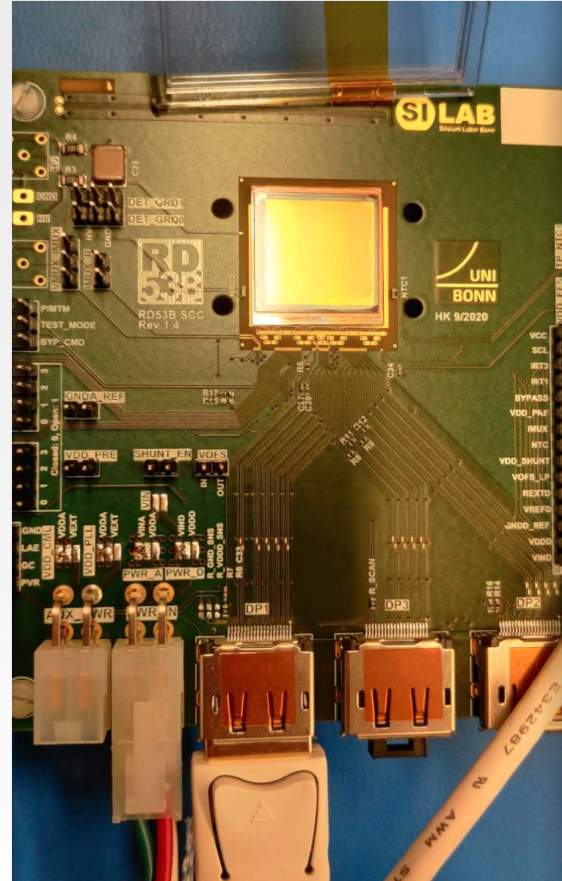


Selenium coated ITkPixV1 chip

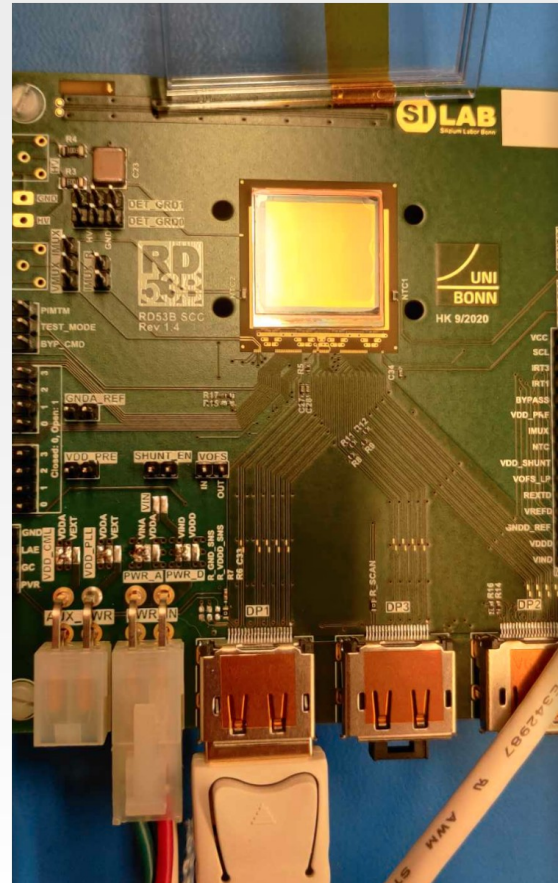
Presenter Simon Huiberts

**Thanks to Maurice, Timon, Maria and Luc
& rest of LBNL ATLAS group**

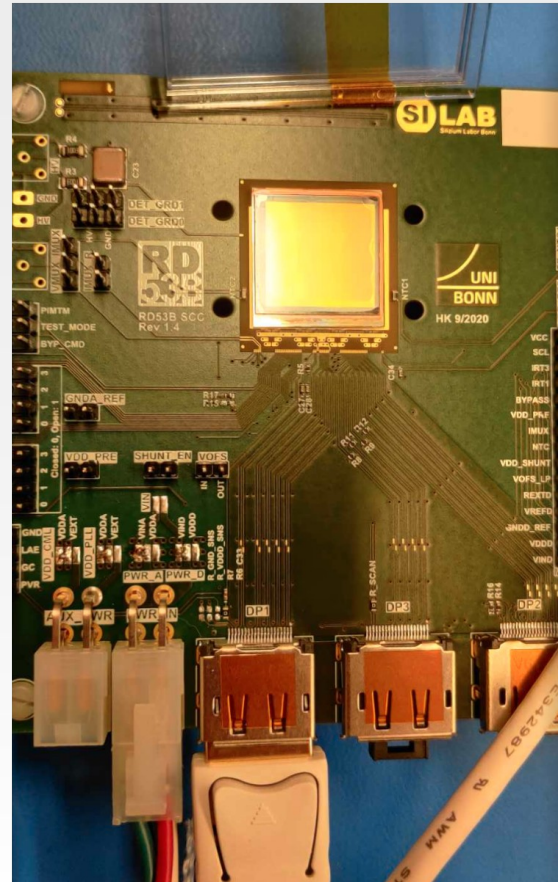
- **Part I – Selenium sensor**
 - What is selenium?
 - How is it deposited?
 - How does it work?
 - What's the advantages?



- **Part I – Selenium sensor**
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- **Part II – Selenium chip at LBL**
 - ITkPixV1.0 w/Se film
 - ~~ITkPixV2 w/Se film~~ -most likely dead :(



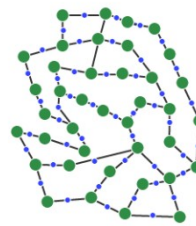
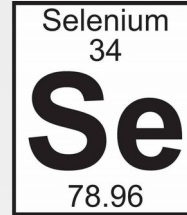
- **Part I – Selenium sensor**
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- **Part III – Results**
 - Pixel hitmaps
 - Hitrate vs. bias
 - Precision Time over Threshold (PToT)



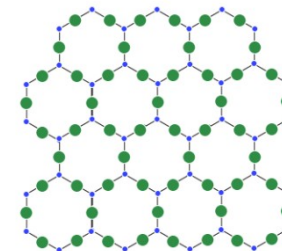
Part I

Basics – Selenium film on chip

- **Selenium** ($_{34}\text{Se}$) – non-metallic element
- Exists in two solid structures – Amorphous or crystal structure
- **Amorphous selenium (a-Se)**

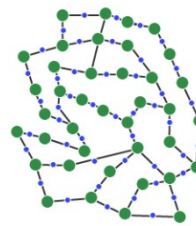
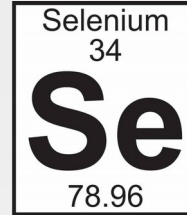


Amorphous Solids

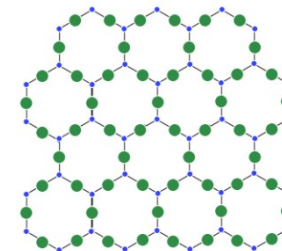


Crystalline Solids

- **Selenium** ($_{34}\text{Se}$) – non-metallic element
- Exists in two solid structures – Amorphous or crystal structure
- **Amorphous selenium (a-Se)**
- High Z-material
- High resistivity
- Slow carrier transport

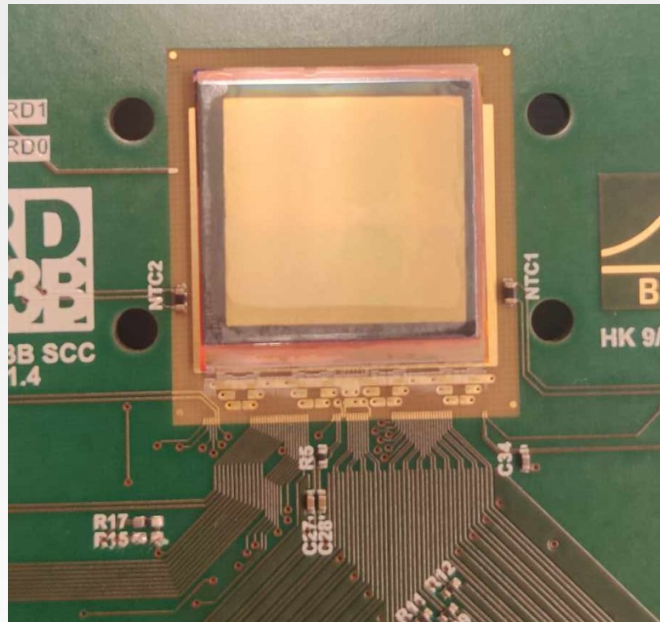


Amorphous Solids



Crystalline Solids

How is it deposited?

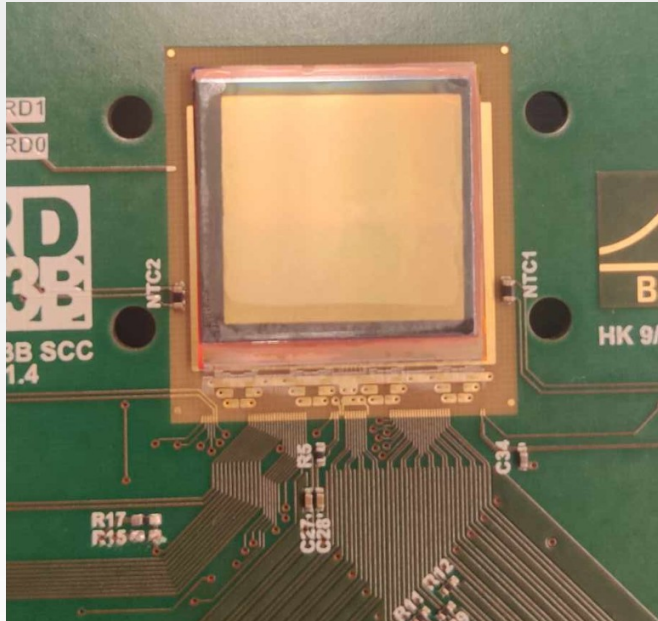


Selenium-coated ITkPixV1



Gold-coated ant

Physical vapour deposition (PVD)



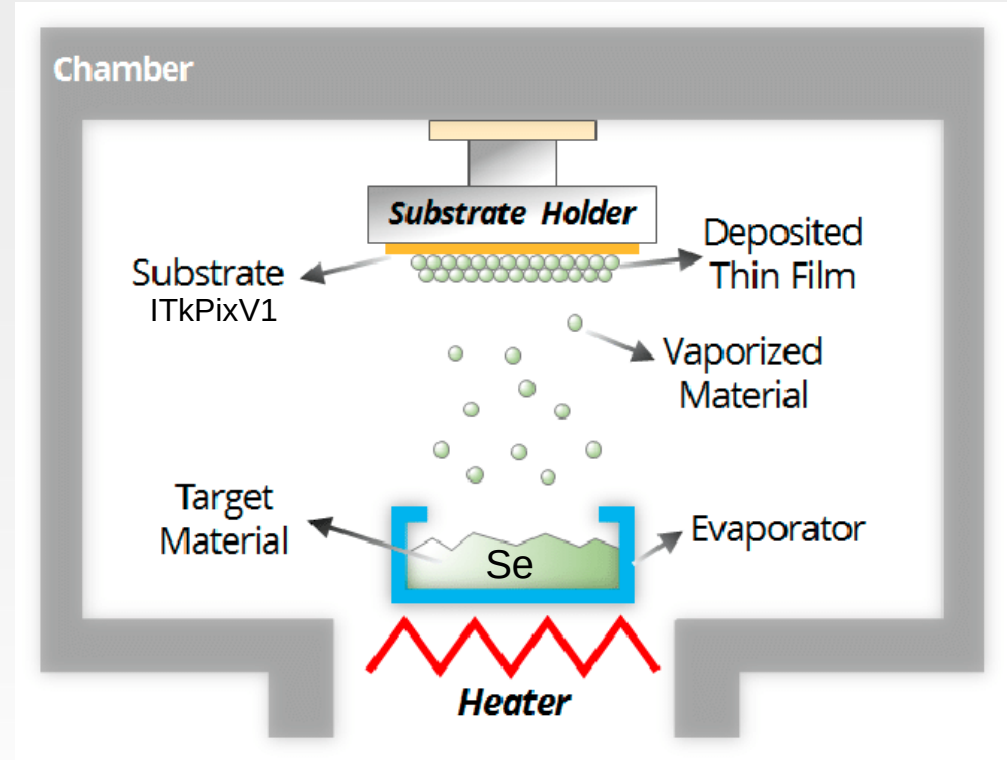
Selenium-coated ITkPixV1



Gold-coated ant

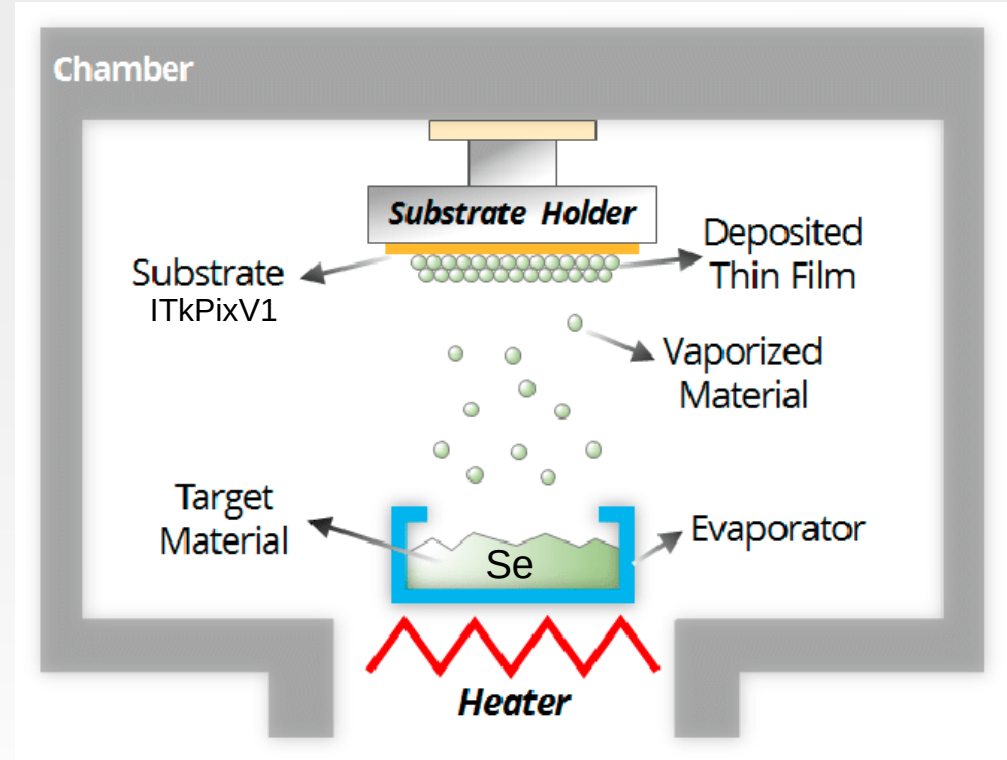
Physical vapor deposition (PVD)

