3D Simulation Studies of Irradiated BNL One-Sided Dual-column 3D Silicon Detector up to 1x10^{16} n_{eq}/cm^2

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Work based on the period 2/15/-4/15/07
at Brookhaven National Laboratory

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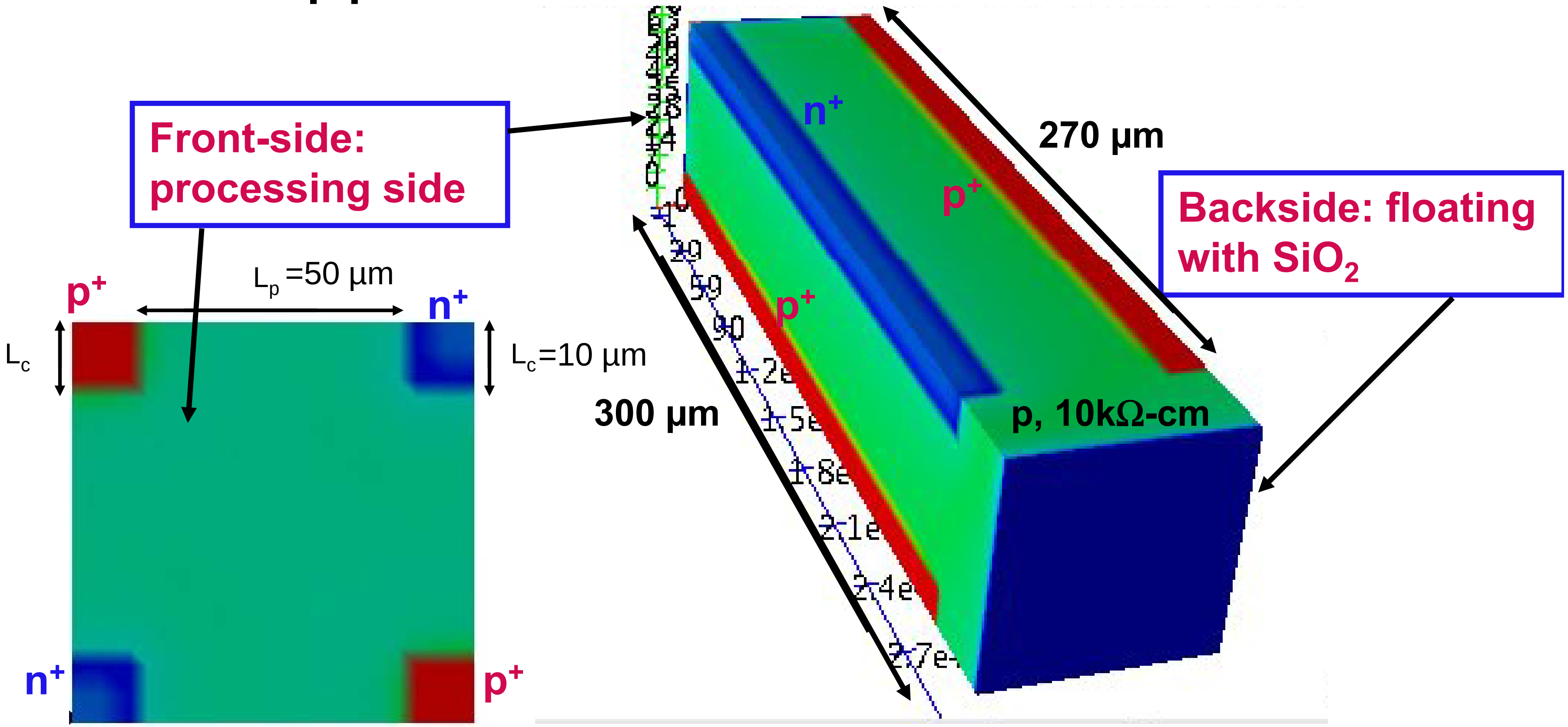
OUTLINE

- **Simulated detector structure**
- **Simulation tools**
- **Simulated full depletion voltage up to $1x10^{16}$ n_{eq}/cm^2**
- **3D profiles of hole concentration and E-field up to $1x10^{16}$ n_{eq}/cm^2**
- **Various other geometries**
- **Summary**

Detector Structure

- BNL's one-sided, dual column 3D detector
- There are two n-type (blue) and two p-type (red) doped columns on p-type substrate
- Same type of doped columns are placed to the opposite corners

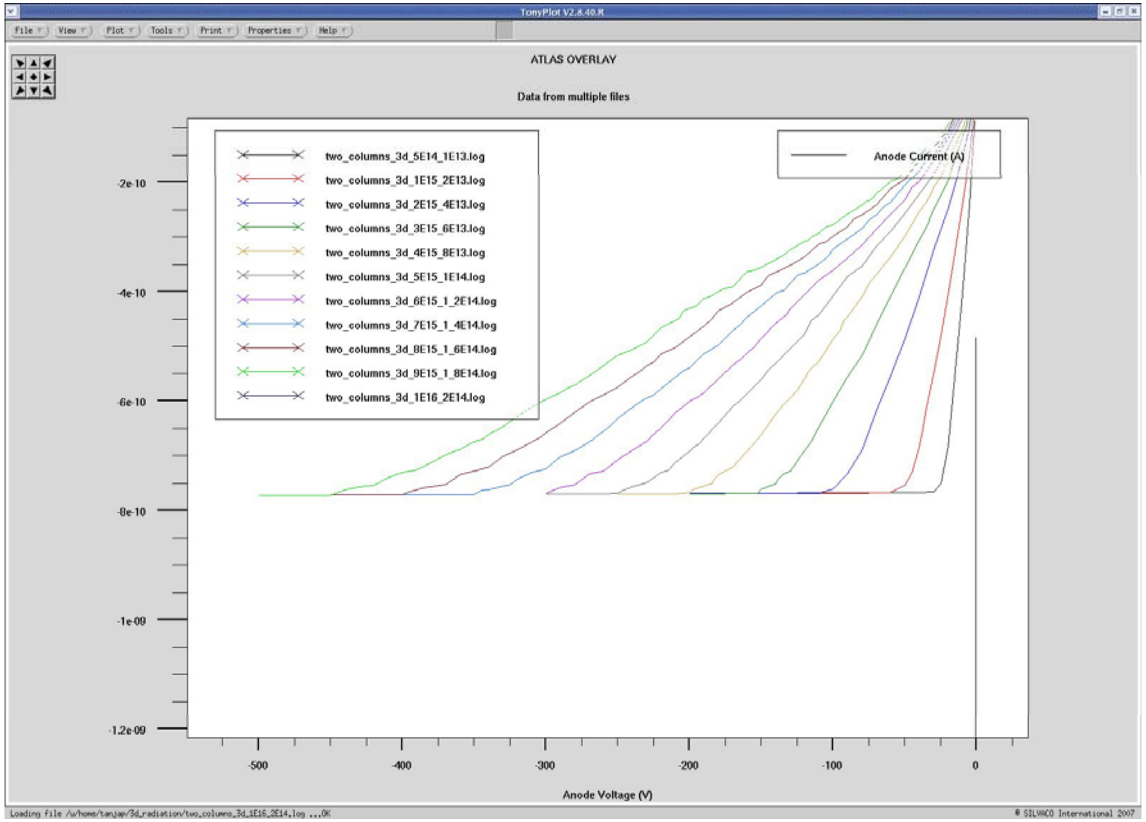


Simulation

- Silvaco DEVEDIT3D, DEVICE3D (ATLAS)
- The detector structure was simulated with different fluencies (N_{eff})
- Oxide charge of $4x10^{11}$ /cm^2 is implemented
- 3D hole and E-field profiles are simulated

Simulated V_{fd} values in dual column 3D detectors with different fluencies

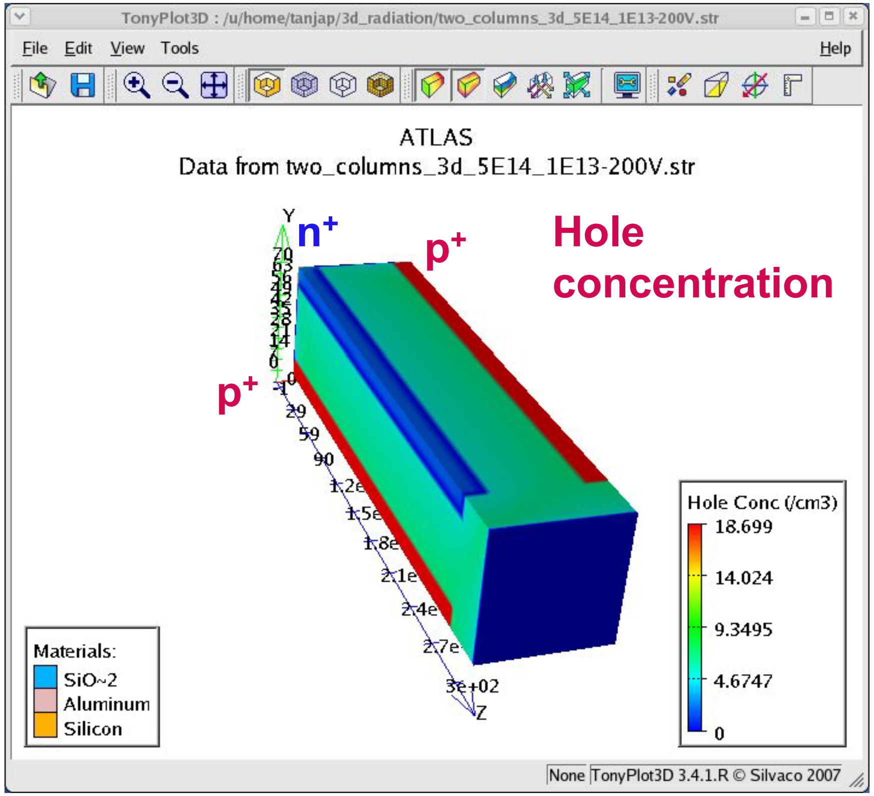
	2d pad detector	*Dual columns 3d detectors*
fluency	**Calculated V_{fd} (d=50um)**	**Simulated V_{fd}**
5.00E+14	**19**	**30**
1.00E+15	**38**	**60**
2.00E+15	**76**	**110**
3.00E+15	**114**	**160**
4.00E+15	**152**	**210**
5.00E+15	**190**	**250**
6.00E+15	**228**	**300**
7.00E+15	**266**	**350**
8.00E+15	**304**	**400**
9.00E+15	**342**	**450**
1.00E+16	**380**	**500**

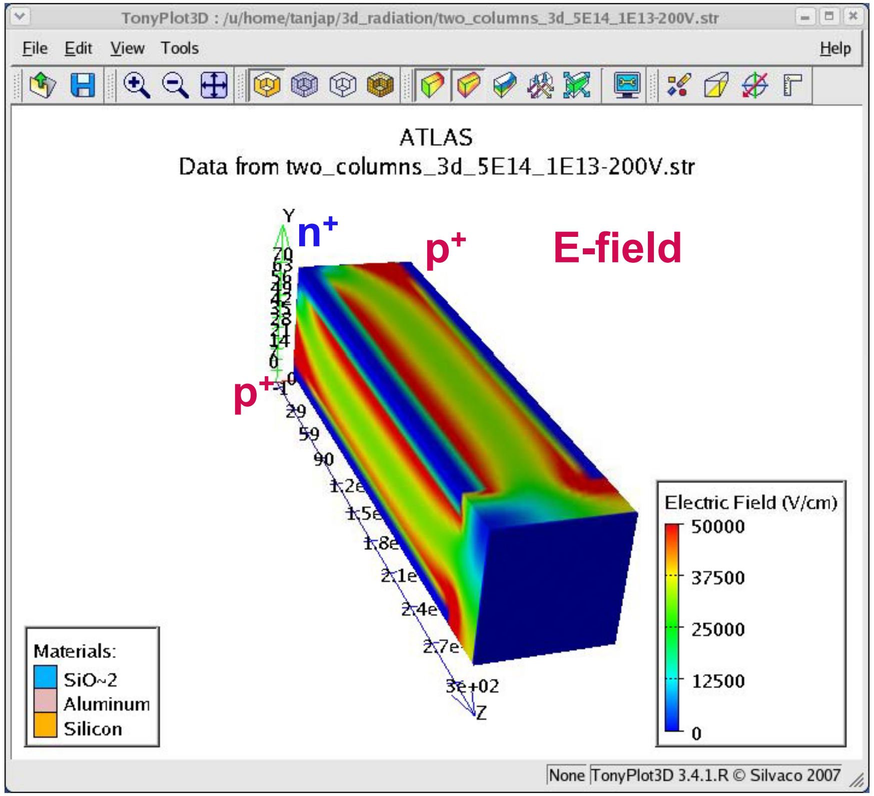


V_{fd} 3D is 1.4 times higher: Small electrodes

Current vs. V (no lifetime degradation entered)

