Investigation of modified ATLAS pixel implantations

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GEFÖRDERT VOM
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FSP 103 ATLAS

ATLAS EXPERIMENT

CERN

The ATLAS pixel detector

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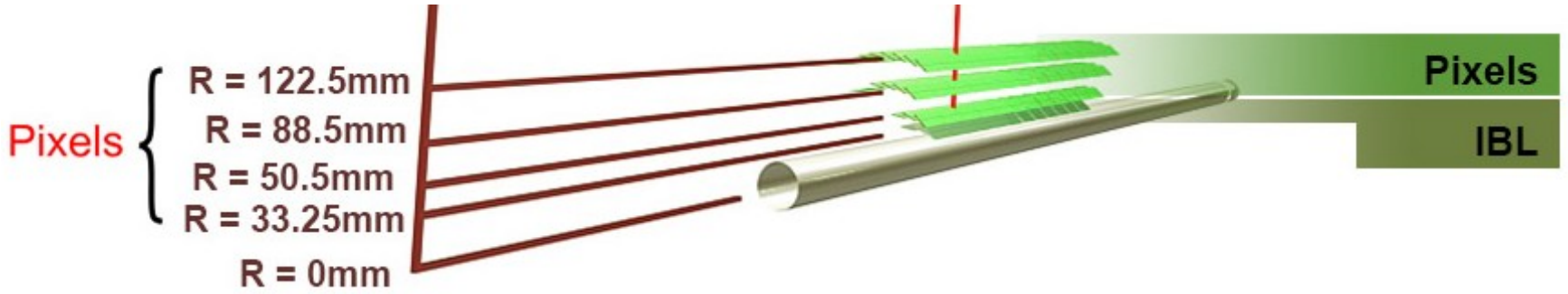
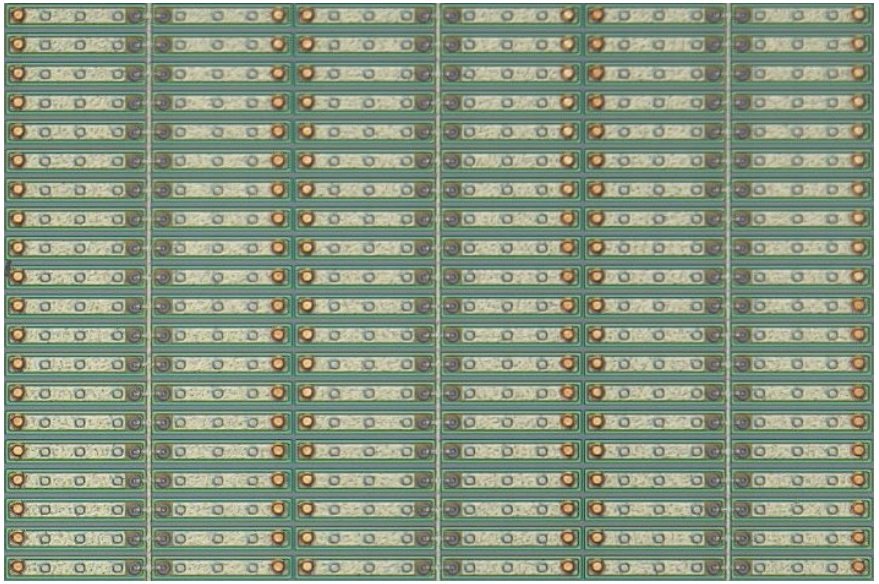
- 3-layer detector sensors:
- Up to 1×10^{15} $n_{eq}cm^{-2}$
- 250 µm thick
- pixel pitch 400×50 μm^2
- FE-I3 ASIC

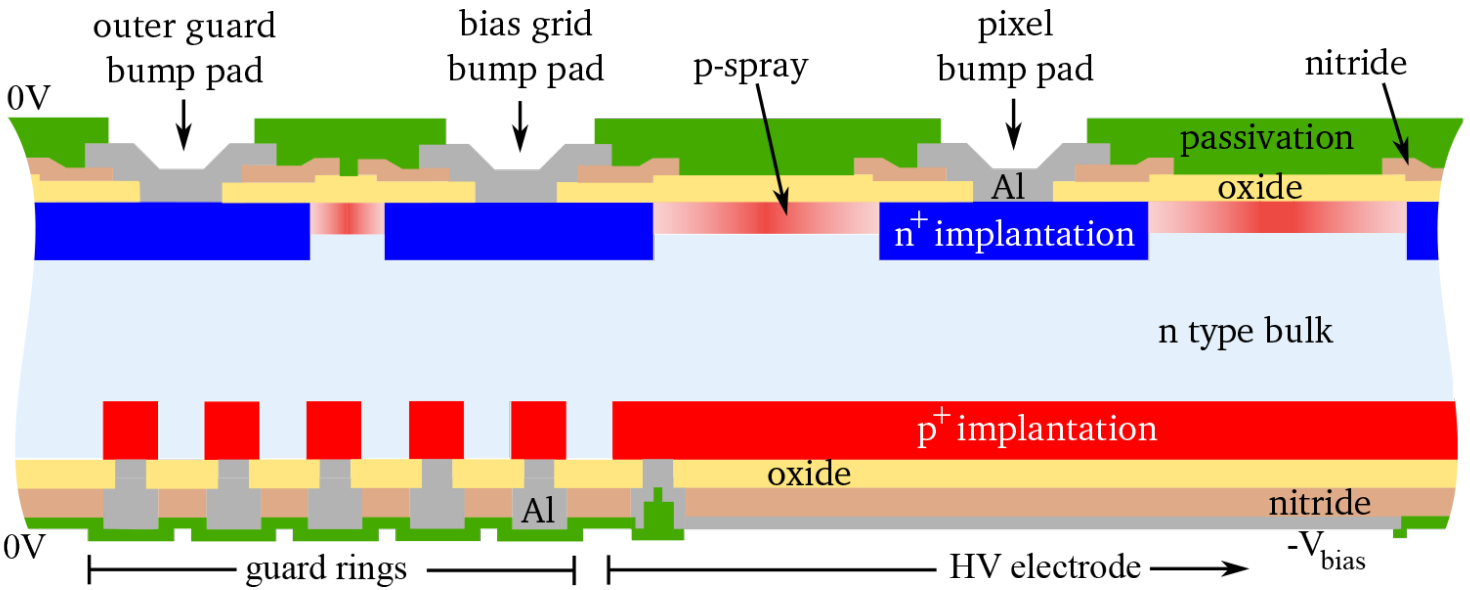
- 4th layer (IBL) sensors:
- Up to 5×10^{15} $n_{eq}cm^{-2}$
- 200 µm thick
- pixel pitch 250×50 μm^2
- FE-I4 ASIC



IBL sensor design

- n^+-in-n silicon
  - 200 µm n-type Bulk
  - n^+ pixel
  - 80 columns x 336 rows
- HV pad & 13 guard rings on p-side
- Double sided wafer process





REINER pixel designs

REdesigned, INnovative, Exciting and Recognizable

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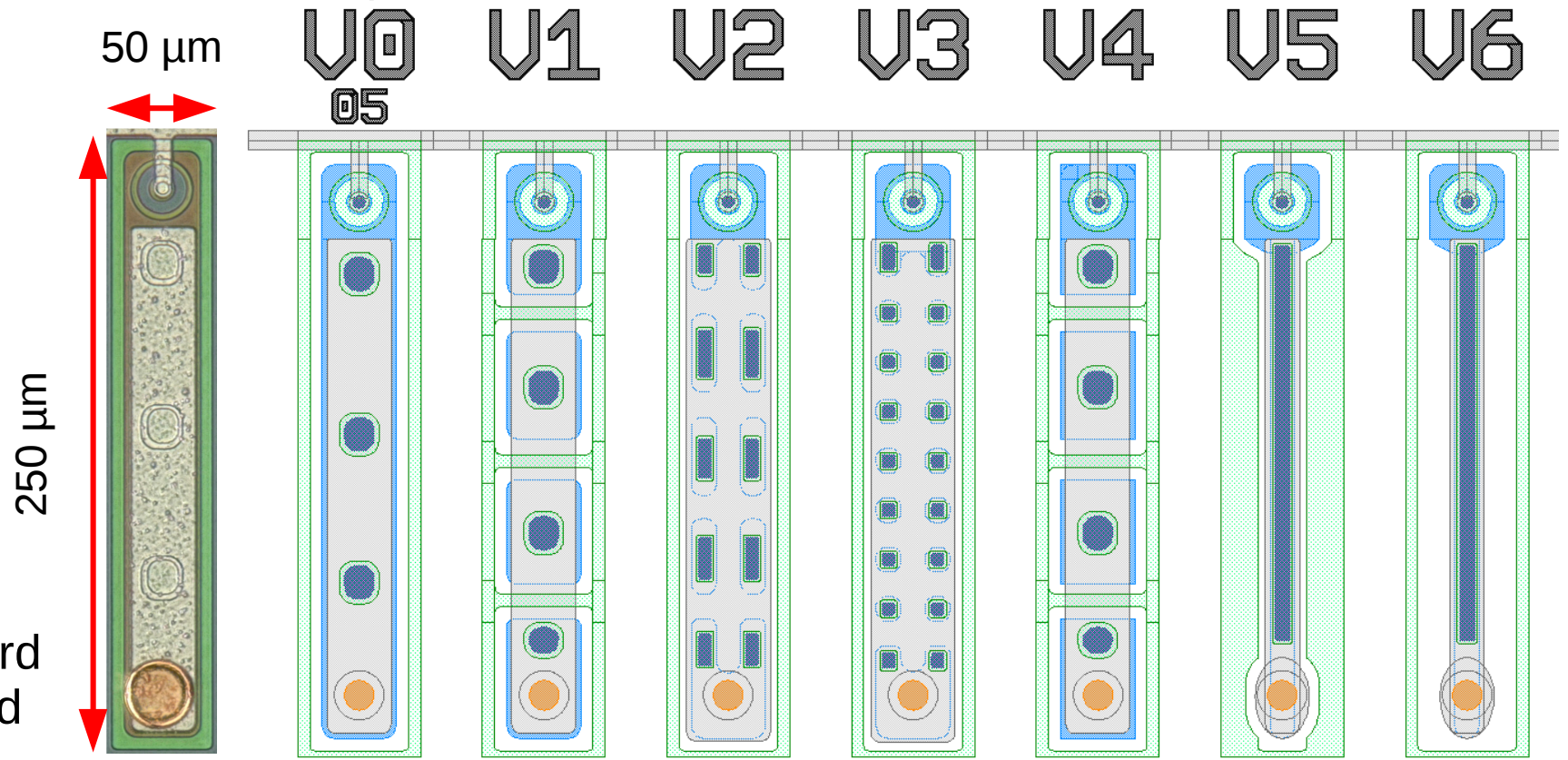
- Six new designs
  - Three divided in 4/10/18 sub implants
  - One with rectangular corners
  - Two with narrowed implant

