Источники тяжелых ионов

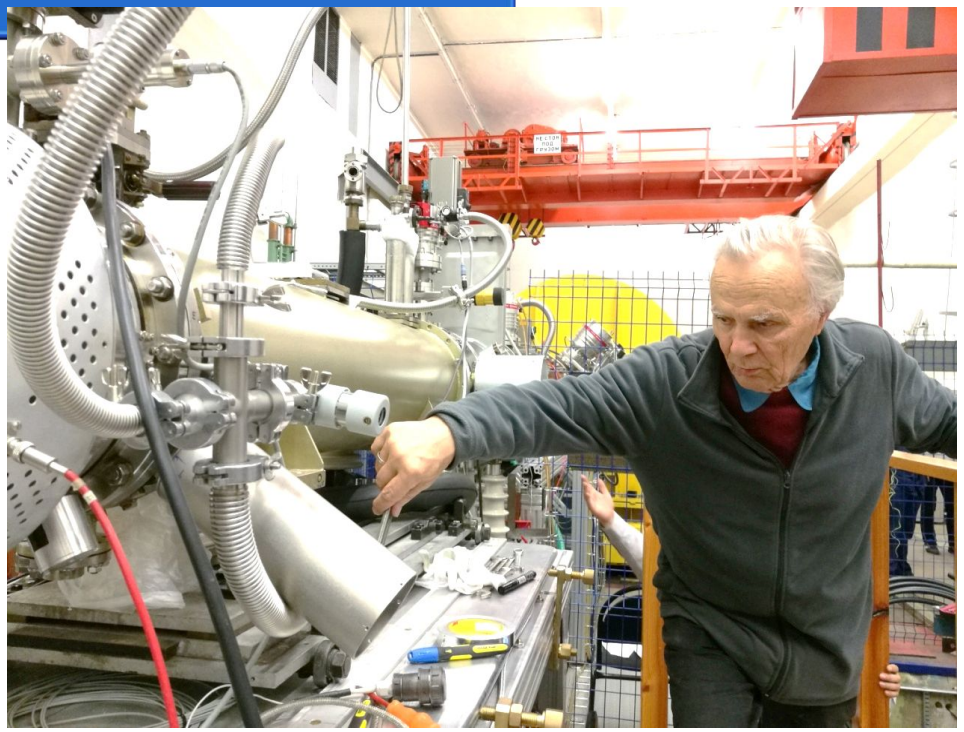
Бойцов А.Ю.

Content

- Необходимость создания
- История создания
- Действующие источники
- Принципиальная схема
- Основные узлы

История создания

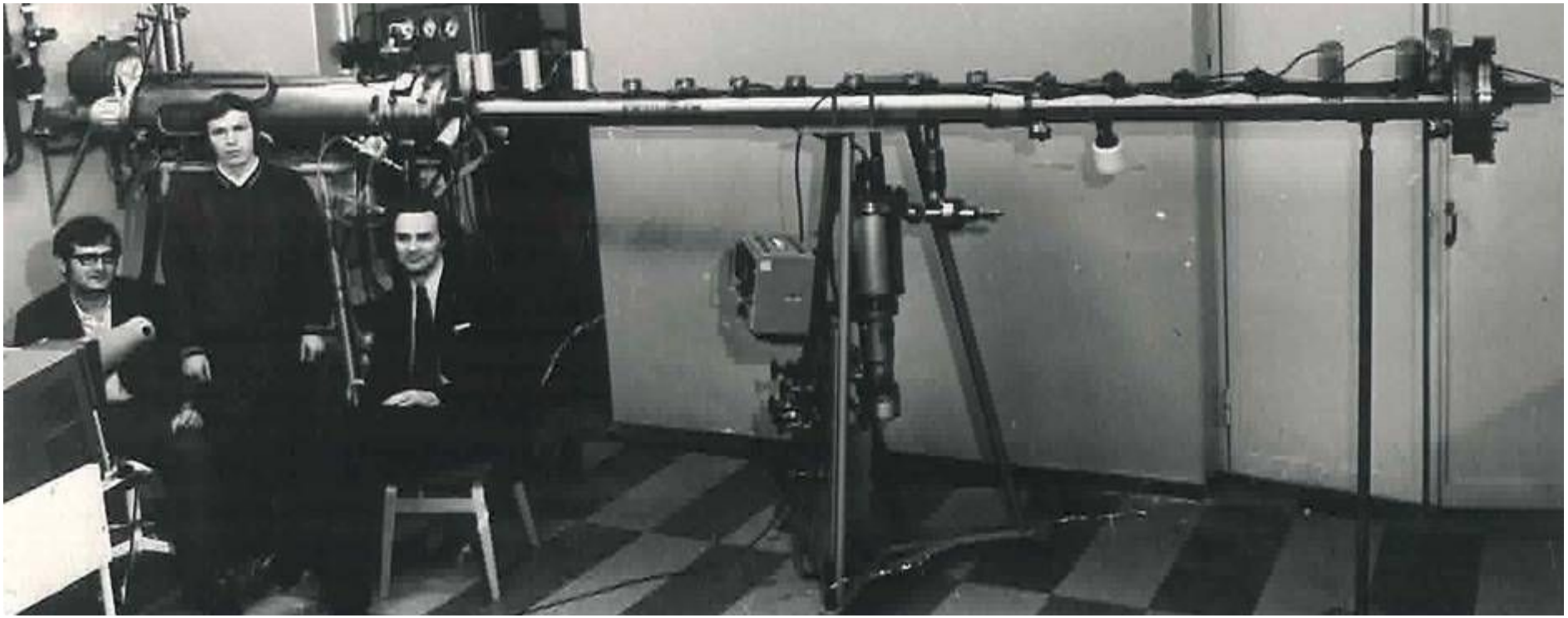
- Invented by E.D. Donets at JINR,Dubna in 1968. Au^{19+} beam in 1969.
- 1970-1985, in Dubna, cryogenic version of EBIS KRION-I,2, bare ions C, N, O, Ne, Ar, Kr, Xe. HCI physics begins.
- 1970-1985, Europe, US, Japan, a lot of EBIS (*EBIS time*), $\mathbf{U^{90+}}$ **!**
- 1982, at Bekerley, EBIT, from EBIS, 1990s, SuperEBIT, U^{92+} !
- Since 1985, in accelerator fields, ECRIS time
- 2001-2005, breakthrough of EBIS at JINR, new idea of ESIS, and high current EBIS at BNL.



Prof. E.D. Donets near Krion-6T ESIS during Nuclotron run #55, JINR, Dubna, February 2018

Синхрофазотрон

Крион-2 1976г.



KRION-2 equipped with time-of-flight mass-spectrometer. V.P. Ovsyannikov, V.V. Salnikov and E.D. Donets (from left to right) - 1976

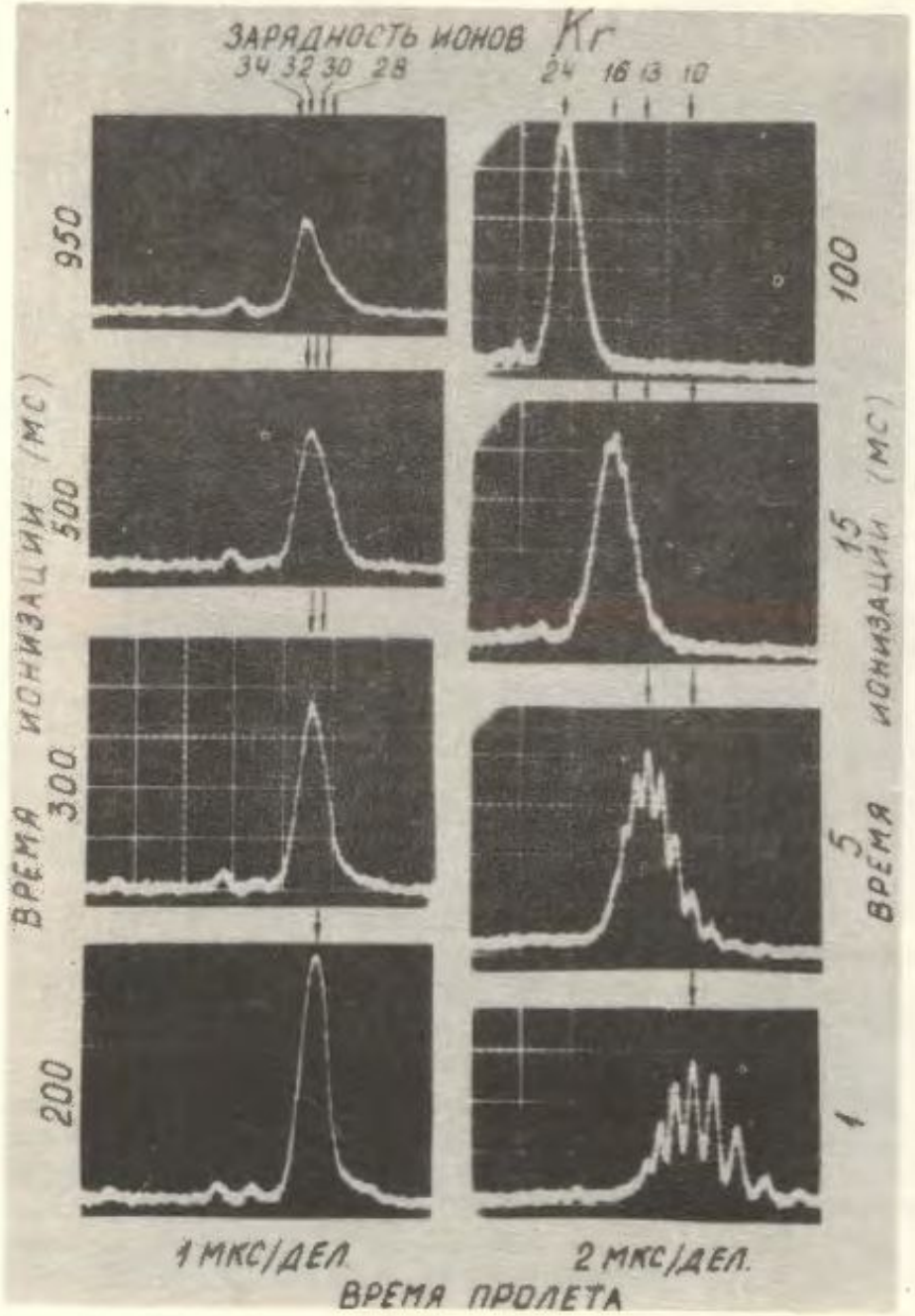


Рис.1. Эволюция спектра зарядностей ионов криптона.

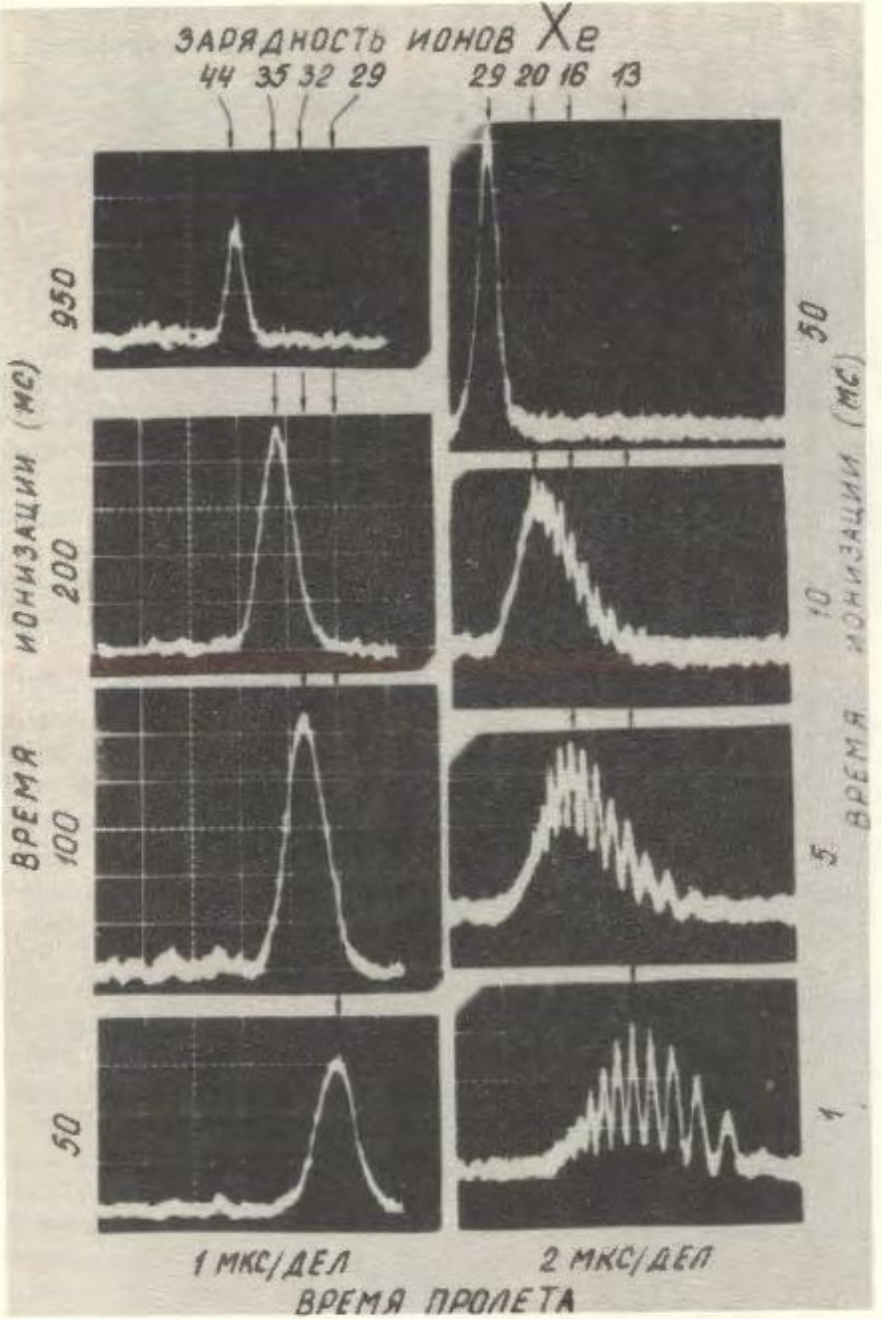


Рис.2. Эволюция спектра зарядностей ионов ксенона.

