Budker Institute of Nuclear Physics
Siberian Branch of the Russian Academy of Sciences

Low energy Electron Cooler for the NICA Booster

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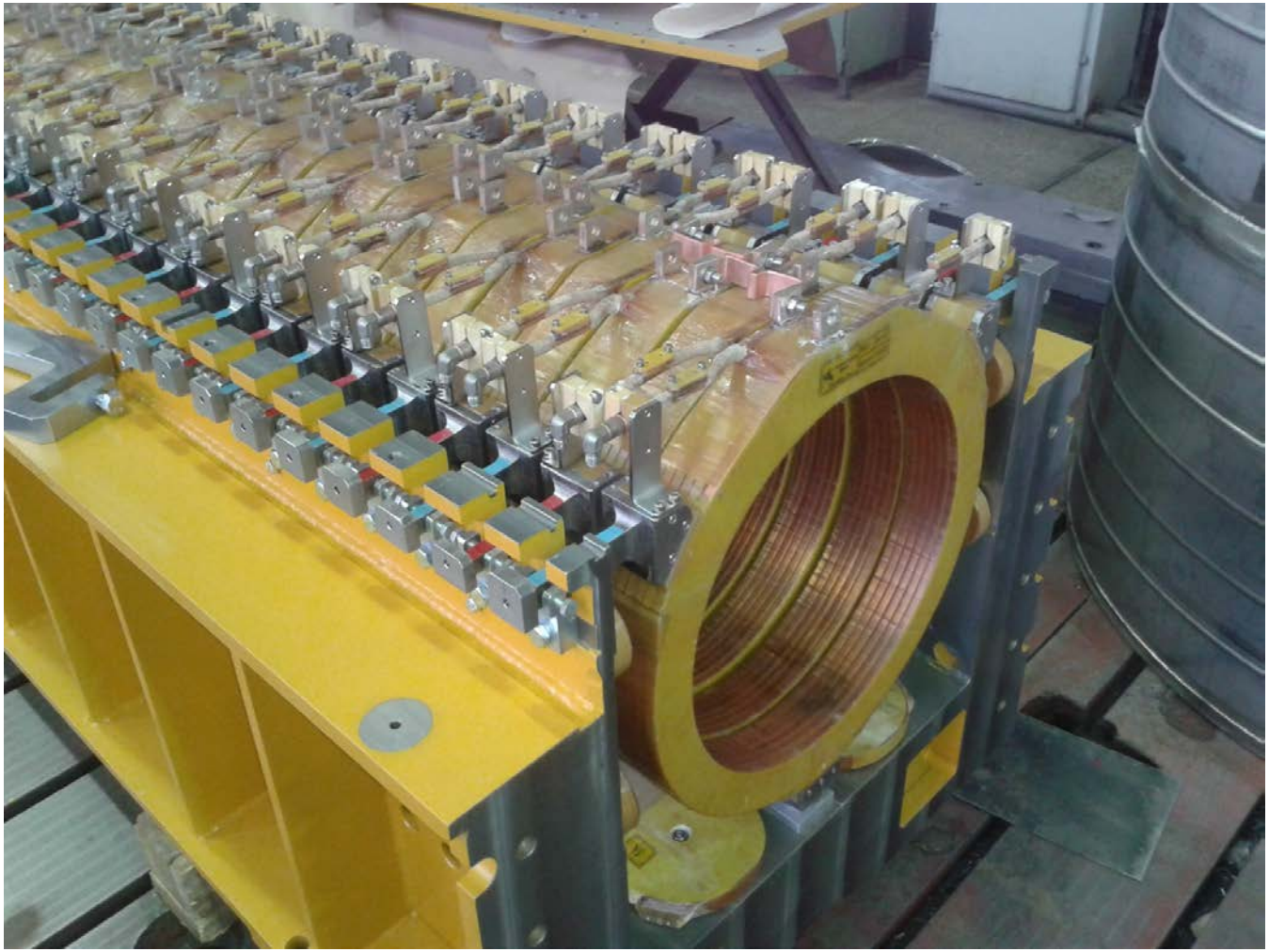
Main parameters of the system

Parameter	Value
Ion type	$^{197}Au^{31+}$
Electron energy, E	1.5÷60 keV
Electron beam current, I	0.2÷1.0 A
Energy stability, ΔE/E	$<10^{-5}$
Electron current stability, ΔI/I	$<10^{-4}$
Longitudinal magnetic field, B	0.1÷0.2 T
Electron current loses, I_{leak}/I	$<3\cdot10^{-5}$
Inhomogeneity of magnetic field, ΔB/B	$<3\cdot10^{-5}$
Transverse electron temperature, T	<0.3 eV
Vacuum pressure, P	$\approx10^{-11}$ mbar

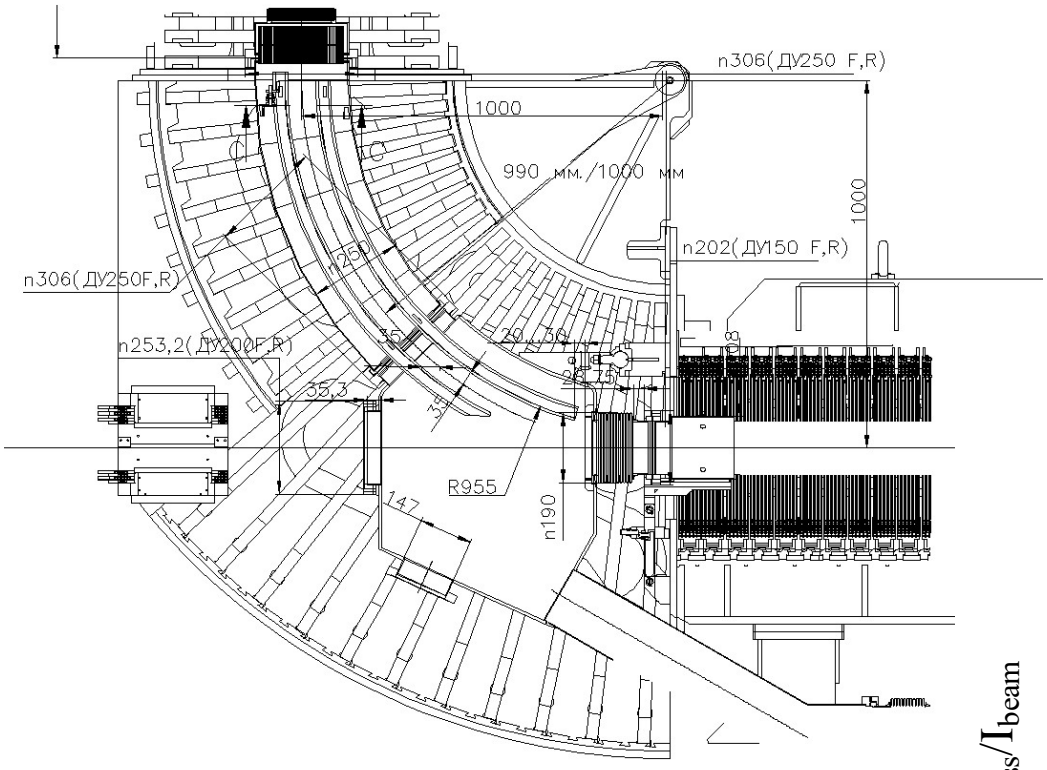
Cooling section

Homogeneity of magnetic field is very important for cooling force.



Solenoid consists of separate coils. Each coil can be rotated in two direction

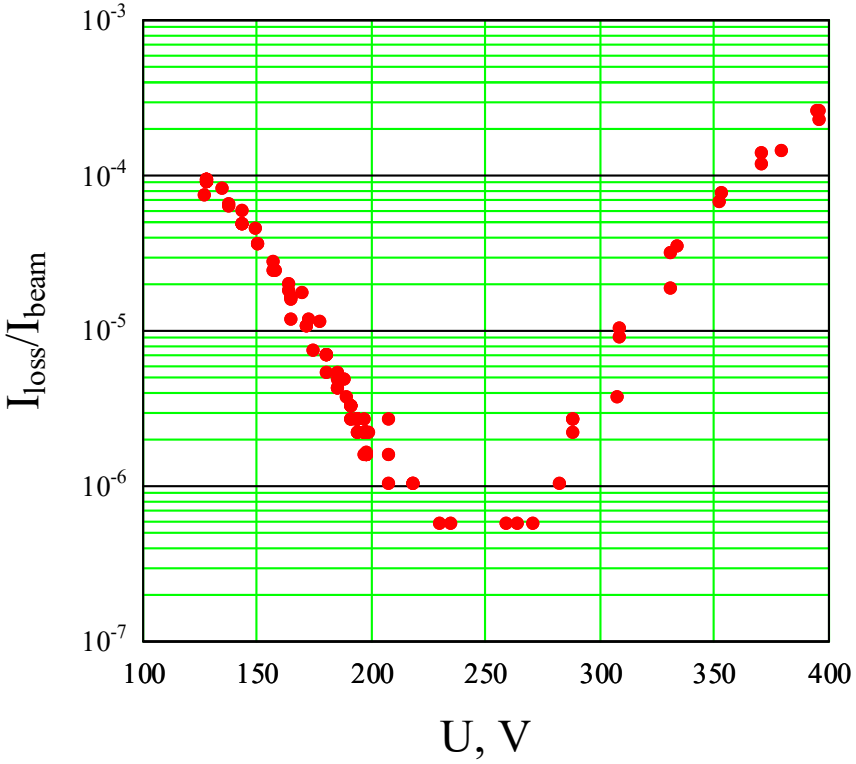
Toroids



$$F = \frac{mV^2}{R} = eE + e\frac{[V \times B]}{c} = const$$

E=0 magnet bending B=pc/eR

B=0 electrostatic bending E=pV/eR



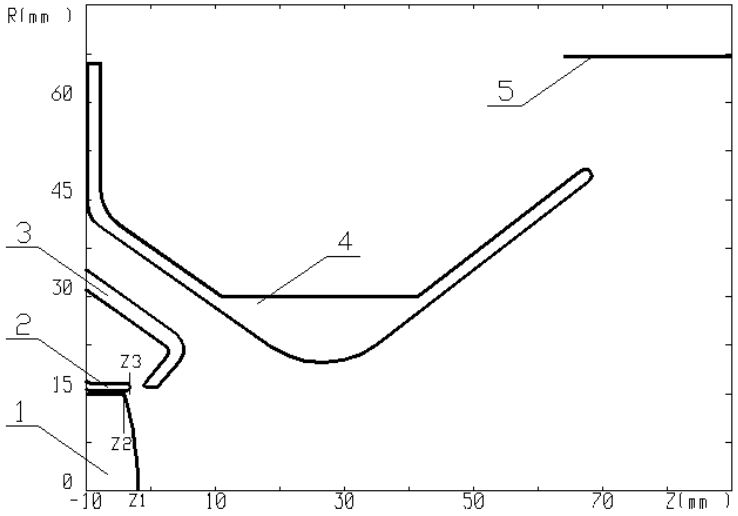
Electrostatic plates are used in toroid.

