DEVELOPMENT OF ELECTRON COOLER COMPONENTS FOR COSY*

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RUPAC-2010

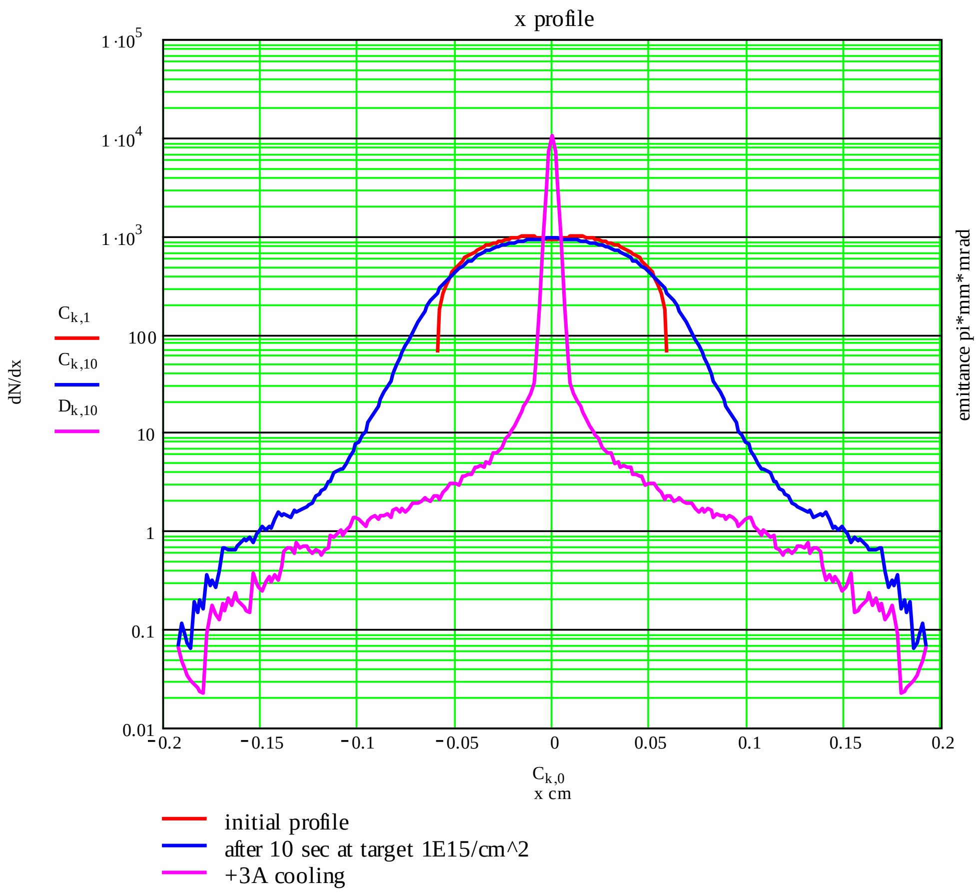
Abstract

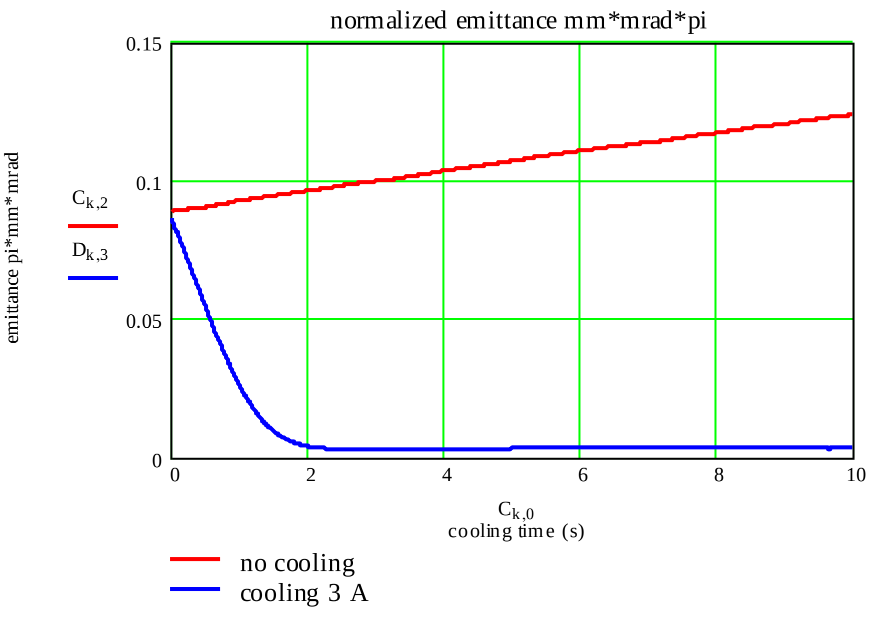
The 2 MeV electron cooling system for COSY-Juelich was proposed to further boost the luminosity even in presence of strong heating effects of high-density internal targets. The project is funded since mid 2009. Manufacturing of the cooler components has already begun with collaboration efforts of two institutes BINP(Novosibirsk) and FZJ(Juelich). The high cooling rate requires using of the high intensity electron beam with strong magnetization at the cooling section. The 2 MeV cooler also well suits in the start up phase of the High Energy Storage Ring (HESR) at FAIR in Darmstadt. At the report experimental testing results of the prototypes of the cooler elements will be discussed.

Basic Parameters and Requirements

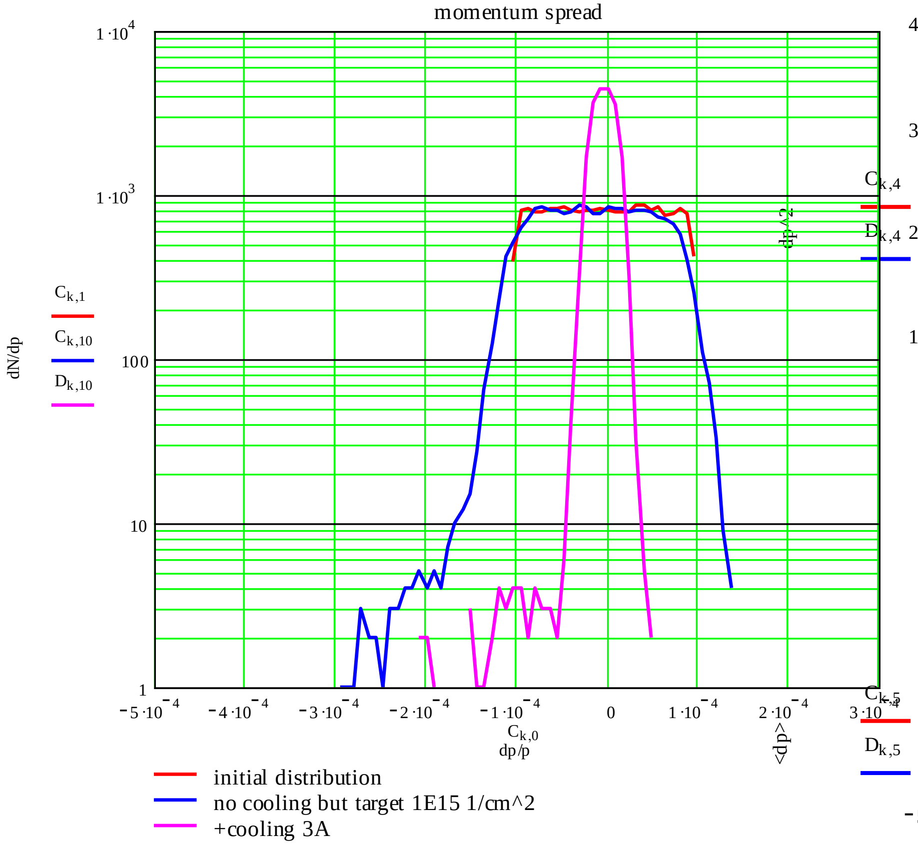
Energy range	**: 25 keV ... 2 MeV**
High voltage stability	**: < 10-4**
Current	**: 0.1 ... 3 A**
Electron beam diameter	**: 10 ... 30 mm**
Cooling length	**: 2.69 m**
Toroid radius	**: 1.0 m**
Variable magnetic field in the cooling section solenoid	**: 0.5 ... 2 kG**
Vacuum in cooler	**: 10^{-9} ... 10^{-10} mbar**
Available overall length	**: 6.39 m**
Maximum height	**: 5.7 m**
COSY beam axis above ground	**: 1.8 m**

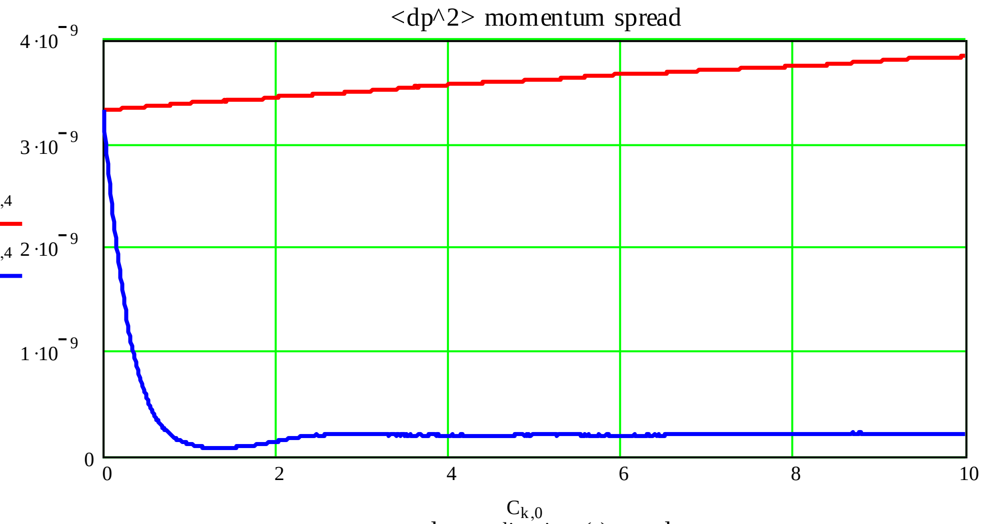
How will act cooler on proton beam in transverse direction?

