Measurement of delta rays in ATLAS silicon

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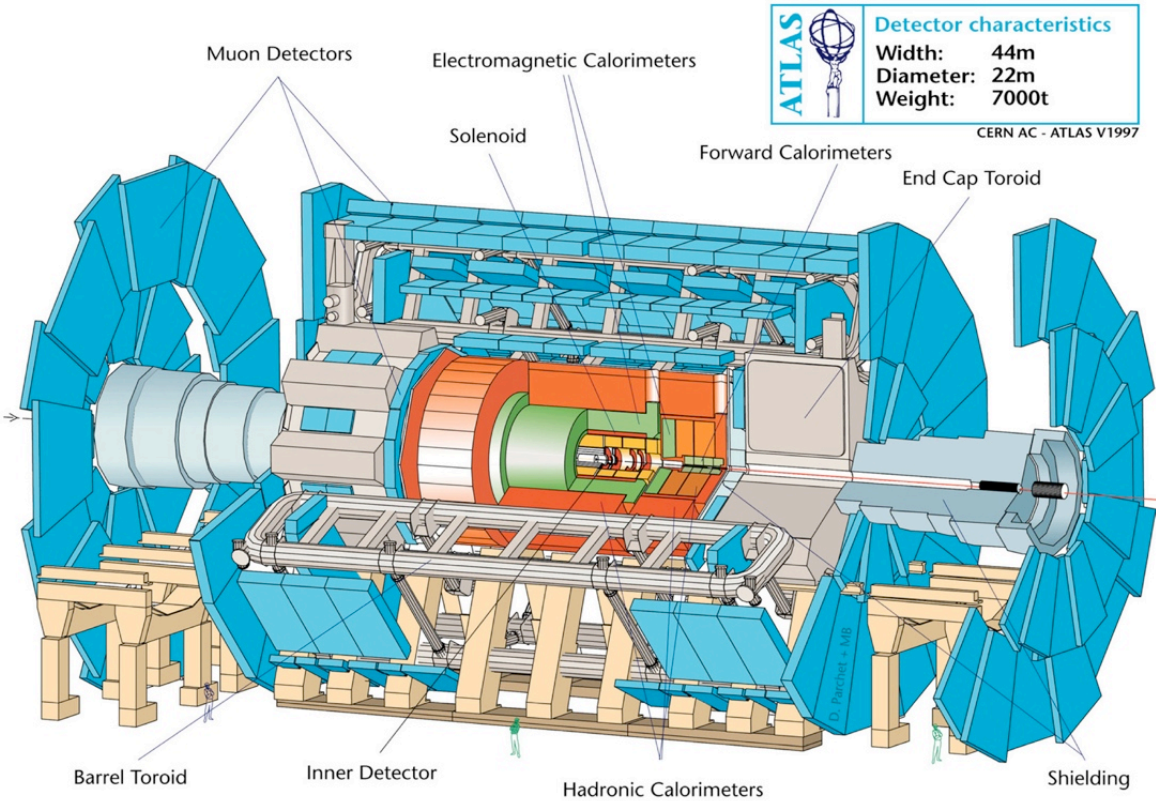
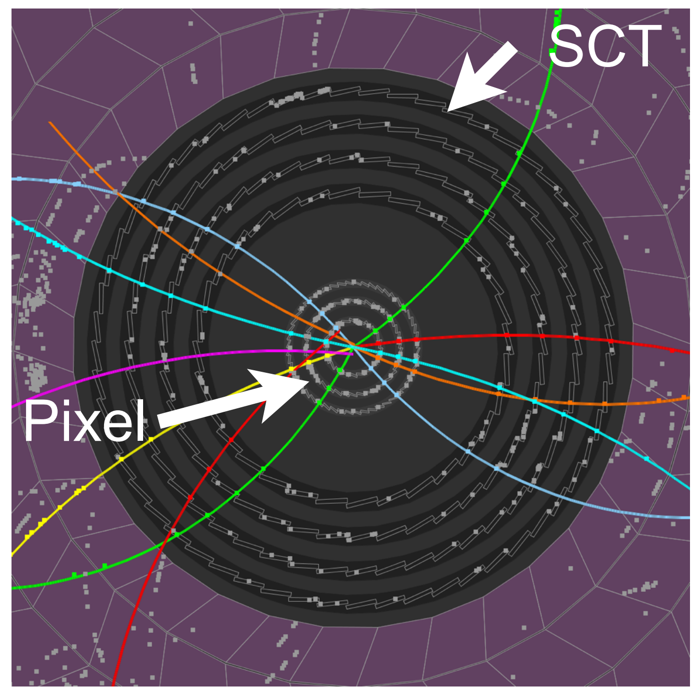
ATLAS and the Inner Detector

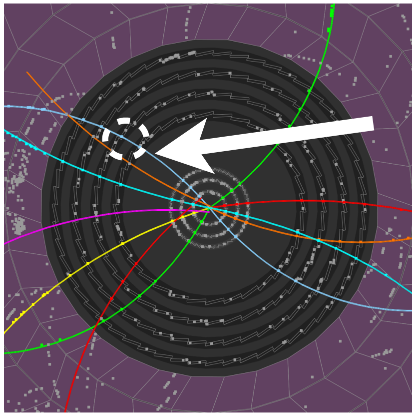


- general purpose detector made up of four systems:
  - Inner Detector
  - Electromagnetic Calorimeter
  - Hadronic Calorimeter
  - Muon Chamber



- Inner Detector detects charged particles
- first two parts consist of seven concentric cylinders made of silicon pixels or strips

Expected cluster width (W_e)



