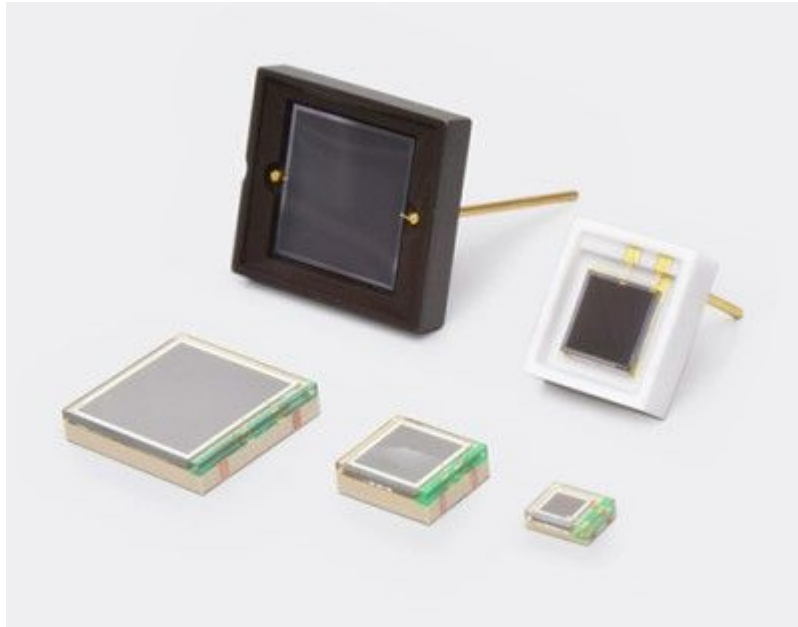
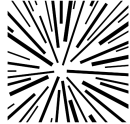


