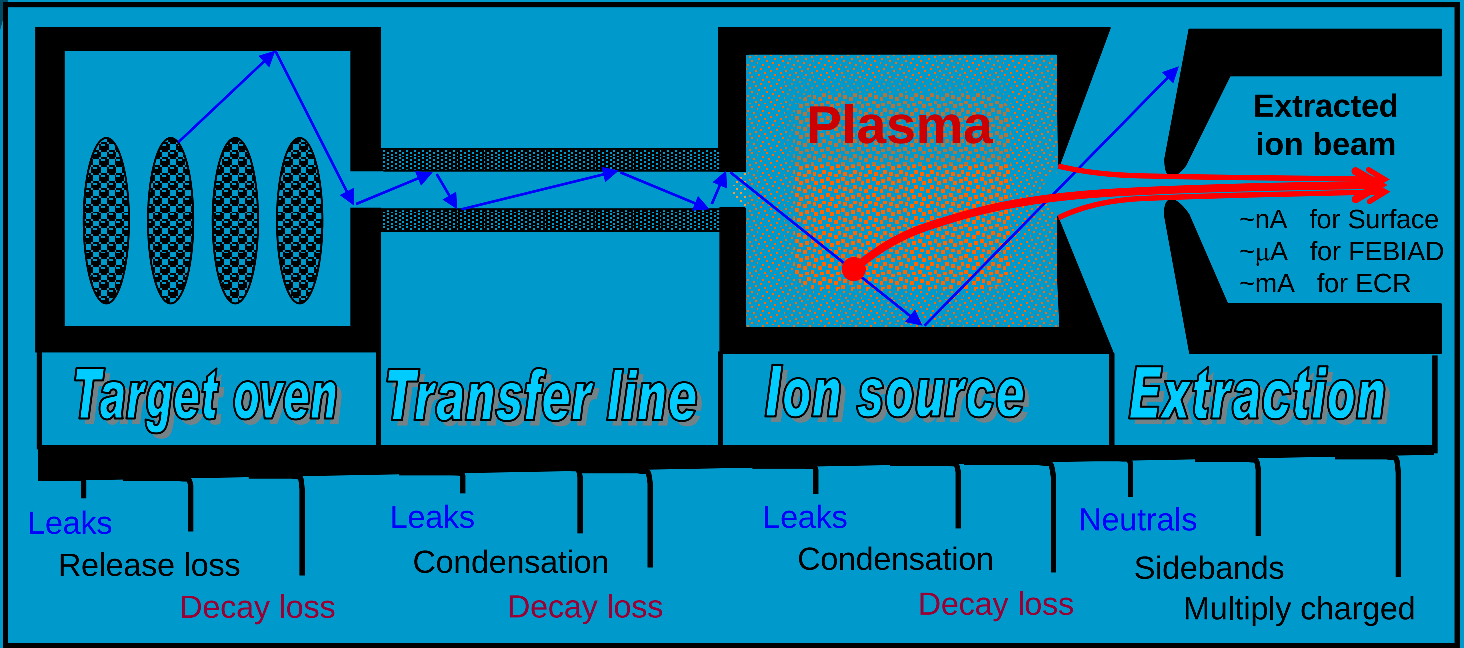
FEBIAD ion source *operation modes* for tuning its selectivity: physics processes, numerical simulations and experimental data.

L.Penescu, R.Catherall, J.Lettry, T.Stora
CERN, AB-ATB-IF (ISOLDE)

ISOLDE Workshop, 17-19 December 2007

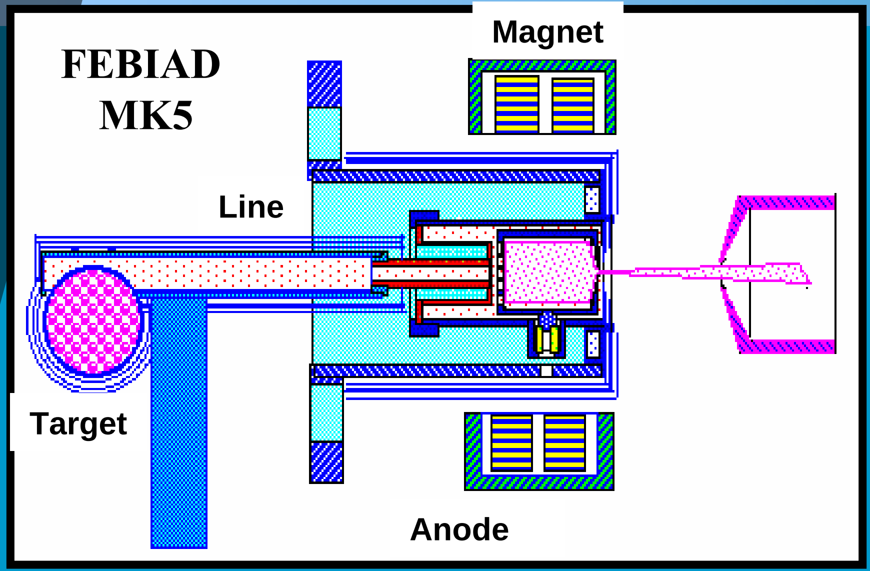
Selectivity in a ISOL target-ion source unit



Selective ISOL steps:

