X-ray and electron irradiations at Karlsruhe and ELSA (Bonn)

Status and plans

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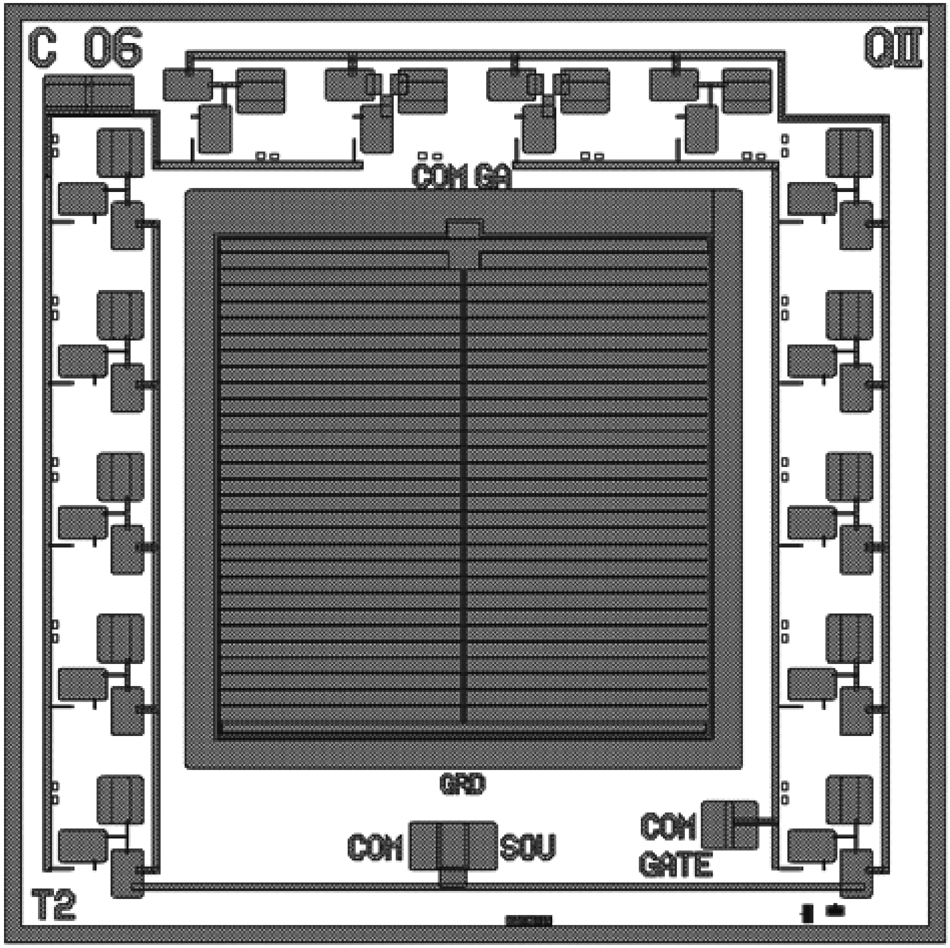
Outline

1. Irradiation in Karlsruhe
    1. Clear Gate
    2. Sensitive area and cross sections
    3. Threshold voltage shift
    4. Influence of Gate voltage
2. Irradiation at ELSA (Bonn)
    1. Setup
    2. Irradiation procedure
    3. Dosimetry and results
3. Conclusion & Outlook

Layout of thin oxide devices



Characteristics of thin oxide structures:

- Wafer divided into 4 quadrants
- Each quadrant stands for one thickness of Si_3N_4. SiO_2 thickness is the same for all
- Central device: Capacitor or Gate Controlled Diode
- 14 Transistor (=2x7), with diff. Gate length and width
- Different doping profiles available

Influence of Gate Voltage during irradiation

X-RAY IRRADIATION IN KARLSRUHE

Goals and setup

Idea

- 10 nm Si_3N_4 has proven to be a promising candidate from previous irradiations campaign

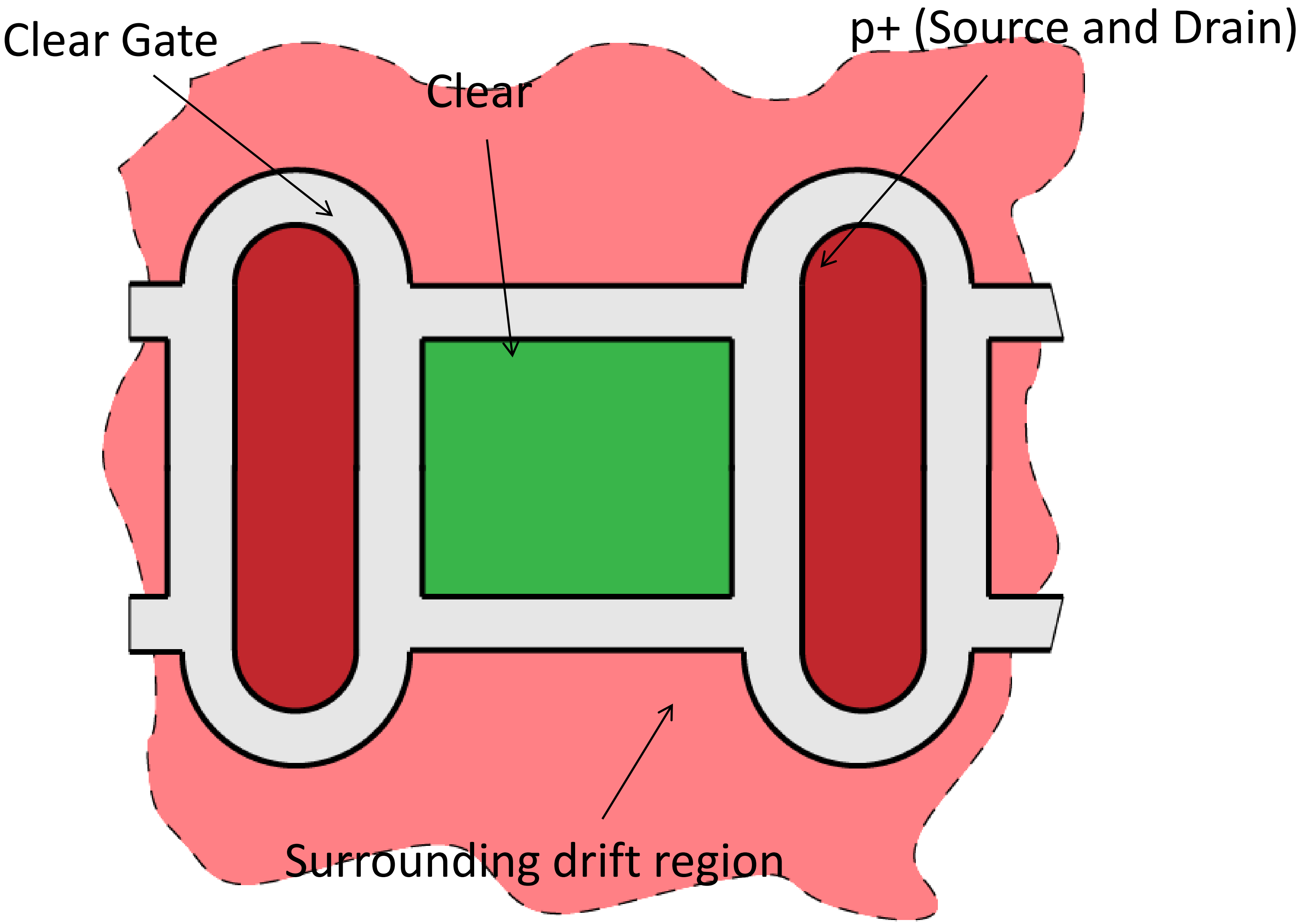
Aim

- Investigate irradiation effects at Clear Gates, especially voltage dependent behavior
- Investigate interface generated leakage currents

Devices

- Doping of chosen transistors is similar to a DEPFET Clear Gate
- Dimensions are similar to PXD 6