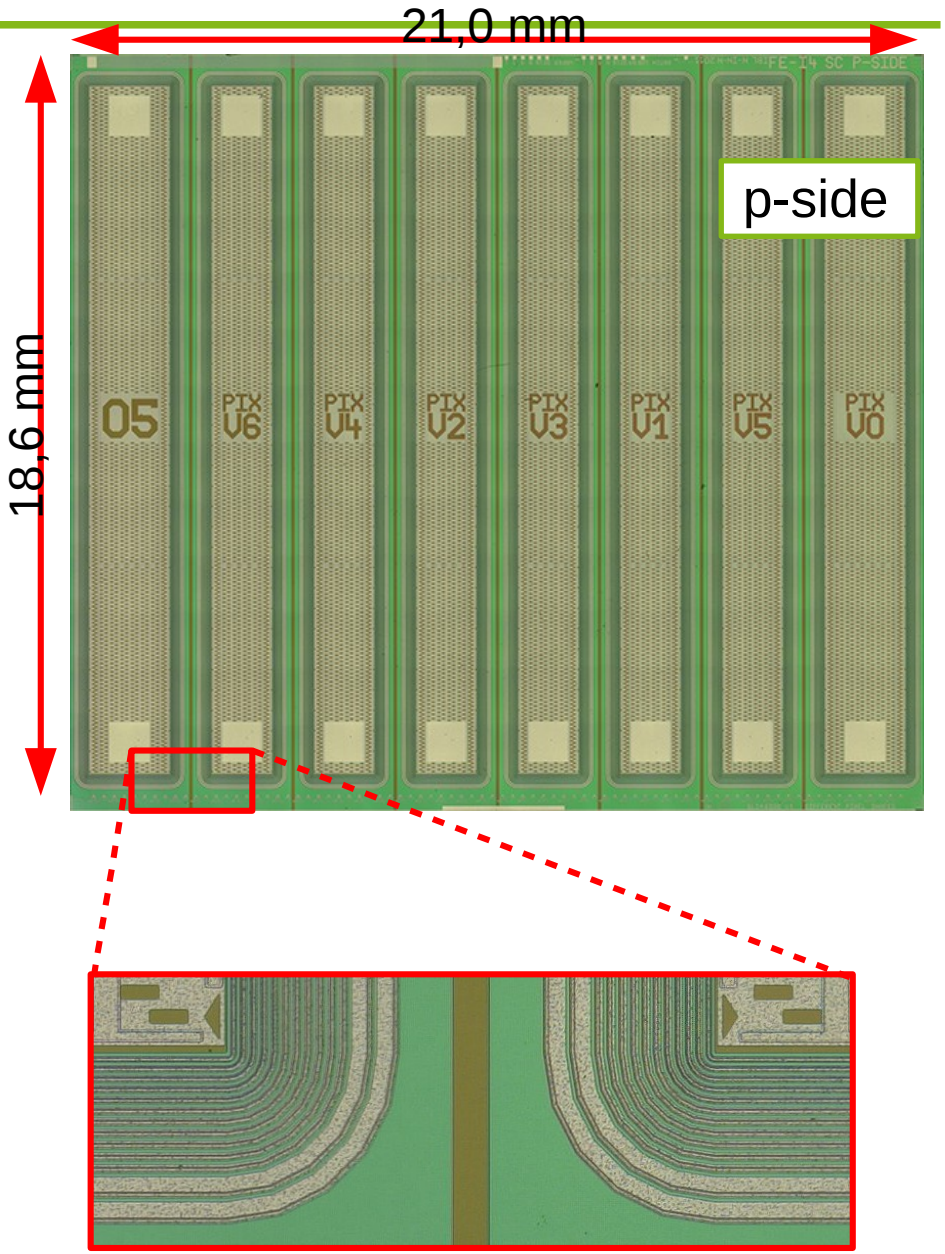
Blue: n+
Grey: metal
Green: Ni openings



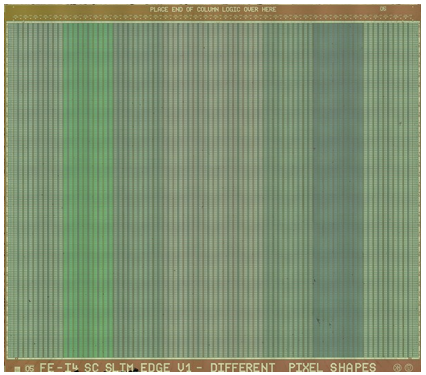
V0: IBL-standard
V1-V6: modified

REINER pixel sensors

- Eight structures on one sensor
  - Two IBL designs
  - Six modified designs
- Each structure consists of 10 columns x 336 rows with the same design
- Separate HV pads
- Individual guard rings
- Readout by one FE-I4



n-side



IV (irradiated)

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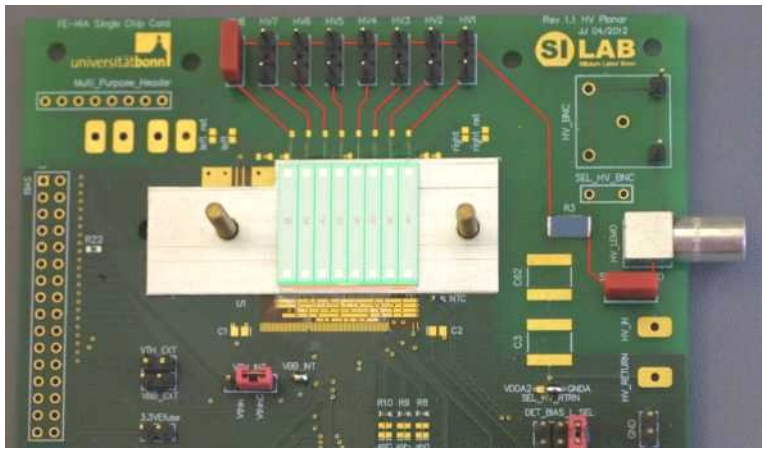
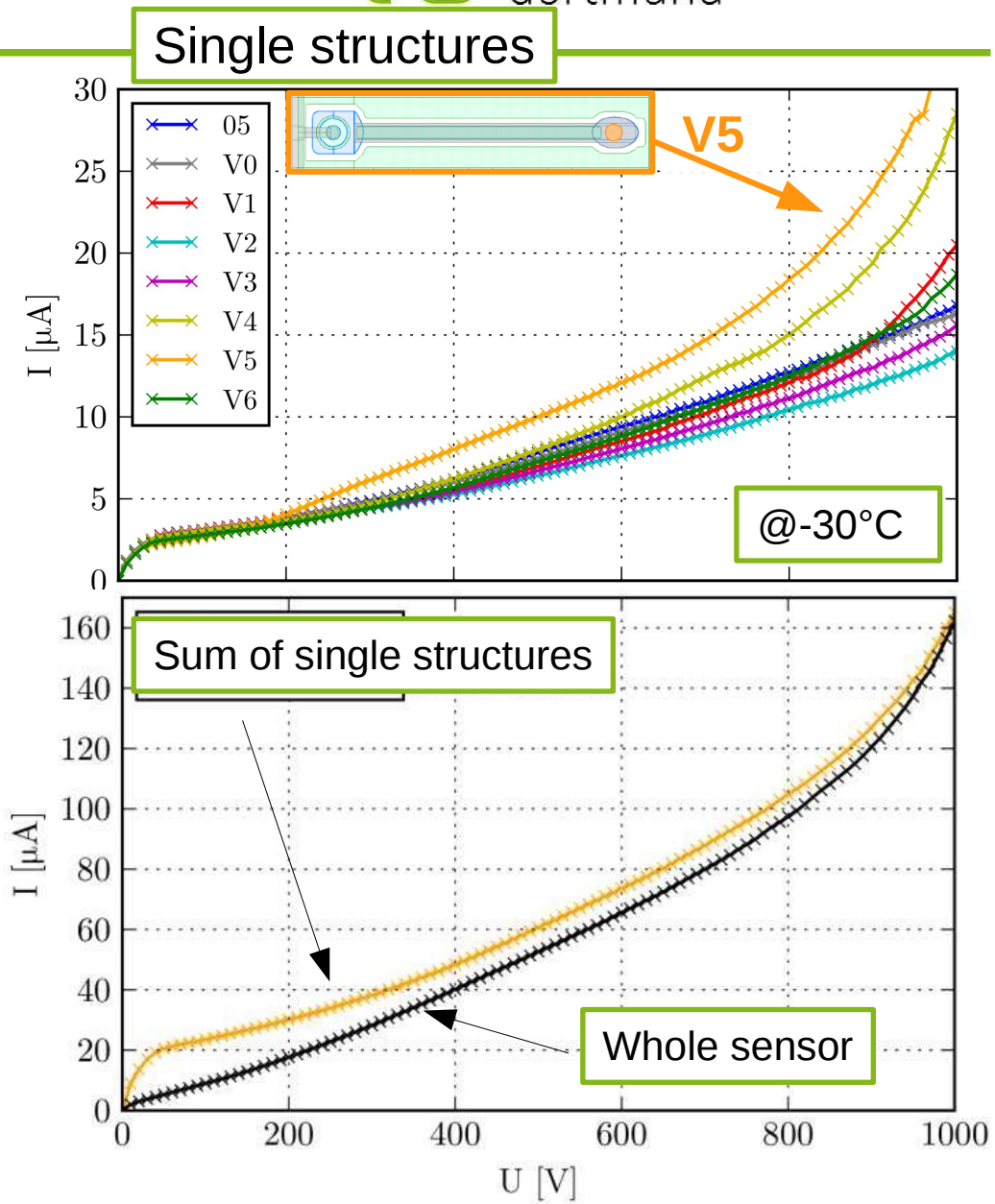
- Φ ~5e15 $n_{eq}cm^{-2}$, Sandia ACRR
- Differences between structures
- Sum of single currents is greater than current of whole sensor
- Also observed at unirradiated sensors