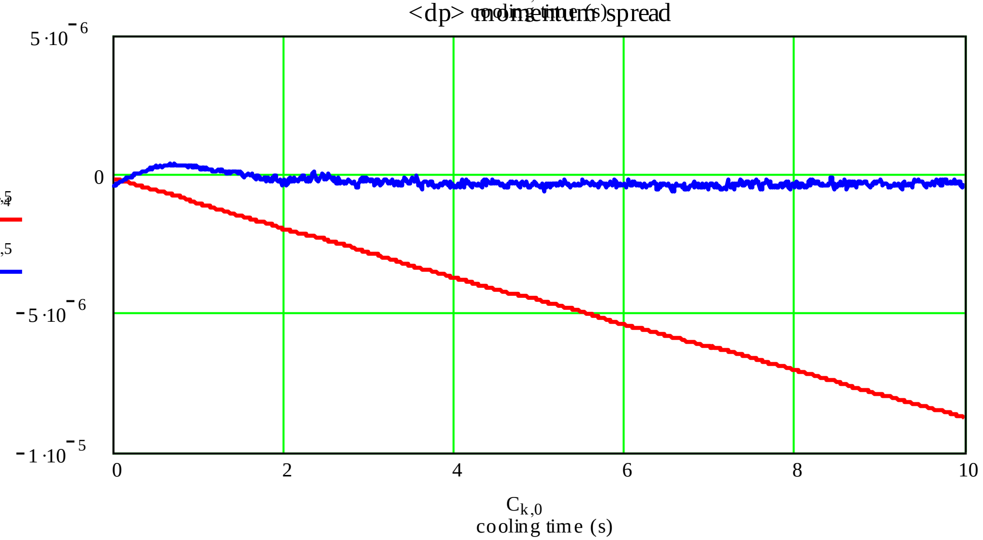




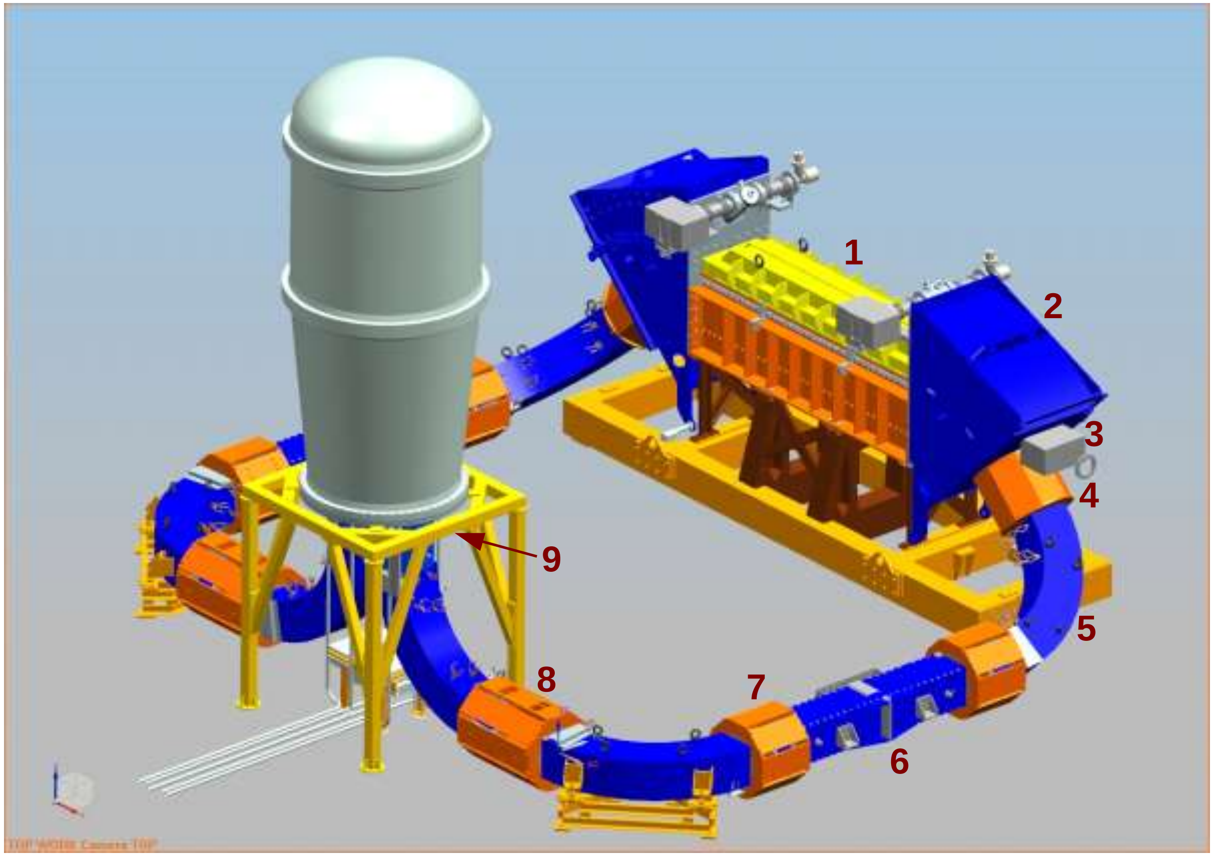
How will cooler act on momentum spread of proton beam?





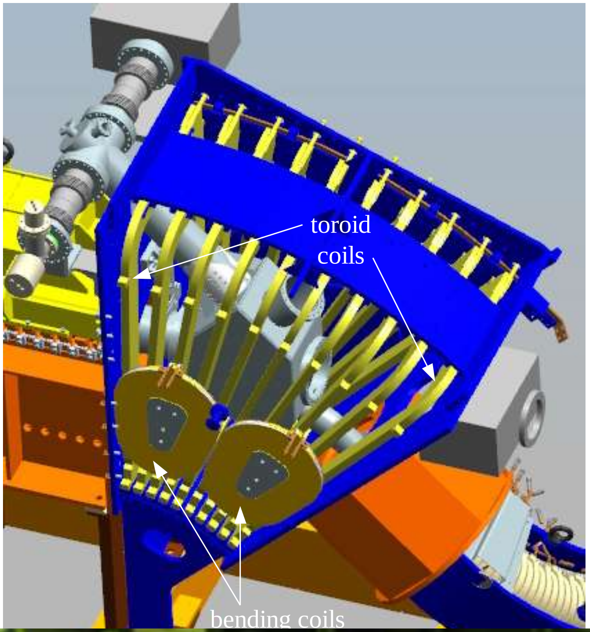


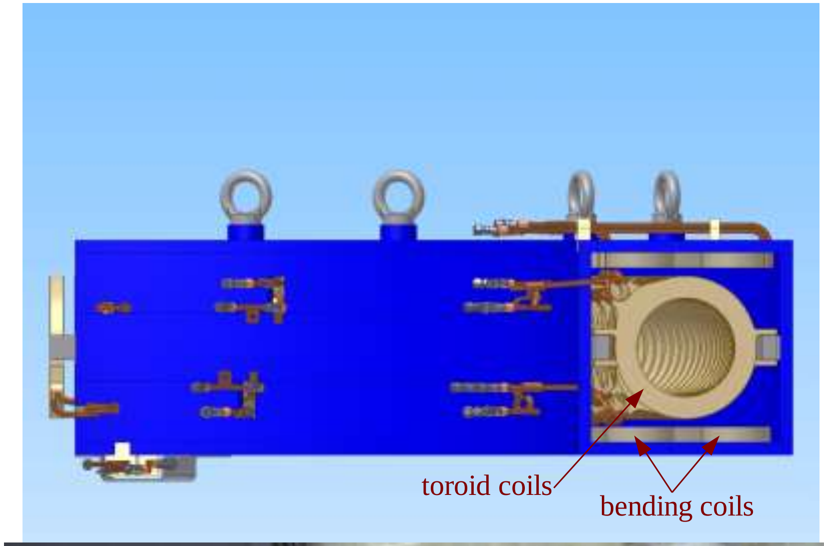
Sketch of COSY 2 MeV cooler

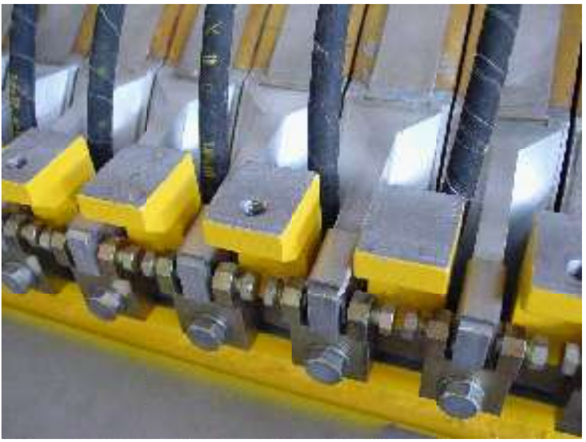


1-cooling section
2-toroidal section
3-dipole for proton beam correction
4-matching solenoid
5-90 degree solenoid
6 technical straight section
7,8,9- matching solenoid

MAGNETIC SYSTEM







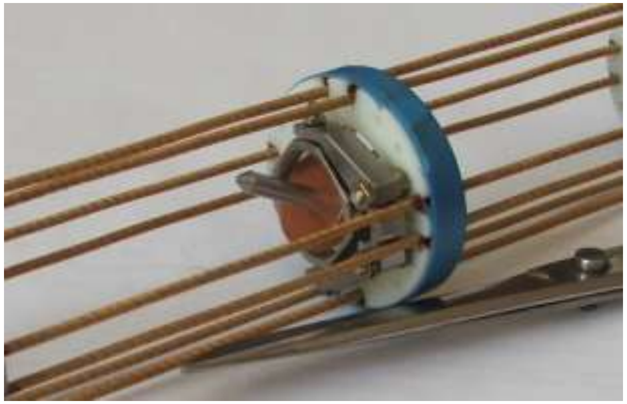
CSRe cooling section

COSY cooler coil

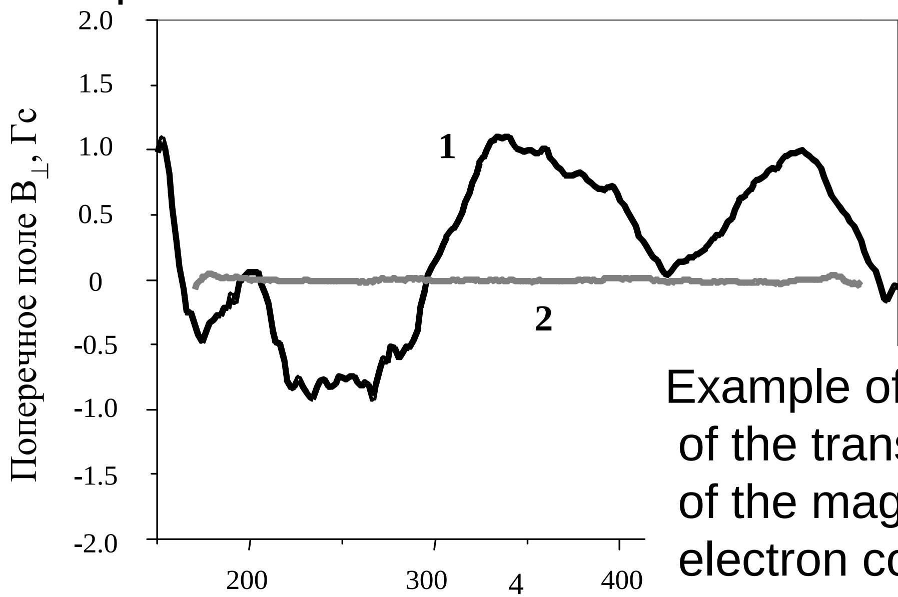
Basic idea of cooling section design is tunable separate coils those can be adjusted after magnetic field measurements

Milling of the box for cooling section

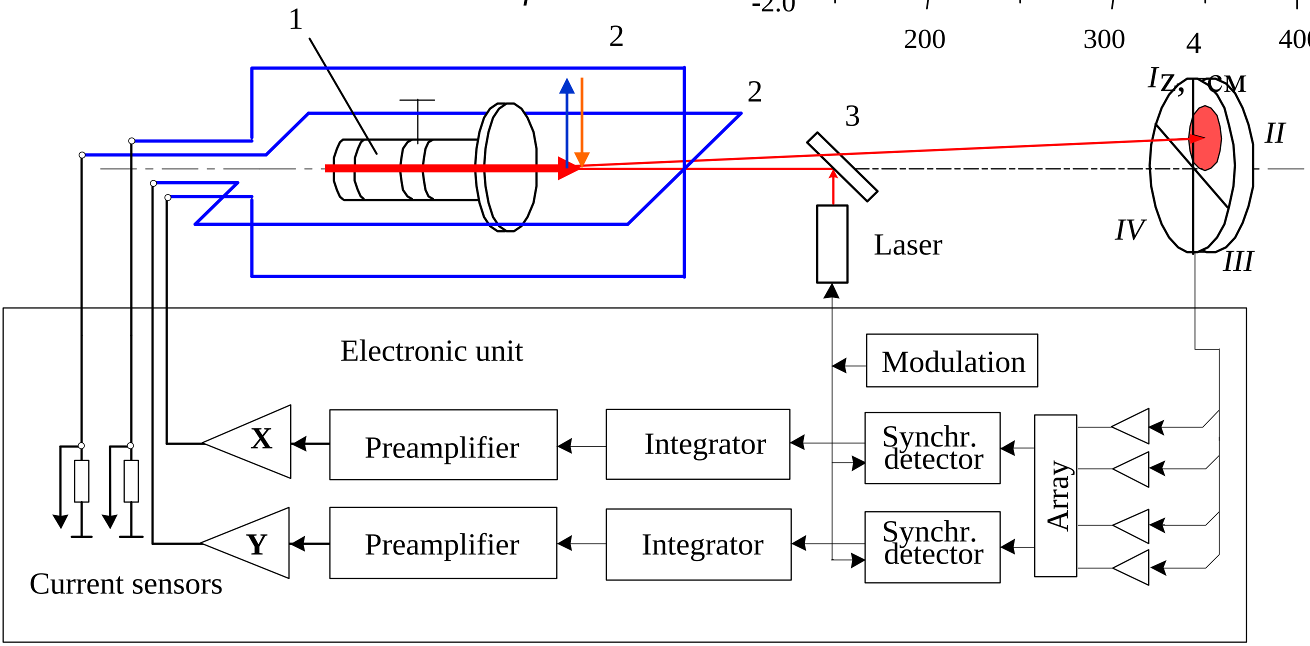
Magnetic line direction measurements



Compass with correction coils



$$Bsolenoid_s + B_\perp - B_{\perp\,feedback}$$

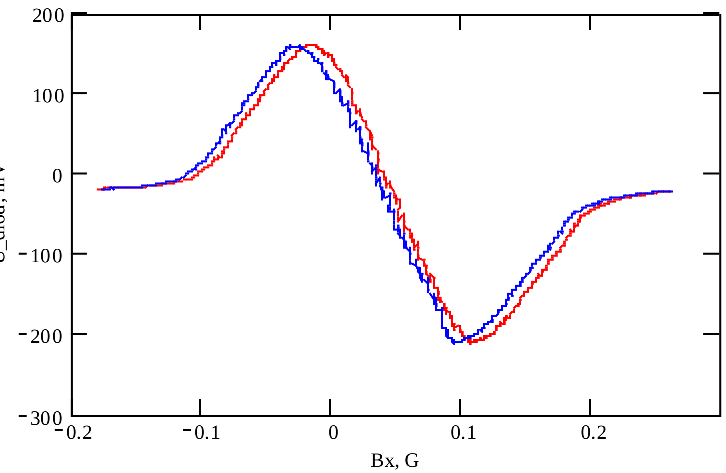


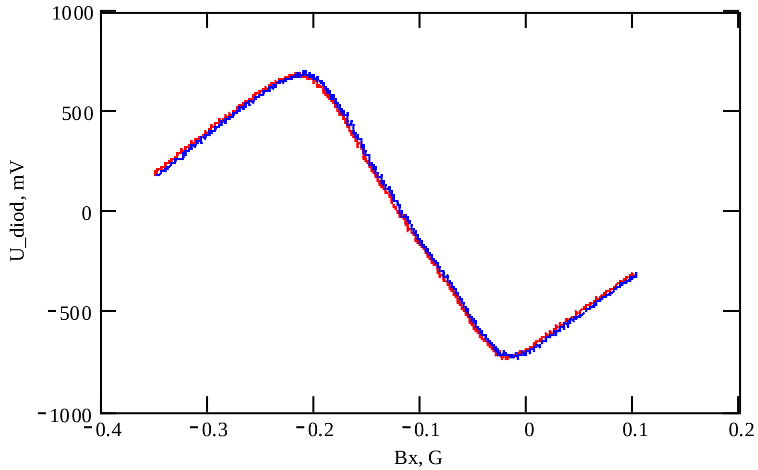
Example of the correction of the transverse compone of the magnetic field at CS electron cooler

