Electron gun and collector of RHIC EBIS and prospects of the electron current density increase for a 10A electron beam.

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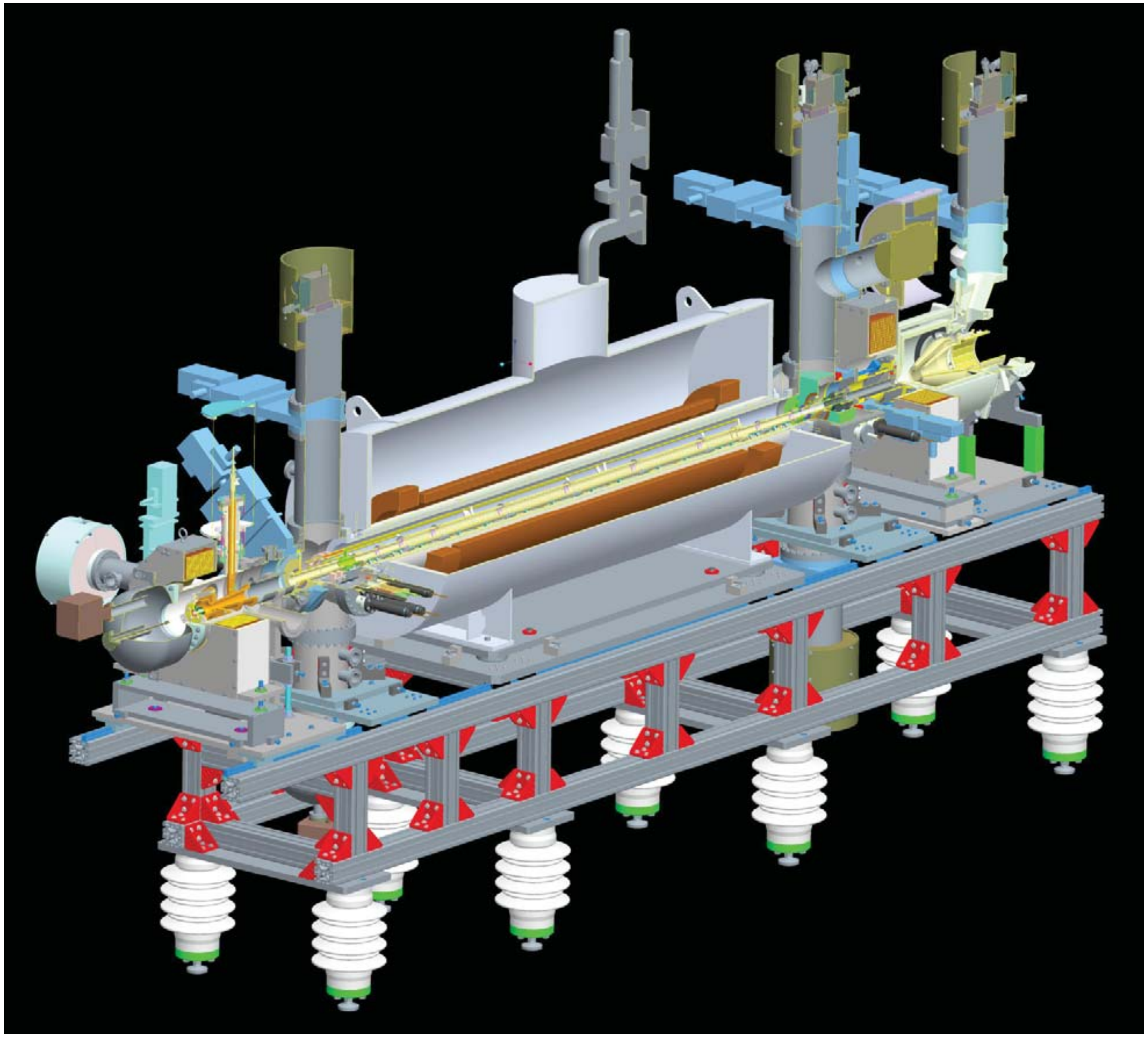
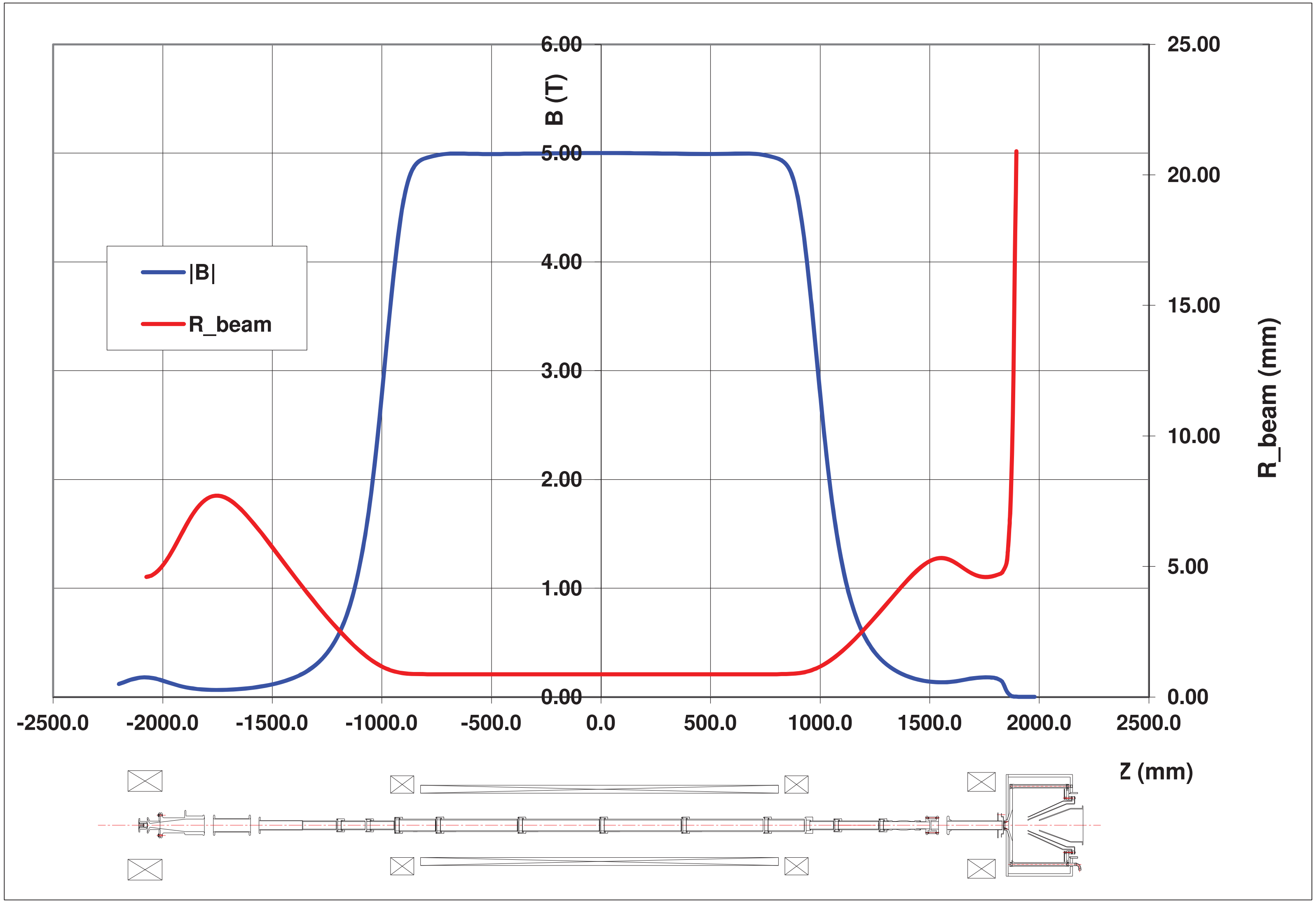
Outline

