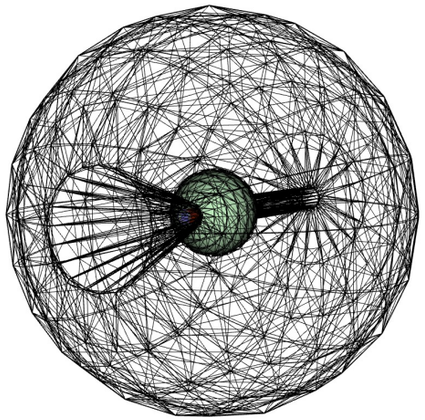
Charge Sharing for AC-LGAD Sensors in Simulation for PIONEER and Beyond

Adam Molnar

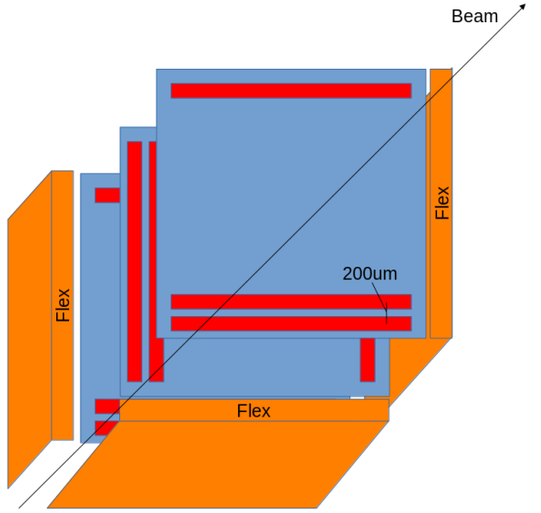
on behalf of the Ultra Fast Silicon Detector Group at SCIPP

Introduction to the PIONEER Experiment

- PIONEER is a next-generation experiment to measure the charged-pion branching ratios to electrons vs muons, $R_{e/\mu}$ and pion beta decay (Pib) $\pi^+ \rightarrow \pi^0 e \nu$
- In the first phase of PIONEER the goal is to improve the $R_{e/\mu}$ measurement by a 15 fold increase on the experimental sensitivity
- In order to do this this experiment is adding a novel element, when compared to previous PION decay experiments (PIENU and PEN) an Active Target (ATAR)
- The ATAR will be instrumented with LGADs, nominally 48 layers of AC-LGAD strip (200 μm pitch/100 μm metallization/2cm long strips) sensors staggered to allow for wire bonding



