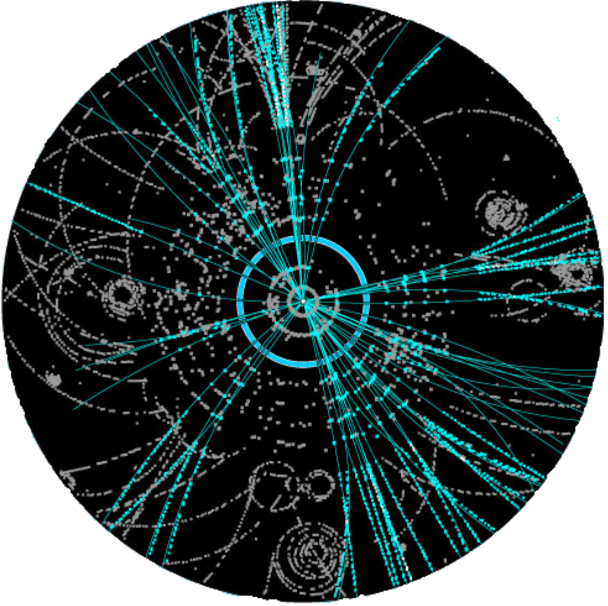
Improved analysis techniques for Charge Dispersion readout Time Projection Chambers

The 4th year work of Stephen Turnbull.

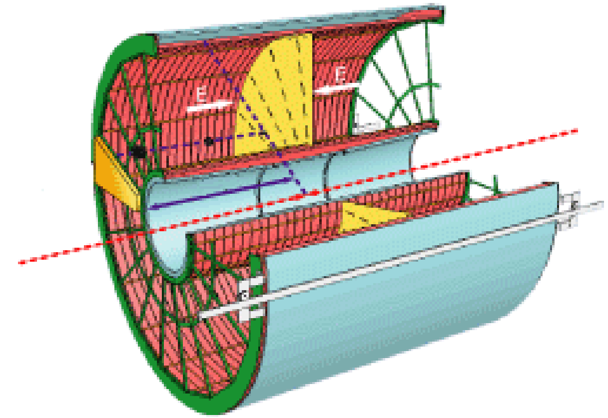
Abstract:
The pad response function (PRF) algorithm presently used to read out the newly developed resistive anode Micro Pattern Gas Detector (MPGD) readout TPCs is sensitive to the particular TPC's construction and operation parameters of the TPC and needs to fine-tuned for each new configuration. New algorithms to compute PRFs were developed. Proposed PRF algorithms were tested using simulated data. The data collected in 2006 in high field cosmic ray tests of Carleton TPC at DESY will be reanalyzed with the new PRF algorithms and results compared to previous analysis.

OverView

- Introduction:
  - TPCs, resistive films, and define Pad Response Functions (PRF’s)
  - The old PRF Function, the variable window width integration.
- The Goals:
  - What we were trying to do
- Results:
  - Comparing two finalists to original published results.
- Conclusion:



The hurdle:



The ILC TPC resolution goal < 100 µm for all tracks up to 2 meter drift

MPGDs can achieve ~ 50 µm resolution with sub-mm width pads

Too many channels

Cost

End cap mass

Heat load

Resistive anode MPGD can achieve ~ 50 µm resolution with ~ 2-3 mm wide pads

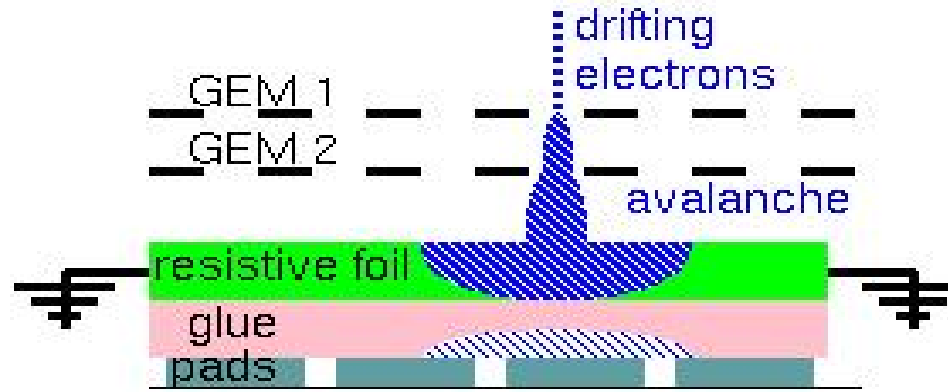
Charge dispersion in a MPGD with a resistive anode

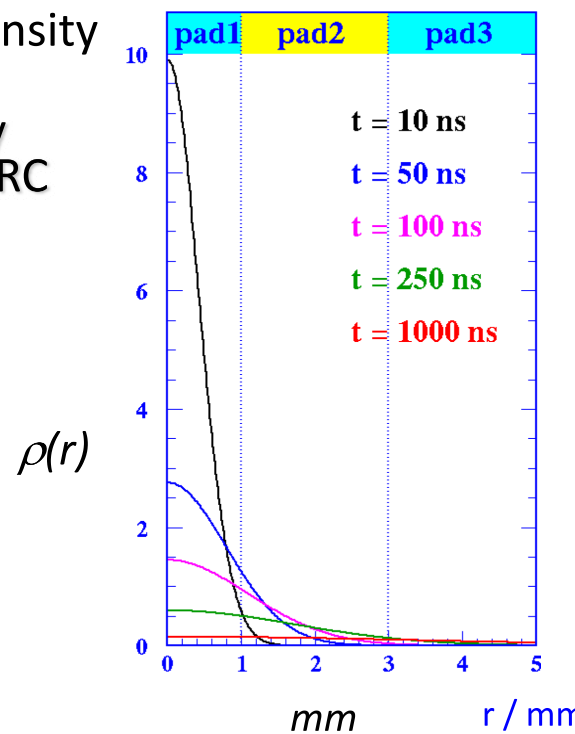
- Modified GEM anode with a high resistivity film bonded to a readout plane with an insulating spacer.
- 2-dimensional continuous RC network defined by material properties & geometry.
- Point charge at r = 0 & t = 0 disperses with time.
- Time dependent anode charge density sampled by readout pads.

