UNIVERSITY OF GOTHENBURG

RILIS

ISOLDE

CERN

Dag Hanstorp

Determination of the electron affinity of astatine and polonium by laser photodetachment

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INTC meeting 3-4 February 2016

Follow up of Letter of Intent **(LOI) INTC-I-148**

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

Preparation of negative ion beams for the determination of the electron affinity of polonium and astatine by laser photodetachment

25.09.2013

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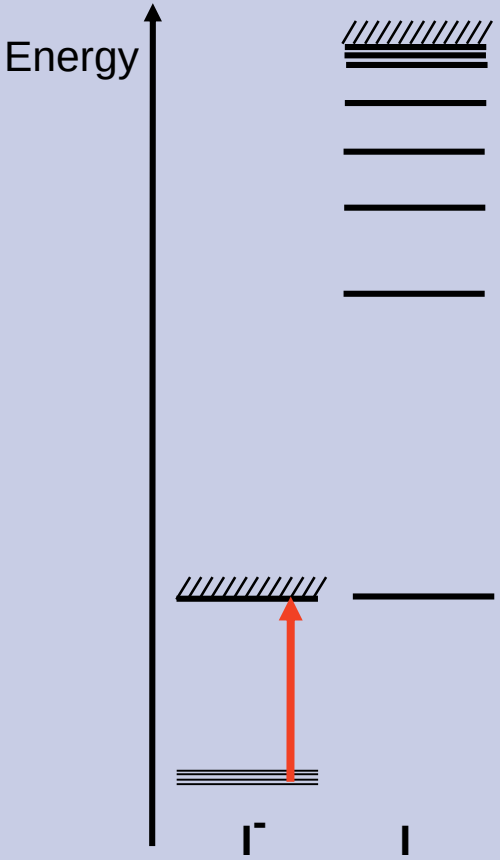
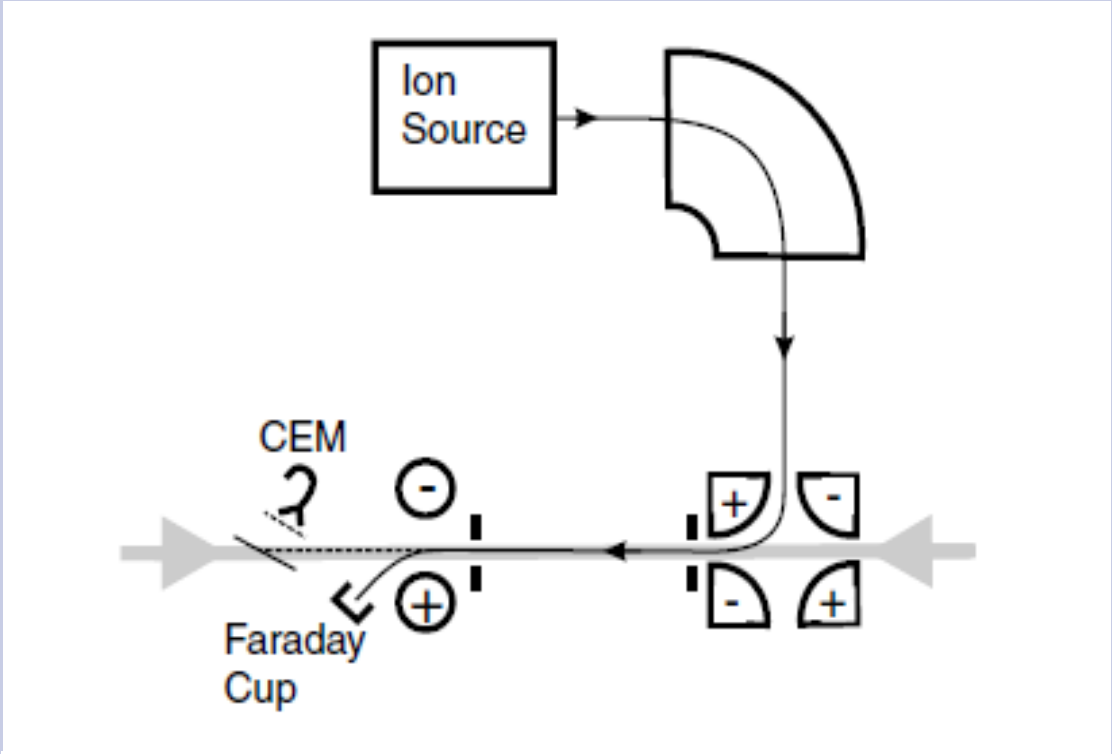
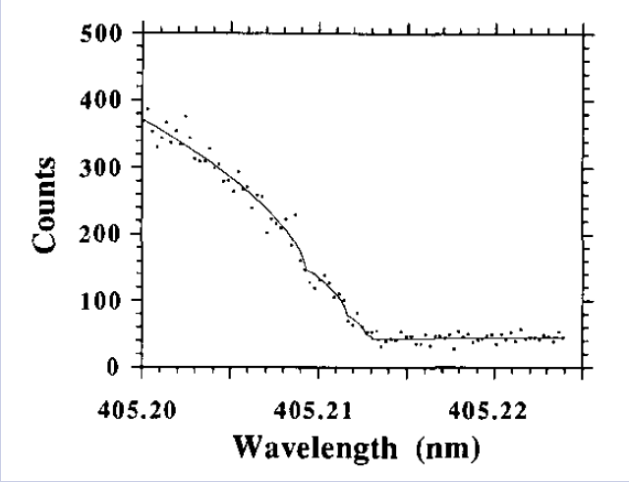
Collinear photodetachment spectroscopy

