Activity I: TCAD simulation studies
Activity II: Readout electronics emulator

Team for Activity I

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Explorer chip: Sector 1

- Deletion region and electric field profile
- Depletion region and electric field profile for various Geometrical arrangement
- Comprehensive study of doping (N-layer, P-layer, Epi-layer)
- I-V and C-V results of an isolated diode pixel
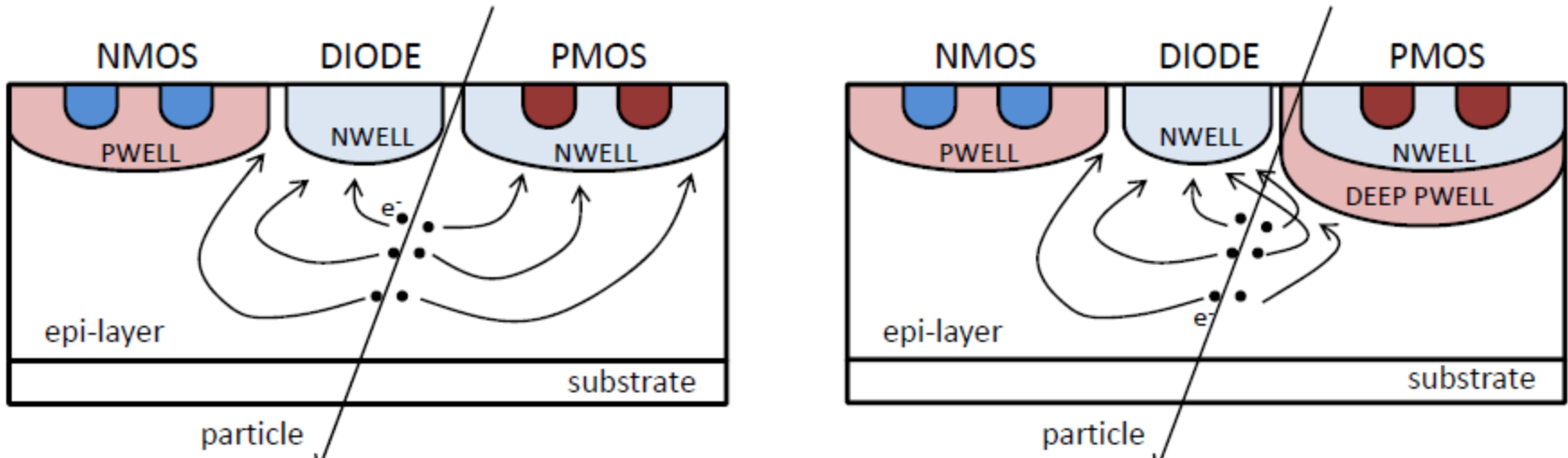
Previous work: Explorer chips

* To optimize the sensors and its configureation
* **Monolithic Active Pixel Sensors** using TowerJazz 0.18 μm CMOS Imaging Process
    * **High-resistivity epitaxial** layer on p-type substrate
    * Special **deep p-well** prevents the n-well containing PMOS transistors from collecting signal charge from the epitaxial layer

MAPS standard CMOS (left) and MAPS with deep p-well(right).
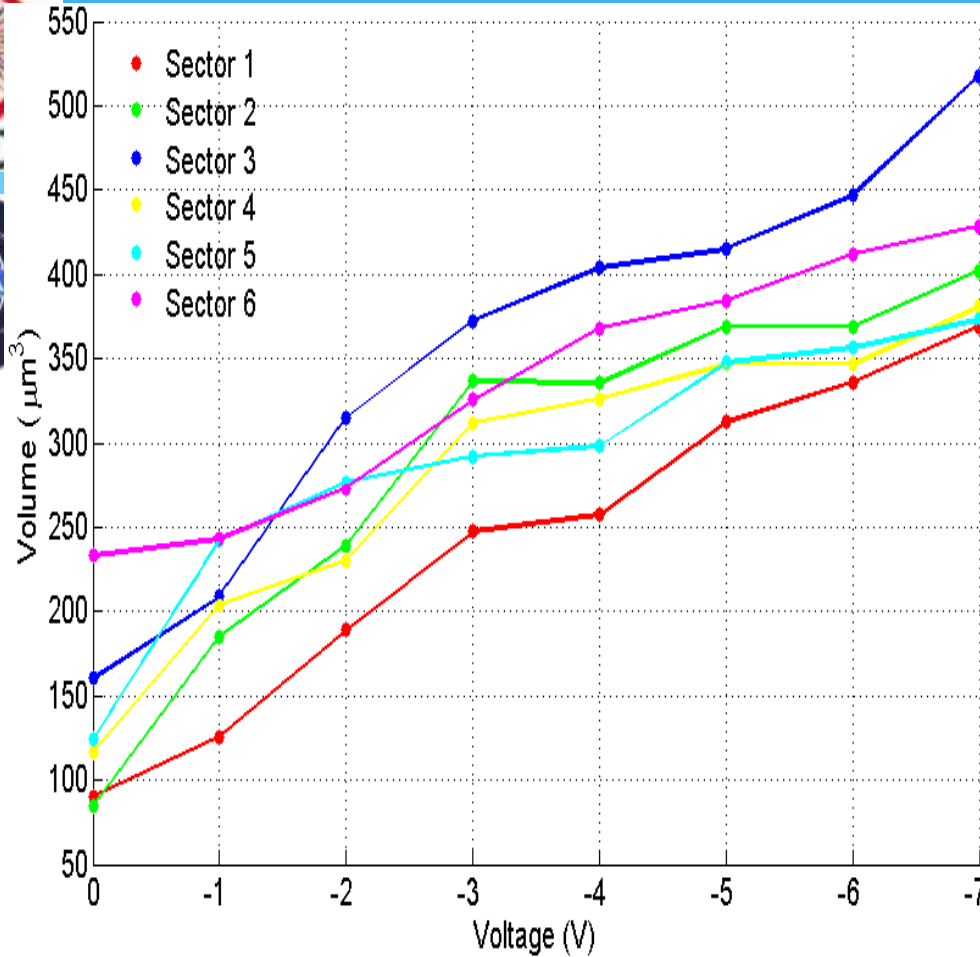
Diode geometries for Explorer chips