1. RHIC EBIS existing electron gun
2. RHIC EBIS existing electron collector
3. Drift structure
4. Prospects of increasing the electron beam current density in RHIC EBIS (gun with electrostatic focusing)

RHIC EBIS: general view



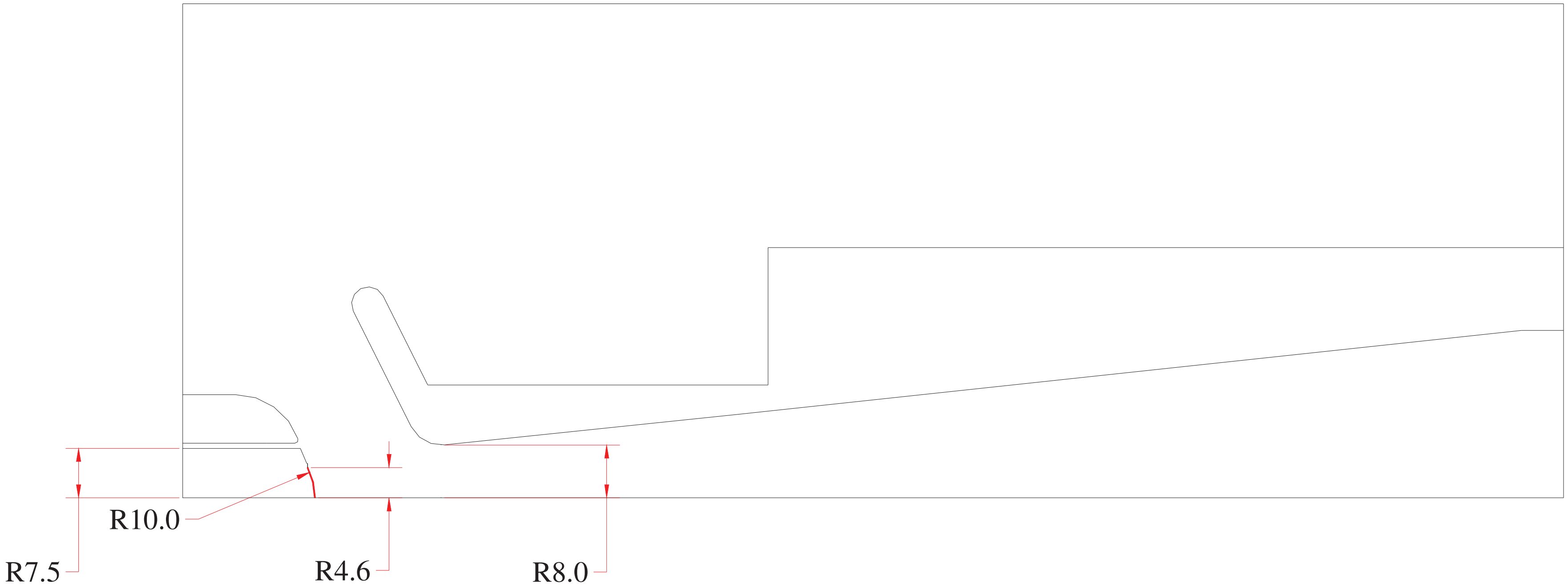
RHIC EBIS magnetic structure



Immersed electron beam

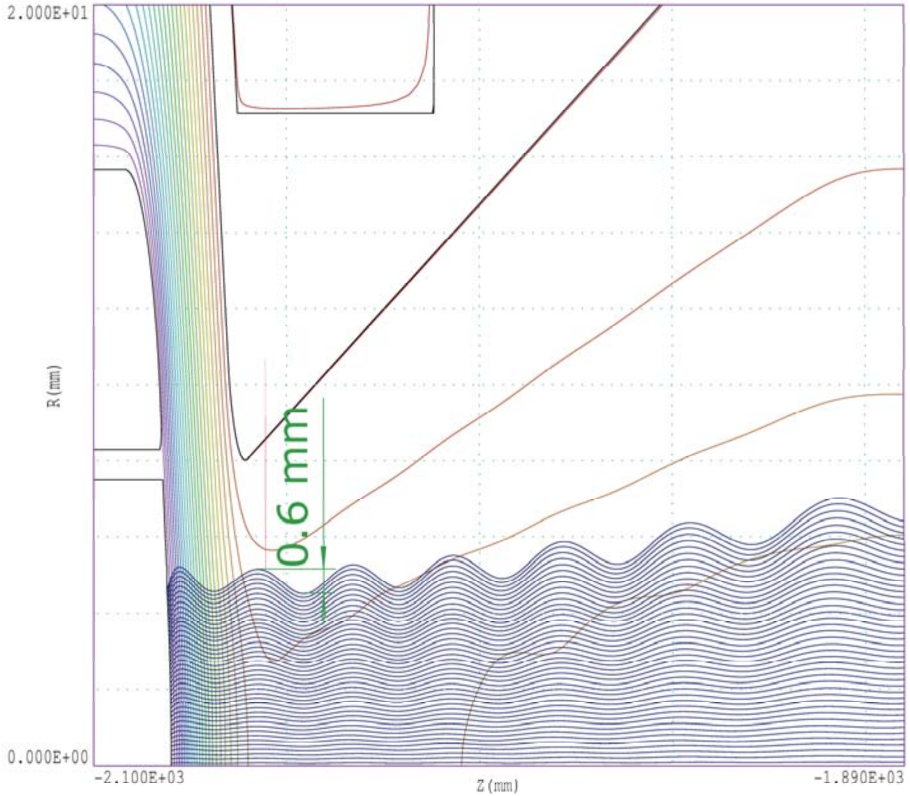
1. Electron current : I_{el} = 10 A
2. Electron energy: E_{el} = 20 keV
3. Magnetic field on the cathode: B_{cath}=1.4 kGs
4. Magnetic field in the center of the SC solenoid: B_{cent}=5.0 T
5. Area compression of the electron beam: B_{cent}/B_{cath}=35.7
6. Cathode radius: r_{cath}=4.6 mm
7. Emission current density: $j_{em}=I_e/(\pi \cdot r_{cath}^2)$=15.0 A/cm^2
8. Current density in the center of the SC solenoid: $j_{el}=j_{em} \cdot (B_{cent}/B_{cath})$=535.5 A/cm^2

