Laser Spectroscopy with the Leuven gas-cell-based Laser Ion Source

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OUTLINE

- Motivation
- Production of exotic beams by RILIS
- In-Gas-Cell Laser Spectroscopy @ LISOL
- Progress on the way to implement In-Gas-Jet Laser Spectroscopy

MOTIVATION

Strategic areas of chart of nuclides → understand nuclear structure effects

- **N ≈ Z nuclei** - Study role of proton-neutron correlations -
- **Proton drip line** - rp process, nuclei far off stability -
- **Proximity doubly magic N = Z = 50** - strong shell correction effects -
- **SHE** - understanding of SHE and those at the limit of nuclear existence -

Gas cell-based resonance ionization laser spectroscopy of :

❑ **^{94}Ag**
High-spin isomerism, β-delayed p, 1- and 2-p emission

❑ **$^{107-101}$Sn**
Test validity of shell-model predictions

❑ **VHE (Z ~ 89 - 102)**
Validate nuclear and atomic theory

Resonance Ionization Laser Ion Source: RILIS

- SELECTIVE (element and isomer) & EFFICIENT PRODUCTION OF RARE ISOTOPE BEAMS

  U. Koester et al., Nucl. Phys. A 701 (2002) 441c

- IN-SOURCE ATOMIC SPECTROSCOPY

  G. D. Alkhazov et al., NIM B69 (1992) 517

➢ Hot Cavity

- No refractory elements
- $T_{1/2}$ element dependent
- Sensitivity 1 ion/s (^{182}Pb)
- Resol~ 4 GHz (^{59}Cu) (Doppler)
- Produced Ion beams ~30 elements

V.N. Fedoseev *et al.*, NIM B266 (2008) 4378

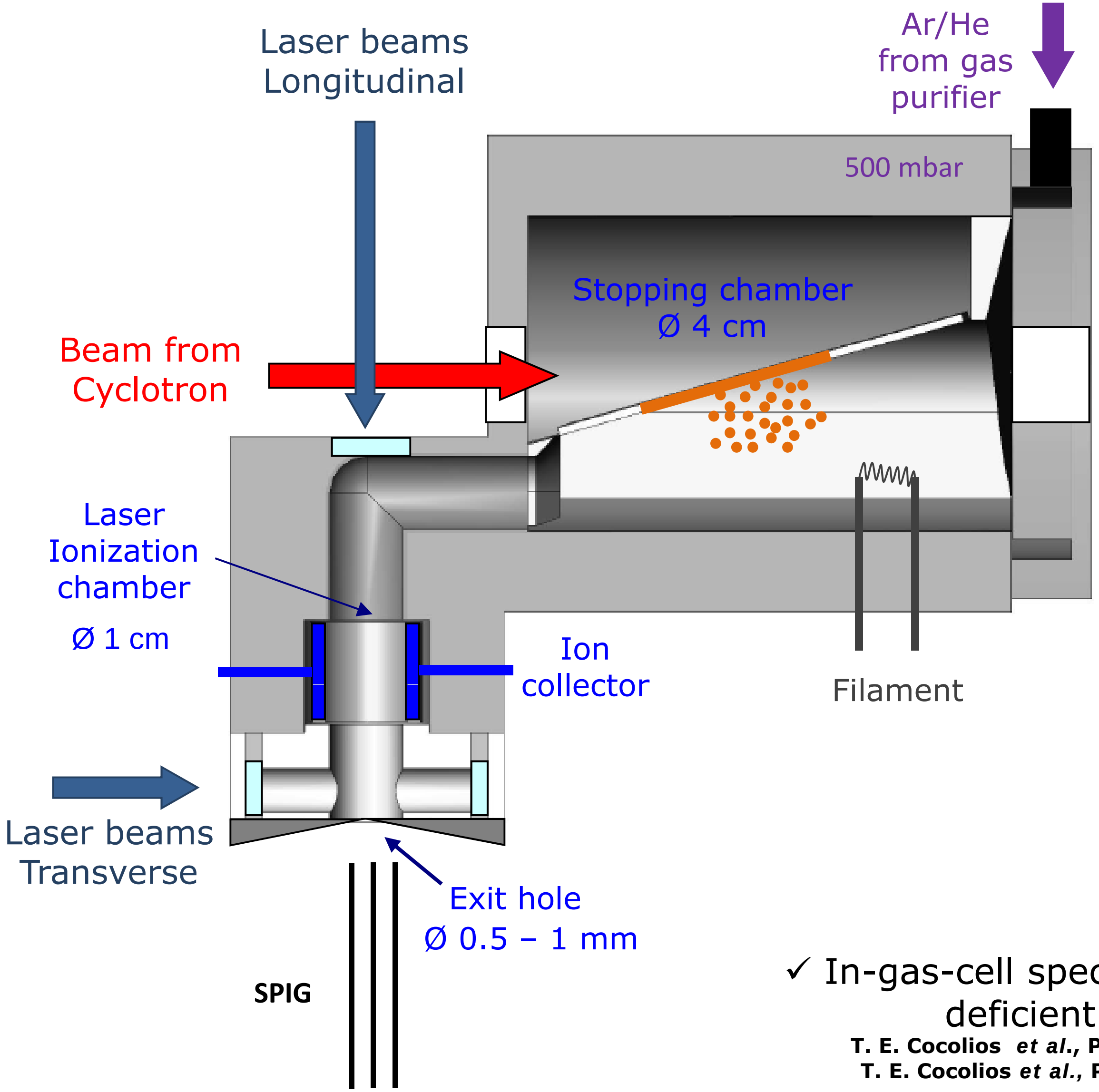
➢ Gas Cell

- "All" elements available
- $T_{1/2}$ cell evacuation time
- Sensitivity < 1 ion/s (^{97}Ag)
- Resol. ~ 3 GHz (^{59}Cu) (Pressure)
- Produced Ion beams ~15 elements

Yu. Kudryavtsev *et al.*, NIM B267 (2009) 2908

T. E. Cocolios *et al.*, PRL 103, 102501 (2009)

Dual Chamber Gas Cell



Separation of stopping and laser ionization volumes improves:

- Laser ionization efficiency for high cyclotron beam current
- Ion selectivity

Production of ^{94}Rh

Selectivity:

[Laser(on)/Laser(off)]