Explorer0				Explorer1			
Sector	Shape	Diameter [μm]	Spacing [μm]	Sector	Shape	Diameter [μm]	Spacing [μm]
1	⊙	2	0	1	□	0.45	3.375
2	⊙	3	0	2	□	1	3.1
3	⬡	4	0	3	□	2	2.6
4	▣	3	0	4	⬡	0.53	3.335
5	⬣	3	0.6	5	⬡	1	3.1
6	⬣	3	1.04	6	⬡	2	2.6
7	⬣	2	1.54	7	□	0.45	0.28(Top)
8	⊙	3	0	8	⬡	0.53	0.28(Top)
9	⬣	3	1.04	9	⬡	3	2.1

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Volume comparison of different sectors of Explorer-1 chip using Electric field data

Sector	Shape	Volume at -1V (μm^3)	Volume at -7V (μm^3)
1		125.7648	369.1045
2		185.3367	402.4172
3		209.0015	517.8140
4		204.1549	380.7218
5		242.3137	372.7135
6		242.9395	428.8307

Explorer1

Optimization of diode separation

* Grouping of two Sector 1s and their formation
* Electric Field Comparison of the structures
* 2x2 matrix of Sector 1
* Summary and Future work

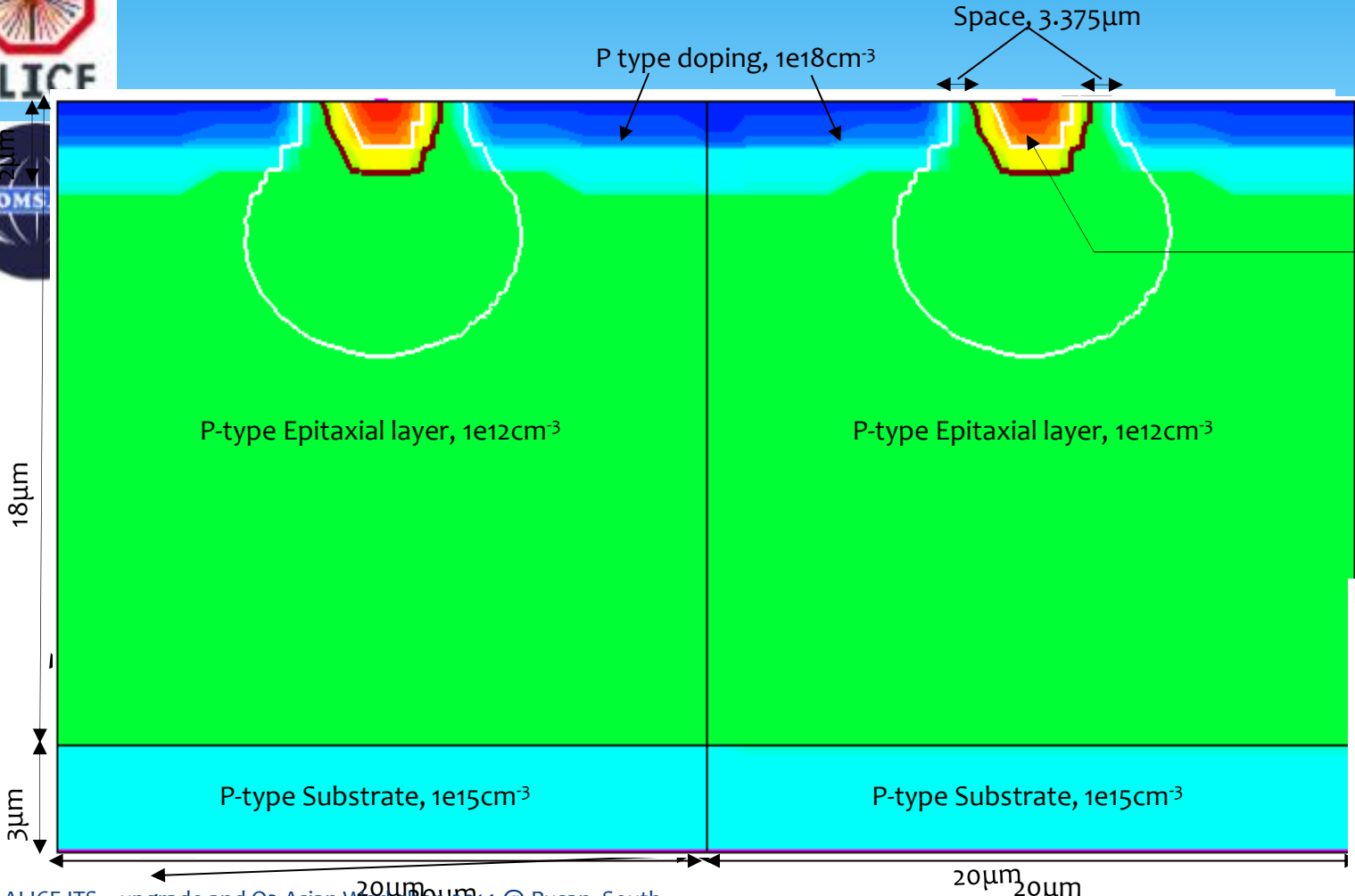# Optimization of diode separation (20 μm to 8 μm)

* Grouping of two Sector 1s and their formation
* Electric Field Comparison of the structures
* 2x2 matrix of Sector 1
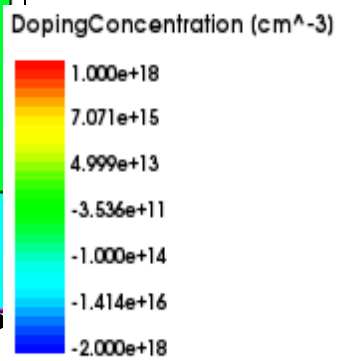* Summary and Future work

