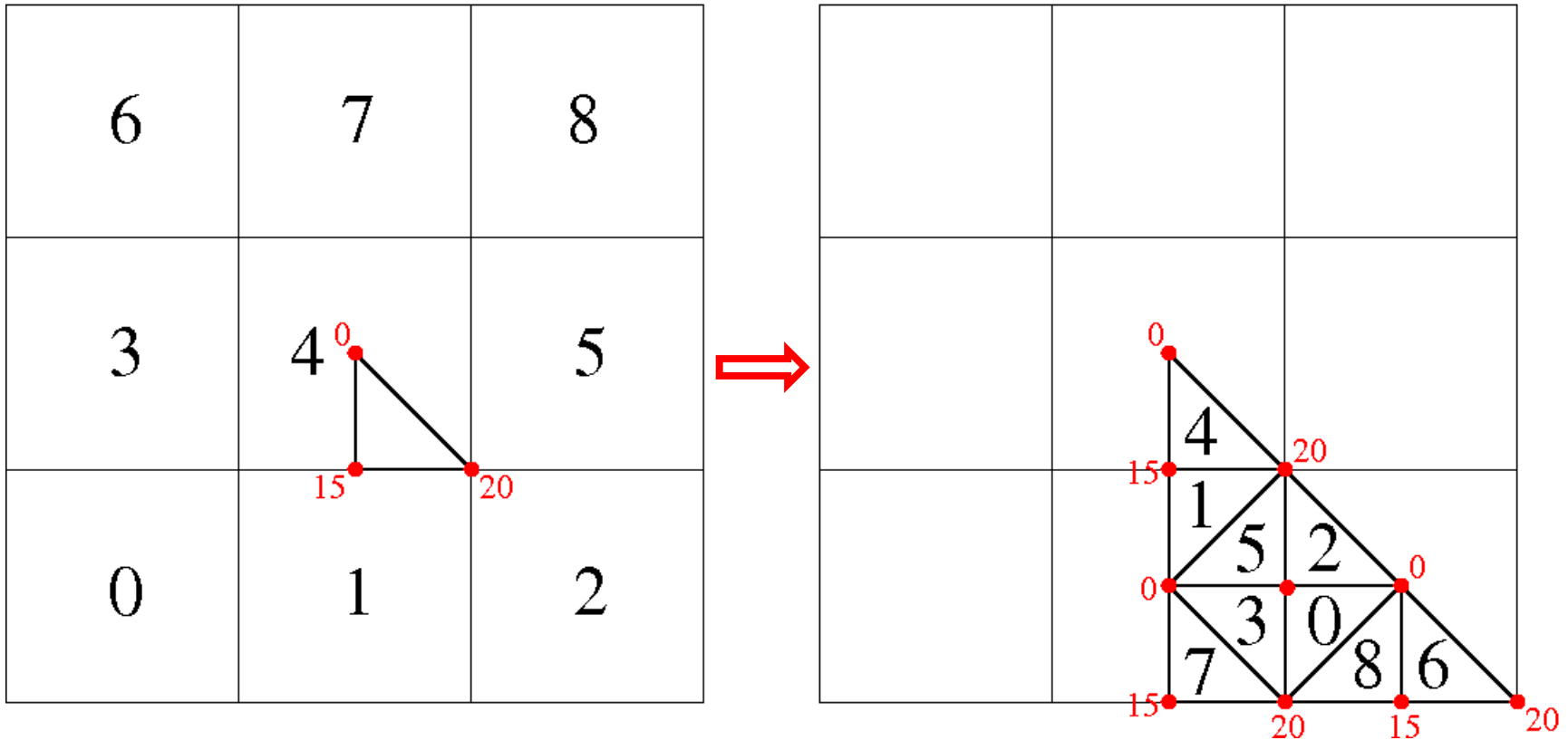

Charge diffusion model results

Paul Dauncey

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

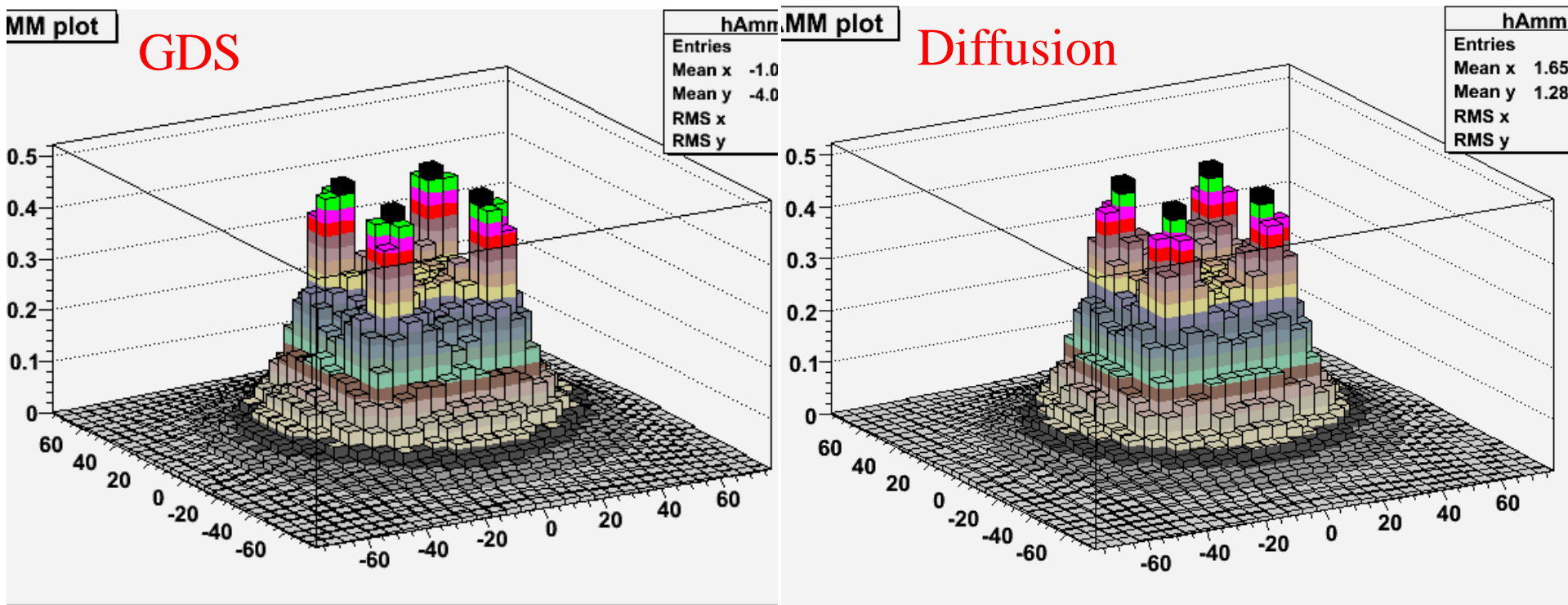
- Basic equations
 - Charge conservation: $\delta\rho/\delta t + \nabla \cdot \mathbf{j} = 0$ (so no recombination)
 - Diffusive movement: $\mathbf{j} = -k\nabla\rho$ where k is the diffusion constant
- These can be combined to give $\delta\rho/\delta(kt) = \nabla^2\rho$
 - Time scaled by k , so no absolute timescale
- Work with 5×5 pixel grid and looks at charge in central 3×3 pixels
 - 50 50 points per pixel, each $1\times 1\mu\text{m}^2$; factor 2.5 finer than previous results
- Divide epitaxial depth with same cell size
 - 12 points, each $12\mu\text{m}/12 = 1\mu\text{m}$; 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



