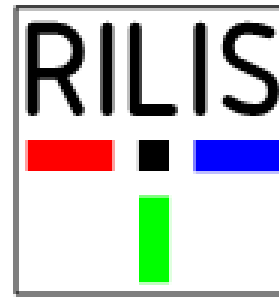




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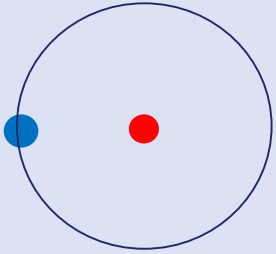
Dag Hanstorp

Measurement of shifts in the electron affinities of chlorine isotopes

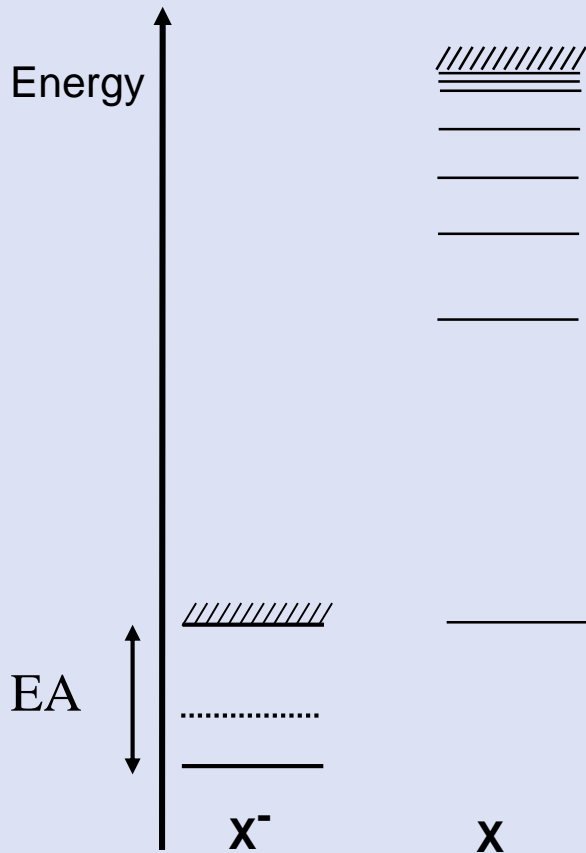
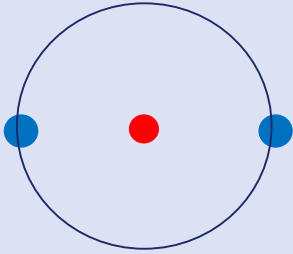
Dag Hanstorp, Jakob Welander, David Leimbach, Annie Ringvall-Moberg, Michel Godefroid, Per Jönsson, Jörgen Ekman, Tomas Brage, Klaus Wendt, Reinhard Heinke, Oliver Forstner, Yuan Liu, Ronald Garcia Ruiz, Shane Wilkins, Adam Vernon, Cory Binnersley, Kieran Flanagan, Gerda Neyens, Agi Koszorus, Kara Lynch, Sebastian Rothe, Tim Giles, Katerina Chrysalidis, Pierre Larmonier, Valentin Fedosseev and Bruce Marsh.

INTC meeting 28th of June 2017

Negative Ions



Negative Ions



- Electron correlation of vital importance
- Small Electron affinities (EA) (appr. 1 eV)
- Few (if any) excited states
- No traditional spectroscopy

Isotope shift

$$IS = MS + VS$$

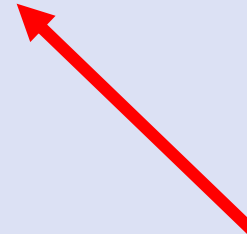
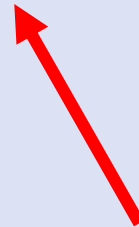
$$IS = NMS + SMS + VS$$

Observable

Trivial

Atomic
Physics

Nuclear
Physics



Isotope shift in electron affinity

Ideal test case for electron correlation

Periodic Table of Elements

Atomic #, Symb, Name, Atomic Mass

States: Solid, Liquid, Gas, Unknown

Categories: Alkali metals, Alkaline earth metals, Lanthanoids, Actinoids, Transition metals, Poor metals, Other nonmetals, Noble gases

