Yanai Krutman, Michael Kanter, Yoram Lasser, Mark Volshonok
Haim Kleinman, Mufit Tecimer, and Zakir Seidov
Malachi Harpaz
Harry Marks
Updated – 1.08.2005, 20.6.06, 22.10.07------21/10/10----08/11/11 – 26/02/2013

The FEL Electron-Optics System

The electron optics data is described in this report in terms of tables. This is only an informative technical report to be used for reference in discussions, and beam transport simulations.

I. Focusing Coils

Table 1.

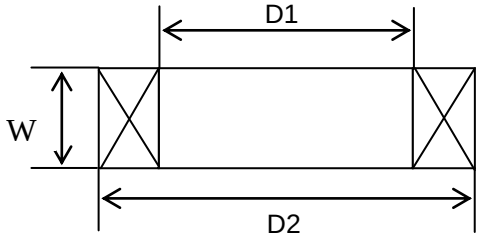
Focusing Coils -Physical parameters

Coil	Z**(mm)	material	turns	R(ohm)	d(mm)	D1(mm)	D2(mm)	Davg(mm)	W(mm)	Imax(A)	B/I (Gs/A)
C1	238.5 (241)*	Al (Wood)	200	0.88 (0.8)	1.45 (1.5)	112 (108)	191 (180)	141 (144)	17 (40)	8	
C2	472	Al	415		1.5	242	296	279	40	8	
C3	1247	Wood	400	3.3	1.5	242 (235)	310	277 (272)	39 (40)	8	
C4	1582	Wood	350	2.9	1.5	235	310	272	40	8	
C5	11305	Al	570	4.9	1.5	240	320	280	40	8	24.6
C6	11625	Al	350	2.3	1.5	176	220	198	41	8	
C7	11925	Al	300	1.9	1.5	176	220	198	41	8	
C8	12448	Wood	530	4.6	1.5	235	310	272	41	8	

*** to the center of the coil*
** old location (till 20 .6.06)*

Index:

d	coil body thickness
D1	internal diameter
D2	external diameter
W	width
Z	from the cathode position



Notes:

The number of turns given is based on resistance measurement made by Miki on 18.02.03. The length of the wire and number of turns are determined from:

$$L = \frac{R}{dR/dl} \; ; \; N = \frac{L}{\pi D_{avg}}$$

The wire resistance per meter was calculated theoretically:

$$\frac{dR}{dl} = \rho \frac{l}{\pi D^2/4} = 1.724 \cdot 10^{-6} \cdot \frac{100}{\pi \cdot 0.15^2/4} = 9.76 \cdot 10^{-3} [\Omega/m]$$

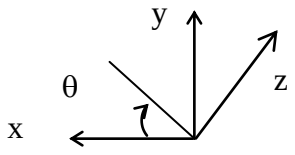
C1 – Based on old data.
C2 – New coil (10/2007)
C3 – Based on R measurement. Other reports (420,400)
C4 – Based on R measurement. Other reports (420,400)
C5 – Based on R measurement
C6 – Based on Haim's count during production. From R measurement: N=379.
C7 – Based on Haim's count during production. From R measurement: N=313.
C8 – Based on R measurement

Tabe2. *Beam rotation angle (for V=43kV - $\gamma\beta$=0.419)*

Coil	θ°(E=43kV)	Conditions
C_1	10.08	I=1A
C_2	21.19(old coil)	I=1A
C_3	20.18	I=1A
C_4	17.66	I=1A
C_5	28.76	I=1A
C_6	17.66	I=1A
C_7	15.13	I=1A
C_8	26.74	I=1A
C_1+C_2	-6.10	I_1=+7.25A,I_2=-3.75A
C_3+C_4	103.94	I_3=+3A,I_4=+2A

$$I_B = \int_{-\infty}^{\infty} B_z(z)dz \qquad \theta = \frac{180}{\pi} \cdot \frac{e}{2\gamma m v_z} \cdot I_B = \frac{3.69 \cdot 10^{-4}}{\gamma\beta} I_B$$

Accelerator coordinates convention:



Note:

The value of the beam rotation parameter is significant mostly for estimating the change in orientation relative to what is meant with the steering coils. In particular the coils C_3+C_4 (for I_3=+3A, I_4=2A) will rotate the beam deviation of VH_1, VH_2 by 100° from screen S_0 on. The effect of the other solenoids on the steering coil and Helmholz coil deflection orientation is complicated because of the overlap and requires simulation.

II. Steering Coils

Table 3.

Coil	Z(mm)	turns	loops space(mm)	diam(mm)	wire diam (mm)	I_{max} (A)	B/I (Gauss/A)	θ/I mrad/A	θ_{max}	X_p/I (mm/A)	X_0/I (mm/A)
V1	576	20	223	153.5	0.67	3.00	0.60	0.7	2.1	3.5	14
H1	576	20	225	153.5	0.67	3.00	0.58	0.7	2.1	3.5	14
V2	850	20	268	153.5	0.67	3.00	0.40	0.5	1.6	0.5	8.5
H2	957	40	154	180x75	0.67	3.00	1.80	0.61	1.81	0	8

Helmholz coil	Z (center) [mm]	N [turns]	Width [mm]	Length [mm]	Wire Diameter [mm]	Height [mm]	B/I (Gauss/A)	θ/I °/A	X_p/I (mm/A)	X_0/I (mm/A)
Hh	442	16	630	1730	1.20	310	0.35	3.41	18	68

Coil	Z(mm)	turns	iron ext (mmxmm)	iron cross (mm)	wire diam (mm)	I_{max} (A)	B/I (Gauss/A)	θ/I mrad/A	θ_{max}	X/I (mm/A)
VH3	1840	65	225x225	12x12	2.00	10.00	1.00			
VH3A	4273	200	124x124	11x11	1.35	6.00	12.24	27.3		
VH4	5654	200	124x124	11x11	1.35	6.00	12.24	23.2	140	
VH5	5916	520	207x207	12x12	0.50	1.50	7.30	41	62	
VH6	7132	160	200x200	12x12	1.20	6.00			140	
VH7	7491	180	124x124	11x11	1.35	6.00	12.24	23.2	140	
VH7a	8917	180	124x124	11x11	1.35	6.00	12.24	23.2	140	
VH8	11685	50	207x207	12x12	2.00	10.00	1.20	15.4	154	

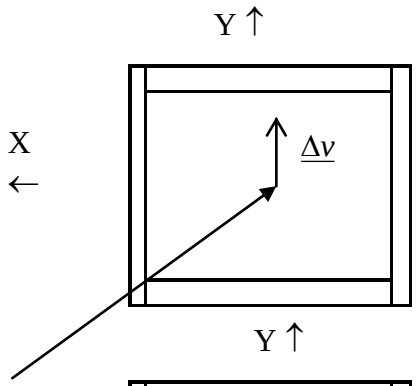
Note: 1. The steering coils parameters were taken from report #25 (Efimov).

2. The Helmholz coil parameter and the deflection angels of VH_1, VH_2 were calculated by Omry 18.02.03.

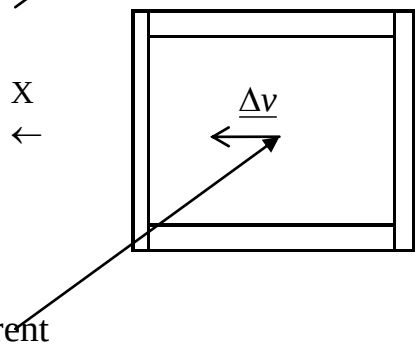
*VH5a is not installed

Steering coils deflection agreement

Vertical +Y deflection with positive coil current:



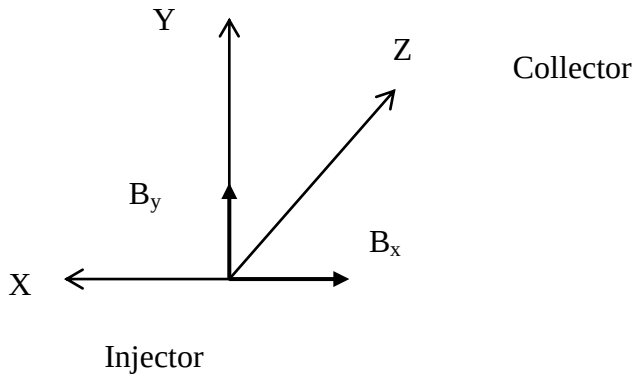
Horizontal +X deflection with positive coil current:



Directions of magnetic fields for positive current

Horizontal steerers (vertical coils):
$I_H>0 \rightarrow B_H>0$ (positive Y direction)

Vertical steerer (horizontal coils):
$I_V>0 \rightarrow B_V<0$ (negative X direction)



Solenoid polarity agreement

Positive current corresponds to axial magnetic field in the + z direction.

III. Screens

Table 3 describes screens position, material, displacement, viewer orientation in relation to the beam propagation Z-axis, geometry, number of holes and grid spacing, holes angle and diameter. The hole positions were measured by Yoram 19.12.02. The sag was determined from alignment report 11.06.95 (this information will be updated after telescopic measurements)

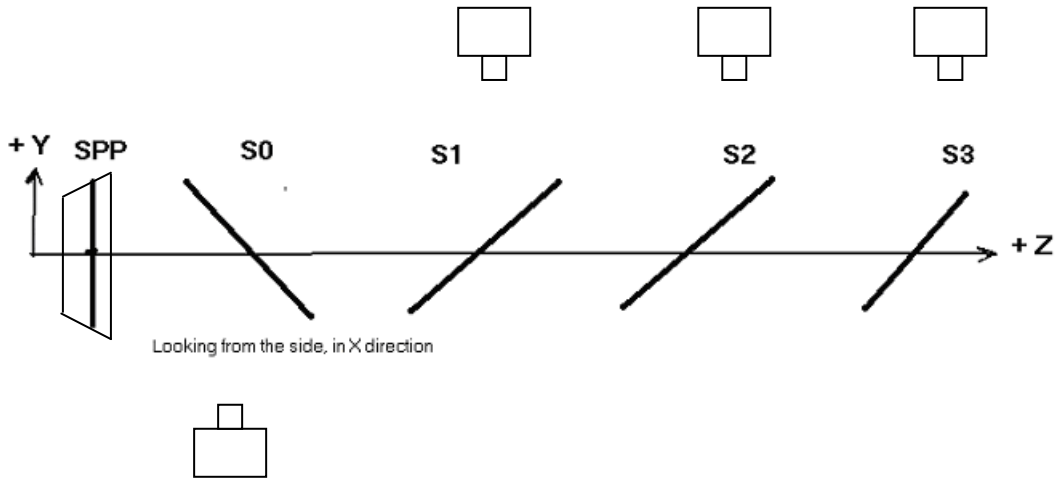
Table 4.

