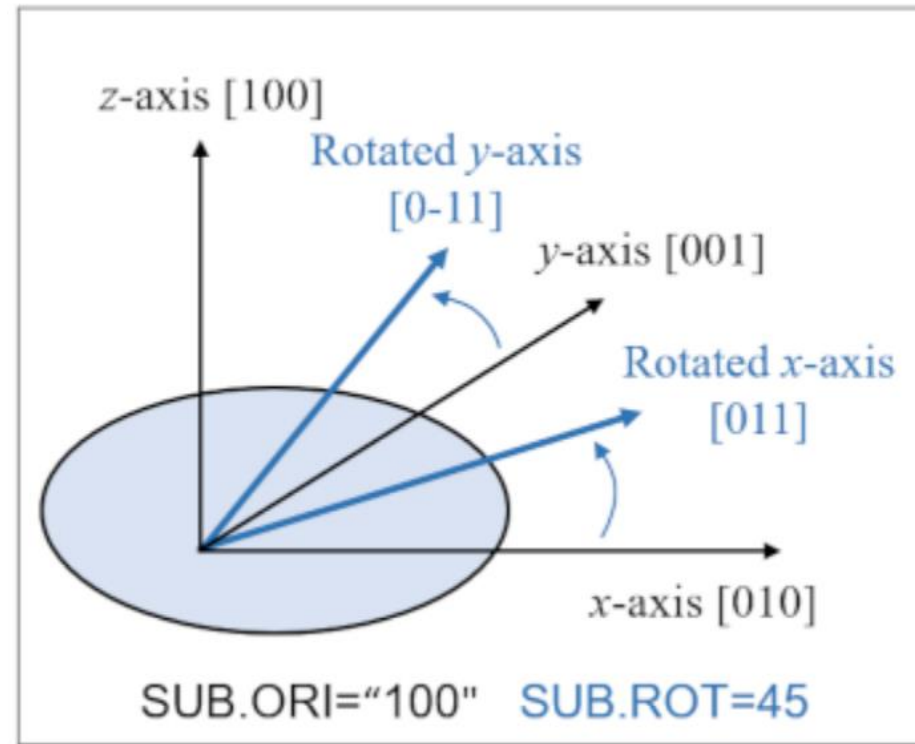
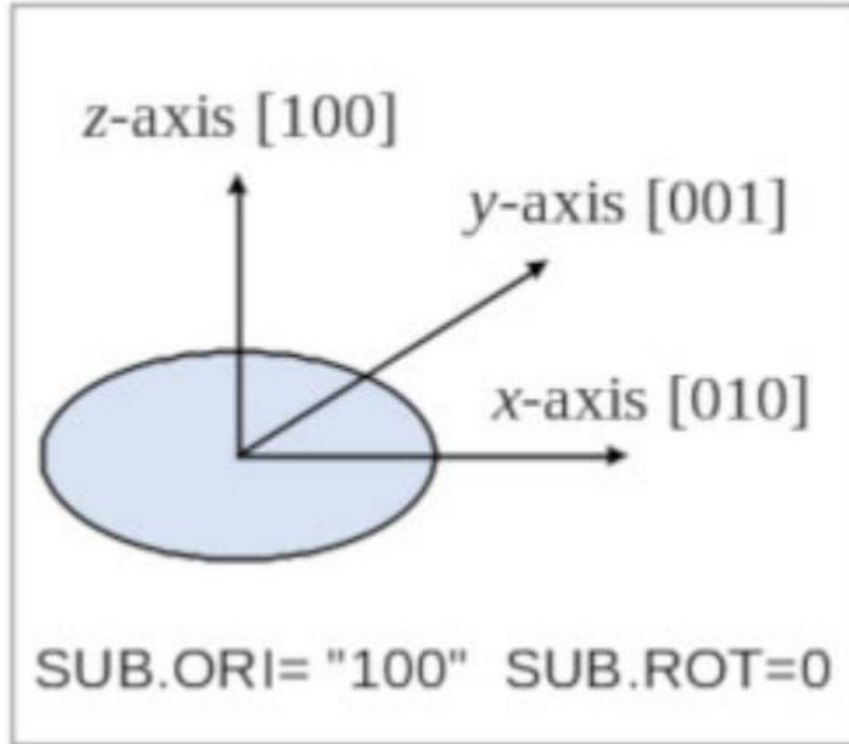


WORKING WITH IMPLANTS

**ECE 595 Semiconductor Device
Integration Through Simulation**

Tom Dungan

Planar HKMG CMOS Flow: Rotation for 110 Channels



The wafer plane is a {100} face, with z in the [100] direction (sub.ori=100). The wafer is rotated 45 degrees, so that the channel length is in a <110> direction; x is [011].

Note: sub.rot=45 ([110] channels) is the default in Victory Process, but it is good practice to specify the value explicitly.