HV jumper



HV



Lab setup source scans

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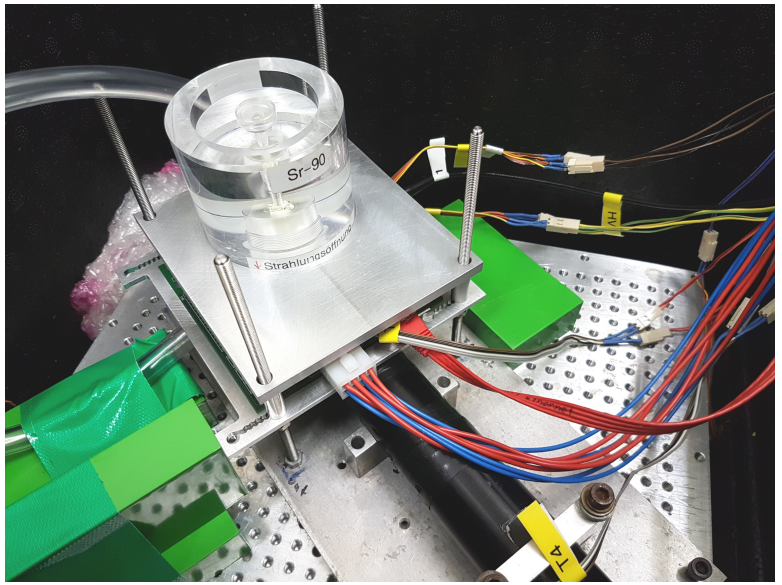
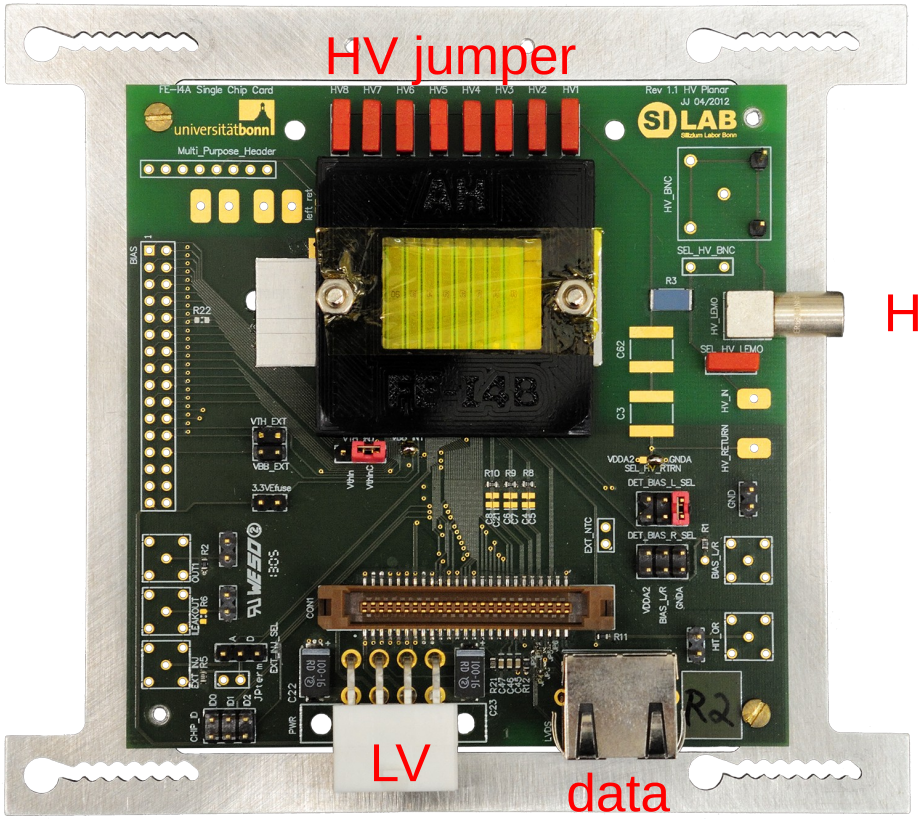
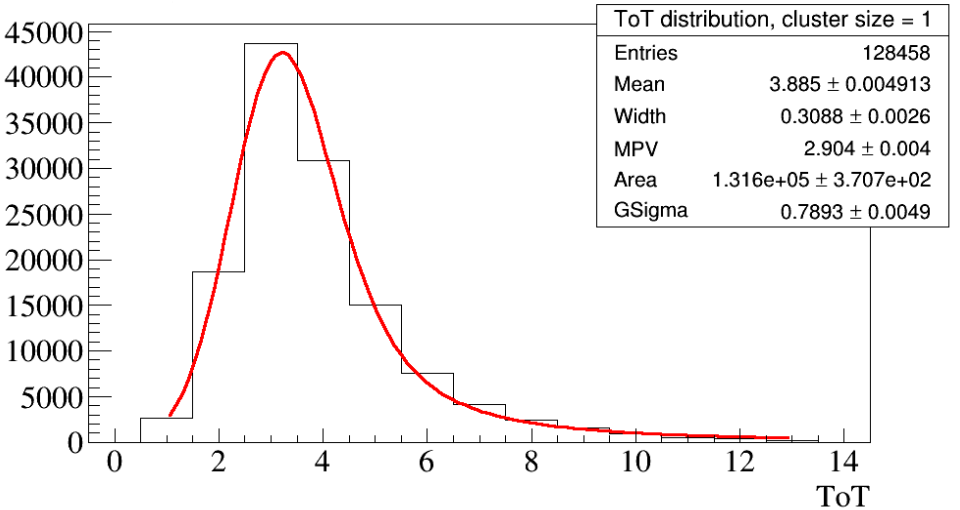
- Special single chip PCB
  - Frame movable by 2,5 mm (10 columns)
- Sr-90 source + trigger scintillator
- Landau-Gaus fit







Guard ring design

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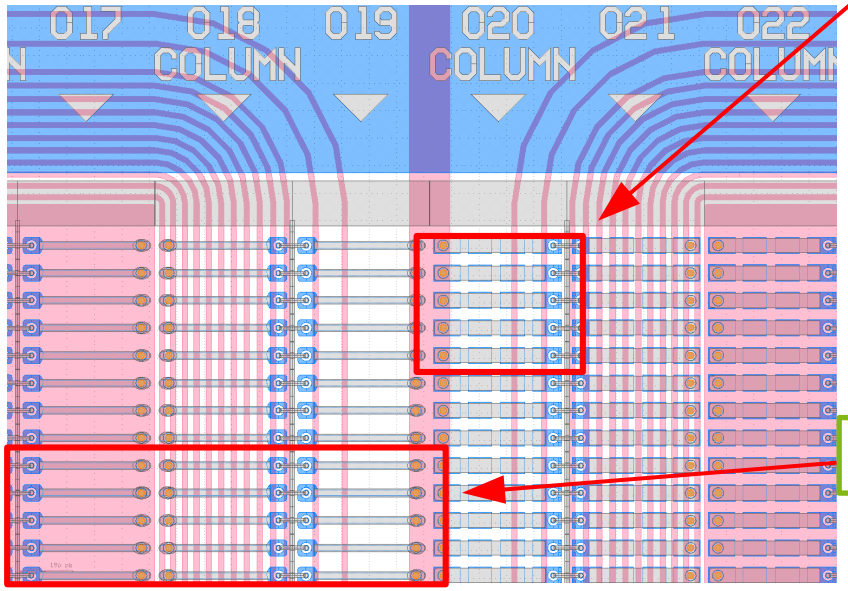
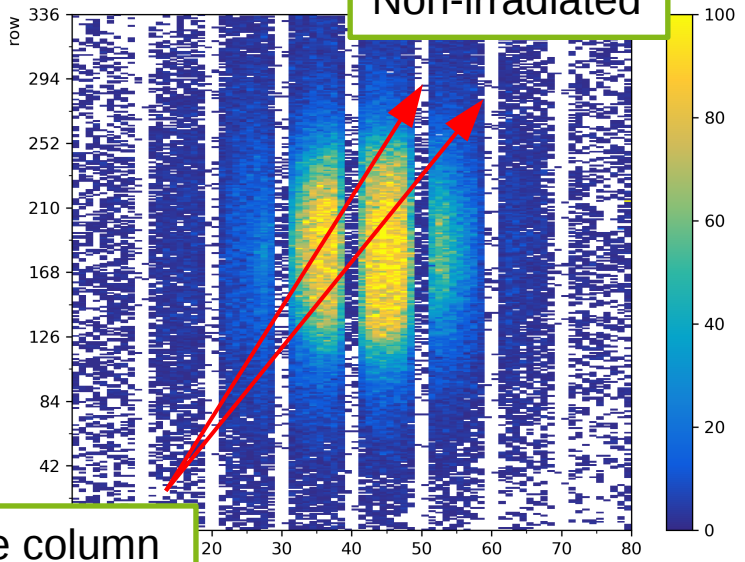
- Expected two grounded columns per design
- Observed current related issues in pixels beneath or near guard rings after irradiation
- ➔ Mask 6 columns of each design

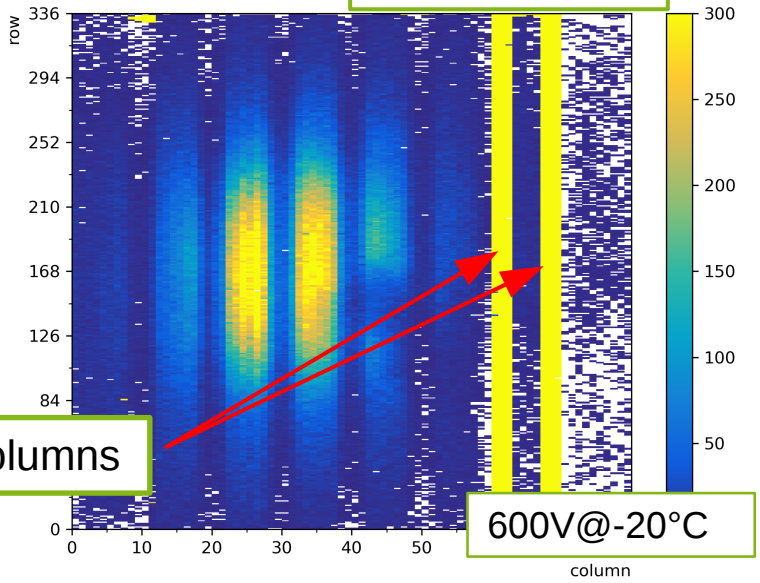


Non-irradiated



One column

Irradiated



Three columns

600V@-20°C

Charge collection vs. voltage

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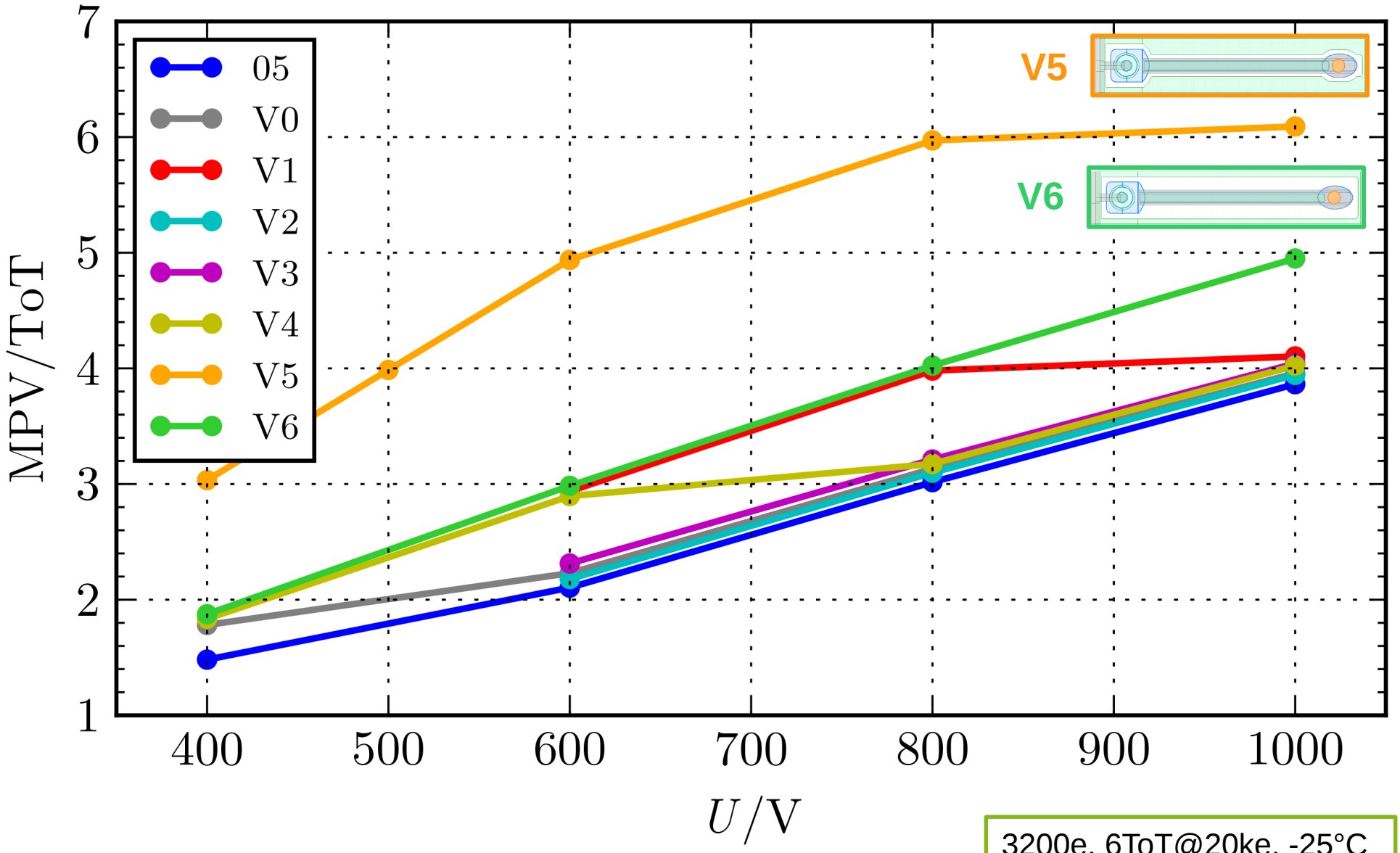