Ion Collector OFF = 450

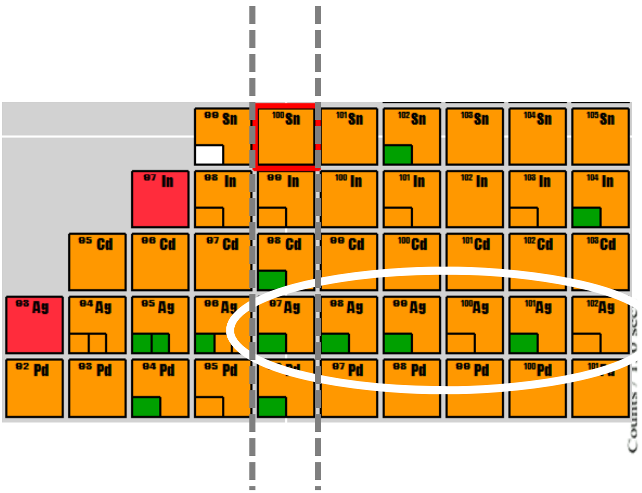
Ion Collector ON = 2200

✓ In-gas-cell spectroscopy of neutron deficient Cu isotopes

T. E. Cocolios *et al.*, PRL 103, 102501 (2009)

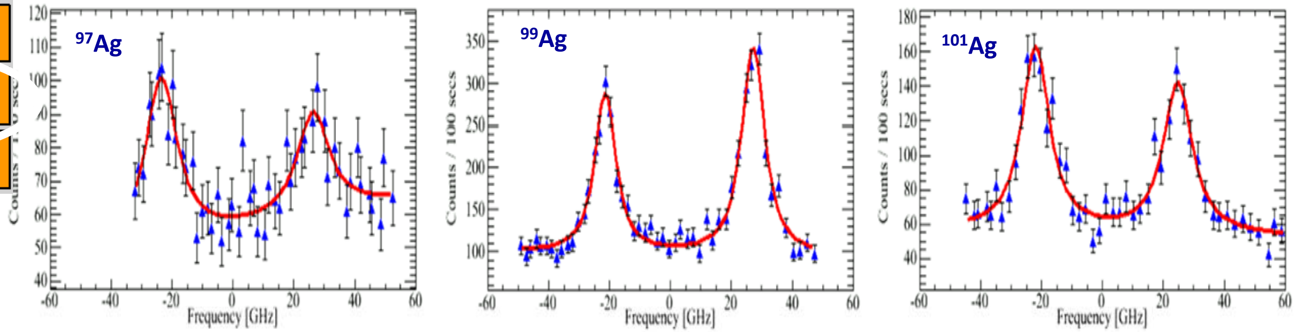
T. E. Cocolios *et al.*, PRC 81, 014314 (2010)

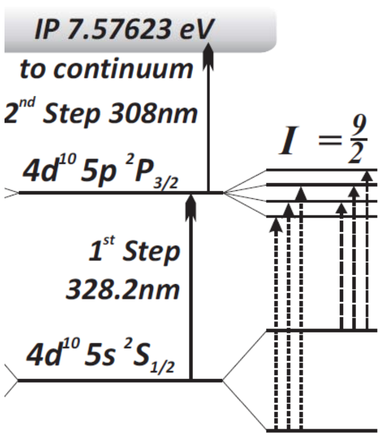
In-Gas-Cell Laser Spectroscopy of Ag

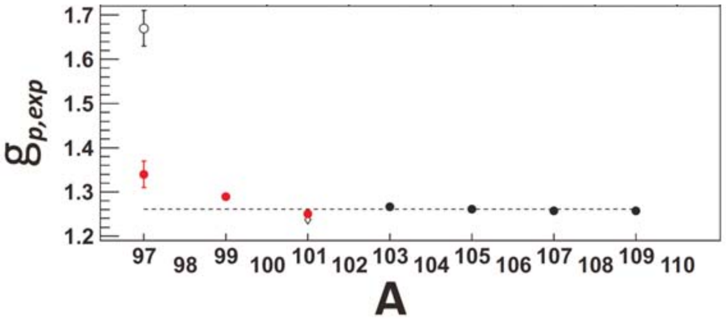


$^{92}Mo(^{14}N - 130\ MeV, 2pxn)^{104-x}Ag$

$^{64,nat}Zn(^{36}Ar - 125\ MeV, pxn)^{101-97}Ag$





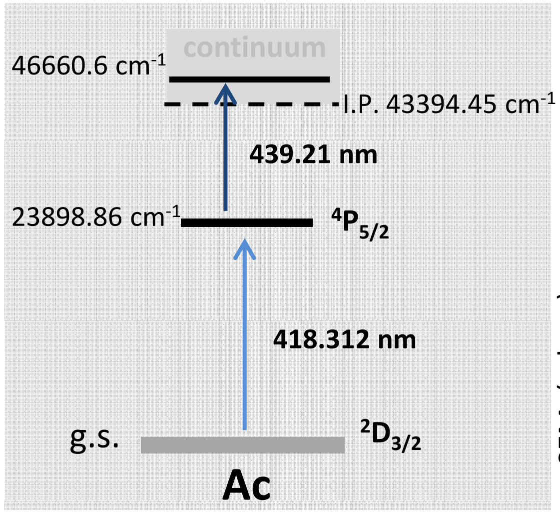


	Splitting (GHz)	I^π	μ_{exp}(st+sys) (nm)	μ_{exp}^{lit} (nm)
102	29.5(1.7)	5^+	3.5(2)	4.6(7)
100	36.2(2)	6^+	4.42(2)	--
98	38.3(6)	5^+	4.60(7)	--
	38.3(6)	6^+	4.67(7)	--
101	46.8(2)	$9/2^+$	5.57(2)	5.7(4)
99	48.7(3)	$9/2^+$	5.80(3)	--
97	50.6(9)	$9/2^+$	6.0(1)	--
	50.6(9)	$7/2^+$	5.9(1)	

U. Dinger et al., Nucl. Phys. A 503 (1989) 331
D. Vandeplassche et al., Hyperfine Interact. 22 (1985) 483

Iain Darby Phys. Lett. B (in preparation)

