Charge diffusion model results

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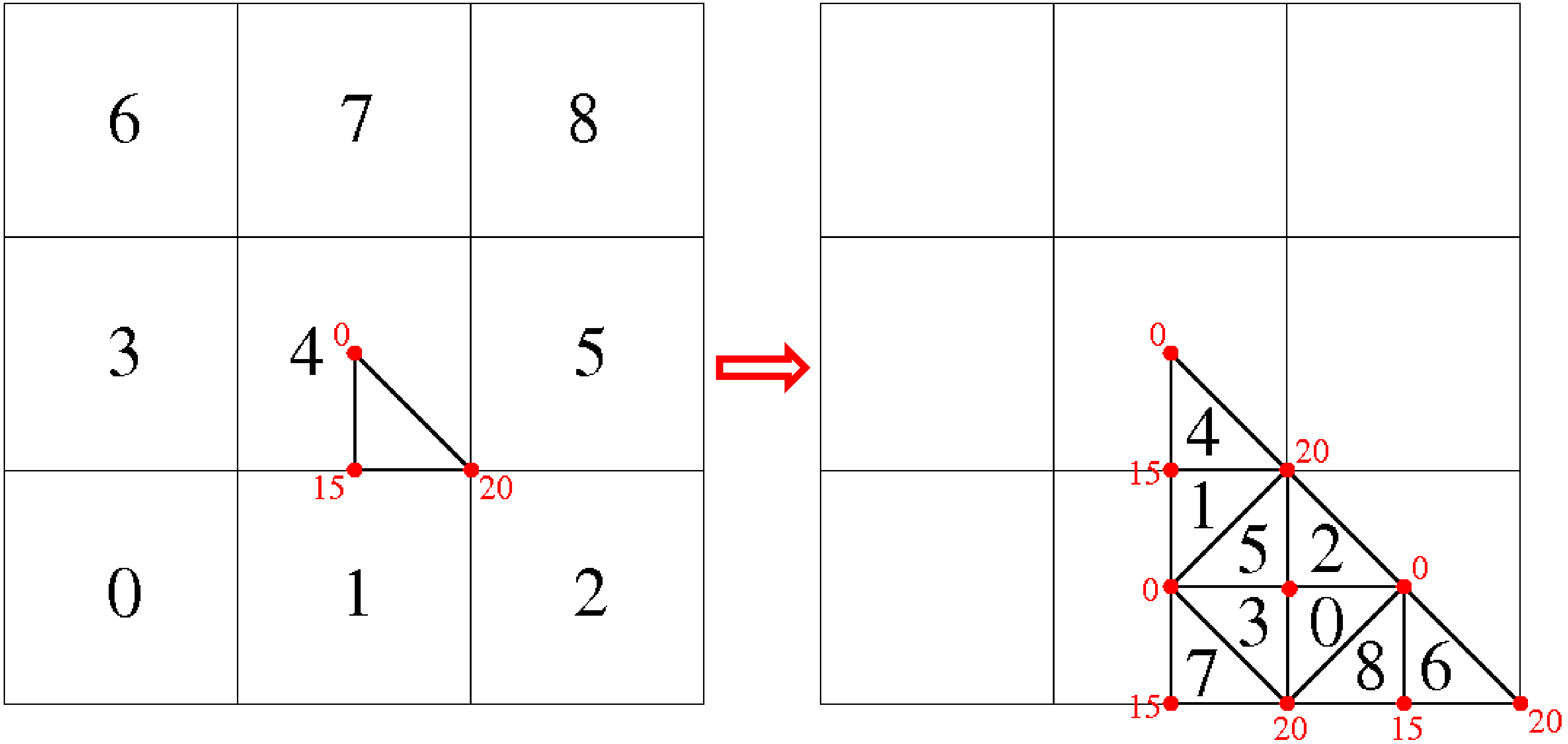
Diffusion model (for details, see 29/2/08)

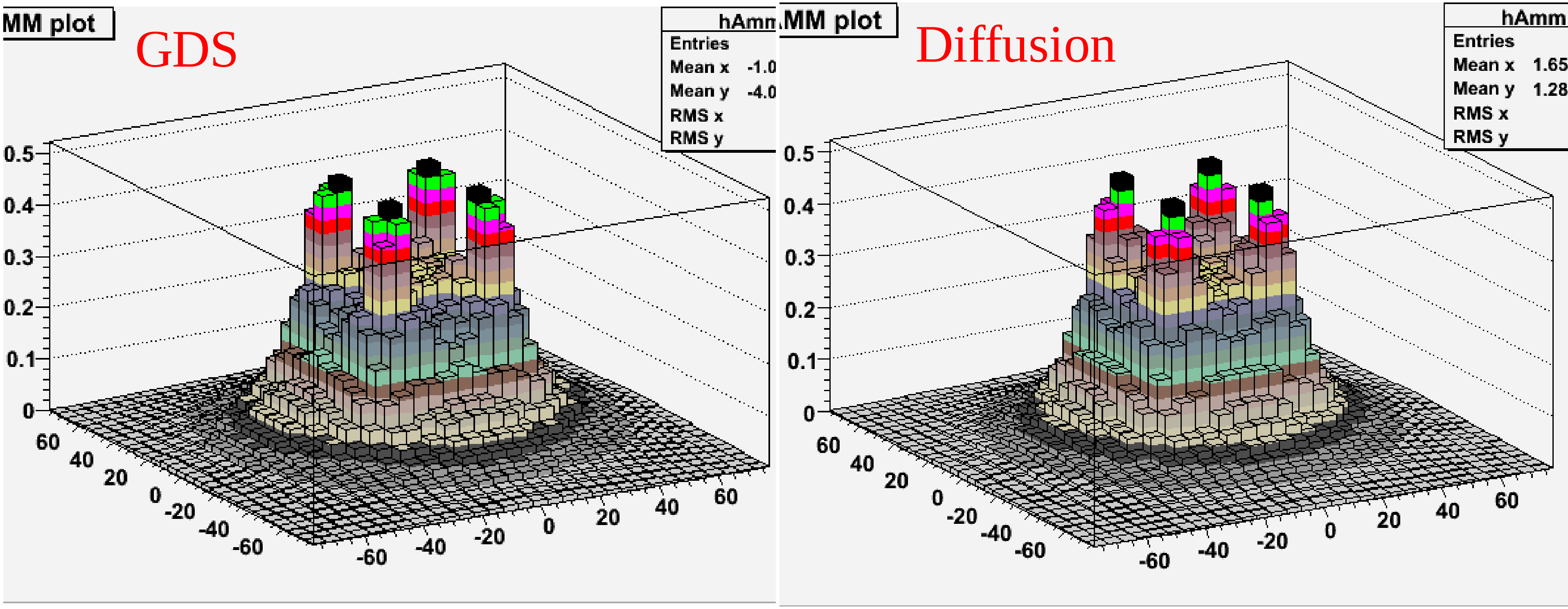
- Basic equations
  - Charge conservation: $\delta\rho/\delta t + \nabla.\mathbf{j} = 0$ (so no recombination)
  - Diffusive movement: $\mathbf{j} = -k\nabla\rho$ where k is the diffusion constant
- These can be combined to give $\delta\rho/\delta(kt) = \nabla^2\rho$
  - Time scaled by k, so no absolute timescale
- Work with 5×5 pixel grid and looks at charge in central 3×3 pixels
  - 50 50 points per pixel, each $1\times1\mu m^2$; factor 2.5 finer than previous results
- Divide epitaxial depth with same cell size
  - 12 points, each 12μm/12 = 1μm; ditto
- Use very simple numerics
  - Three-point $O(\Delta x^2)$ approximation for ∇^2
  - Forward (Newton) $O(k\Delta t)$ approximation for $\delta/\delta(kt)$
- Boundary conditions a bit tricky
  - Perfect boundary at bottom of epitaxial layer (z=0)
  - Fraction of charge removed for some cells at top of epitaxial layer (z=12)
  - Exponential falloff through 5×5 pixel grid edges

Point geometry



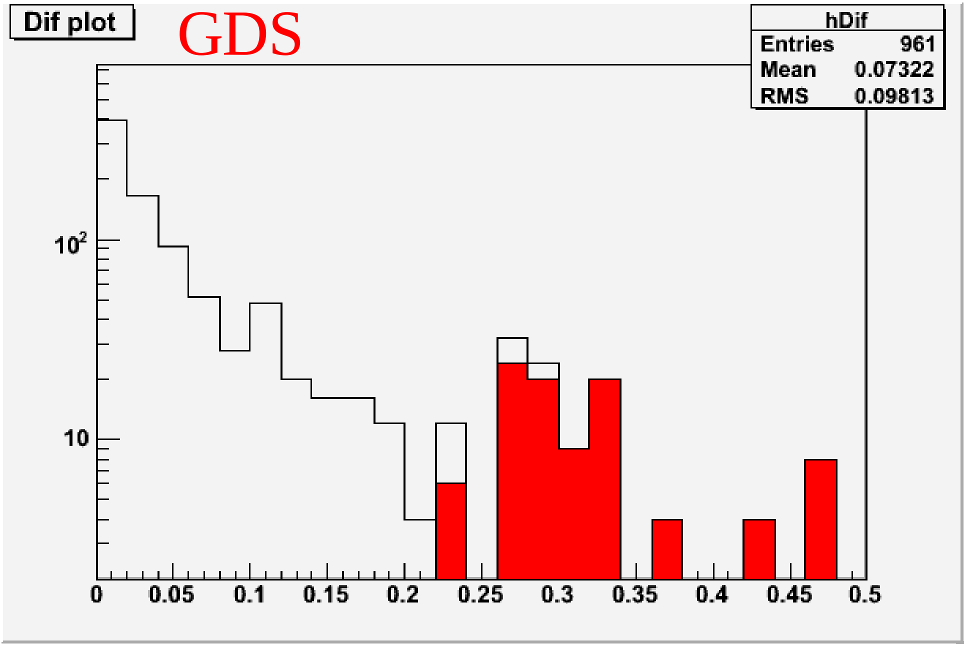
- Giulio's 21 points in triangle × 9 pixels = 189 values
- 136 independent points after averaging
- Reflections/translations copy these to 900 points
  - Most (but not edges/corners) duplicated 8 times

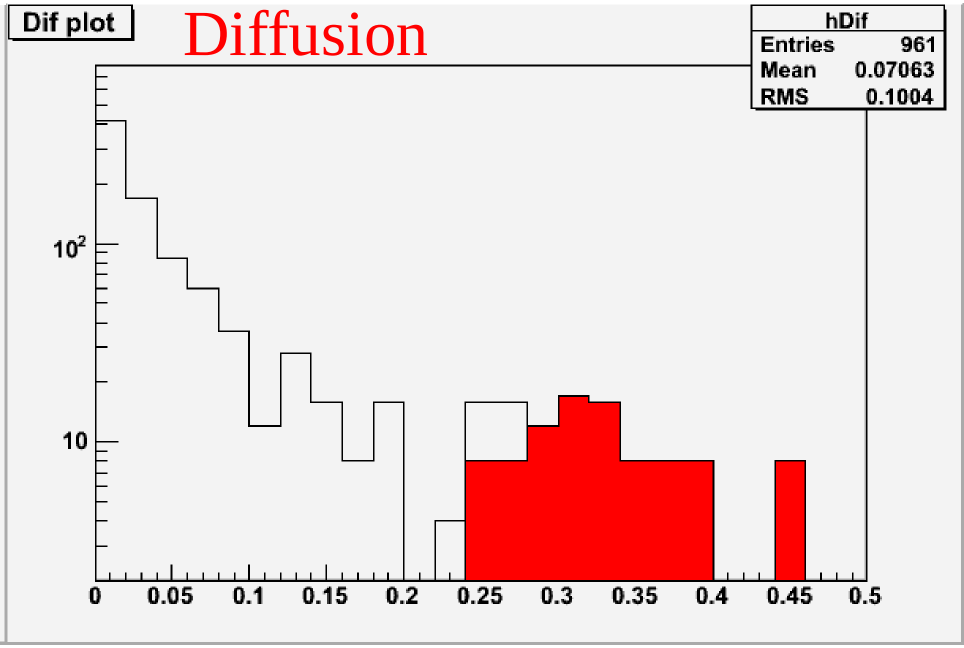
GDS (Giulio) vs diffusion model



- Two parameters to tune using centre point #0
  - Absorption of diodes: use GDS "perfect deep p-well"; gives 44%
  - Absorption of n-well with deep p-well: use full GDS; gives 31%
- All other points then determined from diffusion