Charge collection vs. tuning

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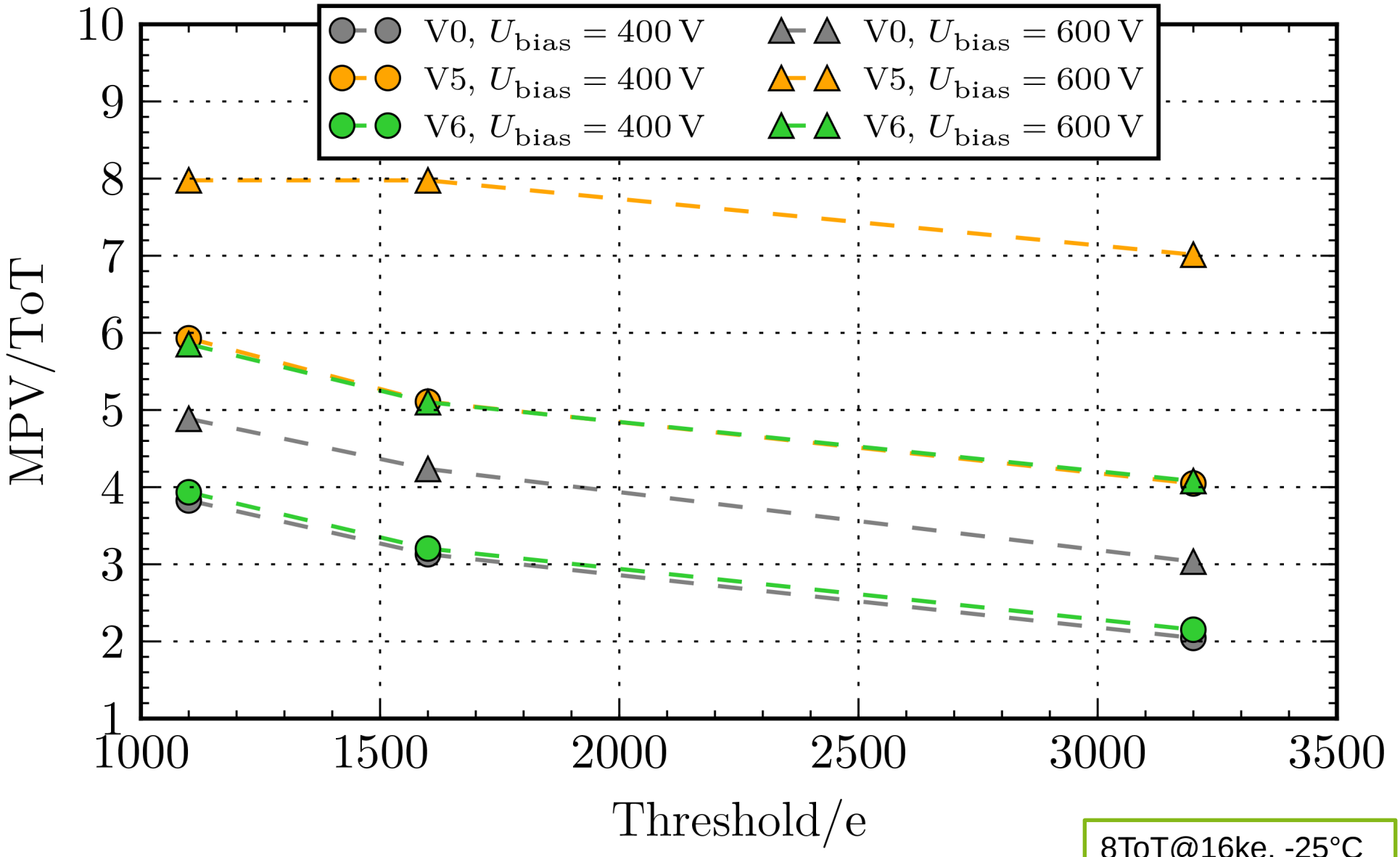

8ToT@16ke, -25°C

Hit rate (Counted hits divided by scan duration)

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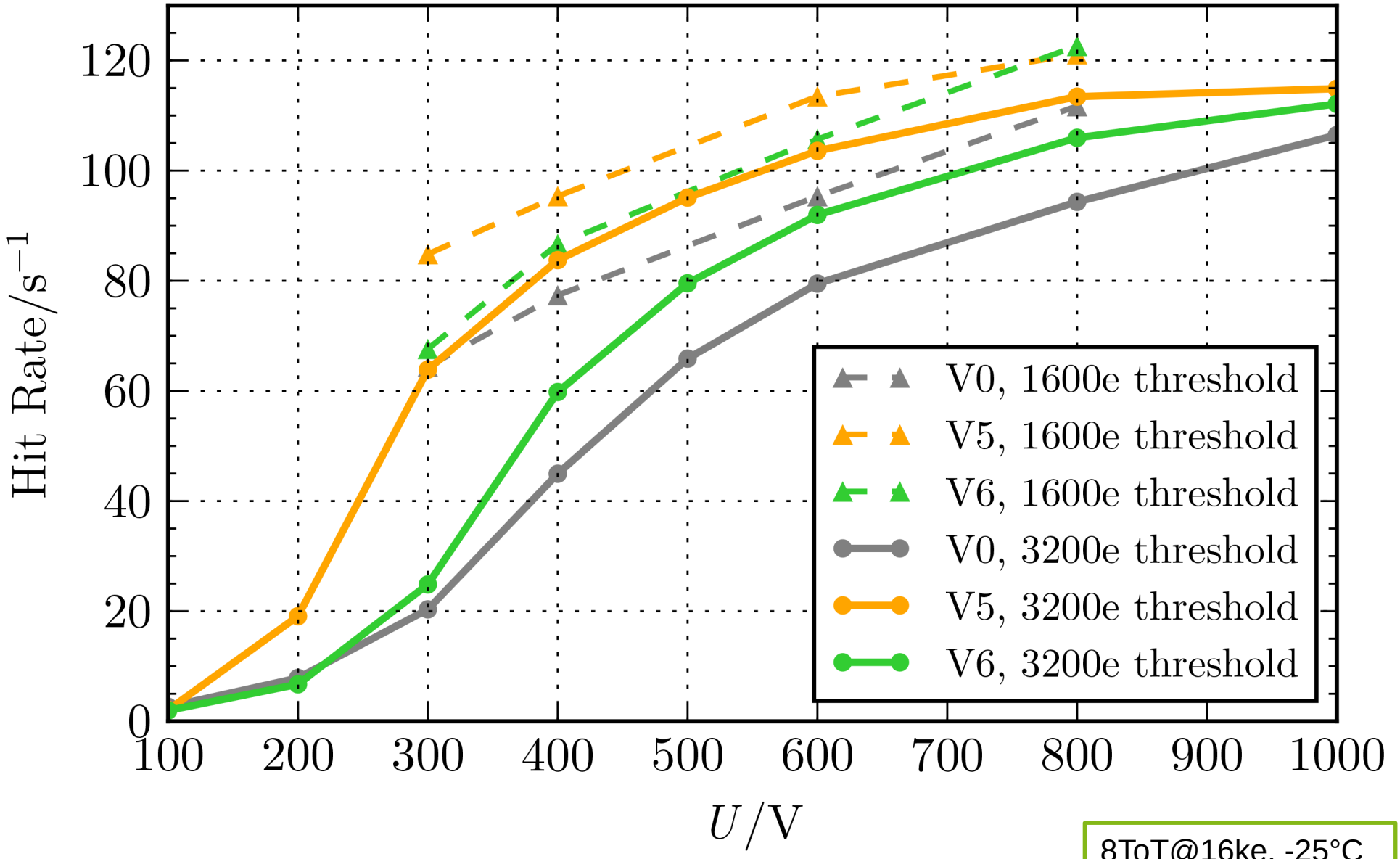

8ToT@16ke, -25°C

CERN Testbeam (Aug '16)

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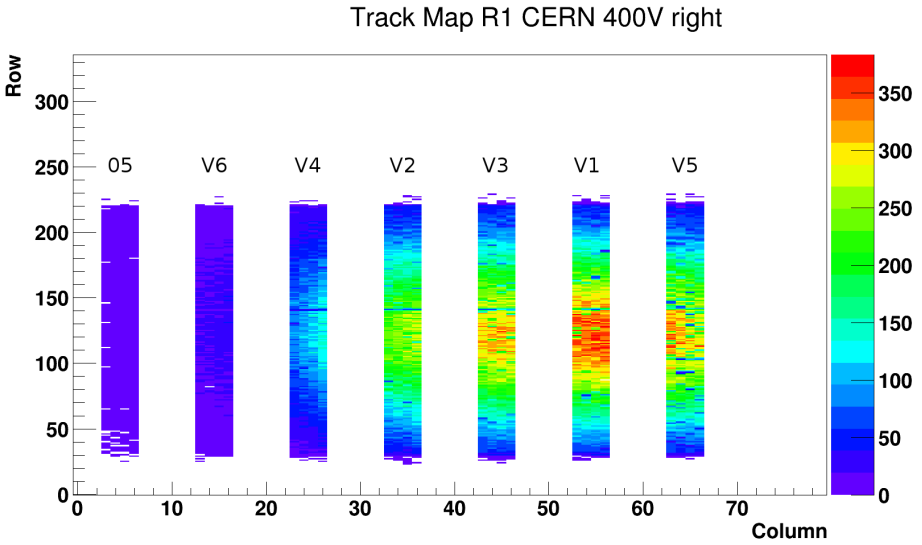
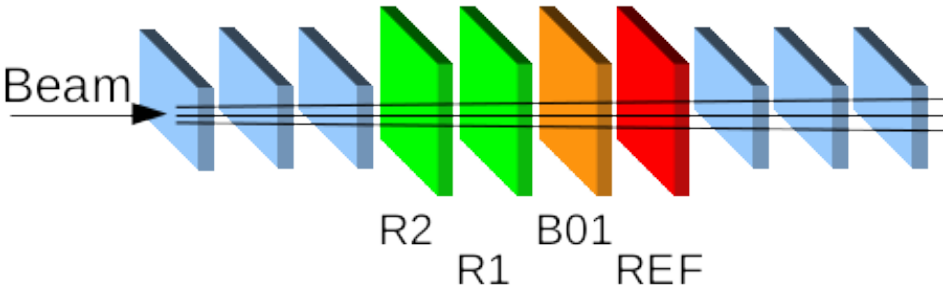
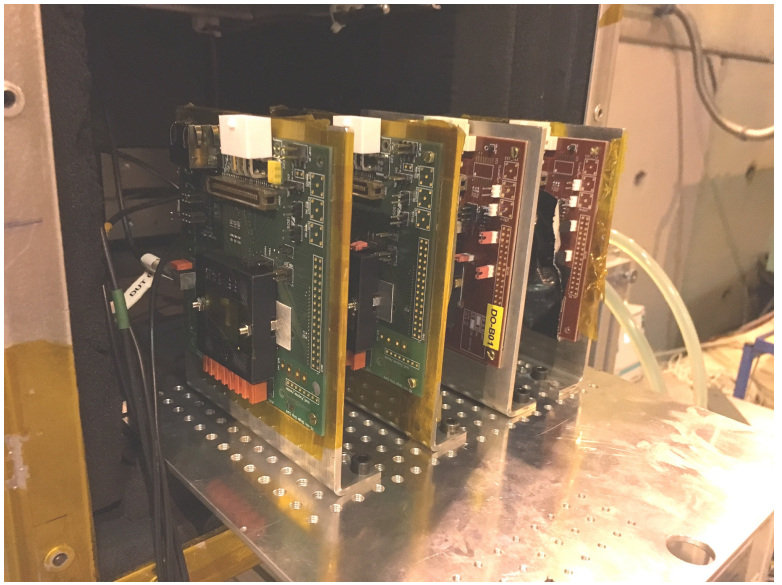
- R2 (unirradiated), R1 (irrad.)
- All structures biased
- 3200e / 6ToT@20ke
- -29°C on-sensor (derived from leakage current)
- 3-4 designs investigated at a time
- Repositioning of box necessary to cover the whole sensor





