Design Parameters of the new AD Electron Cooler

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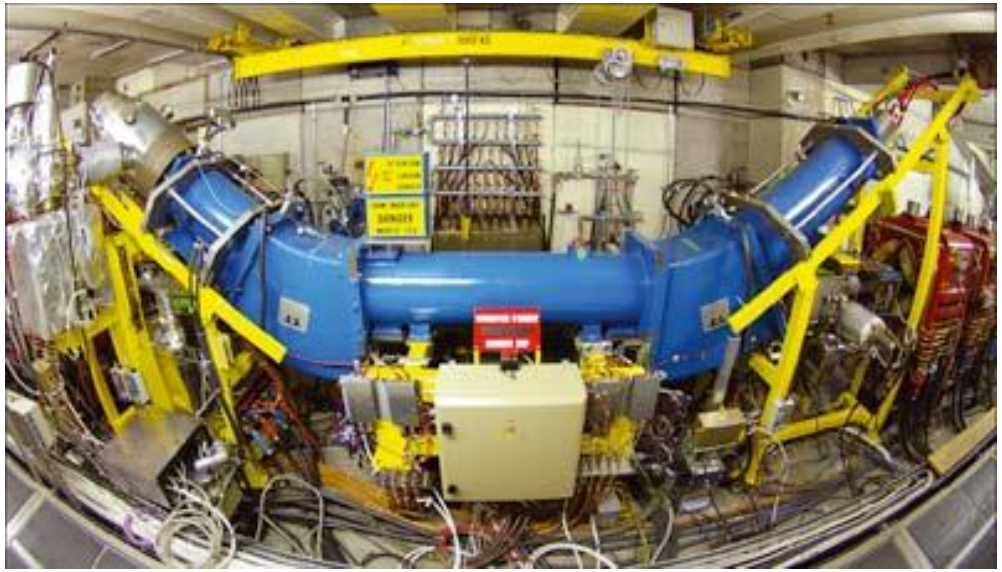
Why a new electron cooler?

Present cooler is more than 40 years old
Missing spares – gun, collector solenoids & toroid
Any intervention is time consuming and requires a lot of resources

Build a new state-of-the-art electron cooler incorporating the latest ideas for :

- enhancing the cooling performance,
- improving the vacuum in the cooling section,
- easier intervention on the cooler,

and above all address the spares situation.



Parameters

Maximum energy:	80 keV
Electron beam energy:	68.125 keV
Antiproton beam momentum:	500 MeV/c
Accelerating voltage:	68.808 kV
Relativistic beta:	0.471
Maximum electron current:	3.5 A
Cathode radius:	1.25 cm
Magnetic field in gun:	2400 G
Magnetic field in drift:	600 G
Expansion factor:	2
Beam radius in drift:	2.5 cm
N_e	7.9×10^{13} m^{-3}
Drift solenoid length:	1.5 m
Cooler orientation:	horizontal
Vacuum chamber diameter:	140 mm

	300 MeV/c	**100 MeV/c**
Electron energy / keV	26.2	3.05
Electron Current / A	2.5	0.1
Electron density / m^{-3}	8.7×10^{13}	1.0×10^{13}
Energy dumped at coll. / kW	65.5	0.3
Magnetic field / Gauss	590	
Electron beam diam. / mm	50	50
Cooling time / s	16	15
Cooling length / m	1.5	
e_x, e_y / p mm mrad	1.6 / 2.4	<1 / <1
Dp/p	$\sim 2 \times 10^{-3}$	$<1 \times 10^{-3}$

What will be different?

- Cooling at a higher antiproton momentum ($\leq$500 MeV/c)
- Horizontal orientation
- Electrostatic plates in each toroid.
- NEG coated vacuum chambers.
- Fast ramping of the expansion solenoid to adapt the electron beam size during cooling.
- New solenoid design using pancakes and iron bars for the return-flux.
- Compact orbit correctors (as used on ELENA).

During the AD deceleration the main losses occur at 300 MeV/c

- x6.6 adiabatic blow-up between FT2 and FT3
- Electron cooling performance relies on good stochastic cooling on FT2
- Larger emittances on FT3 = longer cooling times, tail formation, more critical alignment

