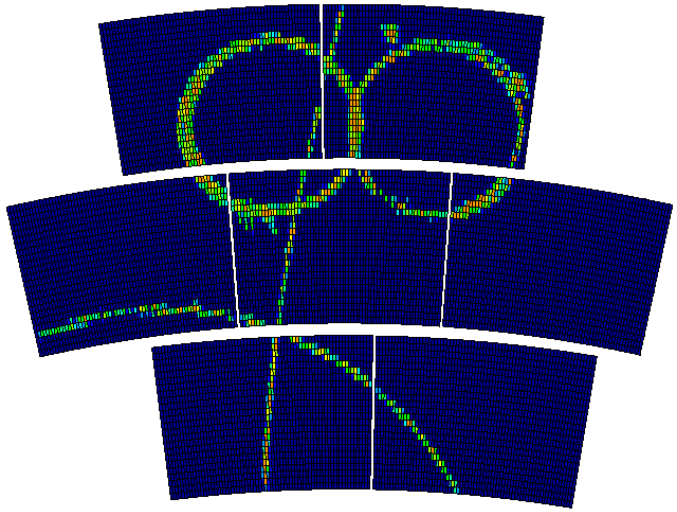
Test Beam 2015/2010 Analysis of Micromegas TPC

D. Attié, D. Bhattacharya,
P. Colas, S. Ganjour

CEA-Saclay/IRFU, Gif-sur-Yvette, France



MM TPC Working Meeting
April 15, 2015

The EUDET/AIDA test beam facility at DESY provide a 6 GeV electron beam

- Consists of a field cage equipped with an endplate with 7 windows to receive up to 7 fully equipped identical modules

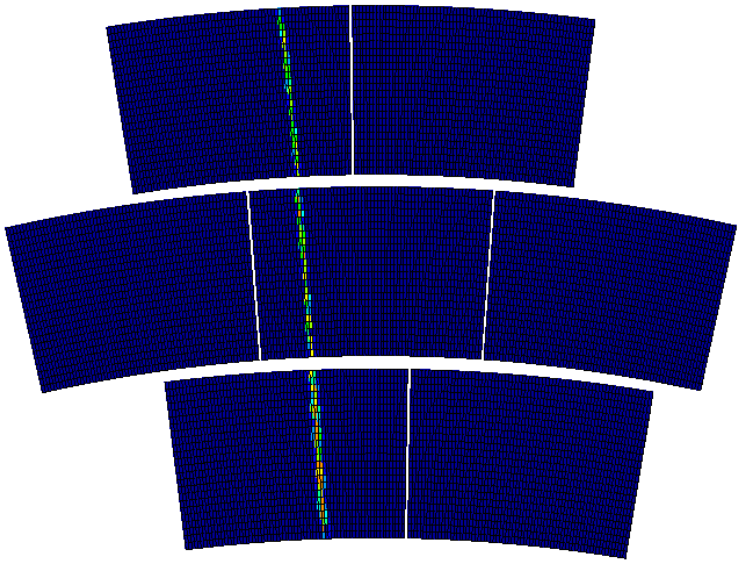
Last beam test of 7 MicroMegas (MM) TPC modules at DESY (Mar. 1– Mar. 14, 2015)

- **Principal goals** of 2015 test beam
  - combined test of 5 Carbon Loaded Kapton (CLK) and 2 Black Diamond (BD) MM modules
  - complete R&D on MM prototype aimed for publication(s) this year

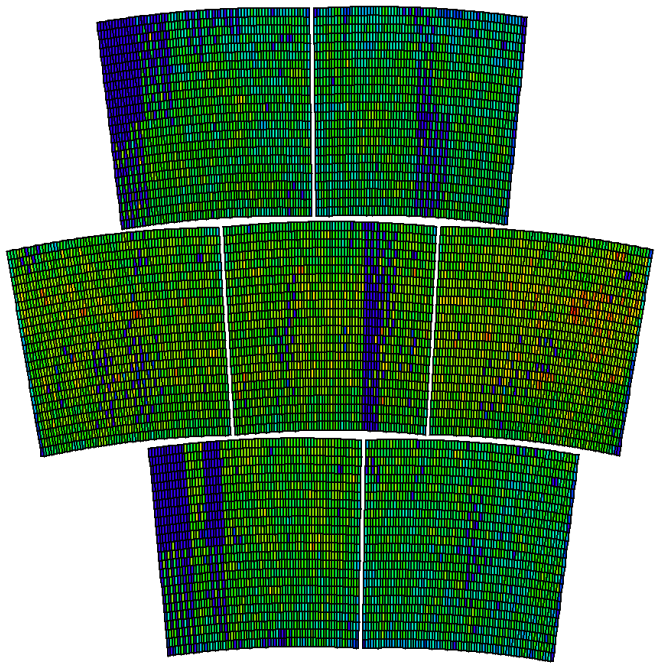
Prehistory of beam tests with MM modules:

- **Mar 2010:** 1 module, start analysis with **FTPC framework**; reanalised with **MarlinTPC framework**
- **May 2011:** cross-talk problem; start using **Marlin framework**
- **Jul 2012:** multimodule setup with 6 fully operated modules; coherent noise
- **Jan-Feb 2013:** multimodule setup with 7 fully operated modules; many disconnected pads; first complete analysis with **MarlinTPC framework**
- **Feb 2014:** same as in 2013 with some pads' connection problem; analysis with **MarlinTPC framework**

- **7 MM modules** with charge dispersion by resistive anode
  - pads of the size 3×7 mm^2
  - 24 rows with 72 pads each
  - 1728 pads per module



- **Beam data taking program:**
  - magnetic field: B=0, 1 T
  - drift field: E=140, 230 V/cm
  - z-scan [5-50]cm every $\Delta z = 5\,\mathrm{cm}$
  - shaping time τ-scan: 100-1000 ns
  - ZS: 4.5σ (baseline) and 3σ
  - beam energy scan [1-5] GeV
  - varying θ angle up to 30°

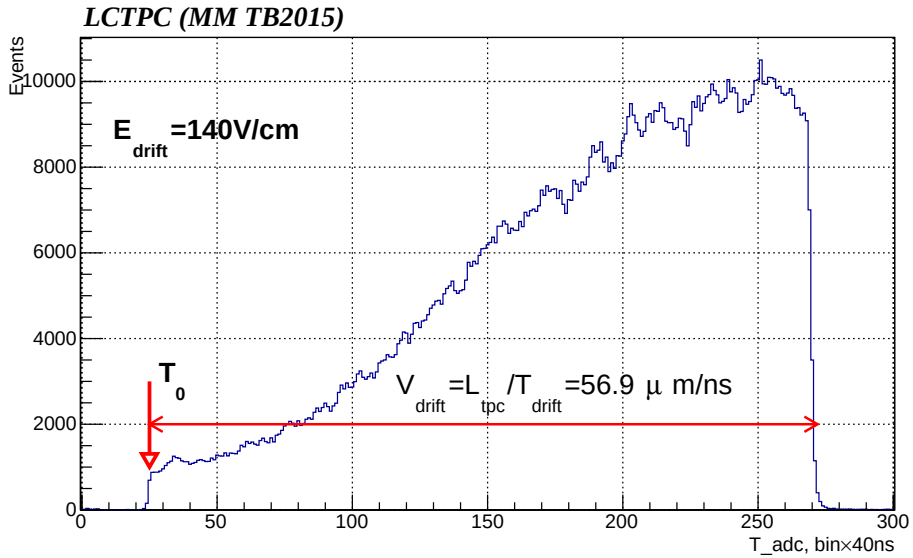


- **Cosmic data:** covere a whole LP volume

T_0 *Calibration and Gas Property*

- Prototype operates with T2K gas
  - Ar(95%), CF_4(3%), iC_4H_{10}(2%)
  - gas purity: 60 ppm O_2, 100 ppm H_2O
  - deploy `Magboltz` calculations
- Absolute T_0 calibration:
  - **beam trigger:** dedicated z-scan at $V_{drift} = 140, 230$ V
    - ➔ $T_0 = 632$ns form fit
  - **cosmic trigger:** accumulate a whole LP volume data events
    - ➔ $T_0 = 22 \times 40\text{ns} = 880\text{ns}$

About 250 ns differnce for T_0 *between 2 trigger configurations*



	E=140 V/cm	E=230 V/cm
V_d `Data`	$58.4 \pm 0.1 \mu m/ns$	$74.4 \pm 0.1\ \mu m/ns$
V_d `Magboltz`	$57.9 \pm 1.0 \mu m/ns$	$75.5 \pm 1.0 \mu m/ns$
$D_\perp$ `Magboltz`	$74.5 \pm 2.5 \mu m/\sqrt{cm}$	$94.8 \pm 3.1 \mu m/\sqrt{cm}$

Analysis Dataflow

- **Dataflow has two major steps:**
  - **DAQ** software store data in **raw format** (calib. view, event dispay, slow control)
  - convert raw data in **slcio format**
  - **Analysis** with **MarlinTPC**
    - ➔ pulse finder, calibration
    - ➔ build hits from pulses
    - ➔ reconstruct tracks (track finder and fit)
    - ➔ analysis (corrections, distortion, resolution)
- **First analysis step:** build `TPCTracks`
  - triplet track finder `(RowTripletBasedTrackFinder)`
  - 5-parametric helix fit `(TrackFitterSimpleHelix)`
- **Second analysis step:** deploy `TPCTracks`
  1. correction `(BiasCorrector)`
  2. distortion `(ModuleDistortionCorrection)`
  3. resolution `(ResolutionPerformance)`

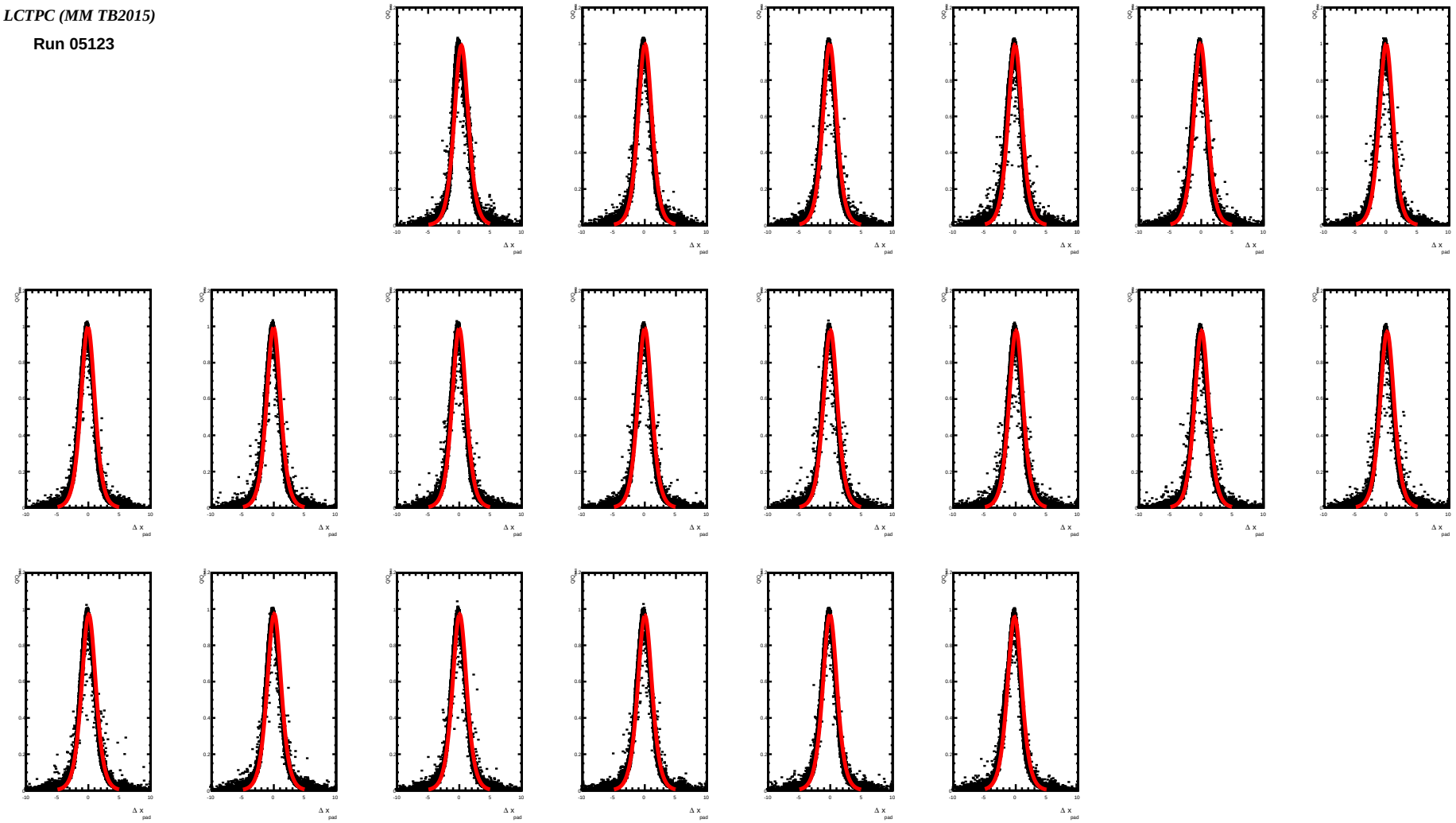
Determine resolution from geometric mean of inclusive and exclusive residuals of the whole 3D track fit

