UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES

Reconstruction, analysis and simulation of the FEI4 telescope SPS data with IBL Planar module and CCPD assemblies

Francesco Armando Di Bello master student

Co-authors: Mathieu Benoit, Sergio Gonzalez Sevilla, Javier Bilbao de Mendizabal

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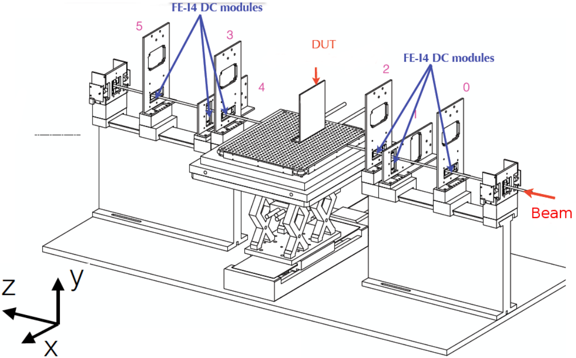
Overview of the latest (November) test-beam at SPS

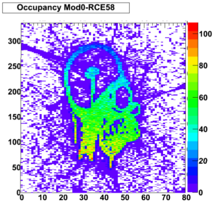
- more than 6 billion triggers.
- more than 1000 runs.
- 5 main samples to be analyzed (work in progress...).
  - CCPDv2: C19, C22 ,G1
  - CCPDv4: 402, 404 $\longrightarrow$ 4 pixel types.
- contributions from:
  U. of Geneva (2 M.a., 1 Phd, 1 Master student),
  U. of Bern (1 Post-doc, 1 Phd)
  and U. of Genova (1 Phd).

The FEI4 Telescope

- Developed by the U. of Geneva, see B. Ristic's talk.
- 6 reference telescope planes: IBL planar FE-I4 modules 50 x 250 μm pixel size.
- Trigger was given by the coincidence of plane 0 and 5.
- Region of interest defined.
- resolution at DUT $\sim$ 10 μm.

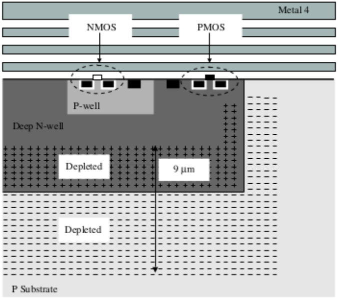


PR Plots for ROI



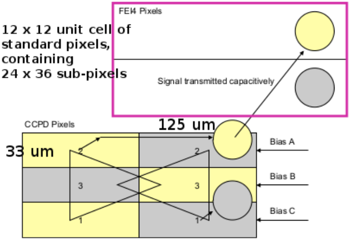
The Device Under Test

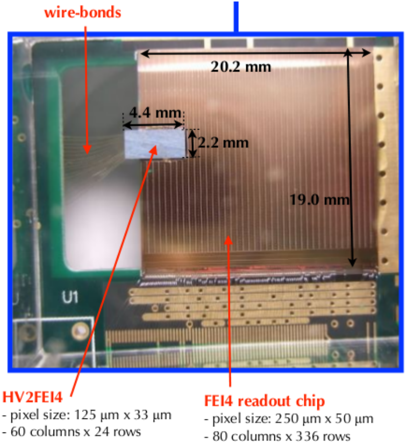
- High-Voltage CMOS (HV-CMOS) technology as a pixel particle detector:
- The entire CMOS pixel electronics are placed inside the deep n-well that acts at the same time as the signal-collecting electrode → "smart diode".
- CCPD: Capacitive Coupled Pixel Detectors.
- Lower cost, lower mass, lower operating voltage, smaller pitch.
- details here: High-voltage pixel sensors for ATLAS upgrade I. Perić et al. Nuclear Instruments and Methods in Physics Research.A 765(2014) 172-176



The Device Under Test

- version 2: C19 (unirr.), C22 ($1{*}10^{15} n_{eq}/cm^2$)





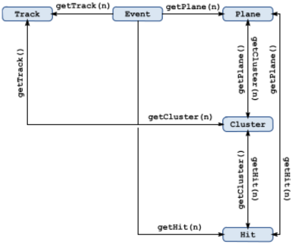
Overview

Judith has been developed by Garrin McGoldrick, Matevž Červ, Andrej Gorišek .
Nuclear Instruments and Methods in Physics Research.A 765(2014) 140-145

