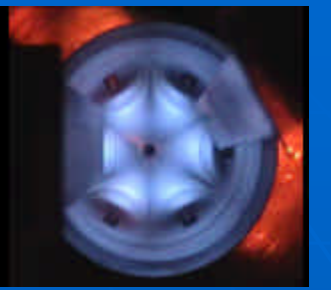
Argonne NATIONAL LABORATORY

ECRIS 2008
18th International Workshop on ECR Ion Sources
Chicago, Illinois USA - September 15 - 18, 2008



ECRIS's Extraction: a New Way to Increase the Beam Brightness?

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ITS LEIF

Grand Accélérateur National d'Ions Lourds
GANIL
Laboratoire commun CEA / DSM - CNRS / IN²P³

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Quertech Ingénierie
Hardion+

Outline

1. Framework

2. The idea – History and Principle

3. Presentation of the ECRIS

4. Case of a singly charged ECRIS
   - Simulations
   - Experiment

5. Case of a multicharged ECRIS
   - Simulations

6. Conclusion

Framework

ITSLEIF Network / Task A of the JRA2 / high-quality atomic ion beams

It is the main objective of the project to create a platform for interdisciplinary research based on the use of high-quality low-energy ion beams (from few eV up to 25 keV). ***ITS LEIF*** will combine the effort of 5 research infrastructures in 5 EU countries.

The Physics

Ion collisions with Atoms, Clusters, Surfaces and Biomolecules

www.its-leif.org

The Idea…

To Increase the brightness of a beam

It means…

-To decrease the emittance of the extracted beam

- To increase the ion current extracted from the source

How…

By biasing negatively the plasma electrode

Some history…

ECRIS OPTIMISATION FOR ON LINE PRODUCTION.

R. Leroy[1], J.C. Angelique[2], P. Bertrand[1], B. Blank[3], M. Ducourtieux[4], P. Foury[1], N. Lecesne[1], A. Lépine[5], M. Lewitowicz[1], C.F. Liang[6], J. Mandin[1], C. Marry[1], L. Maunoury[1], J. Mercier[1], J. Obert[4], N.A. Orr[2], J.Y. Pacquet[1], P. Paris[6], J.C. Potier[4], J.C. Putaux[4], E. Robert[1], M.G. Saint-Laurent[1], P. Sortais[1], A.C.C. Villari[1]

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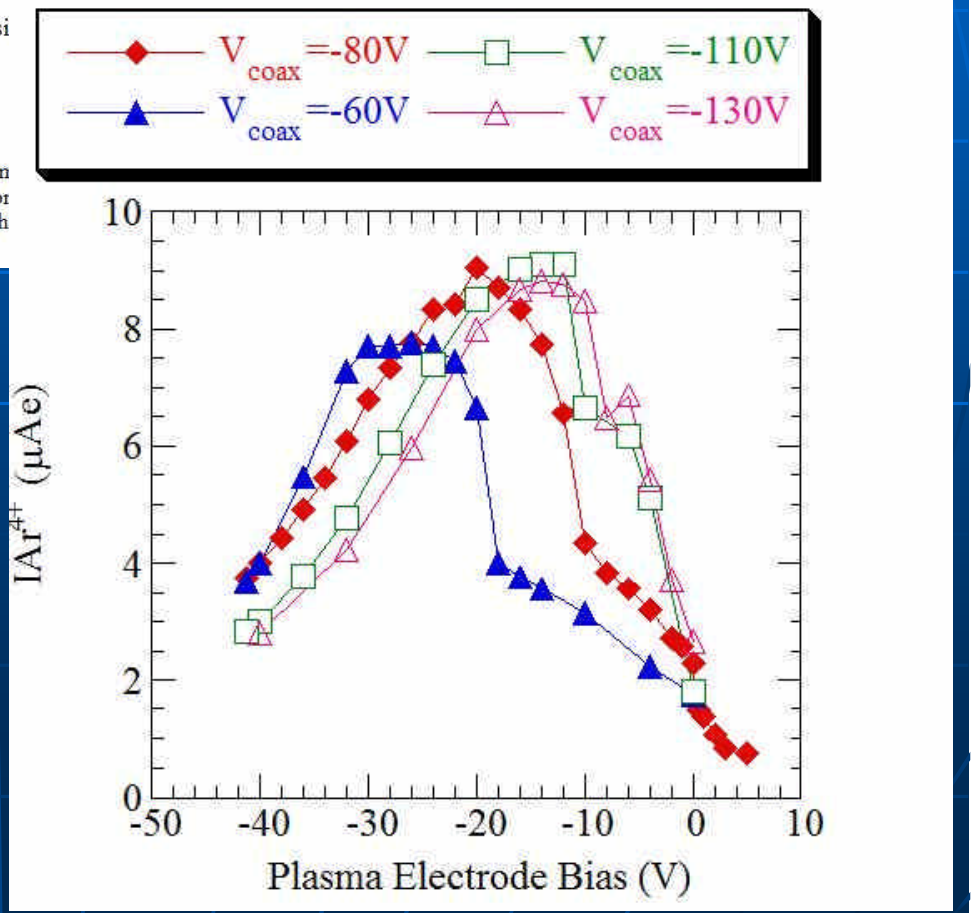
6. CSNSM, Bat 104-108, 91406 Orsay, France

Abstract

The goal of this work is to optimise the production of radioactive-ion beams with short life tin differences between classical ionisation of stable elements and radioactive ion production. Sor have been performed and the results are given. In a second part, we present some ways th performances of the source. Finally, a presentation of a new high-field source is done.

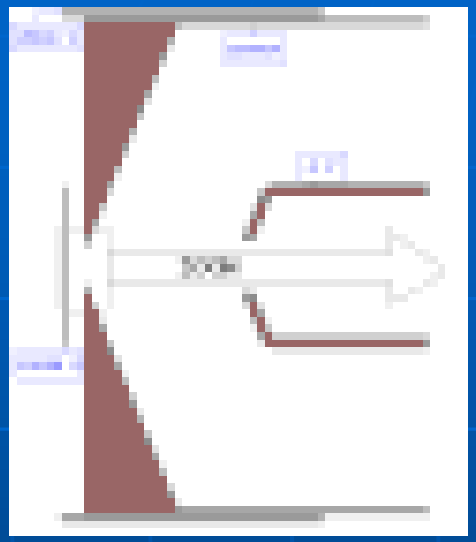


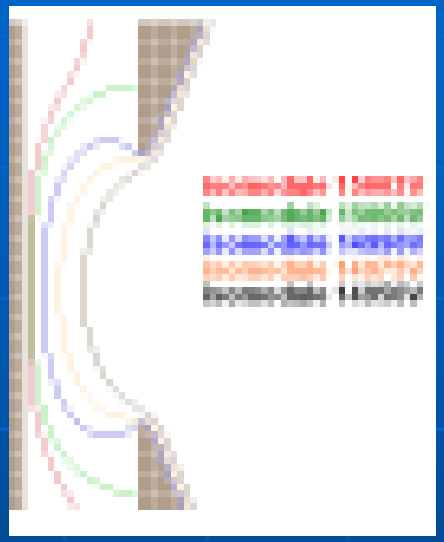
Original paper:

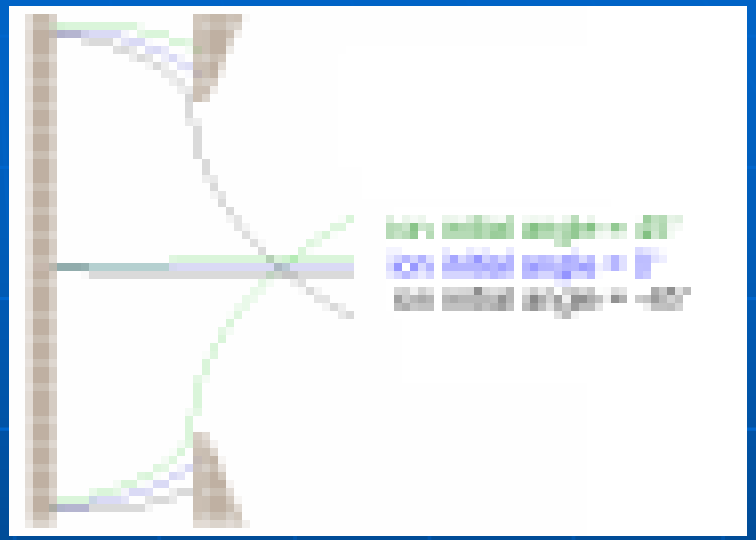
R. Leroy et al.
"Ecris optimisation for on-line production", ECRIS'95, Riken, April 1995, Japan (1995)

The principle…

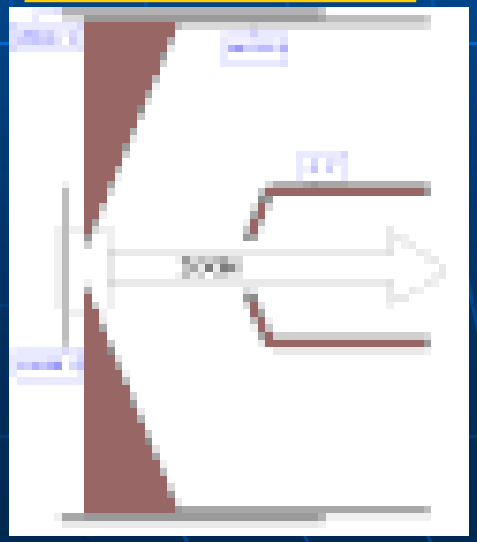
V_{pe} = 0V

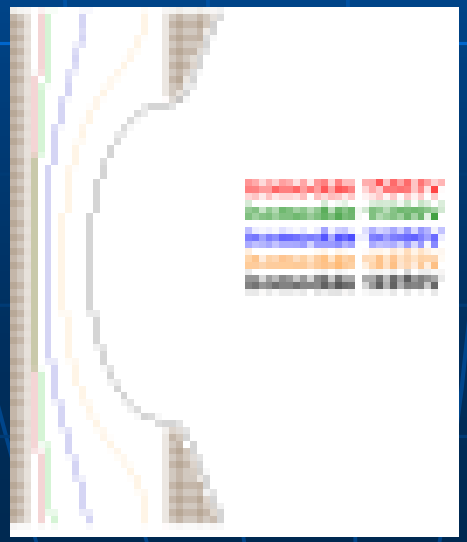






V_{pe} = -30 V





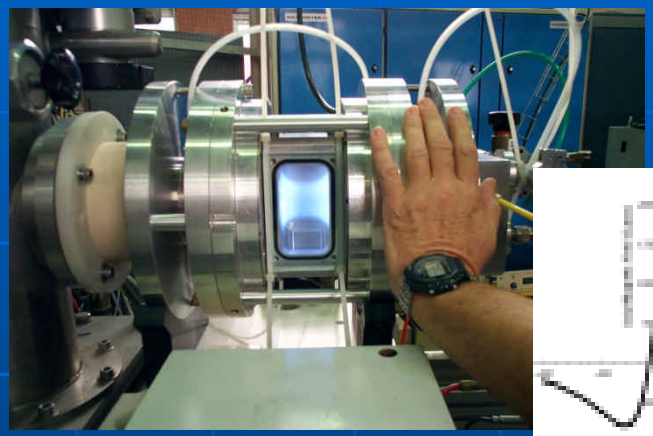
The formula...