$$I^- + h\nu \rightarrow I + e^-$$





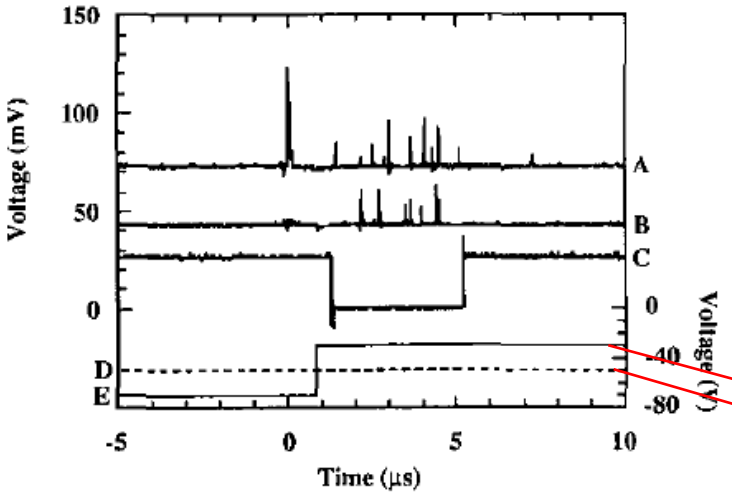


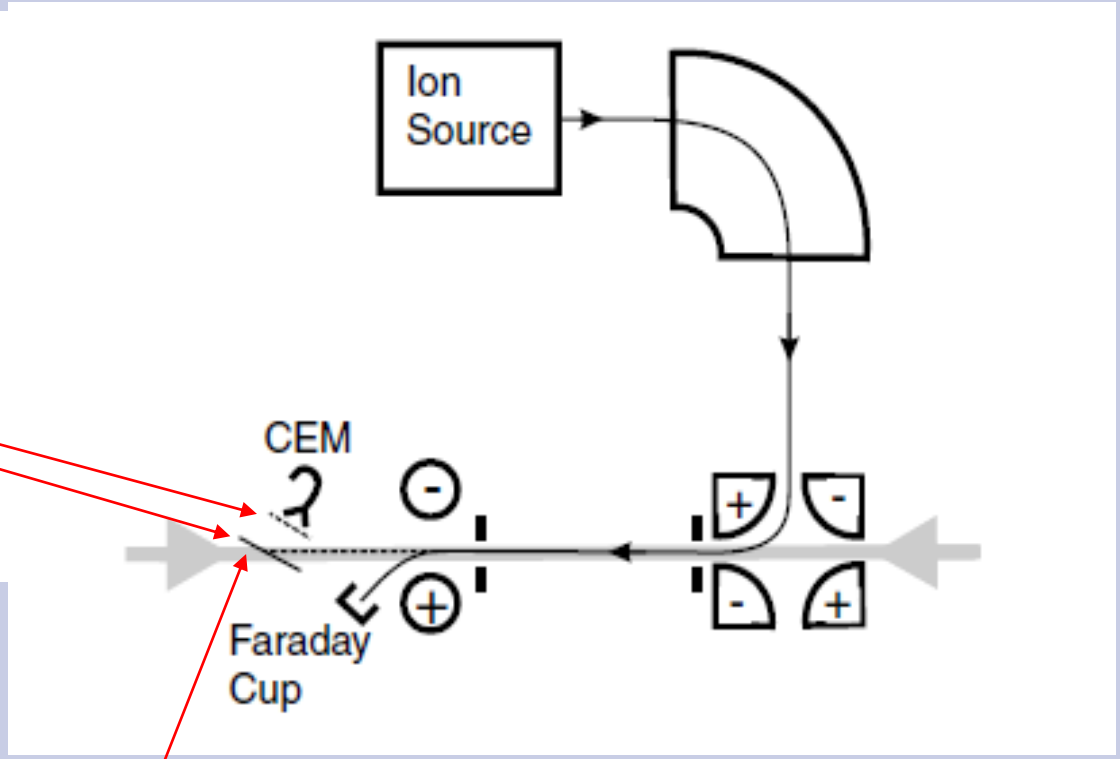
Wigner law:

$\sigma = k\,(E-E_0)^{\,l+1/2}$

D.Hanstorp and M. Gustafsson JPB 25 (1992) 1773

Neutral particle detection in collinear laser spectroscopy





For each laser pulse:

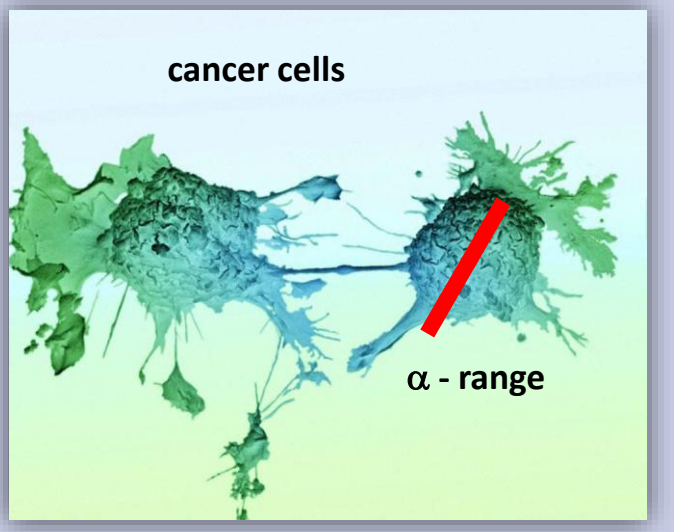
Signal:
0.01 atom

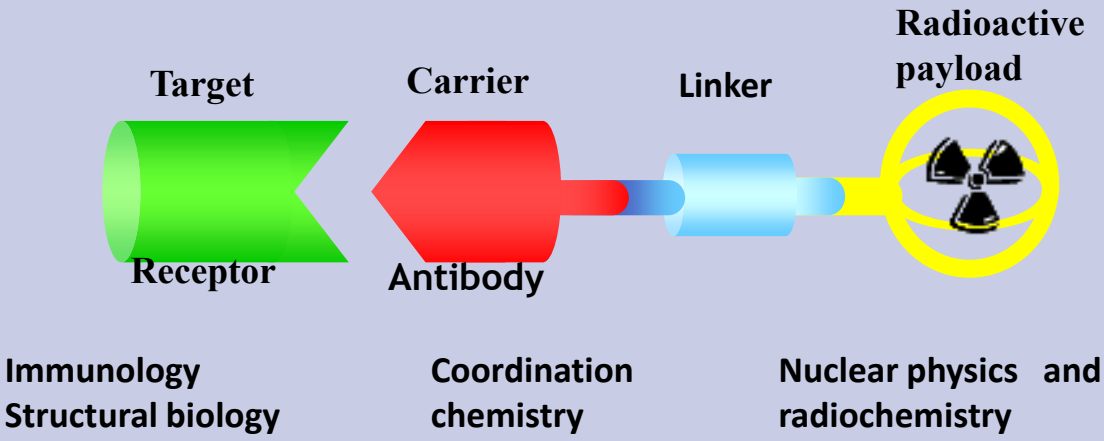
Background:
10^{14} photons

Glass plate coated with ITO (In_2O_3:Sn)

D. Hanstorp, Meas. Sci. Technal. **3** (1992) 523-527.

Targeted Alpha Therapy (TAT)