Planar HKMG CMOS Flow: Rotation for Tilted Implants

When a tilt is imparted to an implant (with respect to the normal to the surface), wafer rotation should also be defined.

Implant rotation is defined with respect to the x-axis direction (which in turn depends on the wafer orientation set in the initialization by sub.rot).

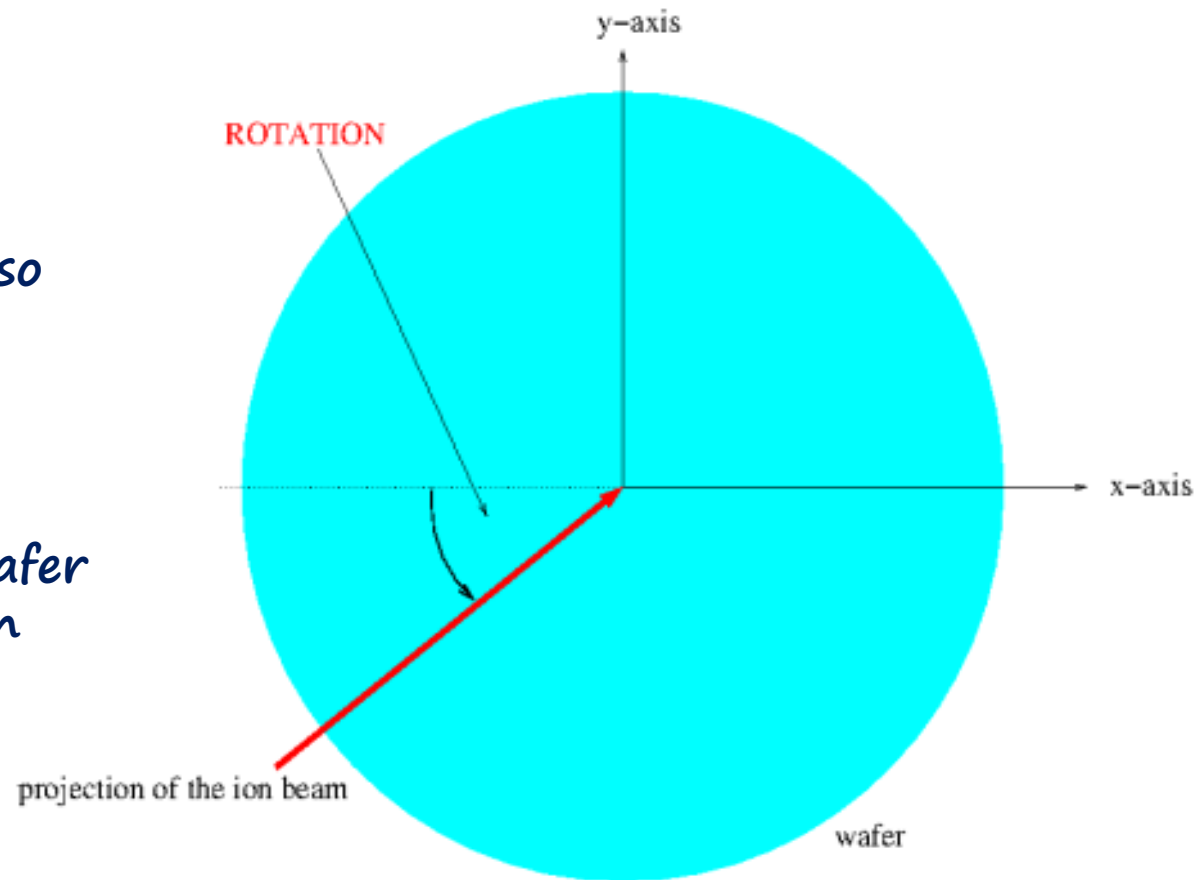
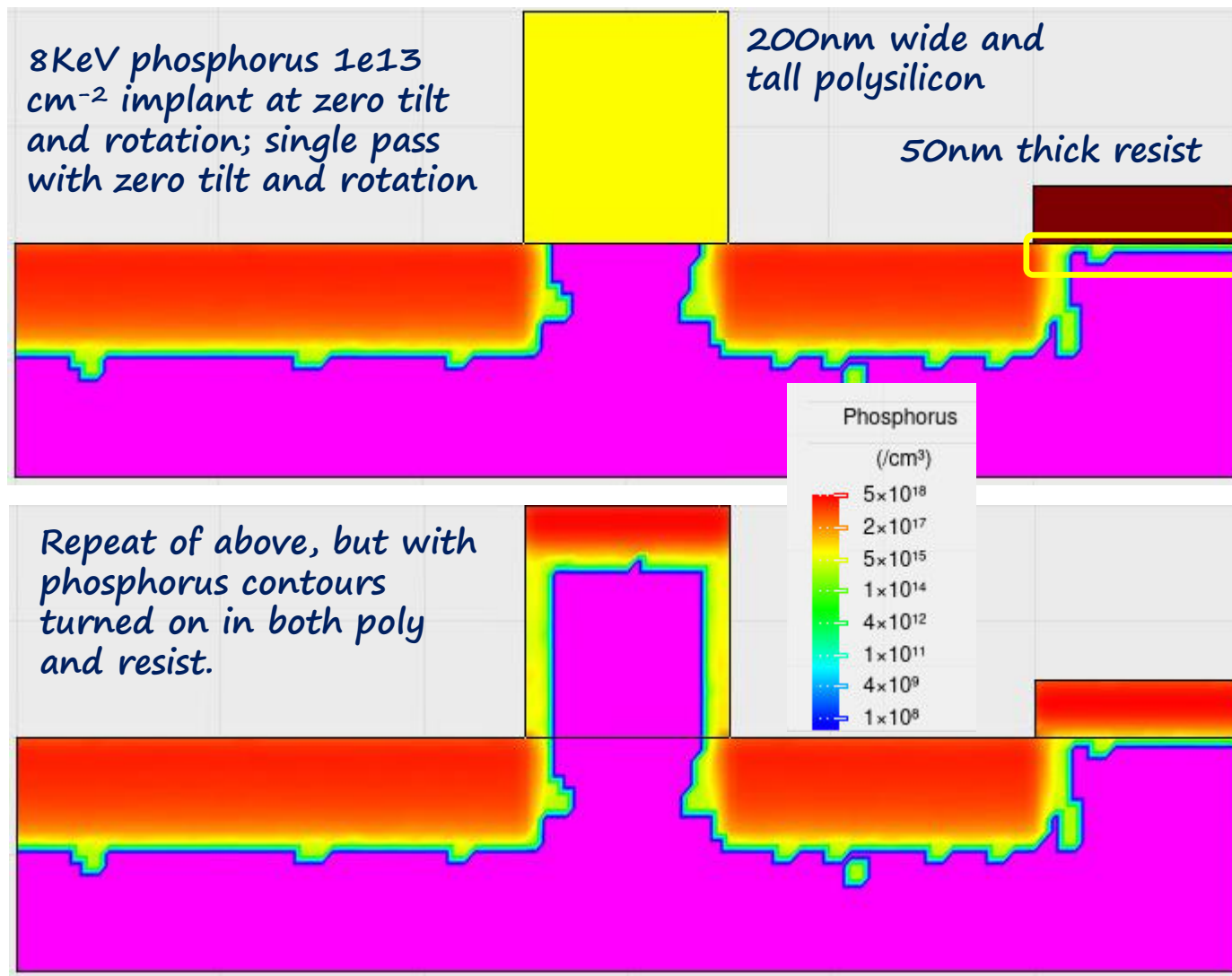


