Optimising the Strip Geometry for Very Fine Pitch Silicon Strip

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Introduction

Future collider experiments will require tracking detectors with more precise silicon sensors for improved **track reconstruction precision** and possibly with the ability to provide input to the **first level trigger**. One way to enhance the tracking performance is the **minimization of the readout pitch.**

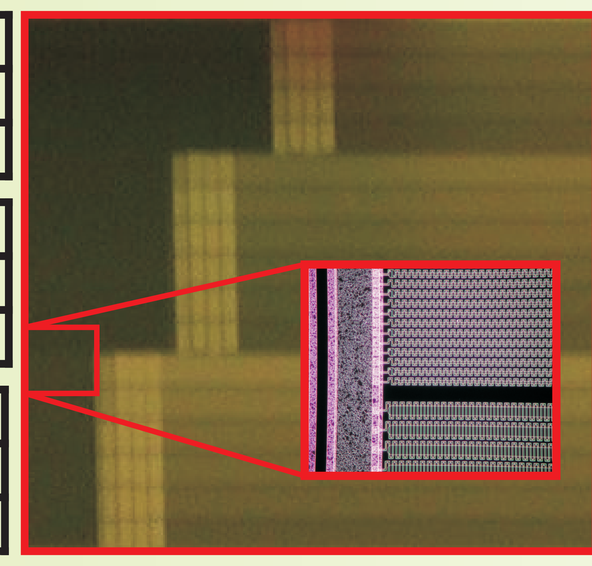
We investigated the performance of such fine pitch strip sensors using *multigeometry testsensors* with a fixed readout pitch of **50 microns** and a varying number of intermediate strips and different strip widths. Results from a testbeam with 120 GeV/c pions are presented, suggesting the **best geometry for optimal resolution performance.**

Furthermore we studied the possibility to derive the incidence angle of a particle from the cluster width, which could be used as a **tracking trigger** on transverse momentum.

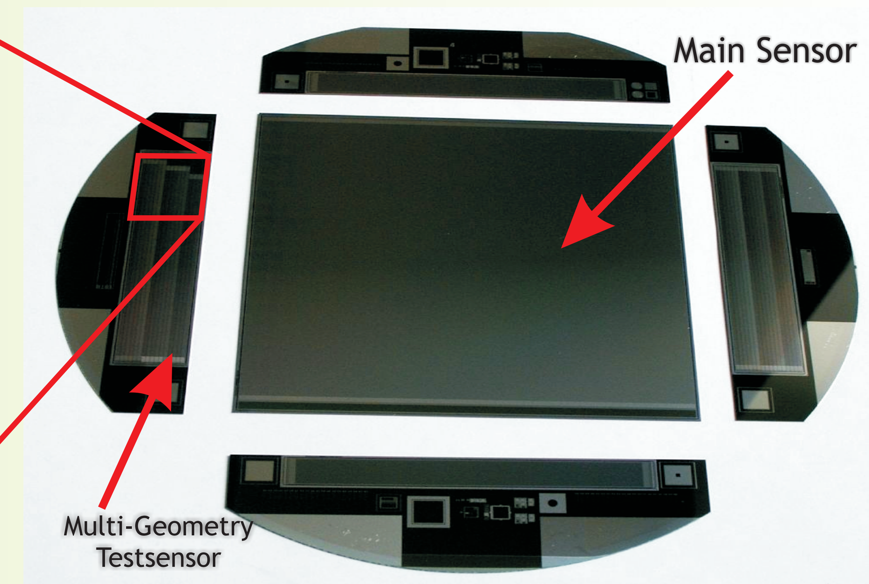
Zone	1	2	3	4	5	6
Width [µm]	6	10	12.5	15	20	25
No intermediate Strips						

