ATAR Geometry in Simulation

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PIONEER Collaboration Meeting

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ATAR Geometry and Motivation

- Nominal ATAR has been put into the simulation sans mechanics (See Peter's talk and further discussions)
- ATAR parametrized to allow for simulation building of different geometries
- Additionally, nominal example .json files
- Attempted to include our best guess for the dead material given our current understanding of the experiment
- This talk will go through the motivation for a lot of the different elements of the ATAR simulation and why the values are what they are


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"debug":true,
"filename":"atar_only_nominal",
"mother":{
    "material":"air",
    "xWidth":2000,
    "yWidth":2000,
    "zWidth":11000
},
"target":{
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    "xPos": 0.0,
    "yPos": 0.0,
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    "layerStagger":0.03,
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    "hvLengthPastSensor":0.04,
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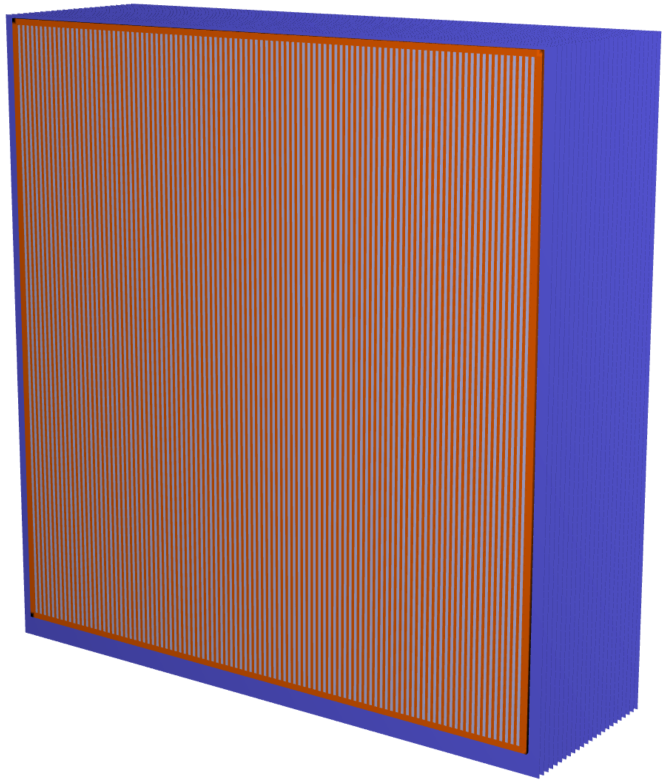
    "makeGuard":true,
    "guardWidth":0.04,
    "guardMaterial":"Silicon",
    "layerBuffer" : 0.0025,
    "debug":false
},
```

ATAR Active Region Basics

- PIONEER's nominal ATAR will consist of 48 layers of LGAD silicon sensors
- The bulk thickness of the sensors are 120μm
- Each layer will have 100 strips per layer each of these are considered as independent active volumes in the simulation
- At this point of time there is no nominal LGAD choice, but TI-LGADs and AC-LGADs are being investigated

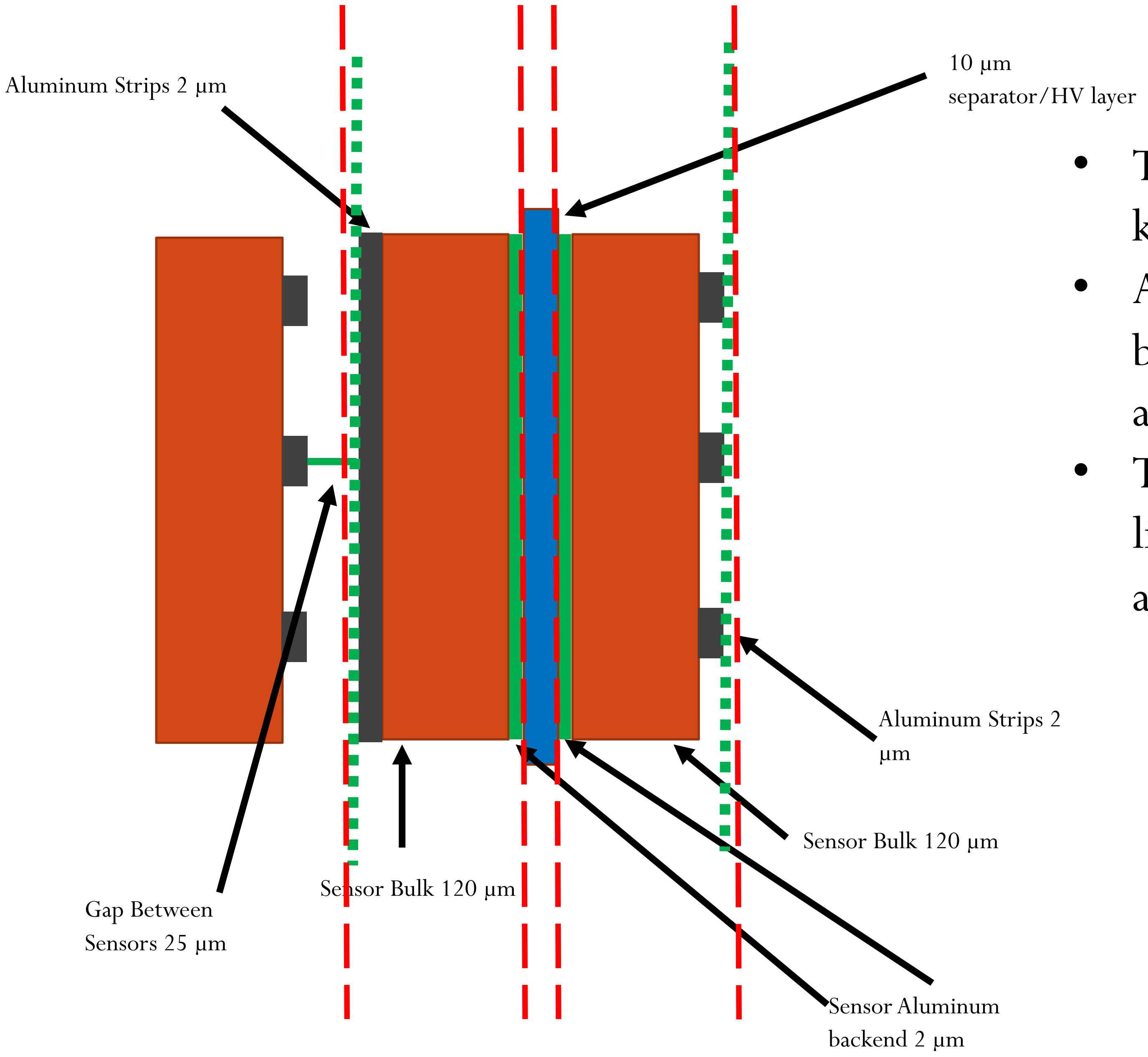


Why the Nominal* Values

120μm Bulk Thickness	200μm Pitch	LGAD	48 Layers	2x2cm