Нуклотрон

Крион-2 2010г

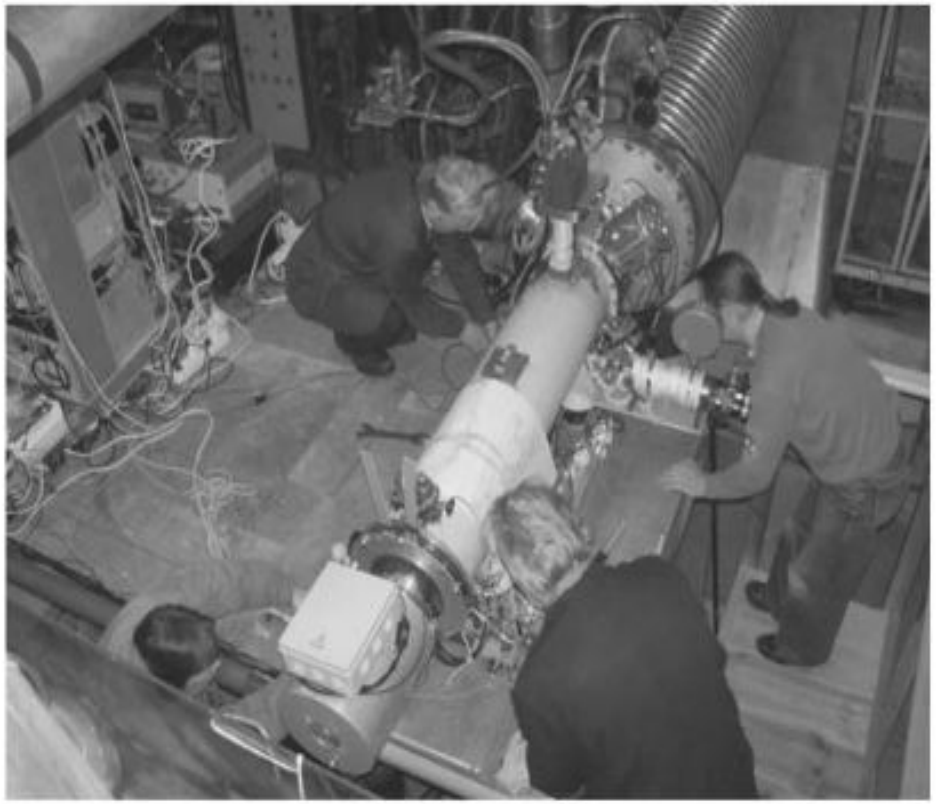


Рис. 1.4. Установка источника «Крион-2» на высоковольтном терминале ЛУ-20

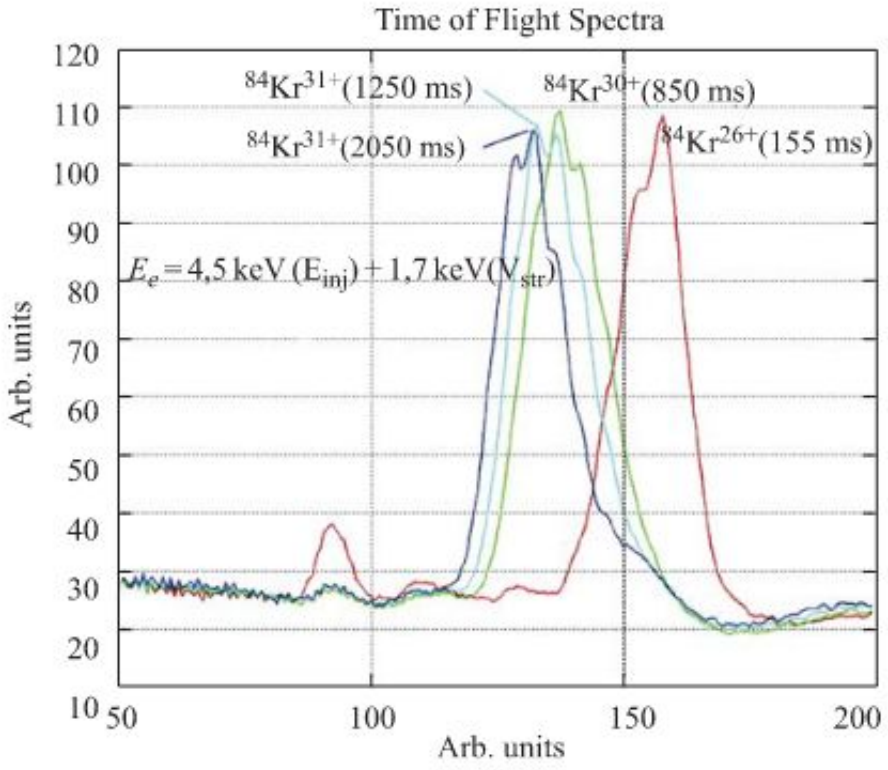
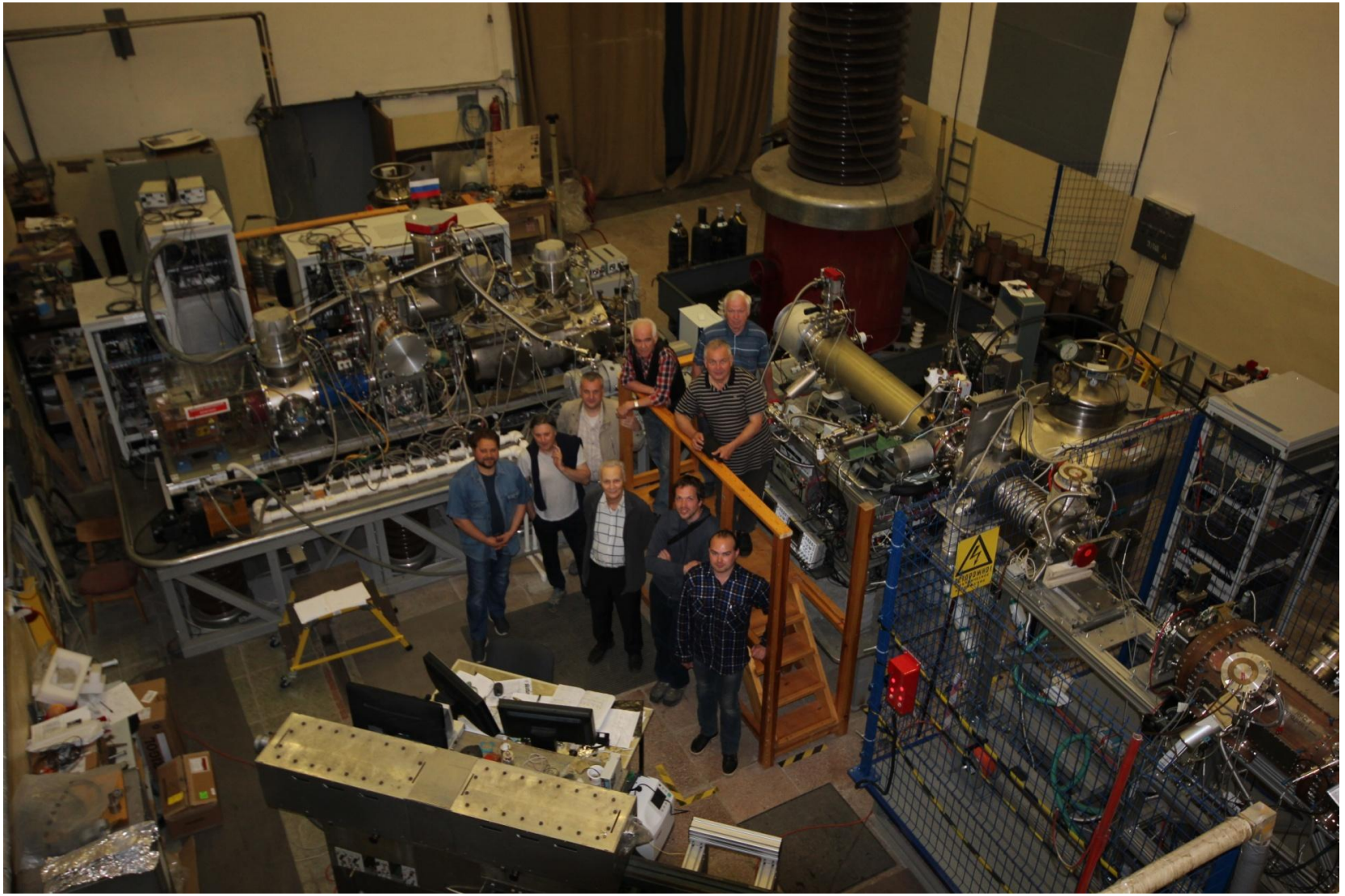
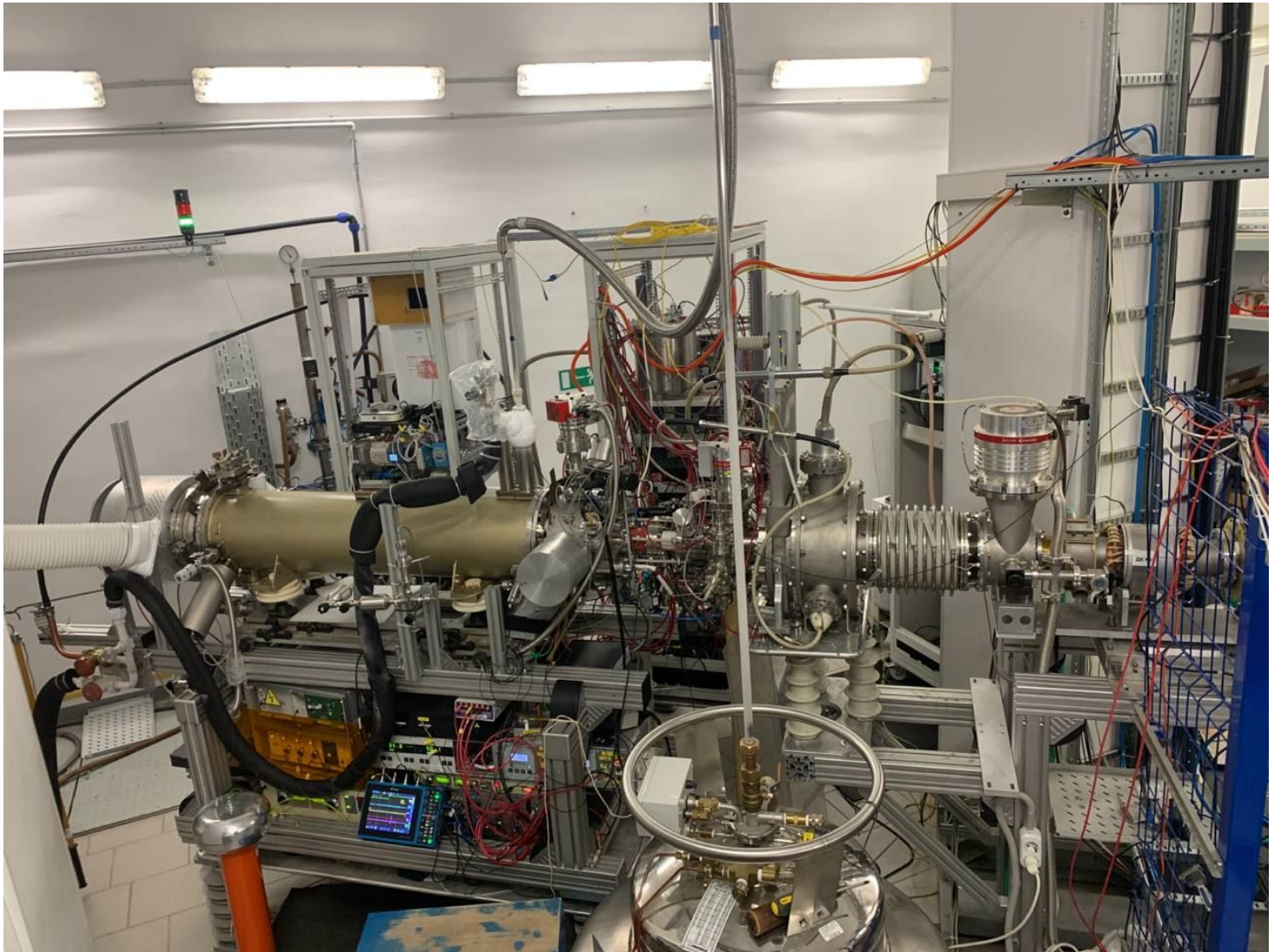


