Radial Strips

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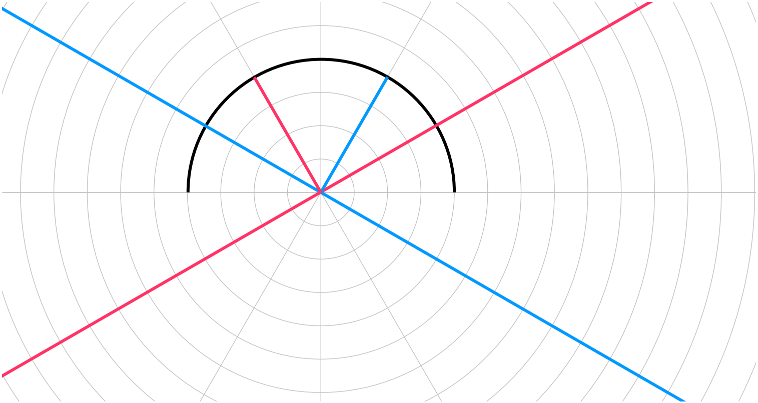
Radial Strips

Two strips red and blue

The transformations stored in the gear will lead to each strip having a non-diagonal covariance matrix in the local frame



The Problem and how this will be Resolved.

- **What are the uncertainties associated to each hit?**
  - Uncertainties are defined in some frame
    $\rightarrow$ **Local** On sensor surface
    $\rightarrow$ **Measurement** Frame in which hit has diagonal covariance matrix.
  - Normally covariance in local frame is diagonal and the same for all hits.
  - In general each hit will have it's own covariance matrix.
- Small updates to pattern recognition and tracking
  - Pattern recognition $\rightarrow$ Must make sure we compare hits along axis with information
  - Tracking $\rightarrow$ Need the correct covariance matrix for each measurement
  - **Both updates require a transformation:**
    Meas (diagonal) $\rightarrow$ Local (Non diagonal)
- Each hit must store an additional transformation to get the correct non diagonal covariance matrix
  - The orientation of the strip in the local frame must be determined
  - This should be combined with cluster size studies already done to get X/Y variance magnitude
- **We can chose the frame in which our residual is defined**

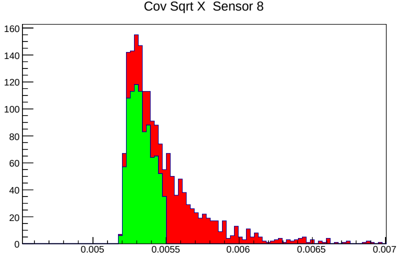
Outstanding concerns....

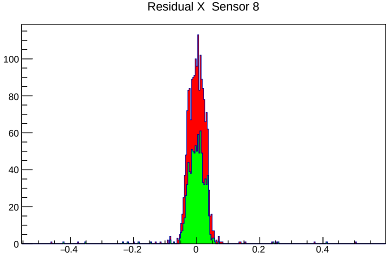
- What frame do you want your residuals?
  - Local frame
  - Measurement frame of each strip
- How do we retrieve this information for a variety of DUTs?
  - Must be a generic way which can be used for any DUT.
  - Need to be able to convert this information from schematics to something we can use
  - Related to last point $\rightarrow$ Make it TGeo volume specific.
    - This method will have to be used for clustering anyway.
  - Use the volume information for each cluster to determine transformation
    - **Must make sure this functionality is available $\rightarrow$ Otherwise need another store of cluster to transformation**

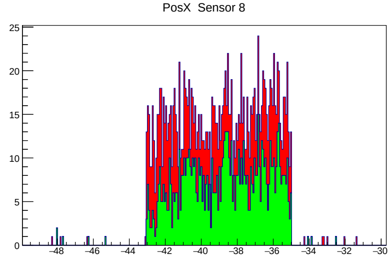
Unrelated Point: Track Selection

Example of track selection for $\sqrt{\sigma^2} < 5.5$ for strip sensor DUT at DESY

$\rightarrow$ Pass cut Fail cut







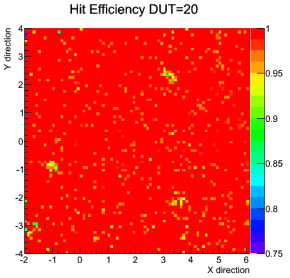
- Shown at testbeam workshop
- Track selection for any variable of interest
- **This might be of interest to some!**

Track Analysis and Selection

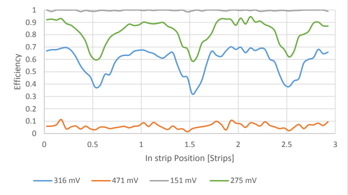
- All track parameters after fitting are displayed
- More indepth analysis needs track selection
  - Track selection can be performed on all track fit variables
  - Selection will produce an orthogonal pass/fail for each track
- Tbmon/ROOT output format available for further analysis

Plots shown here are all part of the examples which are found on github.