By cooling at 500 MeV/c the blow-up is only a factor 4

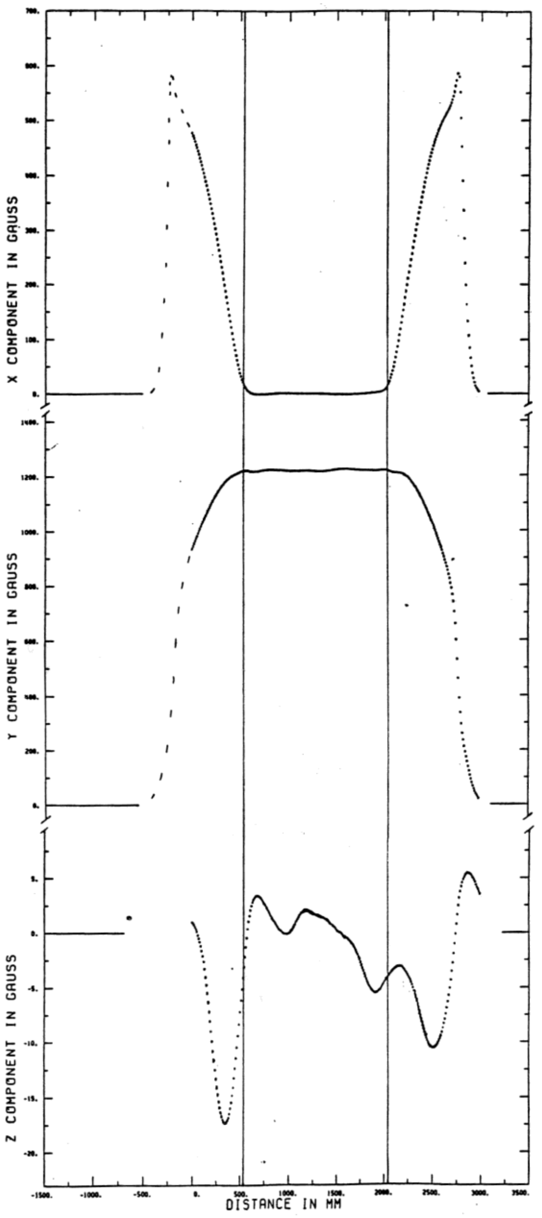
Shorter deceleration time:

- Better control of the tune and closed orbit
- Avoid extra emittance blow-up due to resonance crossing

Intensity and dp/p values

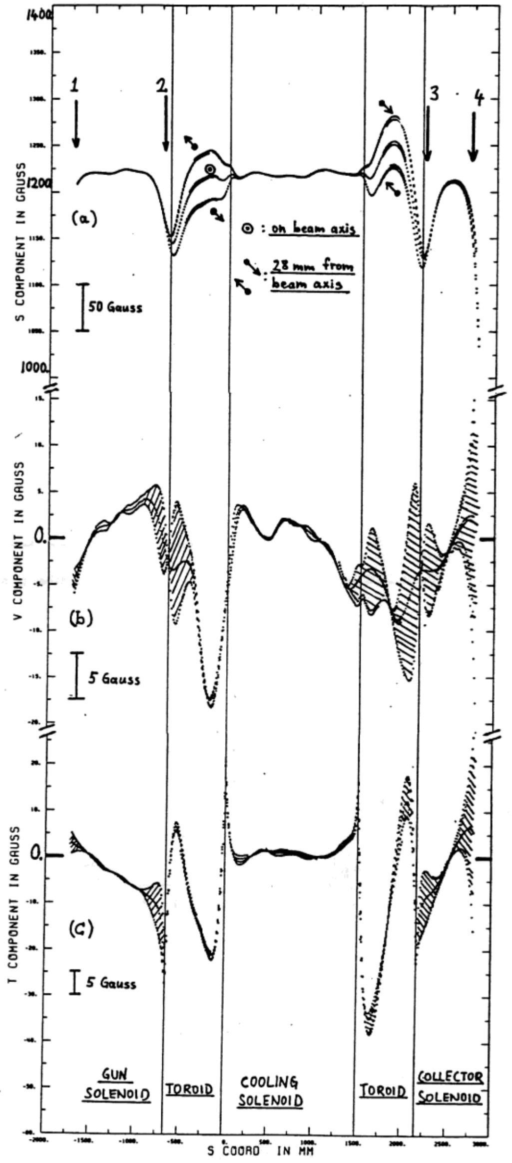
Np (3.5 GeV/c)	2.77 e7	100 %
Np (2 GeV/c)	2.77 e7	100 %
Np (300 MeV/c)	2.32 e7	83 %
Np (100 MeV/c ramp)	2.41 e7	87 %
Np (100 MeV/c end)	2.2 e7	79 %
DE.TFA7049	2.01 e7	72 %

dp/p (3.5 GeV/c)	21.929	0.668
dp/p (2GeV/c)	1.069	0.225
dp/p (300MeV/c)	1.608	0.034
dp/p (100 MeV/c)	0.407	0.613

