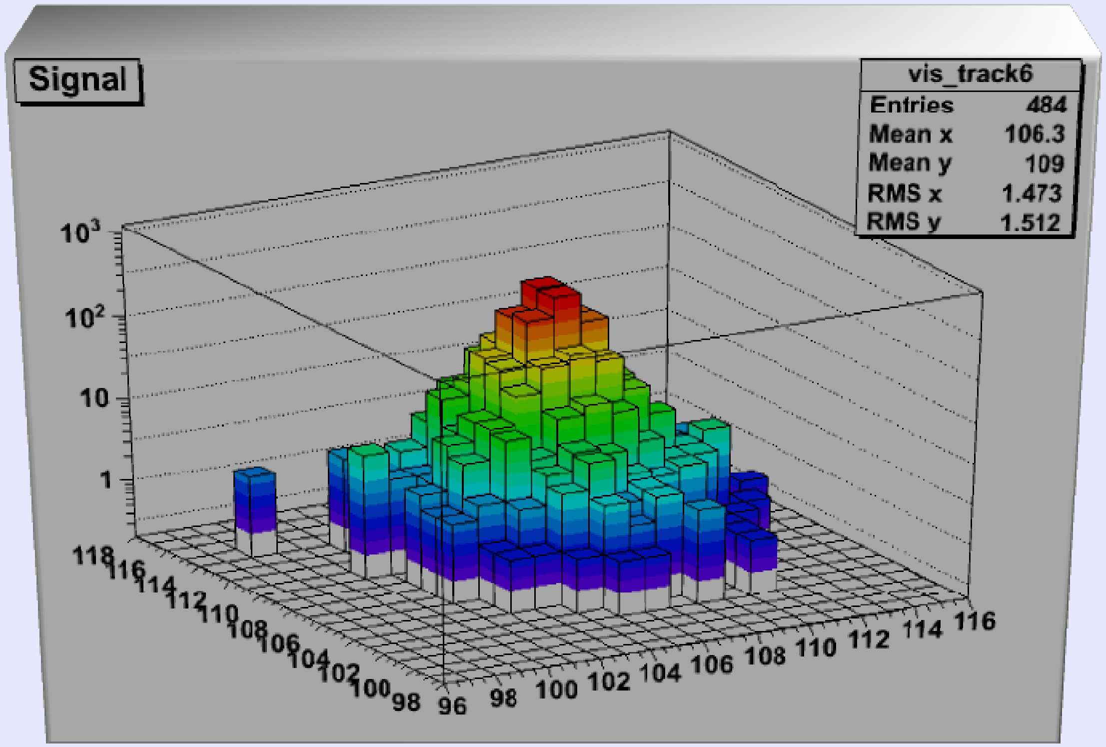
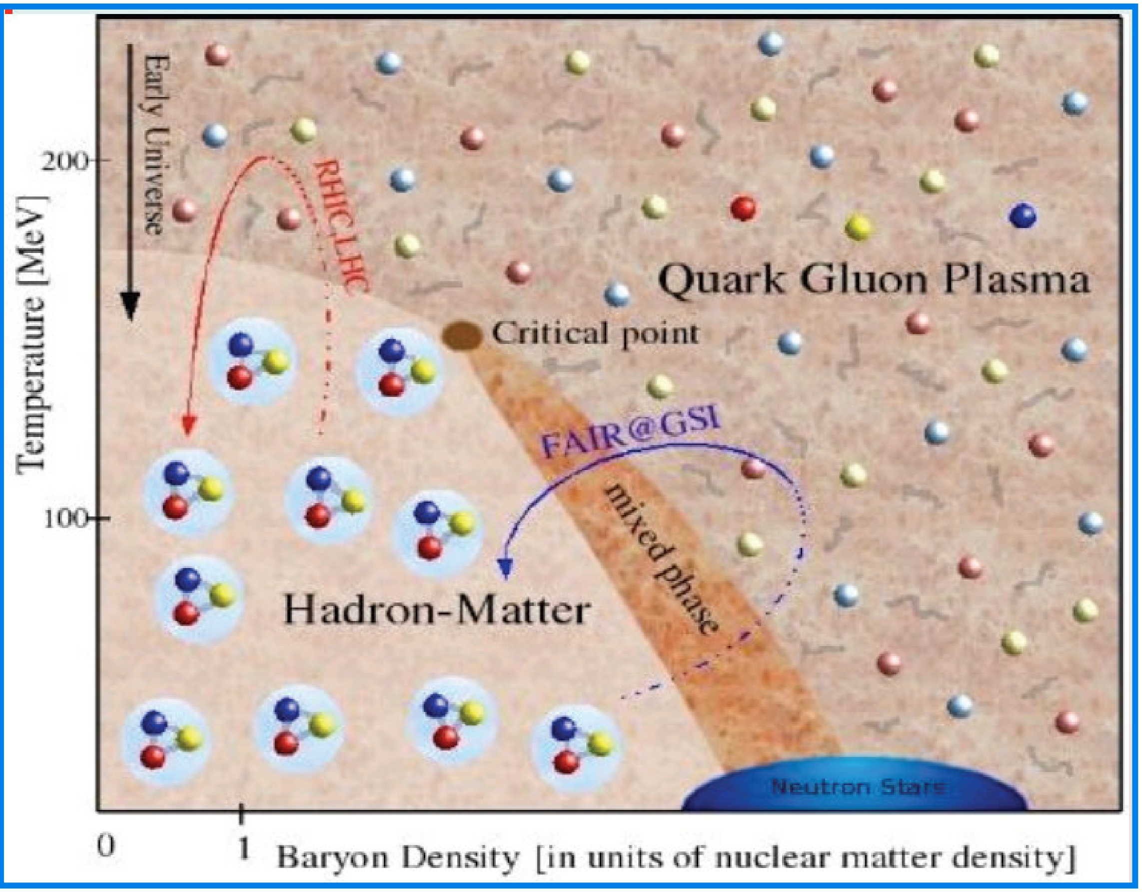
Simulation on the Response of the STAR HFT Pixel Detector



