Spice model of irradiation detectors (SPID)

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Outline

I. SPID, the Spice model of irradiation detectors

II. Test sensor design and manufacture

III. Model parameters for irradiation detectors after irradiation

IV. Prodid, a windows program for computer aided Spice model generation

V. Application examples

VI. Summary

I. SPID, a spice model of irradiation detectors

INNOWATT project SPID

Irradiation detectors

- Pad diodes
- Micro strip detectors
- Micro pixel detectors

Application

- High energy particle physics
- Medicine
- Material diagnose

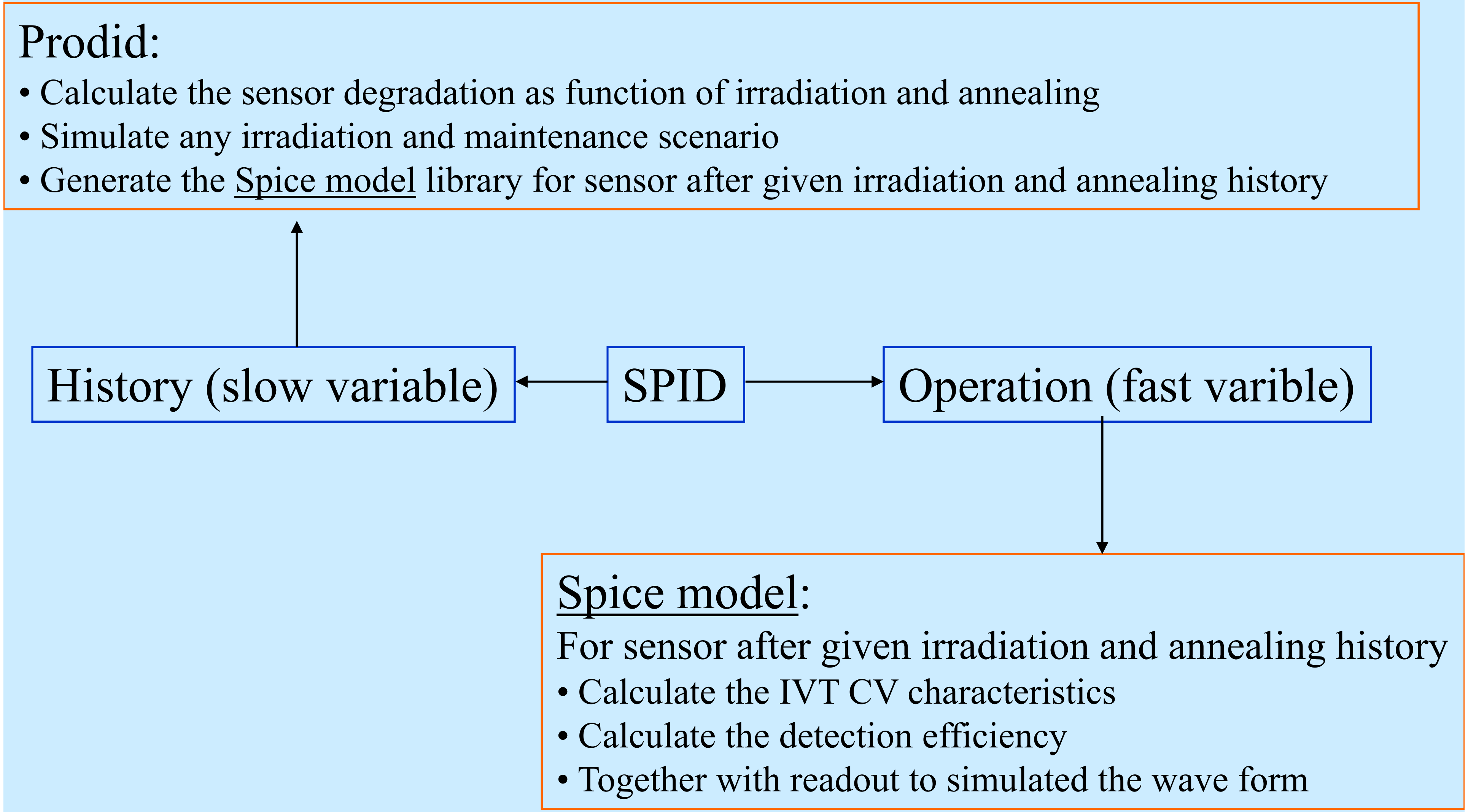
Performance degradation

- Leakage current
- Effective acceptor
- Charge collection efficiency

Operation

- Baising
- Coupling
- Noise suppression

I. SPID, a Spice model of irradiation detectors



Prodid:

- Calculate the sensor degradation as function of irradiation and annealing
- Simulate any irradiation and maintenance scenario
- Generate the Spice model library for sensor after given irradiation and annealing history

History (slow variable)

SPID

Operation (fast varible)

Spice model:

For sensor after given irradiation and annealing history

- Calculate the IVT CV characteristics
- Calculate the detection efficiency
- Together with readout to simulated the wave form

I. The application of Spice model to irradiation detectors

Detector designer

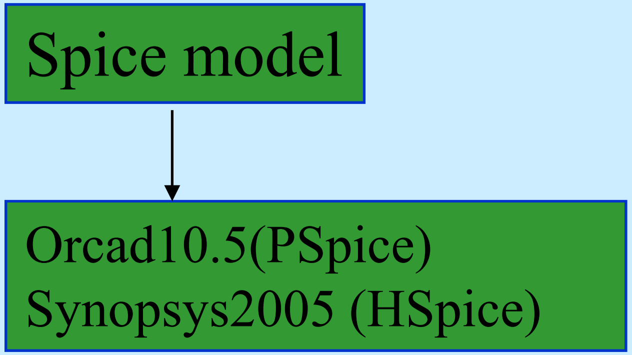
- Process parameters
- Breakdown voltage
- Inter strip capacitance
- Inter strip resistance
- Sensitivity (CCE, MIPS)

System designer

- Detector lifetime
- Resolution
- Event identification

Readout designer

- Shape time
- Amplification
- Noise optimization



Spice model

Orcad10.5(PSpice)
Synopsys2005 (HSpice)

I. The characterization of irradiation detectors

History: (Uni. Hamburg)

- Irradiation
- Annealing and antiannealing T & t

Environment:

- Temperature
- Humidity

Detector properties & response

IV
CV
CCE
Noise

Operation:

- Bias
- Reset (active detector)

Detection (event):

- Particle type
- Energy
- Flux

Variables

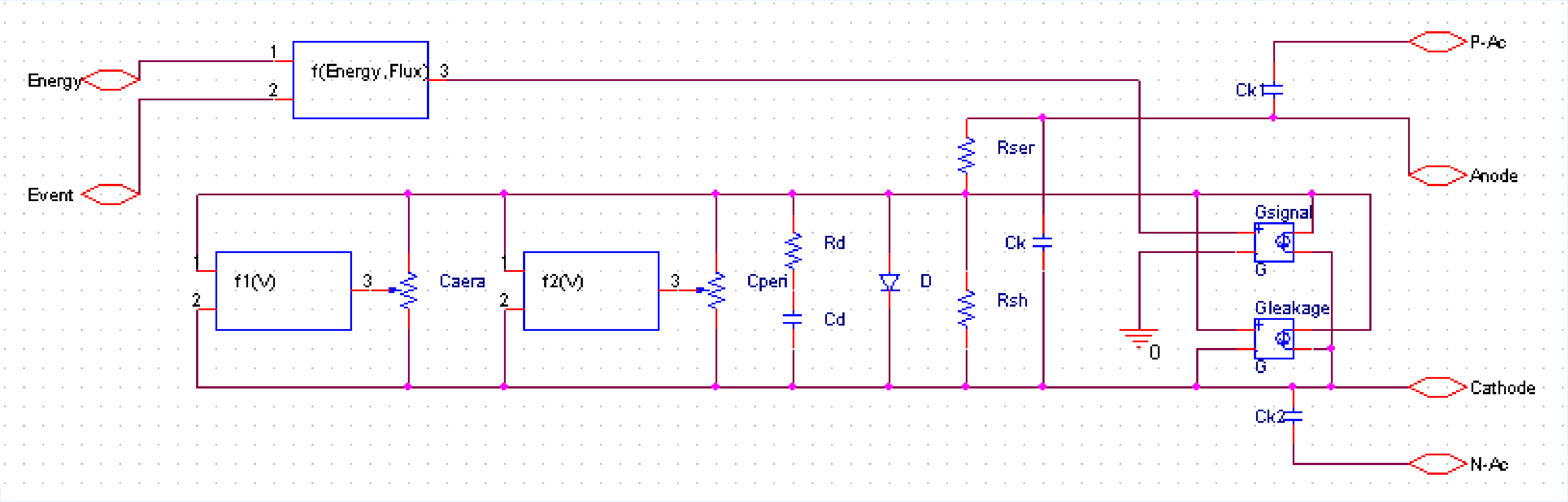
I. The spice mode of irradiation detectors