Two Sector 1's at voltage = - 7 V

Space, 3.375μm
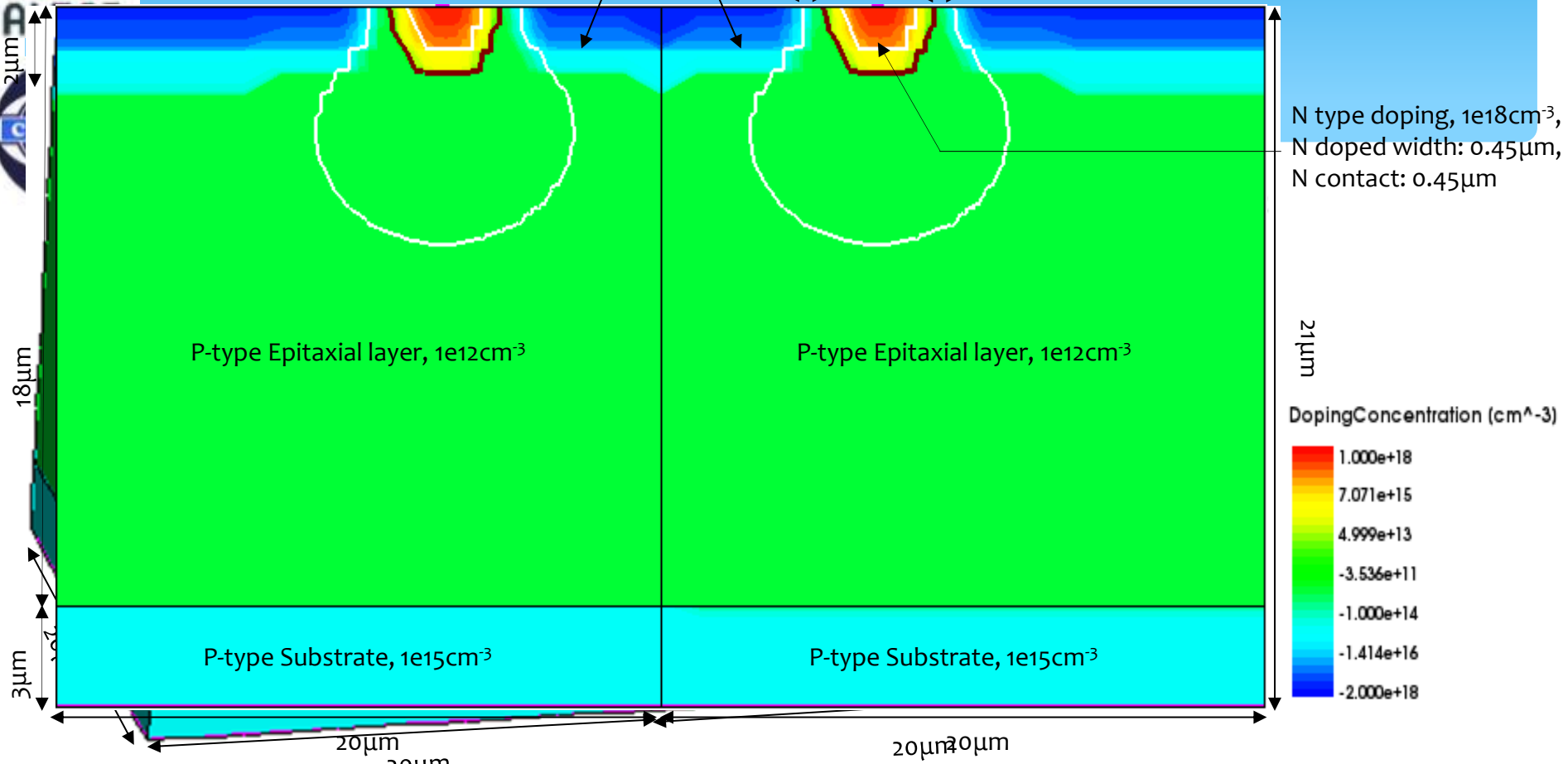
P type doping, 1e18cm⁻³

N type doping, 1e18cm⁻³
N doped width: 0.45μm
N contact: 0.45μm

P-type Epitaxial layer, 1e12cm⁻³

P-type Epitaxial layer, 1e12cm⁻³

2μm

18μm

21μm

3μm

P-type Substrate, 1e15cm⁻³

P-type Substrate, 1e15cm⁻³

20μm 20μm

20μm 20μm

DopingConcentration (cm^-3)

	1.000e+18
	7.071e+15
	4.999e+13
	-3.536e+11
	-1.000e+14
	-1.414e+16
	-2.000e+18

Two Sector 1's at voltage = - 7 V

Space, 3.375μm

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N type doping, 1e18cm⁻³,
N doped width: 0.45μm,
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P-type Substrate, 1e15cm⁻³

2μm

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3μm

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7.071e+15
4.999e+13
-3.536e+11
-1.000e+14
-1.414e+16
-2.000e+18

Two Sector 1's at voltage = - 7 V (merging of depletion zones)
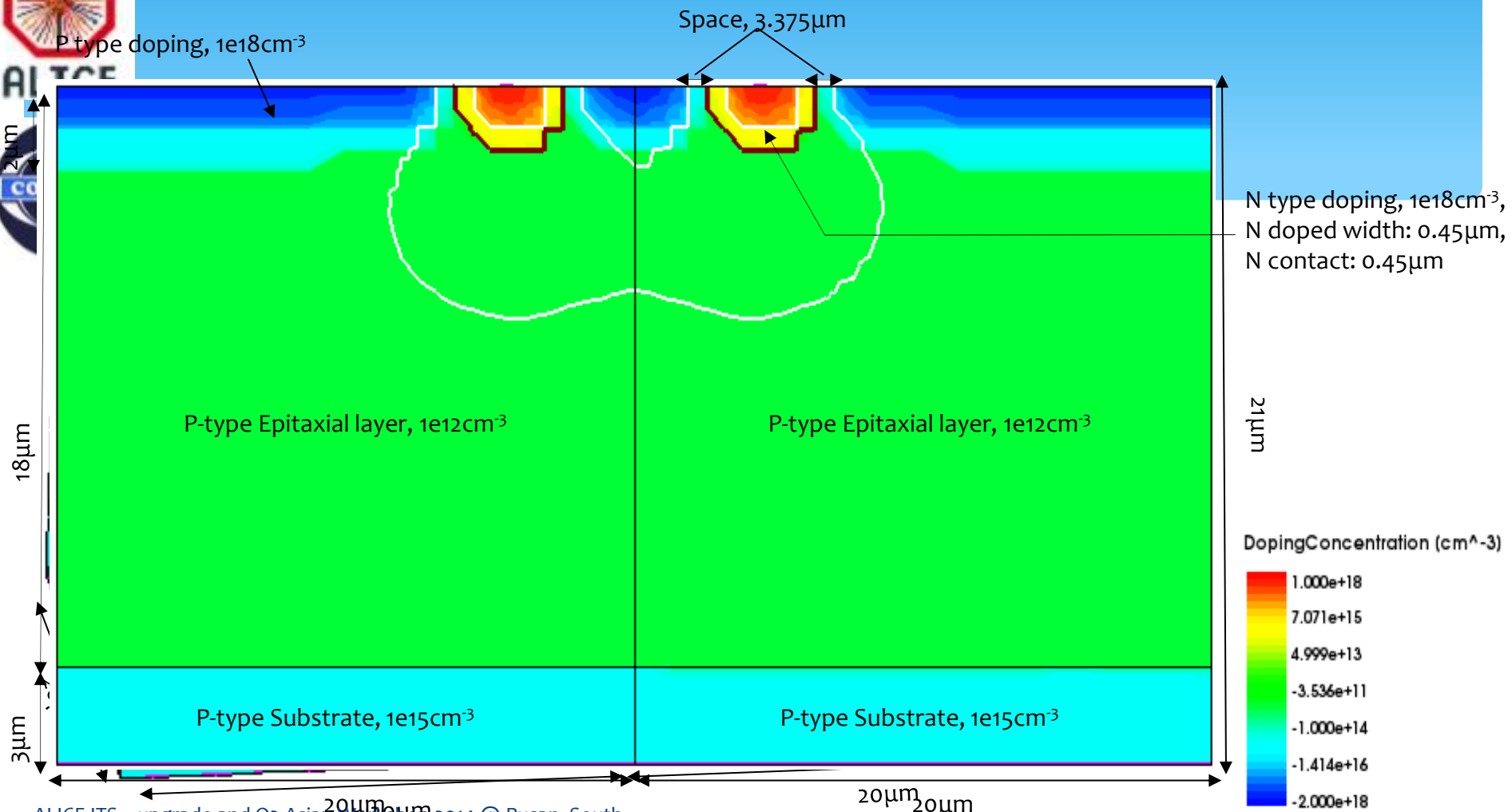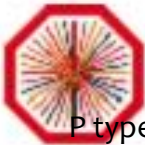
Space, 3.375μm

