Study of grid optimalization for fusion neutron source

Tomáš Skřivan **Jáchym Sýkora**
tutor: Bc. Daniel Krasnický

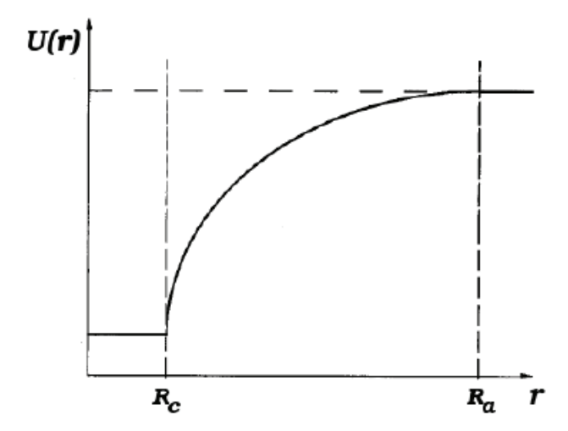
Fusion neutron source

Fusion neutron source is source of fast neutrons based on crashes between two high energy deuterium nucleus, which result in nuclear reaction.

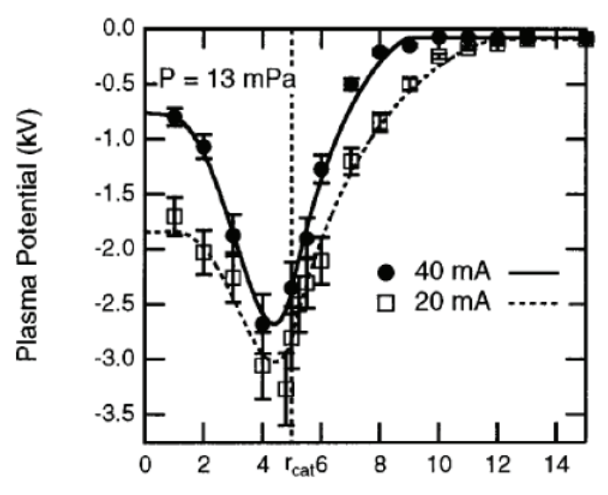
This nuclear reaction has two results, which have same chance to happen:

$$^2H + {}^2H \rightarrow {}^3He\,(0,82MeV) + n\,(2,45MeV)$$
$$^2H + {}^2H \rightarrow {}^3H\,(1,01MeV) + p\,(3,02MeV)$$