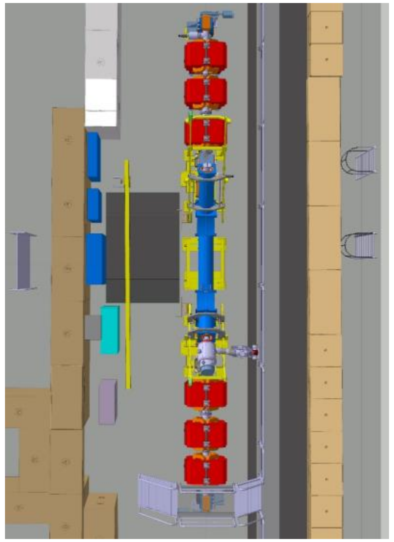


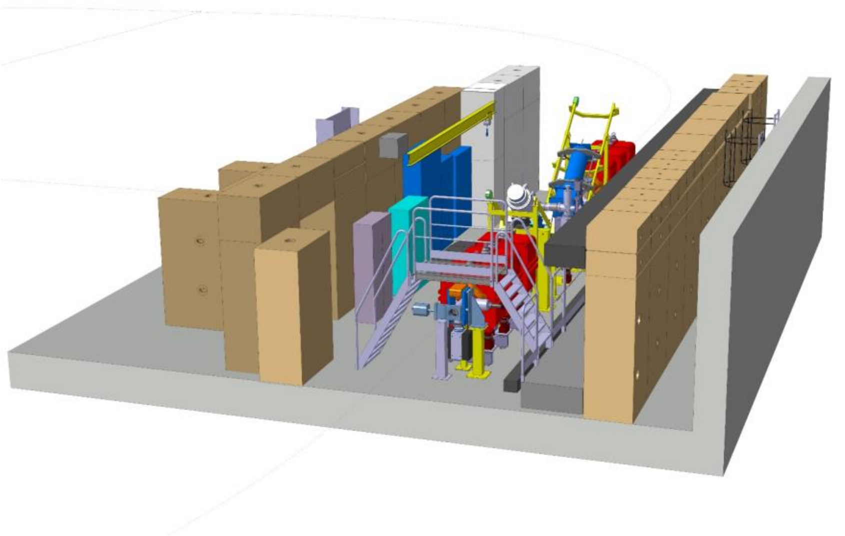
Transverse field in AD ecooler

Drift solenoid is ~ 3×10^{-3}

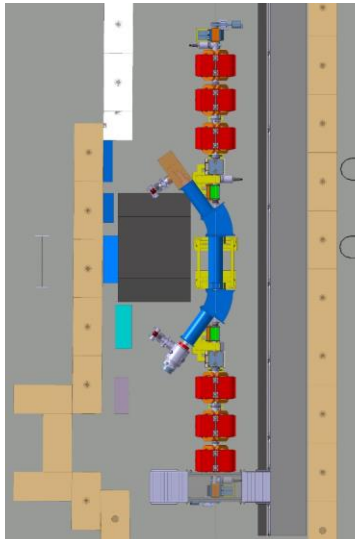


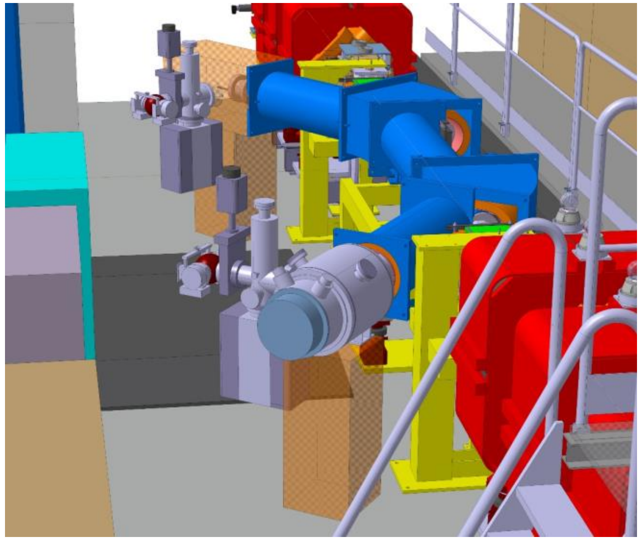
Vertical orientation (present situation)





Horizontal orientation (proposal)