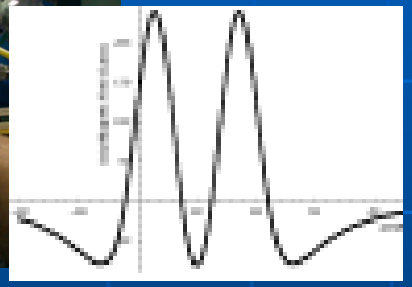
$$B_{rightness} = \frac{2I_{beam}}{\pi^2 \varepsilon_x \varepsilon_y}$$

$$B_{rightnes\,rel\,ative} = \frac{B(V_{\mathrm{pe}})}{B(V_{\mathrm{pe}} = 0\mathrm{V})}$$

The ECRIS's…

MONO1000 : singly charged ECRIS

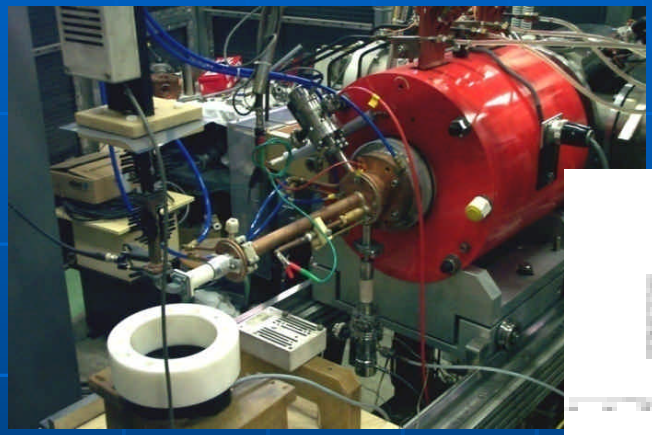


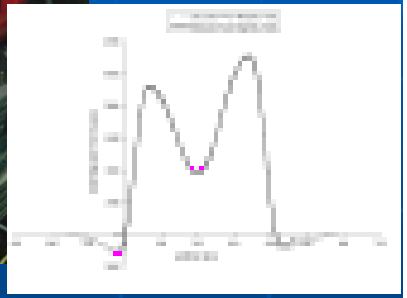


All permanent magnet
No hexapole
RF frequency => 2.45 GHz
Up to 200W
Coaxial _ wave guide adaptation
Air cooling system
Single gap extraction
Plasma electrode ϕ = 7 mm
Puller electrode ϕ = 10 mm

P. Jardin, RSI, 72 (2) 789 2002

SUPERSHyPIE : multi charged ECRIS





Coils + permanent magnet
Hexapole
RF frequency => 14.5 GHz
Up to 1000 W
Direct RF injection
Water cooling system
Single gap extraction
Plasma electrode ϕ = 13 mm
Puller electrode ϕ = 20 mm

L. Maunoury, RSI, 72 (2) 561 2002

Simulations: General assumptions

Two software packages were chosen : SIMION3D and CPO 3D

SIMION3D

Advantages

Fast => a couple of hours
Cheap
Easy to use

Disadvantage

Space charge effect

=> Allow to test many configurations

CPO 3D

Advantage

Space charge effect

Disadvantages

Slow => a couple of days
Expensive
Cares should be paid special attention when using it

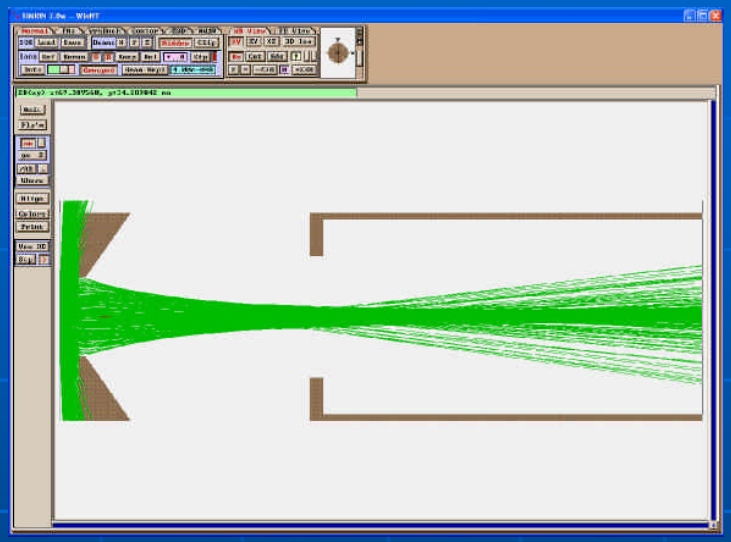
=> Allow to simulate accurately few solutions

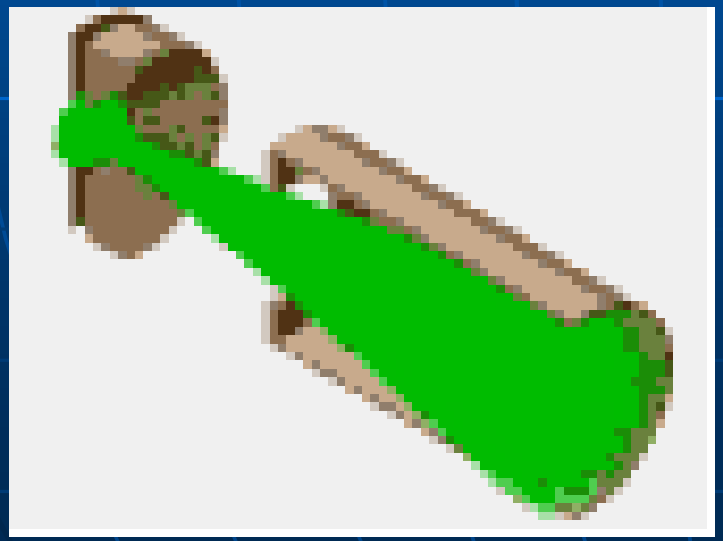
Main comparisons and results in this paper

C. Pierret et al., Preliminary results of the ion extraction simulations applied to the MONO1000 and SUPERSHyPIE electron cyclotron resonance ion sources, RSI, 79 02B703 (2008)