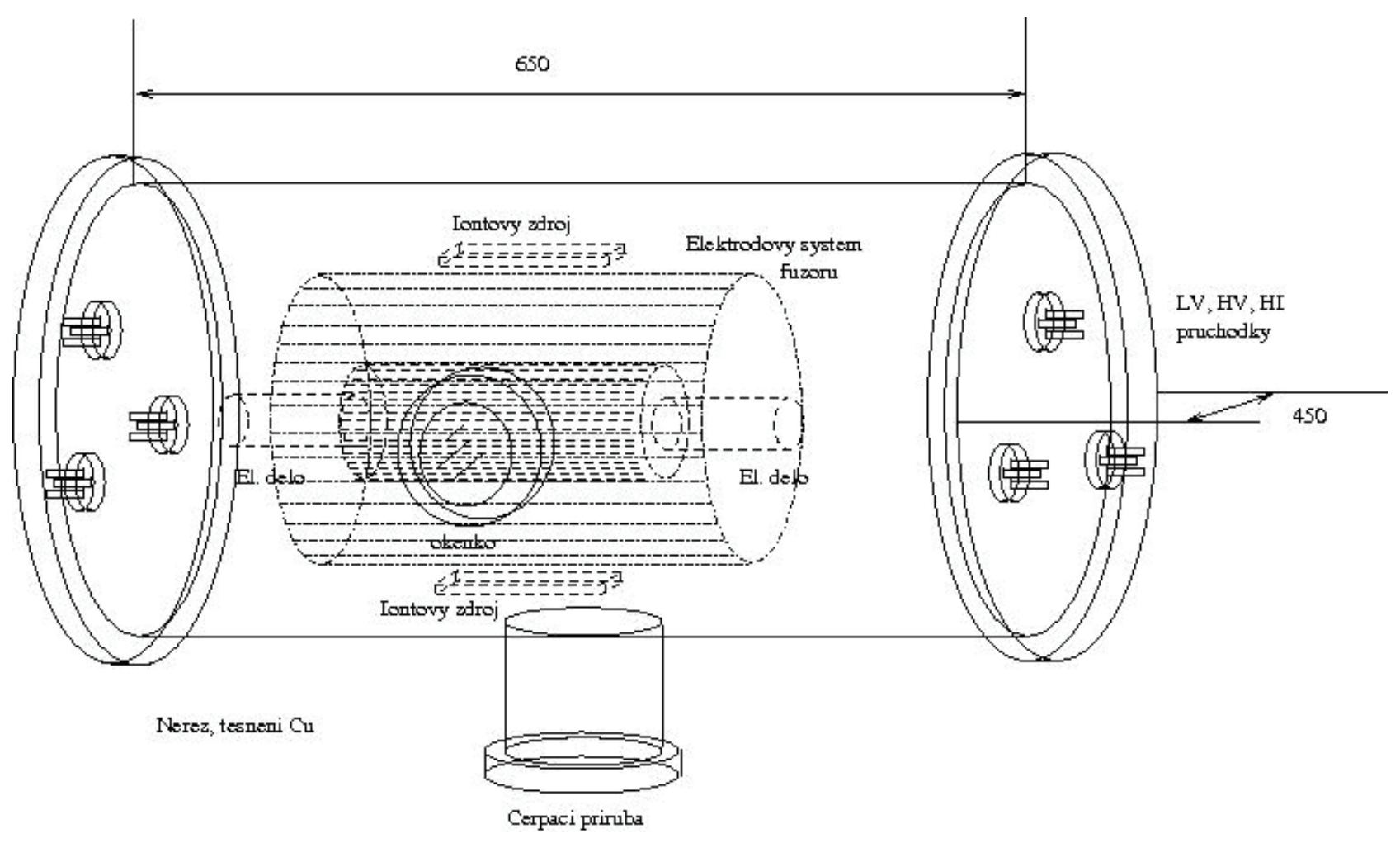
Ideally, when anode and cathode is compact and absolutely transparent grid, there is no ion-cathode collision and ions are accelerated right to the center of apparatus. Real, we have wire grid. Ions are colliding with the grid and with background gas. And irregularity of the grid cause inaccurate focusing. Big density of ions in the center create volume charge (so-called virtual anode pic. 2), which also cause inaccurate focusing. Virtual anode is one of the main occasions of small amount ion-ion collisions.



pic. 1 This graph shows ideal electric field in apparatus. [2]

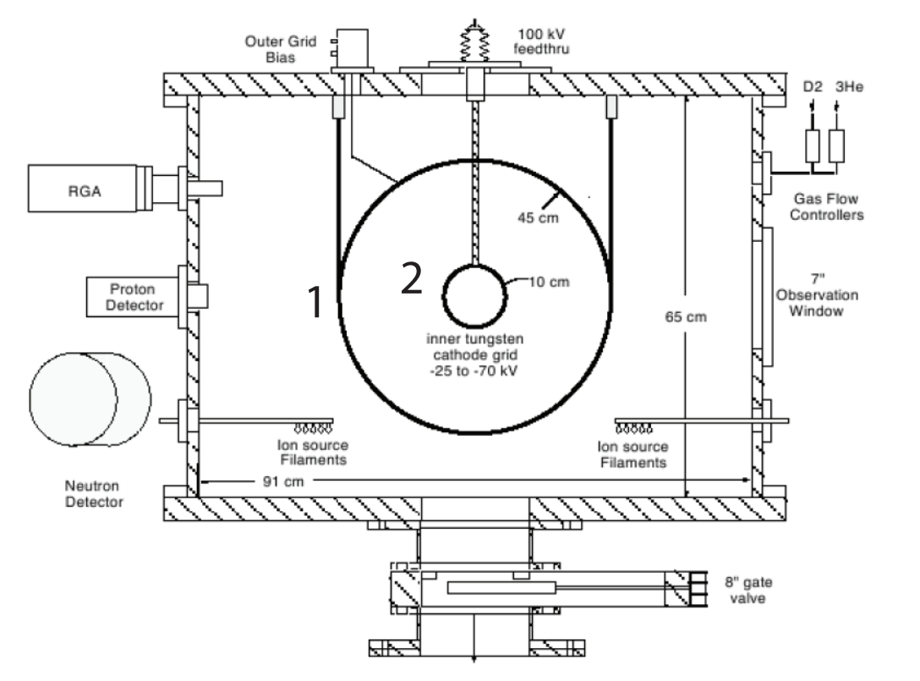


Pic. 2 This graph shows measured electric field inf fusion neutron source at Wisconsin University. [3]



