Position Resolution vs. Clock Speed in Simulations:
Quick Results and looking forward

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Q-Pix Bi-weekly Meeting

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Overview

Since we are using QPix charge detection as a replacement for light detection for determining position, our goal is to use simulations to determine the position resolution as a function of clock precision.

Finding the minimum clock speed that doesn’t affect resolution can tell us how to save on cost and power

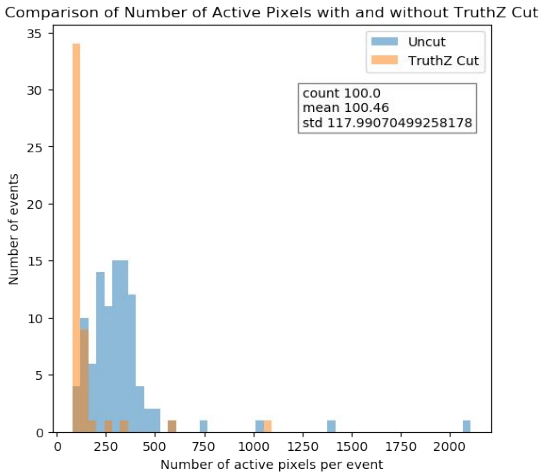
We have done two things:

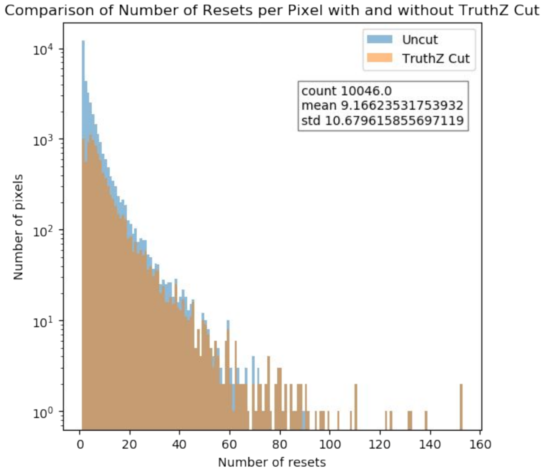
1. Long term: really understand the simulation data and get the resolution out of a cleaned data set
    a. Many more effects than we were expecting. Data needs lots of cleanup from non-MIP events.
2. Short term (Since the summer is ending): Simple results

First quick comments on the data, then preliminary results

First look at the Sample

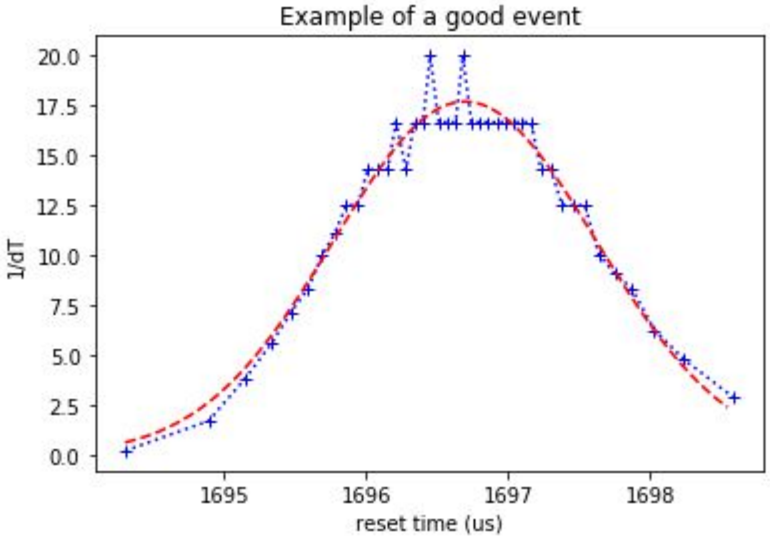
- Full sample of 100 simulated muon events
  - 32,688 active pixels
- Only want to look at pixels corresponding to an explicit drift distance (TruthZ) from the Geant4 data
  - 10,046 active pixels with TruthZ information