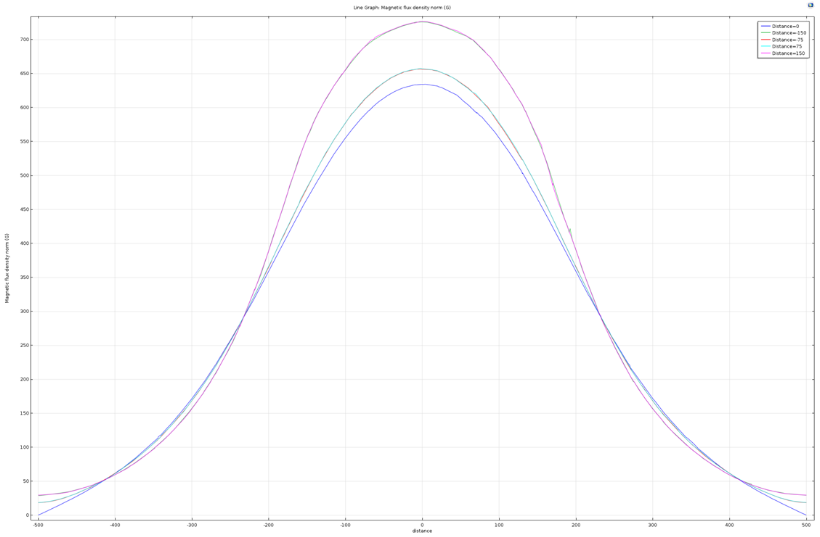


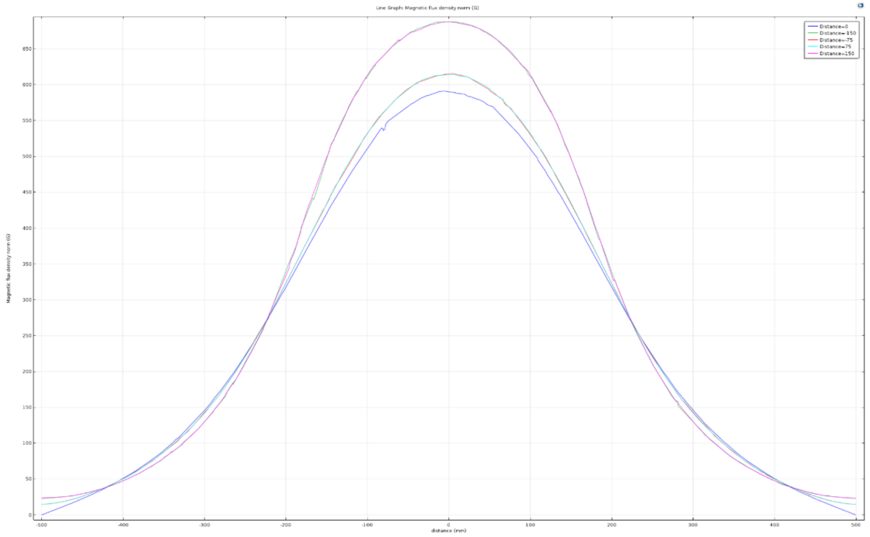


Cooler more accessible. No need for working at heights.

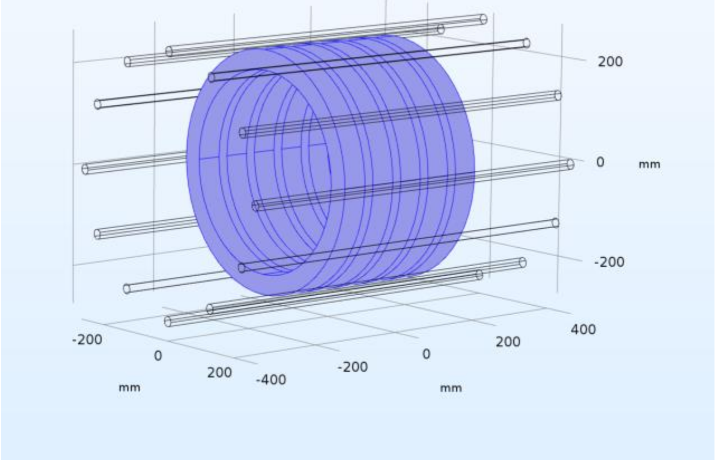
Courtesy of Didier Steyaert & Yannick Coutron

New solenoid design (pancake structure)