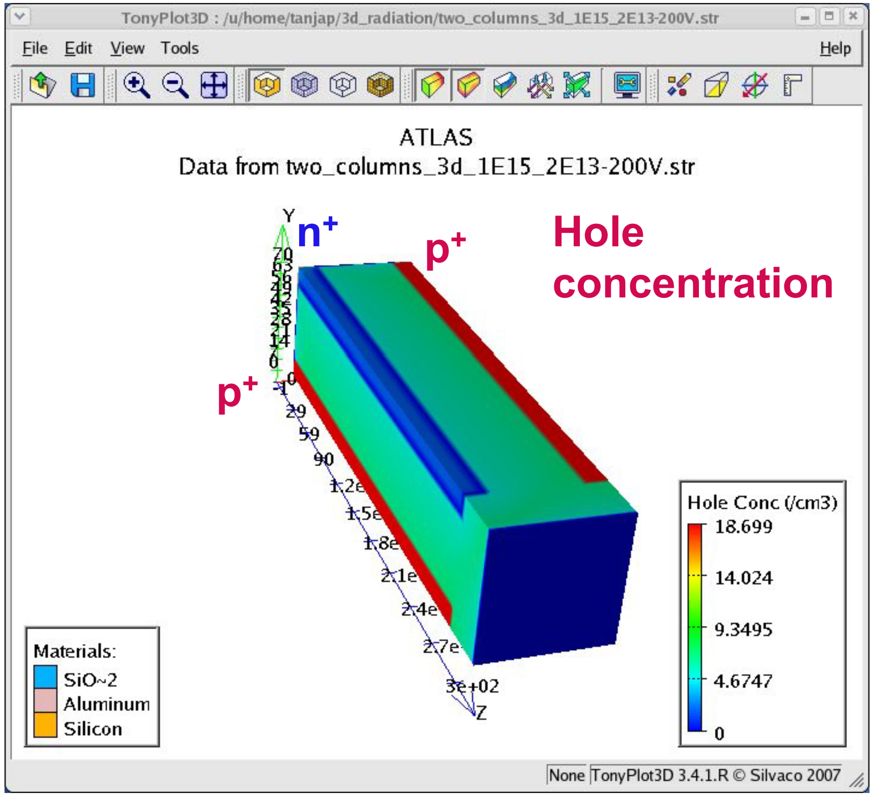
$5x10^{14}\ n_{eq}/cm^2$

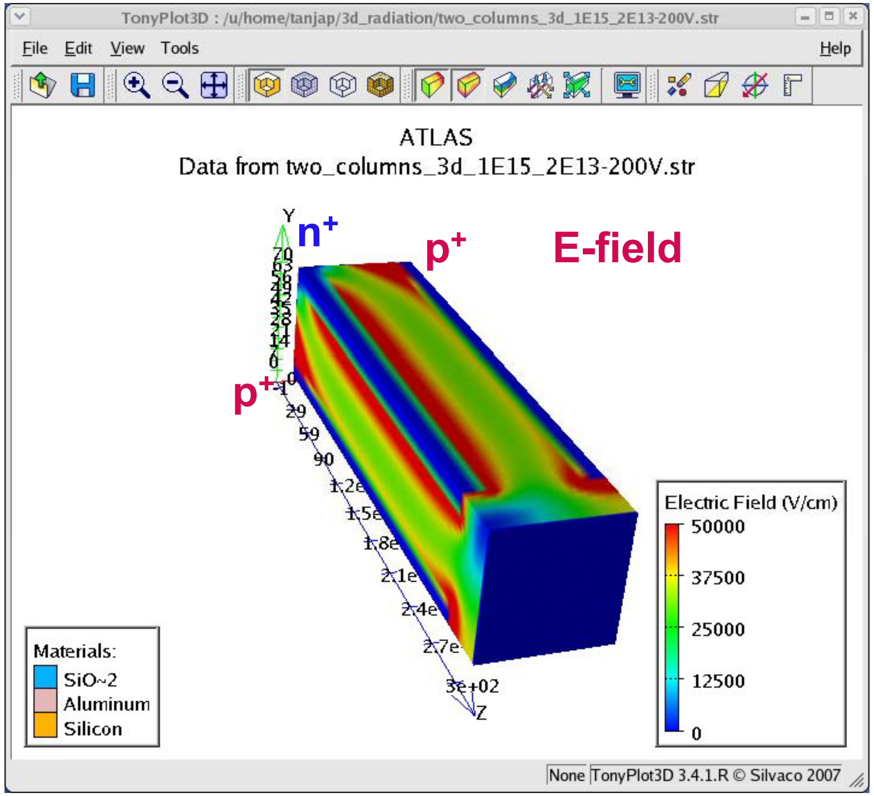




- 200V, hole conc., electric field

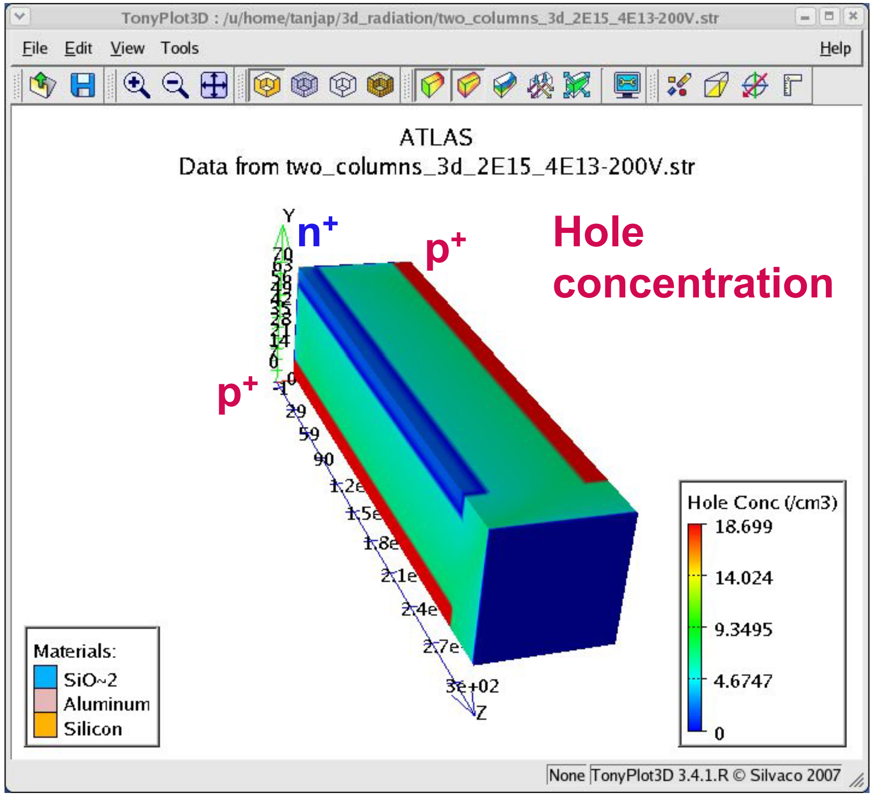
1×10^{15} n_{eq}/cm^2

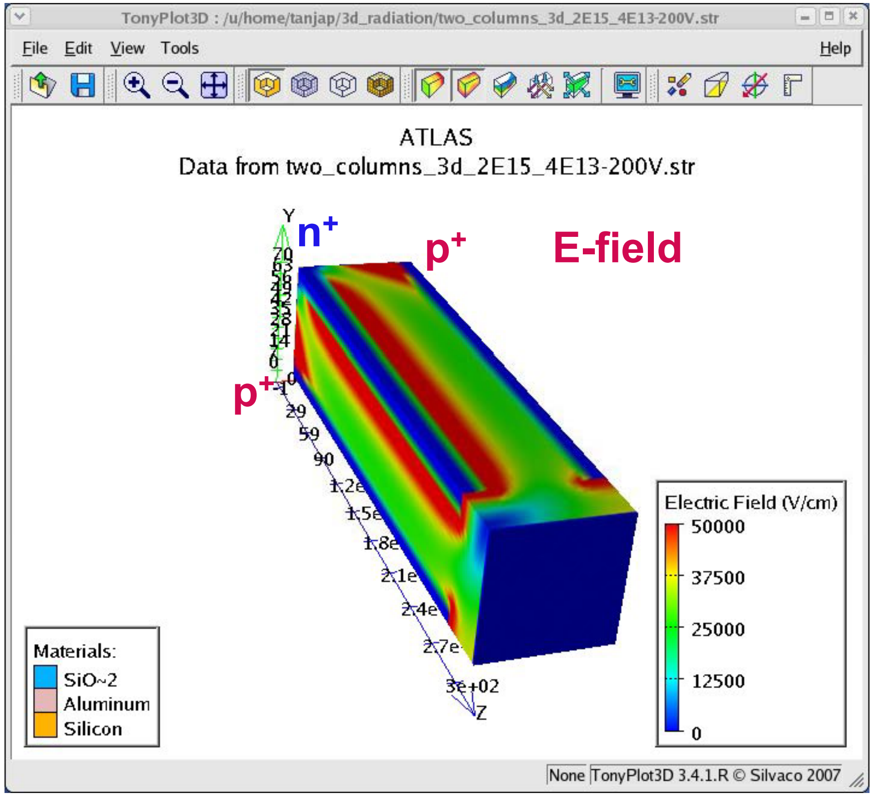




- 200V, hole conc., electric field

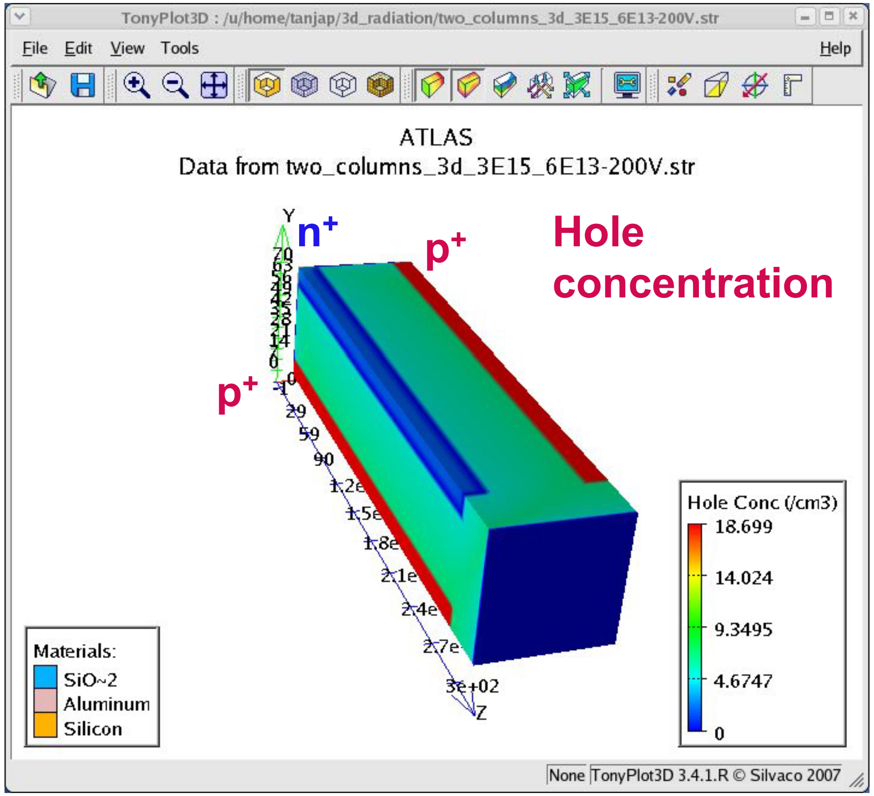
$2x10^{15}$ n_{eq}/cm^2

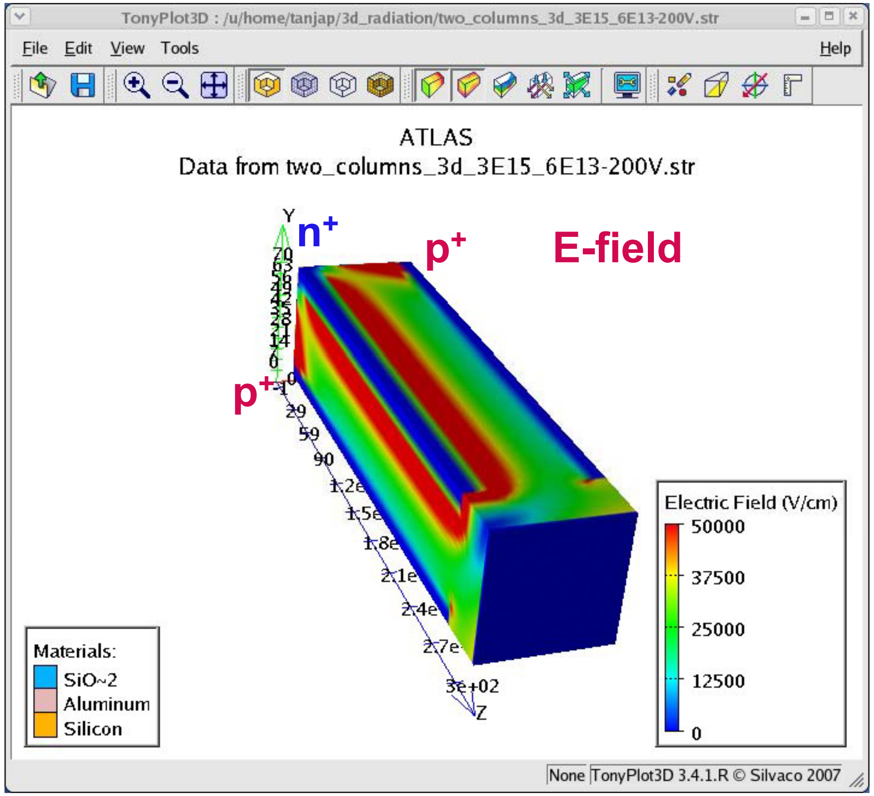




- 200V, hole conc., electric field

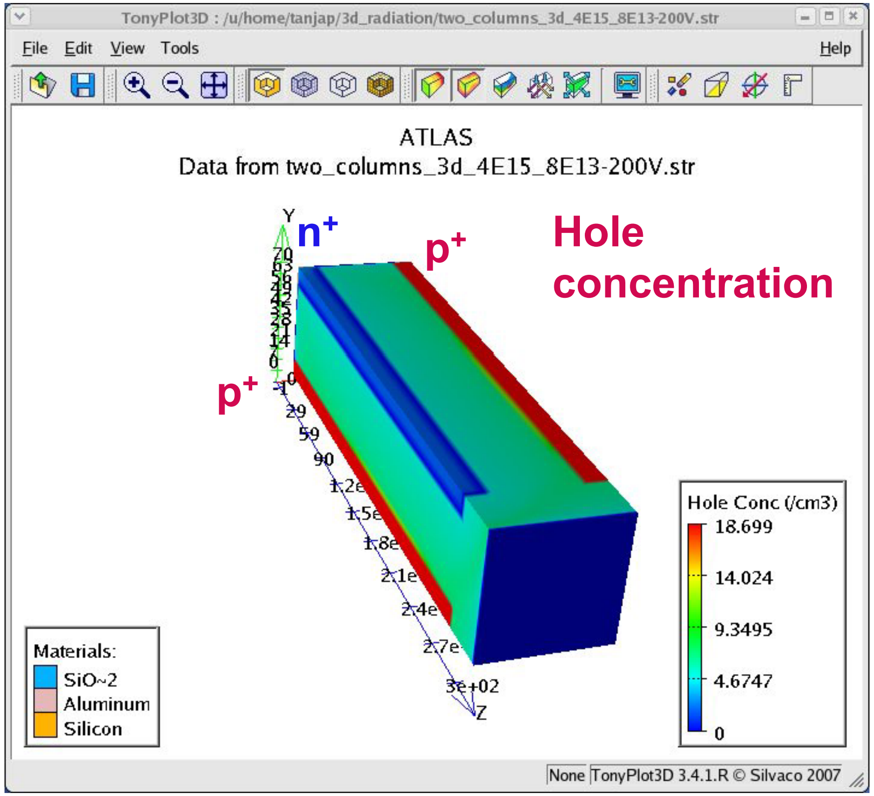
$3\text{x}10^{15}\ n_{eq}/cm^2$

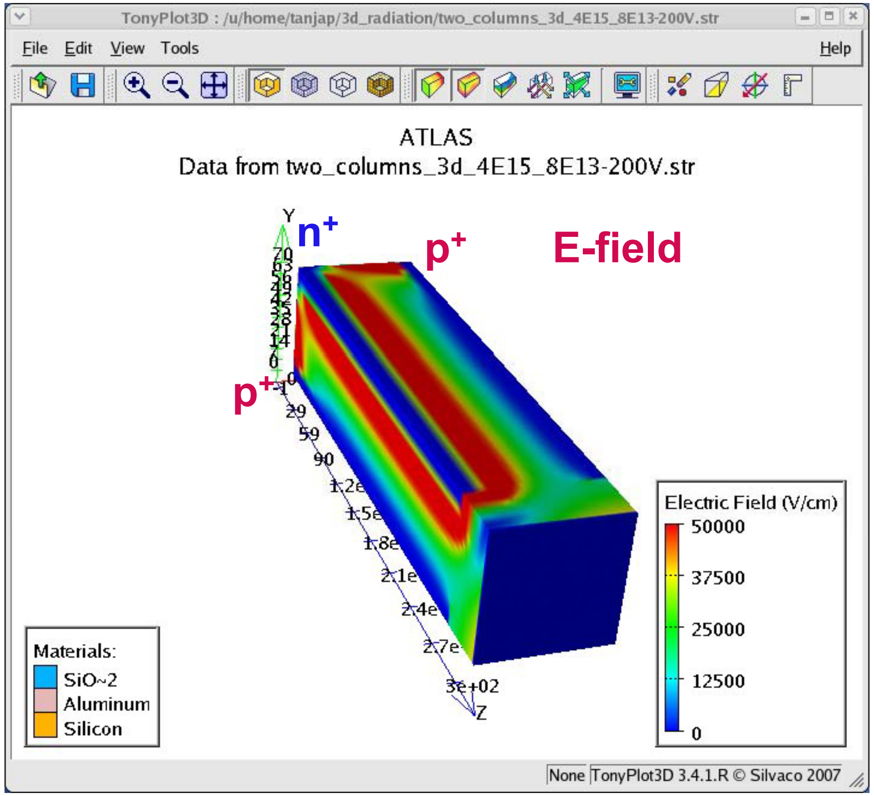




- 200V, hole conc., electric field

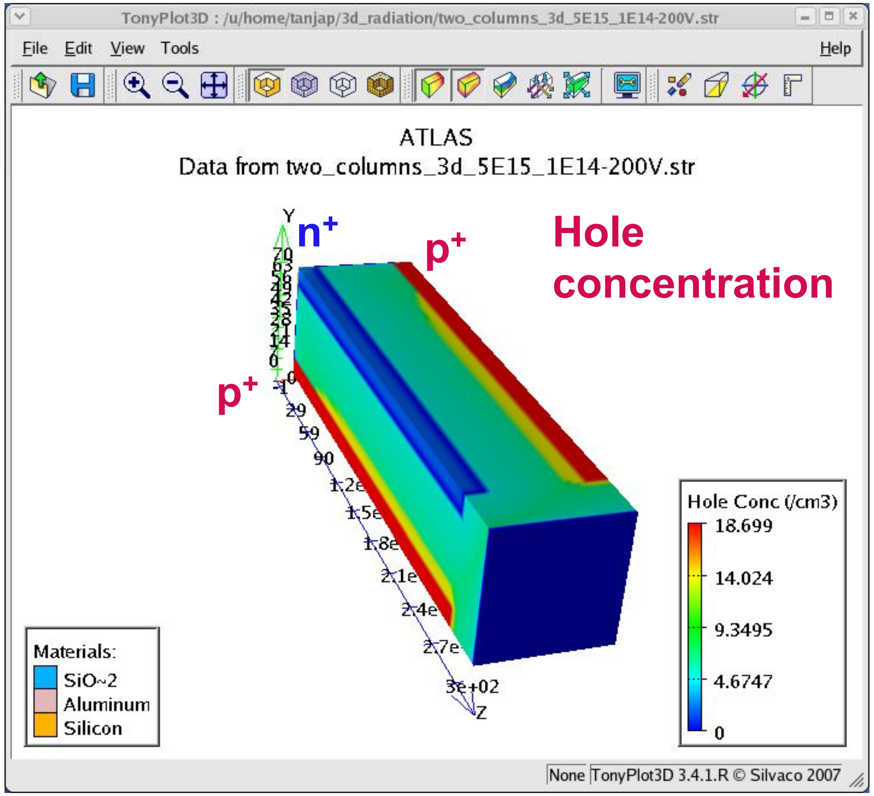
$4x10^{15}$ n_{eq}/cm^2

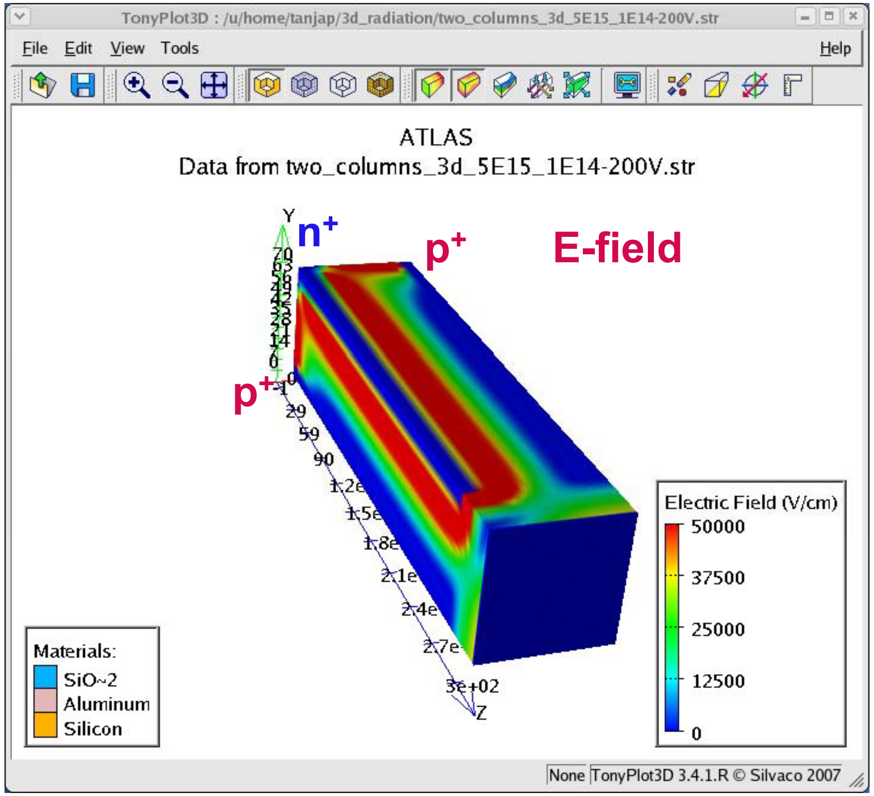




- 200V, hole conc., electric field

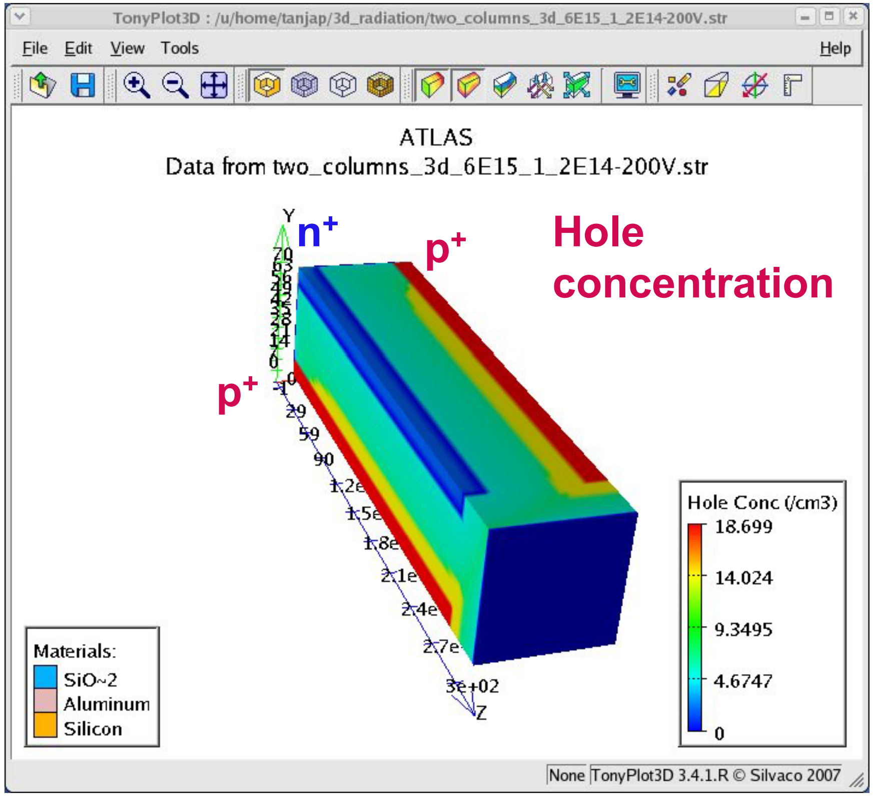
$5x10^{15}$ n_{eq}/cm^2

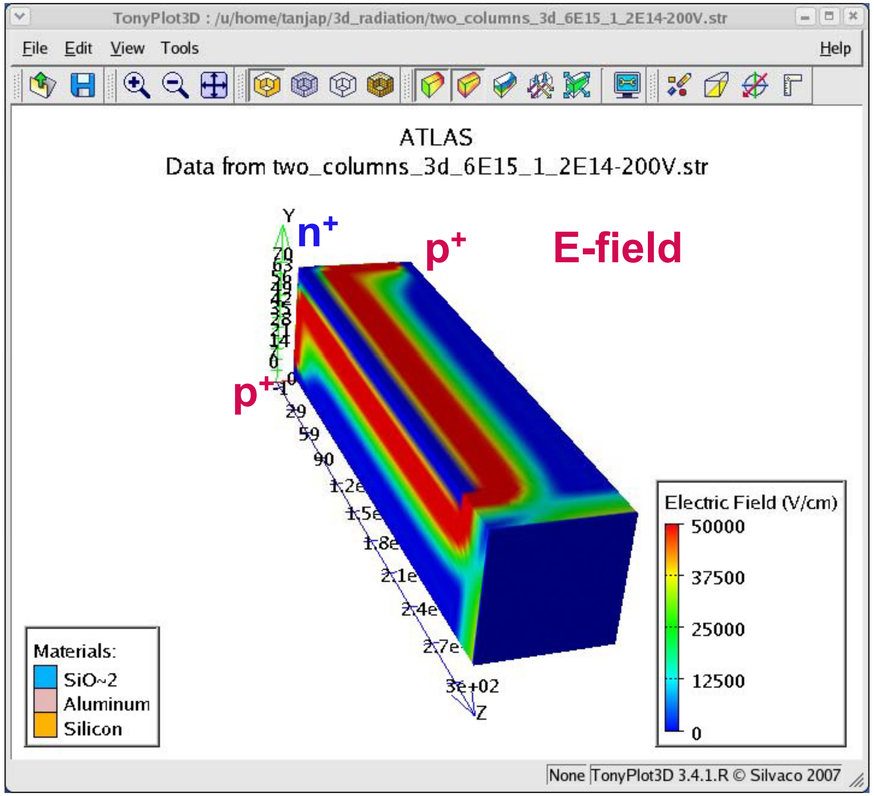




- 200V, hole conc., electric field

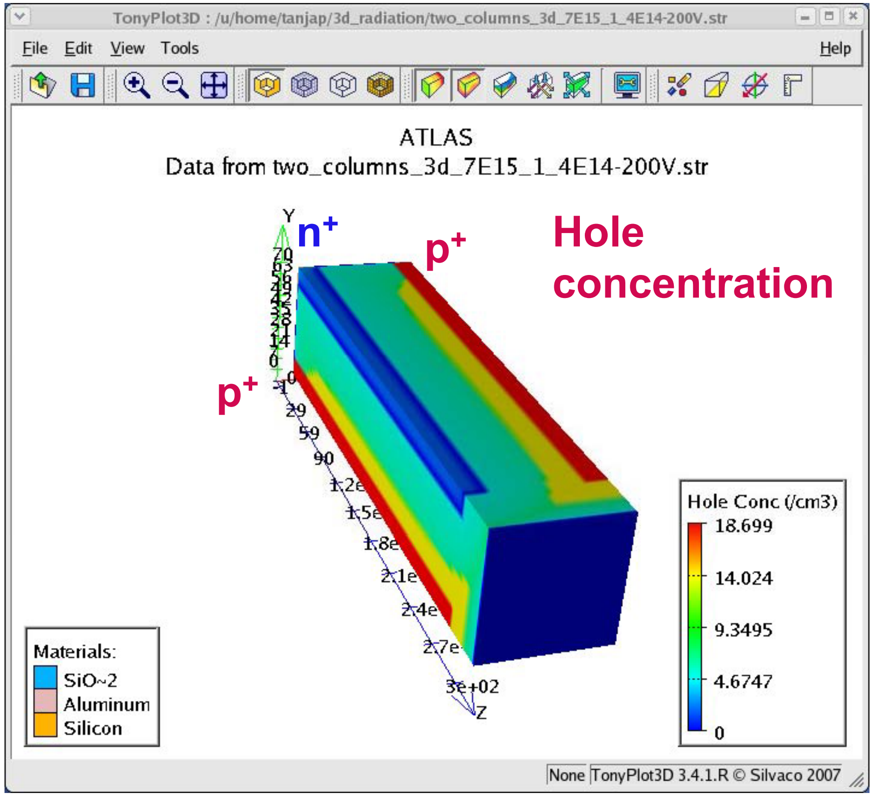
$6x10^{15}\ n_{eq}/cm^2$

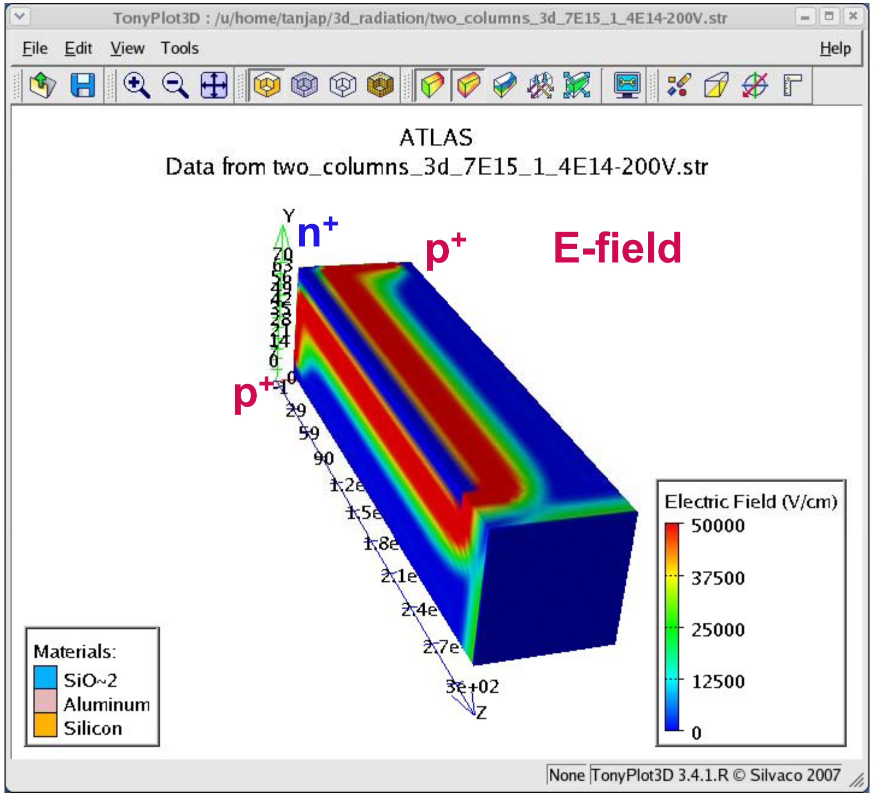




- 200V, hole conc., electric field

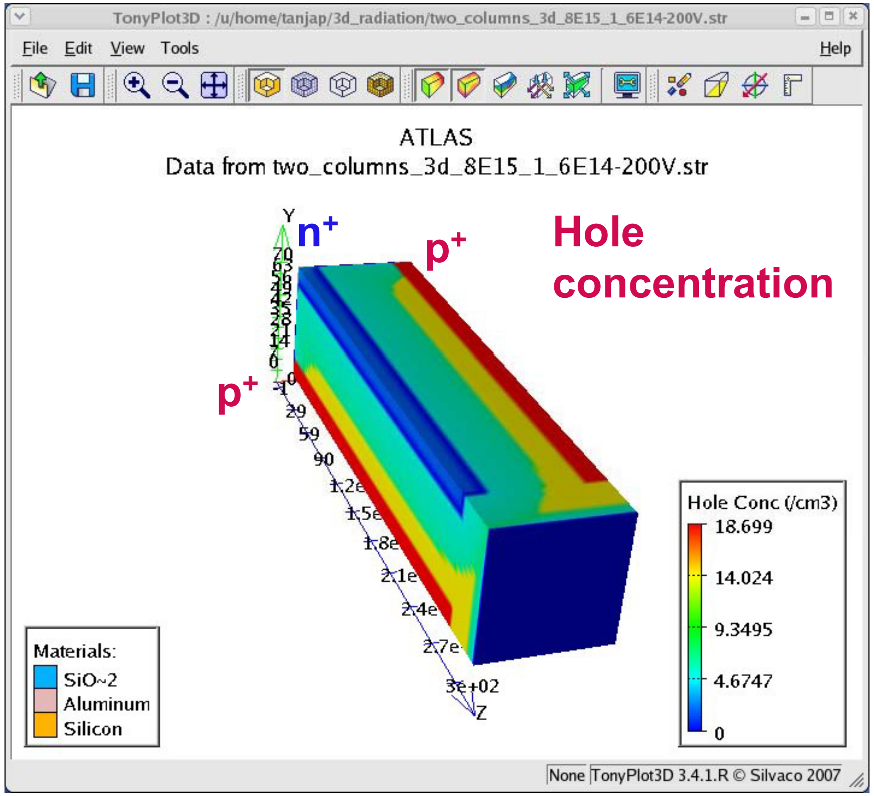
$7x10^{15}\ n_{eq}/cm^2$

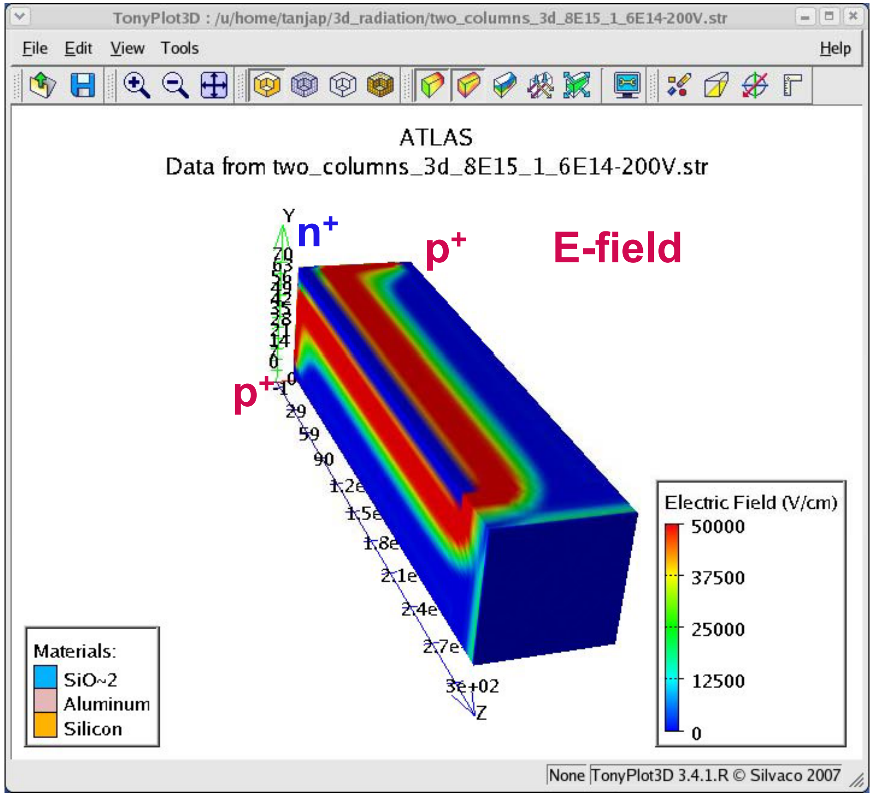




- 200V, hole conc., electric field

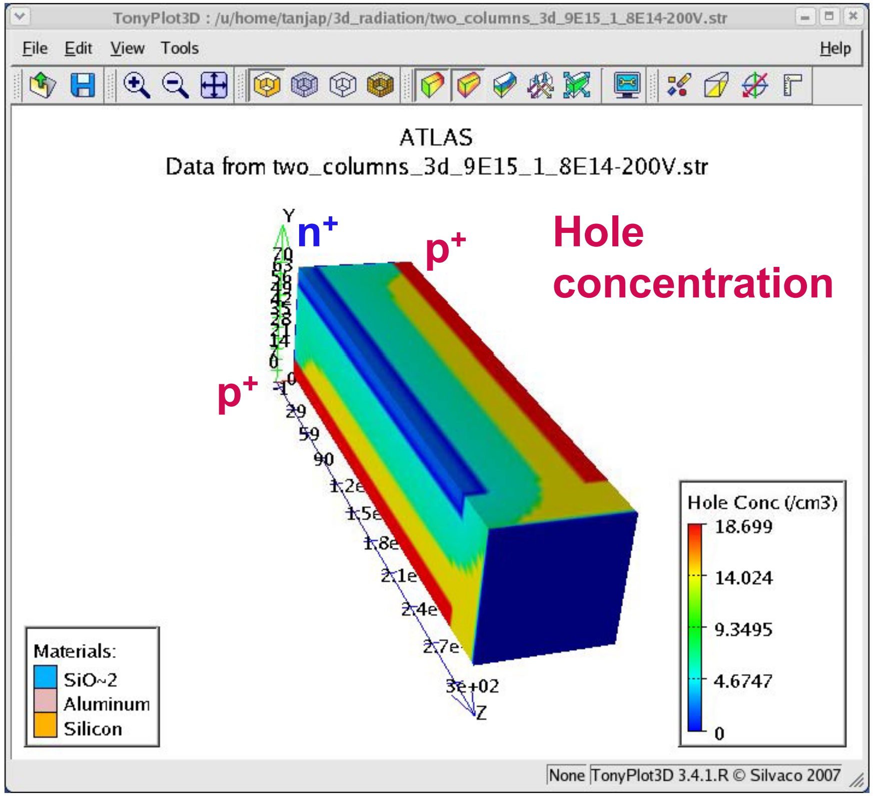
$8x10^{15}\ n_{eq}/cm^2$

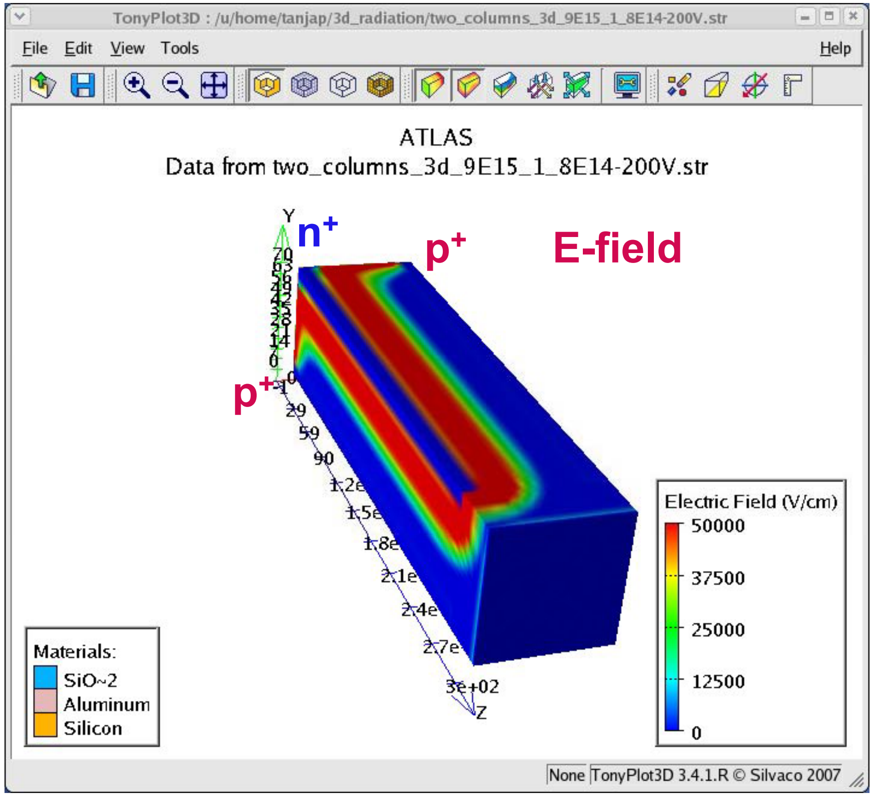




- 200V, hole conc., electric field

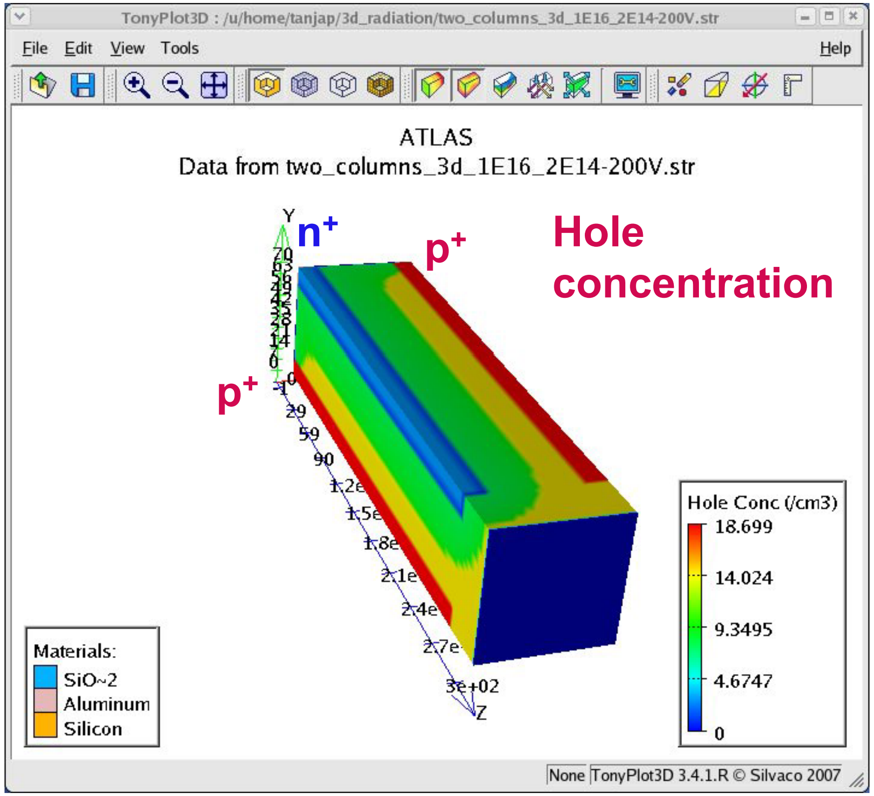
$9\times10^{15}\ n_{eq}/cm^2$

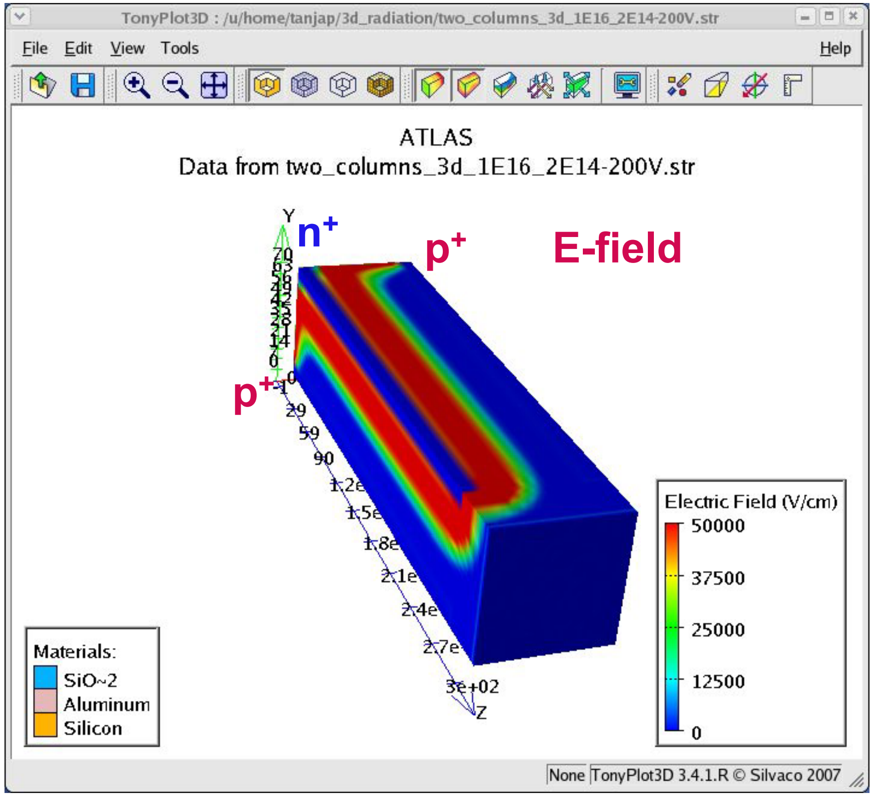




- 200V, hole conc., electric field

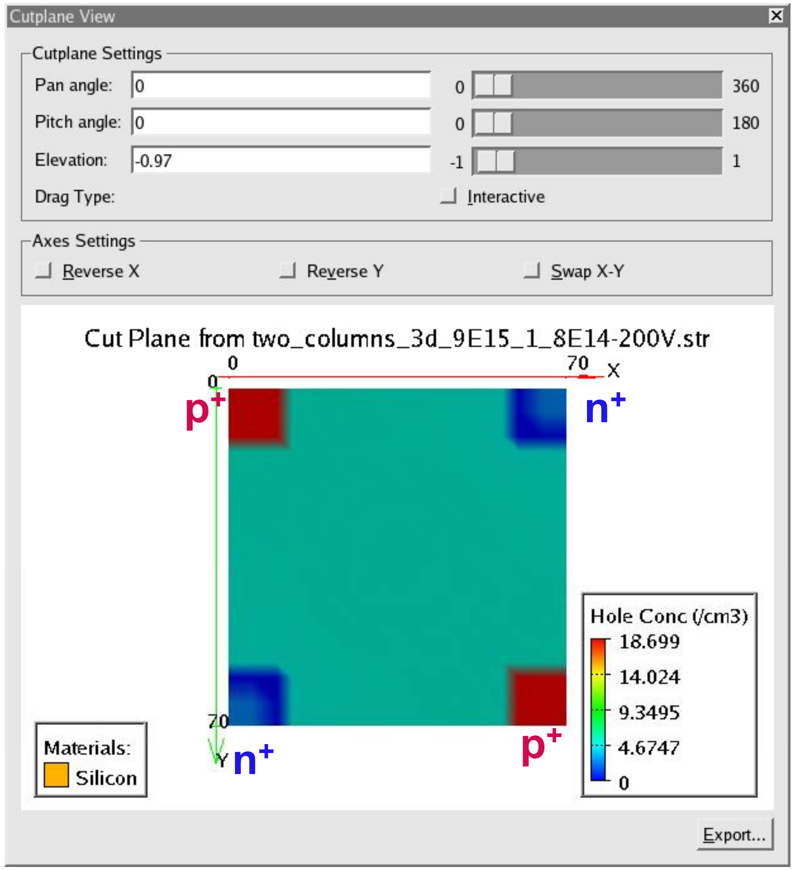
$1x10^{16}\ n_{eq}/cm^2$

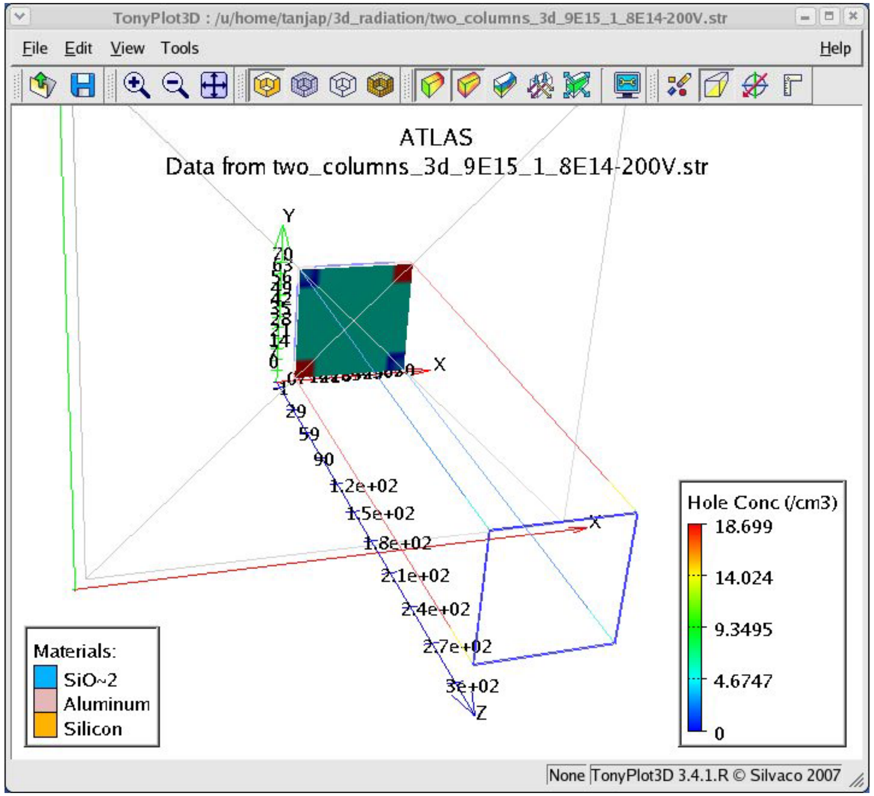




- 200V, hole conc., electric field

$9 \times 10^{15}\ n_{eq}/cm^2$ (200V)

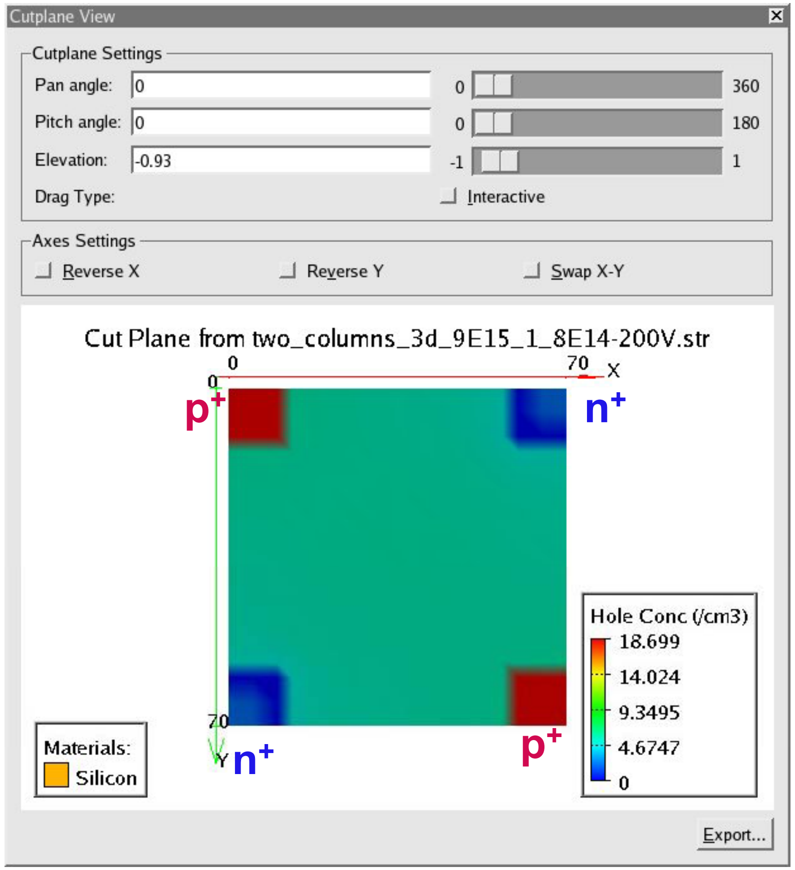


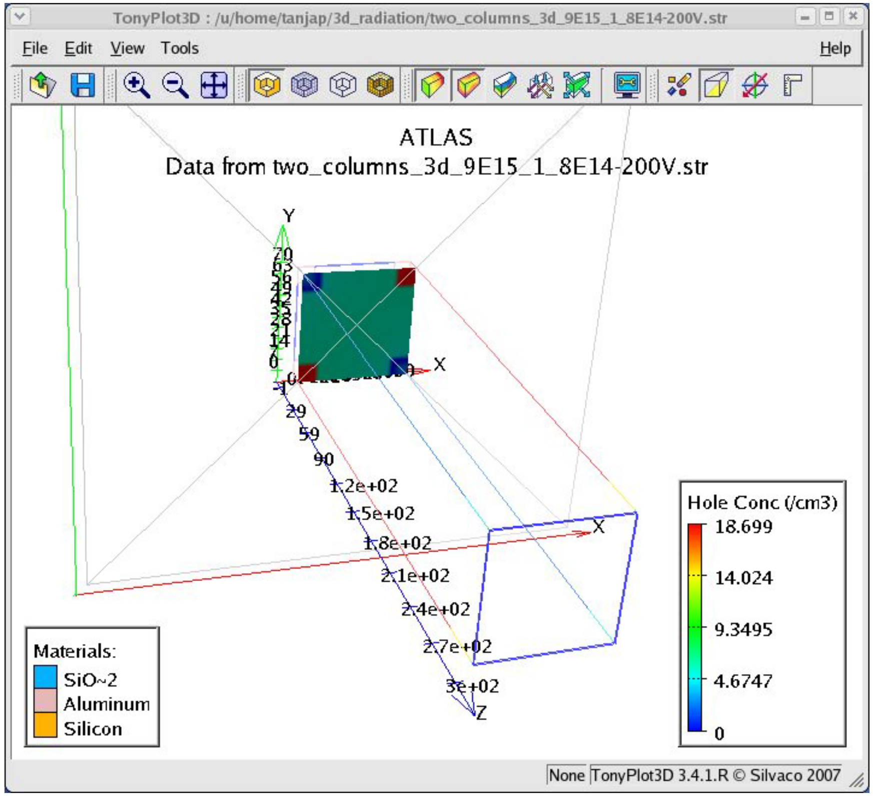


Hole concentration

- hole conc.

