GASDYNAMIC ECR SOURCES OF MULTICHARGED IONS (ReGIS)

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Outline

1. ReGIS vs Geller ECRIS
2. ReGIS principles
3. Ion beam current and quality
4. Ion charge state distribution
5. ReGIS applications
6. Conclusion

Gasdynamic ECR ion sources (ReGIS)

Geller ECRIS

Electron velocity distribution function (EVDF) is anisotropic

$T_e >> T_i$

Gasdynamic mirror traps

Electron velocity distribution function is isotropic

$T_e \leq T_i$ $\tau = L/V_{i\_thermal}$

Gasdynamic ECRIS (ReGIS)

$T_e >> T_i$

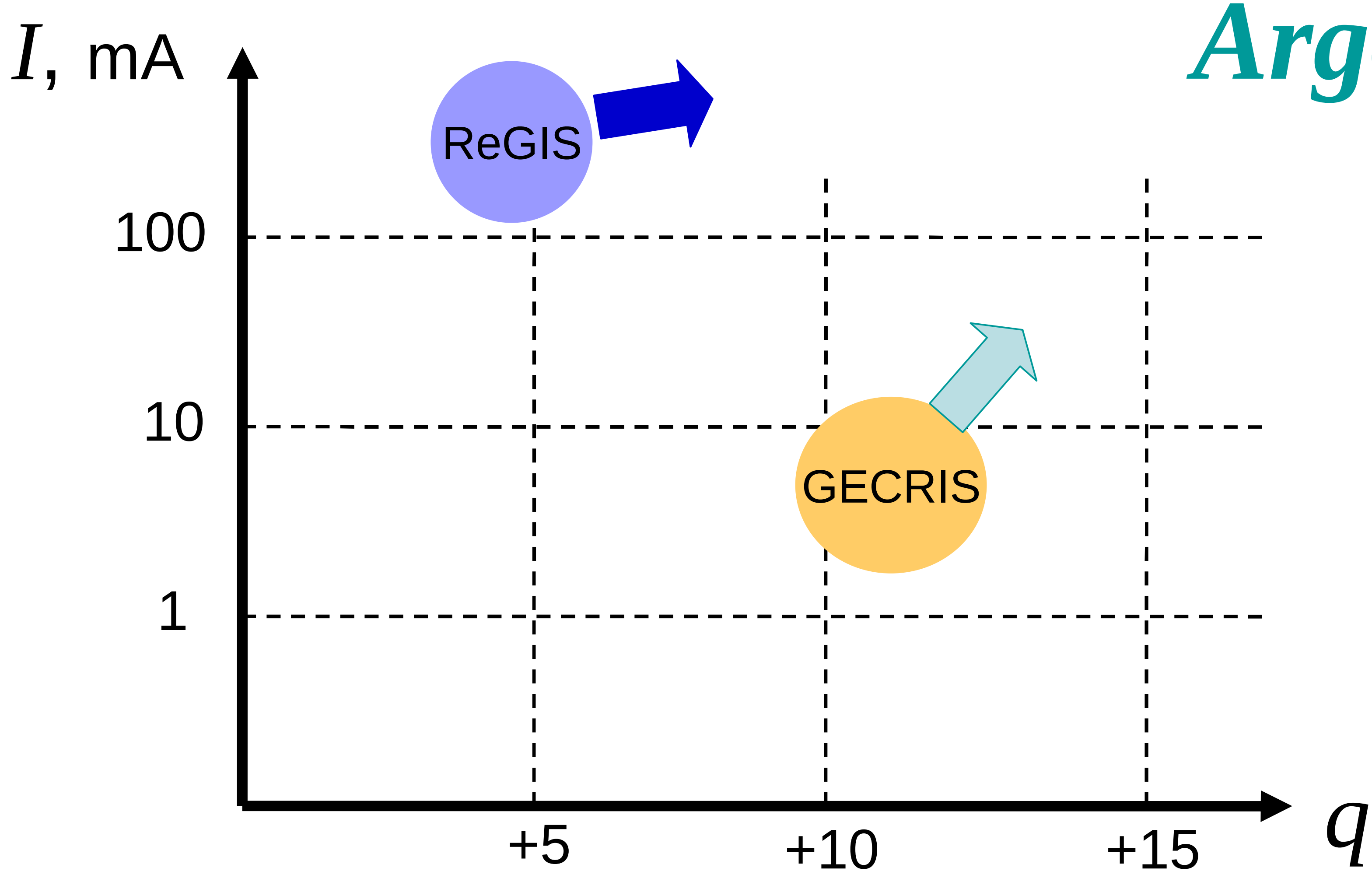
Collisional plasma
Loss cone is filled;
EVDF is isotropic

