APPLICATION OF AN ECR ION SOURCE FOR IONIC FUNCTIONALIZATION OF IMPLANT MATERIALS ON THE NANOSCALE

Institute for Nuclear Research
Hungarian Academy of Sciences

R. Rácz
S. Biri
P. Hajdu
A. Csik
K. Vad

Faculty of Dentistry
University of Debrecen

Cs. Hegedűs
T. Radics
J. Bakó
V. Hegedűs

Faculty of Science and Technology
University of Debrecen

S. Kökényesi
I. Csarnovics
J. Pálinkás

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Motivation

	A	B	C
Target material	Ti	Ti	ZrO_2
Beam	Au	Ca	Si

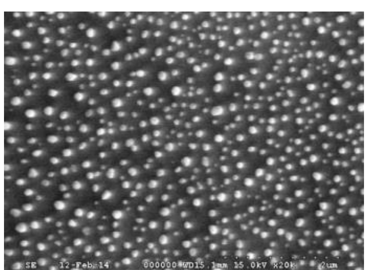
Motivation

A.

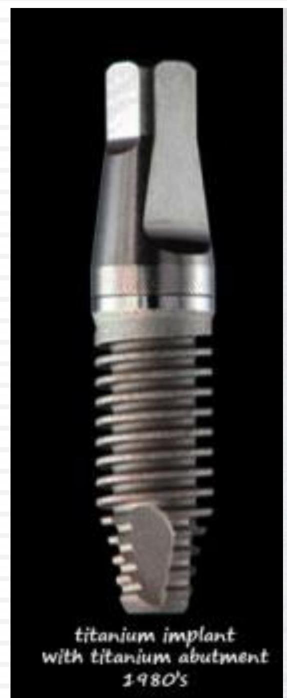
- GNPs (**G**old **N**ano-**P**articles) can chemically bond many types of biomolecules.

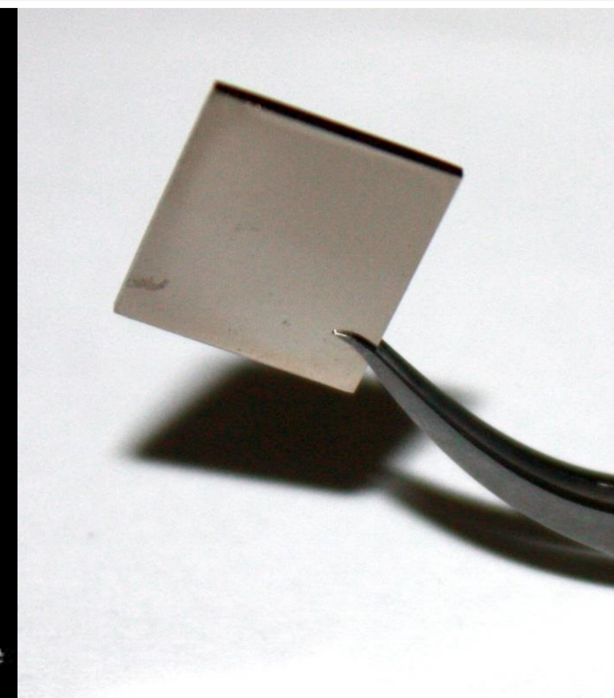
- Plasmon effect of the GNPs: energy transfer between the implants covered by GNPs and the light with appropriate wavelength may be able to destroy the bacteria molecules around the implants.

GNPs



	A	B	C
Target material	Ti	Ti	ZrO_2
Beam	Au	Ca	Si

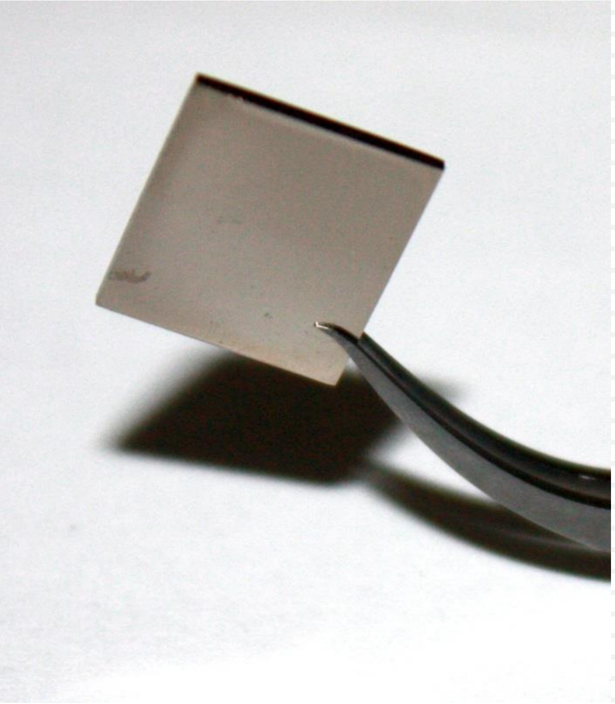




Motivation

B.
The implanted Ca ions may can increase and accelerate the adherence of the human tissue due to diffusion.

	A	B	C
Target material	Ti	Ti	ZrO_2
Beam	Au	Ca	Si

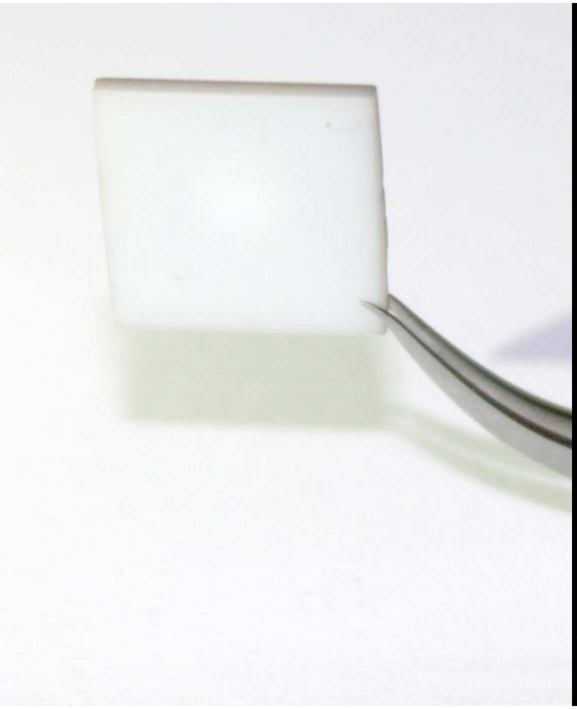


Motivation

C.

- ZrO_2 (non-silica-) based restorations have become very popular in the dentistry (esthetic).
- Silicon implantation in order to bond polymer molecules to the ceramic.

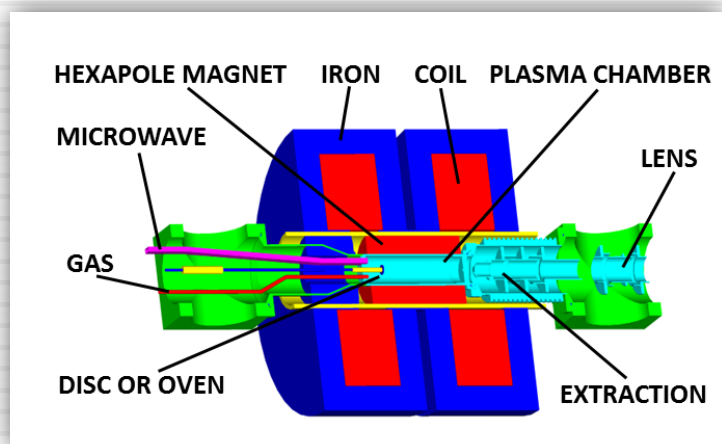
	A	B	C
Target material	Ti	Ti	ZrO_2
Beam	Au	Ca	Si



Motivation

Using an ECR Ion Source for ionic implantation:	
Advantages - High gas efficiency - Plasmas and beams produced from solid - Beam energy range, implantation depth is ideal - Effect of the charge state of the incident ions	**Disadvantages** - Relatively high operational costs - Inhomogenity of the beam - Using non analyzed beam (not pure)

The Atomki ECR Ion Source



Microwave frequency	14.3 GHz (6-18GHz)
Microwave power	0.1 - 1000 W
Resonant field	(14.3 GHz) 0.52 Tesla
Axial magnetic field peak	1.2 Tesla
Maximum of the radial field (hexapol)	1.2 Tesla
Plasma chamber L and ID	5.8 cm / 20 cm
Extraction voltage	50V - 30 kV

-Standard, stand-alone device. **No post acceleration.**

- Strong advantage is the modularity of the source

Requirements and difficulties

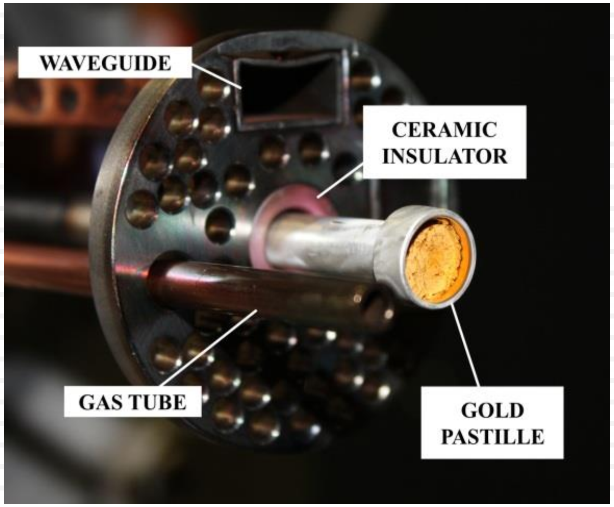
Requirements and difficulties

- Metallic (gold, calcium and silicon) ion beam is necessary for the planned treatments.
- The implantation depth must be characterized and precisely controlled.
  - Depth profile analysis of the samples made e.g. by SNMS is necessary
  - Theoretical calculation for realistic prediction.
- Clinical tests require a series of the samples (at least 60 paces)
- Relatively big size of the samples (10 mm x 10 mm)
- Inhomogenity of the beam.
- Dose requirements: it must be controlled from 10^{16} ion/cm^2 up to 10^{18} ion/cm^2.
- Insulation target e.g. ZrO_2