Broadband Spectroscopy on Ac

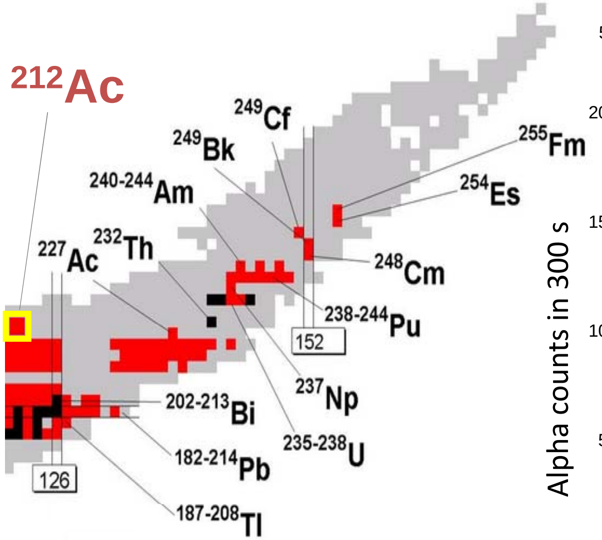


^{197}Au(^{20}Ne-145 MeV,4-5n)^{212,213}Ac

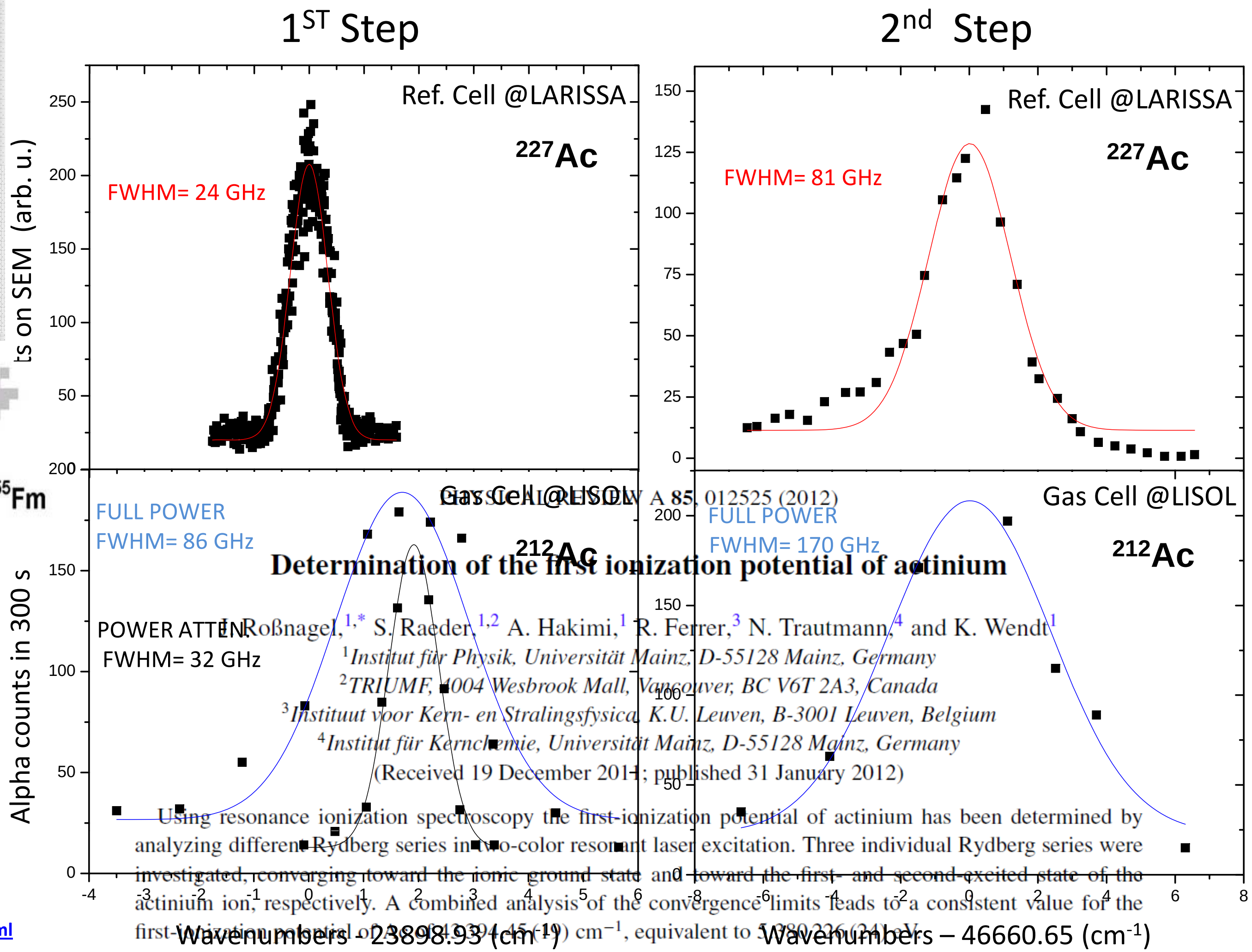
Cross section 2.3 mb for ^{212,213}Ac

A. Andreyev *et al.* Nucl. Phys. A 568 (1994) 323

JOHANNES GUTENBERG UNIVERSITÄT MAINZ



http://www.gsi.de/forschung/ap/projects/laser/survey.html



A 85, 012525 (2012)

Determination of the first ionization potential of actinium

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Using resonance ionization spectroscopy the first-ionization potential of actinium has been determined by analyzing different Rydberg series in two-color resonant laser excitation. Three individual Rydberg series were investigated, converging toward the ionic ground state and toward the first- and second-excited state of the actinium ion, respectively. A combined analysis of the convergence limits leads to a consistent value for the first-ionization potential of 43394.45(19) cm^{-1}, equivalent to 5.380226(24) eV.

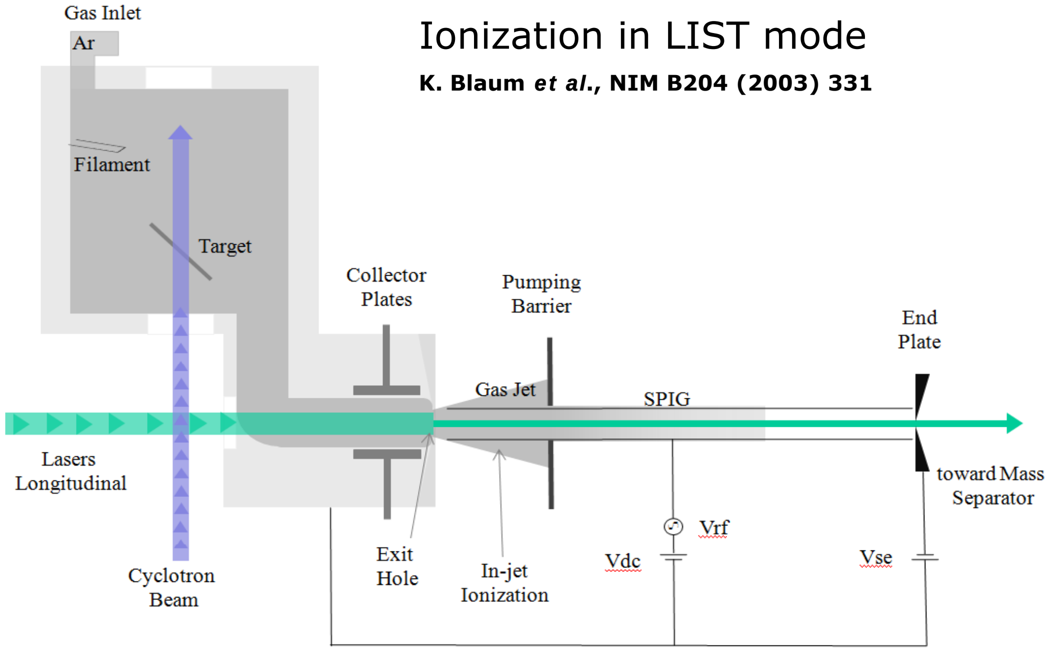
In-Gas-Jet Laser Spectroscopy

- Increase Resolution and Selectivity

- Ionization in cold jet expanding out of the gas cell

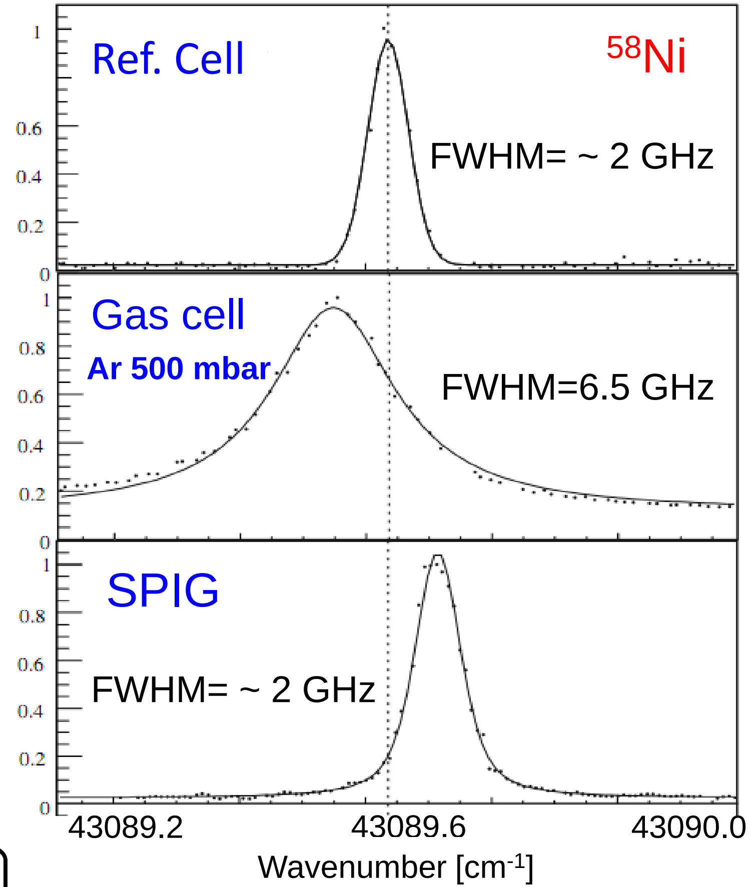
Ionization in LIST mode

K. Blaum *et al.*, NIM B204 (2003) 331



Demonstrated proof of principle @ LISOL

T. Sonoda *et al.* NIM B267 (2009) 2918



- Requirements to obtain maximum benefits:

-**Improve time overlap** : Test of a high pulse repetition rate laser system (Uni-Mainz,GANIL, JYFL, IPN Orsay, JINR)

R. F. & V. Sonnenschein *et al.*, NIM B. In preparation

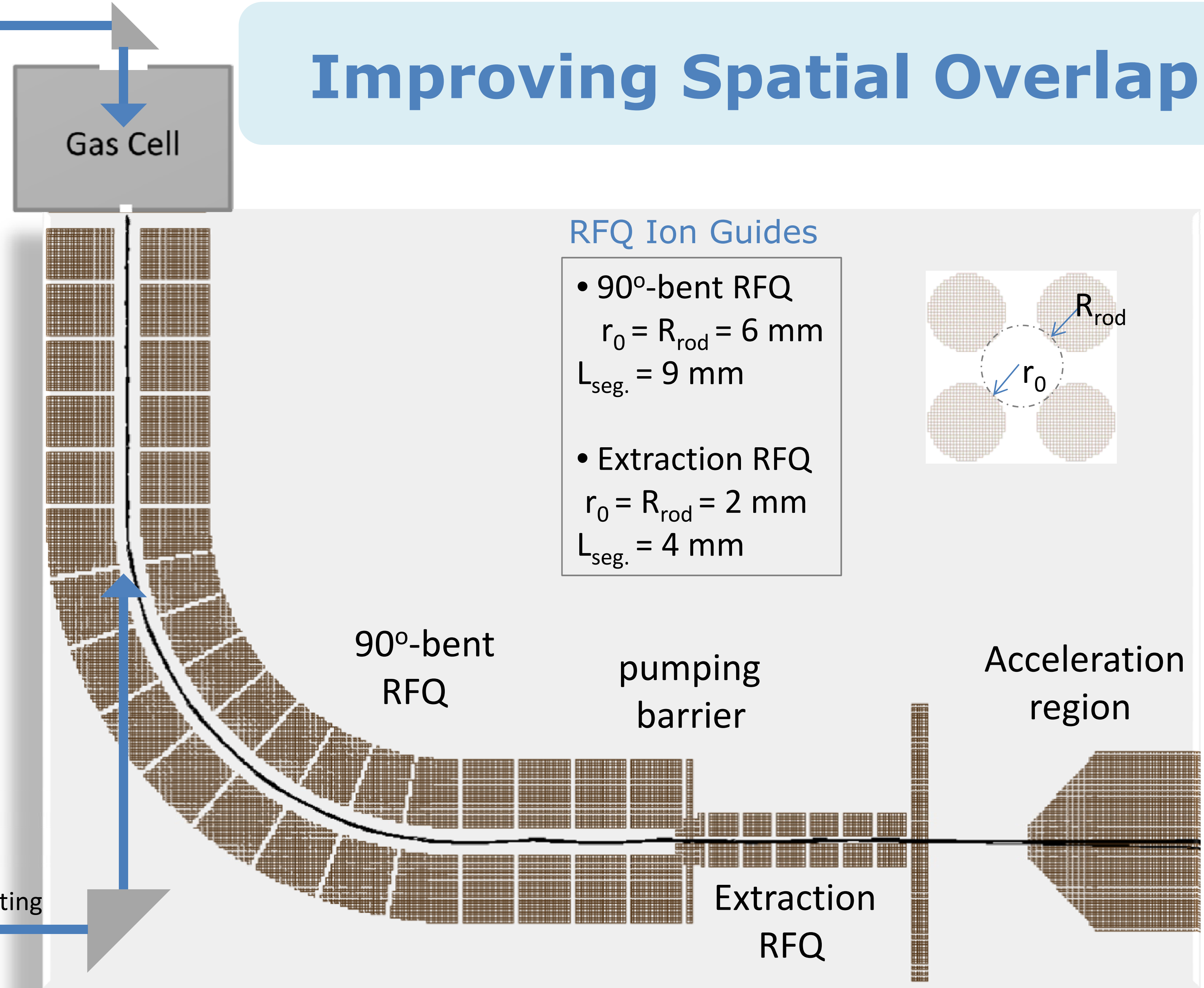
-**Improve spatial overlap**

HELIOS @ KU Leuven

European Research Council
Established by the European Commission

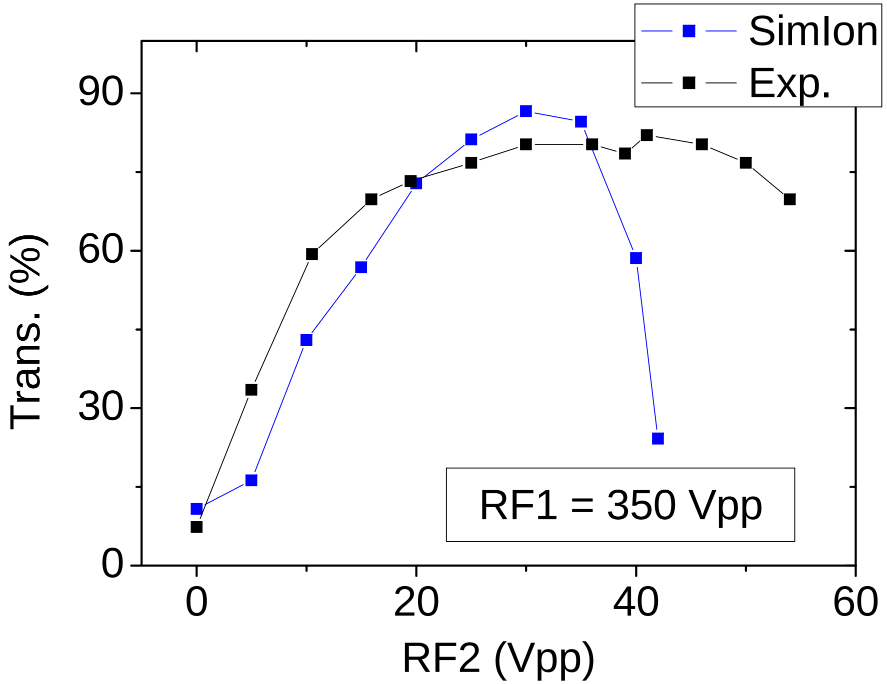
Improving Spatial Overlap

M. Reponen *et al.*,
NIM A 635 (2011) 24



Transmission through RFQ Ion Guides

Comparison experiment vs. simulation (bkg p = 1e-3 mbar)