Alex Cimaroli
Purdue University
Advisor: Prof. Xie

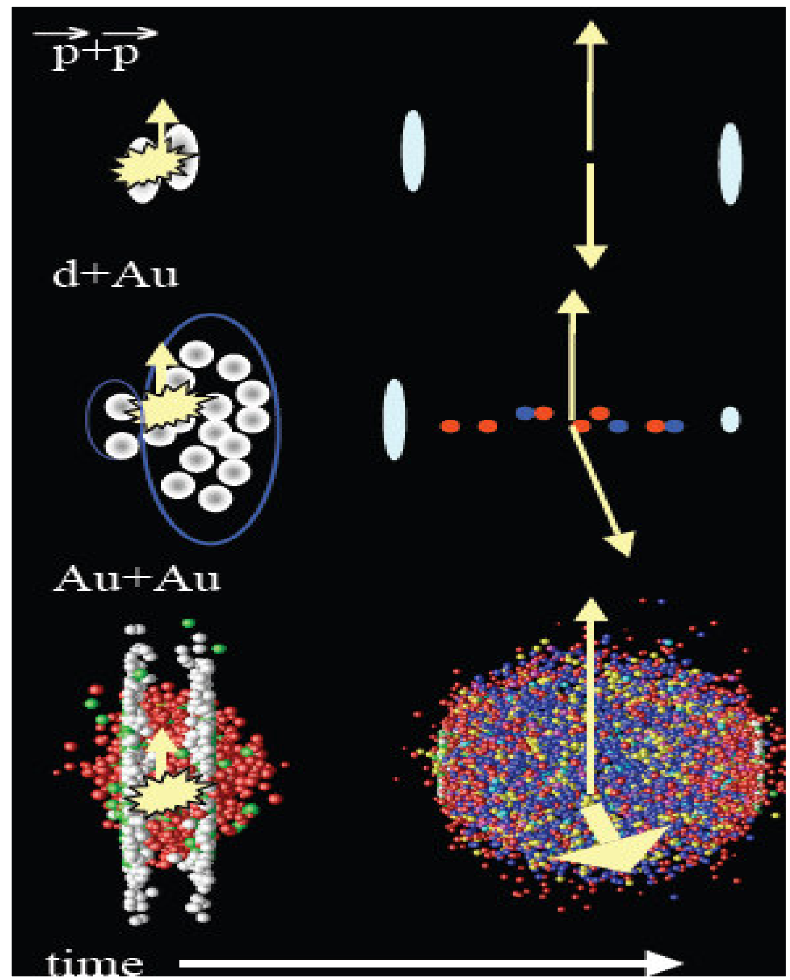
07/23/09



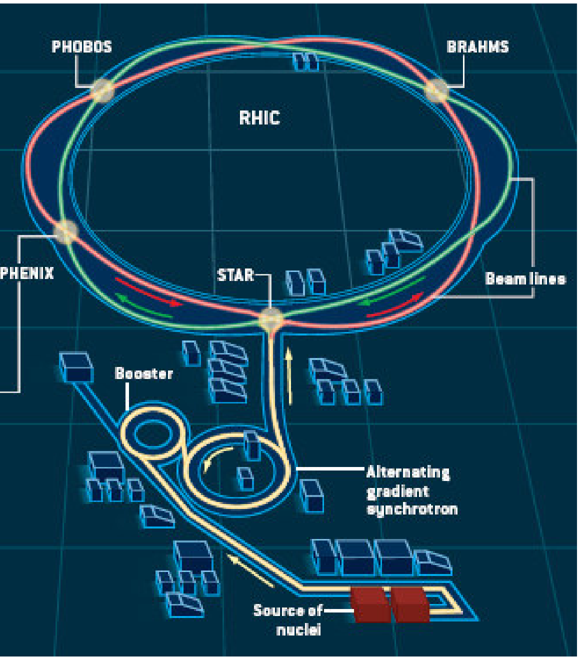
- Quarks come in six varieties: up, down, strange, charm, bottom, and top.

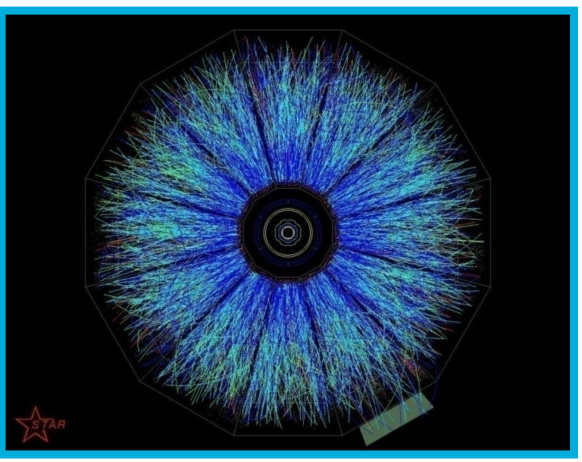
Gluons bind quarks into mesons (2 quarks) and baryons (3 quarks) – this is called "confinement".

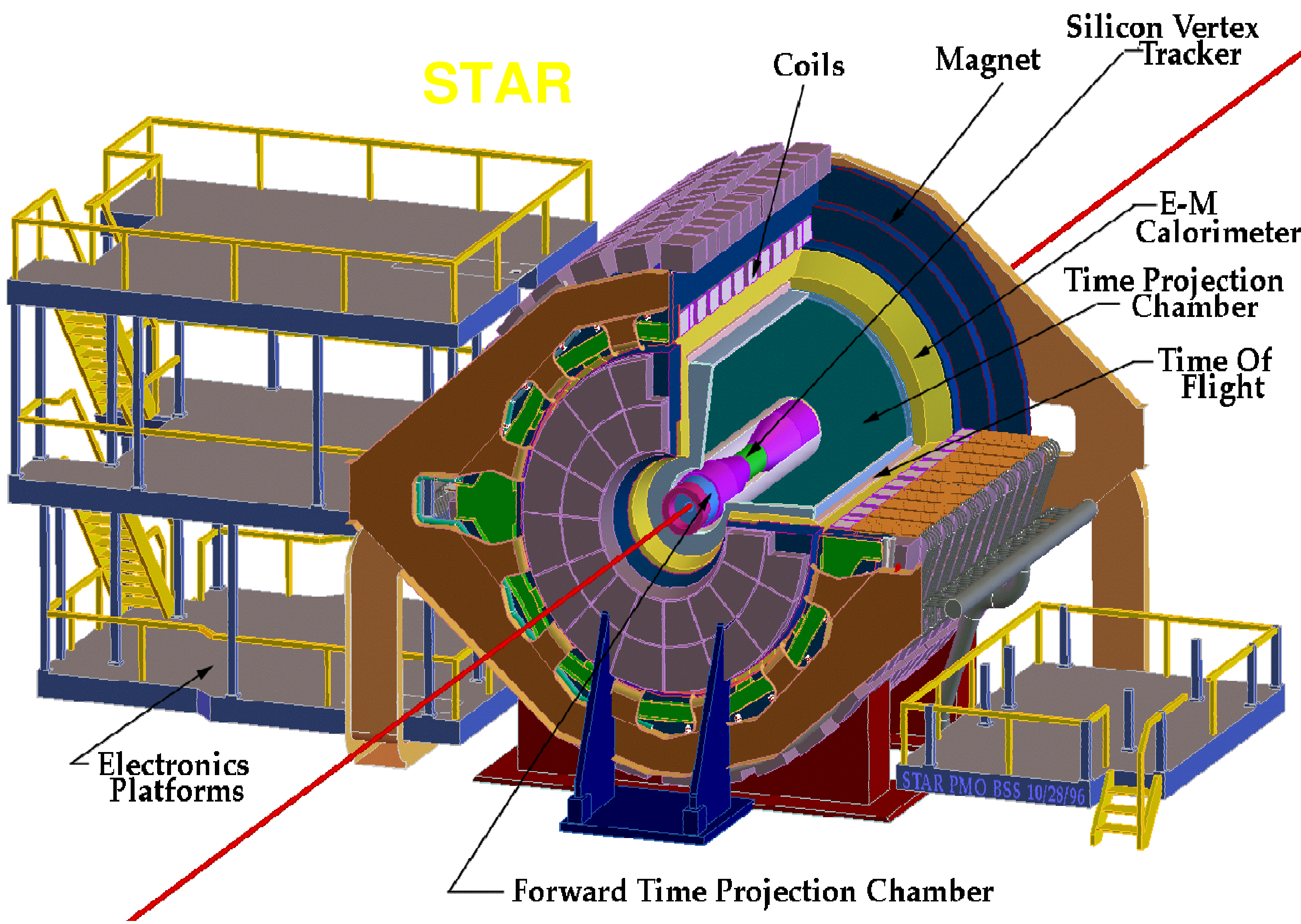
- Scientists believe that quarks were free from "confinement" during the first few moments after the Big Bang, and formed **quark-gluon plasma.**
- During heavy-ion collisions, a "perfect fluid is observed.
- The QGP is expected to form in heavy-ion collisions in RHIC experiments.



