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Extraction by Stripping of Heavy Ion Beams from AVF Cyclotrons

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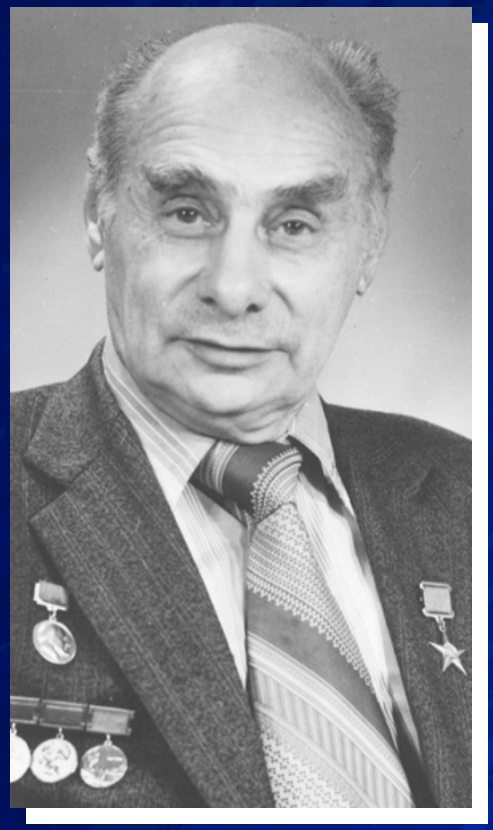
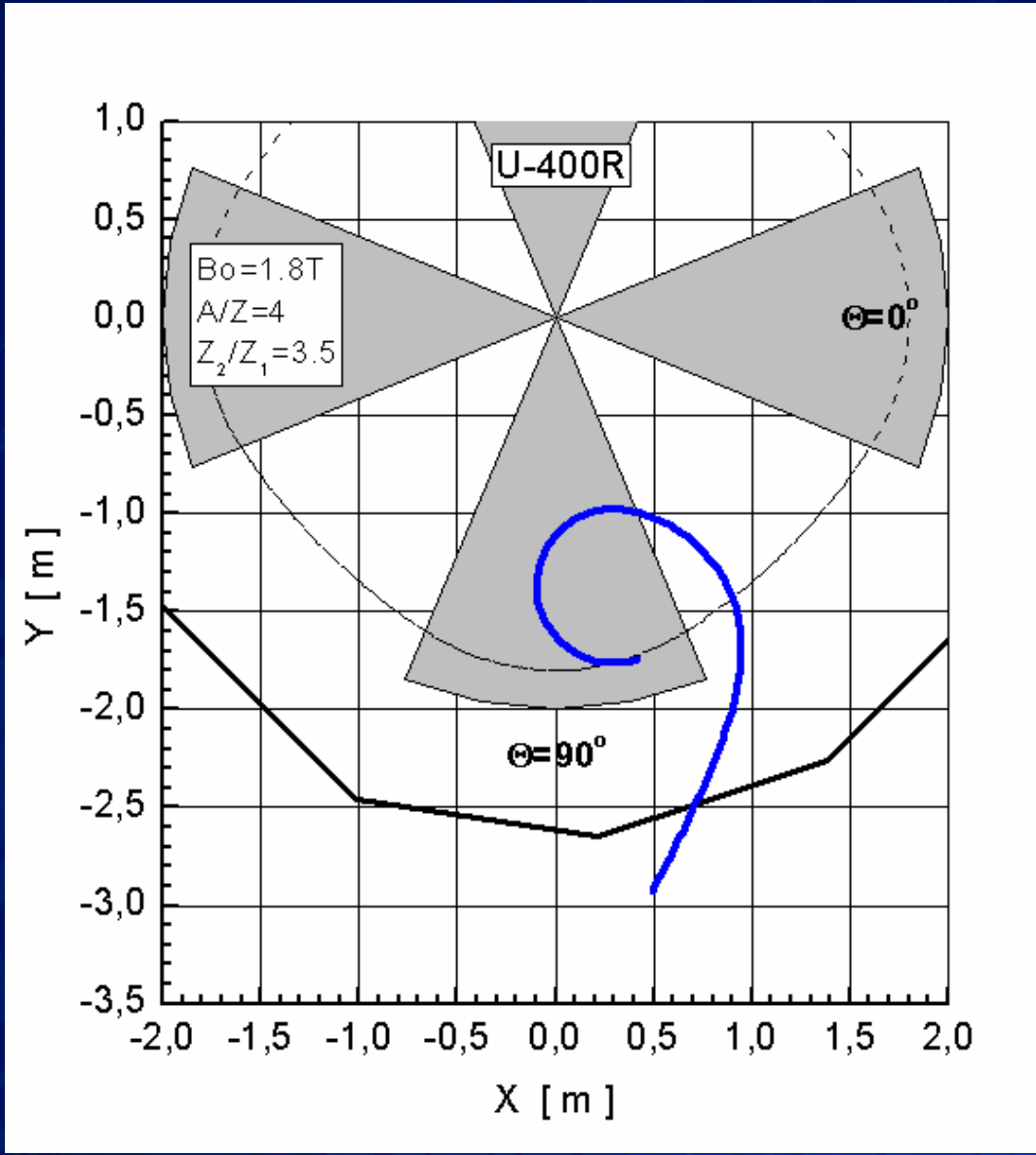
The method of heavy ion beam extraction from AVF cyclotrons was suggested by G.N. Vialov, G.N. Flerov and Yu.Ts. Oganessian in 1964 [1]



Academician of the RAS
G.N. Flerov

Academician of the RAS
Yu.Ts. Oganessian

[1] G.N. Vialov, G.N. Flerov, Y.Ts. Oganessian.. JINR Preprint • 1884, Dubna, 1964



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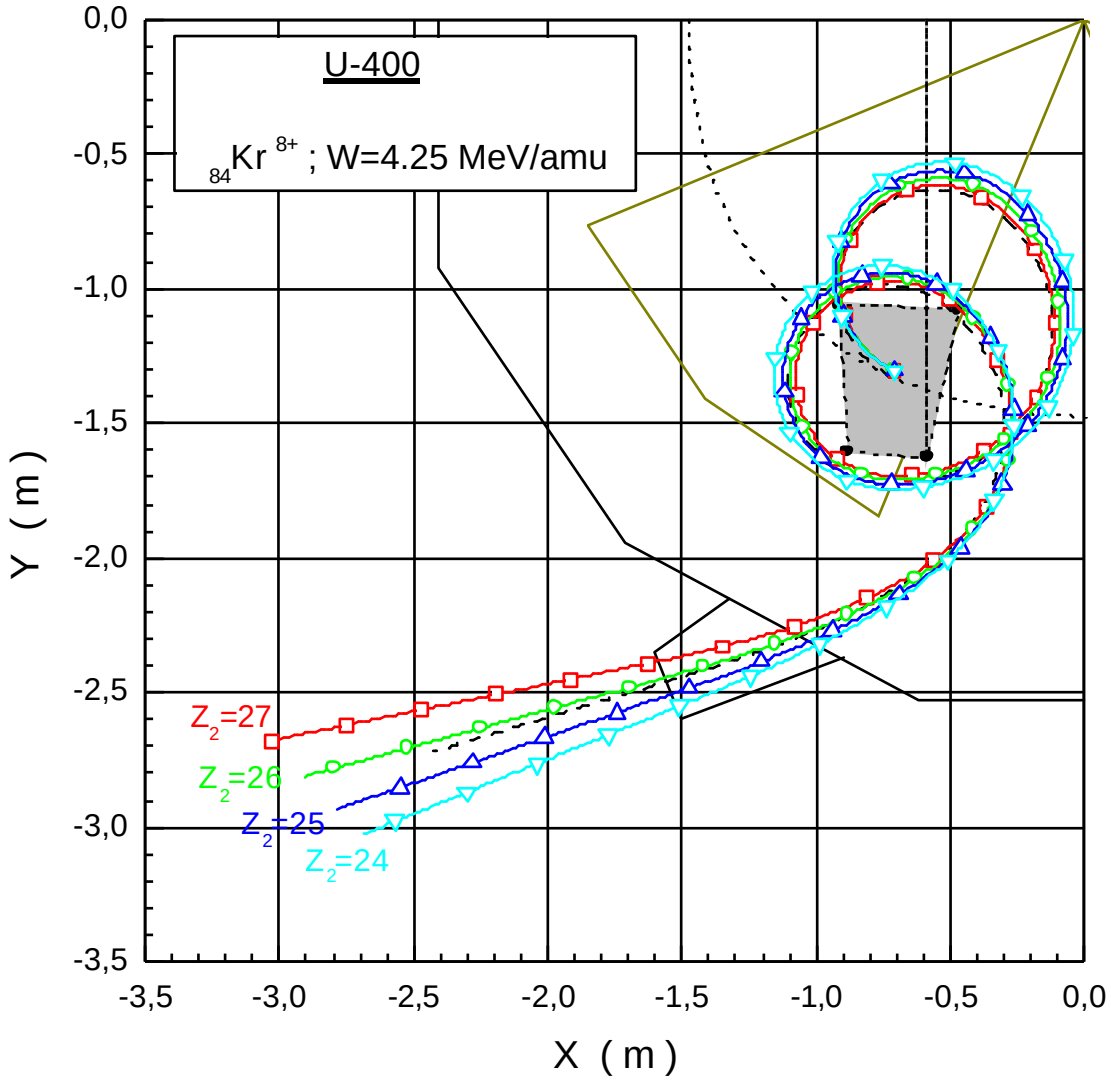


