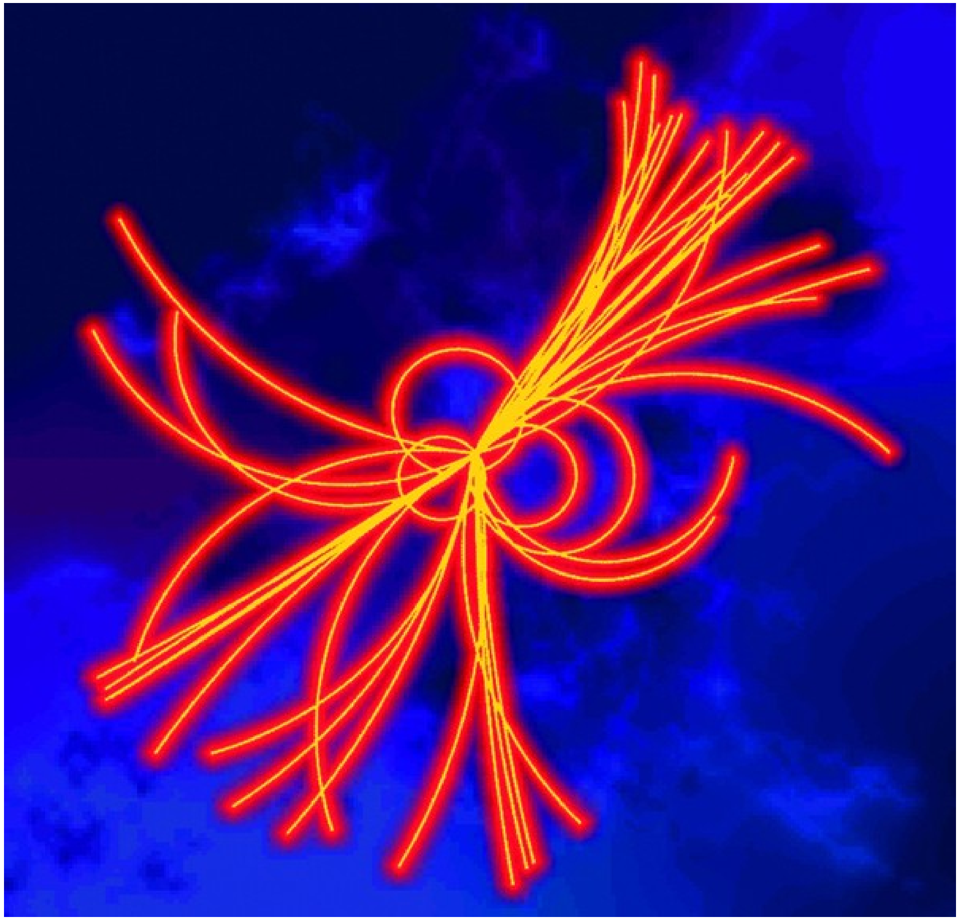
LP TPC Analysis Code and Results



Nicholi Shiell
Carleton University
November 27th 2011
Saclay, France

Talk Outline

- Purpose – What and Why?
- Background – What has been shown before?
- Experimental Setup
- Analysis Methods
  - 2011 DESY data (Fit Max Point)
  - 2011 DESY data (Quadratic fit)
  - 2011 DESY data (Quadratic fit, new PRF)
  - 2011 DESY data (Reintegration, new PRF)
- Comparison of 2011 and 2010 data
- Future work
- Conclusion

Purpose?

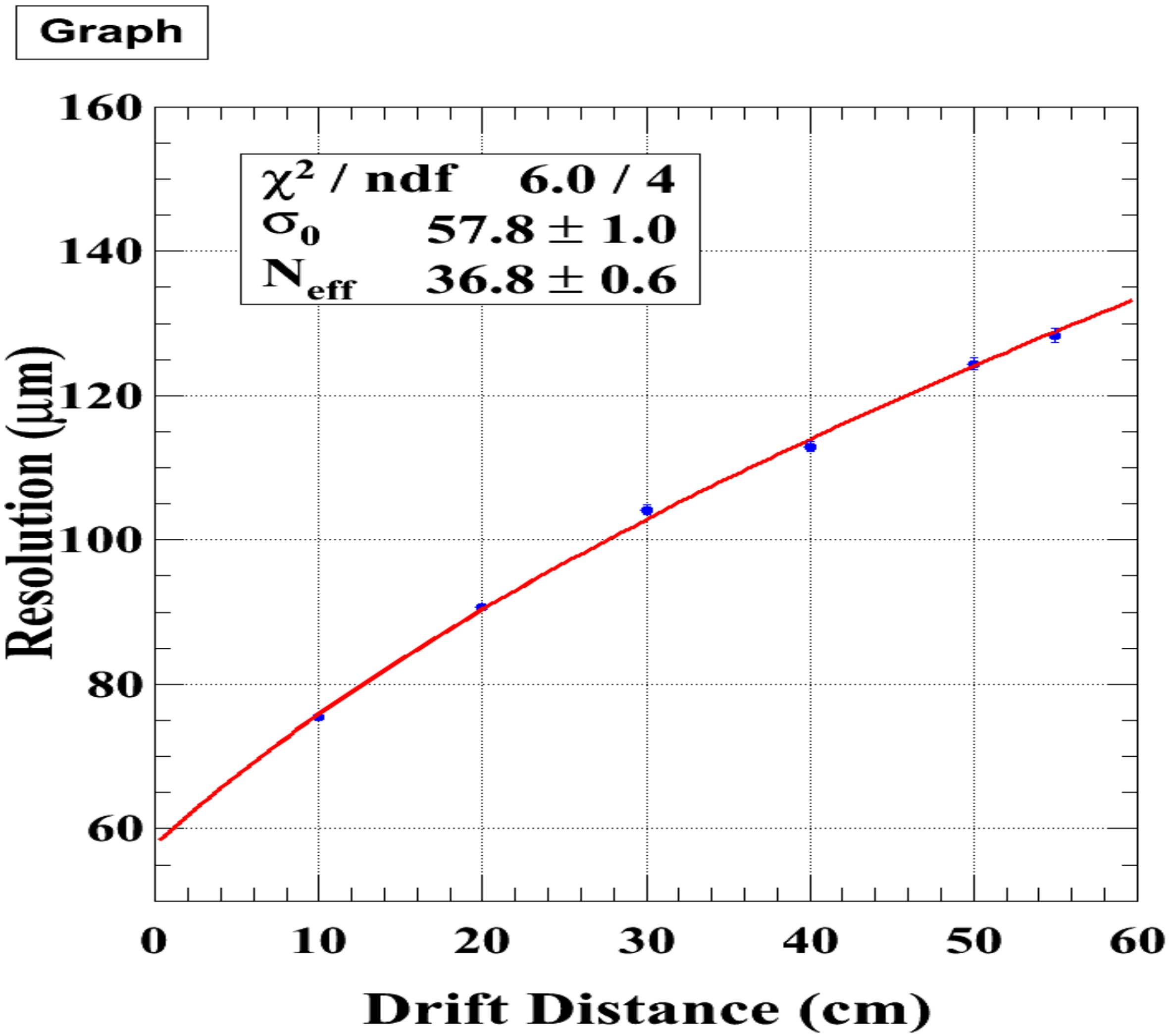
What did we do?

1. Measure the resolution of a 3MOhm/sqr charge dispersion LP-TPC readout array at different peaking times.
2. Determine if it is possible to use short peaking times to achieve good resolution at both short and long drift distances.

Why are we doing this?

1. Determine if 3MOhms/sqr is a good resistivity for the readout array.
2. To increase time resolution of tracks and to achieve better 2 track resolution.

Background – 2010 DESY Data



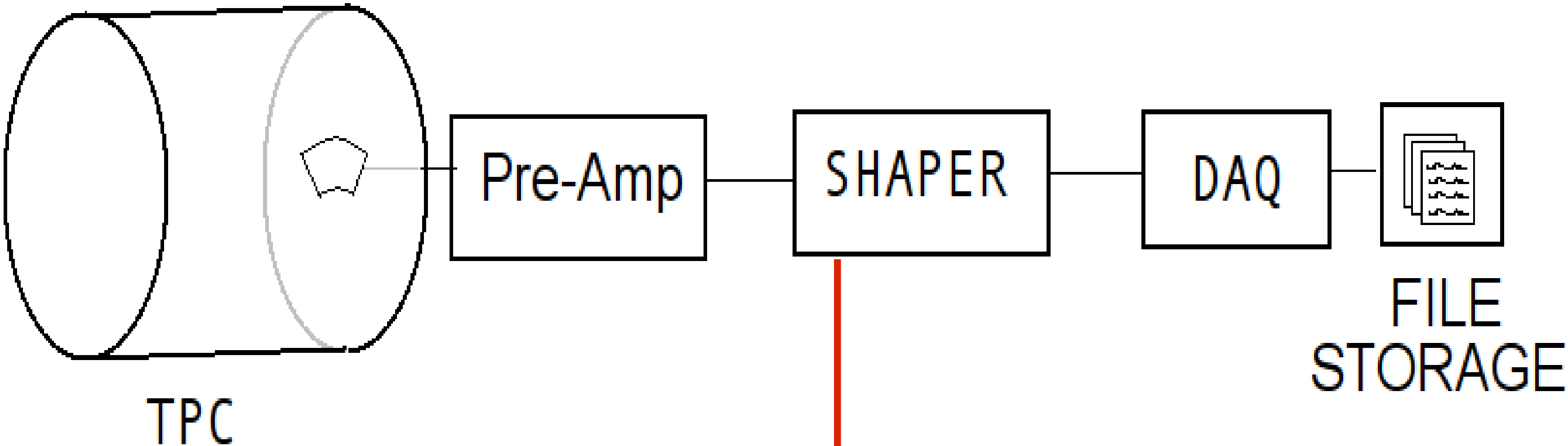
Detector Specs:

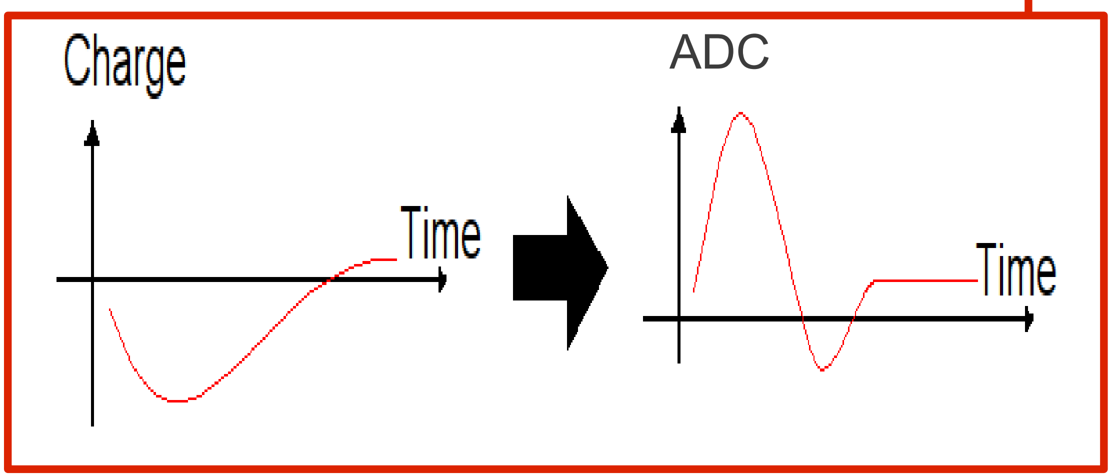
- 5 MOhm/sqr.
- 1 Telsa B-Field
- 500 ns Peaking Time
- 230 V/cm E_{drift}
- Gas 95Ar:2C_4H_{10}:3CF_4

