Characterisation And Implementation Of HV-CMOS For High Radiation Environments

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Christmas Meeting
2nd Year

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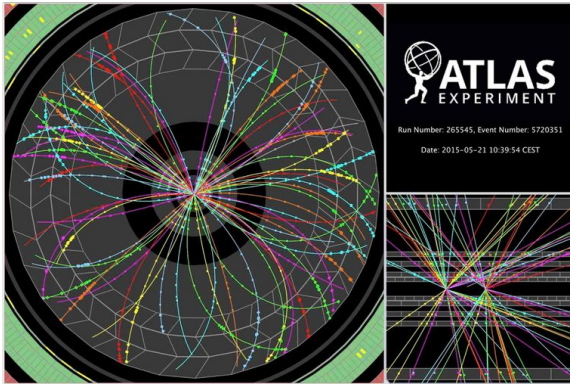
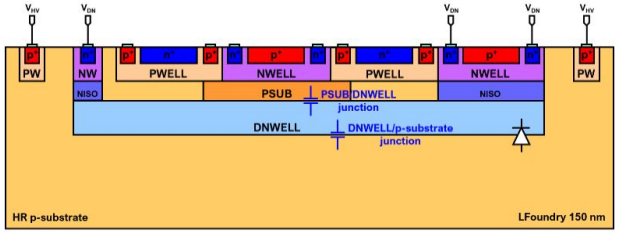
HV-CMOS
Motivations And Such





Placed close to collision center → Sensors receive high radiation dose

High rate of events
MHz-GHz rate of bunch crossings → Fine spatial resolution required
Good time resolution

Minimal track disruption → Thin sensors

Higher collision energies → More radiation, finer detail needed

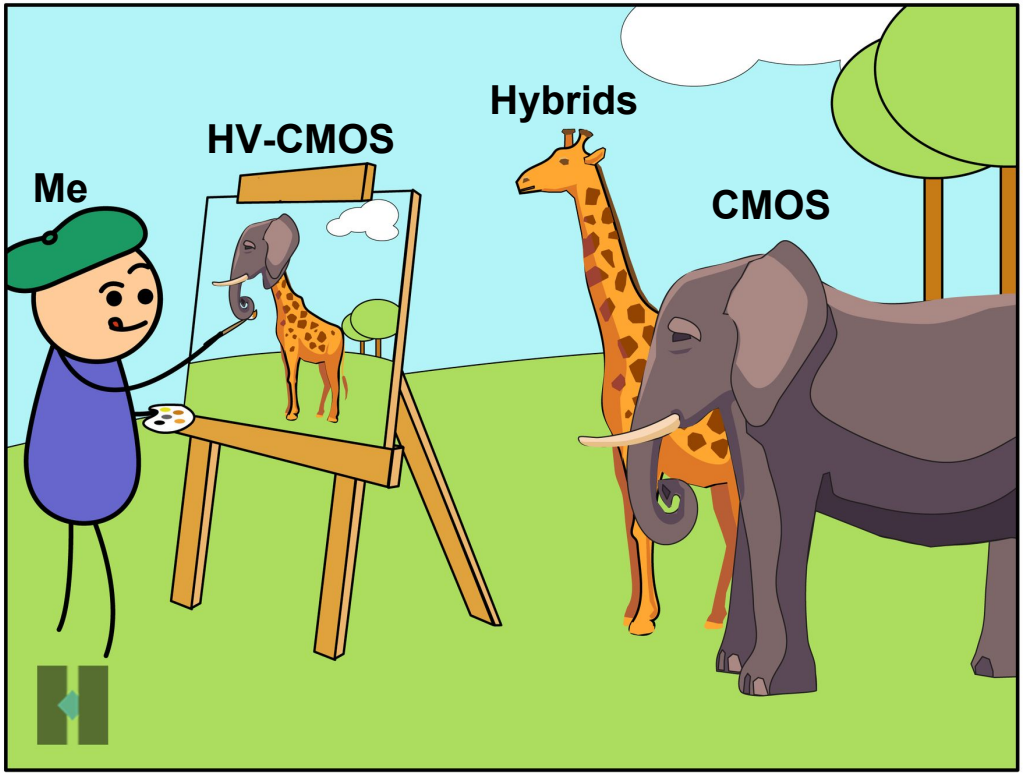
Integrated Readout Circuitry:
- ✔ Thin sensors
- ✔ Industrial standard
- ✔ Cost effective