- Event reconstruction
  - clustering algorithm
  - track reconstruction algorithm
- Correct the positions and orientations of all sensor planes.
  - coarse alignment
  - fine alignment
- DUT analysis

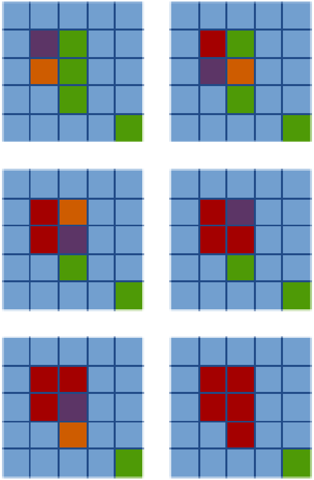
Judith Overview

- Judith is written in C++ and provides an intuitive object based event model
- The Judith data is stored as a ROOT n-tuple where each event corresponds to a trigger
- Input parameter and main cuts are defined in config. files



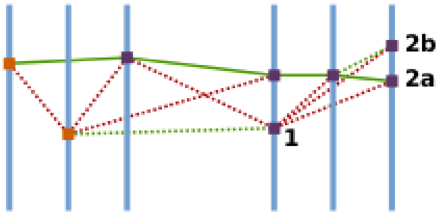
Clustering algorithm

- recursive search for neighbouring hits.
- legend:
  - green: unclustered hit
  - purple: seed for neighbour search
  - orange: found neighbour
  - red: hit belonging to the cluster
- Digital charge sharing. Center of the cluster is taken.



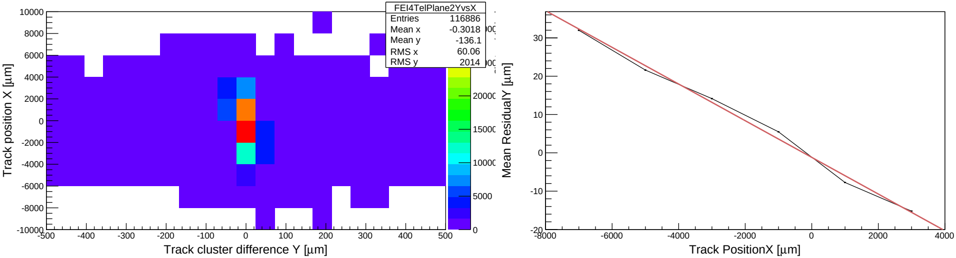
Tracking algorithm

- The tracking algorithm chooses a seed cluster in the first plane.
- The seed then searches up to 2 planes further for a cluster within a certain "beam spot".
- The track can bifurcate if more than one cluster is found. The best is then chosen (minimize χ^2).



The alignment procedure

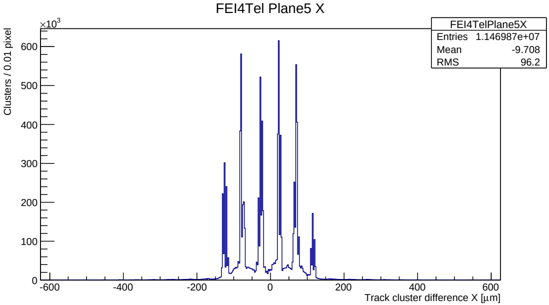
- Coarse alignment: Computes the offset using cluster difference between sensors
- Residuals are defined as the difference between the cluster position of a plane and the position extrapolated from the track in that plane.
- Fine alignment: Iterative process based on unbiased (excluding the hit of that plane in the track fit) residuals it estimates: rotZ, offX, offY

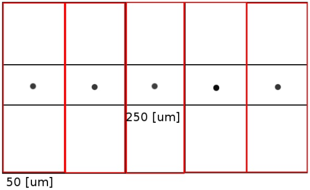


What is the minimum angle we can correct for? Studying with simulations.