Рис. 1.1. Спектр ионов криптона, полученный времяпролетным методом. В скобках указано оптимальное время ионизации

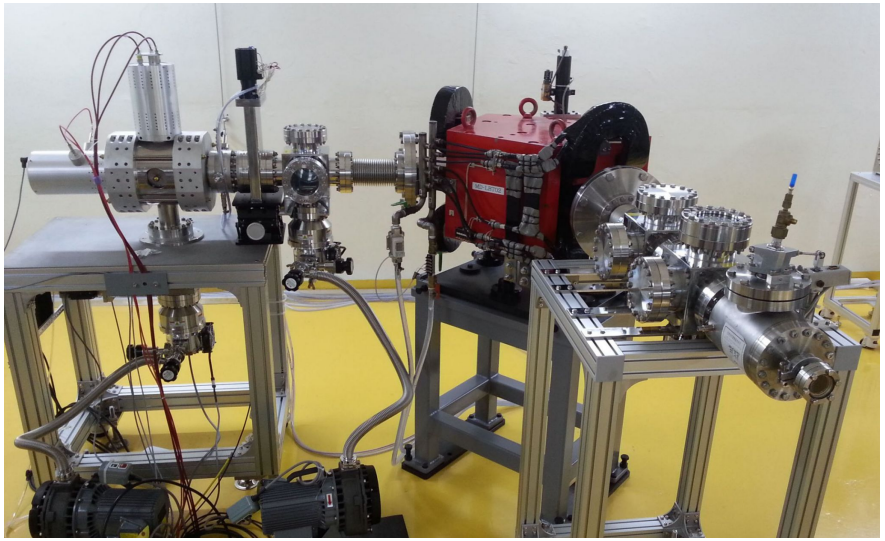
Крион-6Т 2018г.

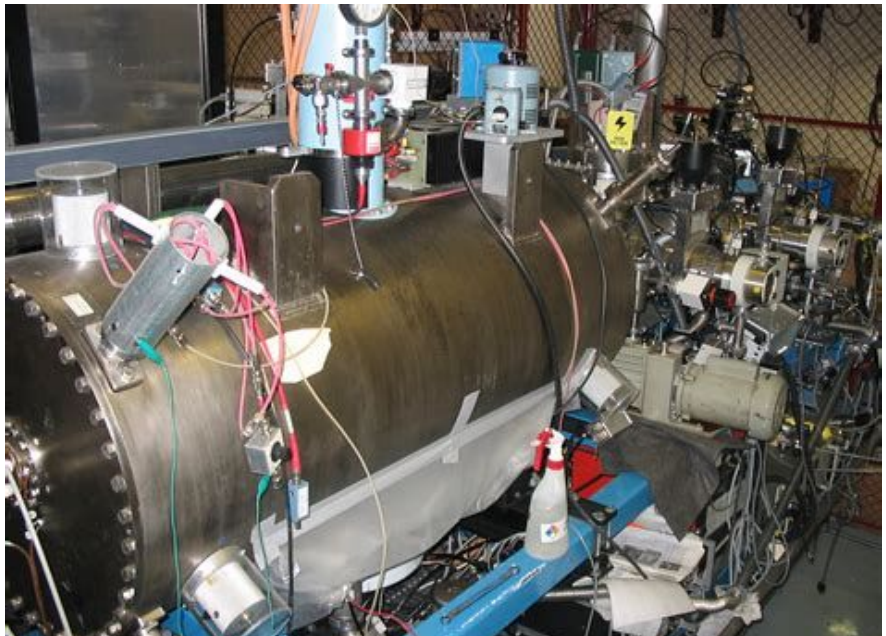


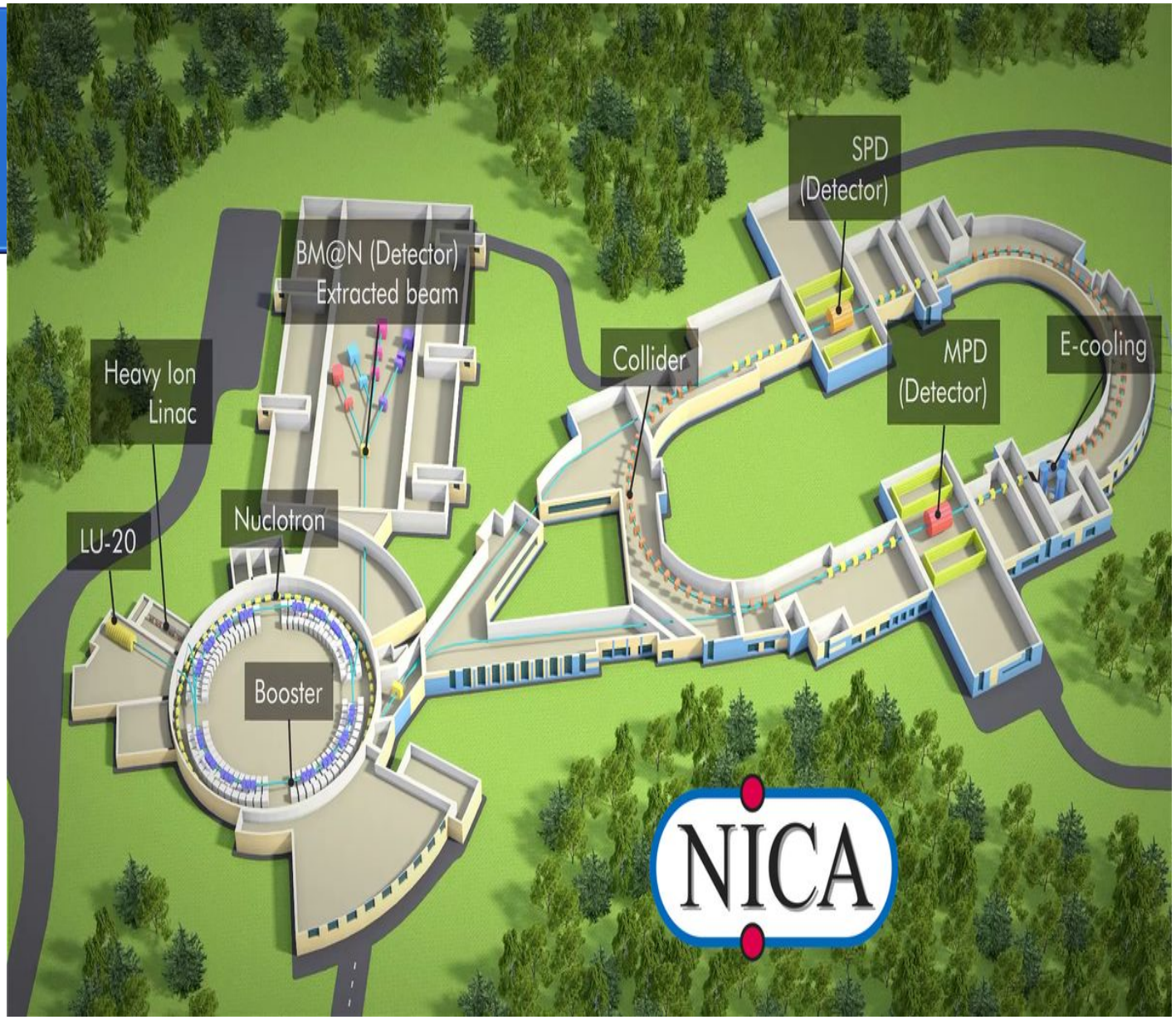
Крион-6Т 2022г



Источники в мире







Requirements for ion source:
Au^{32+} 10^9 particles per pulse
Repetition rate 50 Hz (3 pulses to Booster, less 20ms)

Ионизация электронным ударом

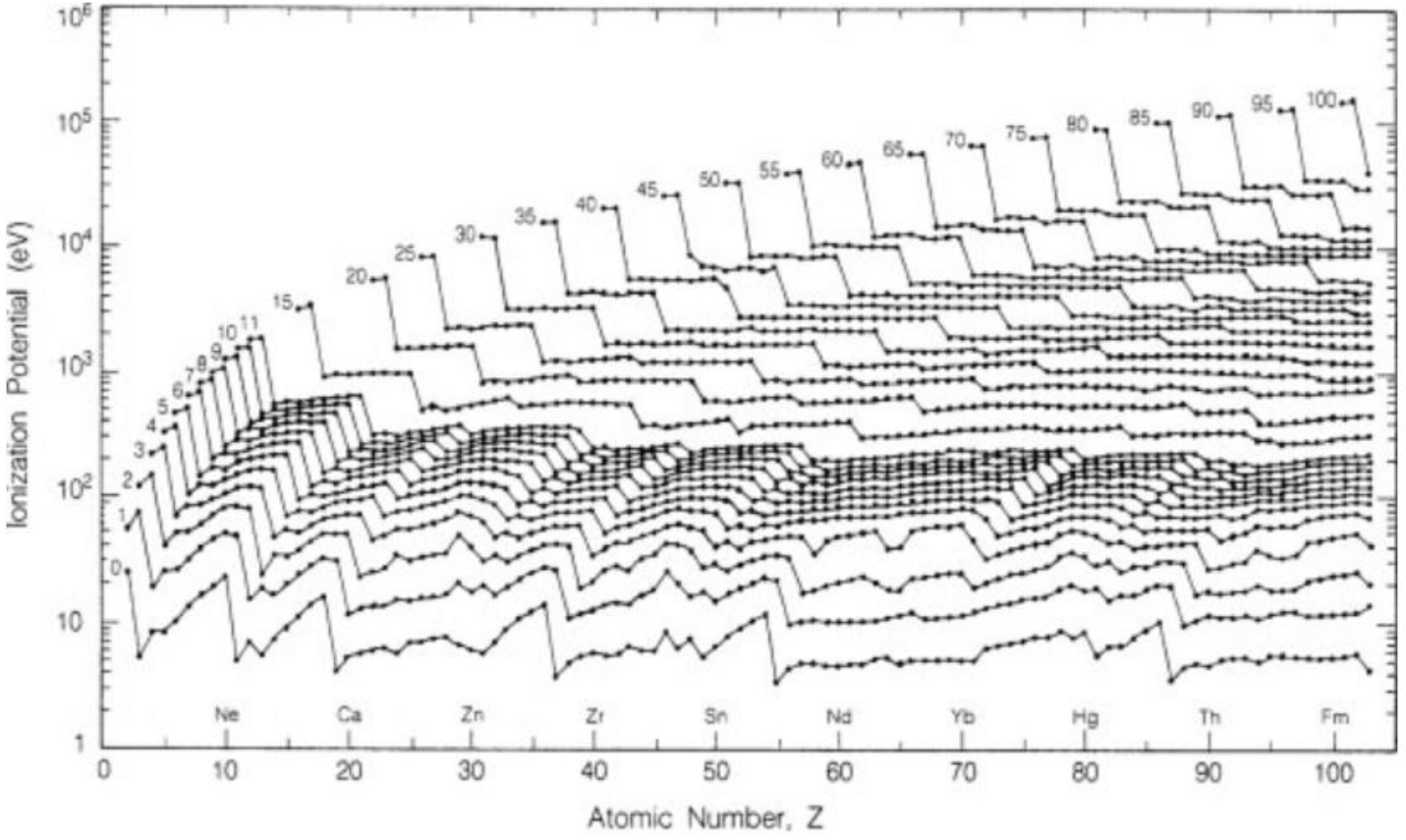


Figure 2.3 Ionization potentials for multiply charged ions of all of the elements [15].

