A Portable Telescope Based on the Alibava System for Test Beam Studies

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The Alibava Telescope

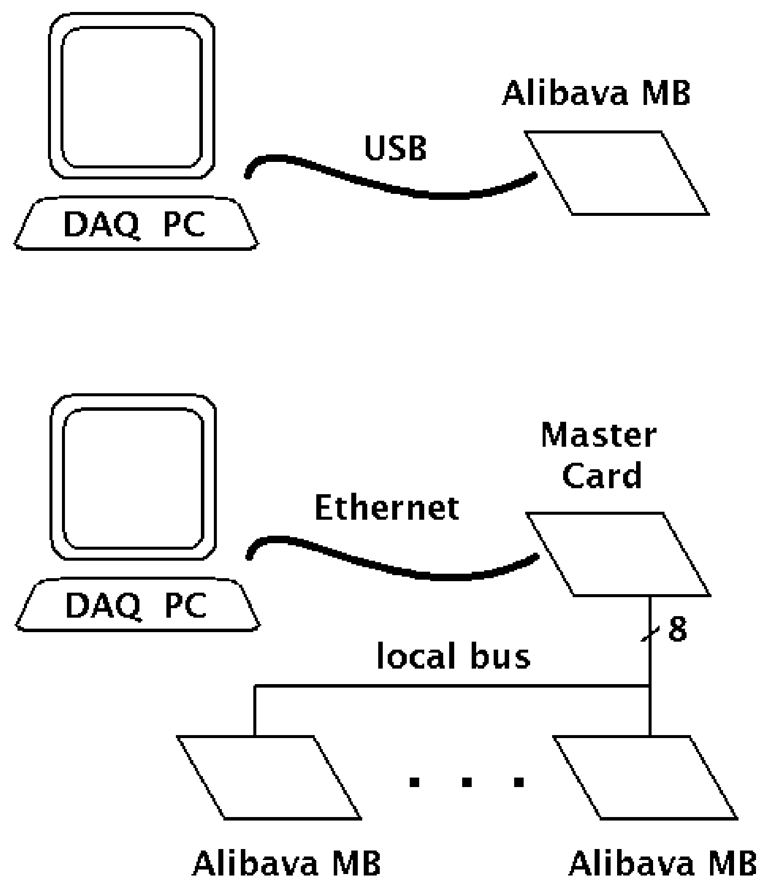
- The Alibava based test beam telescope is a system with four 2D strip detectors which measures track parameters with reasonable precision and determines the position of the beam particle interactions with a device under test (DUT).
- Characteristics of detectors before and after irradiation, as a function of bias voltage or other variables (temperature, influence of magnetic field, etc.) can be studied in real operation conditions.

The Alibava Telescope

- **Usually, the set-up of a test beam is laborious and time consuming.**
- **Our telescope has been conceived**
  - **to be easy handling and portable,**
  - **to minimize the set-up time,**
  - **provide high resolution and high rate tracking**
  - **with early feedback from analysis of the recorded data**

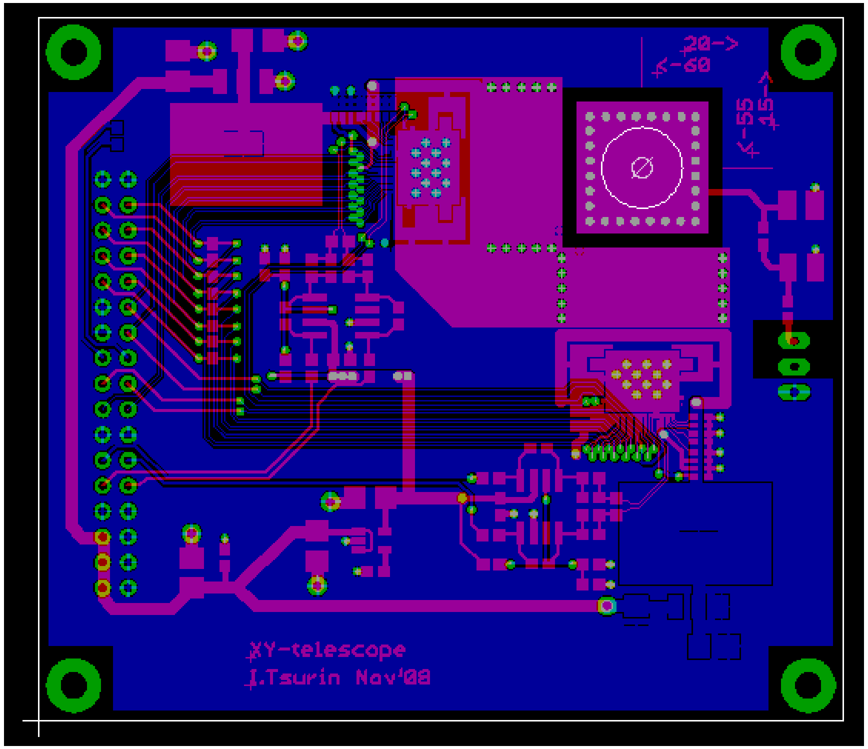
Hardware Architecture

- It is based on the existing Alibava readout system we have developed a multi plane system to be used as a test beam telescope.
- Every Alibava Mother Board is controlled and synchronized by a Master Card and a PC
- The standard MB have the USB controller substituted by a faster interface
- Local data/address bus between the master card and Alibava MBs
- Log data to PC via 100M Ethernet