$$\text{efficiency} = \frac{\text{hits}}{\text{tracks}}$$



Efficiency R2 (unirradiated)

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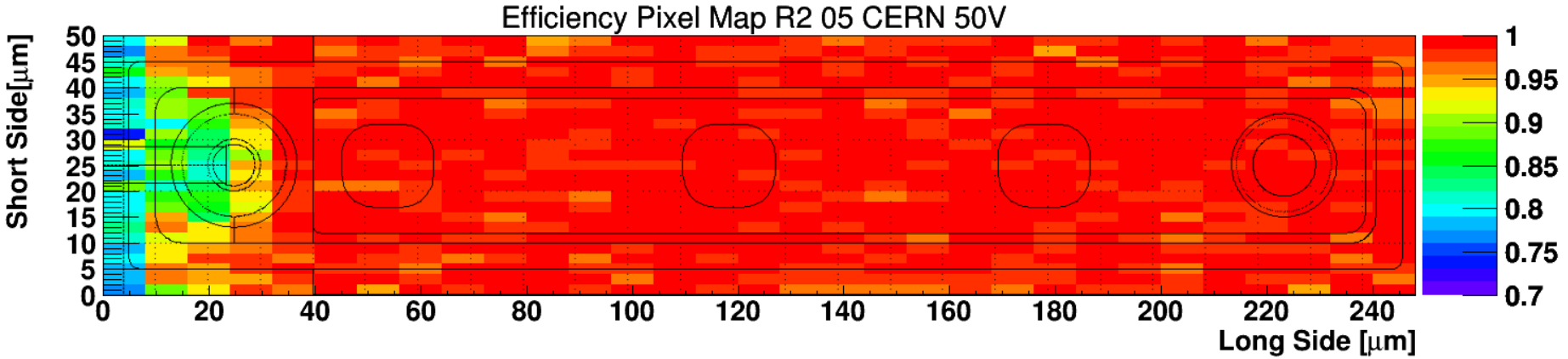

Pixel design	Efficiency [%]	# Tracks
05	97,1 ± 0,3	123 084
V6	95,8 ± 0,2	142 374
V4	96,3 ± 0,2	159 014
V2	96,2 ± 0,3	158 170
V3	96,3 ± 0,3	170 754
V1	96,4 ± 0,2	146 609
V5	96,2 ± 0,5	150 110

Efficiency R1 (irradiated): V05 (IBL)

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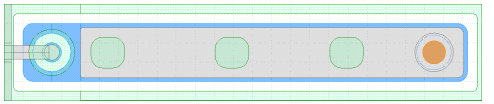

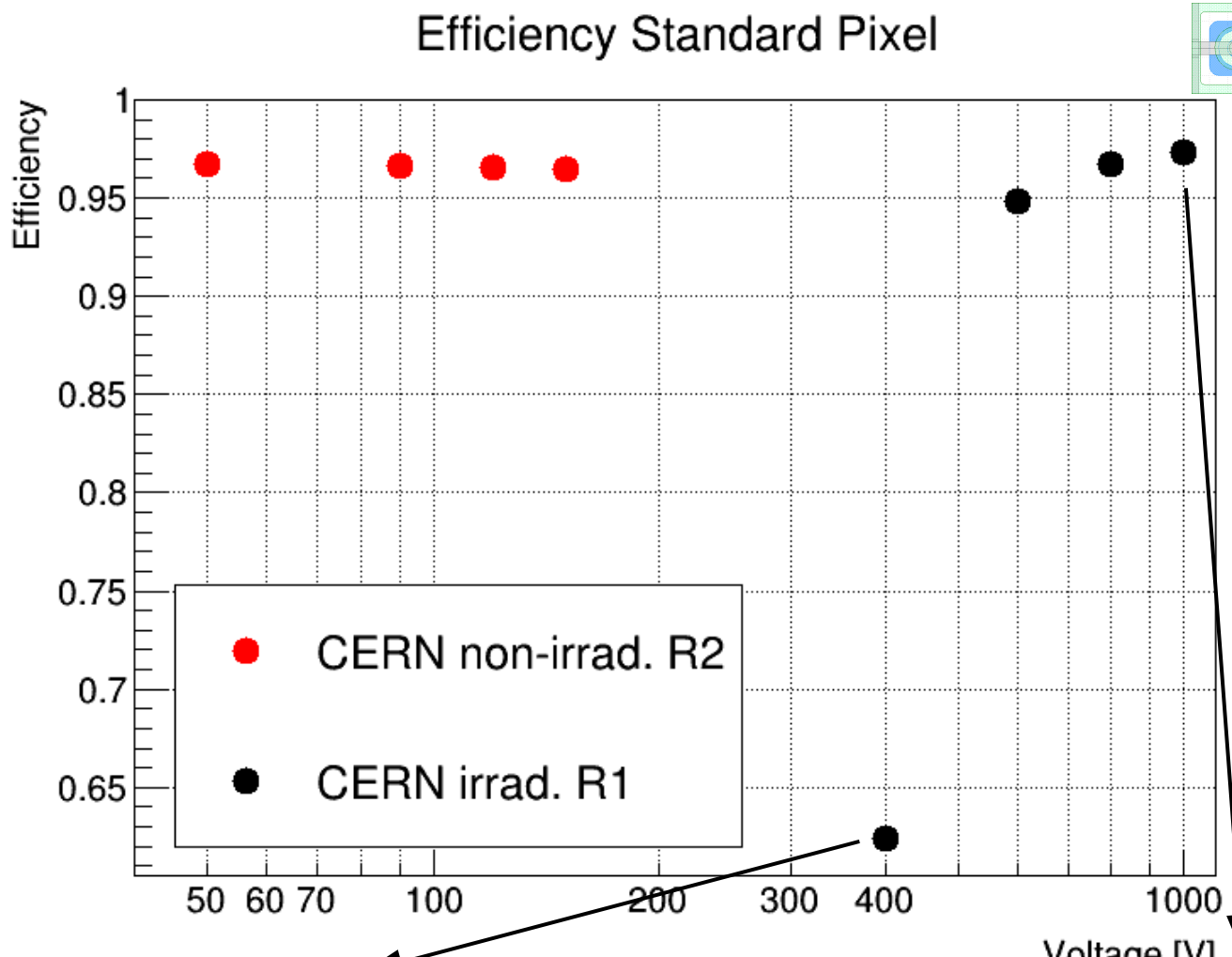

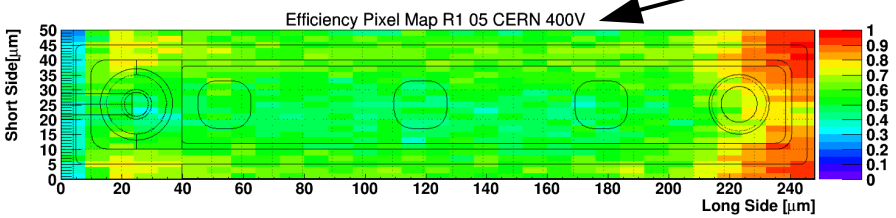

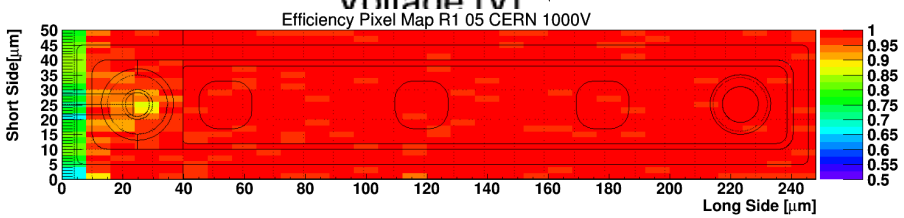

Efficiency R1 (irradiated): V2 & V3

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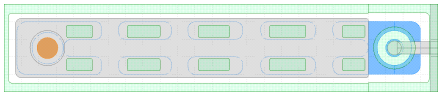