$\tau = L/V_{is}$

L **– geometrical factor of a trap,**
V_{is} ion sound velocity

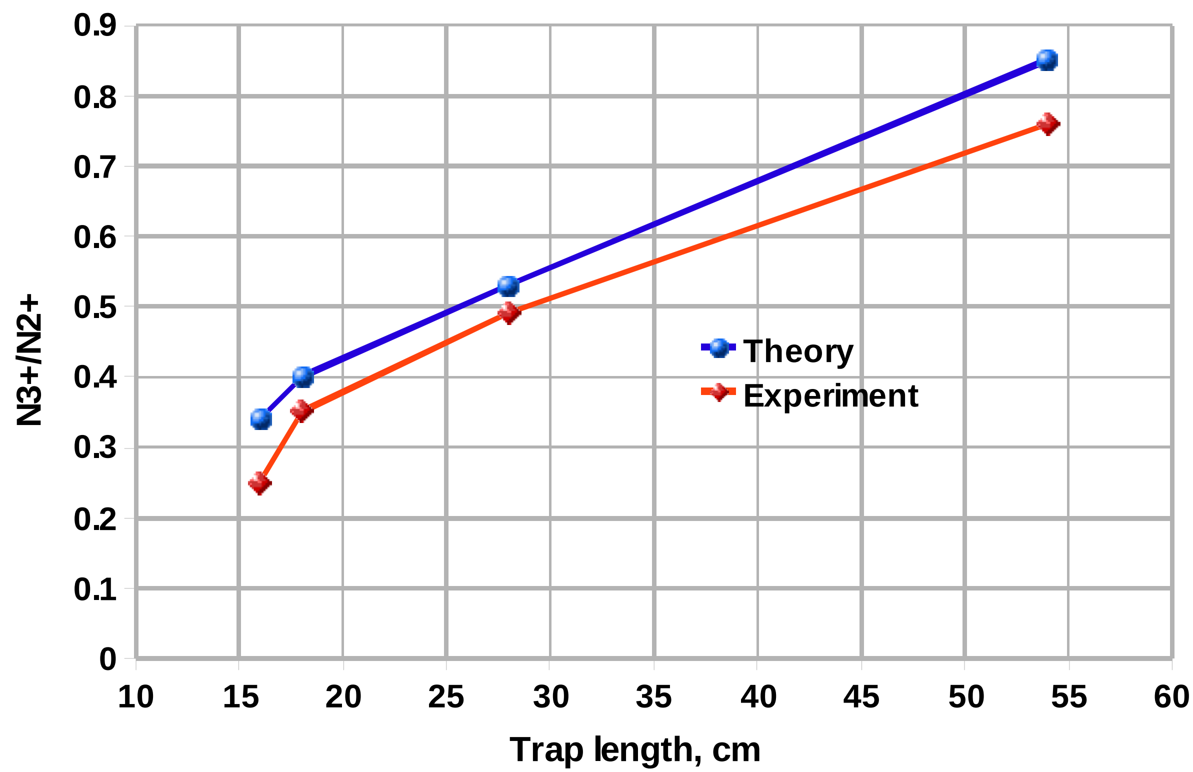
GECRIS vs ReGIS

Argon



Ion charge vs trap length

$$\tau_l = \frac{L_{eff}}{V_{is}}$$

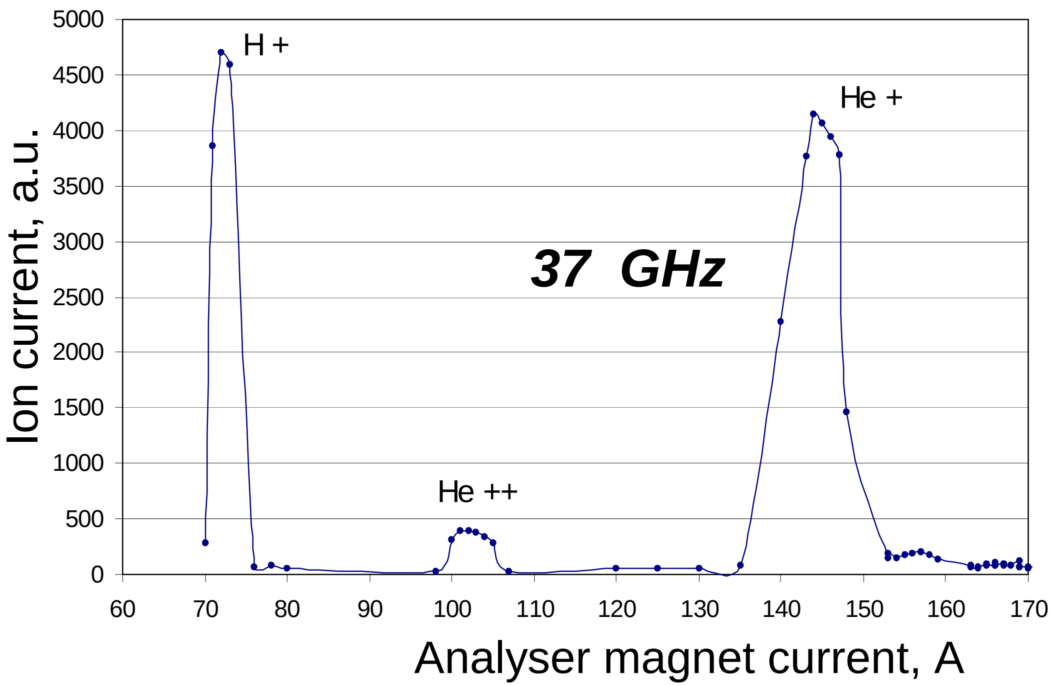


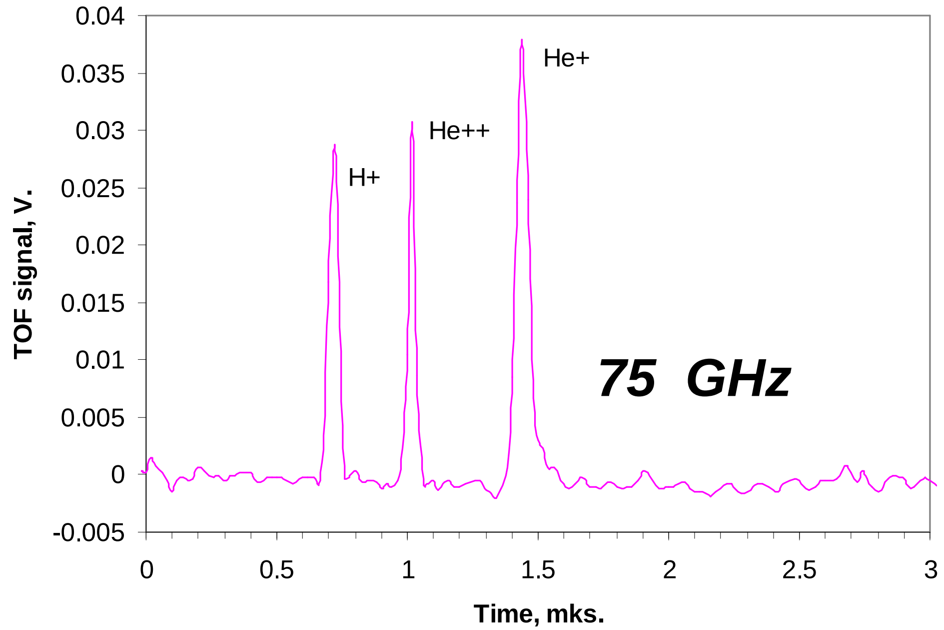
Ion charge vs microwave frequency

Limitation on plasma density: $N_e < N_c = \dfrac{m\omega^2}{4\pi e^2}$

$$q \sim n_e \cdot \tau_e \sim \omega^2$$