RHIC STAR Experiment

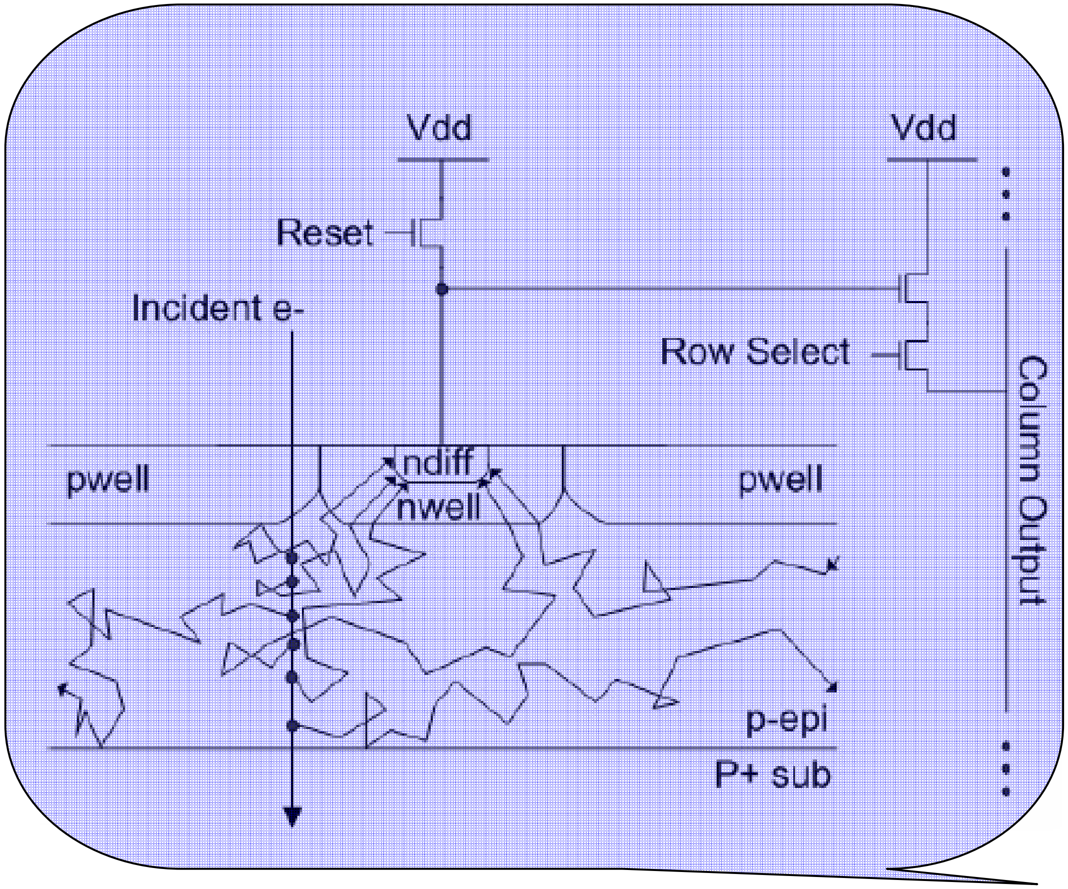


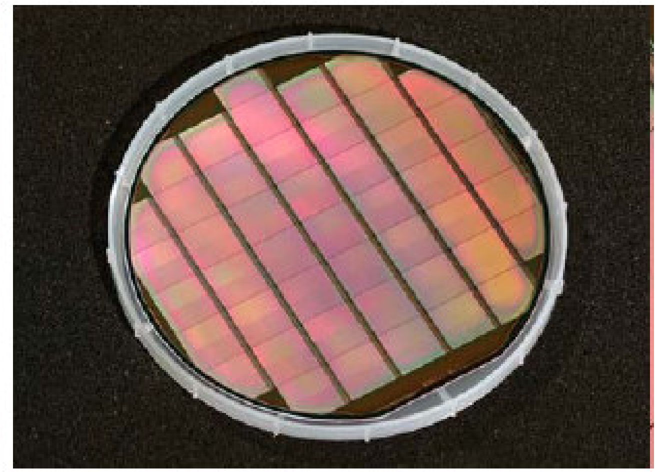


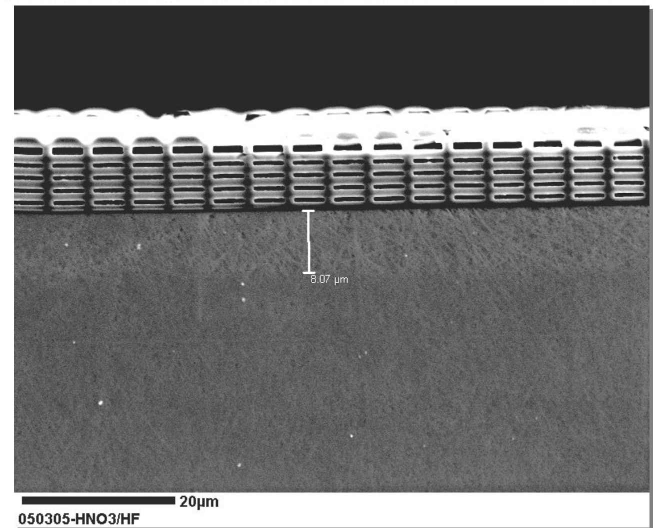


The Solenoidal Tracker at RHIC (STAR) detector is located at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL). STAR's main task is to study the characteristics of the matter produced in these collisions, particularly the quark-gluon plasma (QGP), which is expected to have been created a few microseconds after the "Big Bang." The Heavy Flavor Tracker (HFT) is the core of the future STAR heavy flavor physics program and will soon enable STAR to directly measure heavy flavor mesons.

CMOS Active PIXEL Sensor (APS)







The HFT is using the CMOS Active PIXEL Sensor (APS) technology for several reasons:

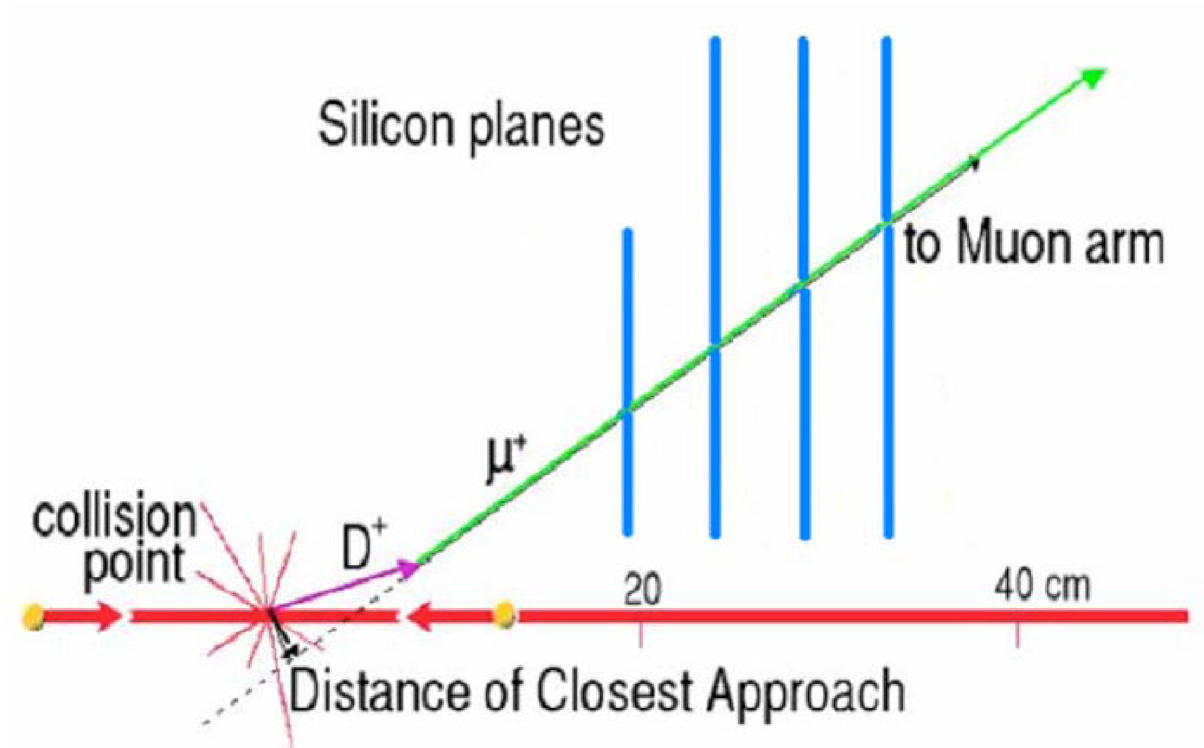
•Capable of excellent spatial resolution and charge collection efficiency.

•Satisfactory radiation tolerance.

•When a charged particle traverses the PIXEL sensor, it creates ionized electrons in the epi and sub-layer, and these electrons can diffuse freely in these layers until they are collected by the n-well or recombined.