Coherent analysis of all data is performed in MarlinTPC framework including legacy 2010

Pad Responce Funciton

LCTPC (MM TB2015)

Run 05123



Row-by-row illustrations are for **module#0 (BD2)**

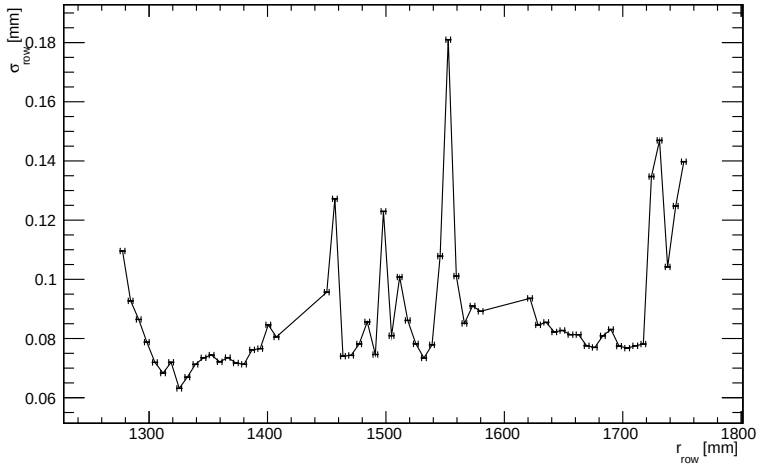
Similar plots for other modules are not shown unless they can generate specific message

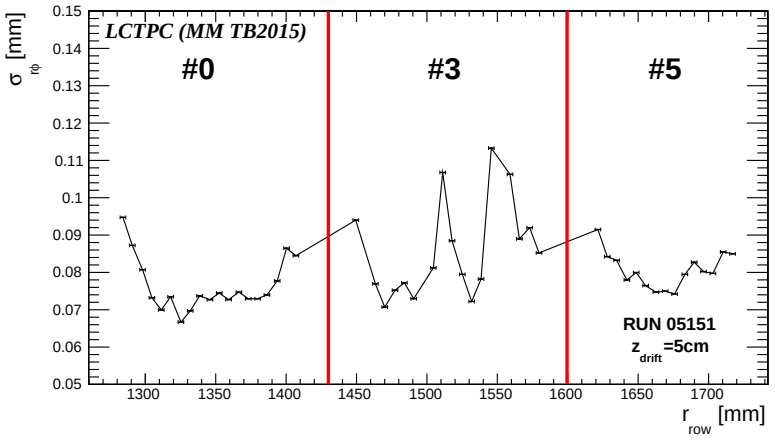
Some connector problems still take place while data taking

- **Dead (hot) channels**
  - are well established at pedestal run
  - can be identified with cosmic data
- Mask whole rows before hit finder
  - 2 inner(outer)most rows 0-1,22-23
  - rows with dead chennel(s)
    - ➔ **mod#0:** row 2
    - ➔ **mod#3:** rows 3, 9, 17
    - ➔ **mod#5:** rows 17-21
  - **mod#3:** row 11 is possibly noisy, but is not excluded

Yield **51 rows** *in total for average resolution performance*

Presence of dead pad in a hit degrades row resoluiton





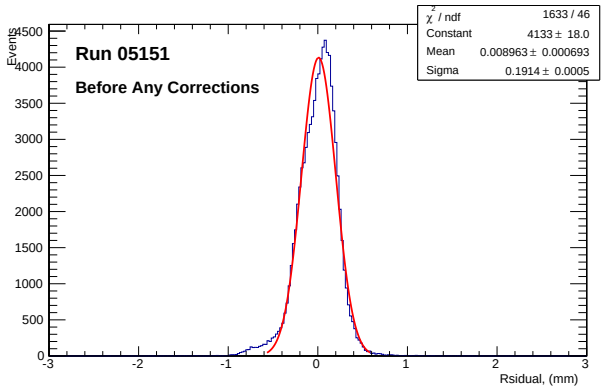
Same fraction (70%) of deployed rows as for GEM

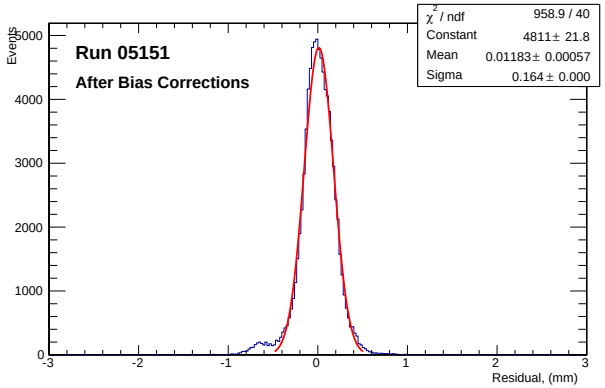
- Resolution is determined from the same statistical sample as the one for track fit
  - geometric mean of inclusive and exclusive residuals of the whole 3D track fit:

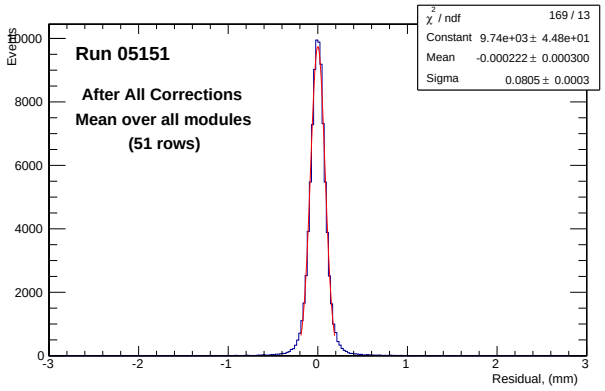
$$\sigma_{\mathrm{i}} = \sqrt{\sigma_{\mathrm{in}} \cdot \sigma^{\mathrm{i}}_{\mathrm{ex}}}$$

  offers unbias resolution estimator

- **Important requirements for σ_{i}:**
  - gaussian-like (low fraction of outliers)
  - zero off-set (systematic error)



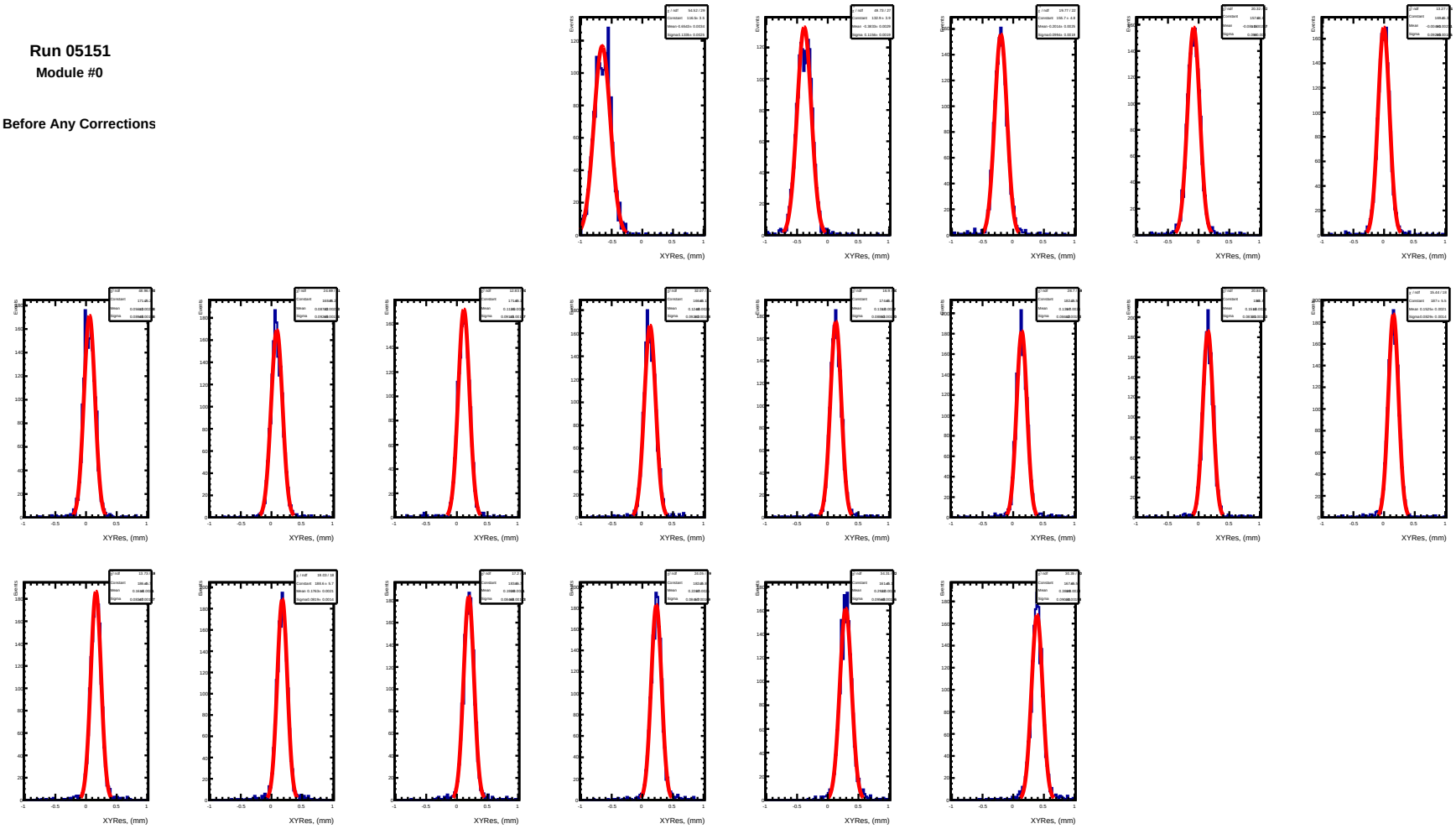




Residuals

Run 05151
Module #0

Before Any Corrections



Row-by-row illustrations are for **module#0 (BD2)**.

Systematic offset about 1 mm is observed for residuals in modules#0 and #5.

