INT 139/88

NEW DESIGN OF THE ELECTRON GUN FOR THE 115 GHZ GYROTRON

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March 88

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1. Introduction

The first design of the electron gun was done in october 86. To reduce the development cost to a minimum, the gun geometry is identical to that of the 120 GHz gyrotron. Only the beam duct was modified due to the dimensions of the new coils.

During the the conditioning of the 120 GHz gun, arcing between the control electrode and the anode was sometimes observed. Therefore, the idea of reducing this unwanted effect by changing the shape of the electrodes came up naturally. The purpose of this study is to round off the electrode and the anode and to investigate its influence on the electron beam.

2. Gun geometry

The geometrical parameters are described in Fig.1. The new electrode and the new anode have larger radii of curvature (r_{c3} , r_{c4}) and the gap between them is no more defined by two flat surfaces facing each other, like in a Penning ionization gauge.

Geometrical Parameters	Design of October 86	New design
CATHODE		
R_k	0.89305 cm	Unchanged
l_k	0.332	Unchanged
α_1	30°	Unchanged
α_2	25°	Unchanged
z_{c1}	1.875	Unchanged
r_{c1}	0.3995	Unchanged
z_t	2.2745	Unchanged
R_t	1.4354	Unchanged
R_a	0.81005	Unchanged
z_k	0.93939	Unchanged
CONTROL ELECTRODE		
d_k	0.4105 cm	0.4105
r_{c2}	0.37083	0.4
L_e	0.755	0.55896
r_{c3}	0.10083	0.4
d_e	2.37583	2.37
R_{e1}	1.08917	1.16
R_{e2}	2.0	2.0

Geometrical Parameters	Design of October 86	New design
ANODE AND BEAM DUCT		
d_{an}	2.025 cm	2.025
r_{c4}	0.42917	0.44404
R_{b1}	0.85	0.85
d_{b1}	5.59917	5.18142
β_1	2.905°	2.9°
R_{b2}	0.6	Unchanged
d_{b2}	10.	Unchanged
β_2	1.43°	Unchanged
R_{b3}	0.5	Unchanged
d_{b3}	10.	Unchanged
β_3	0.5729°	Unchanged
R_{b4}	0.5	Unchanged
d_{b4}	16.8	Unchanged
β_4	0.°	Unchanged

Figs. 2 and 3 show the electron trajectories. The beam characteristics obtained by numerical simulations are summarized below:

Beam parameter	Design of October 86	New design
Cathode voltage [kV]	70.	70.
Electrode voltage	30.	28.5
Anisotropy α		
10 cm from the cathode	0.277 ± 1.8 %	0.275 ± 4.2 %
interaction region	1.228 ± 14.6 %	1.289 ± 13.5 %
Relativistic γ	1.134 ± 0.031	1.134 ± 0.021
Beam radius R_b [mm]	2.075 ± 7.1 %	2.069 ± 7.2 %
Magnetic field [Teslas]		
at cathode (B_k)	0.245	0.225
at interaction region (B_0)	4.687	4.45

Since October 86, the geometry of the coils has been slightly modified. The spacing of the main coils has increased by 1 mm to 128 mm. The outer diameter of the gun coils has been reduced to 28 cm. Fig. 4 show the contour plot of $|B|$. Previously the magnetic field value B_k corresponding to 120 GHz has been used in the numerical simulations.

Because the coil spacing is somewhat larger than in the Helmoltz setup, the maximum B field is not at the interaction region (z = 0). The magnetic field profile on axis exhibits 2 bumps at $z = \pm 8.4$ cm. At these points $B_z = 5.09$ Teslas, while it is 4.45 at z = 0.

This enhances the risk of beam mirroring and prevents reaching high values (1.5 - 2) of the anisotropy α . This is the price one has to pay for a more compact design of the coil system.