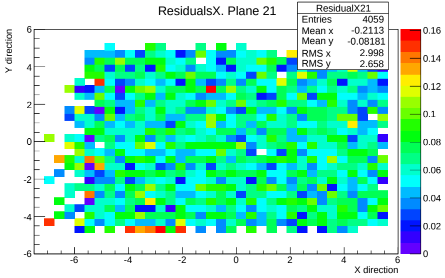
Examples



Efficiency measurements with AC pixel sensor biased 20V



Strip efficiency for a range of thresholds



Local frame X axis residual of Quad module

A variety of different examples

Encouraged to use the example as a template for further work

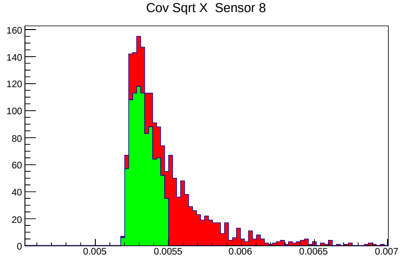
Willing to create new examples for new datasets

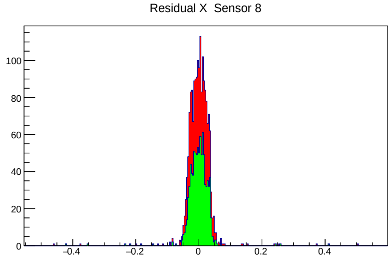
Plots: Helen Hayward/Richard Peschke

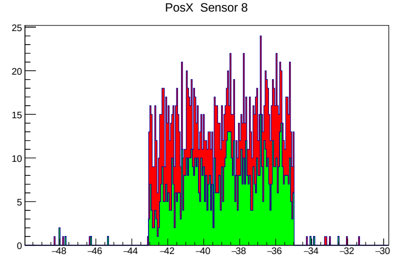
Selection based on Prediction on DUT

Example of track selection for $\sqrt{\sigma^2} < 5.5$ for strip sensor DUT at DESY

$\rightarrow$ Pass cut Fail cut





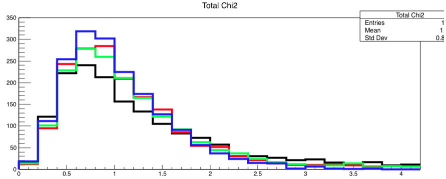


- DUT $\rightarrow$ Plane 8
- Selection will be used to analyse poor fit datasets

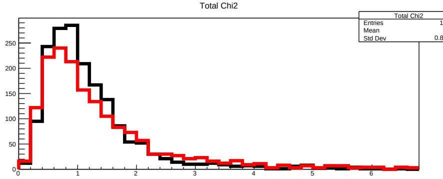
Comparison of Estimators

A quick comparison of different estimators on the same dataset

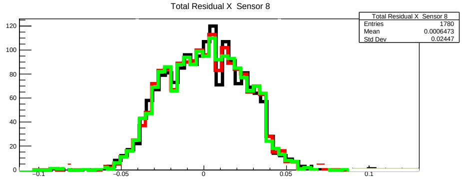
→ chi2 Cauchy Huber Tukey



All estimators applied for a single iteration



Both Cauchy. One iteration , Two iterations, 5th iteration the same as 2nd



Residual on sensor for each estimator. Note Tukey not included

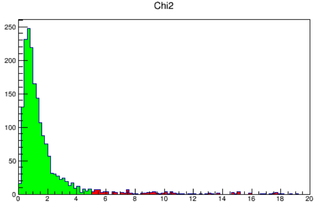
- Not much difference between estimators
- More than 1 iteration required before convergence
- A combination of weightings might show some improvements
- Millepede downweighting → Cauchy,Cauchy,Huber