Charge sharing between adjacent pads is not linear (well-known S-curve effect)

- Distance from center of leading pad:

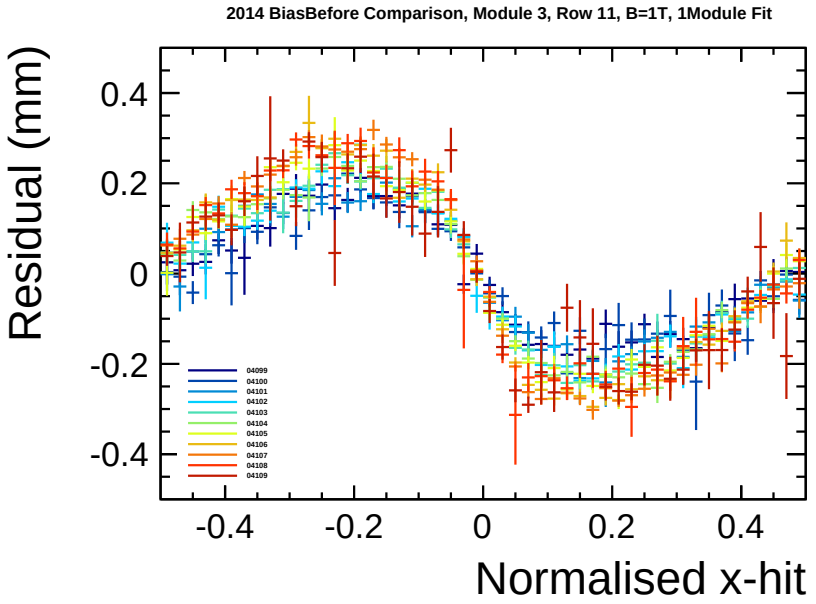
$$\mathbf{x_{rel}} = \frac{\mathbf{x_{hit}} - \mathbf{x_{pad}}}{\mathbf{d} + \mathbf{\Delta}}, \ [\mathbf{-0.5, 0.5}]$$

- About 400μm residual oscillation occurs, if weighted mean position estimator is used for x_{hit}
  - PRF takes into account real charge distribution and addresses S-curve

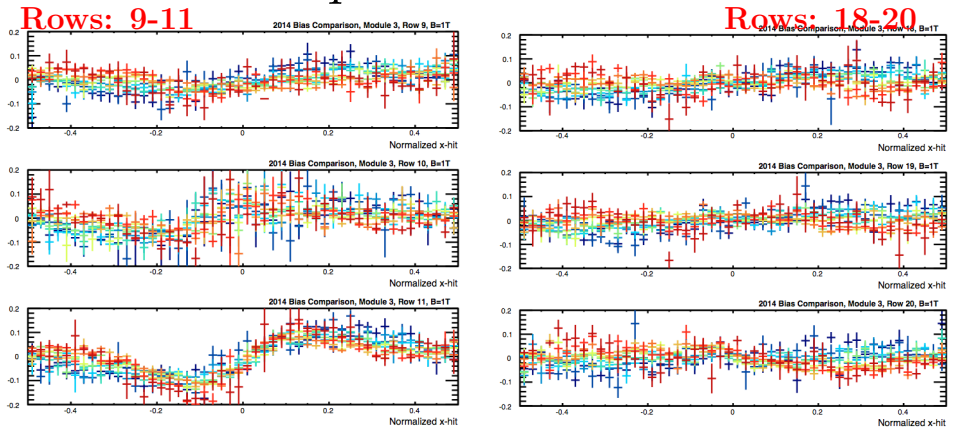
Remnant oscillation about 100 μm occurs periodically even for PRF position estimator

- Non accounted charge in outliers (PRF imperfection) could introduce such dependence from the pad center

Weighted mean position estimator

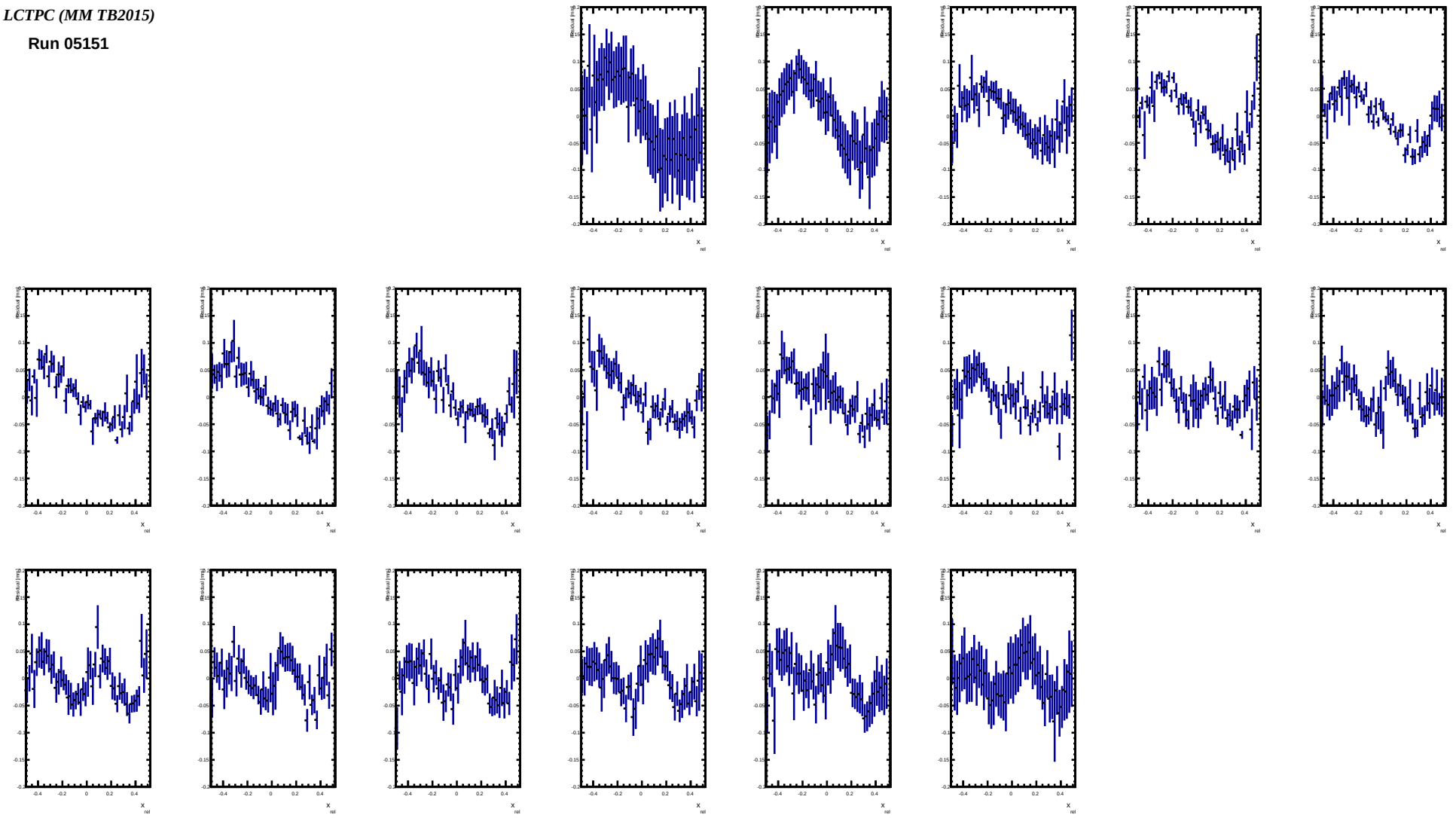


PRF position estimator



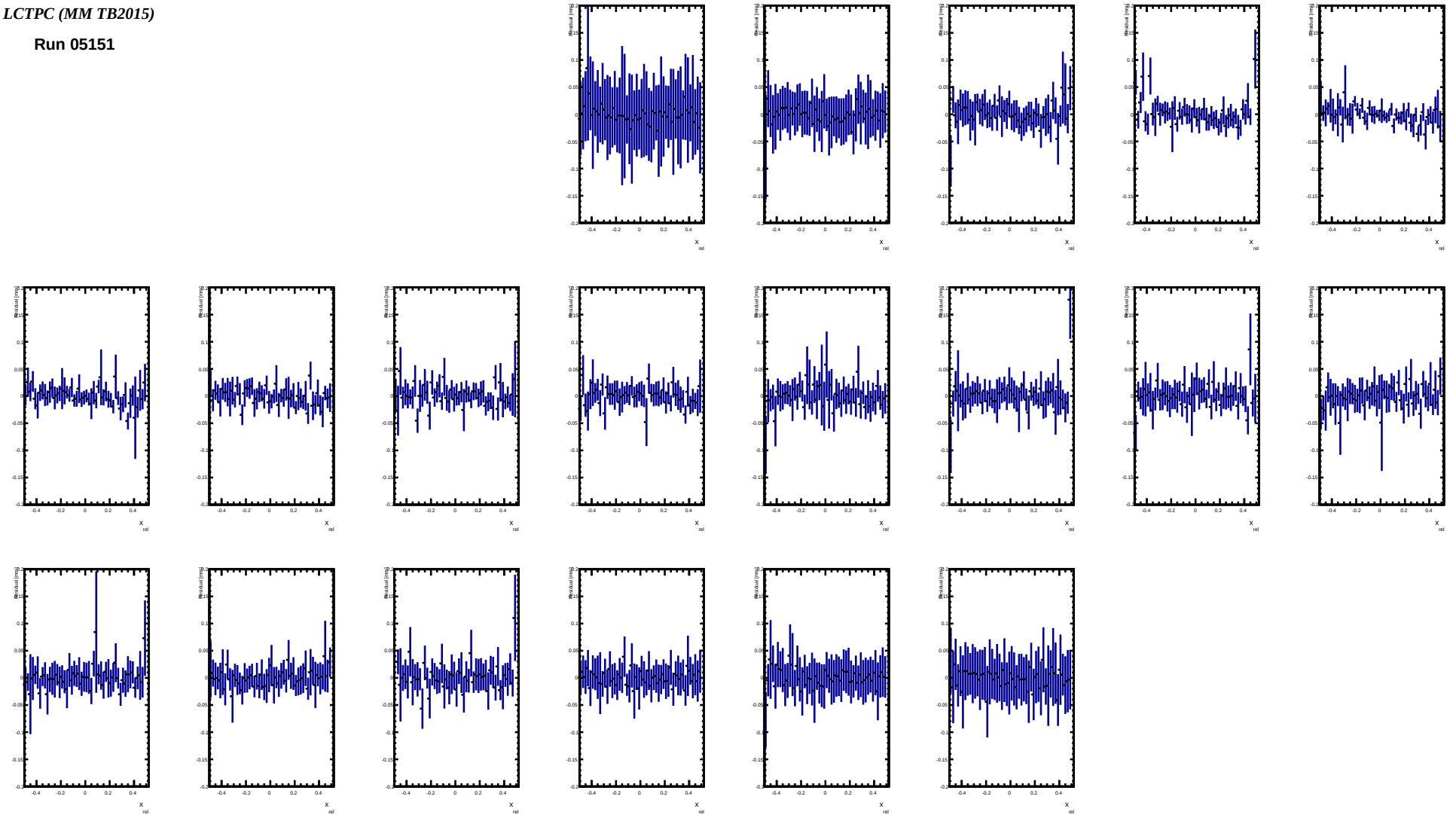
LCTPC (MM TB2015)

Run 05151



LCTPC (MM TB2015)