Motivation - Possible Pixel Layout



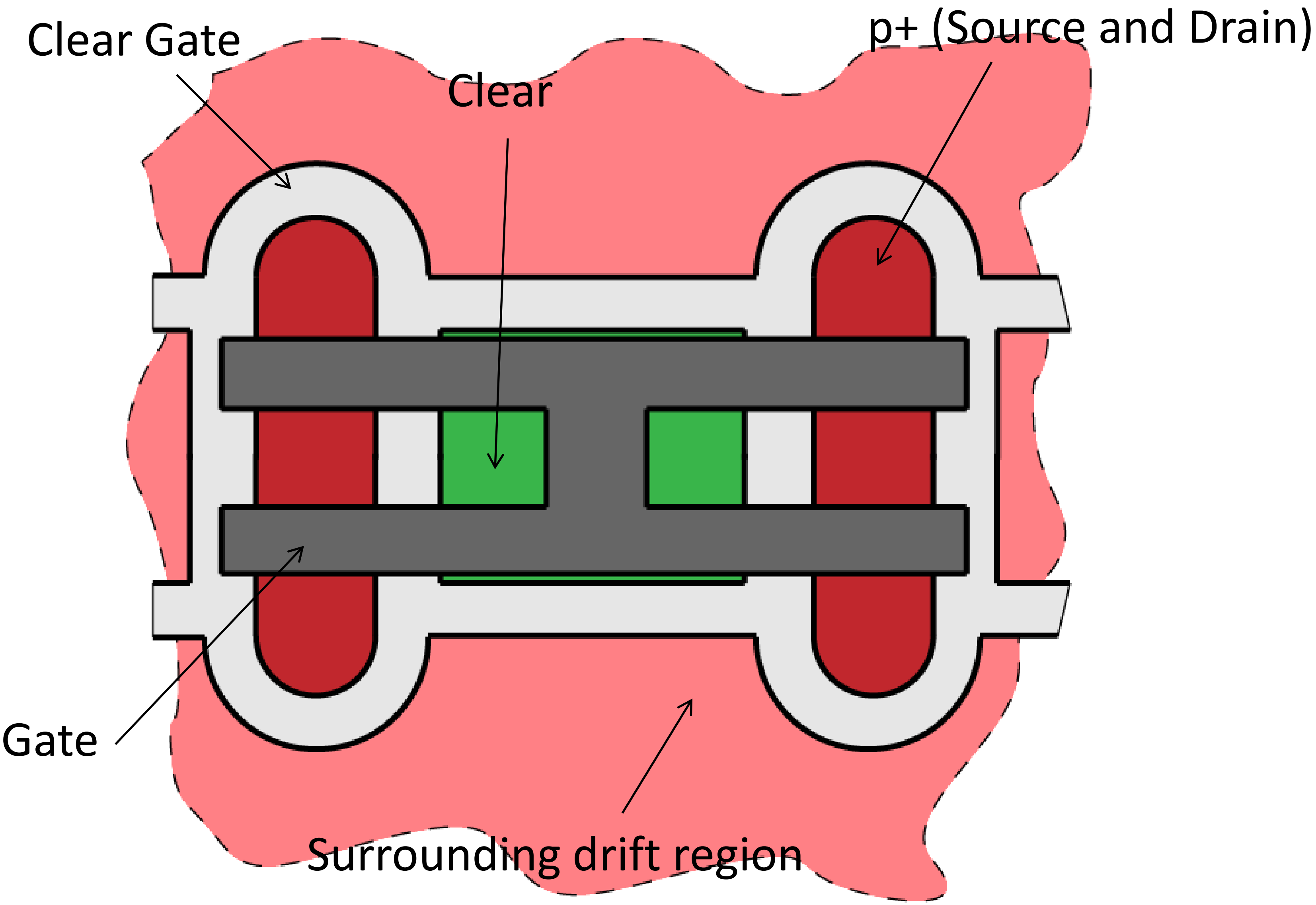
Clear Gate

Clear

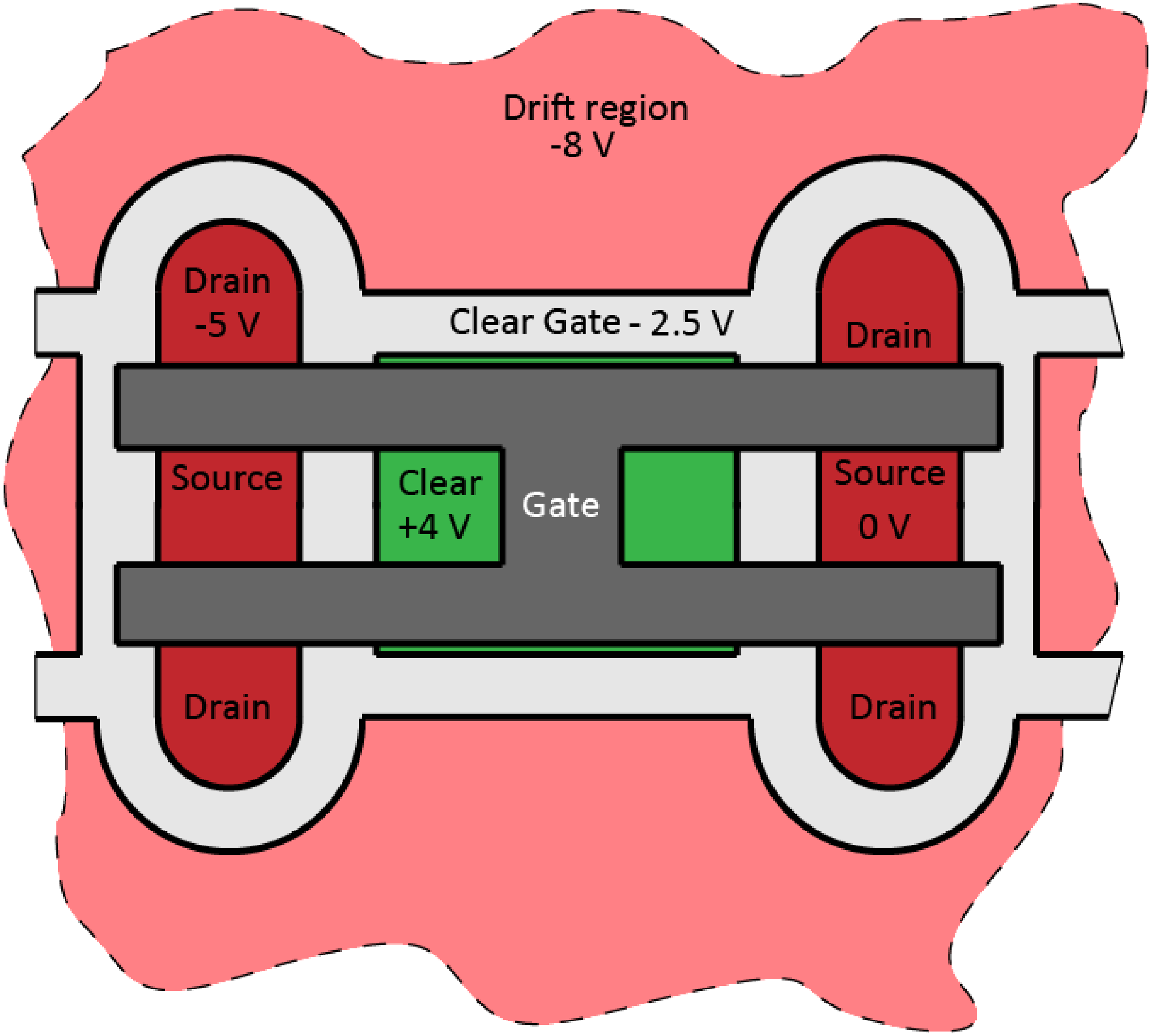
p+ (Source and Drain)