High Voltage Pixel:
- ✔ More radiation tolerant
- ✔ Fast charge collection (Drift)

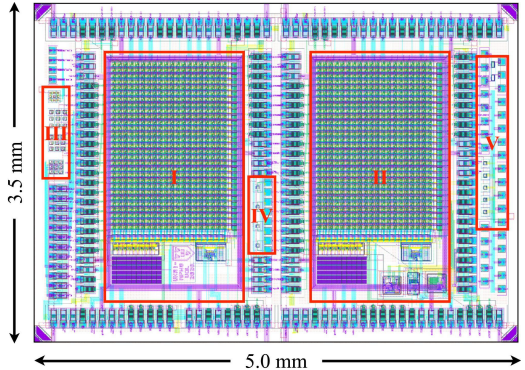
Sensors need to be thin, fast, radiation tolerant, and within budget

DISCLAIMER: I do not work for ATLAS, this is just an example

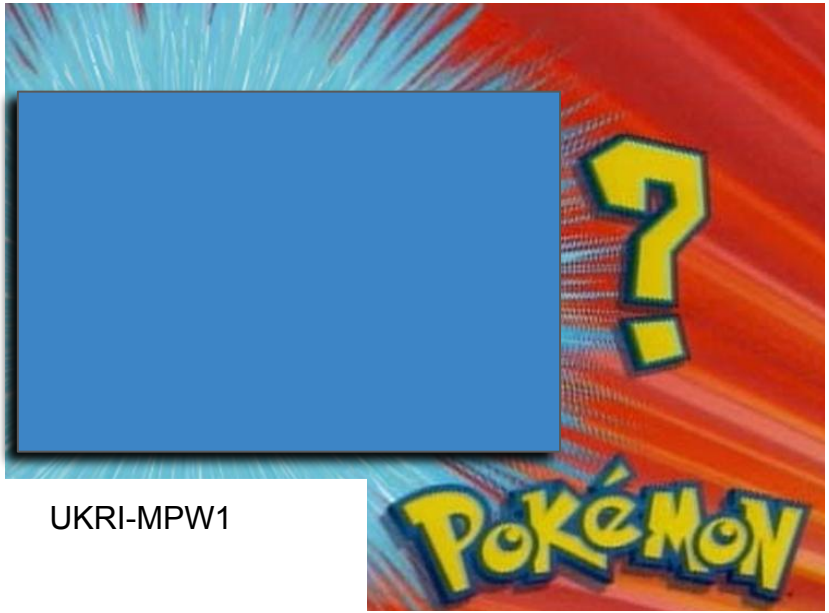
HV-CMOS
Motivations And Such



UKRI
Work Over The Last Year



UKRI-MPW0



UKRI-MPW1

- Characterisation of depletion region (eTCT)
- Effects of Non Ionising Energy Loss (NIEL) radiation on depletion region
- Conference proceedings published

- TCAD simulation
- Interpixel channel reduction
- Breakdown simulations

Ultimate goal:

- Improve radiation tolerance of HV-CMOS sensors
- Replace Hybrid-pixels
- TAKE OVER THE WORLD