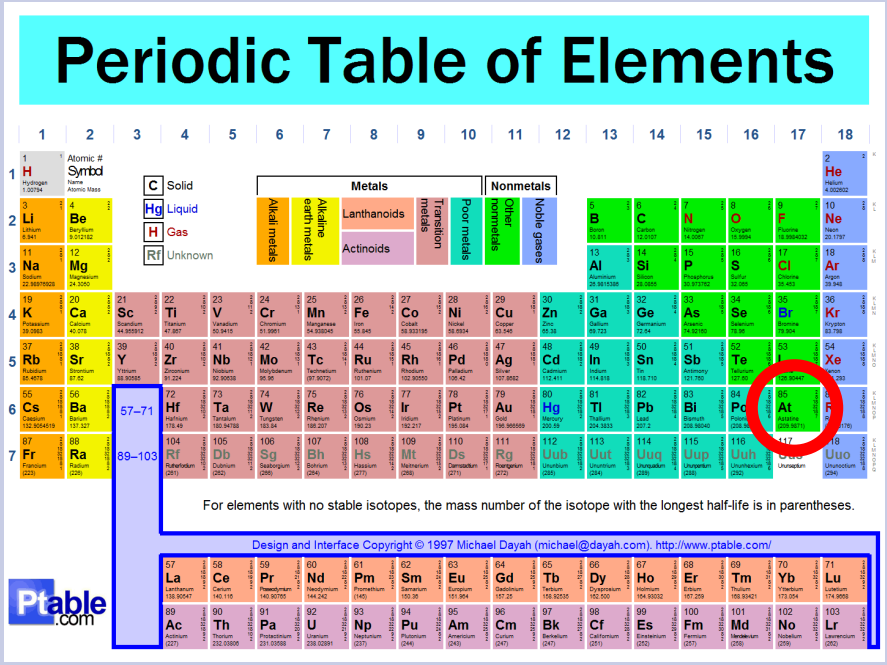


^{211}At particularly suitable isotope

- 7 h lifetime
- No long lived daughters
- Non-toxic daughters
- Suitable α energy

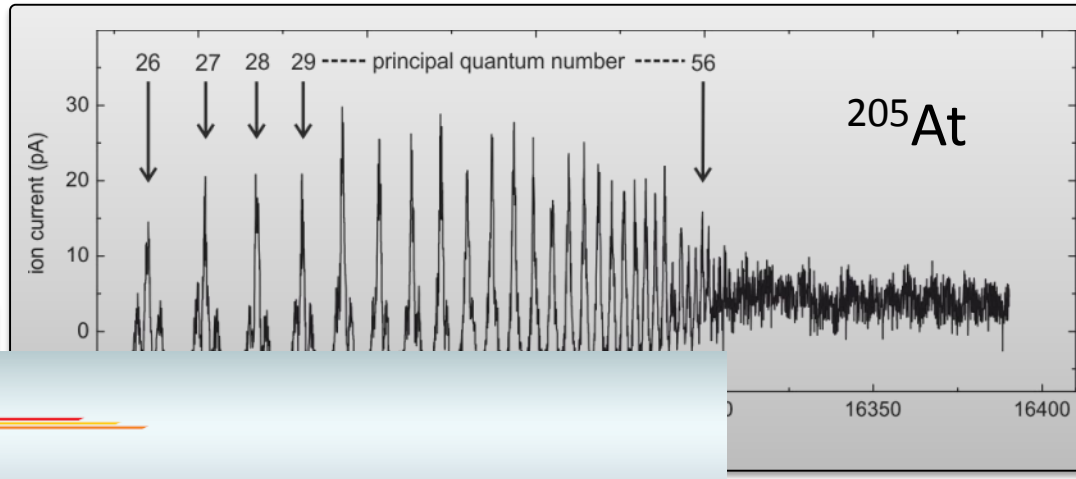
Astatine

- Least abundant element on earth
- 70 mg in the crust of the earth (1 atom per 100 kg mass)
- Small knowledge about chemical and physical properties
- Halogen or metal?