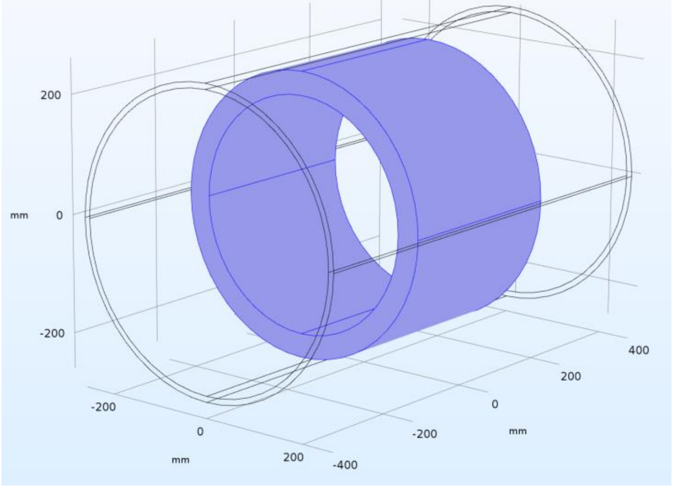




5 x 5cm coils
2cm gap
12 x 1cm iron rods for the return flux



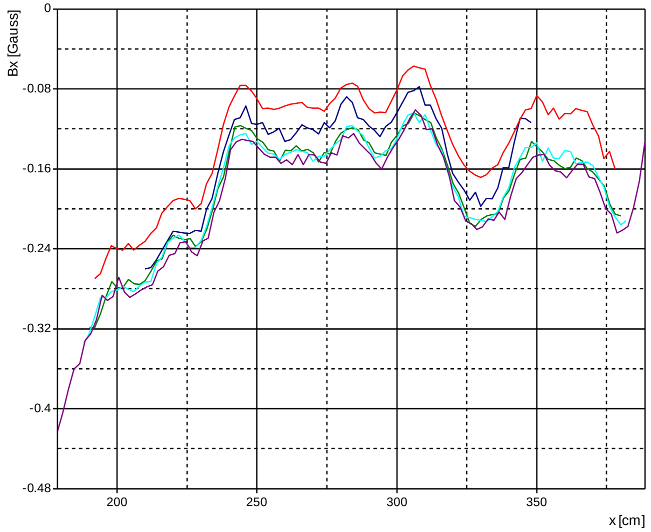
33cm coil
1cm iron shield



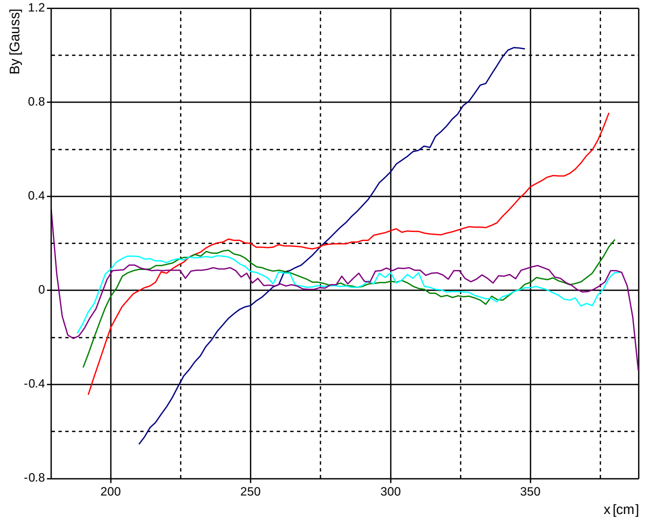
- Fine adjustment of magnetic field possible
- Only a handful of spare coils will be needed
- Easier mounting
- Lighter structure

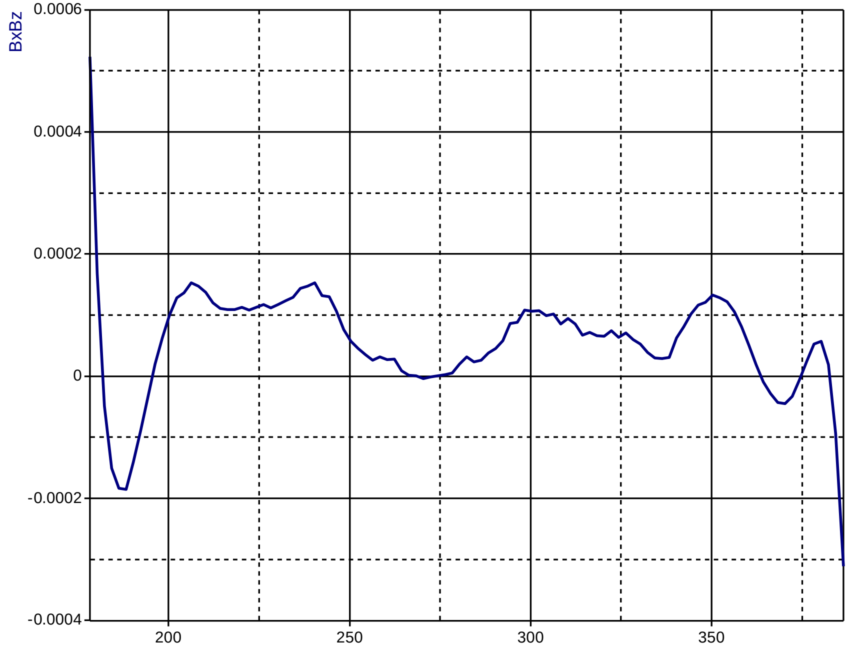
Transverse Magnetic Field Measurements in the LEIR Cooler (compass)

B_x



B_y





B_y/B_z for 750 Gauss

Beam expansion

- Needed for:
  - Adapting the electron beam size to the injected beam size for optimum cooling.

$$B_{//} r^2 = const \Rightarrow r = r_o \sqrt{\frac{B_o}{B}}$$

B_o=0.24T, B=0.06T, r_o=12.5mm => r=25mm

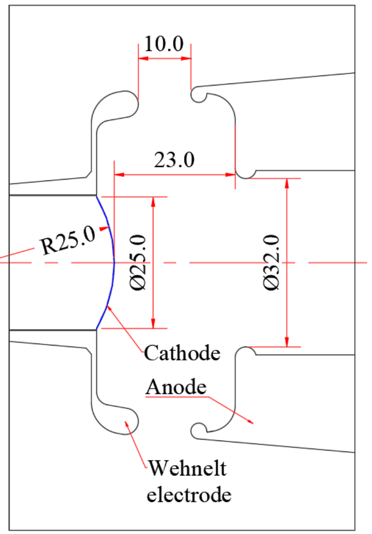
– Reducing the magnetic field in the toroids, thus reducing the closed orbit distortion.

