Digitizer Validation using Test Beam Data

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Test Beam and Monte Carlo Setup



Test beam setup at CERN SPS 2009 (120 GeV pions)



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Geometry for MC validation studies

Noise and Pedestal Stability



Distribution of raw signal

Raw signal can be described with a gaussian distribution.
Pedestal and noise of a pixel is calculated as mean and rms of the raw signal distribution in absence of a hit. Differences of noise and pedestal maps between two runs 8 days apart

- Noise and pedestal is constant over time.
- Run-to-run calculation is sufficant.

Mechanical Stability



Relative change of alignment constants x, y and φ_z as a funciton of event number

The frame of reference is spanned by first (mod 0) and last module (mod 5).

Residuals TB2009



Residuals in x and y of H3.0.04, H3.0.07 and H3.0.01. Telescope and DUT hits reconstructed with eta px couple algorithm.

Devices Under Test

	H3.0.04	H3.0.01	H3.0.07
Matrix Size	64x256 px	64x256 px	64x256 px
Thickness	450 μ m	450 μ m	450 μ m
Pixel pitch	$24 \mu { m m} imes 24 \mu { m m}$	$32 \mu { m m} imes 24 \mu { m m}$	$20 \mu { m m} imes 20 \mu { m m}$
Gain g _q	360 <i>pA/e</i> ⁻	$500 pA/e^-$	650 <i>pA/e</i> ⁻
S/N ratio	120	145	205
Residual X	1.51μ m	2.51μ m	1.58μ m
Residual Y	1.49μ m	1.77μ m	1.56μ m



Cluster und Seed Charges of DUT studied in TB 2009

Edge Effect



Deviation of mean of residual of module H3.0.07 as a function of the column (top), of the row and the absolute deviation as a function of position on matrix (right). Field inhomogenities lead to deformation.

In the rows and columns hits are reconstructed with a bias towards the border of the matrix.



Edge Voltage Scan



Residuals vs. hit position with reference edge voltage (top to bottom) 0, 0 and 0 Volts on DUT 3.0.04.

Edge Voltage Scan



Residuals vs. hit position with edge voltage (top to bottom) -10, -5 and -3 Volts on DUT 3.0.04.

Hit-Reconstruction

Usage of η -algorithm for precise reconstruction of hit from seed S_S and (highest) neighbor S_N .

$$\eta := \begin{cases} -\frac{S_N}{S_N + S_S} & \text{if } S_N \text{ to the left} \\ \frac{S_N}{S_N + S_S} & \text{if } S_N \text{ to the right} \end{cases}$$



Simulated charge distribution on sensor surface





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Error in Reconstruction



Resolution in Y as a function of in-pixel xy-position (top) and theoretical resolution using the eta reconstruction as a function of the in-pixel position (right)

- Prezision of hit reconstruction is not homogenious.
- Hits on pixel border: high charge sharing \rightarrow best resolution.
- Hits in pixel center: lower charge

sharing \rightarrow decrease of resolution.

- Resolution limit depends on:
- * signal to noise ratio (100)
- * pitch (24µm)
- * diffusion of charge



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Geometry for MC validation studies.

- Geant 4 based simulation of full telescope and DUT.
- Simulation of all materials in beam (i.e. Al windows and Si sensors).

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- Gun position smeared in x and y position.
- Missalignment of sensor planes in x and y.

Analysis Chain Flow Chart for Data and Monte Carlo



- Entry of MC simulated clusters is at an early point of the analysis chain.
- * Hitmaking , Alignment and Trackfitting is done in the same ILC processors.
- * Benchmark plots along the chain are easy comparable.



- Low energy region seem to be captured by the mc simulation.

 Deviation from the theoretical Landau distribution have different origin:

* In Data the effects originate from start-gate-effects; are electronic artifacts.

* In MC delta electrons produce low energy clusters.

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χ^2 and Cluster Size Distribution



– χ^2 distribution for straight line fit.

- MC and Data in good agreement.

- χ^2 of MC and Data tend to higher values than theoretical χ^2 since $\rho_{\chi^2}(ndf = 4)$ does not consider multiple scattering. - Diffusion constant is tuned using the cluster size distribution.

 Cluster size distribution of MC has also fairly good agreement with Data from angular scans.

- MC and Data deviate up to 6% systematically.

η Distribution



Eta distributions for DUT of test beam 2008 (left) and 2009 (right) in X direction. Gap size in eta distribution and cluster size as a function of bias voltage (bottom).





- Eta distribution of MC and Data of TB 2008 in good agreement.

Asymmetry in TB 2009 Data can not be reproduced with Digitizer.
Gap width is correlated to the diffusion constant.

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Straight Line Fit Residuals



 $\sigma_{\text{Residual}} = \sigma_{\text{Intrinsic}} + \sigma_{\text{Telescope}} + \sigma_{\text{MultipleScattering}}$

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Eutelescope Analytical Track Fit Residuals



 $\sigma_{\text{Residual}} = \sigma_{\text{Intrinsic}} + \sigma_{\text{Telescope}} + \sigma_{\text{MultipleScattering}}$

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Monte Carlo Truth Resolution



 $\sigma_{Residual} = \sigma_{Intrinsic} + \sigma_{Telescope} + \sigma_{MultipleScattering}$

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