Updates of Lorentz Angle for Silicon Strips

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Plan of talk

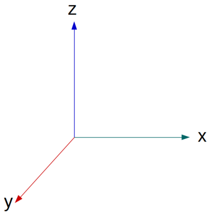
- Definition
- Method
- Calculation

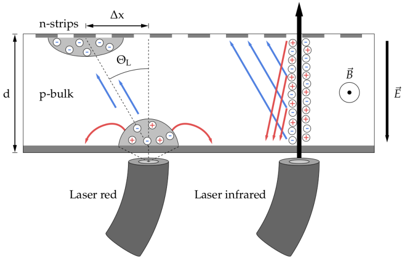
When a charged particle is moving in electromagnetic field then the force acting on that particle is given by,

$$\mathbf{F}=q(\mathbf{E}+\mathbf{v}\times\mathbf{B})$$

- The magnetic part of this force is balancing the centripetal force as that the particle bends from its original track under the influence of magnetic field.
- In CMS detector the beam line is surrounded by different type of detectors(Tracker, ECAL,HCAL etc)
- To collimate the beam which are going to collide each-other we need to apply high magnetic field so that the detector is submarged in intense magnetic field which will further affect the trajectory of moving charge particles following the principle given by Lorentz force equation.

Lorentz angle is defined as the deflection of charged carriers in a silicon sensor under the influence of magnetic field **B** transverse to the drift direction. Measurement can be done in this way, by injecting charges at the surface on one side and observing the drift through the sensor by measuring the position of the charge on the opposite side.Two different types of carrier are collected in the p and n side respectively.





Geometry

The corresponding geometry of this physical procces can be realized here in this cartoon.The **x coordinate** of the path endpoint at the junction side for hole formed at dept $z(\leq 0)$ is given by $\Delta x(z, \theta_t) = z \cdot \tan\theta_t + \delta x(z)$ where $z \cdot \tan\theta_t$ is the horizontal projection of the track and $\delta x(z)$ is the endpoint displacement of holes due to the Lorentz force.

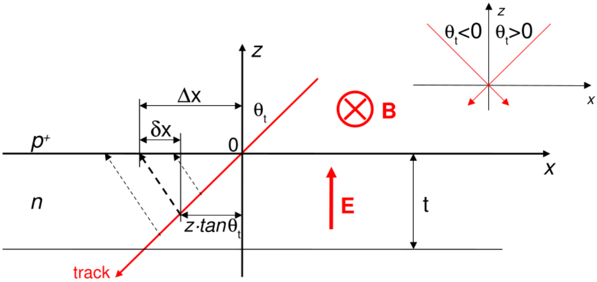


Figure 2 : Hole Δx displacement due to the Lorentz force

Method

- Without **B:** In the absence of magnetic field the hole drift follows the direction of **E** which are perpendicular to the strips so that tracks orthogonal to the strips achieve minimum cluster width.
- With **B:** In presence of **B** the drift direction is no longer along the electric field , them the minimum cluster size is found for particles moving through the detector with same inclination as the drift lines (irrespective of the small shift due to **B**).

So in both cases measurement of track incident angle for which the cluster is minimum provides a direct measurement of LA.

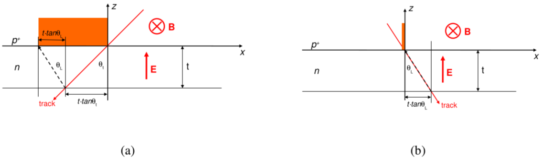


Figure 3 : Minimization of cluster

Calculation

- tsoslocaltheta=theta of the trajectory with respect to the local reference frame of the module (Z axis perperndicular to module)
- tsoslocalphi=phi of the trajectory with respect to the local reference frame of the module (Z axis perperndicular to module)
- tsosglobalZofunitlocalY=global Z projection of unitary local vector (0,1,0)
- clusterwidth=cluster width, e.g. number of strips forming the custer.