- The Se is heated and vaporized in vacuum



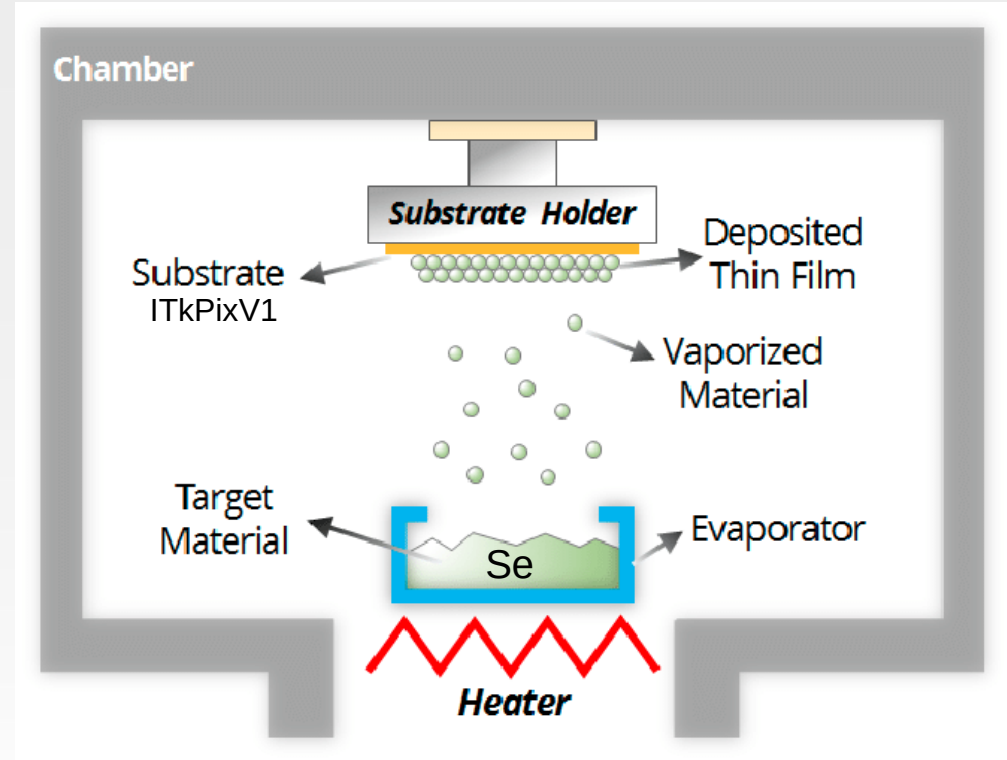
Physical vapor deposition (PVD)

- The Se is heated and vaporized in vacuum
- Condenses onto the cooler substrate surface
 - Substrate – ITkPix chip
- Forms a uniform thin film on substrate

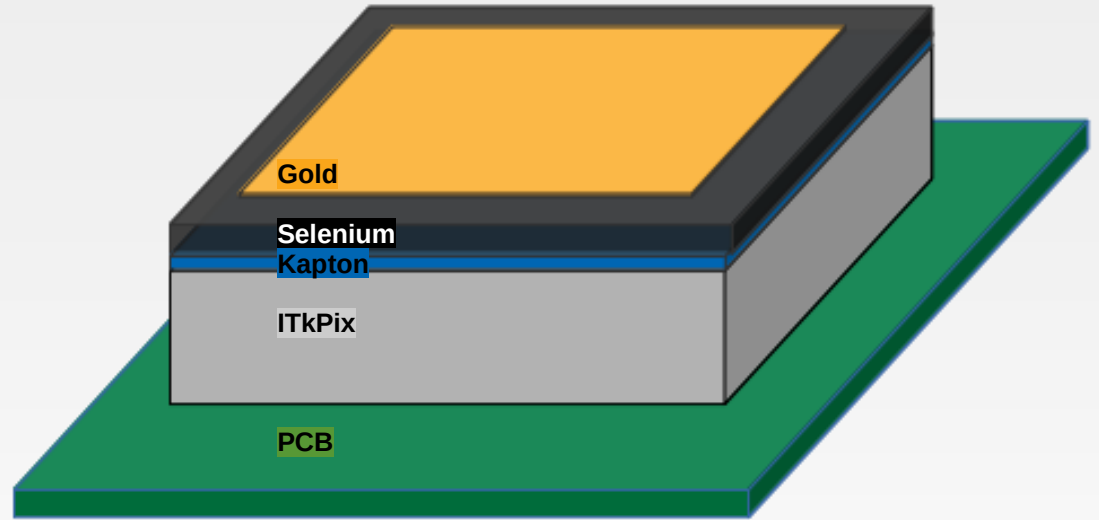
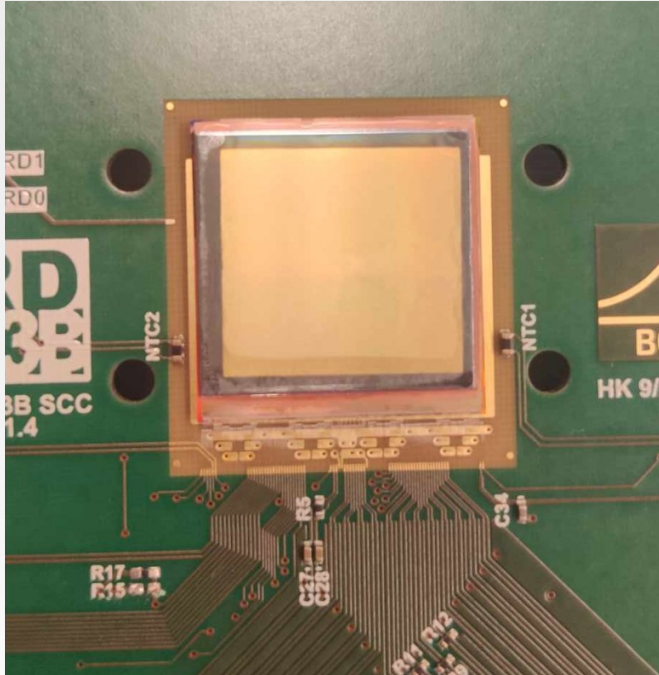


Physical vapor deposition (PVD)

- The Se is heated and vaporized in vacuum
- Condenses onto the cooler substrate surface
 - Substrate – ITkPix chip
- Forms a uniform thin film on substrate
- **Advantages**
 - High purity
 - Easily control the thickness
 - Duration and evaporation rate
 - Low temperature – keep chip alive