Ионизация электронным ударом

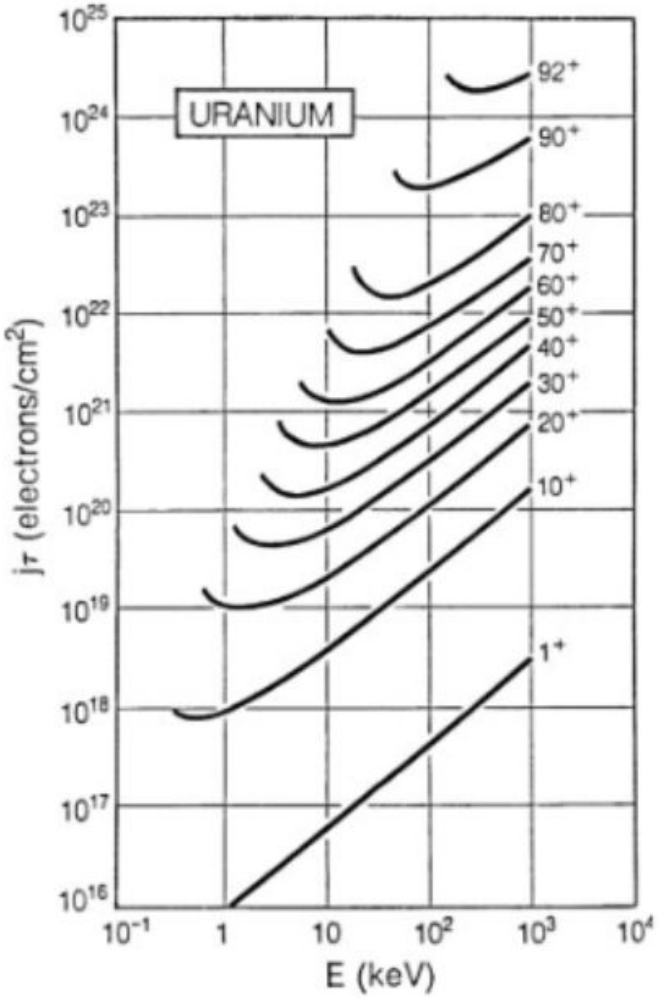
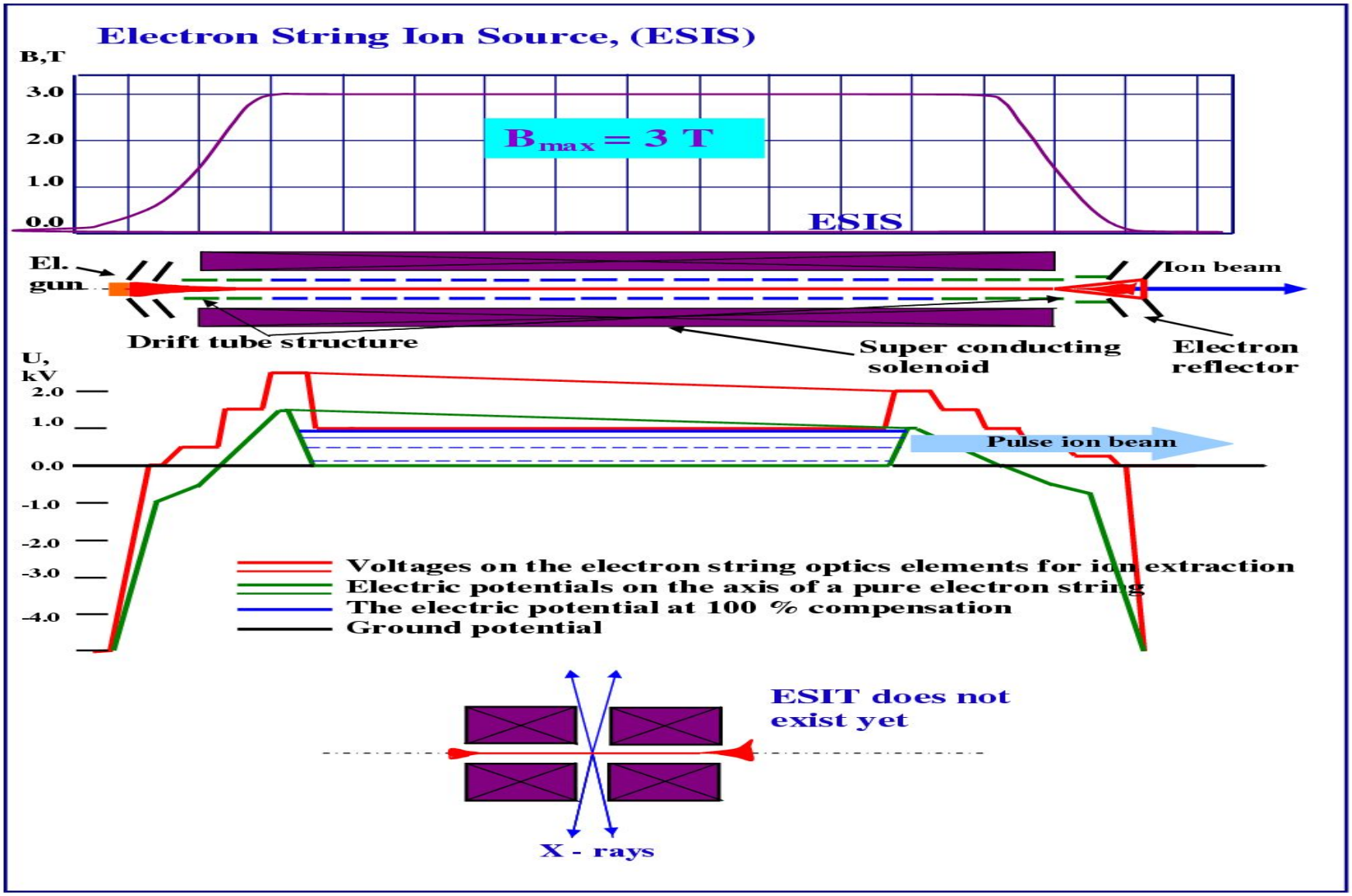


Figure 2.4 $j\tau$ needed to produce various charge states of uranium as a function of electron energy [18].


Electron String Ion Source, (ESIS)
B,T
3.0
2.0
1.0
0.0
$B_{max} = 3$ T
ESIS
El. gun
Drift tube structure
Super conducting solenoid
Ion beam
Electron reflector
U, kV
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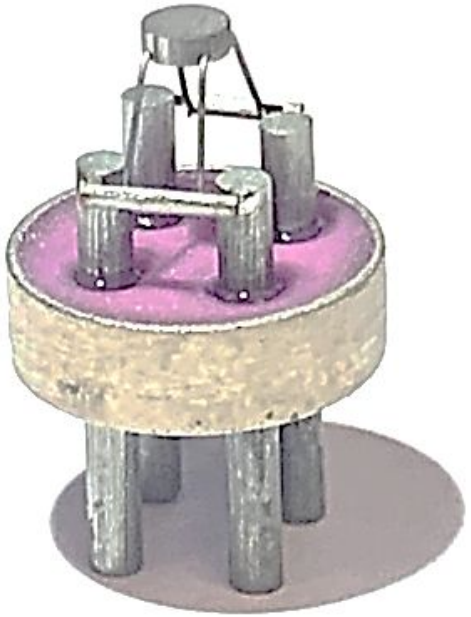
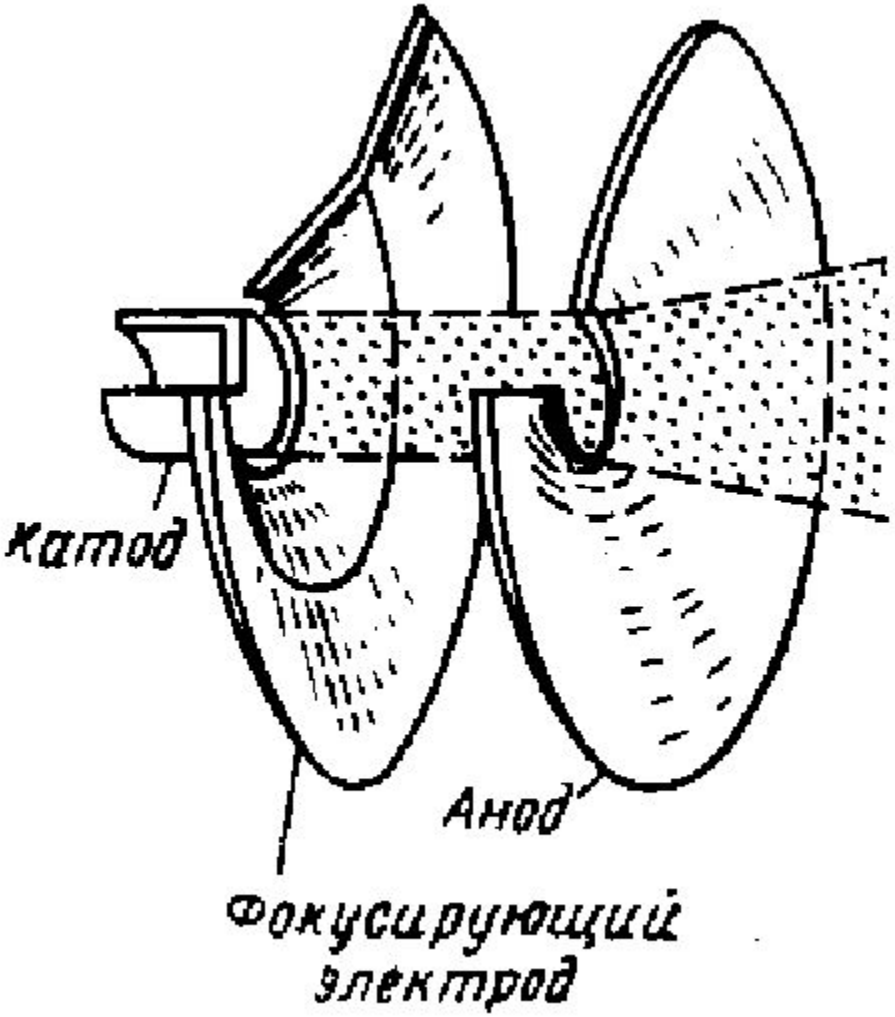
Pulse ion beam
Voltages on the electron string optics elements for ion extraction
Electric potentials on the axis of a pure electron string
The electric potential at 100 % compensation
Ground potential
ESIT does not exist yet
X - rays