Trackangle($\tan\theta$)=tan(tsoslocaltheta)*cos(tsoslocalphi)*tsosglobalZofunitlocalY

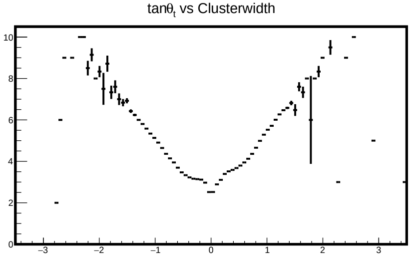


Figure 4 : Without any cut of η

Calculation

The Tracker cover a pseudorapidity range $0 < |\eta| < 2.5$ as a whole, but for barrel and endcaps cut-off to η is different. Barrel covers a pseudorapidity range $|\eta| < 1.4$

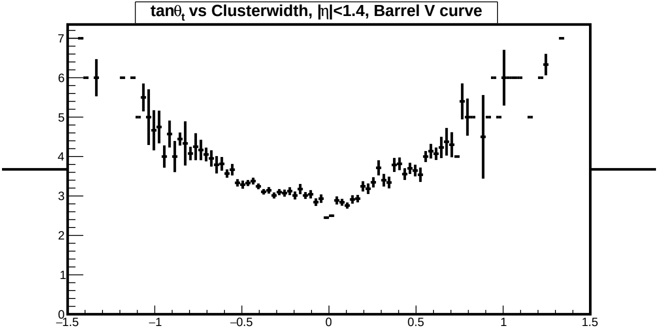


Figure 5 : Giving a cut of choice of $\eta, 1.4$ in barrel region

And also for endcap region covers the psedorapidity range $0.9 < |\eta| < 2.4$, we are getting this curve trackangle vs clusterwidth

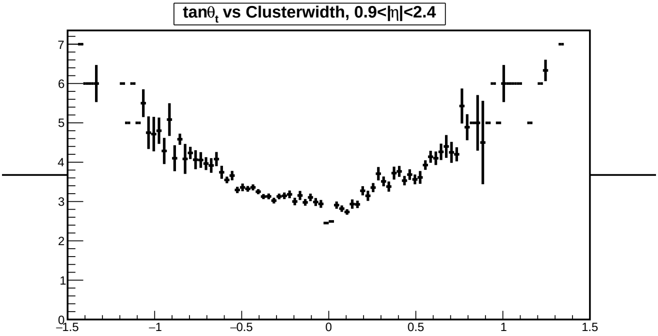


Figure 6 : Cut to η is $0.9 < \eta < 2.4$ in the endcap region

Now we are dealing with two NTuples, say for example :1. NTuple1.root I have downloaded from Gregory's repository.
2. Ntuple2.root which I have produces myself.
The motivation to move to new NTuples was driven by Andreas Nrnberg thesis *Studies On Irradiated Silicon Sensors For The CMS Tracker At The HL-LHC* he has produced these plots average clustervariance vs trackangle for 2 strip cluster and 3 strip cluster in layer 1 of TIB. But in old NTuple there was no such information or varible regarding to **layerwheel=layer for the barrel subdetectors/wheel for the endcap subdetectors**. To calculate mobility for Si strip coming from different layers we need that variable.

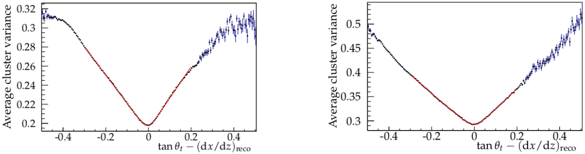


Figure 7 : Cluster Variance vs track angle for layer 1in TIB, *Nurnberg Thesis*

So I booked a new Ntuple after getting instructions from Suchandra Ma'am, variable I have been booked from SiStrip tree format twiki page and adding package CalibTracker/SiStripLorentzAngle. We have run over the release

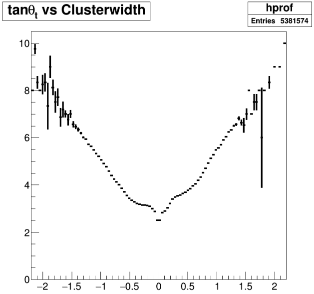
CMSSW-8-0-0/RelValTTbar-13/GEN-SIM-RECO/PU25ns-80X-mcRun2-asymptotic-v4-v1