Surrounding drift region

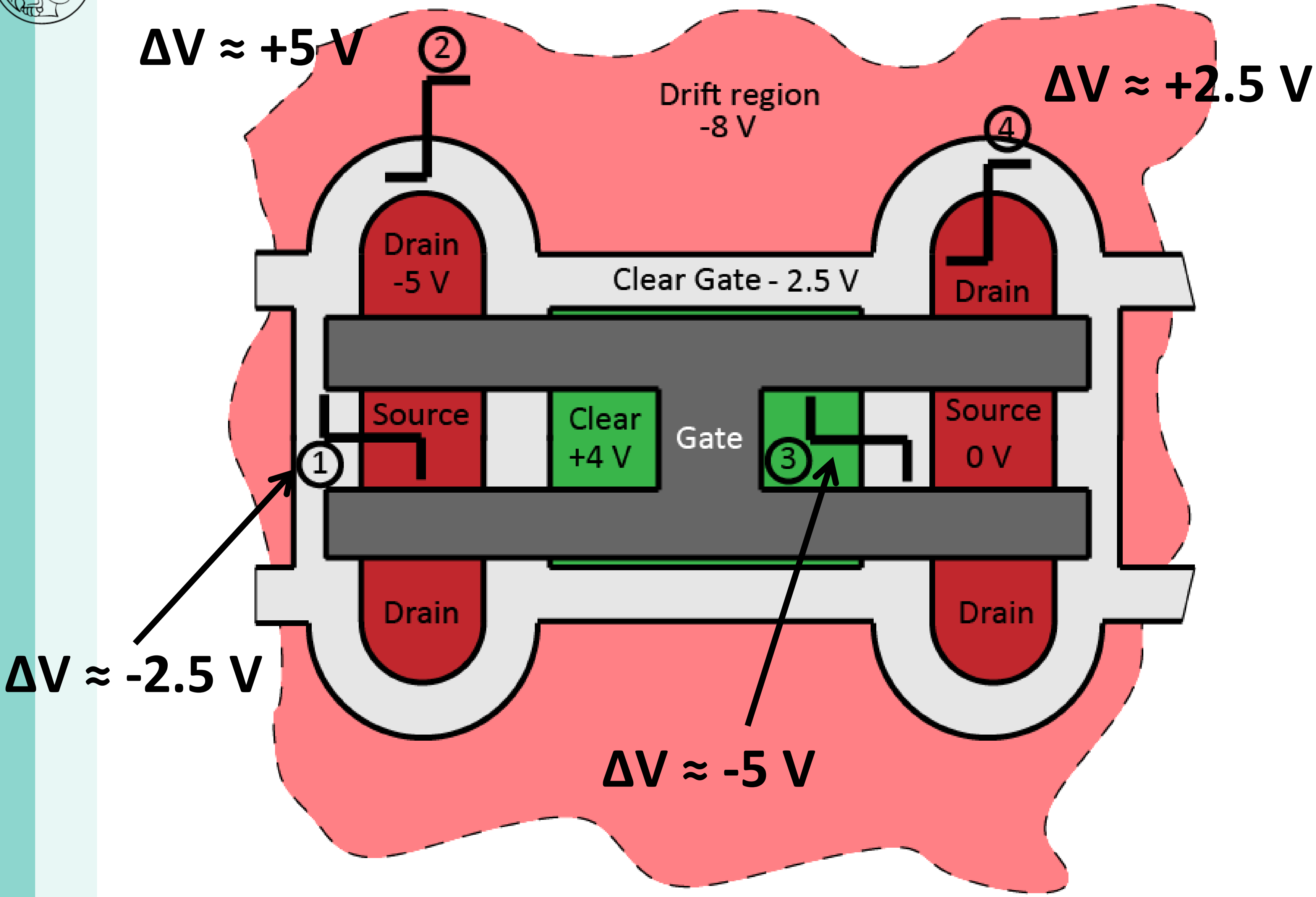
Motivation (II)- Possible Pixel Layout



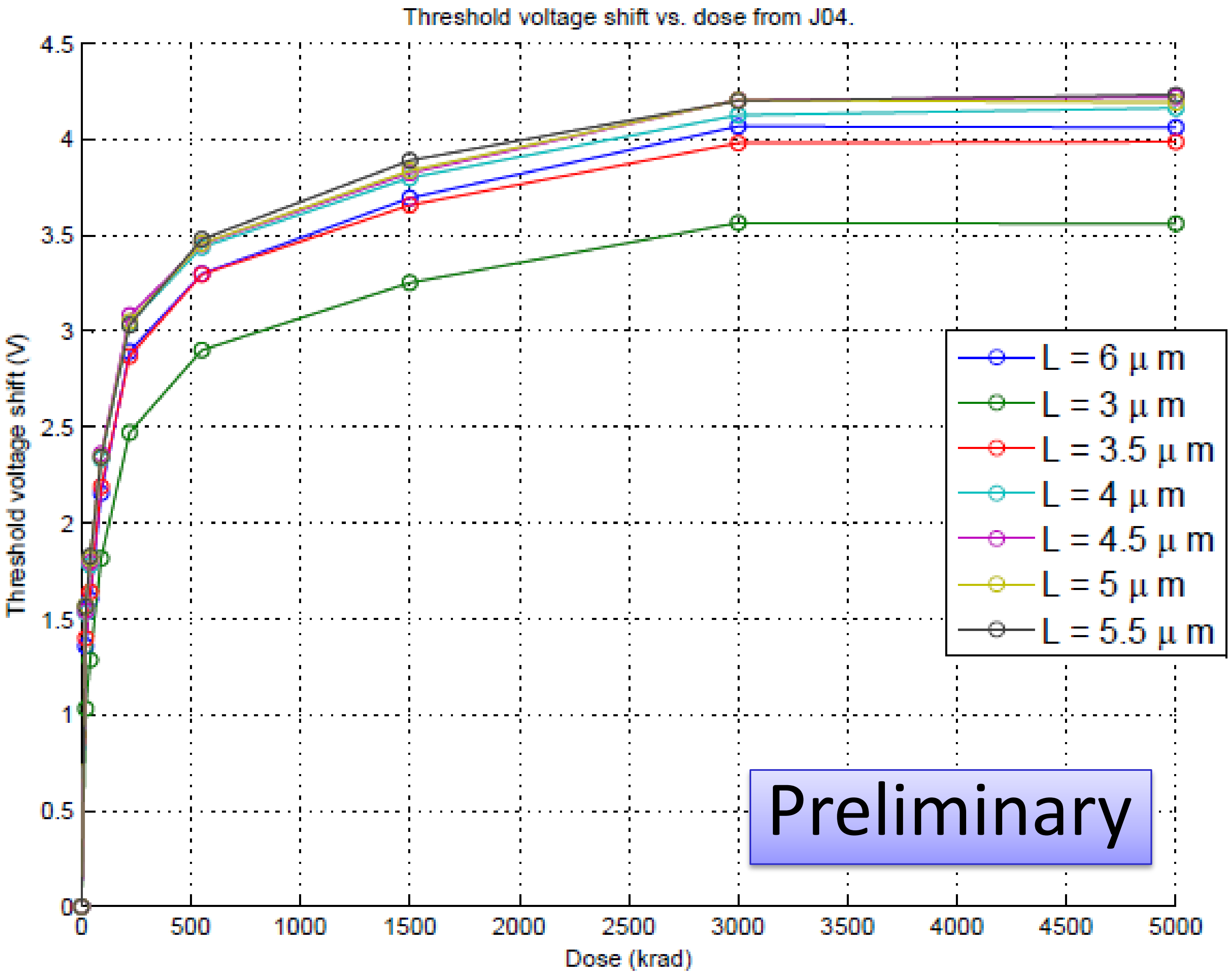
Motivation (III)- Possible Pixel Layout and Potentials



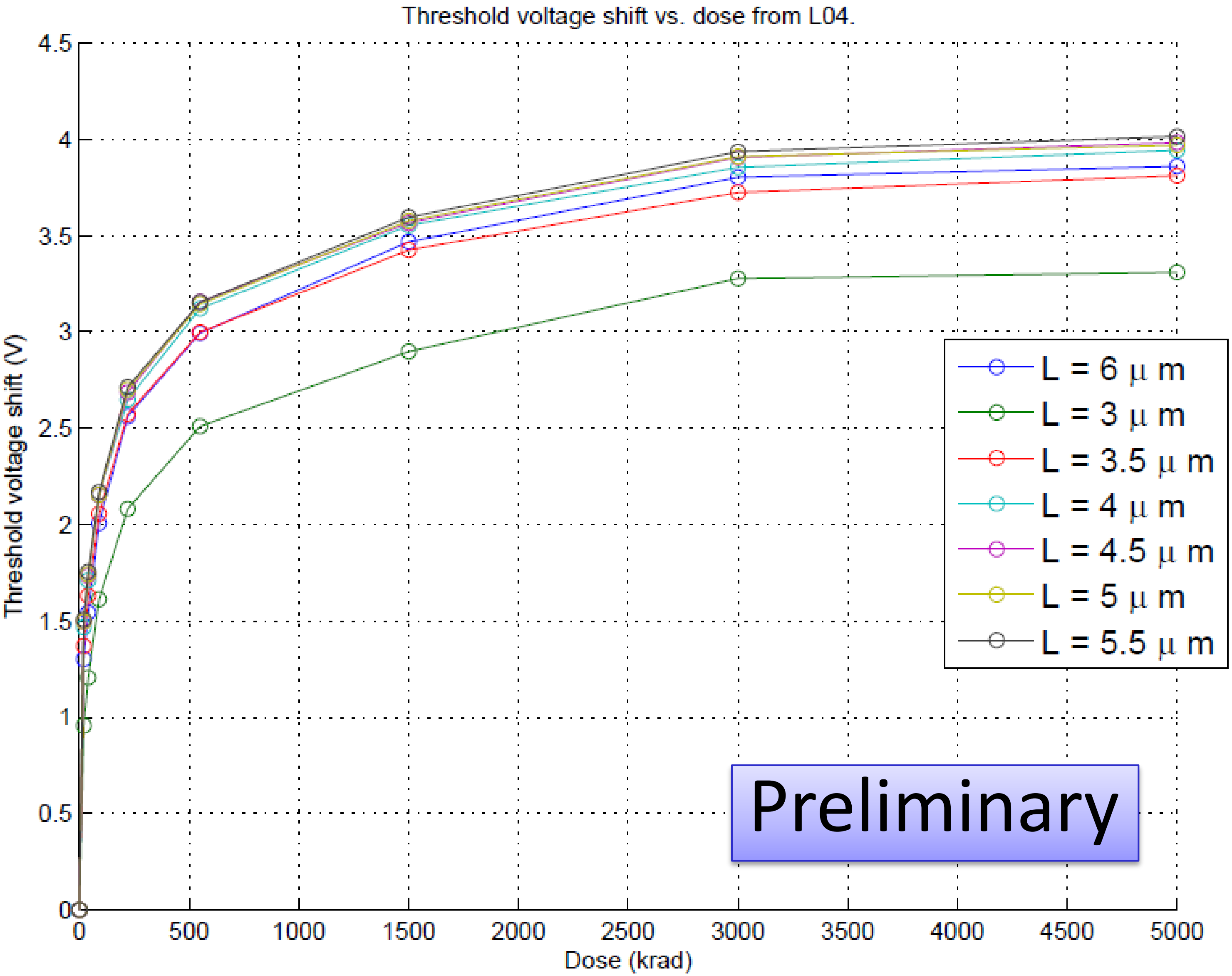
Motivation (IV)- Possible Pixel Layout and relevant cross sections



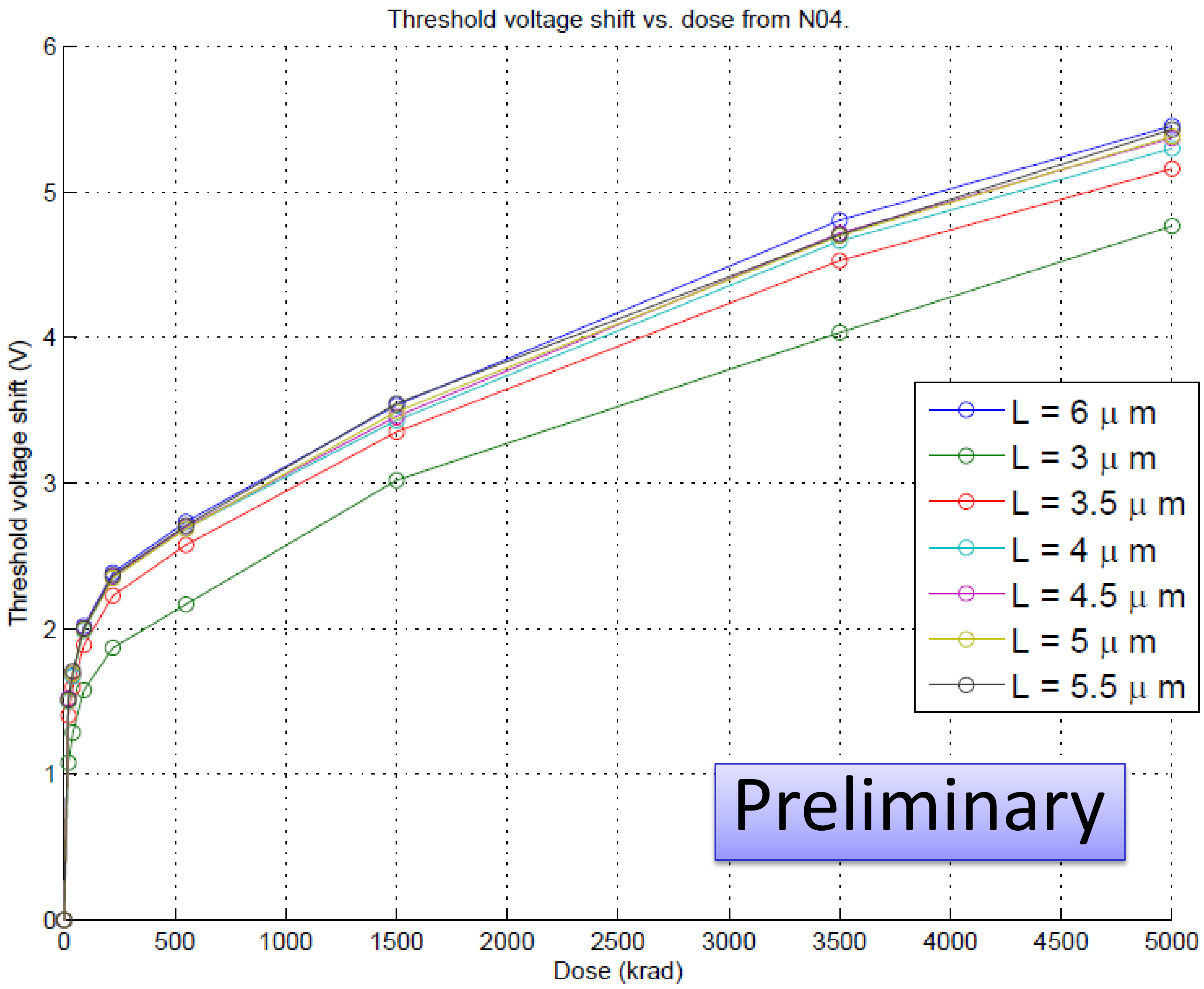
Clear Gate Results, -5 V during Irradiation