- Performance of ion guides found to be in agreement with expectation

-Transmission efficiency ε= 80%

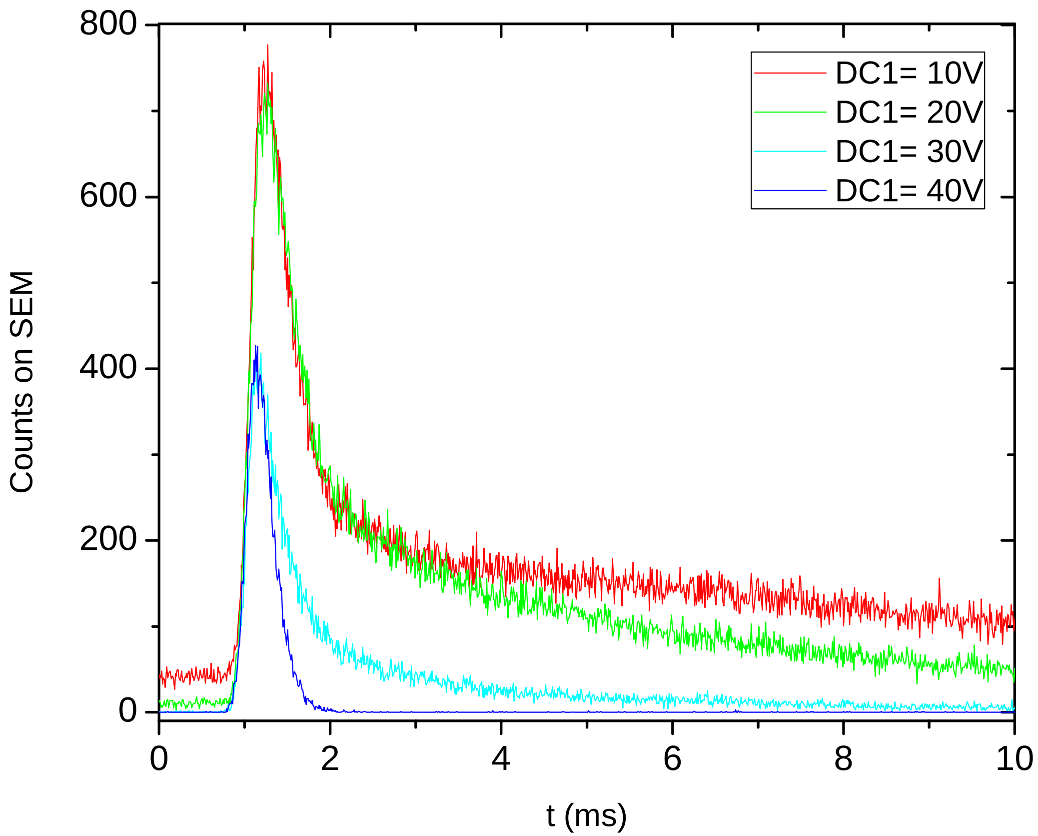
-Similar transmission found for bkg p=0.1 mbar