Two-turn extraction from U400

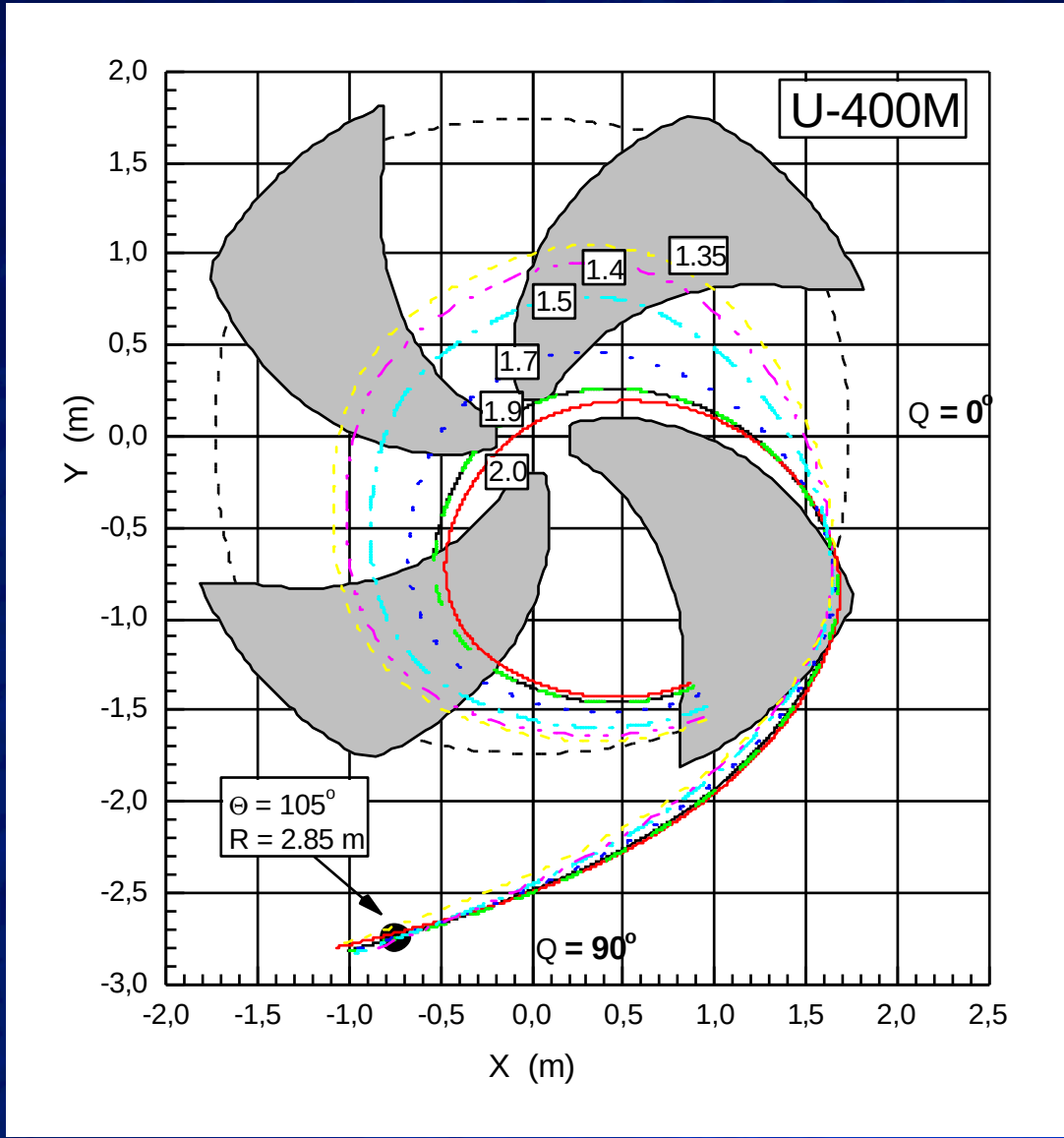
U400

some parameters of accelerated and extracted ion beams

Ion	Z_1	W Mev/amu	Z_2	Z_2/Z_1	EXT_{eff} %	I_{target} pμA
^{7}Li	1	8,6	3	3	100%	10
^{12}C	2	16,6	6	3	95%	6
^{40}Ar	4	5,1	16	4	50%	2
^{48}Ca	5	5,2	18	3,6	45%	1,5
^{136}Xe	15	5,5	42	2,8	25%	0,1

EXT_{eff} - extraction efficiency

I_{target} - the extracted beam intensity



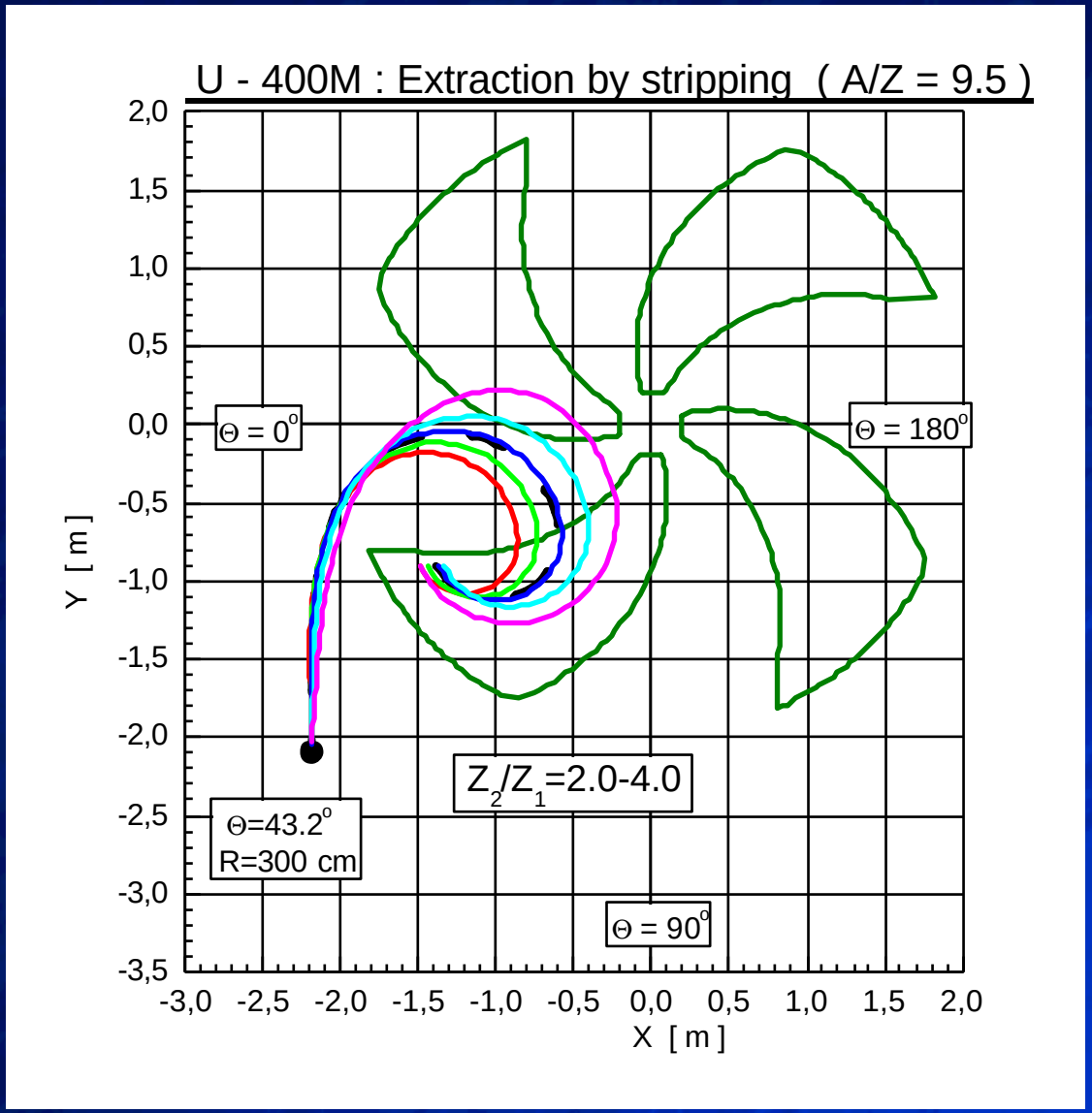
The reference particle trajectories of the ions extracted from U400M cyclotron by method 2