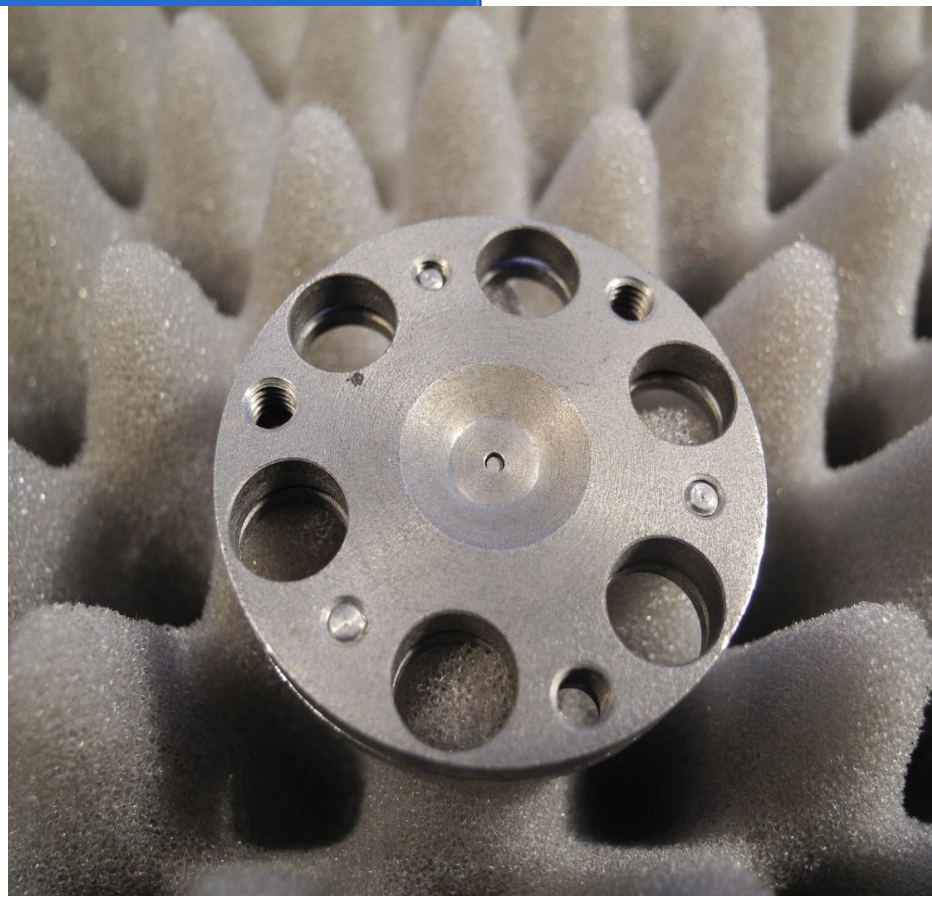
Термоэмиссионный катод

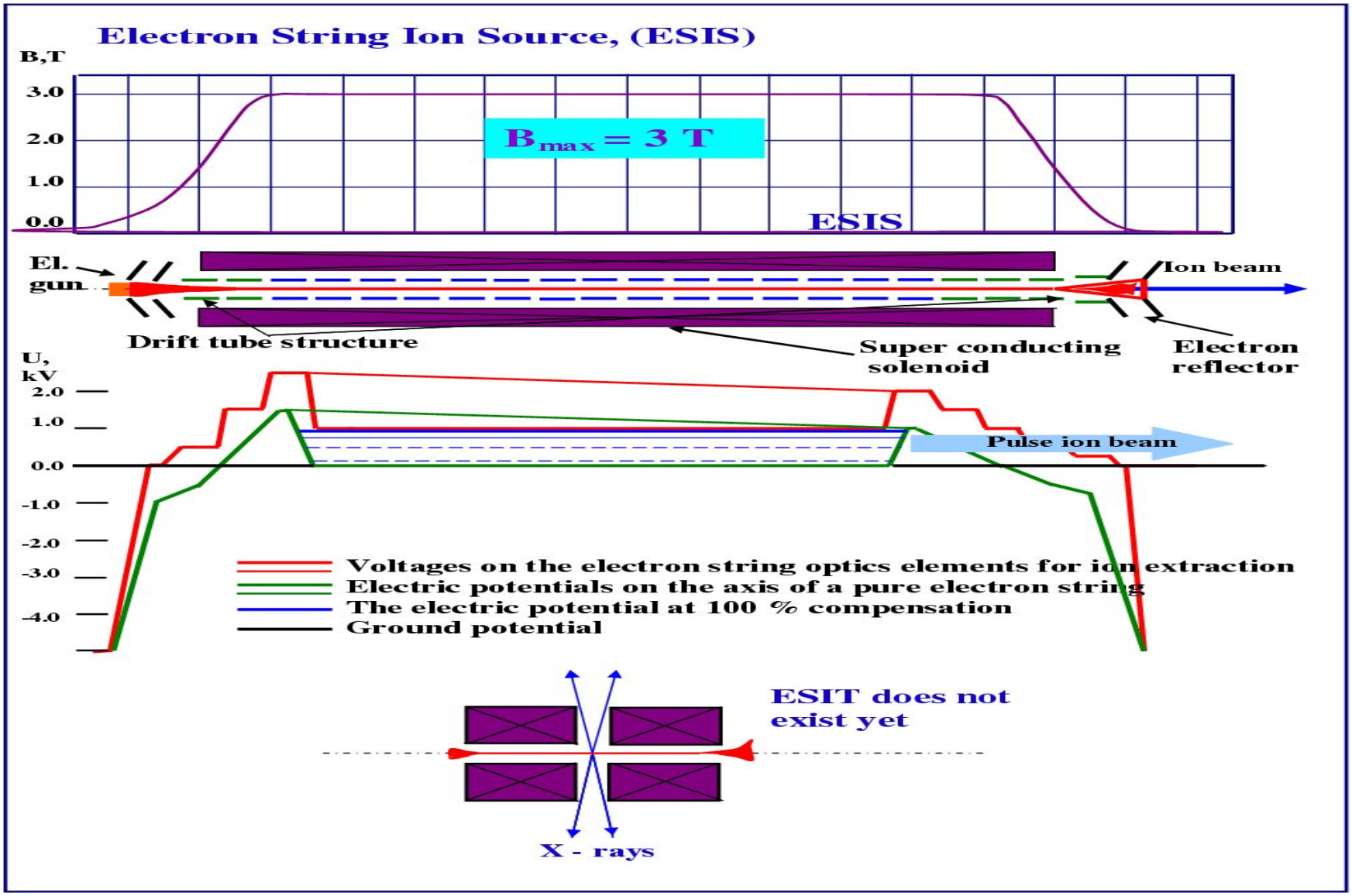
- material **IrCe**
- emission: **thermionic**
- small size **1.2 mm**
- emission current **6 mA**
- heating power **AC 1.5V 10A**



Электронная пушка



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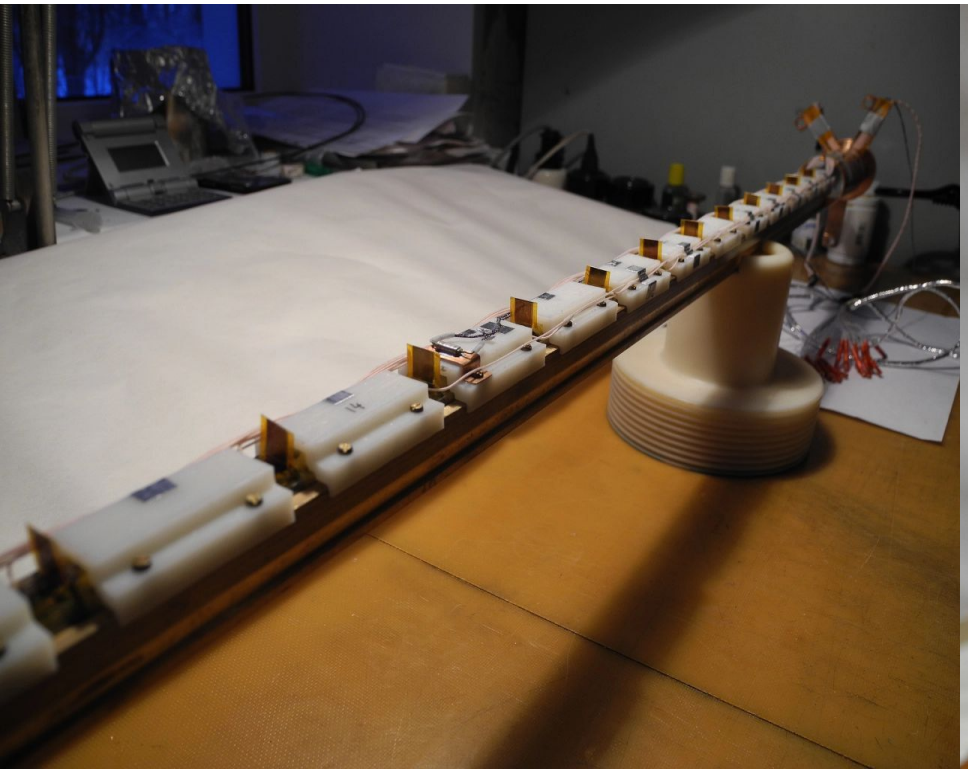
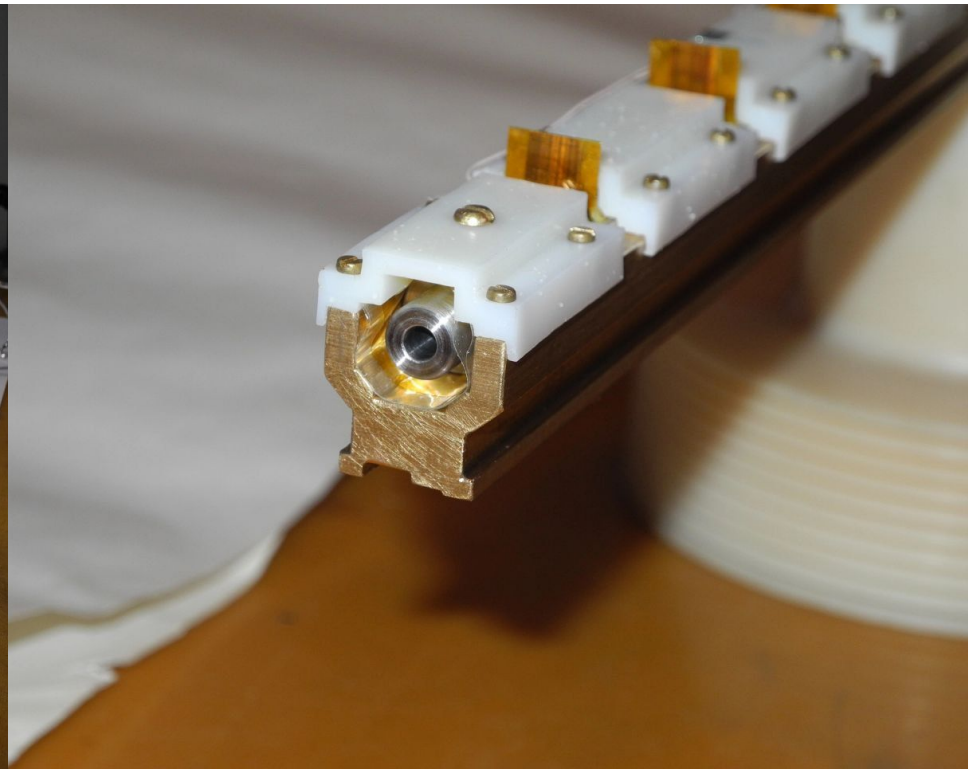
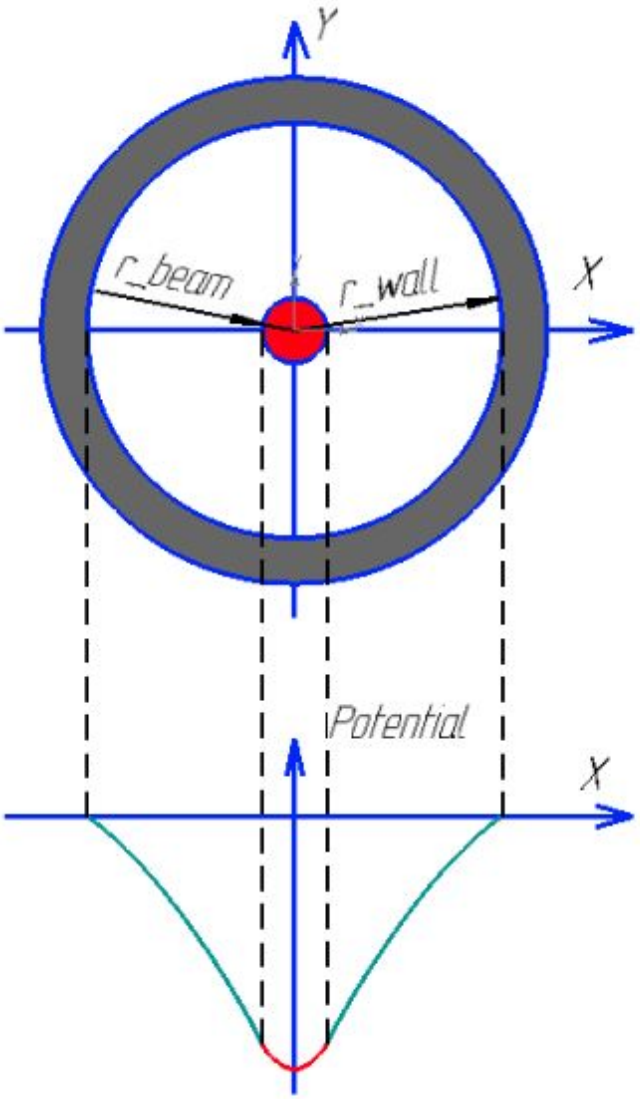
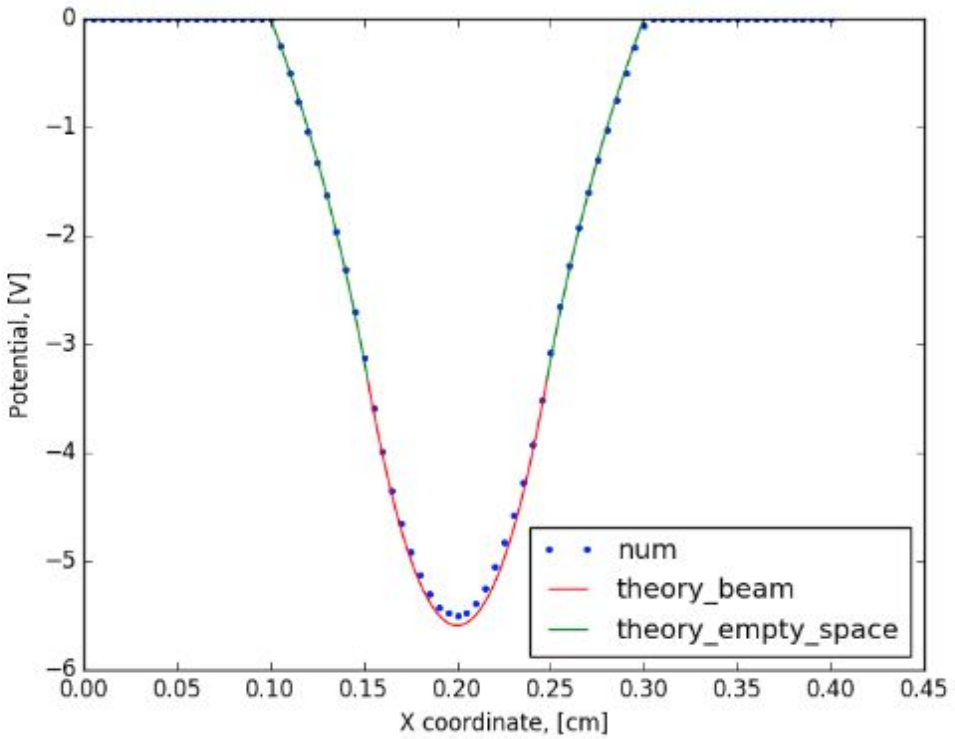
Структура дрейфа