RHIC EBIS electron gun simulation model



Cathode assembly

Electron gun simulation



I_{el}=10.0A, U_{an}=24.3V

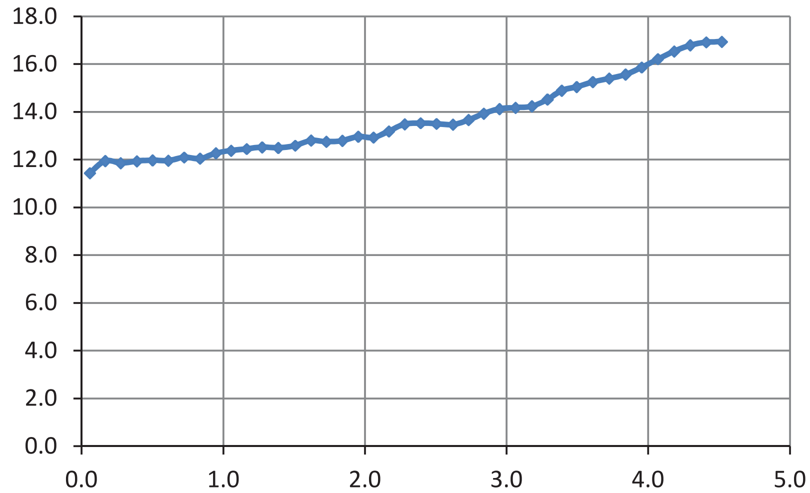
P_{gun}=2.6E-6 A/V$^{1.5}$

B_{cath}=1.4 kGs

Δr=0.6 mm

$\Delta r/r$=0.13

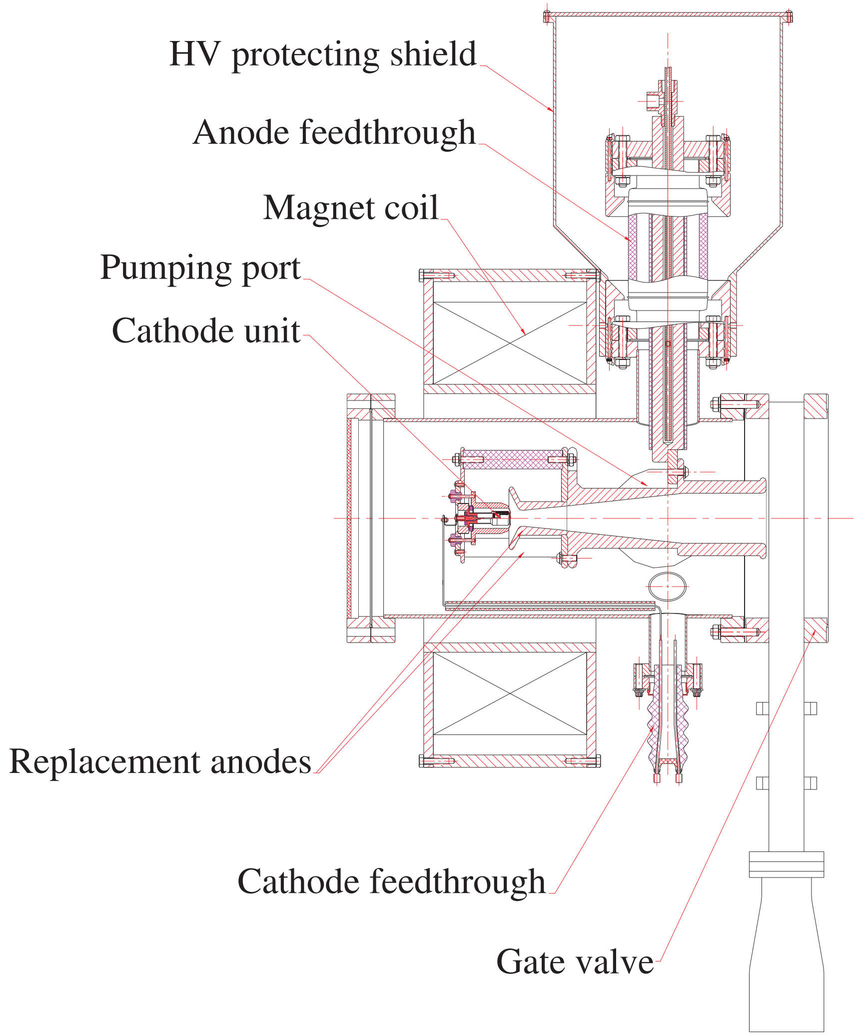
Emission current density distribution

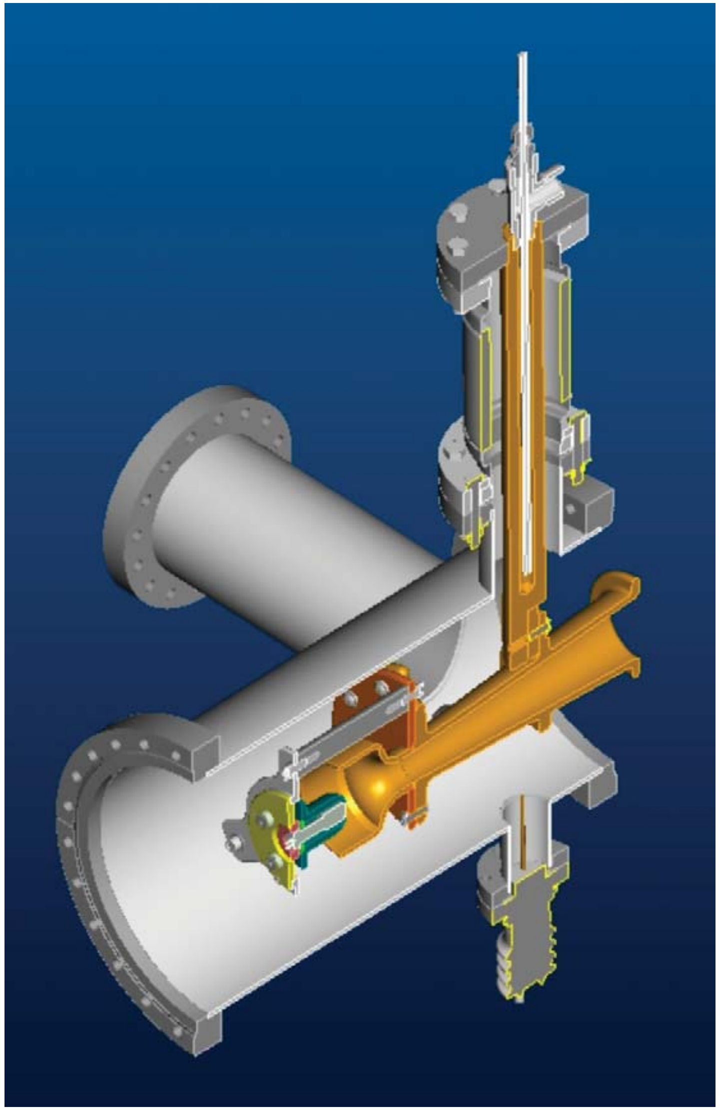


I.V.Alyamovskiy:

$$\Delta r = 4.14 \cdot \frac{\sqrt{U_{an}(V) \cdot P_{\mu}}}{B_c(Gs)}$$ =0.7 mm

Electron gun design