$9x10^{15}\ n_{eq}/cm^2$ (200V)

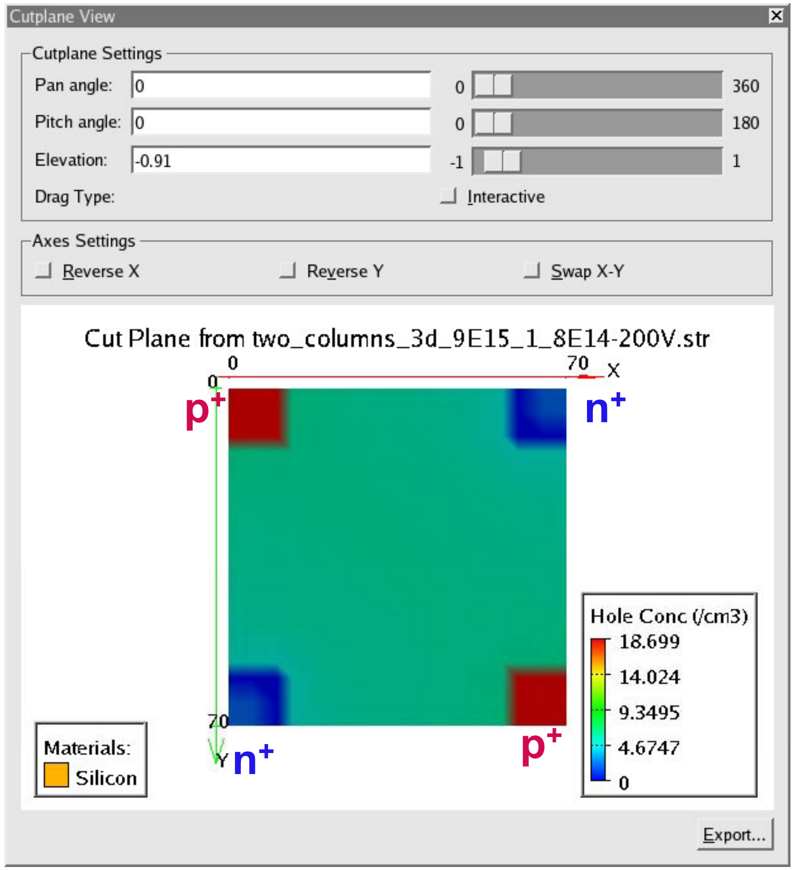


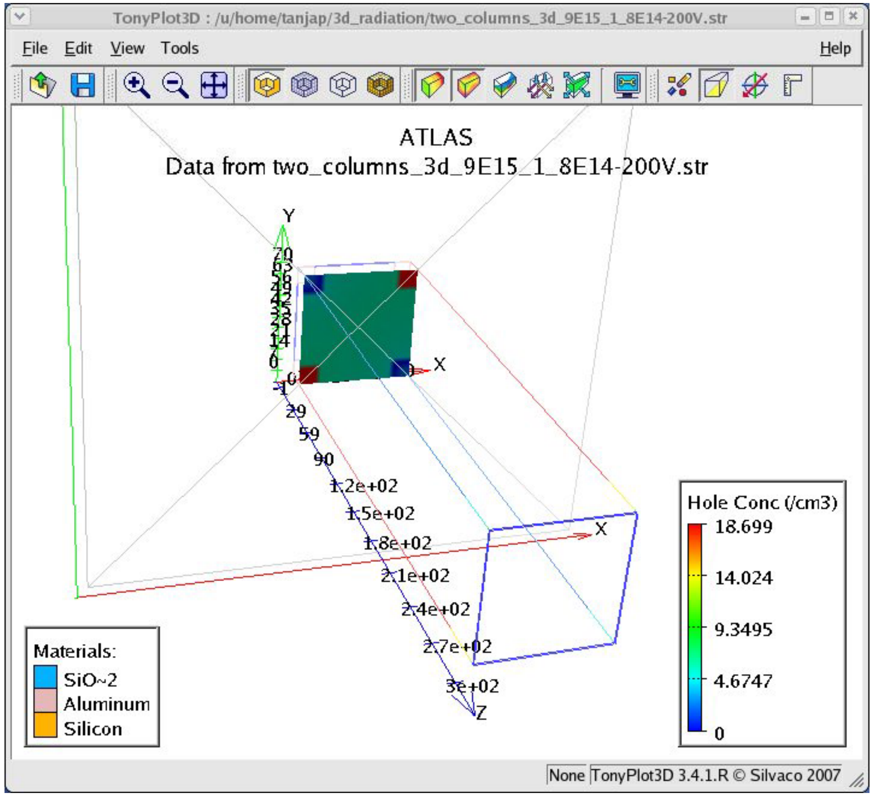


Hole concentration

- hole conc.

$9x10^{15}$ n_{eq}/cm^2 (200V)





Hole concentration

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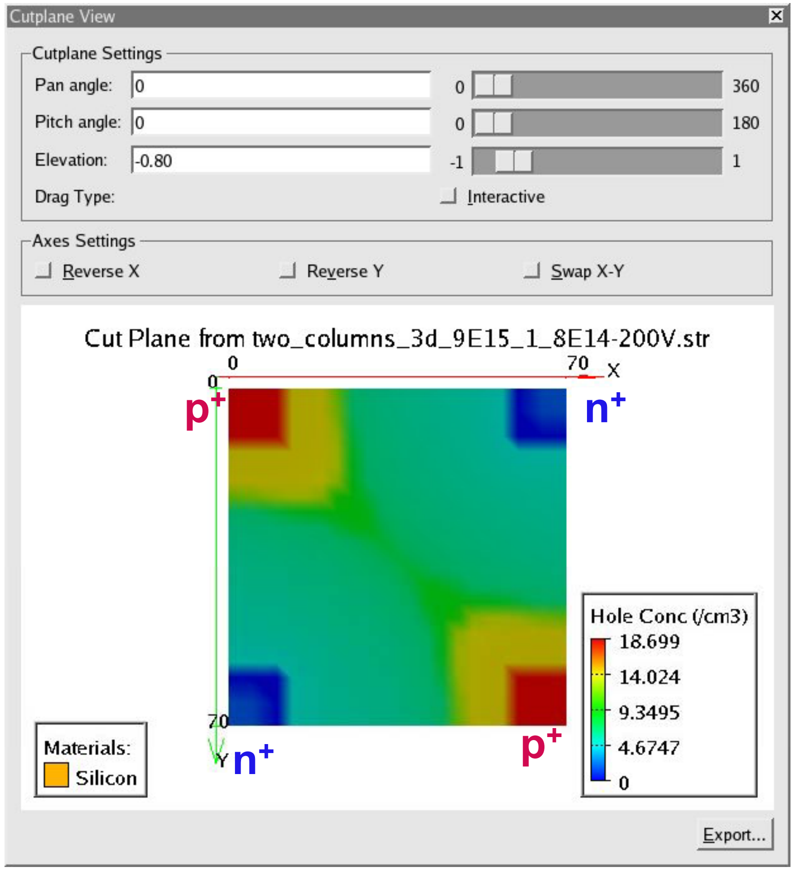

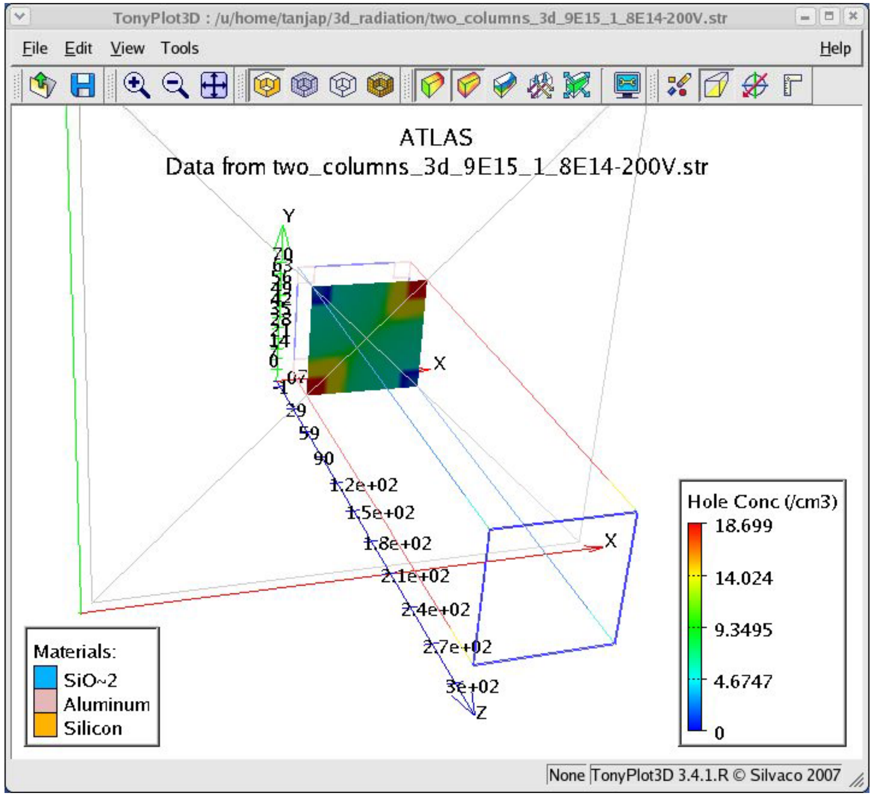

Hole concentration

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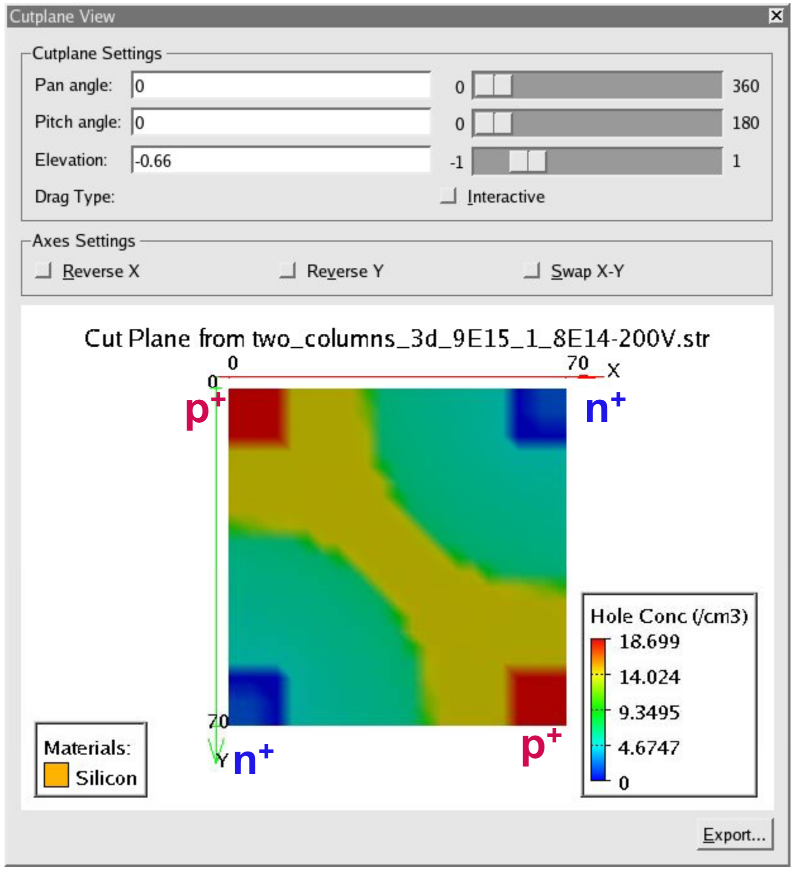

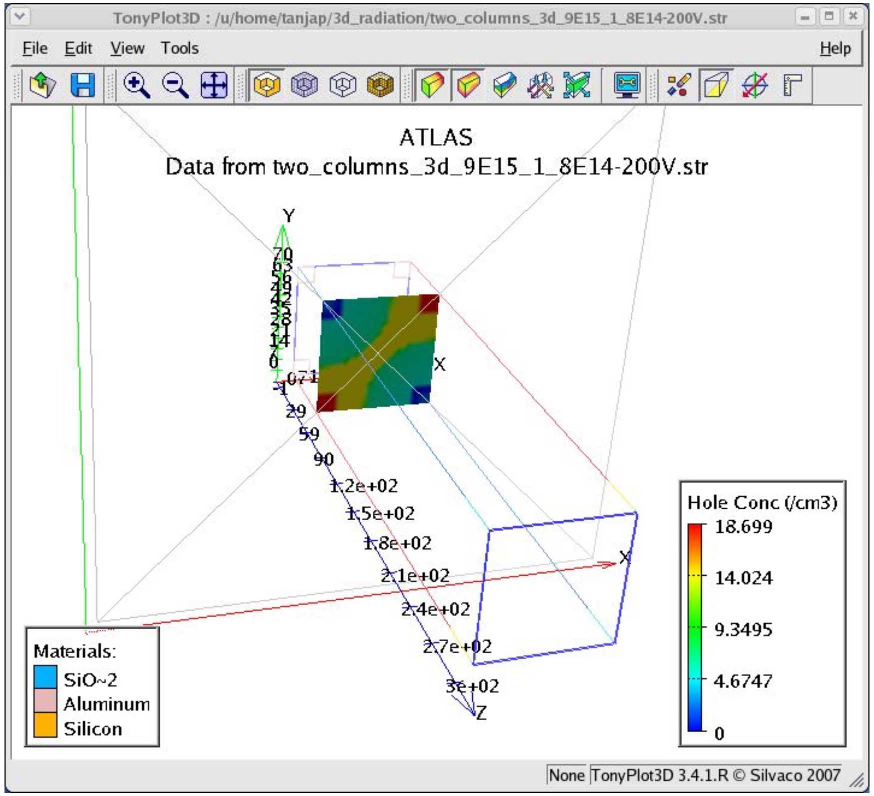

Hole concentration

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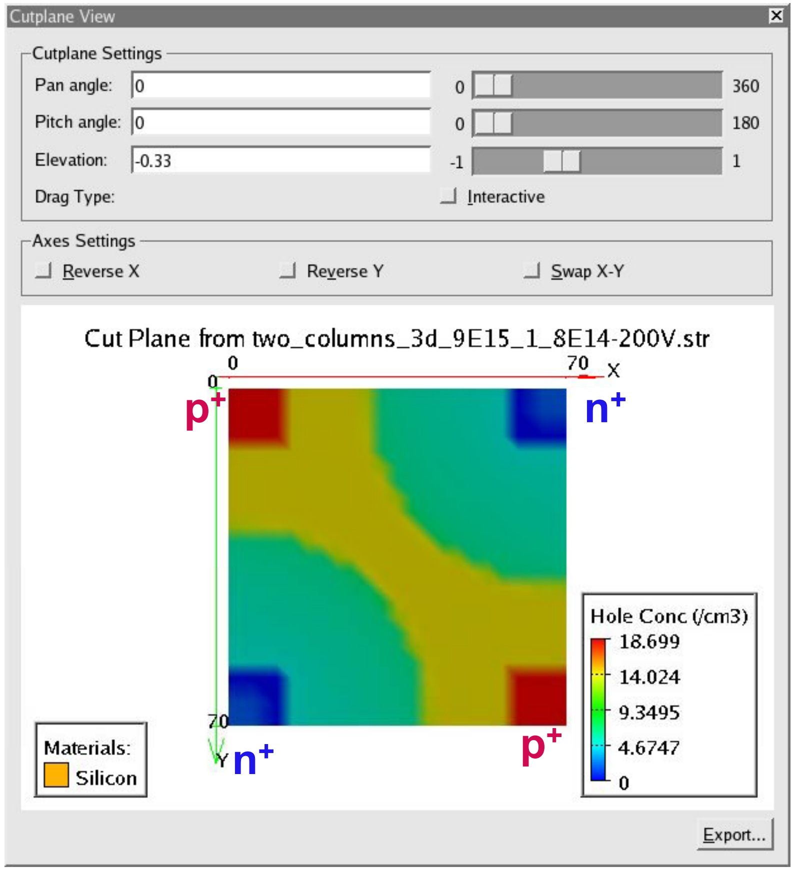
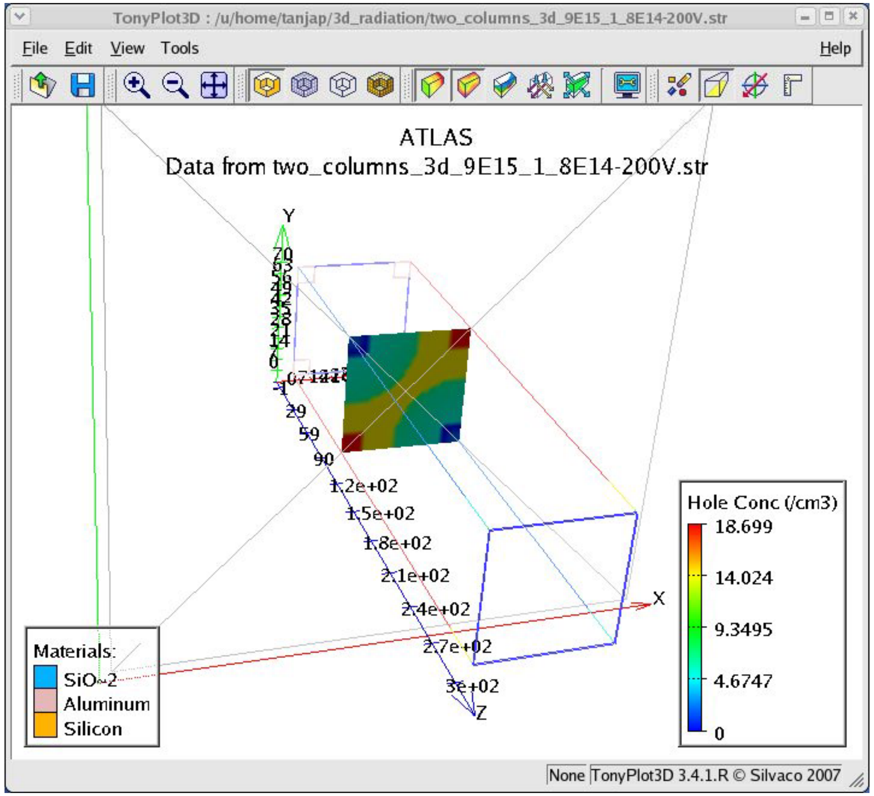
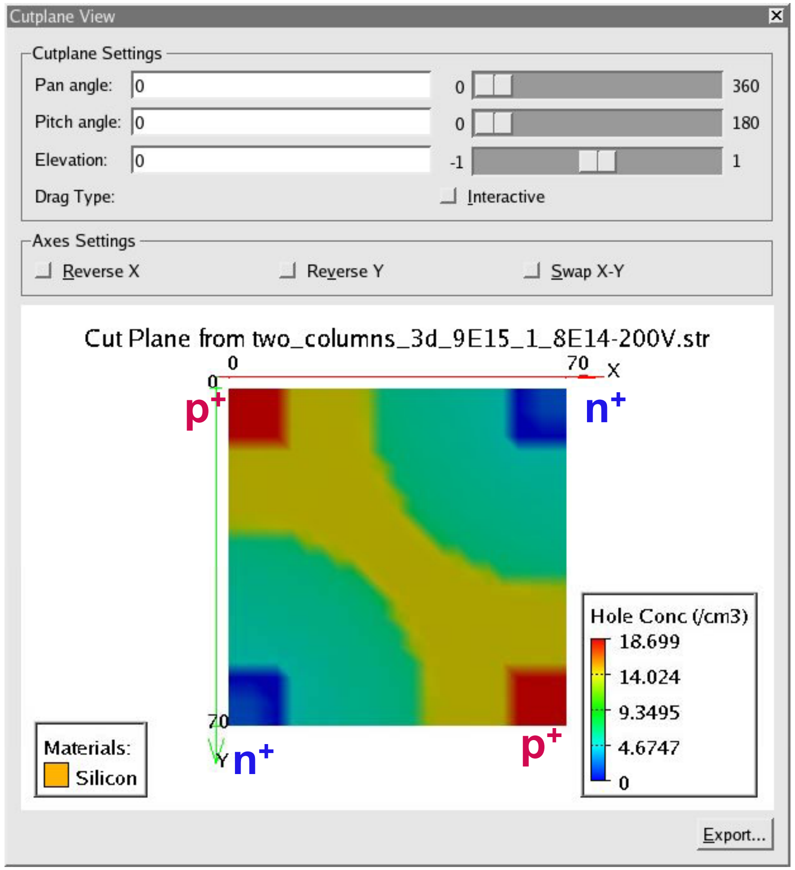


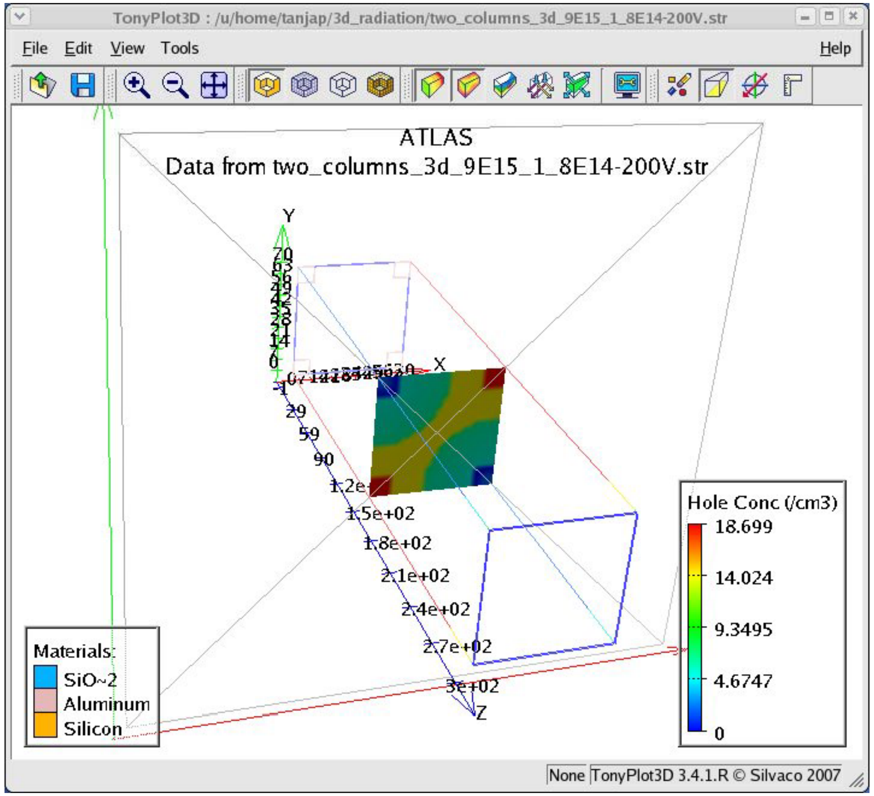


Hole concentration

- hole conc.

9×10^{15} n_{eq}/cm^2 (200V)

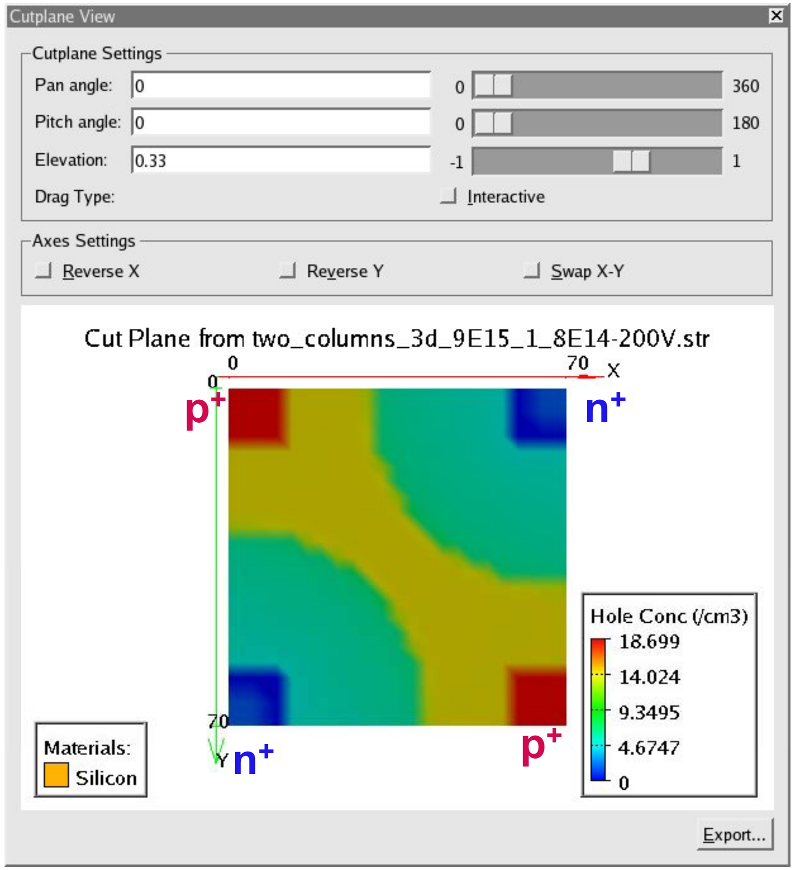


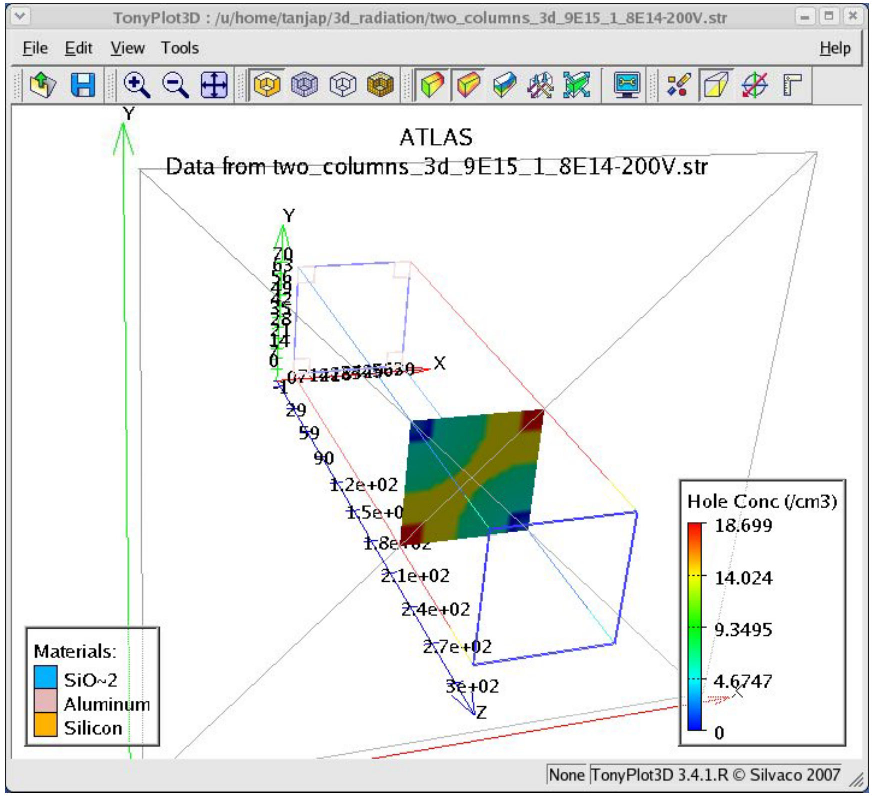


Hole concentration

- hole conc.

$9x10^{15}$ n_{eq}/cm^2 (200V)

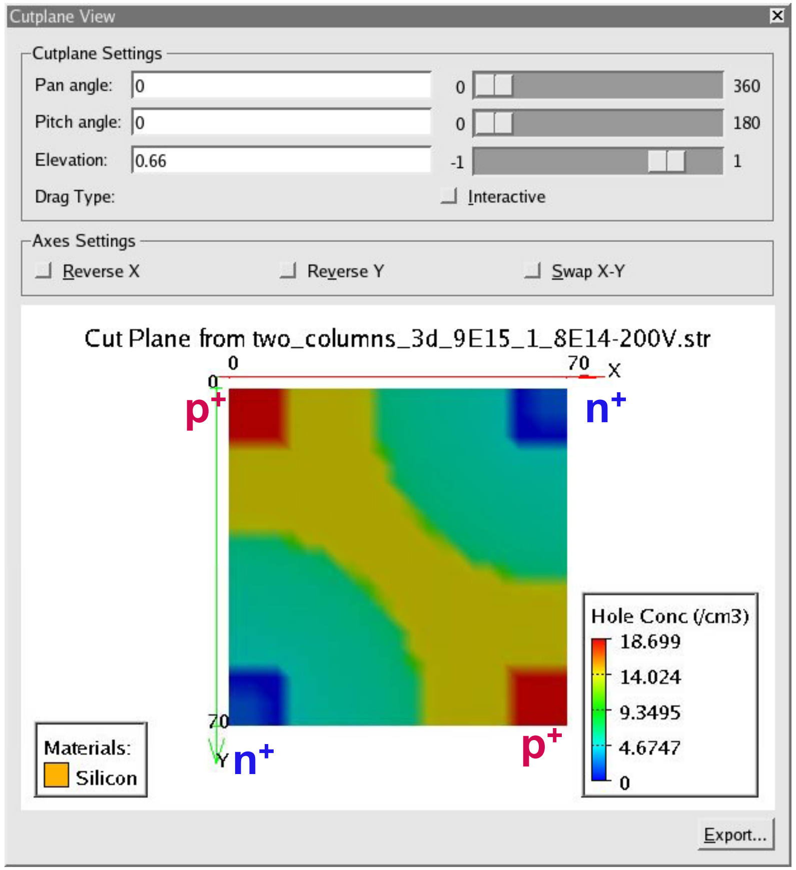


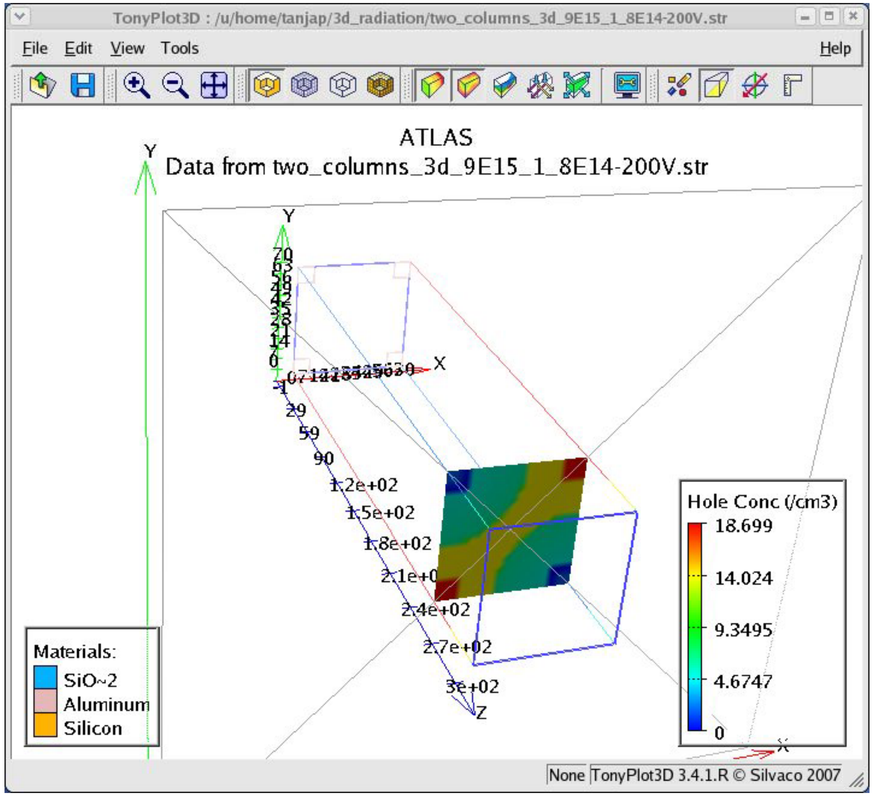


Hole concentration

- hole conc.