Spectroscopy of Rydberg levels

- $IP_{Threshold}$ allowed choice of laser dye
- High resolution laser scan across the IP
- ^{205}At measured on Faraday cup
- 50 Rydberg levels found



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Measurement of the first ionization potential of astatine by laser ionization spectroscopy

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ds versus n
meters)
es

berg-Ritz formula

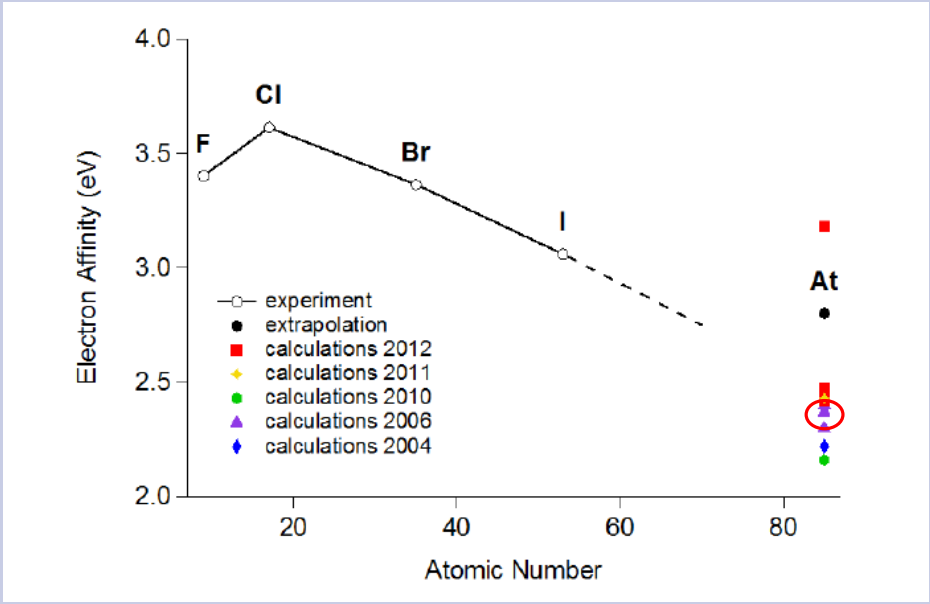
$$= \square\square - \frac{\square}{E\square - \square F}$$

$IP_{Rydberg}(At) = 75150.8(7)\ cm^{-1}$

Motivation for EA measurement of At and Po

Astatine

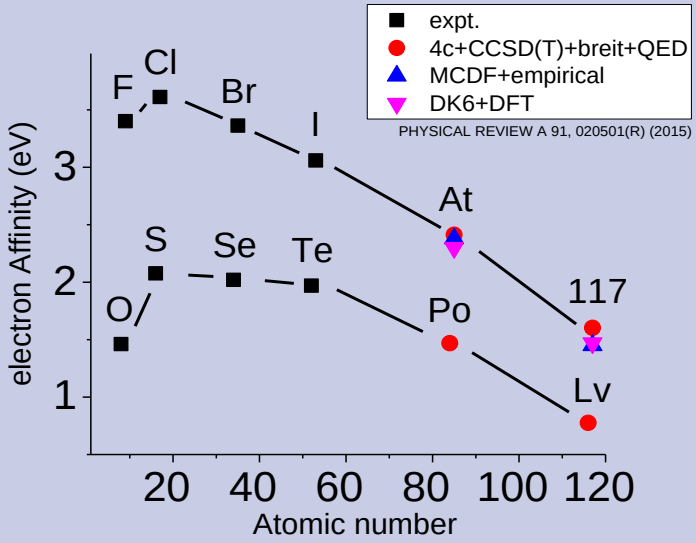
- EA equally important as the IP
  - → determine electronegativity
  - → nature of chemical bonds
- Important for computer simulations for binding of At to receptor
- No experimental value for EA(At) yet
- Scattering of theoretical predictions ~1 eV



PHYSICAL REVIEW A 91, 020501(R) (2015)

Polonium

- Po is considered important component of the natural radiation affecting humans
- Physico-chemical properties need to be understood to develop decorporation treatments



GANDALPH

Gothenburg **AN**ion **D**etector for **A**ffinity measurements by **L**aser **PH**otodetachment