zoom in on one layer

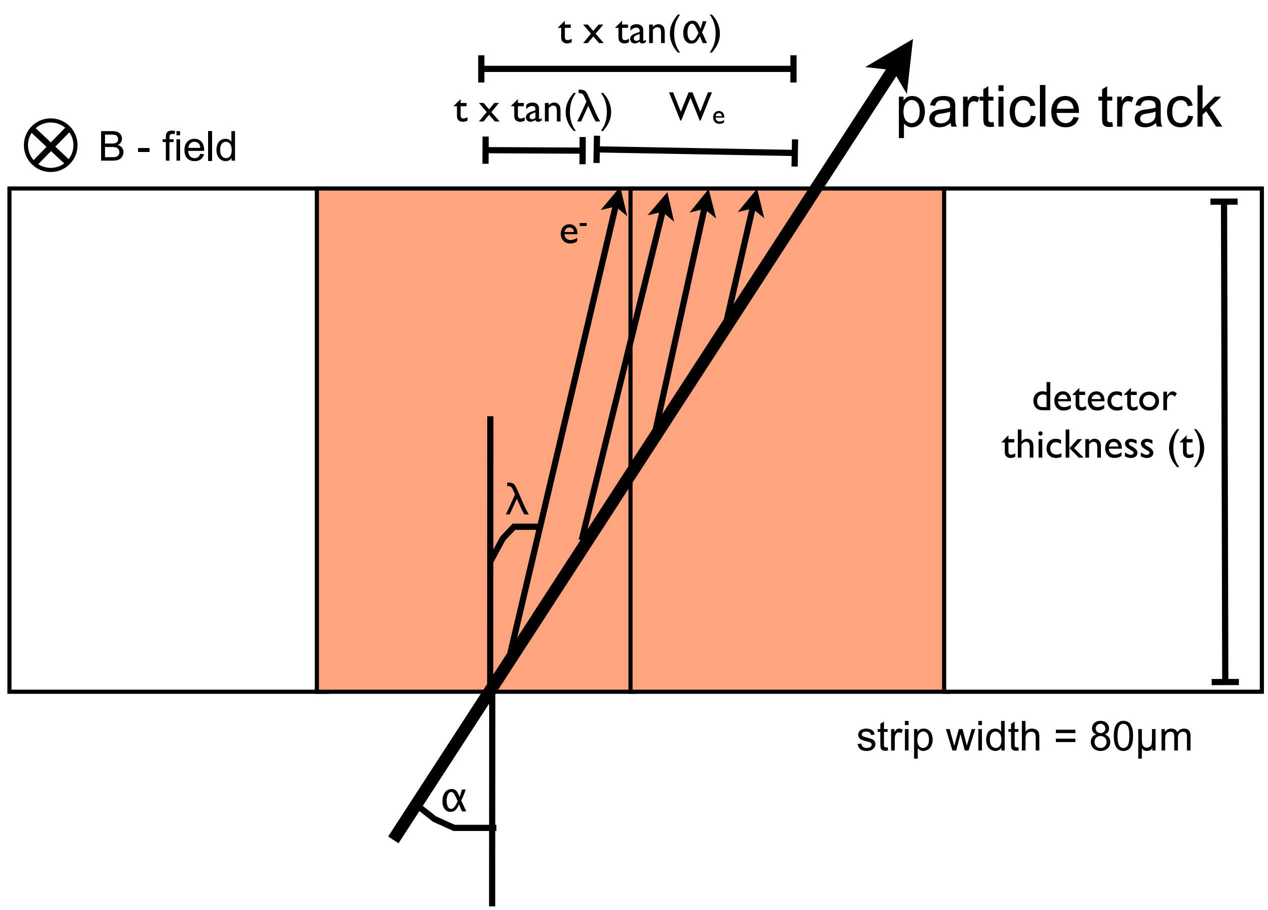
- high energy particles traveling through the detector ionize electrons/holes that drift to the surface

$$W_e = t[\tan\alpha - \tan\lambda]$$

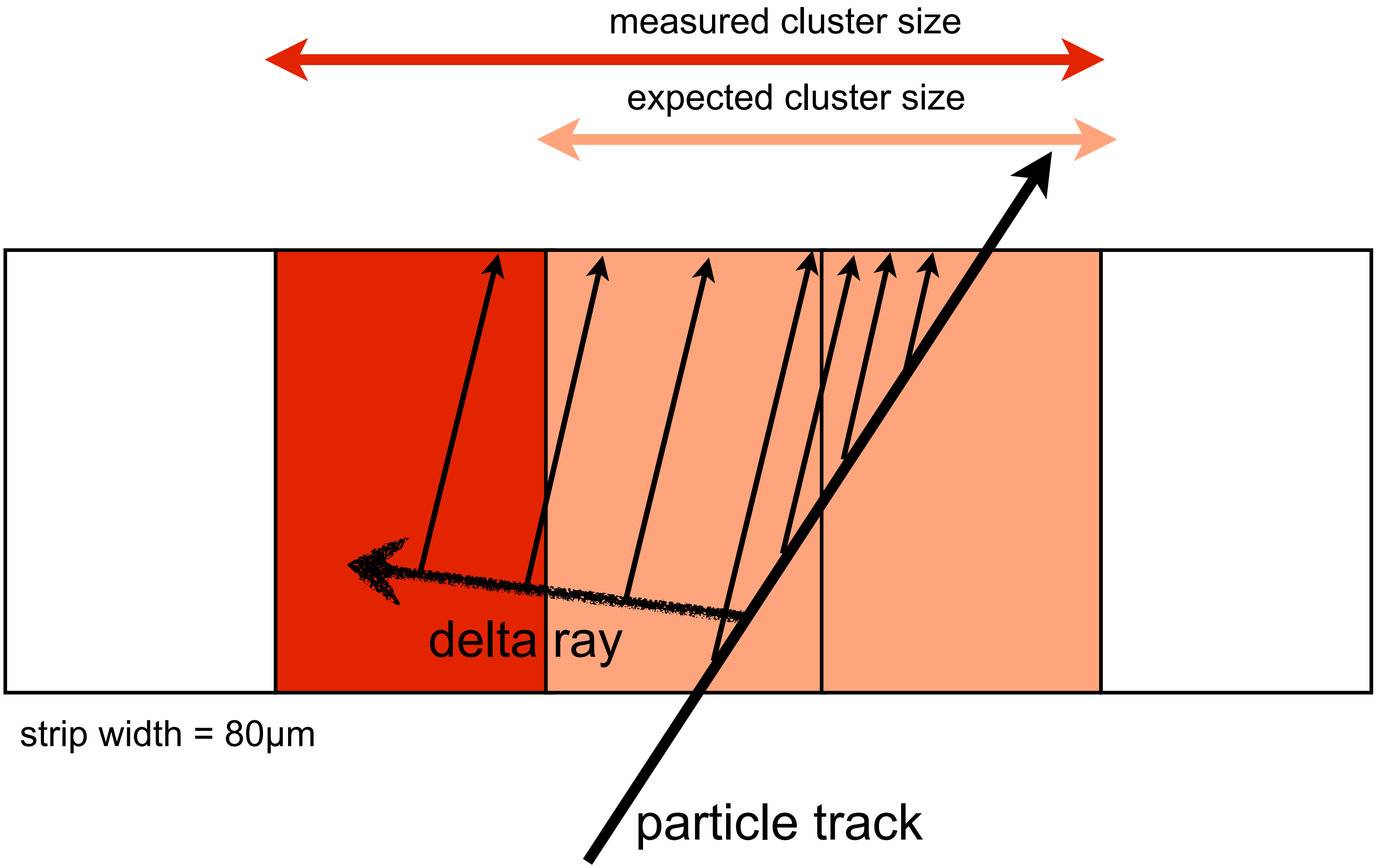
- W_e is a geometrical quantity computed from the *reconstructed* track
- calculated without using the observed width W_o (quantized in units of strip width)