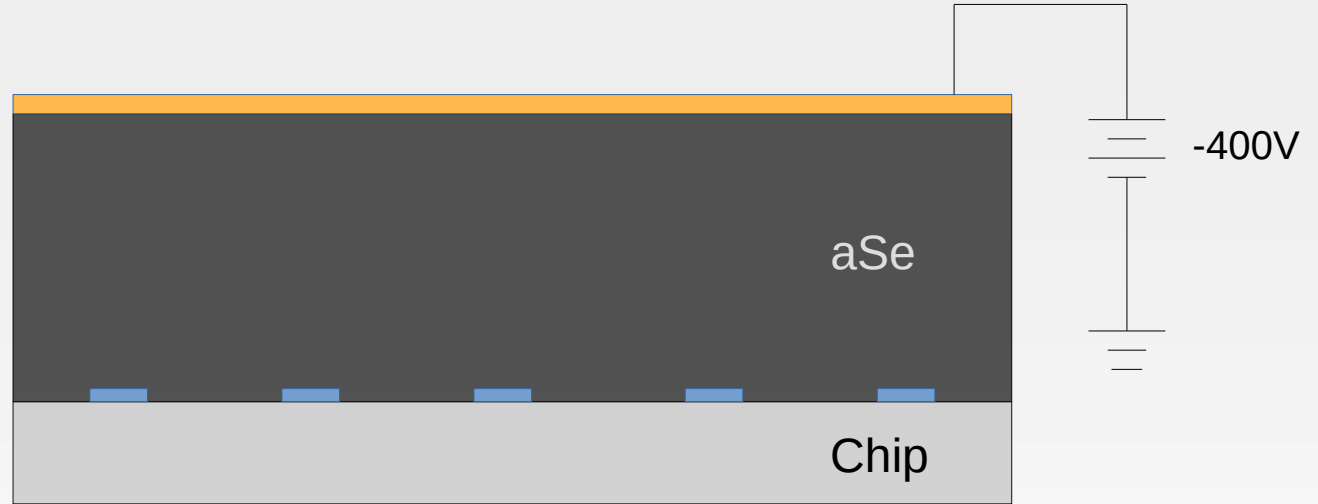


Selenium chip stack

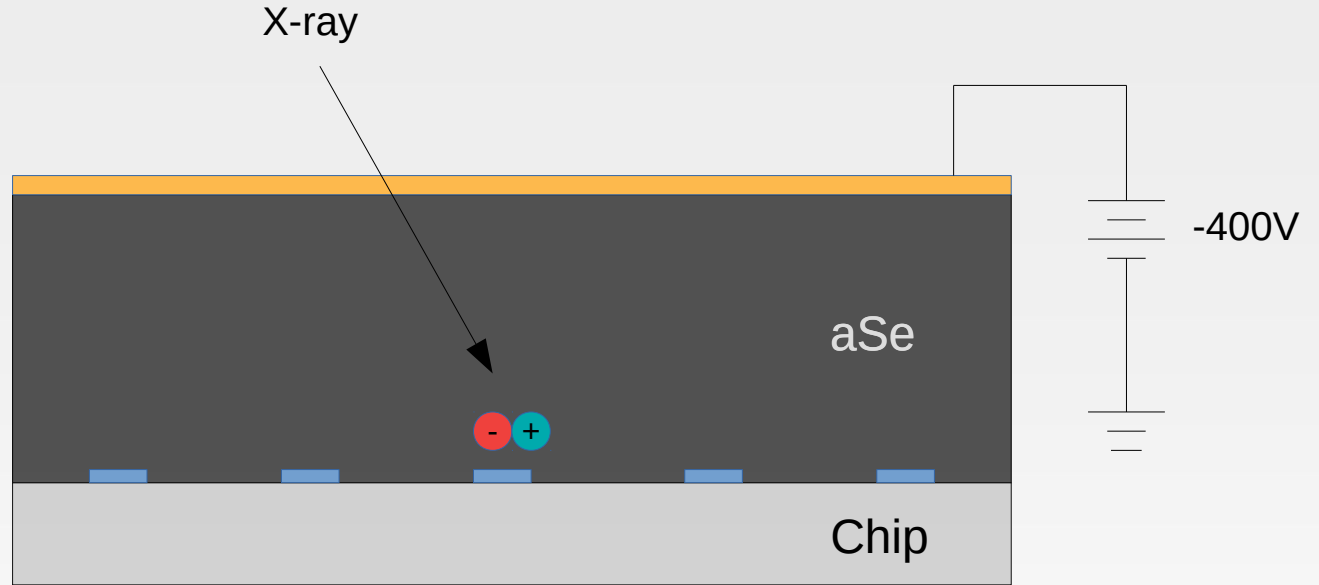


Selenium chip as detector

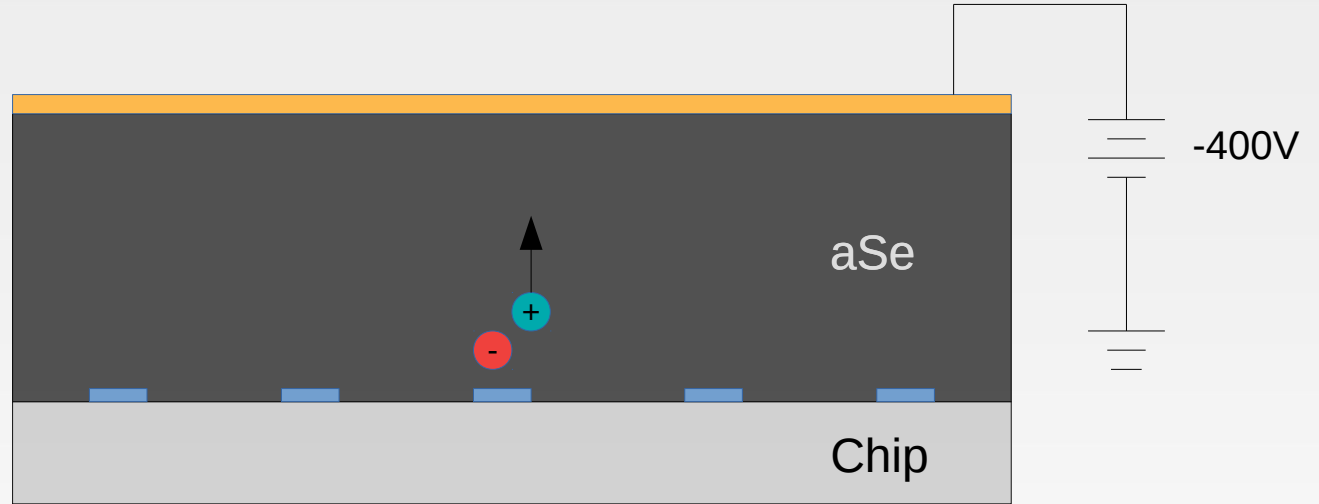
- Operation
- High negative voltage



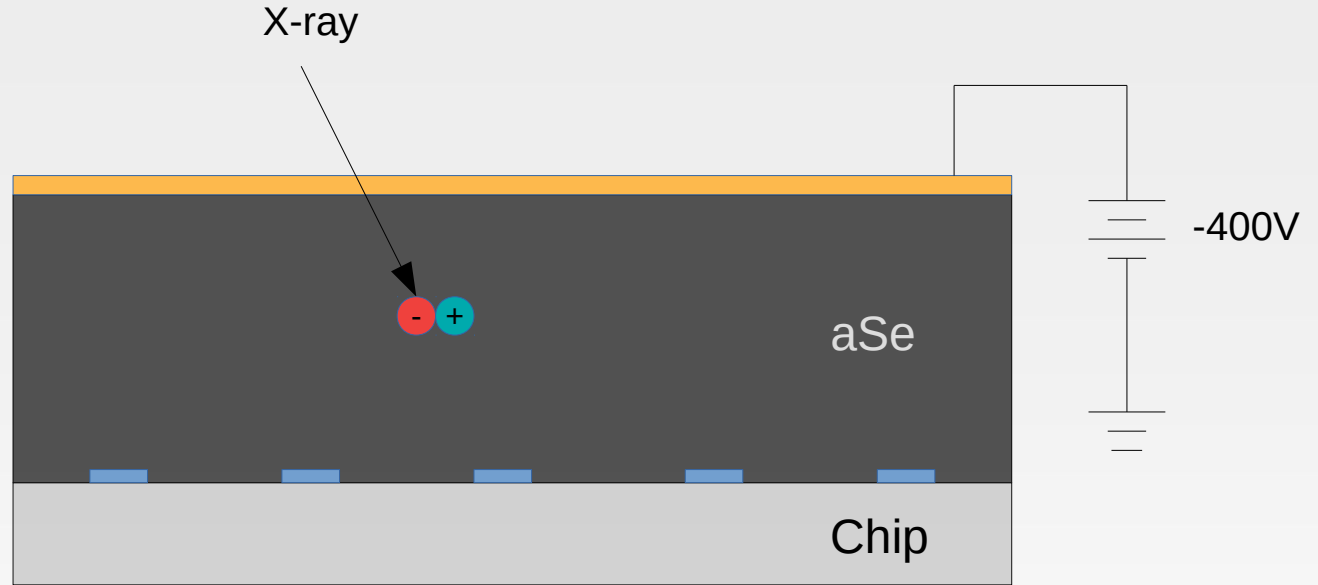
- **Operation**
- High negative voltage
- **Case 1**
- X-ray absorbed
- Create e-h pair



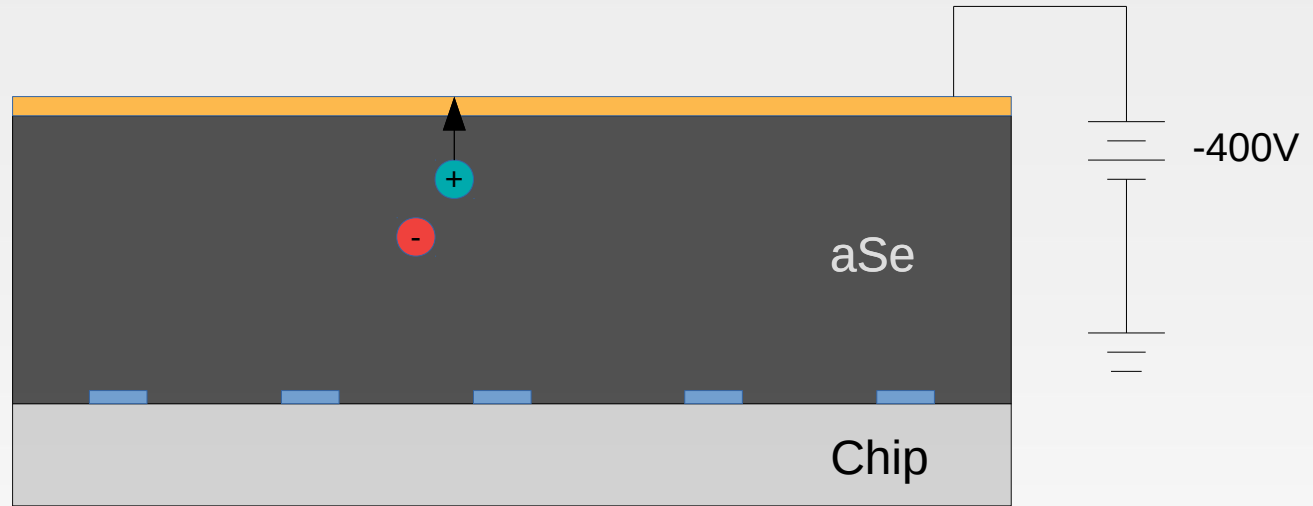
- **Operation**
- High negative voltage
- **Case 1**
- X-ray absorbed
- Create e-h pair
- Electrons drift very slowly
- Holes induce negative charge



- **Operation**
- High negative voltage
- **Case 2**
- e-h pair created further from the pixels

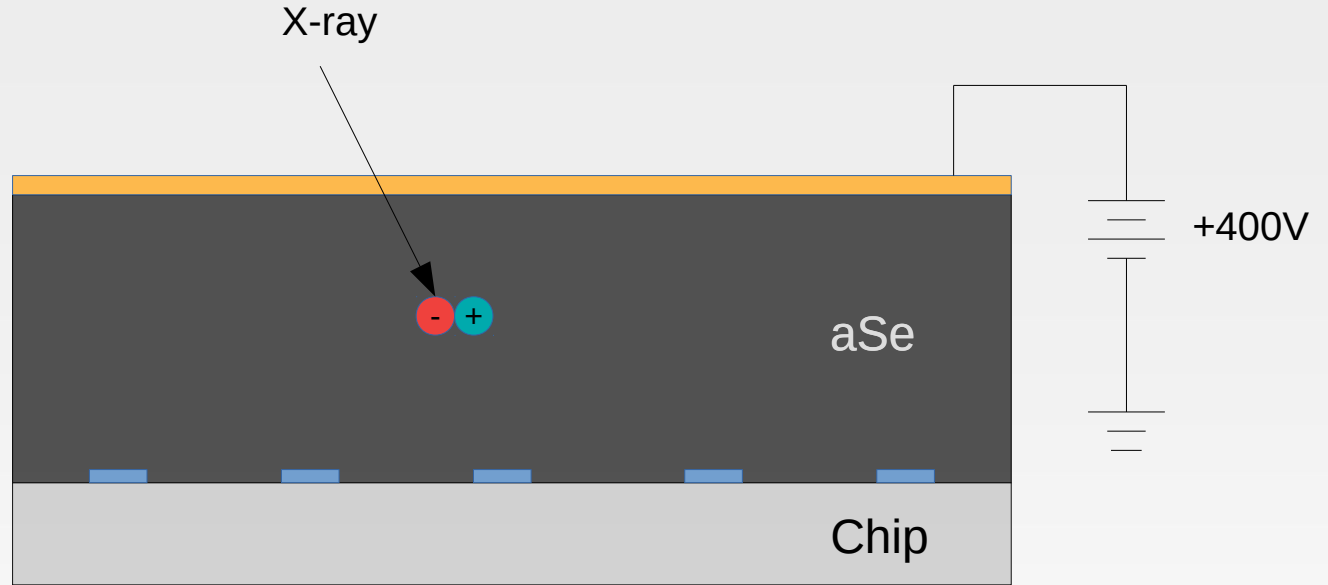


- **Operation**
- High negative voltage
- **Case 2**
- e-h pair created further from the pixels
- Holes too far to induce any current
- Won't see any hits

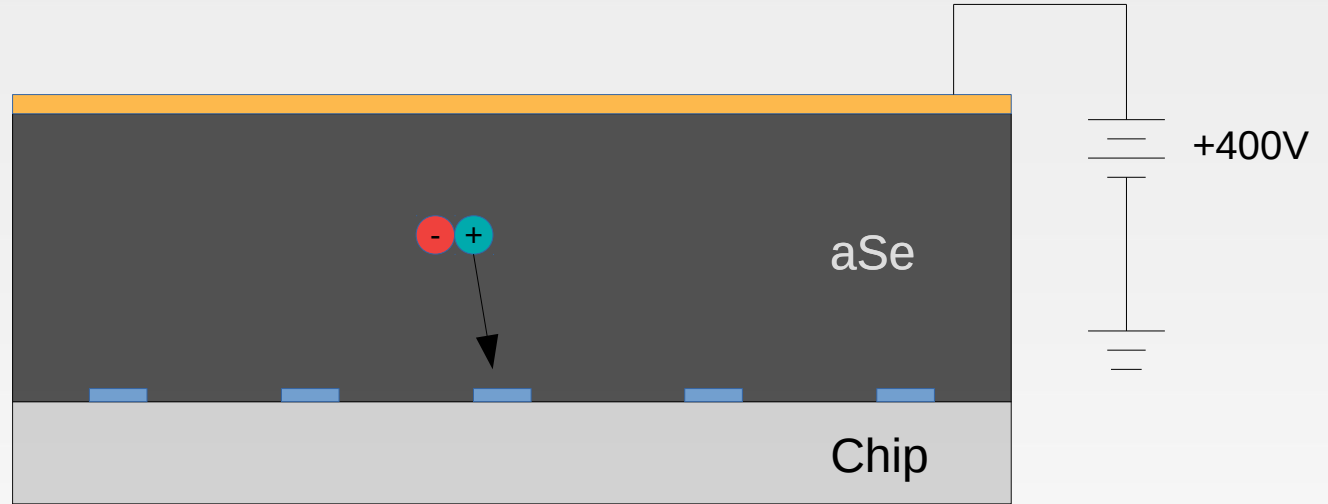


Selenium chip as detector

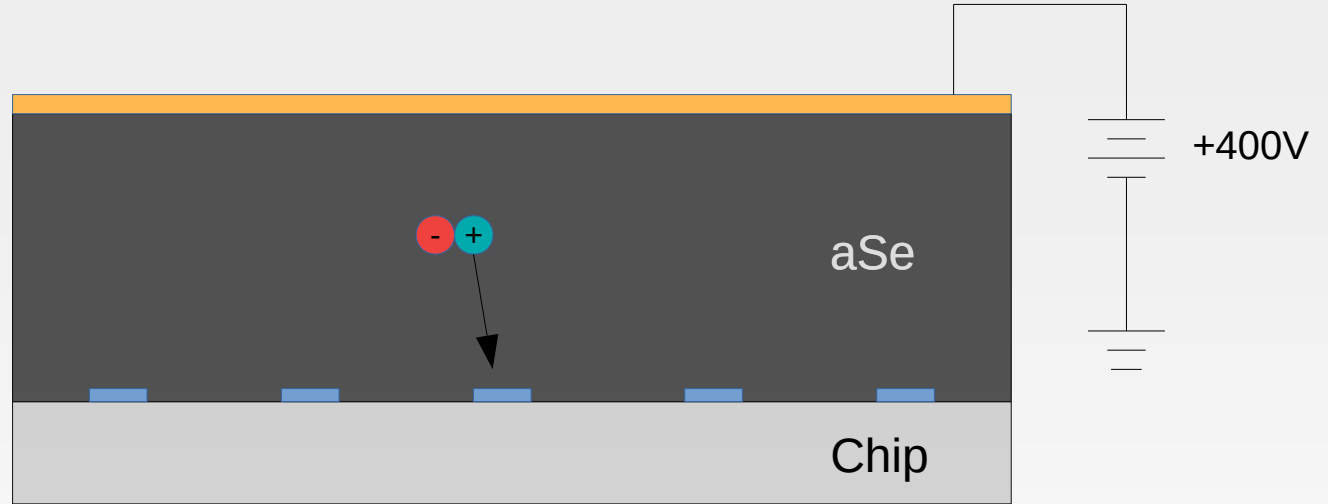
- Operation method 2
- High positive voltage



