Marlin TPC status

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MarlinTPC basics

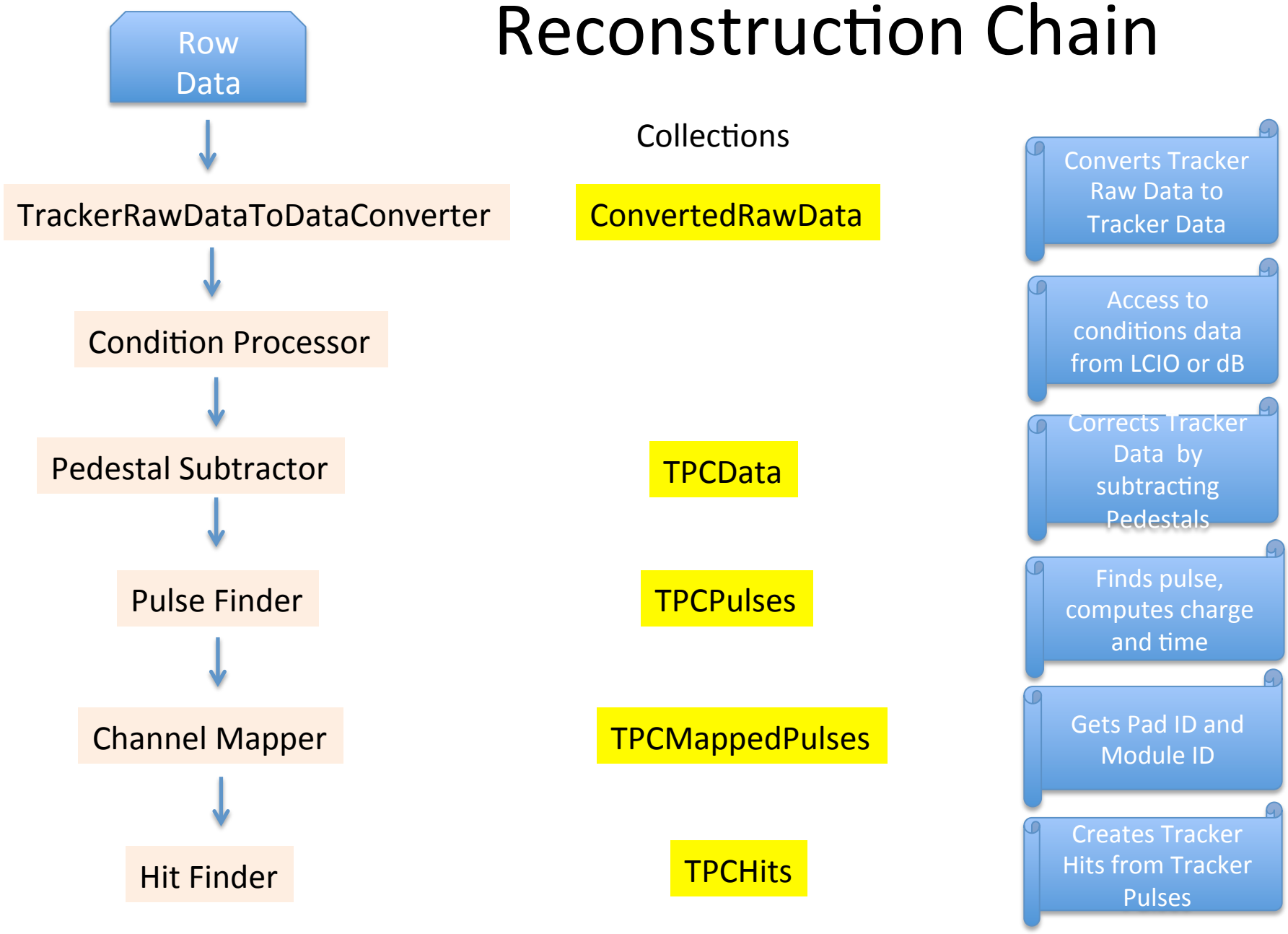
- ILC TPC reconstruction and analysis framework
  - Modular structure (modules == processors), allows plugging various processors for tests/trials.
  - Able to use LCCD (Linear Collider Conditions Data): data taking conditional parameters, slow control.
  - Uses GEAR (Geometry API for Reconstruction): allows to access geometry info for simulation, reconstruction etc.
  - LCIO common data format, ensure persistency.

Status since 2014

- Development of uniform analysis platform with MM and GEM by Astrid Muennich, Peter Hayman, Felix Muller and Phillipe Gros.

MMAdvancedCalibrationProcessor	calibrates the PRF by minimizing it while fitting the track.
MMScatterProcessor	creates necessary scatter-plots and fits appropriate data to calibrate the PRF.
MMRefitTool	Calc. χ2 of hits and track. Used in PRF optimization on event-by-event basis.
MMPadResponseFunction	Fits PRF functional to PRF data.
MMHitTimeCorrectionProcessor	Corrects the time estimate and z position for MM hits.
MMHitFinderProcessor	Creates Tracker Hits from Tracker Pulses.
BiasCorrectorProcessor	Calculates and Corrects bias – residuals as a function of hit position on pad.
BiasCalculatorProcessor	

Reconstruction Chain

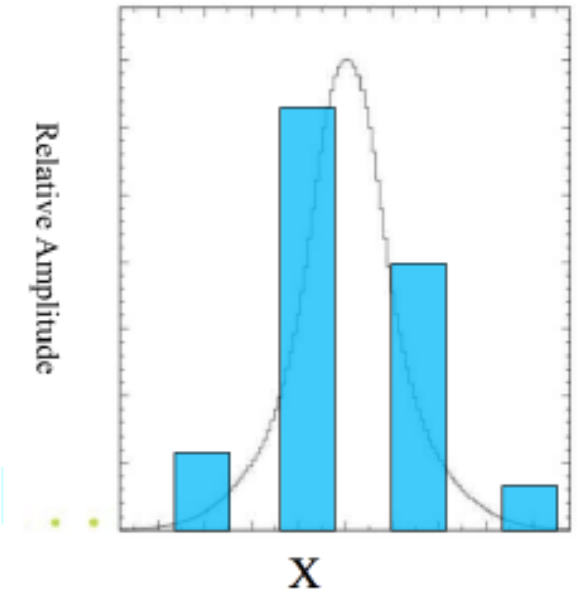


PRF determination

For resistive anode in MPGD TPC the pulse shape is dependent on the track position.