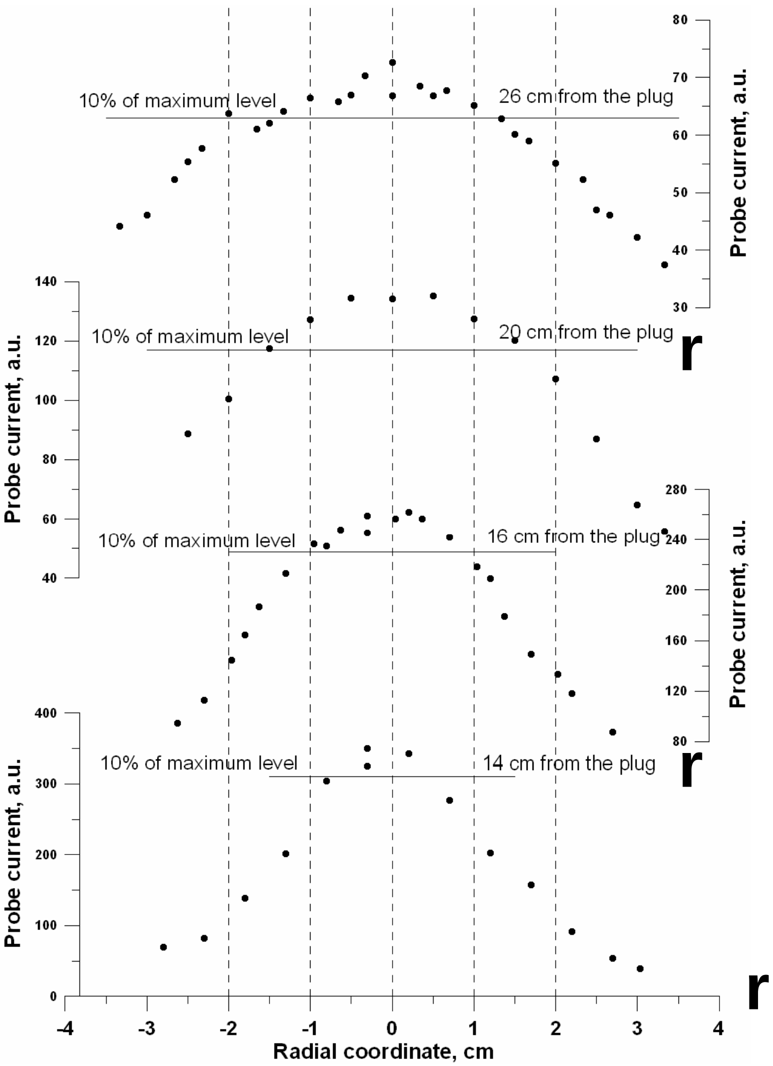
Experiments with 37 and 75 GHz, He

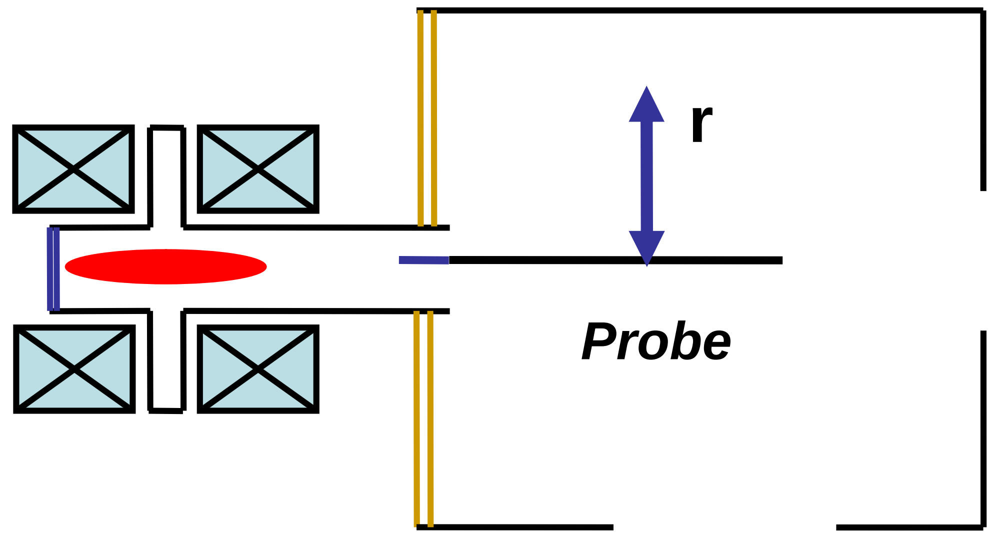


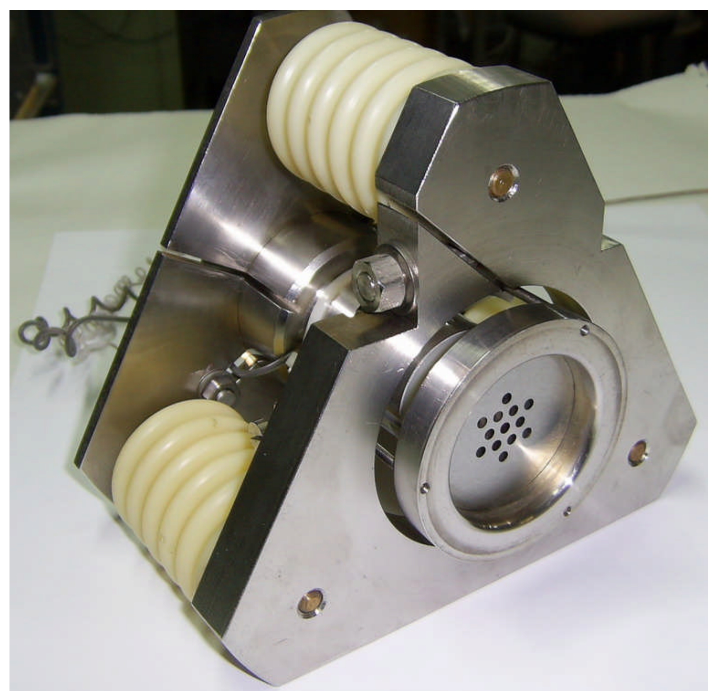


Uniformity of radial plasma distribution

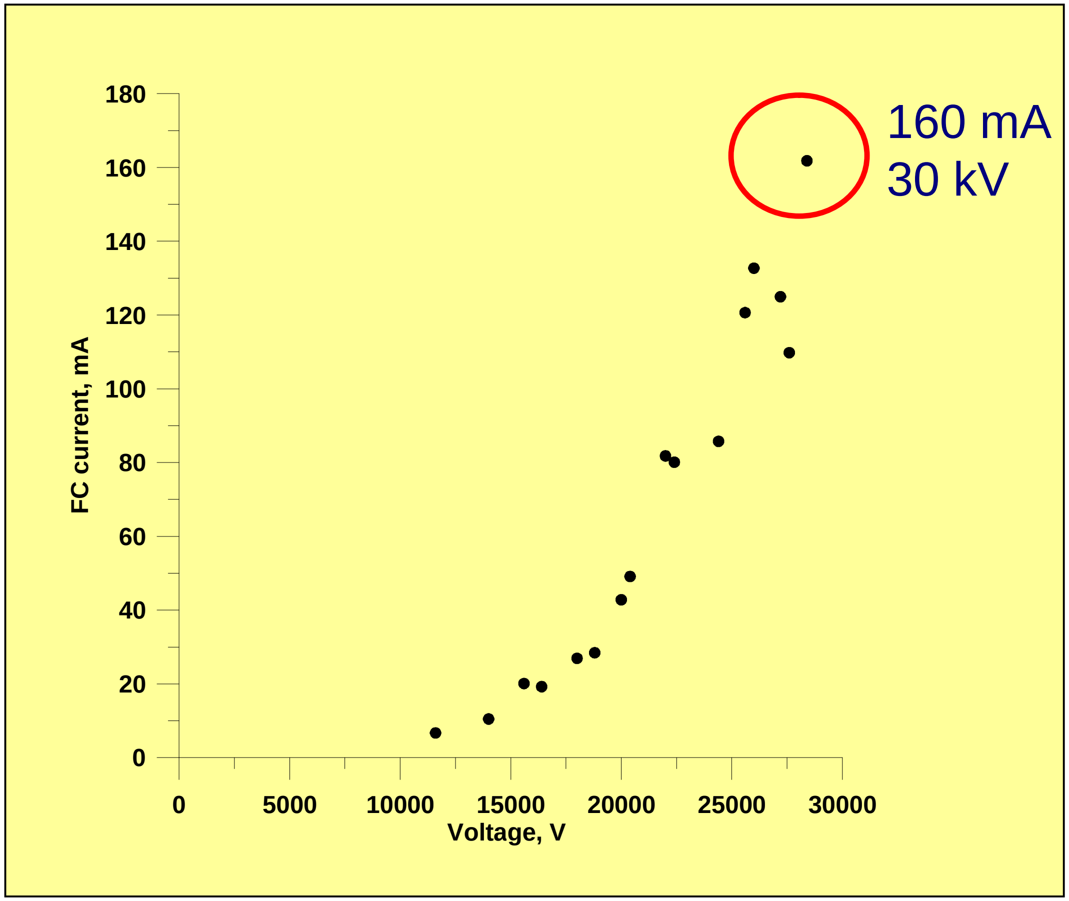
Plasma flux uniformity

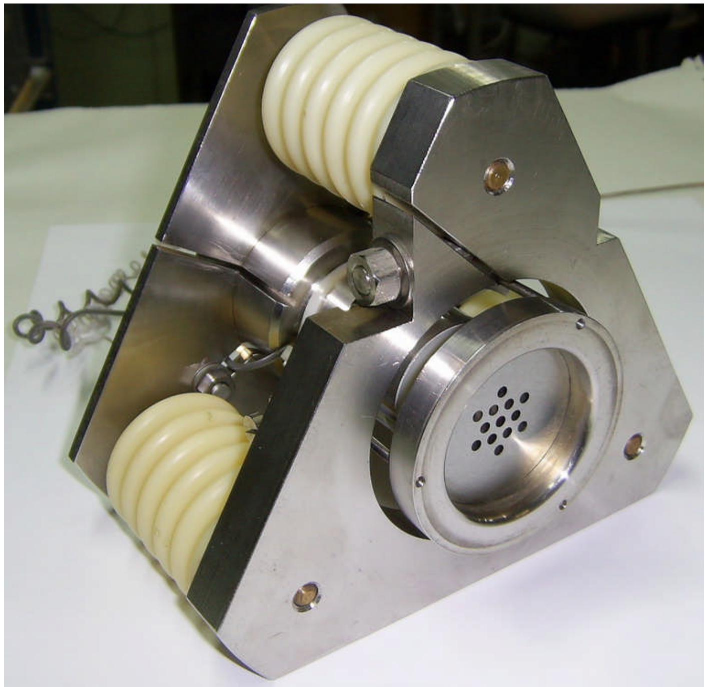




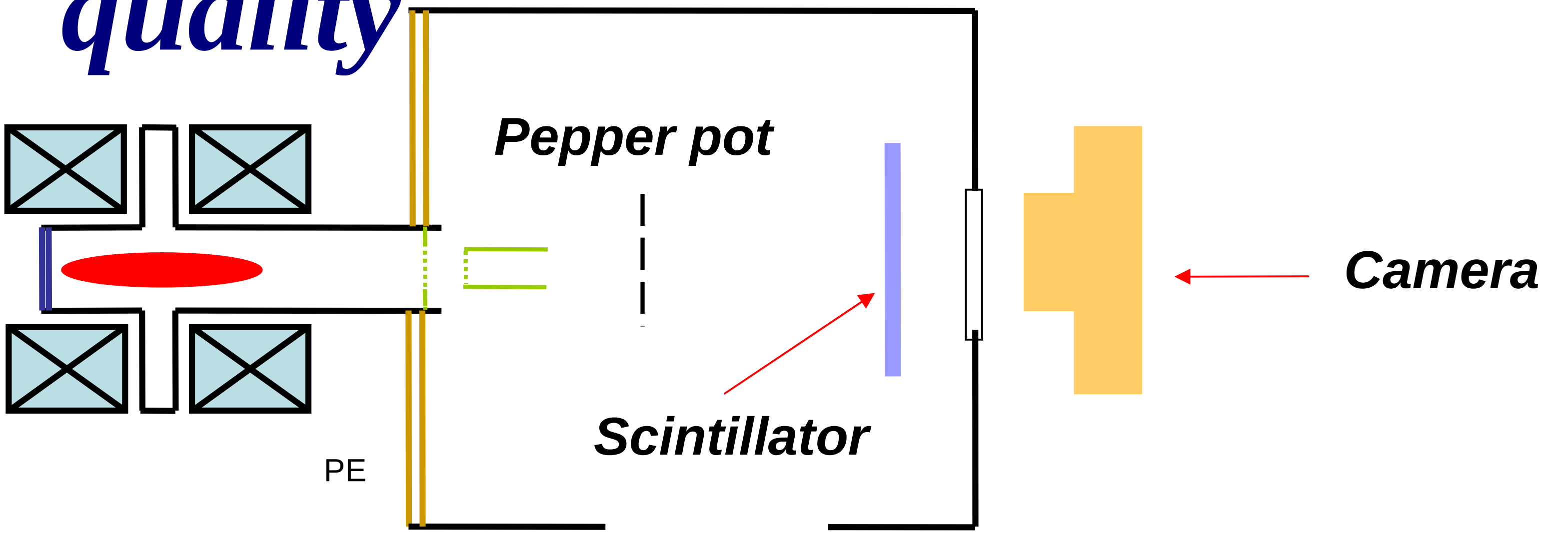


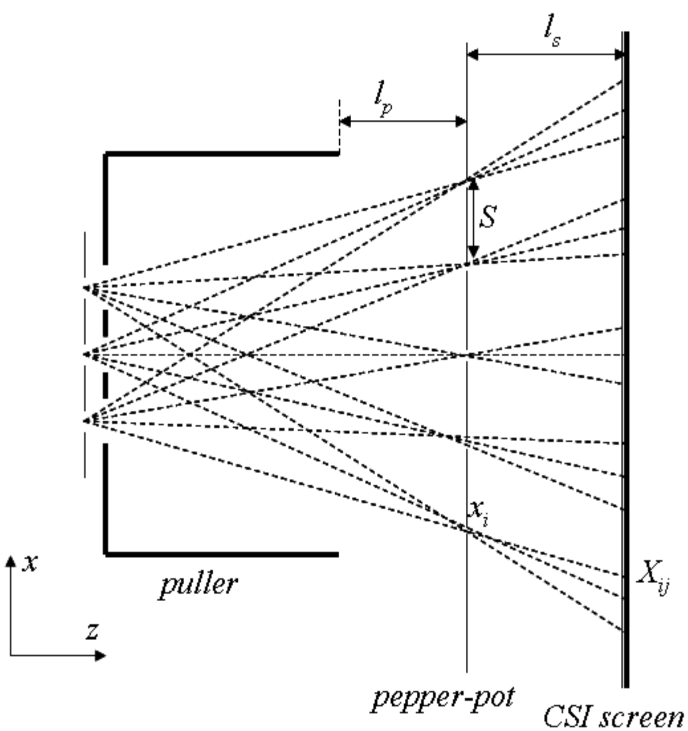
160 мA ion beam (not a limit!!!)