Data Specs:

- 25MHz sampling
- Zero suppressed
- Maximum Signal Height Amplitude
- Zero Suppressed

Experimental Setup





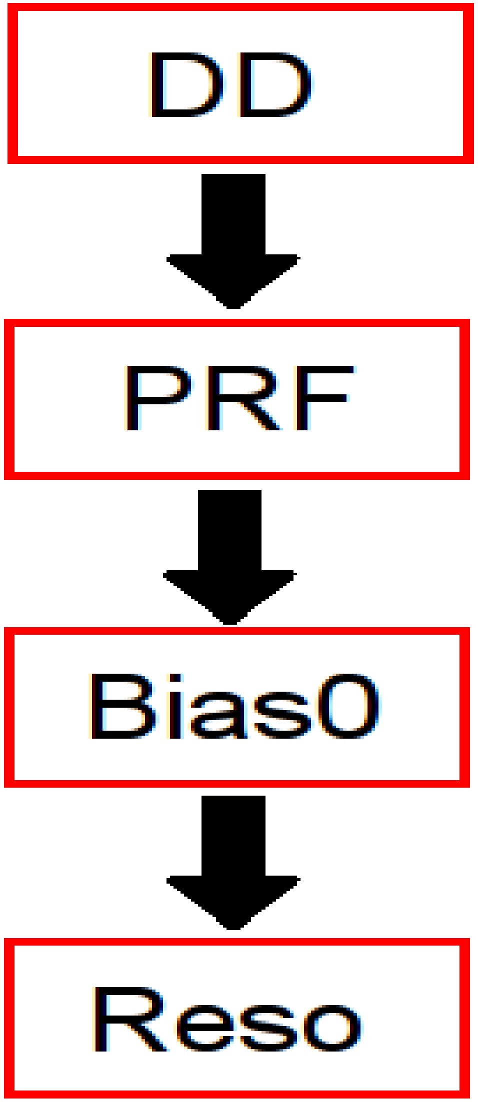
<u>Shaper Specifications:</u>

- Turns raw current pulses into shaped pulses
- Shape characterized by “peaking time”.
- 100ns, 200ns, 400ns, 500ns

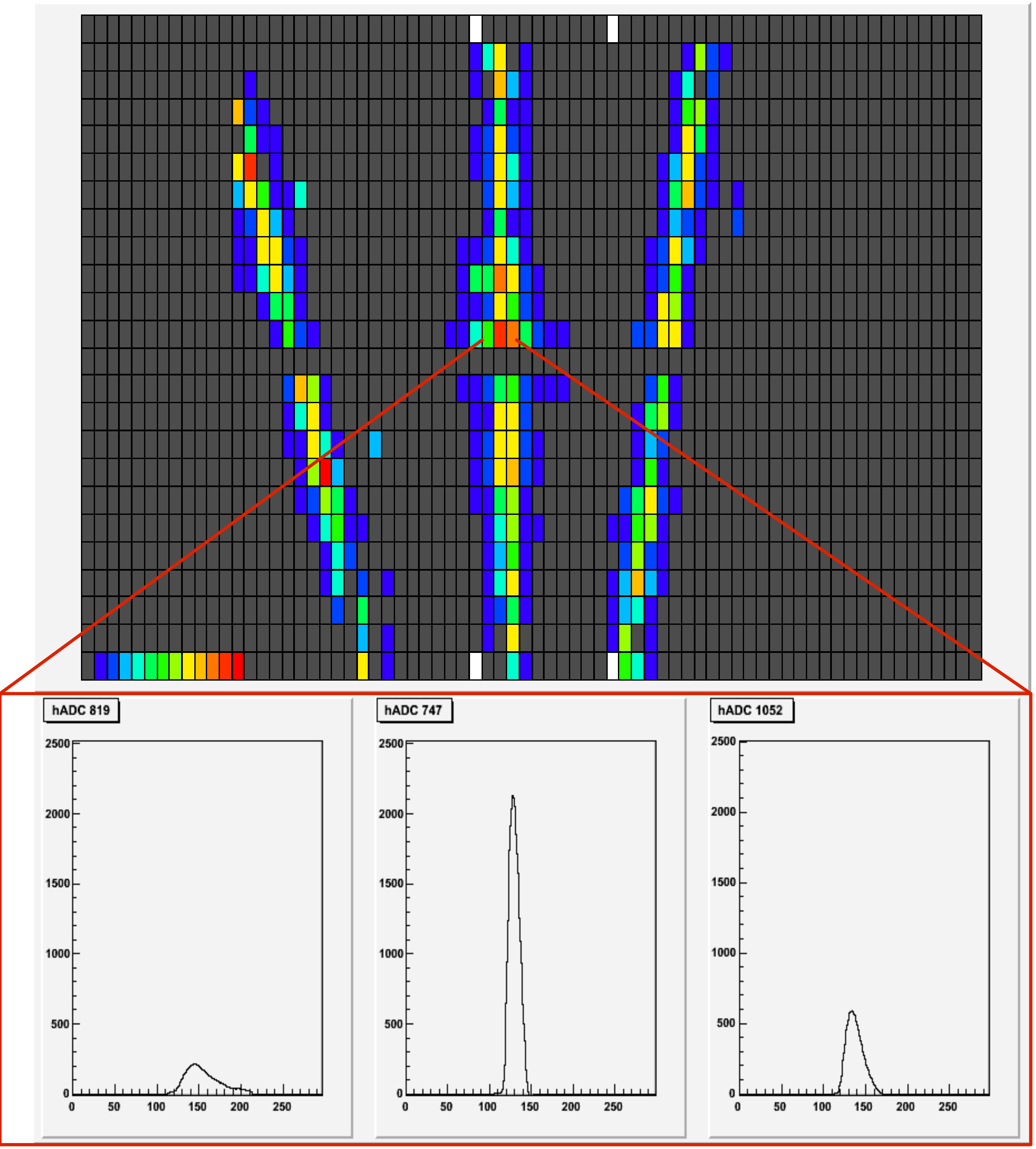
Method - Analysis Overview

<u>4 Analysis Steps:</u>

1. Conversion of raw pulses into amplitudes and hit times.
2. Determination of the pad response function (PRF).
3. Calculation of bias corrections.
4. Application of bias corrections and calculation of resolution.



Method - Dense Data

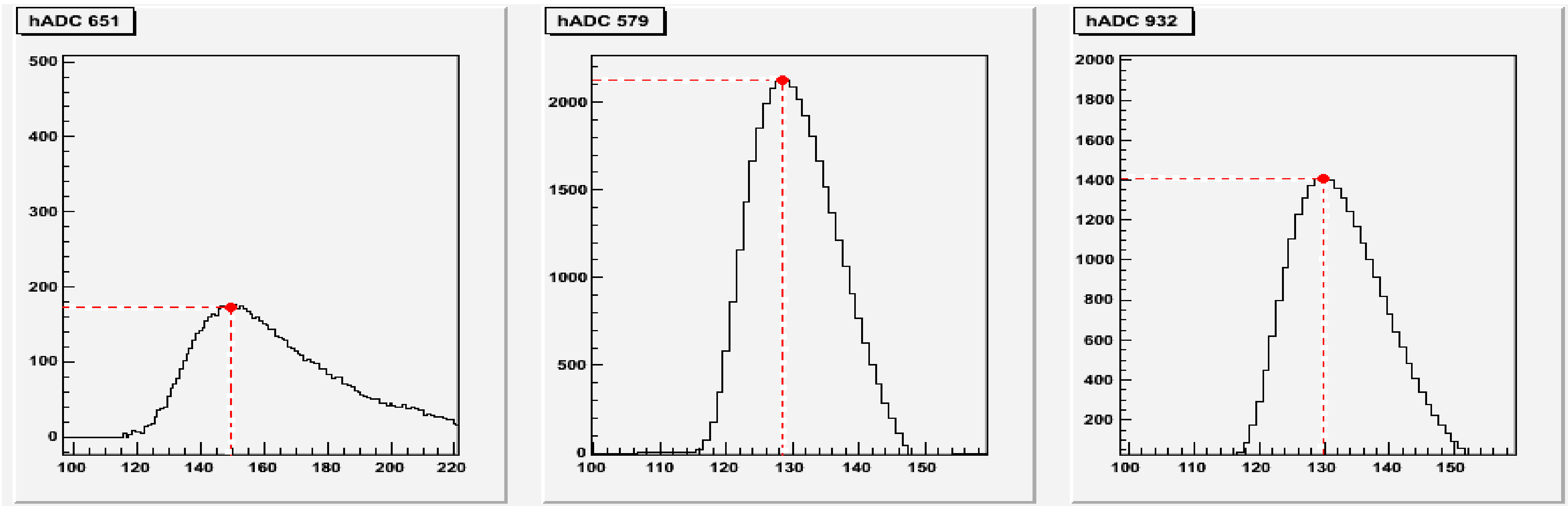


What is done by DD?

- Conversion of raw signal files into useable .dd files.
- Calculation of "amplitudes" from signals.
- Calculation of t0
- Pedestal calculation and removal.
- Elimination of underflow and overflow events.

Need two #s:
1. Amplitude
2. Time0

Method - Dense Data (Old Method)



Fit Point Max:

Amp = Maximum Pulse Height

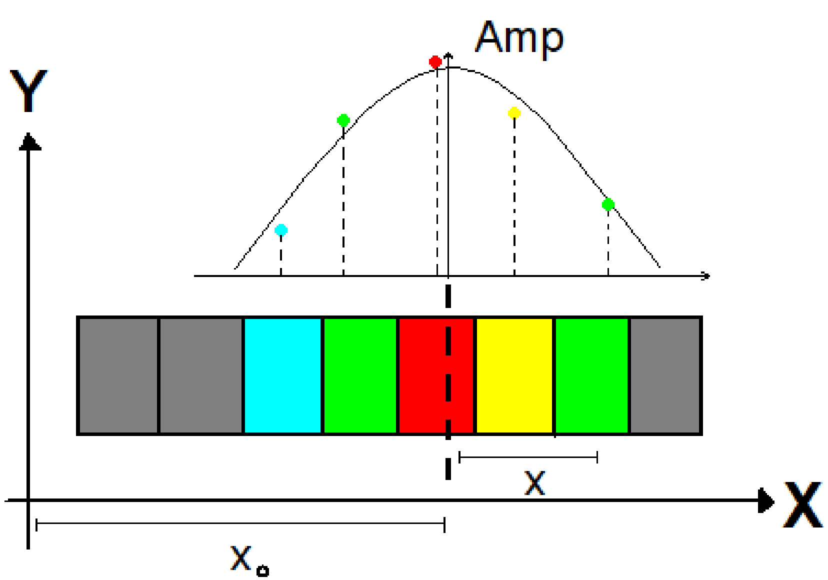
T0 = Time of bin with maximum signal

Method – Pad Response Function

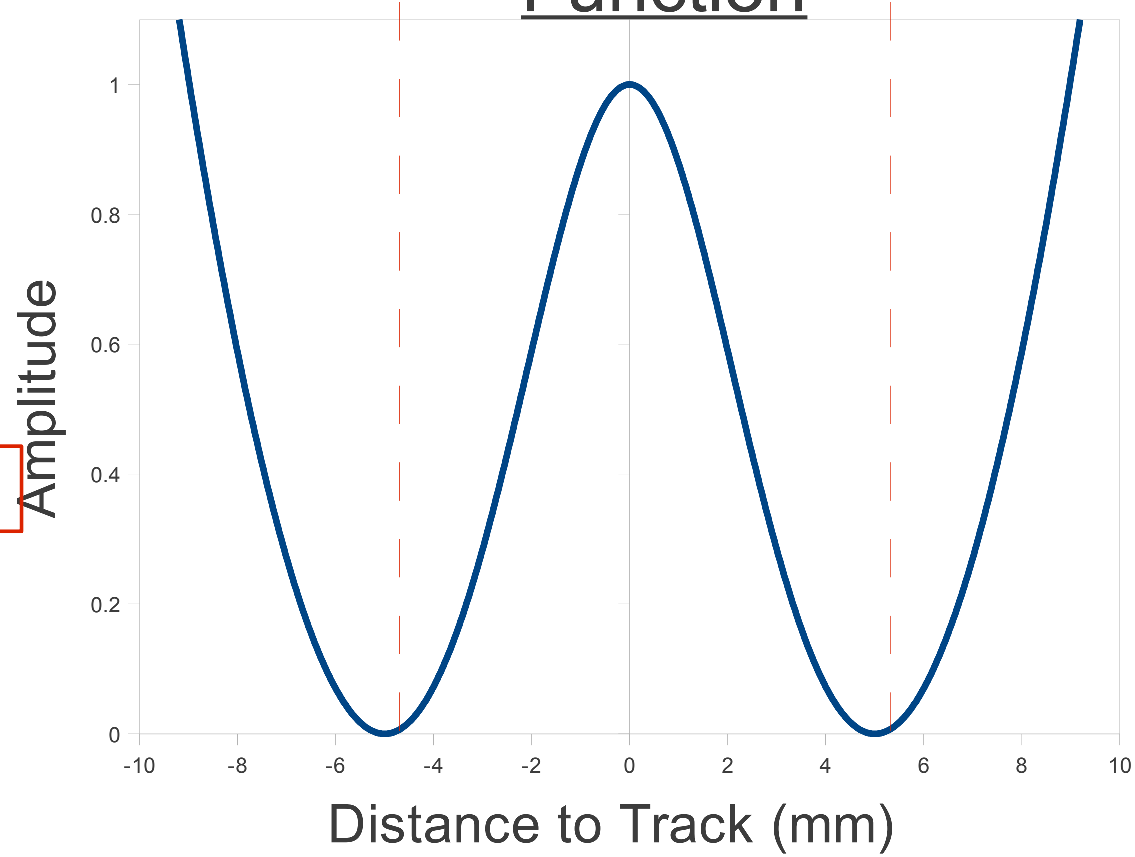
What is a PRF?

A function relating the distance between a pad centre and a track to the amplitude measured by the pad.

PRF(Distance to Track) = Amplitude

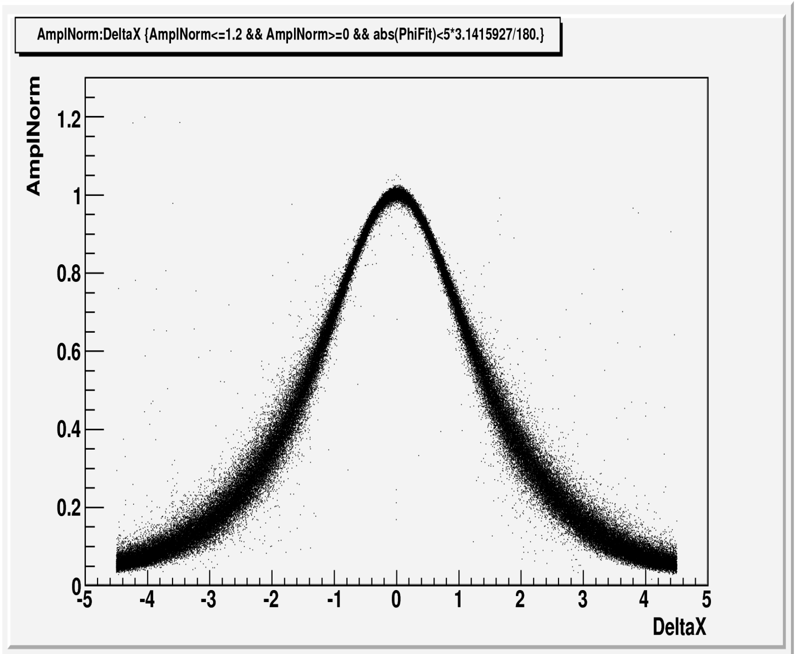


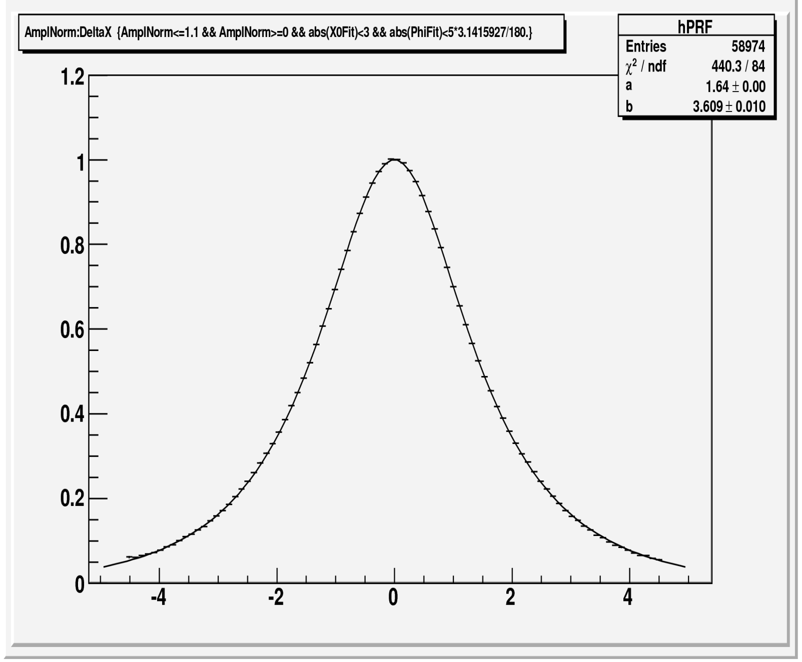
Q-Ratio Pad Response Function



Method – Pad Response Function

$$PRF(\Gamma, \Delta, a, b; x) = \frac{1 + a_2 x^2 + a_4 x^4}{1 + b_2 x^2 + b_4 x^4}$$

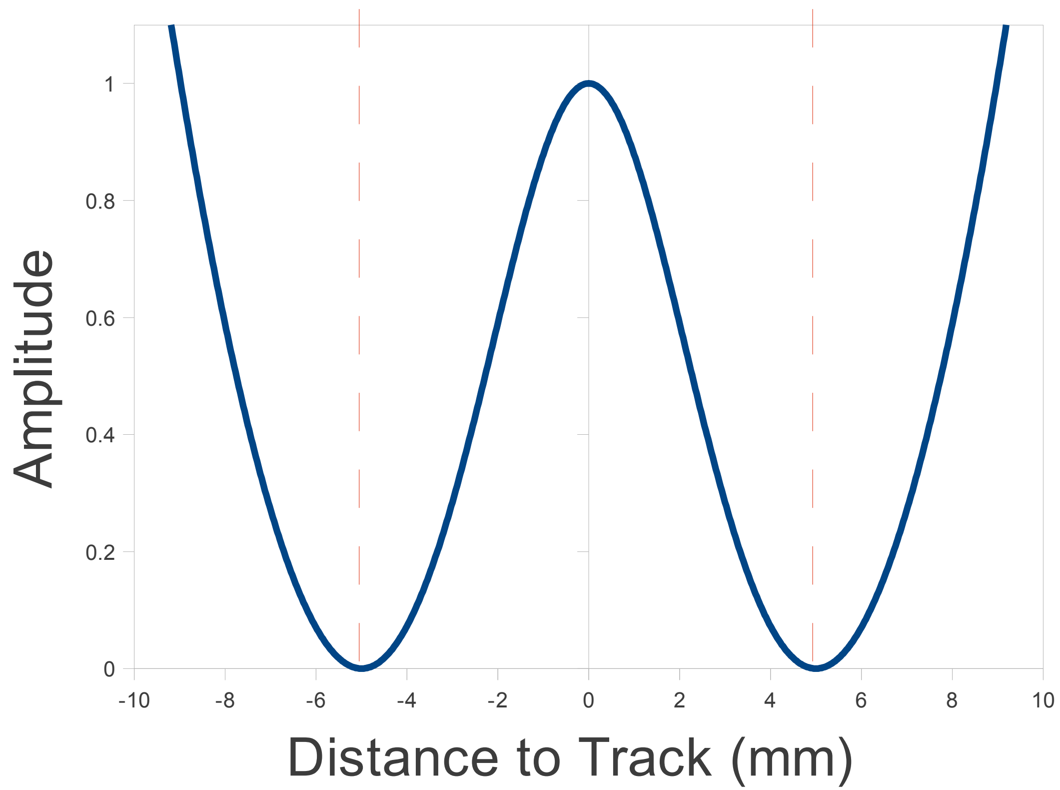




How is the PRF determined?

- Select set of PRF parameters (Γ, Δ, a and b)
- Use PRF to fit tracks in data (A, x_0)
- Record distance from pad to track (deltaX) and normalized pad amplitude (AmplNorm) in histogram.
- Fit PRF to histrogram
- If selected is close to fitted and/or chi-square small. PRF is a good model of amplitudes.

Method – Pad Response Function



<u>Q-Ratio PRF:</u>

Pros:

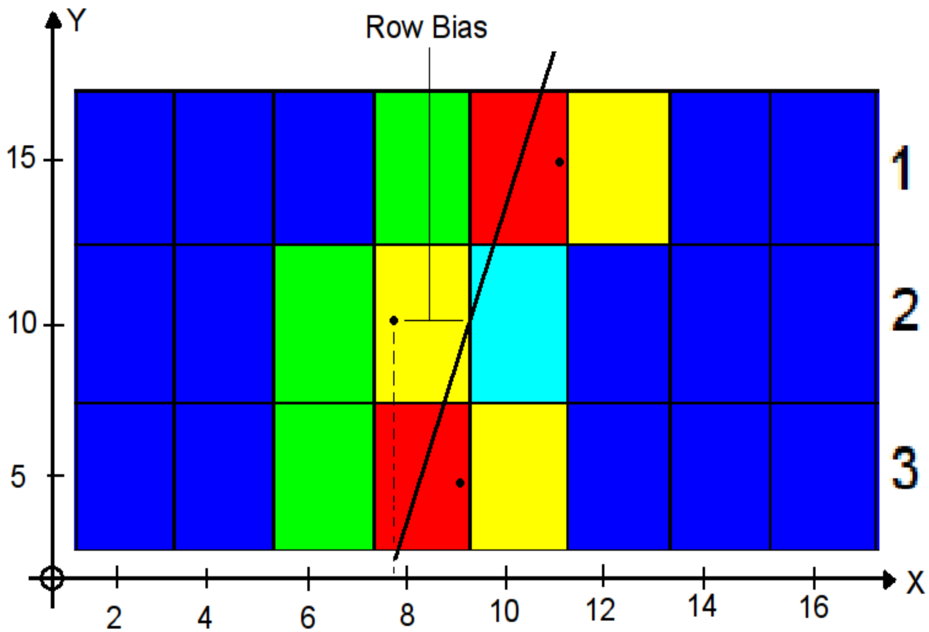
- “Physical” interpretation of parameters

Cons:

- Highly unstable
- Many parameters
- Strongly correlated parameters

$$PRF(\Gamma, \Delta, a, b; x) = \frac{1 + a_2 x^2 + a_4 x^4}{1 + b_2 x^2 + b_4 x^4}$$

Method – Bias Calculation



How is the bias correction calculate?