U400M
some parameters of accelerated and extracted ion beams

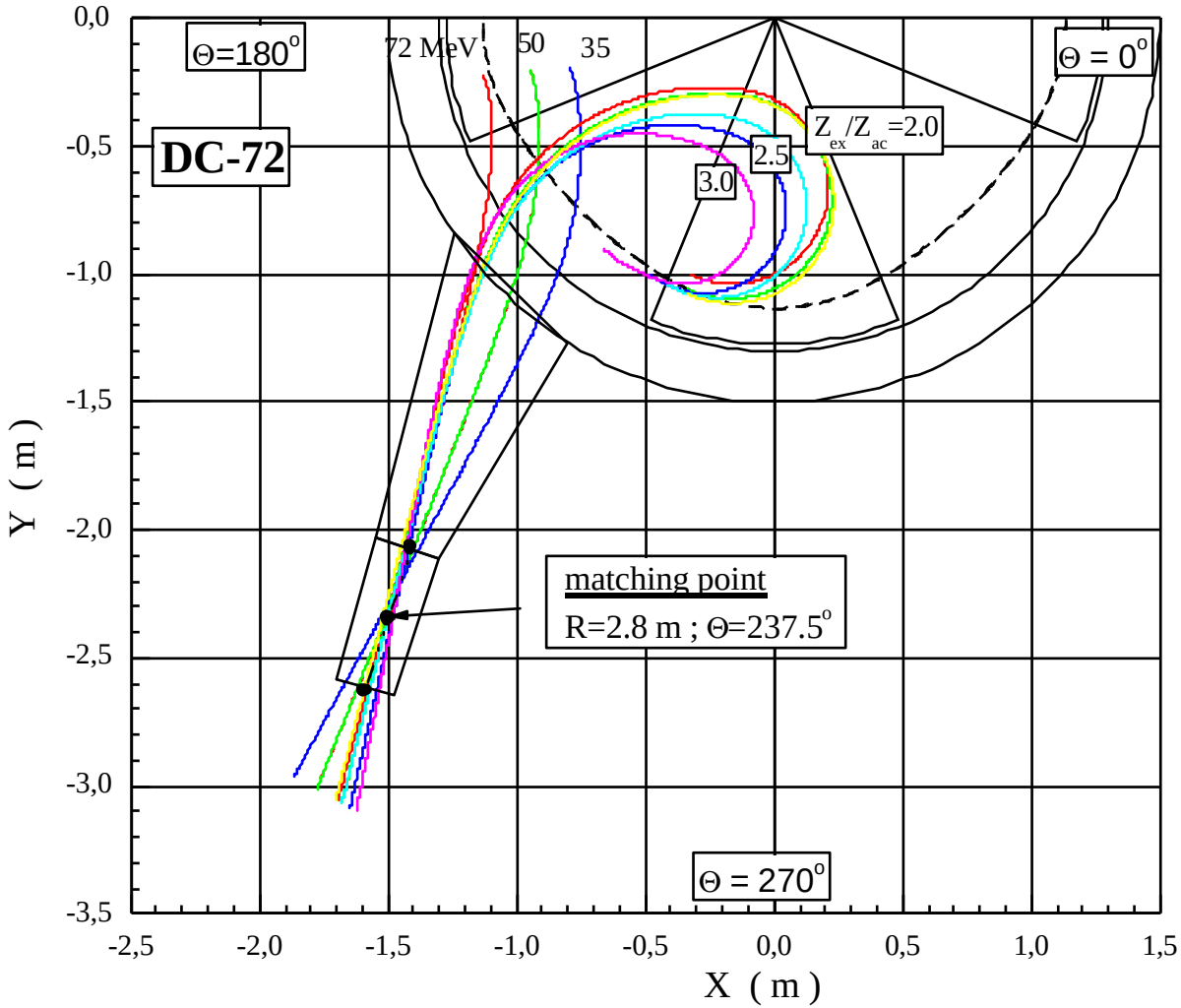
Ion	W Mev/amu	Z_1	Z_2	Z_2/Z_1	EXT_{eff} %	I_{target} pμA
^{7}Li	35	2	3	1,50	100	10
^{11}B	32	3	5	1,66	100	10
^{15}N	50	5	7	1,40	95	2
^{20}Ne	43	7	10	1,43	90	1.3
^{40}Ar	40	13	18	1,38	70	0.1

EXT_{eff} - extraction efficiency

I_{target} - extracted beam intensity



The trajectories of the low energy ion beams extracted from U400M cyclotron by method 1



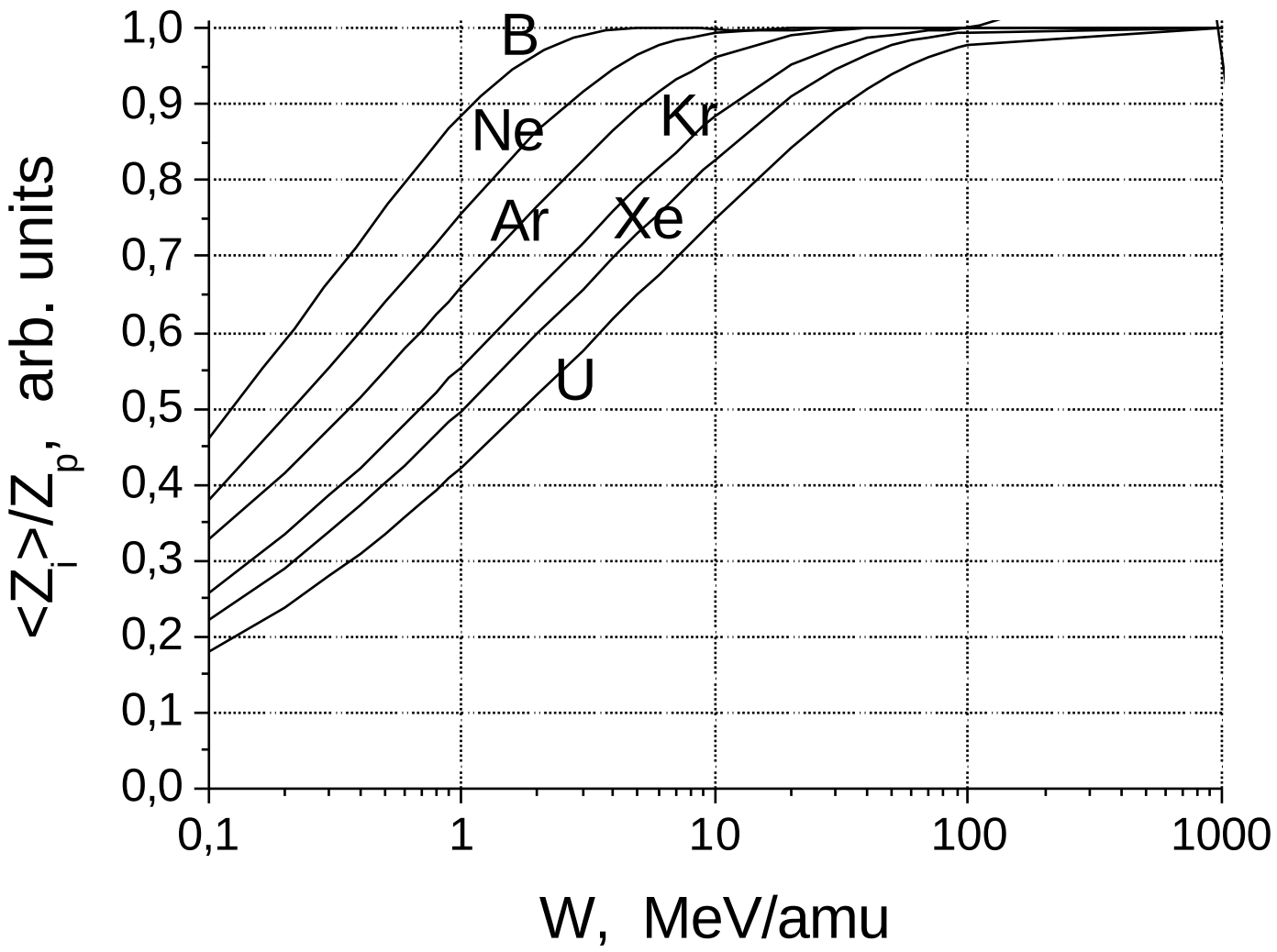
Reference trajectories of the ions extracted from DC-72 cyclotron

STRIPPING FOILS

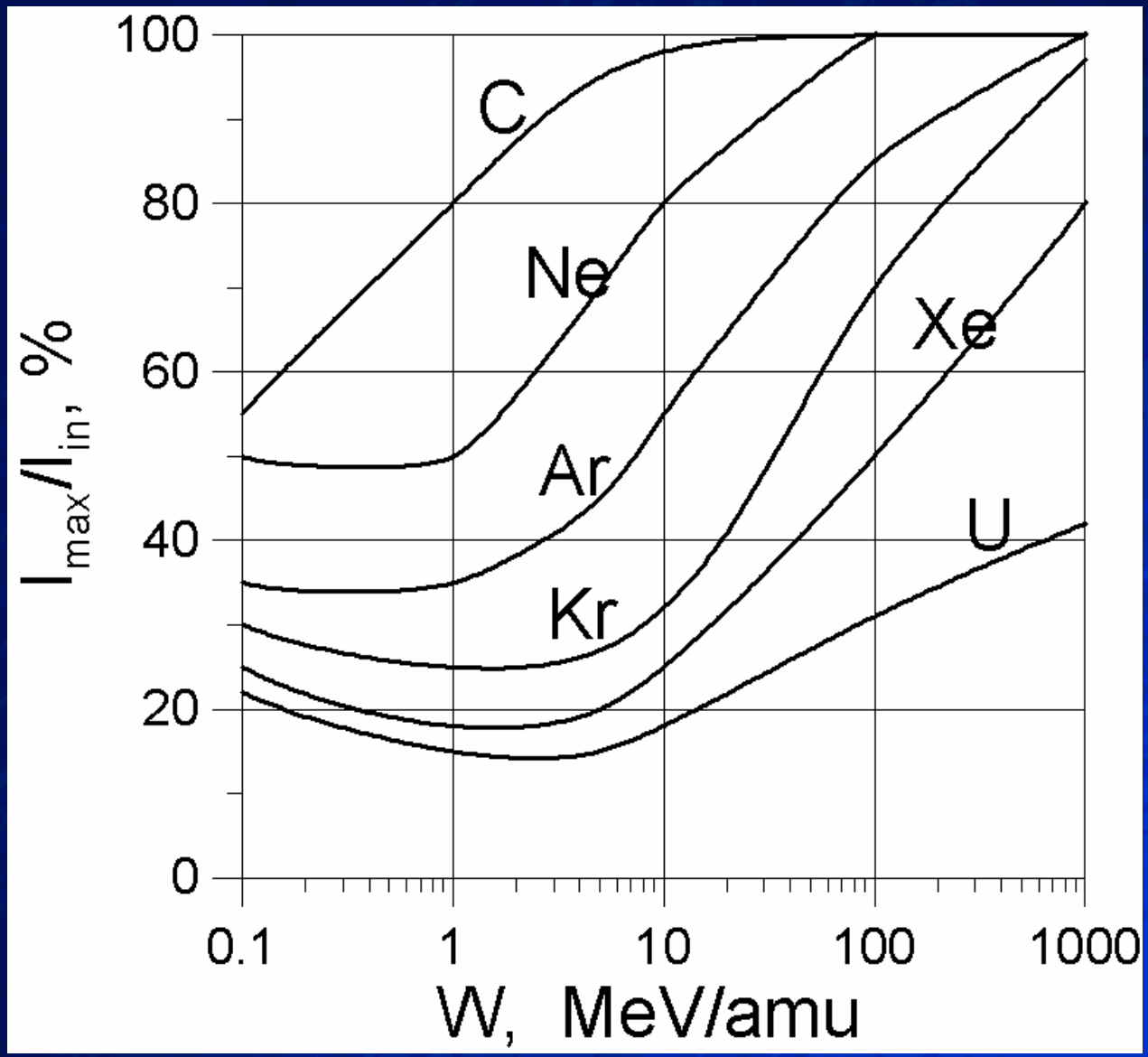
Be, C, Al, Al_2O_3, mailar

For every accelerated ion there is so called “equilibrium thickness” of the foil at which increasing the charge distribution does not change but the angle scattering keeps on growing