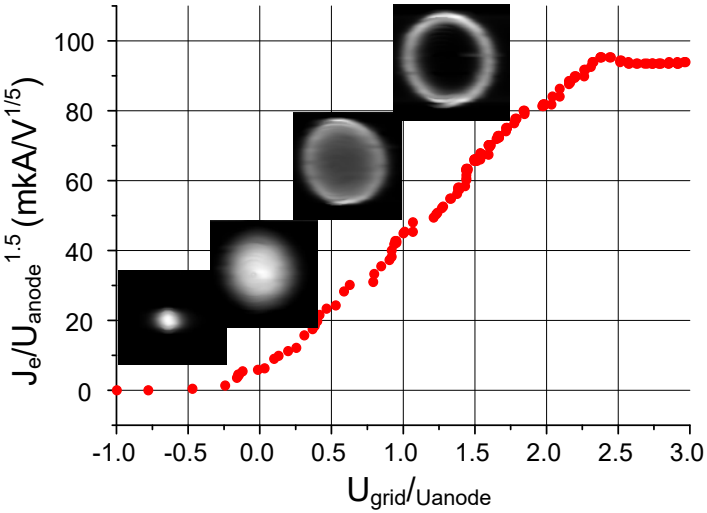
Recuperation efficiency increases to

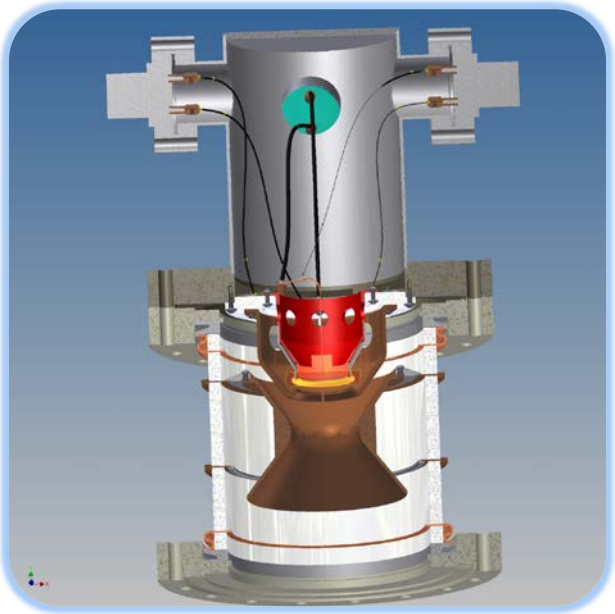
$$\frac{I_{leak}}{I} \approx 10^{-6}$$

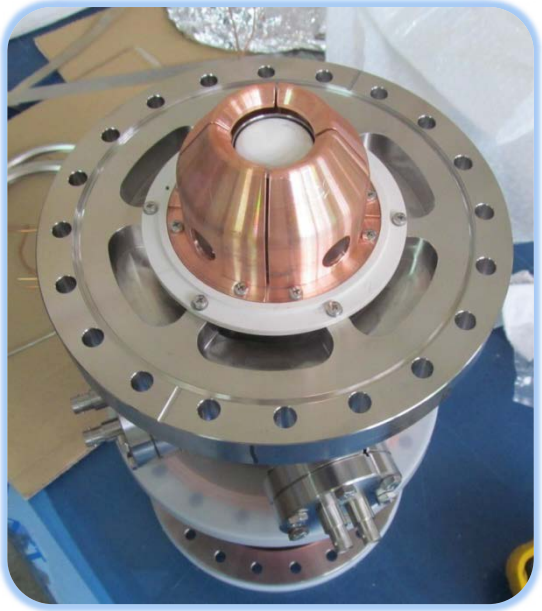
Electron gun

The gun is based on construction from HV COSY cooler.