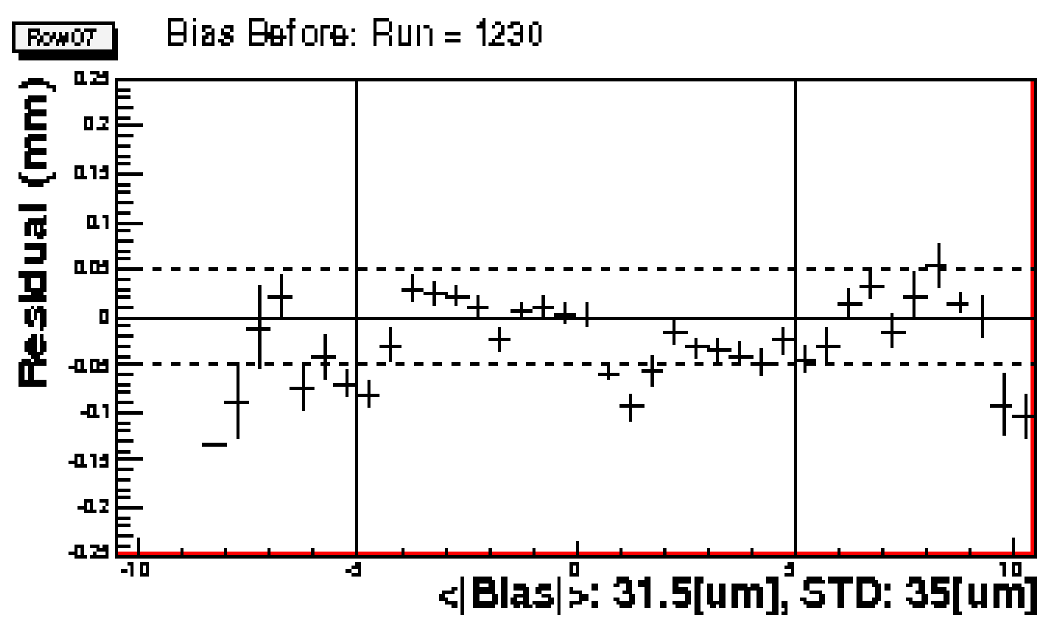
1. Use PRF on each row to find x_0
2. Chi-Square track fit
3. bias $= x_{track} - x_0$
4. Record bias corrections

How is the bias correction used?

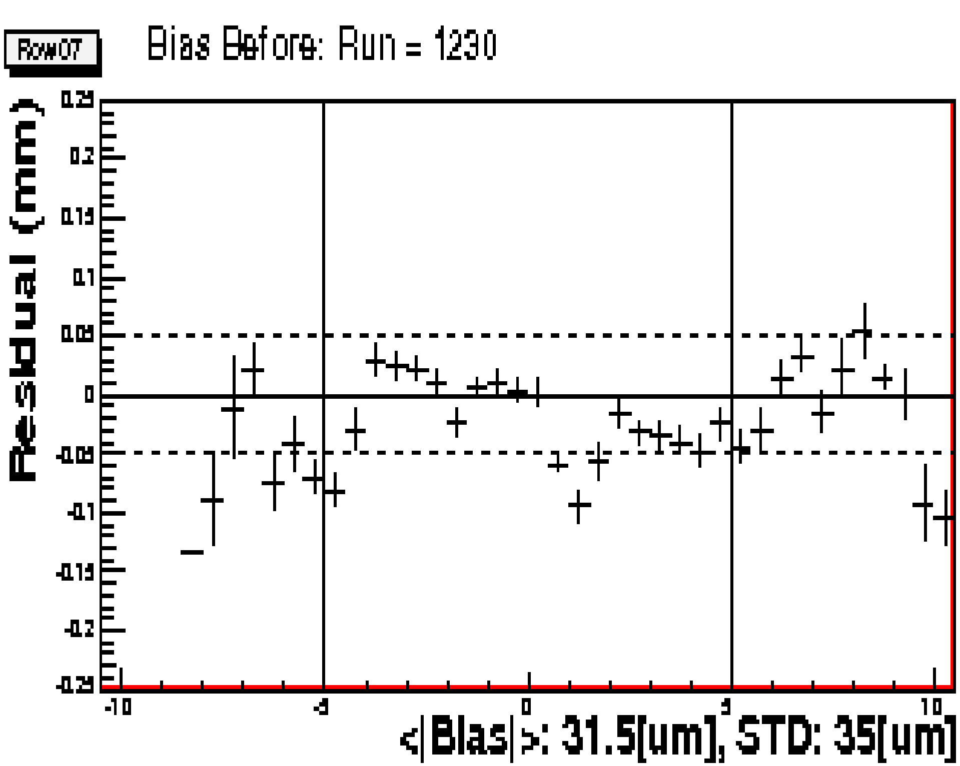
- Applied after PRF fit

$x_{0,corrected} = x_0 - \text{bias}(x_0)$

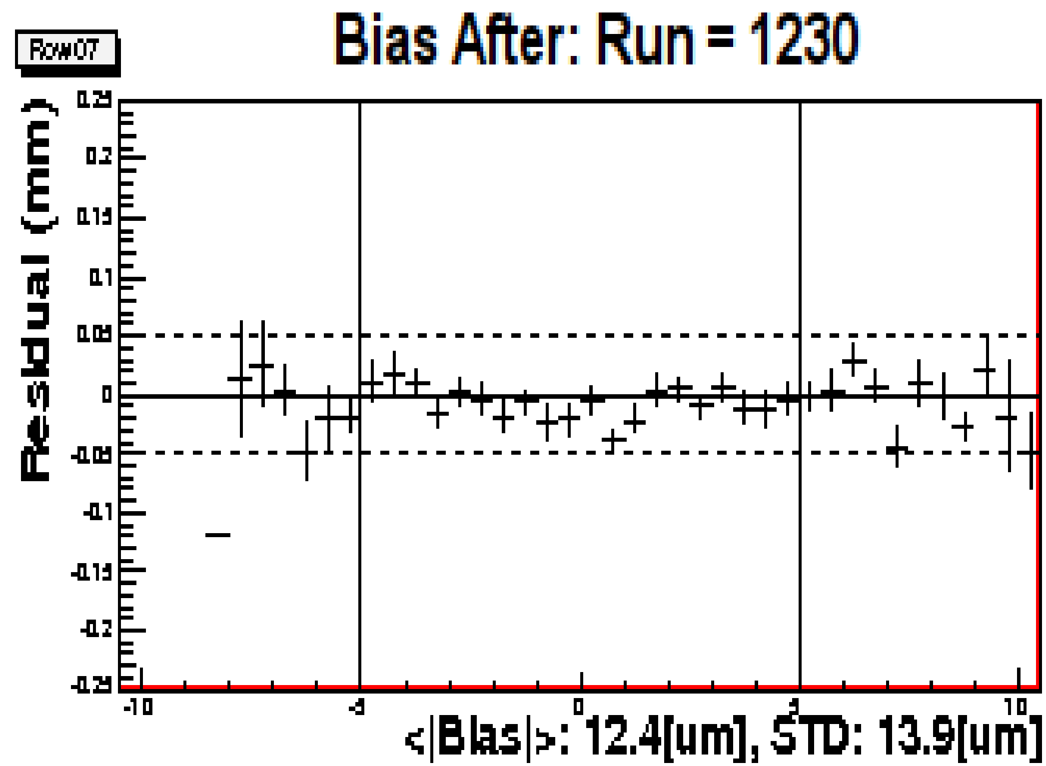
- Corrected x_0's then used in track fit