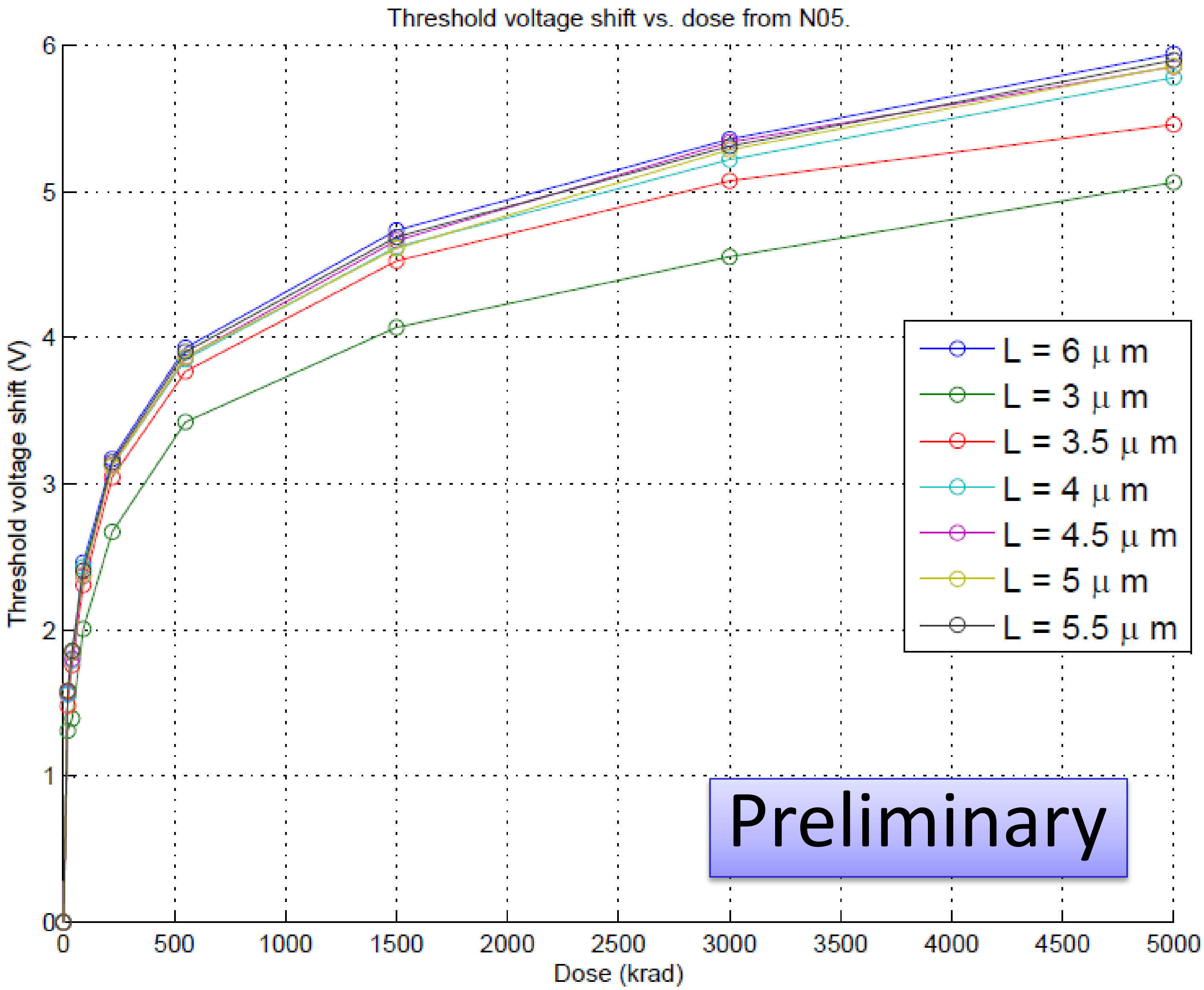
Clear Gate Results, -2.5 V during Irradiation



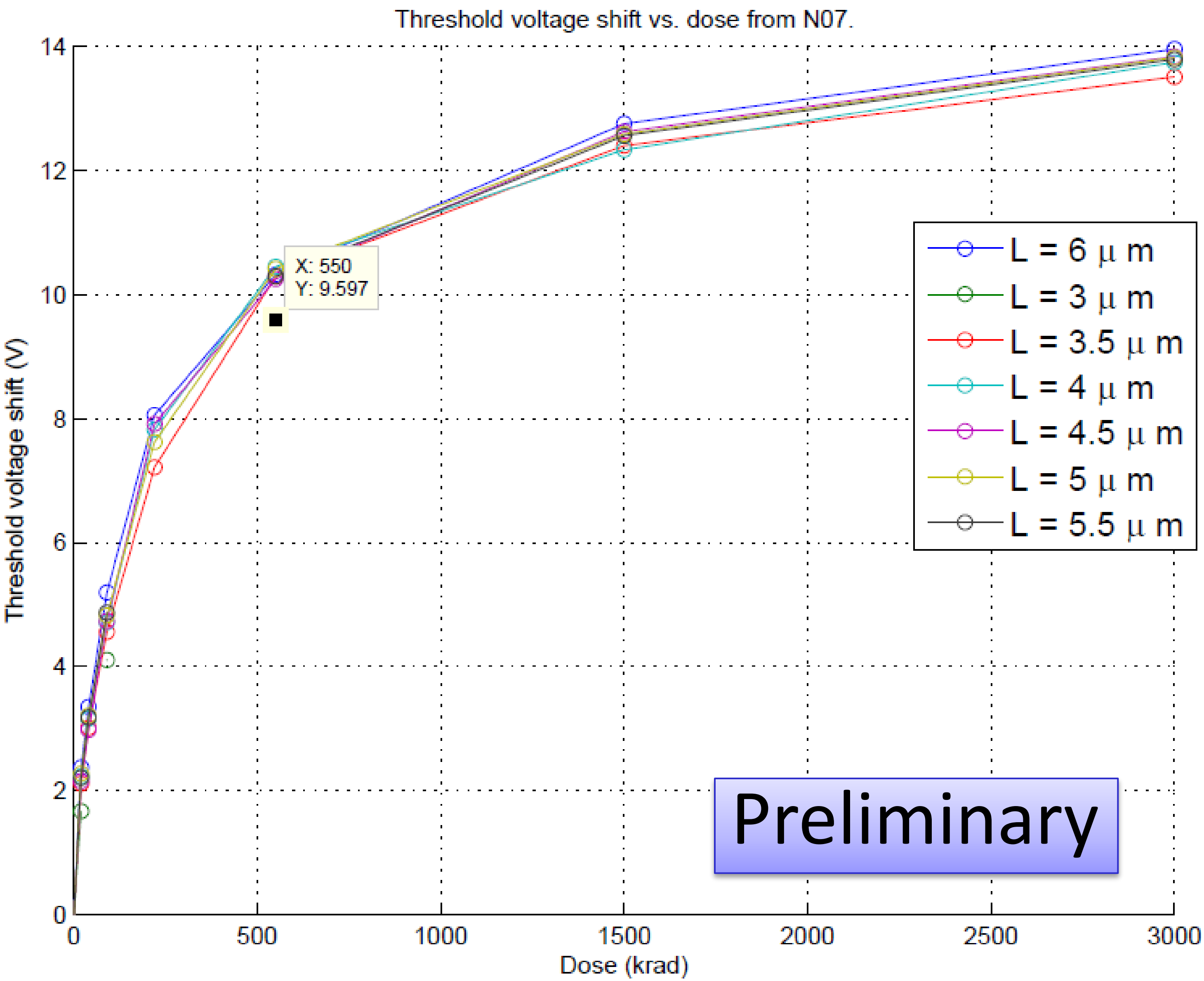
Clear Gate Results, 0 V during Irradiation



