Modeling of Defect Properties in Bragg Peak

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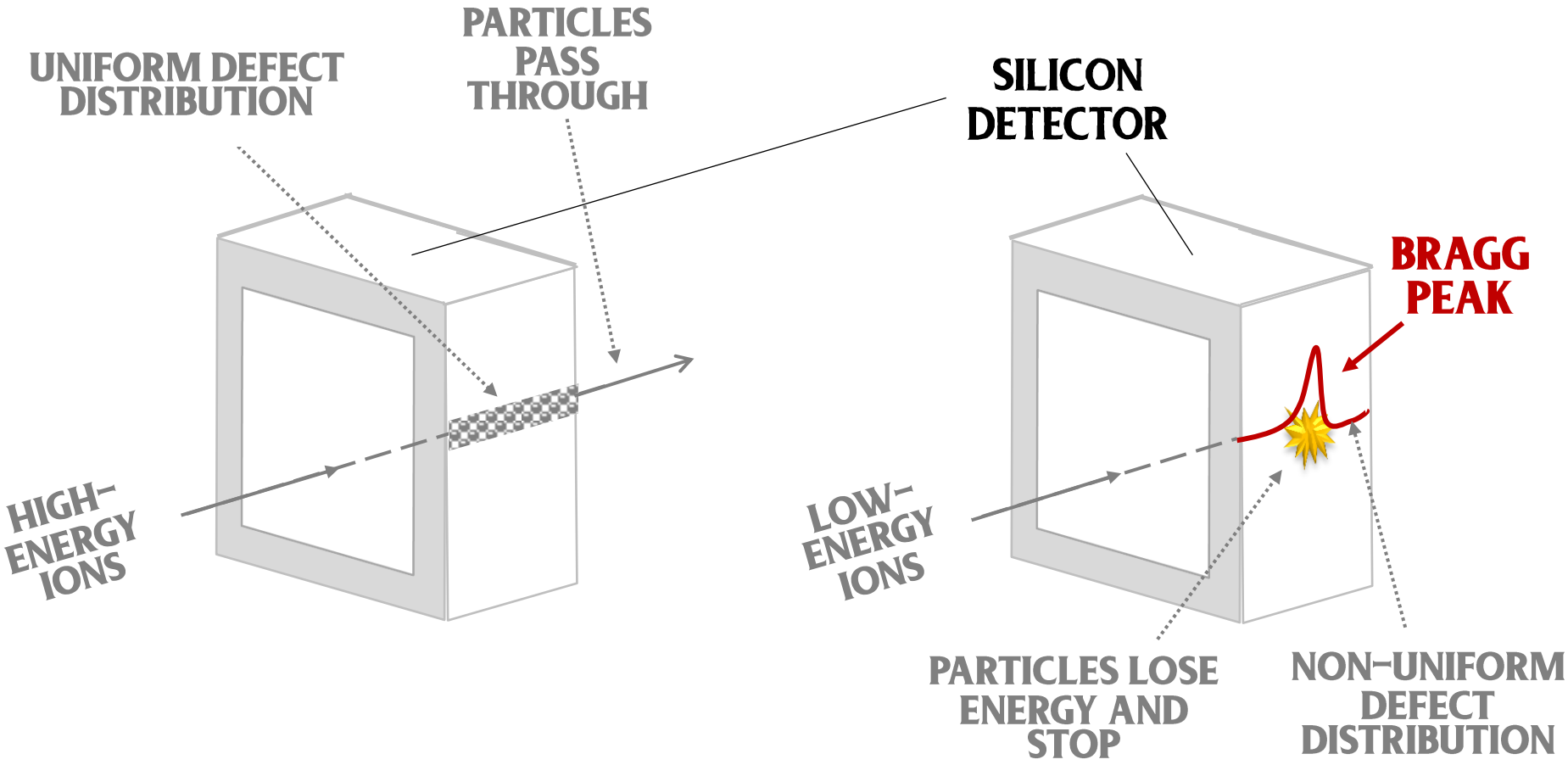
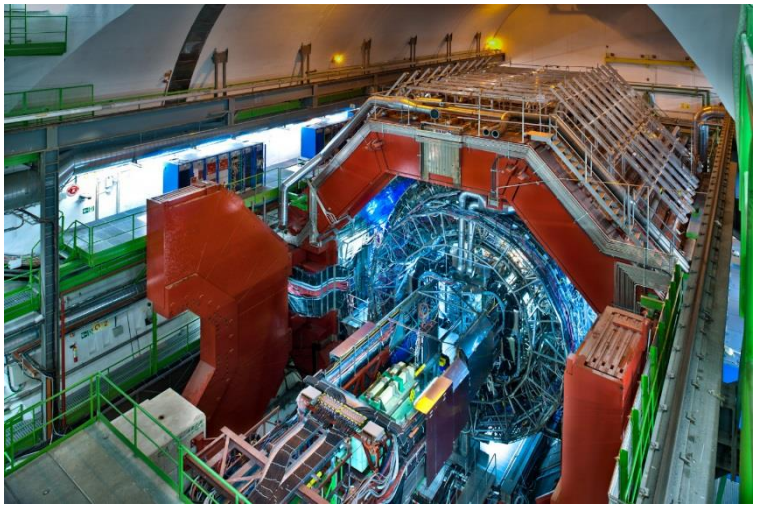
Outline

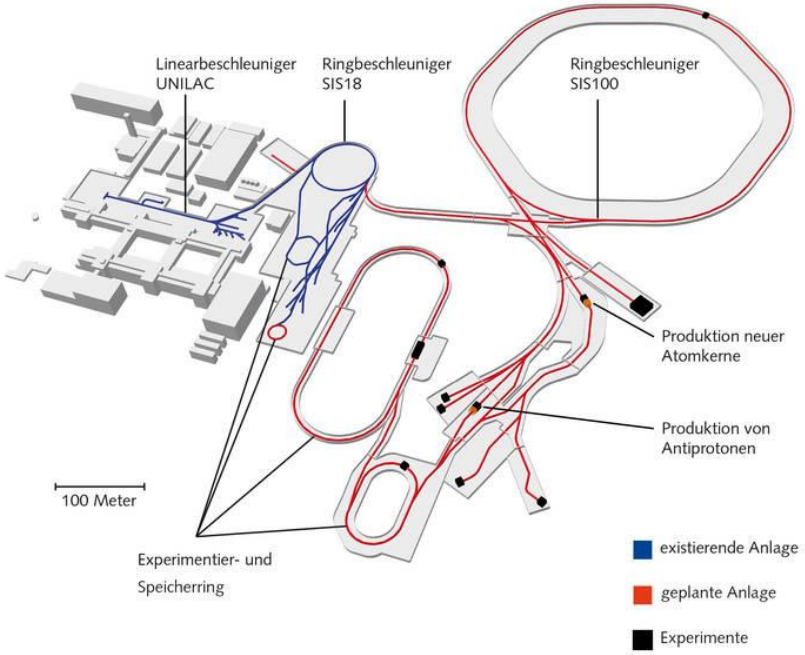
- Bragg Peak
- Motivation & Goal
- Detectors & Irradiation
- Modeling
- Bragg Peak influence on DLTS spectra
- Summary

Bragg Peak


UNIFORM DEFECT DISTRIBUTION
PARTICLES PASS THROUGH
SILICON DETECTOR
BRAGG PEAK
HIGH-ENERGY IONS
LOW-ENERGY IONS
PARTICLES LOSE ENERGY AND STOP
NON-UNIFORM DEFECT DISTRIBUTION

Motivation





ALICE facility at CERN, Geneva

FAIR facility at GSI, Darmstadt

Goal

- To create a highly-disordered region in the bulk of the detectors via low energy irradiation;
- To carry out the main measurements of irradiated samples (I-V, C-V);
- To reveal issues of electrophysical properties which could not be described as part of the classical knowledge;
- To propose a model of a disordered region and establish its correspondence to experimental data.