Fig. 5 show how α varies with the electrode voltage V_E. Above 29 kV the dispersion becomes large and the onset of mirroring is about 30 kV. At 28.5 kV an α comparable with the previous design is obtained. It is thus possible to modify the electrode and the anode while keeping the same beam quality.

Since the gun has already been manufactured at ABB, only small changes have been investigated. It is quite possible that by redisigning completely the gun from scratch that the α can be improved. For example, extending the control electrode by 1 - 2 mm descreases the dispersion.

File GYR115/UN=STEF

```
 NGUN1(0)  VE = 30. KV  I = 10. A   03/10/86.  CRPP-EPFL
 $INPUT0
  RLIM=80, ZLIM=400, POTN=6, INTPA=.TRUE.,
 $END
 $INPUT1
  POT=0., 70000., 0., 0., 0., 30000., MI=3, TYME=10000,
  LSTPOT=0,
 $END
 $INPUTA
  RLMAG=81, ZLMAG=403,  ! Older version of EGUN was in use !
 $END
 $INPUTB
  DELR=.025, DELZ=.025, RR0=0., ZZ0=0., ZORG=-33.90000, ZLENGT=0.0,
 $END
  000
2., 10., .025, 0., 2.2745, 4, 0/
'A', 4, 65., 0., 1.875/
'L', 4, 1.060, 155./
'L', 1, 0.332, 150./
'L', 4, 0.810, 150./
'L', 4, .1, 180./
'L', 0, 0.474, 90./
'L', 6, .1, 0./
'L', 6, 1.43, -30./
'A', 6, 30., 1.46, 1.52/
'L', 6, .755, 0./
'A', 6, 90., 1.19, 2.275/
'L', 6, .82, 90./
'L', 0, 2.025, 0./
'L', 2, .458, -90./
'A', 2, 86., 1.542, 4.83/
'L', 2, 5.03, -4./
'L', 2, .2, 0./
'L', 0, .770, -90./
'E'/
  888
 $INPUT4
  MAXRAY=51, NMAG=0,
 $END
 $INPUT5
  RC=33.5, ZC=42., NS=50, UNIT=.00025, ZEND=400,
  ZMAG=406, SPC=1., AV=10, AVR=10., STEP=.2, ERROR=10.,
  DENS=5.838, MAGORD=4, RMAG=36.0,
  CZ=400., CR=147., CM=243000.,
  IZS=69,
 $END
```

File JMAG115/UN=AP1

```
JOBST,STLYY.     FILE JMAG115: CREE LE FICHIER DU CHAMP B POUR EGUN
USER,AP1,.                     GYROTRON 115 GHZ  ALPHAC = 20.
JOB,JN=MAG115,MFL=400000,T=400.
ACCOUNT,AC=20007,APW=SANDRA,US=AP1,UPW=,NUPW=.
*
*PRINT THE OUTPUT
*DISPOSE,DN=$OUT,SDN=OUT,DC=ST,TEXT='CTASK.ROUTE,OUT,TC=13.',DEFER.
*
ACCESS,DN=MAGNET,OWN=AP1.
ACCESS,DN=VECTORA,NA,UQ.
DELETE,DN=VECTORA,NA.
RELEASE,DN=VECTORA.
MAGNET.
SAVE,DN=VECTORA,RT=100.
DISPOSE,DN=$OUT,SDN=OUT,DC=ST,TEXT='CTASK.ROUTE,OUT,DC=WT.'
'GET,GUN115T/UN=AP1.GO,GUN115T.'.
EXIT.
/EOF
 $SELECT
  NCOAX=+1,   NFORCE=0,   NPRINC=0,
 $END
 $DATA2
  NBF=1,
  RPI=0.00000,
  DRP=0.00025,
  ZPI=-.500000,
  DZP=0.00025,
  NPTR= 100,
  NPTZ= 2200,
 $END
 $COILS
  NC=4,
  UN=3,
 $END
 $DATA
  Z1(1)=-0.514,Z2(1)=-0.459,A1(1)=0.070,A2(1)=0.14 ,AT(1)=  -1185.,
  Z1(2)=-0.464,Z2(2)=-0.409,A1(2)=0.070,A2(2)=0.14 ,AT(2)=  -1185.,
  Z1(3)=-0.129,Z2(3)=-0.064,A1(3)=0.085,A2(3)=0.185,AT(3)= 902400.,
  Z1(4)= 0.064,Z2(4)= 0.129,A1(4)=0.085,A2(4)=0.185,AT(4)= 902400.,
  KSWI=2,
 $END
 $LINES
 $END
```