Conclusion

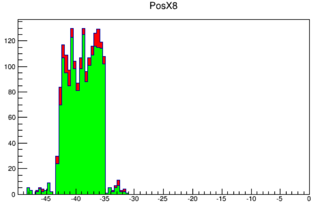
- The GBL algorithm has been implemented into EUTelescope
- Many examples exist for a variety of sensors
- Further development:
  - The track model must be validated
    $\rightarrow$ Use Allpix as part of a processor for easy simulation of possible testbeams
  - Further integration with other fitters.
    $\rightarrow$ LCIO format differences/Similar implementations

Track Selection with May 2015 Strip Data

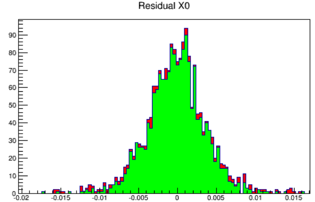
Example of track selection for $\chi^2 < 5$. Pass cut. Fail cut.



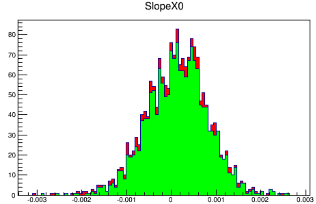
Chi2



DUT local position X



Sensor 1 Residual X



Sensor 1 local Slope X

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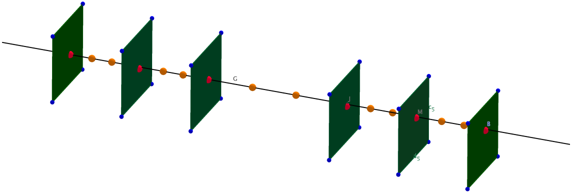
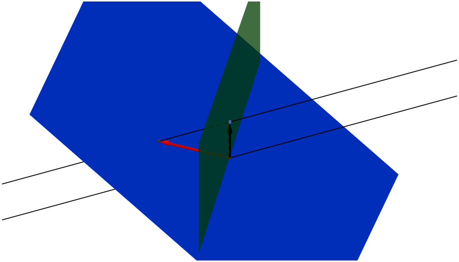
1 The Discrete Track



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

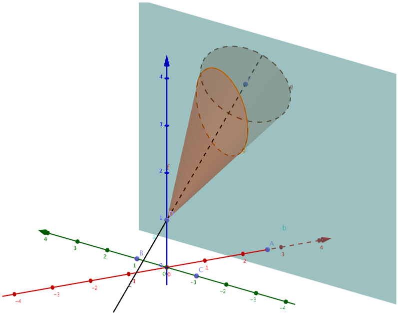
2 Add Measurements



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

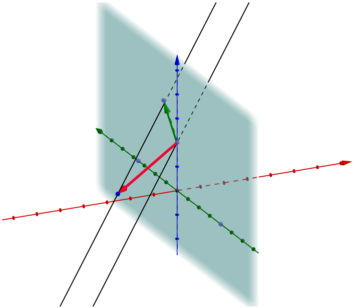
3 Add Scattering



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.

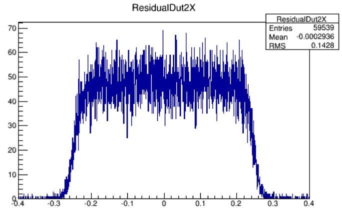
4 Alignment



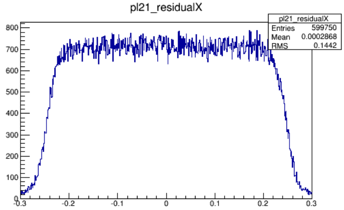
Black Line: Track
Red Arrow: The change in location of track due to change in coordinate system of sensor
Green Arrow: Change on sensor surface in global frame.