Residuals shape

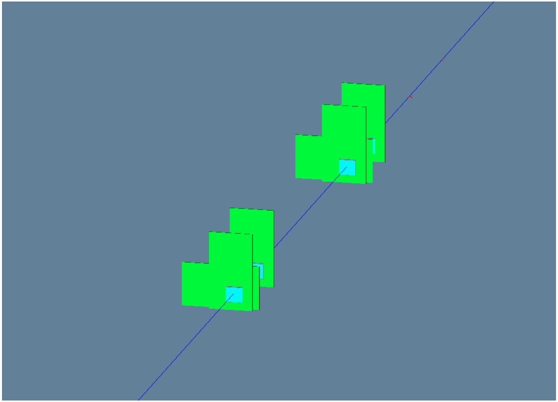
- peaks separated by 50 μm in the transverse plane; pixel $length(x) = 250\ \mu m$ vs $length_{transverse}(x) = 50\ \mu m -> 5$ pixels "granularity"





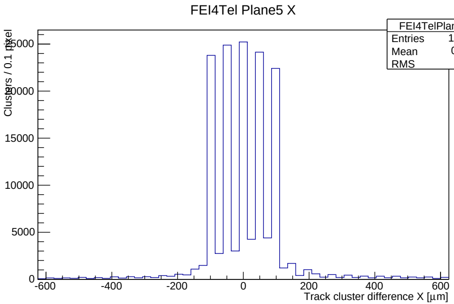
Residuals using Allpix

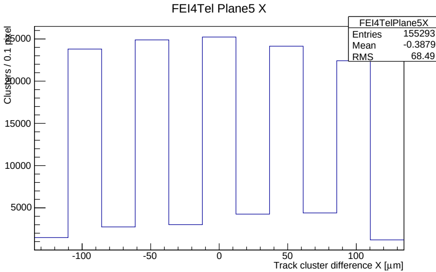
- developed by Mathieu Benoit and John Idarraga
- https://twiki.cern.ch/twiki/bin/view/Main/AllPix



Residuals shape using simulations

- Only the energy loss from M.C. simulations is taken into account.

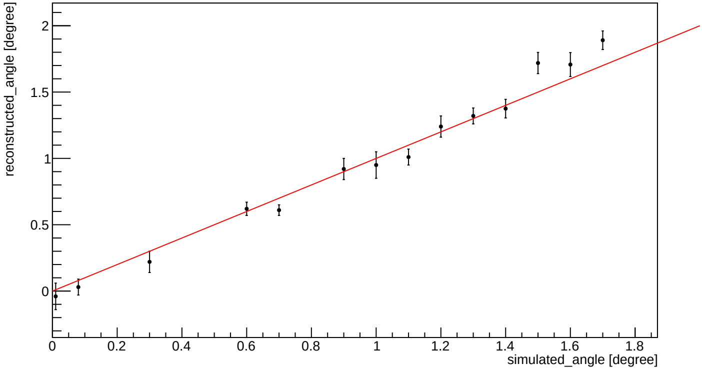




Simulations confirm 5 peaks divided by 50 μm.

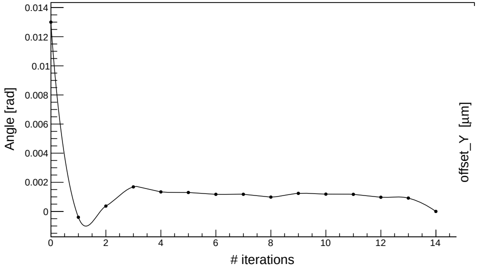
Alignment study

- Simulations have been used also to study the alignment.
- A rotation around z for the third plane has been implemented in simulations keeping the other planes perfectly aligned.

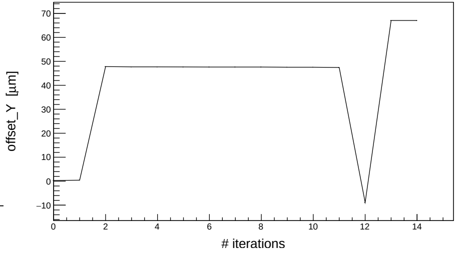


Alignment study

- The algorithm converges (data).

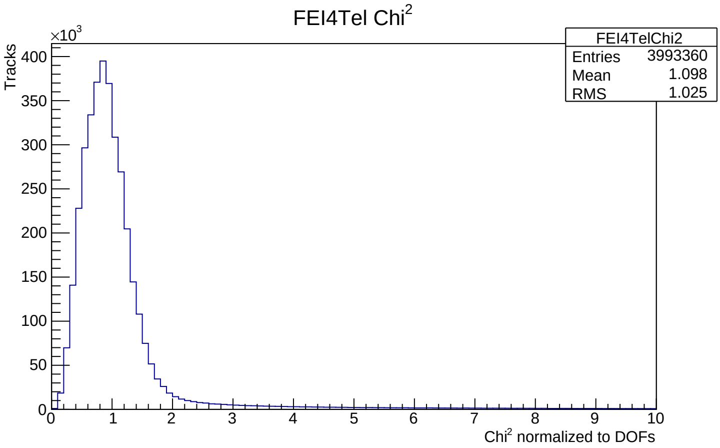


- But is some cases (simulation)...