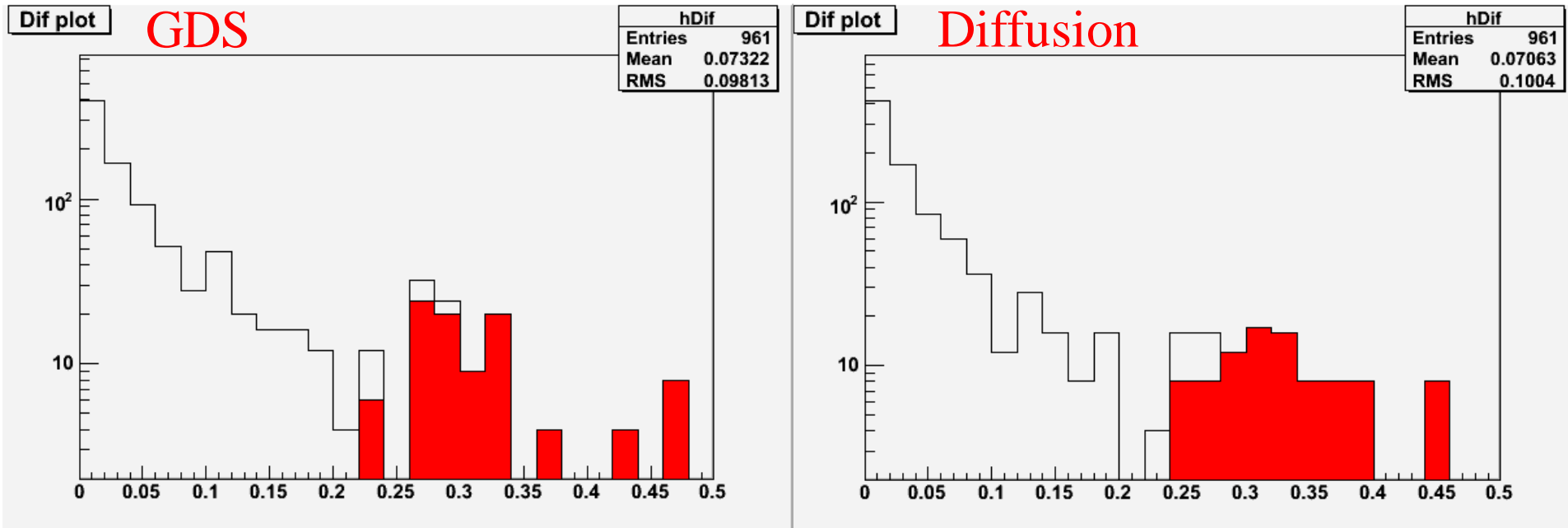
- Giulio's 21 points in triangle \times 9 pixels = 189 values
- 136 independent points after averaging
- Reflections/translations copy these to 900 points
 - Most (but not edges/corners) duplicated 8 times

GDS (Giulio) vs diffusion model



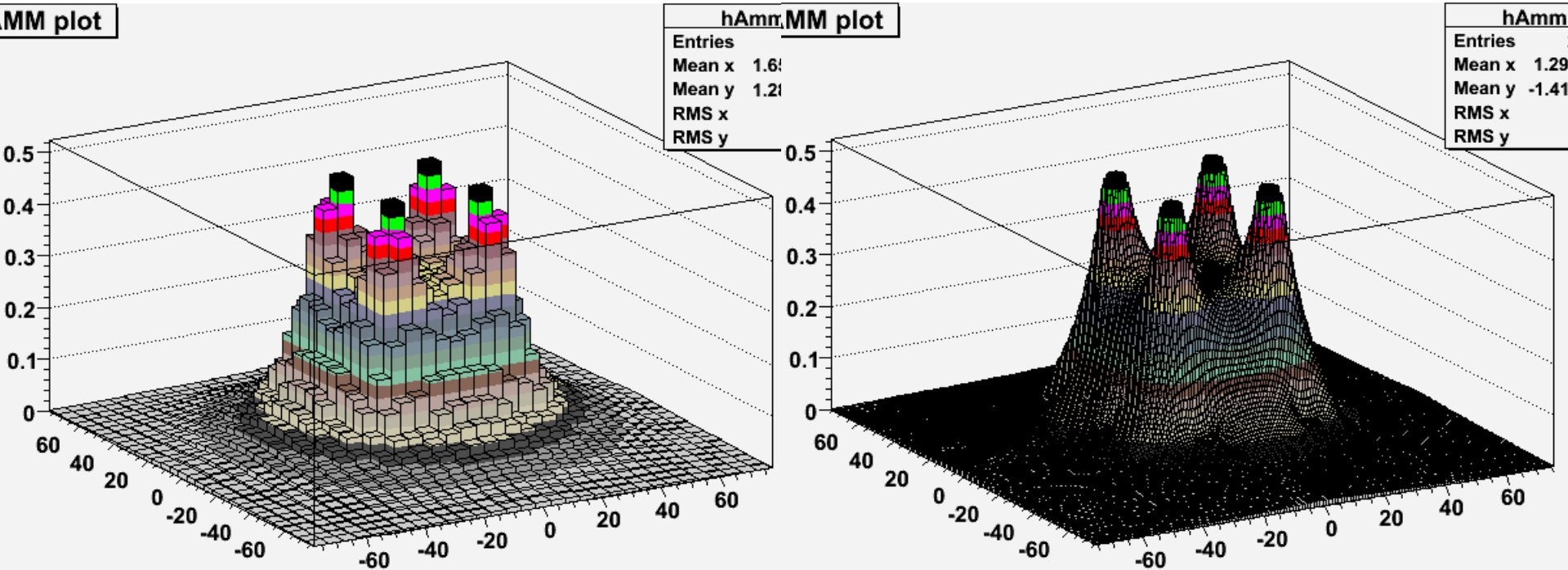
- Two parameters to tune using centre point #0
 - Absorption of diodes: use GDS “perfect deep p-well”; gives 44%
 - Absorption of n-well with deep p-well: use full GDS; gives 31%
- All other points then determined from diffusion

