The GBL Tracking Algorithm in EUTelescope

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EUDET/AIDA Pixel Beam Telescope

- The telescope is a series of pixel sensors used to reconstruct particle trajectories
- To reconstruct a particles trajectory the position/time must be determined with the following
  1. 6 CMOS pixel detectors $\rightarrow$ 18.4x18.4 μm^2 , 115.2 μs integration time/frame.
  2. Additional timing plane used in efficiency measurements to reduce the time resolution to 25 ns.
- EUTelescope is a reconstruction framework for this setup.

The telescope setup composed of 6 pixel sensors.

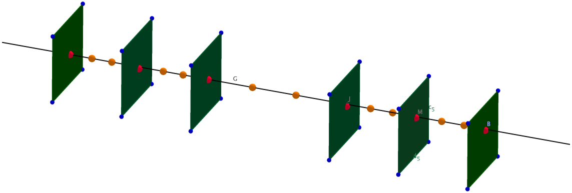
Track Reconstruction in EUTelescope

- Broken lines track fitting is χ^2 minimisation with scattering taken into consideration.
- Two track fitting techniques are used at the moment.

1. Deterministic Annealing Filter $\rightarrow$ DAF.
   - Pattern recognition is combined with track fitting
     - Does not allow addition of new pattern recognition methods.
   - Models all scatterers as thin.
   - **Track fitting not possible with magnetic fields.**
   - Usual method for track reconstruction
2. General Broken Lines Algorithm $\rightarrow$ GBL
   - A generic track fitting package written by Claus Kleinwort in C++.
   - Fit parameters are curvature and offsets.
   - Scattering information is included in fit in the form of kink angles.
   - **Fitting with arbitrary magnetic fields.**
   - Easy to add additional track parameters of interest.
     - X0 measurements use this feature

A single track can be constructed in 4 steps...

1 The Discrete Track



Red Dots: Measurements/Scattering Orange Dots: Scattering

- As many planes as you need can be added around the telescope.
- Homogeneous sensors are modeled as thin scatterers
- Inhomogeneous dead material between sensors modeled as two thin scatterers

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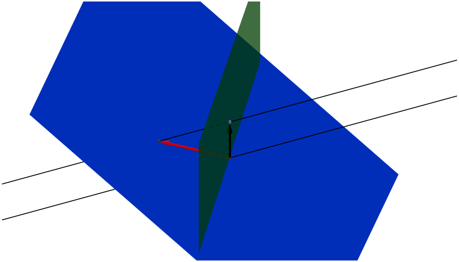
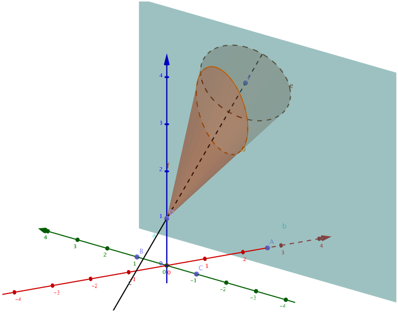
2 Add Measurements



Green Plane: Local coordinate system XY plane (The sensor surface)
Blue Plane: Global Coordinate system which is shared by all sensors
Black Lines: Track before/after motion
Black Arrow: Change on track position in local frame
Red Arrow: Change in track position in global frame

- Each plane has its own measurement frame.
- Each hit contains all information needed to allow different locations on the sensor to have different measurement frames

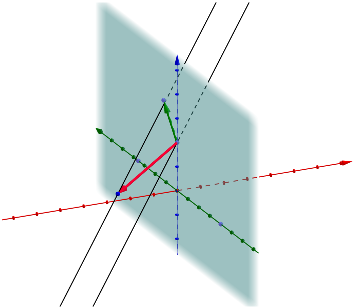
3 Add Scattering



Black Line: Track Orange Cone: The position errors due to a thin scatterer Blue Plane: Measurement plane.