Method – Residual Comparison



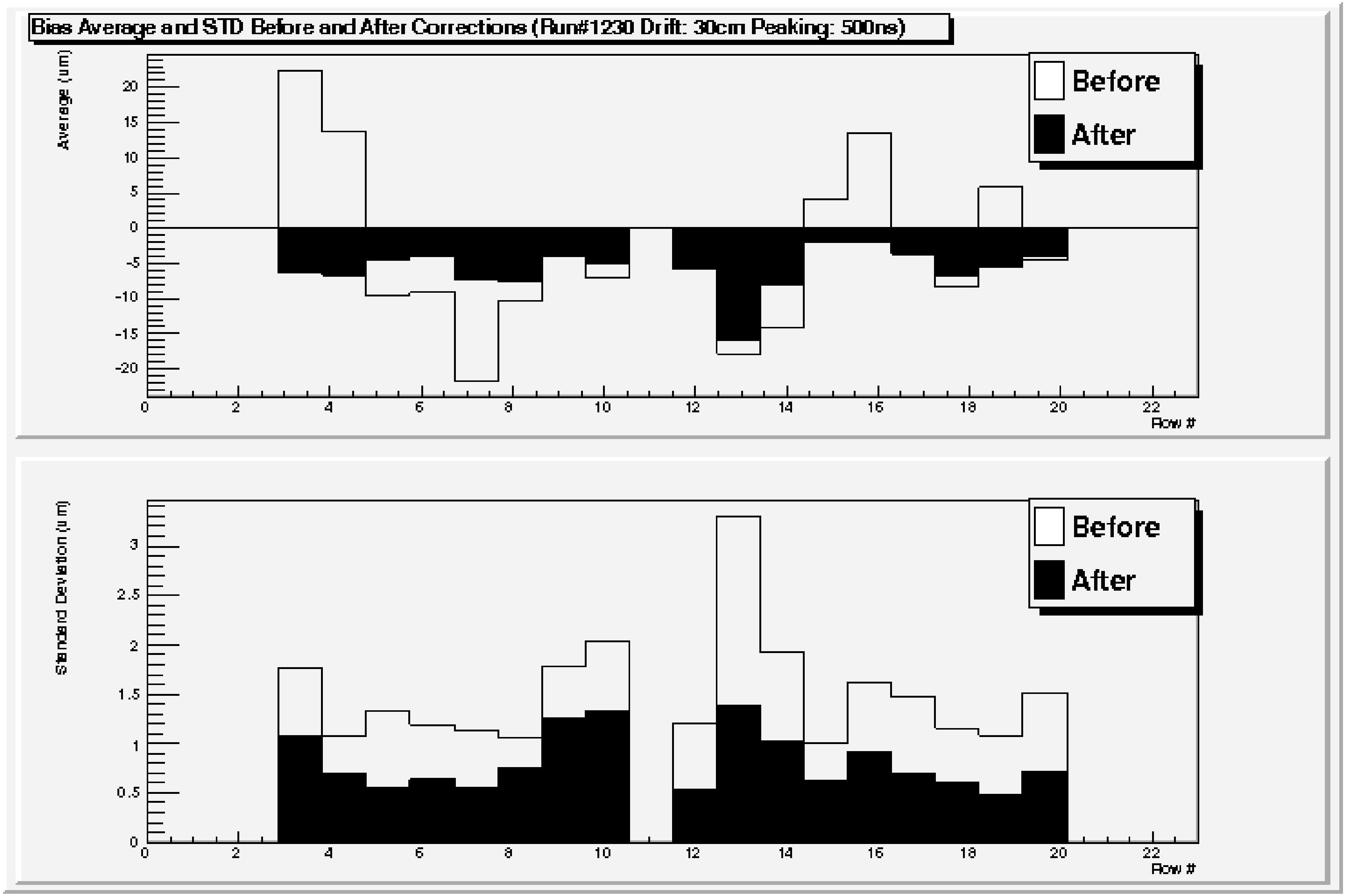
Row residual BEFORE bias correction



Row residual AFTER bias correction

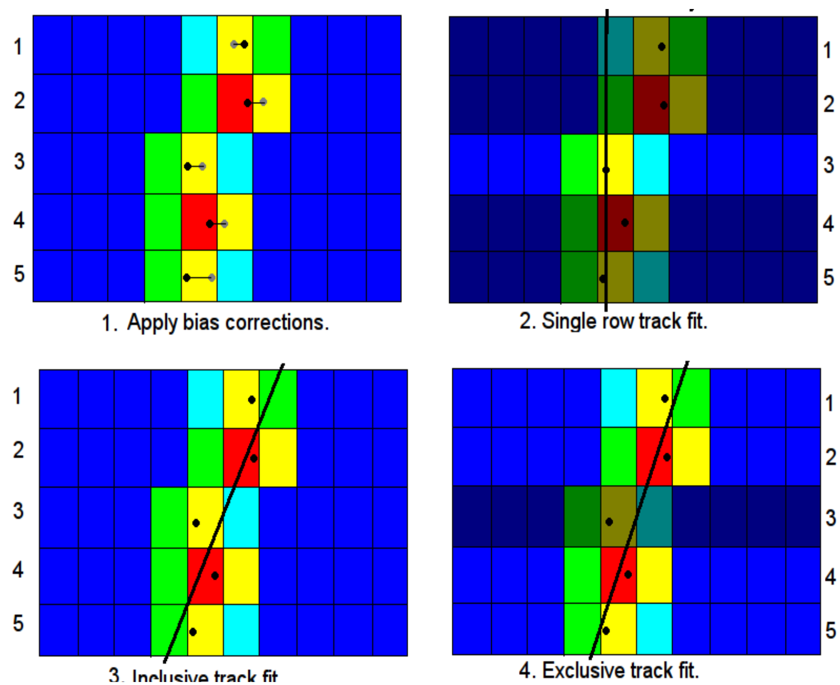
$$\Delta x = x_{row} - x_{fitted}$$

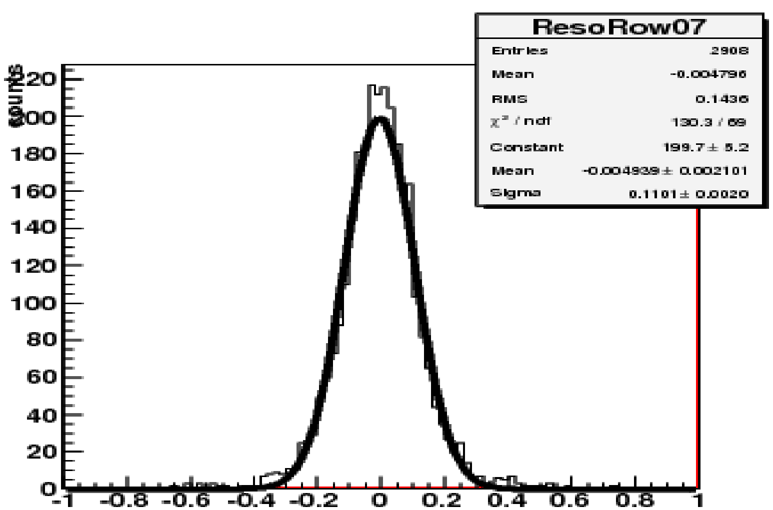
Method – Residual Comparison



Method – Resolution Calculation

<u>4 Steps to Calculate Row Resolution</u>





<u>Detector Resolution Calculation:</u>

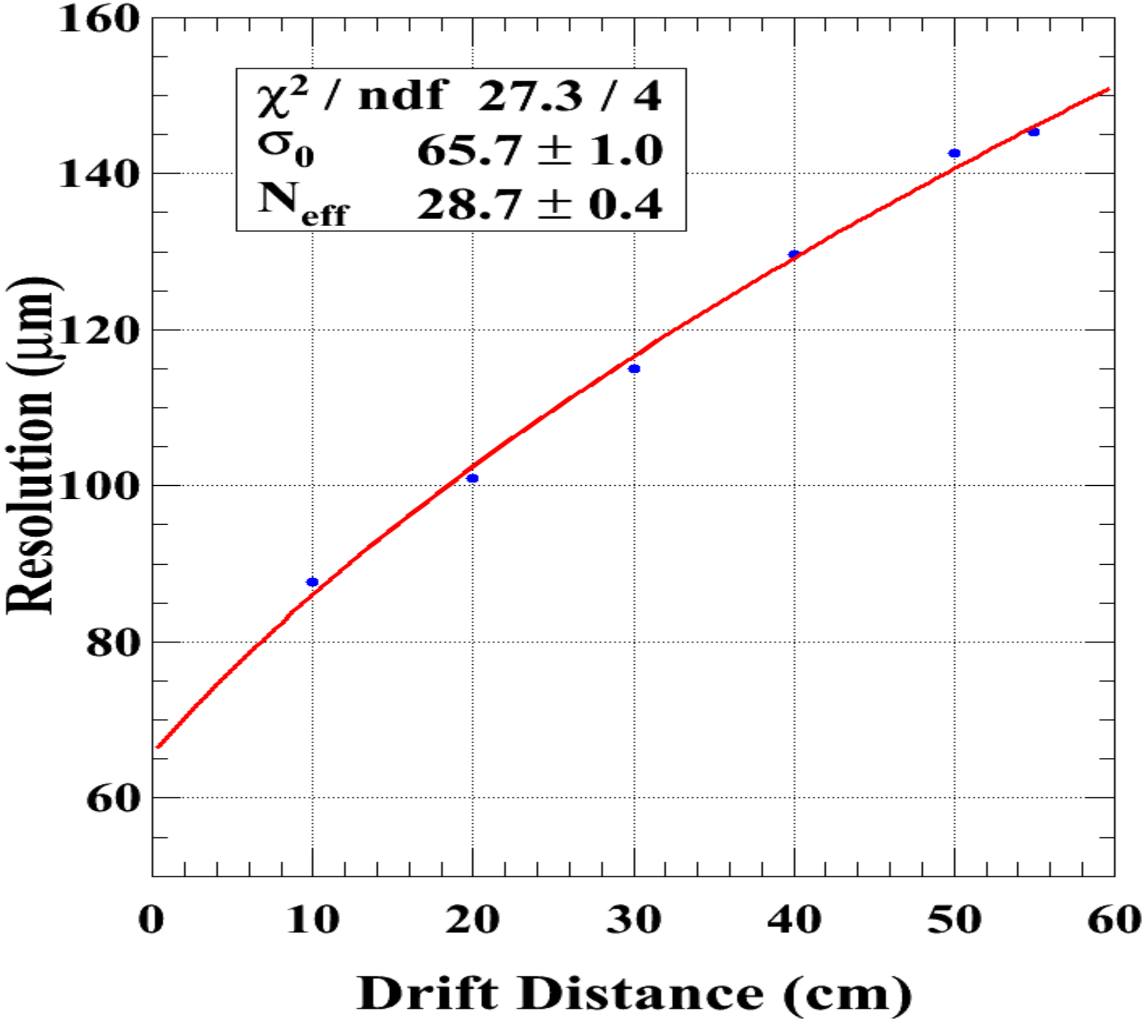
1. Determine inclusive, Δx_{in}, and exclusive, Δx_{ex}, row residuals.
2. Estimate row resolution using the following estimator:

$$\sigma = \sqrt{\Delta x_{¿} \Delta x_{ex}}$$

3. Combine row resolution estimates to determine detector resolution.

Results – Old Analysis Technique

□



<u>Analysis Summary:</u>

- 500 ns peaking time
- zero suppressed data
- Amp = Fix Max Point
- PRF = Q-Ratio

How Can Resolution be Improved?

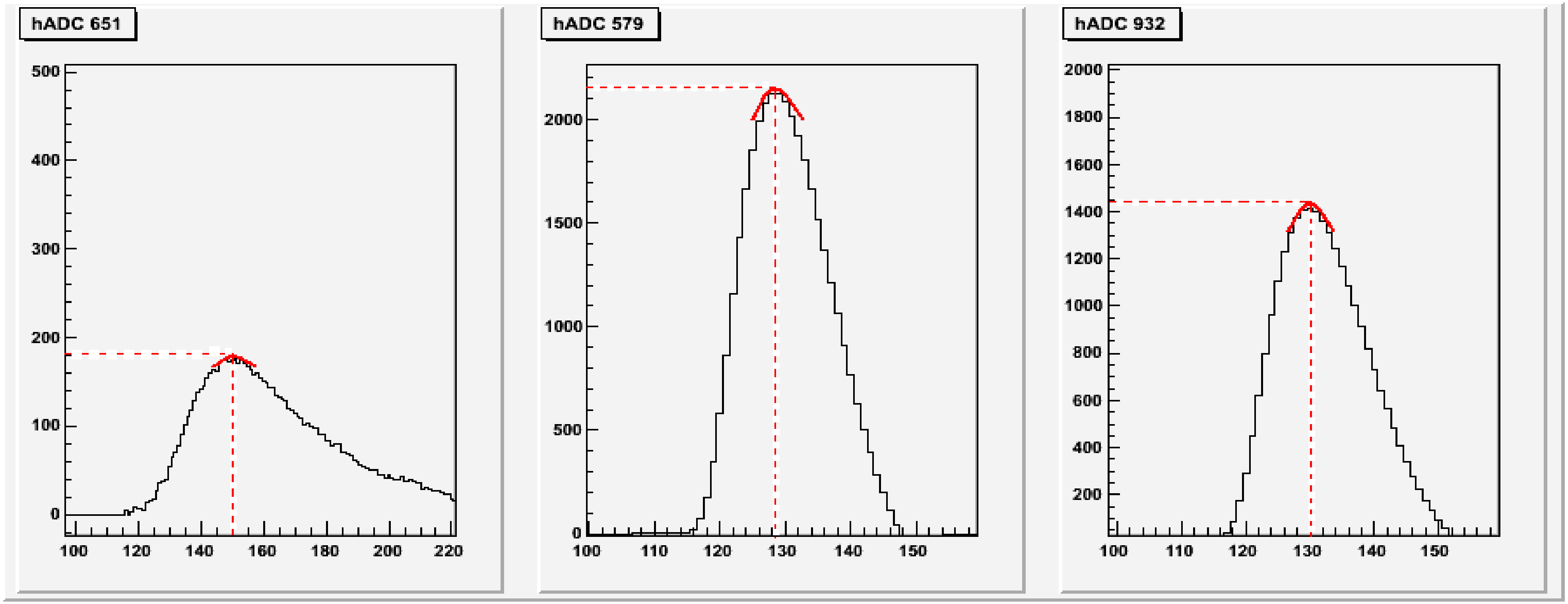
Problems:

- Previous amplitudes considered only a single point
  - Effected strongly by noise!
- Previous time0 measurements quantized to bin widths

Solutions:

- Average out noise by considering neighbouring signals
  - Fit function to 5 largest signals!
- Use location of fit function maximum as time0
  - No longer quantized!