α = incidence angle

λ = Lorentz drift

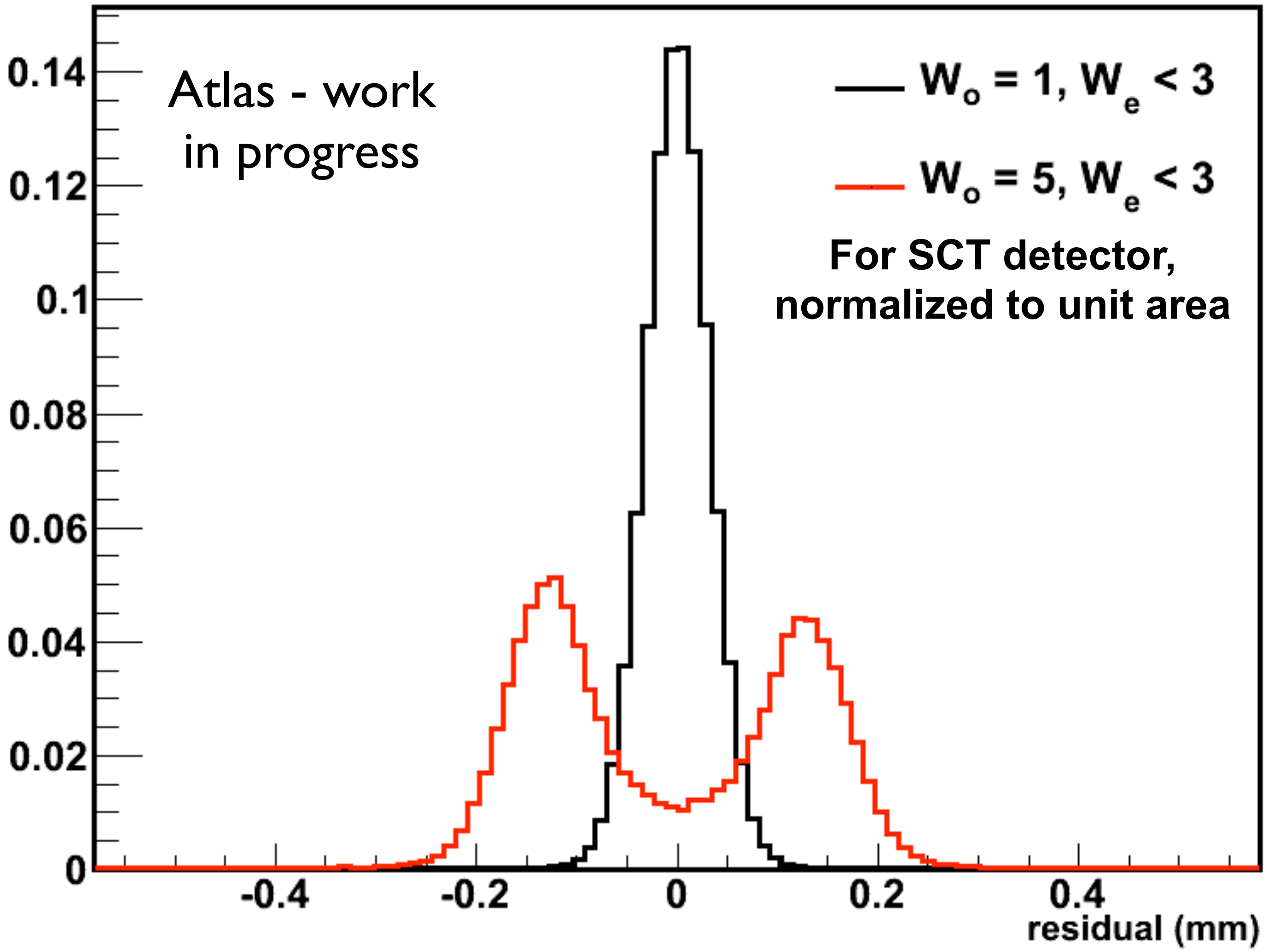


Delta rays can artificially enlarge clusters

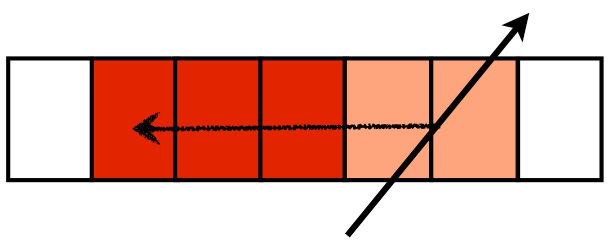


delta rays have energy of 10 - 500 keV and can ionize further electrons

Delta rays introduce a systematic shift in the residual distribution

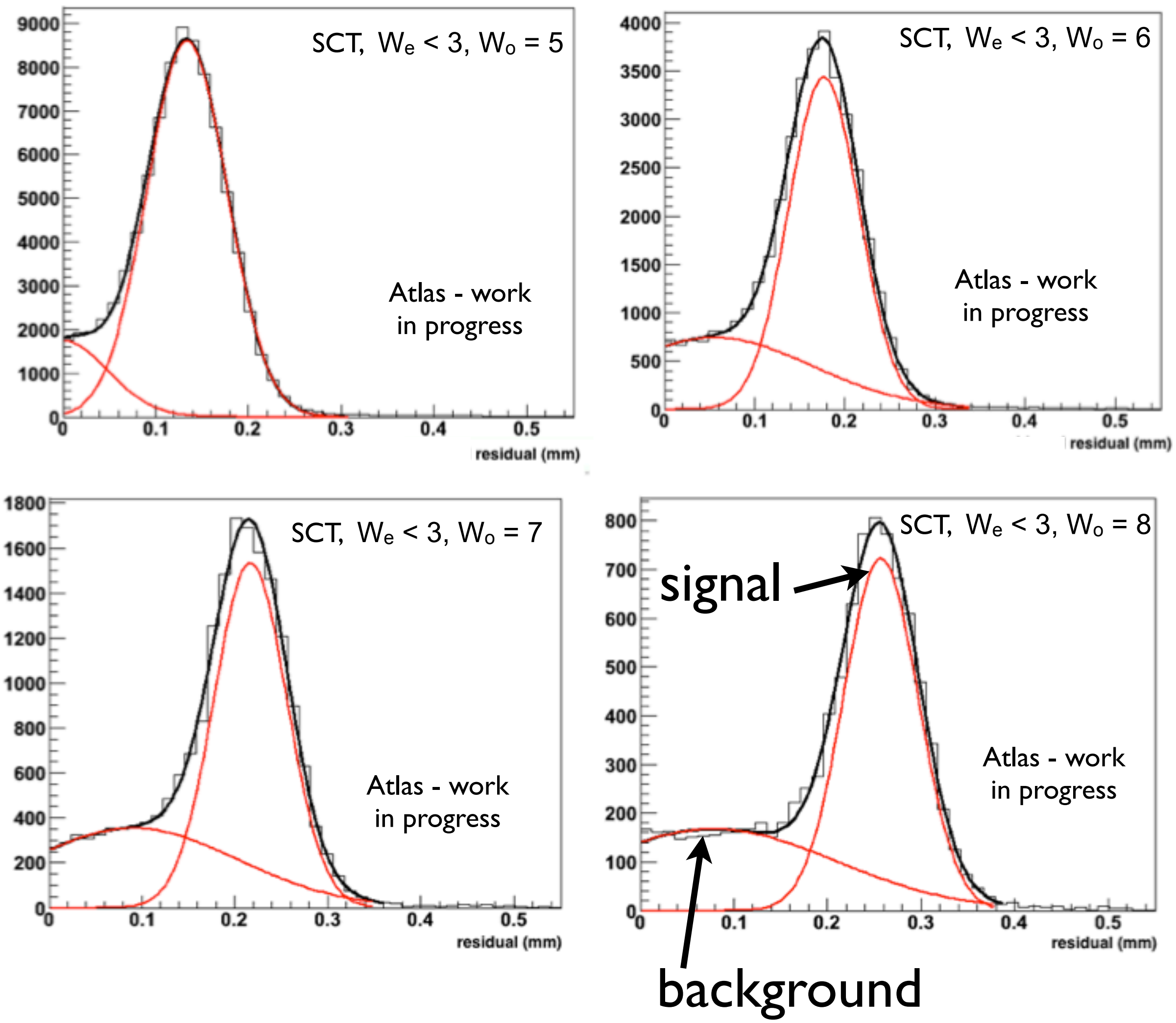


- two "signal peaks" away from zero correspond to single delta rays going to the left or to the right.