- Operation method 2
- High positive voltage
- Case 1 & Case 2
- X-ray absorbed
- Holes drift towards the pixels and induce a **positive** charge

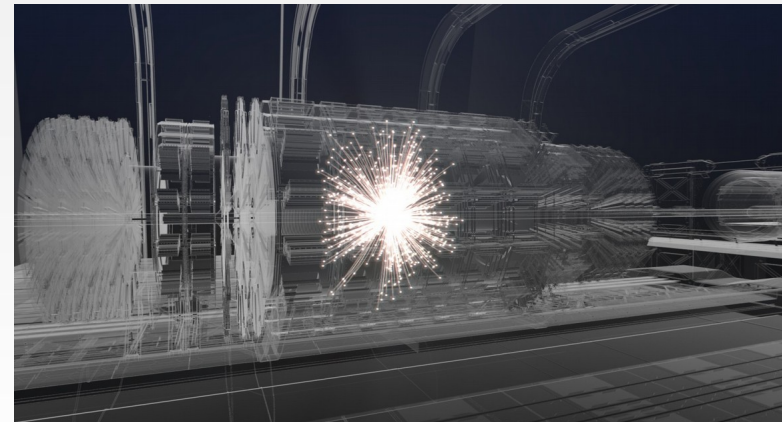
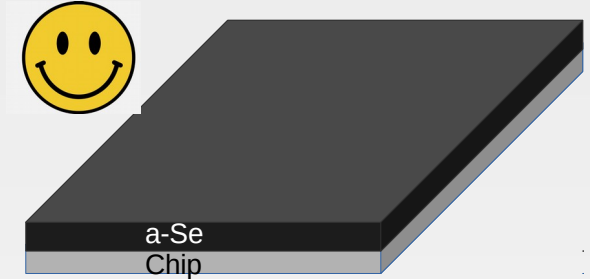
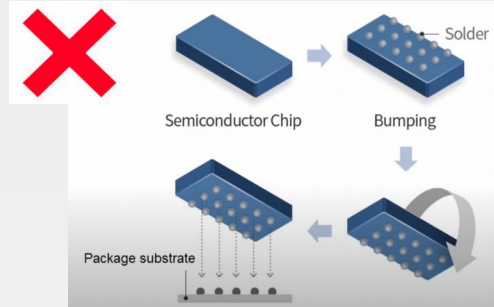


- **Operation method 2**
- High positive voltage
- **Case 1 & Case 2**
- X-ray absorbed
- Holes drift towards the pixels and induce a **positive** charge
- **NB:** Chip designed to only handle negative charge
- **Invert the signal polarity of the chip's FE**



- **Advantages of selenium film detector**

- No bump-bonding required
 - Lower mass (like MAPS)
 - FCC-ee
 - Lower cos
- Keep the 65 nm CMOS functionality
- Sensitive to X-rays - >
 - Application in medical imaging



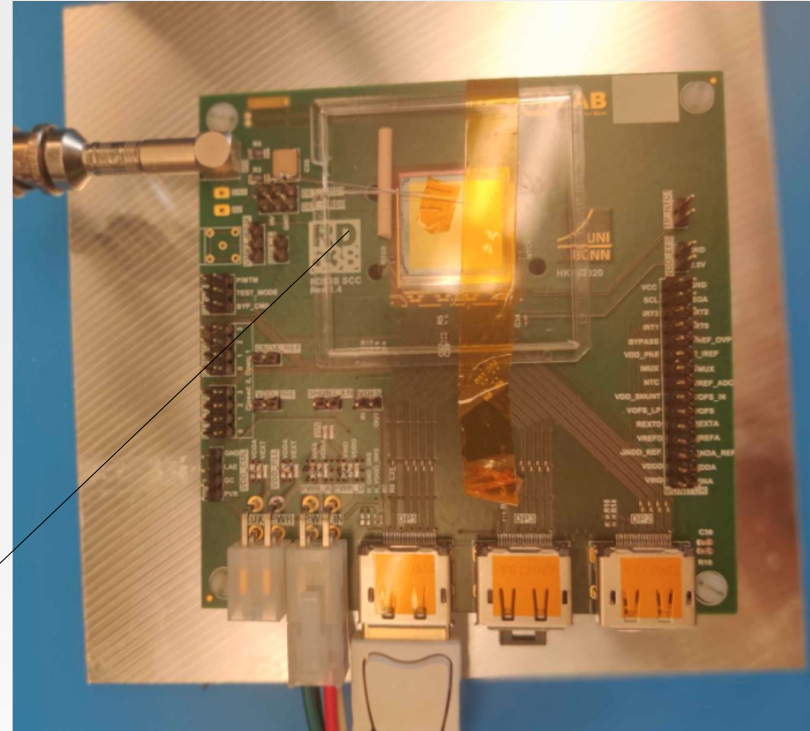
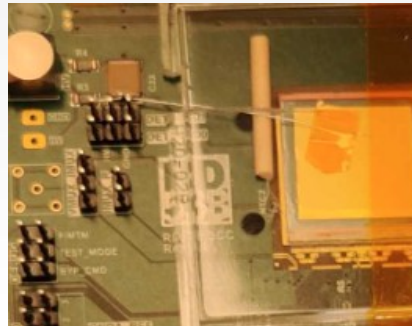
FCC: 100km circular electron-positron collider to probe new physics reaching 100 TeV in second stage

Part II

Selenium detector at LBL

Selenium-coated ITkPixV1.0

- 60 μm thick selenium film
- Soldered metal wire touching the sensor
- ITkPixV1.0 – ToT memory bug
 - Reset the ToT before operation
 - Use HitOr/PToT
 - Tune $\sim 700\text{e}$



Lead container

- Selenium chip inside lead container
- Americium-241 source
 - Low energy gamma rays
 - ~ 100 mCi (37 billion Bq)
- Lead container open and close

Power supply

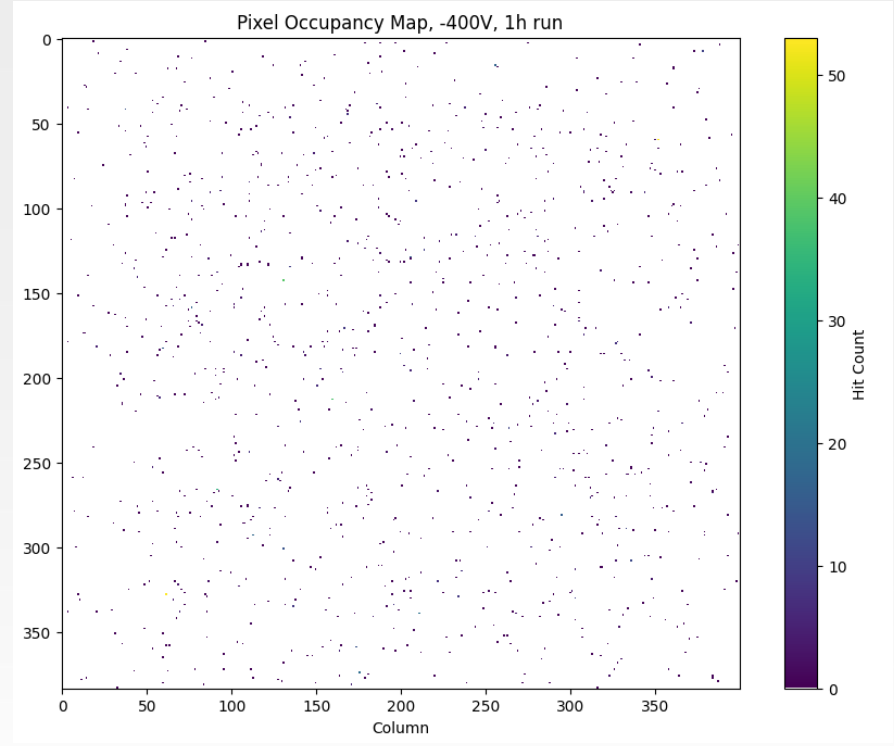
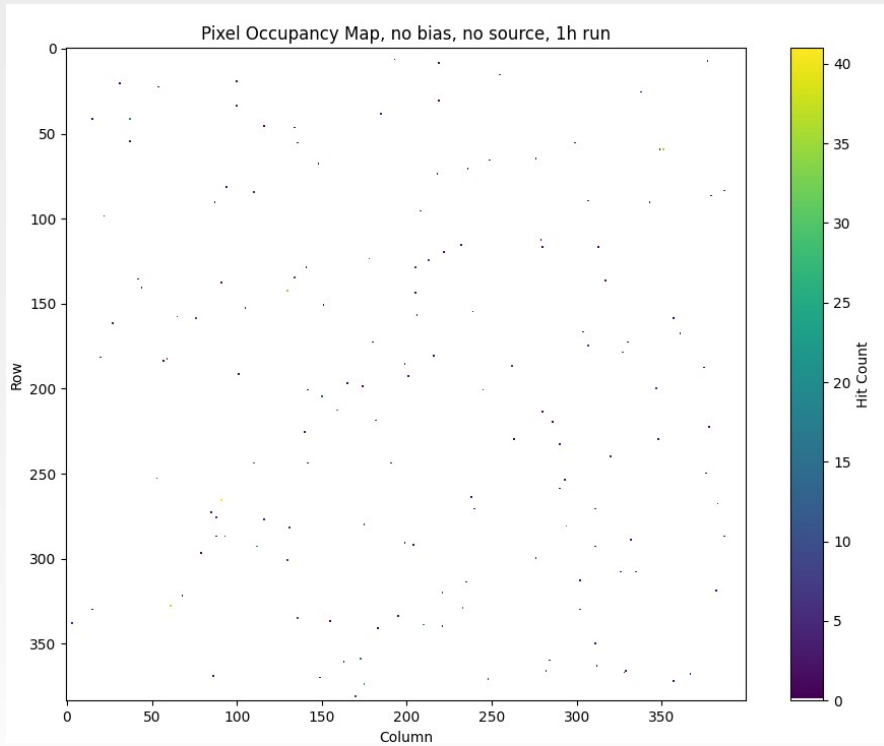
- Keithley Sourcemeter
- Did not go higher than -400V

- > Spark

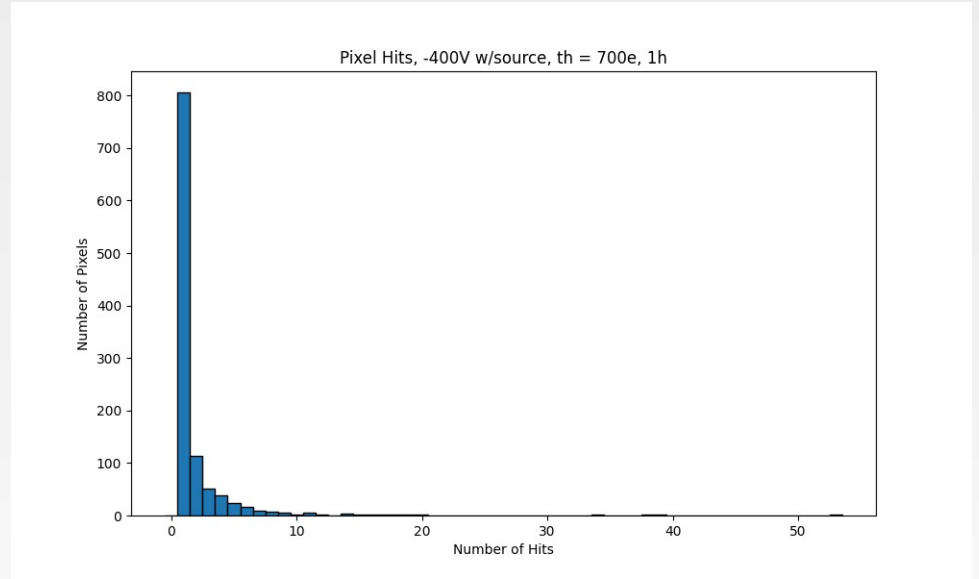
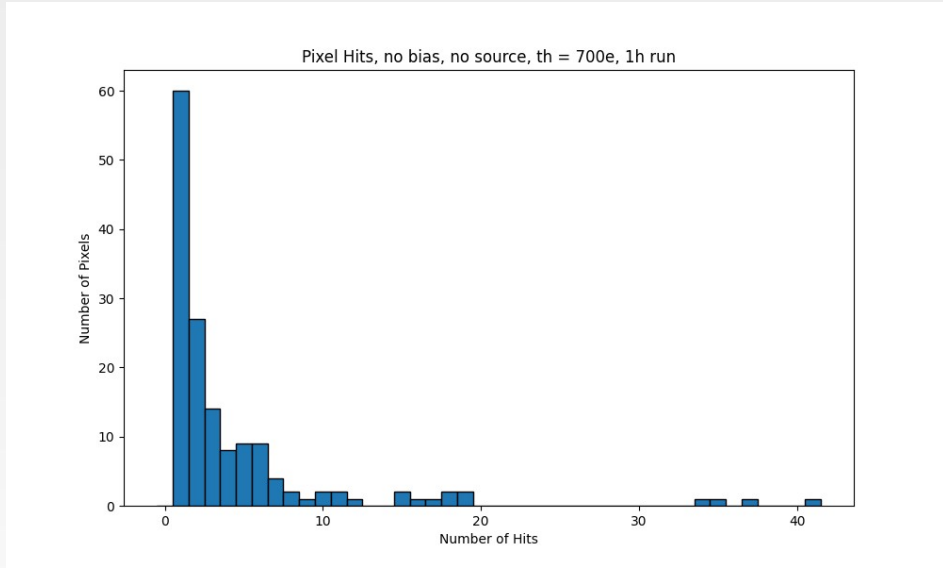