Zone	7	8	9	10	11	12
Width [µm]	6	7.5	10	12.5	15	17.5
One intermediate Strip						

Zone	13	14	15	16
Width [µm]	6	7.5	10	12.5
Two intermediate Strips				

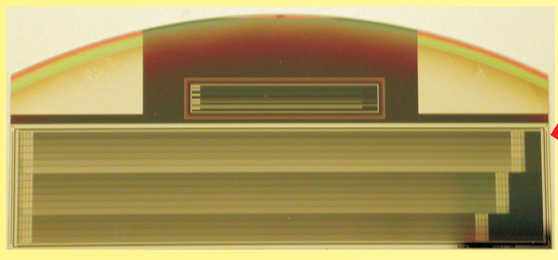


The *multigeometry testsensor* contains 16 zones with 16 strips per zone separated by a *missing strip*. Each zone has a different combination of strip width and number of intermediate strips which are not read out. The strip pitch is fixed for all zones at 50 µm as the resistance of the polysilicon resistors connecting each strip to the bias ring which was set to 20 MΩ. The different lengths of the resistors, as seen on the picture, is due to the different number of intermediate strips which limits the space for the polysilicon meanders. Nevertheless the net length and therefore the absolute resistance of each resistor remains the same.

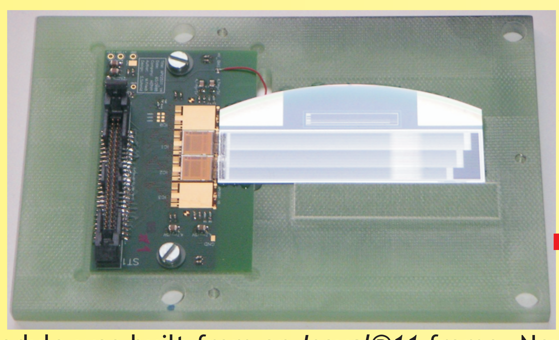


The full wafer as produced by *Hamamatsu Photonics K. K., Japan* contains an AC-coupled single sided strip detector with 1792 strips at 50 µm pitch and several teststructures surrounding it. The wafer material is 320 µm thick n-type silicon with a resistivity of 6.7 kΩcm. We only utilized the *multigeometry testsensor* for our studies.