- for our purposes, we only want the number of *single* delta rays, so need to subtract out background due to multiple delta rays



n.b. : the residual is the distance between the cluster center and the track

Fits of the residual distribution to two gaussians



- can now plot the progression of the “signal gaussian” area.
- semi-empirically model the probability for delta ray emission as:

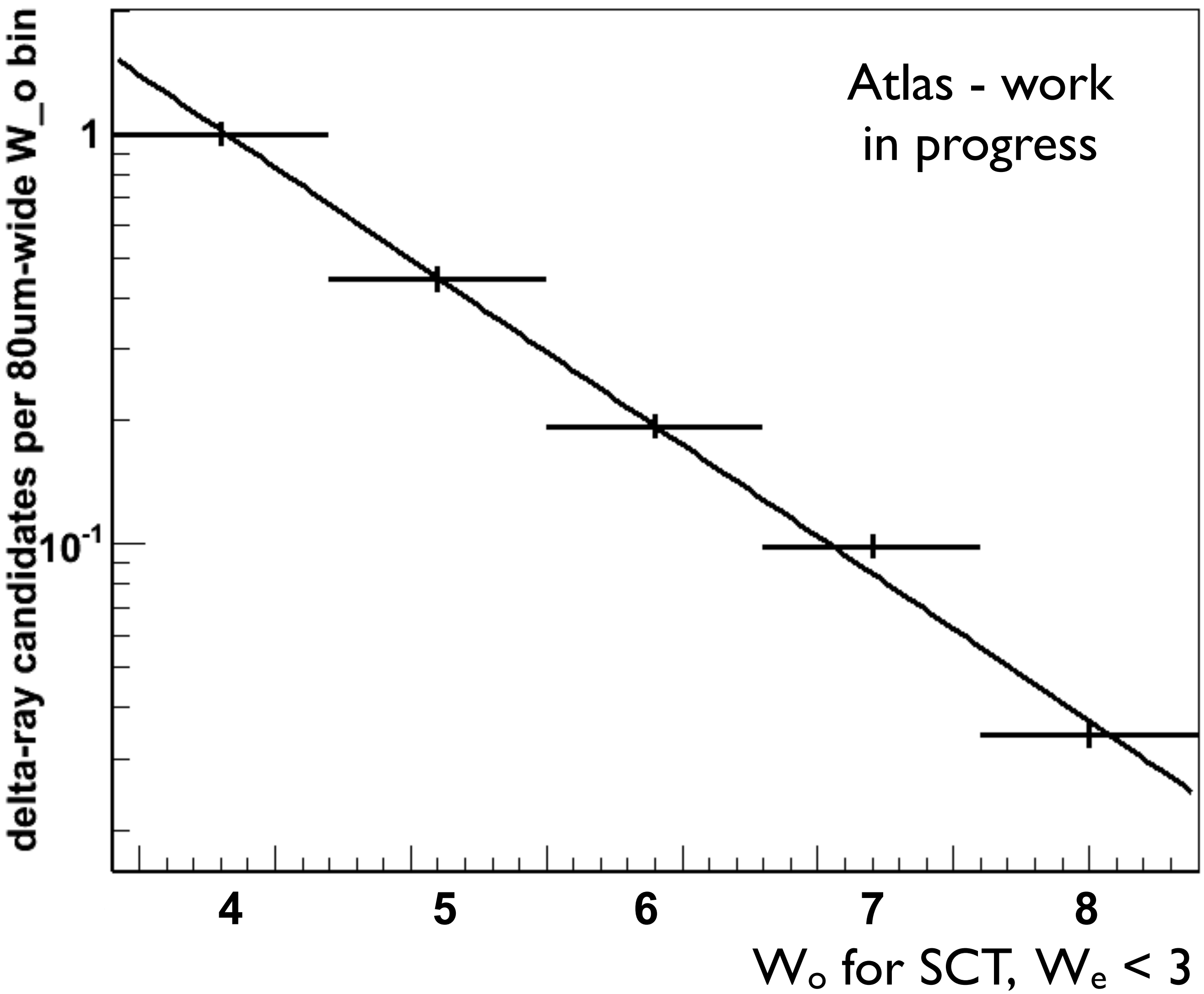
$$P_\delta = Ae^{-x/\rho}$$

x: distance the delta ray travels in μm.

A: rate normalization constant.

ρ: range in μm.