Detectors & Experiment

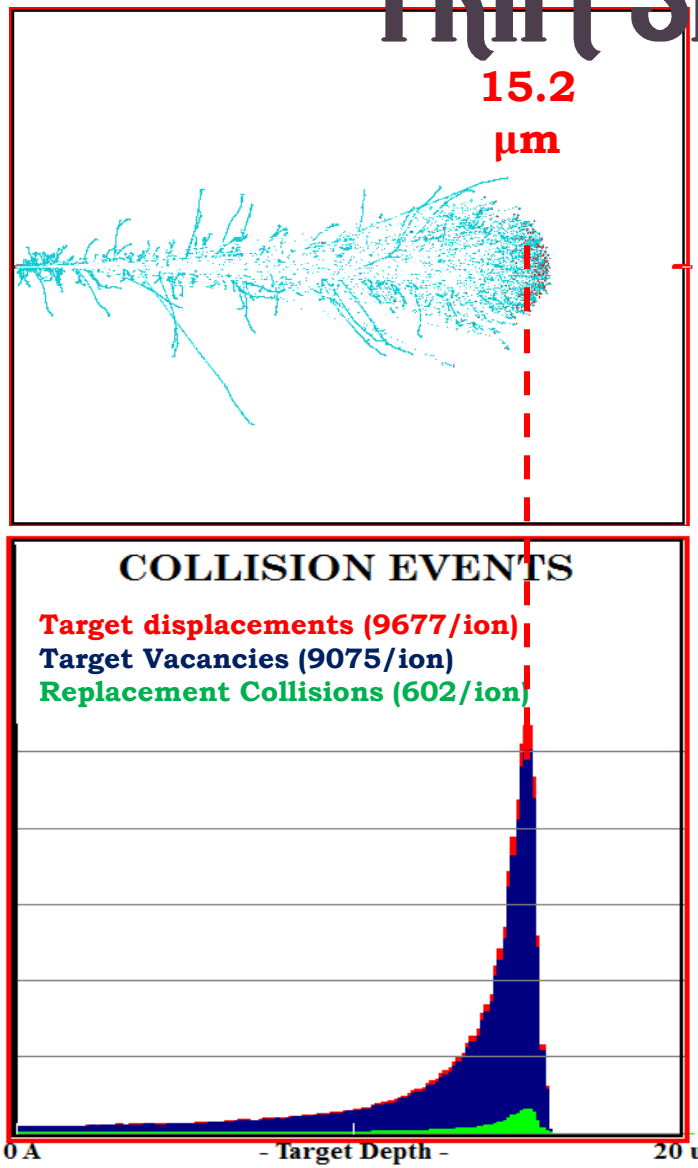
Structure

- p-on-n
- thickness 300 µm
- resistivity 60 Ωcm

Irradiation

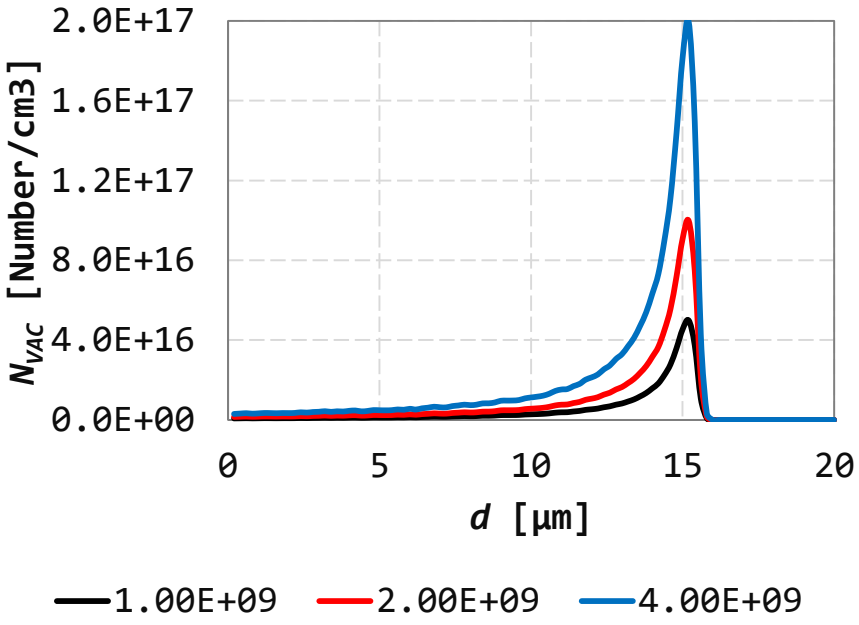
- ^{40}Ar ions
- irradiation energy 53.4 MeV
- stopping range 15.2 µm
- fluencies: 1×10^{9}, 2×10^{9} and 4×10^{9} cm^{-2}

TRIM SIMULATION

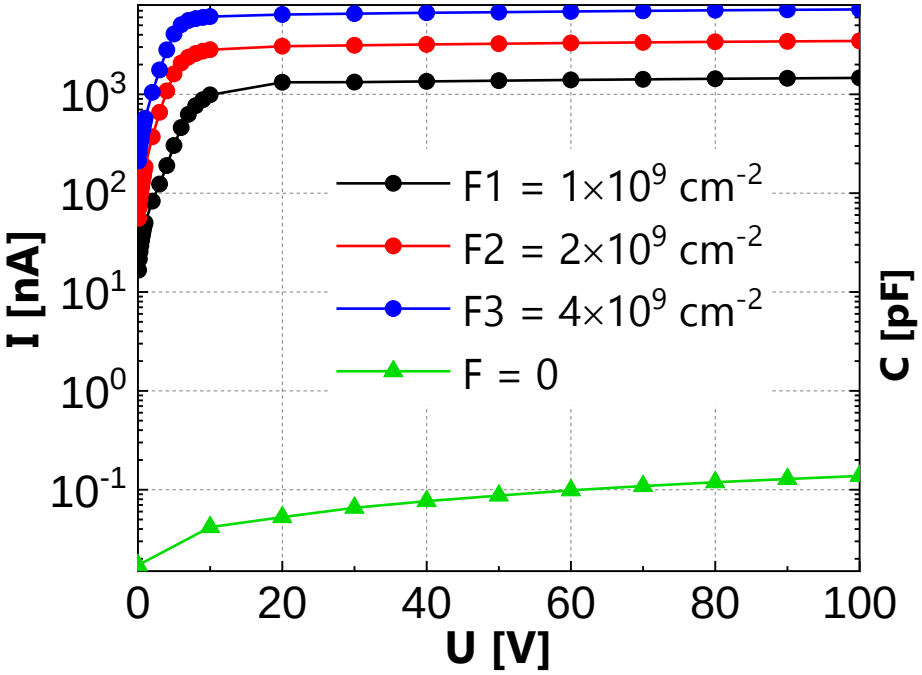


Density of primary vacancies:

$$N_{VAC} = Vac(x) \cdot F$$

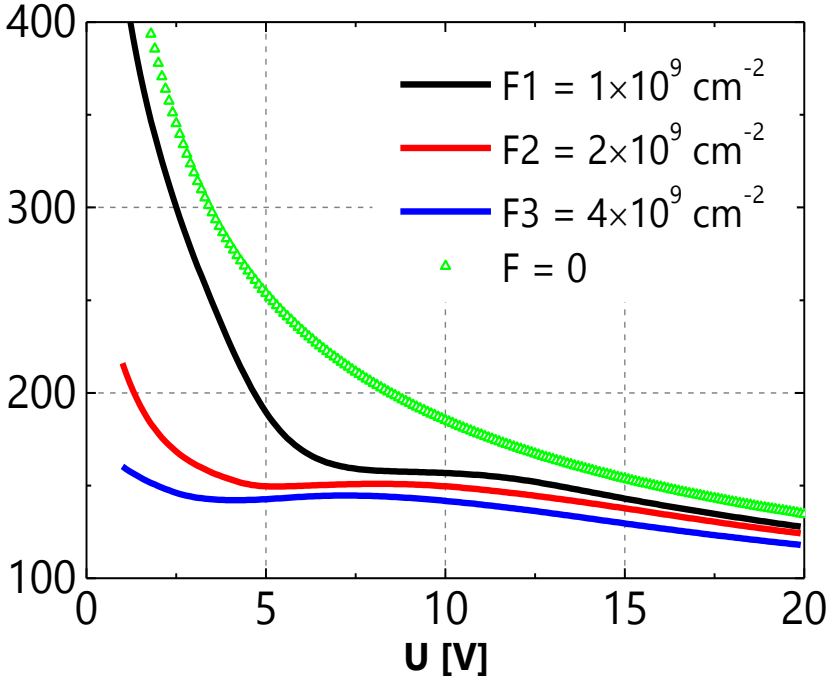


Detectors after irradiation



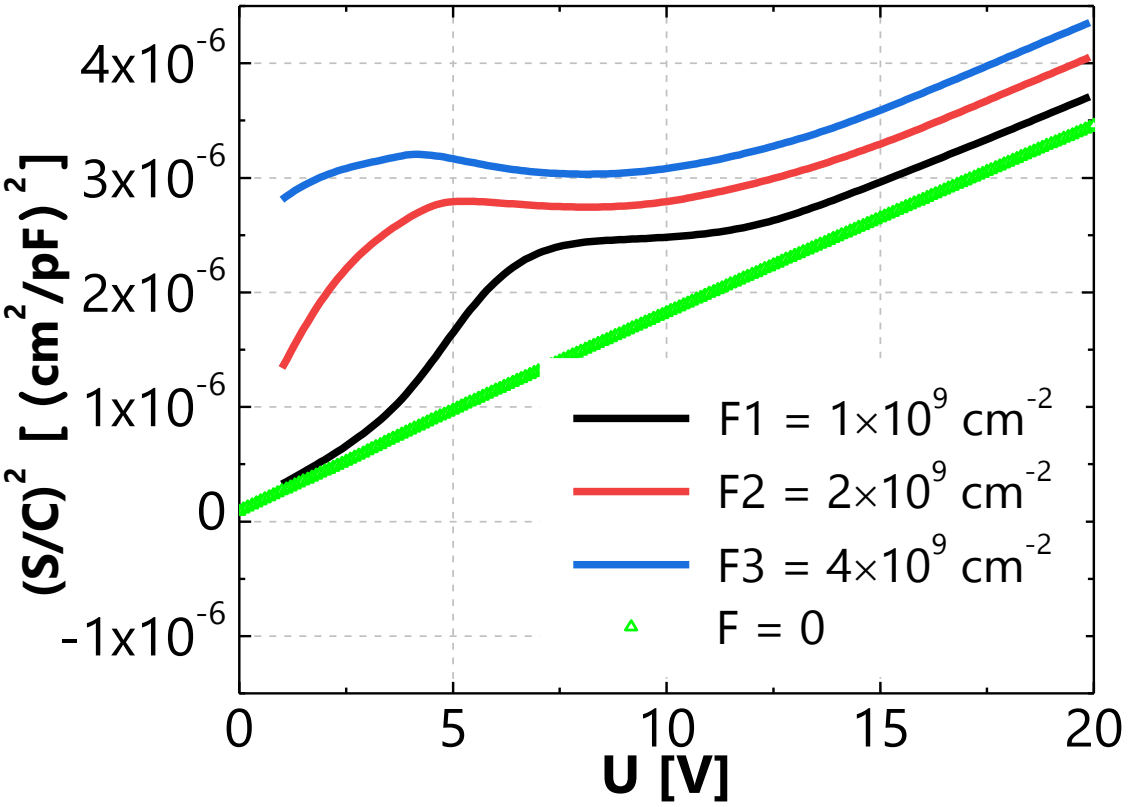
IV characteristics

Generation current saturated after **25 V**!