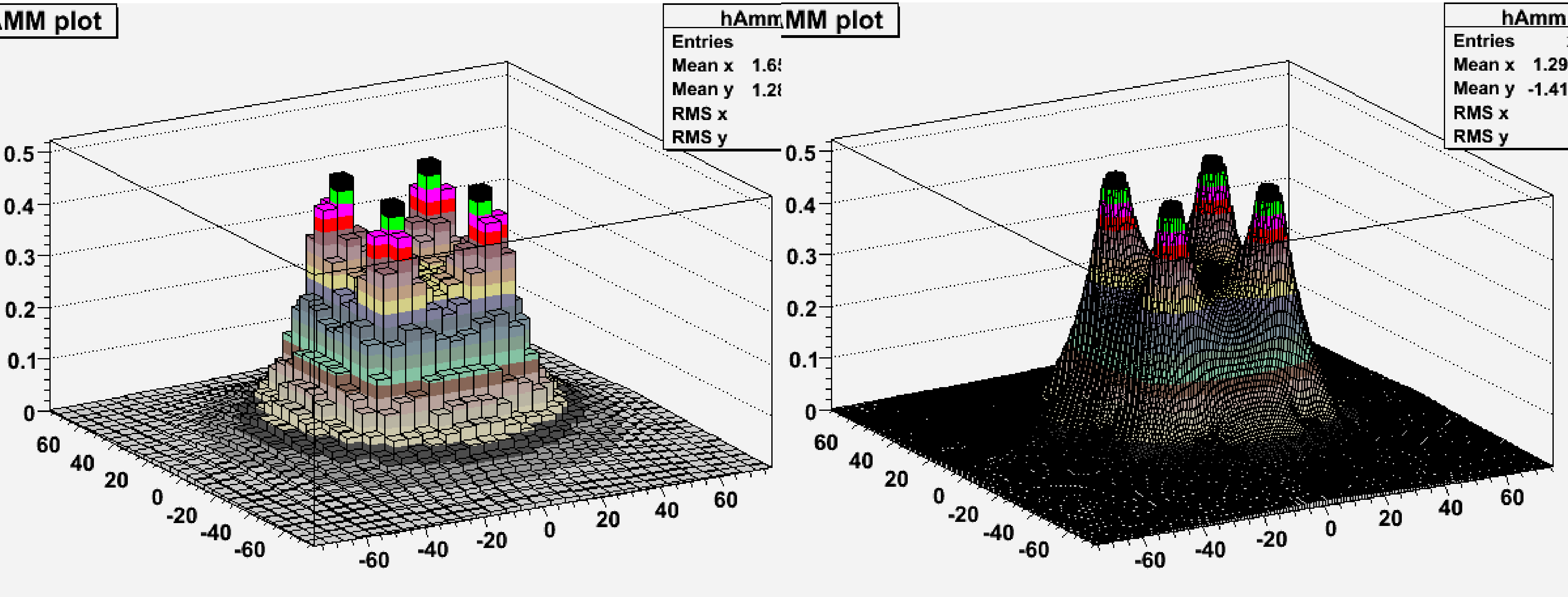
Fractional charge spectra for models





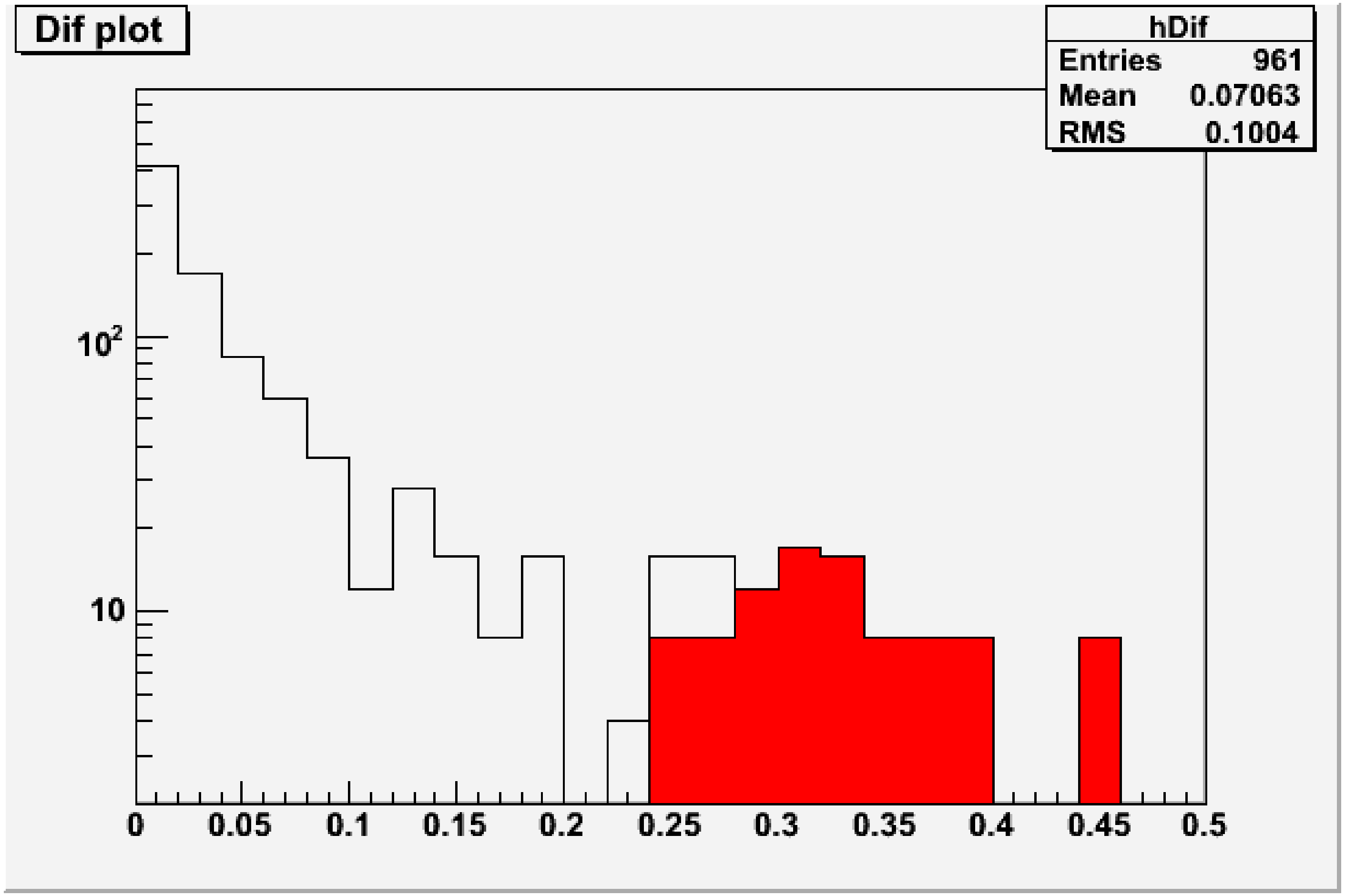
- Fraction of charge seen in centre pixel for uniform deposits over 3×3 pixel array
  - MIP-like spread in z direction
- Red shows distribution in centre pixel
  - Corresponds to distribution of maximum signal if reading all pixels
- Suggestion of peak at charge fraction ~0.3?

Scale up from 5μm to 1μm steps

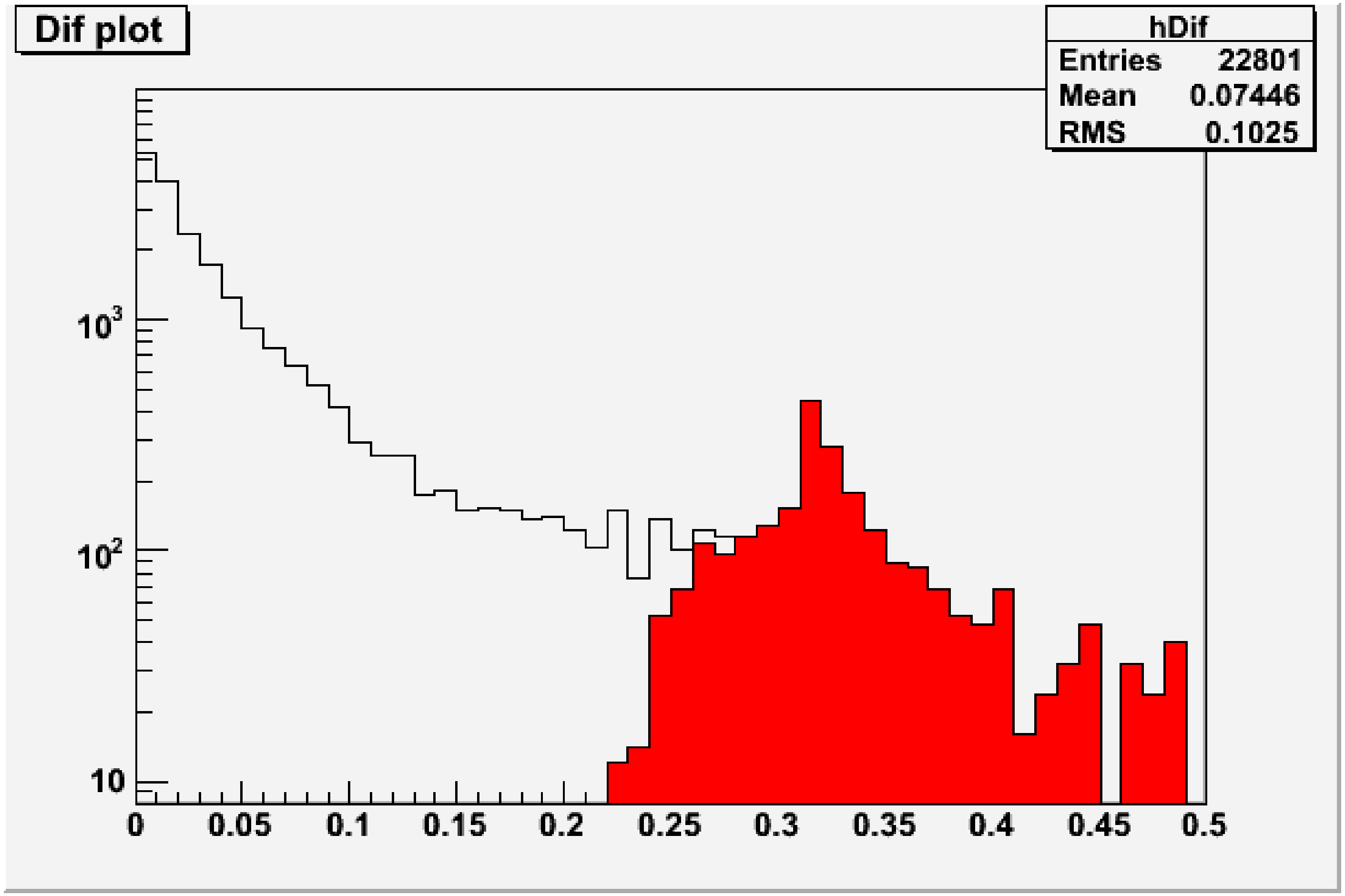


- 21 → 351 points in triangle × 9 pixels = 3159 values
- 136 → 2916 independent points after averaging
- Copy these to 150×150 = 22500 points
  - Much larger fraction of points duplicated 8 times