– Reducing the transverse thermal temperature of the electron beam.

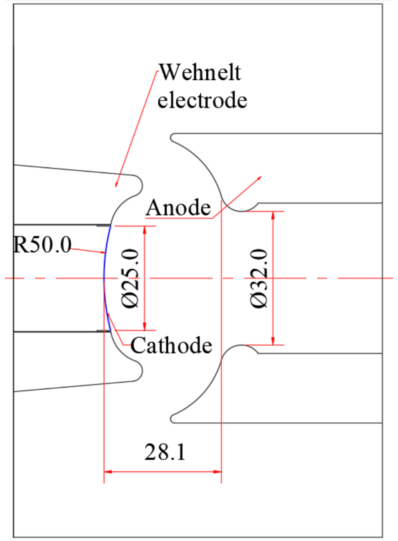
$$\frac{E_t}{B_{//}} = const \Rightarrow E = E_o \frac{B}{B_o}$$

B_o=0.24T, B=0.06T, E_o=100meV => E=25meV

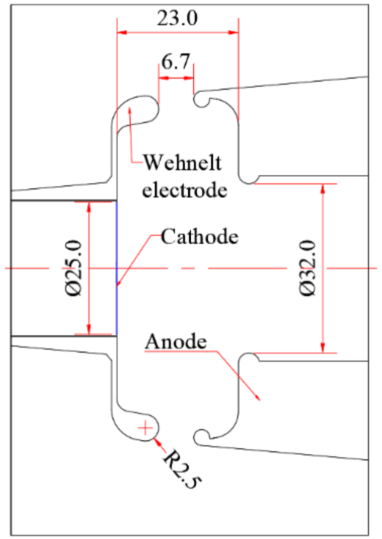
New electron gun design (courtesy of Alexander Pikin)



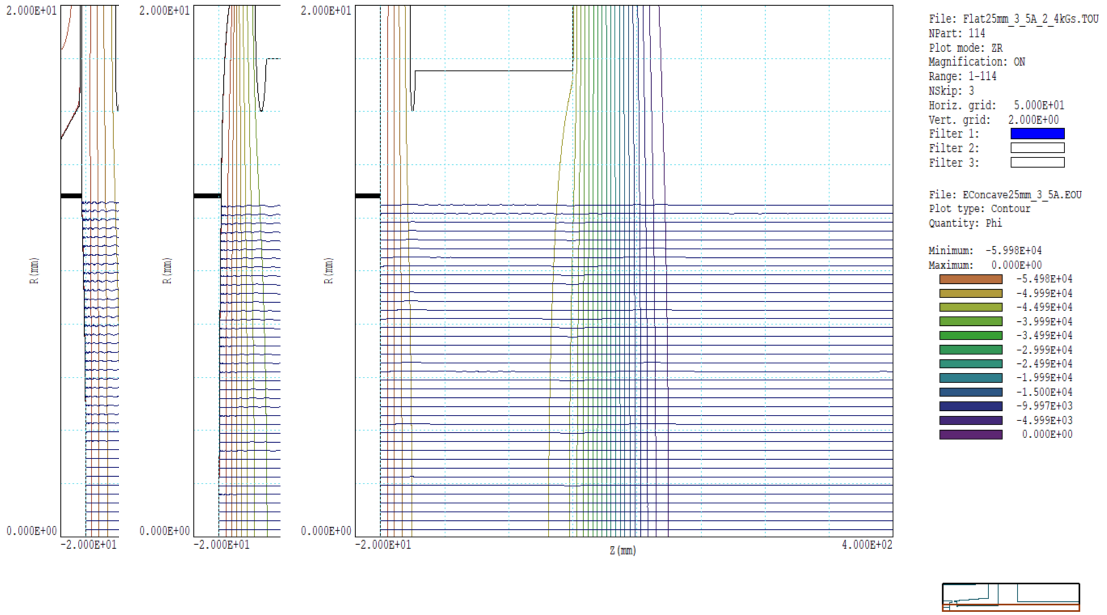
Perveance = 2.93 A/V$^{1.5}$
(anode:11.2 kV)