Pic. 3 Scheme of on-coming fusion neutron source at FJFI-CVUT

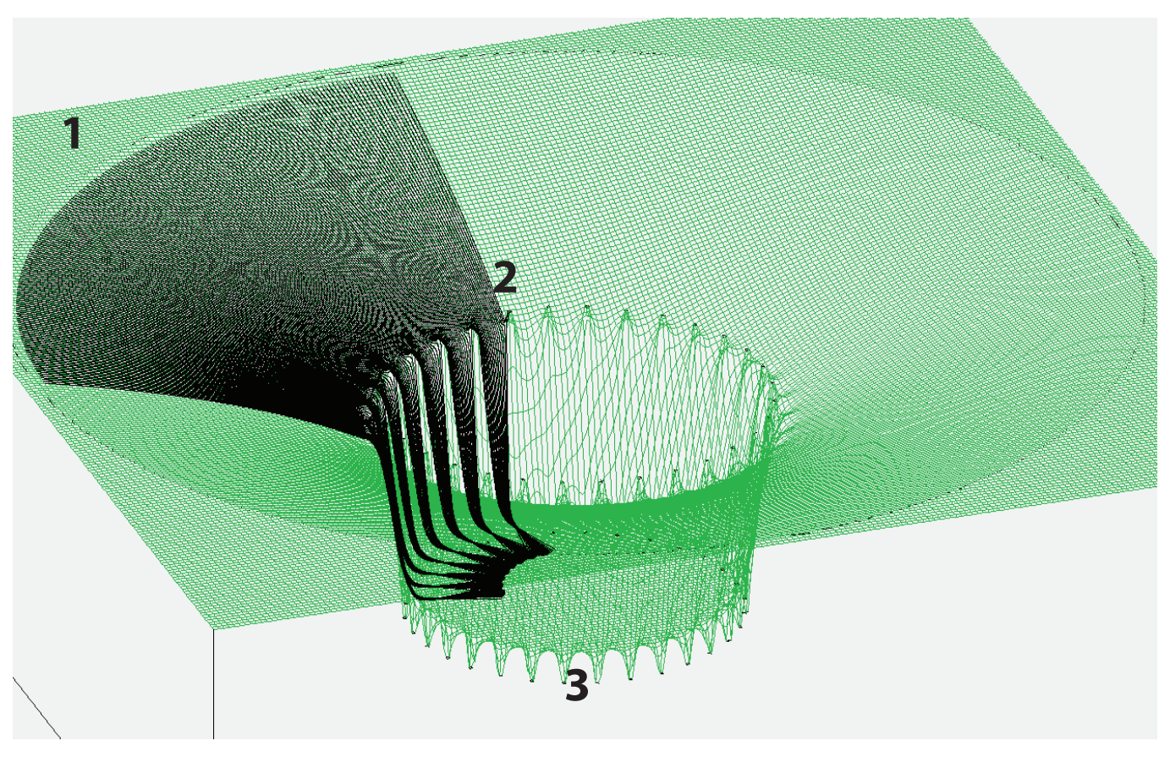
Majority of previous experiments used spherically convergent ion focus model but we chose cylindrical convergent ion focus model (Pic. 3). This brings us several advantages. We are able to create more accurate electrostatic fields. Grid manufacturing is very easy. And we can partially solve problem with virtual anode, by inject electron beam to decrease positive charge (virtual anode) in center of apparatus.