P type doping, 1e18cm^{-3}

N type doping, 1e18cm^{-3},
N doped width: 0.45μm,
N contact: 0.45μm

P-type Epitaxial layer, 1e12cm^{-3}

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Outline

* Grouping of two Sector 1s and their formation
* Electric Field Comparison of the structures
* 2x2 matrix of Sector 1
* Summary and Future work

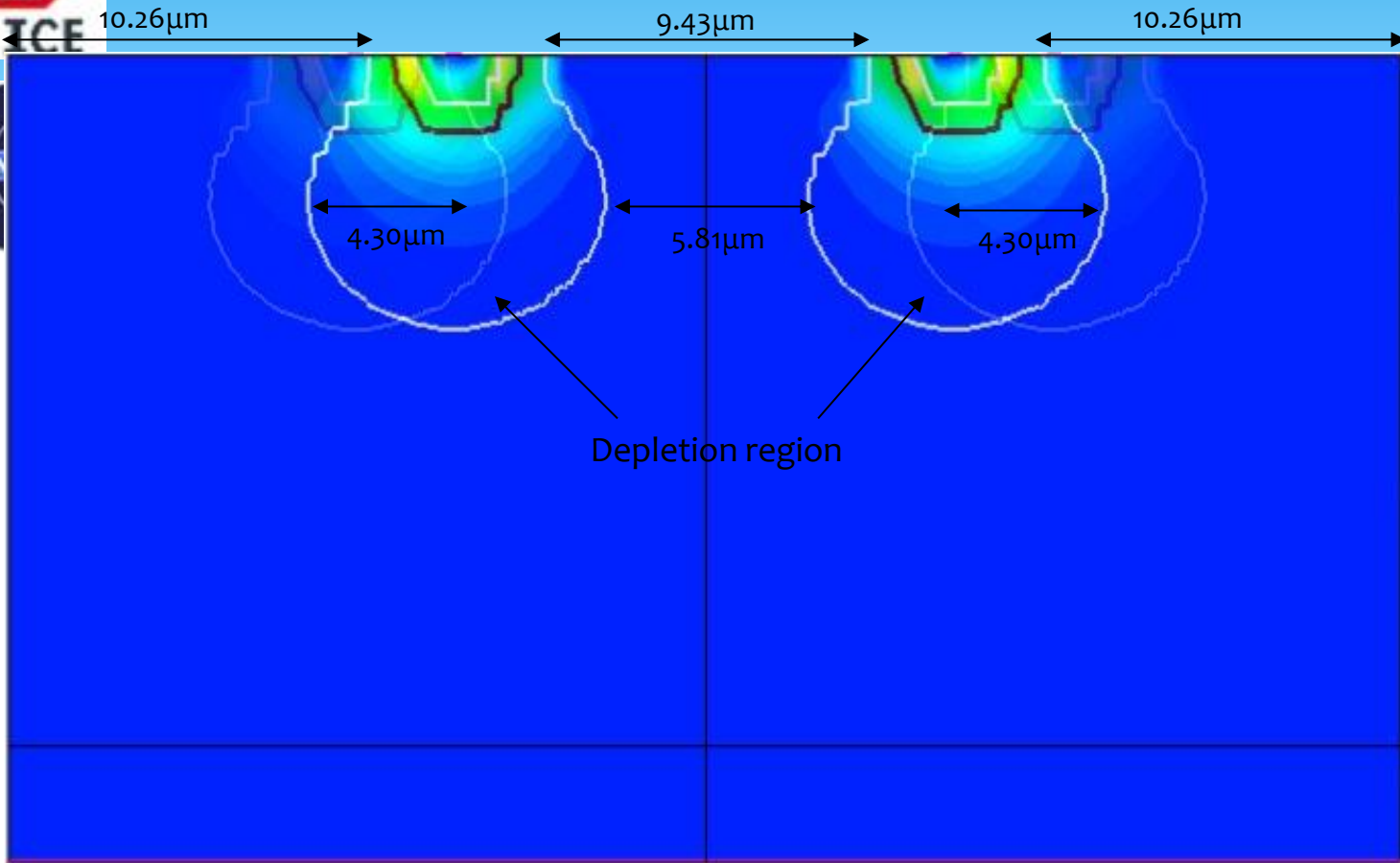# Electric Field profile of the structure with no N-region Shift