$9x10^{15}\ n_{eq}/cm^2$ (200V)

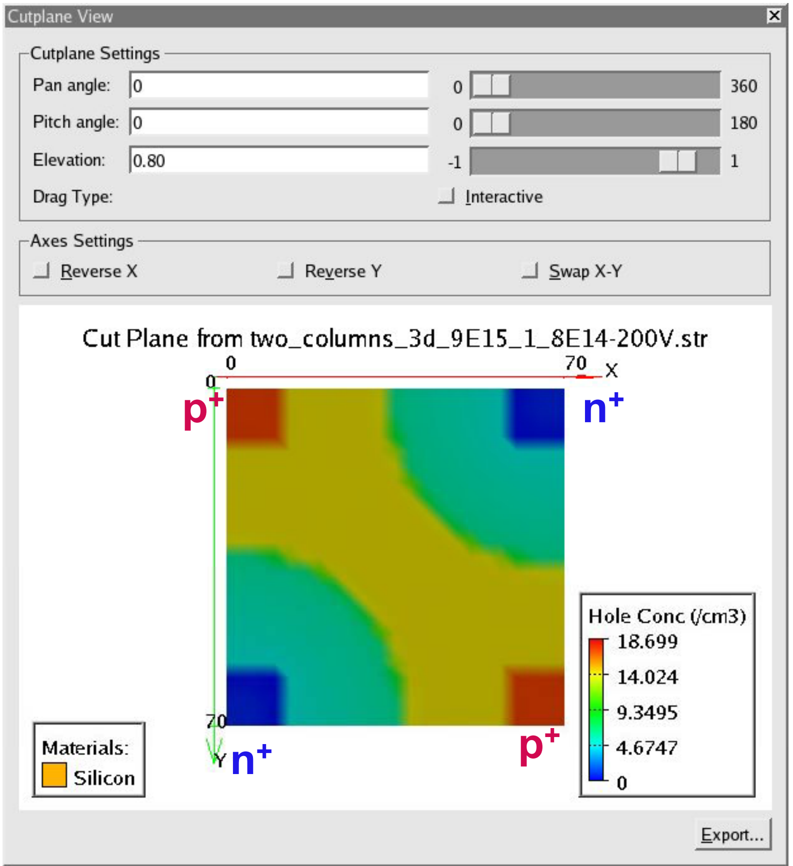


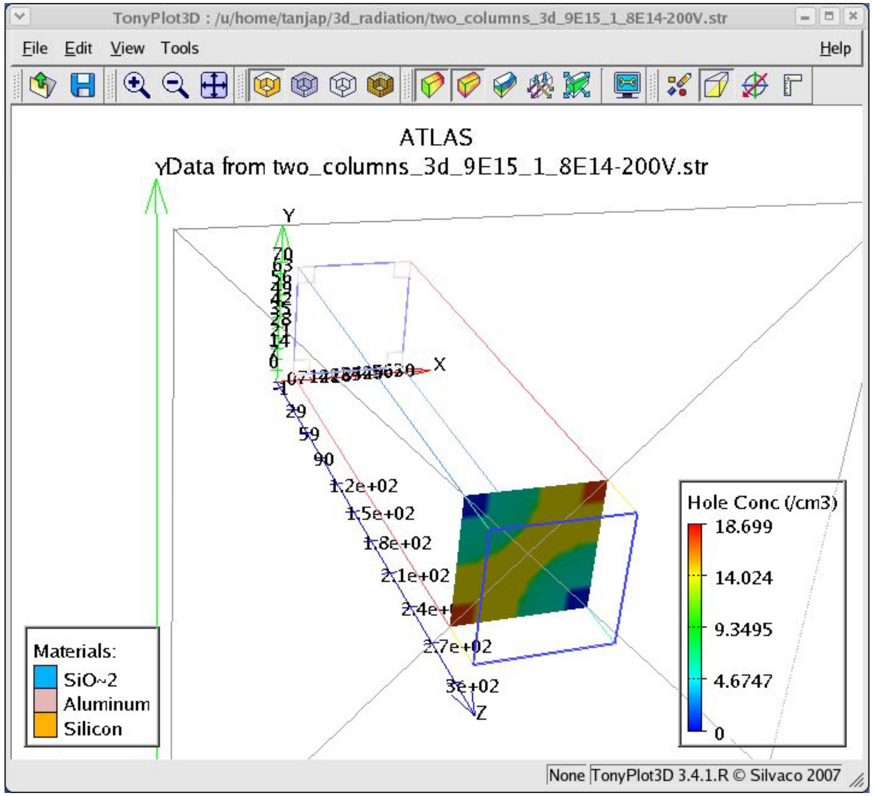


Hole concentration

- hole conc.

$9x10^{15}$ n_{eq}/cm^2 (200V)

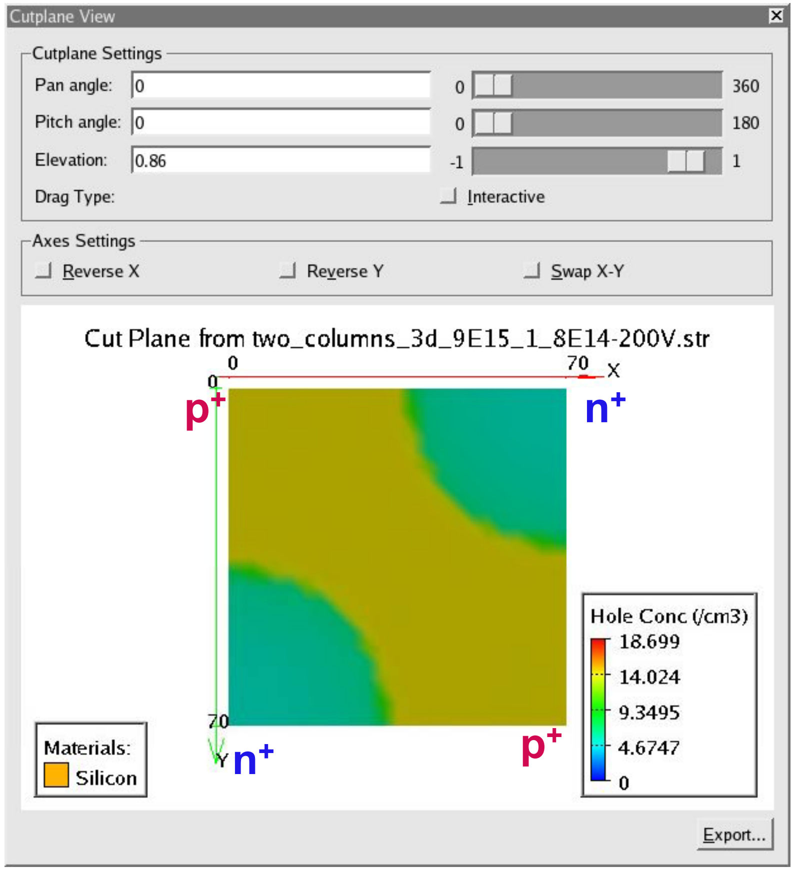


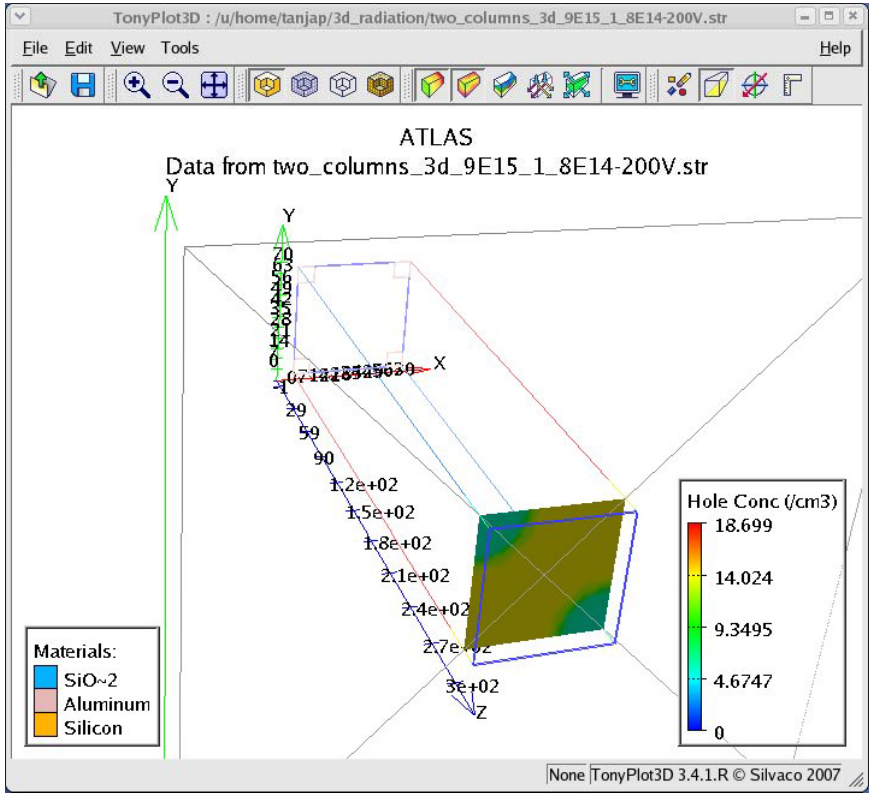


Hole concentration

- hole conc.

$9x10^{15}$ n_{eq}/cm^2 (200V)

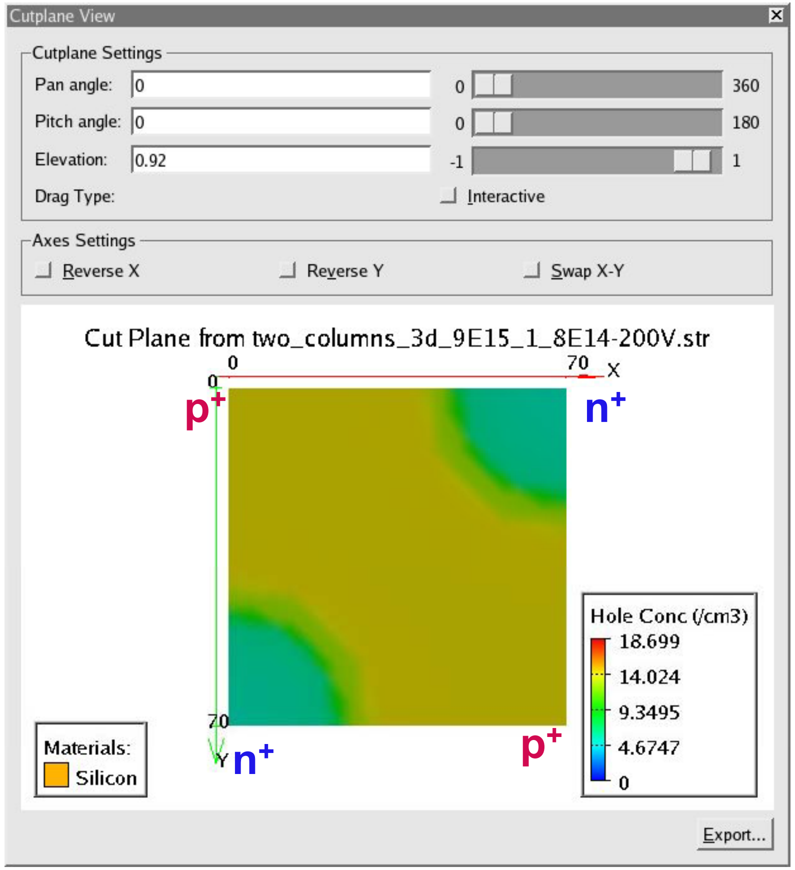


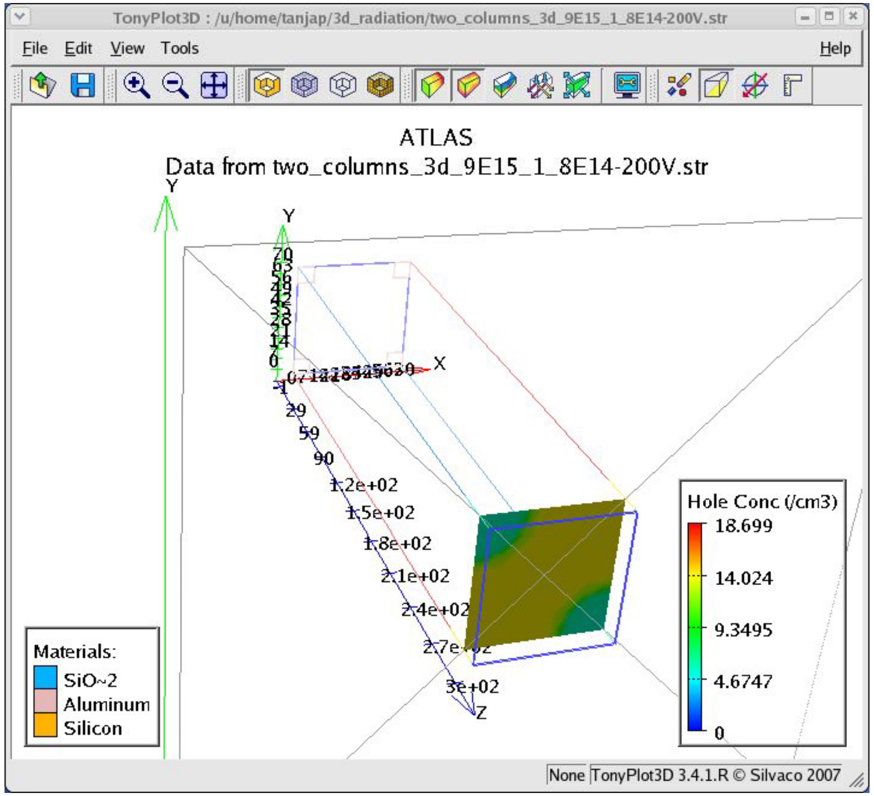


Hole concentration

The volume under the columns can be depleted with modest E-field: not dead area, and providing a sensitivity under the columns

$9x10^{15}$ n_{eq}/cm^2 (200V)

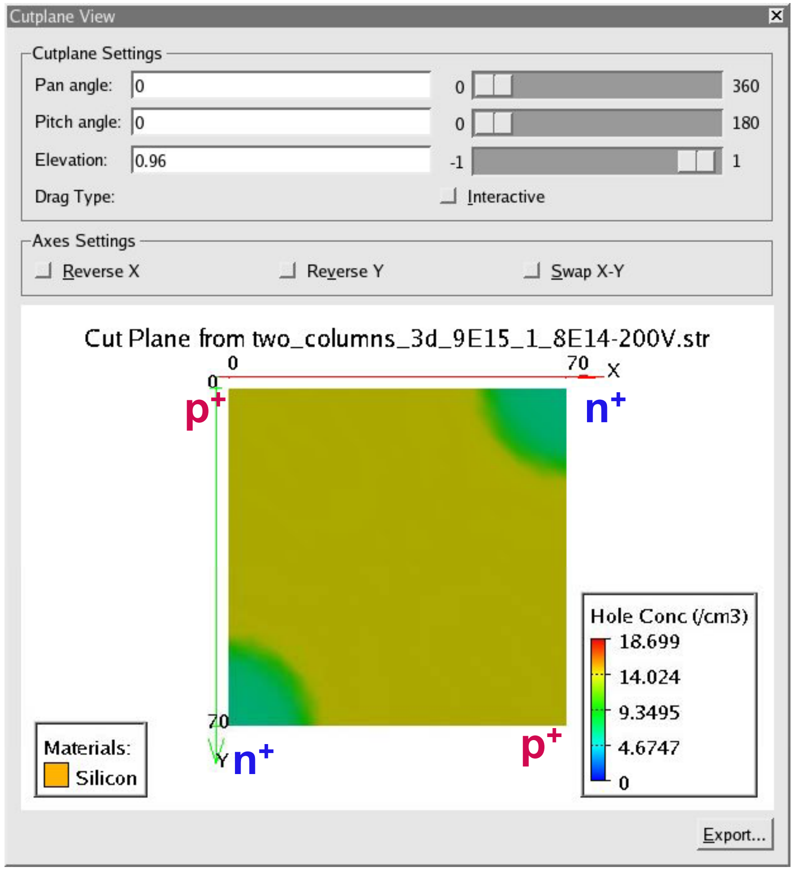


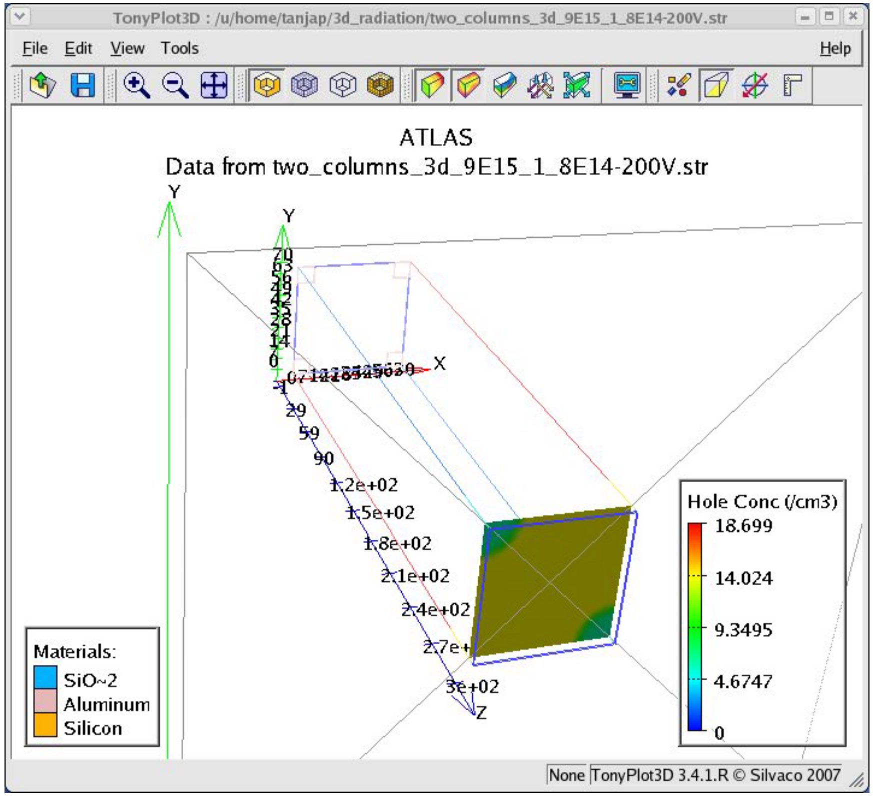


Hole concentration

- hole conc.

$9x10^{15}$ n_{eq}/cm^2 (200V)

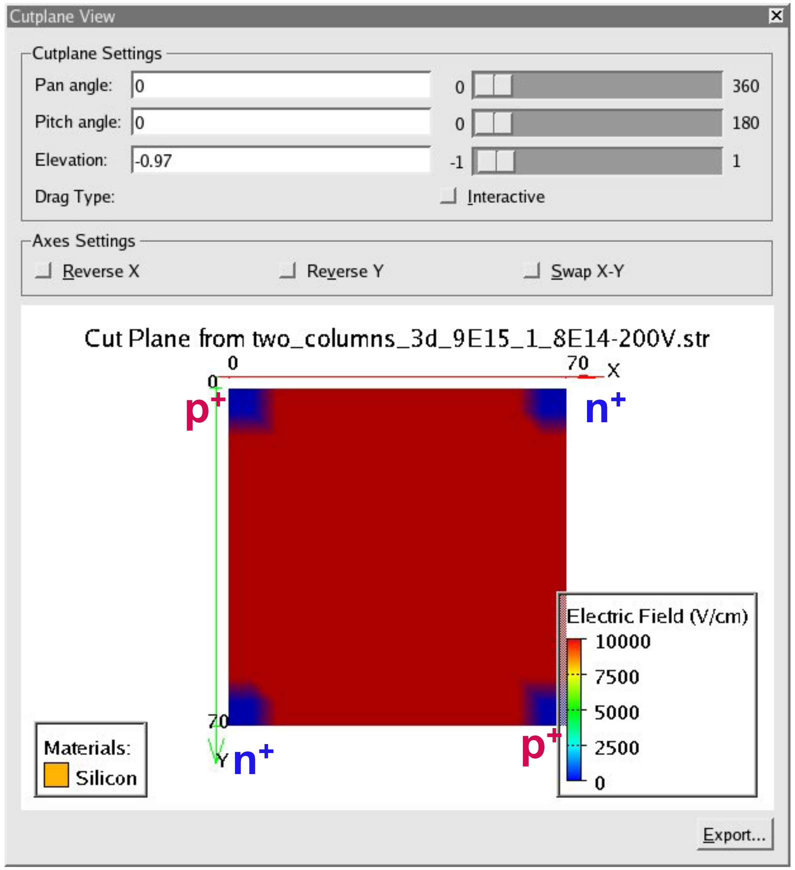


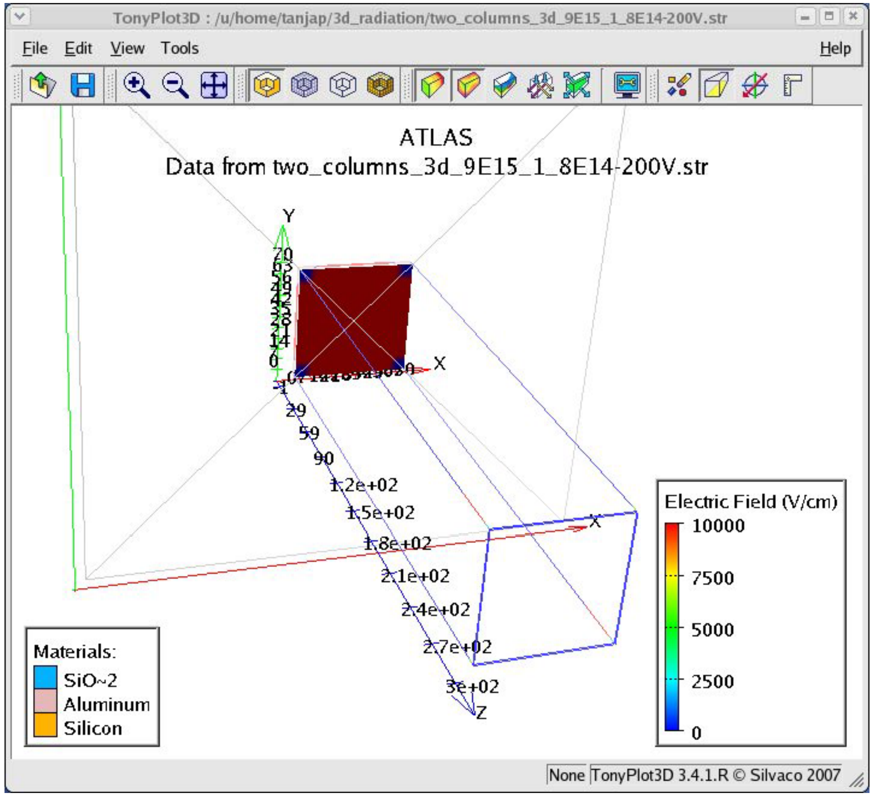


Hole concentration

- hole conc.

$9x10^{15}$ n_{eq}/cm^2 (200V)

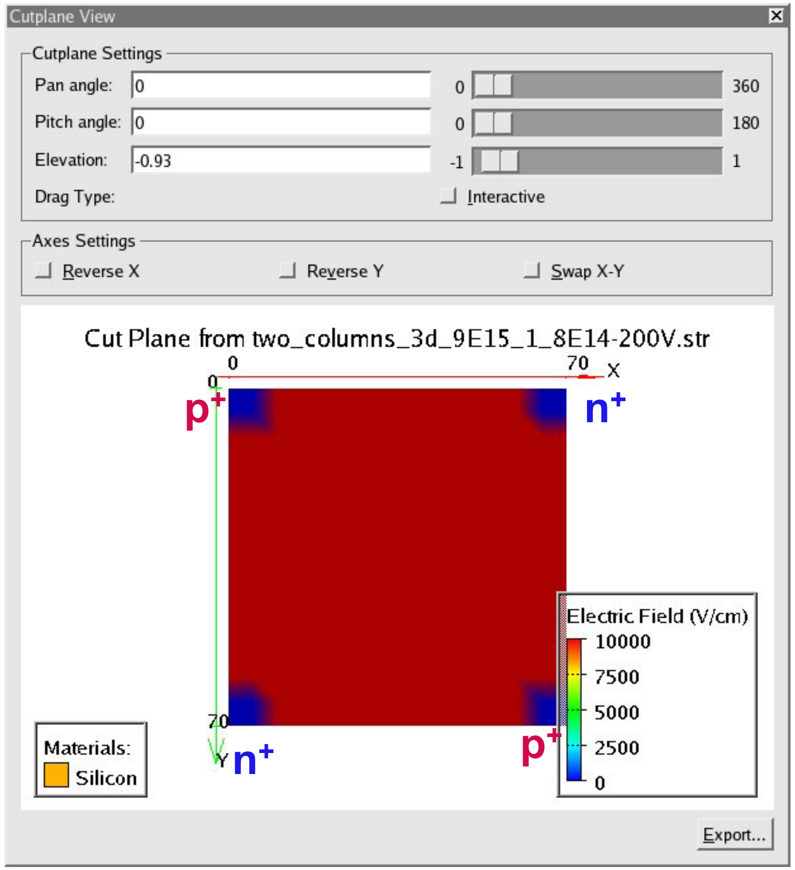


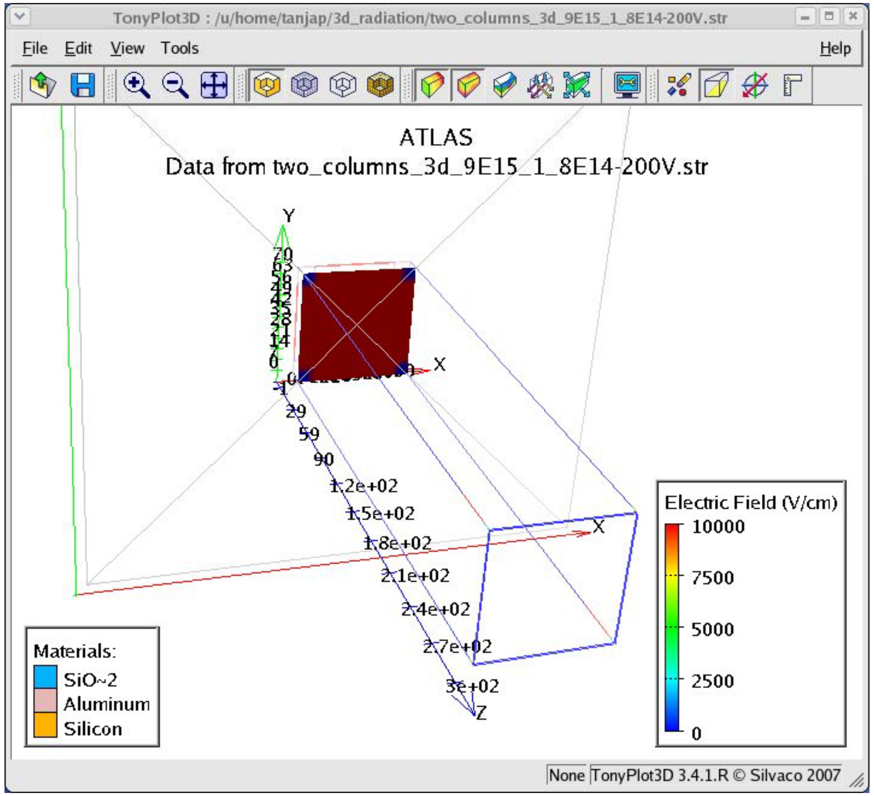


E-field

- electric field

$9x10^{15}$ n_{eq}/cm^2 (200V)

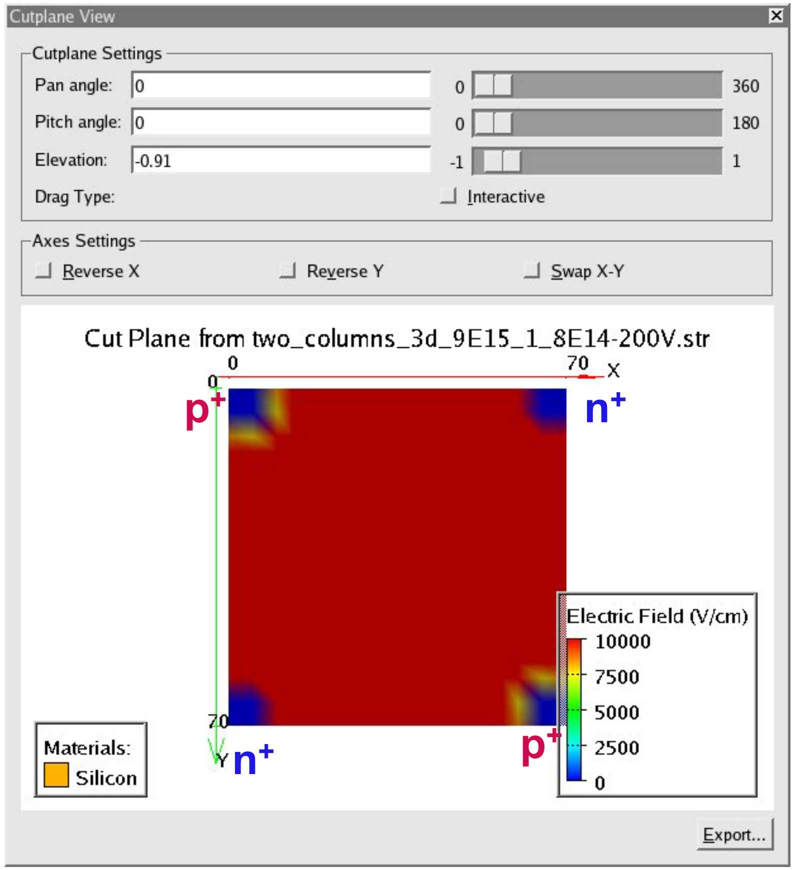


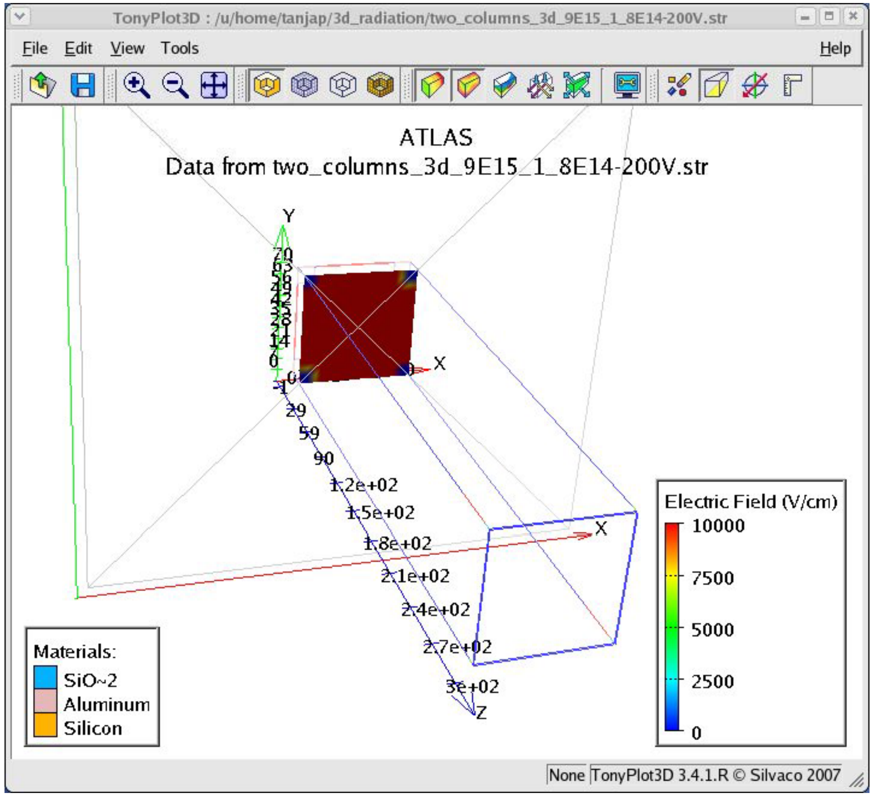


E-field

- electric field

$9x10^{15}\ n_{eq}/cm^2$ (200V)

