Full 3D Simulations of BNL Silicon 3D Detectors and Comparisons with other Types of 3D Detectors

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at Brookhaven National Laboratory

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OUTLINE

- 3D Simulation tools
- Simulated 3D detector structures
  - BNL one-sided single column
    - Comparing with Trento single column
  - BNL one-sided dual column
    - Comparing with Trento/CNM 2-sided dual column and UH dual column
- Advantages and disadvantages
- Summary

3D detector simulations

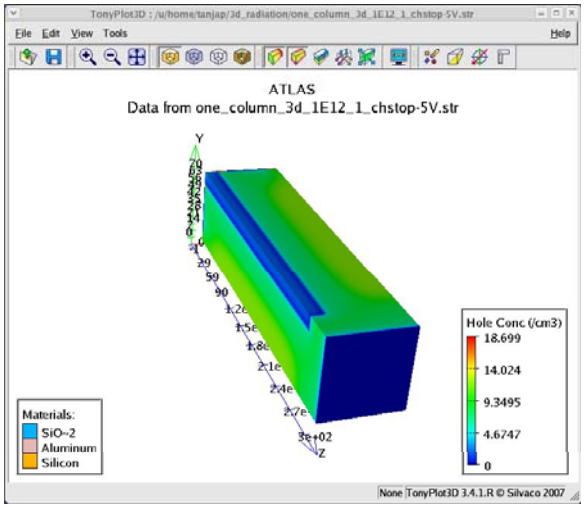
- Silicon radiation 3D detectors were simulated in three-dimensional with simulation software Silvaco
  - DEVEDIT3D

    Used to define the detector structure by defining the mesh, material regions and impurities
  - DEVICE3D (ATLAS)

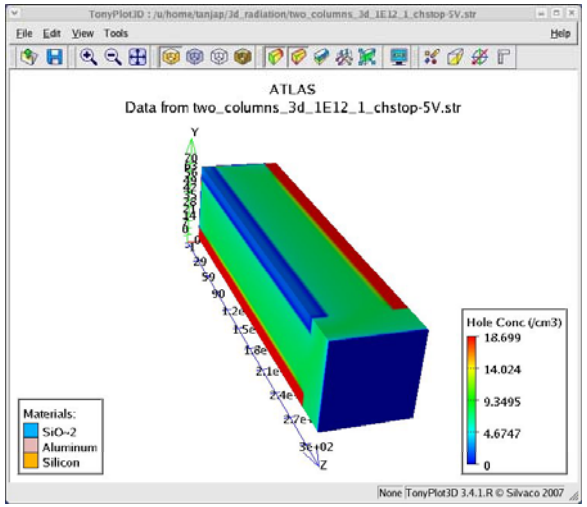
    Same as S-PISCES in ATLAS 2D, the device simulation, used to solve device parameters

3D detector structures

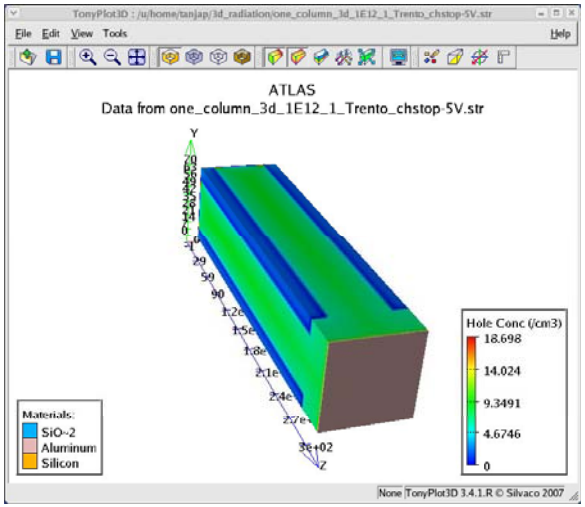
- Four different 3D detector structures were under investigation.
- In the all cases, the bulk was p-type.



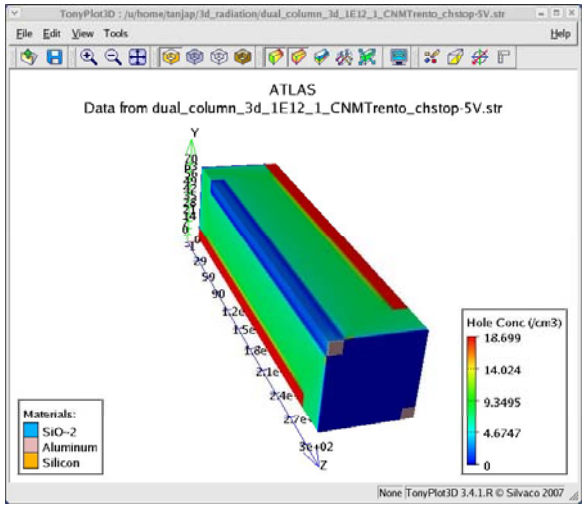
a) BNL single column



b) BNL dual column



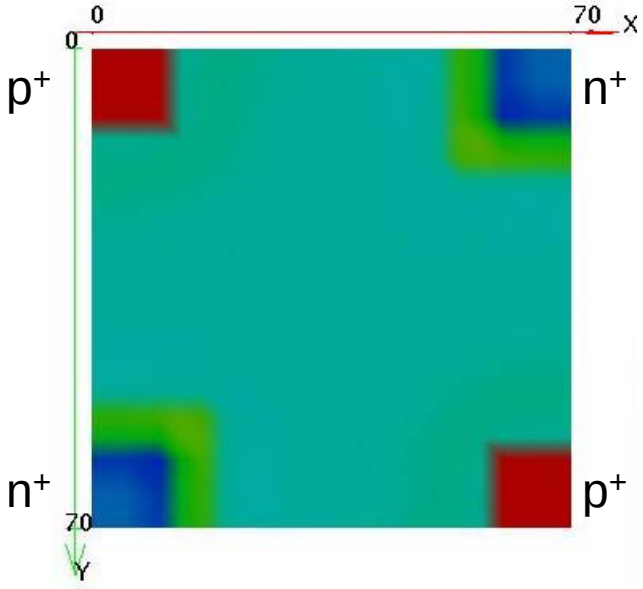
c) Trento single column

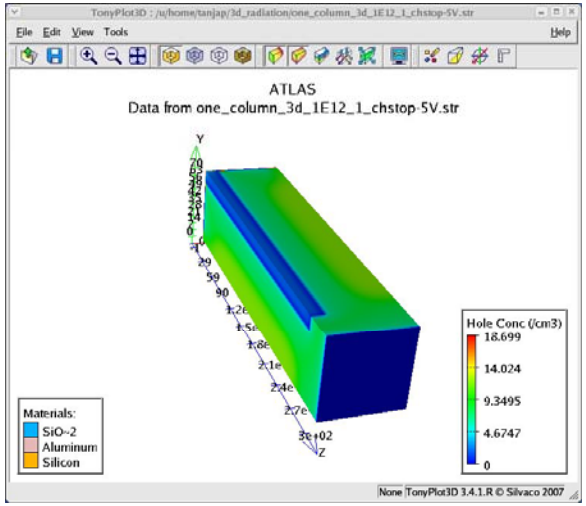


d) CNM, Trento dual column

BNL Single N-type column one-sided 3D detector

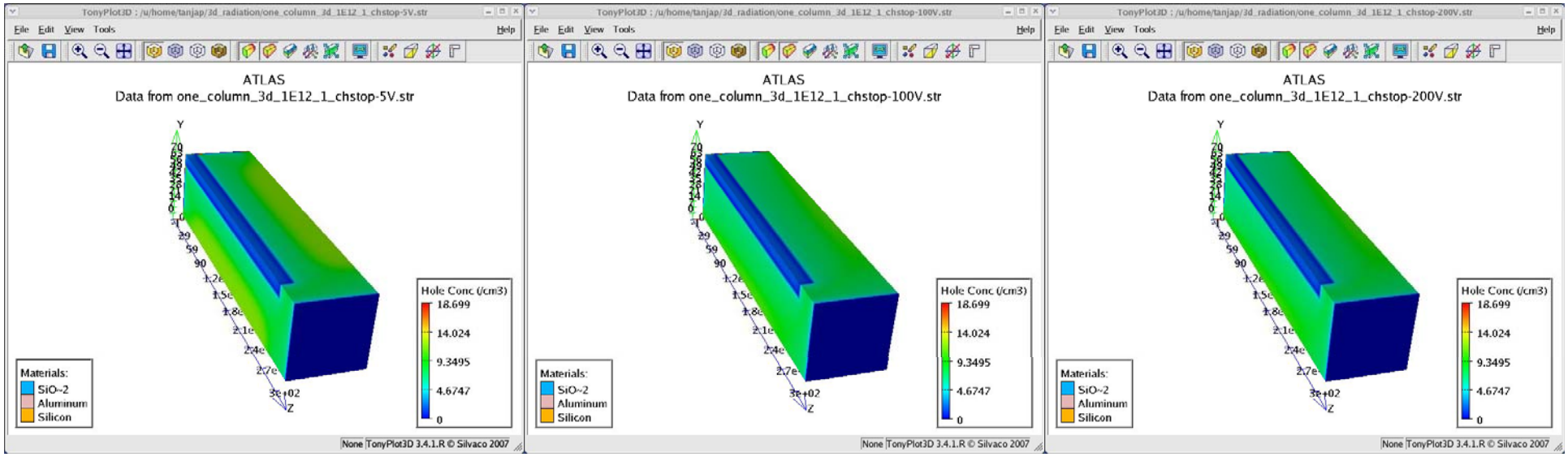
- BNL
- One unit cell has two n-type columns (270um) on the opposite corners, and they are surrounded by p-stops
- Two other corners have p-implants (0.5um)





BNL Single N-type column one-sided 3D detector

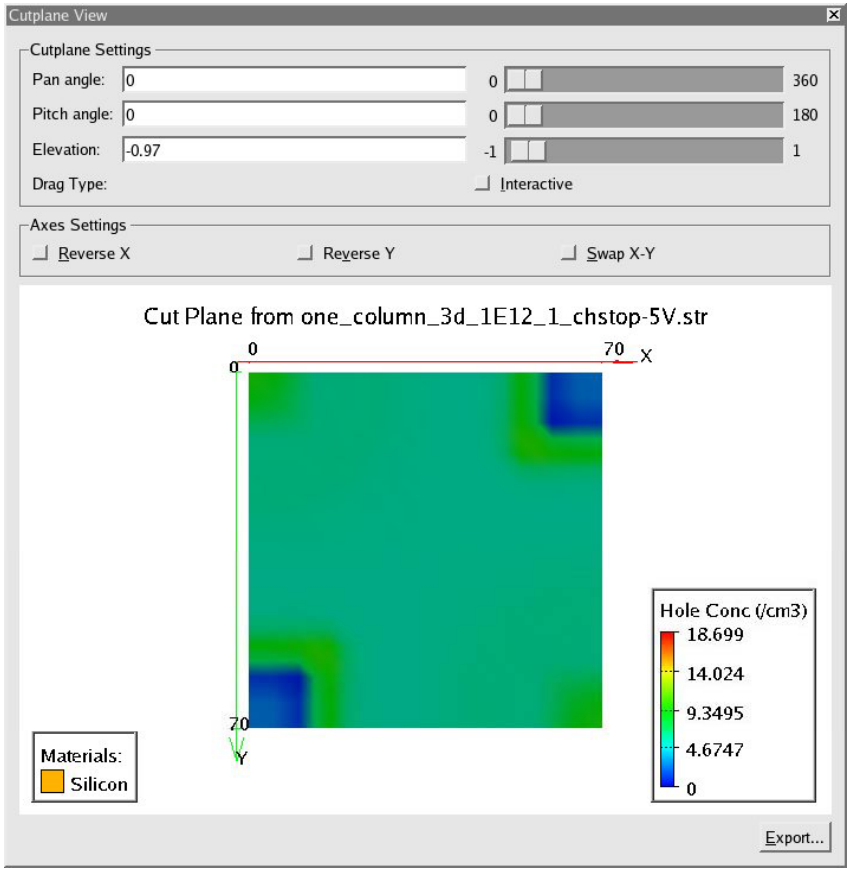
5V 100V 200V

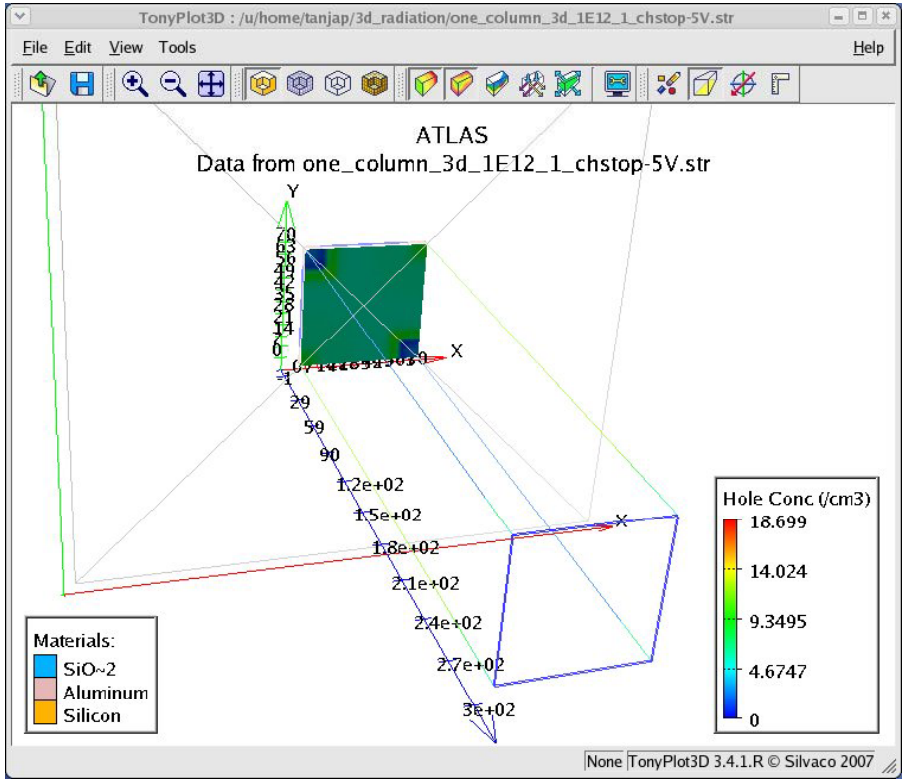


Hole concentration
All fully depleted

t1

BNL Single N-type column one-sided 3D detector (5V)





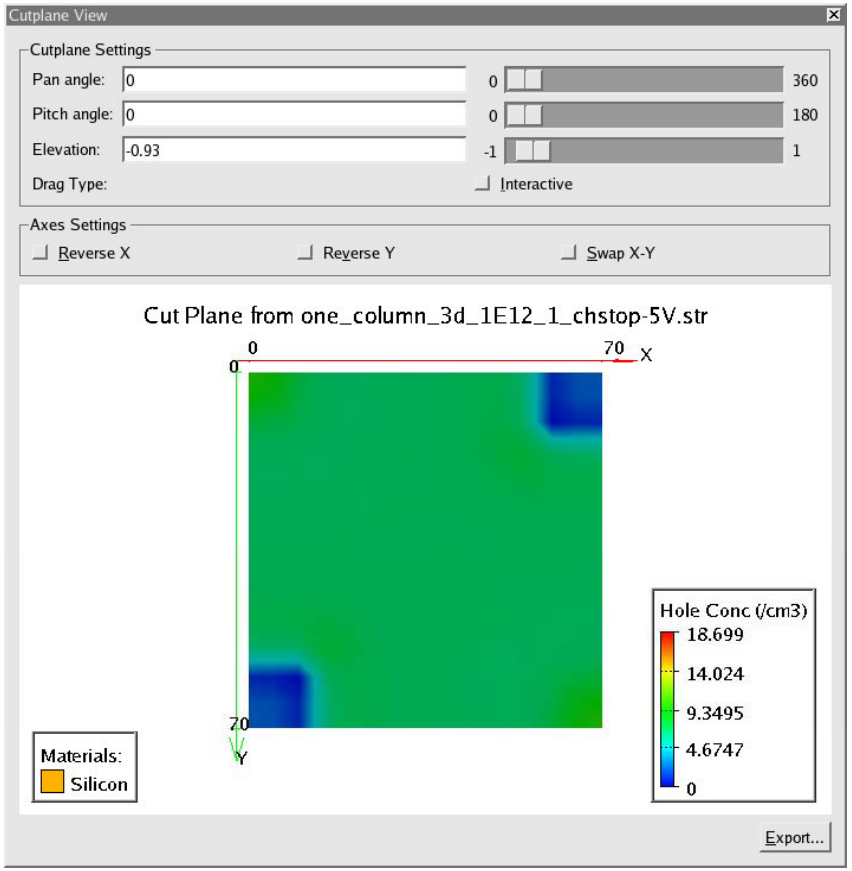
Hole concentration

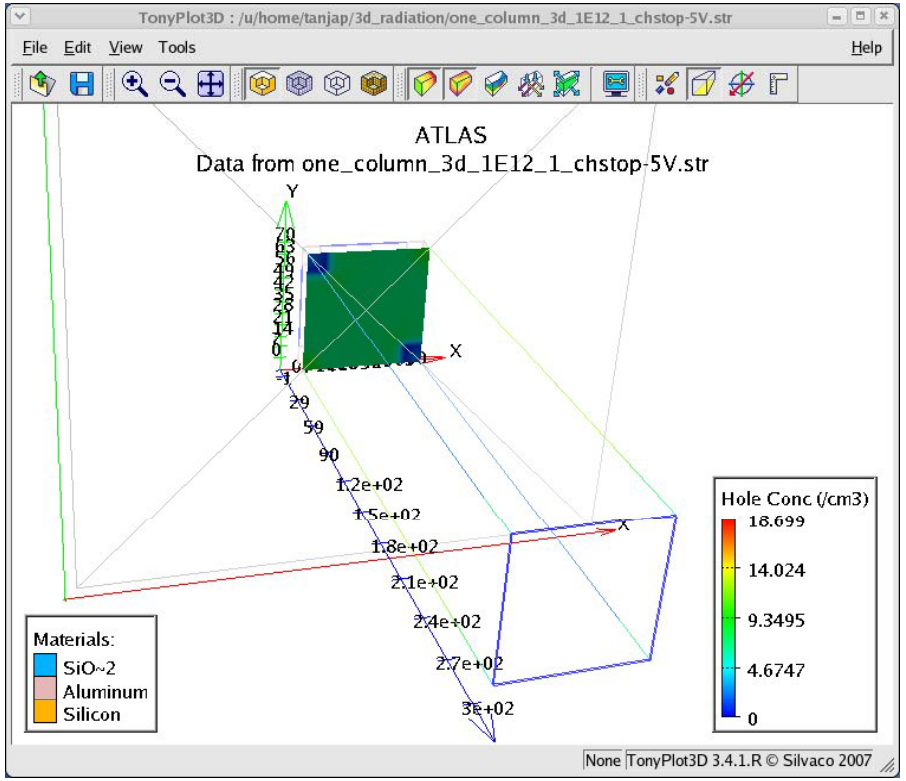
Slide 7

t1

Make a ovie, insert timing
Stop at the first middle and the end slides
tanjap, 4/13/2007

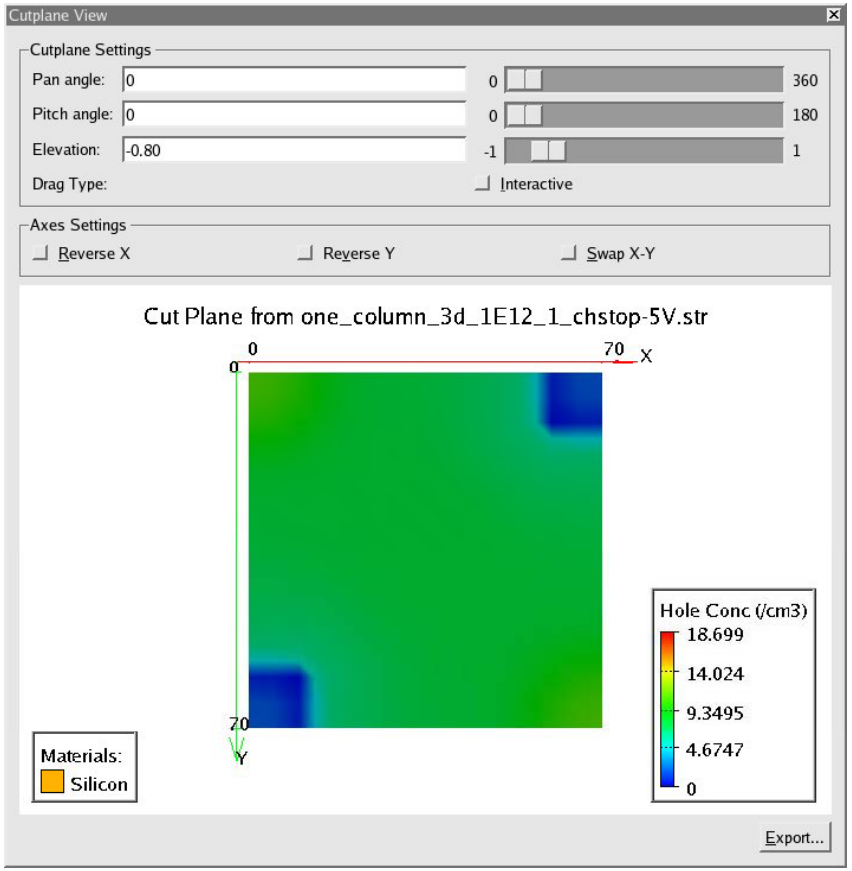
Single N-type column one-sided 3D detector (5V)

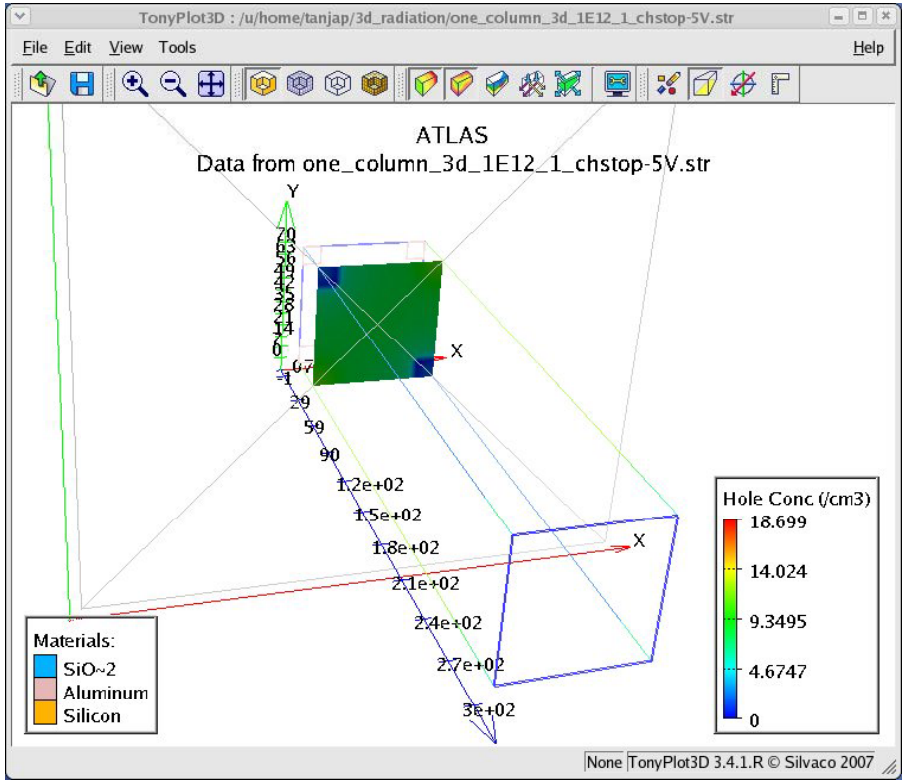




Hole concentration

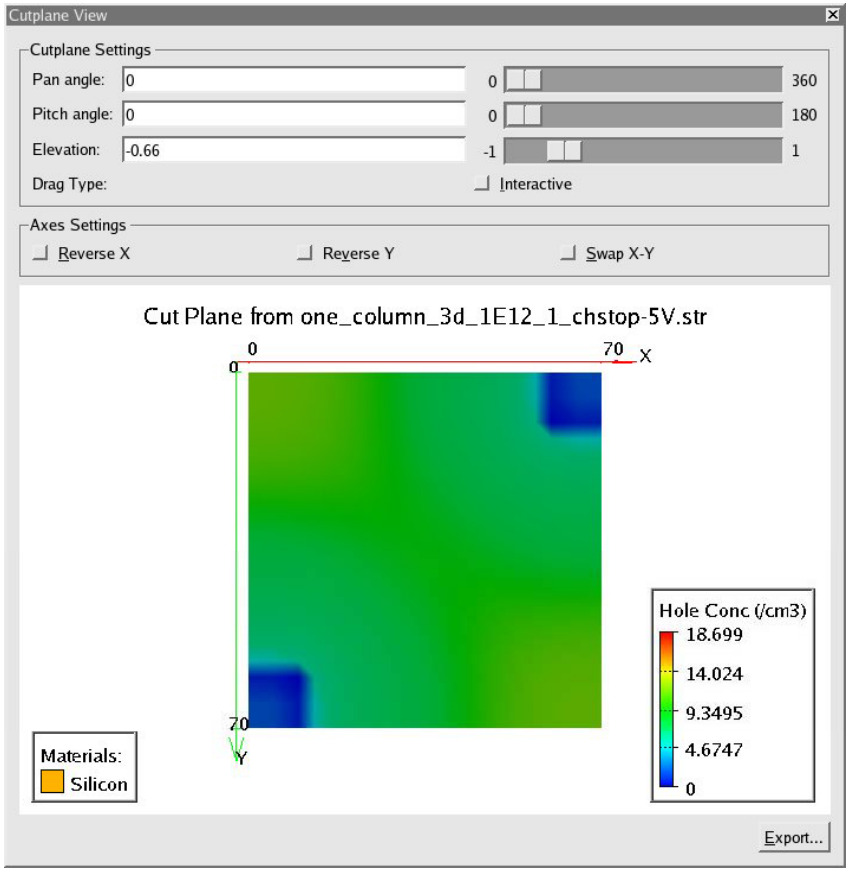
Single N-type column one-sided 3D detector (5V)

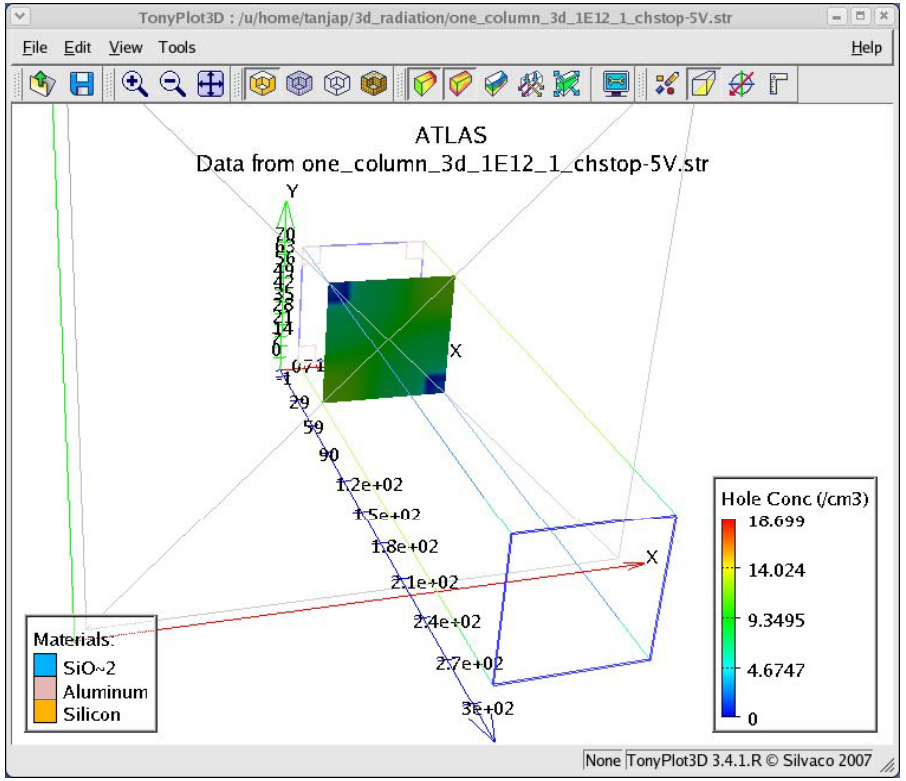




Hole concentration

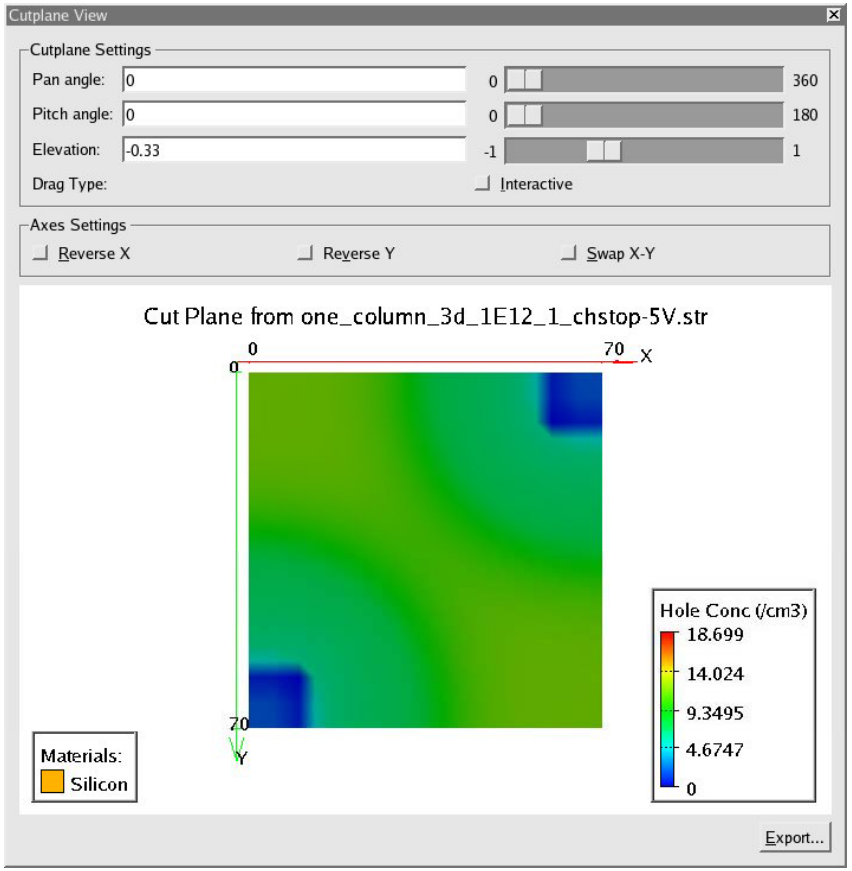
Single N-type column one-sided 3D detector (5V)

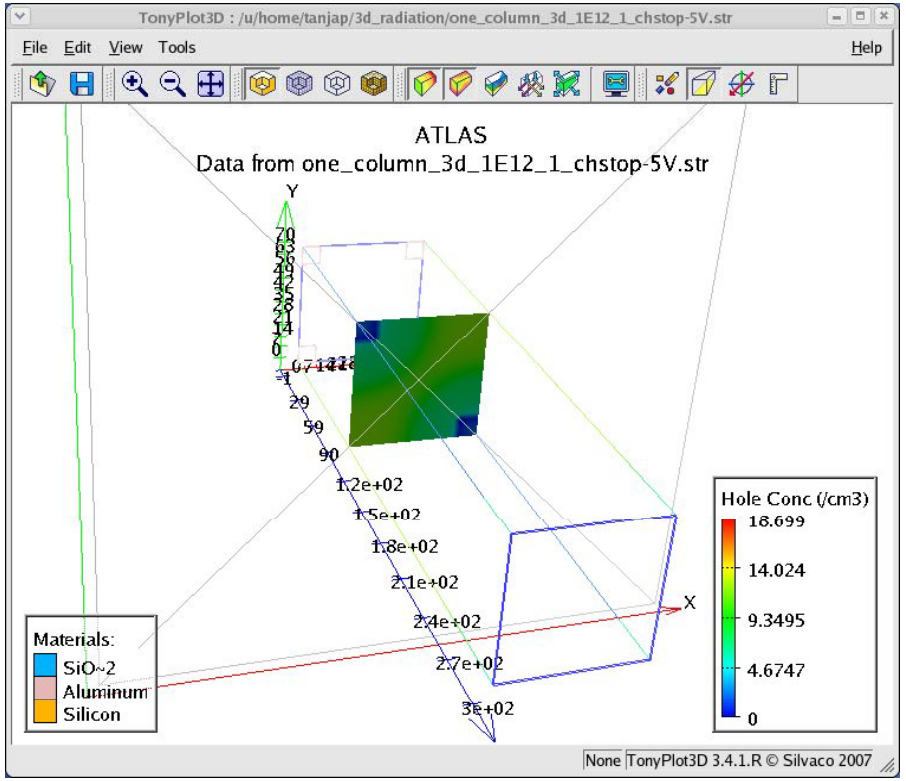




Hole concentration

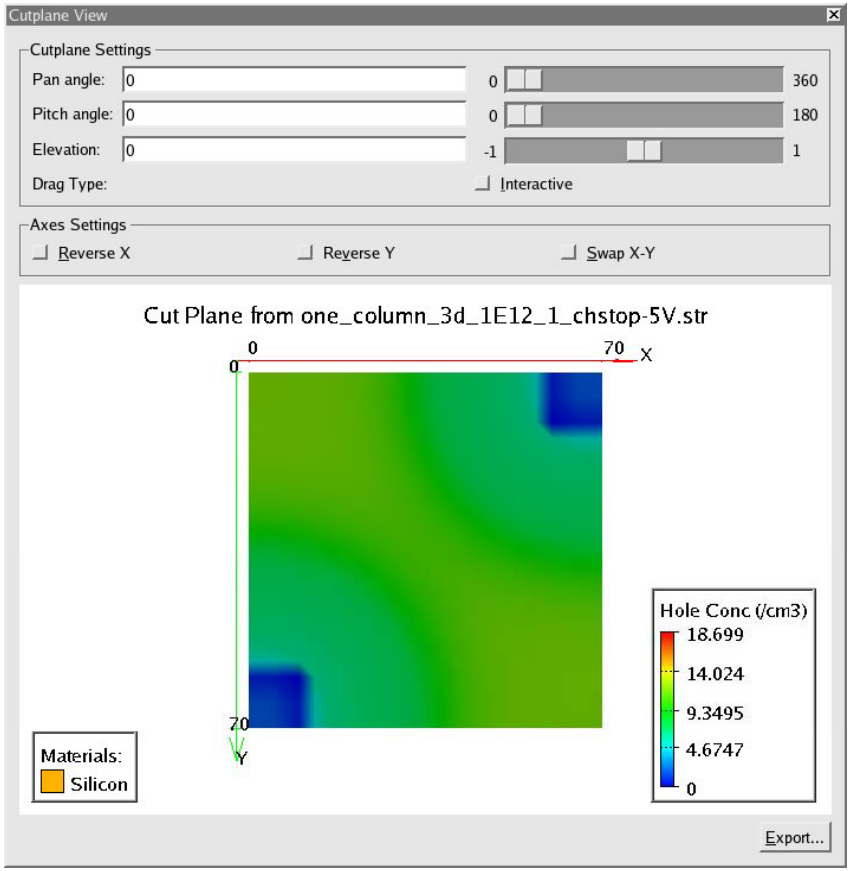
Single N-type column one-sided 3D detector (5V)

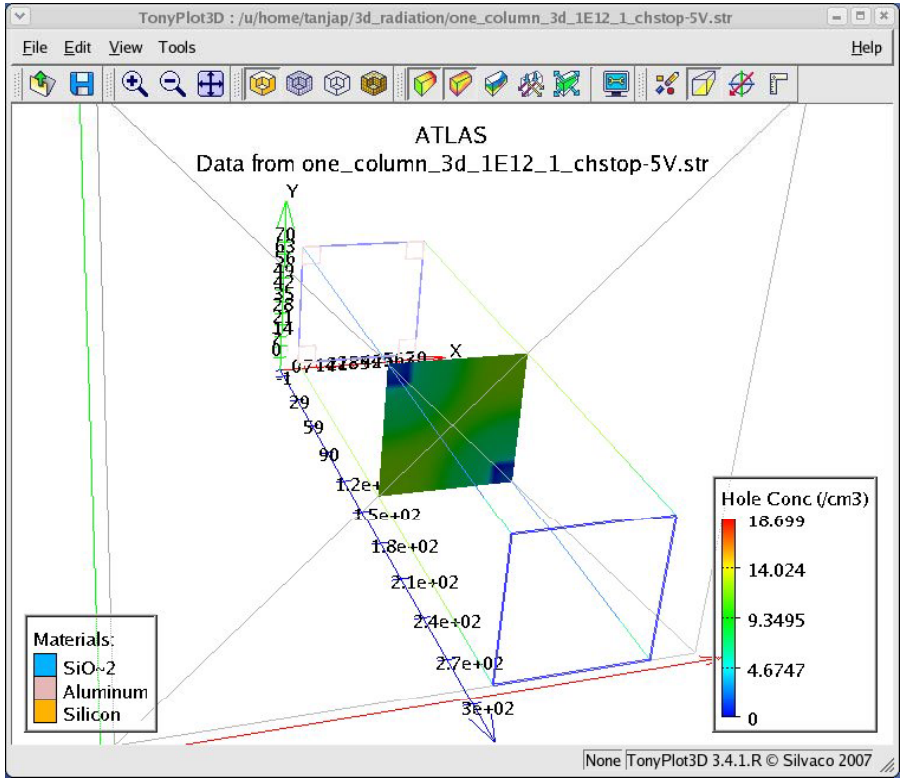




Hole concentration

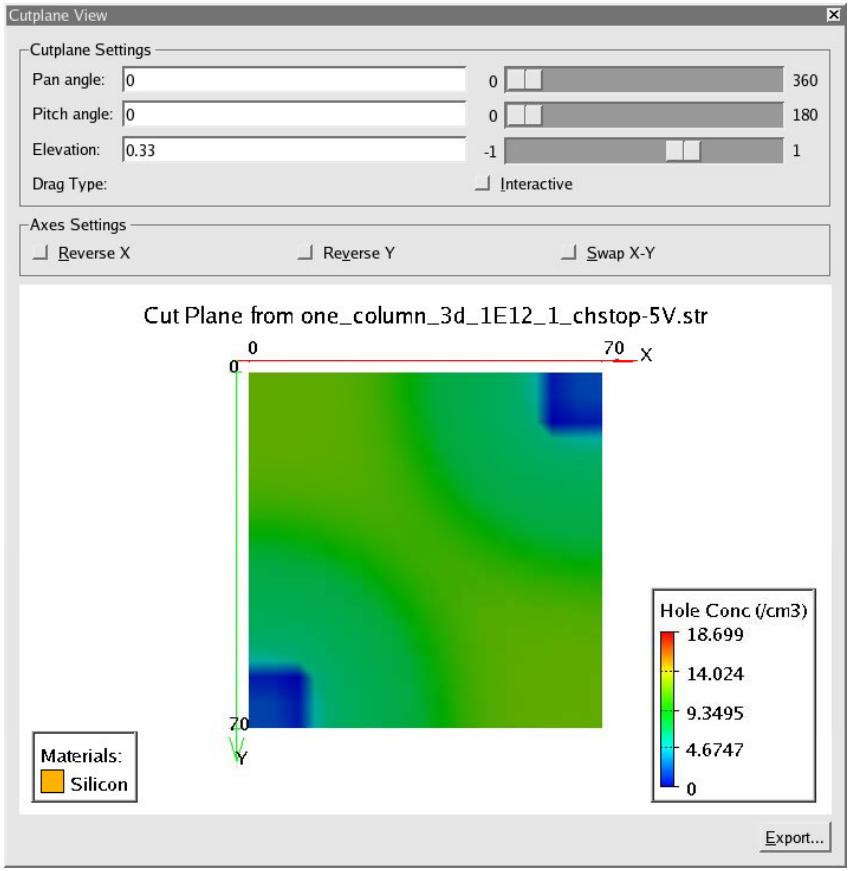
Single N-type column one-sided 3D detector (5V)

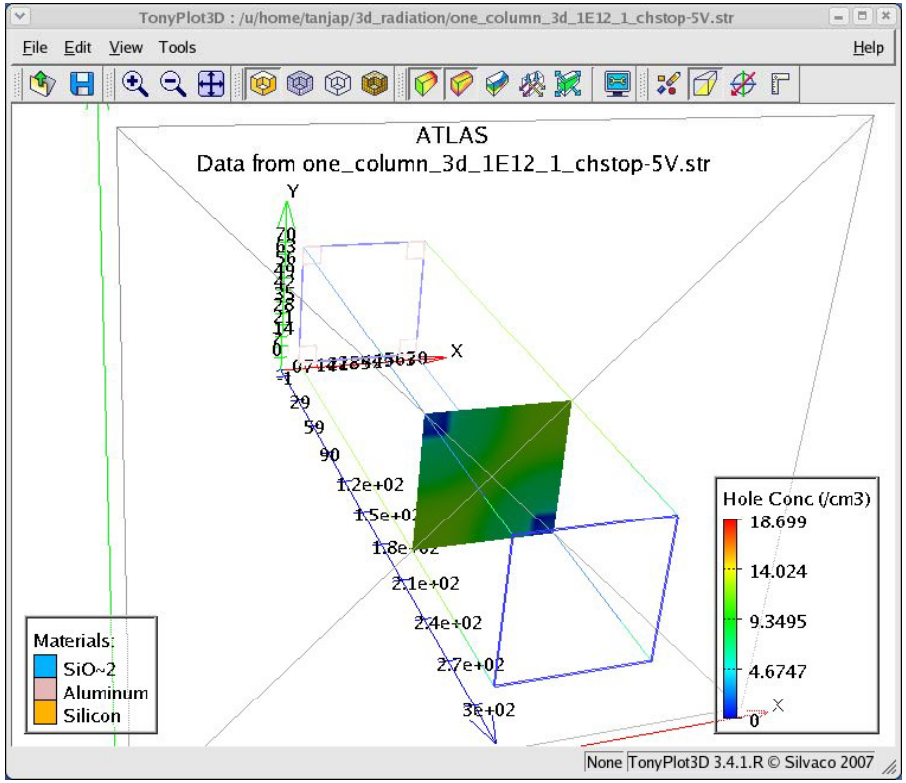




Hole concentration

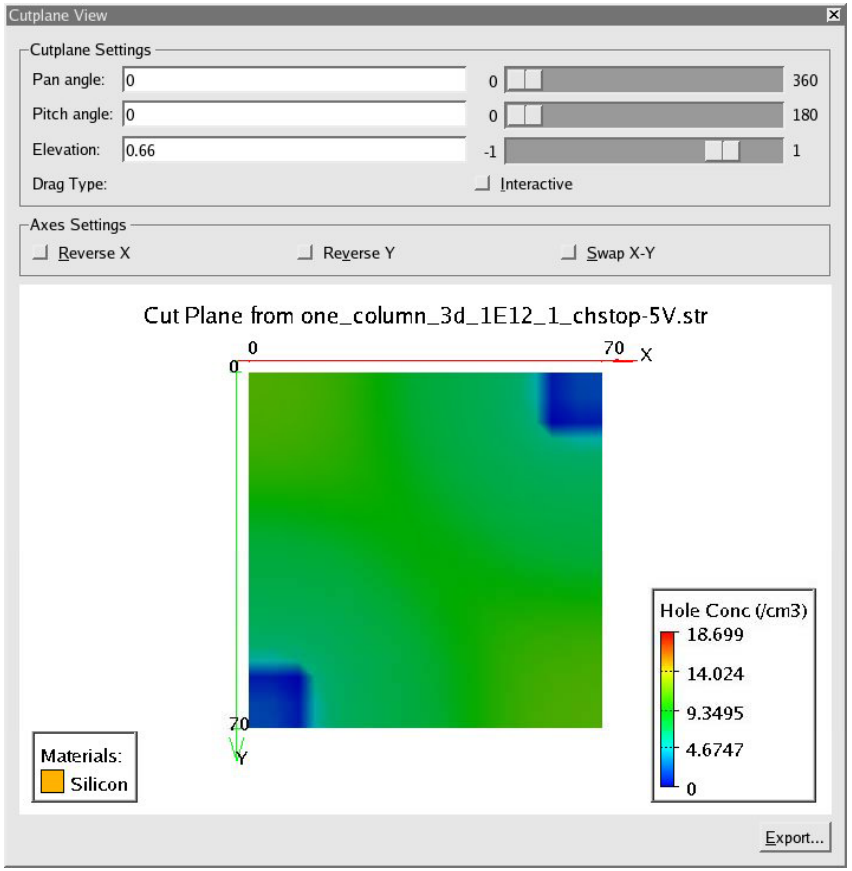
Single N-type column one-sided 3D detector (5V)

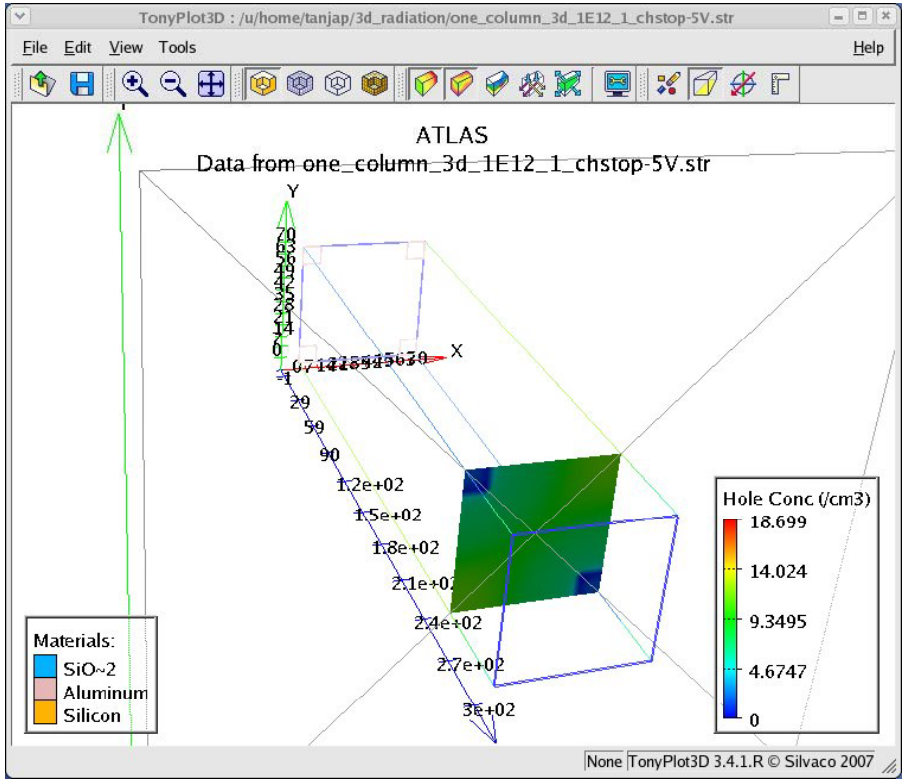




Hole concentration

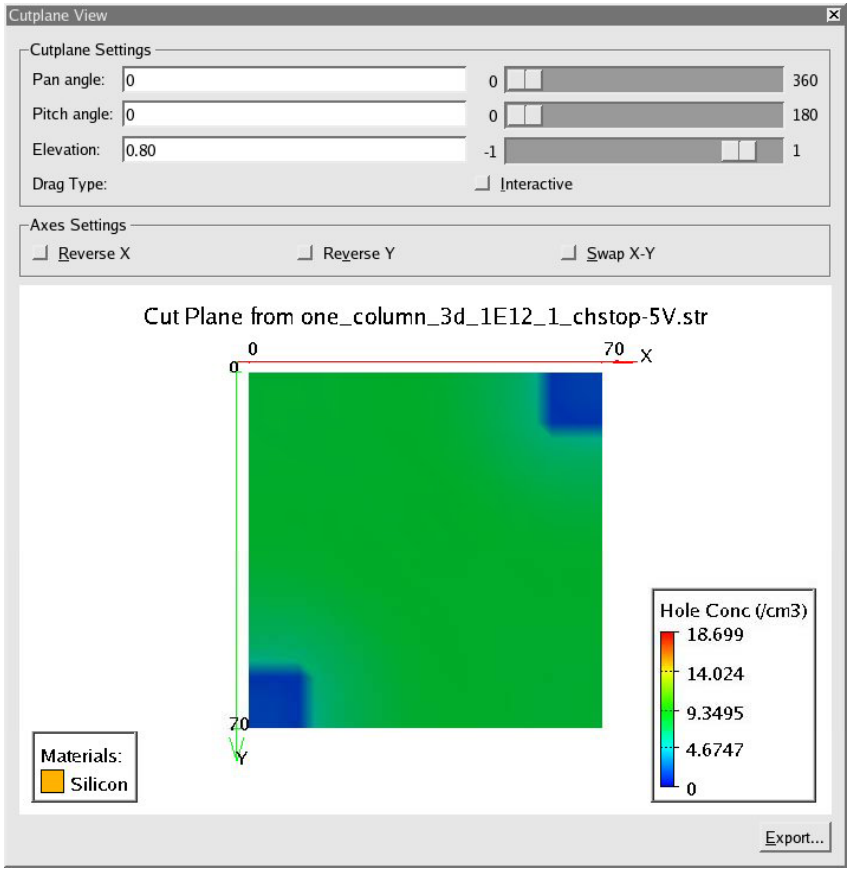
Single N-type column one-sided 3D detector (5V)

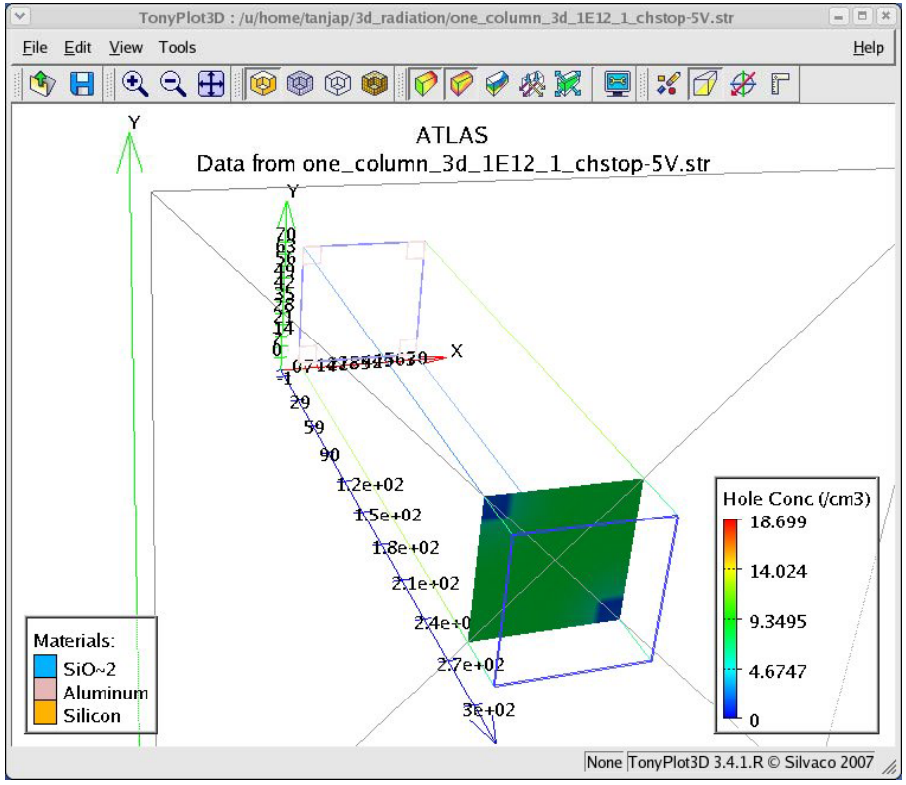




Hole concentration

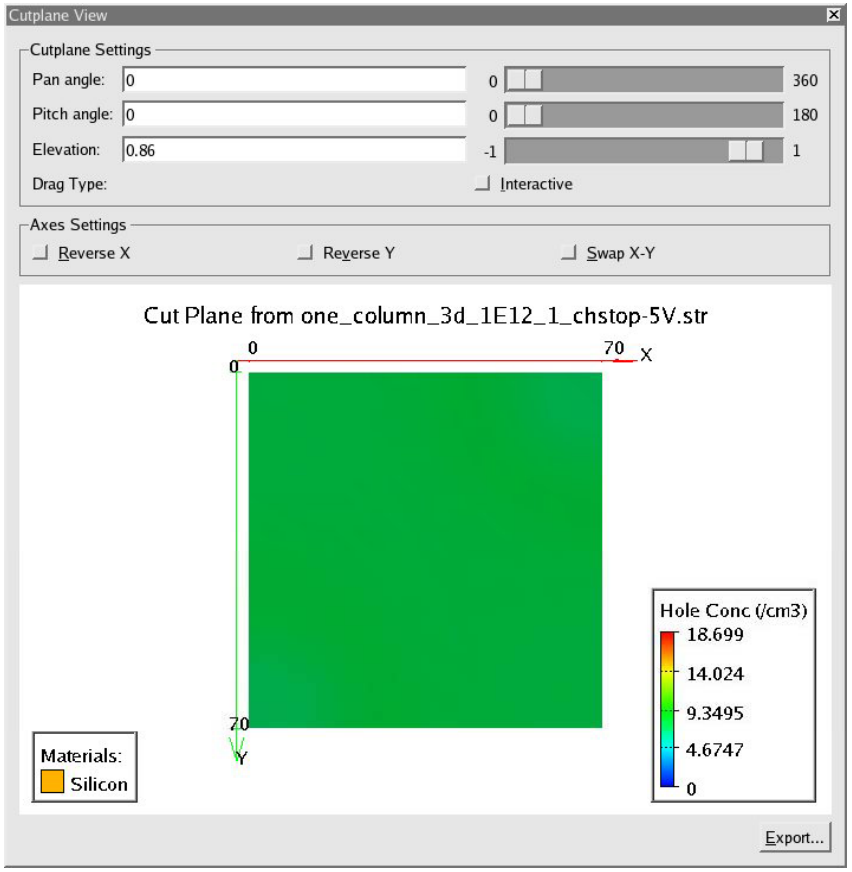
Single N-type column one-sided 3D detector (5V)

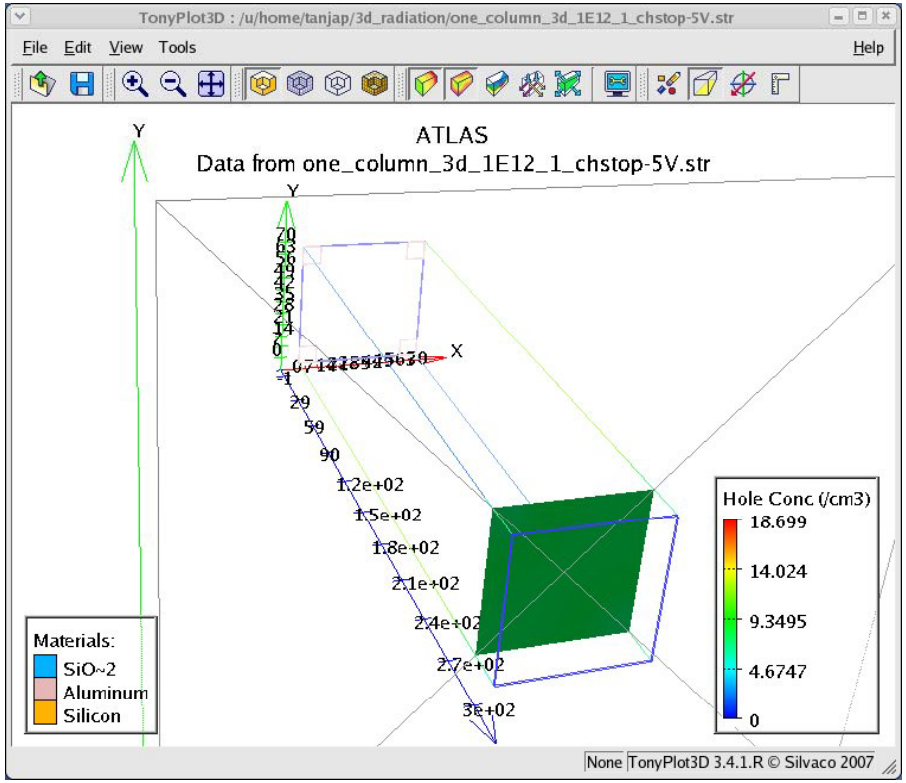




Hole concentration

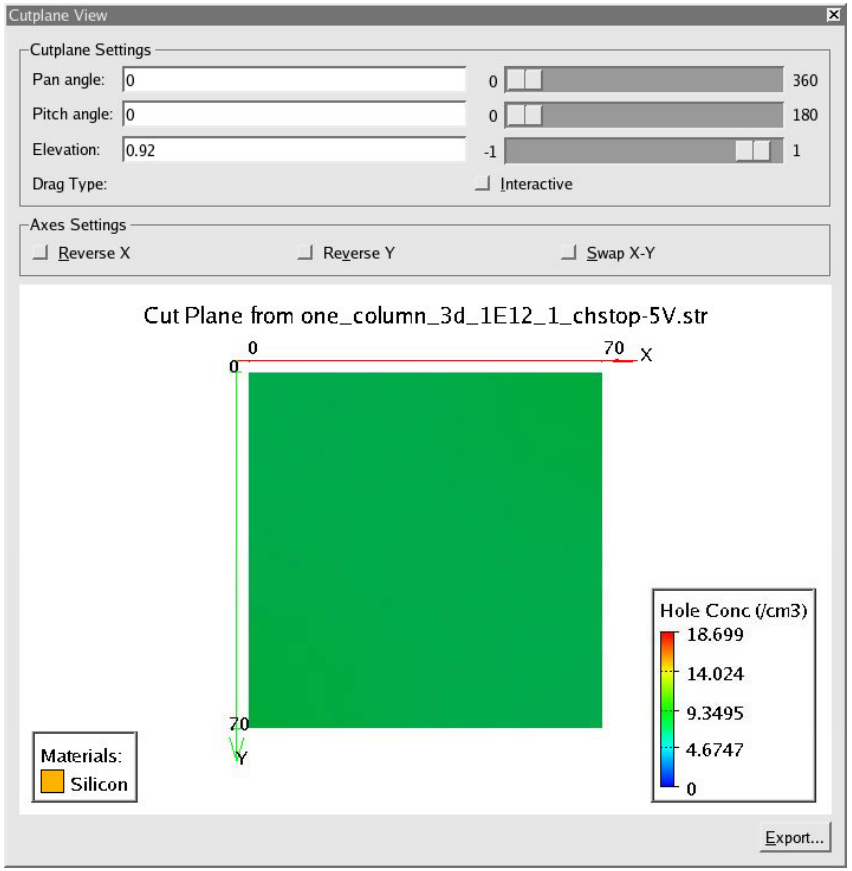
Single N-type column one-sided 3D detector (5V)

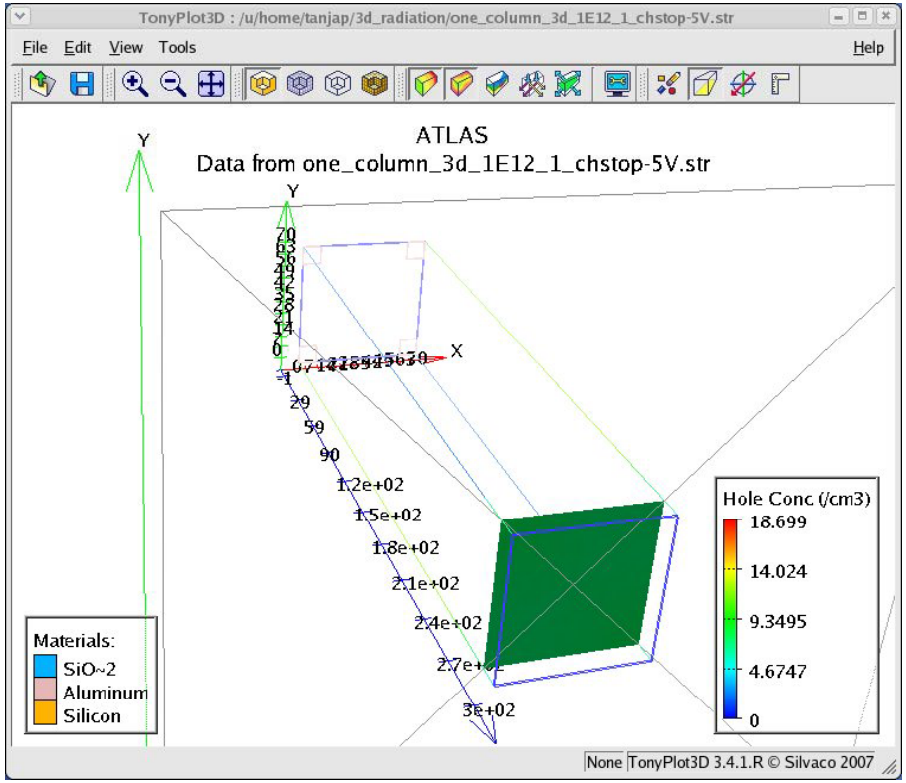




Hole concentration

Single N-type column one-sided 3D detector (5V)





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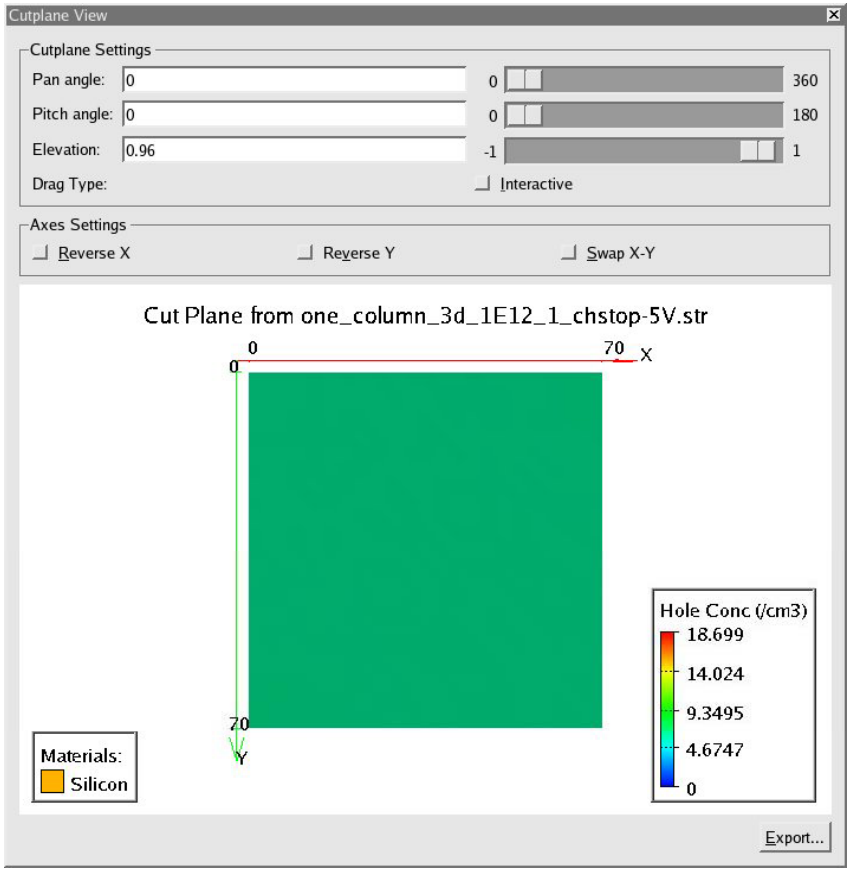

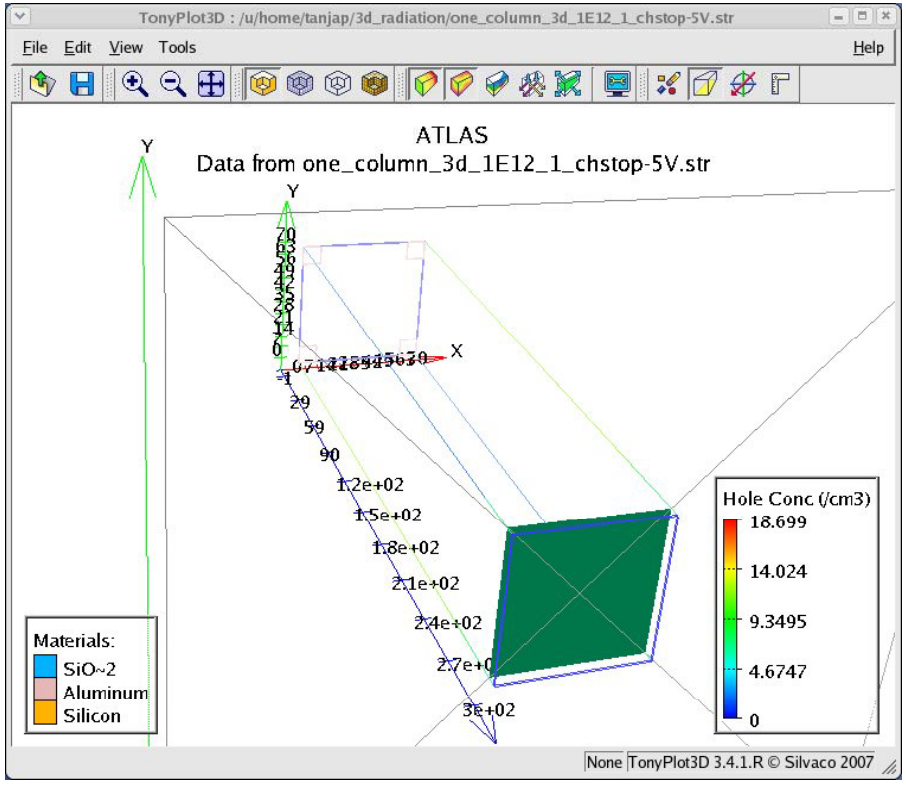

Hole concentration

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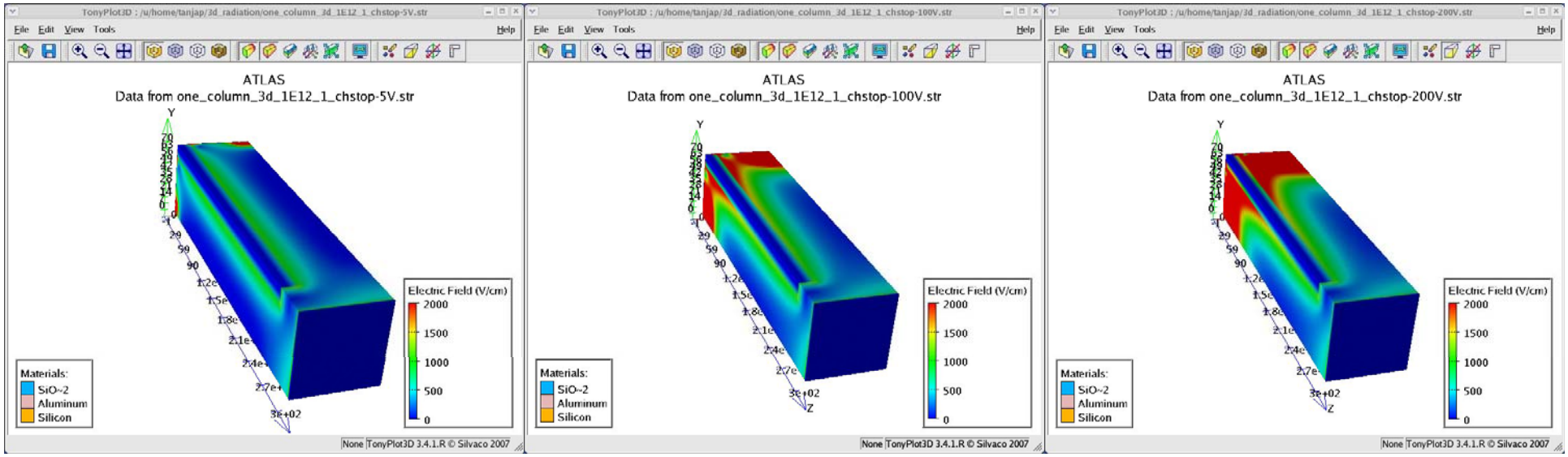
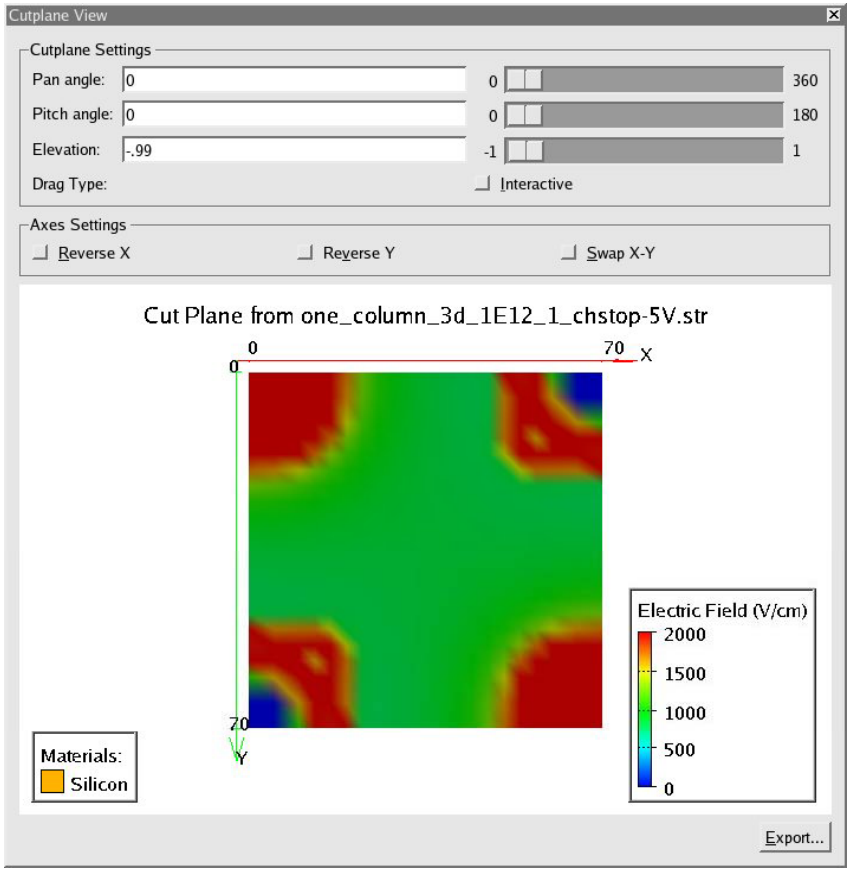
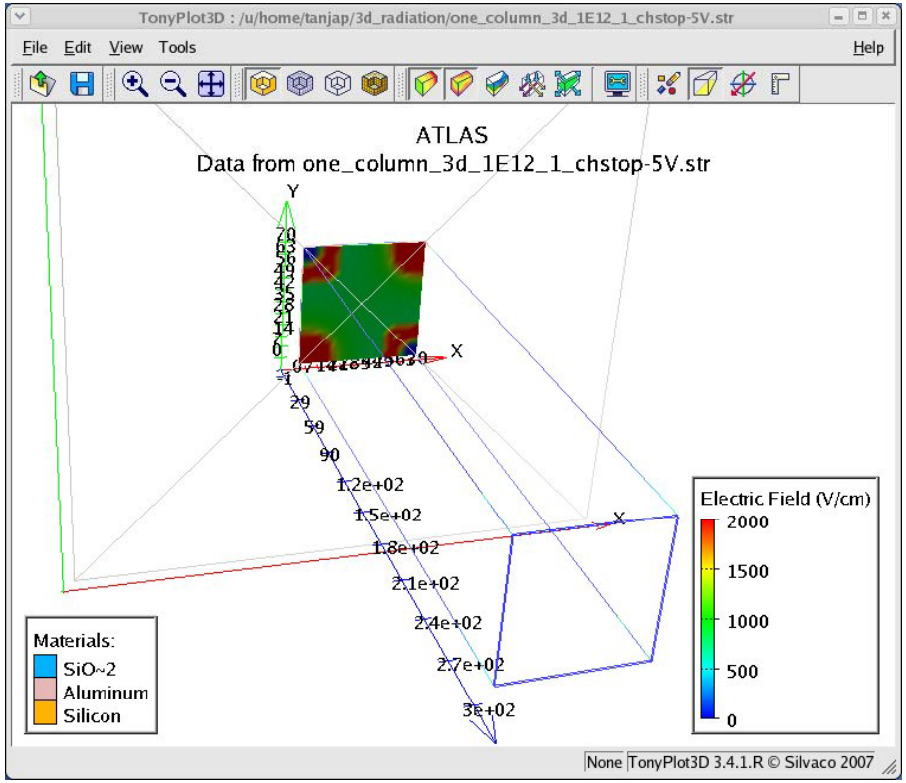


Electric field

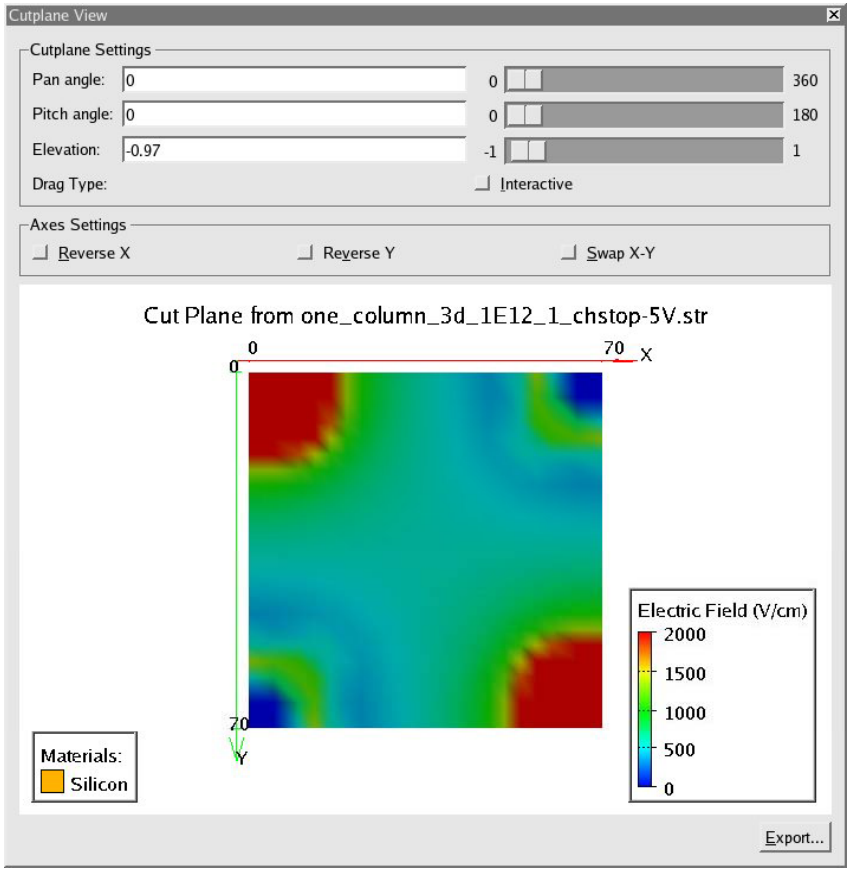
Single N-type column one-sided 3D detector (5V)

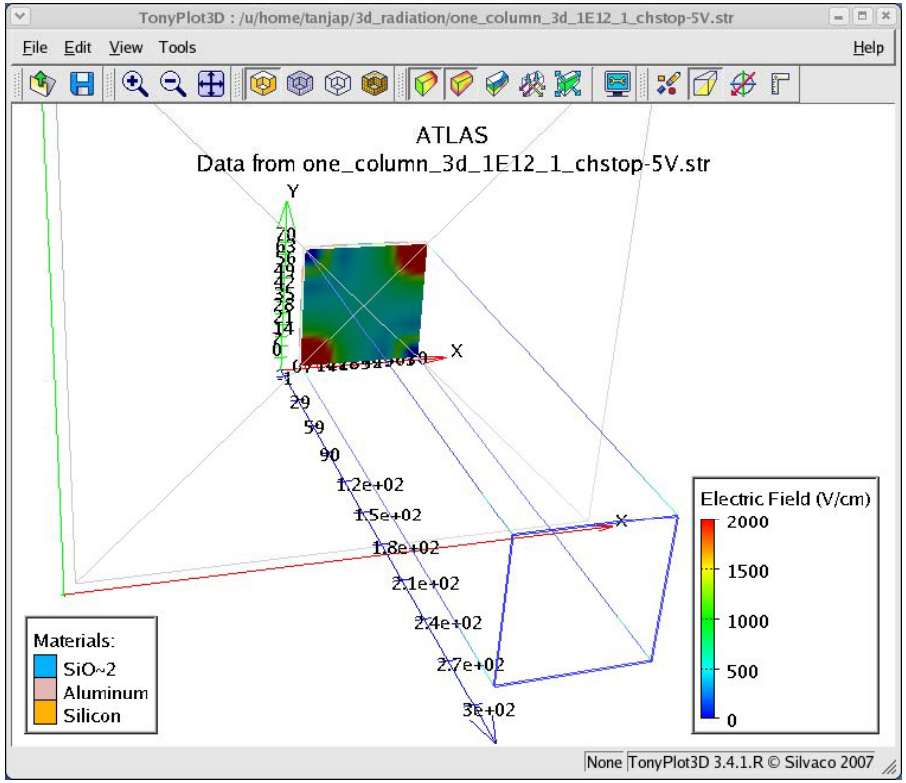




Electric field

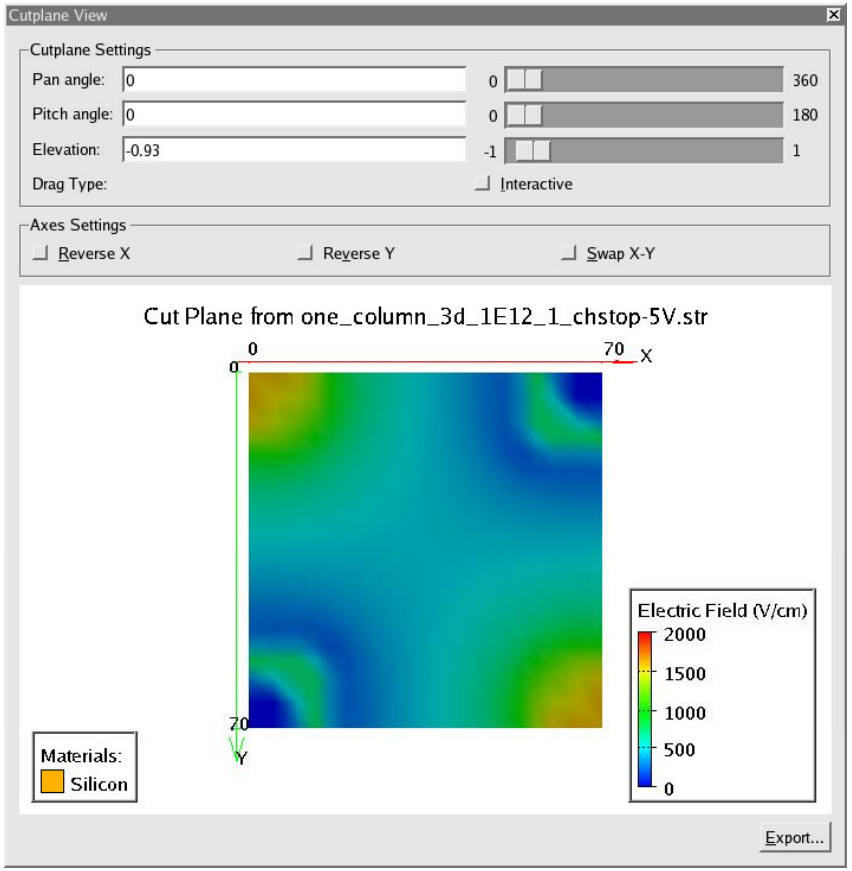
Single N-type column one-sided 3D detector (5V)

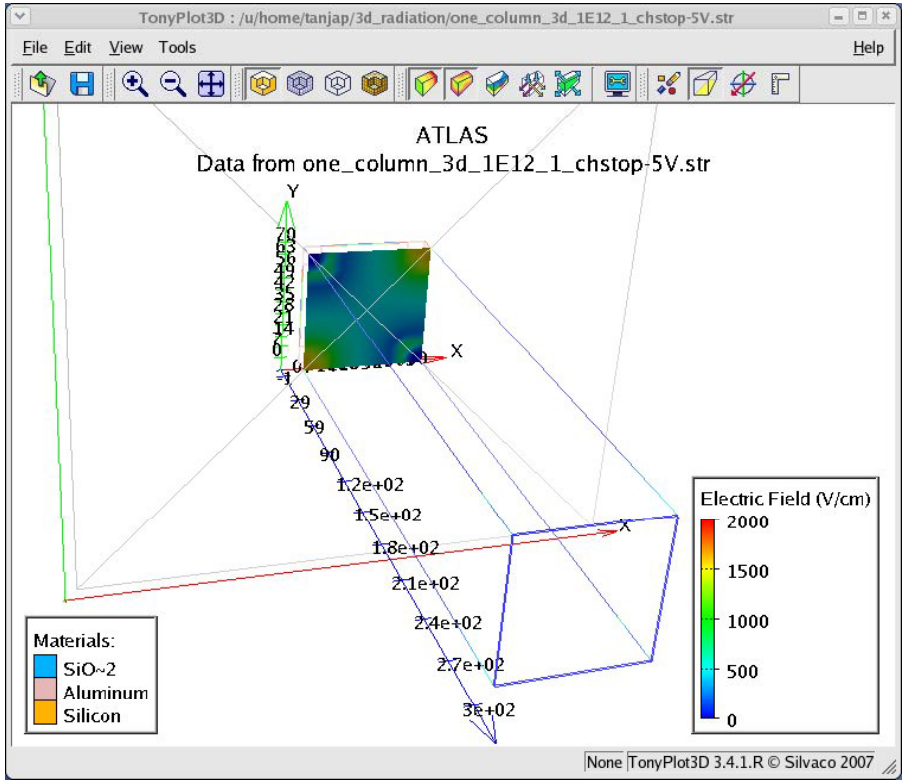




Electric field

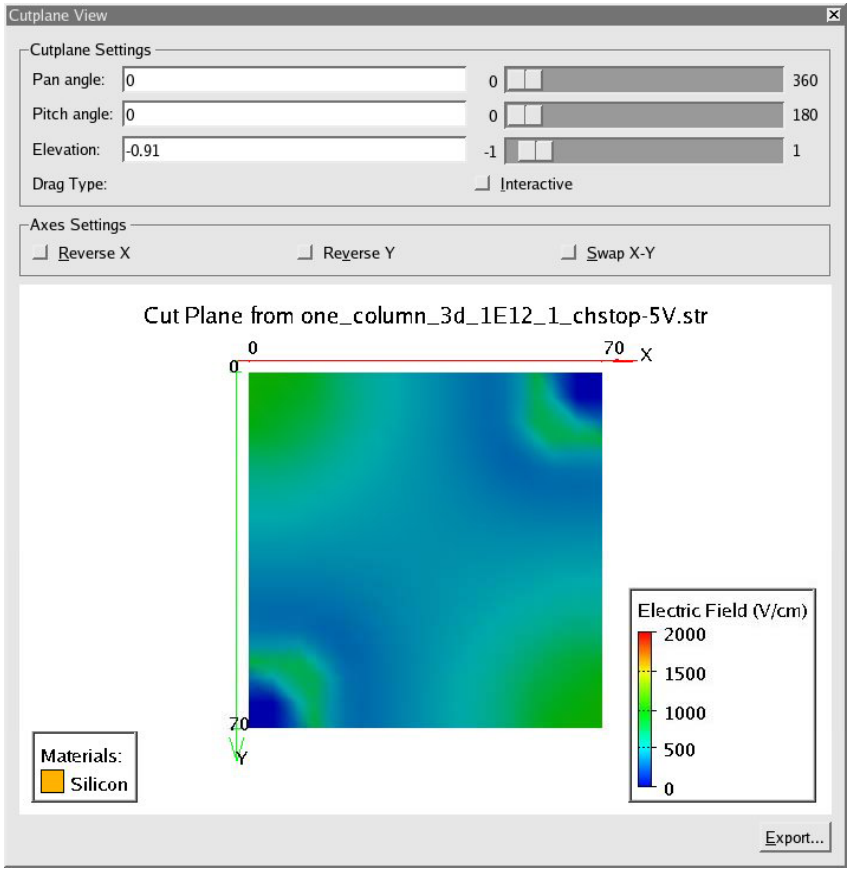
Single N-type column one-sided 3D detector (5V)

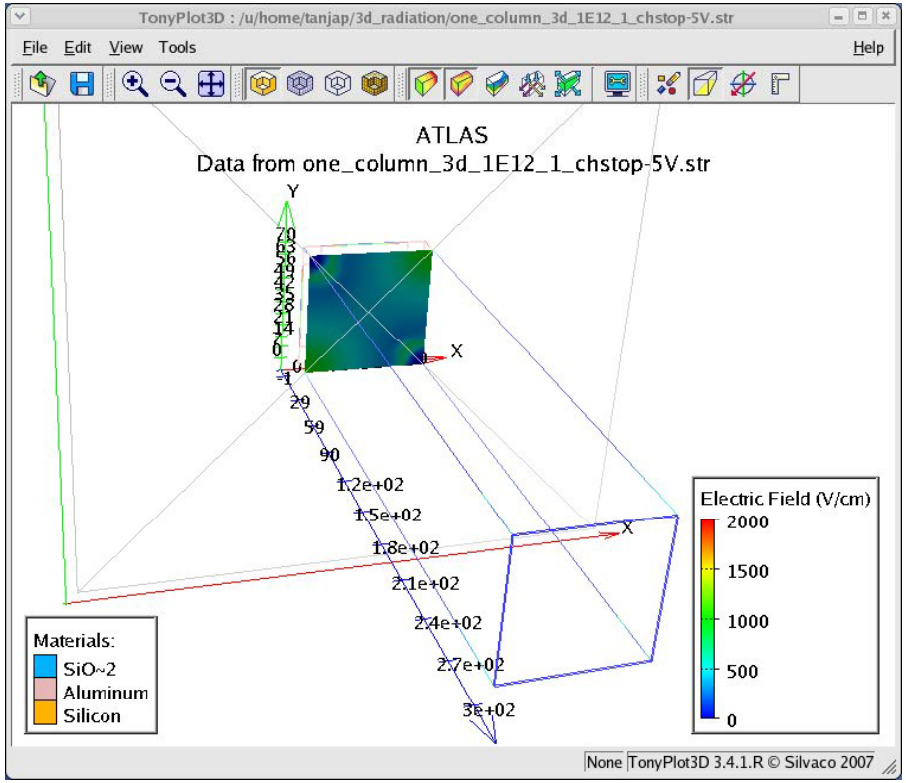




Electric field

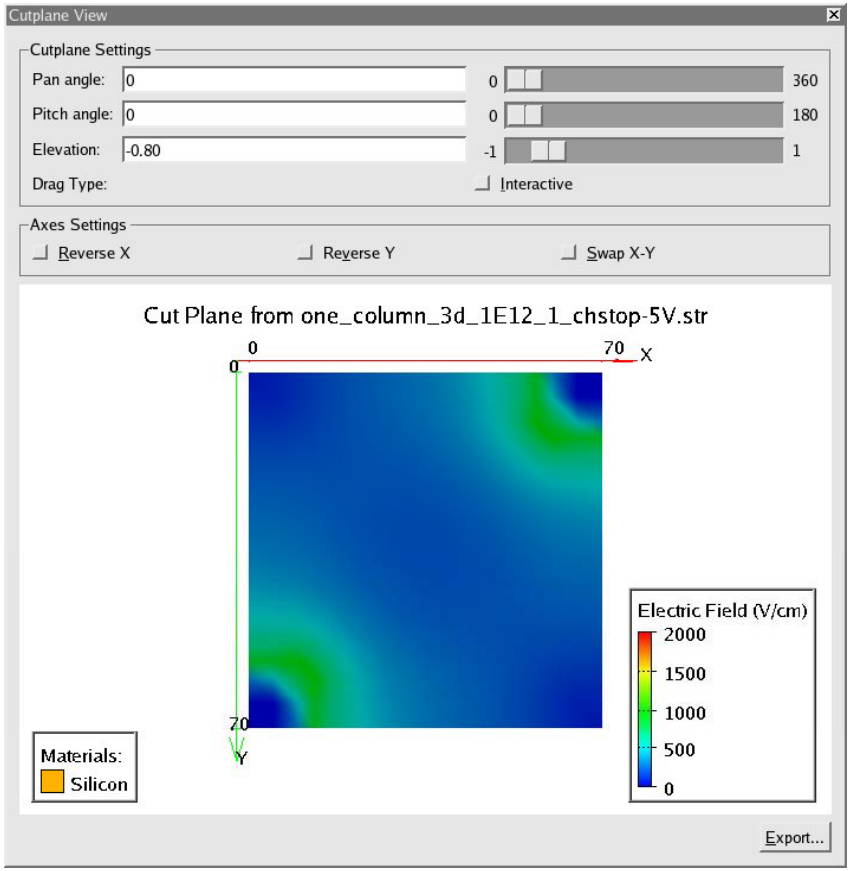
Single N-type column one-sided 3D detector (5V)