Automated SiPM Surface Imperfection Analysis

Jesse Lior - Summer High School Intern at Wright Lab, RHIG Yale

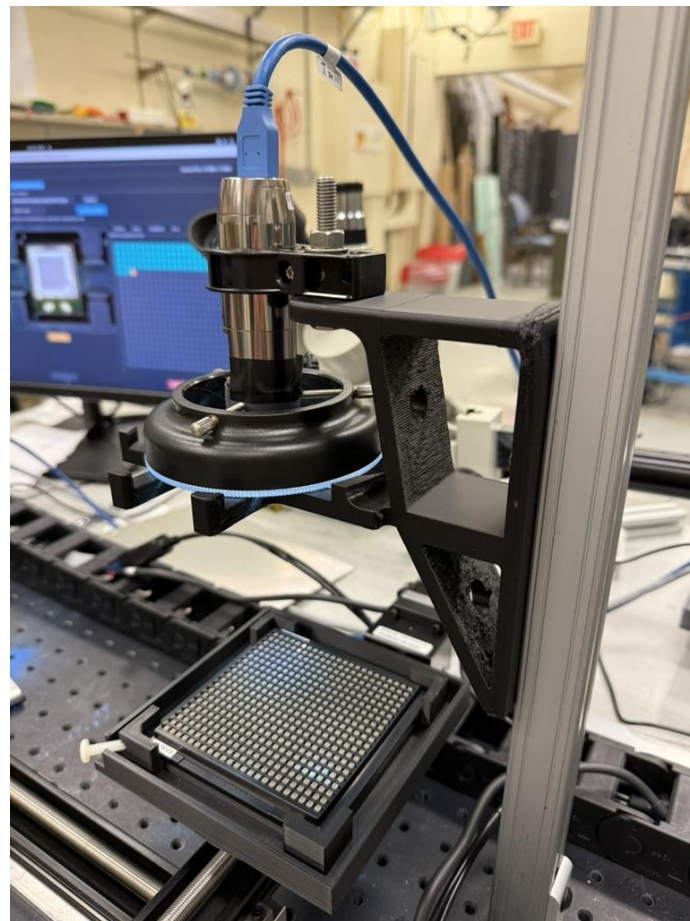


Yale

 Wright
Laboratory

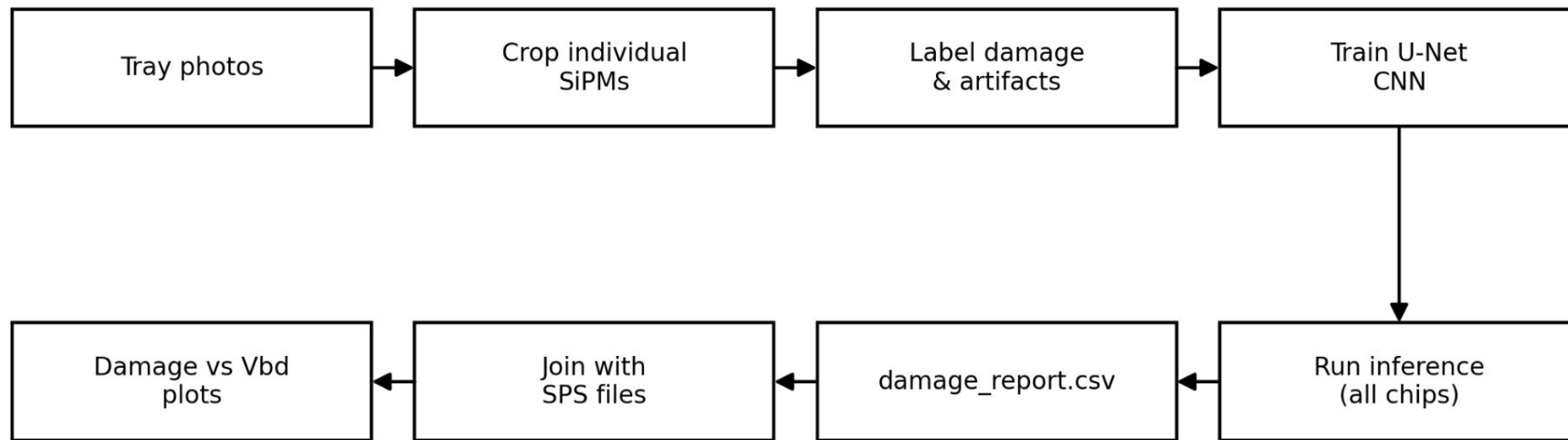
Questions Addressed in This Study

- Do surface imperfections on SiPMs correlate to trends in SPS breakdown voltage?
- How effective are CNN's(convolutional neural network) to analyze thousands of SiPMs and their damage profile?

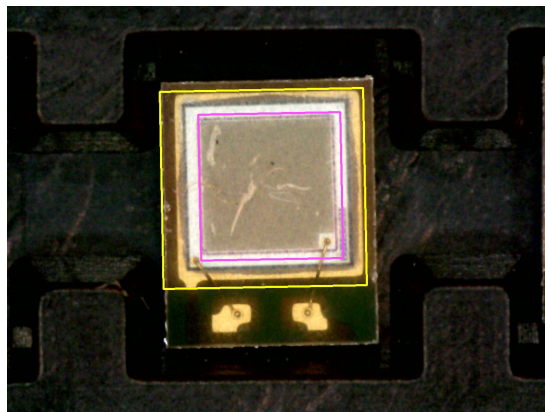


Details of this set-up were presented by Levante: [Presentation](#)

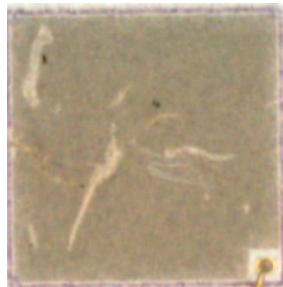
Complete CNN Workflow



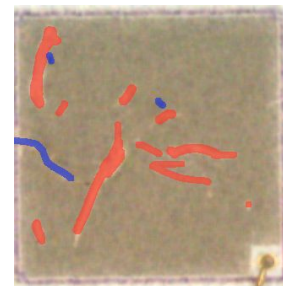
Training Dataset Preparation



Cropping algorithm overlay



Cropped Image



Painted and labeled image

Colored “paint” masks teach the model to differentiate between damage and debris - 3 classes important for the model not to default