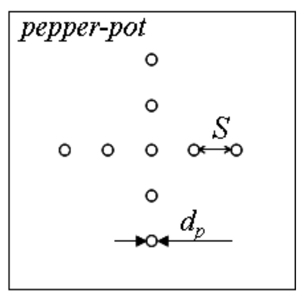


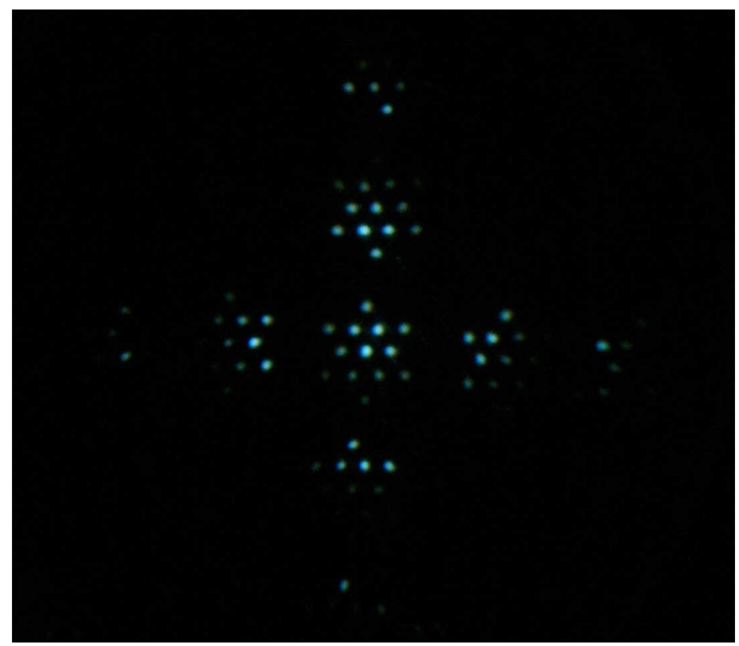


Multiaperture extracting, beam quality



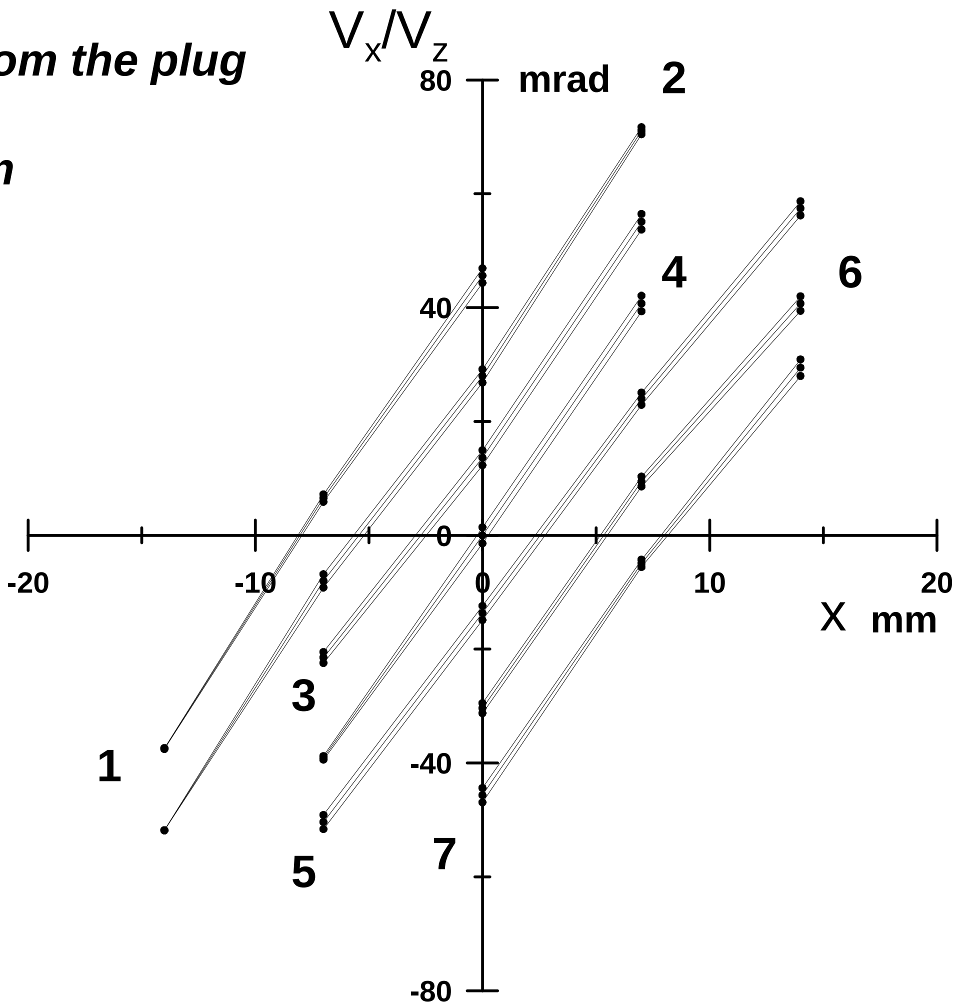


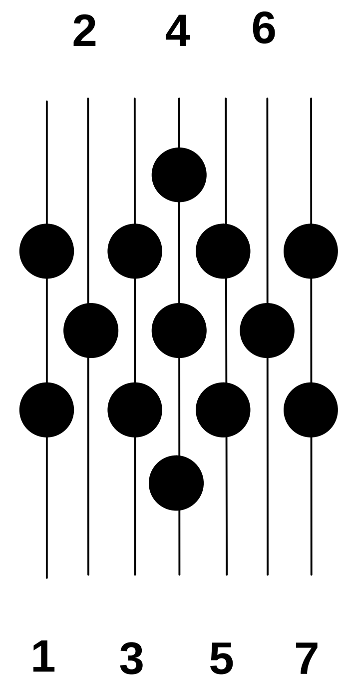


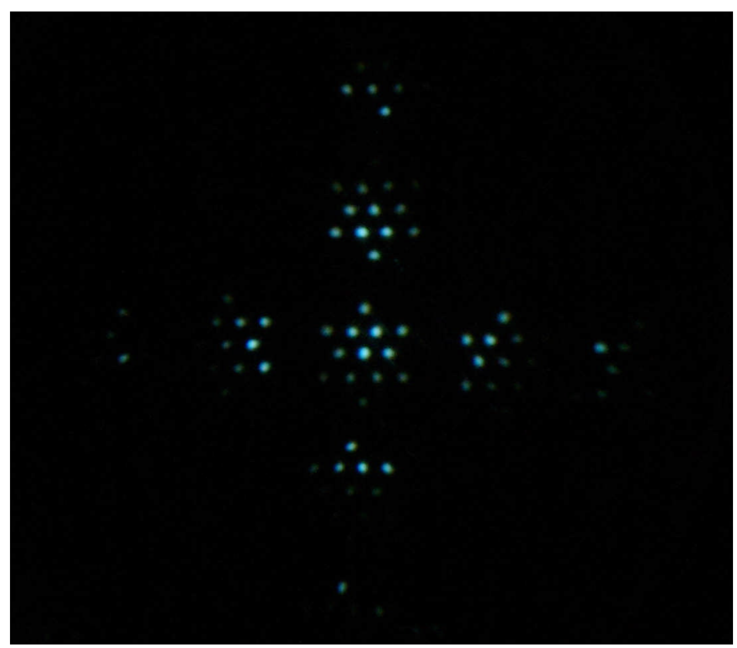