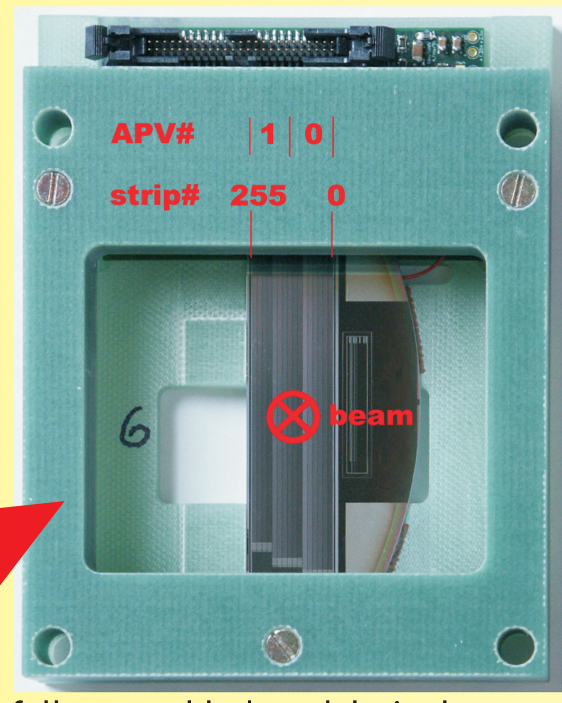
Testbeam



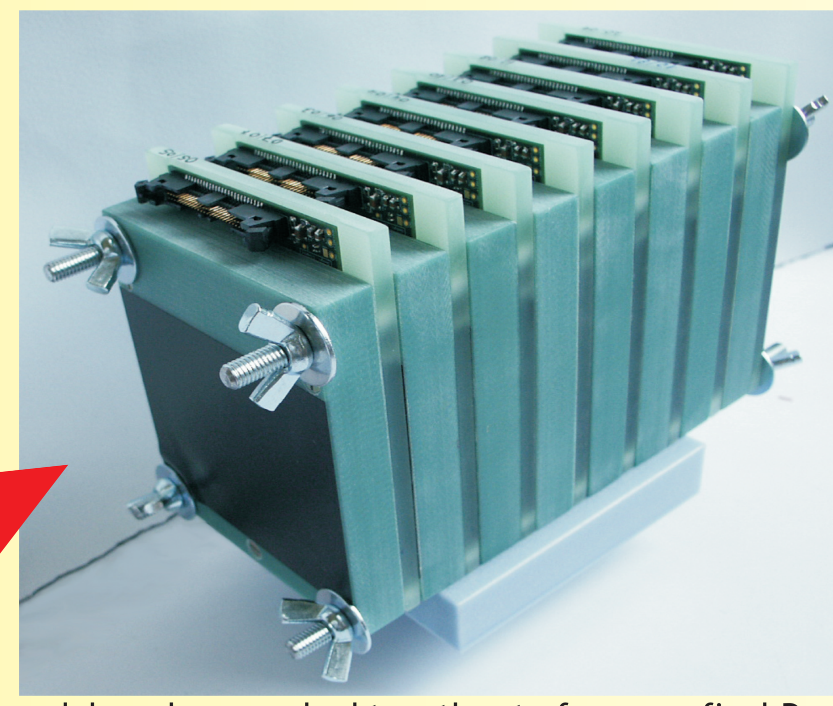
The *multigeometry testsensor* was cut from the wafer including the unused space towards the wafer's edge. This halfmoon shape was retained to increase the contact area for glueing the sensor to the module.



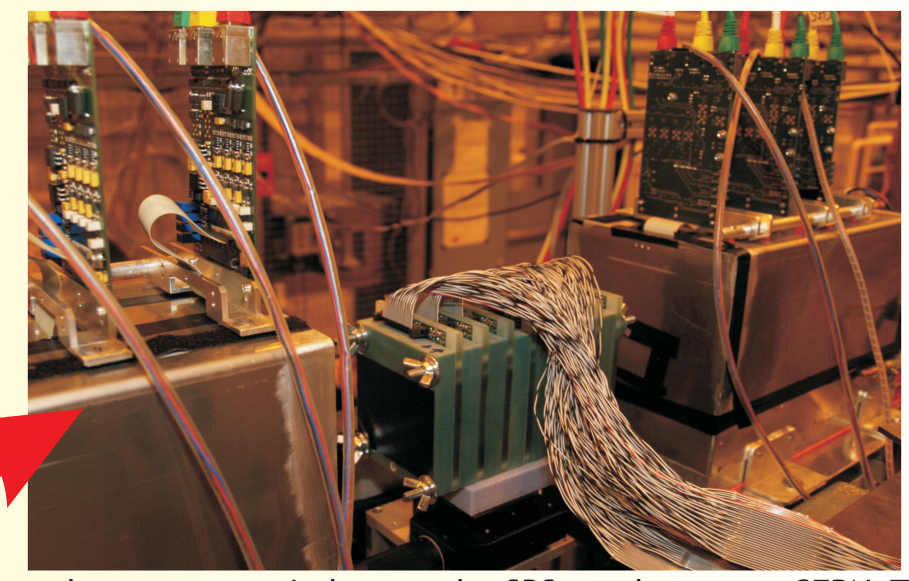
A module was built from an *Isoval®11* frame. Next to the testsensor itself it houses a small printed circuit board with two APV25 readout chips wire bonded to the sensor and a connector.



The fully assembled module is shown with its large opening for the beam. The window was later on covered with an aluminium foil and adhesive tape to make the module light tught.



8 modules where packed together to form our final Device Under Test (**DUT**). Using such a construction, we could increase the data rate by taking 8 measurements per event. Angle scans were performed with a single module only.