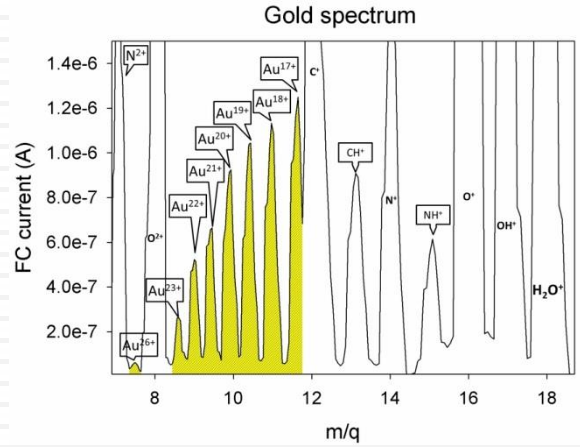
Ion beam developments

Production of **gold** ion beam:

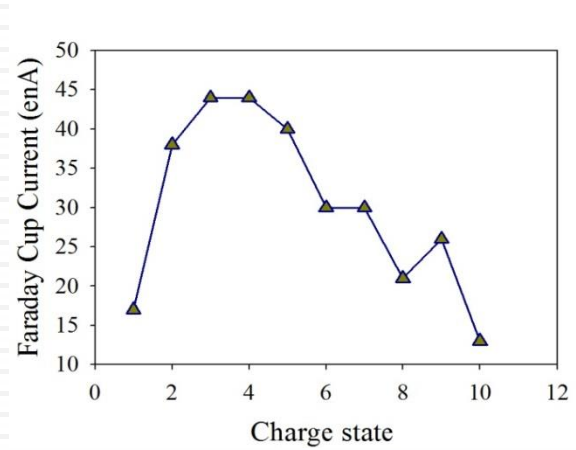
- Sputtering technic
- Sputtering electrode temperature
- Sputtering electrode: 2 kV
- Support gas: oxygen



The movable sputtering electrode mounted axially instead of biased disc.



Optimized for midle charge states (Us=10 kV)

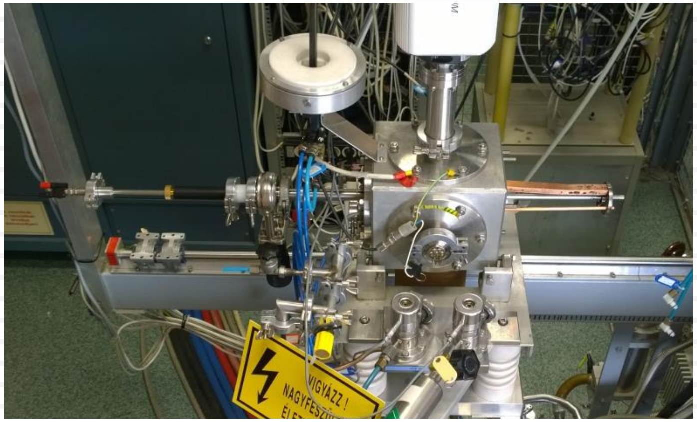


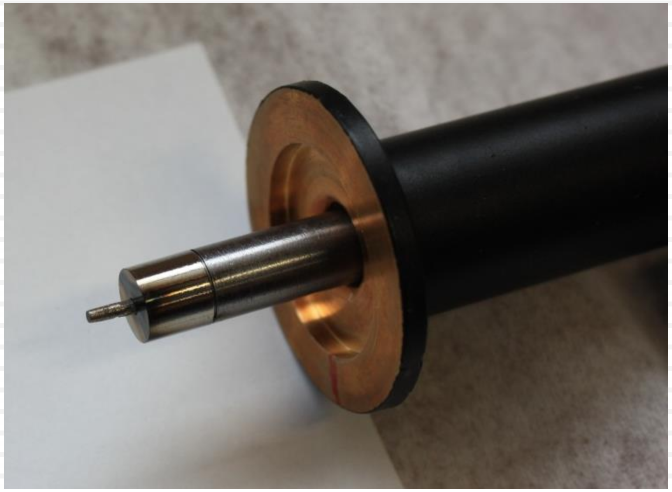
Optimized for low charge states (Us=2 kV)

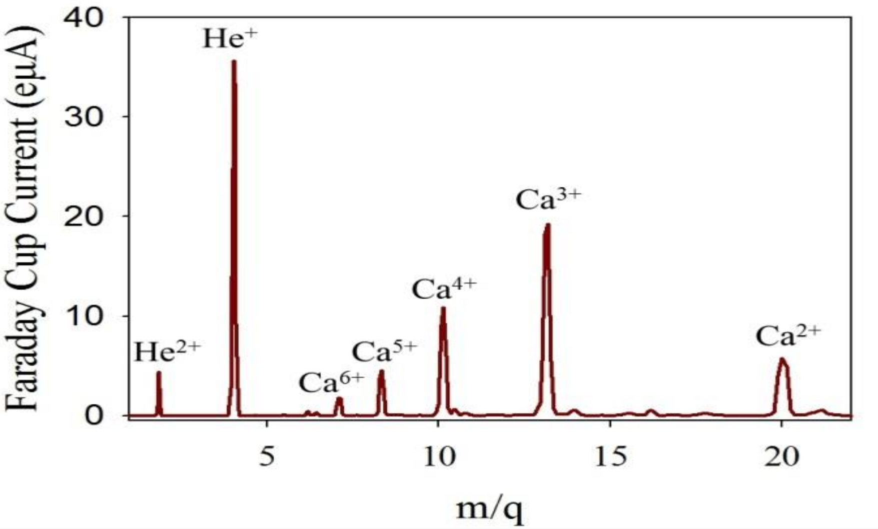
Ion beam developments

Production of **calcium** ion beam:

- Oven technique (Large capacity oven of Pantechnik)
- Filled by pure calcium
- Placed on the axis
- Temperature: 500°C -700 °C
- Support gas: helium
- Strong getter effect





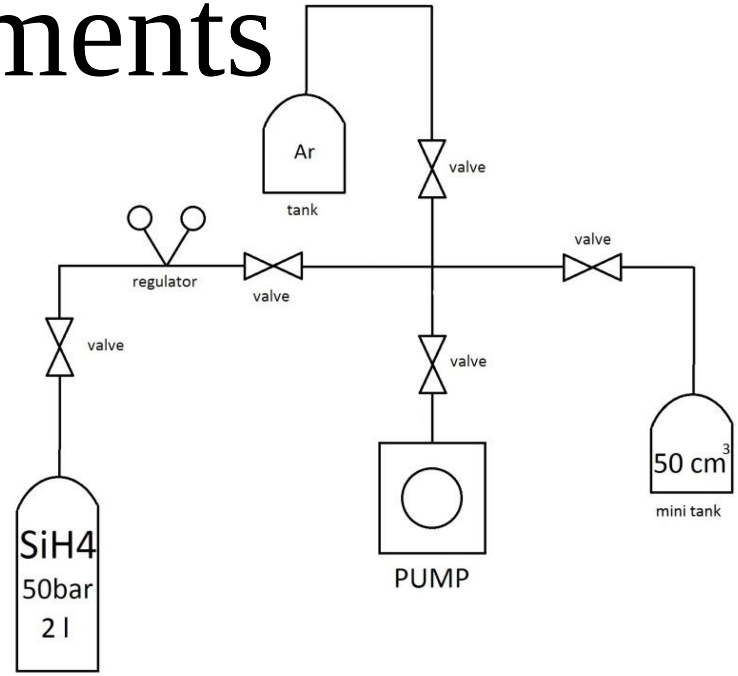


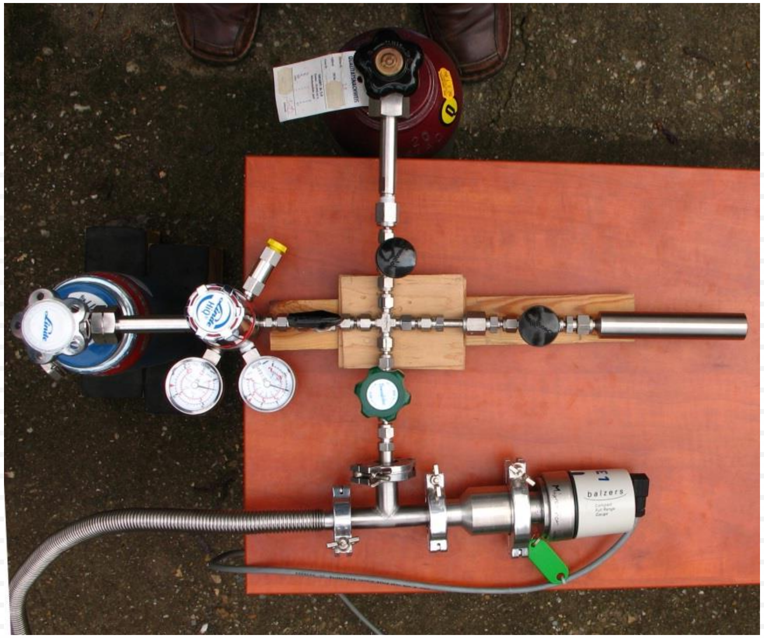
Calcium spectra, optimized for Ca^{3+}

Ion beam developments

Production of **silicon** ion beam:

- Using silane gas for plasma production
- Special care (flammable, auto ignition)
  - 1.37 % < C < 4.5 % flammable mixture
  - C > 4.5 % metastable
- System for transferring the gas from high volume high pressure (2 dm^3 and 50 bar) gas bottle to a smaller (50 cm^3 and 1.5 bar) one.