SiPM photo setup takes ~40 min per tray

Training Setup

3 trays painted → 1380 SiPMs, 998 pristine and 332 with surface imperfections with a max of 22.3% damage on an individual chip

Model: U-net + ResNet-34

Encoder: initialized with ImageNet weights

Loss: Dice + Focal

Optimizer: Adam

Learning rate: $1e-4$

Batch size: 8

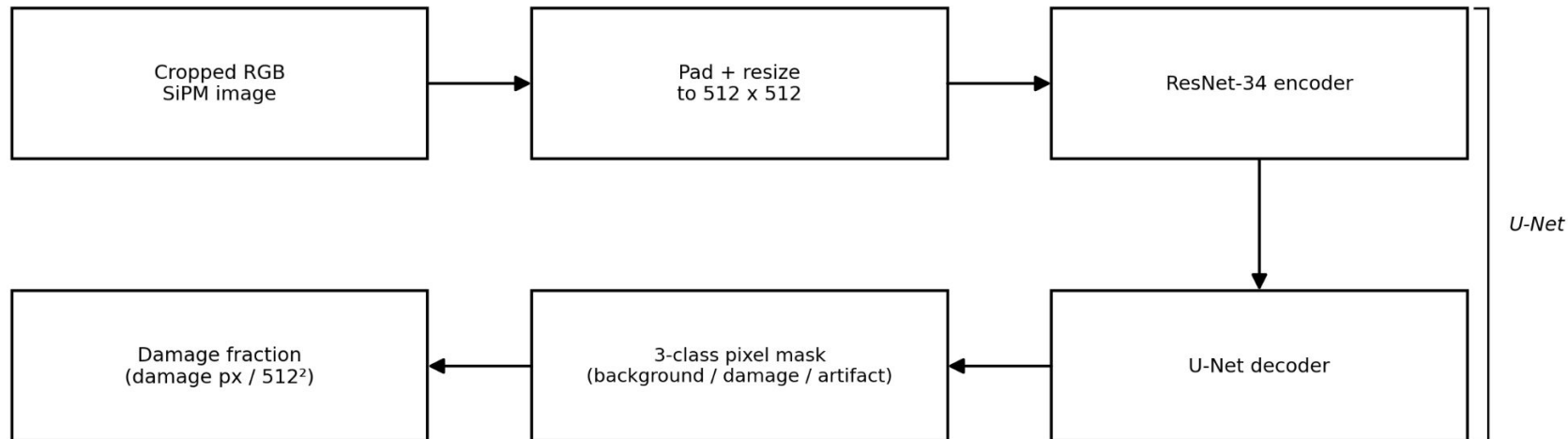
Epochs: 15

Augmentation: flips, small rotations, shifts, scaling

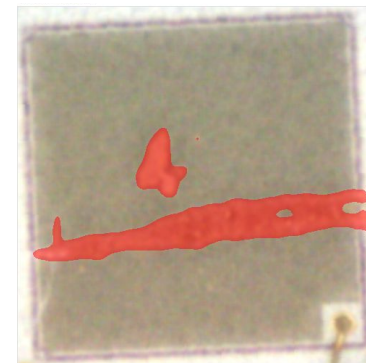
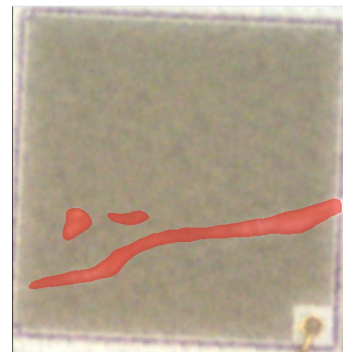
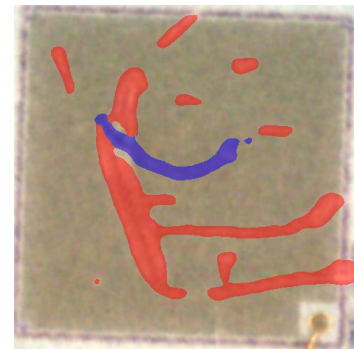
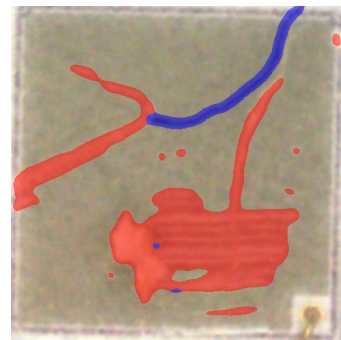