File GUN115T/UN=AP1

```
JOBST,STLYY.     GUN115 - MODIFIED
USER,AP1,.
JOB,JN=GUN115T,MFL=750000,T=1500.
ACCOUNT,AC=20007,APW=SANDRA,US=AP1,UPW=,NUPW=.
*
*  ELECTRON GUN DESIGN : COMPUTATION ON CRAY, PLOT ON CYBER
*
ACCESS,DN=BOUNDY,OWN=AP1.
ASSIGN,DN=ZOUT,A=FT09.
ASSIGN,DN=TAPE6,A=FT06.
BOUNDY.
REWIND,DN=ZOUT.
COPYD,I=ZOUT,O=$OUT.
RELEASE,DN=ZOUT.
REWIND,DN=TAPE6.
*COPYD,I=TAPE6,O=$OUT.
REWIND,DN=TAPE6.
COPYD,I=TAPE6,O=INSUGUN.
REWIND,DN=INSUGUN.
RELEASE,DN=BOUNDY:TAPE6:ZOUT.
*
REWIND,DN=INSUGUN.
ACCESS,DN=VECTORA.
ASSIGN,DN=ZOUT1,A=FT09.
ACCESS,DN=EGUN,OWN=AP1.
EGUN.
*
* SAVE PLOTGUN AND DATPLT ON CYBER (INPUT FILES OF PLTGUN)
*
DISPOSE,DN=PLOTGUN,DC=ST,TEXT='CTASK.ROUTE,PLOTGUN,UJN=TAPE1,DC=WT.',WAIT.
DISPOSE,DN=DATPLT,DC=ST,TEXT='CTASK.ROUTE,DATPLT,UJN=TAPE12,DC=WT.'
'GET,PLOTG45/UN=AP1.GO,PLOTG45.'.
*
REWIND,DN=ZOUT1.
COPYD,I=ZOUT1,O=$OUT.
RELEASE,DN=INSUGUN:NRNZ:EGUN.
*
EXIT.
REWIND,DN=ZOUT1.
COPYD,I=ZOUT1,O=$OUT.
/EOF
 GUN115T    VE = 28.5 KV  I = 10. A   17/03/88.  CRPP-EPFL  RUN 29
 $INPUT0
  RLIM= 80, ZLIM=1872,  POTN=6, INTPA=.TRUE.,
 $END
 $INPUT1
  POT=0., 70000., 0., 0., 0., 28500., MI=3, TYME=100.,
  LSTPOT=0,
 $END
```

File GUN115T/UN=AP1 cont'd

```
 $INPUTB
  RR0=0., ZZ0= -128. , ZORG=-46.8, ZLENGT=0.0,
 $END
  000
2., 46.8, .025, 0., 2.2745, 4, 0/
'A', 4,                       65., 0., 1.875/
'L', 4, 1.060,  155./
'L', 1, 0.332,  150./
'L', 4, 0.810,  150./
'L', 4, 0.1,    180./
'L', 0, 0.474,   90./
'L', 6, 0.1,      0./
'L', 6, 1.28218,-30./
'A', 6,                       30., 1.56, 1.41104/
'L', 6, 0.54164,  0./
'A', 6,                      180., 1.56, 1.97/
'L', 6, 0.04,    90./
'L', 0, 2.6062,   0./
'L', 2, 0.05,   -90./
'L', 2, 0.11322,-135./
'A', 2,                      132.1, 1.55596, 4.84104/
'L', 2, 5.1881,  -2.9/
'L', 2, 10.005,  -1.43/
'L', 2, 10.,     -0.5729/
'L', 2, 16.8,     0./
'L', 0, 0.5,    -90./
'E'/
  888
 $INPUT4
  MAXRAY=51, NMAG=0,
 $END
 $INPUT5
  RC=33.5, ZC=42.0, NS=50, UNIT=.00025, ZEND=1872,
  ZMAG=1878, SPC=1., AV=10, AVR=10., STEP=.2, ERROR=10.,
  DENS=5.83800, MAGORD=4, RMAG=36.0,SX=100.,SY=28.,
  CZ=400., CR=147., CM=243000.,
  IZS=69,
 $END
/EOF
```