For EBIS with immersed flow electron beam the requirement on emission current density $j_{emission}$ >10 A/cm^2. The only acceptable option is a high-temperature thermionic cathode.
Candidates for the cathode materials: LaB_6 , CeB_6 Scandate, IrCe
According to the existing literature the evaporation rate of CeB_6 is approx. 30% lower, than of LaB_6.
We are using IrCe cathodes (G. Kuznetsov)

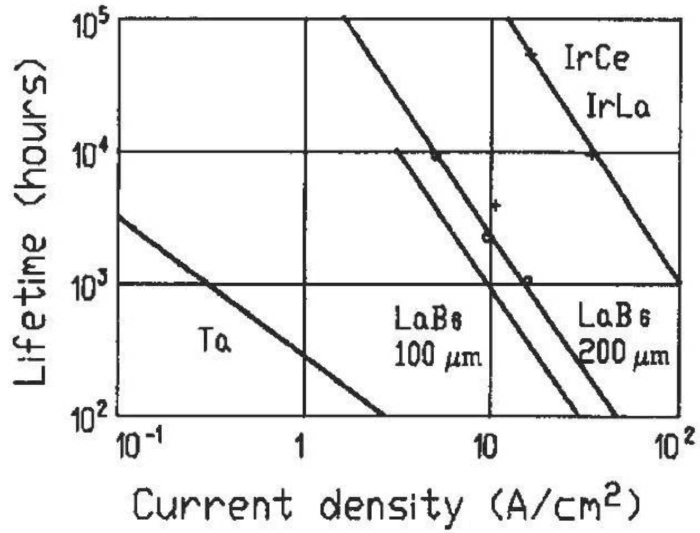
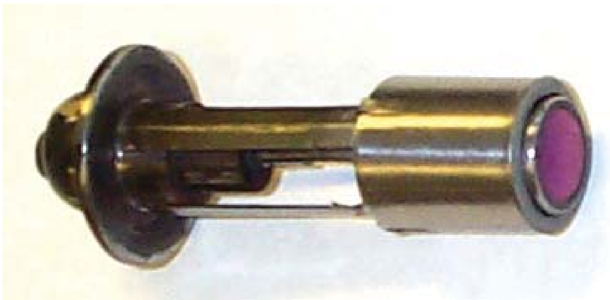