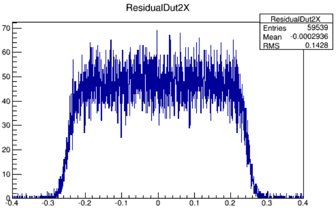
- Kink angles are included in fit rather than placed as addition uncertainty.
- A simple or complex determination of the radiation length with the particles path can be used.

4 Alignment

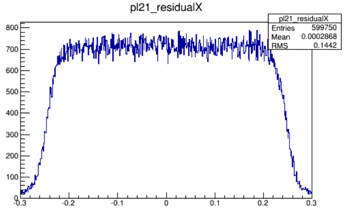


Black Line: Track
Red Arrow: The change in location of track due to change in coordinate system of sensor
Green Arrow: Change on sensor surface in global frame.

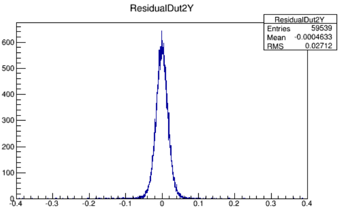
- All track variables are included as local (nuisance) parameters.
- Geometry information is updated and stored in a single location.
- Final track fitting results are output in ROOT/LCIO format.
- Analysis and selection code exists



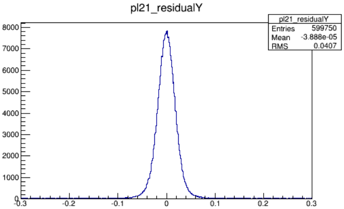
GBL X residual



DAF X residual



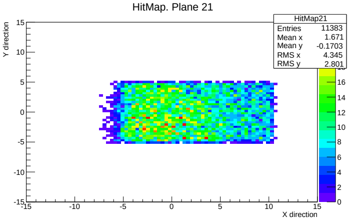
GBL Y residual



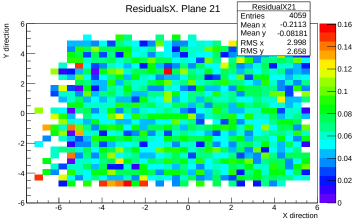
DAF Y residual

Plots: Ryan Nelson

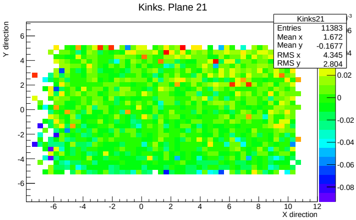
Example Output from the Quad Module



Hit map after tracking in local frame
(Beam spot can be seen here)



Residual on surface of sensor in local X direction
(∼70 μm intrinsic resolution)



Kinks in local frame
(Expect to be zero since scattering is random process about the initial incidence)

Quad modules are large area pixel sensors mounted on 4 FEI4 readout ASICs

Results look as expected for 250x50 μm^2 sensor assuming uniform distribution on each pixel.

Efficiency measurements will be performed on these modules with particular interest in the long/ganged pixel regions.

Track/State/Hit/Cluster objects are arranged in a simple hierarchy to allow easy additions to code.

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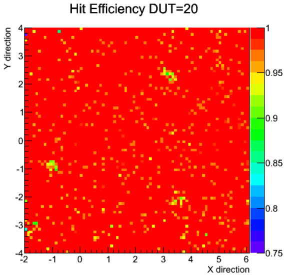
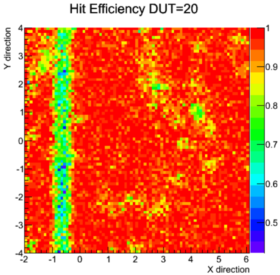
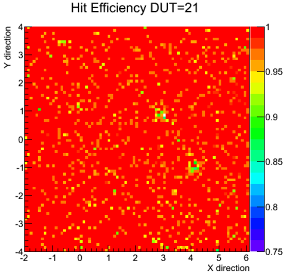
Efficiency Measurements



AC Sensor biased 20V



AC Sensor irradiated to $10^{15}\ n_{eq}cm^{-2}$ **biased 200V.**



DC Sensor biased 20V

In effort toward the ATLAS upgrade, efficiency measurements have been performed on different sensors irradiated to different fluencies at the DESY testbeam.