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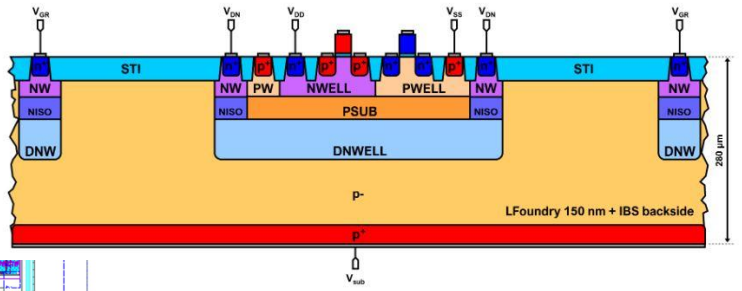
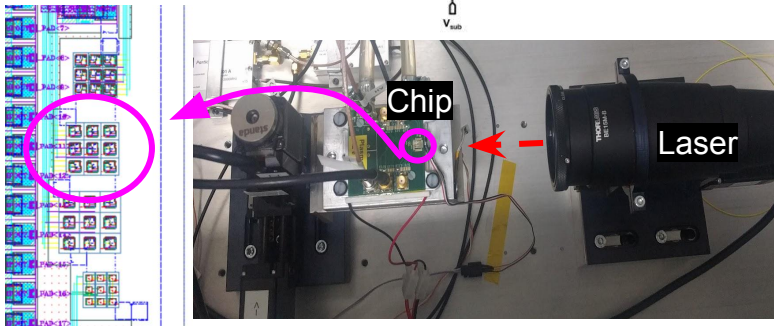
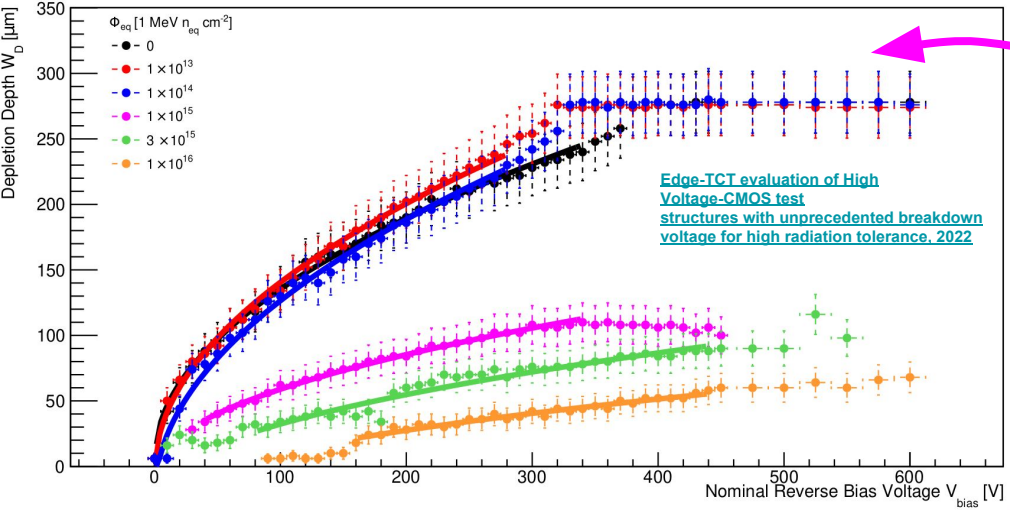
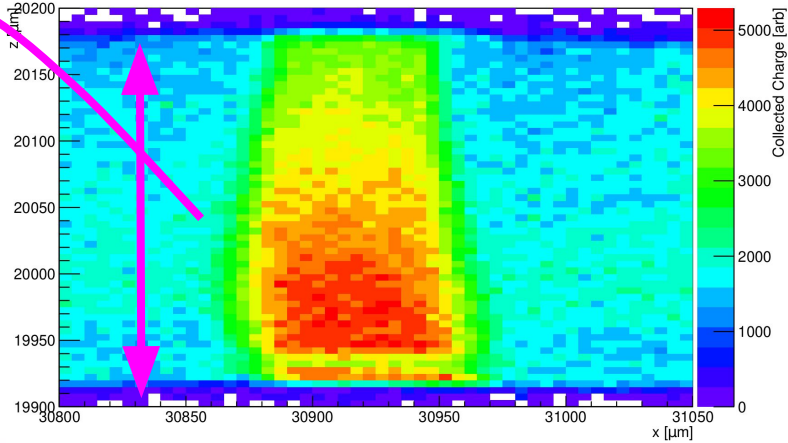
UKRI-MPW0
Depletion Region Evaluation

- Evaluation by edge Transient Current Technique (eTCT)
- IR laser on 3x3 passive test structure
- Beam waist penetrates generating signal in depletion region
- Move in x,y,z to map region
- Map reduction in depletion depth with radiation
- 50 µm depletion depth at 1 x10^{16} 1 MeV n_{eq} cm^{-2} (Orange line at the bottom)









UKRI-MPW0
To MPW1

To Keep

High Substrate resistivity
Backside Biasing

✔ Breakdown Voltage ~ 600 V
Highest in field but can be increased

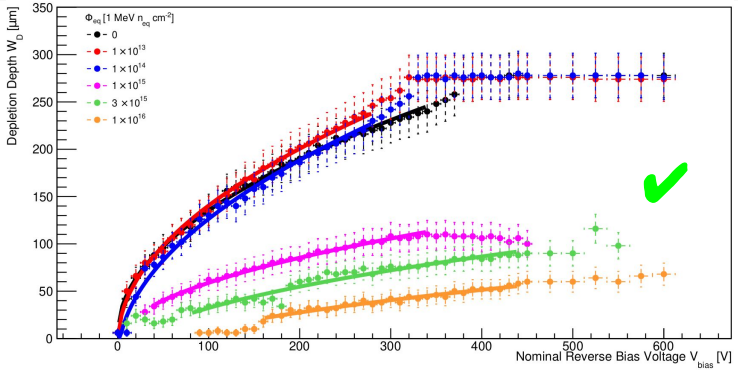
✔ 50 µm depletion depth at 1 x10^{16} 1 MeV n_{eq} cm^{-2}
Down from 280 µm unirradiated… Excellent