Emittance diagram

21 cm from the plug
l_p=1 mm
l_s=55 mm



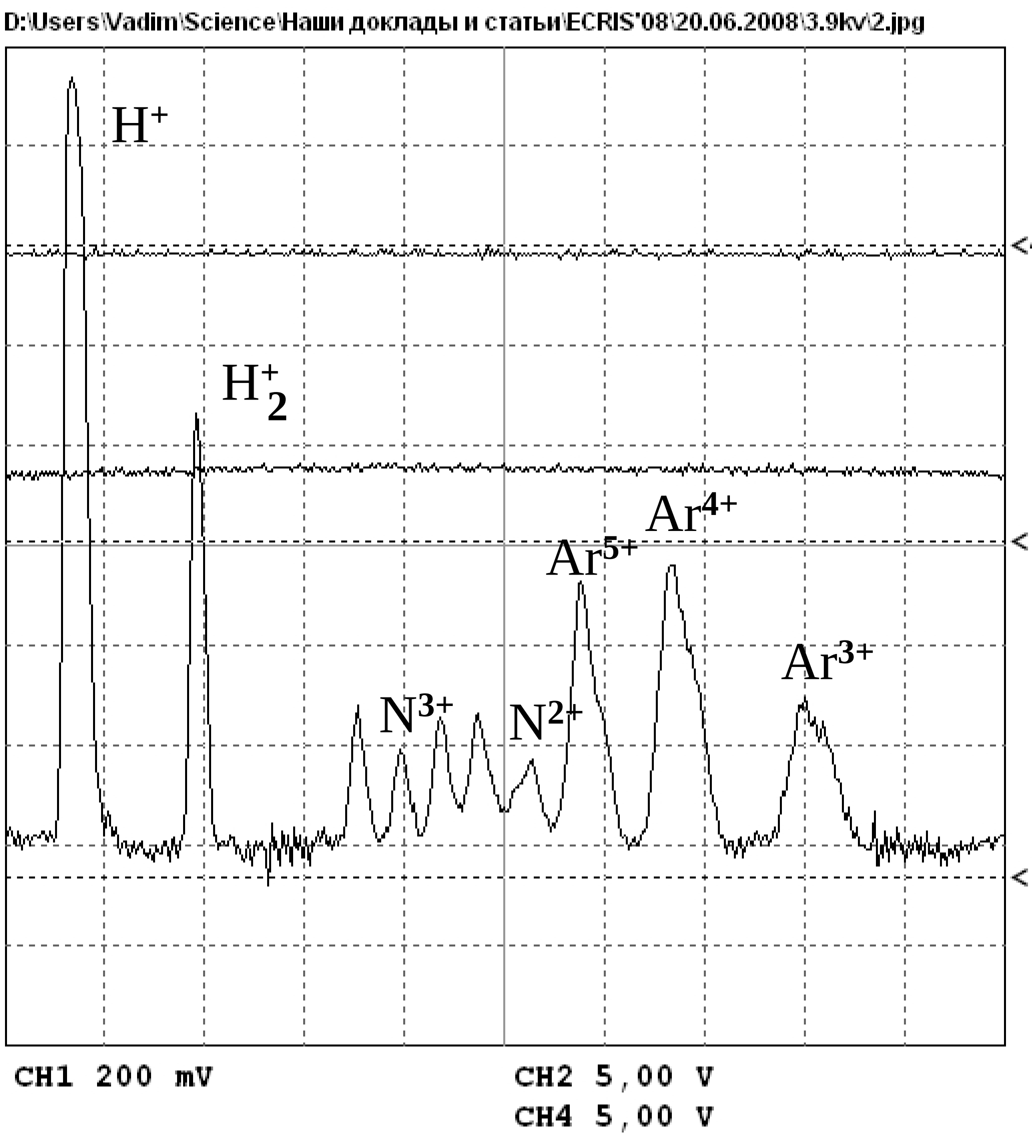


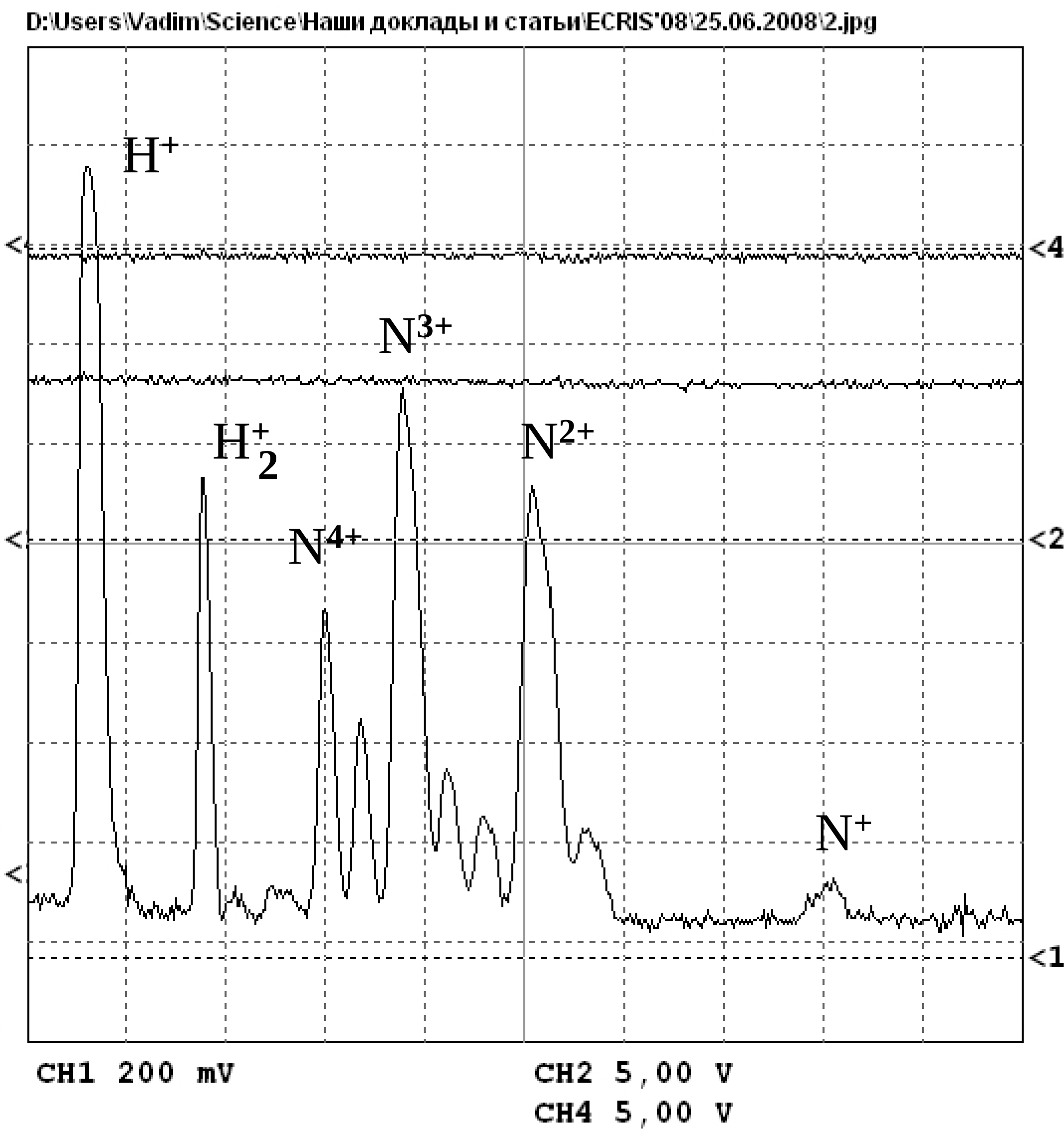


ε =450 $\pi \cdot$ mm $\cdot$ mrad

ε_n=0.9 $\pi \cdot$ mm $\cdot$ mrad

Ion charge state (short pulse)