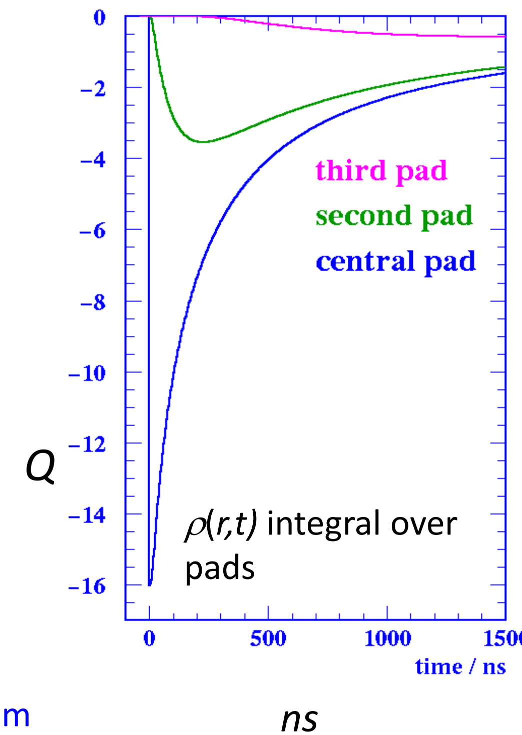
Equation for surface charge density function on the 2-dim. continuous RC network:

$$\frac{\partial \rho}{\partial t} = \frac{1}{RC}\left[\frac{\partial^2 \rho}{\partial r^2} + \frac{1}{r}\frac{\partial \rho}{\partial r}\right]$$

$$\Rightarrow \rho(r,t) = \frac{RC}{2t} e^{\frac{-r^2 RC}{4t}}$$

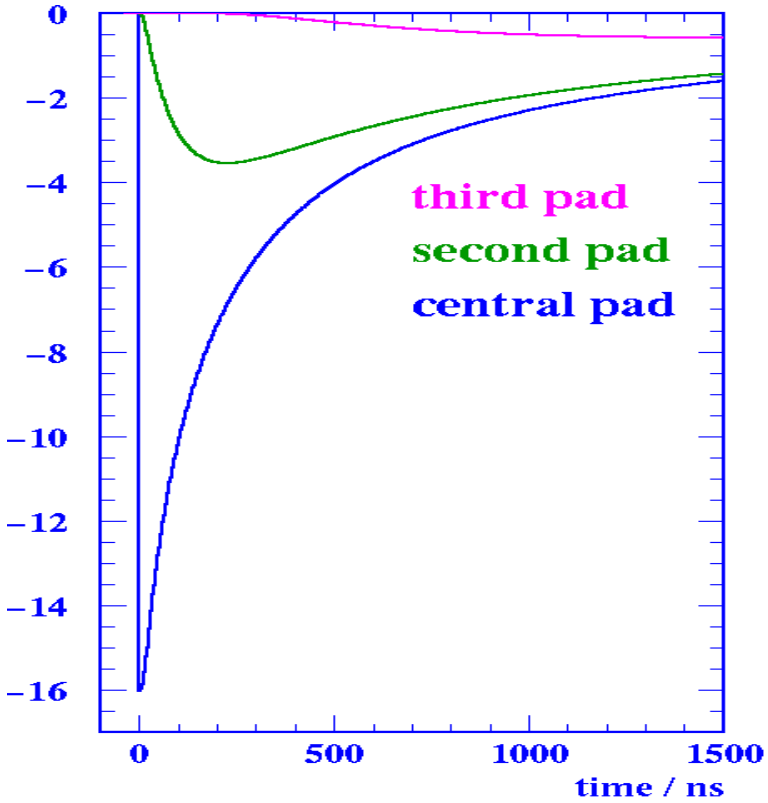


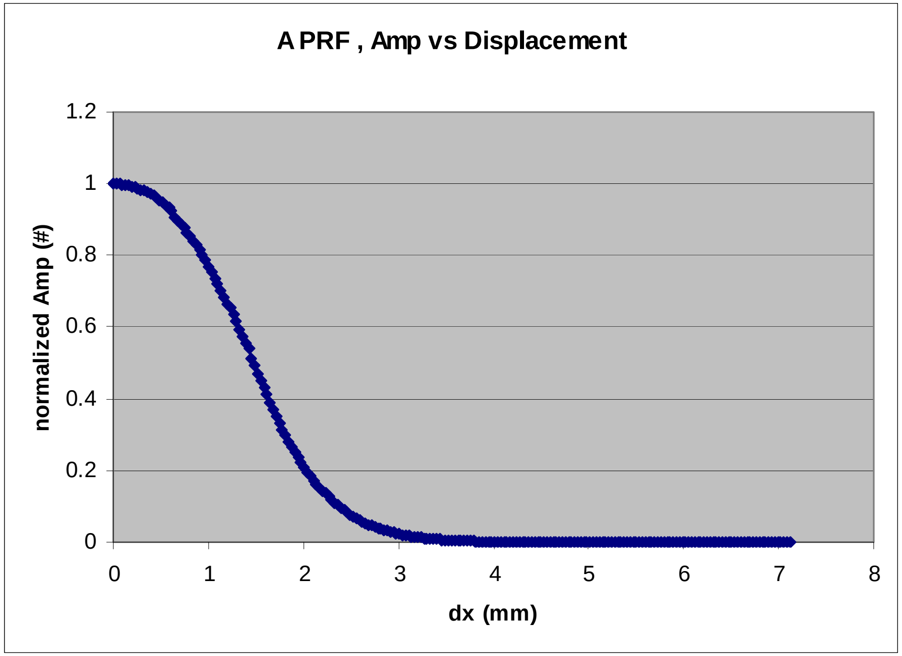




M.S.Dixit et.al., Nucl. Instrum. Methods A518 (2004) 721.