Built in spring 2015 in Gothenburg

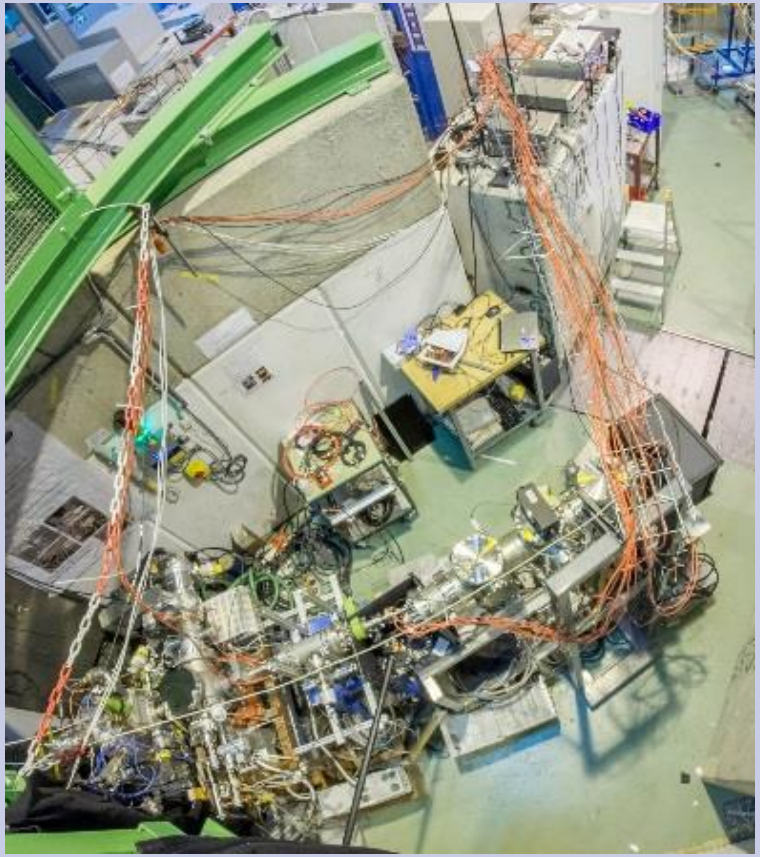
Moved to ISOLDE, June 2015

Installed and put into operation at GLM

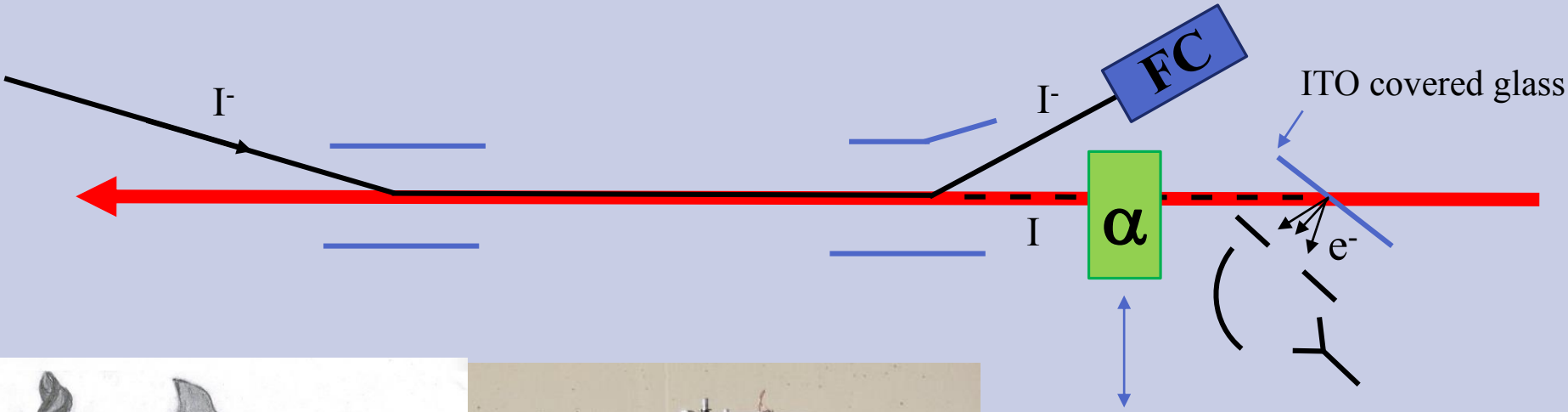
full control of system

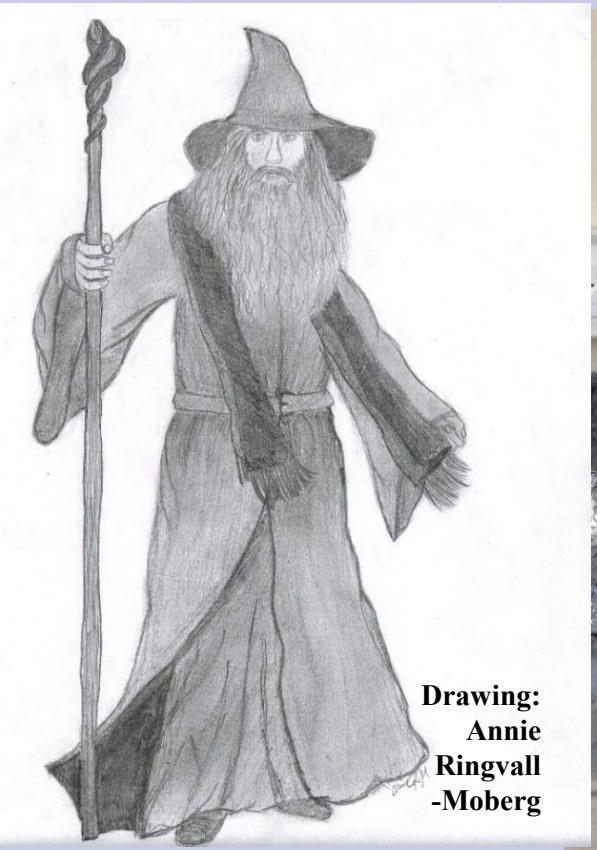
Laser transport from RILIS

Photodetachment of I^-, July 2015



GANDALPH





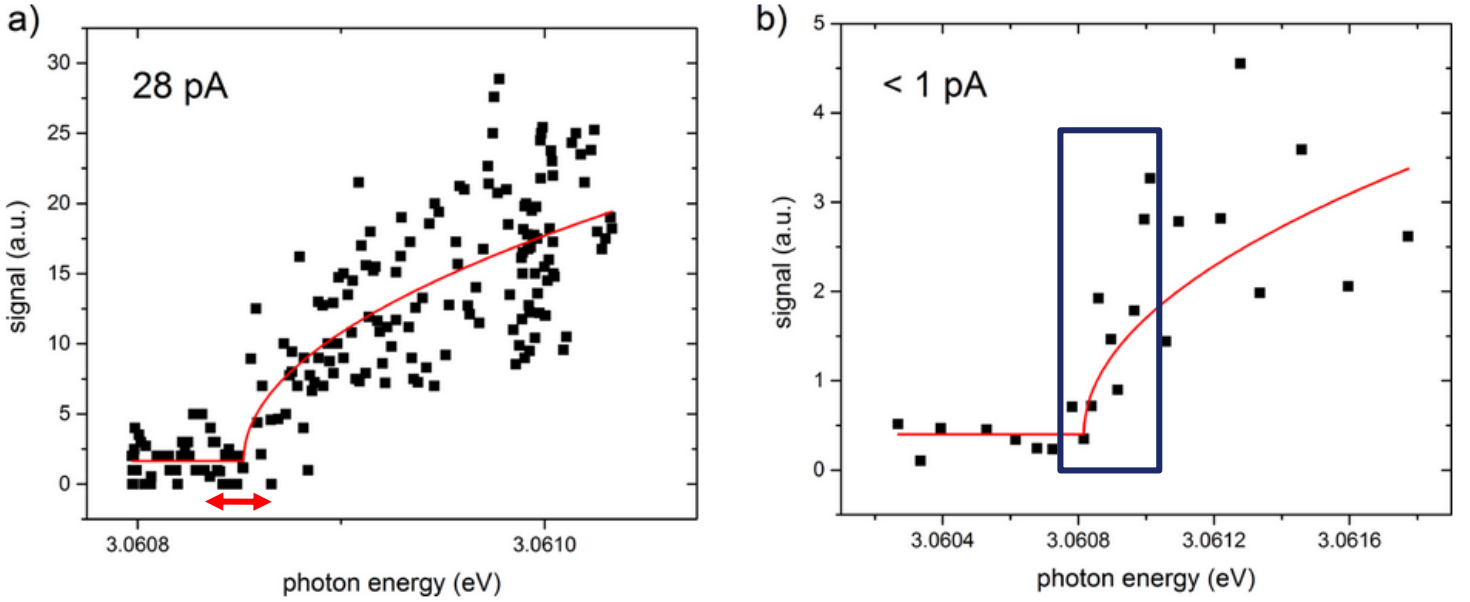
Test of GANDALH: Photodetachment of stable I^-

Low 10^{-8} mbar vacuum

~ 8% transmission to the neutral detector

Photodetachment signal of I^-

Threshold still measurable at very low ion rates (<1 pA, FC noise)



Improvements prior to next run:

- Improve transmission → additional Einzel-lenses
- Low 10^{-8} mbar to high 10^{-10} mbar →new ion pump + baking
- Moveable α-detector → detection of selected At isotopes

BEAM TIME REQUEST

4.3 Summary of requested shifts

We request a total number of 16 shifts preceded by 4 shifts for the offline setup and initial reference scans.