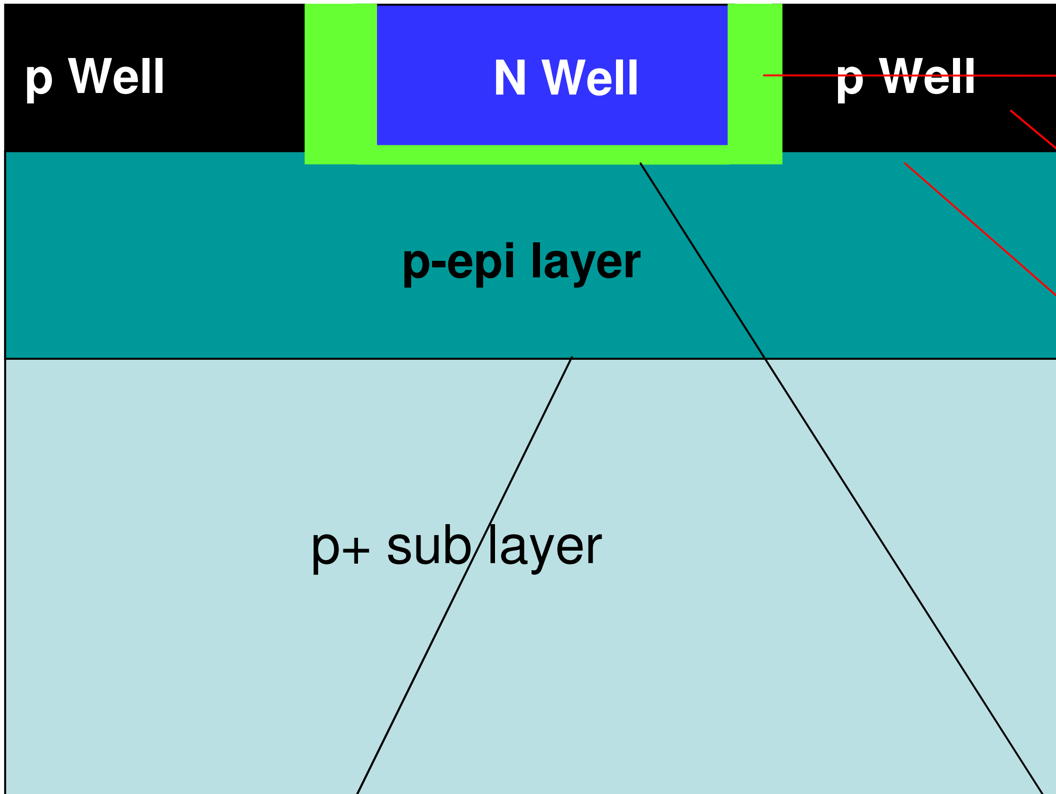
The output electronics converts collected charge to voltage level before passing it to readout electronics, thus gaining the name "active pixel."

How to "Detect" Heavy quarks



The Distance of Closest Approach is used to determine if a quark
Is light or heavy.

PIXEL Response - Boundary Conditions



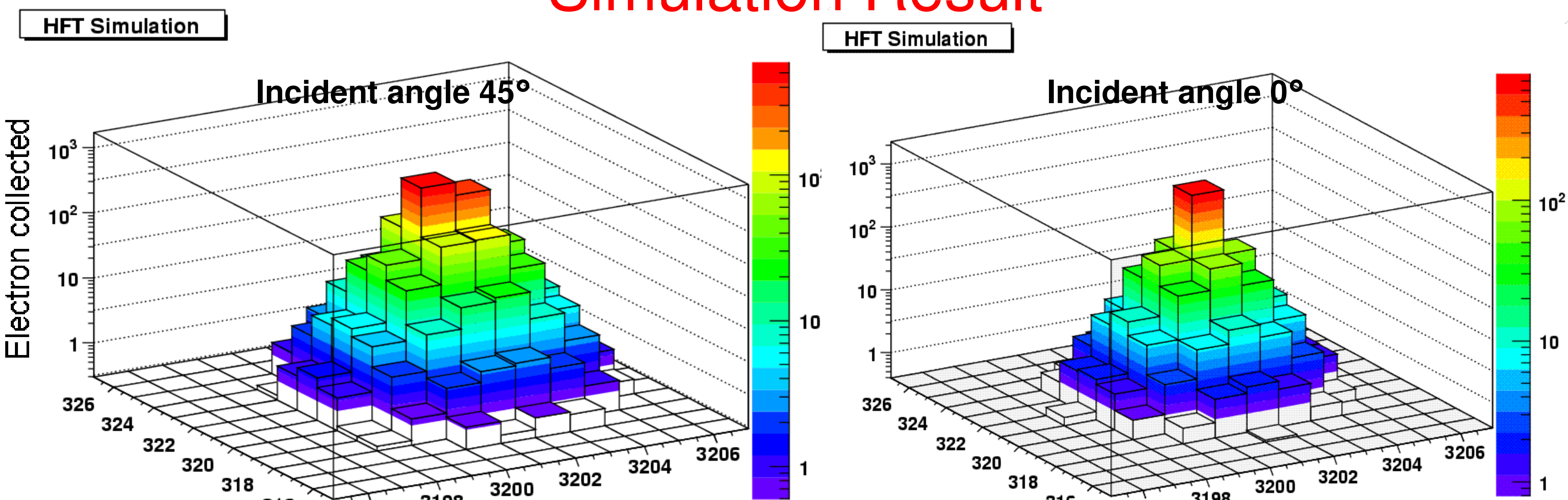
- When the electron fall into the depletion region between N-Well and P-Well or the N-well region, it will be fully collected into the readout electronics.
- Electrons in the p-well region will be neglected.

- When electron hits the p-epi and p well interface, the p-well/p-epi interface can be recognized as a boundary with total reflection for electrons in the epitaxial silicon because pWell are more heavily doped and electric field in the depletion region will reflect the electron away.

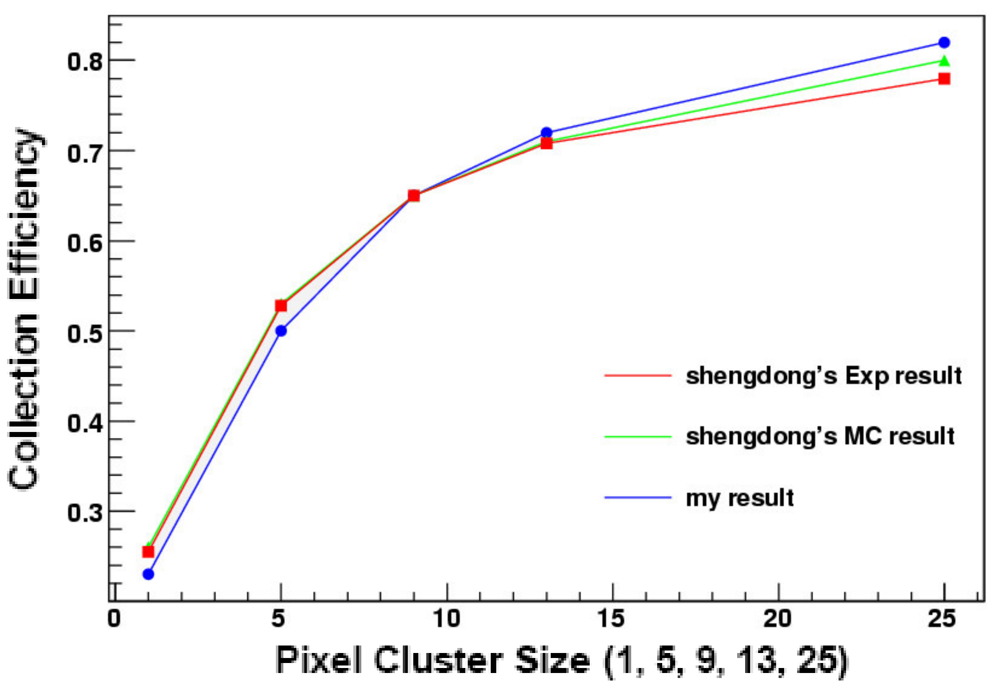
- when the p-epi electron hit p-epi/p+ substrate, because p+ substracte is more heavily doped, interface is recognized as a boundary with total reflection for electrons in the epitaxial silicon.
- when the p+ substrate electron hit p-epi/p+ substrate interface, the interface is totally transparent.

- When electrons hit the n-well/p-epi depletion region, has very little chance to be reflected but pass through. Consequently, the n-well/p-epi interface can be recognized as a boundary with total absorption.

Simulation Result



Collected electron distribution in PIXEL array



Experiment and MC comparison

PIXEL cluster size: the number of PIXEL summed with the hit PIXEL as center (e.g. 5 x 5 PIXEL array is a cluster of 25 PIXELs)

Collection efficiency: the number of electrons collected within the PIXEL cluster divided by the total number of electrons collected by the whole PIXEL array.