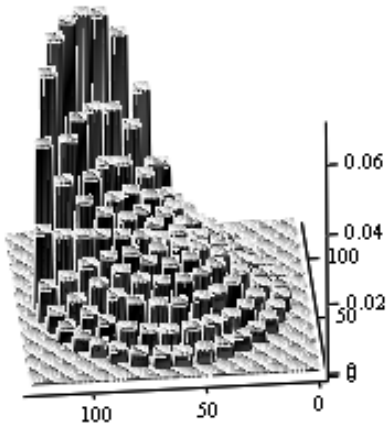




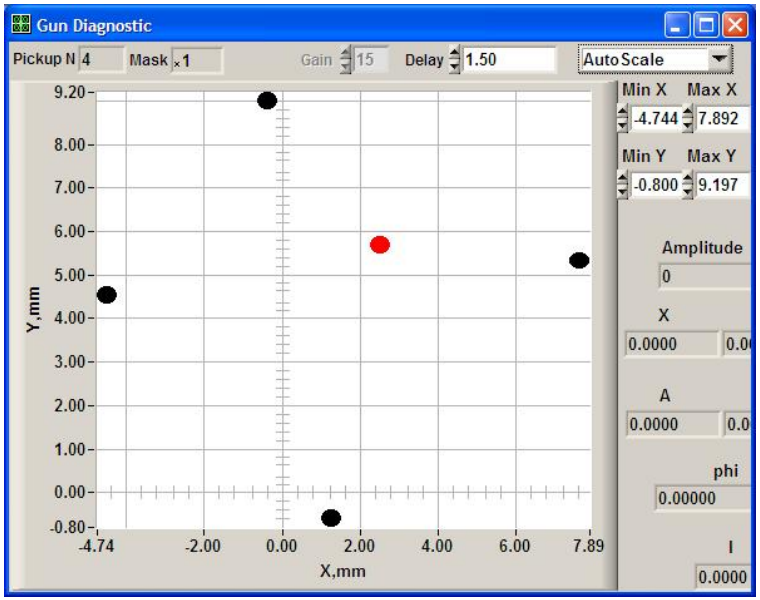


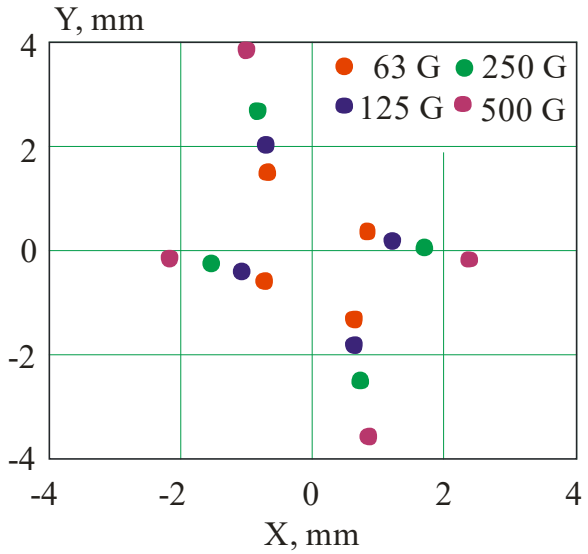


4-sector control electrode

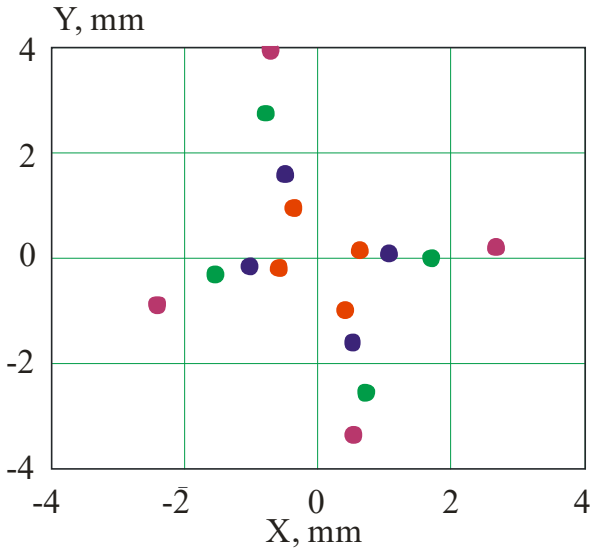


Voltage is applied to one sector



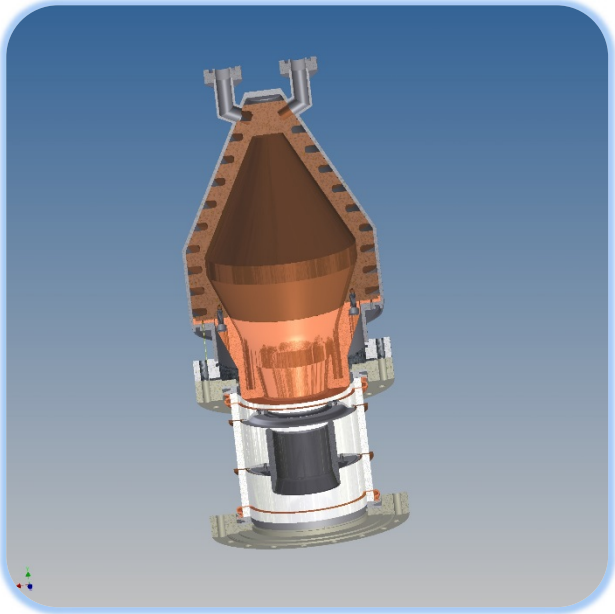


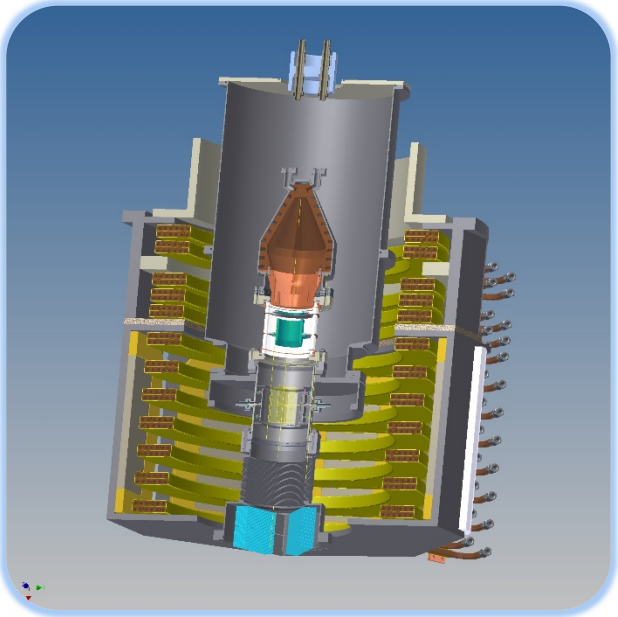
Different values of magnetic field

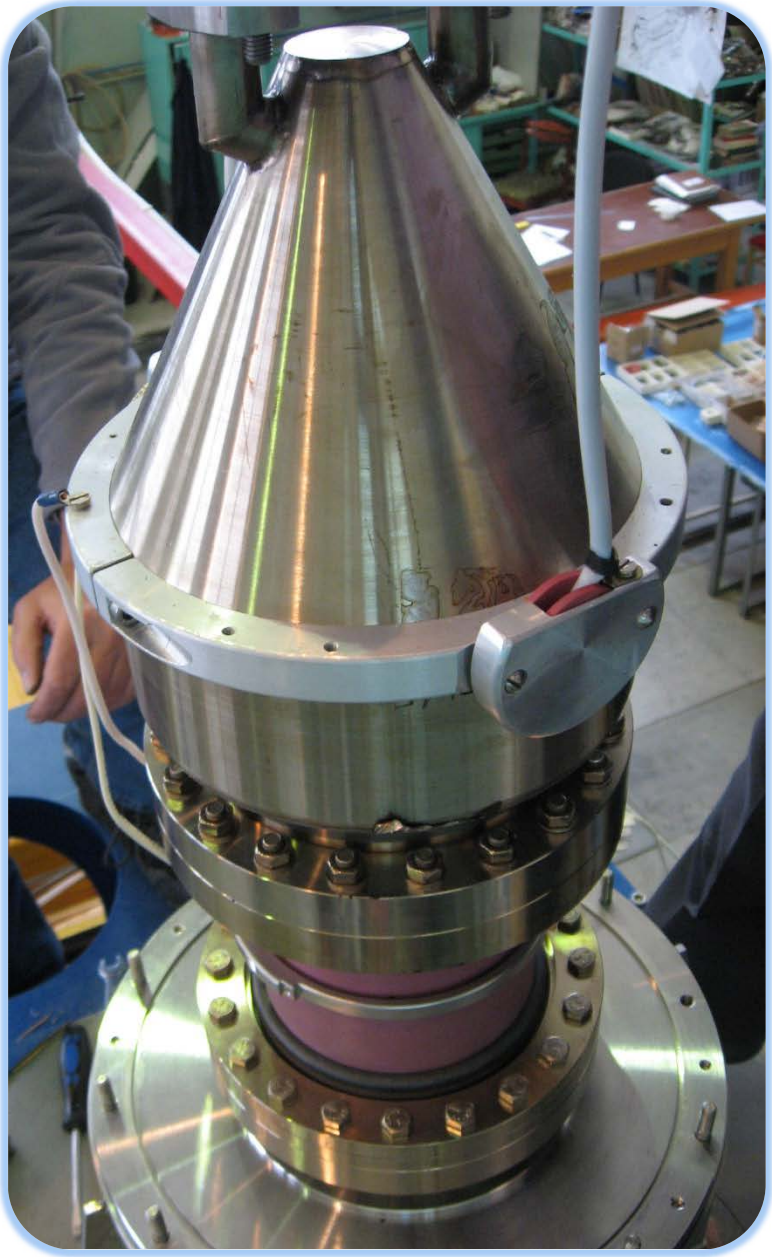


Different regimes of gun work

Electron collector

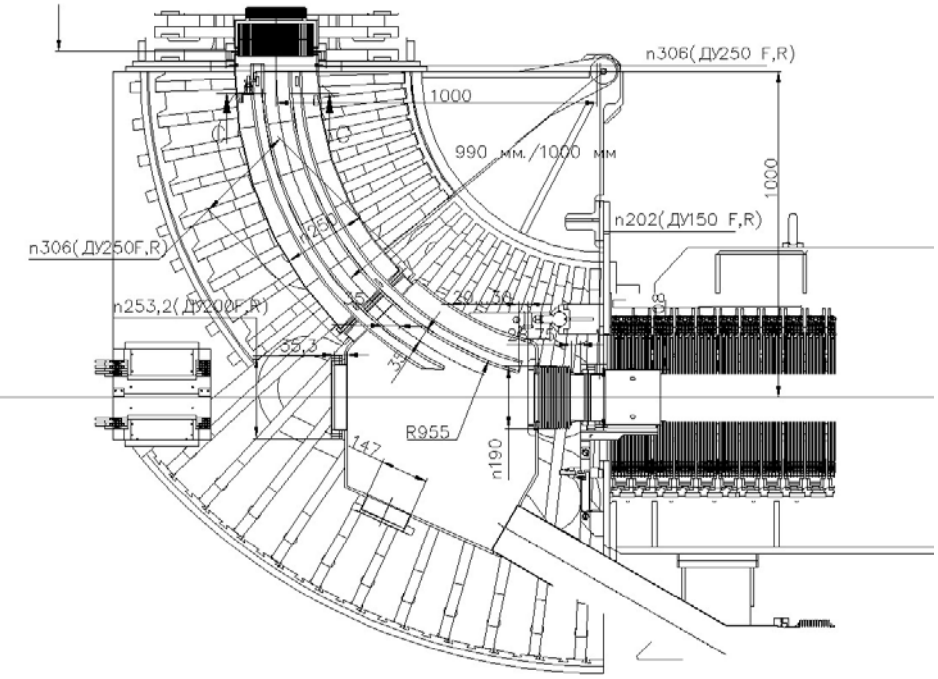


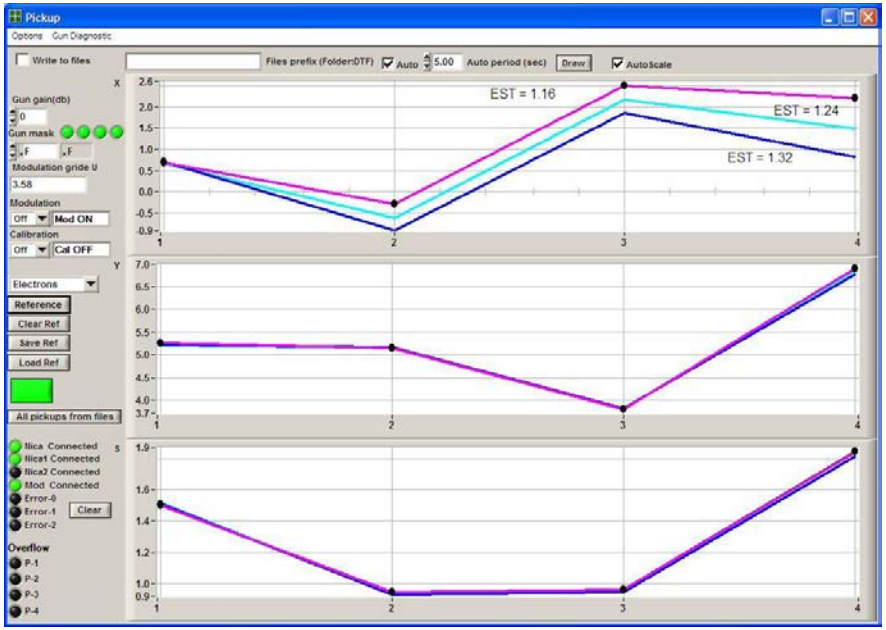




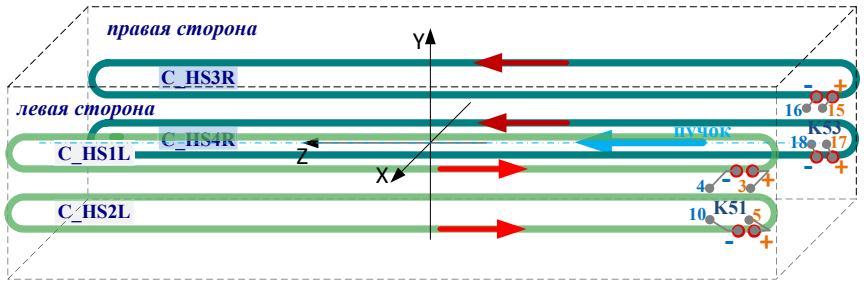
BPMs

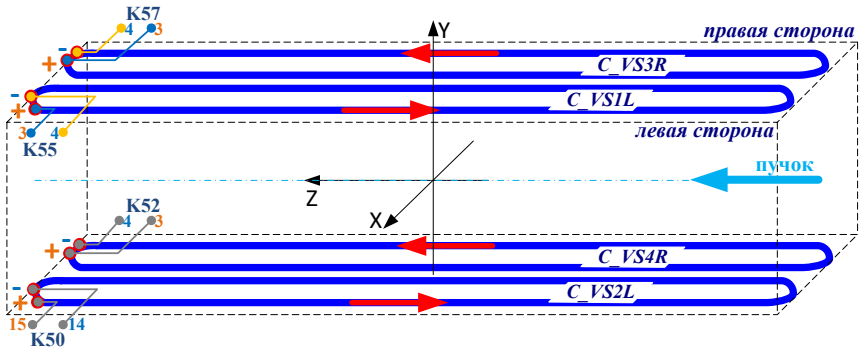
2 electrostatic bends shift beam in horizontal direction 2 times.