Fractional charge spectrum for 5μm steps

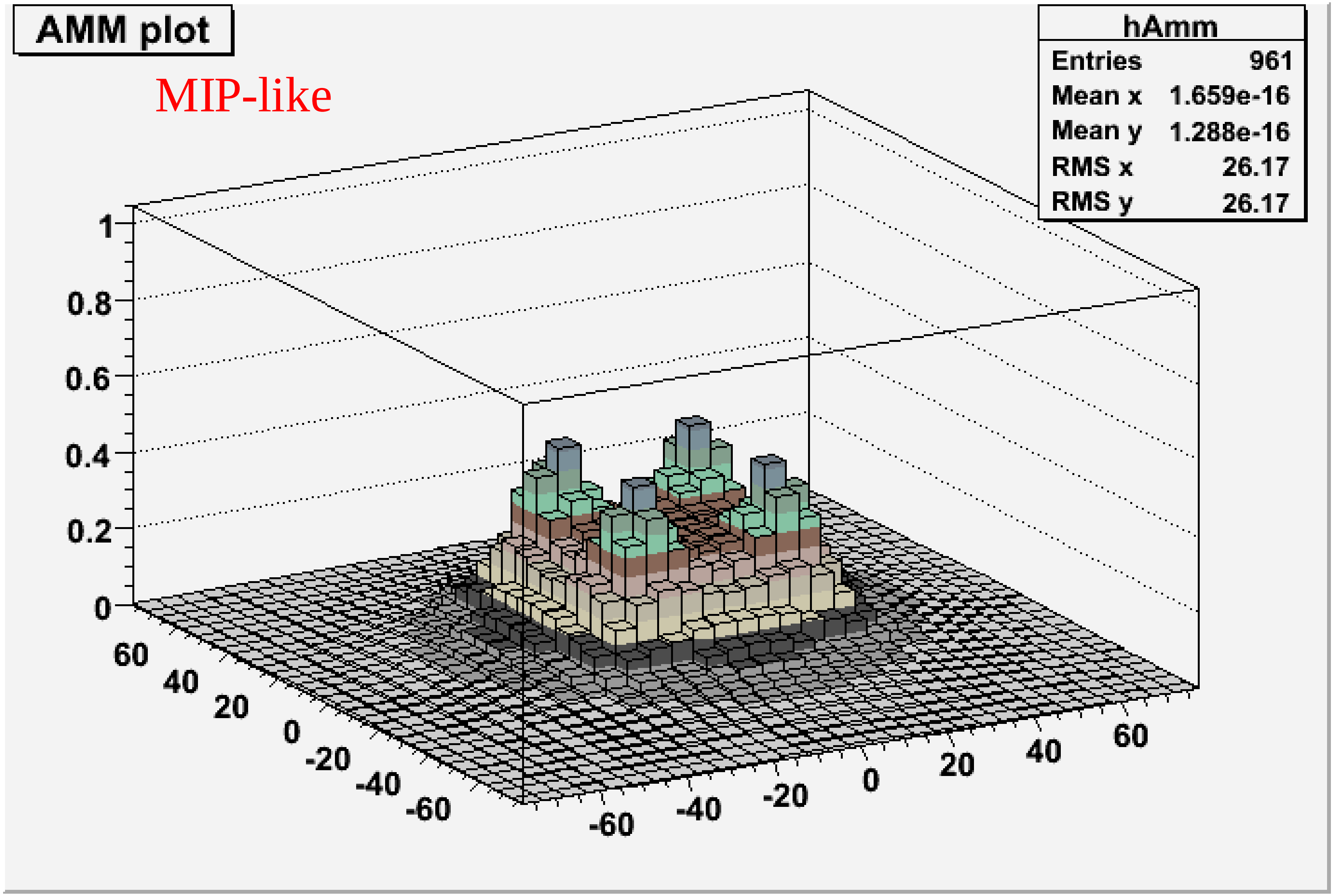


Fractional charge spectrum for 1μm steps

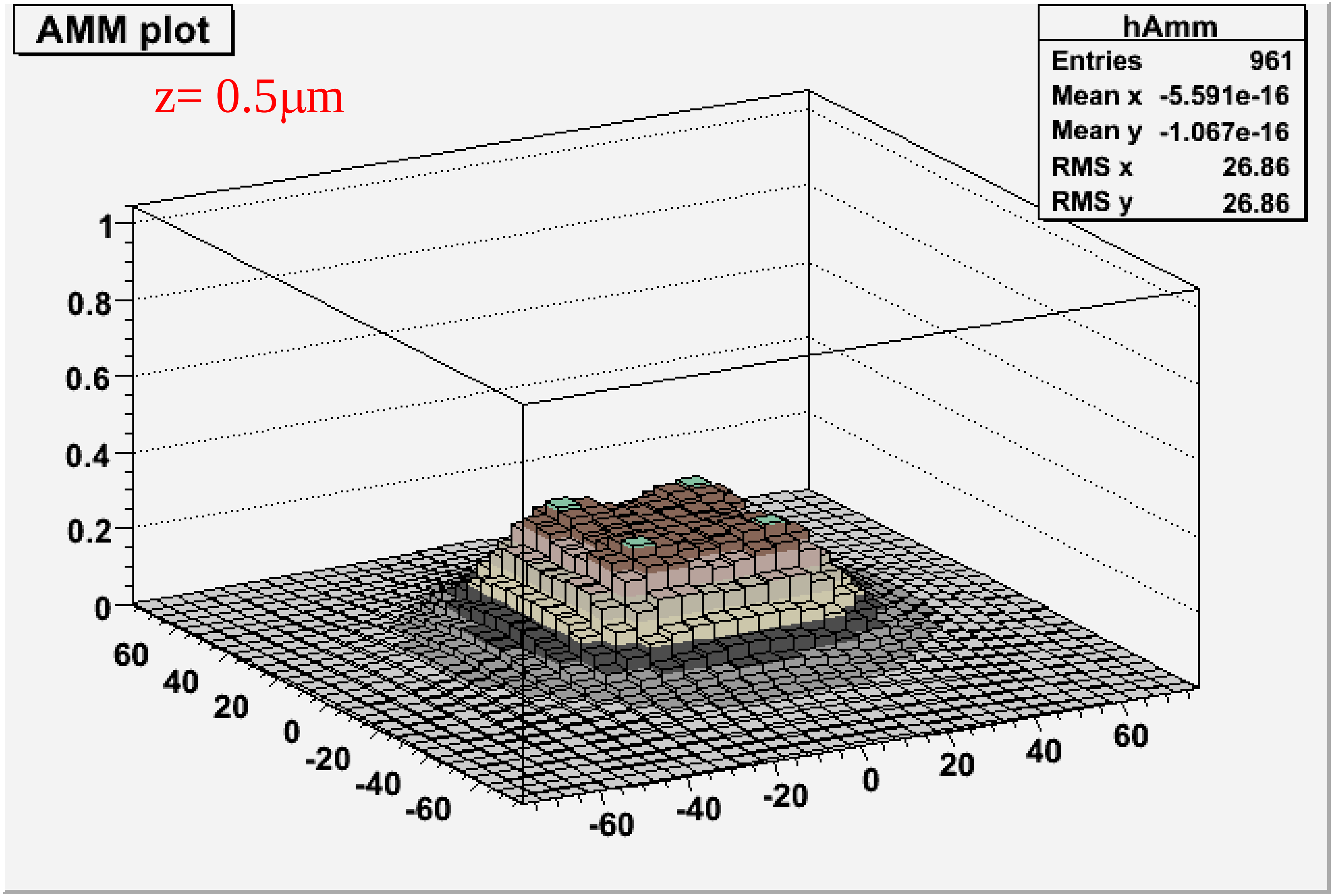


- Peak at fraction of ~0.32 of total charge; approx 3% of hits
- Results from wide flat region between pixels