Pristine SiPM

CNN Architecture



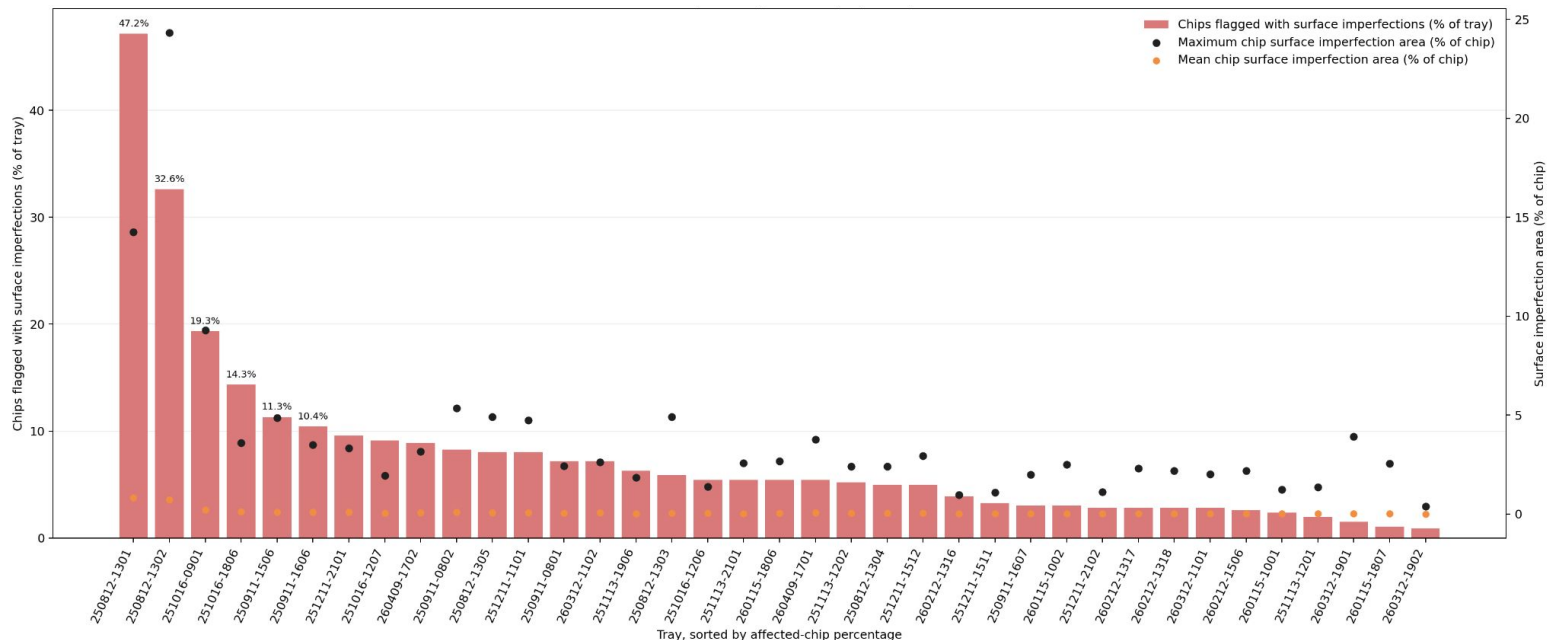
CNN Outputs For 4 Different SiPMs



Extremely accurate analysis from CNN overall - the model correctly classified 95% of the 43 damaged SiPMs on the held out tray 260409-1702