CV characteristics

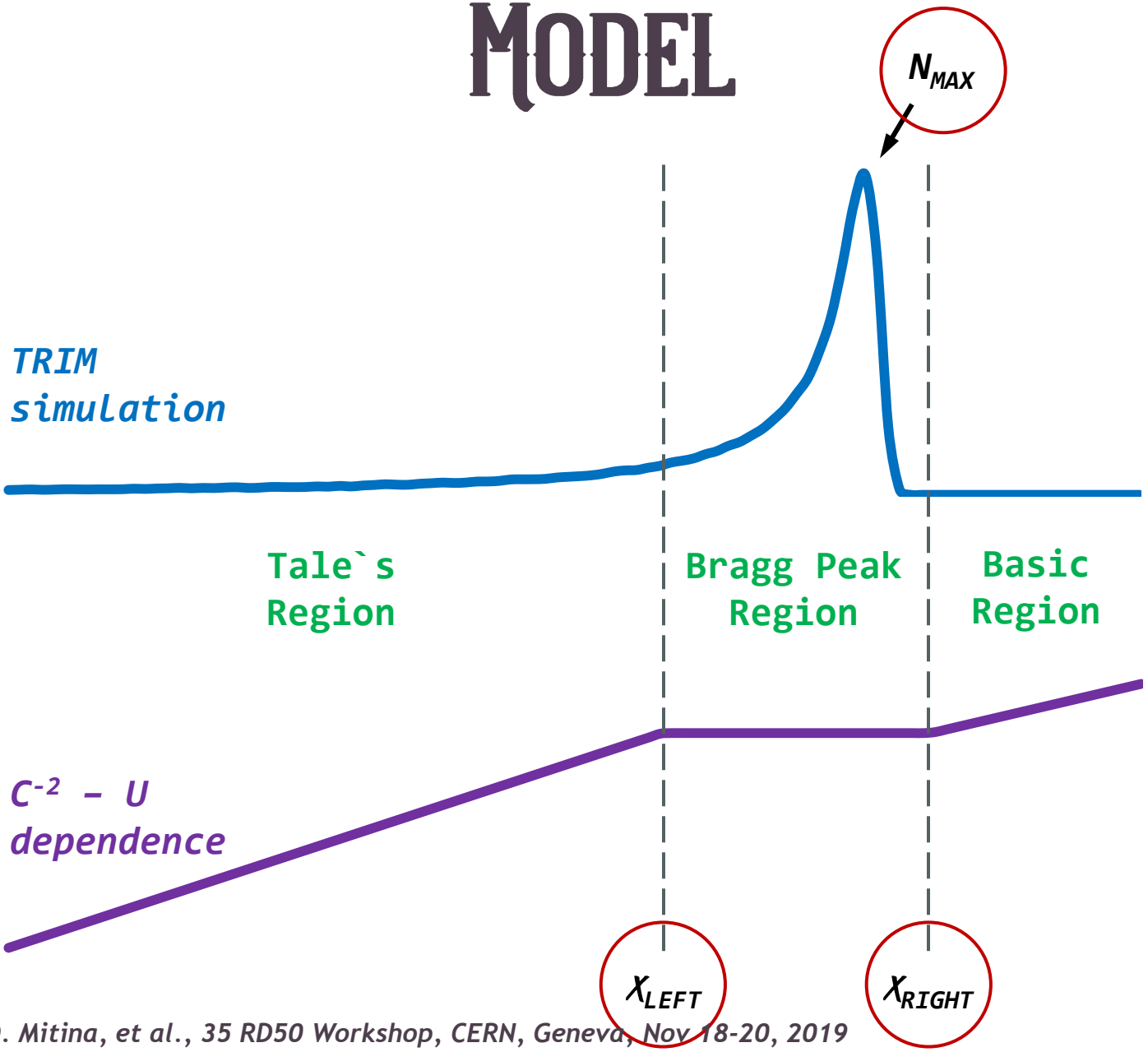
Concentration Profile



$$\left(\frac{S}{C}\right)^2 = \frac{1}{e\varepsilon\varepsilon_0}\frac{U_{bi}-U}{N_{eff}}$$

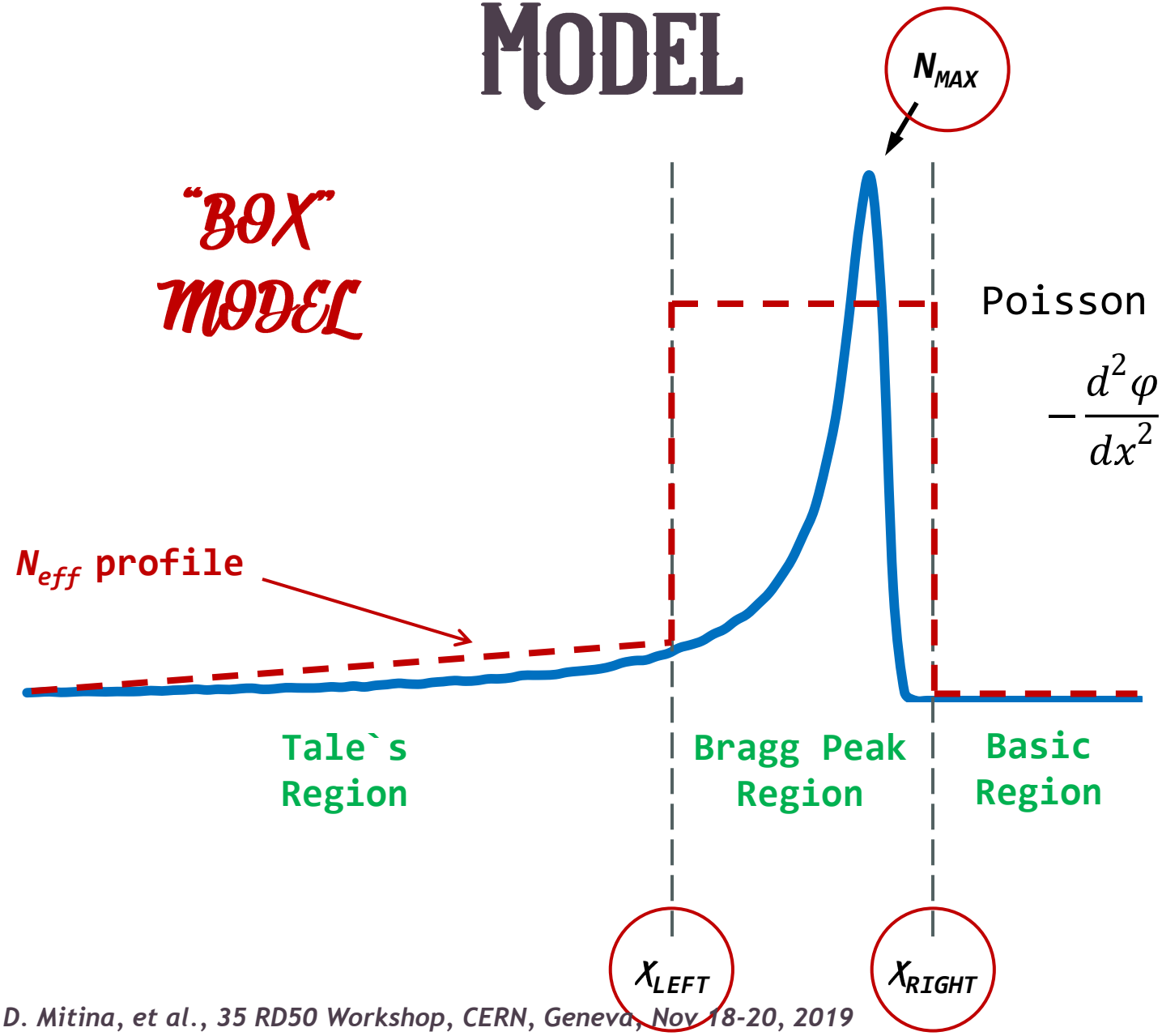
Classical data processing is only applicable after 15 V!