→ Neutron converter;
→ Thermochromatography in the transfer line;
→ Ion source type; RILIS ionization;
→ Molecular compounds
→ **Plasma ion source tuning & customization**

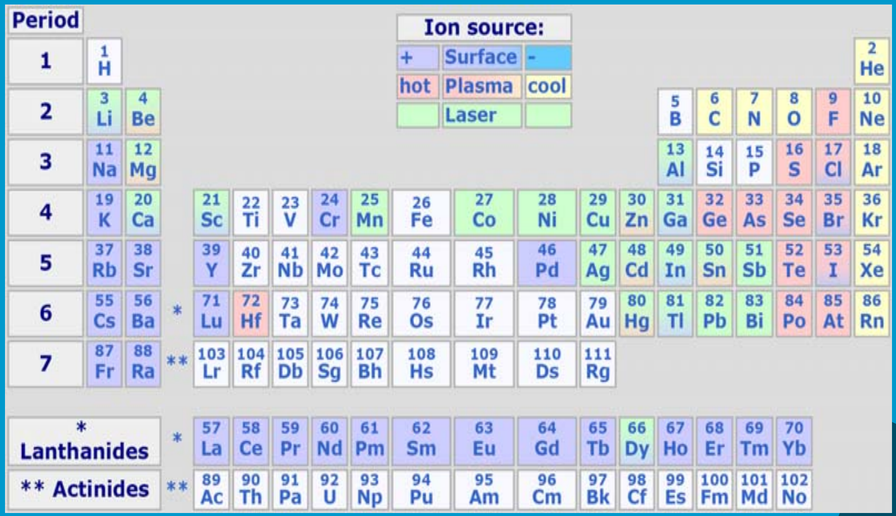
FEBIAD ion sources



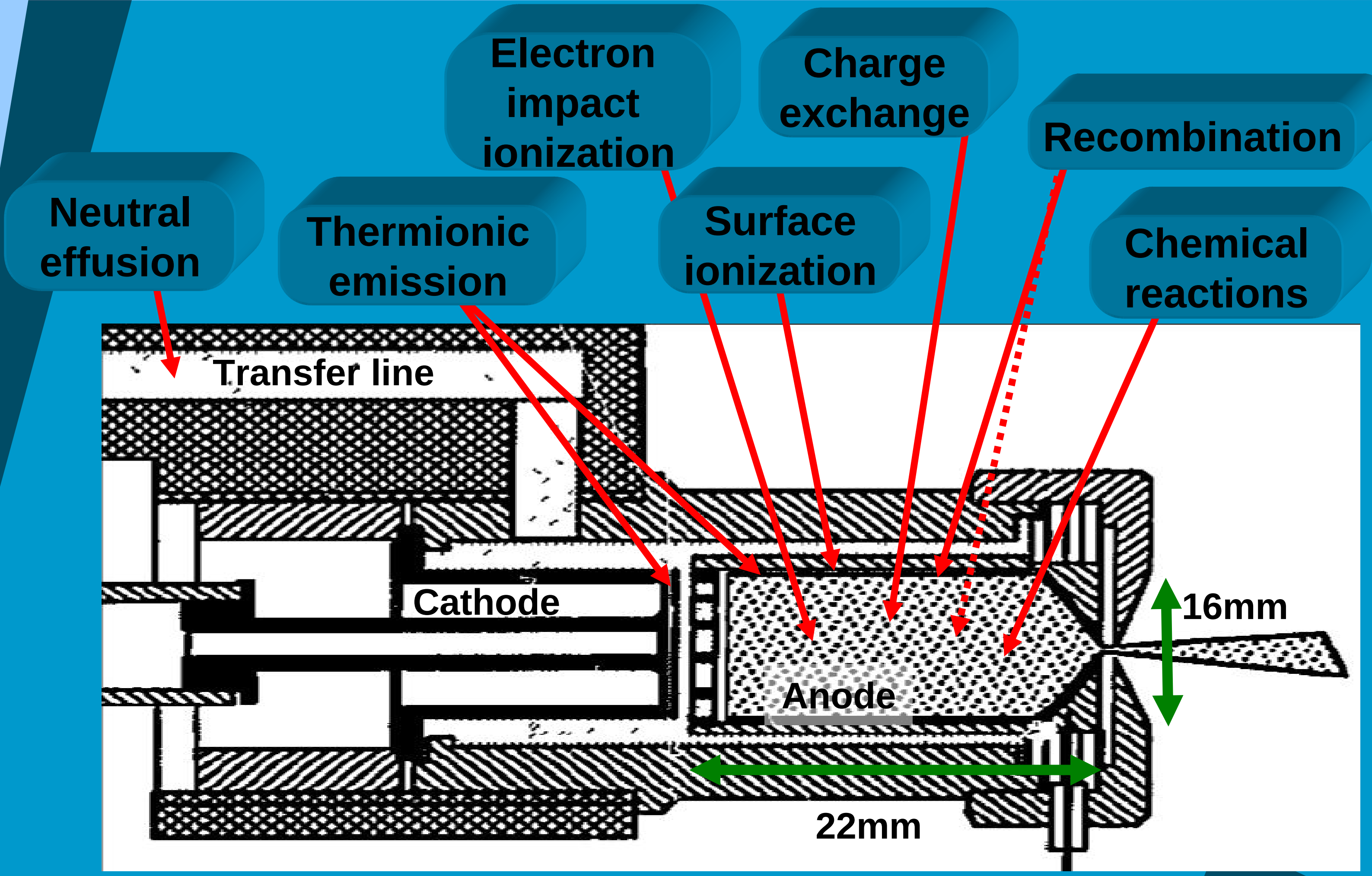
→ No limit concerning the ionization potential;
→ Limitation given by the element's volatility:

$\Delta Ha < \sim 6eV$

Ionised elements:



The arc discharge plasma



Selectivity in the arc discharge plasma

→ Making use of the shifts in the **maximum/ minimum/ inflexion regions** for all possible phenomena;

→ Selectivity for **different element classes** *(different mass, volatility, ionization mechanism or potential…)*

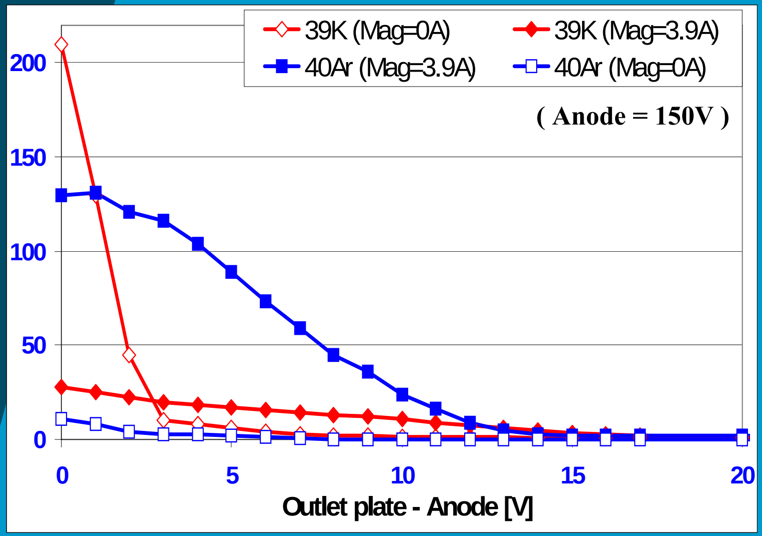
- **Neutral effusion;**
  Active parameters: temperature, volume
- **Impact ionization;**
  Active parameters: cross section, secondary electron energy, pressure
- **Charge exchange;**
  Active parameters: cross section, residence time, pressure
- **Plasma confinement;**
  Active parameters: magnetic field, temperature, electron beam energy, pressure, source materials

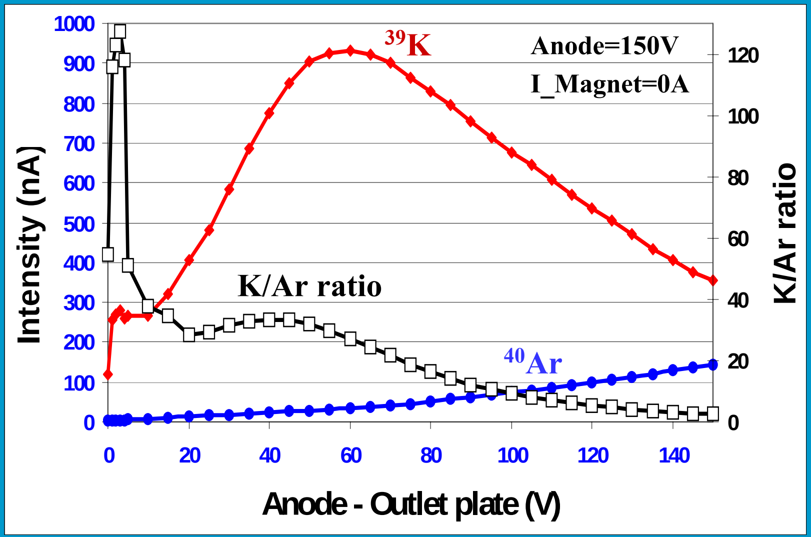
Selectivity for different ionization mechanisms