- 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

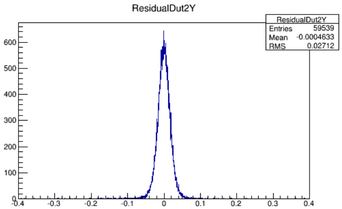
A Quick Comparison of DAF and GBL



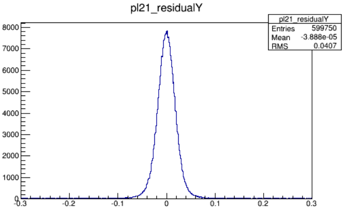
GBL X residual



DAF X residual



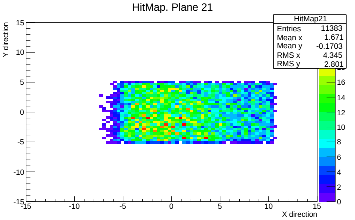
GBL Y residual



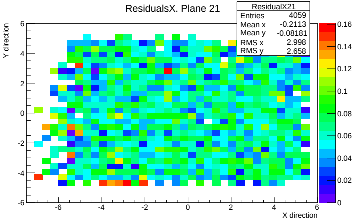
DAF Y residual

Plots: Ryan Nelson

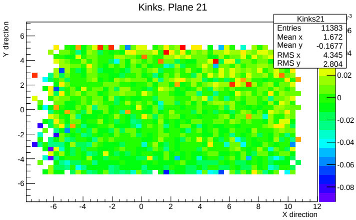
Example Output from the Quad Module



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



Residual on surface of sensor in local X direction
($\sim$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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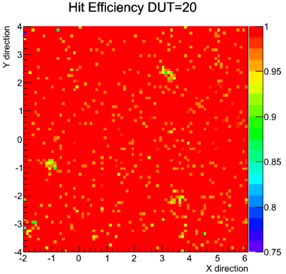
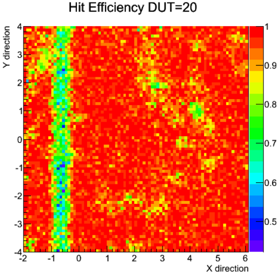
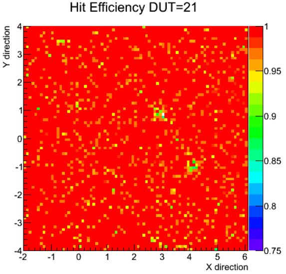
Efficiency Measurements



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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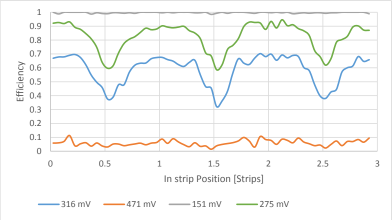
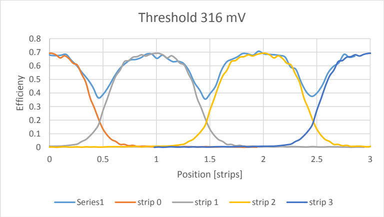
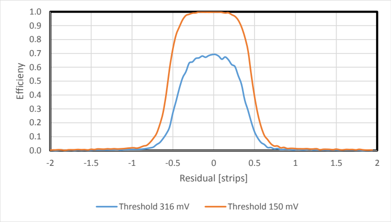
Efficiency Measurements with ATLAS12 Strip Sensor



Combined efficiency for each strip with different thresholds



Combined efficiency for each strip for 316 mV threshold.



Efficiency with distance from centre of strip.

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.

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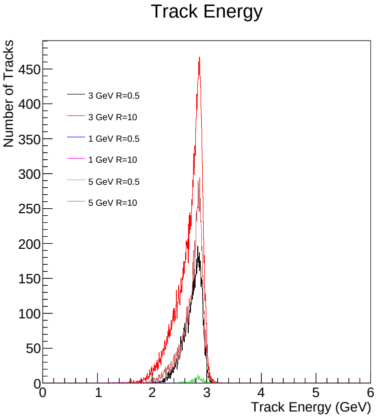
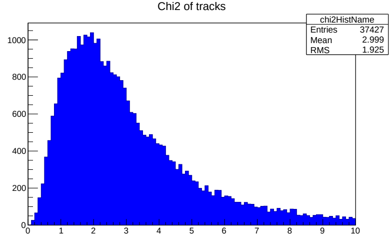
Backup

Magnetic Fields

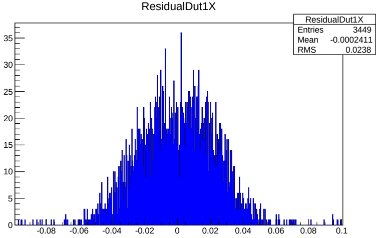


Different pattern recognition inputs to check the consistency of the track fitting

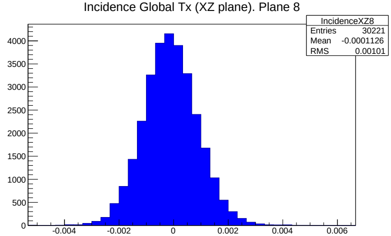
Current Testbeam Reconstruction (October 2015)



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.