Part III

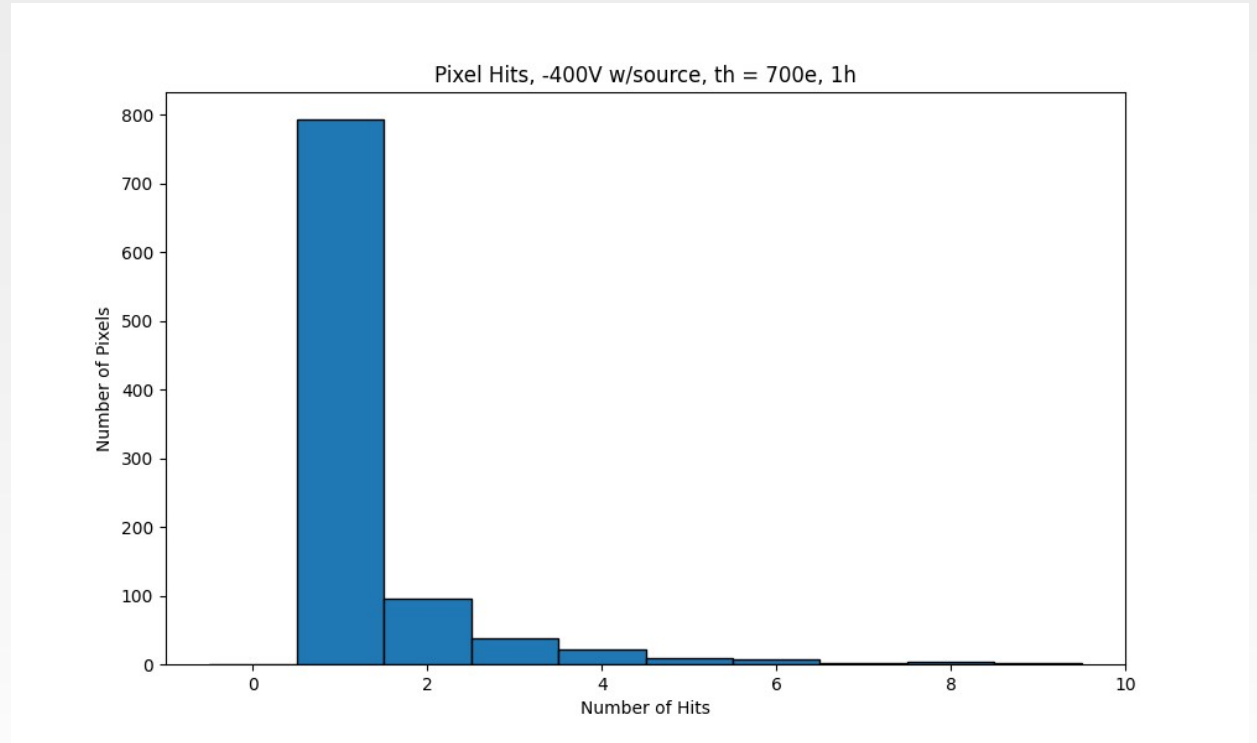
Results



Histogram - Number of hits for each pixel



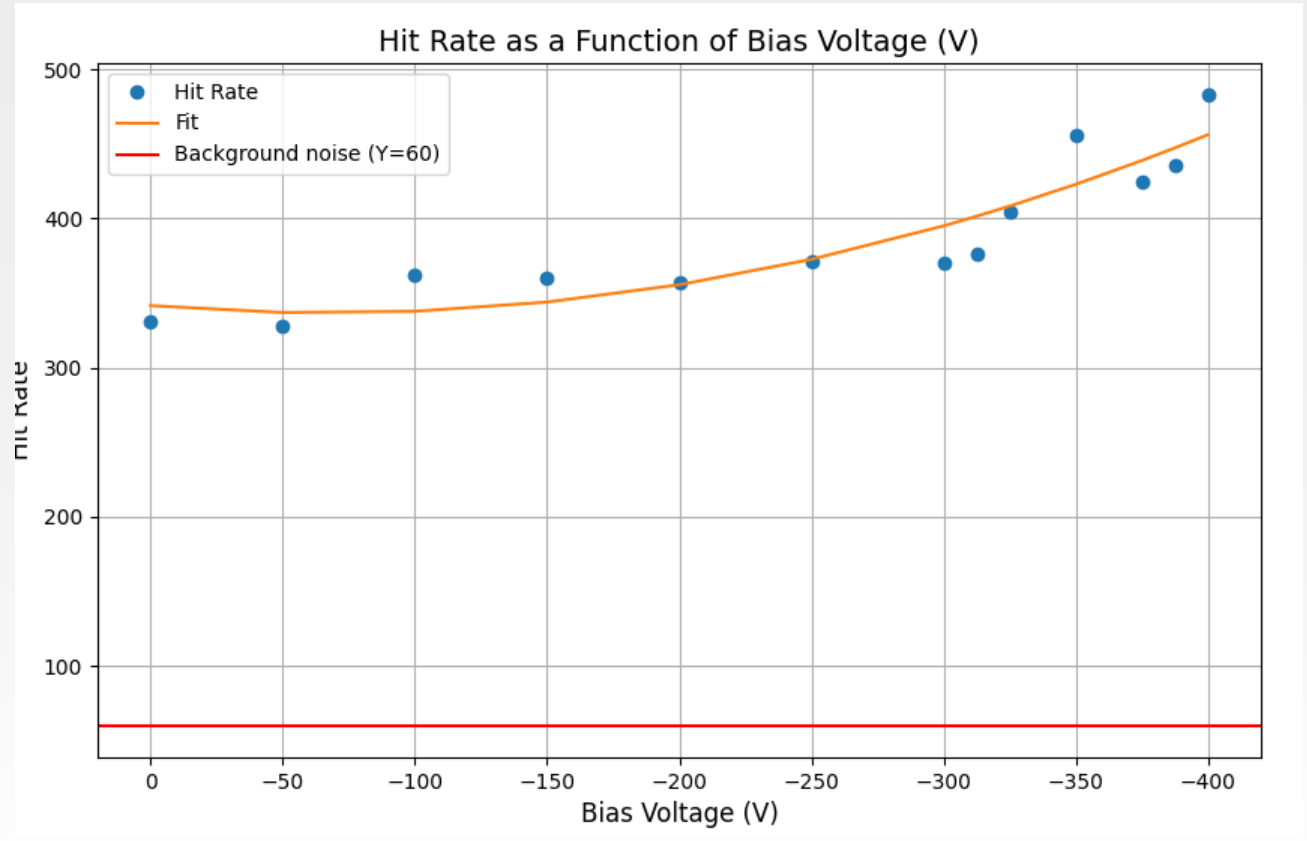
- Pixel hit Histogram
 - Removed noisy pixels from background run
- No pixels with high amount of hits
- Study number single pixels vs. bias



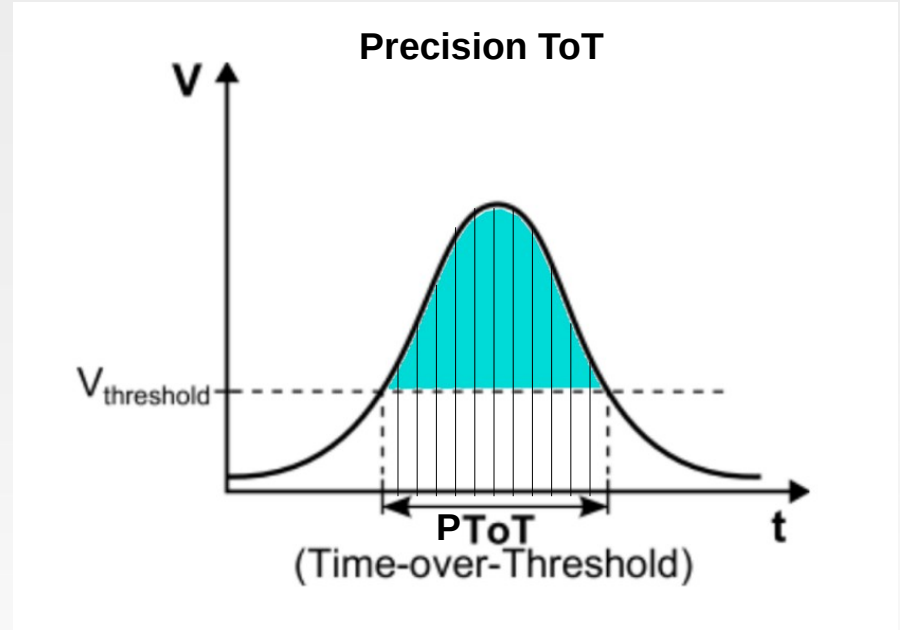
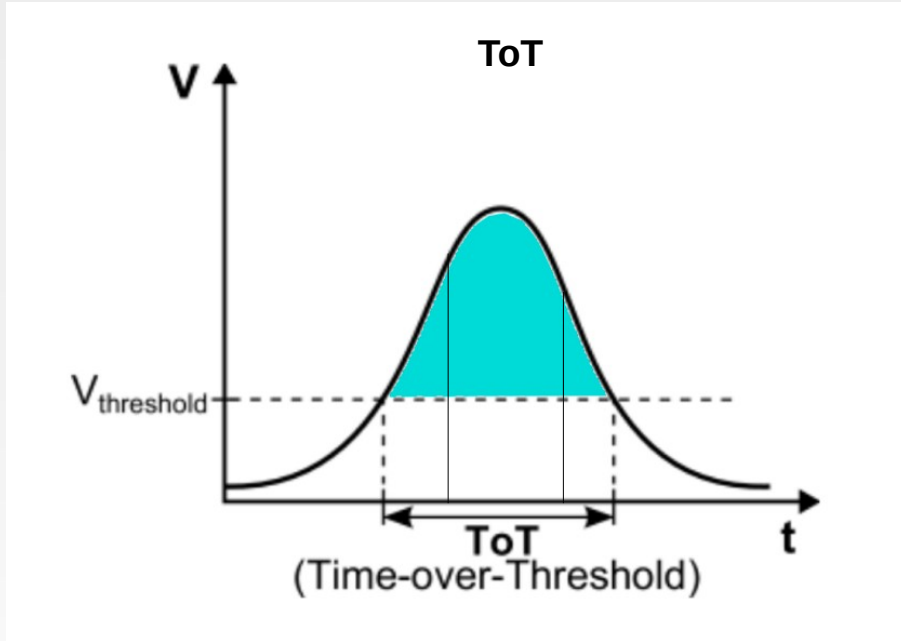
- **Single pixel hits vs bias**
- Run 30 min at each point
- Red – Background line:
 - No source or bias
 - ~50 counts

Results

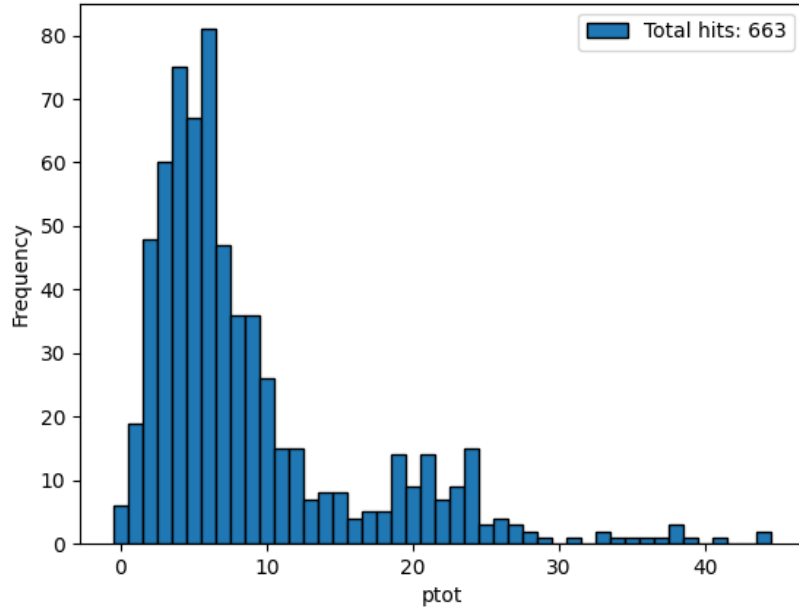
- Particle hits at 0V
- Increase with bias
- Basically - more pixels are activated at higher bias