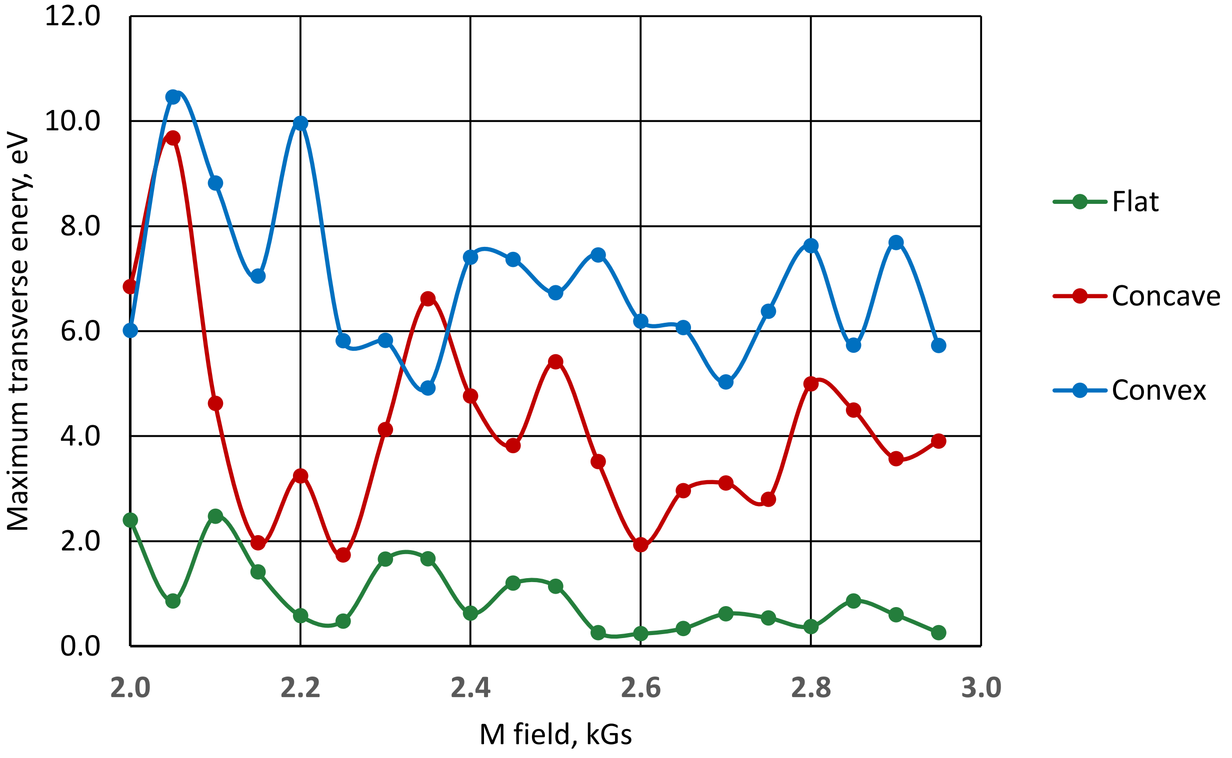
Perveance = 1.38E6 A/V$^{1.5}$
(anode:18.6 kV)