Screen	Position (mm)	Material	Displacement	Viewer Orientation	Geometry	No. of holes diam(mm)	Grid-spacing (mm)	Holes angle (deg)	Holes diam (mm)
Sp	(-0.4,0.2,859)	Ti-Al2O3	manual	(-) X	square	34	5	90	1
					center	1	----	45	2
S0	(12,0,1713)	Ceramic	step-motor	(-) Y	Ellipse	14	10	90	1
					center	1	---	45	2
S1	(0.2, 0.8,4137)	Ti-Al2O3	coil	(+) Y	Ellipse	34	5	45	1
Sag*	(0.2,0.2,4137)				center	1	---	45	1.5
(-0.6)									
S2	(0.7,0.88,5829)	Ti-Al2O3	coil	(+) Y	Ellipse	8	2.5	90	0.5
Sag*	(0.7,-0.12,5829)					14	5	90	1
(-1.0)					center	1	---	45	1.5
S3	(0,0.14,7361)	Ti-Al2O3	coil	(+) Y	ellipse	8	2.5	90	0.5
Sag*	(0,-0.84,7361)					14	5	90	1
(-1.0)					center	1	---	45	1.5

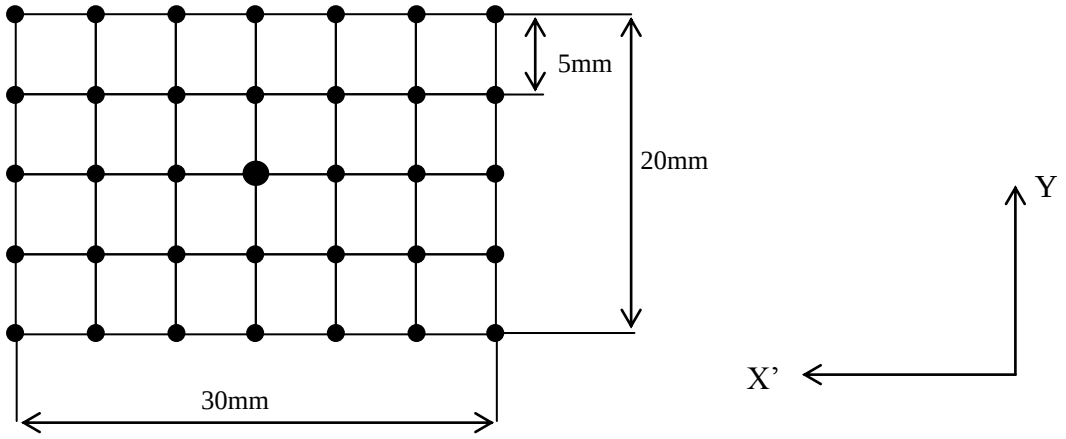
* MODIFITED. Position after pressuring the tank

Screens orientation

Cameras position

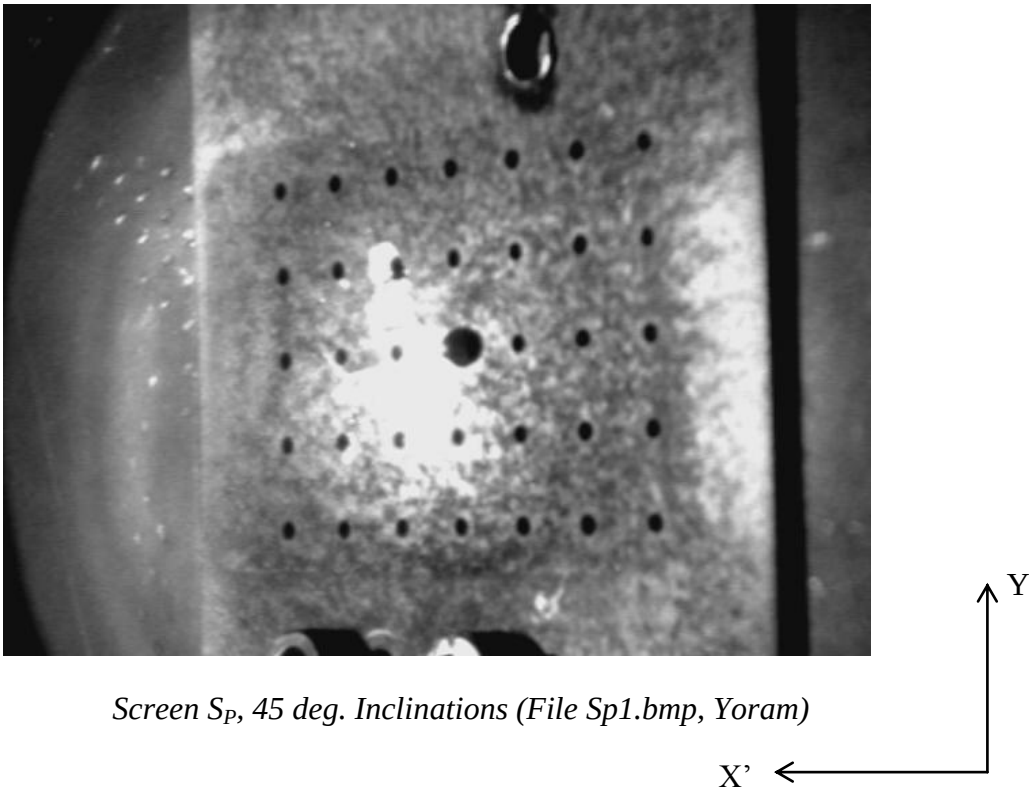


Pepper pot screen (Sp)



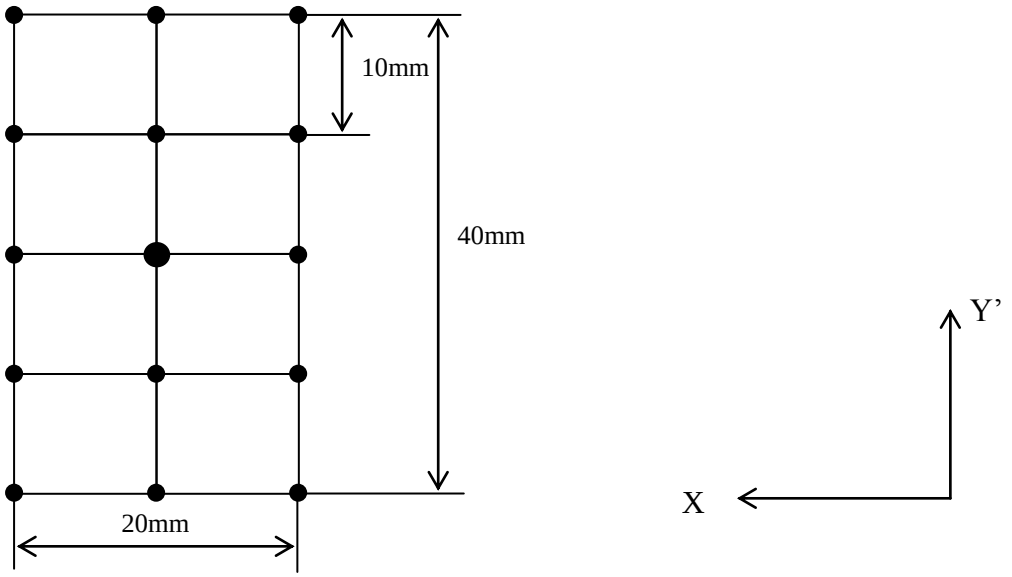
Distance between holes is 5 mm on screen plane in both X' and Y directions, the central hole diameter is 2mm with inclination 45°, and other holes diameter is 1mm with inclination 90^0.

Pepper pot screen



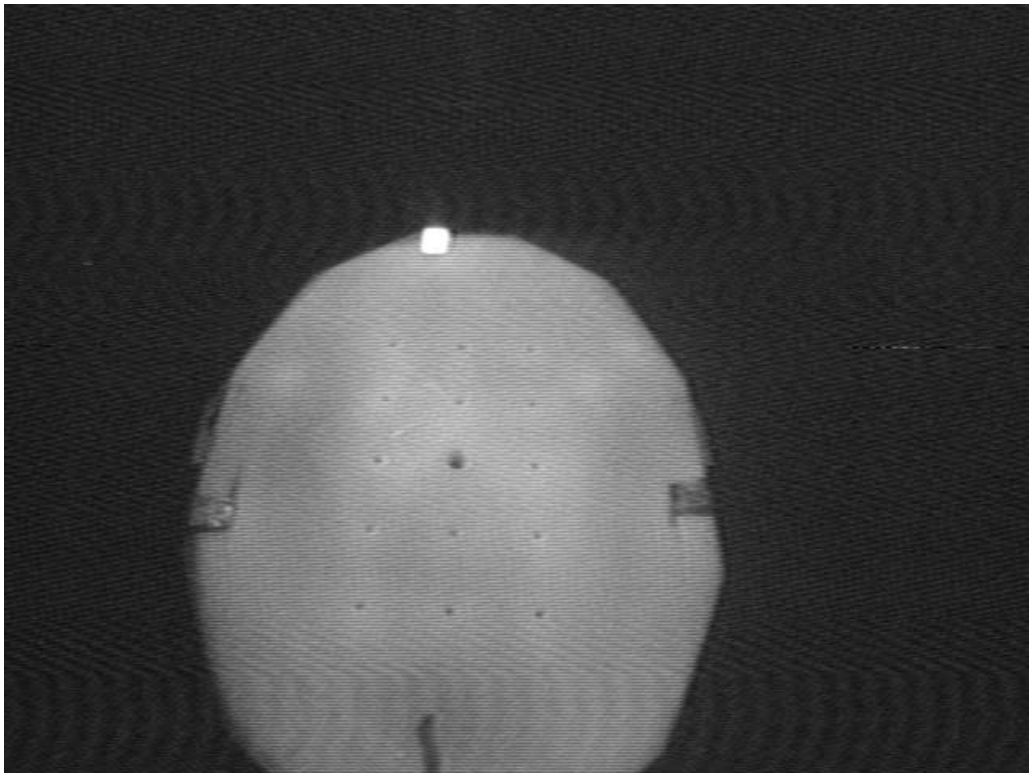
Screen S_P, 45 deg. Inclinations (File Sp1.bmp, Yoram)

Screen S_0

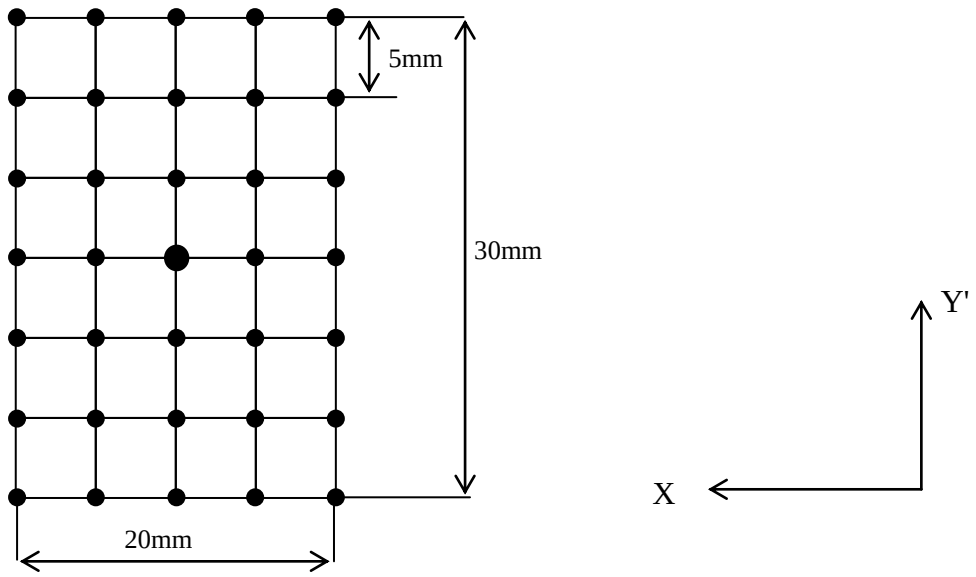


Distance between holes is 10 mm on screen plane in both X' and Y directions, the central hole diameter is 2mm with inclination 45°, and other holes diameter is 1mm with inclination 90^0.