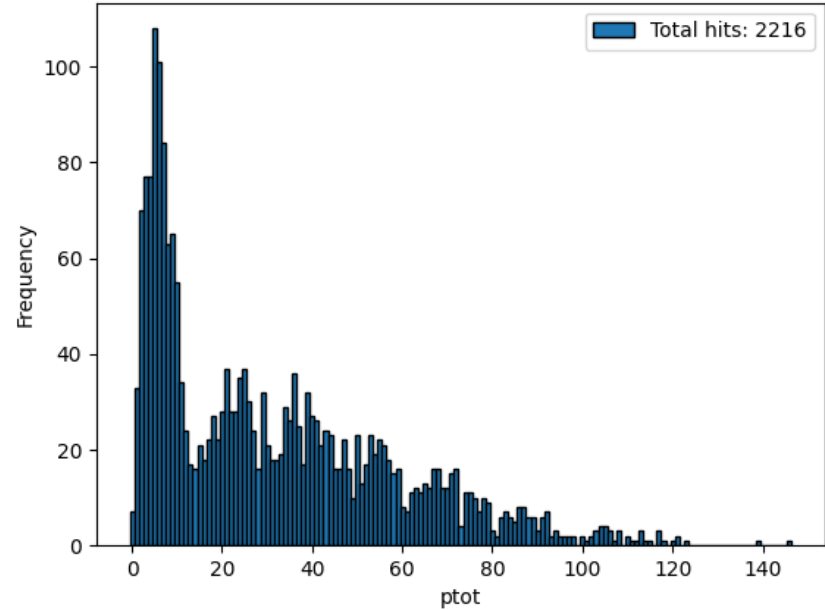
Quick recap: Time over Threshold

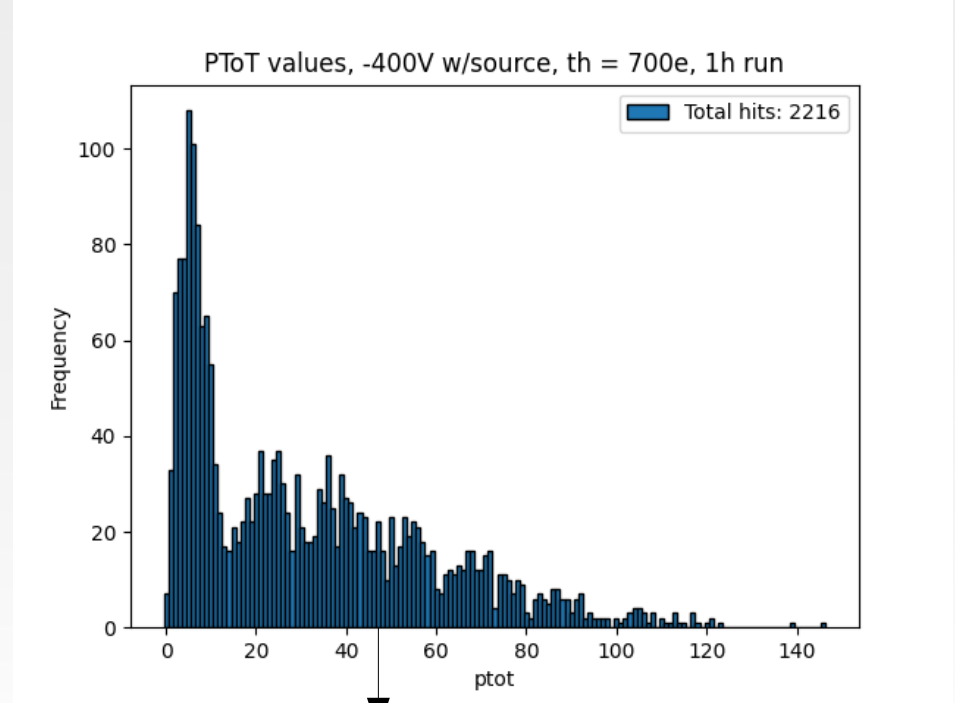
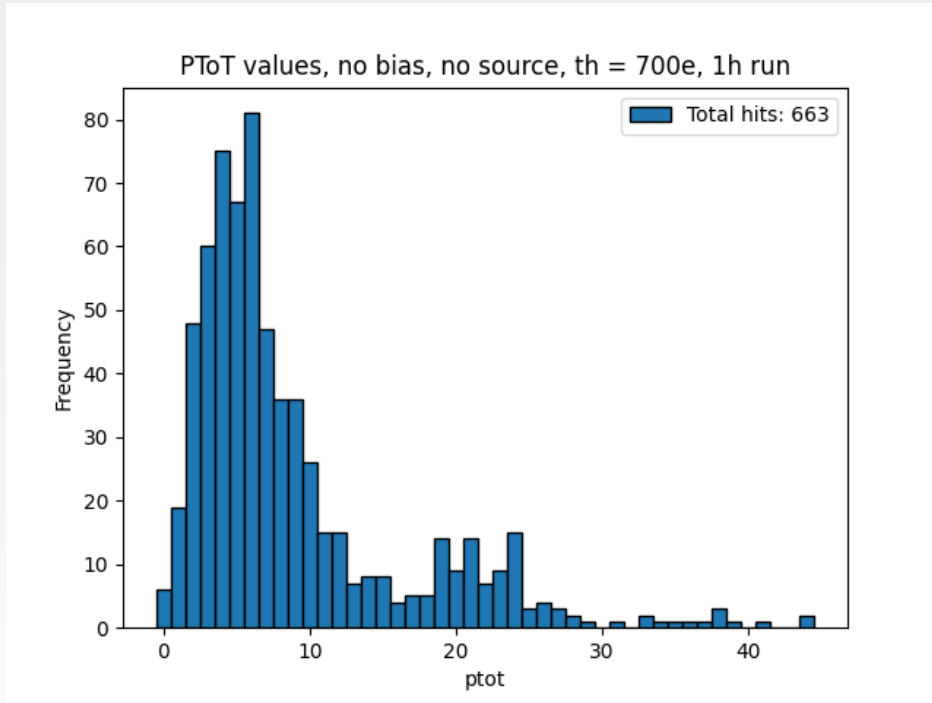


PToT values, no bias, no source, th = 700e, 1h run



PToT values, -400V w/source, th = 700e, 1h run



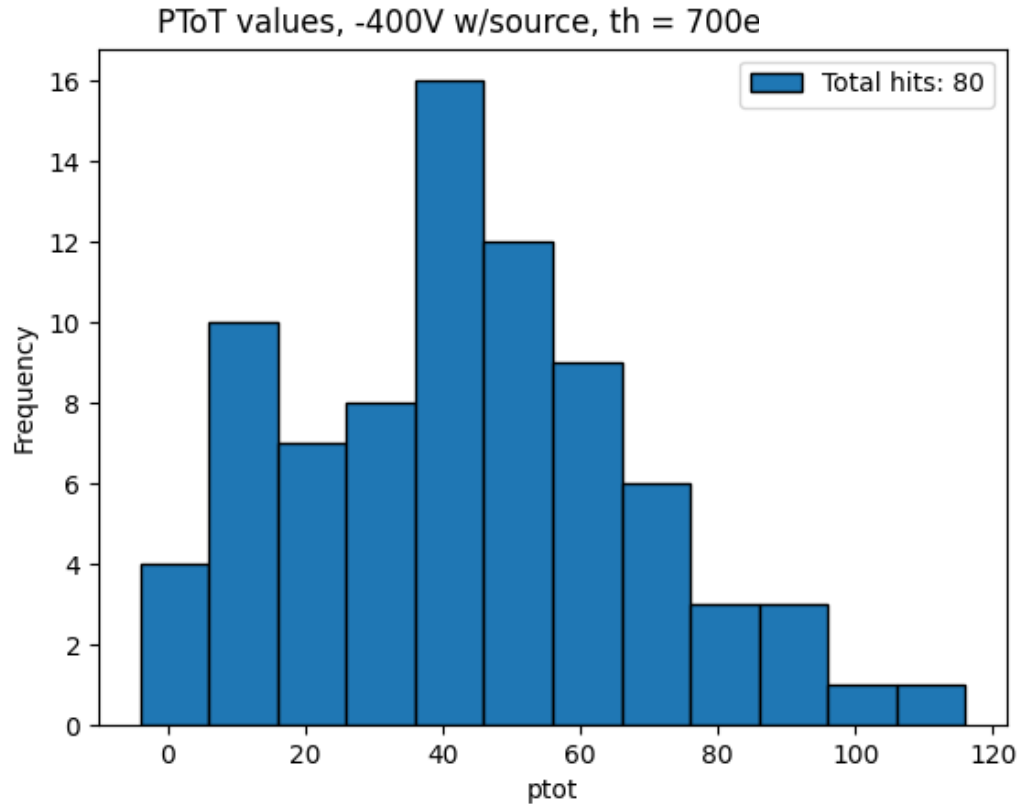


PToT x 1.56ns \rightarrow Time over Threshold \rightarrow 78 ns

- Precision ToT for a **single pixels**
- Study the charge pulse
- Left it running 30 hours total
- Got 80 hits from one pixels
- Binning size = 10

Results

- Lacks statistics
- **Ongoing**



Backup

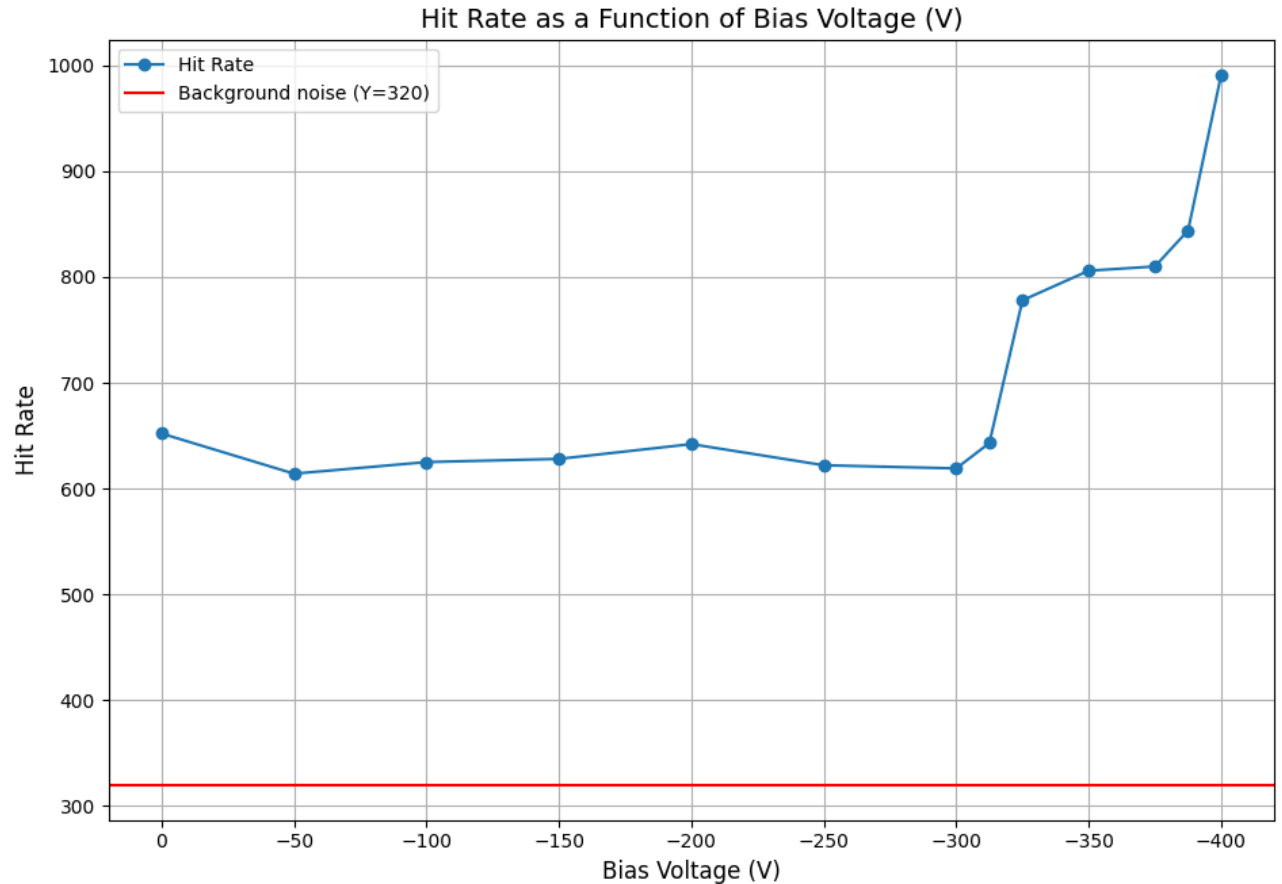
- Run 30 min for each point
- Background noise:
 - No source
 - ~320 counts