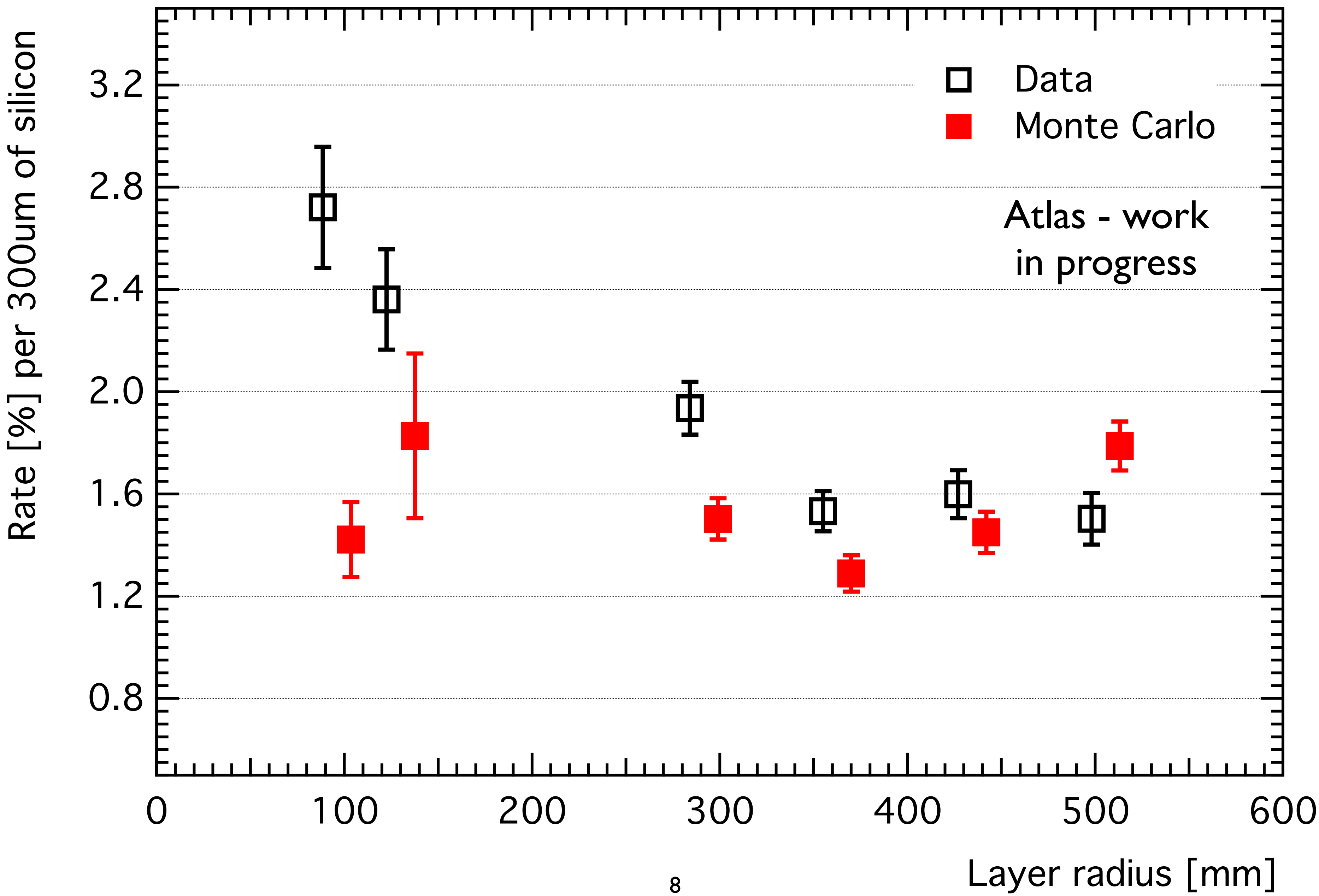
The distribution of delta ray candidates falls off exponentially