Run 05151

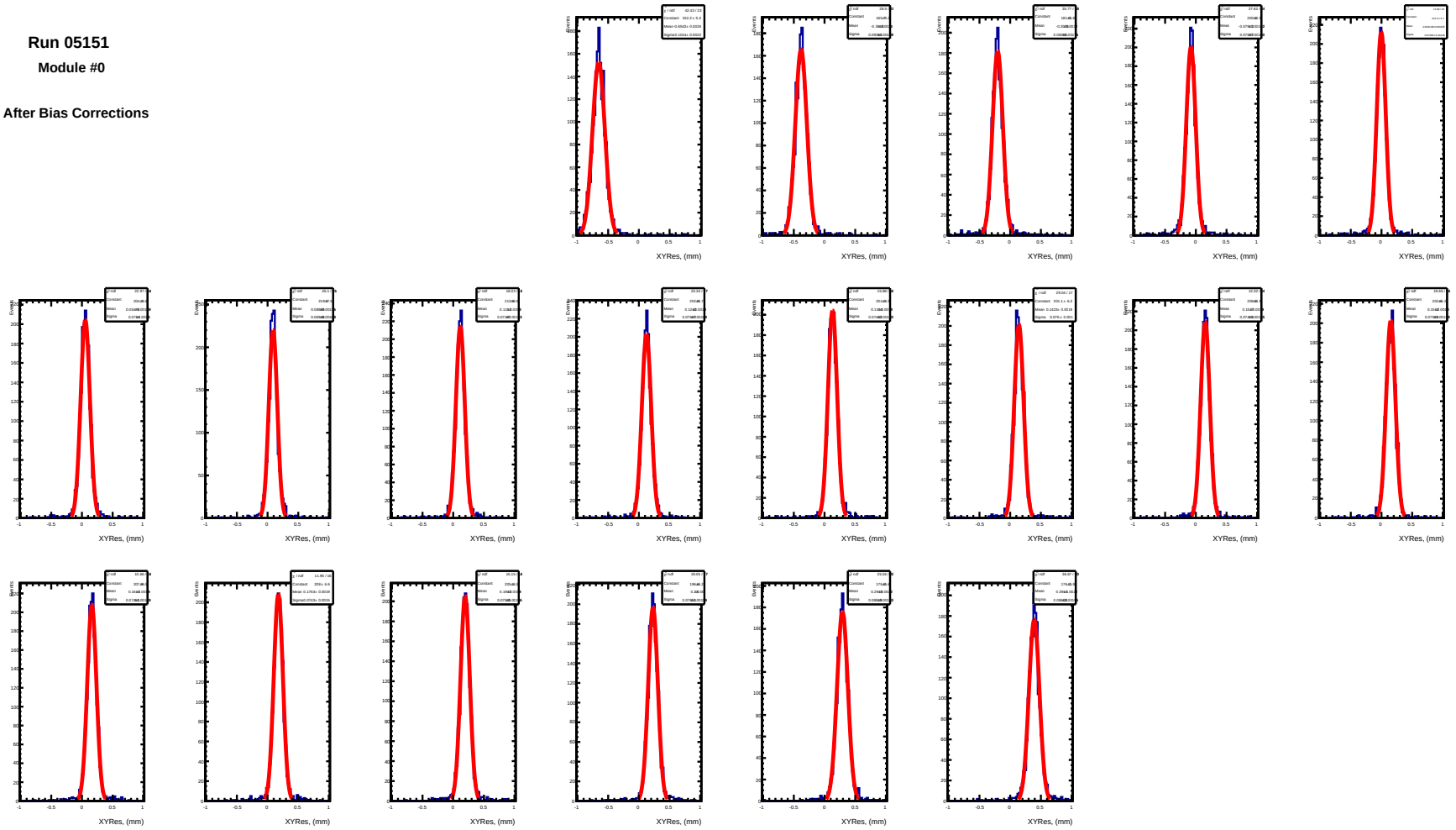


Residuals After Bias Corrections

Run 05151

Module #0

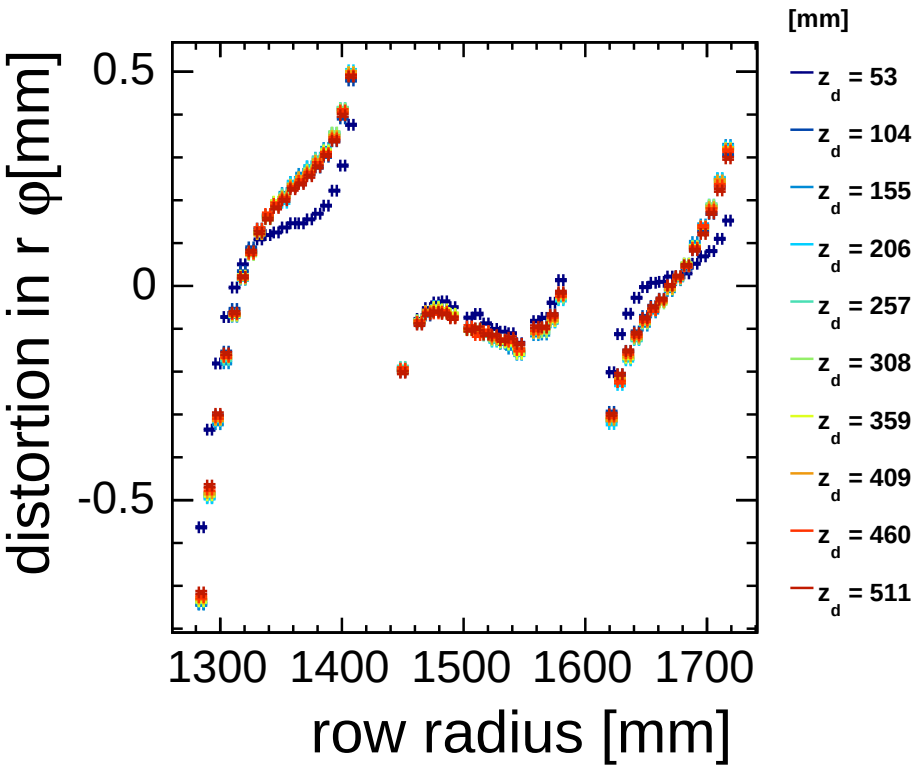
After Bias Corrections

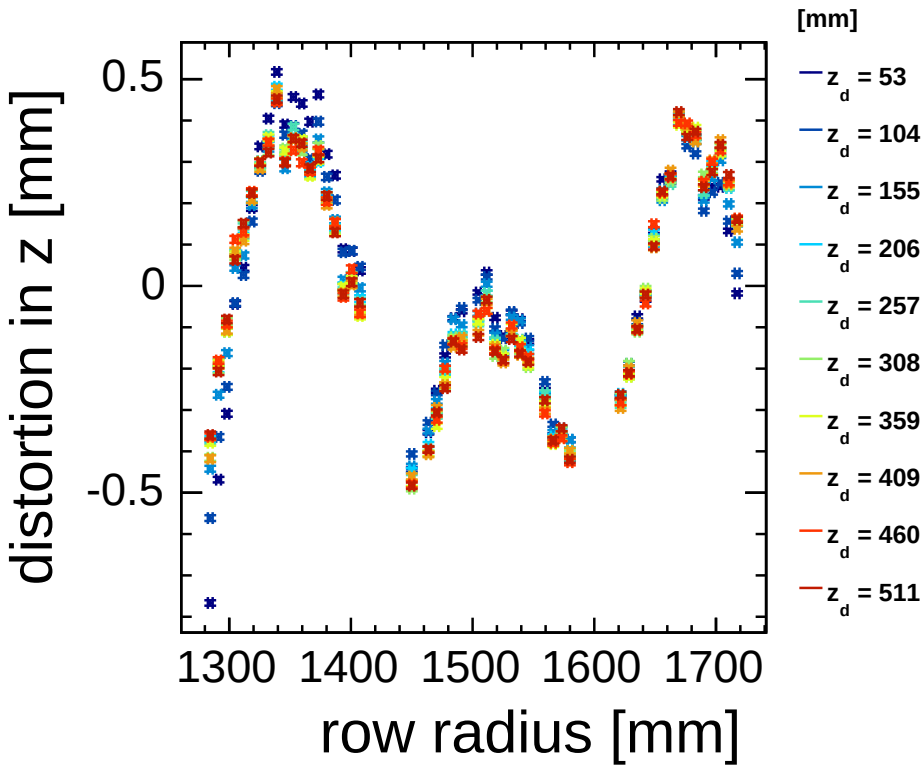


Row-by-row illustrations are for **module#0 (BD2)**.

Systematic offset about 1 mm remains for residuals in modules#0 and #5.

Distortions After Bias Corrections

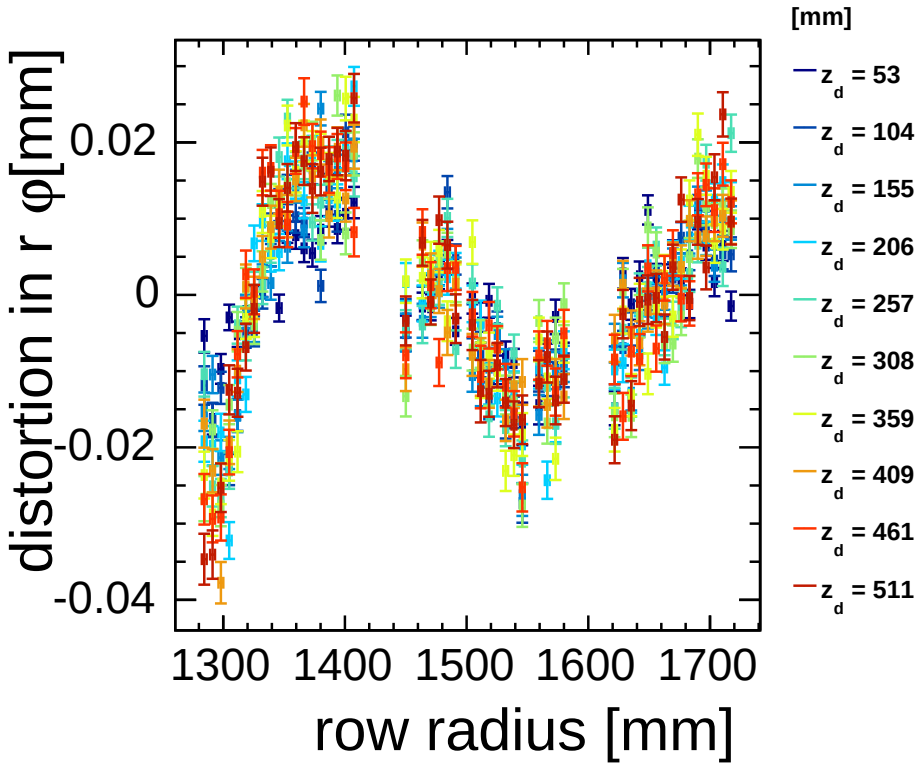


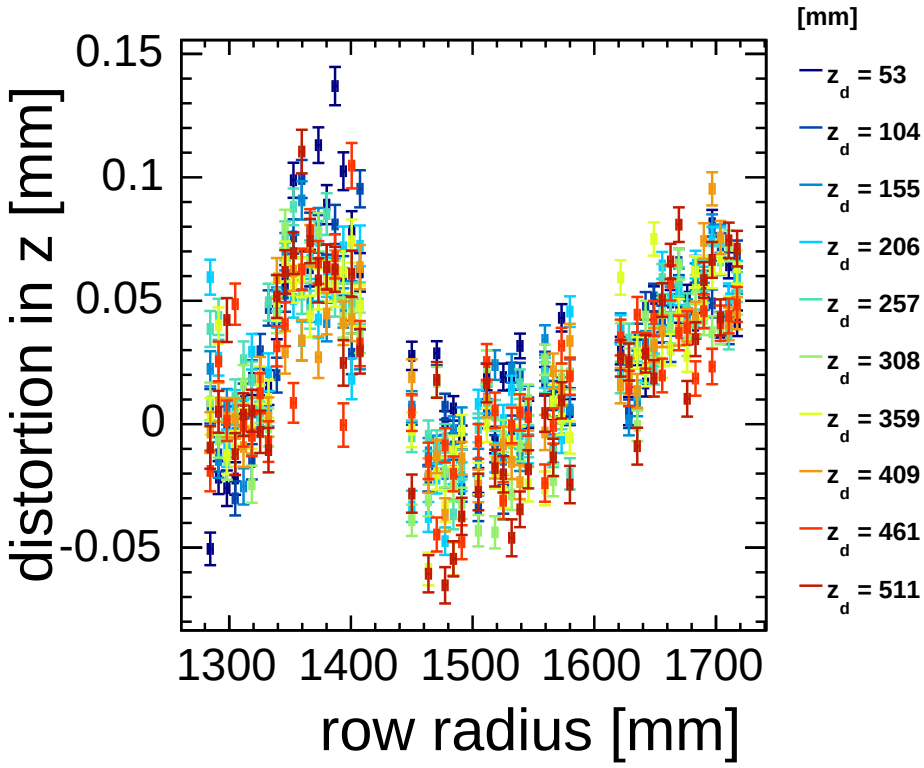


☞ Non-uniform E-field near module boundaries induces ExB effects

- ➠ distortions about 1 mm are observed after bias corrections
- ➠ bias corrections are applied with respect to residual mean