Thinnest self supporting sensor, also want the sensor thin for granularity and repetition rate	Balance between getting enough points of the muon track, but keeping overall channel count low along with having a geometry that can easily be matched to a flex/PCB	Better S/N ratio than standard PIN, better timing resolution, and allows the use of a fast amplifier for an increased, fast repetition rate	From the beam profile, the pions stop on average after 24 layers (dependent on bulk thickness)	From the beam parameters this is the shape that fits the "supposed" pion beam

Asterisk, as these parameters are the initial stab at a design but will likely change as our ATAR simulation campaign begins

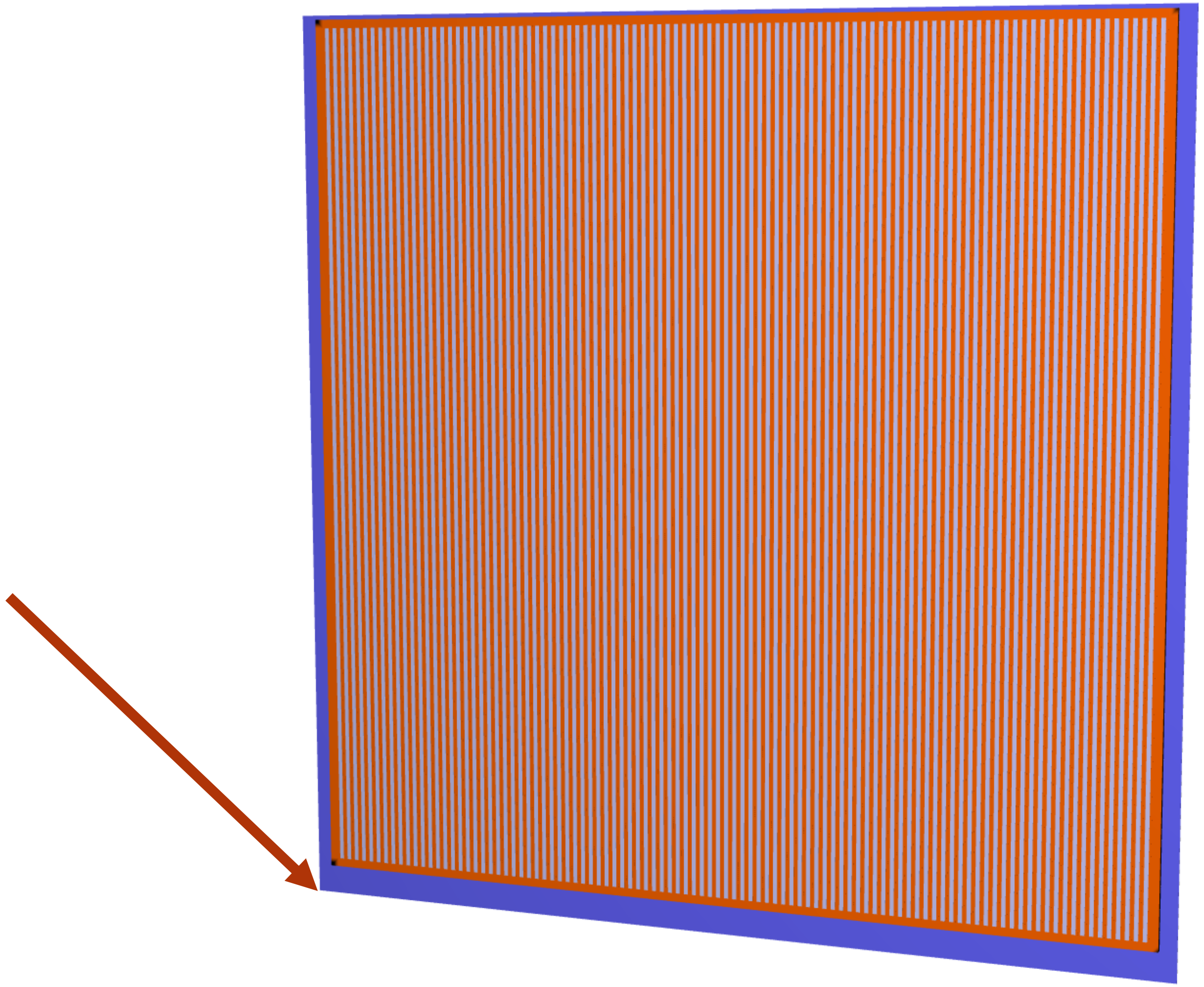
ATAR Meta Objects



- The simulation is organized into meta objects known as sensors and sandwich layers
- A sandwich layer consists of the items in between the green dotted lines, 2 sensors and 1 high voltage region
- The sensors correspond to the red dashed lines, which include the aluminum strips and a backing region

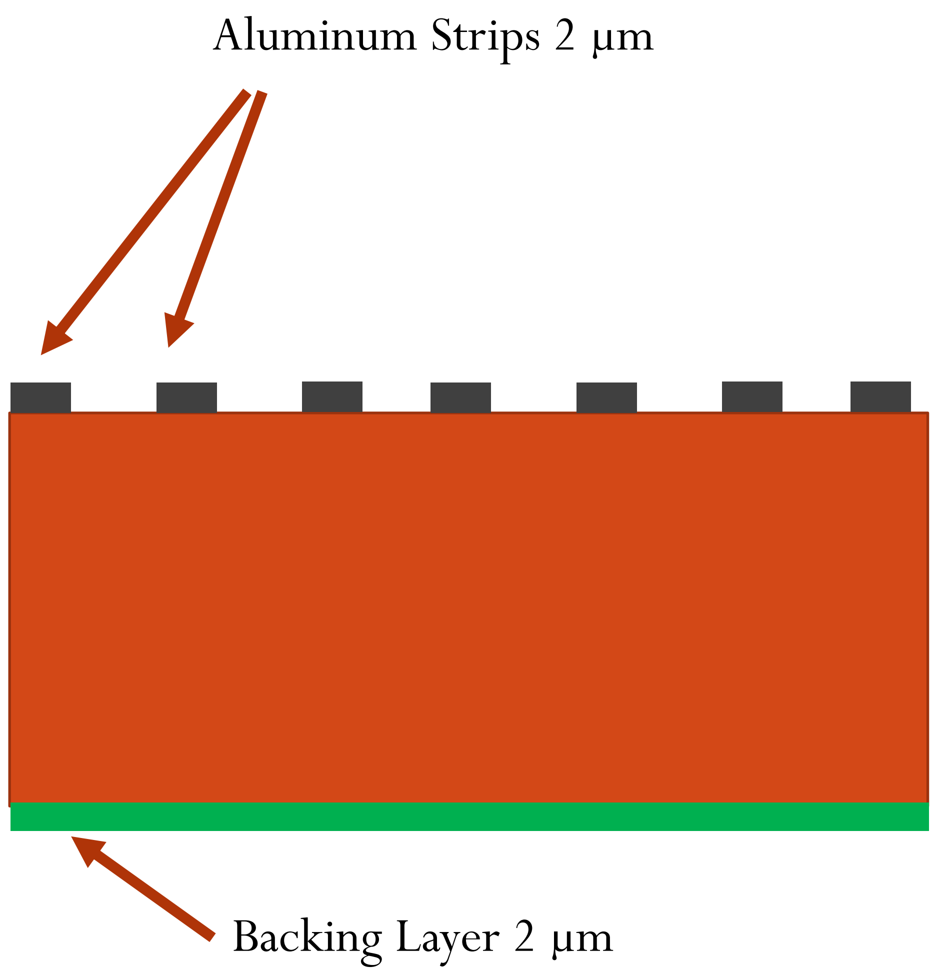
ATAR Inactive Regions: High Voltage Layer

- What I call the HV layer is a model of what will be a more complex object for the final ATAR
- These LGAD sensors need high volage biasing and a mechanical object to support the sensors
- In the simulation this HV layer is a Kapton model of a nominal thickness of 10μm
- Furthermore, we envision that four rods would go through the corners of this region to provide support for the ATAR, unsure exact "overflow"



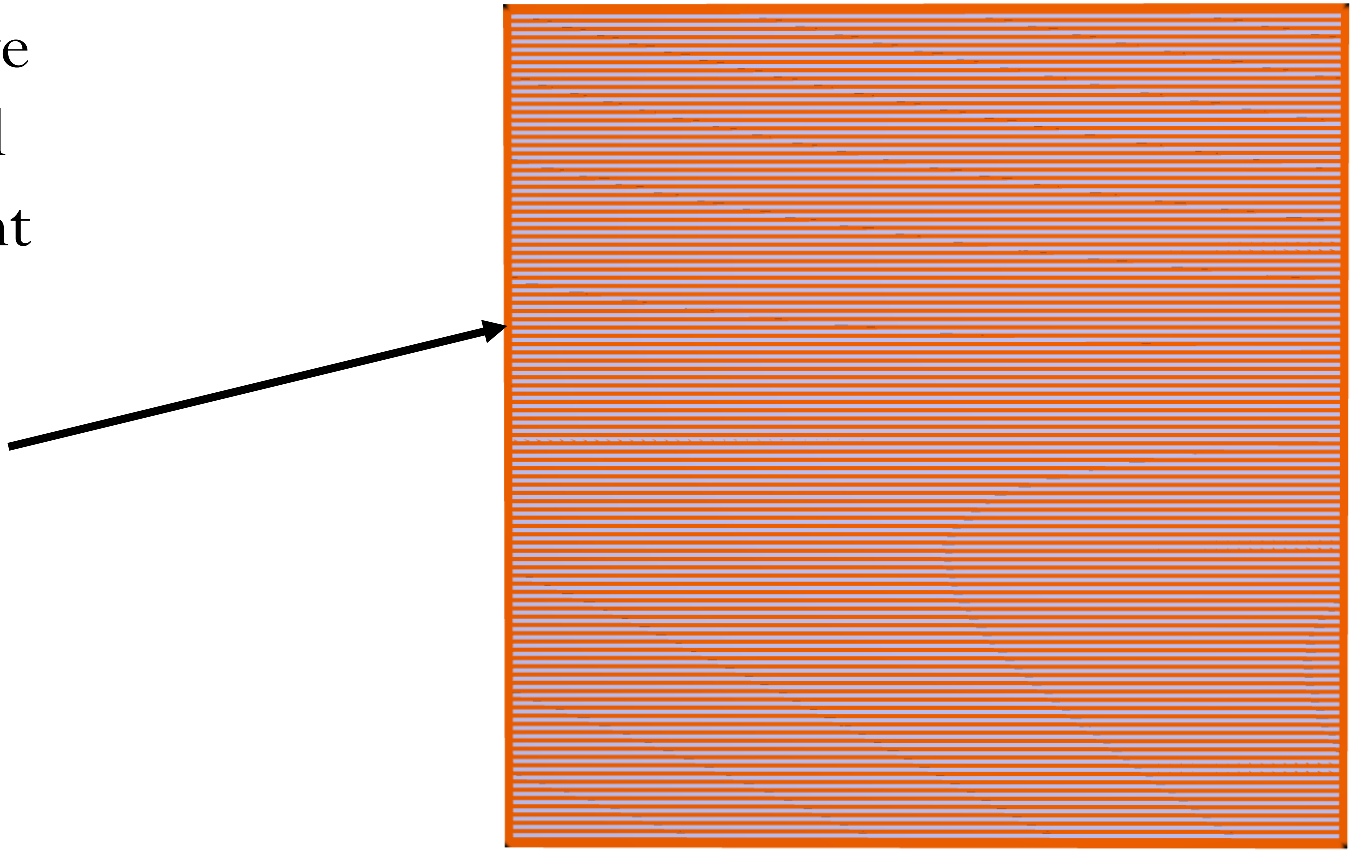
ATAR Inactive Regions: Sensor Metallization

- On every sensor there are two regions of aluminum metallization
- On the front side are the electrodes that read out the signals from the bulk of the sensor
- For the simulation assumed 100μm wide electrodes
- In the simulation electrodes sit on top of the strips, which are the active region