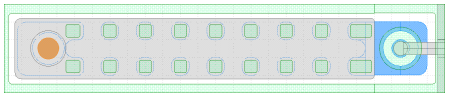

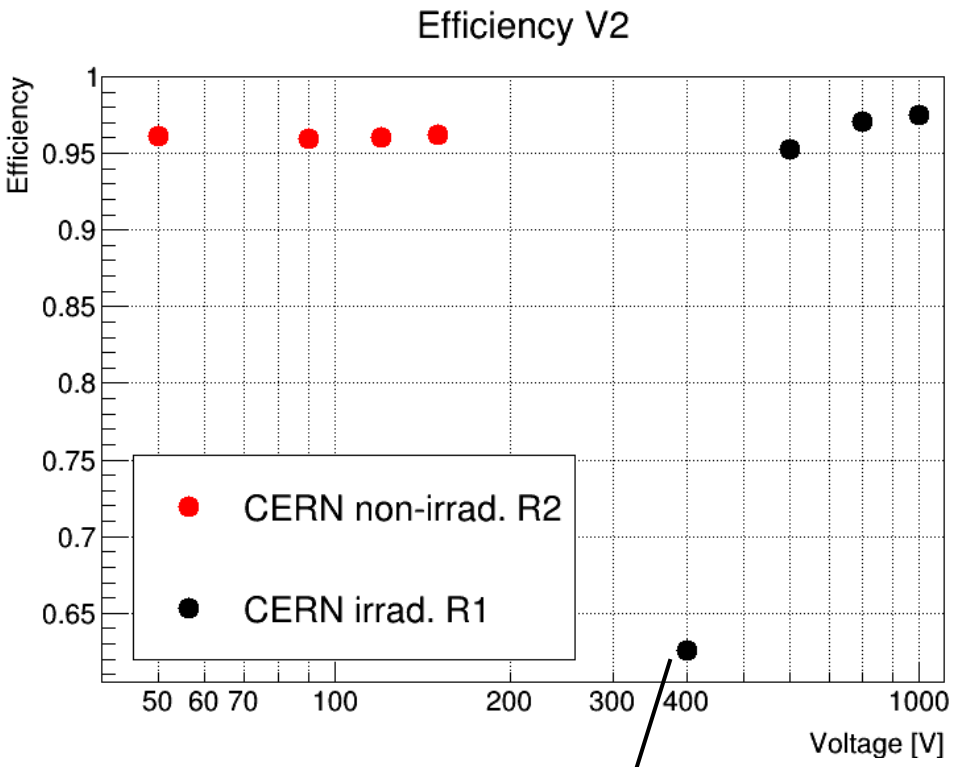

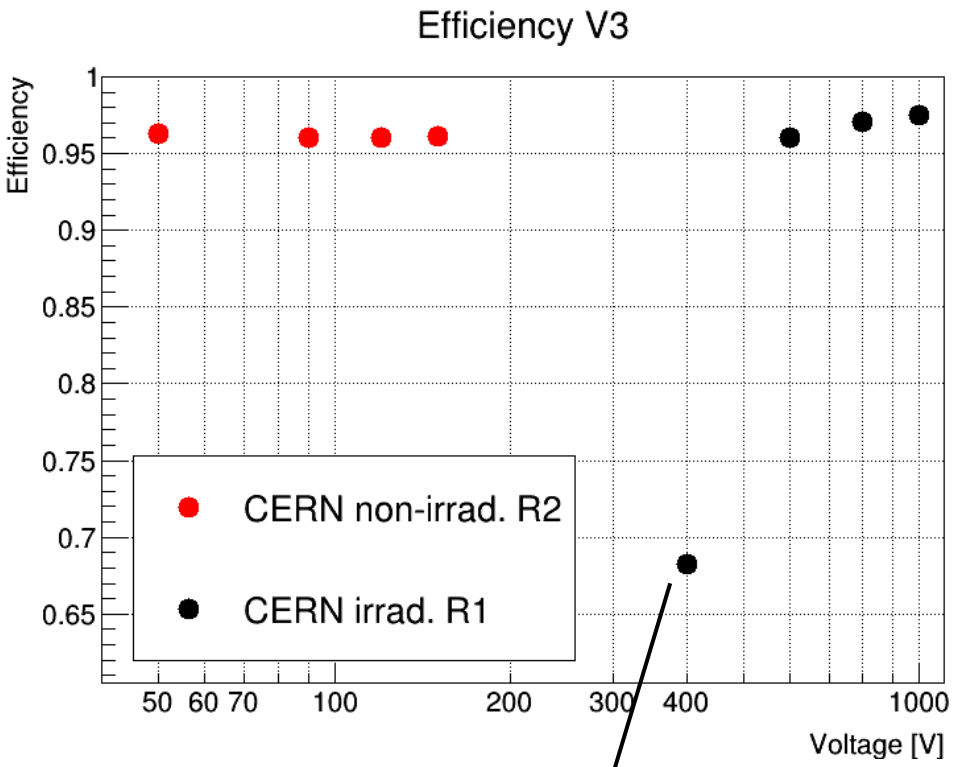

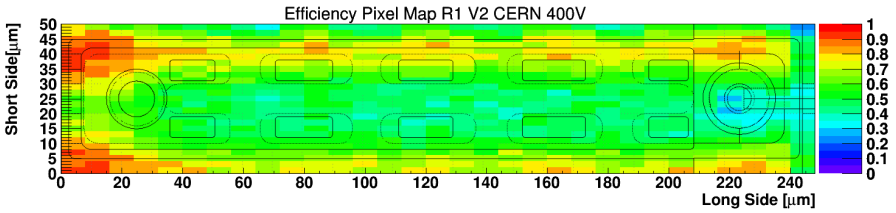

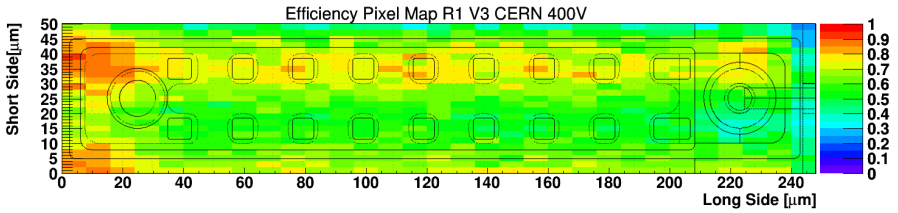

Efficiency R1 (irradiated): V1 & V4

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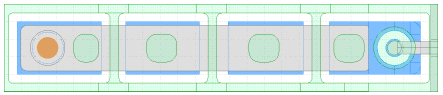
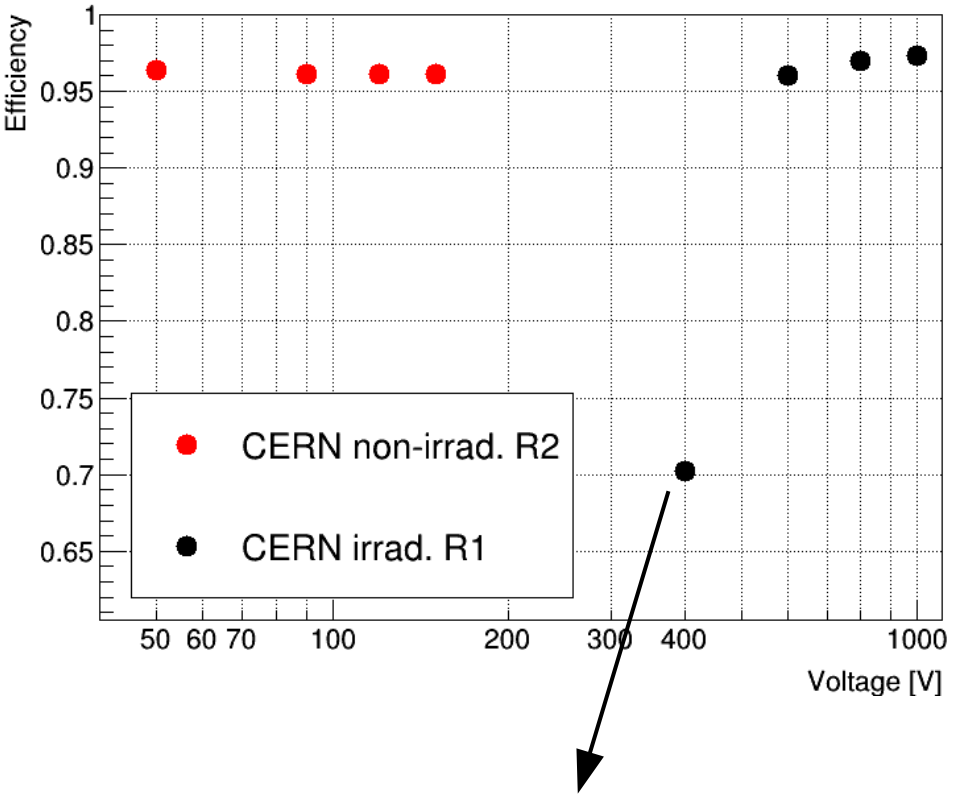
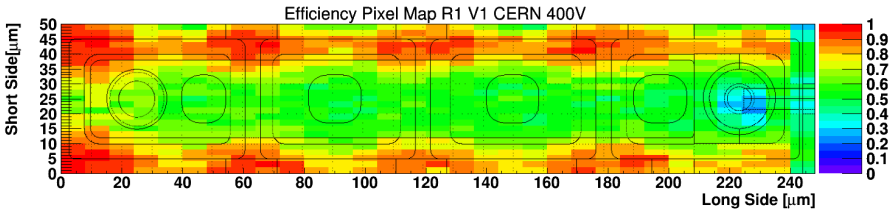
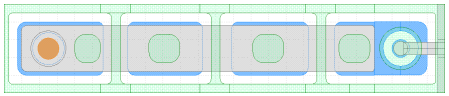


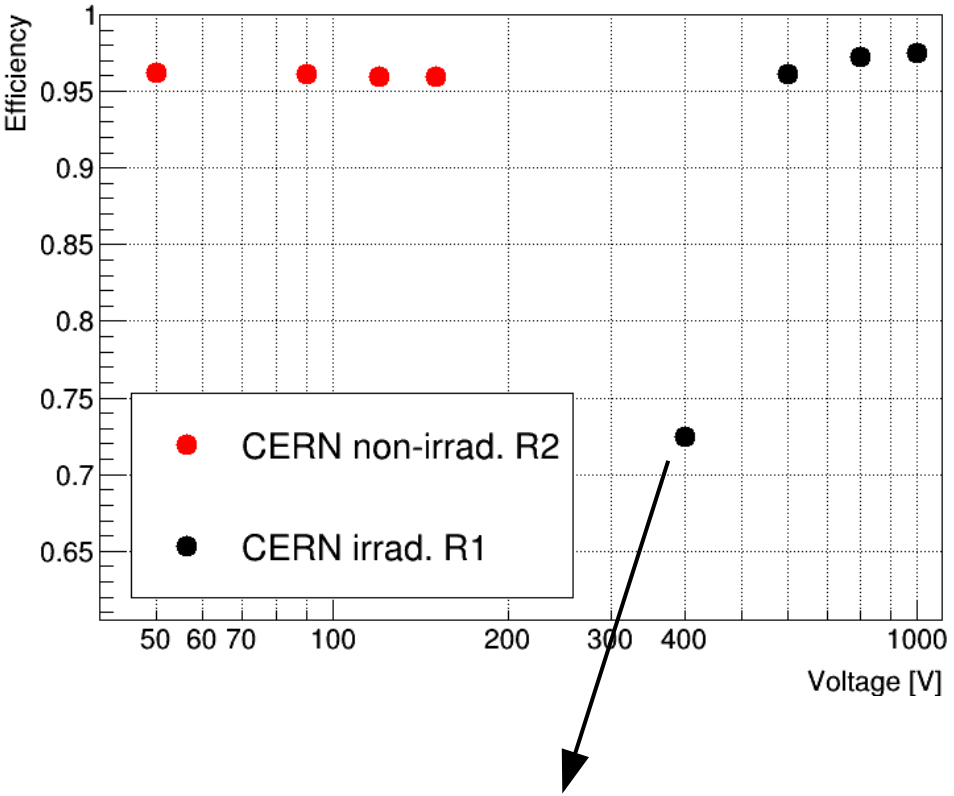
Efficiency V1

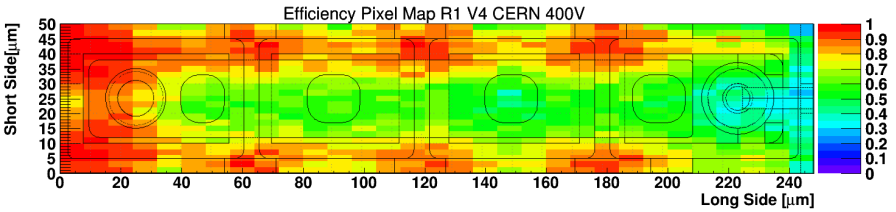






Efficiency V4





Efficiency R1 (irradiated): V5 & V6

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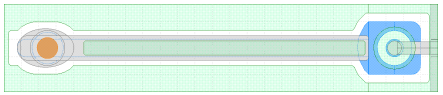