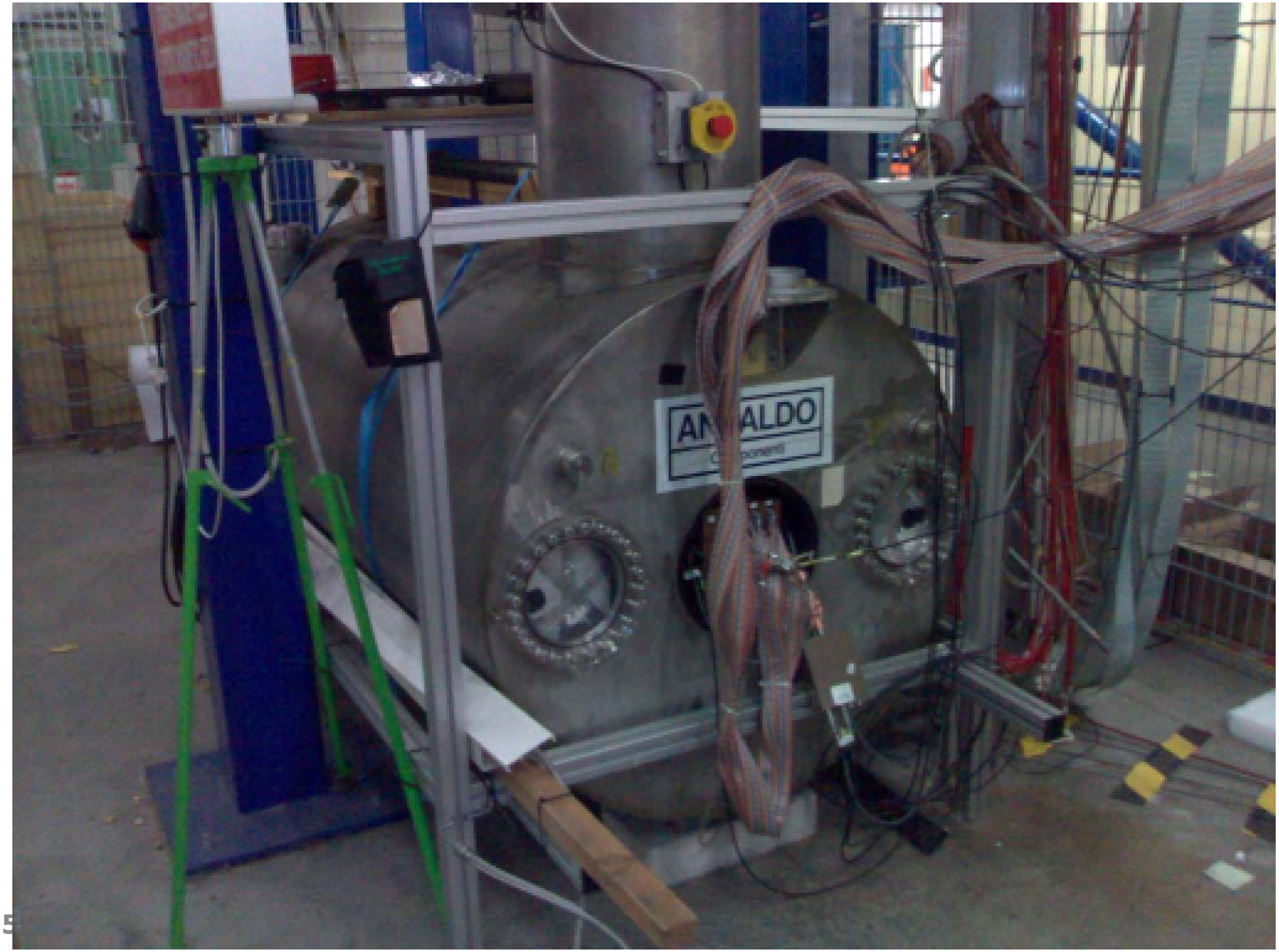
Pad Response Function (PRF)



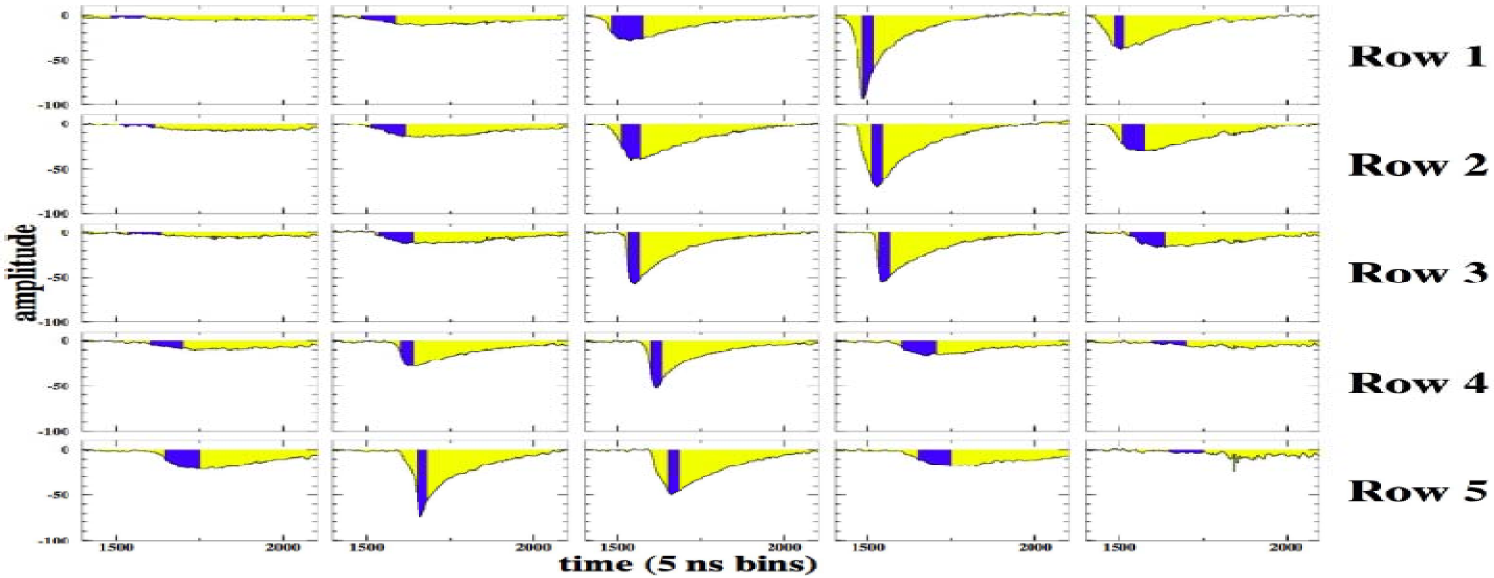


Displacing charge track position changes the amplitude seen on each pad.
PRF = Pad signal amplitude as a function of track position relative to the pad.