- On the backside is what we call the backing layer this is also metallized and will be giving the sensor it's high voltage bias
- Made the assumption that the electrodes and backing layer will always be the same thickness nominally 2μm



ATAR Inactive Regions: Guard Ring

- Around the active portion of the strips silicon sensors have an inactive region that in the simulation we call the guard ring, which is one element of that inactive region
- In the simulation this is nominally a 200μm frame and is also made of silicon
- There have been discussions of the fact that there is further dead material outside of the guard ring that could increase this area of dead region even up to 500μm



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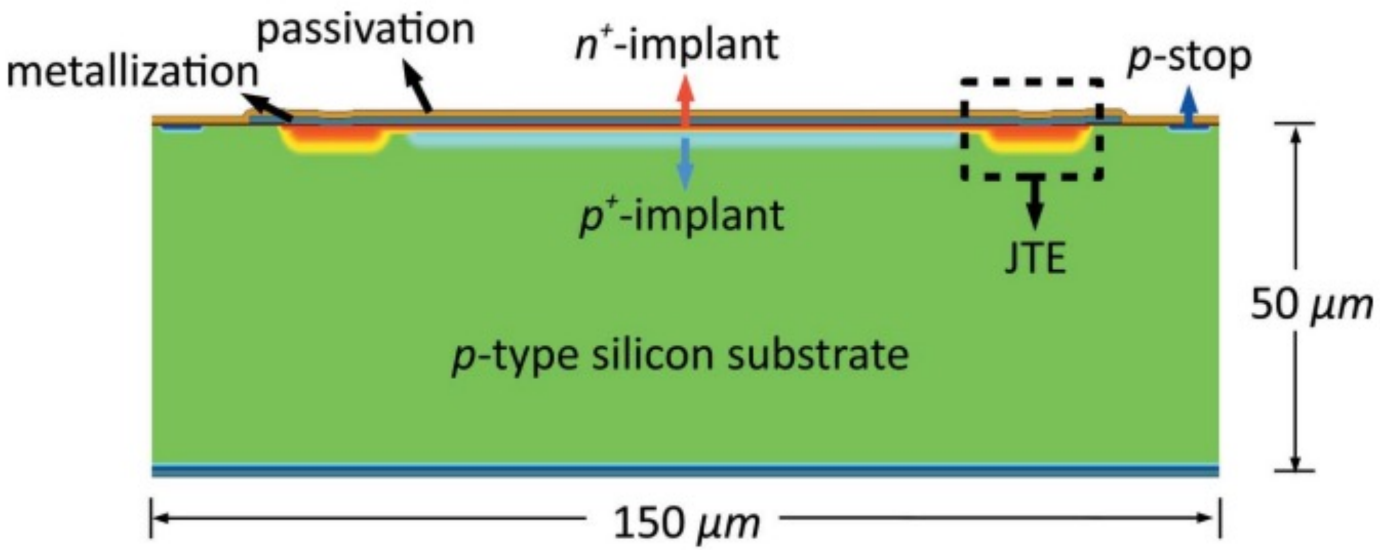
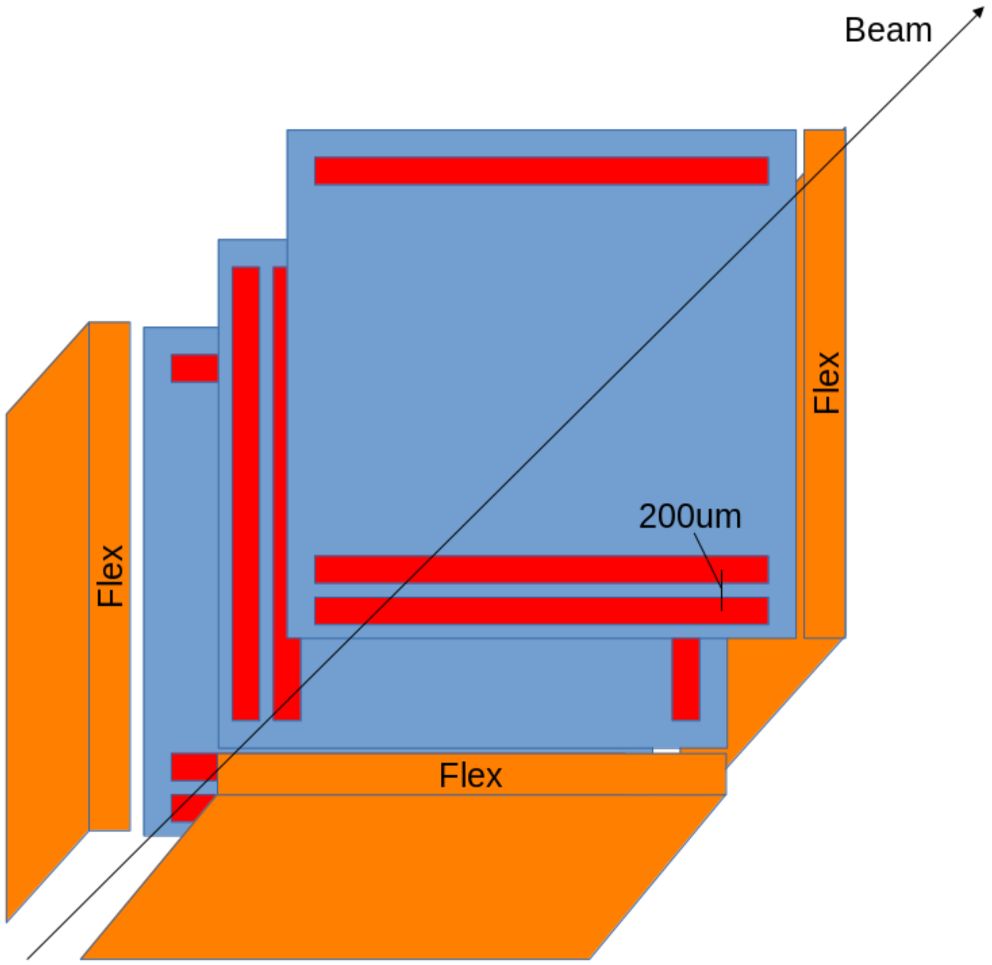
ATAR Inactive Regions: Passivation Layer



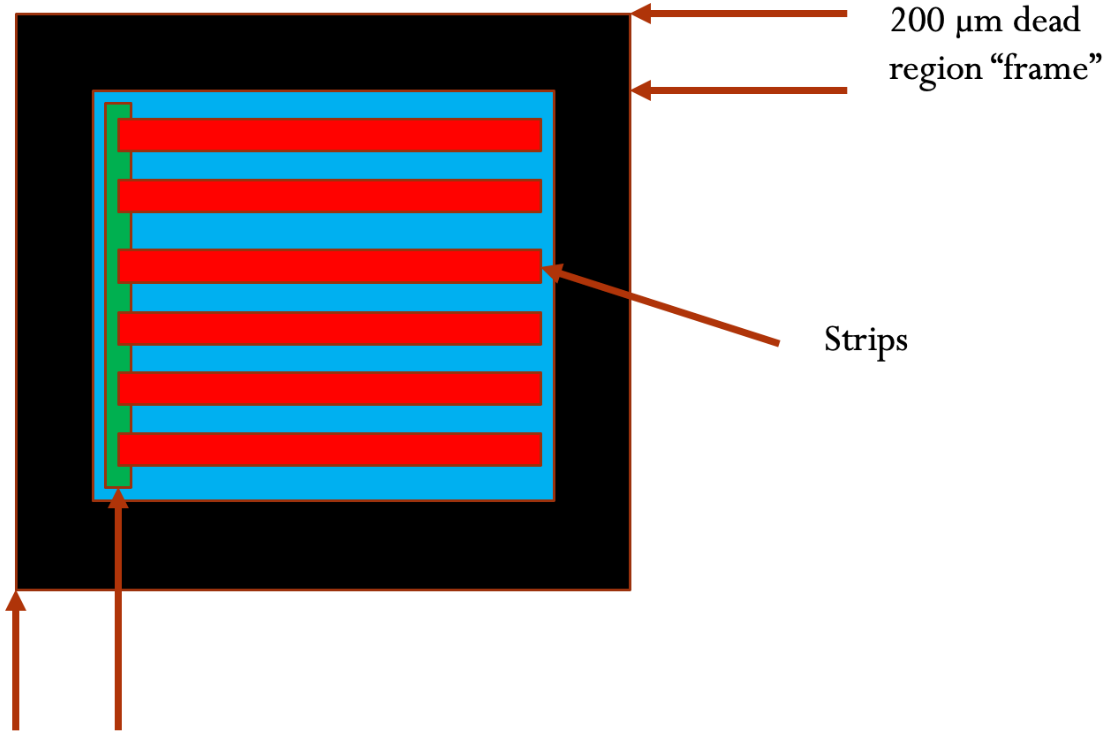
- Recently added to the simulation one can add a passivation layer to the sensors
- The passivation layer is a small region of inactive material deposited below the electrodes to stabilize the semiconductor chemically and electrically

ATAR Sensor Staggering

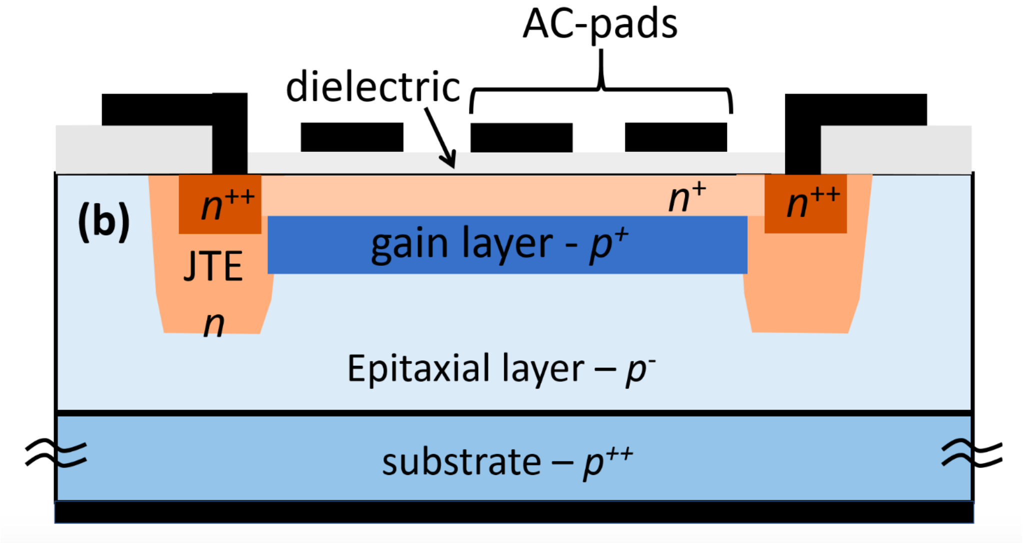
Sensors staggered for readout. Each layer has 2 sensors. Each layer will oscillate but only the “front” and “back” sensors. For example layer 1 sensor 1 will be read out on the right and layer 1 sensor 2 the bottom. Then layer 2 sensor 1 will be read out left and layer 2 sensor 2 top.



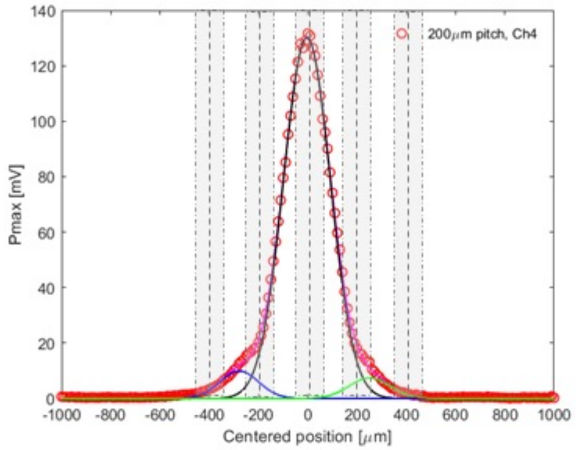
Staggering by 300 µm total 200 for dead region than an extra 100 µm

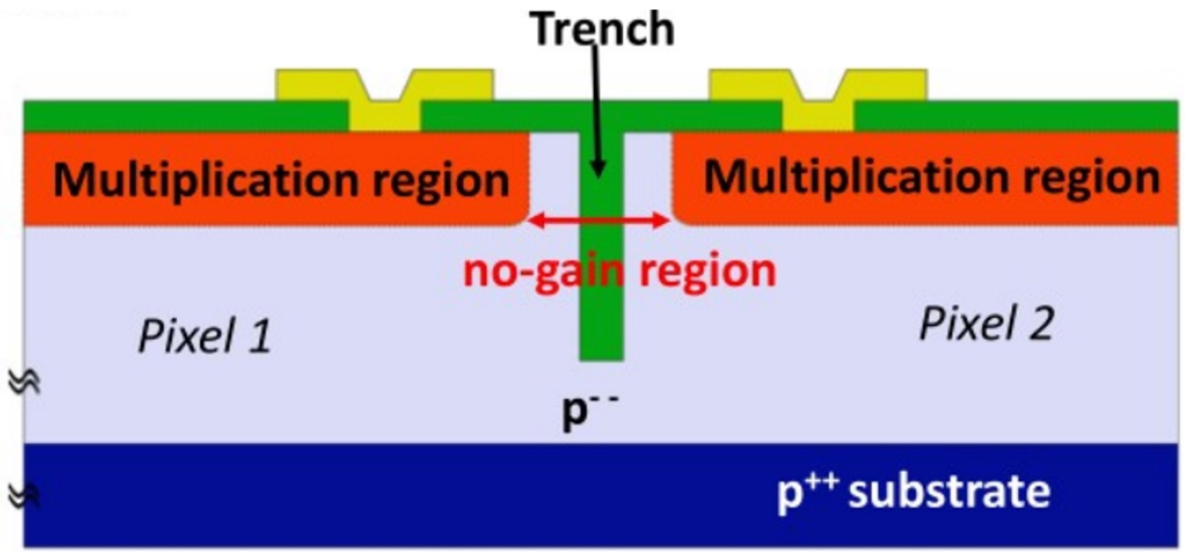


ATAR Sensor Types/Variations

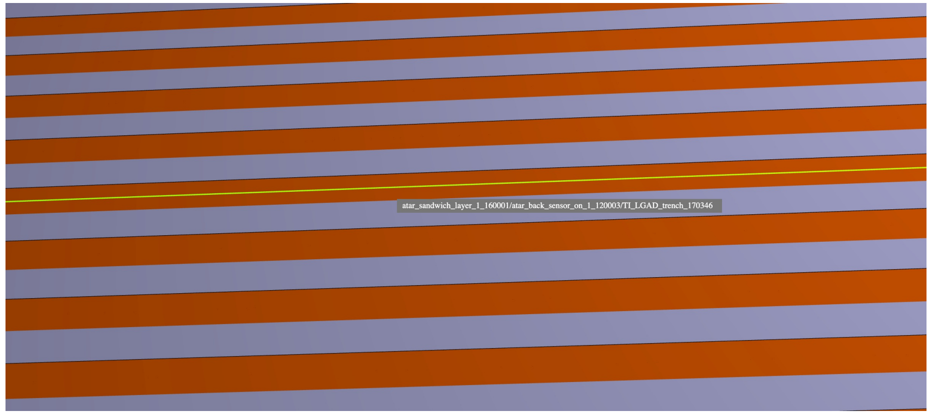


Working on developing AC-LGAD smearing. Have developed a triple Gaussian model, but have yet to incorporate it into the simulation framework.