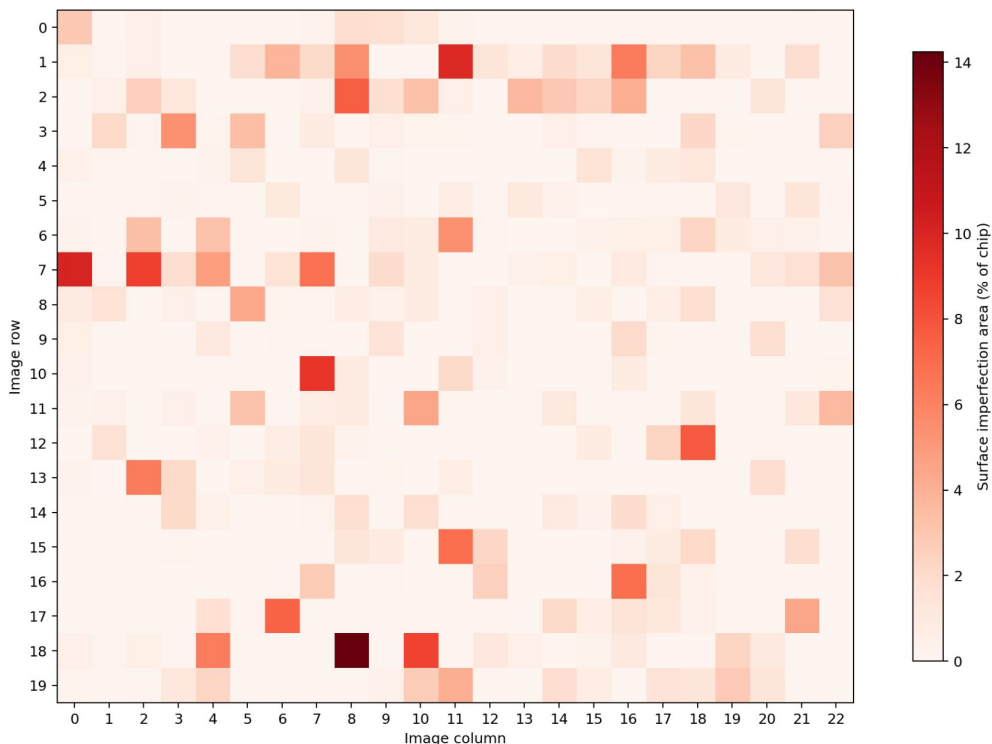
Imperfection Distribution by Tray

A few standout trays but for the most part trays have minimal imperfections



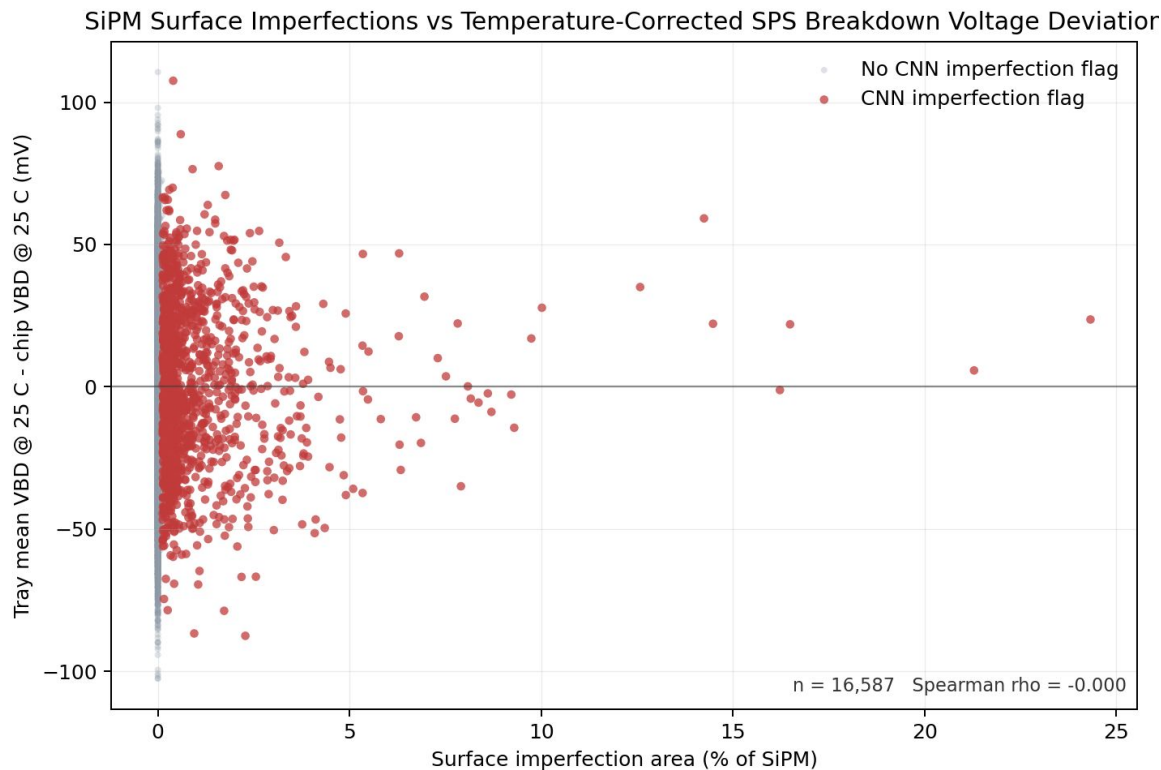