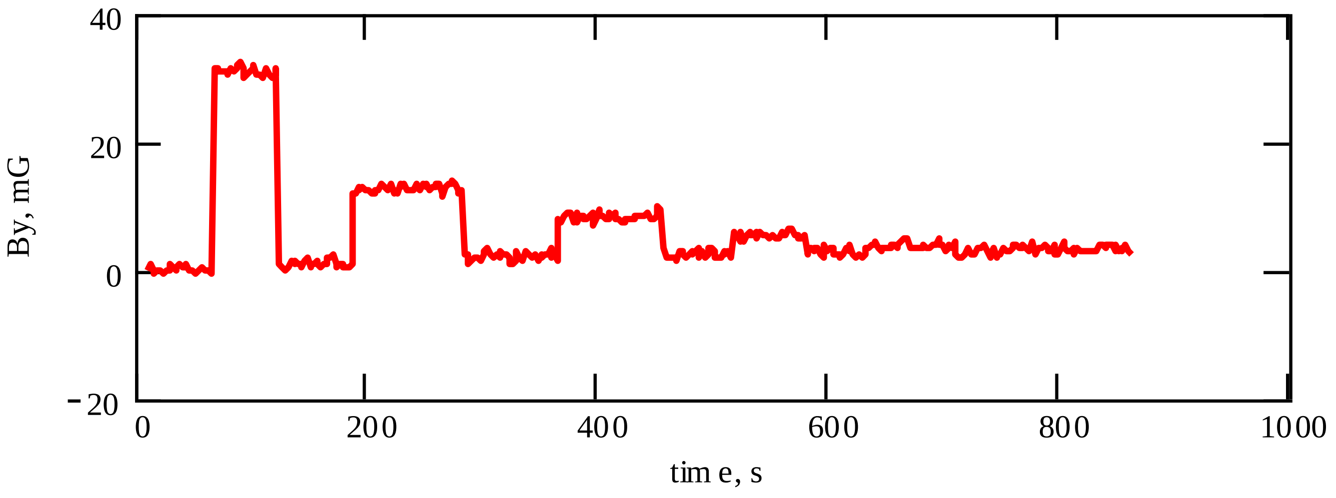
1- just after assembling

2- after inclining coils according to results of measurements

Calibration compass with gimbal suspension and wire suspension



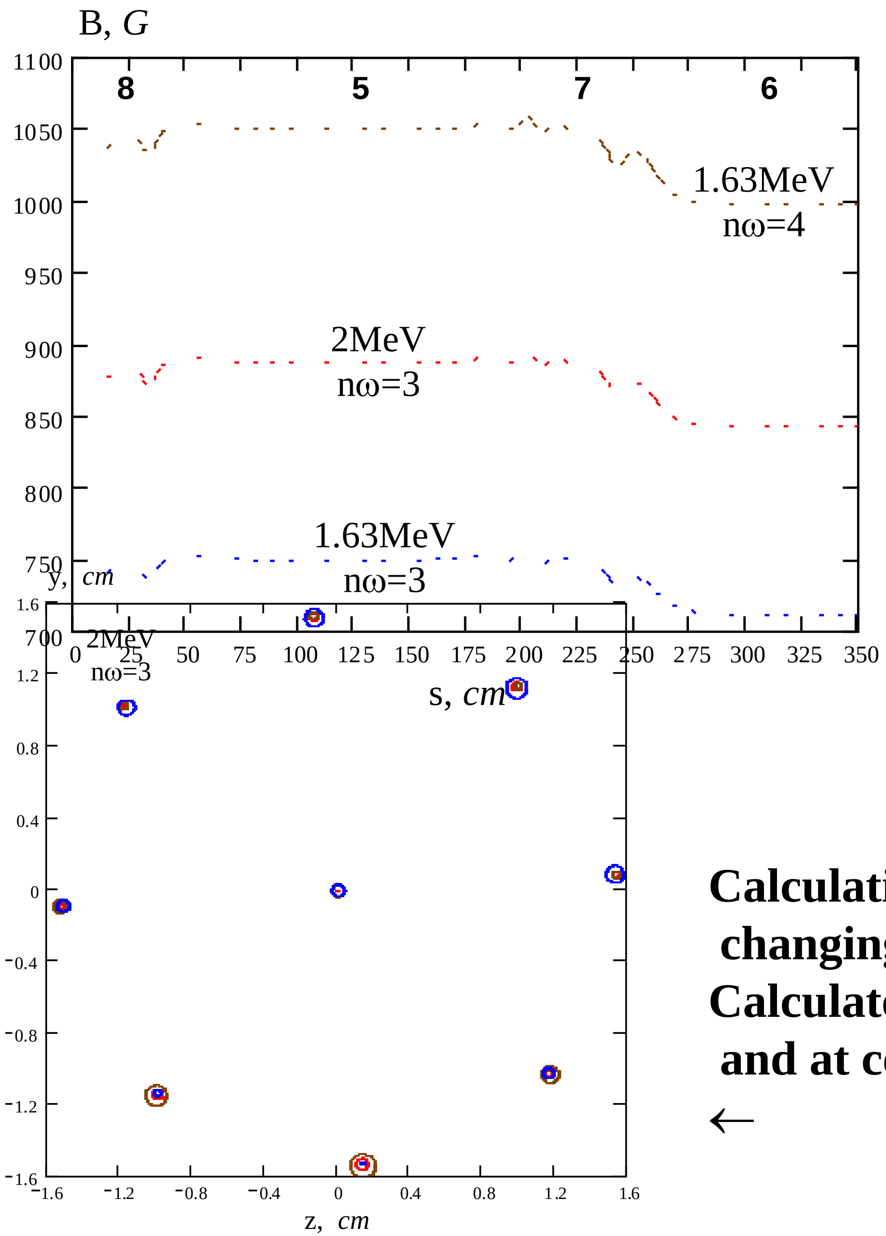


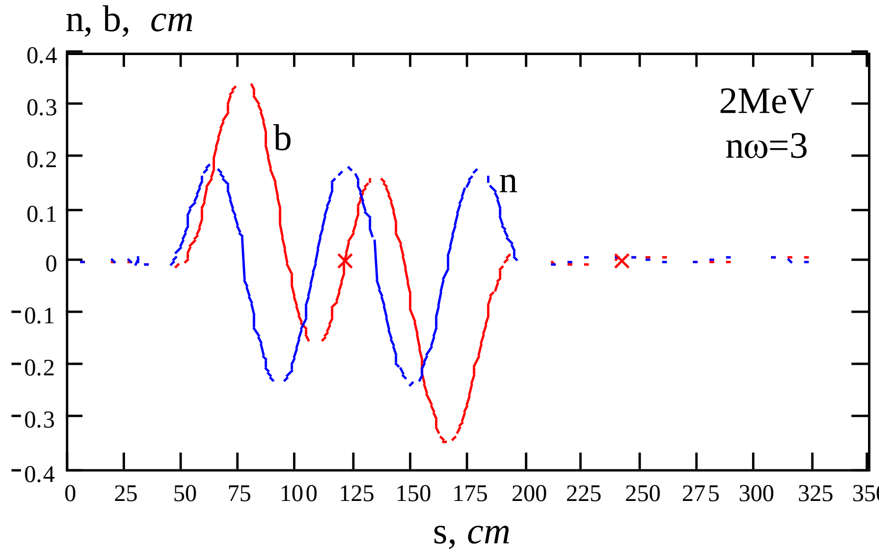


dB noise near 10^{-3} Gauss

dB/Bs near 10^{-6}

Optimal longitudinal magnetic field at the transport channel. For this field an electron passes transport system without heating

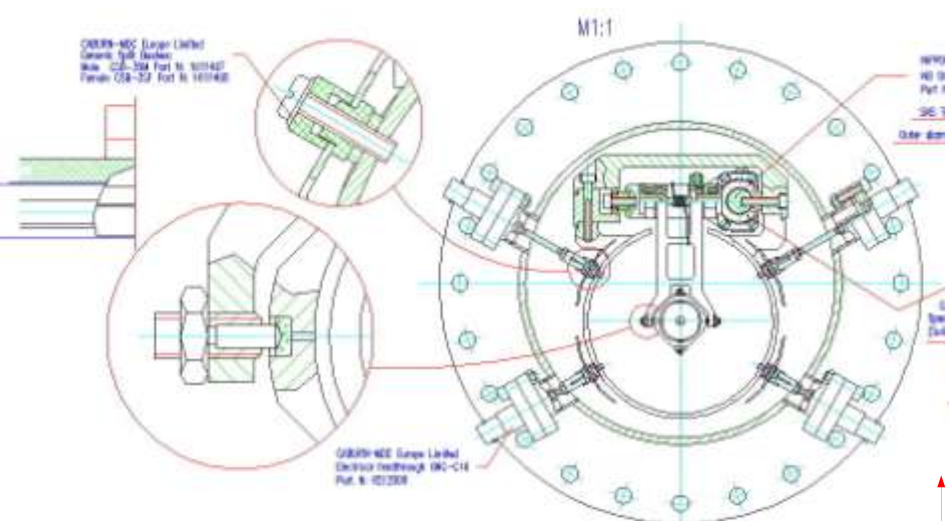


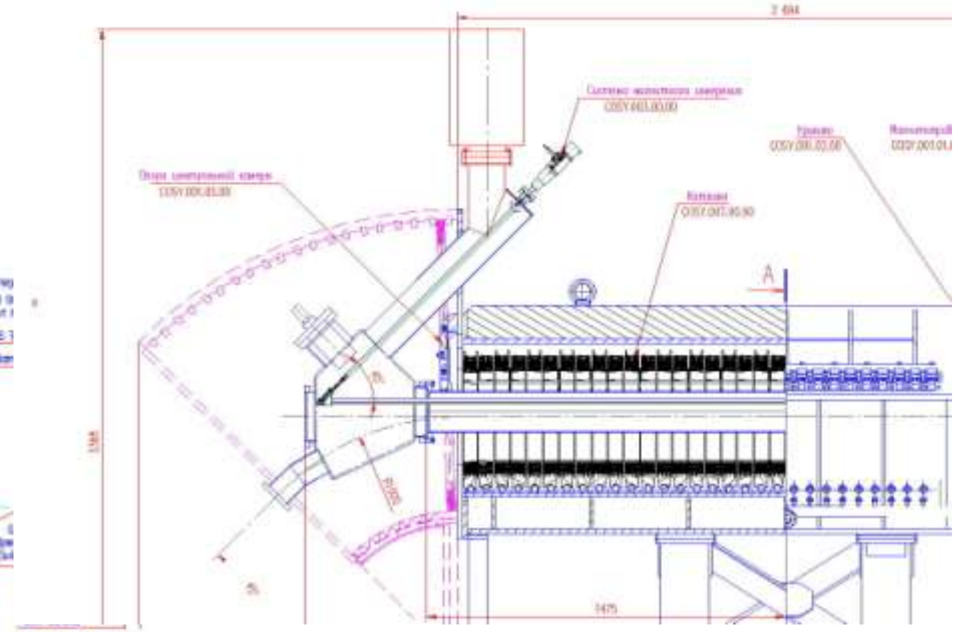


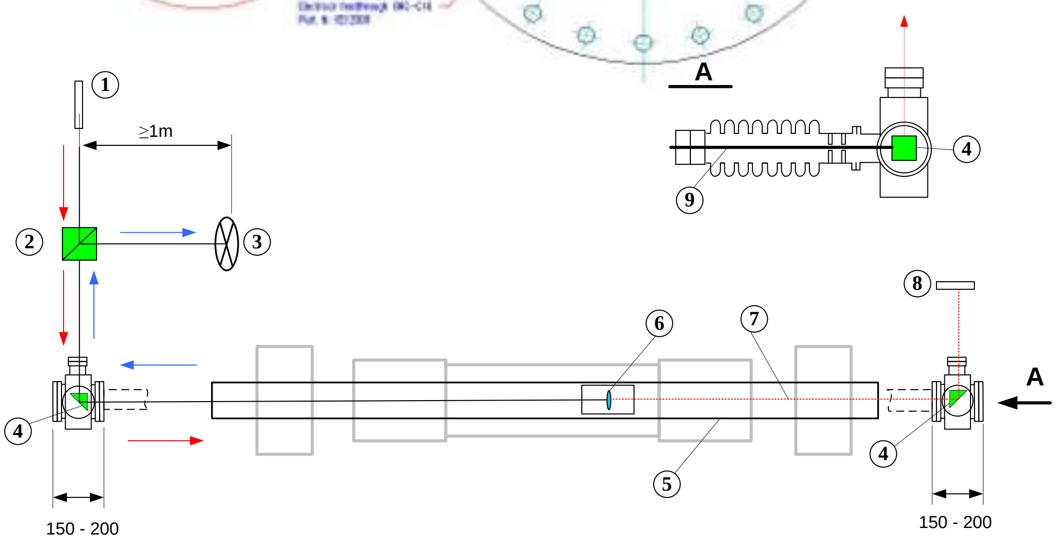
Calculation of the rest transverse electron motion with changing magnetic field +-1% from optimum.
Calculated trajectory across the electrons beam and at center of beam.