Clear Gate Results, +2.5 V during Irradiation

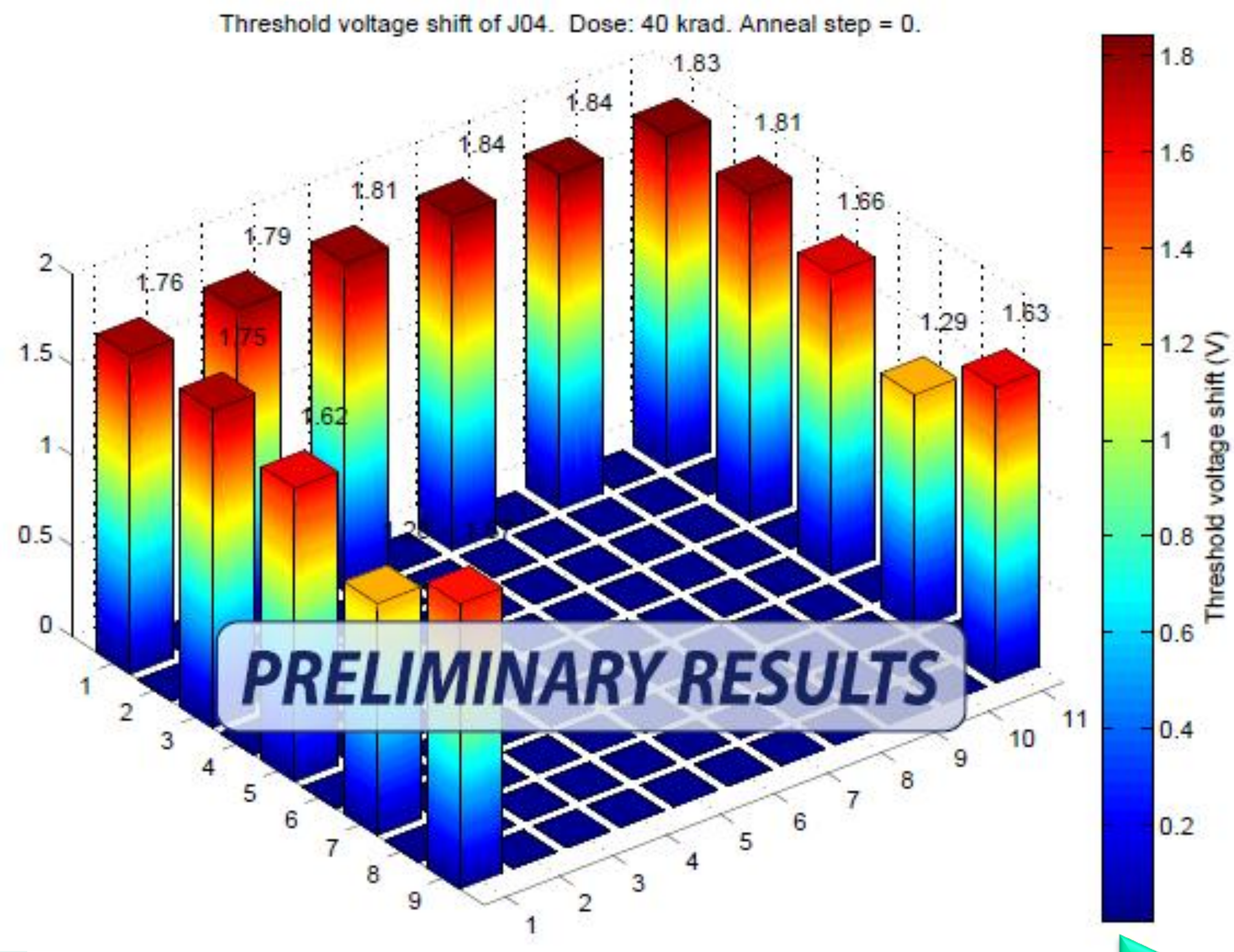


Clear Gate Results, +5 V during Irradiation



Preliminary

Homogeneity of Beam

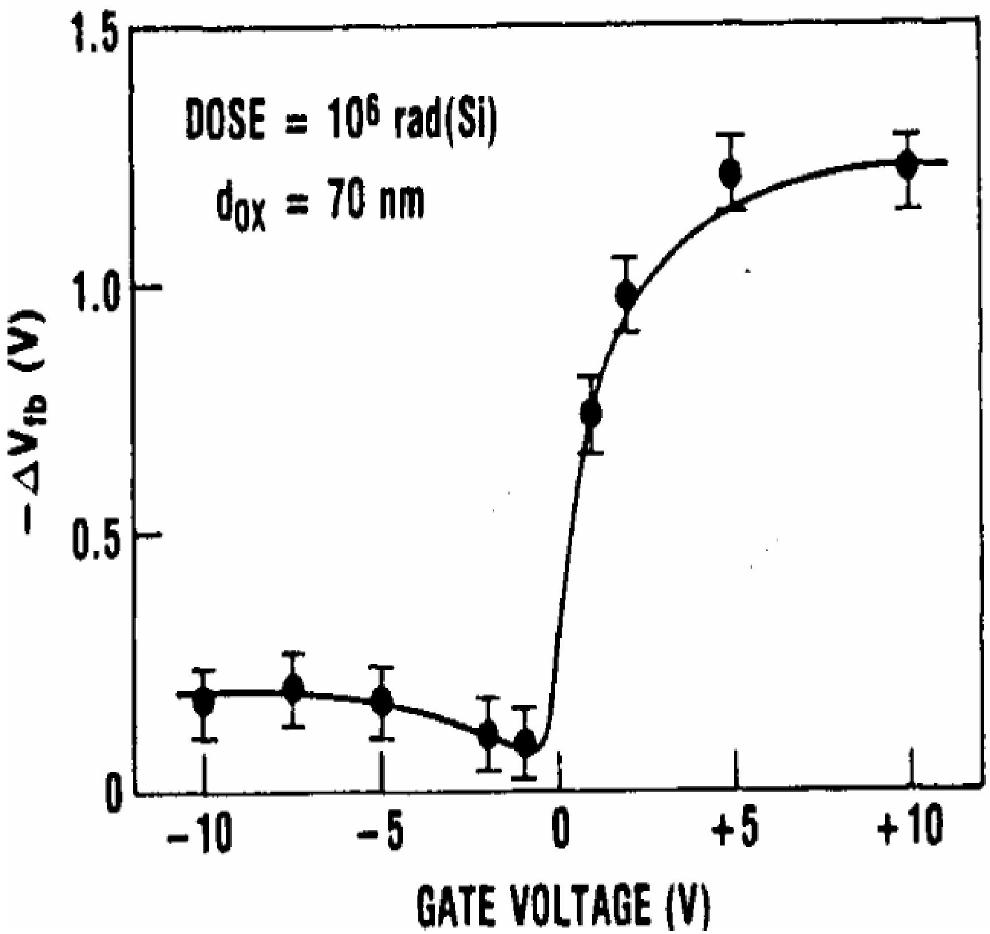


Beam /Tube parameters:

- Distance: Exit window – DUT = 123 mm
- Fe-filter
- 60 kV, 33 mA
- Beam radius = 6.6 mm

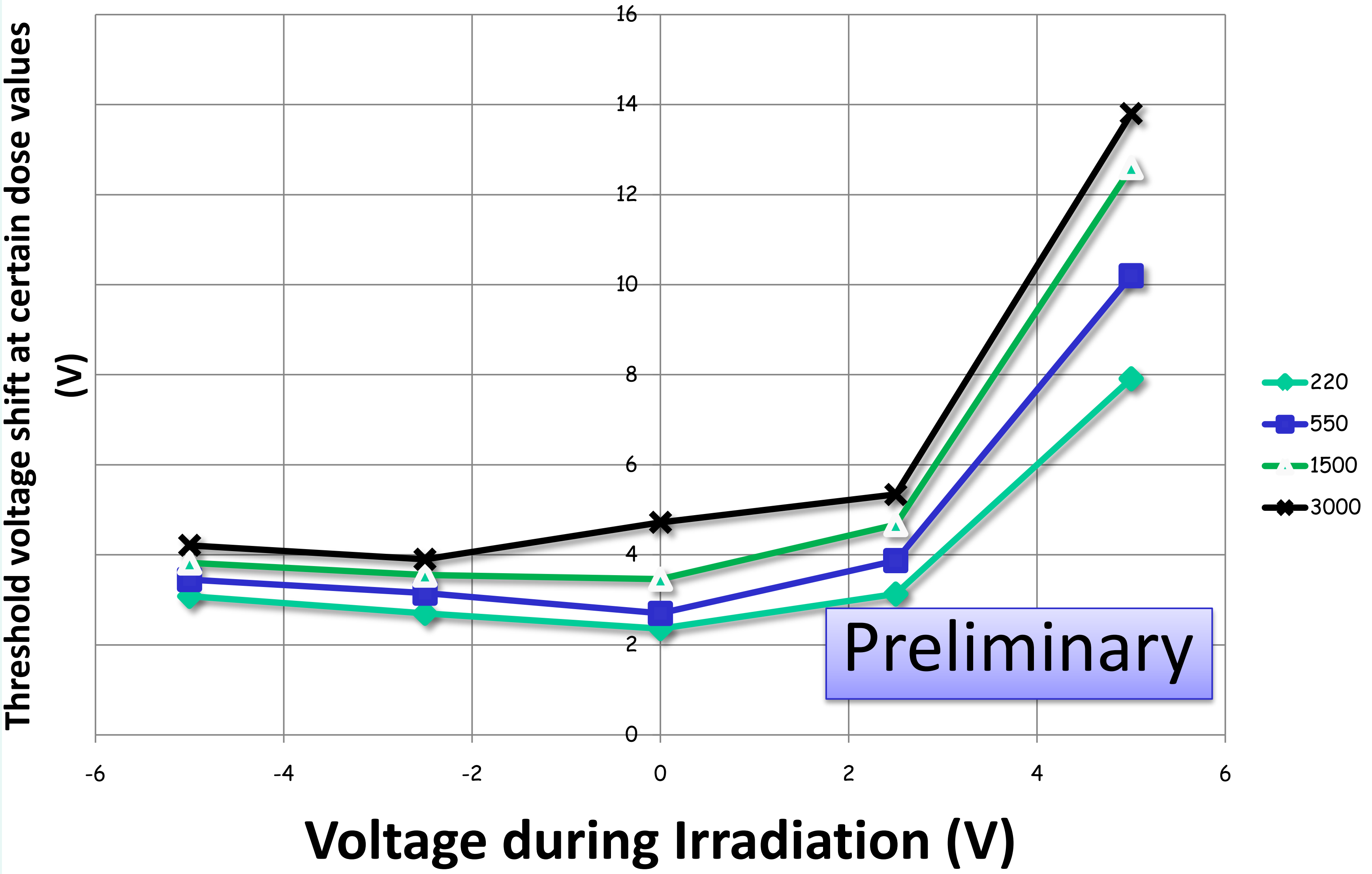
Lower dose rate, but more homogeneous beam