COSMo TPC in the DESY 5 T magnet Nov-Dec 2006)



PRFs the old way



Resistive readout can be tuned to optimize resolution & 2-track resolution
But, no standard pulse shape, highly variable rise & fall times
Amplitudes & shape depend on track position, gas diffusion & drift velocity
Many possible ways to measure track r-phi from pulse shape & amplitude
First attempt in learning how to measure resolution used a sliding windowed technique.
Integrate over windows of variable width for each pulse following a recipe

COSMo 5T Cosmic ray tests at DESY (Nov-Dec 2006)

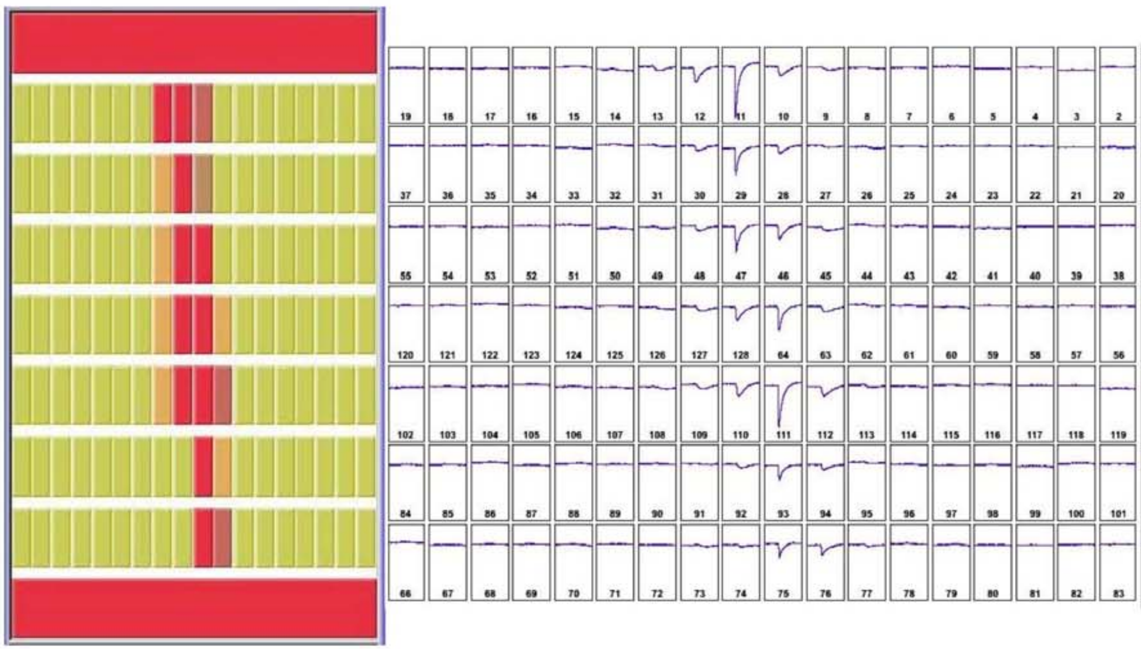


Fig. 4. Cosmic ray signals with charge dispersion observed for seven rows of 2 mm x 6 mm readout pads. At 5 Tesla, the track charge width is negligible compared to the pad width.

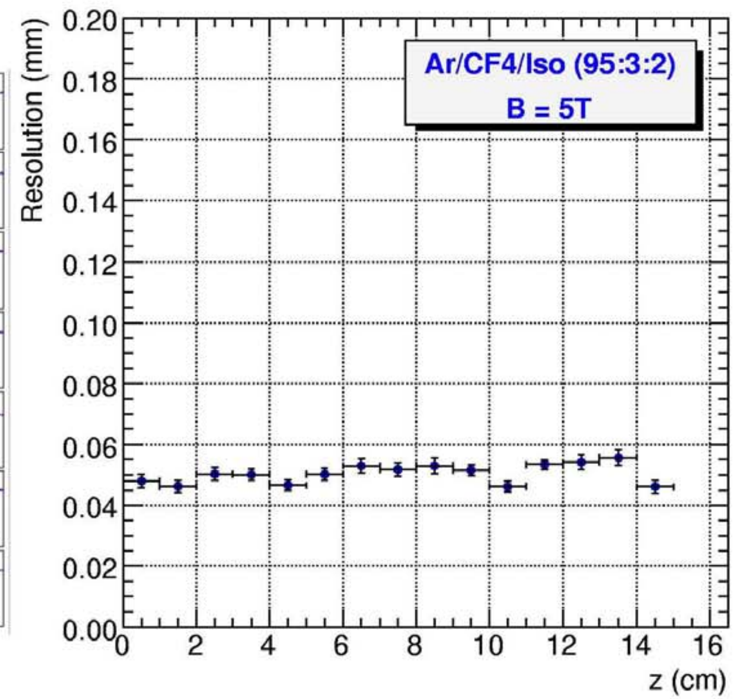


Fig. 5. With diffusion effects negligible, a flat ~ 50 μm resolution was measured over the full 15 cm TPC drift length.

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The challenge

- Stephen’s project was to develop a easy to use method that does not need fiddling.
- Develop new ideas with simulated data
- Apply and test new techniques to reanalyze real data and compare with DESY 5 T magnetic field results.