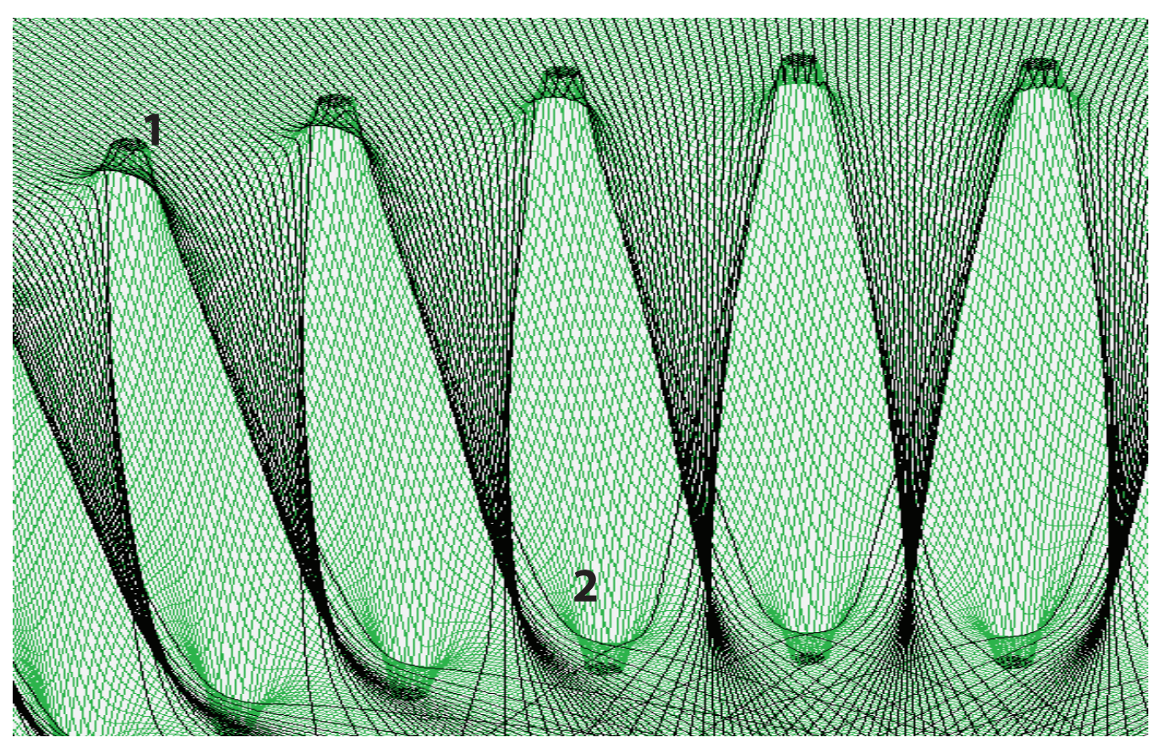
Pic. 4 Scheme of fusion neutron source at Wisconsin University. 1-anode 2-cathode [1]

Double grid

We achieved the best results with so-called double grid (principle of double lens pic.8,9). With right settings of voltage on middle grid, we can get ion beam focus point to the apparatus center, this is not possible with simple grid. With double grid we can achieve even ten times better results.



Pic. 8 Scheme of electric field with double grid, height shows electrical potential.
1-anode (0 V), 2-middle grid (-15kV),
3-inner grid (-50kV)



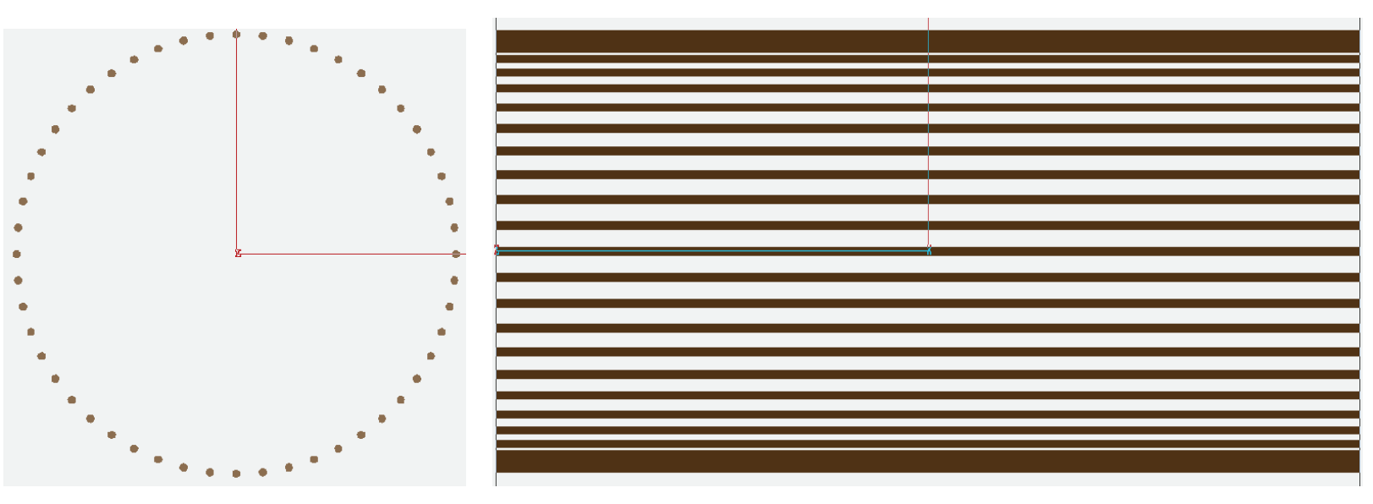
Pic. 9 Double grid zoom in.
1- middle grid (-5kV), 2- inner grid (-50kV)

wires	0 transits	R [mm]	n/R	P
32	38	1.1.2000	161.29	0.15
92	100	0.22	449.74	0.36
132	142	0.10	557.25	0.43
12_double	26	0.03	5127.28	0.99