The simulation is in good agreement with the experimental results

The Fast Simulation

- Look-Up Table (LUT) generated from full simulation

- Create a grid system based on the geometry of the pixel.

- Generate a track.

- The number of electrons generated for a single track depends on the Bischel function.

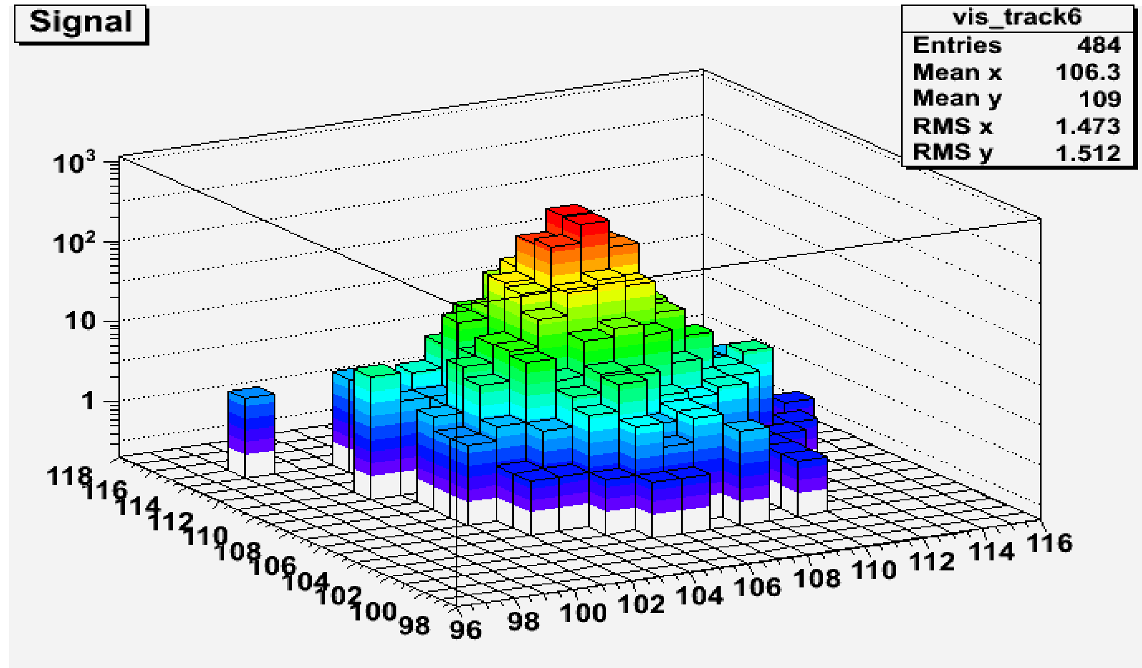
- Randomly generate electrons along the track and determine the closest grid point.

- Use the Look-Up Table to figure out where a single electron goes

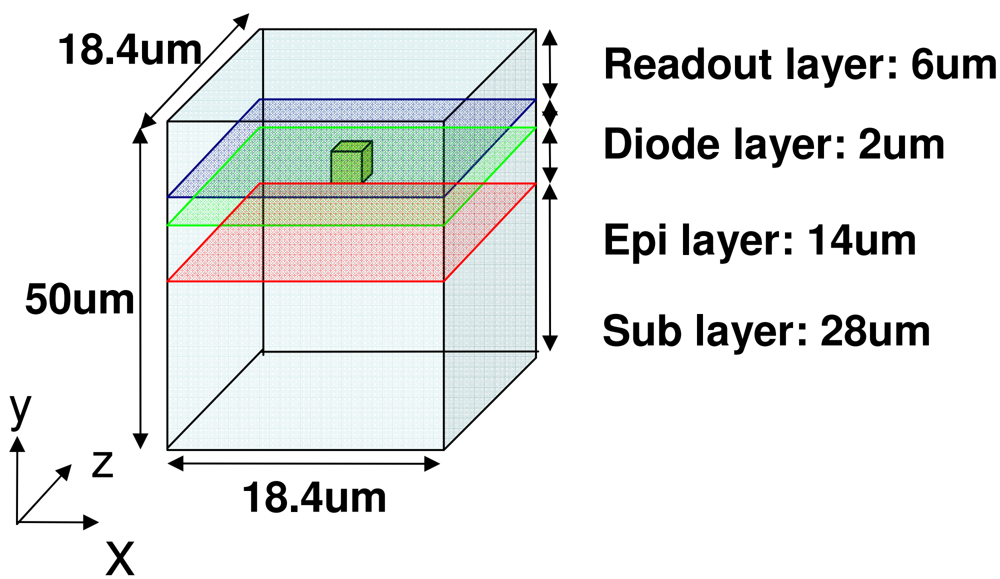
- Add up the contribution of every electron to produce a signal.

The Fast Simulation

•LUT generated from full simulation.

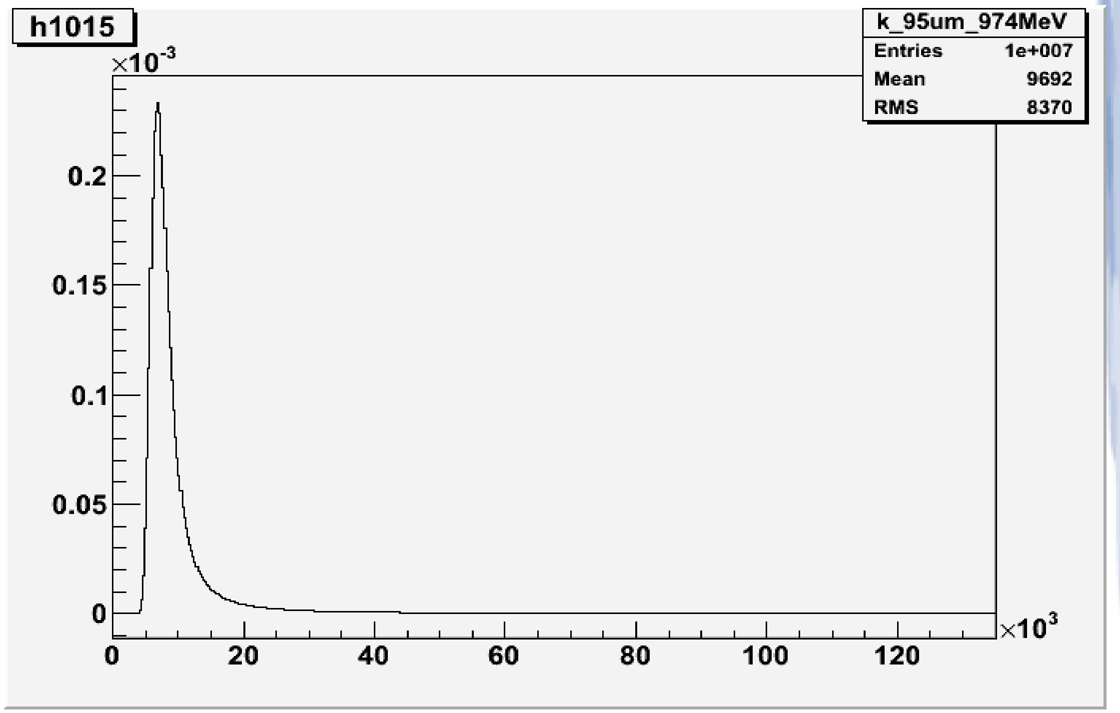


•Create a grid system based
on the geometry of the pixel.