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

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Highlighted elements: H (1), C (6), S (16), Pb (82)

$^1\text{H} / ^2\text{H}$

$^{35}\text{Cl} / ^{37}\text{Cl}$

$^{16}\text{O} / ^{17}\text{O} / ^{18}\text{O}$

$^{32}\text{S} / ^{34}\text{S}$

$^{12}\text{C} / ^{13}\text{C}$

$^{206}\text{Pb} / ^{208}\text{Pb}$

Lykke, Murray and Lineberger, *Phys. Rev. A* **43** (1991) 6104

Berzinsh et al. *Phys. Rev. A* **51**, (1995) 231

Blondel et al. *Phys. Rev. A* **64** (2001) 052504

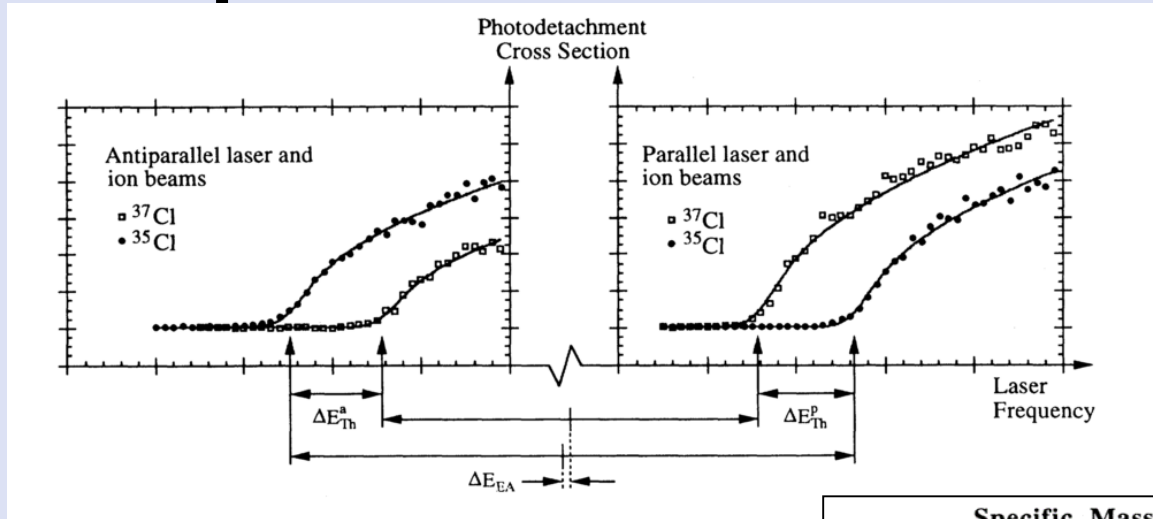
Carette, et al. *Phys. Rev. A* **81** (2010) 042522

