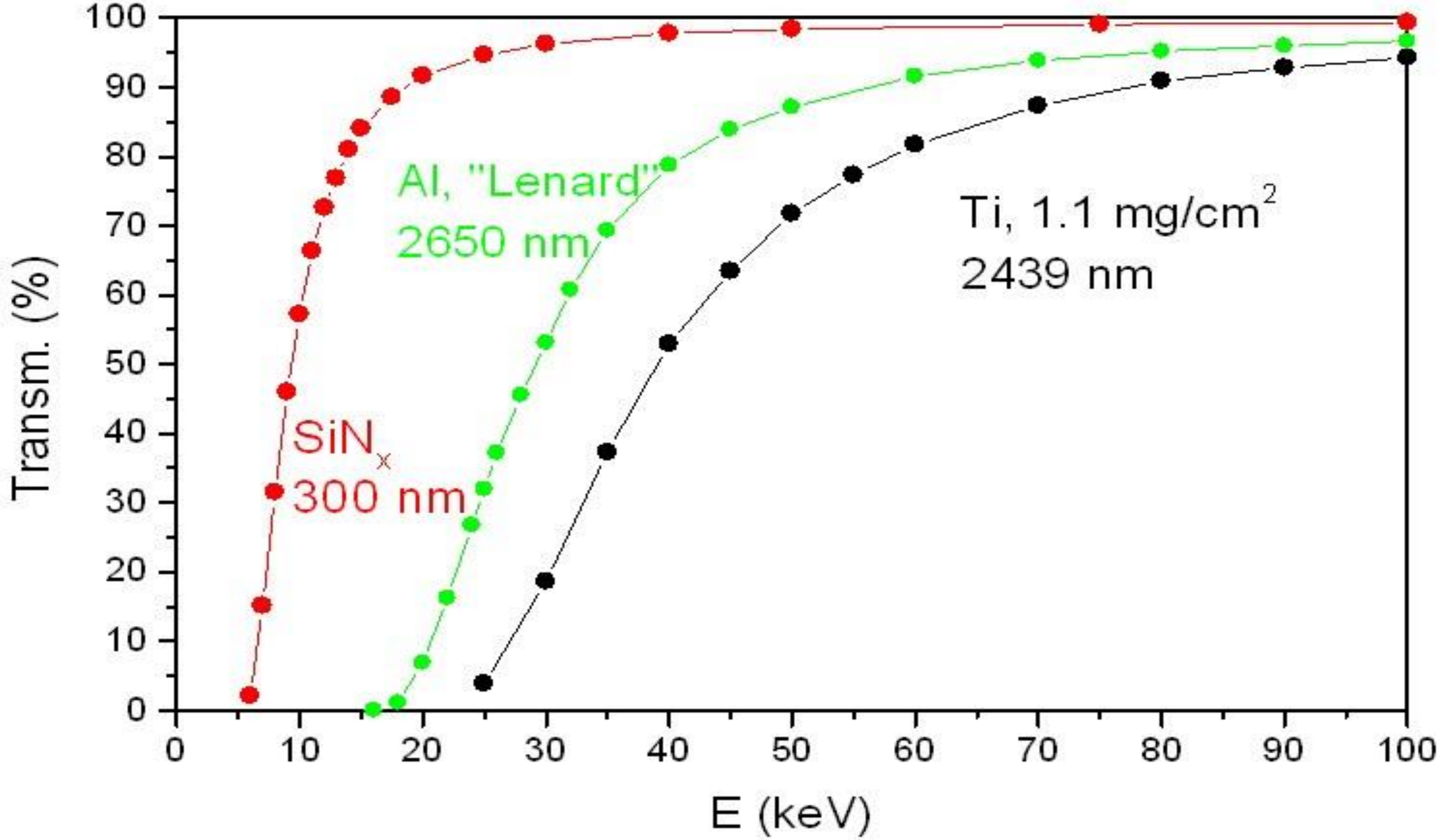
only 300 nm „thick“ ceramic membranes !



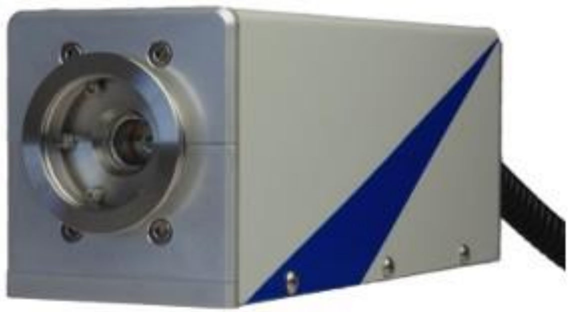


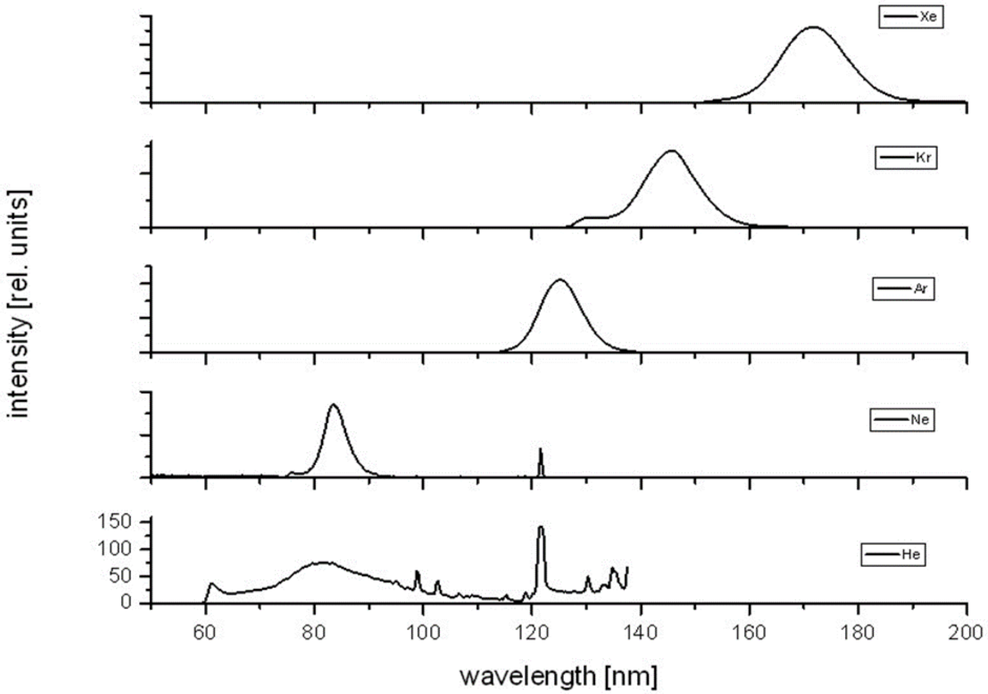
Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration München (IZM-M)

Transmittierte Elektronenenergie



VUV Light Sources E-Lux





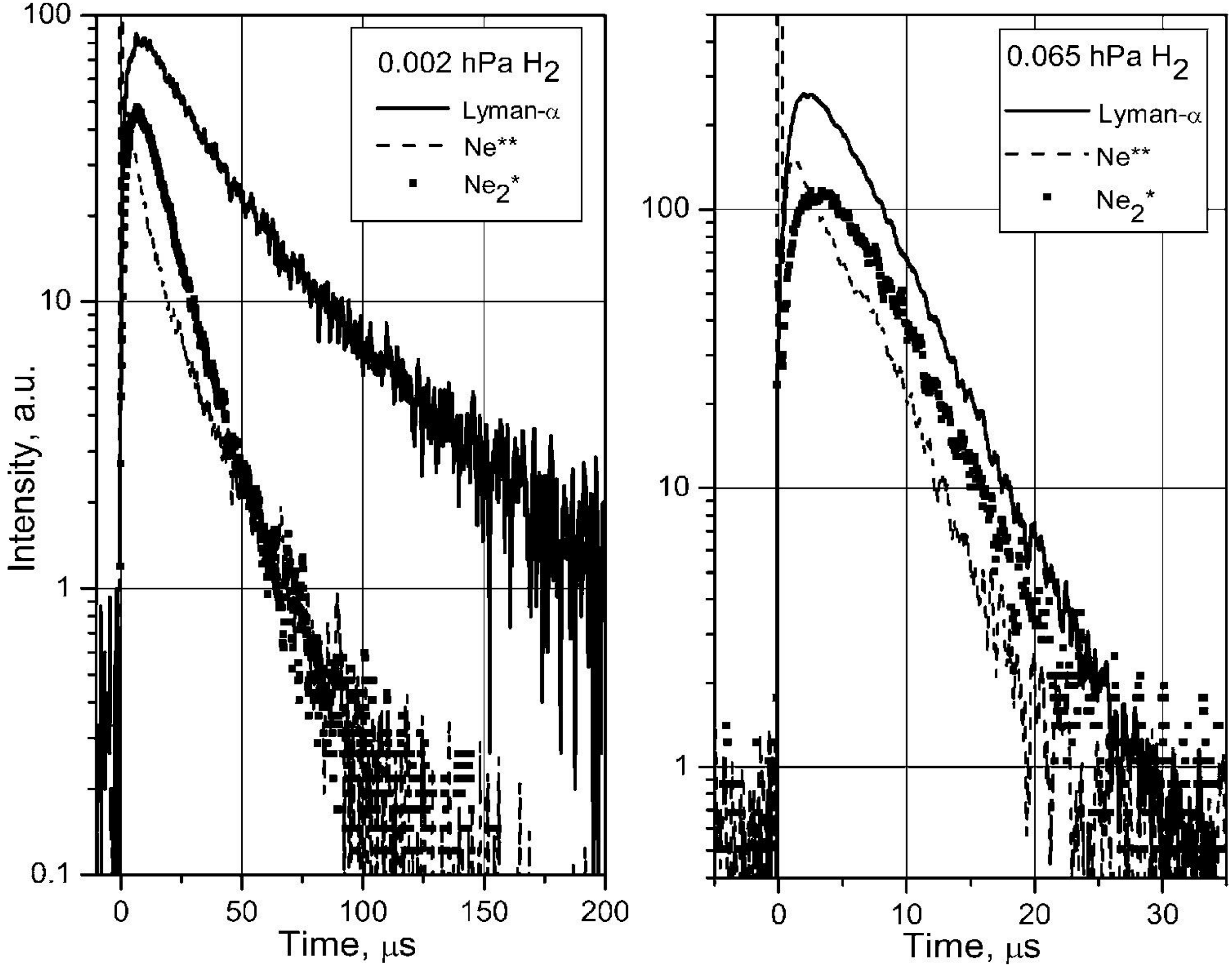
Gaskinetic Studies/VUV Spectroscopy

Time-resolved measurements

Ne, 1bar

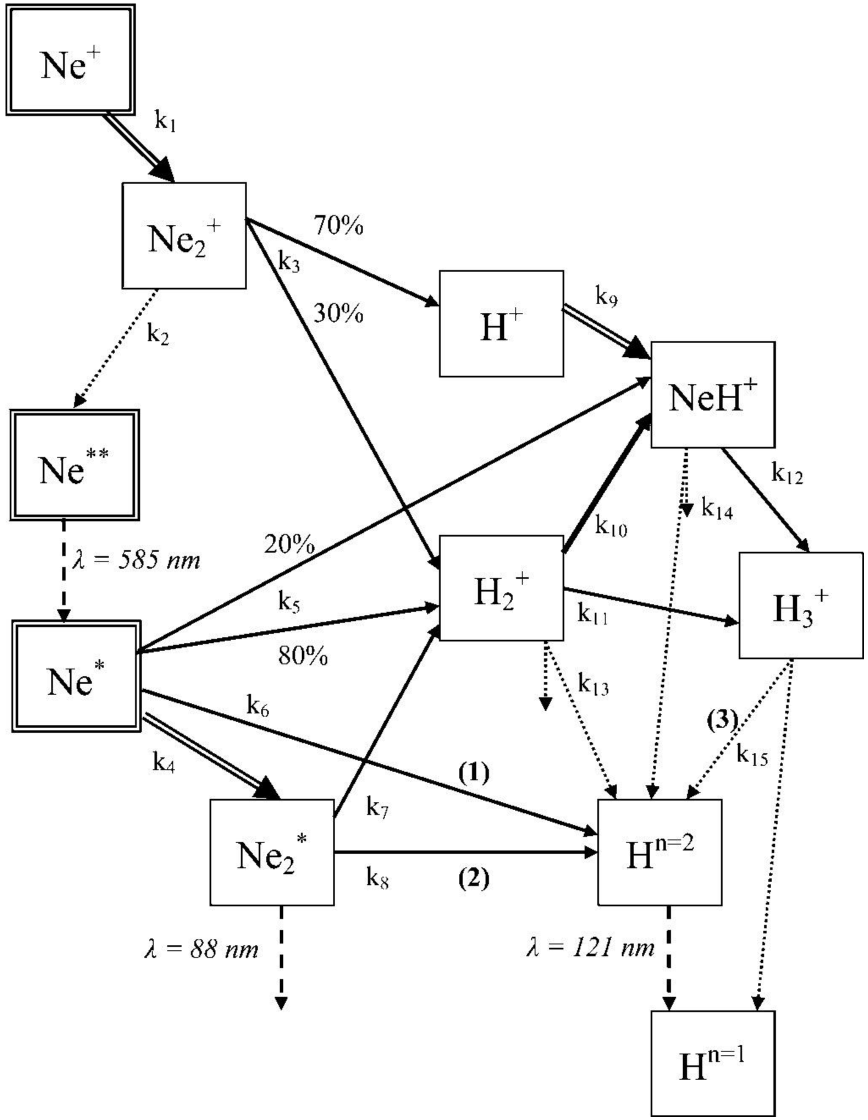
5ns excitation

Photon-counting



A.Morozov, R.Krücken, A.Ulrich, J.Wieser, T.McCarthy, Energy-transfer processes in neon-hydrogen mixtures excited by electron beams, J.Chem. Phys. **123**, 234311 (2005)

Gaskinetic studies/Spectroscopy

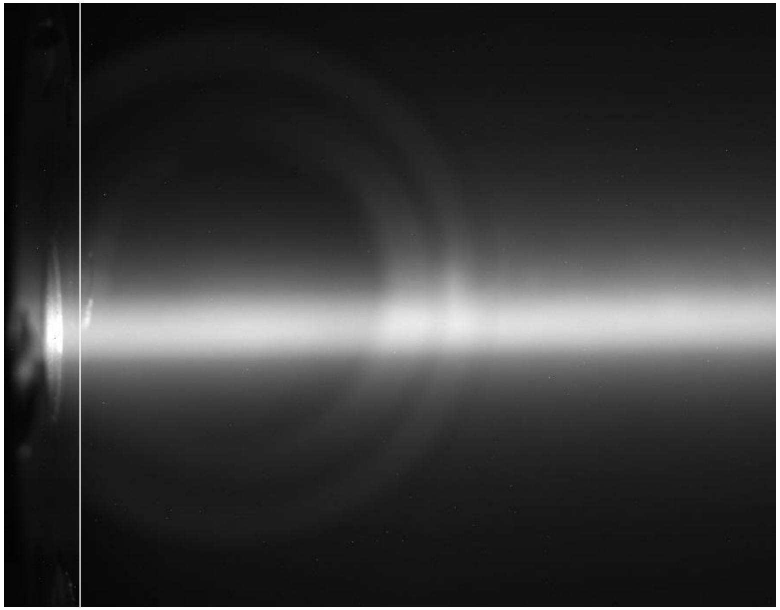


A.Morozov, R.Krücken, A.Ulrich, J.Wieser, T.McCarthy, Energy-transfer processes in neon-hydrogen mixtures excited by electron beams, J.Chem. Phys. **123**, 234311 (2005)

NOW: optical beam profile determination:

Question:

„Ion beam“ or „secondary electrons“

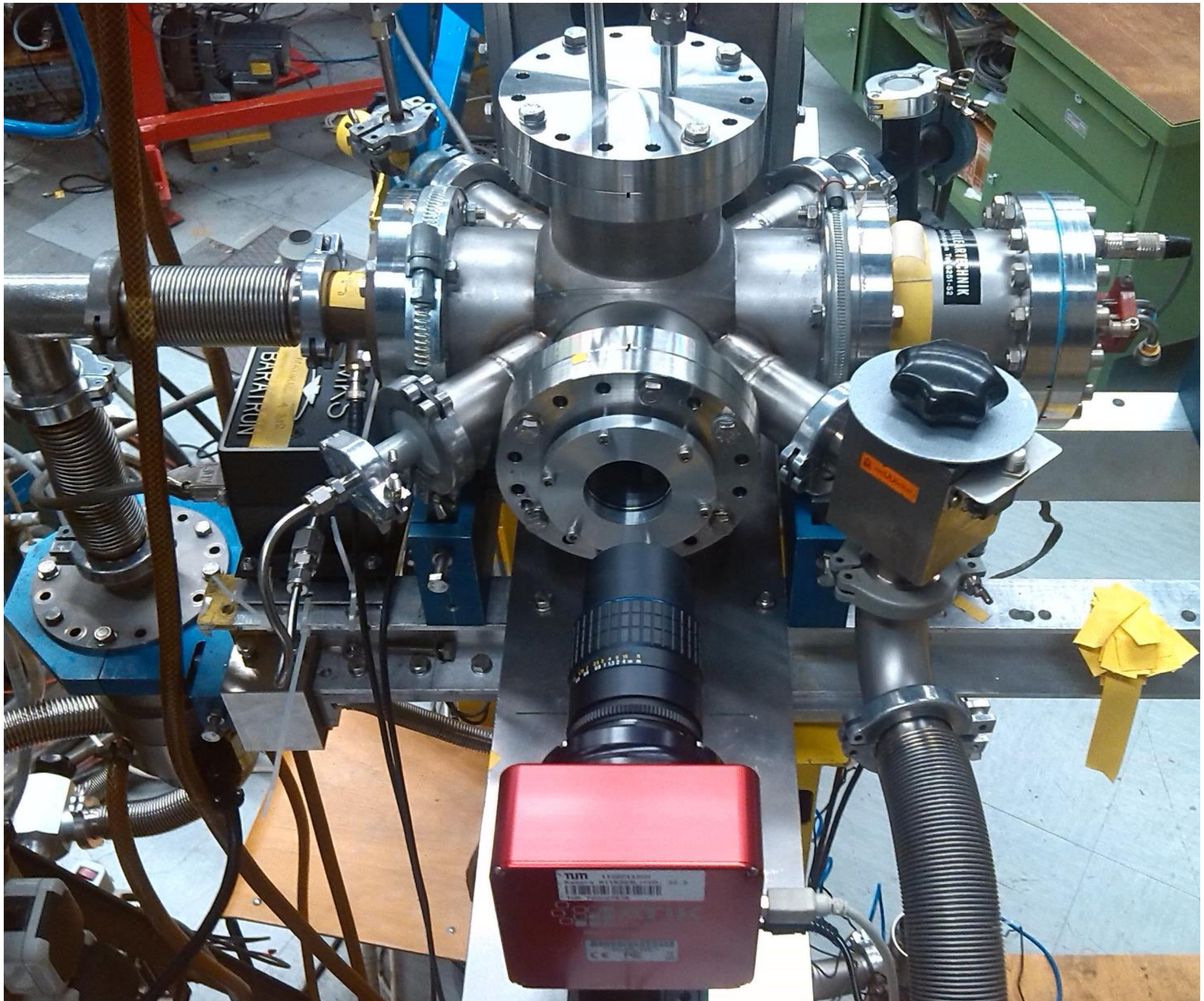


Ne, 585nm filter,
3mbar, 1mm aperture

Ion beams from the Munich Tandem Accelerator

dc beams, ~100MeV ^{32}S ions

Target cell



Titanium entrance foils

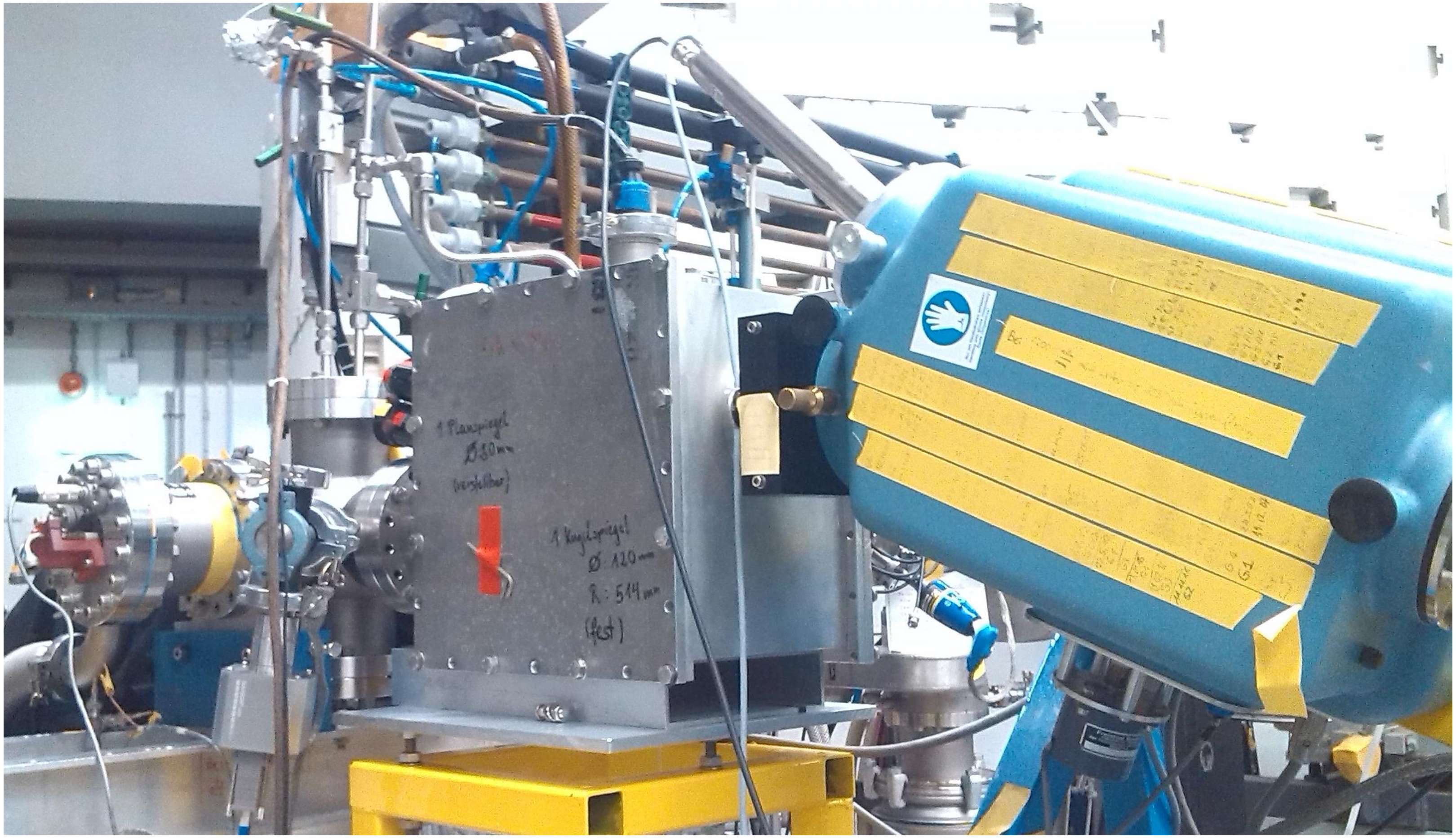
Differential pumping 1mm diameter

Gas purification

Quartz window

MgF_2 window

Spectrosopic setup (110nm to 3.5µm)



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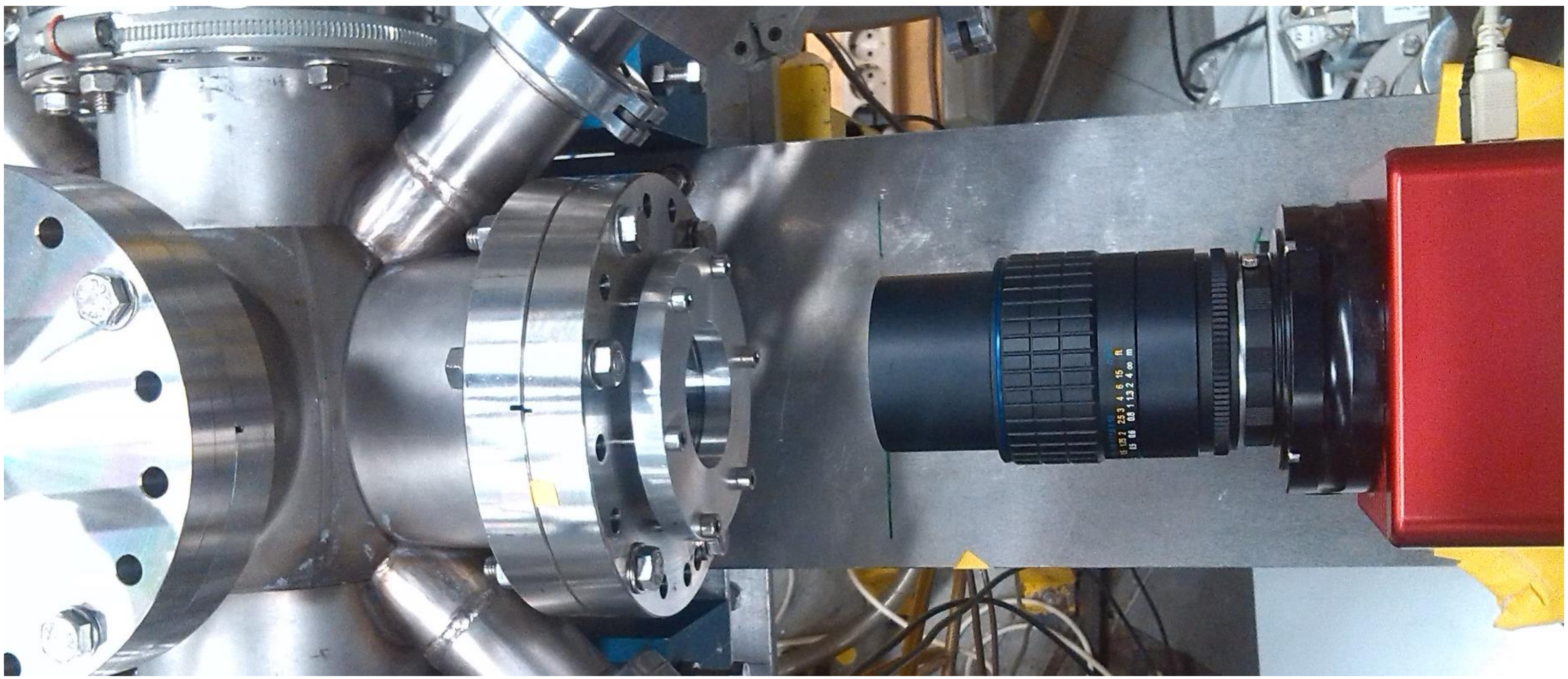
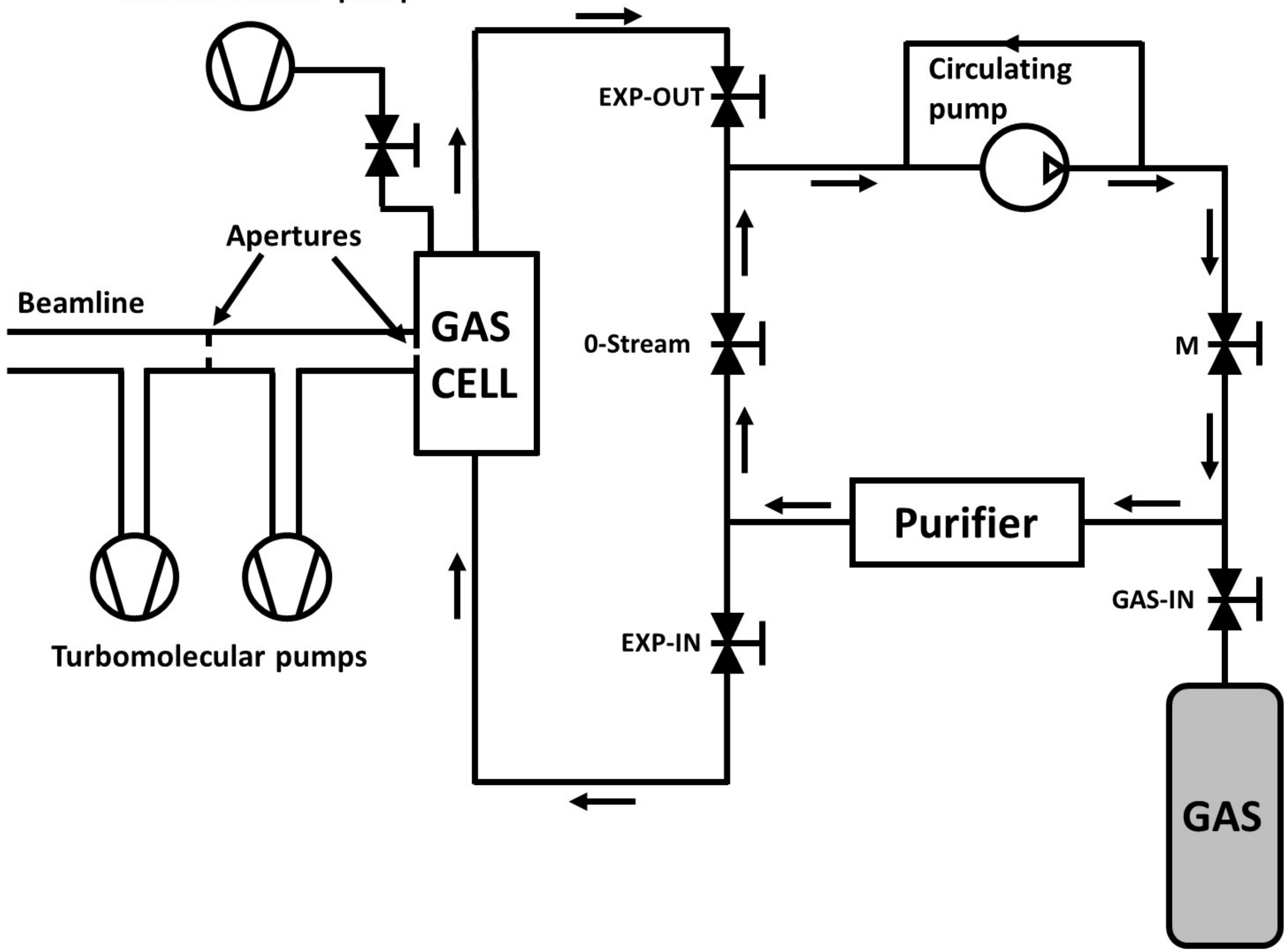
Preliminary beam profile monitor:

apocromatic lens 300 to 1100nm, ATIK CCD camera (Si), set of filters

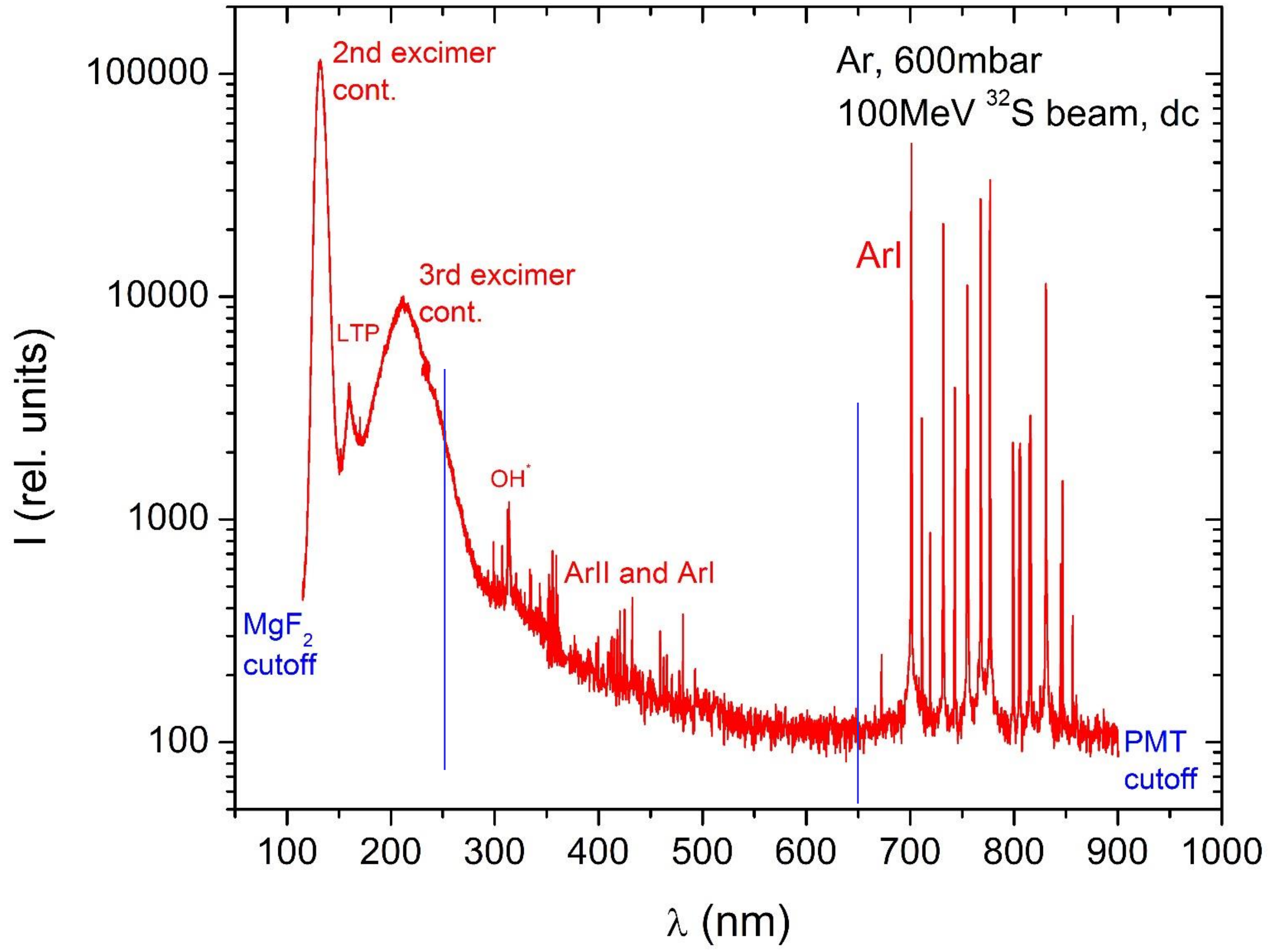


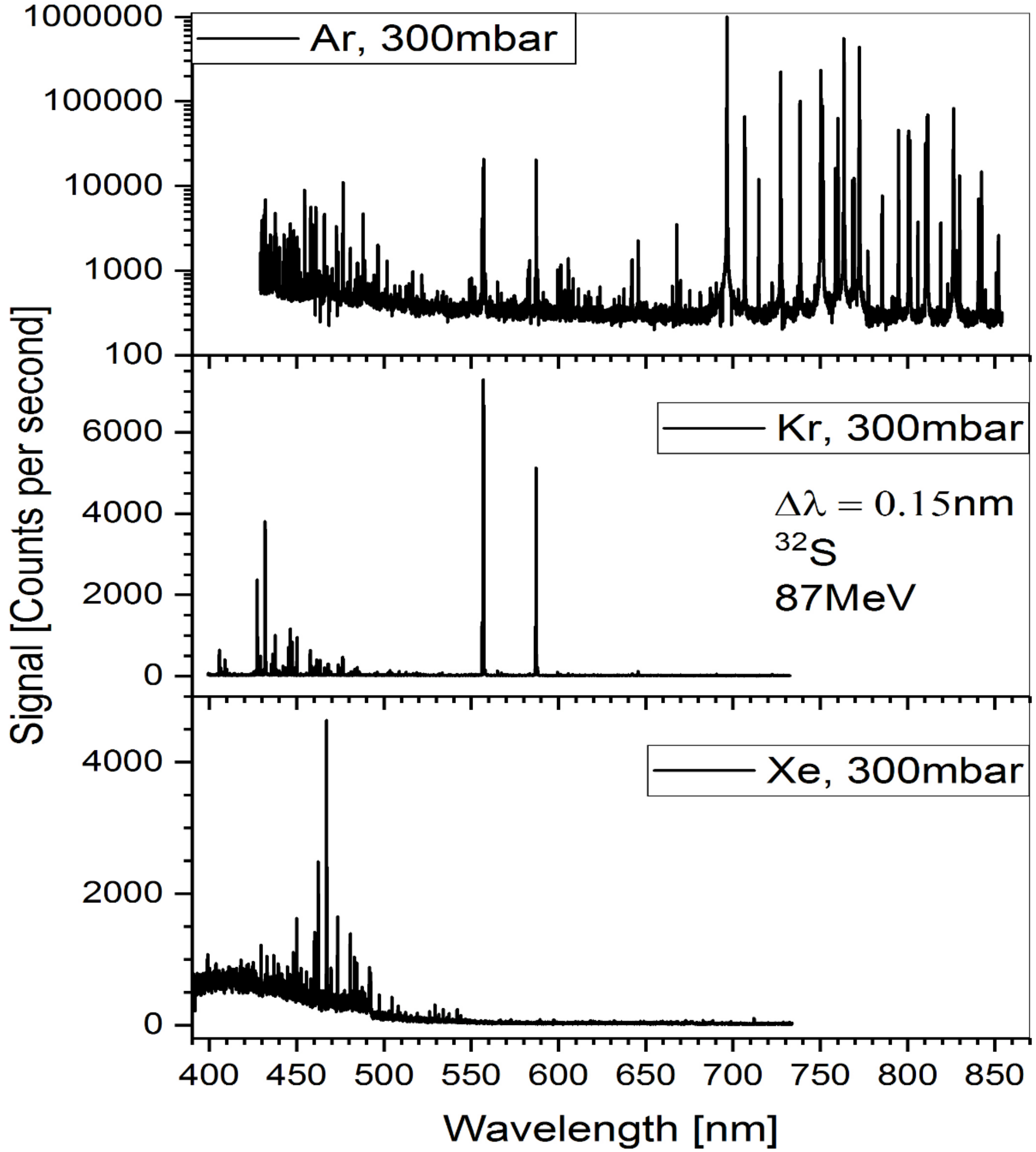
Gas system

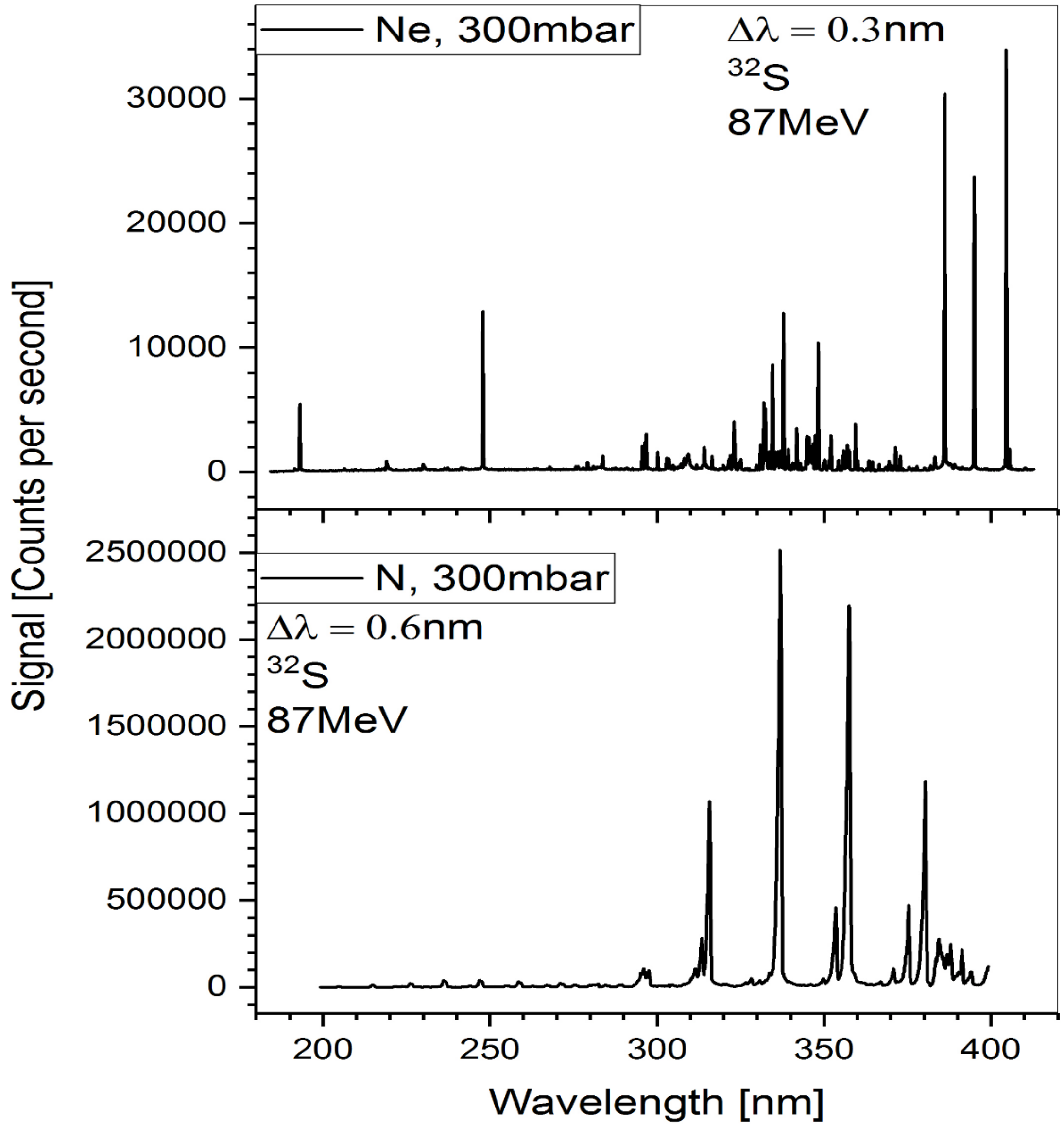

Turbomolecular pump
Apertures
Beamline
GAS
CELL
Turbomolecular pumps
EXP-OUT
0-Stream
EXP-IN
Circulating
pump
M
Purifier
GAS-IN
GAS

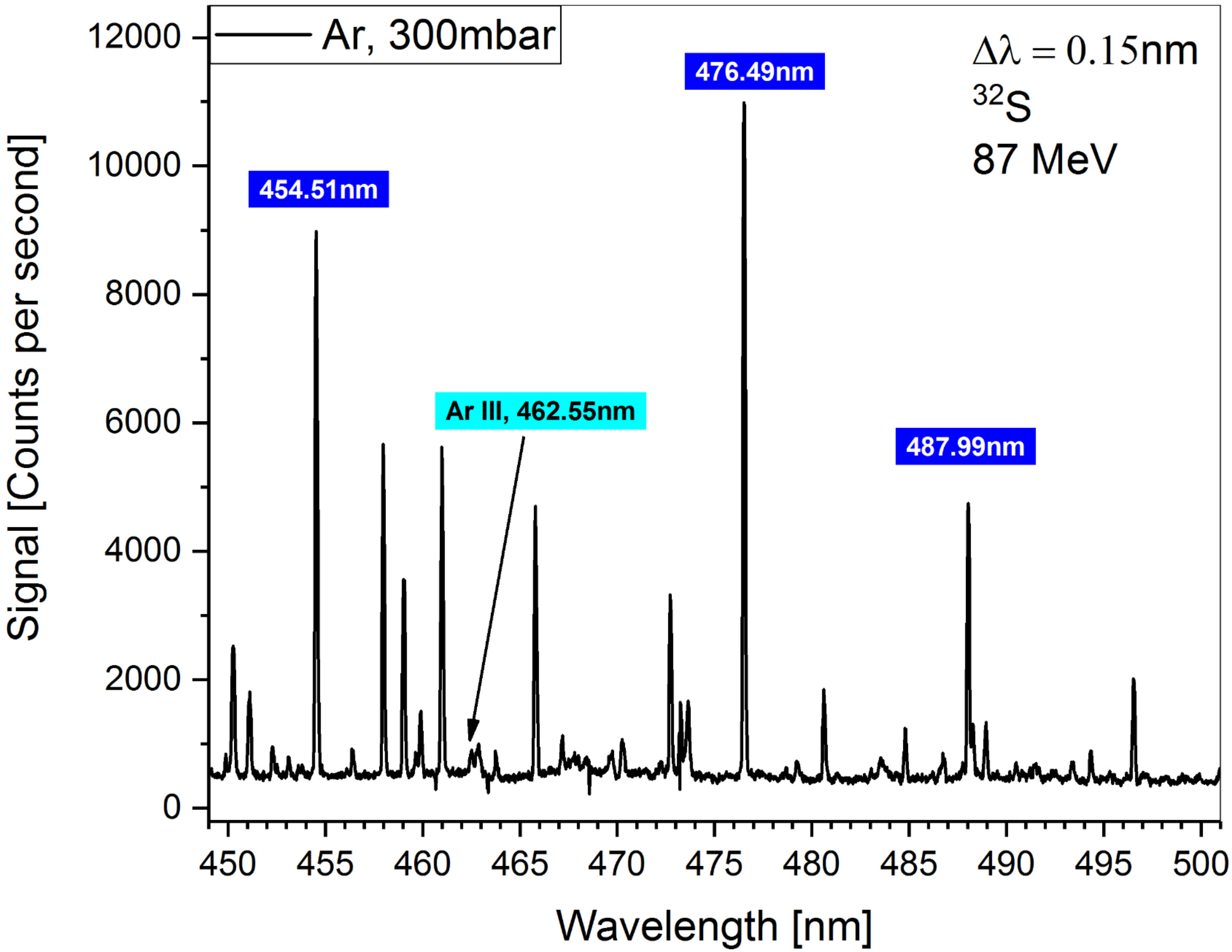
Spectroscopic results

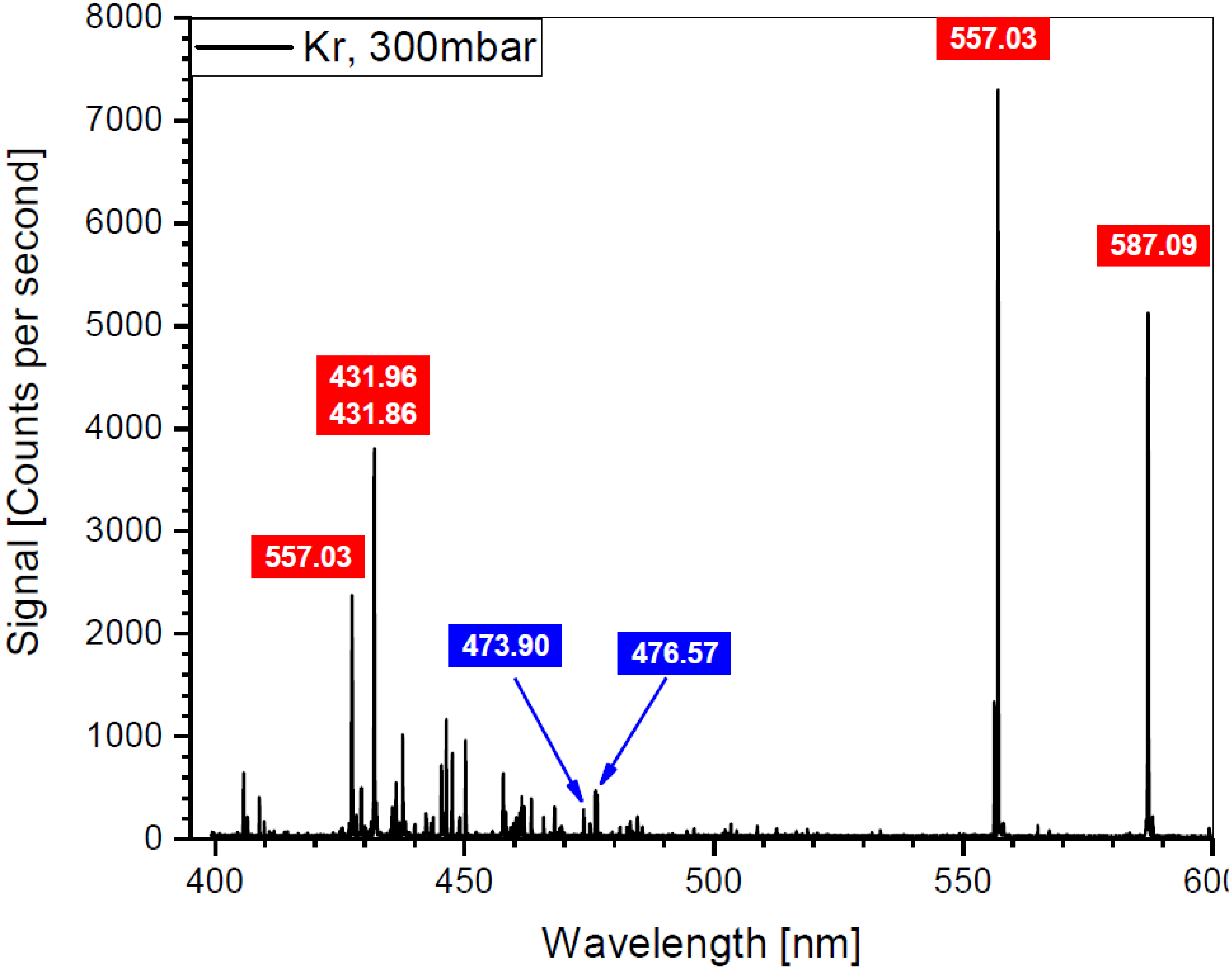
Overview: Light emission from pure rare gases



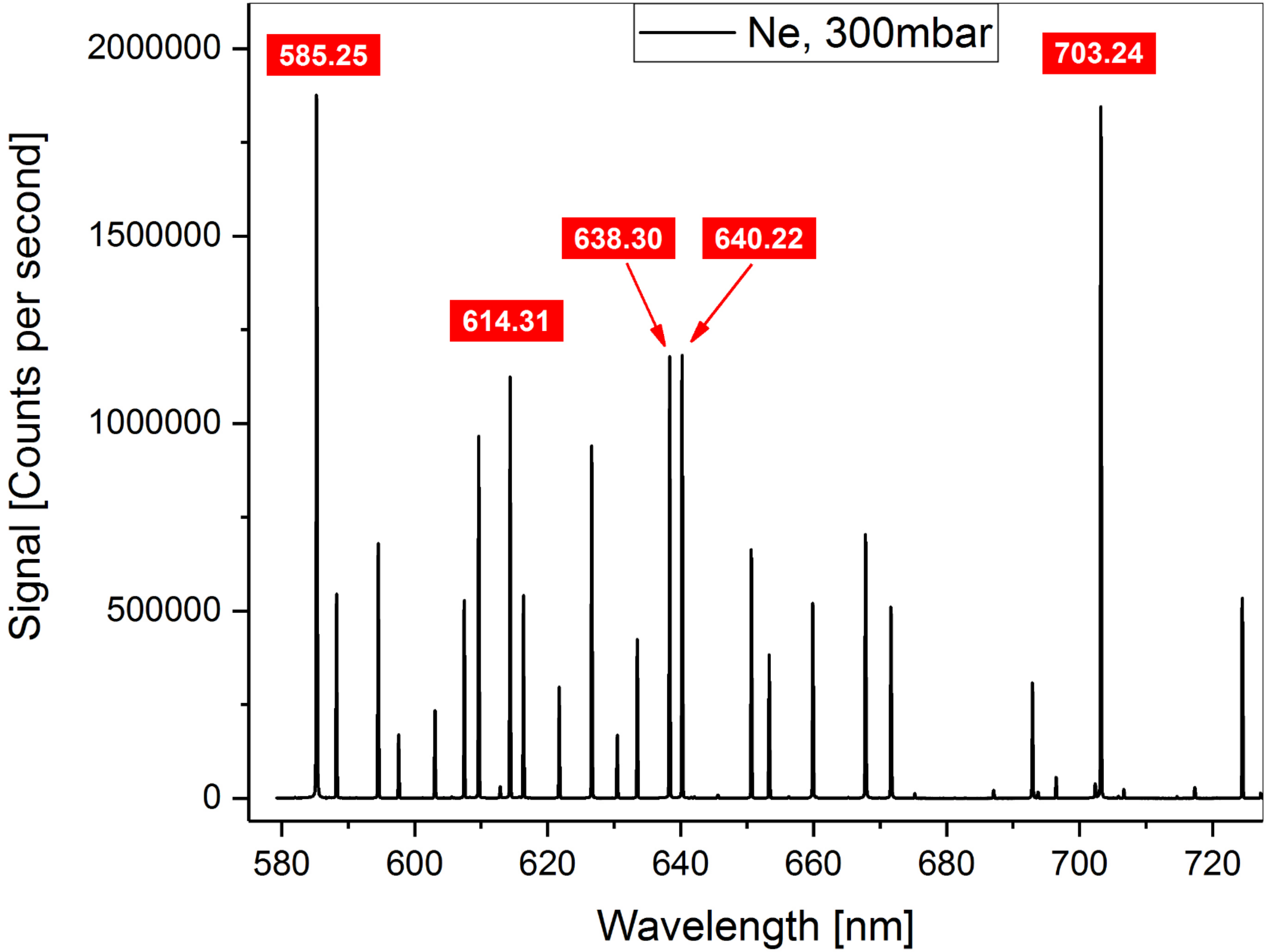

Ar, 300mbar
Kr, 300mbar
Xe, 300mbar
Δλ = 0.15nm
32S
87MeV
Signal [Counts per second]
Wavelength [nm]
1000000
100000
10000
1000
100
6000
4000
2000
0
4000
2000
0
400
450
500
550
600
650
700
750
800
850