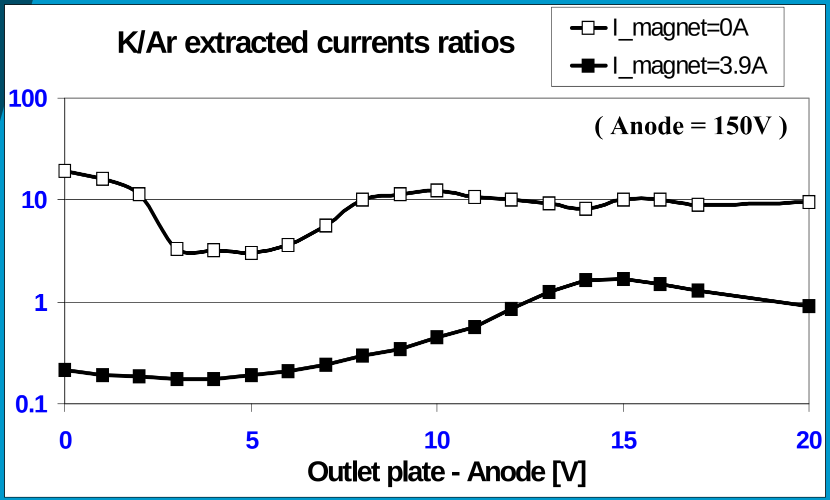
ISOLDE CERN

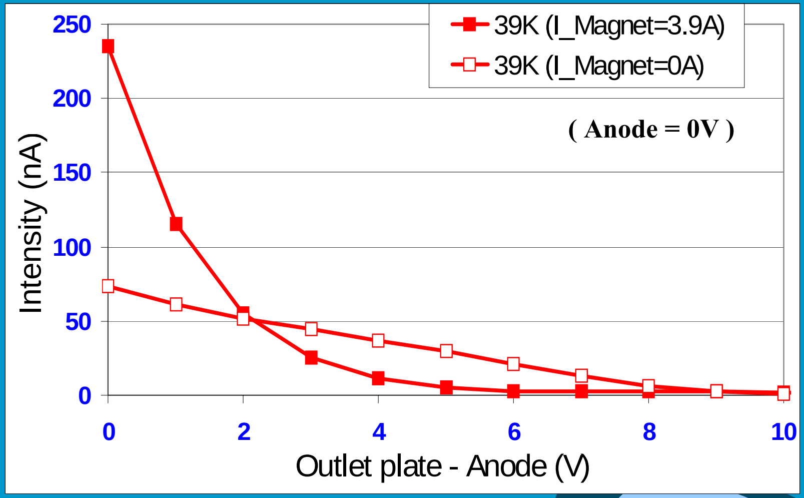
MARIE CURIE FELLOWSHIPS

Electron impact ionization ⇠ (FEBIAD) ⇢ **Surface ionization** ⇠ (RILIS) ⇢ **Laser ionization**