Screen S_0

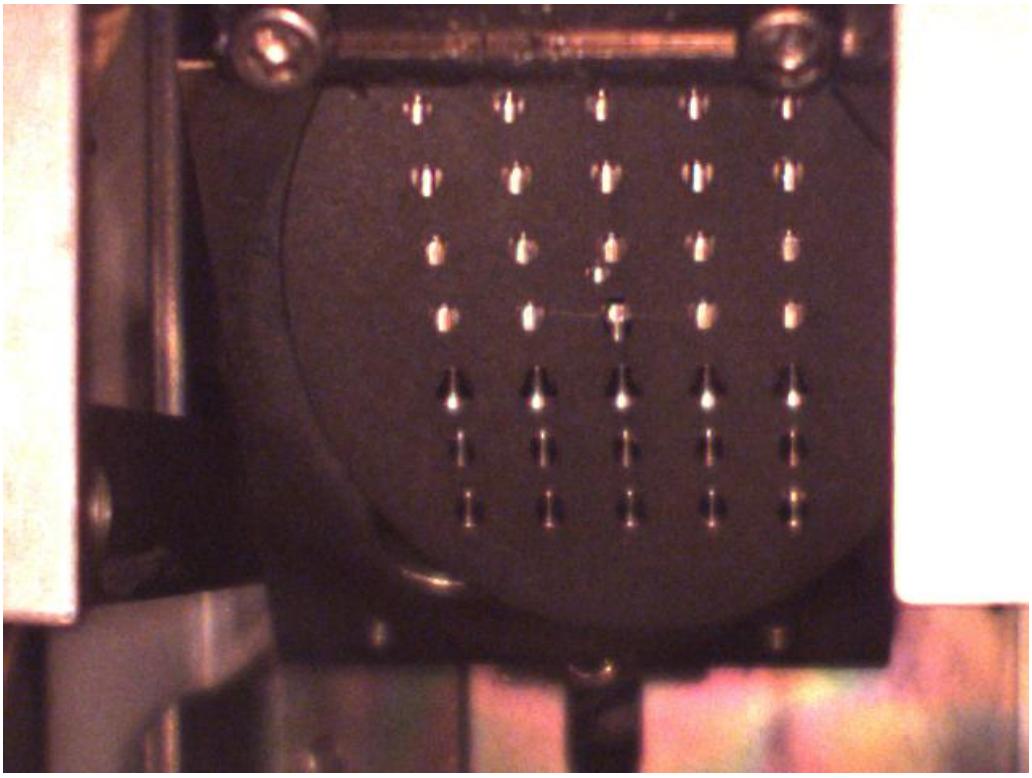


Screen S_1



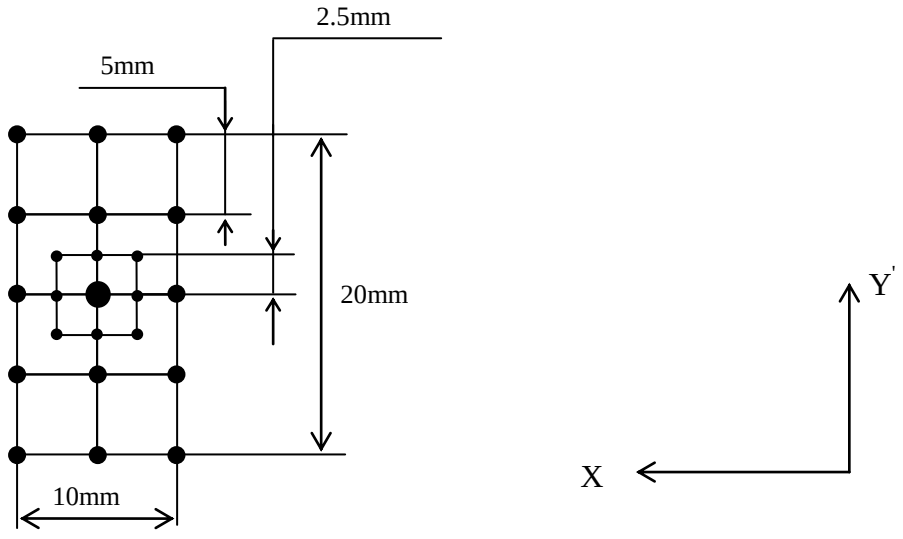
Distance between holes is 5 mm on screen plane in both X' and Y directions. Central hole diameter is 1.5mm. Other holes diameter is 1mm. Inclination of all holes 45°. Renewed in 2013, Ti screen produced by NEC and machined in Ariel. Checked at SP & found to work.

Side of screen facing electron beam

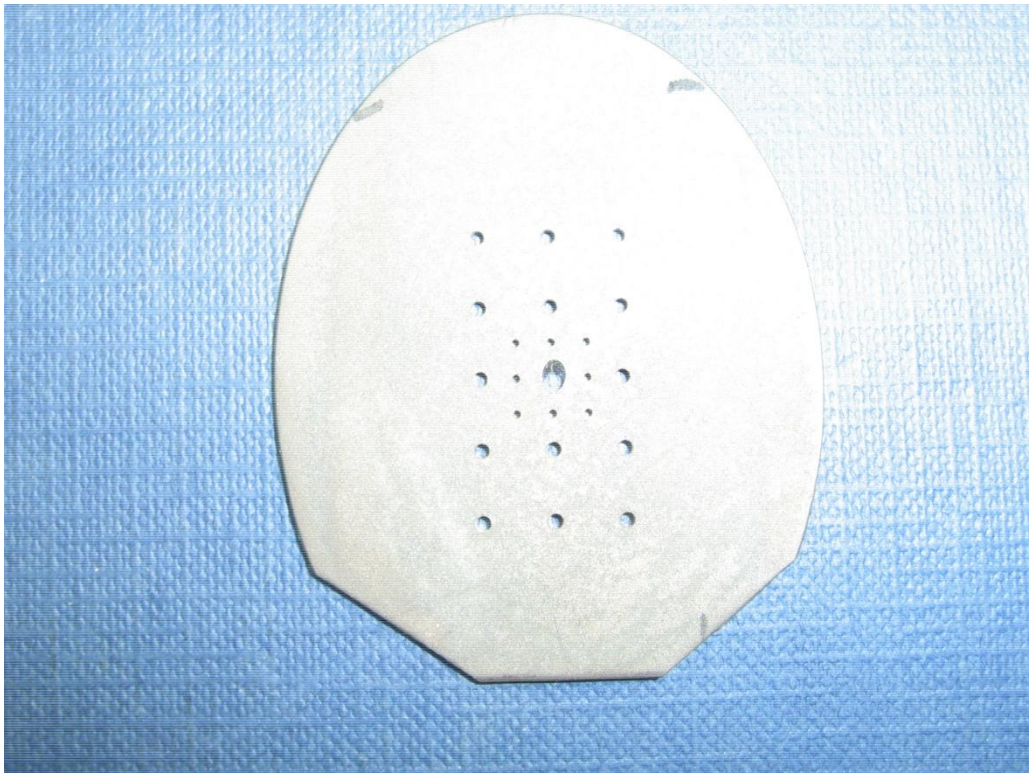


Screen 1 in position within the tank.

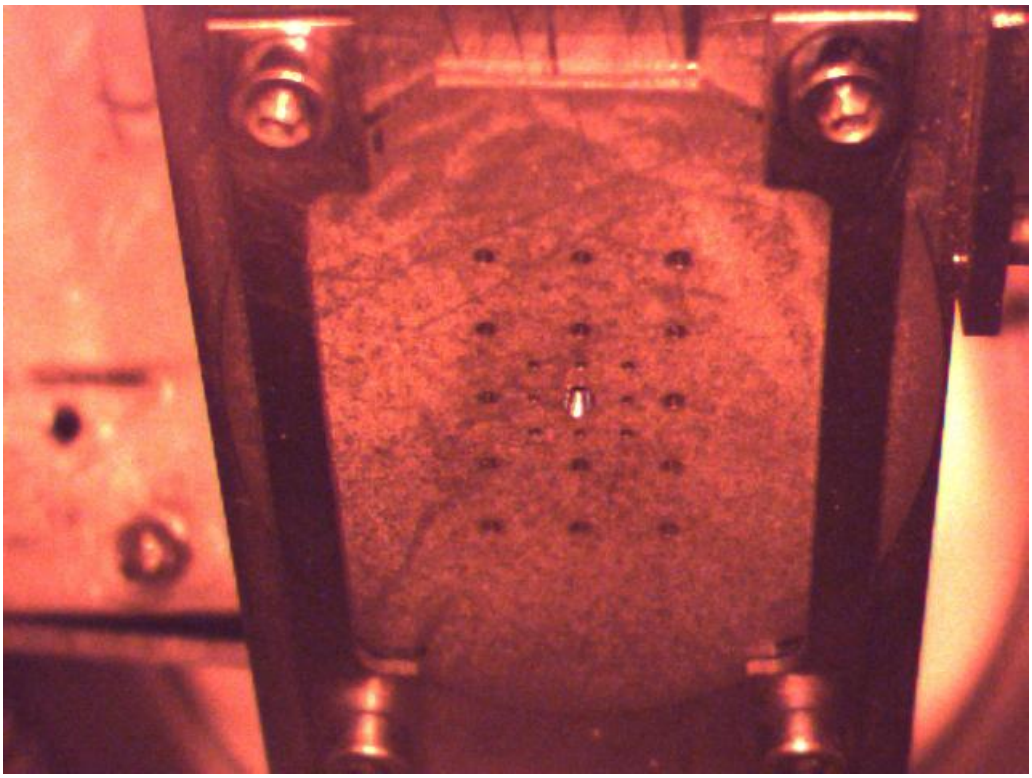
Screen S_2 & S_3



Central hole diameter is 1.5 mm. Its inclination angle is 45 deg to screen surface (such that in working position of screen, the hole is along the beam); 8 holes of .5 mm diameter spaced 2.5 mm apart, and 14 holes of 1 mm diameter, spaced 5mm apart are all normal to the screen surface.