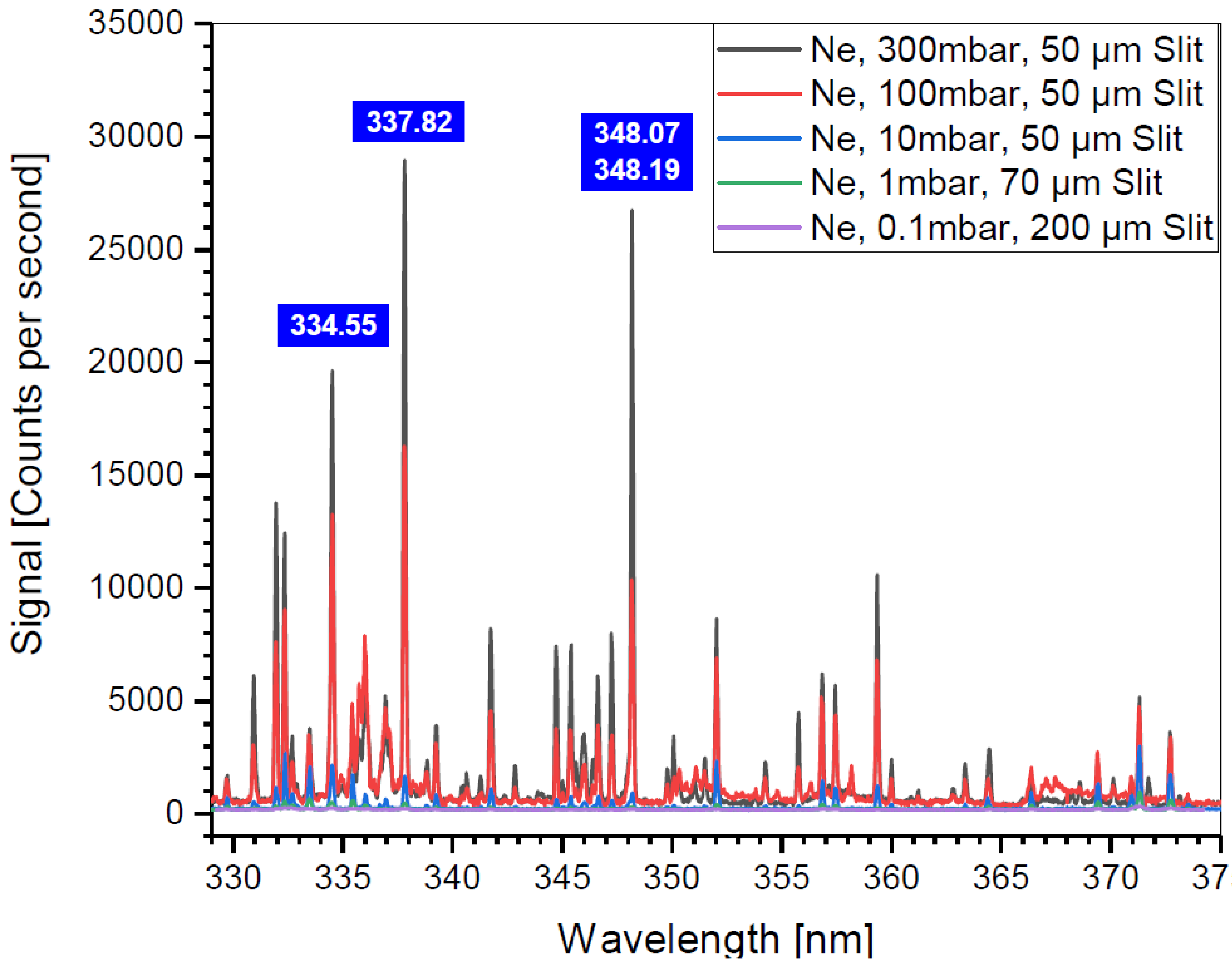

Ne, 300mbar
$\Delta\lambda = 0.3$nm
^{32}S
87MeV
N, 300mbar
$\Delta\lambda = 0.6$nm
^{32}S
87MeV
Signal [Counts per second]
Wavelength [nm]
30000
20000
10000
0
2500000
2000000
1500000
1000000
500000
0
200
250
300
350
400


Ar, 300mbar
$\Delta\lambda = 0.15$nm
^{32}S
87 MeV
454.51nm
476.49nm
Ar III, 462.55nm
487.99nm
12000
10000
8000
6000
4000
2000
0
450
455
460
465
470
475
480
485
490
495
500
Signal [Counts per second]
Wavelength [nm]

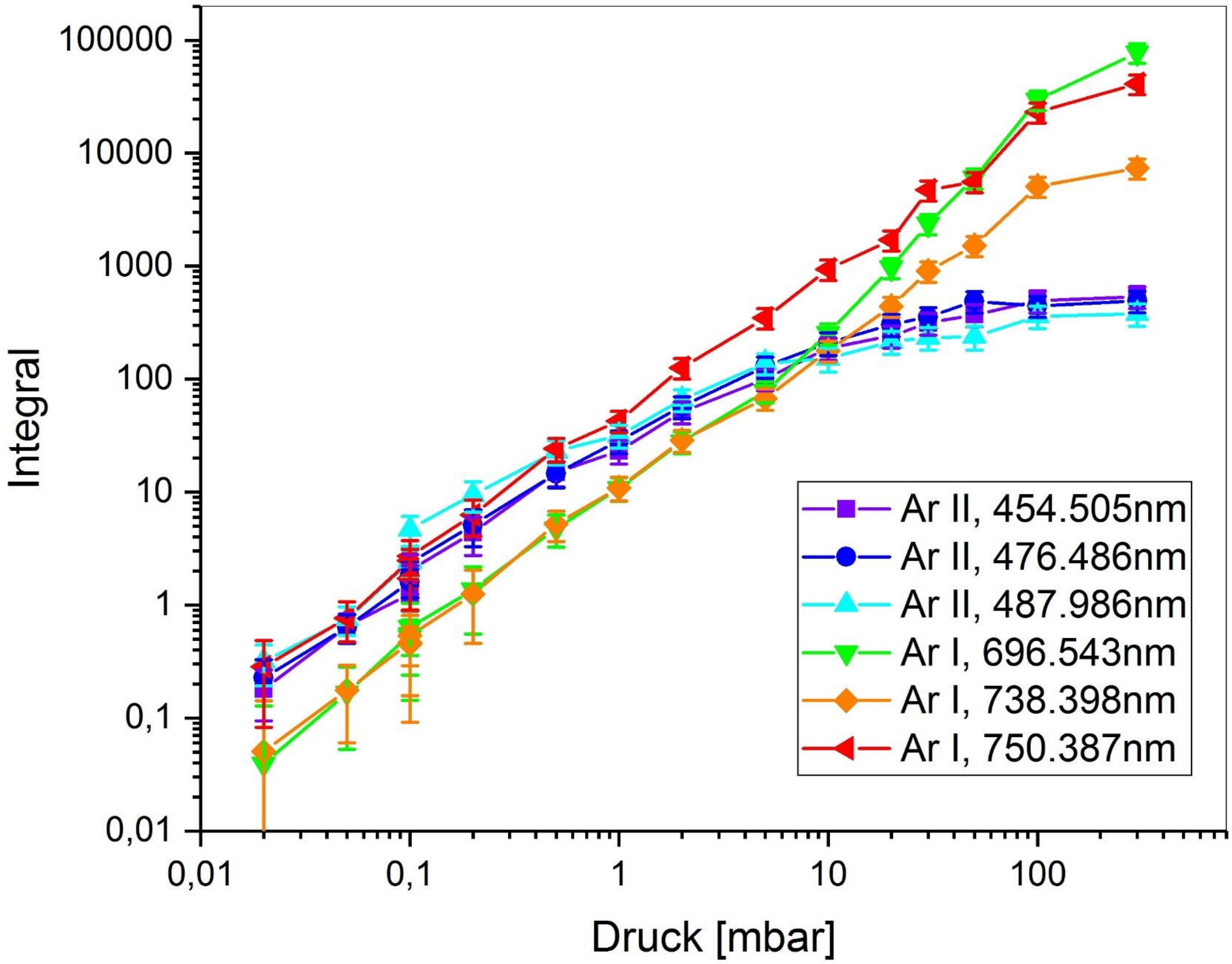


Kr, 300mbar
557.03
587.09
431.96
431.86
557.03
473.90
476.57
Signal [Counts per second]
Wavelength [nm]
0
1000
2000
3000
4000
5000
6000
7000
8000
400
450
500
550
600

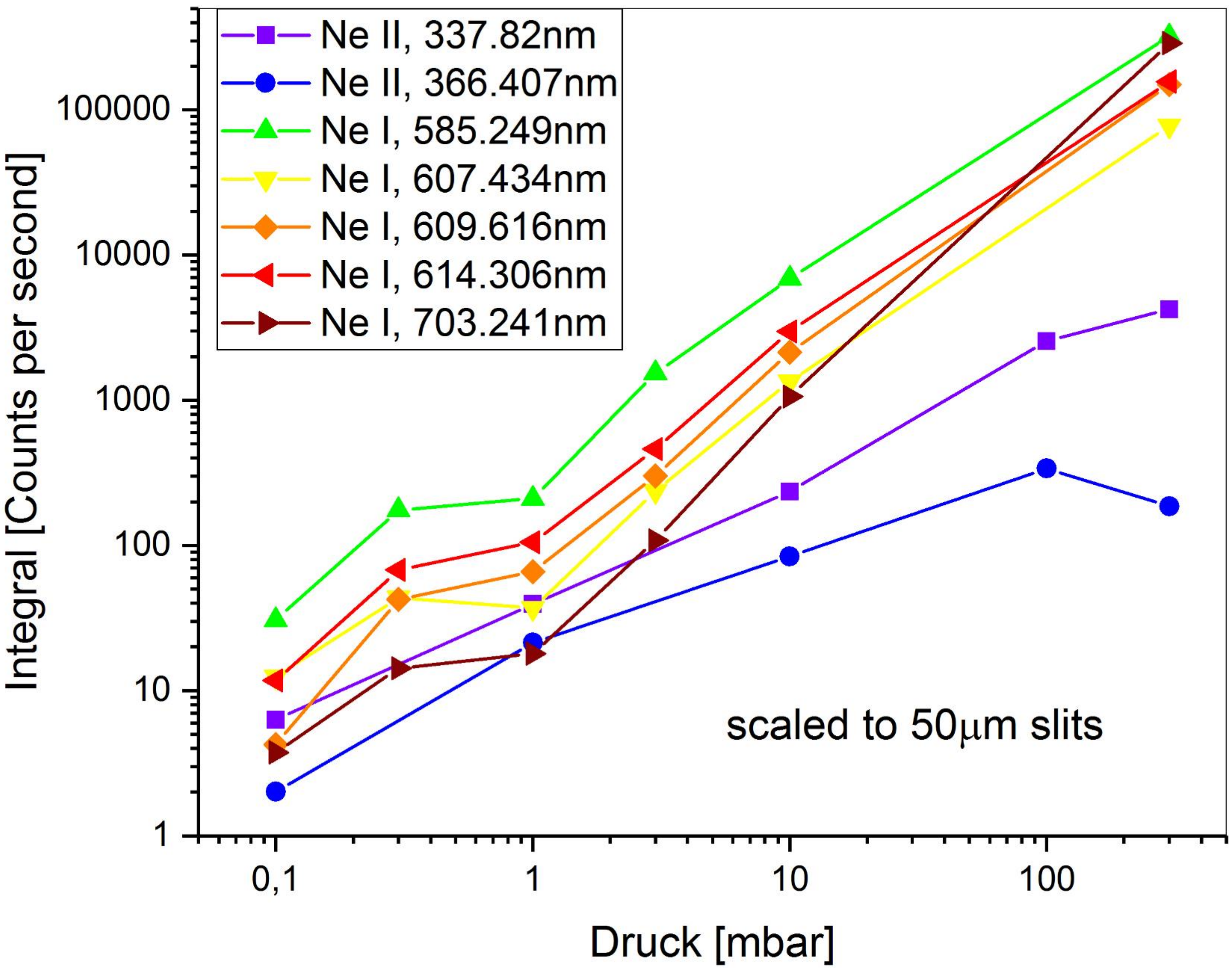

Ne, 300mbar
585.25
614.31
638.30
640.22
703.24
Signal [Counts per second]
Wavelength [nm]
2000000
1500000
1000000
500000
0
580
600
620
640
660
680
700
720



Signal [Counts per second]
35000
30000
25000
20000
15000
10000
5000
0
330
335
340
345
350
355
360
365
370
Wavelength [nm]
Ne, 300mbar, 50 µm Slit
Ne, 100mbar, 50 µm Slit
Ne, 10mbar, 50 µm Slit
Ne, 1mbar, 70 µm Slit
Ne, 0.1mbar, 200 µm Slit
337.82
348.07
348.19
334.55



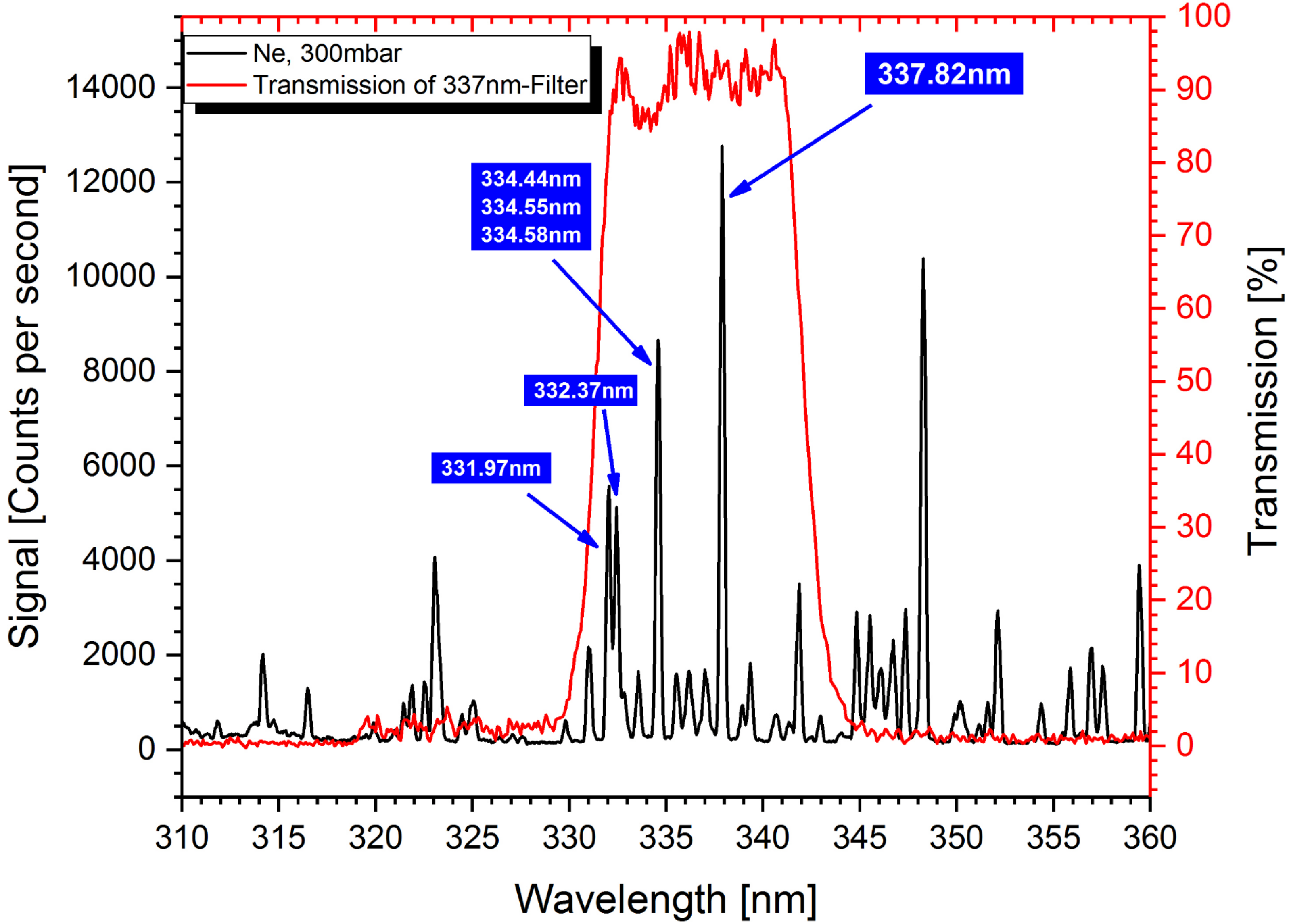
Integral
100000
10000
1000
100
10
1
0,1
0,01
0,01
0,1
1
10
100
Druck [mbar]
Ar II, 454.505nm
Ar II, 476.486nm
Ar II, 487.986nm
Ar I, 696.543nm
Ar I, 738.398nm
Ar I, 750.387nm