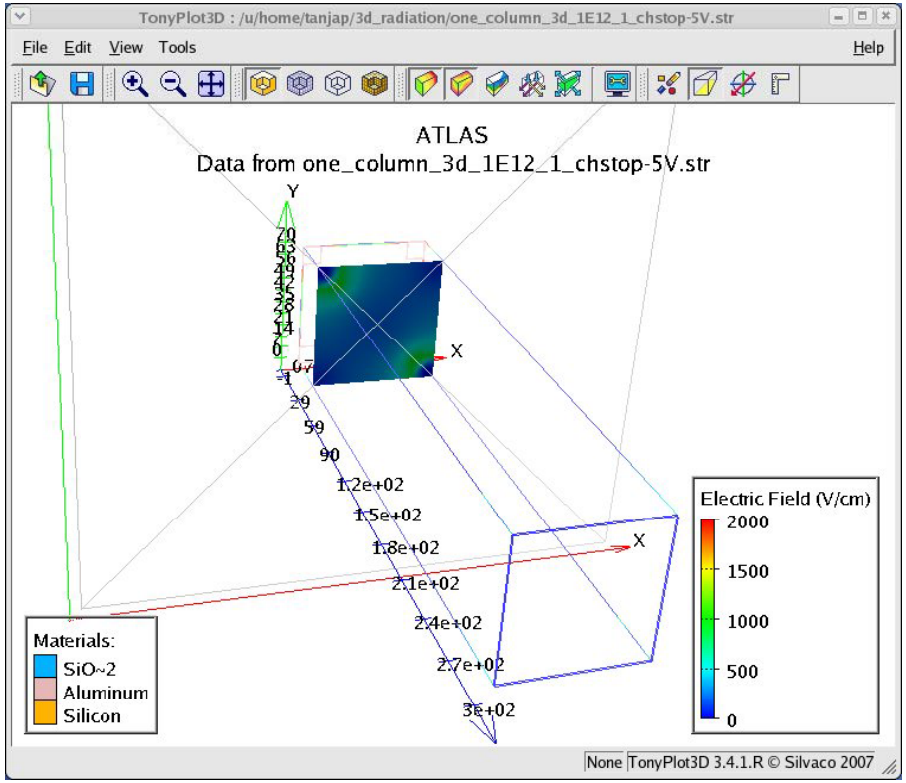




Electric field

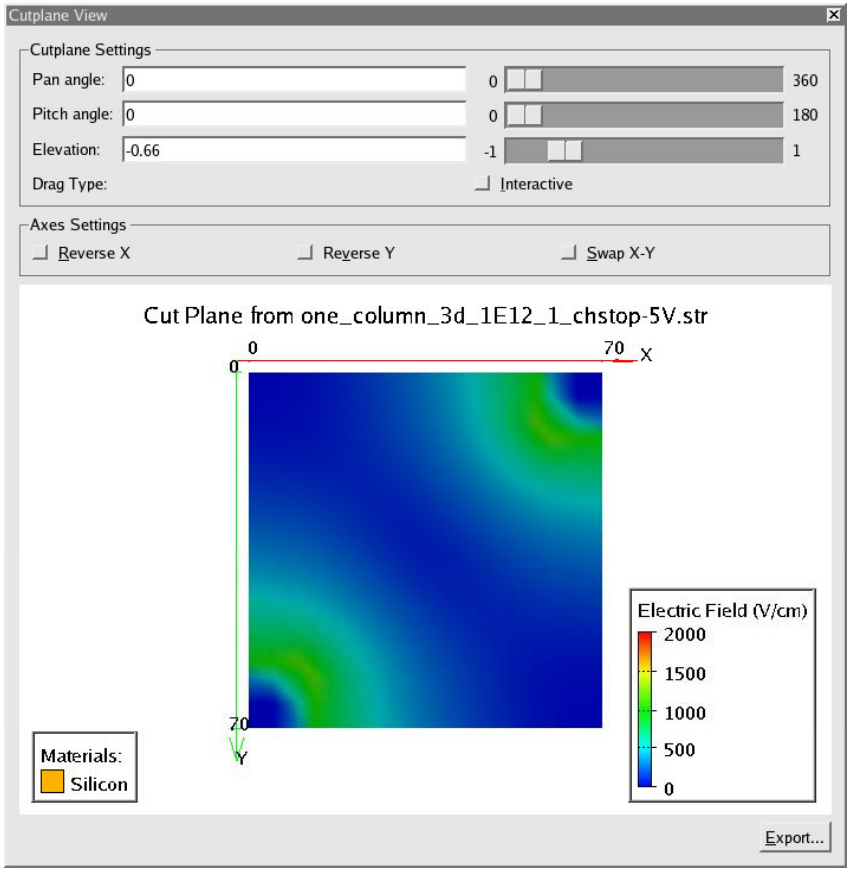
Single N-type column one-sided 3D detector (5V)

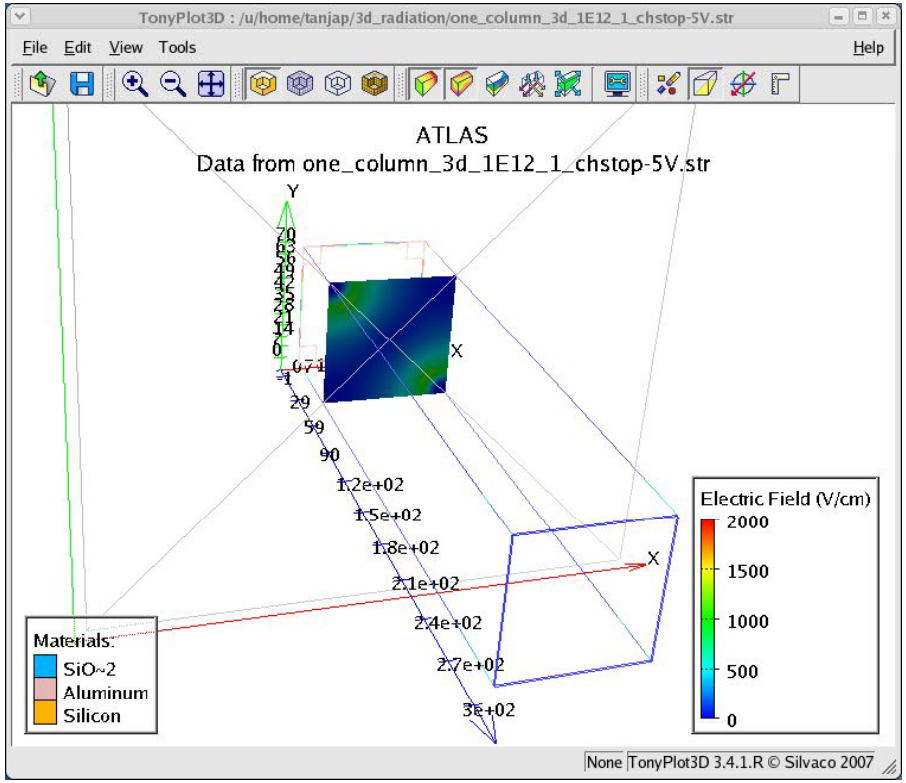




Electric field

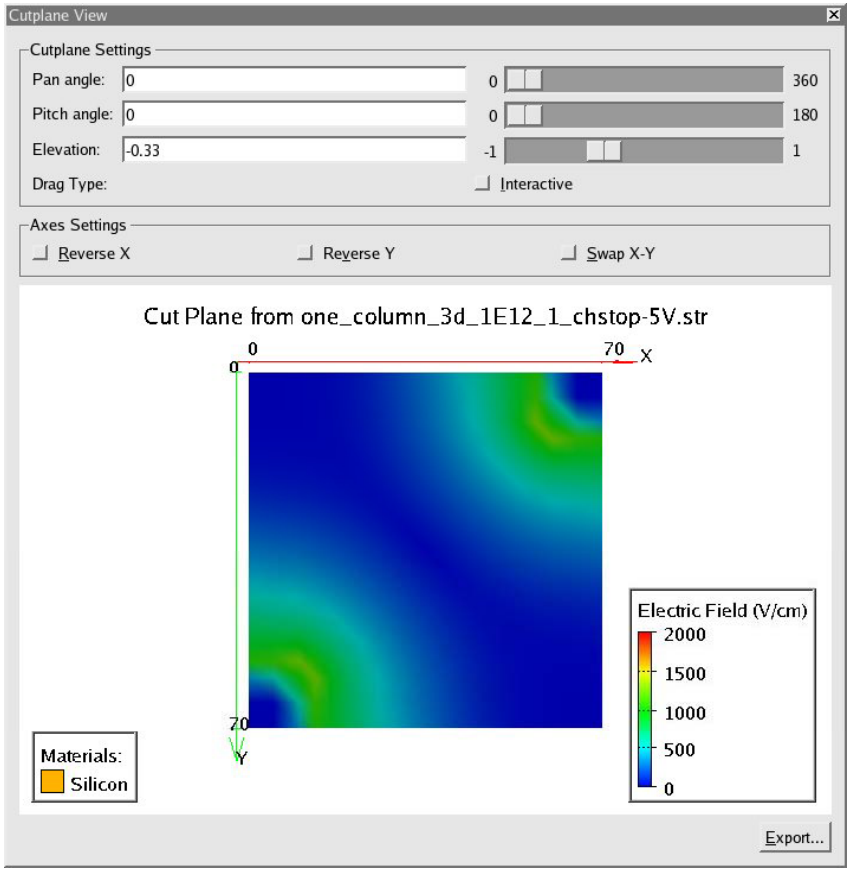
Single N-type column one-sided 3D detector (5V)

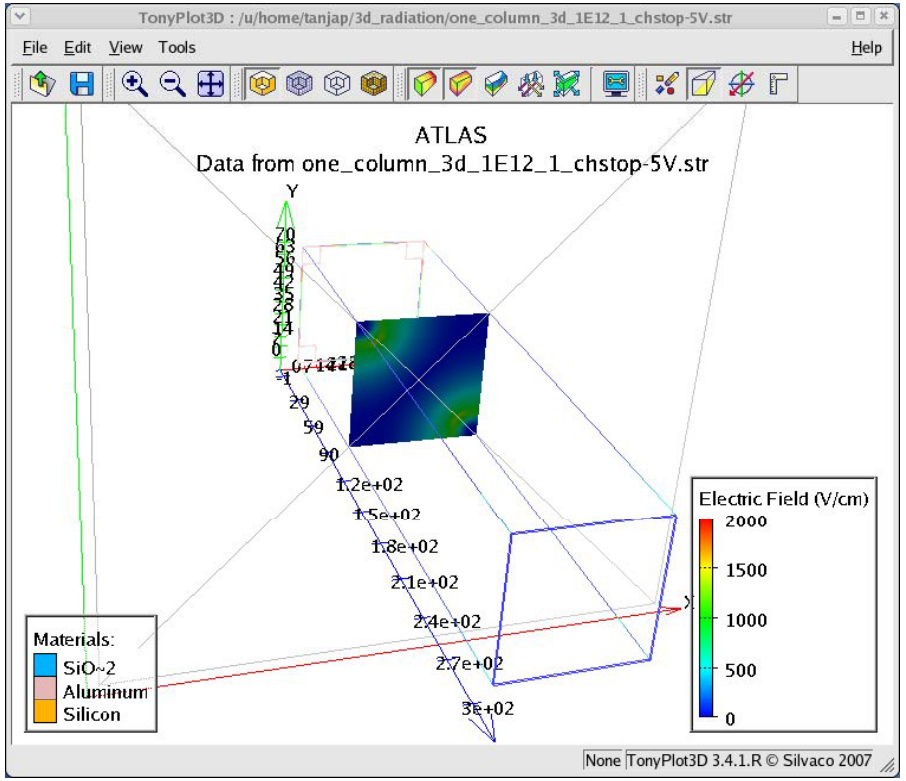




Electric field

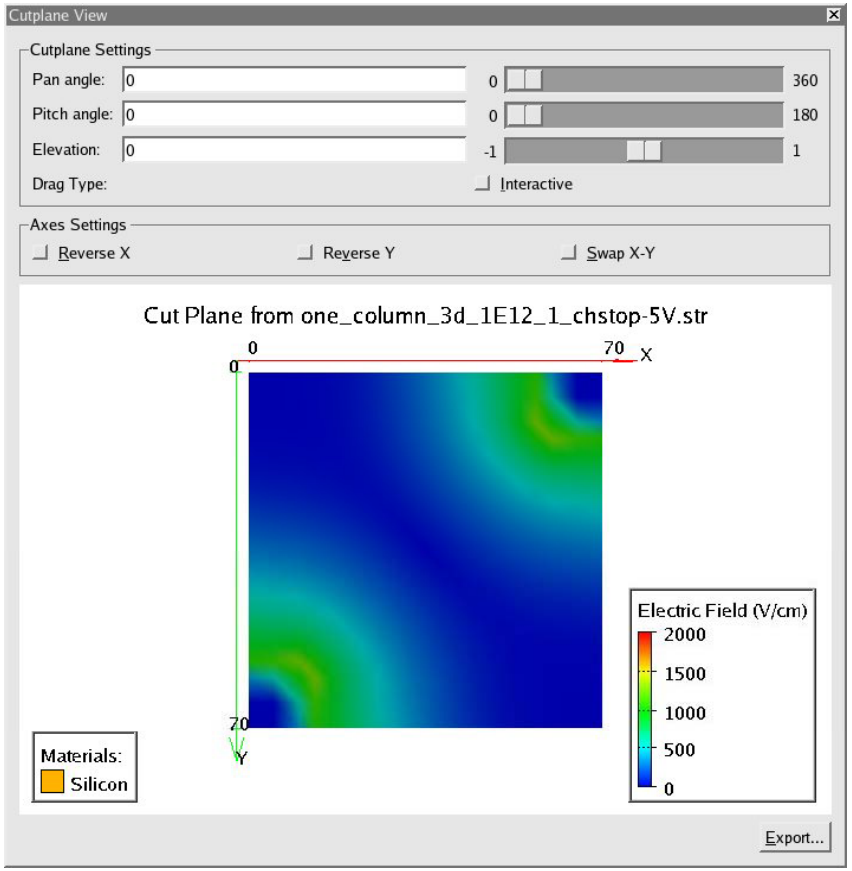
Single N-type column one-sided 3D detector (5V)

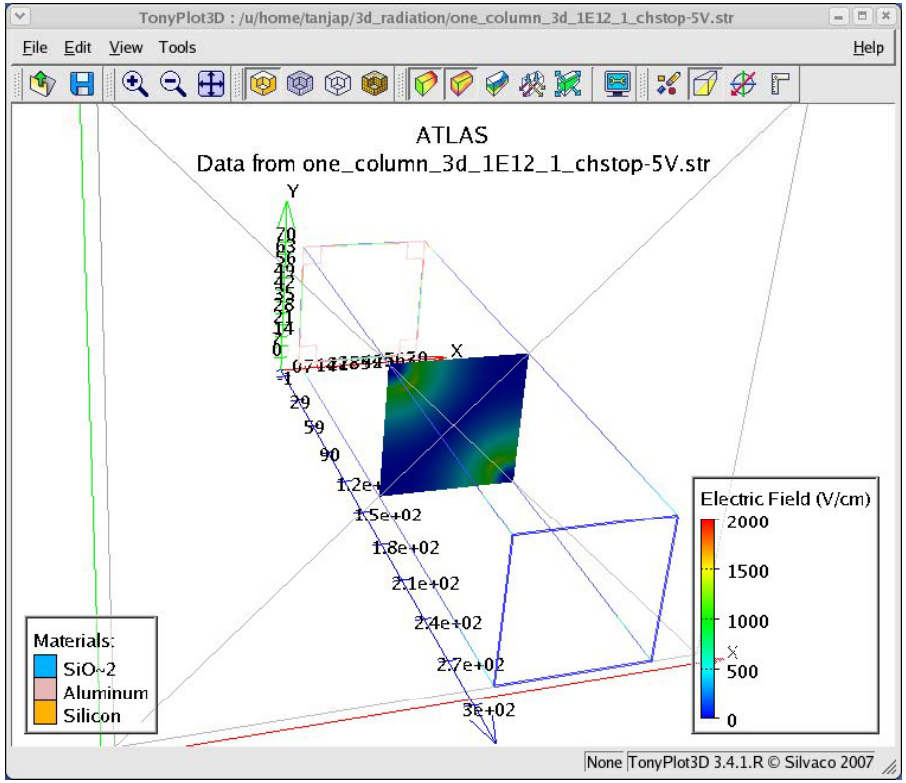




Electric field

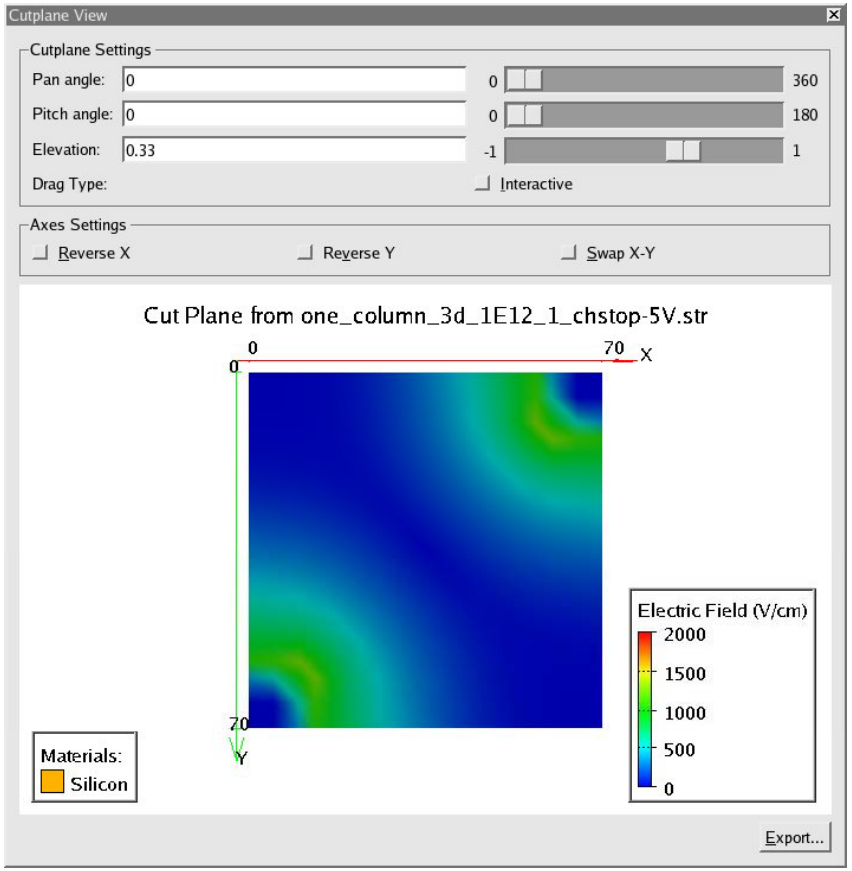
Single N-type column one-sided 3D detector (5V)

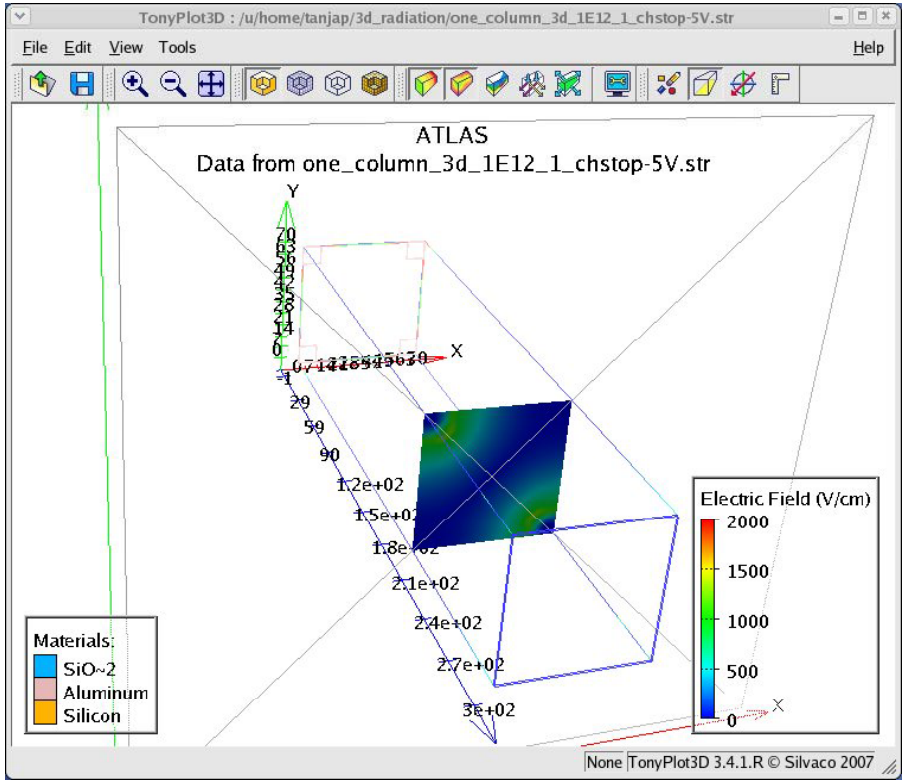




Electric field

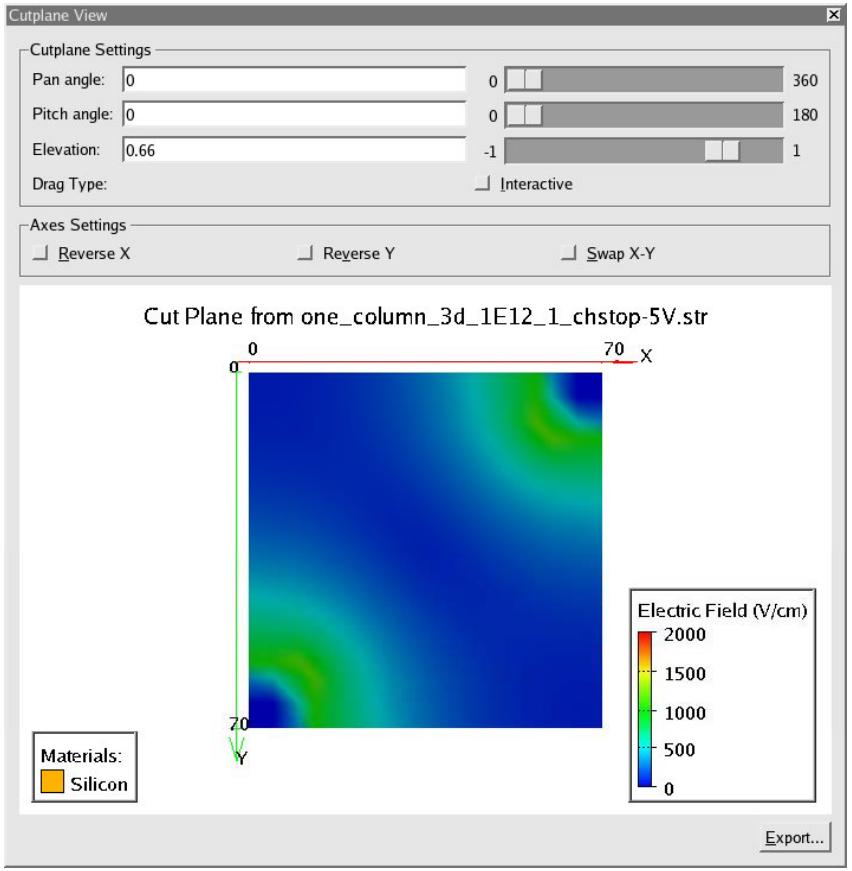
Single N-type column one-sided 3D detector (5V)

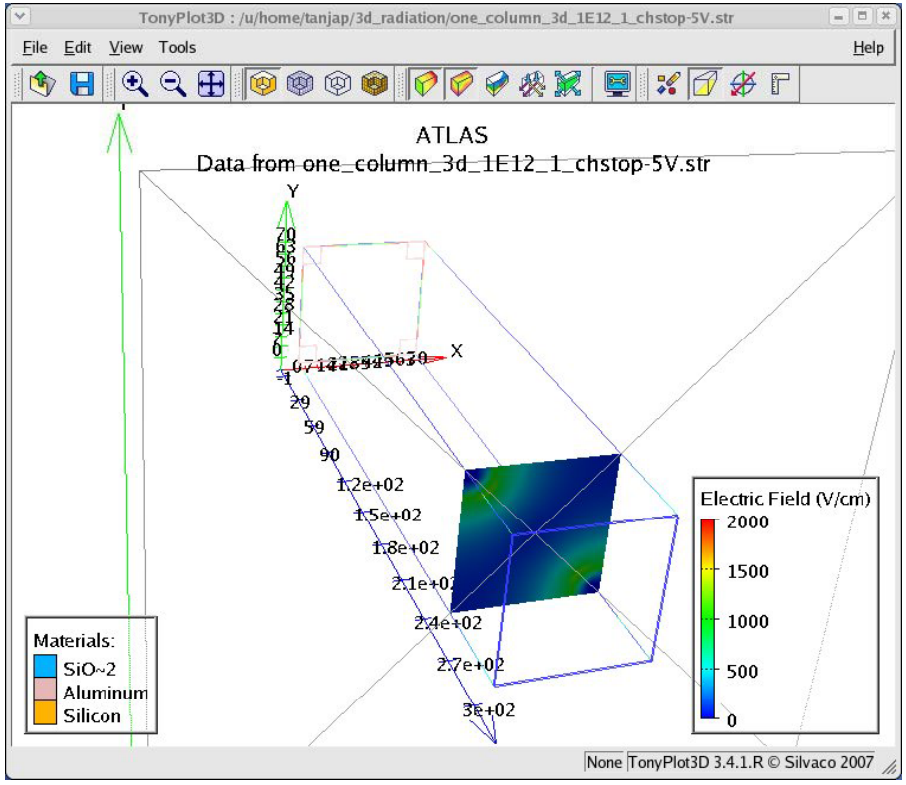




Electric field

Single N-type column one-sided 3D detector (5V)





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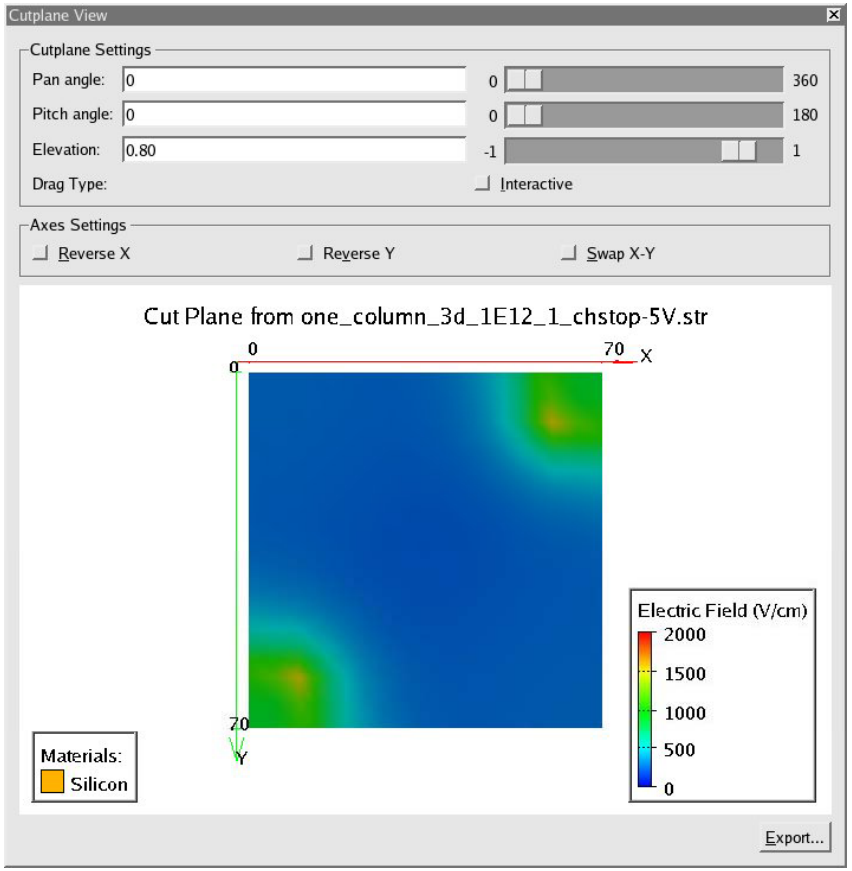

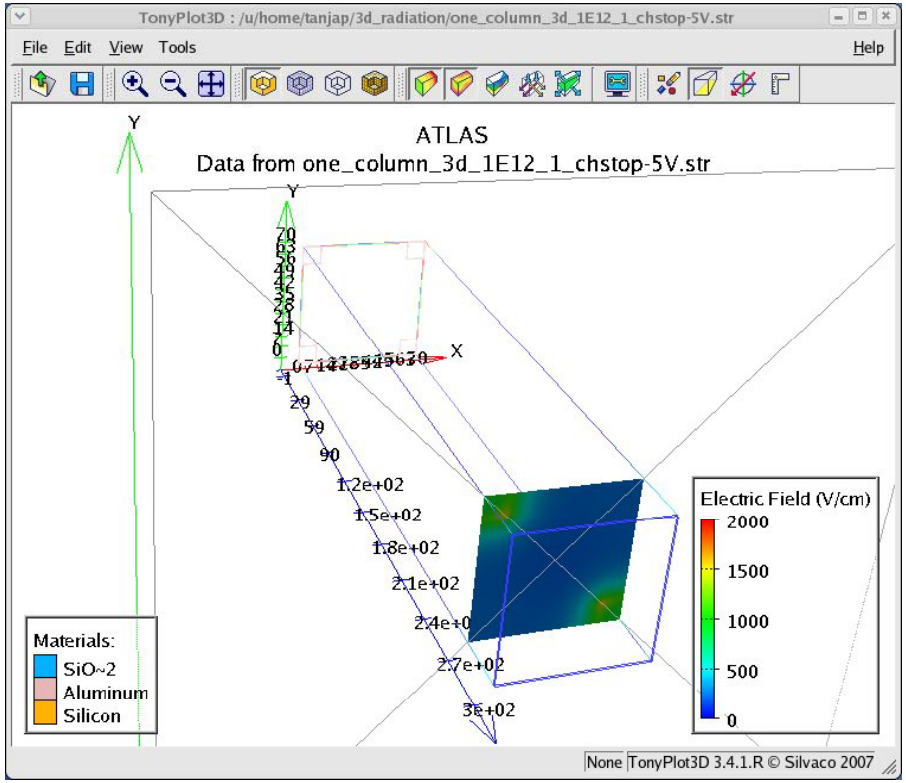

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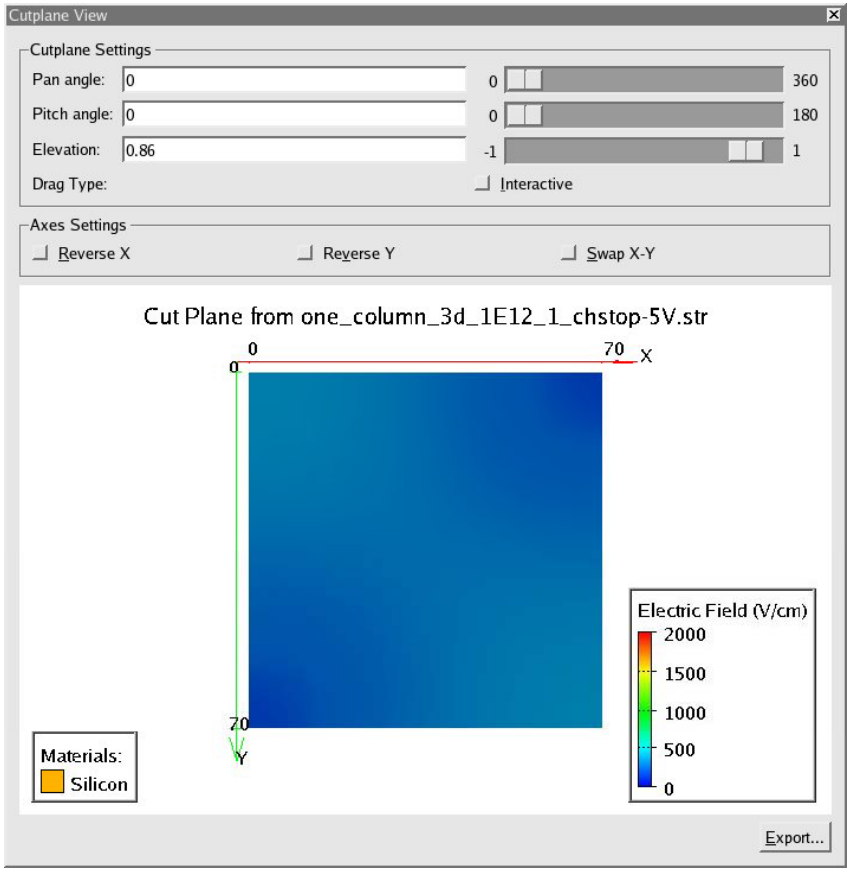
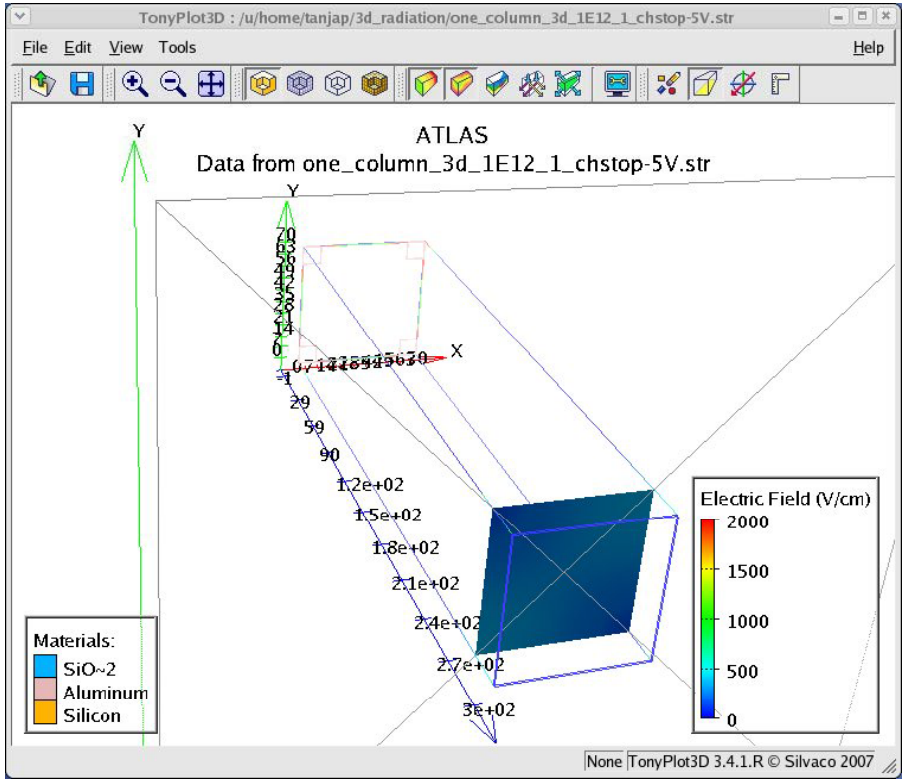
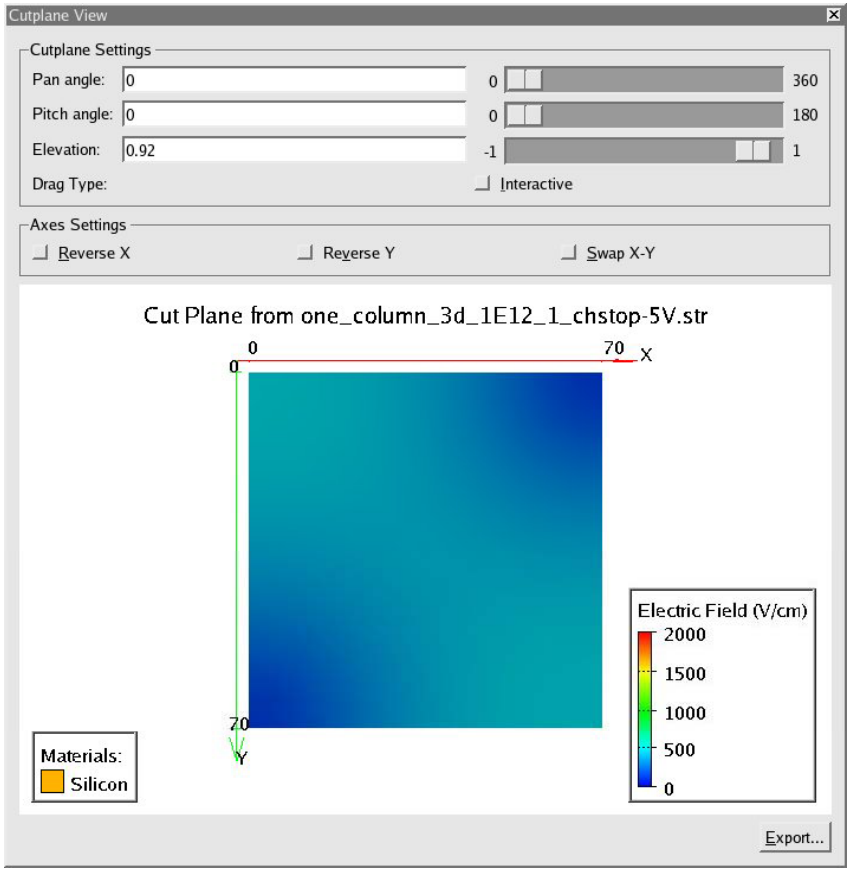
Single N-type column one-sided 3D detector (5V)

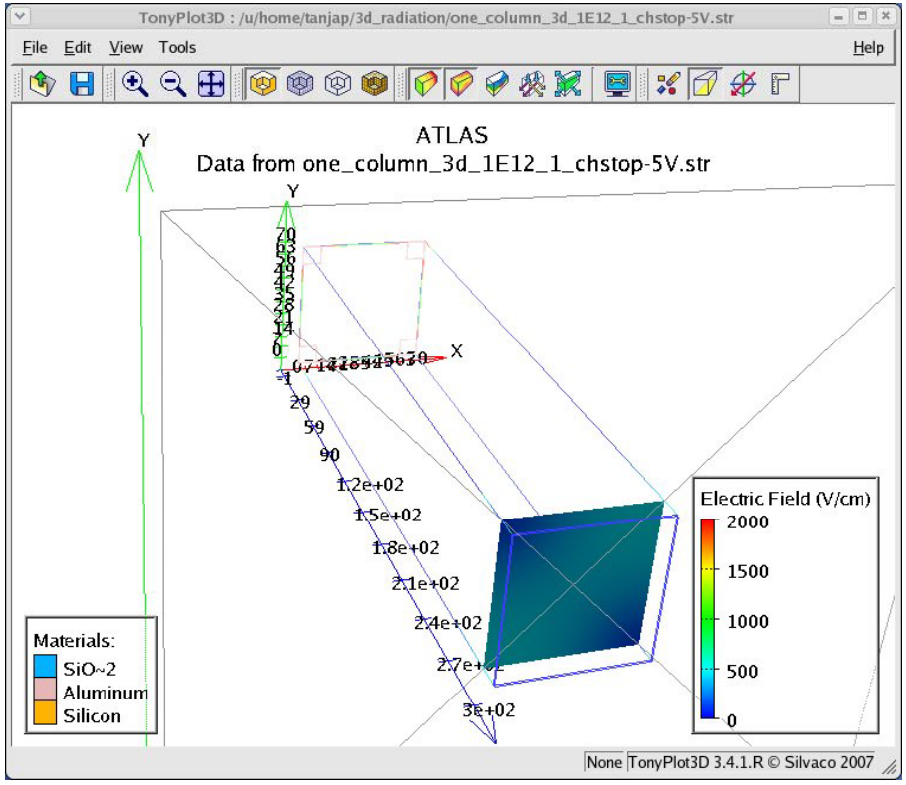




Electric field

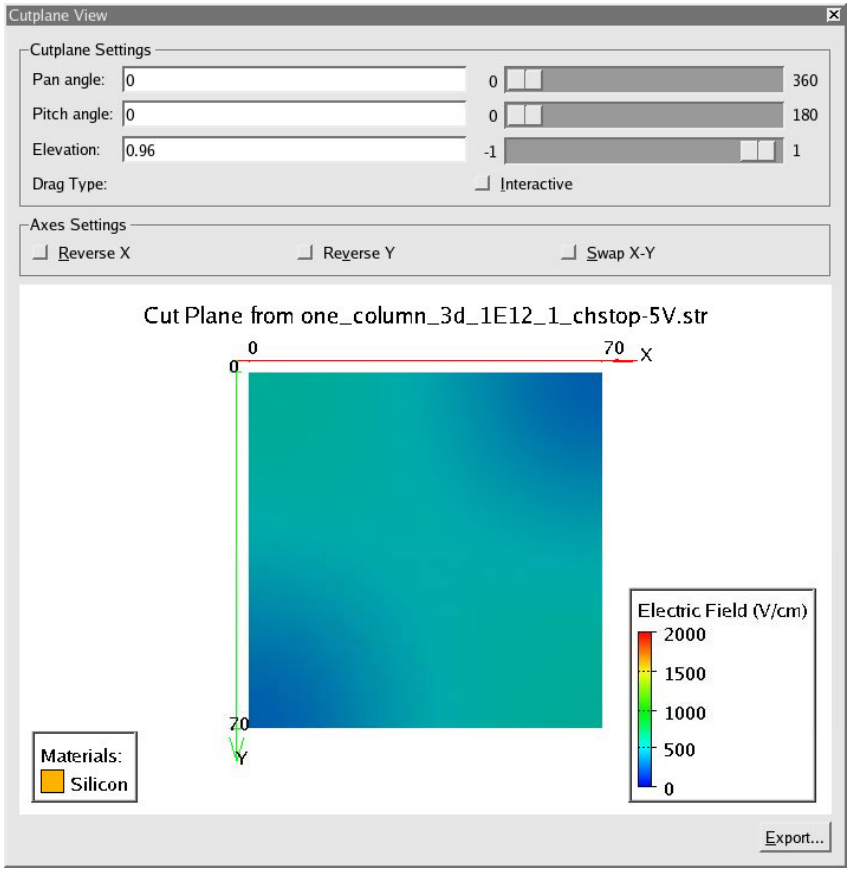
Single N-type column one-sided 3D detector (5V)

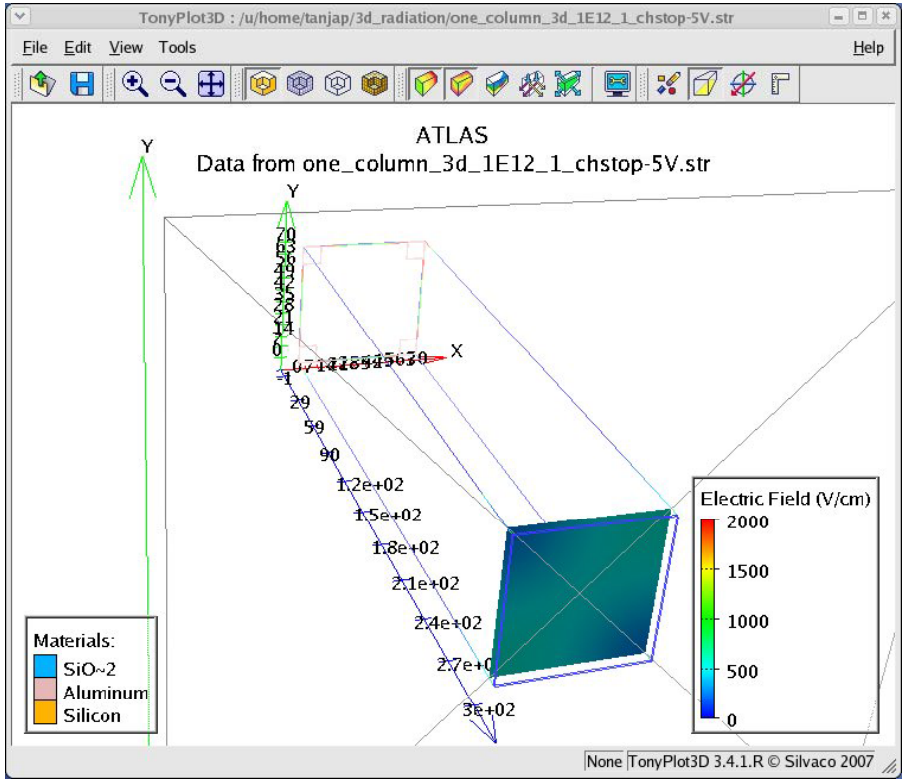




Electric field

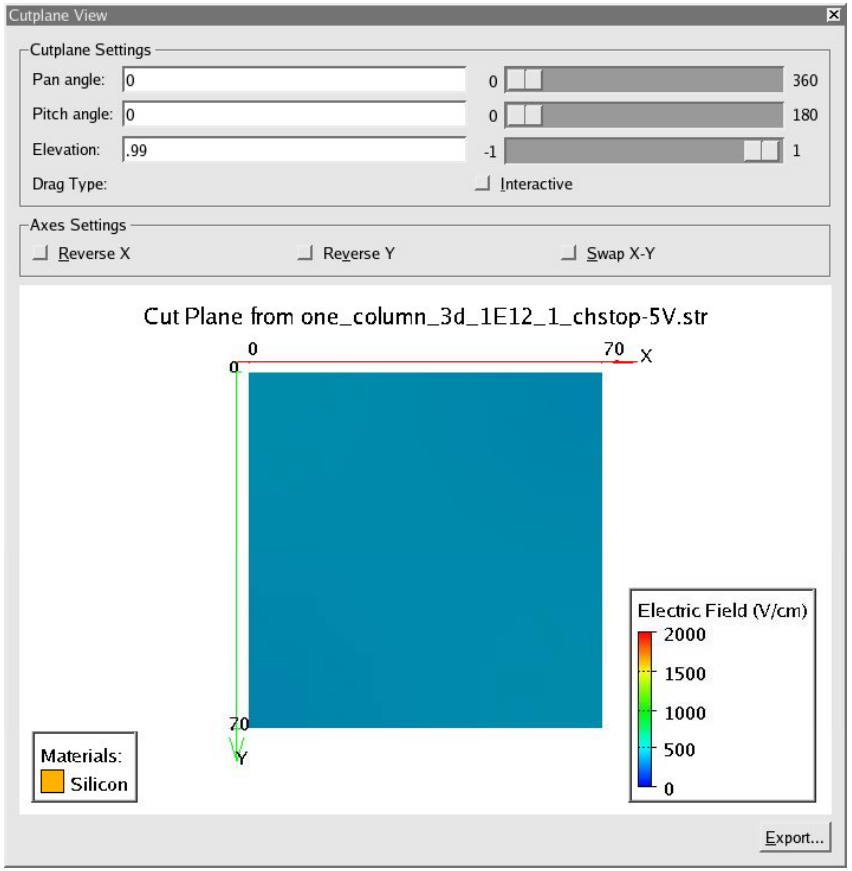
Single N-type column one-sided 3D detector (5V)

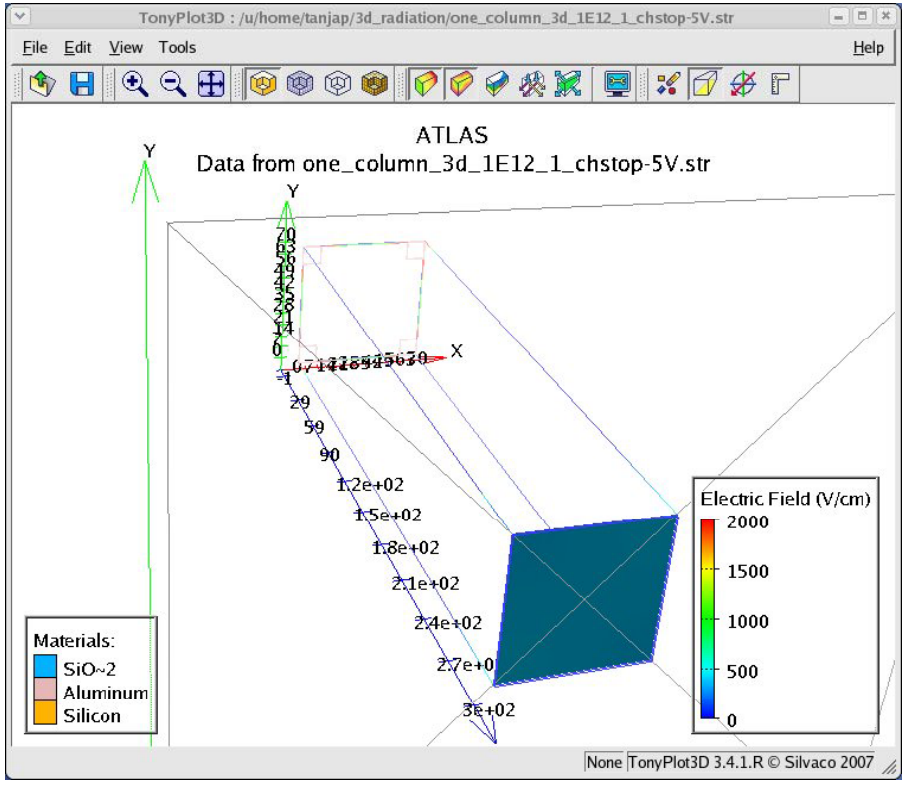




Electric field

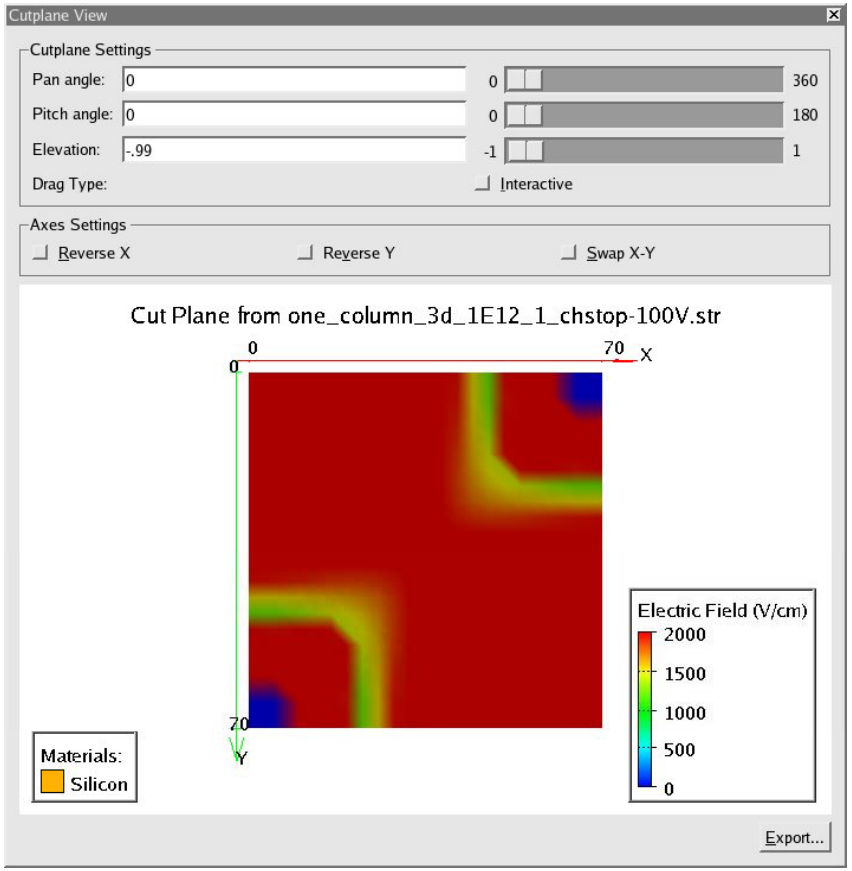
Single N-type column one-sided 3D detector (5V)

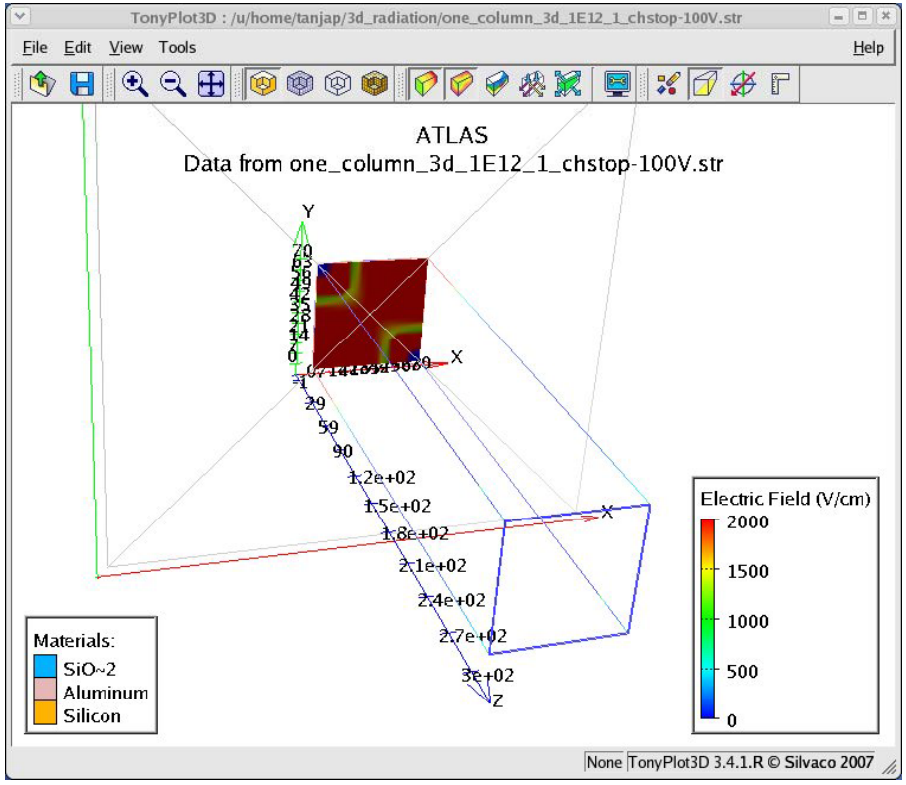




Electric field

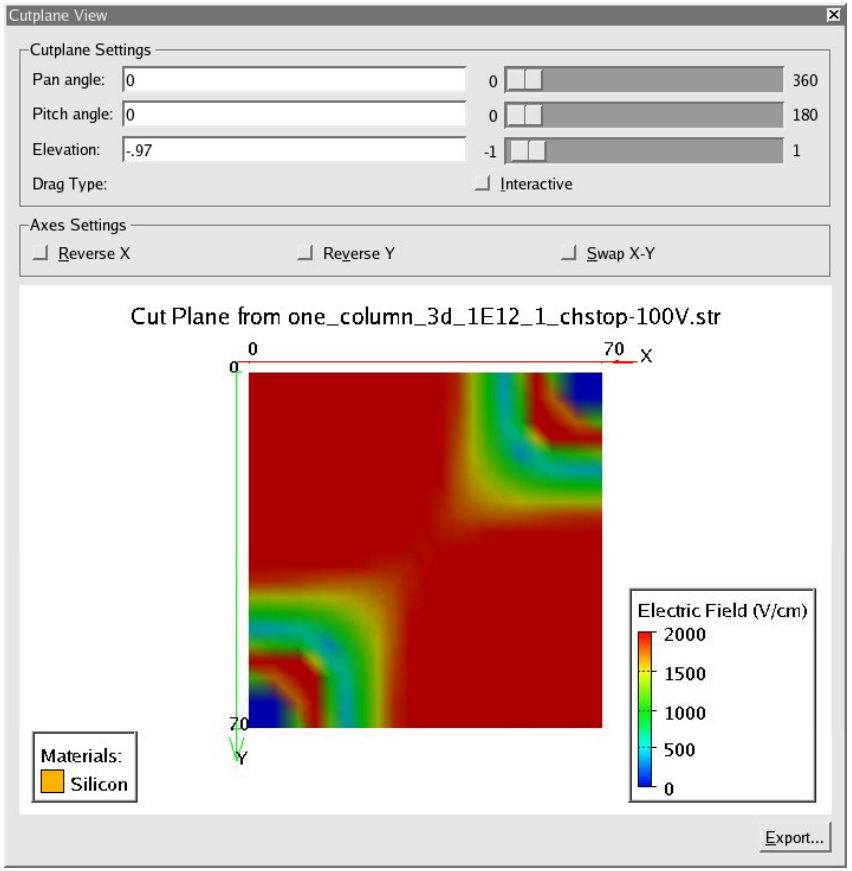
Single N-type column one-sided 3D detector (100V)

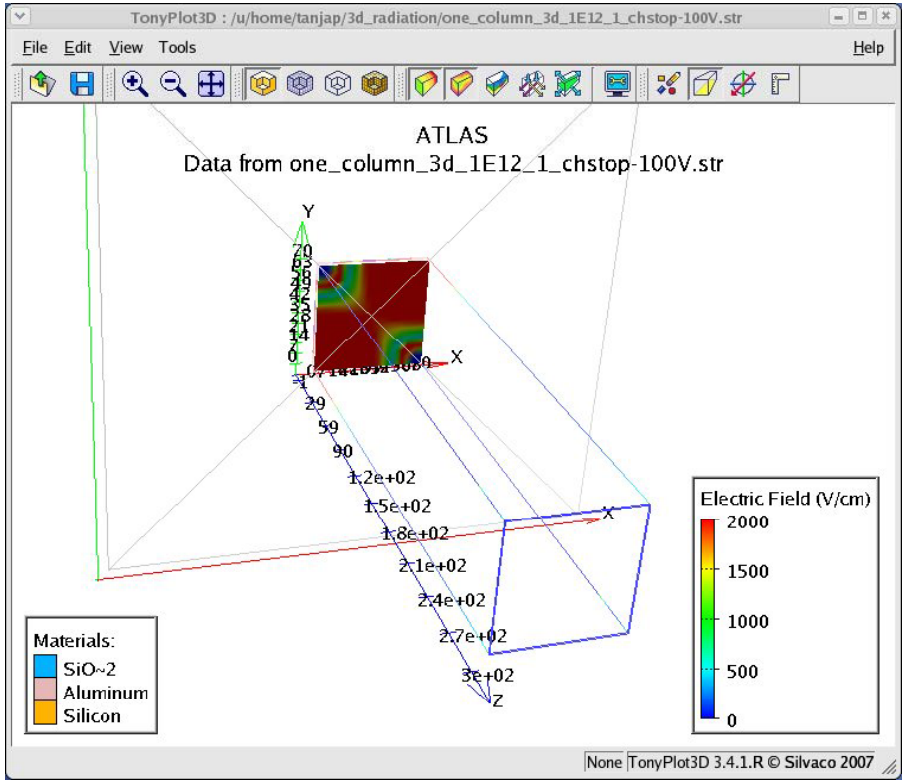




Electric field

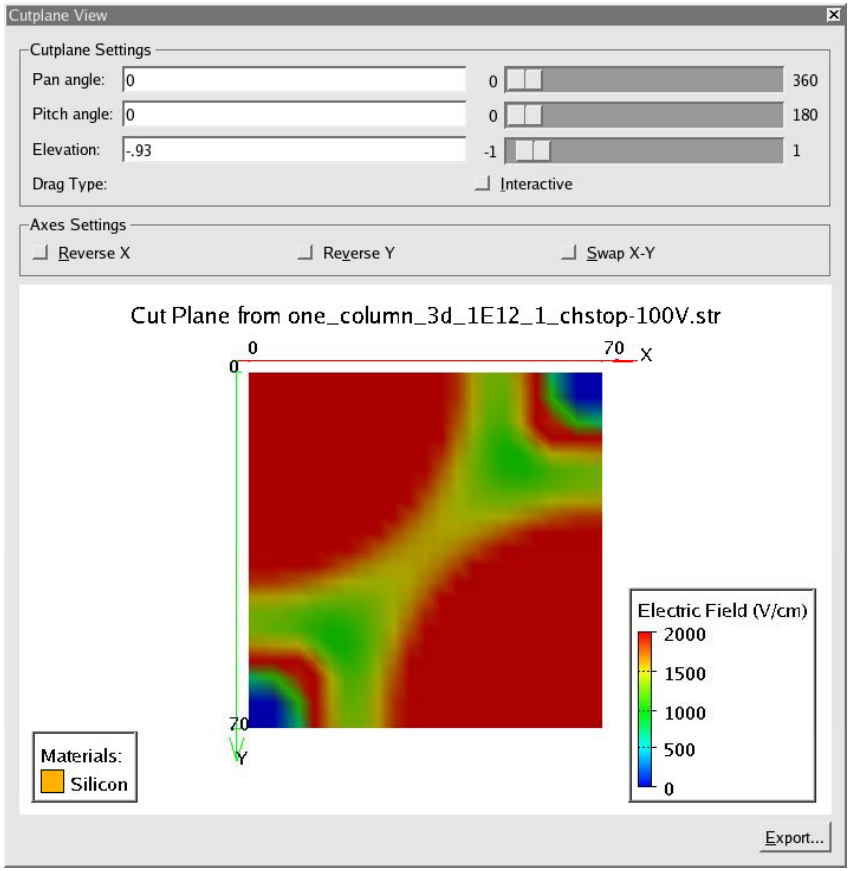
Single N-type column one-sided 3D detector (100V)

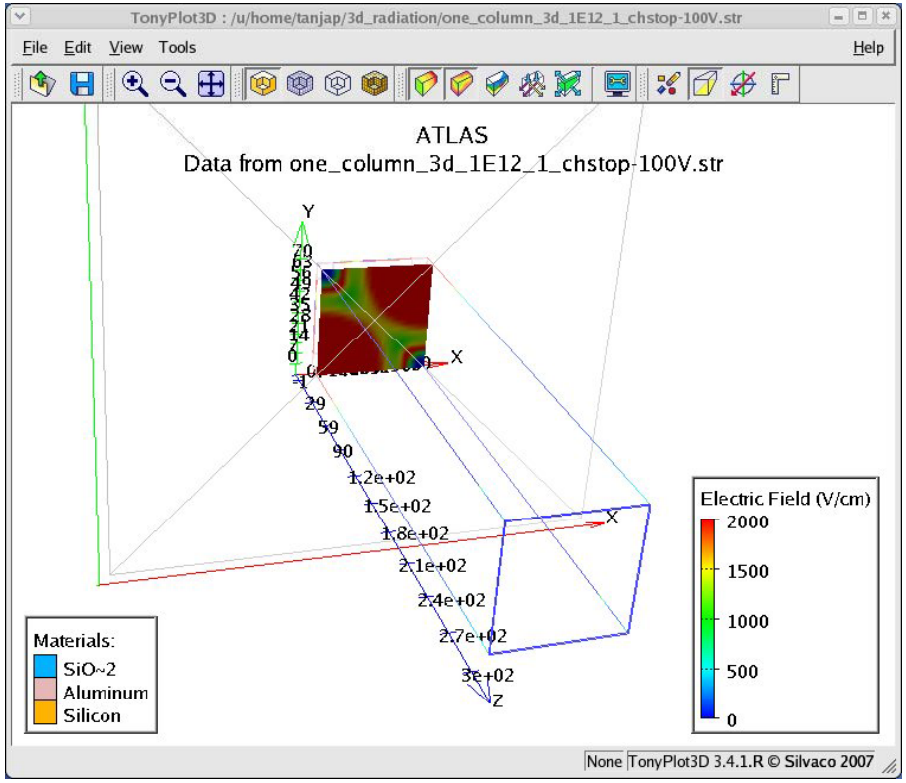




Electric field

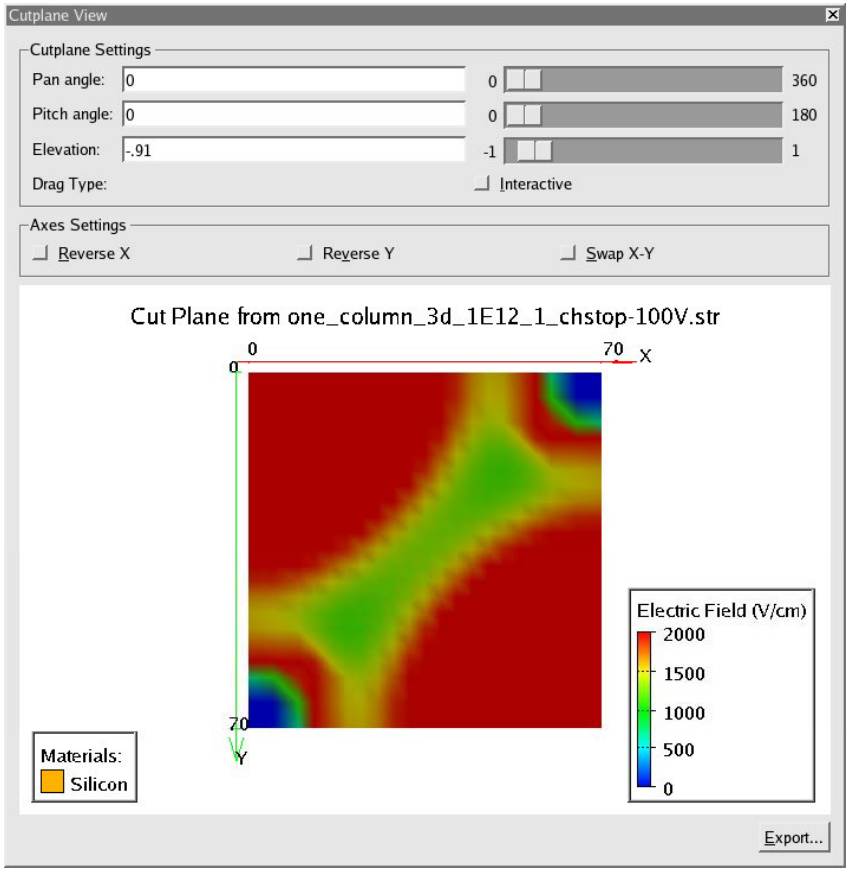
Single N-type column one-sided 3D detector (100V)

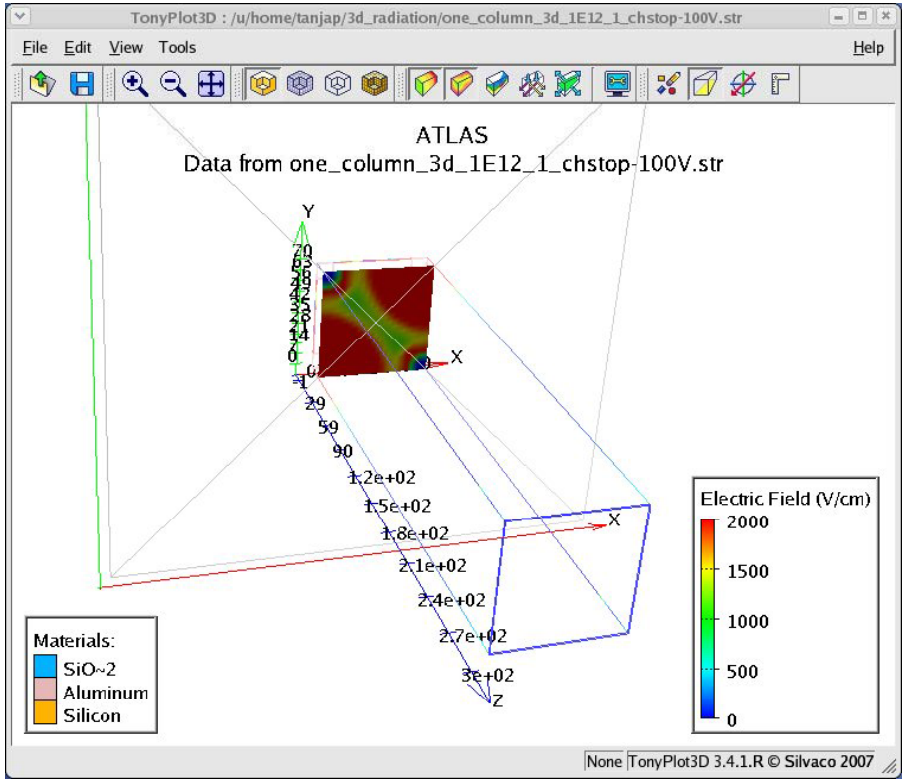




Electric field

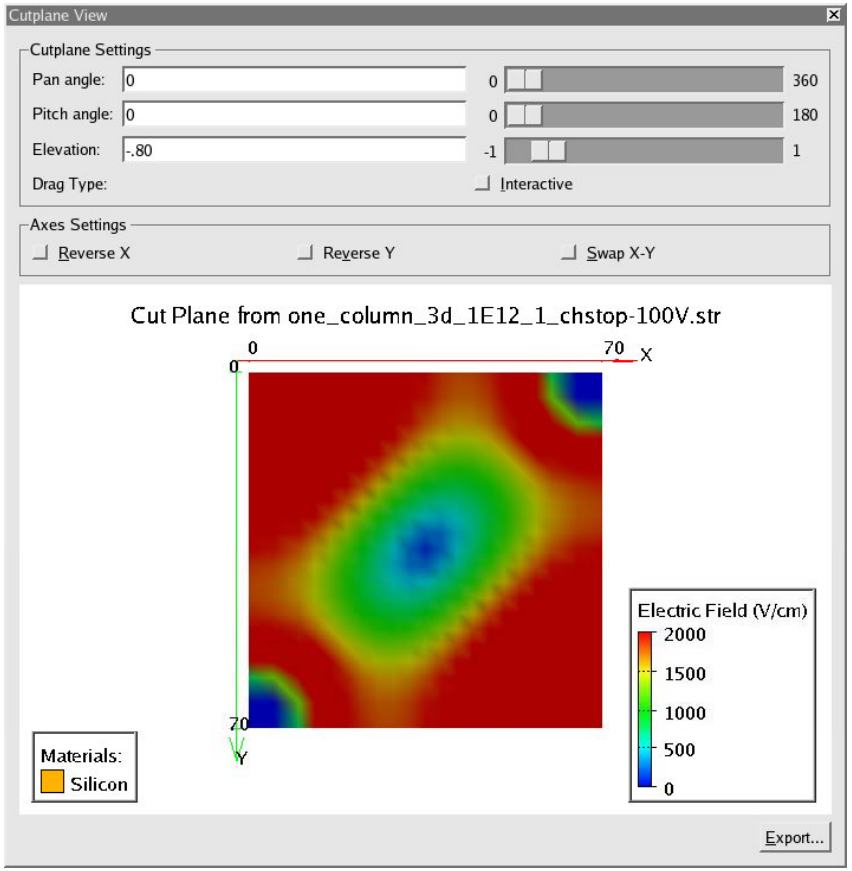
Single N-type column one-sided 3D detector (100V)

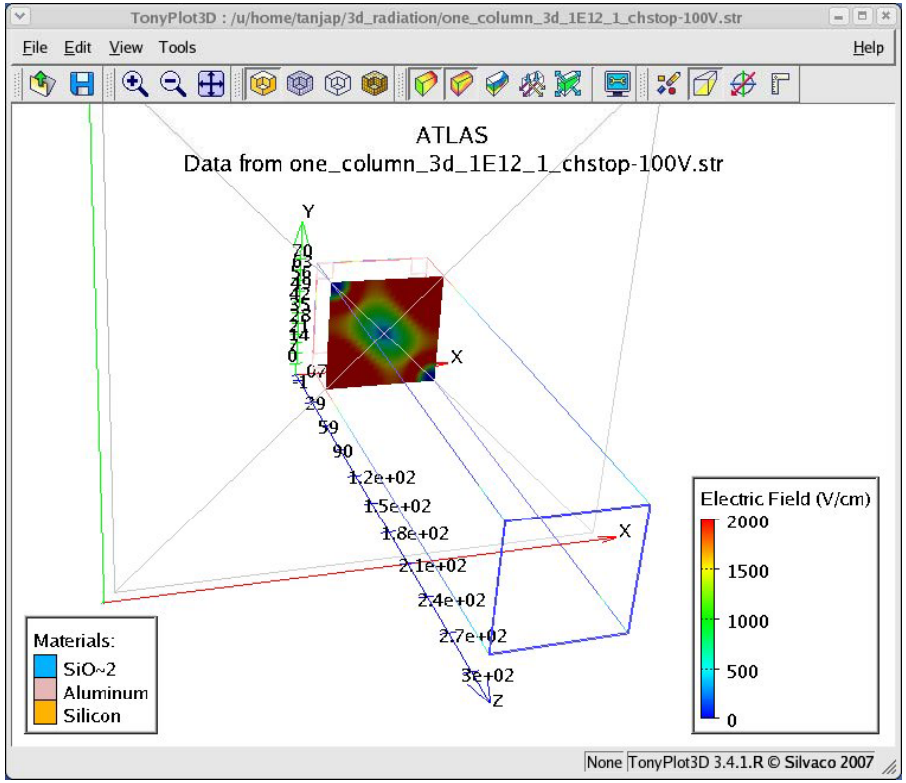




Electric field

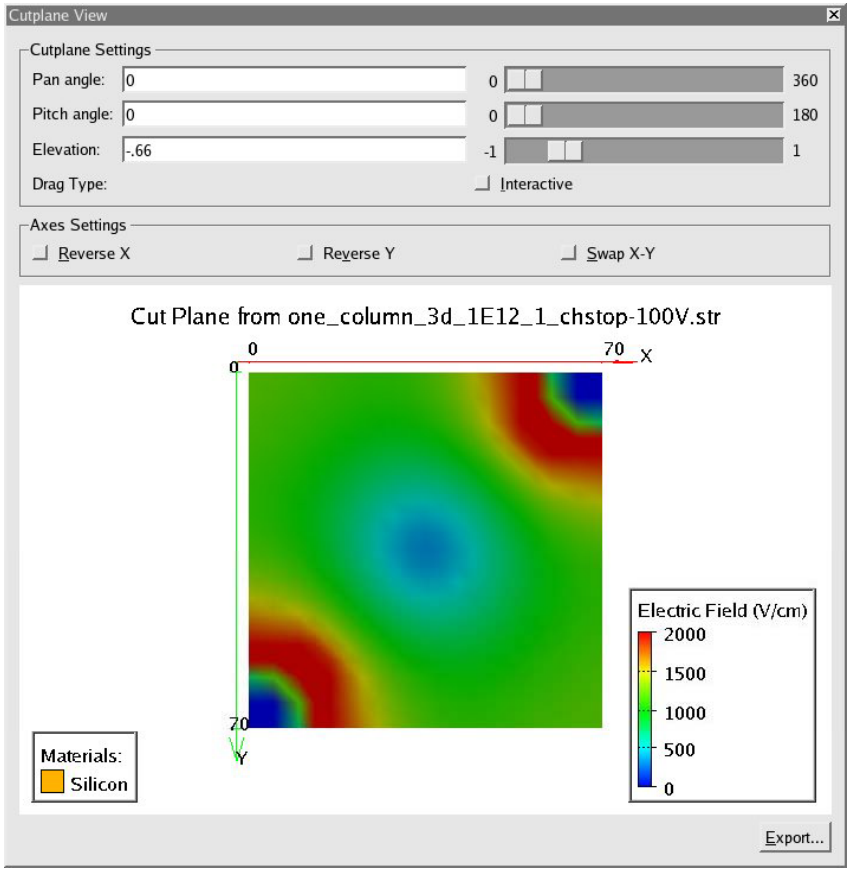
Single N-type column one-sided 3D detector (100V)

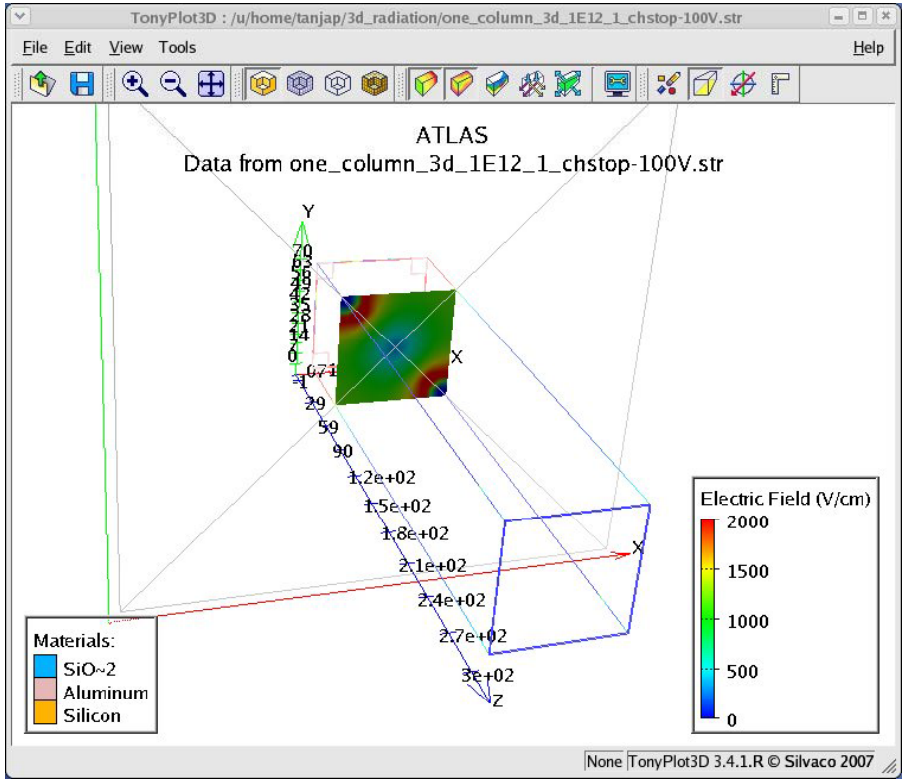




Electric field

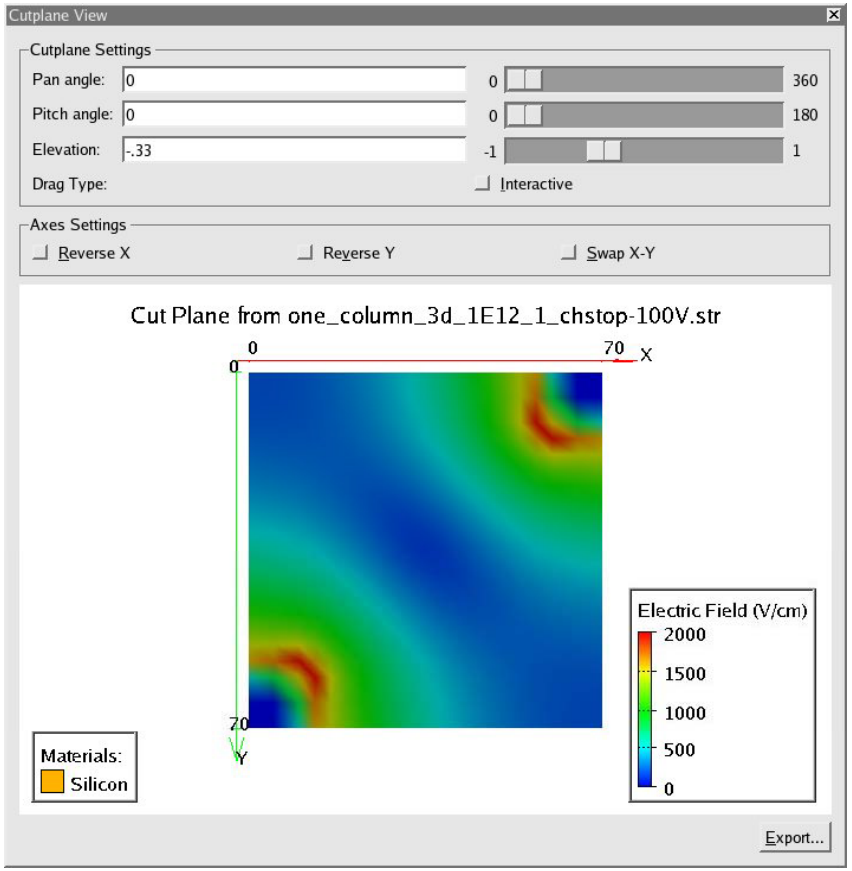
Single N-type column one-sided 3D detector (100V)

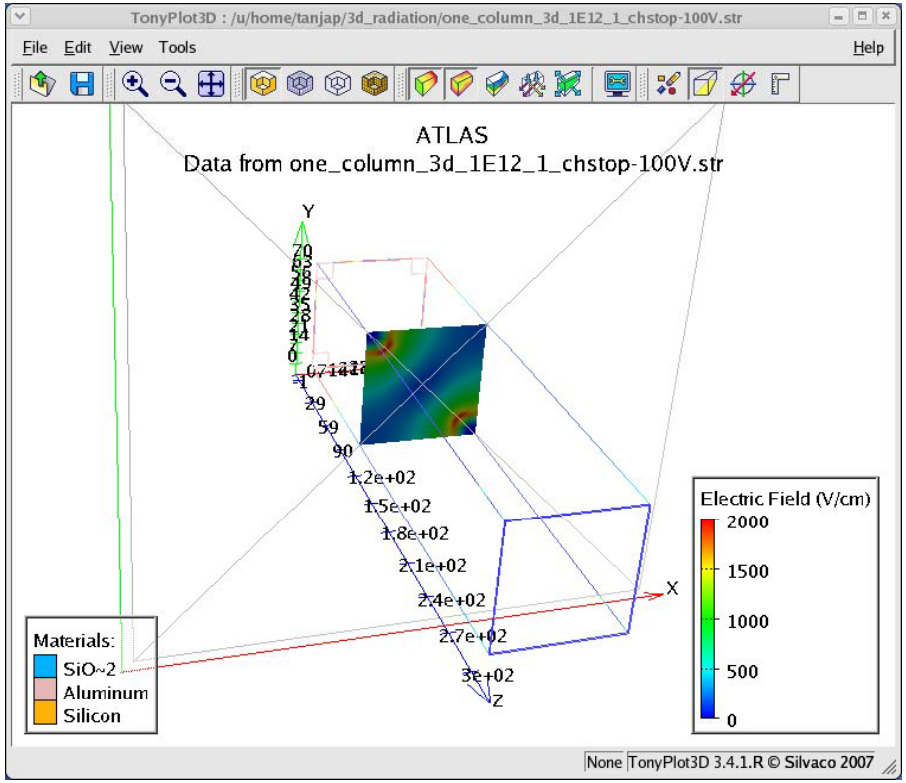




Electric field

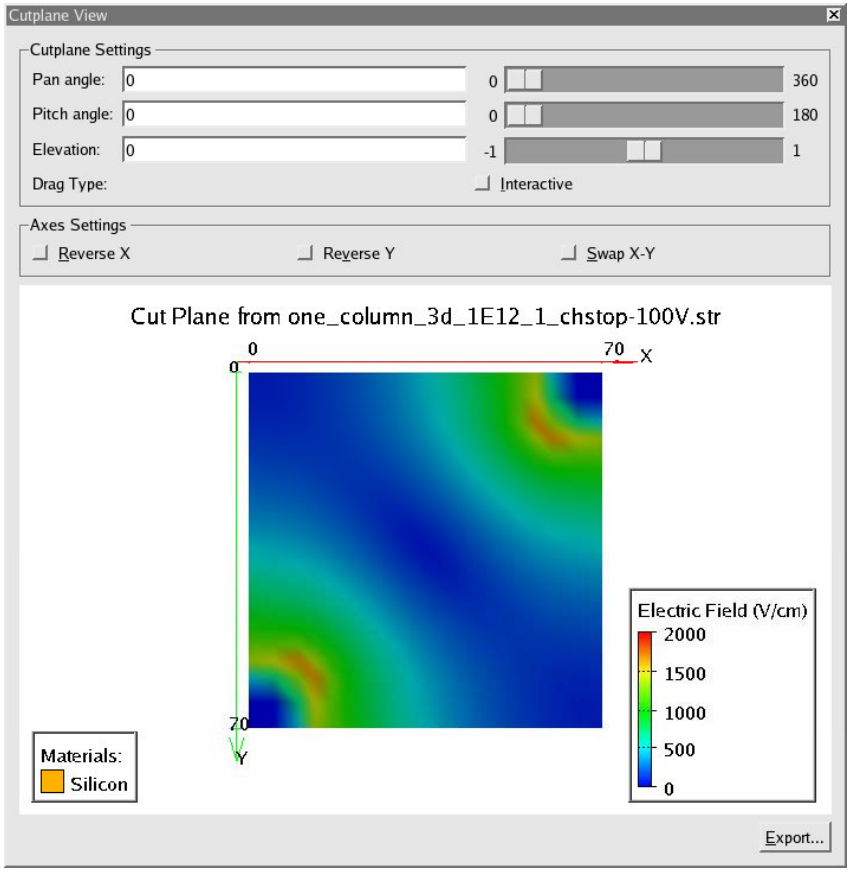
Single N-type column one-sided 3D detector (100V)

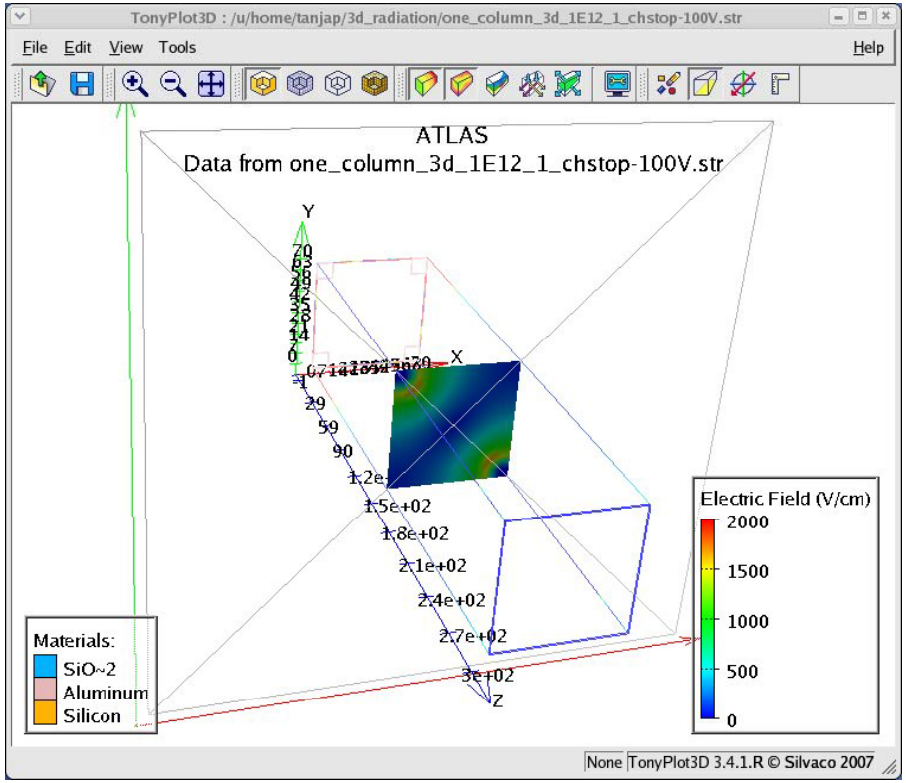




Electric field

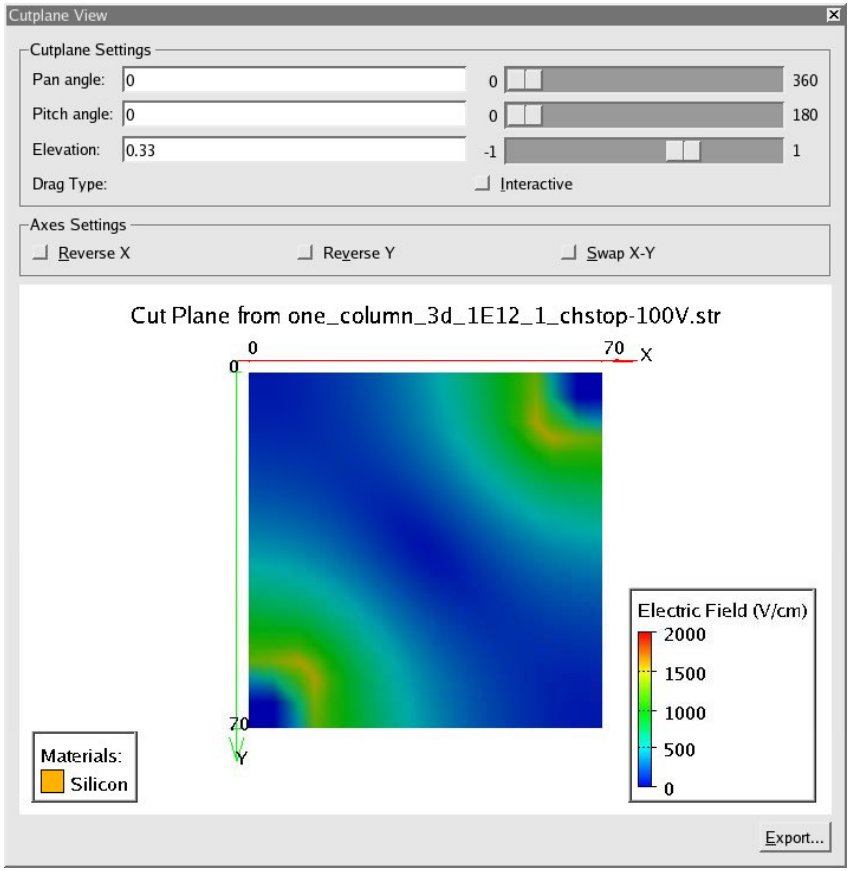
Single N-type column one-sided 3D detector (100V)