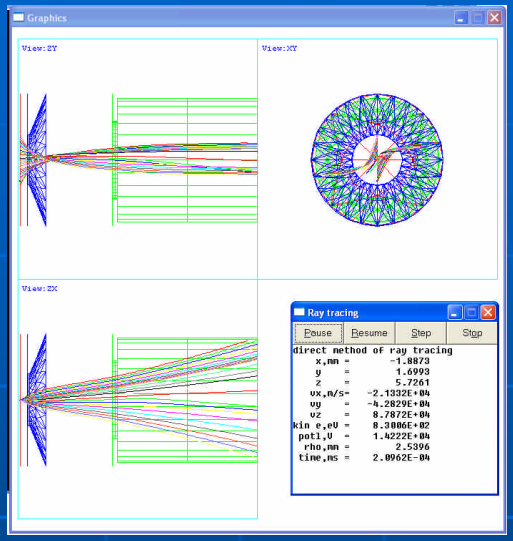
Case of SUPERSHyPIE

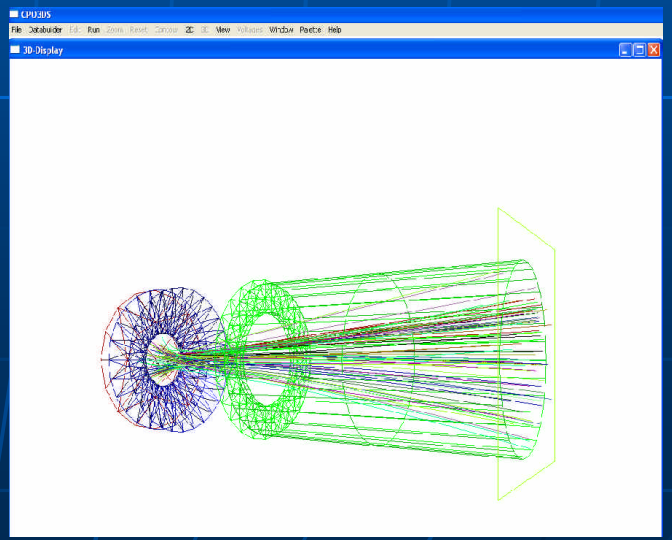
SIMION 3D



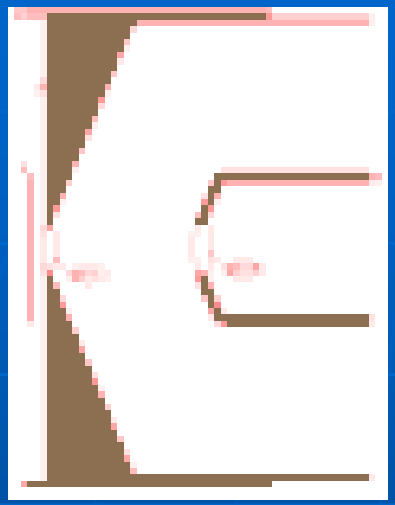


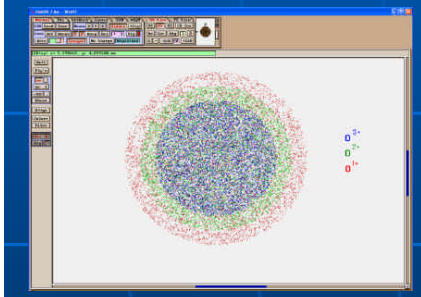
CPO 3D

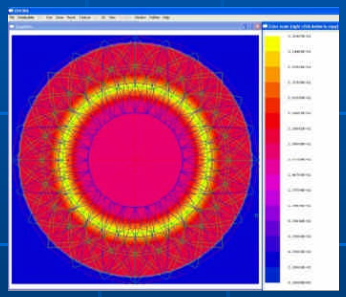




Case of MONO1000

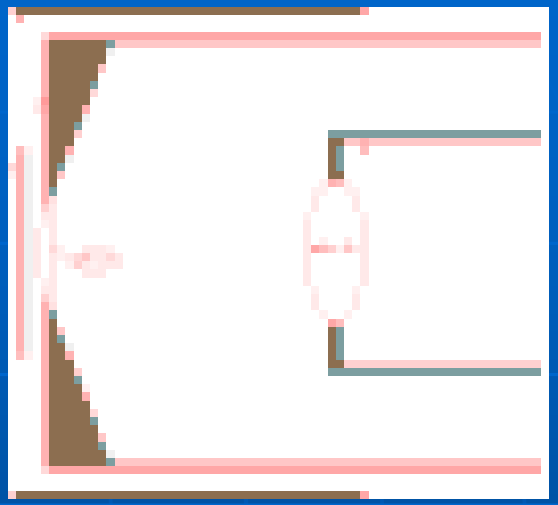


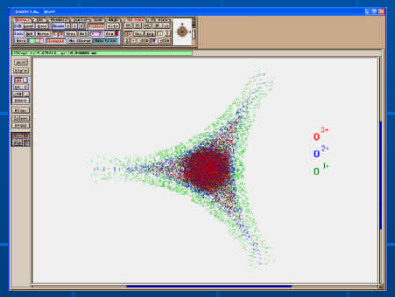


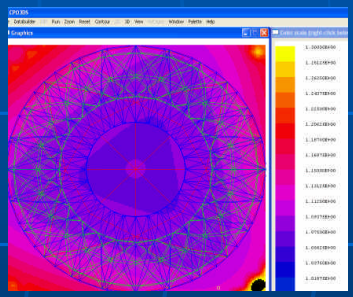


- Random generation of the ions
- ϕ = 15 mm
- Plasma potential 8 eV
- Ion energy 0.1 eV
- Angle of emission ± 90°
- Brightness calculated at 65 mm from the EP

Case of SUPERSHyPIE



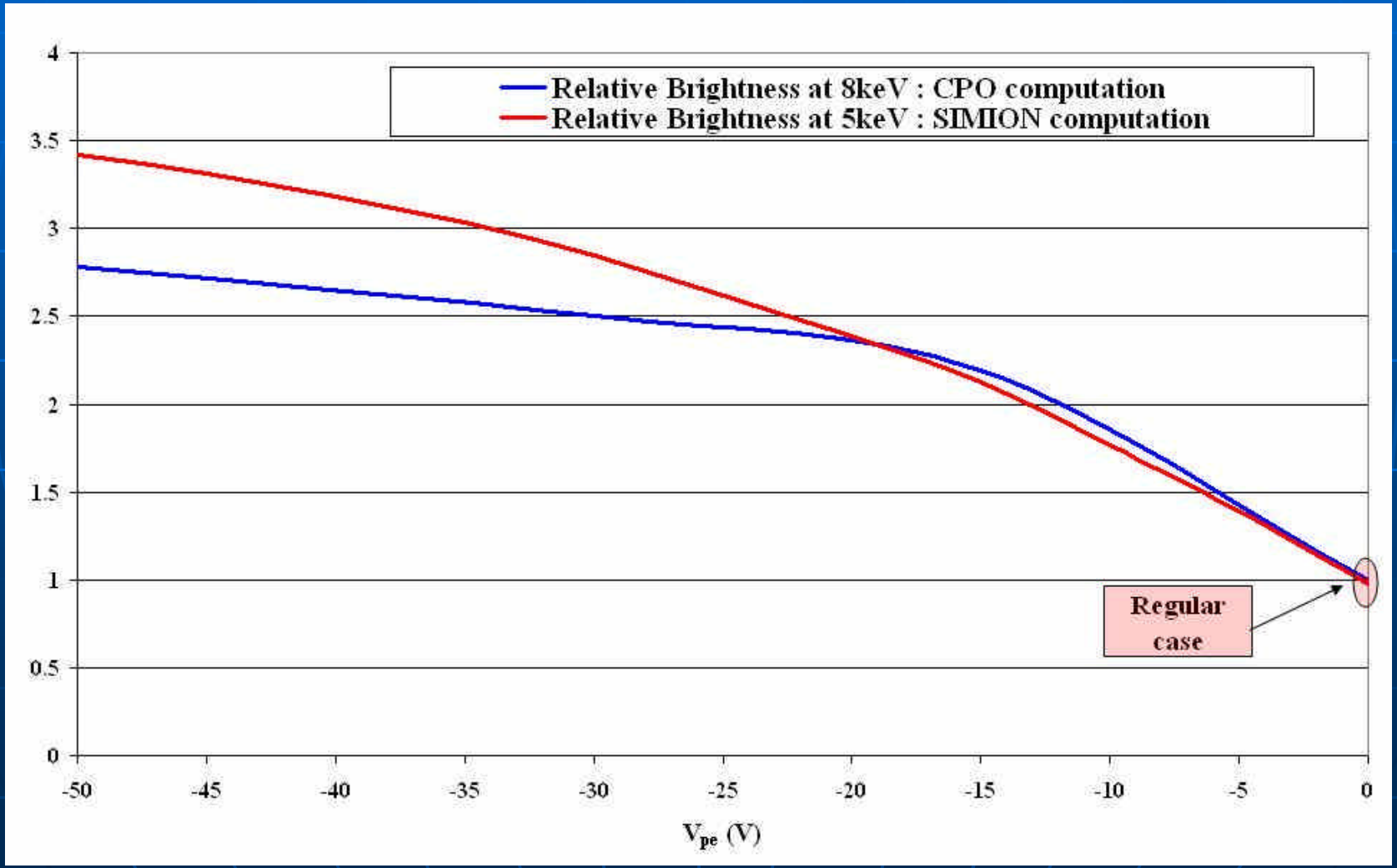




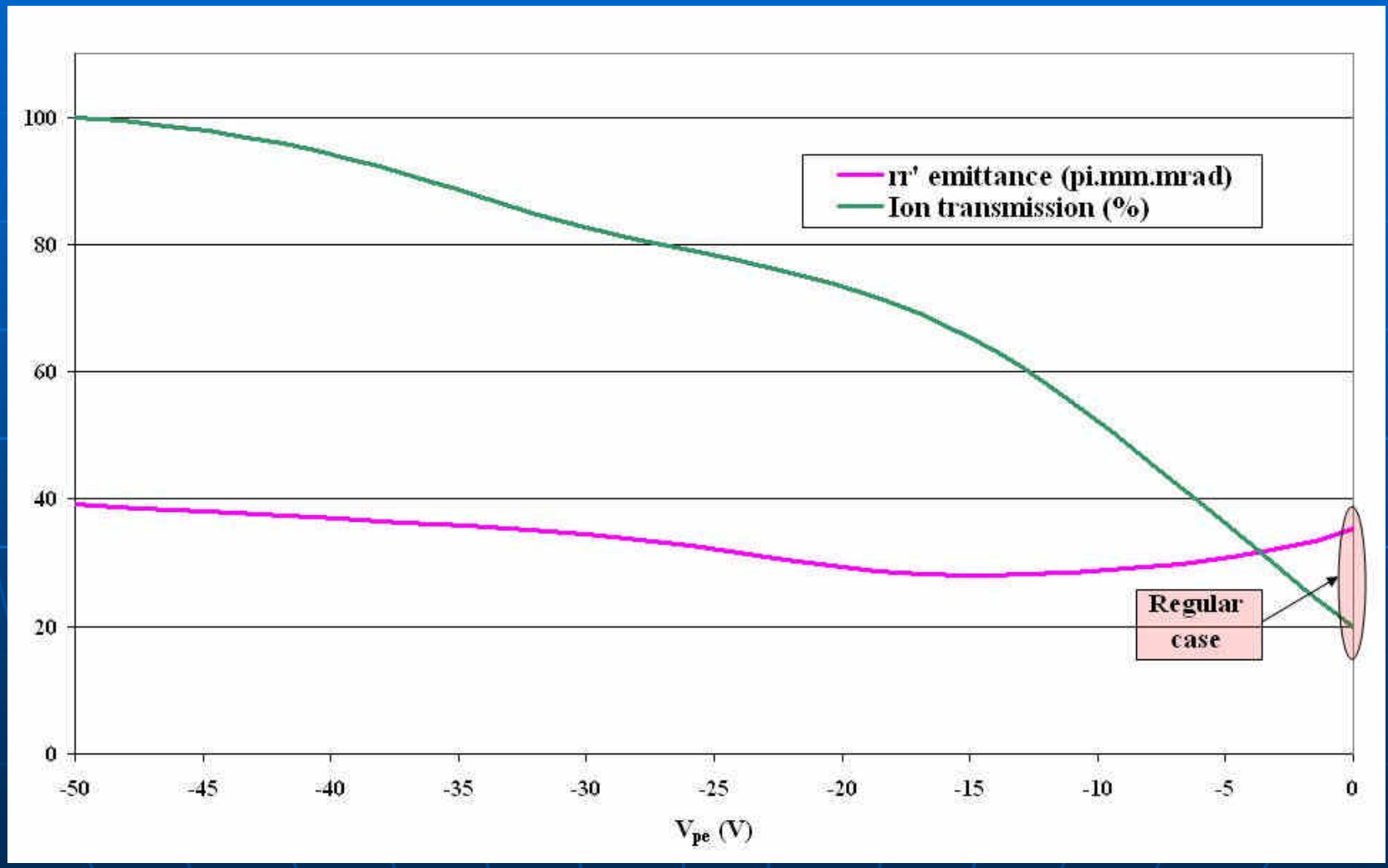
- Random generation of the ions
- ϕ = 15 mm
- Higher is the charge more concentrated is the distribution
- Plasma potential 8 eV
- Ion energy 1 eV
- Angle of emission ± 90°
- Brightness calculated at 70 mm from the EP