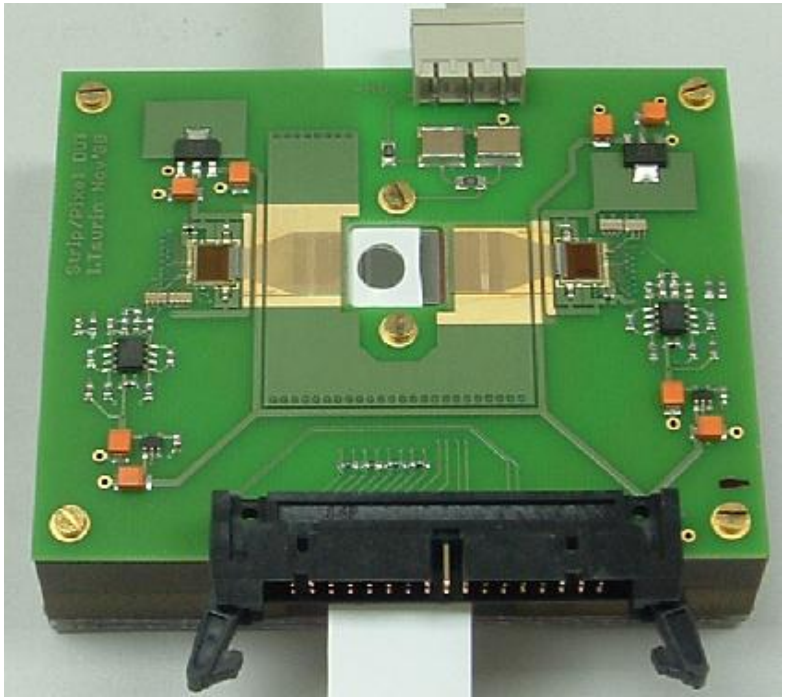
Daughter Board

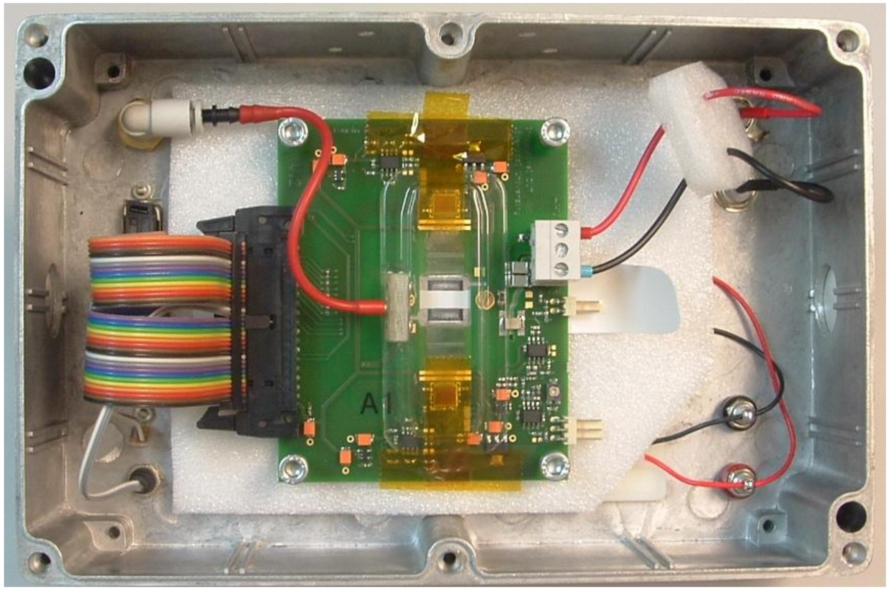
- There is a new DB with two detectors at 90 degrees
- Each DB constitute an XY plane

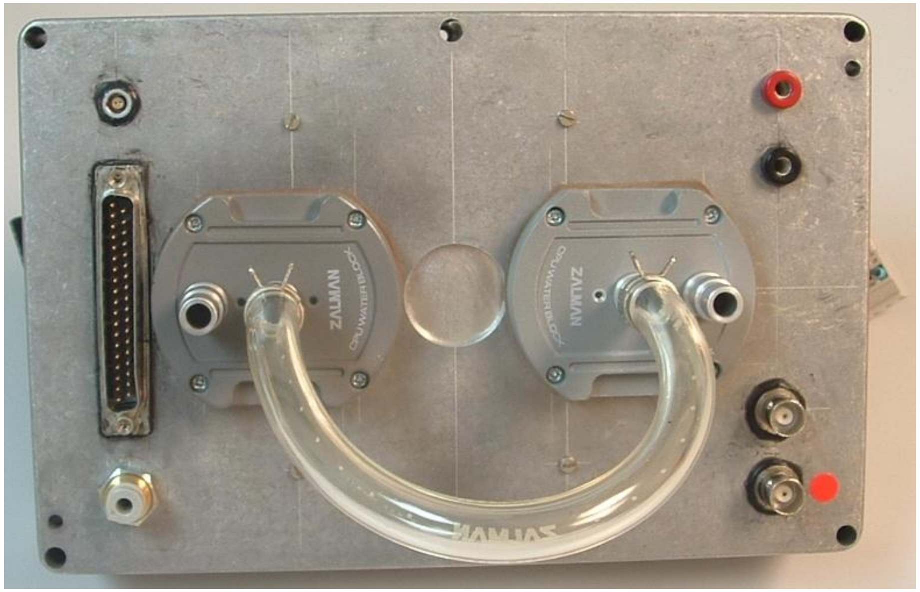


DUT box

- **To read out the DUT there is a new daughter board and a cooling box for irradiated detector testing**





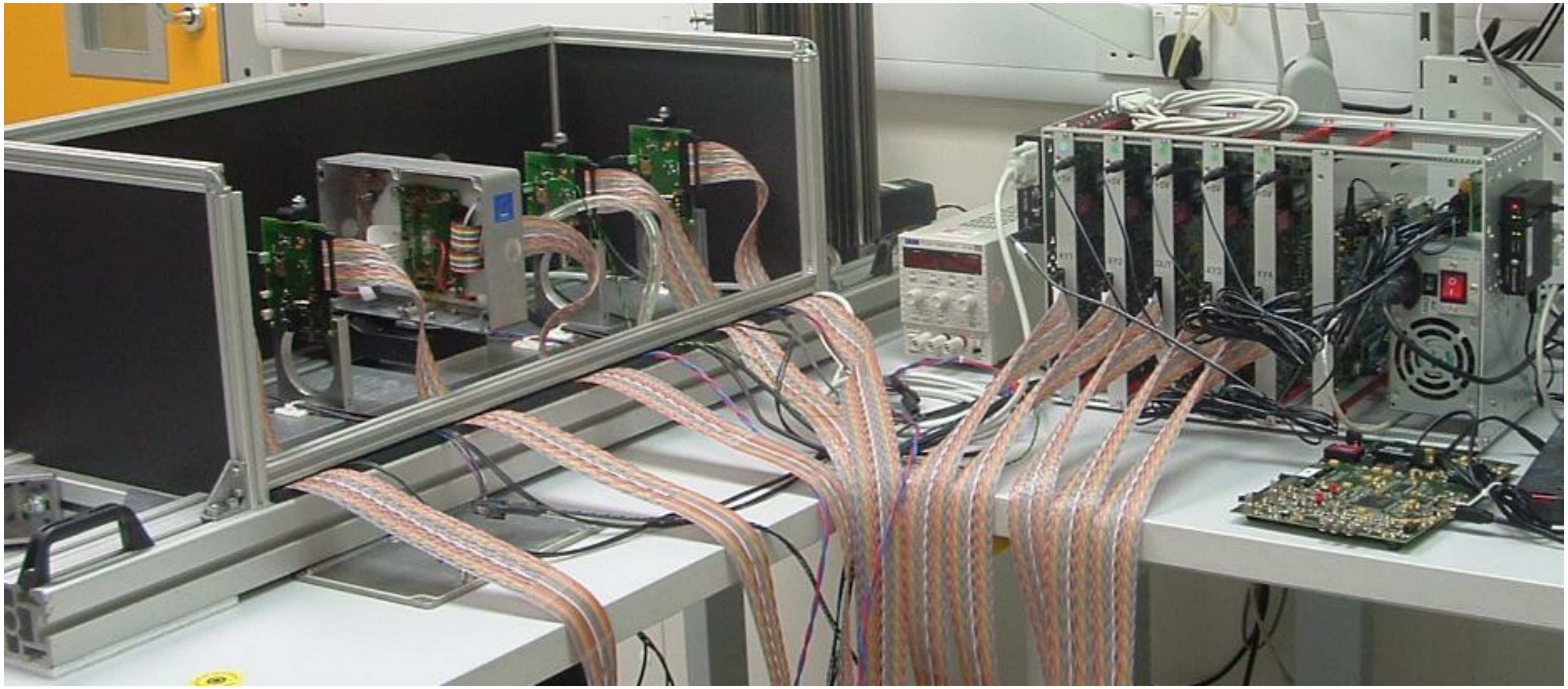


Mechanics

- **The prototype is installed in an aluminum crate with a protecting box**

Prototype

- **The first prototype is built with four XY planes**
- **It is already working and we have taken data at CERN**
- **We are working in the improvement of the track reconstruction algorithm**