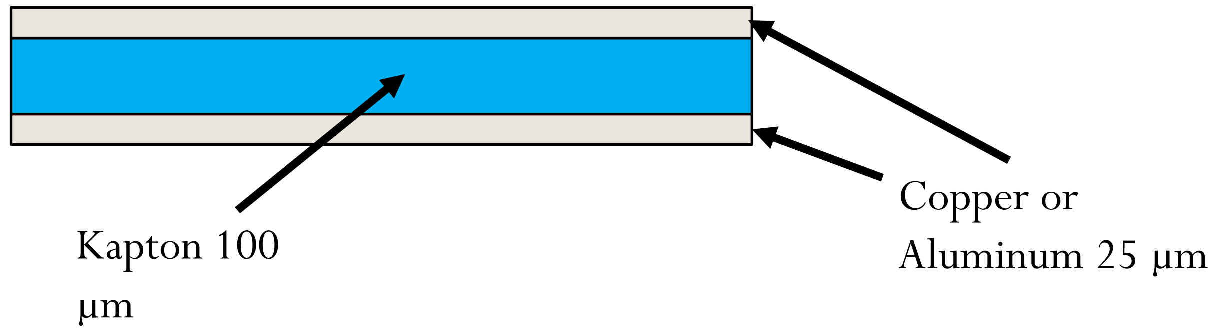
Have implanted the TI-LGADs into the simulation as an inactive region. Technically the regions would produce signal, but have no gain.

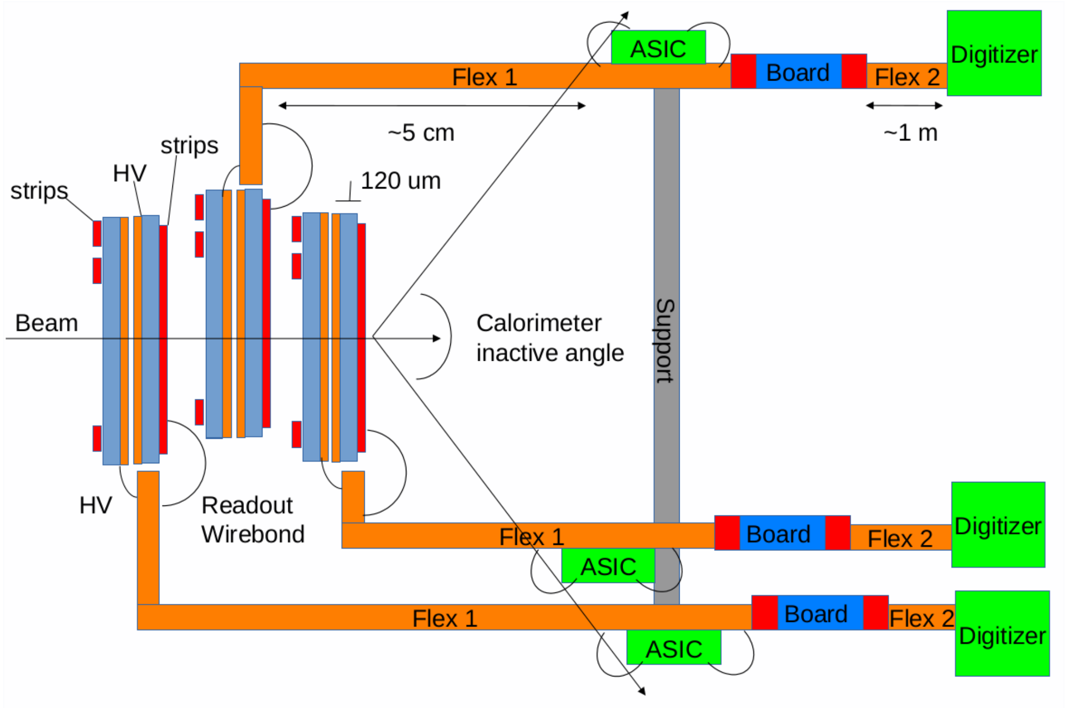


ATAR Services

- Desire from the collaboration to include ATAR services in the simulation geometry
- Since moving to Pacman geometry there is no nominal services and must be determined (Peter's Talk)
- Once again if someone has expertise in viewing and manipulating GDML files in a cad viewer please let us know

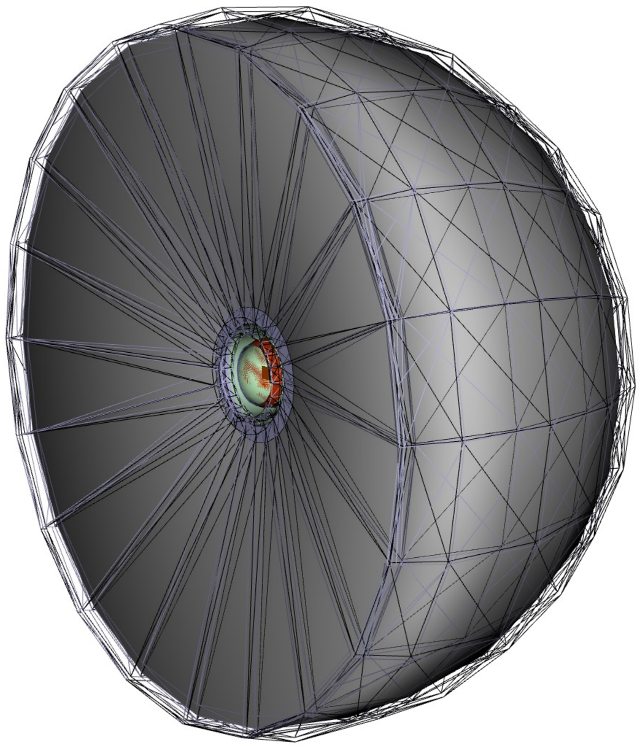
Tentative Simulation Flex Model For One Flex





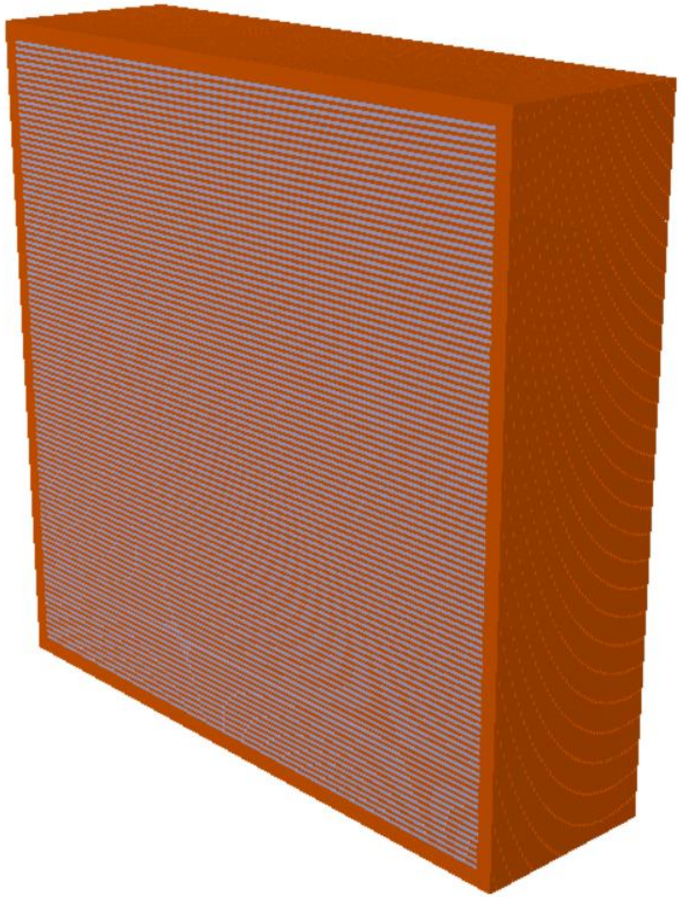
Conclusions and Future Work

- Much of the baseline ATAR is in the simulation and ready to begin a simulation campaign
- We need to determine a nominal design for the services and then coming up with a model to code into the geometry
- Melding the ATAR simulation effort back into the larger simulation framework effort
- Build in more accurate detector response