Strip detector (one unit)

Ac-coupling, Double side

Non electrical terminals

To bias ring
To neighbor strip



All parameters are function of parameters of last slide

Model parameters are generated by the windows program PRODID

An example in model library

II: Model parameters

Parameters of sensor in initial condition:

- a spectrum of sensor designed and manufactured in frame of SPID
- published data
- Simulation

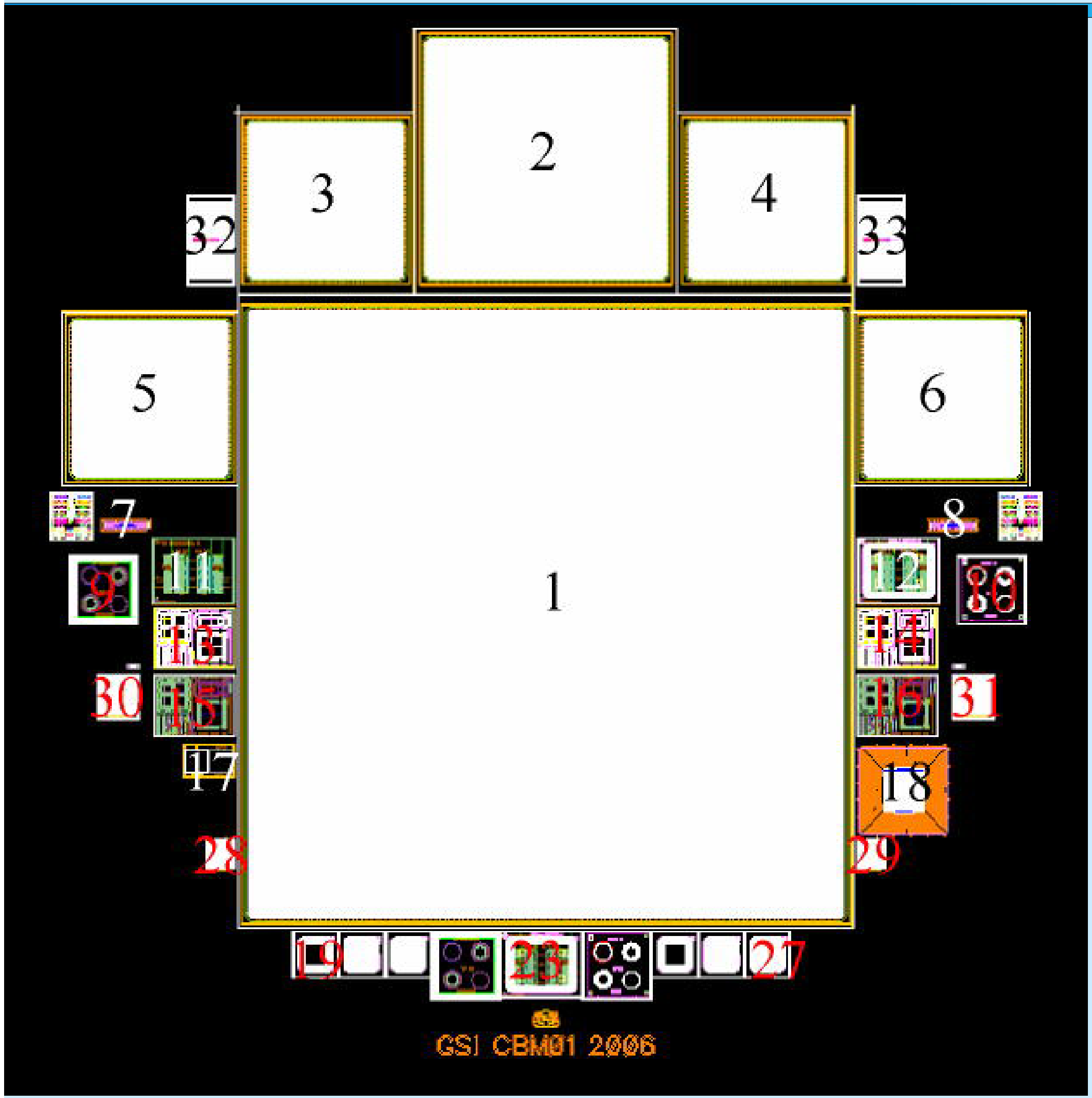
Id, C, Cinter, Ccoup, CCE
~ geometry, doping and defect

Parameters of sensor degradation:

- Output of RD50
- Published data
- Looking for possible irradiation test for SPID sensors.

Id, Neff, CCE, Q, Noise
~ irradiation dose, annealing temperature and time

II. Before irradiation, CBM



1	SRTW01	CBM01
2	CSRTW01	CBM01B1
3	BSRTW01	CBM01B2
4	BSRTW01	CBM01B2
5	BSRTW01	CBM01B2
6	BSRTW01	CBM01B2
7	DMCONN	TF-Metal
8	DMCONN	TF-Metal
9	CAP_GCDIODE_N	Gate diode
10	CAP_GCDIODE_P	Gate diode
11	TS_MULT_PIXEL	TF
12	TS_MULT_PIXEL_PN	TF
13	PDTF02P	TF
14	PDTF02P	TF
15	PDTF02N	TF
16	PDTF02N	TF
17	SIMS1	SIMS
18	CHIP01	Switch
19	DIODE1	Pad diode
20	DIODE2	Pad diode
21	DIODE3	Pad diode
22	CAP_GCDIODE_N	Gate diode
23	TS_MULT_PIXEL_PN	TF
24	CAP_GCDIODE_P	Gate diode
25	DIODE1	Pad diode
26	DIODE2	Pad diode
27	DIODE3	Pad diode
28	BTSPO	TF
29	BTSPO	TF
30	CTSPO	TF
31	CTSPO	TF
32	CTSADC	TF
33	CTSADC	TF

CBM detector designed by GSI Darmstadt, Layout designed by CiS Erfurt

II. The process of CBM detector

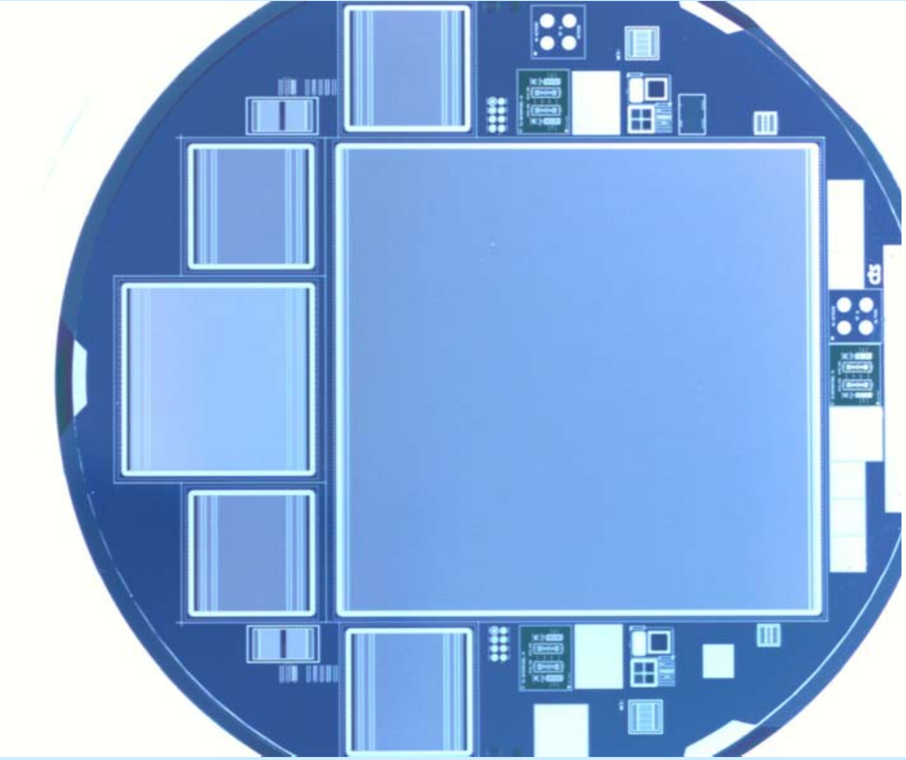
Material applied:
n-Si <111> 4~6kΩcm 285µm
Double side polished

Double layer metallization is developed and introduced to the production line.