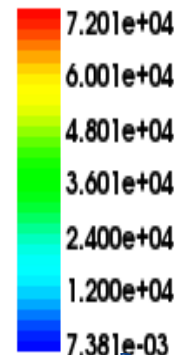ALICE ITS – upgrade and O2 Asian Workshop 2014 @ Pusan, South Korea
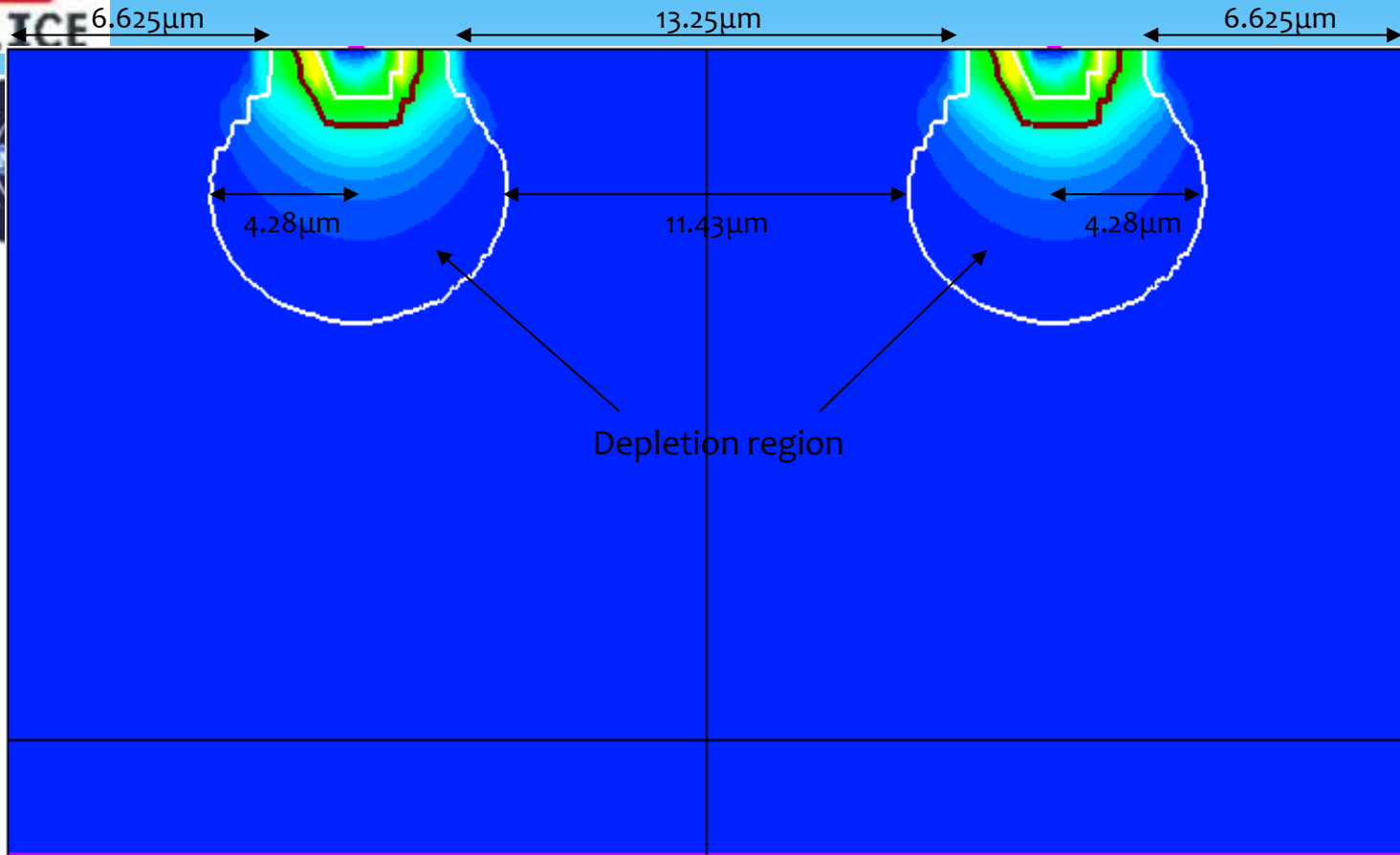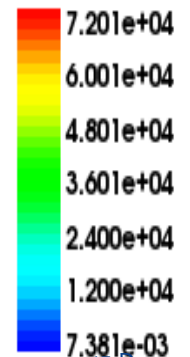
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Electric Field of the structure with N-region Shift
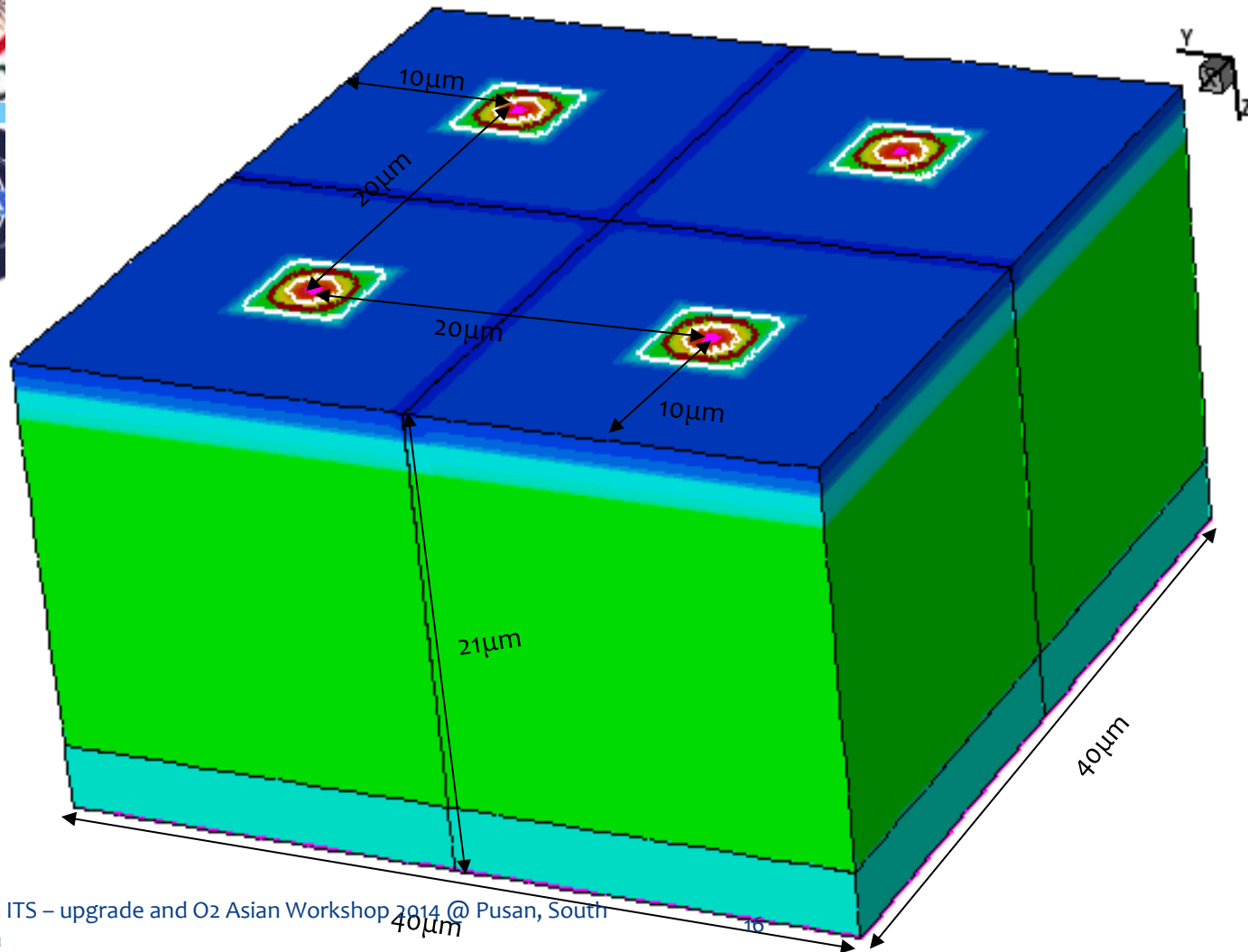
Electric Field of the structure with N-region Shift at center