Figure 14-1 Definition of ROTATION

Working with Implants: Mask and Overlayer Thicknesses



Always check both resist, hardmask layers, and overlayers for implant profile.

Resist and hardmask thickness should be selected based on the implant species and energy to properly block the implant. (Note small amount of implant penetrating the 50nm resist in this example.)

For best control, when implanting through an overlayer (often an oxide), energy should be selected so that the greater part of the implant penetrates the overlayer.

Monte-Carlo implants with 1 million ions; background is $1e15$ boron; {100} surface at 45-degree substrate rotation (channel is $\langle 110 \rangle$)

Working with Implants: Overlayer Thickness Example

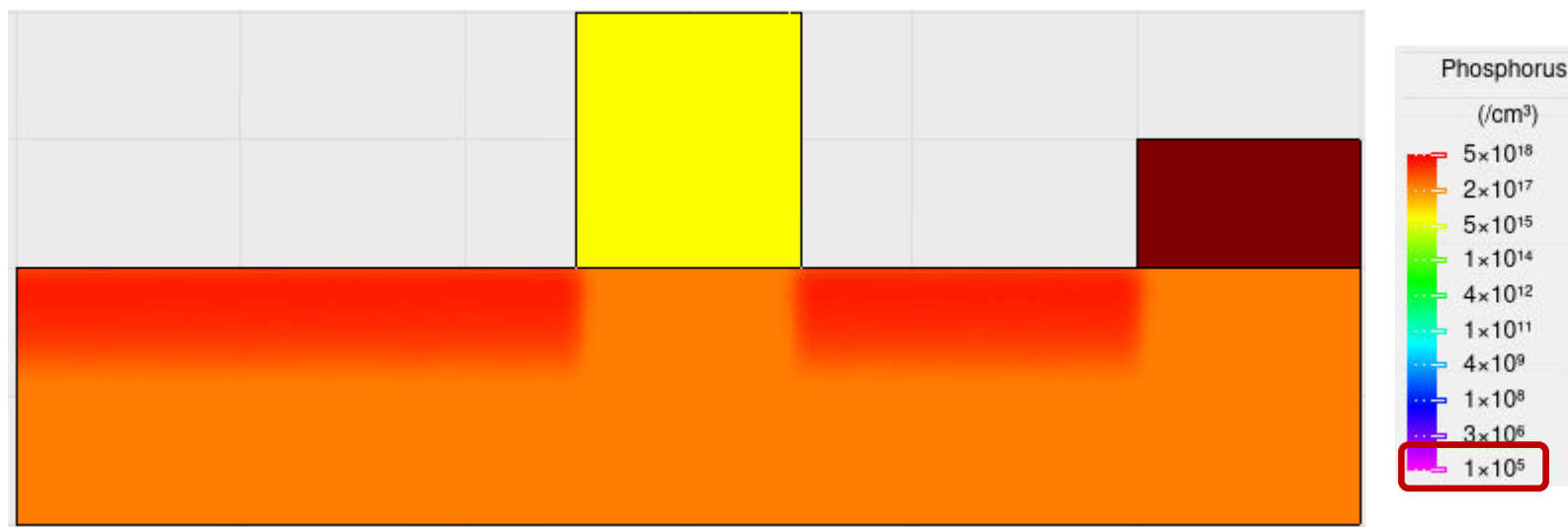
1.2KeV arsenic $1e13 \text{ cm}^{-2}$
implant with 7° tilt and
 22° rotation, in 4 passes,
through 3nm SiO_2

In this example, a very shallow
implant is performed through 3nm
of oxide.

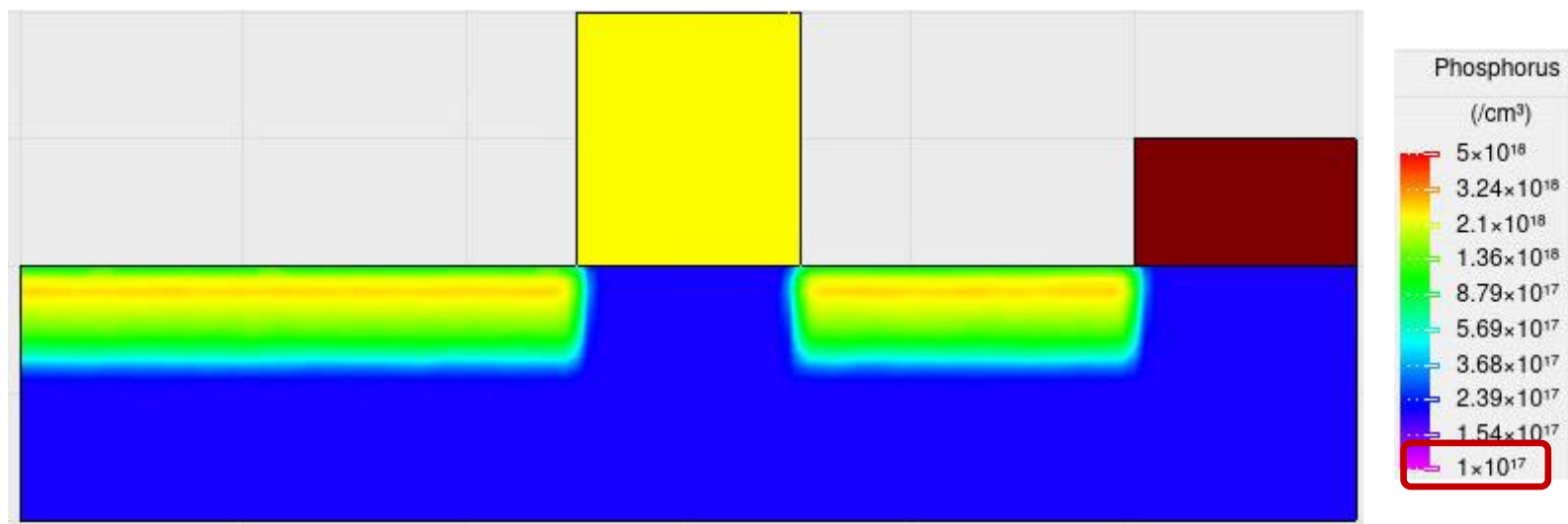
3nm SiO_2 {

From the image with the arsenic
contours turned on in the oxide, it
is apparent that just slightly more
than half of the implant makes it
into the silicon.