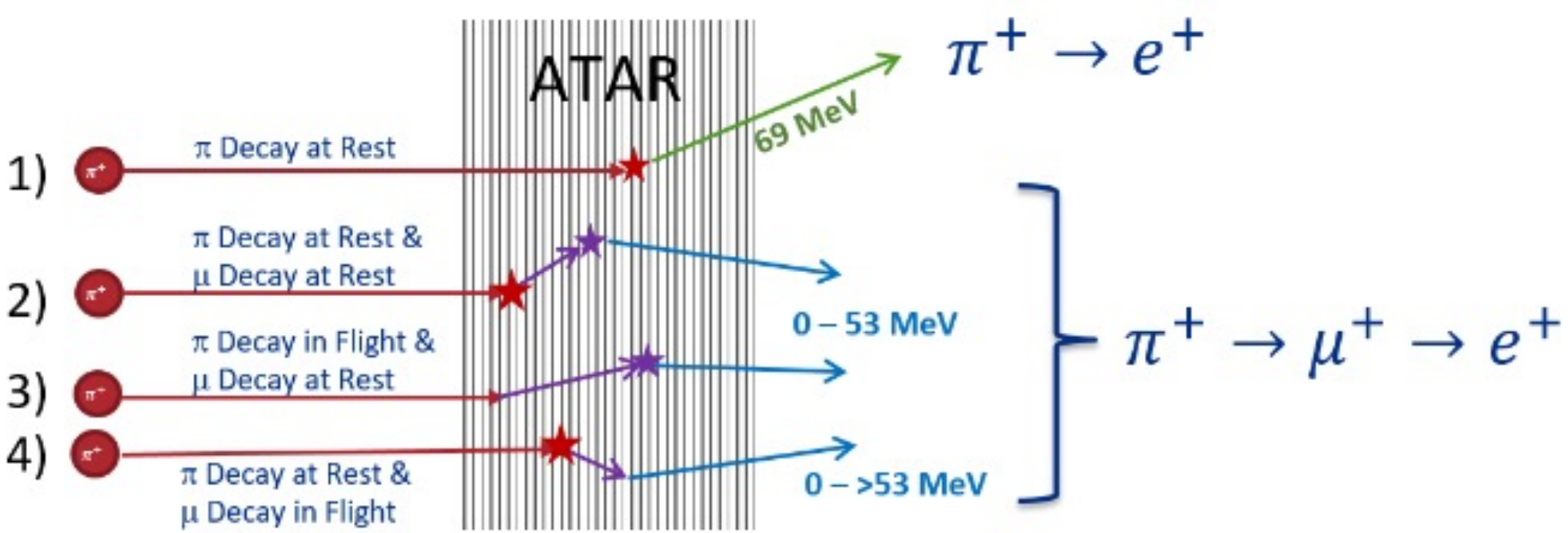
PIONEER Experiment



ATAR

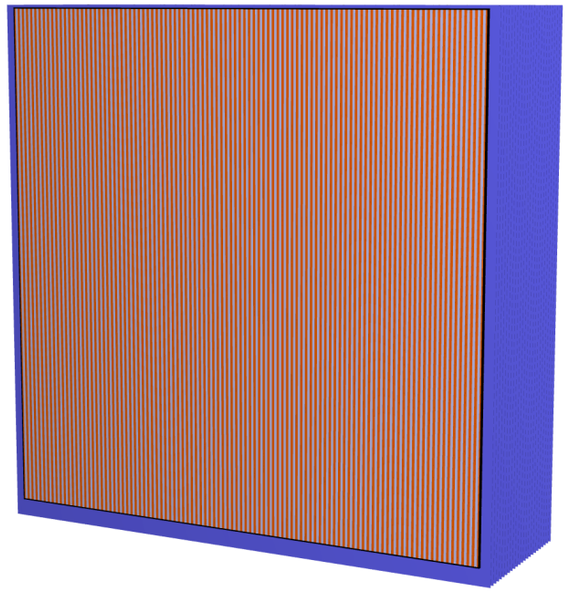
Why an ATAR?

- The full power of 5 dimensional tracking (x, y, z, t, and E) is needed to reach the desired sensitivity
- Namely need to be able to differentiate two body signal decay (1) from the different background decay methods (2-4)
- The ATAR will experience a large dynamic range in energy ranging from MIP signals from the positrons to several MeV signals from pions or muons
- A lot of current work is going into determining what kind of silicon detector will instrument the ATAR due to factors such as gain suppression, AC-LGAD charge sharing, and LGAD dead material