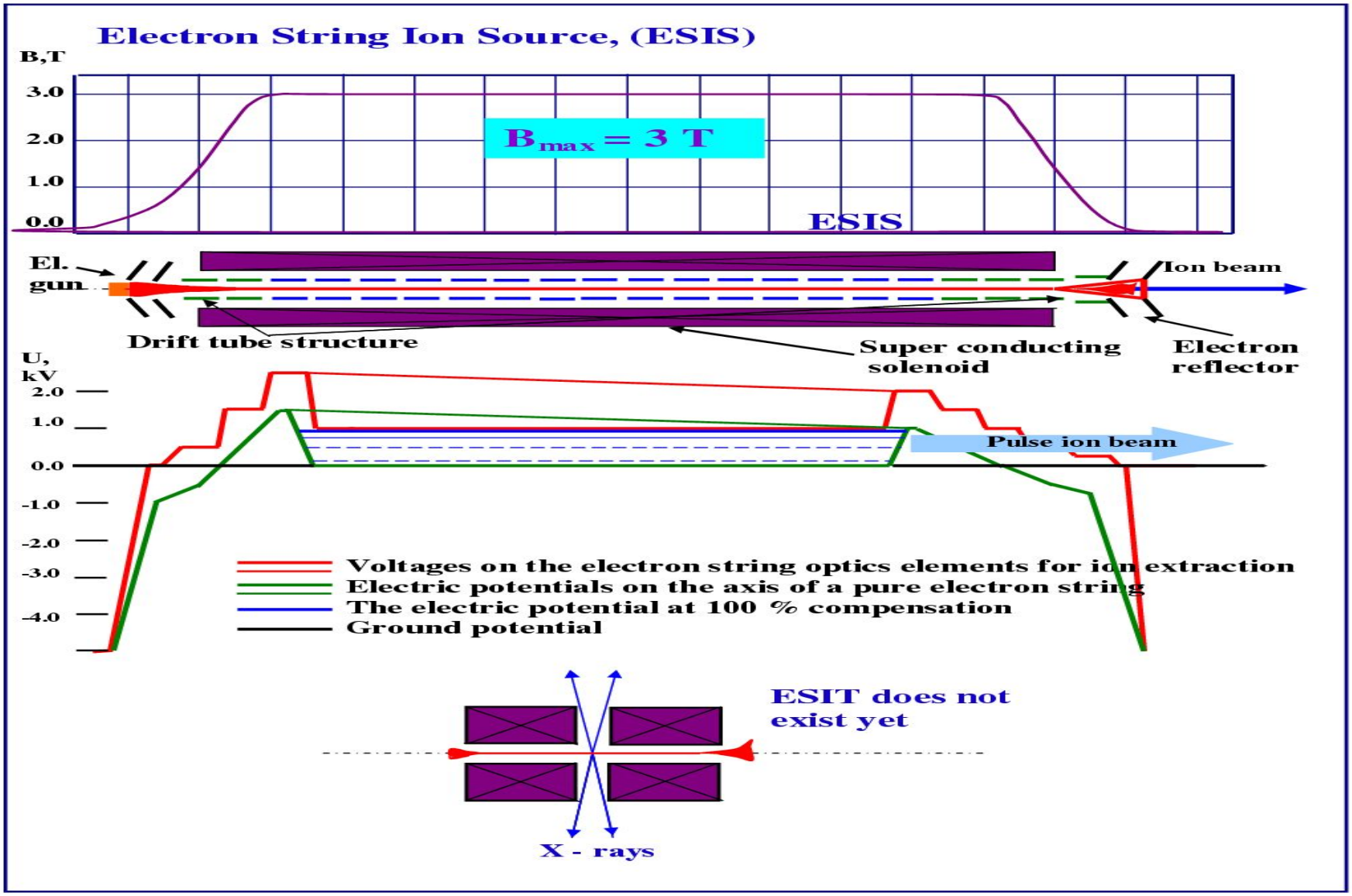
Potential well of cylindrical beam in tube





$$\phi_1(r) = U_0 + k[r^2 - r_{beam}^2(1 - 2\ln\frac{r_{beam}}{r_{wall}})],\ 0 \leqslant r \leqslant r_{beam}$$

$$\phi_2(r) = U_0 + 2kr_{beam}^2 \ln\frac{r}{r_{wall}},\ r_{beam} \leqslant r \leqslant r_{wall}$$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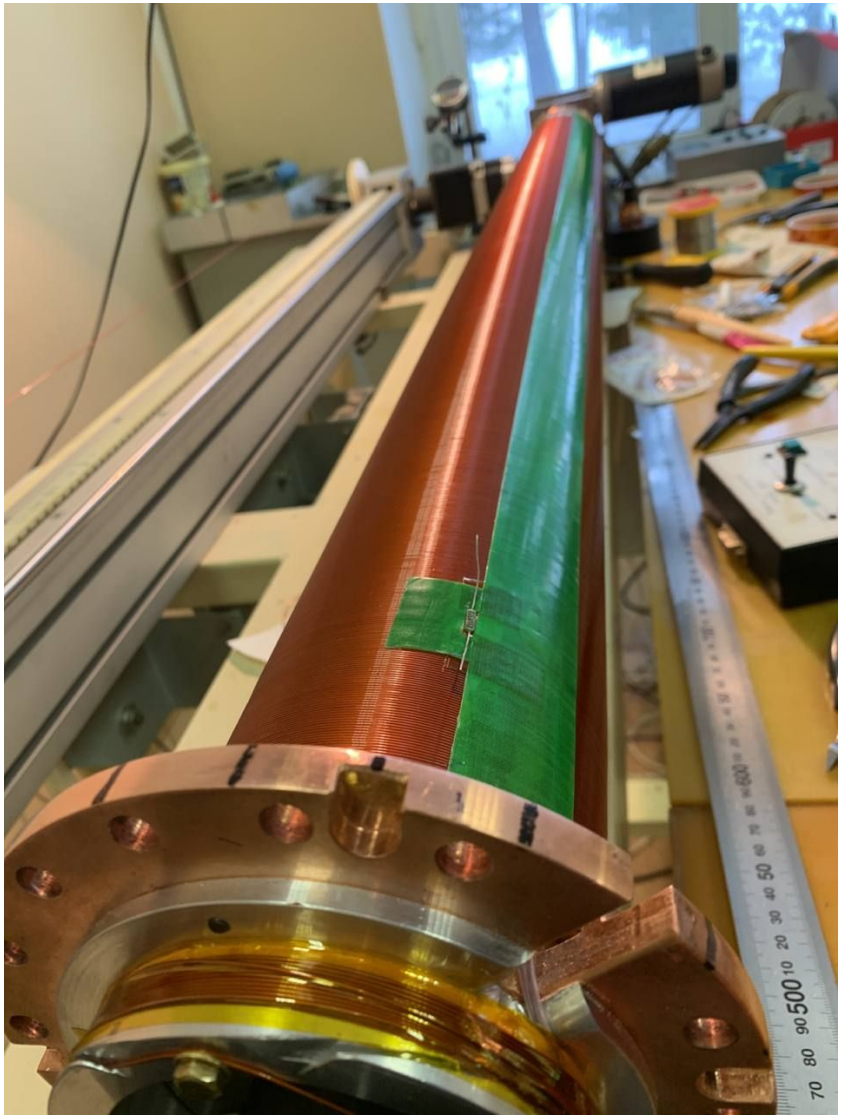
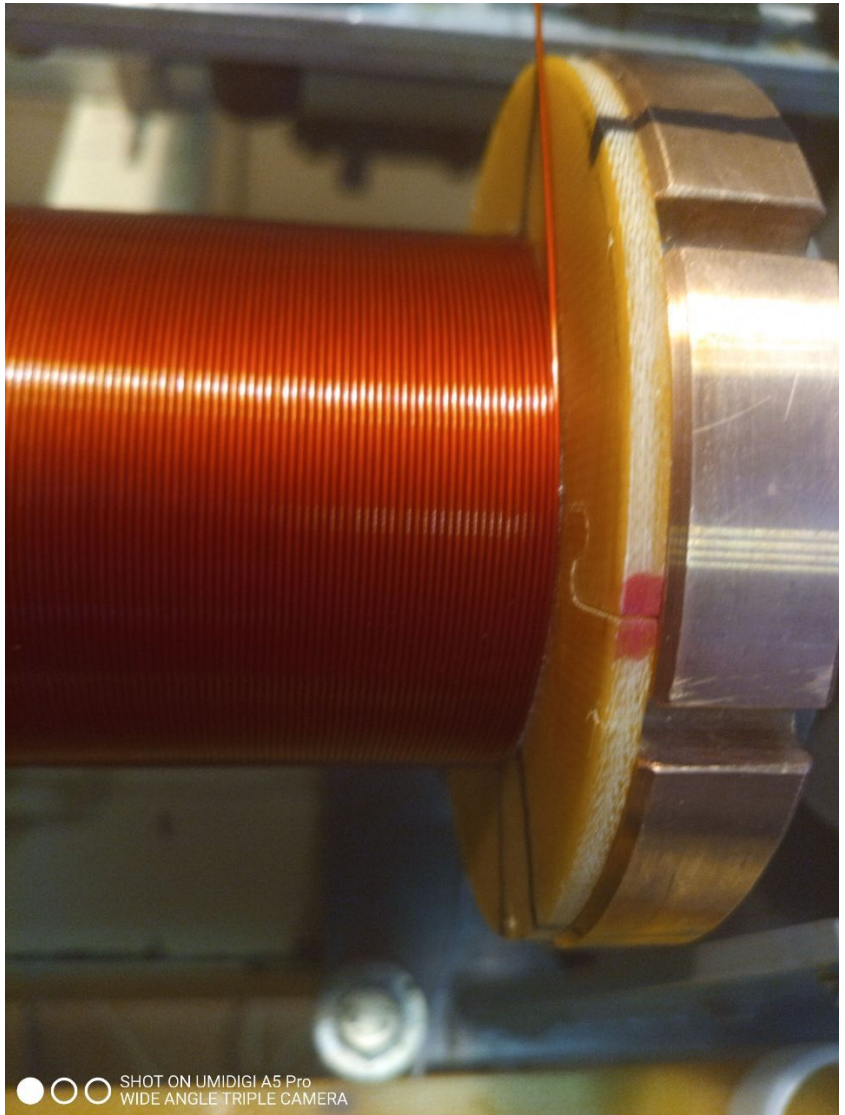
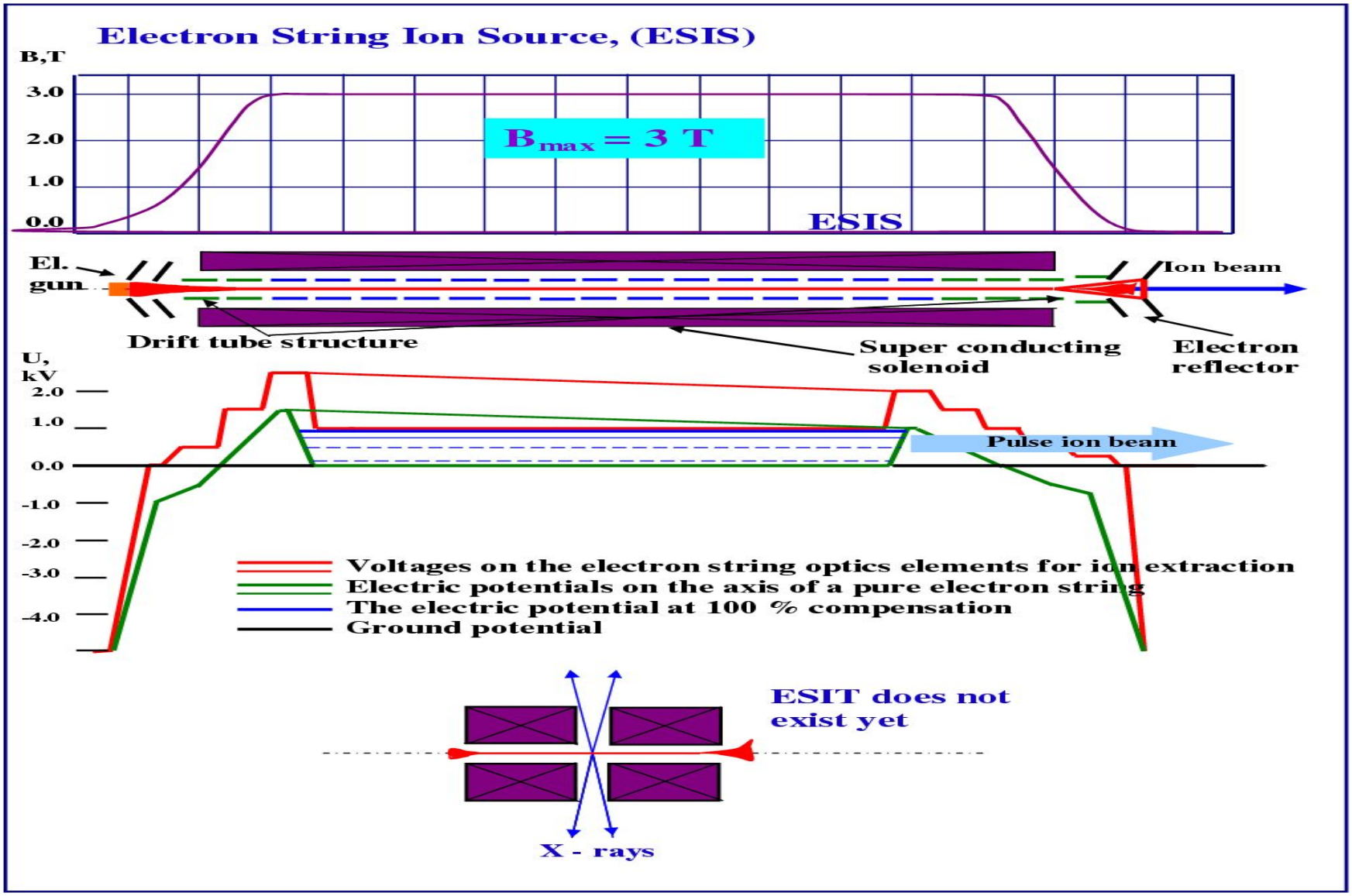
Сверхпроводящий соленоид