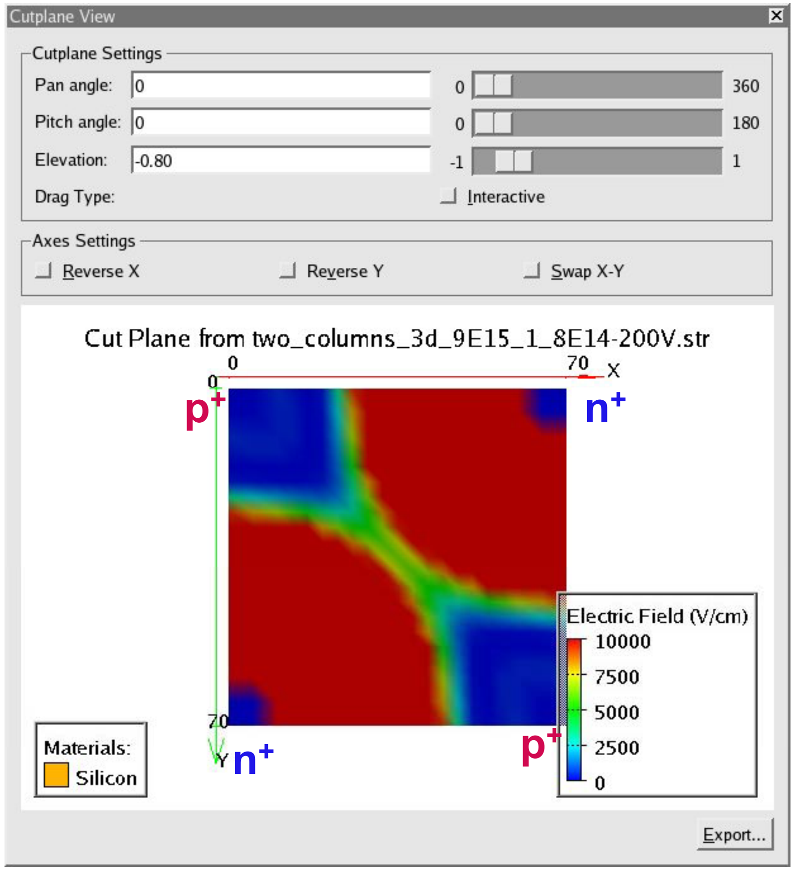


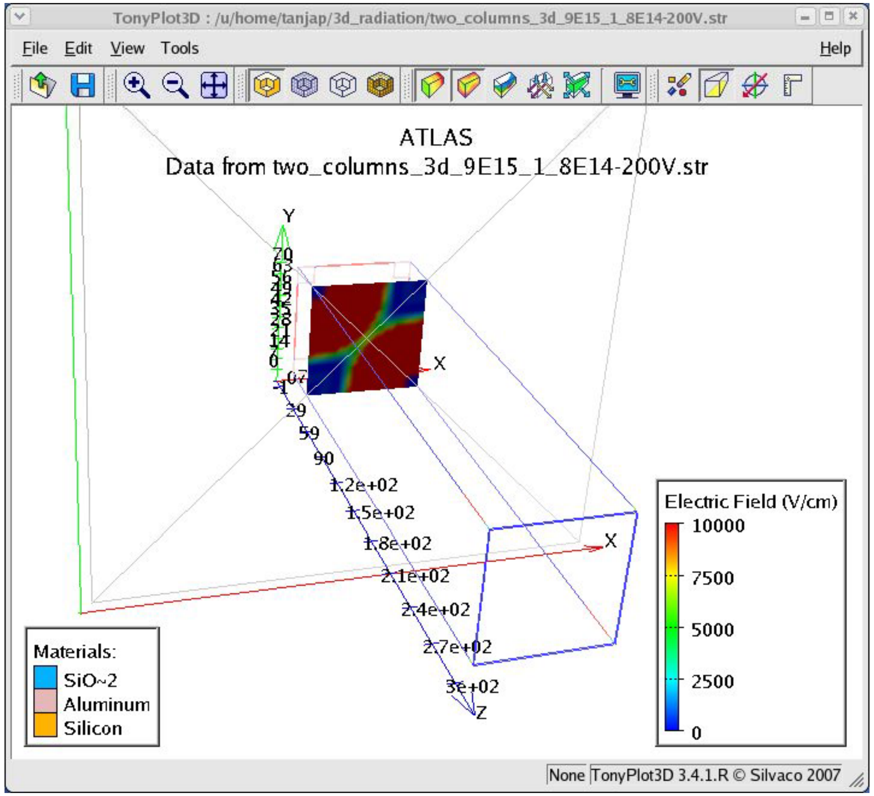


E-field

- electric field

$9x10^{15}$ n_{eq}/cm^2 (200V)

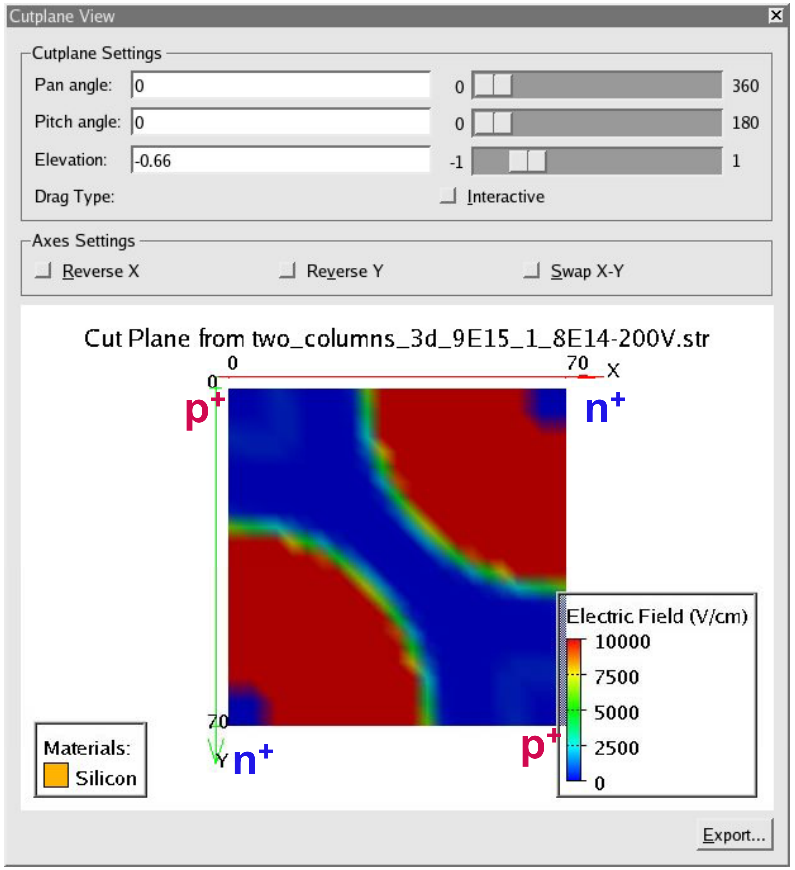


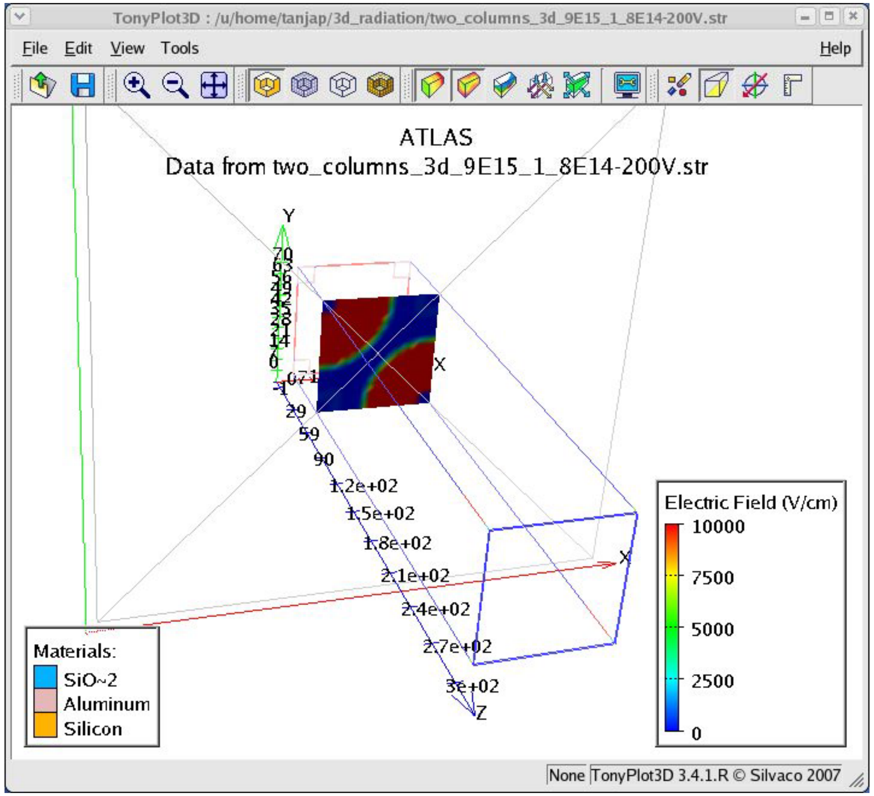


E-field

- electric field

$9x10^{15}$ n_{eq}/cm^2 (200V)

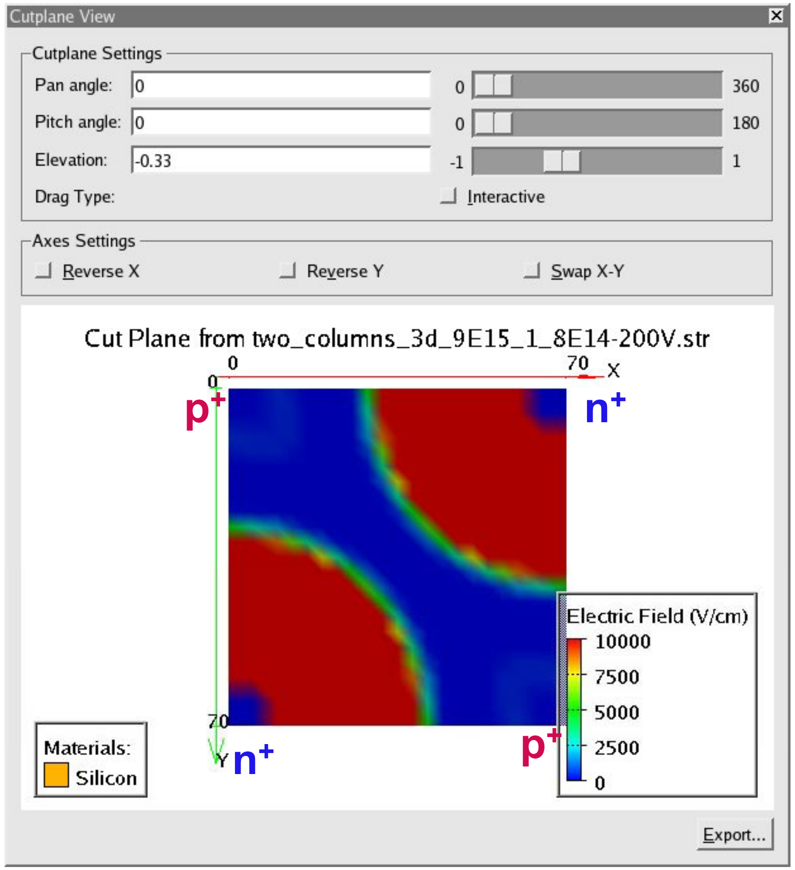


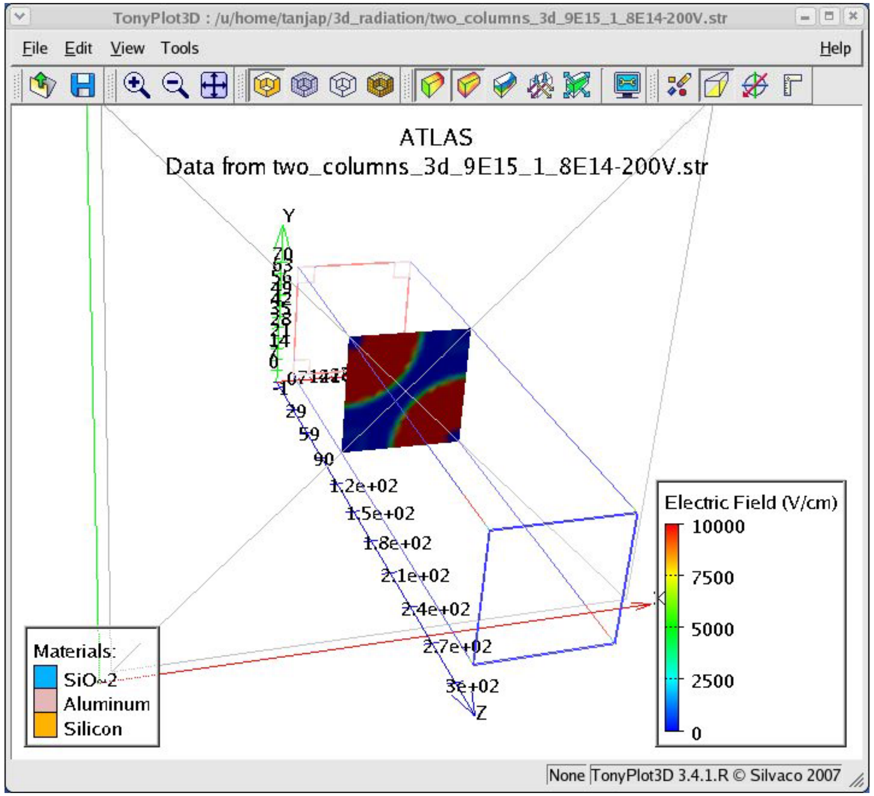


E-field

- electric field

$9x10^{15}$ n_{eq}/cm^2 (200V)

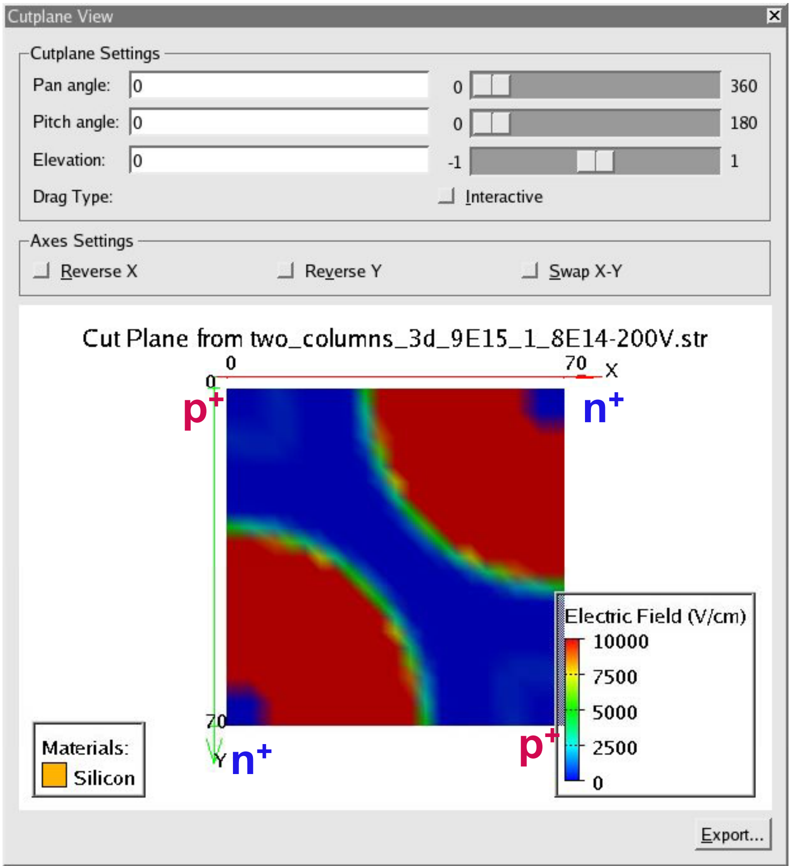


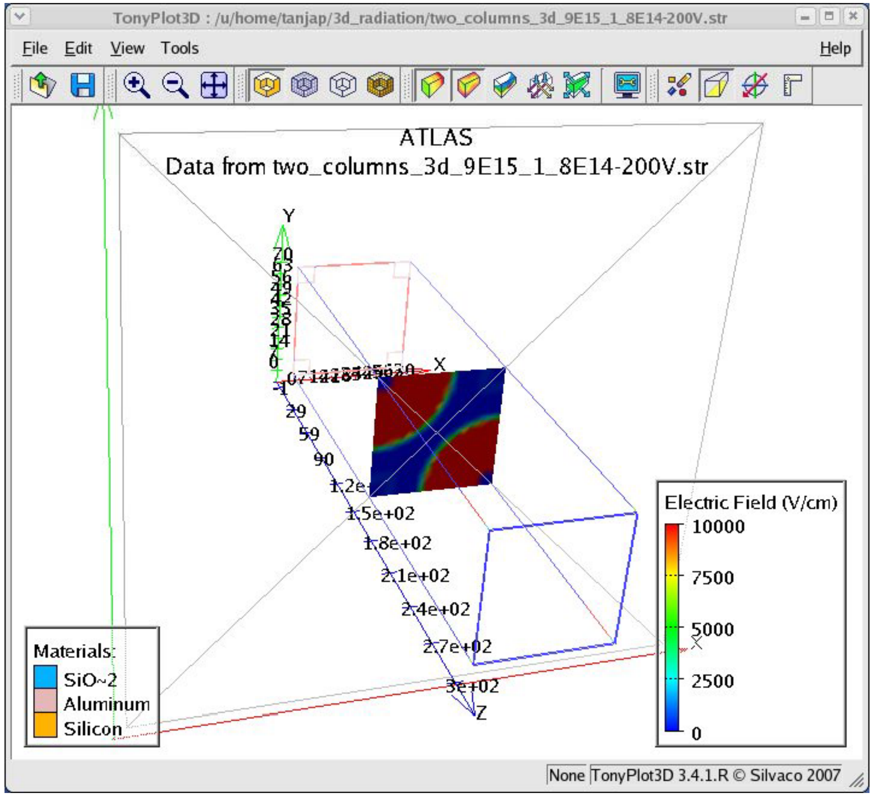


E-field

- electric field

$9x10^{15}$ n_{eq}/cm^2 (200V)

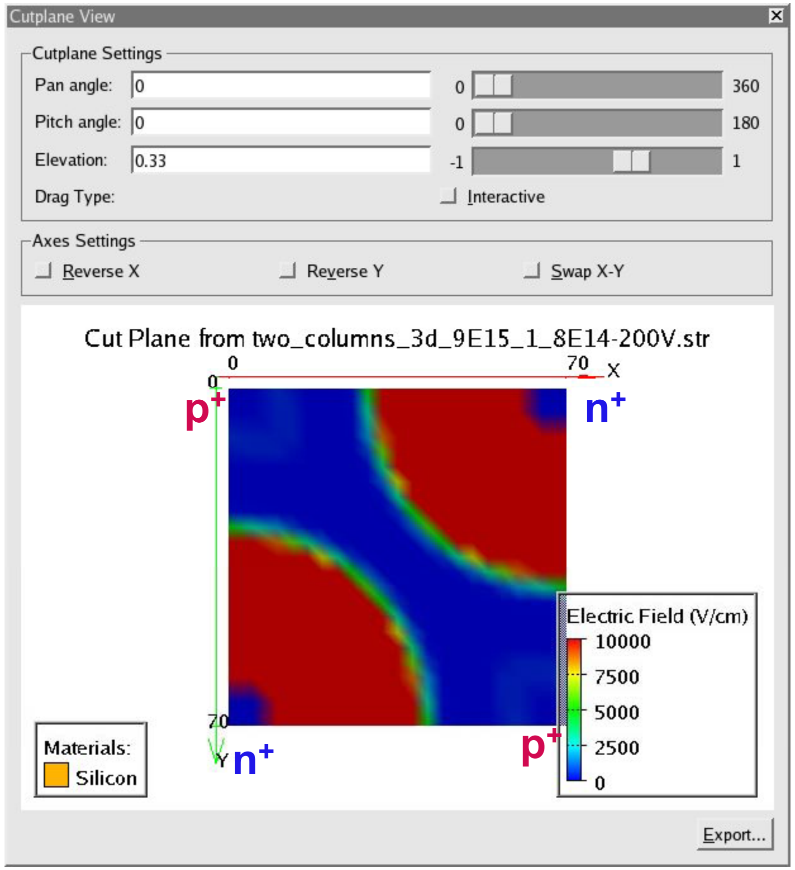


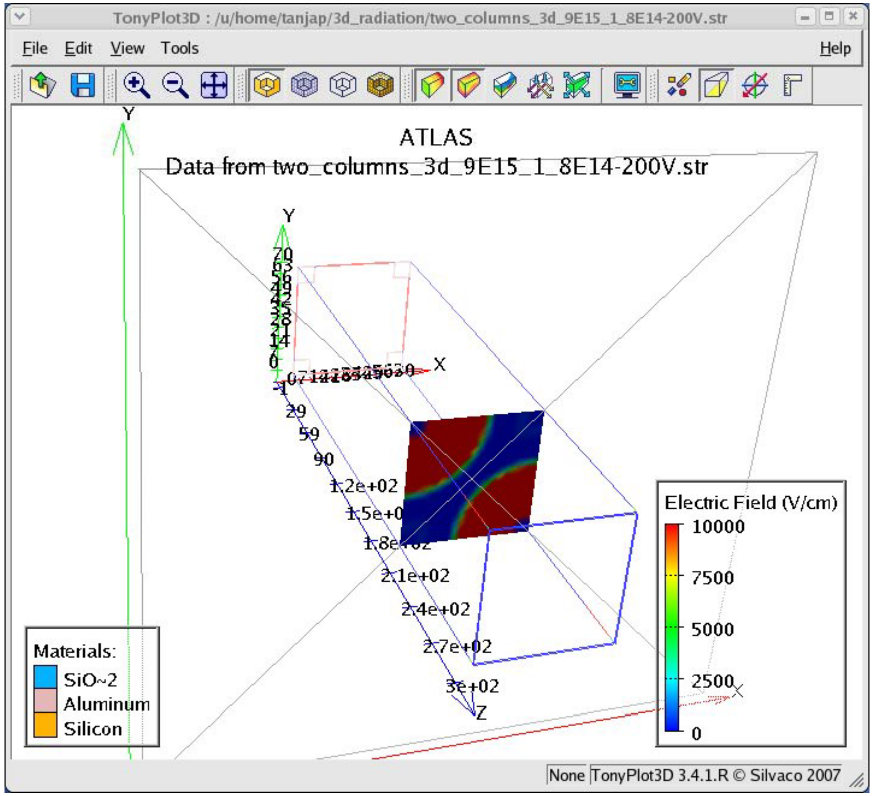


E-field

- electric field

$9x10^{15}$ n_{eq}/cm^2 (200V)

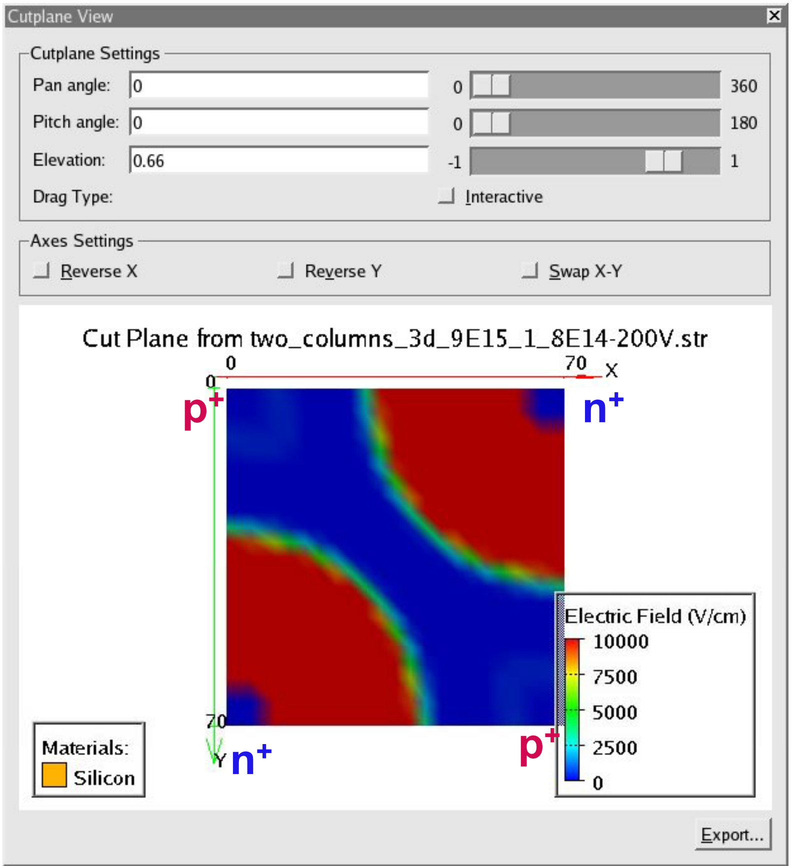


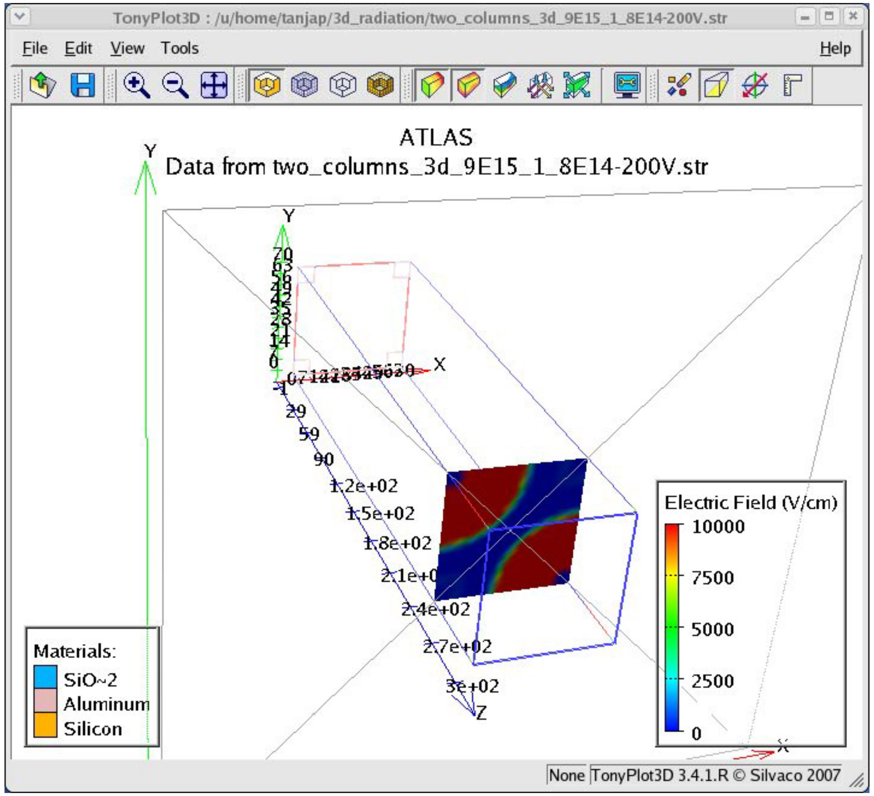


E-field

- electric field

$9x10^{15}\ n_{eq}/cm^2$ (200V)

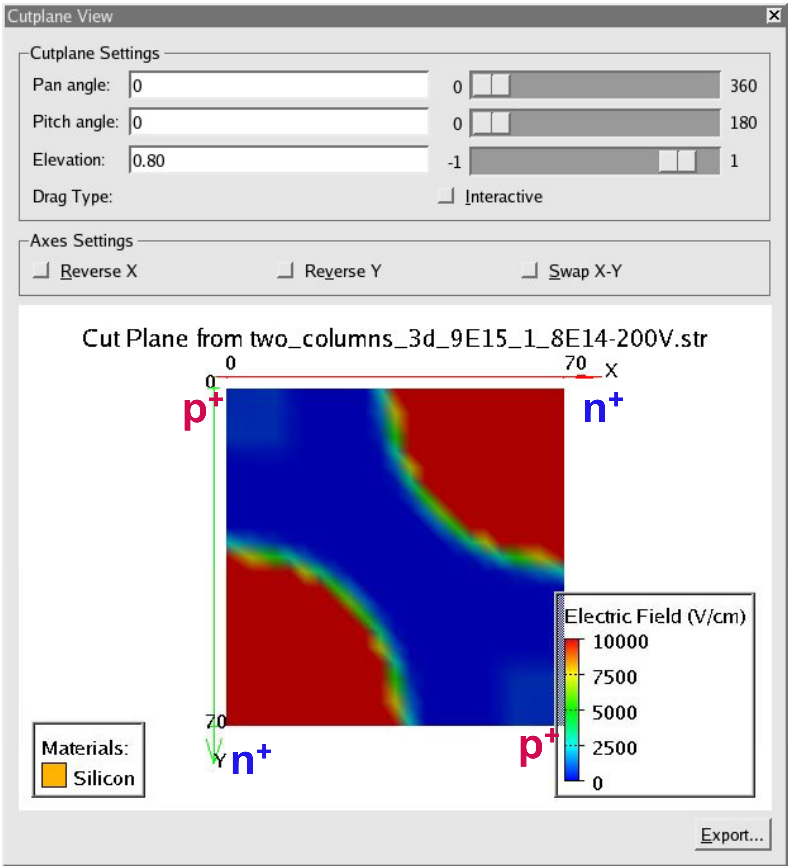


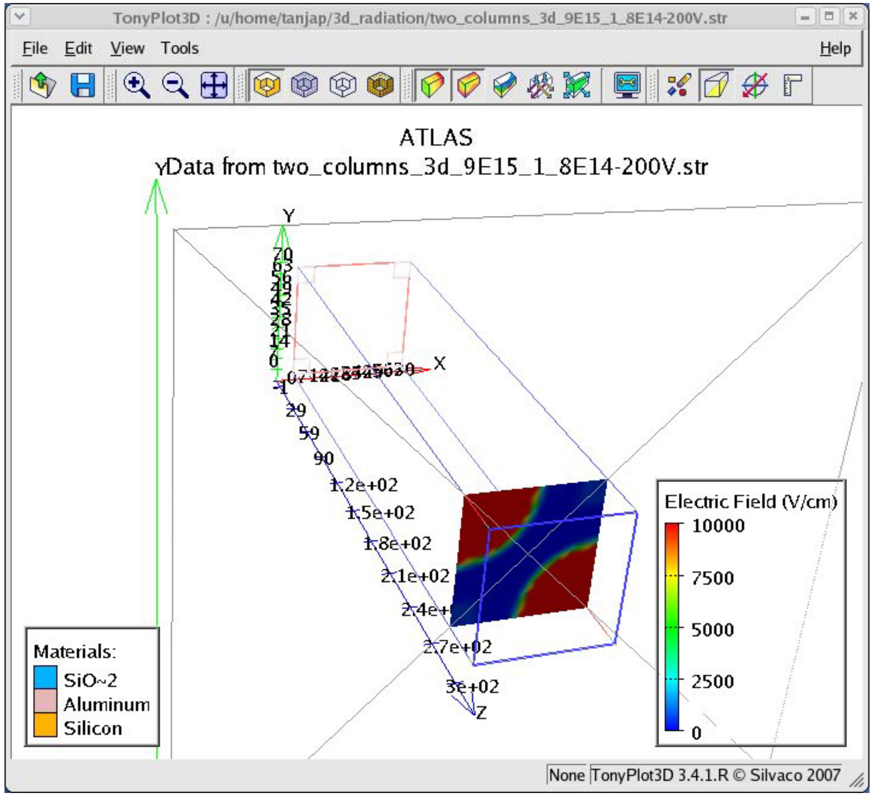


E-field

- electric field

$9 \times 10^{15}\ n_{eq}/cm^2$ (200V)

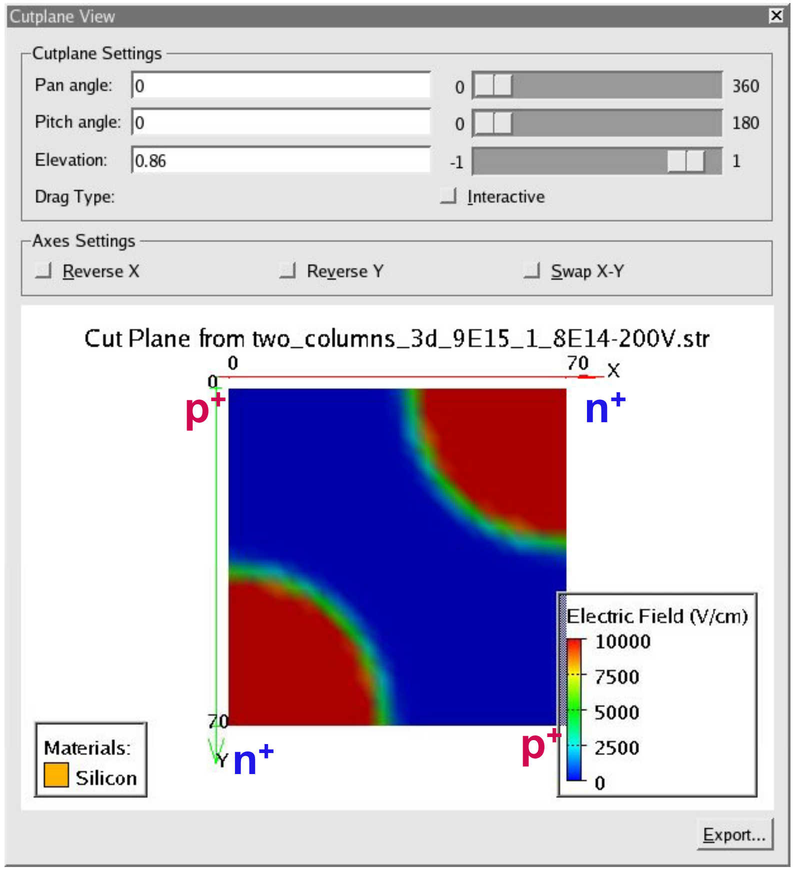


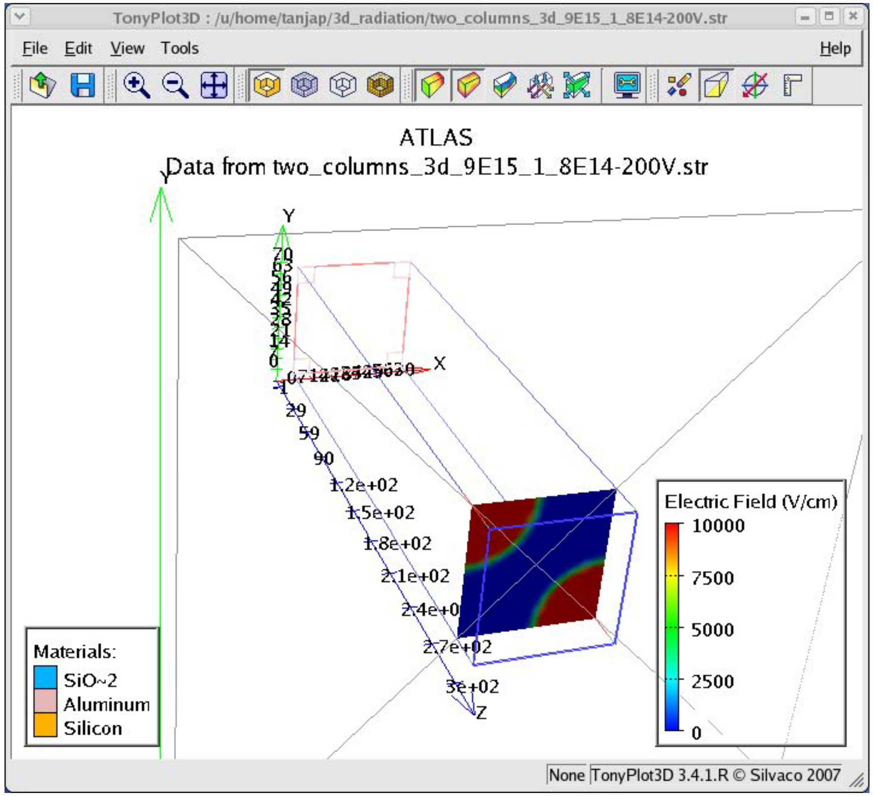


E-field

- electric field

$9x10^{15}$ n_{eq}/cm^2 (200V)