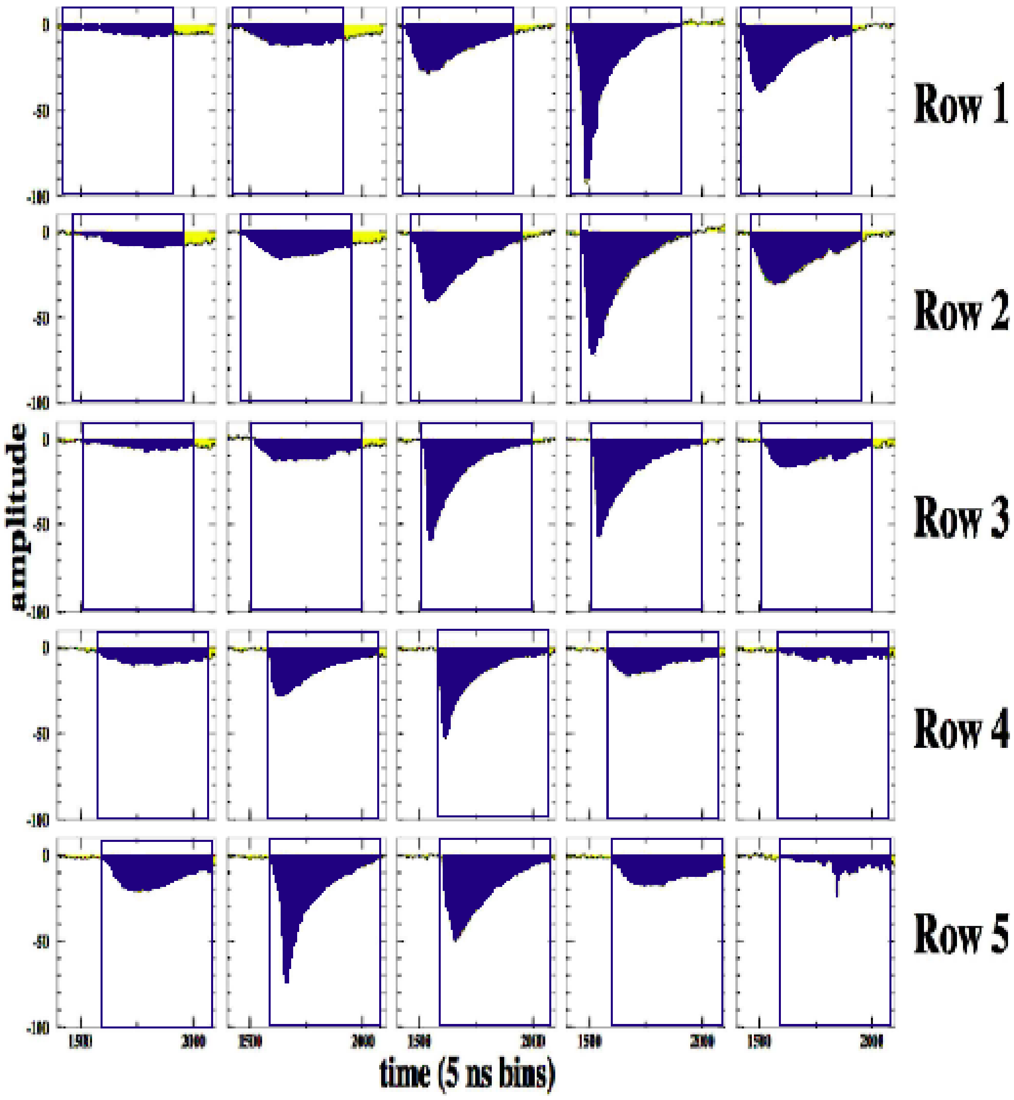
The contestants

Tested and rejected by simulation:

- Average (Ai^2)
- Average (Ai*Ti)/ Average (Ai)
- Average (Ai*Ti)/ Average (Ai)
- (Average (Ai))^2/Sum (Ai*Ti)
- Average amp. 500ns

Pasted Simulation tests, applied to real data;

- (Average amp.)^2 500ns
- Average amp. 700ns



Results: compare and contrast

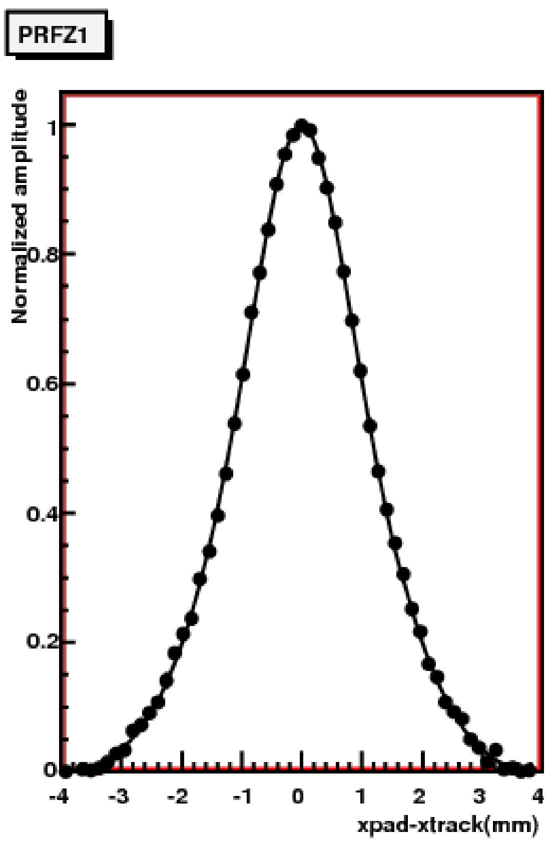
The three measures of success.

- PRF can be applied consistently and easily over a wide range of TPC operating conditions.
- Observed resolution function is Gaussian.
- New Measured resolution is as good or better then obtained previously.

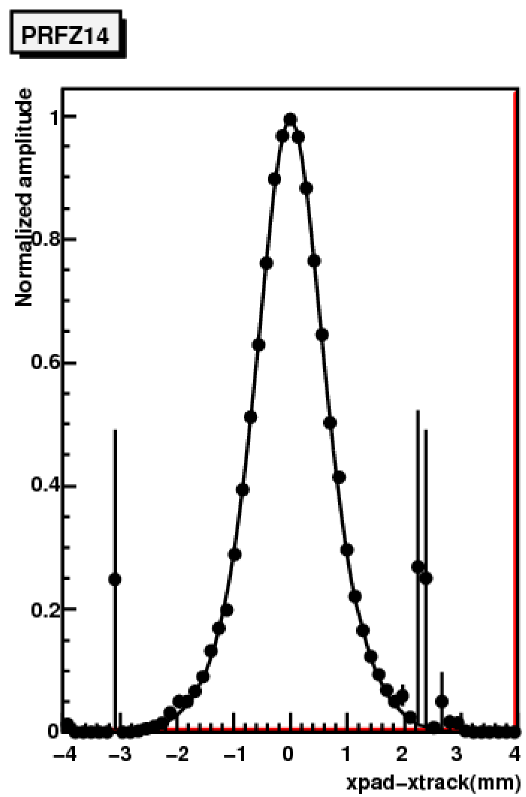
PRF comparisons

For each method one example of a PRF defined by the data.

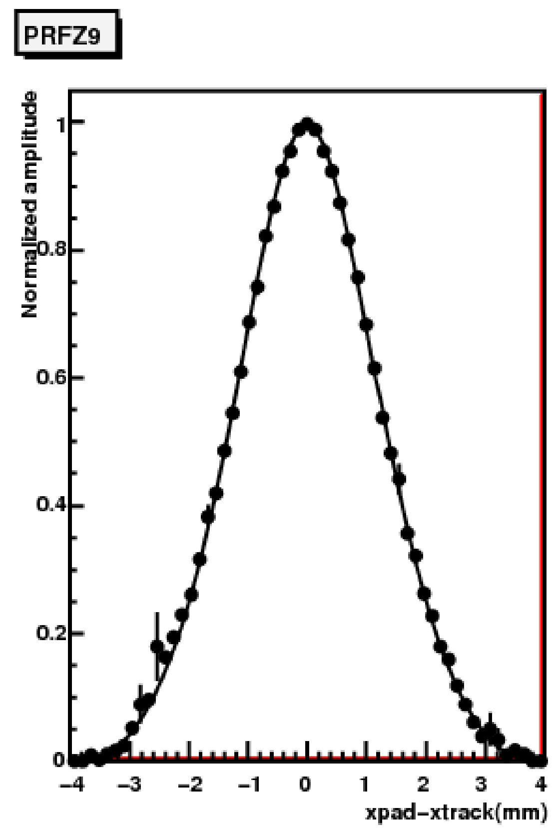
Old variable length integration method.