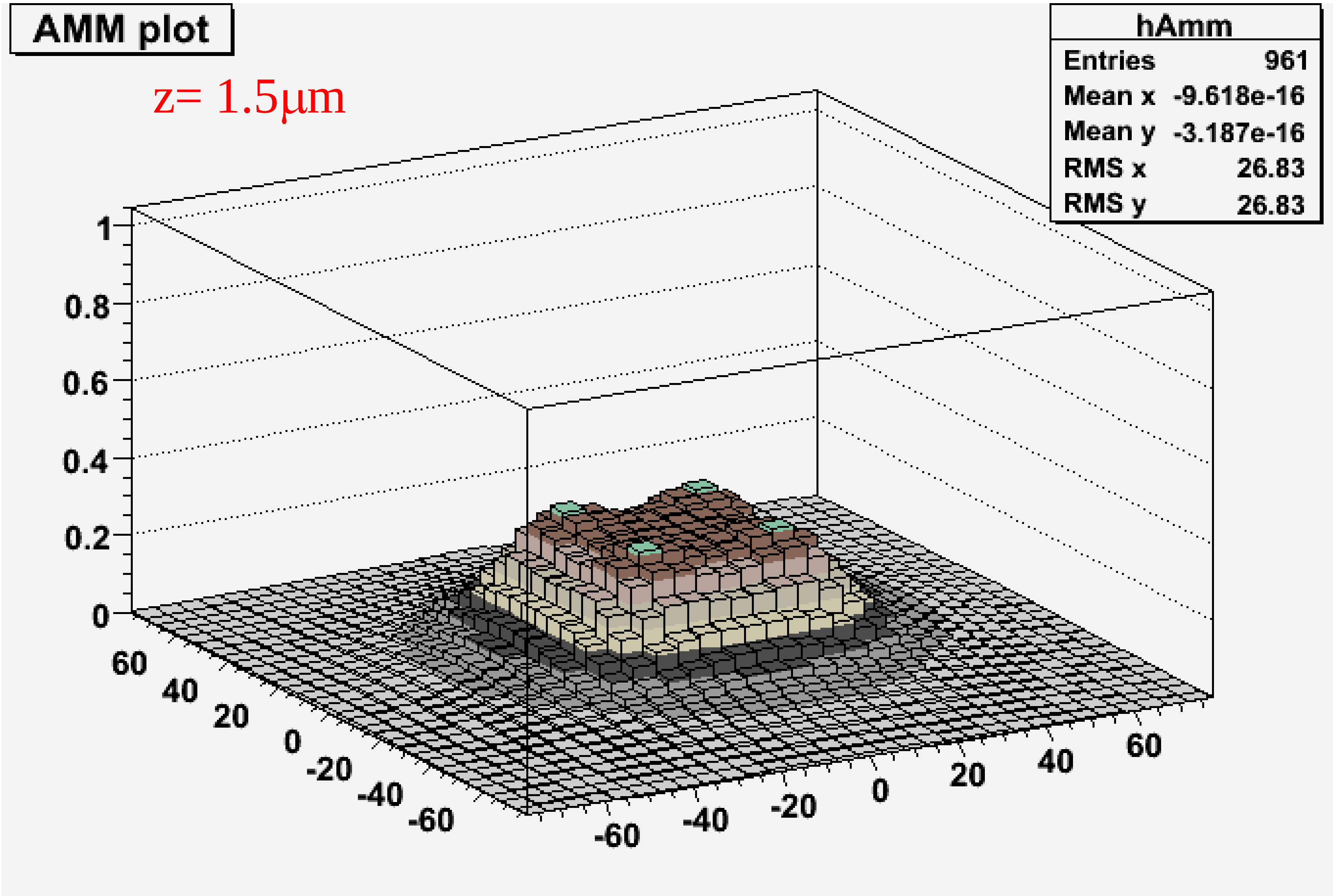
Depth dependence



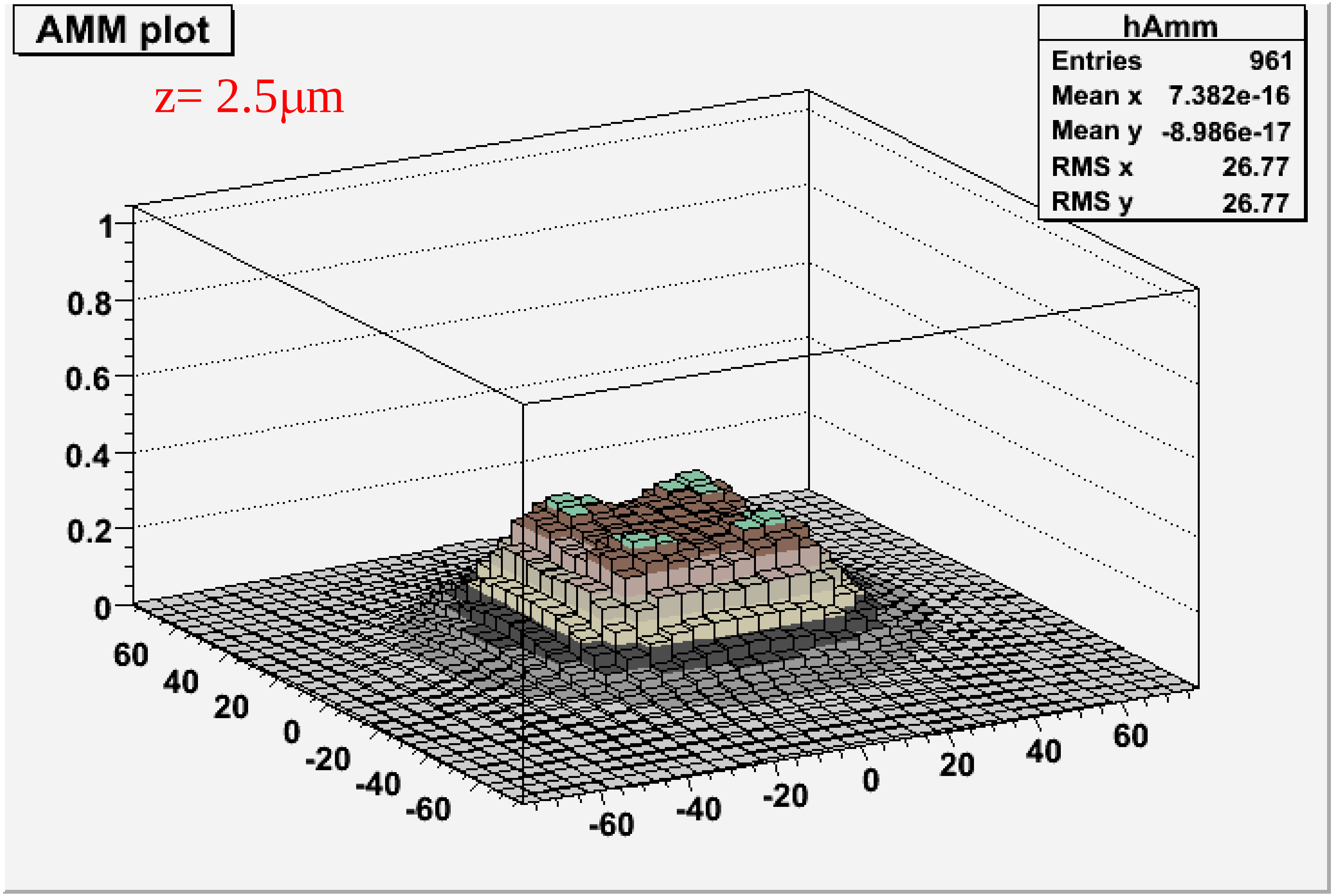
Depth dependence



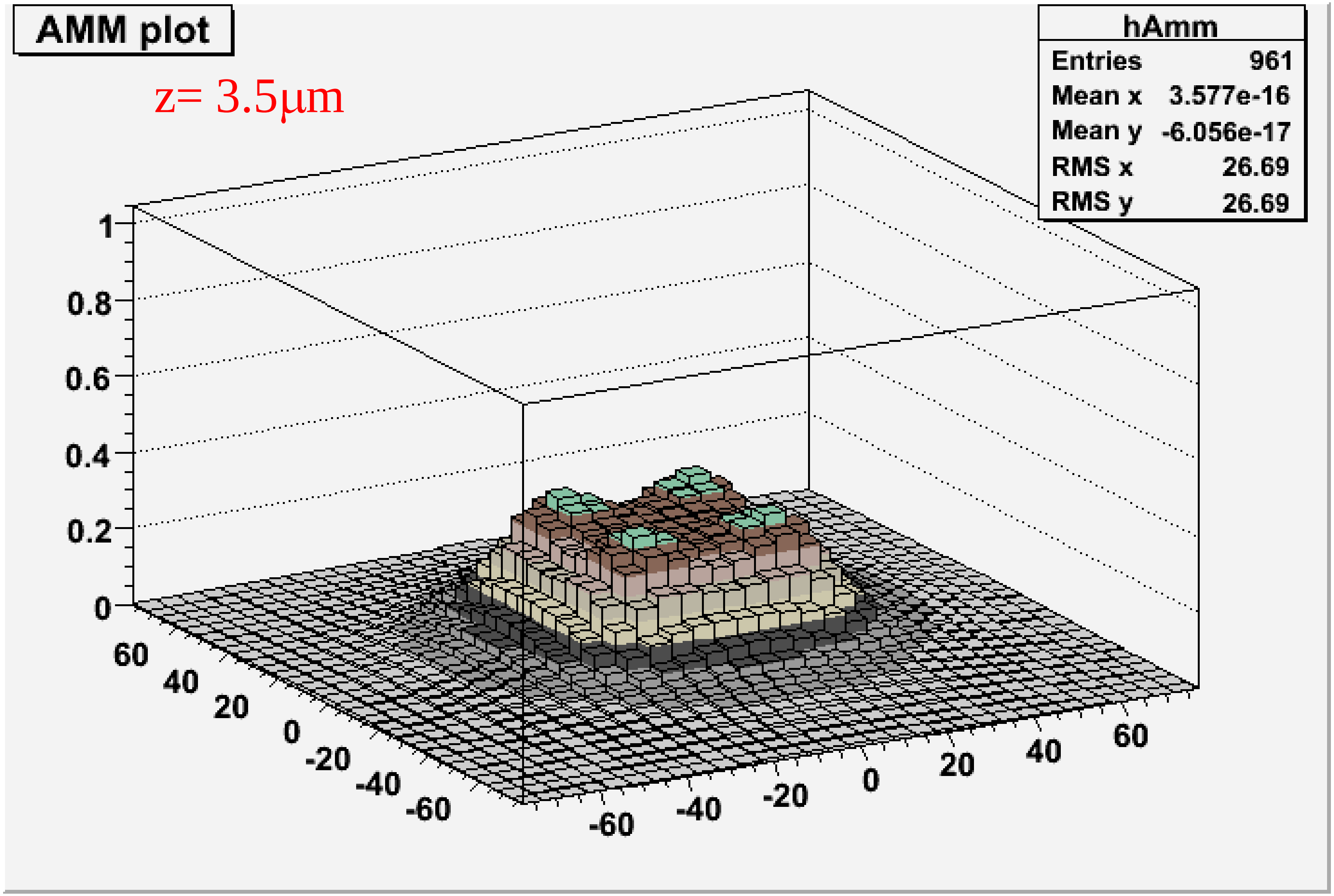
Depth dependence



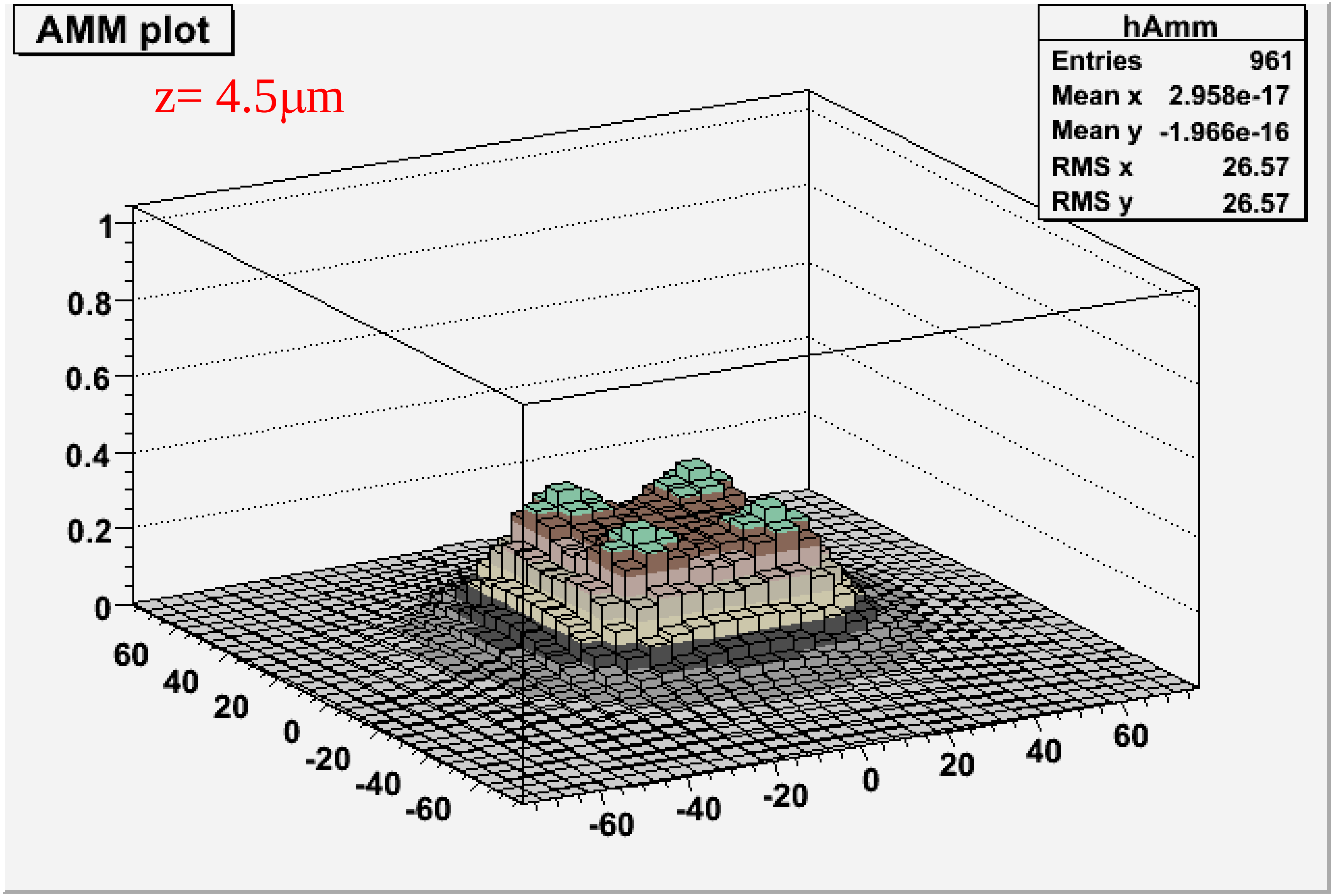
Depth dependence