Fractional charge spectra for models



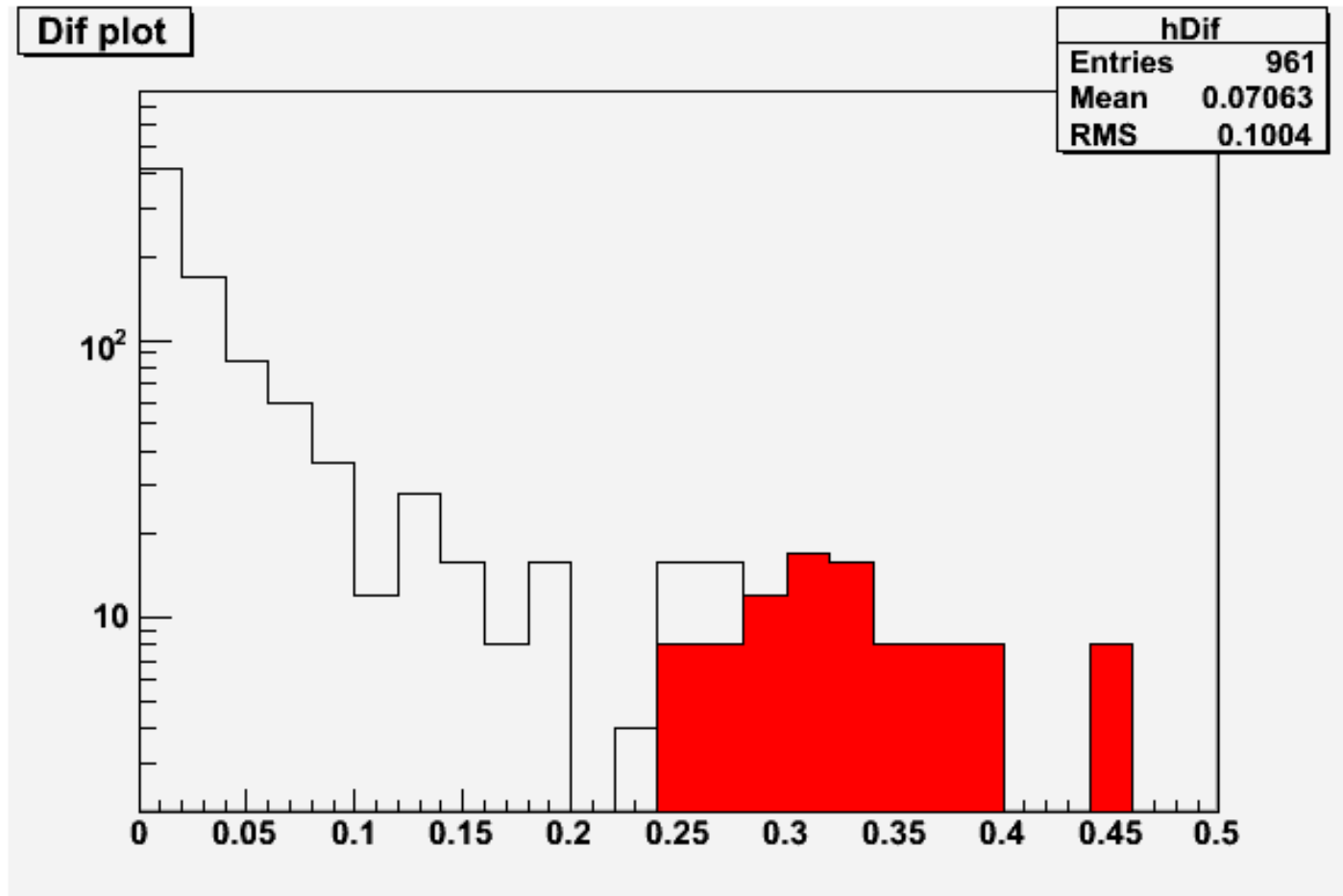
- Fraction of charge seen in centre pixel for uniform deposits over 3×3 pixel array
 - MIP-like spread in z direction
- Red shows distribution in centre pixel
 - Corresponds to distribution of maximum signal if reading all pixels
- Suggestion of peak at charge fraction ~ 0.3 ?