←

Compass inside of the vacuum chamber of COSY cooler is moveable along cooling section







Electron beam collector with Wien filter

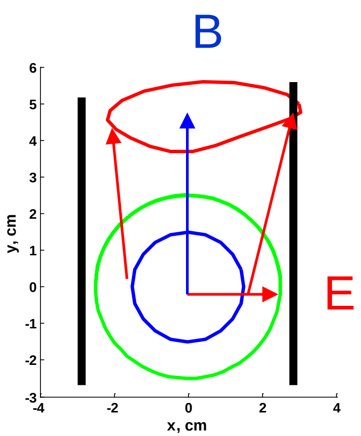
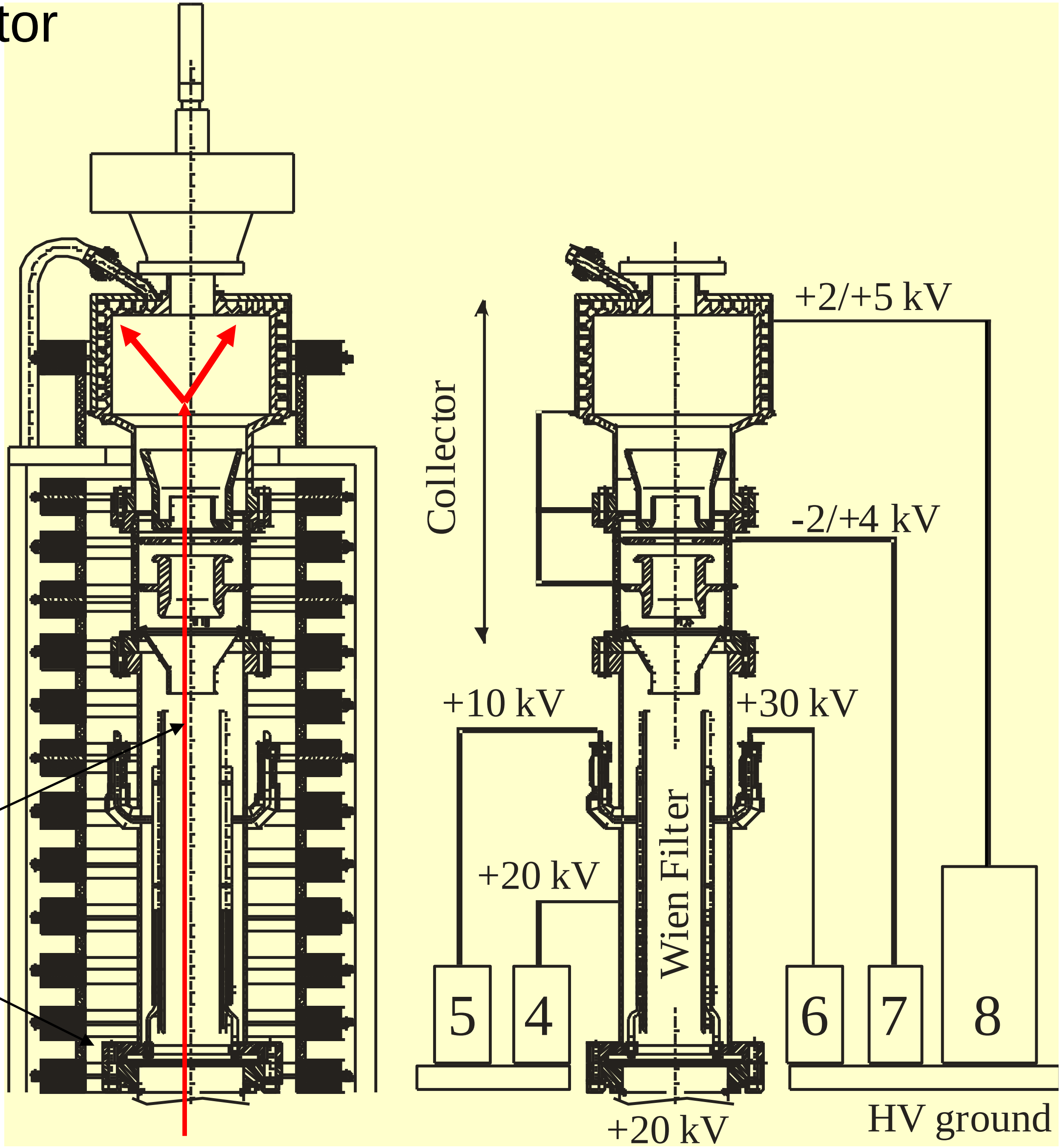
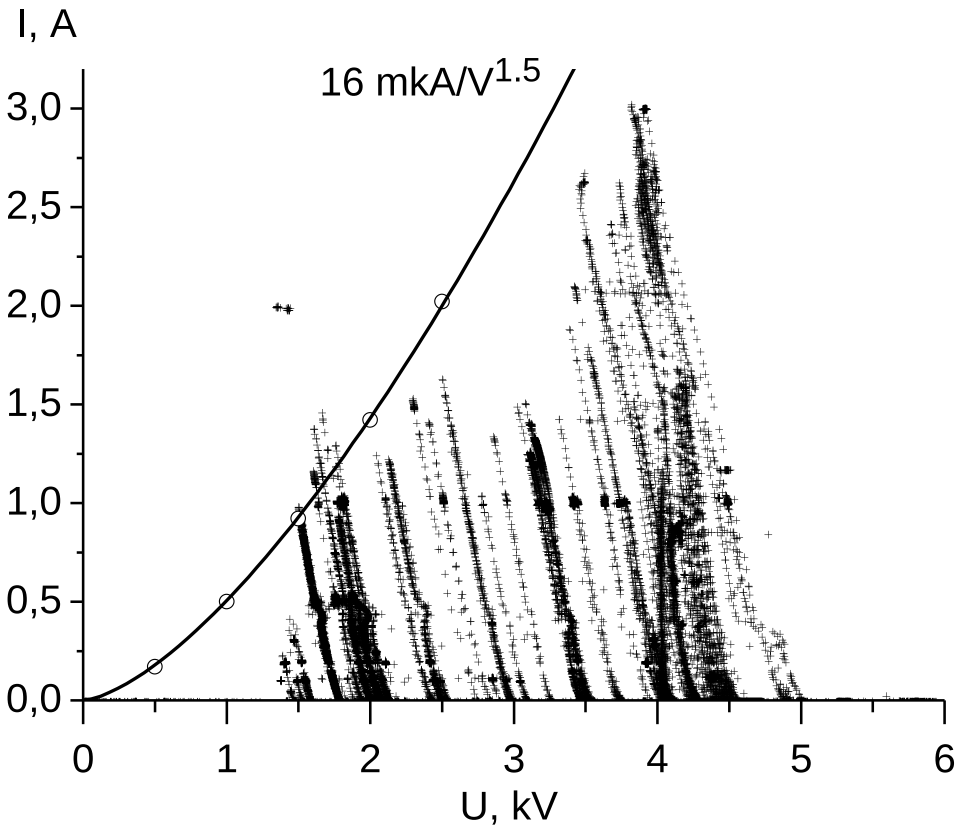


Fig. 11. Displacement of the secondary beam in Wien filter after reflection from collector. Blue – secondary beam before filter, red – secondary beam after filter, green – internal size of diaphragm.



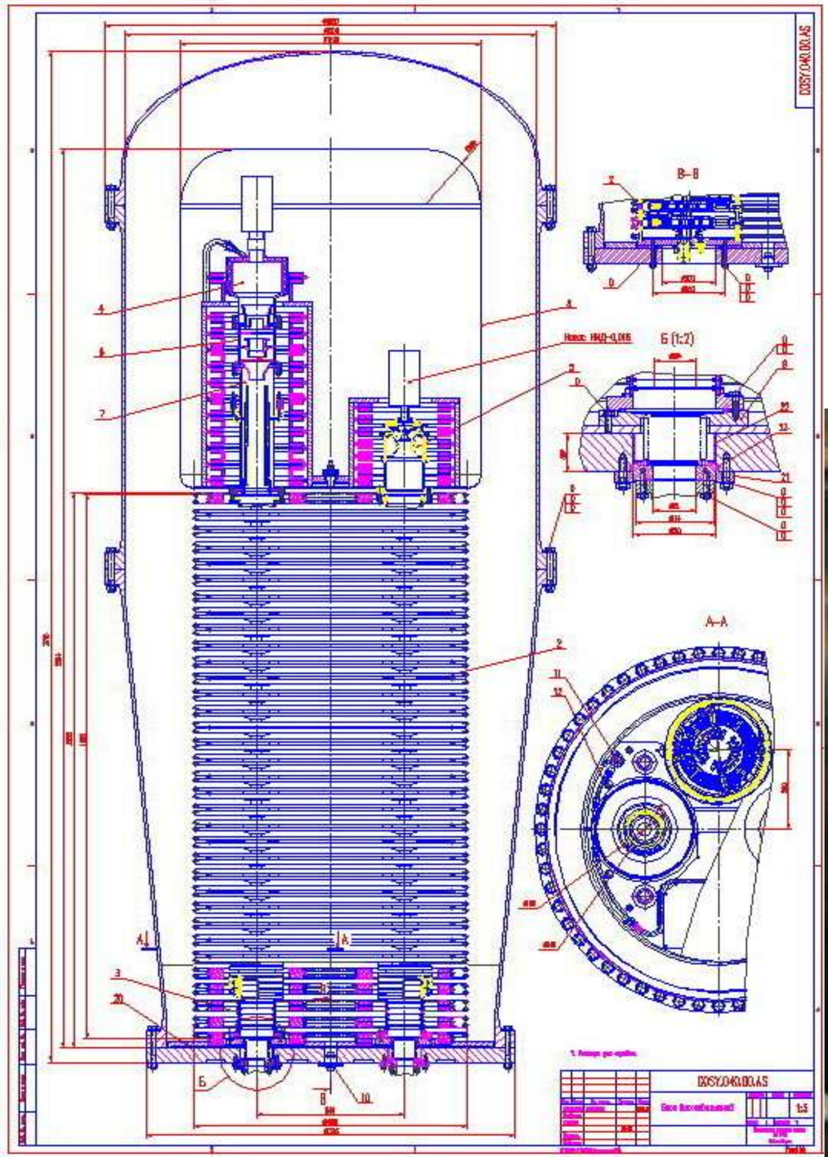
Milling of water channel for cooling of the electron beam collector

The electron beam collector characteristic

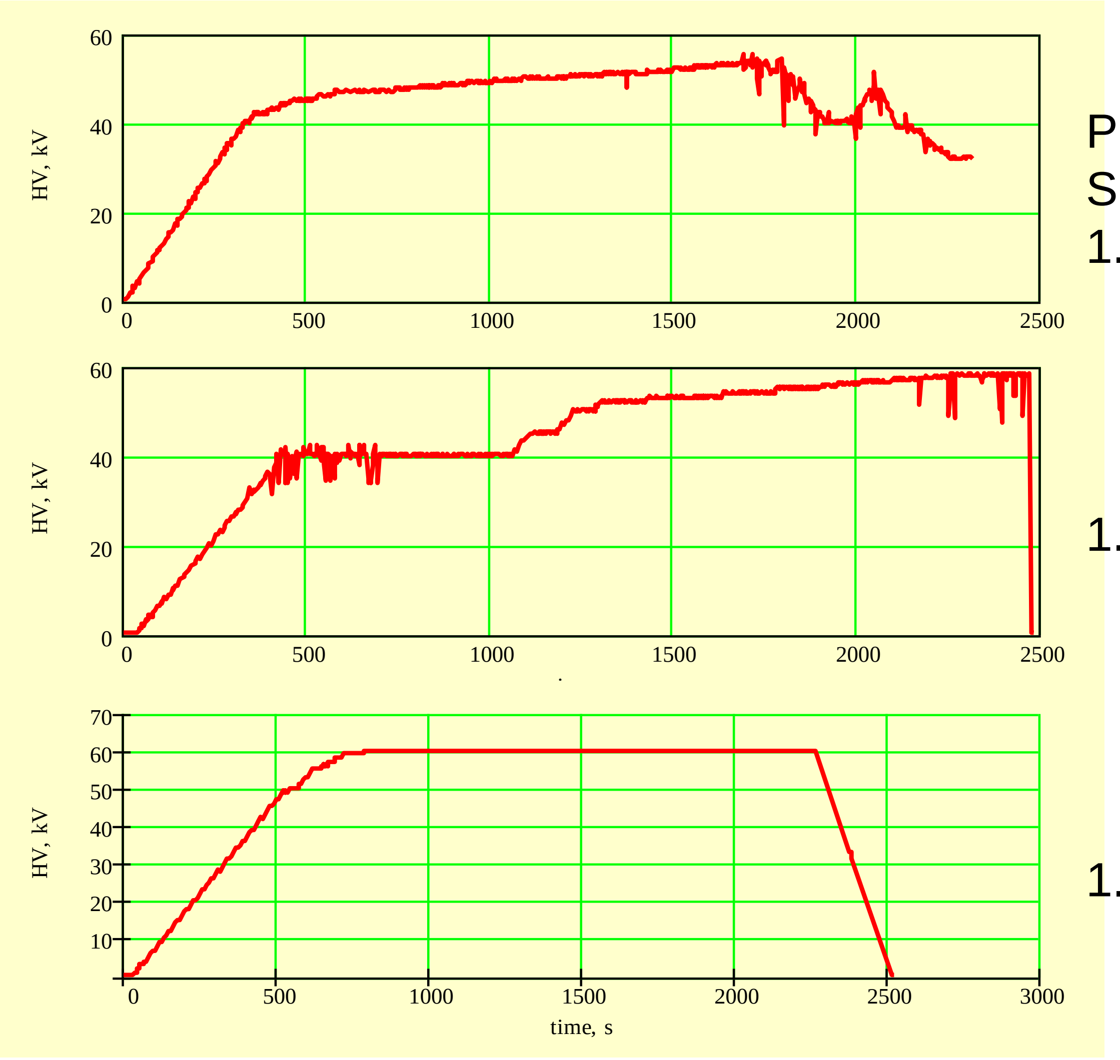


The dependence of the collector current on the collector voltage. Values of current for different values of voltage are shown.