Fig. 9. Gun lifetime with LaB_6 and Ir-based cathodes.
G. Kuznetsov "High temperature cathodes for high current density" *Nuclear Instruments and Methods in Physics Research A 340 (1994) 204-208*

Desirable: $j_{emission}$≈ 13 – 15 A/cm^2,
T_{cath}>10000 Hours

LaB_6 cathode from BINP (G. Kuznetsov):



RHIC EBIS old electron collector

Design criteria:

for 20A 15 kV pulsed electron beam and 24 mA extracted ion beam

1. Beam power removal: critical power density to water interface

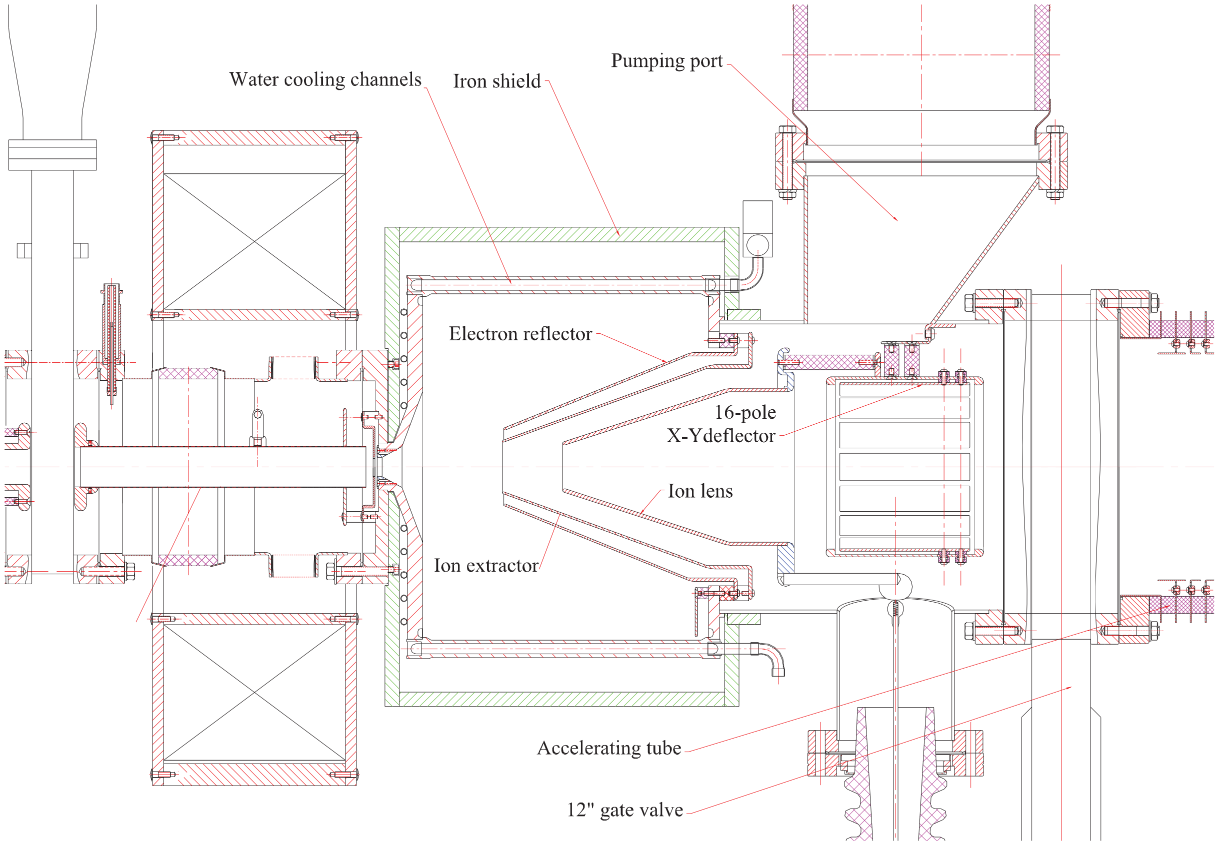
2. Fatigue (lifetime)