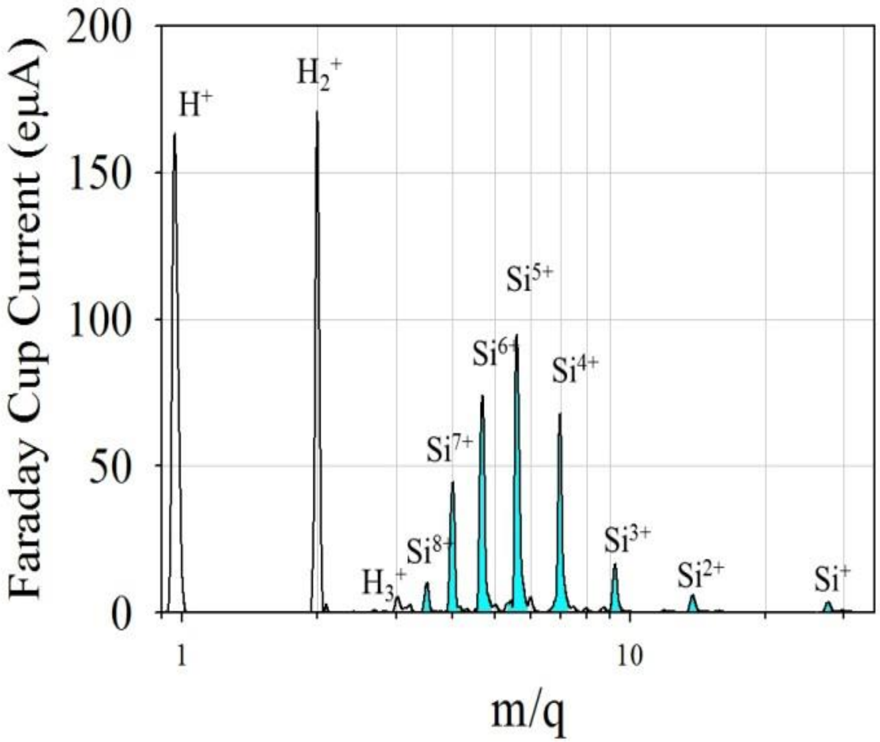




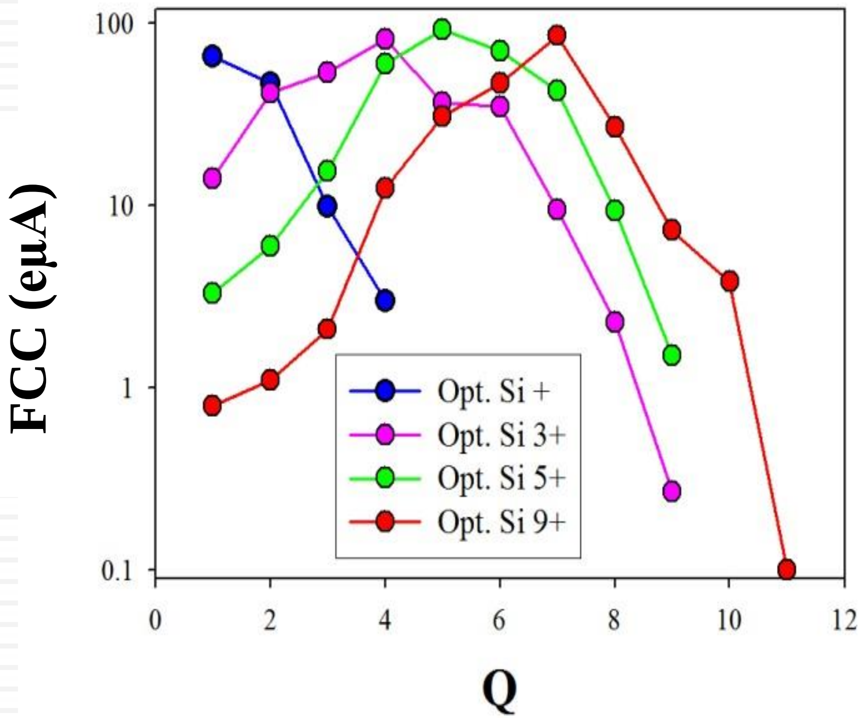
Ion beam developments

Production of **silicon** ion beam:

Using silane gas for plasma production



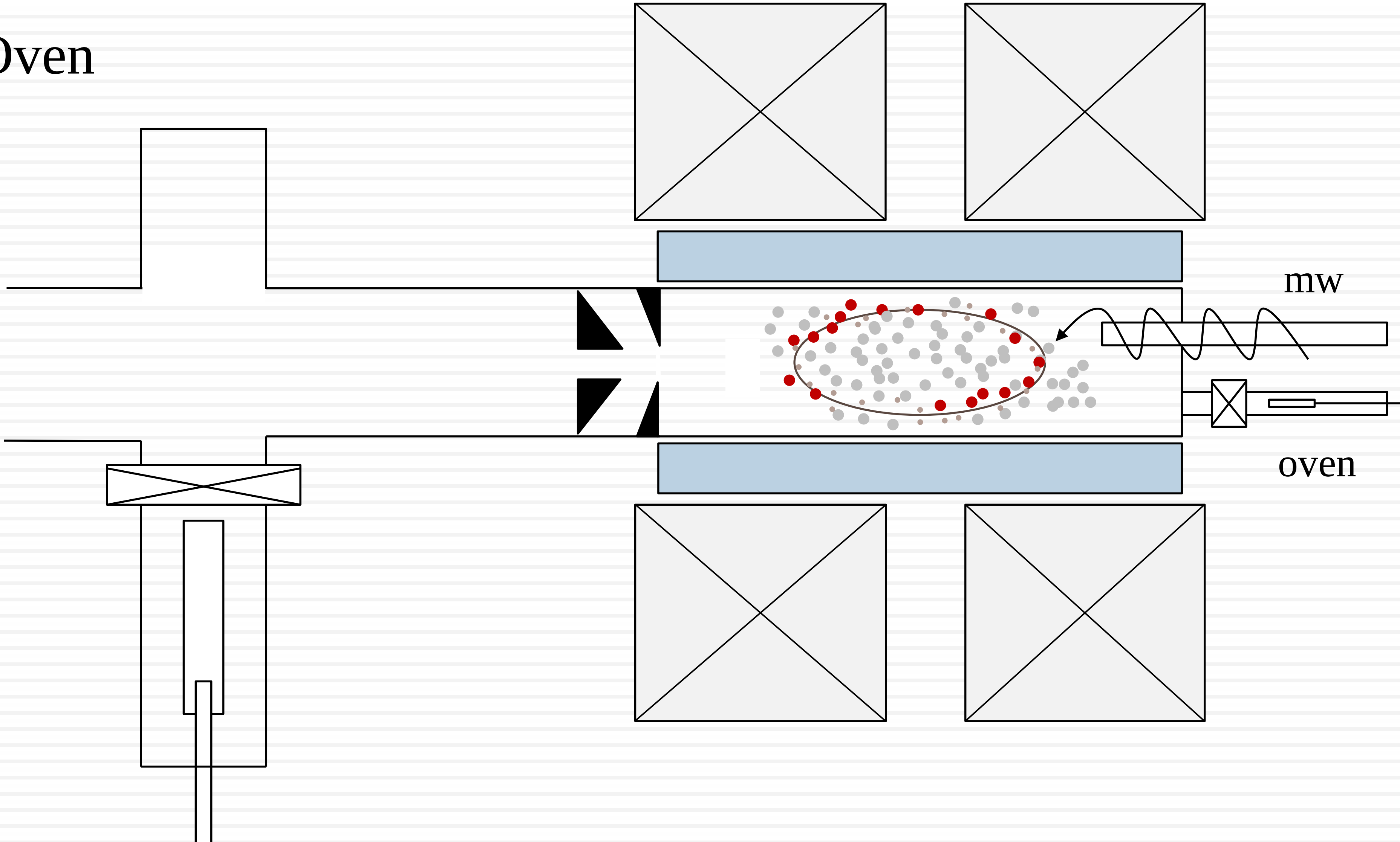
Typical silicon ion spectra. Optimized for 3+ production



CSDs of the silicon ion beam spectra as function of the optimized charge state

Technical developments

Oven



Technical developments

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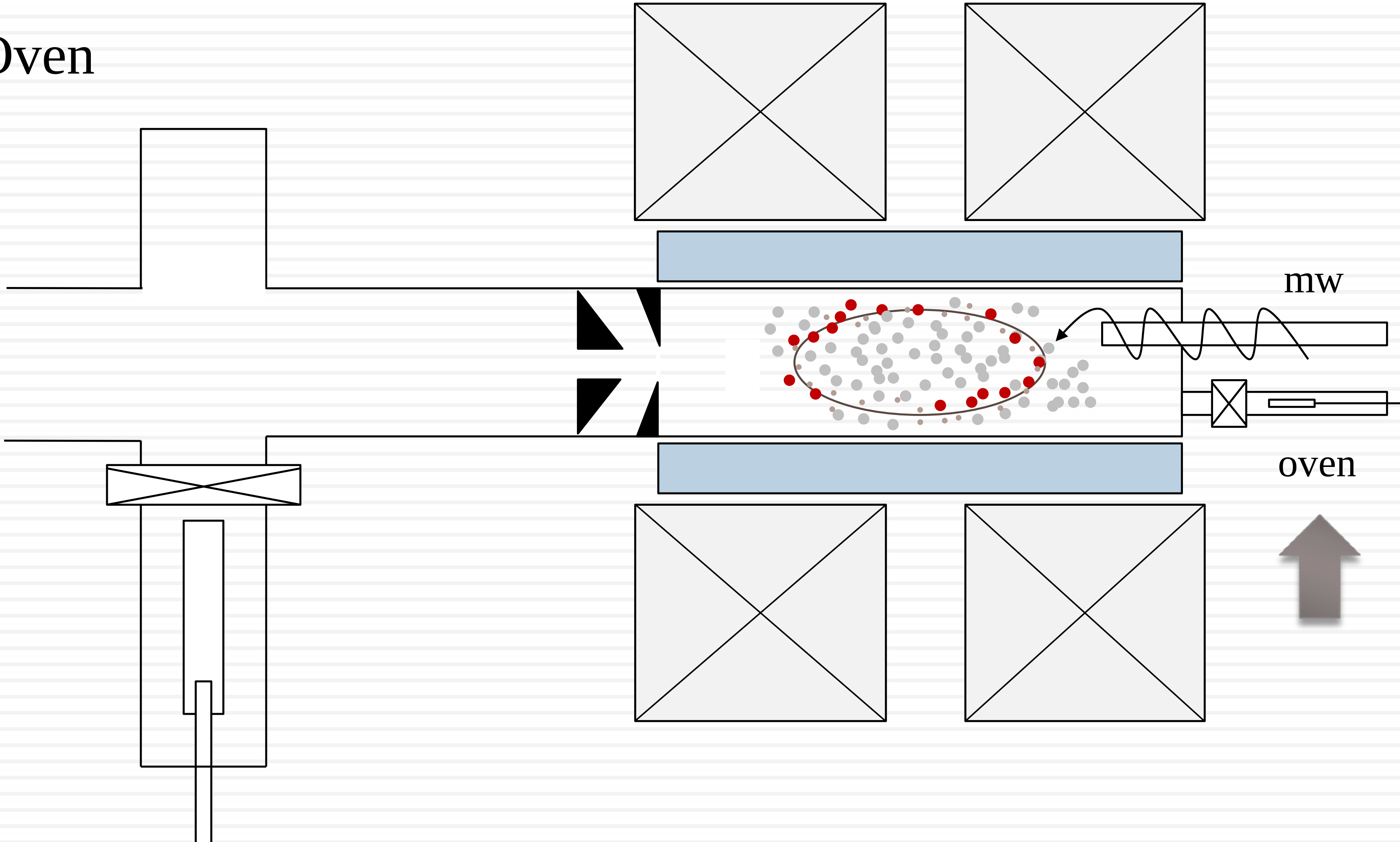