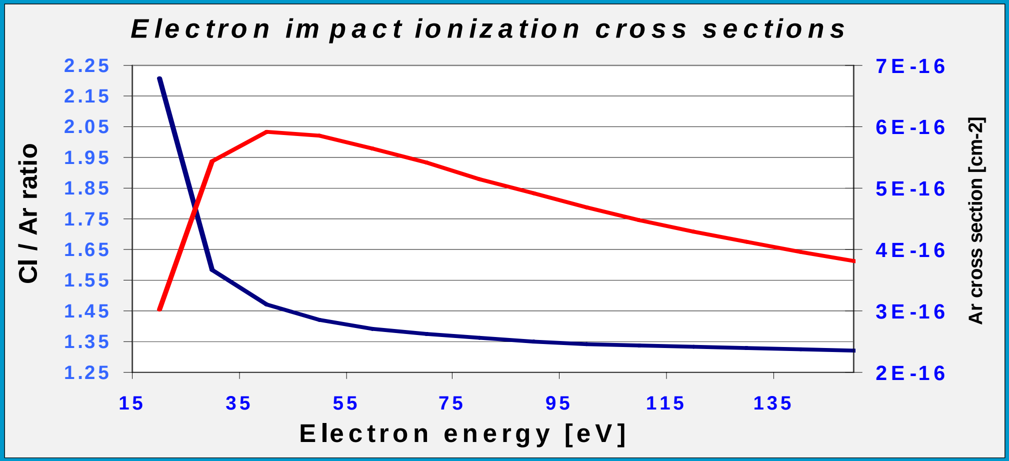




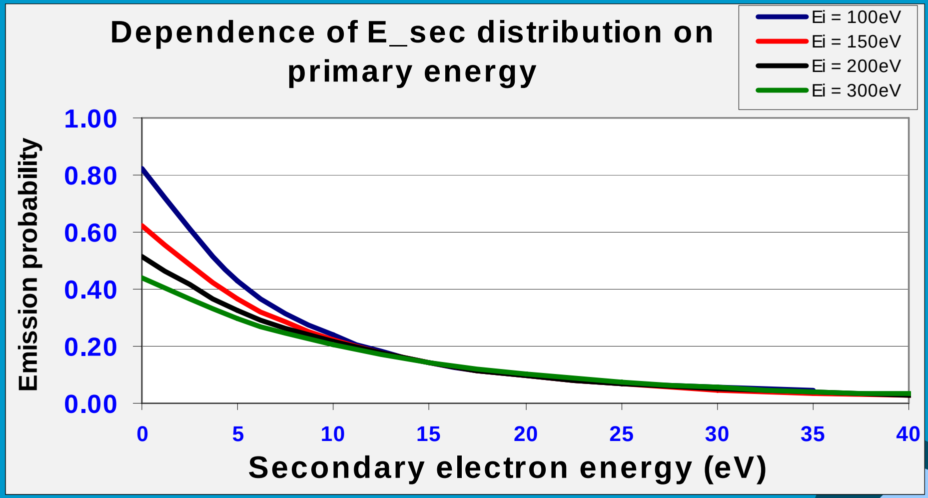


Selectivity for different ionization potentials

- **Difference in ionization cross section**



Ar: E_i =15.76 eV
Cl: E_i =12.97 eV

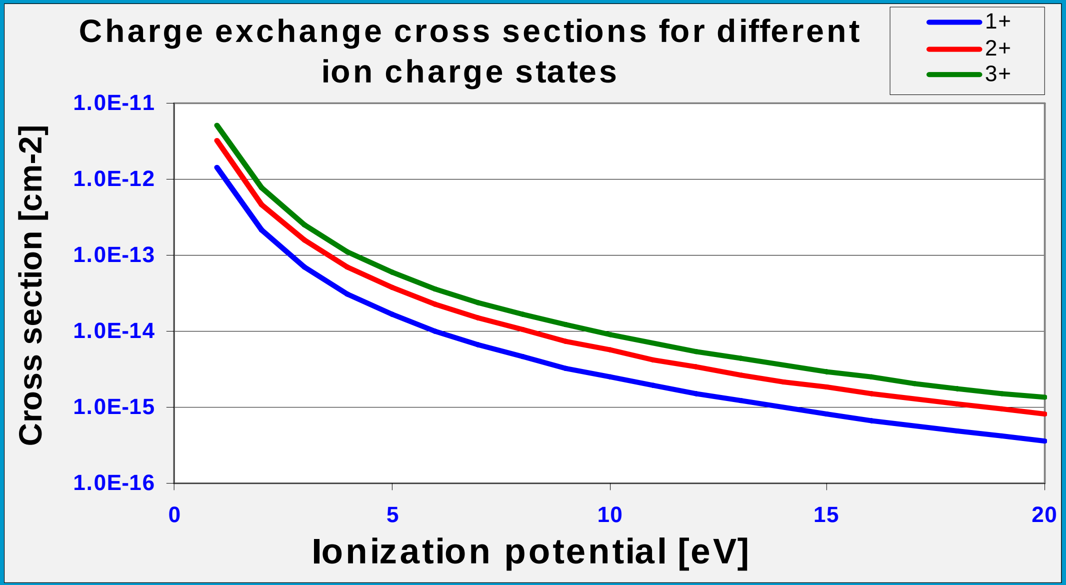


Primary electrons energy:
0 ÷ 300 eV

Secondary electrons energy: →

Selectivity for different ionization potentials

- **Difference in charge exchange cross section**



Ar: E_i =15.76 eV
Cl: E_i =12.97 eV

=> Cl/Ar cross section ratio: **1.7**

→ The ionization ratio between two elements can be estimated for the saturated regime (favouring the one with a lower ionization potential);

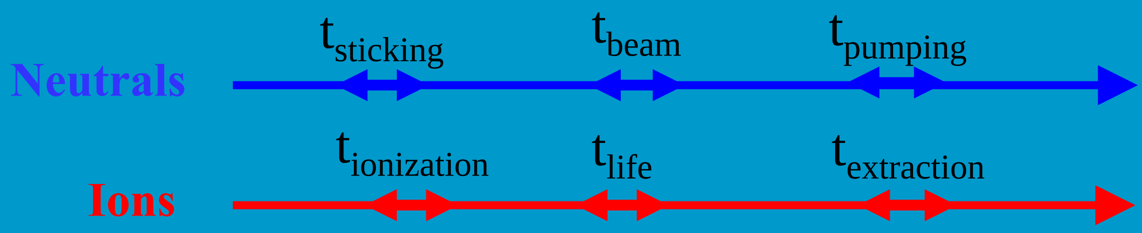
→ The ionization of the element with a higher ionization potential can be favored by reducing the ion lifetime in the plasma;

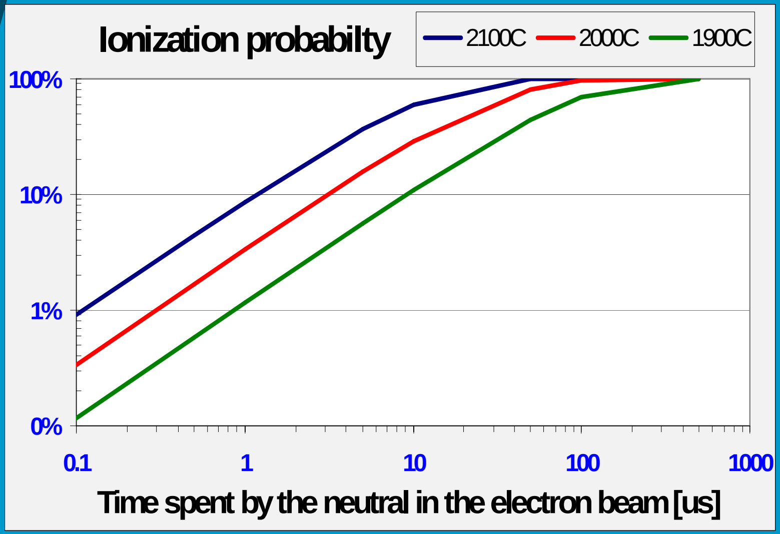
→ The dominant element in the ion source establishes a *threshold in the ionization potential* above which the ionization efficiency drops rapidly.

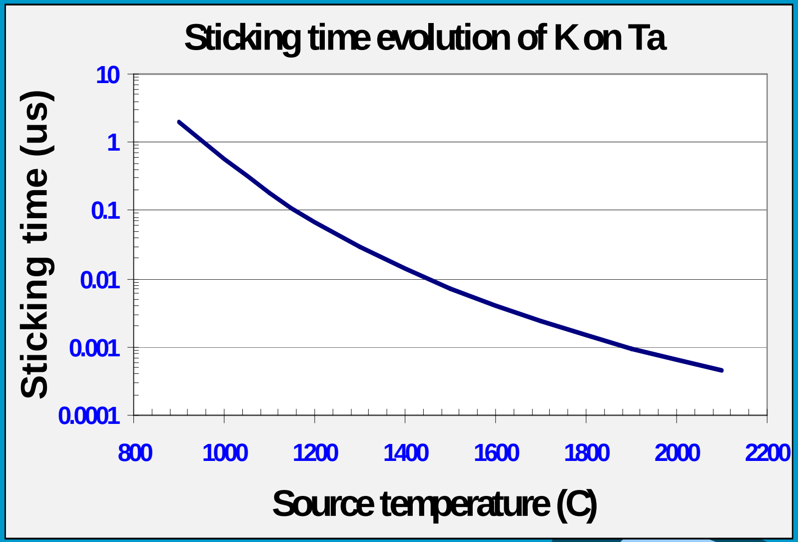
Selectivity for different volatilities

→ Employed everywhere in the target&ion source unit, but having different weighting factors here