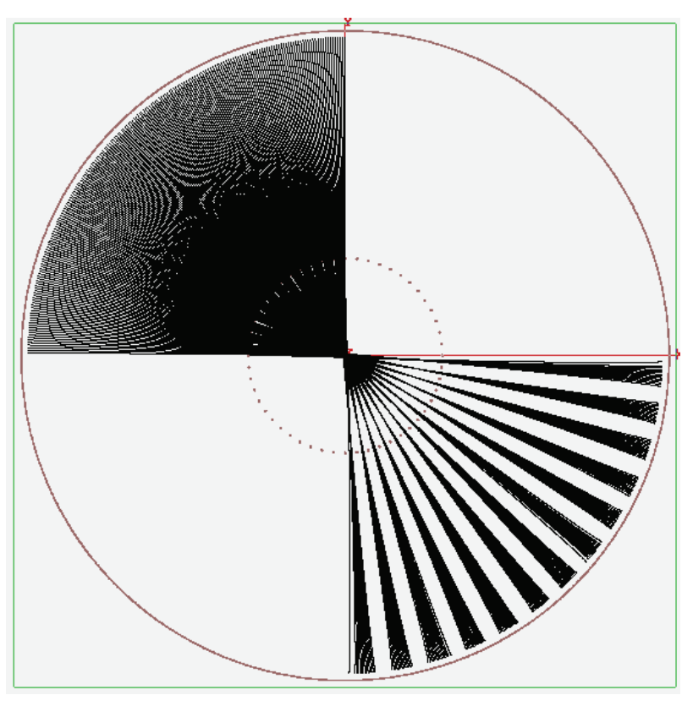
Here we can see comparison between simple grids and double grid (12_double - 12 wires). We achieved ten times better results, because we fit the focus point in the apparatus center.

Simion

To investigate grids behavior we used program Simion 8.0. Simion simulates ions flows in electrostatic field. We investigated few different types of grids and their combinations. The best grid is formed from several wires arranged to a cylinder (pic. 5).