3. Returned electrons

1. Ion optics (no loss, low aberration, flexibility)

2. HV holdoff, discharges

3. Vacuum: high pumping speed



Simulation conditions

E_prim=10.0A

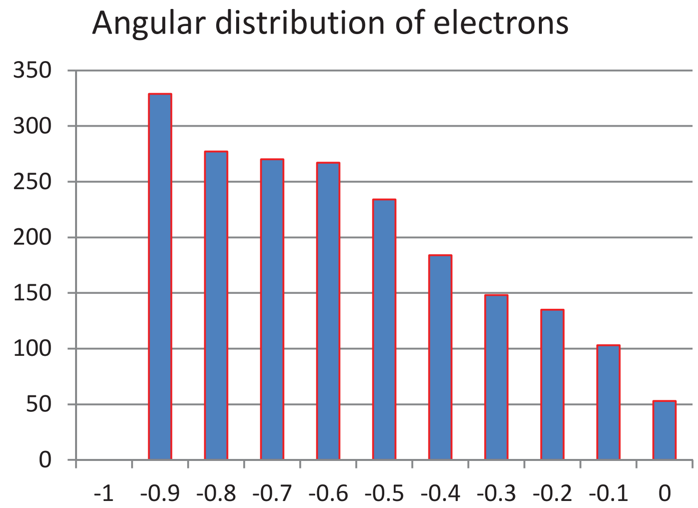
E_prim=10.0 keV

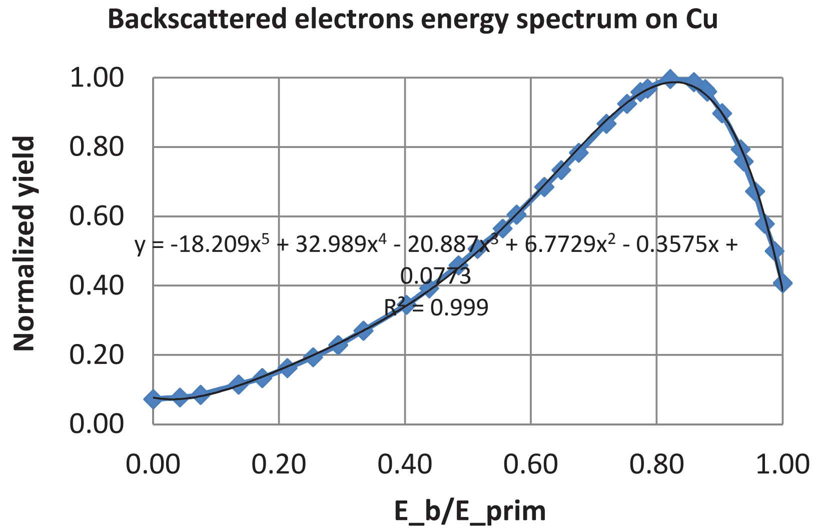
$K_{bacscat}$=0.3 (copper)

N_{traj}=2000 (each of primary, secondary and backscattered)

Angular distribution: cosine

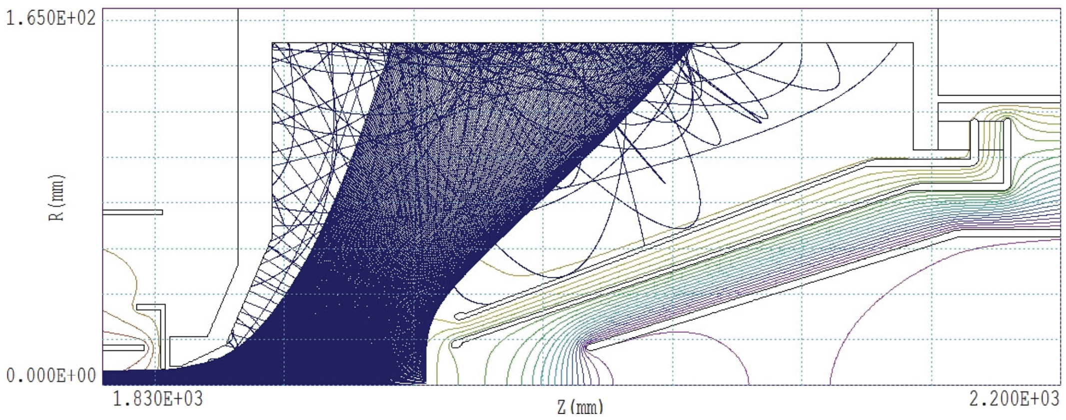
Energy spectrum – available from the published literature