Breseau, Drag and Blondel, *Phys. Rev. A* **93** (2016) 013414

Chen and Ning, *J. Chem. Phys.* **145** (2016) 084303

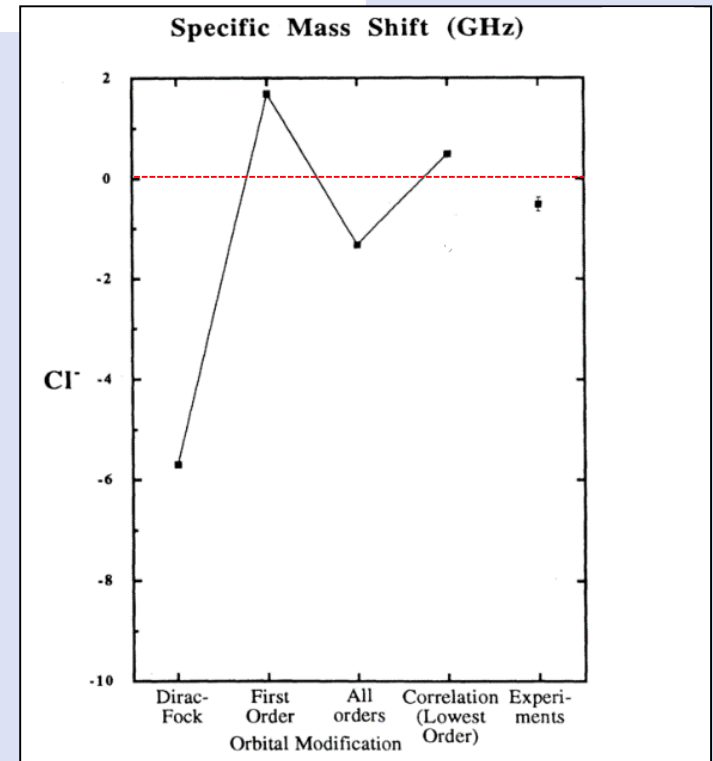
Only stable isotopes investigated

Isotope shift in EA of $^{35/37}\text{Cl}$



$$\text{SMS} = -0.51(14) \text{ GHz}$$

Berzinsh et al. *Phys. Rev. A* **51**, (1995) 231



Isotope shift in EA of $^{35/37}\text{Cl}$

Isotope shift on the chlorine electron affinity revisited by an MCHF/CI approach

T Carette^{1,2} and M R Godefroid²

	SMS	MS	FS	RIS	IS
			This work		
HF	-1.348	-0.607	-0.003(22)	-1.351(22)	-0.610(22)
val. FC-MCHF	-0.674	+0.067	-0.002(20)	-0.676(20)	+0.065(20)
val. MCHF	-0.495	+0.246	-0.003(21)	-0.497(21)	+0.244(21)
final results	-0.535(51)	+0.206(51)	-0.003(22)	-0.538(72)	+0.203(72)
			Berzinsh <i>et al</i> [7]		
Exp.				-0.51(14)	+0.22(14)
DF	-1.3	-0.6	+0.014(14)	-1.3	-0.6
MB low corr.	+0.50	+1.24	+0.014(14)	+0.51(2)	+1.26(2)

Proposal: Measure EA of Cl isotopes

Measure IS for two well separated even isotopes

GLM beamline, RILIS lasers ($\lambda = 343$ nm)

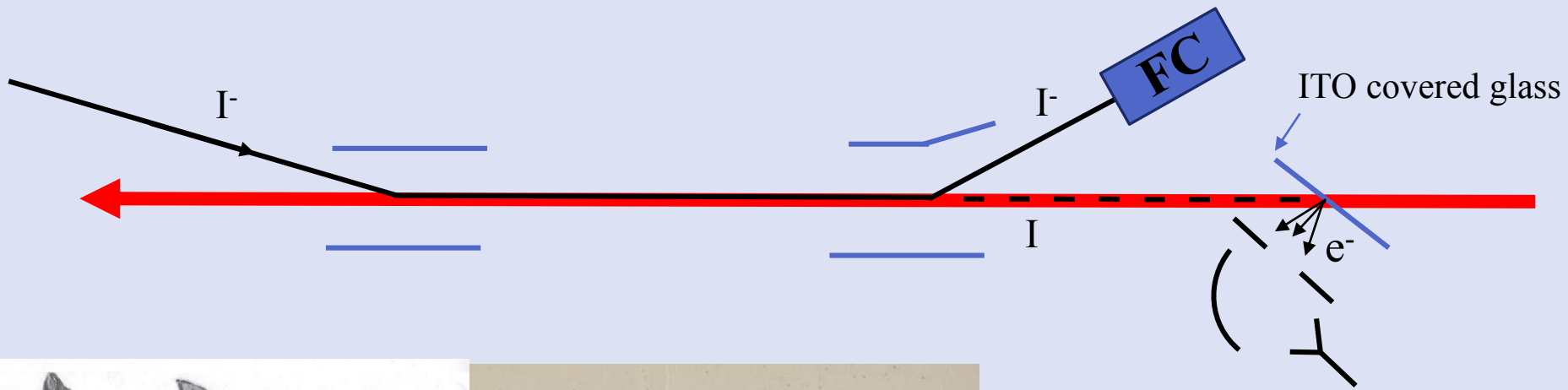
Goal: data for improved atomic theory calculations using full relativistic multiconfiguration Dirac-Hartree-Fock (MCDHF)