Pitch 250x50 μm^2 with different coupling.

DC and AC sensor shows comparable efficiencies.

Radiation damage is clearly visible for irradiated sensor.

Plots: Helen Hayward.

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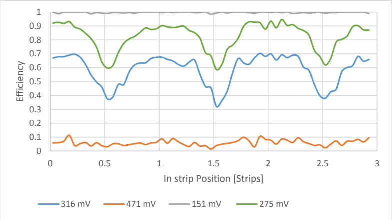
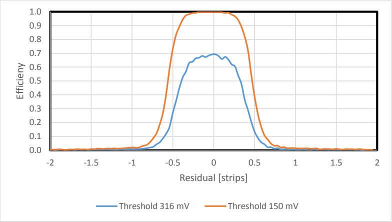
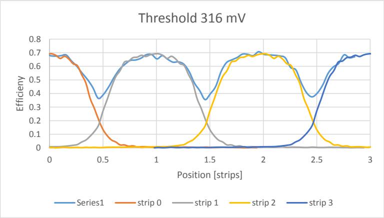
Efficiency Measurements with ATLAS12 Strip Sensor



Combined efficiency for each strip with different thresholds



Efficiency with distance from centre of strip.



Combined efficiency for each strip for 316 mV threshold.

ATLAS12 Strip Sensor (74.5 μm^2 pitch).

Interested in individual strips efficiency. Requires accurate prediction on DUT.

Using analysis code which is part of the SCT example.

Plots: Richard Peschke.

Conclusion

A generic track fitting model has been implemented into EUTelecope.

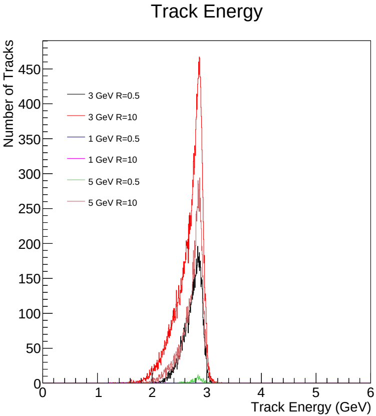
- Many working examples which can be used as the bases for future work.
- Designed to work for the widest range of testbeam setups.
- Output comes in a range of formats for different analysis tools and packages.

Future additions

- Radial strips and improvement in the implementation of the measurement frame.
- Replacing the old GEAR file format to allow more complex geometries.

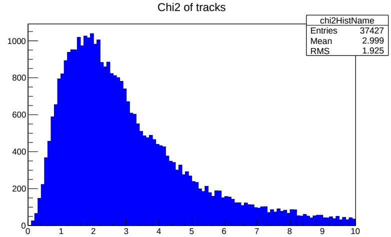
Backup

Magnetic Fields

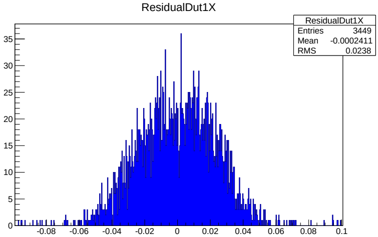


Different pattern recognition inputs to check the consistency of the track fitting

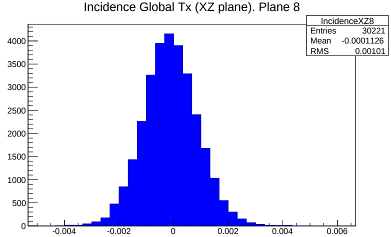
Current Testbeam Reconstruction (October 2015)



Not so perfect χ^2/ndf.



Residual on DUT for local X axis.



Incidence of track on DUT for local X axis.

Some initial results from this weeks testbeam.

Reconstructed tracks are lower than expected at 0.5 per event (Expect about 1.5 in most cases).

Beam divergence is as expect and the residual RMS is dominated by the intrinsic error: $\sim$ 21 μm^2.

However overall fit is still not perfect.