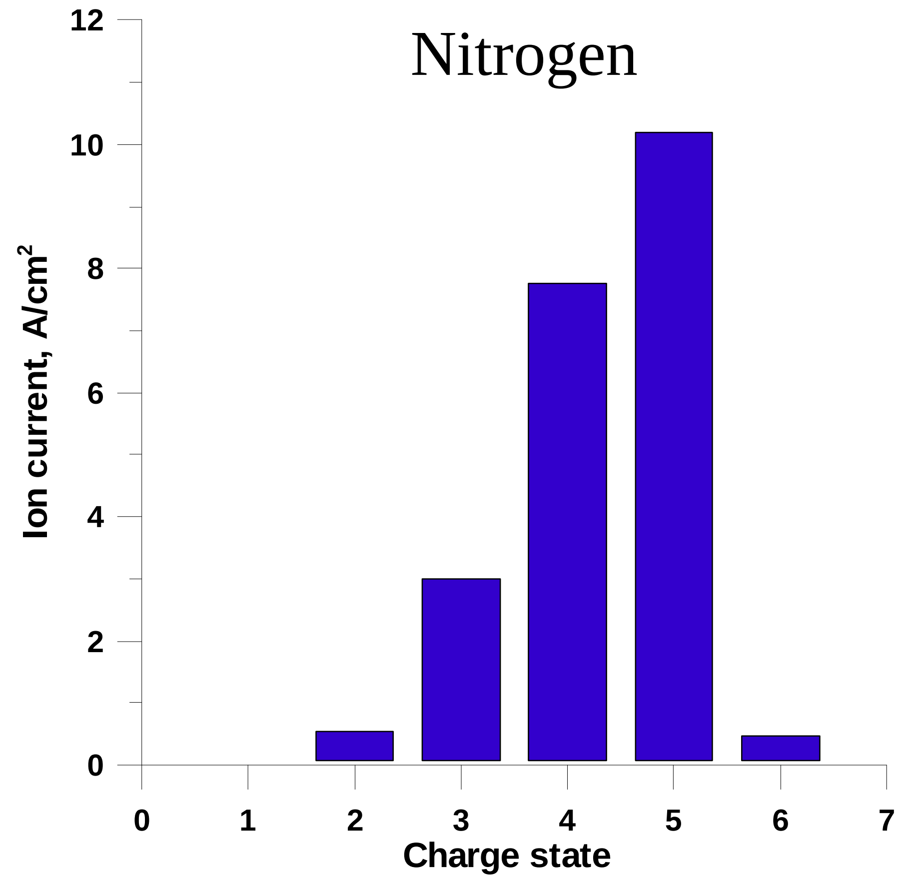




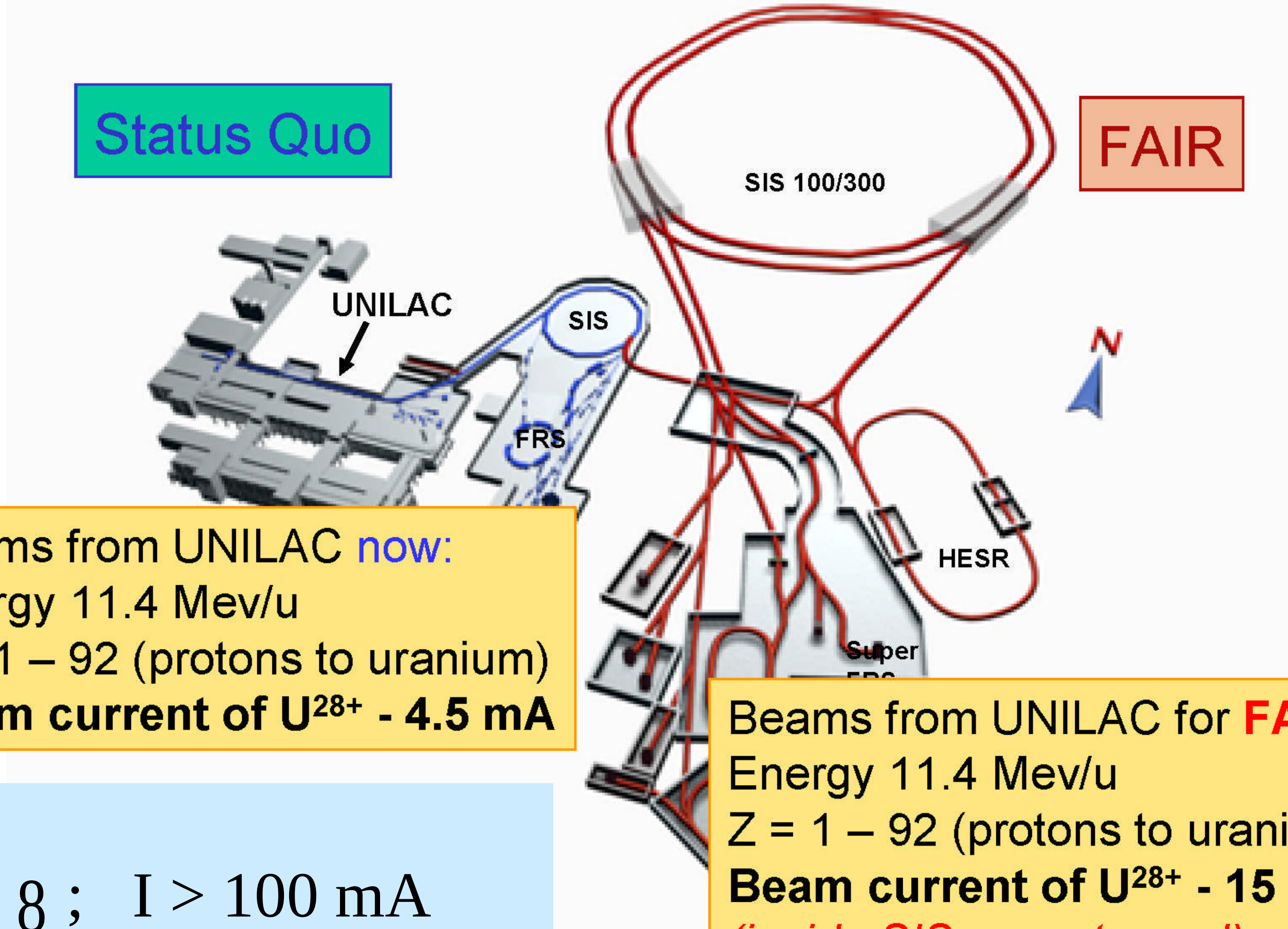
ReGIS 100 GHz

Calculations 100 GHz, 500 kW, L_{eff}=100 cm :

Operating gas	Charge state	Ion current density (in plug) A/cm^2
Carbon	+4	10
Nitrogen	+5	10
Oxygen	+6	10
Argon	+10	6
Xenon	+15	1



Future International Accelerator Facility at GSI: FAIR (Facility for Antiproton and Ion Research)



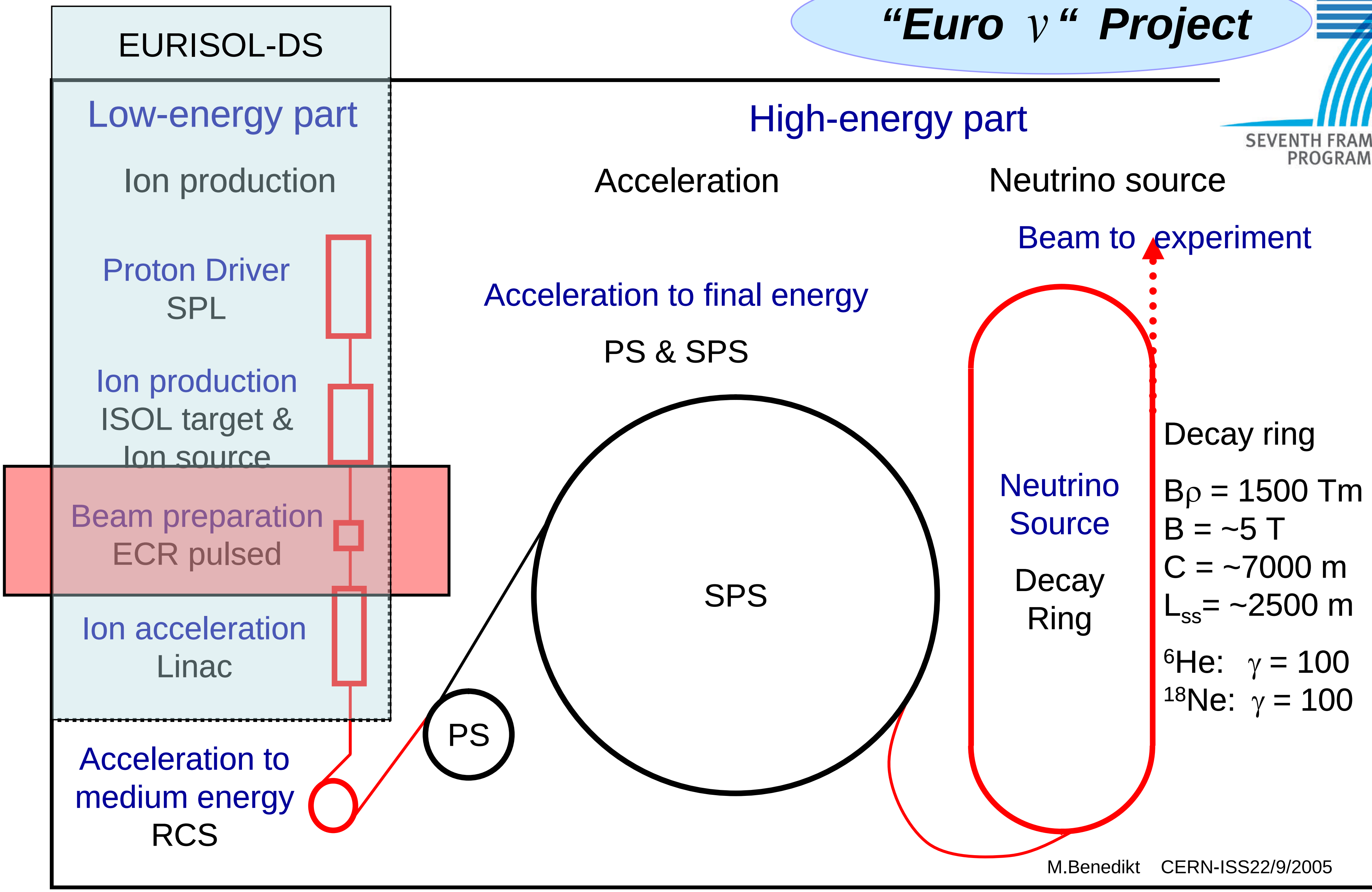
Beams from UNILAC now:
Energy 11.4 Mev/u
Z = 1 – 92 (protons to uranium)
Beam current of U^{28+} - 4.5 mA

Beams from UNILAC for FAIR
Energy 11.4 Mev/u
Z = 1 – 92 (protons to uranium)
Beam current of U^{28+} - 15 mA
(inside SIS acceptance !)