  - AC-LGAD charge sharing
  - Gain suppression



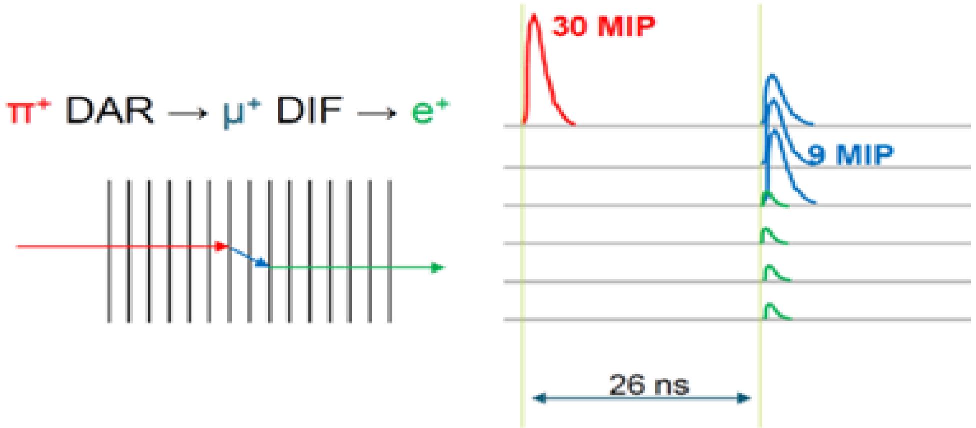
Double Sided Readout – Overview

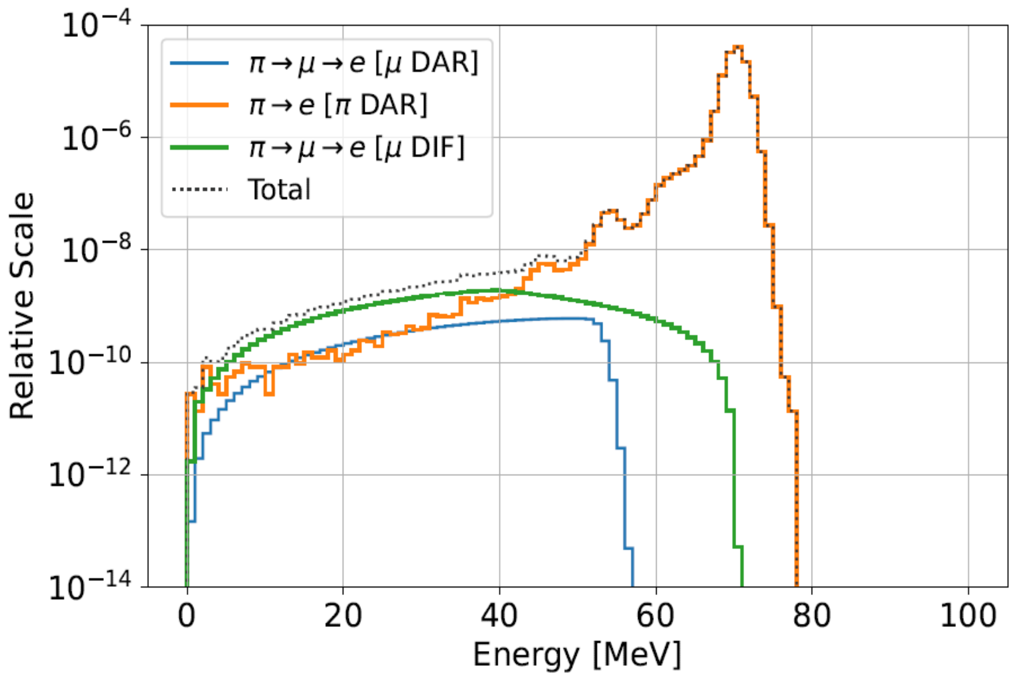
- Double Sided Readout Motivation
- ATAR Assembly Concept
- Structure of physical sensors
- Implementation into geometry



Brief Motivation

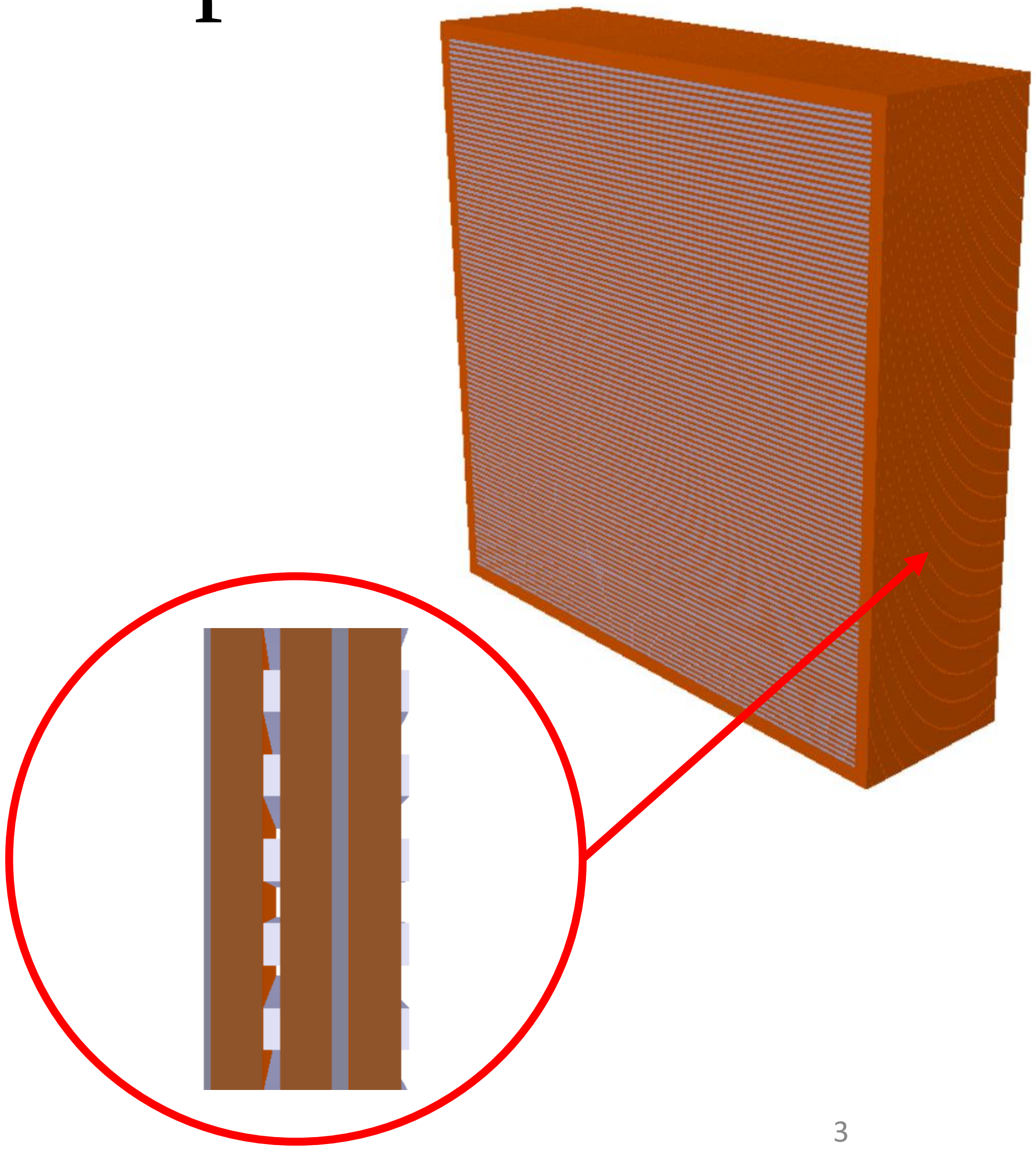
- Background rejection capability for μDIF
  - Need to achieve at least 1% of πeν tail
  - To identify energy deposit of 0.1-0.2 MIP ->must be able to see muon travelling 1 – 2 μm
- Large angle with respect to strips
- Need to minimize dead material and inter-sensor gaps!
  - Nominal geometry utilizes 25 μm layer gap
    - High chance of missing muon decay
    - Additional benefit of improved S/N
      - Reduced crosstalk and input capacitances -> lower ENC





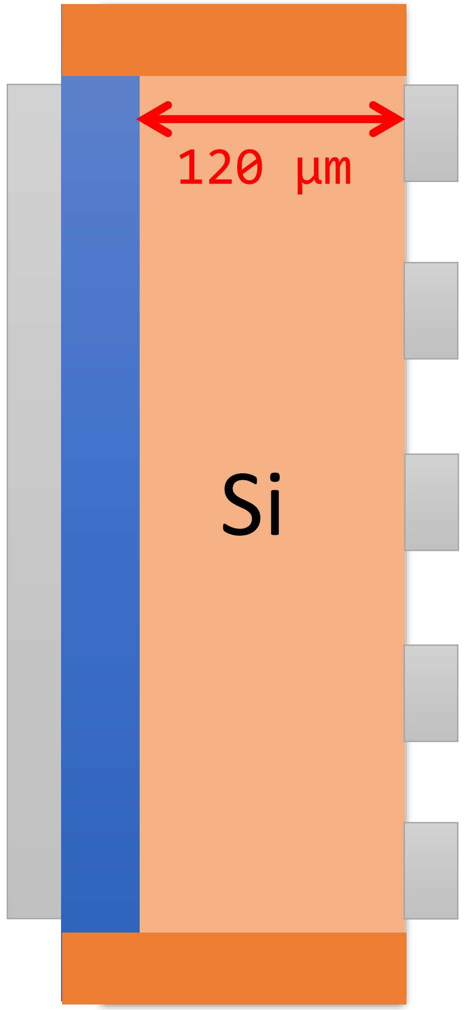
V1 Double Sided Assembly Concept

- Stacks of sensors with both sides instrumented for readout
  - V1 keeps each sensor the same dimensions
  - V2 will implement “pyramid scheme”
- Neighboring Si layers share readout