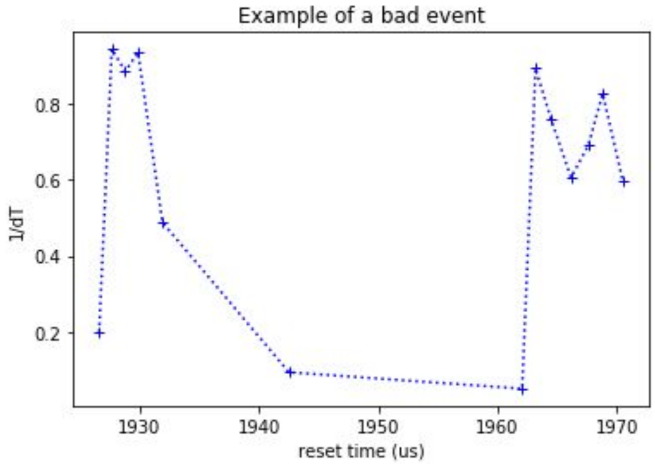




Good vs Bad Events

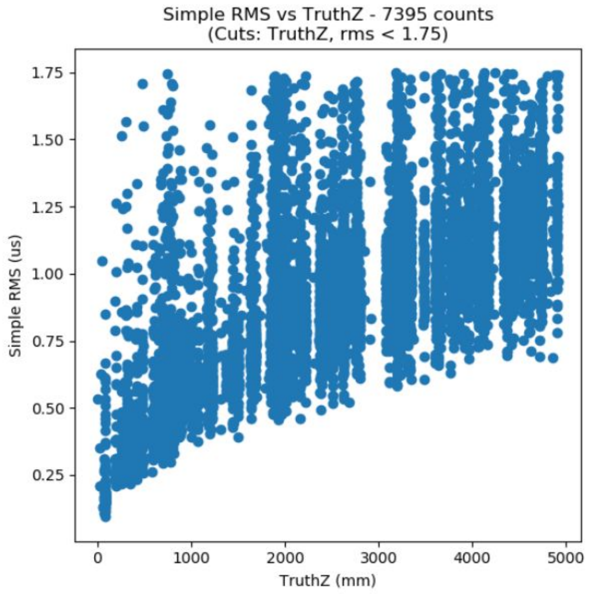
- We expect the diffused electron swarm produced from a MIP event to have a Gaussian density (current) both longitudinally and transversely in current as a function of time
  - Only care about longitudinal distribution for now
- Good (MIP-like) events will be Gaussian
- Bad events are not Gaussian or have multiple peaks
  - Still understanding their causes and developing methods to fix/remove them





Start with simple cleanup cuts

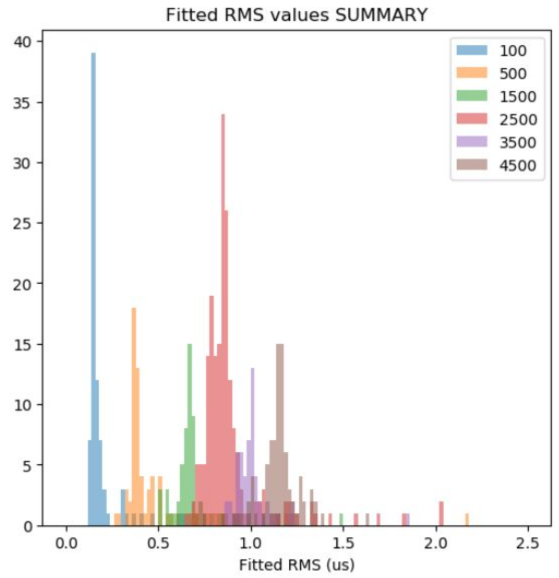
- Select a sample of MIP-like events with simple baseline cuts
  - TruthZ exists
  - nResets > 3
  - Simple RMS < 1.75
- Note that many events have larger than expected RMS because they dont look like MIPs

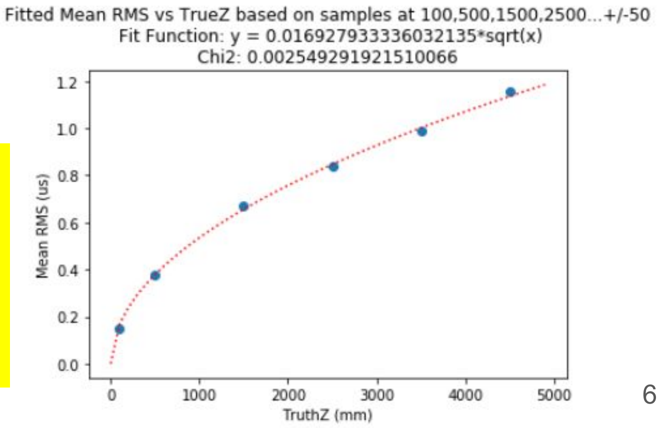


Fitted RMS for various TruthZ bins

- After cleanup, fit the pixel and then group by TruthZ to determine the RMS vs. TruthZ relationship
  - If the pixel could not be fit, it was cut
- Consider events for a number of TruthZ distance - bin size of 100
- Fit each to a Gaussian in a restricted range to ignore long tails for simplicity
- Gives the expected sqrt RMS vs Z relationship
  - Resolution as a function of TruthZ is relatively flat (~0.04 - not shown here)
  - Can use this to determine clock speed recommendation