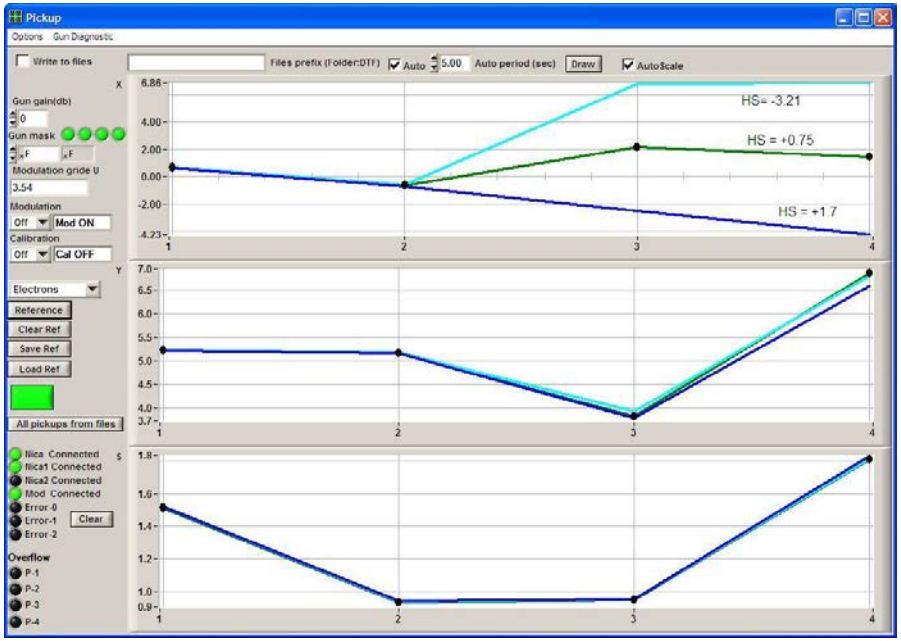


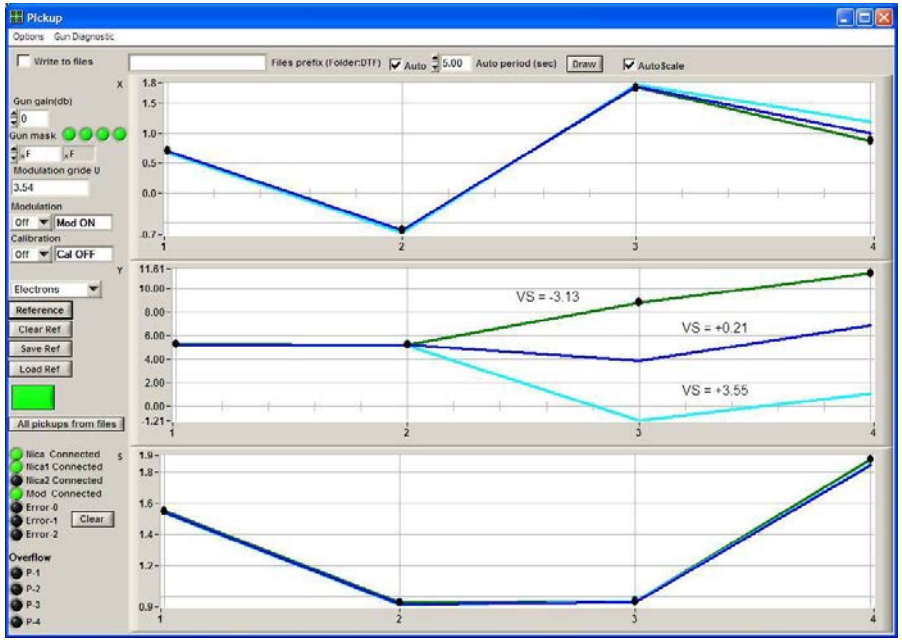


BPMs


правая сторона
C_HS3R
левая сторона
C_HS4R
C_HS1L
C_HS2L
пучок
Y
Z
X
K53
K51
16
15
18
17
4
3
10
5

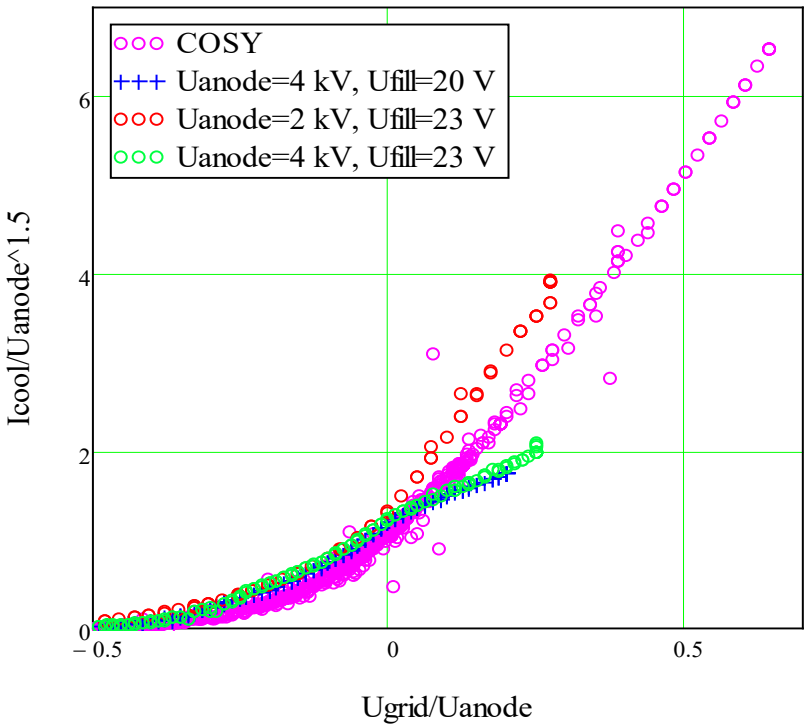

K57
4
3
правая сторона
C_VS3R
C_VS1L
левая сторона
K55
пучок
Y
Z
X
K52
C_VS4R
C_VS2L
15
14
K50

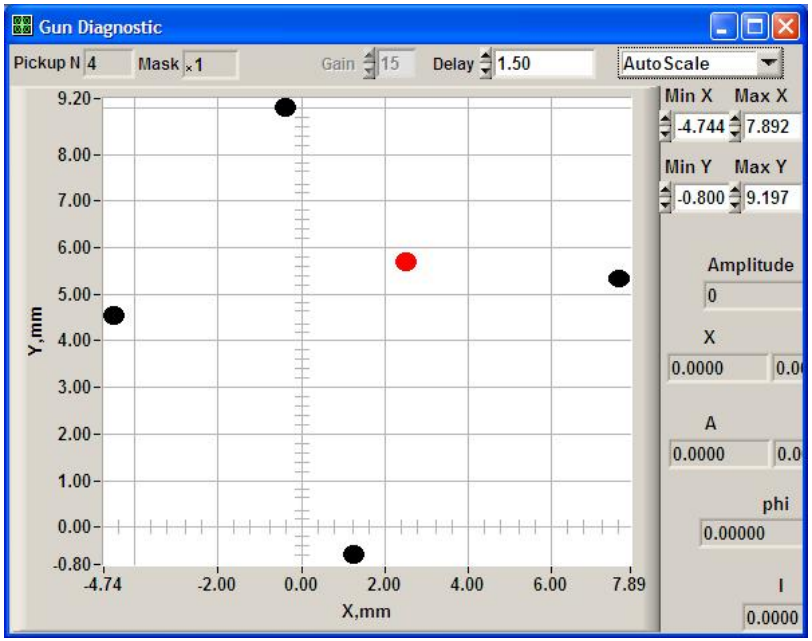

Pickup
Options
Gun Diagnostic
Write to files
Files prefix (Folder:DTF)
Auto
5.00
Auto period (sec)
Draw
AutoScale
Gun gain(db)
Gun mask
Modulation grride U
3.54
Modulation
Off
Mod ON
Calibration
Cal OFF
Electrons
Reference
Clear Ref
Save Ref
Load Ref
All pickups from files
Nica Connected
Nica1 Connected
Nica2 Connected
Mod Connected
Error-0
Error-1
Error-2
Clear
Overflow
P-1
P-2
P-3
P-4
HS= -3.21
HS = +0.75
HS = +1.7


Pickup
Options
Gun Diagnostic
Write to files
Files prefix (Folder:DTF)
Auto
5.00
Auto period (sec)
Draw
AutoScale
Gun gain(db)
Gun mask
Modulation grride U
3.54
Modulation
Off
Mod ON
Calibration
Cal OFF
Electrons
Reference
Clear Ref
Save Ref
Load Ref
All pickups from files
Nica Connected
Nica1 Connected
Nica2 Connected
Mod Connected
Error-0
Error-1
Error-2
Clear
Overflow
P-1
P-2
P-3
P-4
VS = -3.13
VS = +0.21
VS = +3.55

Current–voltage characteristic of the gun

The rescale allows to compare measures with different U_{anode} .