The testbeam was carried out at the *SPS accelerator* at *CERN*. The low intensity beam delivered 120 GeV/c pions. We used the EUDET beam telescope to record high precision tracks and synchronized the telescope with our DUT readout using information from a trigger which was created utilizing various two scintillators up- and two downstream of the telescope. In four days we collected around **1.5 million events** in various configurations of the DUT.

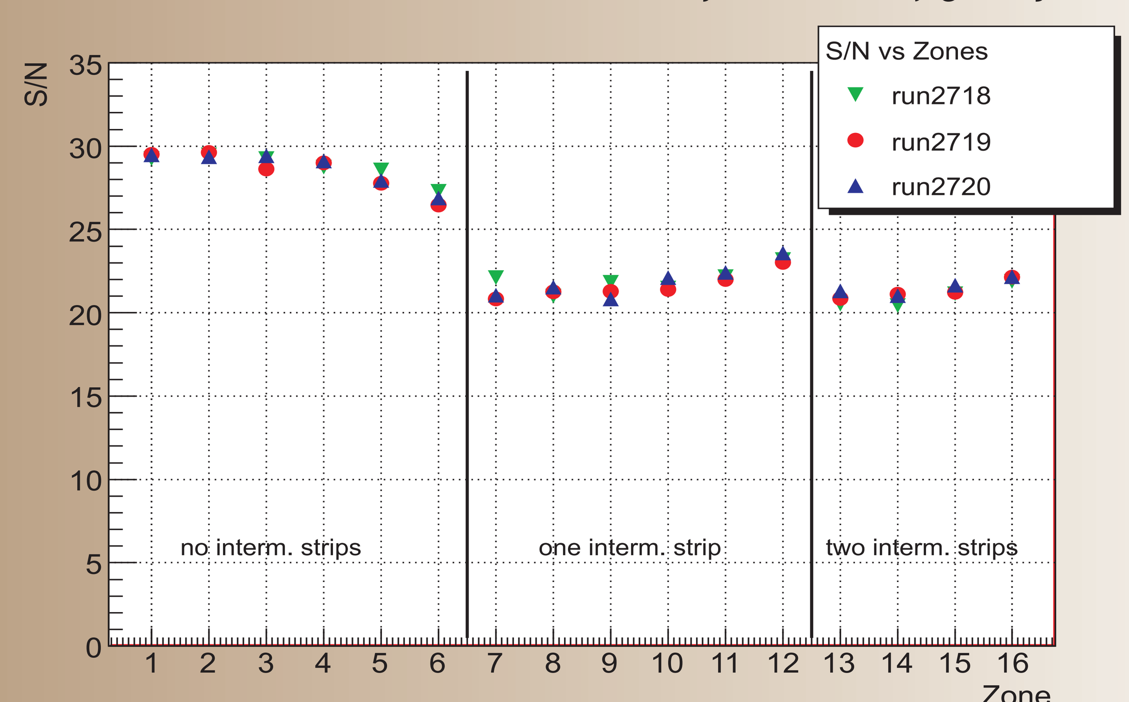
Resolution Studies

Data Analysis - First Stage: Cluster Finding and Hit Calculation

After calculating the *noise per strip* (**σ**) and applying a *Common Mode Noise subtraction*, we implemented a standard algorithm which uses three cuts on the strip signal to find clusters (i.e. charge created by an incident particle and collected by several strips):

1 - **Seed [S_{seed}]**: Search for a strip signal which is > $S_{seed} \times \sigma_{strip}$,
2 - **Neighbour [S_{nb}]**: Add the signal of neighbouring strips where the strip signal is > $S_{nb} \times \sigma_{strip}$,
3 - **Cluster [$S_{cluster}$]**: If the sum of the signal is > $S_{cluster} \times \sigma_{strip}$ we have found a hit.

The final estimation for the location of the hit is calculated by the *center-of-gravity* method.