Ballpark uncertainty in Z at 2500 mm:
- We see an RMS of our measurement at about 0.04 on a mean of about 0.8. Call this about 5% measurement on RMS. Since Z prediction goes as RMS^2, we get about a 10% prediction of Z which is about 250 mm

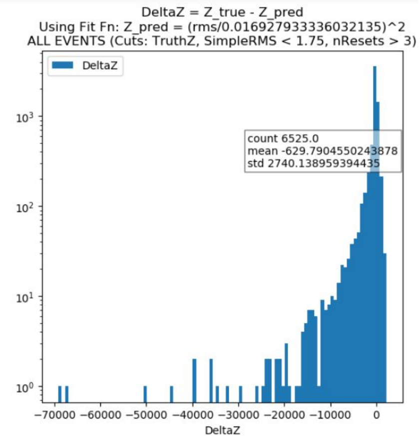




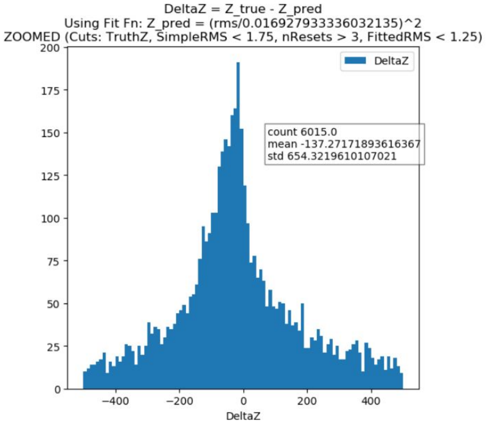
Long run strategy:

- *How well do we measure the Z value using the simple event selection methods?*
  - Determined measured_Z from fitted RMS of the pixel
  - Right: DeltaZ = true_Z - measured_Z
- Dominated by long tails of mis-measured events. Will take more study
- RMS in the peak is about ~150mm
  - Can be compared to 250mm (expected to change as a function of TruthZ)
  - 150mm isn't a fair estimate since we are summing Gaussians with different resolutions

Full range of events

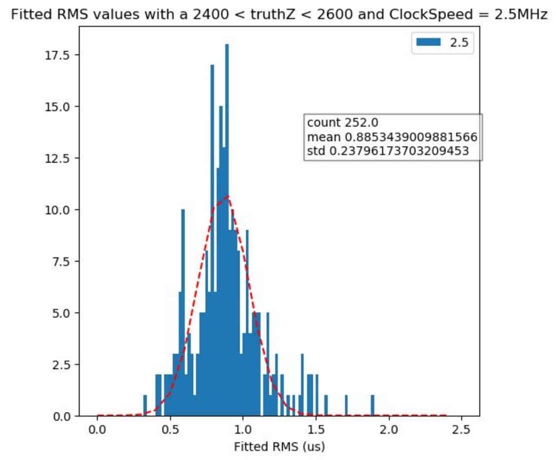


Zoomed to [-500,500]

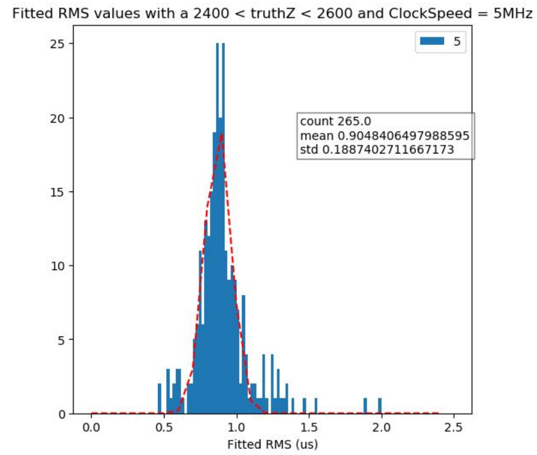


Simple method for determining resolution as a function of clock speed: Pick a single point in Z