Tray 250812-1301 Imperfection Distribution

217 out of 460 chips have imperfections, with a maximum area of imperfections as 14.25%



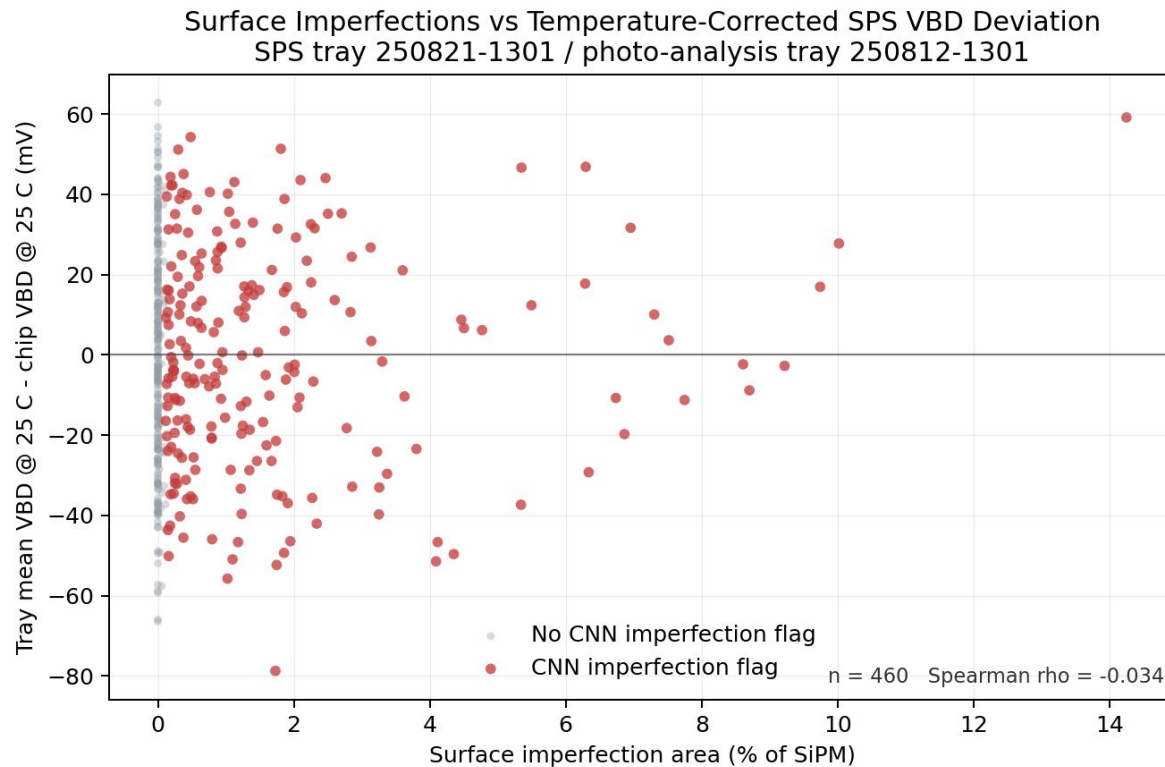
Imperfections vs SPS Breakdown Voltage For All Trays