Model


N_{MAX}
TRIM simulation
Tale`s Region
Bragg Peak Region
Basic Region
C^{-2} – U dependence
X_{LEFT}
X_{RIGHT}

Model

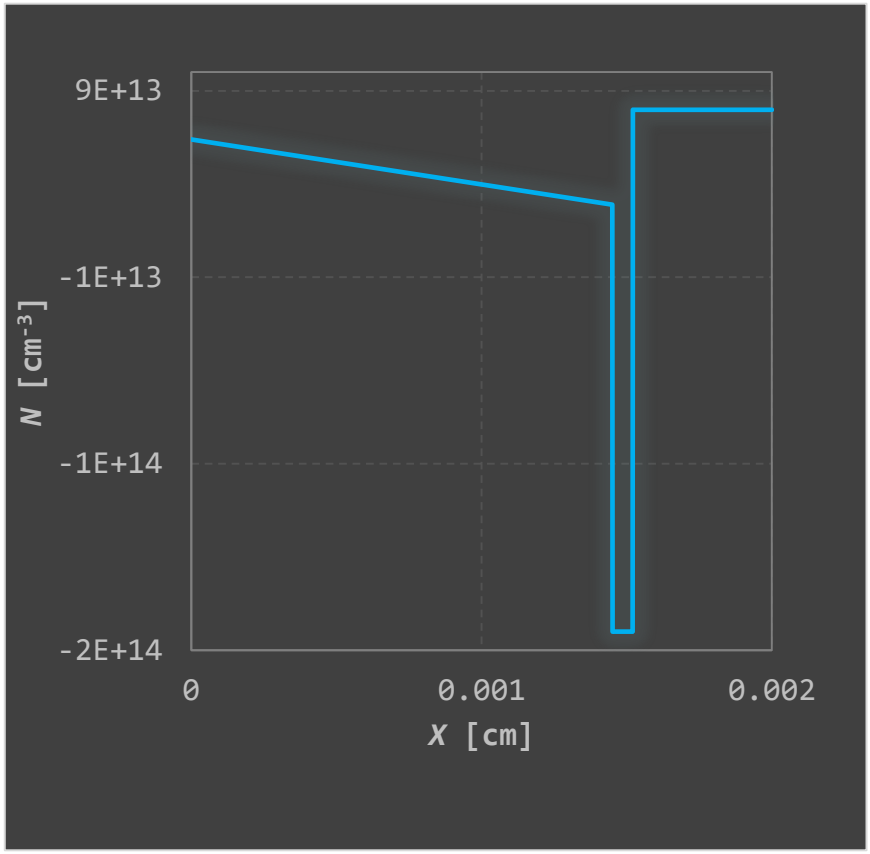
"Box" model



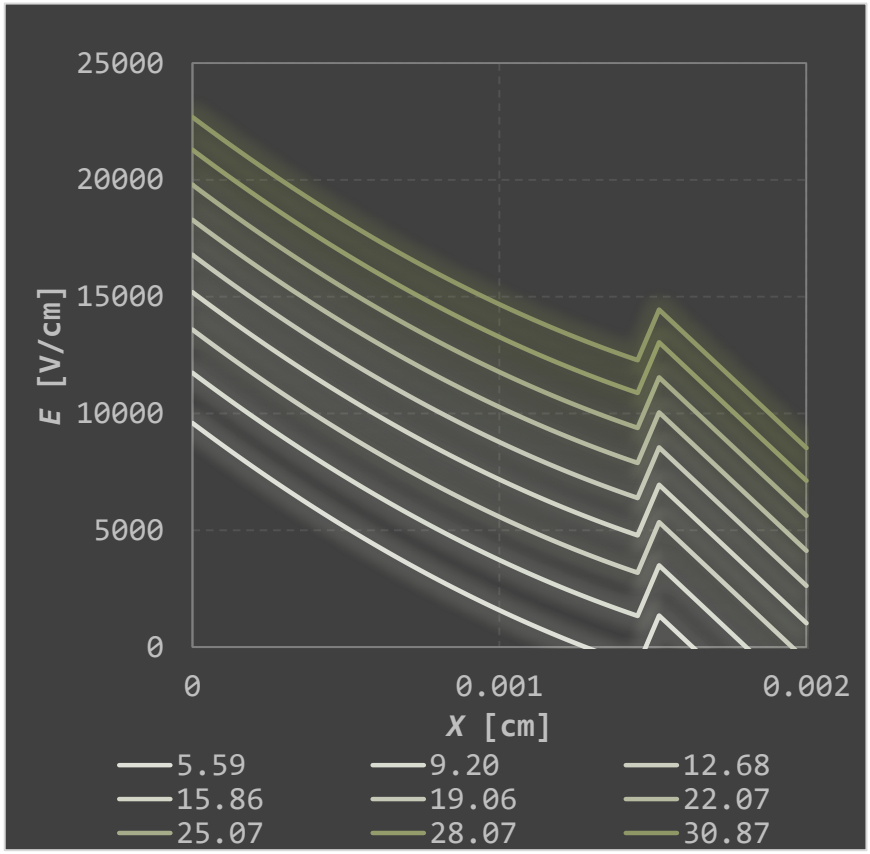
Poisson Equation:

$$-\frac{d^2\varphi}{dx^2} = \frac{eN_{eff}}{\varepsilon\varepsilon_0}$$

1. Modeling with compensation

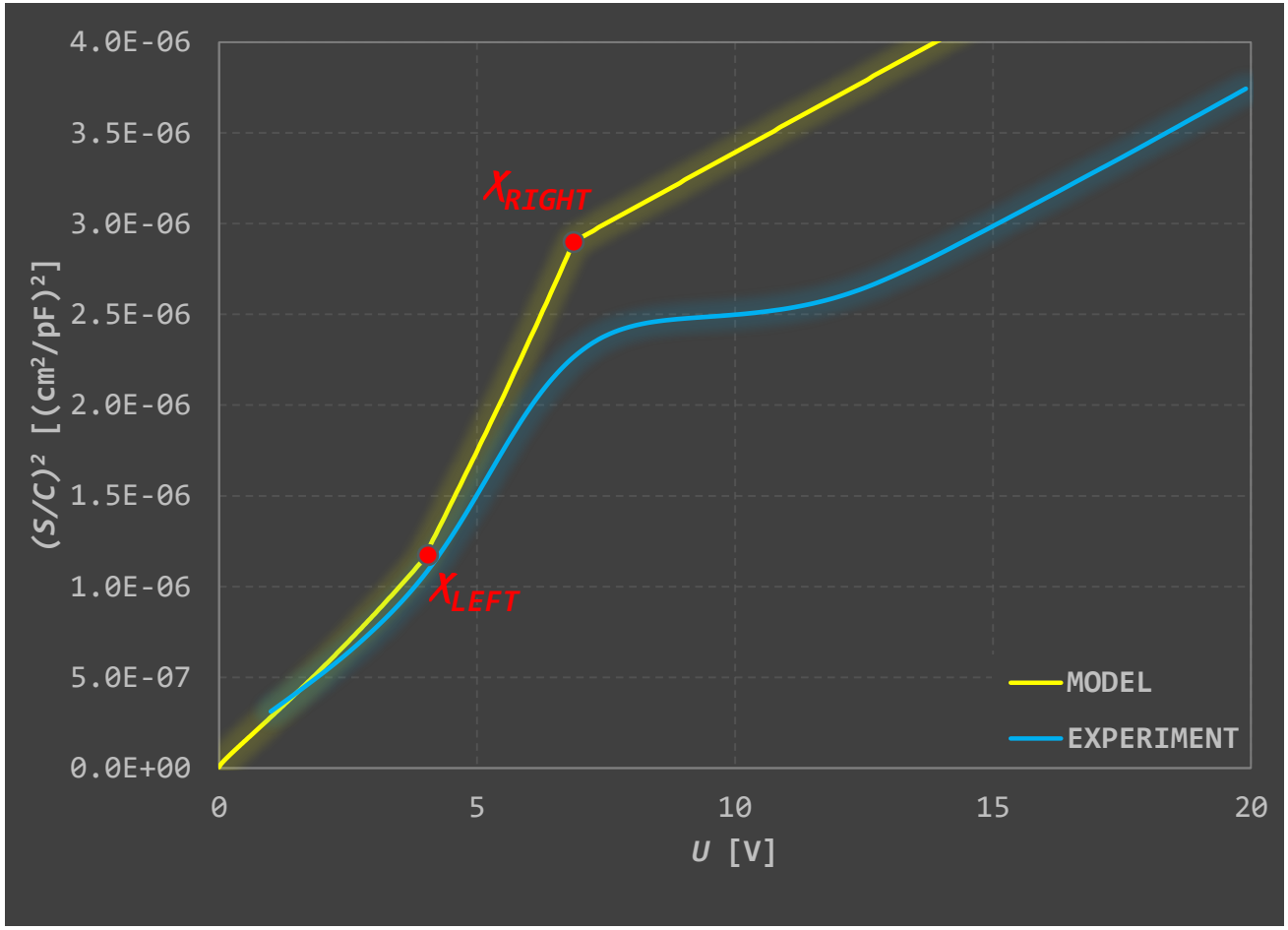


Profile of the effective concentration



Electric field distribution for the bias set

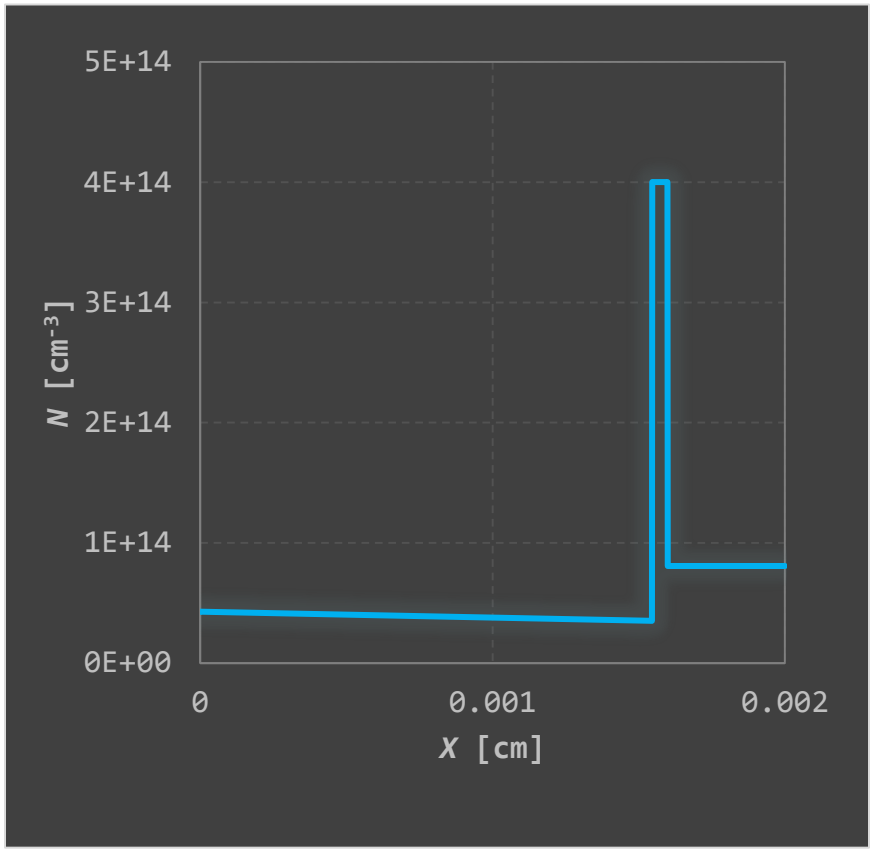
1. Results



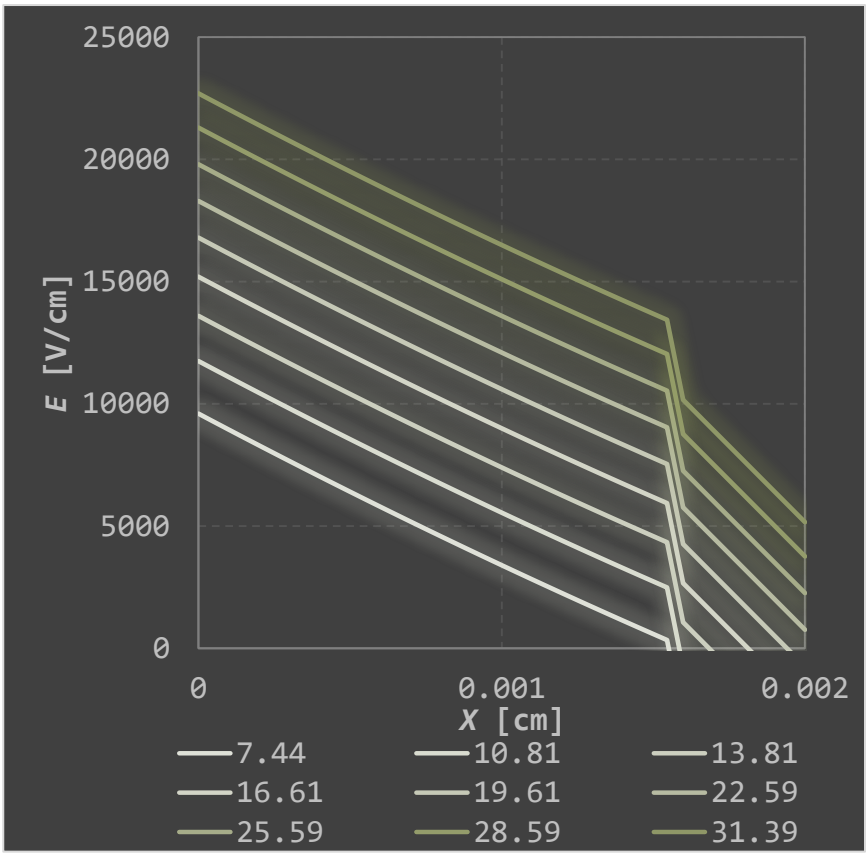
- Agreement only at the Tale Region;
- Strong discrepancy at the Basic Region