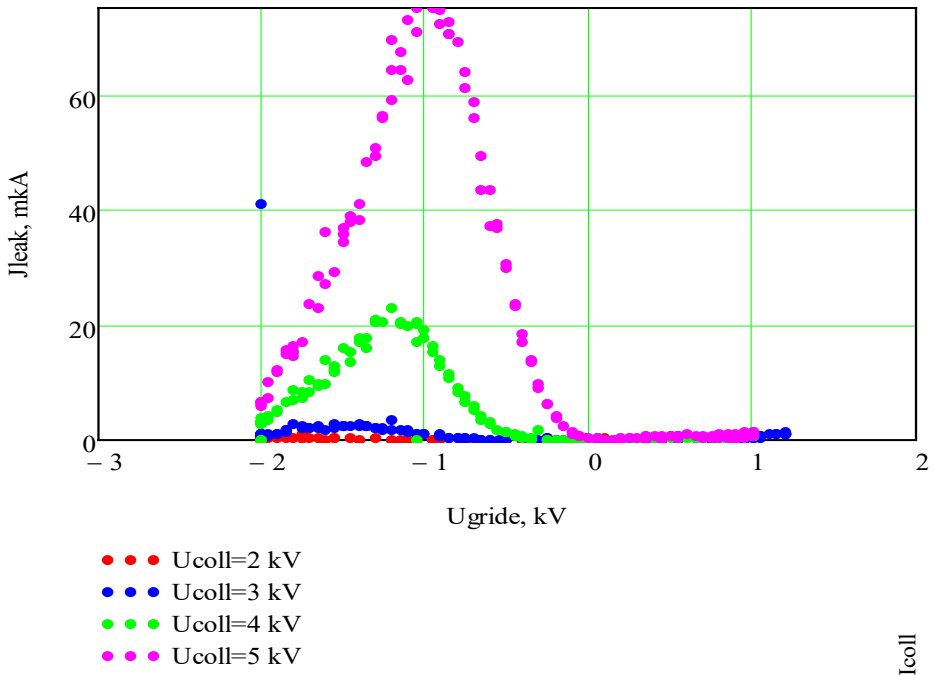




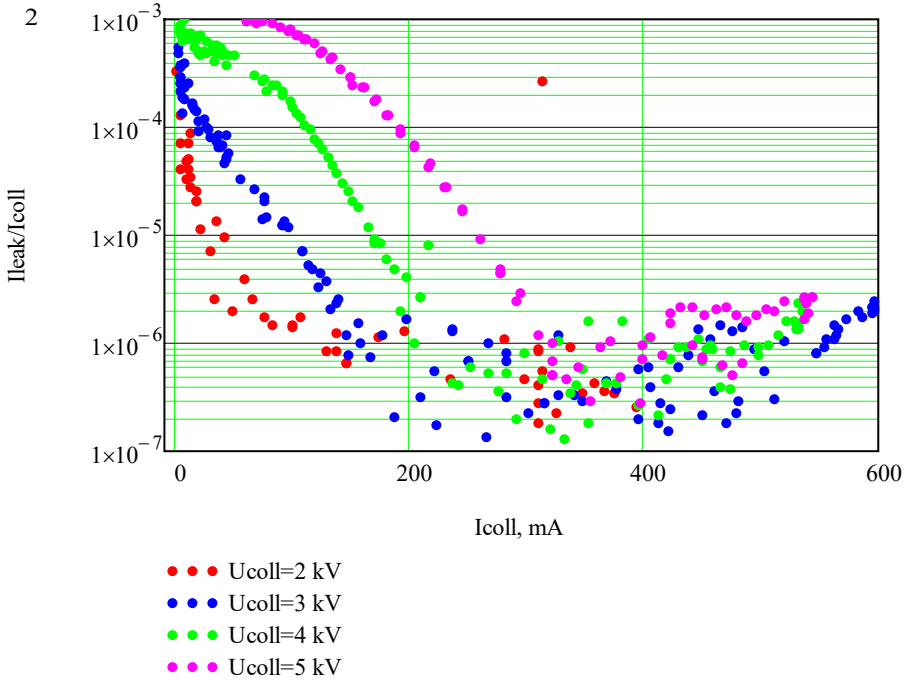
Because of problems with cathode activation, emission ability is not enough for high current.

Comparison with COSY gun shows, that there is small difference in gun construction.

Electron beam recuperation

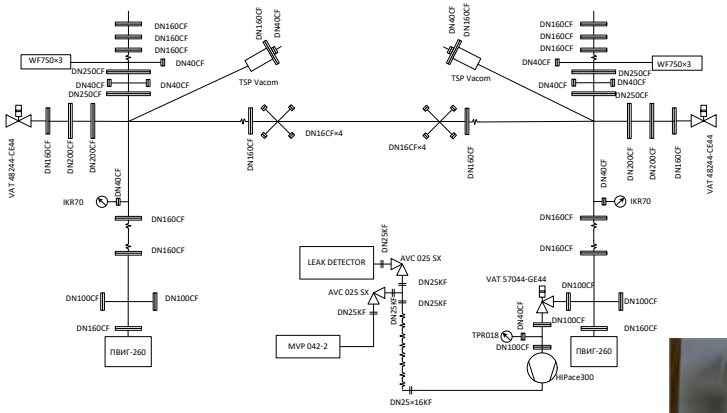


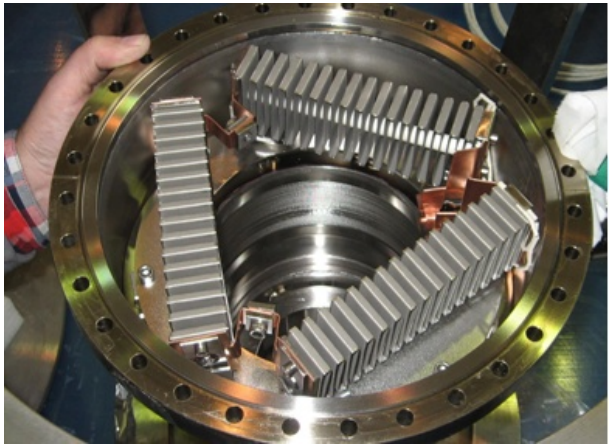
Dependence of leakage current on U_{grid}.



Dependence of recuperation efficiency on electron beam current. The value is $\approx 10^{-6}$.

Vacuum system



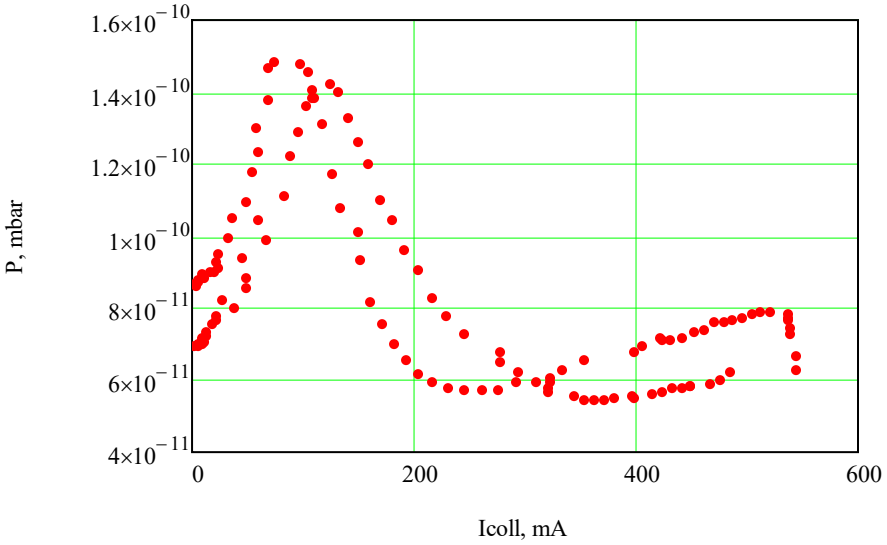


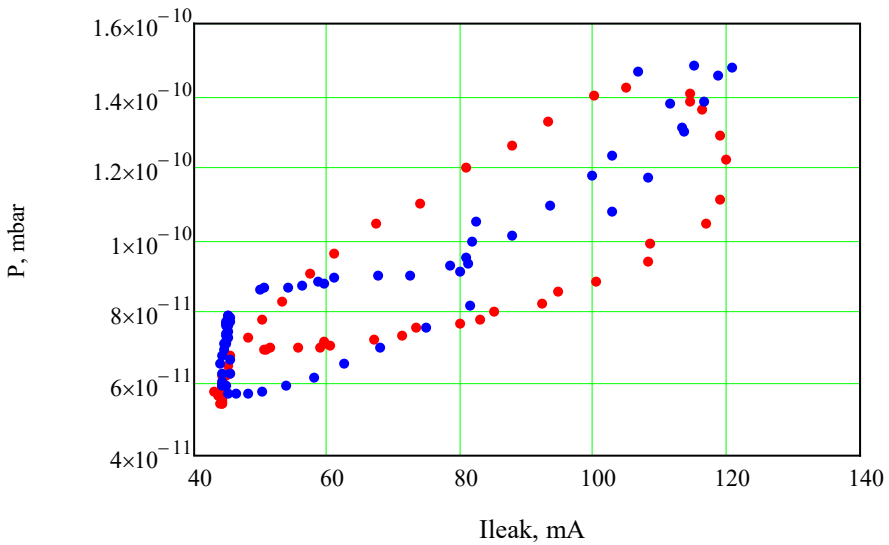
Ion – getter pup.