Scale up from $5\mu\text{m}$ to $1\mu\text{m}$ steps

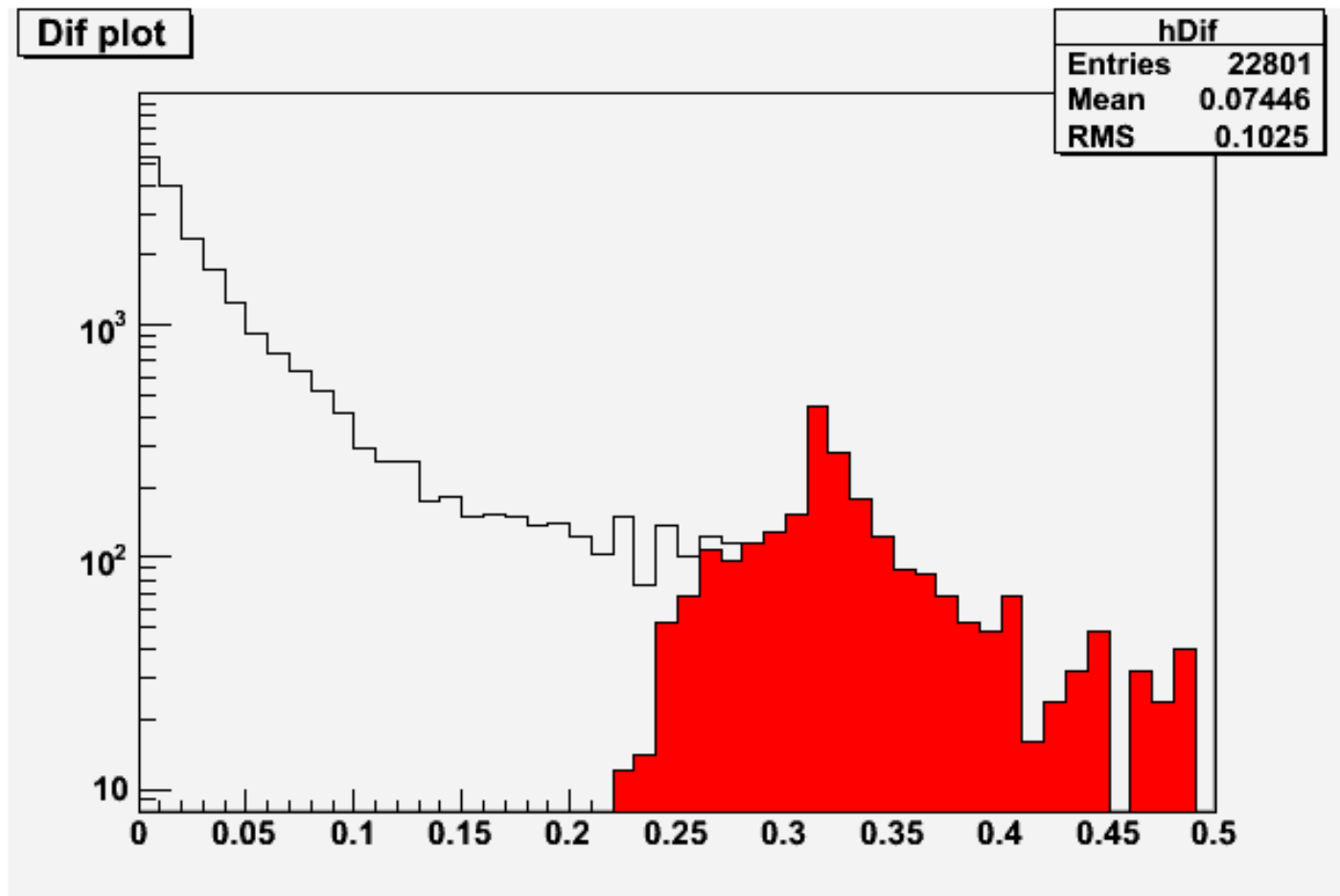


- $21 \rightarrow 351$ points in triangle $\times 9$ pixels = 3159 values
- $136 \rightarrow 2916$ independent points after averaging
- Copy these to $150 \times 150 = 22500$ points
 - Much larger fraction of points duplicated 8 times