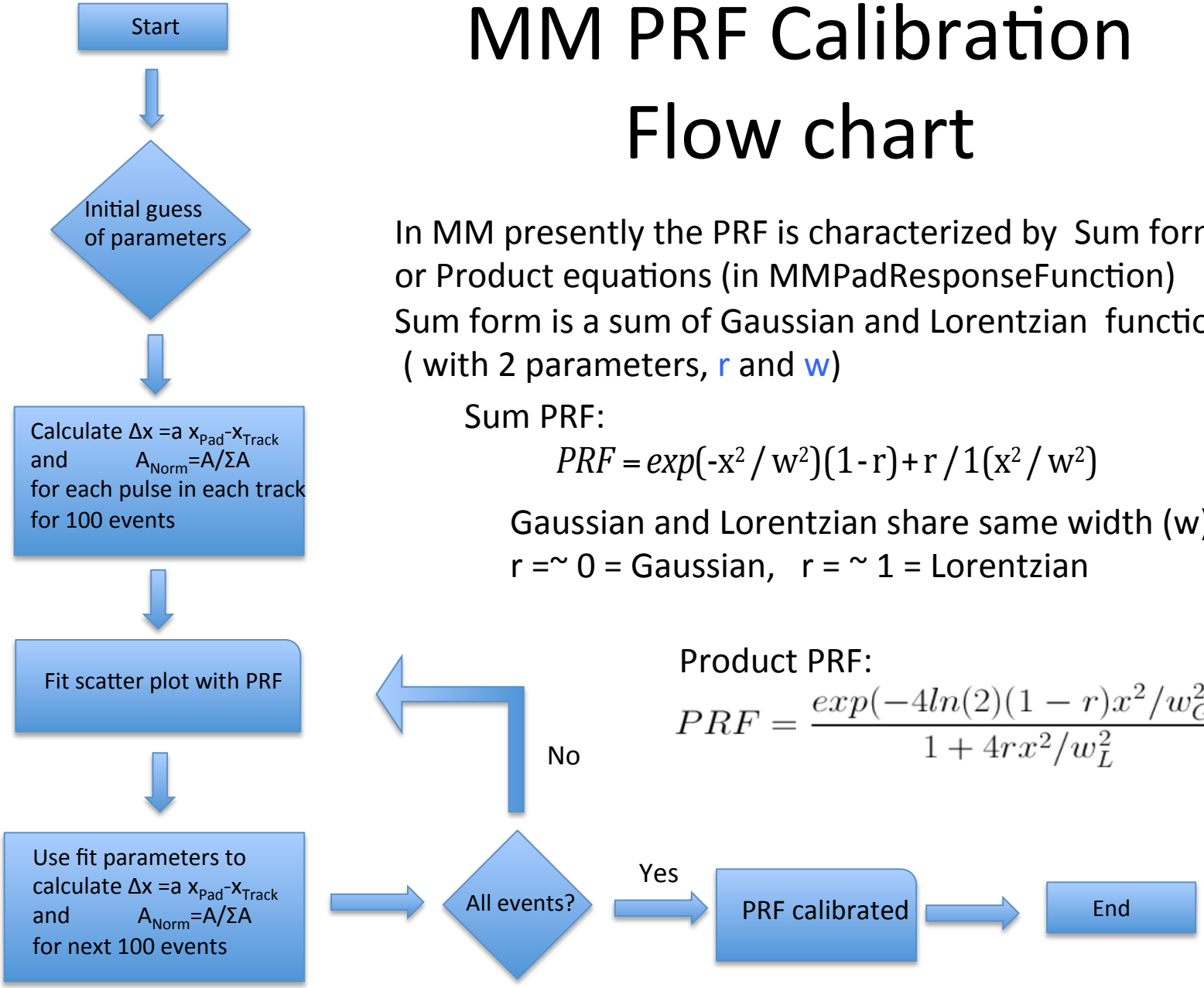
Pad Response Function (PRF) relates the distance between the pad center and a track, to the pad amplitude.

In order to use PRF to determine x-coordinate, it must be calibrated to the drift distance of the run and shaping time.
Once PRF is calibrated, it can be used to fit tracks to the observed pulse amplitude.



MicroMegas software has two main methods to calibrate PRF:
MMAdvancedCalibrationProcessor calibrates PRF by minimizing it with all hits in a track, using N+3 parameters.
The second method (and applied for this analysis) is using MMScatterProcessor to fit PRF and schematically shown on the next slide.

MM PRF Calibration Flow chart



In MM presently the PRF is characterized by Sum form or Product equations (in MMPadResponseFunction)
Sum form is a sum of Gaussian and Lorentzian functions.
(with 2 parameters, r and w)

Sum PRF:

$$PRF = exp(-x^2/w^2)(1-r)+r/1(x^2/w^2)$$

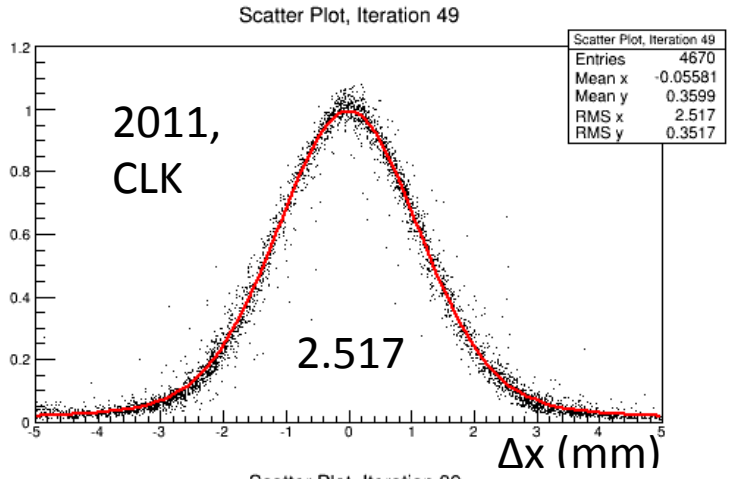
Gaussian and Lorentzian share same width (w),
r =~ 0 = Gaussian, r = ~ 1 = Lorentzian