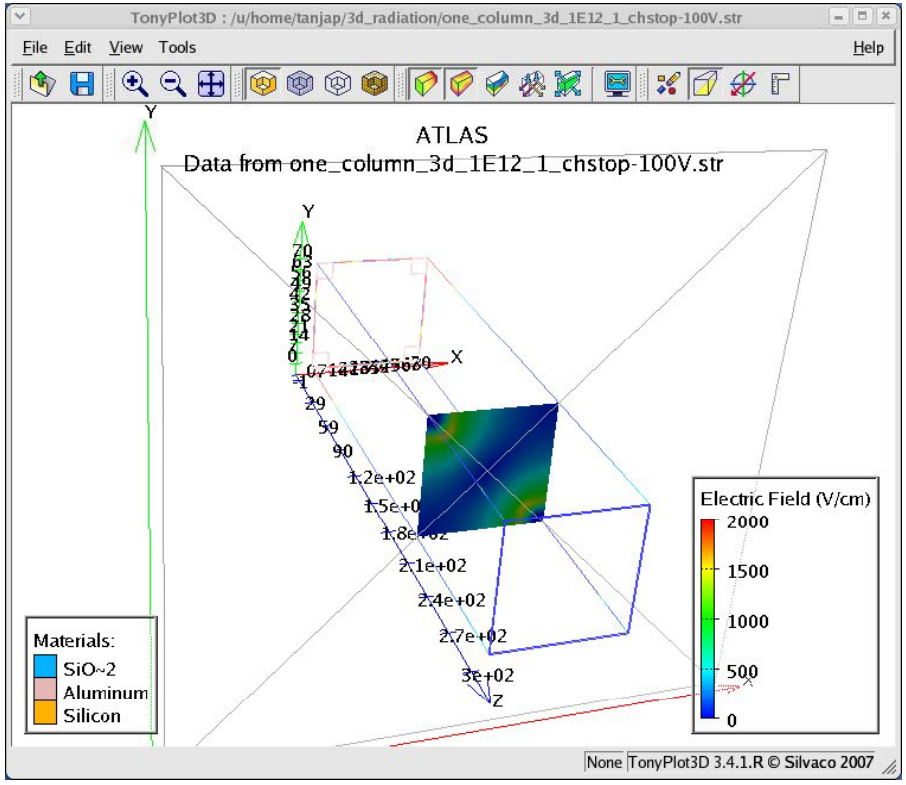




Electric field

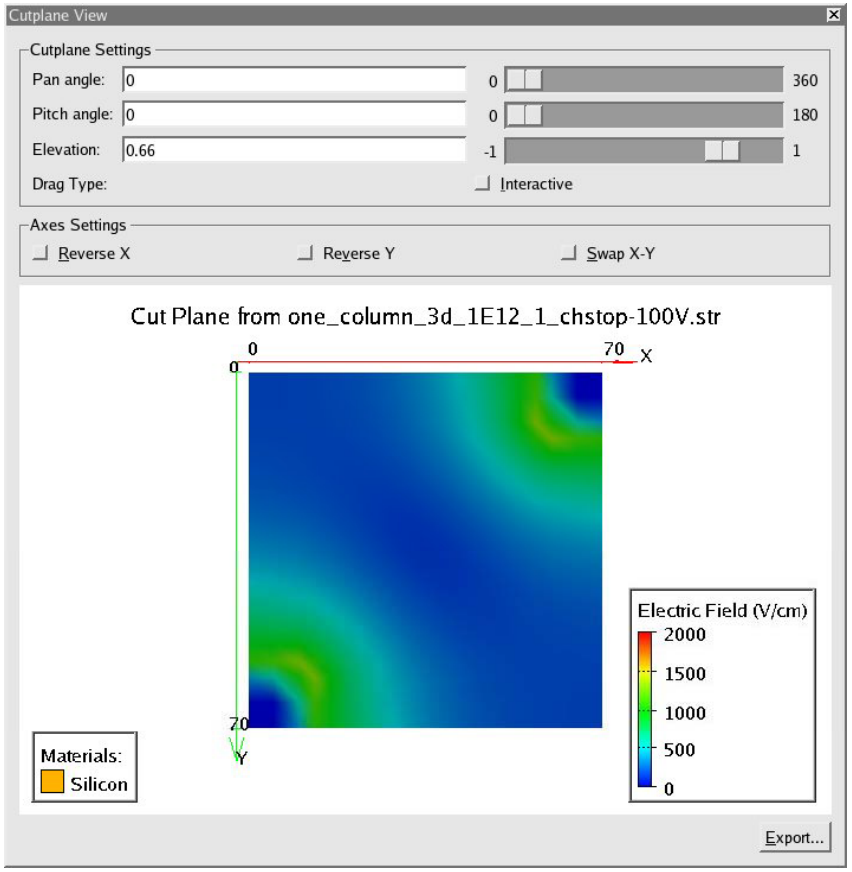
Single N-type column one-sided 3D detector (100V)

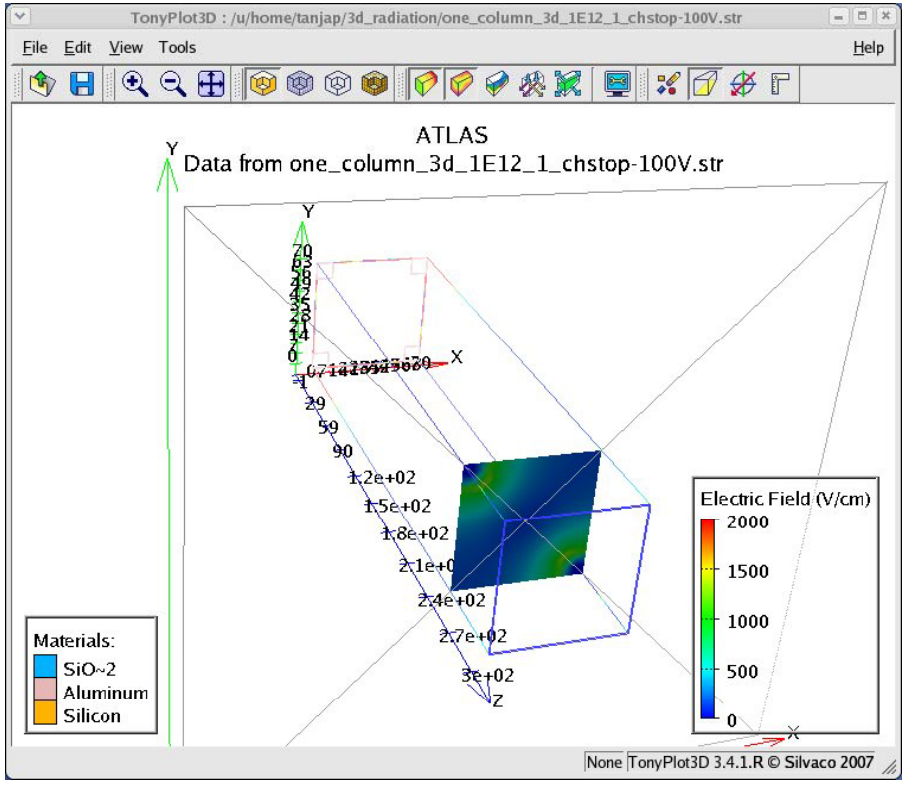




Electric field

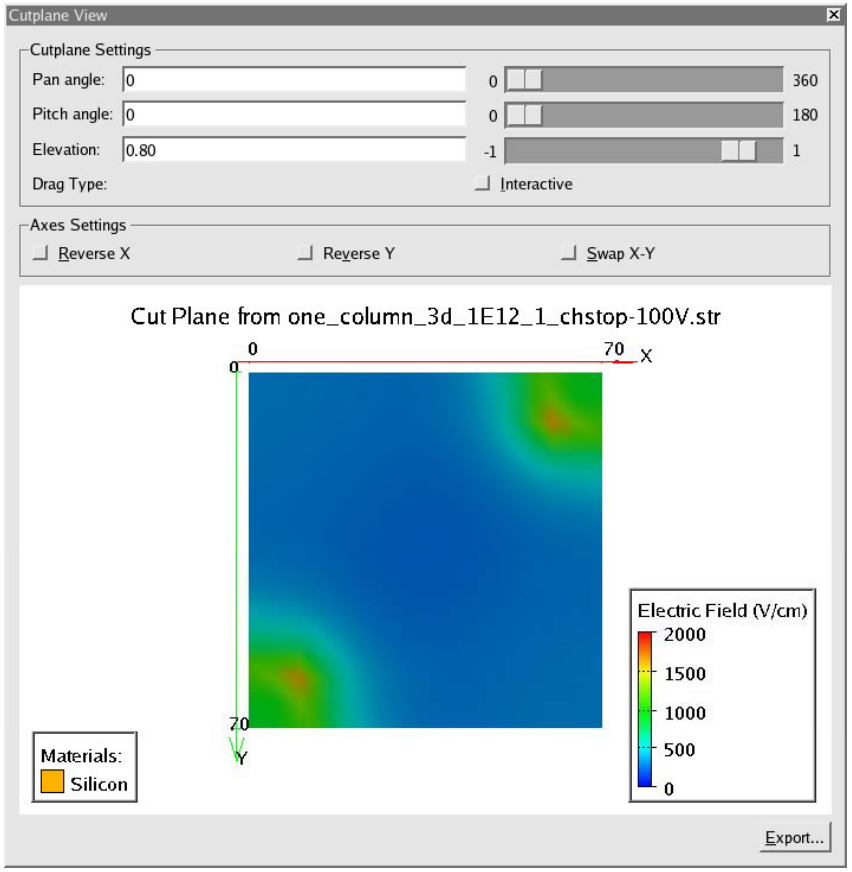
Single N-type column one-sided 3D detector (100V)

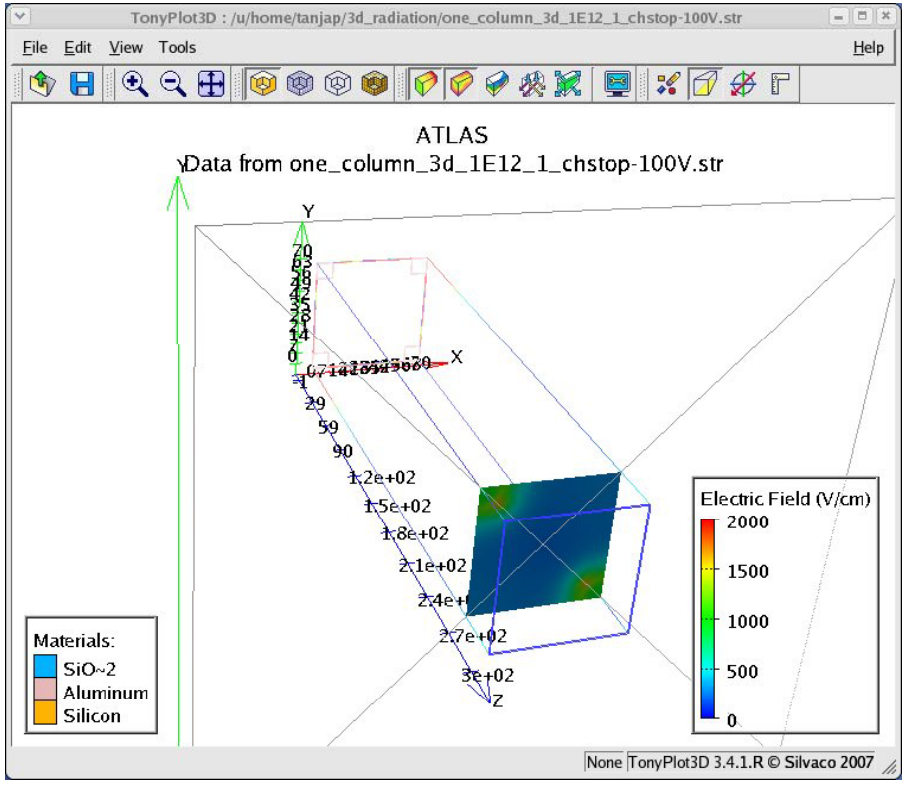




Electric field

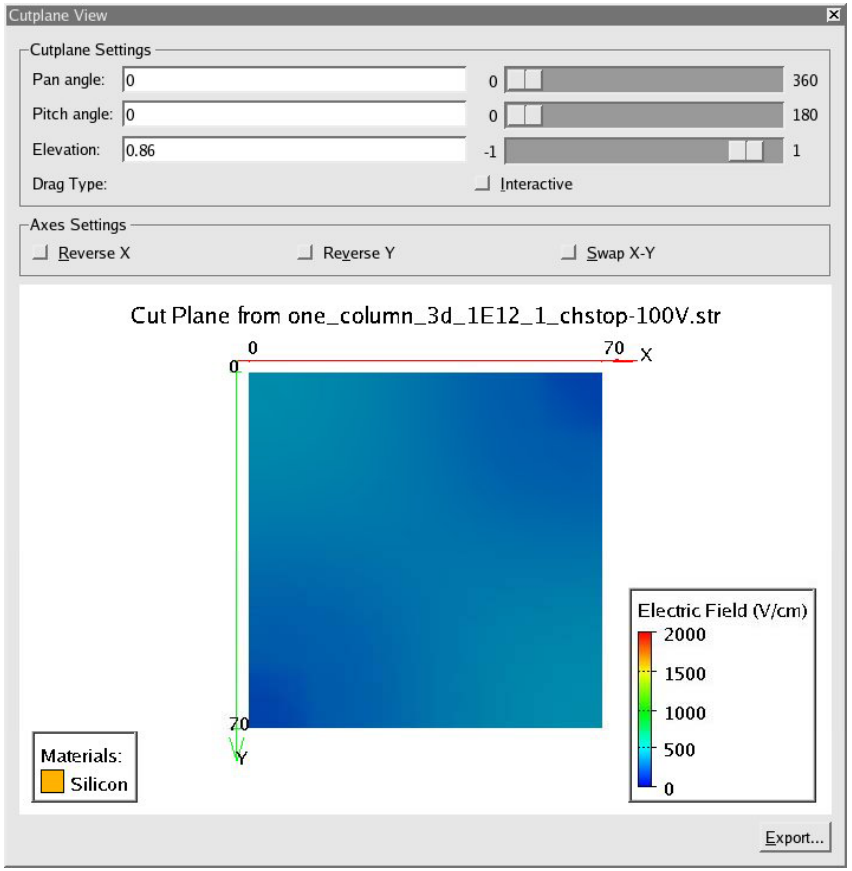
Single N-type column one-sided 3D detector (100V)

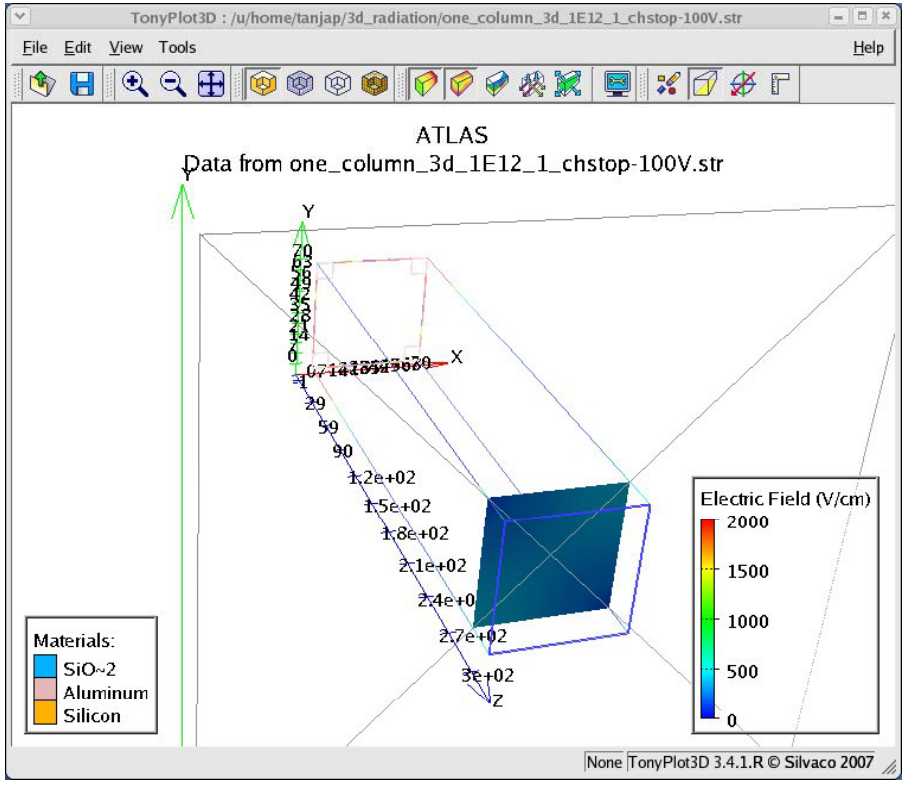




Electric field

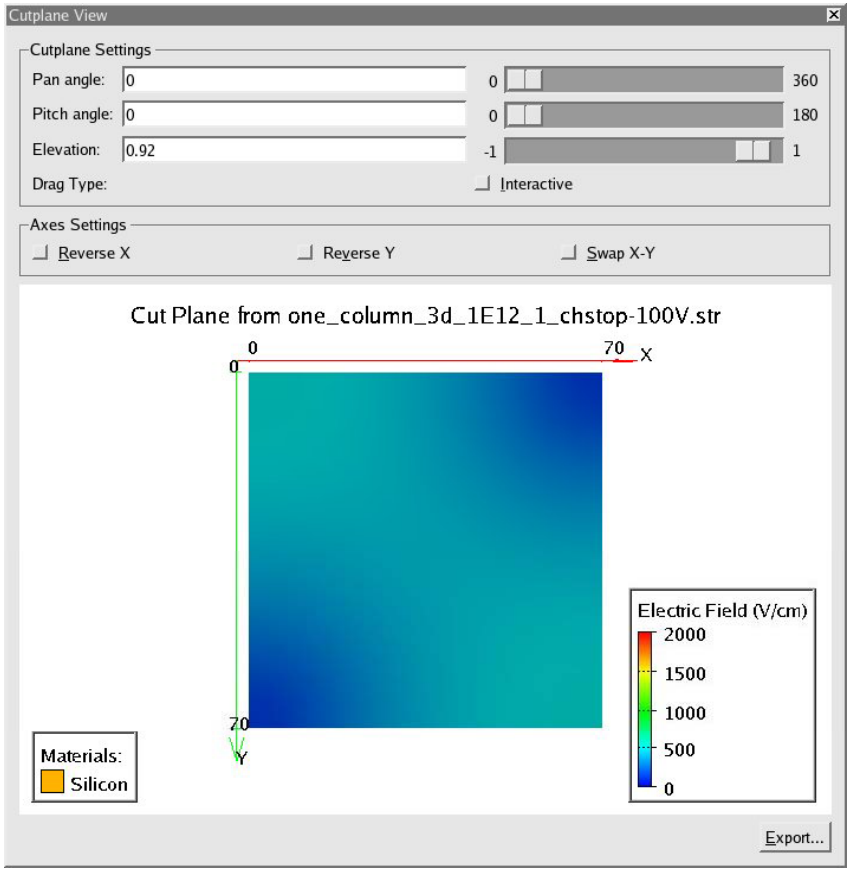
Single N-type column one-sided 3D detector (100V)

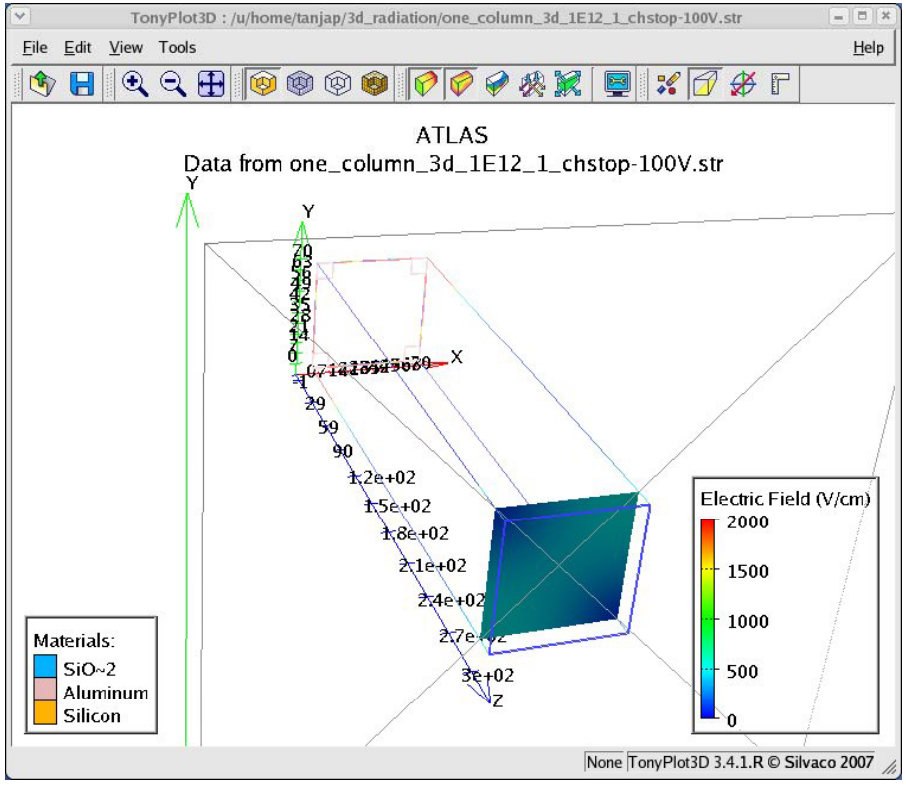




Electric field

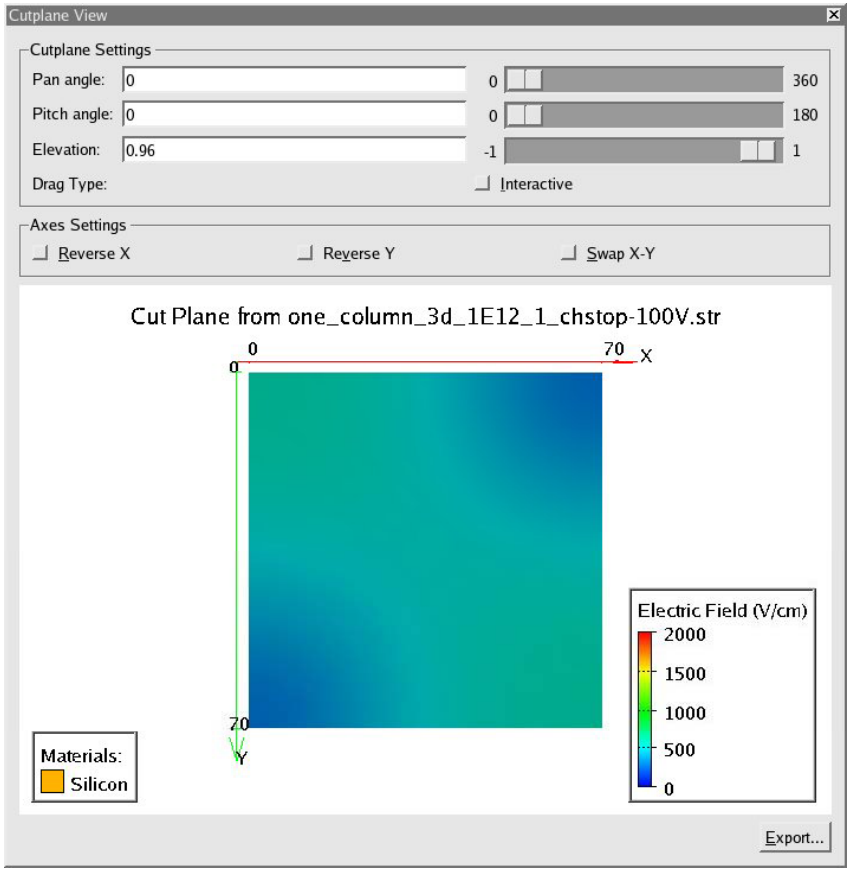
Single N-type column one-sided 3D detector (100V)

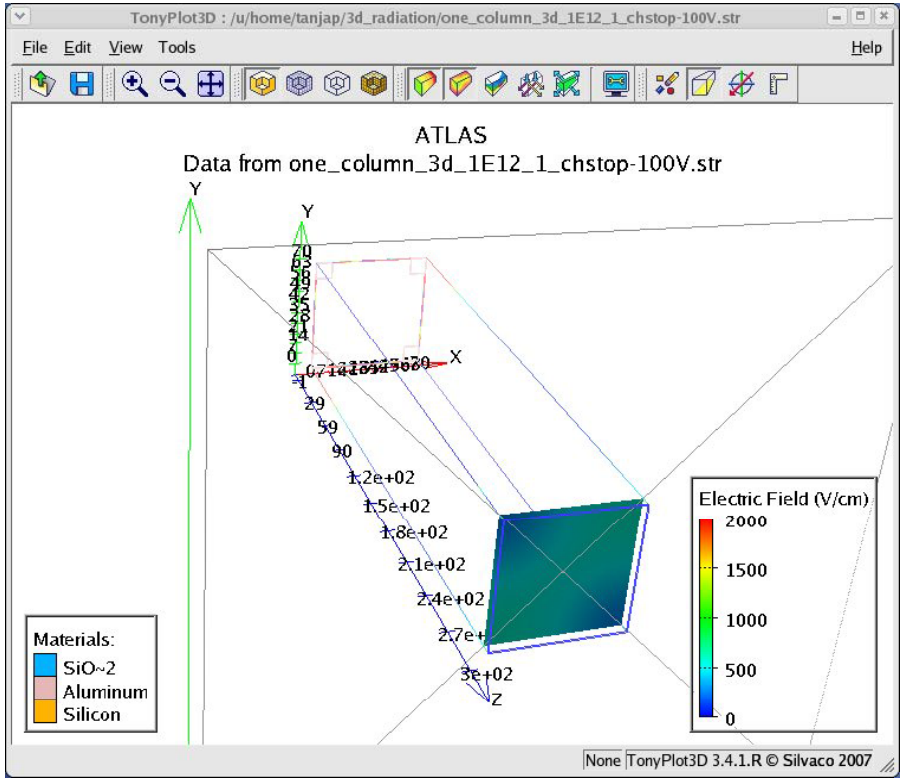




Electric field

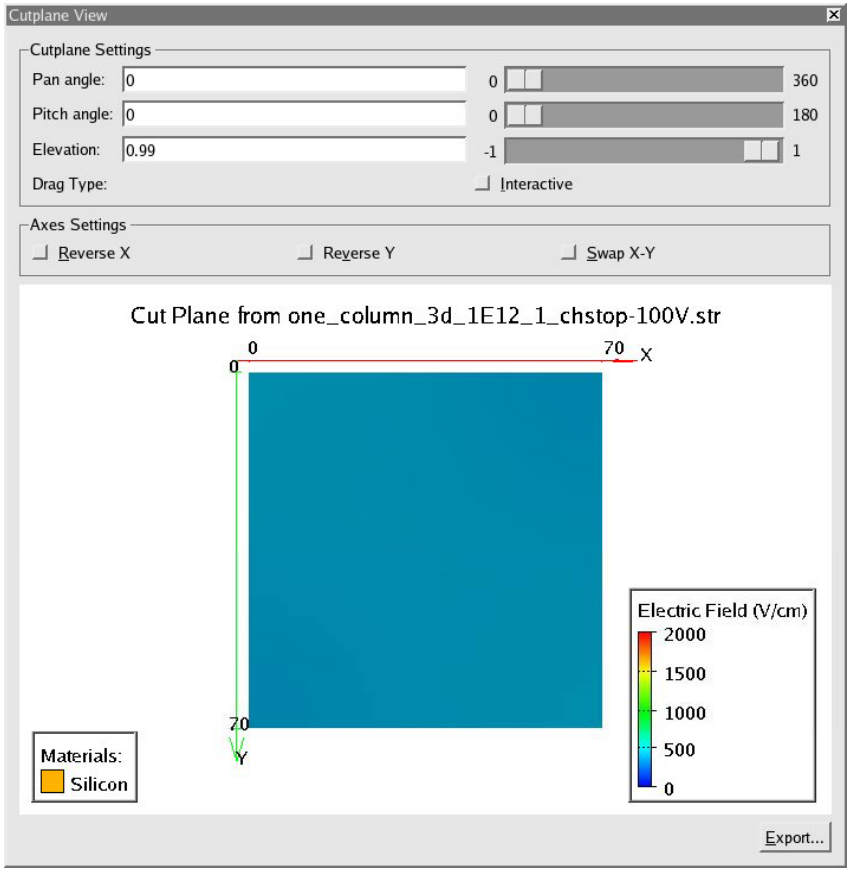
Single N-type column one-sided 3D detector (100V)

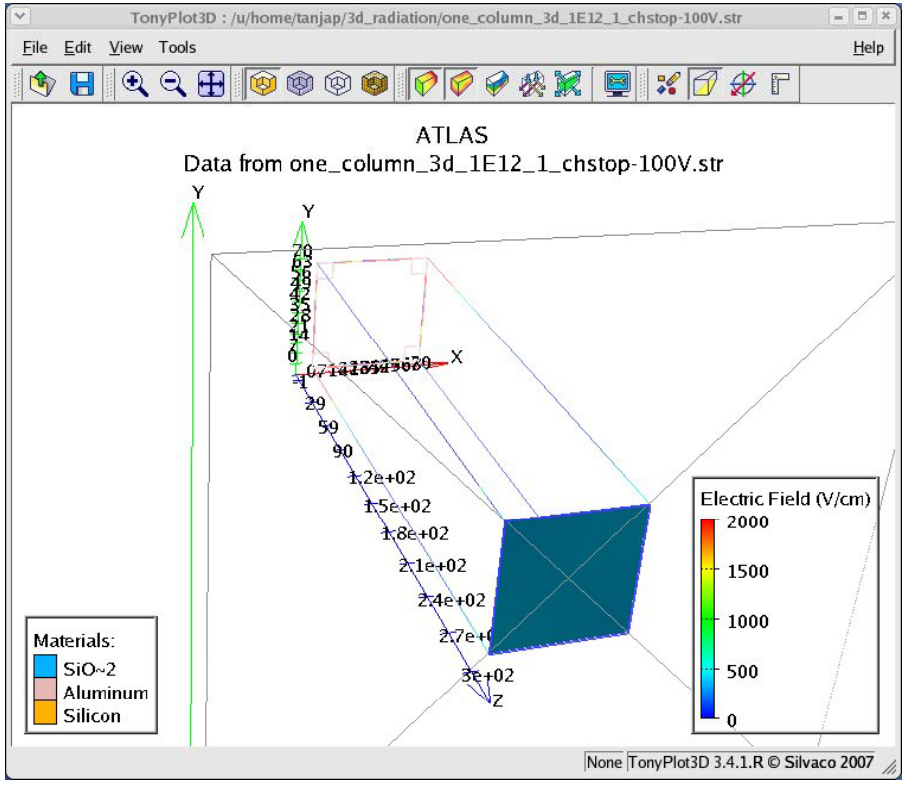




Electric field

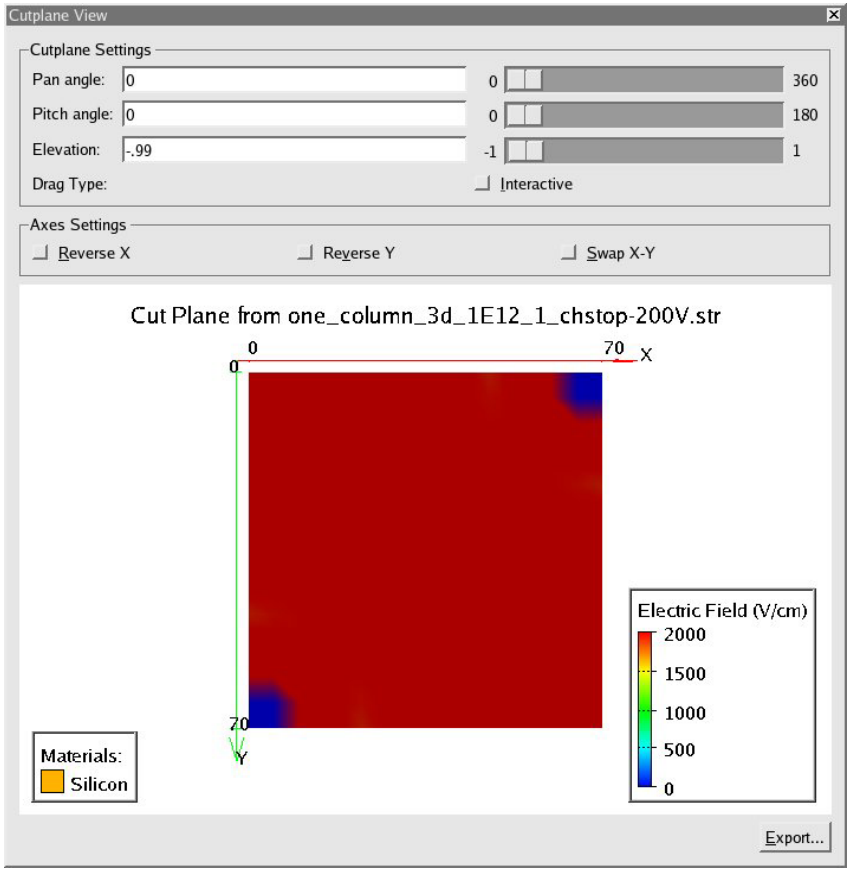
Single N-type column one-sided 3D detector (100V)

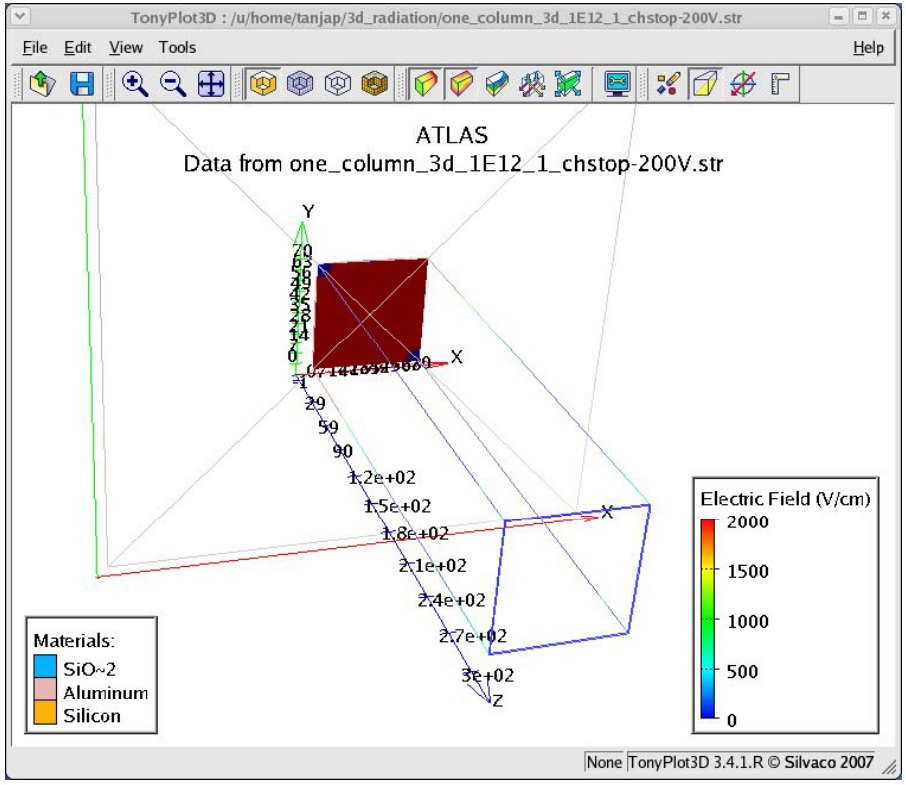




Electric field

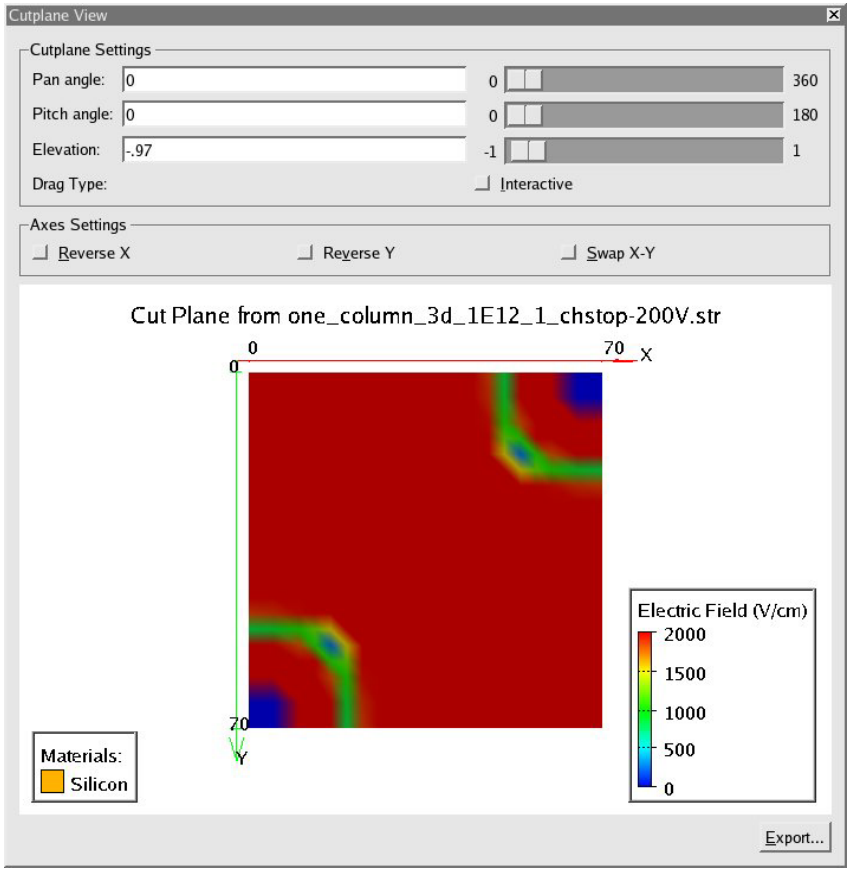
Single N-type column one-sided 3D detector (200V)

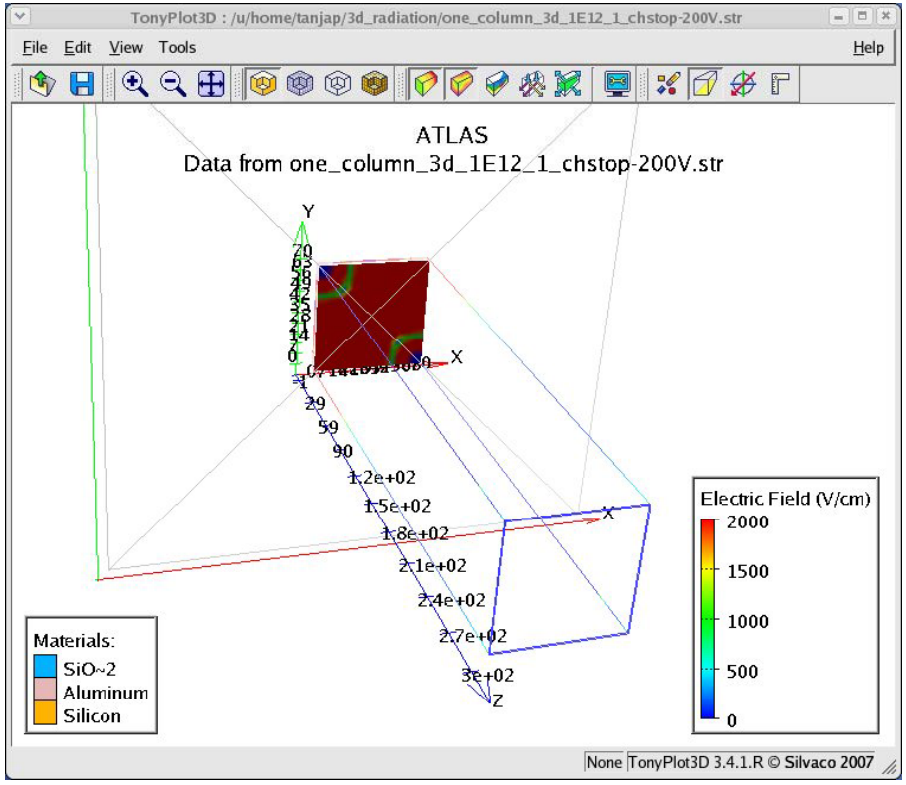




Electric field

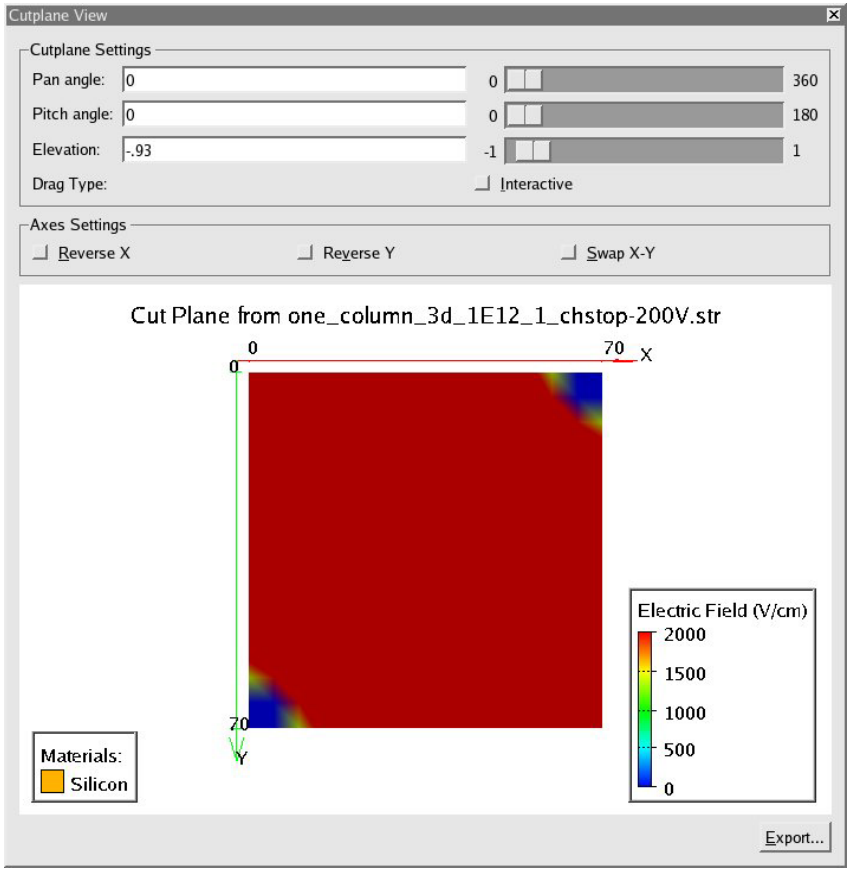
Single N-type column one-sided 3D detector (200V)

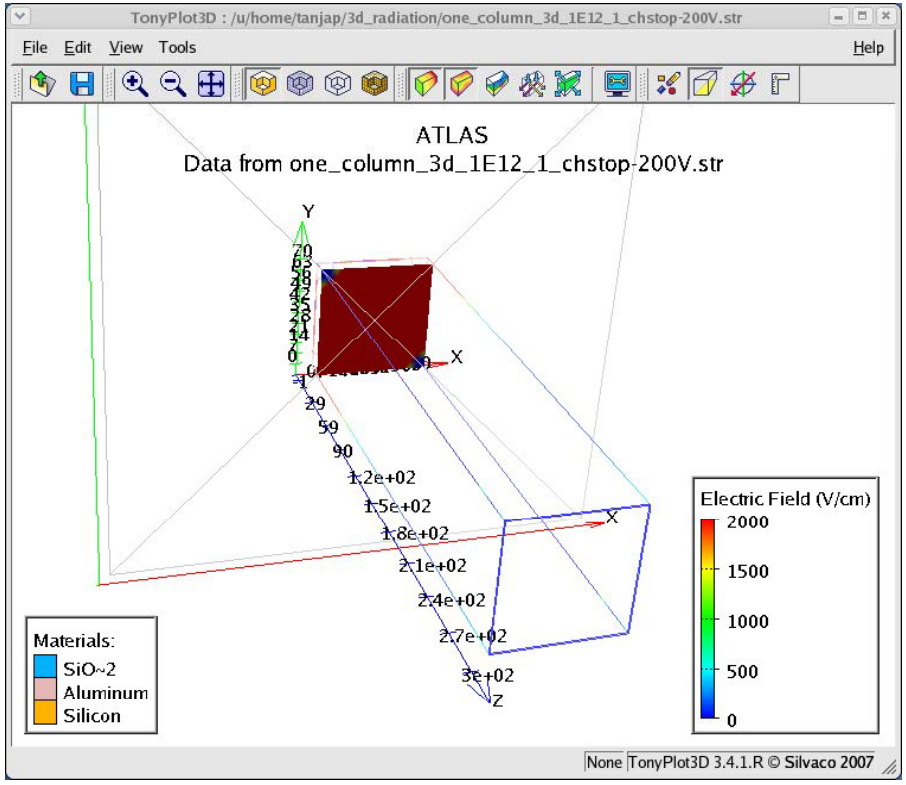




Electric field

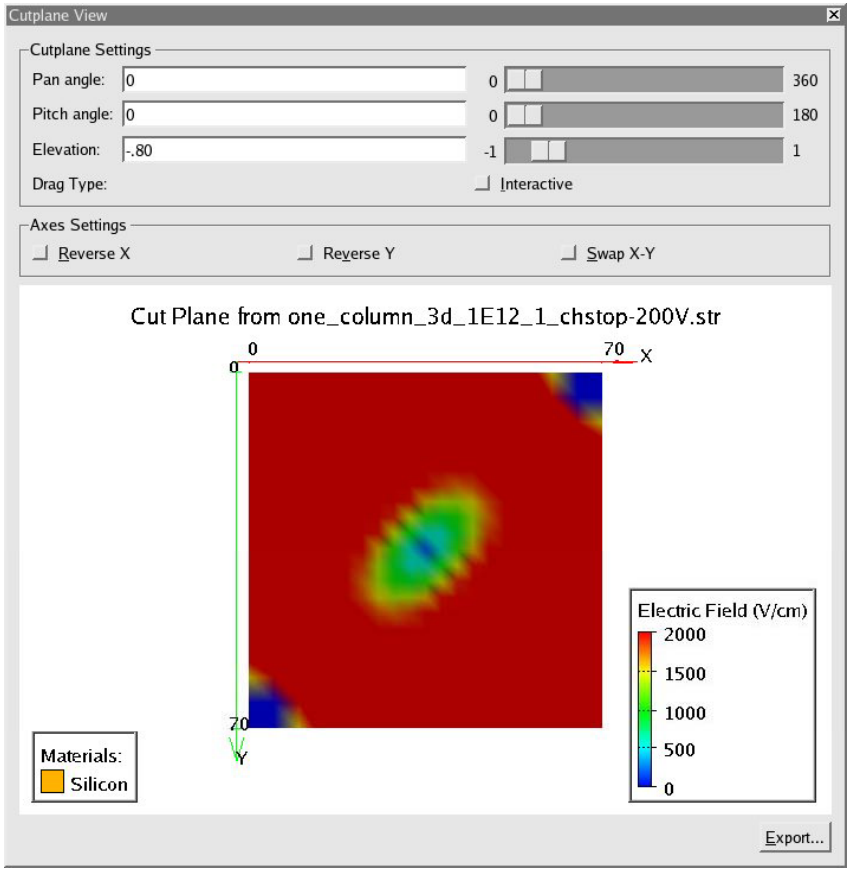
Single N-type column one-sided 3D detector (200V)

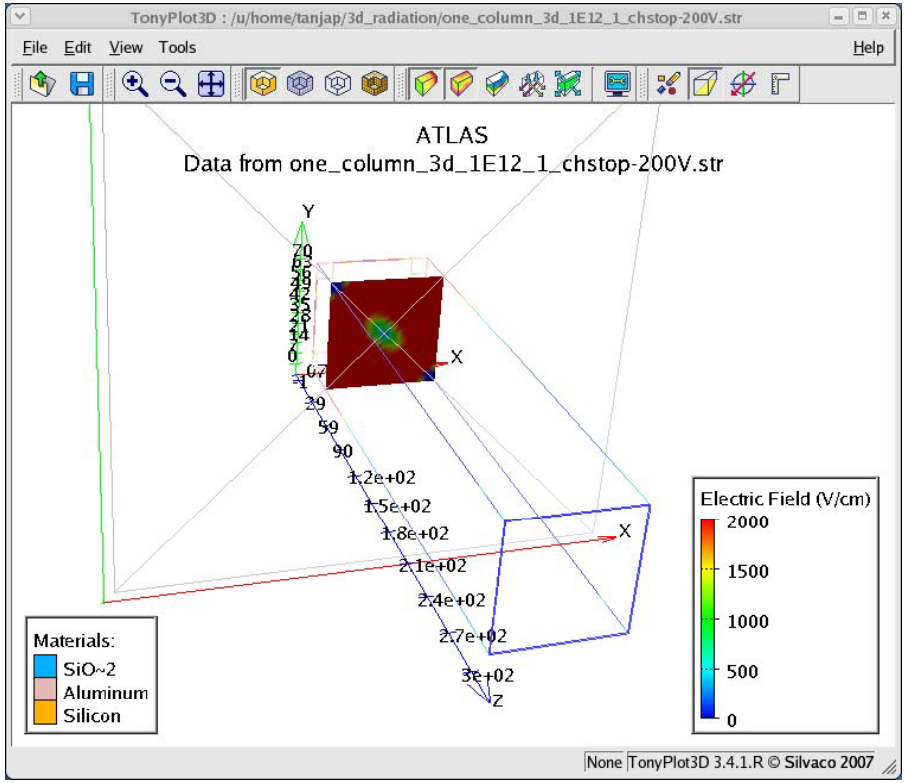




Electric field

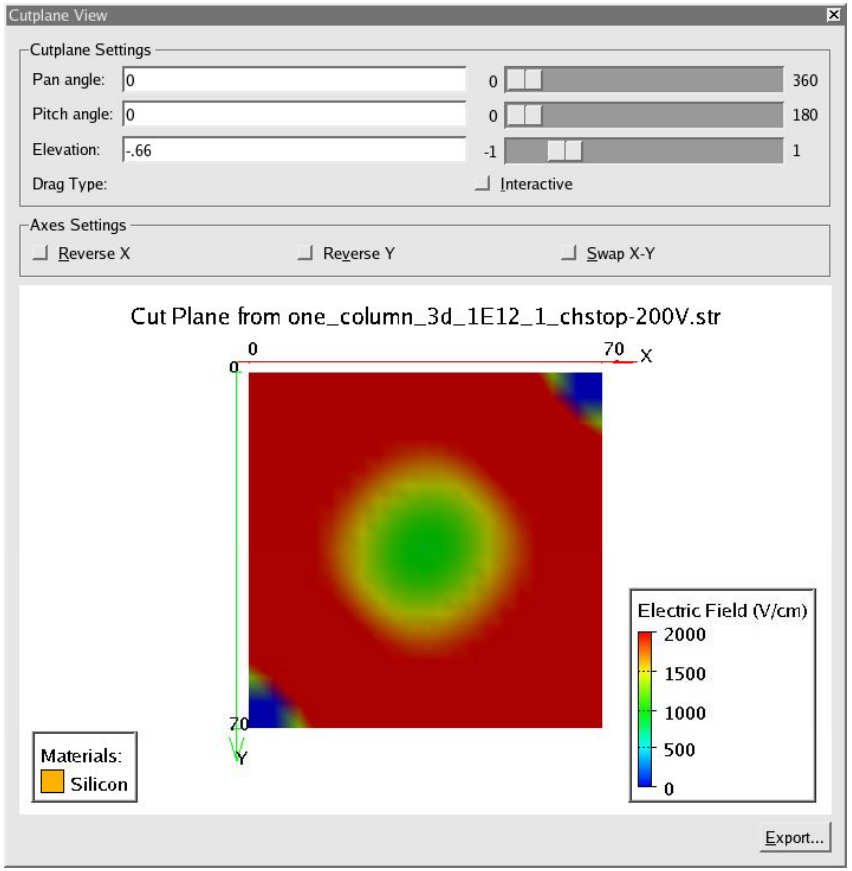
Single N-type column one-sided 3D detector (200V)

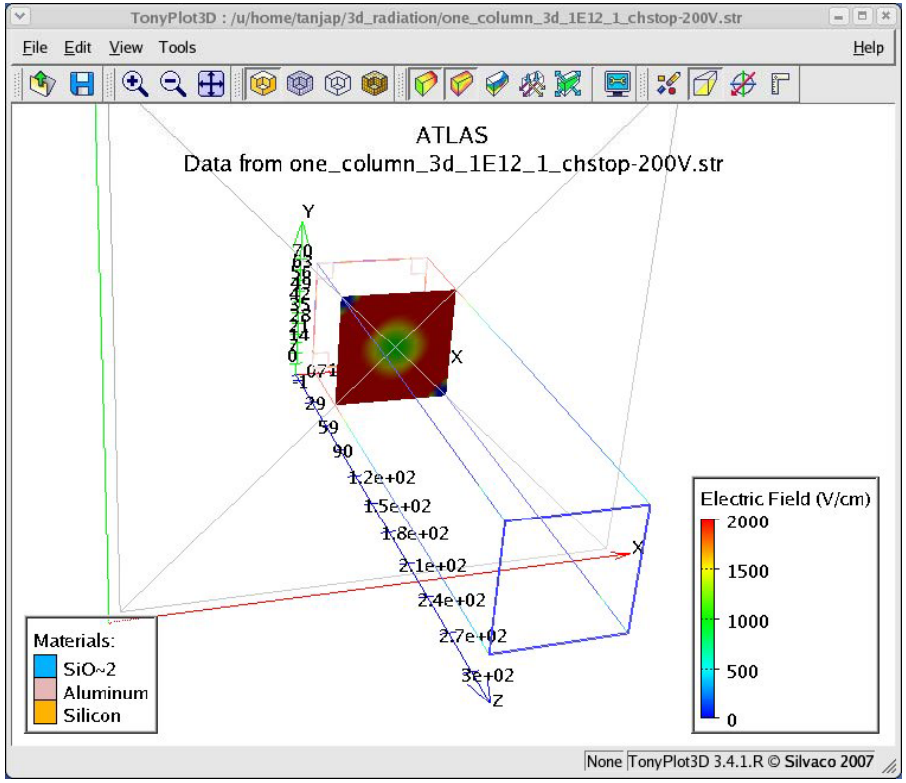




Electric field

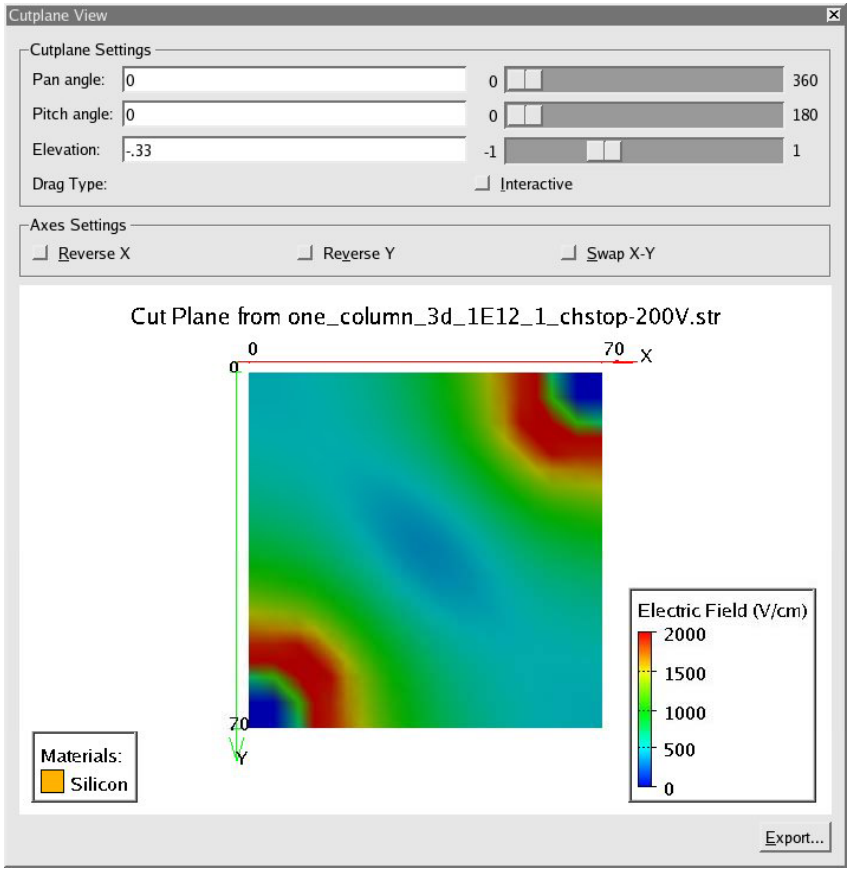
Single N-type column one-sided 3D detector (200V)

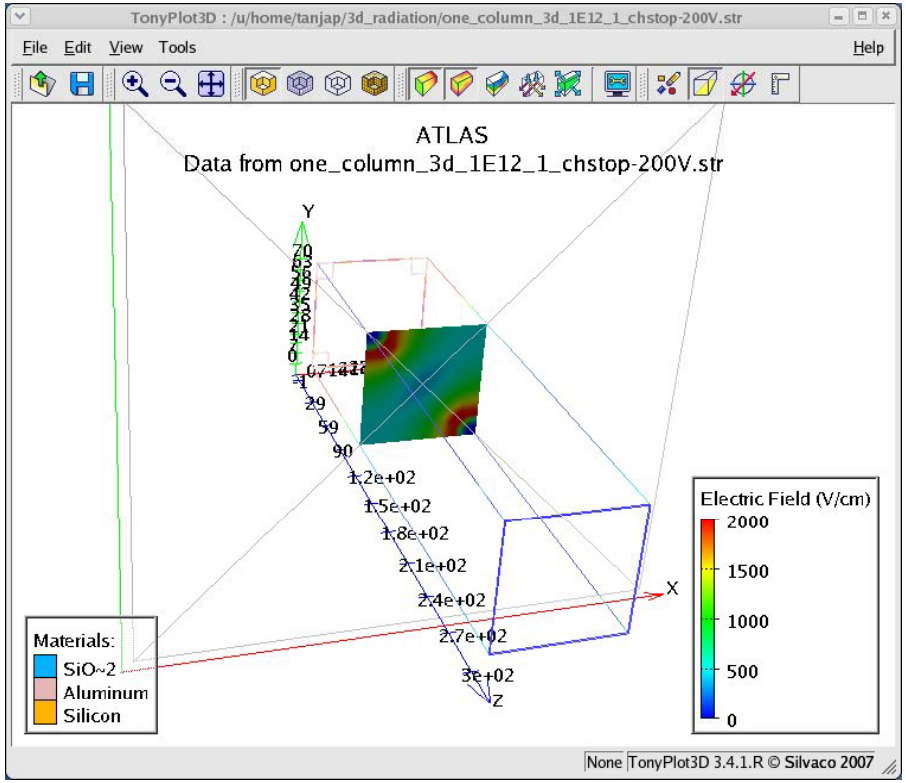




Electric field

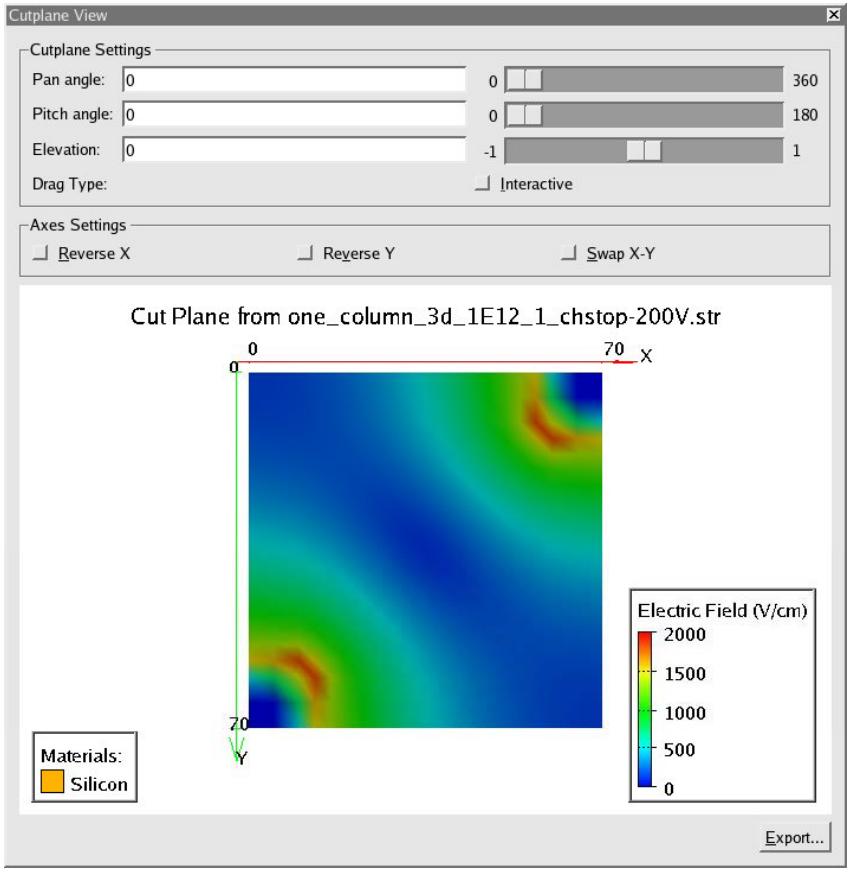
Single N-type column one-sided 3D detector (200V)

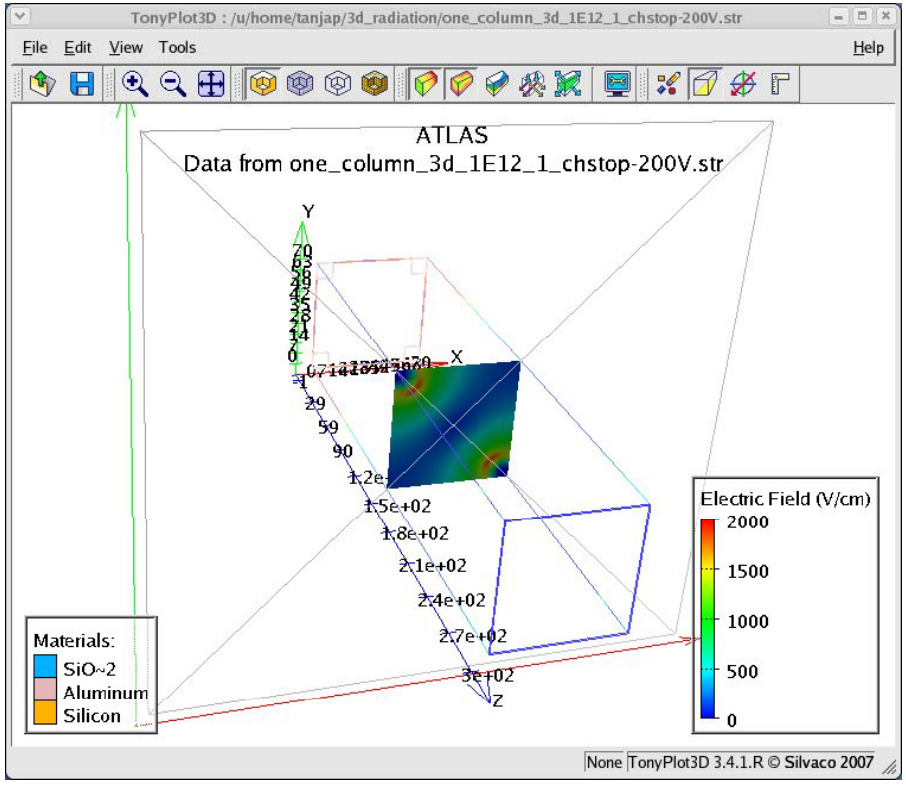




Electric field

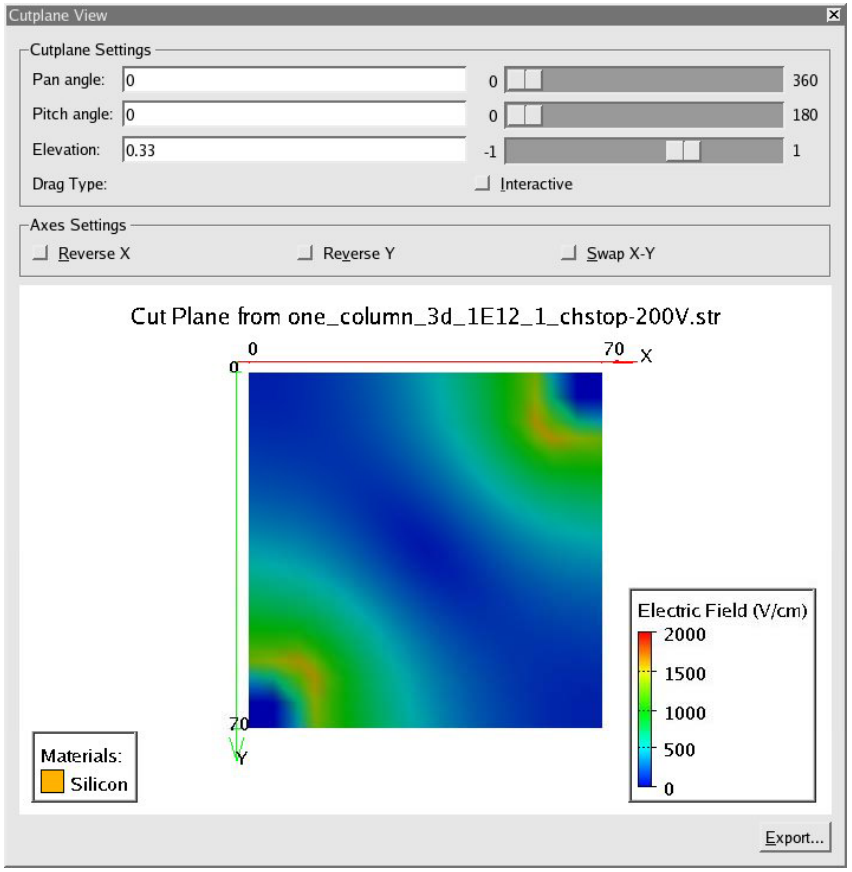
Single N-type column one-sided 3D detector (200V)

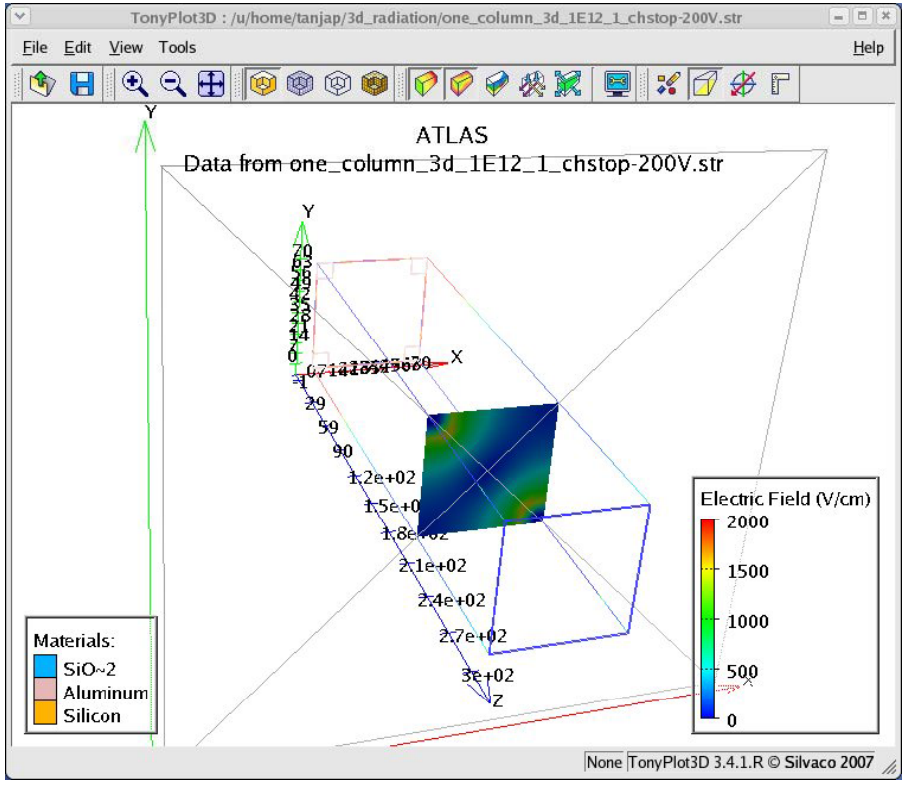




Electric field

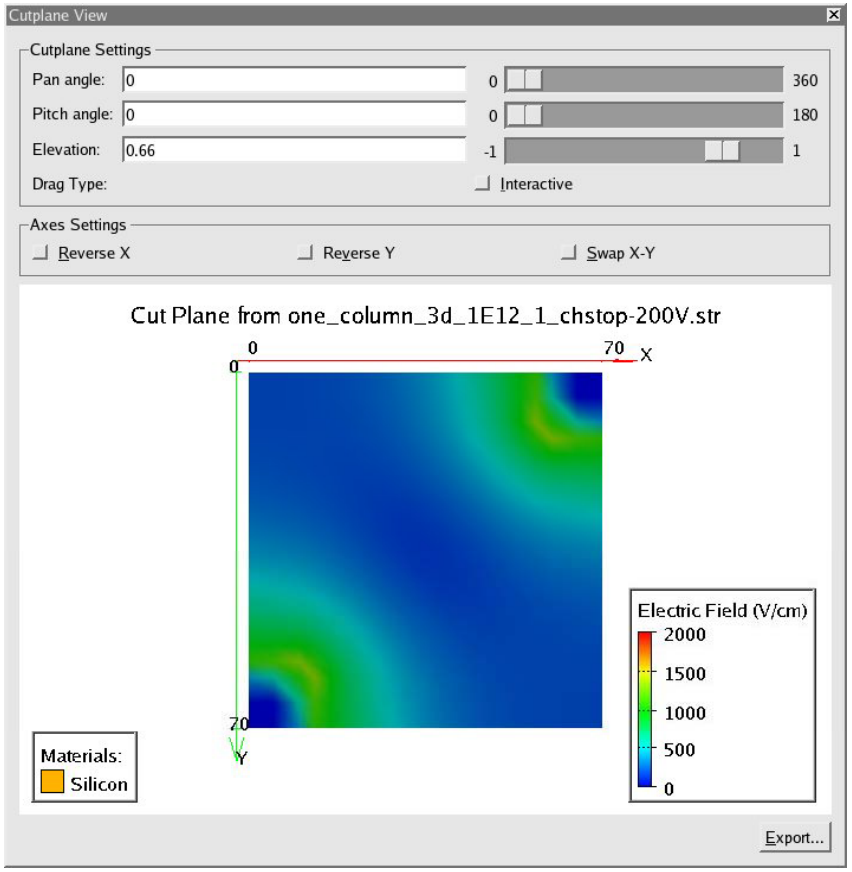
Single N-type column one-sided 3D detector (200V)

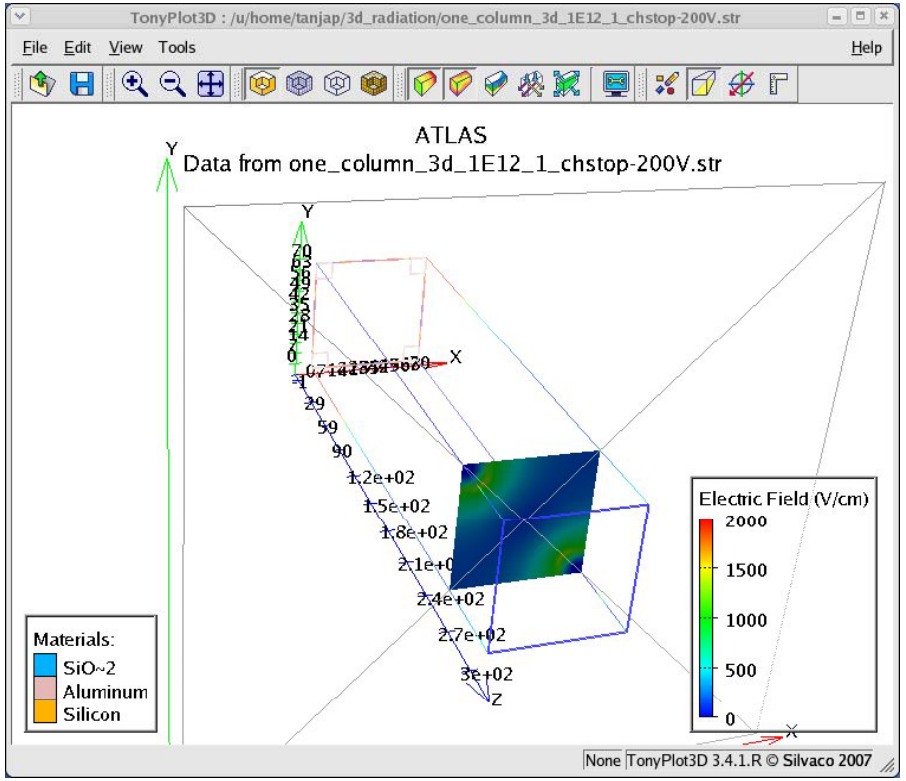




Electric field

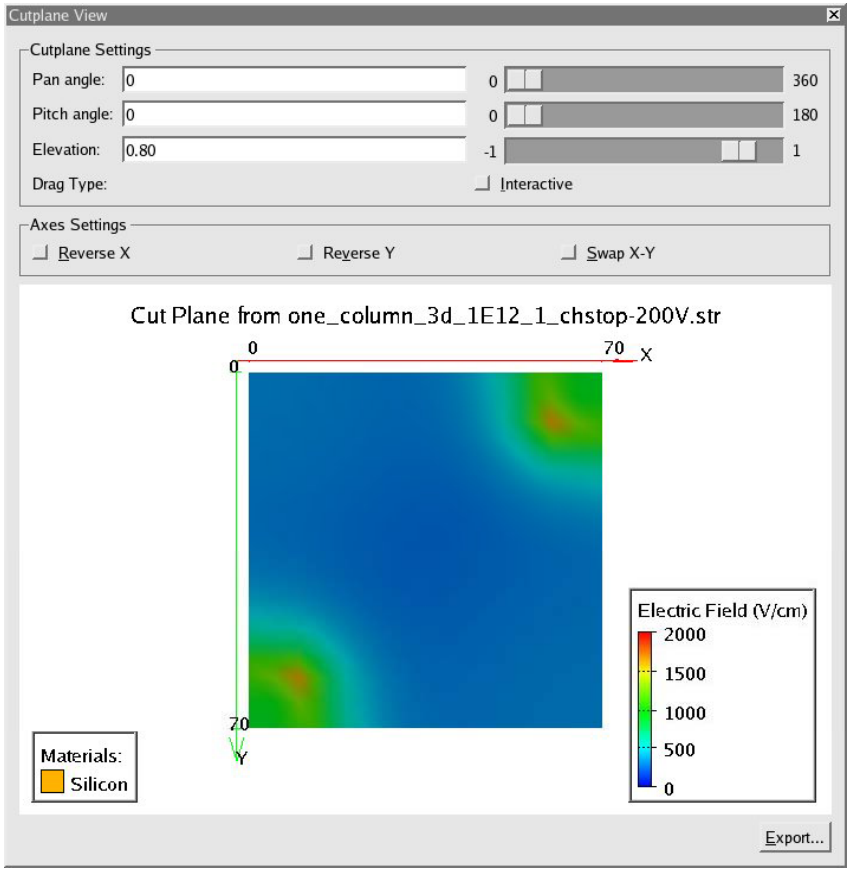
Single N-type column one-sided 3D detector (200V)

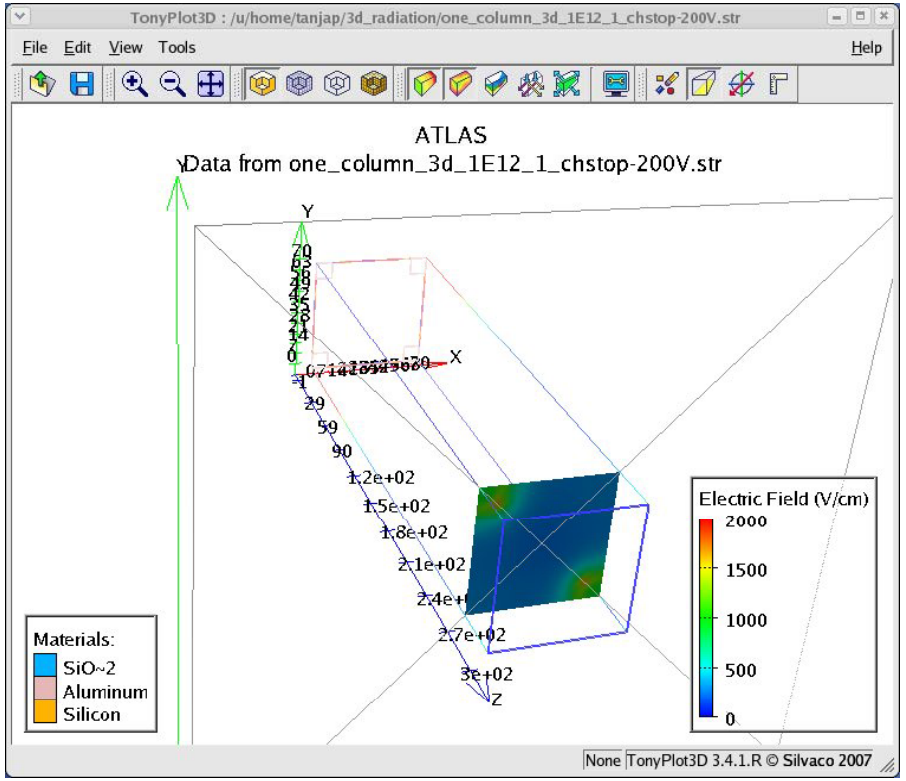




Electric field

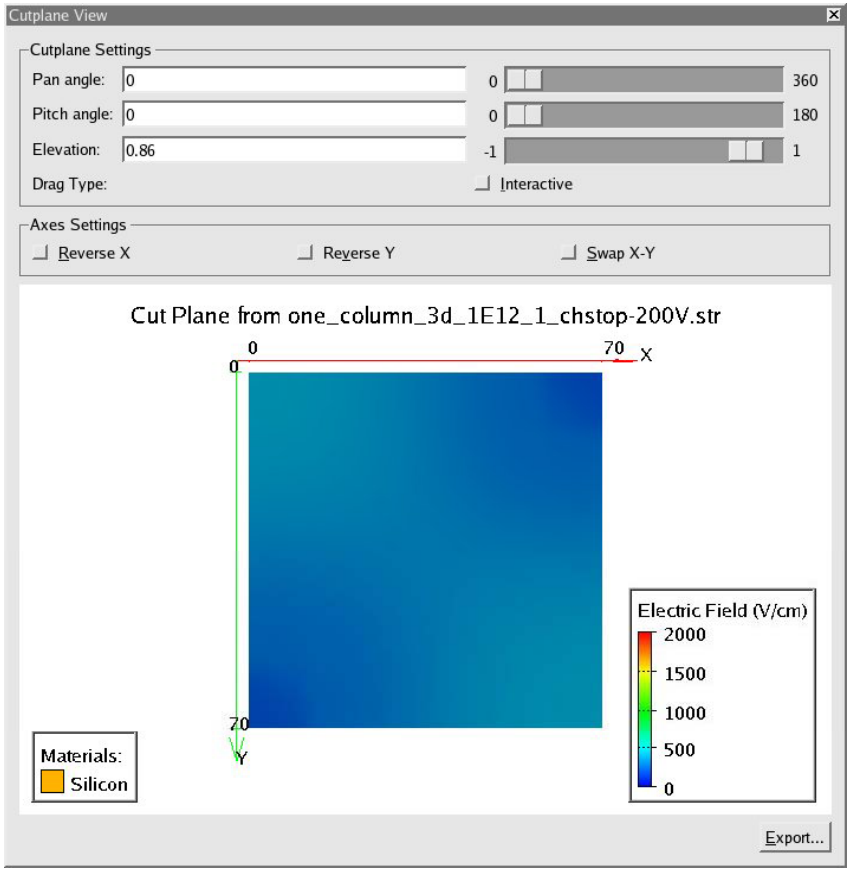
Single N-type column one-sided 3D detector (200V)

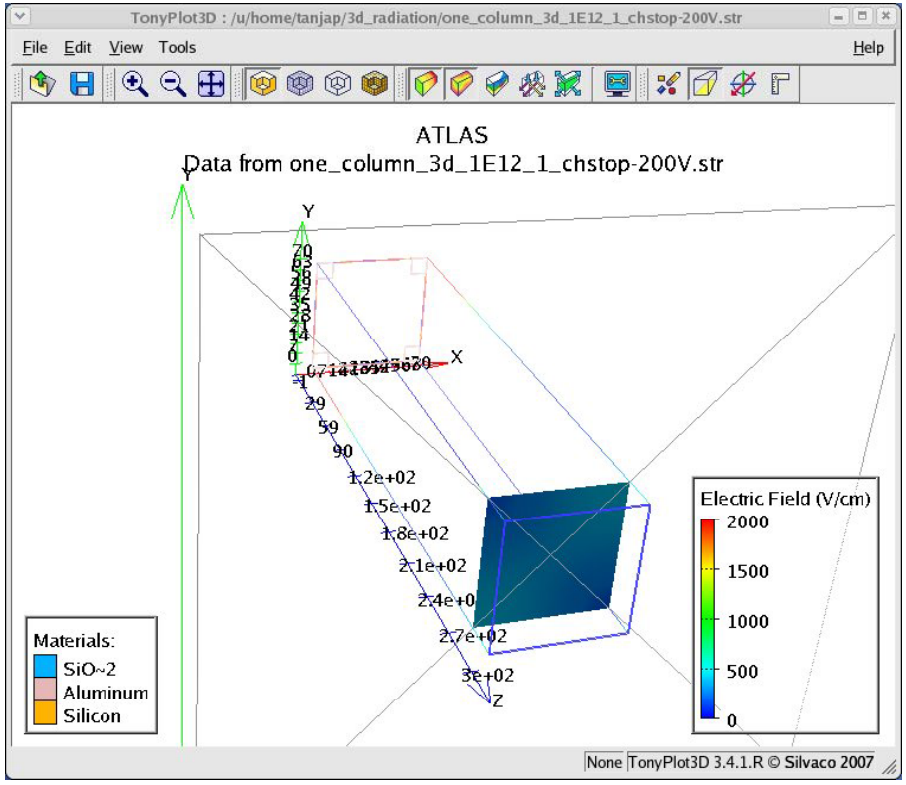




Electric field

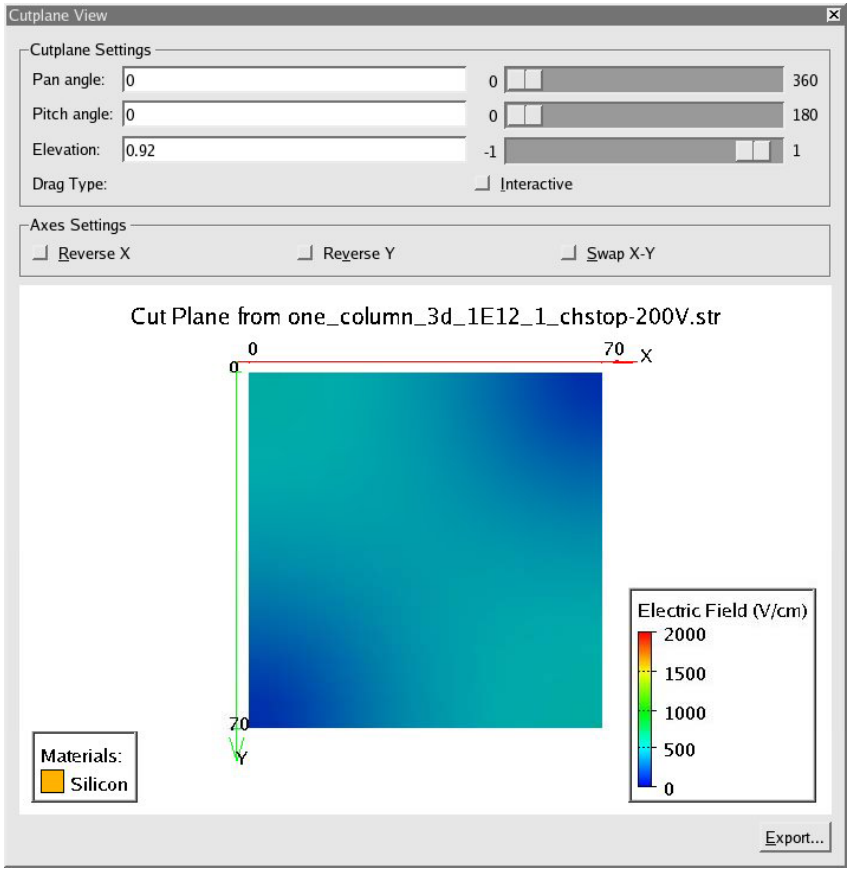
Single N-type column one-sided 3D detector (200V)

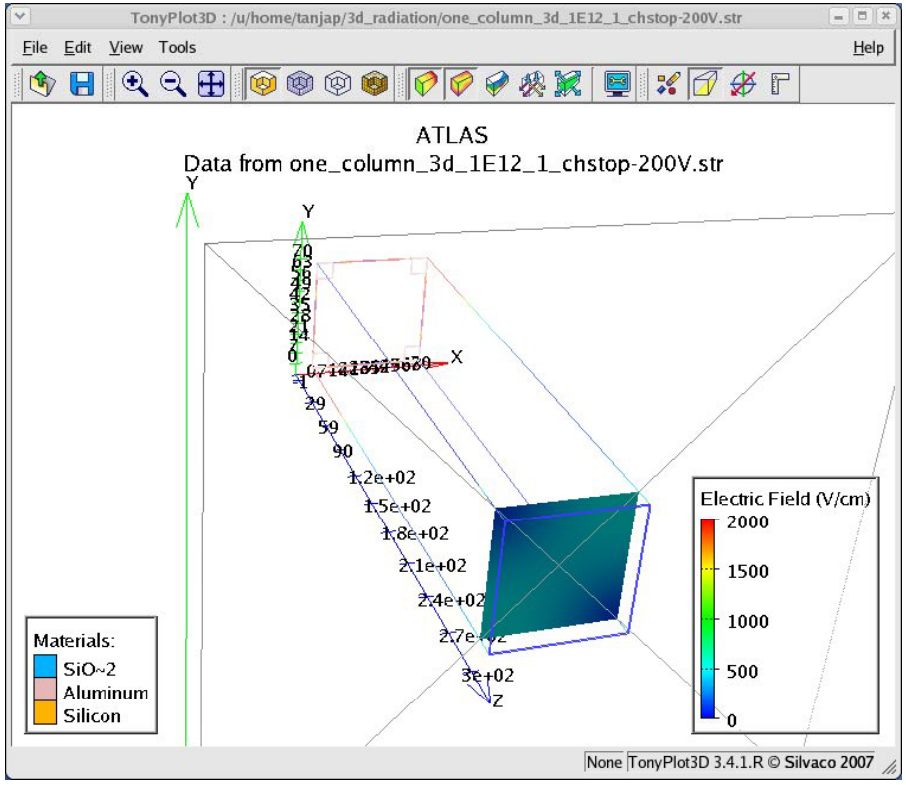




Electric field

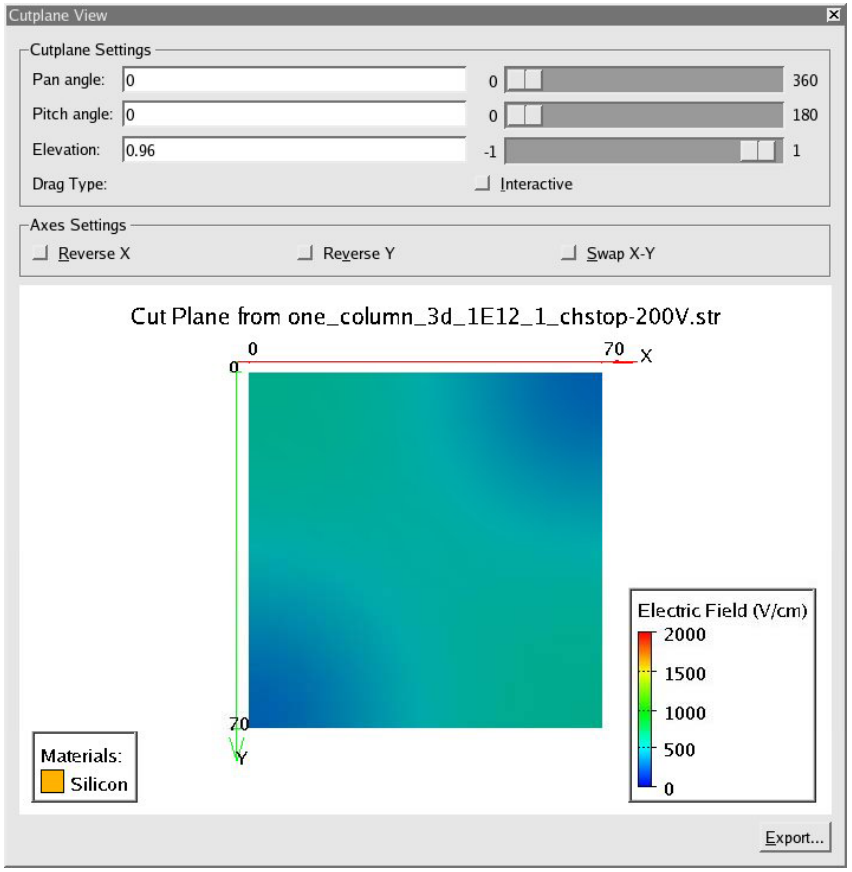
Single N-type column one-sided 3D detector (200V)