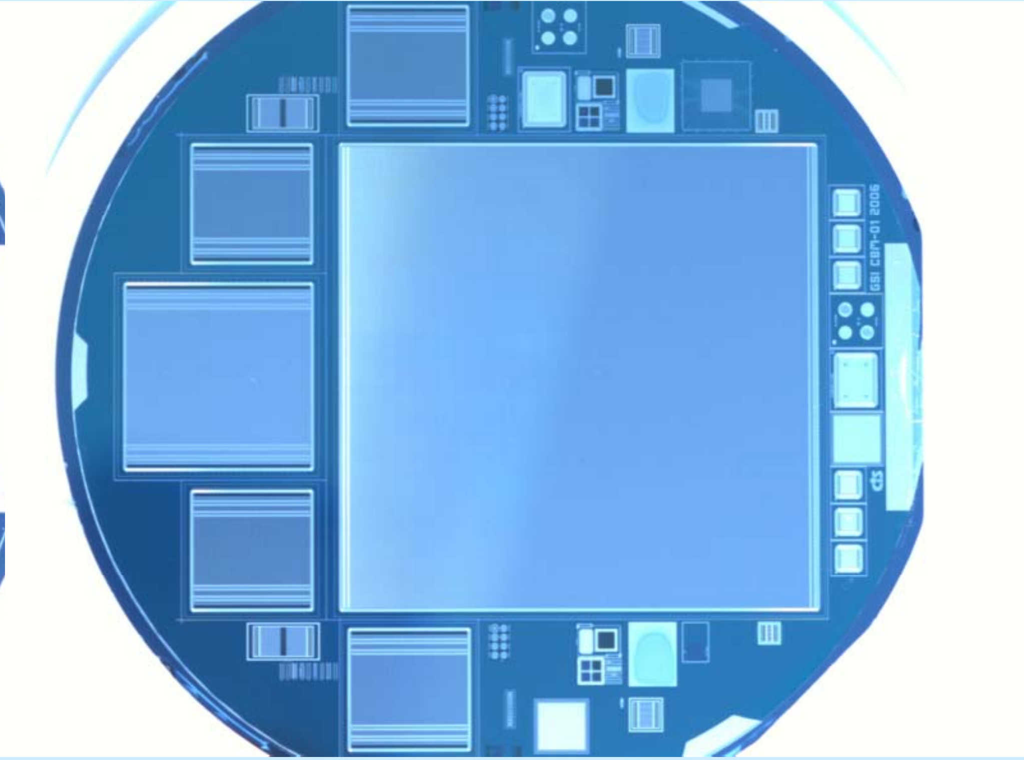
The other process steps are standard for irradiation detector.

Yield: full detector 20 good from 24 wafers

II. The process of CBM detector

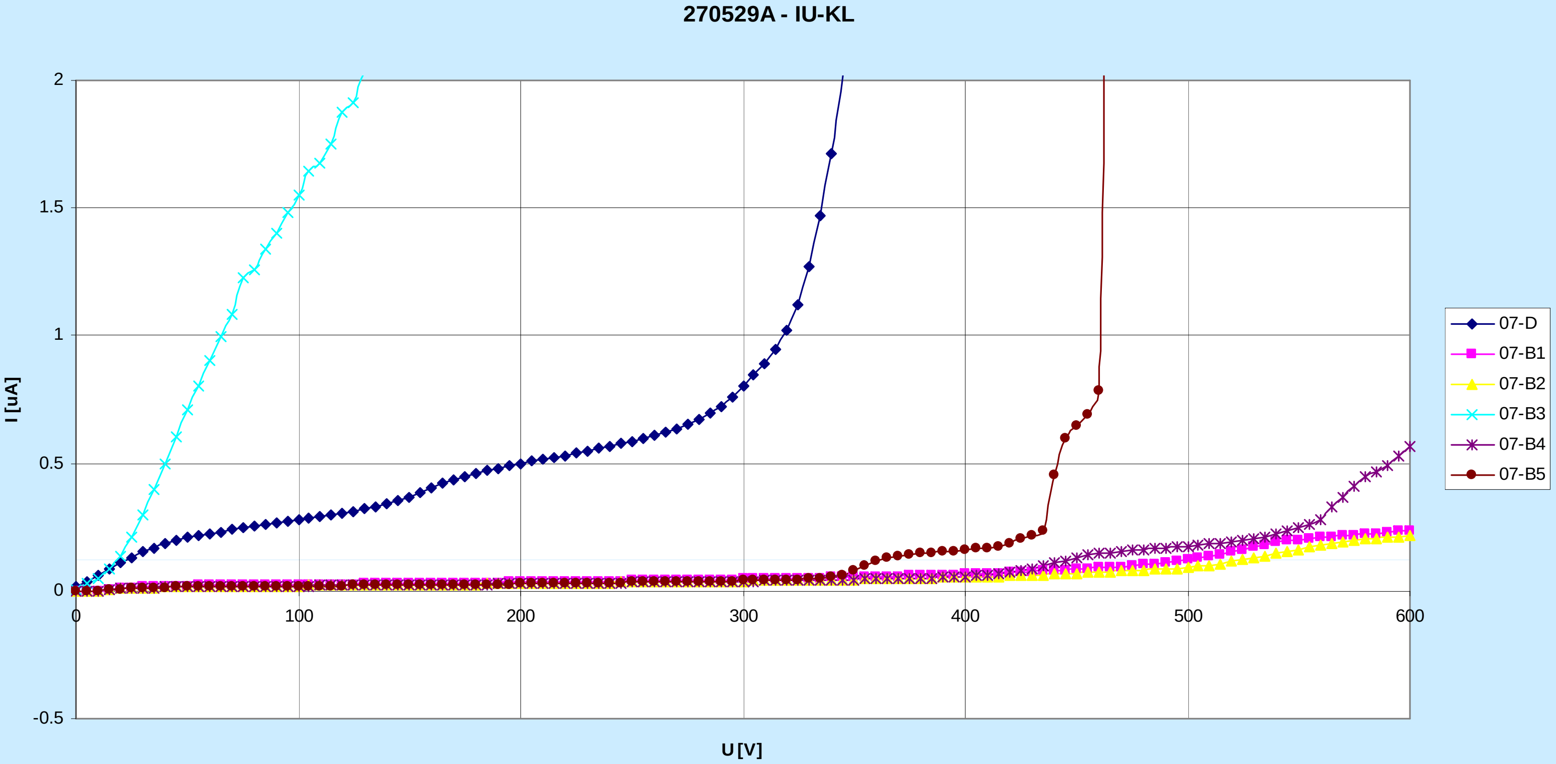


1. CBM_01 Detector front side



2. CBM_01 Detector back side

II. Performance of CBM



The IV curves of detectors form Wafer #7

(The dark current of bias ring with guard rings floating)

Active area: S_D=27.5cm^2, S_{B1}=4.2cm^2, $S_{B2\sim B5}$=1.7cm^2

Dark current of D at operation bias ~10nA/cm^2, at 300V < 1μA.

II. SPID

In frame of INNOWATT project “SPID “, we are planning the second iteration of manufacture to test more possibilities.

Status: simulation & layout finished, process started.