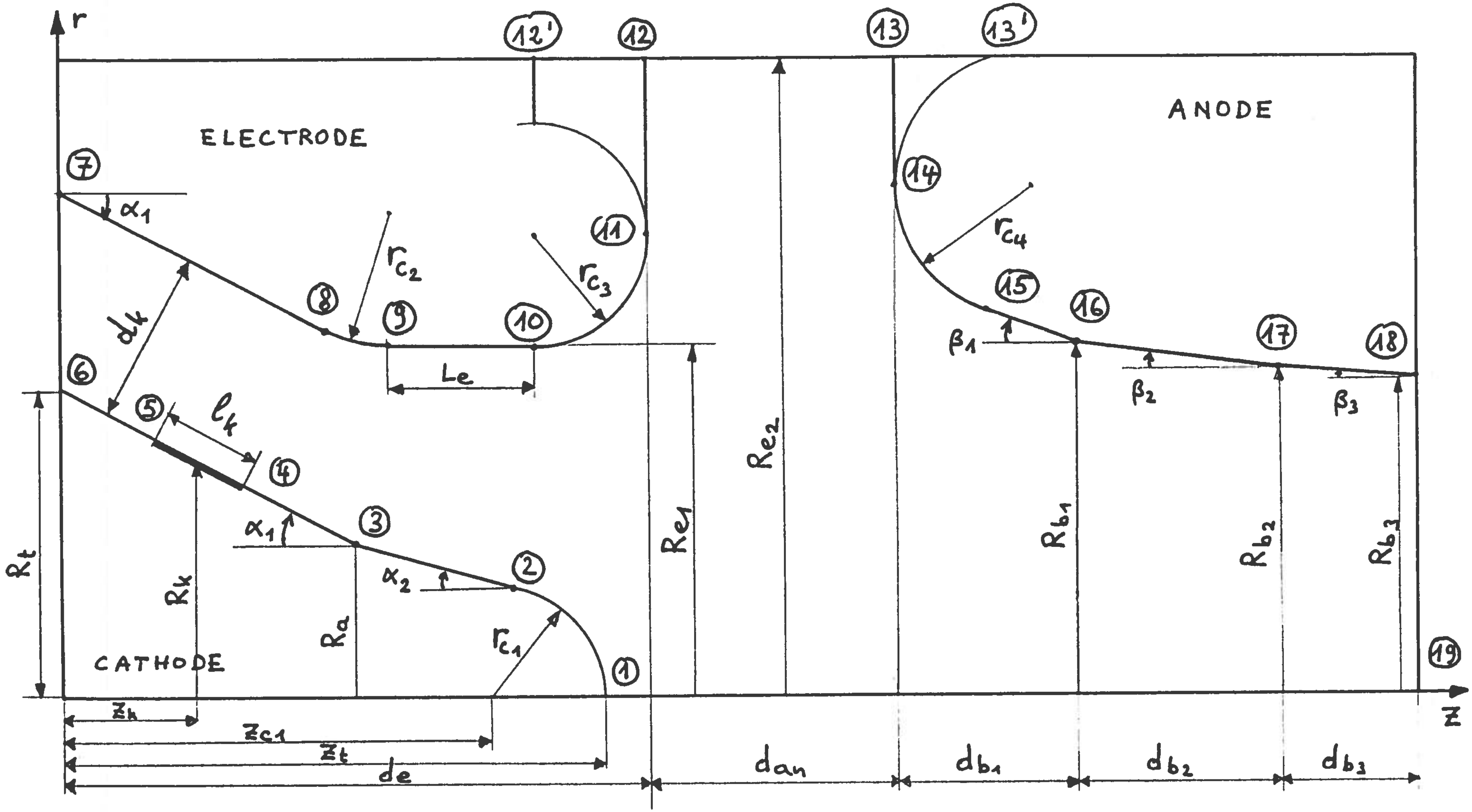


Fig. 1 Definition of the geometrical parameters.