- Understanding this behavior is complicated. Comparison with EUDET (Millepede) would help a lot!

Validation plot

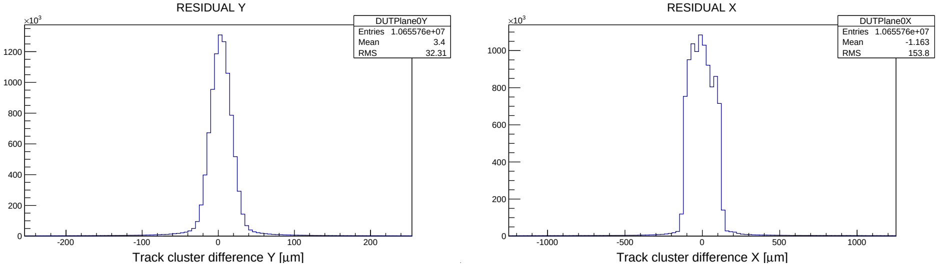


DUT analysis

- Quality cuts on tracks:
  - the track must have a cluster in each reference planes.
  - the track must have $\chi^2/n.d.f < 5$
- Extrapolate the track position to the silicon DUT plane
  - Match between the track and the cluster position in the DUT (ellipse to accommodate the rectangular shape of the pixel)

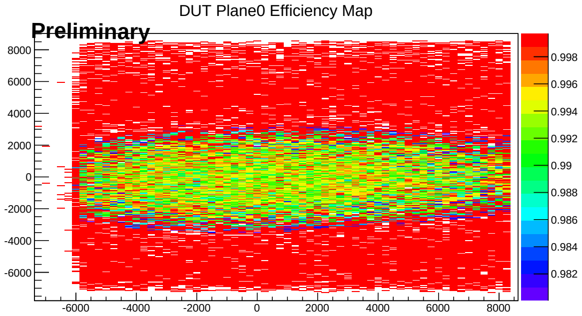
Some results: Residuals IBL Planar sensor

- Start observing the peaks in the long pixel direction (X).
- Gaussian shape in the short pixel direction (Y).



Some results: Planar IBL sensor

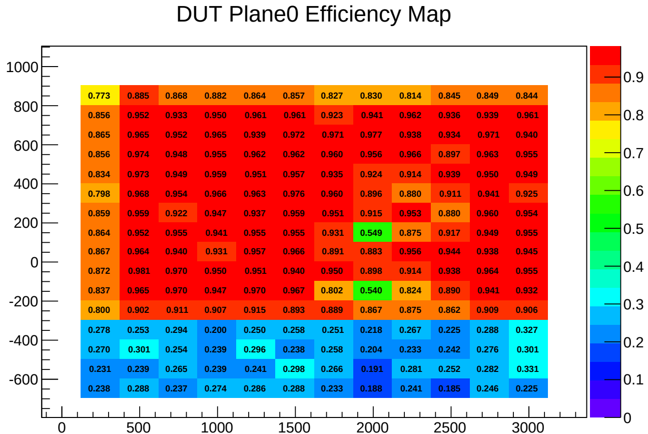
- $V_{bias} = 50$ V



- $\epsilon = 99\%$. This give us confidence about the validity of the reconstruction.

Some results: C22 efficiency

- Previous results at PS: CCPDv2 C19 (unirradiated) $\rightarrow \epsilon \approx 96\%$
- CCPDv2: irradiated $(1{*}10^{15} n_{eq}/cm^2)$
- $V_{bias} = 80$ V, $\epsilon = 95\%$ for "standard" pixels



Conclusion and further plans

- Availability of the software for the reconstruction of the FEI4 telescope .
- Data results and simulation results give us confidence about the validity of the reconstruction.
- The comparison with results obtained using Judith and EUDET will give us further confidence.
- Work in progress analyzing this promising technology.

Backup

Summary of the Judith reconstruction

- Alignment (coarse + fine) $\sim$ 20 m (1 M triggers), 10 iterations
- Process reference planes $\sim$ 1.4 m (1 M)
- Process the DUT $\sim$ 30 s (1 M)
- Efficiency studies $\sim$ 30 s (1 M)

Fast and friendly framework.