Working with Implants: Setting Limits to Make Profiles Visible



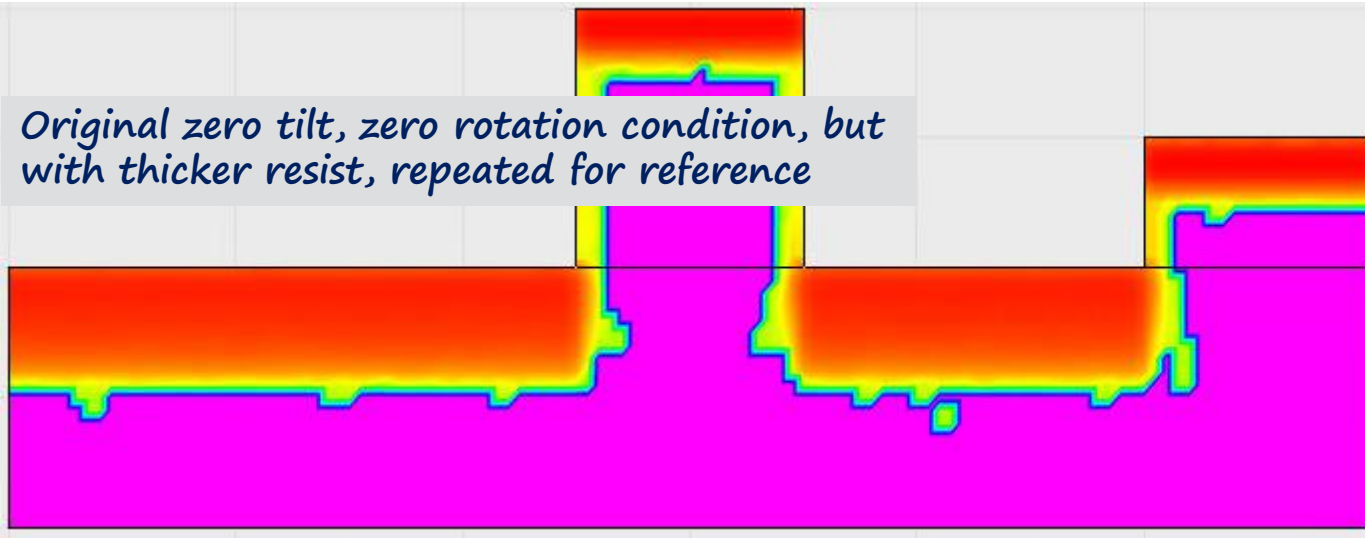
When one implant is placed over a prior background of the same dopant type (for example, when a halo is implanted into a well), the contours can be made distinct by increasing the contour minimum.



Same 8KeV $1\text{e}13\text{cm}^{-2}$ phosphorus from original slide, but with background changed from boron to $2\text{e}17\text{cm}^{-2}$ phosphorus

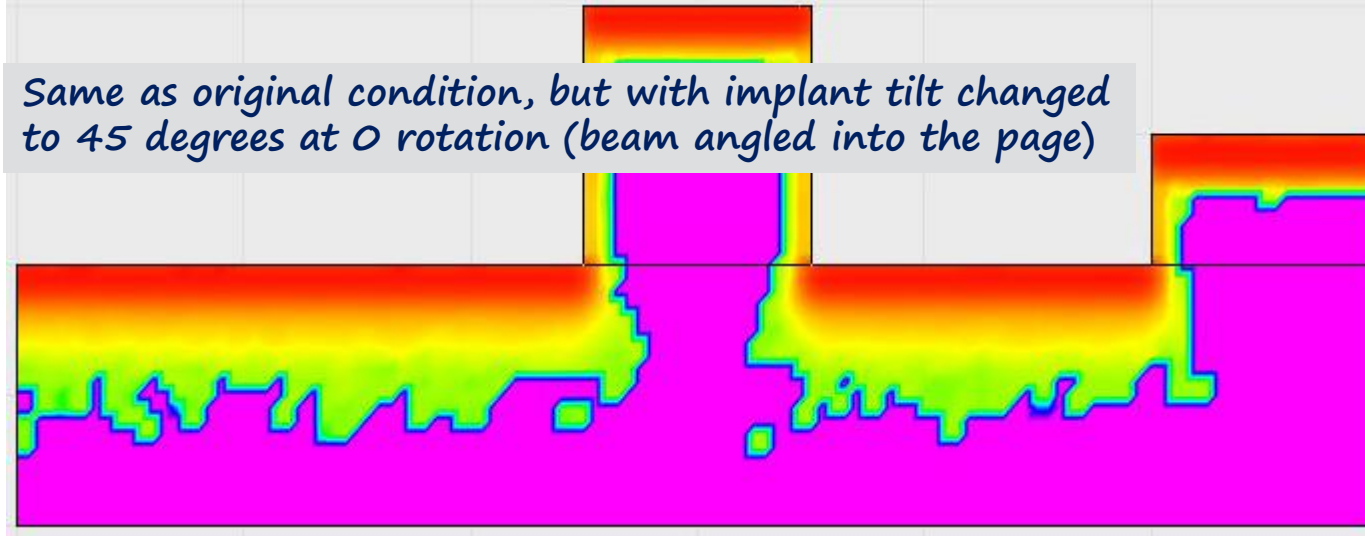
Working with Implants: Angled Implants Parallel to Features