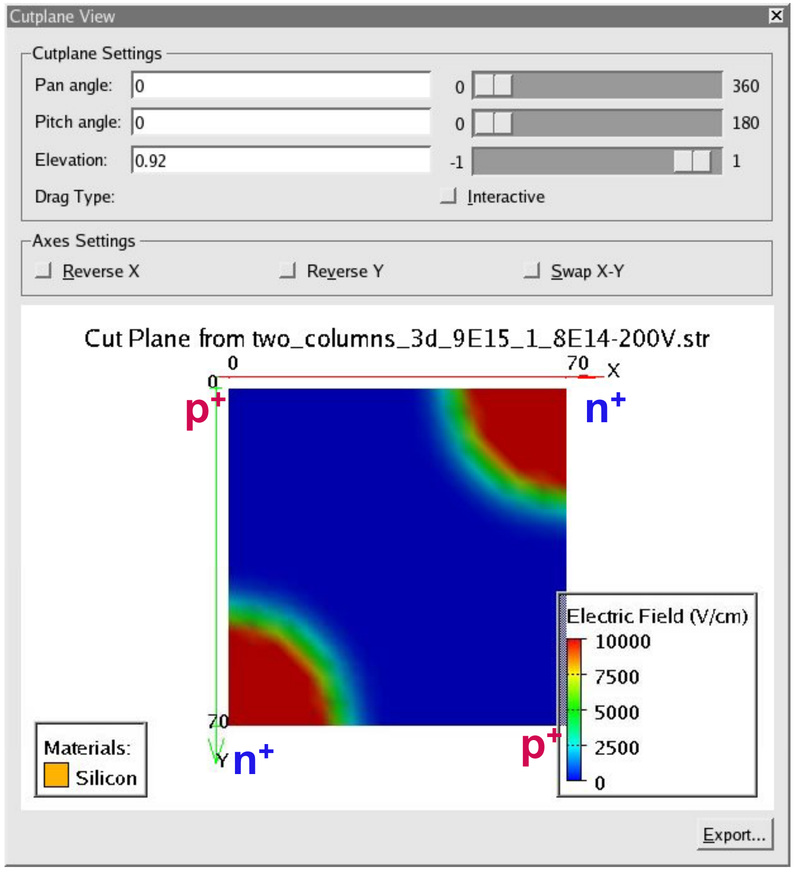


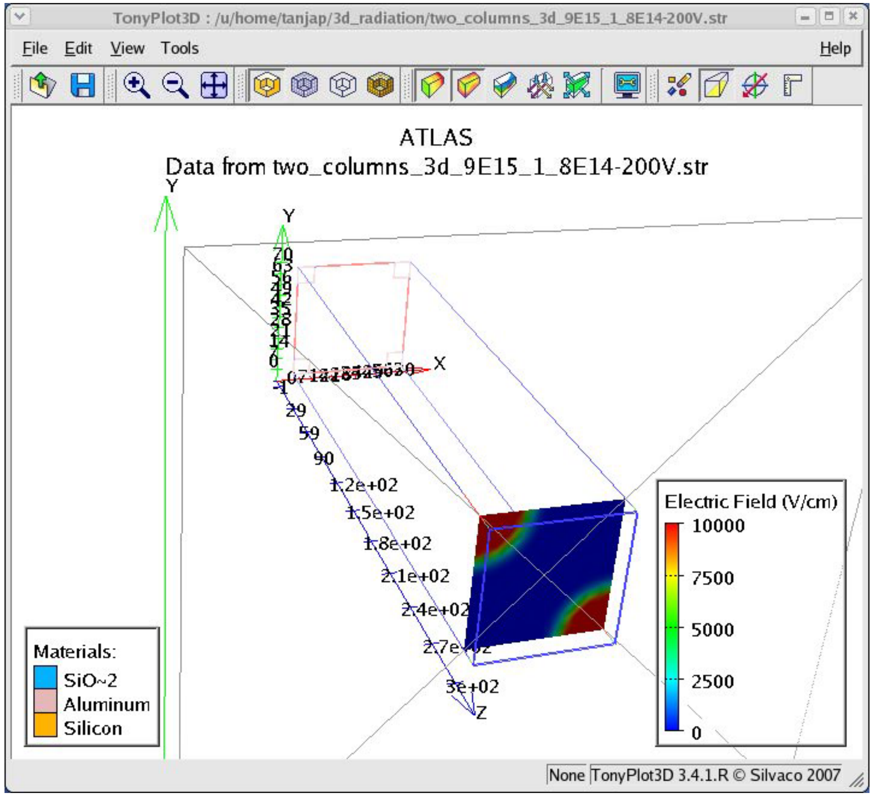


E-field

- electric field

$9x10^{15}\ n_{eq}/cm^2$ (200V)

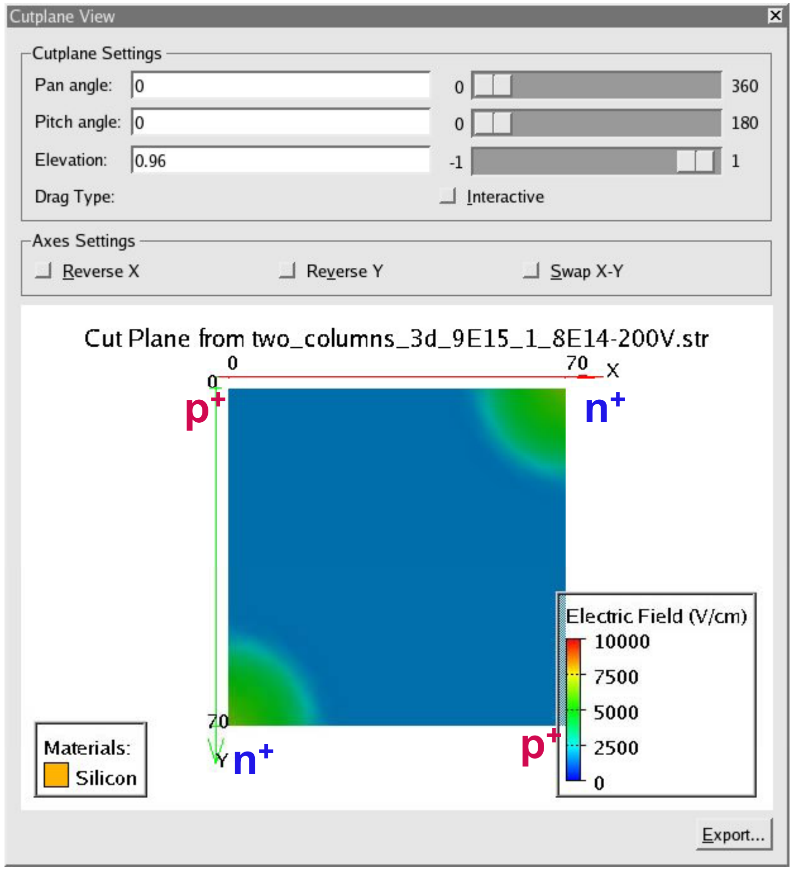


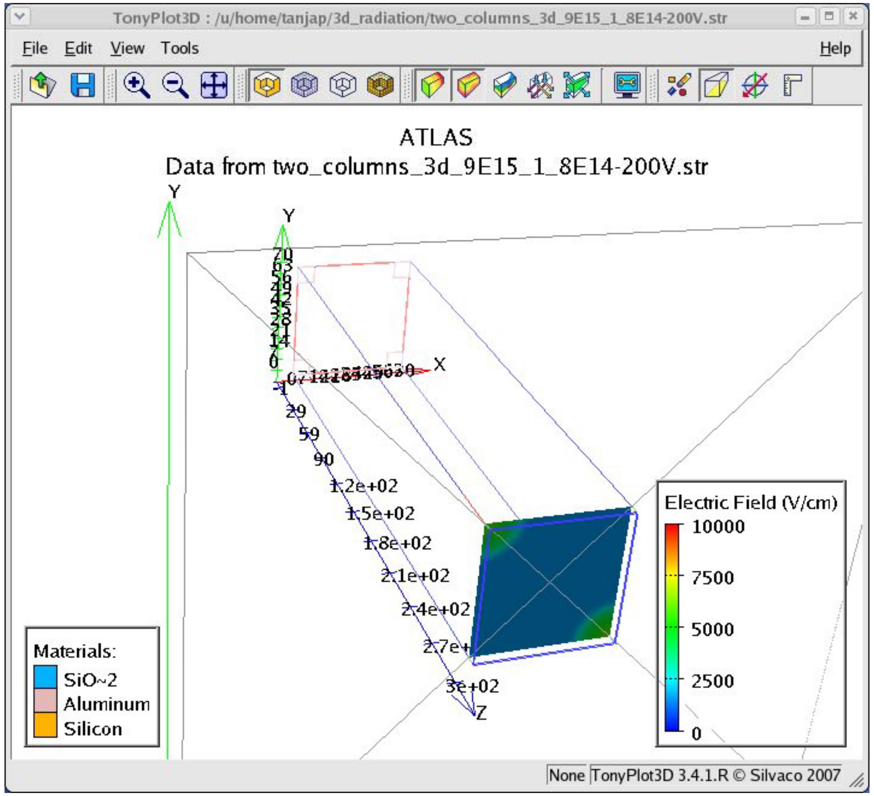


E-field

- electric field

$9x10^{15}$ n_{eq}/cm^2 (200V)