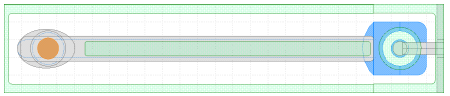

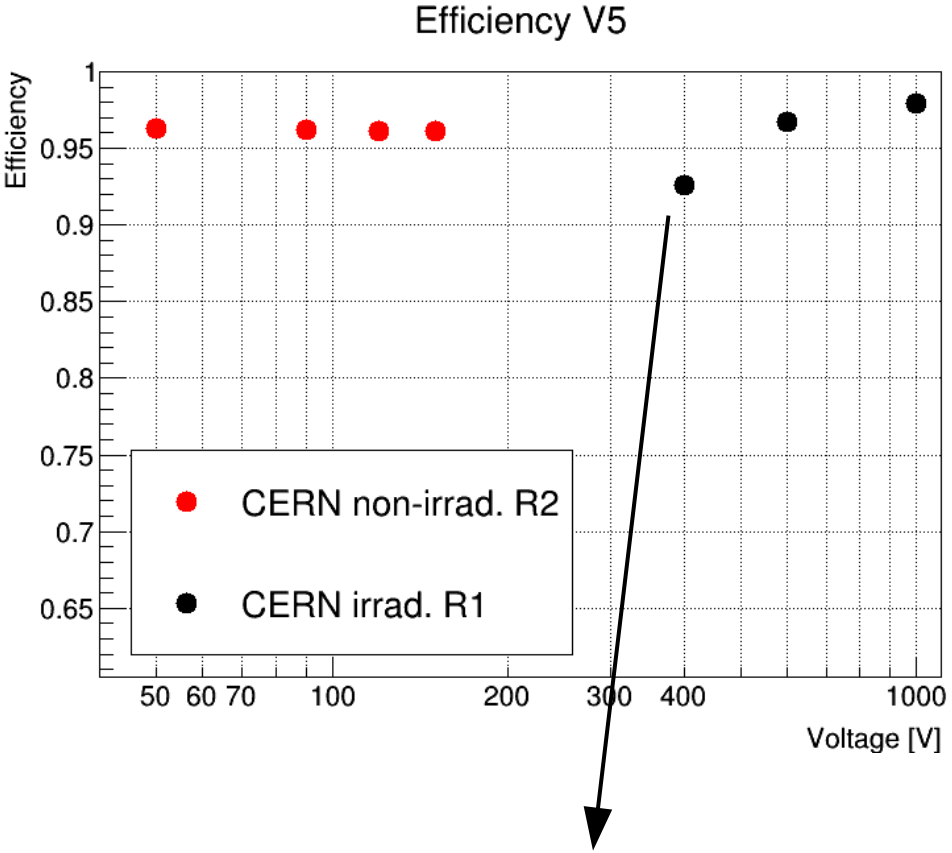

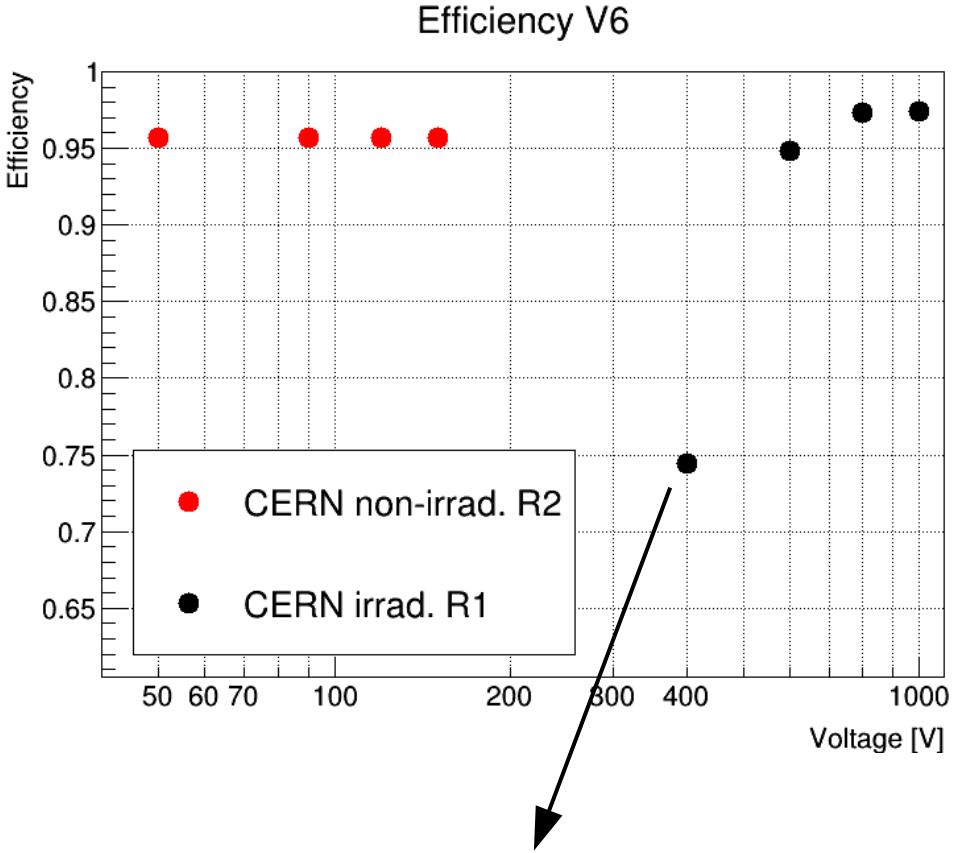

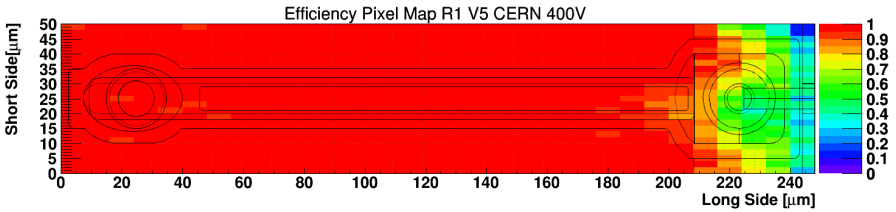

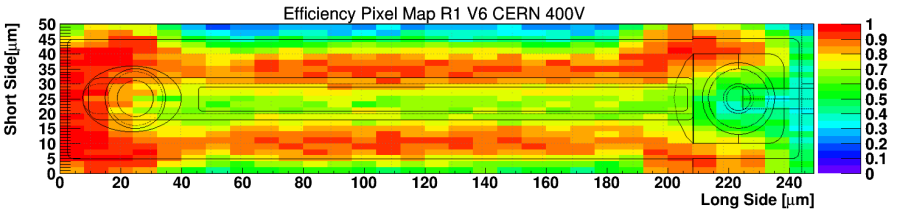

Efficiency R1 (irradiated)

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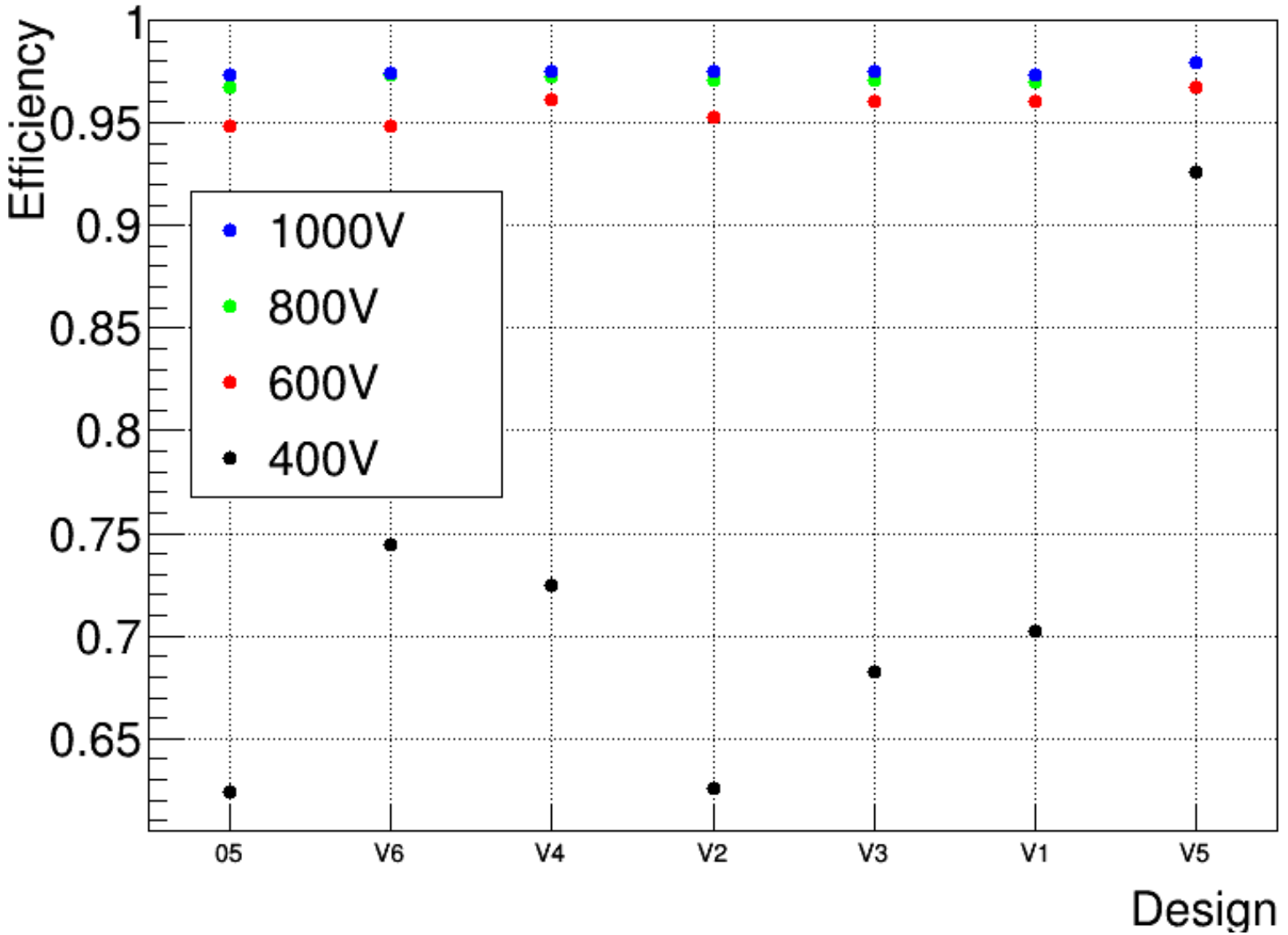