Change in threshold voltage shift due to certain Gate voltages



Ma/Dressendorfer

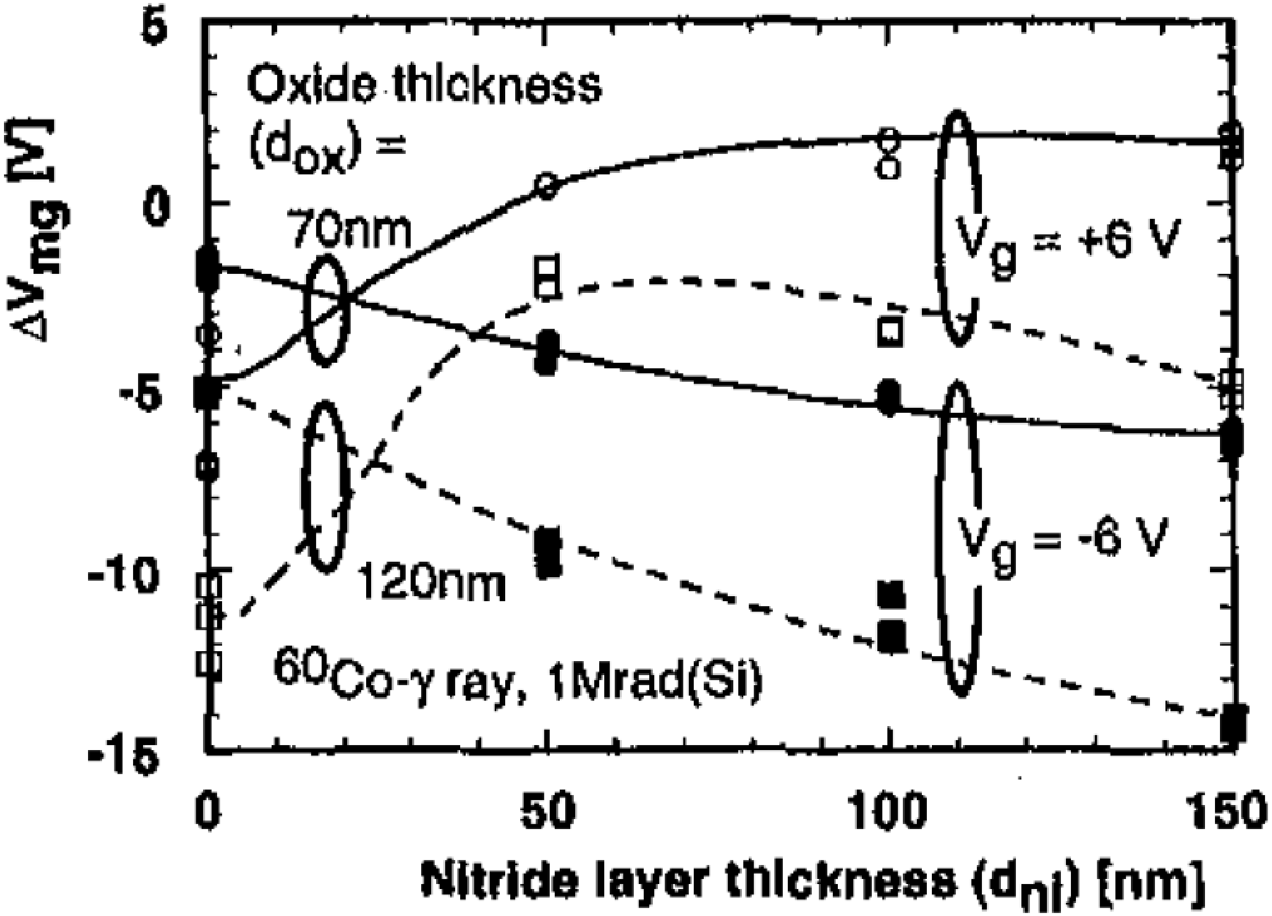
Change in threshold voltage shift due to certain Gate voltages



Thick nitride and Gate voltages

Thicker nitride could be a solution to the problem at hand.

Up to now, only irradiations on diff. nitride thicknesses (TO chips) were conducted with zero gate voltages during irradiation.



Radiation-Induced Trapped Charge in
Metal-Nitride-Oxide-Semiconductor Structure; Takahashi et. al.
IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOX 46, NO 6, DECEMBER 1999

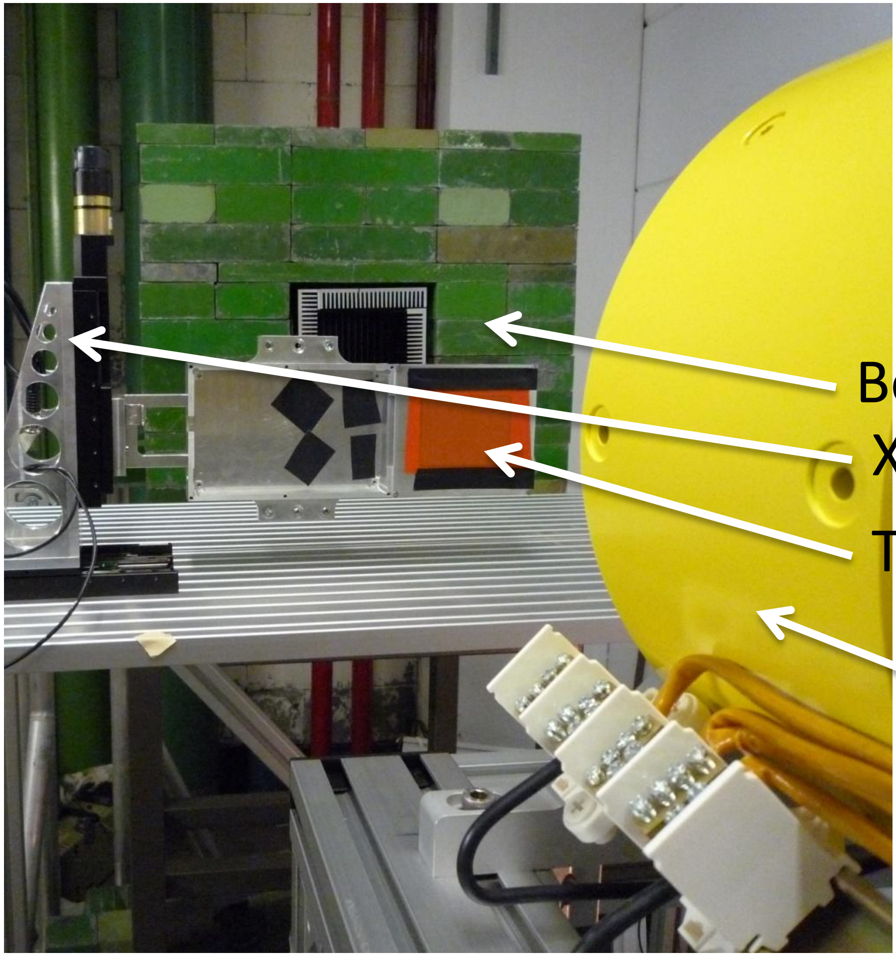
Damage of electrons in Gate oxide

ELECTRON IRRADIATION AT ELSA (BONN)

ELSA Setup

Setup and procedure at ELSA:

- TROVIDUR foil for beam size measurements
- Diode for dose measurements
- Thin oxide structures for Gate oxide damages



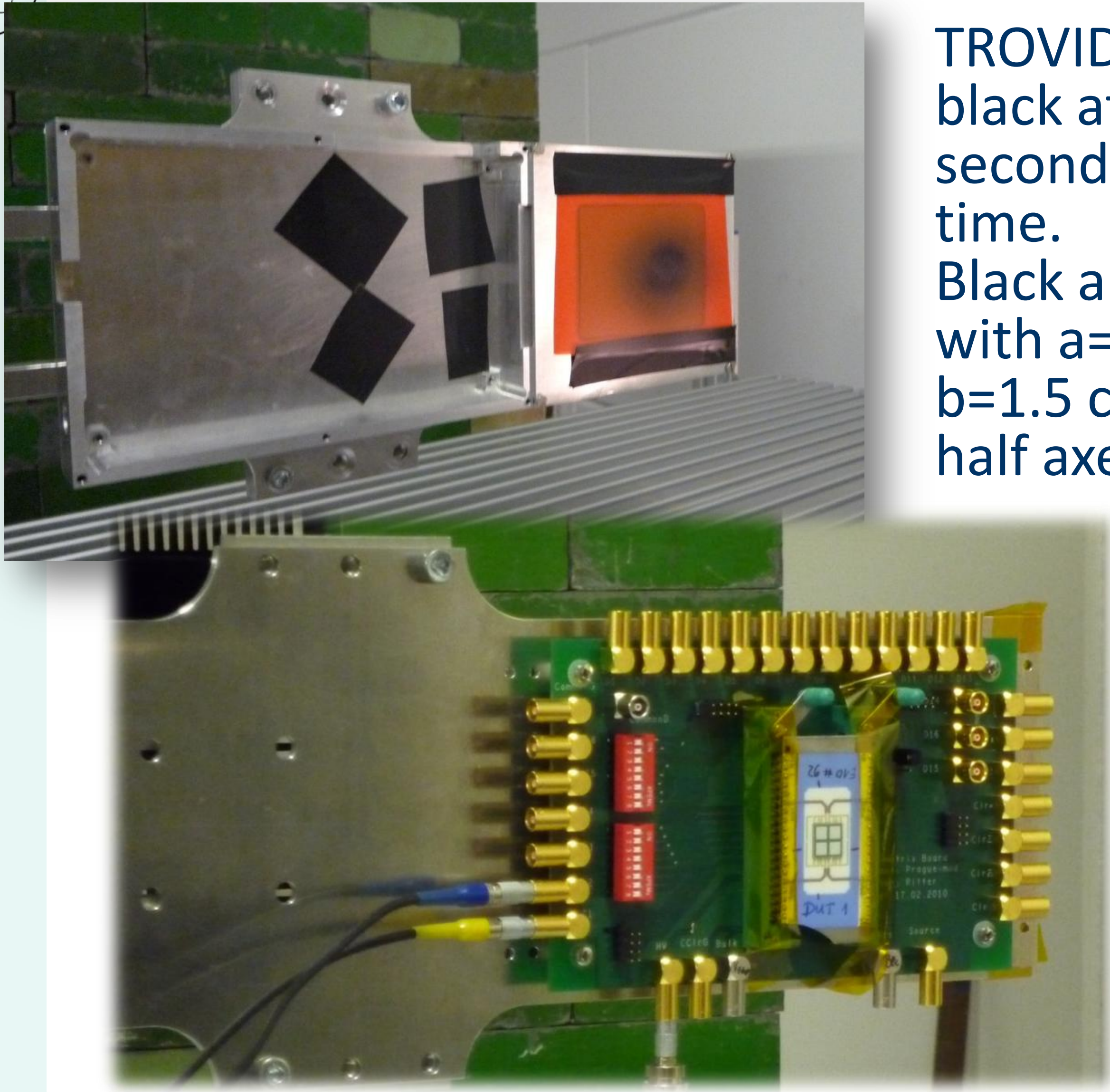
Beam dump

XY-stage

TROVIDUR foil

LINAC1 beam line

Measurement procedure



TROVIDUR foil turns black after some seconds of beam time.
Black area is elliptic, with a=1.0 cm and b=1.5 cm for the half axes

Mounting of DUT to XY-stage. Biasing conditions during irradiation:

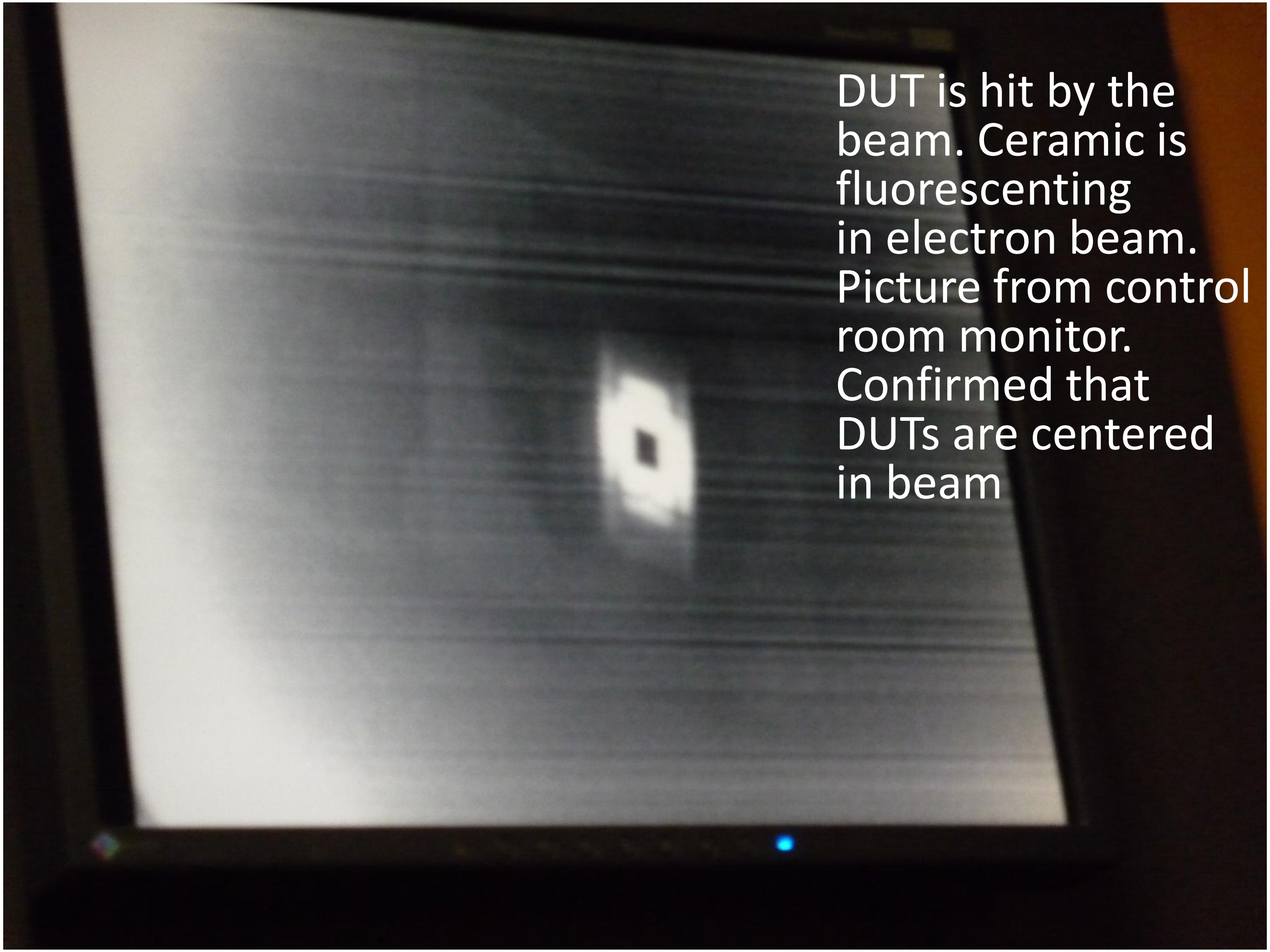
Diode:

$V_{Reverse} = 35$ V

TO chips:

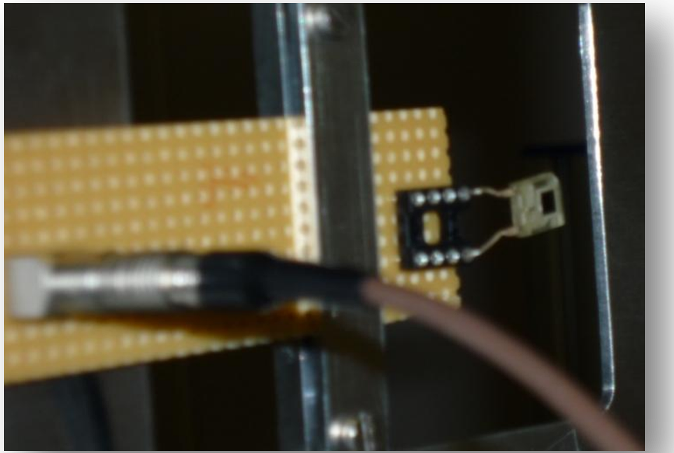
$V_{Bulk} = +10$ V,
$V_{Gates(all)} = 0$ V

DUT positioning



DUT is hit by the beam. Ceramic is fluorescenting in electron beam. Picture from control room monitor. Confirmed that DUTs are centered in beam

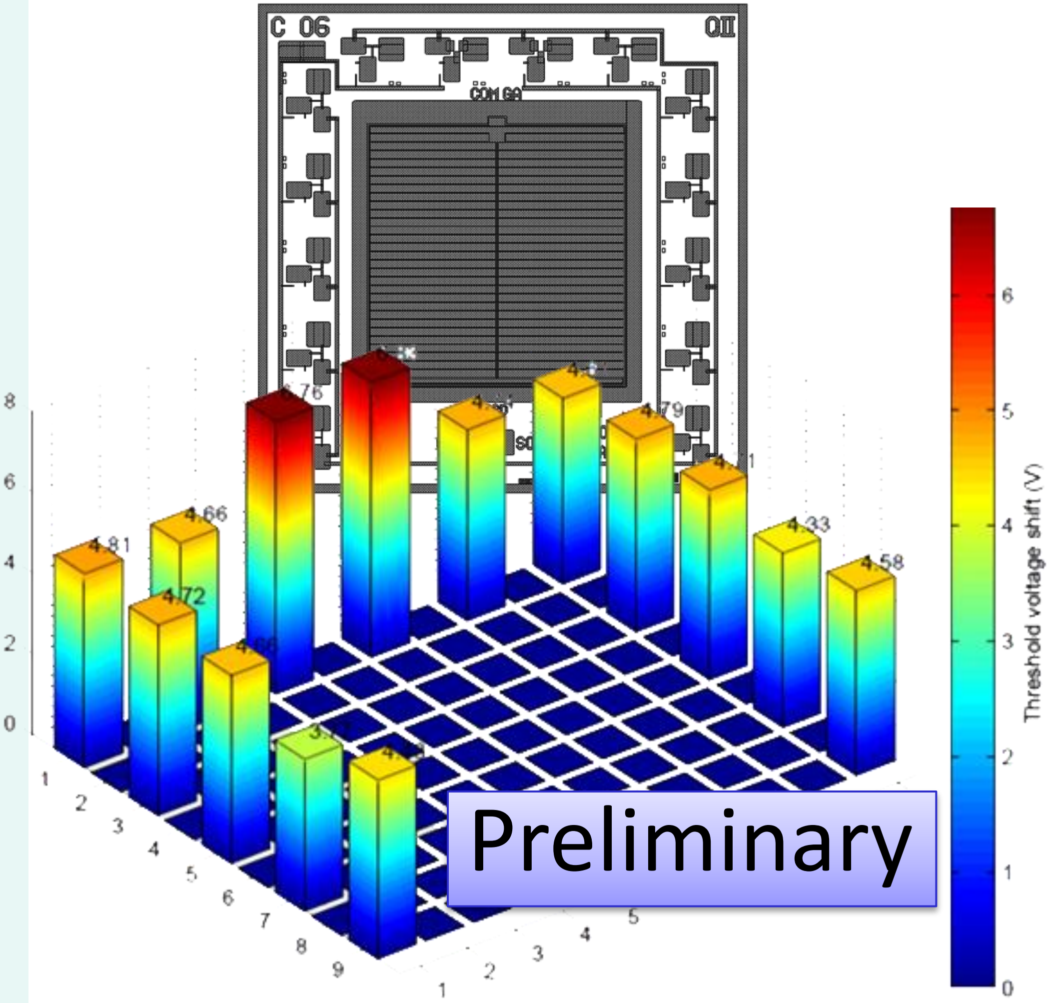
Diode measurements - dosimetry



Goal: Use generation current in diode for dose measurements.

- Several PIN diodes in Beam
- Current measurements prove to be difficult, due to 50 Hz pulse repetition rate. Pulse duration time $t_{pulse} \approx 1\ \mu s$
- Needed oscilloscope for current measurements (50 Ω impedance)
- Still, problems remained; possible saturation problem in diode during pulse?