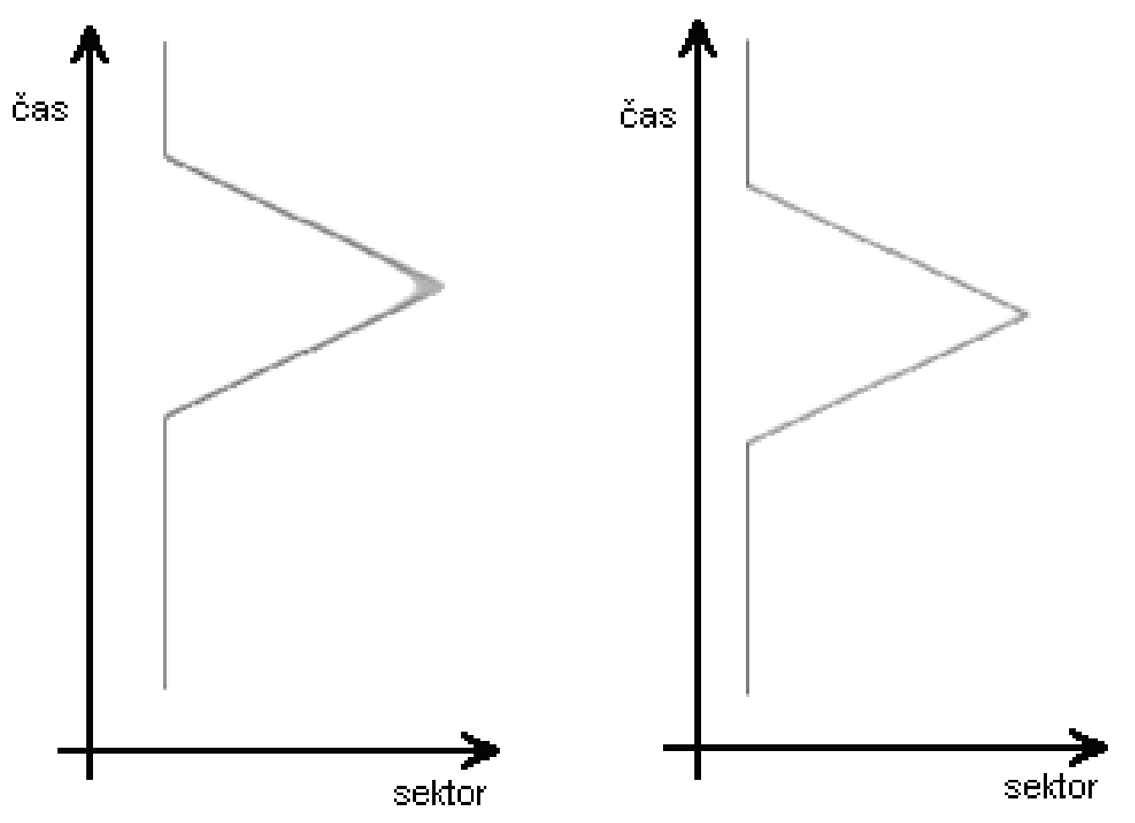


Pic. 5 Example of the best type of grid (front and side view)



Pic. 6 Example of one ions transit through apparatus center. Simion simulation preview.

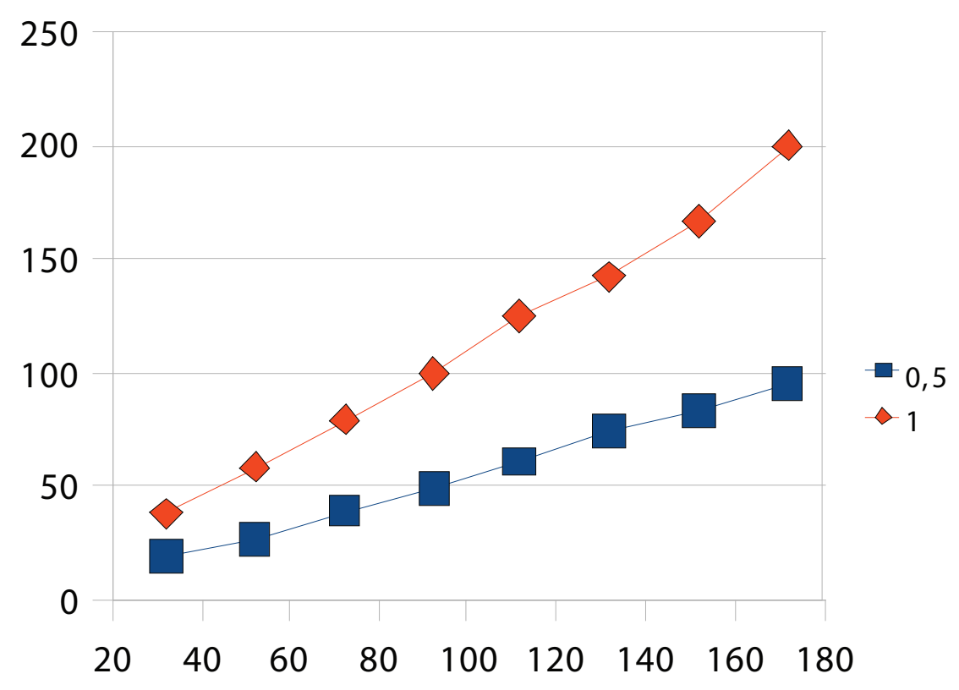
We needed to learn, how many wires and which thickness we need to achieve the best results. That means, grid which has sufficient transparency and focusing.