Technical developments

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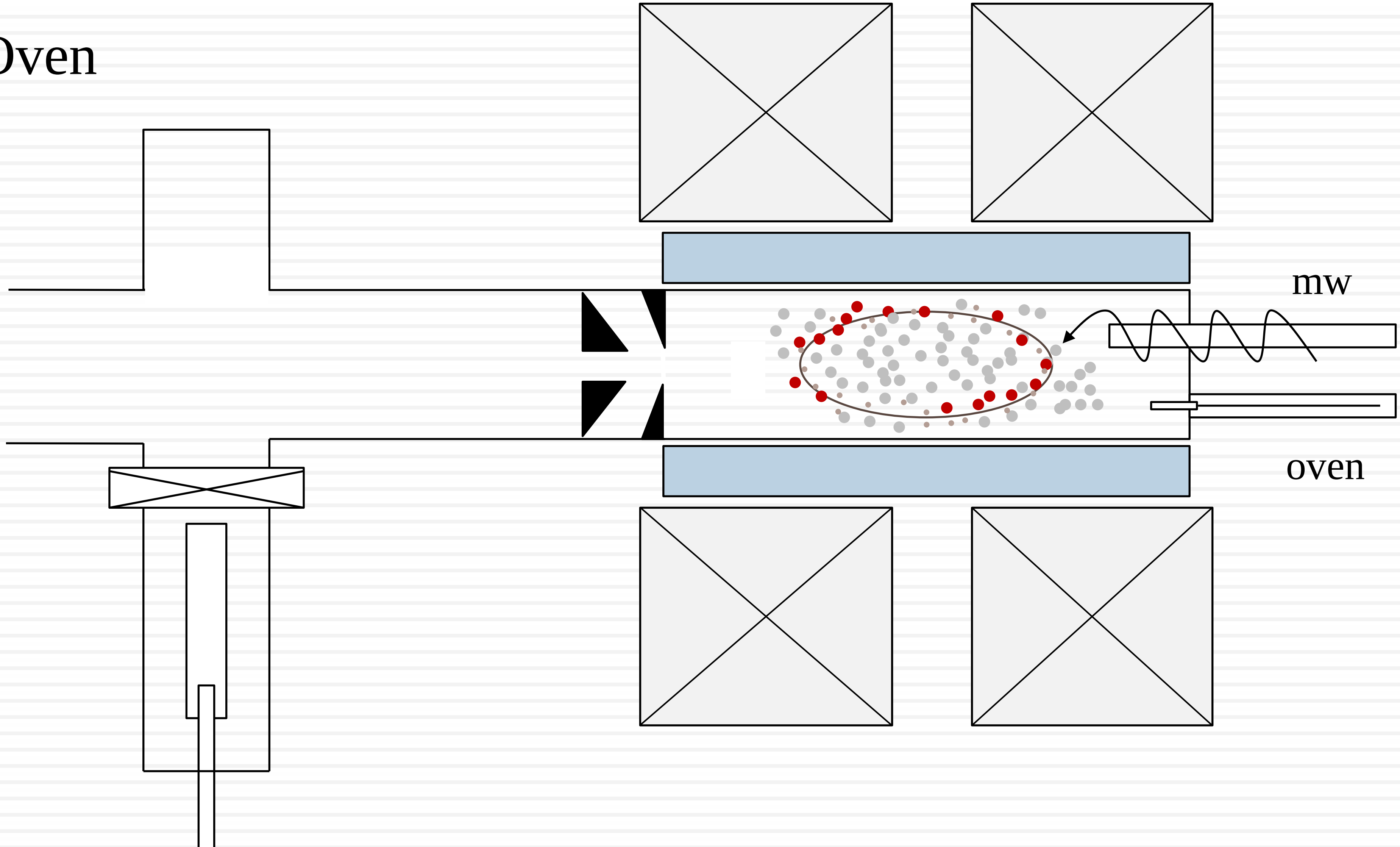
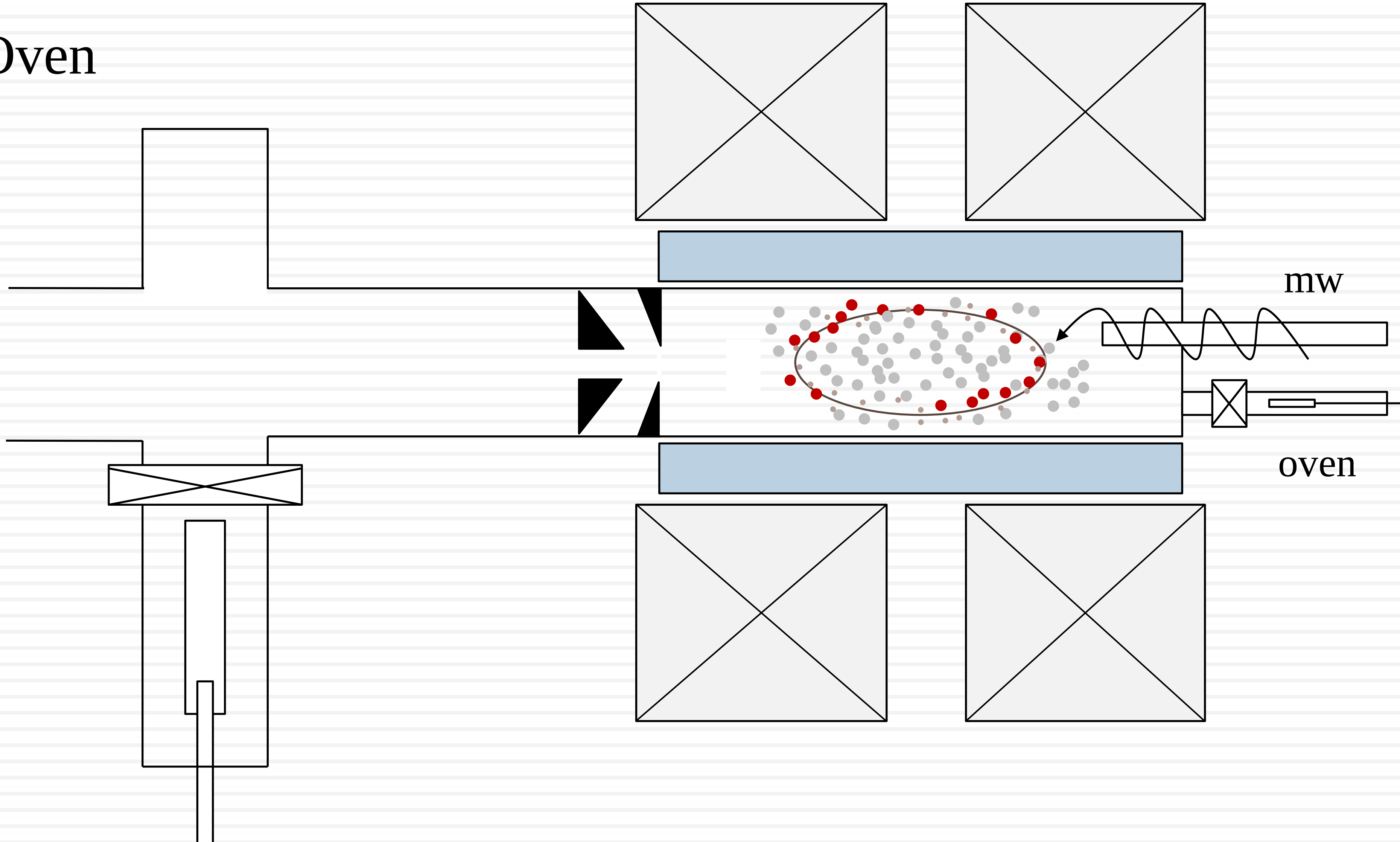