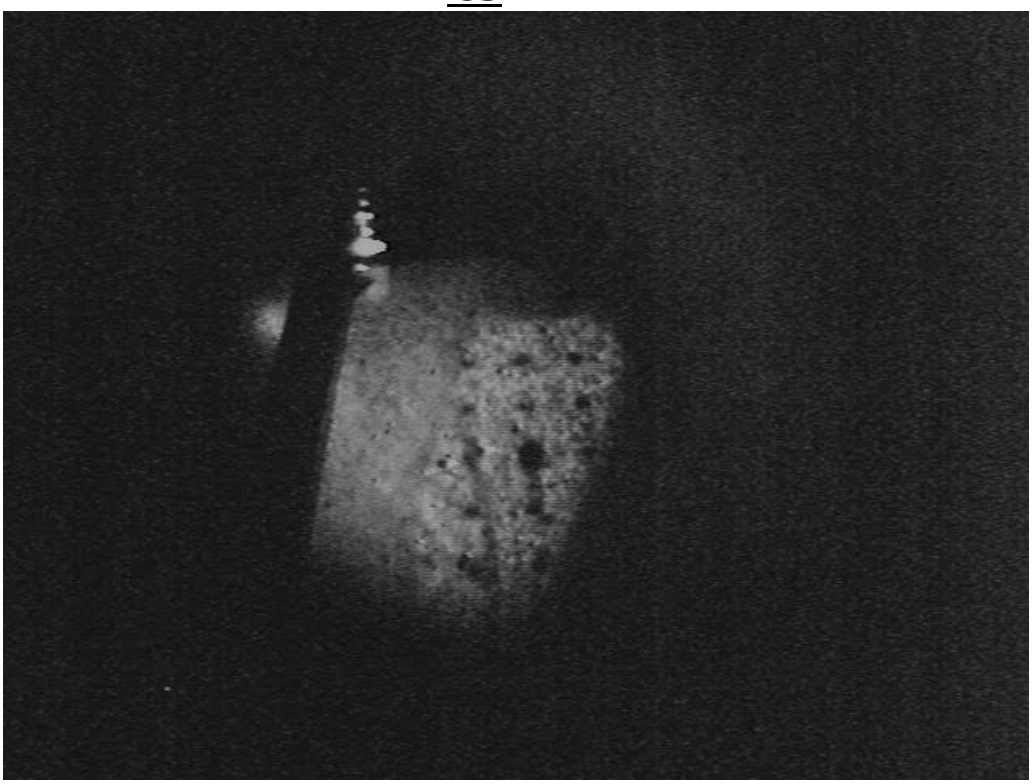


S2 outside the tank

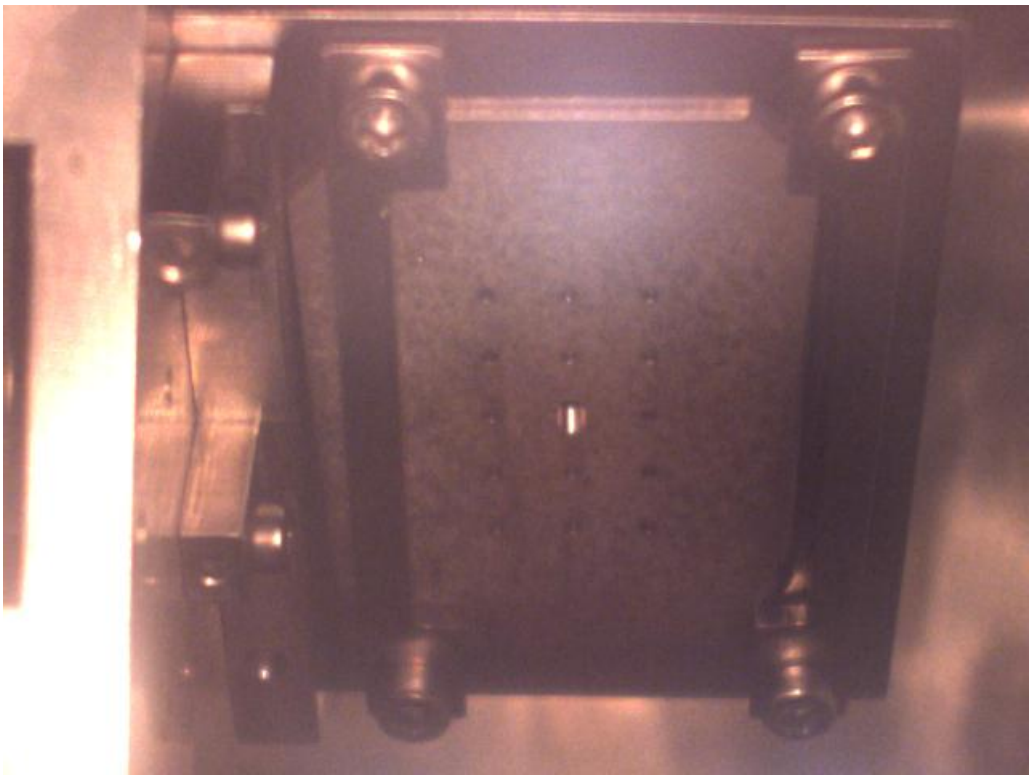


View of S2 after being fixed in position.

s3



S3 – Beam on S3 after passing through the wiggler.



S3 – Viewed from within the tank.

V. Pearson Coils Calibration Table

	Diameter [mm]	Position [mm]	V/I [V/A]	V_{out}/V_{in} [mV/0.5V]	I_{beam}/V_{scope} [mA/mV]	Dynamic range [A]
P1	53	3909	1	9.8	51	2
P2	53	5773	0.5	10.4	48	2
P3	53	7176	0.5	6.3	79	2
P4	53	7451	-----	5.2	98	0

VI. Quadrupoles (see report#13)

$$\left.\frac{dB}{drdI}\right|_{r=0} = 1.522[Gs/A-mm] = 0.1522[Tes/A-m]$$

Effective width: 140mm

Sign convention:

I_Q positive $\Rightarrow$ focusing in X & defocusing in Y.

Quad	Position
1	4420
2	4766
3	5099
4	5451
5	7654
6	7797
7	8354
8	8690

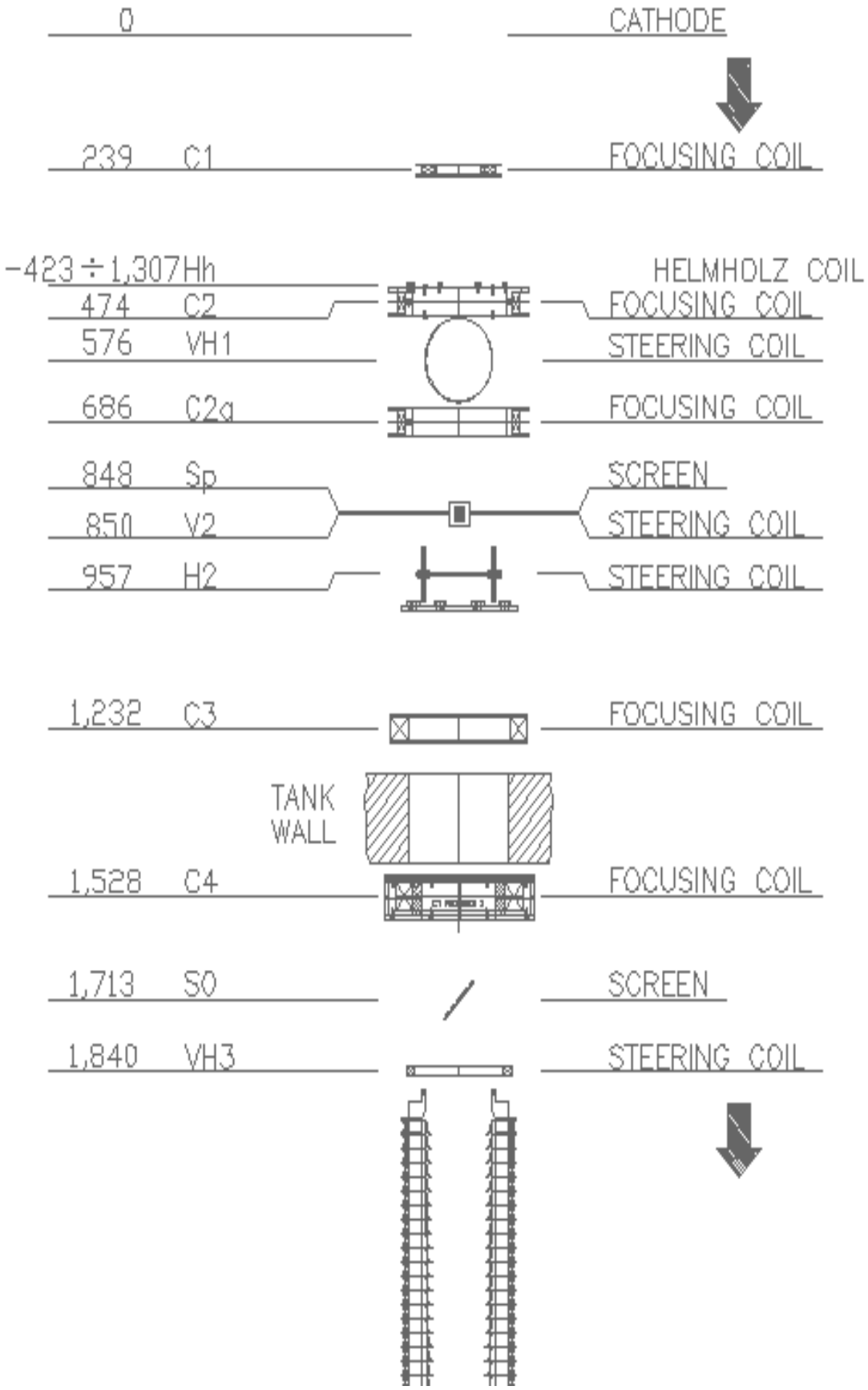
VII. LIST OF FEL ELCTTRON-OPTICS COMPONENTS. Oct. 2012