Control software

- There is no control GUI yet, acquisition is controlled by a C program on terminal mode
- Clock and trigger are controlled by the Master Board and sen to the rest of MBs
  - Trigger generated by two scintillators situated at each end of the telescope
  - Trigger rate is 4 kHz although acquisition is much slower at the present moment
- Data are stored in a binary file with the following structure:
- and off-line analyzed by the Track Reconstruction Software

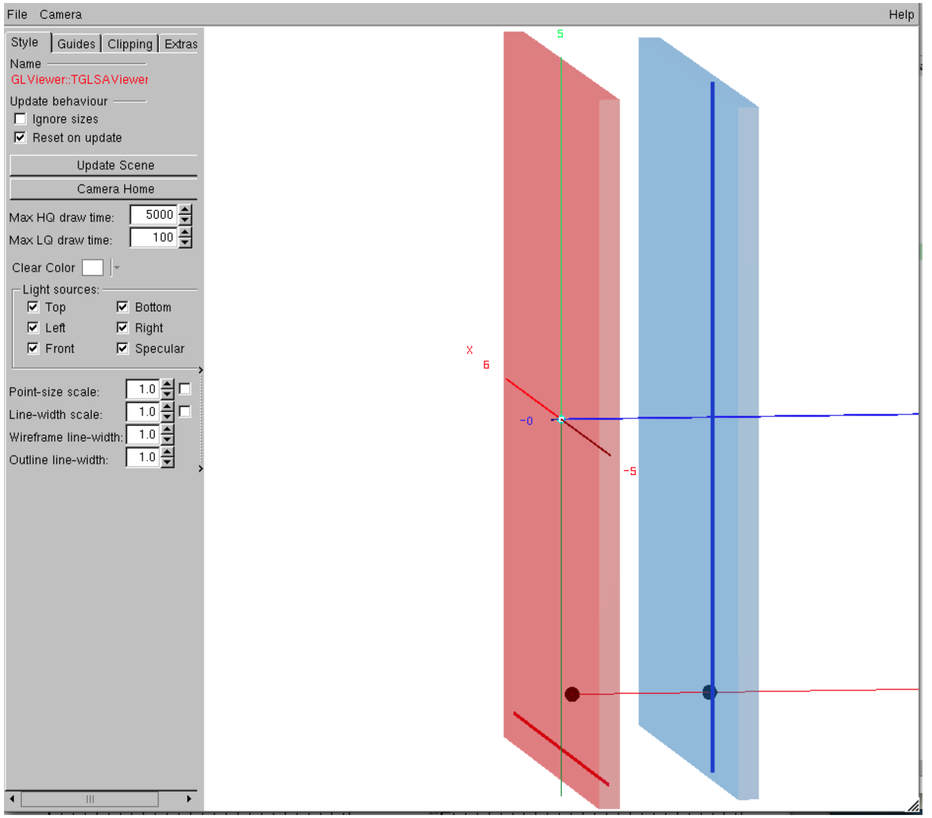
Event structure:

- 4 bytes event number
- 26 bytes DUT temperatures
- 5x 658 bytes motherboard data block:
  - 6 bytes MAC header
  - 2 bytes Status register
  - 4 bytes Event number
  - 4 bytes TDC value
  - 320 bytes ADC values ASIC 0
  - 320 bytes ADC values ASIC 1
  - 2 bytes NTC reading

Track reconstruction: System Geometry

- Track reconstruction software based on ROOT
- Geometry package uses the ROOT geometry package:
  - #include "TGeoManager.h"
  - #include "TGeoMaterial.h"
  - #include "TGeoMedium.h"
  - #include "TGeoVolume.h"
  - #include "TGeoMatrix.h"
  - #include "TGLViewer.h"

Example of XYT station with two planes. The first with the strips running along X And the second along Y direction

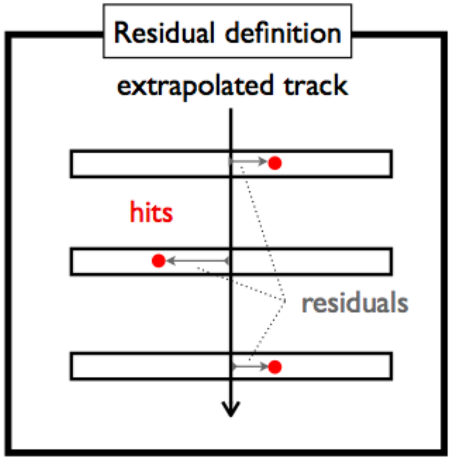


Track fitting

- **The track fitting is performed via the minimization of the track-hit residuals χ^2**

$\mathbf{t}$ = Track parameters

$$\chi^2 = \mathbf{r}^T V^{-1} \mathbf{r} \qquad \frac{d\chi^2}{d\mathbf{t}} = 0$$



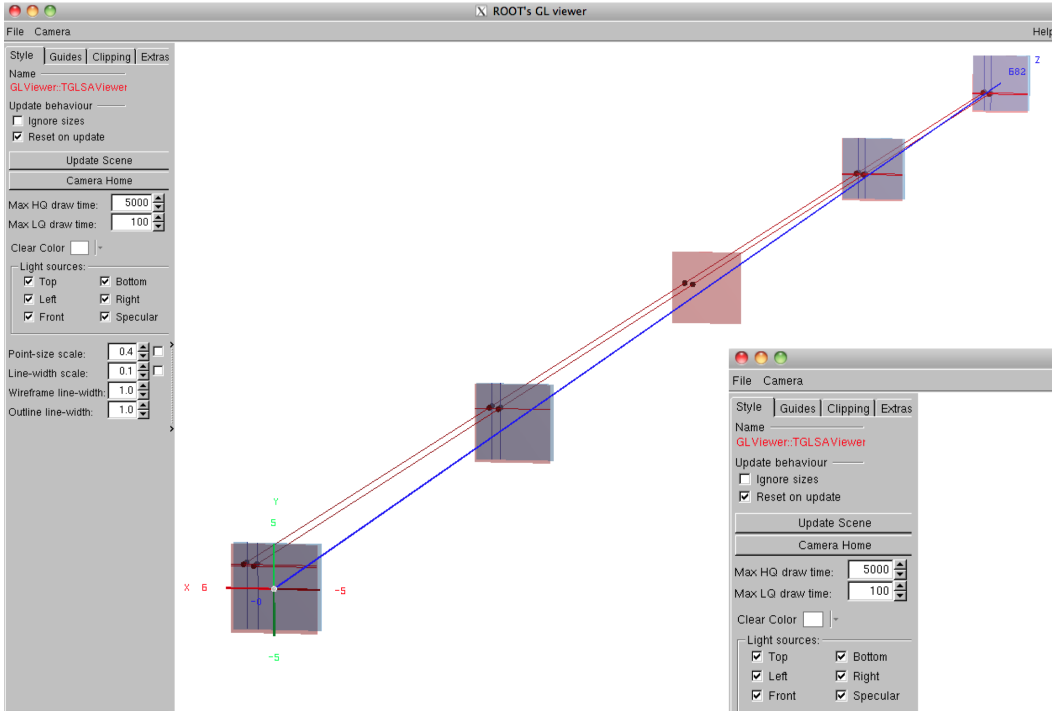
Measured point
Extrapolated point
And residual vector

$$\mathbf{m} = \begin{pmatrix} m_1 \\ m_2 \\ \vdots \\ m_N \end{pmatrix} \quad \mathbf{e} = \begin{pmatrix} e_1 \\ e_2 \\ \vdots \\ e_N \end{pmatrix} \quad \rightarrow \quad \mathbf{r} = \mathbf{m} - \mathbf{e}$$