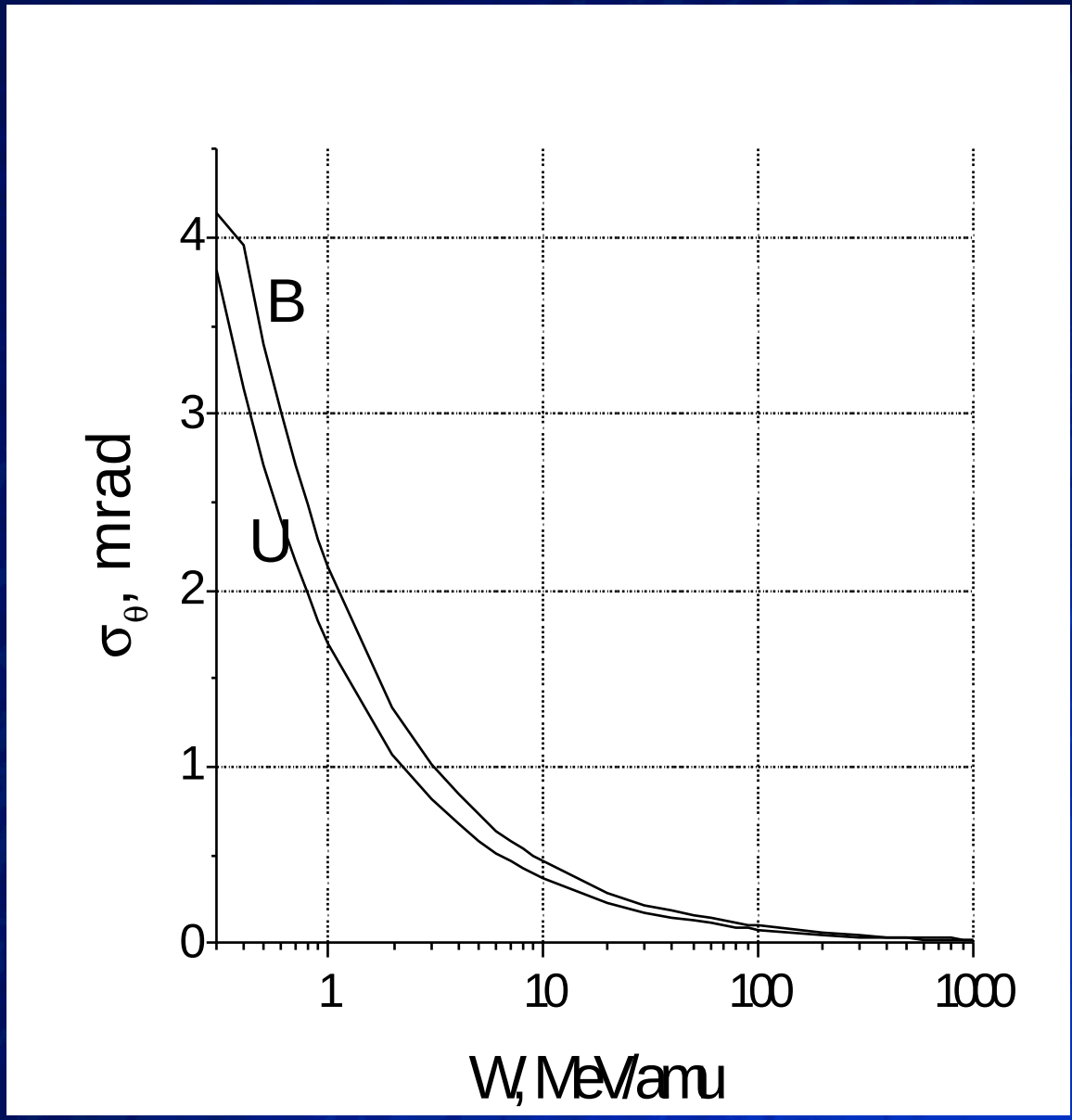
- $\infty \left[mg \cdot cm^{-2} \right] \approx 30 \cdot W^{0,6} \left[MeV / amu \right]$



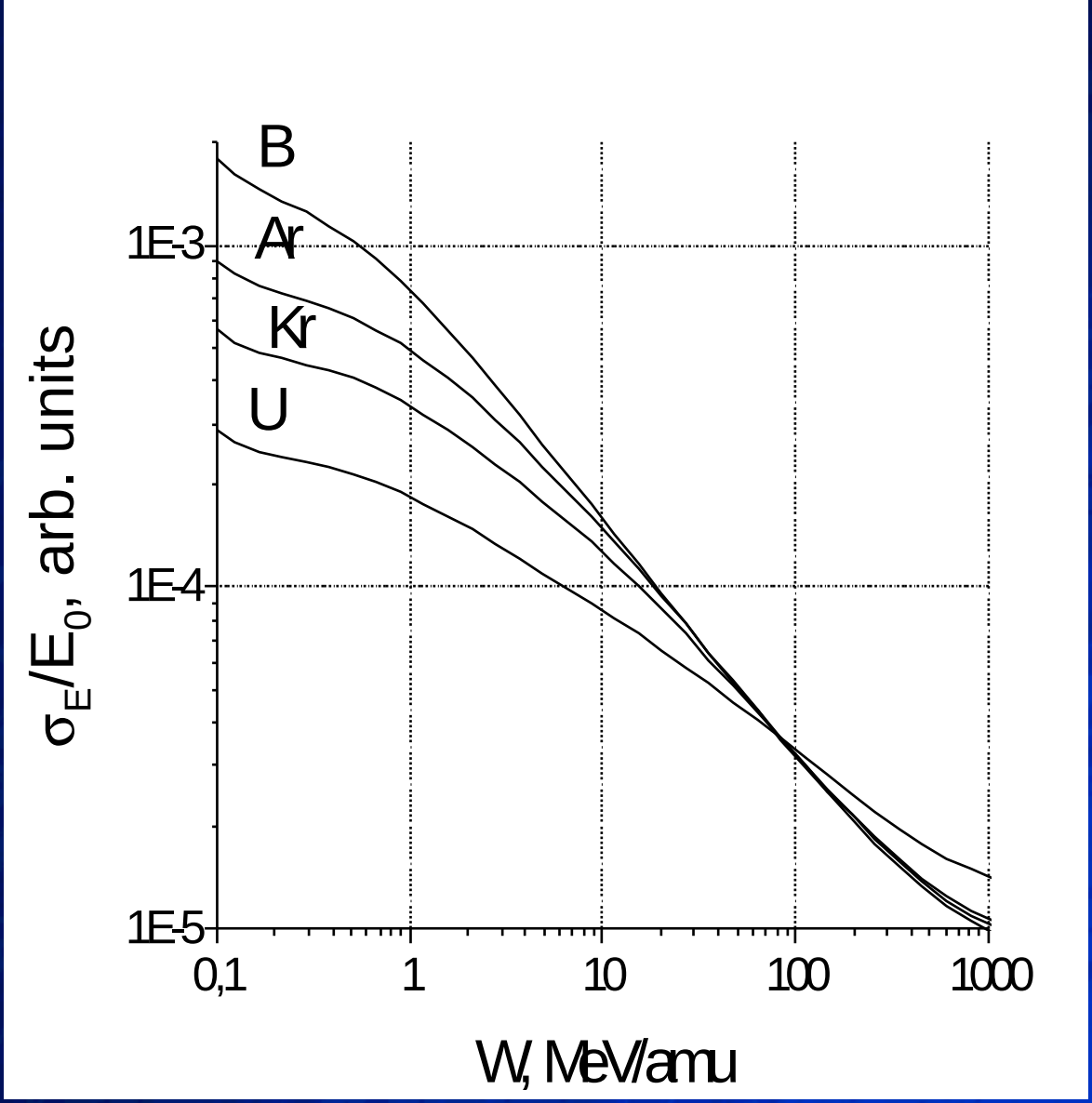
Dependence of the ion stripping degree on the ion energy



Dependence of the maximum efficiency of a single charge extraction by stripping versus the ion energy



Dependence of the scattering angles for B and U in the carbon foils having the equilibrium thickness