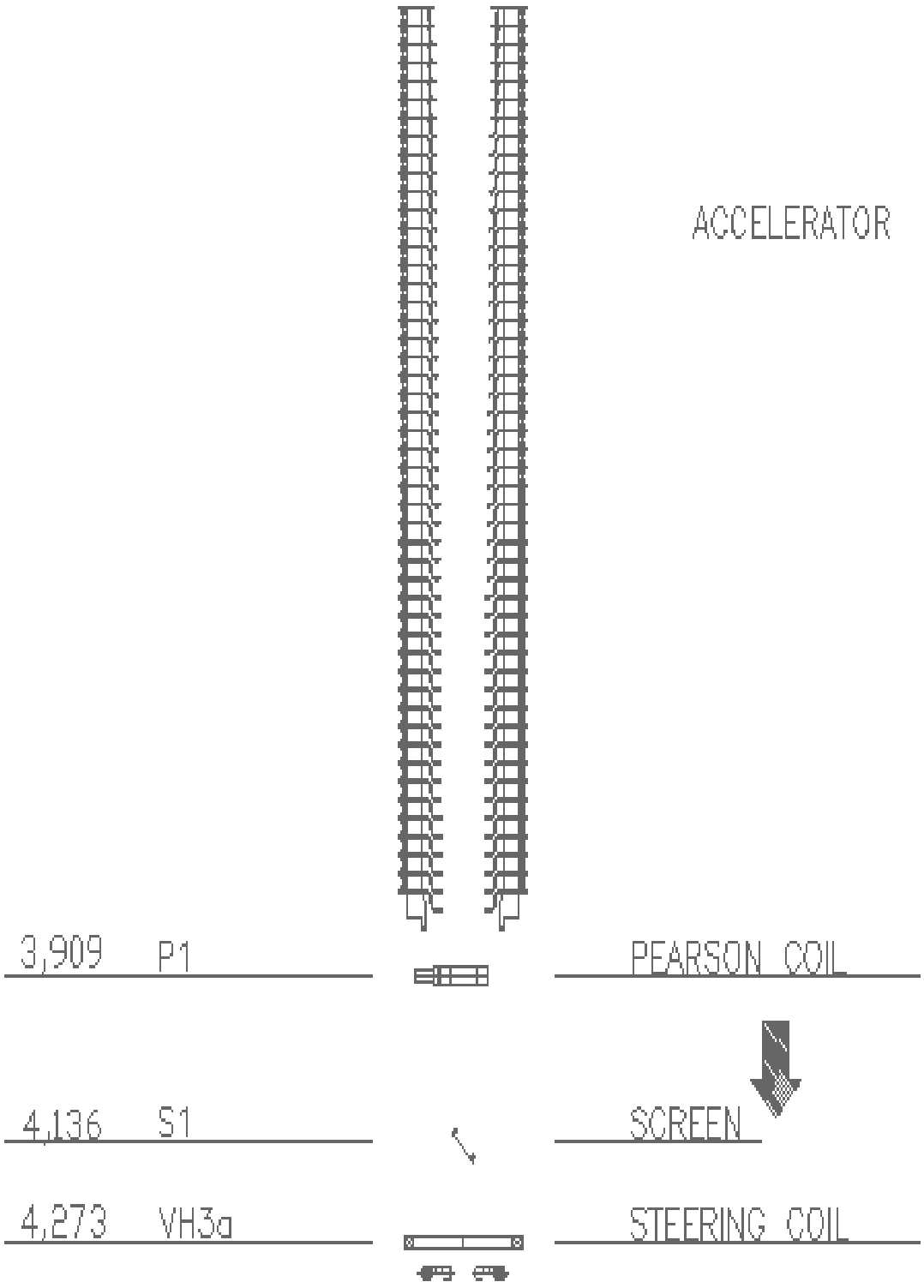
* Previous measurements

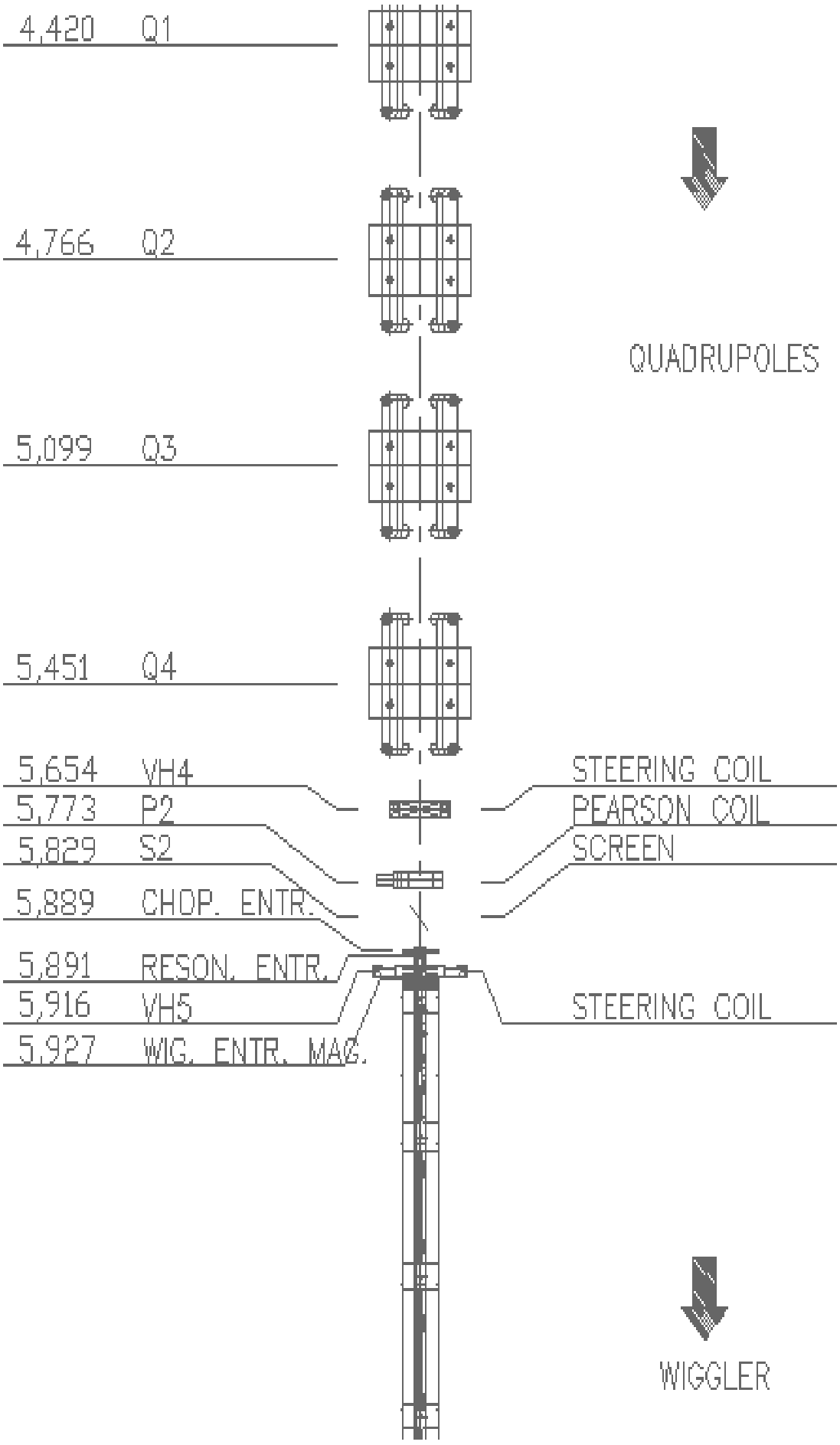
Z (mm) from Cathode	+/-(mm)	Component
-4,167	2	Target, Wall
-288		Back Flange, gun ceramics tube
0		Cathode
239	1	C_1 Focusing Coil
* -423÷1,307		Hh Helmholz Coil
474	1	C_2 Focusing Coil
576	1	VH_1 Steering Coil
686	2	C_2a Focusing Coil
848	1.5	S_P Screen, "Pepper Pot"
850	2	V_2 Steering Coil
957	2	H_2 Steering Coil
1,247	2	C_3 Focusing Coil
1,528	2	C_4 Focusing Coil
1,713	2	S_0 Screen
1,840	1.5	VH_3 Steering Coil
* 3,909		P_1 Pearson Coil
4,136	1.5	S_1 Screen
4,273	2	VH_3a Steering Coil
4,420	2	Q_1 Quadrupole
4,766	2	Q_2 Quadrupole
5,099	2	Q_3 Quadrupole
5,451	2	Q_4 Quadrupole
5,654	2	VH_4 Steering Coil
* 5,773		P_2 Pearson Coil
5,829	1.5	S_2 Screen
5,889	2	Chopper Entrance
5,891		Resonator Entrance
5,916	2	VH_5 Steering Coil
5,927	2	Wiggler Entrance, magnets
7,129	2	Wiggler Exit, magnets
7,132	2	VH_6 Steering Coil
7,216	2	Lower Confocal Mirror
7,374	2	S_3 Screen
* 7,451		P_4 Pearson Coil
7,491	3	VH_7 Steering Coil
7,654	2	Q_5 Quadrupole
7,797	2	Q_6 Quadrupole
8,354	2	Q_7 Quadrupole
8,690	2	Q_8 Quadrupole
8,917	2	VH7a Steering Coil
* 9,218		Decelerator Tube, gun side

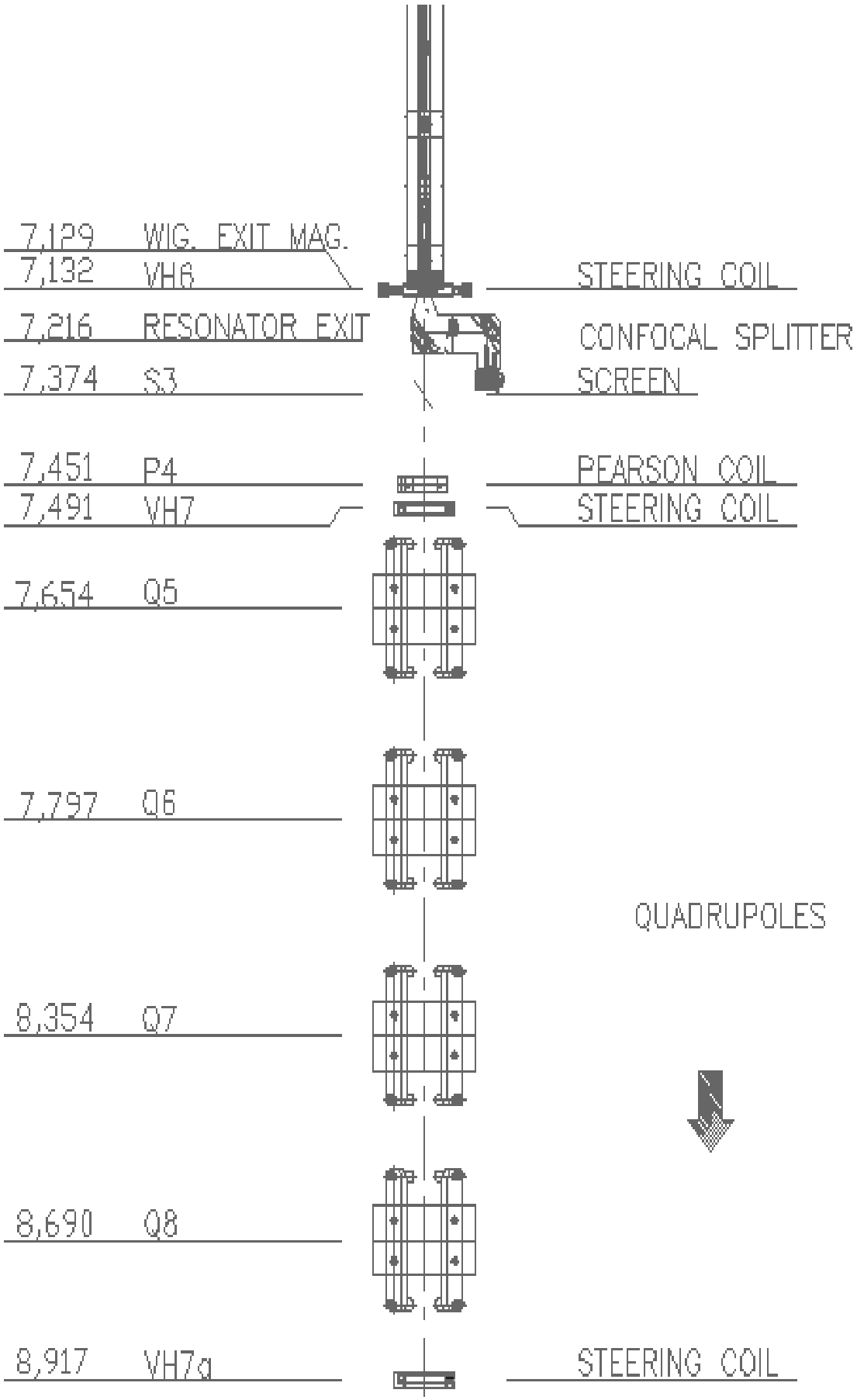
* 10,766		Collector Entrance
* 11,227		Decelerator Tube, collector side
11,600	3	C_6 Focusing Coil
11,685	3	VH_8 Steering Coil
11,960	3	C_7 Focusing Coil
* 12,448		C_8 Focusing Coil
13,483		Collector End
13,483	2	C_{col} Pearson Coil
16,683		Alignment Telescope