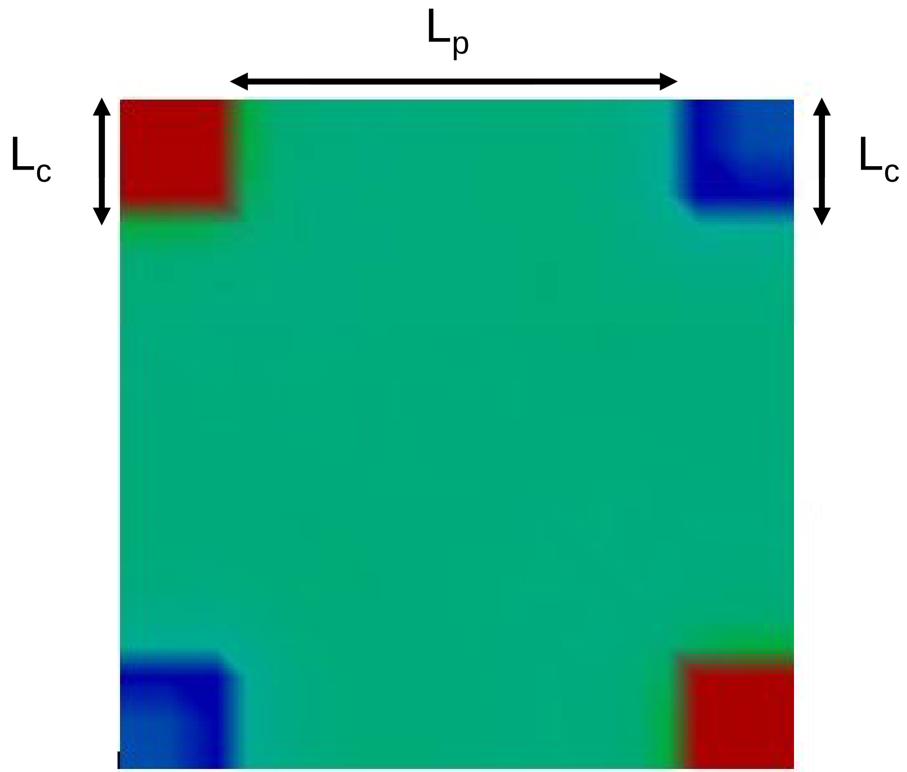


E-field

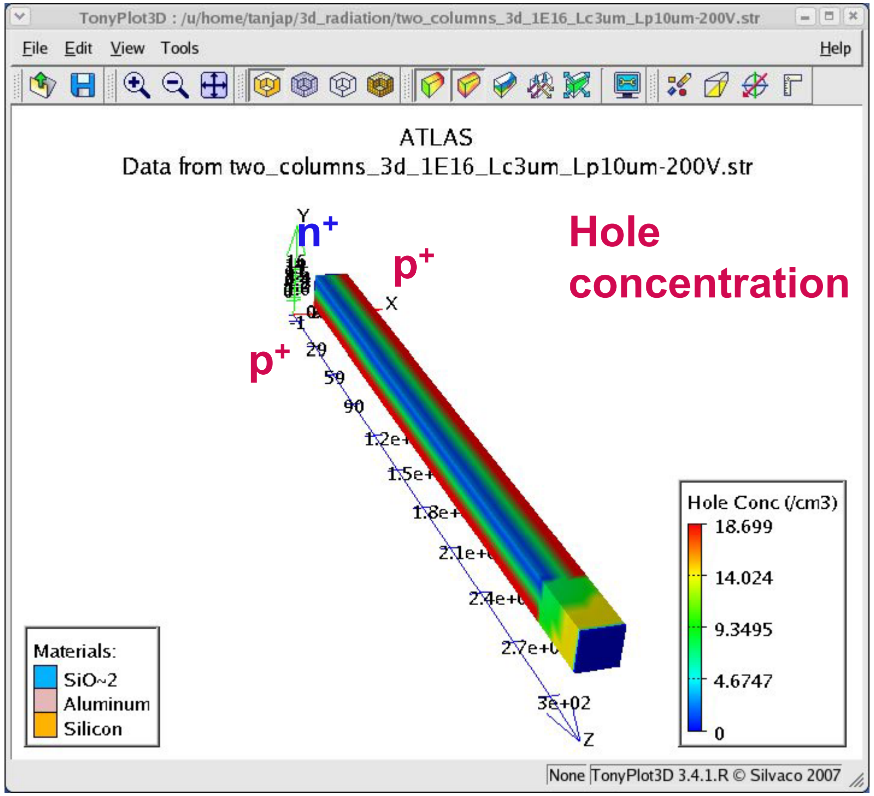
- electric field

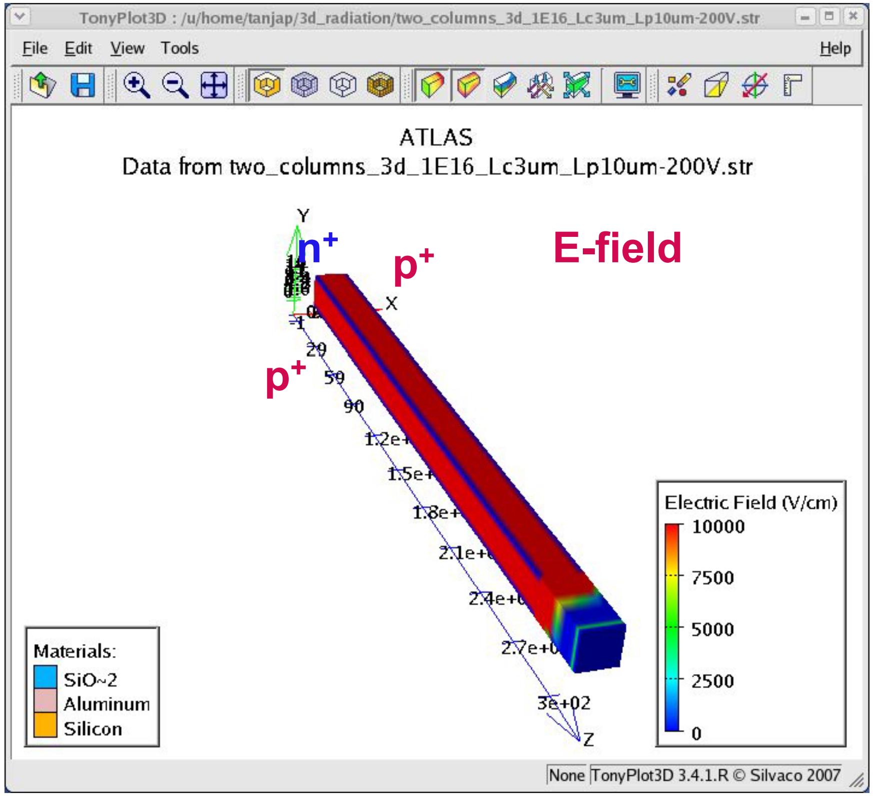
Varieties in detector geometry

- The pad size (L_c) and the distance between pads (L_p) were varied



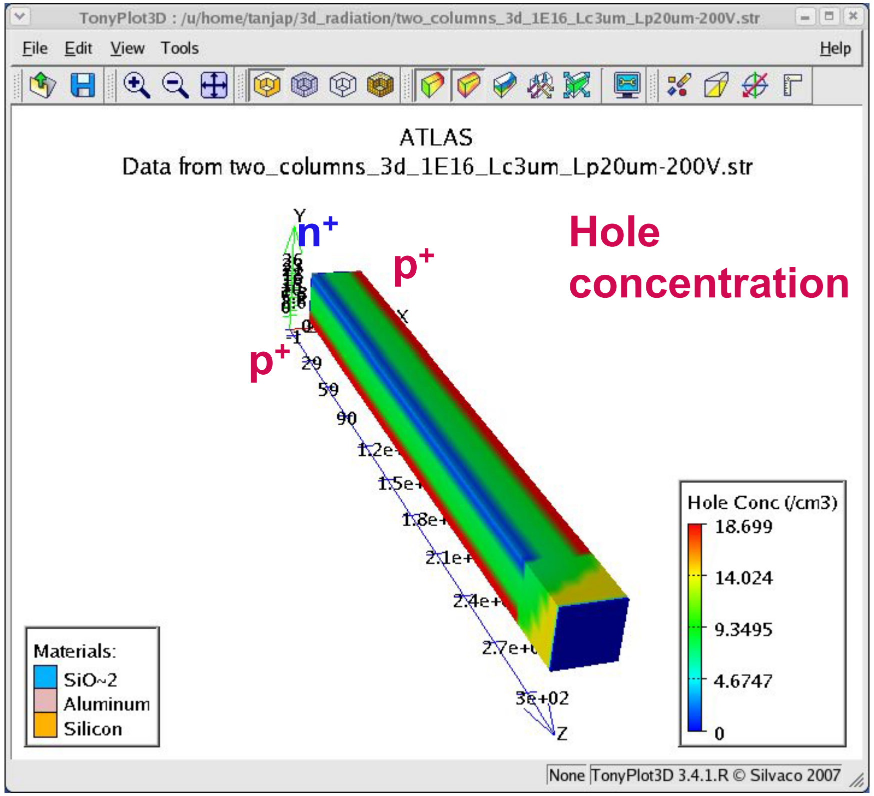
L_c=3um, L_p=10um

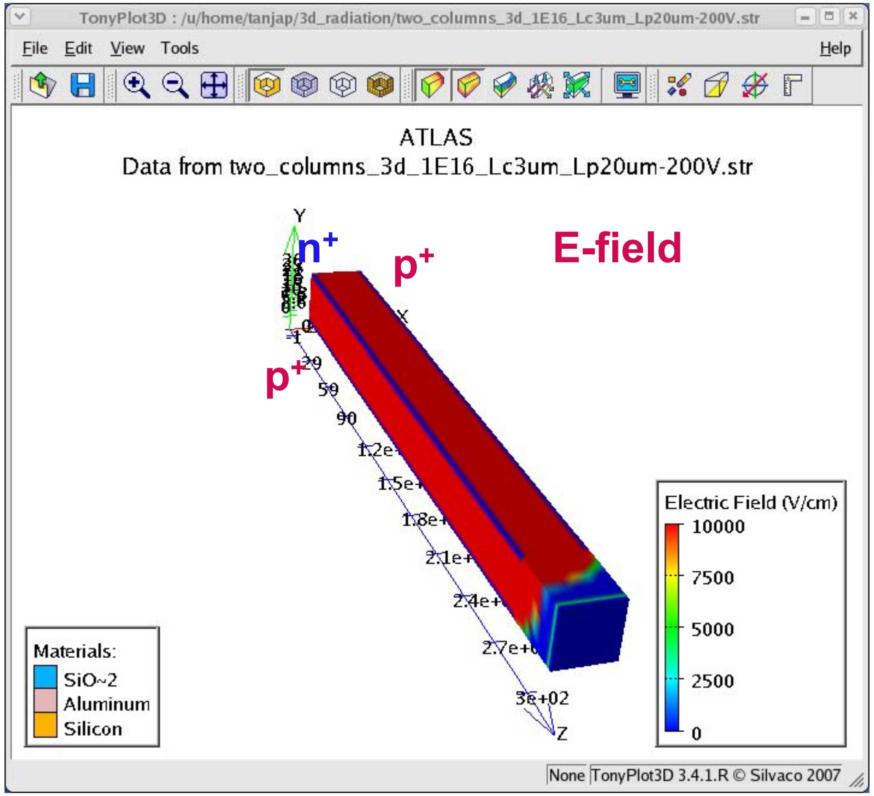




- 200V, hole conc., electric field

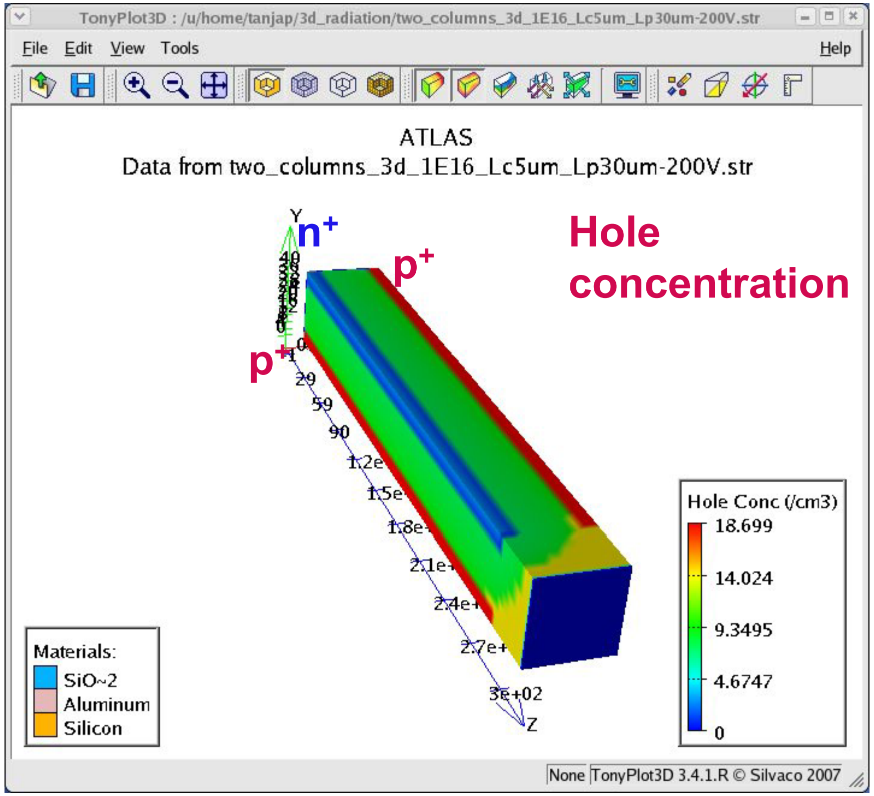
L_c=3um, L_p=20um

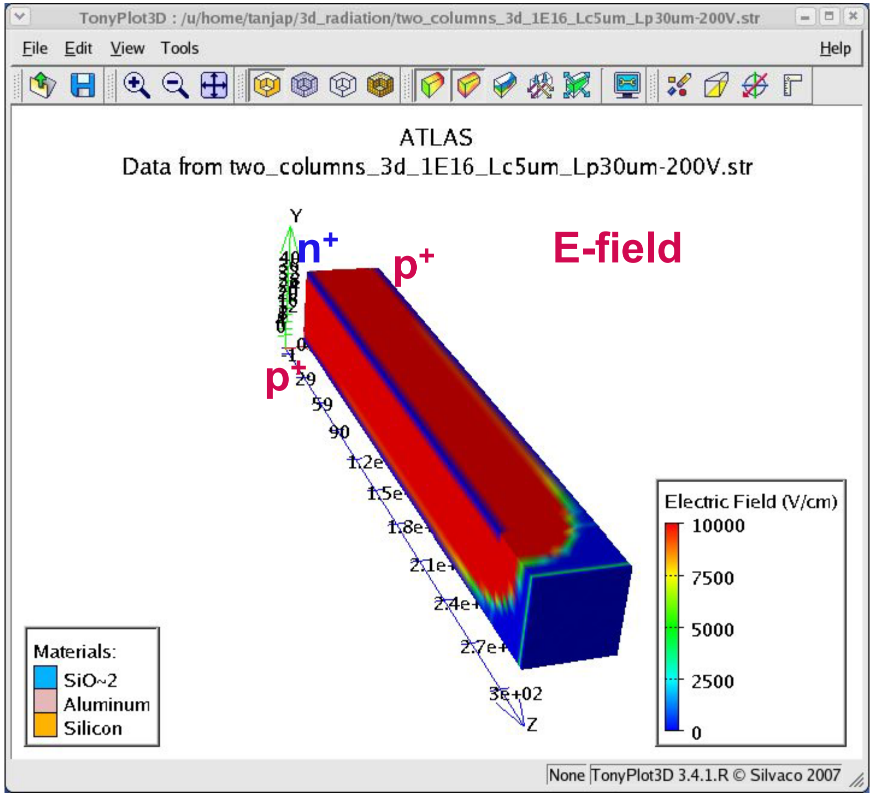




- 200V, hole conc., electric field

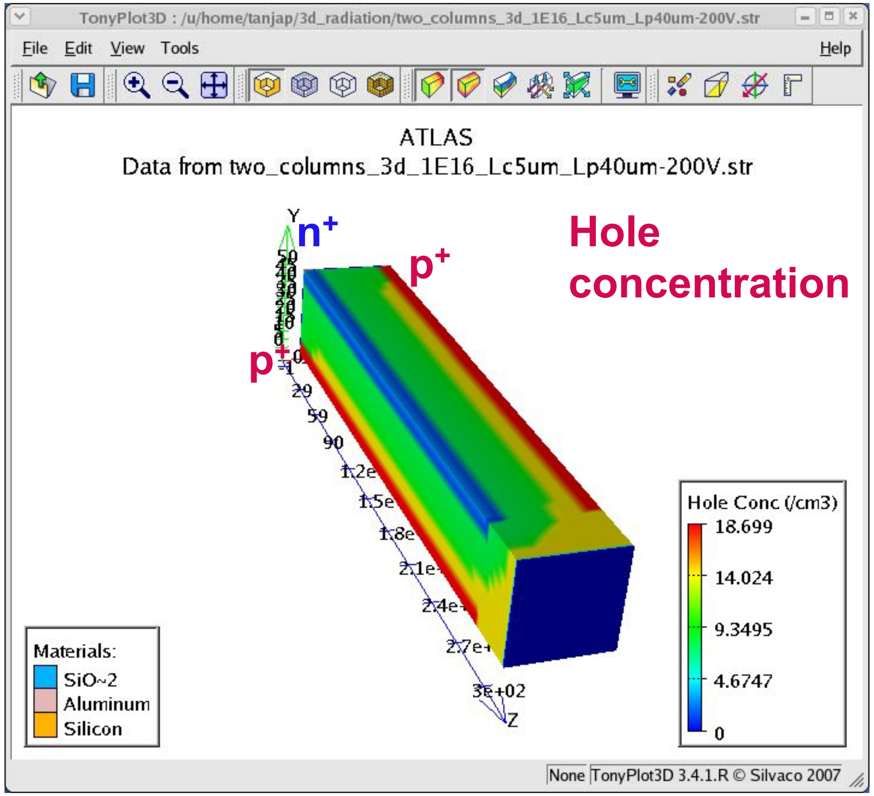
L_c=5um, L_p=30um

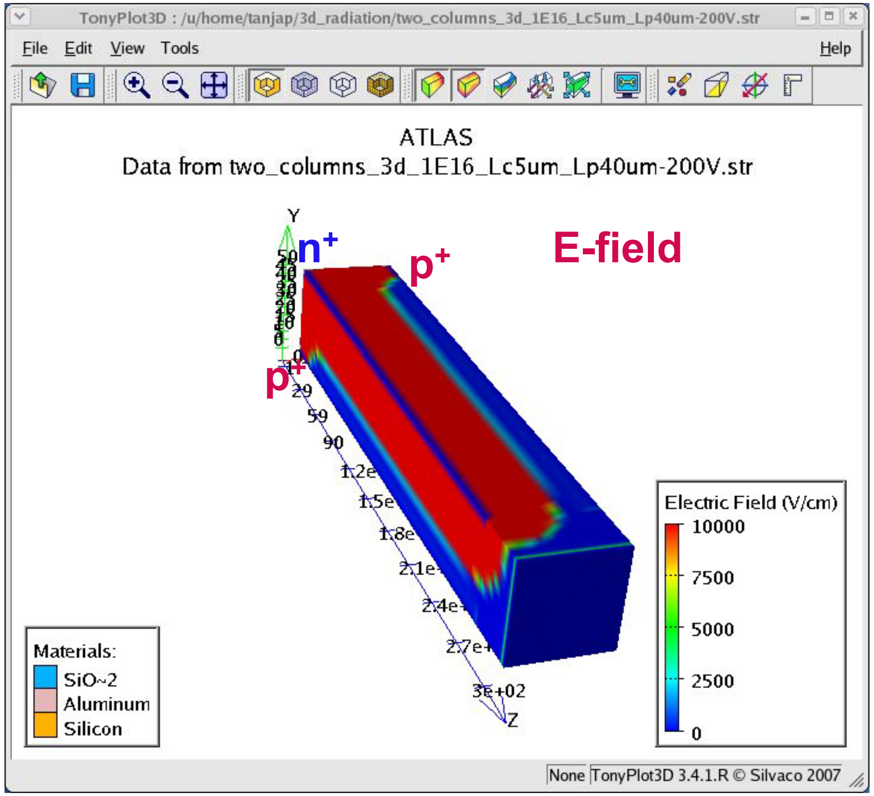




- 200V, hole conc., electric field

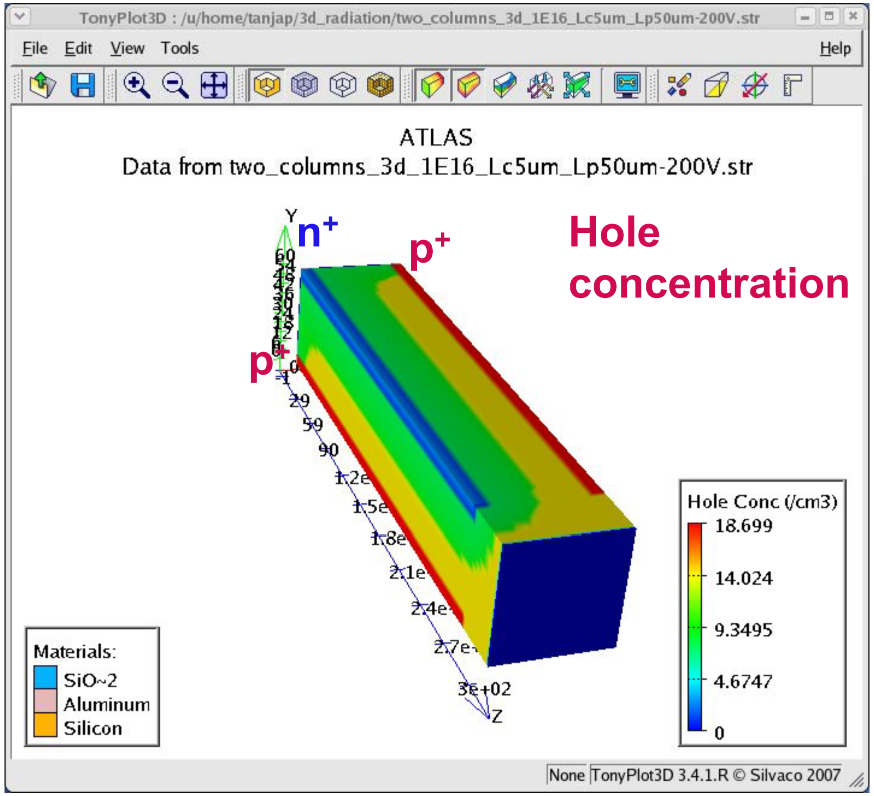
L_c=5um, L_p=40um

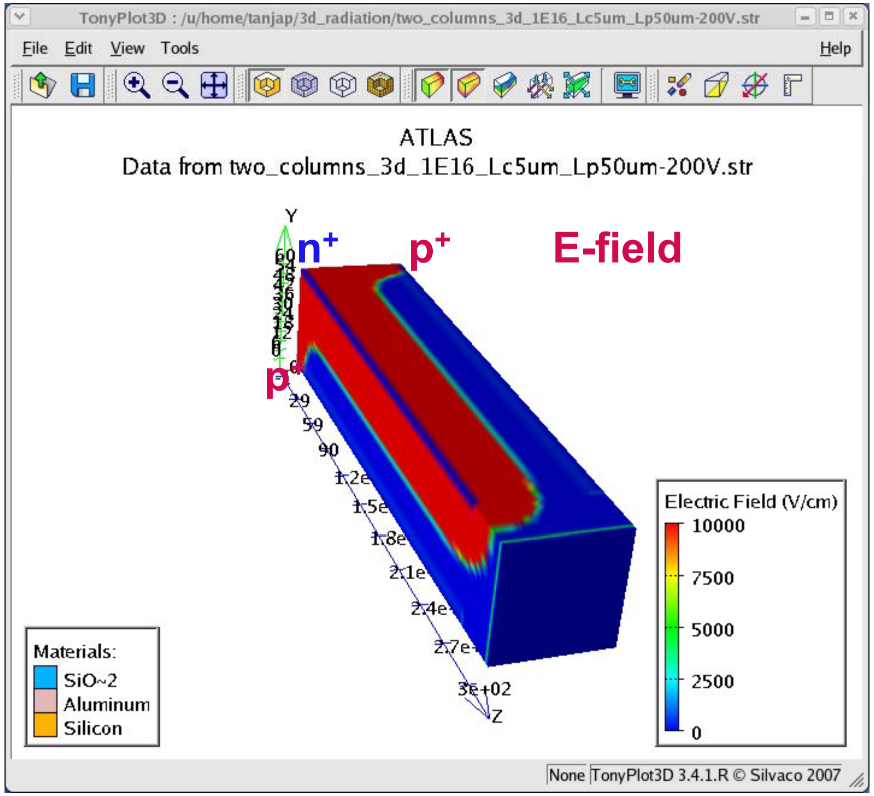




- 200V, hole conc., electric field

L_c=5um, L_p=50um





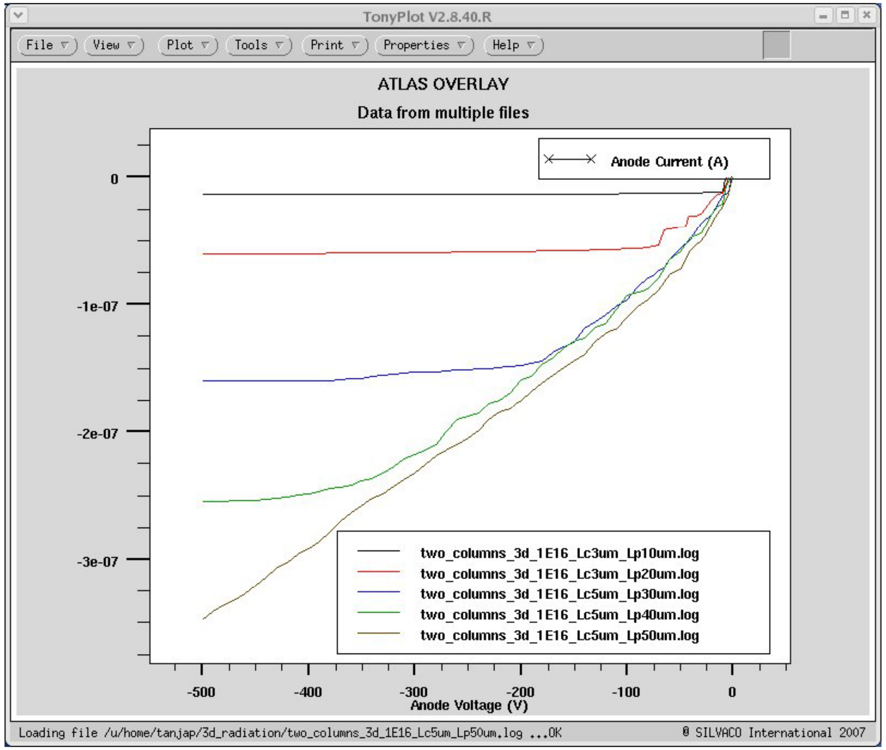
- 200V, hole conc., electric field

Simulated V_{fd} values for different geometries in detector

$L_p \leq 30um$

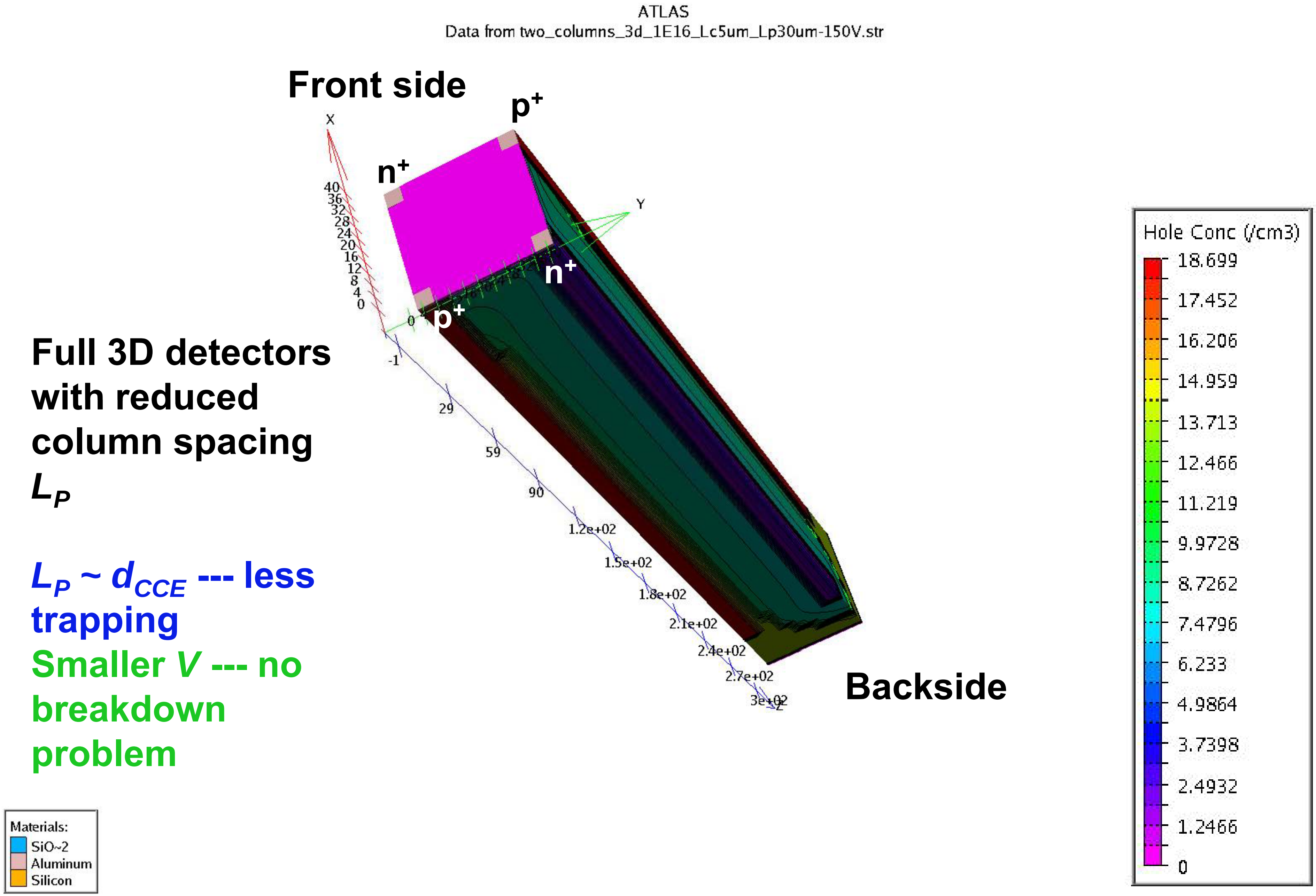
Simulated V_{fd} for dual columns 3D detectors

Fluency	L_c=3um L_p=10um	L_c=3um L_p=20um	L_c=5um L_p=30um	L_c=5um L_p=40um	L_c=5um L_p=50um
1.00E+16	**10**	**80**	**200**	**460**	**>500**



With lifetime degradation

BNL-2C-3D, p-type bulk (300 μm), p^+ and n^+ columns (270 μm)
L_P = 30 μm, $1x10^{16}$ n_{eq}/cm^2, V = 150 V

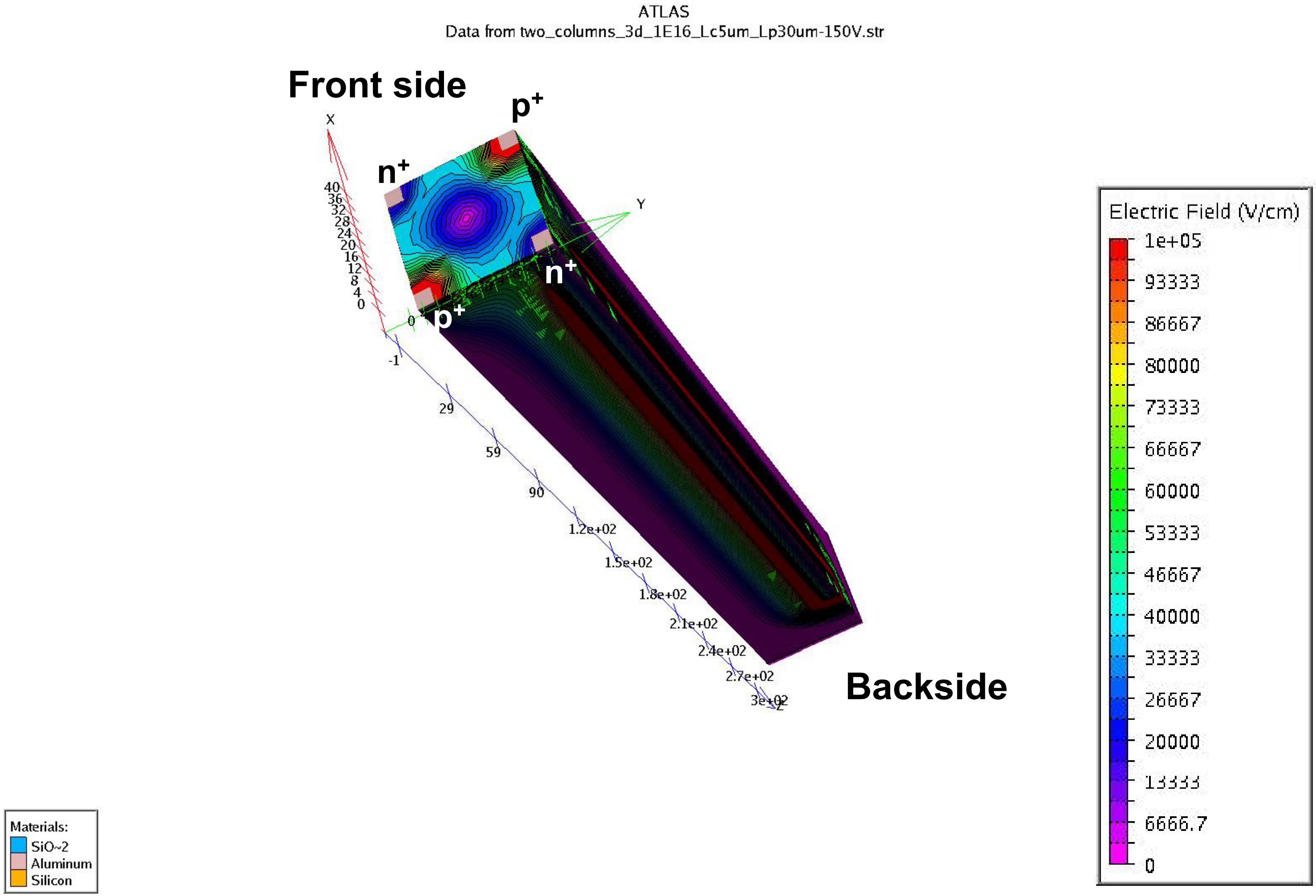


Full 3D detectors with reduced column spacing L_P

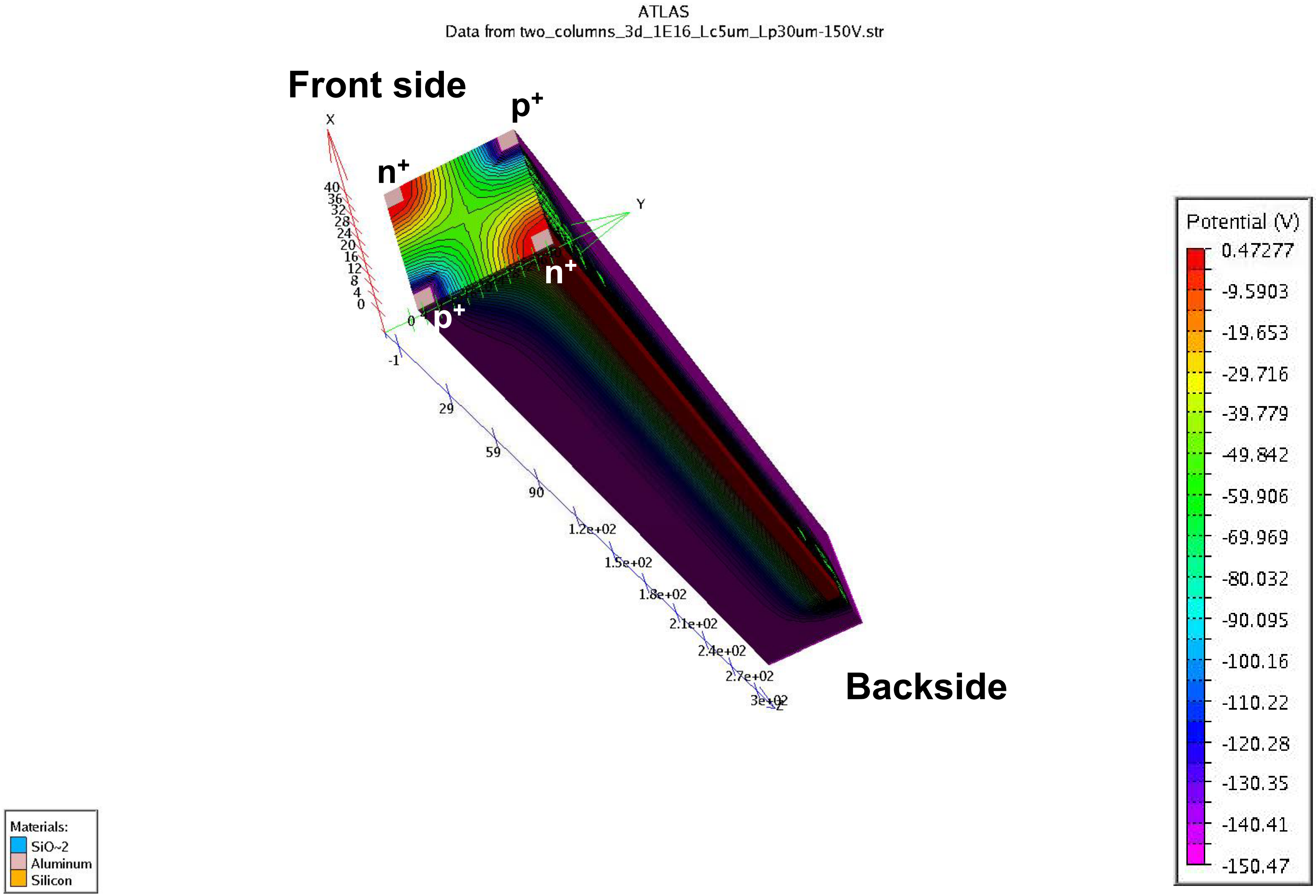
$L_P \sim d_{CCE}$ --- less trapping

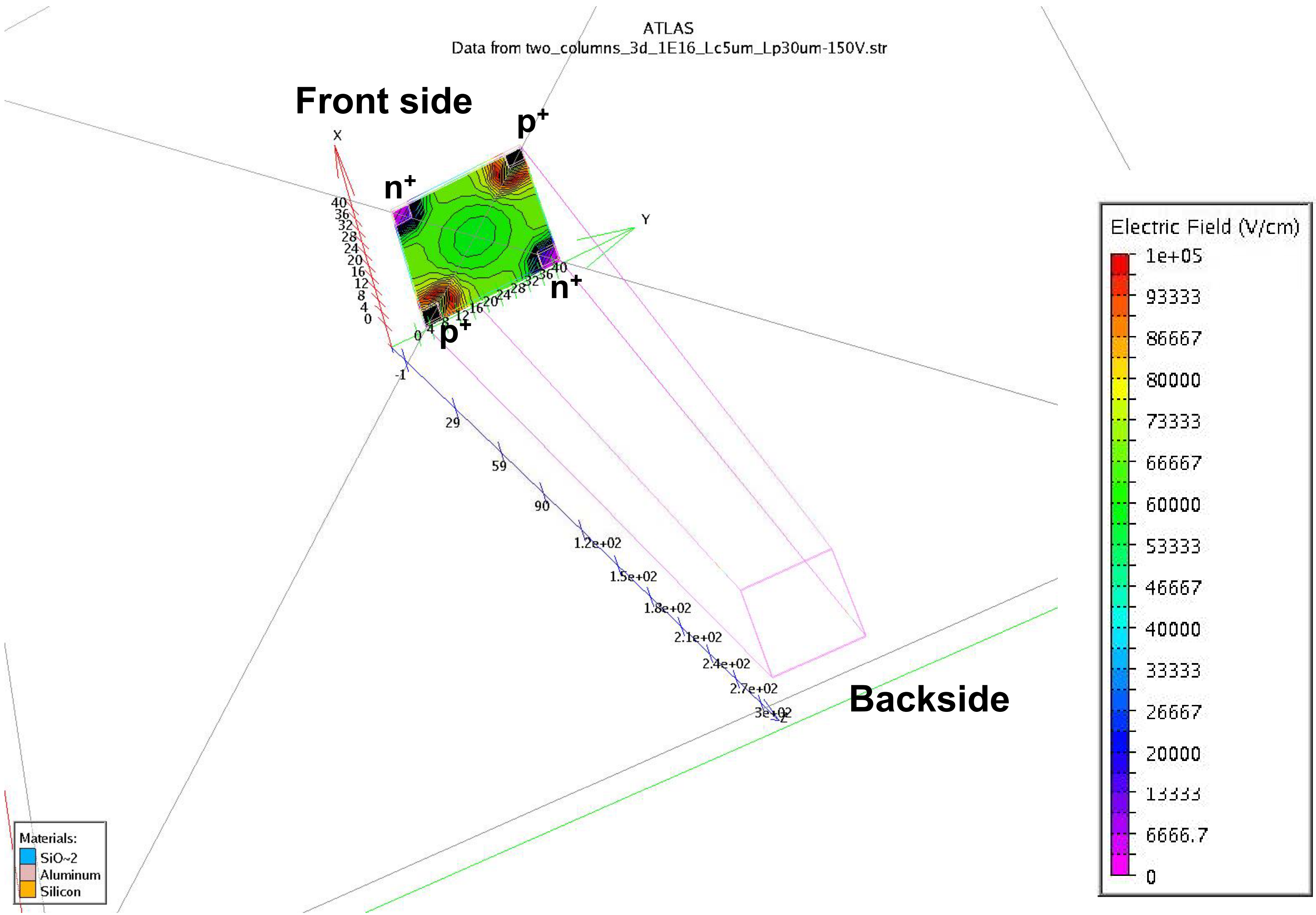
Smaller *V* --- no breakdown problem

BNL-2C-3D, $1x10^{16}$ n_{eq}/cm^2, 150 V

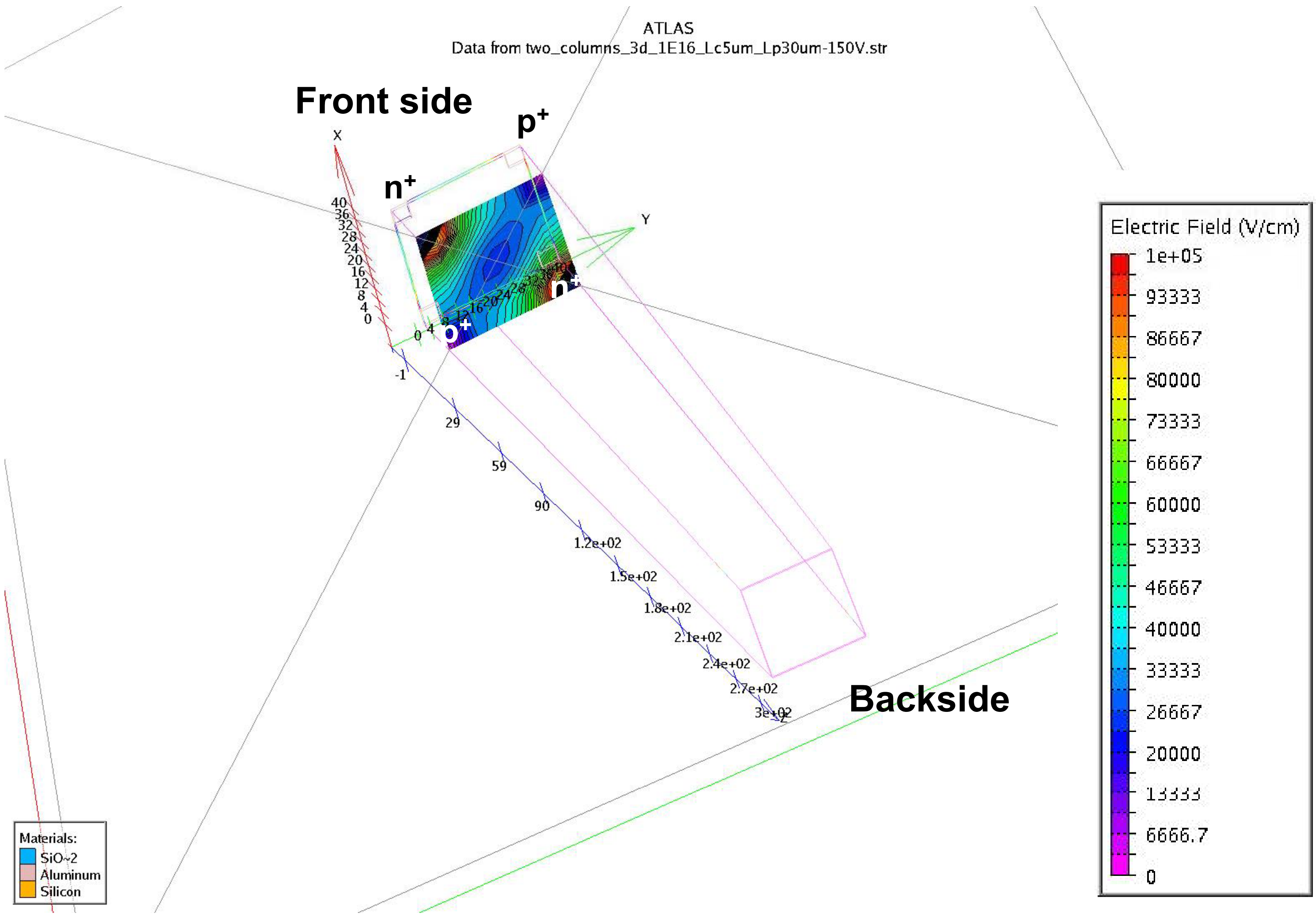


BNL-2C-3D, 1×10^{16} n_{eq}/cm^2, 150 V

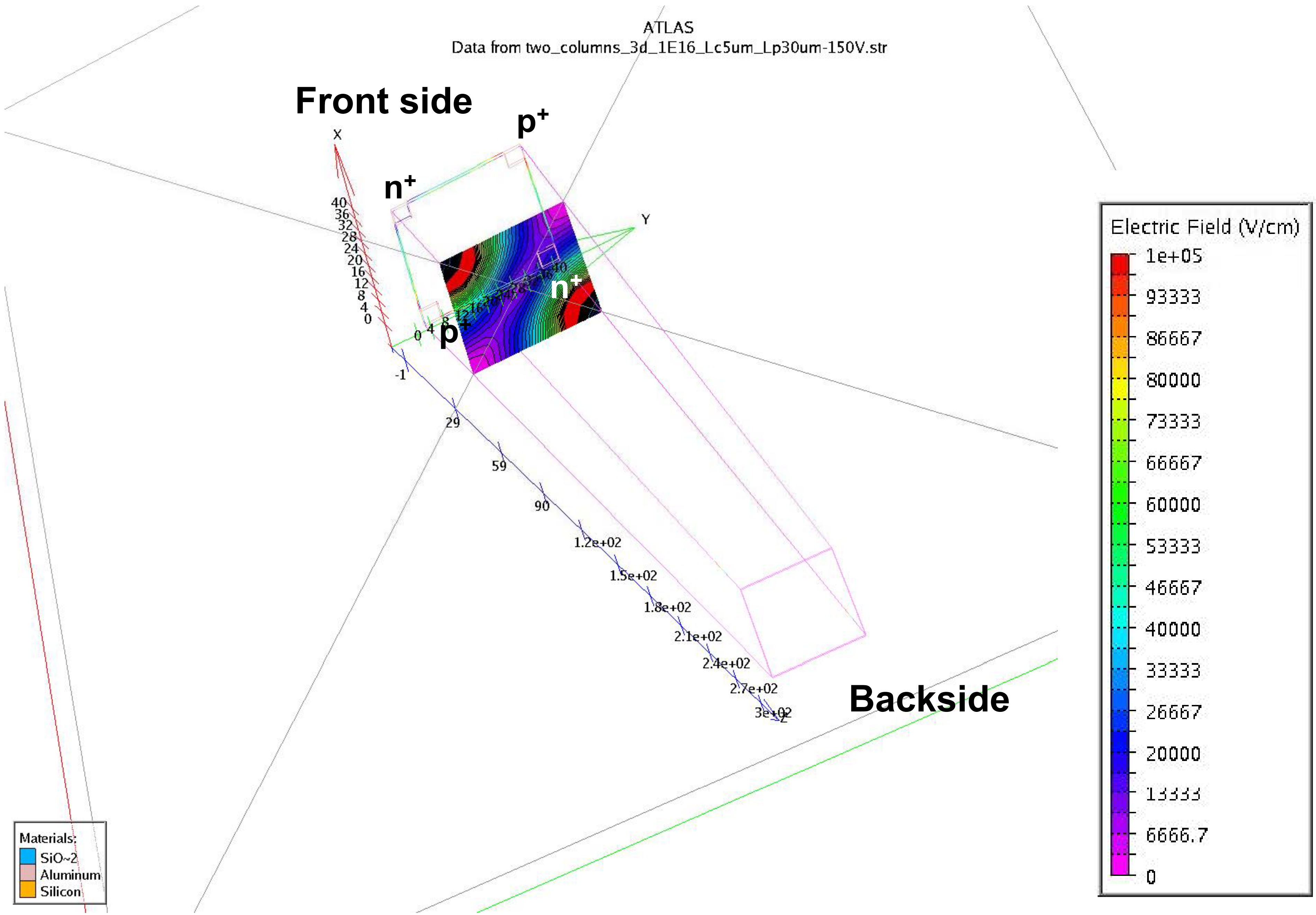


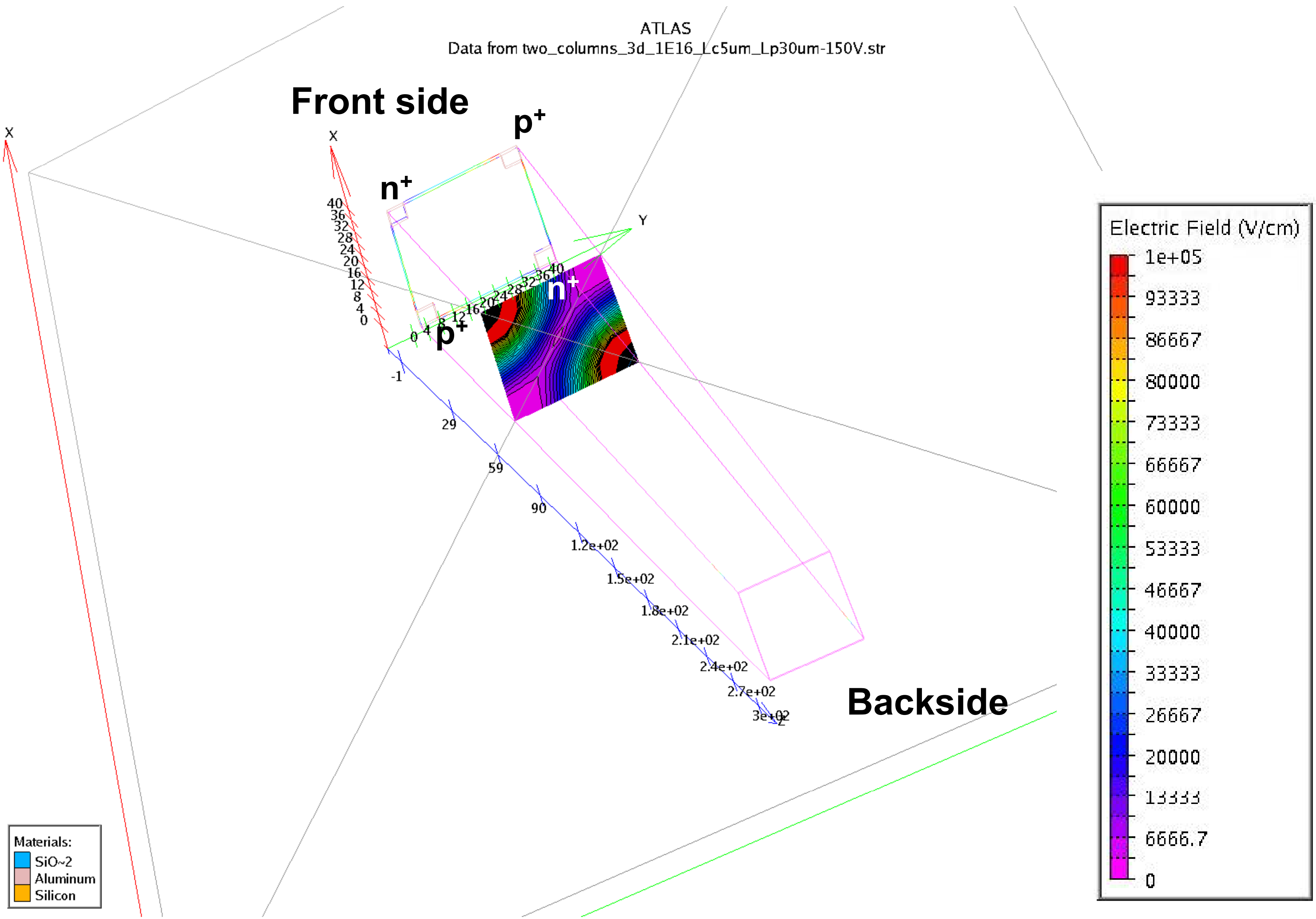


ATLAS
Data from two_columns_3d_1E16_Lc5um_Lp30um-150V.str
Front side
p^+
n^+
n^+
p^+
X
Y
Backside
Electric Field (V/cm)
1e+05
93333
86667
80000
73333
66667
60000
53333
46667
40000
33333
26667
20000
13333
6666.7
0
Materials:
SiO~2
Aluminum
Silicon