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Система управления движением ионов

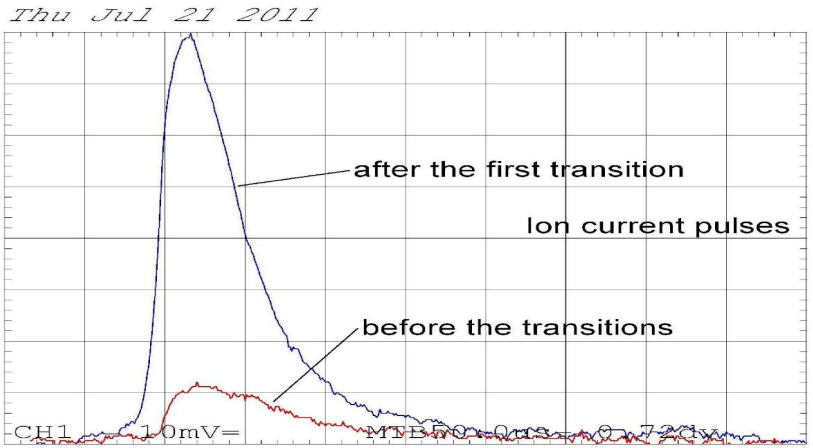
Электронная струна

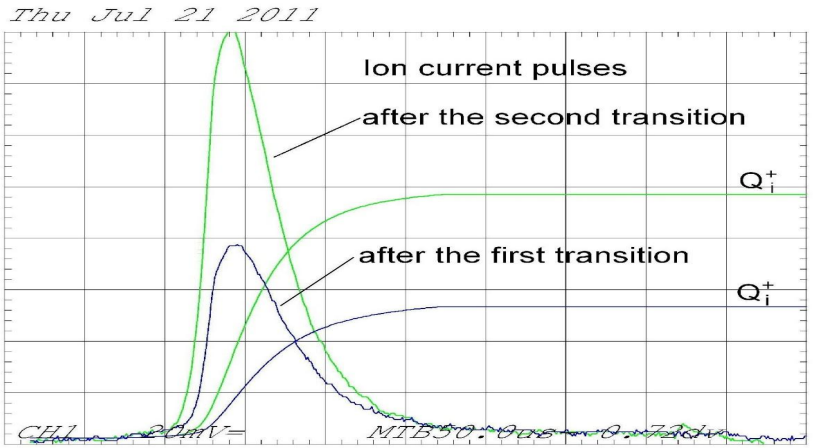
Total ion current pulse before (red),

after 1-st transition (blue)

and after 2-nd transition (green)

to e-string state





- the **jτ** ionization factor is the most important value giving information about the performance of the ESIS
- impossible to measure directly the electron string current, but possible to measure **effective jτ,** using the extracted ions spectrum.

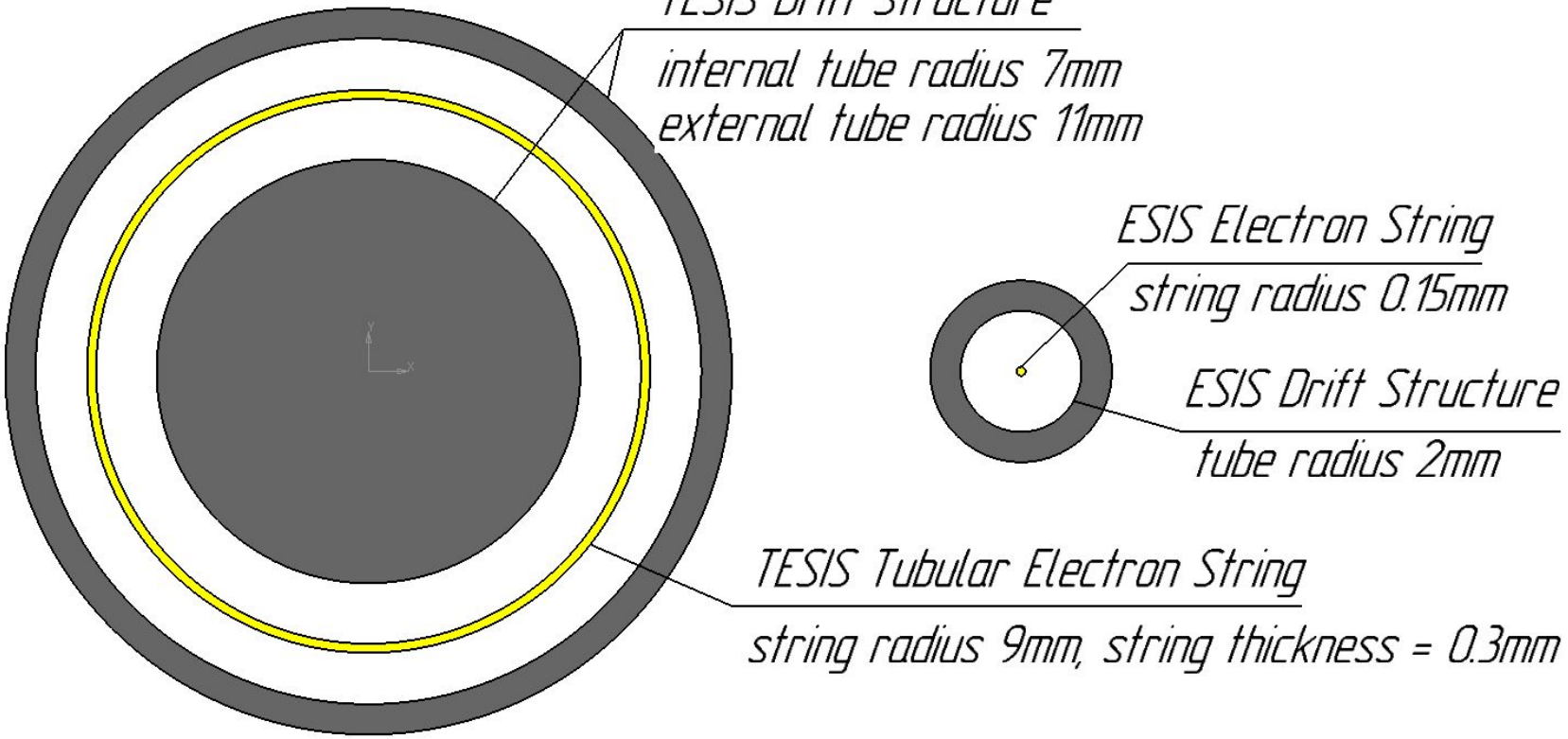
Ion specious	Effective electron string current density **j**, A/cm^2
Kr^{15+}	665
Kr^{18+}	591
$Kr^{24,6+}$	847
$Xe^{23,2+}$	1090
$Xe^{24,9+}$	1579
$Xe^{25,4+}$	1587
$Tm^{40,8+}$	1092

Examples of number of particles per pulse and times of ionization for different ions

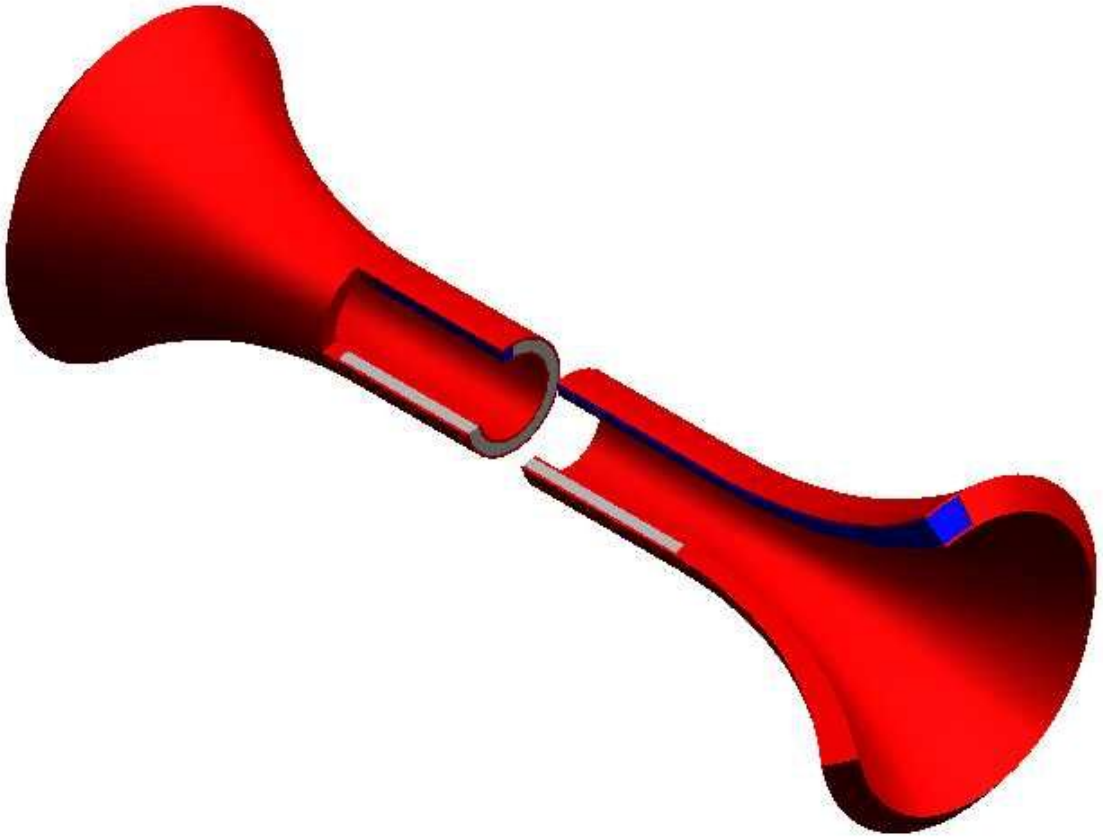
C^{4+}	$7x10^9$	-
Xe^{42+}	$5x10^9$	350 ms
Xe^{32+}	-	40 ms
Tm^{50+}	$3x10^7$	-
Au^{33+}	-	30 ms

The new KRION-6T ion source has much higher effective **j** (up to 1600 A/cm^2) in comparison with the KRION-2 which had only 200 A/cm^2. Another typical EBIS devices have only 100 - 300 A/cm^2.