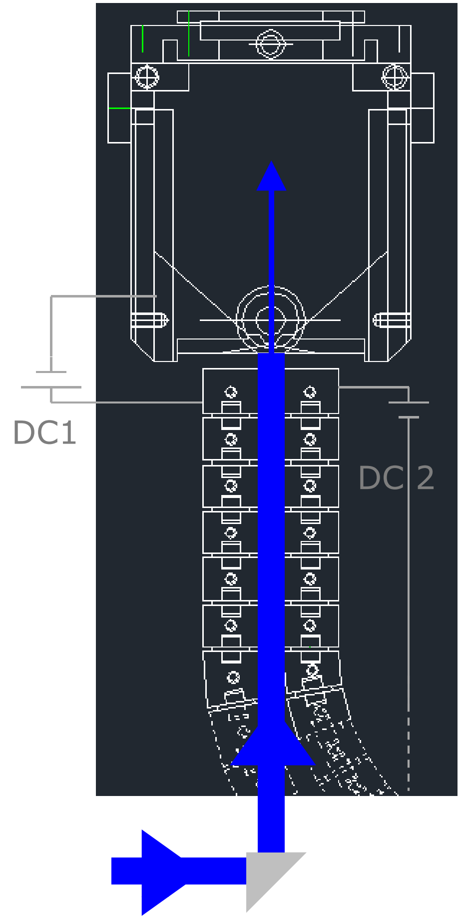
Selection of Ions from the Gas Jet

- Time profiles with lasers in counterpropagating direction

A/Q= 63
DC2= 10 V

- Determination of blocking potential DC1

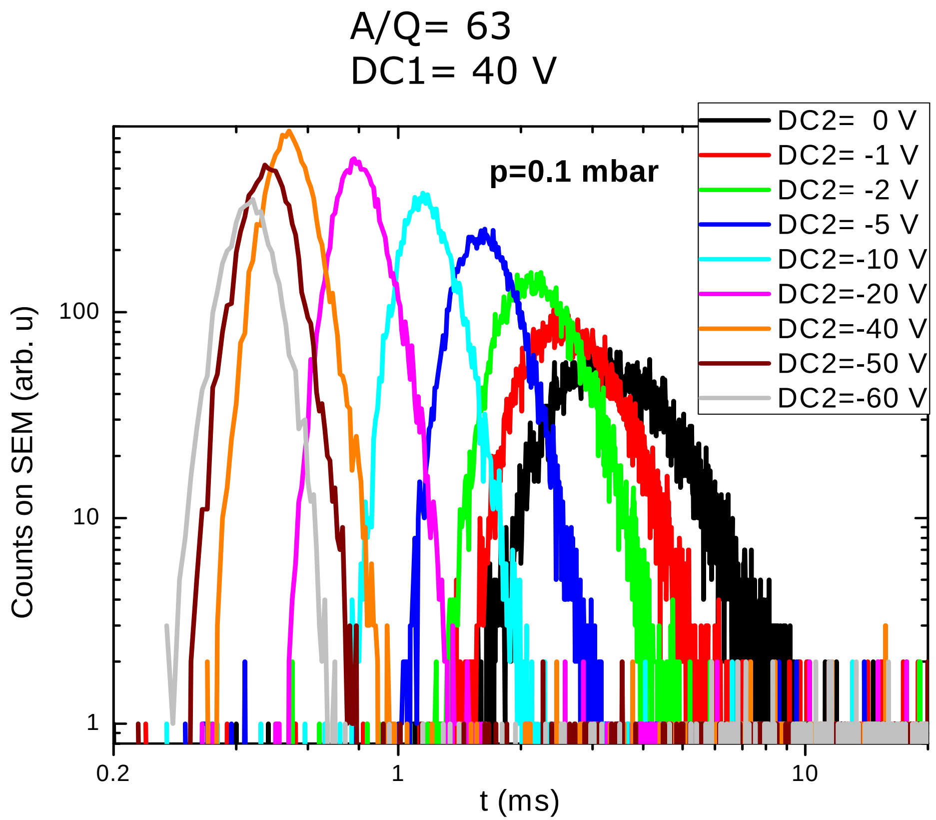


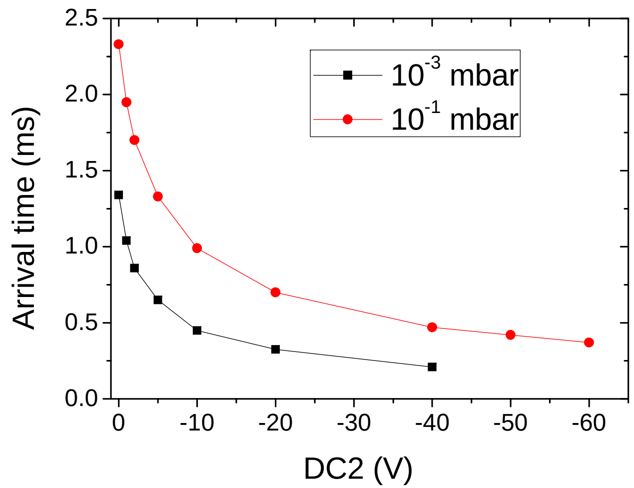


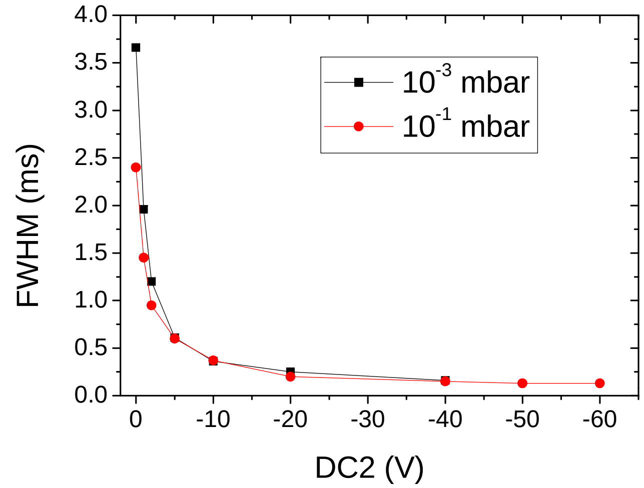
- Bias voltage of 40 V is sufficient to block all ions from the gas cell

Effect of dc gradient on the Ion Beam

- Time profiles with lasers in counterpropagating direction



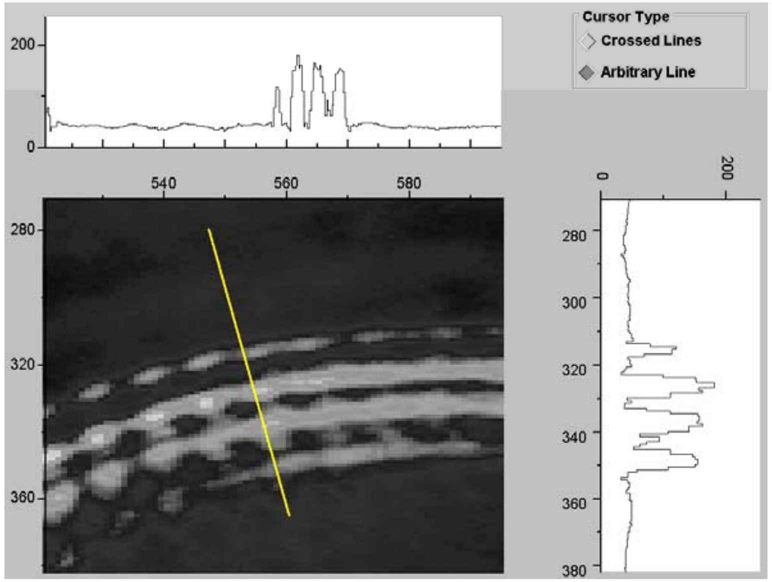




✓ Manipulation of ions by dc gradient

Reduction of the Laser Bandwidth

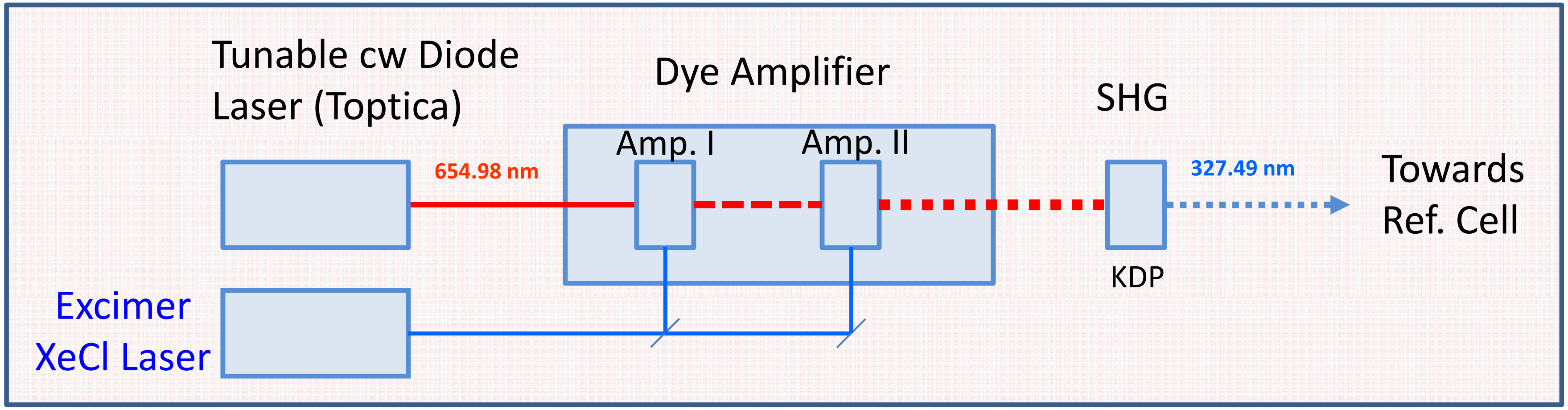
- Study of typical LISOL narrow-band pulse using FP interferometer



- Radial profile of interference ring shows four oscillation modes

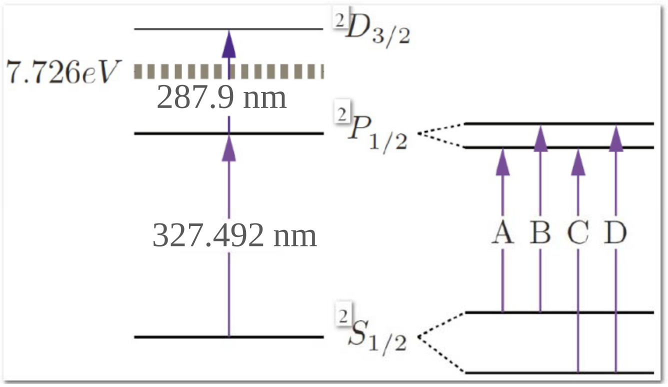
- Separation between modes is 400 MHz
  → mode FWHM= 150MHz
  Laser bandwidth ~1.4 GHz (SHG)