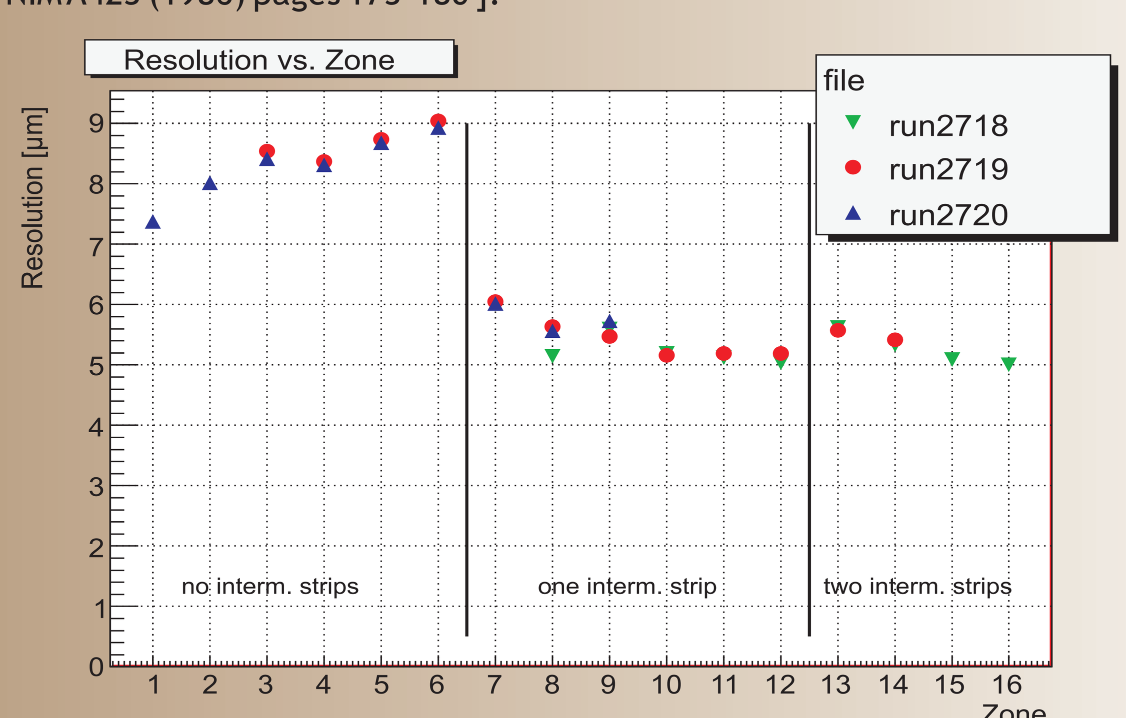


Signal-to-Noise (S/N) for each of the 16 different zones. Each data point is calculated from more than 50.000 hits, error bars are therefore too small to be visible.

Data Analysis - Second Stage: Pattern Recognition and Track Fitting

Due to the low intensity beam, the multiplicity was very low which made the pattern recognition (finding the hits from a single track) very easy. Multiple scattering is negligible for a 120 GeV/c pion beam in a few millimeters of silicon.

The majority of the tracks traverse different zones in the eight detector planes. To correctly estimate the resolution for each zone in a linear model, a method was used allowing measurement errors to be unequal [Frühwirth, *"Estimation of variances in a linear model applied to measurements of trajectories"*, NIM A423 (1986) pages 173-180].



Resolution in each of the 16 different zones. Each data point is calculated from more than 10.000 hits, error bars are therefore too small to be visible.

Summary

Our resolution studies for strip detectors with 50 µm pitch suggest a configuration with a single intermediate strip and a strip width of 12.5 µm to 17.5 µm (zones 10 - 12) to achieve the best possible resolution. In this configuration we obtained a resolution of about 5 µm.