Results

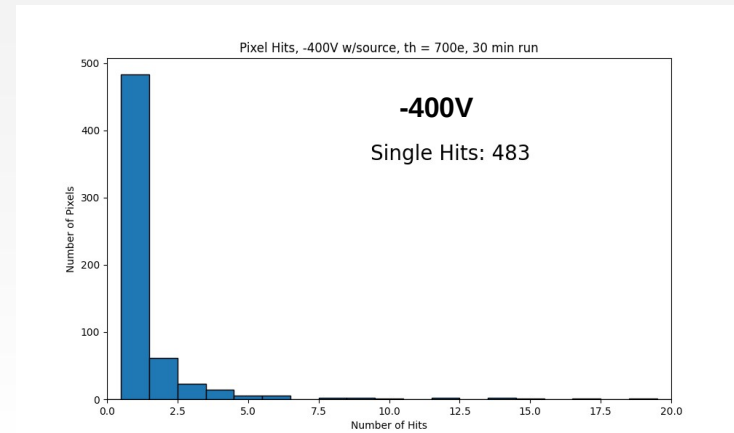
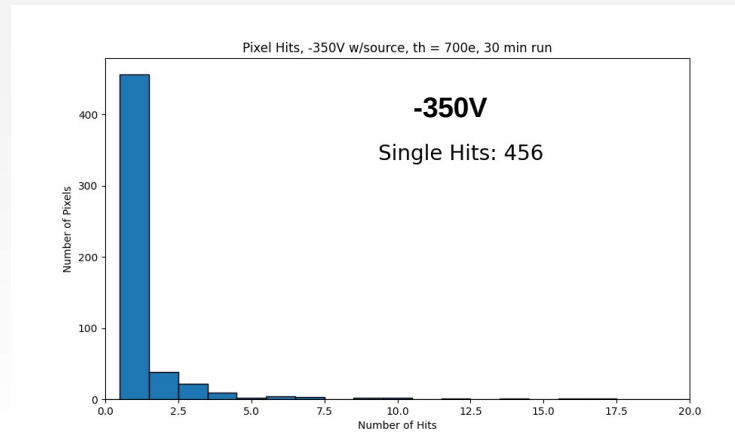
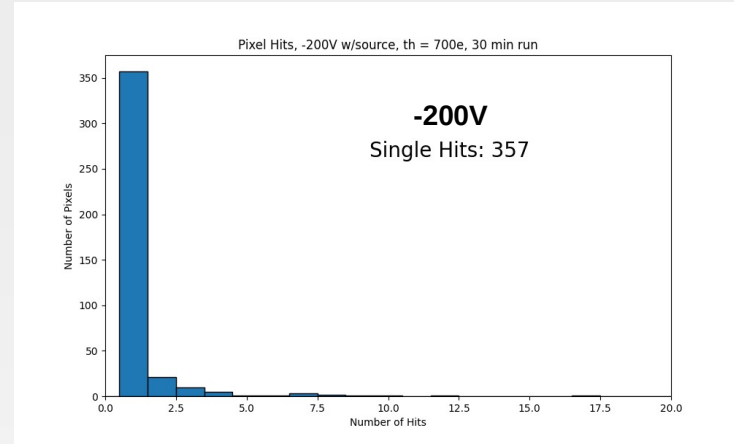
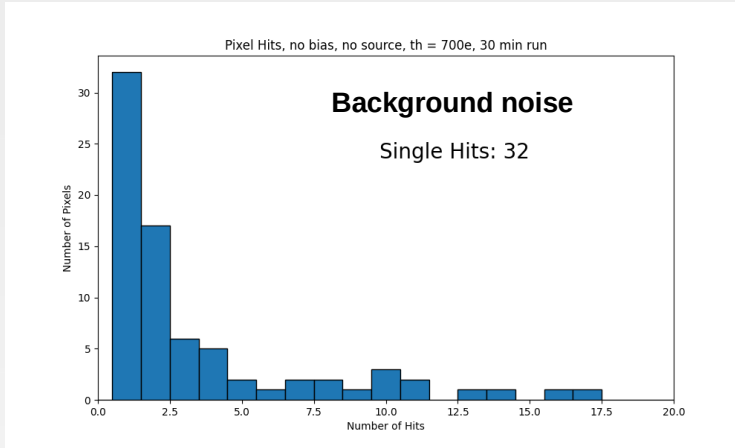
- See particle hits at 0V
 - Caused by diffusion

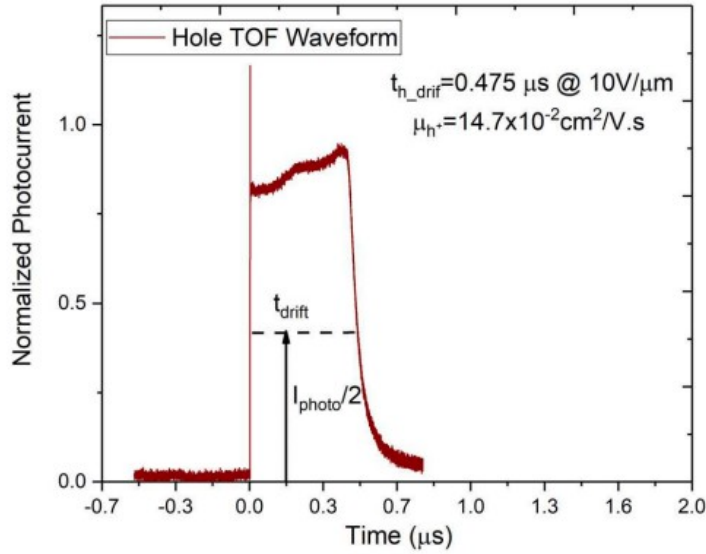
Unexpected results

- Sudden increase in hits
 - -300V and -400
- Suspected few pixels get noisy

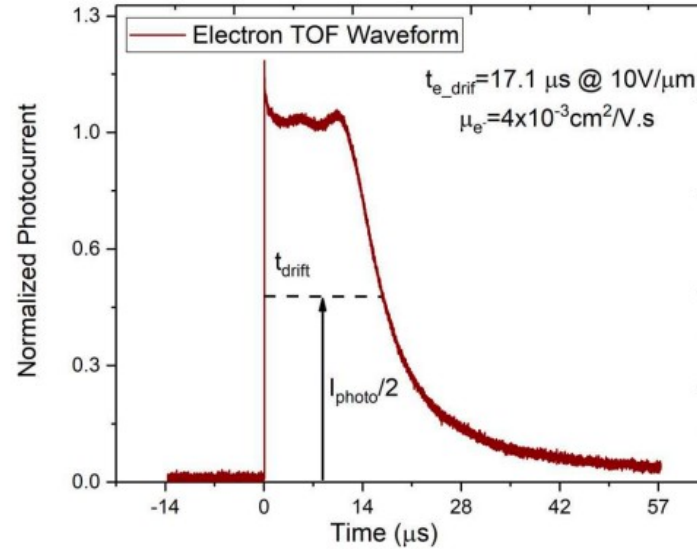


Histogram - Number of pixel hits





(a)

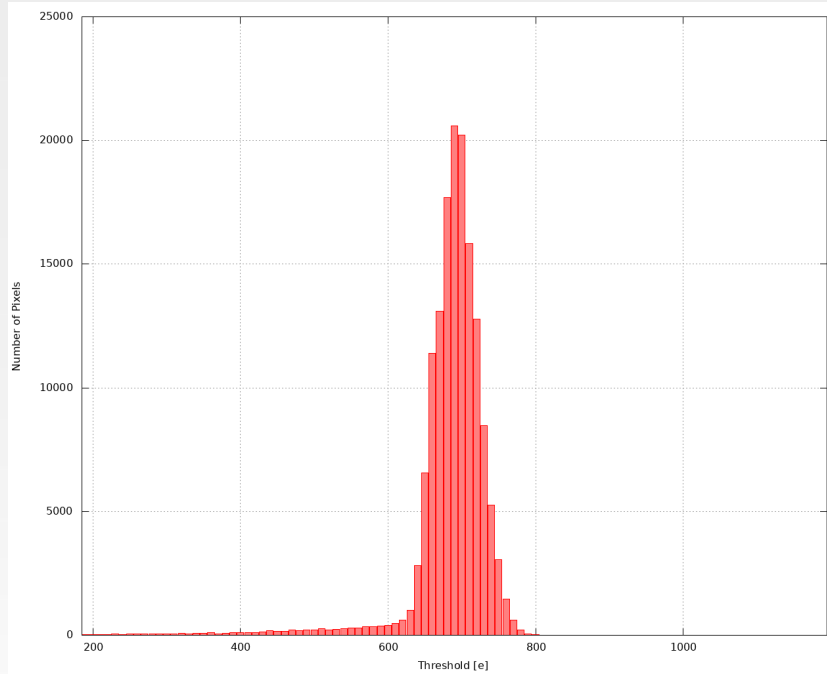


(b)

Fig. 1. Time-of-flight transient photoconductivity measurements of a 100-mm² 70- μ m-thick a-Se sensor showing the response of (a) holes and (b) electrons.

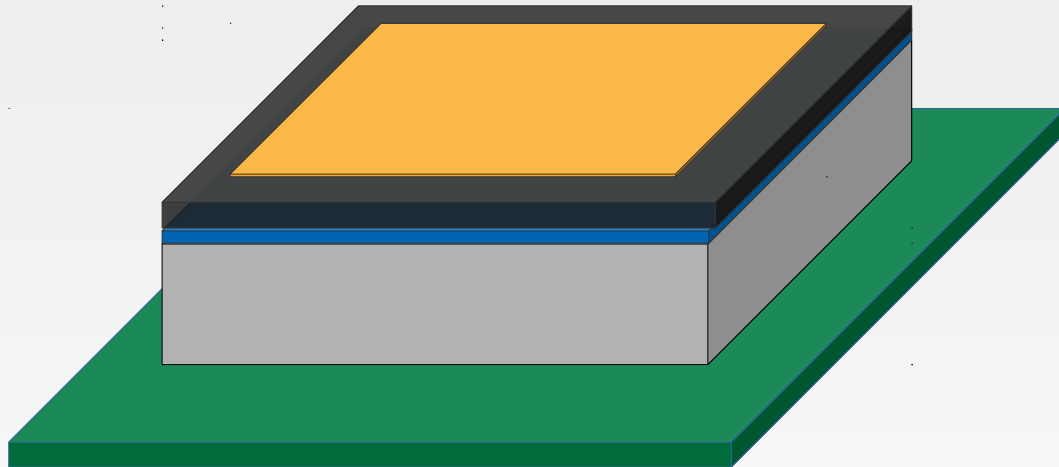
Lower threshold and Vff

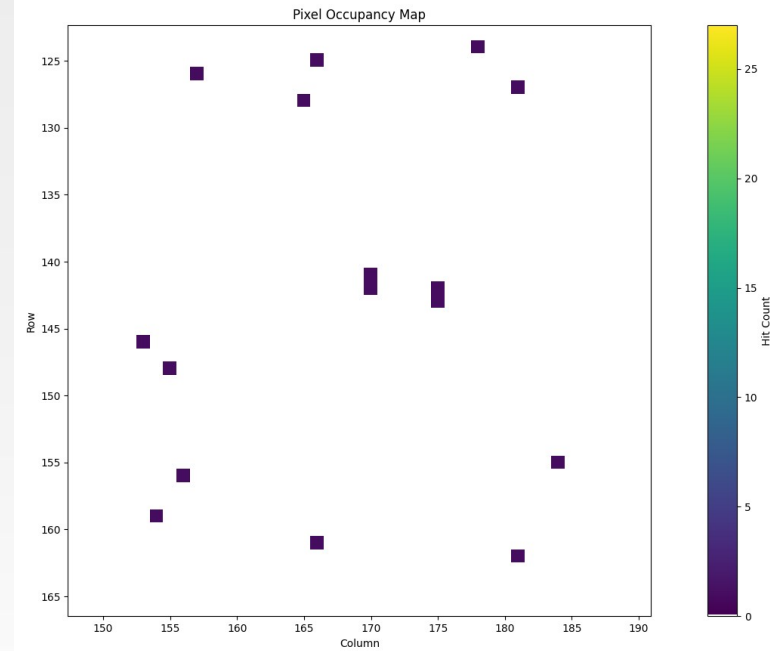
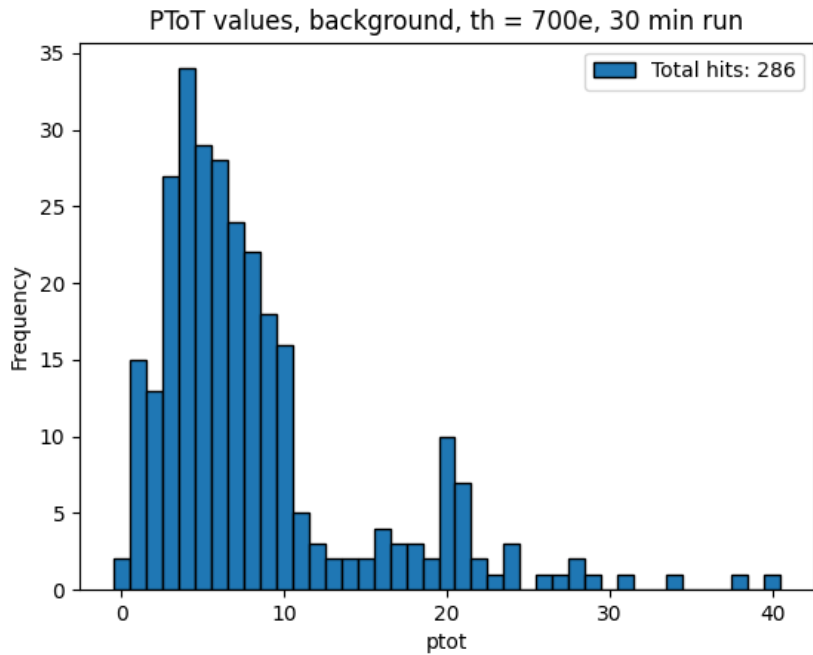
- Lowered return to baseline:
 - "DiffVff": 160 – 100
- Less discharge of the signal
- Re-tuned with ptot to $\sim 700e$