DD – Quadratic Fit

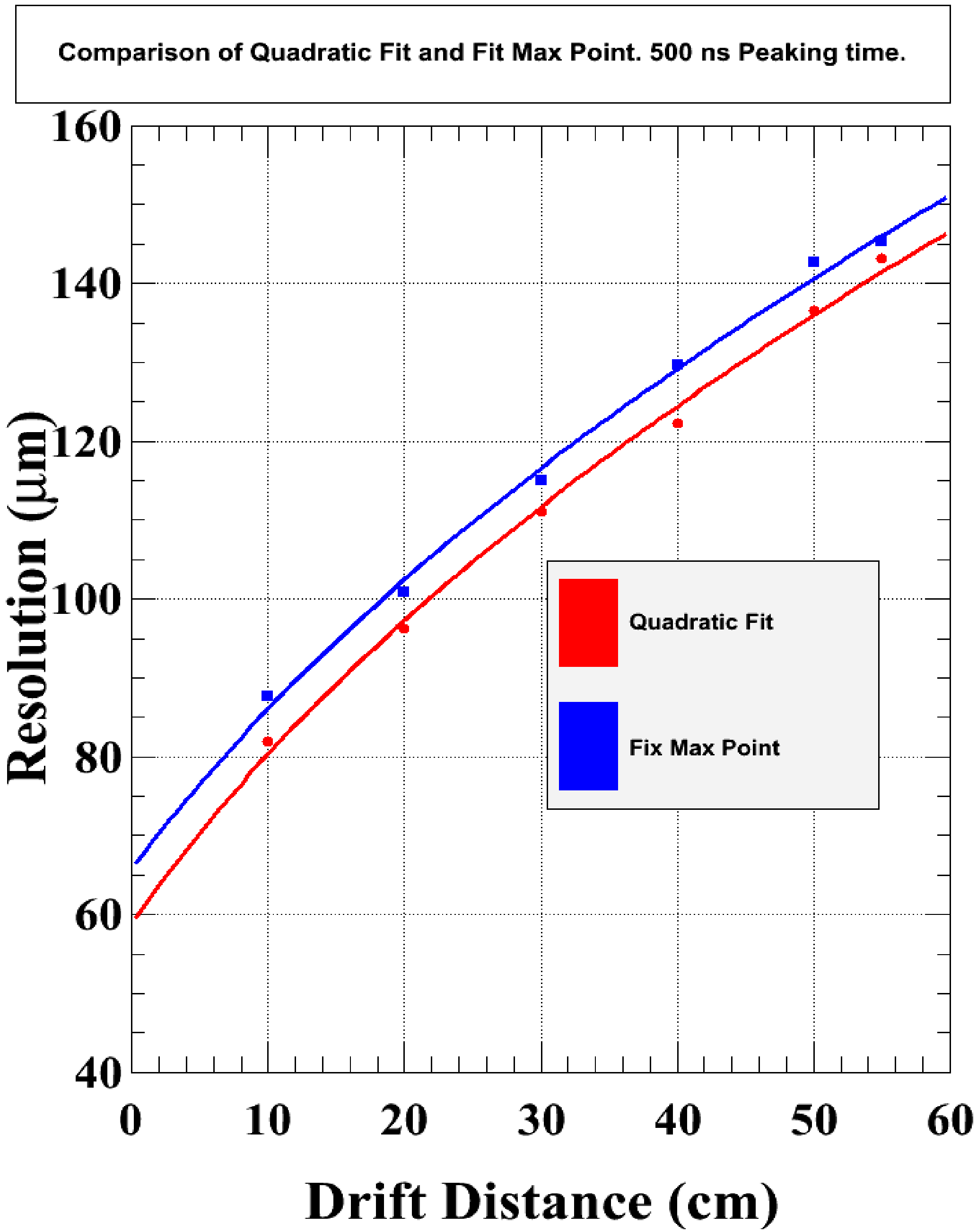


<u>Quadratic Fit:</u>

Amp = Max Pt. of fit

T0 = Time of Max Pt.

Results – Using Quadratic Fit



Analysis Summary:

- 500ns peaking time
- zero suppressed data
- Amp = Quad. Fit (red)
- Amp = Fix Max Pt. (blue)
- PRF = Q-Ratio (Both)

Conclusions:

- Modest improvement in resolution
- None quantized time0

How Can PRF Determination be Simplified?

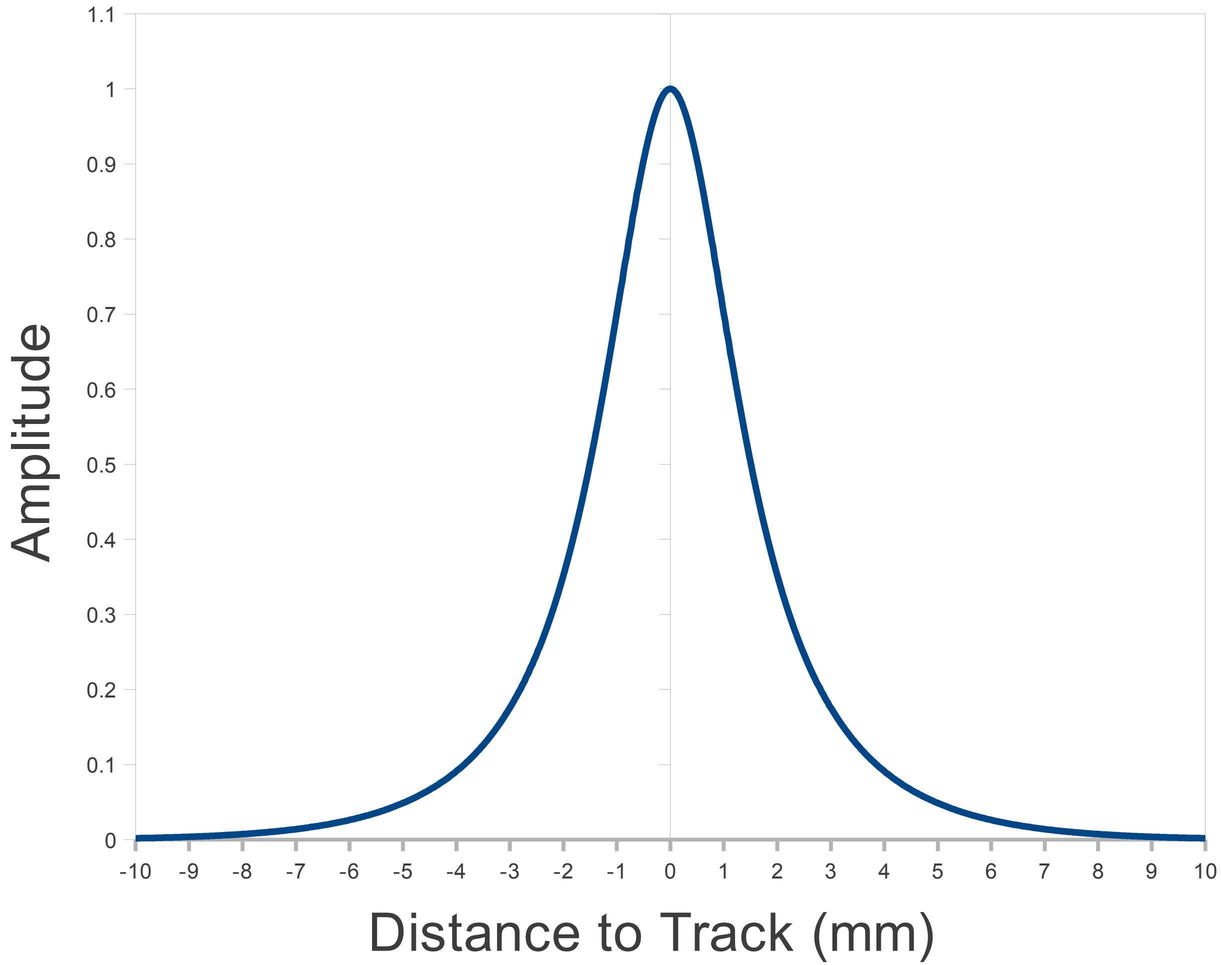
<u>Problems:</u>

- Q-Ratio PRF has many strongly correlated parameters.
  - Difficult for computer minimization.
- Q-Ratio is highly unstable. It can take on many different shapes.
  - Can't be left to computer to find good PRF

<u>Solutions:</u>

- Choose simplified PRF with fewer less correlated parameters.
- And has simple stable shape.

PRF – Pad Response Function



<u>Synthetic PRF:</u>

Pros:

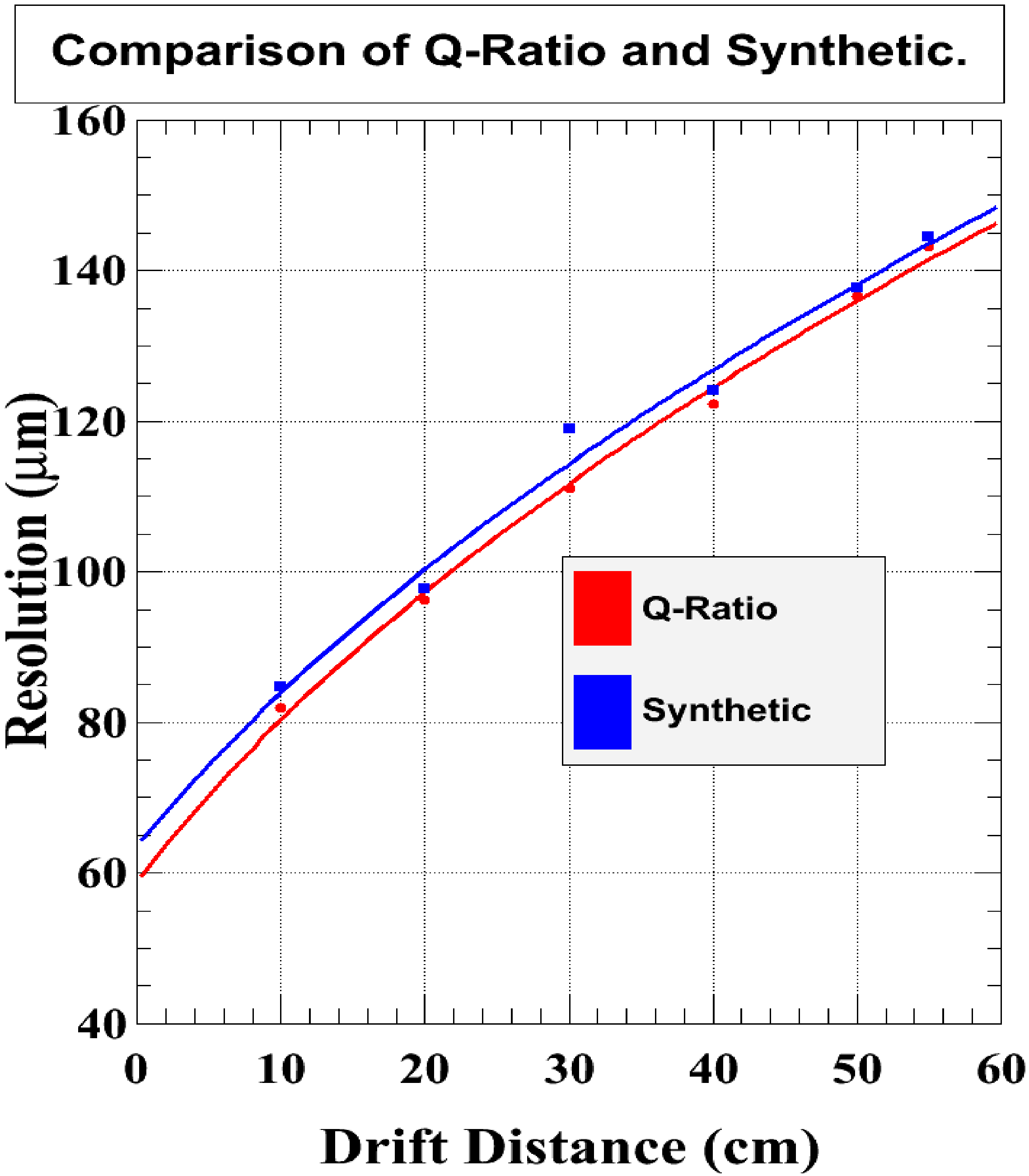
- Fewer and uncorrelated parameters
- Stable
- Able to fit short drift distance (Z = 3cm) data