Homogeneity



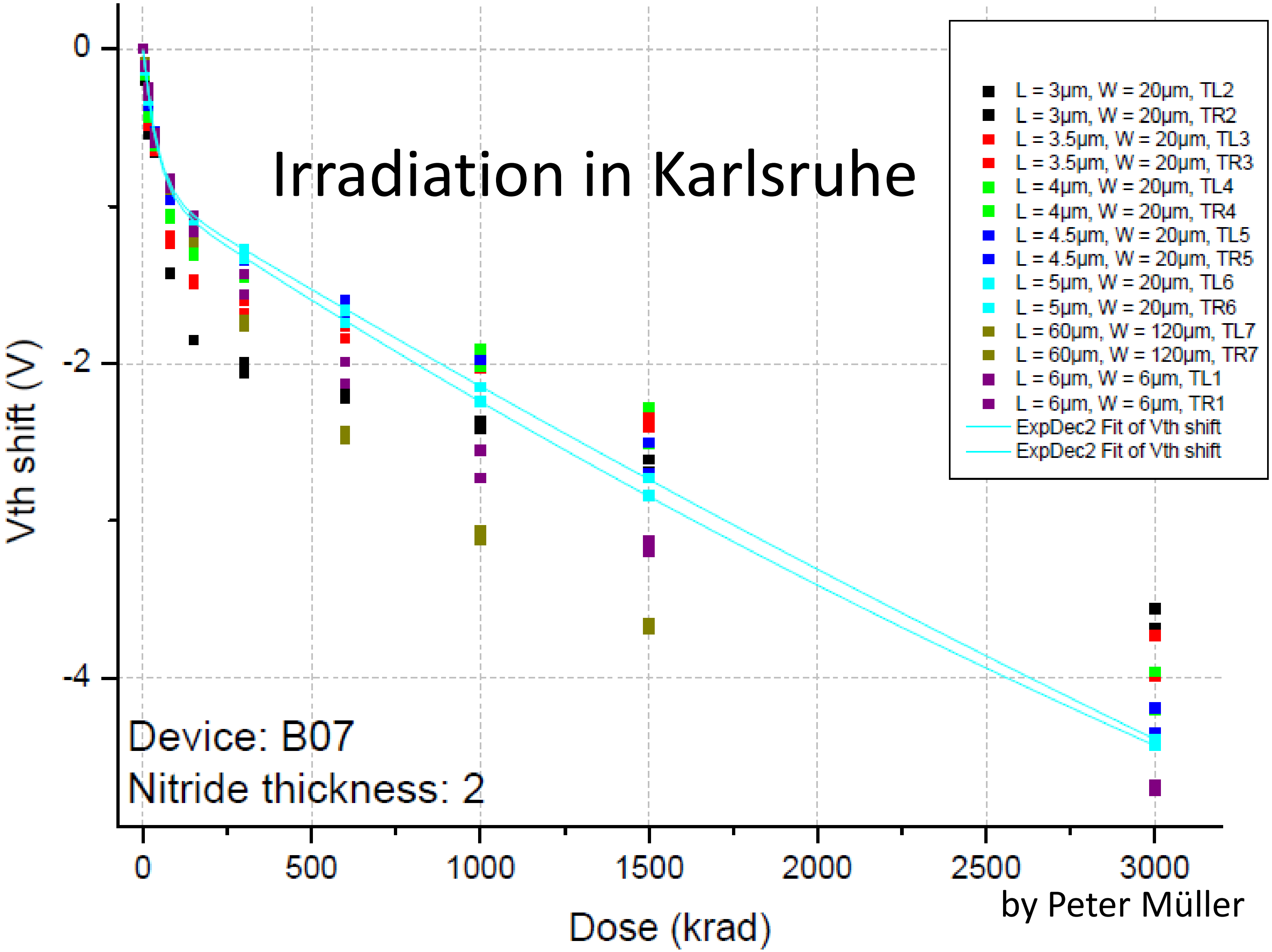
Preliminary

As can be seen by TO chips, beam profile is not homogenous. Therefore dose estimation is difficult.

Two possibilities:

1. Use beam and area parameters to estimate dose (assuming homogenous profile)
2. Use results of samples irradiated in Karlsruhe to estimate dose

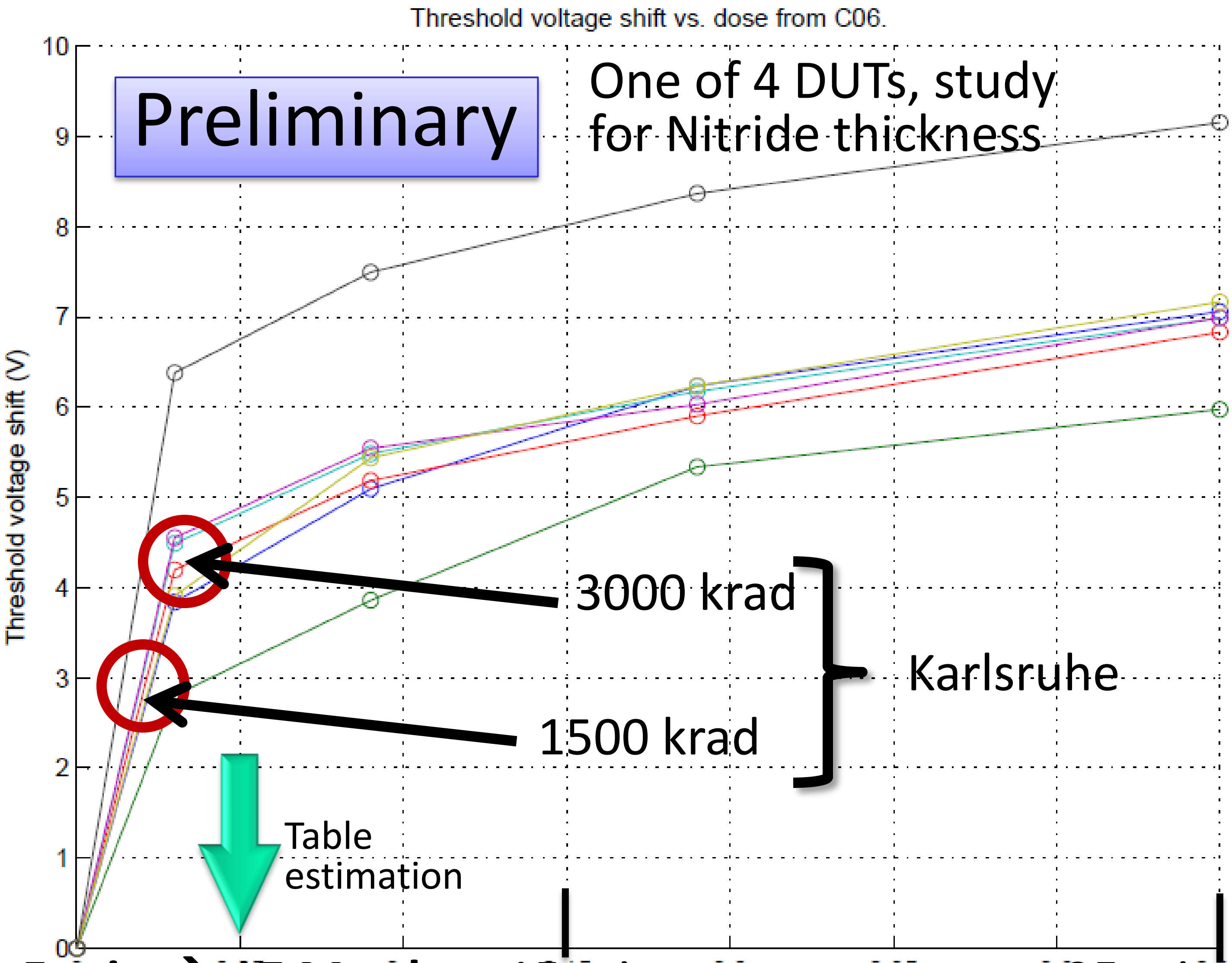
Dosimetry via Karlsruhe?



Irradiation in Karlsruhe

by Peter Müller

Threshold voltage shift vs. dose – dose estimation



Preliminary

One of 4 DUTs, study for Nitride thickness

3000 krad

1500 krad

Karlsruhe

Table estimation

5 min → 17 Mrad 15 min exposure 35 min exposure

Dose estimation of ELSA

Beam area of Ellipsoid on foil	**4.71E+00**	**cm²**
DUT AreaTransistor (w,L = 20,6µm)	*1.20E-06*	*cm²*
Thickness SiO2	1.00E-05	*cm*
Charge in Beam/Pulse	*8.00E-09*	*C*
Pulsduration	*1.00E-06*	*s*
Pulsfrequency	*5.00E+01*	*Hz*
Particles per pulse	**5.00E+10**	
Partickes in beam per sec.	**2.50E+12**	
Beam current	**4.00E-07**	**A**
Particles per pulse in transistor area	1.27E+04	
Dep. Energy per e- in SiO2	4.52E-05	MeV
Dep. Energy per pulse	2.26E+06	MeV
Dep. Energy in SiO2 per sec.	1.13E+08	MeV
Mass SiO2	3.19E-11	g
Dose per sec.	5.67E+02	Gy
	5.67E+01	krad
Dose per min.	3.40E+04	Gy
	3.40E+03	**krad**

Either electron damage is not so severe, or estimation is too rough

Conclusion and Outlook

Clear Gates in Karlsruhe

- Influence of Gate voltage during Irradiation is severe, especially positive voltage. This happens in the cross section from Clear Gate to drift regions
  - More irradiation campaigns needed to see, whether more nitride can help
  - New design of selected areas?

Electrons at ELSA

- Dosimetry is a problem
  - Electron calibration/studies in Darmstadt(LINAC)?
  - Bulk damage measurement not done, Diode problems

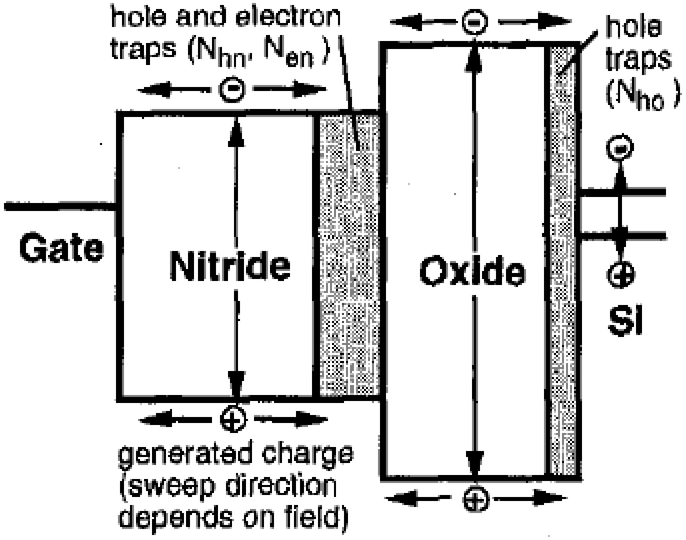
Outlook

- Swing, g_m, interface currents yet to be analyzed
- More irradiations →ELSA, Karlsruhe, Darmstadt?

Thanks for listening and special thanks to Karlsruhe, ELSA (operator, Julia & Sergey)

Backup

Trapping in insulator layer



$+V_G$

1. Holes in oxide to Si-SiO_2 interface
2. Holes in Si_3N_4 and electrons from SiO_2 to N-O interface
3. Recombination rate in Si_3N_4 higher than in SiO_2 → more e^- trapped at N-O
4. Build-up of e^- reduces field in oxide → saturation

$-V_G$
Field always present

Thick Si_3N_4
→ Reduces field in ox → saturation