Important results when extracting VS from measured IS

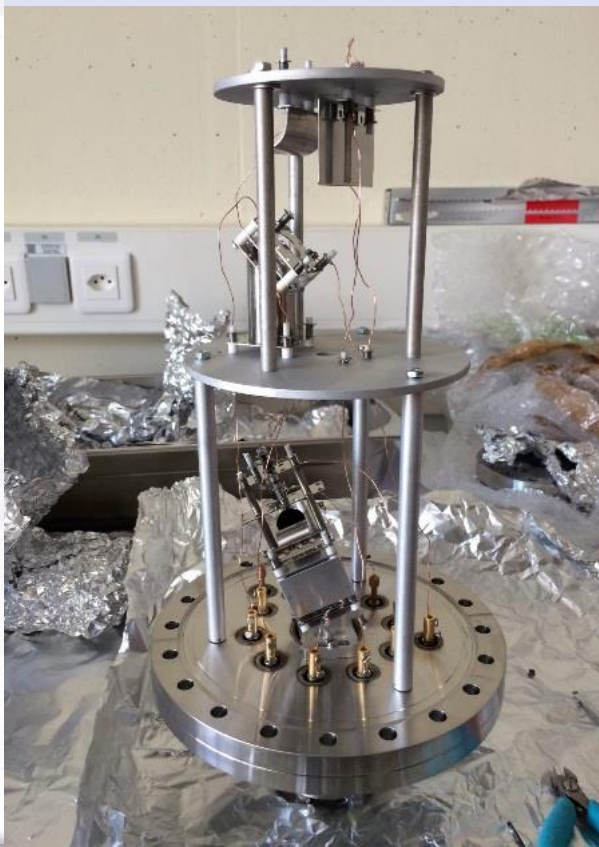
Question from TAC:

Not clear if n-def Cl is also required? Does this affect the beam request?

GANDALPH



Drawing:
Annie
Ringvall
-Moberg

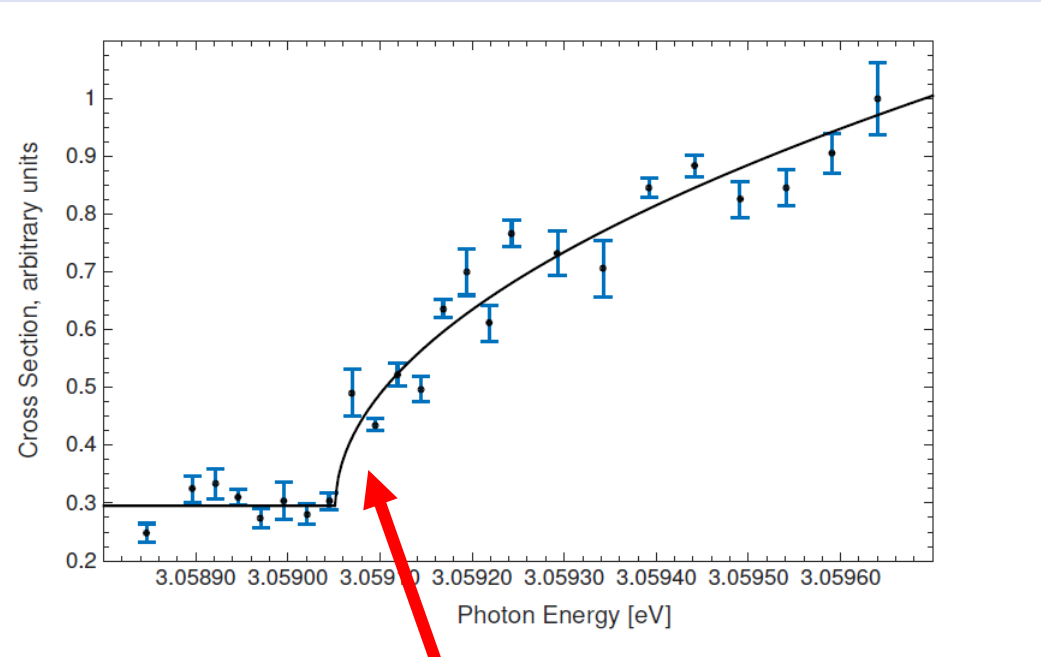


Studies of atomic negative ions at CERN

Laser photodetachment of radioactive ^{128}I

Sebastian Rothe, Julia Sundberg, Jakob Welander, Katerina Chrysalidis, Thomas Day Goodacre, Valentin Fedosseev, Spyridon Fiotakis, Oliver Forstner, Reinhard Heinke, Karl Johnston, Tobias Kron, Ulli Koster, Yuan Liu, Bruce Marsh, Annie Ringvall-Moberg, Ralf Erik Rossel, Christoph Seiffert, Dominik Studer, Klaus Wendt, and Dag Hanstorp