N_{MAX} = 2×10^{14} cm^{-3}
X_{LEFT} = 14.51 µm
X_{RIGHT} = 15.21 µm

2. Modeling with half-compensation



Profile of the effective concentration



Electric field distribution for the bias set

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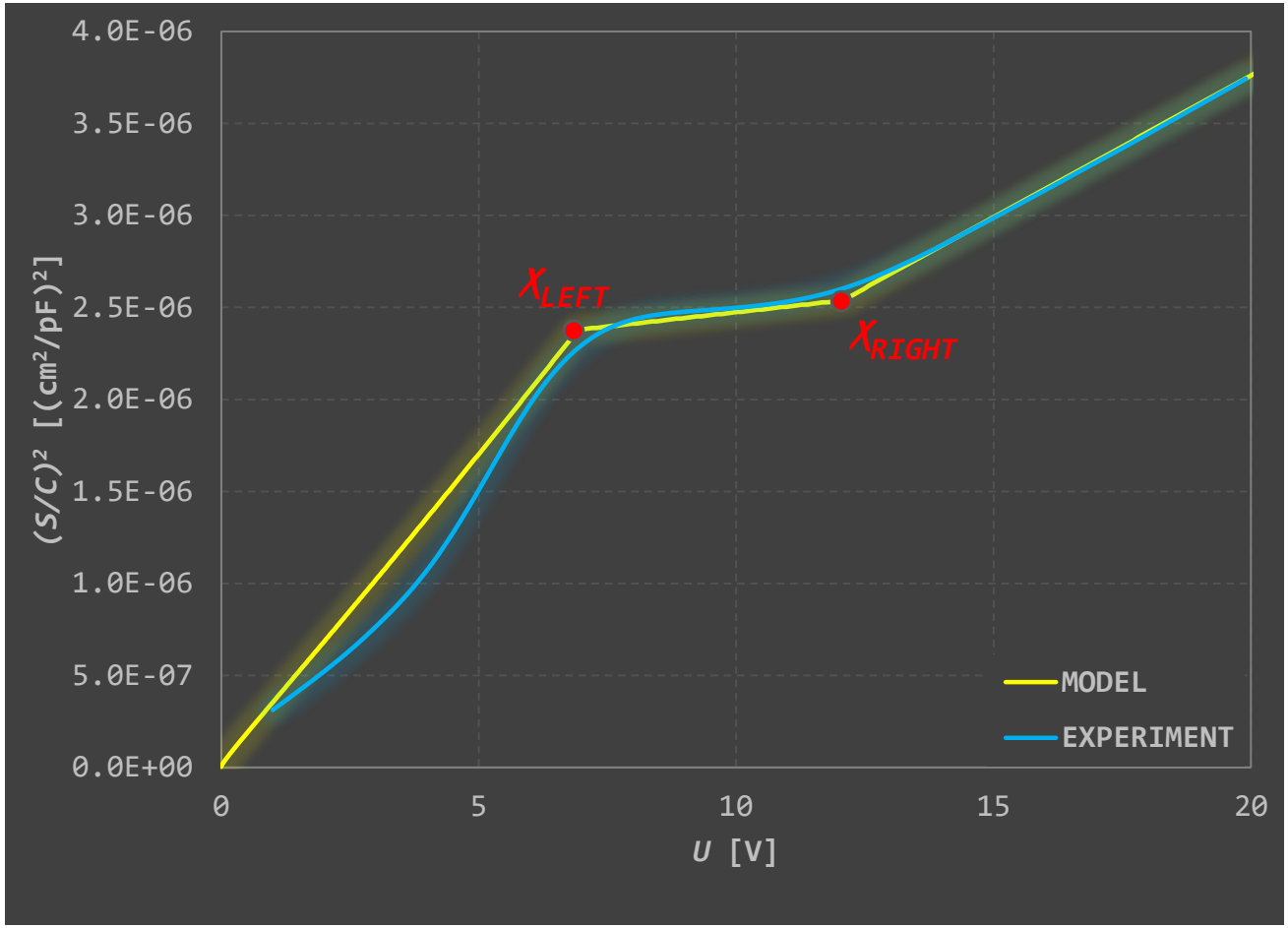
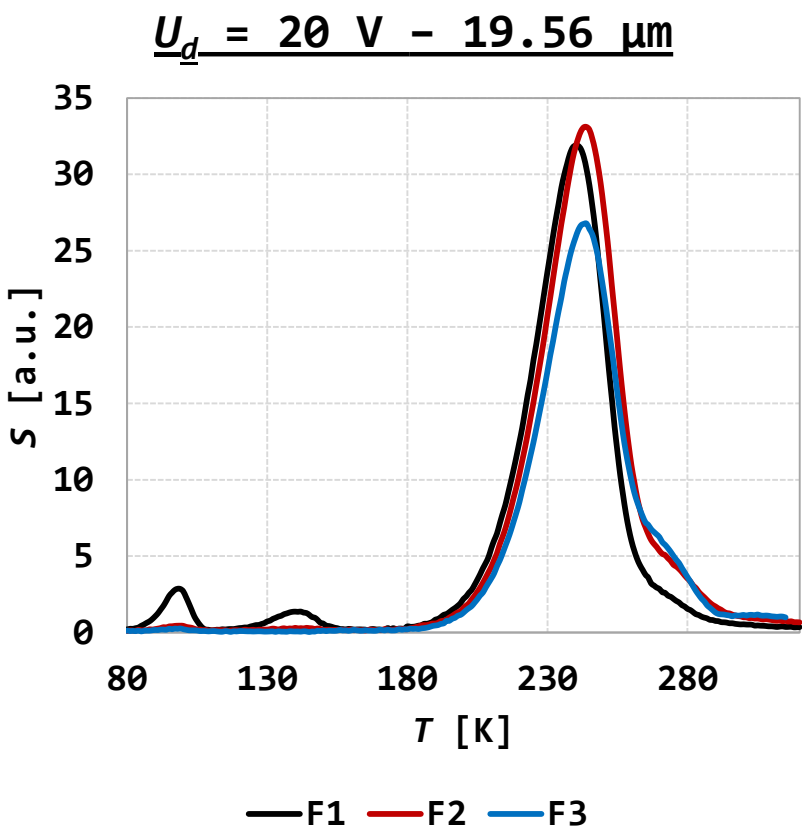
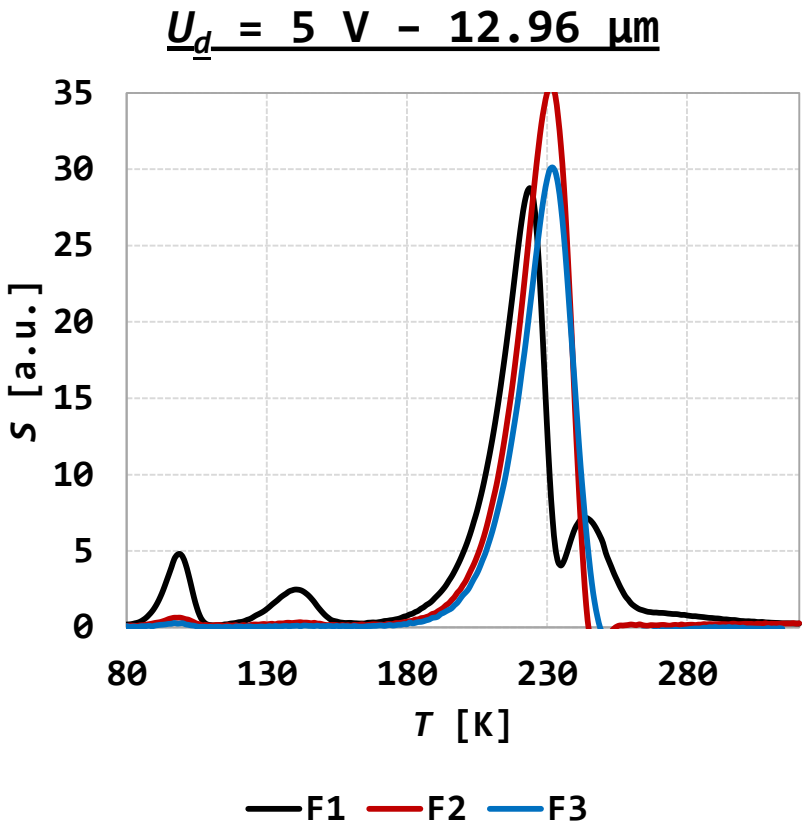