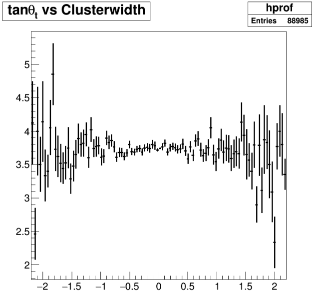
```
import FWCore.ParameterSet.Config as cms

from CalibTracker.SiStripCommon.ShallowClustersProducer_cfi import *
from CalibTracker.SiStripCommon.ShallowTrackClustersProducer_cfi import *
from CalibTracker.SiStripCommon.ShallowTracksProducer_cfi import *
#from CalibTracker.SiStripCommon.ShallowSimTracksProducer_cfi import *
LorentzAngleOutputCommands =  [ 'keep *_shallowClusters_clusterdetid_*',
                                'keep *_shallowClusters_clusternumber_*',
                                'keep *_shallowClusters_clustersubdetid_*',
                                'keep *_shallowClusters_clustermodule_*',
                                'keep *_shallowClusters_clusterwidth_*',
                                'keep *_shallowClusters_clustervariance_*',
                                'keep *_shallowClusters_clustercharge_*',
                                'keep *_shallowClusters_clusterlayerwheel_*',
                                'keep *_shallowClusters_clusterside_*',
                                'keep *_shallowClusters_clusterseedcharge_*',
                                'keep *_shallowClusters_clusterston_*',
                                'keep *_shallowClusters_clusternoise_*',
                                'keep *_shallowClusters_clusterseedindex_*',
                              'keep *_shallowClusters_clusterseednoise_*',
                                'keep *_shallowTrackClusters_tsostrackmulti_*',
                                'keep *_shallowTrackClusters_tsostrackindex_*',
                                'keep *_shallowTrackClusters_tsosclusterIdx_*',
                                'keep *_shallowTrackClusters_tsoslocalpitch_*',
                                'keep *_shallowTrackClusters_tsosglobaltheta_*',
                                'keep *_shallowTrackClusters_tsosglobalphi_*',
                                'keep *_shallowTrackClusters_tsosstrip_*',
                               # 'keep *_shallowTrackClusters_tsosdriftx_*',
                               # 'keep *_shallowTrackClusters_tsosdriftz_*',
                                'keep *_shallowTrackClusters_tsosprojwidth_*',
                               # 'keep *_shallowTrackClusters_tsosstrip_*',
                                'keep *_shallowTrackClusters_tsoslocaltheta_*',
                                'keep *_shallowTrackClusters_tsoslocalphi_*',
                                'keep *_shallowTrackClusters_tsosBdotY_*' ,
                                'keep *_shallowTrackClusters_tsosglobalZofunitlocalY_*',
                                'keep *_shallowTracks_tracknumber_*',
                                'keep *_shallowTracks_trackchi2_*',
                                'keep *_shallowTracks_trackndof_*',
                                'keep *_shallowTracks_trackchi2ndof_*',
                                'keep *_shallowTracks_trackcharge_*',
```

Figure 8 : ntuple-cff.py

But now the problem is we are getting something which is not expected. Left side is showing clusterwidth vs trackangle with old ntuple and right is showing the same with new ntuple. After getting this I am moving to new macro with selection of tracks and clusters corresponding to tracks. For that I have modified Prabhats Sir's macro. The algorithm is following, declaration of variables, defining histograms, selection of tracks and clusters , then calculation of LA.