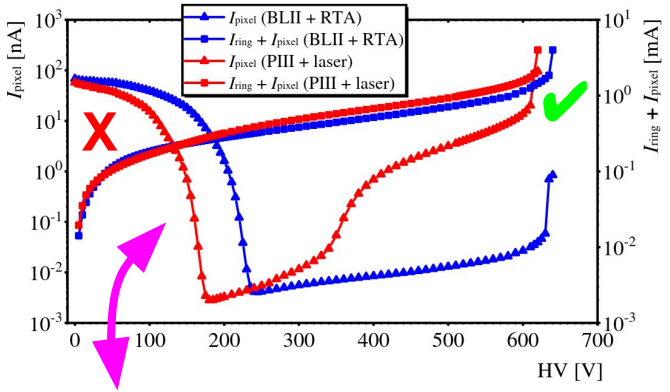
To Improve

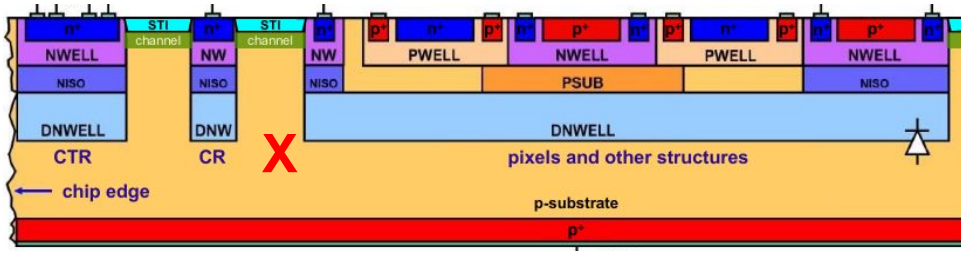
Guard Ring Structure
STI/Si Interface

X High leakage current 4 mA
Bad, needs reducing

X Current between pixels at low biases
Caused by intrinsic charge on oxide insulation