Simulations with the MONO1000 ECRIS

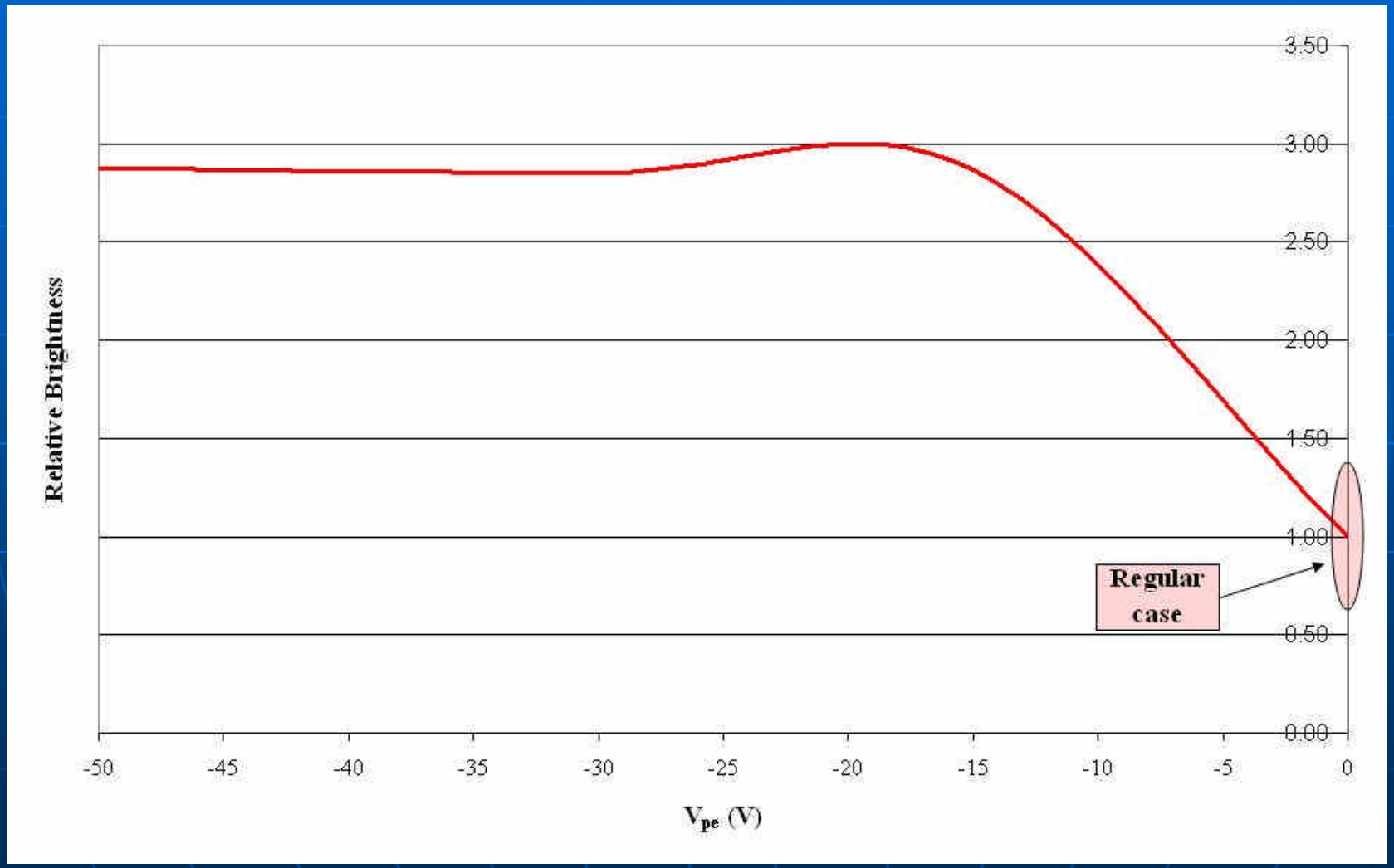
Ar^{1+} case at low energy (5/8 keV)



Ar^{1+} case at high energy (15 keV)
CPO calculations



Ar^{1+} case at high energy (15 keV)
CPO calculations



The Experiment with the MONO1000 ECRIS

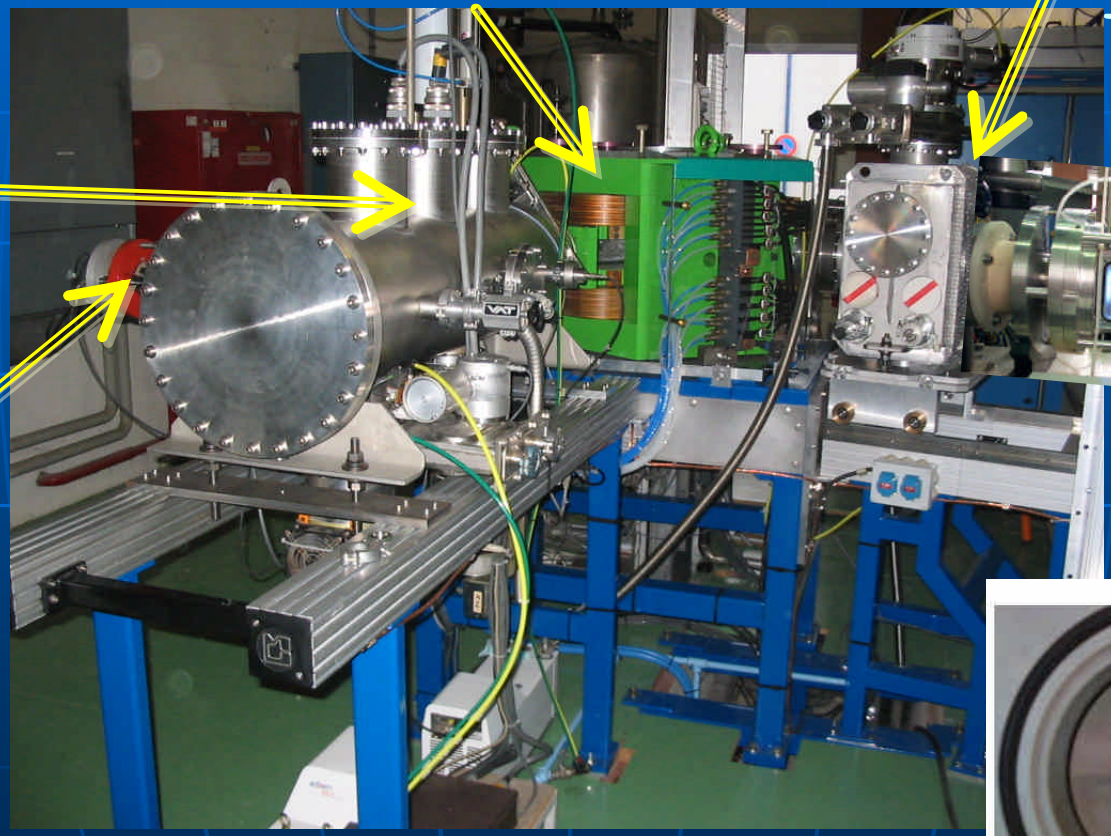
The double focusing
Analyze magnet
Br_{max} = 0.244 T.m