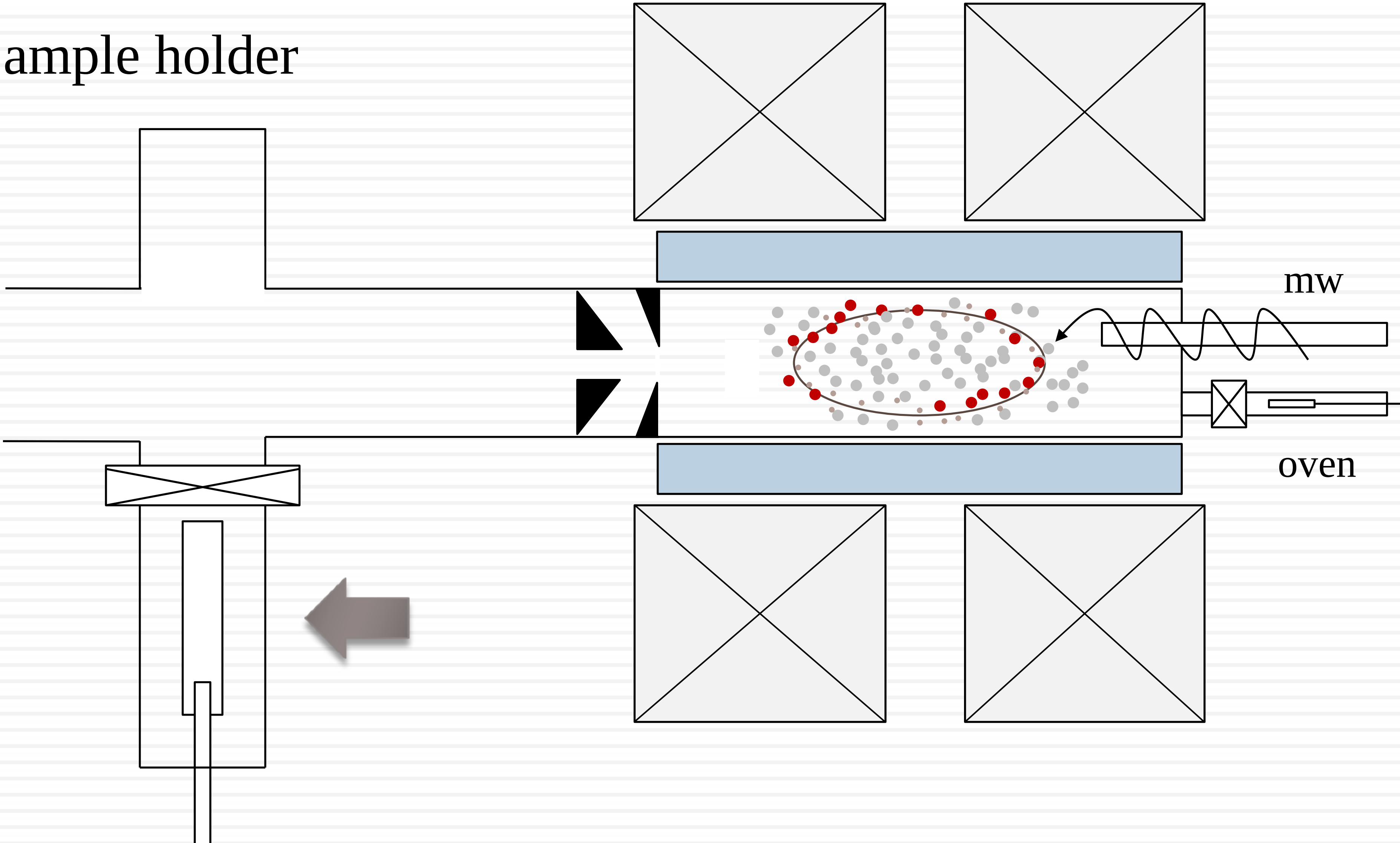
Technical developments

Oven



Technical developments

Sample holder



Technical developments

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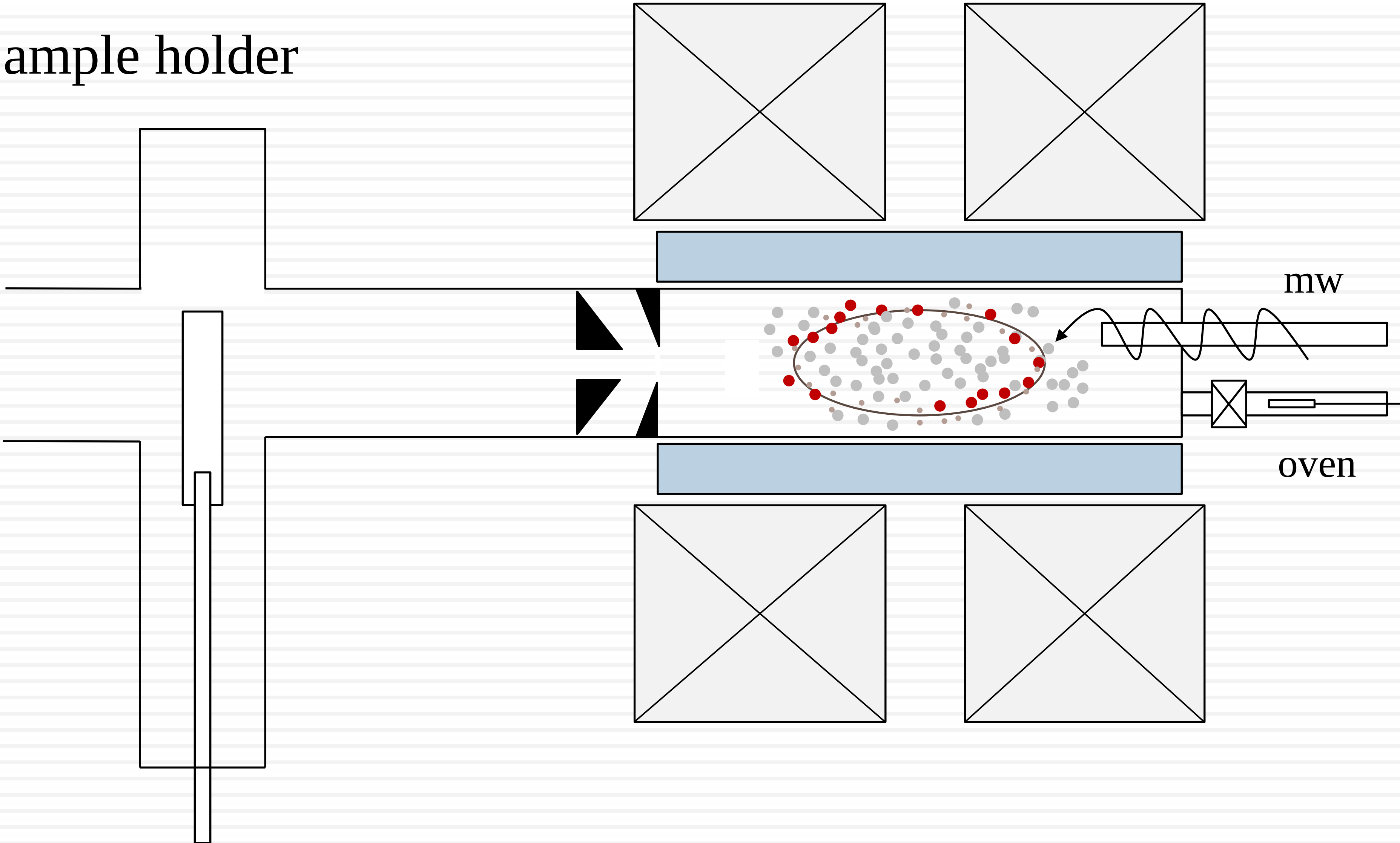
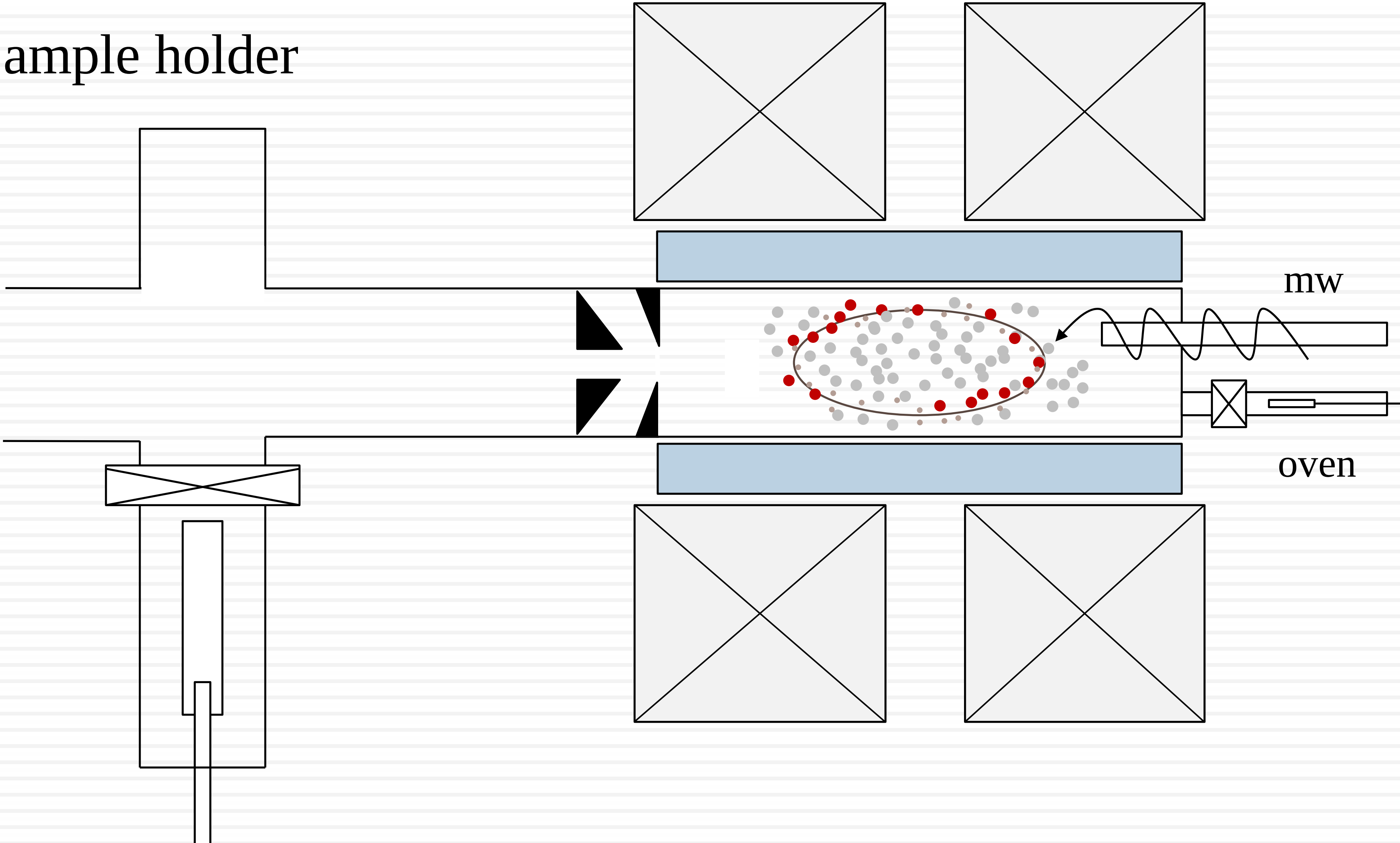
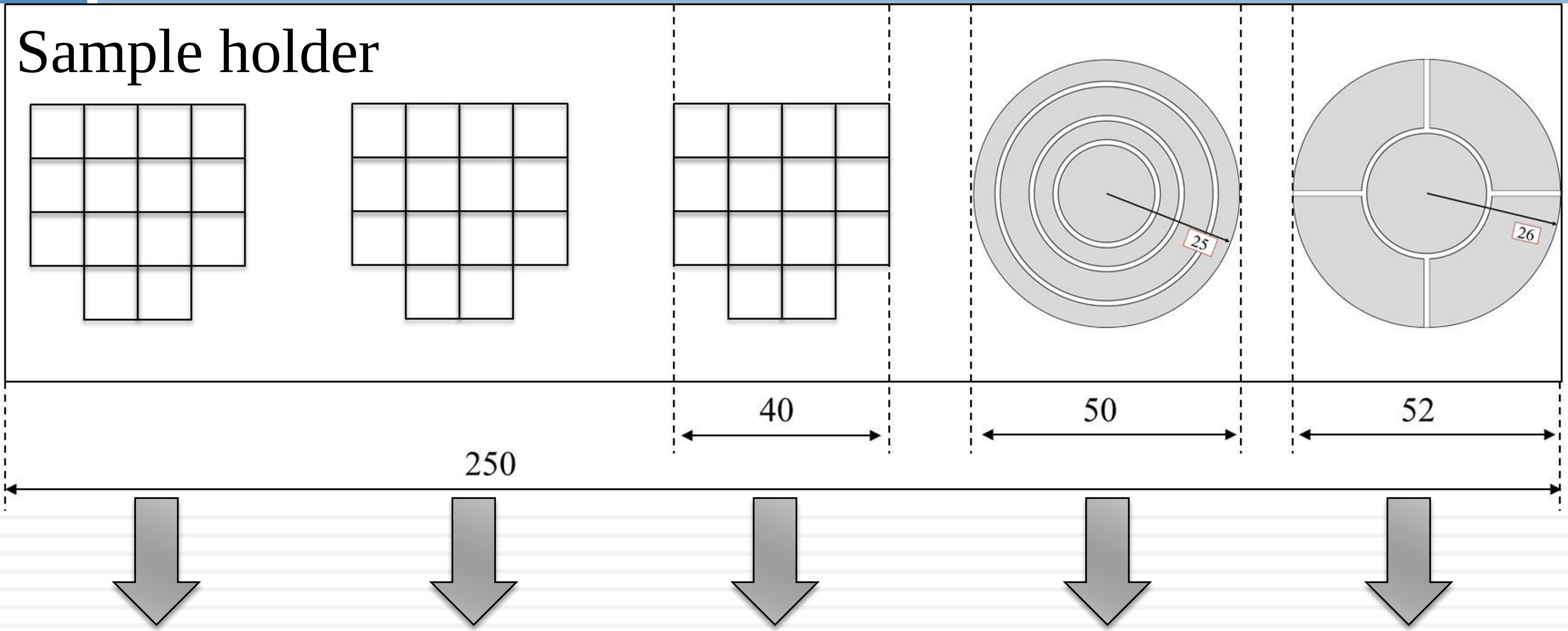