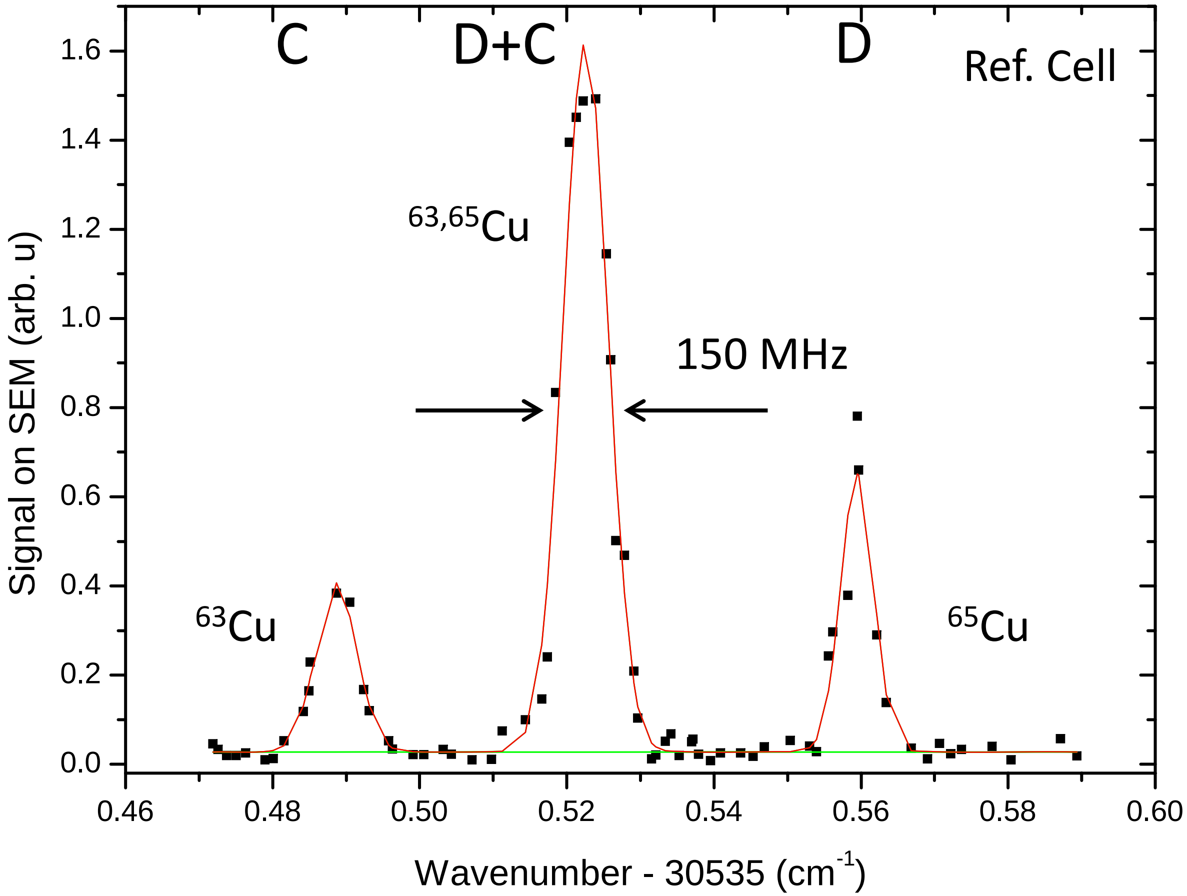
- Amplification of CW Single Mode Diode Laser in Pulsed Dye Amplifier



Reduction of the Laser Bandwidth

HFS of the 327 nm transition in $^{63,65}Cu$





• 90 MHz Fourier-limited (5ns) laser bandwidth affected by residual Doppler broadening → final linewidth of 150 MHz

In-gas-jet laser spectroscopy will allow high-sensitivity and high resolution experiments with a Leuven-type laser ion source

Acknowledgments

LISOL team:

R.F, L. Ghys, M. Huyse, Yu. Kudryavtsev, D. Pauwels, D. Radulov, L. Rens, P. Van den Bergh, C. Van Beveren, and P. Van Duppen

LISOL Alumni: T. Cocolios, I.G. Darby, T. Sonoda

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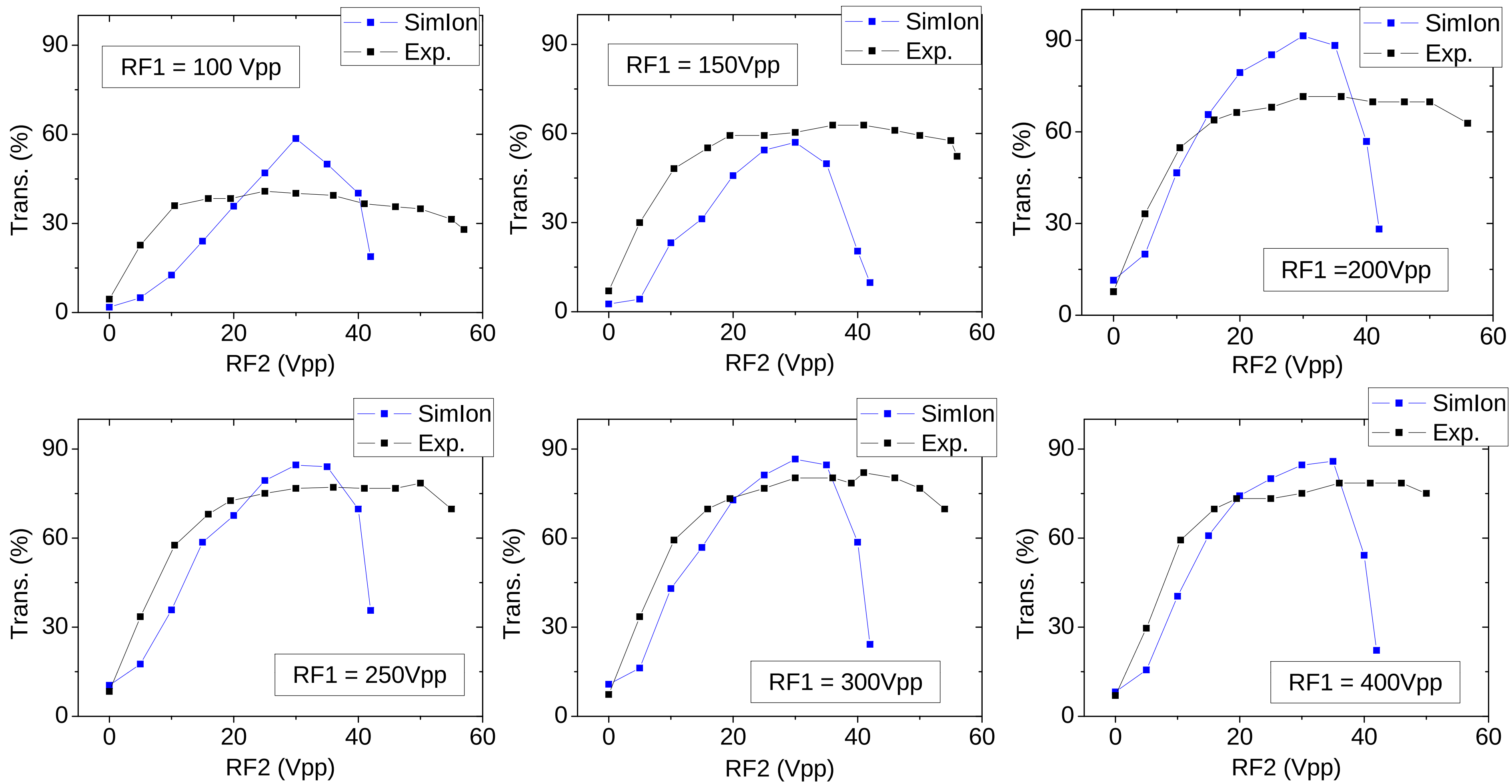
GANIL-SPIRAL2- IPN Orsay
B. Bastin, S. Franchoo, N. Lecesne, F. Lutton, B. Osmond, H. Savajols , J. C. Thomas