Description	Element	Number of shifts (offline)	Protons
Stable beam tuning	iodine	(4)	no
determining threshold region	astatine	4	yes
fine scan collinear	astatine	3.5	yes
reference scans	iodine	1	no
fine scan anticollinear	astatine	3.5	yes
attempt threshold region	polonium	4	yes

~We can select the most suitable isotope
(Any isotope could be used to determine EA)

Experiment possible with 3 10^5 ions (but with lower resolution)

Requested 3 10^7 ions but experiment possible also with 3 10^5

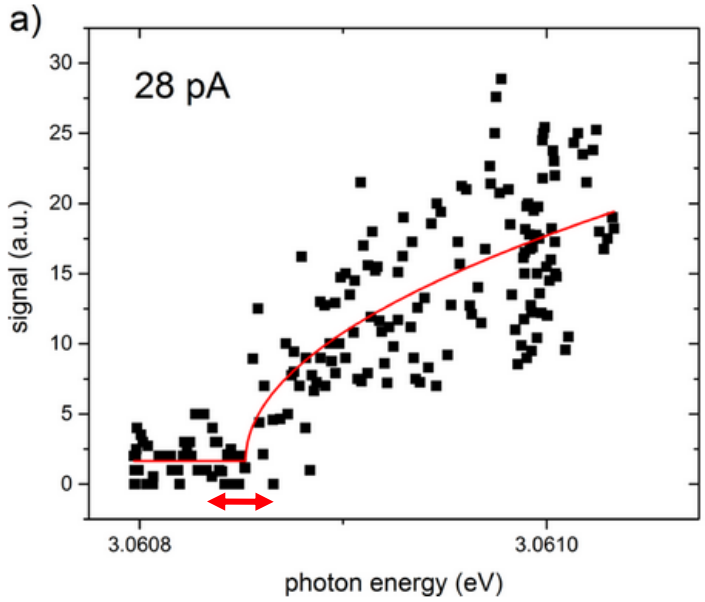
- The background (collisions) proportional to ion beam intensity

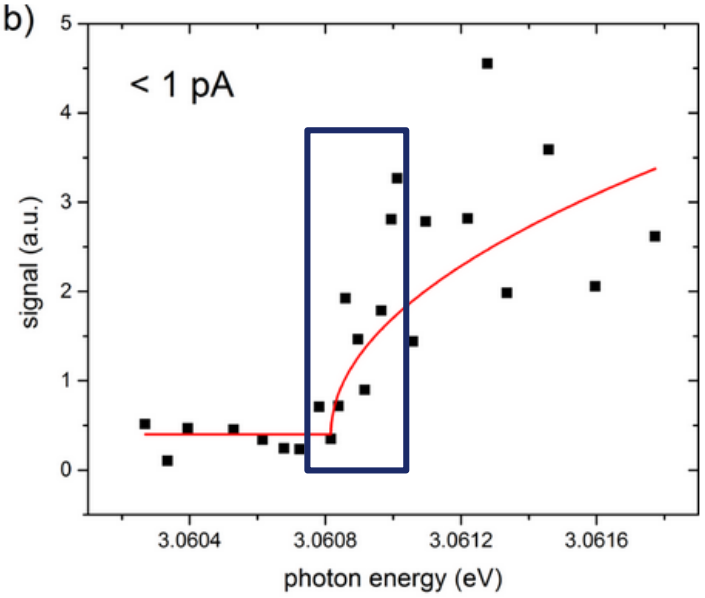
  → Lower current compensated with increased acquisition time

- Pressure down x20 → x20 reduction in background

- Photodetachment is a threshold process:
  Lower current compensated with larger steps in photon energy
  → threshold measurement but with lower resolution

- Goal: Determine EA with resolution of 40 μeV
  but: **today is today completely unknown!**
  Even resolution 10 meV is very important result


a)
28 pA
signal (a.u.)
photon energy (eV)
0
5
10
15
20
25
30
3.0608
3.0610


b)
< 1 pA
signal (a.u.)
photon energy (eV)
0
1
2
3
4
5
3.0604
3.0608
3.0612
3.0616

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Thank you for your attention!