Original zero tilt, zero rotation condition, but with thicker resist, repeated for reference



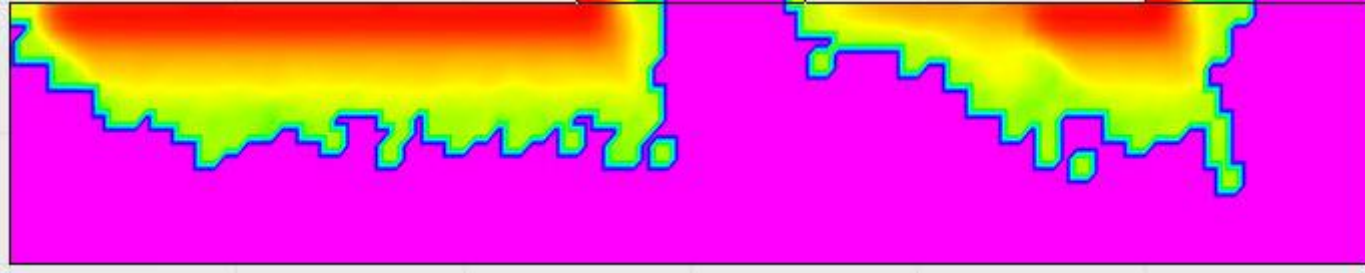
With the beam angled parallel to the poly and resist edges, (lower diagram) the implant only becomes more shallow, without significantly changing the lateral penetration.

Same as original condition, but with implant tilt changed to 45 degrees at 0 rotation (beam angled into the page)



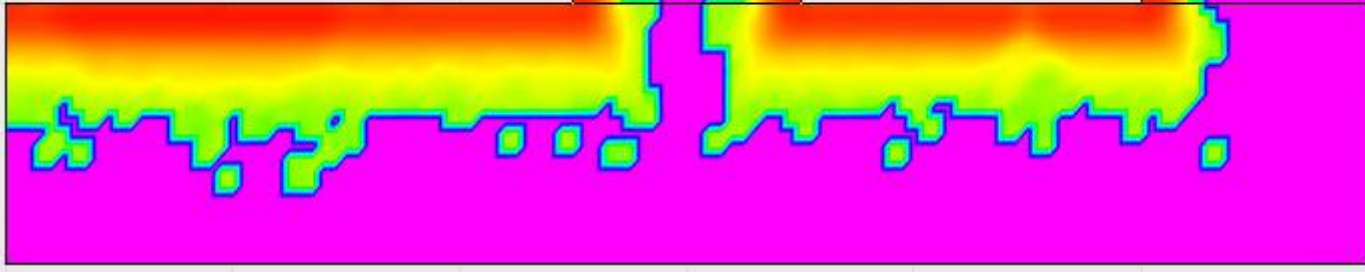
Working with Implants: Angled Implants Perpendicular to Features

45-degree tilt, 90-degree rotation, single pass (n.rot=1)



With a single pass with the beam perpendicular to the features, the implant is shadowed and asymmetric (note the effect at the left boundary).

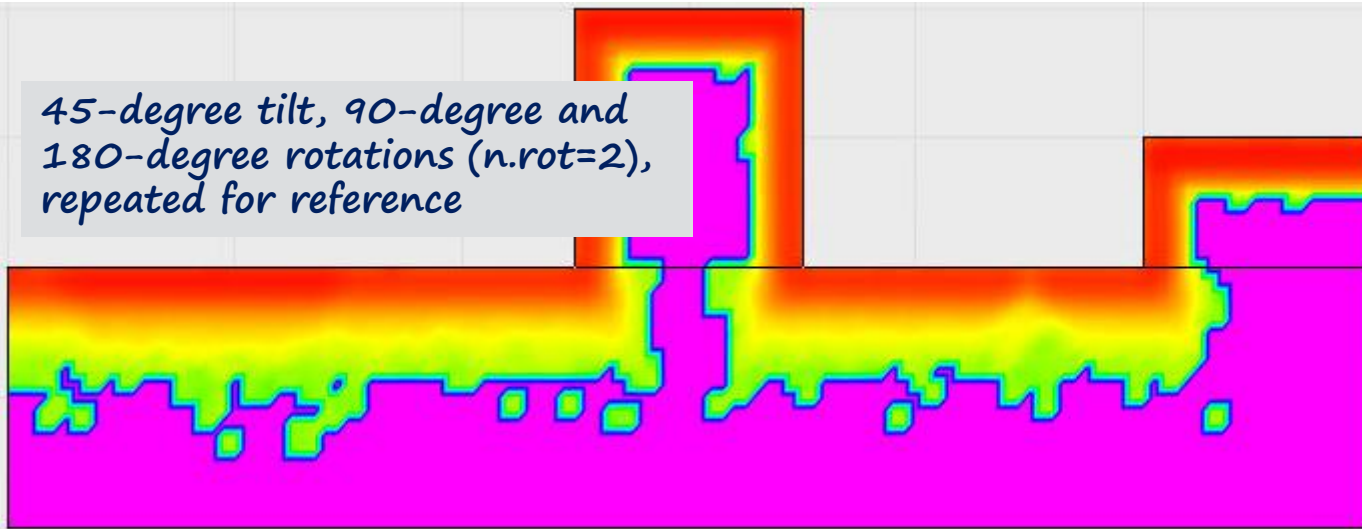
45-degree tilt, 90-degree and 180-degree rotations (n.rot=2)