13.10μm   3.66μm   13.10μm

This region can be utilized for VLSI implementation

This region can be utilized for VLSI implementation

3.85μm

17.13μm

Depletion region

ElectricField (V*cm^-1)

- 4.788e+04
- 3.990e+04
- 3.192e+04
- 2.394e+04
- 1.596e+04
- 7.981e+03
- 7.381e-03

Outline

* Grouping of two Sector 1s and their formation
* Electric Field Comparison of the structures
* 2x2 matrix of Sector 1
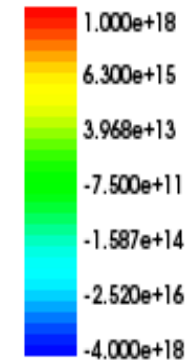* Summary and Future work

2x2 matrix of Sector 1

Electric Field of 2x2 matrix Sector 1

7.44μm   15.03μm   7.44μm

4.35μm   11.26μm

Depletion region

Electric Field (V*cm^-1)

🟥	7.170e+04
🟨	5.975e+04
🟩	4.780e+04
🟩	3.585e+04
🟦	2.390e+04
🟦	1.195e+04
🟦	8.012e-03

Space, 3.375μm

P type doping, 1e18cm^{-3}

N type doping, 1e18cm^{-3},
N doped width: 0.45μm,
N contact: 0.45μm

P-type Epitaxial layer, 1e12cm^{-3}

P-type Epitaxial layer, 1e12cm^{-3}

18μm

21μm

DopingConcentration (cm^-3)

1.000e+18
6.300e+15
3.968e+13
-7.500e+11
-1.587e+14
-2.520e+16
-4.000e+18

P-type Substrate, 1e15cm^{-3}

P-type Substrate, 1e15cm^{-3}

3μm

20μm

20μm

Electric Field of 2x2 matrix Sector 1 with shifted N-regions

11. 63μm   6.94μm   11.63μm

This region can be utilized for VLSI implementation
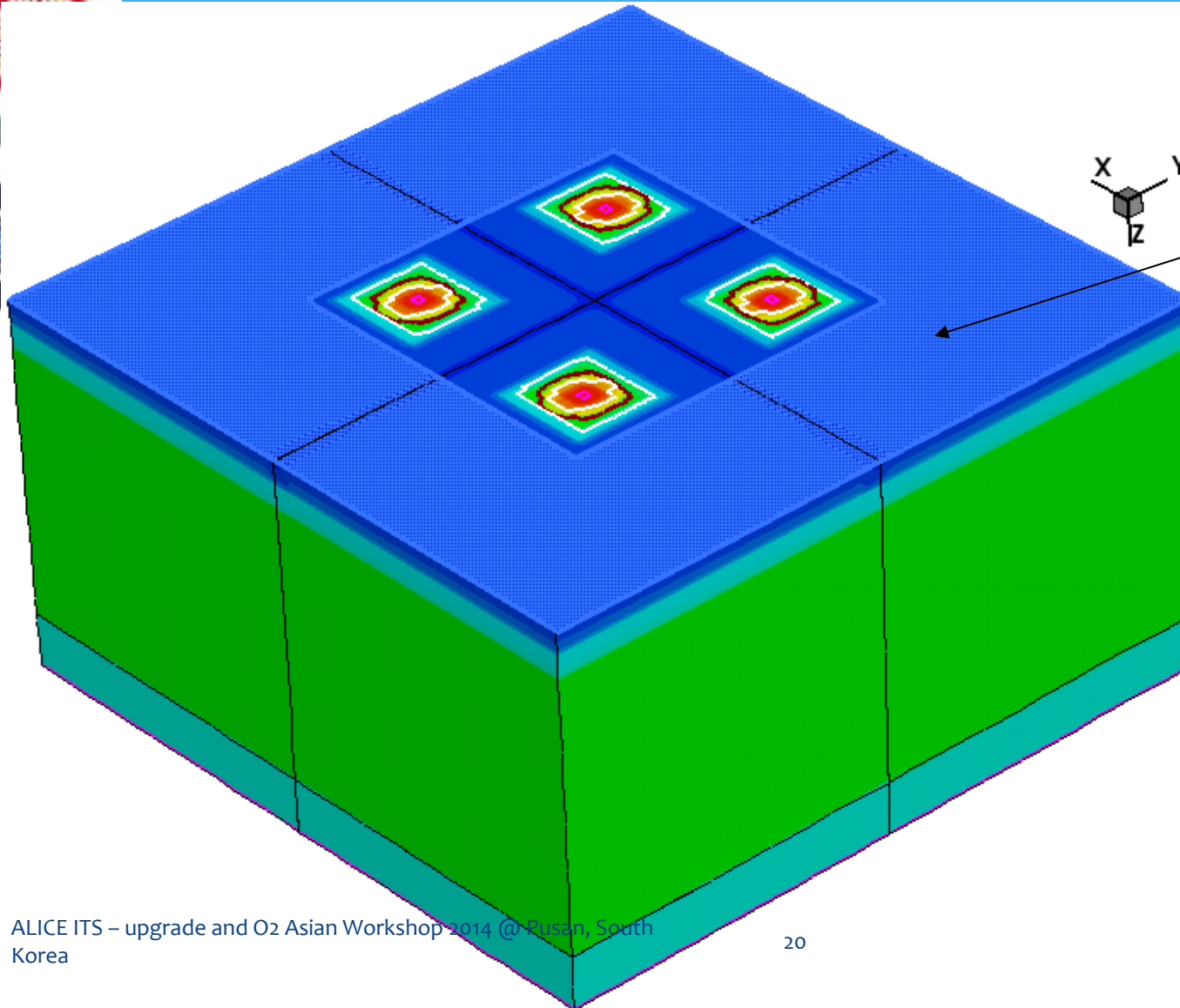
This region can be utilized for VLSI implementation