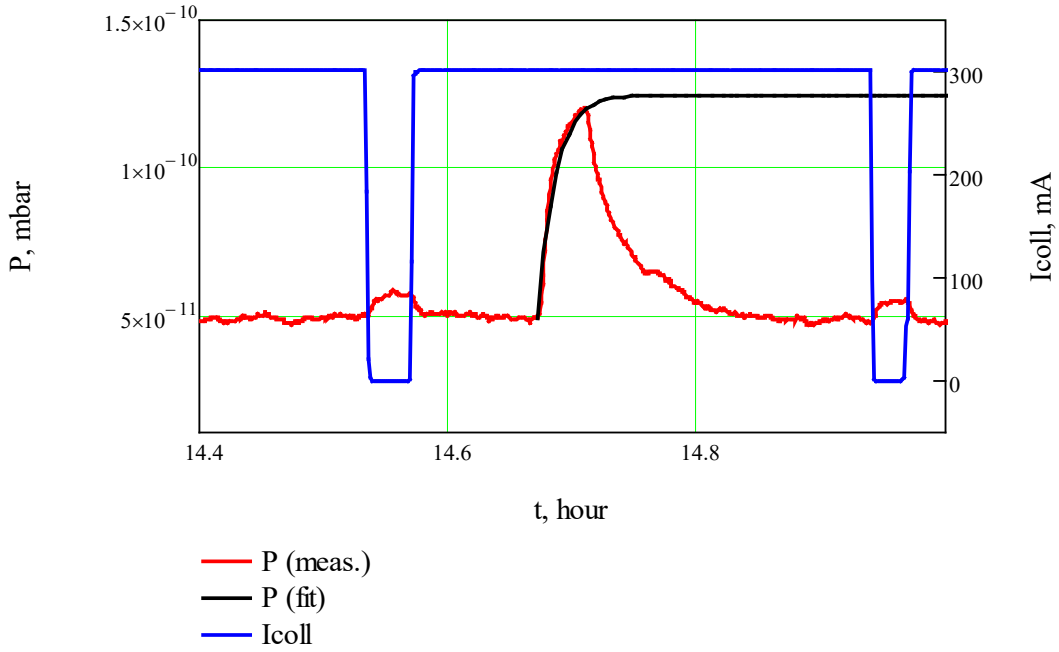
Titanium sublimation pump

NEG pup.