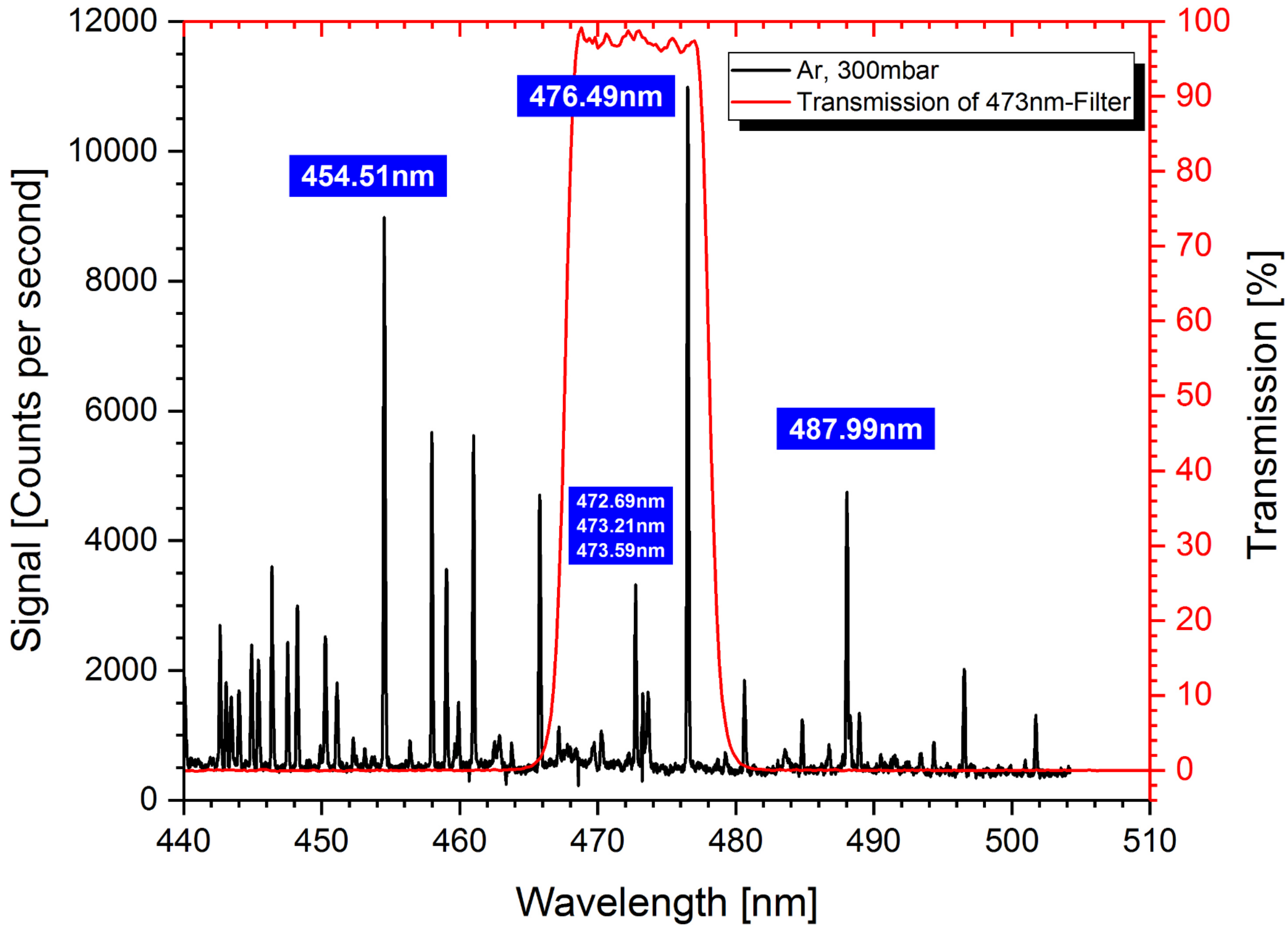

Ne II, 337.82nm
Ne II, 366.407nm
Ne I, 585.249nm
Ne I, 607.434nm
Ne I, 609.616nm
Ne I, 614.306nm
Ne I, 703.241nm
Integral [Counts per second]
100000
10000
1000
100
10
1
0,1
1
10
100
Druck [mbar]
scaled to 50μm slits

Filter for the beam profile monitor

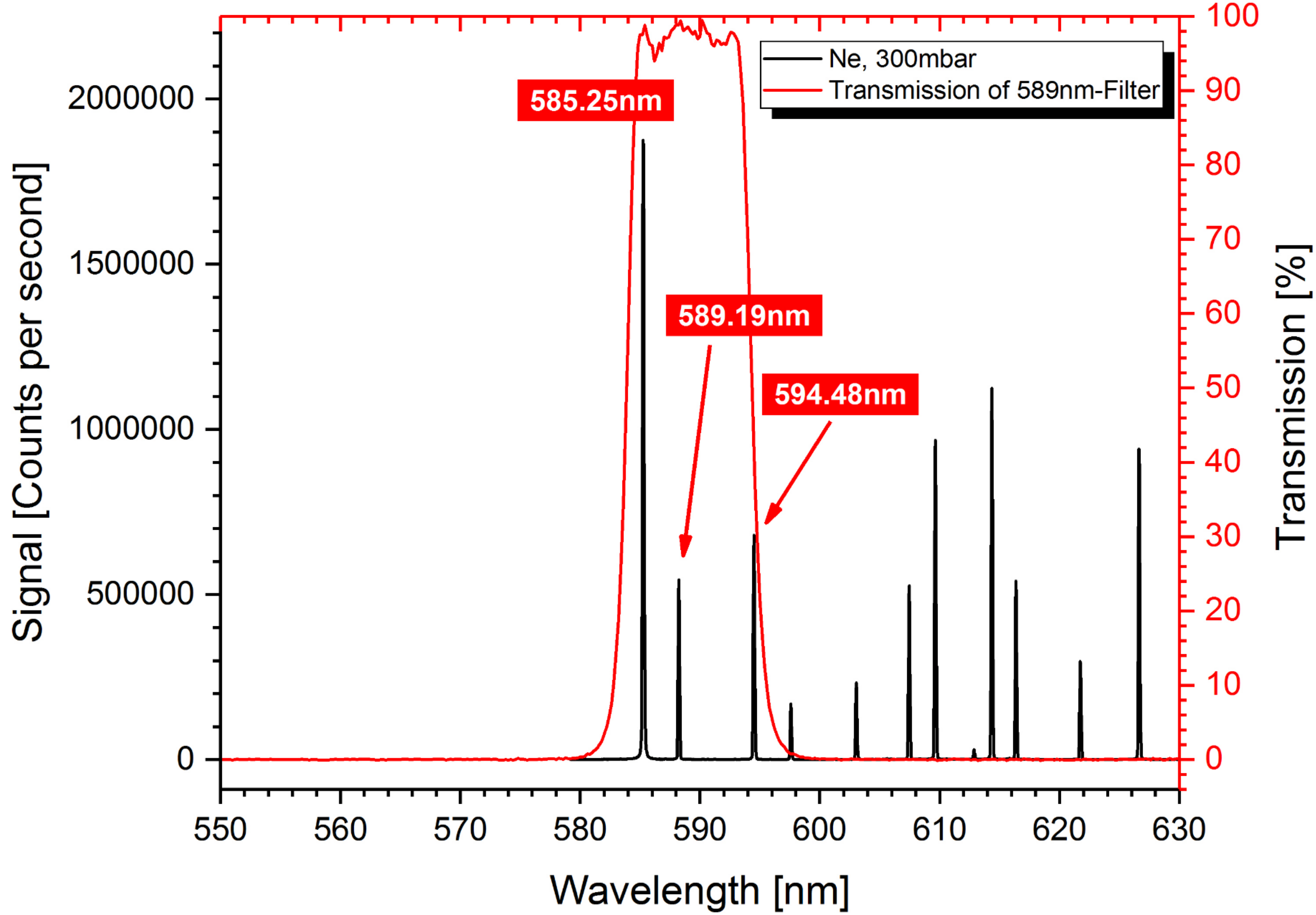
Selection of ion lines and
Lines emitted from neutral atoms (molecules)

„Filters from Stock!“

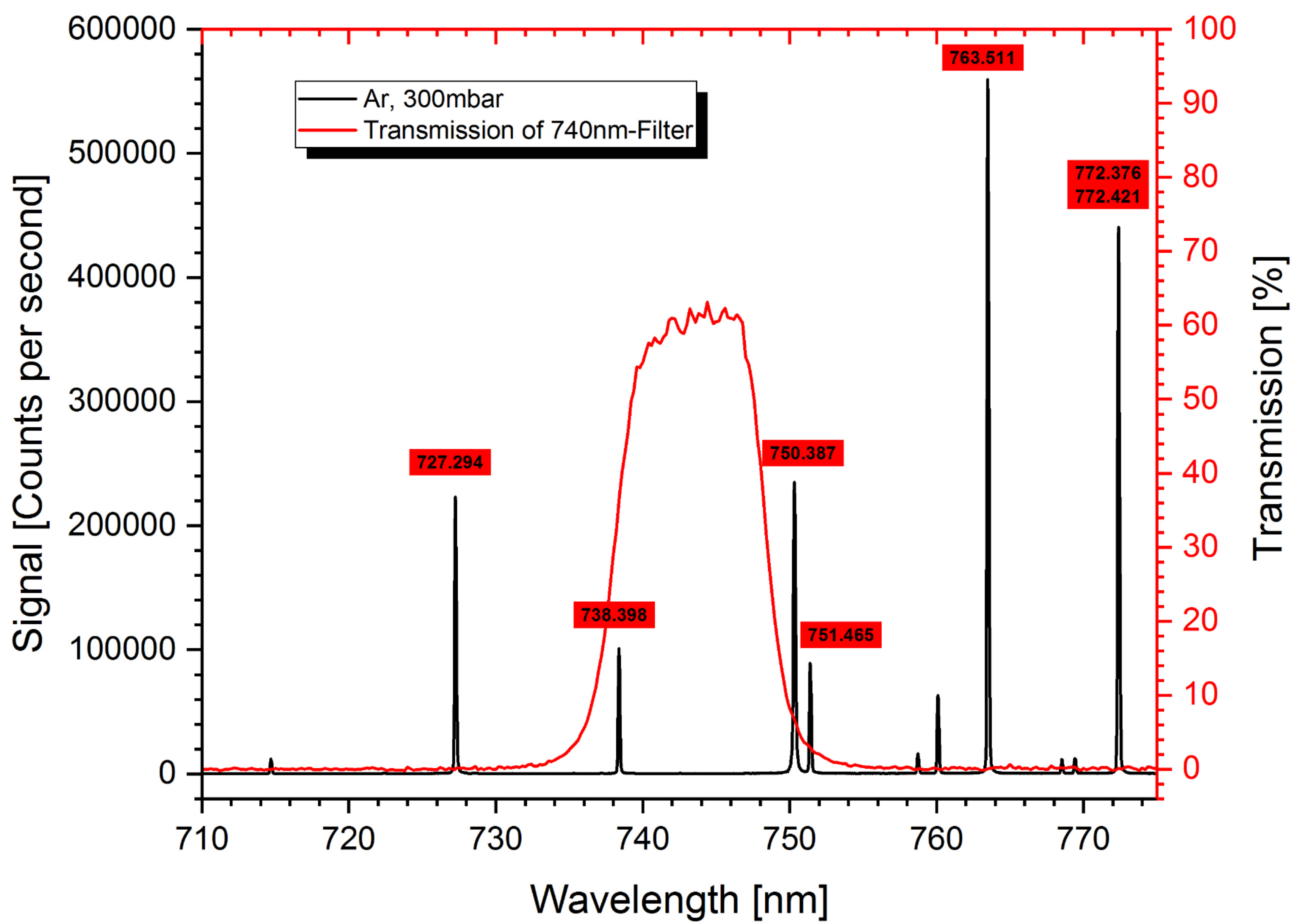

Ne, 300mbar
Transmission of 337nm-Filter
337.82nm
334.44nm
334.55nm
334.58nm
332.37nm
331.97nm
Signal [Counts per second]
Transmission [%]
Wavelength [nm]
0
2000
4000
6000
8000
10000
12000
14000
0
10
20
30
40
50
60
70
80
90
100
310
315
320
325
330
335
340
345
350
355
360



Signal [Counts per second]
Transmission [%]
Wavelength [nm]
Ar, 300mbar
Transmission of 473nm-Filter
454.51nm
476.49nm
487.99nm
472.69nm
473.21nm
473.59nm
12000
10000
8000
6000
4000
2000
0
100
90
80
70
60
50
40
30
20
10
0
440
450
460
470
480
490
500
510