A Quick Detour: EUDET/AIDA Pixel Beam Telescope

- 6 CMOS pixel detectors (18.4x18.4 μm^2) $\rightarrow$ 1152 columns x 576 rows 2x1 cm^2.
- Rolling shutter $\rightarrow$ continuous readout $\rightarrow$ 115.2 μs integration time/frame.
- Additional FEI4 device used for Region of Interest (ROI) and time stamping.
- TLU and EUDAQ act as hard/soft layer for data acquisition.
- EUTelescope is an advanced reconstruction framework for this setup, the latest workshop can be found here.

The mimosa sensors with a device under test (DUT).

EUTelescope

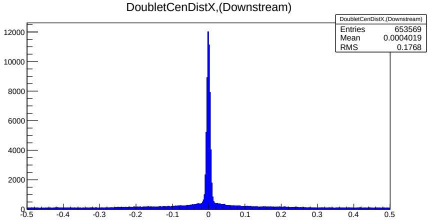
- EUTelescope is a highly generic testbeam reconstruction and analysis framework.
- It is a software package which is part of ILCsoft. A list of packages can be found here.
- Relies on two packages for data structures and reconstruction.
  1. Modular Analysis Reconstruction for the LINear Collider $\rightarrow$. Marlin.
  2. Linear Collider Input Output $\rightarrow$ LCIO.
- On top of this additional software packages are used.
  1. Millepede $\rightarrow$ Algorithm designed for least squares fit problems with a large set of parameters.
  2. TGeo $\rightarrow$ A ROOT geometry package used to describe the small/large scale characteristics of the setup.

The idea is to go from individual hit strips/pixels - or more complex - to the final reconstructed tracks. A general introduction is given here.

Pattern Reconstruction

You want to associate hits on each plane to a single track. This is more art than a science with many different procedures appropriate for different geometries and enviroments.

- Pattern Recognition comes with two regimes with GBL in EUTelescope.
  1. Clustering: Extrapolate all hits to first plane and cluster (Useful if some planes have a low efficiency).
  2. Triplets Use both arms of the telescope to form triplets then link (Low fake rate. Recommended!).
- Both regimes work with arbitrary magnetic field.



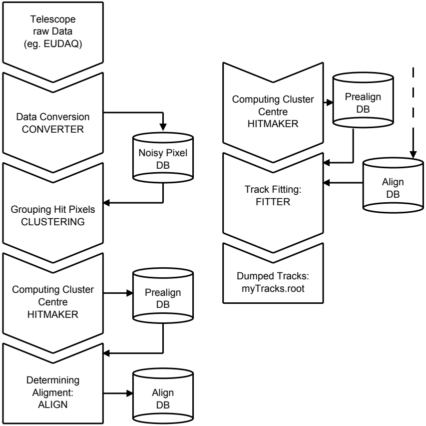
Residual (mm) of prediction - measurement. A series of cuts is applied to determine signal from background.

The Fitter in Action

EUTelescope is a collaborative effort first and foremost and to that end many working examples have been created to aid further analysis. The full analysis chain is described for each example and works from installation (Data on DESY AFS). Brief Manual here

- **noDUTExample** This example demostrates the use of the fitter with magnetic fields and varying beam energies.
- **Quad** Quad module with reference DUT at the DESY testbeam .
- **QuadSLAC** Quad module and reference DUT at the SLAC testbeam.
- **Pixels** High radiation length enviroment using the gear file to describe dead material. Two APIX devices at DESY testbeam.
- **mappingAPIX** Two APIX DUTs using the mapping processor between channel number and geometric cluster position.
- **mappingAPIXSLAC** This is the same as the other mapping example but at SLAC and with highly irradiated sensors.
- **SCT** Strip example which has been used for efficiency measurements.
- **StripAlibava** ATLAS12 strip device using the alibava system as readout.
- **X0** The use of the kink angle estimation is demonstrated here.