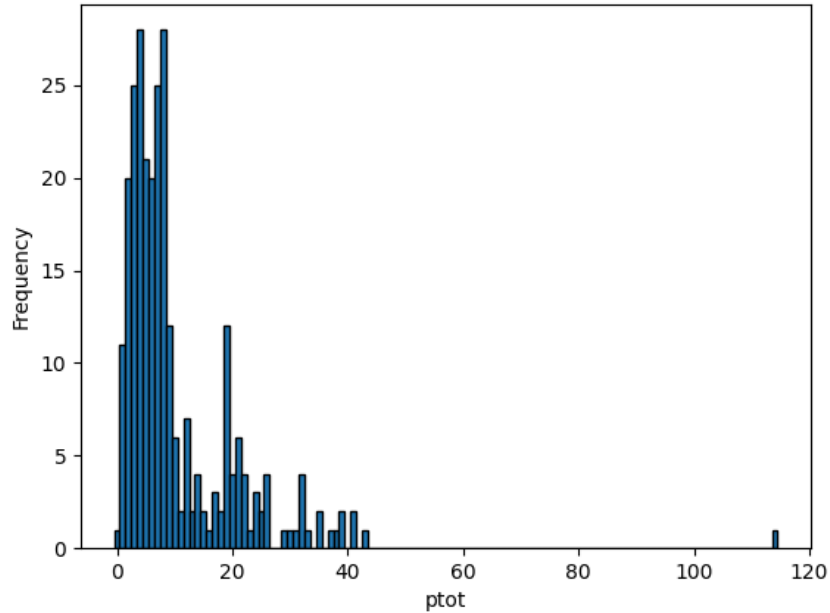



```
[ScanConsole] .. started threads of Fe 0
[ScanConsole] [1;31m#####[0m
[ScanConsole] [1;31m## Run Scan ##[0m
[ScanConsole] [1;31m#####[0m
[Rd53bDataProcessor] Started raw data processor thread for 0x16abc.
[StdDataGatherer] execPart2 /home/huiberts/YARR/src/LibYarr/StdDataGatherer.cpp:57 IMPORTANT! Going into endless loop unless timelimit is set, interrupt with ^c (SIGINT)!
[Rd53bDataProcessor] Hit: row(276) col(372) tot(0)
[Rd53bDataProcessor] Hit: row(295) col(109) tot(0)
[Rd53bDataProcessor] Hit: row(1) col(380) ptoa(10) ptot(2047)
[Rd53bDataProcessor] Hit: row(295) col(109) tot(1)
[Rd53bDataProcessor] Hit: row(275) col(109) tot(3)
[Rd53bDataProcessor] Hit: row(295) col(109) tot(3)
[Rd53bDataProcessor] Hit: row(376) col(383) tot(3)
[Rd53bDataProcessor] Hit: row(276) col(372) tot(1)
[Rd53bDataProcessor] Hit: row(1) col(380) ptoa(13) ptot(2047)
[Rd53bDataProcessor] Hit: row(276) col(372) tot(5)
[Rd53bDataProcessor] Hit: row(376) col(383) tot(1)
[Rd53bDataProcessor] Hit: row(276) col(372) tot(0)
[Rd53bDataProcessor] Hit: row(295) col(109) tot(5)
[Rd53bDataProcessor] Hit: row(1) col(380) ptoa(10) ptot(2047)
[Rd53bDataProcessor] Hit: row(276) col(372) tot(5)
[Rd53bDataProcessor] Hit: row(295) col(109) tot(1)
[Rd53bDataProcessor] Hit: row(376) col(383) tot(0)
[Rd53bDataProcessor] Hit: row(295) col(109) tot(2)
[Rd53bDataProcessor] Hit: row(376) col(383) tot(0)
[Rd53bDataProcessor] Hit: row(1) col(380) ptoa(10) ptot(2047)
[Rd53bDataProcessor] Hit: row(295) col(109) tot(0)
[Rd53bDataProcessor] Hit: row(376) col(383) tot(2)
```

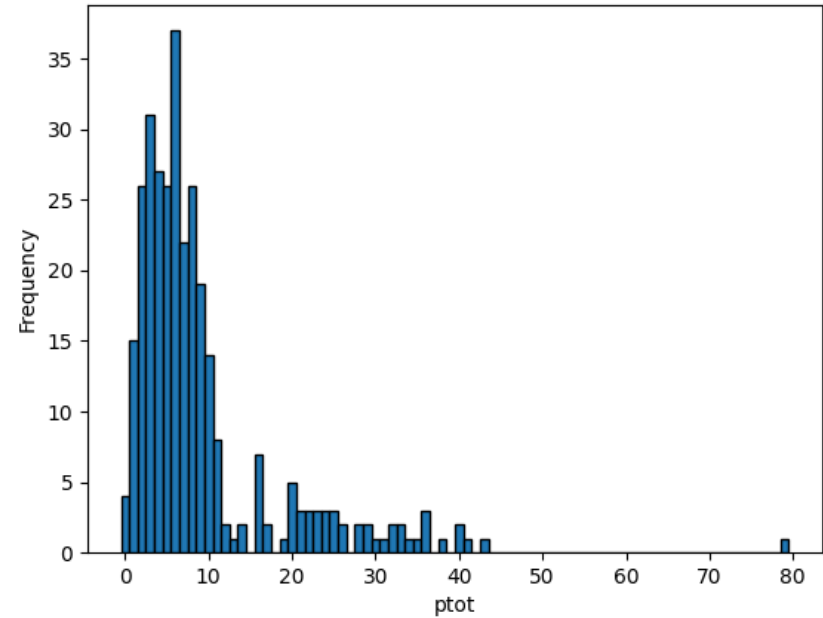




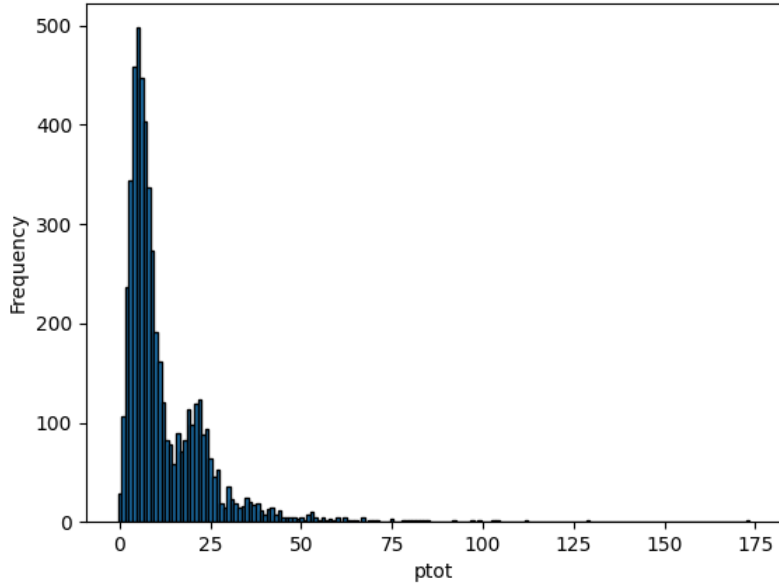
Ptot values w/source, -350V bias, 10 min run.



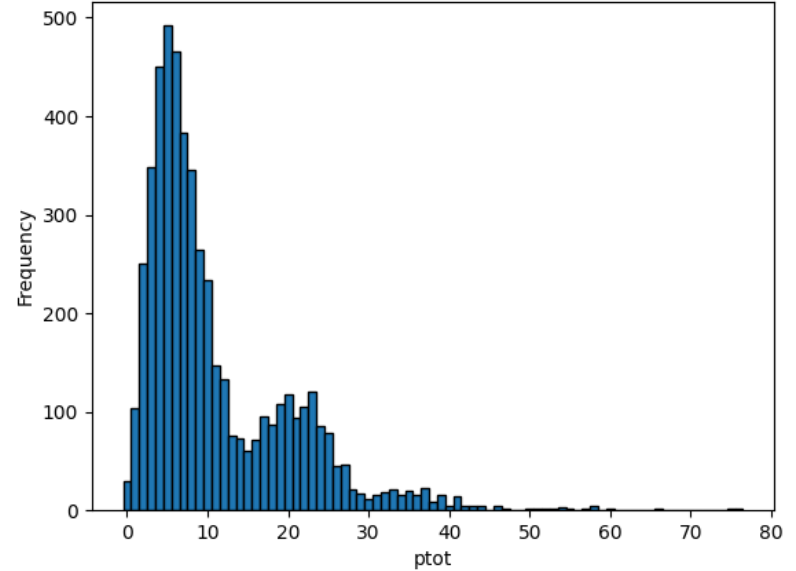
Ptot values no source, no bias, 10 min run.



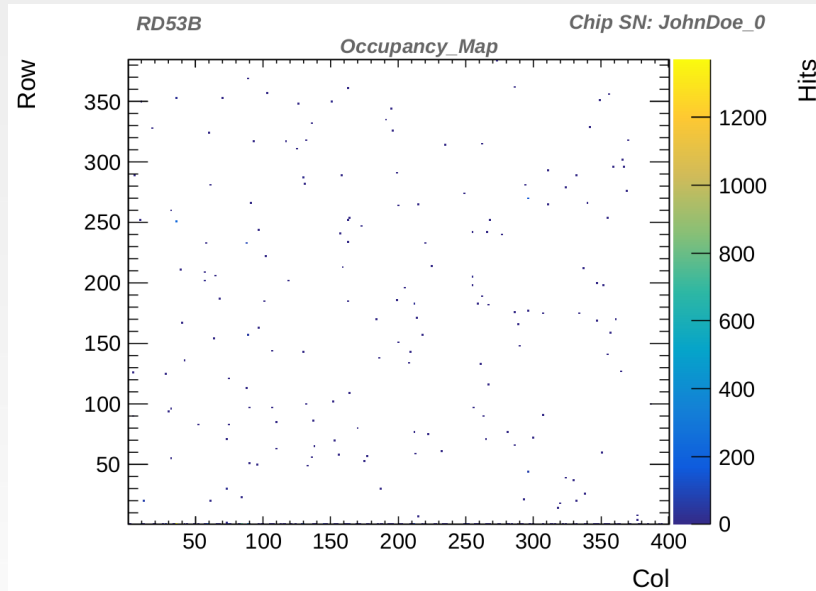
Ptot values -350V bias, 700e, 10 min run.



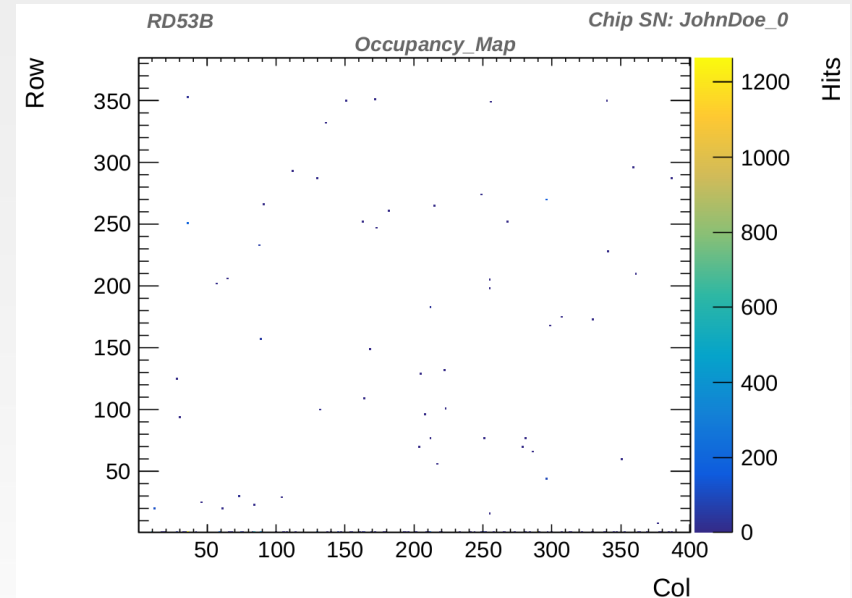
Ptot values no source, no bias, 700e, 10 min run.



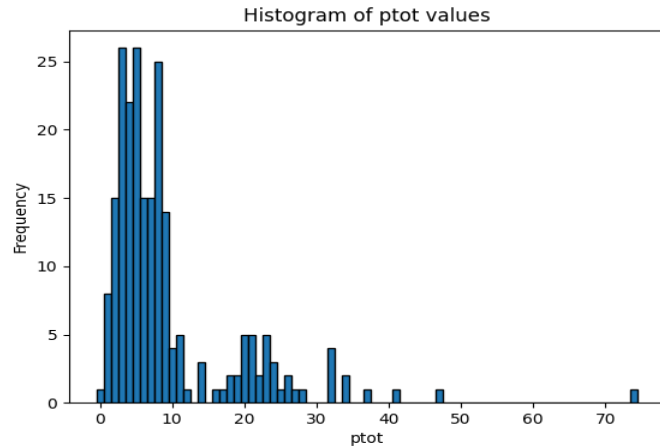
Occupancy Map -350V, with bias



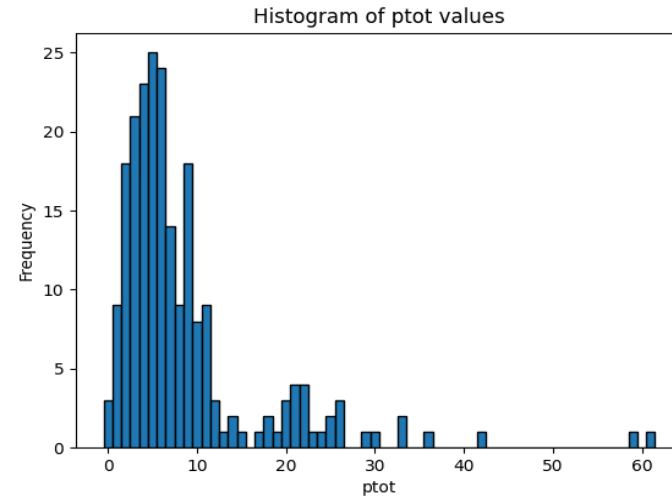
Occupancy Map No source or bias



Source on, voltage off, 5 min



Source on, voltage on, 5 min





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