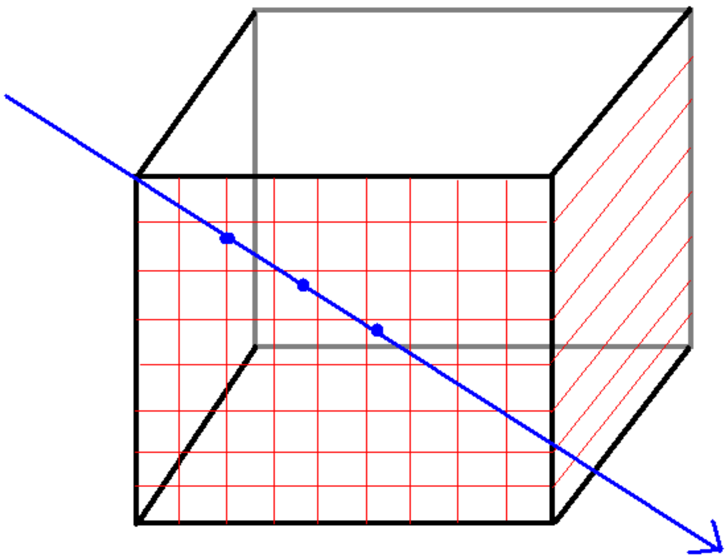


The Fast Simulation

•The number of electrons generated
for a single track depends on the Bichsel
function.



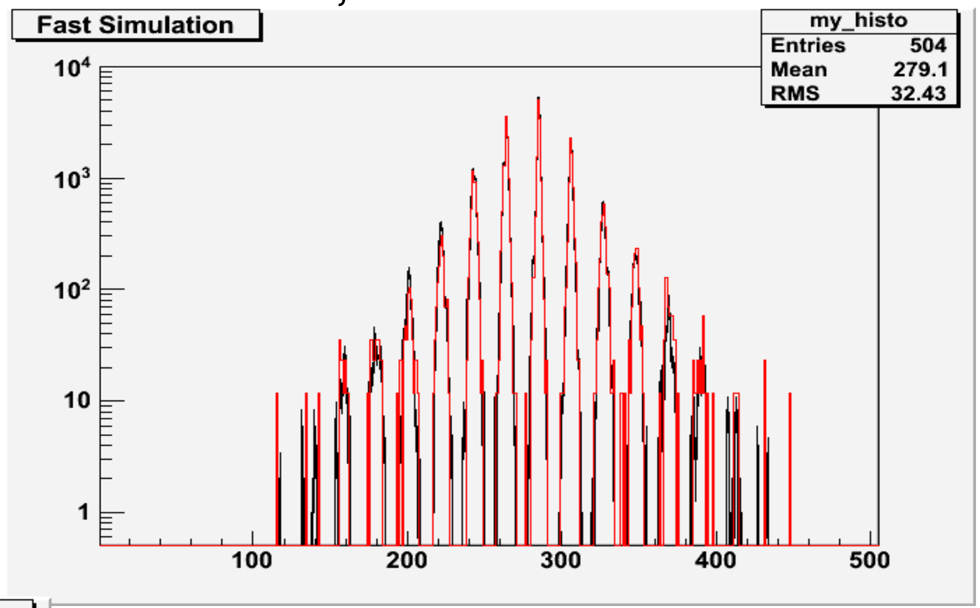
•Randomly generate electrons along
the track and determine the closest grid
point.



Track Comparison

- Since both the full simulation and the fast simulation are based in random, there will be a noticeable variance between the two.

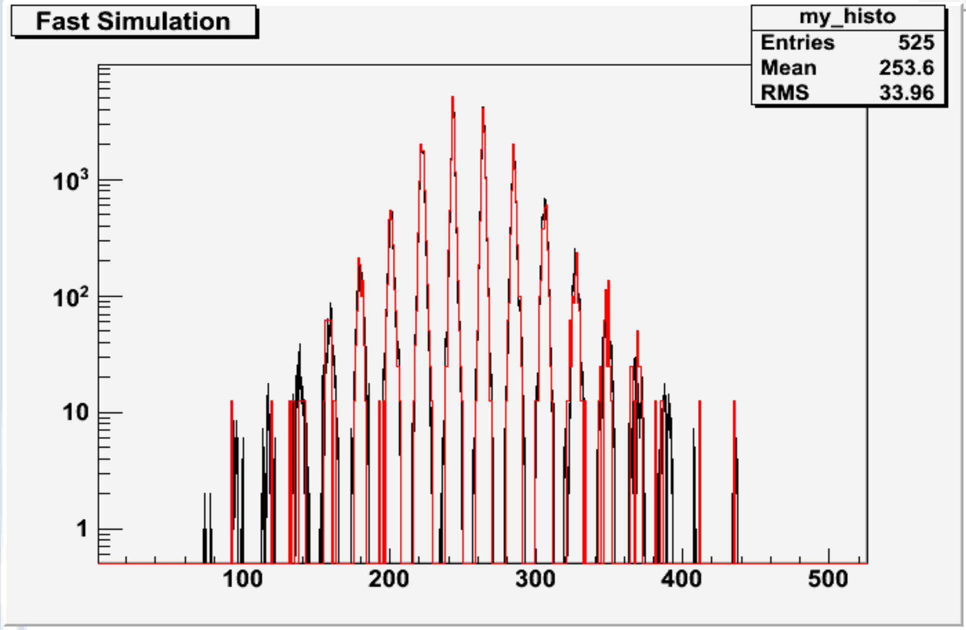
118,409 electrons



Track: (0.001104,0.00185)->(-0.00612,0.0009)

45 out of 175 were outside 3 sigma

132,549 electrons

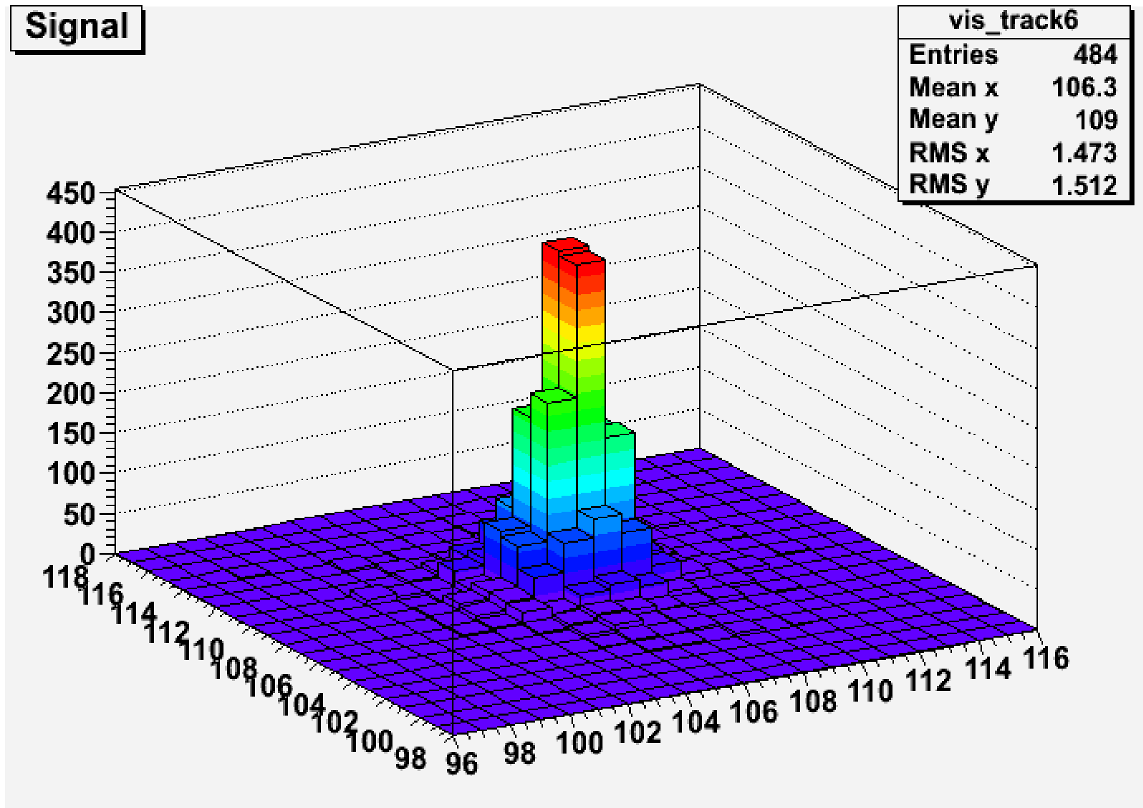


Track: (-0.0092,0.0001)->(0.001472,-0.0011)