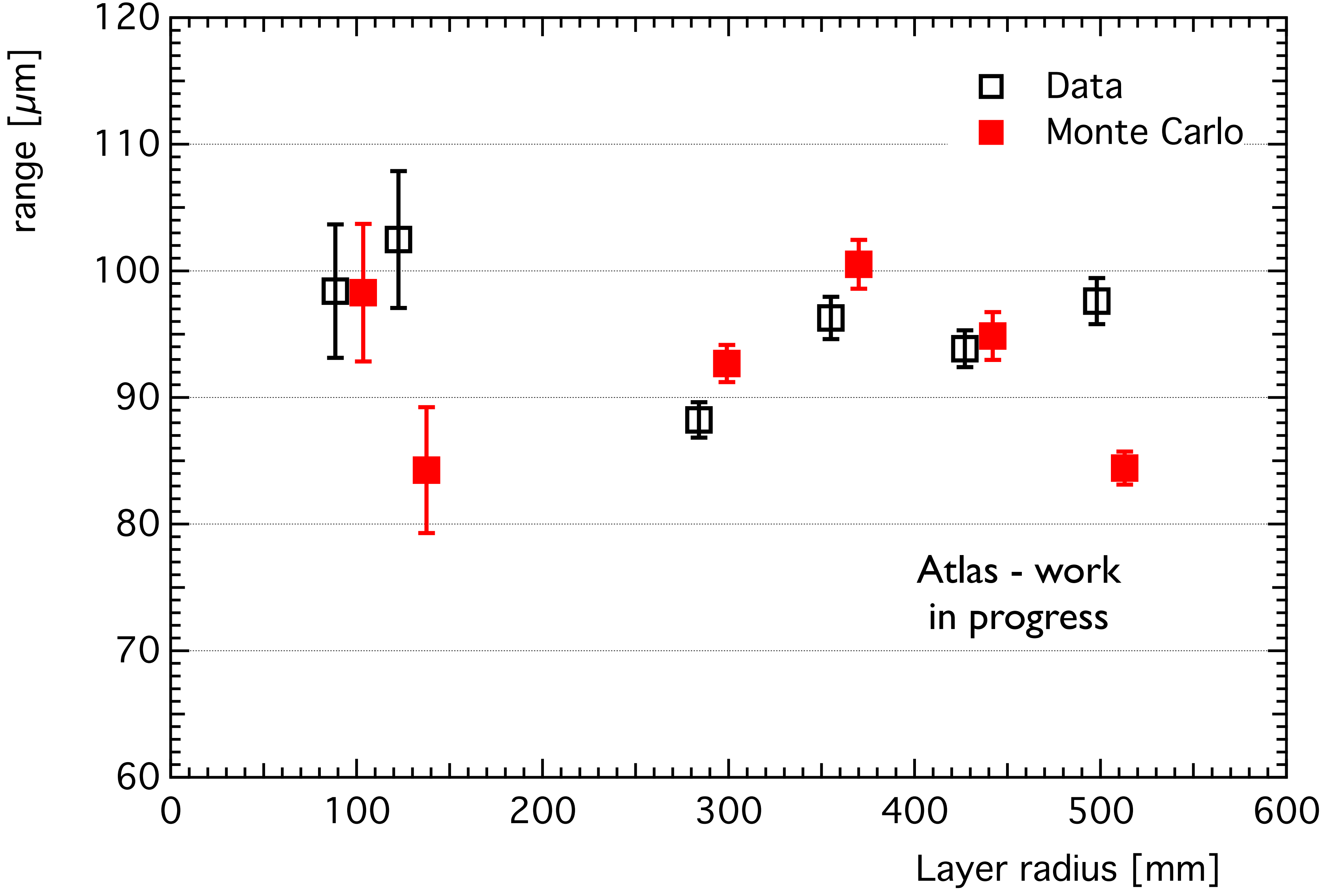
$$P_\delta = Ae^{-x/\rho}$$

- the inverse of the slope is the range *ρ.*
- the rate A can be calculated from the number of entries in the bins and *ρ.*
- divide the data into bins of detector layer, momentum and path length and measure A and *ρ* for each.

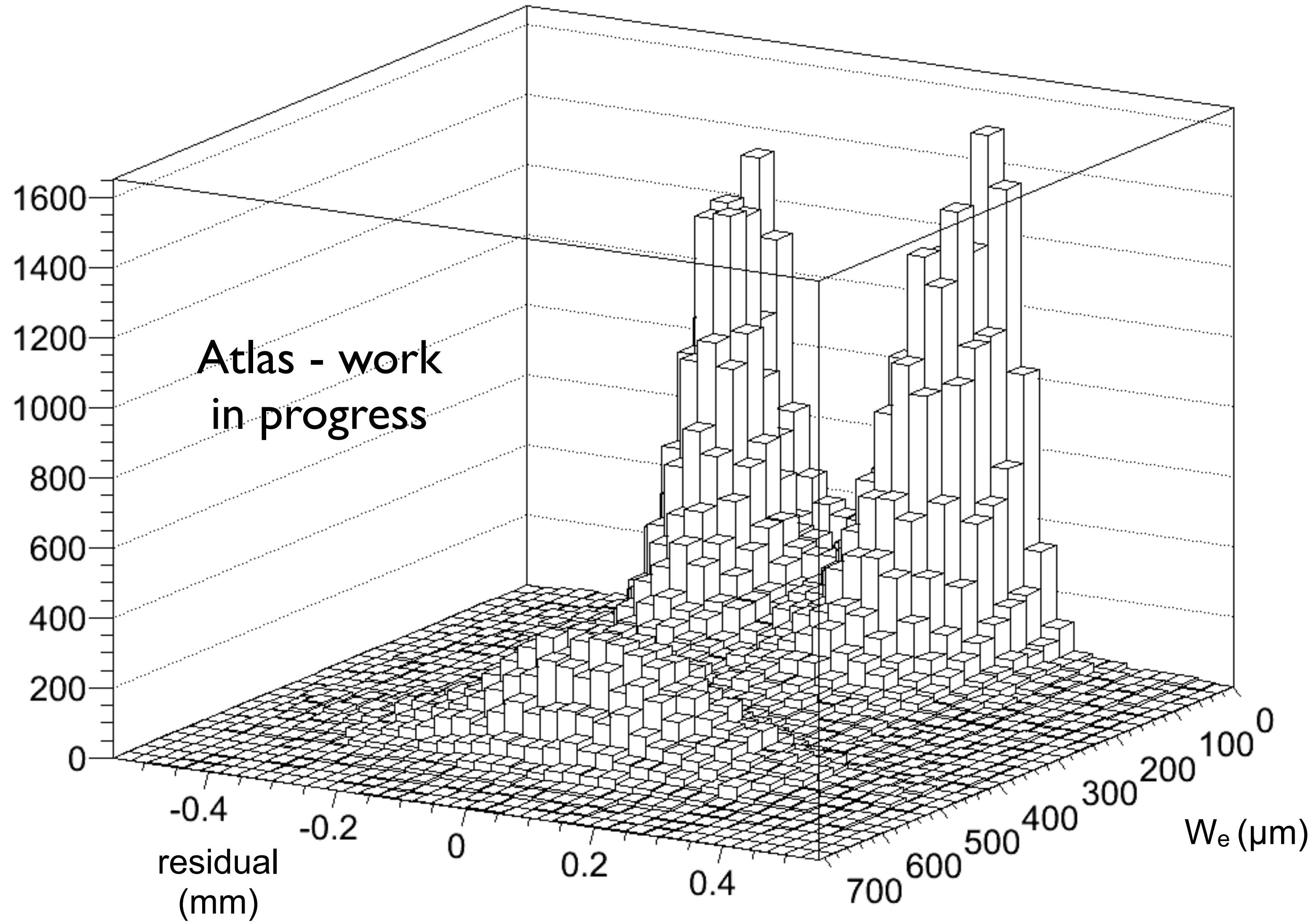
Rate vs. detector layer (statistical error only, excluding Pixel L0, MC artificially shifted for better recognition)



Range vs. detector layer (statistical error only, excluding Pixel L0, MC artificially shifted for better recognition)