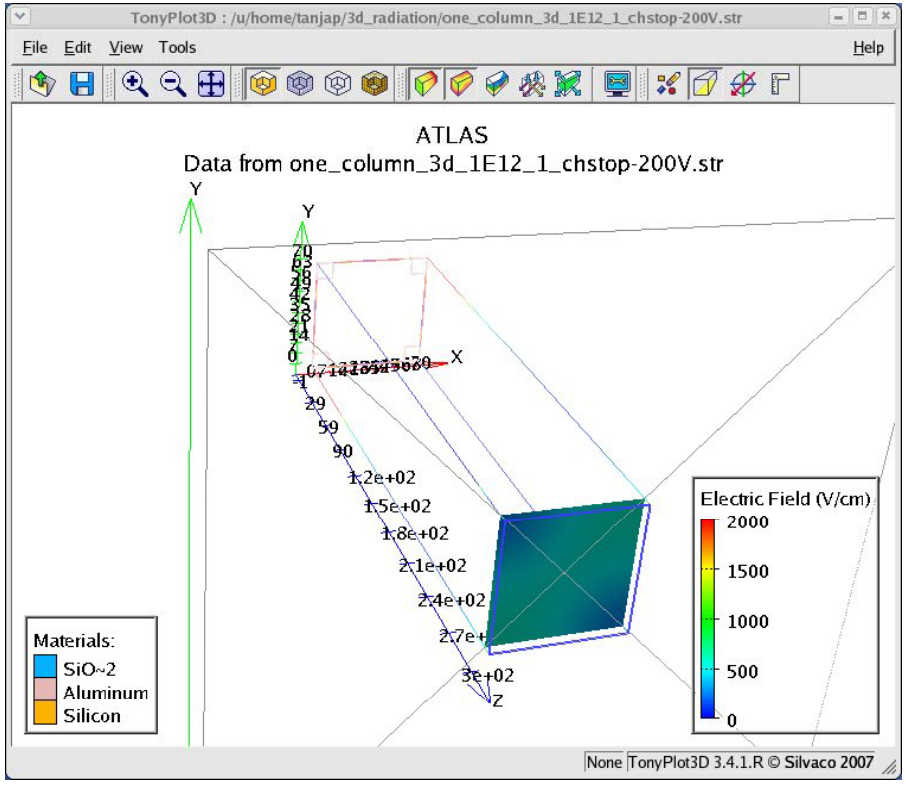




Electric field

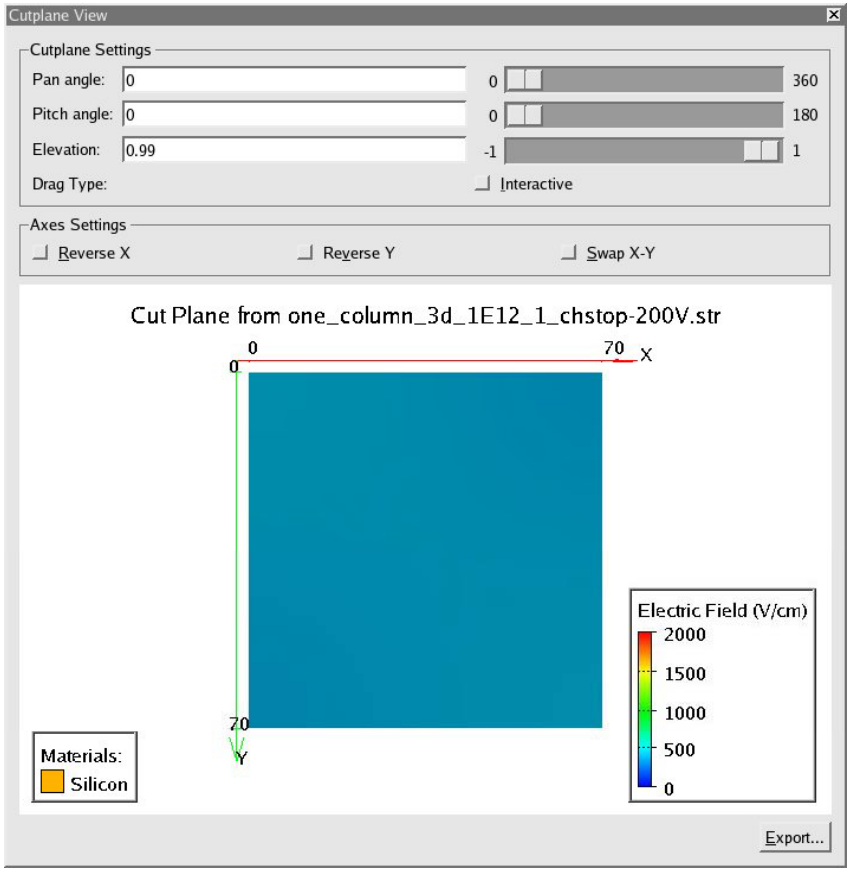
Single N-type column one-sided 3D detector (200V)

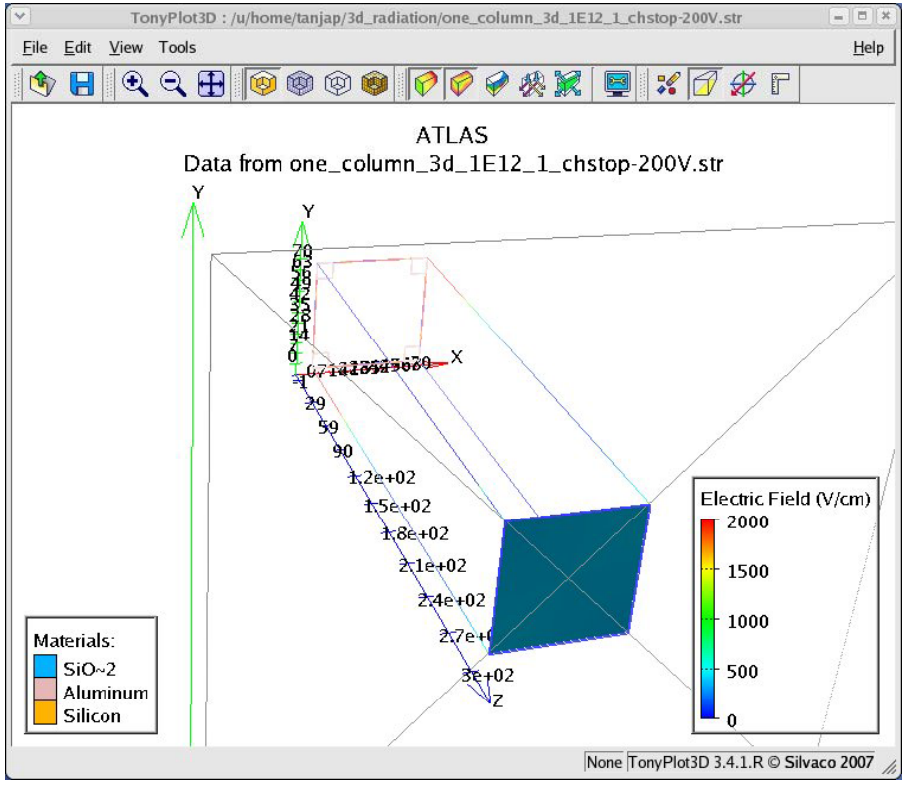




Electric field

Single N-type column one-sided 3D detector (200V)

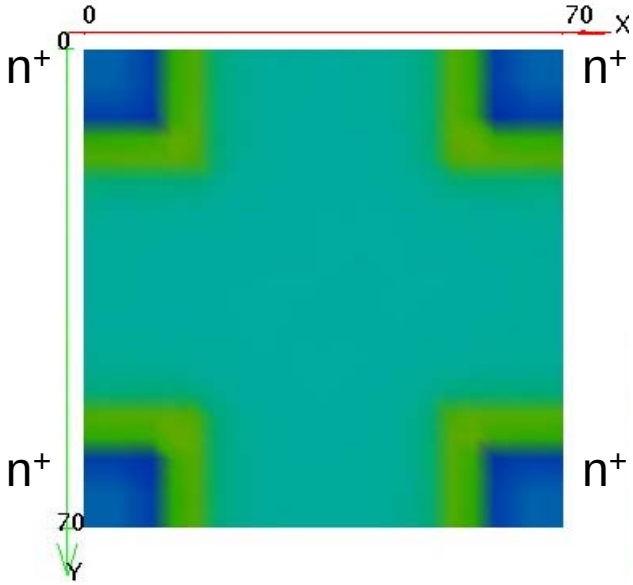


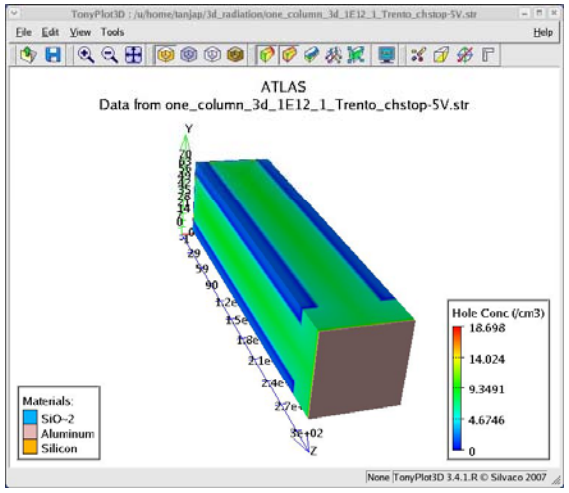


Electric field

Trento Single column one-sided 3D detector

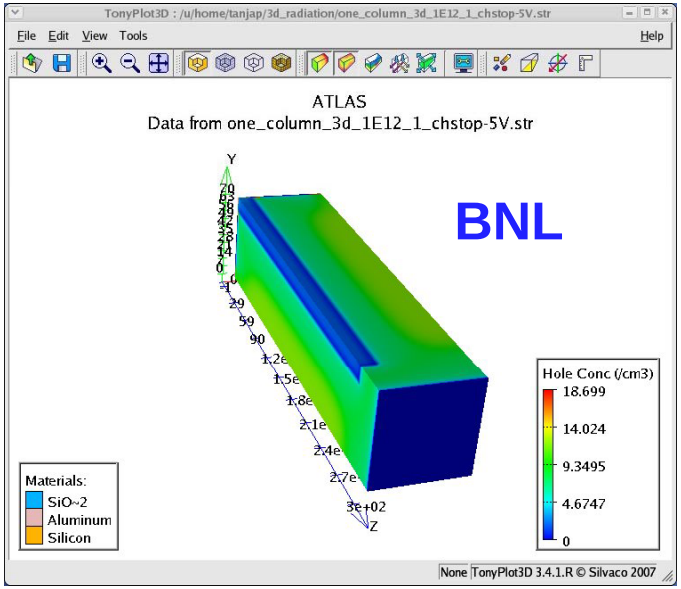
- Trento
- N-type columns penetrate to the p-type bulk from the top surface
- N-columns are surrounded by p-stops

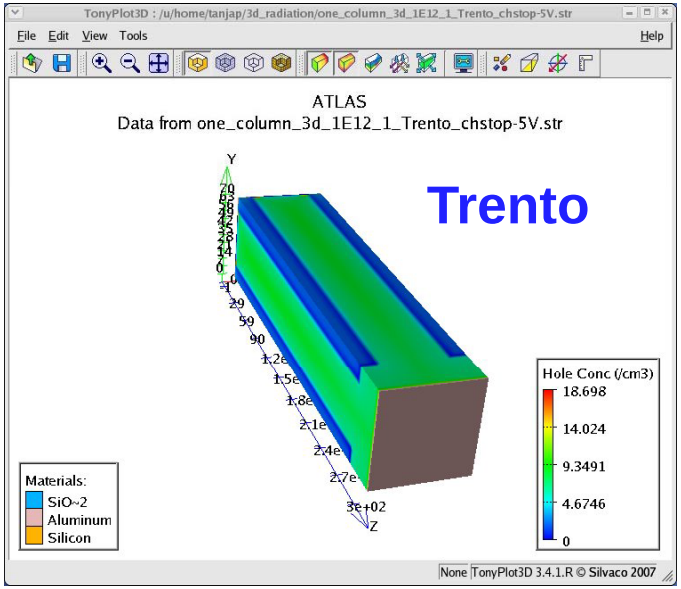




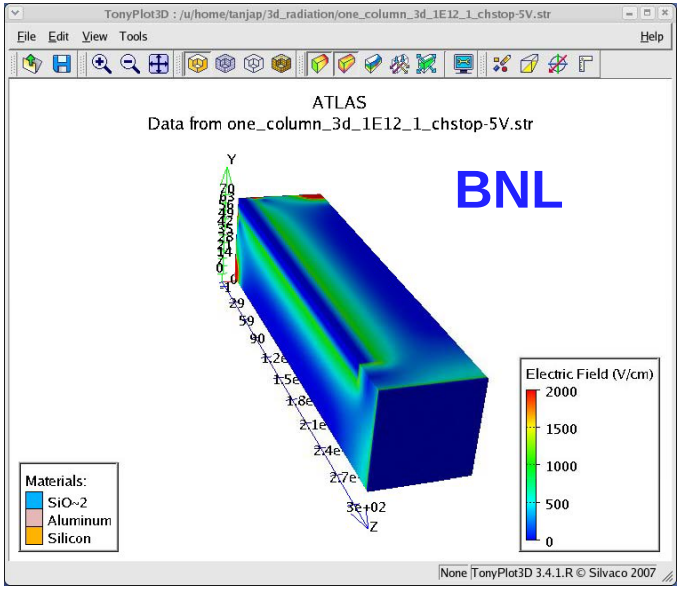
Comparing single column 3D detectors (5V)

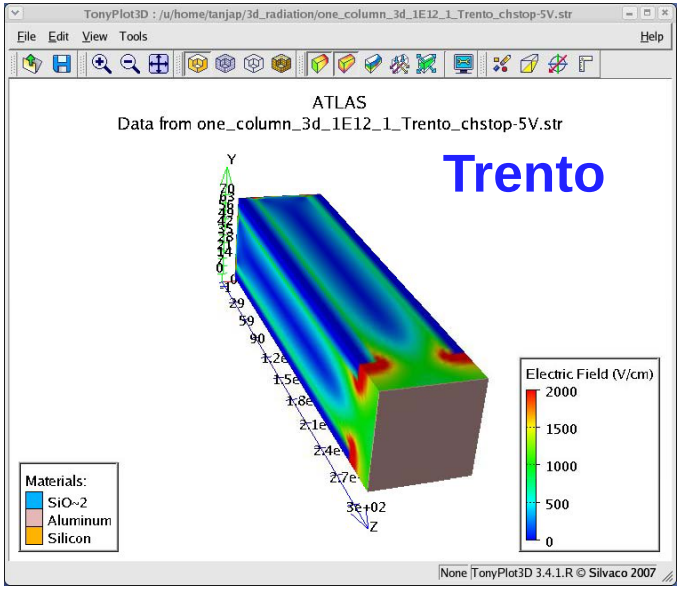
Hole concentration





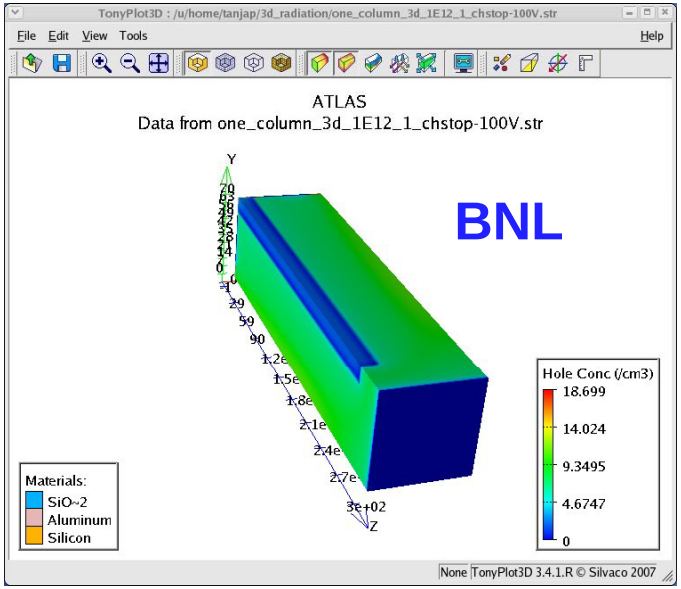
Electric field

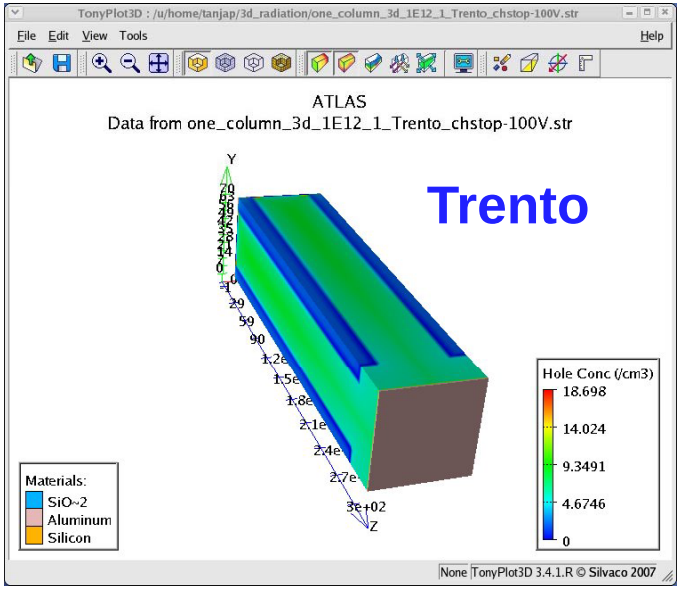




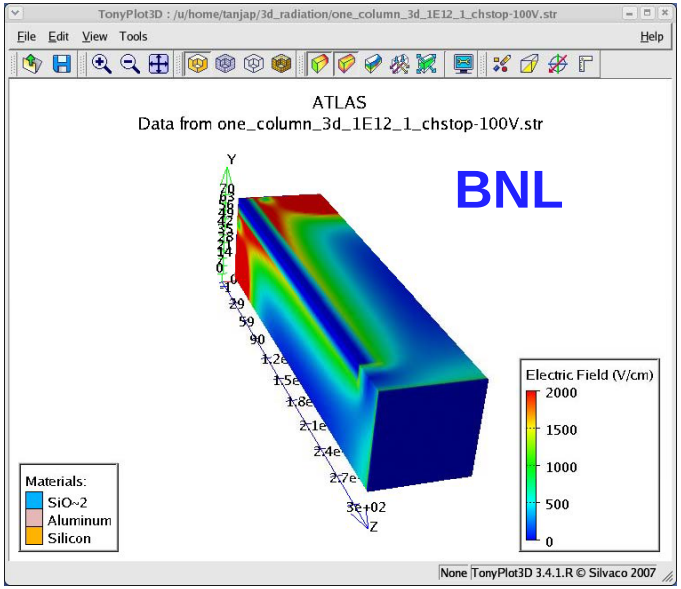
Comparing single column 3D detectors (100V)

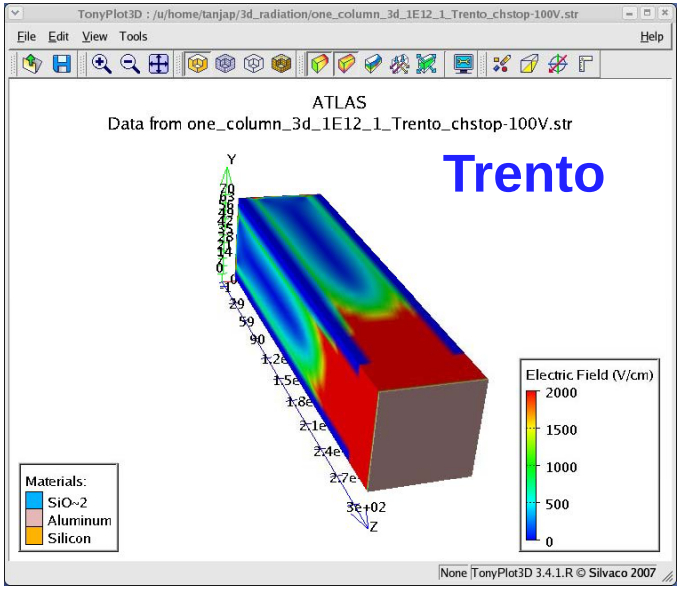
Hole concentration





Electric field

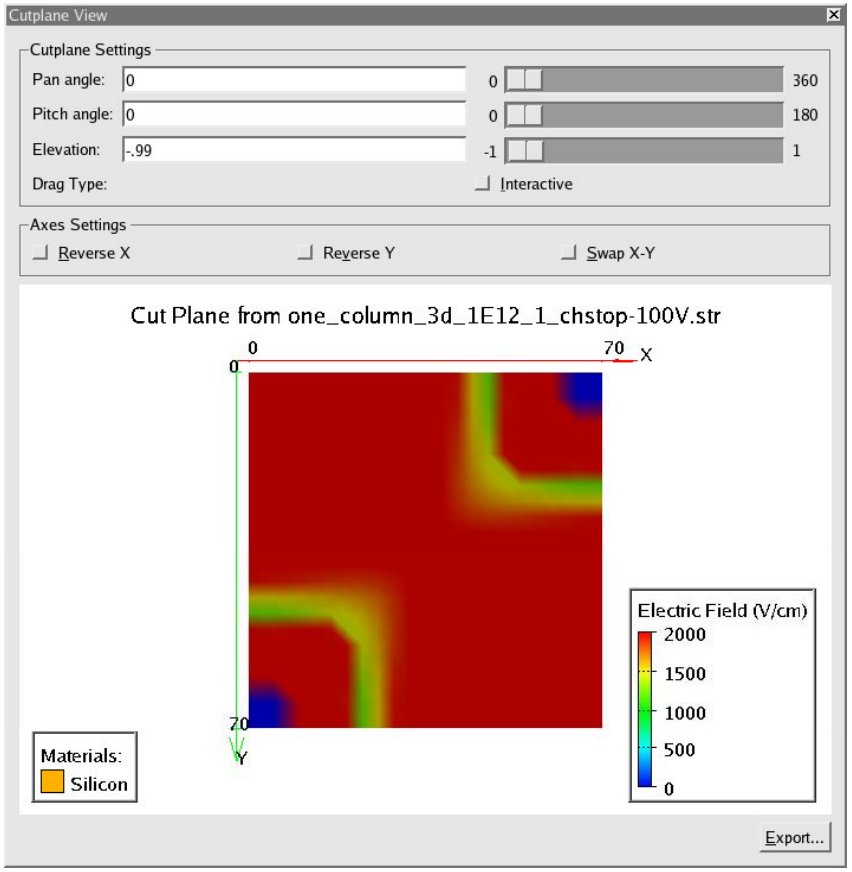




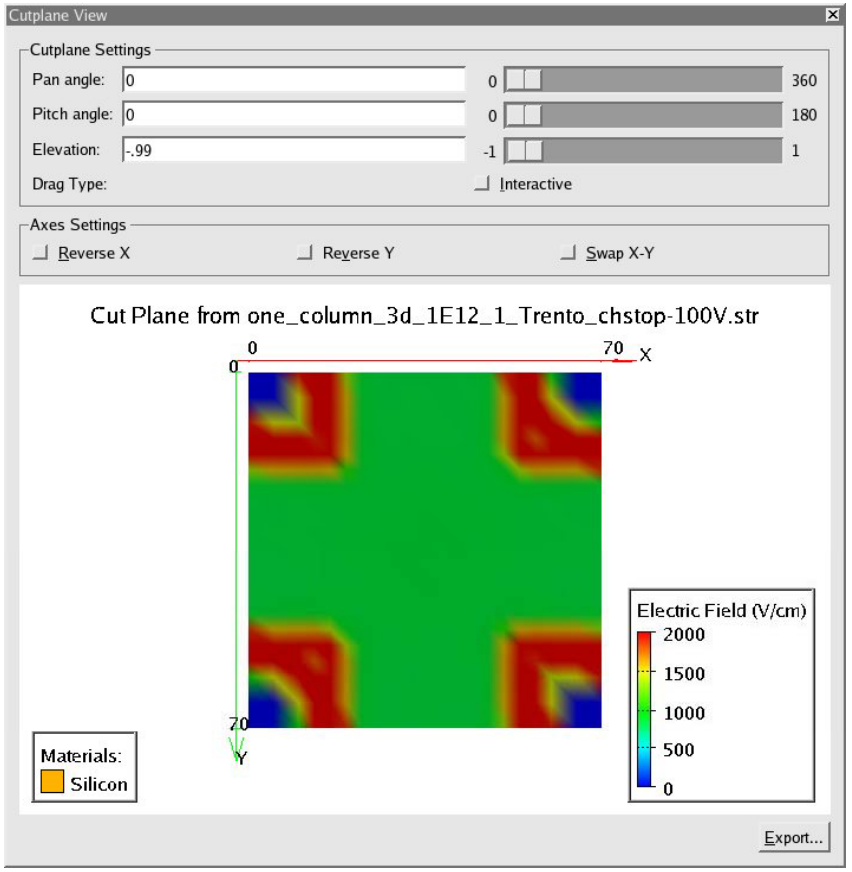
t2

Comparing single column 3D detectors (100V)

BNL



Trento



1 µm from the front surface

Electric field

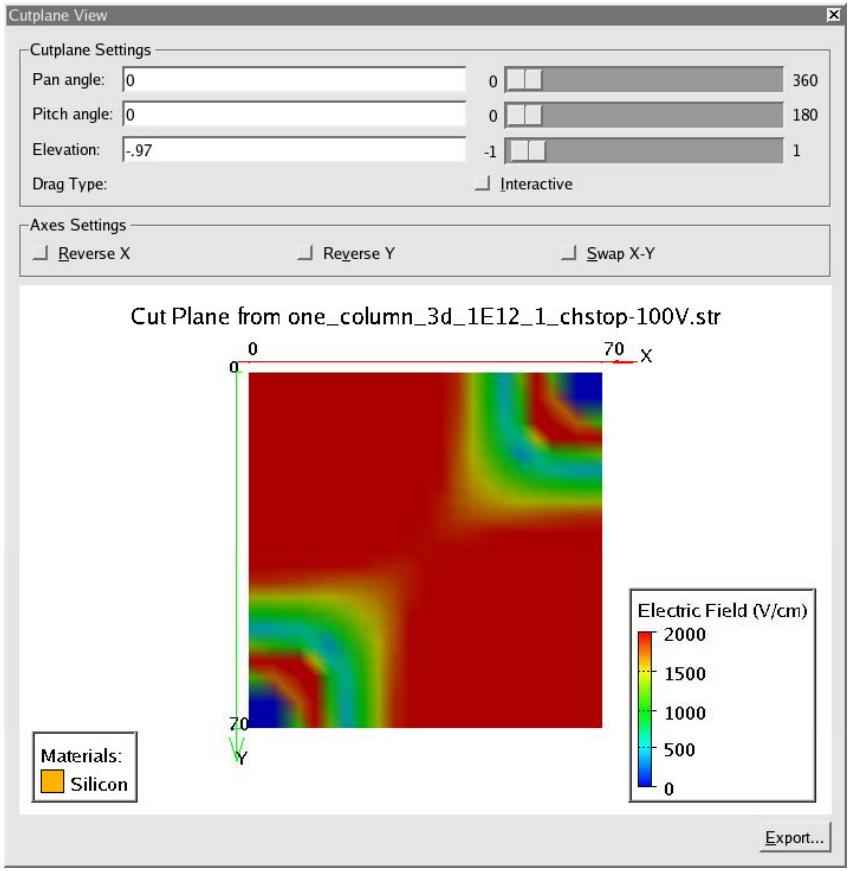
Slide 67

t2 Insert microns to explain where the cut is taken

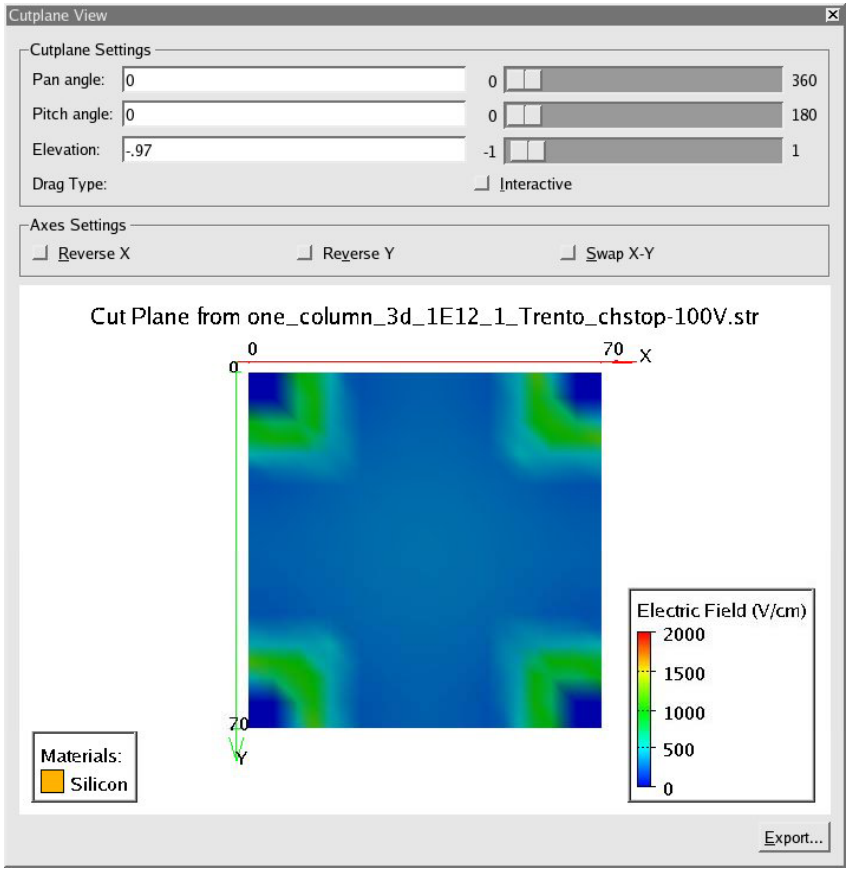
tanjap, 4/13/2007

Comparing single column 3D detectors (100V)

BNL



Trento

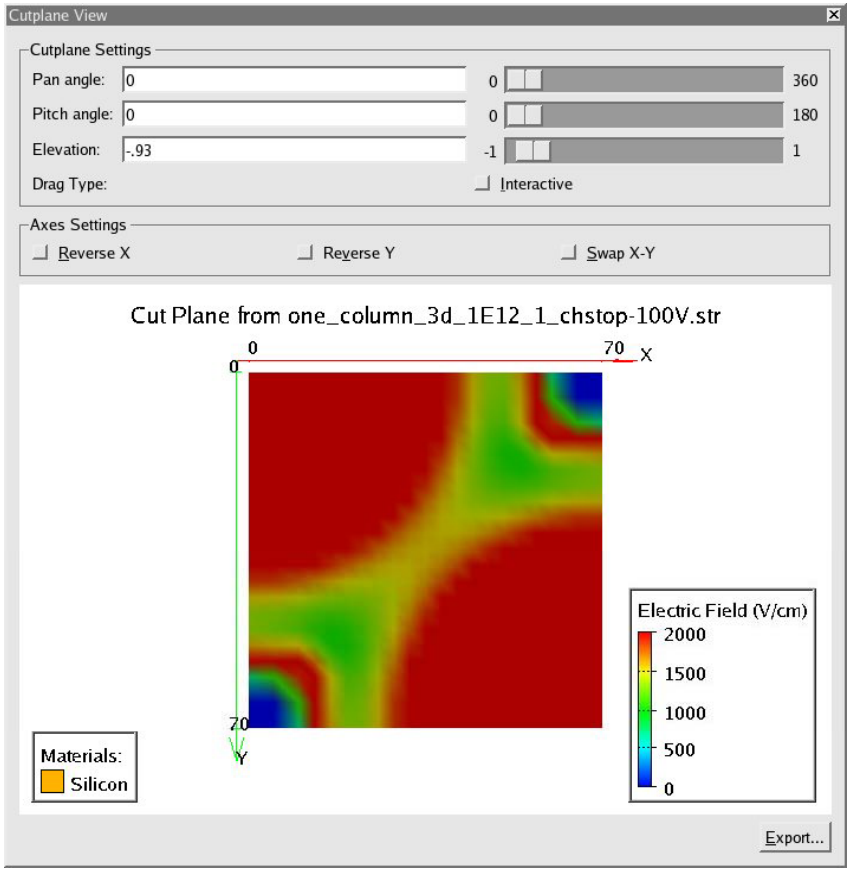


5 µm from the front surface

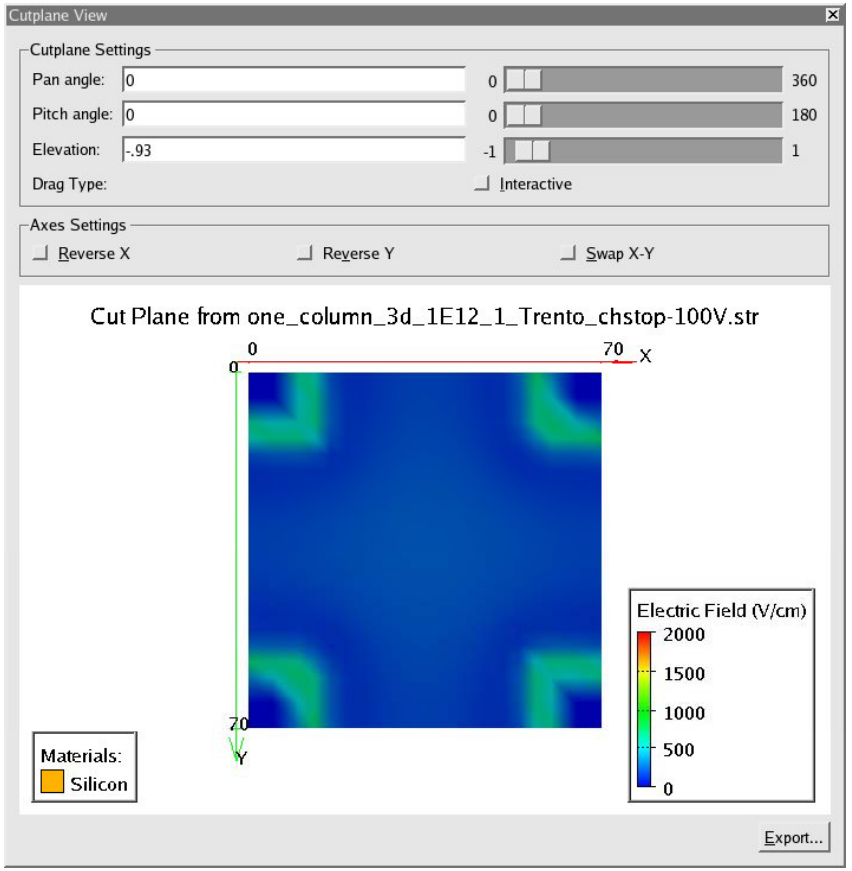
Electric field

Comparing single column 3D detectors (100V)

BNL



Trento

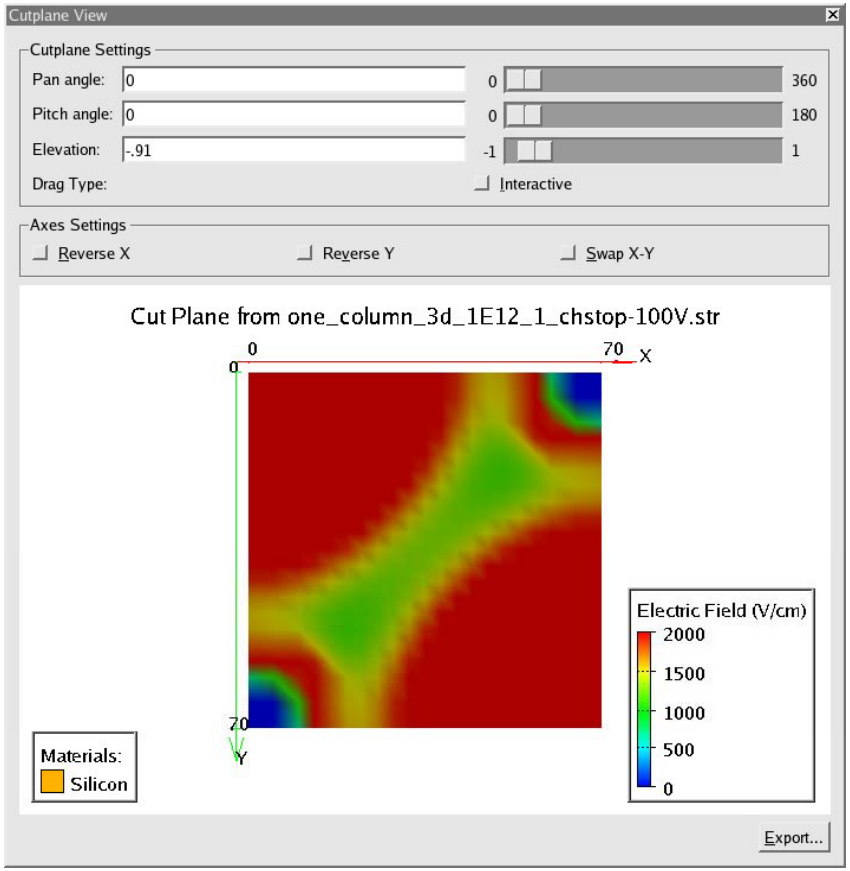


10 µm from the front surface

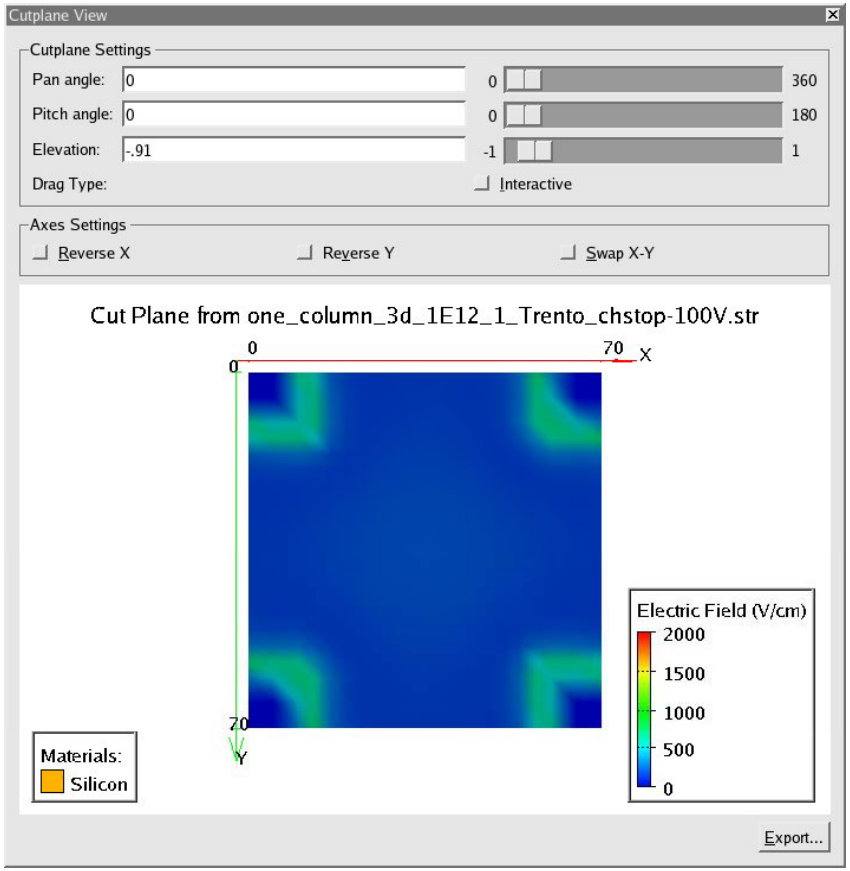
Electric field

Comparing single column 3D detectors (100V)

BNL



Trento

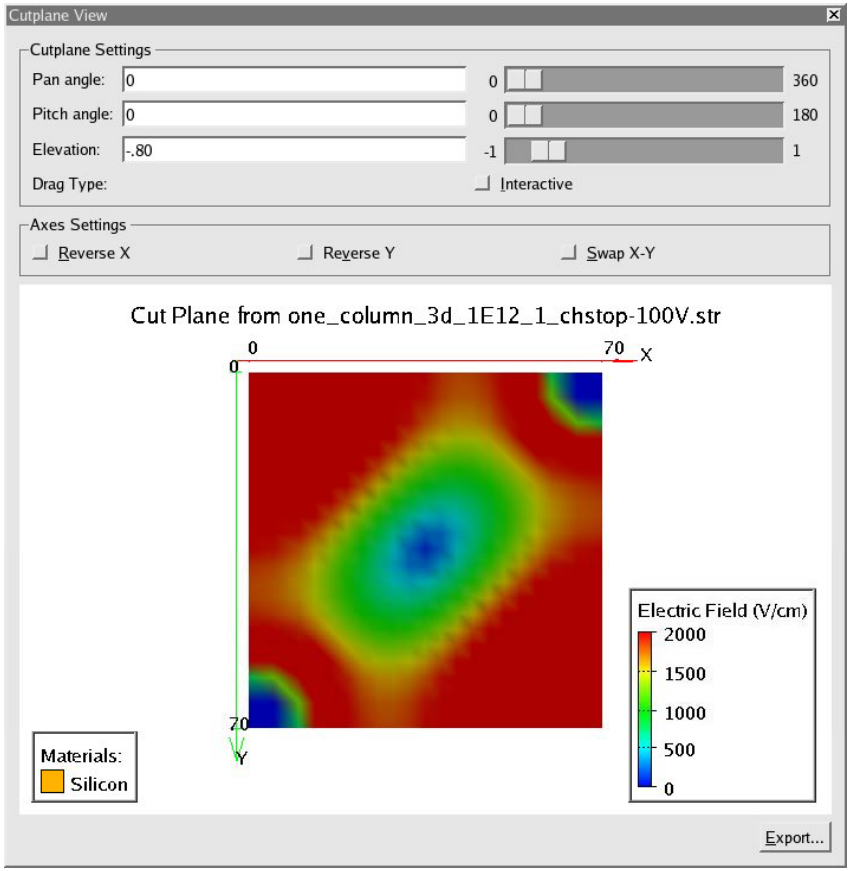


15 µm from the front surface

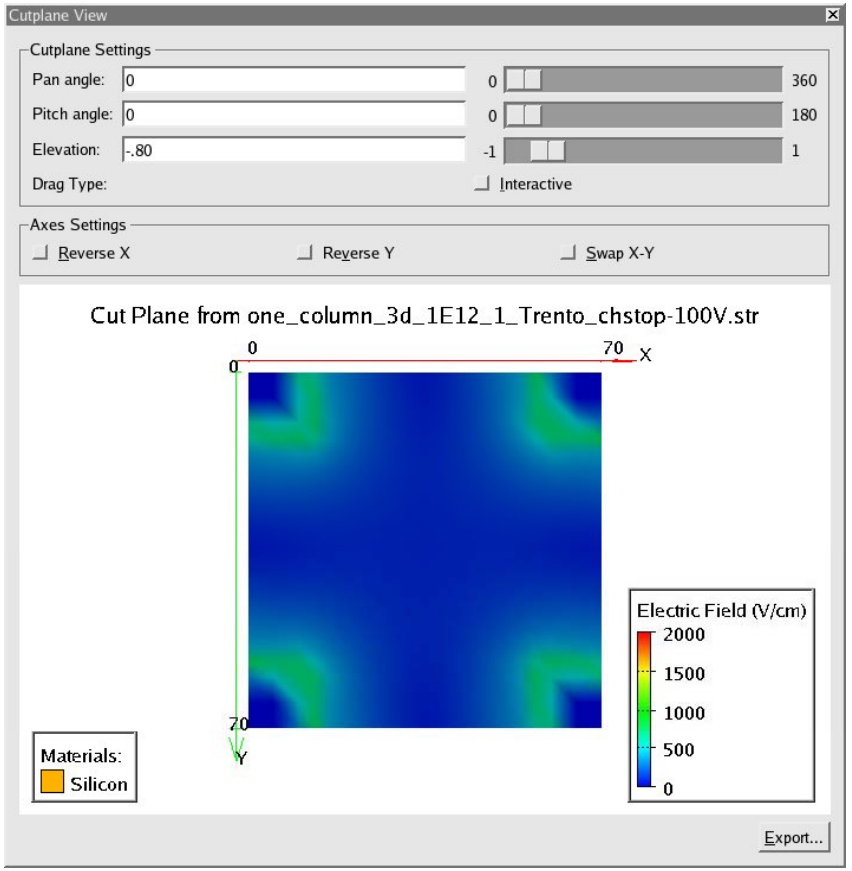
Electric field

Comparing single column 3D detectors (100V)

BNL



Trento

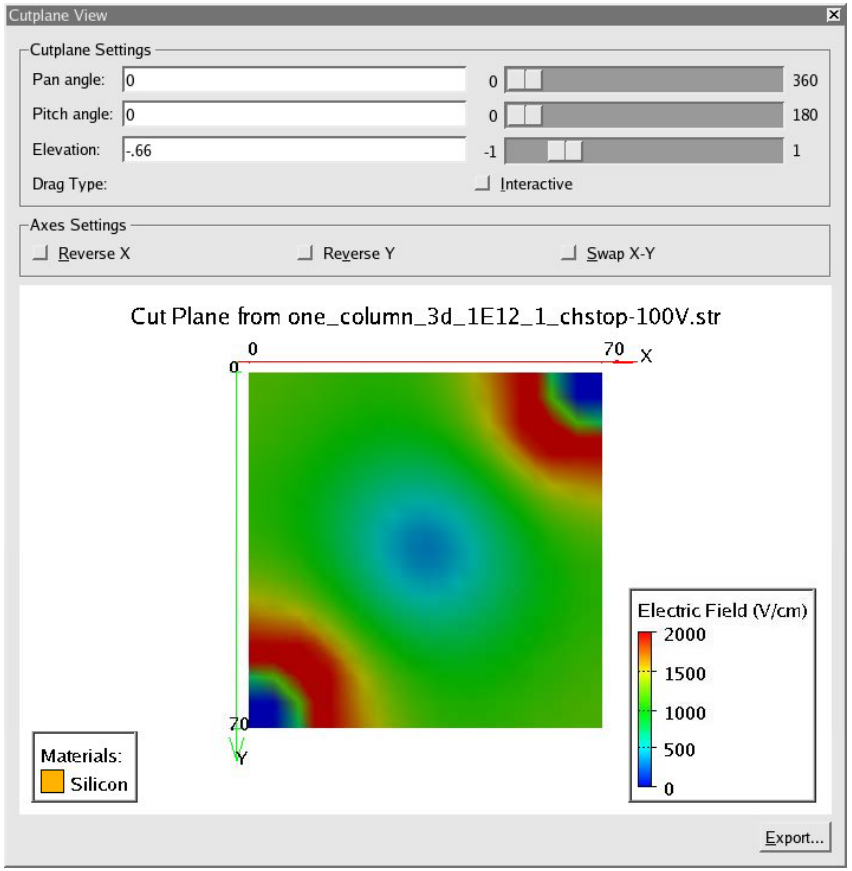


30 µm from the front surface

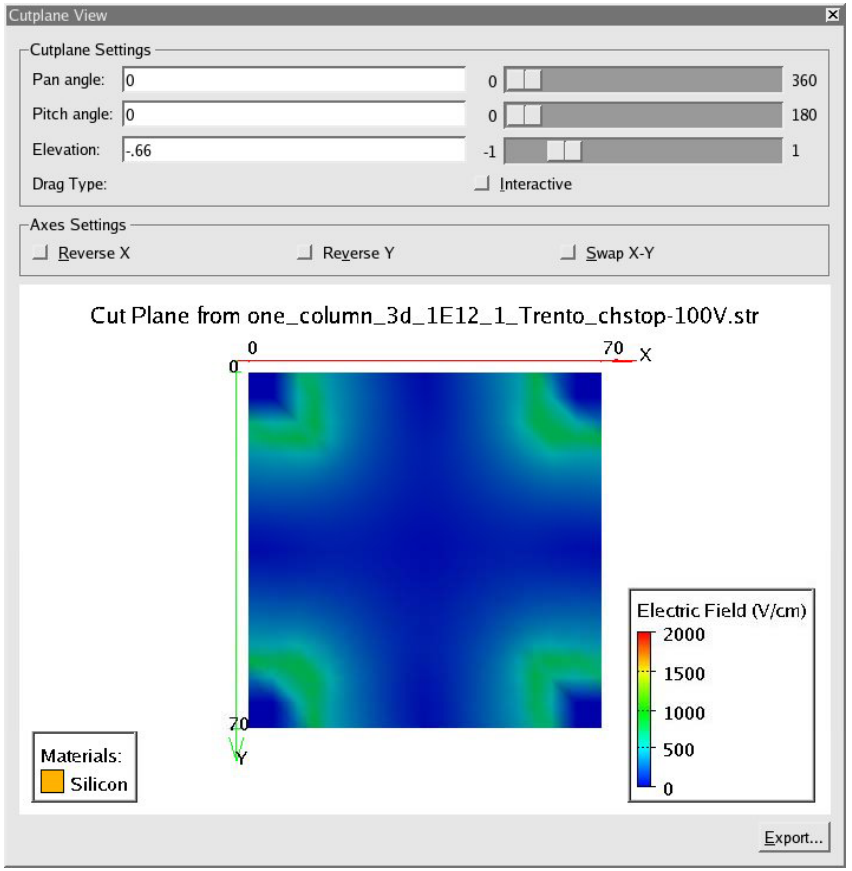
Electric field

Comparing single column 3D detectors (100V)

BNL



Trento

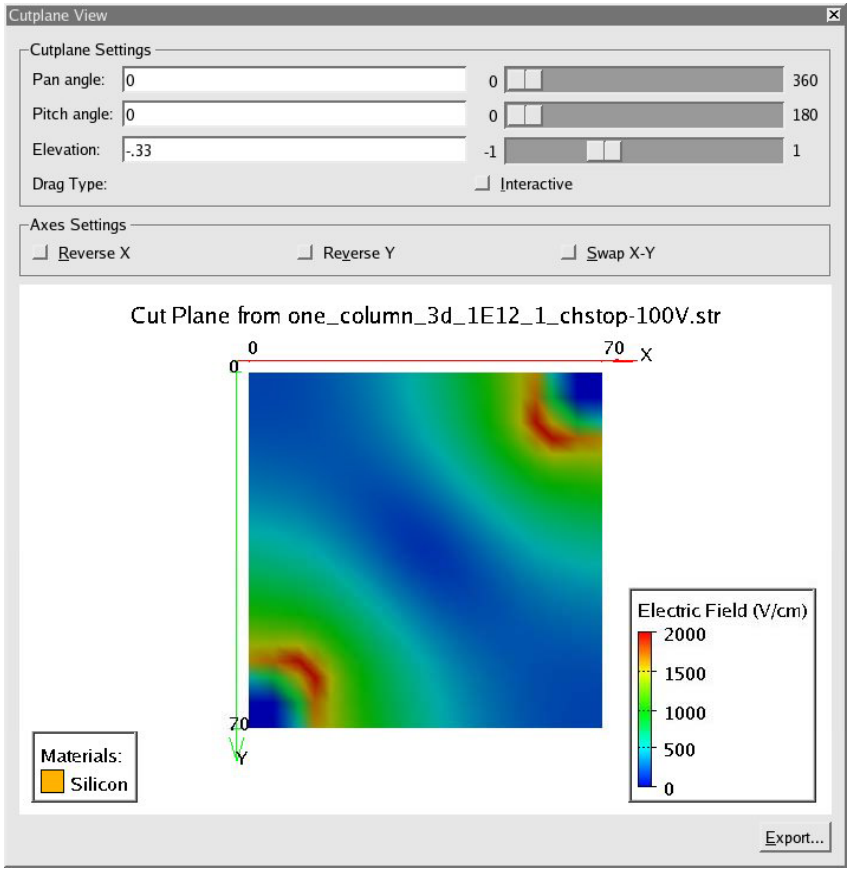


50 µm from the front surface

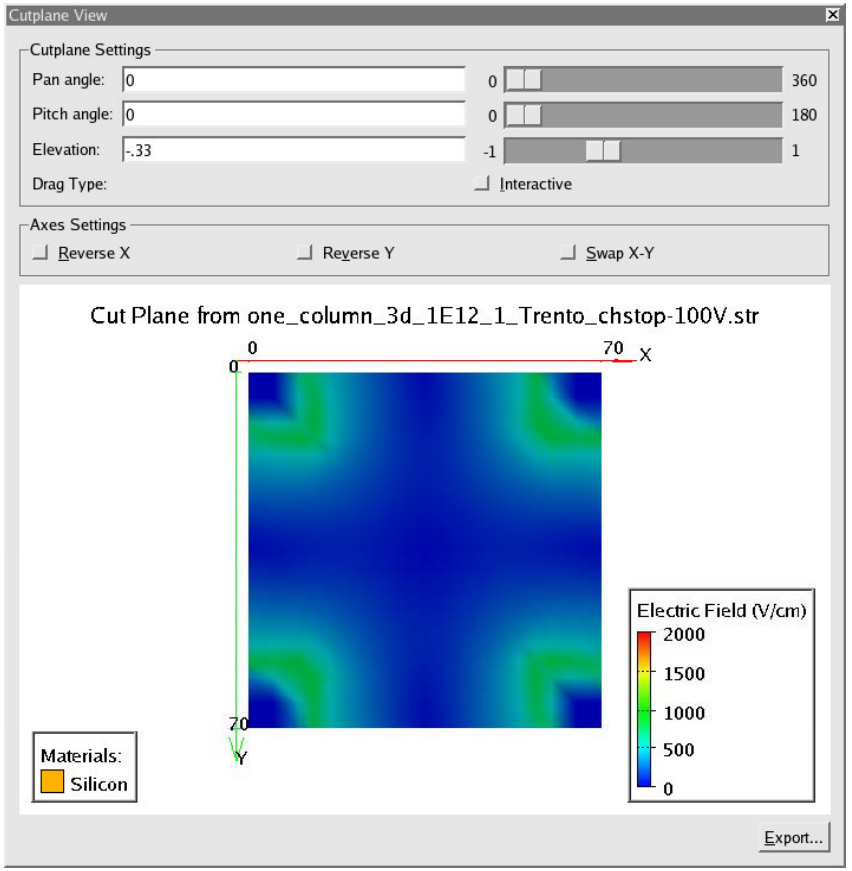
Electric field

Comparing single column 3D detectors (100V)

BNL



Trento

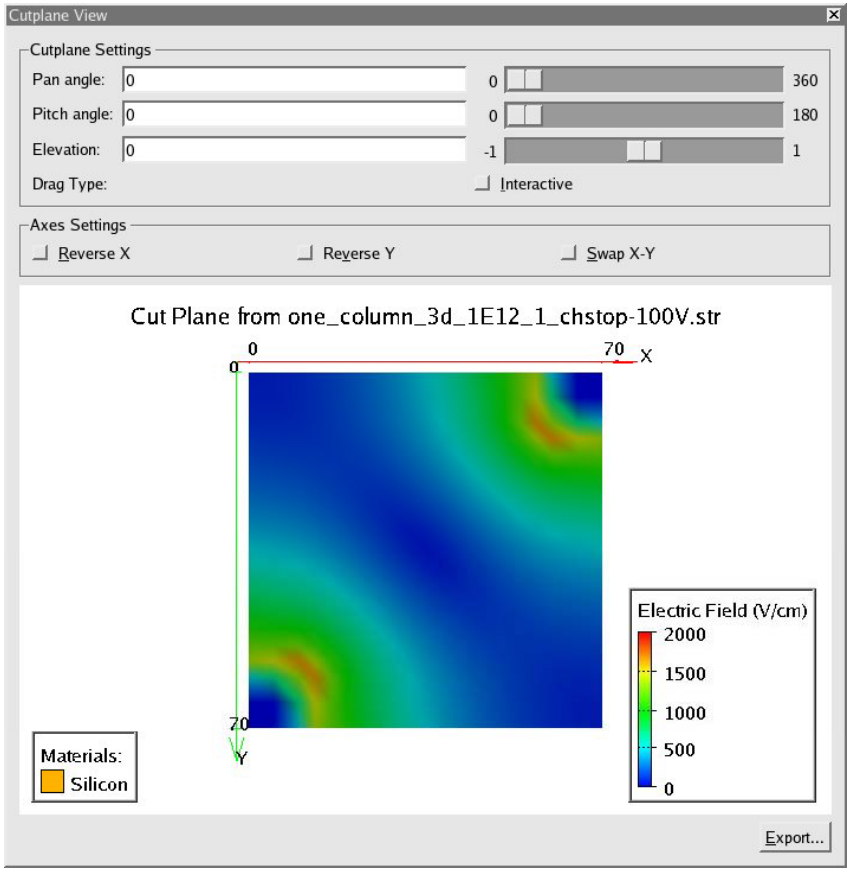


100 µm from the front surface

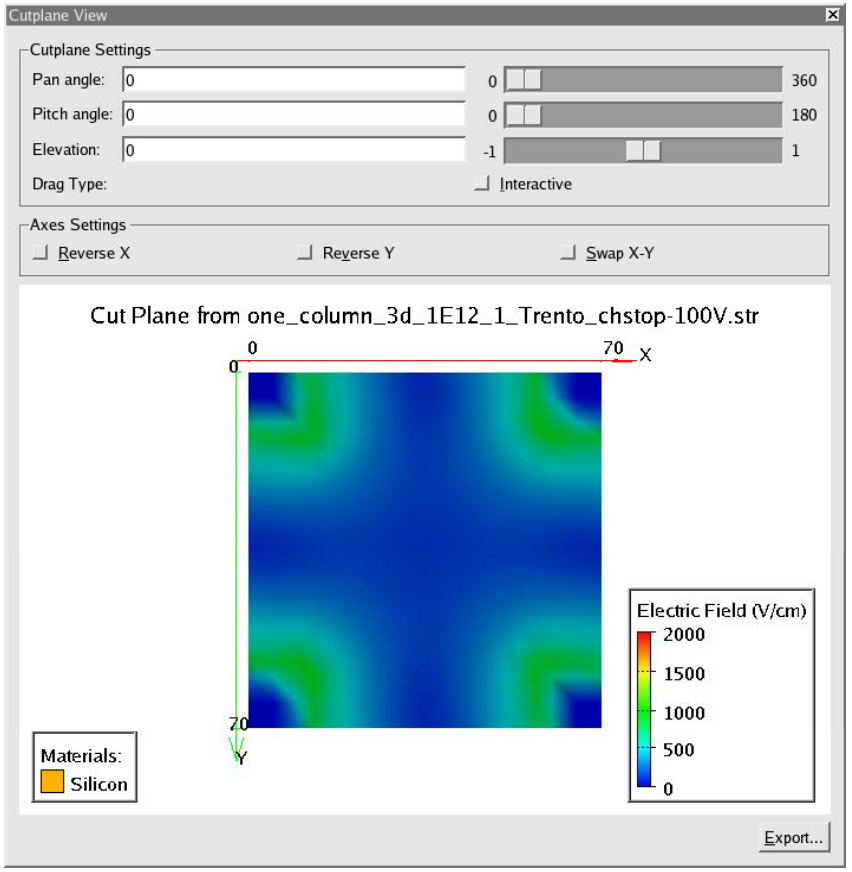
Electric field

Comparing single column 3D detectors (100V)

BNL



Trento

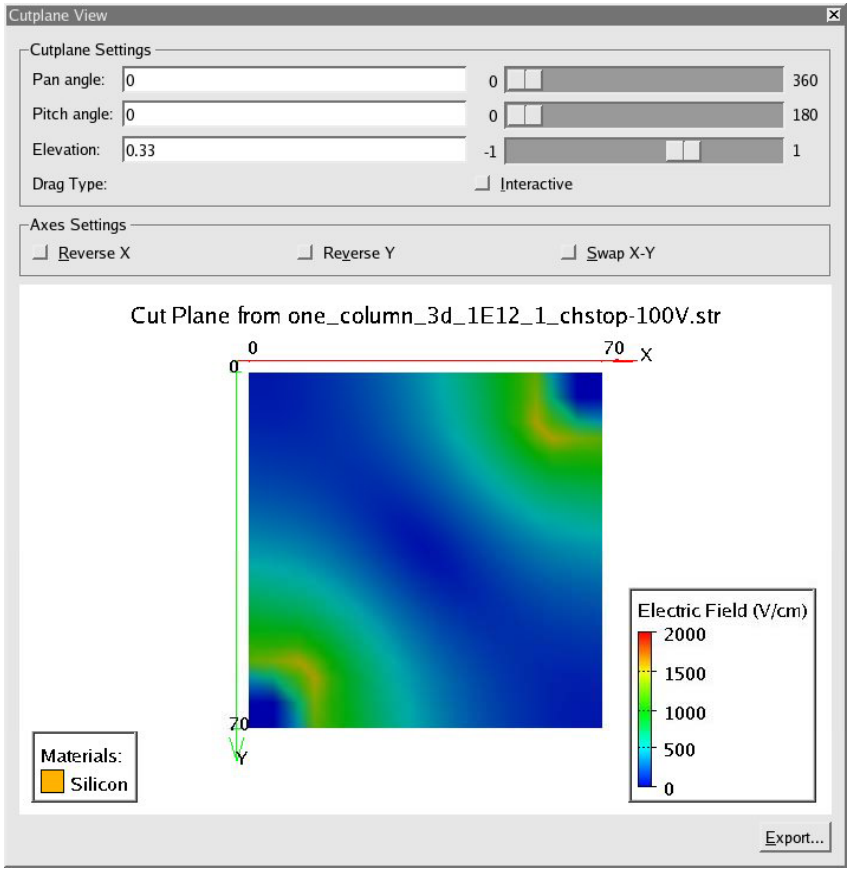


150 µm from the front surface

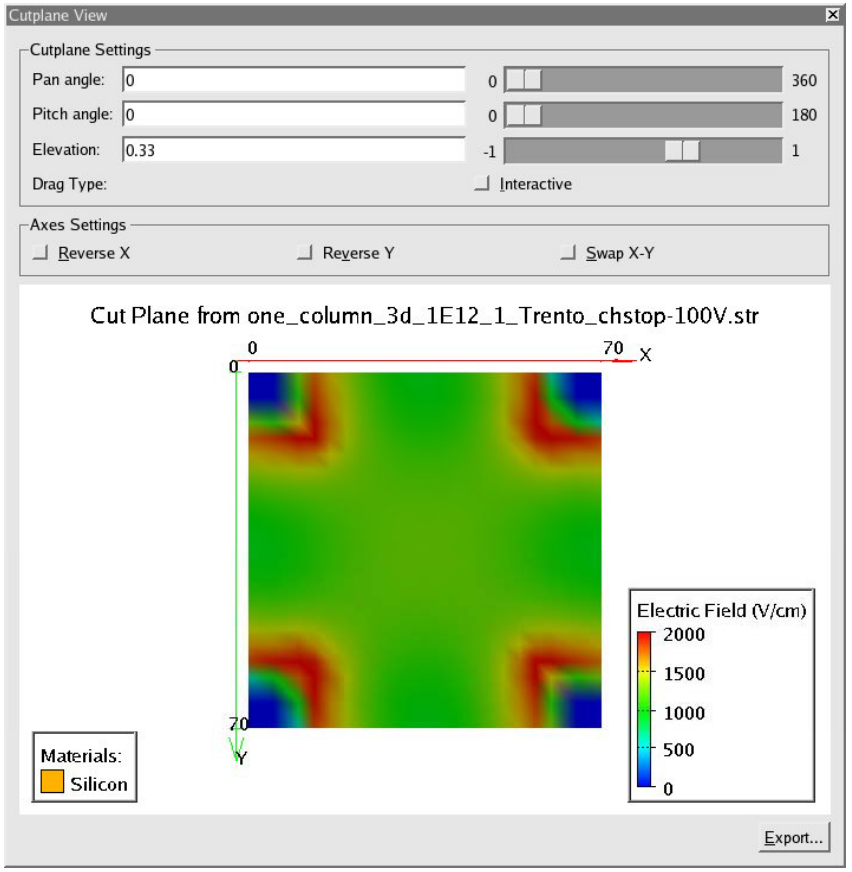
Electric field

Comparing single column 3D detectors (100V)

BNL



Trento

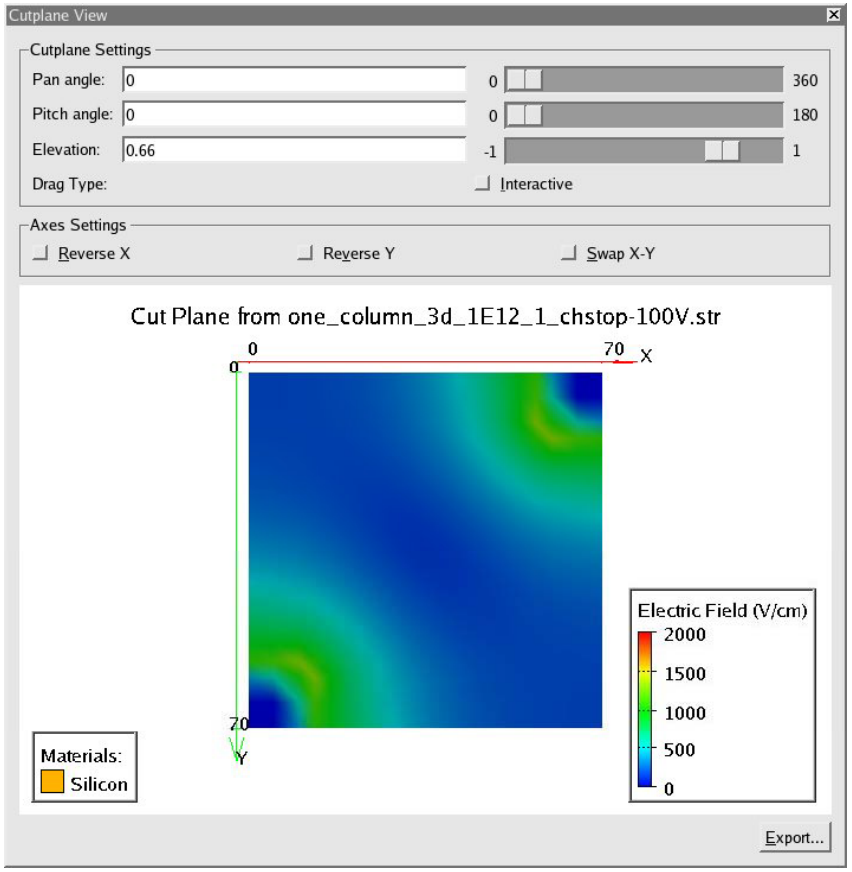


200 µm from the front surface

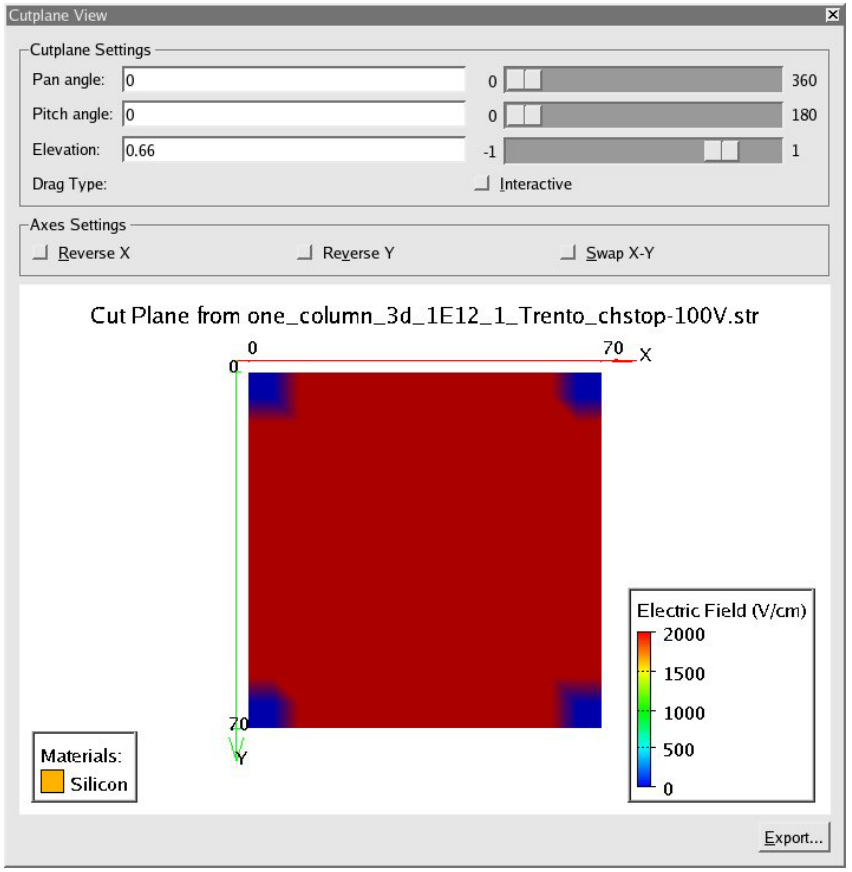
Electric field

Comparing single column 3D detectors (100V)

BNL



Trento

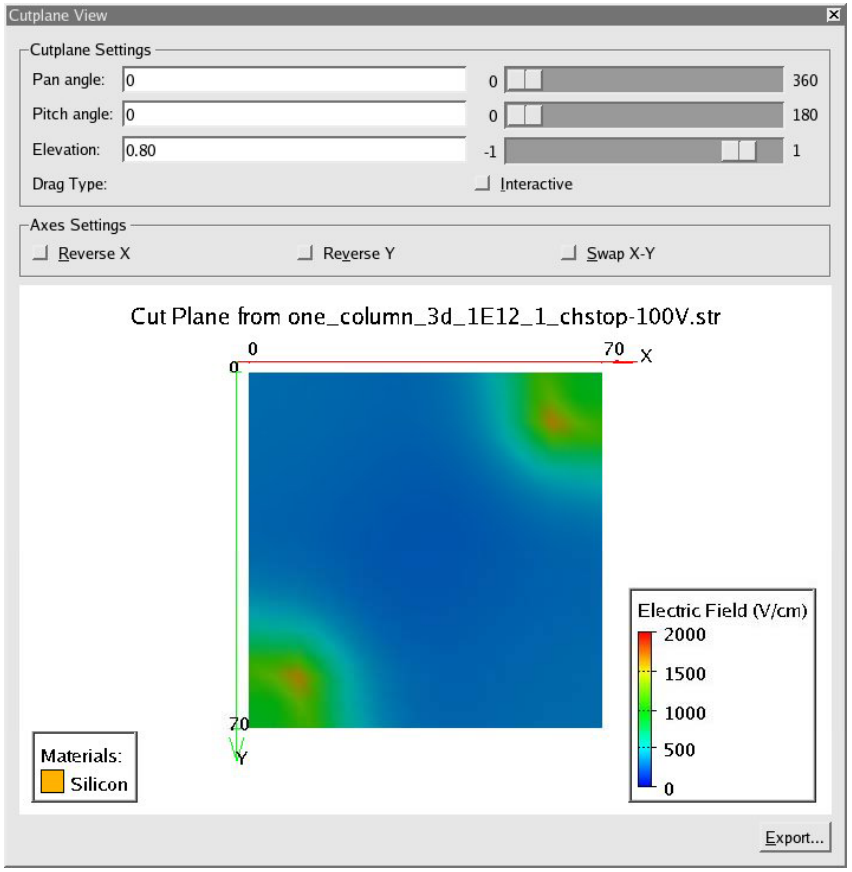


250 µm from the front surface

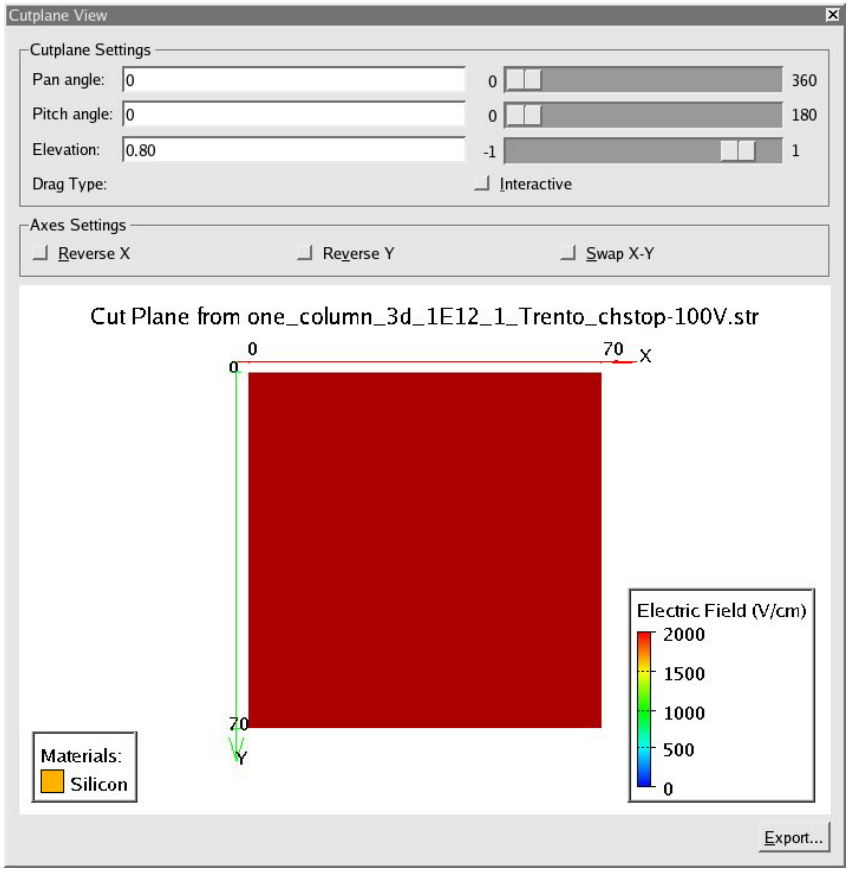
Electric field

Comparing single column 3D detectors (100V)

BNL



Trento

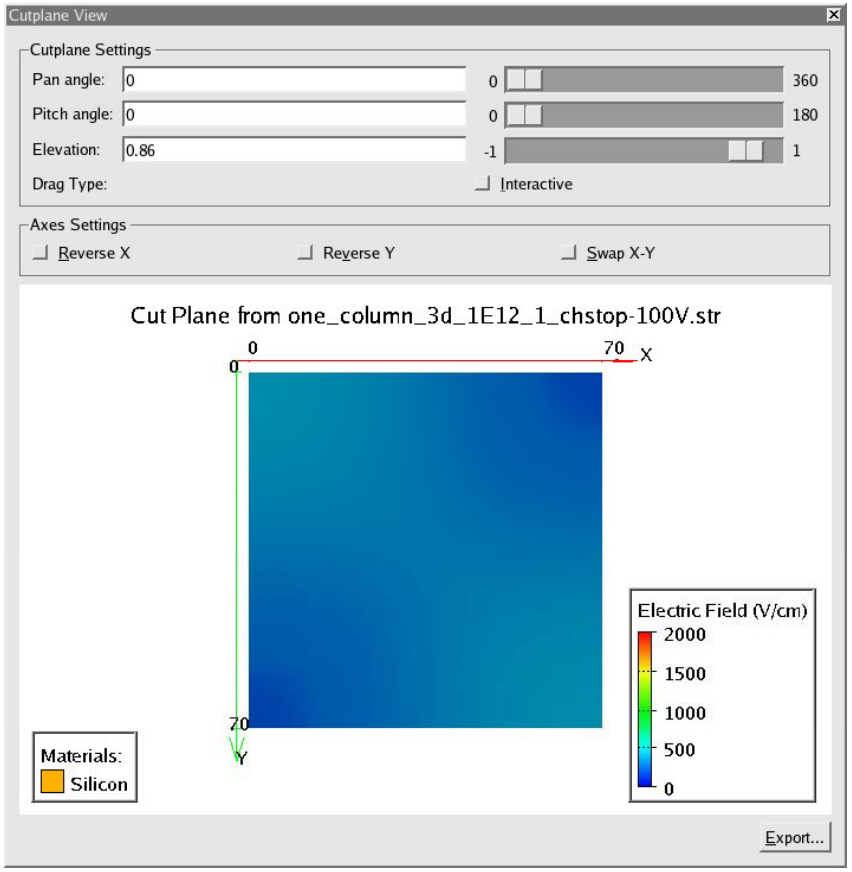


270 µm from the front surface

Electric field

Comparing single column 3D detectors (100V)

BNL



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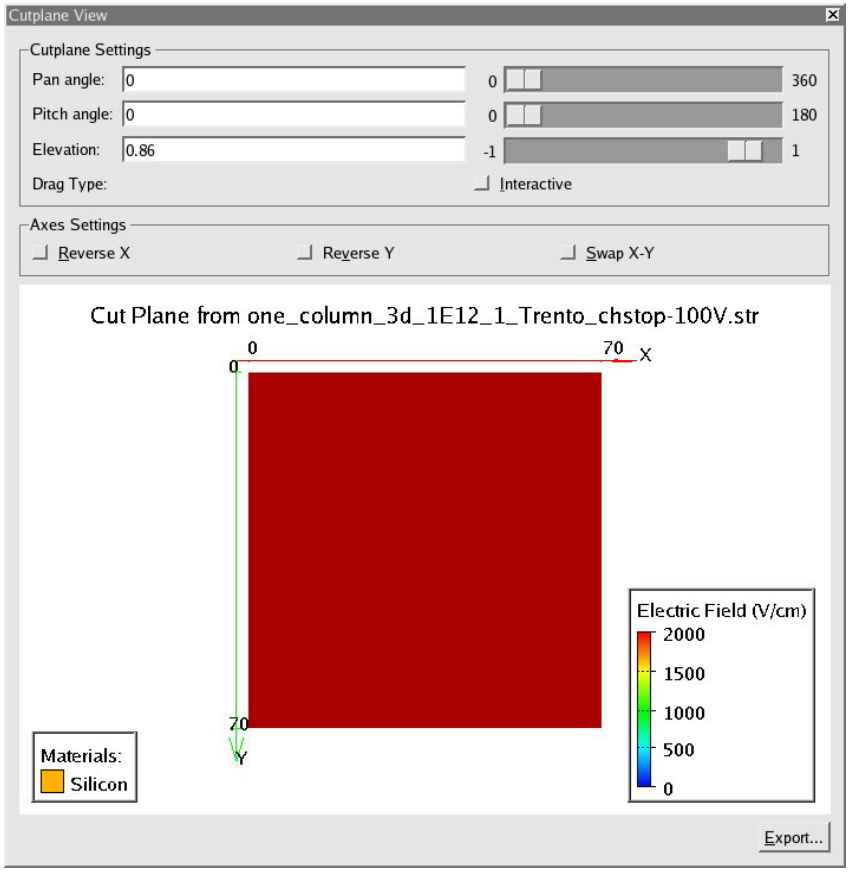
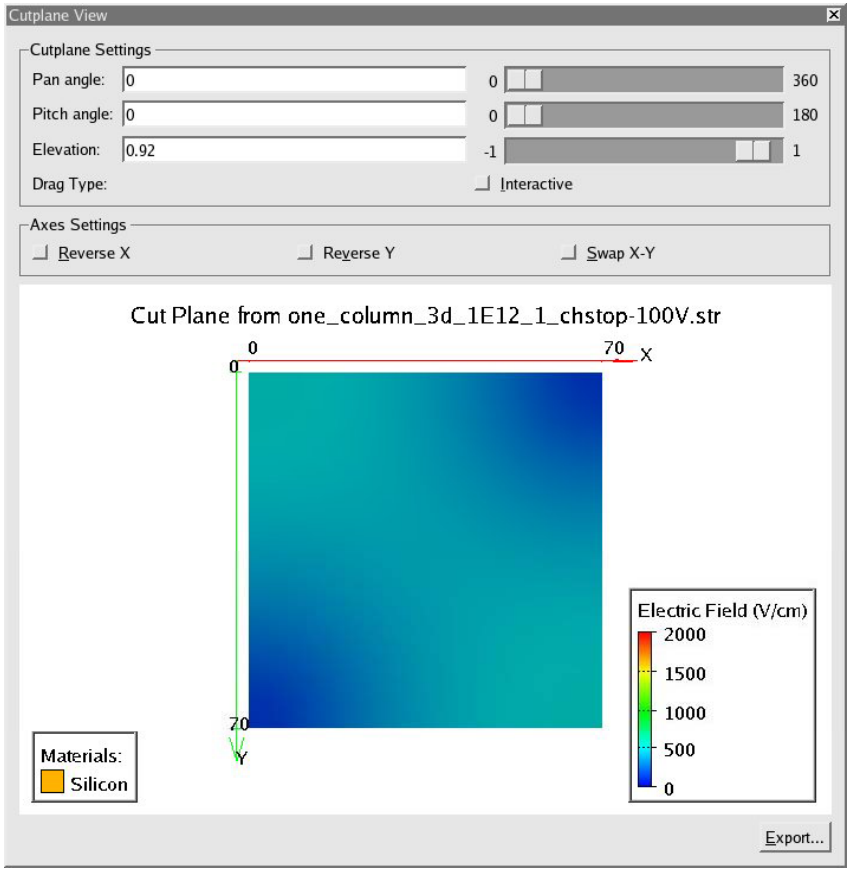


280 µm from the front surface

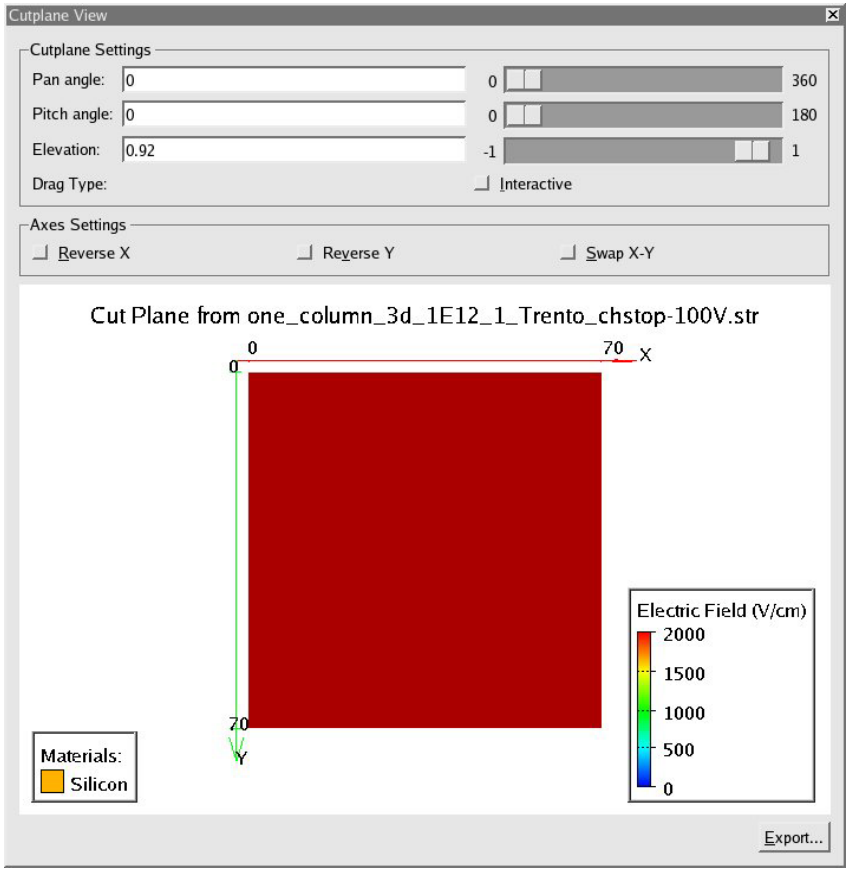
Electric field

Comparing single column 3D detectors (100V)

BNL



Trento

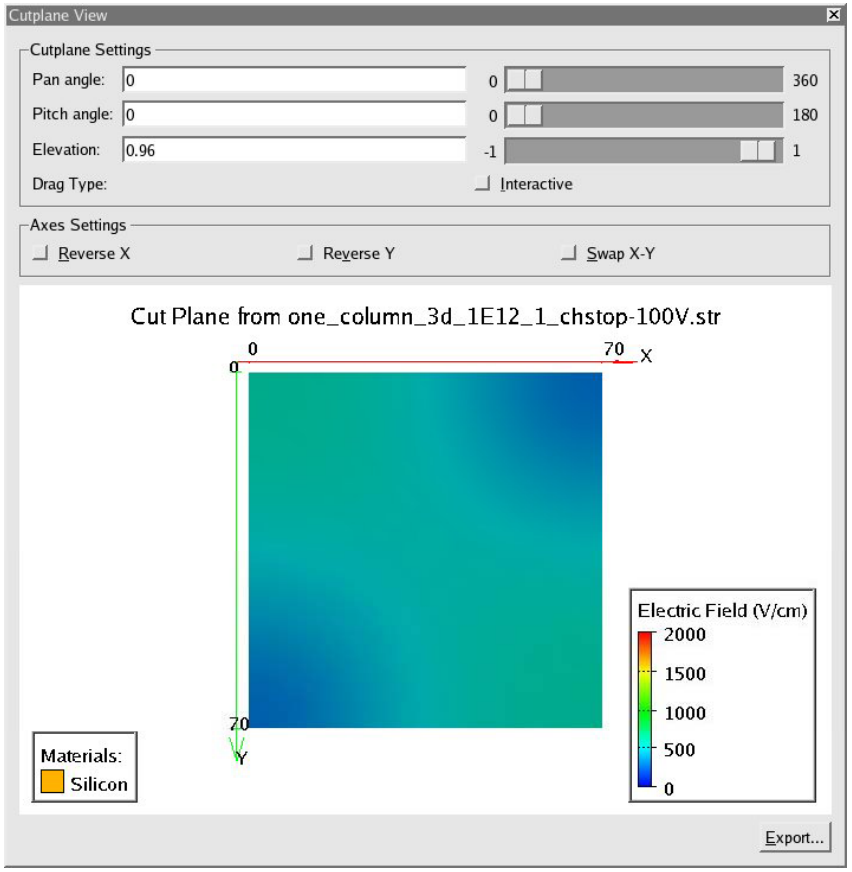


290 µm from the front surface

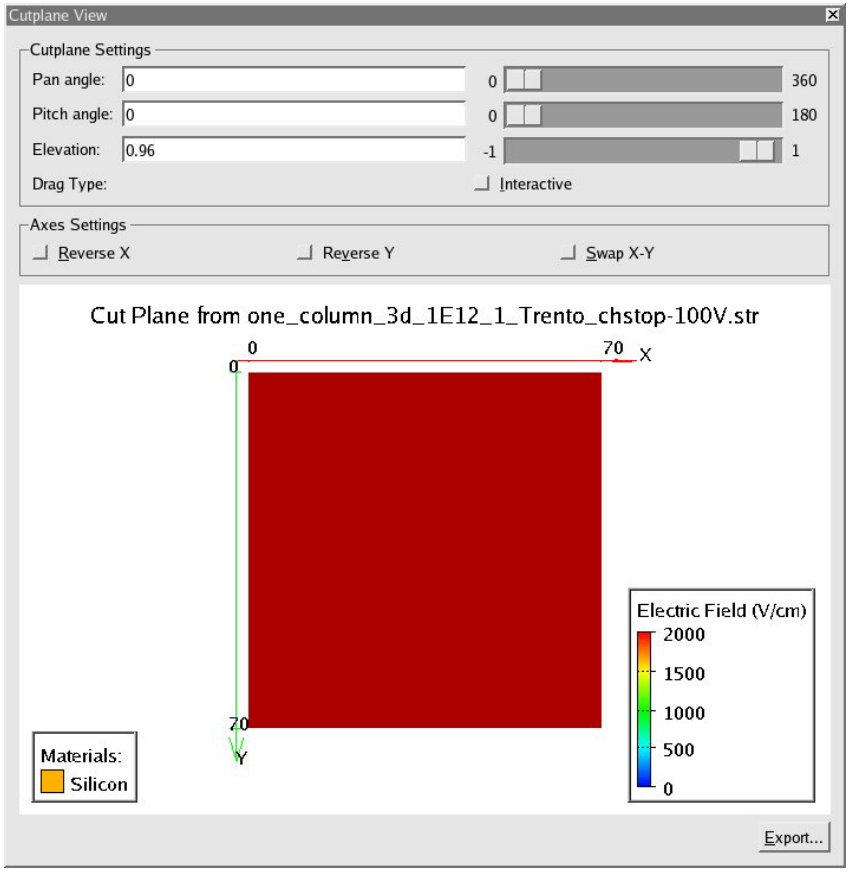
Electric field

Comparing single column 3D detectors (100V)

BNL



Trento

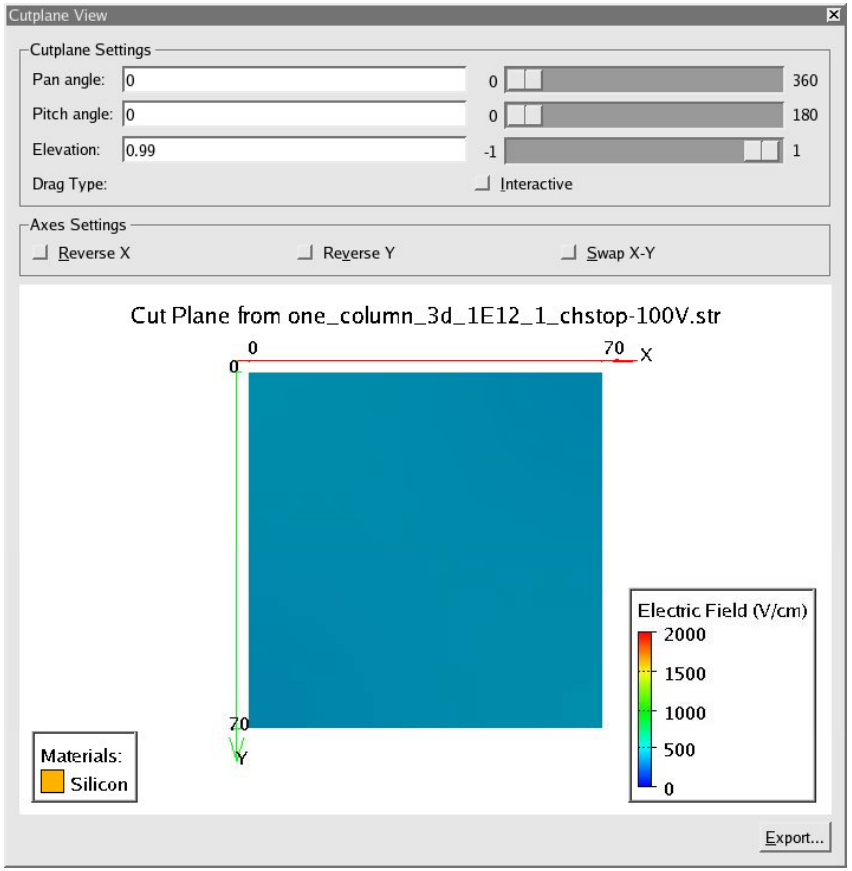


295 µm from the front surface

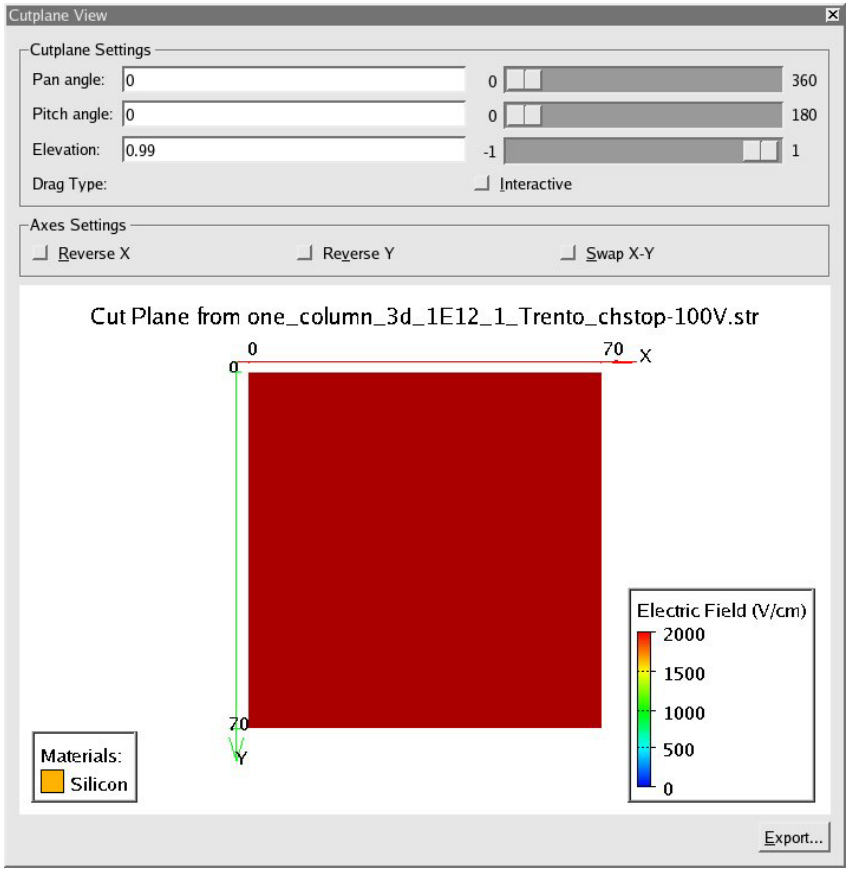
Electric field

Comparing single column 3D detectors (100V)