41 out of 191 were outside 3 sigma

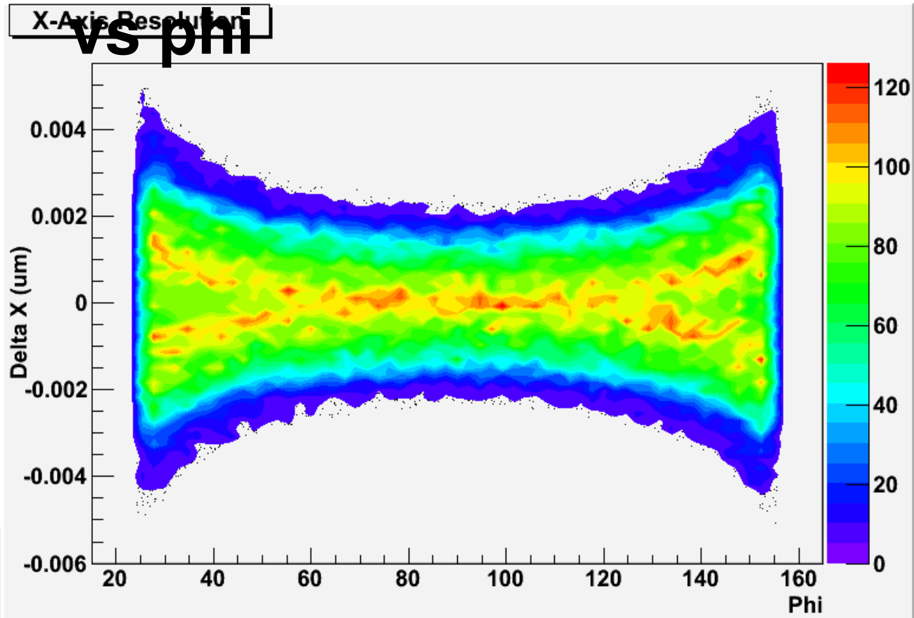
- Overall, the fast simulation does well to imitate the results of the full simulation.

Cluster Analysis

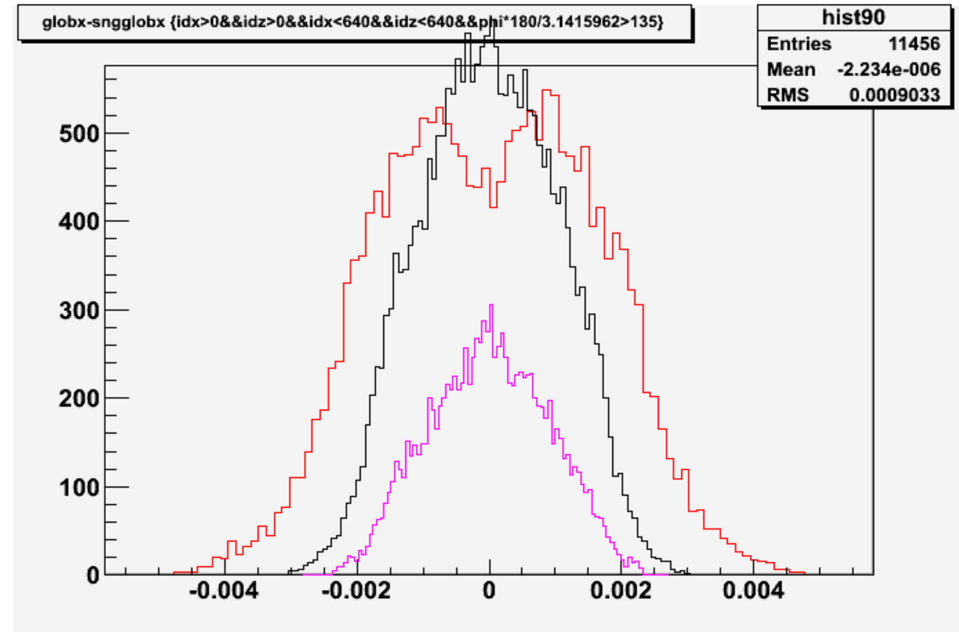


Two different analyses:
- Single Peak
- Double Peak

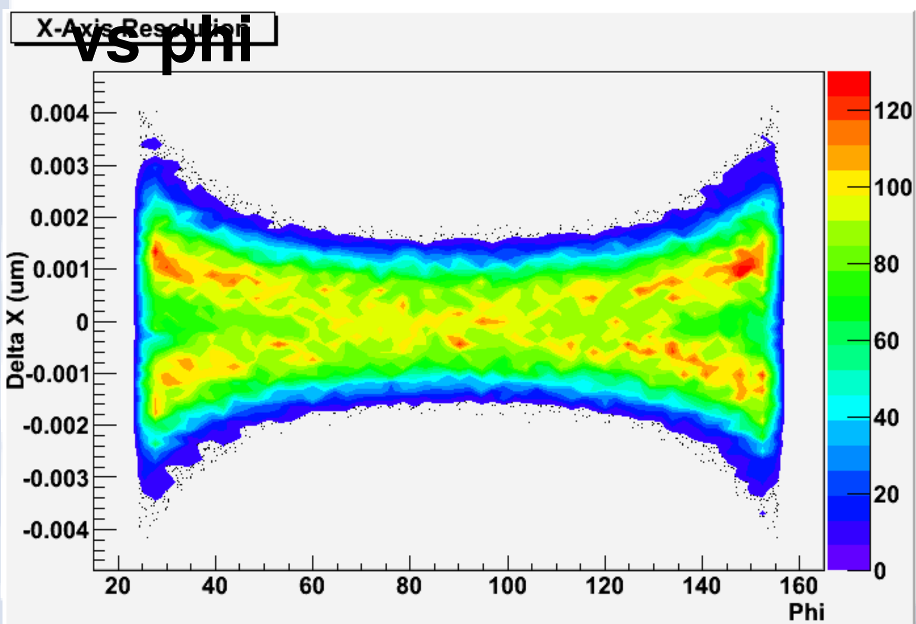
Single Peak Analysis: ΔX vs phi



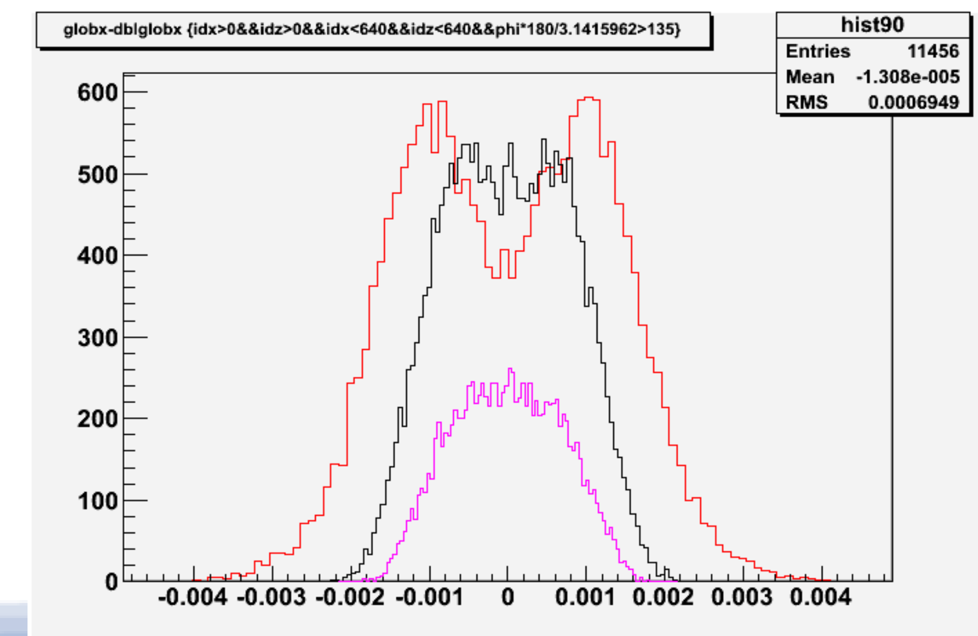
Single Peak Analysis Cuts:



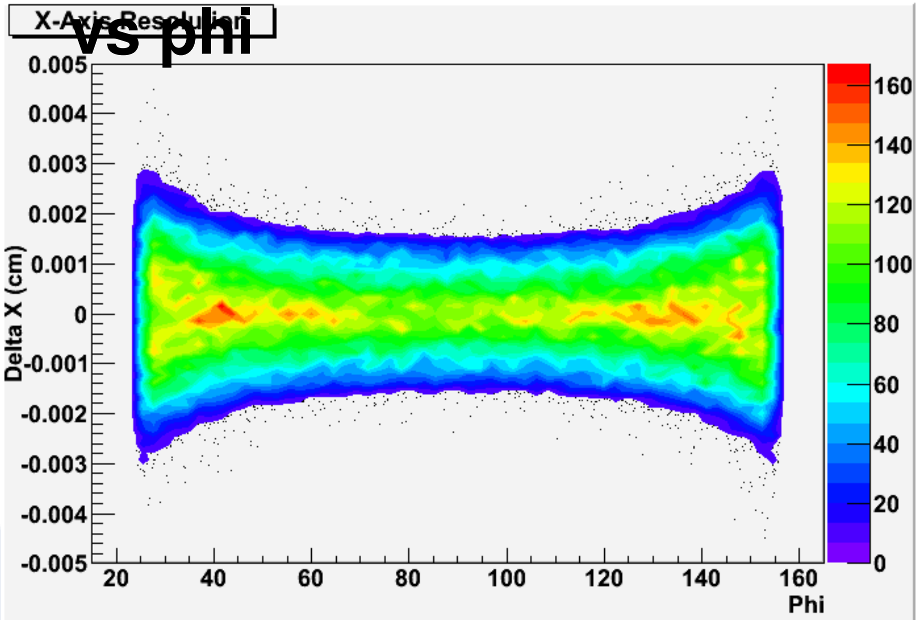
Double Peak Analysis: ΔX vs phi



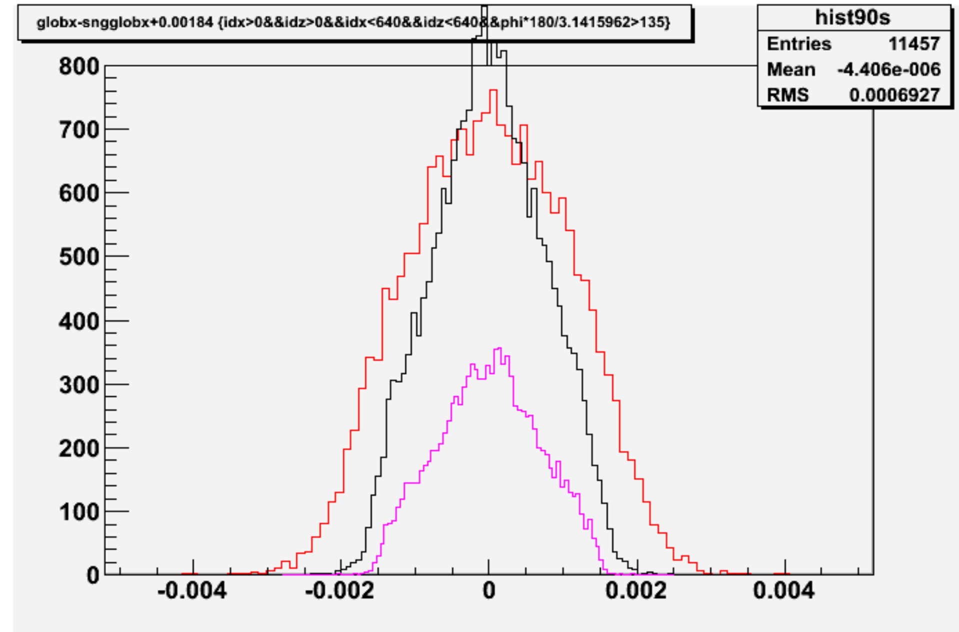
Double Peak Analysis Cuts: 90,



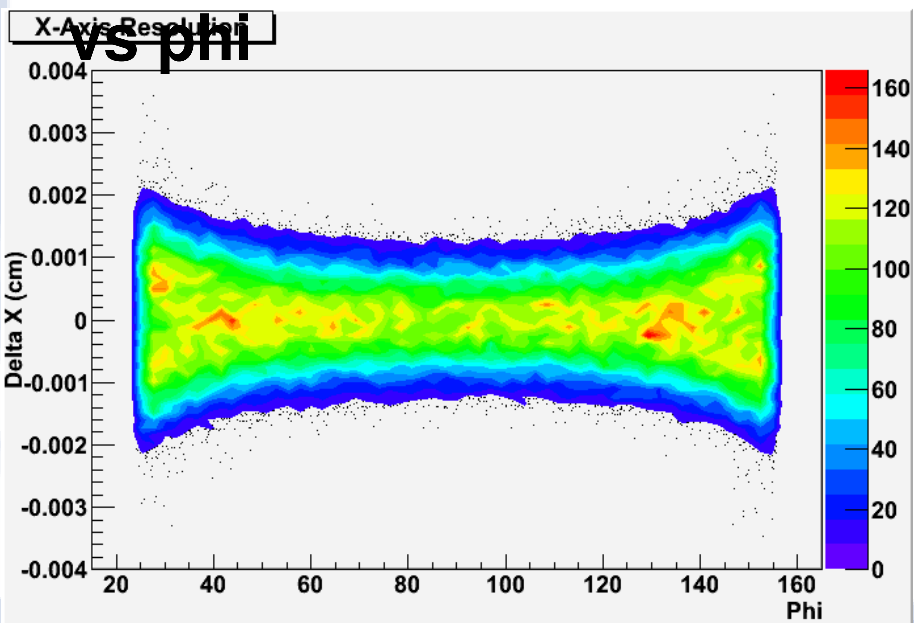
Single Peak Analysis: ΔX vs phi



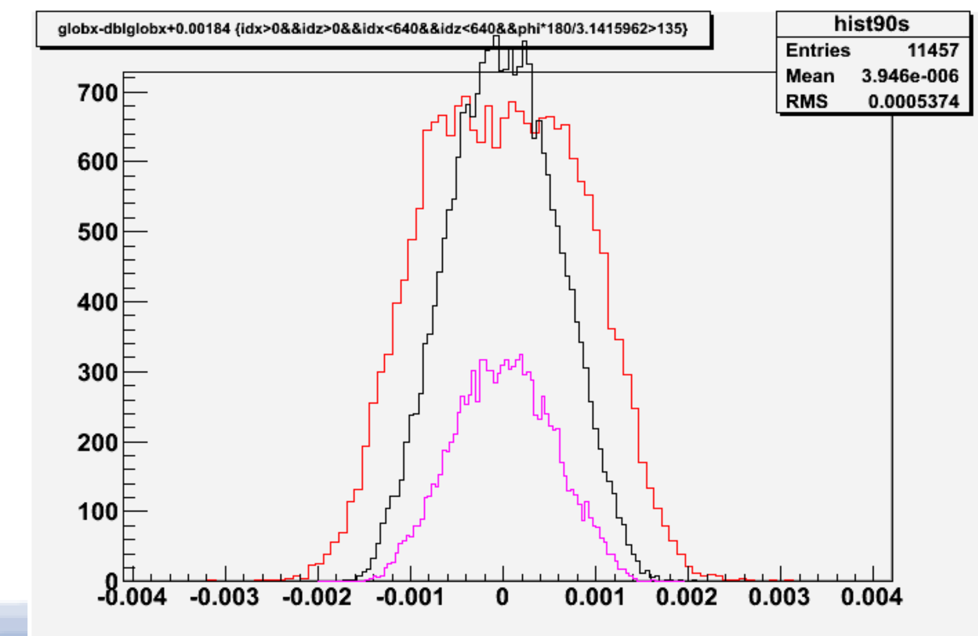
Single Peak Analysis Cuts:



Double Peak Analysis: ΔX vs phi



Double Peak Analysis Cuts: 90,



Recap and Future Efforts

Full Simulation time for one track: 1 hr in RCAS computer
Fast Simulation time for one track: 2 sec in RCAS computer

Regenerate the LUT using the final pixel dimensions.
-Done

Submit an abstract and poster to the APS CEU.

Refine the accuracy of the fast simulation if necessary.

Special Thanks

- Professor Wei Xie
- Xin Li
- Dustin Hemphill
- Purdue University Physics Department
- Brookhaven National Lab Computing Facility