Technical developments

Sample holder



Technical developments



Place to irradiate 14 pieces samples	Place to irradiate 14 pieces samples	Place to irradiate 14 pieces samples	4-segments concentrical monitor to set the size and the homogeneity of the beam spot	5-segment profile monitor to set the x-y position of the beam

First physical results

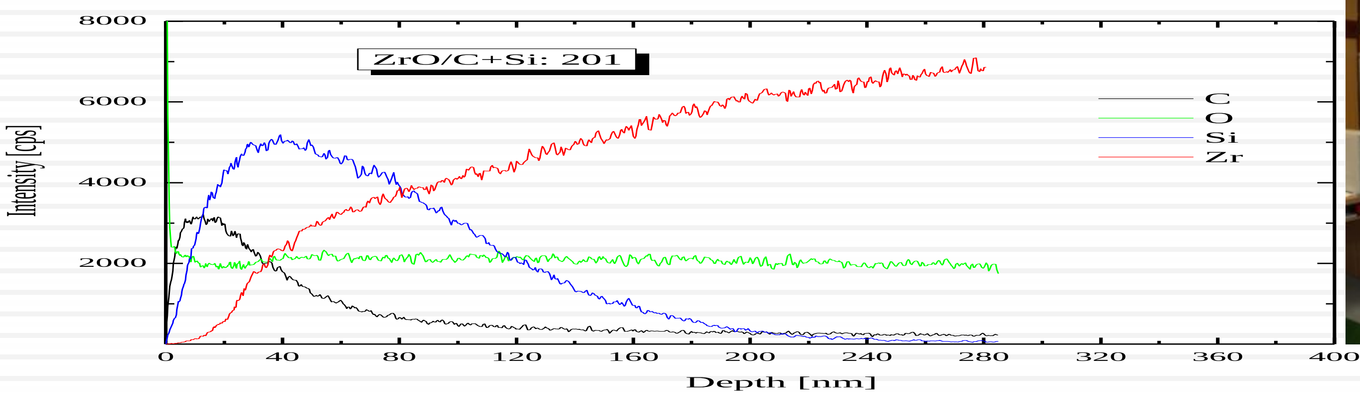
Samples were irradiated by the produced beams

Project	Ion	$\overline{Q}$	Dose (ion/cm^2)	Time (hour)
A	Au	1.3	10^{16}	8
B	Ca	2.2	10^{17}	4.5
C	Si	3.1	10^{17}	1.25

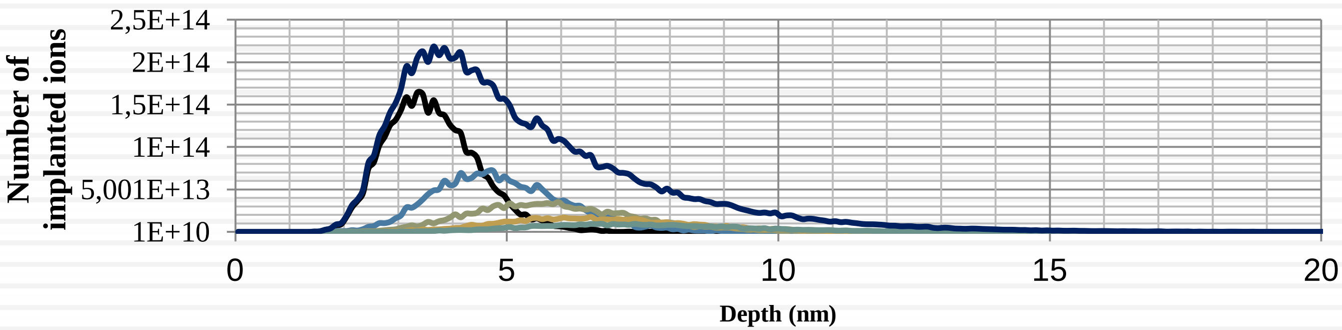
First physical results

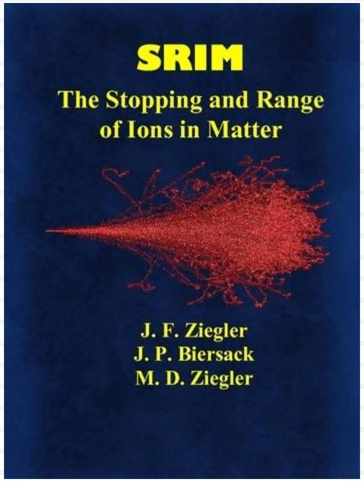
Implantation depth:

Possible to measure by SNMS (Secondary Neutral Mass Spectrometer)



Possible to predict by SRIM (Stopping and Range of Ions in Matter)





First physical results

Implantation depth:

Representative parameter to compare the calculation and measurement.

Ion	Target	U_s (kV)	Depth (nm)	Calc. depth (nm)
Au	TiO_2	2	1-10	7
Ca	TiO_2	3	8	9
Si	ZrO_2	3	6 !	25