This is the snap shot of selection of cluster and tracks in the corresponding macro.This is a long code and it is giving M-range-error, may be we are reading vector more that its length. I hope if we fix this error then we have good results soon.

```
// Loop over the list of clusters ______________________________________________________________________________
  for(unsigned int k=0;k<clusterdetid->size();k++)
  {
    if(tsostrackmulti->at(k) != 1) continue; // ???

    // Retrieve the informations related to the cluster ________________________________________
    Clusterid = clusterdetid->at(k);
    Width = clusterwidth->at(k);

    if(clusterseedcharge){ClusterSeedCharge = clusterseedcharge->at(k); hClusterSeedCharge->Fill(ClusterSeedCharge);}
    if(clusterston){ ClusterStoN = clusterston->at(k);  hClusterStoN->Fill(ClusterStoN);}
    if(clusternoise){ ClusterNoise = clusternoise->at(k); hClusterNoise->Fill(ClusterNoise);}
    if(clusterseednoise){ ClusterSeedNoise  = clusterseednoise->at(k);hClusterSeedNoise->Fill(ClusterSeedNoise);

   // Identify the track the cluster belongs to ______________________________________________
    if(TrackIndex != tsostrackindex->at(k)) TrackIndex = tsostrackindex->at(k);

   // Retrieve the informations related to that track ________________________________________
    if(trackpt)        Trackpt        = trackpt->at(TrackIndex);
    if(trackchi2ndof)  TrackChi2ndof  = trackchi2ndof->at(TrackIndex);
    if(trackndof)      Trackndof      = trackndof->at(TrackIndex);
    if(trackhitslost)  TrackHitsLost  = trackhitslost->at(TrackIndex);
    if(trackhitsvalid) TrackHitsValid = trackhitsvalid->at(TrackIndex);

if(trackpt && trackchi2ndof && trackndof && trackhitslost && trackhitsvalid)
    {
      if(Trackpt>0.3 && TrackChi2ndof<1.5 && Trackndof>4 && TrackHitsLost==0 && TrackHitsValid>3)
        TrackId = true;
    }
    else if(trackpt && trackchi2ndof && trackhitslost && trackhitsvalid)
    {
      if(Trackpt>0.3 && TrackChi2ndof<1.5 && TrackHitsLost==0 && TrackHitsValid>3)
        TrackId = true;
    }
    else if(trackpt && trackchi2ndof && trackhitsvalid)
    {
      if(Trackpt>0.3 && TrackChi2ndof<1.5 && TrackHitsValid>3)
        TrackId = true;
    }
    else
      TrackId = false;
```

Figure 10 : Macro

Also I have tried to move in moduler form of make class of the new ntuple. We are trying to finish this job as soon as possible.

```cpp
//////////////////////////////////////////////////////////
// This class has been automatically generated on
// Wed Mar 15 15:47:16 2017 by ROOT version 5.34/34
// from TTree tree/
// found on file: LorentzAngleInputVariables.root
//////////////////////////////////////////////////////////

#ifndef LorentzAngle_MD_h
#define LorentzAngle_MD_h

#include <TROOT.h>
#include <TChain.h>
#include <TFile.h>

// Header file for the classes stored in the TTree if any.
#include <vector>
#include <vector>
#include <vector>
#include <vector>

// Fixed size dimensions of array or collections stored in the TTree if any.

class LorentzAngle_MD {
public :
   TTree          *fChain;   //!pointer to the analyzed TTree or TChain
   Int_t           fCurrent; //!current Tree number in a TChain

   // Declaration of leaf types
   vector<double>  *trackchi2;
   vector<double>  *trackchi2ndof;
   vector<double>  *trackdsz;
   vector<double>  *trackdxy;
```

```cpp
#define LorentzAngle_MD_cxx
#include "LorentzAngle_MD.h"
#include <TH2.h>
#include <TStyle.h>
#include <TCanvas.h>

void LorentzAngle_MD::Loop()
{
//   In a ROOT session, you can do:
//      Root > .L LorentzAngle_MD.C
//      Root > LorentzAngle_MD t
//      Root > t.GetEntry(12); // Fill t data members with entry number 12
//      Root > t.Show();       // Show values of entry 12
//      Root > t.Show(16);     // Read and show values of entry 16
//      Root > t.Loop();       // Loop on all entries
//

//     This is the loop skeleton where:
//    jentry is the global entry number in the chain
//    ientry is the entry number in the current Tree
//  Note that the argument to GetEntry must be:
//    jentry for TChain::GetEntry
//    ientry for TTree::GetEntry and TBranch::GetEntry
//
//       To read only selected branches, Insert statements like:
// METHOD1:
//    fChain->SetBranchStatus("*",0);  // disable all branches
//    fChain->SetBranchStatus("branchname",1);  // activate branchname
// METHOD2: replace line
//    fChain->GetEntry(jentry);       //read all branches
//by  b_branchname->GetEntry(ientry); //read only this branch
   if (fChain == 0) return;

   Long64_t nentries = fChain->GetEntriesFast();
```

Thank you