BNL



Trento

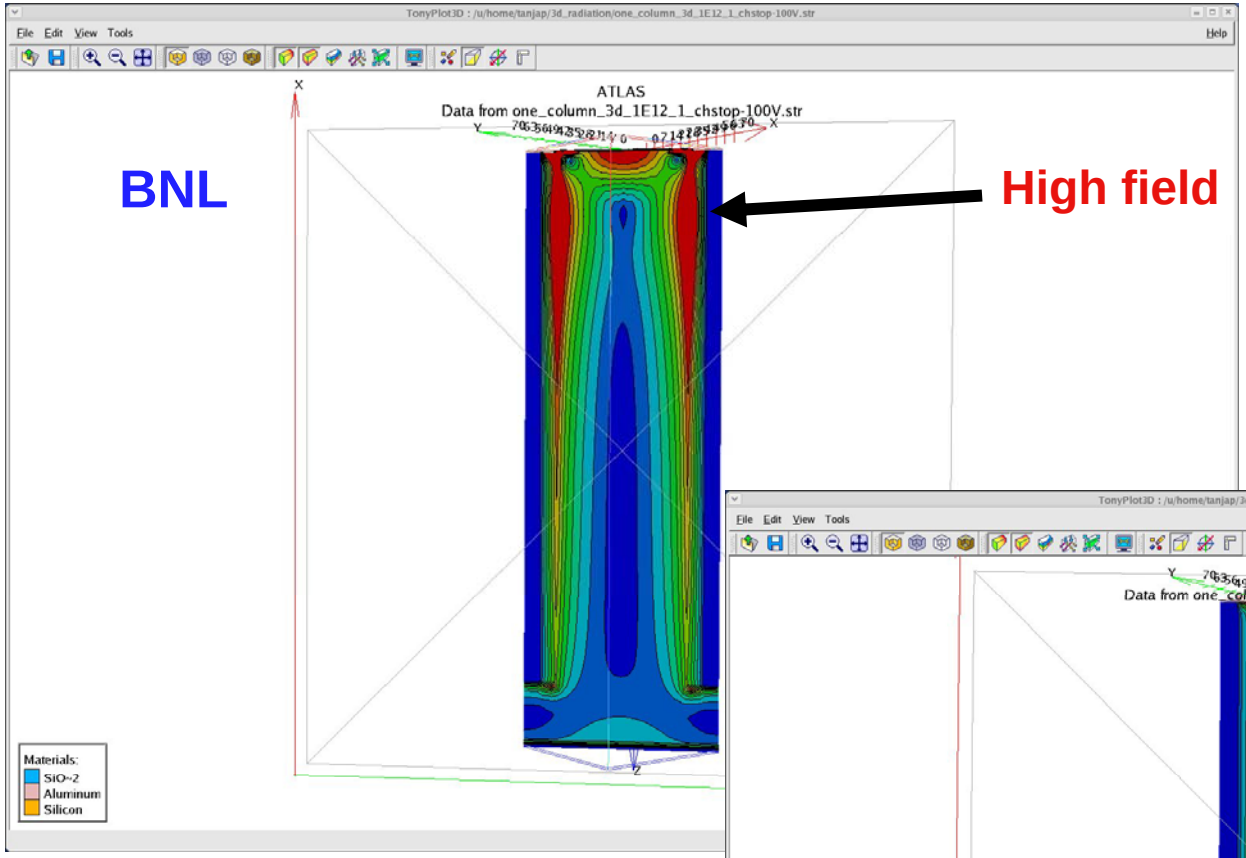


299 µm from the front surface

Electric field

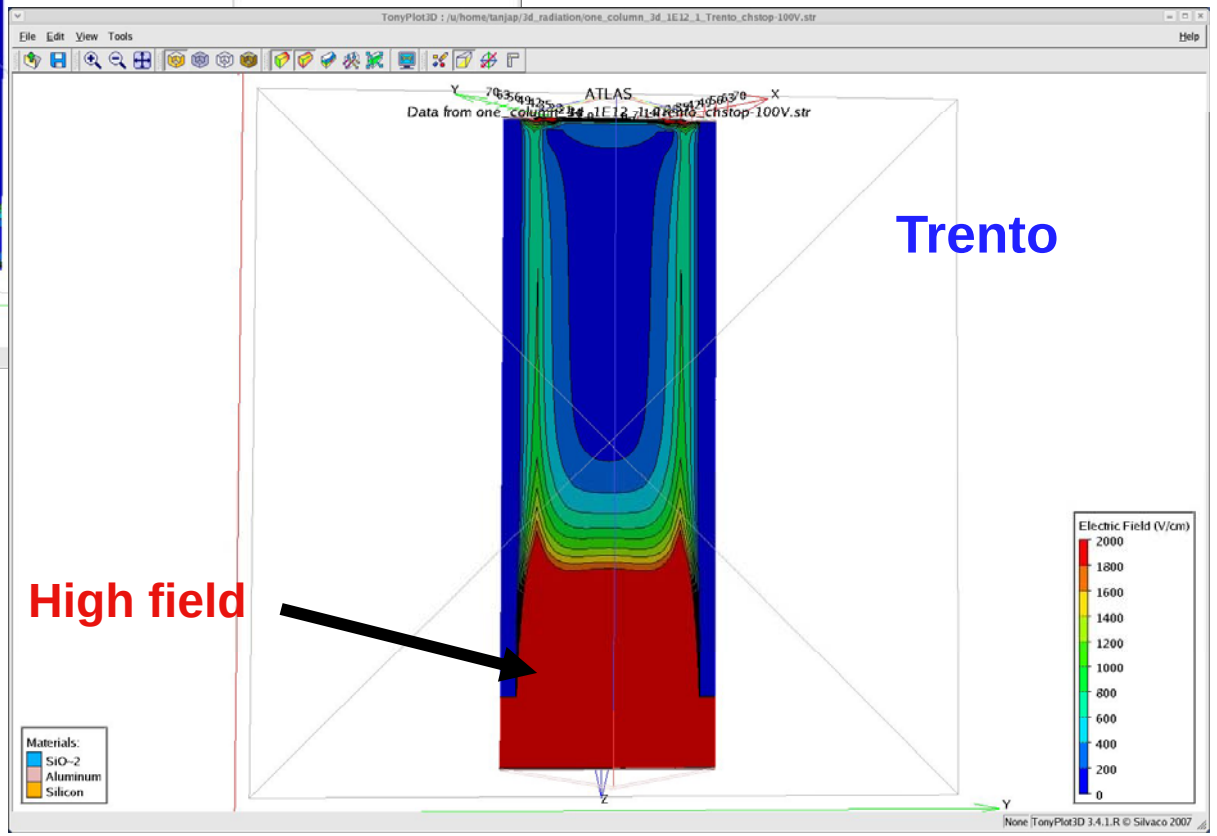
t3

Electric field between n-columns in 1-C detectors



BNL

High field



Trento

Electric field

100V

High field

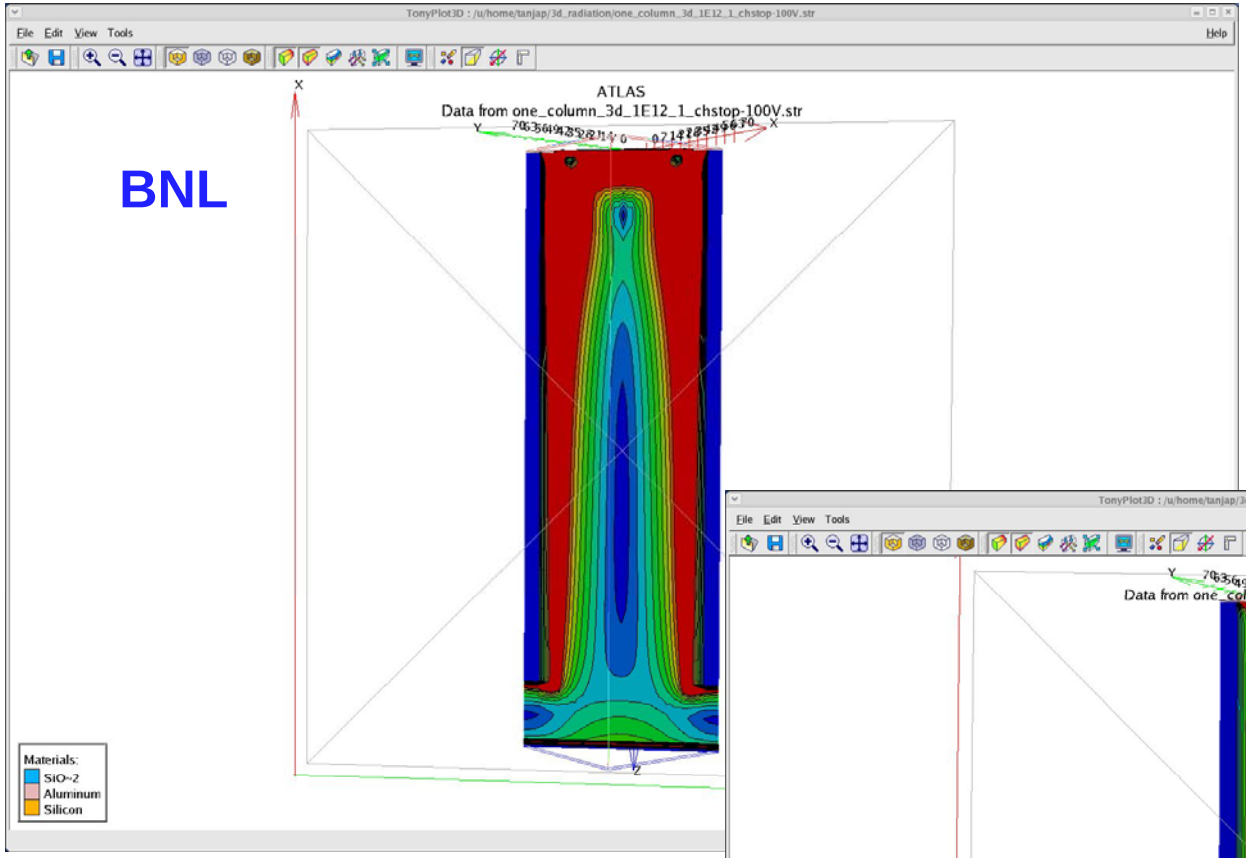
Slide 82

t3 Make an arrow to show where the most of the high field is (fronside-BNL, backside-Trento)

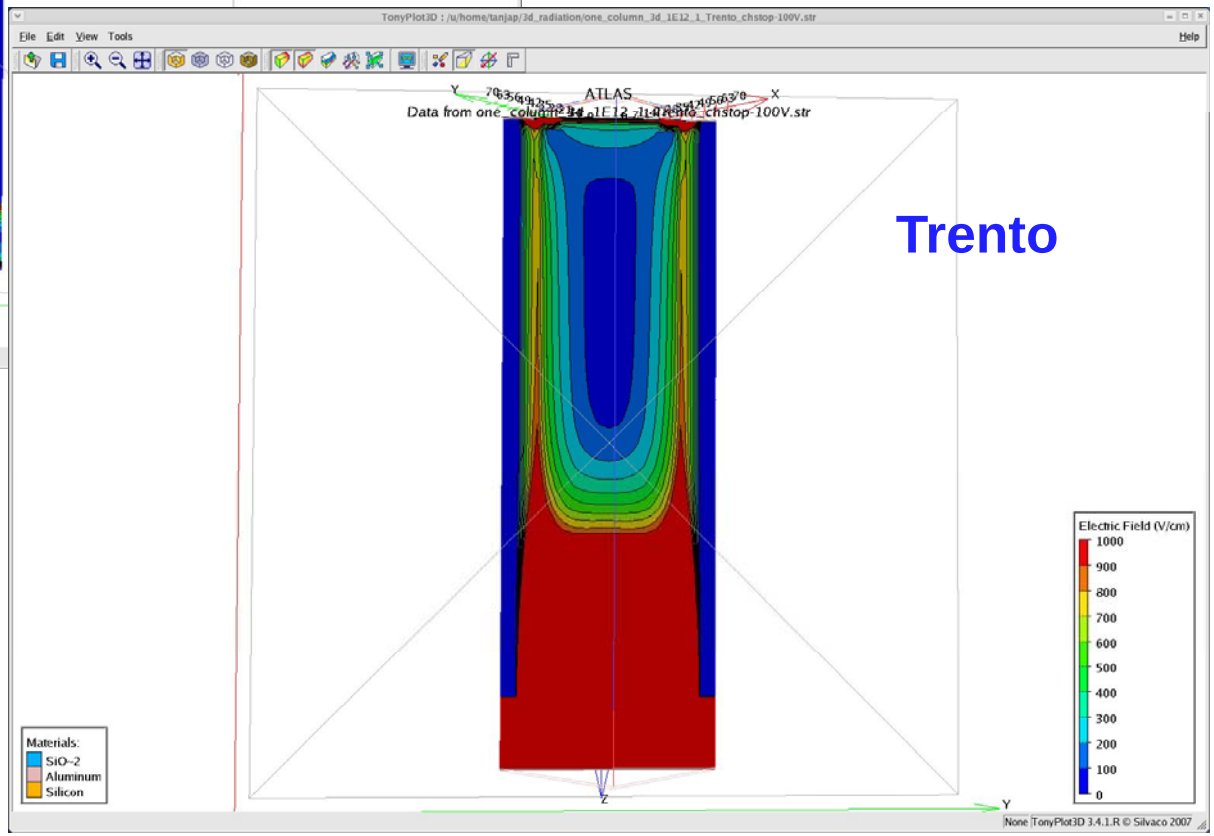
Explain that the cut is same only the scale is changed to see more accurate the field
tanjap, 4/13/2007

Electric field between n-columns in 1-C detectors

BNL



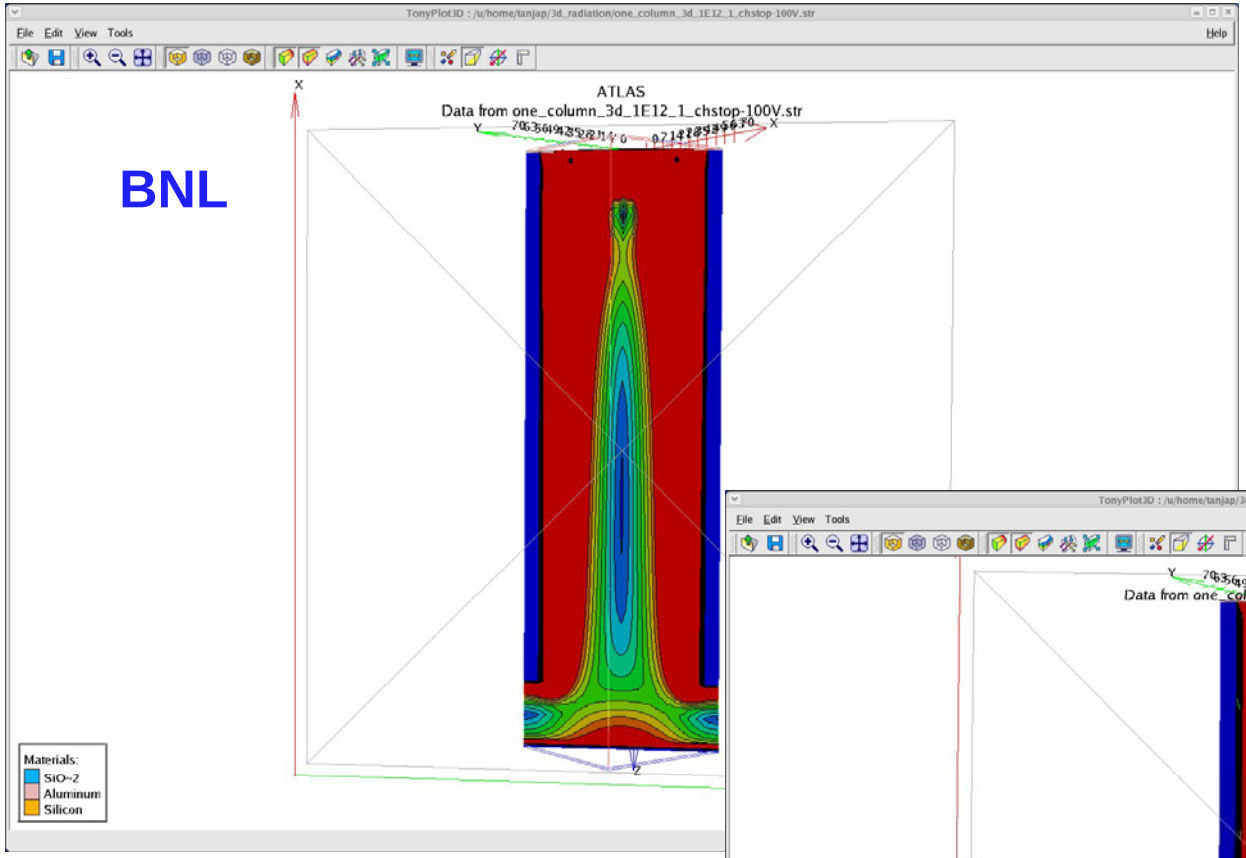
Trento



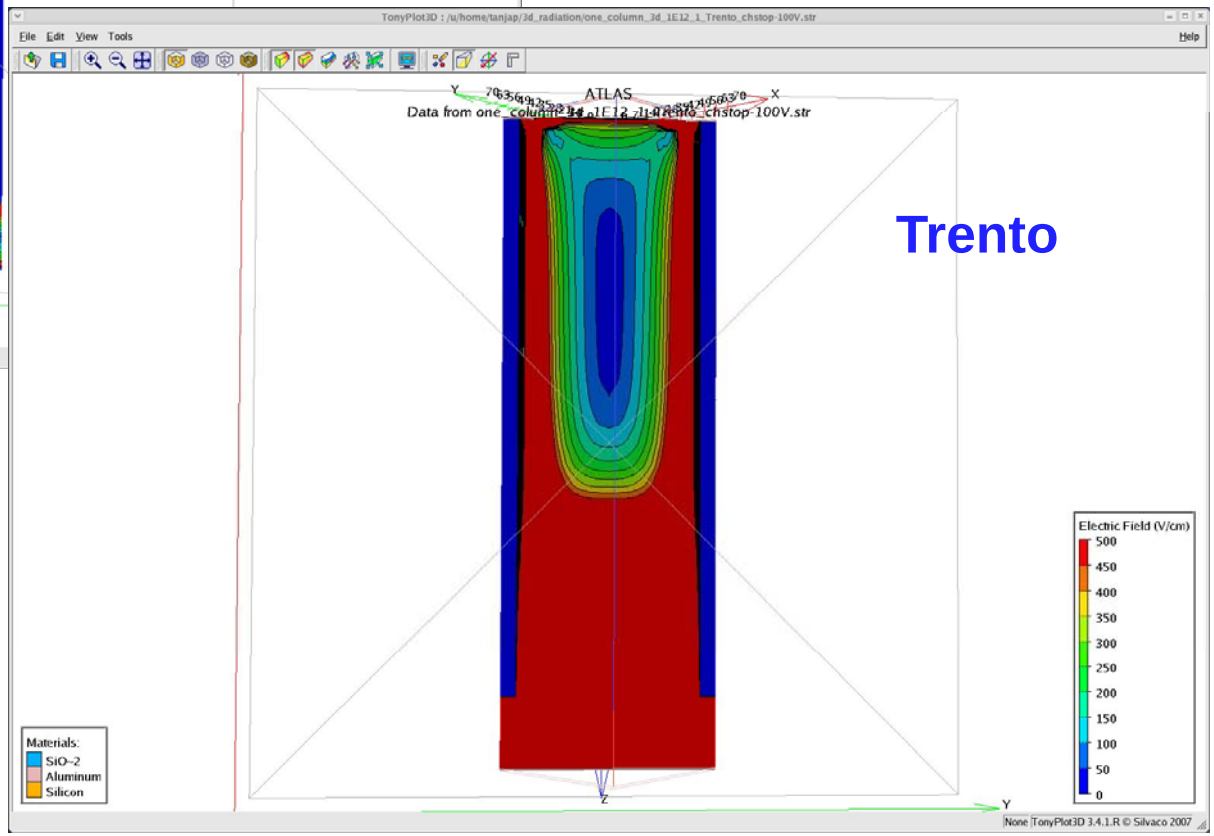
Electric field

100V

Electric field between n-columns in 1-C detectors



BNL

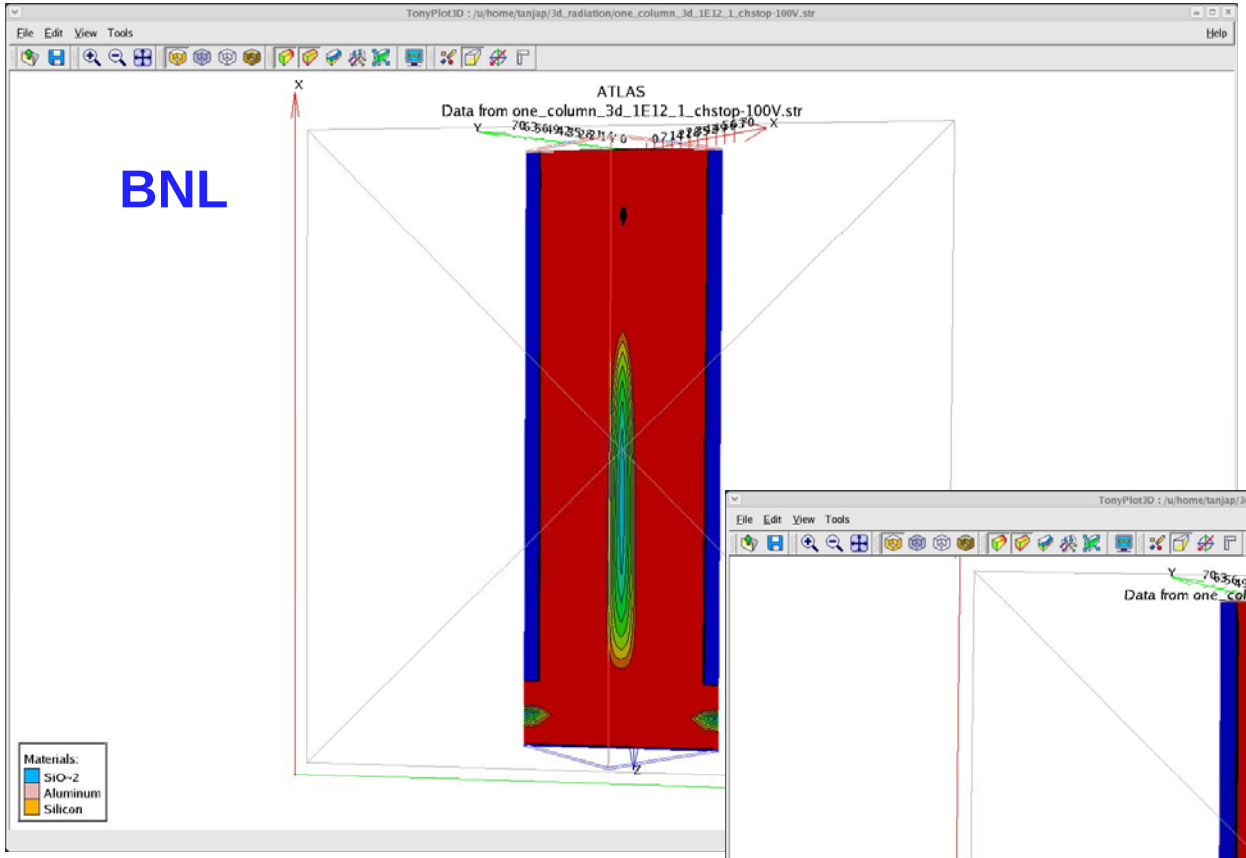


Trento

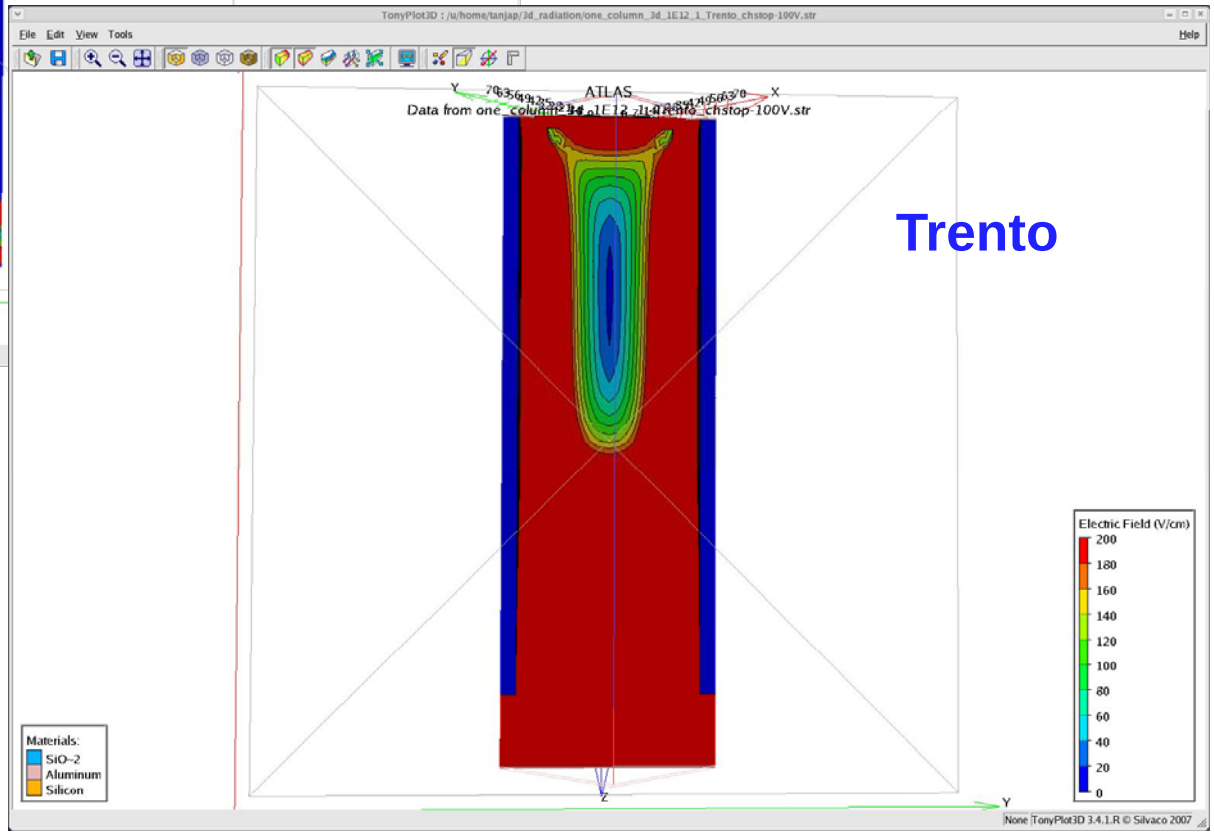
Electric field

100V

Electric field between n-columns in 1-C detectors



BNL

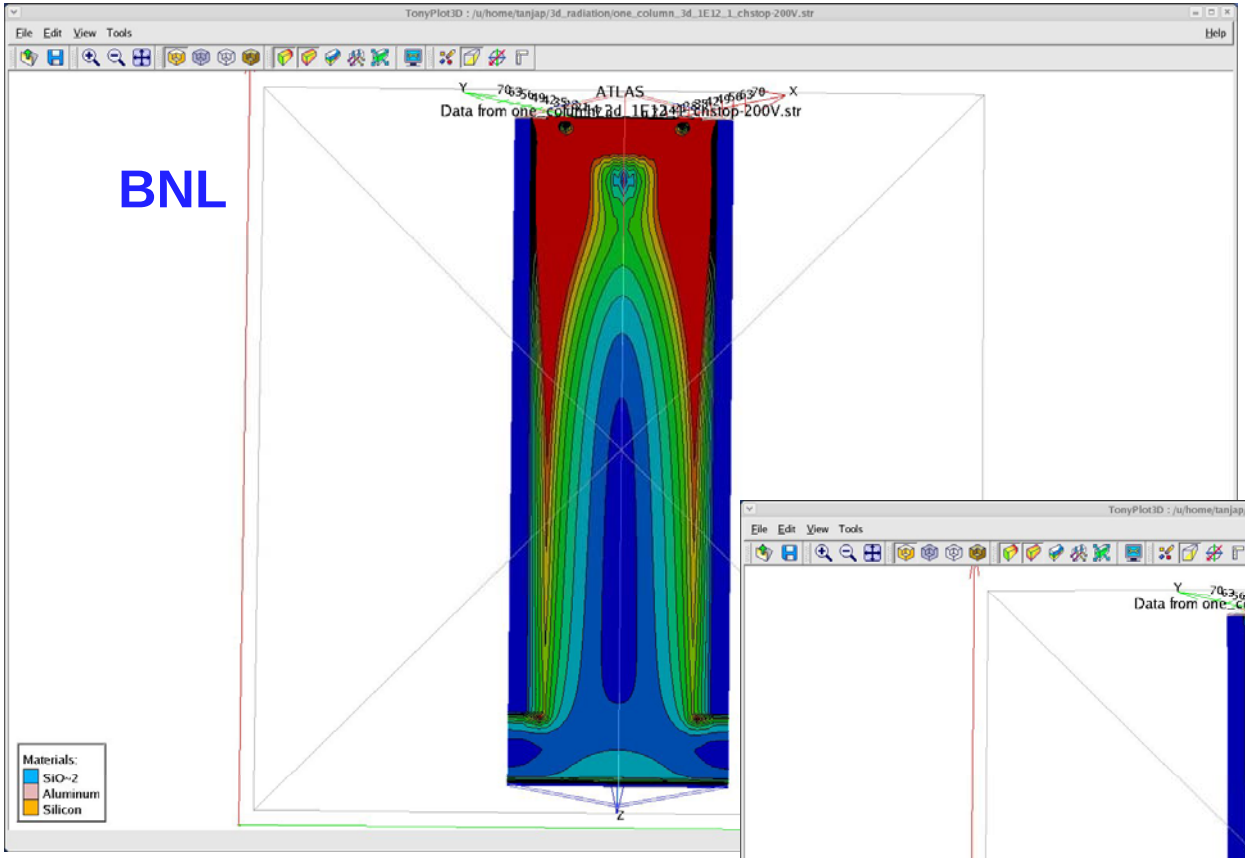


Trento

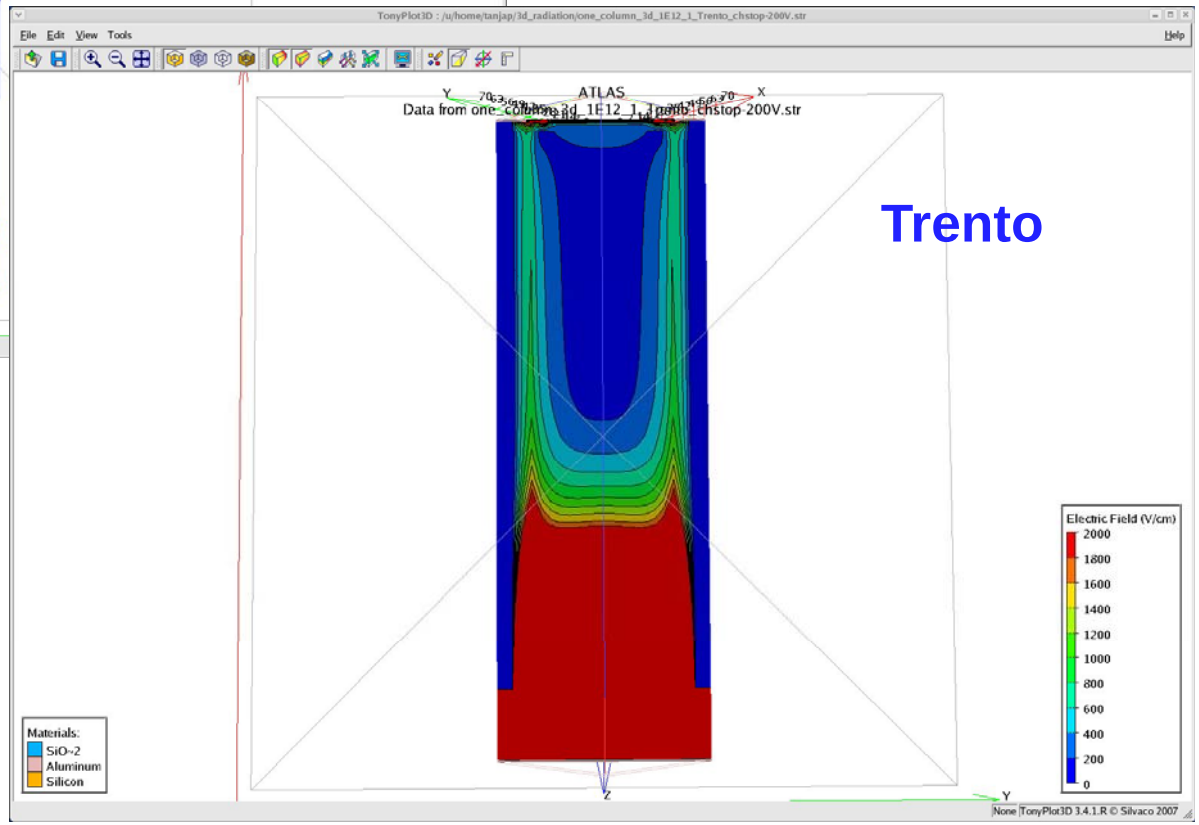
Electric field

100V

Electric field between n-columns in 1-C detectors



BNL

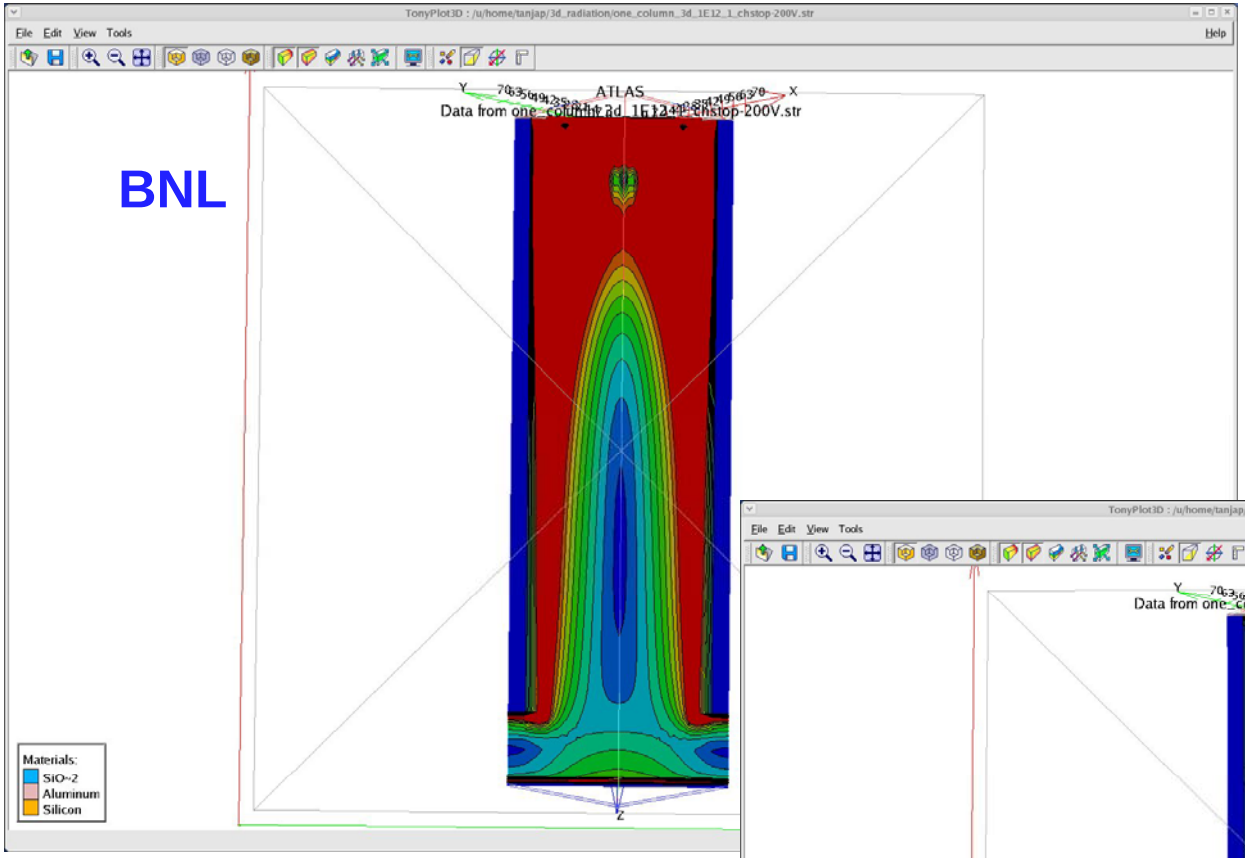


Trento

Electric field

200V

Electric field between n-columns in 1-C detectors



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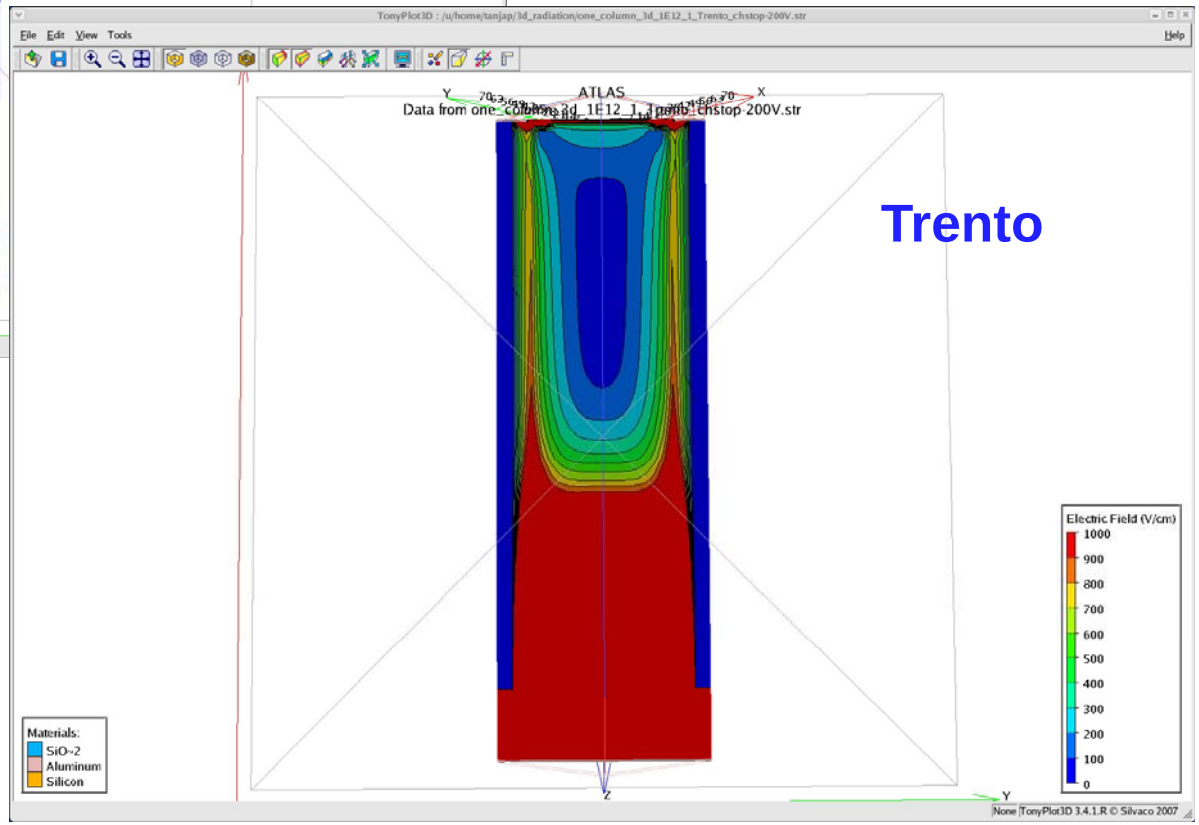
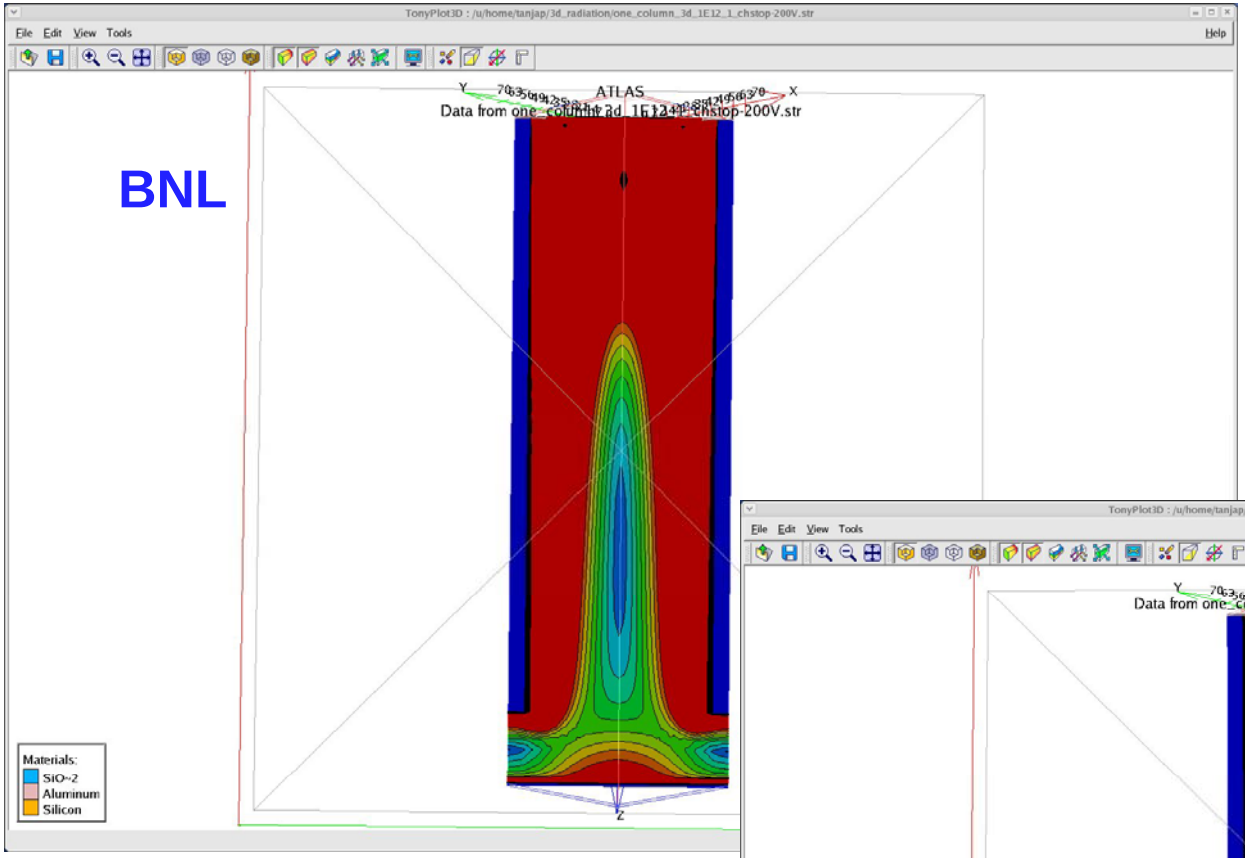


Trento

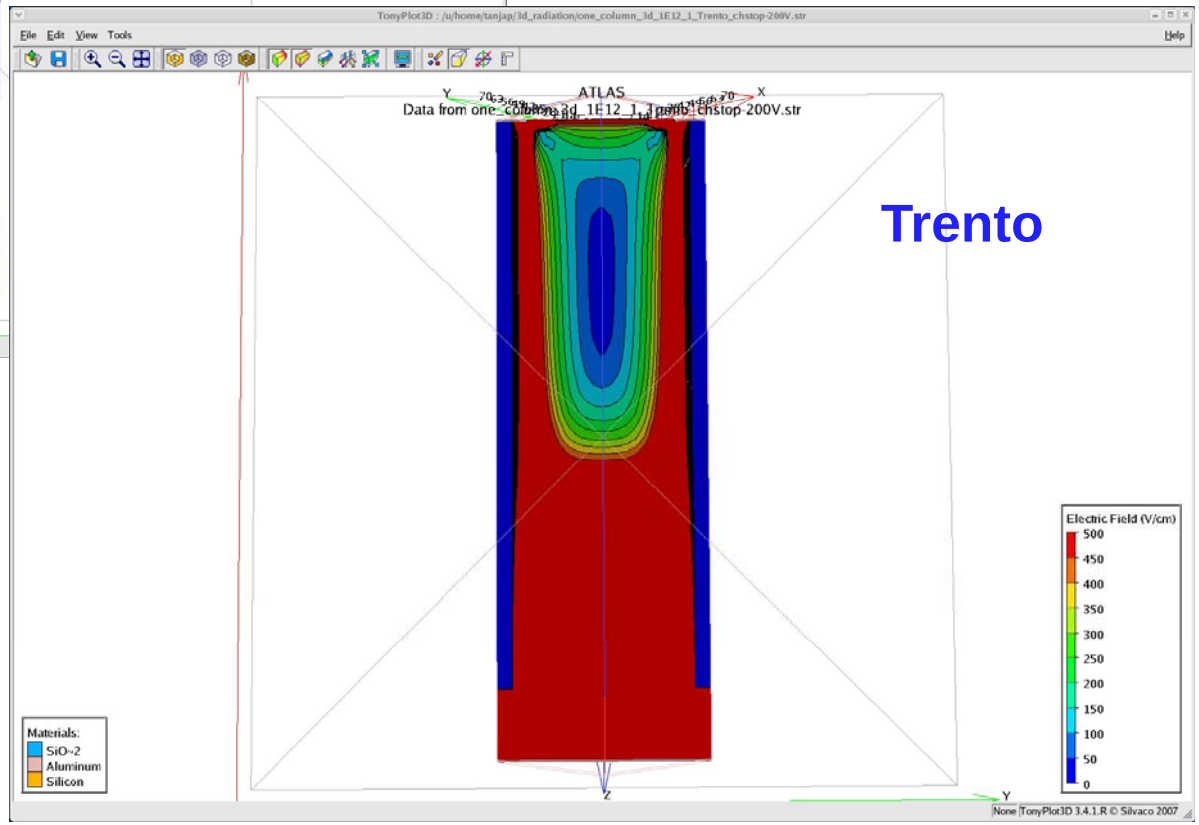
Electric field

200V

Electric field between n-columns in 1-C detectors



BNL

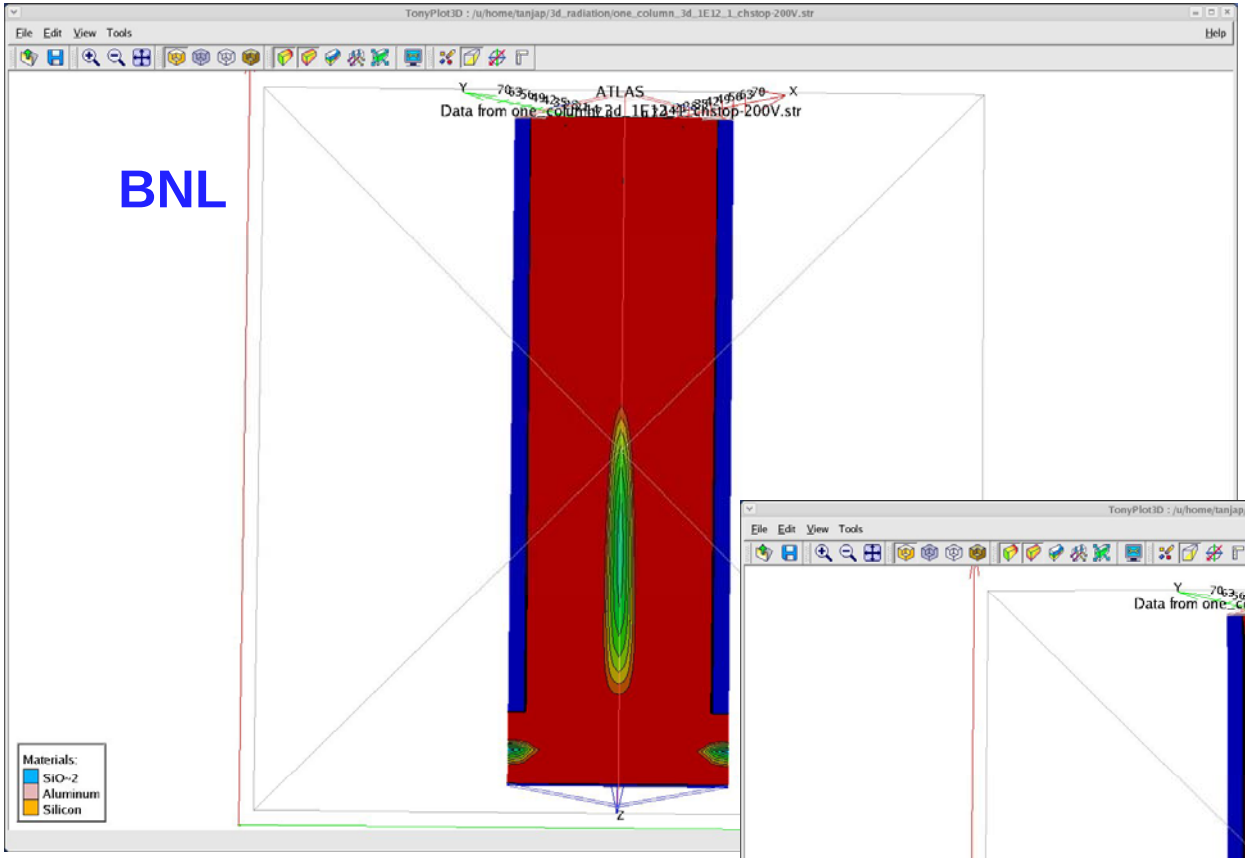


Trento

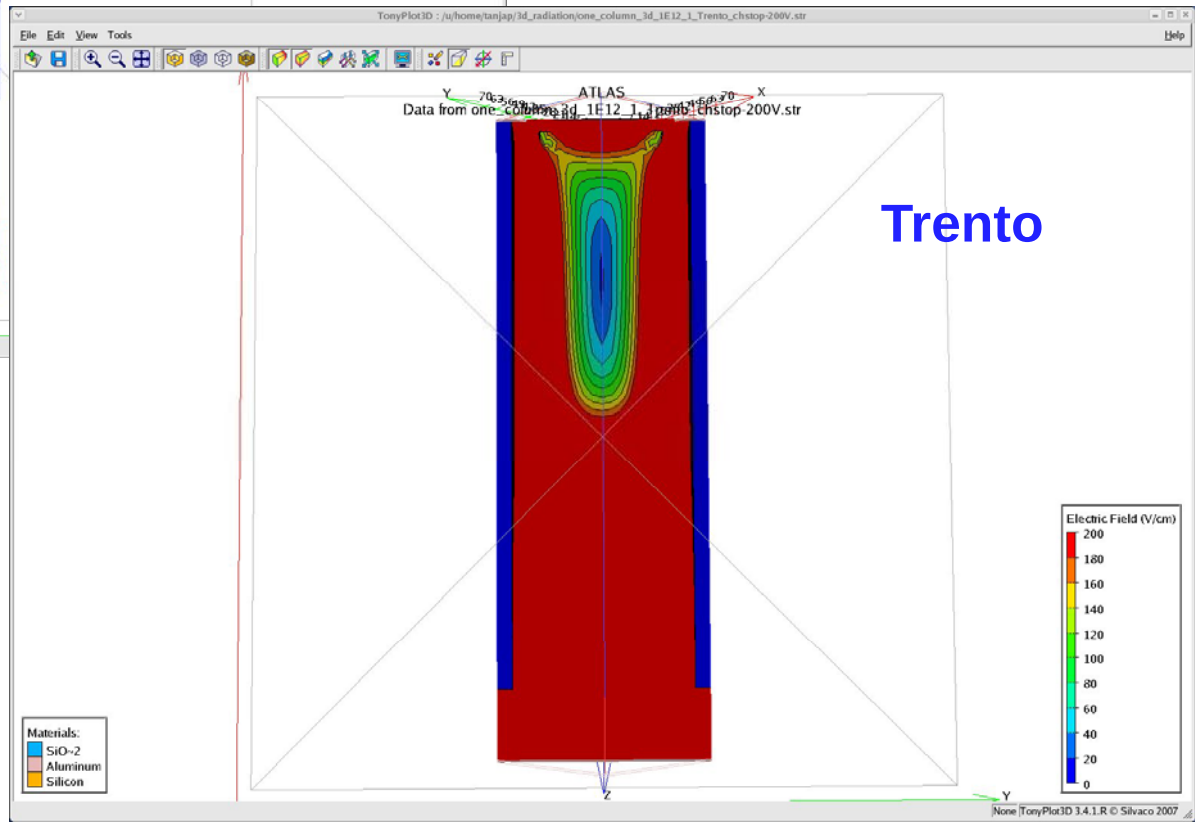
Electric field

200V

Electric field between n-columns in 1-C detectors



BNL



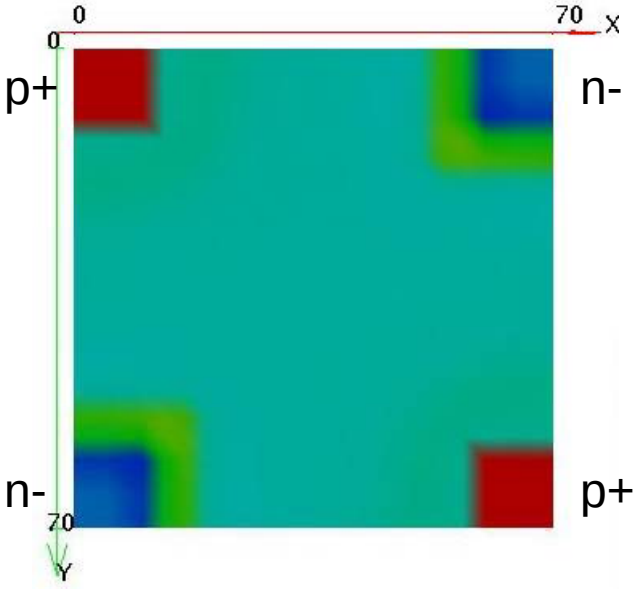
Trento

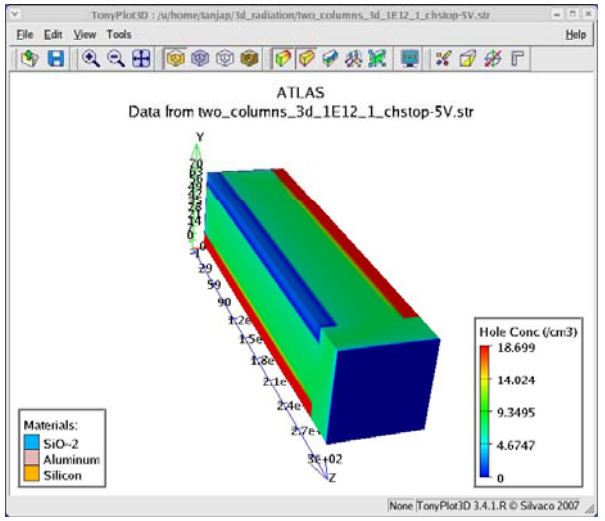
Electric field

200V

BNL dual column one-sided 3D detector

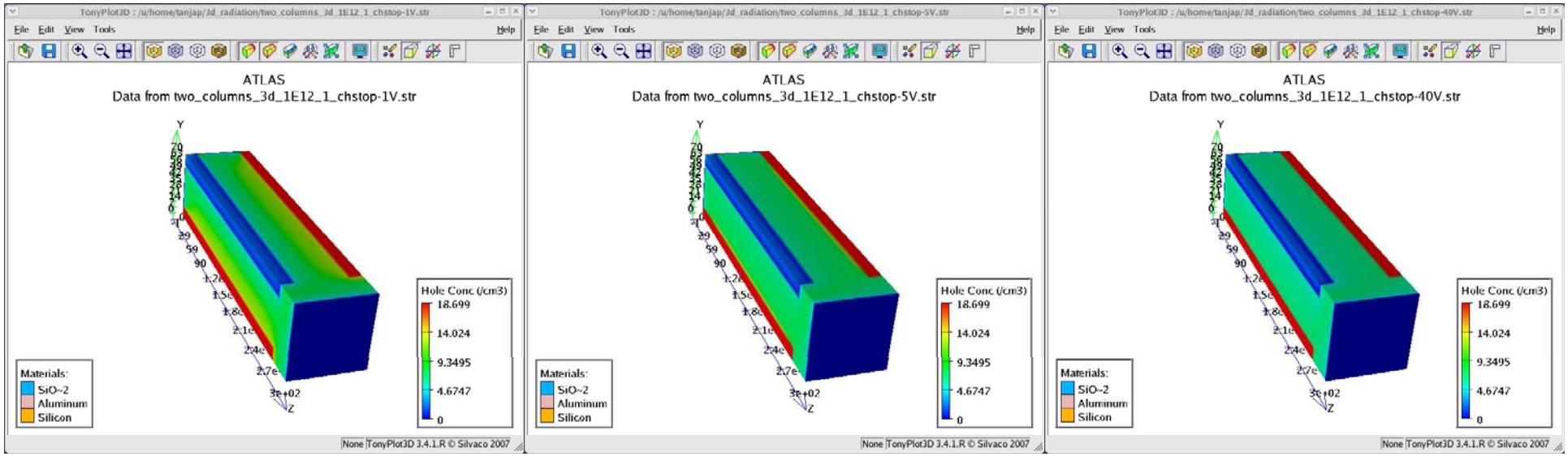
- BNL
- In this structure there are two n-type (blue in the pictures) and two p-type (red in the pictures) doped columns on p-type substrate
- Same type of doped columns are placed to the opposite corners
- N-columns are surrounded by the p-stops
- All columns are 270um long





BNL dual column one-sided 3D detector

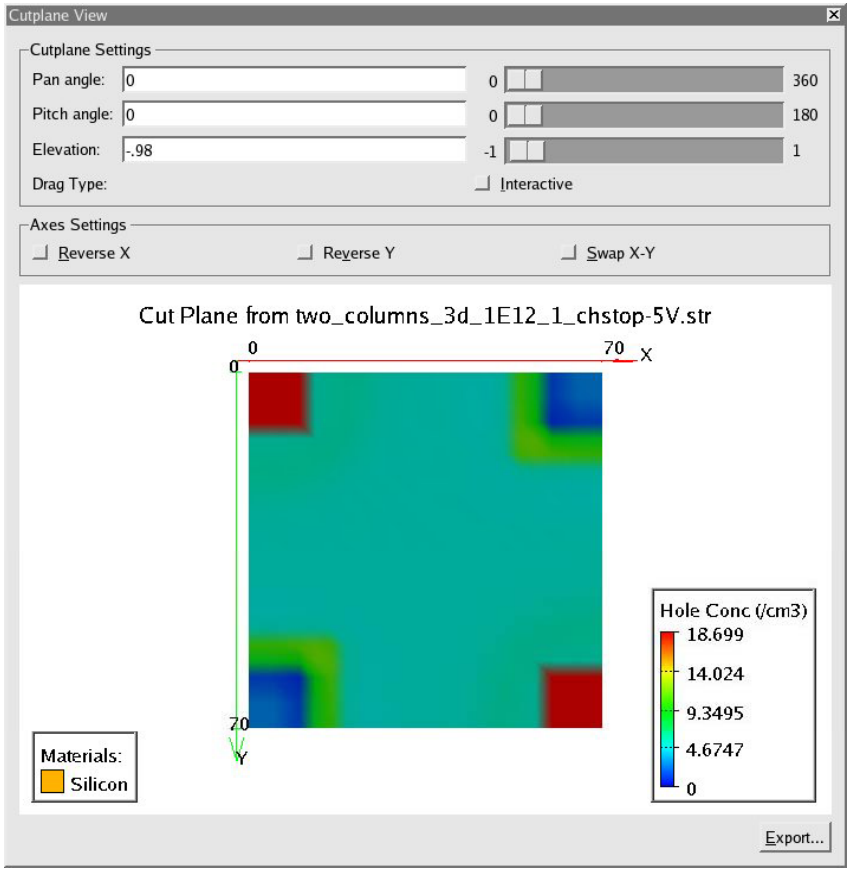
1V 5V 40V

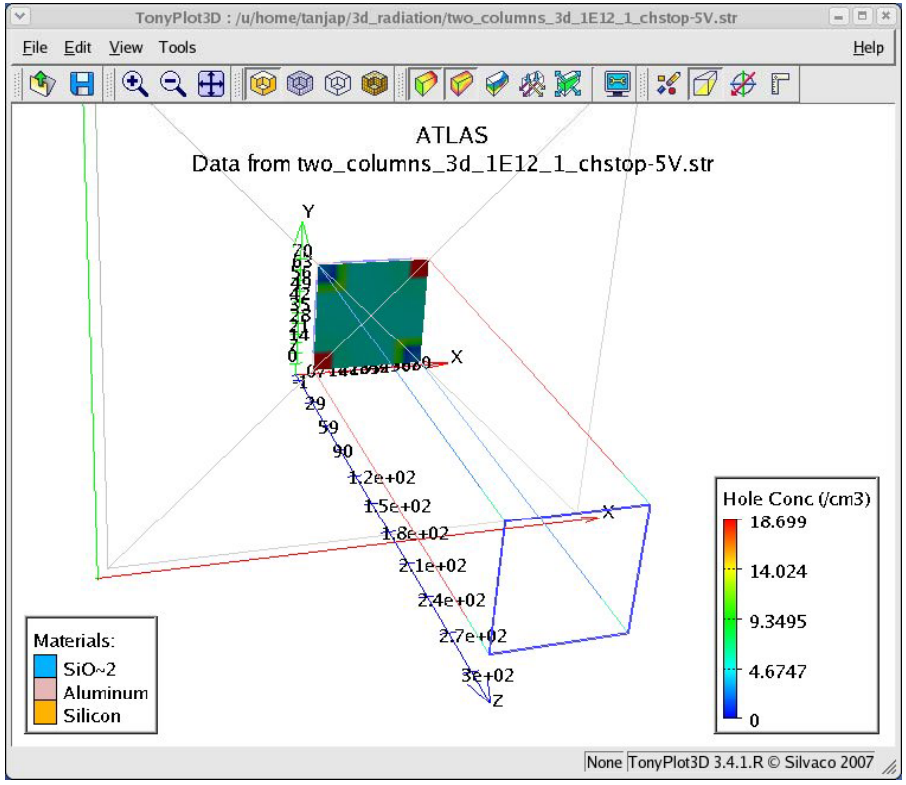


Hole concentration

t4

Dual column one-sided 3D detector (5V)



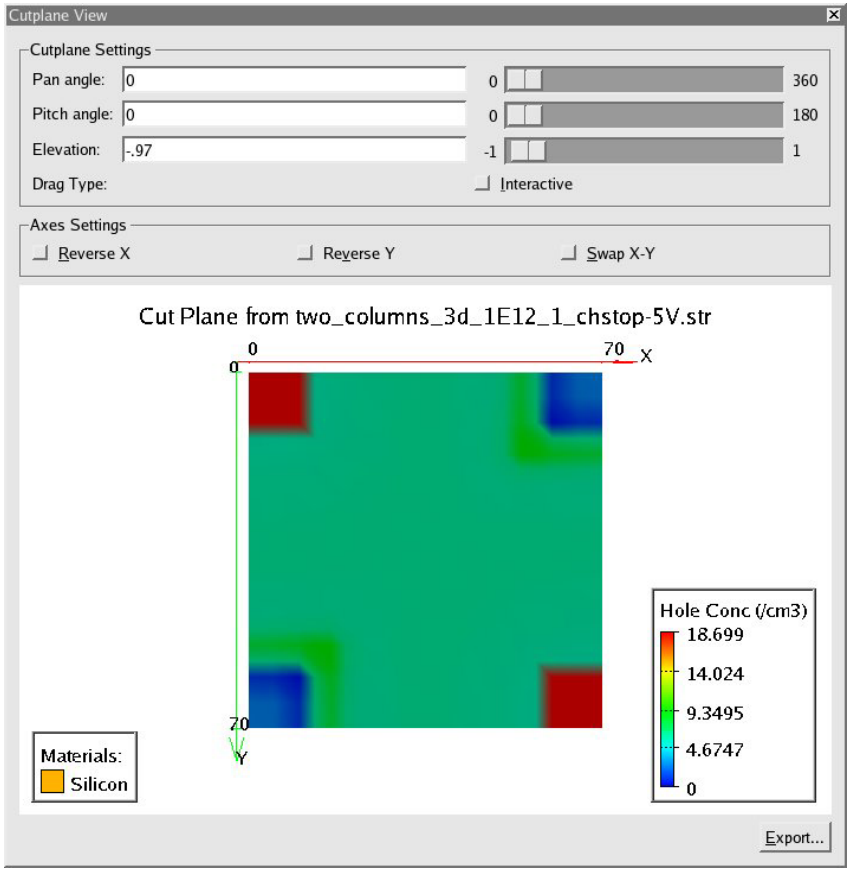


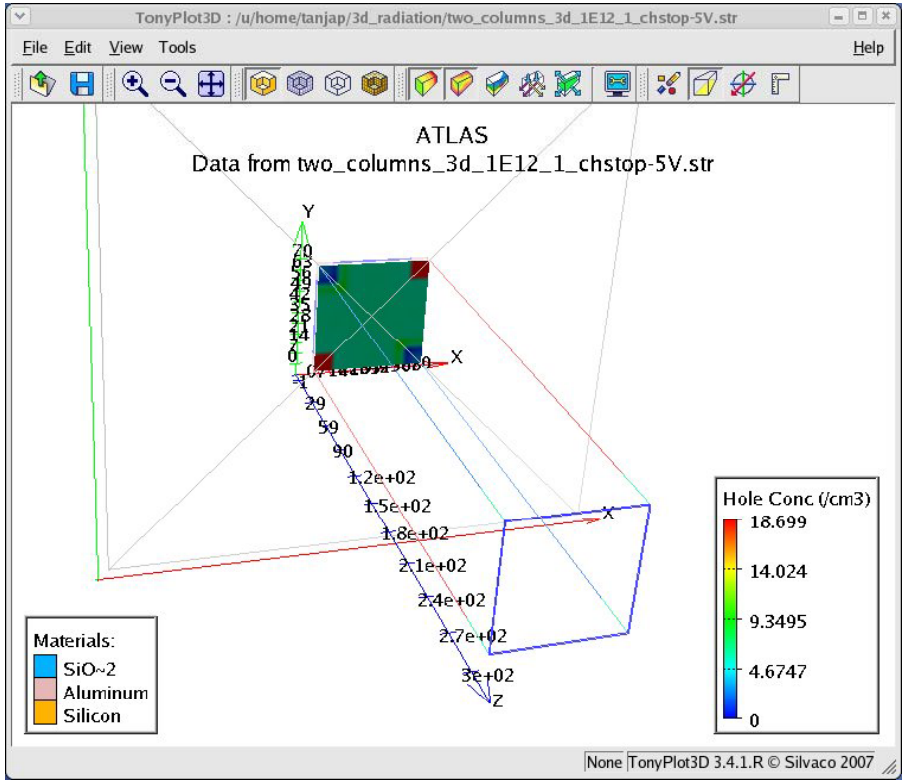
Hole concentration

t4 Make a movie

tanjap, 4/13/2007

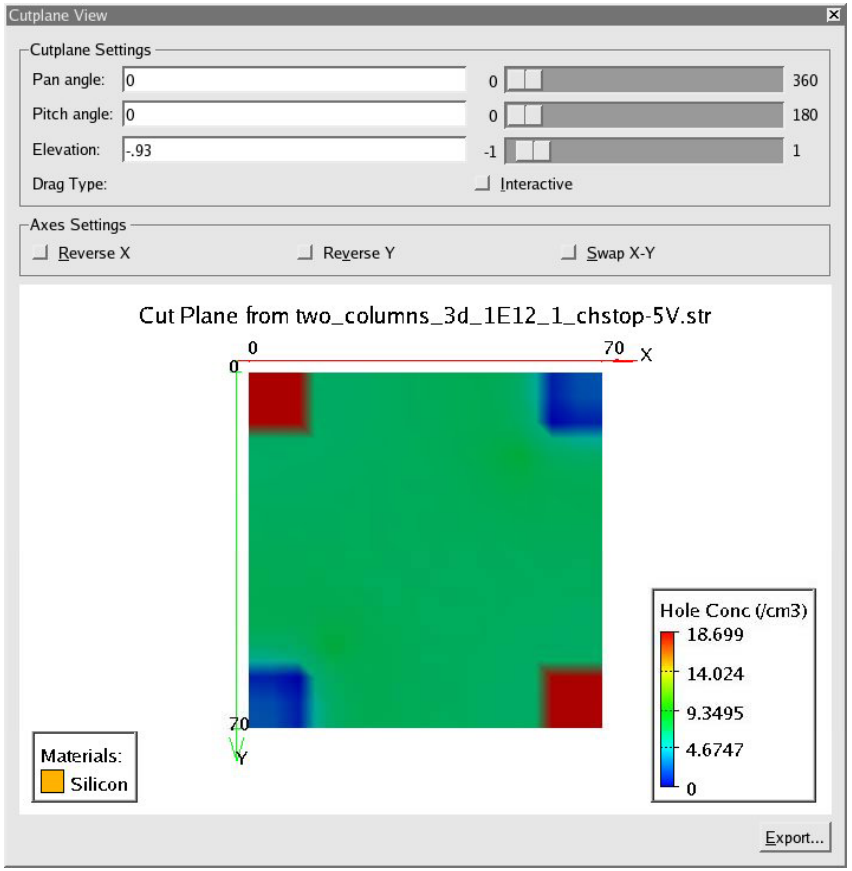
Dual column one-sided 3D detector (5V)

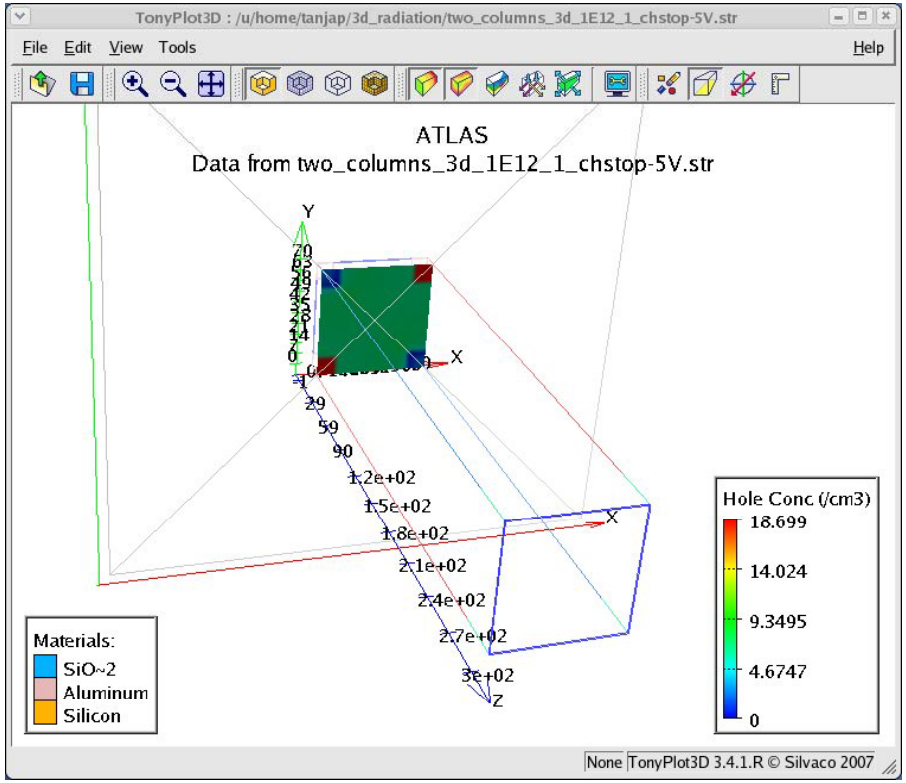




Hole concentration

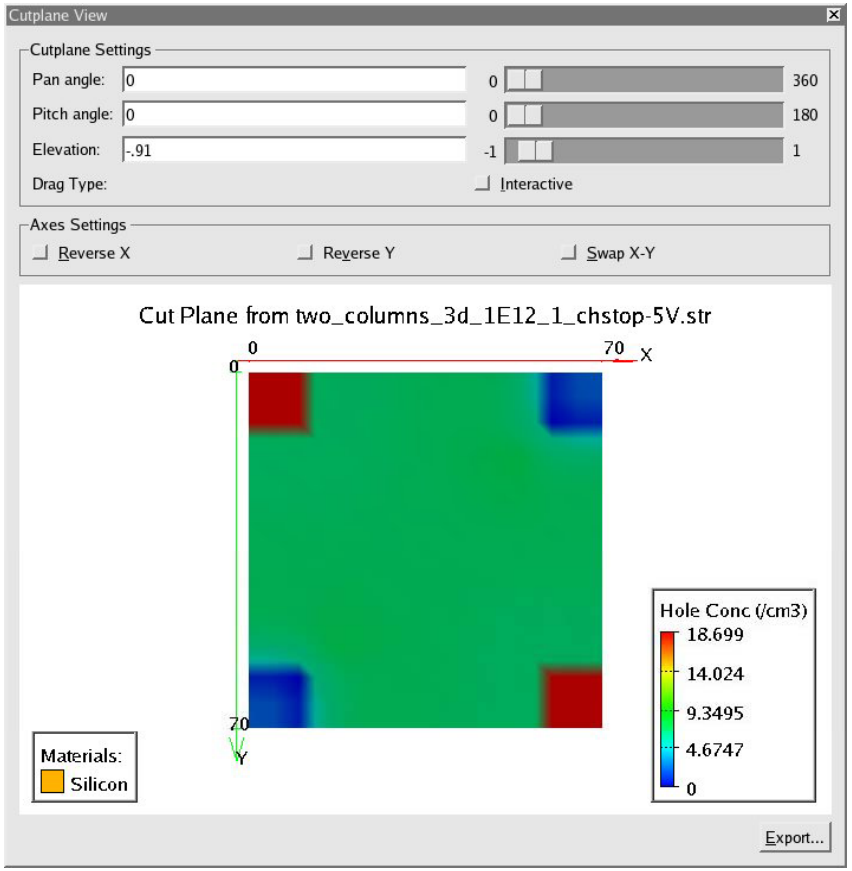
Dual column one-sided 3D detector (5V)

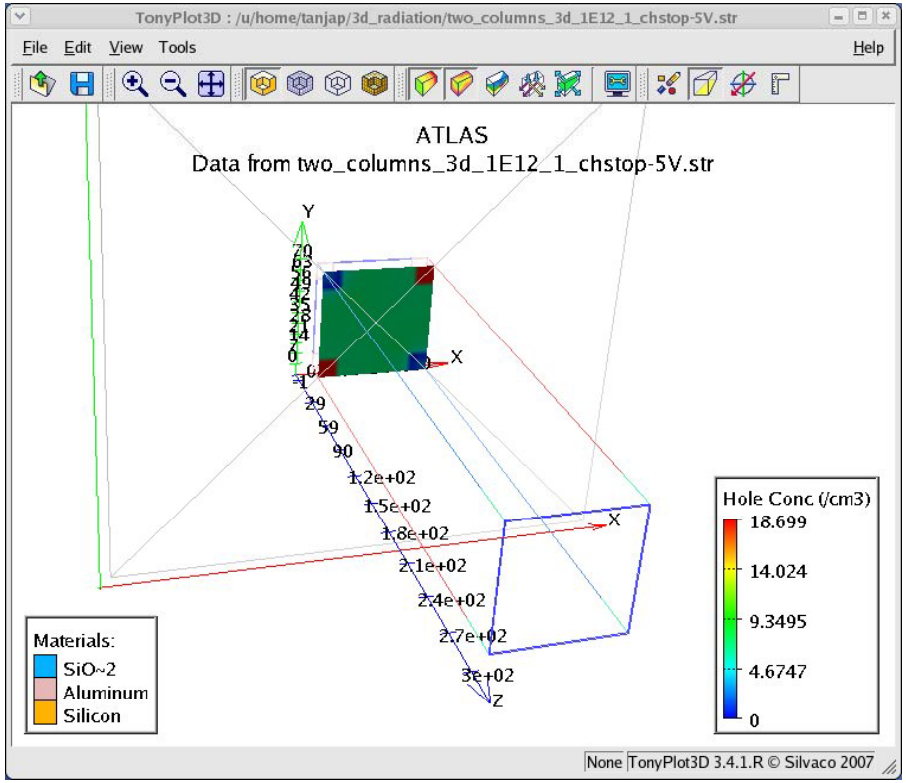




Hole concentration

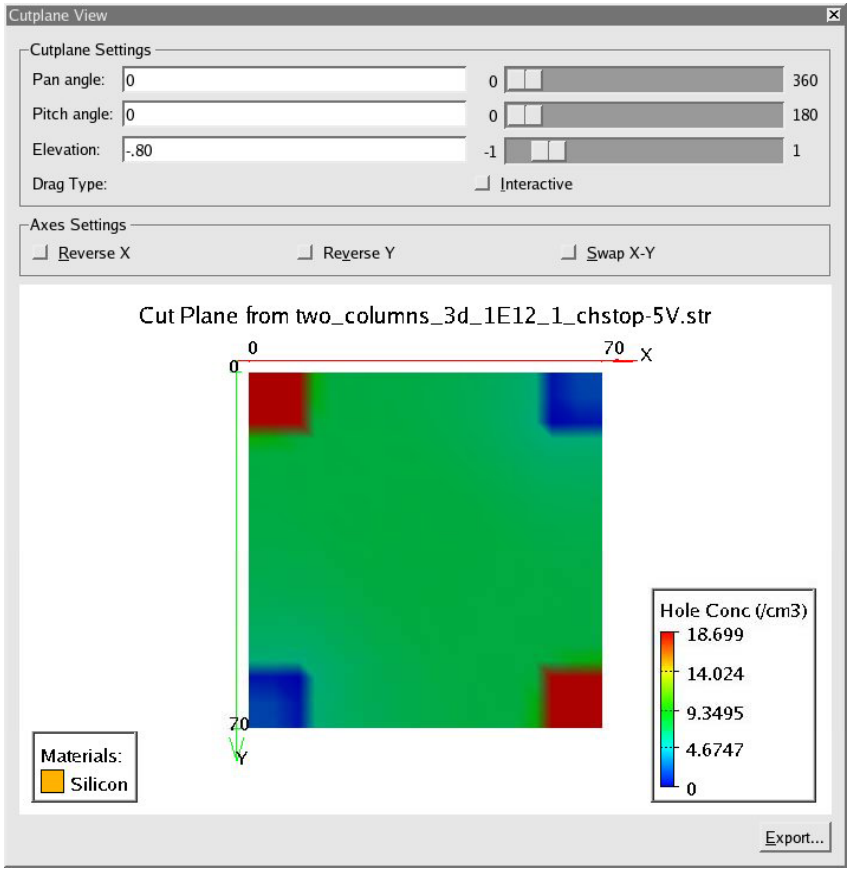
Dual column one-sided 3D detector (5V)

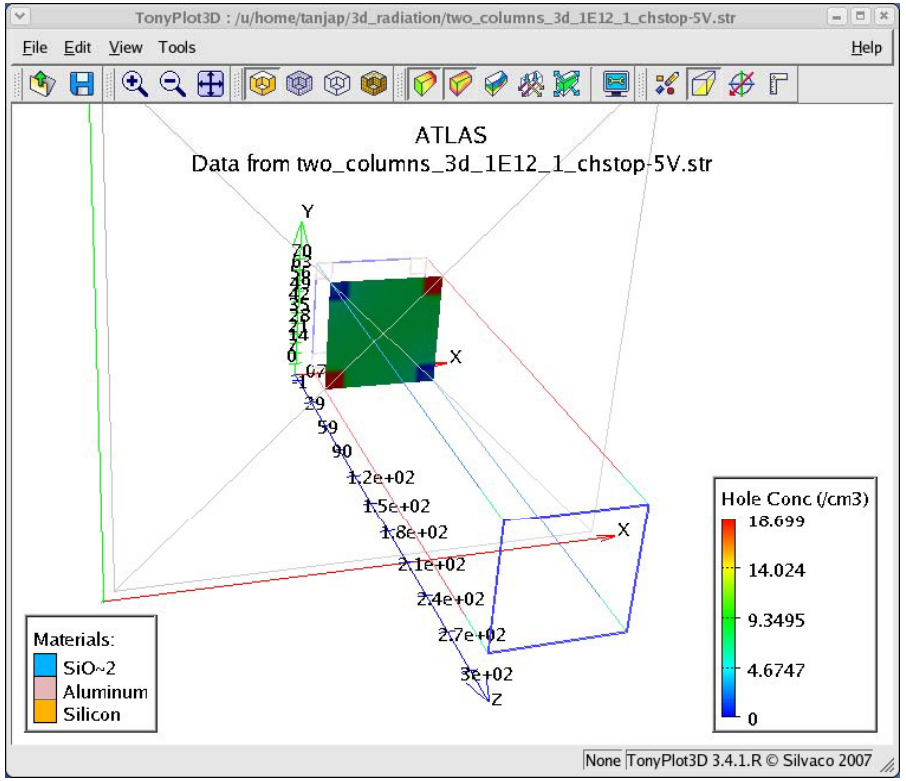




Hole concentration

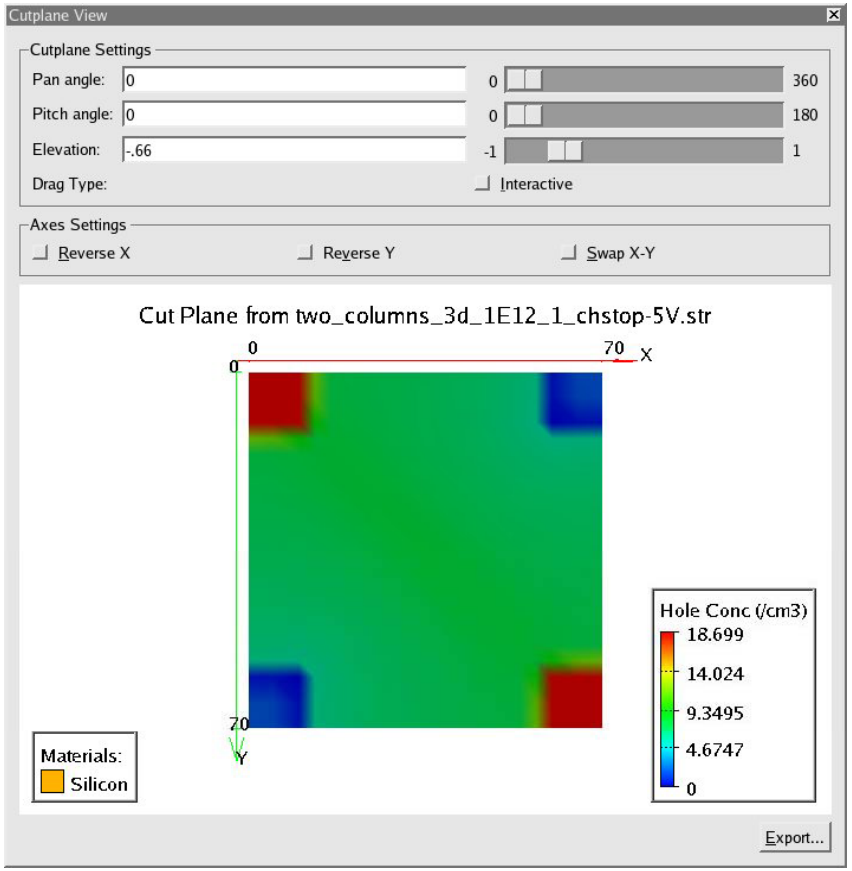
Dual column one-sided 3D detector (5V)

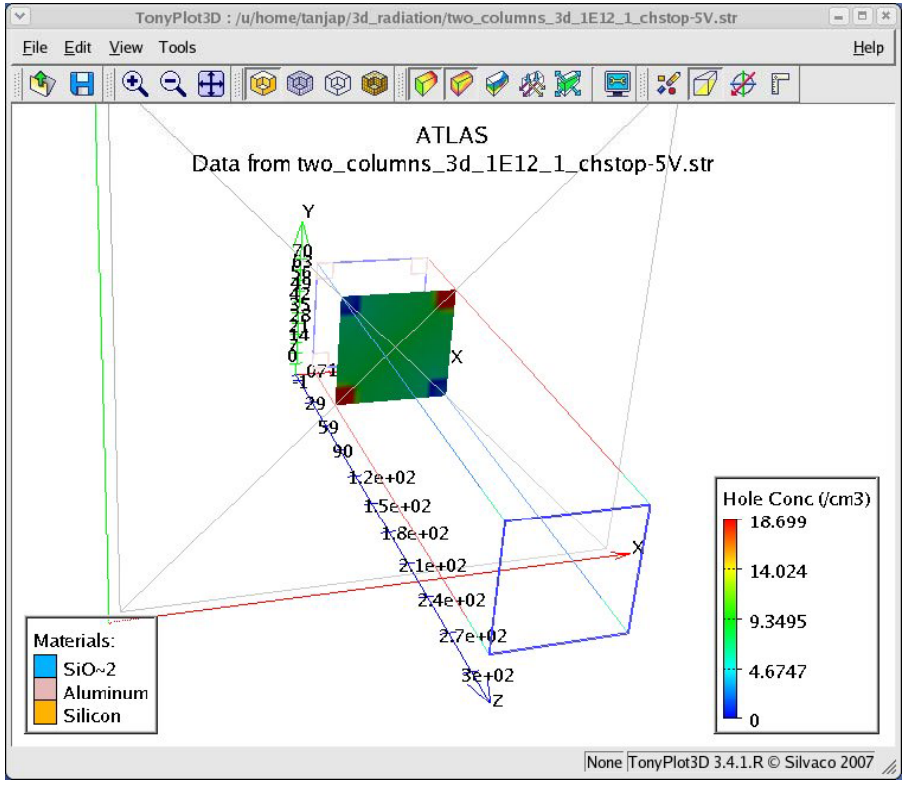




Hole concentration

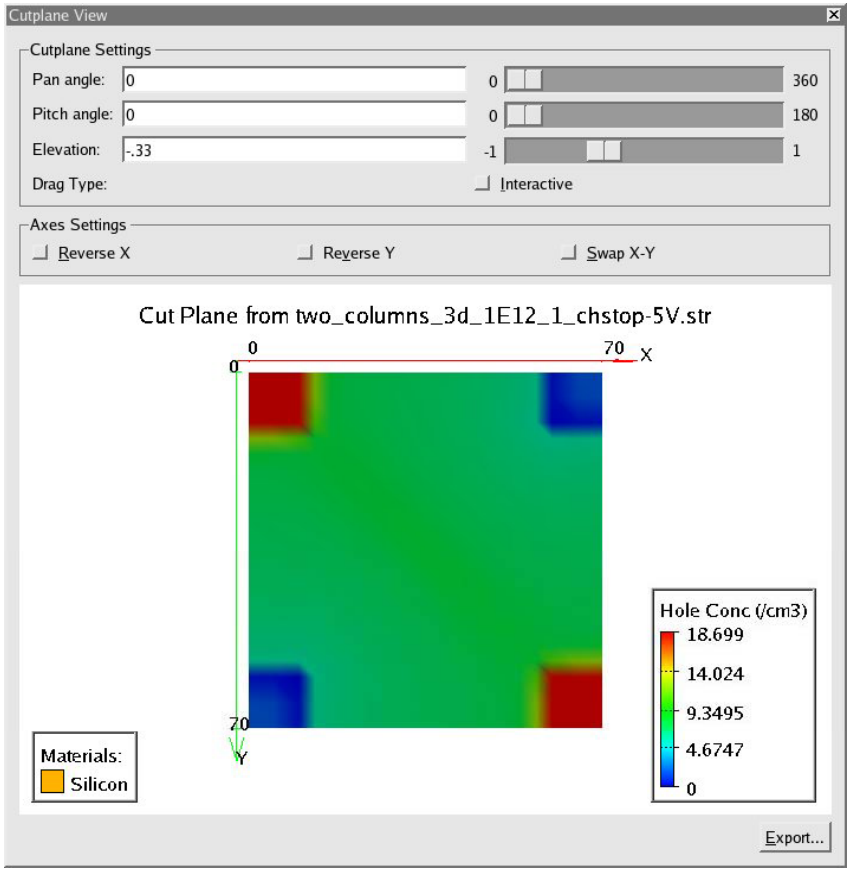
Dual column one-sided 3D detector (5V)