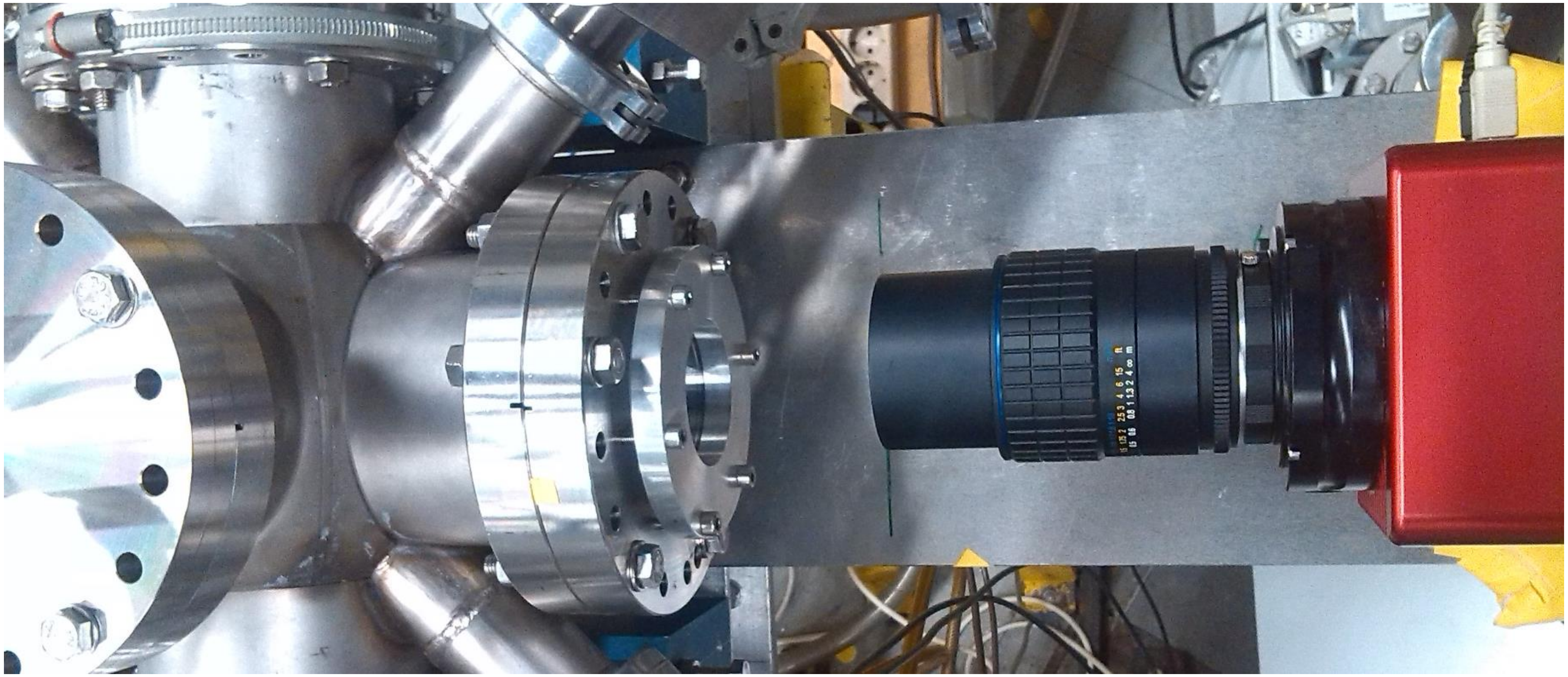


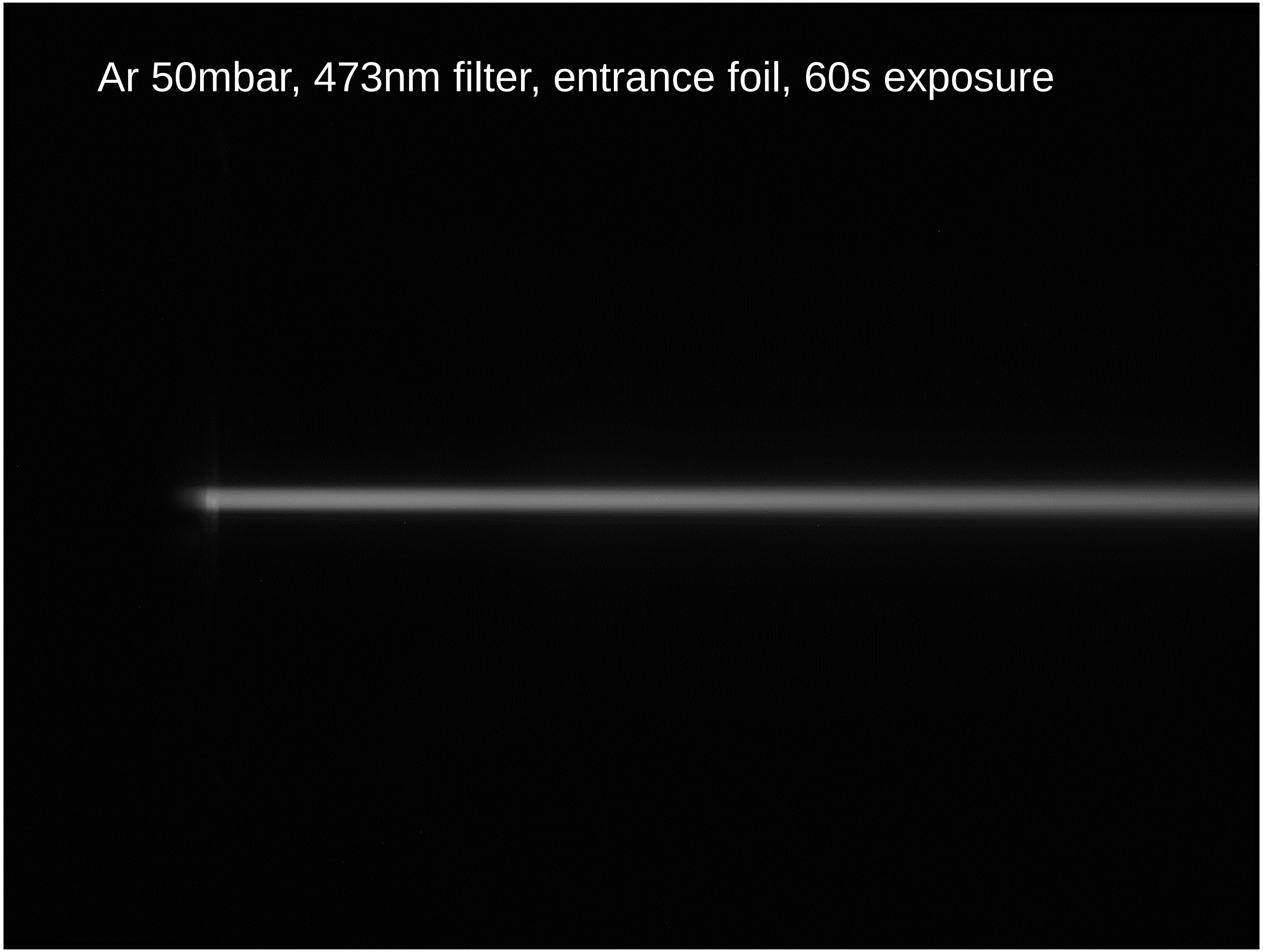
585.25nm
589.19nm
594.48nm
Ne, 300mbar
Transmission of 589nm-Filter
Signal [Counts per second]
0
500000
1000000
1500000
2000000
Transmission [%]
0
10
20
30
40
50
60
70
80
90
100
550
560
570
580
590
600
610
620
630
Wavelength [nm]

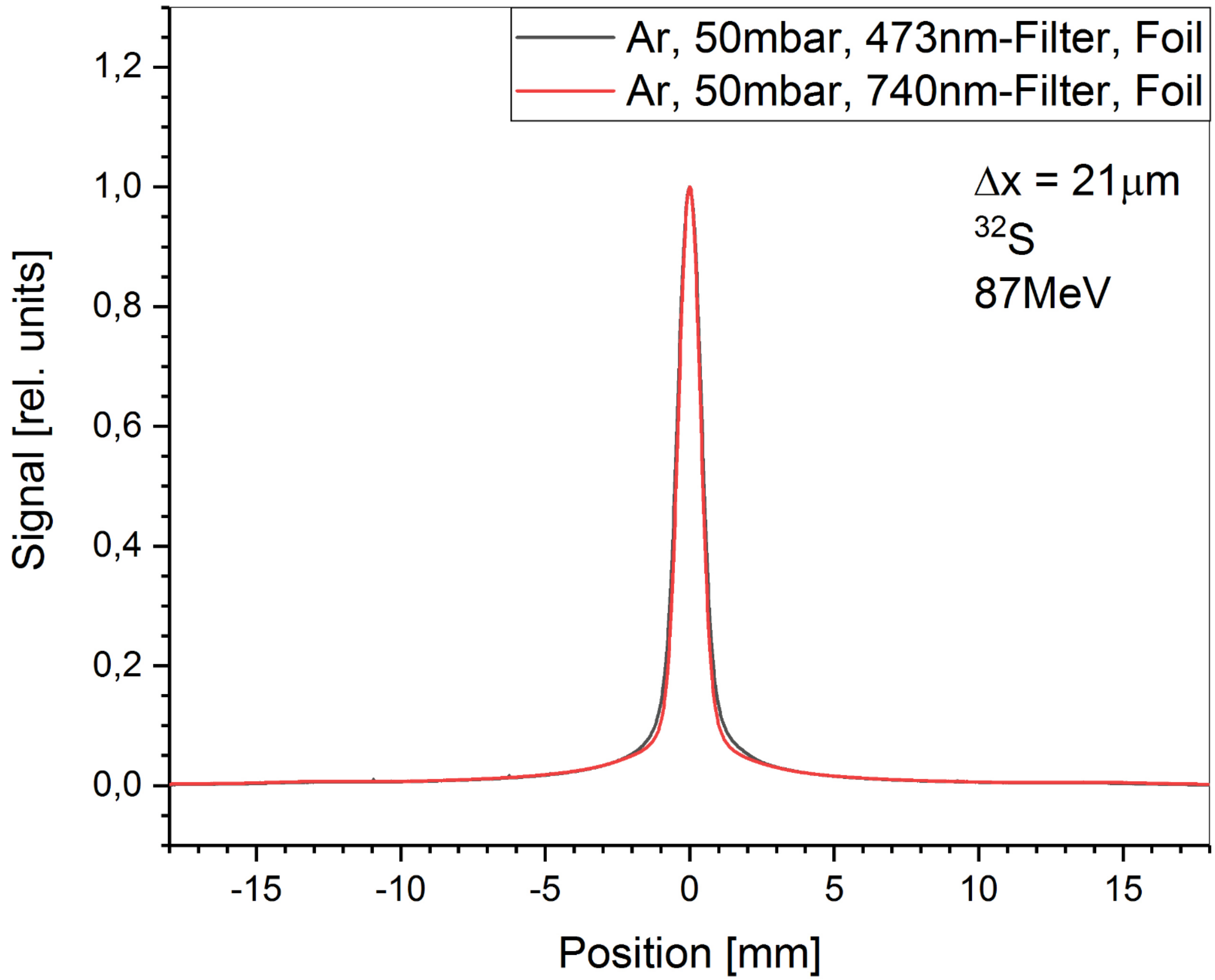


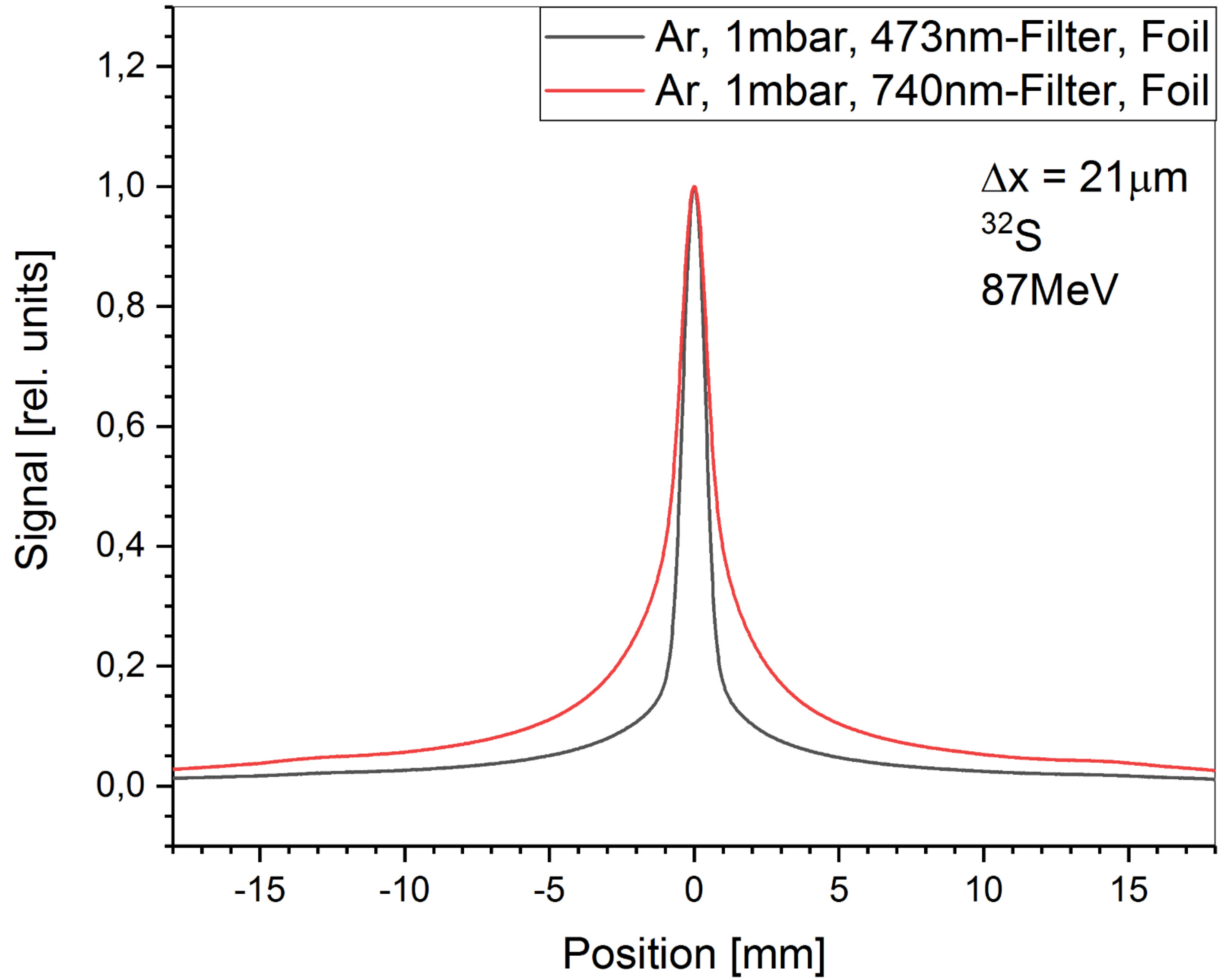
excitech
Ar, 300mbar
Transmission of 740nm-Filter
763.511
772.376
772.421
727.294
750.387
738.398
751.465
Signal [Counts per second]
Transmission [%]
Wavelength [nm]
600000
500000
400000
300000
200000
100000
0
100
90
80
70
60
50
40
30
20
10
0
710
720
730
740
750
760
770