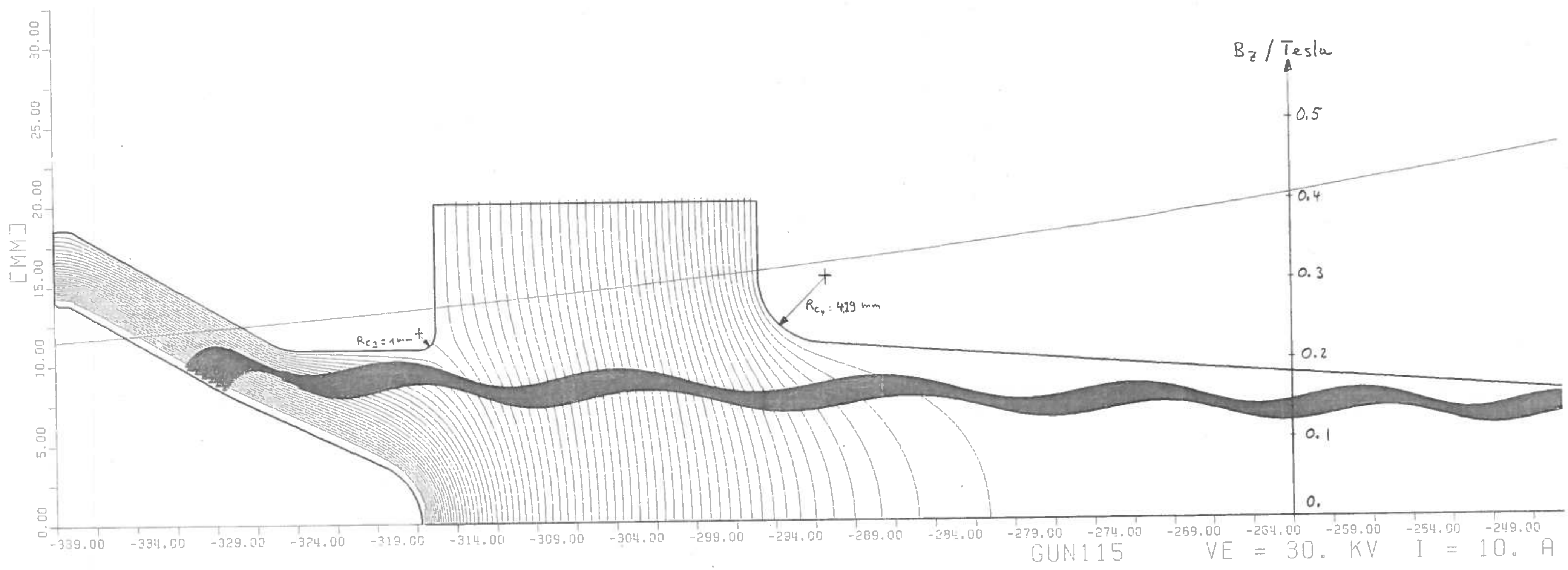


Fig. 2 Electron trajectories. Design of October 86.
V_A = 70 kV, V_E = 30 kV.