First physical results

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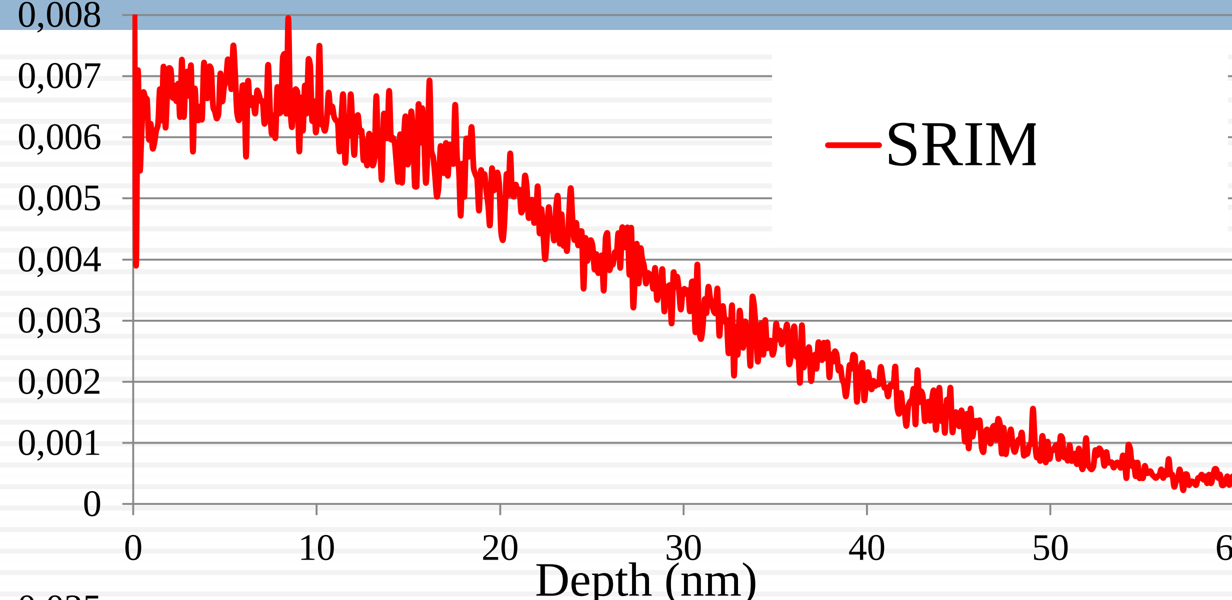
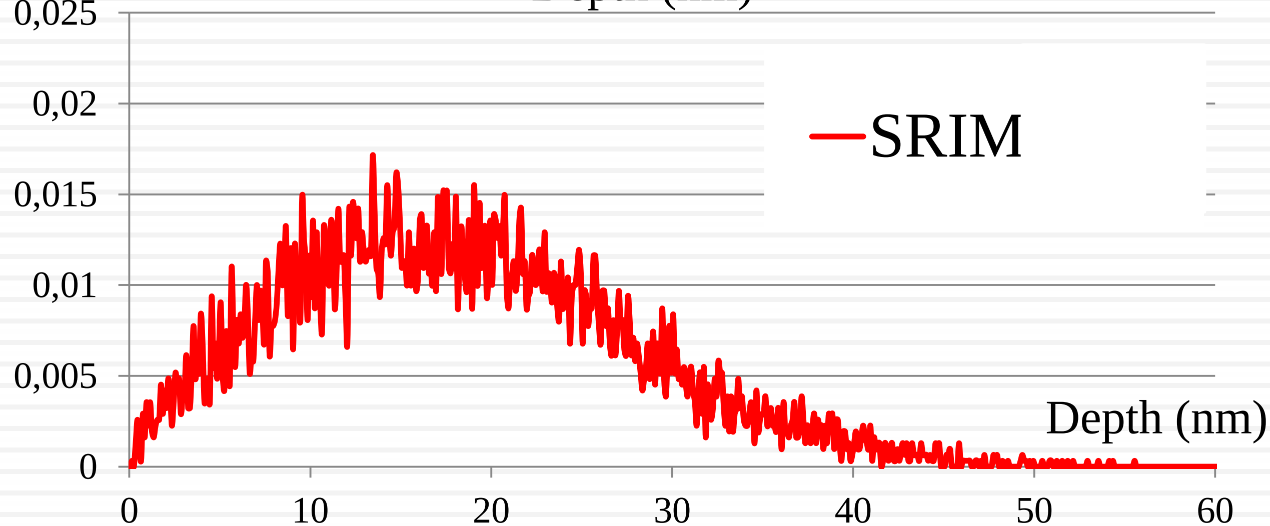
Si	ZrO_2	3	6	25
Si	ZrO_2 +25 nm C layer	10	25	25

Depth profile in ZrO_2

30 keV Si 3+

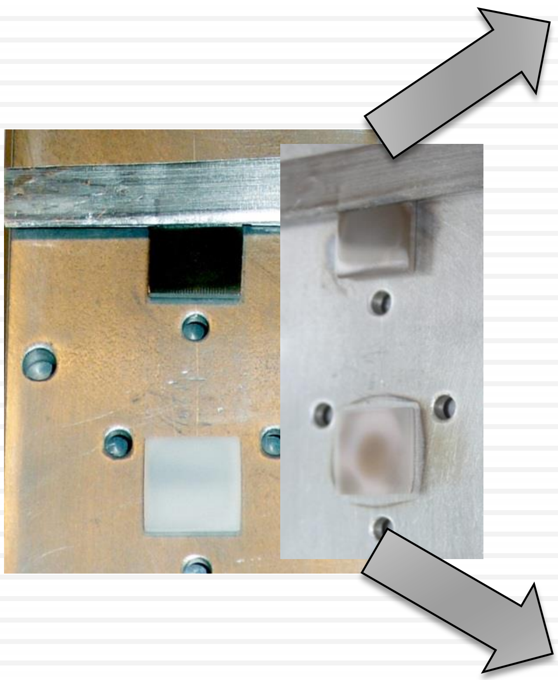


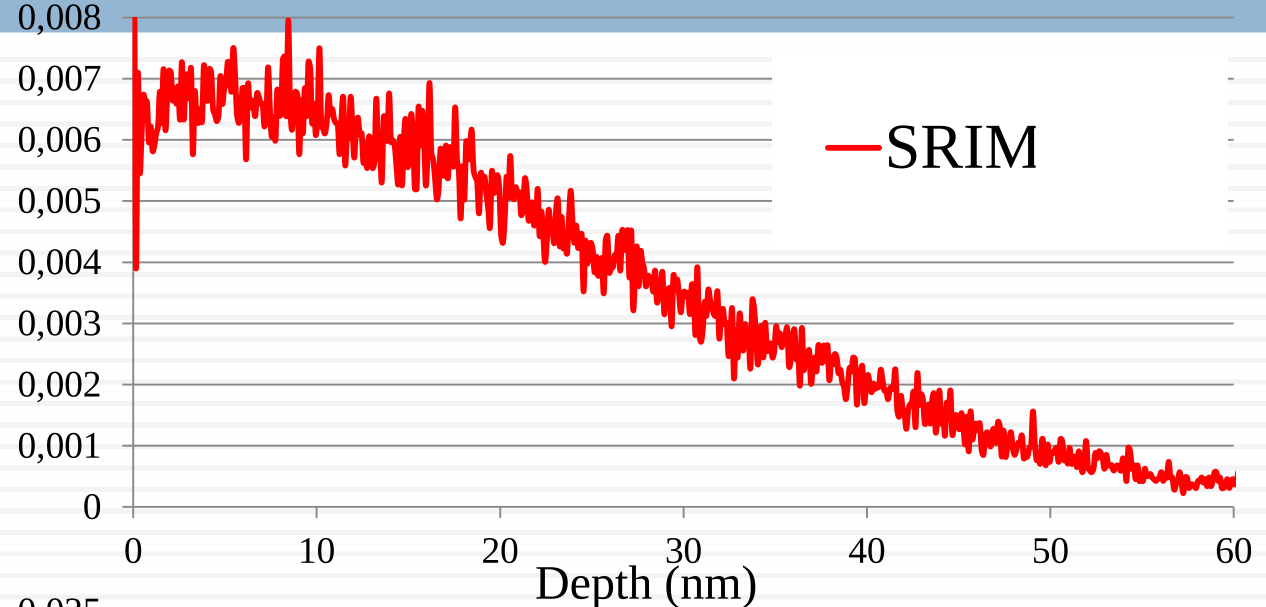


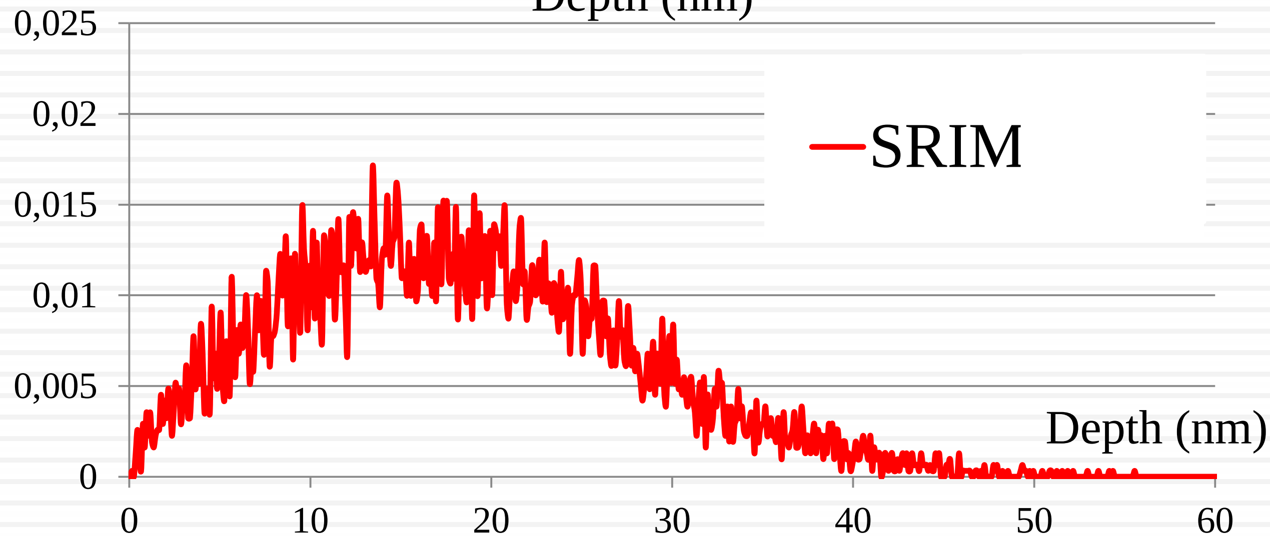
9 keV Si 3+

Depth profile in ZrO_2

30 keV Si 3+







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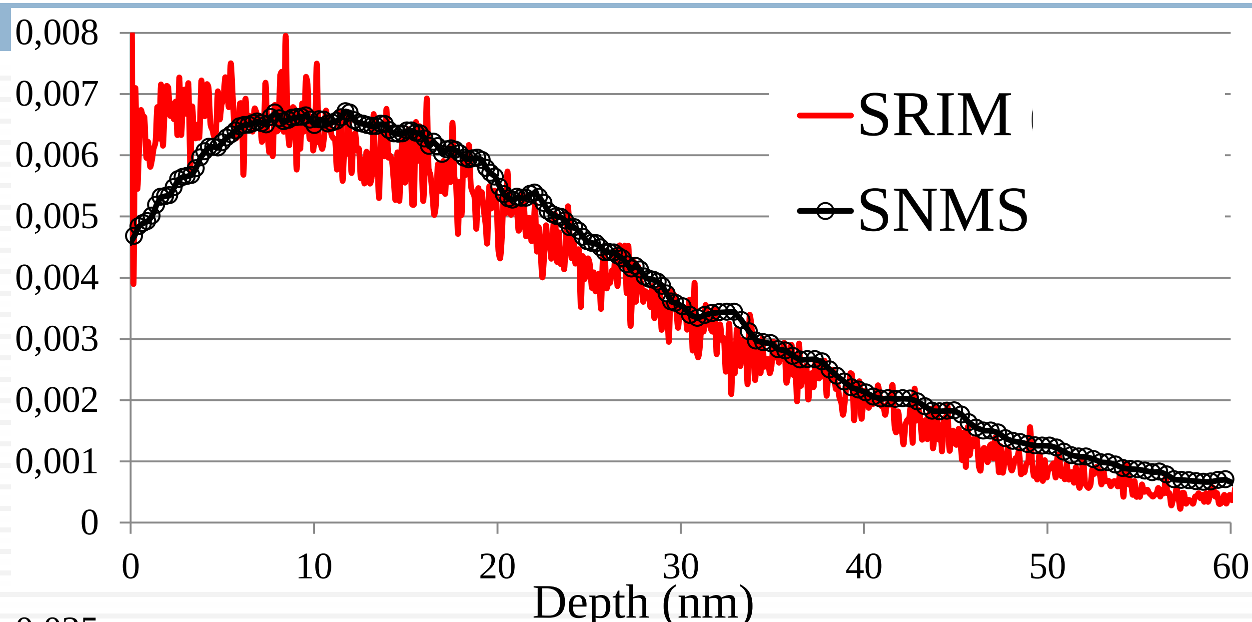