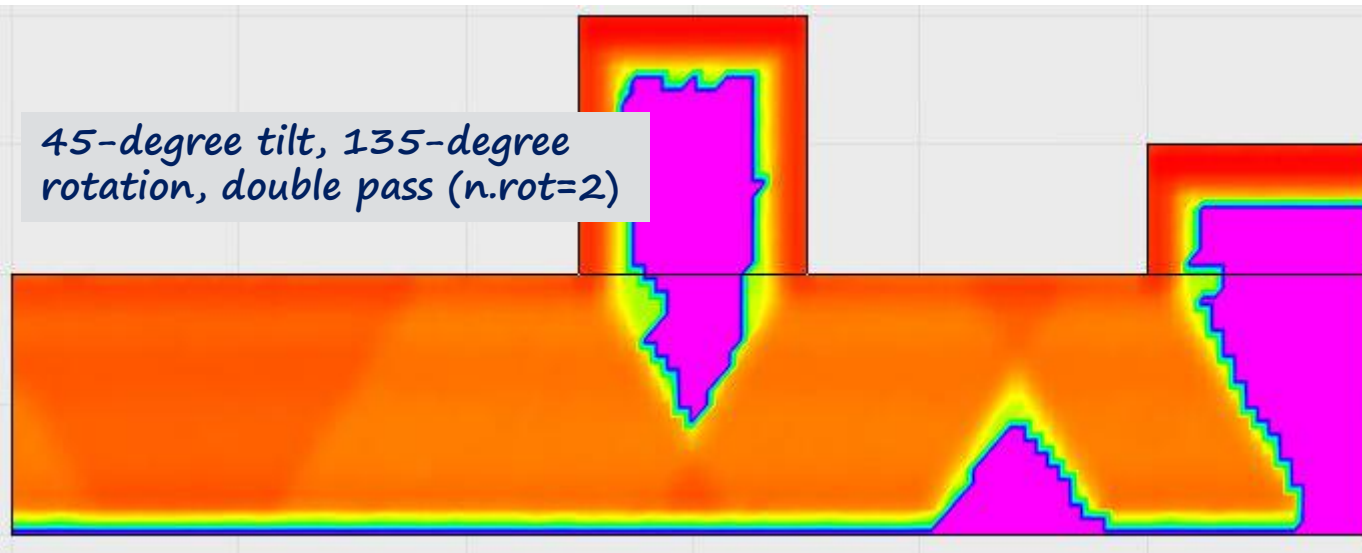
With passes in both perpendicular directions, the profile becomes symmetric, with the implant edges pushed under the masking features.

Working with Implants: Channeling with High-Tilt Implants

45-degree tilt, 90-degree and 180-degree rotations (n.rot=2), repeated for reference