High voltage column



Testing of the sparking at the sections



Pressure

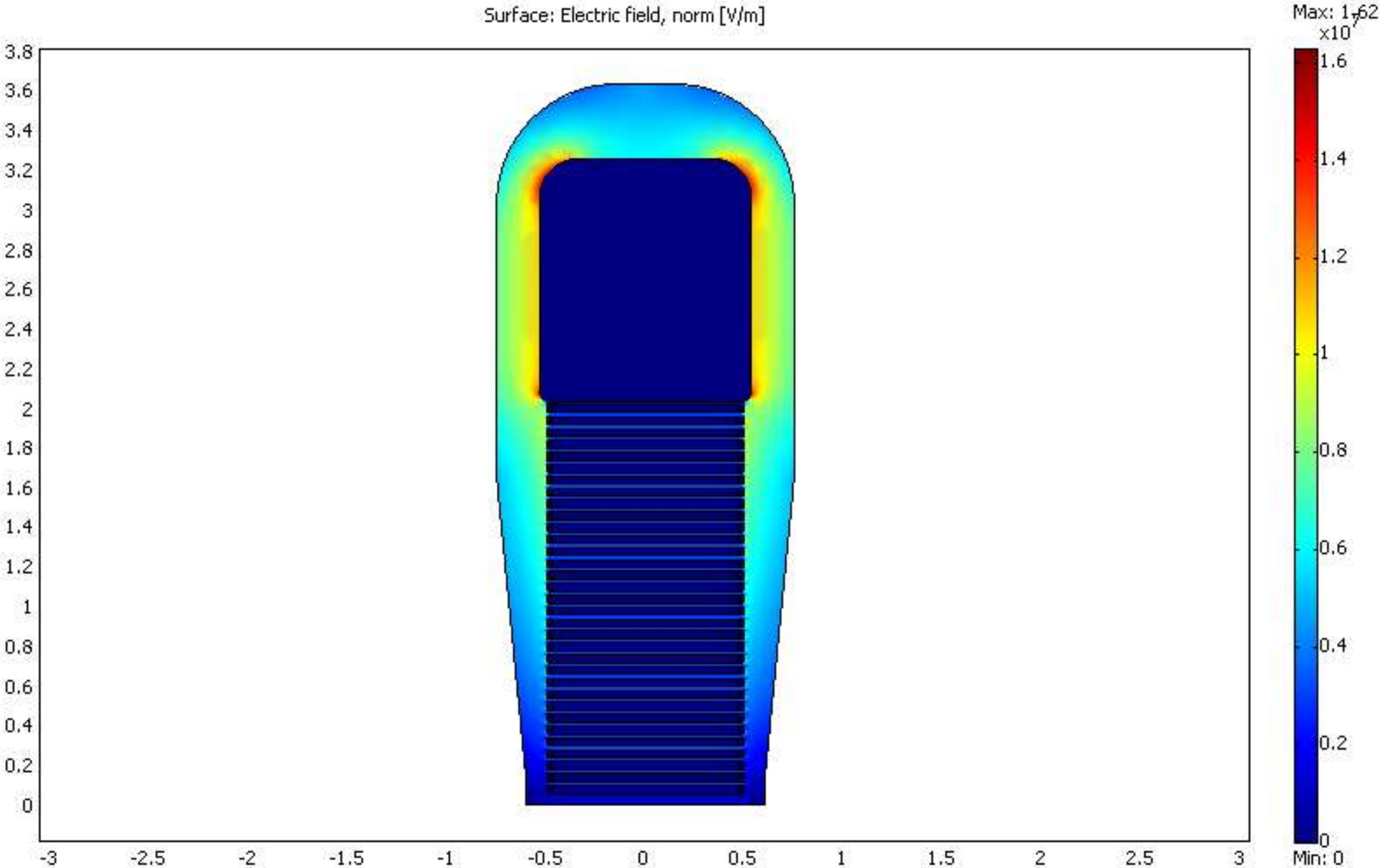
SF_6

1.2 bar

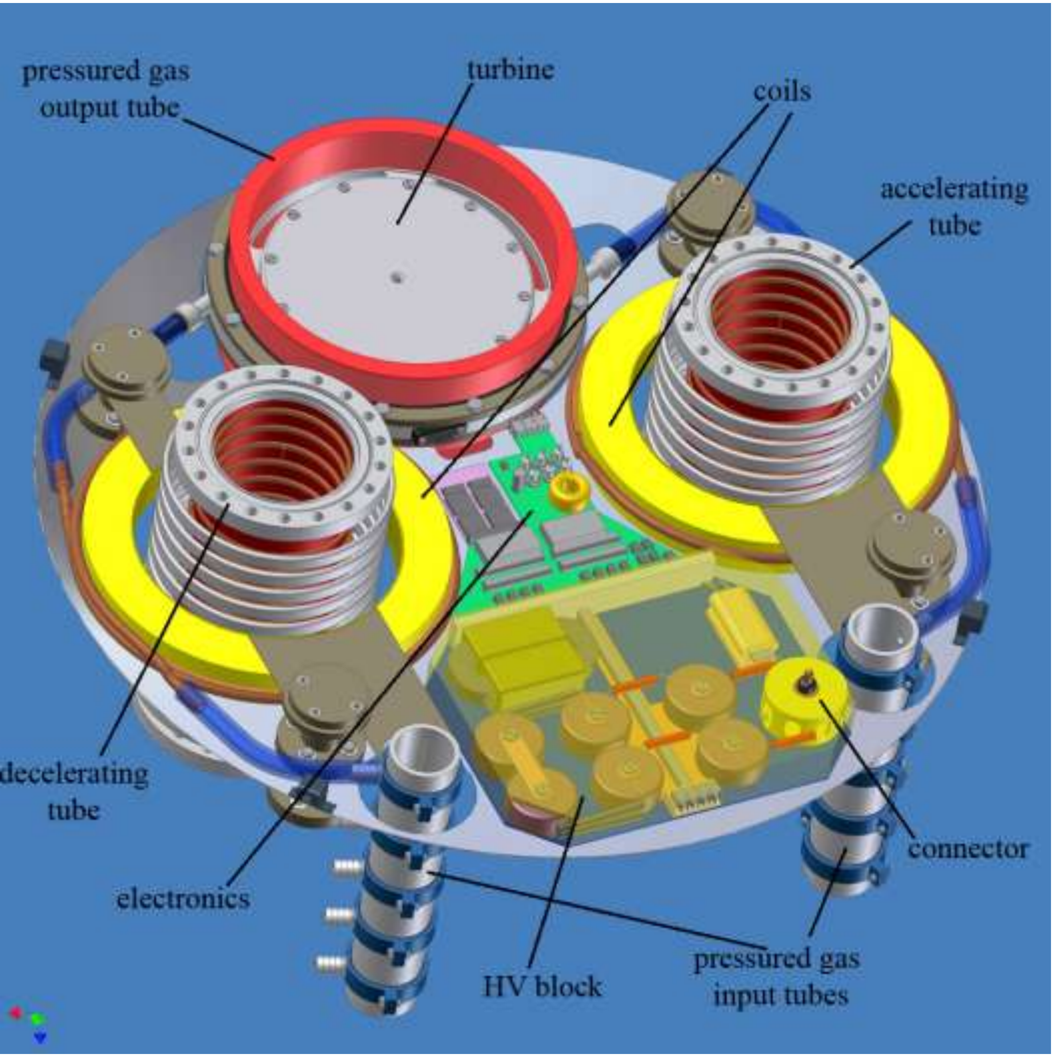
1.4 bar

1.6 bar

Electric field calculation



Wide energy range (0.025-2 MeV) operation and transportation of the electron beam in longitudinal magnetic field



$c := 3 \cdot 10^{10}$ $\quad ae := 1$ $\quad Je := 3$

$\gamma := 1 + \frac{4}{0.511}$ $\quad \beta := \sqrt{1 - \frac{1}{\gamma^2}}$ $\quad re := 2.8 \cdot 10^{-13}$

$$ne := \frac{Je}{1.6 \cdot 10^{-19} \cdot \pi \cdot ae^2 \cdot c \cdot \beta \cdot \gamma}$$

$$\omega := c \cdot \sqrt{2 \cdot \pi \cdot ne \cdot re}$$

$dl := \frac{c \cdot \beta}{\omega} \cdot \gamma$ $\quad dB := \frac{c \cdot \beta \cdot \gamma}{\omega L}$ $\quad B := 1000$

1 kGauss

dl- distance of the space charge plasma oscillations

dB-distance of magnetic field “focusing”

dl=9 cm, dB=0.54 cm for 0.025 MeV

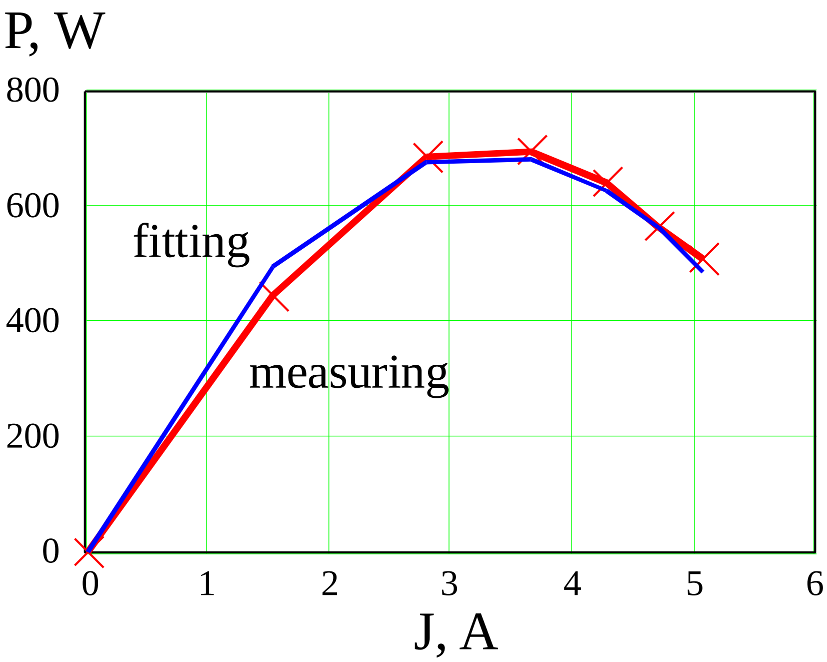
dl=500 cm dB=8cm for 2 MeV

dl=1388 cm dB=15 for 4 MeV (FNAL)

Source for power distribution along acceleration column coils

Gas turbine tested and now used for AMS (few months without servicing, but we need its running for years!)