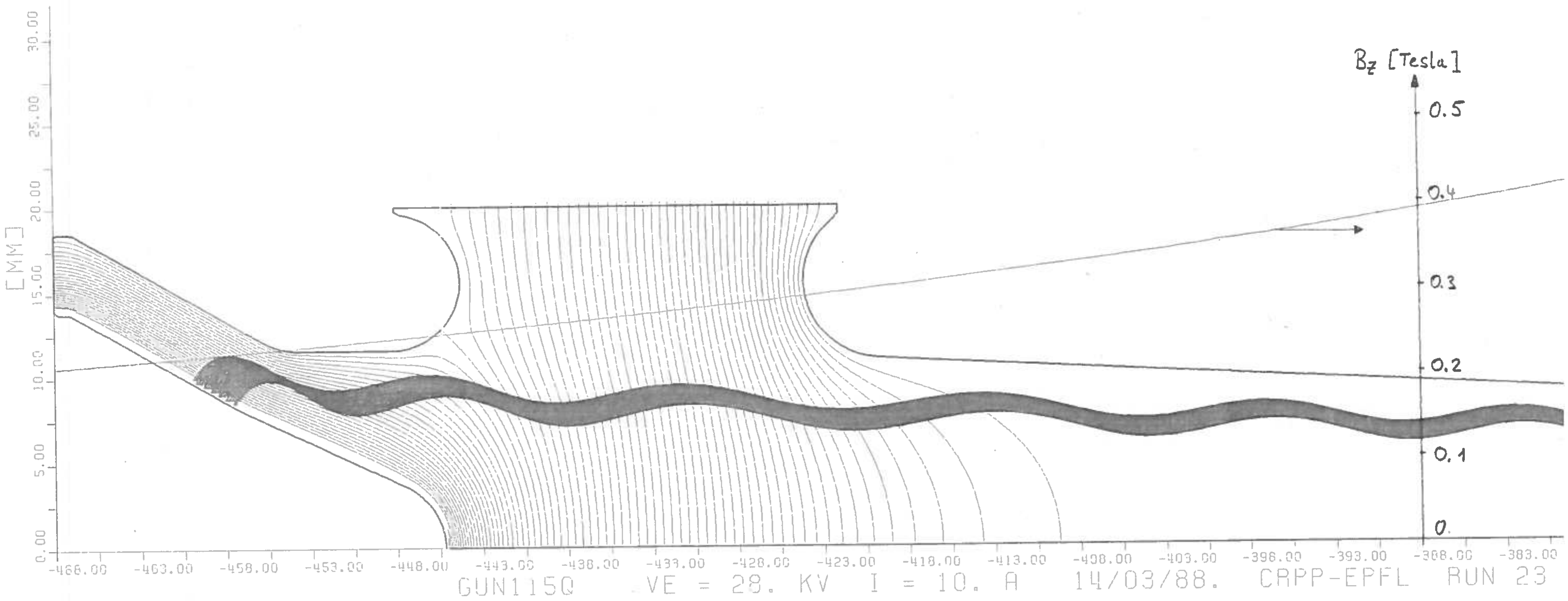


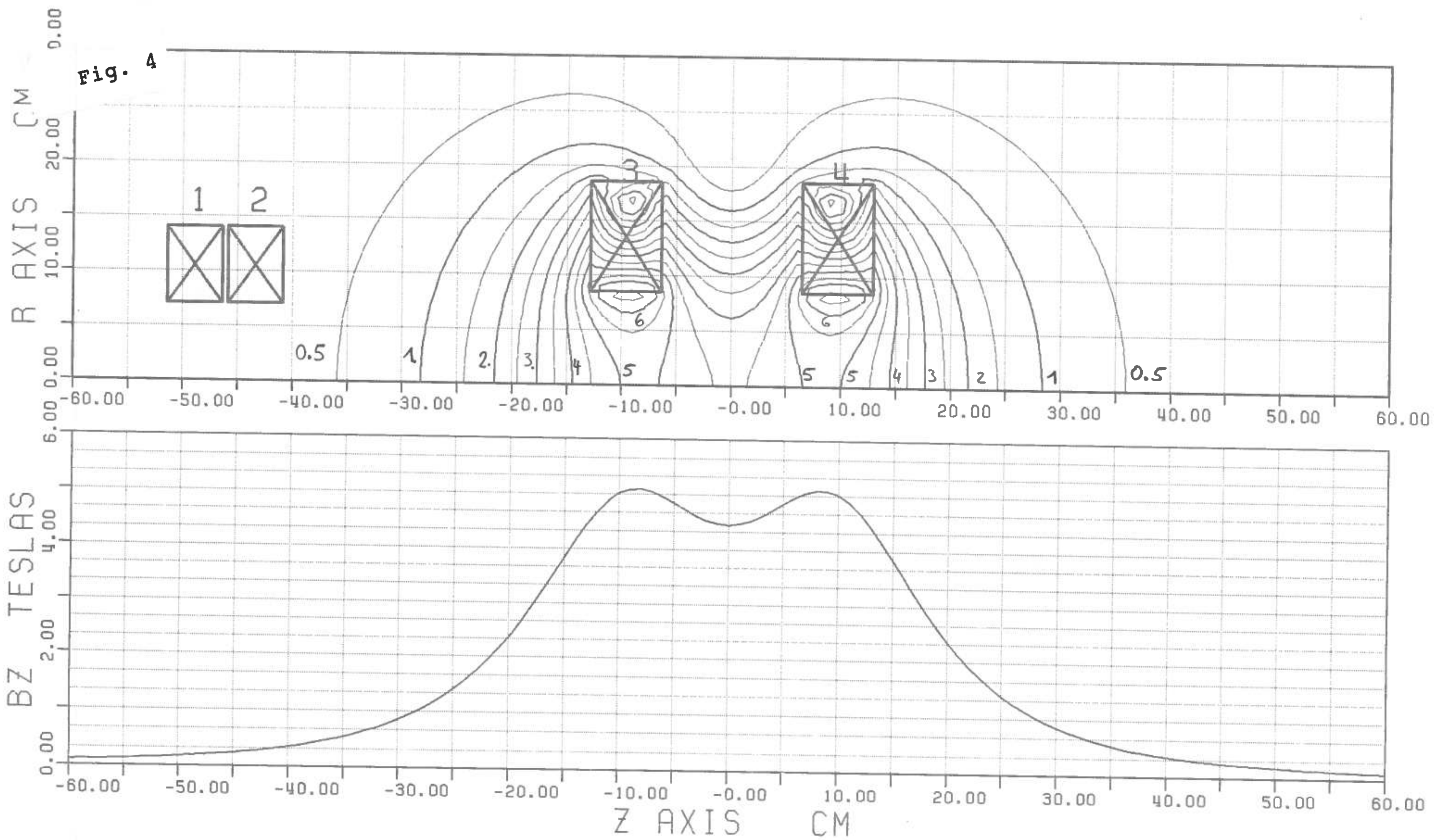
Fig. 3 Electron trajectories. New design.
V_A = 70 kV, V_E = 28.5 kV.

CONTOUR PLOT OF STATIC MAGNETIC FIELD
115 GHZ GYROTRON ALPHAC = 20.

GYROTRON PROJECT
CRPP 88/03/15. 15.49.34.