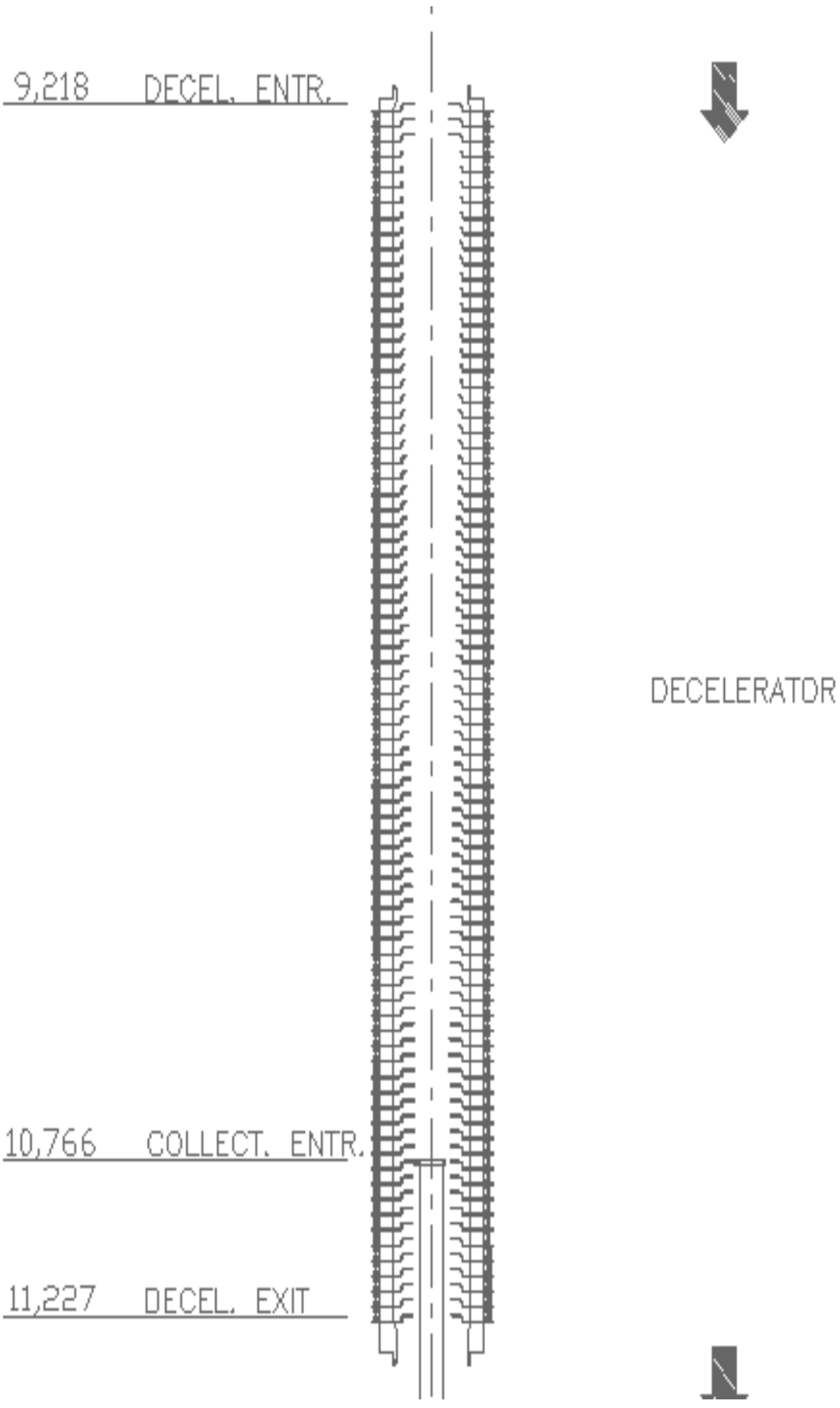
ELECTRON-OPTICS COMPONENTS DIAGRAM

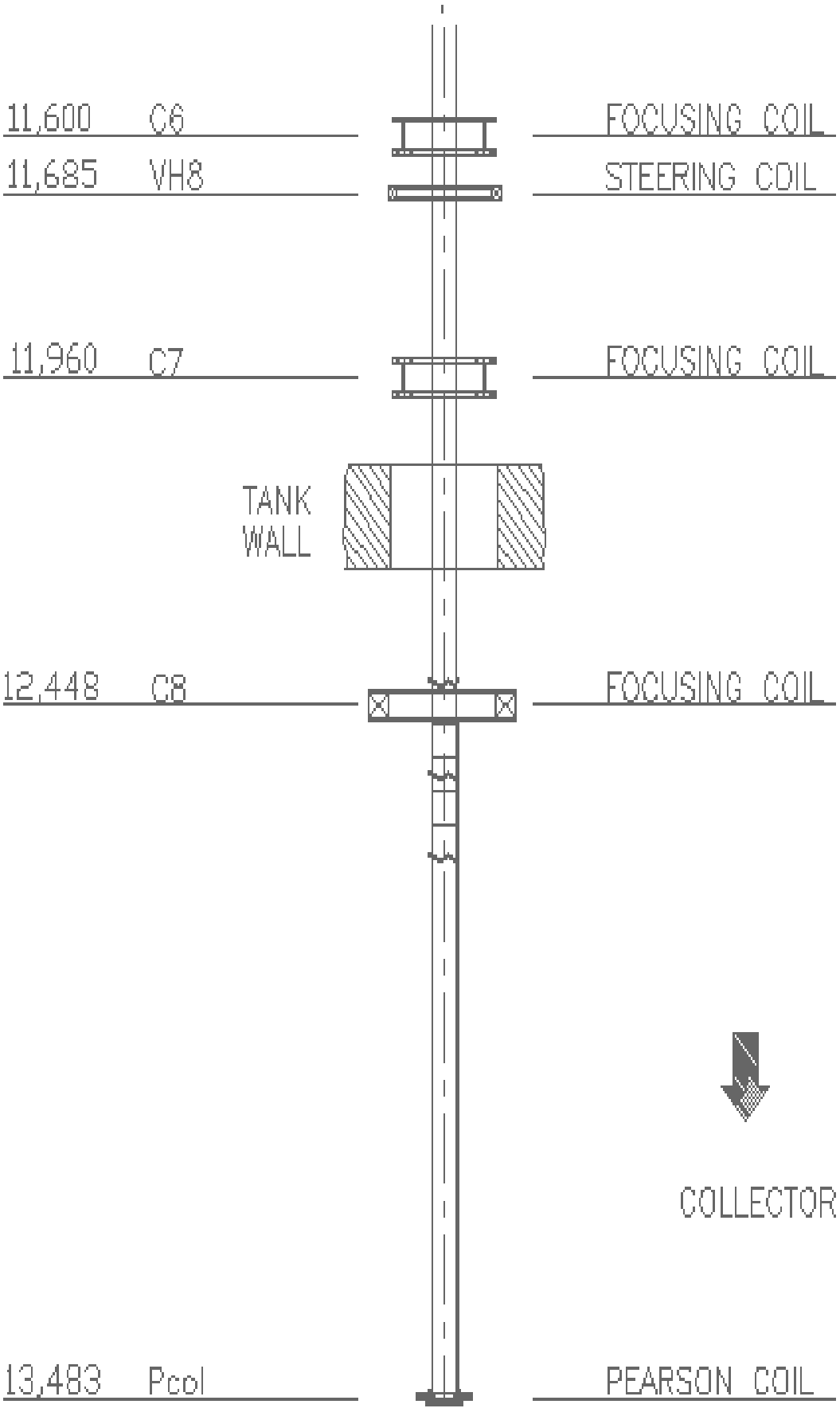



ACCELERATOR
3,909 P1
PEARSON COIL
4,136 S1
SCREEN
4,273 VH3a
STEERING COIL


4,420 Q1
4,766 Q2
QUADRUPOLES
5,099 Q3
5,451 Q4
5,654 VH4
5,773 P2
5,829 S2
5,889 CHOP. ENTR.
5,891 RESON. ENTR.
5,916 VH5
5,927 WIG. ENTR. MAG.
STEERING COIL
PEARSON COIL
SCREEN
STEERING COIL
WIGGLER


7,129 WIG. EXIT MAG.
7,132 VH6
STEERING COIL
7,216 RESONATOR EXIT
CONFOCAL SPLITTER
7,374 S3
SCREEN
7,451 P4
PEARSON COIL
7,491 VH7
STEERING COIL
7,654 Q5
7,797 Q6
QUADRUPOLES
8,354 Q7
8,690 Q8
8,917 VH7g
STEERING COIL


9,218 DECEL. ENTR.
DECELERATOR
10,766 COLLECT. ENTR.
11,227 DECEL. EXIT


11,600 C6
FOCUSING COIL
11,685 VH8
STEERING COIL
11,960 C7
FOCUSING COIL
TANK
WALL
12,448 C8
FOCUSING COIL
COLLECTOR
13,483 Pcol
PEARSON COIL