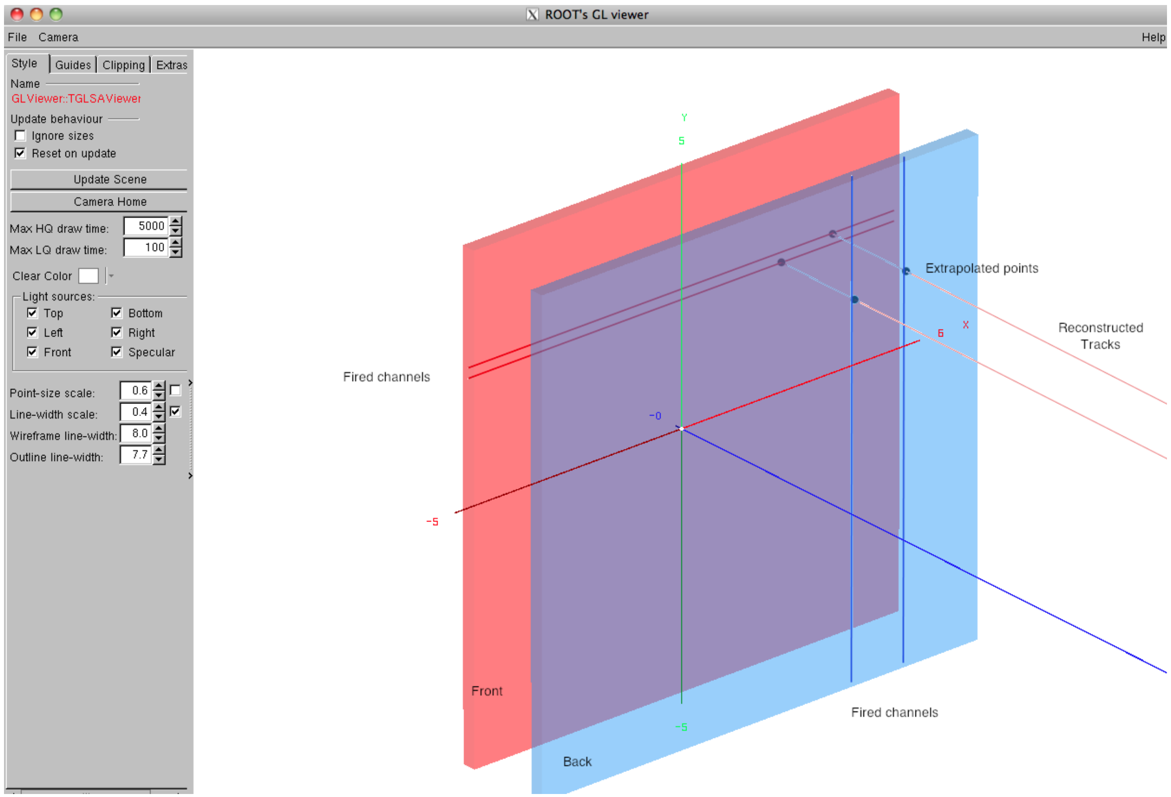
Hit error
covariance matrix

$$V = \begin{pmatrix} \sigma_1^2 & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & \sigma_N^2 \end{pmatrix}$$