  - Orthogonal electrodes for x-y coverage
  - Mixed signal can be deconstructed
  - Known “cross talk”
- Gap between active regions defined by electrode thickness

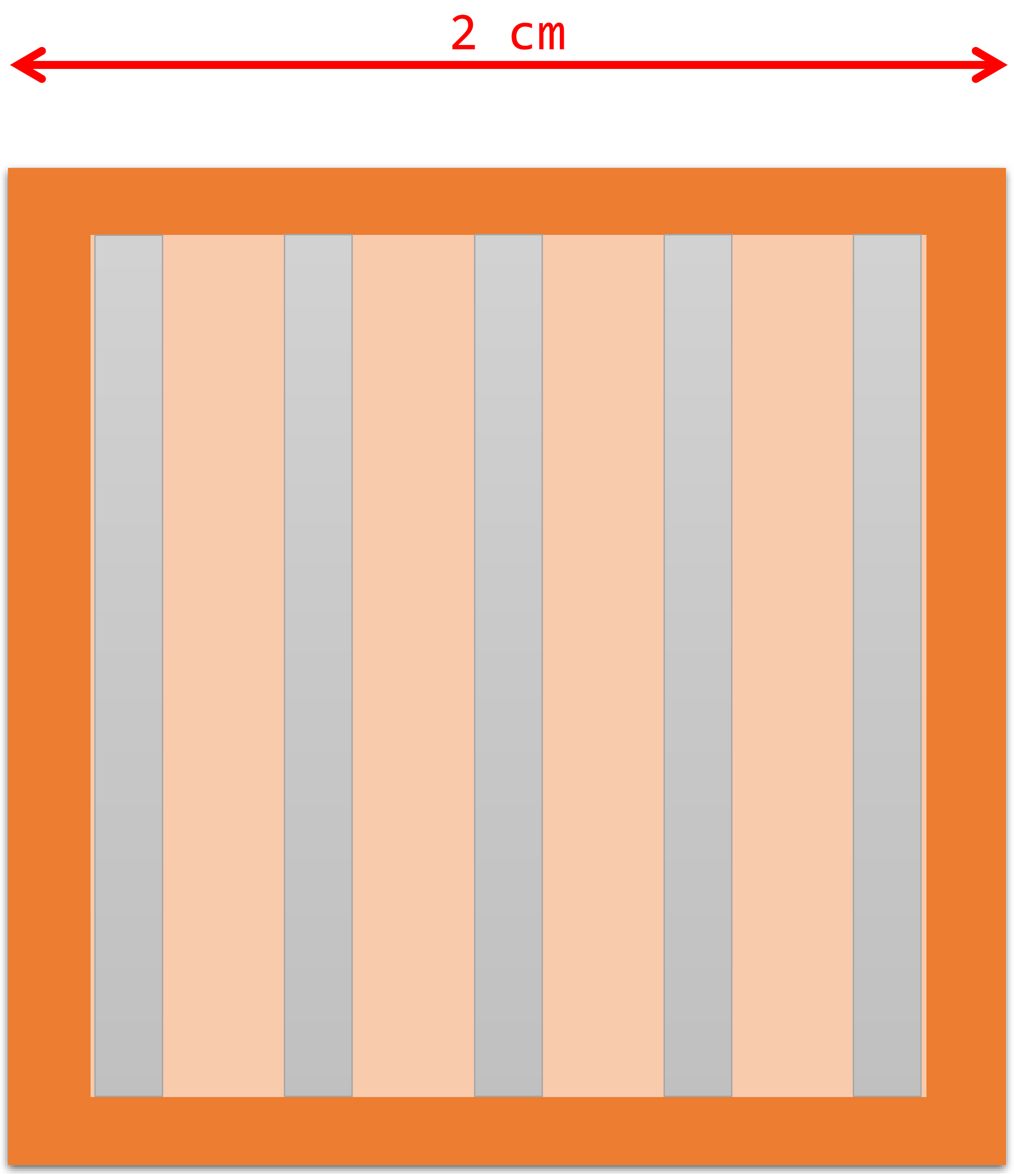


Geometry Implementation

- Si Bulk
  - 2 cm x 2 cm
  - 120 μm thickness



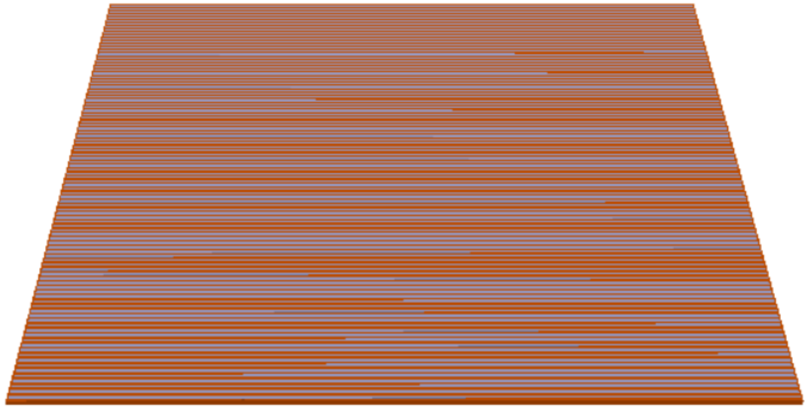
Side cross section

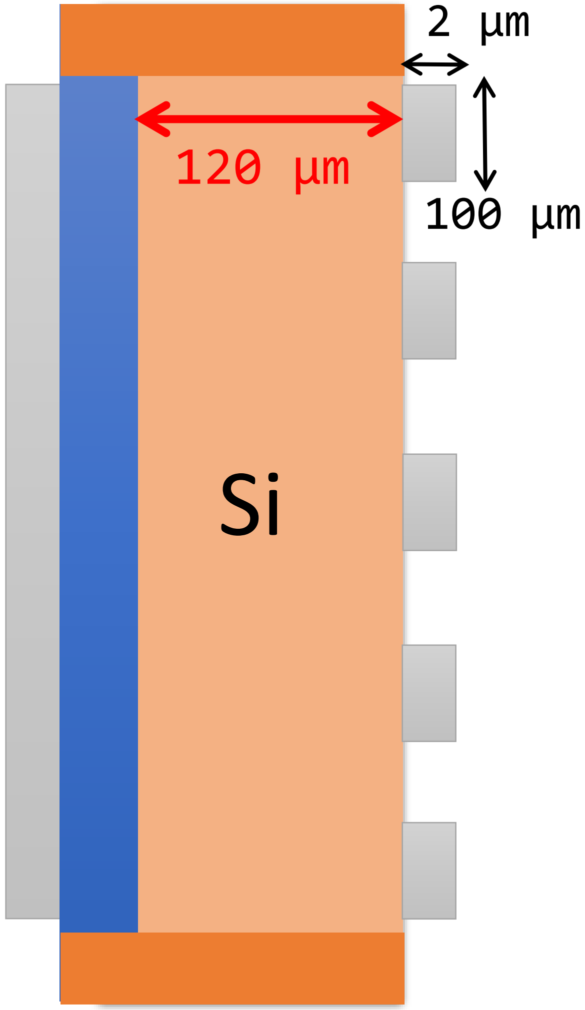


Top down

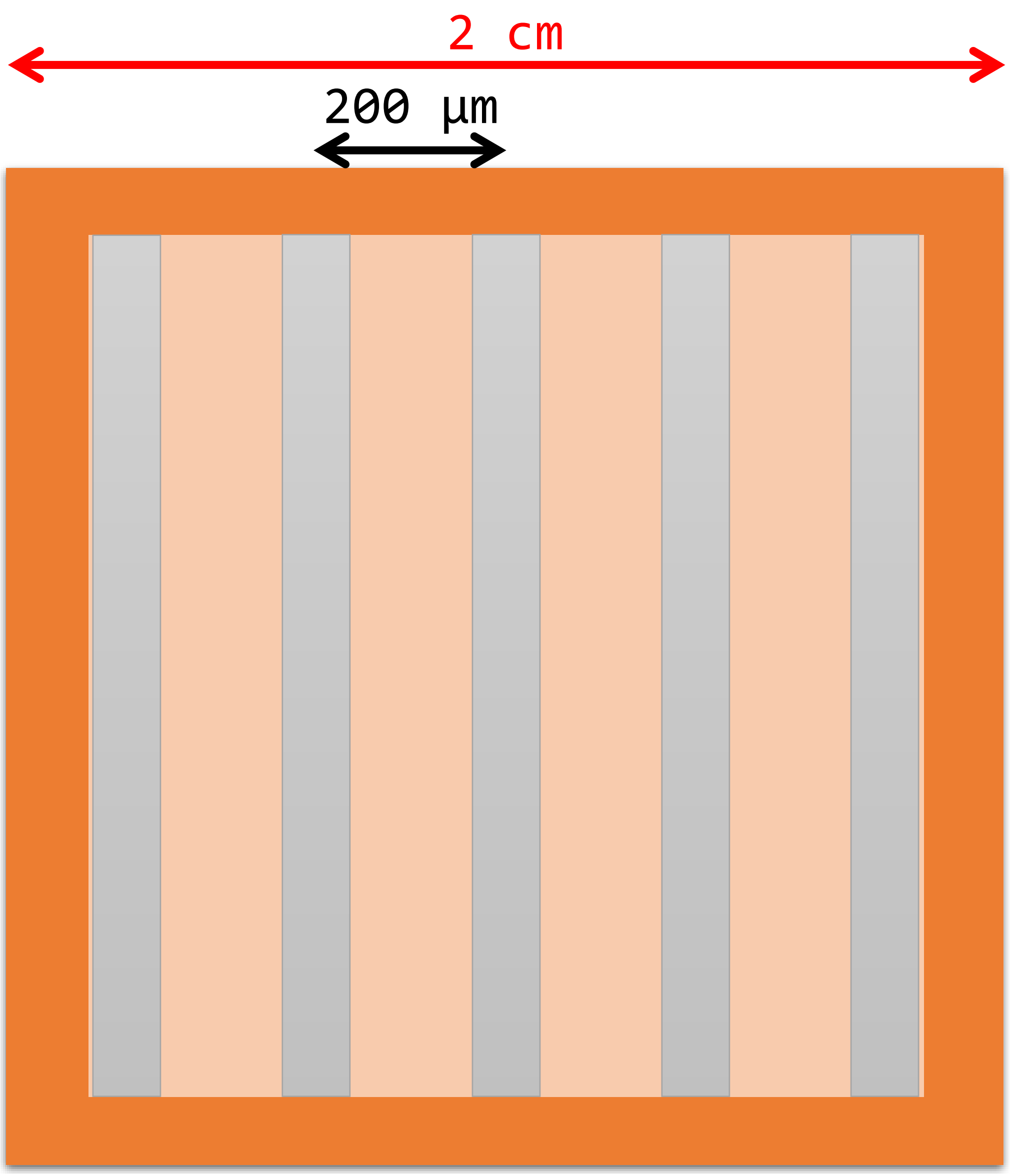
Geometry Implementation

- Si Bulk
  - 2 cm x 2 cm
  - 120 μm thickness
- 100 Electrodes each side
  - 2 μm thickness
  - 100 μm width
  - 200 μm pitch





Side cross section

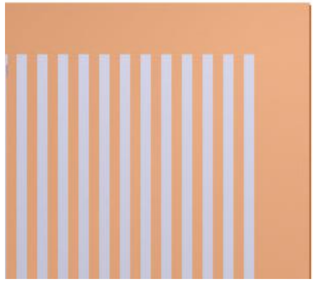


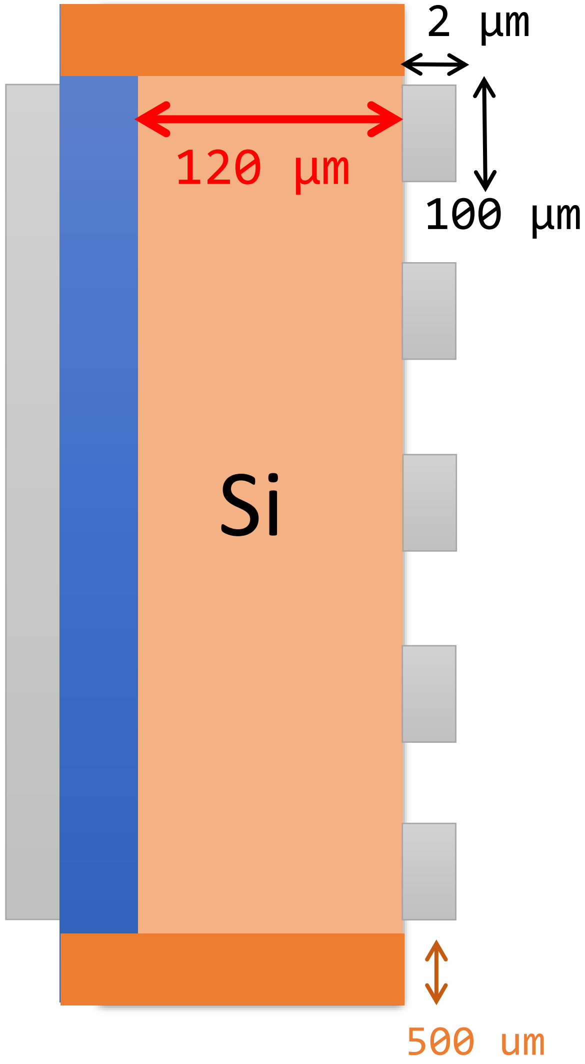
Top down

Geometry Implementation

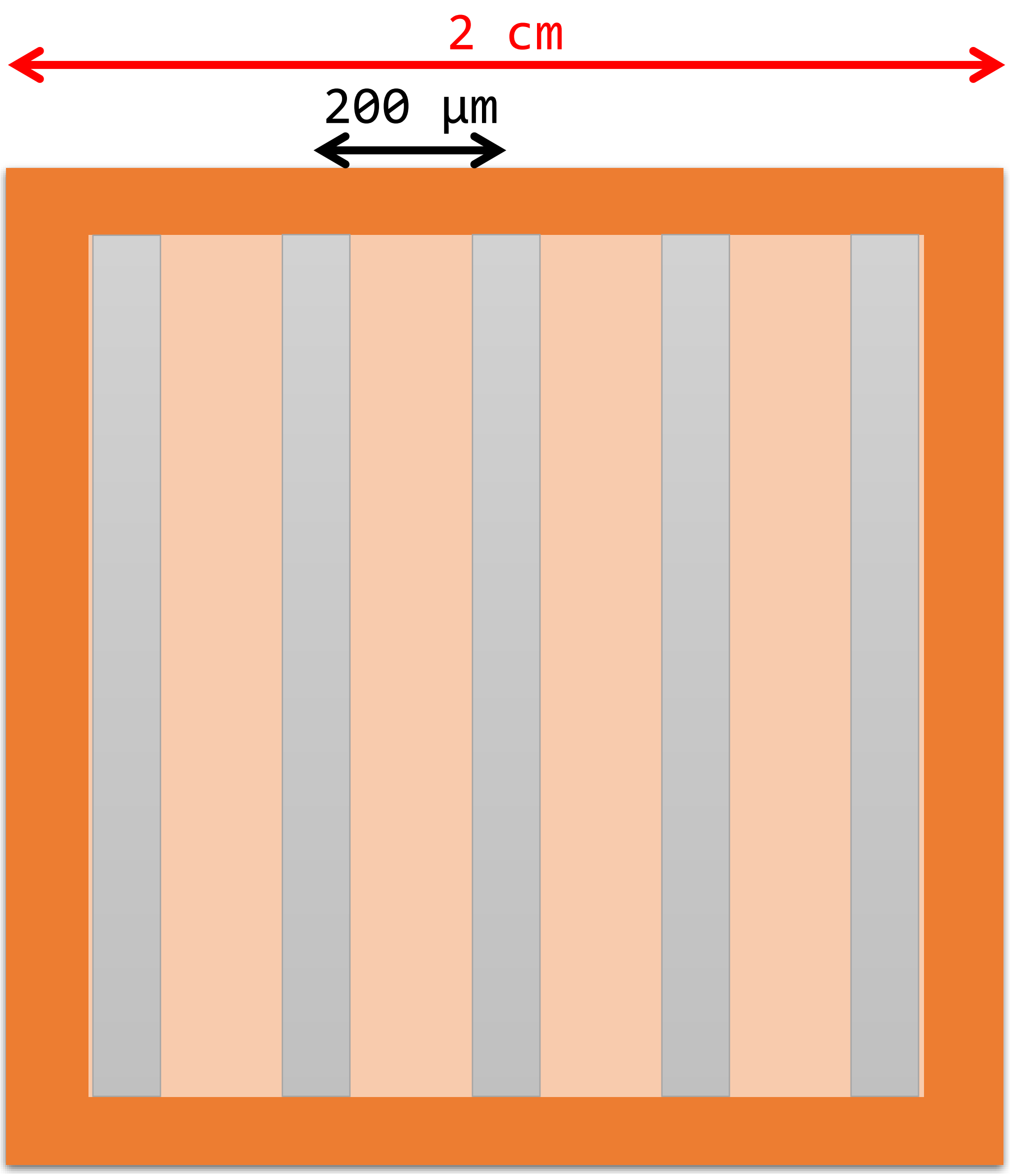
- Si Bulk
  - 2 cm x 2 cm
  - 120 µm thickness
- 100 Electrodes each side
  - 2 µm thickness
  - 100 µm width
  - 200 µm pitch
- Guard Ring
  - For geometry purposes just a wall of Si
  - 500 µm width

Motivated by current sensors produced by Gabriele!