Distortion corrections are necessary on top of bias corrections





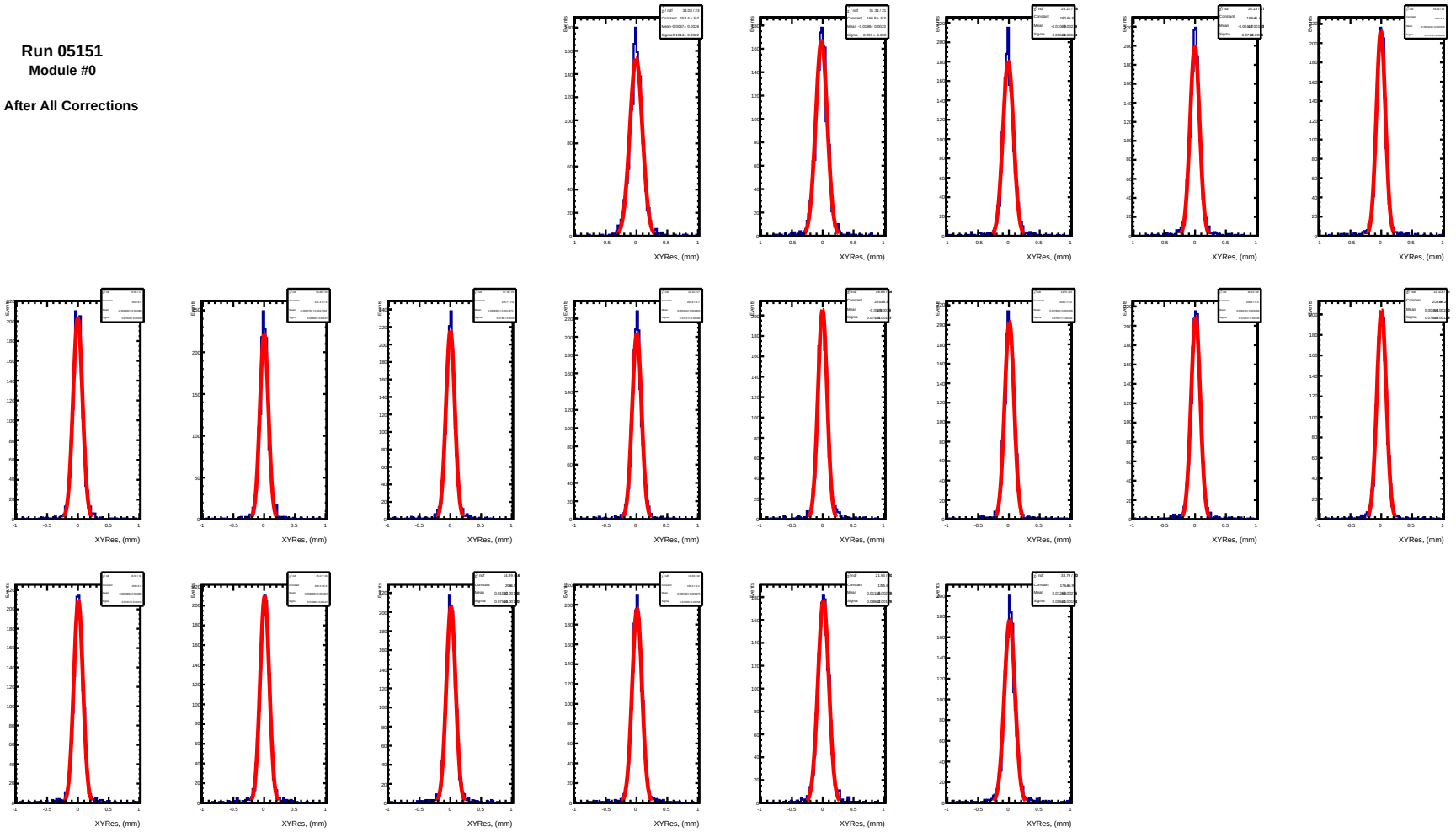
☞ Conventional distortion correction procedure allows resuduals to be better than

20 μm in $r\phi$ plane and *100 μm in z coordinate*

Residuals

Run 05151
Module #0

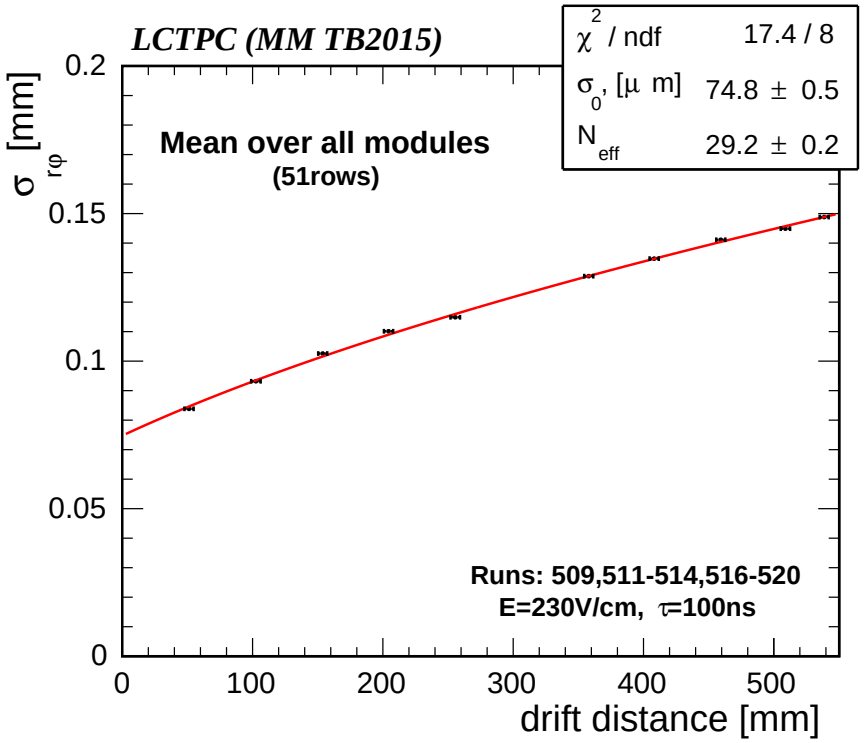
After All Corrections

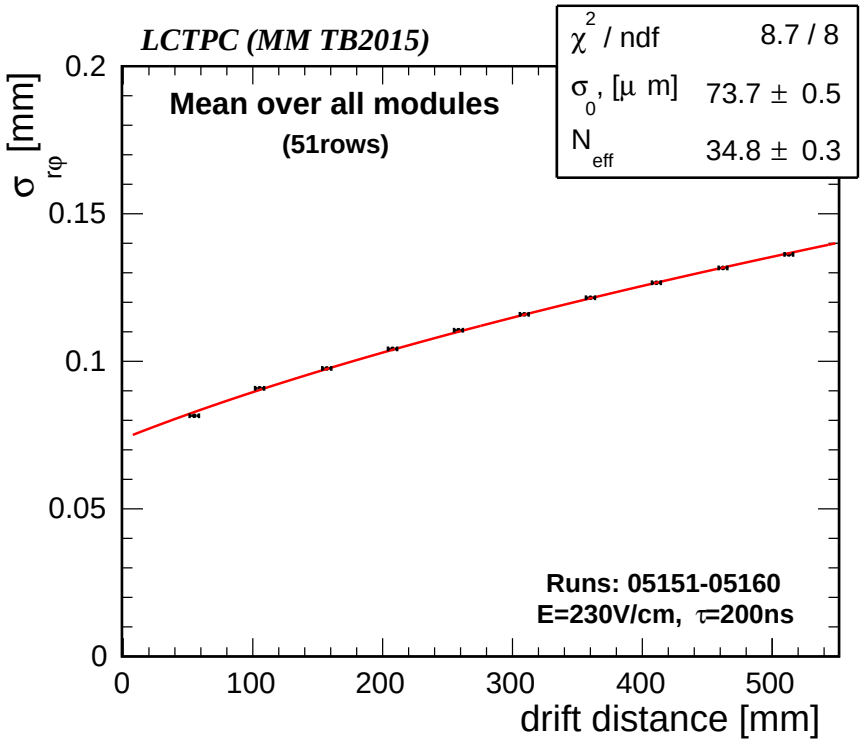


Row-by-row illustrations are for **module#0 (BD2)**.

Zero offset for residuals is observed for all modules.