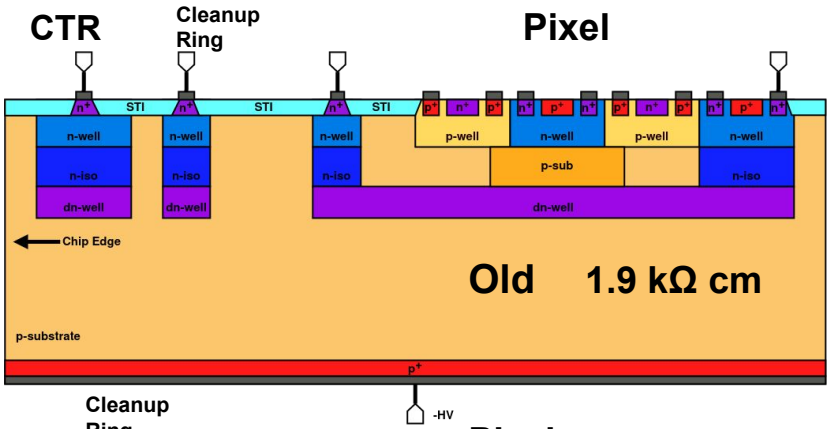


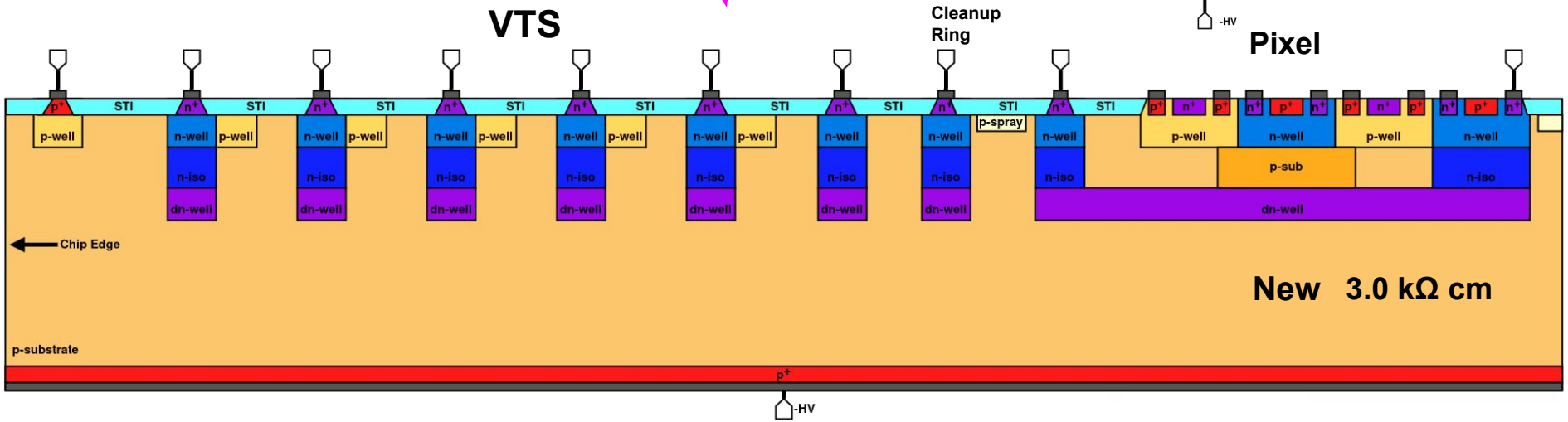




UKRI-MPW1
Design

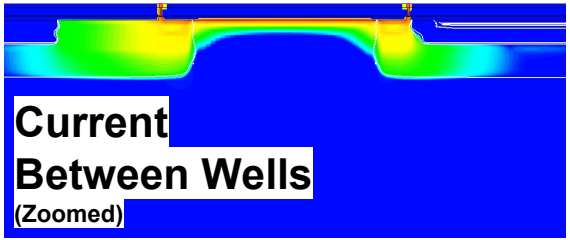
- Changed the cross section
- Change ring structure Current Terminating Ring (CTR) to Voltage Terminating Scheme (VTS)
- Implement a doping profile to stop leakage channel (p-spray)
- Increase substrate resistivity
- Keep backside biasing