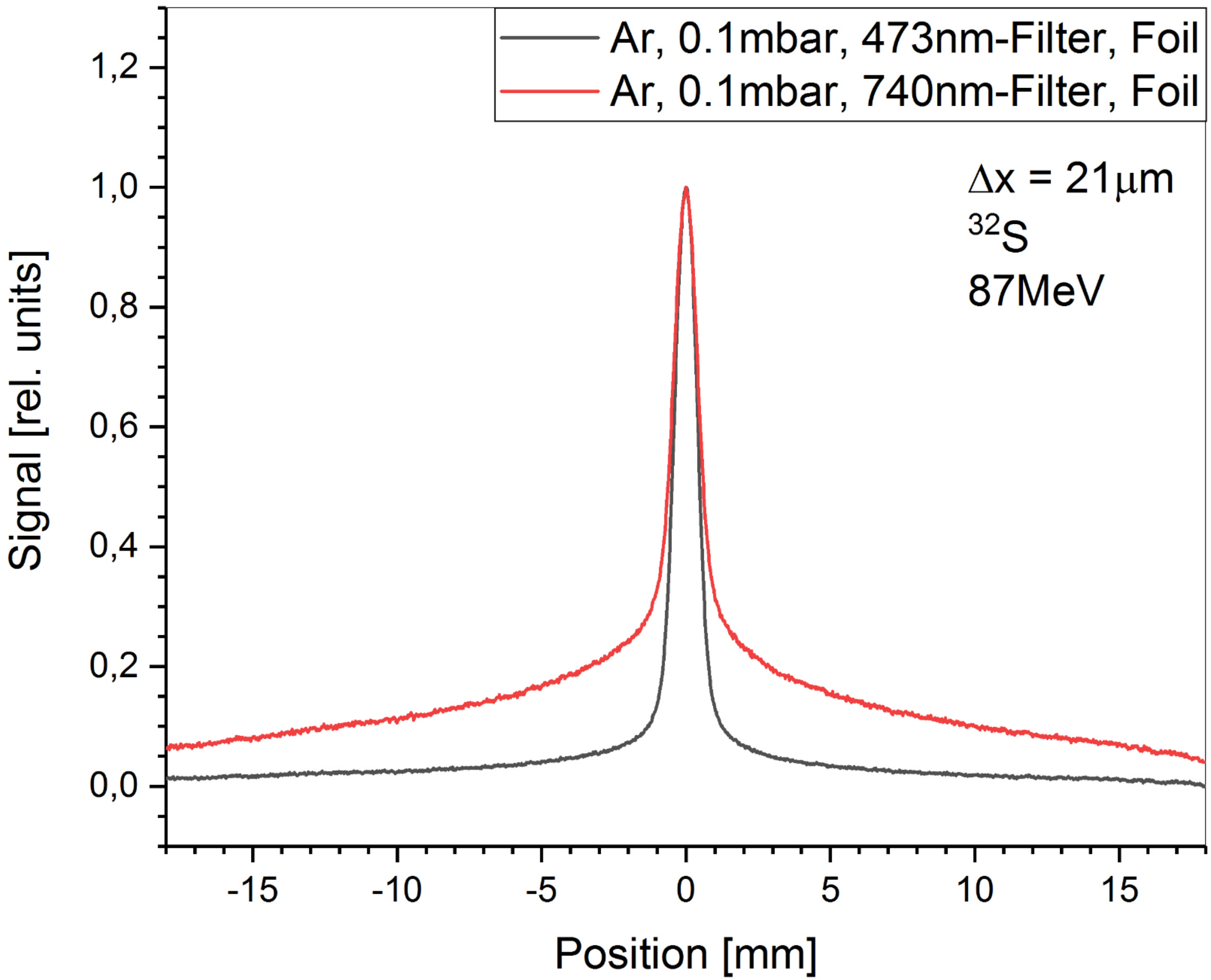
Beam profiles

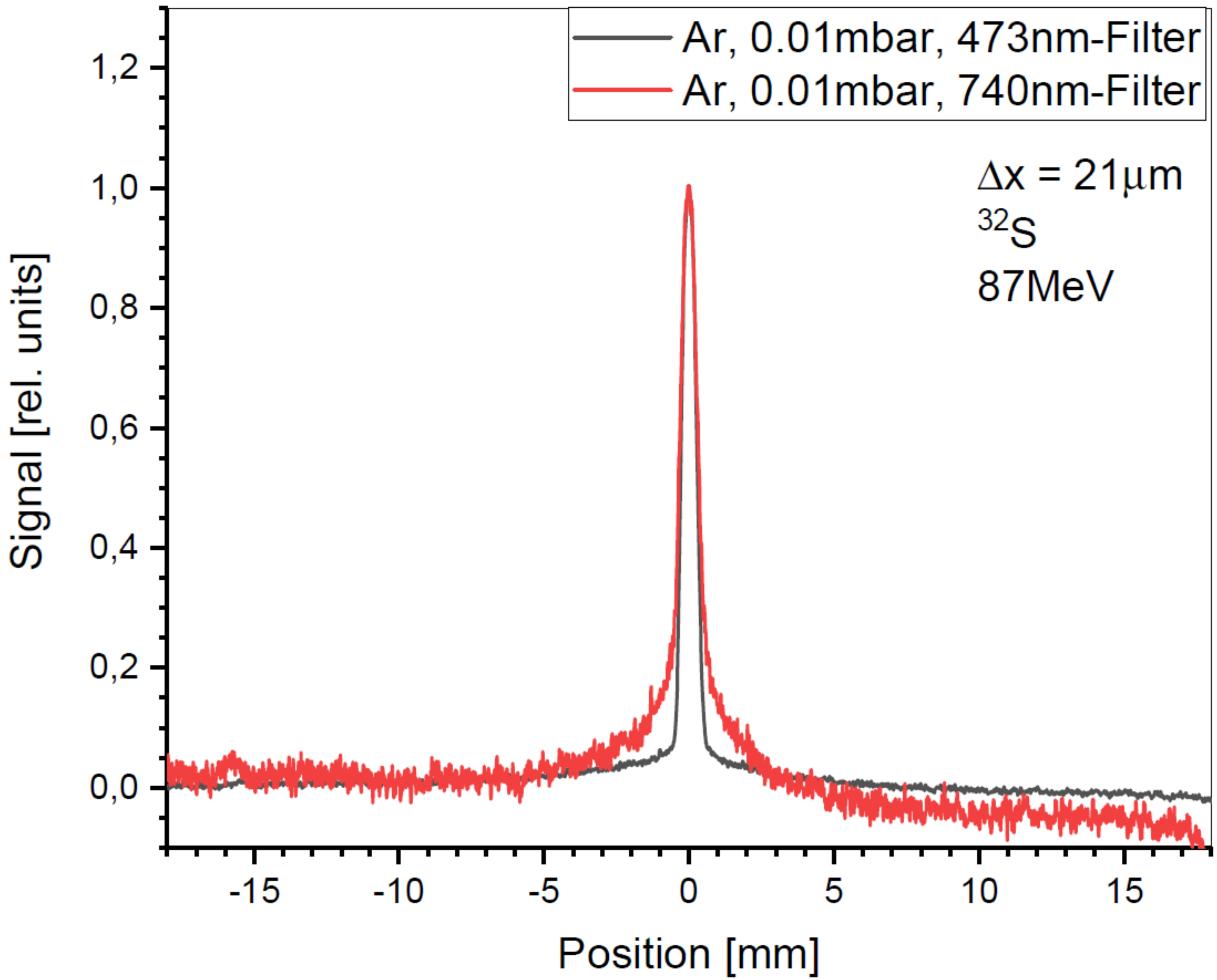



Ar 50mbar, 473nm filter, entrance foil, 60s exposure

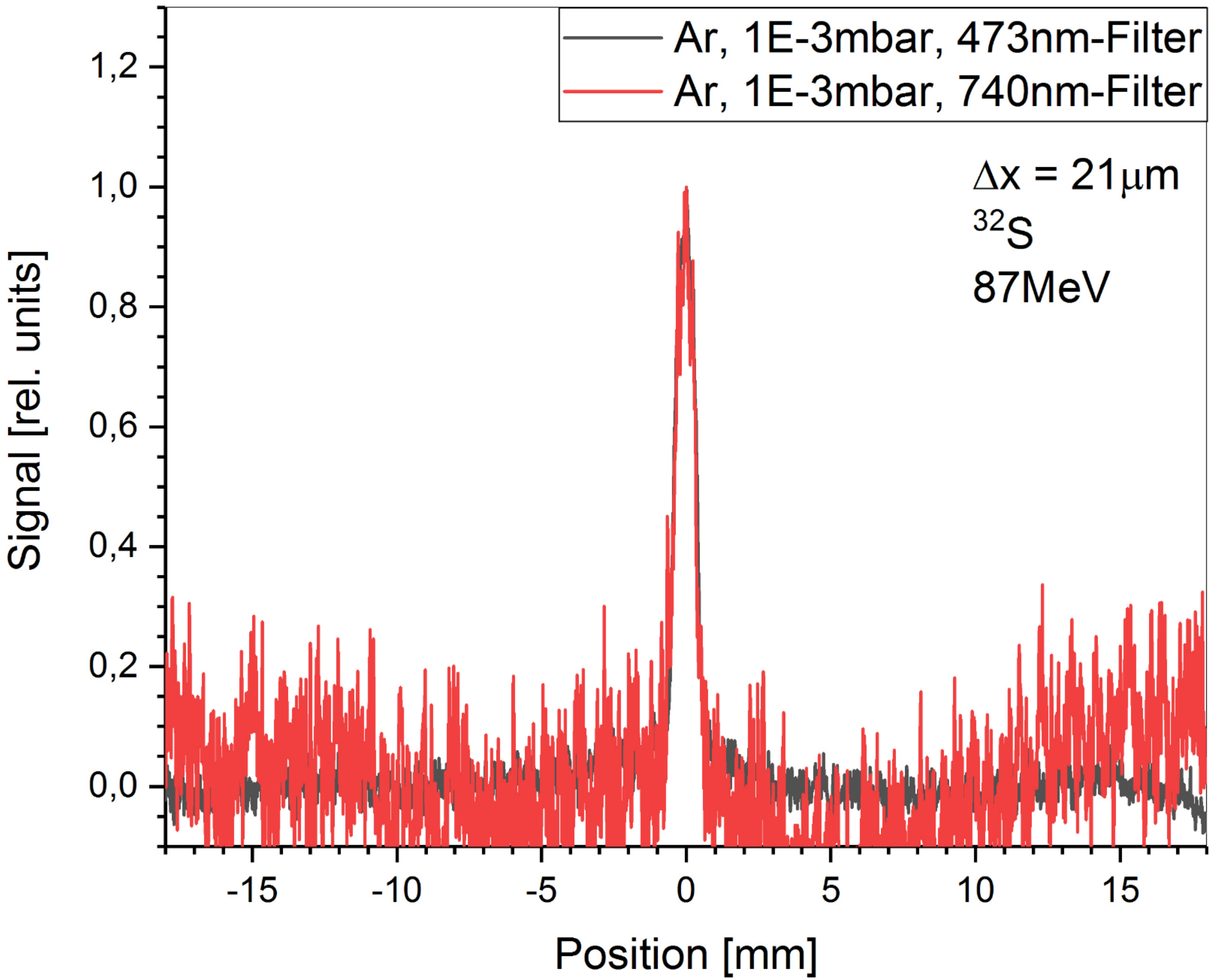

Ar, 50mbar, 473nm-Filter, Foil
Ar, 50mbar, 740nm-Filter, Foil
Δx = 21μm
32S
87MeV
Signal [rel. units]
1,2
1,0
0,8
0,6
0,4
0,2
0,0
-15
-10
-5
0
5
10
15
Position [mm]

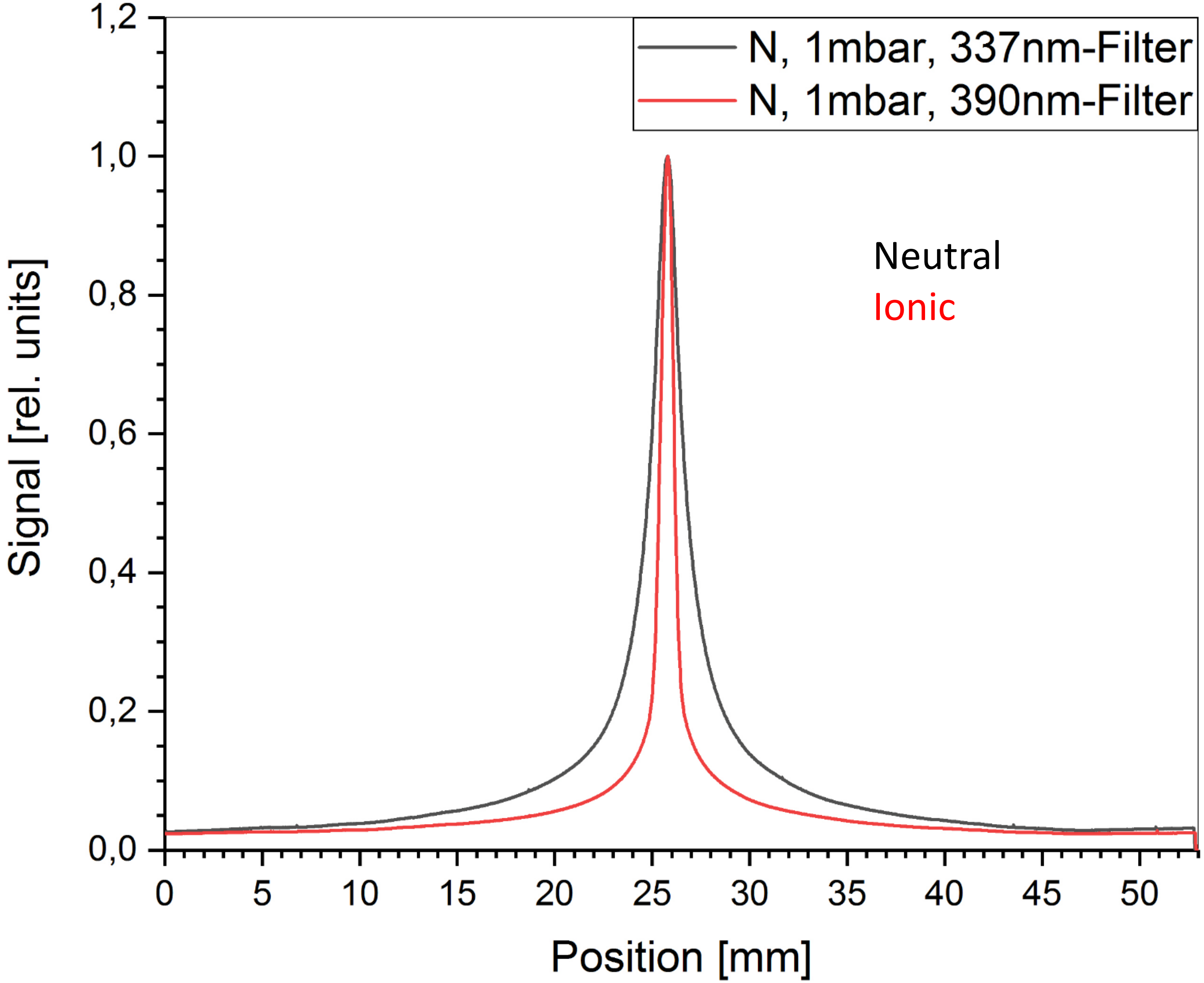

Ar, 1mbar, 473nm-Filter, Foil
Ar, 1mbar, 740nm-Filter, Foil
Δx = 21μm
32S
87MeV
Signal [rel. units]
1,2
1,0
0,8
0,6
0,4
0,2
0,0
-15
-10
-5
0
5
10
15
Position [mm]

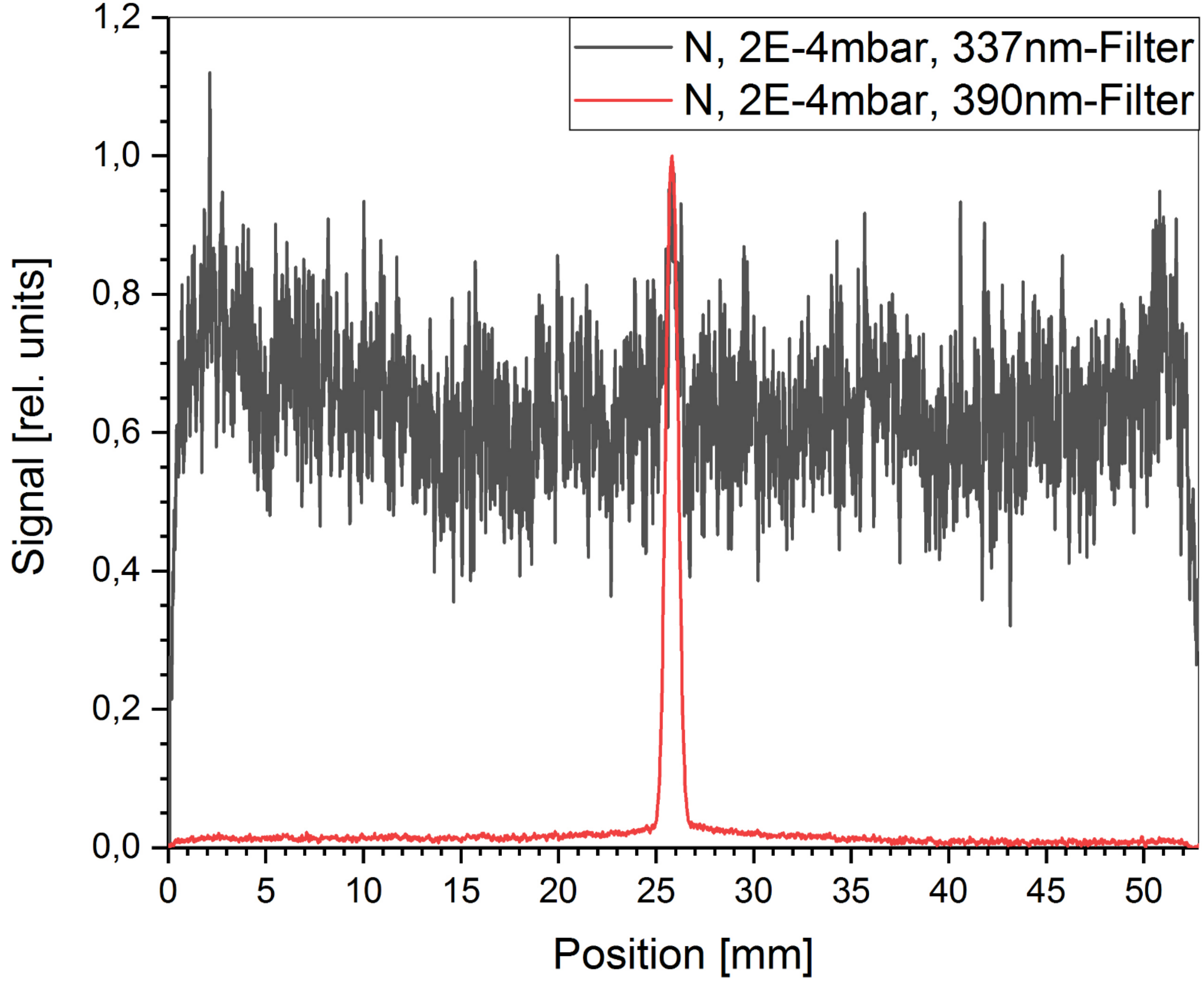

Ar, 0.1mbar, 473nm-Filter, Foil
Ar, 0.1mbar, 740nm-Filter, Foil
Δx = 21μm
32S
87MeV
Signal [rel. units]
1,2
1,0
0,8
0,6
0,4
0,2
0,0
-15
-10
-5
0
5
10
15
Position [mm]



Ar, 0.01mbar, 473nm-Filter
Ar, 0.01mbar, 740nm-Filter
Δx = 21μm
^{32}S
87MeV
Signal [rel. units]
Position [mm]
1,2
1,0
0,8
0,6
0,4
0,2
0,0
-15
-10
-5
0
5
10
15

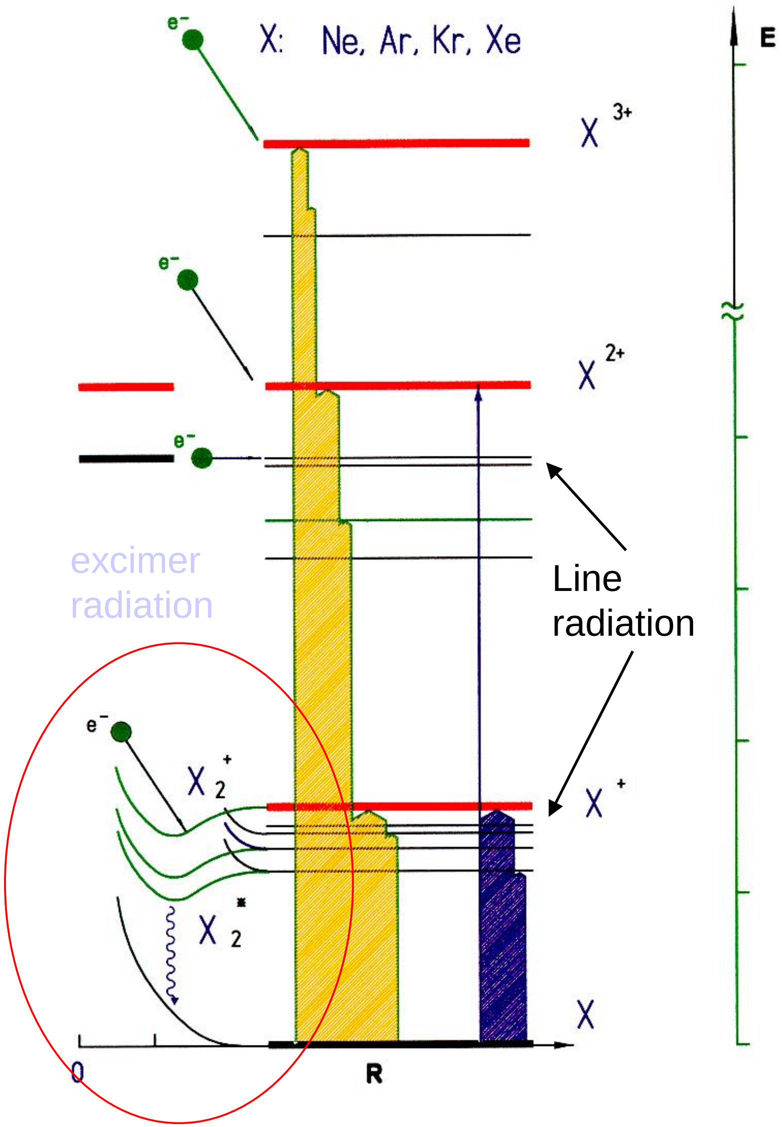

Ar, 1E-3mbar, 473nm-Filter
Ar, 1E-3mbar, 740nm-Filter
Δx = 21μm
32S
87MeV
Signal [rel. units]
Position [mm]
1,2
1,0
0,8
0,6
0,4
0,2
0,0
-15
-10
-5
0
5
10
15

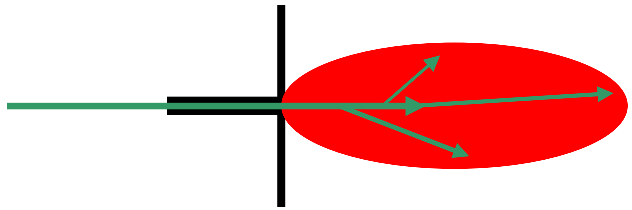

N, 1mbar, 337nm-Filter
N, 1mbar, 390nm-Filter
Neutral
Ionic
Signal [rel. units]
Position [mm]
1,2
1,0
0,8
0,6
0,4
0,2
0,0
0
5
10
15
20
25
30
35
40
45
50