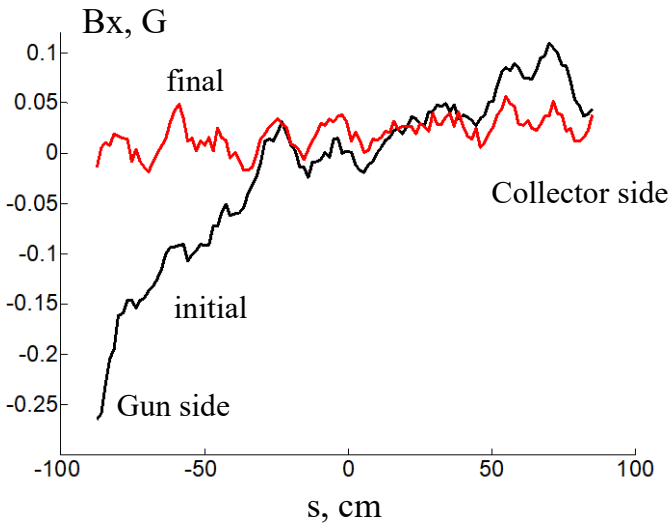
Influence of electron beam on vacuum

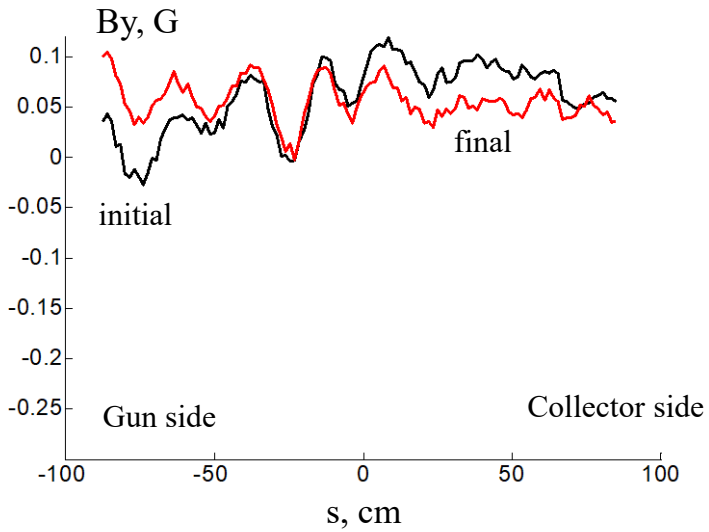




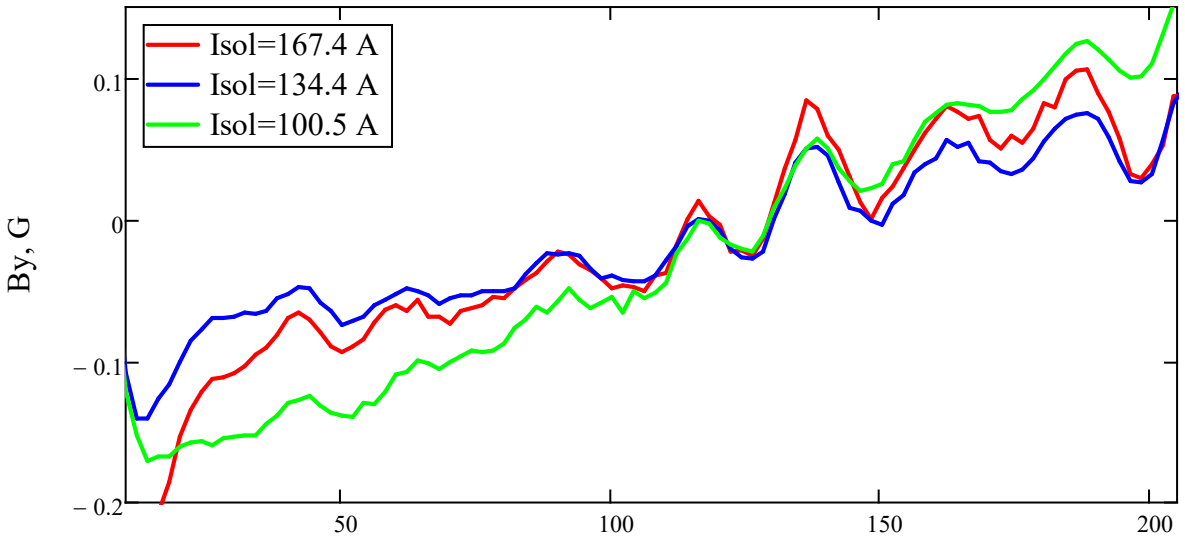


Correction of field line straightness

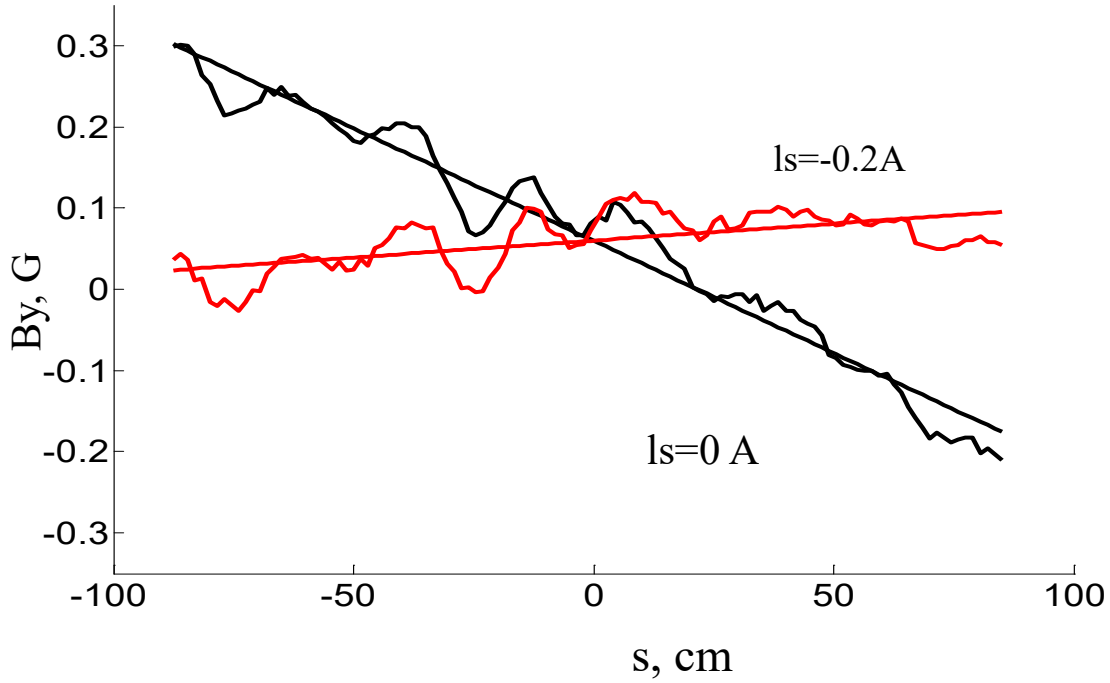




Correction of field line straightness

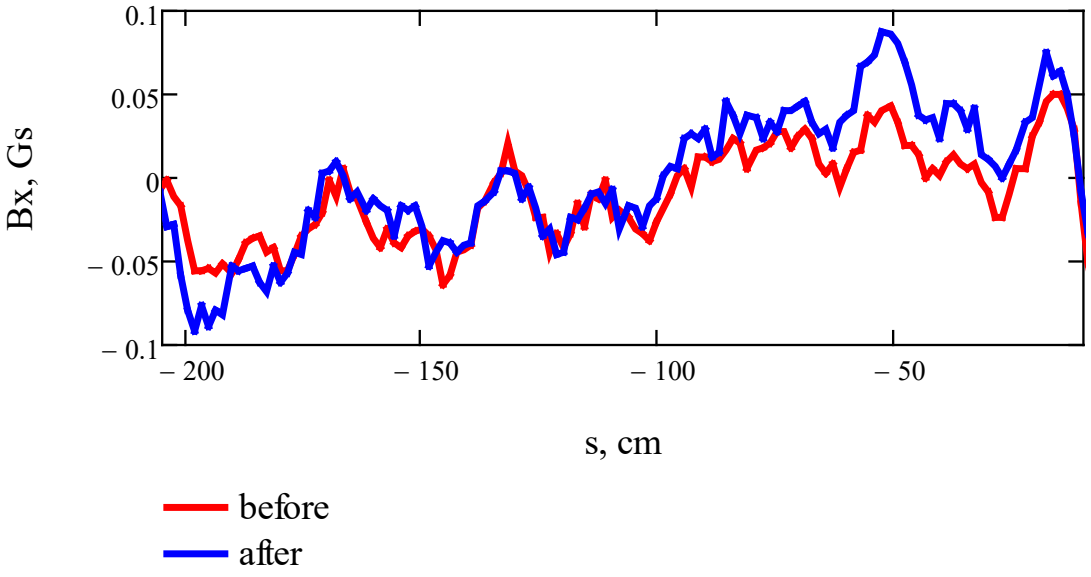


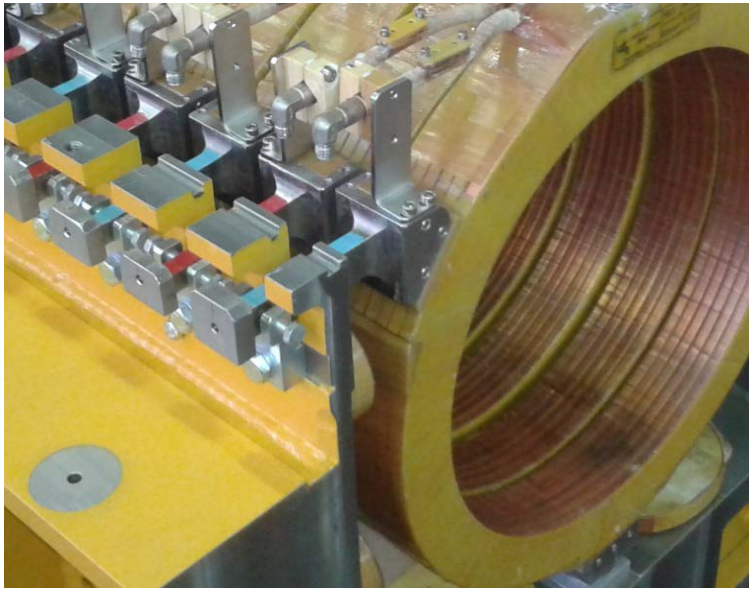
Vertical component of the magnetic field at different longitudinal field.



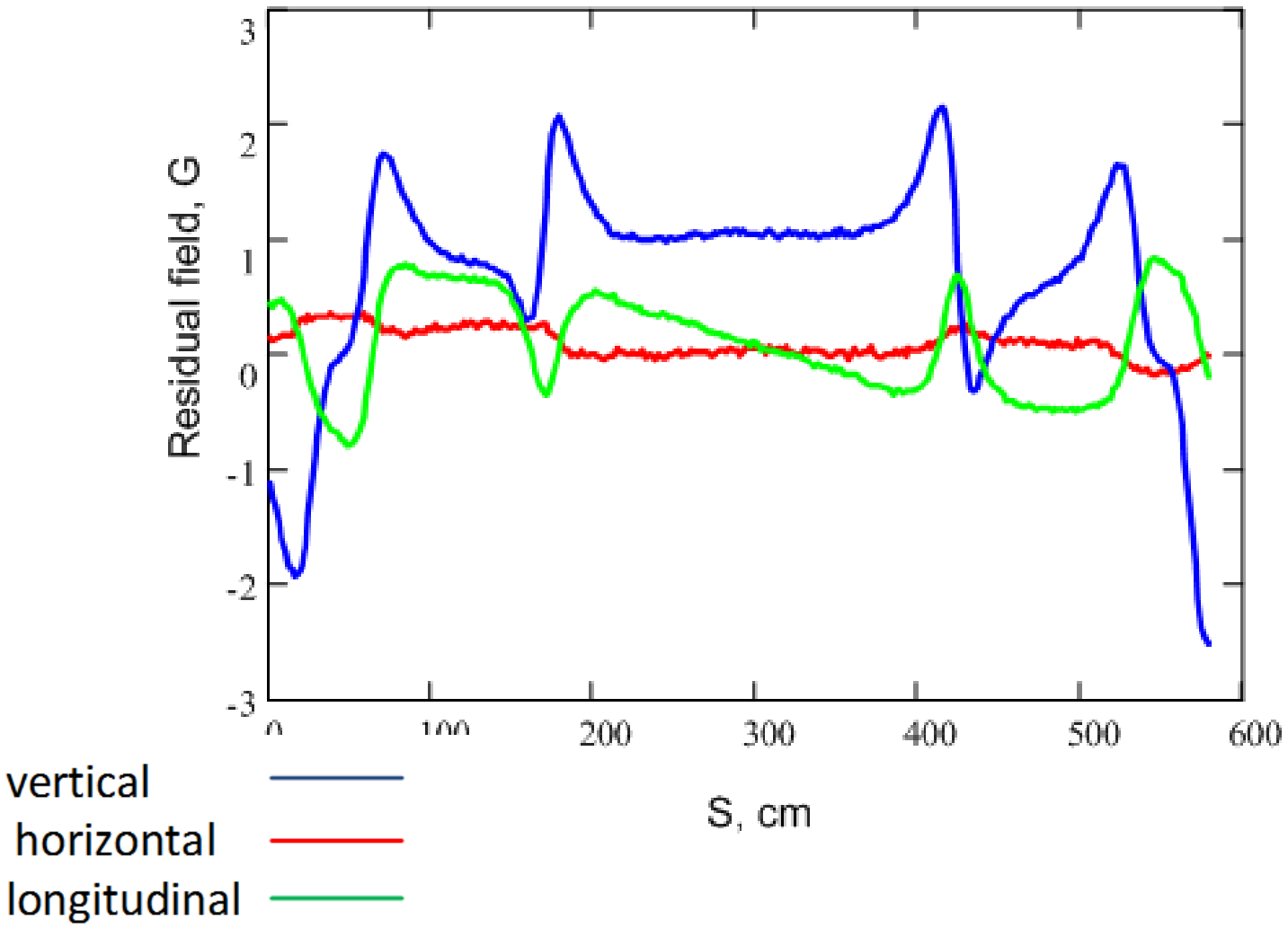
Vertical correction.