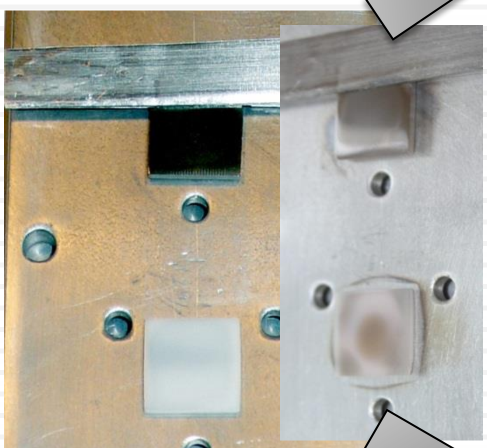

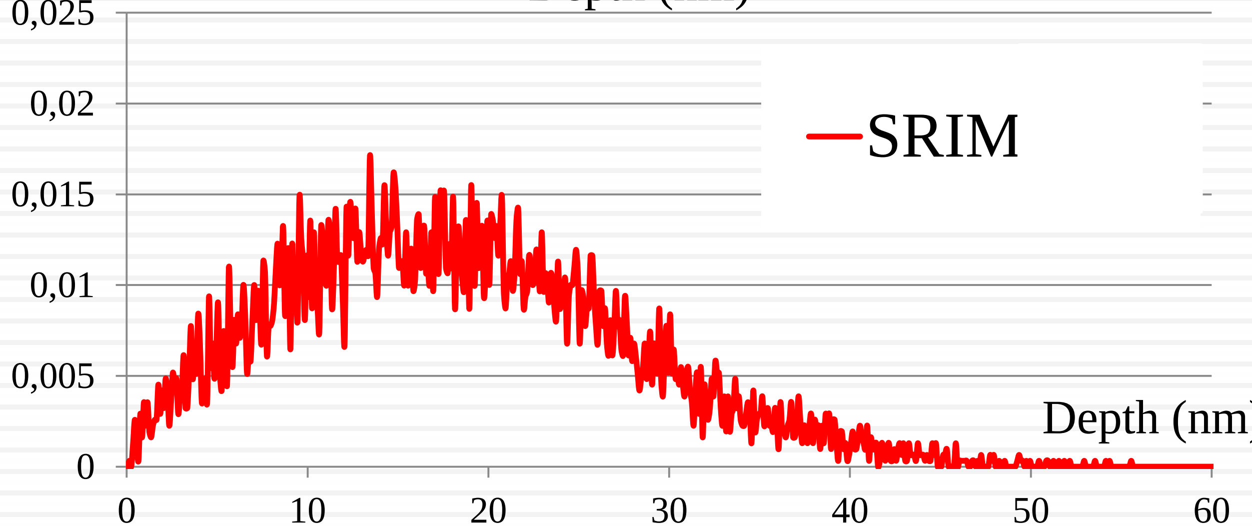

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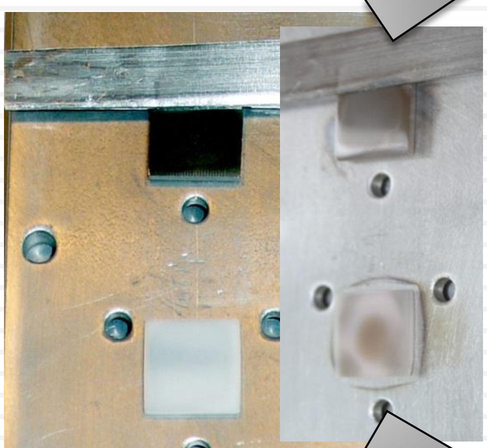

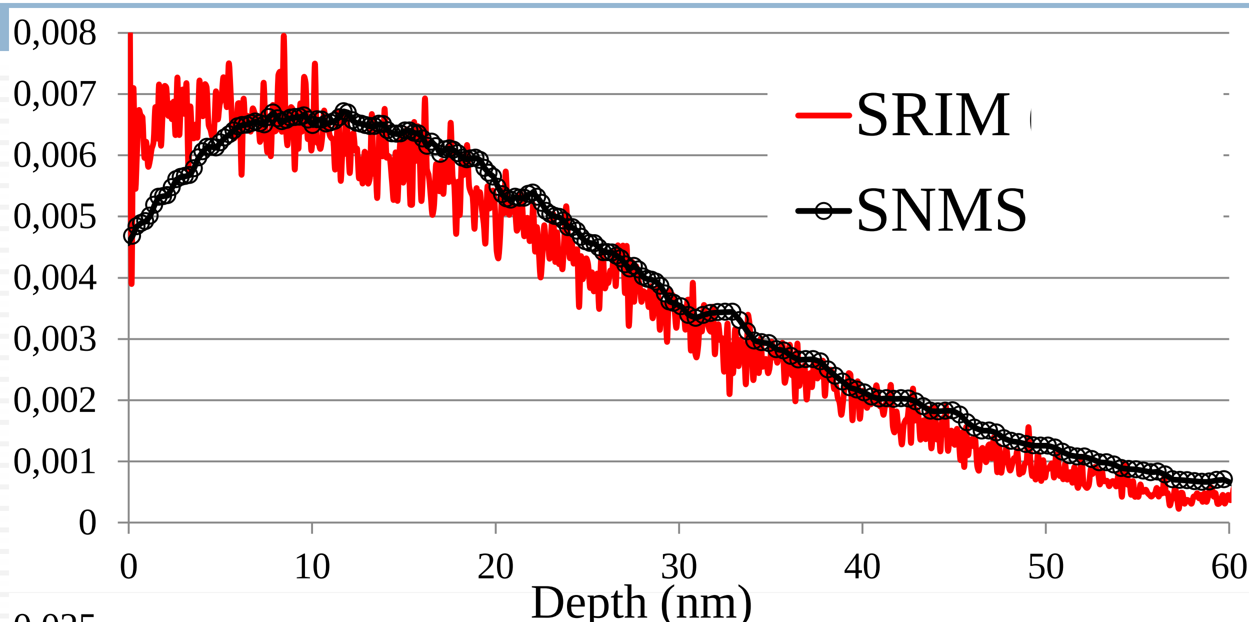

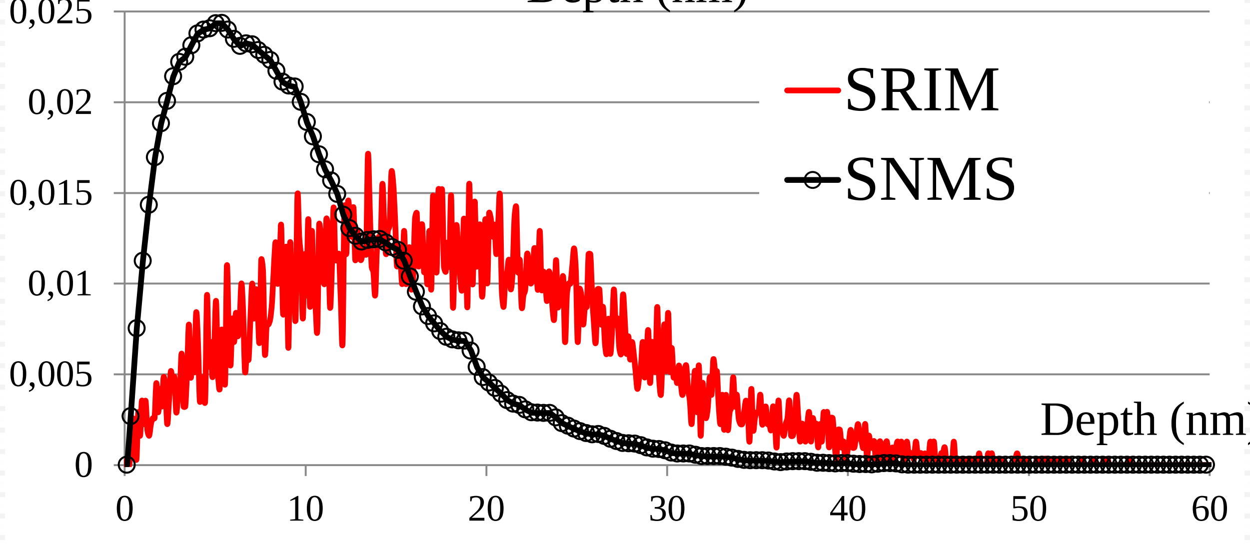

9 keV Si 3+

Summary

- Production of new ion beam (Au, Ca, Si) by the Atomki ECRIS
- New irradiation facility (vacuum chamber, sample holder) to handle high number of samples
- Irradiation of the first series of samples.
- Depth profile analysis and calculation

Plan

- Further investigation
  - Adhesion measurement
  - Morphology (AFM)
  - Clinical investigation
  - Exploring the effect of the q.
  - Improving the LCI intensities.

Acknowledgement

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Thank you for your attention!