Additional energy spread of the extracted ion beam

RADIATION DAMAGE

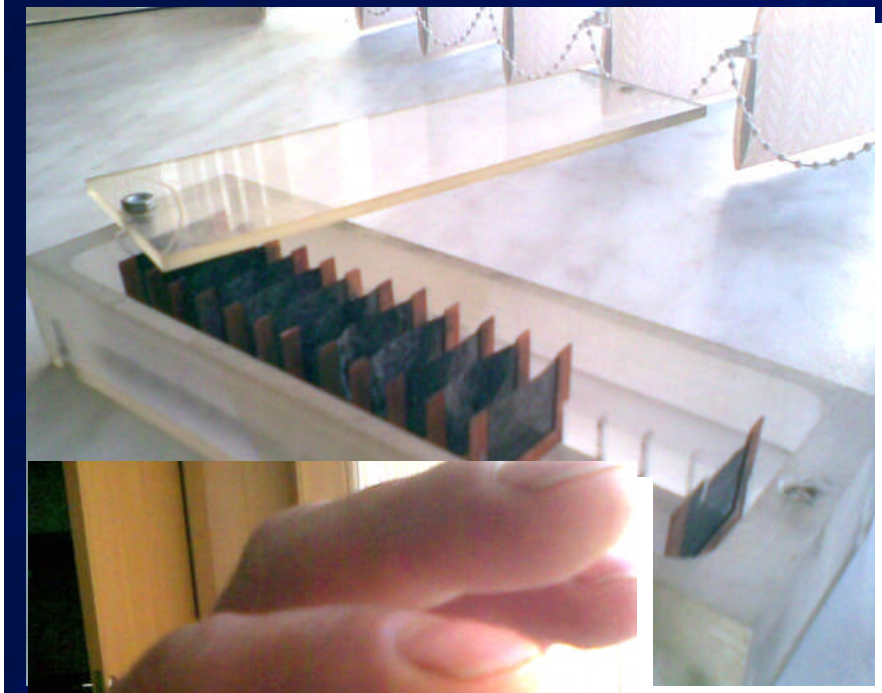
Estimation of the foil lifetime

$$T\ [\text{hours}] \approx (3 \div 6) \cdot 10^3 \frac{W\left[\frac{MeV}{amu}\right]}{Zp^2 \cdot j\left[p\text{m}A \,/\, cm^2\right]}$$

Z_p - ion element number,

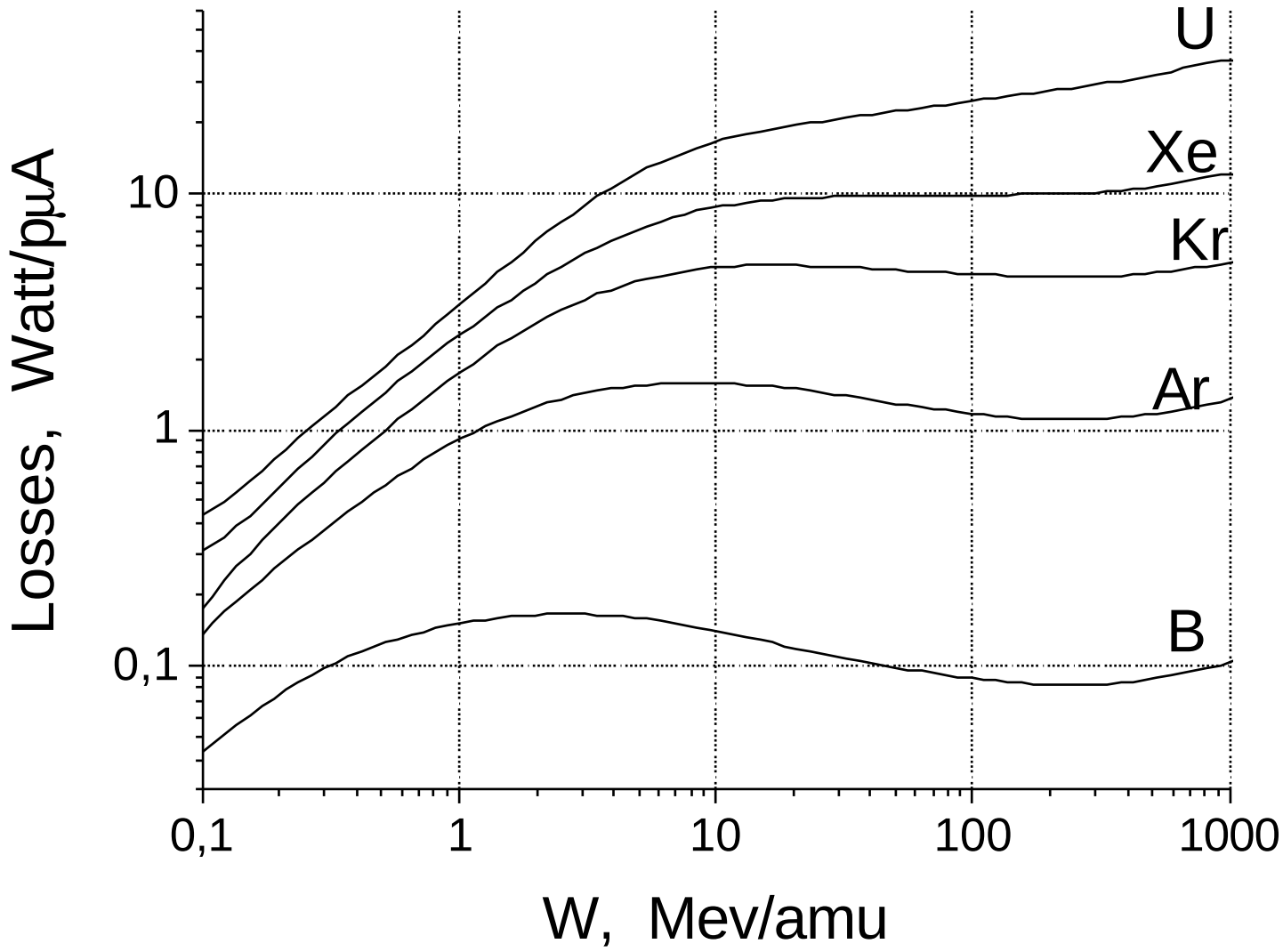
W - ion energy,

J - beam current density.