$$\frac{M}{q} = 8 \; ; \quad I > 100 \text{ mA}$$

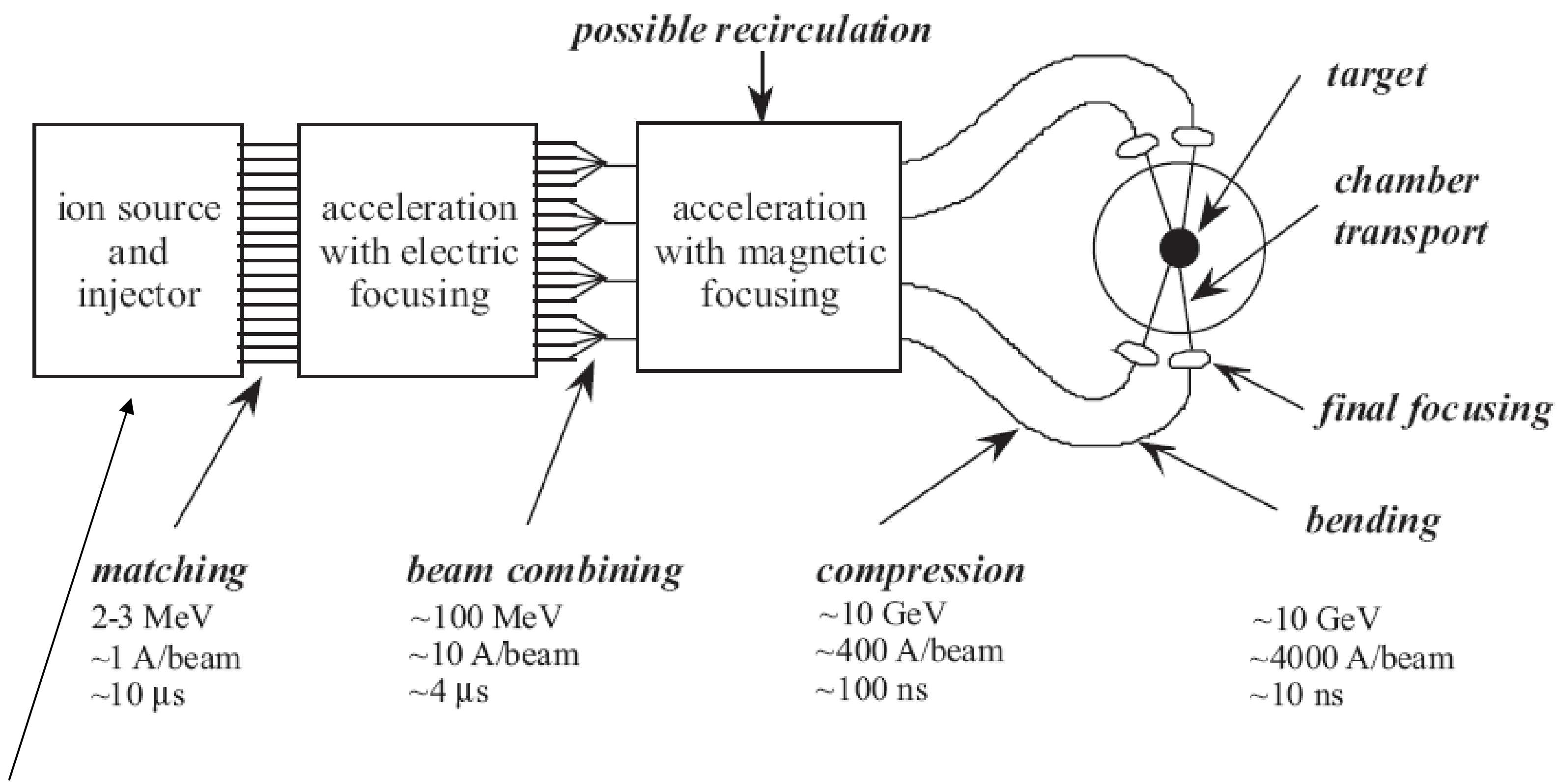
β-beam baseline design

"Euro ν" Project



M.Benedikt CERN-ISS22/9/2005

Typical heavy ion beam driver for inertial fusion energy[1]



Requirement for ion beam:

Energy	**1.6-2 MeV**
Current per channel	**0.5 A**
Ion mass	**84-238**
Emittance (norm.)	**<1 π mm mrad**

[1]Physics and Technology of Ion Sources, Second Edition. Ian Brown (Ed.)

Conclusion

- Gasdynamic ECR ion sources (ReGIS) are quite different from classical ones.
- ReGIS are able deliver quality ion beams with current more than 100 mA
- Increasing of ion charge for ReGIS is a realizable task, ways are obvious.

ИПФ РАН

Many thanks to:

Organizing committee of the workshop

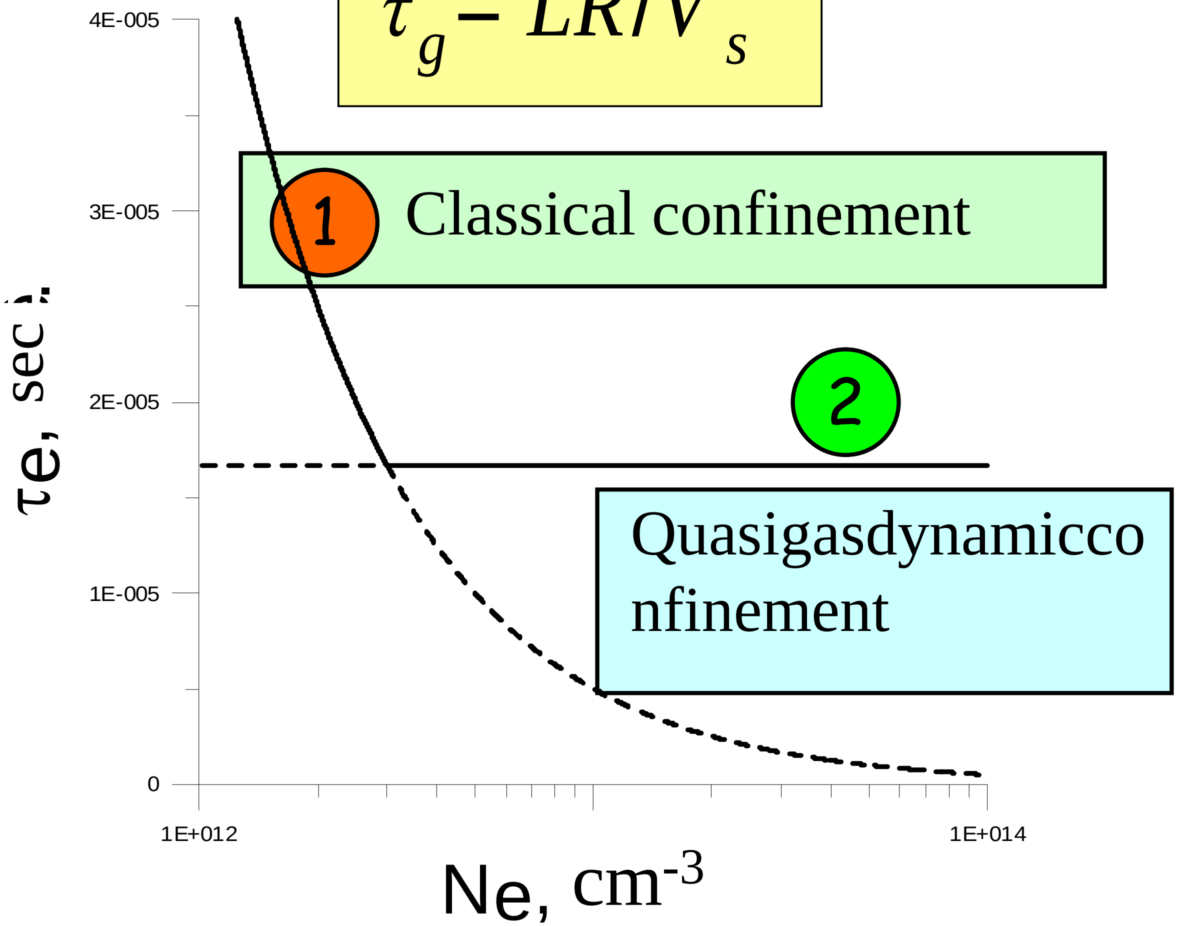
&

GSI: P. Spaedtke
and
LPSC Grenoble team:
R. Geller, T. Lamy, T. Thuillier

Plasma confinement in an ECR ion source

$$\tau_c = \ln R / \nu_{ei}$$

$$\tau_g = LR / V_s$$



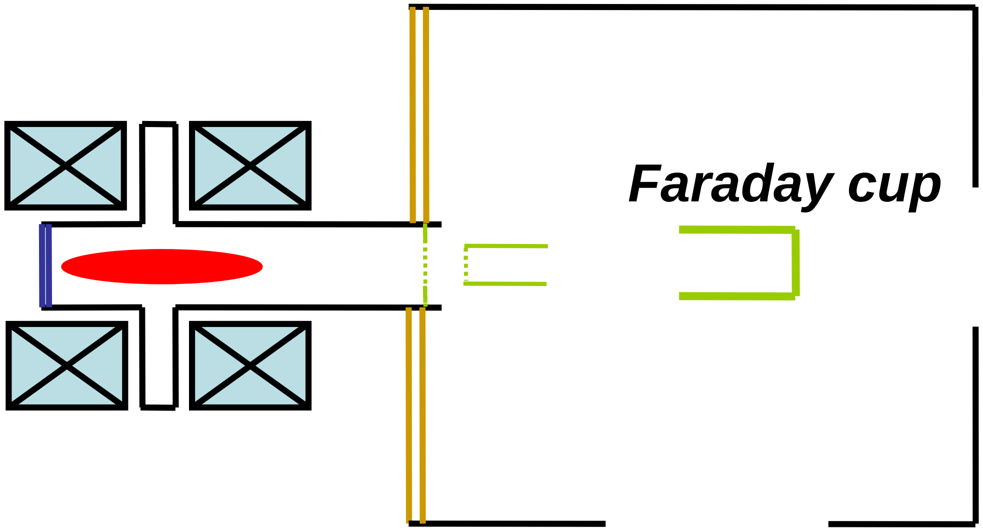
Averaged ion charge

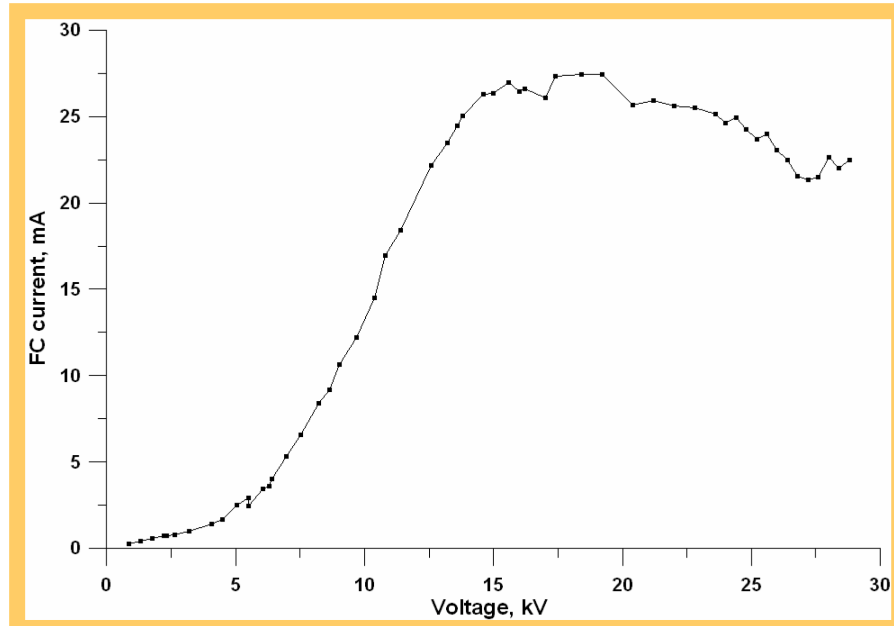
$$q \sim n_e \tau_e$$

Total ion current

$$I \sim \frac{n_e}{\tau_{e_{Ion}}}$$

Multiaperture extracting system

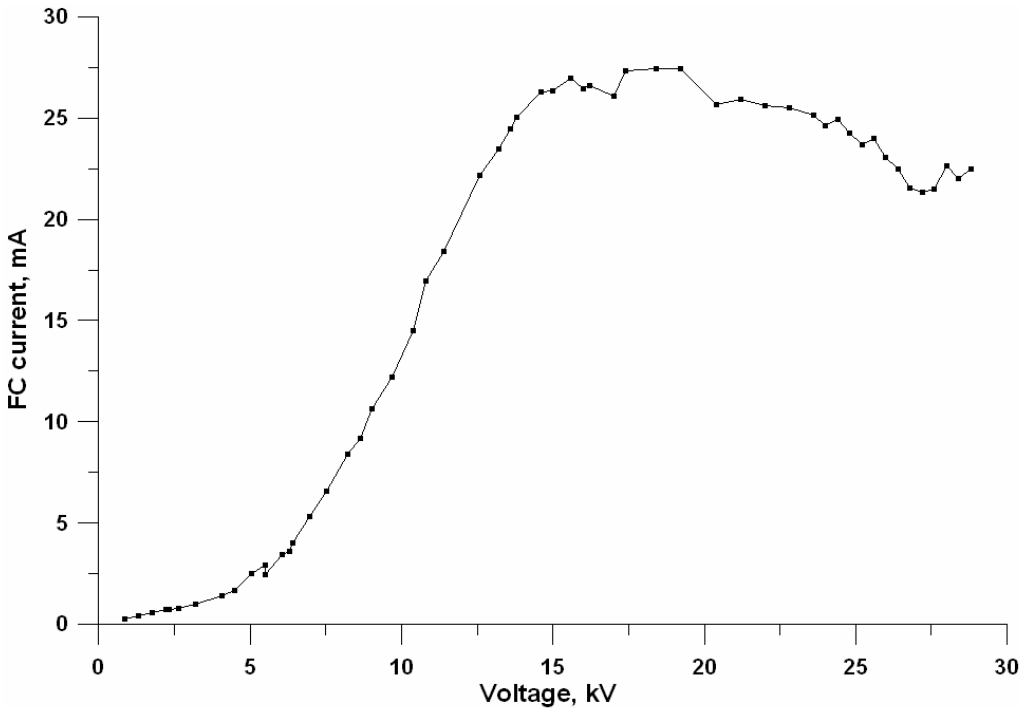


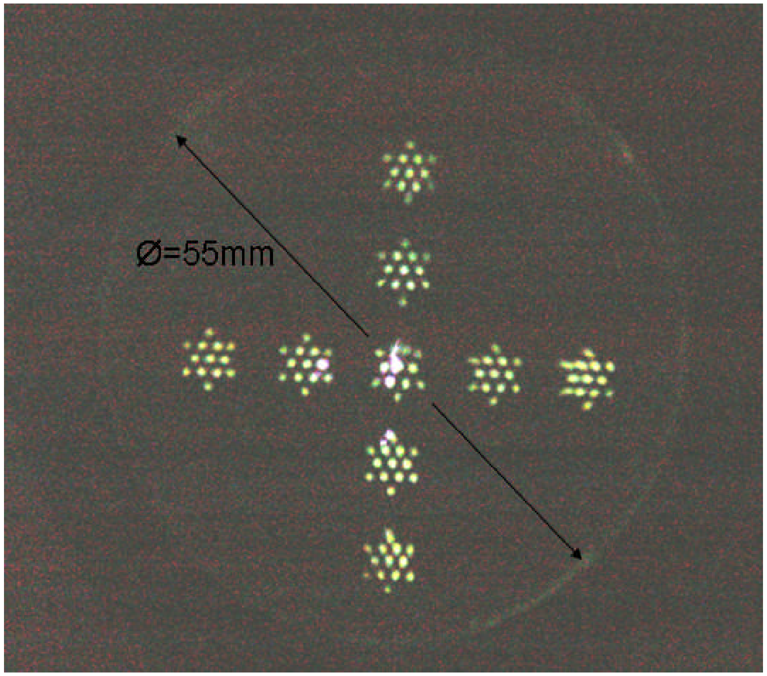


Ion current density more 60 mA/cm²

Diameter of each hole 3 mm.
13 holes, total square 92 mm²

30 мA ion beam





Boundary GECRIS – ReGIS: plane T_e - N_e

$$T_e >> T_i$$

Coulomb electron scattering into the loss-cone

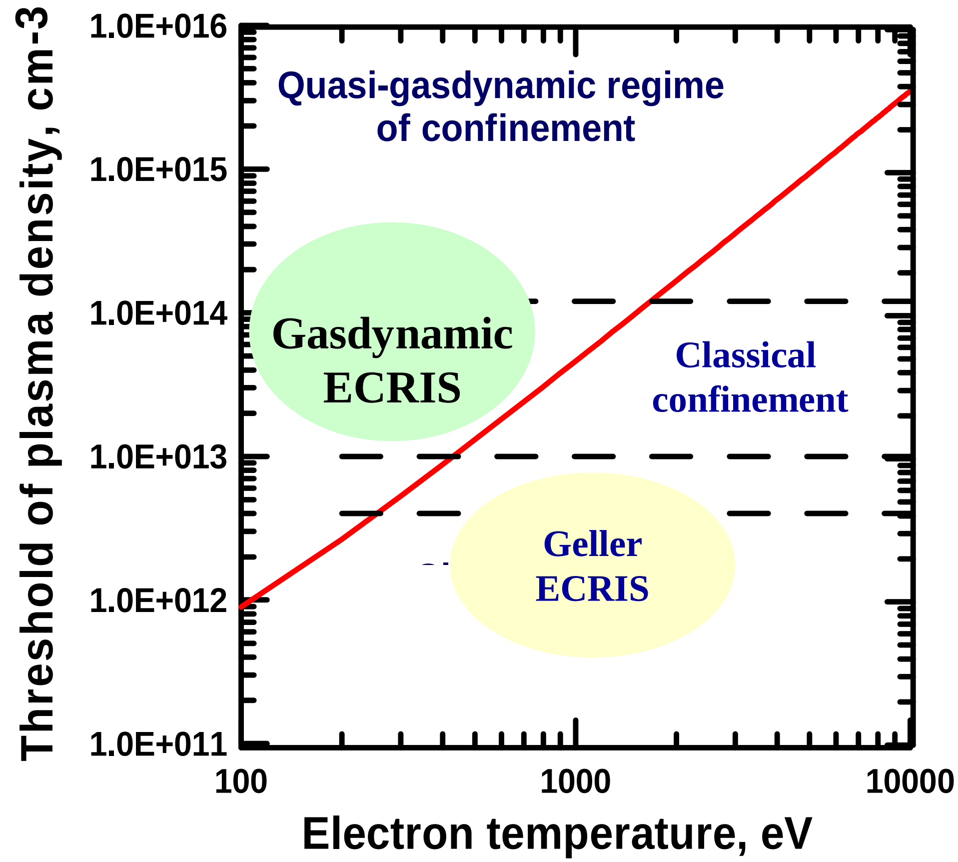
$$\tau_c = \ln R / \nu_{ei}$$

τ_c □ τ_g (collisionless)

τ_c □ τ_g (collisional)

Duration of plasma escape

$$\tau_g = L_{eff} / V_s$$



V_s – *ion sound velocity*

L_{eff} – *effective trap length*