(500 ns integration)^2



700 ns integration

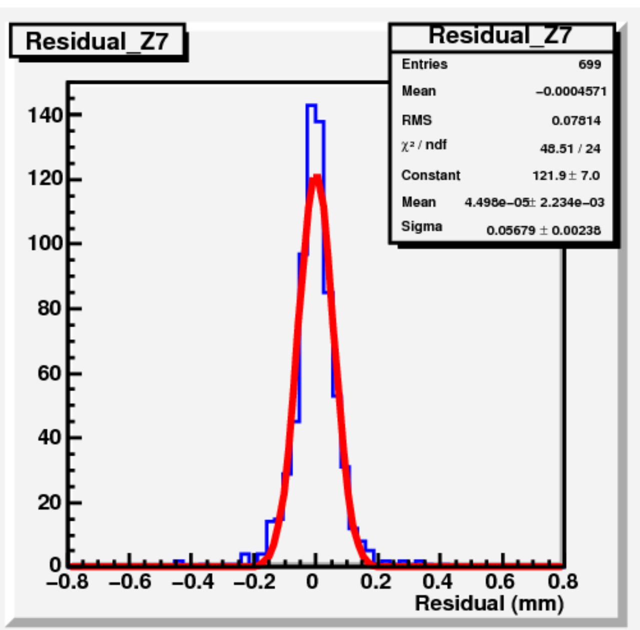


Comparison of resolution function

Distribution of measured track position on each row of pads with respect to the known track position.

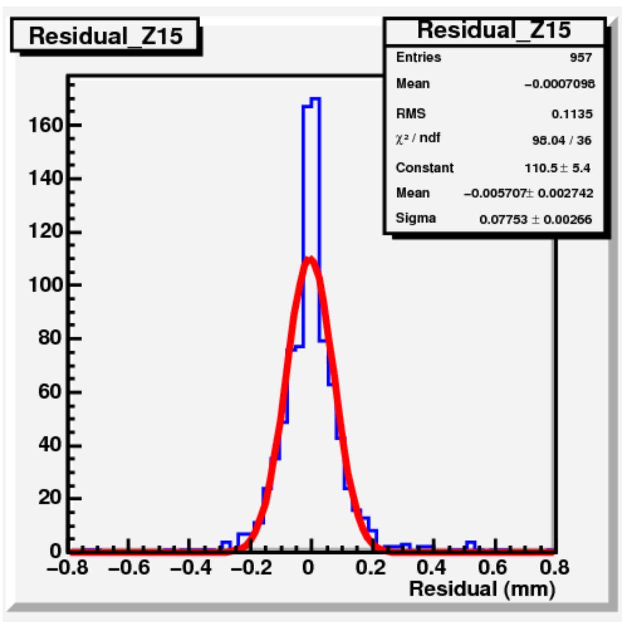
Old variable length integration method.