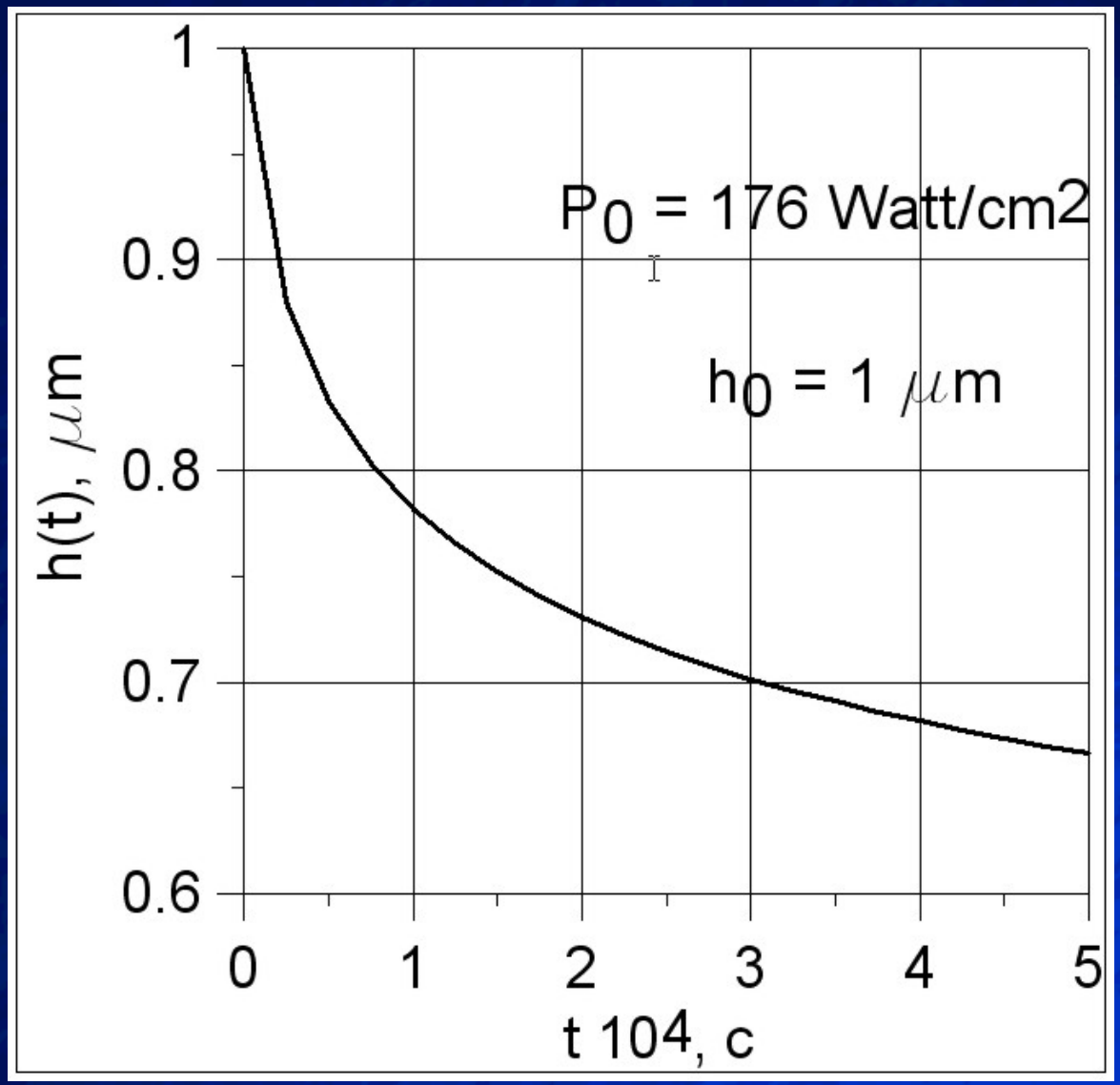


The stripping foil before using

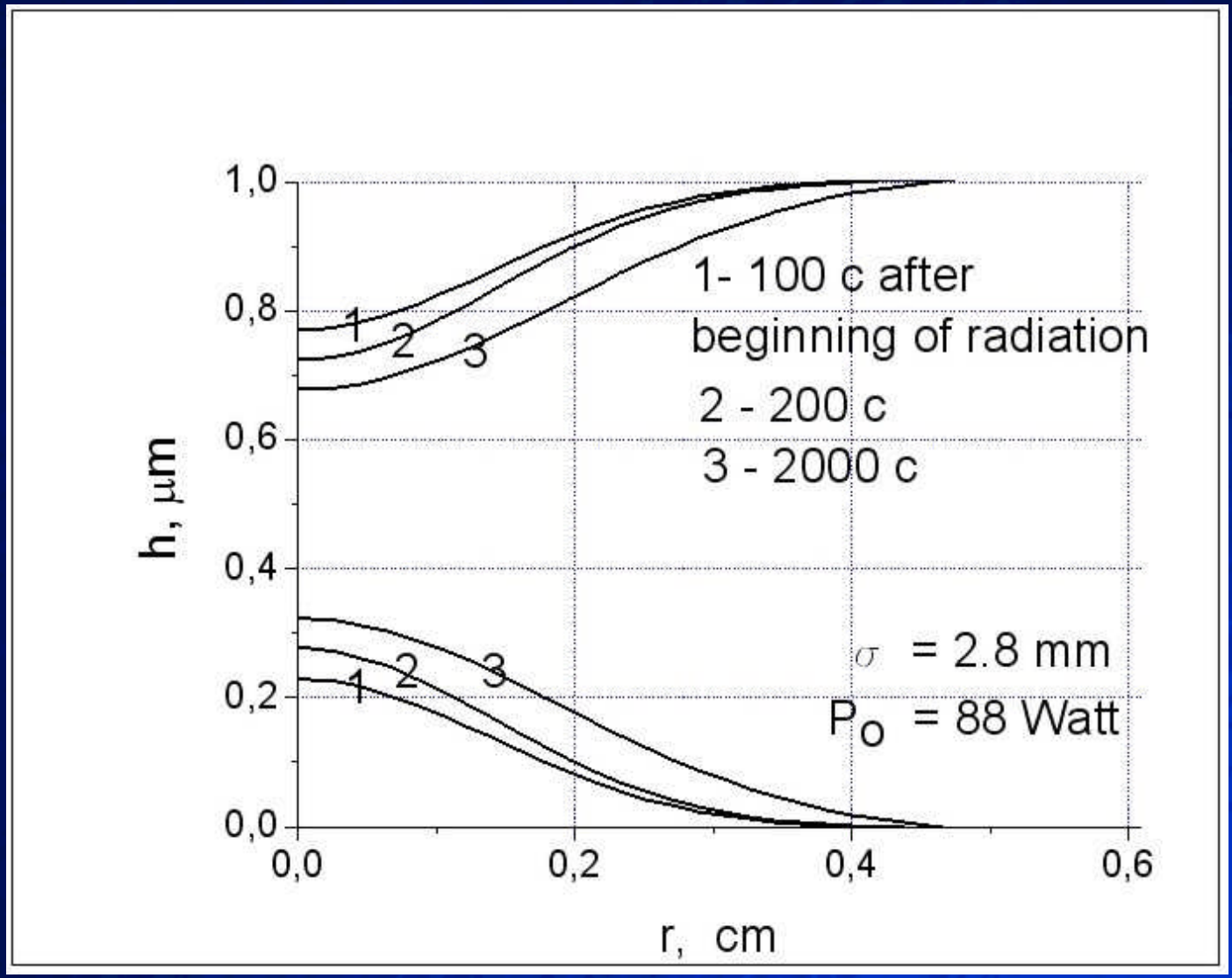
Probe head of U400 cyclotron with the stripping foil



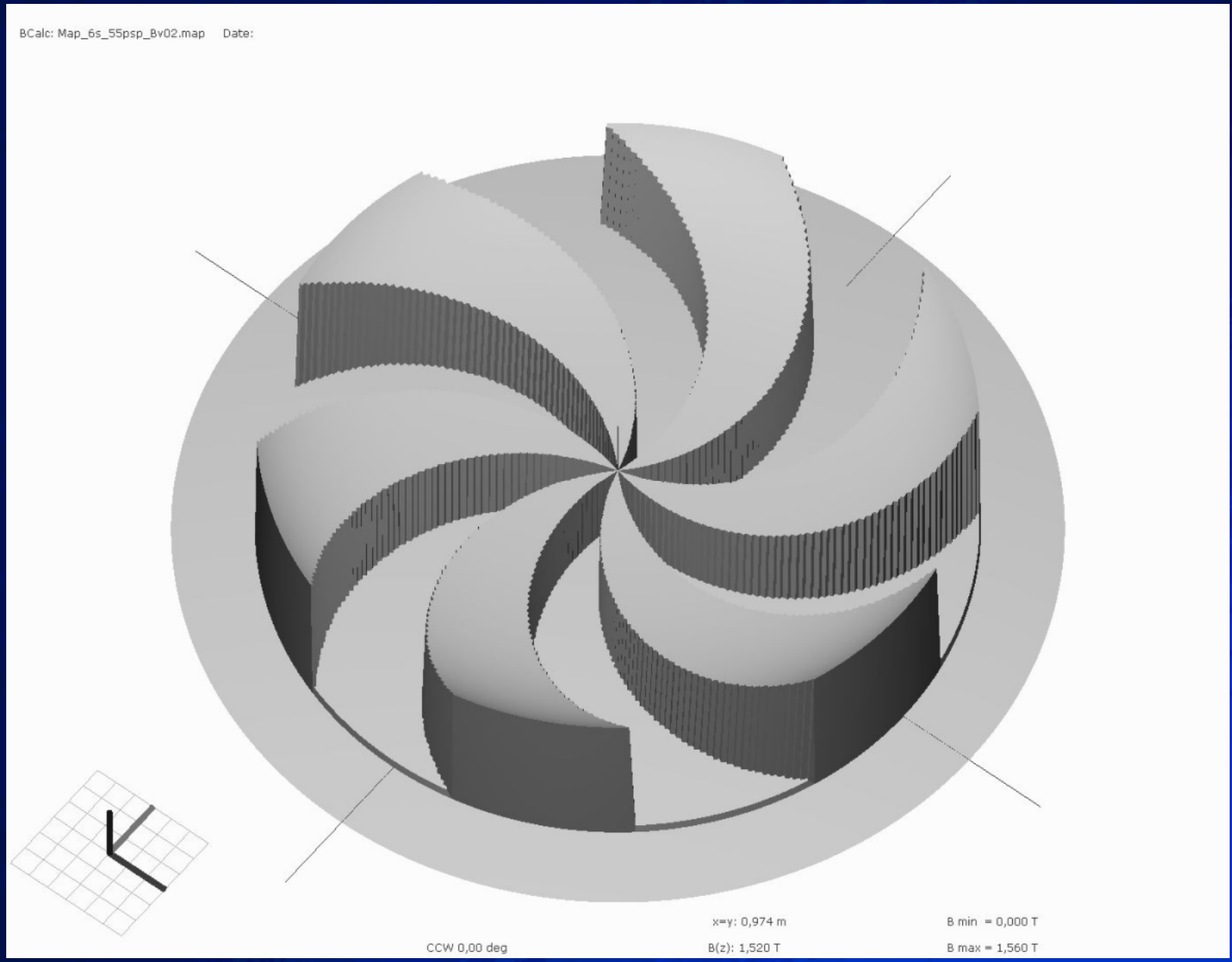
Power losses of the ion beam in the stripping foil



Thermal evolution of the carbon foil thickness



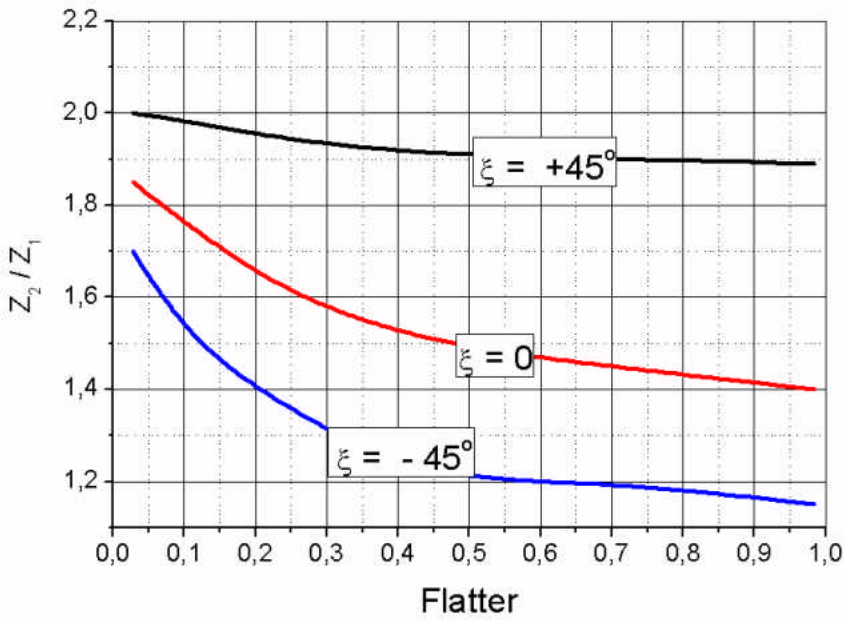
Thermal evolution of the carbon foil with thickness 1 μm by the beam having Gaussian distribution