- Perfect agreement at the Basic Region;
- Good agreement at the Tale Region;
- At the Bragg Peak Region…

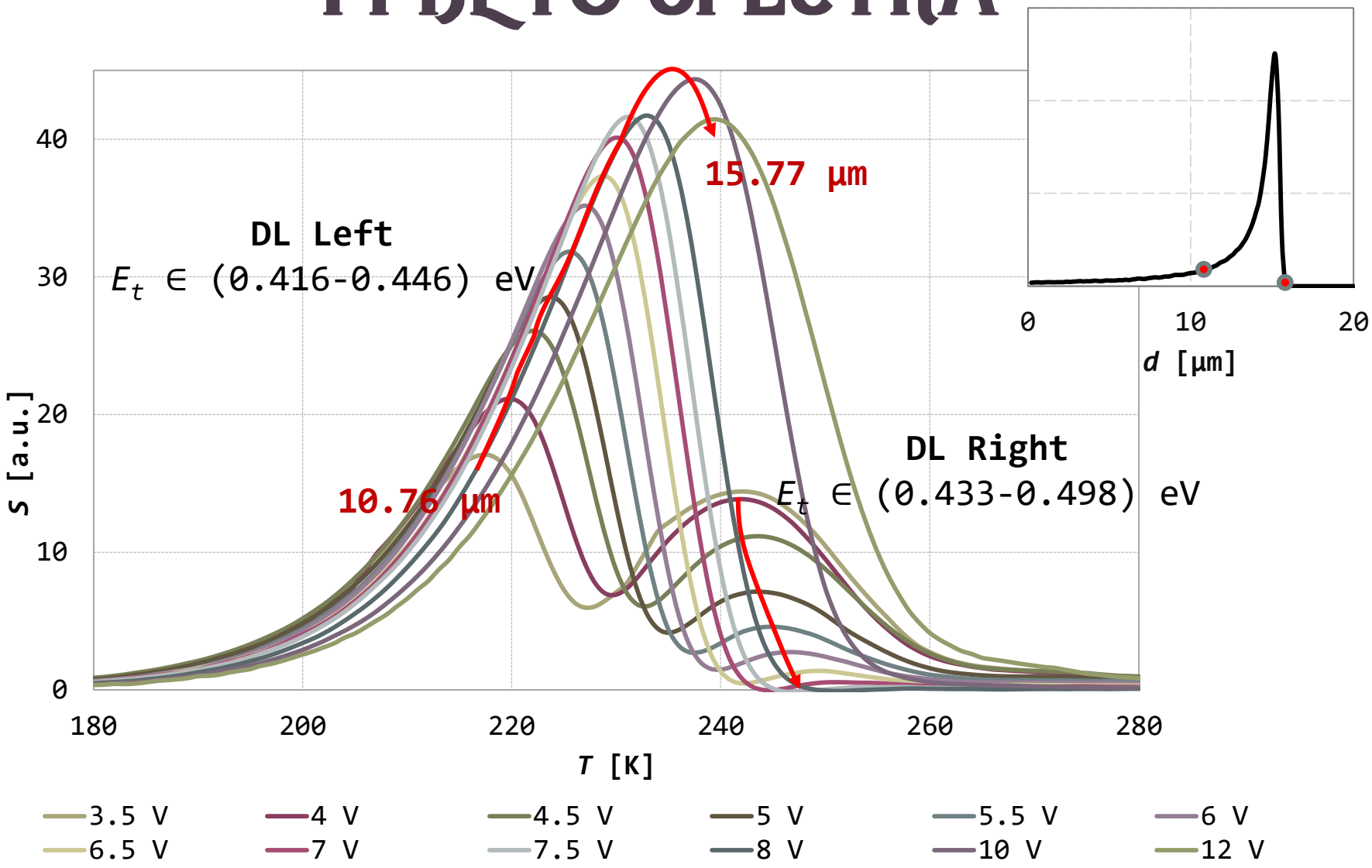
N_{MAX} = 4×10^{14} cm^{-3}
X_{LEFT} = 15.45 µm
X_{RIGHT} = 15.98 µm

DLTS SPECTRA





F1 DLTS SPECTRA



Summary

- The highly-disordered regions have been created in the p-on-n silicon detectors via low energy irradiation;
- Capacitance characteristics at the higher fluencies demonstrate capacitance increase at the area of the projected range, which makes classical data processing incorrect;
- The presented “box” model of the effective concentration has well agreement with experiment at the lower fluence;
- DLTS spectra are very sensitive to bias voltage and display non typical behavior of energy state of deep levels.

Thank you for attention!

Hamburg Model Calculations

Hamburg Model:
donor removal
+
acceptor introduction

$$N_{eff}(F) = N_0 e^{-cF} - \beta F$$