Events passing all cuts: 3652



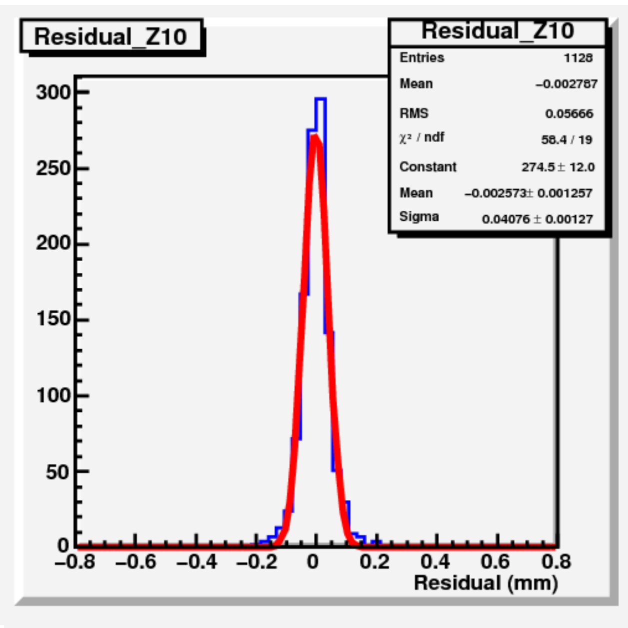
(500 ns integration)^2

Events passing all cuts: 4567



700 ns integration

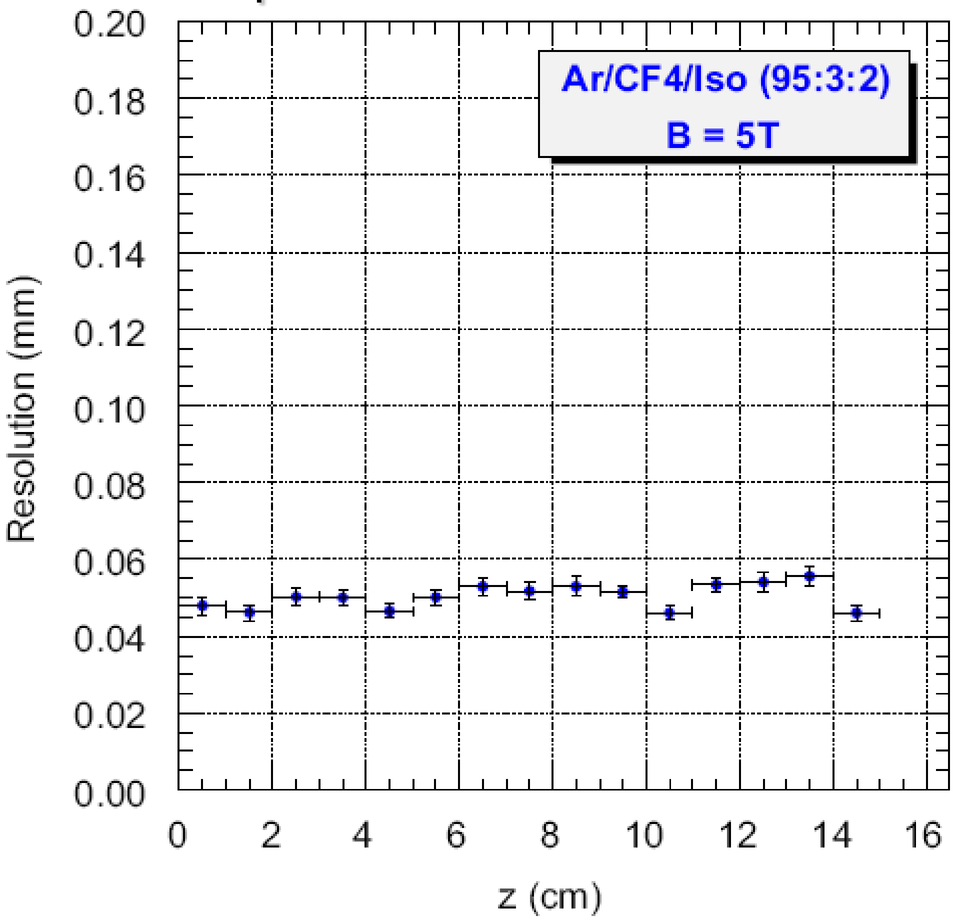
Events passing all cuts: 5663



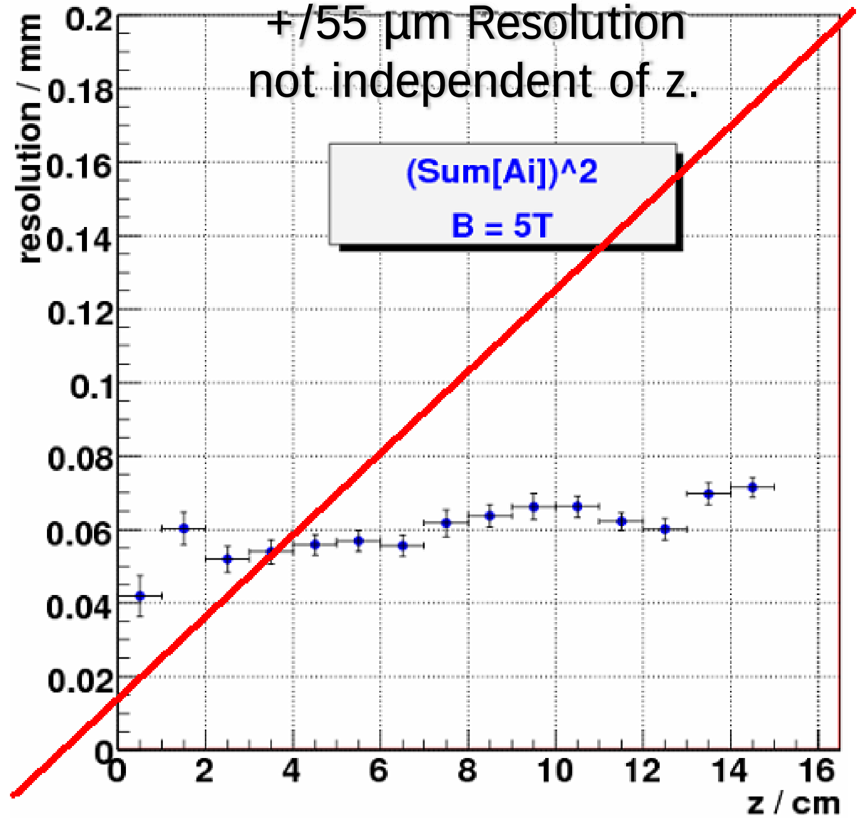
Data Set used for residual calculation has 17669 events.

Resolution comparison: Old Method Vs (Average(500ns))^2

Old Method
Flat 50 µm Resolution
Independent of z over 15 cm.



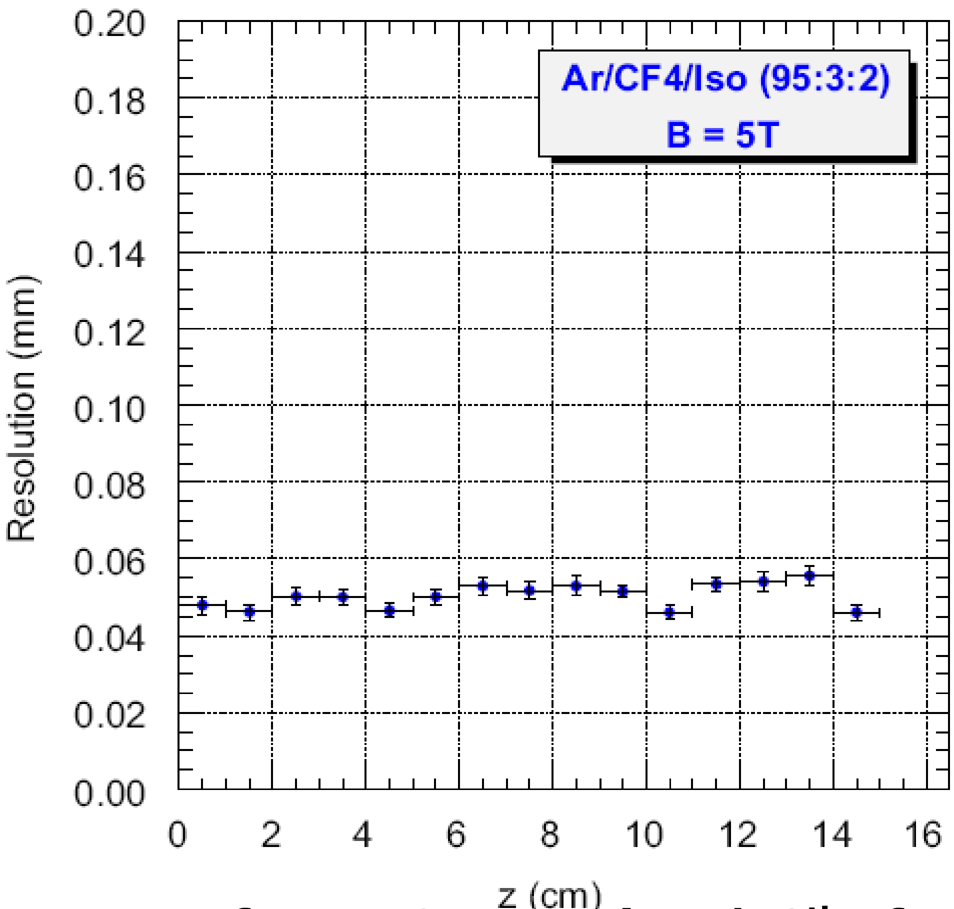
Squared sum method:
+/55 µm Resolution
not independent of z.