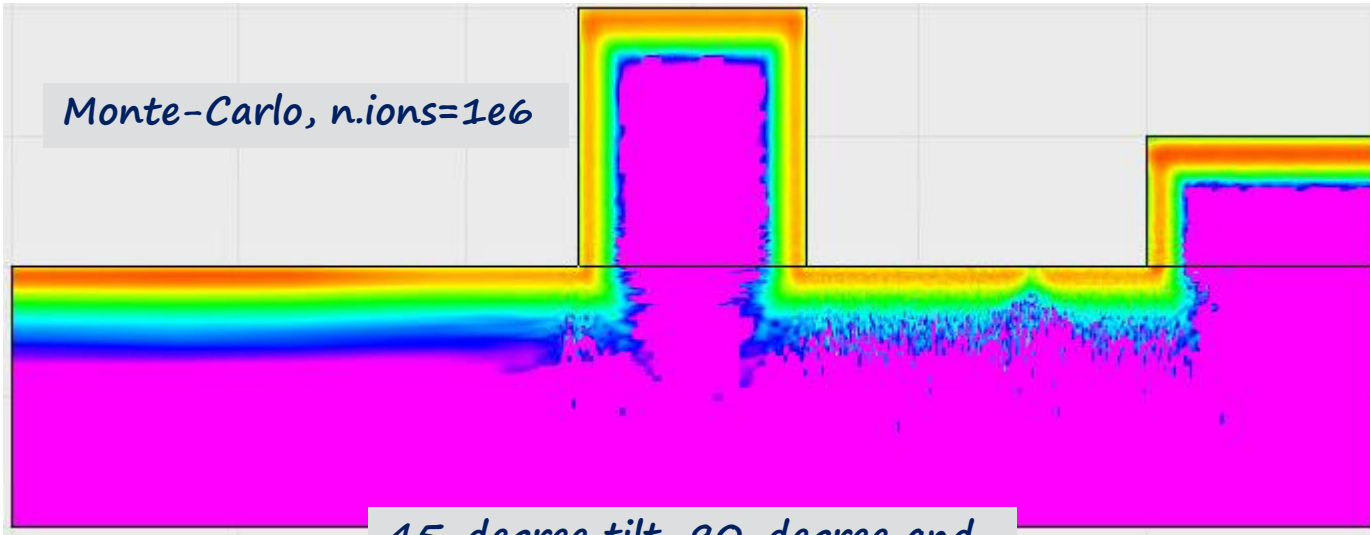


45-degree tilt, 135-degree rotation, double pass (n.rot=2)

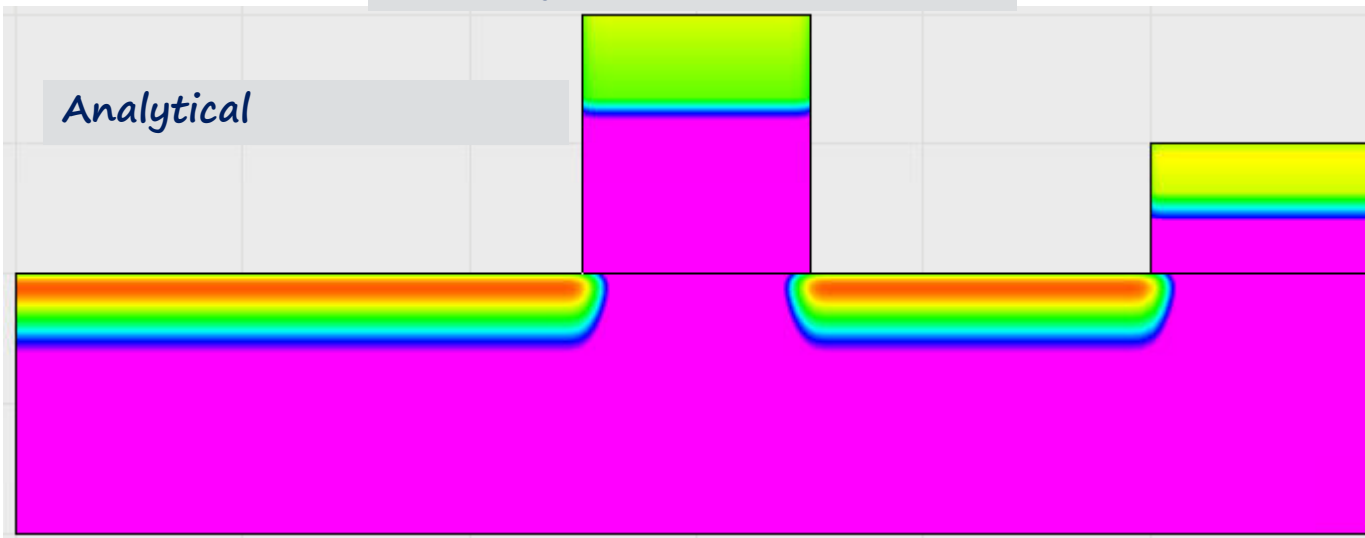
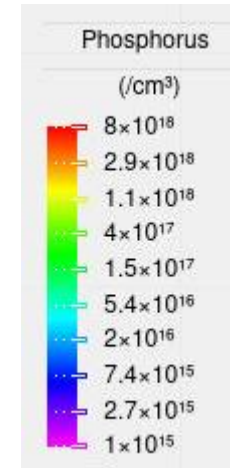


With high tilt angles, some rotations will directly align the implant with open lattice channels, where the only change from the top to bottom is shifting the angle from 90 degrees to 135 degrees.

Working with Implants: Comparison of Monte-Carlo and Analytic with Tilt



45-degree tilt, 90-degree and
180-degree rotations ($n.rot=2$)



The Monte Carlo two-pass results replotted using a finer volume mesh compared to analytical solution for the same conditions.

ECE 595 Semiconductor Device Integration Through Simulation