Load characteristic of the turbo generator



One of the problem was too low temperature of gas exhaust after turbine and condensation of water inside plastic tubes

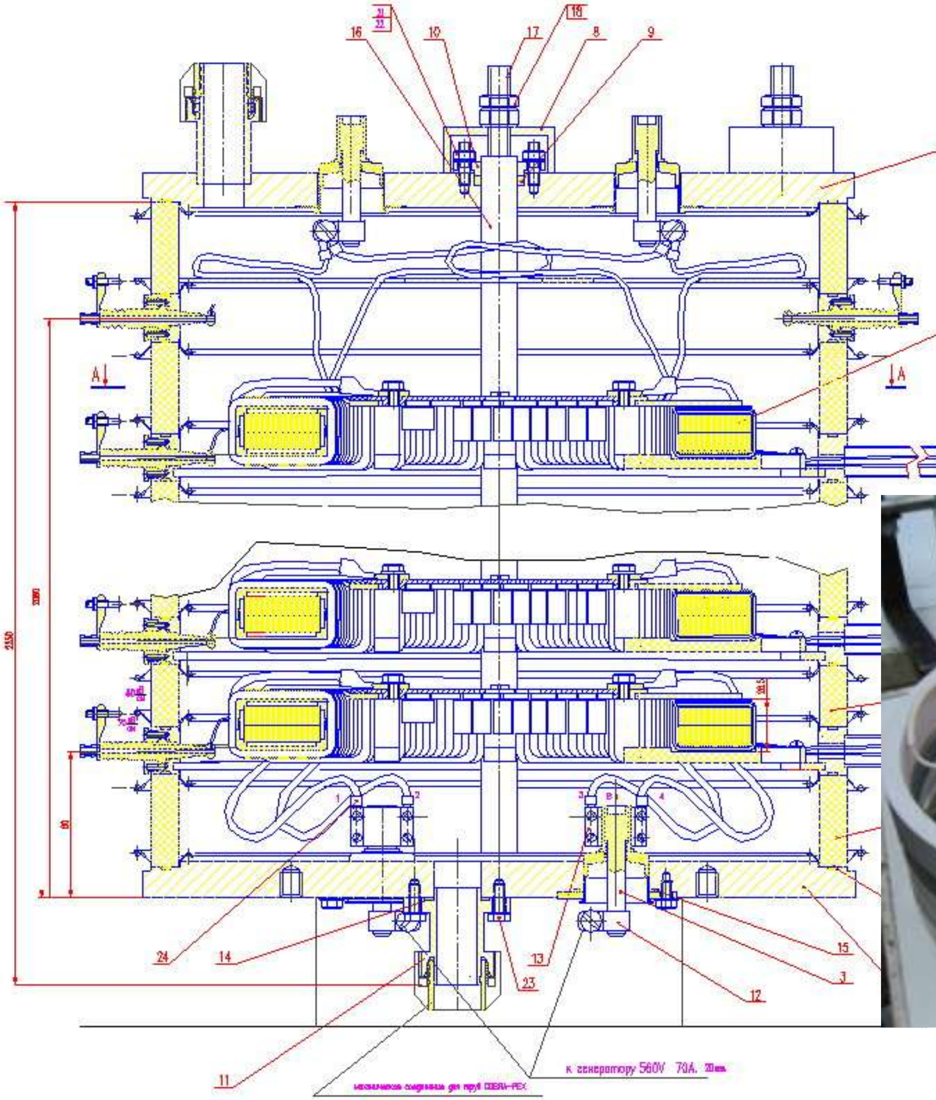
Other problem- short life time of cars bearing. Cheap but works only few months (3 months*20 days*8 hours= 50000 km)

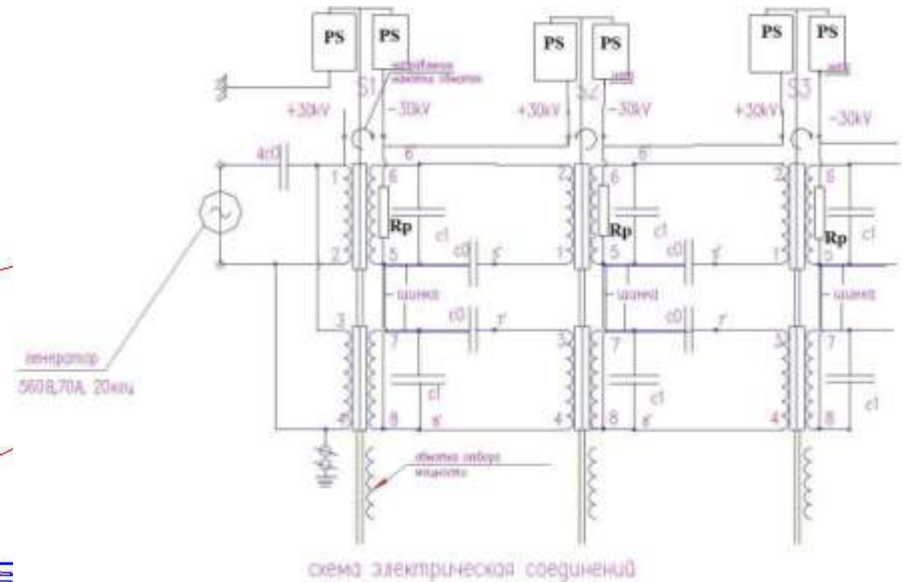
For <2 MeV the cascade transformer looks as simpler solution

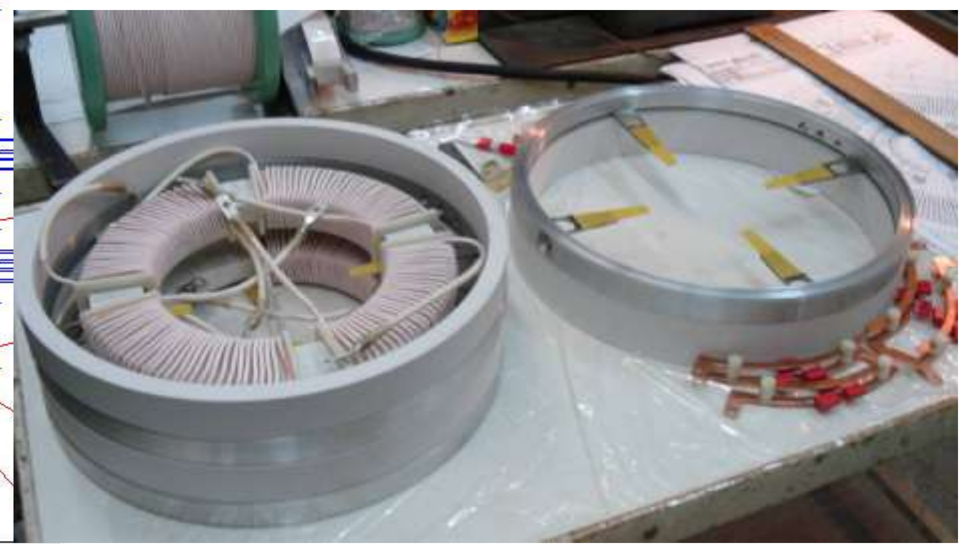
Cascade transformer

For core of the cascade transformer we will use

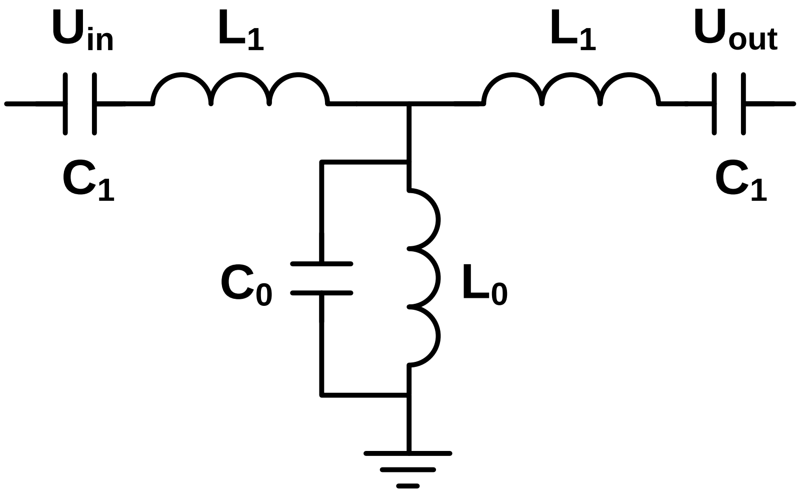
the amorphous iron of Russian plant (http://www.amet.ru/



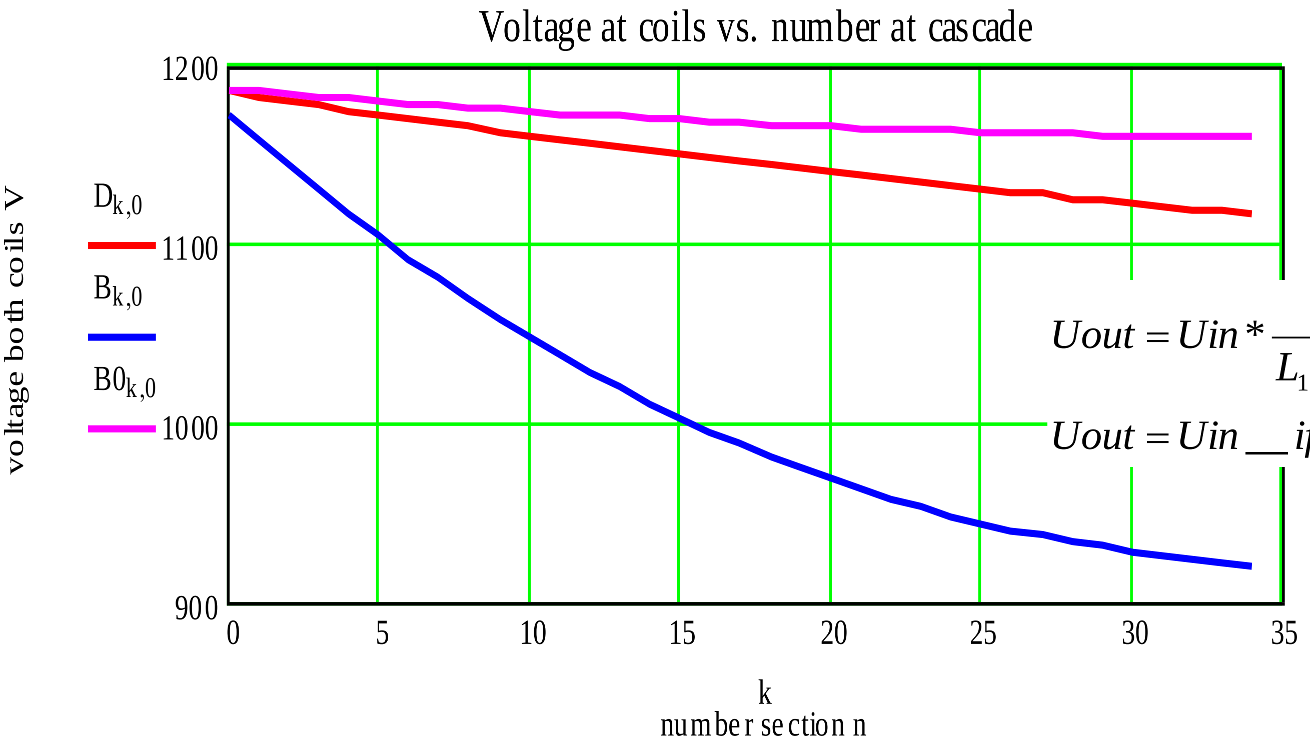




Compensation of the parasitic inductivity at transformer. Only small resistive components at coils make transformation coefficient less then 1. !



$$\frac{1}{\iota\omega C1} + \iota\omega L1 = 0$$



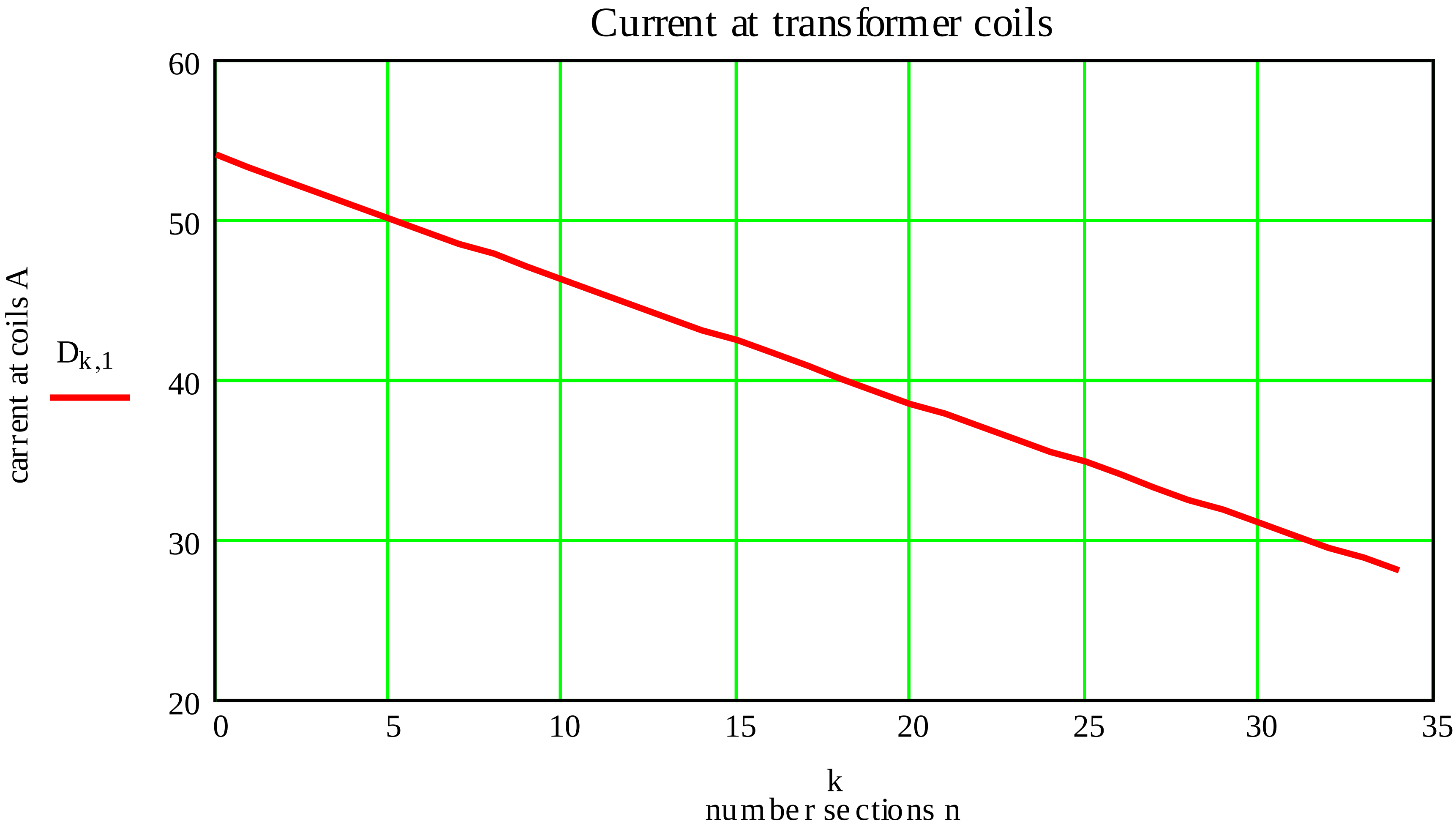
$$Uout = Uin * \frac{L_1}{L_1 + L_0} \; without\_compensation$$