Event display

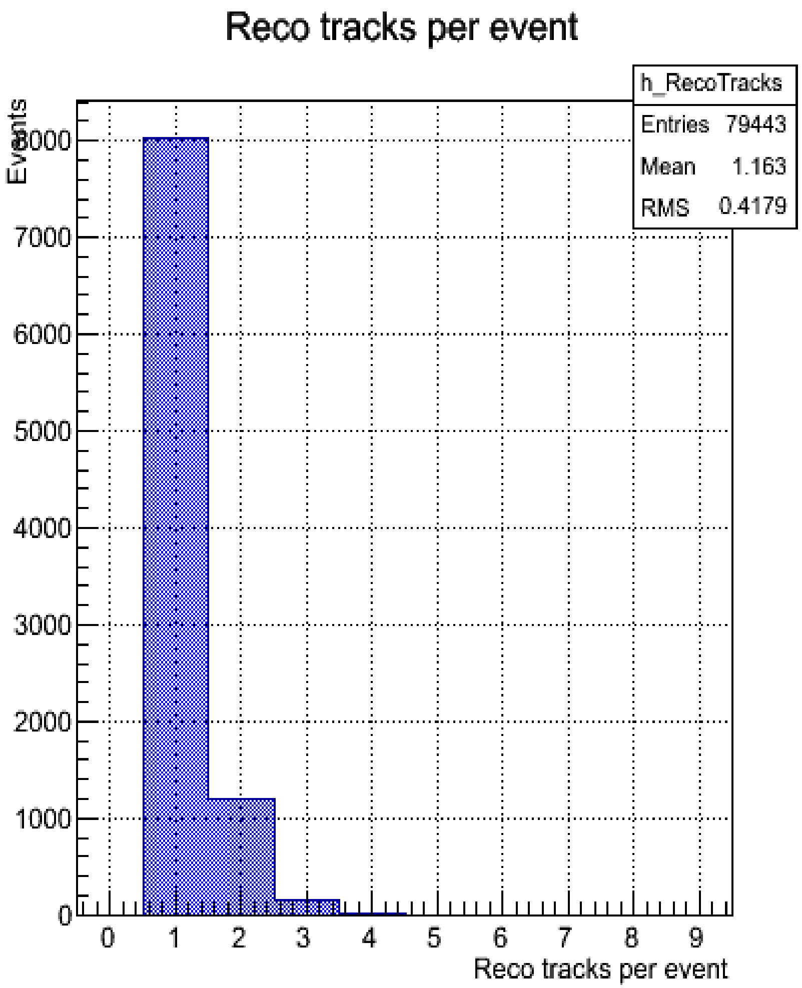


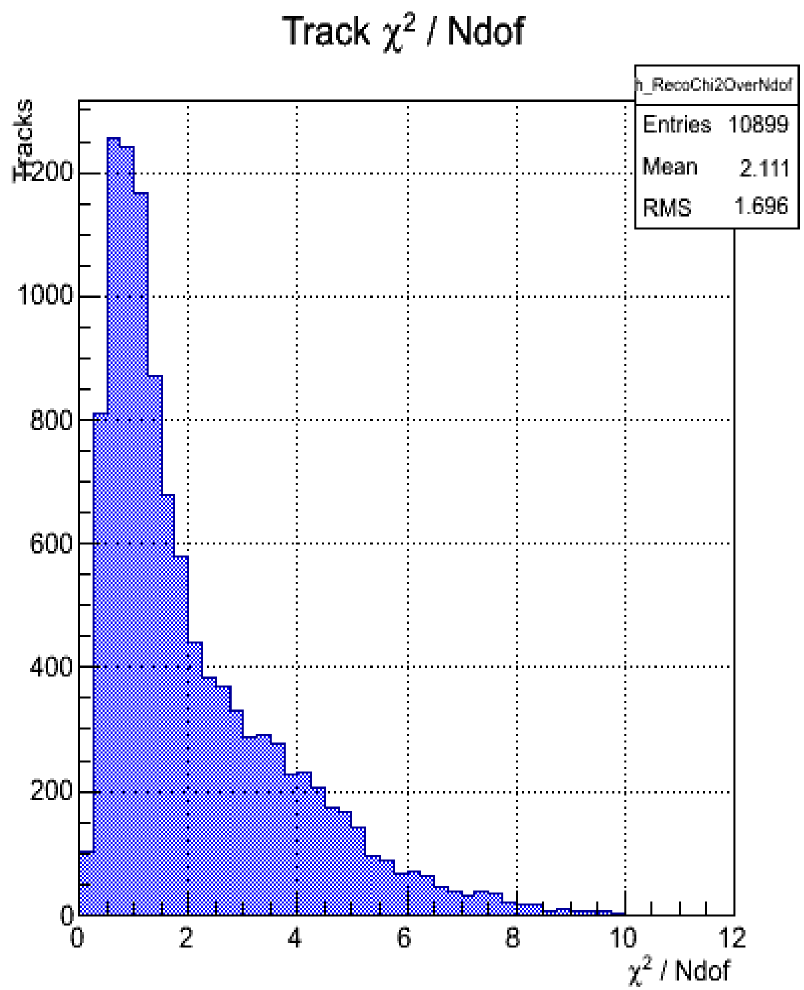
Event with two parallel tracks



Closer look to first module

Track fitting





Hit maps

- Used hits per plane

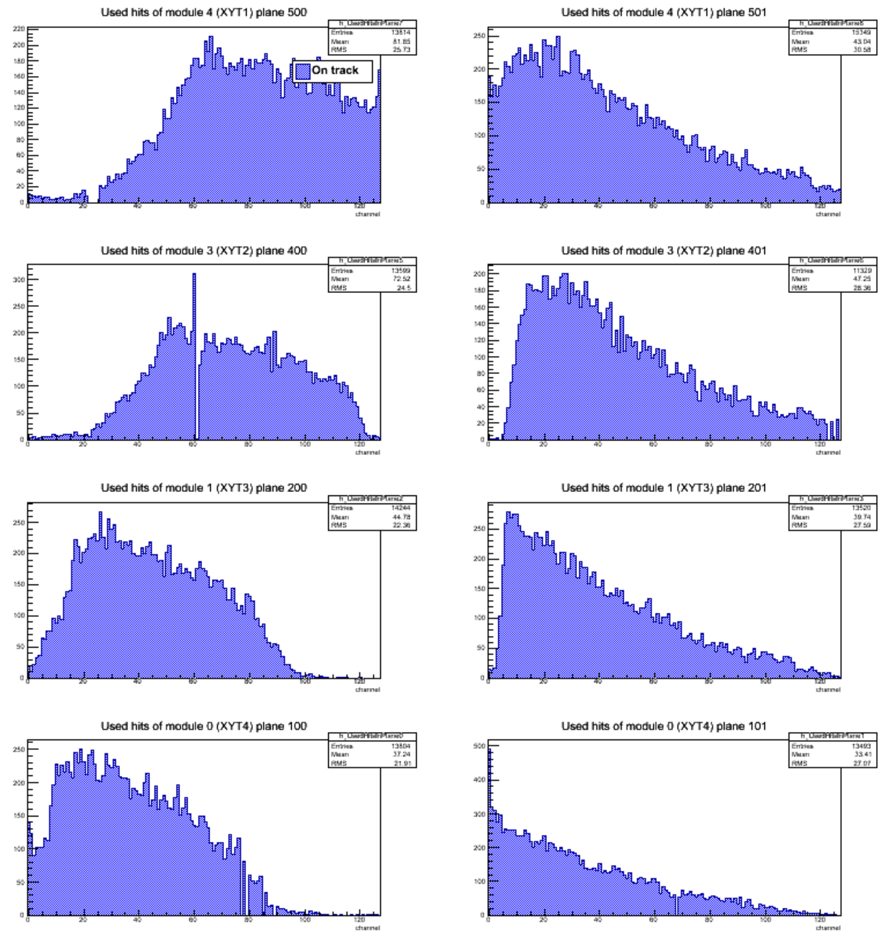
Front plane **Back plane**

Module 3

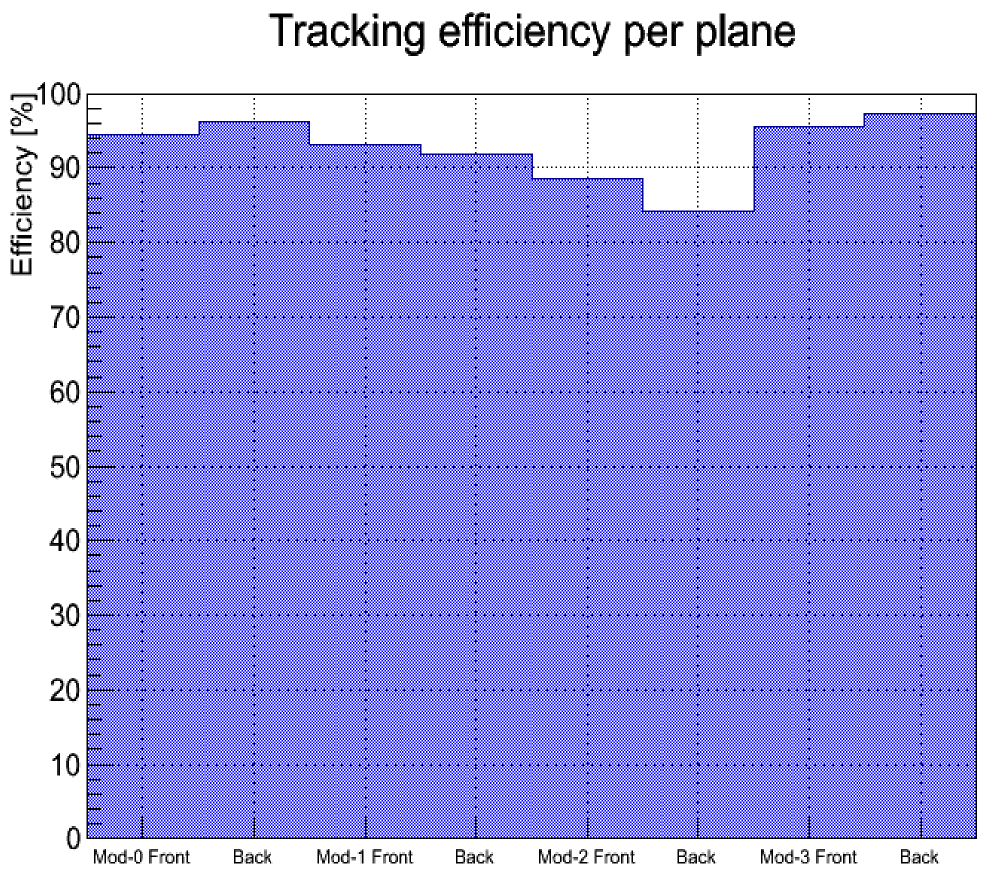
Module 2

Module 1