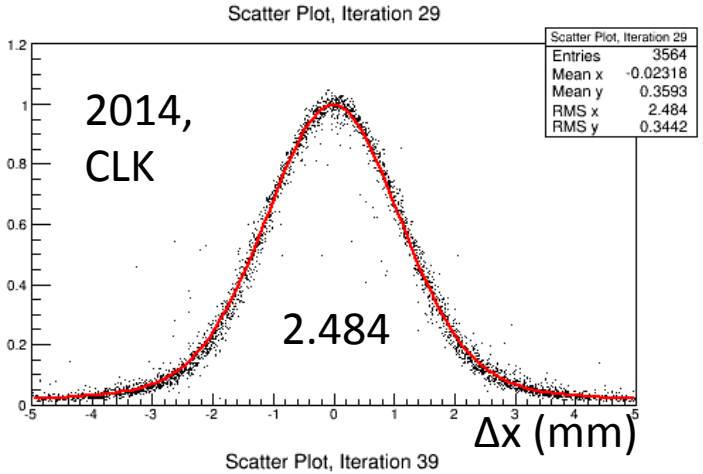
Product PRF:

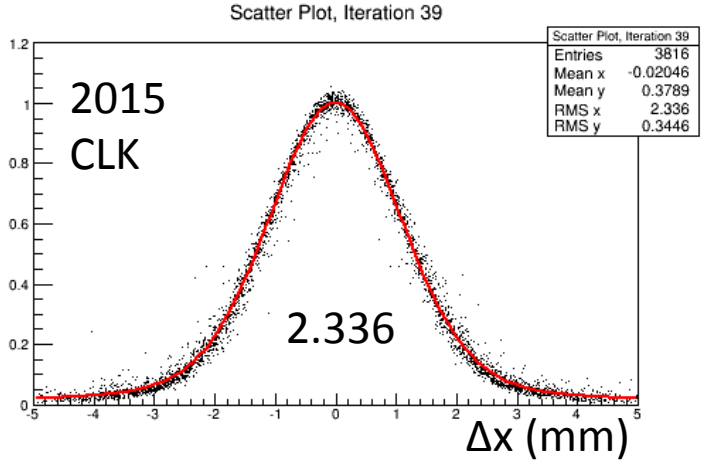
$$PRF = \frac{exp(-4ln(2)(1-r)x^2/w_G^2)}{1+4rx^2/w_L^2}$$

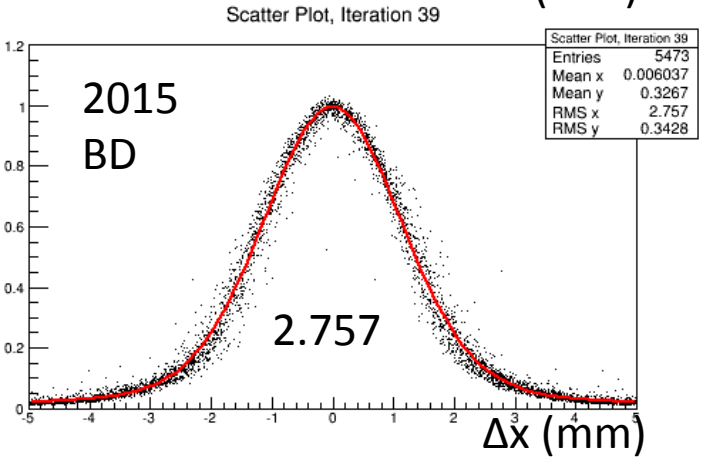
MM PRF Fit examples

100 ns shaping time, 10 cm drift

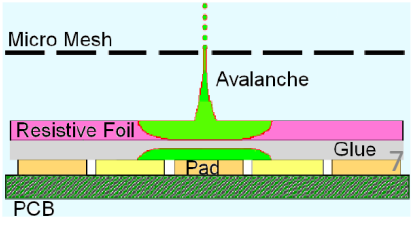




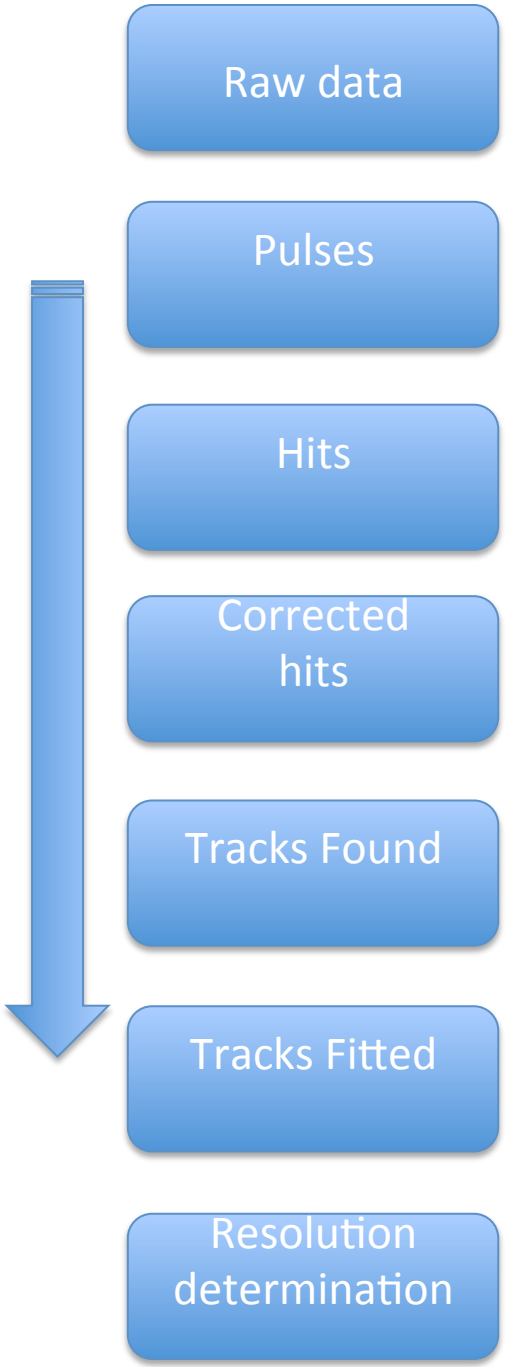




Width of PRF was more narrow in 2013-2014, in 2015, with new Black Diamond module, it is wider and that is good for MM technology.



MM process flow example



Thresholds and
noise cuts aaplied

Group pulses together, and
find centre of hit based on PRF

Time of hit is precisely calculated
with some fit

Hits are fed into an algorithm that
groups hits together into a "track
candidate”

Hit from from track candidates are fed into
an algorithm that *assumes* they belong to
a track, calculates the parameters of that track.