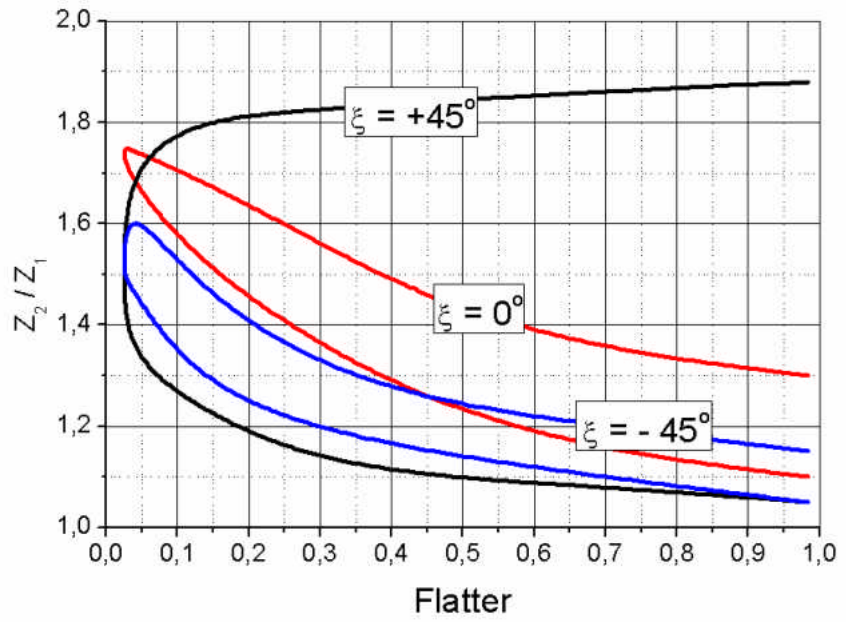


6-sector cyclotron model

Certainly this information is only an indication that there is a possibility of the beam extraction by stripping especially near the region borders. Simulation of the trajectories and envelopes must be carried out in real magnetic fields

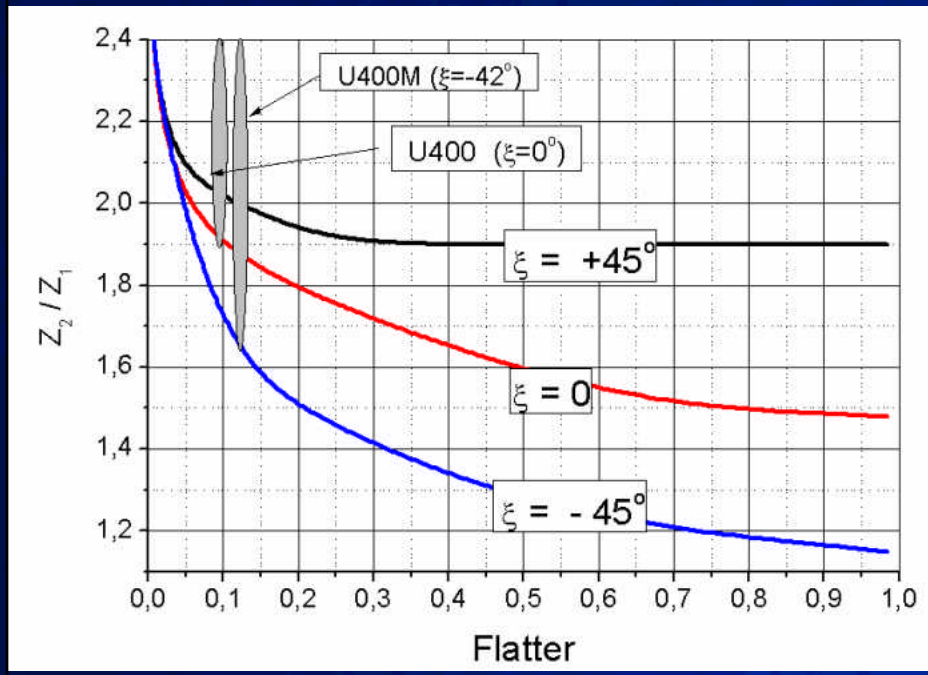
N3, M1, • = 1.01, • = 0;±45°	A	N3, M2, • = 1.01, • = 0;±45°	B

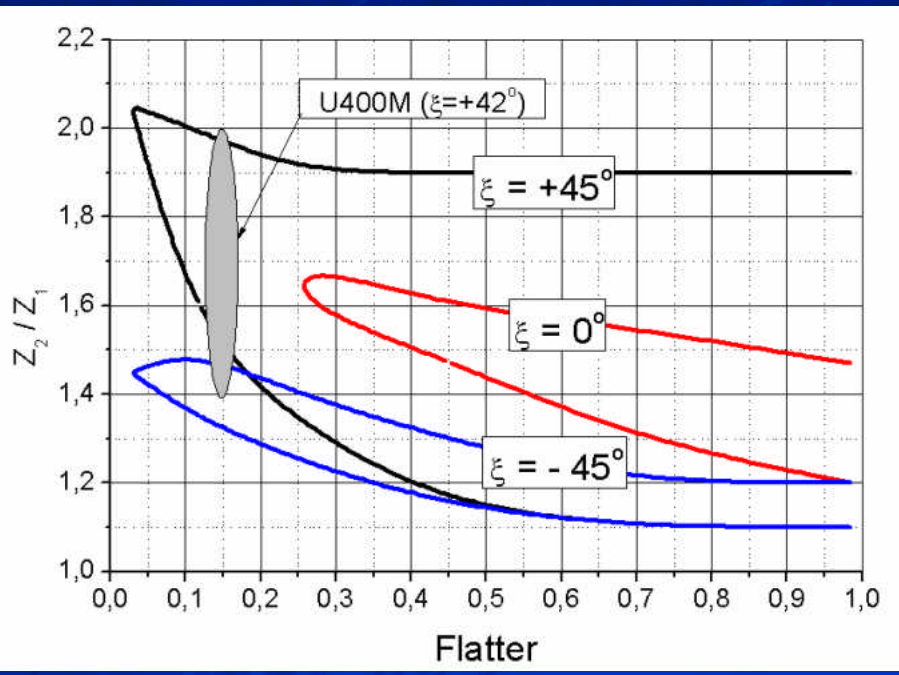




Simulation results for borders of the admissible stripping coefficient (1/4)

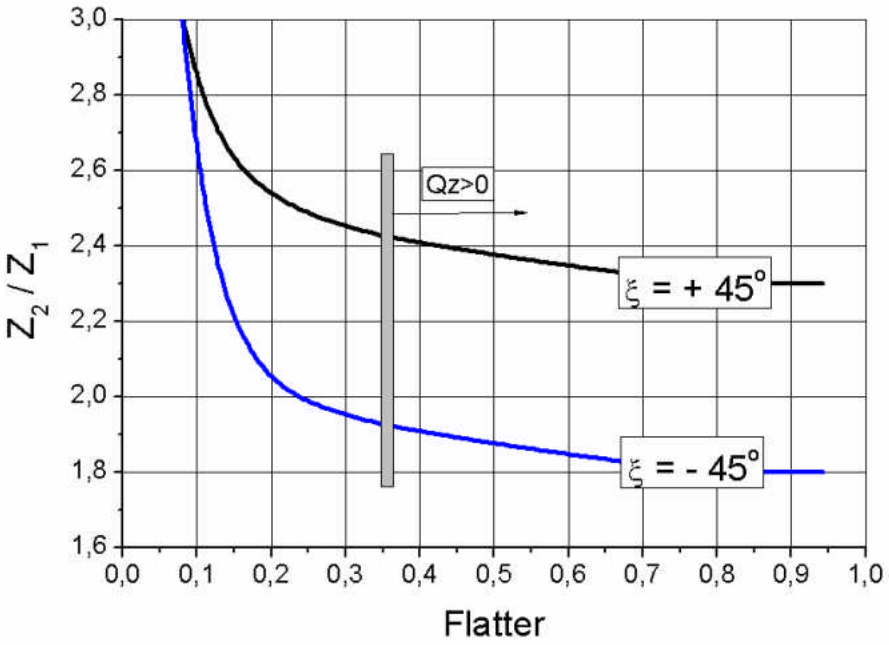
N4, M1, • = 1.01, • = 0; ±45º	C	N4, M2, • = 1,01, • = ±45º	D

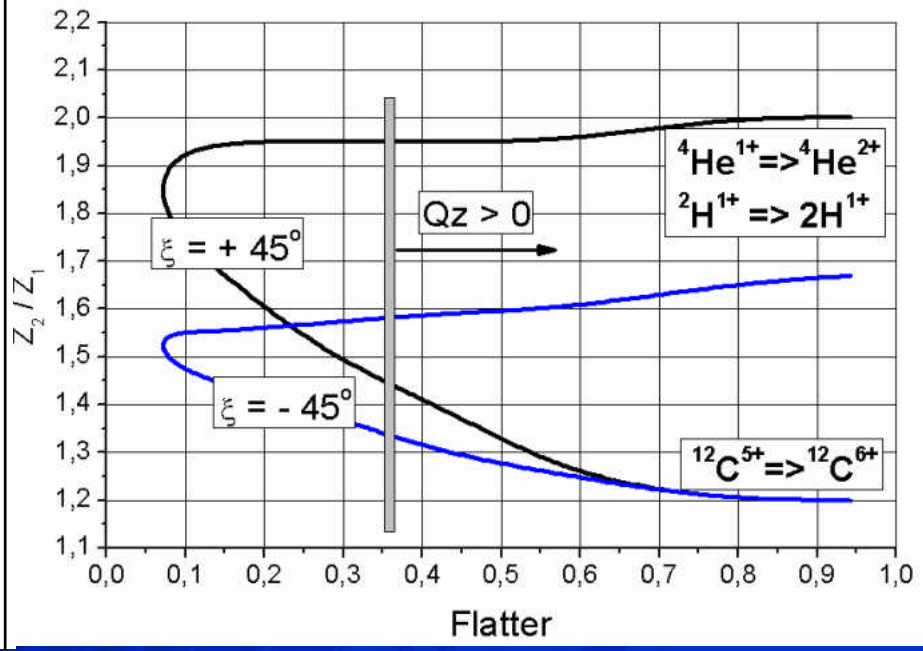




Simulation results for borders of the admissible stripping coefficient (2/4)