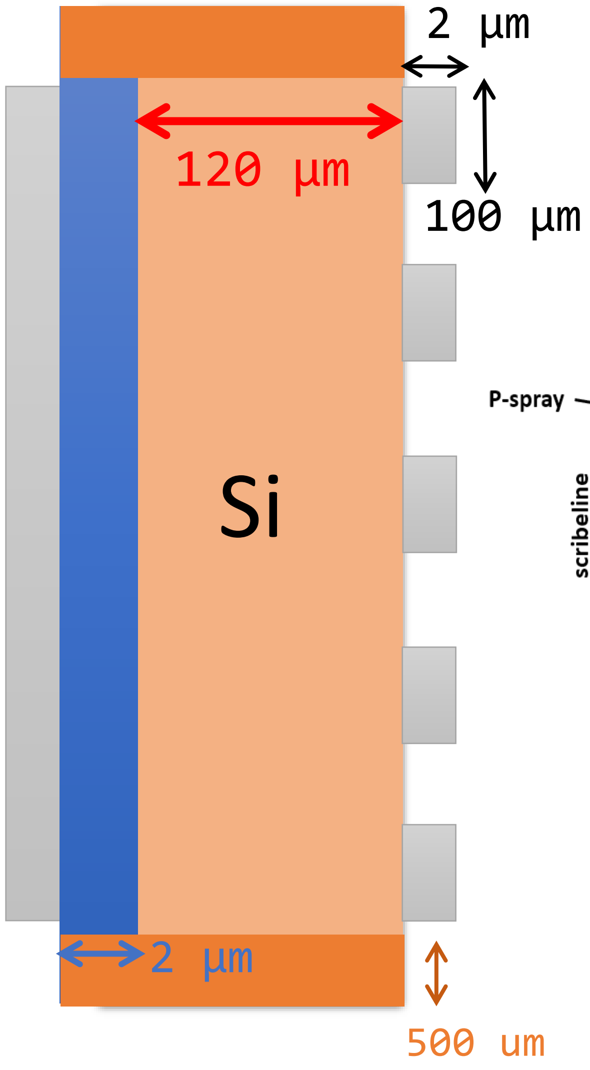
Side cross section



Top down

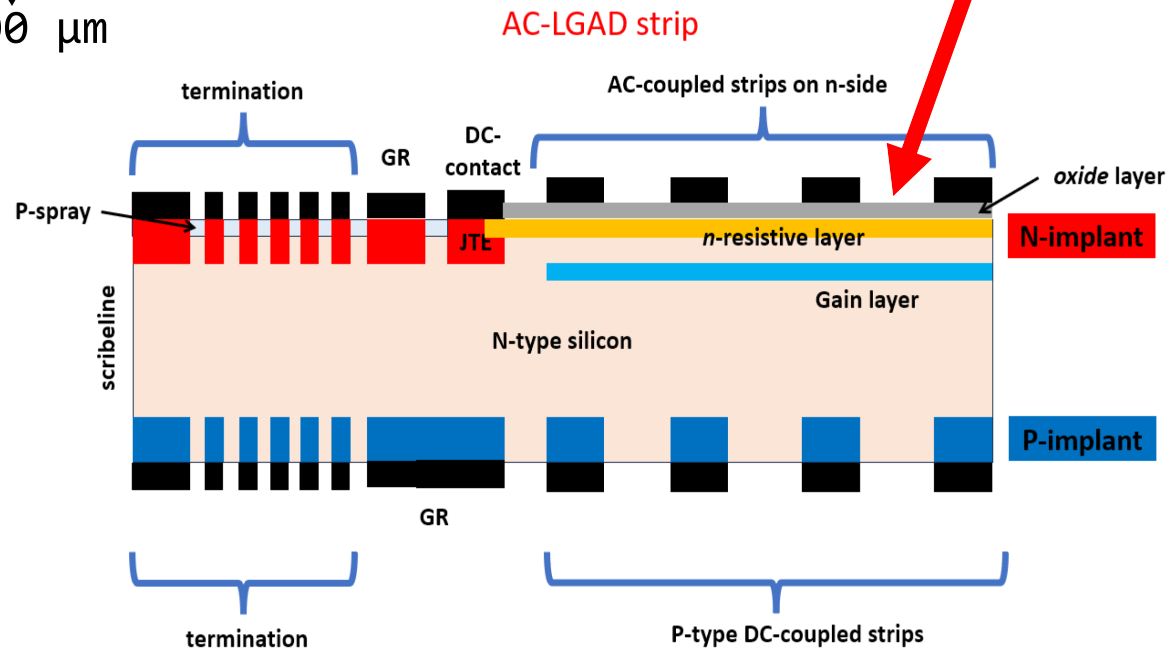
Geometry Implementation

- Si Bulk
  - 2 cm x 2 cm
  - 120 μm thickness
- 100 Electrodes each side
  - 2 μm thickness
  - 100 μm width
  - 200 μm pitch
- Guard Ring
  - For geometry purposes just a wall of Si
  - 500 μm width
- Dead Material
  - Representative of oxide and passivation
  - Also just Si
  - 1-2 μm thickness depending on sensor type



Side cross section

Under electrodes and above gain layer for AC LGADS



Gabriele Giacomini, 2023

Geometry Implementation

- Si Bulk
  - 2 cm x 2 cm
  - 120 μm thickness
- 100 Electrodes each side
  - 2 μm thickness
  - 100 μm width
  - 200 μm pitch
- Guard Ring
  - For geometry purposes just a wall of Si
  - 500 μm width
- Dead Material
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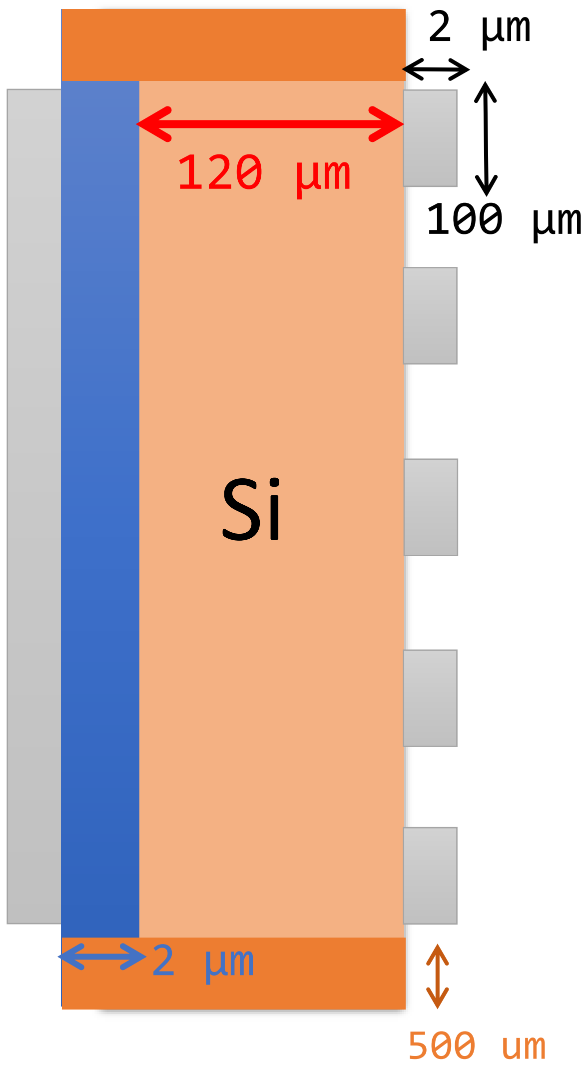
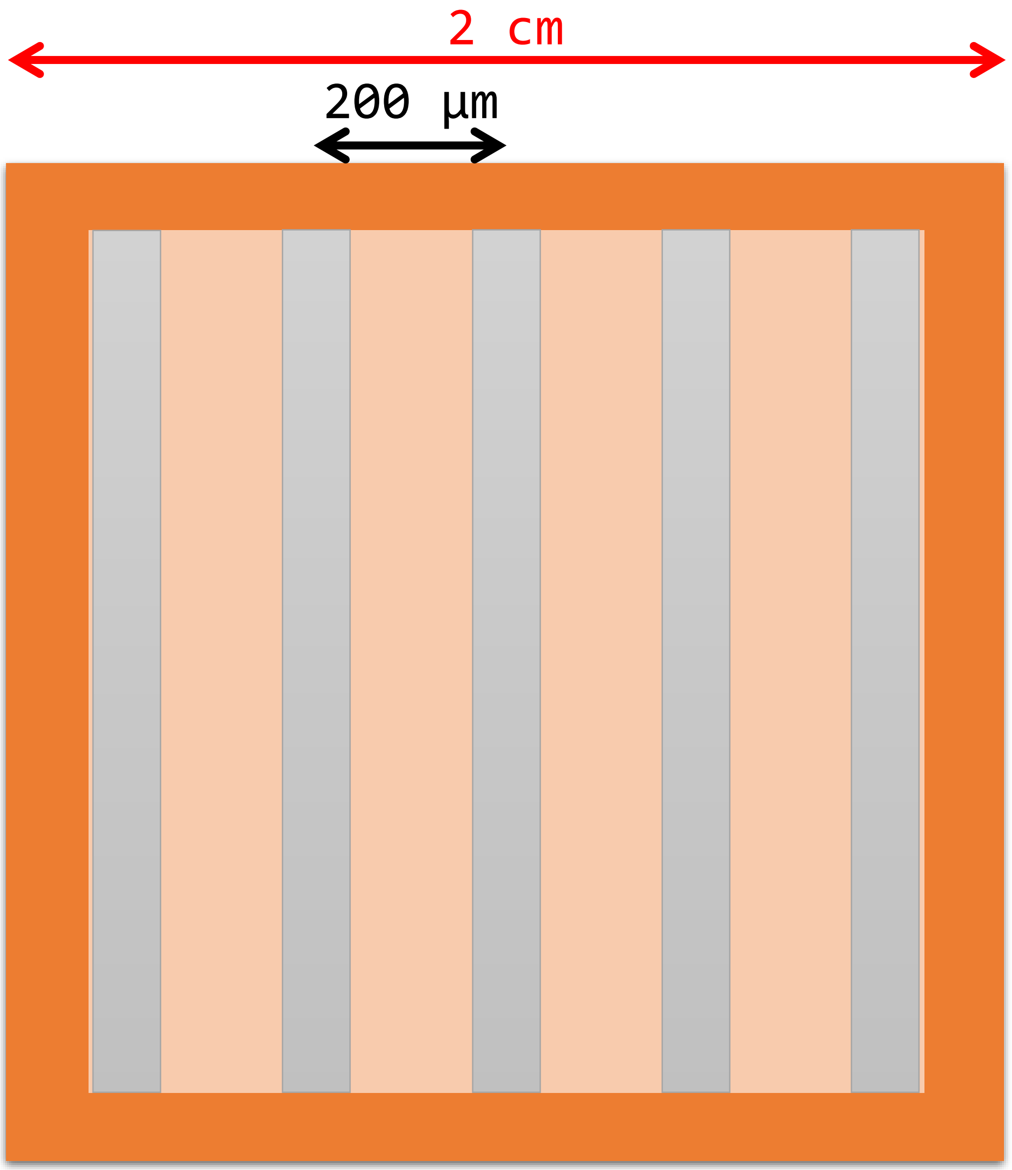


Side cross section



Top down

Parameters

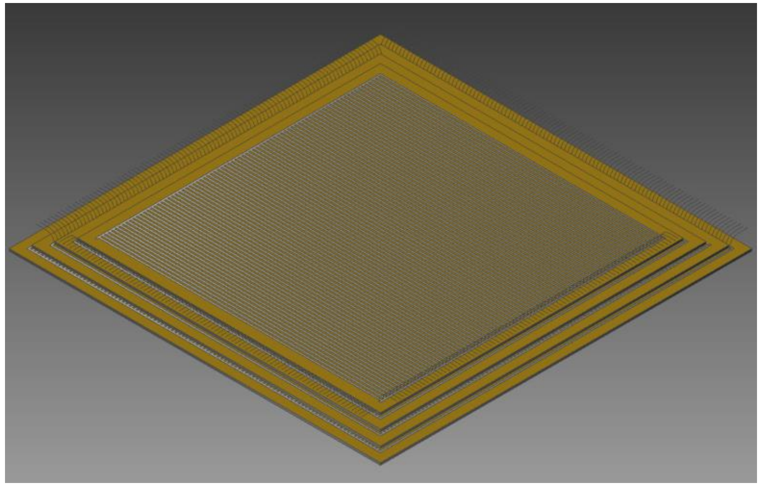
- "DoubleSided" boolean to use this geometry
  - Allows for single atar.py file with different configs (.json)
- Requires square sensor area
  - Strip width x N_{strips}= strip length
  - Required for proper alignment of electrodes

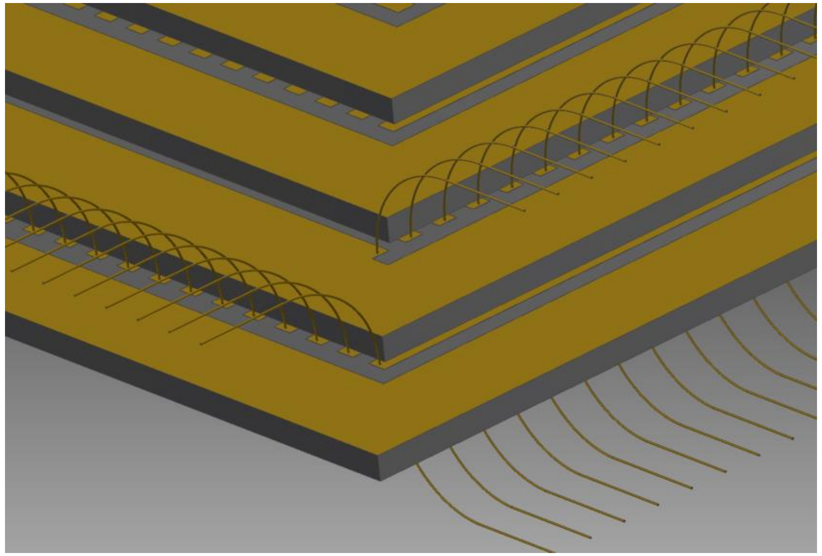
```
"target":{
    "DoubleSided": true,
    "xPos": 0.0,
    "yPos": 0.0,
    "zPos": 0.0,
    "nLayers"    : 48,