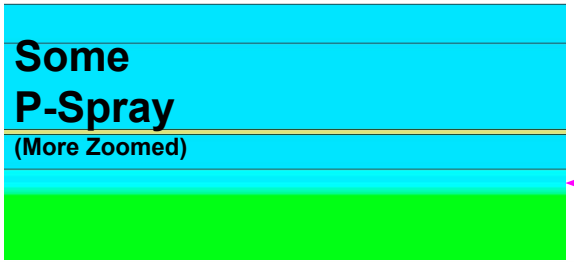




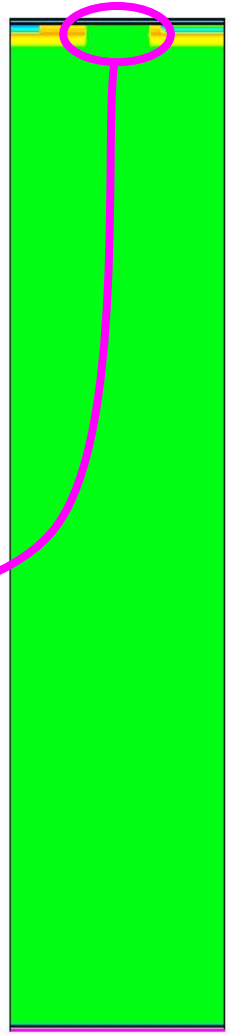
UKRI-MPW1
TCAD

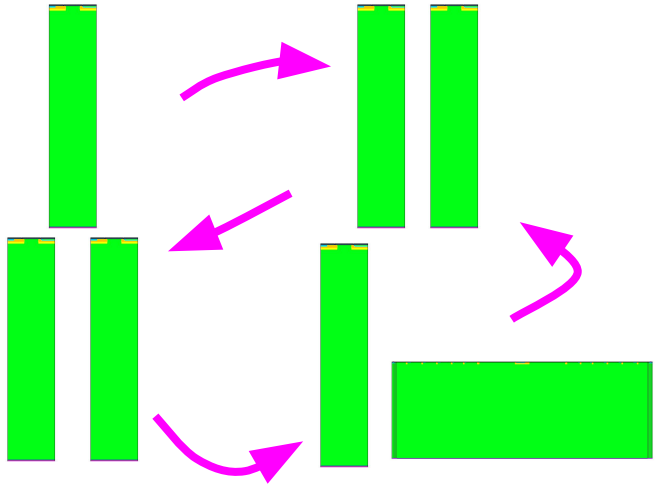
- Create and evaluate simulations for efficacy
- Done with Sentaurus Workbench, Synopsys (Using 3 to 4 different programming languages)
- Simulate current between pixels
- Apply several p-spray profiles
- Apply to a wider chip for effects on breakdown
- Iterate for desired current reduction and breakdown