COIL	CURRENT A*T	CURRENT DENSITY A/CM**2
1	-.11850E+04	-.33857E+02
2	-.11850E+04	-.33857E+02
3	.90240E+06	.13883E+05
4	.90240E+06	.13883E+05

Fig. 4



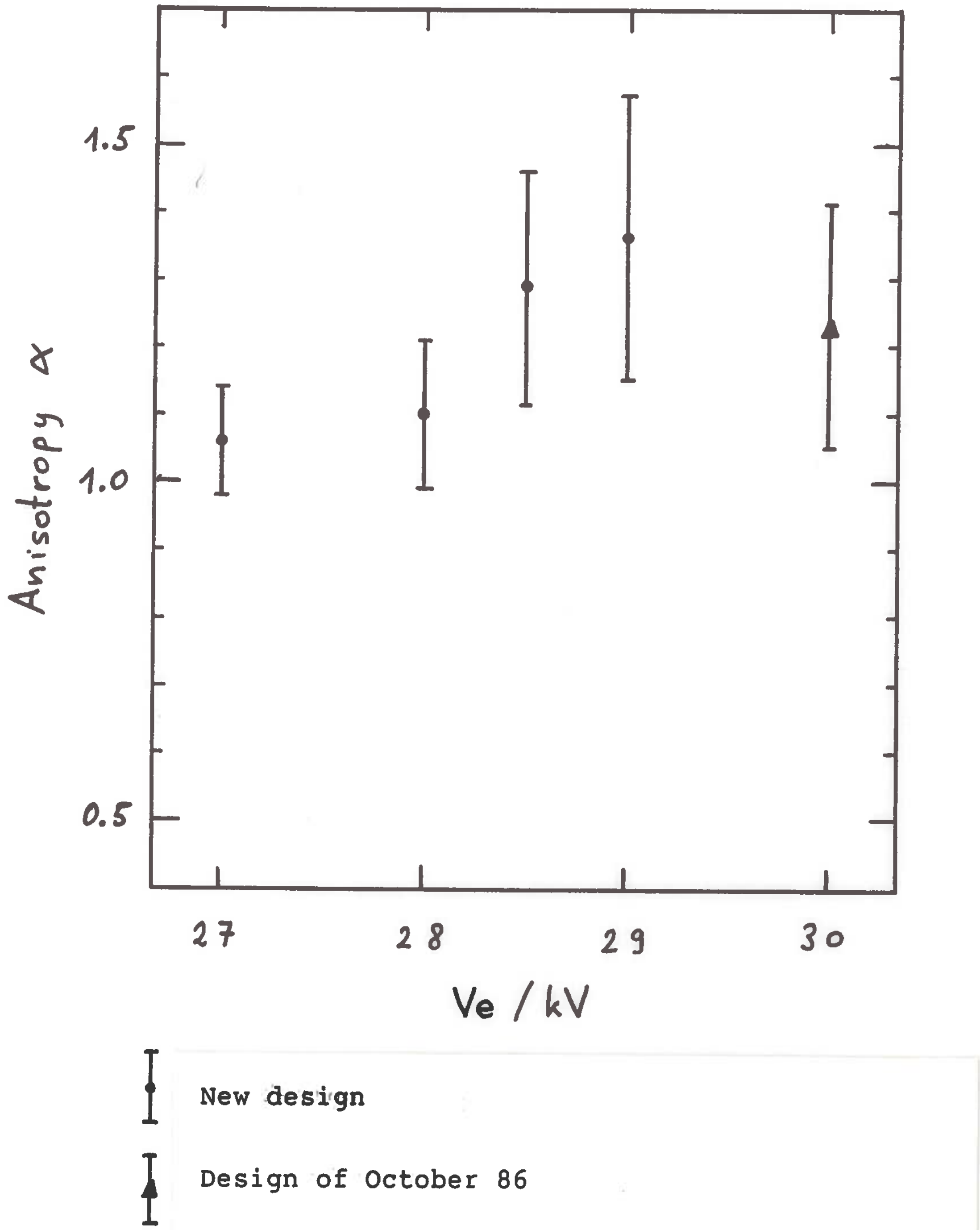


Fig. 5 Beam anisotropy $\alpha = \frac{V_\perp}{V_\parallel}$ at the interaction region as a function of the electrode voltage V_E, V_A = 70 kV.