The new extraction box

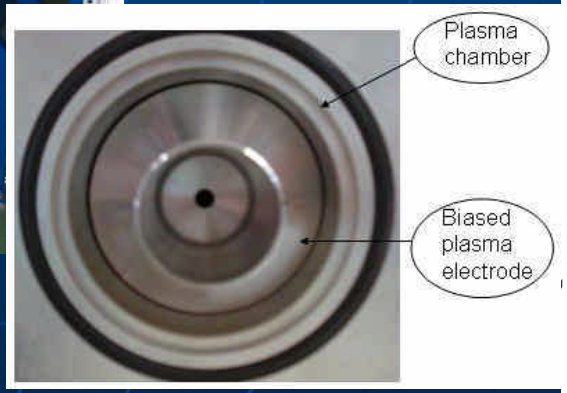
The MONO1000 ECRIS

The vertical and
Horizontal slit sets

The Faraday cup

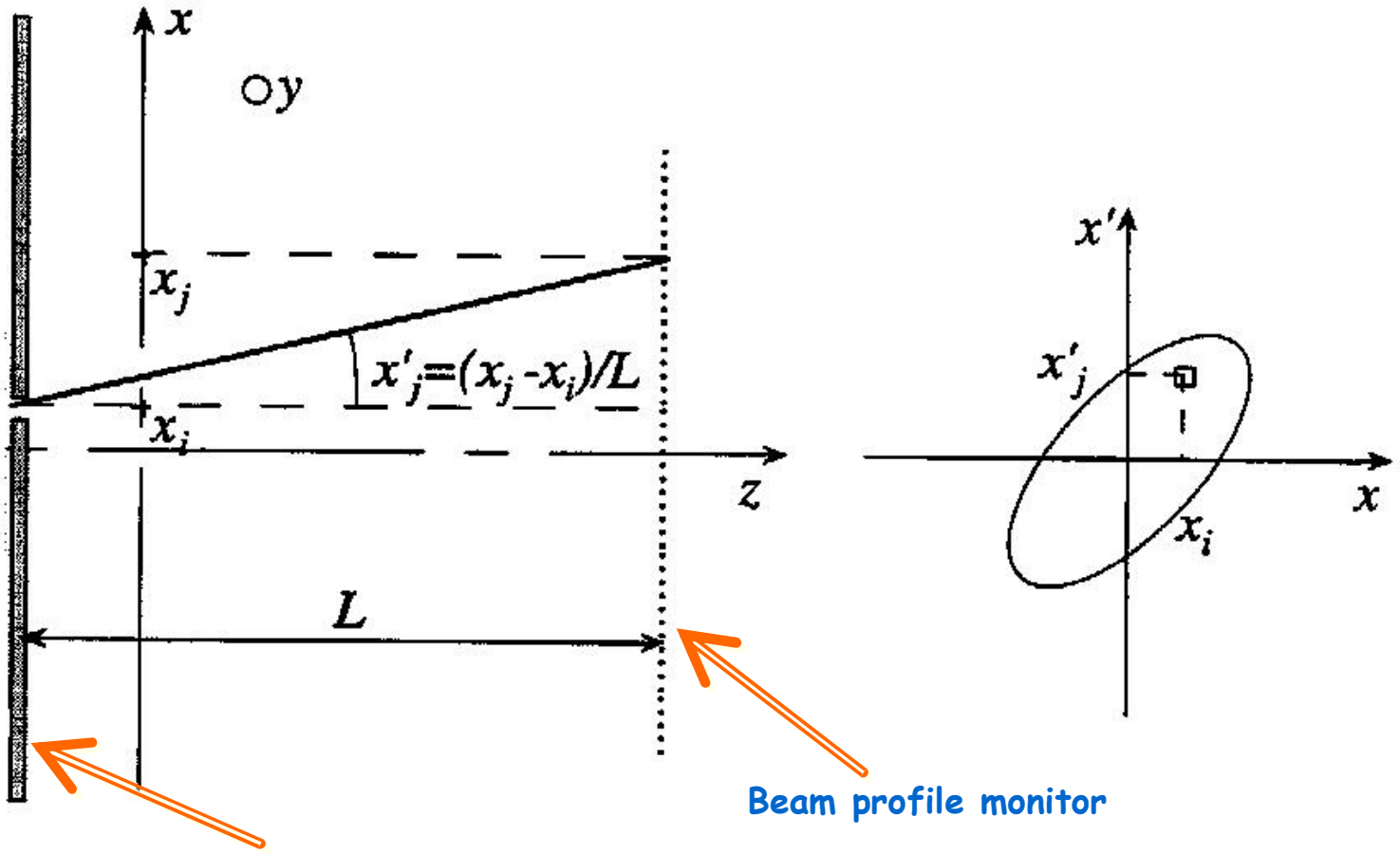


The plasma
electrode in detail



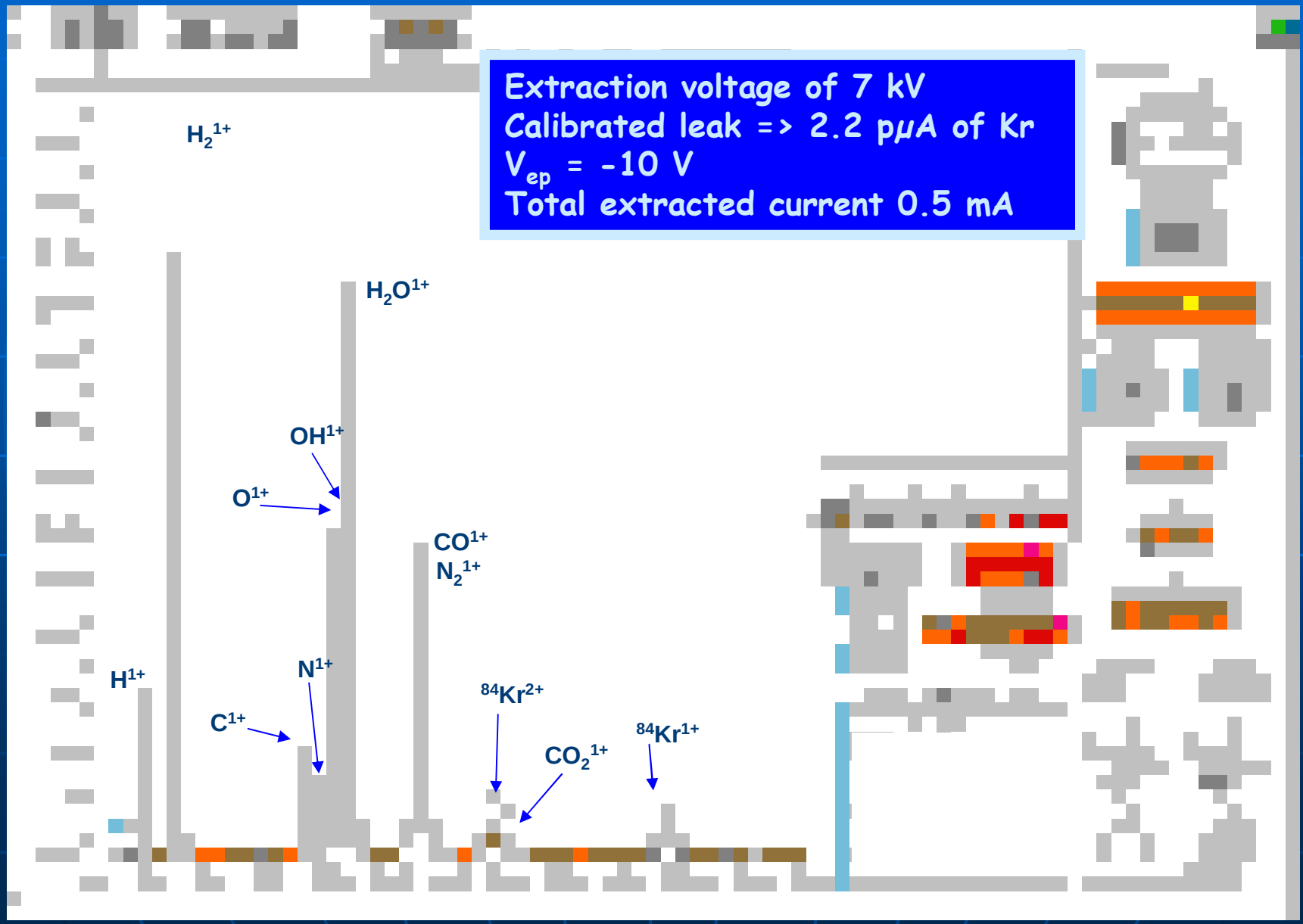
Emittance measurement method

$$x'_j = (x_j - x_i)/L.$$



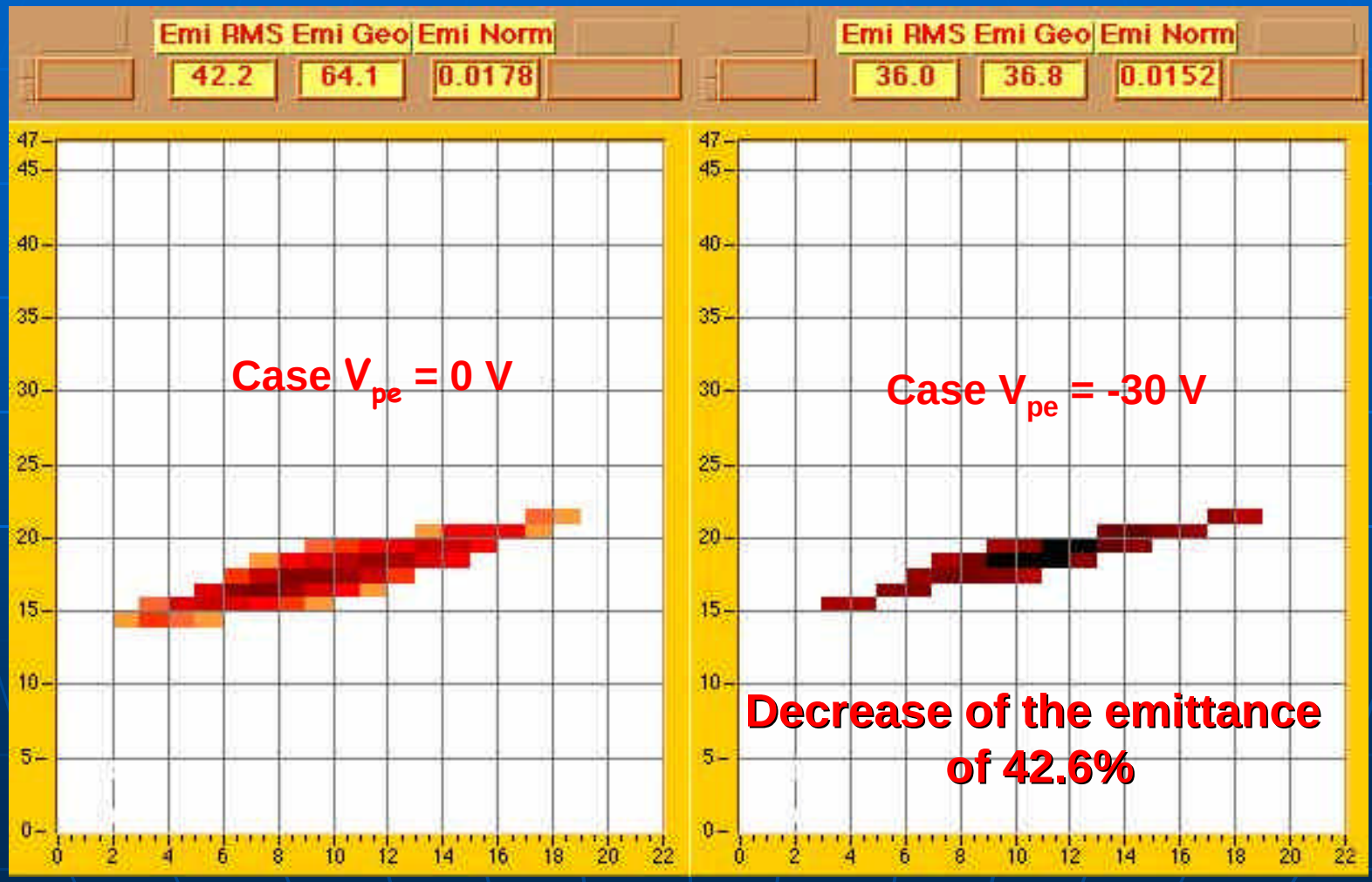
J. Mandin, PhD-Thesis, Caen University (1997)