$$Uout = Uin\_\_if\_C1 = 1/L1/\omega^2$$

Optimal capacitor C=0.674 mkF

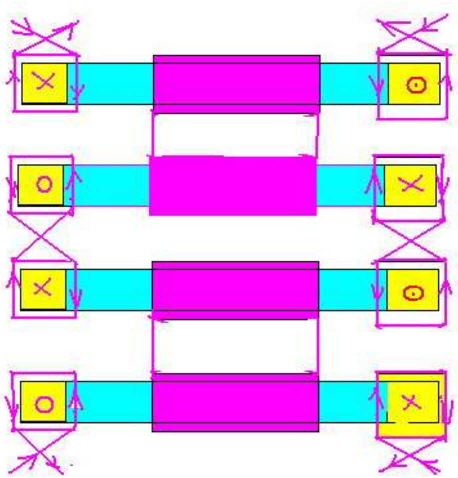
Not optimal capacitor 0.674*0.95 -5%!

Optimal but Je=0.3 A instead 3 A



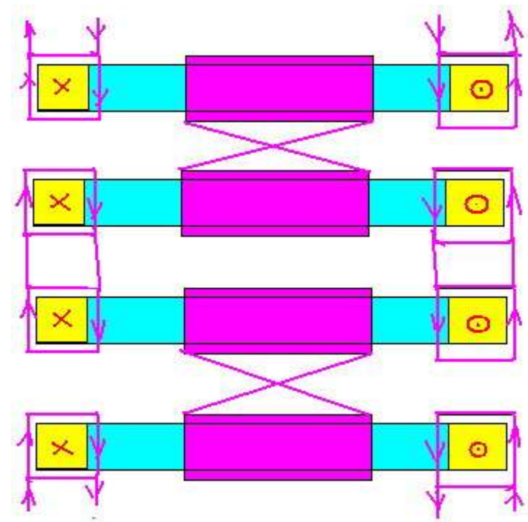
In input section current about 55 A, then along colons current decreases up to 25 A. The reason is using power at each section about 400 Wt *33= 13 kWt for powering the solenoids along the acceleration tube.

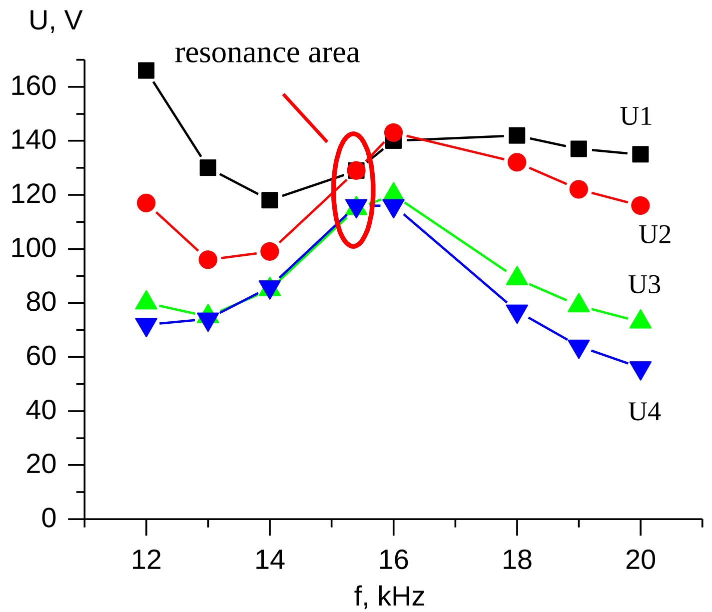
Comparison the cascade characteristic with different coils commutation

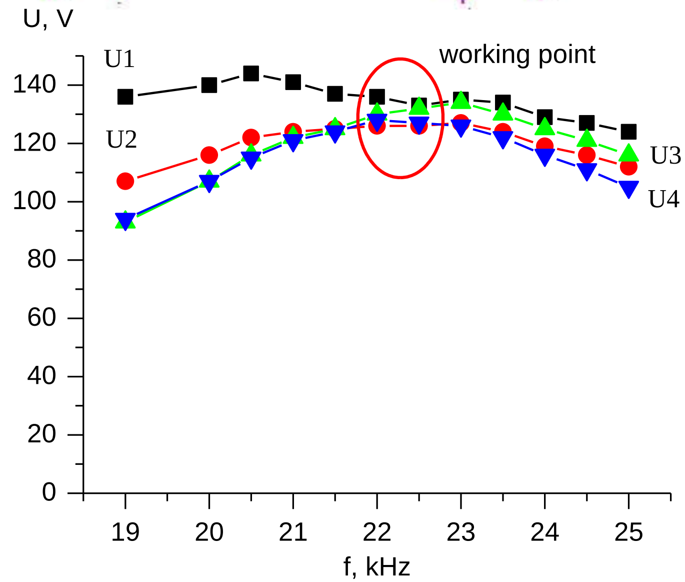


Magnet field change polarity

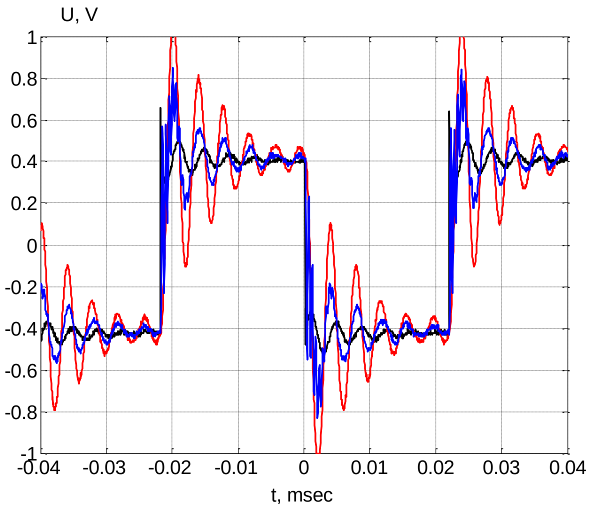
Magnet field at all coils parallel



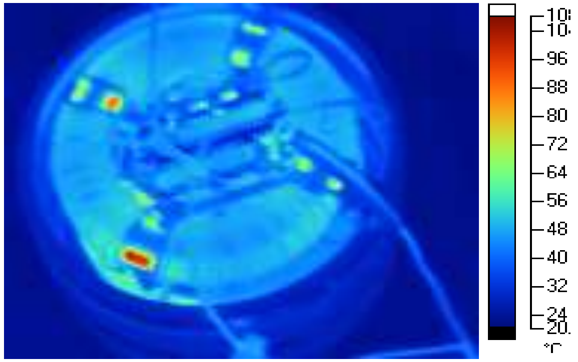




Test the prototype of cascade transformer with high power



The voltage oscillation on three sections transformer if input voltage is taken from rectangular wave form generator. Measurements had made without resistive load.



the photo of thermo distribution was made after 5-10 minutes of operation of the transformer with high power 15 kWt. This measurenents was made without oil cooling and we think that cooling will decrease the temperature down to the normal value.

COSY cooler electronic production status

Lab. 6-0 -Medvedko A.S.

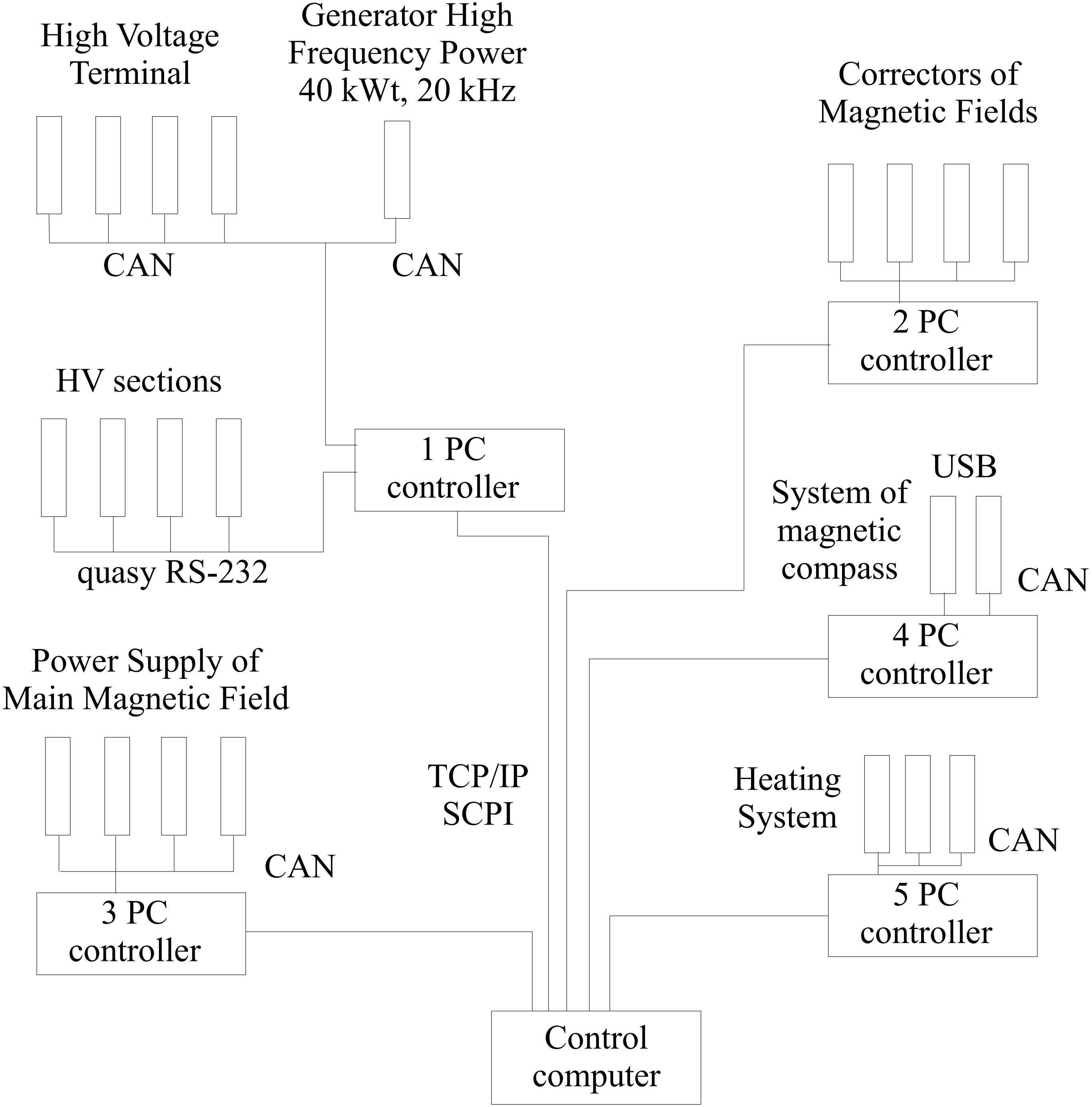
Senkov D.V;	Power supply 20 kHz for collector
Pureskin D.N	and high voltage column
Skorobogatov D.N.	Electronics of column
Gusev I.A	Power supply for collector
Erokhin A.I.	High power supply system
Gorchakov K.M., Veremeenko V.F.	Power supply magnet
Cherniakin A.D.	Power supply
Belikov O.V.	Power supply for correcting magnets;
Karpov G.V., Bekhtenev E.A., Cherepanov V.P.	Beam diagnostics

Lab. 6-1 -Kuper E.A.

Kozak V.R.	
Fedotov M.G.	Electronics of compass
Chekavinsky V.A.	High voltage terminal, electron gun
Mamkin V.R.	Digital control

Lab. 5-2 -Parkhomchuk V.V.