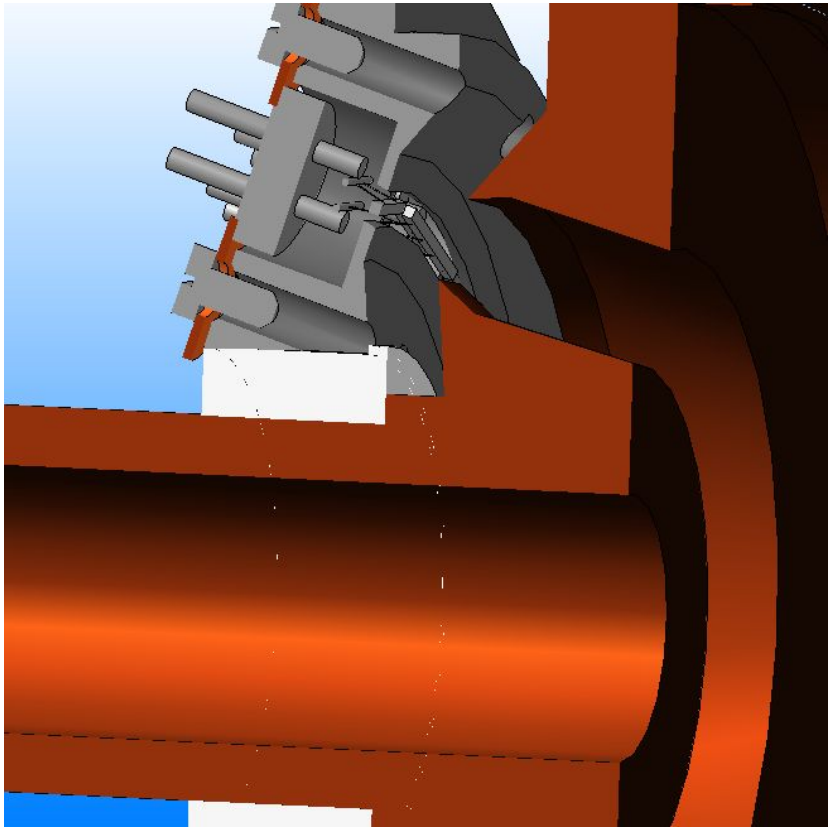
Трубчатый источник

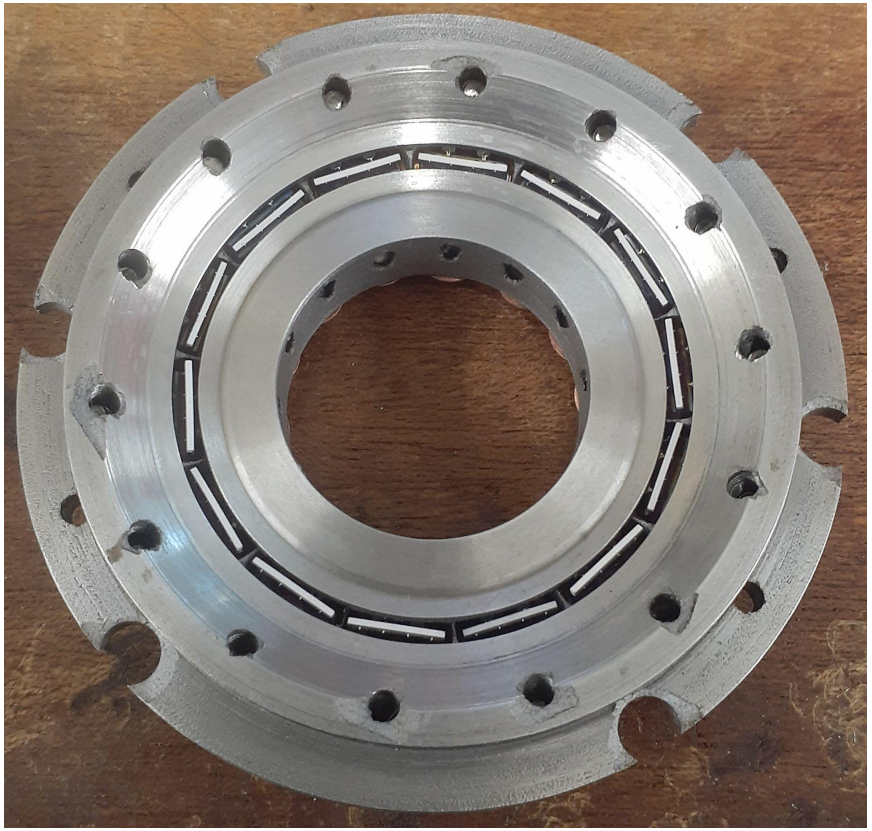


Electron beam volume



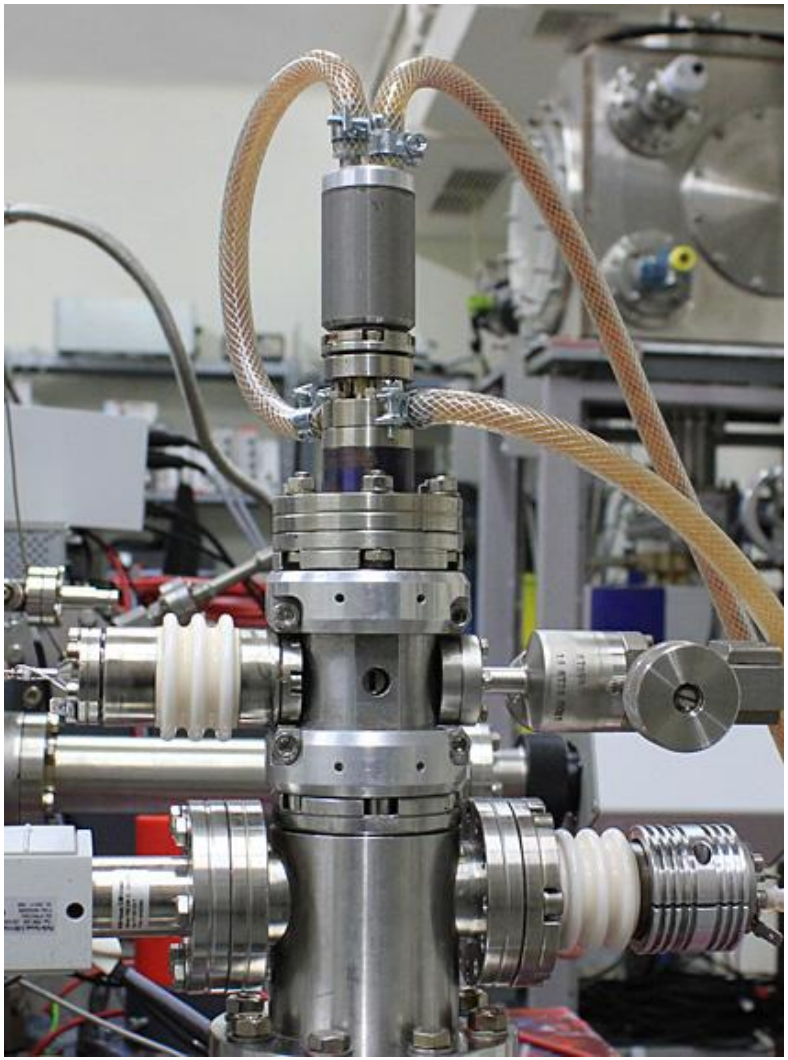
Electron gun

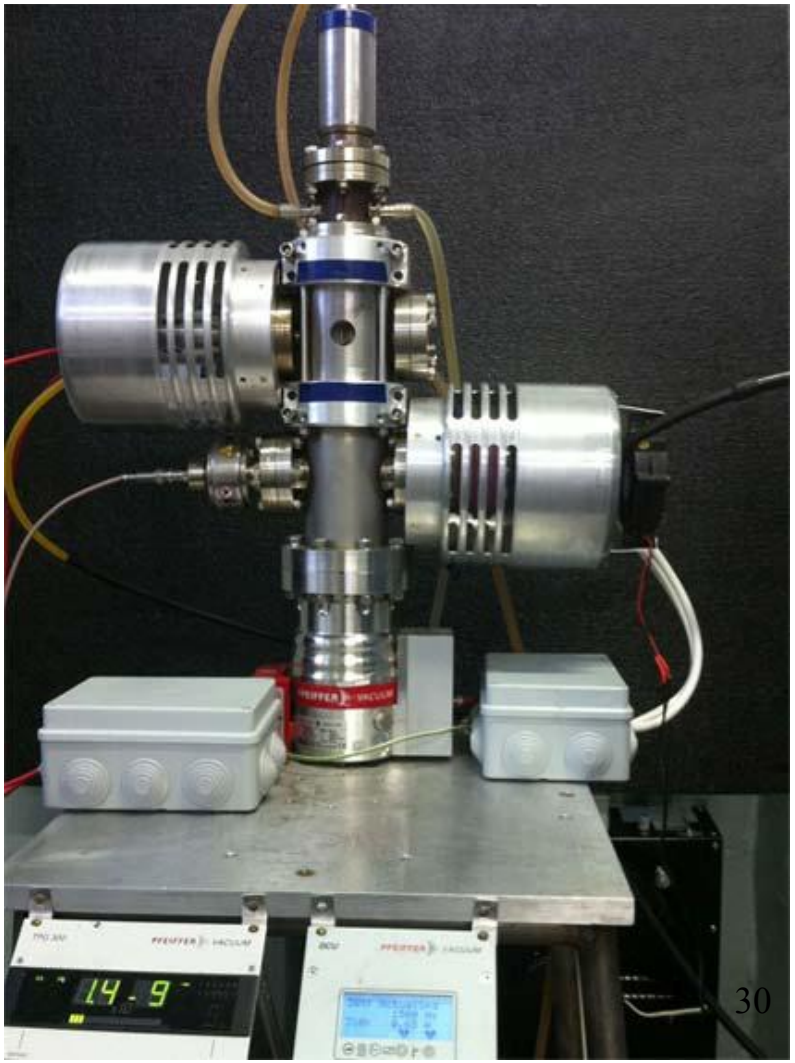




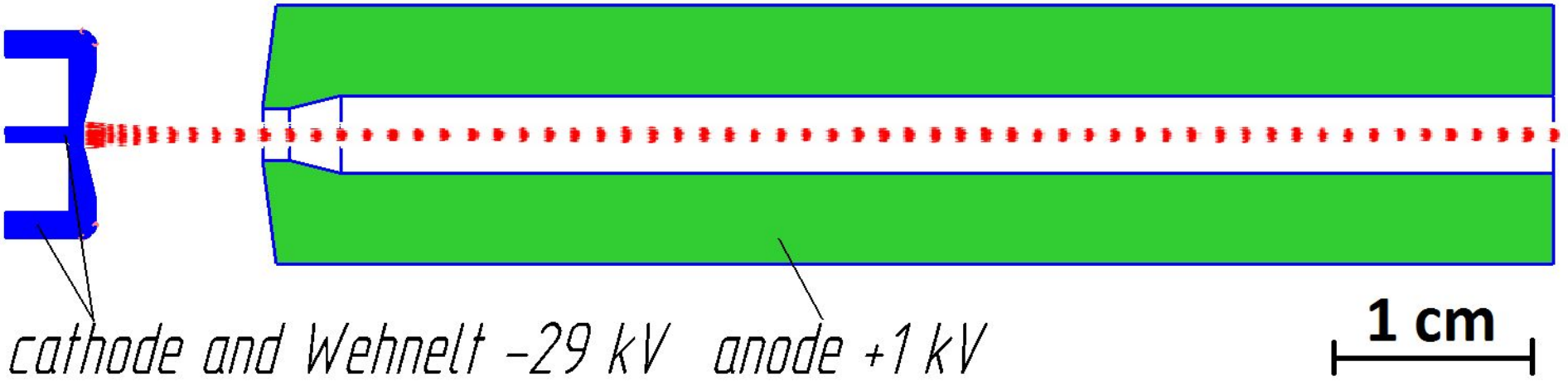
14 IrCe cathodes, ring diameter = 40mm

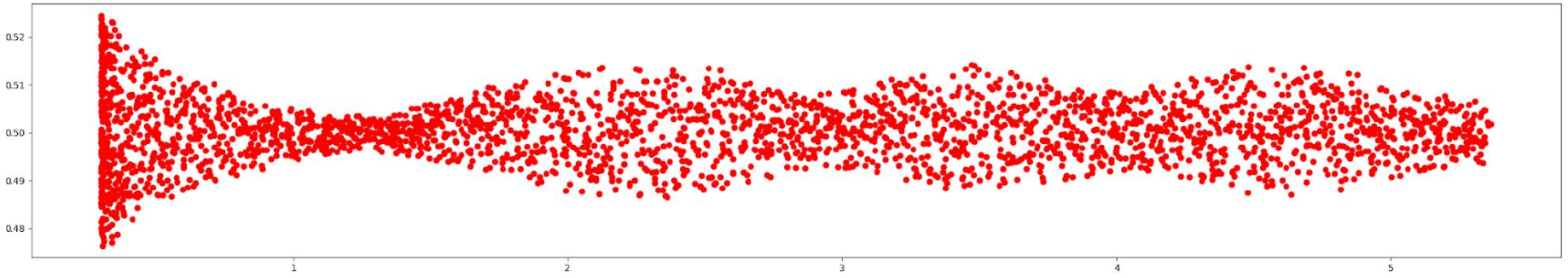
Main Magnetic Focus Ion Source

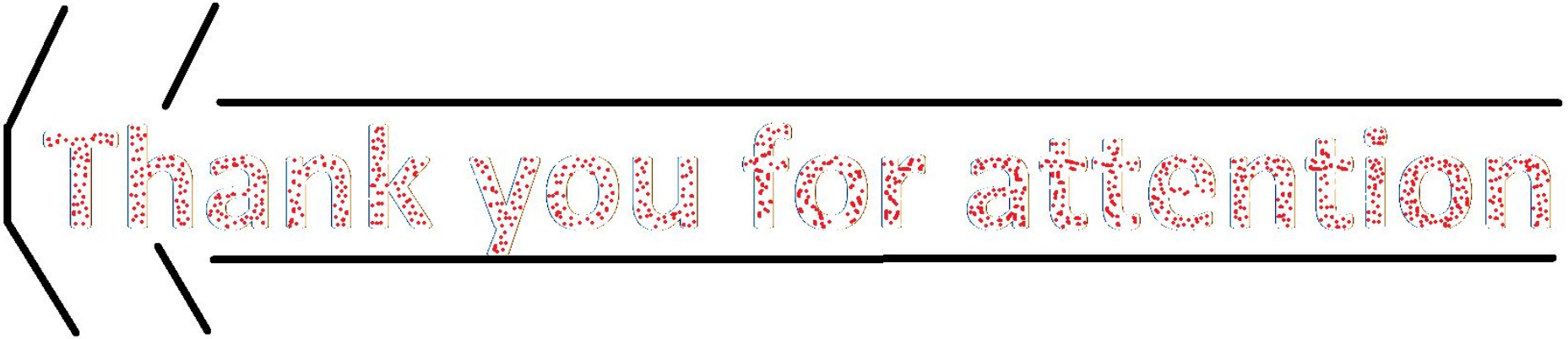




Results


cathode and Wehnelt -29 kV
anode +1 kV
1 cm


0.52
0.51
0.50
0.49
0.48
1
2
3
4
5


Thank you for attention