    "layerStagger":0,
    "stripWidth": 0.02,
    "stripLength": 2.0,
    "stripThickness":0.012,
    "nStrips"    : 100,
    "stripMaterial": "Silicon",
    "electrodeWidth": 0.01,
    "electrodeMaterial":"Aluminum",
    "instrumentWithTILGAD":false,
    "TILGADTrenchWidth":0,
    "backingAndElectrodeThickness":0.0002,
    "backingMaterial":"Aluminum",
    "hvThickness":0,
    "hvLengthPastSensor":0,
    "hvMaterial":"Kapton",
    "makeGuard":true,
    "guardWidth":0.1,
    "guardMaterial":"Silicon",
    "layerBuffer" : 0,
    "debug":false,
    "passivationLayer" : true,
    "passivationThickness" : 0.0002
```

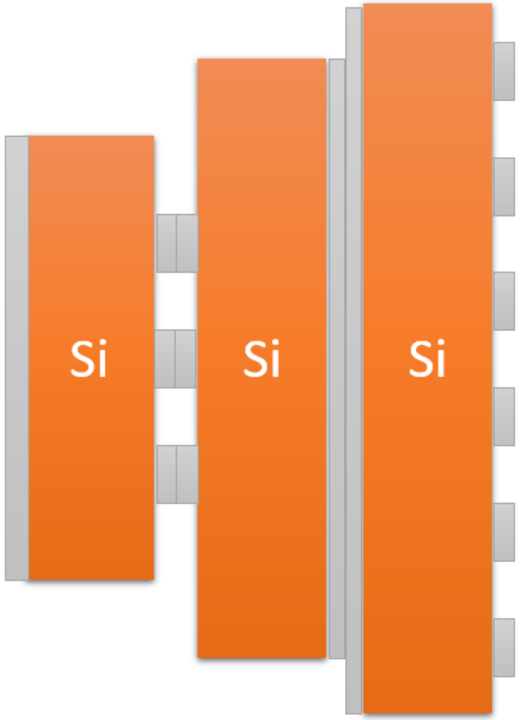
examples/atar_only_doubleside.json

Next Steps

- Geometry additions
  - V2 “Pyramid Scheme”
  - Readouts/Route in HV
- Framework to handle Double Sided
  - Not implementing strips -> use voxelization/segmentation
    - Needs to be figured out (Guidance appreciated)





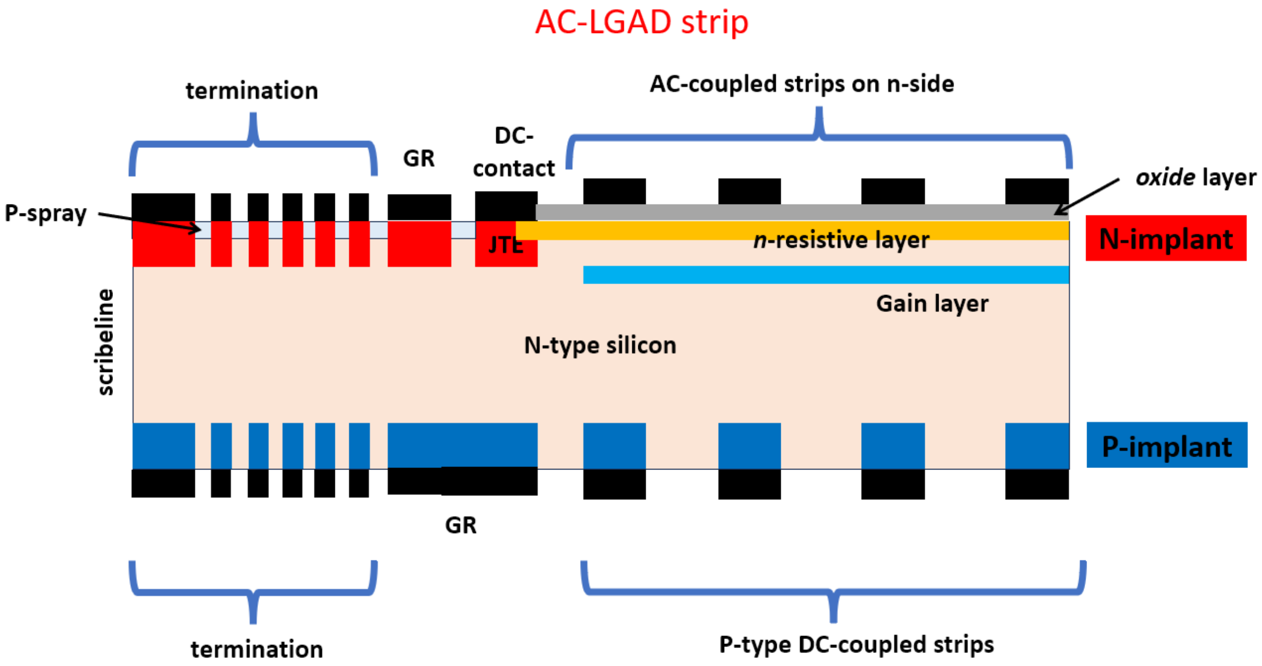


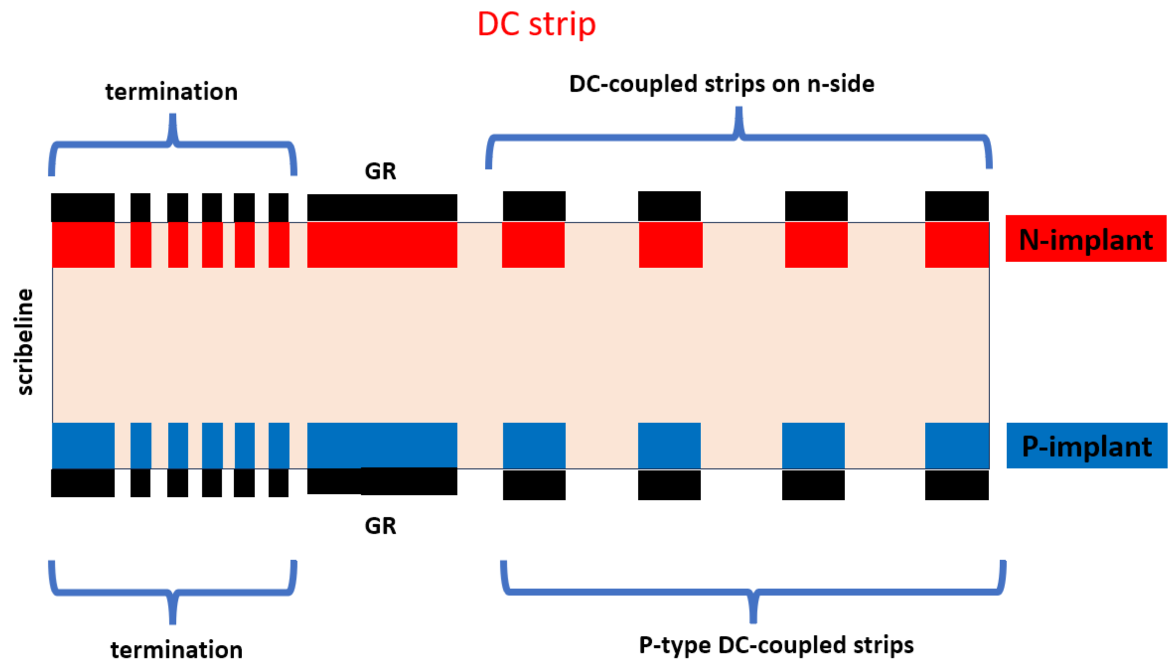
Next Steps

1. First demonstrate readout capability
2. Overall improvement on background rejection compared to nominal
3. Effectiveness of gap reduction
   - 25 -> 4 μm (2x electrode thickness)
4. Performance over different Si bulk thicknesses
   - Challenges in producing 120 μm wafers at BNL
   - How much can we afford to increase?

Backup

BNL Sensors





Gabriele Giacomini, 2023