Cons:

- No "physical" interpretation of parameters

$$PRF(a,b;x) = \frac{a^2}{x^2 + a^2} exp^{\frac{-x^2}{2b^2}}$$

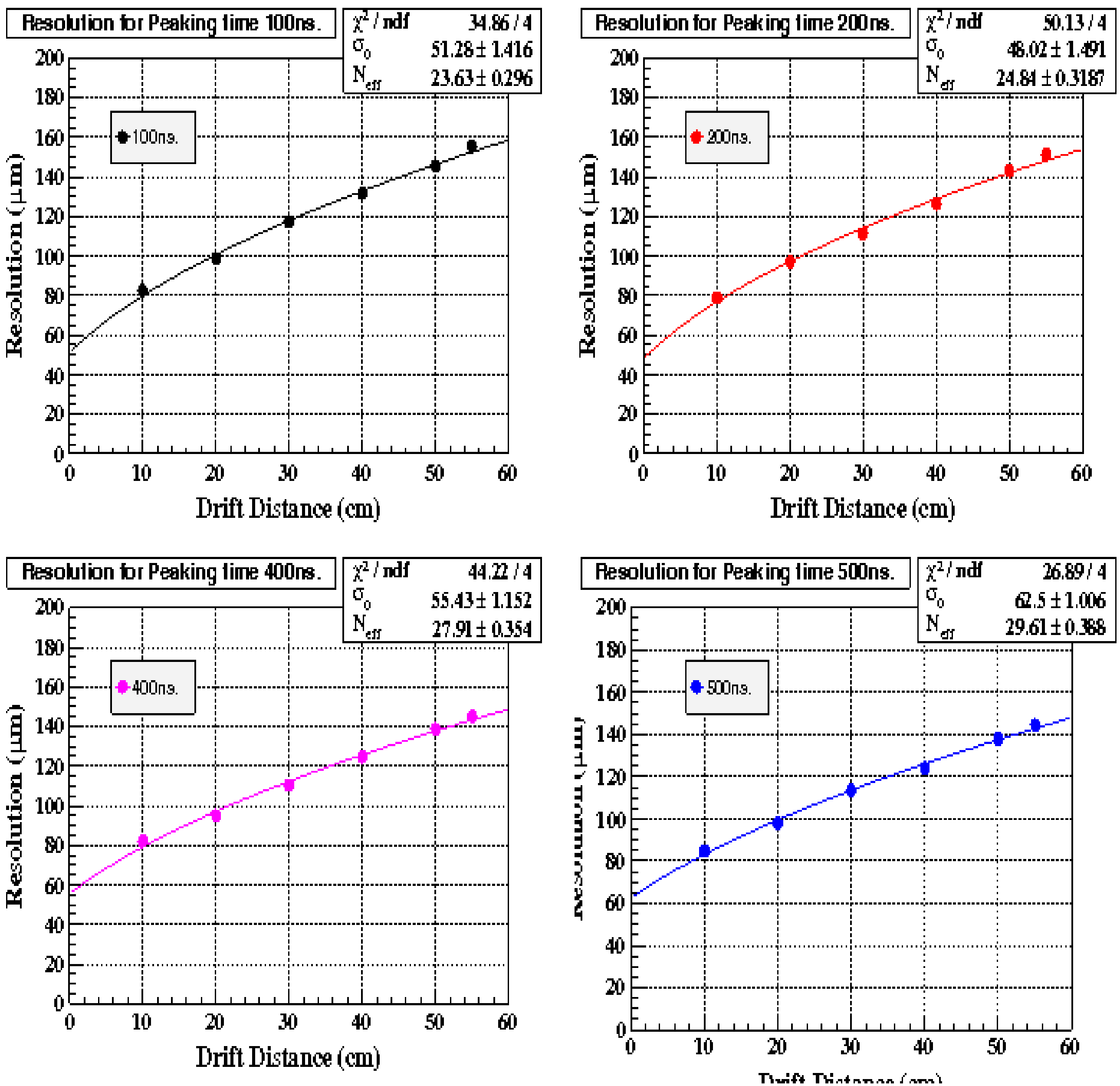
Results – Effects of Synthetic PRF



<u>Analysis Summary:</u>
- 500ns peaking time
- zero suppressed data
- Amp = Quad. Fit (both)
- PRF = Q-Ratio (red)
- PRF = Synthetic (blue)

<u>Conclusions:</u>
- Slight decrease in resolution, not statistically significant.
- Considerably easier fit
- Must do more cost/benefit analysis

Results – DESY May 2011Data



Detector Specs:

- 3 MOhm/sqr.
- 1 Telsa B-Field
- 230 V/cm E_{drift}
- Gas Ar90:$CO_2$10

Data Specs:

- 25MHz sampling
- Zero suppressed
- Quadratic fit amplitude

LONGER PEAKING TIMES LEAD TO IMPROVED RESOLUTIONS

How Can the 100ns Peaking Time Resolution be Improved?

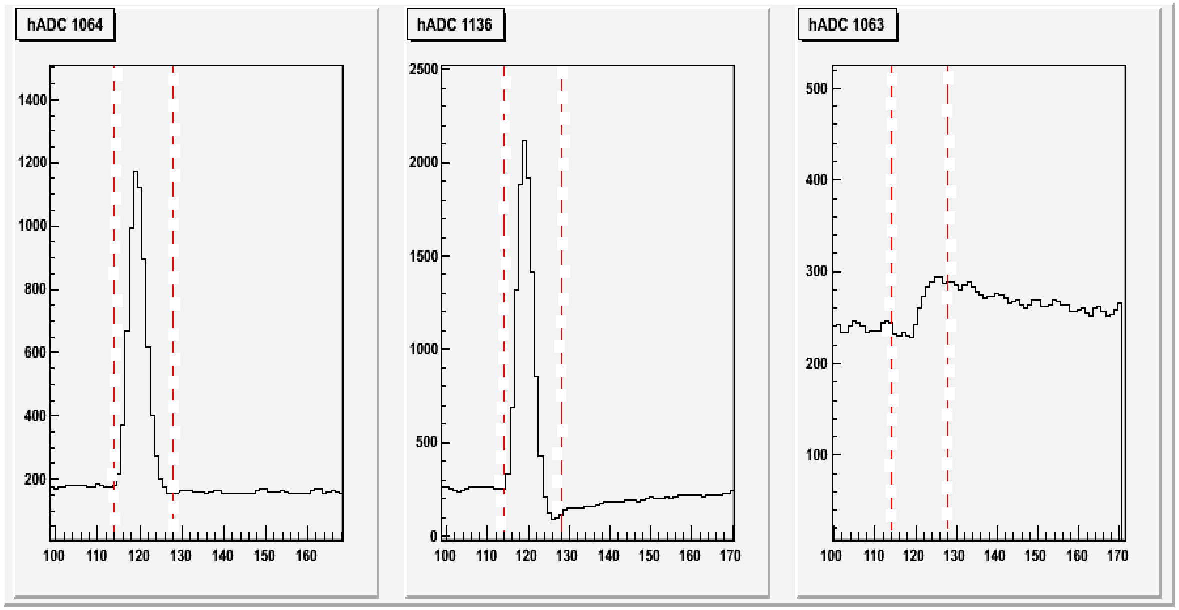
Reintegration Method:

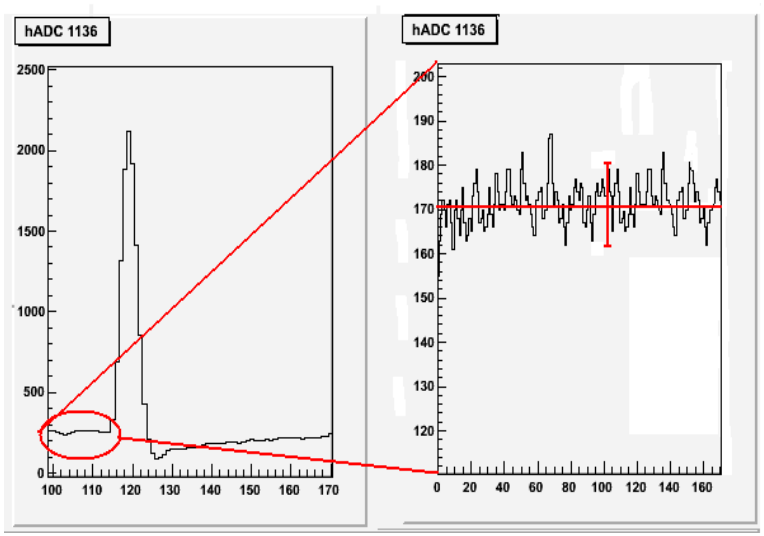
$$Amp = \sum_{i=n}^{n+w} |s_i|$$

$$n = t_{signal > 4\ RMS} - 5$$

$$w = \text{integration width}$$

$$T0 = ???$$

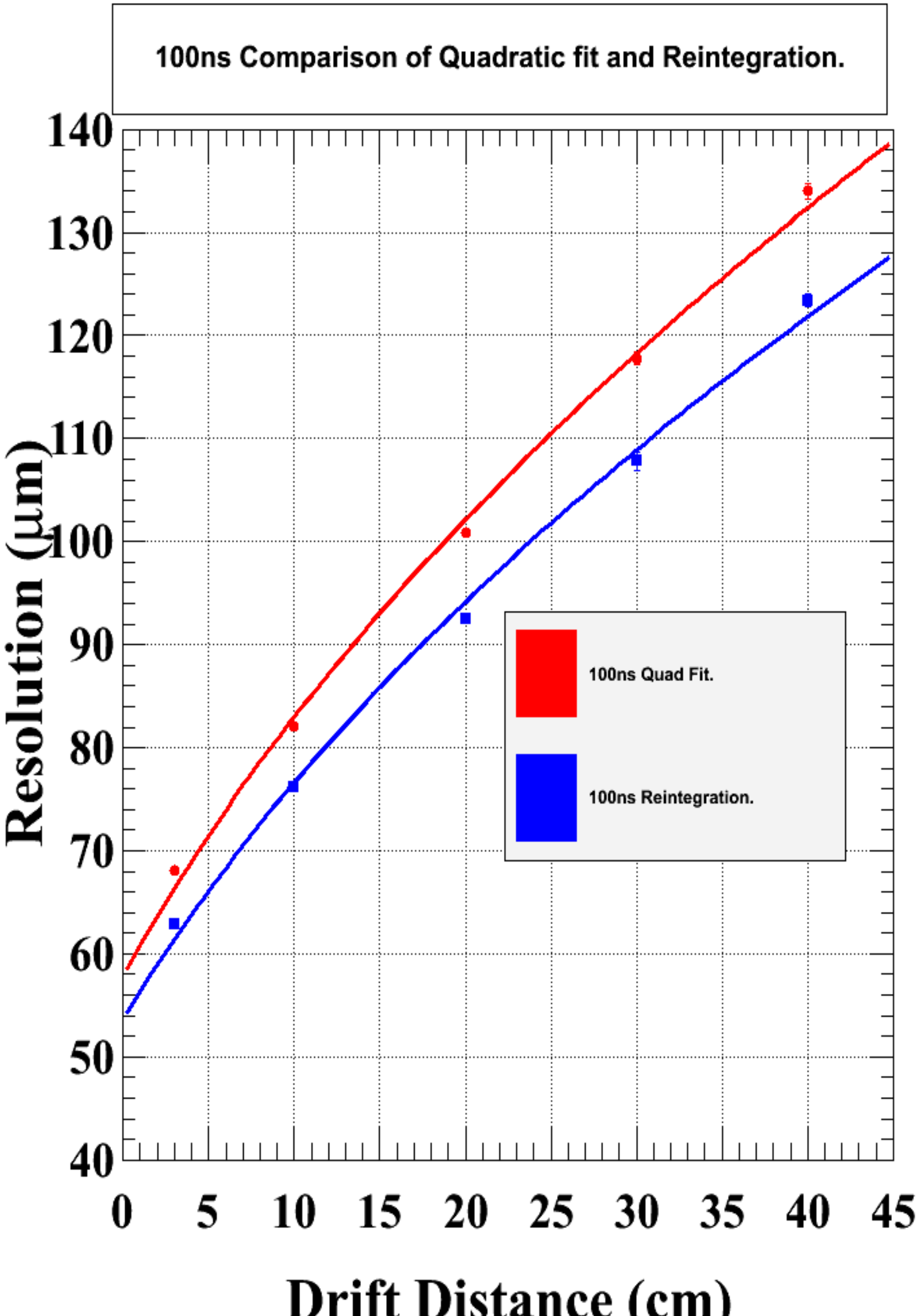




Pedestal Subtraction:

- Averaged and RMS calculated
- Average subtracted from signals
- RMS used to define beginning of integration

Results – 100ns Peaking Resolution



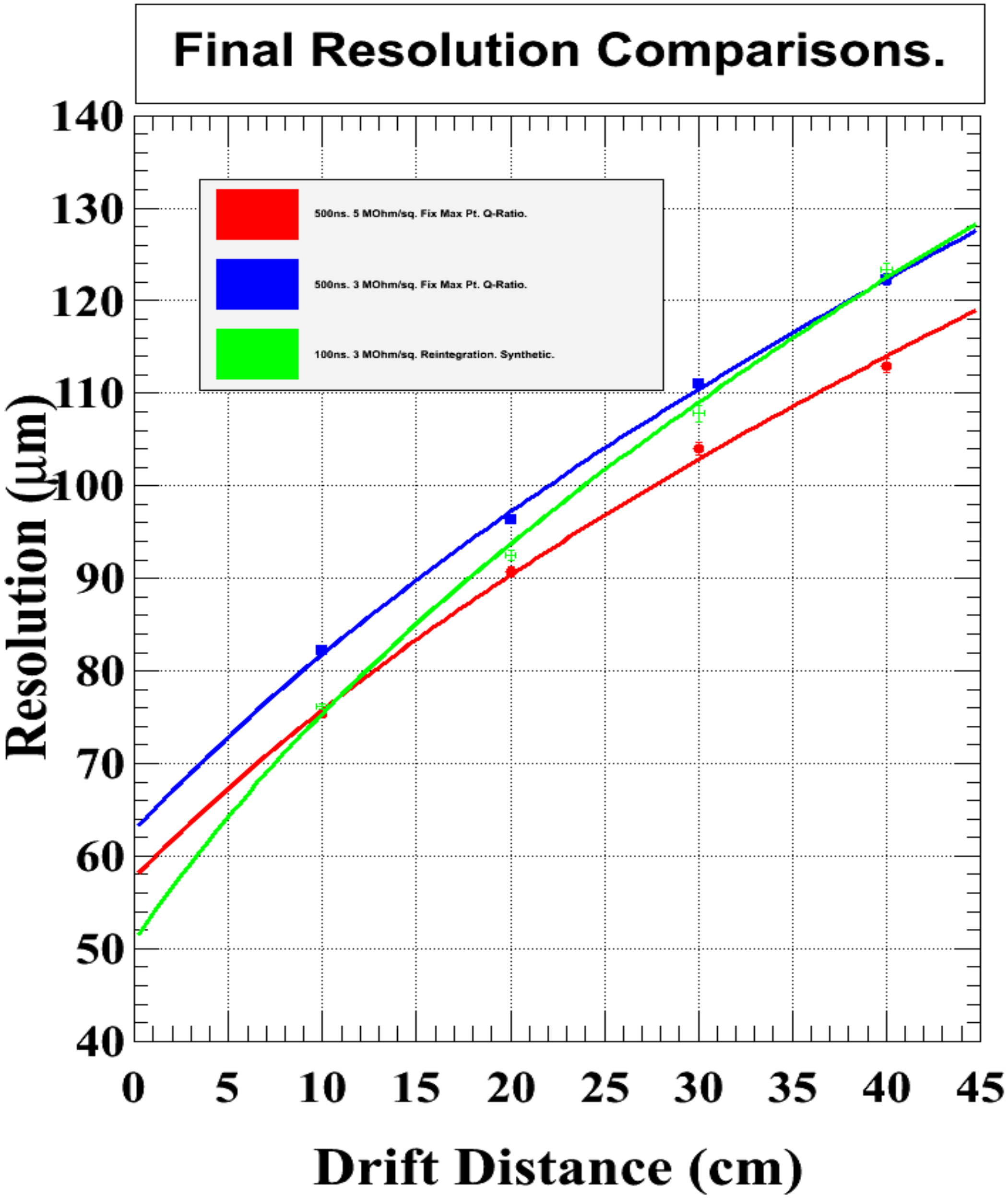
Analysis Summary:

- 100ns Peaking time
- None ZS data.
- Reintegration method optimized for z = 30cm.
- Corrupt data at longer drift distances (50 and 55 cm)

Conclusions:

Reintegration method significantly improves resolution at 100ns.

Results – 5MOhm/sq. vs. 3MOhm/sq.



<u>Analysis Summary:</u>

- Optimal resolution measurements for 2010 and 2011 data.
- Green reintegration method optimized for z = 30cm.
- Corrupt data at longer drift distances (50 and 55 cm) for 100ns none ZS

<u>Conclusions:</u>

100ns peaking time resolution comparable to 500ns!

Future Work

- Time resolution studies
- Dependence of optimal integration width, w, on drift distance
- Analysis of 200ns non zero suppressed data with reintegration method.
- Determine if synthetic PRF allows more events through
- Analyze reintegration data using Q-Ratio
- Determine nature of discontinuity in 100ns None ZS data

Lots more work to do!

Conclusion

What is the resolution of 3 MOhm/sqr LC-TPC Readout array?

Peaking Time (ns)	PRF	Amplitude	σ_0	n_{eff}
500	Q-ratio	Quad Fit	59.4 +/- 1.0	29.7 +/- 0.4
500	Synthetic	Quad Fit	63.5 +/- 1.0	29.4 +/- 0.4
100	Synthetic	Reintegration	53.5 +/- 0.9	29.6 +/- 0.5

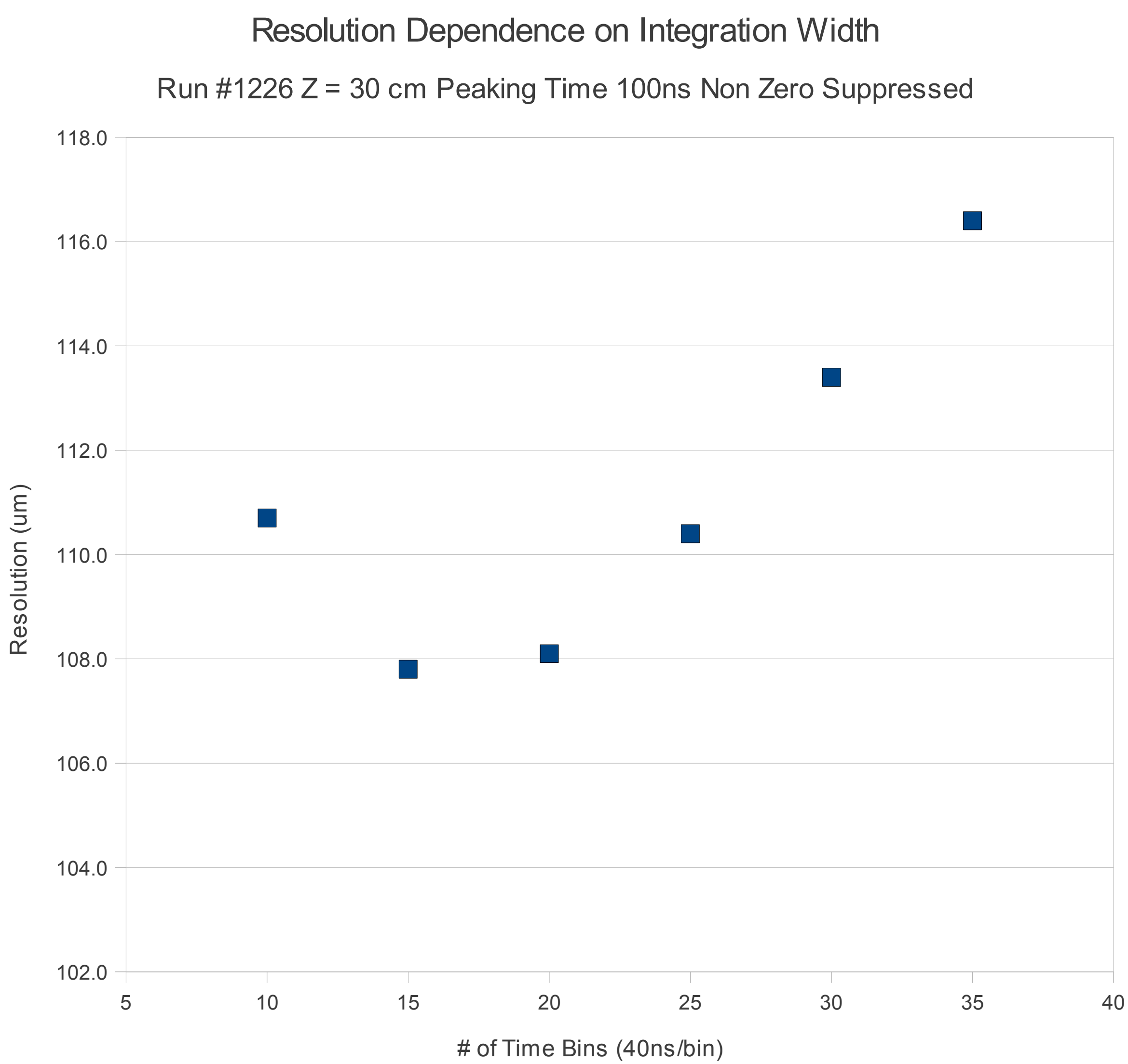
Though these are the best results obtained they are still worse then the 2010 5 Mohm/sqr resolutions.

Was it possible to Improve the 100ns Peaking time resolution?

YES! Using the reintegration method 100ns peaking time resolutions were made comparable to 500ns peaking times at both long and short drift distances.

BACK UP SLIDES

Results – Determining Optimal Integration Width



Reintegration Method:

$$Amp = \sum_{i=n}^{n+w} |s_i|$$

$n = t_{\text{signal > 4 RMS}} - 5$

w = integration width