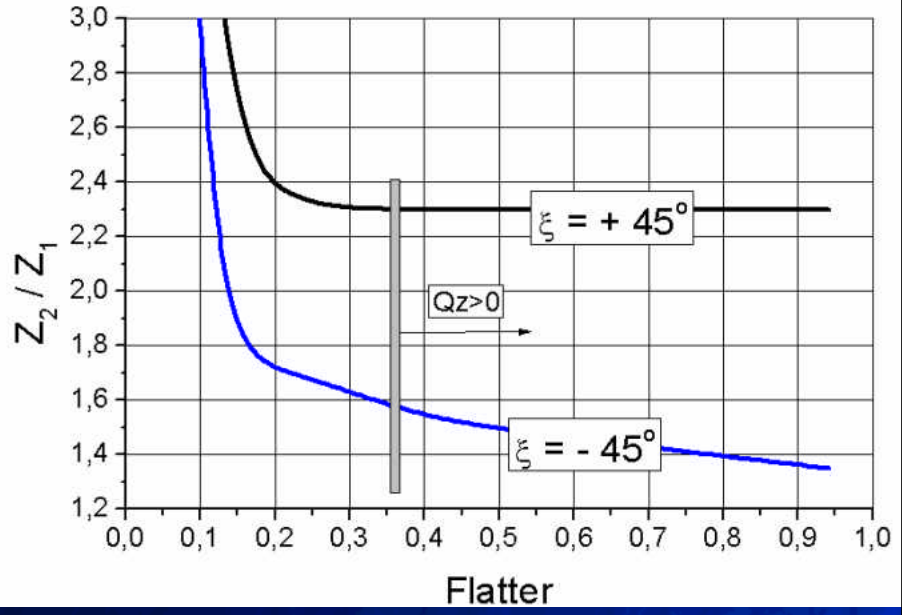
N4, M1, • = 1,43, • = ±45°	E	N4, M2, • = 1,43, • = ±45°	F

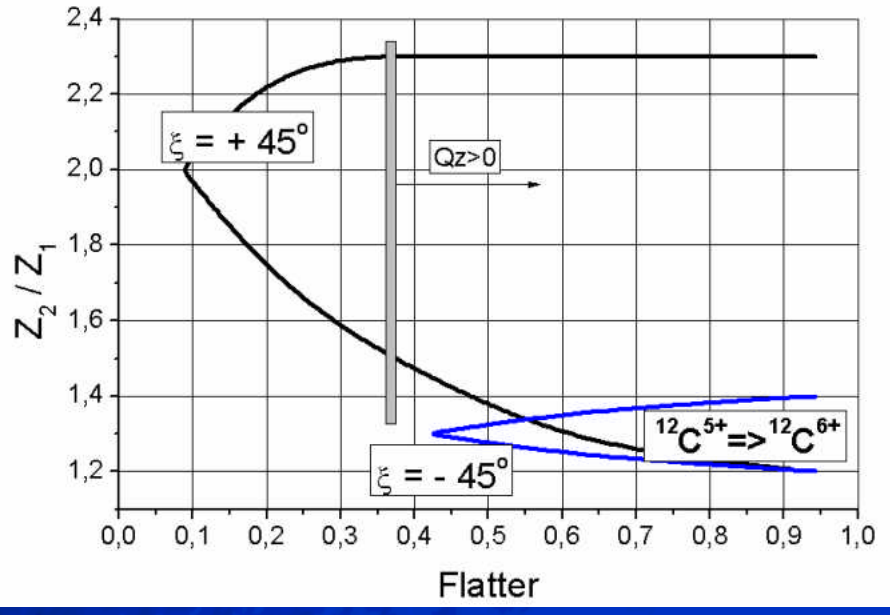




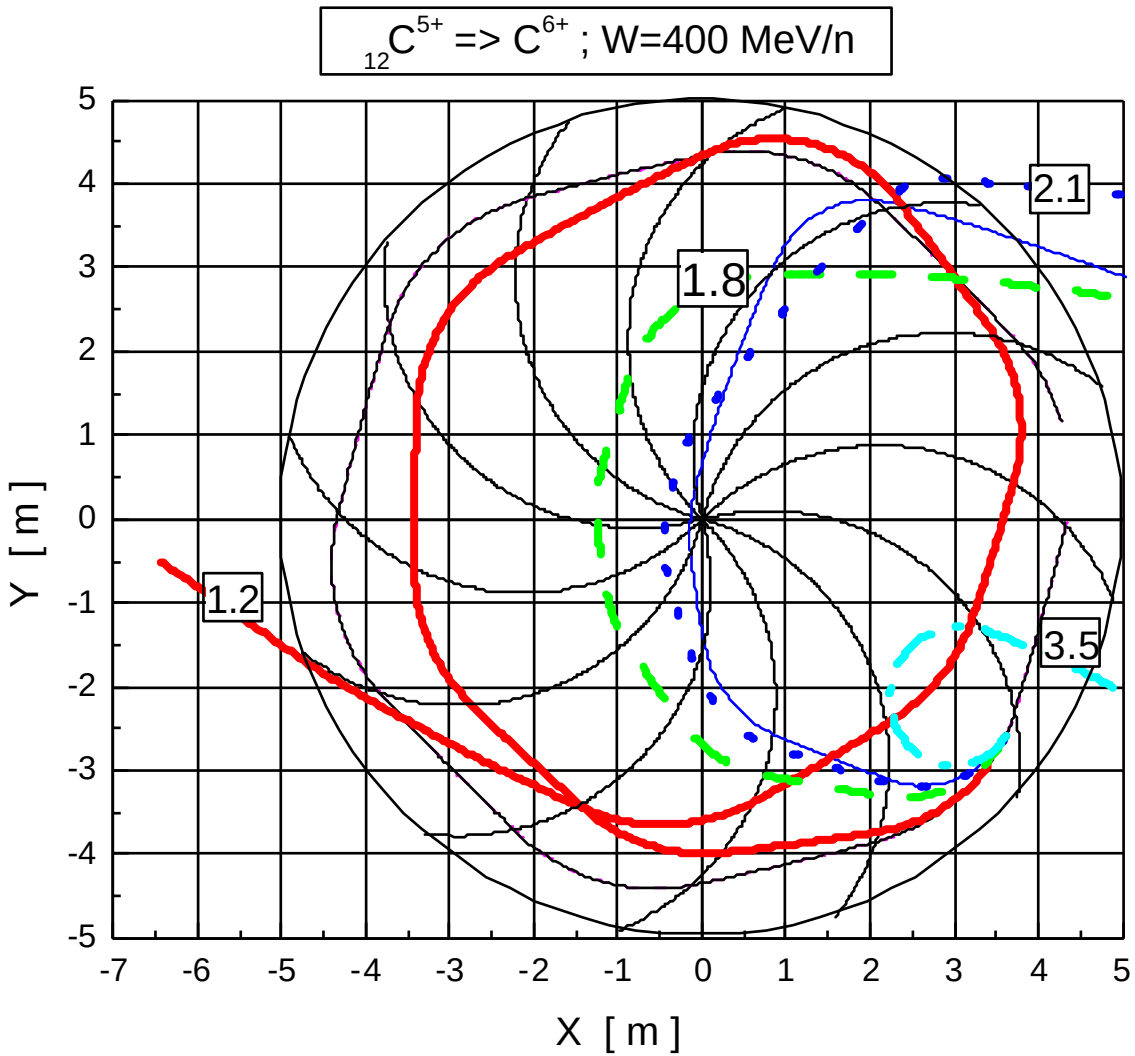
Simulation results for borders of the admissible stripping coefficient (3/4)

N6, M1, • = 1,43, • = ±45º	G	N6, M2, • = 1.43, • = ±45º	H





Simulation results for borders of the admissible stripping coefficient (4/4)



Extraction trajectories by stripping (N6, •=1.43, •=+45•, flatter=1)

CONCLUSION

- Extraction of the heavy ion beams by stripping from AVF cyclotrons is convenient in realization. The extraction efficiency of sum of the charges after stripping is about 100% and for a single charge it is from 20 up to 100% in dependence of the ion type and energy.
- The stripping foil weekly affects on the extracting beam quality. The foil lifetime can be well estimated by the radiation damage. Under high power losses (> 150 W/cm^2) sublimation of carbon defines the foil lifetime.
- The magnetic structure type of AVF cyclotron strongly affects on the possibility of the ion extraction by stripping. It is possible to extract by stripping the ion beams ^{12}, $^{5+}$, $^{6+}$, $_2^{1+}$, ^{2}, $^{1+}$, ^{4}, $^{1+}$, $^{2+}$ with the energy 400 MeV/amu from 4 and 6-sector AVF cyclotrons

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THANKS FOR YOUR ATTENTION

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