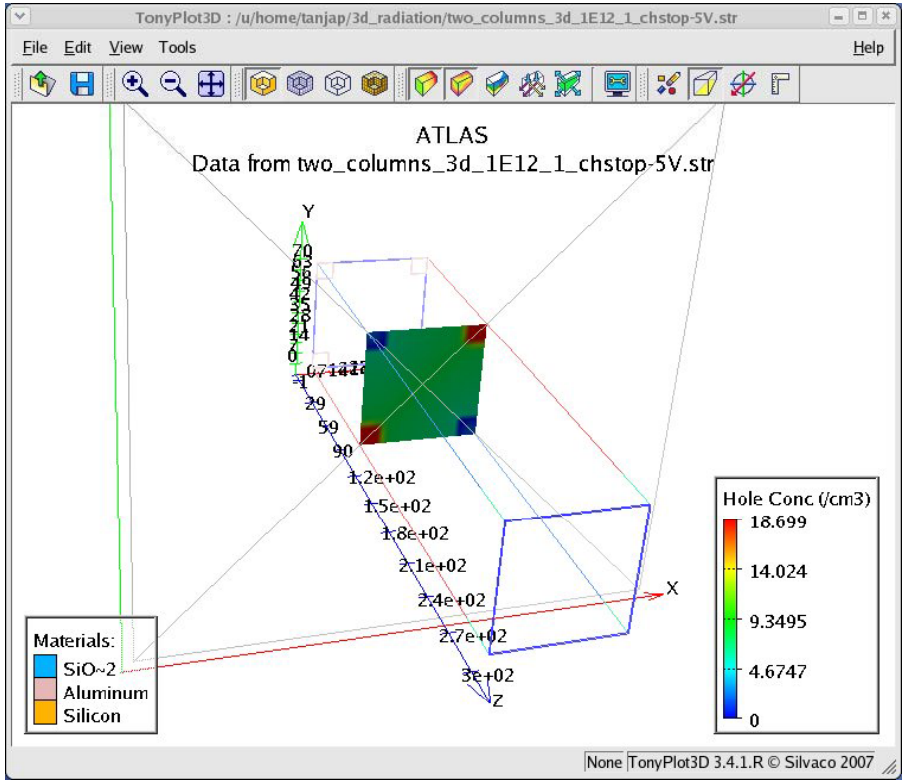




Hole concentration

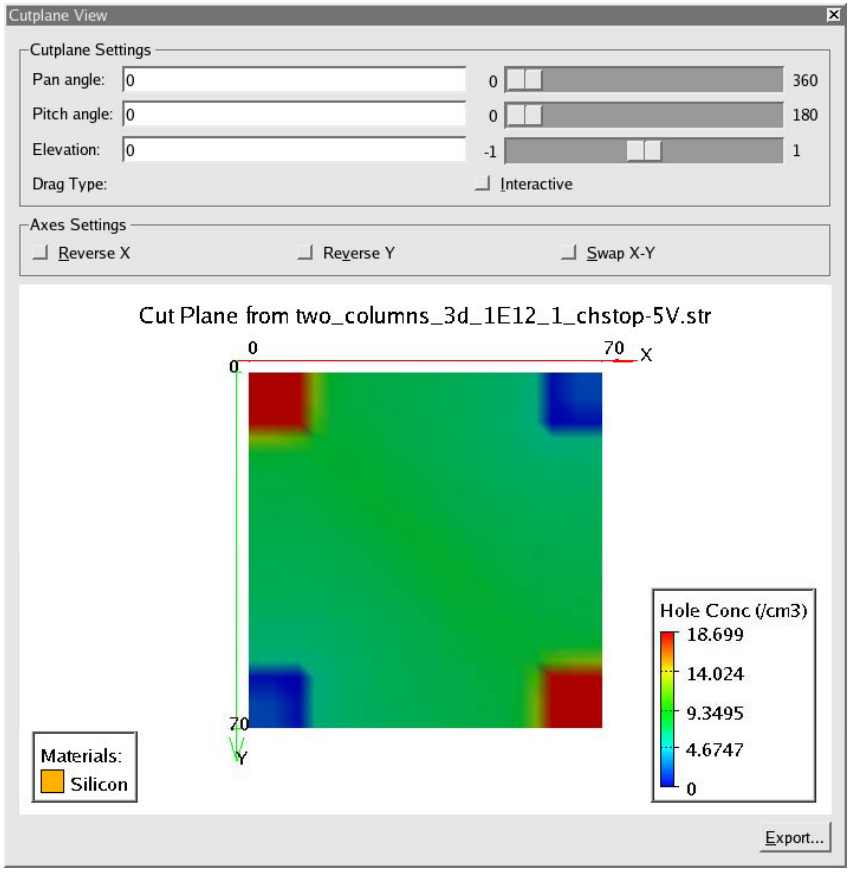
Dual column one-sided 3D detector (5V)

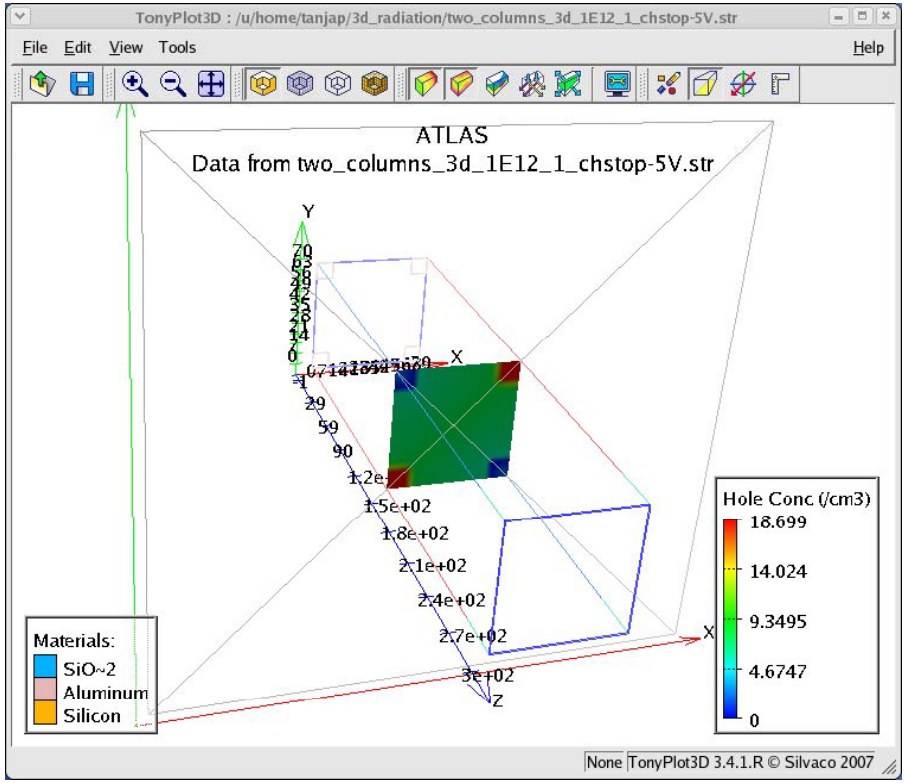




Hole concentration

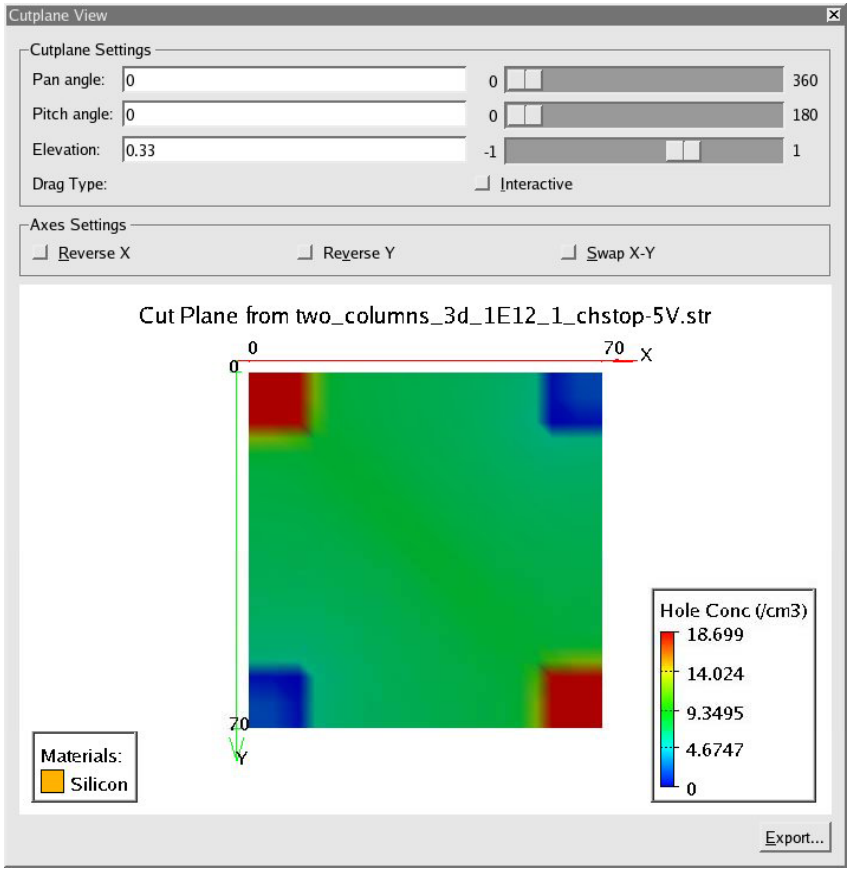
Dual column one-sided 3D detector (5V)

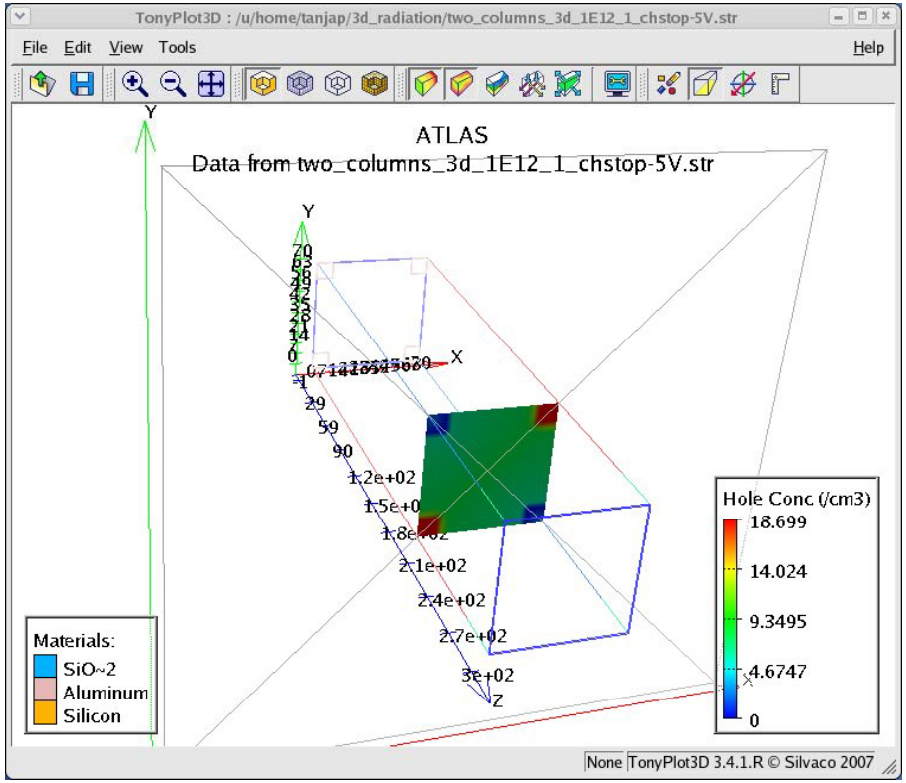




Hole concentration

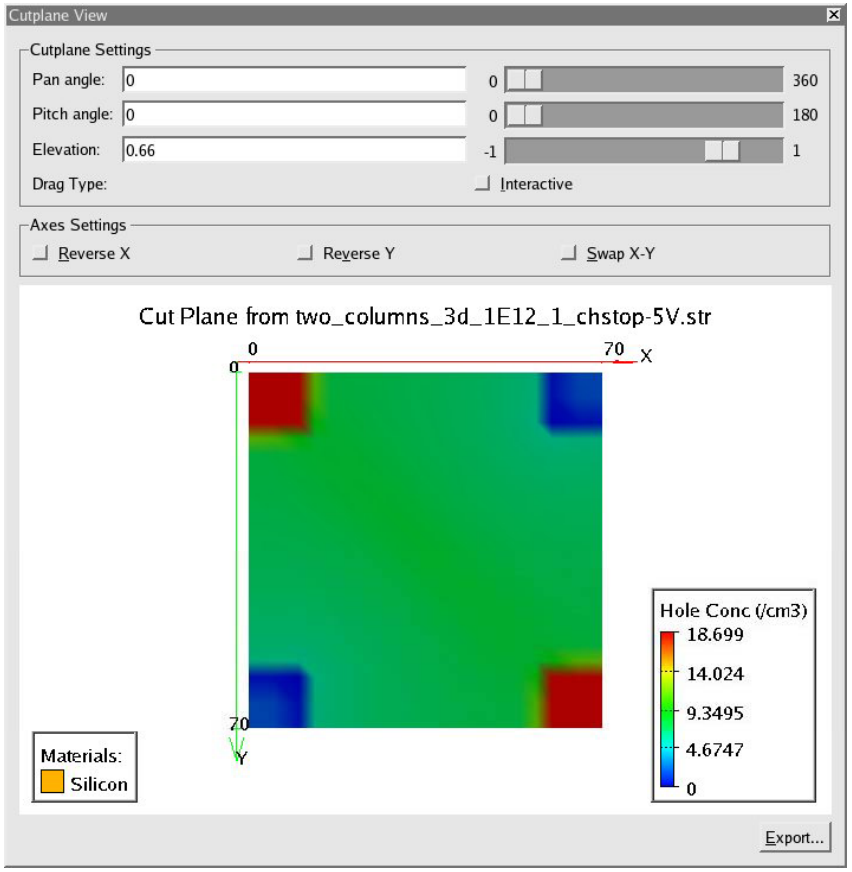
Dual column one-sided 3D detector (5V)

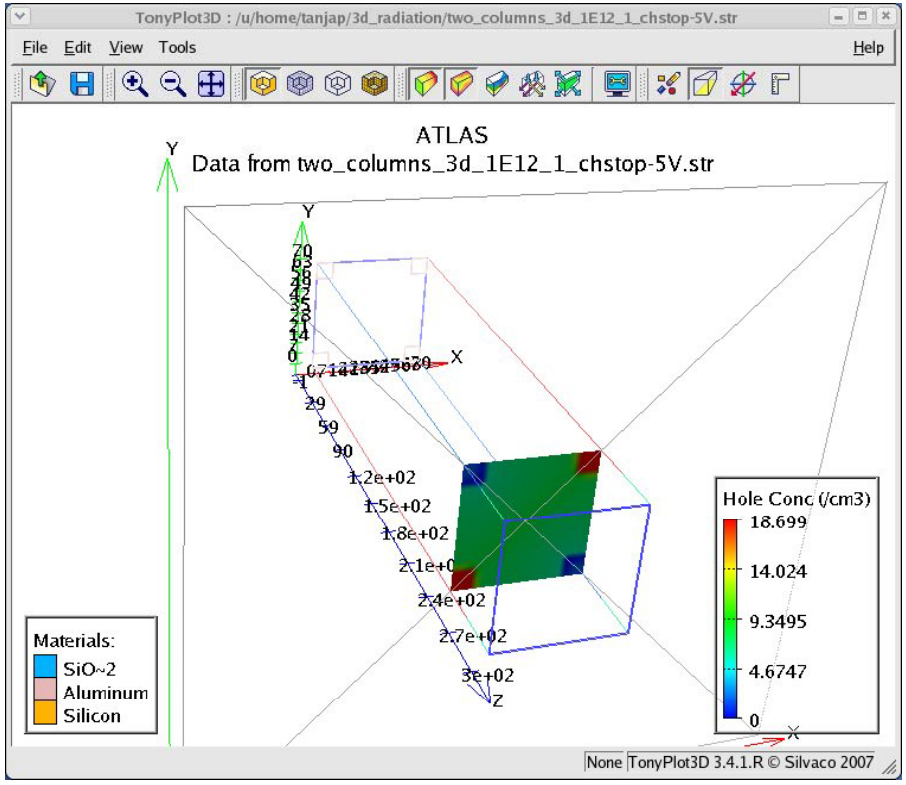




Hole concentration

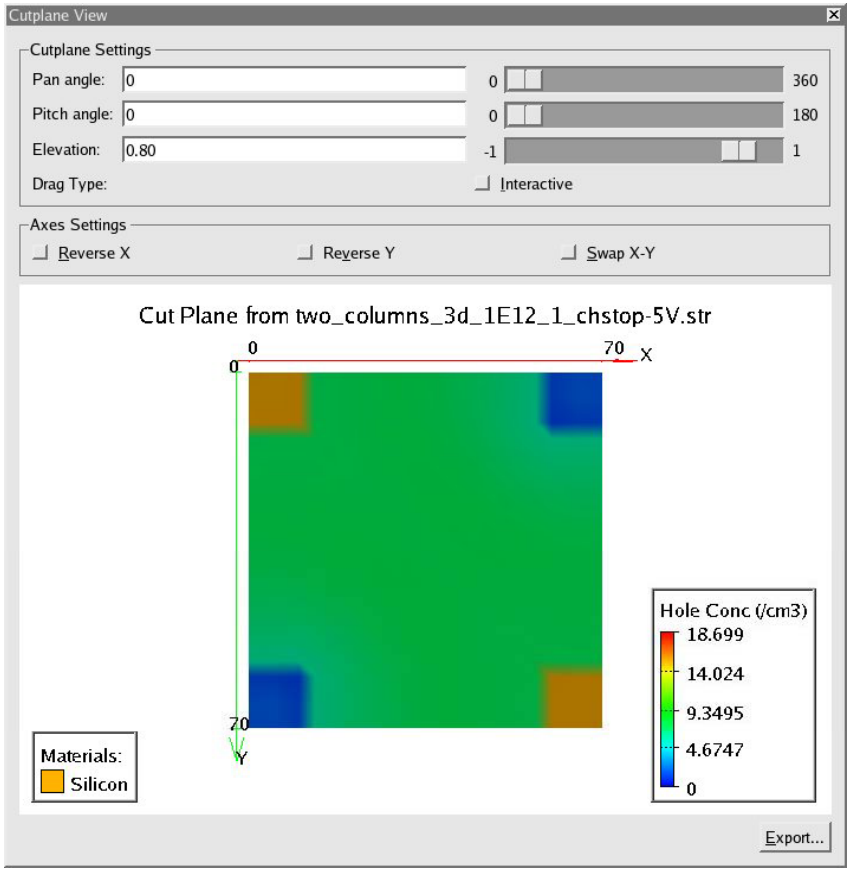
Dual column one-sided 3D detector (5V)

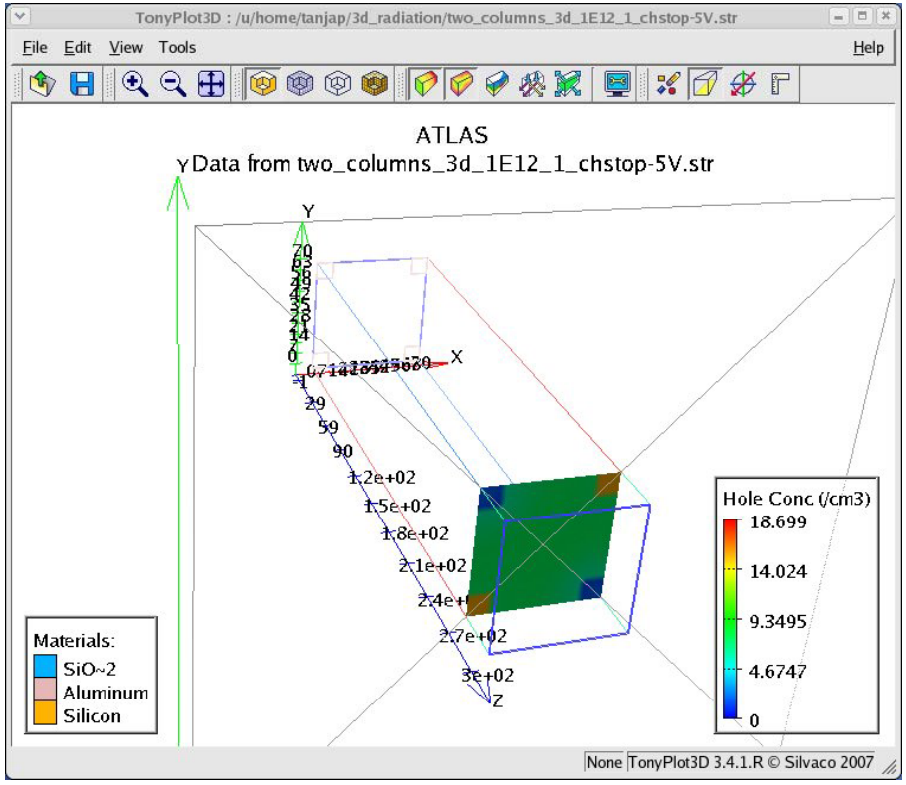




Hole concentration

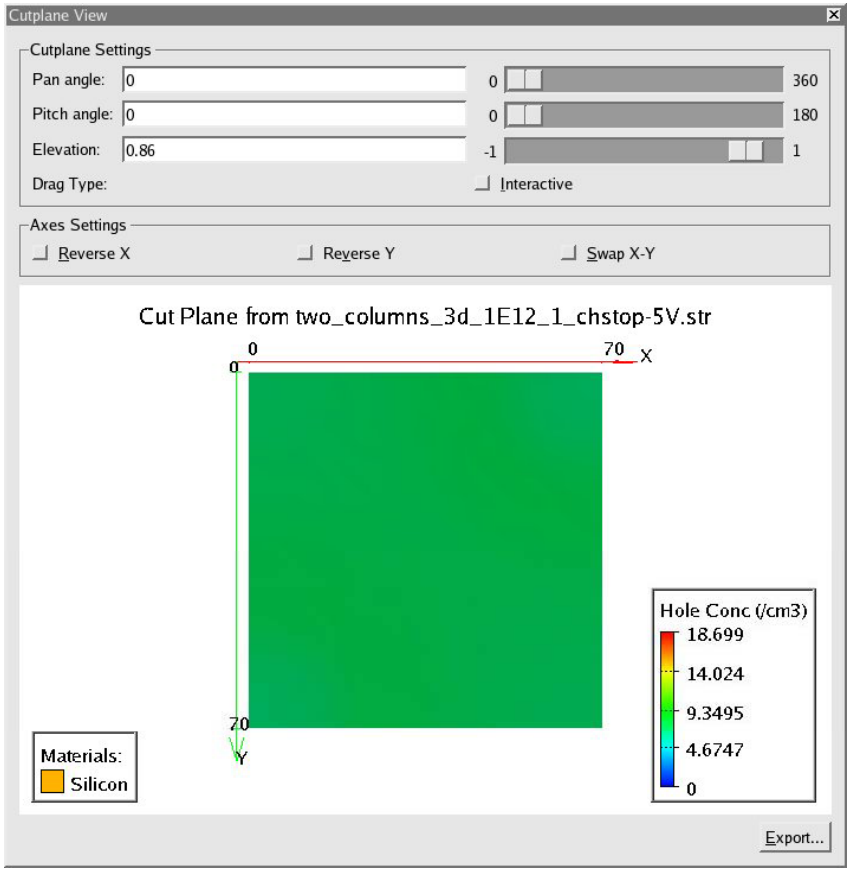
Dual column one-sided 3D detector (5V)

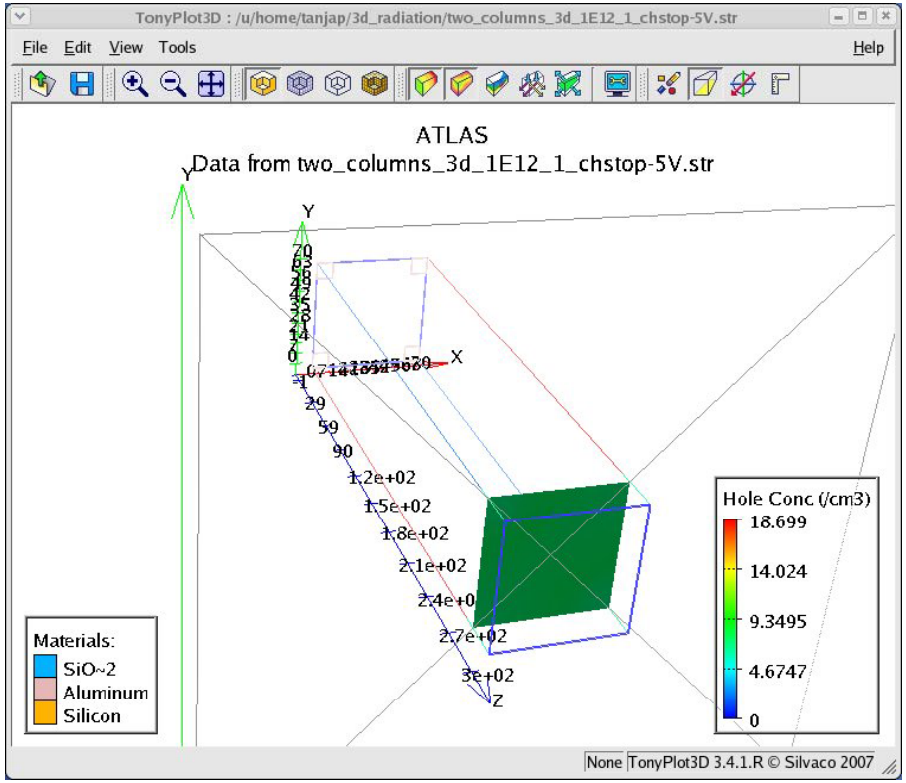




Hole concentration

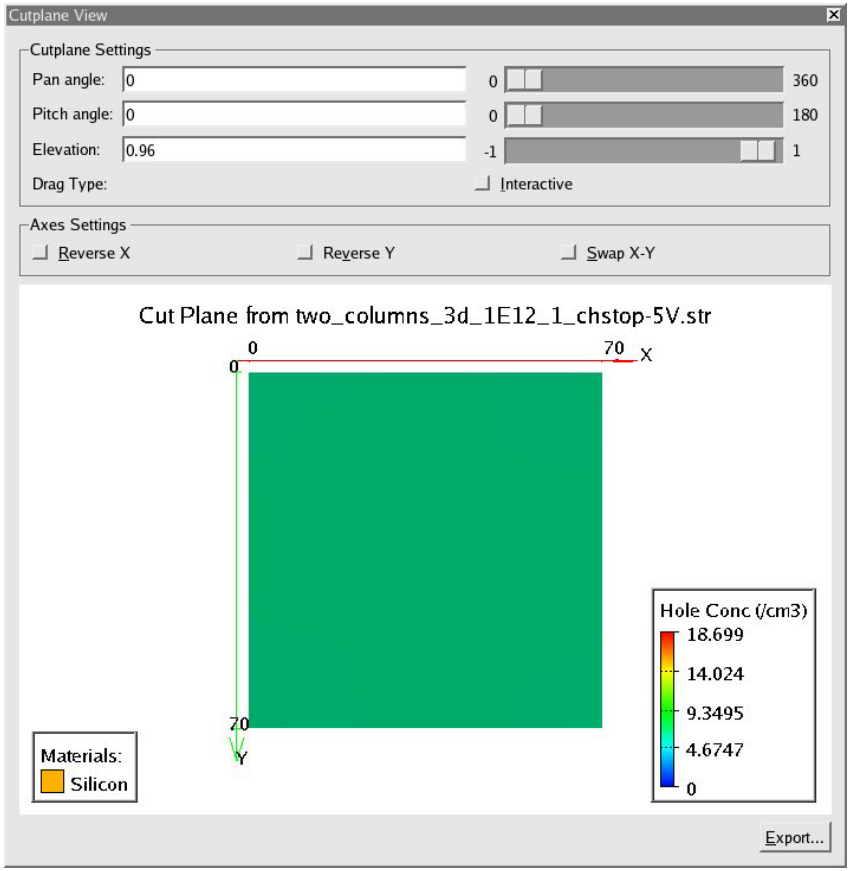
Dual column one-sided 3D detector (5V)

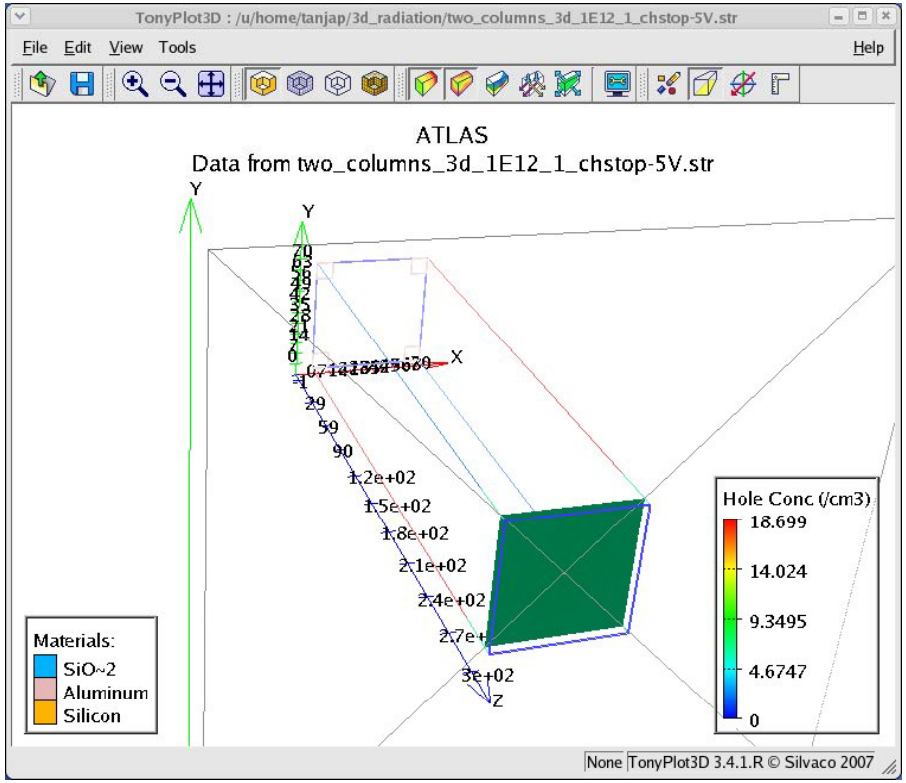




Hole concentration

Dual column one-sided 3D detector (5V)

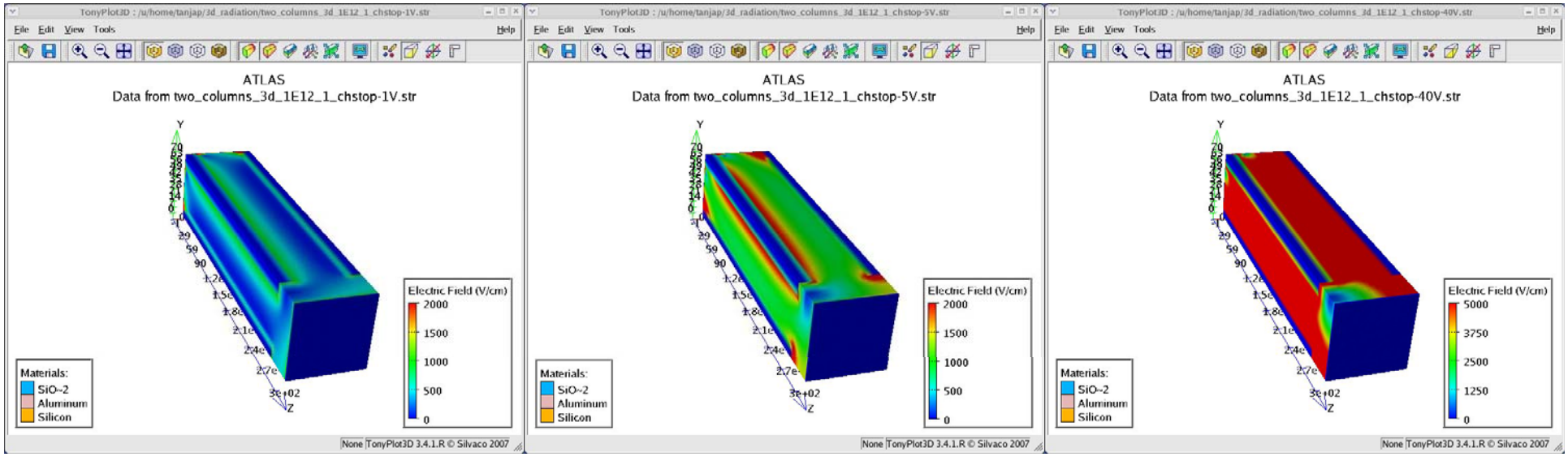




Hole concentration

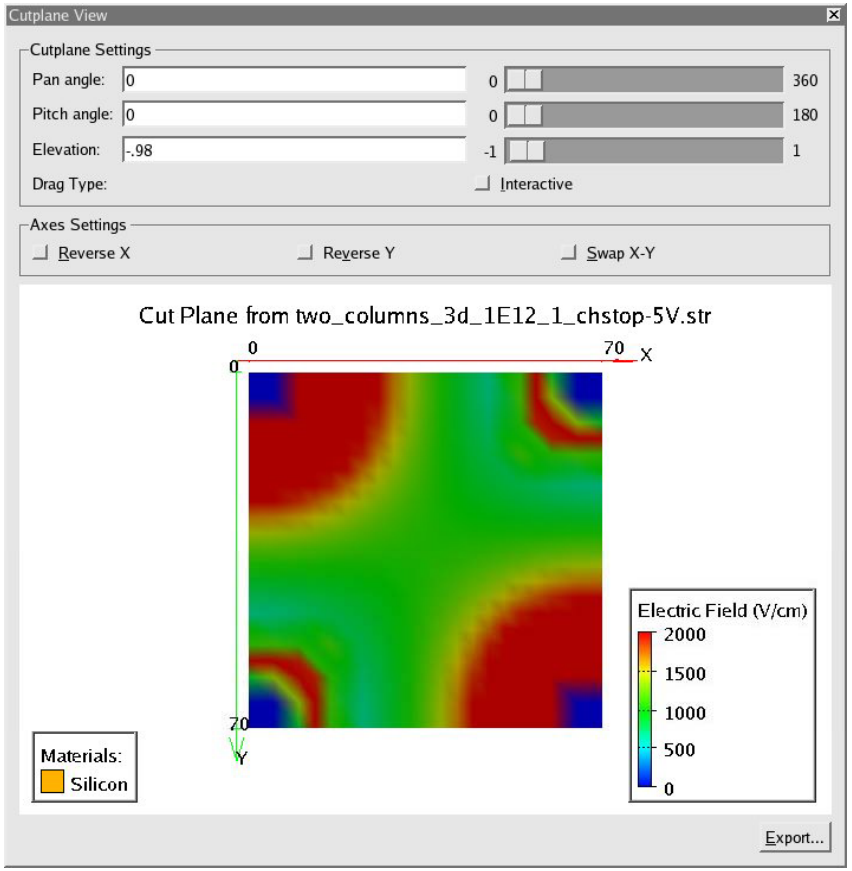
Dual column one-sided 3D detector

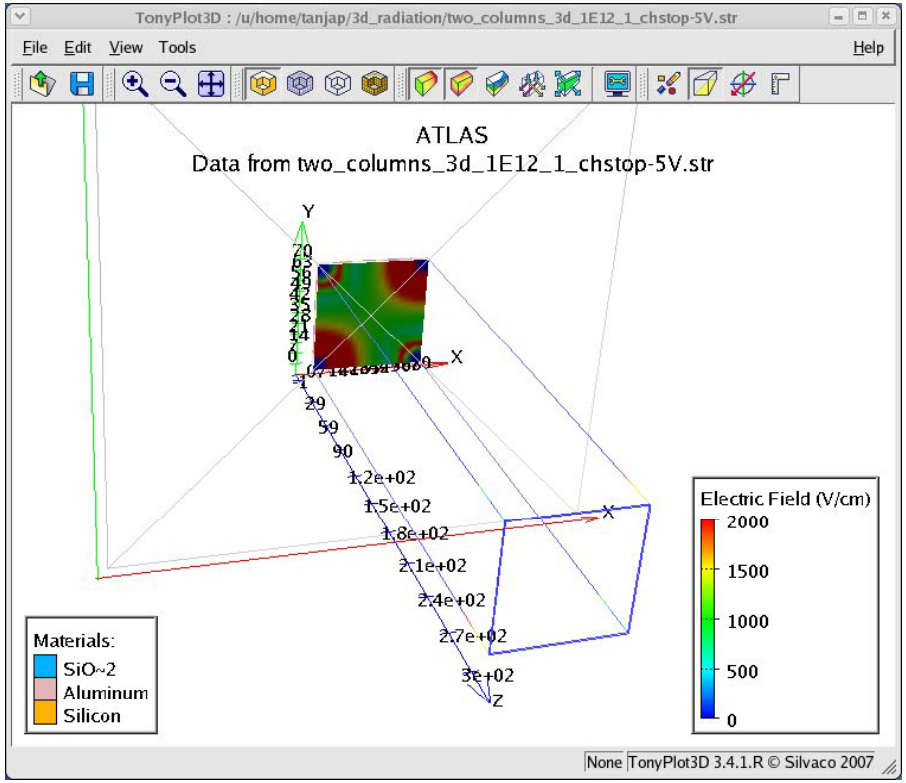
1V 5V 40V



Electric field

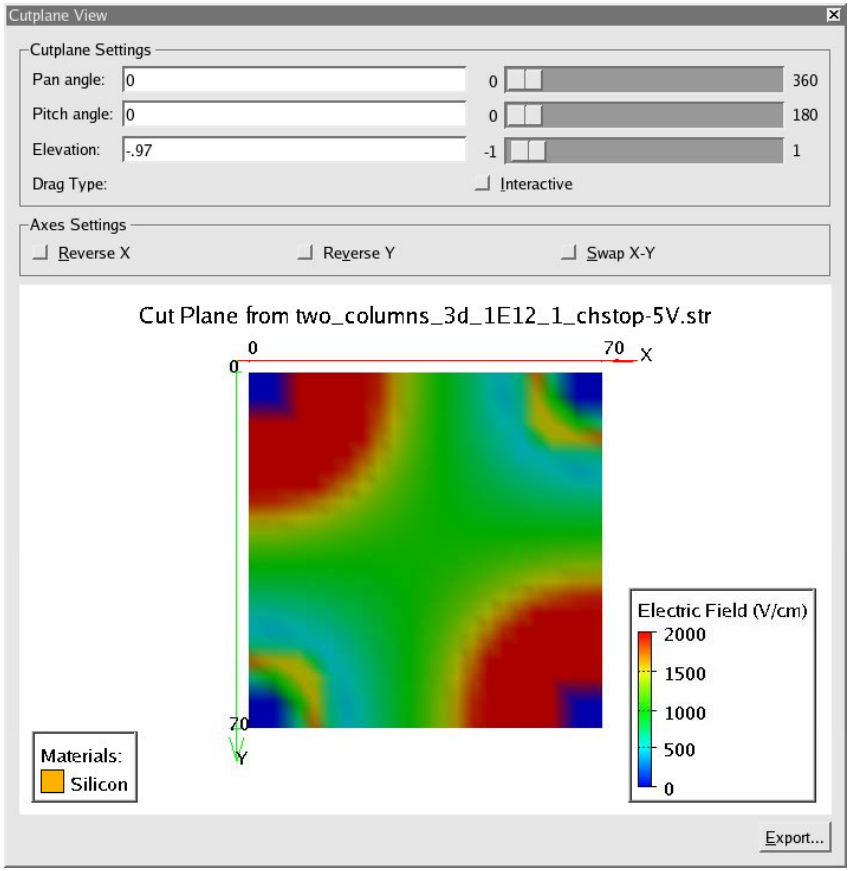
Dual column one-sided 3D detector (5V)

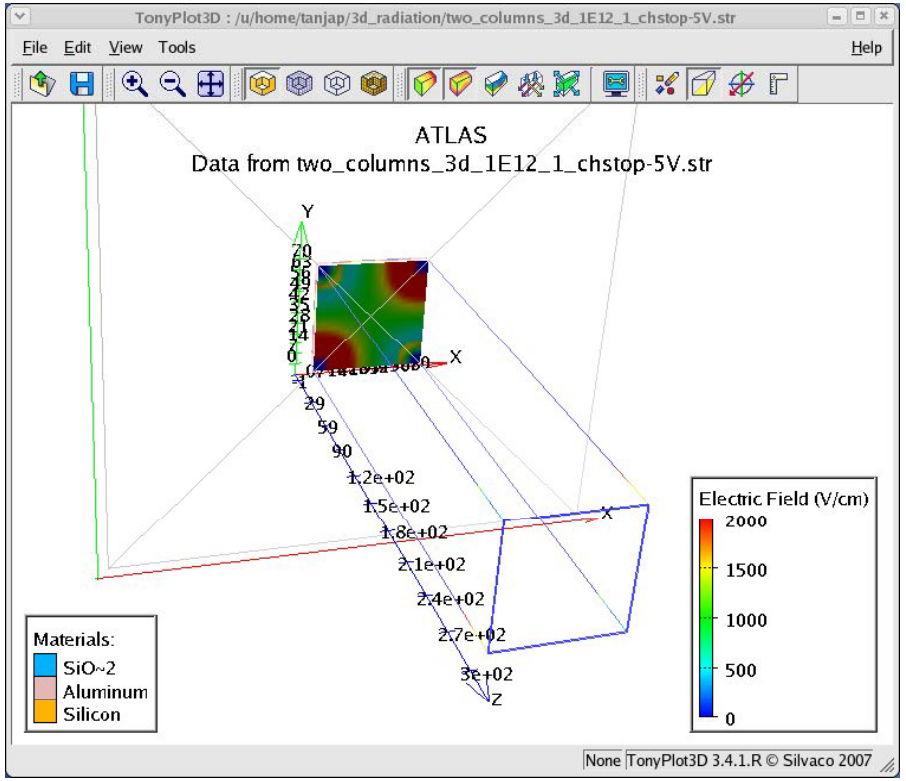




Electric field

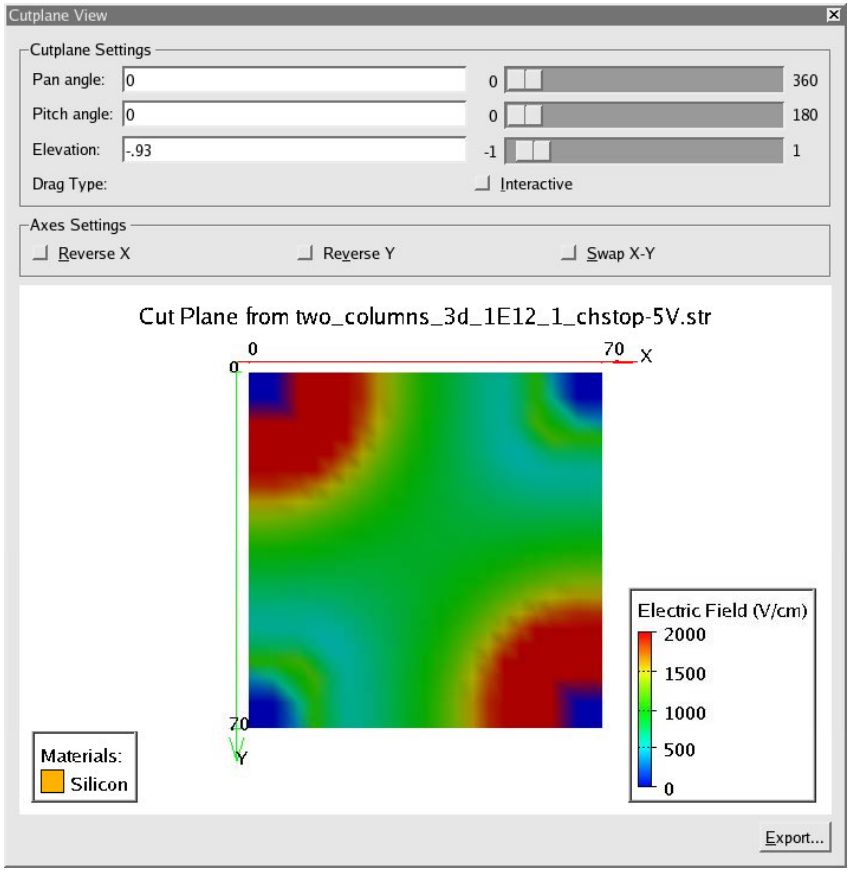
Dual column one-sided 3D detector (5V)

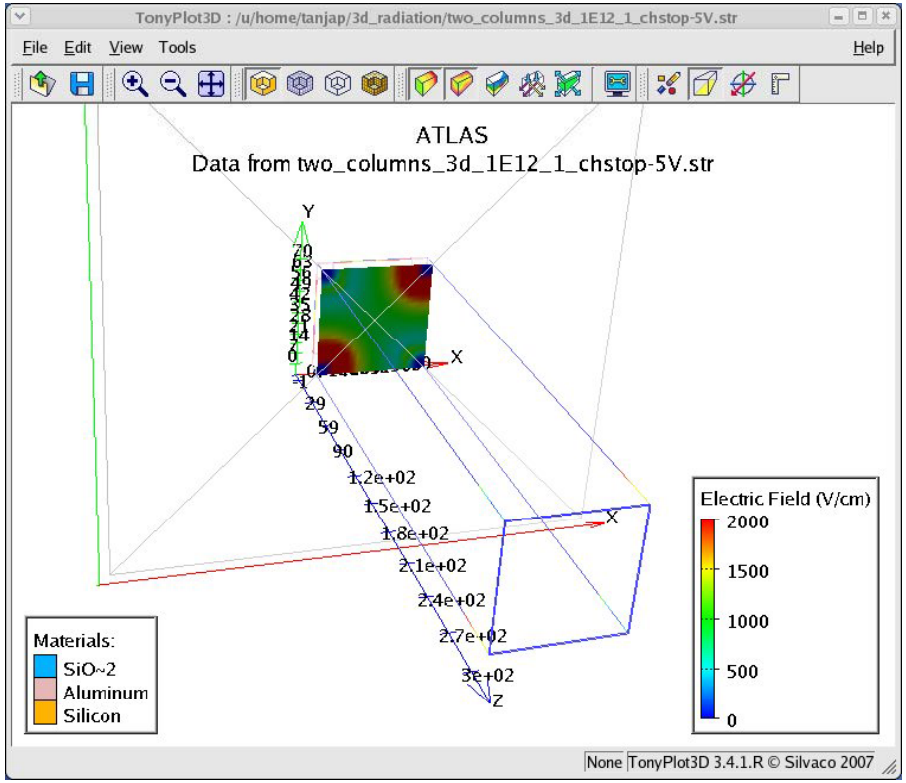




Electric field

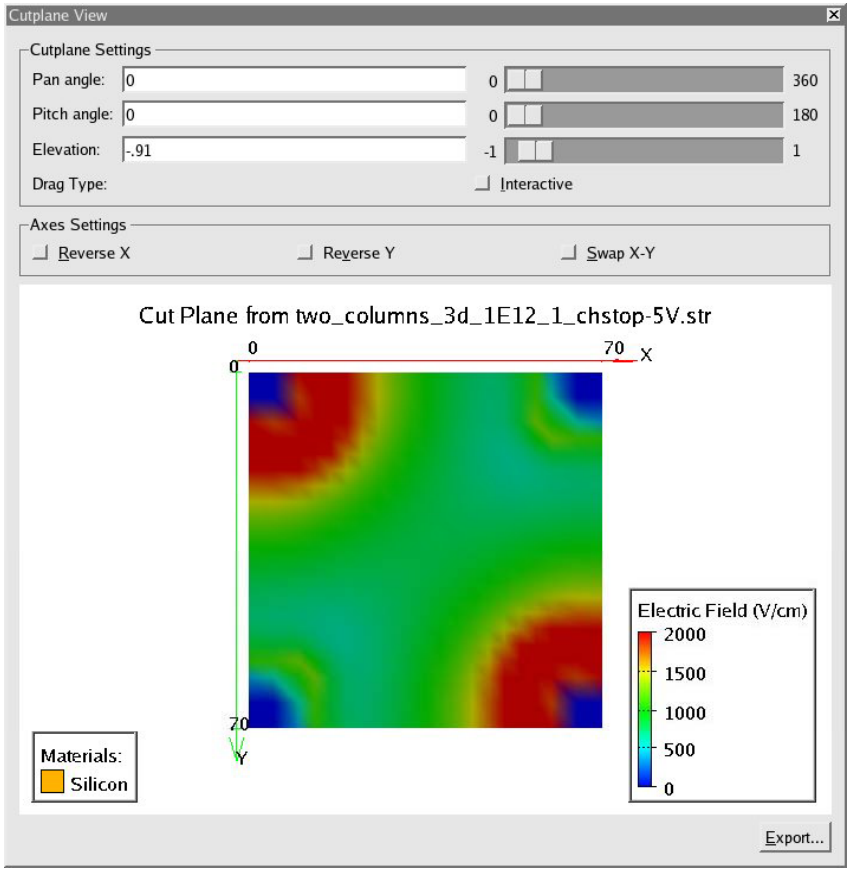
Dual column one-sided 3D detector (5V)

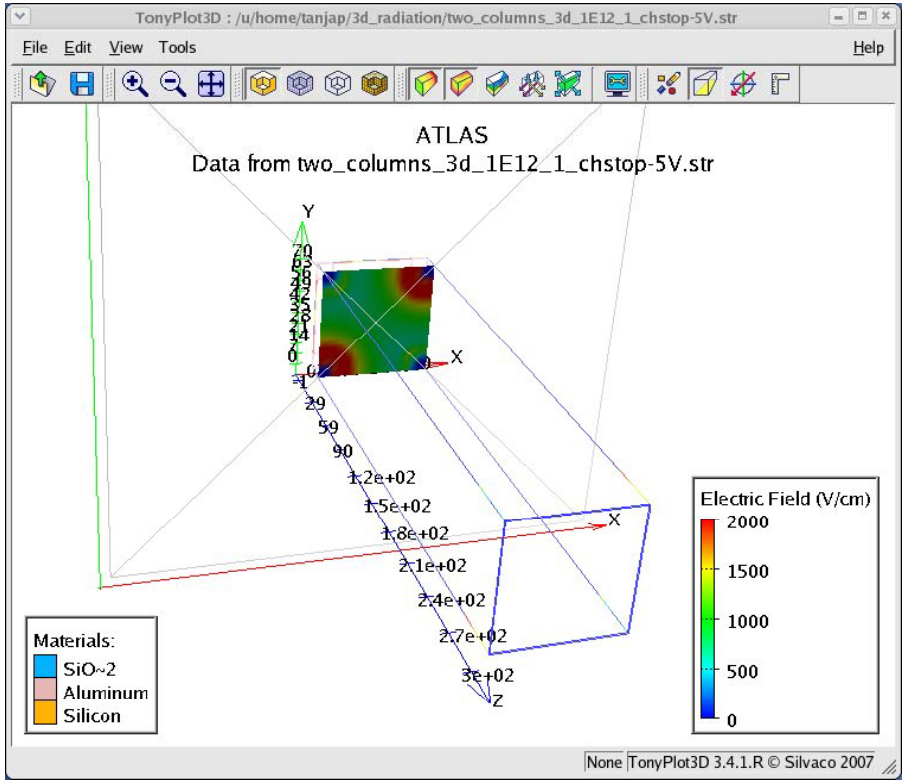




Electric field

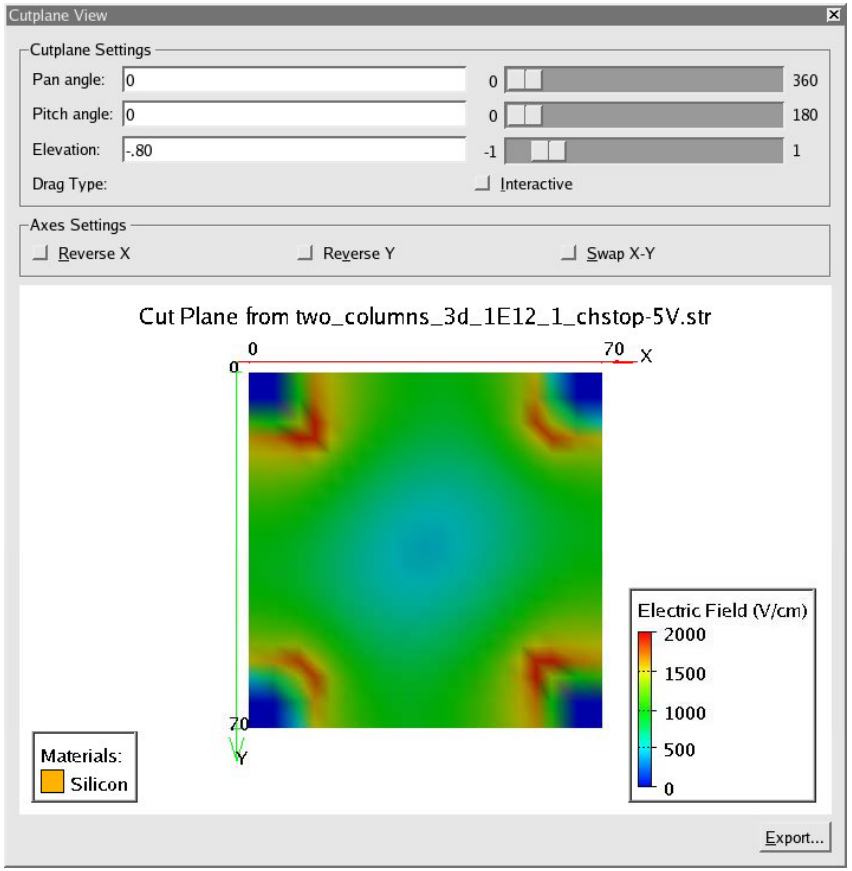
Dual column one-sided 3D detector (5V)

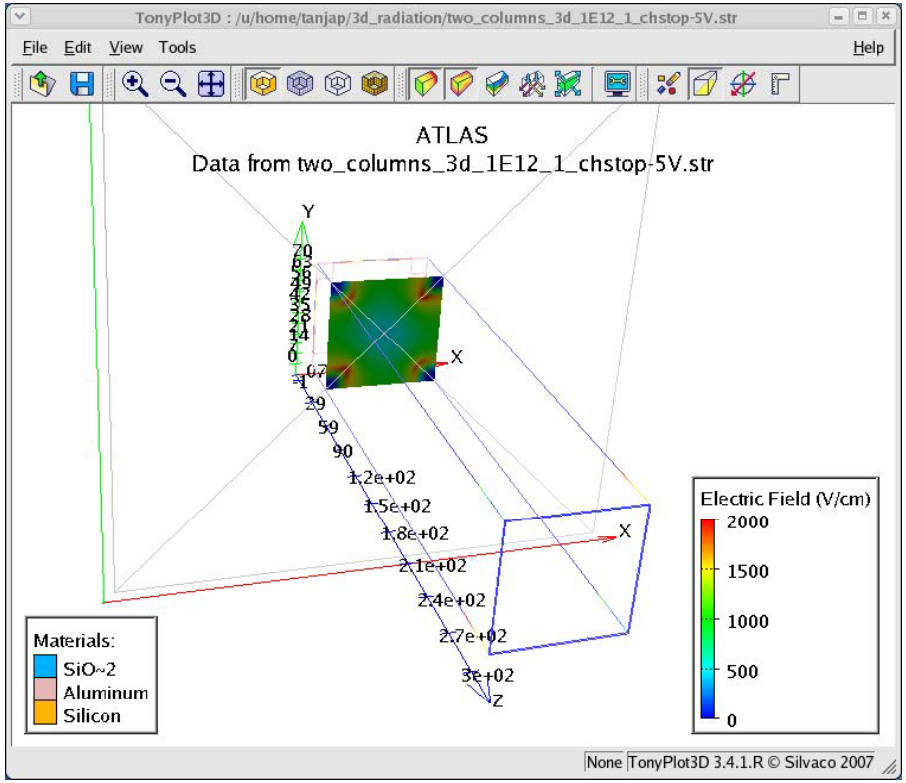




Electric field

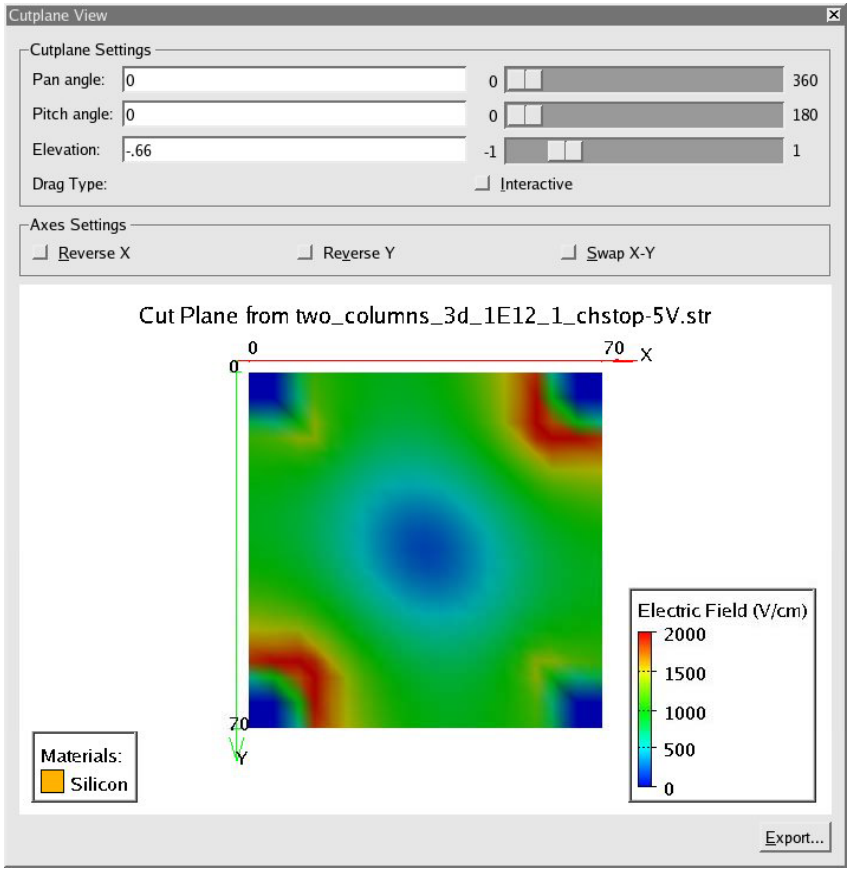
Dual column one-sided 3D detector (5V)

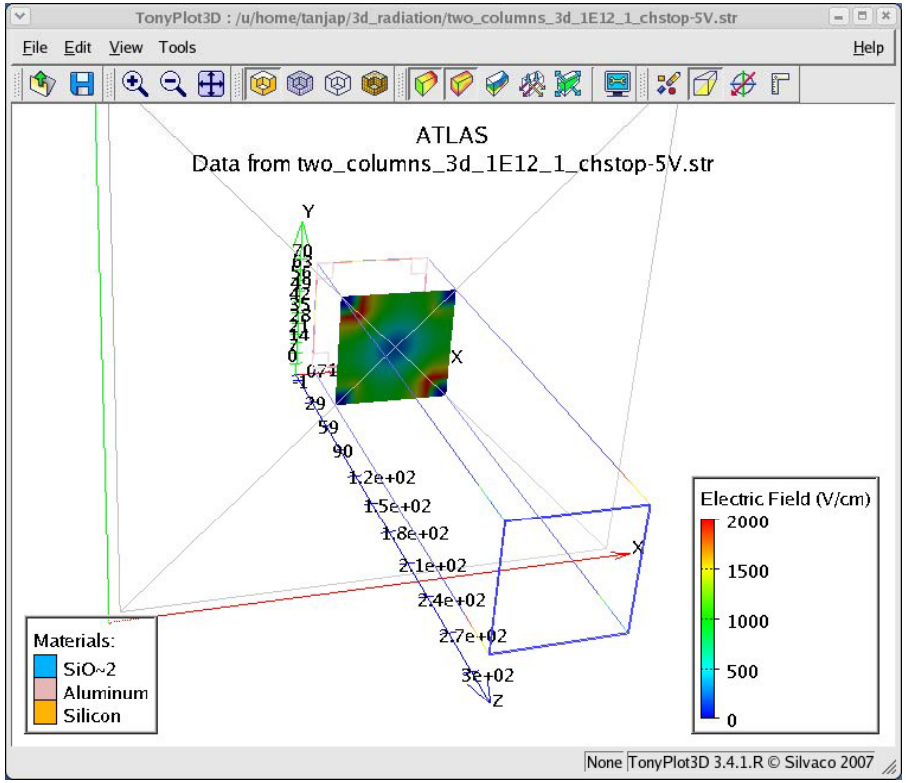




Electric field

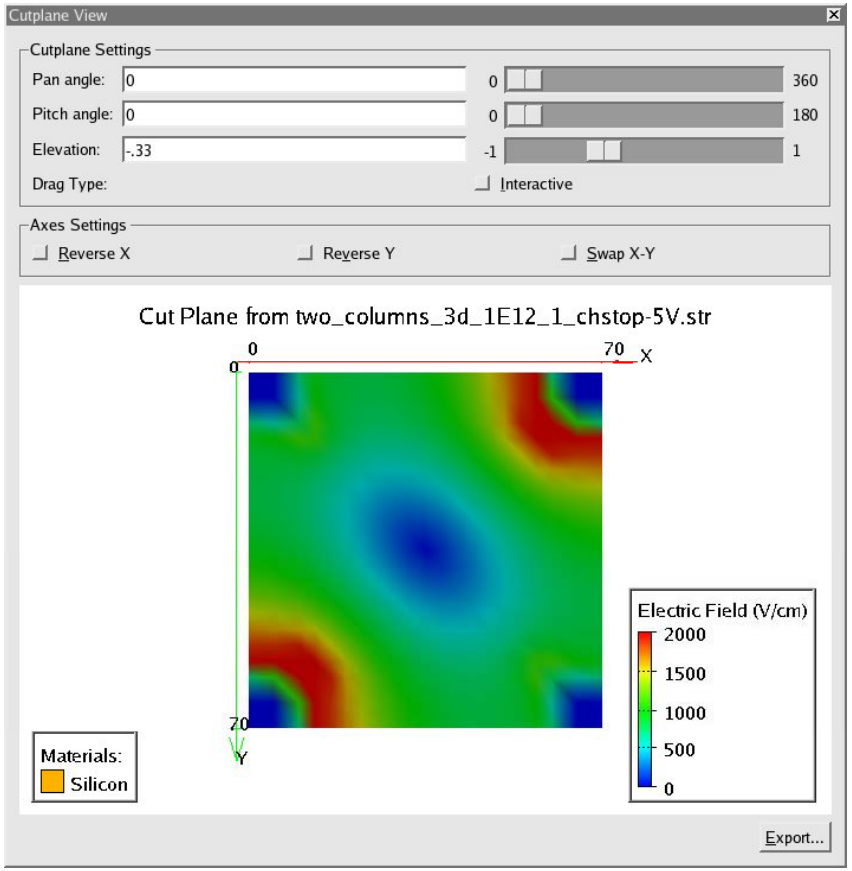
Dual column one-sided 3D detector (5V)

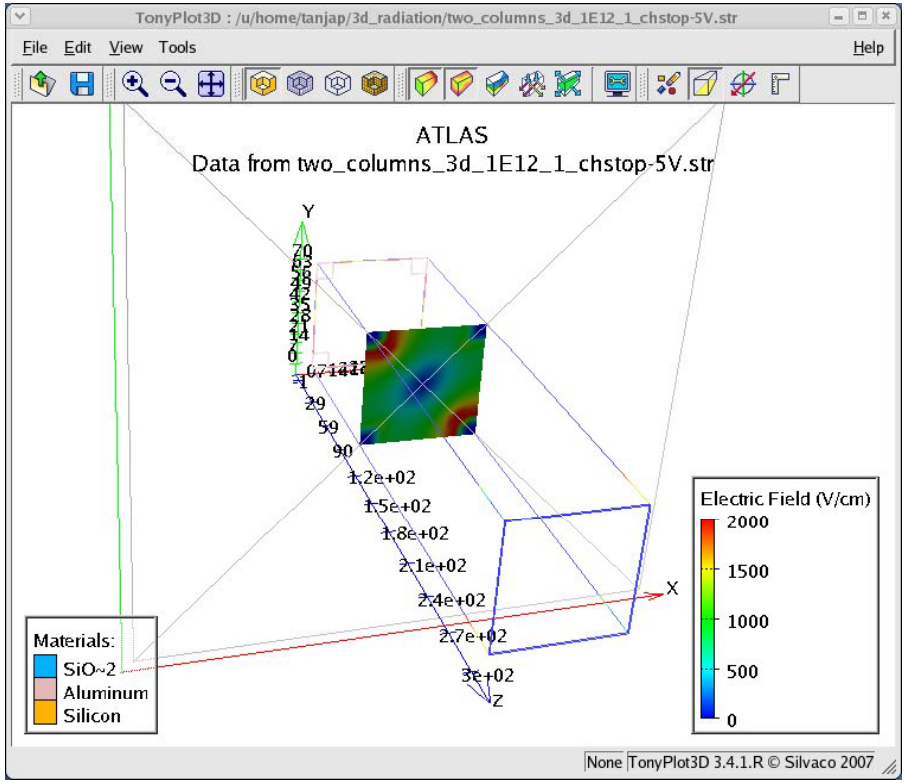




Electric field

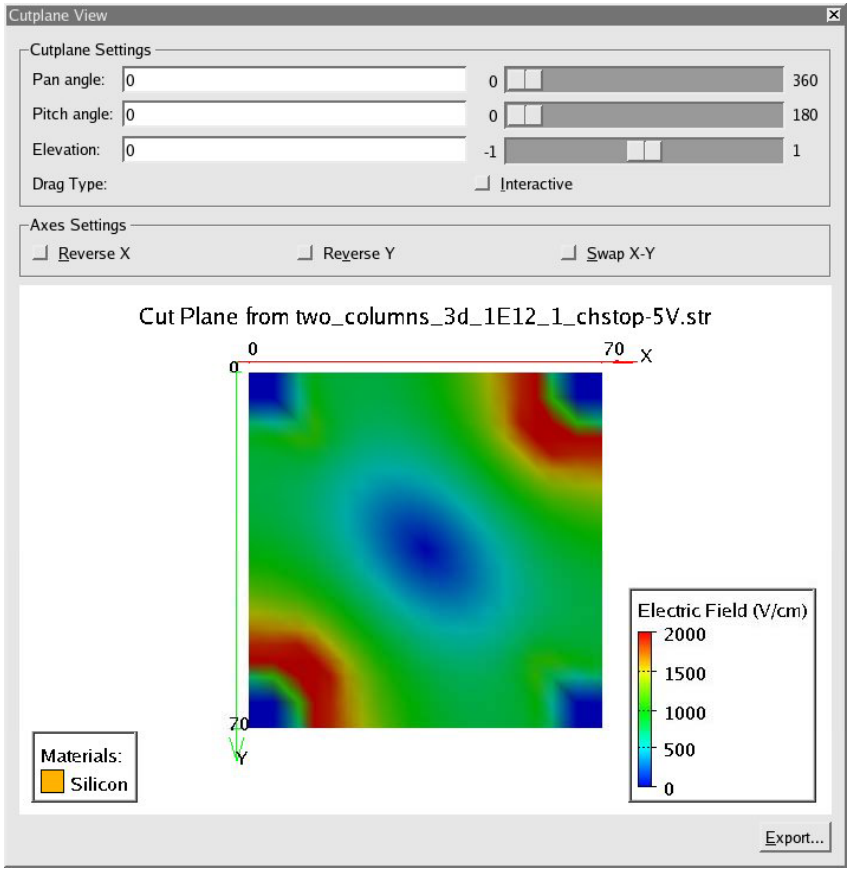
Dual column one-sided 3D detector (5V)

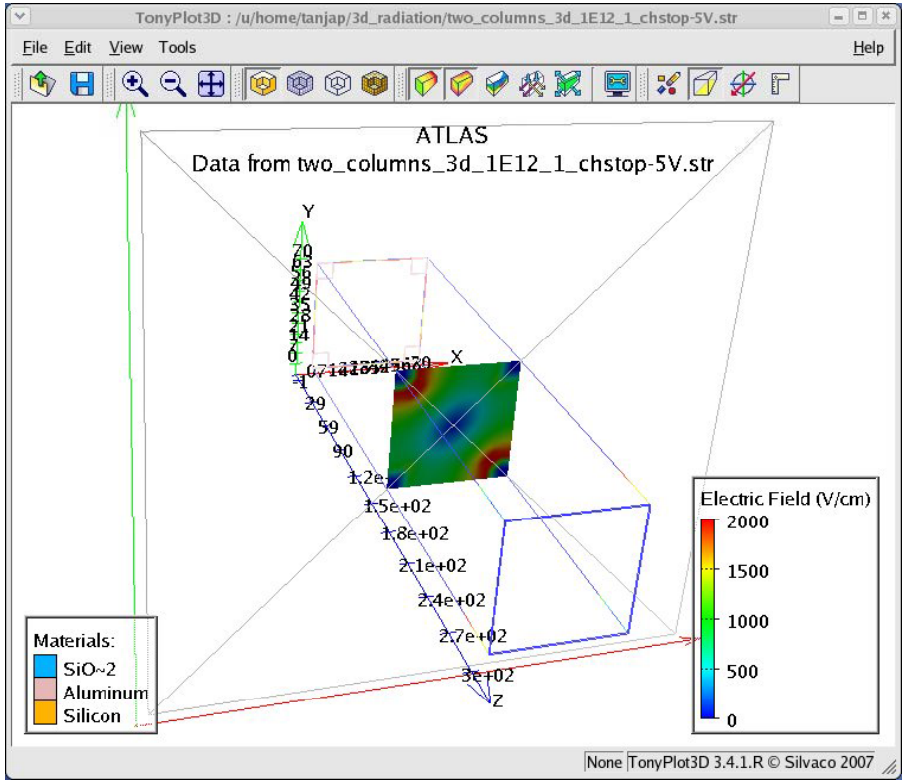




Electric field

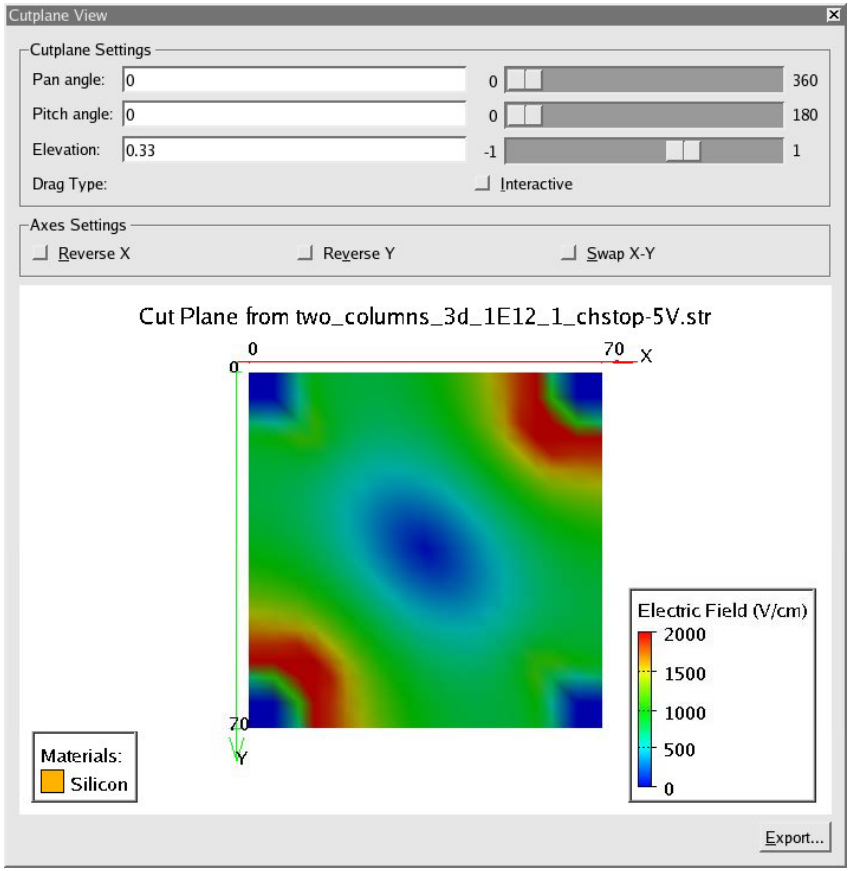
Dual column one-sided 3D detector (5V)

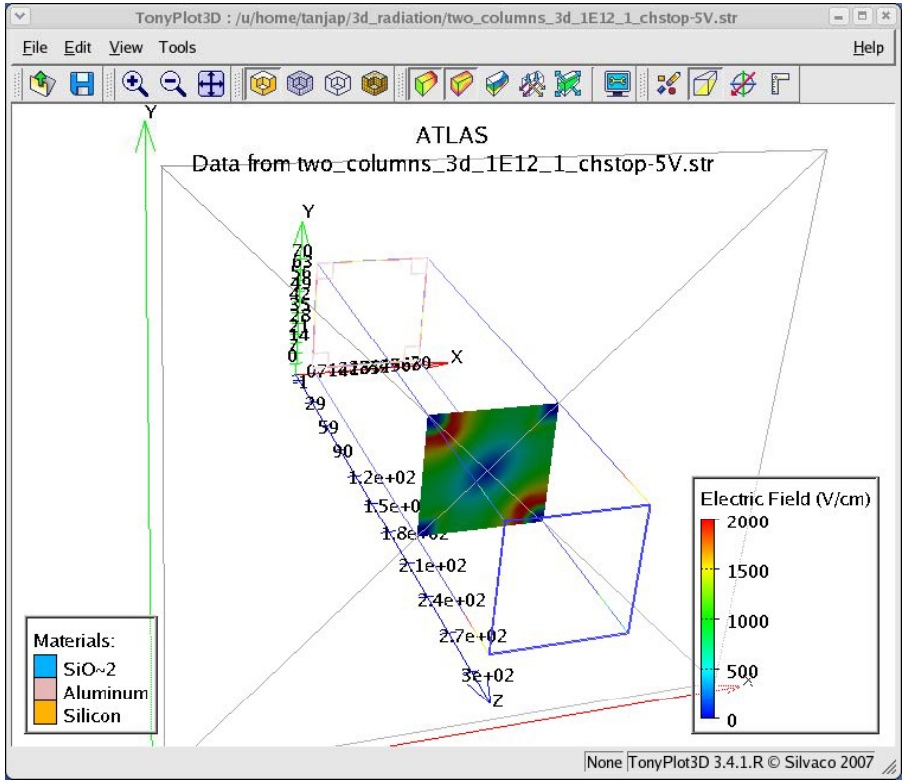




Electric field

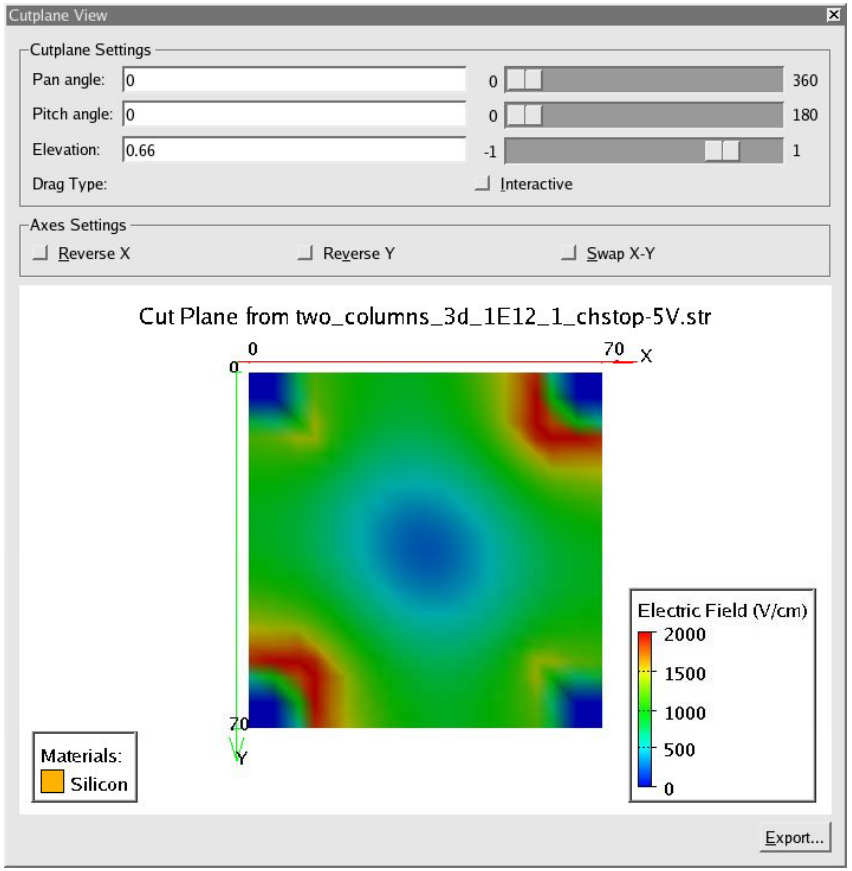
Dual column one-sided 3D detector (5V)

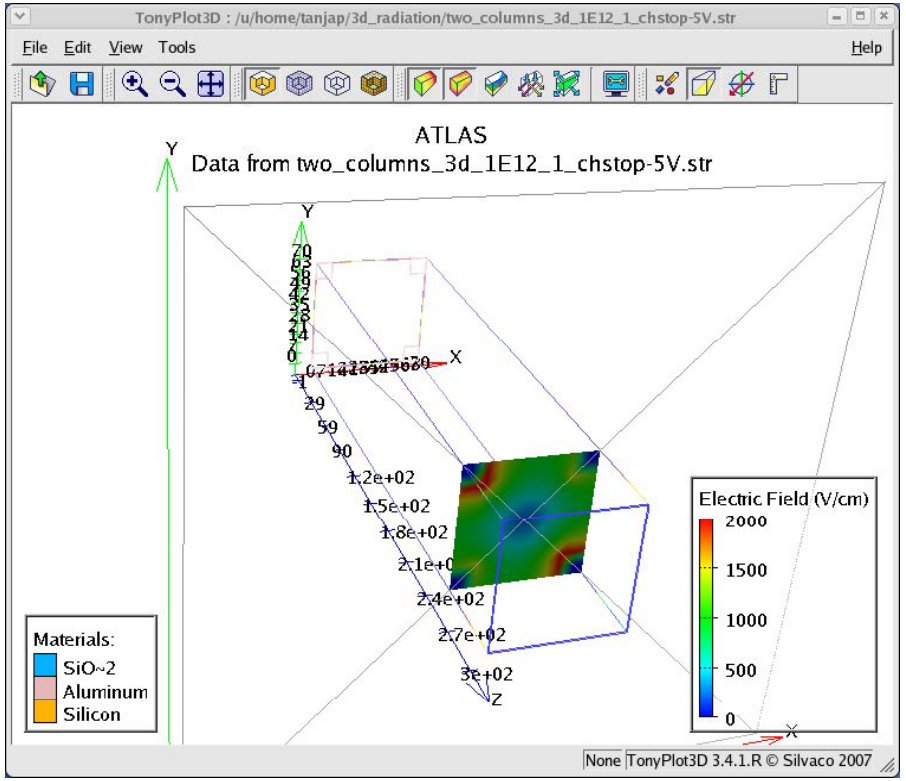




Electric field

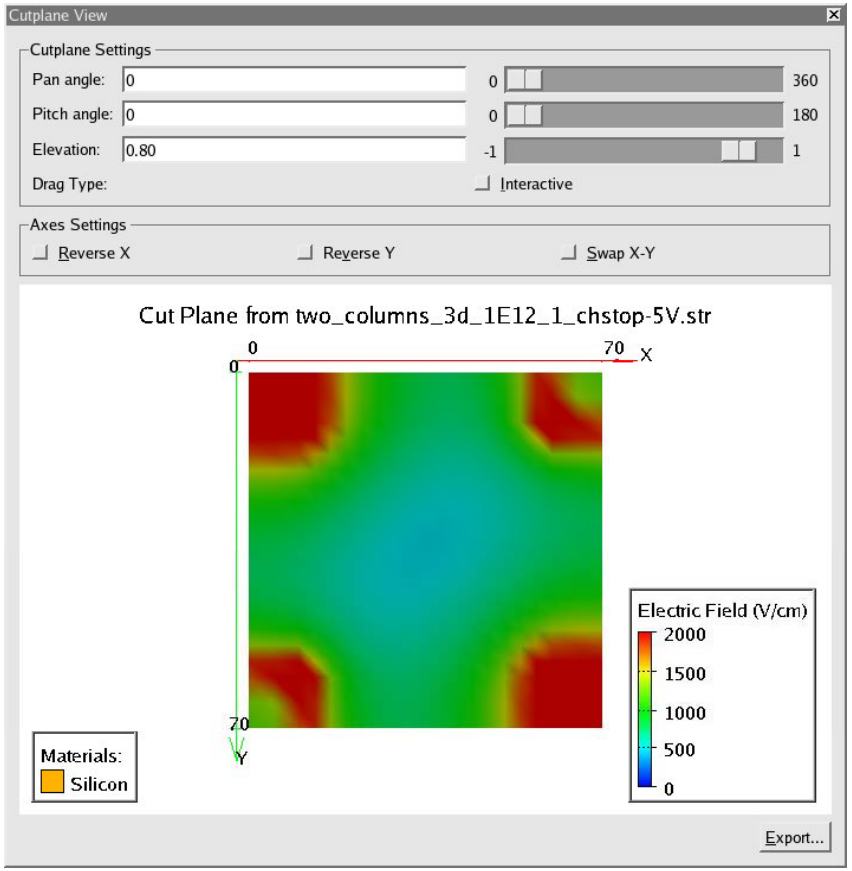
Dual column one-sided 3D detector (5V)

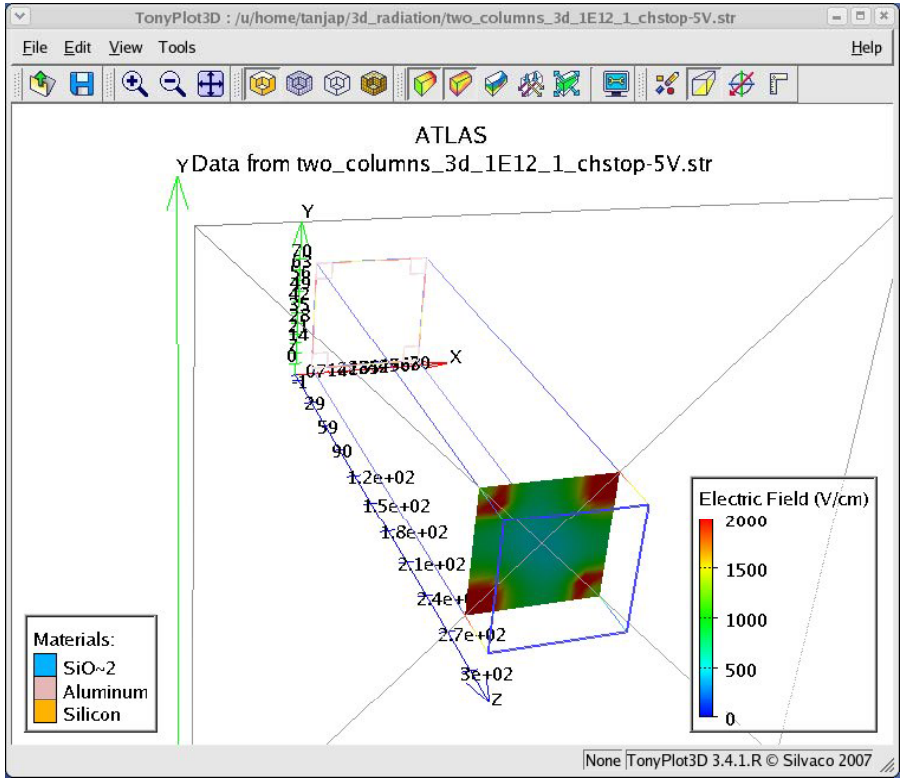




Electric field

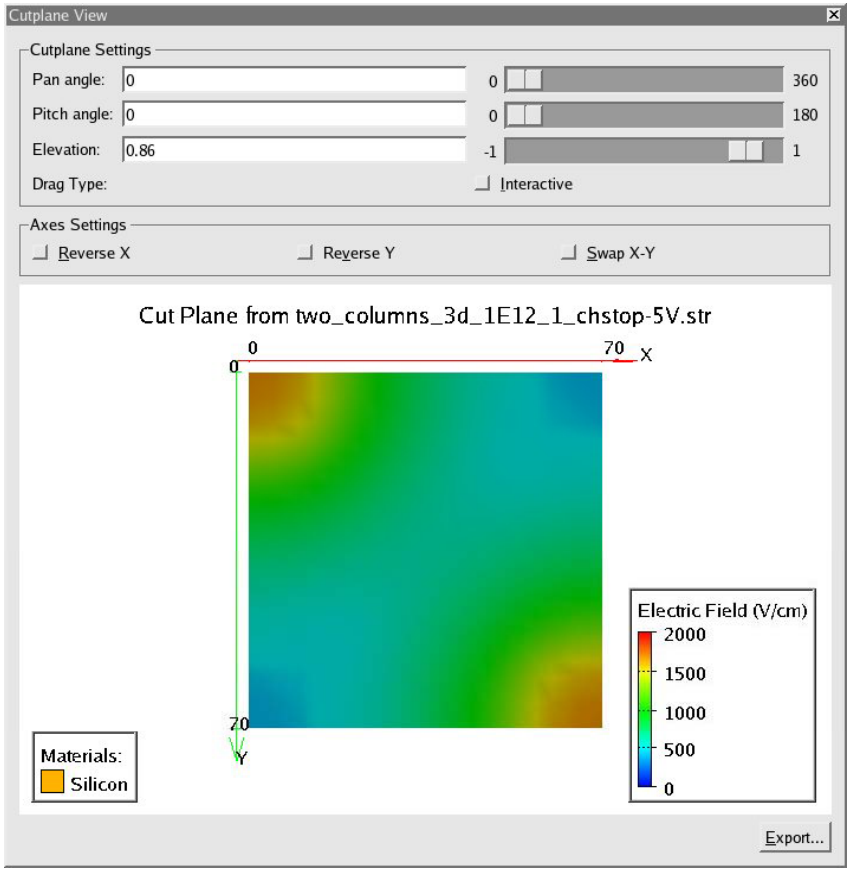
Dual column one-sided 3D detector (5V)

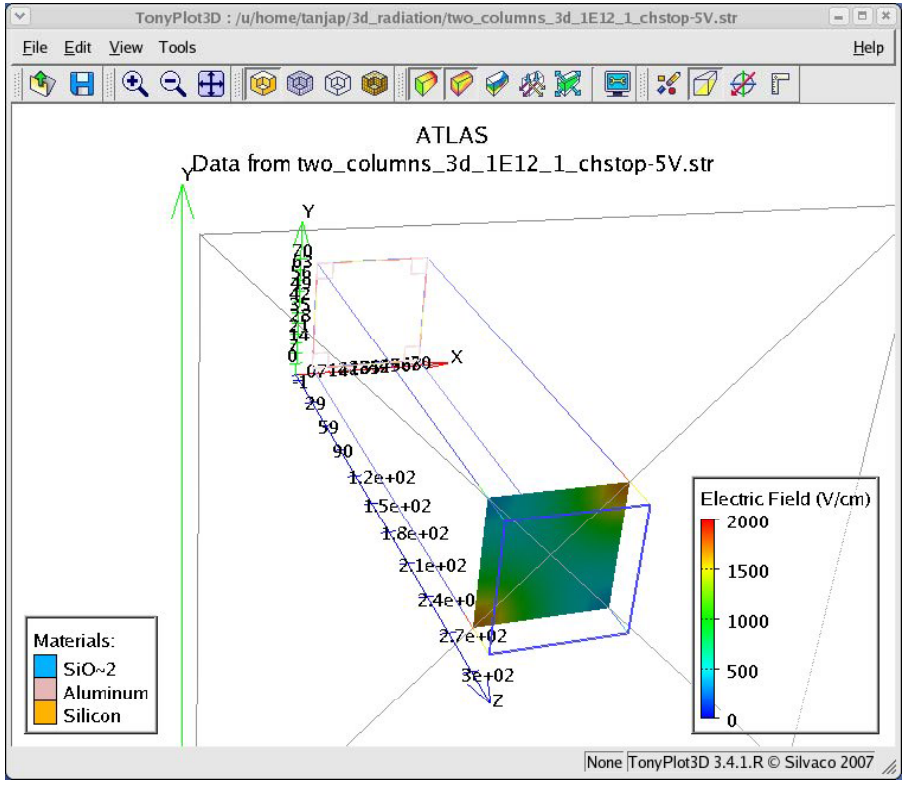




Electric field

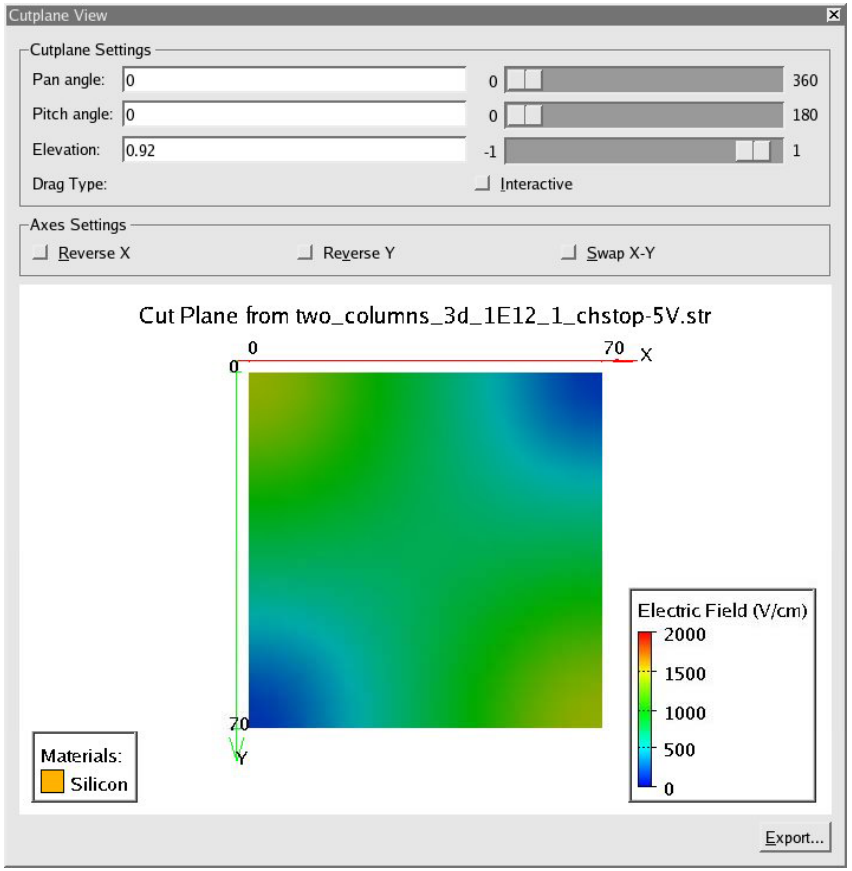
Dual column one-sided 3D detector (5V)