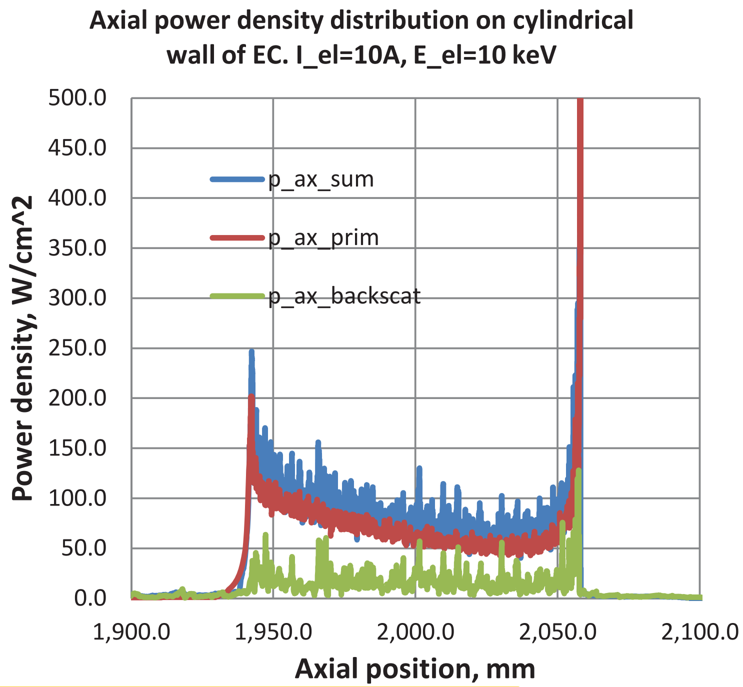


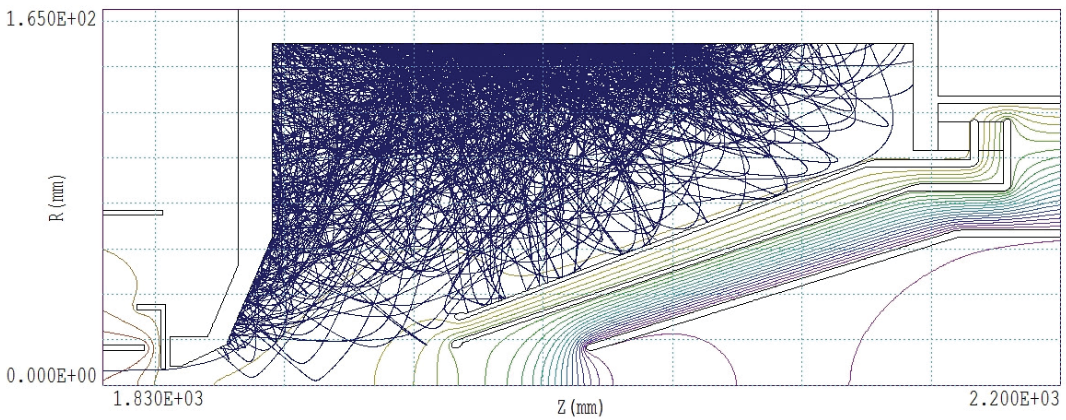


Electron collector optical simulations

I_{el}=10.0 A, E_{el}=10.0 keV, U_{repel}=-2.6 kV, $U_{ion\ extr.}$=-7.0 kV







Region number	Number of hits	Total current (A)
0	14	4.2293E-04
4	3849	1.2773E+01
5	32	9.2713E-02

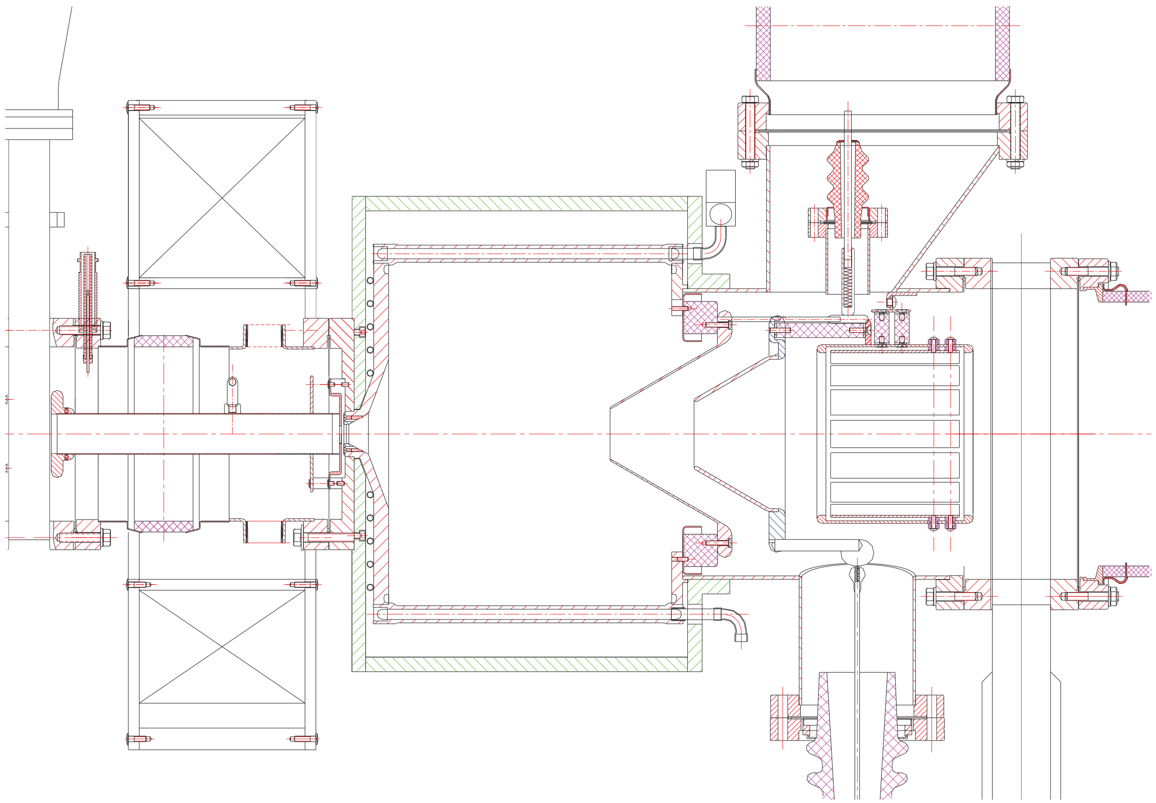
Only primary

Only backscat

I_{repel}=93 mA, approx. 600 watt

T_{repel}>400^{0}C

Purpose of the modification:
exclude heating of the repeller electrode by the backscattered electrons