REINER pixel sensor Mark II

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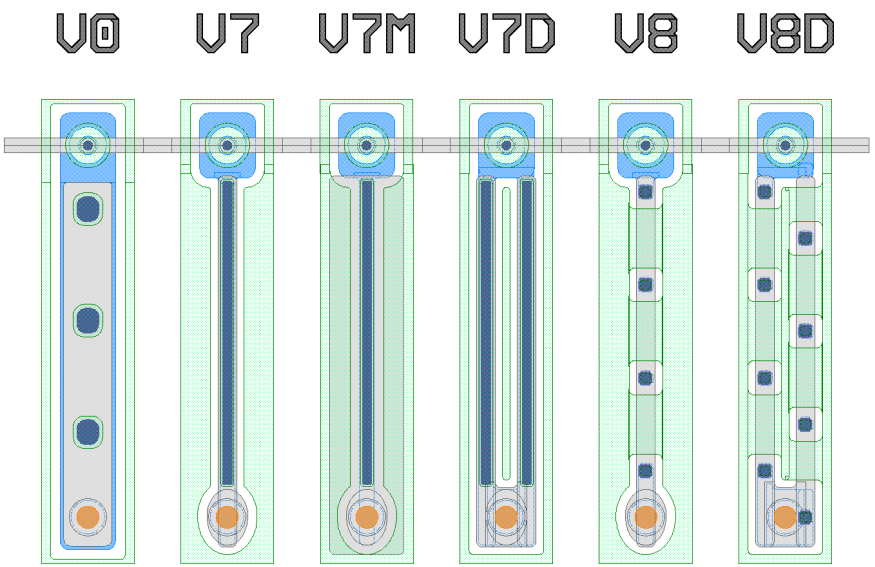
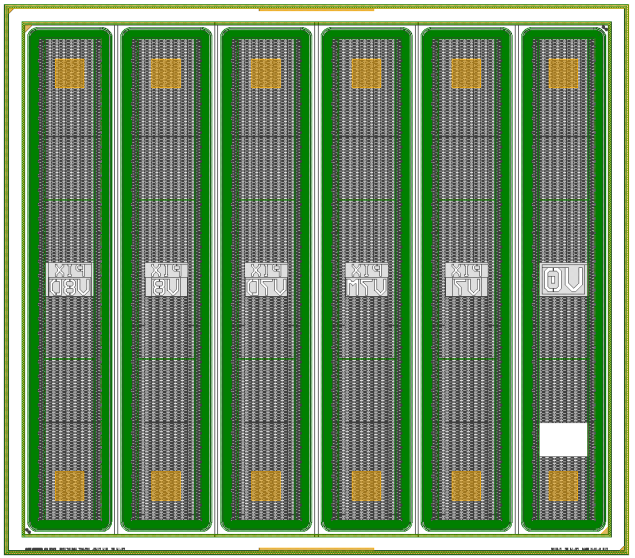
- New follow-up designs
- 12 + 4x14 + 12 columns
- 5 new designs, based on V5
- Narrow n+ implant (8 µm)
- Wide p-spray
- Influence of metal layer (V7M)
- Prestudies for pixel sizes of 25x100 µm² (V7D, V8D) or 50x50 µm² (V8)





Summary & Outlook

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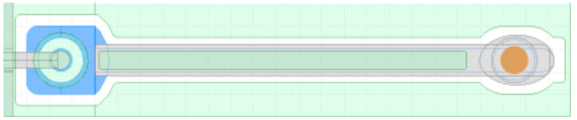
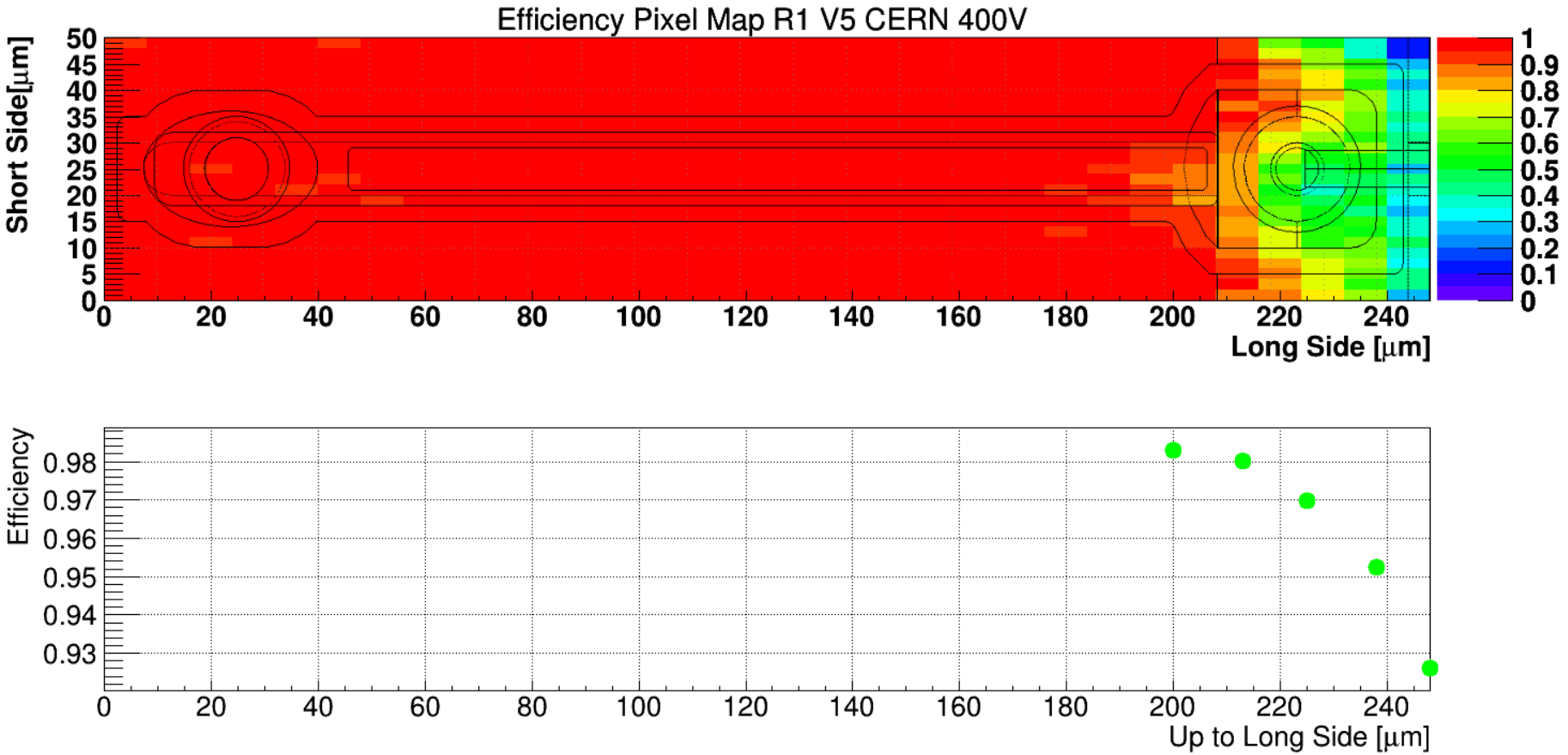
- Six modified IBL pixel designs have been investigated
- After 5e15 $n_{eq}cm^{-2}$, new designs similar or better than IBL design in case of charge collection and efficiency
- Reach satisfying efficiency at lower voltages
- V5 most promising new design

V5 

- R2 currently at CERN-PS irradiation
- New R&D n-in-n producion submitted

Efficiency vs. long pixel side



Overview REINER Mk I

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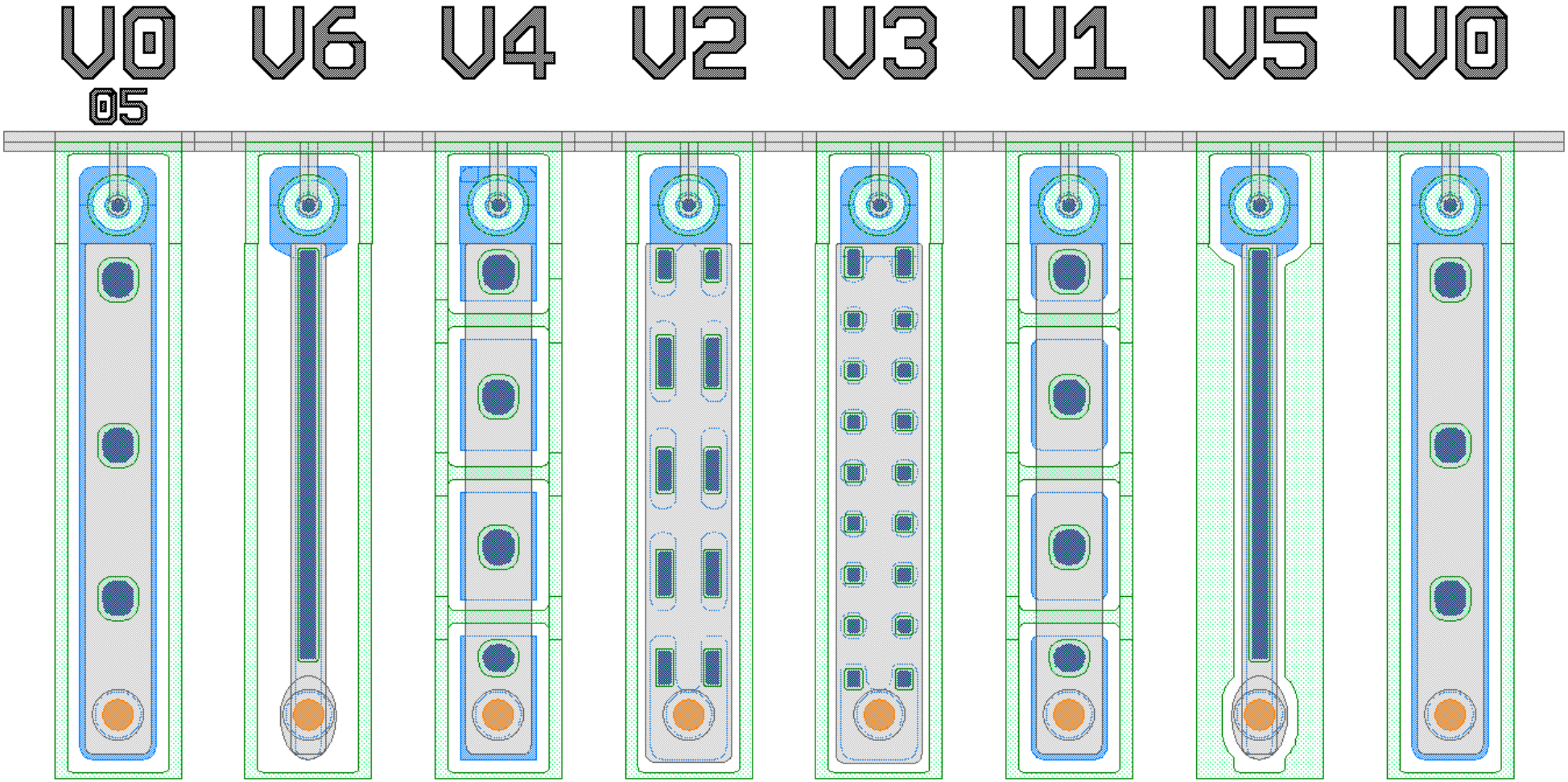

Overview REINER Mk II

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