→Useful for changing the ratio of the **specific times** of a **plasma discharge**:







Selectivity for different masses

→ NEUTRAL STATE

Higher neutral residence time for higher masses:

$$t_i = k \cdot t_0 = k \cdot \frac{d_0}{v_i} = k d_0 \sqrt{\frac{m_i}{3k_b T}} \quad => \quad t_i \propto \sqrt{m_i}$$

k – number of collisions
d_0 – average time between 2 wall collisions

} constants for a given geometry

→ ION STATE

Higher drain rates through plasma boundary for lower masses:

$$j_i = f \cdot n_i \cdot \sqrt{\frac{kT_{el}}{m_i}}$$

f - Bohm factor
T_{el} – electron temperature

^{35}Cl versus ^{35}Ar

^{35}Ar run; *Target:* CaO; *Ion Source:* MK7 (GPS, October 2007)

→ Same ionization mechanism

→ No mass difference

→ Different chemical reactivity

→ Different origin & path

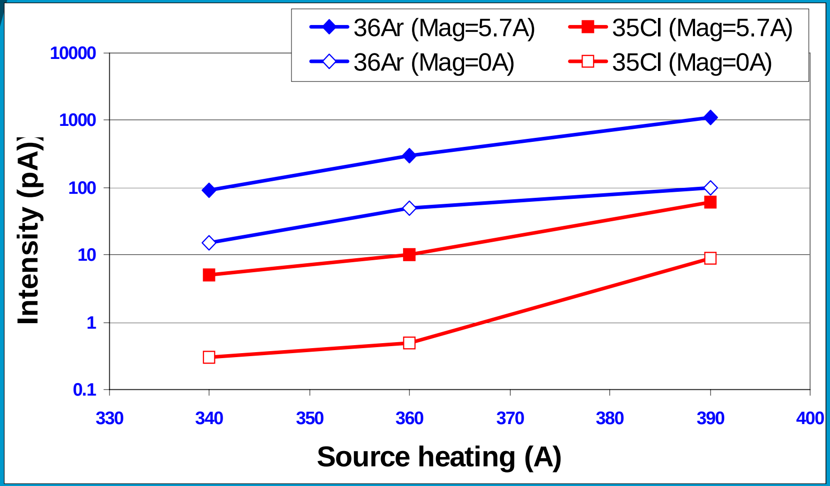
→ **Small difference in the ionization potential**

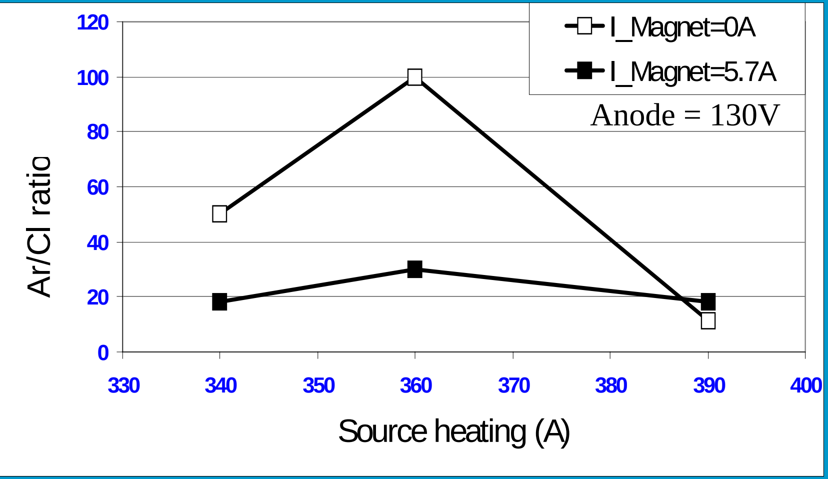
→ **Different volatility**

On-line results

^{35}**Ar run**; *Target:* CaO; *Ion Source:* MK7 (GPS, October 2007)