4.5μm   0.69μm   5.64μm

20.97 μm

Depletion region

Electric Field (V*cm^-1)

6.531e+04
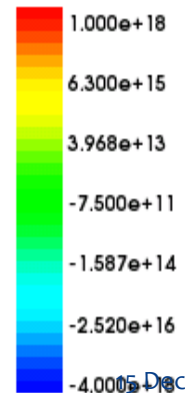5.442e+04
4.354e+04
3.265e+04
2.177e+04
1.088e+04
8.009e-03
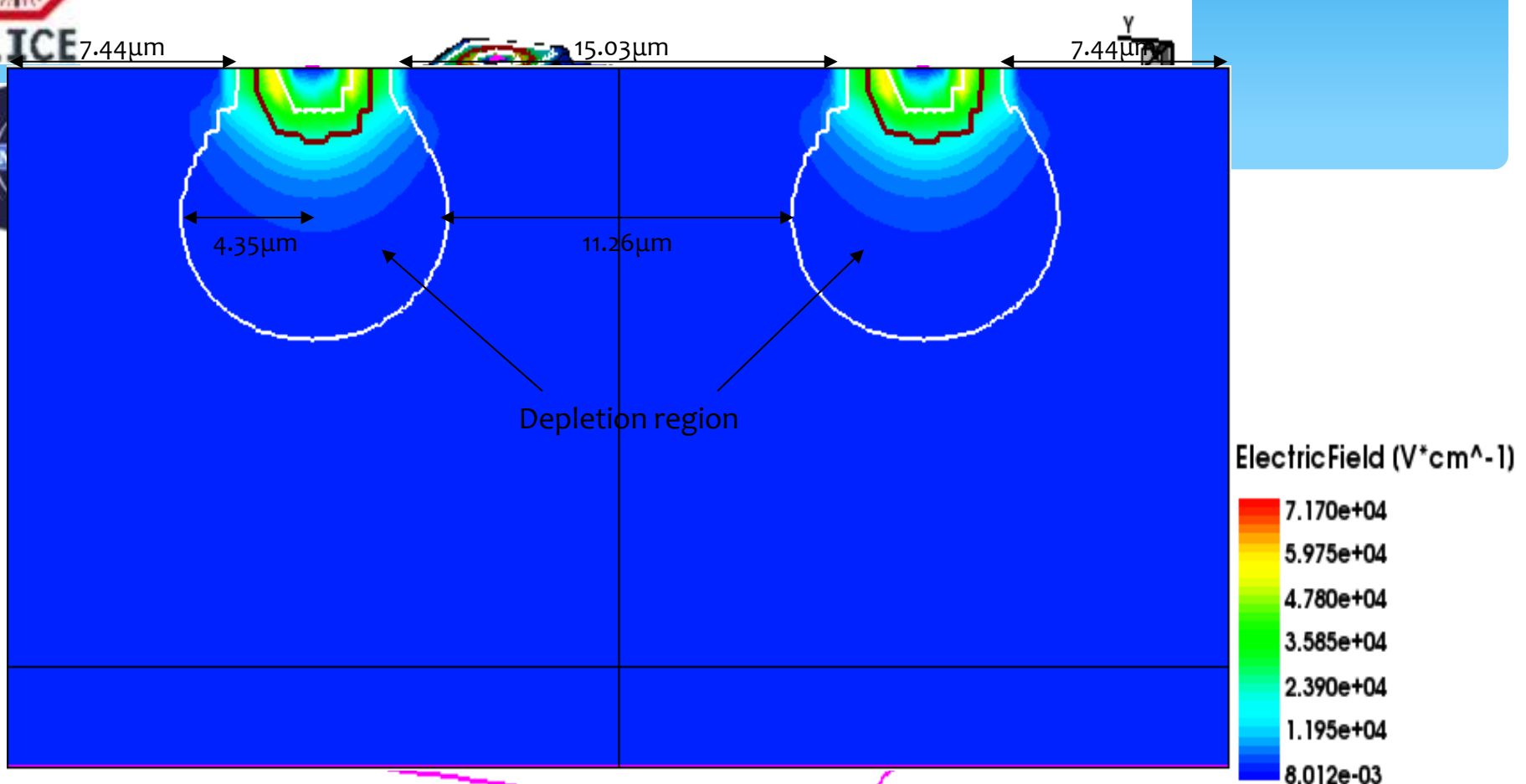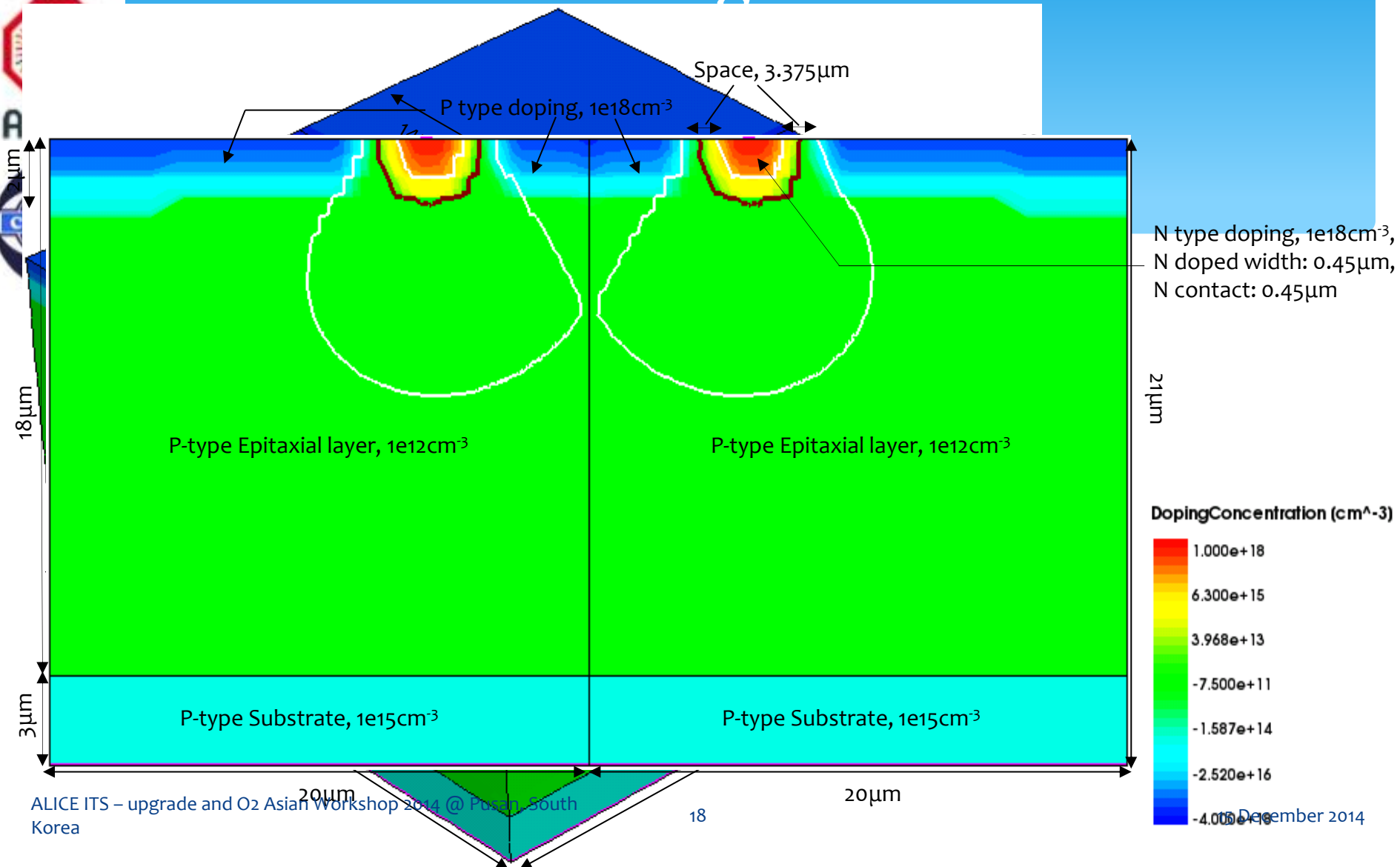
Electric Field of 2x2 matrix Sector 1 with shifted N-regions