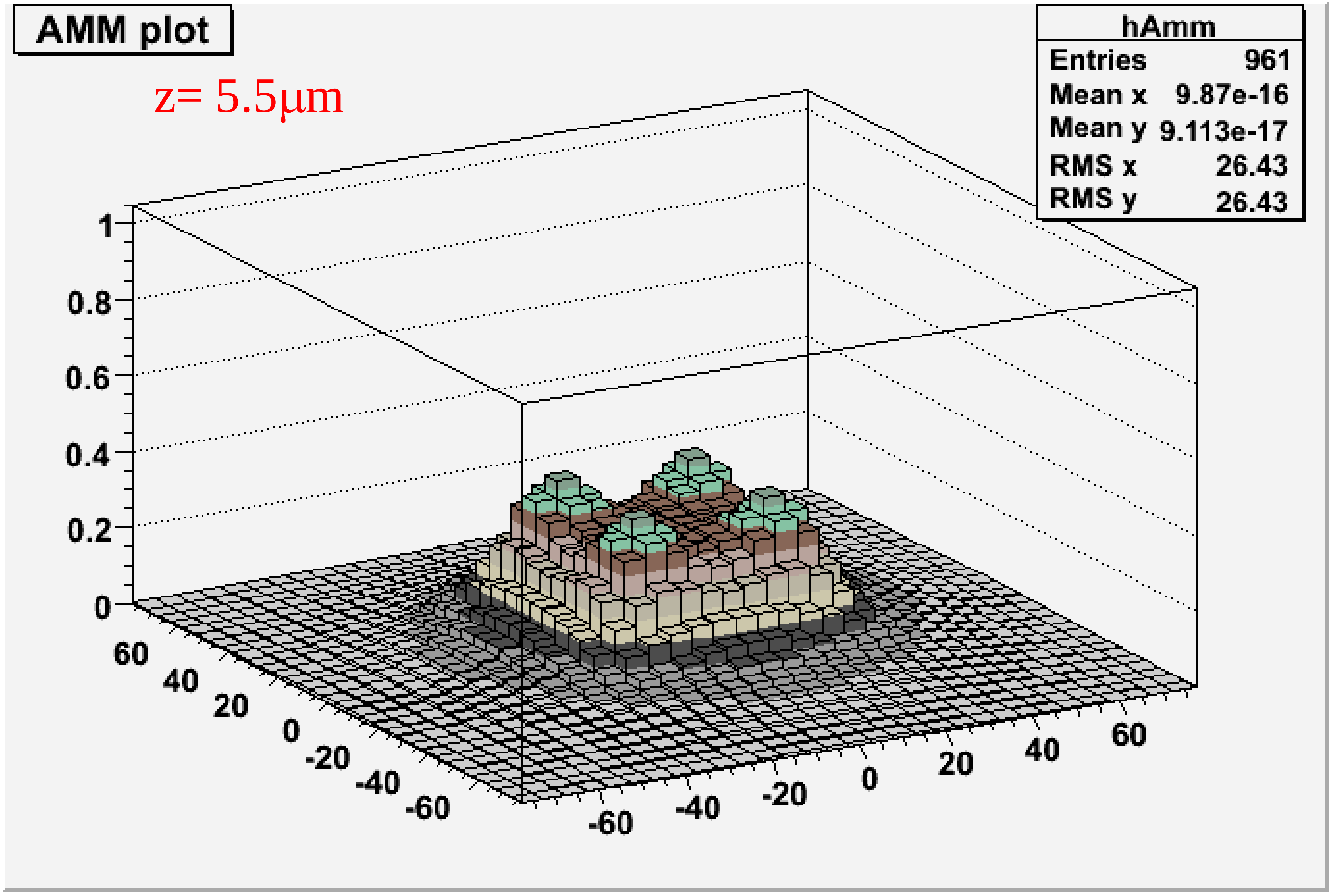
Depth dependence



Depth dependence



Depth dependence



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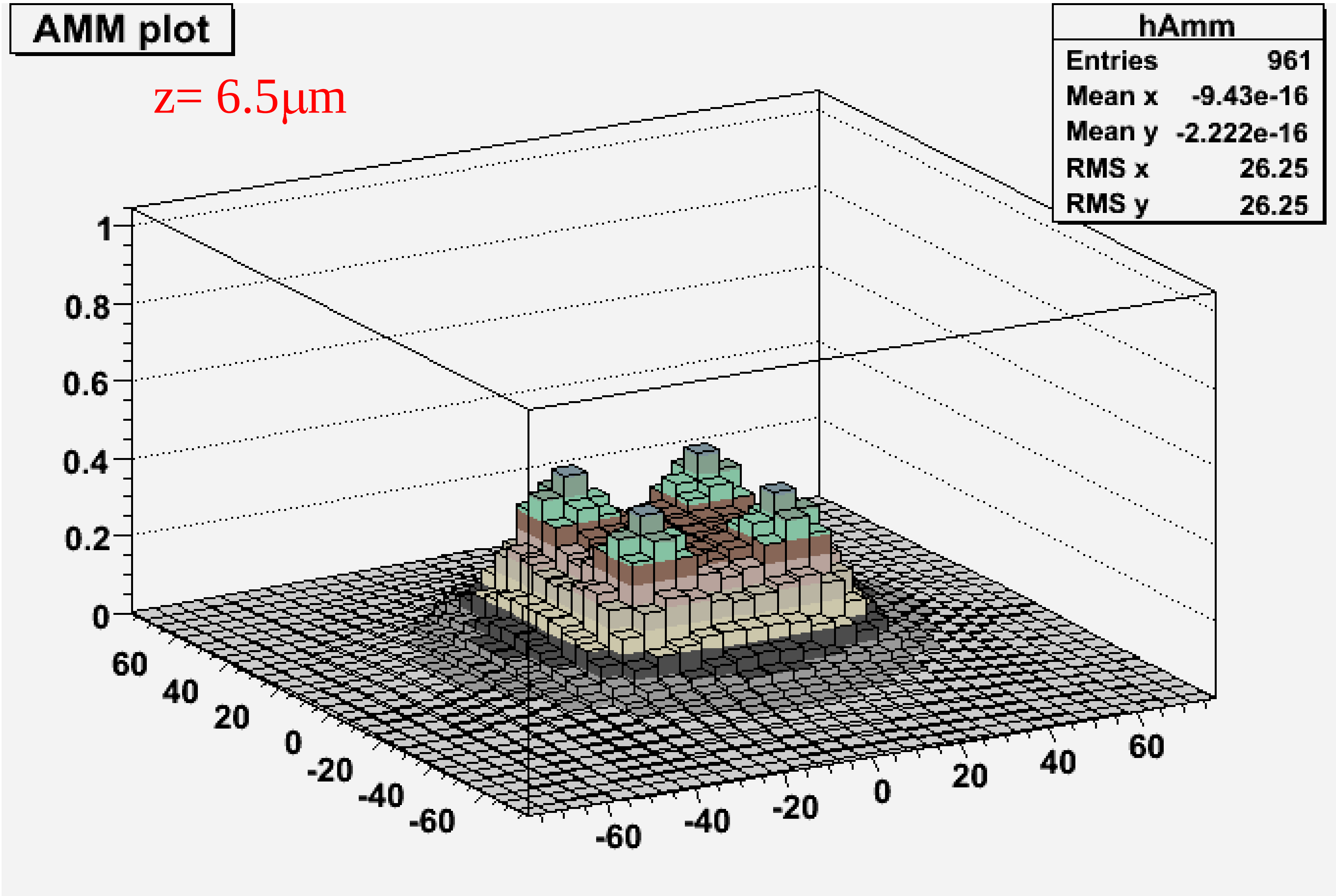
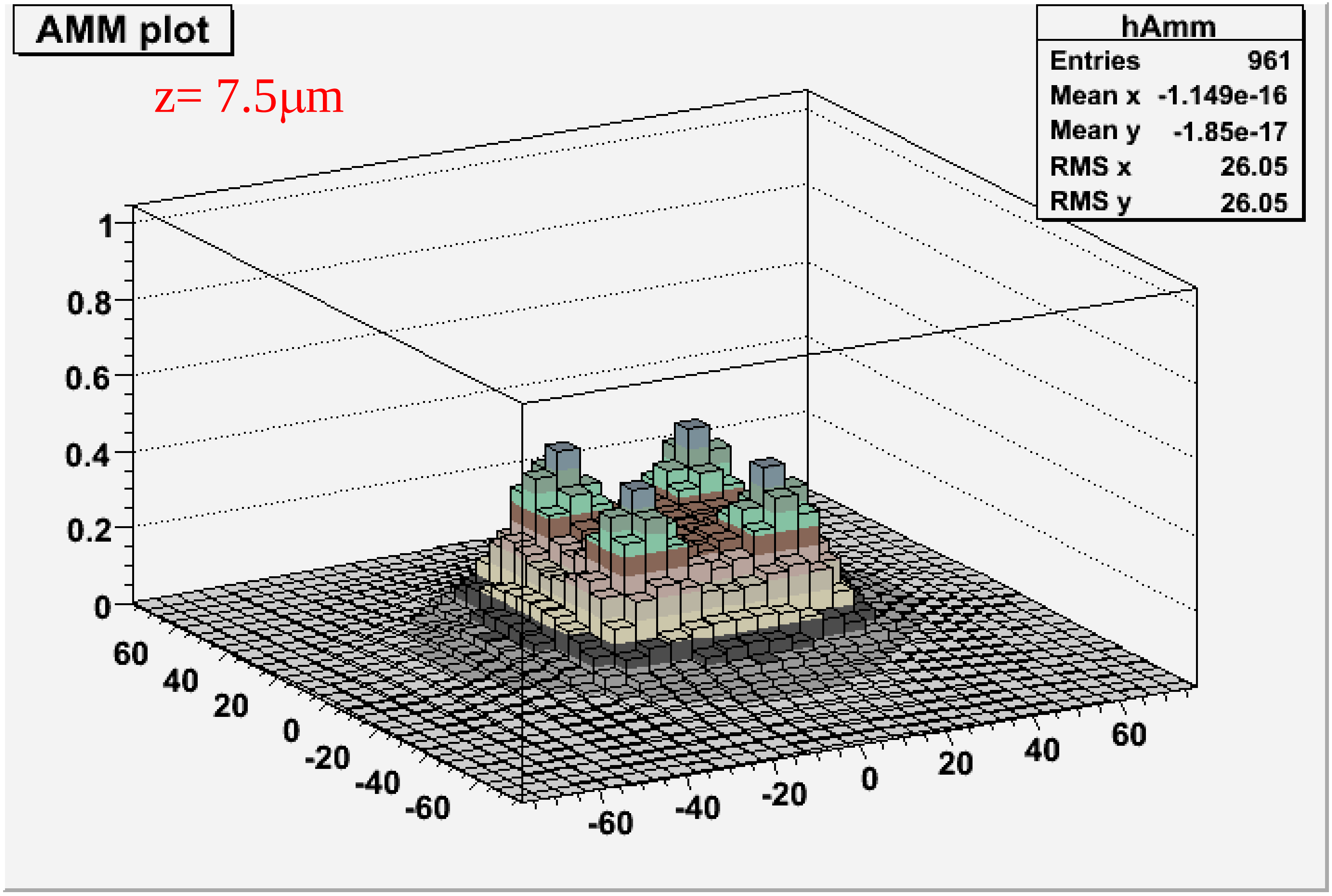
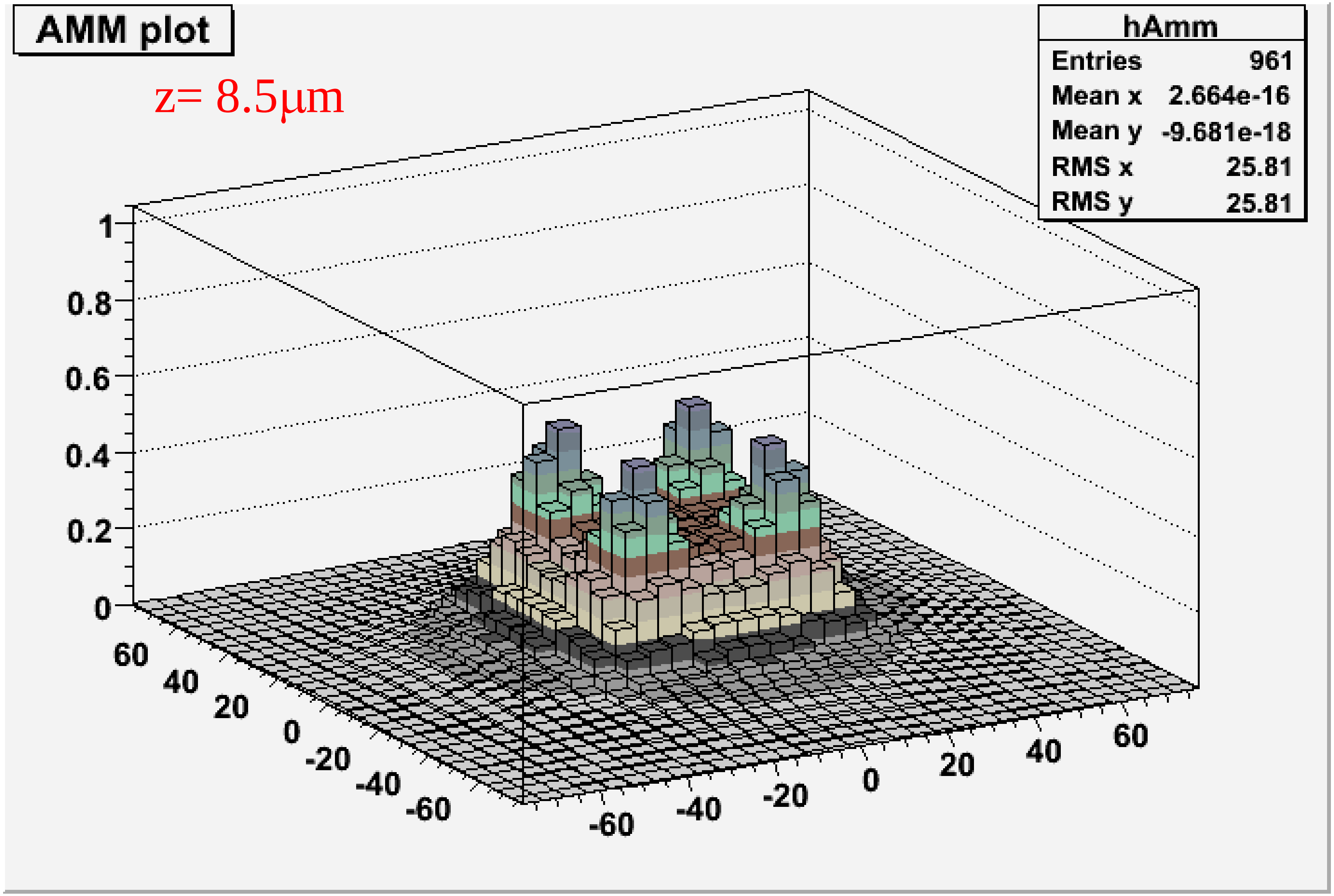