JYFL University of Jyväskylä
I. Moore, M. Reponen, V. Sonnenschein

JINR-Dubna S. Zemlyanoy

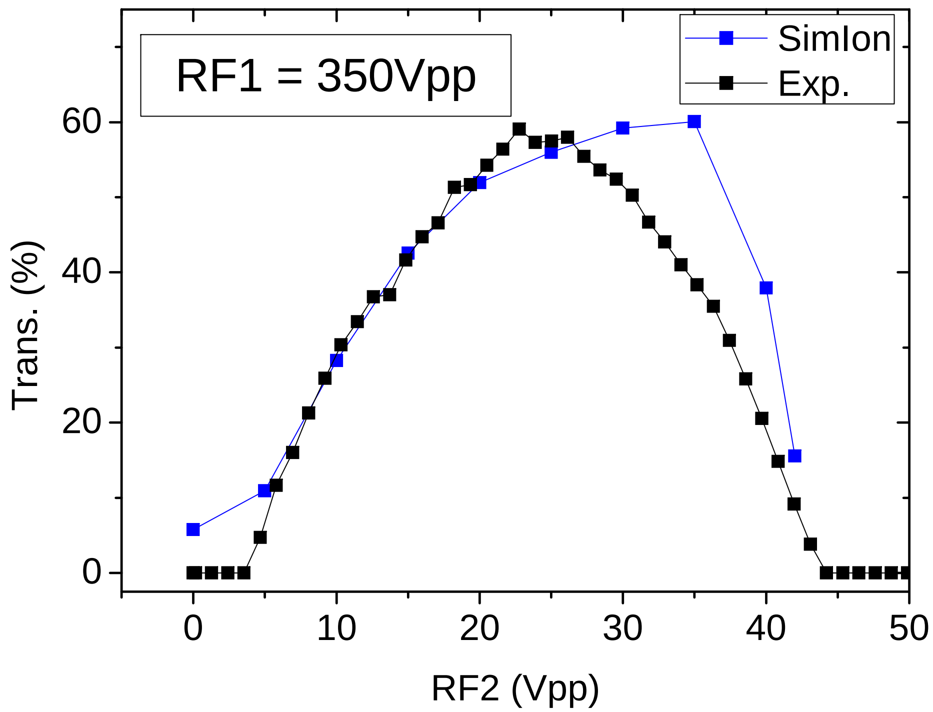
Transmission through RFQ Ion Guides

- Performance of ion guides found to be in agreement with expectations
- Transmission efficiency ε= 80% (bkg p = 1e-3 mbar)



Transmission through Mass Separator

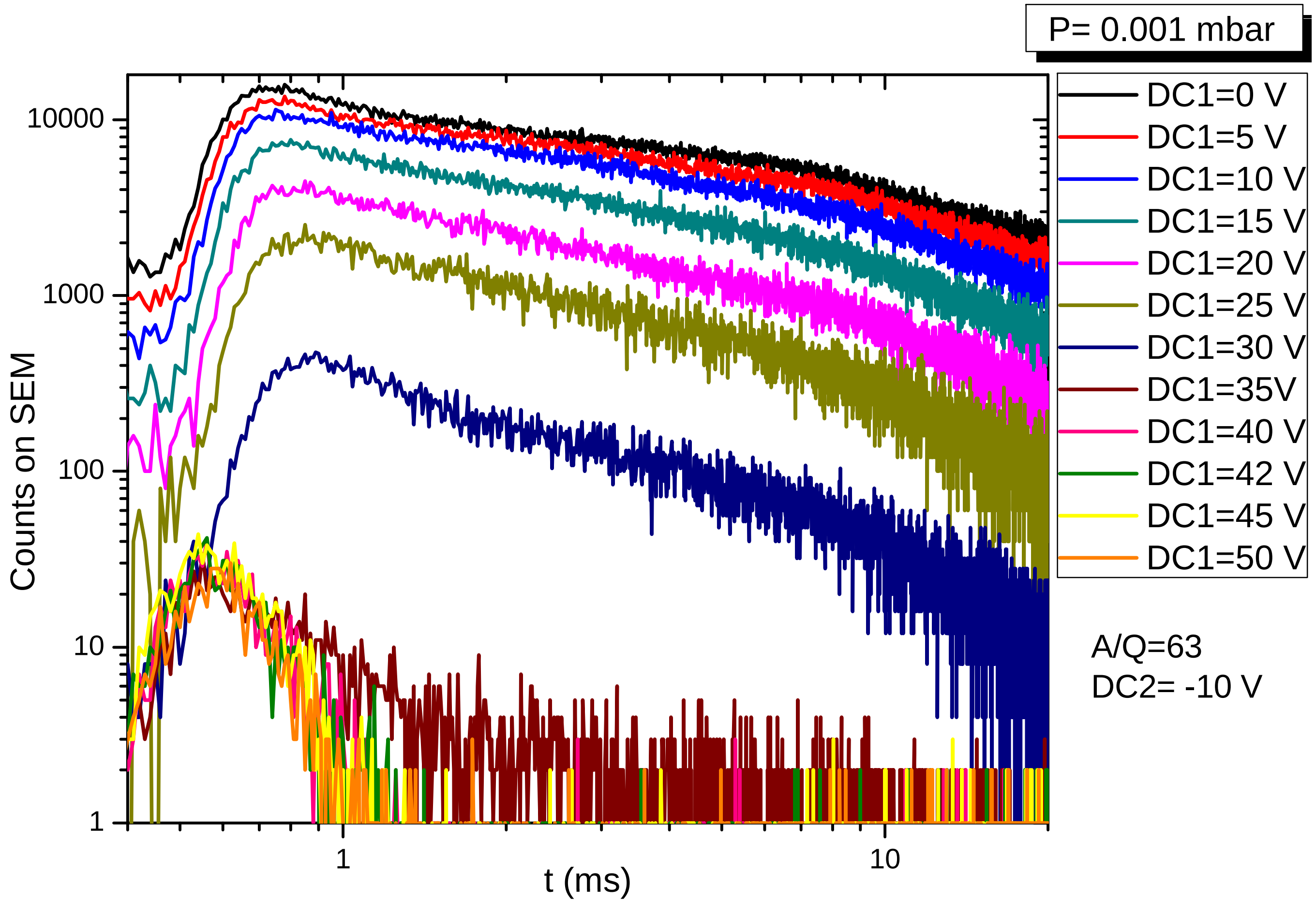
Transmission ^{63}Cu (bkg pressure 0.1 mbar)

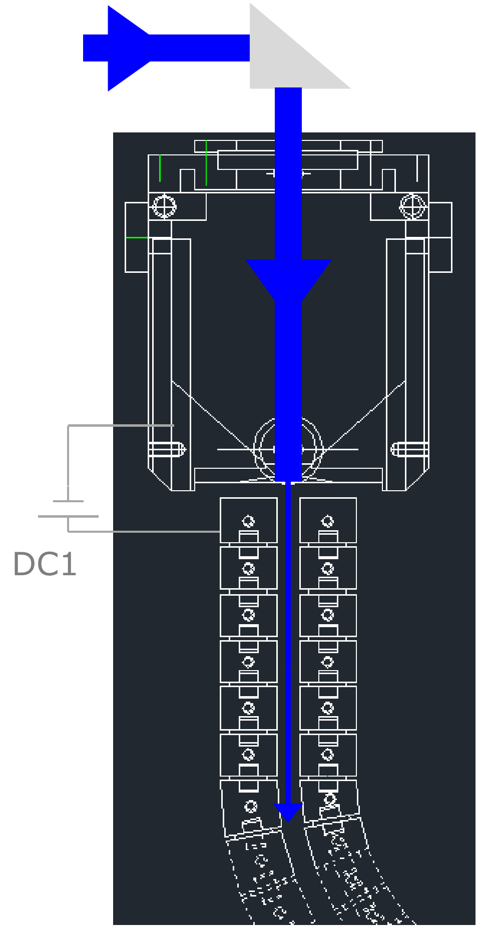


After increasing dragging field through ion guides we get the same transmission as for lower pressure (p=1e-3 mbar)

Selection of Ions from the Gas Jet

- Time profiles with lasers in propagating direction





- Bias voltage of 40 V is sufficient to block all ions from gas cell