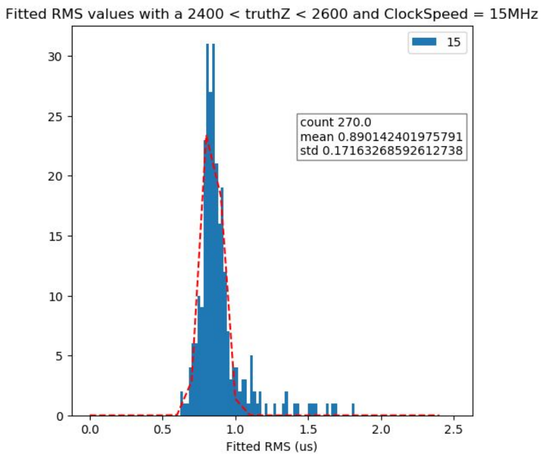
Expand range from 2400 < TruthZ < 2600 to get higher statistics, and look at distribution for different clock speeds. Resolution gets worse for slower clock speeds.




```
a = 10.848538144290 51 ---- unc: 0.883593196008633
mean = 0.866163916032286 ---- unc: 0.016267086647620 82
var = 0.029138870516594816 ---- unc: 0.005715736371260217
[21, 0.87, 0.28891739354978613]
<class 'function'> <class 'list'> <class 'list'> <class 'list'>
```



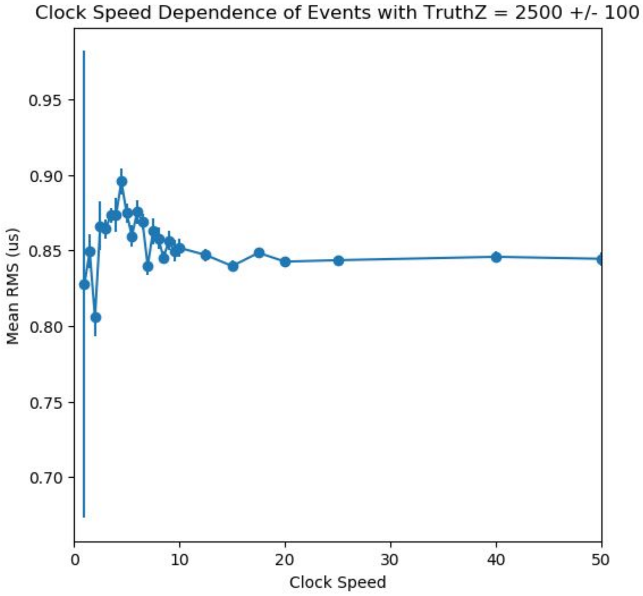

```
a = 19.687001389904722 ---- unc: 1.1566035734286602
mean = 0.8745658583021488 ---- unc: 0.006099599953414 4444
var = 0.008088987222698147 ---- unc: 0.0011045047107235602
[23, 0.87, 0.23446877358241 25]
<class 'function'> <class 'list'> <class 'list'> <class 'list'>
```

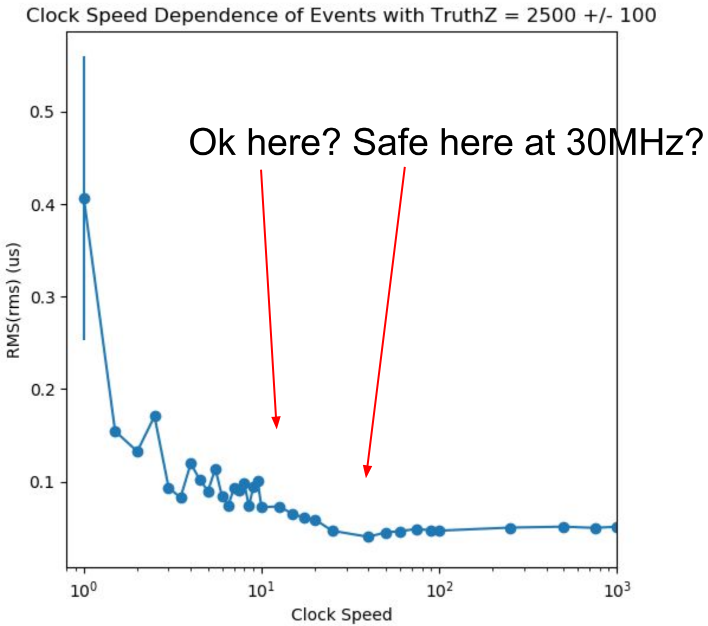



```
a = 28.125635646852785 ---- unc: 1.2973097036523538
mean = 0.8396019868769987 ---- unc: 0.0034744302958493404
var = 0.004256006491470612 ---- unc: 0.0004533671008773532
[32, 0.87, 0.18621015942099448]
<class 'function'> <class 'list'> <class 'list'> <class 'list'>
```

Results

Best fit measured_Z stays about the same (as expected), and resolution (width of the RMS distribution) gets worse for slower clock speeds. More statistics would smooth this out.





Conclusions? Next steps

- Looks like we can get an expected resolution of about ~200mm but that it should be Z dependent
- A 30MHz clock speed appears safe. Getting a more robust number will take more work
- Many events still don't have the correct Z measurement due to non-Gaussian charge collection. Cleaning up the sample is our next step