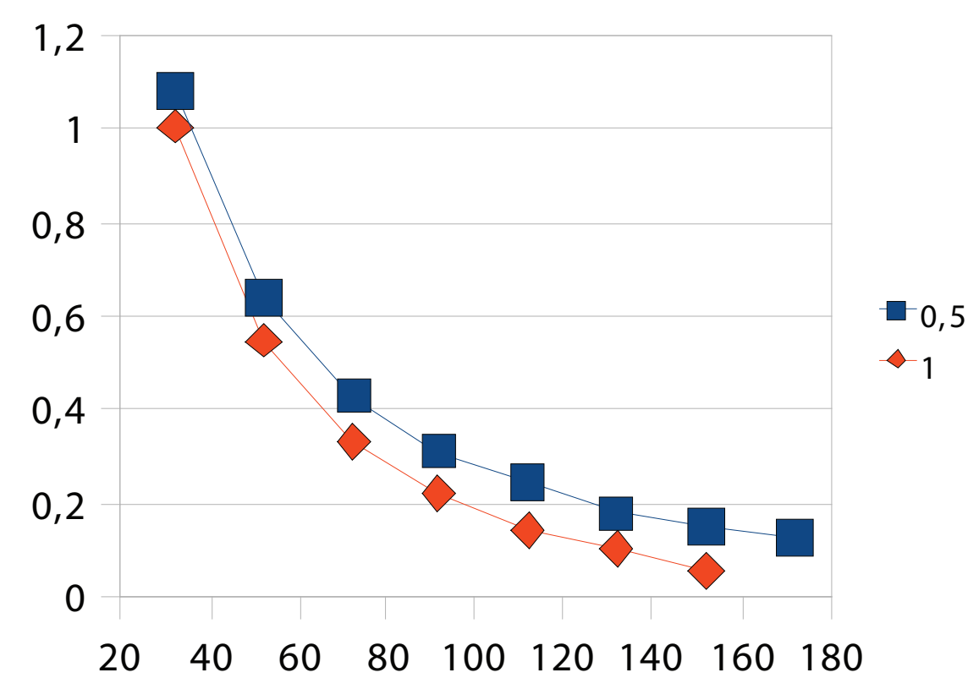
Pic.7 Exemplary graph of focusing. Grid with 32 wires (left) and with 92 wires (right). Vertical axis shows time. Horizontal axis shows a distance between ion and the center of apparatus (to the right decrease the distance from center). And intensity shows ion quantity. Grid with 92 wires much more concentrate ions in the center.

Grid optimalization

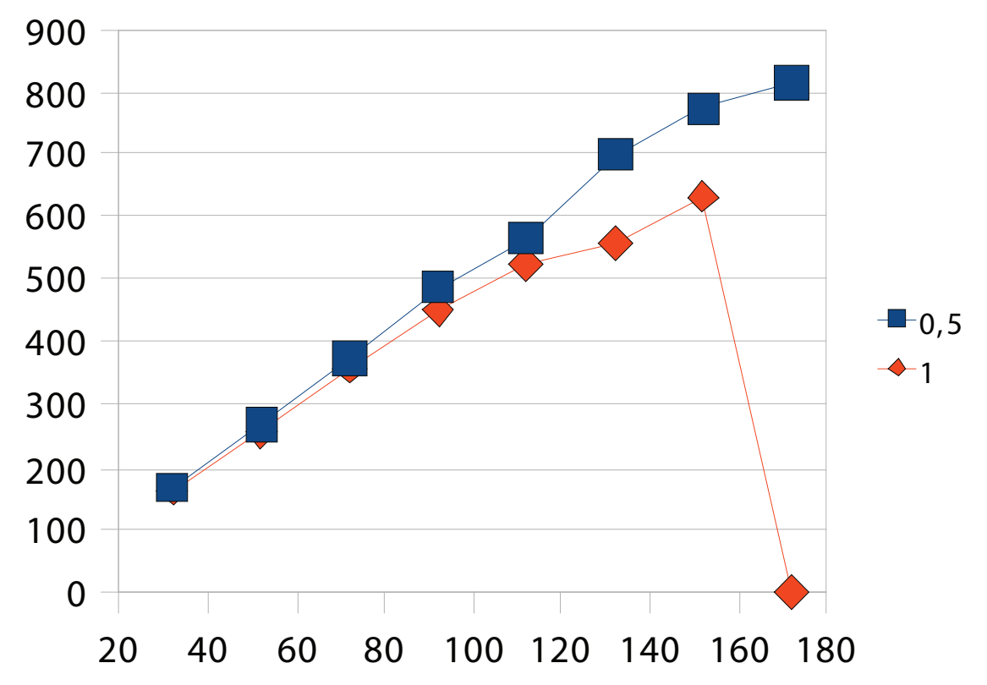
Data, which we were recording due the simulations, shows us how many ions made how many transits. Also we were recording the radius (R) of smallest circle that all ions crossed. This radius shows us a dispersion of a ion beam. From these values we get additional numbers (n/R, P s. graph 3,4), which help us to decide, which grid is the best.