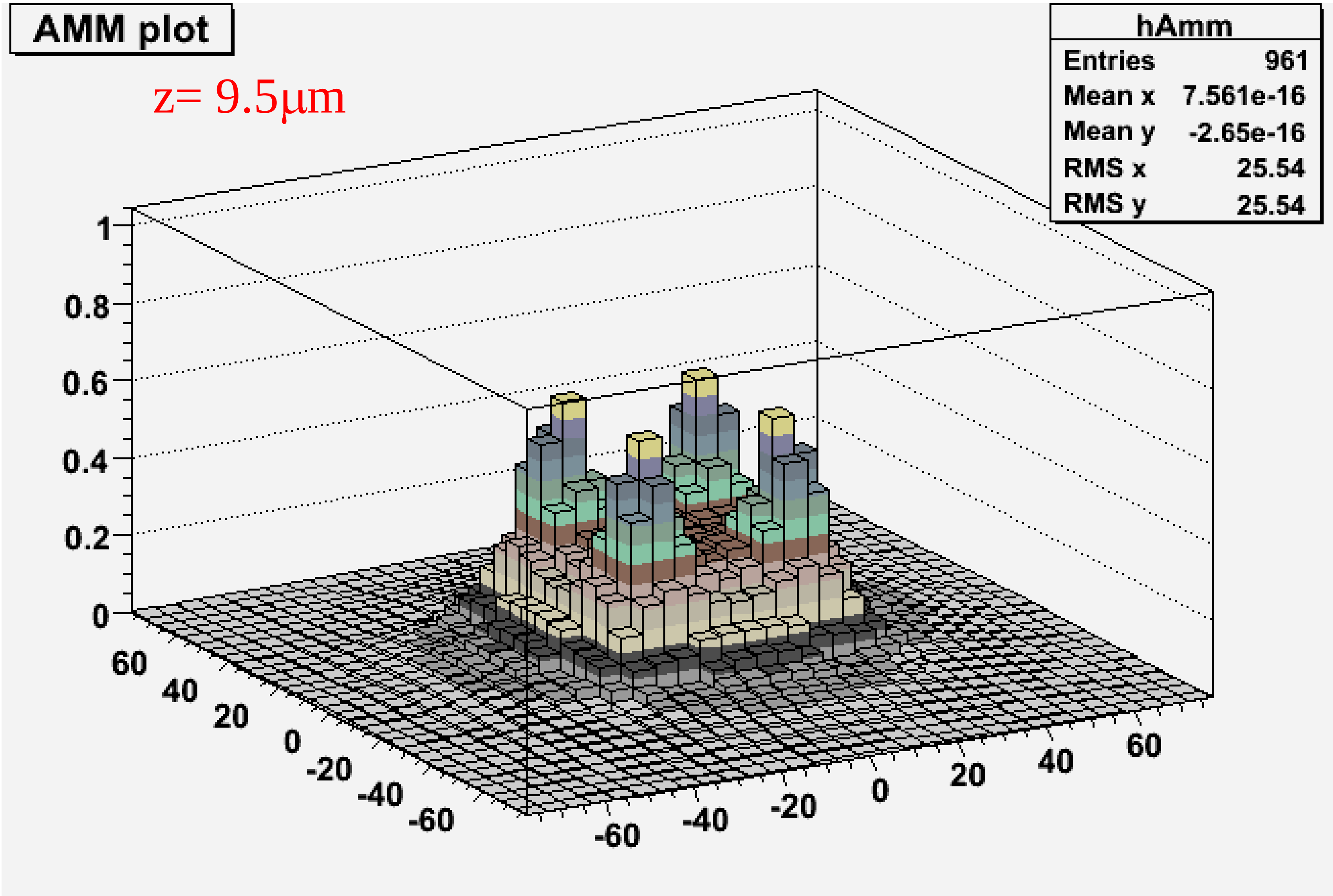
Depth dependence



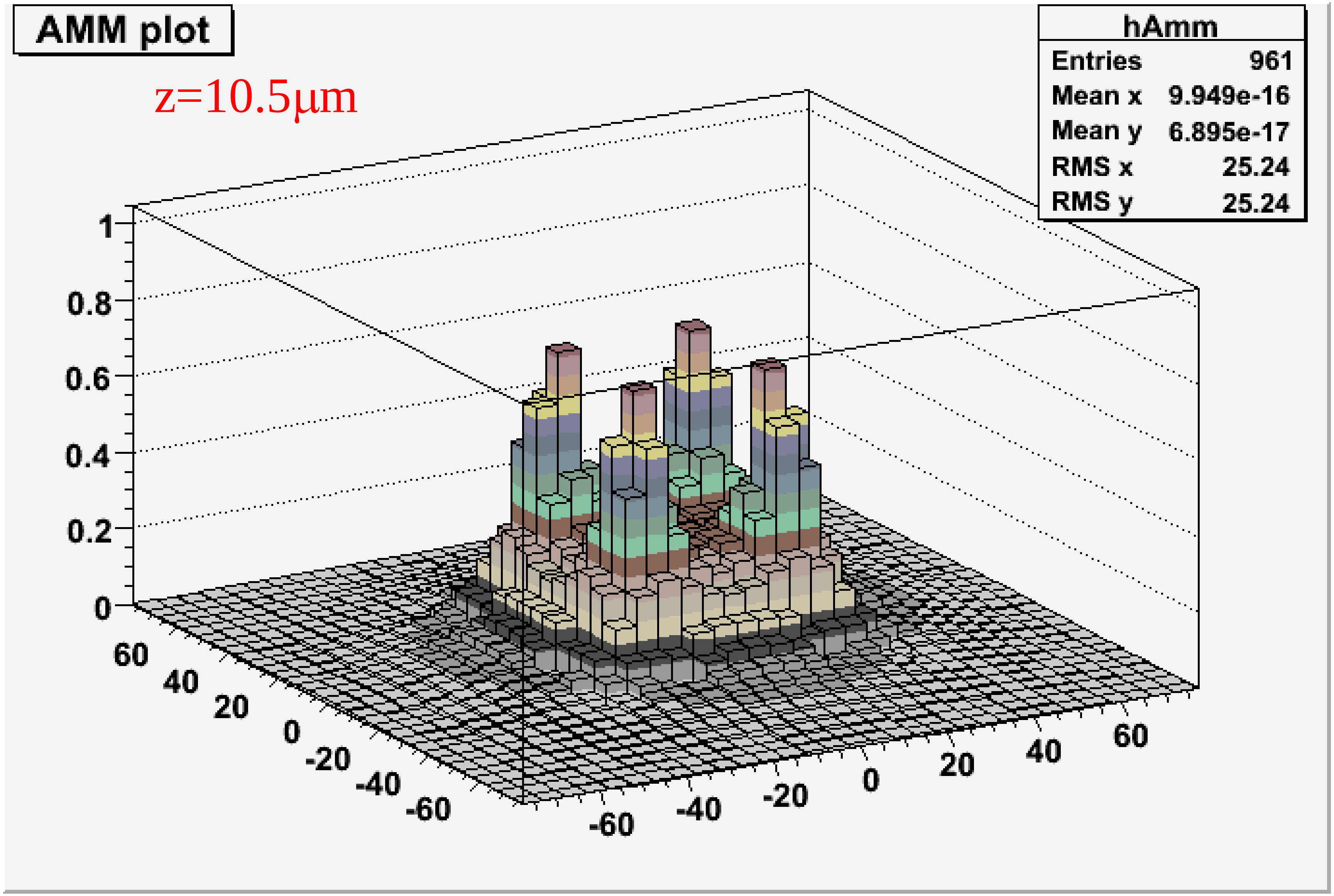
Depth dependence



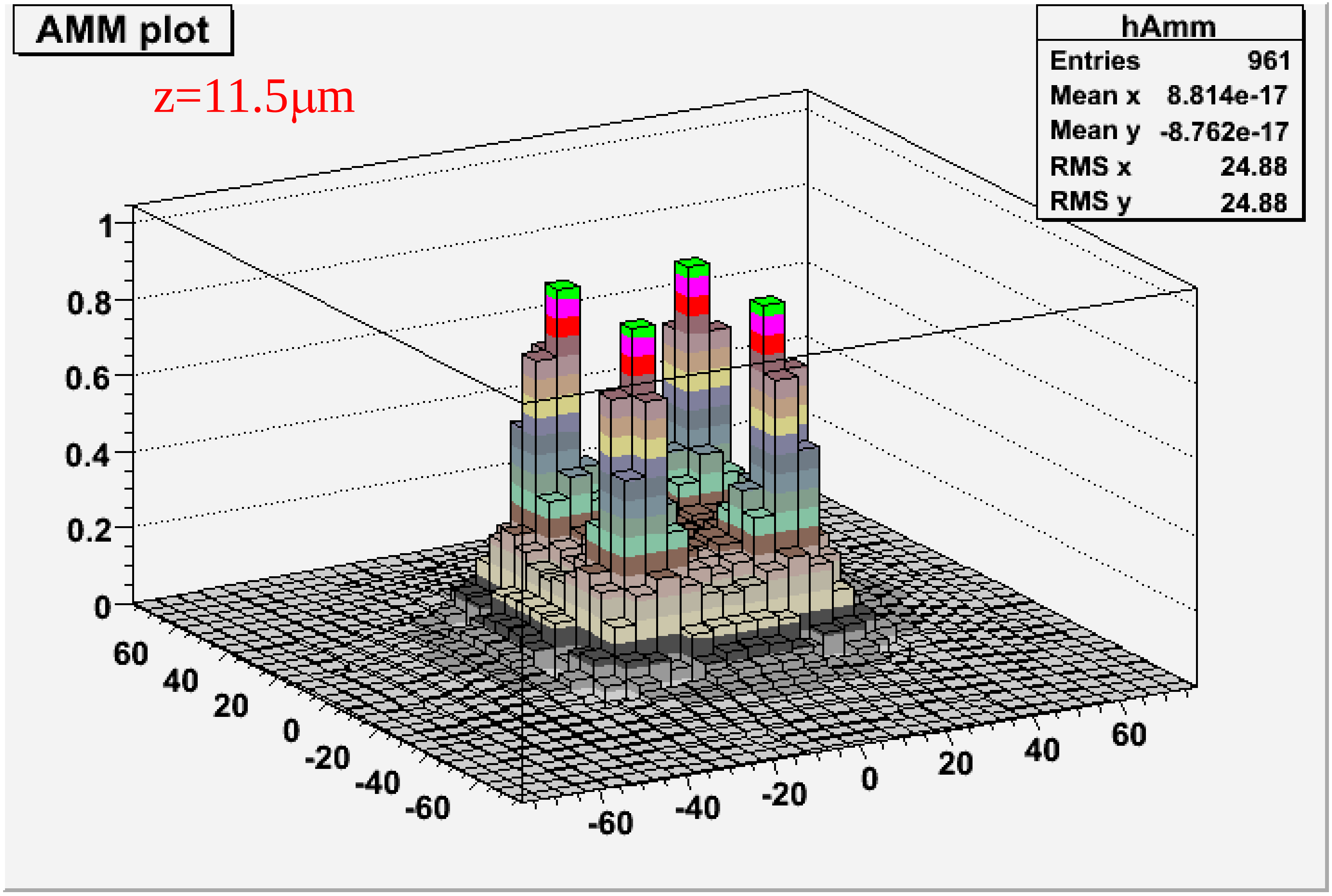
Depth dependence



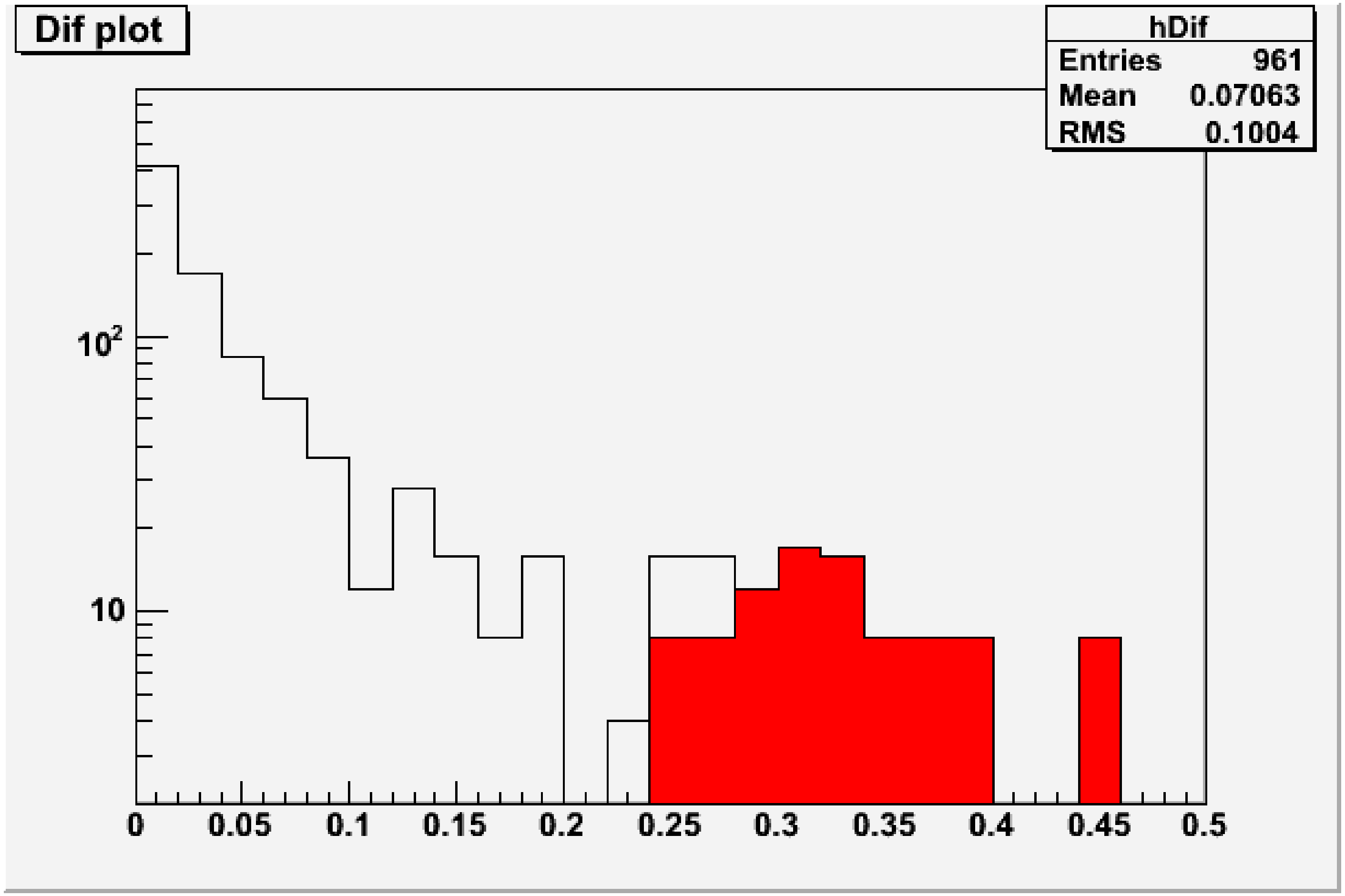
Depth dependence



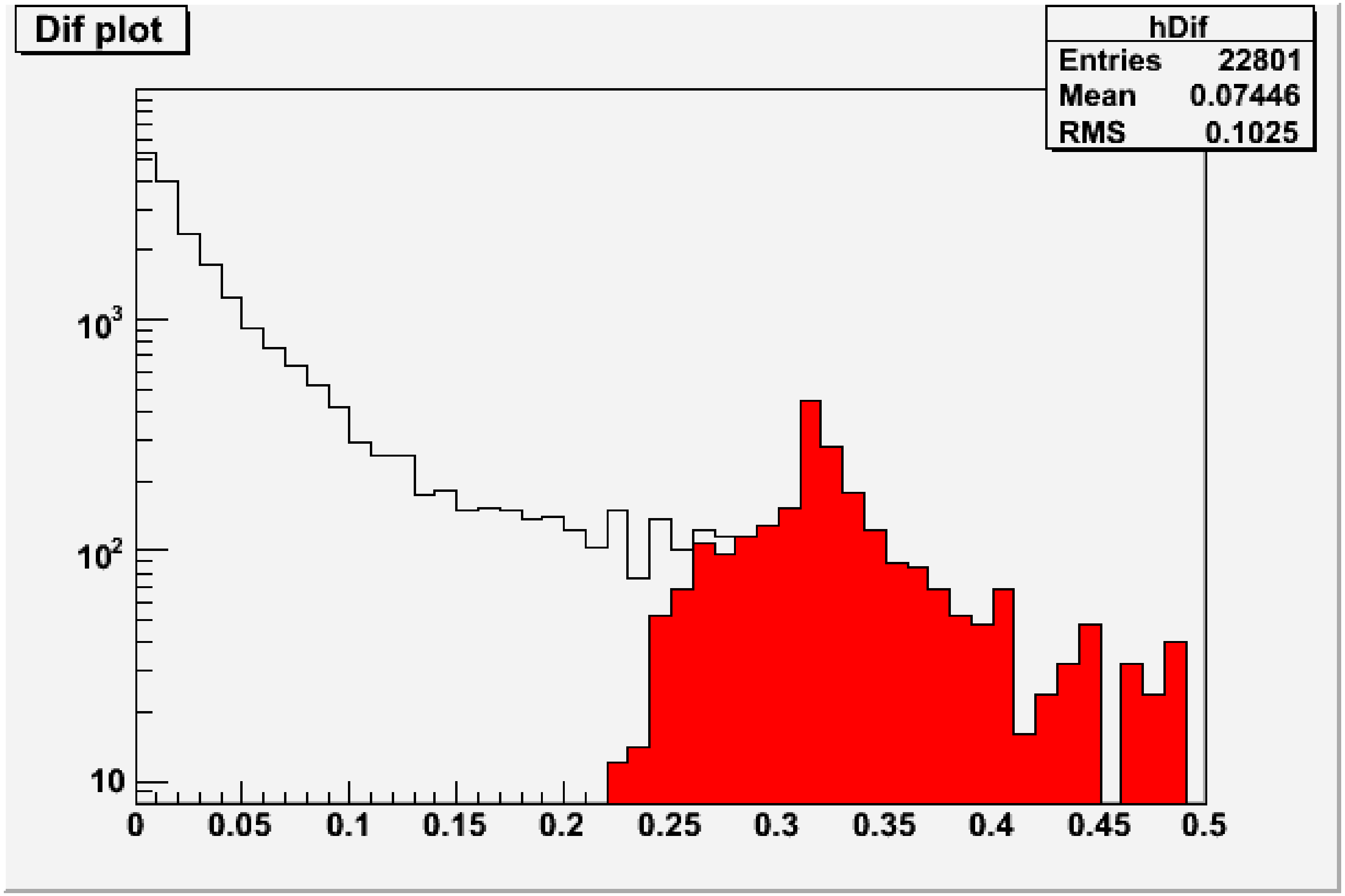
Depth dependence



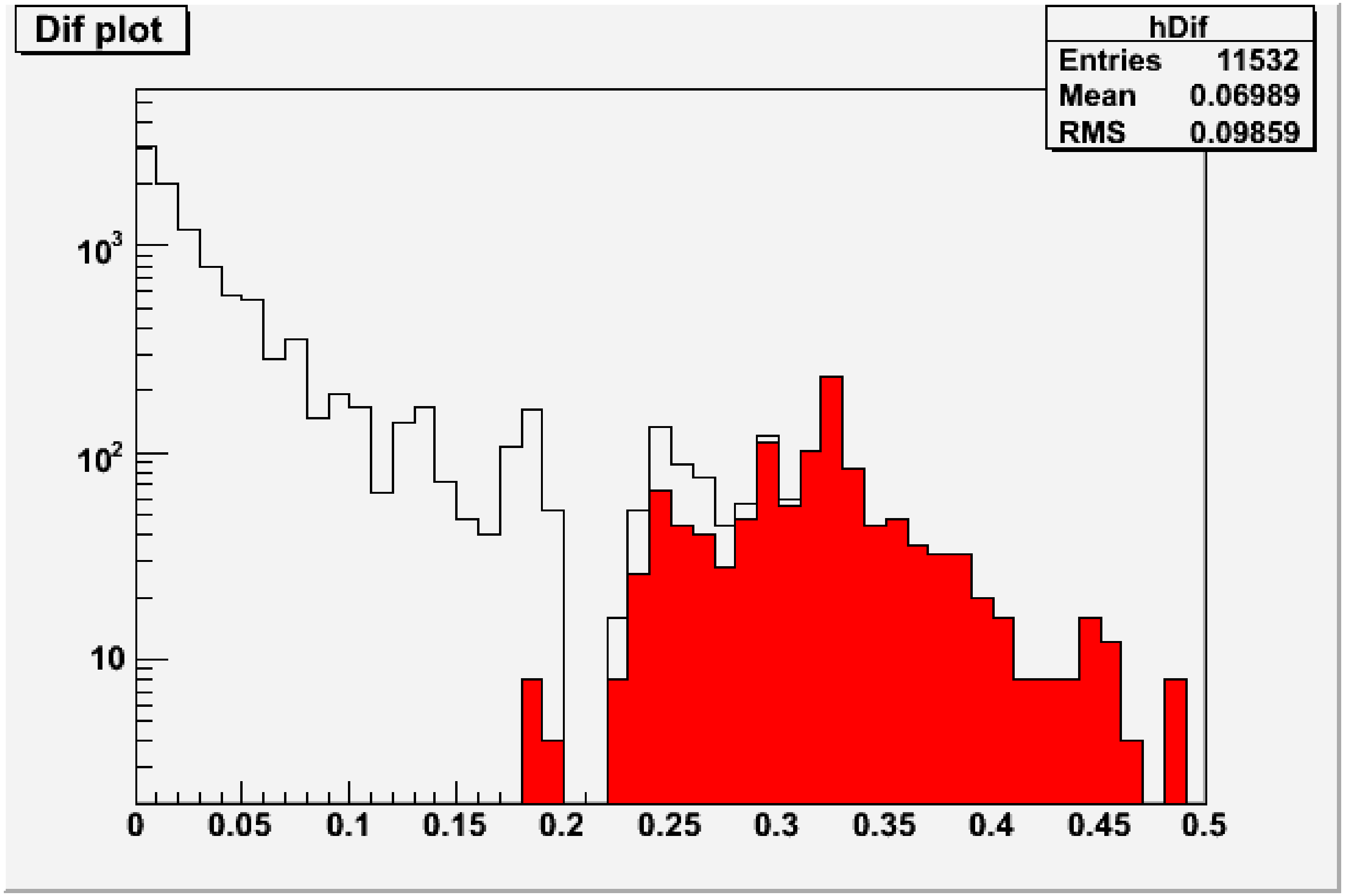
Fractional spectrum 5μm with MIP-like z



Fractional spectrum 1μm with MIP-like z

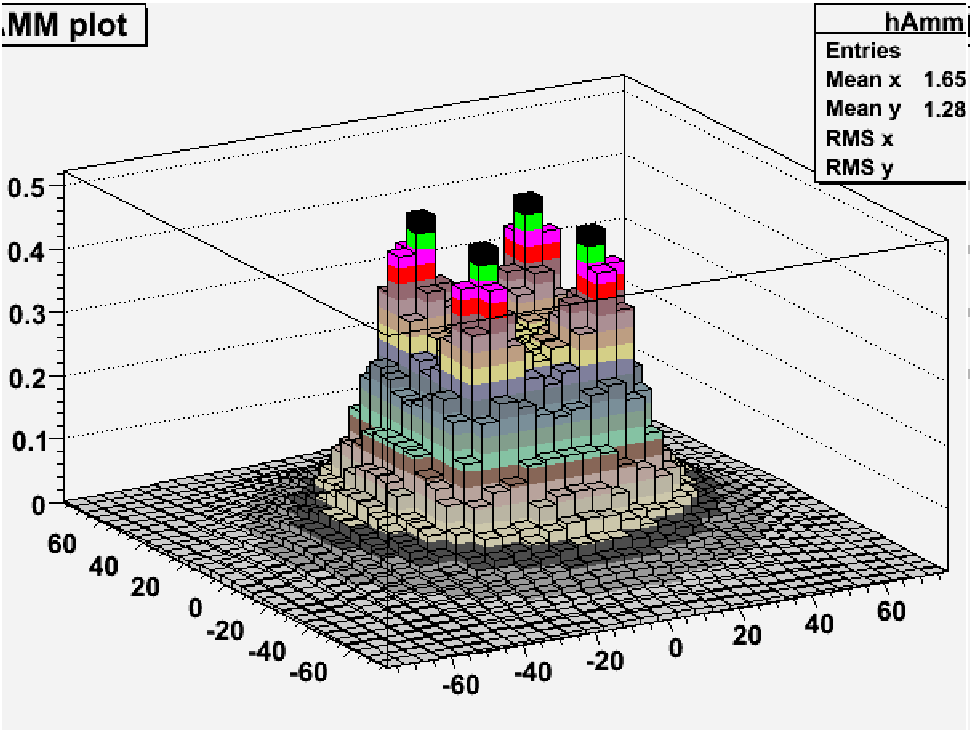


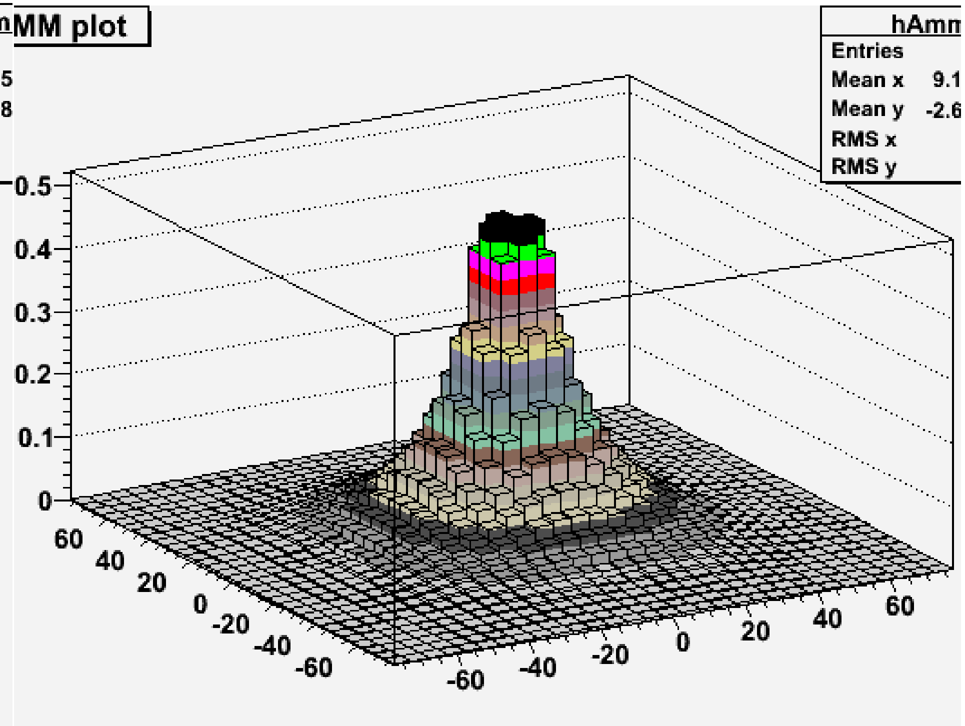
Fractional spectrum 5μm with ^{55}Fe-like z



- Still shows peak but details differ