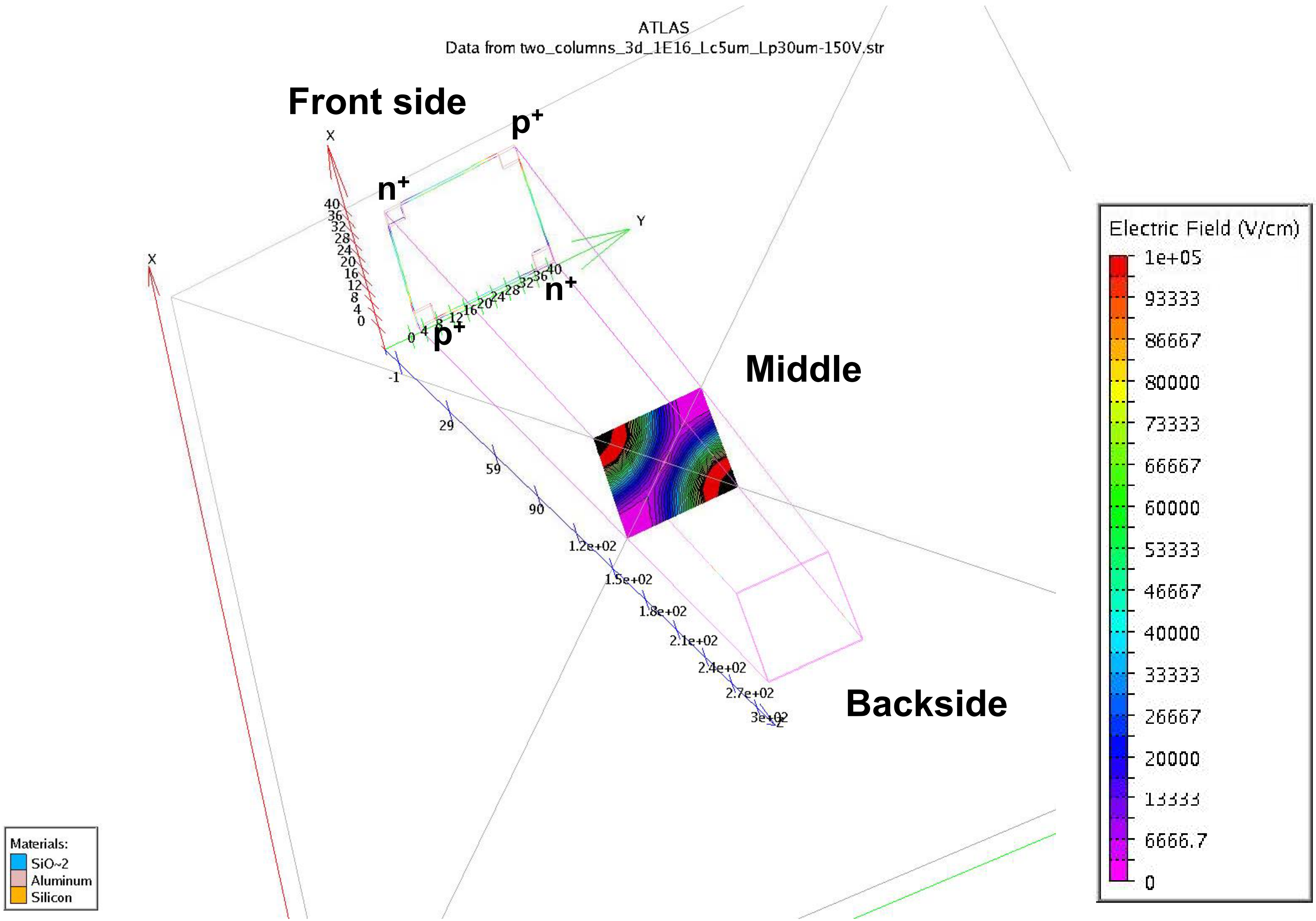


ATLAS
Data from two_columns_3d_1E16_Lc5um_Lp30um-150V.str
Front side
p+
n+
n+
p+
Backside
X
Y
Electric Field (V/cm)
1e+05
93333
86667
80000
73333
66667
60000
53333
46667
40000
33333
26667
20000
13333
6666.7
0
Materials:
SiO~2
Aluminum
Silicon

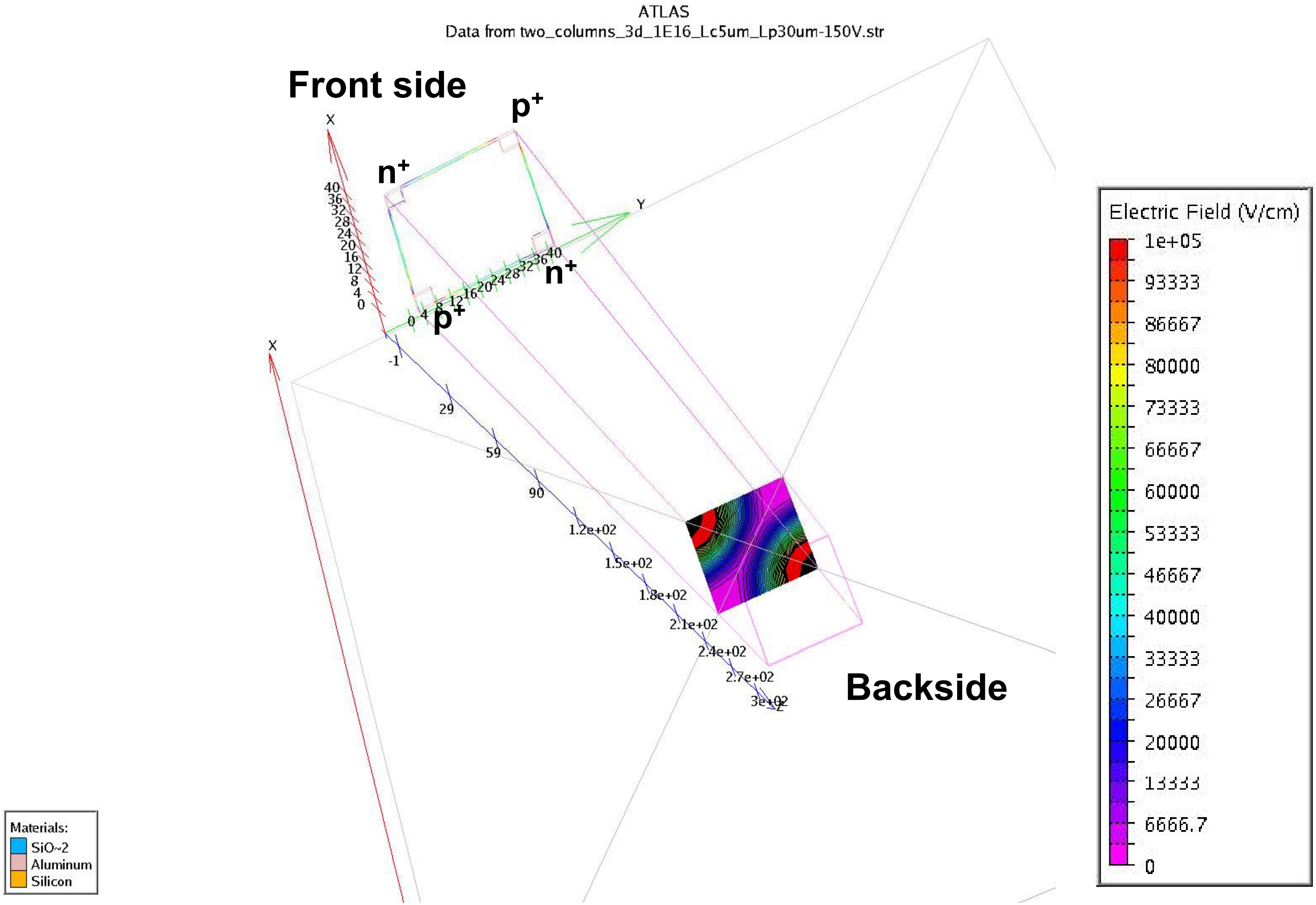

ATLAS
Data from two_columns_3d_1E16_Lc5um_Lp30um-150V.str
Front side
p+
n+
n+
p+
Backside
X
Y
Z
Electric Field (V/cm)
1e+05
93333
86667
80000
73333
66667
60000
53333
46667
40000
33333
26667
20000
13333
6666.7
0
Materials:
SiO~2
Aluminum
Silicon

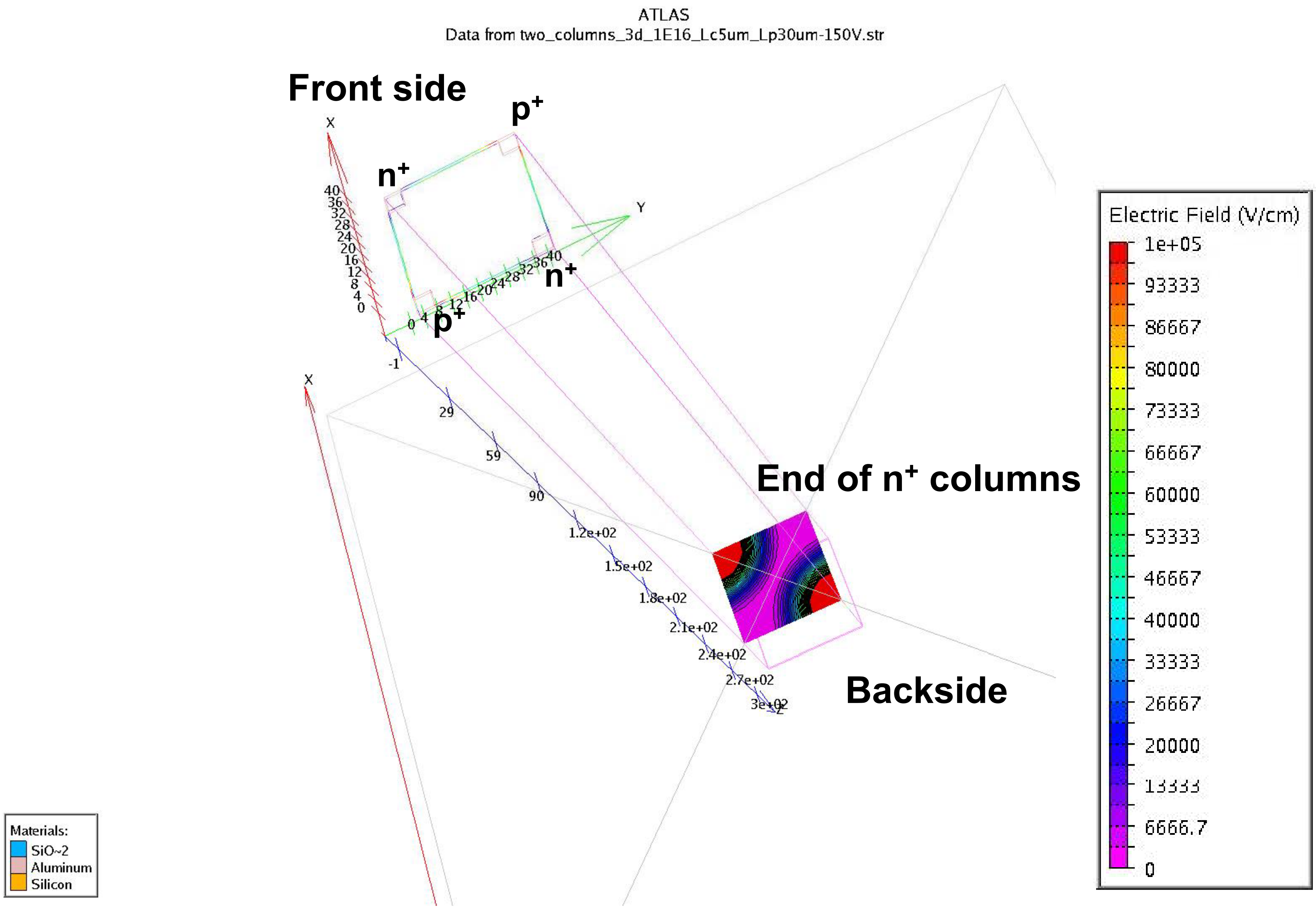


ATLAS
Data from two_columns_3d_1E16_Lc5um_Lp30um-150V.str
Front side
p+
n+
n+
p+
Backside
X
Y
Z
Electric Field (V/cm)
1e+05
93333
86667
80000
73333
66667
60000
53333
46667
40000
33333
26667
20000
13333
6666.7
0
Materials:
SiO~2
Aluminum
Silicon

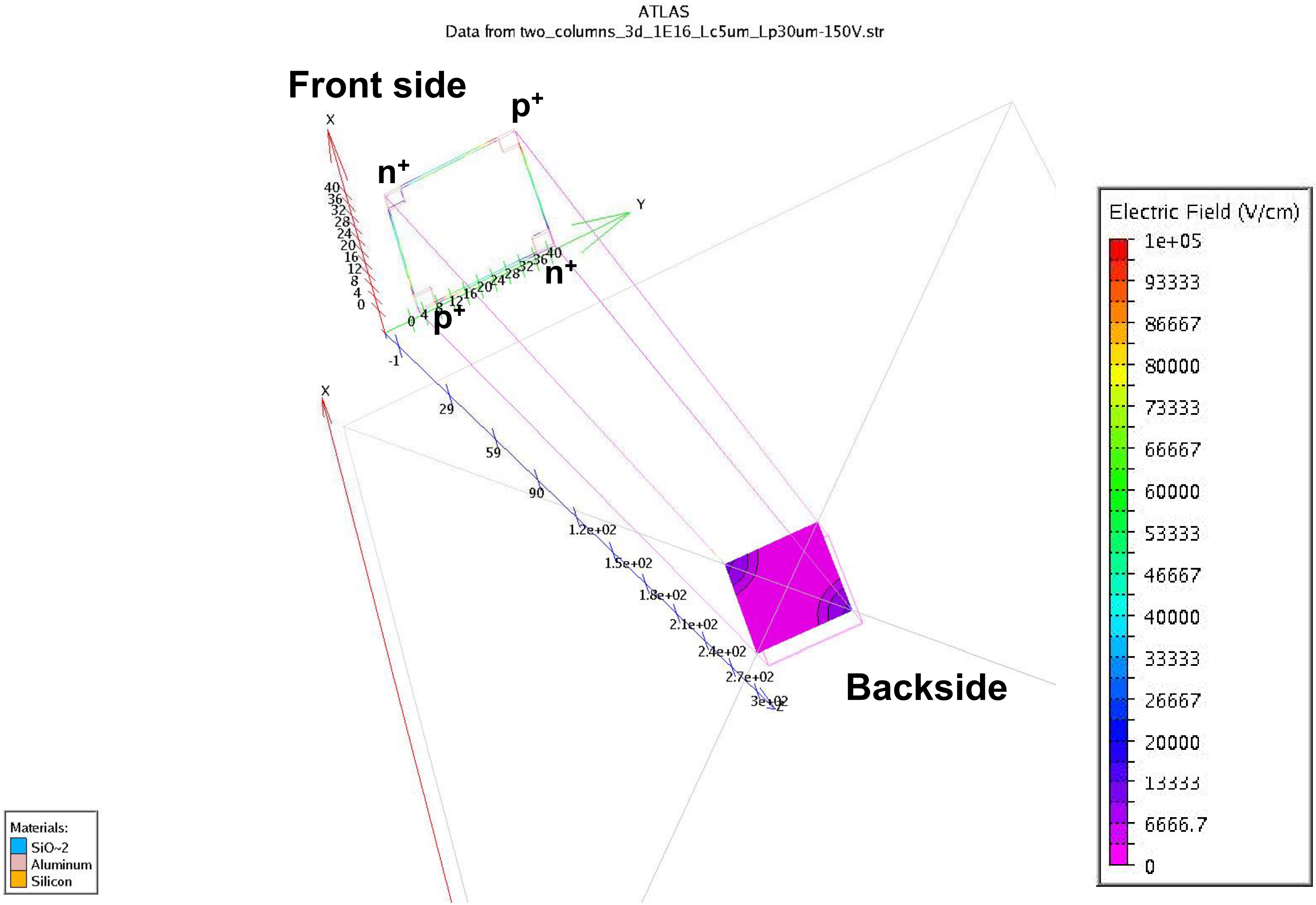


ATLAS
Data from two_columns_3d_1E16_Lc5um_Lp30um-150V.str
Front side
p+
n+
n+
p+
Middle
Backside
Electric Field (V/cm)
1e+05
93333
86667
80000
73333
66667
60000
53333
46667
40000
33333
26667
20000
13333
6666.7
0
Materials:
SiO~2
Aluminum
Silicon


ATLAS
Data from two_columns_3d_1E16_Lc5um_Lp30um-150V.str
Front side
p^+
n^+
n^+
p^+
Backside
Electric Field (V/cm)
1e+05
93333
86667
80000
73333
66667
60000
53333
46667
40000
33333
26667
20000
13333
6666.7
0
Materials:
SiO~2
Aluminum
Silicon

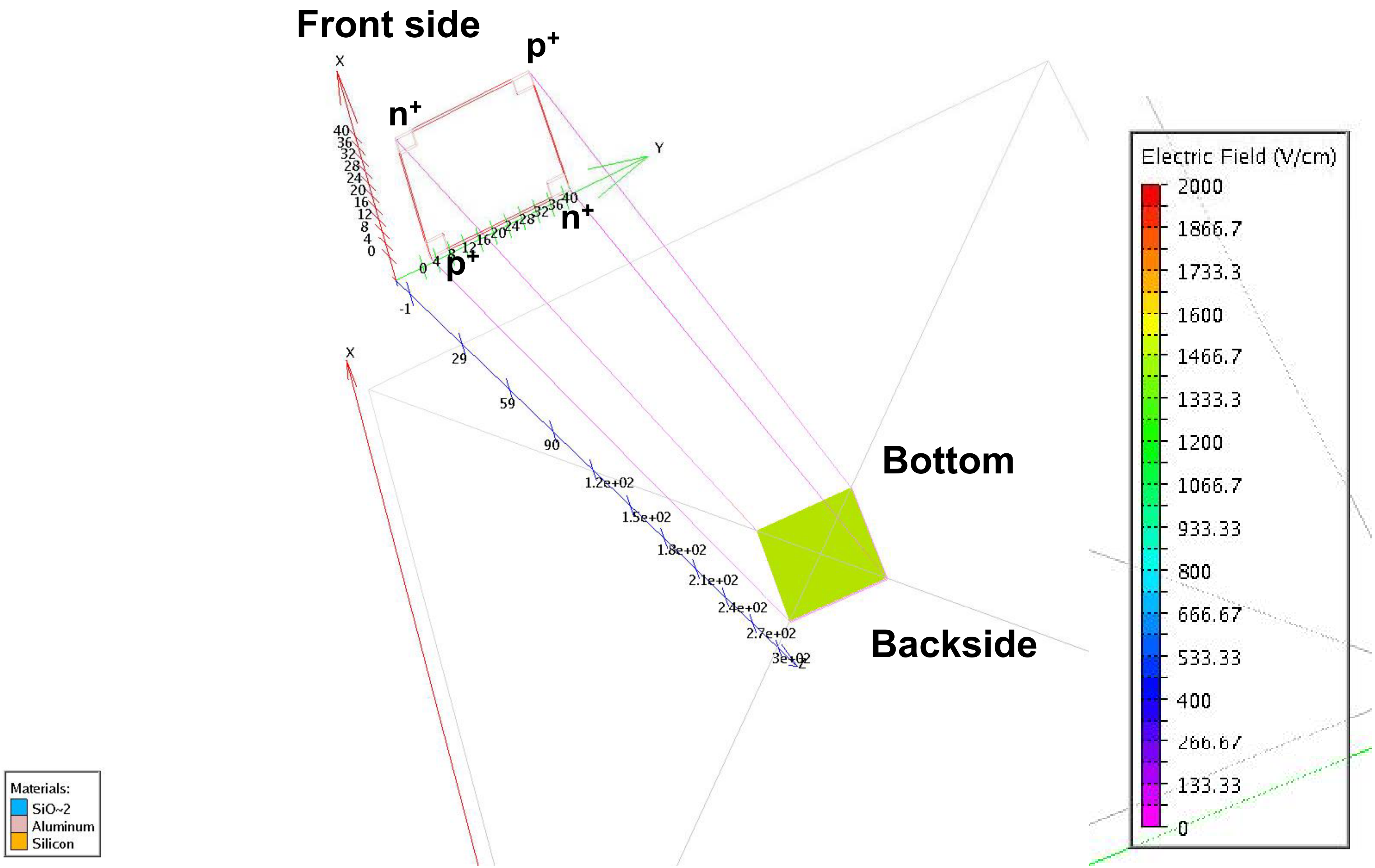


ATLAS
Data from two_columns_3d_1E16_Lc5um_Lp30um-150V.str
Front side
p+
n+
n+
p+
End of n+ columns
Backside
Electric Field (V/cm)
1e+05
93333
86667
80000
73333
66667
60000
53333
46667
40000
33333
26667
20000
13333
6666.7
0
Materials:
SiO~2
Aluminum
Silicon



ATLAS
Data from two_columns_3d_1E16_Lc5um_Lp30um-150V.str
Front side
p+
n+
n+
p+
Backside
Electric Field (V/cm)
1e+05
93333
86667
80000
73333
66667
60000
53333
46667
40000
33333
26667
20000
13333
6666.7
0
Materials:
SiO~2
Aluminum
Silicon

ATLAS
Data from two_columns_3d_1E16_Lc5um_Lp30um-150V.str



Characterization of new BNL 3d Si test detectors

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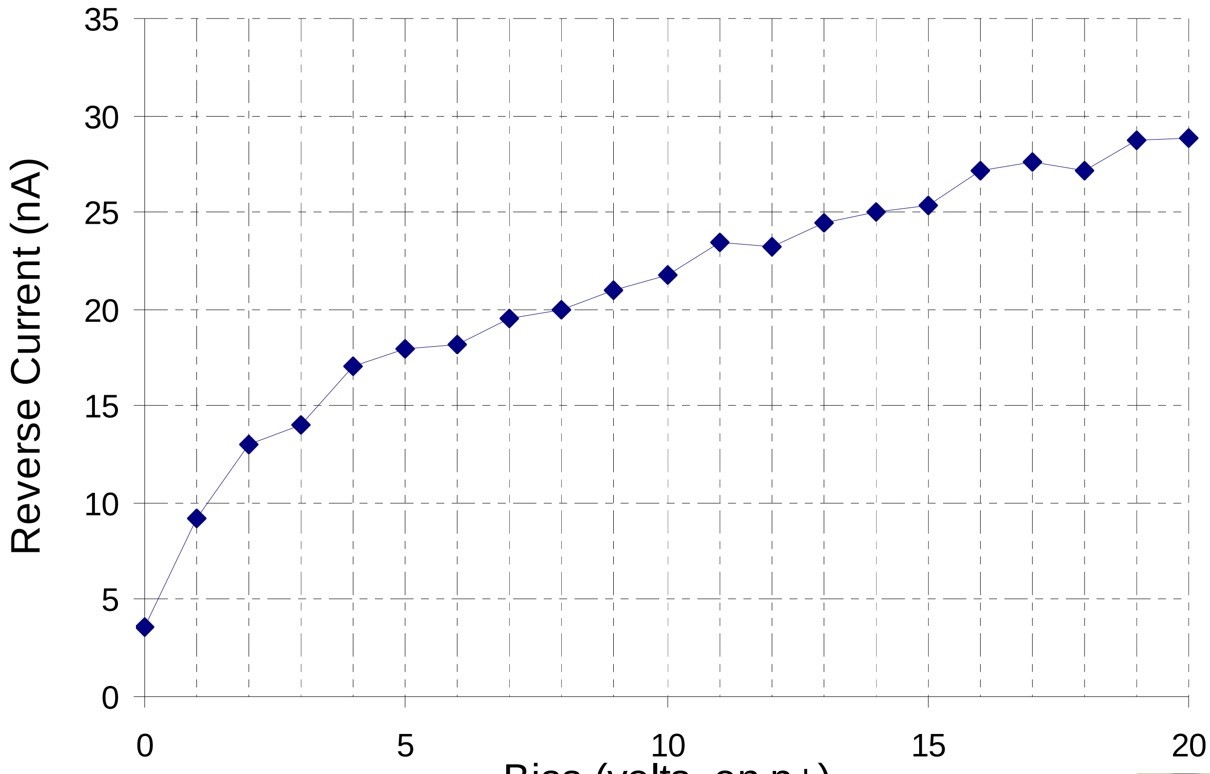
M.Lozano[2], G.Pellegrini[2]

[1]Instituto de Física Corpuscular, Aptdo. de correos 22085 E-46071, Paterna (Valencia), Spain

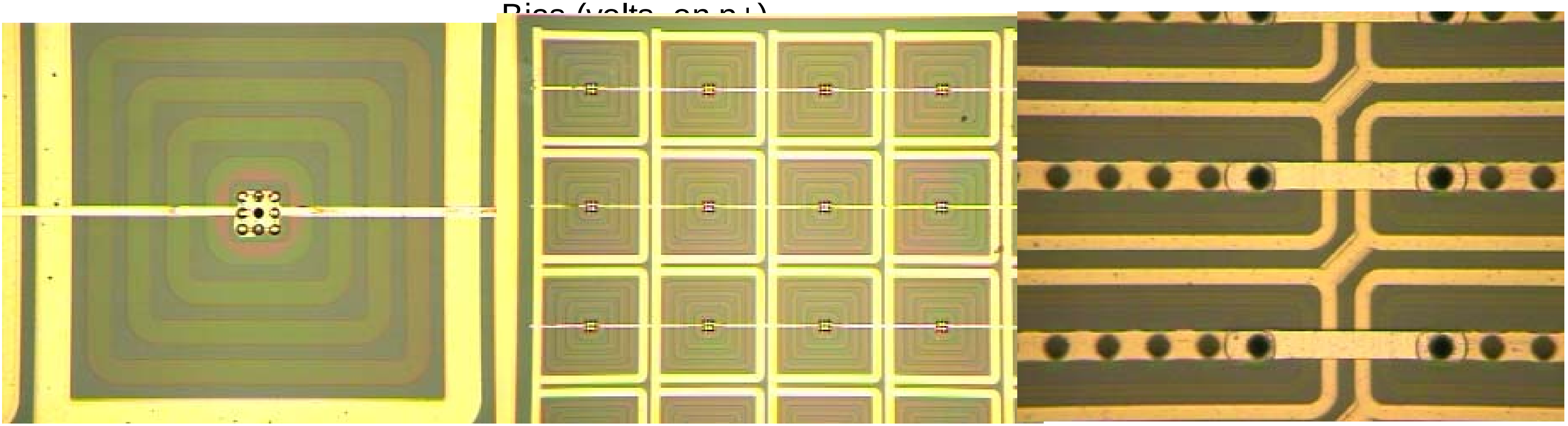
[2]Centro Nacional de Microelectrónica, Campus …rsidad … Autónoma de Barcelona, 08193, …erra (Barcelona), Spain

Current measurements

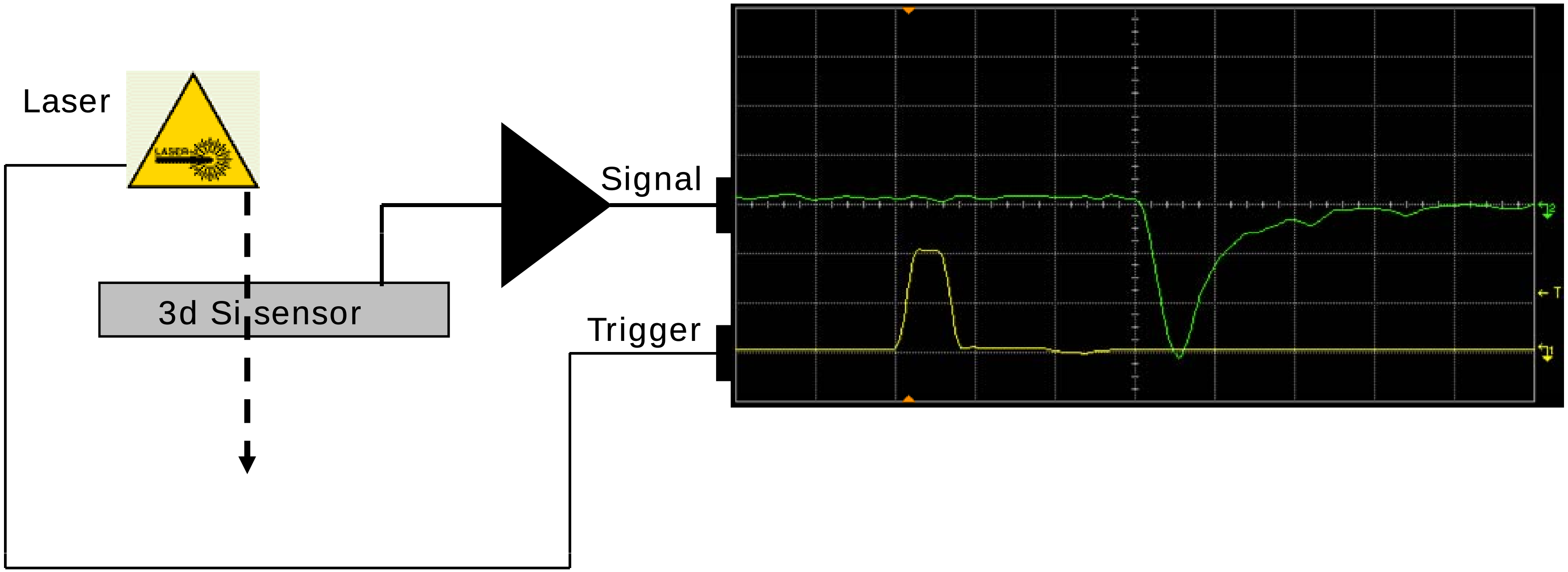


- Ta= 23ºC
- Biasing all Y p^+ strips negative
- Guard ring grounded

BNL 3D stripixel



Setup in Valencia



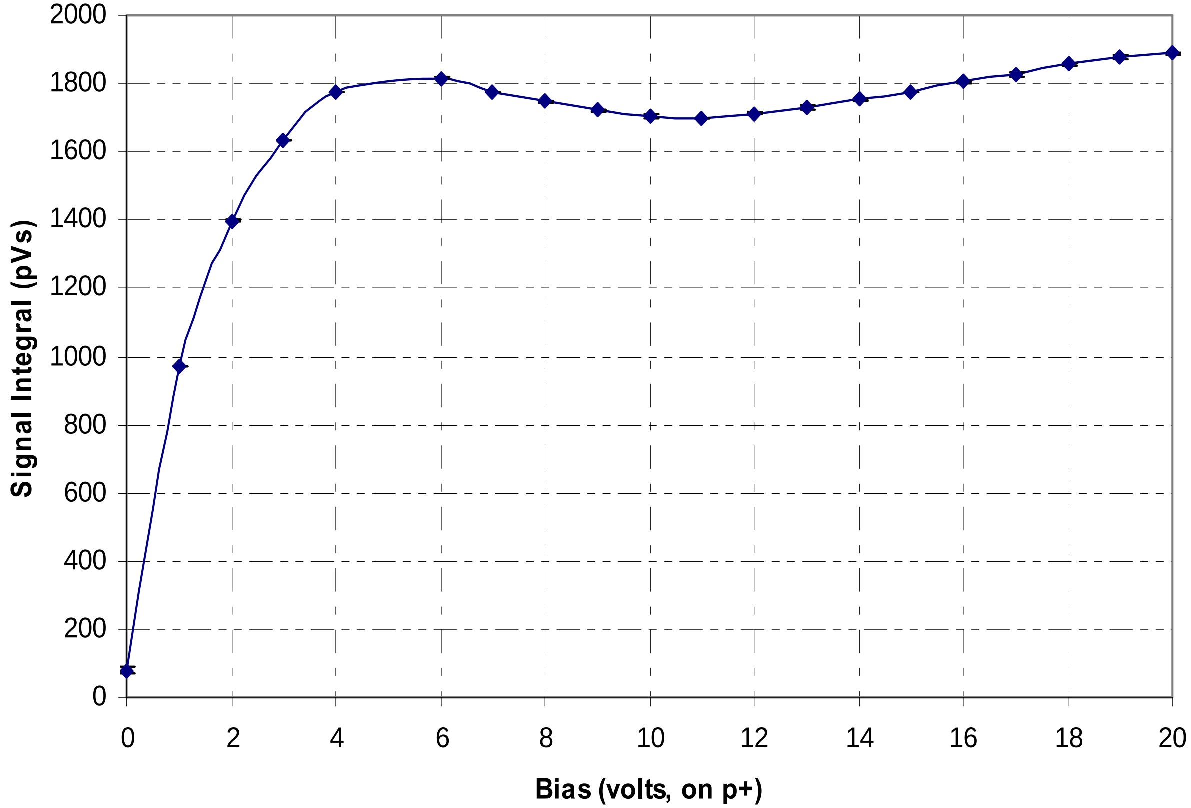
- Laser light is generated by exciting a laser source with an external pulsed signal

(2 V and 1 MHz rate)

Laser properties:

- λ=1060 nm (Near Infrared)
- Laser energy of photons=1.170 eV

Charge collection measurements



- Biasing all Y p^+ strips negative
- The signal corresponds to the X n^+ holes
- Fully depleted at about 4 volts

SUMMARY

- Simulated V_{fd} for a dual-column 3D detector is about 1.4 time higher than that of a 2D pad detector with $d = L_p$
- Highest E-field is near the n^+ column, and high field mainly distributes between the n^+ and p^+ columns.
- Low E-field is between the two p^+ columns, and the lowest E-field is in the center of the unit cell
- In order to fully deplete a dual-column 3D detector at 1×10^{16} n_{eq}/cm^2 with a reasonable bias (<200 V), the n^+-p^+ column spacing L_p should be reduced to 40 μm (<50 μm)
- The volume under the column can be depleted with modest biases: not a dead area, and providing a sensitivity under the columns