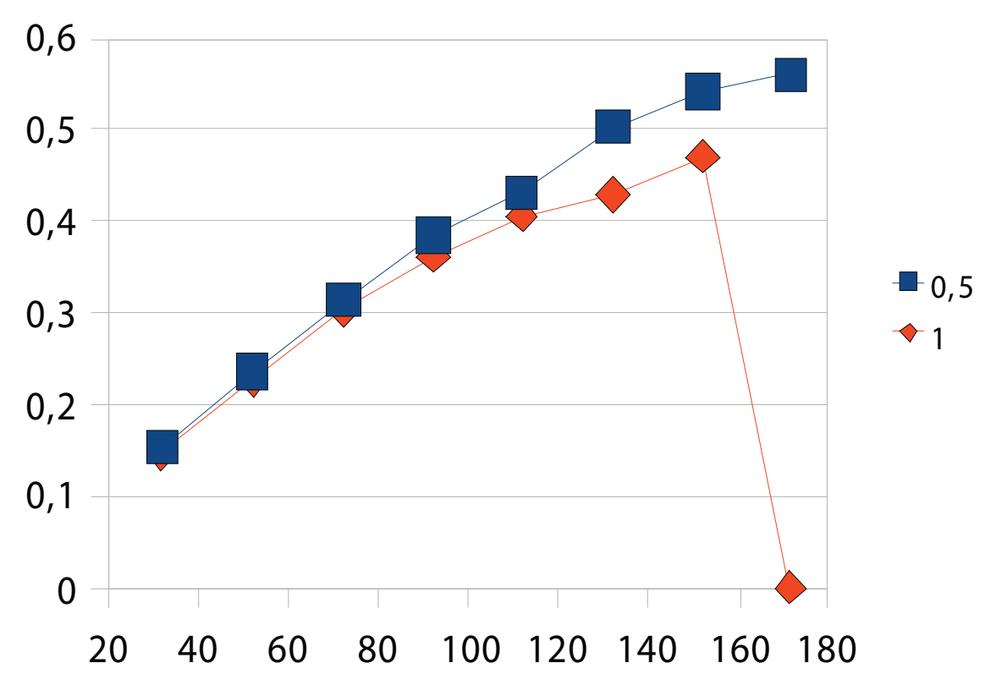
Graph no. 1 Ion quantity, which crashed on cathode due first transit depending up wires count.



Graph no. 2 Radius R in dependence on wires count.



Graph no. 3 Ratio (n/R) of ions quantity (at the center) to radius R in dependence on wires count.



Graph no. 4 Value P equal to probability of D-D crash in dependence on wires count.

Wires count	D_d [mm]	0 transits	R [mm]	n/R	P
32	0.5	19	1.08	167.74	0.15
52	0.5	27	0.64	269.81	0.24
72	0.5	39	0.43	374.48	0.31
92	0.5	49	0.31	485.7	0.39
112	0.5	61	0.25	564.04	0.43
132	0.5	75	0.18	695.95	0.5
152	0.5	84	0.15	774.21	0.54
172	0.5	96	0.13	815.42	0.56
32	1	38	1	161.29	0.15
52	1	58	0.55	259.35	0.23
72	1	80	0.33	359.56	0.3
92	1	100	0.22	449.74	0.36
112	1	125	0.14	521.86	0.41
132	1	142	0.1	557.25	0.43
152	1	166	0.05	629.38	0.47
172	1	200		0	0

Data recorded due simulation for different grids.
D_d - wire diameter,
0 transits - ion quantity, which crashed on cathode due first transit,
R - the radius of smallest circle that all ions crossed,
n/R – ratio of ions quantity (at the center) to radius R,
P – value equal to probability of D-D crash

Acknowledgments

[1] K.M. Subramanian, Diagnostic Study of Steady State Advanced Fuel (DD and D-3He) Fusion in an IEC Device. PhD. thesis, Fusion Technology Institute, University of Wisconsin, 2004
[2] Daniel Kresnický, Studium fokusace iontových svazků pro fúzní neutronový zdroj. Bakalářská práce, ČVUT Praha 2007
[3] T. A. Thorson et al., Convergence, electrostatic potential, and density measurements in a spherically convergent ion focus. Phys. Plasmas 4 (1), January 1997
[4] T.A. Thorson et al., Fusion reactivity characterization of a spherically convergent ion focus. NUCLEAR FUSION, Vol. 38, No. 4 (1998)
[5] Janusz Groszkowski, Technika vysokého vákua. SNTL Praha 1981
[6] SIMION® 8 (c) 2003-2008 Scientific Instrument Services, Inc. SIMION® 8.0 User Manual.