- Need to do 351 points in xy ×12 points in z
    - Around ~ 2 weeks saturated running

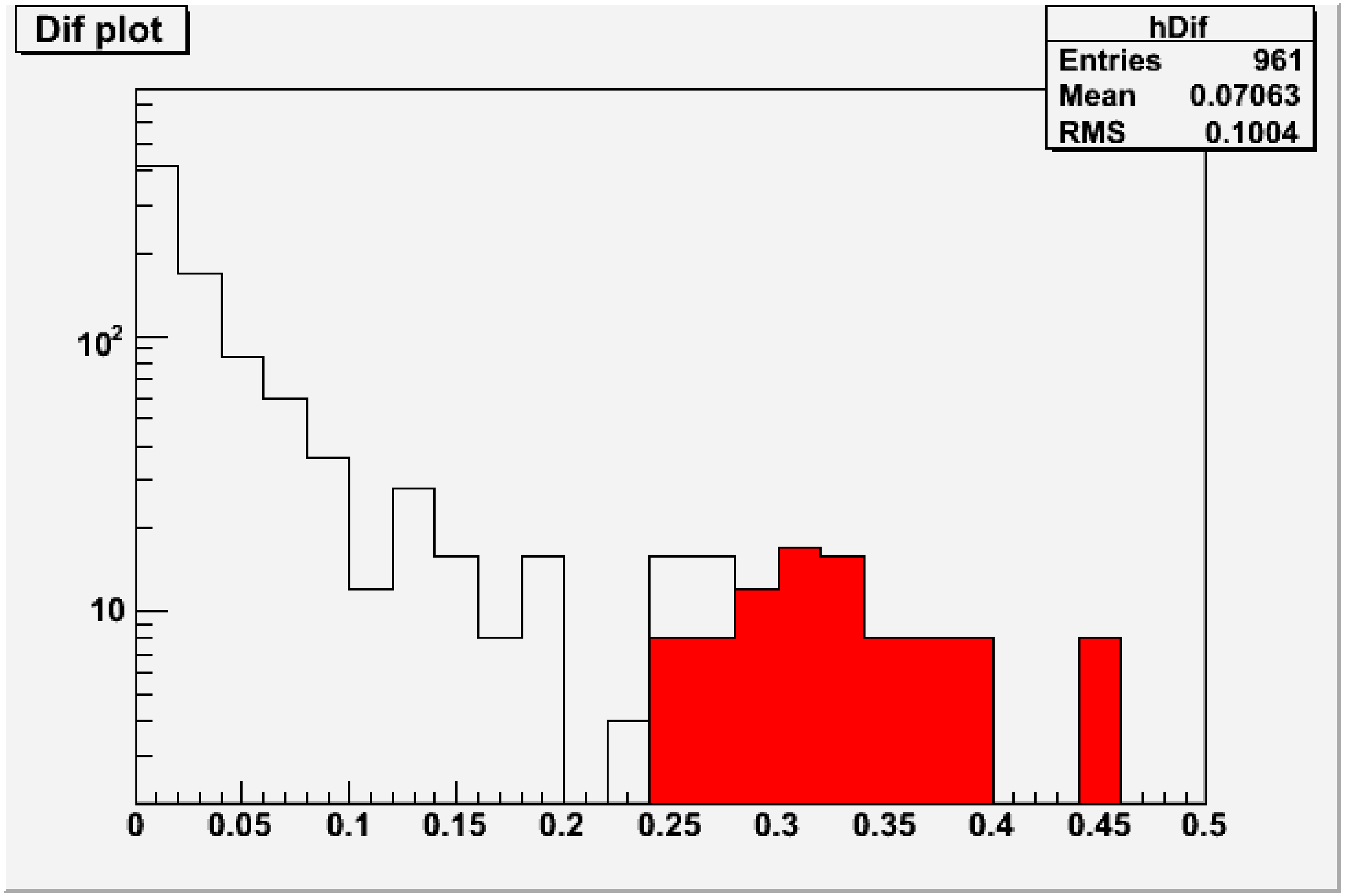
Comparison with single diode



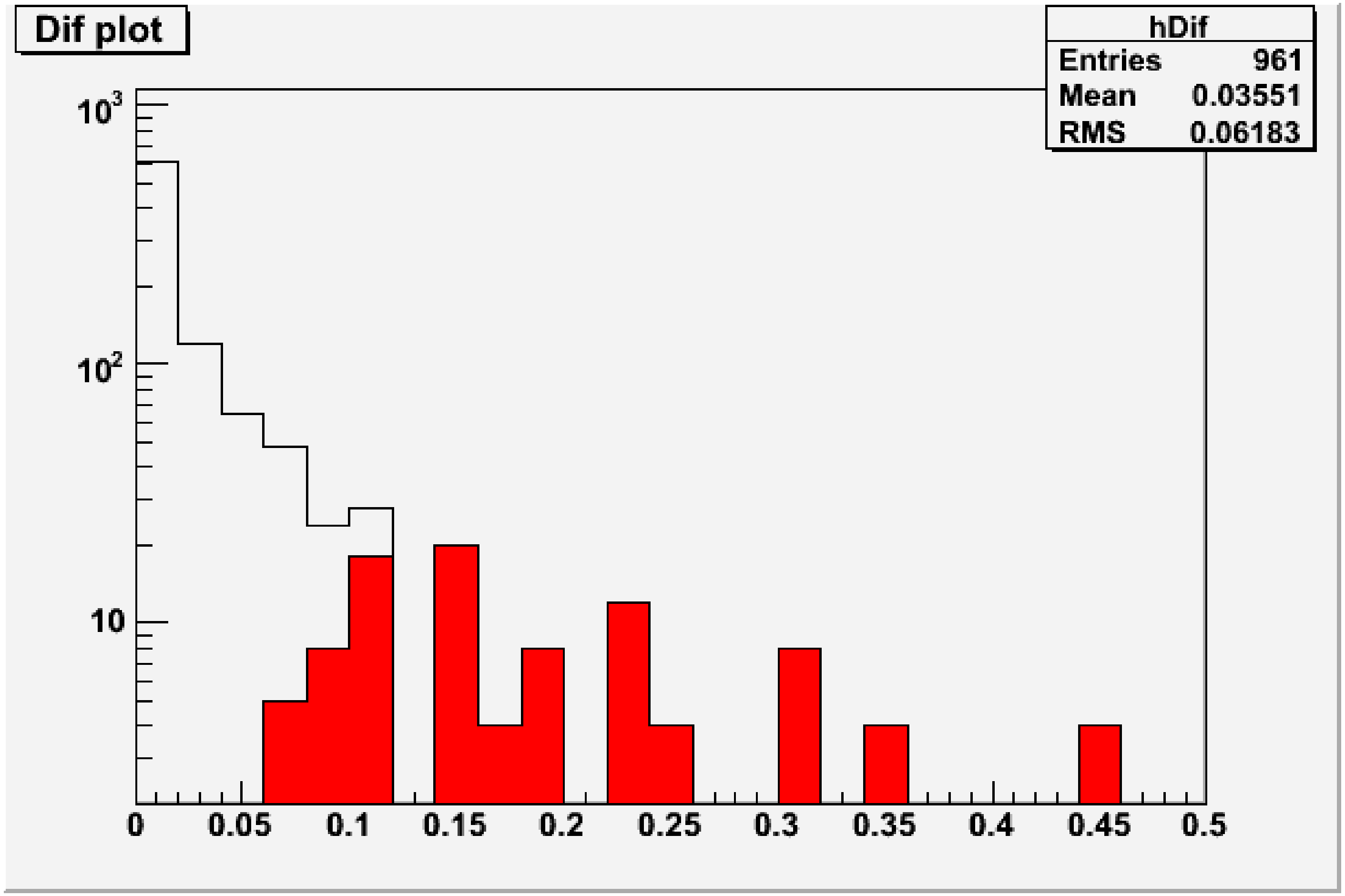


- Simple model; $6 \times 6 \mu m^2$ diode in centre of $50 \times 50 \mu m^2$ pixel
- Most of the rest of the pixel is n-well with deep p-well
  - Absorption parameters have same values

Fractional spectrum 5μm for four diodes



Fractional spectrum 5μm for single diode



- Average fraction seen in centre pixel ~half of four diode average

Conclusions

- The peak at ~0.3 of the charge seems to be reproducible
  - Details vary so exact position is not reliably known
  - Shows up in both MIP-like and ^{55}Fe-like deposits
- There is a significant dependence on the z depth of the charge deposited
  - Charge from the bottom of the epitaxial layer is not all lost by transverse diffusion to other pixels
  - Implies a thicker epitaxial layer would increase signal size
- A single diode may give ~0.5 of the signal of four diodes
  - Very preliminary; geometry parameters are not fixed
  - Would need full GDS-based simulation to cross-check a few points