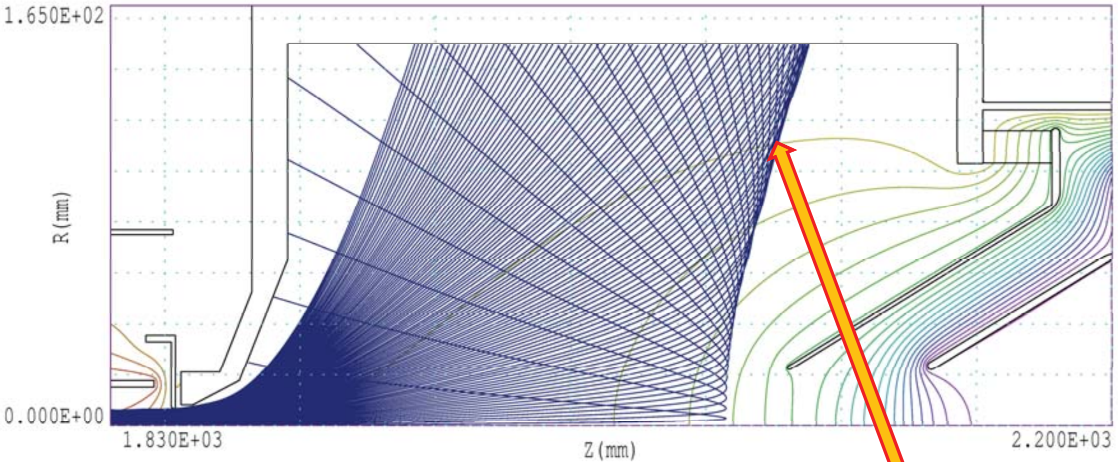


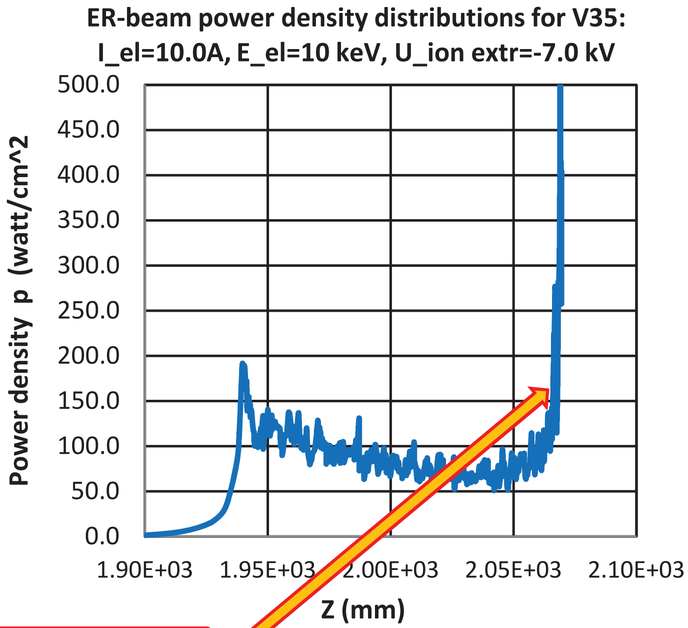
Modification:

1. The repeller is removed.
2. The electrodes are pulled out further from the EC entrance aperture
3. The distances between electrodes are increased
4. Radii of edges are increased to reduce the electric field
5. Electrode mounting are sturdier, wiring is better
6. General concept of ion optics is preserved.
7. Geometrical acceptance for injected ions is smaller

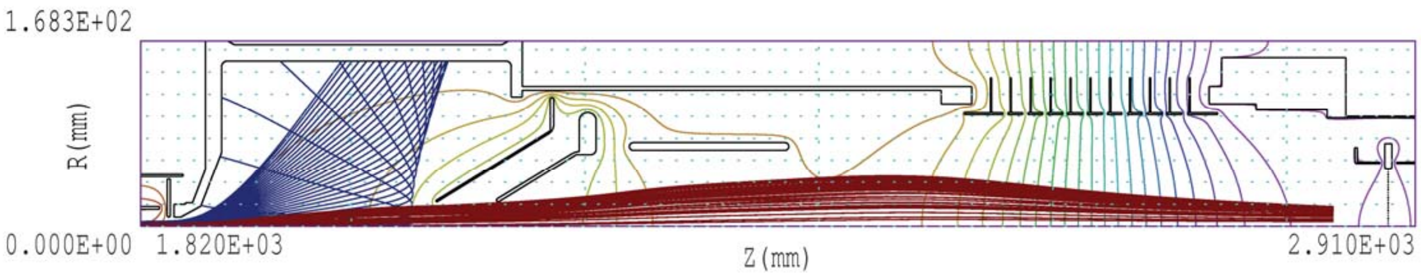
Electron beam simulation in a new optical configuration of EC

Electrons 10A:





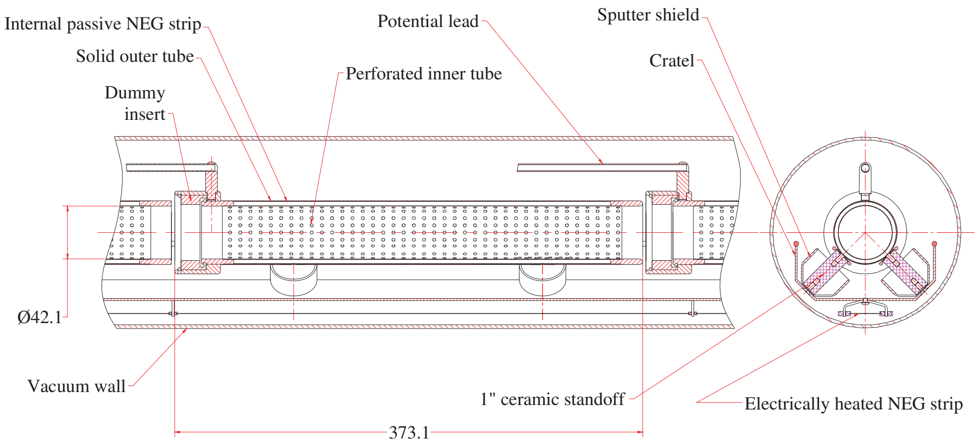
Electrons 10A and ions (Au^{32+}, 24 mA)



RHIC EBIS drift tubes

Considerations on DT ID choice:

1. Ion losses during the long confinement
2. Space charge contribution to an axial extracting el-stat gradient
3. Alignment tolerance of the drift structure
4. Voltage requirements to the power supplies
5. Voltage holdoff, discharge conditions



Electron beam with electron current I_{el}=10 A and j_{el}≈5,000 – 20,000 A/cm^2

This is uncharted territory.

Main concern: will such electron-ion system be stable?

If successful, can find applications in many other EBIS/EBIT devices.

BNL consideration on electron gun with higher current density

BNL EBIS goals:

1. Reduce emittance of the extracted ion beam
2. Reduce energy dissipated on EC, improve vacuum
3. Reduce residual gas influx into the ion trap
4. Increase charge state of extracted ions for NASA applications (higher energy of the accelerated ions

Desired current density: j_{el} ≈2000A/cm^2

Not desired: dependence of j_{el} on the e-beam neutralization

For BNL EBIS optimum would be an immersed electron beam with moderately high current density (combined electrostatic and magnetic compression)

Such gun looks complex and it is still a work in progress