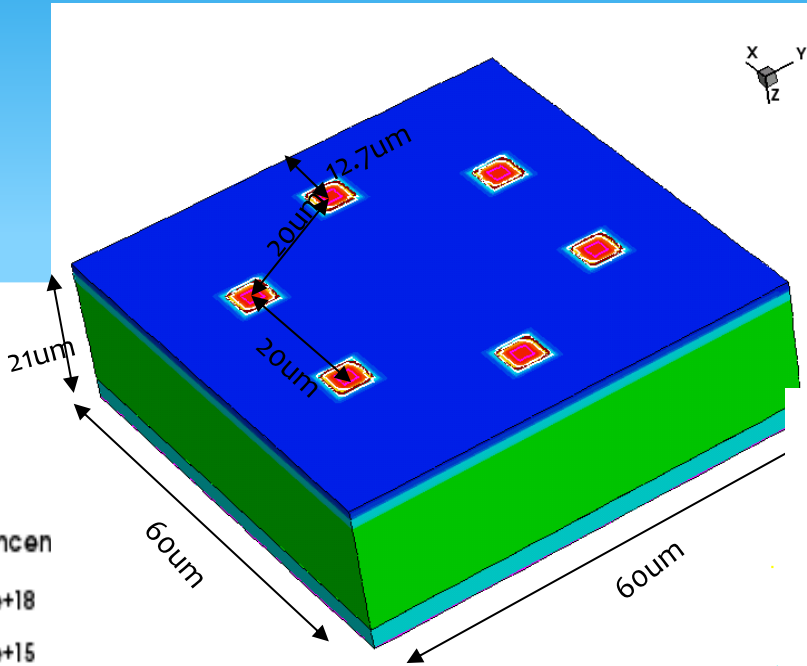Available region for front-end complex CMOS circuitry

DopingConcentration (cm^-3)

1.000e+18
6.300e+15
3.968e+13
-7.500e+11
-1.587e+14
-2.520e+16
-4.000e+18

Hexagonal shaped matrix of Sector 3

P type doping, 1e12cm^{-3}
N type doping, 1e18cm^{-3},
N doped width: 2μm,
Space N+ vs P+: 2.6μm

DopingConcen

1.000e+18
6.300e+15
3.968e+13
-7.500e+11
-1.587e+14
-2.520e+16
-4.000e+18

12.7um
20um
20um
21um
60um
60um
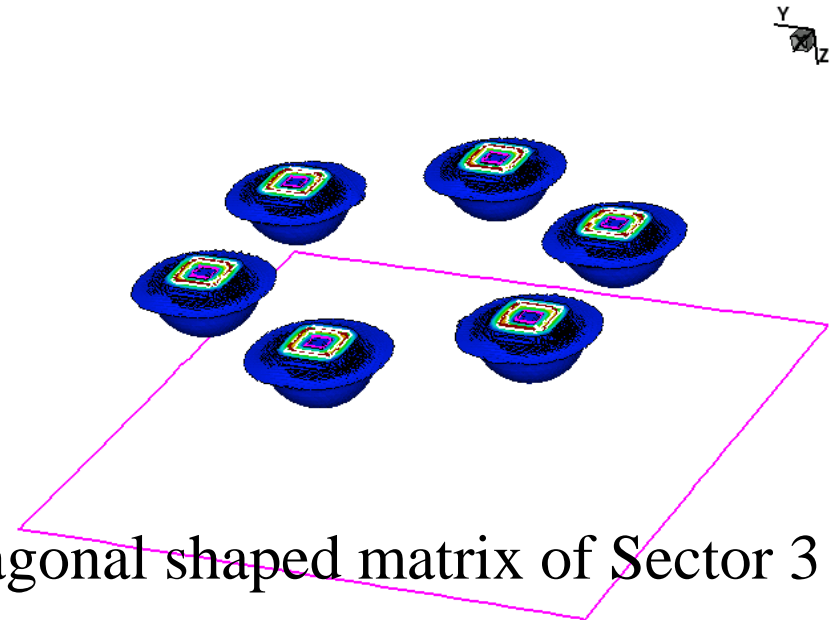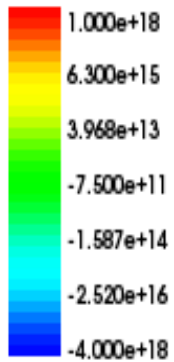
Electric Field of Hexagonal shaped matrix of Sector 3

Future work

* Space for VLSI implementation.
* The optimized minimum distance between two anode is observed to be 16um in diamond and hexagonal shaped matrix.
* Next step: Grouping seven Sector 3 in body centered hexagonal shape.

Detailed studies of Doping densities

* The effect of various doping profile on depletion region of the collecting diode.

* Reverse biased current characteristics by using different doping profile

* Capacitance voltage characteristics