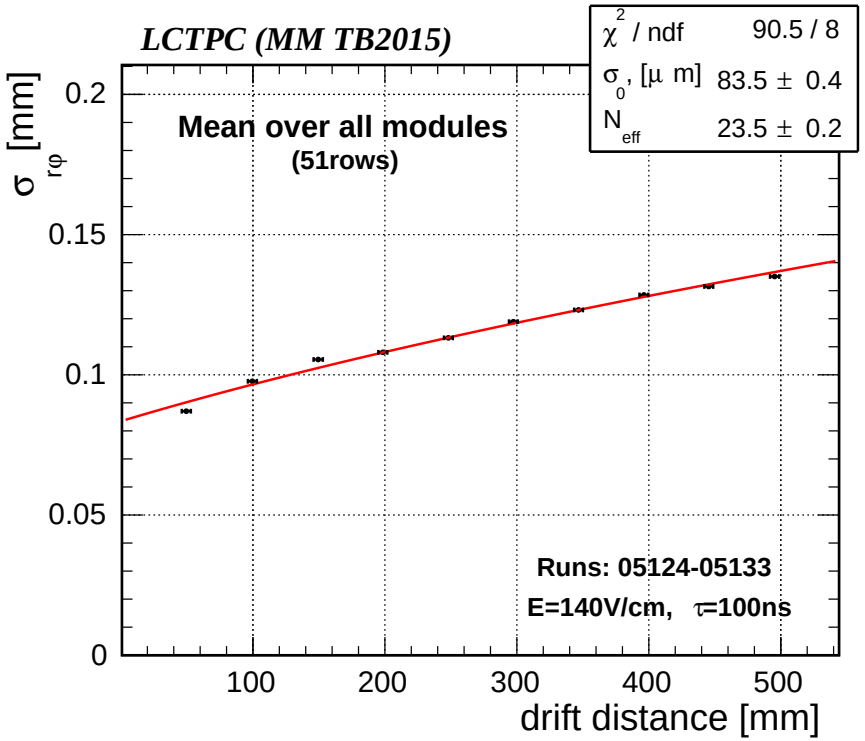
$r\phi$ Resolution: 230V/cm

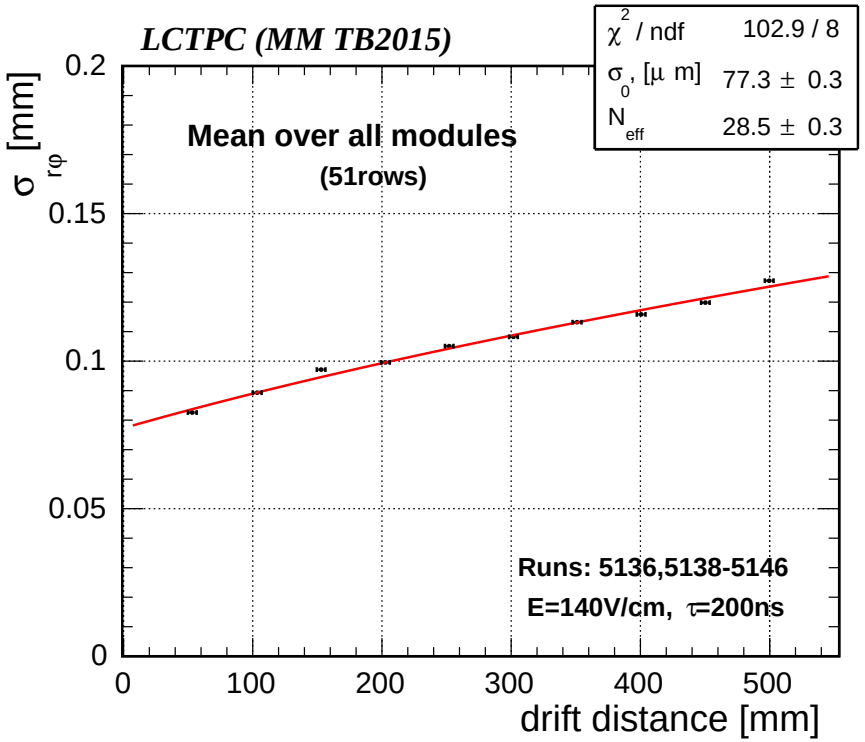




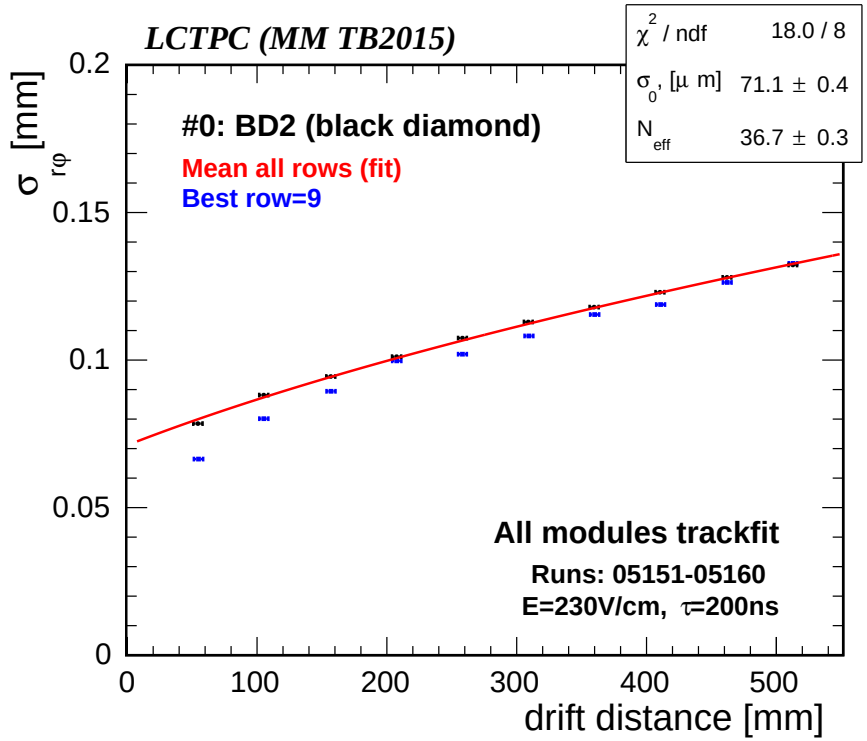
☞ Magboltz calculations of $D_\perp$ at about 3% precision (100 steps)

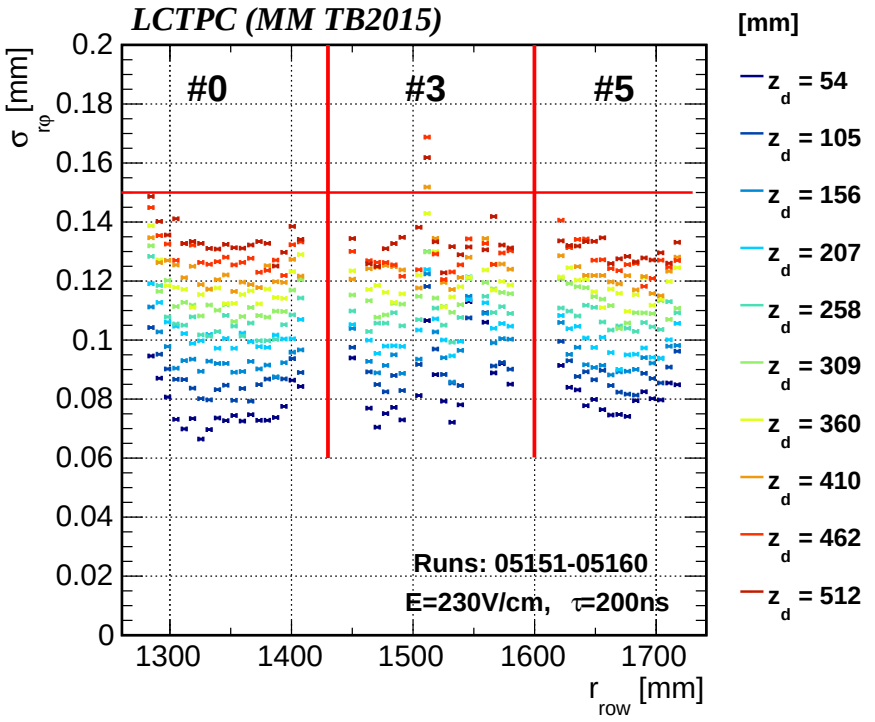
$r\phi$ Resolution: 140V/cm





☞ Magboltz calculations of $D_\perp$ at about 3% precision (100 steps)





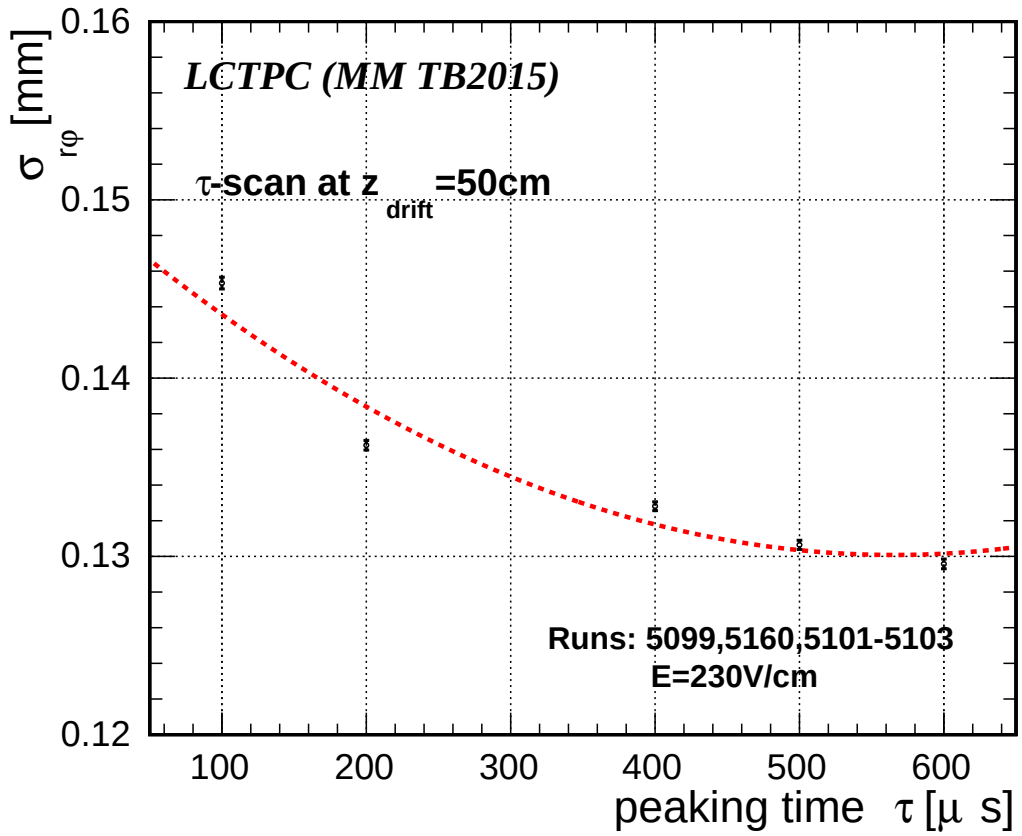
☞ Slightly better overall resolution can be claimed for module#0 (BD2)

➠ about 10% better σ_0 observed at same $\mathrm{N_{eff}}$ then for overall

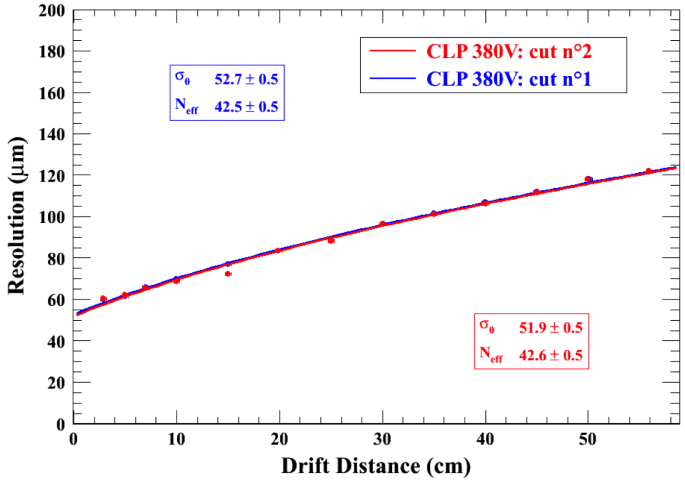
Peaking Time scan: 230V/cm

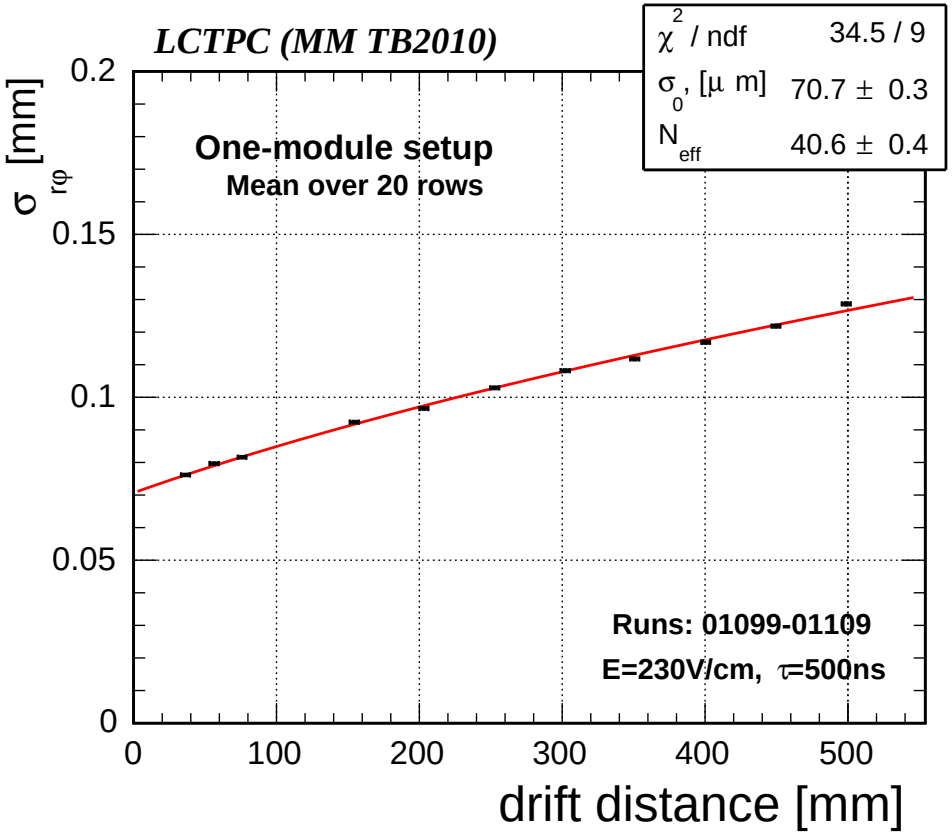
- Have a quick look of the peaking time scan at z=50 cm
  - consistent with expectation
  - will be updated adding up to $\tau = 1\mu\mathrm{m}$ data