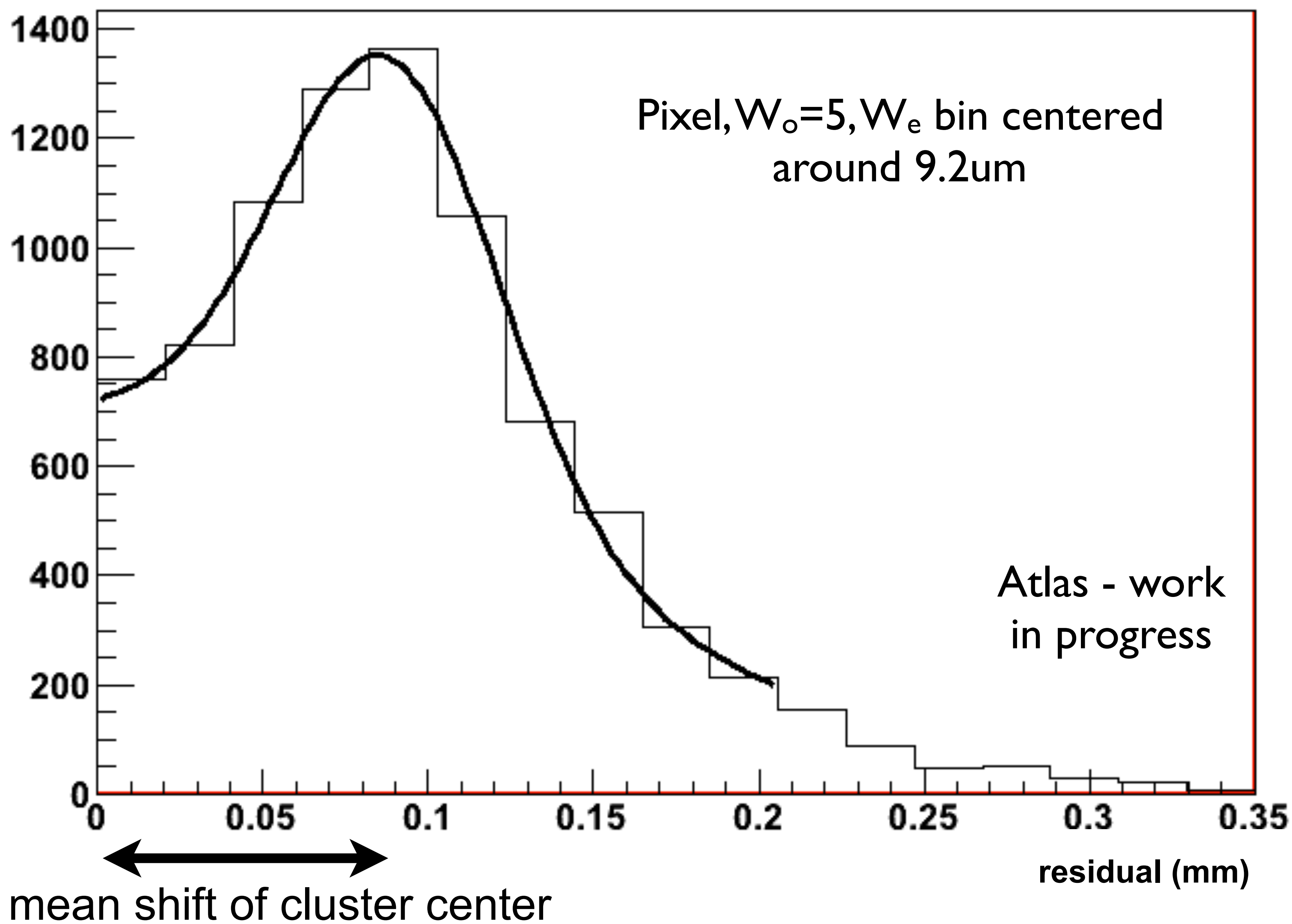


W_e vs. residual for SCT detector, W_o = 6 (equivalent to W_e > 320 μm)

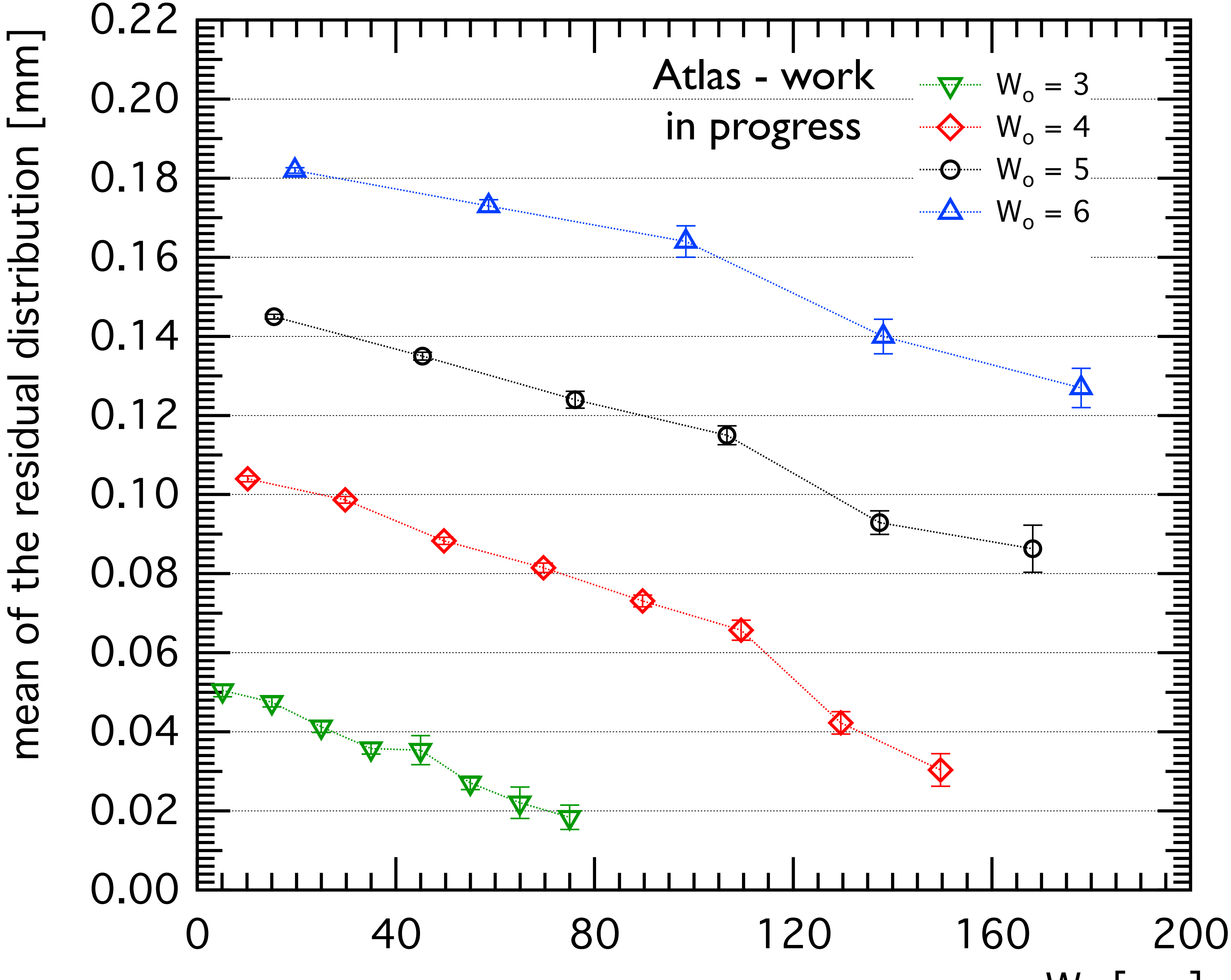


the shift of the residual decreases with increasing W_e, where large cluster sizes become likely