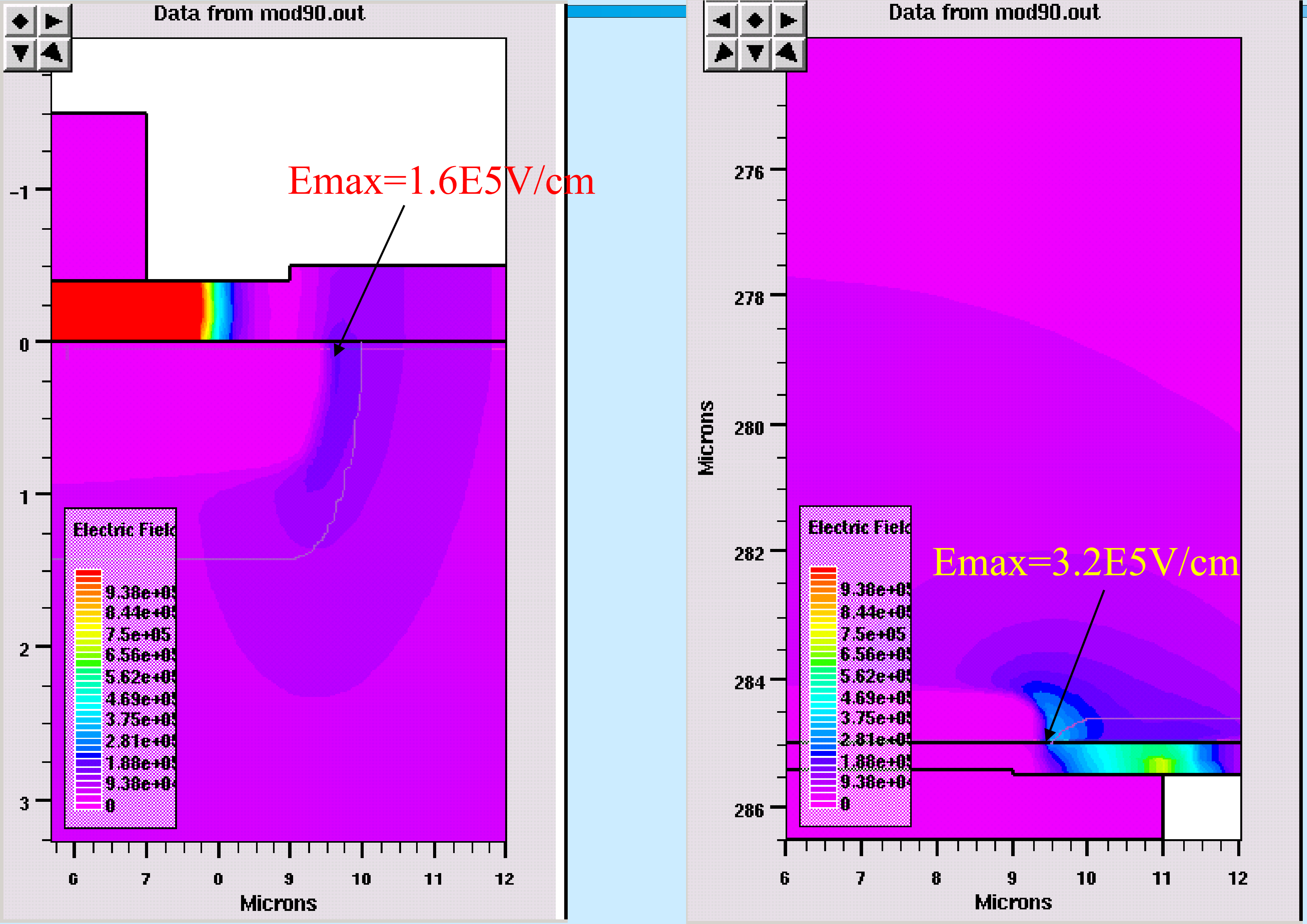
Material: n-silicon

Bias method:
Punch through, Poly-silicon (Bias resistance 1MΩ->4.3k Ω /□)

Isolation technology:
pspray , pstop, field plate

Breakdown voltage:
Charge, Micro discharge

II. SPID

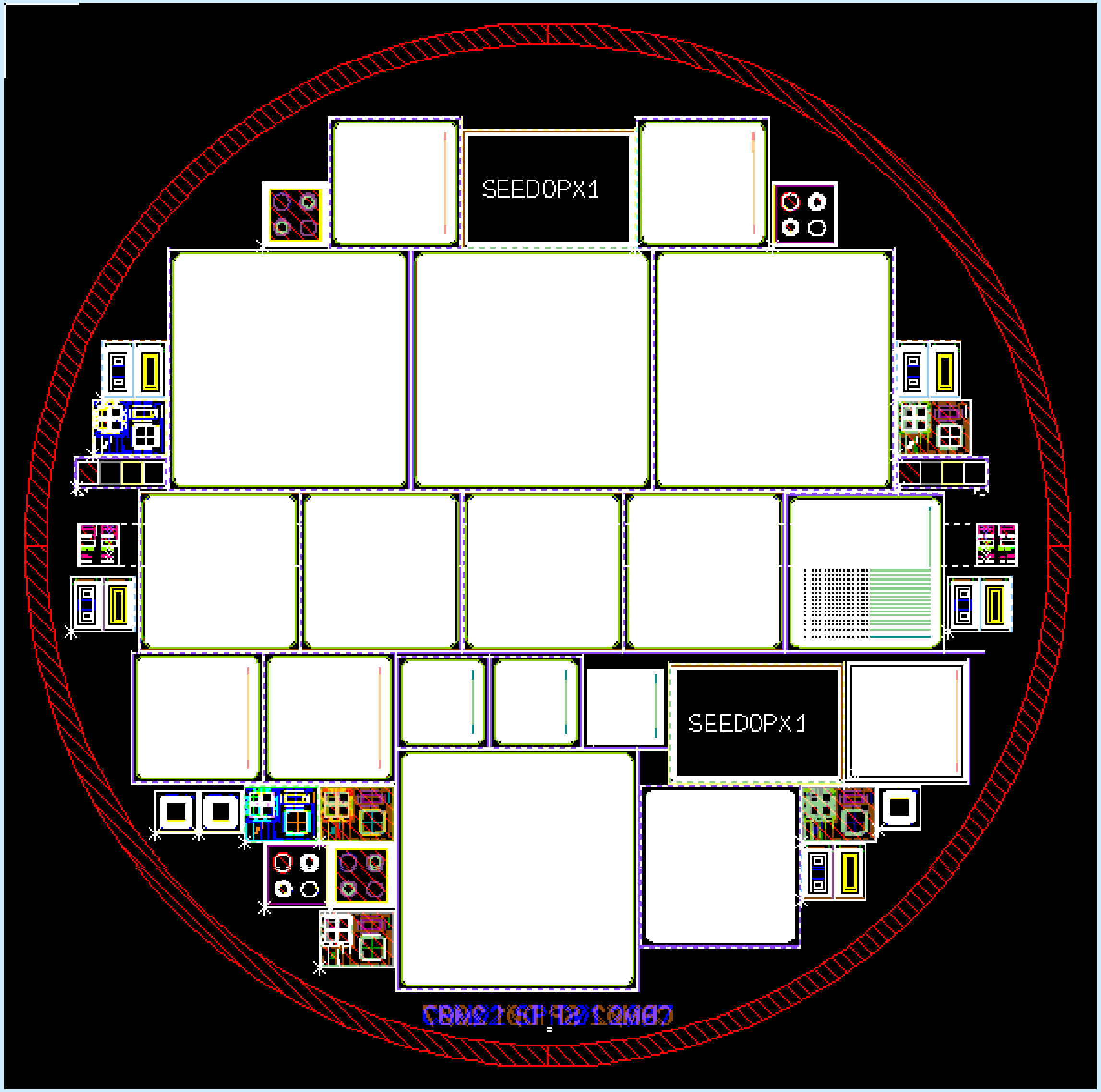


Emax=1.6E5V/cm

Emax=3.2E5V/cm

Field distribution of junction and ohmic side (500V)

II. SPID Layout



Layout of SPID designed by CiS Erfurt

II. SPID, sensor variants

Group	Quantity	biasing	isolation	pitch	Guard
Twpsp15	1	Poly	Spray	80,48	Guard
Twpsp12	1	punch	Spray	80	Guard
Twpsp13	1	Poly+punch	Pstop	80	Guard
Twpsp14	1	punch	Spray	80	Guard
Twpsp2	1	Poly	Spray	50	Guard
Twpsp22	1	punch	Spray	50	Guard
Twpsp23	1	poly+punch	Pstop	50	Guard
Twpsp24	1	poly+punch	Plate	50	Guard
Twpsp25	1	punch	Spray	50	2xguard
Twpsp5	1	Poly+punch	Spray	80	No
Twpsp6	1	poly+punch	Spray	50	No
Twpsp7	1	Punch	Spray	w/p	Guard
Twpspg5	2	poly+punch	Spray	80 w/p	Guard
Twpspg6	1	poly+punch	Spray	50 w/p	Guard
Twpx1	1	Punch	Pixel	80*120	No
Twpx3	1	Punch	Pixel	80*120	Guard
Twsp5	2	Punch	Spray	80	Guard
Twsp6	1	Punch	Spray	50	Guard
mastercis	5	Punch	Pixel		Guard