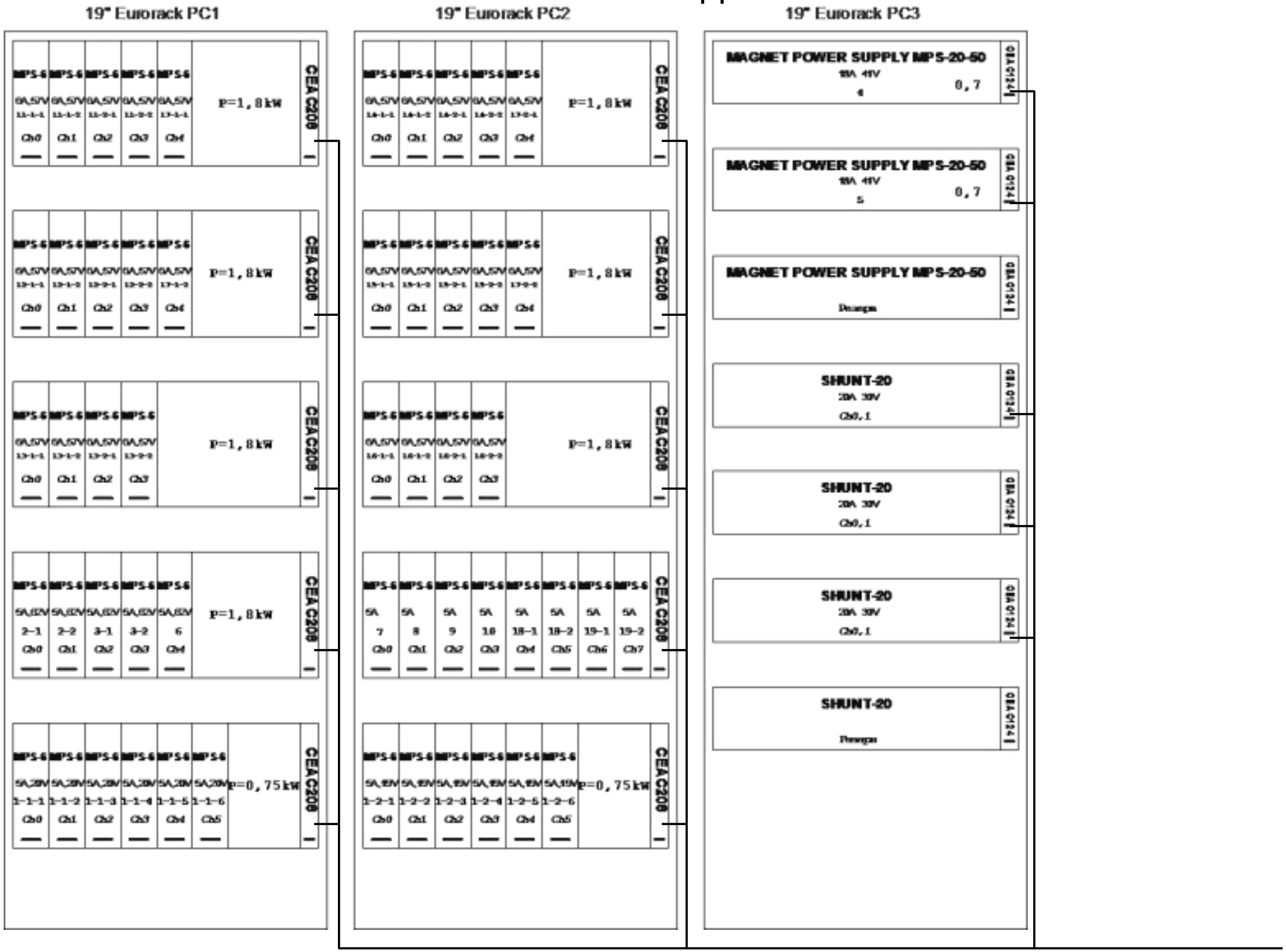
Reva V.B.	Control system and coordination all electronic
Goncharov A.D.	Cascade transformer



High Voltage Terminal
Generator High Frequency Power 40 kWt, 20 kHz
CAN
CAN
Correctors of Magnetic Fields
2 PC controller
HV sections
1 PC controller
quasy RS-232
USB
System of magnetic compass
CAN
4 PC controller
Power Supply of Main Magnetic Field
TCP/IP SCPI
Heating System
CAN
CAN
3 PC controller
5 PC controller
Control computer

Cosy cooler automation

Low Current Power Supplies



10*CEAC208 – http://www.inp.nsk.su/~kozak/designs/cac208e.pdf (english)

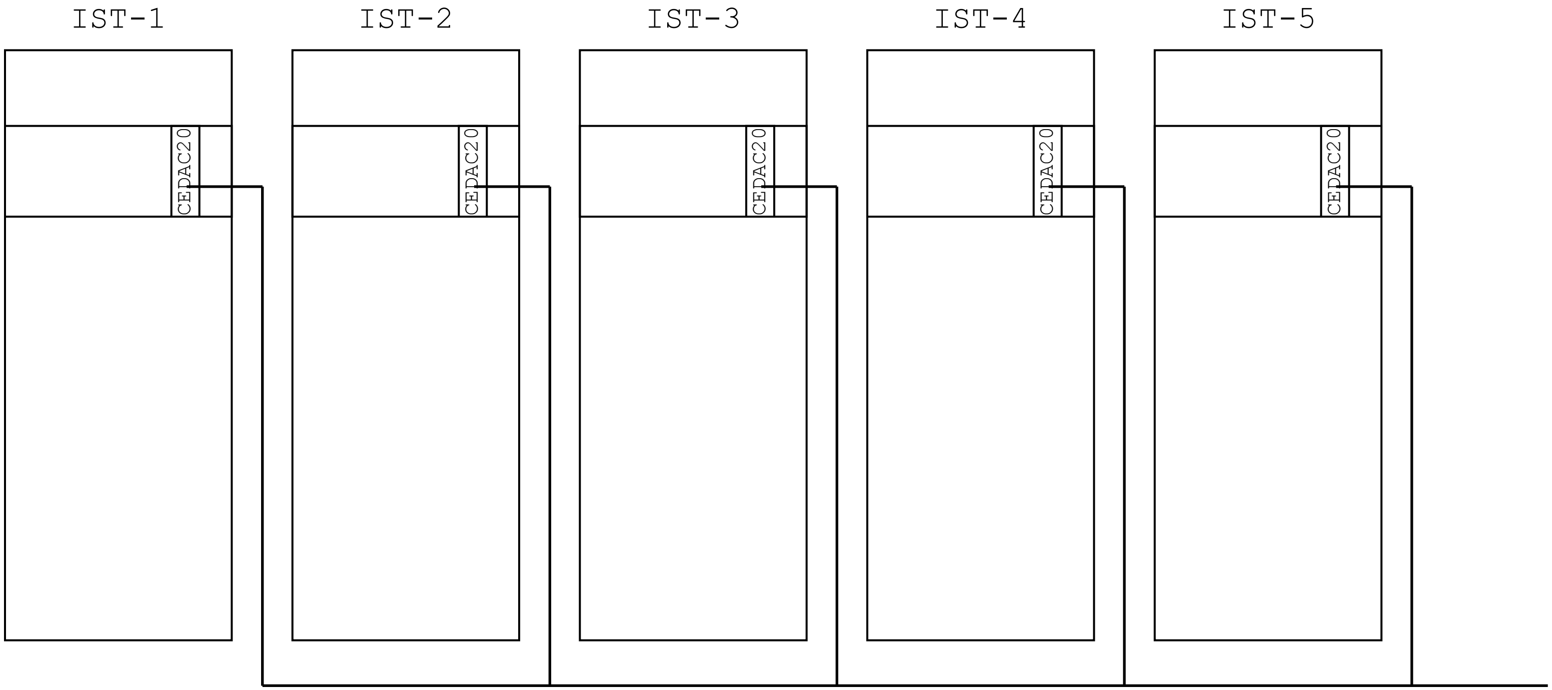
6*CEAC124 – http://www.inp.nsk.su/~kozak/designs/ceac124e.pdf (english)

CEAC208
Block for control
Correction
Power supply

Parameter	Value
ADC resolution	23 bits
ADC noise resolution	19-20 bits
ADC accuracy	0,003%
DAC resolution	16 bits
DAC accuracy	0,05%
Digital input/outputs	8+8 bits

COSY cooler automation

High Current Power Supplies



5*CEDAC20 - http://www.inp.nsk.su/~kozak/designs/cdac20me.pdf (english)

Status report
for the COSY 2MeV magnetic system power supplies
High power current sources IST

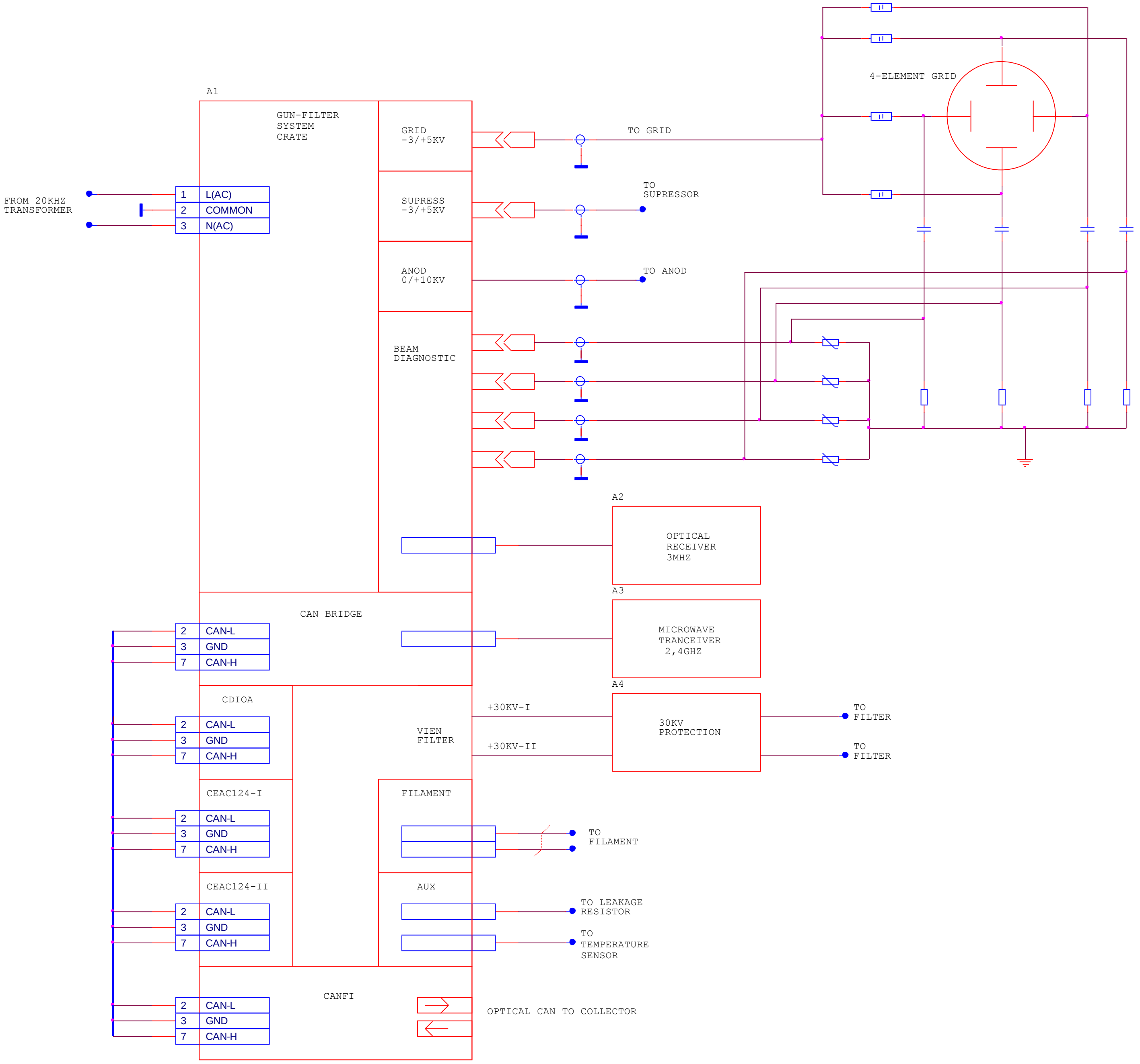
Power supply IST (stabilized current source) is intended for the magnets' powering where the high stability of the current is needed.
The power supplies are unipolar. Five of such power supplies are needed for the Cooler magnet system.
The difference between all of them lies in the output current and voltage levels
(as a result – in the nominal output power level). These parameters are presented at the Table 1.

Parameter	Unit	Value				
		№1	***№2***	***№3***	***№4***	***№5***
Nominal output current	A	**330**	**1040**	**320**	**300**	**350**
Nominal output voltage	V	**350**	**180**	**410**	**250**	**120**
Nominal output power	kW	**120**	**190**	**130**	**75**	**42**

The status at manufacturer side:
1.All components for the production are ordered. Most of them are delivered, including Euro racks Schroff.
2.Design is finished.
3.Main transformers are ready (Fig.1.).
4.Filter chokes and ripples transformers are on the final stage of the production.
All other small components (buses, holder…) are on the starting stage of the production

New IST

GUN-FILTER SYSTEM CONNECTIONS



ACKNOWLLEDGMENTS

- The cooler design and production is a results of active work of big BINP team of designers and engineers. We like to thank of this team for help at cooler construction.
- Authors thanks for many usefully discussions and support this project: Skrinsky A.N, Medvedko A.S. Kuper E.A., Schijnkov S.V., Anashin V.V., Churkin I.N.

CONCLUSION

- 2 MeV COSY cooler now under production at collaboration JFK and BINP.
- About half elements now at final stage production and assembling expected to be at end 2010.