Dependence on source temperature





Lower source temperature

Lower cathode electronic emission

Lower wall electronic emission

Lower ionization rate

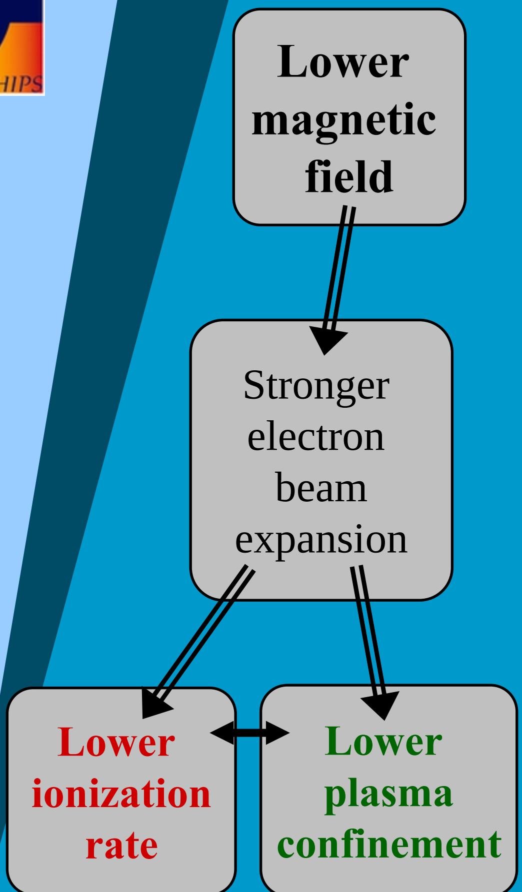
Lower plasma confinement

On-line results

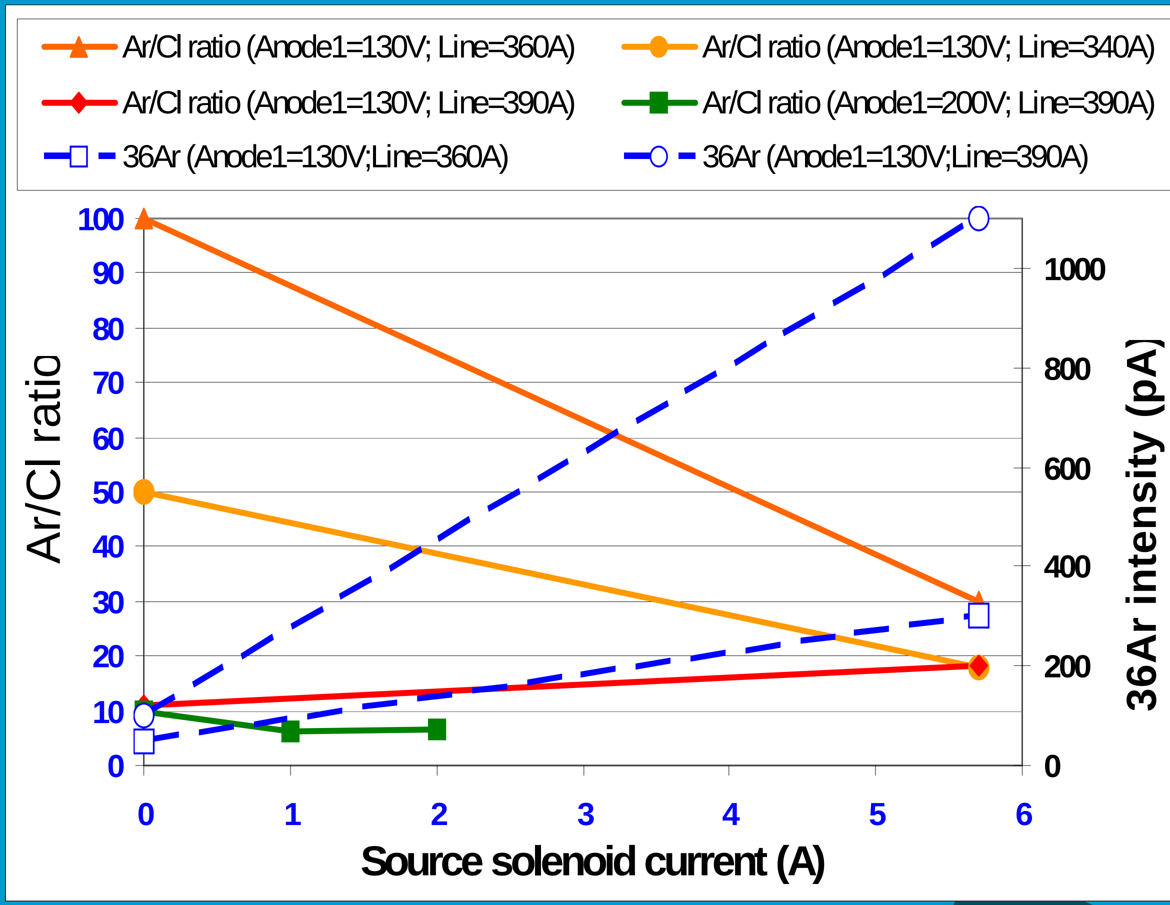
ISOLDE CERN

MARIE CURIE FELLOWSHIPS

^{35}**Ar run**; *Target:* CaO; *Ion Source:* MK7 (GPS, October 2007)