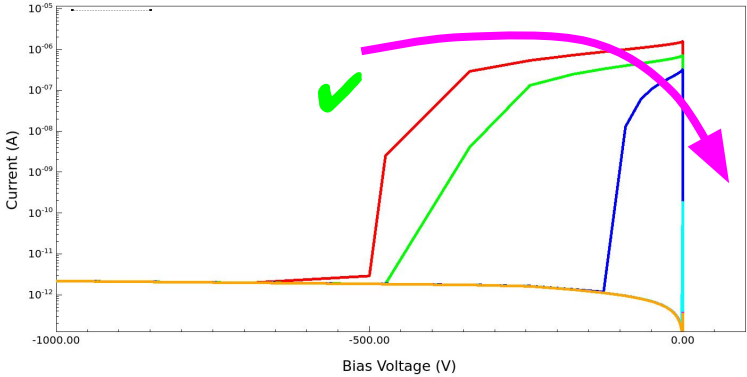




P-Spray

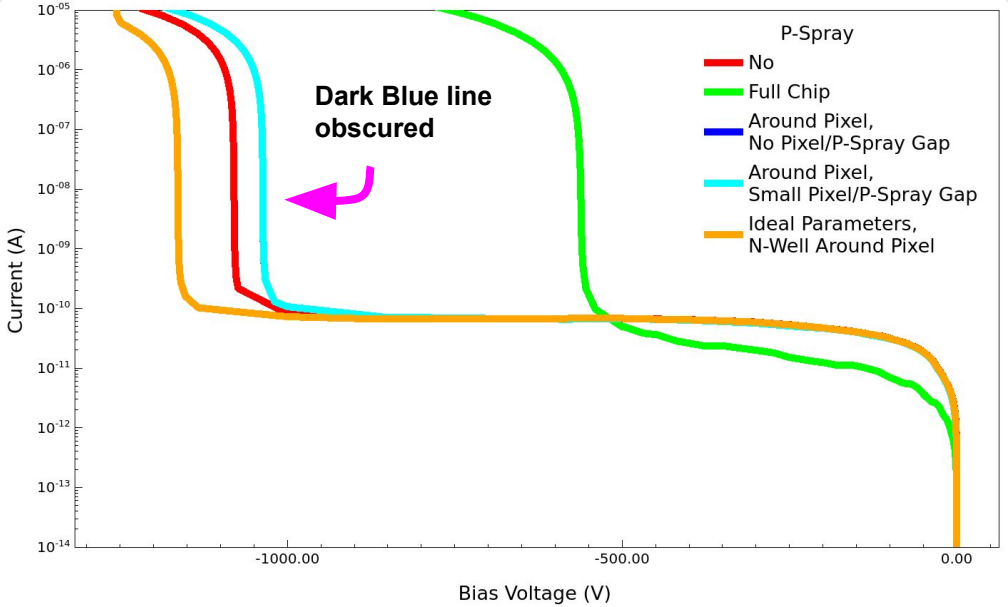






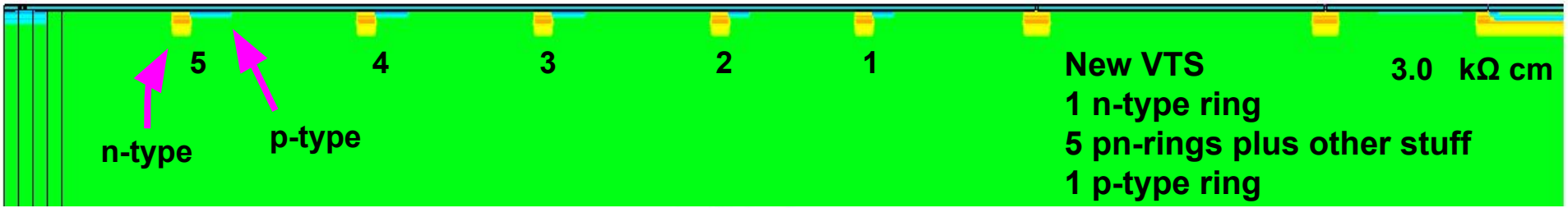
UKRI-MPW1
TCAD Continued

- Setup new chip
- Simulate 1 pixel and ring structure both sides
- Carefully position p-spray
- Give LFoundry p-spray parameters
- Simulations not perfect
- Final chip design breaks ~ 1000 V (orange line)



Other half this way

P-type seal ring



Outlook

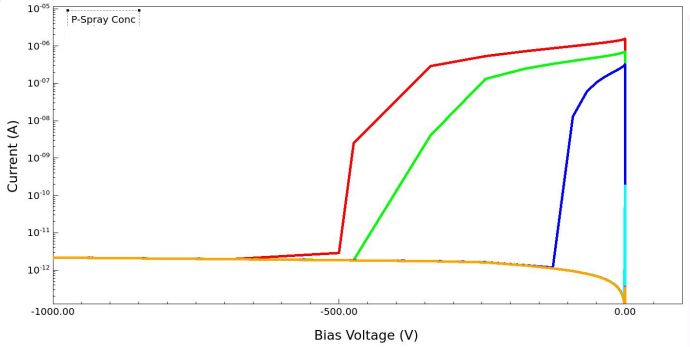
Done

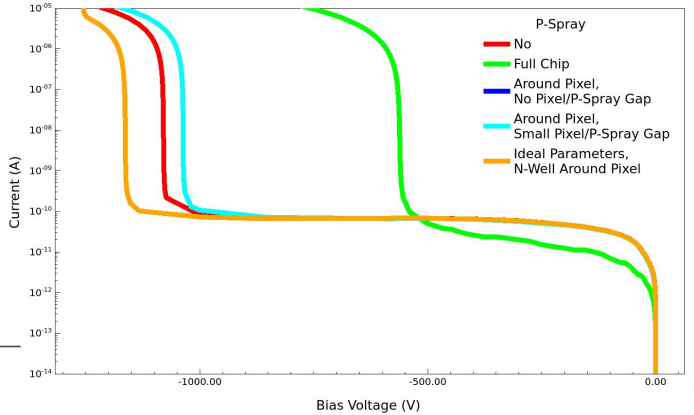
- Some measurements
- Published conference proceedings
- Some TCAD
- Gave LFoundry a new doping profile

To Do

- Finish characterising old chip
- Write paper on UKRI-MPW1 TCAD
- Start characterising new chip
- See how accurate simulations are
- Starts TCADing next iterations and ideas (MPW2)

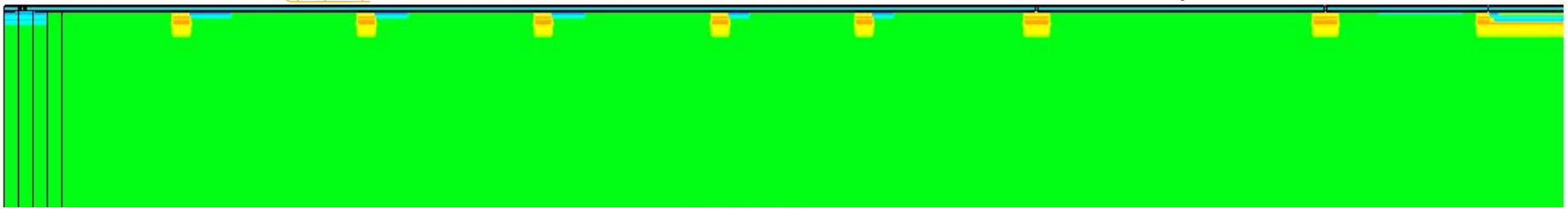
Merry Christmas!