Appendix A

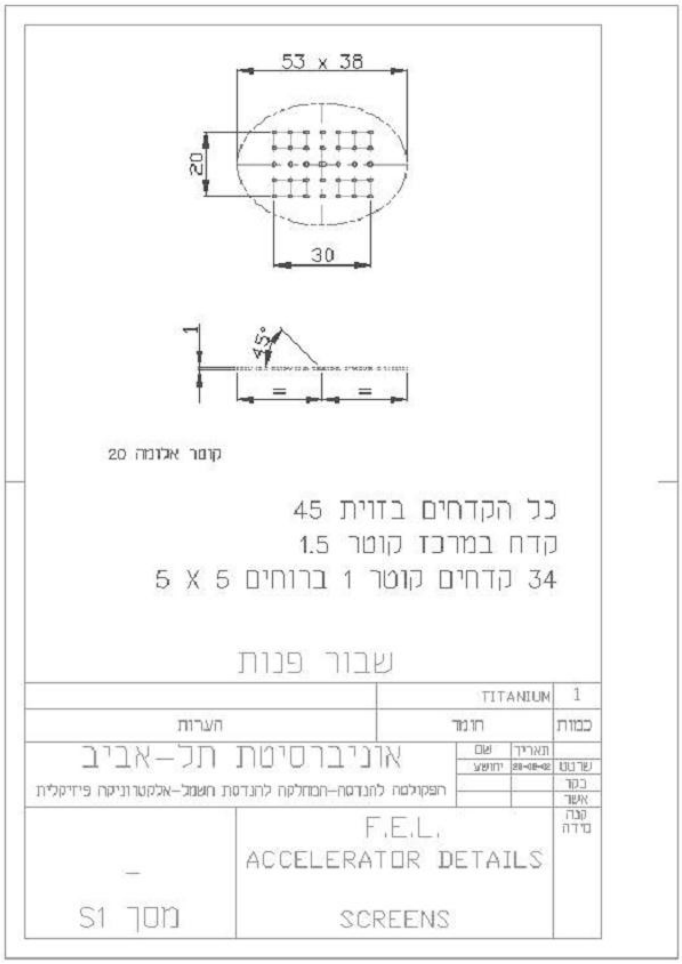
Standard Injector currents :

C1 [A]	7.16
C2 [A]	3.2
C3 [A]	3.6
C4 [A]	0.1
V1 [A]	1.3
H1[A]	3
V2 [A]	0.26
H2[A]	-1.1
V3 [A]	0.8
H3 [A]	0.5

בס"ד

בדיקה ותיעוד של המסכים הפלורוסנטיים
נובמבר 2012 – יורם לסר

מסך s1

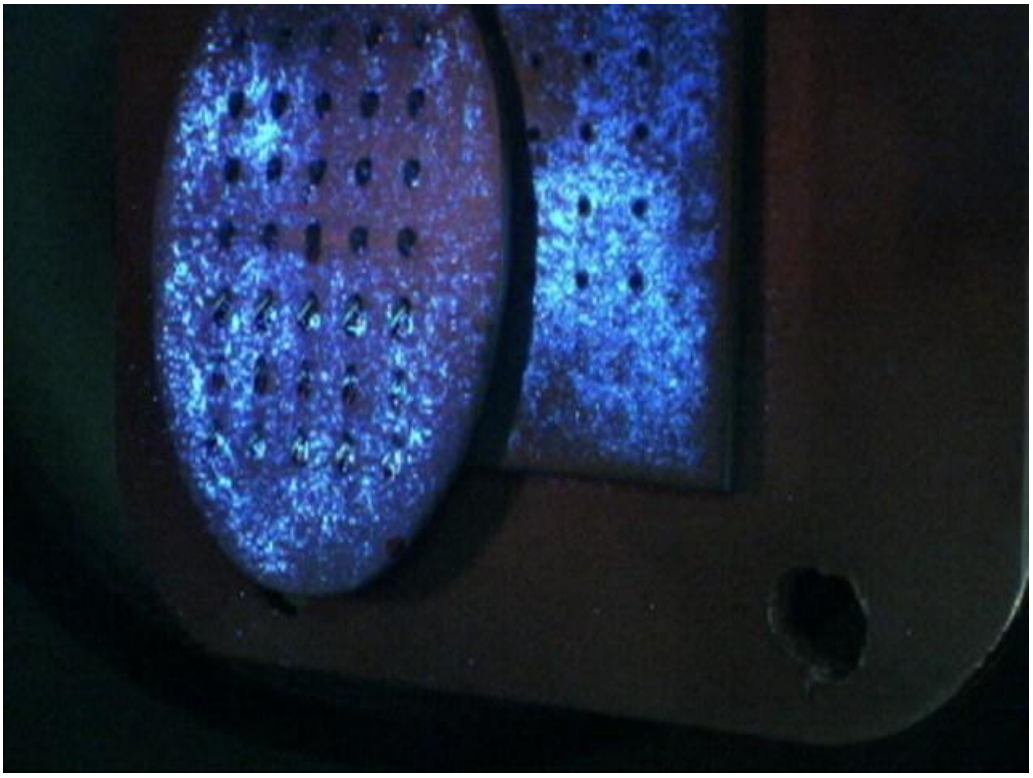


איור 1 שרטוט s1

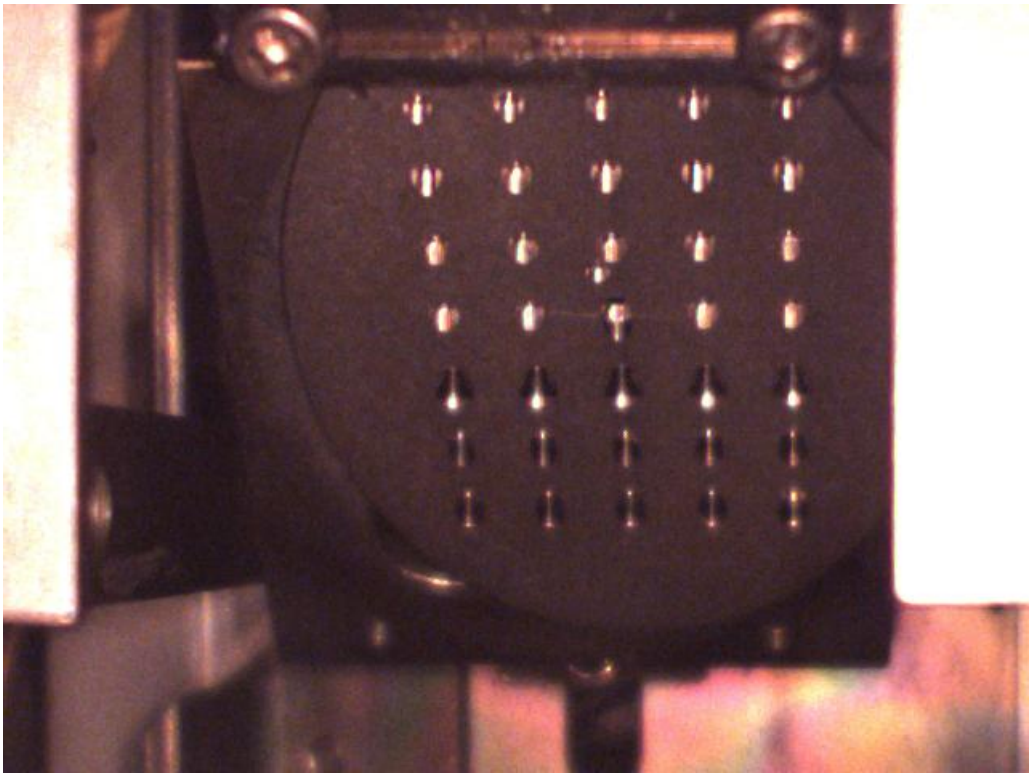
הותקן מסך טיטניום שיוצר ב-NEC וחורר בבית המלאכה באריאל. המסך נבדק בעמדת sp ונמצא תקין.
כמו כן נמדדו המרחקים בין החורים ומצאו תואמים לשרטוטים :
קוטר החור המרכזי 1.5±0.1 מ"מ
קוטר החורים הקטנים 1.0±0.1 מ"מ
מרחק בין כל זוג חורים אנכי (ציר Y) 5±0.2 מ"מ
מרחק בין כל זוג חורים אופקי (ציר X) 5±0.2 מ"מ
זווית כל הקדחים $45^{\circ}\pm2^{\circ}$
כל המדידות נעשו בצד האחורי של המסך בגלל שבצד הקדמי (כפי שניתן לראות בתמונה) ישנו קדח מוביל קצת יותר גדול.

איור 2 מסך s1 (צד קדמי) לפני התקנה, ה"ביס" בצד ימי נצרך כדי למרכז את המסך.

איור 3 מסך s1 (צד קדמי) לפני התקנה, ה"ביס" בצד ימי נצרך כדי למרכז את המסך.



איור 4 מדידת הארה של המסך ב-sp המסך הימני הוא sp והשמאלי הוא המסך שנבדק



איור 5 s1 מבט מהמצלמה אחרי קיבוע

מסך s2

איור 6 שרטוט מכאני s2 ו-s3

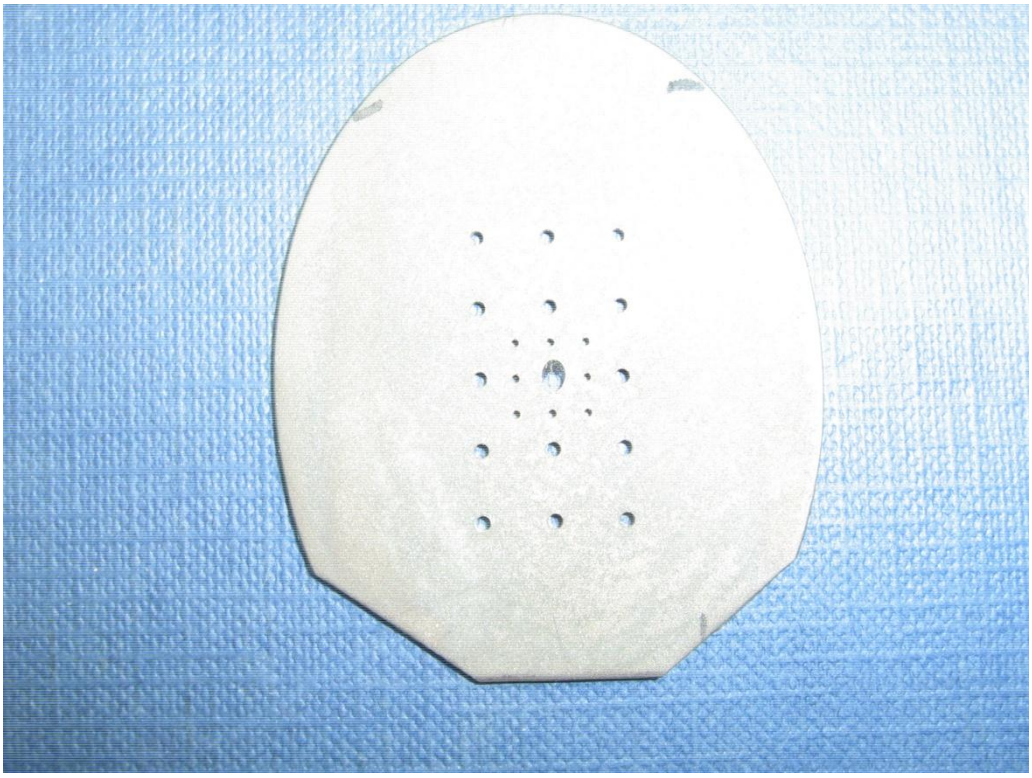
הותקן מסך טיטניום שיוצר ב-NEC וחורר בבית המלאכה במכון וויצמן לפני מס' שנים . המסך נבדק בעמדת sp ונמצא תקין.