Cluster Width Studies

Calculating Particle Momentum from Local Incidence Angle

The *curvature radius* **R** of a particle track in the R- plane in a *magnetic field* **B** depends on the *transverse momentum* p_t of the particle:

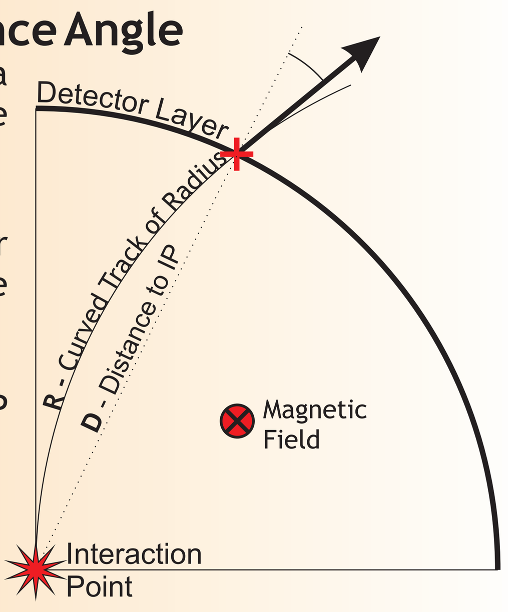
$$R = p_t/qB.$$

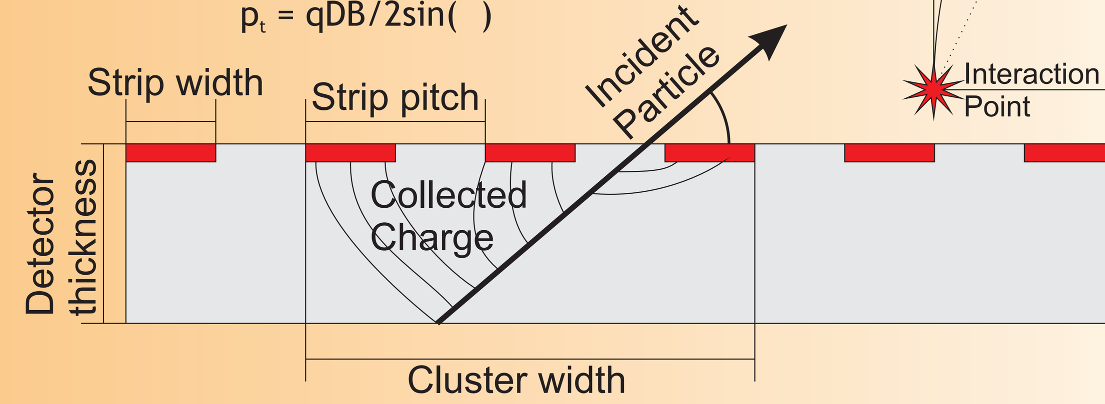
Therefore the *incidence angle* of a particle which hits a detector layer at a *distance* **D** from the interaction point depends on the curvature radius:

$$= \arcsin(D/2R).$$

We can now calculate the p_t of a particle which originated from the IP and hits a detector at a distance **D** from the IP:

$$p_t = qDB/2\sin(\ )$$





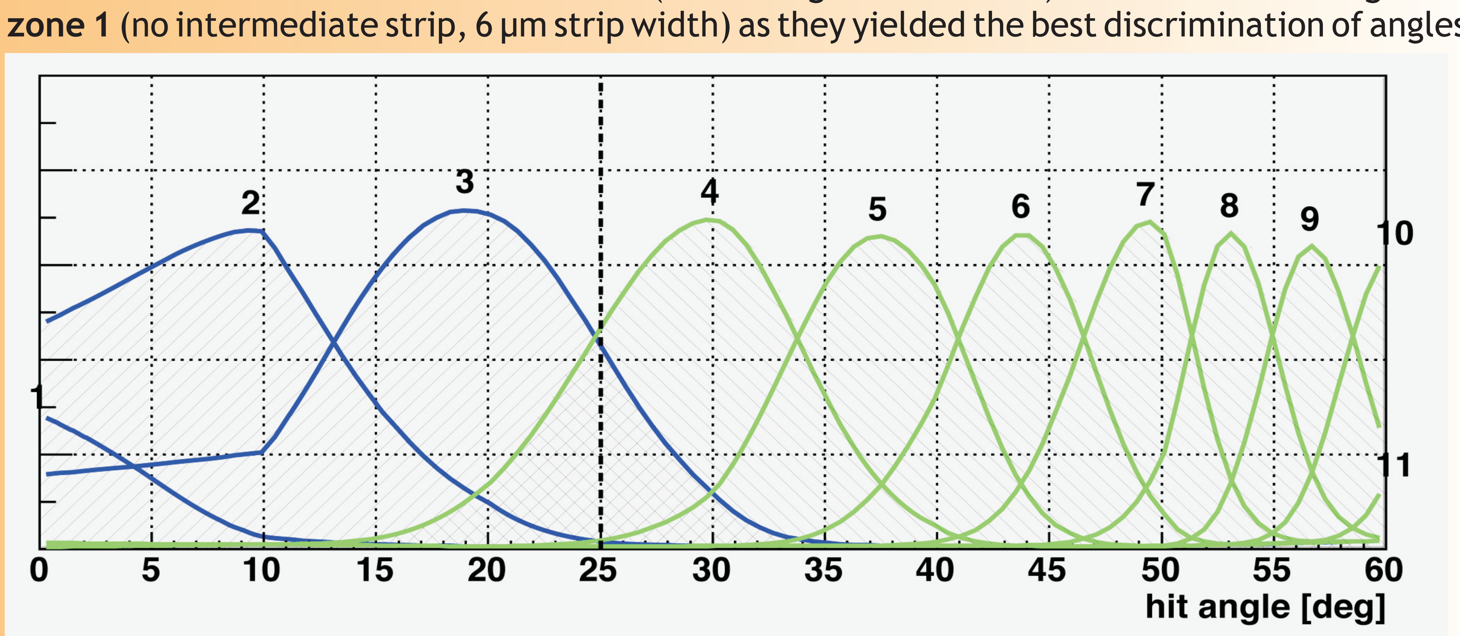
Estimating Local Incidence Angles from the Cluster Width

We want to measure the *incidence angle* of a single particle and therefore its p_t using silicon strip detectors. We estimate the angle from the number of strips which collected the charge that was generated by the incident particle. This value depends on the detector thickness,on strip pitch and width, and on the electric field responsible for collecting the charges.

We used the multigeometry testsensor to study the cluster width distribution for various angles. We collected data with the beam hitting the detector module at incidence angles of 0 to 60 in 10 steps.

The cluster width was calculated from the data using the same *cluster finding algorithm* explained in the section on the left, with a small modification to prevent cluster splitting: the modified algorithm connects clusters when there is a *single strip below the threshold* between them.

The set of cuts used for our results were **5/3/5** (Seed/Neighbour/Cluster) and we were looking at data from **zone 1** (no intermediate strip, 6 µm strip width) as they yielded the best discrimination of angles.



The plot shows the angle distributions from 0° to 60° for cluster widths from 1 to 11. The Y-axis is in arbitrary units. The actually measured distribution of cluster widths per incident angles were assumed to be gaussian, and the distribution of the incidence angles themself are uniformly distributed.

As an example, let's assume an angle cut at 25° and a corresponding cluster width cut at 3. This would discard all the green hits and accept only hits in blue. Blue hits right of the 25° threshold are false positives, while the green hits left of the 25° threshold are false negatives.

Summary

Using strip sensors with 50 µm pitch, it is possible to estimate the transverse momentum of a single particle where the 95% confidence interval contains about 10° to 15°.

To improve the discrimination of incidence angles it might be necessary to *modify the cluster finding algorithms* for calculating the cluster width, as the existing ones where typically targeted at good spatial resolution.

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