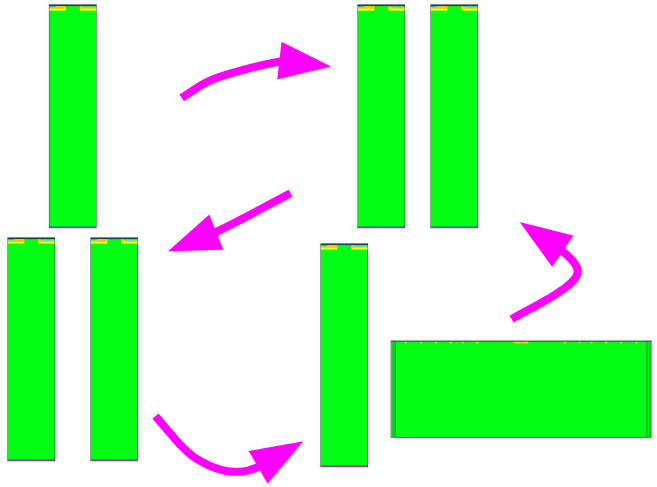
Edge-TCT evaluation of high voltage-CMOS test structures with unprecedented breakdown voltage for high radiation tolerance

B. Wade,[a,*] M. Franks,[a,b,1] J. Hammerich,[a] N. Karim,[a,2] S. Powell,[a] E. Vilella[a] and C. Zhang[a]



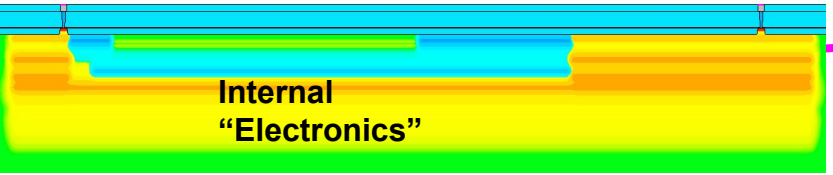
UKRI-MPW1 TCAD

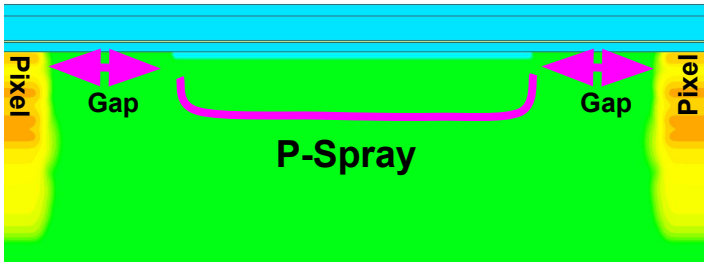
BACKUP

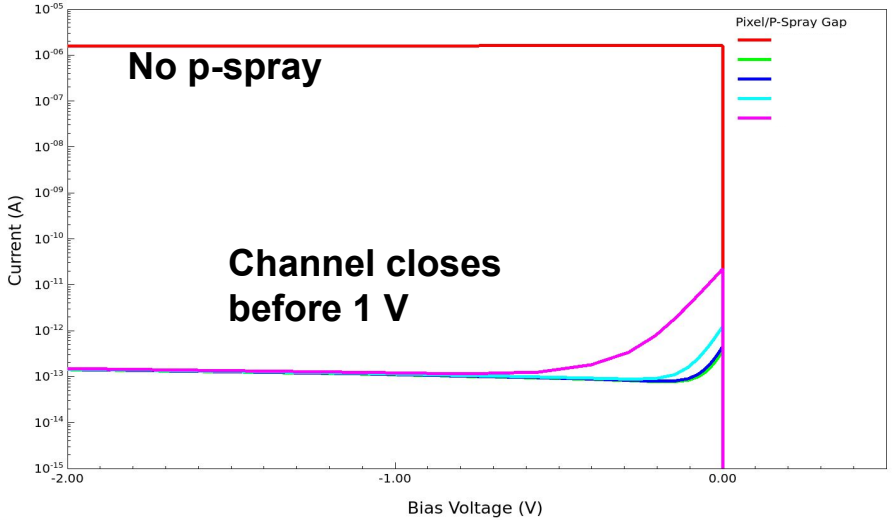


- Need to see how this p-spray affects the wider breakdown of the chip itself
- Make the simulation
- Iterate through some different p-spray doping profiles
- Apply these to a “Full chip” simulation

- Can’t put p-spray inside pixel
- Trial gaps between p-spray and pixel







UKRI-MPW0/MPW1
All Changes compared

BACKUP

- Change from Current Terminating Scheme (CTS) to Voltage Terminating Scheme (VTS)
- Old substrate resistivity 1.19 kΩ cm measured (1.9 kΩ cm nominal)
- New substrate resistivity 3.0 kΩ cm