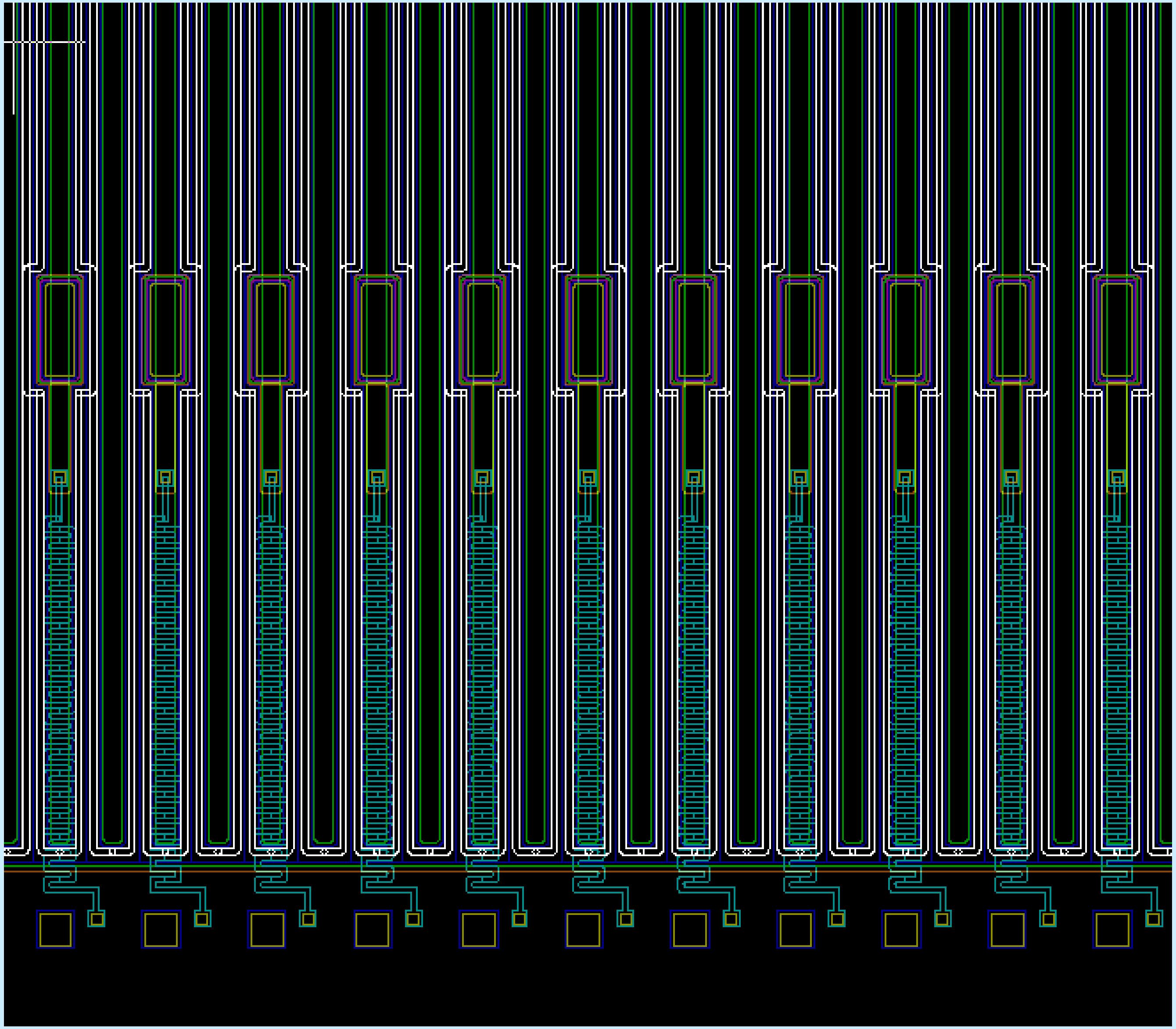
Cooperation partners:

- GSI Darmstadt
- CPPM
- Uni. Bonn

Irradiation test:

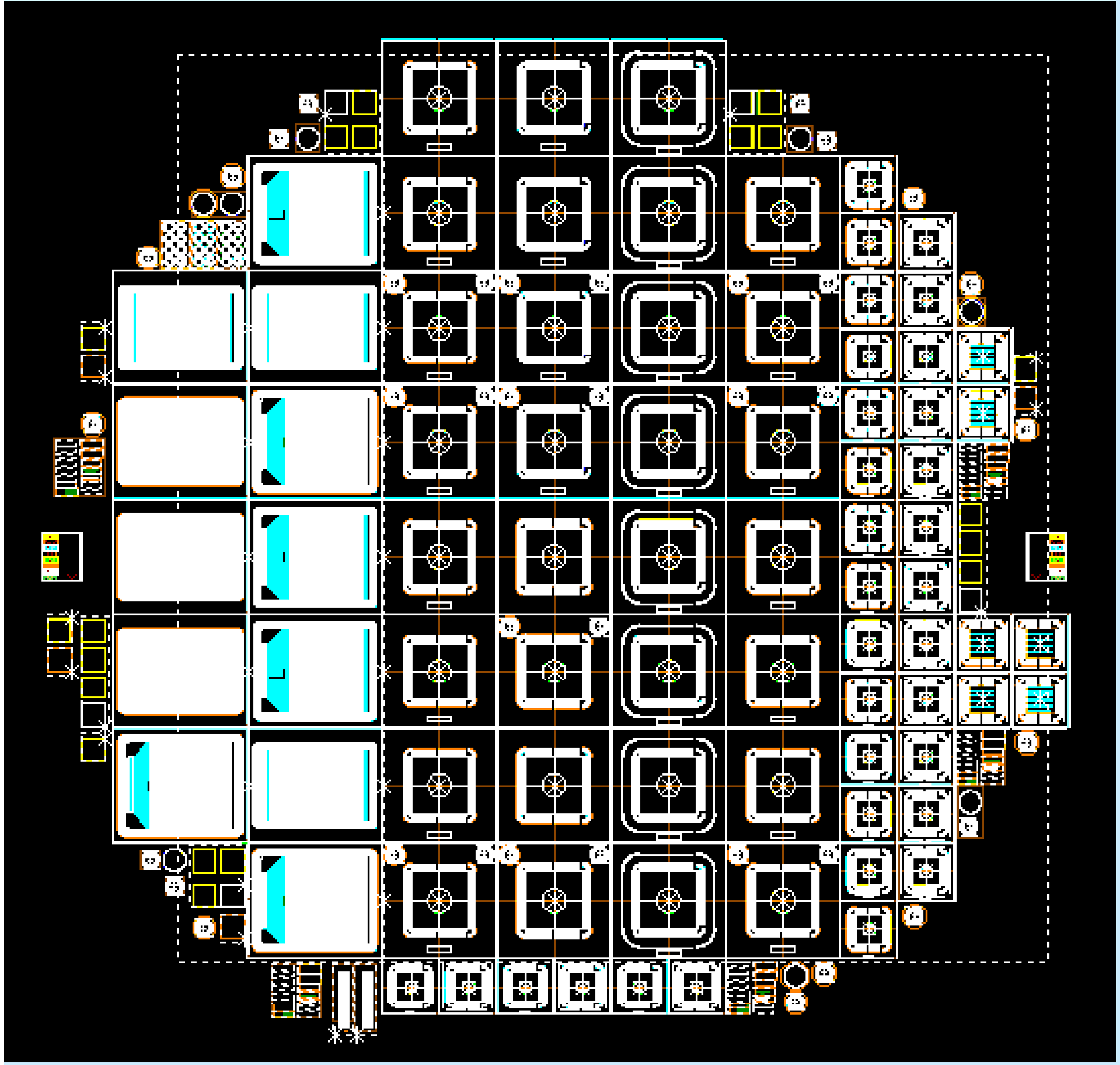
- Different biasing
- Different isolation
- No budget
- Sample

II. SPID



A detector with pstop and poly-silicon biasing

II. SSD



Material:
P-Silicon

Thank the support from:
- Uni. Hamburg
- MPI. Munich

Layout designed by CiS Erfurt

III. After irradiation

Results from RD50, e.g. Hamburg model and update

Use effective fluence of 1MeV neutron

Exceptions can be handled, proton, neutron, gamma

If necessary microscopic model of defect formation and evolution can be involved.