Resolution is calculated from output
of previous step

Track Finder/Fitter

For Track finder, various ILC group used/tried following:

- TripletFinderProcessor (used by GEM, MM)
- TrackMakingKalmanFitterProcessor (used mostly by AsianGEM)
- Clupatra
- PathFinder/FastHoughTransformation Pattern recognition, nearest neighbors
- GeneralBrokenLines does refit for alignment studies, MPII

For Track fitter choice of preference:

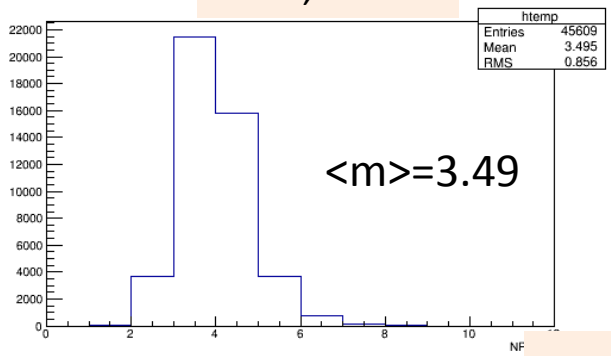
- SimpleHelixTrackFitterProcessor Karimaki Fit for curved tracks
- SimpleLinearTrackFitterProcessor Linear regression, straight tracks
- KalmanFitterProcessor

These are subclasses of TrackFitterBase class.

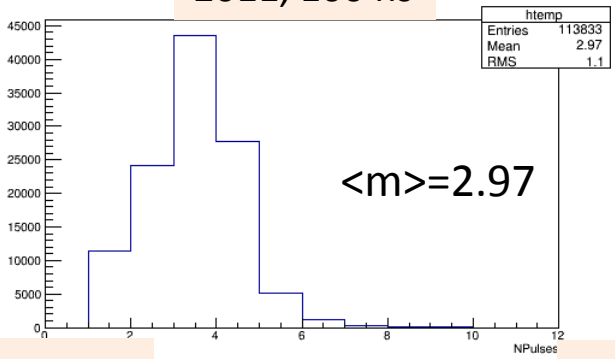
More details about tracking /reconstruction in Bo Li talk, that follows this one.