Consistent with TB2010 reanalysed data at z=50 cm: $\sigma_{r\phi} = 130\mu m!$



One-Module setup analyzed with both **FTPC and MarlinTPC frameworks**





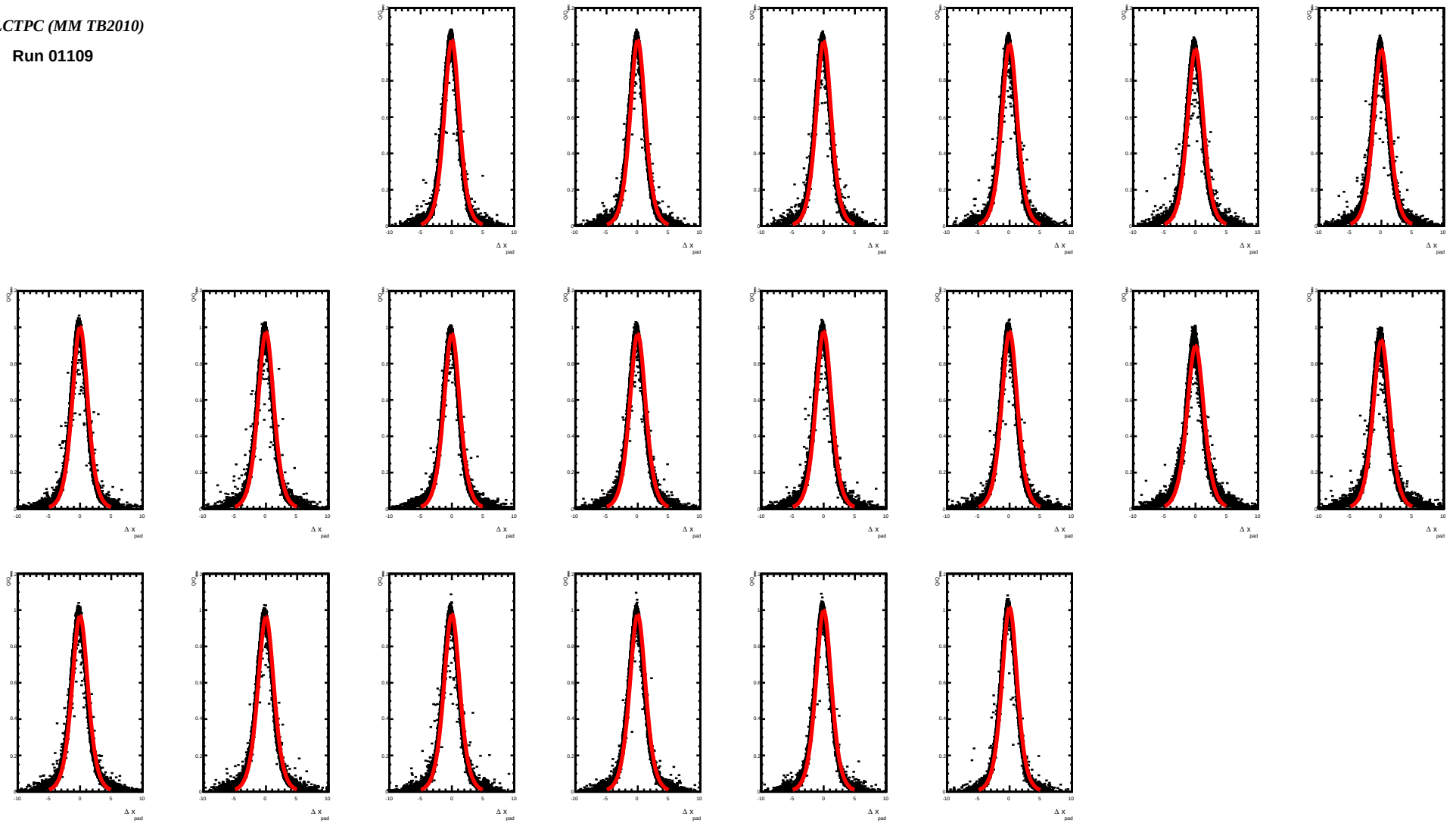
☞ Deployed simple selections to enrich "**single track**" event content

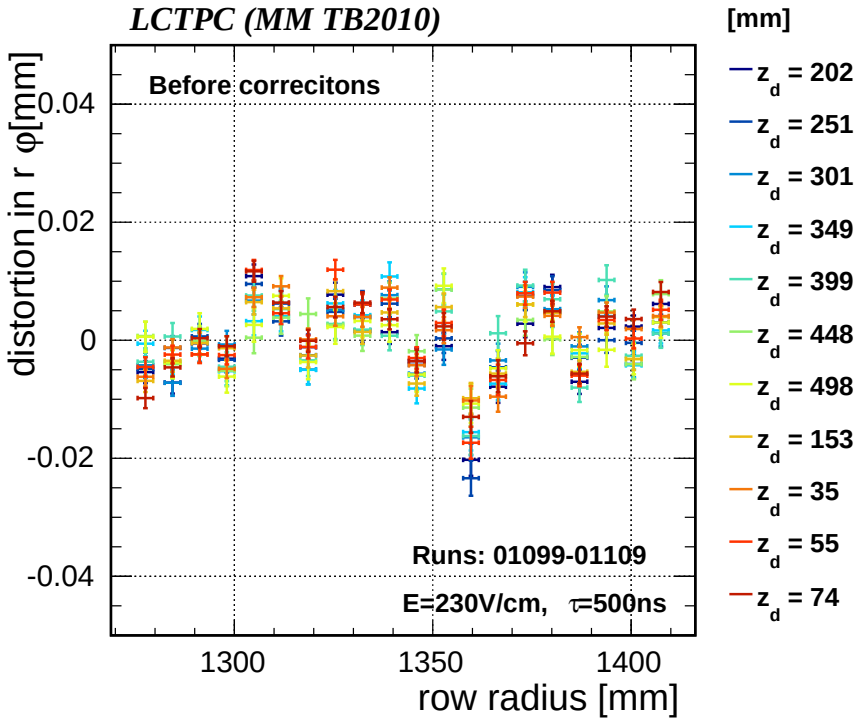
- reject multiple-track events
- require less than 5 hits with more than 40 ADC counts outside 10 central pad lines

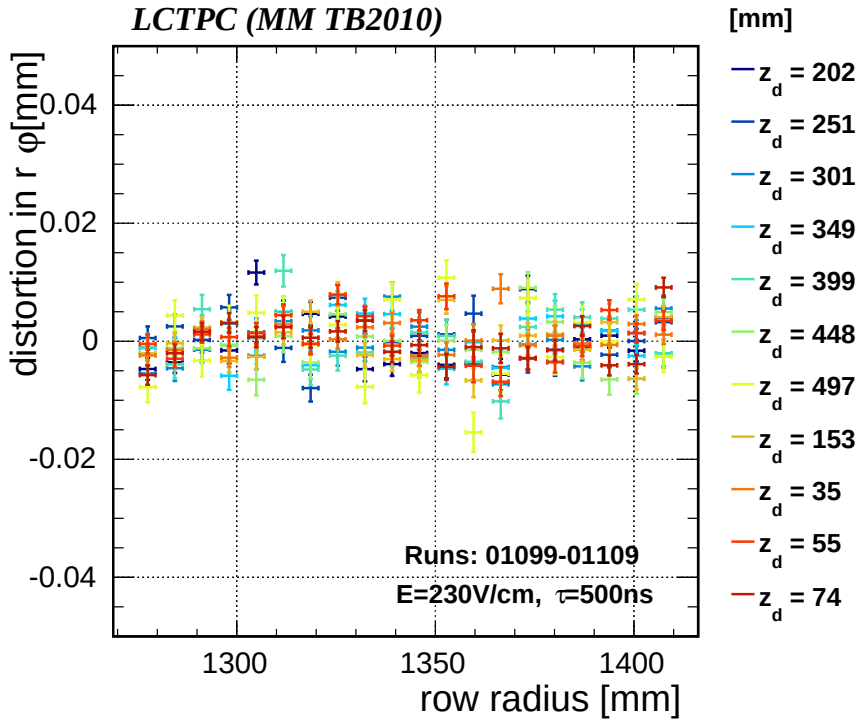
Consistent result with both frameworks

LCTPC (MM TB2010)