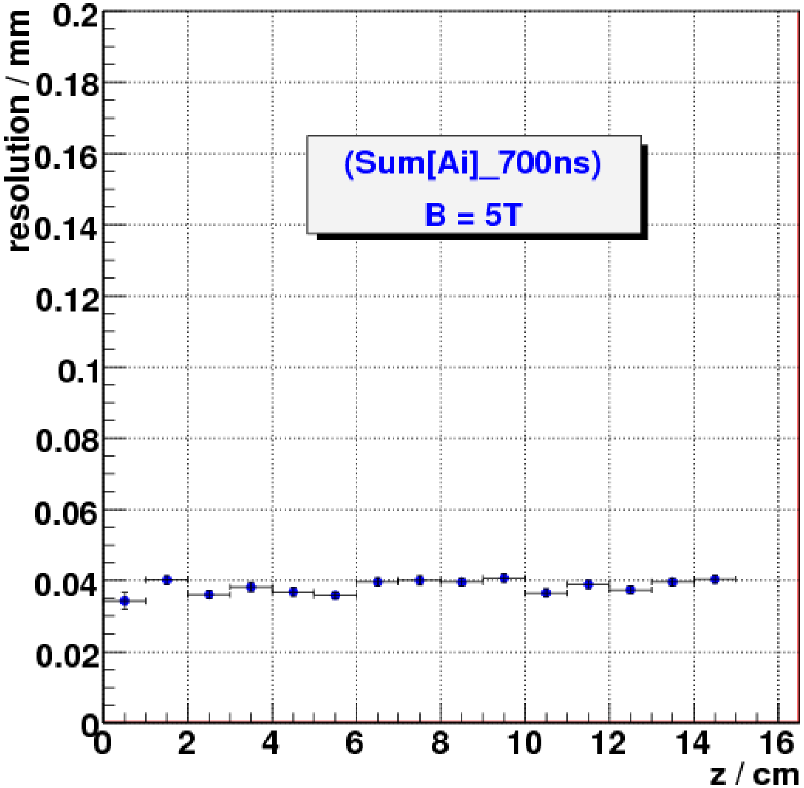


Resolution comparison: Old Method Vs average(700ns)

Old Method **3652/17669**
Flat 50 µm Resolution
Independent of z over 15 cm.

New method **5663/17669**
Flat 40 µm Resolution
Independent of z.



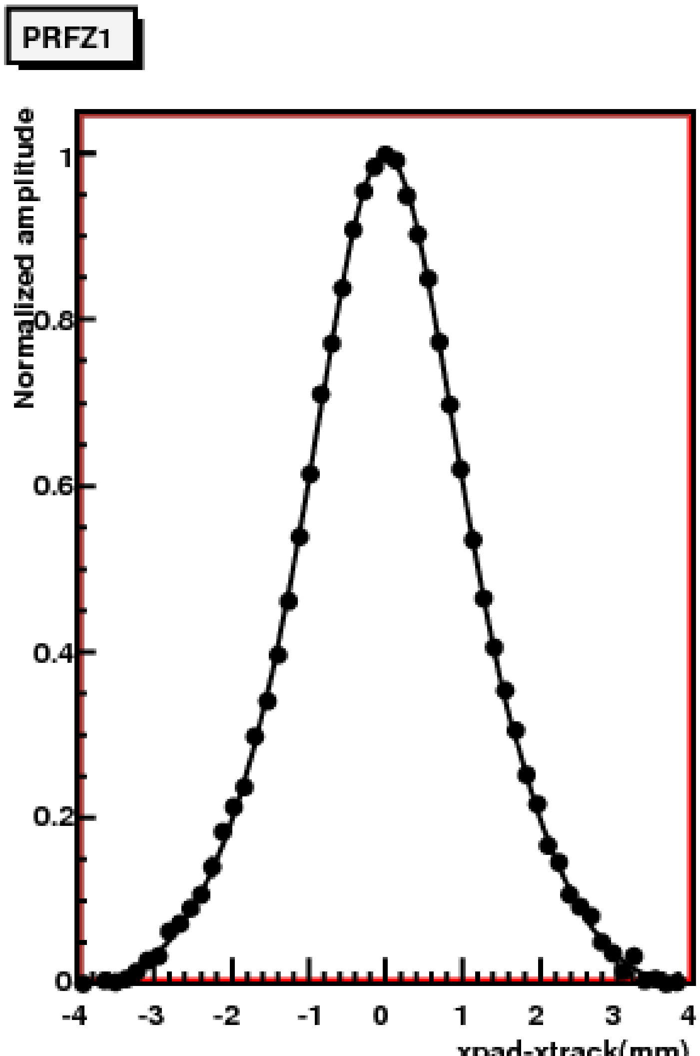


Note: for our 2mm pads, 1/40th of pad width, vs 1/50th for new method.

Conclusion

- Surprising, but overall very good, results were obtained
- Better resolution, fewer events rejected
- The narrowest PRF did not have better resolution contrary to initial expectations.
- New method now needs to be applied the rest of our DESY 2006 data (Ar/C4H10 95/5) and data taken at low gain (~2500)
- We will also be testing it with our newest data from the present run

The Benchmark: Previously results from DESY data.

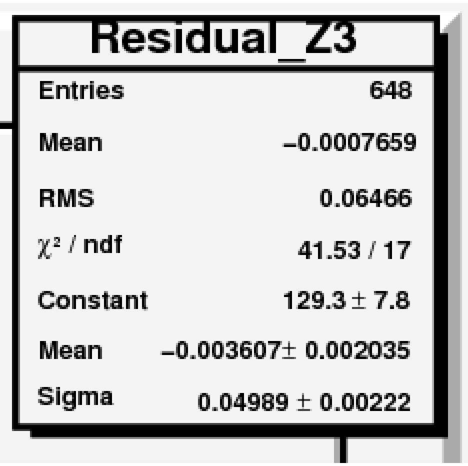


Events Used: 3652

One example, out of 15 of a PRF defined by data using the old windowing technique.
Ideally we want functions which are independent of z, and slightly lower Γ, Δ.

$\Gamma = 5.83 + 0.012*z$
$\Delta = 7.58 + 0.0049*z$
a= 0.85 Constant
b= 0 Constant

Precision: Residuals



When determining resolution one of the key measures of precision is named the residual;
The change in position of a track when it's position is recalculated after removing one pad row from the equation.