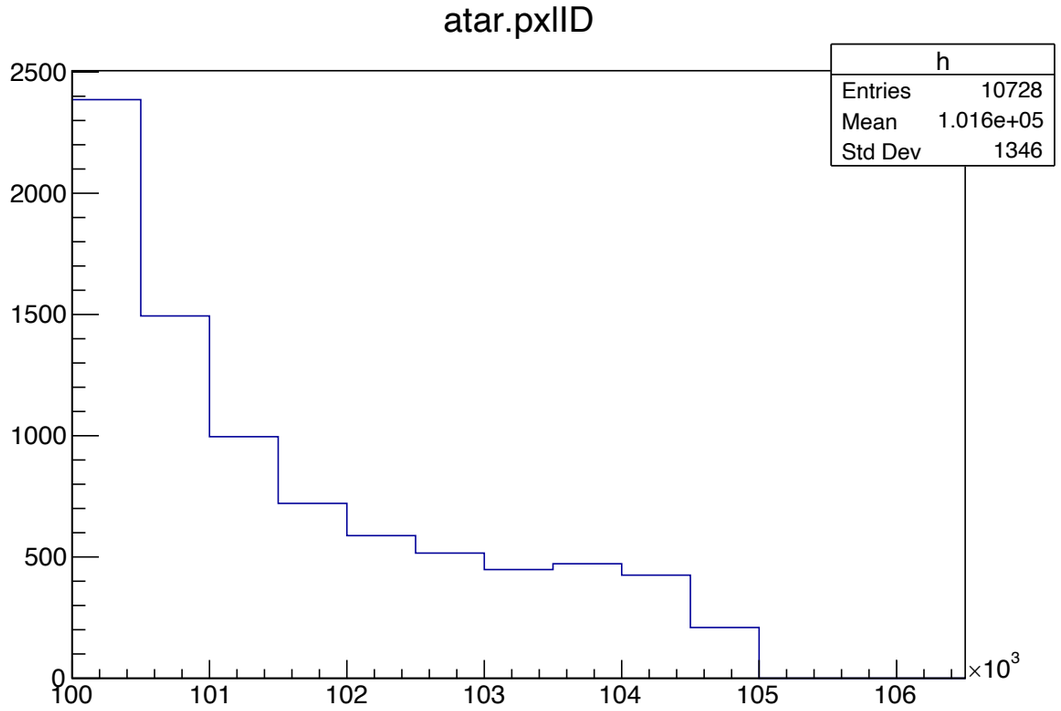
PIONEER Simulation

- A multi institute effort to understand the intricacies of the PIONEER experiment
- I am leading the ATAR simulation effort on behalf of SCIPP
- Until now focused efforts on implementing a more accurate geometry of the ATAR into the simulation
- In the near future will be starting the PIONEER “simulation challenge”. An effort to run the full PIONEER analysis package



Detector Response

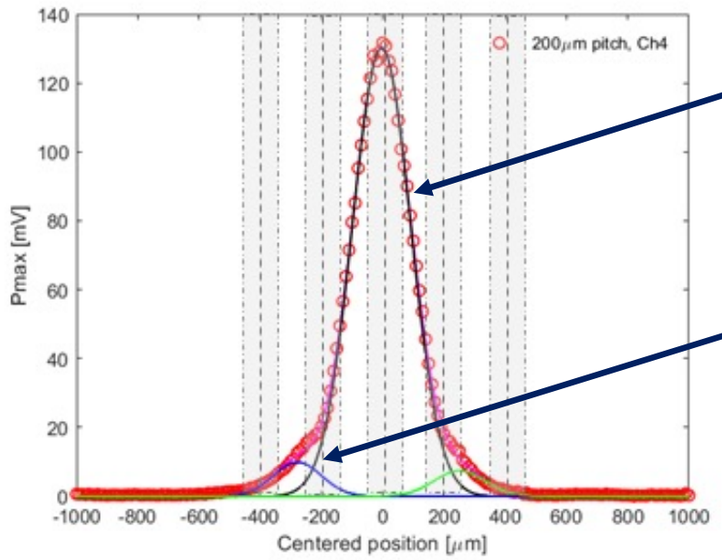
- Currently turning my efforts to implementing detector signal response (PiN, AC-LGAD, TI-LGAD, etc)
- Namely this includes implementing AC-LGAD charge sharing into the PIONEER experiment
  - Implementing AC-LGAD charge sharing both spatially and temporally is currently in the initial phases of deployment
- Currently there is only truth level hit information for each of the strips in the PIONEER simulation



Charge Sharing Model

- The charge sharing model that SCIPP has deduced from data is a triple Gaussian model
  - Depends on some variables such as the n+ layer plan to make general using data + simulation
- The primary largest Gaussian corresponds to the metallization of the primary strip
- The secondary and tertiary gaussians are sharing on the neighbors and next to neighbors
- Charge sharing will be three Gaussian peaks that can be parametrized according to test beam or laser data plus a constant noise offset

Test Beam Data Charge Sharing Profile



Primary Gaussian

Secondary Gaussian

Data Taken from Jenni Ott

How we can Help the TOF Group

- Provide this model and fits for the Gaussian for the nominal PIONEER geometry
  - And provide a way to account for metallization/pitch
- Work with the group, and identified student, on developing the charge sharing code,
  - I am actively working on this code for the PIONEER collaboration

- What will not be applicable for PIONEER:
  - Provide a model for pixels
  - Build in a way to account for bulk thickness

Questions?