Neutral
Ionic

Preliminary interpretations





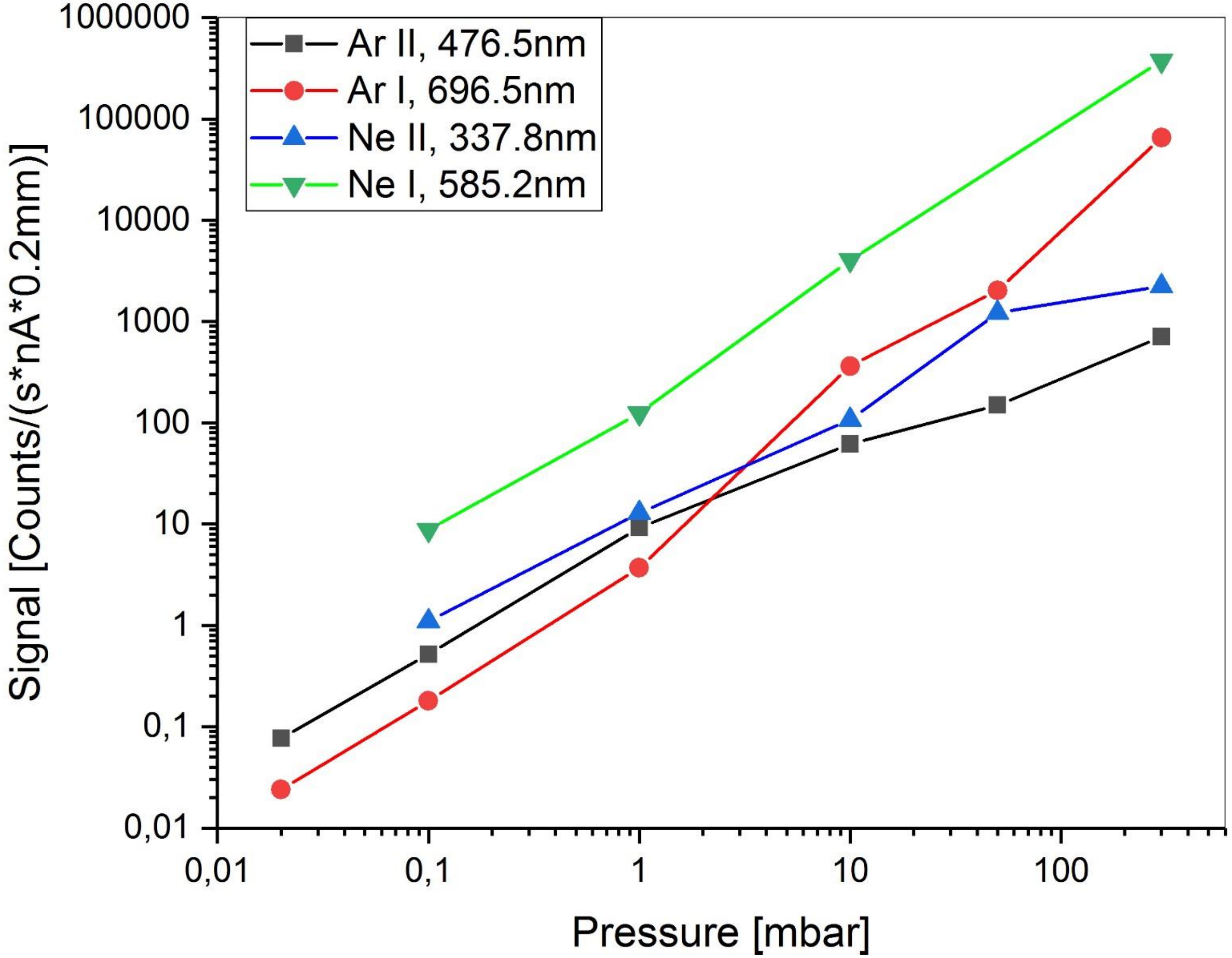
Excitation by the heavy ion projectiles

Excitation by the secondary electrons

Result:

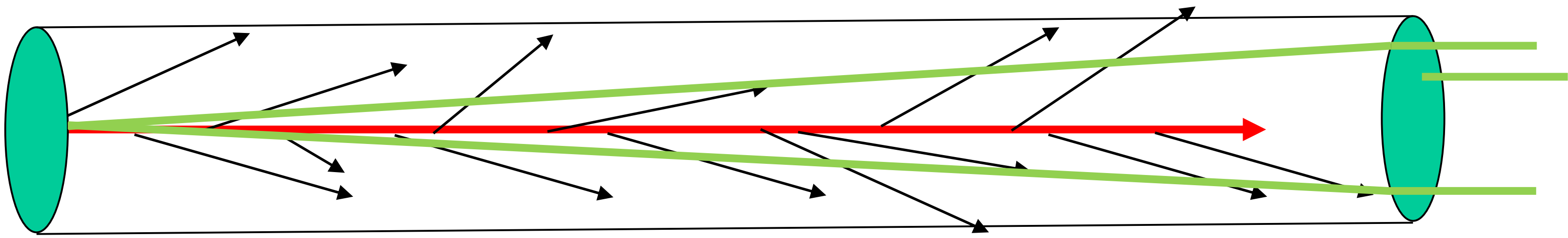
Excited atoms and ions in a cold environment !!!

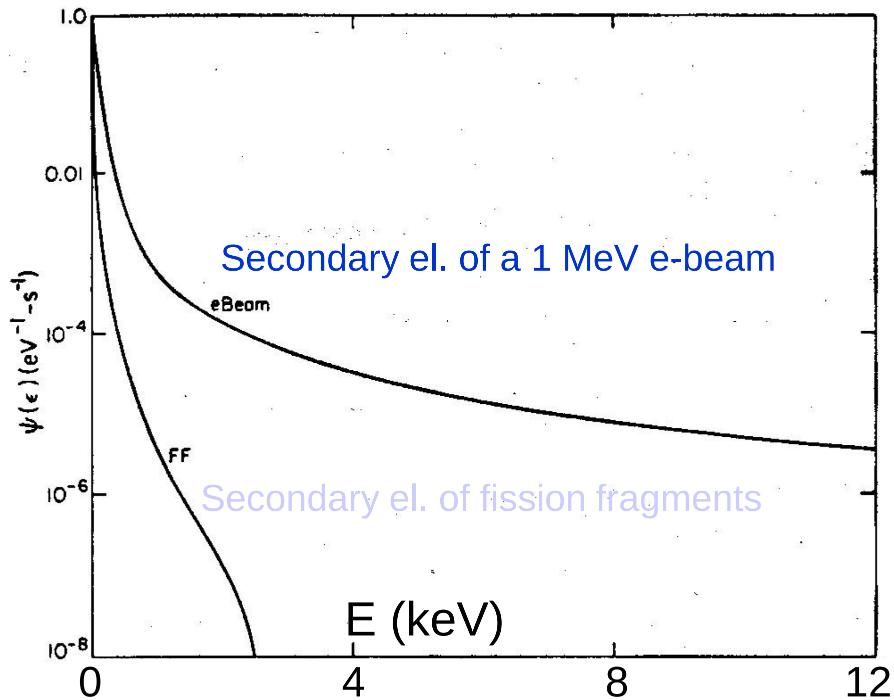
Strongest lines ! Normalized to 200µm slit width, 1nA beam, 1sec integration



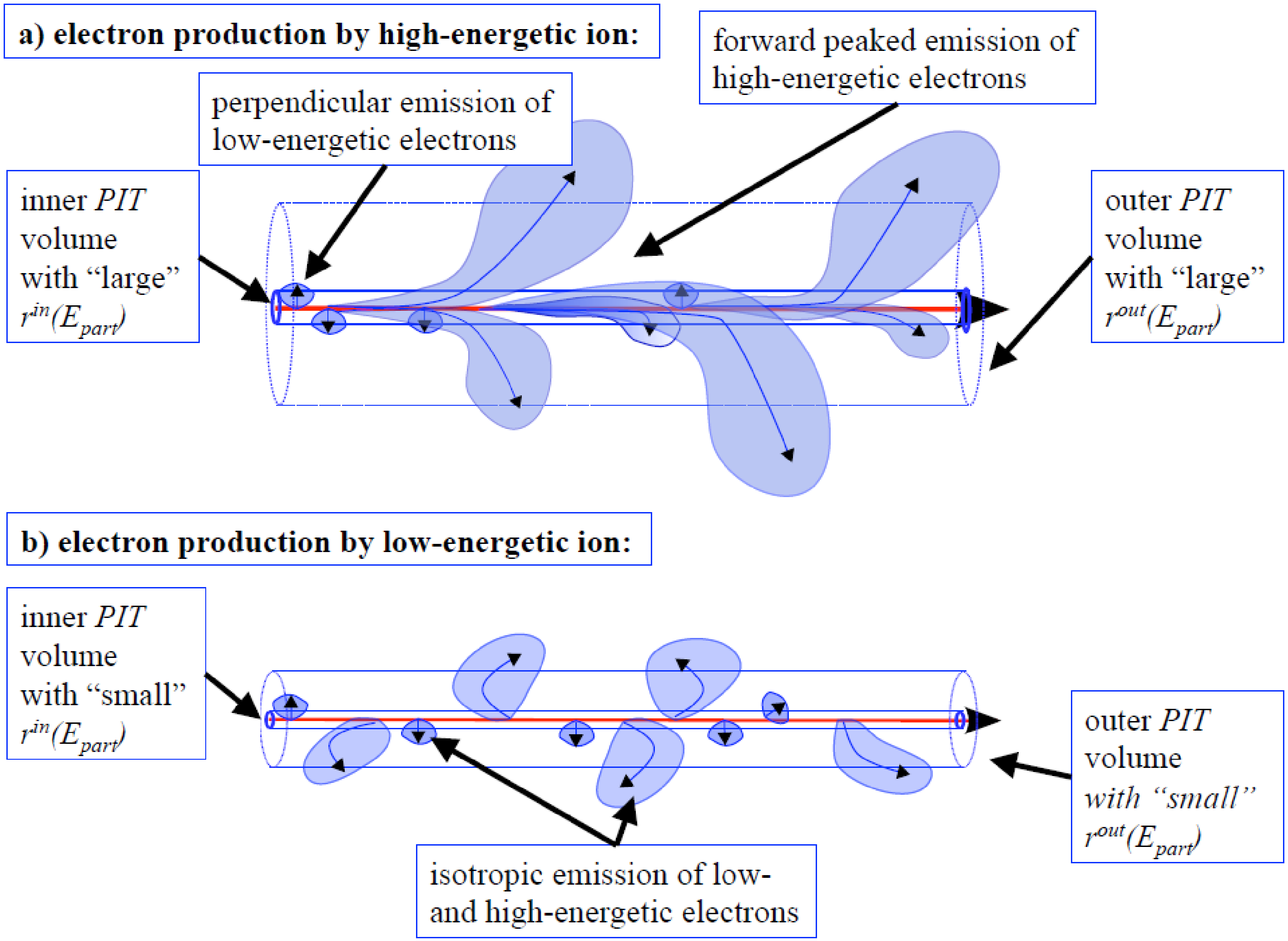
excitech

The track of an ion beam in a gas target





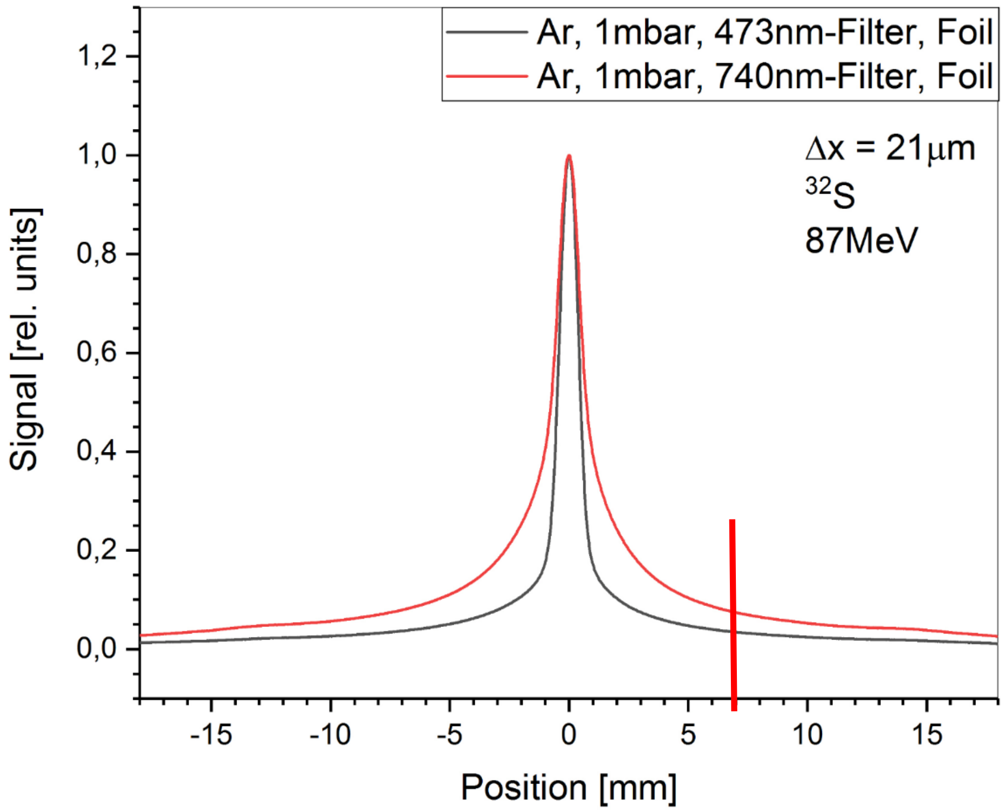
T.J. Moratz and M. Kushner J.Appl. Phys. **63**, 1798 (1988)



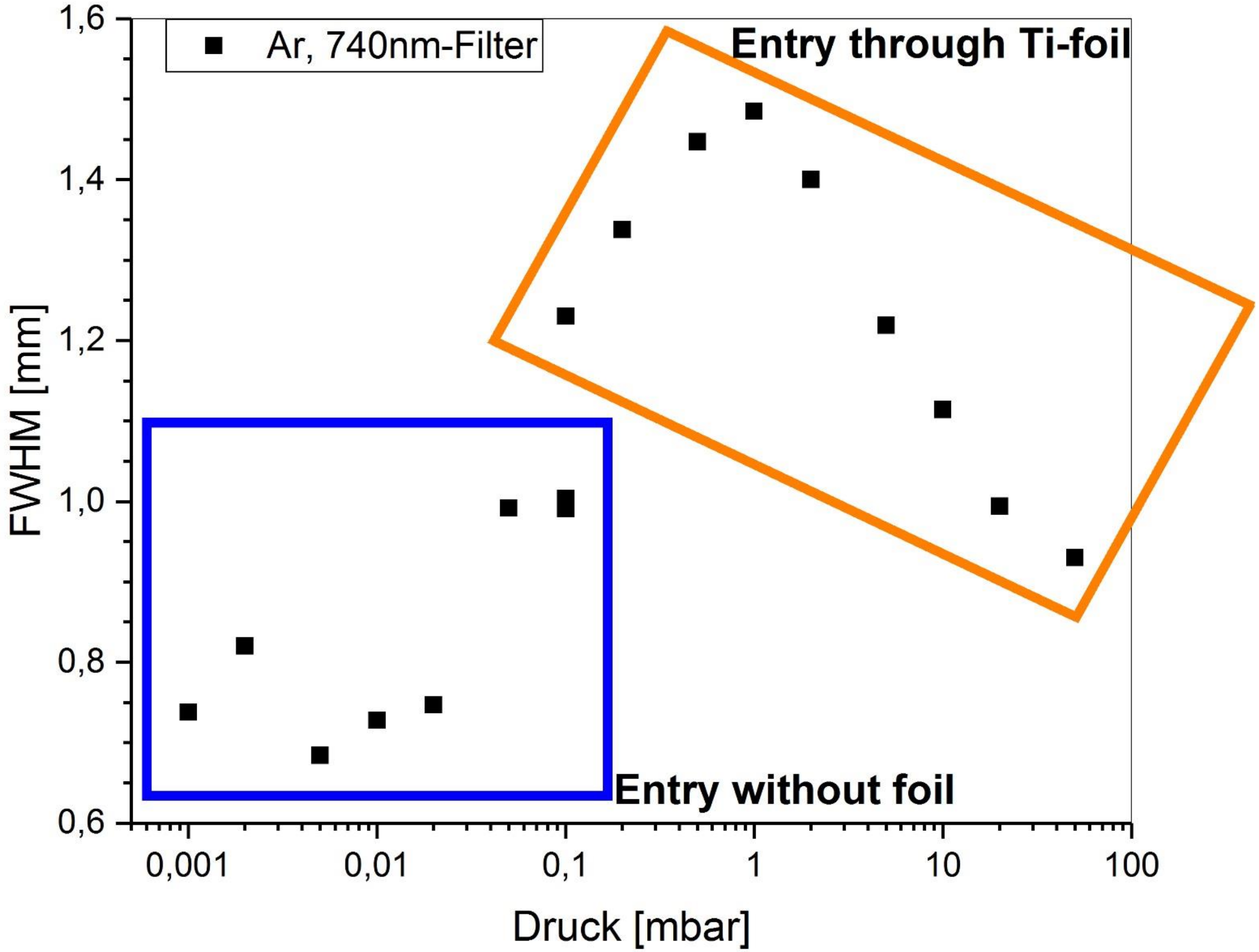
Dissertation: Sabine Roth TUM 2013

The track structure of the ions appears when the range of the secondary electrons is larger than the beam diameter!

Secondary electrons: 66% of the energy within 7mm range @ 1mbar Ar, room temperature.



Profile vs. Pressure atomic line



Information from spectra and their pressure dependence

Excited states

Excitation cross sections

Collisional quenching

Recombination processes

(Emission from recoiling species – Doppler effect)

Information from beam profiles

Spatial resolurion

Range of secondary electrons

Angular scattering

(Ion range)

Outlook

Interprete the profiles based on ion track studies

Mesurements using other projectiles (protons, e-beam)

High resolution (1pm) spectroscopy (velocity of radiating species)

Beam profile monitor with amplifier and sensitivity in the VUV

Experiments at GSI/FAIR

Extract information about coll. processes from spectra

Thank you for your attention !