For all trays, the mean temperature controlled Vbd minus SiPM temperature controlled Vbd does not deviate from 0 as damage increases, showing no trend



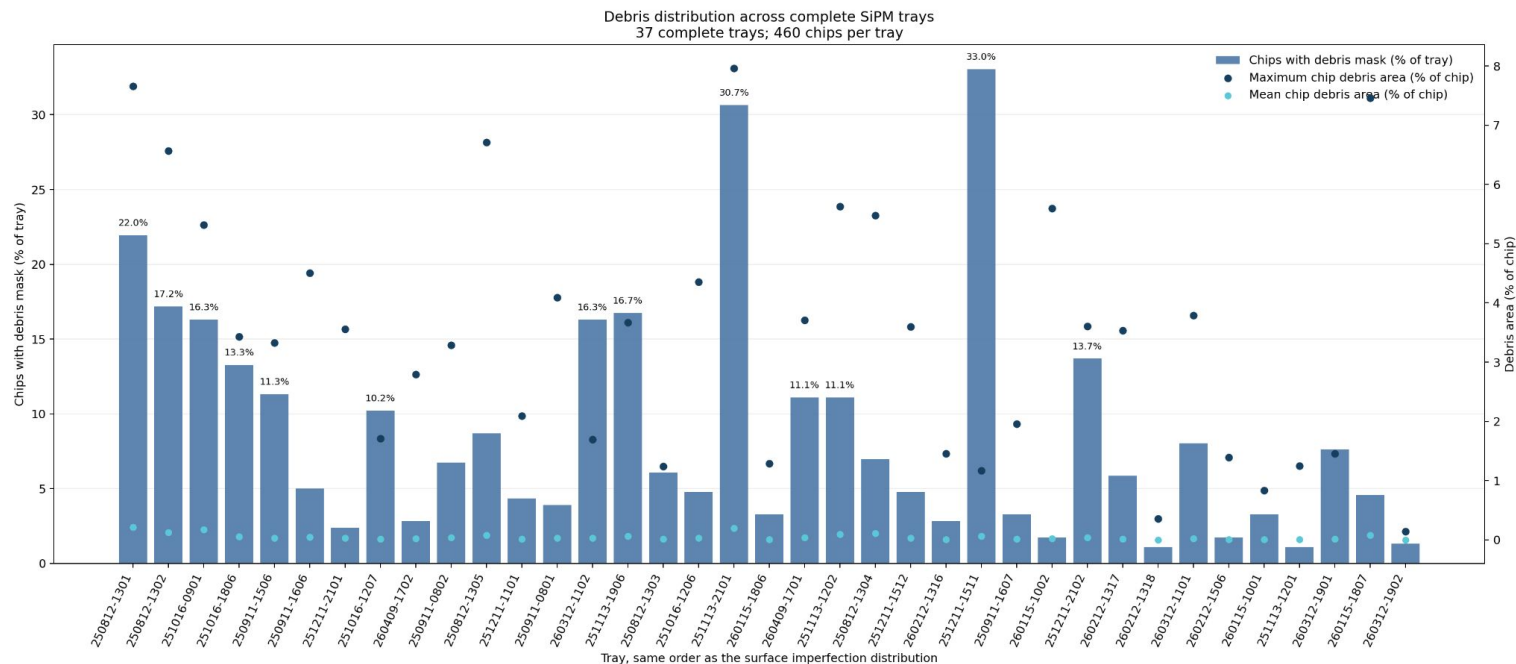
Imperfections vs Breakdown Voltage for Tray 250812-1301