Pulses & Hits: # Pads per Hit

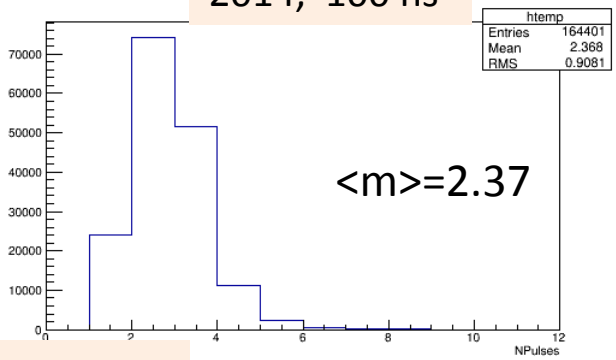
2010, 500 ns



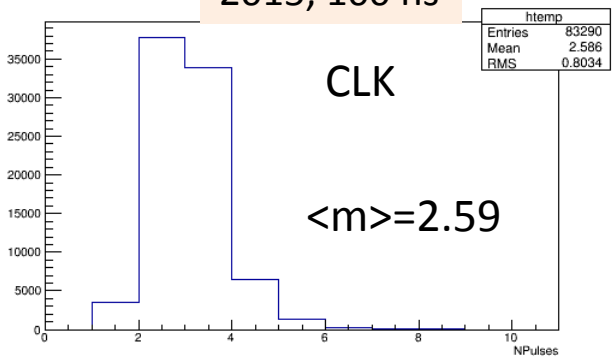
2011, 100 ns



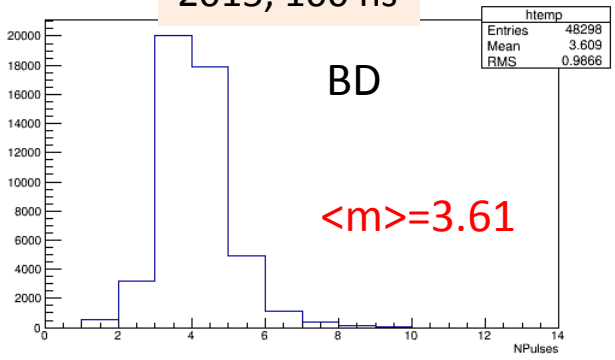
2014, 100 ns

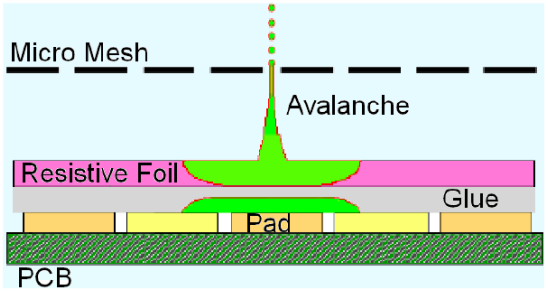


2015, 100 ns



2015, 100 ns



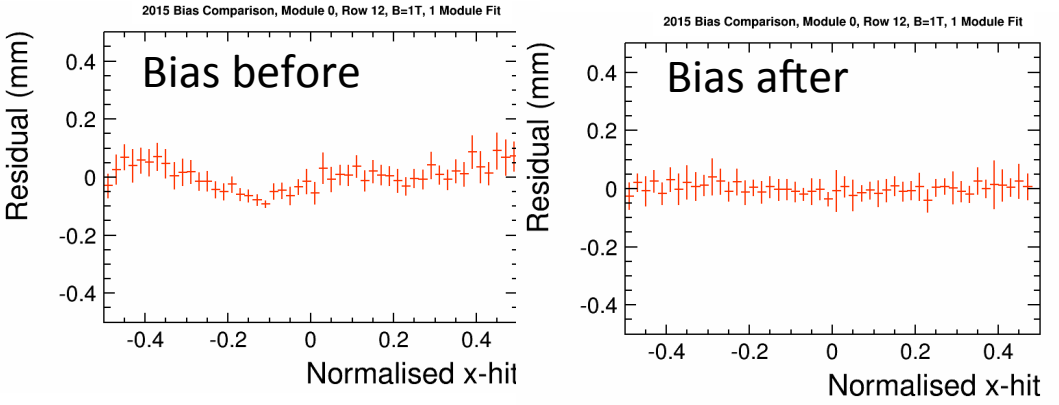


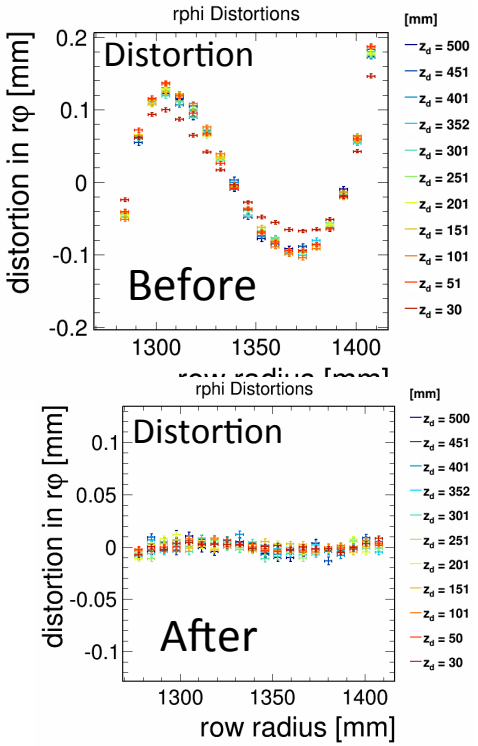
Sufficiently large number of pad "fired" – a large charge dispersion is a key to achieve good resolution performance for MM!
New Black Diamond (BD) module demonstrates reasonable number of pads per hit.

Bias/Distortions correction

- Local RC imperfections in the anode readout structure introduces position dependent systematic bias in calculated hit positions. This bias is calibrated and removed by bias correction.
- Distortions corrections – corrects calculated track hit positions for the distortion of the track near the module due to ExB effect

Bias correction





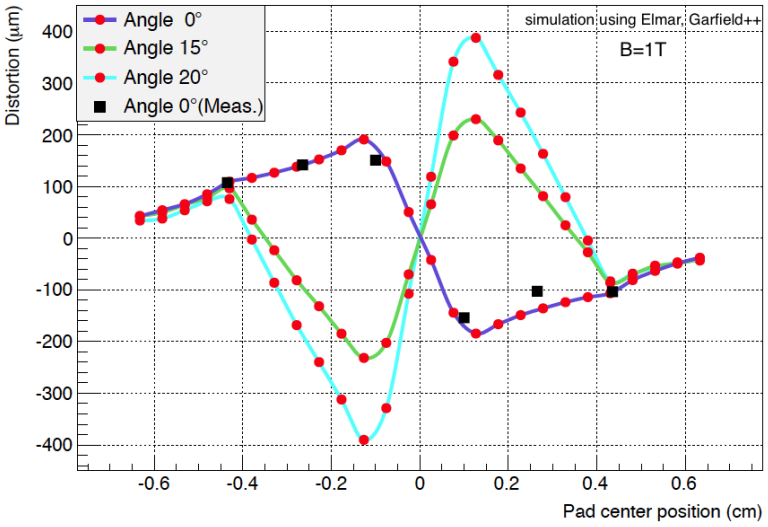
Both, BiasProcessor and Distortion Correction Processor, seem able to correct for these effects.

Still room for improvements for distortion correction methodology, perhaps.

More on Distortion corrections

Asian GEM recent effort

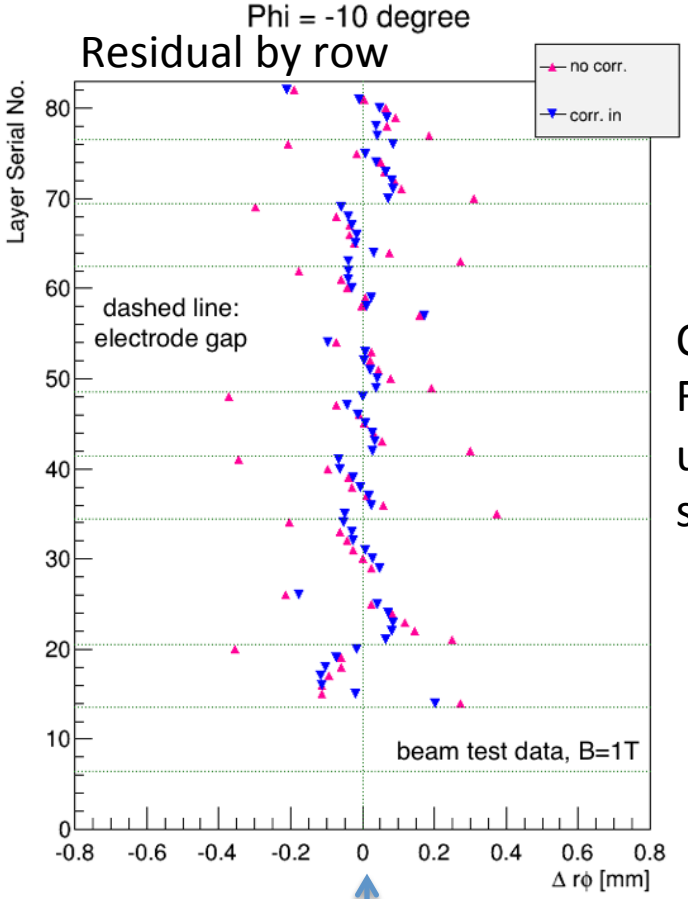
From Bo (Tsinghua U).



Simulations (in red) show very good agreement with data (black points) near electrode gaps

Looks very promising and simulations could be used to properly account for distortions in data. Work in progress.

From Mai (Saga U)



Correction Function used from simulation.

Electrode gap

Resolution determination

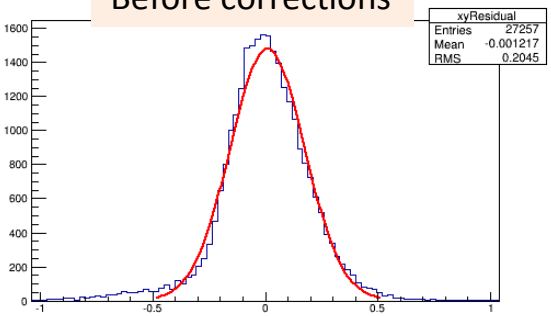
Resolution of the detector is determined from the width of Gaussian fit to row-by-row residual distributions, from cumulative distribution of all single row residuals.
The row residual is the difference between the true track position and the fitted track position In a row.
Without external reference, the residuals are estimated with

$$R = \sqrt{\sigma_{in}\sigma_{ex}}$$

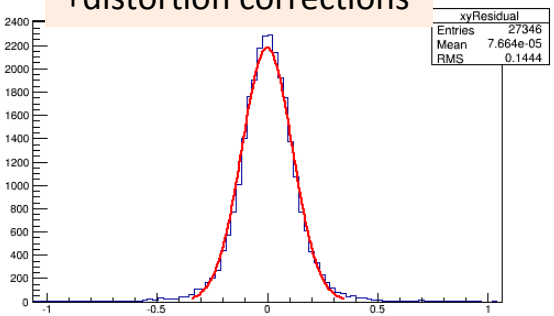
$$\Delta x^i = x^i_{track} - x_{row} \qquad \Delta x^e = x^e_{track} - x_{row}$$