Correction of field line straightness





Correction of field line straightness

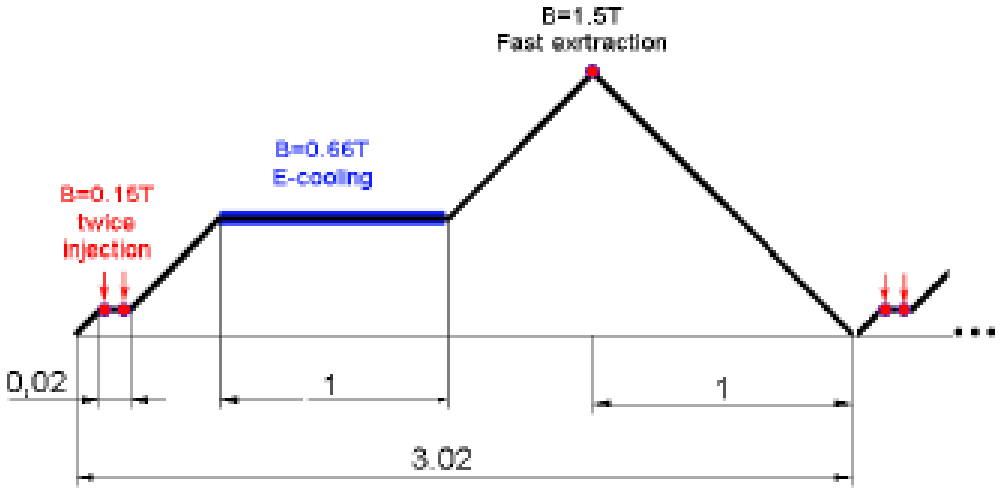


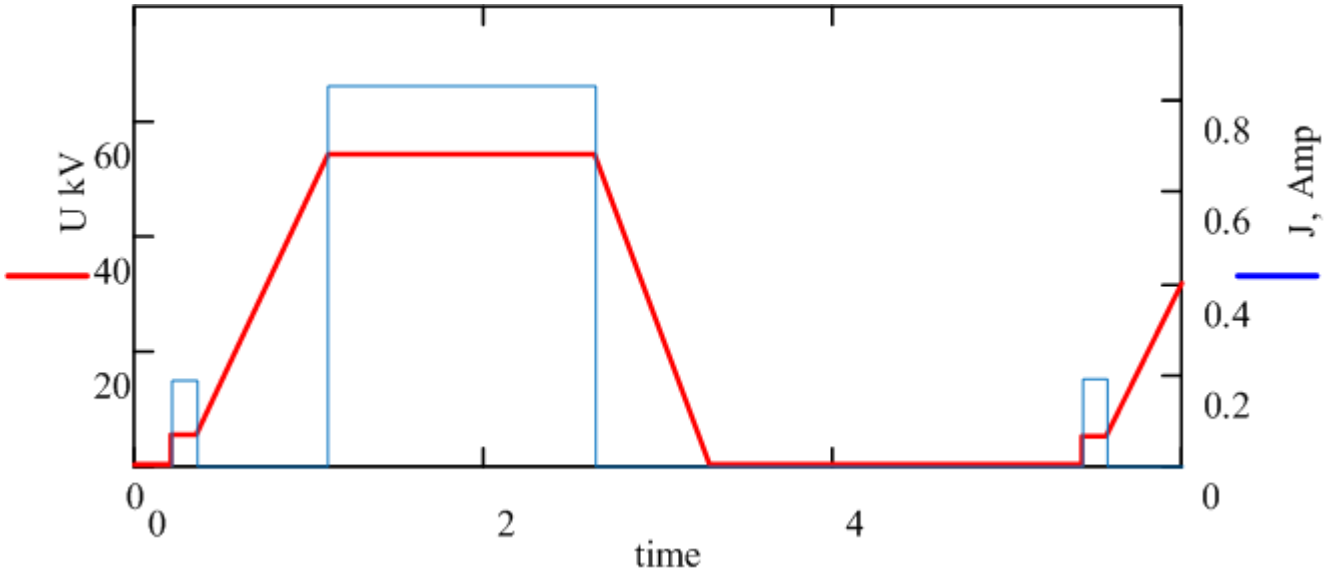
Residual field distribution

Mechanical adjustment system

Residual field compensation

In-vacuum measurements

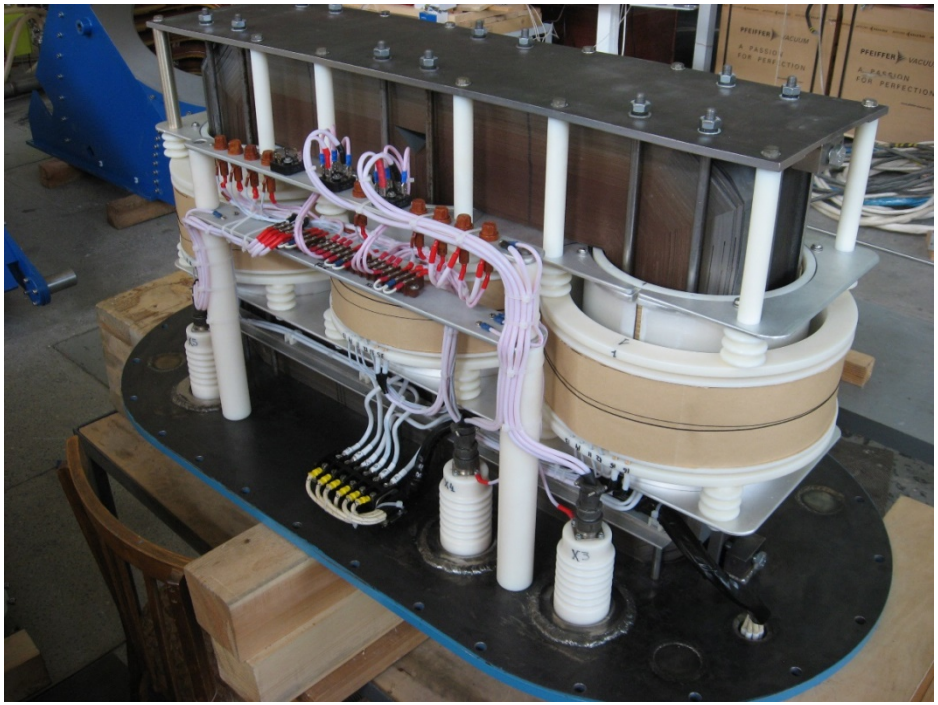

B=1.5T
Fast extraction
B=0.66T
E-cooling
B=0.15T
twice
injection
0,02
1
1
3.02


U kV
60
40
20
0
0
2
4
time
0.8
0.6
0.4
0.2
0
J, Amp

High voltage system

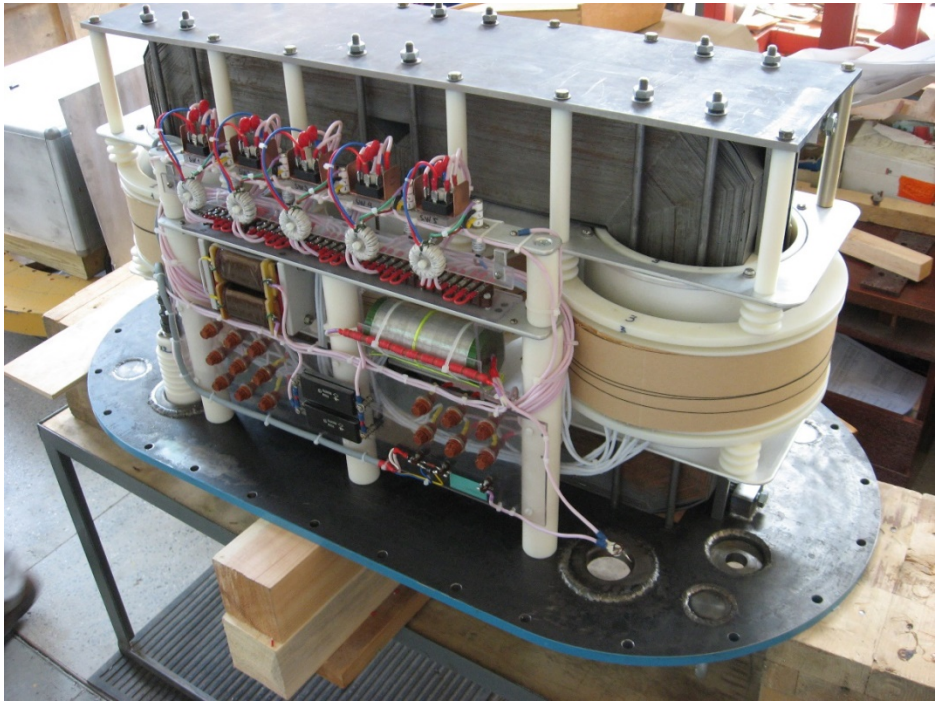
Transformer: 5 kV, 15 kW. (right))
power supply: 60 kV 10 mA (

Collector power supply

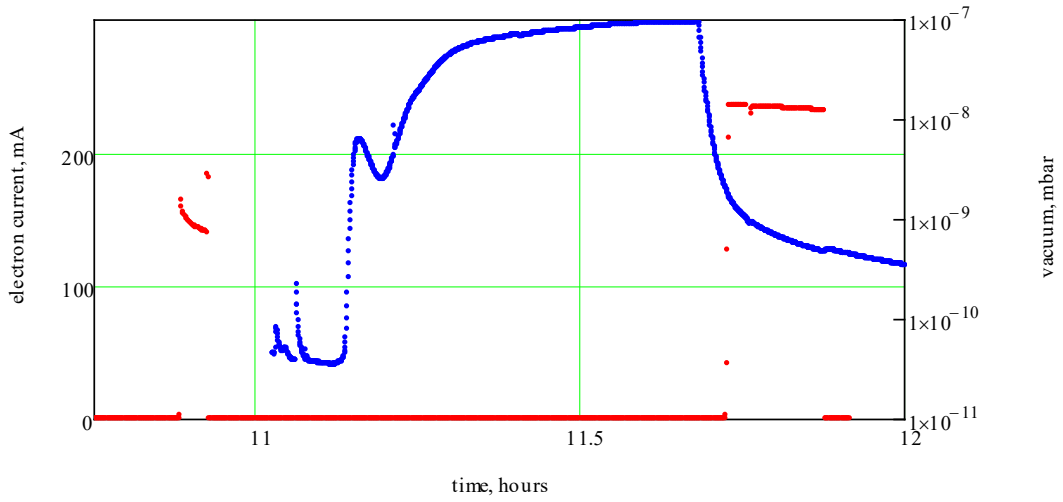


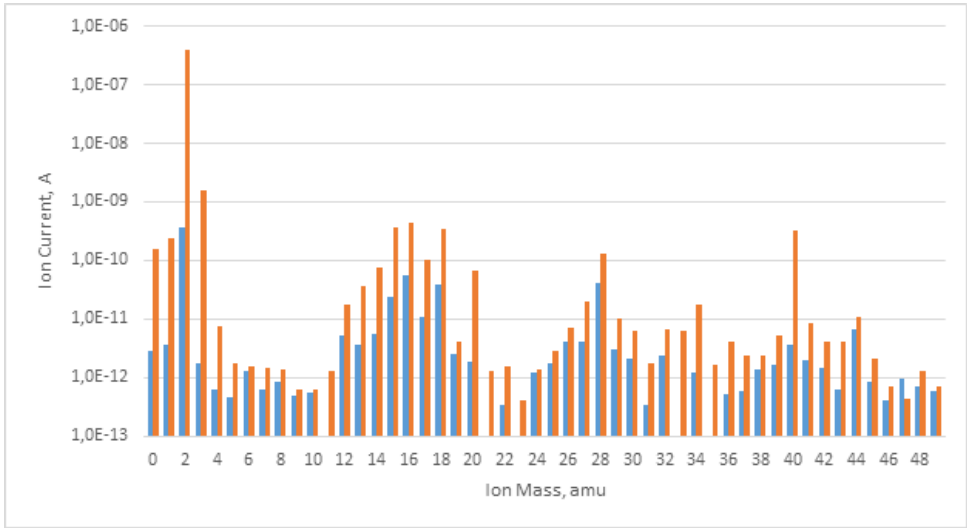
The transformer is based on UNICORE core.

The transformer also contains winding to feed power supplies which control gun and collector.

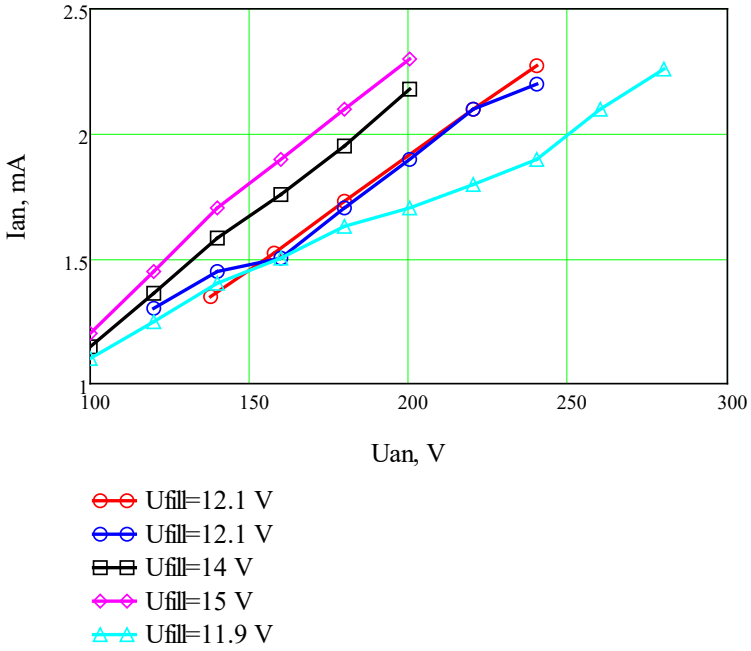


influence of the residual gases released during NEGs regeneration on oxide cathode





Thank you for your attention!


2.5
2
1.5
1
100
150
200
250
300
Ian, mA
Uan, V
Ufill=12.1 V
Ufill=12.1 V
Ufill=14 V
Ufill=15 V
Ufill=11.9 V