Typical spectrum of Kr^{q+}



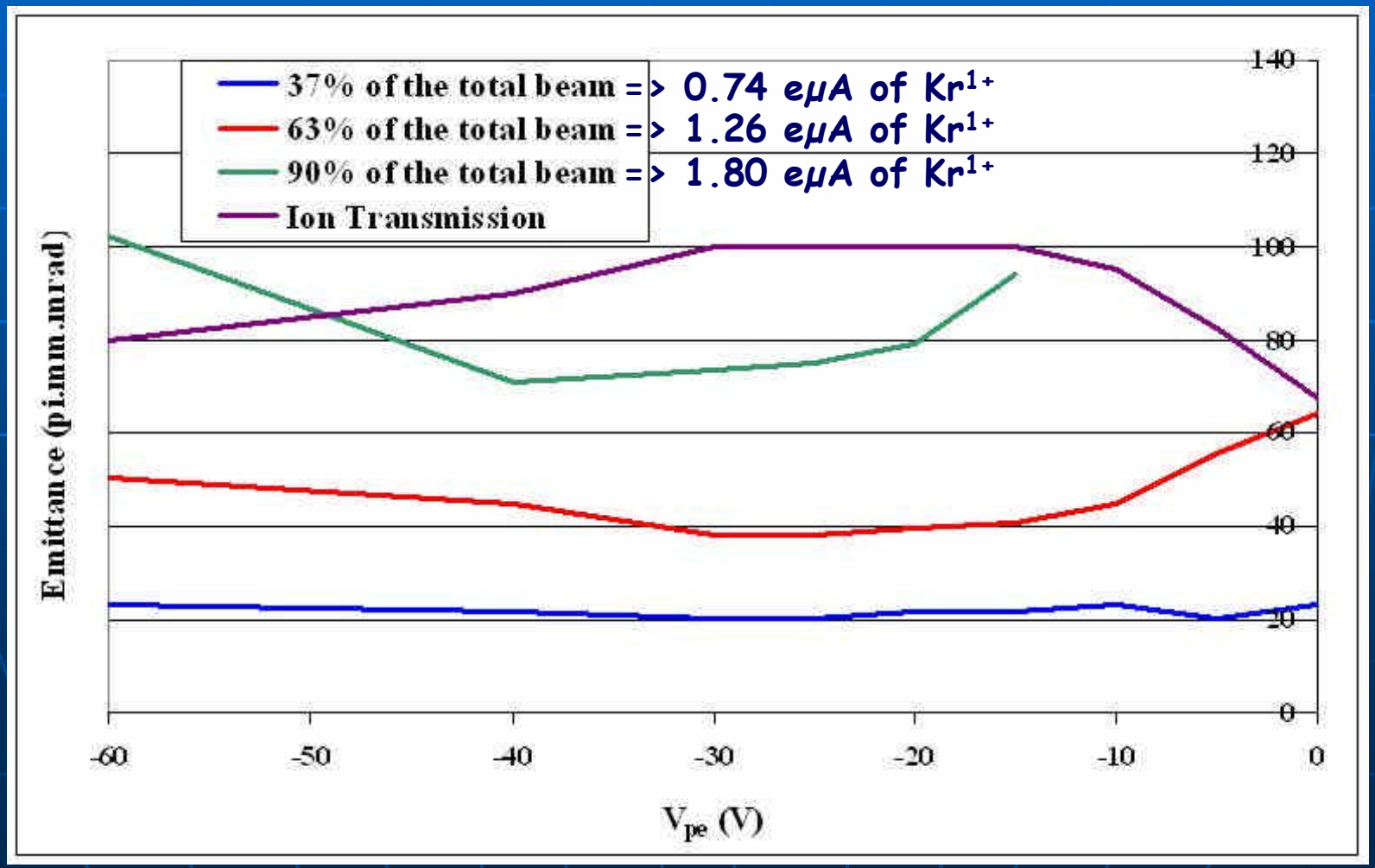
Typical emittance of $^{84}Kr^{+}$ beam

Vertical emittance analyzed such to have 63% of the current in the emittance

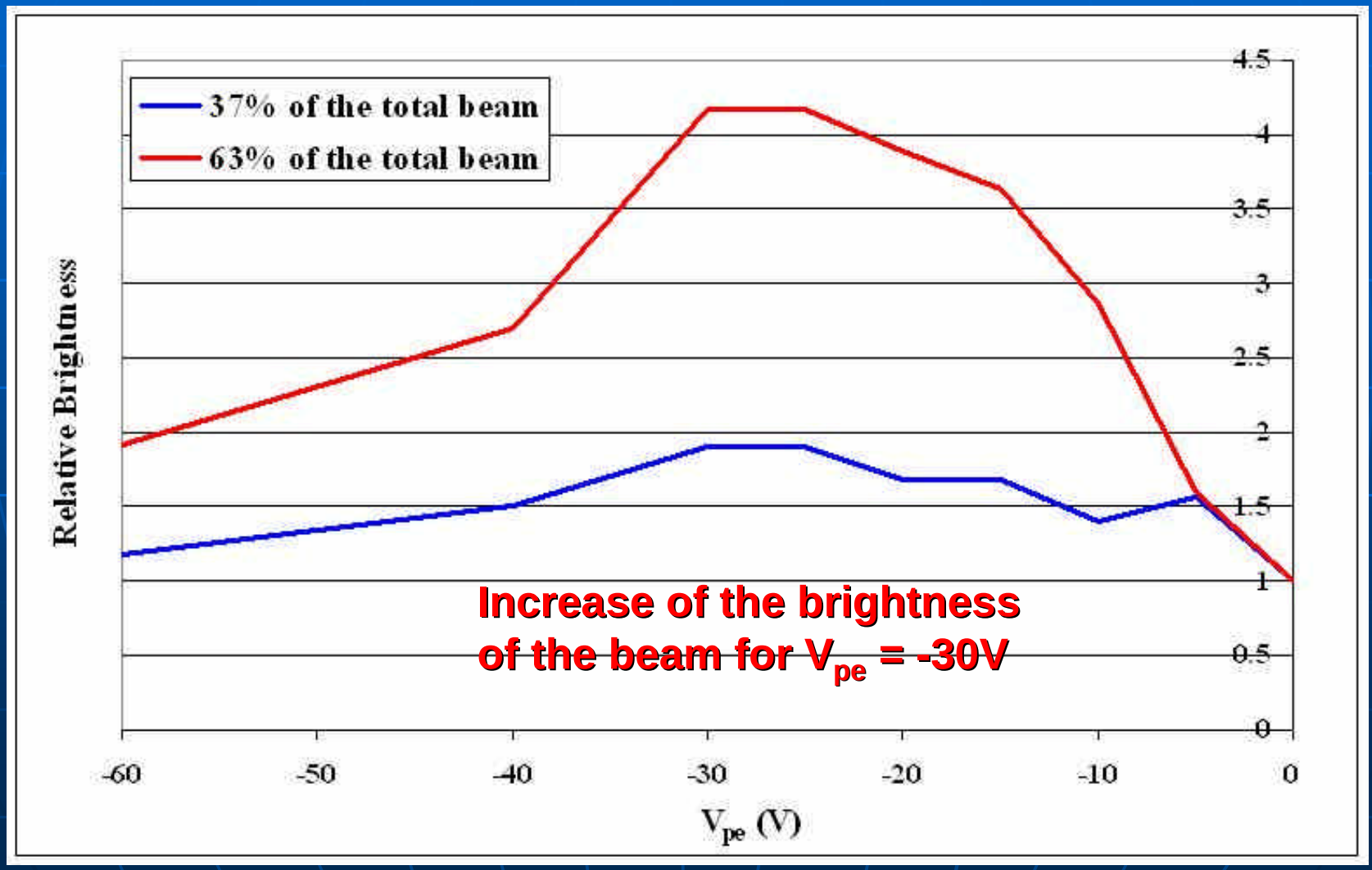


Evolution of the emittance with V_{ep} For the $^{84}Kr^{+}$ beam

Total beam => 2 eμA of Kr^{1+}

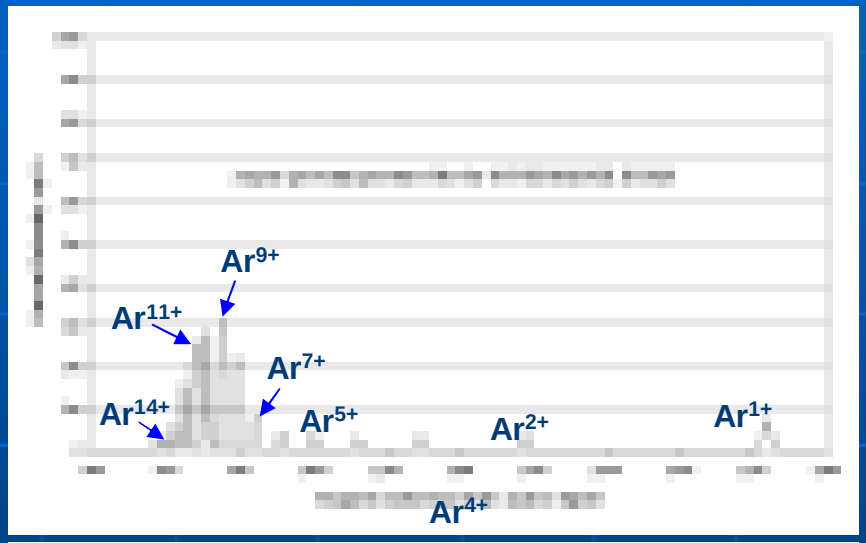


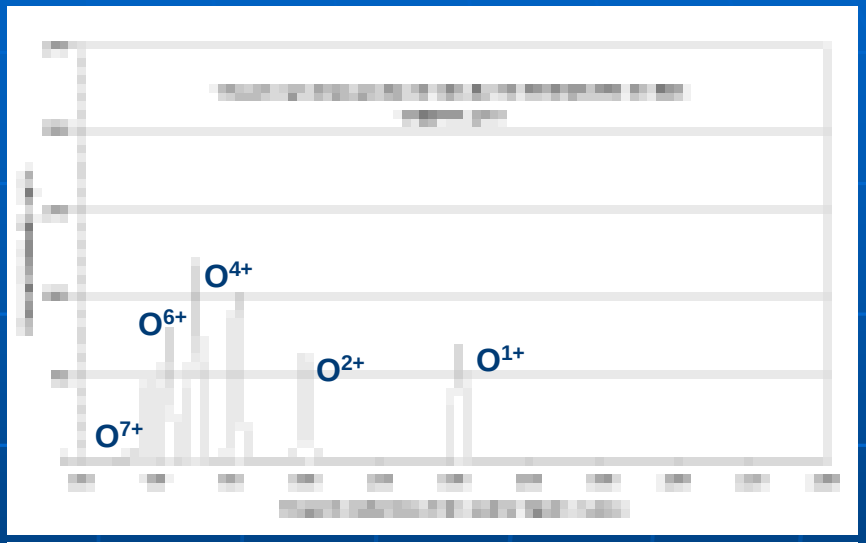
Evolution of the relative brightness with V_{ep} for the $^{84}Kr^{+}$ beam