III. After irradiation

Variation of effective doping

$$\Delta N_{eff}(\Phi_{eq}, t(T)) = N_C(\Phi_{eq}) + N_a(\Phi_{eq}, t(T)) + N_Y(\Phi_{eq}, t(T))$$

$$N_C(\Phi_{eq}) = N_{C0}(1 - \exp(-c\Phi_{eq})) + g_C\Phi_{eq}$$

$$N_{C0} = (0.60 - 0.90) N_{eff\,0}$$

$$c = (1 - 3) \times 10^{-13}\, cm^2$$

$$g_C = (1.49 \pm 0.03) \times 10^{-2}\, cm^{-1}$$

$$N_Y(\Phi_{eq}, t(T)) = N_{Y\infty}(1 - \exp(-t/\tau)) \approx N_{Y\infty}(1 - \frac{1}{1 + t/\tau})$$

$$N_{Y\infty} = g_Y \Phi_{eq}$$

$$g_Y = (5.16 \pm 0.09) \times 10^{-2}\, cm^{-1}$$

$$\tau(60°C) = 100\,\min; \tau(20°C) = 350 days$$

$$N_a(\Phi_{eq}, t(T)) = N_{A,0} \exp(-t/\tau)$$

$$N_{A,0} = g_a \Phi_{eq}$$

$$g_a = (1.92 \pm 0.05) \times 10^{-2}\, cm^{-1}$$

$$\tau(60°C) = 20\,\min; \tau(20°C) = 2 days$$

Variation of dark current

$$\Delta I / V = \alpha \Phi_{eq}$$

$$\alpha(t) = \alpha_0 \exp(-t/\tau_I) + \alpha_1 + \alpha_2 \ln(t/t_0)$$

$$\alpha_0 = (1.23 \pm 0.06) \times 10^{-17}\, A/cm.$$

$$1/\tau_I = k_{OI} \exp(-E_I / kT)$$

$$k_{0I} = 1.2^{+5.3}_{-1.0} \times 10^{13}\, S^{-1}$$

$$k_{0I} = 1.2^{+5.3}_{-1.0} \times 10^{-18}\, S^{-1}$$

$$E_I = (1.11 \pm 0.05) eV$$

$$\alpha_2 = (3.07 \pm 0.18) \times 10^{-18}\, A/cm$$

$$\alpha_1(T_a) = \alpha_{10} + \alpha_{11} \times 1/T_a$$

$$\alpha_{10} = -(8.9 \pm 1.3) \times 10^{-17}\, A/cm$$

$$\alpha_{11} = (4.6 \pm 0.4) \times 10^{-14}\, AK/cm$$

N-Si FZ, DOFZ

Further parameters or formulea for
P-Si, Epilayer, MCZ, CZ
Under the same empirical formalism or new

M. Moll, TN/01-04.; G. Lindstroem, M. Moll, E. Fretwurst, NIMA 426 1-15

IV. Prodid, a windows program for computer aided model generation

VC++ 6.0
Update to VC 2005
N-FZ-DOFZ-Silicon implemented

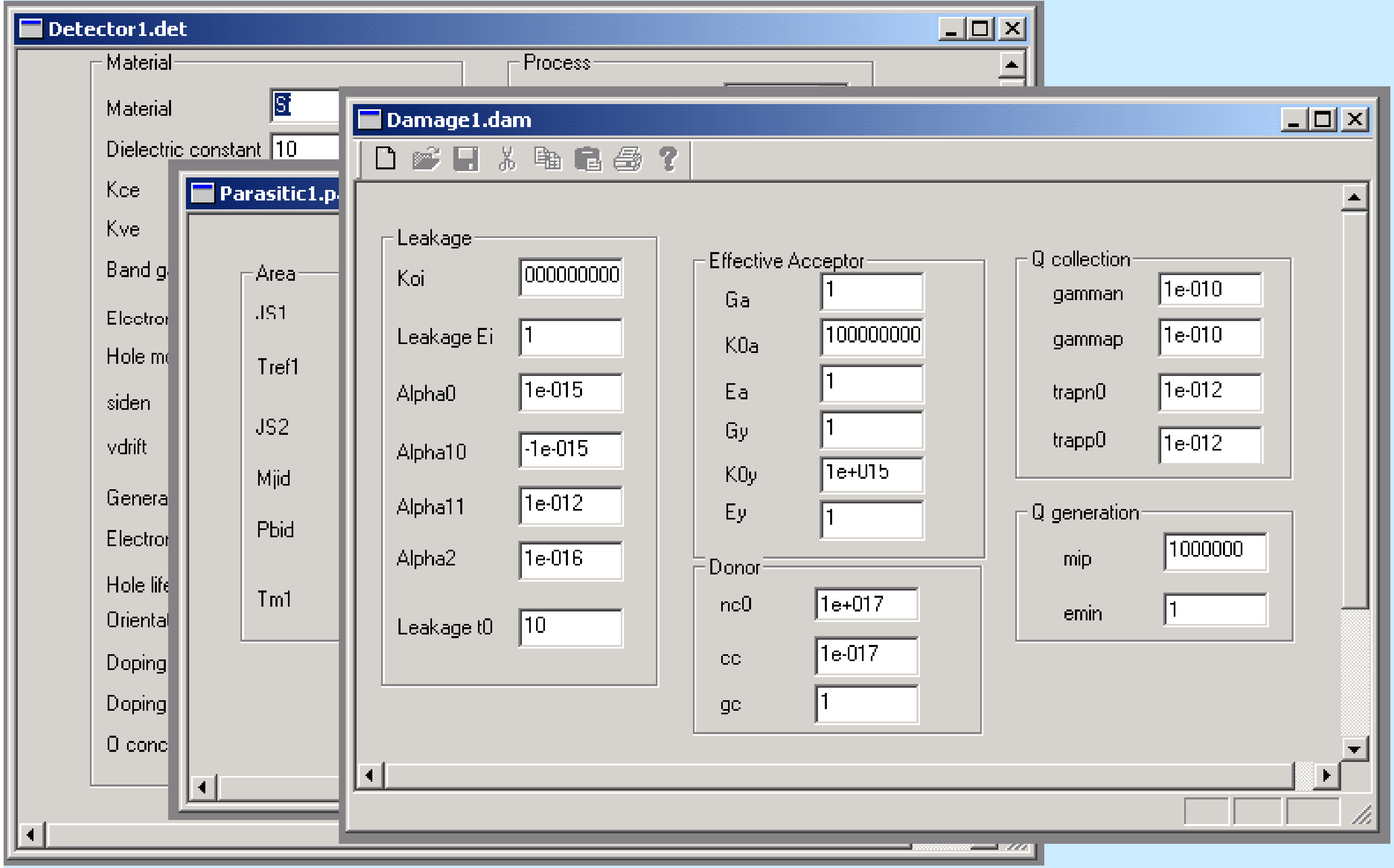
4 input forms for sensor description

- Detector (.det: material, process and geometry)
- Damage (.dam: leakage, Neff, CCE, detection)
- Irradiation (dose, temp, time)
- Parasitic (.par: area, periphery, parasitic)

2 actions:

- Scenario: leakage current, effective doping as a function of time
- Spice: Spice model generation for sensor at given time

IV. Prodid



Material

Material: Si
Dielectric constant: 10
Kce
Kve
Band g
Electro
Hole m
siden
vdrift
Genera
Electro
Hole life
Orienta
Doping
Doping
O conc

Process

Area

JS1
Tref1
JS2
Mjid
Pbid
Tm1

Leakage

Koi: 000000000
Leakage Ei: 1
Alpha0: 1e-015
Alpha10: -1e-015
Alpha11: 1e-012
Alpha2: 1e-016
Leakage t0: 10