Module 0

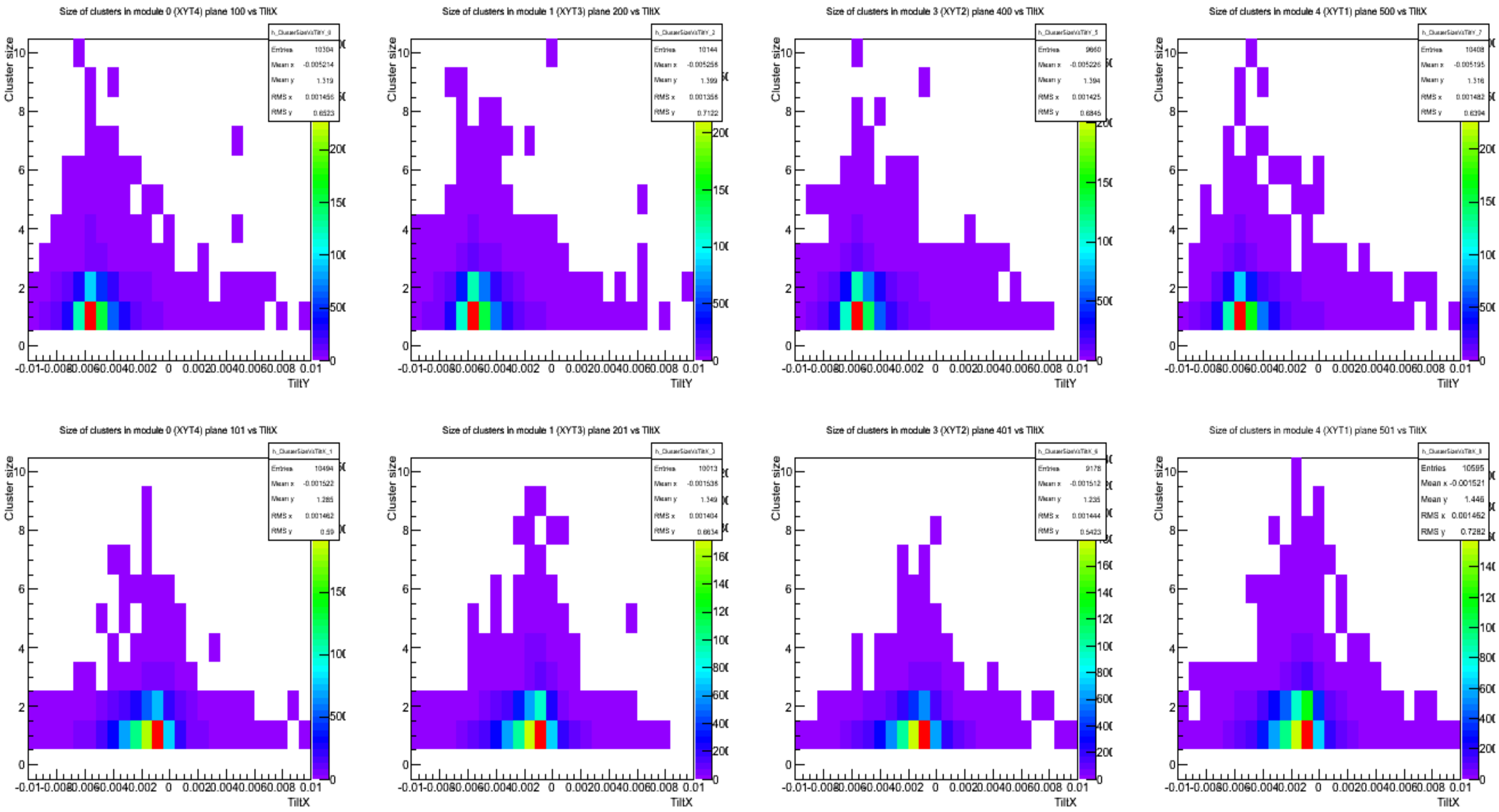


Tracking efficiency



Tracking efficiency = seen hits in a plane / expected hits in that plane

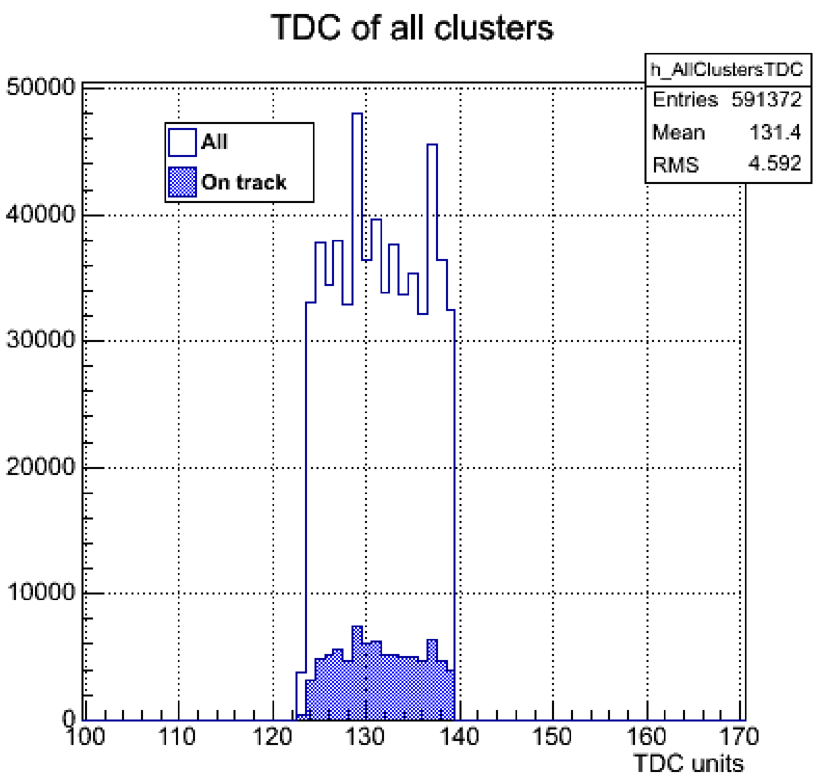
Cluster size

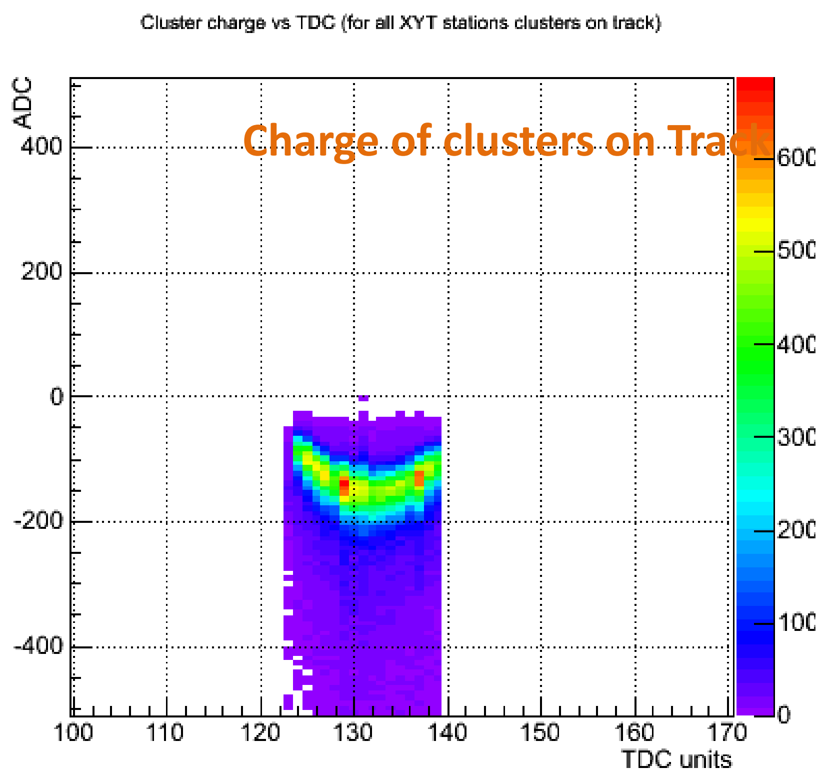


Cluster size in each plane vs track tilt

Cluster charge

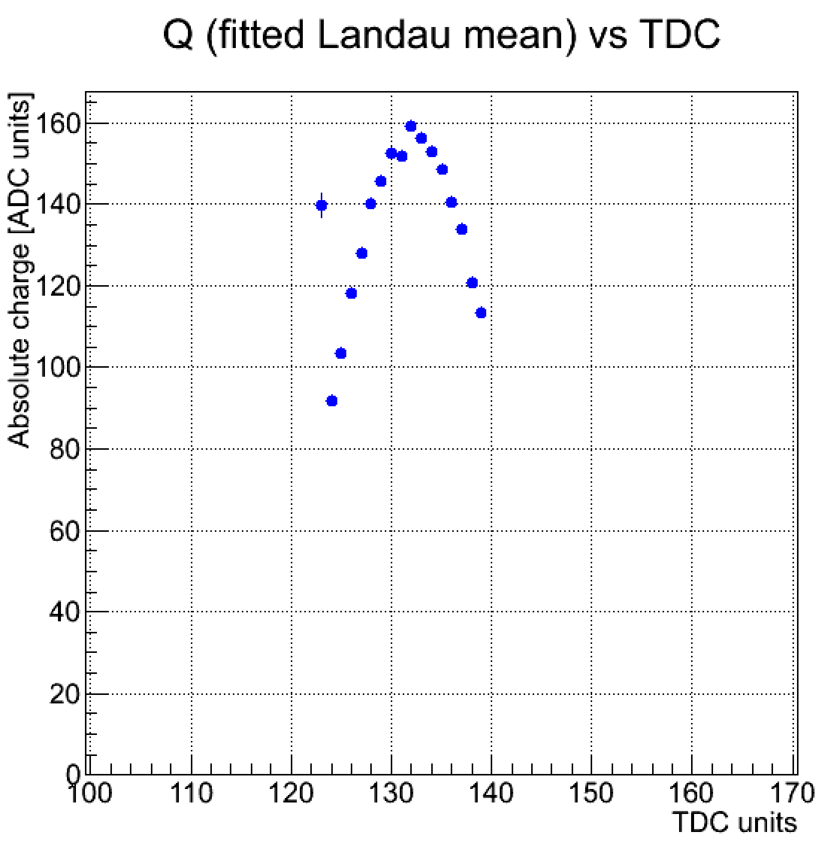