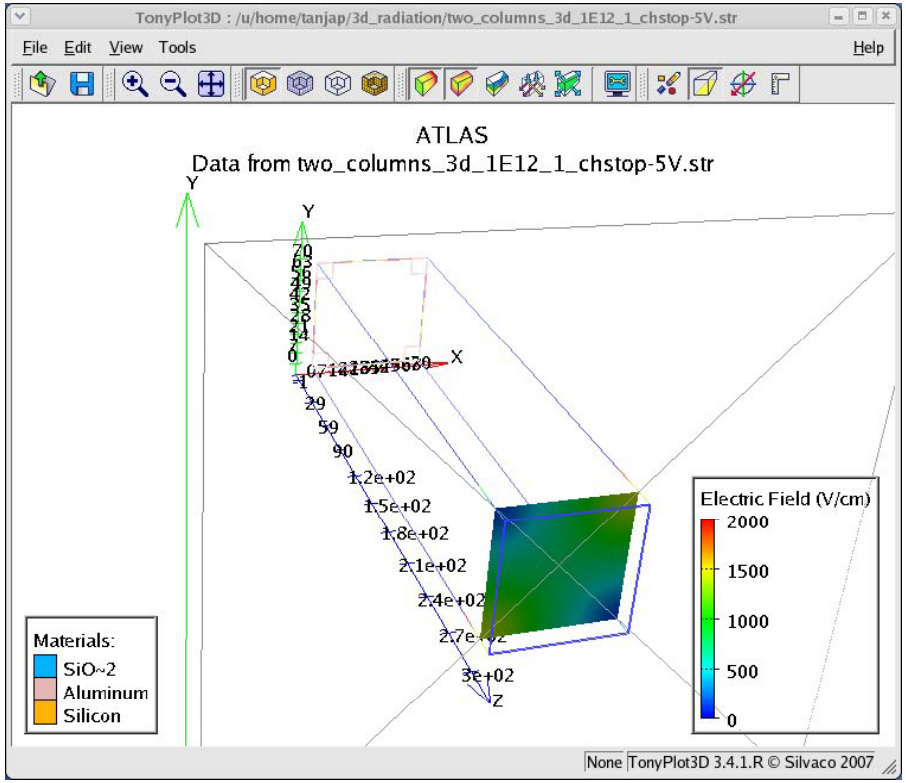




Electric field

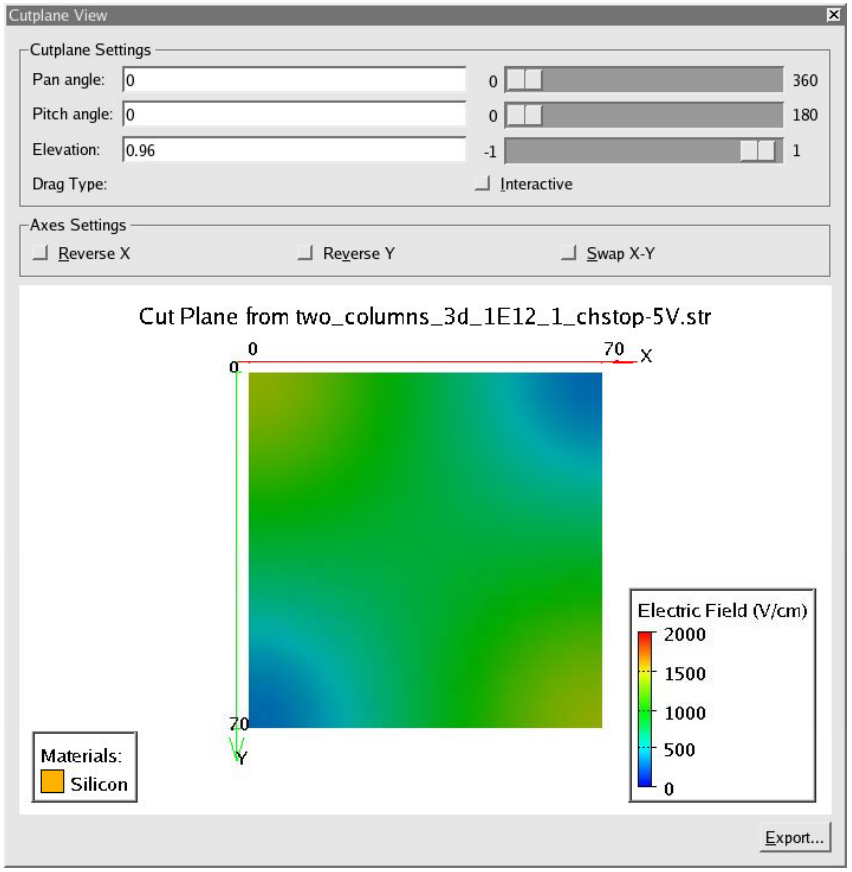
Dual column one-sided 3D detector (5V)

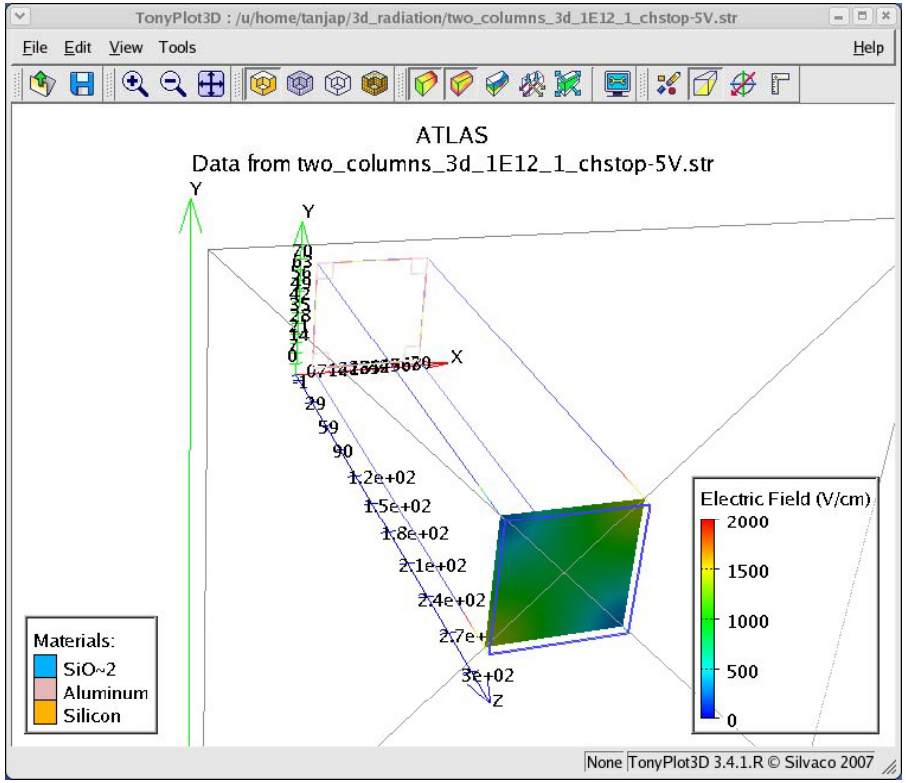




Electric field

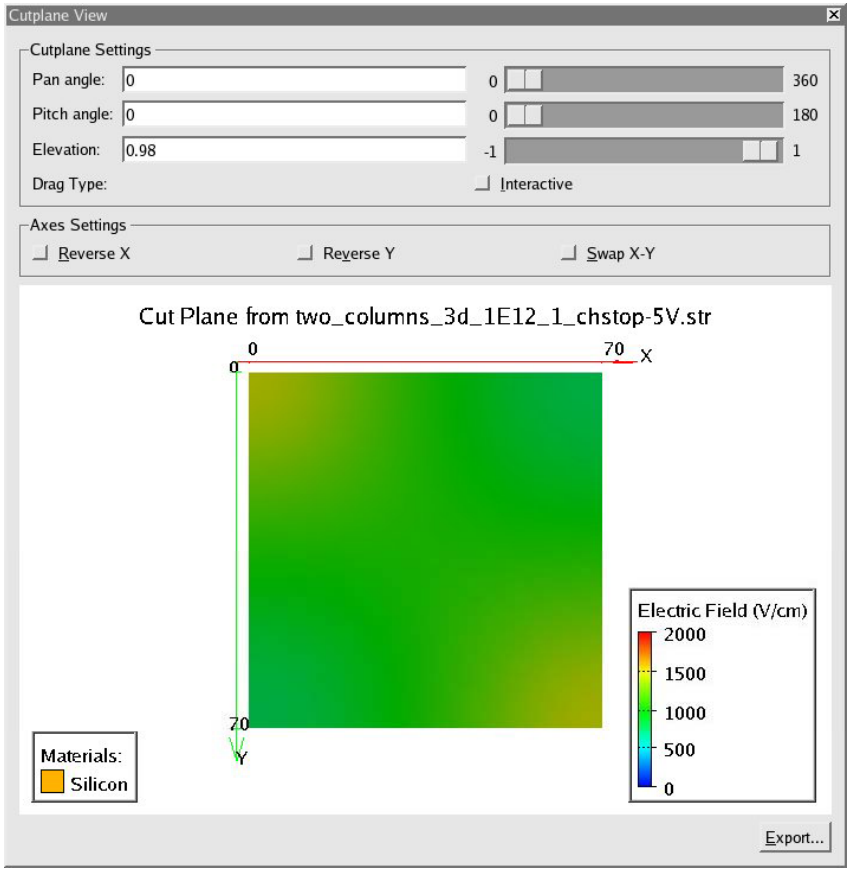
Dual column one-sided 3D detector (5V)

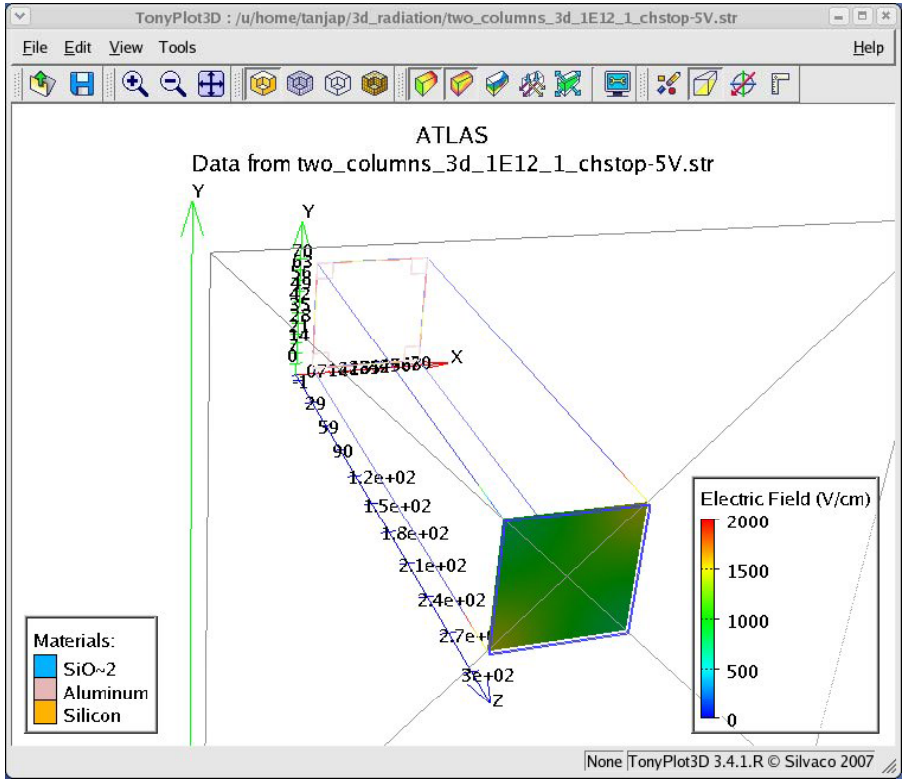




Electric field

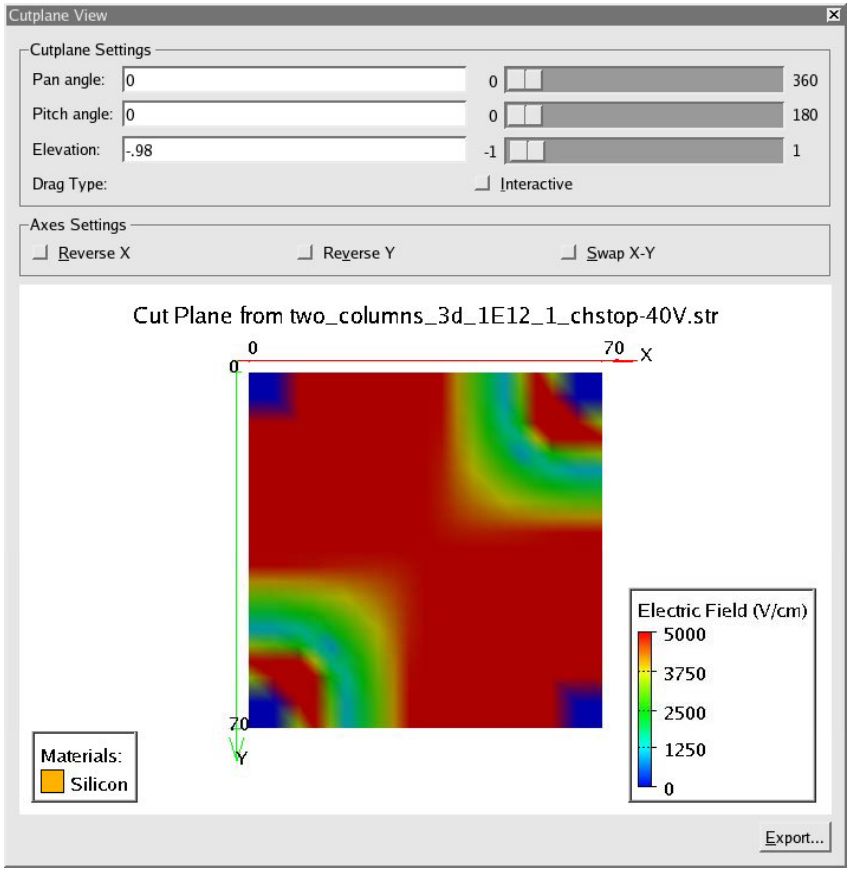
Dual column one-sided 3D detector (5V)

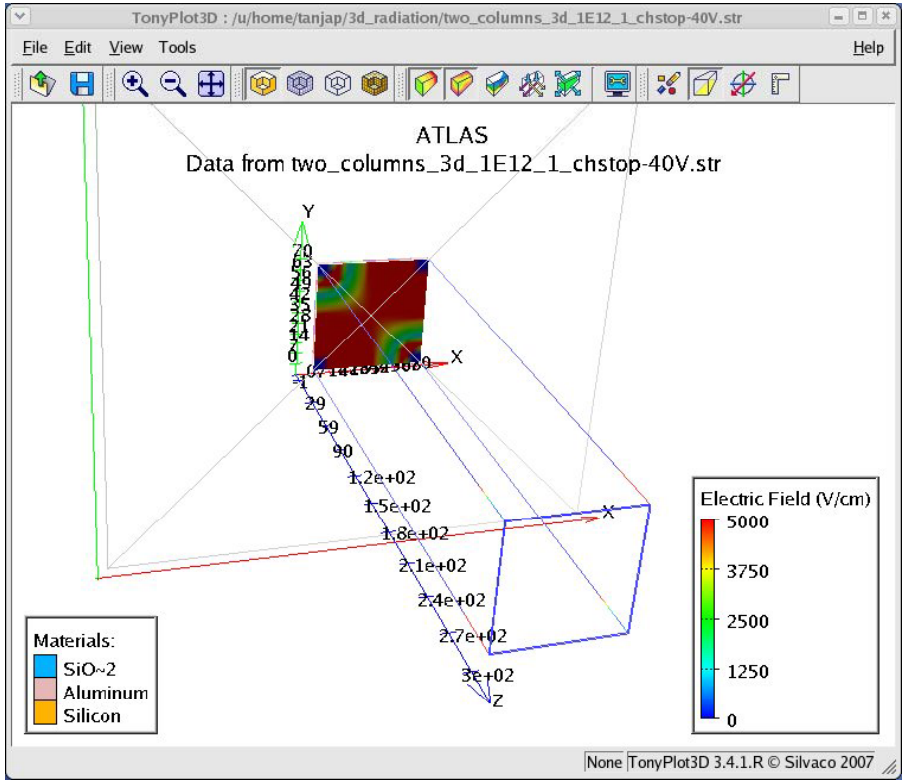




Electric field

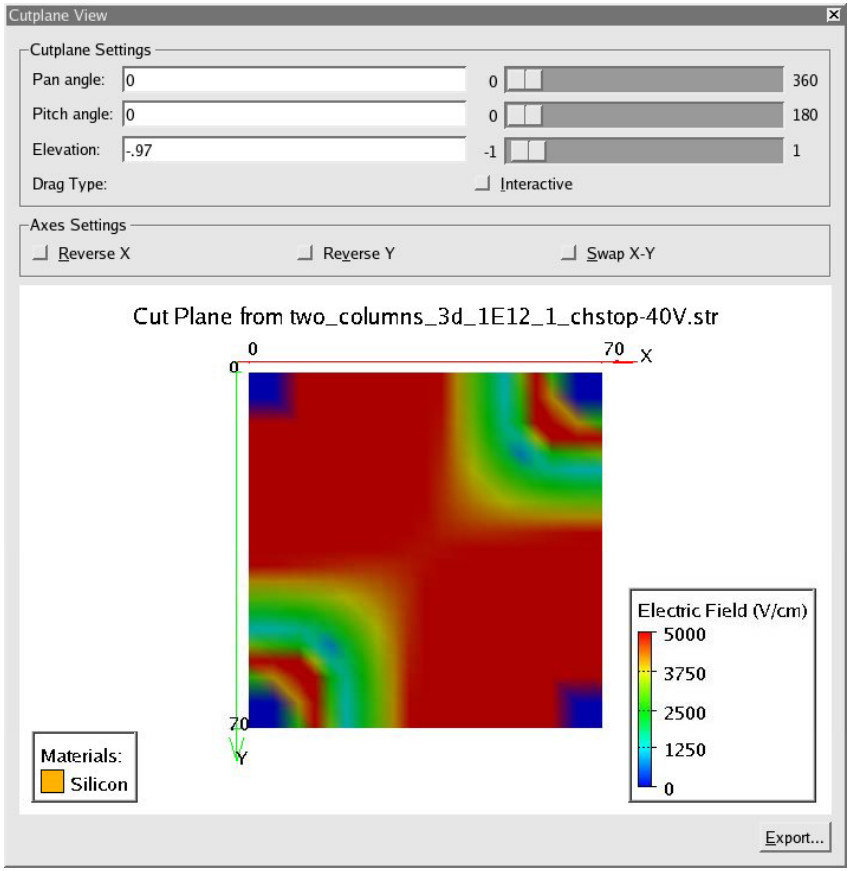
Dual column one-sided 3D detector (40V)

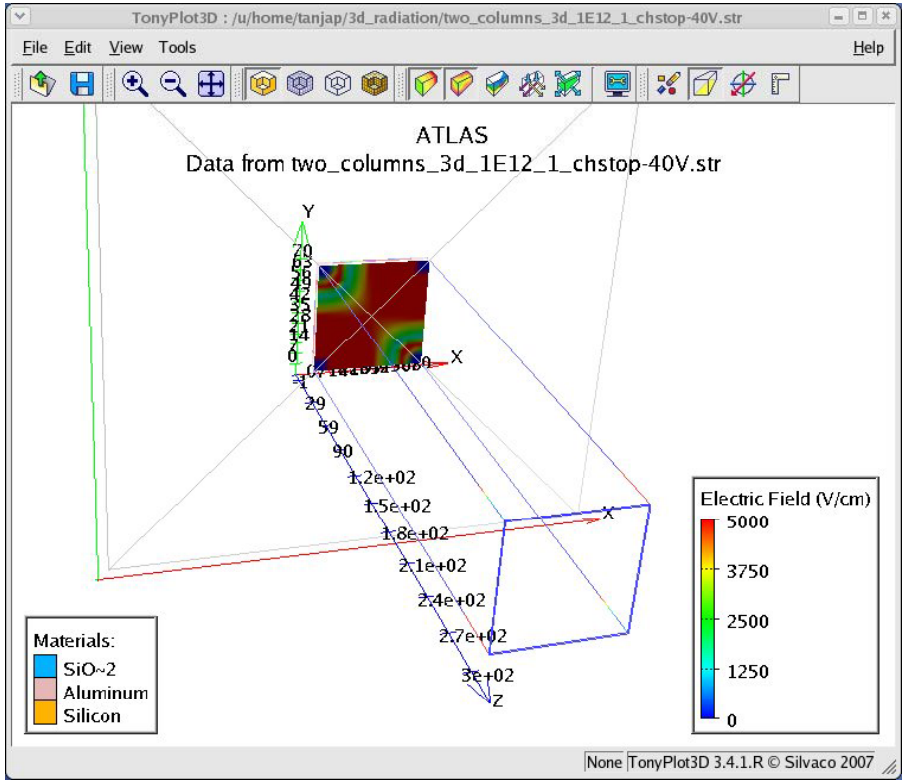




Electric field

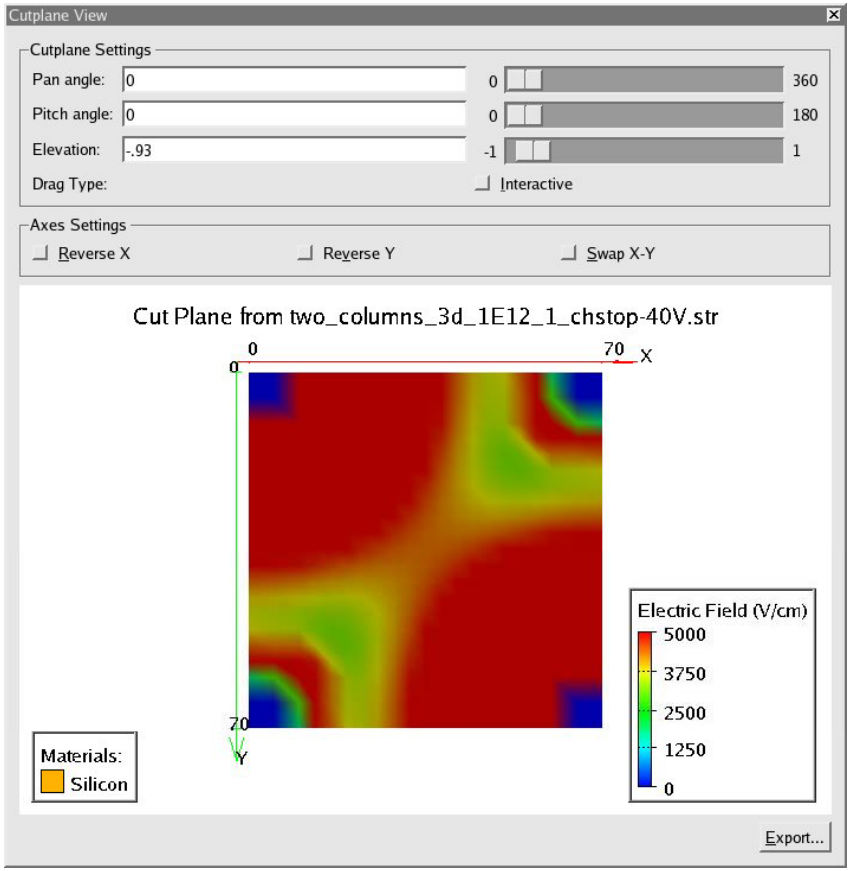
Dual column one-sided 3D detector (40V)

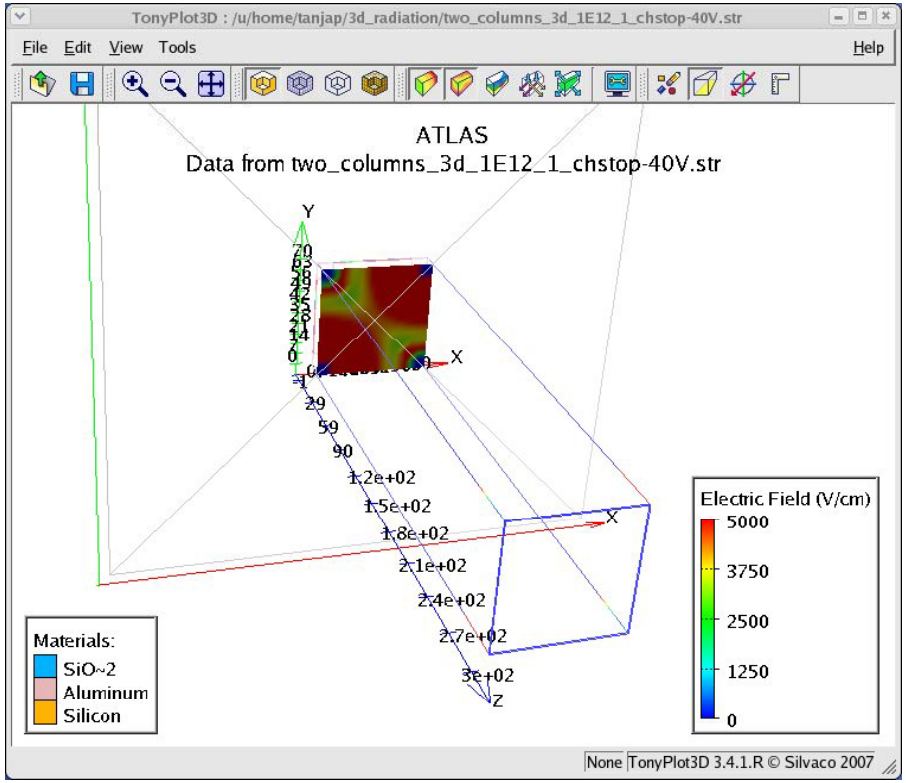




Electric field

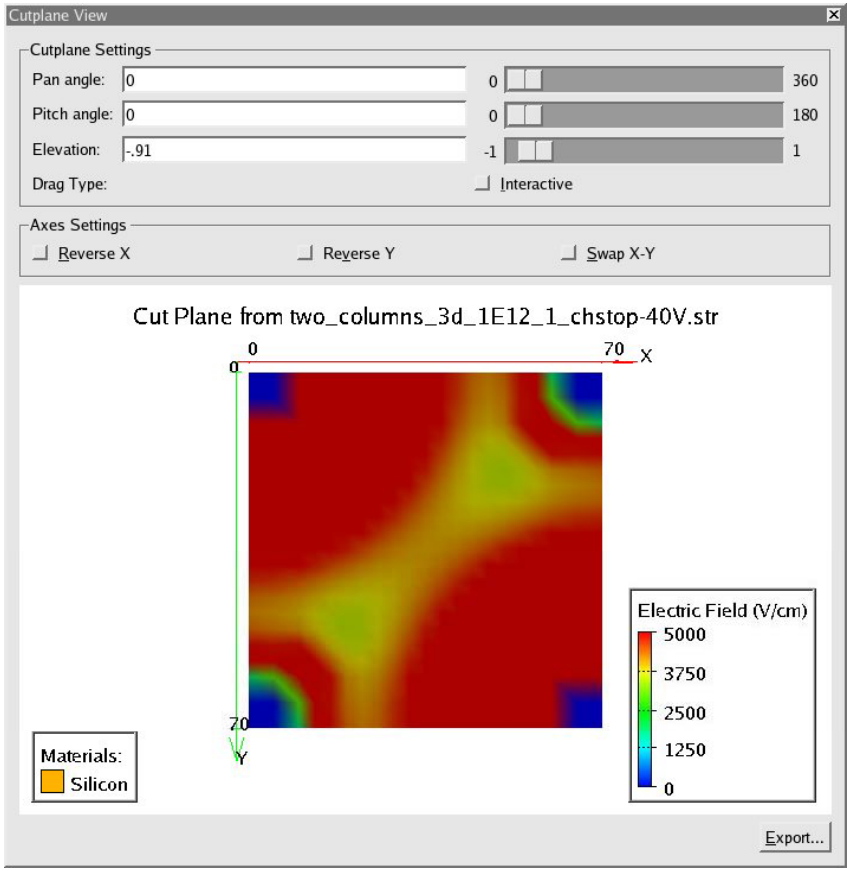
Dual column one-sided 3D detector (40V)

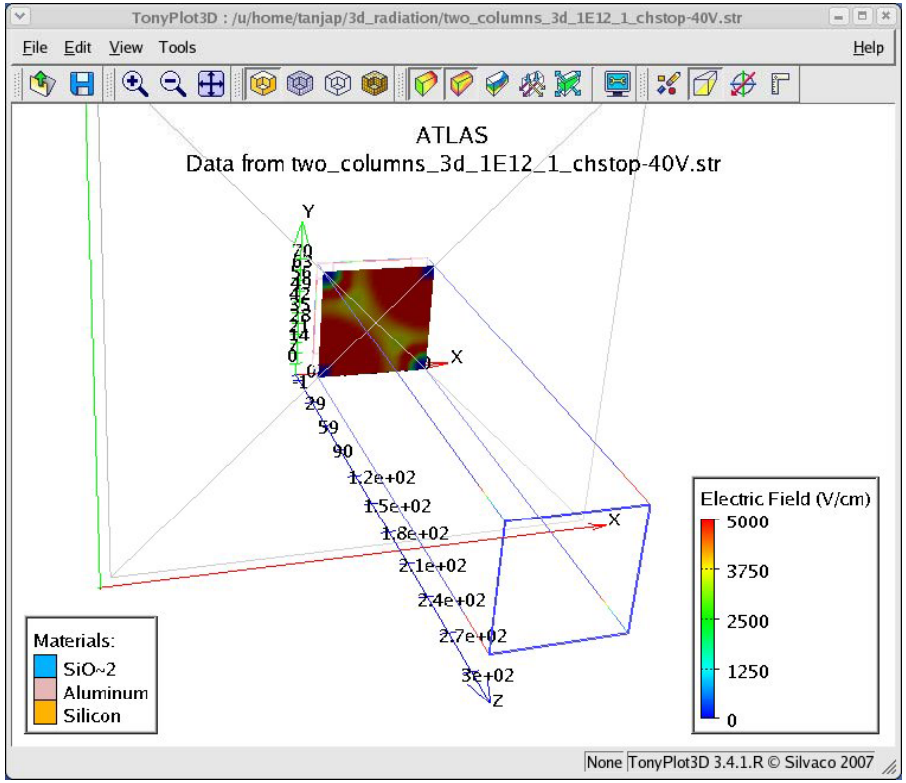




Electric field

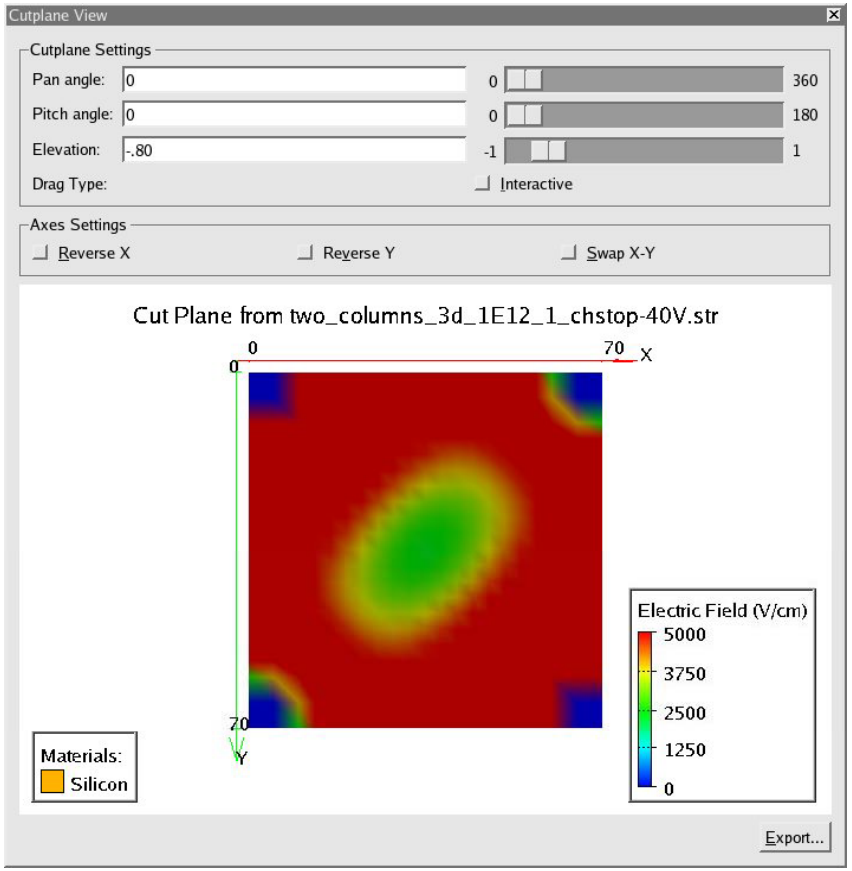
Dual column one-sided 3D detector (40V)

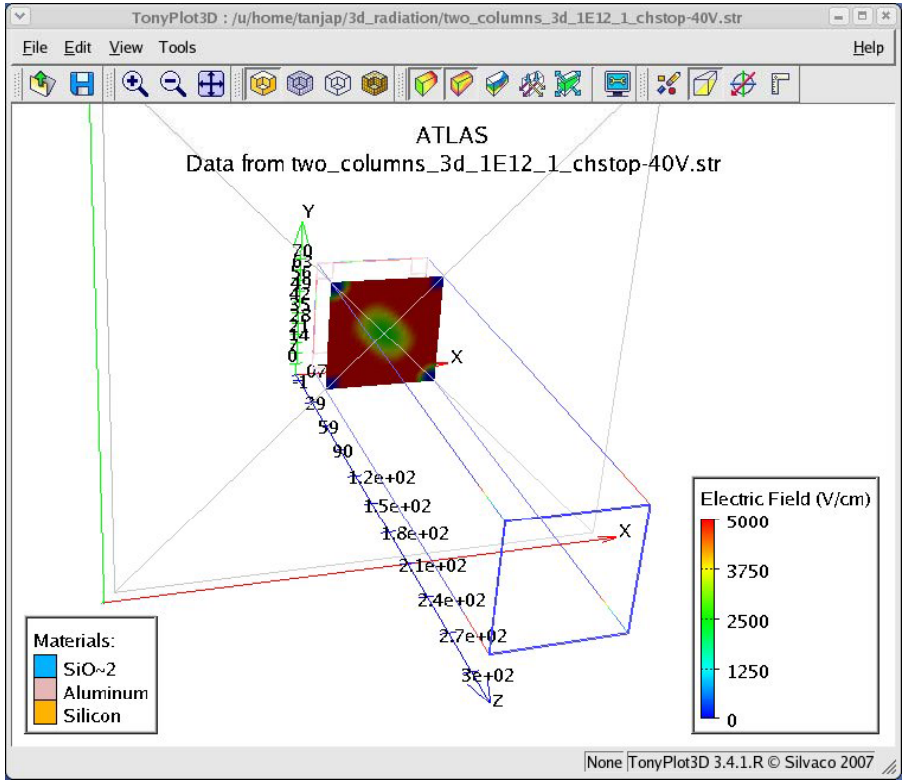




Electric field

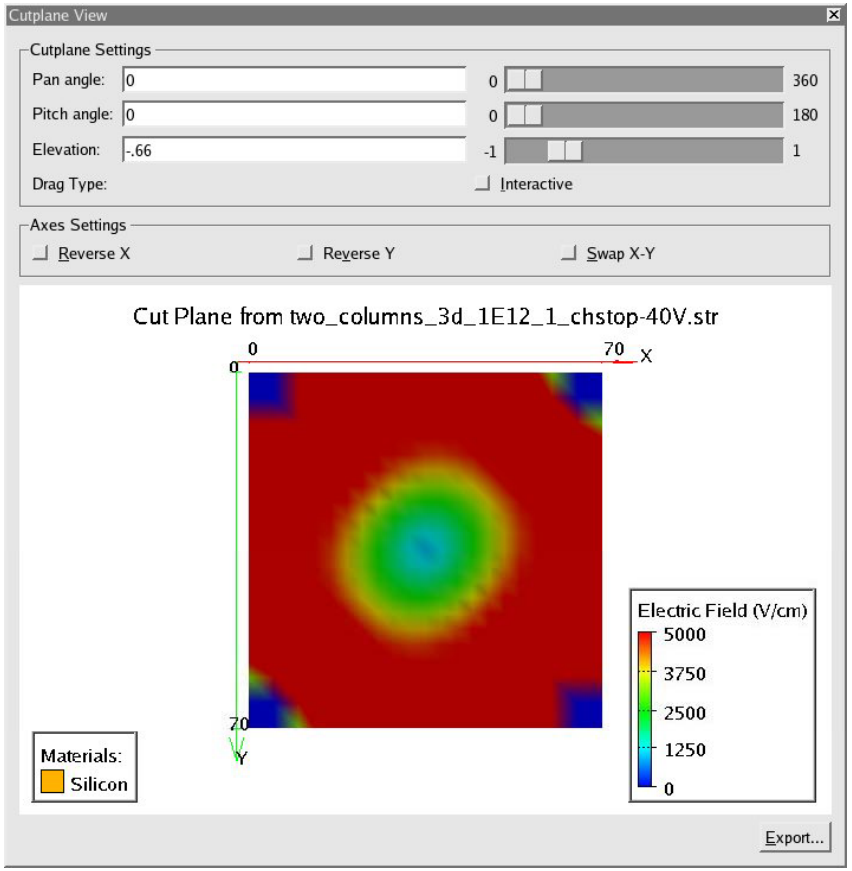
Dual column one-sided 3D detector (40V)

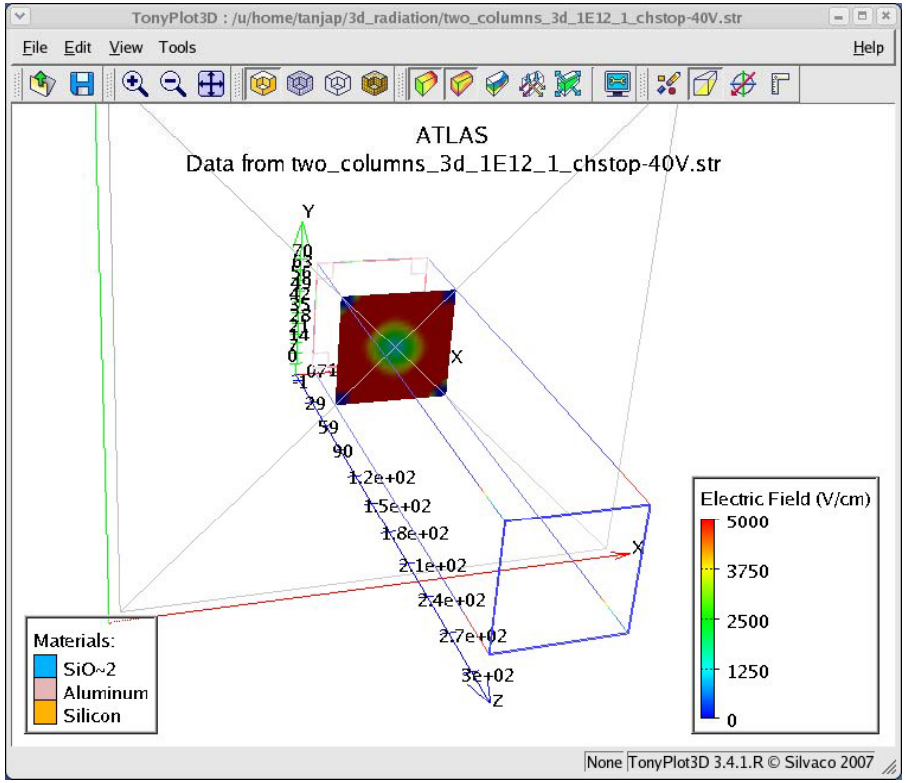




Electric field

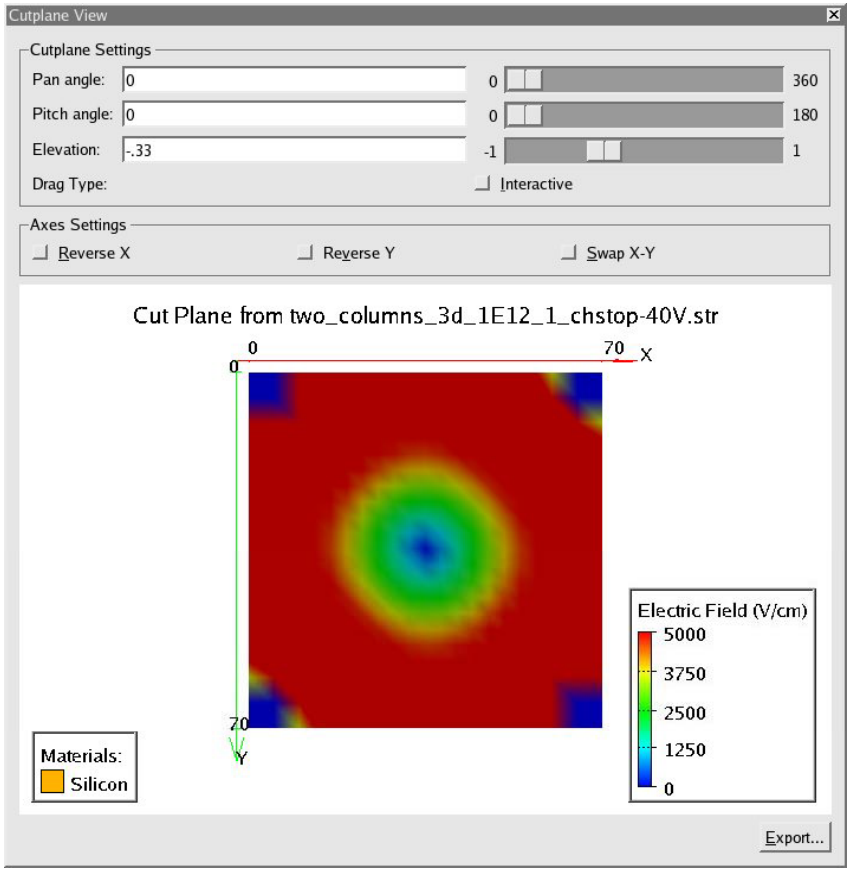
Dual column one-sided 3D detector (40V)

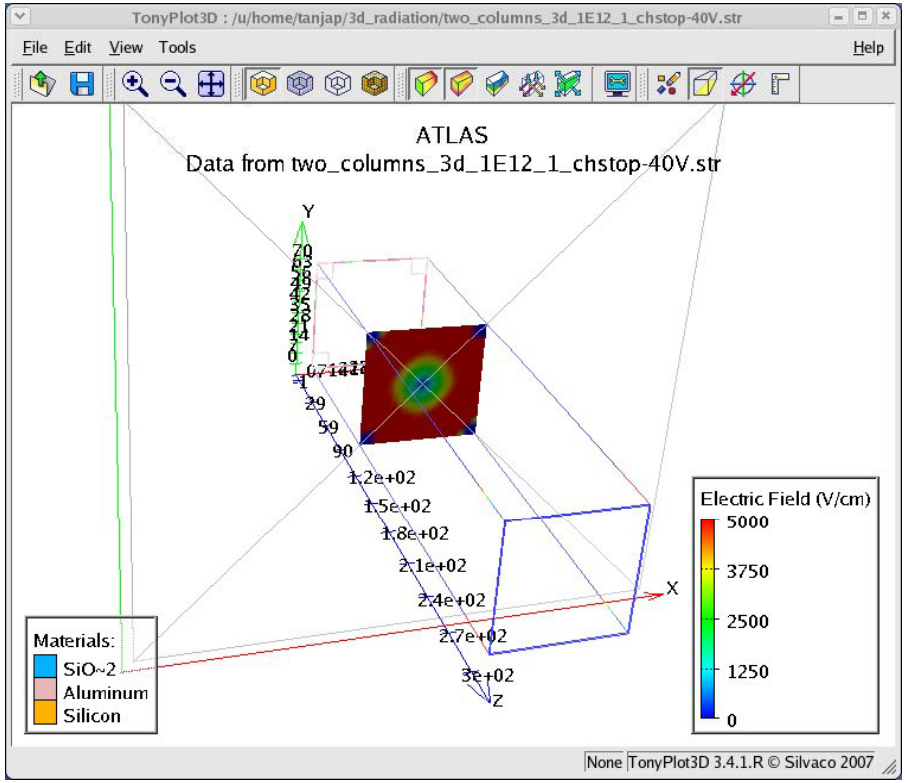




Electric field

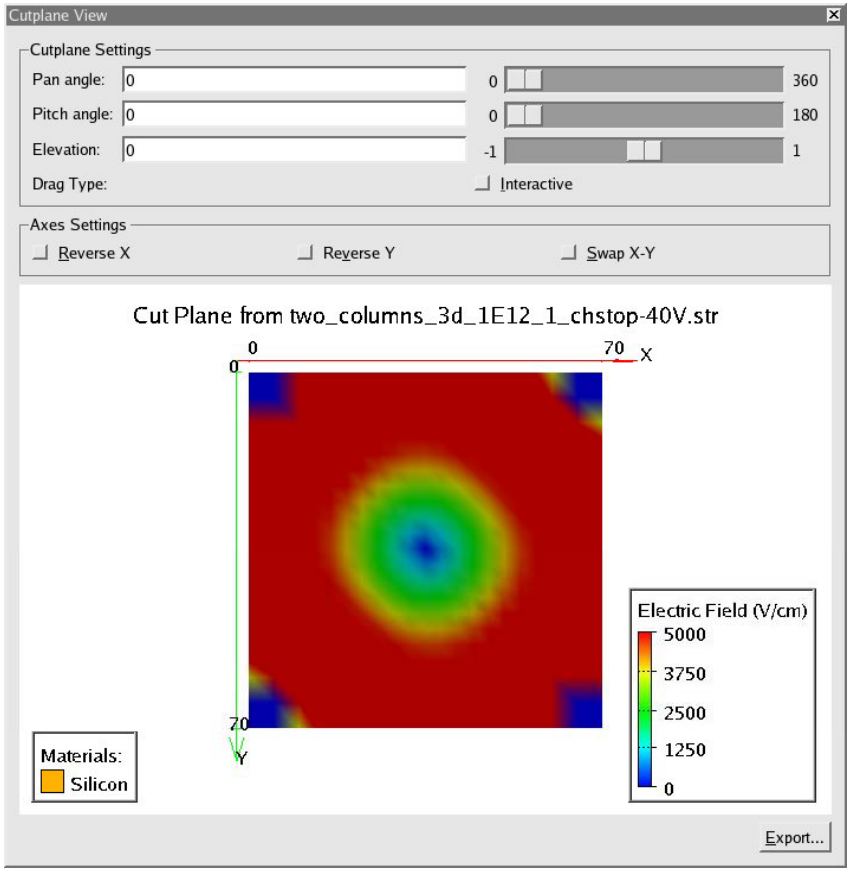
Dual column one-sided 3D detector (40V)

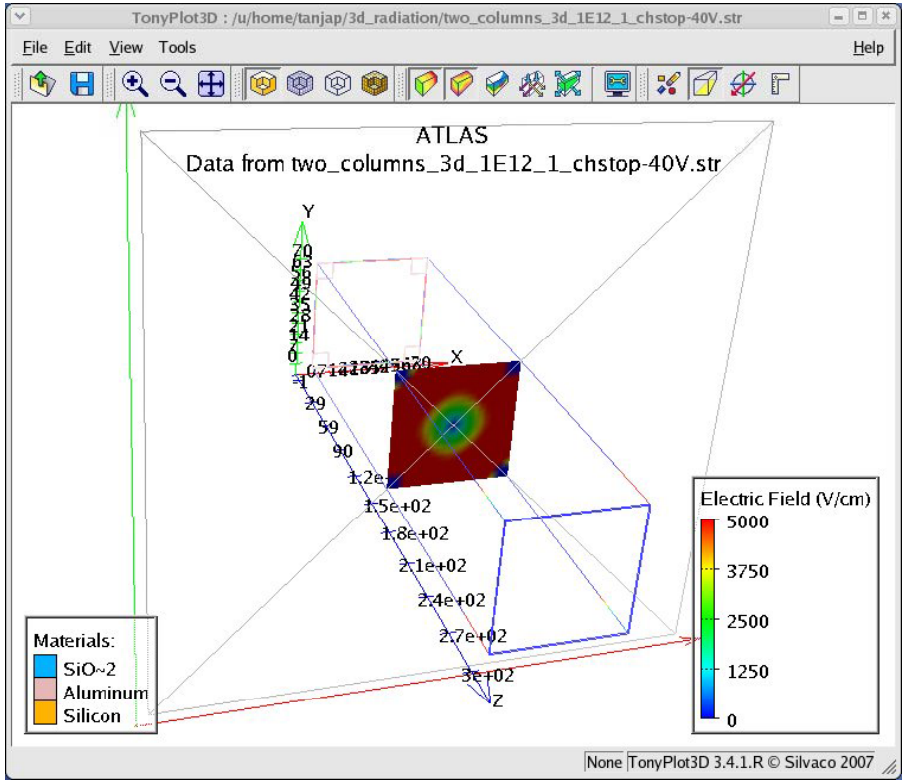




Electric field

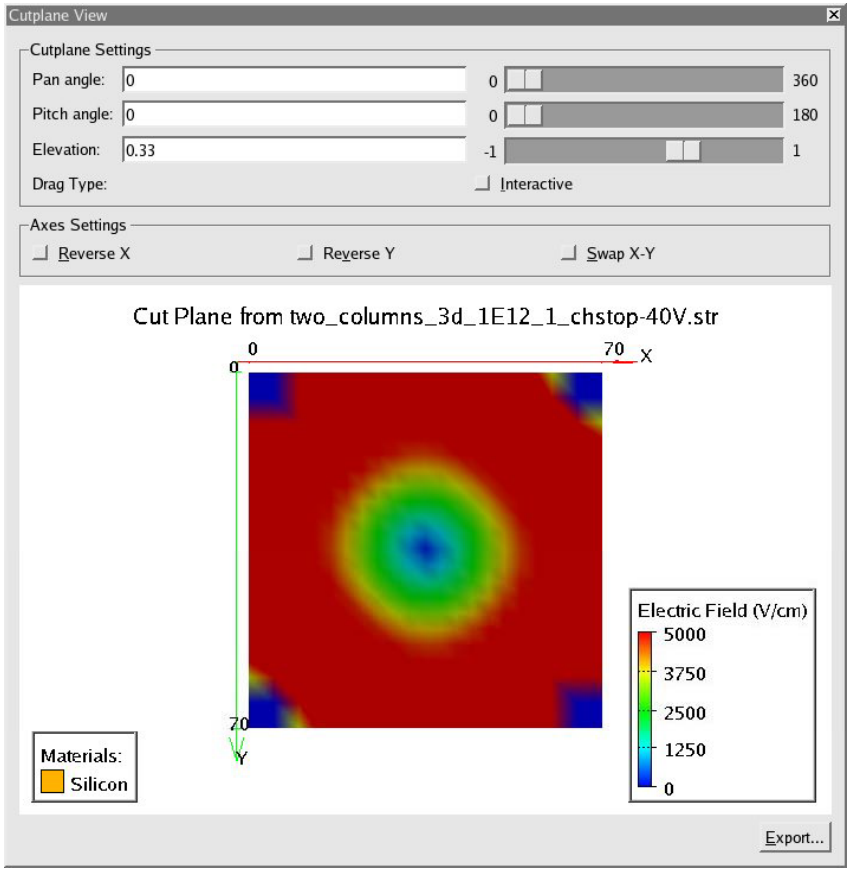
Dual column one-sided 3D detector (40V)

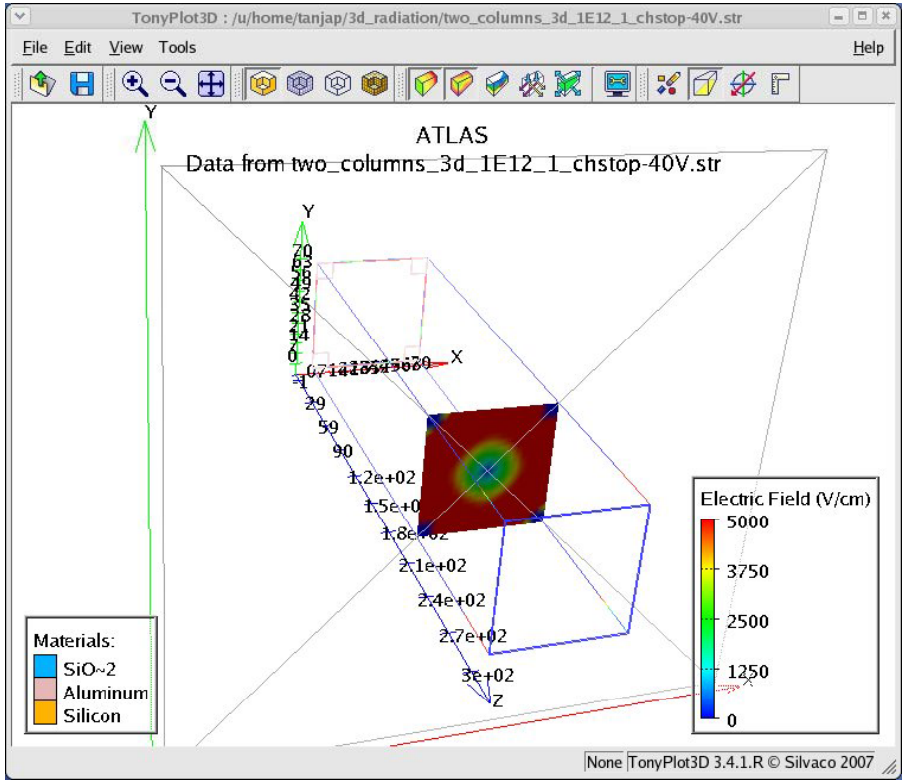




Electric field

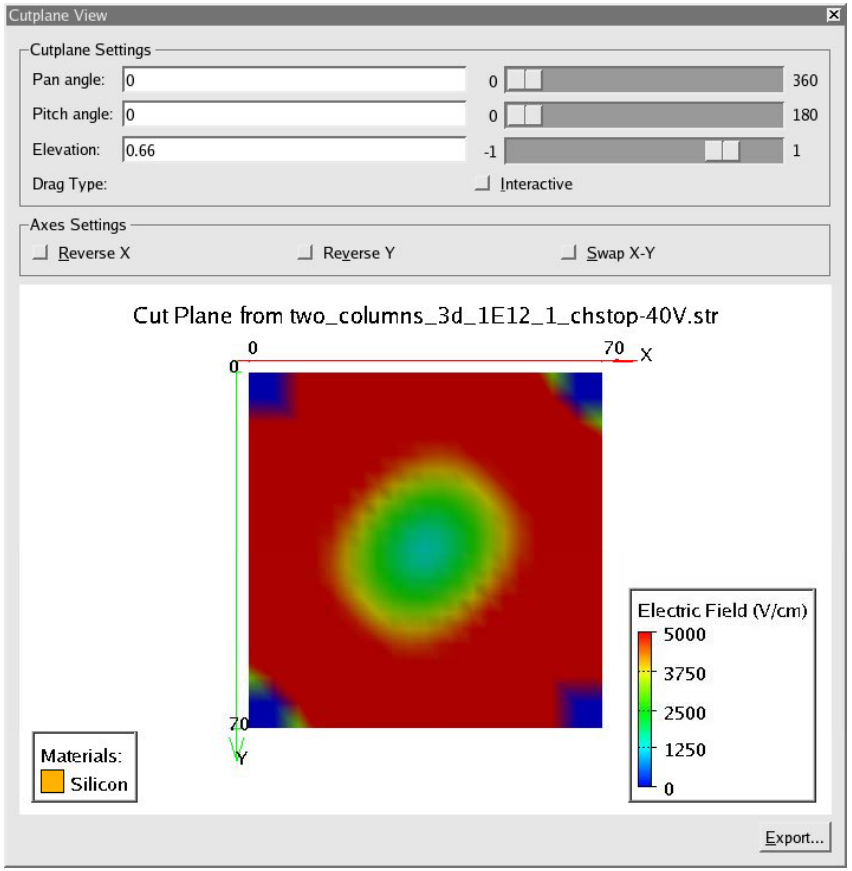
Dual column one-sided 3D detector (40V)

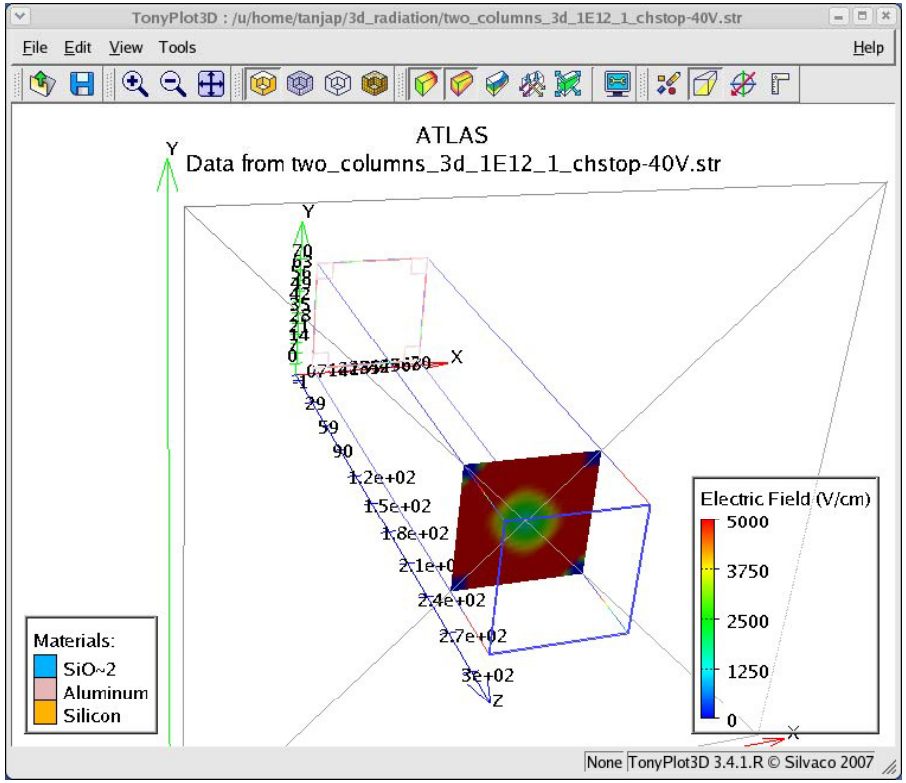




Electric field

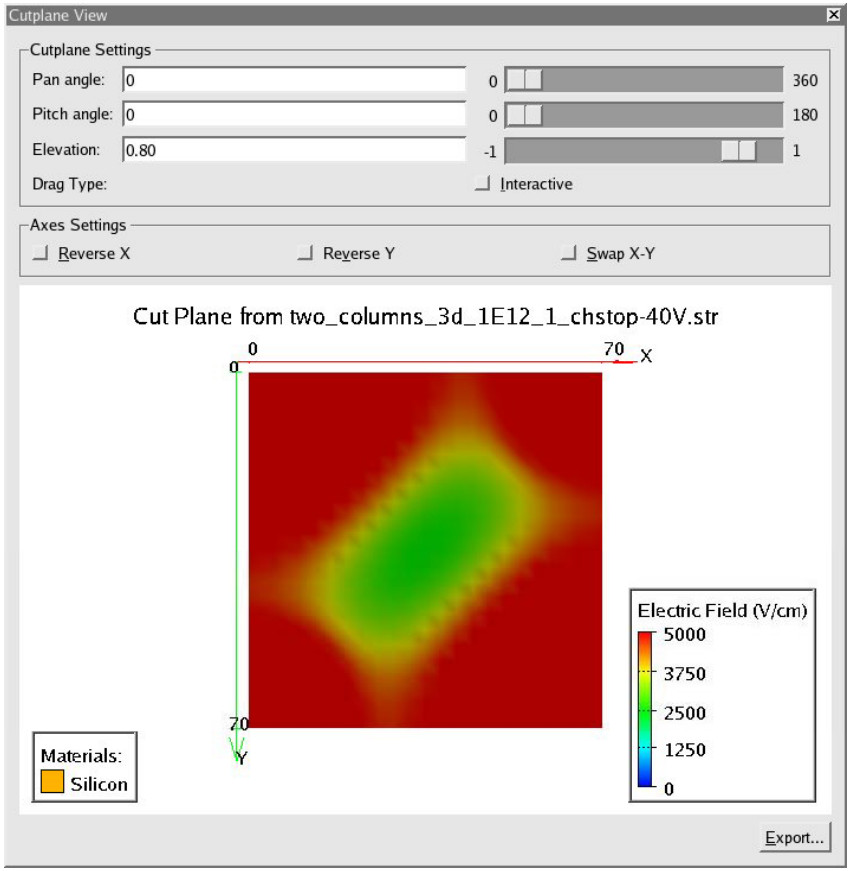
Dual column one-sided 3D detector (40V)

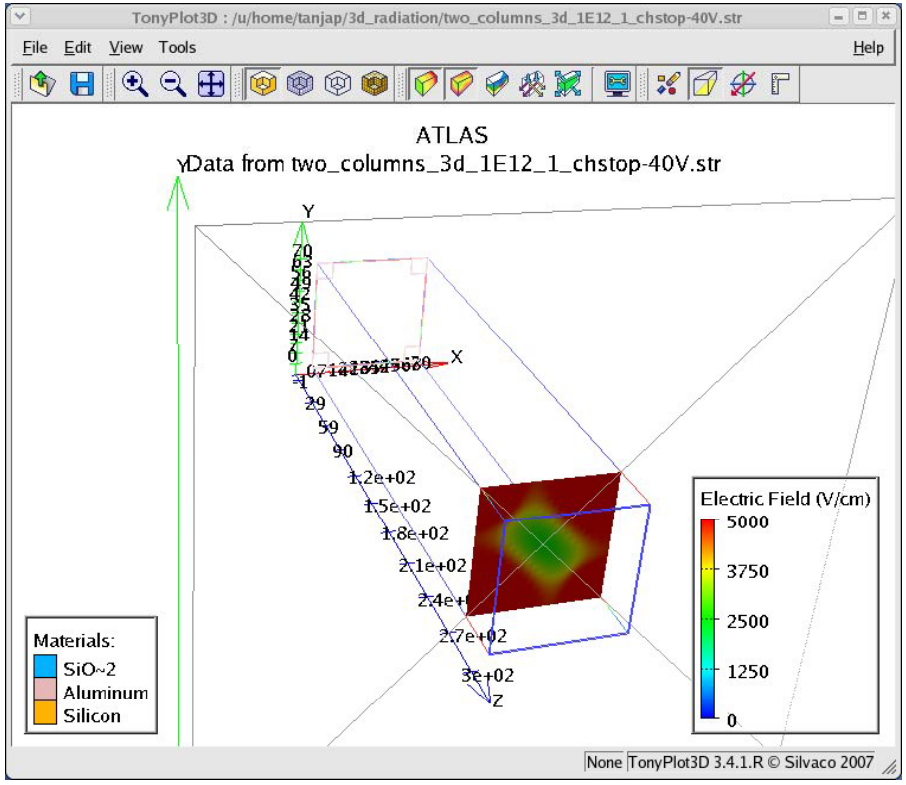




Electric field

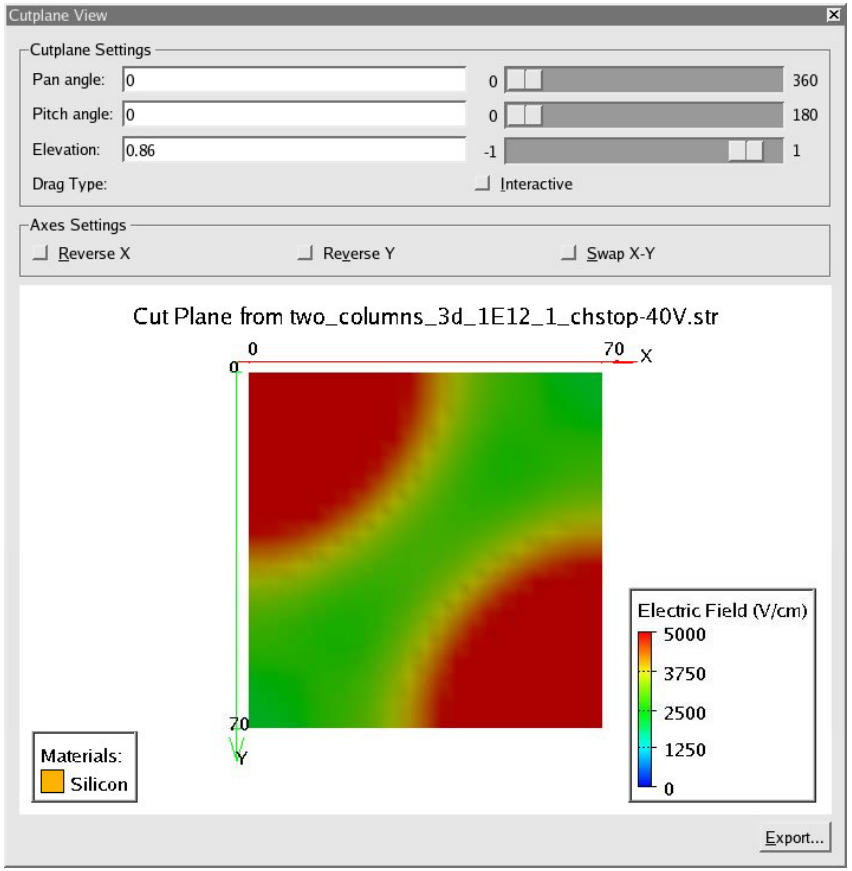
Dual column one-sided 3D detector (40V)

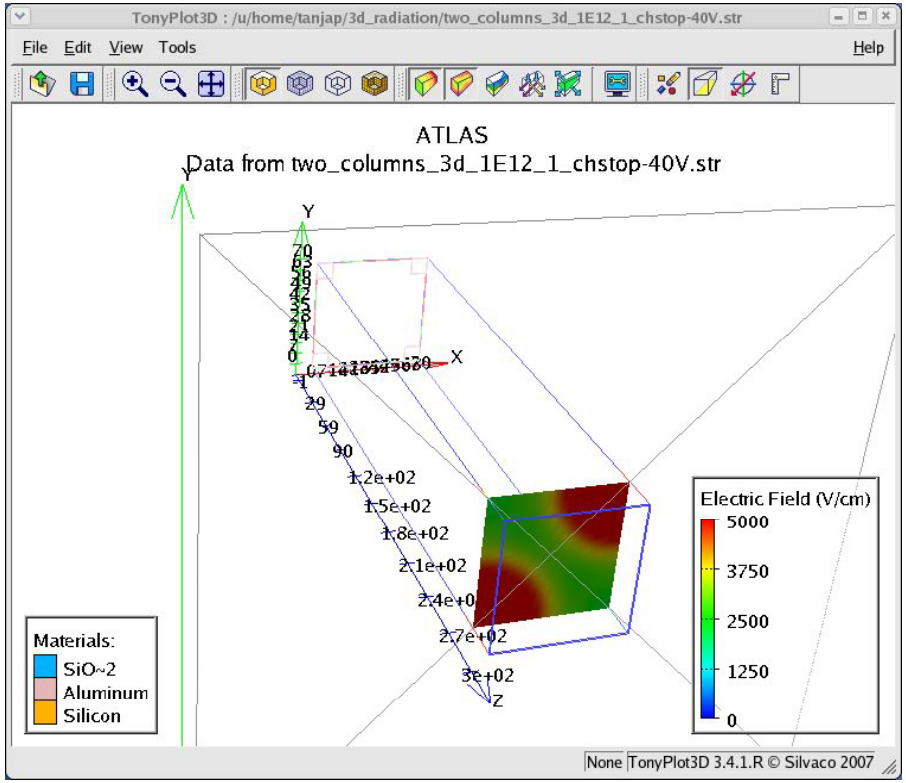




Electric field

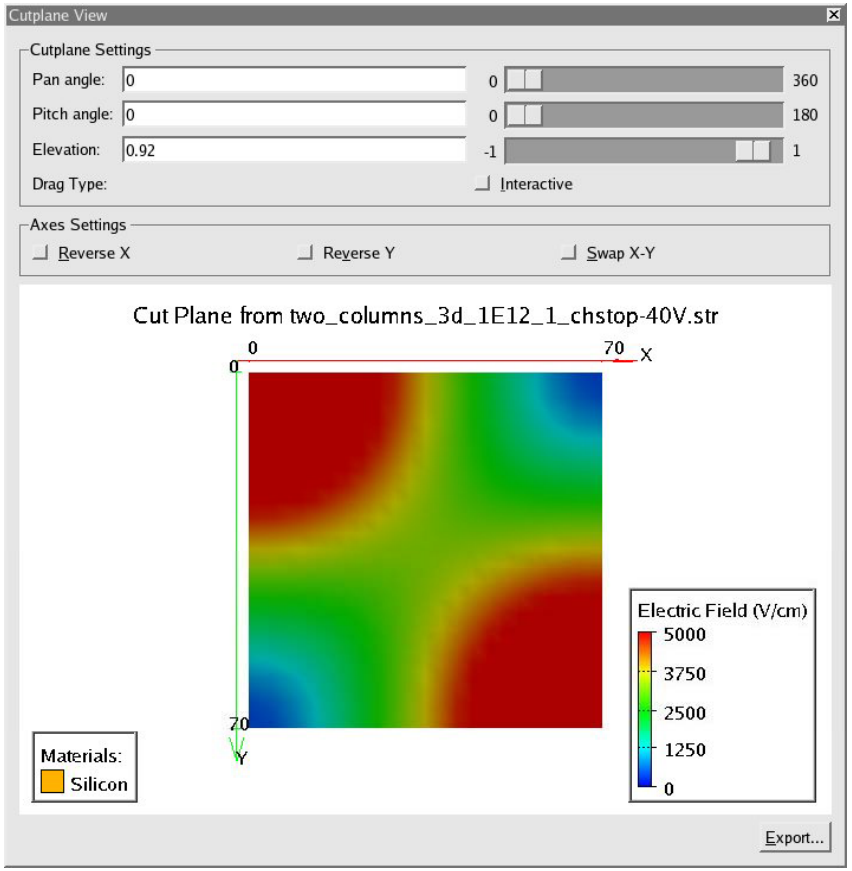
Dual column one-sided 3D detector (40V)

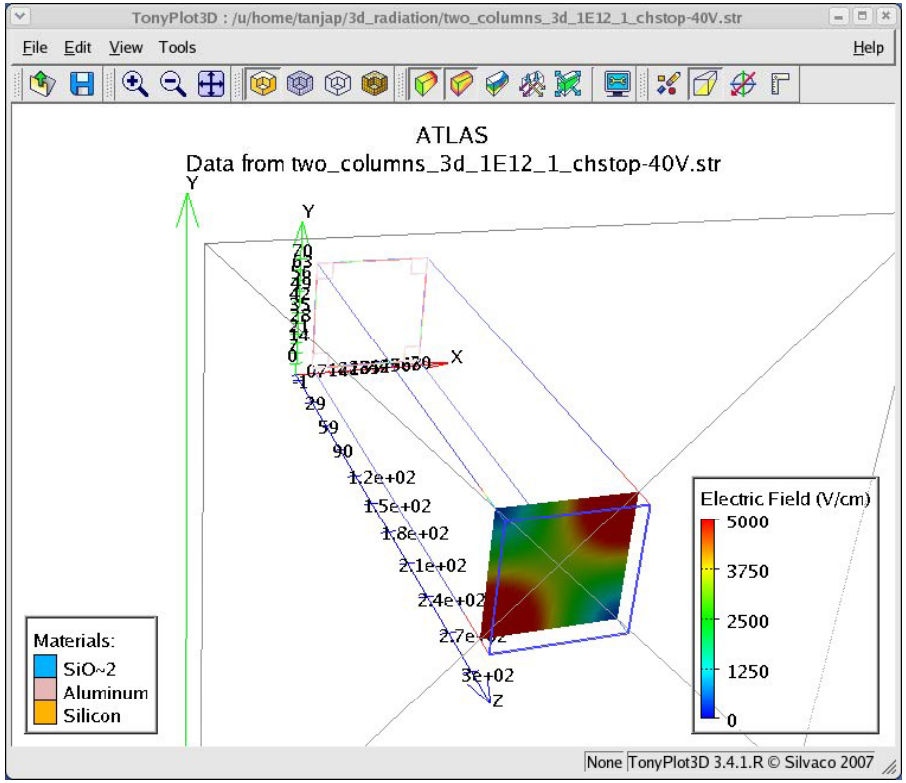




Electric field

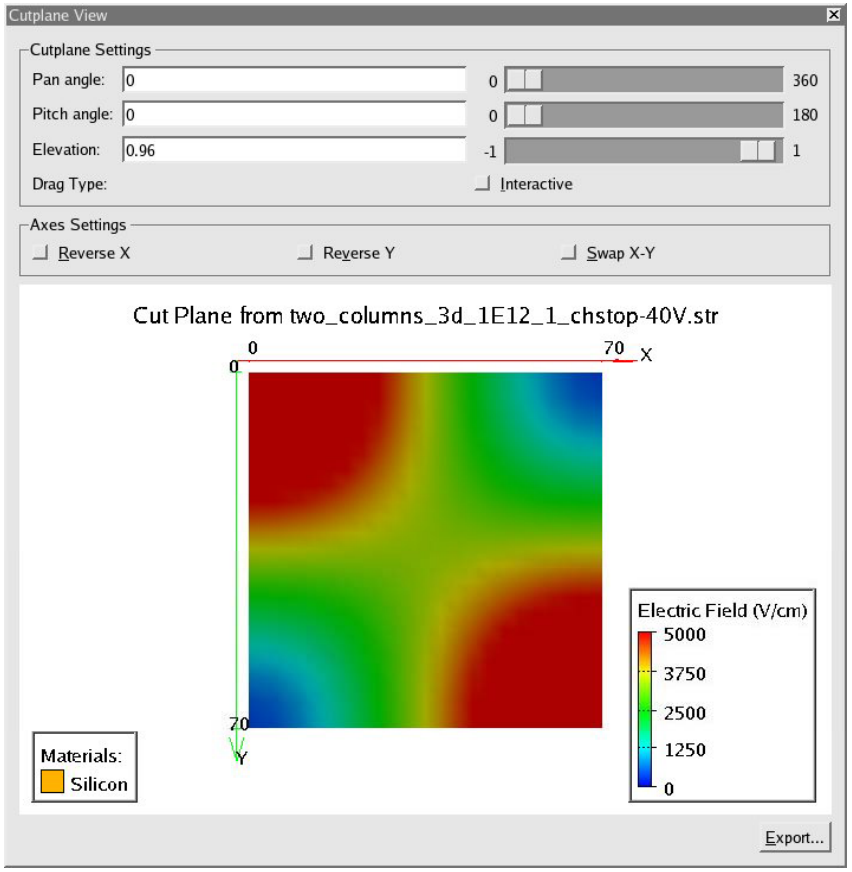
Dual column one-sided 3D detector (40V)

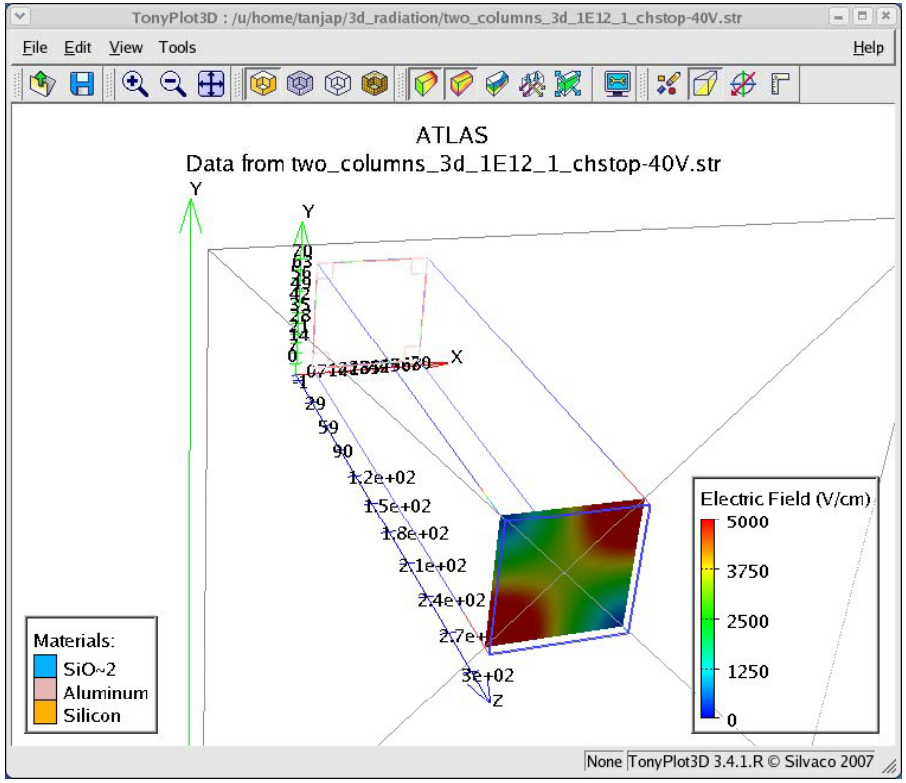




Electric field

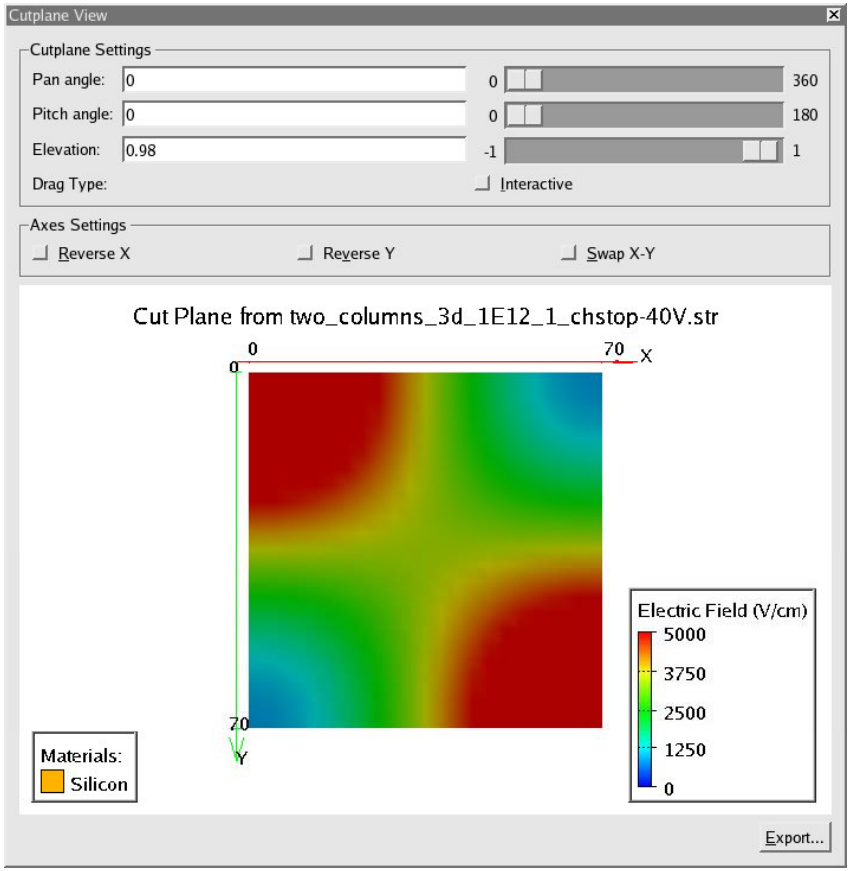
Dual column one-sided 3D detector (40V)

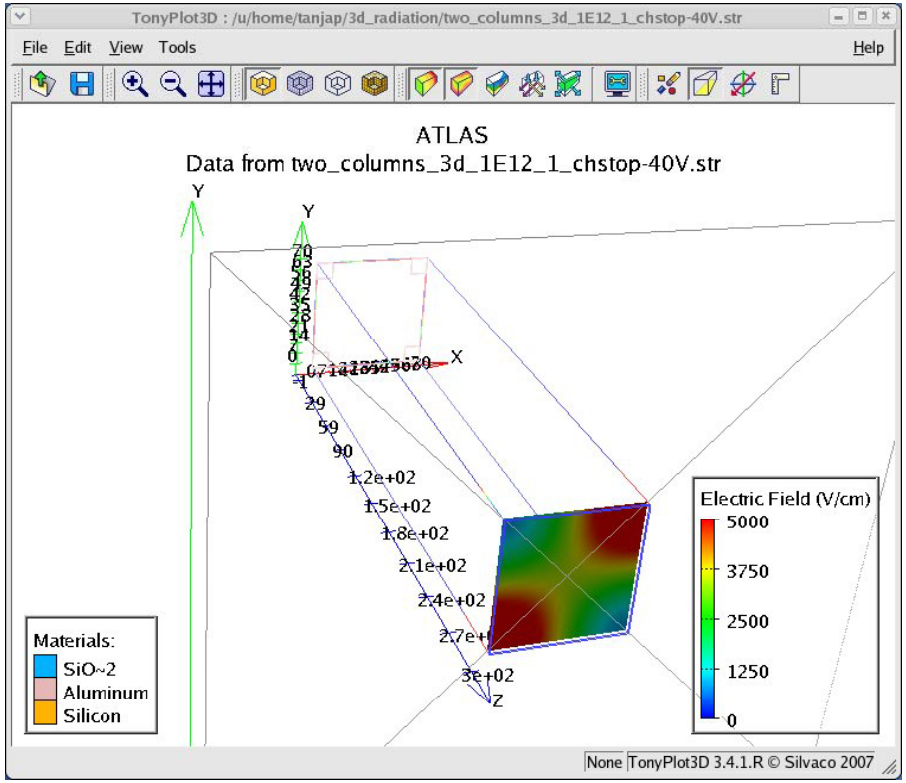




Electric field

Dual column one-sided 3D detector (40V)



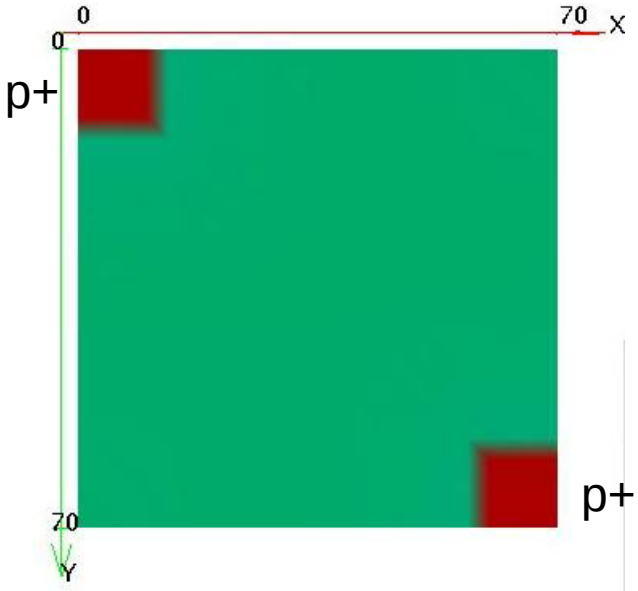


Electric field

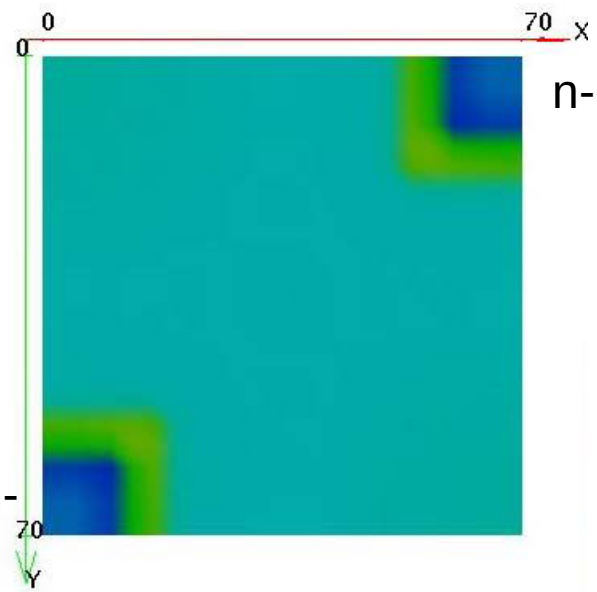
CNM/Trento dual column double-sided 3D detector

- Under processing at CNM, Barcelona
  RD50 collaborative work (CNM, Glasgow, Valencia,…)
- P-type columns (red) and n-type columns (blue) are placed to the opposite surface, n-type columns are surrounded by p-stops

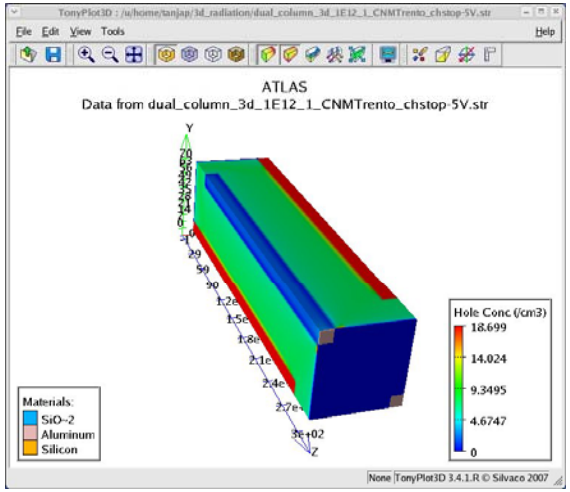
top



bottom

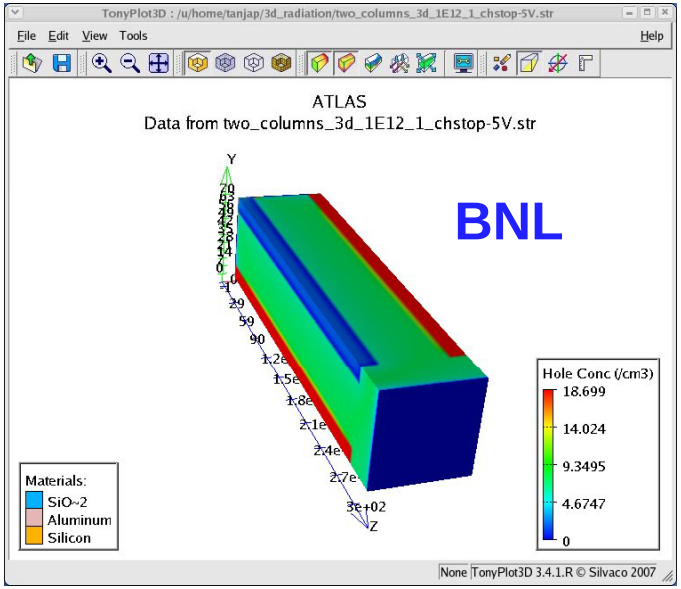


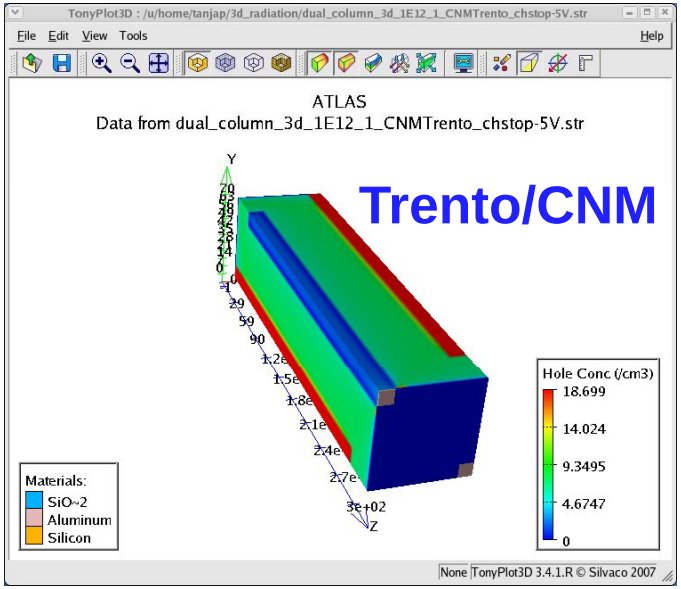
p+ n-



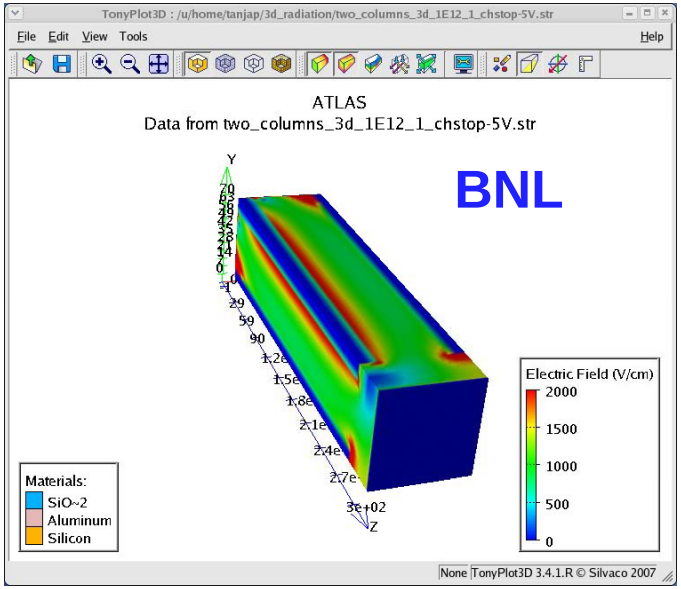
Comparing dual column 3D detectors (5V)