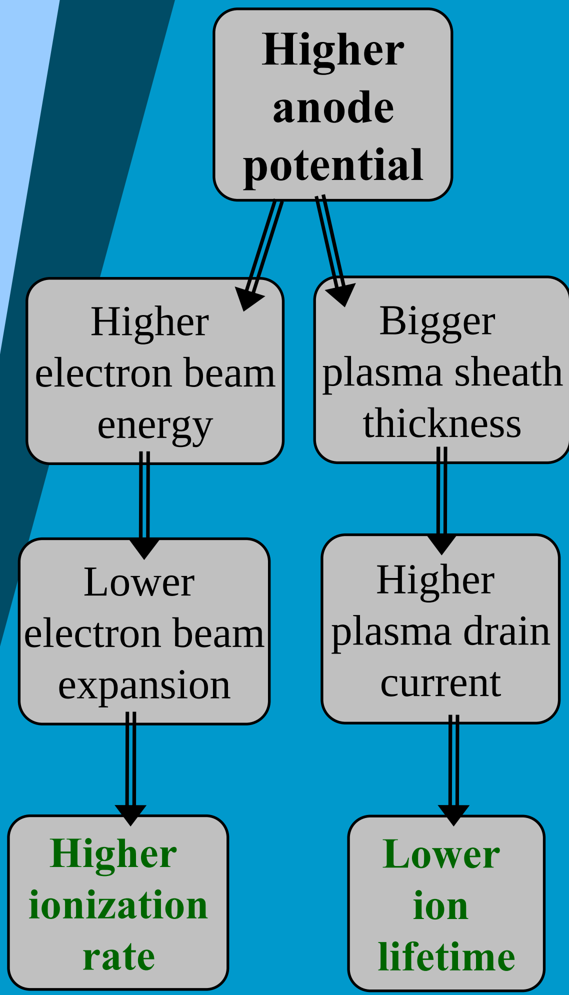
Dependence on the internal magnetic field



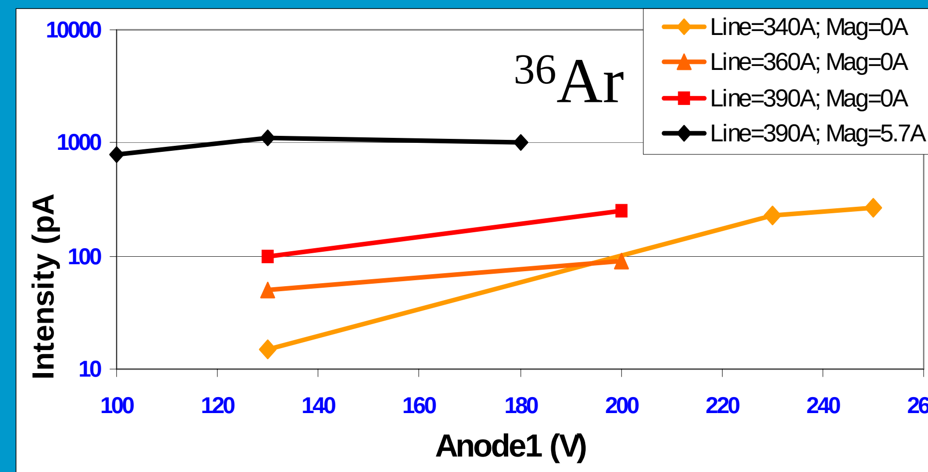
On-line results

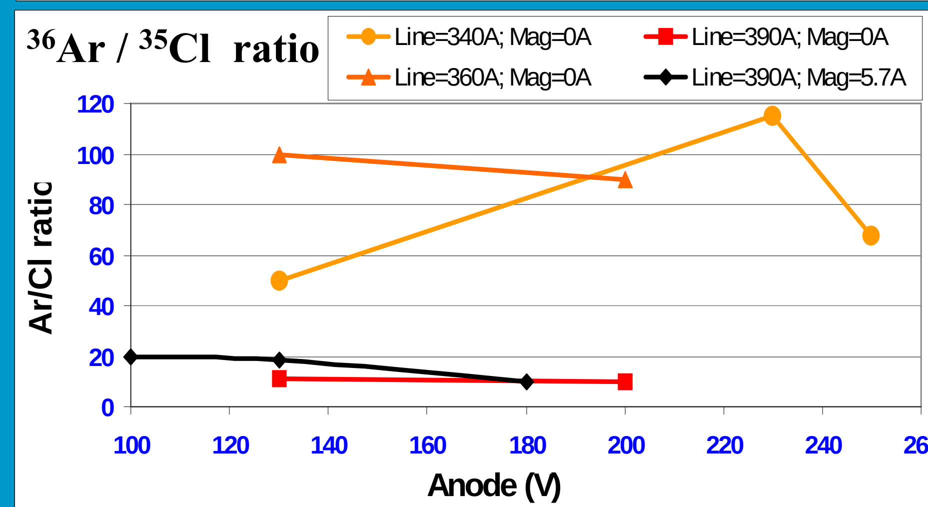
ISOLDE CERN

^{35}**Ar run**; *Target:* CaO; *Ion Source:* MK7 (GPS, October 2007)



Dependence on anode potential





Ion source customization

GOALS:

→ Reducing the contaminants for specific elements of interest

→ Improving the *ionization efficiency* and/or *source emittance* and/or *residence time*

→ Optimization of laser ionization

→ Adapting the ion source to higher operating pressures

WAYS:

→ Electric field configuration

→ Ion source geometry

→ Wall materials favouring *electron emission* or *surface ionization*

→ Extraction system

Tools for customization

THEORY

SIMULATION

→ RIBO ("**R**adioactive **I**on **B**eam **O**ptimizer")

→ CPO ("**C**harged **P**article **O**ptics")

→ VORPAL ("**V**ersatile , **O**bject-oriented, **R**elativistic, **P**lasma **A**nalysis code with **L**asers ")

EXPERIMENT

→ Off-line separator

→ Emittance meter

→ Response time measurement system (under testing)

→ Beam energy measurement system (under testing)

Thank you

for

your attention!