- **The collected charge depends on the elapsed time between the trigger and the 40 MHz clock edge**
- **That time is measured by the built-in ALIBAVA TDC**

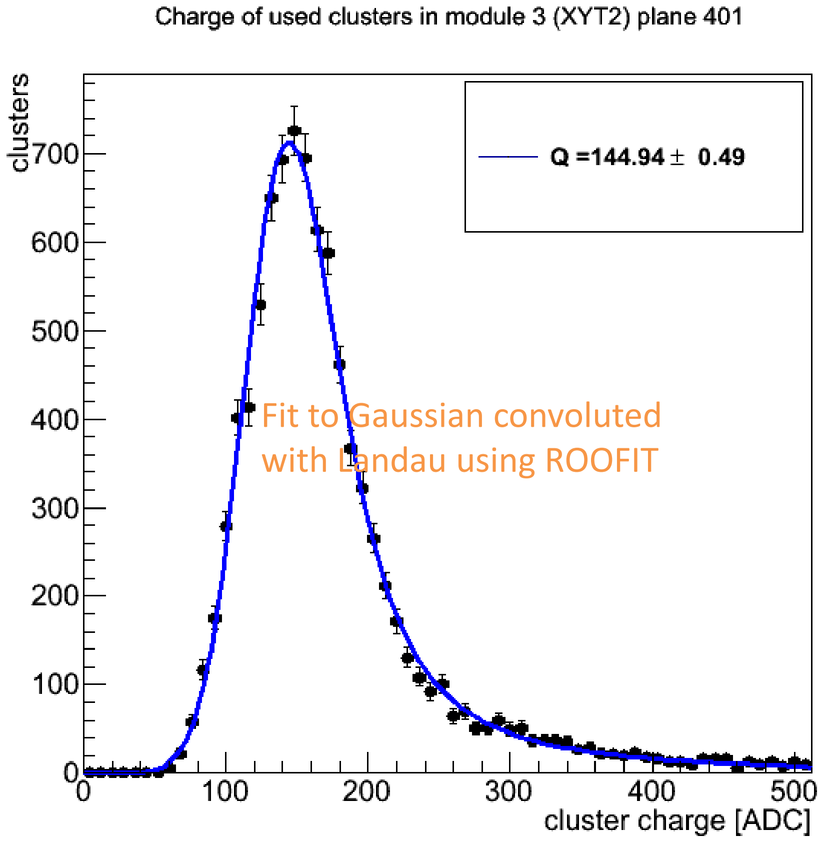




Cluster charge

- **The cluster charge is defined as the sum of the charge of all channels in the cluster Channels are considered if S/N > 3**