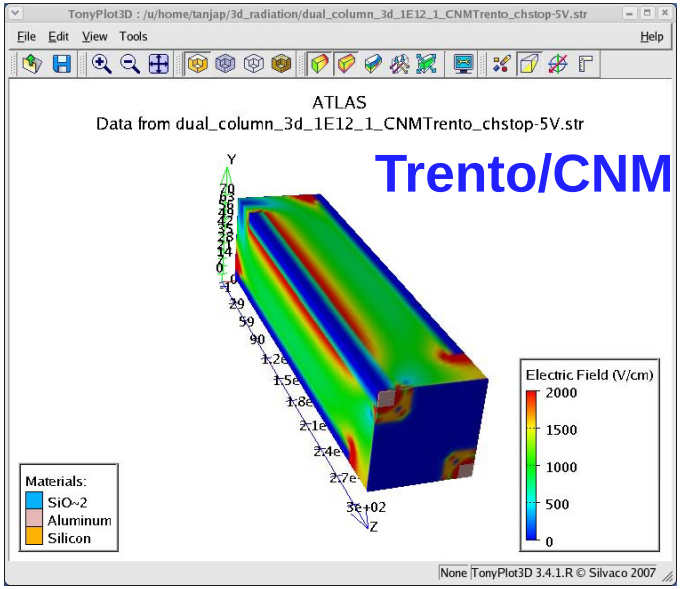
Hole concentration





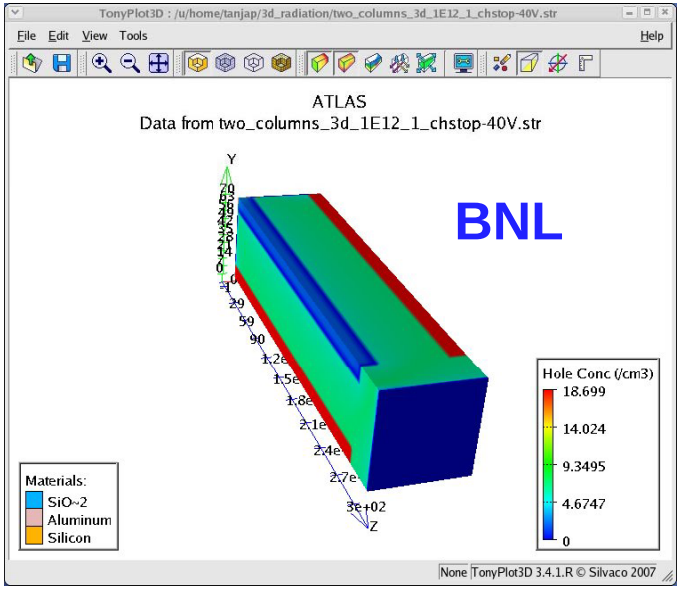
Electric field

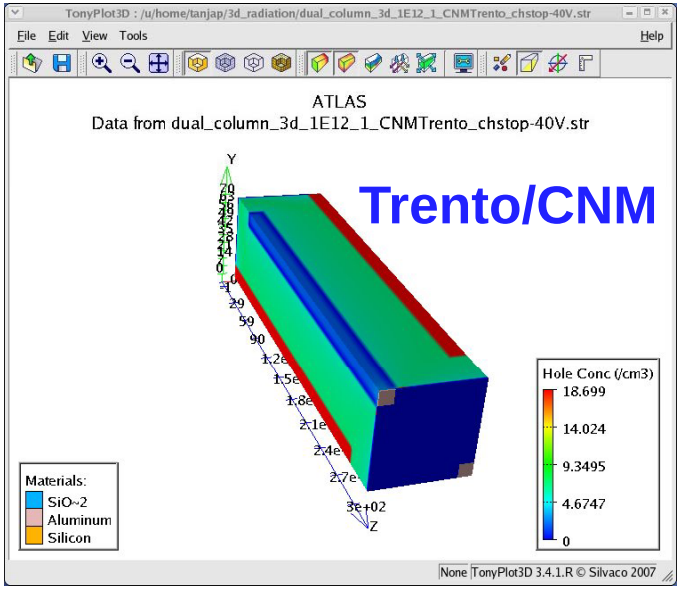




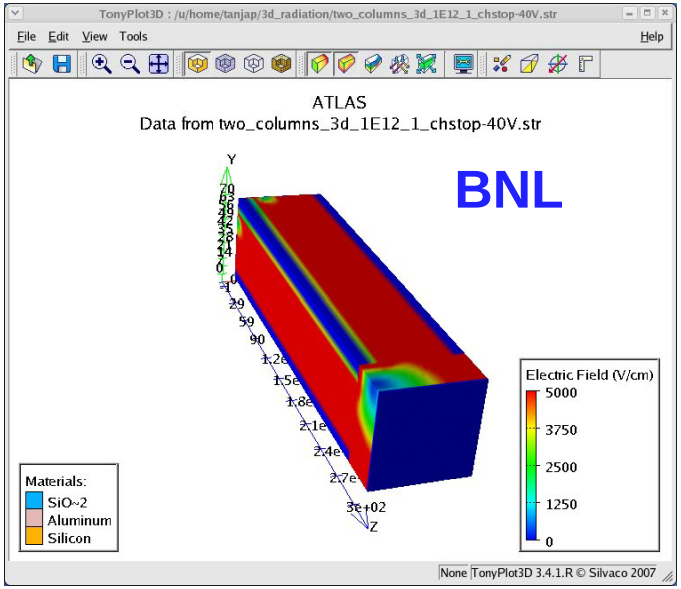
Comparing dual column 3D detectors (40V)

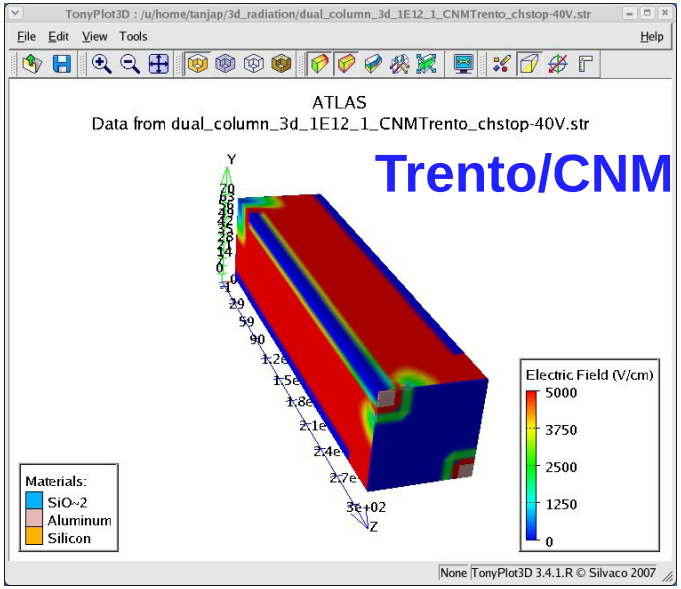
Hole concentration





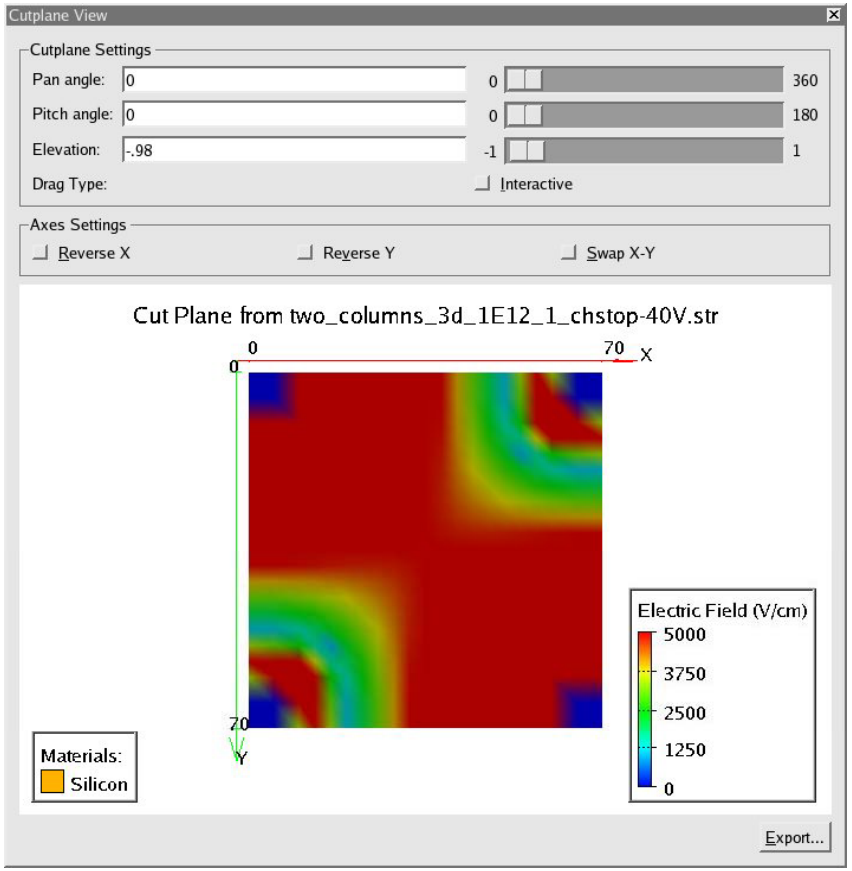
Electric field



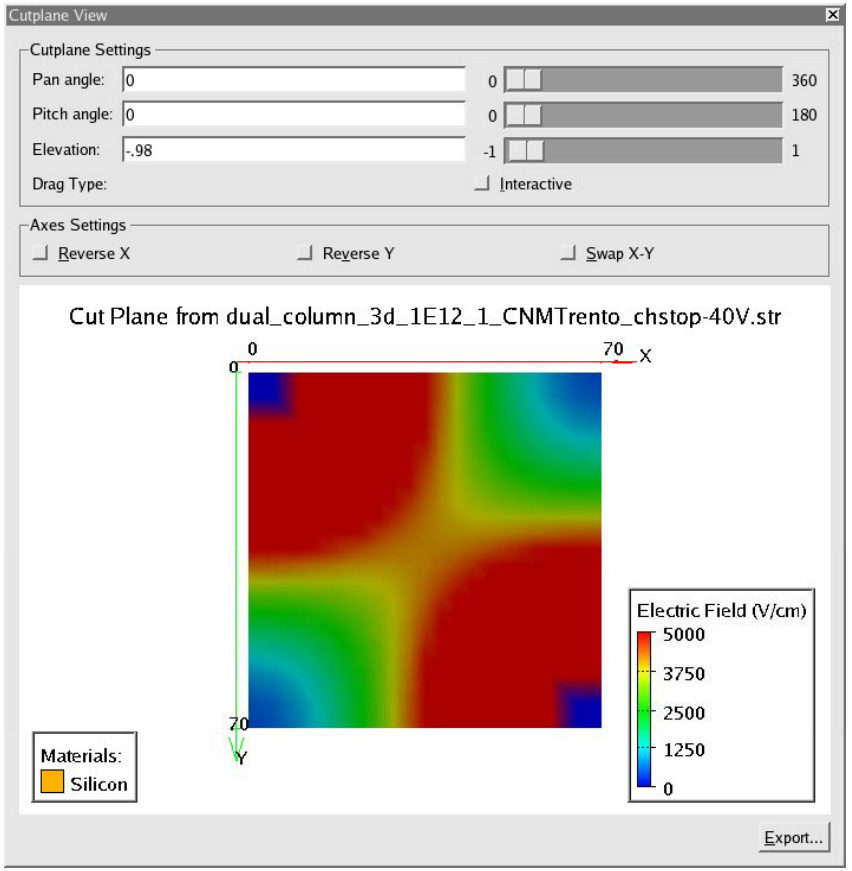


Comparing dual column 3D detectors (40V)

BNL



Trento/CNM

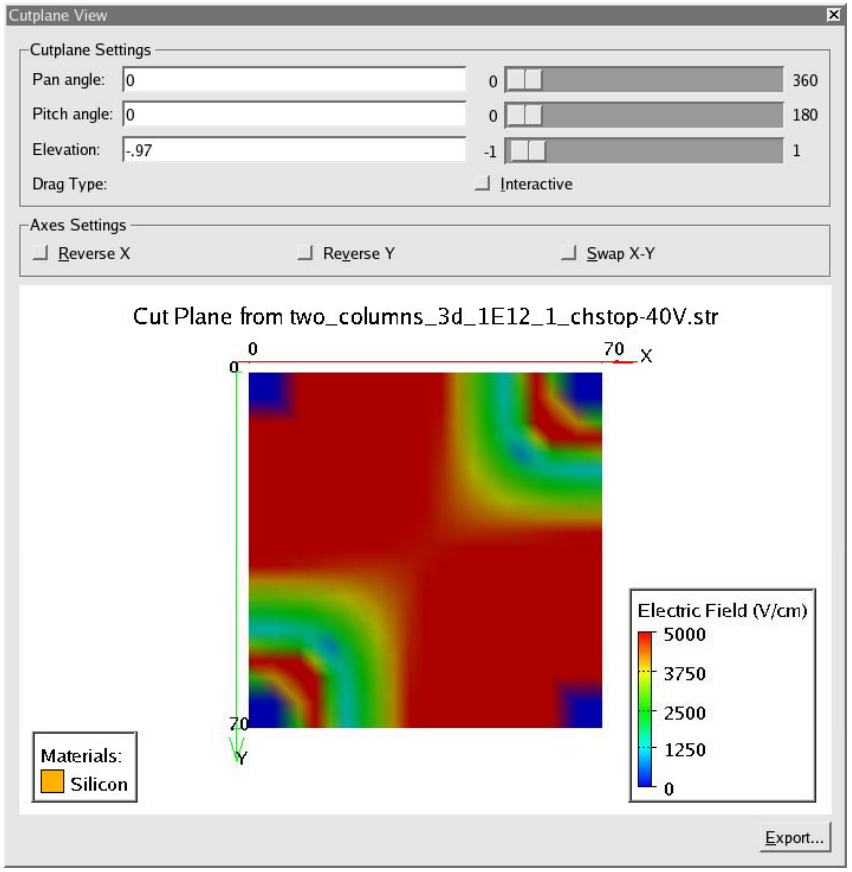


1 µm from the front surface

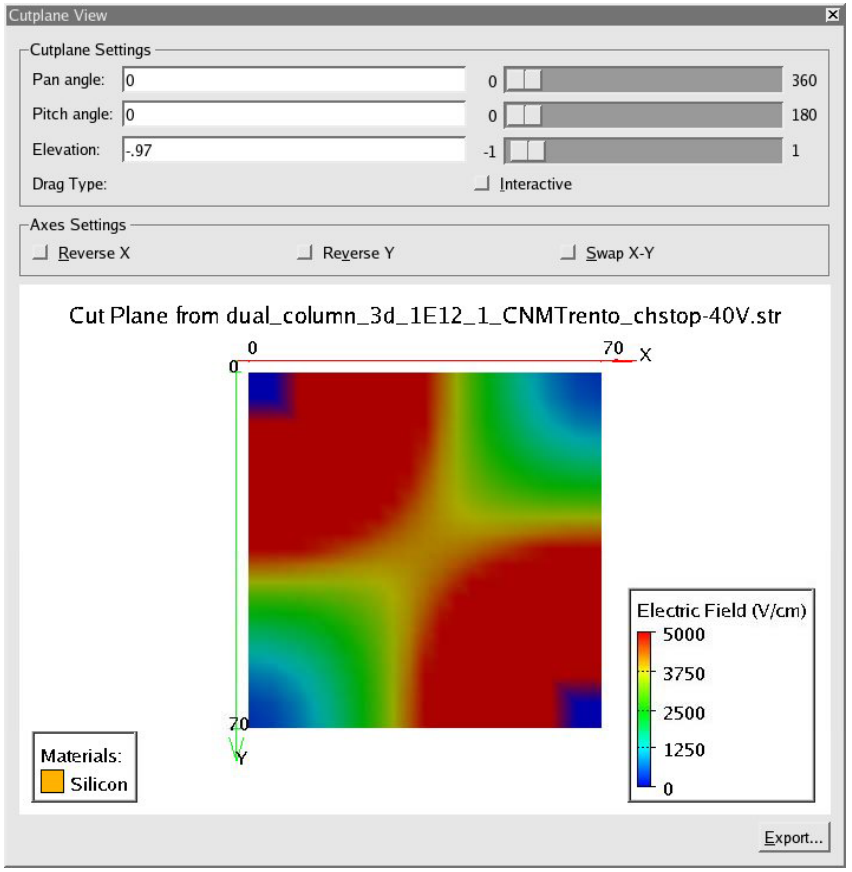
Electric field

Comparing dual column 3D detectors (40V)

BNL



Trento/CNM

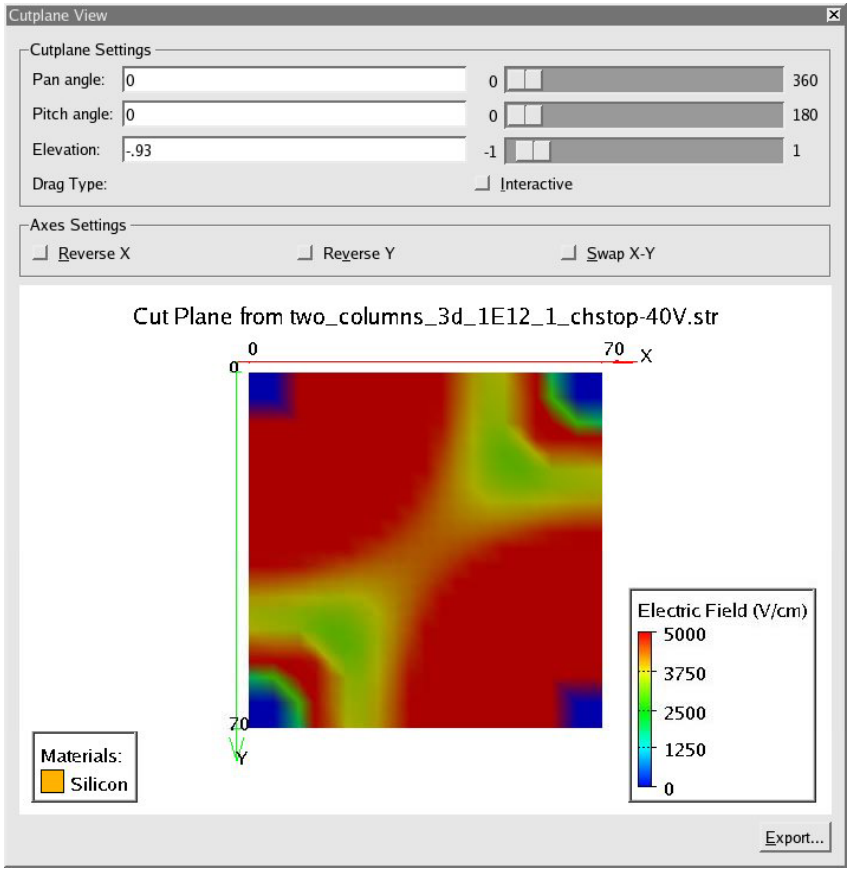


5 µm from the front surface

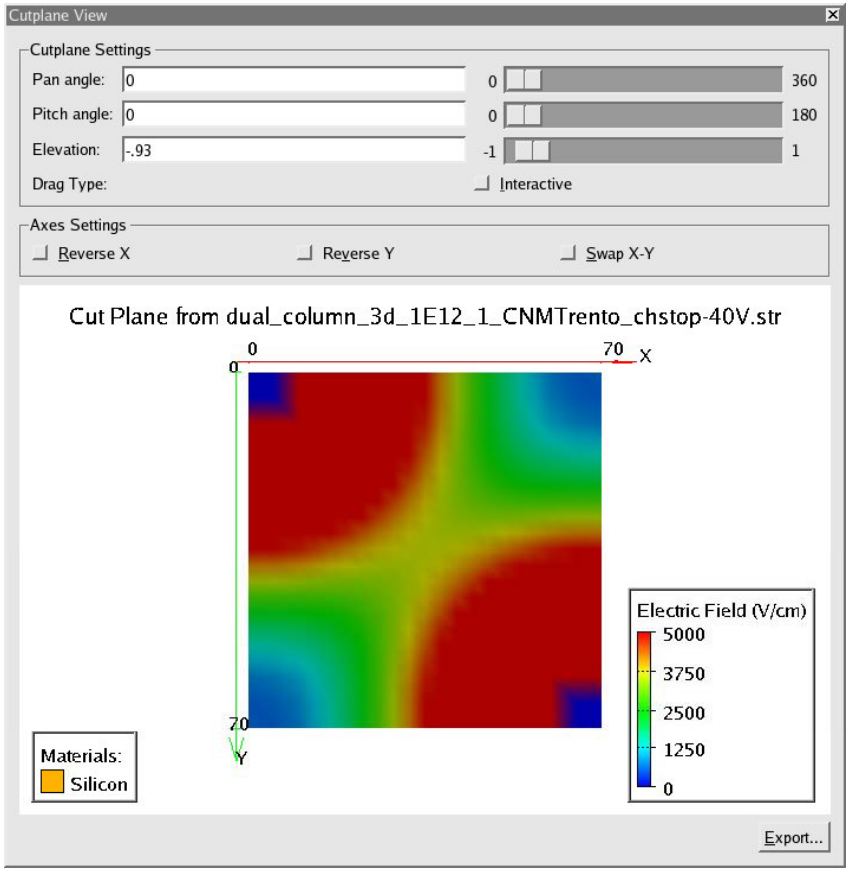
Electric field

Comparing dual column 3D detectors (40V)

BNL



Trento/CNM

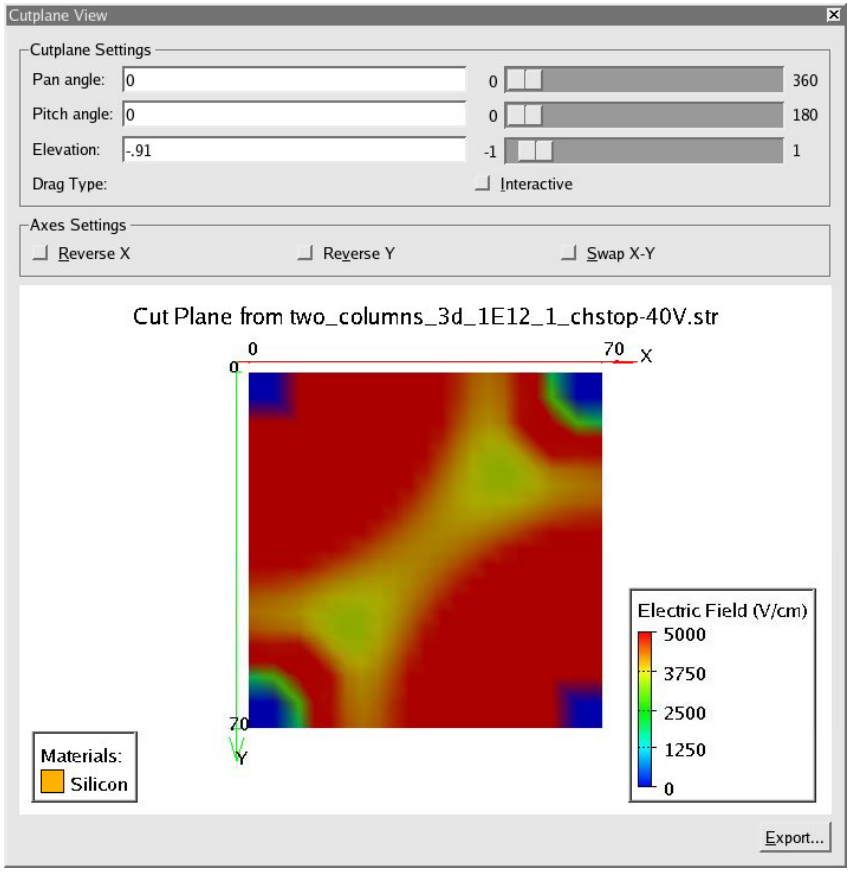


10 µm from the front surface

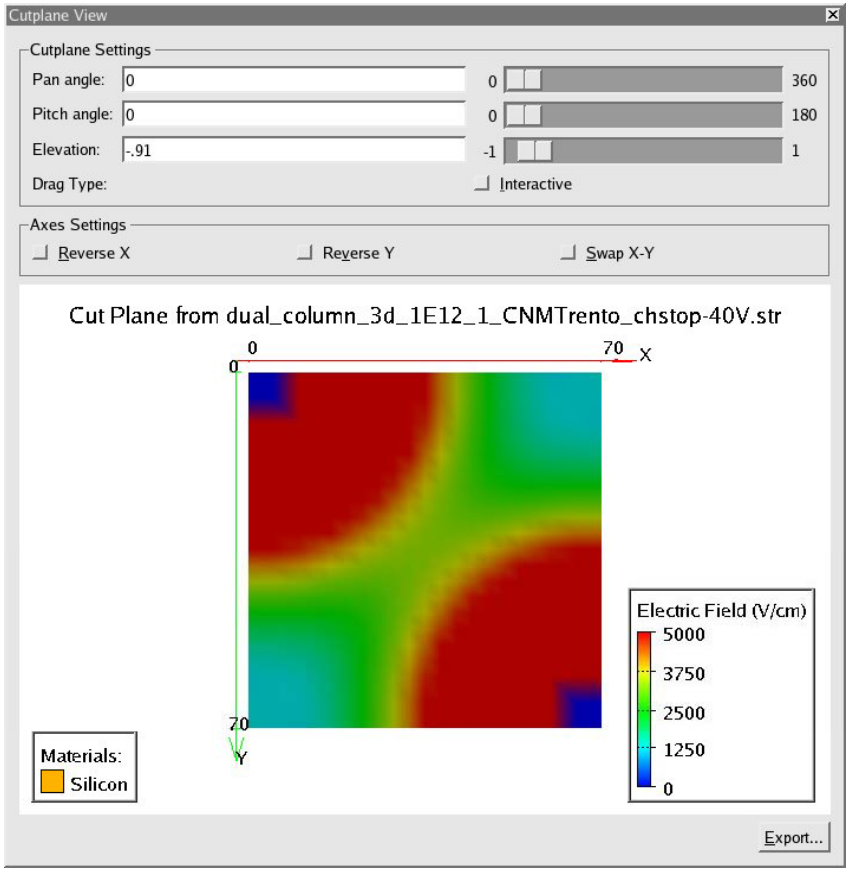
Electric field

Comparing dual column 3D detectors (40V)

BNL



Trento/CNM

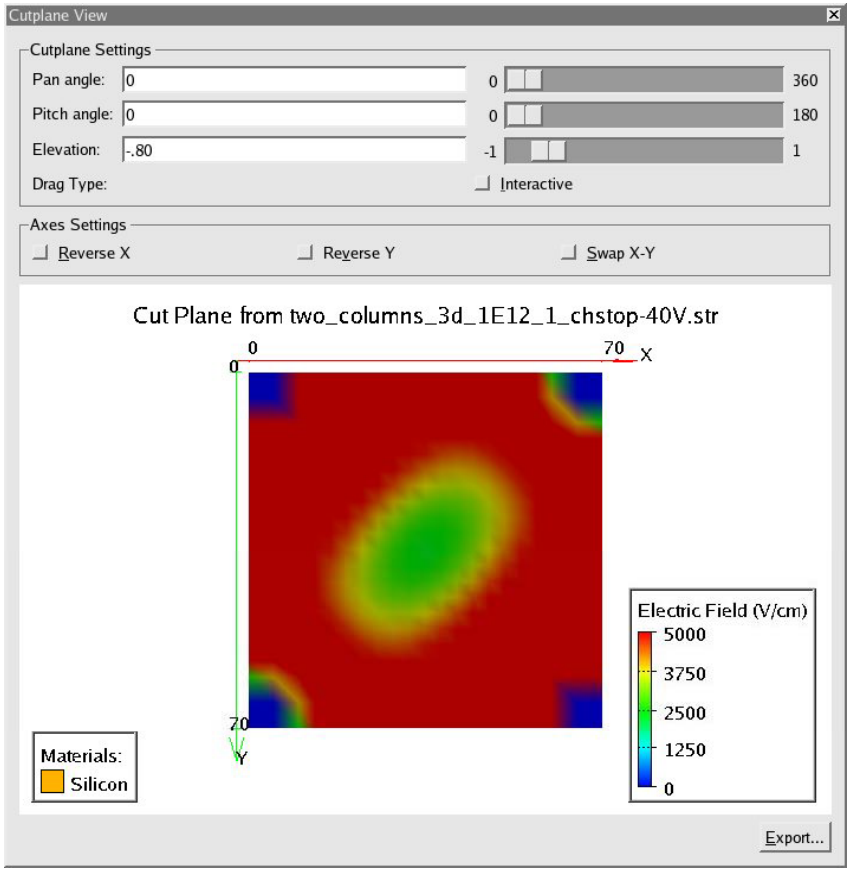


15 µm from the front surface

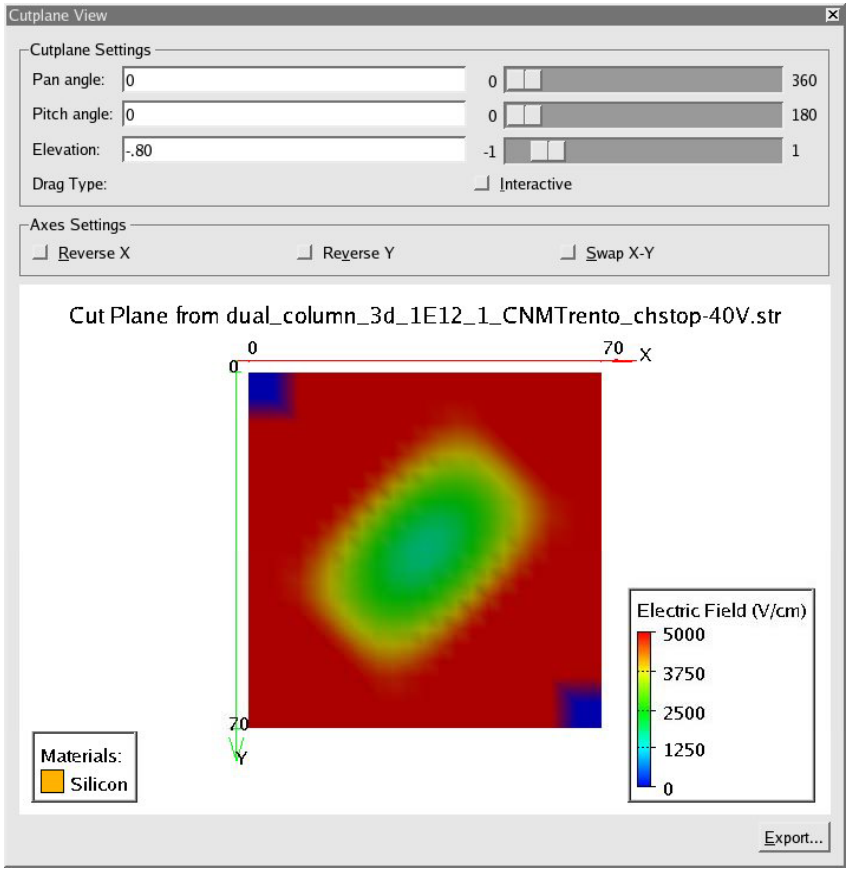
Electric field

Comparing dual column 3D detectors (40V)

BNL



Trento/CNM

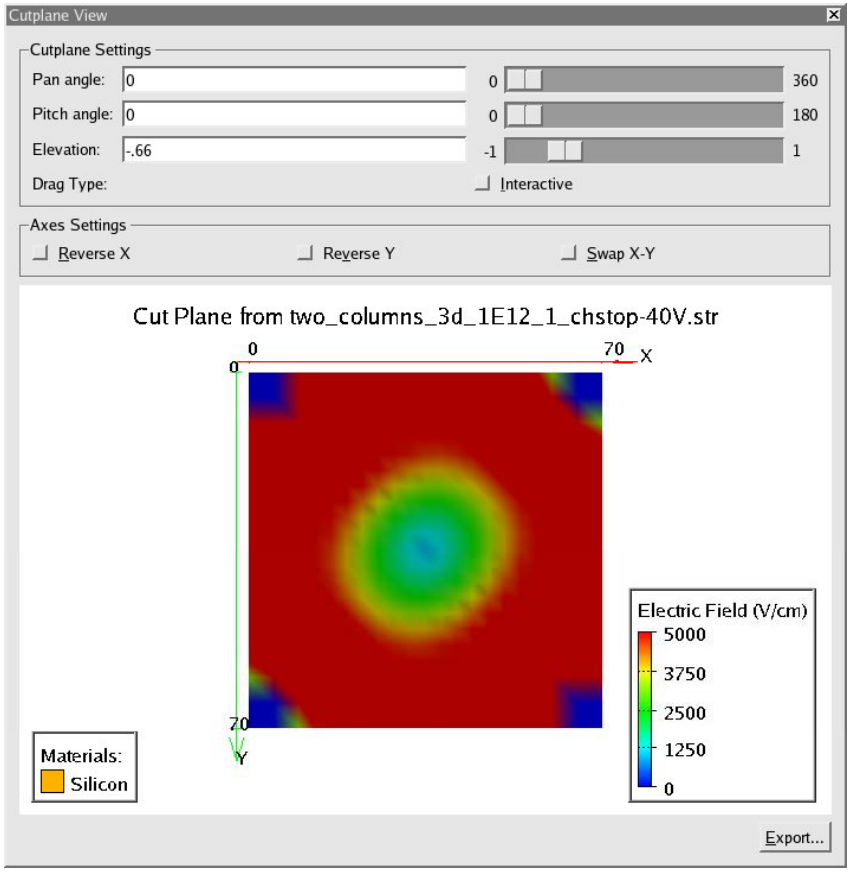


30 µm from the front surface

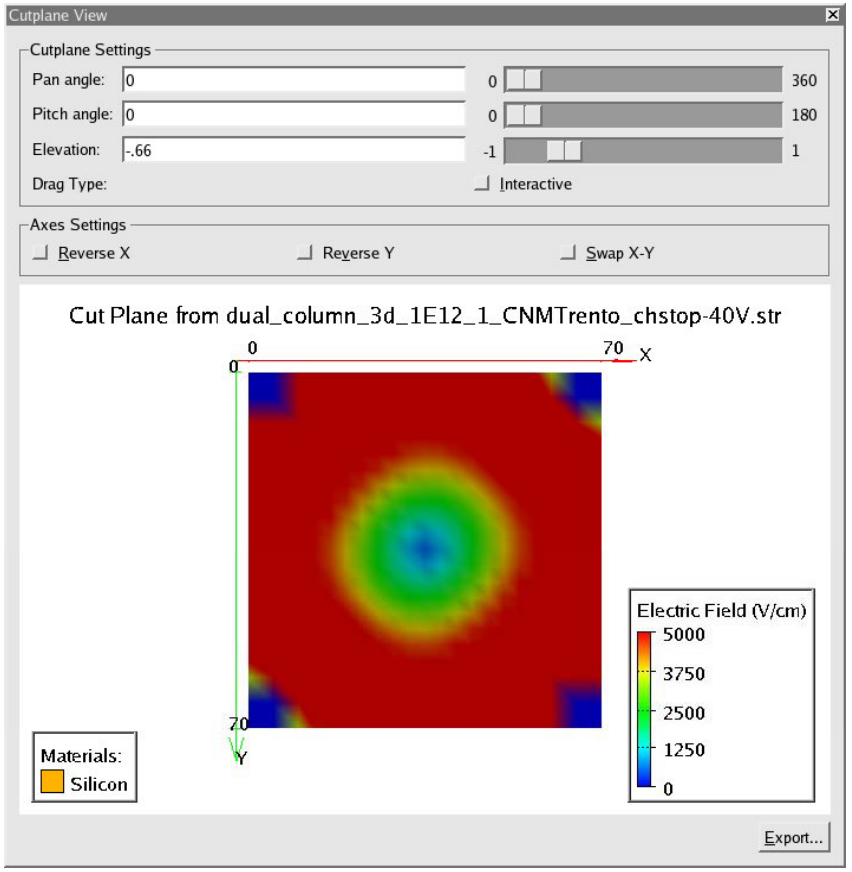
Electric field

Comparing dual column 3D detectors (40V)

BNL



Trento/CNM

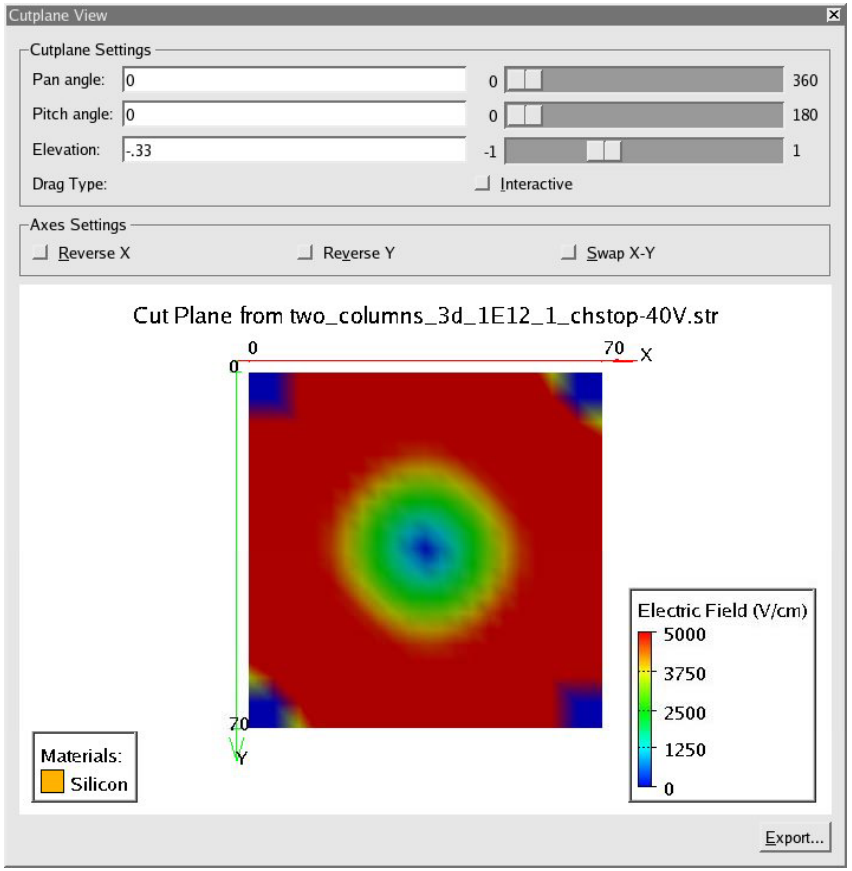


50 µm from the front surface

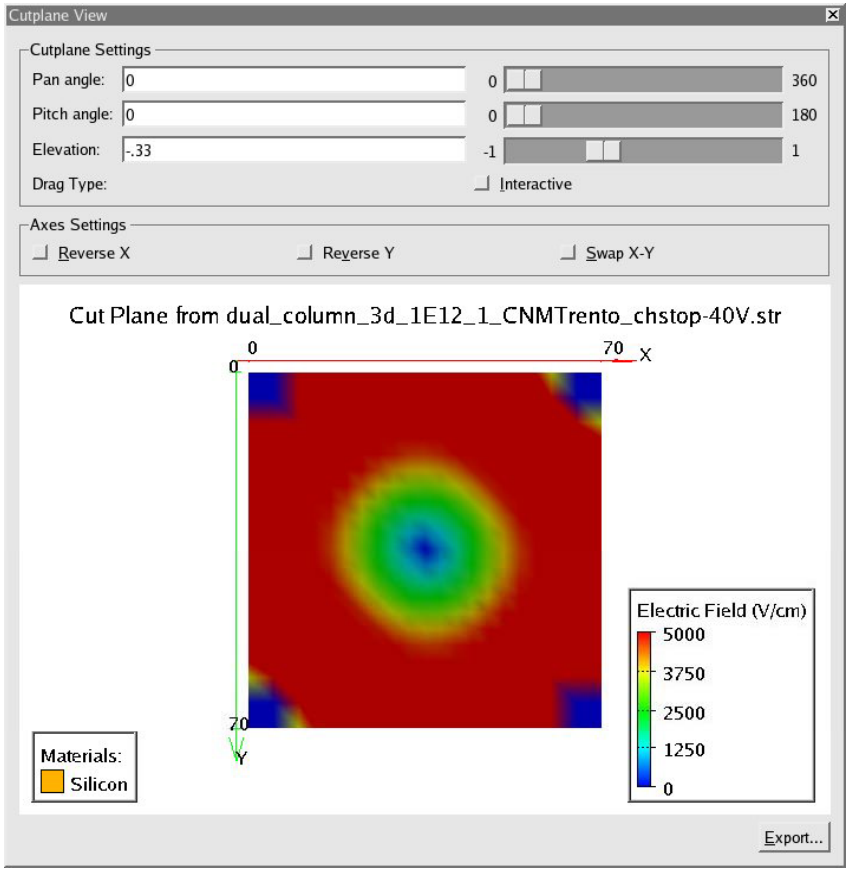
Electric field

Comparing dual column 3D detectors (40V)

BNL



Trento/CNM

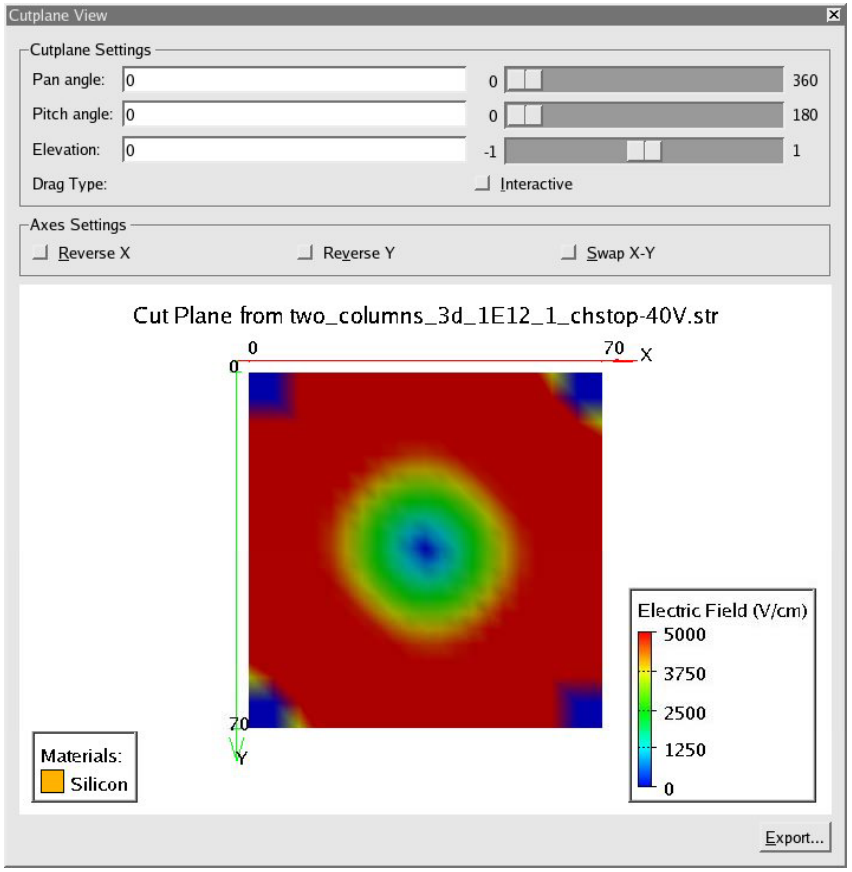


100 µm from the front surface

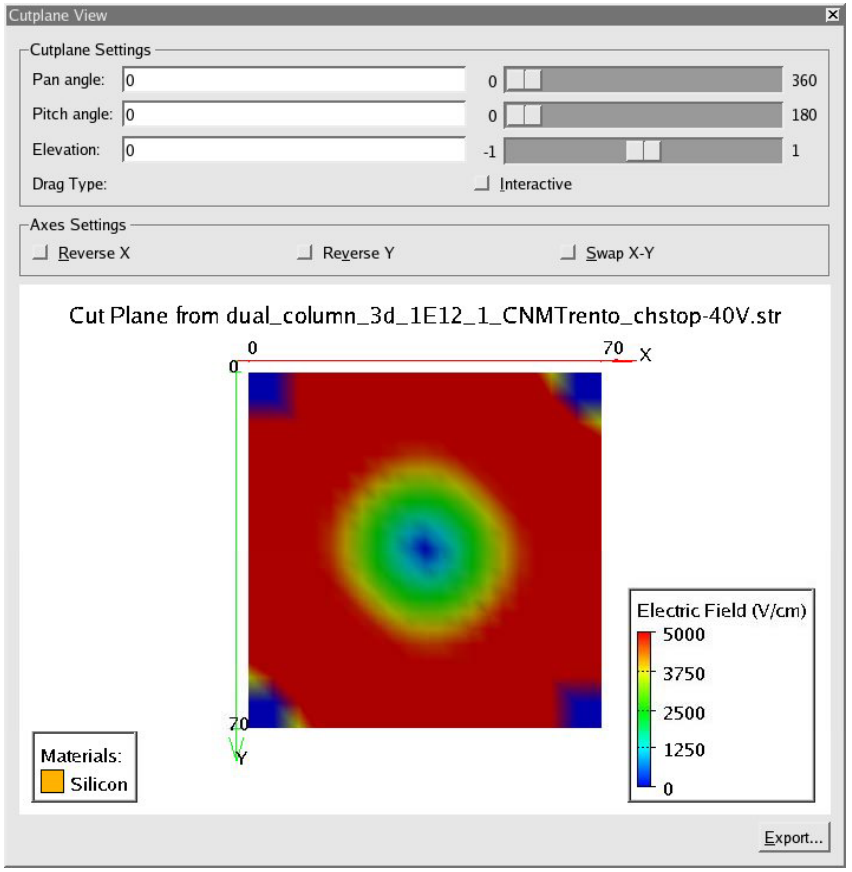
Electric field

Comparing dual column 3D detectors (40V)

BNL



Trento/CNM

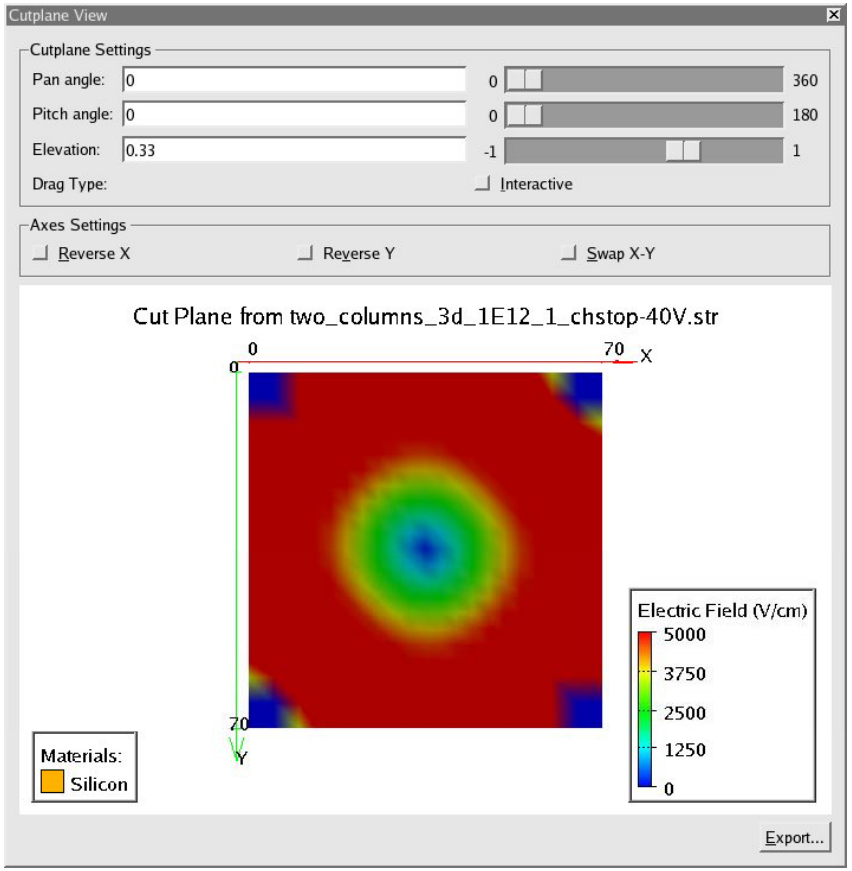


150 µm from the front surface

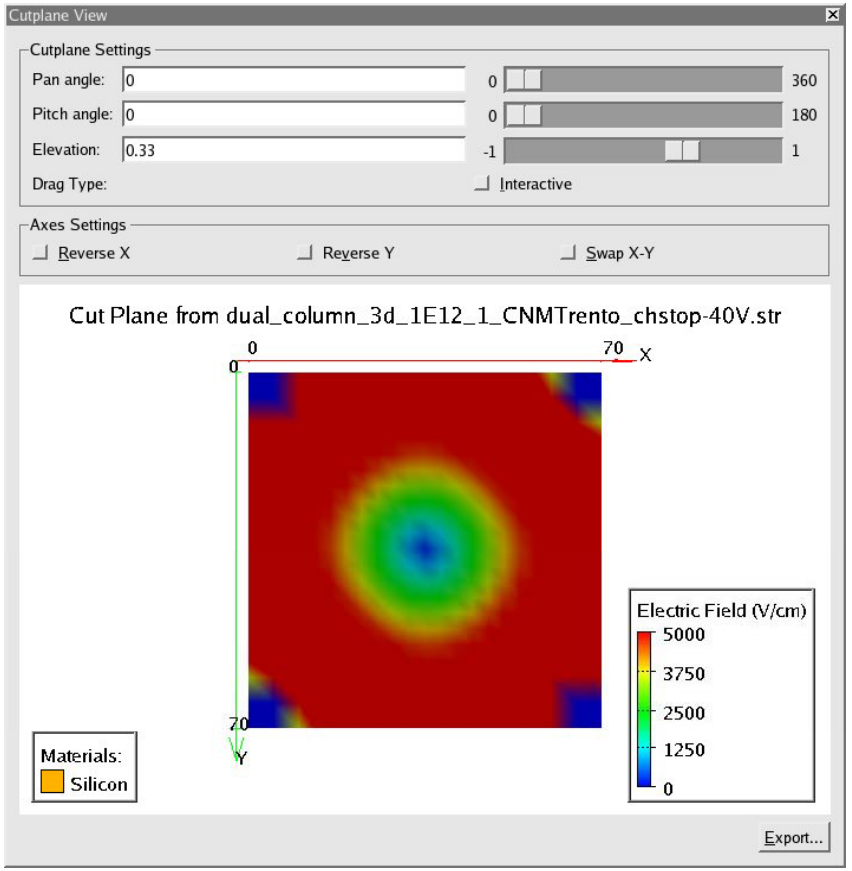
Electric field

Comparing dual column 3D detectors (40V)

BNL



Trento/CNM

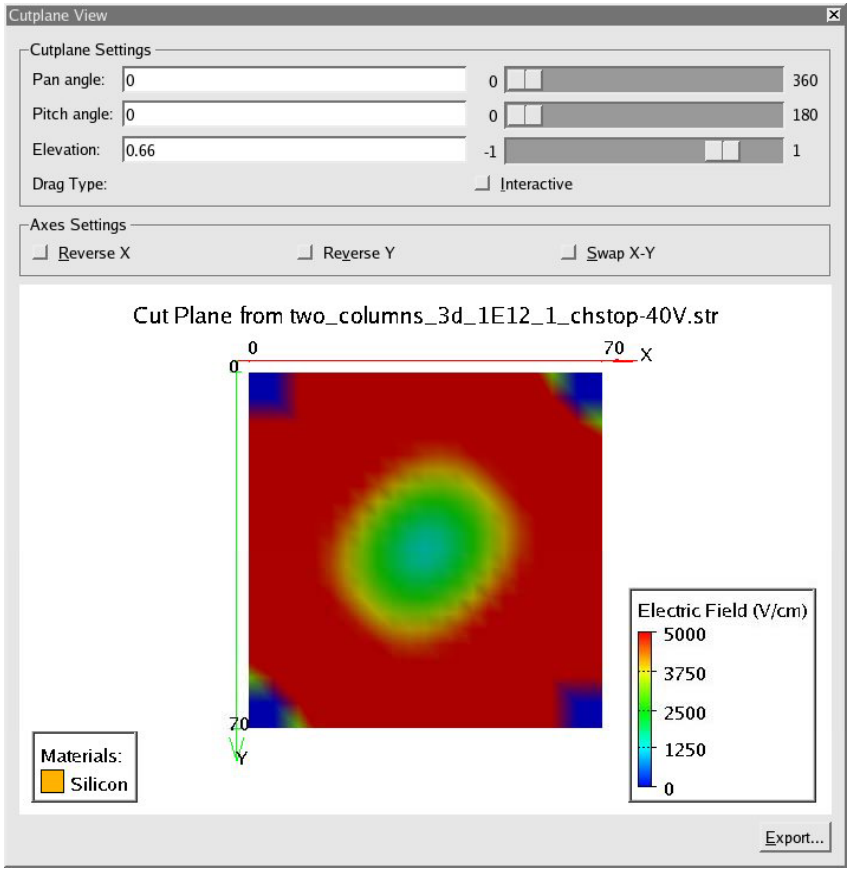


200 µm from the front surface

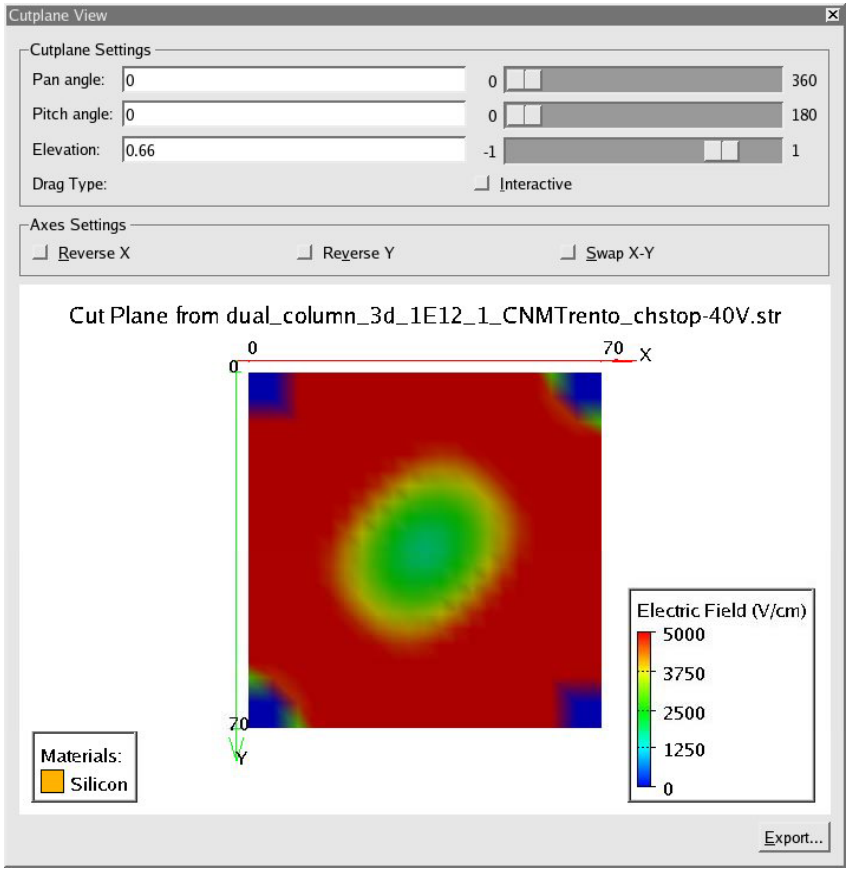
Electric field

Comparing dual column 3D detectors (40V)

BNL



Trento/CNM

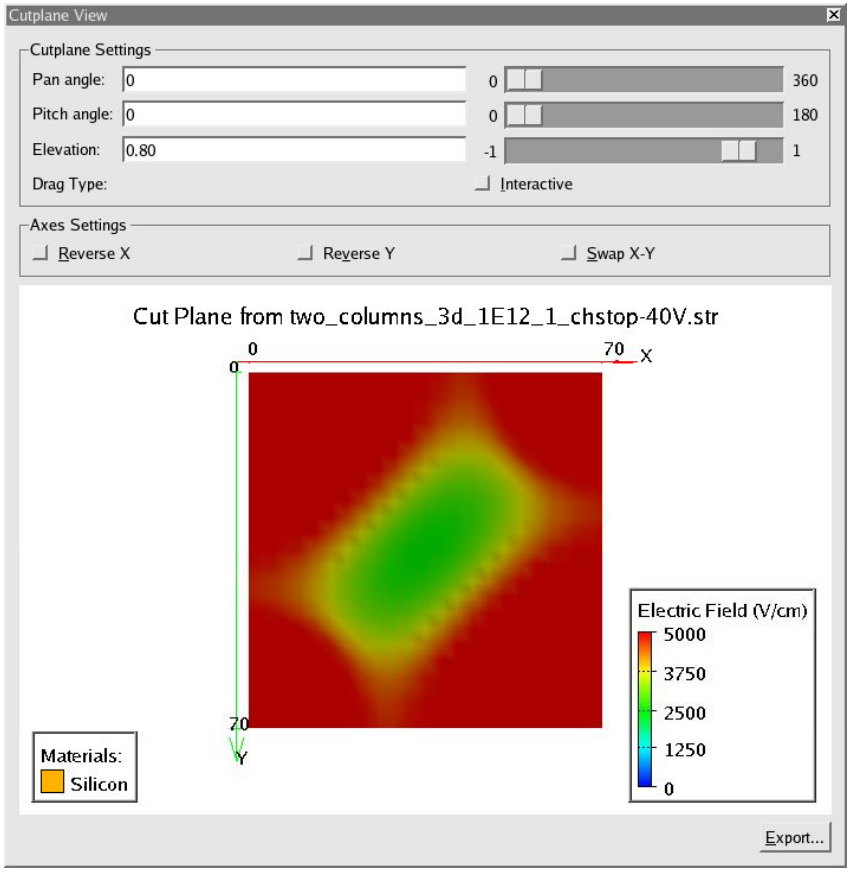


250 µm from the front surface

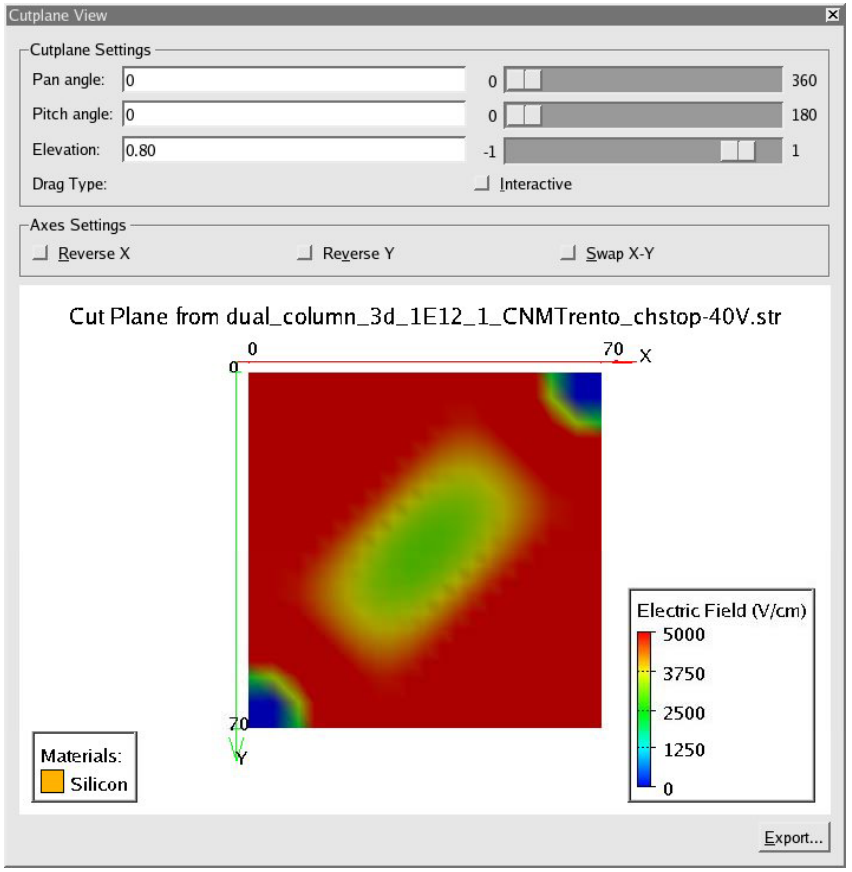
Electric field

Comparing dual column 3D detectors (40V)

BNL



Trento/CNM

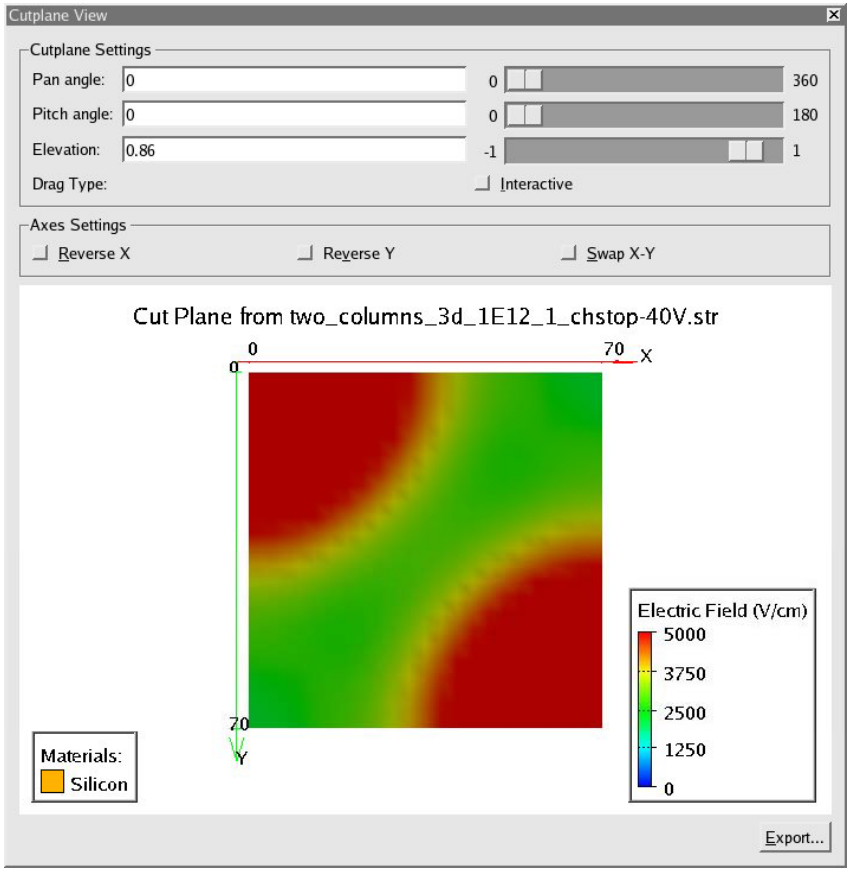


270 µm from the front surface

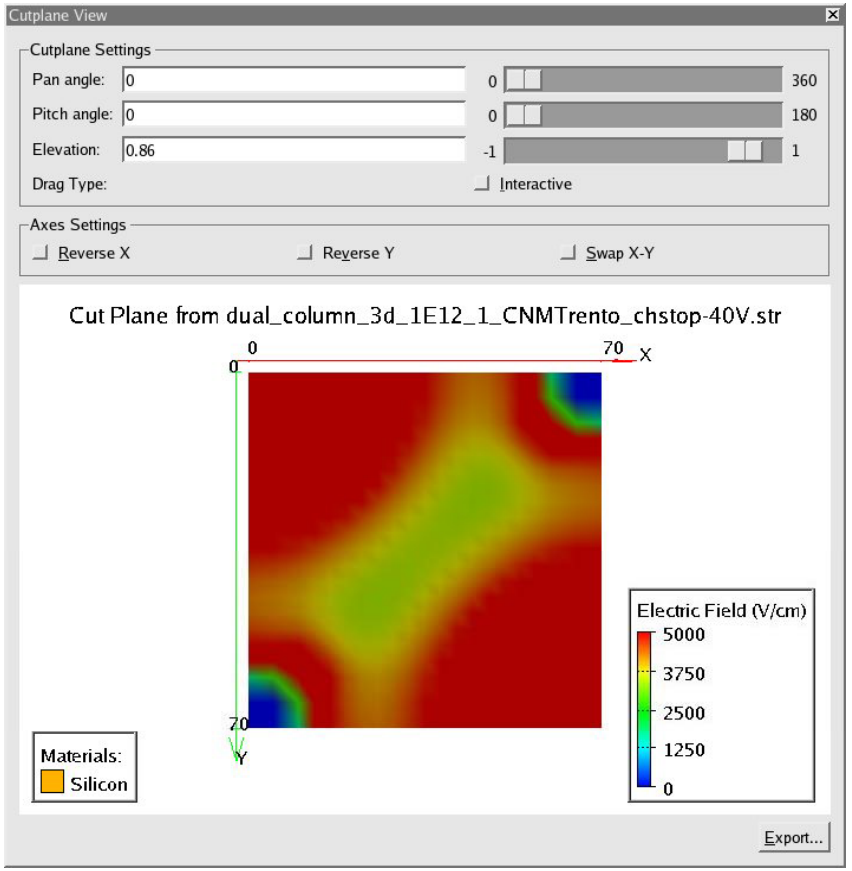
Electric field

Comparing dual column 3D detectors (40V)

BNL



Trento/CNM

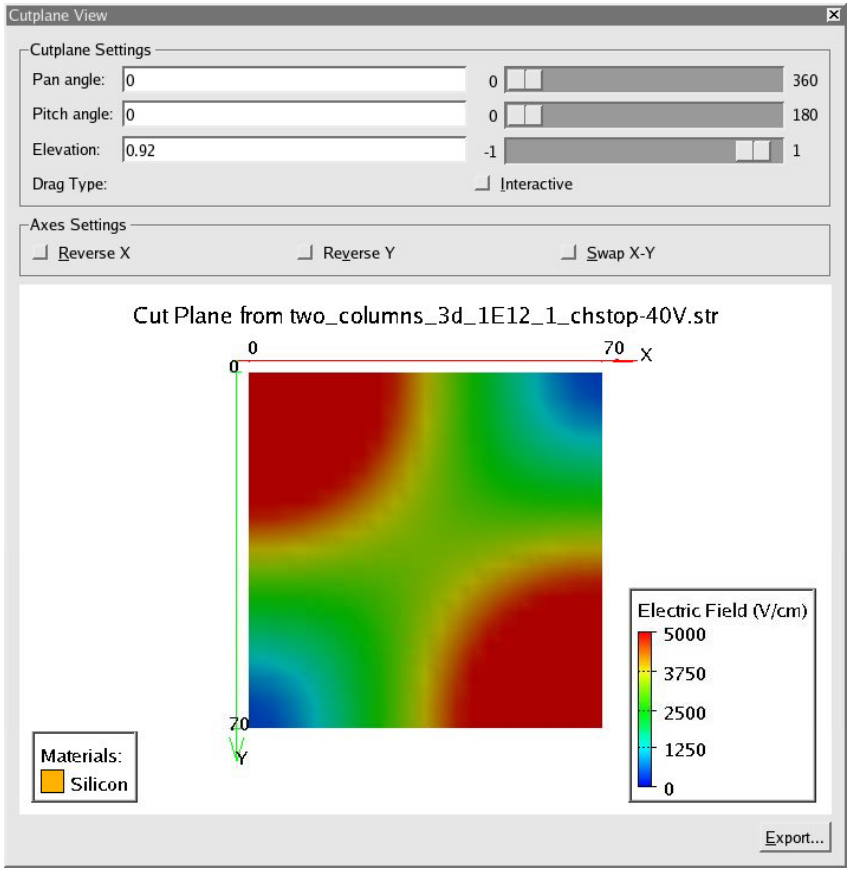


280 µm from the front surface

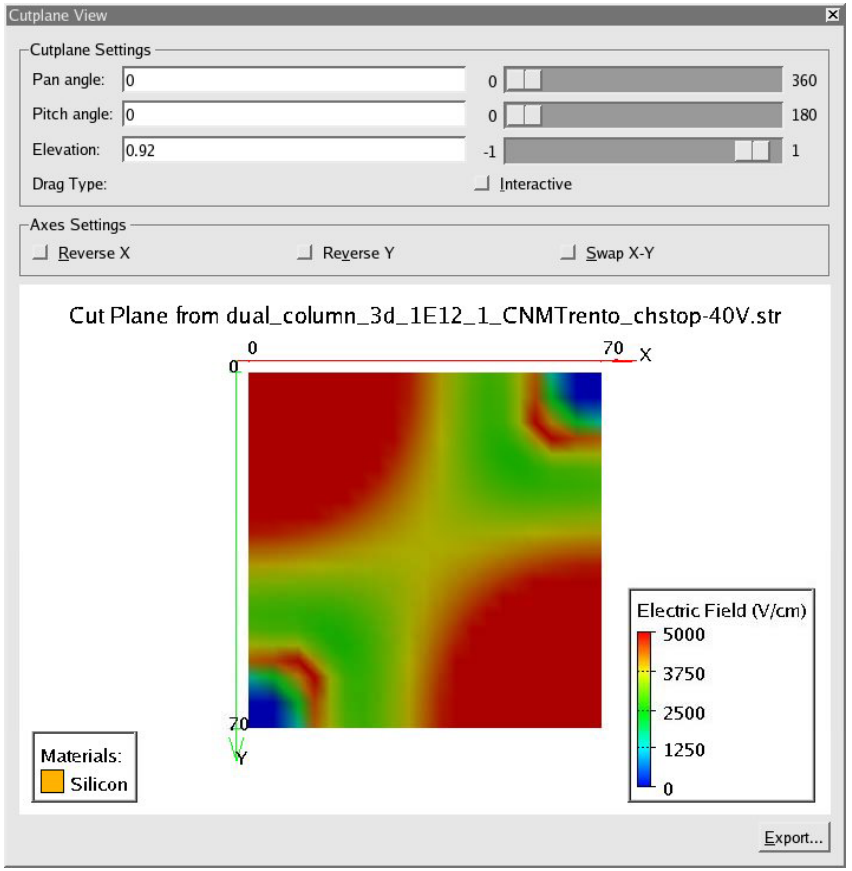
Electric field

Comparing dual column 3D detectors (40V)

BNL



Trento/CNM

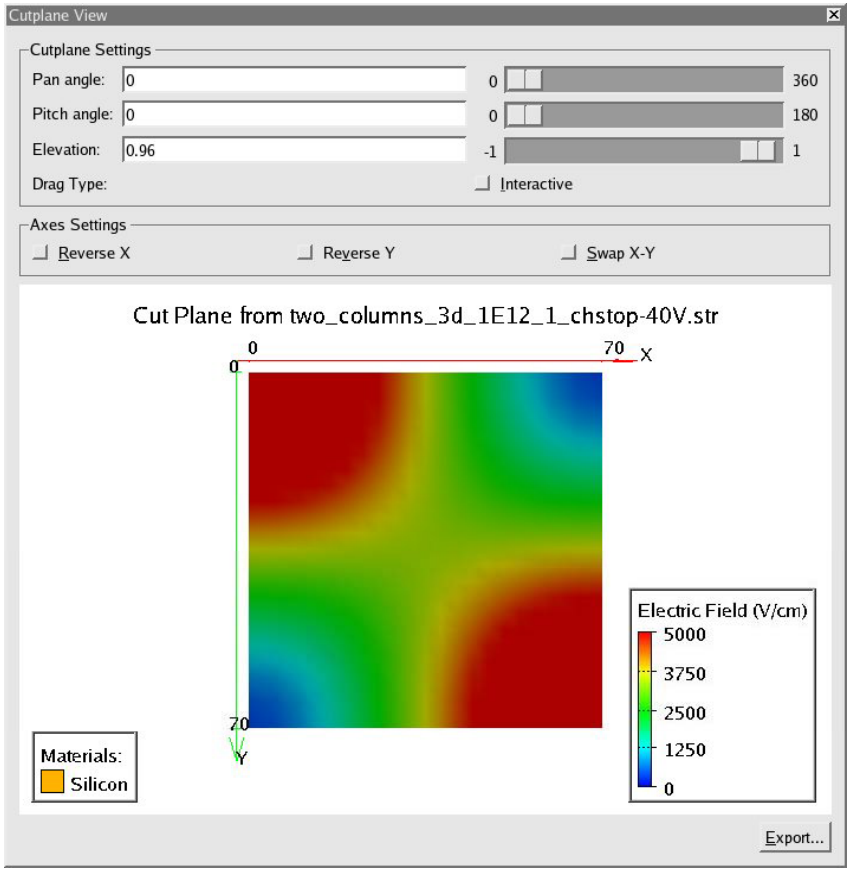


290 µm from the front surface

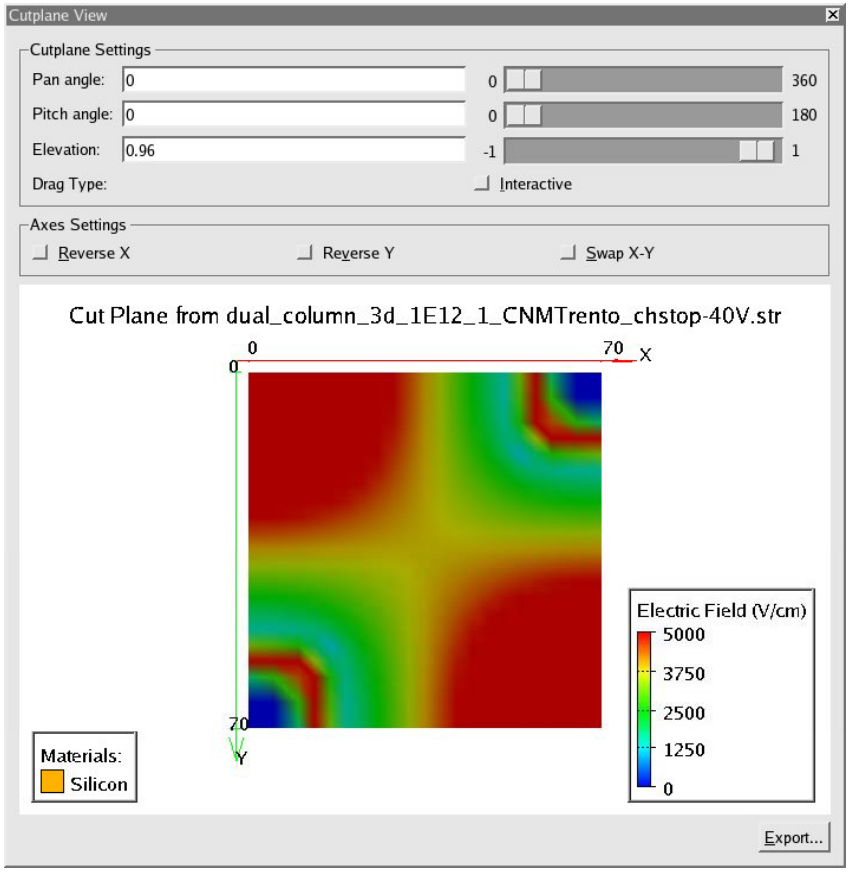
Electric field

Comparing dual column 3D detectors (40V)

BNL



Trento/CNM

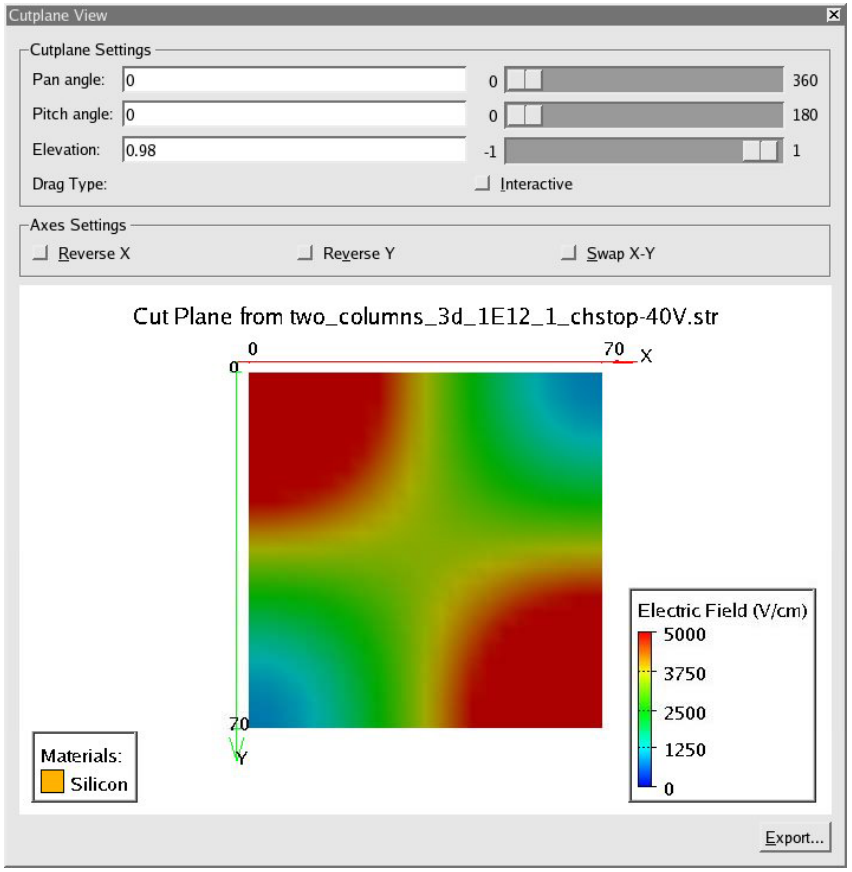


295 µm from the front surface

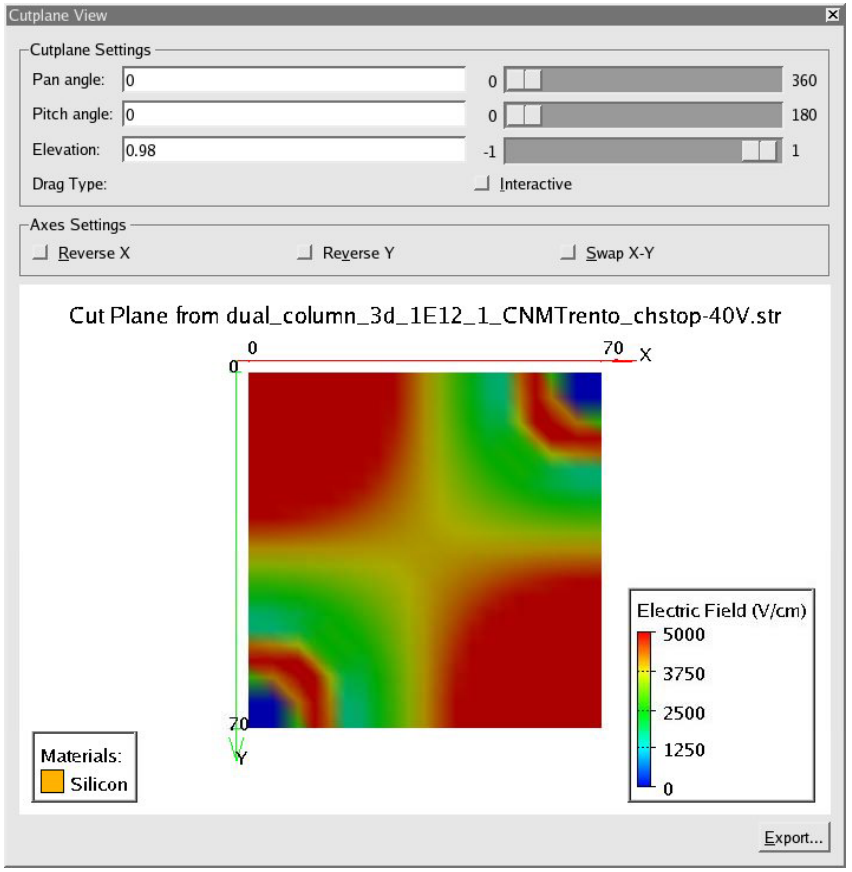
Electric field

Comparing dual column 3D detectors (40V)

BNL



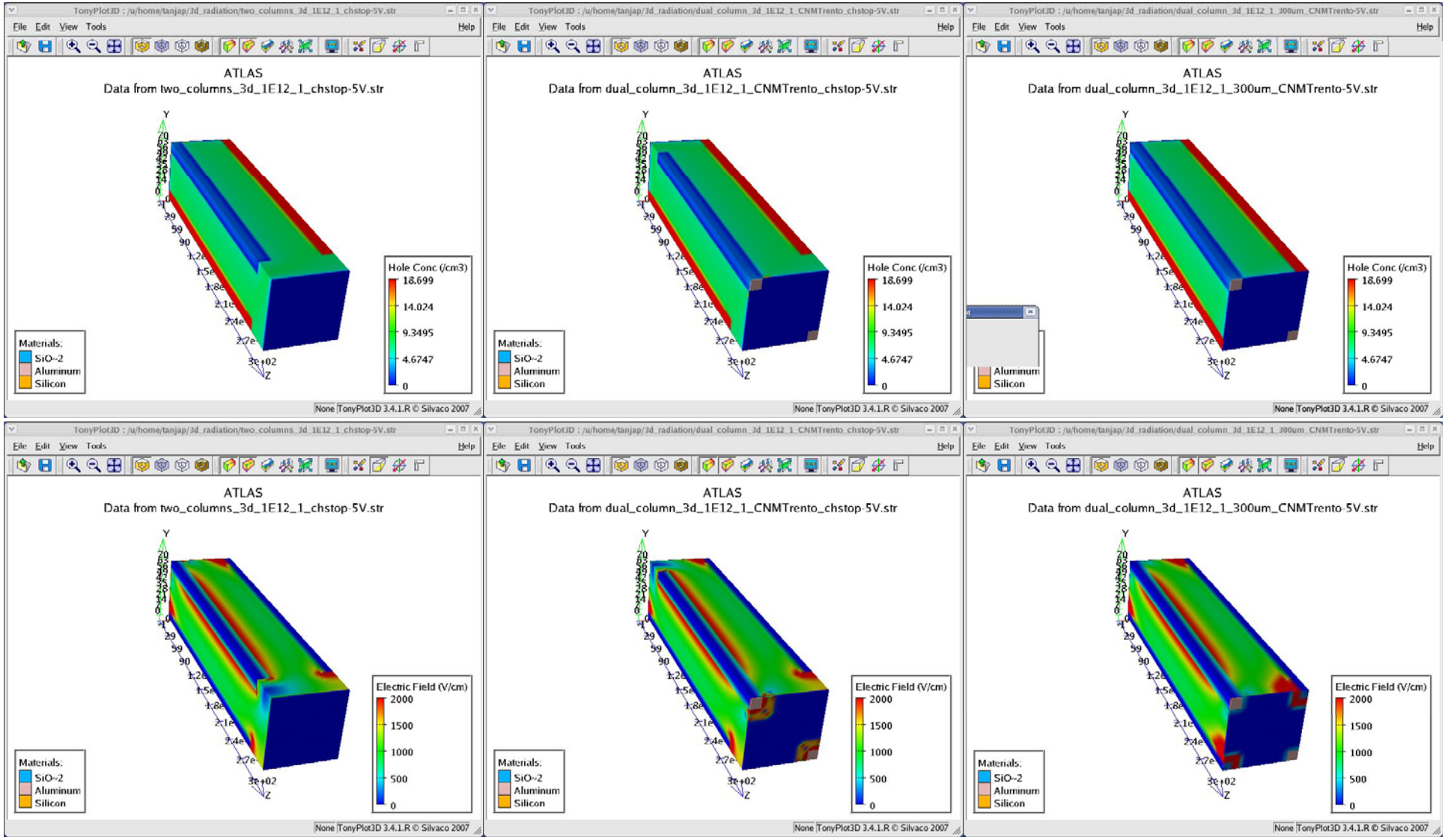
Trento/CNM



299 µm from the front surface

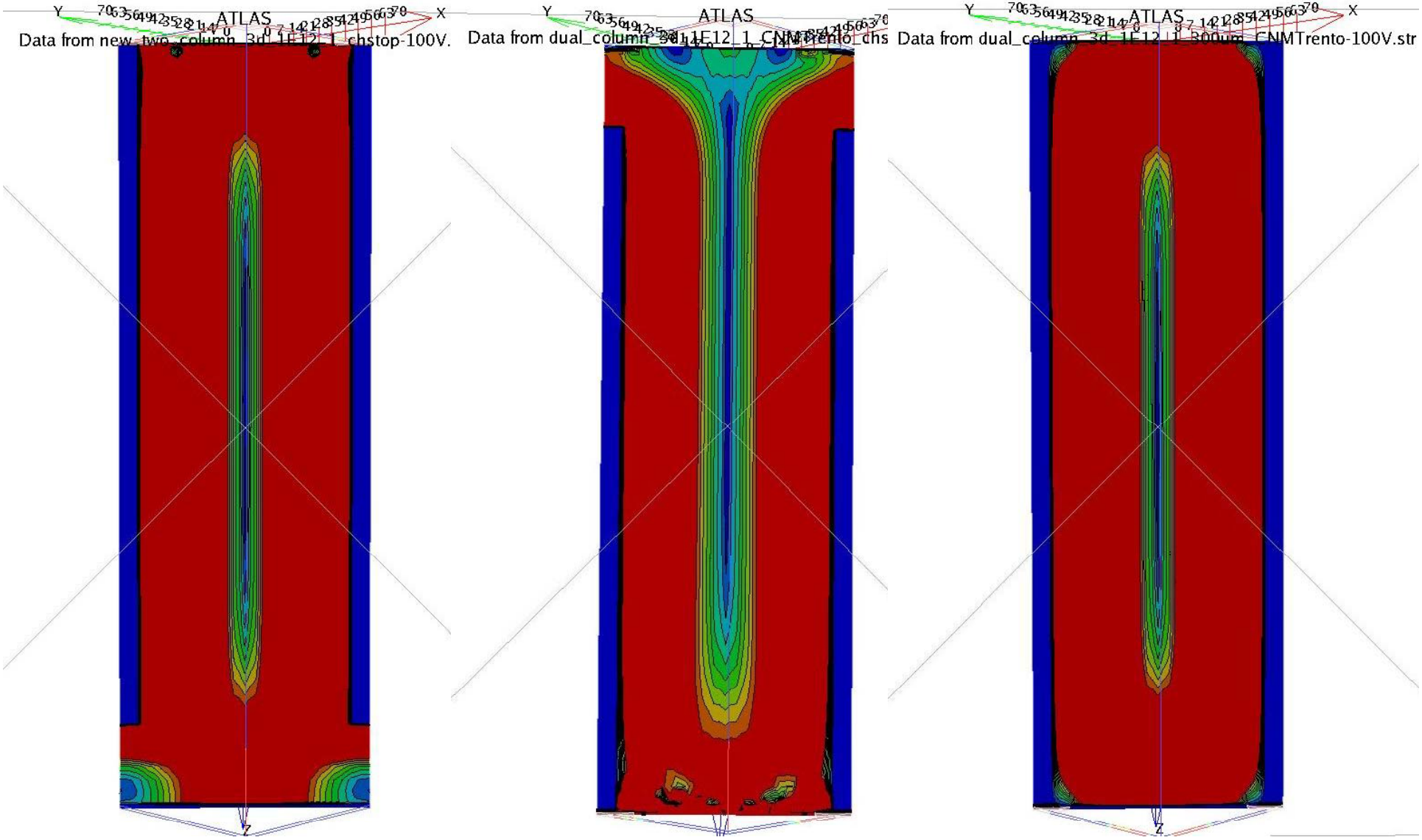
Electric field

Dual column 3D detector, 5V, hole concentration and electric field



BNL CNM, Trento UH, Parker et al.

Dual column 3D detector, 100V, electric field between n-columns



BNL CNM, Trento UH, Parker et al.

Profiles are similar, minor differences on surfaces

Advantages and disadvantages

- **1-column vs. dual column**
  - **1-column: one-sided process (BNL: true one-sided process); one-sided access; wafer mechanical strength; more rad-hard than 2d**

    Non-uniform e-field along the column, not super-radiation hard
  - **Dual column: better e-field, super-radiation hard**

    Complicated processing
- **BNL 1-column vs. Trento 1-column**
  - **BNL: true-one-sided process; high e-field on the pixel side; some high e-field can be developed along the junction column at high voltages**

- **BNL dual-column vs. UH dual-column**
  - **BNL: true one-sided process; one-sided access; wafer mechanical strength; sensitivity under the columns (reducing the dead volume)**

- **BNL dual-column vs. Trento/CNM dual-column**
  - **BNL: true-one-sided process**
  - **Trento/CNM: 2-sided access: separation of two different high bias voltages**

    double-sided process
- **E-field profiles are all similar**

Structure	E-field profile	Rad-hard	Mechanical integrity	Processing	Accessibility	Sensitivity under the column
Std 3d (UH)	Good	Super	No	Difficult	One-side	No
BNL dual-C	Good	Super	Good	True one-sided	One-side	Some
Trento/CNM dual-C	Good	Super	Good	Double-sided	Two-side	Some
BNL single-C	Low field on the back side	Good	Good	True one-sided	One-side	Some
Trento single-C	Low field on the front and center	Good	Good	One-sided	One-side	Some

Conclusions

- **BNL one-sided single column and dual column 3D Si detectors have been simulated in detail and compared to various 3D detector structures.**
- **Dual column detectors are best in the radiation-hard, but single column detectors are easier to process.**
- **Disadvantage of these single column detectors is the non-uniform e-field.**
- **In BNL single column 3D detectors, some high field can be developed along the junction column.**