Effective Acceptor

Ga: 1
K0a: 100000000
Ea: 1
Gy: 1
K0y: 1e+015
Ey: 1

Donor

nc0: 1e+017
cc: 1e-017
gc: 1

Q collection

gamman: 1e-010
gammap: 1e-010
trapn0: 1e-012
trapp0: 1e-012

Q generation

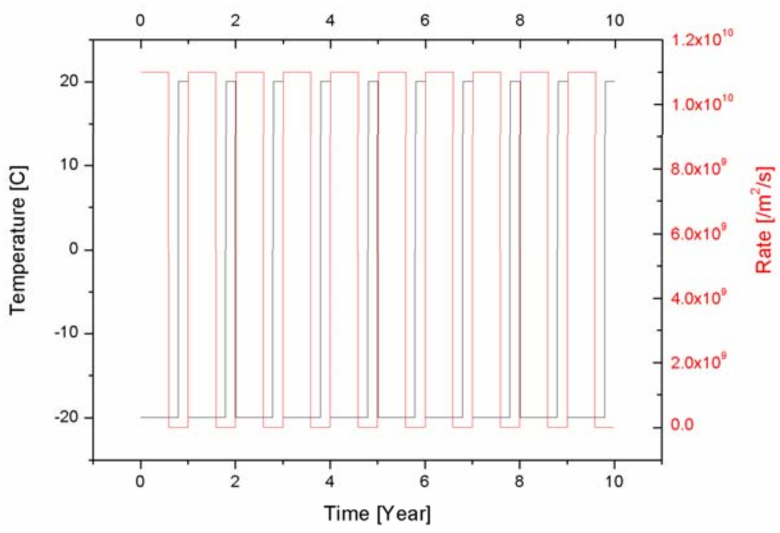
mip: 1000000
emin: 1

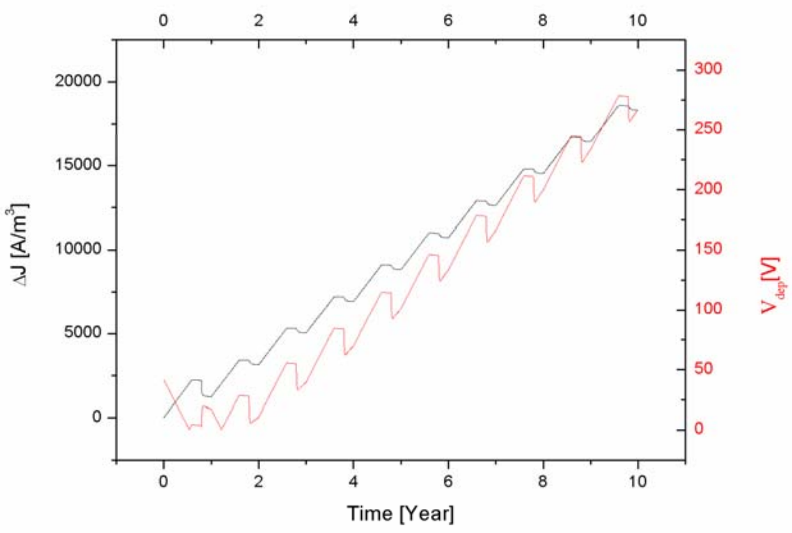
Input forms

IV. Prodid

- Fast, due to the separation of fast and slow process
- Charge sharing, charge division can be simulated
- CCE charge trapping induced degradation can be implemented
- Assist front end electronic development
- Extend to complicated system
- If Irradiation degradation can not be uniquely described by the empirical formulae, database can be planned

V. Examples

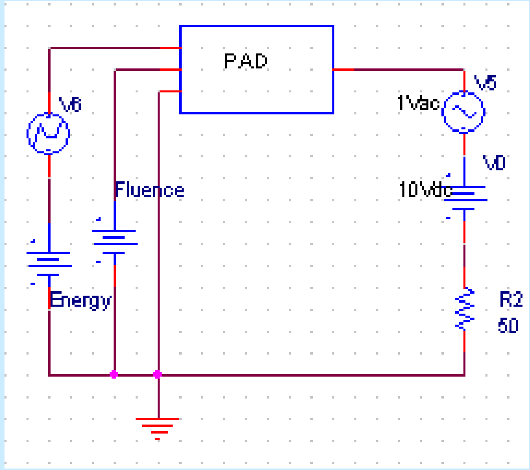




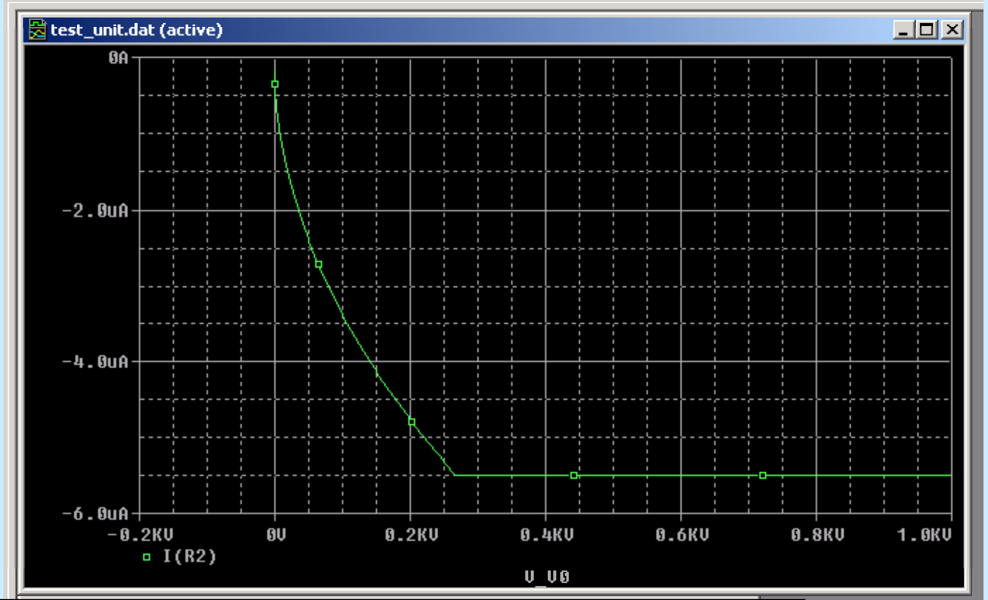
Irradiation fluence and temperature scenario

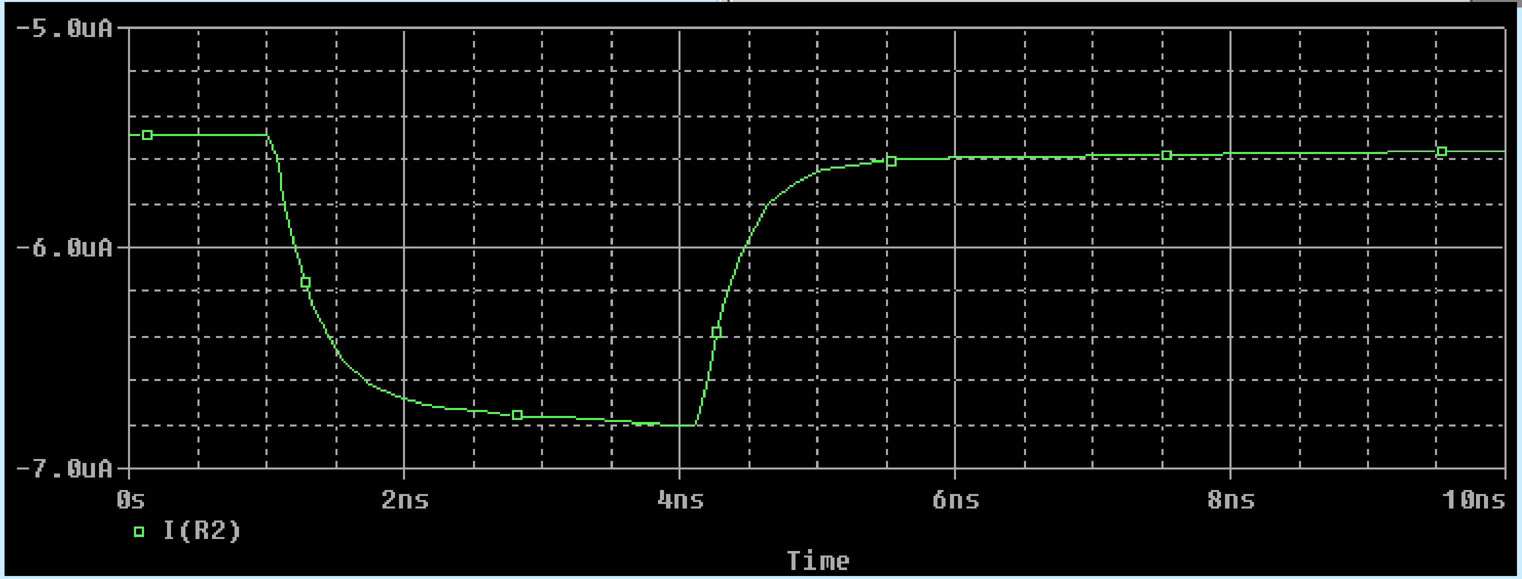
Degradation of leakage current and effective doping