2015 data, 100 ns, one module:

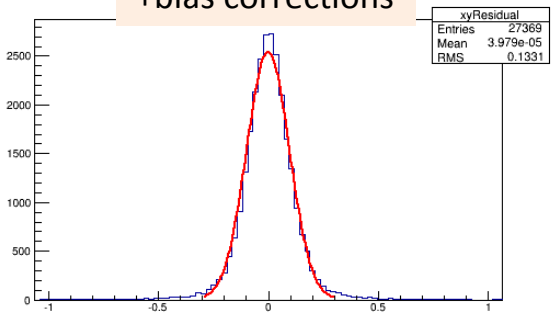
Before corrections



+distortion corrections



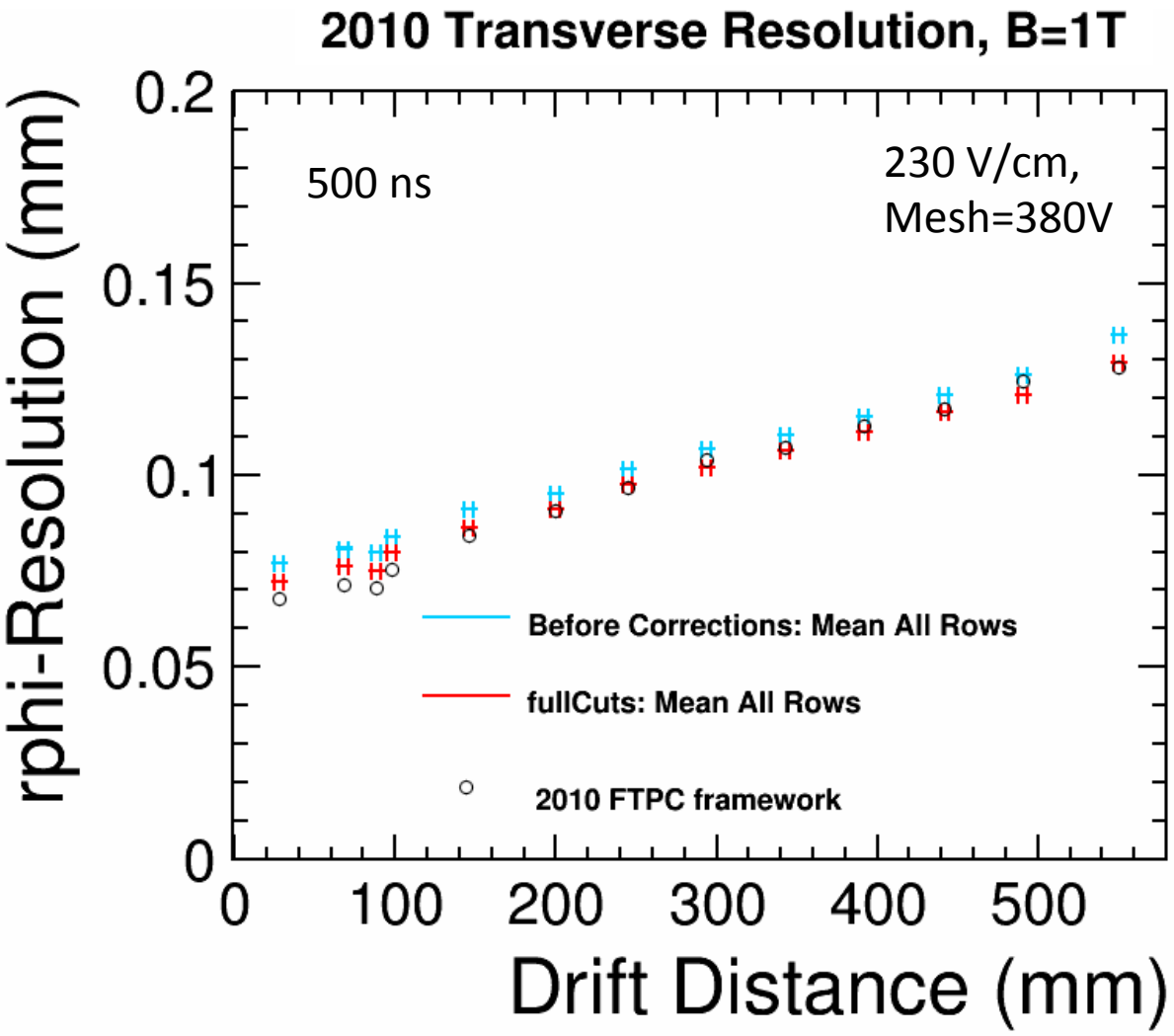
+bias corrections



Distortion correction shifts the center of gravity of a hit, corrects a systematic offset.
Bias corrections affect the width, thus, improving the resolution determination.
In analysis, fits are performed within 3 sigma range.