Reconstruction in a Nutshell

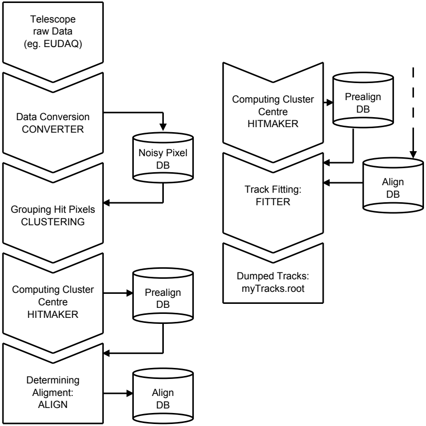


A typical reconstruction chain. Different processors can reconstruct the clusters/hits/track in different ways depending on the analysis.

Reconstruction comes in a series of steps with track fitting coming last in the chain.

- Converter: Takes unique output from readout system and creates an LCIO file with the required format. (Can combine telescope and DUT data further down the chain).

Reconstruction in a Nutshell



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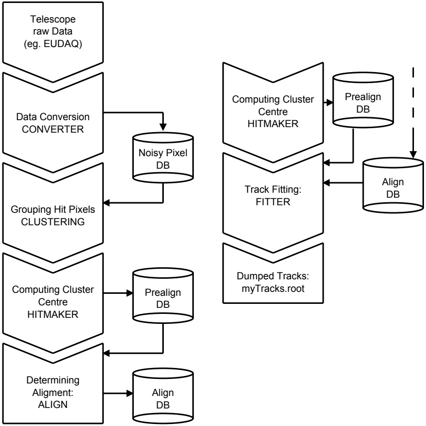

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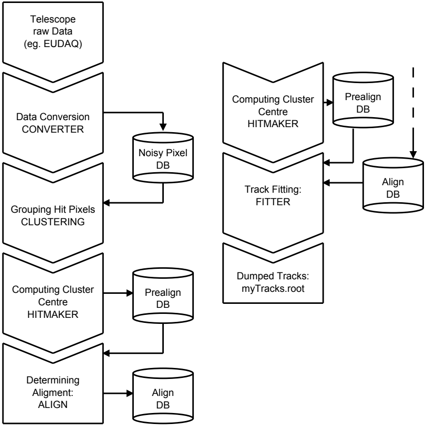

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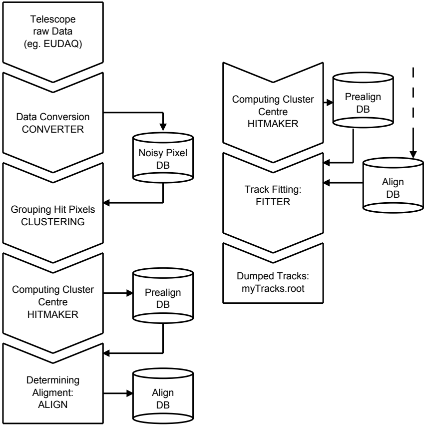
- Hitmaker: Relates clusters to a single hit position with intrinsic measurement errors.
- Pre/Full Alignment: Determines physical position of sensors. Different track models and alignment parameterizations can be used. However all methods depend on Millepede for least squares fitting for local/global parameters.

Reconstruction in a Nutshell



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- Clustering: TGeo used here to relate fired channel number to a geometric pixel (Many different types of cluster can be classified using different techniques).
- Hitmaker: Relates clusters to a single hit position with intrinsic measurement errors.
- Pre/Full Alignment: Determines physical position of sensors. Different track models and alignment parameterizations can be used. However all methods depend on Millepede for least squares fitting for local/global parameters.
- Tracking: The most likely track given initial assumptions is deduced, the final tracks are output in lcio/root formats.

Track Fitting with GBL Algorithm

The GBL algorithm has easy interfaces to include the needed information for a track fit and recovering the fit parameters. This information would be needed in any tracking situation and a quick introduction is presented now:

The five fold way

1. Need to link discretized points to form a full trajectory. Figure **??** shows the specific setup for EUTelescope.
2. The trajectory must contain measurements with errors. Figure **??** Red Points.
3. Points which model scattering have kink angles and errors added. Figure **??** Orange Points.
4. Global derivatives which relate motions of the sensors with local frame residuals are added for alignment.
5. *If needed: Local derivatives are added to determine parameters which relate to the track's residual on certain planes.*