Still no significant
trend found despite
this tray having
many imperfections



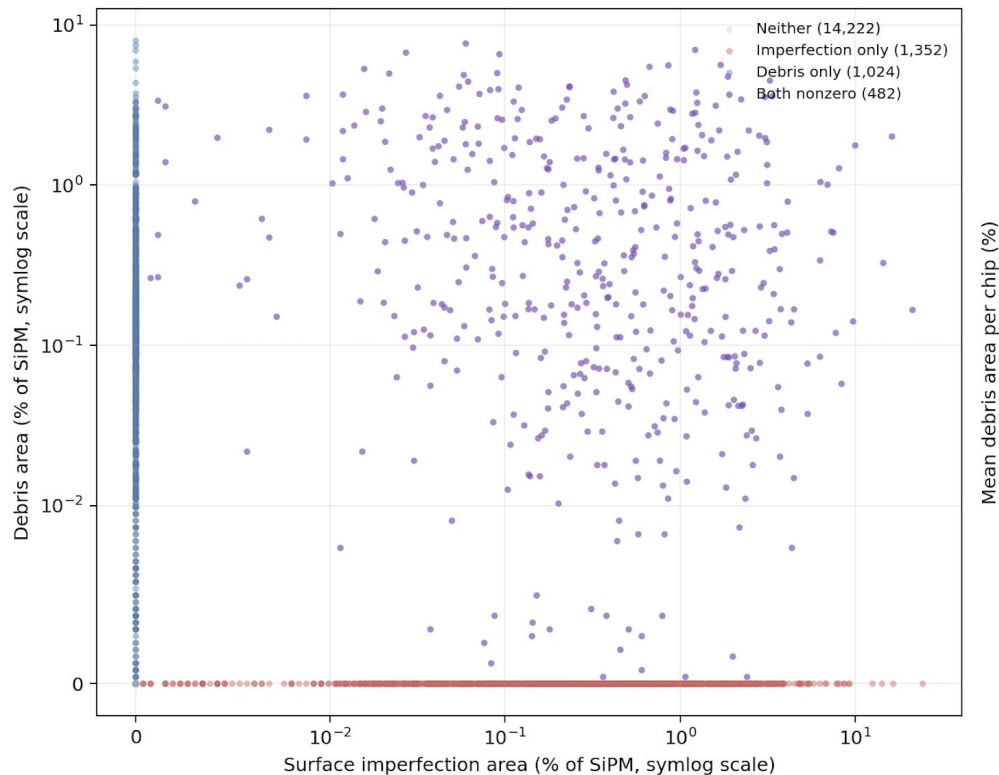
Debris Distribution For All Trays

8.8% of chips had at least one recognizable pixel of debris.



Verifying Lack of Correlation Between Debris and SiPMs with Imperfections

No clear correlation is shown when plotting SiPMs with imperfections vs debris



Conclusions

Using a U-Net with a ResNet-34 Encoder to automatically analyze SiPMs for surface imperfections is significantly effective- **95%** validation accuracy on the training dataset

- **17,080** chips analyzed by the CNN
- Few standout trays while most trays contain minor scratches
 - **7.7%** of all chips were flagged with damage
 - Tray number **250812-1301** had **47%** flagged chips, while **250812-1302** had **33%** flagged chips
- No clear trend between the amount of SiPM imperfections and SPS breakdown voltage data
- CNN training on three trays took **12 minutes** on Google Colab T4 GPU
- CNN analysis takes **3 minutes** per tray on my Macbook M1 Pro CPU