Run 01109



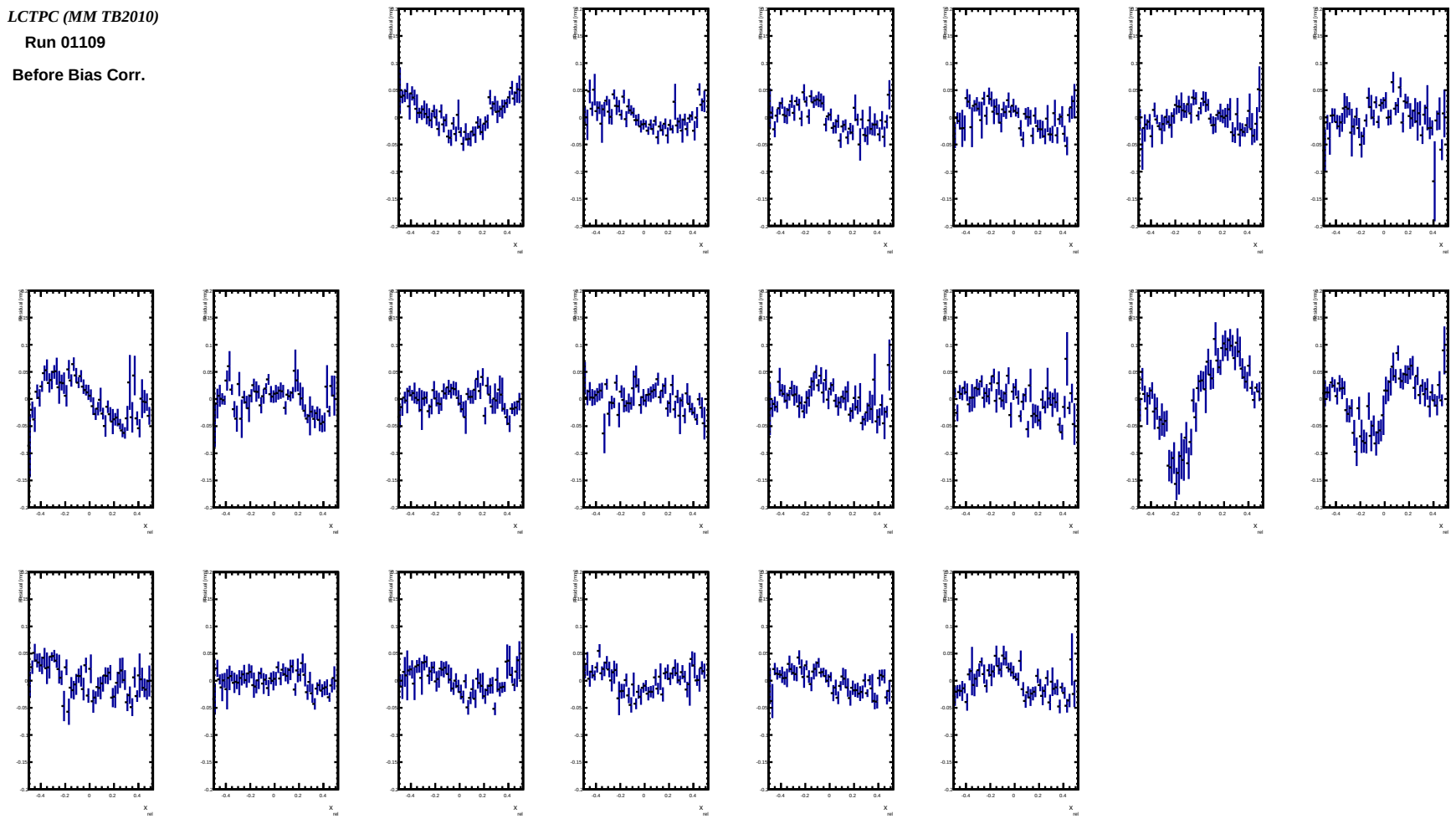




☞ Small distortions are observed in a single-module setup

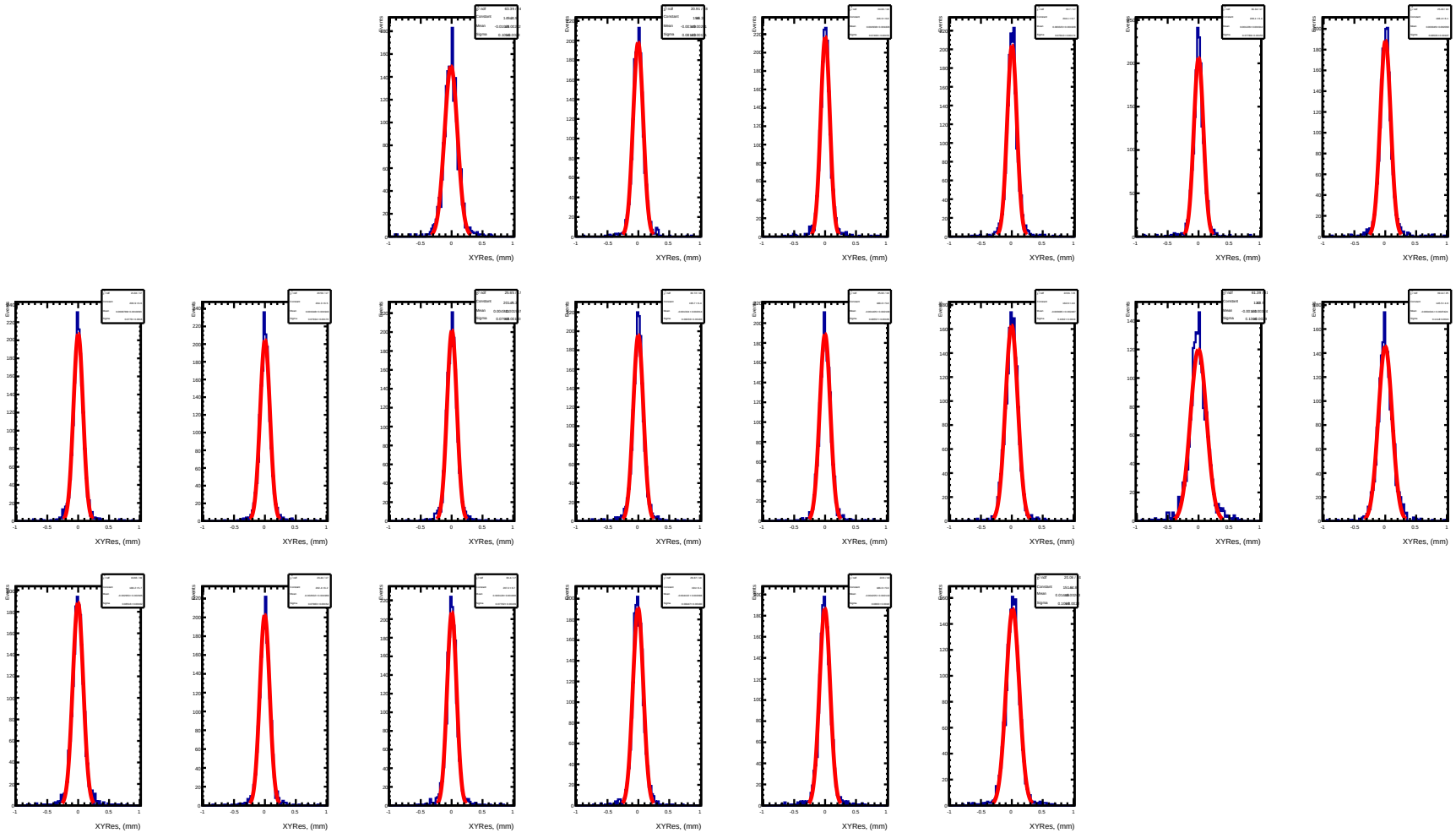
- ➠ possibly compensated by track curvature
- ➠ oddly spike takes place in row 14

Bias TB2010



☞ Smaller bias is observed in a single module setup

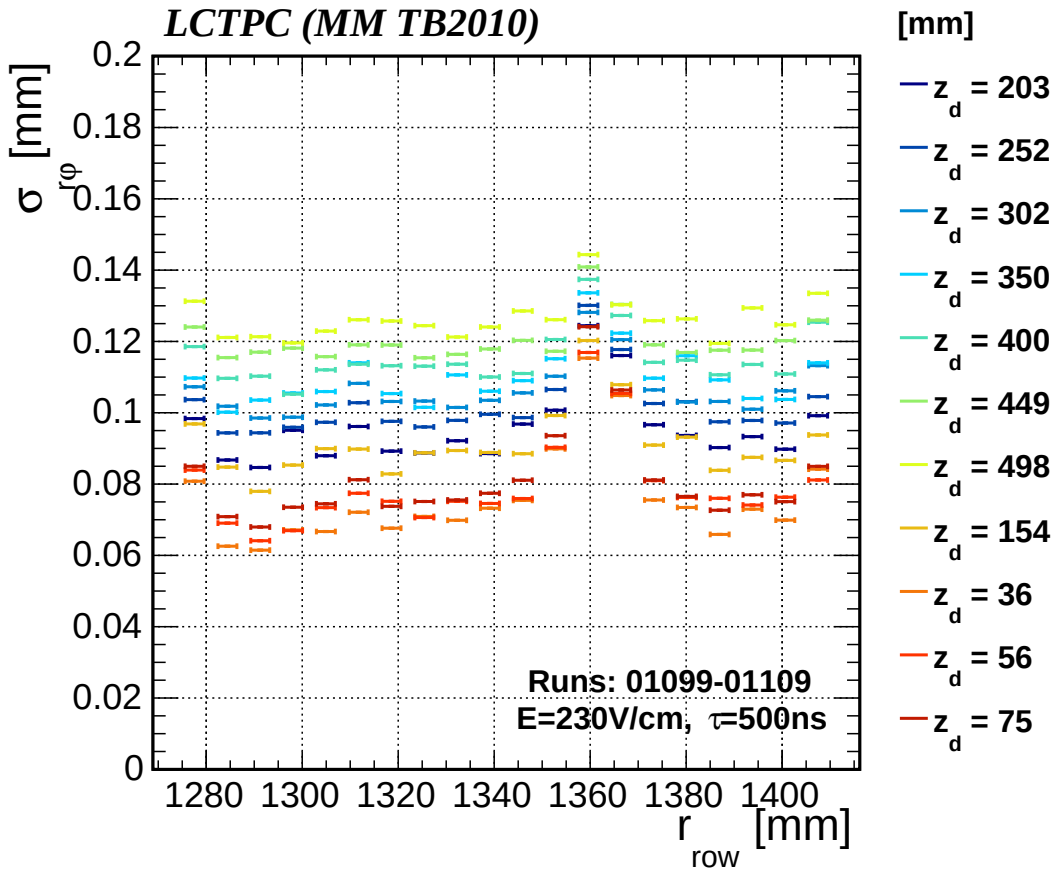
➠ significantly enhanced in rows 14 and 15 (dead/noisy channel?)

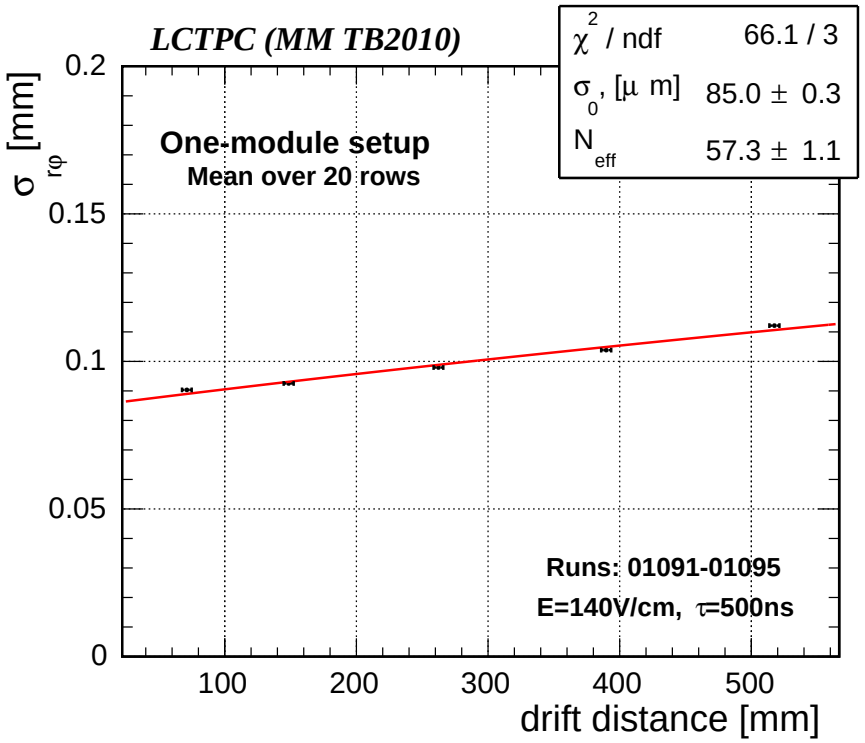


☞ Worse resolution in rows 14 and 15 (dead/noisy channel?)

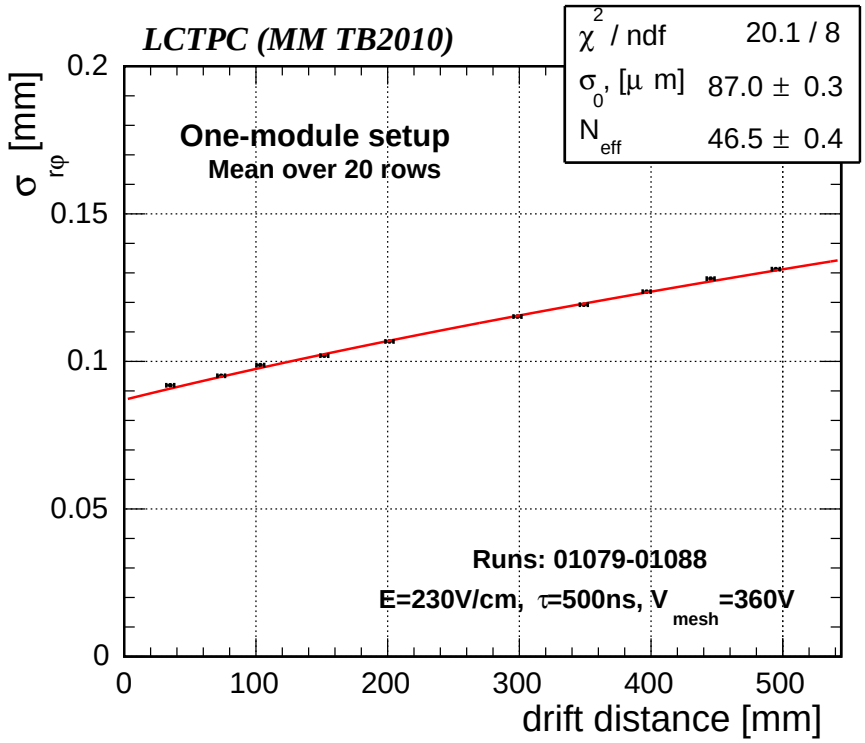
- **General uniformity is satisfactory**

  Worse resoliution in rows 14 and 15





Reach about $\sigma_{r\phi} = 110\mu m$ at large drift distance (very high N_{eff})



Lower gain degrades resolution at small drift distance (increase σ_0 and N_{eff})

- **Preliminary analysis of resolution carried out for TB2015 data**
  - generic strategy for the analysis data flow is undertood
  - current result is based on triplet track finder and helix track fit
  - general correction sequence has been investigated by controlling residual distributions
    - ➔ bias corrections improves a dependence from the distance of a pad center
    - ➔ distortion corrections are necessary to overcome a systematic offset in residuals
- **Further fine-tuning is warrent**
  - study of track finding and fitting algorithms impact on corrections
  - check commutativity of corrections
  - alignment corrections; impact from $\mathrm{B} = 0\ \mathrm{T}$ data
- **Legacy analysis of TB2010 data carried out using MarlinTPC**
  - reasonable agreement achieved with TB2015 and FTPC public result
  - smaller corrections are observed for one-module setup
  - 2 rows are a bit problematic
  - needs to determine the publication strategy

Backup