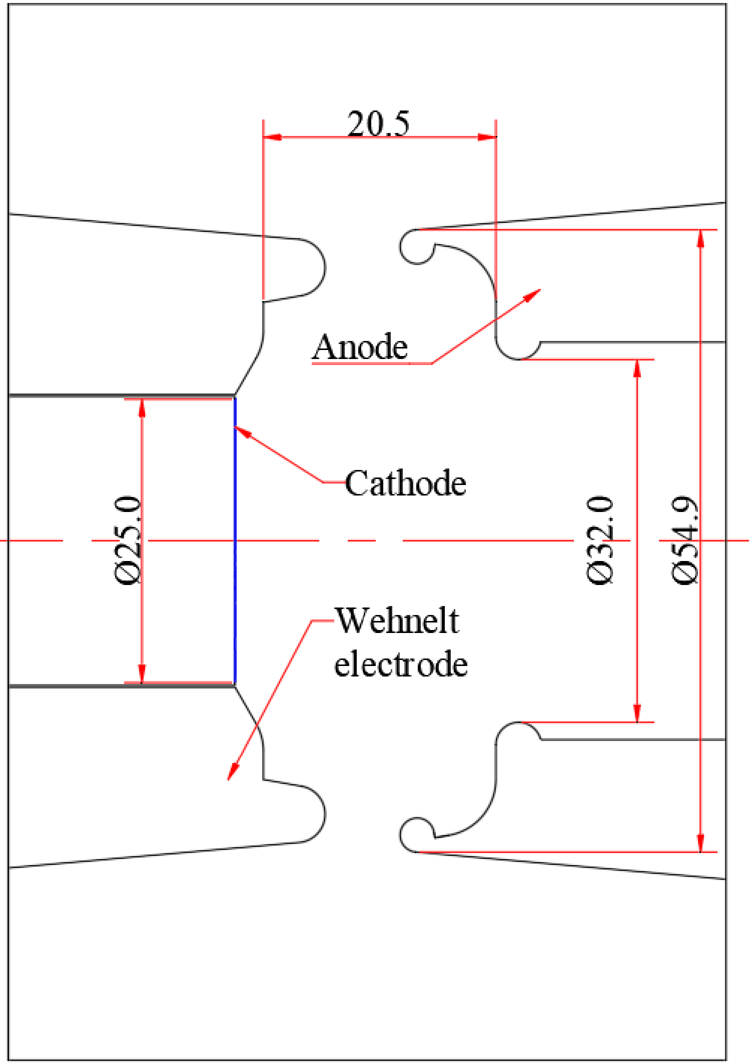


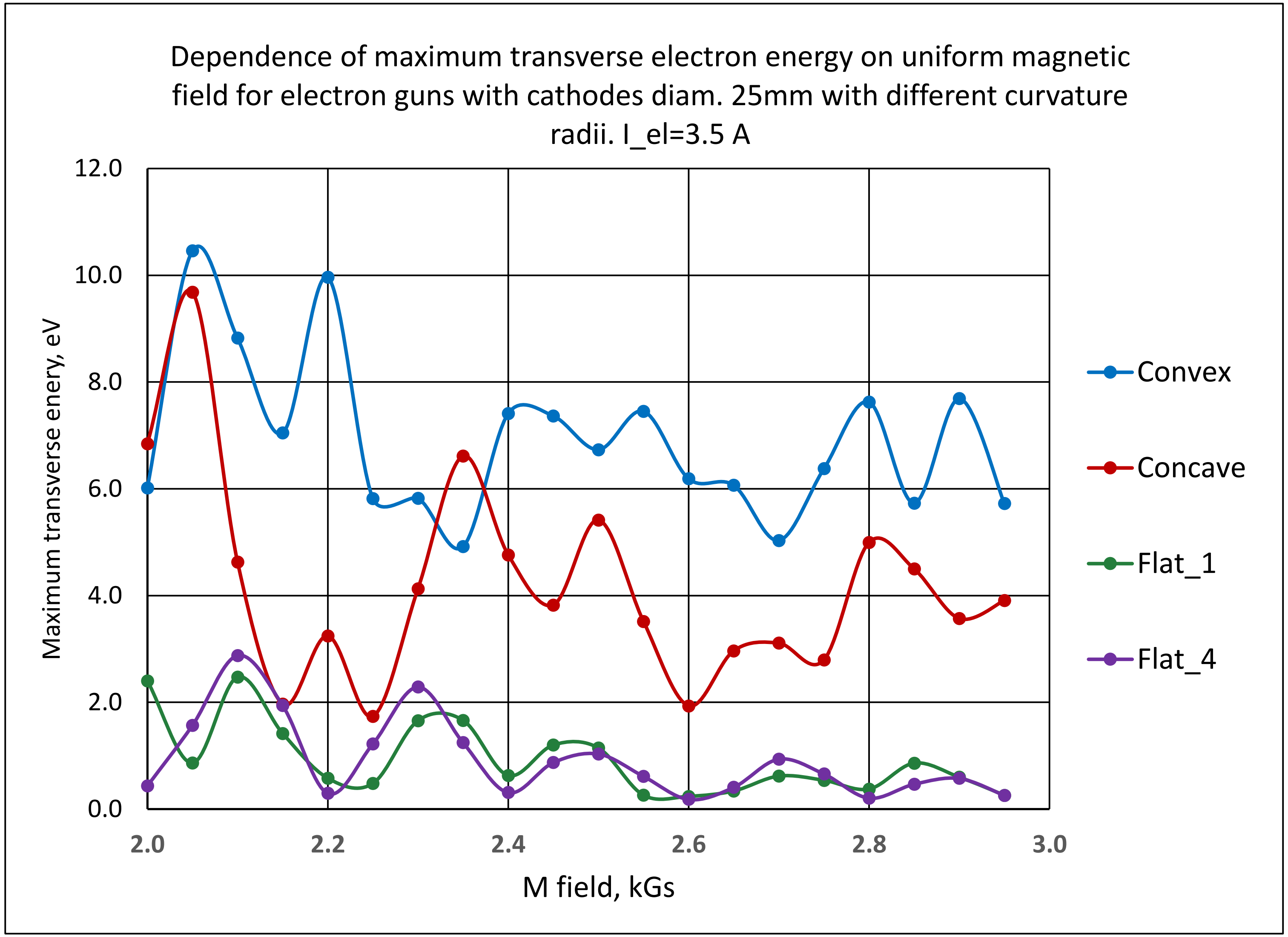
Perveance = 2.613E6 A/V$^{1.5}$
(anode:12.15 kV)



Dependence of maximum transverse electron energy on uniform magnetic field for electron guns 25 mm diameter cathode with different curvature radii. I_el=3.5 A.




20.5
Anode
Cathode
Wehnelt
electrode
Ø25.0
Ø32.0
Ø54.9


Dependence of maximum transverse electron energy on uniform magnetic field for electron guns with cathodes diam. 25mm with different curvature radii. I_el=3.5 A
Maximum transverse enery, eV
M field, kGs
12.0
10.0
8.0
6.0
4.0
2.0
0.0
2.0
2.2
2.4
2.6
2.8
3.0
Convex
Concave
Flat_1
Flat_4