Accepted by *J. Phys G*



Ion rate: $35\,000\text{ s}^{-1}$

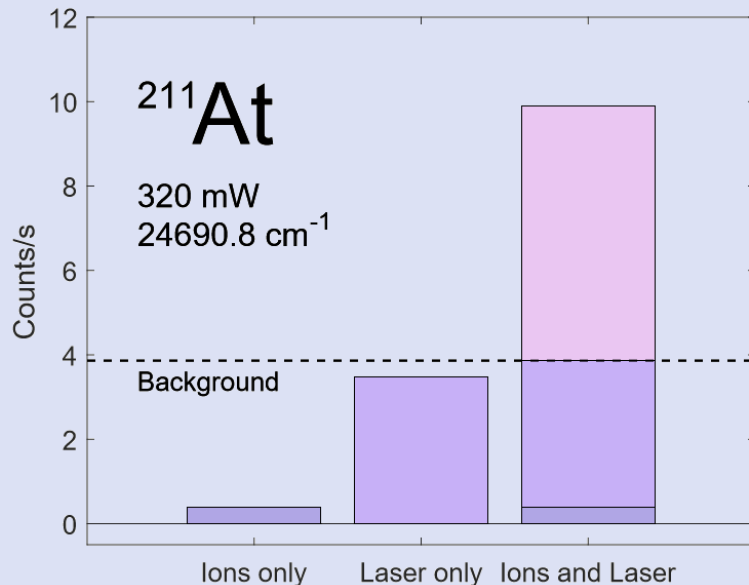
Measurement time: 39 min

EA: $3.059\,052(38)\text{ eV}$

The Wigner law: $\sigma = k (E - E_{EA})^{l+1/2}$

Proposal INTC-P-462: Determination of the electron affinity of astatine and polonium

- 70 mg in the crust of the earth (1 atom per 100 kg mass)
- Small knowledge about chemical and physical properties
- Used in Targeted Alfa Therapy



- Ion rate ($^{211}\text{At}^-$): $6\ 200\ \text{s}^{-1}$
- Measurement time: ~1 h
- Upper limit for EA(At): $< 3.06\ \text{eV}$

Current activity

Master student David Leimbach improving GANDALPH:

- **Beam diagnostics**

 - Dedicated particle detector for tuning

 - Segmented collimators

- **Improve Vacuum further**

- **Surface ion source for off-line tests**

- **Computer controlled ion optics**

BEAM TIME REQUEST

Description	Element	Number of shifts (offline)	Protons
<i>Run 1</i>			
Compatibility tests	stable chlorine	(3)	no
<i>Run 2</i>			
Stable beam tuning	stable chlorine	(4)	no
Yield measurements	chlorine isotopes	2	yes
Threshold determinations	chlorine isotopes	6	yes
Reference stable isotope scans	stable chlorine	(1)	no

~We can select two well separated isotopes where we get sufficient yield

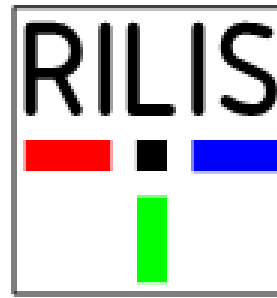
Experiment possible with $3 \cdot 10^5$ ions at GLM port

OUTLOOK: GANDALPH @ CRIS

- Only elements with $EA > 2,6$ eV, i.e. halogens be produced efficiently with surface ionizer
 - Negative ions are already produced in the charge exchange cell at CRIS
 - Narrow bandwidth lasers of CRIS needed for IS measurement
- **Collaboration between GANDALPH AND CRIS teams initiated**
- **GANDALPH will be placed behind CRIS (during LS2)**



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Thank you for your attention!