כמו כן נמדדו המרחקים בין החורים ומצאו תואמים לשרטוטים :

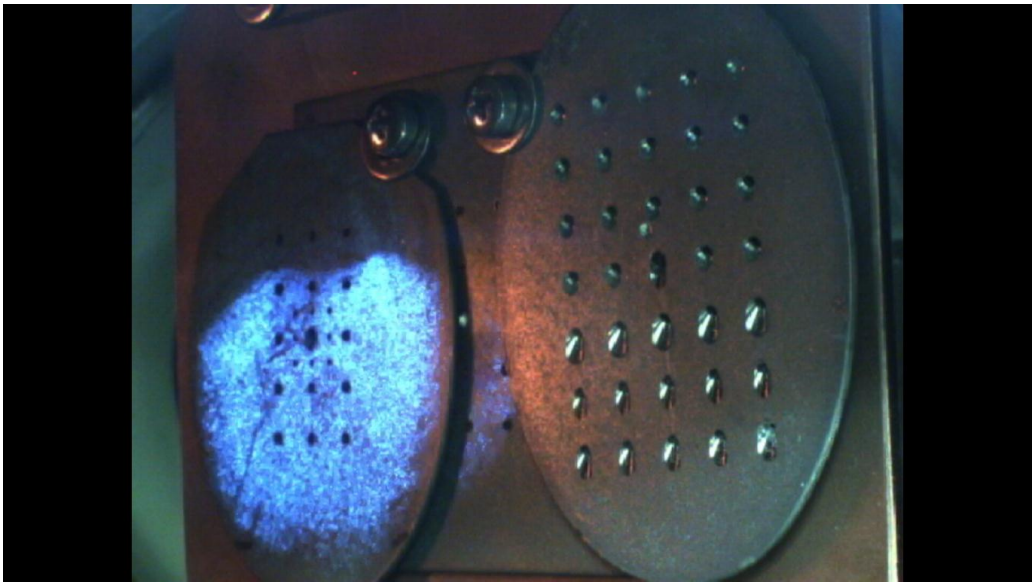
מרחק בין כל זוג חורים (הגדולים) אנכי (ציר Y) 5±0.2 מ"מ

מרחק בין כל זוג חורים (הגדולים) אופקי (ציר X) 5±0.2 מ"מ

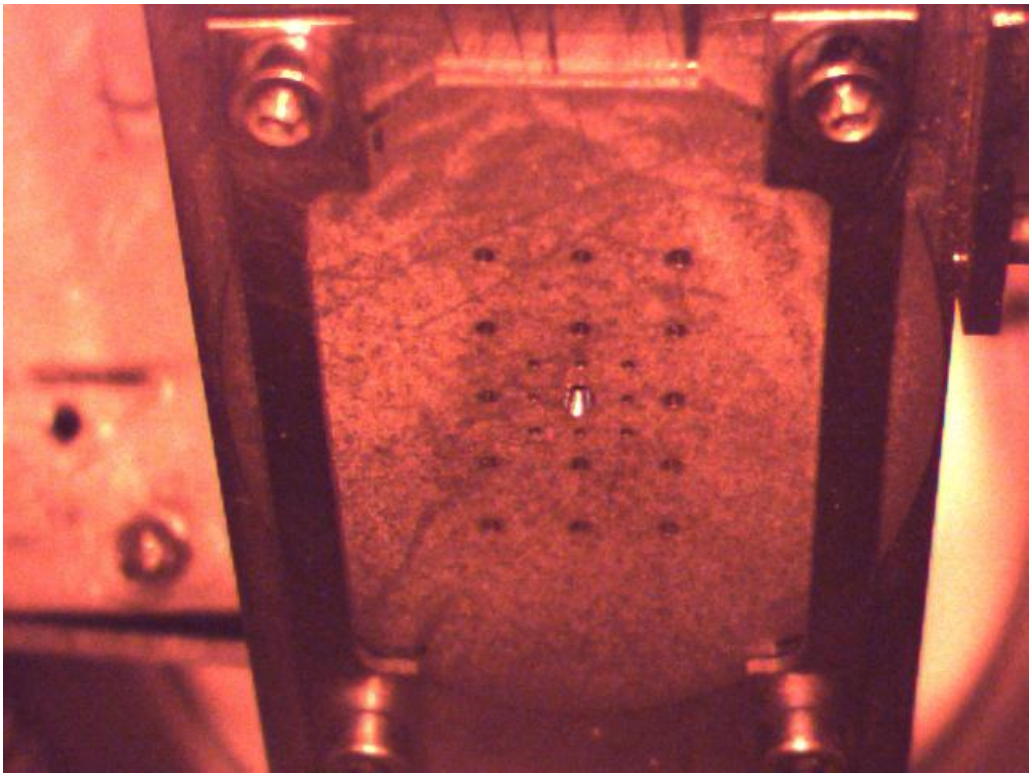
קוטר החור המרכזי 1.5±0.1 מ"מ ובזווית של $45^{\circ}\pm2^{\circ}$



איור 7 מסך S2 (צד קדמי) לפני התקנה



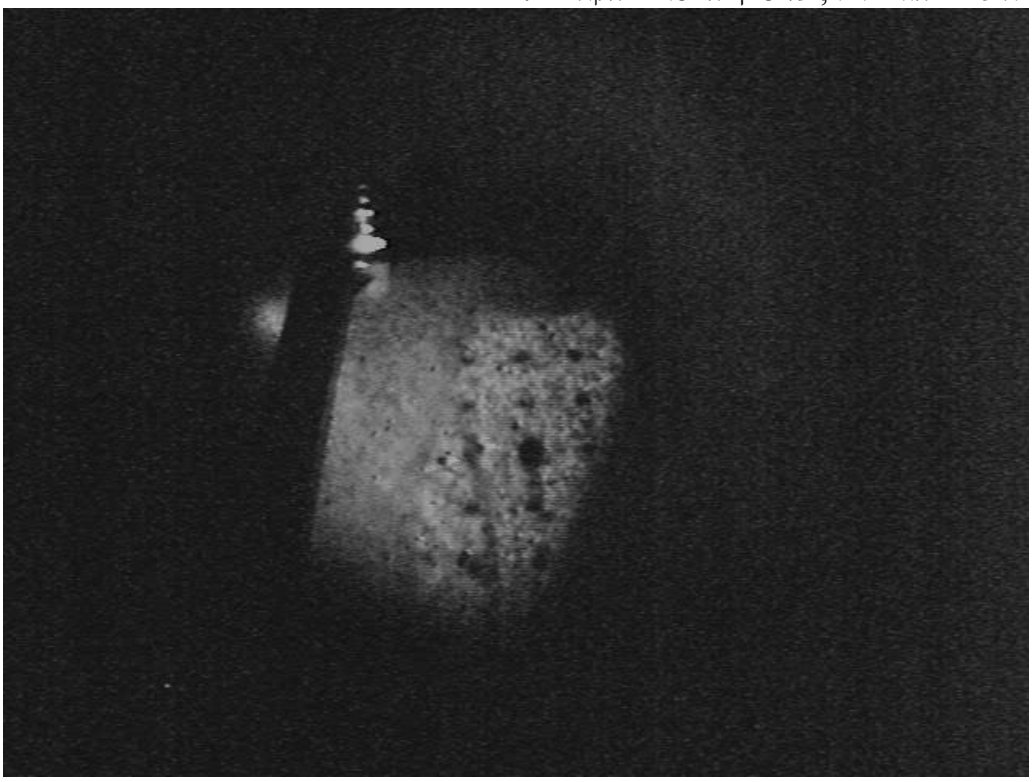
איור 8 מדידת הארה של מסך s2 ב-sp



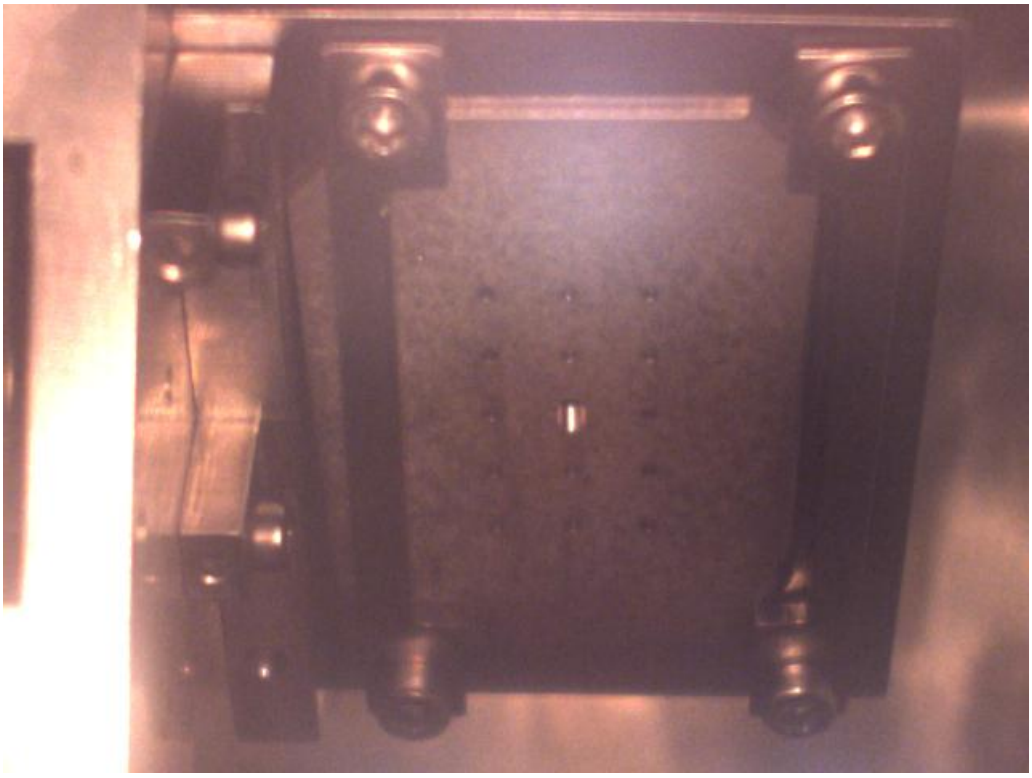
איור 9 s2 מבט מהמצלמה אחרי קיבוע

מסך s2

מסך טיטניום תוצרת חברת NEC שהיה מותקן במערכת ולכן לא הוצא ונבדק כמו הקודמים, אבל אנחנו יודעים שהוא מאיר, על סמך הניסויים הקודמים.



איור 10 פגיעת האלומה ב-s3 תמונה מניסוי מחודש מרץ 2012 (איכות התמונה בגלל המצלמה המיושנת בה השתמשנו)



איור 11 s3 מבט מהמצלמה אחרי קיבוע