Few examples of (one module) data analysis results

2010 single module data

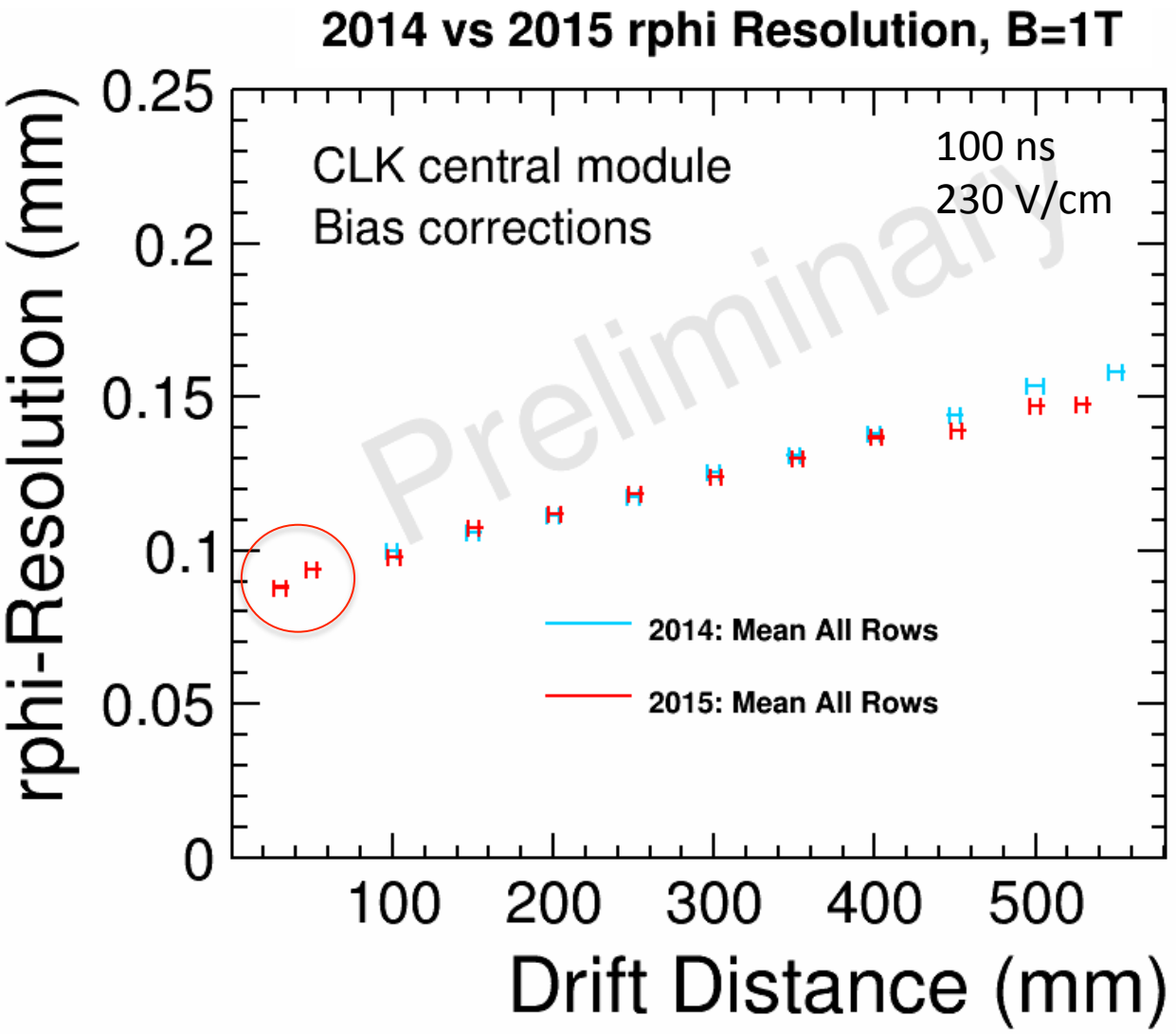


"Validation" of MarlinTPC framework.

The possible source of remaining small difference might be the exclusion of delta rays in FTPC, not used in MarlinTPC.
Needs verification.

Analysis based on MarlinTPC is pretty close to legacy FTPC (Fortran) framework results used for MM analysis.

Transverse Resolution in 2014-2015



Analysis in Central (single) CLK module 100 ns

2015 only data

The resolution results are worse than in 2011 (100 ns)

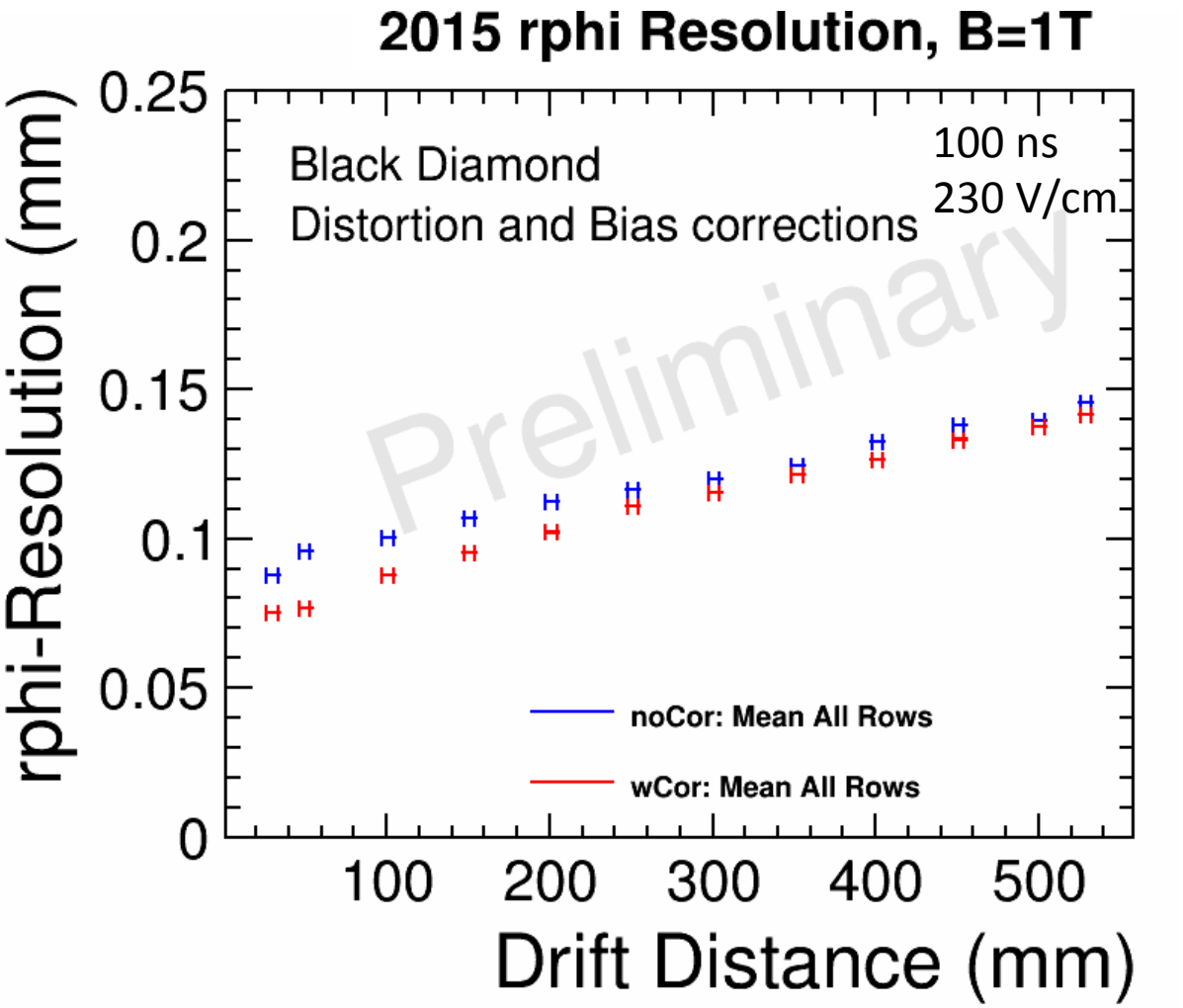
Recall that the charge dispersion measure - number of pads per hit - smaller than in 2011!