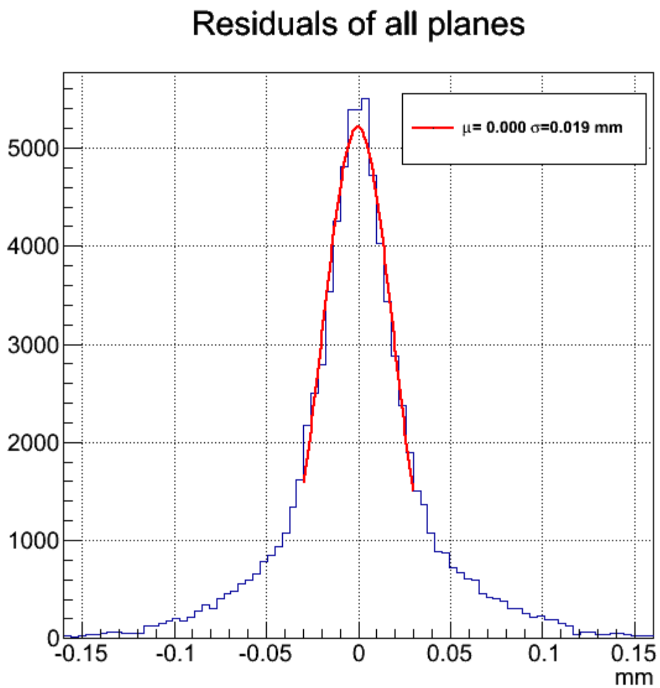


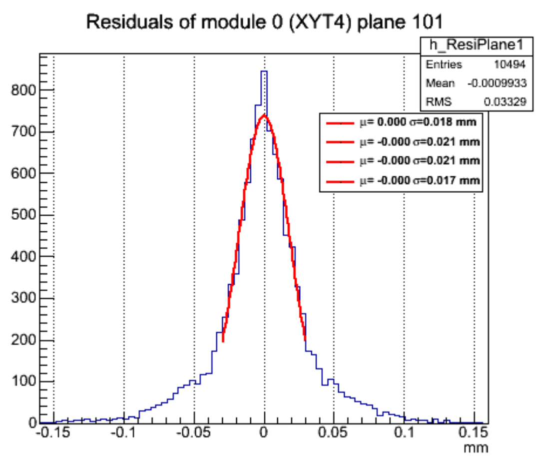


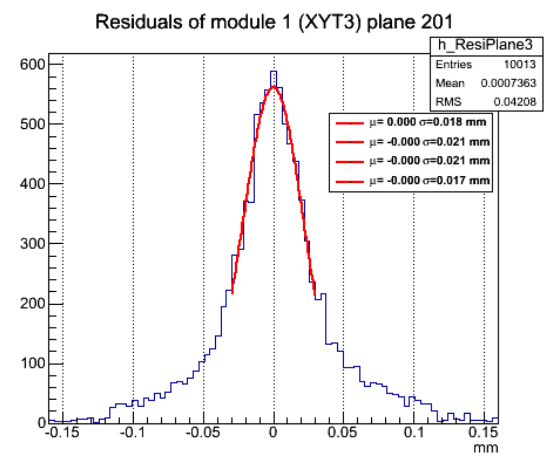
Track-hit residuals

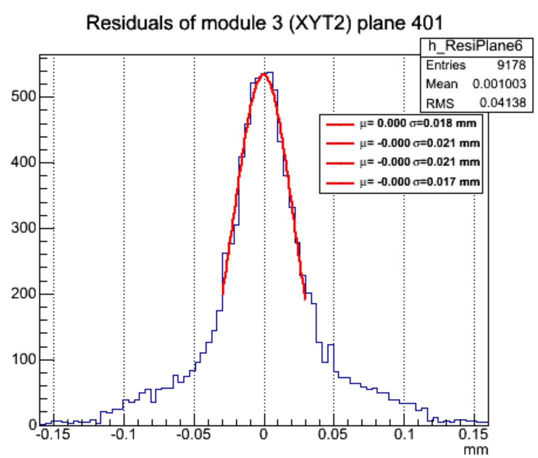
- The residuals are computed as the difference between measured point and the track extrapolation

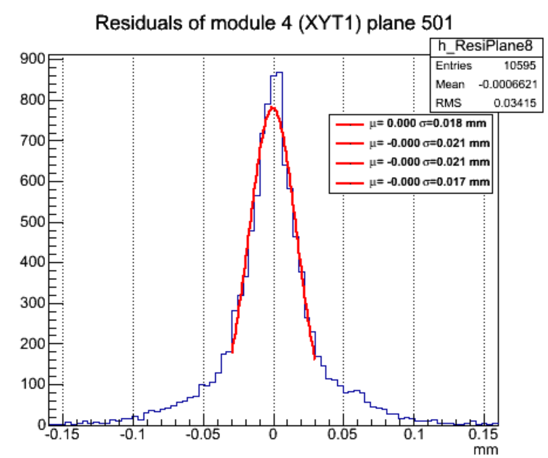
$$\mathbf{r(t) = m - e(t)}$$







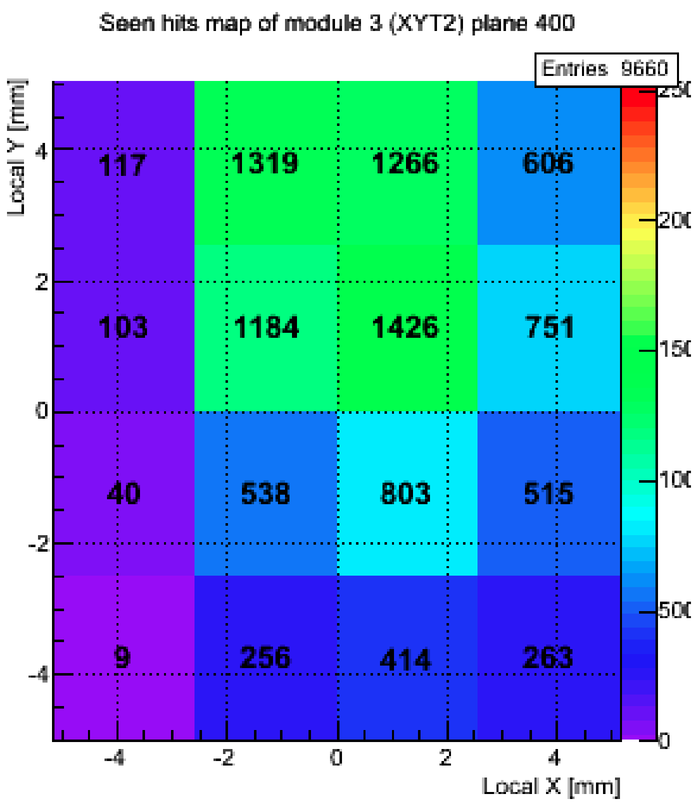




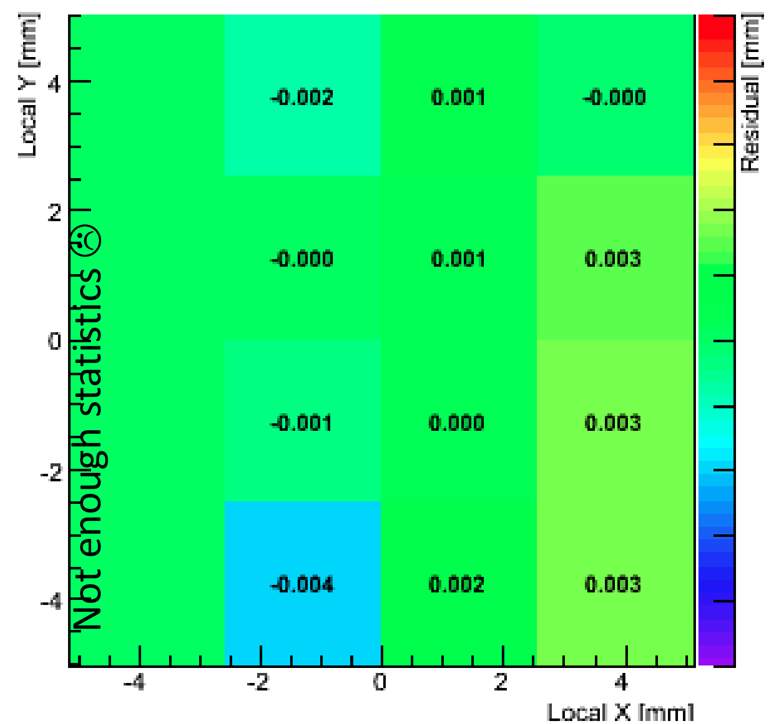
M. Loz

Detailed track-hit residuals

- **Divide each plane in a 4x4 grid (2.5 x 2.5 mm2)**
- **Study the hit map and residuals in each cell**
  - **Fit residuals only if cell has enough statistics**
  - **Draw mean of residuals map**



Internal structure of residuals seen
➔Need to align rotations



Summary and outlook

- **We have developed a Compact Track Telescope based on standard Alibava readout System**
- **The first prototype is working**
- **Preliminary version of the tracking code is up and running**
  - Use ROOT geometry package
  - 3D event display
- **Track & hits analysis available**
  - TDC, cluster size, cluster charge, hit efficiency, residuals
- **Working on:**
  - new pattern recognition & align within plane rotations
  - Hope to improve further the resolution