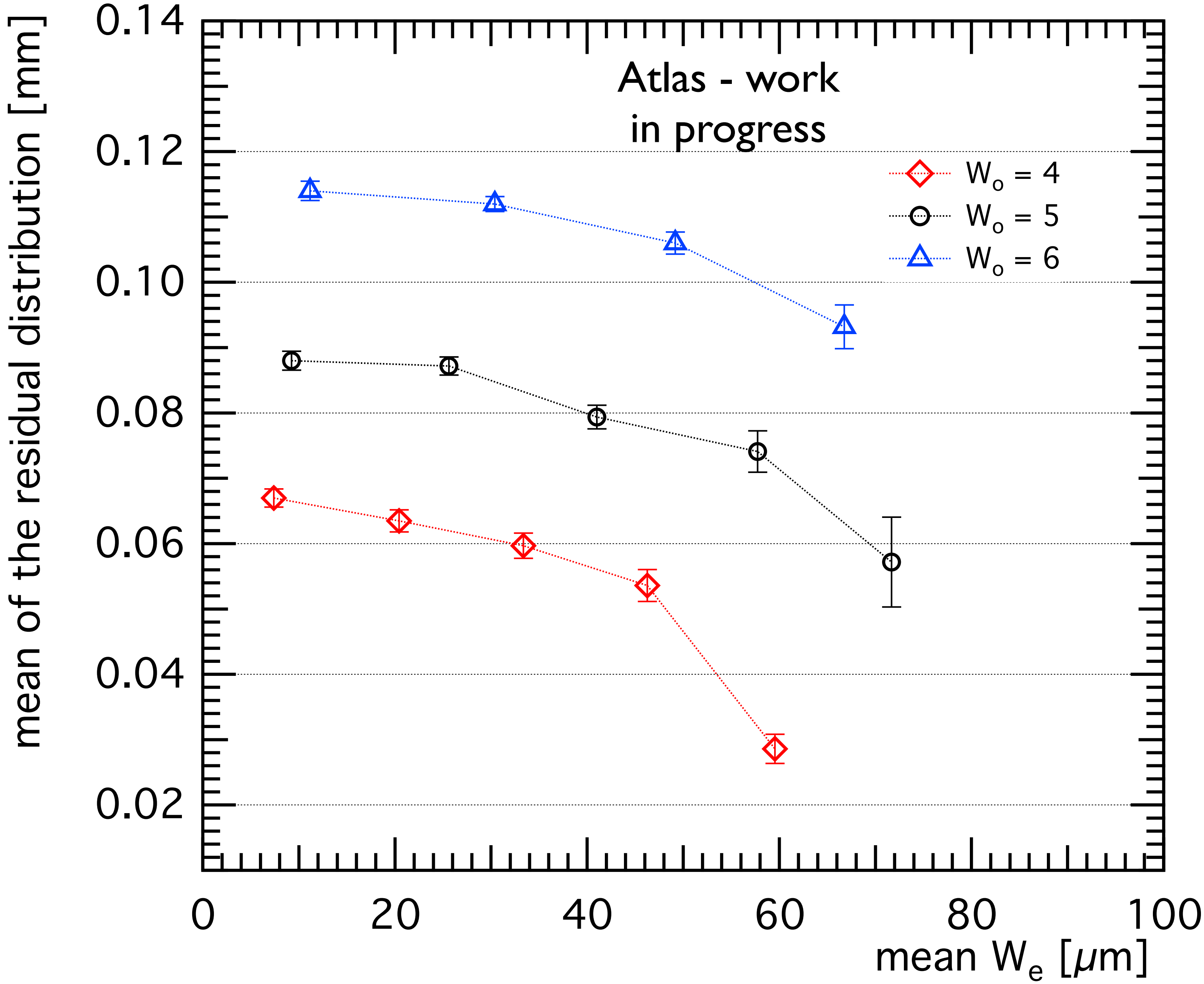
Compute the mean shift of cluster center in bins of W_e



Mean of SCT residual gaussian



Mean of Pixel residual gaussian



Conclusion

- present a method that identifies single delta rays and measure their rate and range.

- find the range to be a constant within uncertainty as function of path length in silicon, track momentum and detector layer. Find rate to depend linearly on path length and consistent with being constant as function of momentum.

- standard production simulation agrees reasonably with data.

- the shift in the residual for delta rays can be used to correct the bias introduced by them in the track reconstruction. This can be used to correct the cluster center of any artificially enlarged cluster.

    - this work is in progress right now.

Backup

Rate extraction

- the rate A is extracted by integrating the dP_∂ formula.
- is normalized to the total number of tracks.

$$N_\delta(w_o, b) = N_1 \frac{AL}{\rho} \int_{(2w_o-3)s/2}^{(2(w_o+b)-1)s/2} e^{-x/\rho} dx + N_2 \frac{AL}{\rho} \int_{(w_o-2)s}^{(w_o+b-1)s} e^{-x/\rho} dx$$

- here, N_1 and N_2 are the number of true 1- and 2-hit cluster.
- N_∂ is the number of ∂-rays traveling in the distance range between the limits of integration.
- w_o is the W_o bin at which fitting starts and b is the number of W_o bins included in the fitting, i.e. for how many clusters and from which cluster size the fits are performed.

Sources of systematic errors

- the double gaussian fit is only an approximation, and we estimate the introduced error to be of order 5% by varying the mean of the background gaussian and its width.

- the contamination by shared clusters is found to be negligible, since the rate does not decrease with layer radius, while it found to do so for shared clusters (decreased occupancy).

- approximation made in the calculation of A introduce an error of about 3%. This is found by comparing the approximation to the exact value for a few toy examples.

- ρ is expected to be constant for all bins, since it is a property of silicon. The variance of measured values is bigger than statistical σ^2, so we take the 5% variance as a systematic.

- The total systematic uncertainties on A and ρ are of order 7.5%.

Way to correct residual of enlarged clusters

- in a second-pass refit, one could calculate W_e and compare it with W_o

- could make a lookup table of the mean shift and then correct the residual by that shift

- would have to do it twice, adding and subtracting, because have no a priori way of knowing if the delta ray went to the right or to the left

- this corrects all enlarged clusters, also those caused by merged clusters, since their shift is the same

- very interesting for SCT, since there is no other method of correcting these clusters. For pixels, there is a way using neuronal networks

Quality cuts

- At least 3 pixel hits
- At least 8 SCT hits
- No pixel holes + hit in first layer
- Chisquare/ dof < 10
- |Z0|<75mm, |D0|<5mm
- at least 10 TRT hits
- no shared cluster

- additional pixel cuts:
- PixDeltaCol <=2
- PixHasGanged !=1