There is no large difference in results with CLK modules in 2014 and 2015.
CLK module performance is mostly consistent in 2014 and 2015.

2015 Black Diamond module

Two step corrections:

1. Apply distortion – correct the center of gravity for a hit
2. Apply Bias – correct bias along x.



Track Fit restricted to single module only.

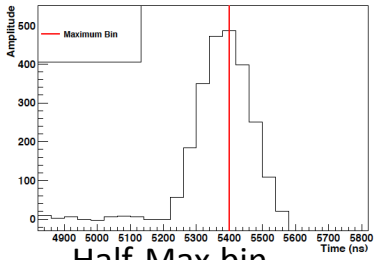
Runs: 5109,5111-5121

Transverse resolution in the Black Diamond module is better than in the CLK module (c.f. Page 15).

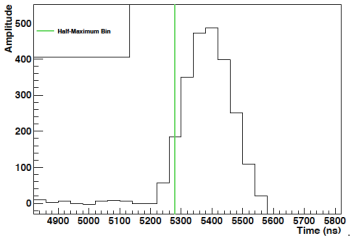
More details about 2015 multi-module analysis in S. Ganjour's talk in this session.

Z resolution determination

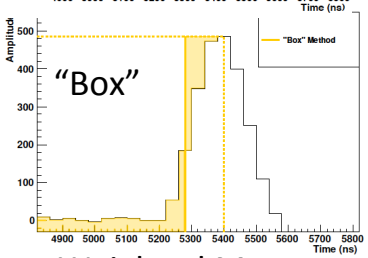
Max.bin



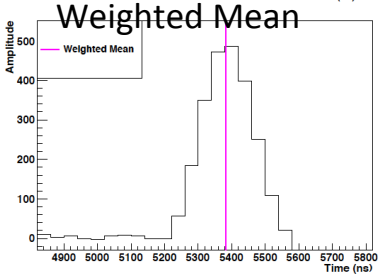
Half-Max.bin



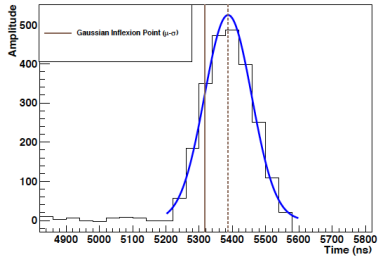
"Box"



Weighted Mean

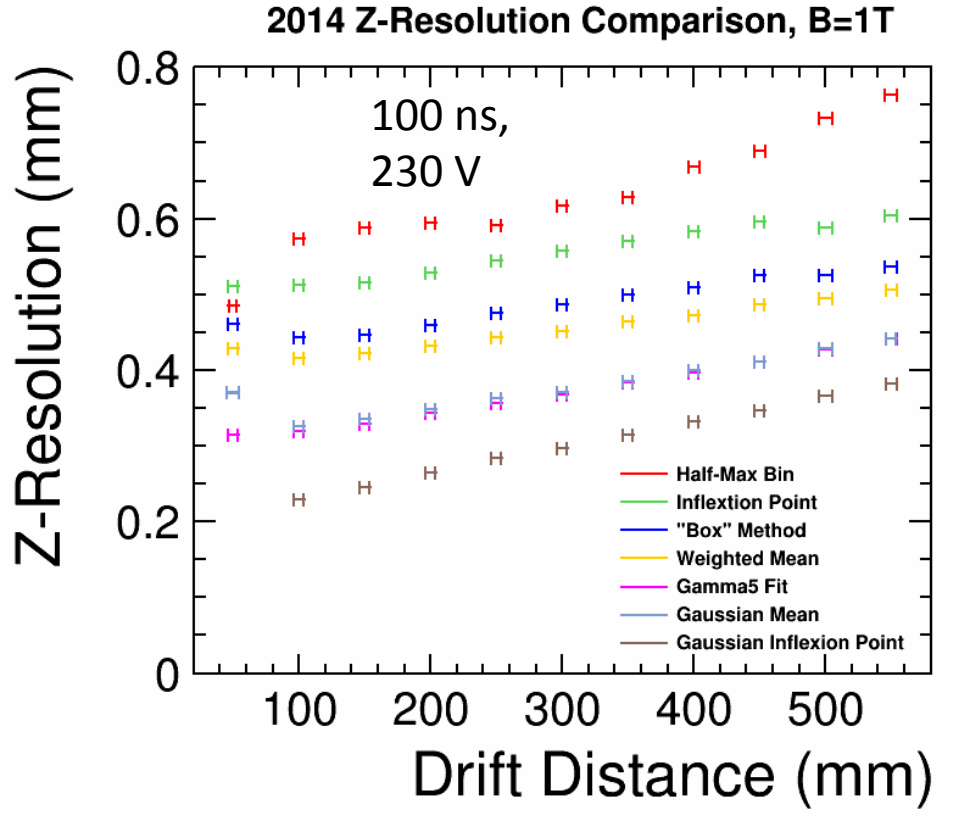


Gaussian Inflexion



MMHitTimeCorrectionProcessor used to estimate the time of the hit in longitudinal direction.

A large number of embedded methods are tested. The best performance so far has been achieved with Gaussian Inflexion Point (μ – σ) method.



TripletFinder + SimpleHelixFitter

Increase at large drifts due to diffusion.

Summary

- MarlinTPC software is in a good shape.
- It is essentially modular and allows plug in various methods/processors for reconstruction and analysis.
- There is still room for improvements in analysis software area: misalignment correction, theta resolution dependence processor (F.Mueller), revive reintegration method (sum charge over fixed time interval) etc.
- Perhaps it's long overdue to run regular Analysis meeting to exchange ideas/results/code/scripts – that could be very positive step towards better and robust MarlinTPC reconstruction and analysis framework and work coordination.
- Many thanks for our LCTPC colleagues and analysis efforts from Carleton and Saclay MM groups!