V. Examples



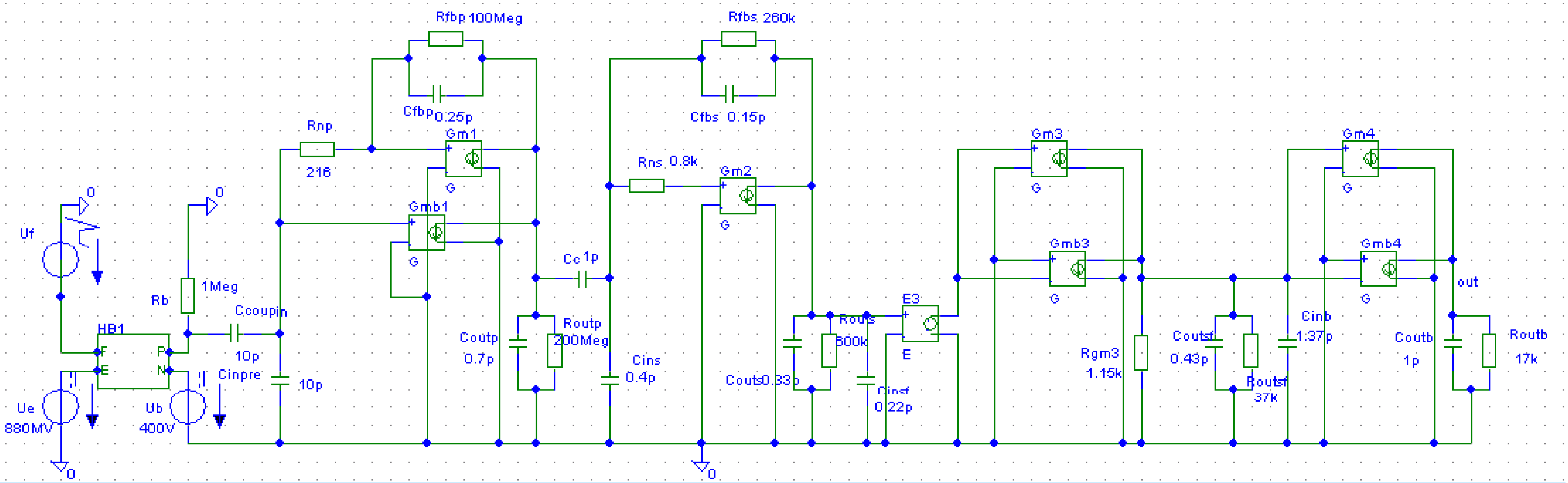
400V DC





Pad 1mm*1mm, 300μ thick, after 2e14/cm2 detecting 1 particle of 880MeV

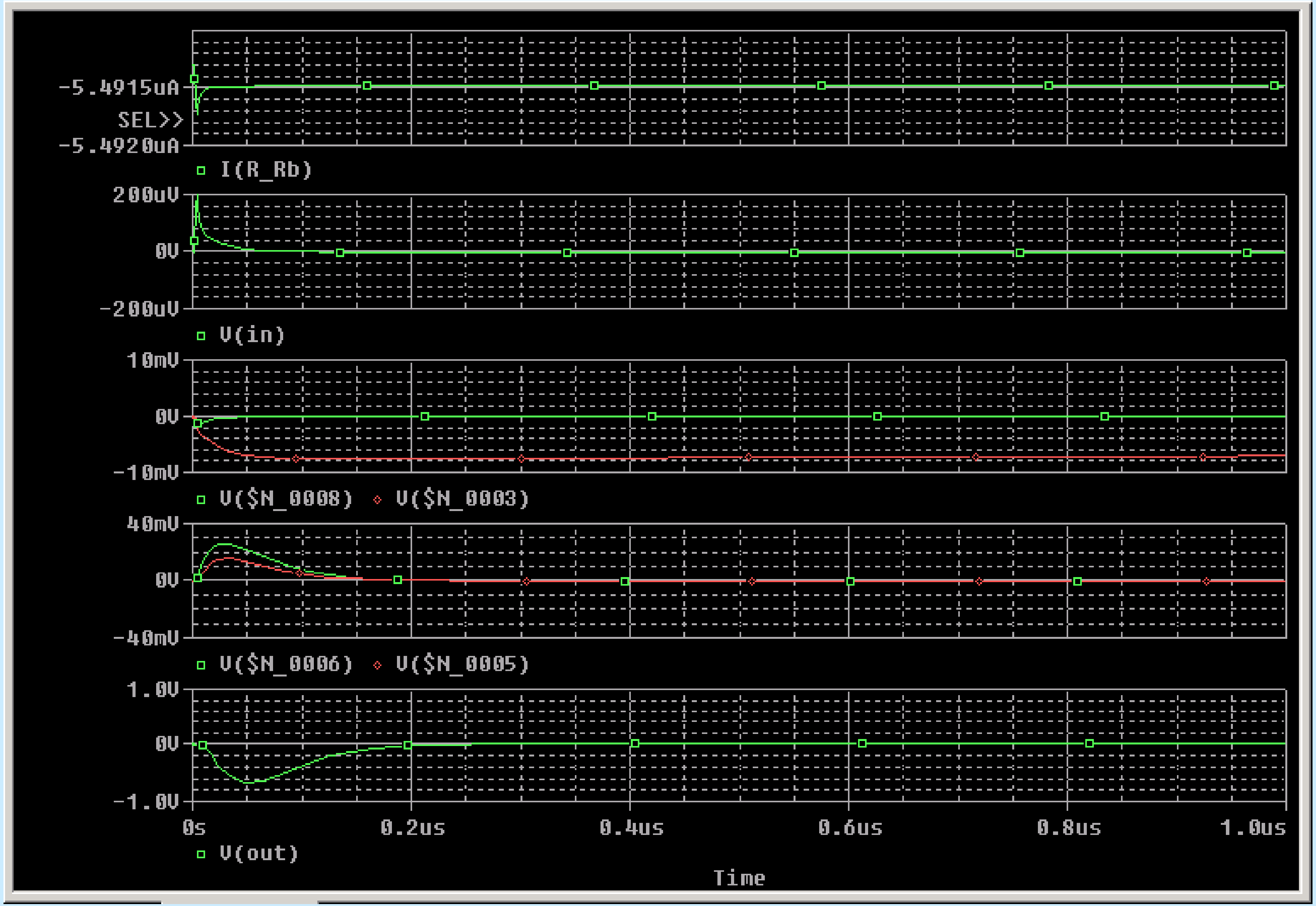
V. Examples



One channel: 1mm*1mm, 300μ thick, after 2e14/cm2 1MeV neutron irradiation
Detecting 1 particle of 880MeV
Front end: CSA, Shaper, SF, Buffer. E. Nygard,…, NIMA 301, 1991, p506.

One channel of detector

V. Examples


-5.4915uA
SEL>>
-5.4920uA
□ I(R_Rb)
200uV
0V
-200uV
□ V(in)
10mV
0V
-10mV
□ V($N_0008) ◇ V($N_0003)
40mV
0V
-40mV
□ V($N_0006) ◇ V($N_0005)
1.0V
0V
-1.0V
0s
0.2us
0.4us
0.6us
0.8us
1.0us
□ V(out)
Time

VI. Summary

- SPICE model for irradiation detectors
- PRODID n-silicon FZ DOFZ material
- Irradiation induced degradation
- Test sensors manufacture: 50~80μm pitch
  N-Si, P-Si
  Different bias, isolation technology, double metallization
- Sensors test: external
  Readout, Irradiation test.
- Tested the wave form of readout
- Fast, due to separation
- Multiple channels application with charge sharing