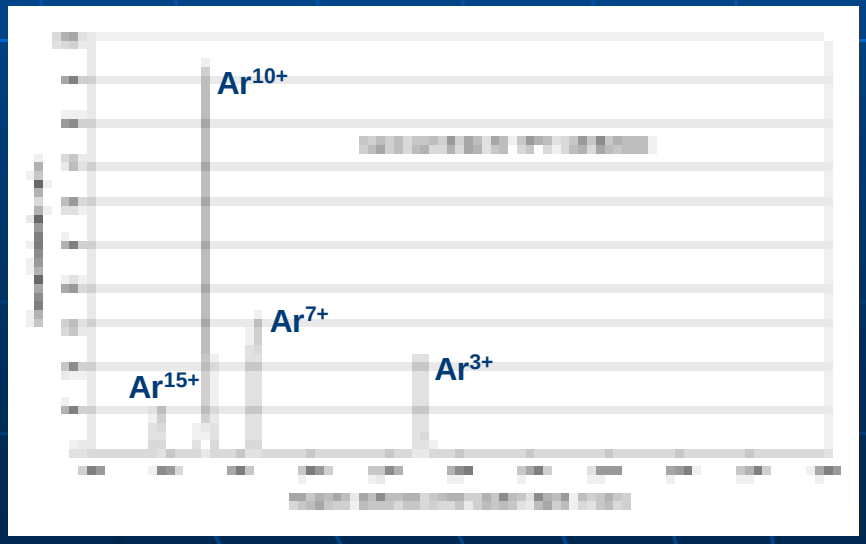


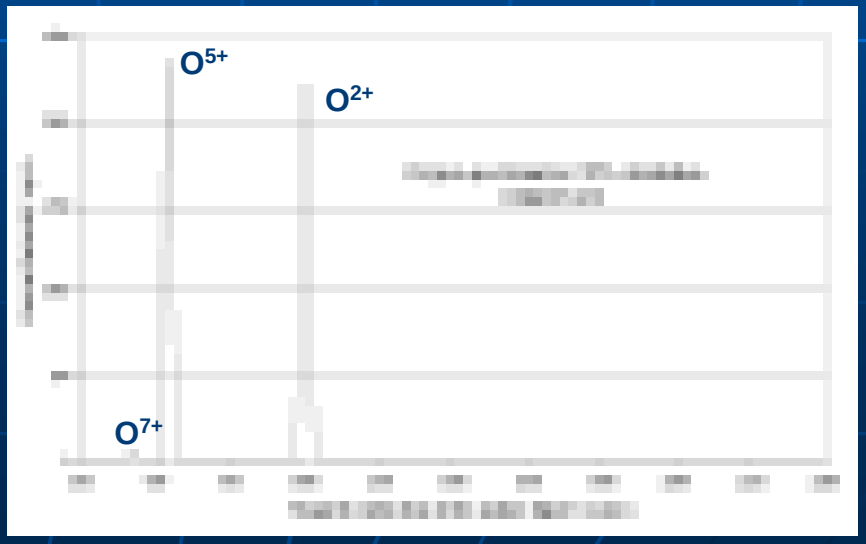
Simulations with the SUPERSHyPIE ECRIS

A realistic case has been chosen / only CPO results will be showed



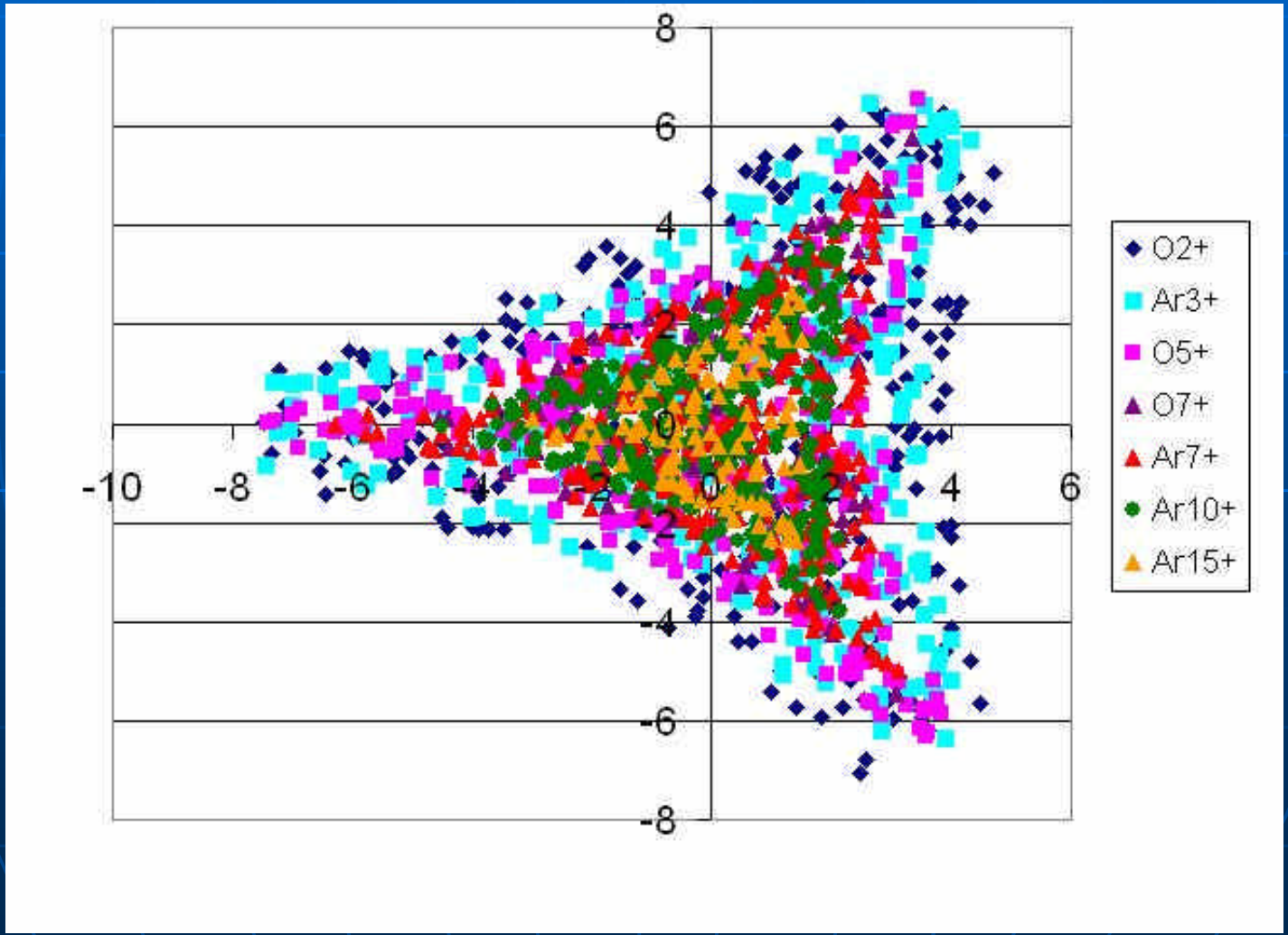




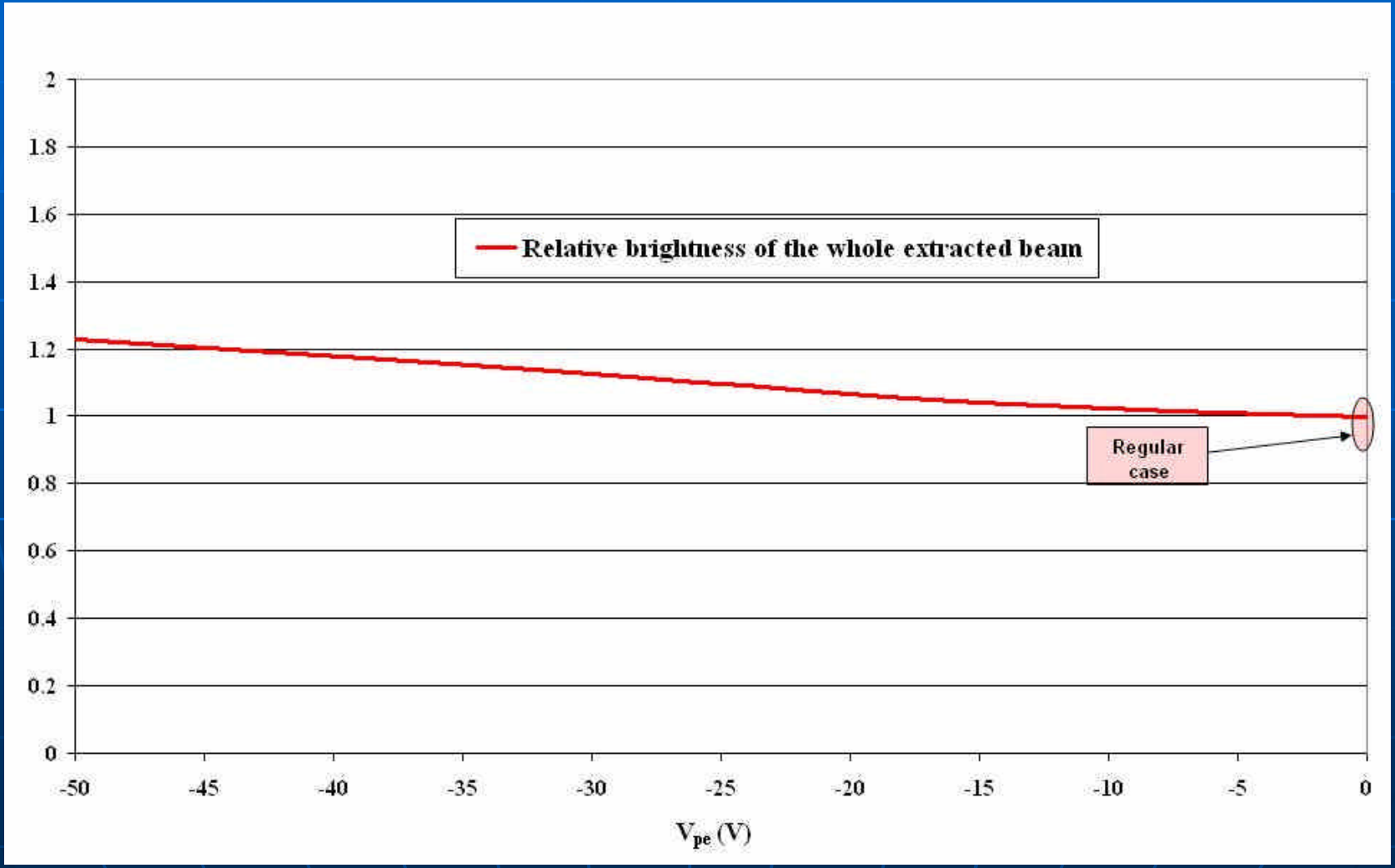


Ar^{q+} and O^{q+} initial distribution

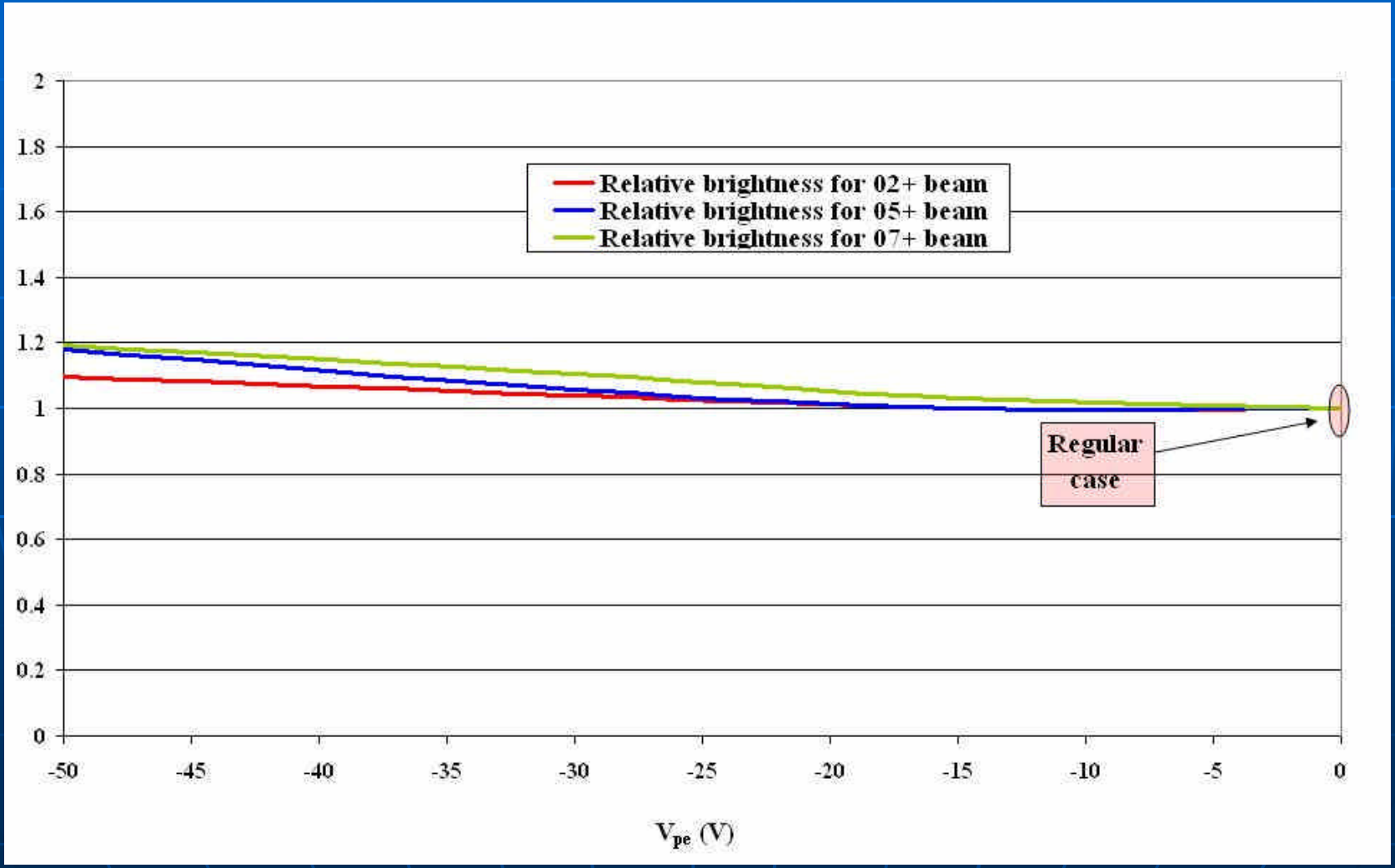
I_{total} = 6.6 emA
$V_{extraction}$ = 15 kV



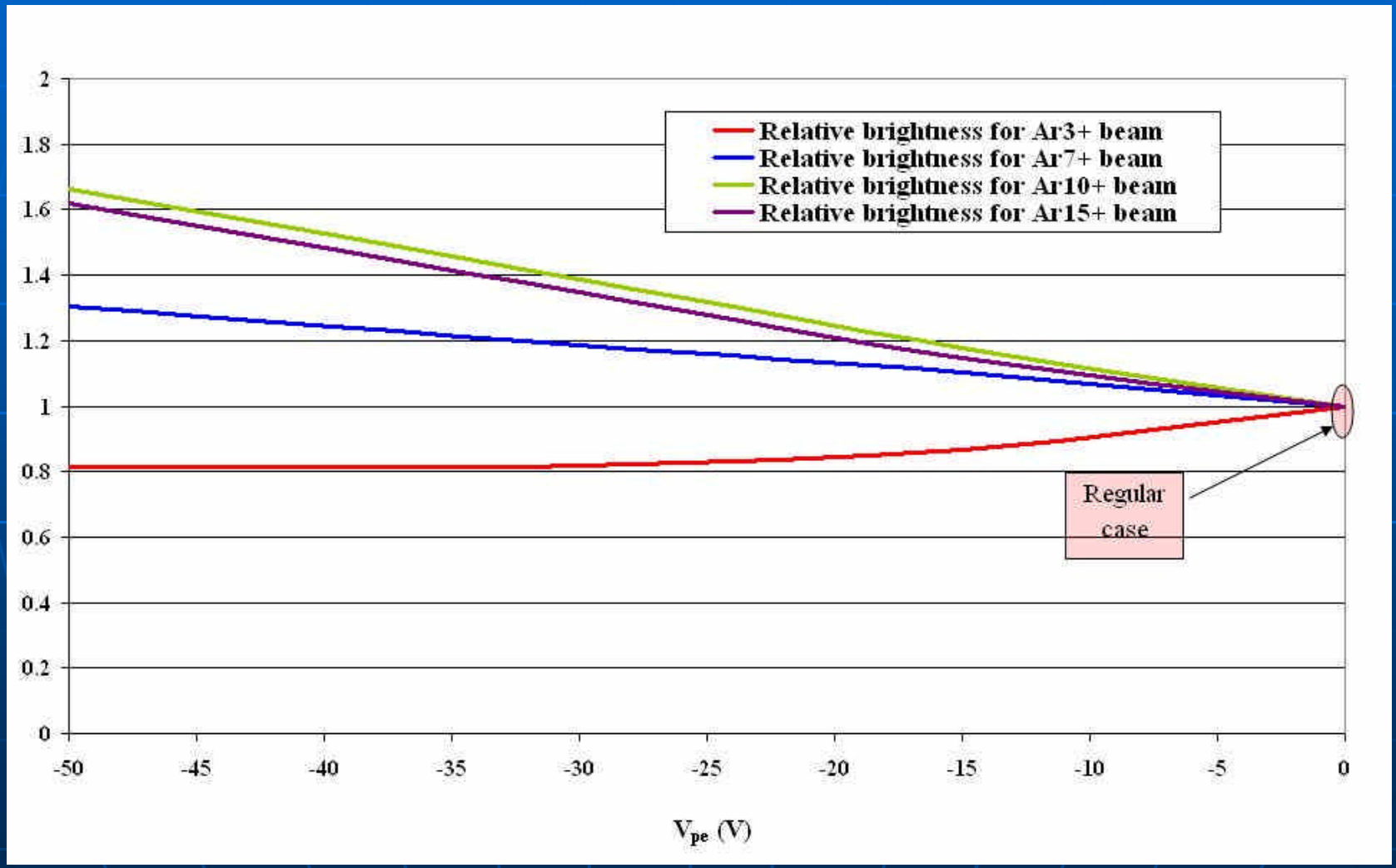
Evolution of the relative brightness with V_{ep} for the whole extracted beam



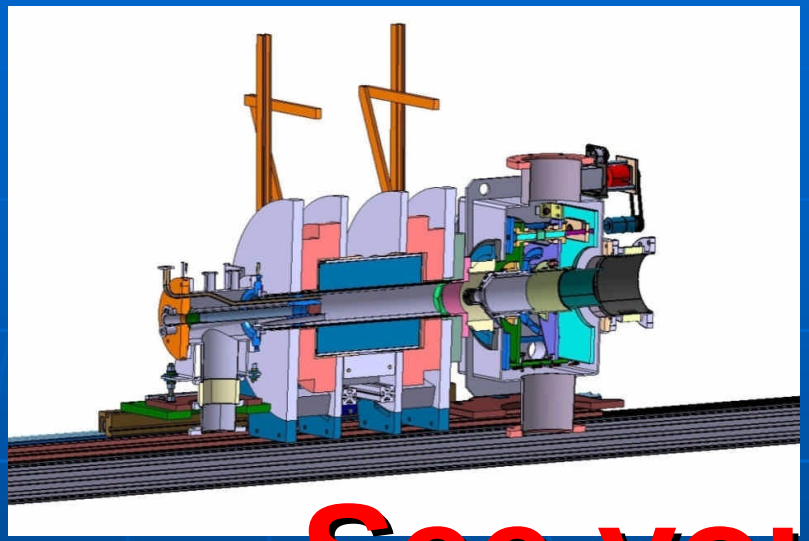
Evolution of the relative brightness with V_{ep} for the O^{q+} extracted beam



Evolution of the relative brightness with V_{ep} for the Ar^{q+} extracted beam



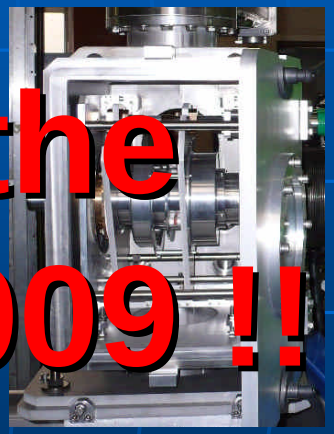
Next experiments…



Sketch of the GTS

Will be intalled instead of the SUPERSHyPIE ECRIS

Installation during the
second half year 2008
Under operation 14.5 GHz =>
january 2009



See you at the next ICIS 2009 !!

An experiment is planned also next year with the ATOMKI ECRIS

Test of this method applied to a multicharged ECRIS => validation or not of this technique

More studies...

From the results above, the negative bias of plasma electrode seems to be enhancing the brightness of the beam extracted from an ECRIS

BUT

Many studies should be undertaken:

☑ **From the simulation point of view:**

- ☞ Enhancement of the initial ion distribution (gaussian distribution, bohm criterion etc...
- ☞ Simulation of the whole test bench for a better comparison with the experiment
- ☞ Introduction of the space charge compensation
- ☞ Feedback with a large amount of data is needed

☑ **From the experiment point of view:**

- ☞ Experiments with several multicharged ECRIS
- ☞ Dependency on the brightness enhancement with the Charge state, Extraction voltage, Masses, Gap between plasma electrode and puller electrode etc...

Special thanks to my co-workers

Thank you

Jean Yves Pacquet
GANIL
CAEN

Christophe Pierret
CIMAP
CAEN