Fractional charge spectrum for $5\mu\text{m}$ steps



Fractional charge spectrum for $1\mu\text{m}$ steps

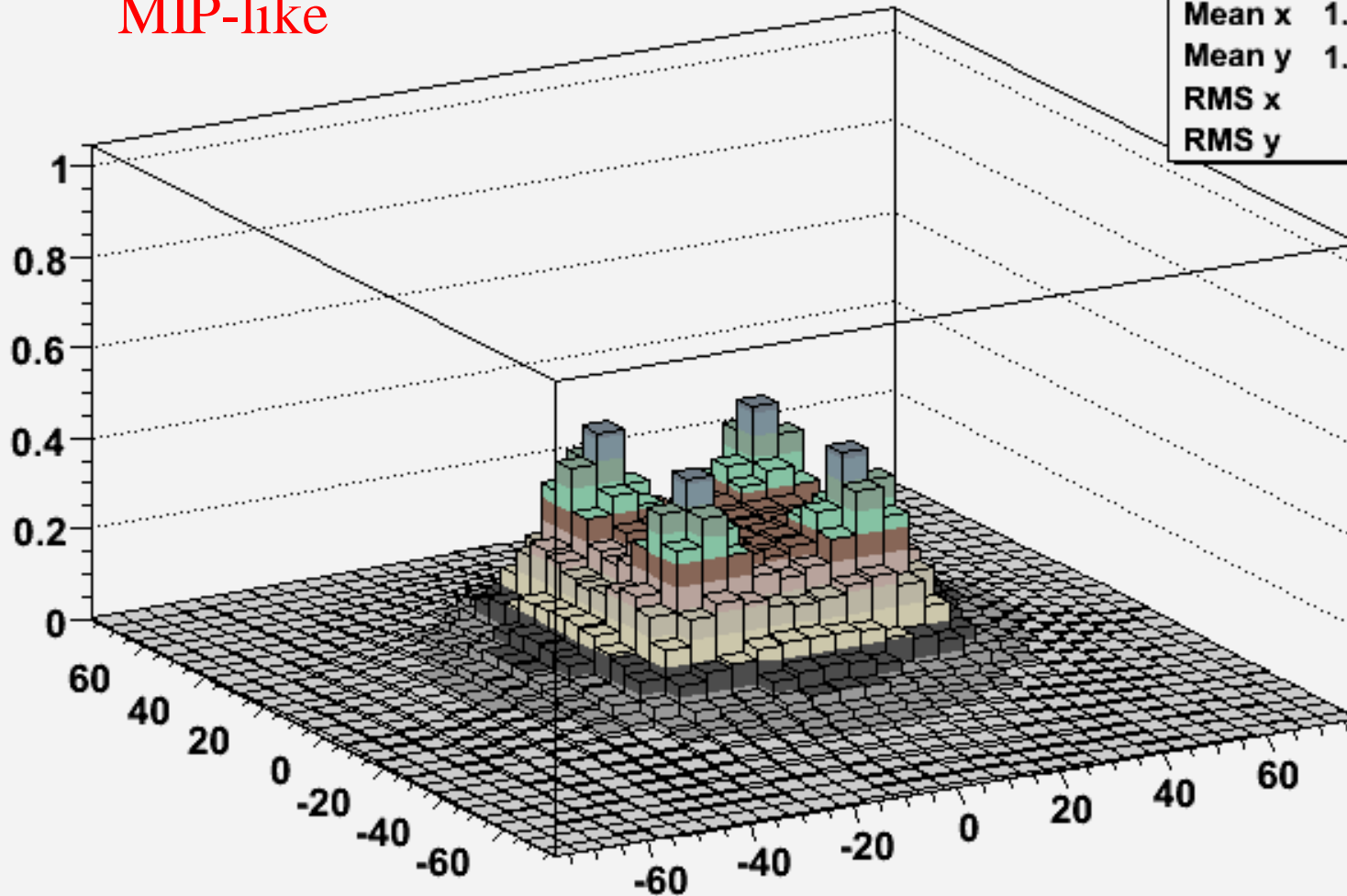


- Peak at fraction of ~ 0.32 of total charge; approx 3% of hits
- Results from wide flat region between pixels

Depth dependence

AMM plot

MIP-like

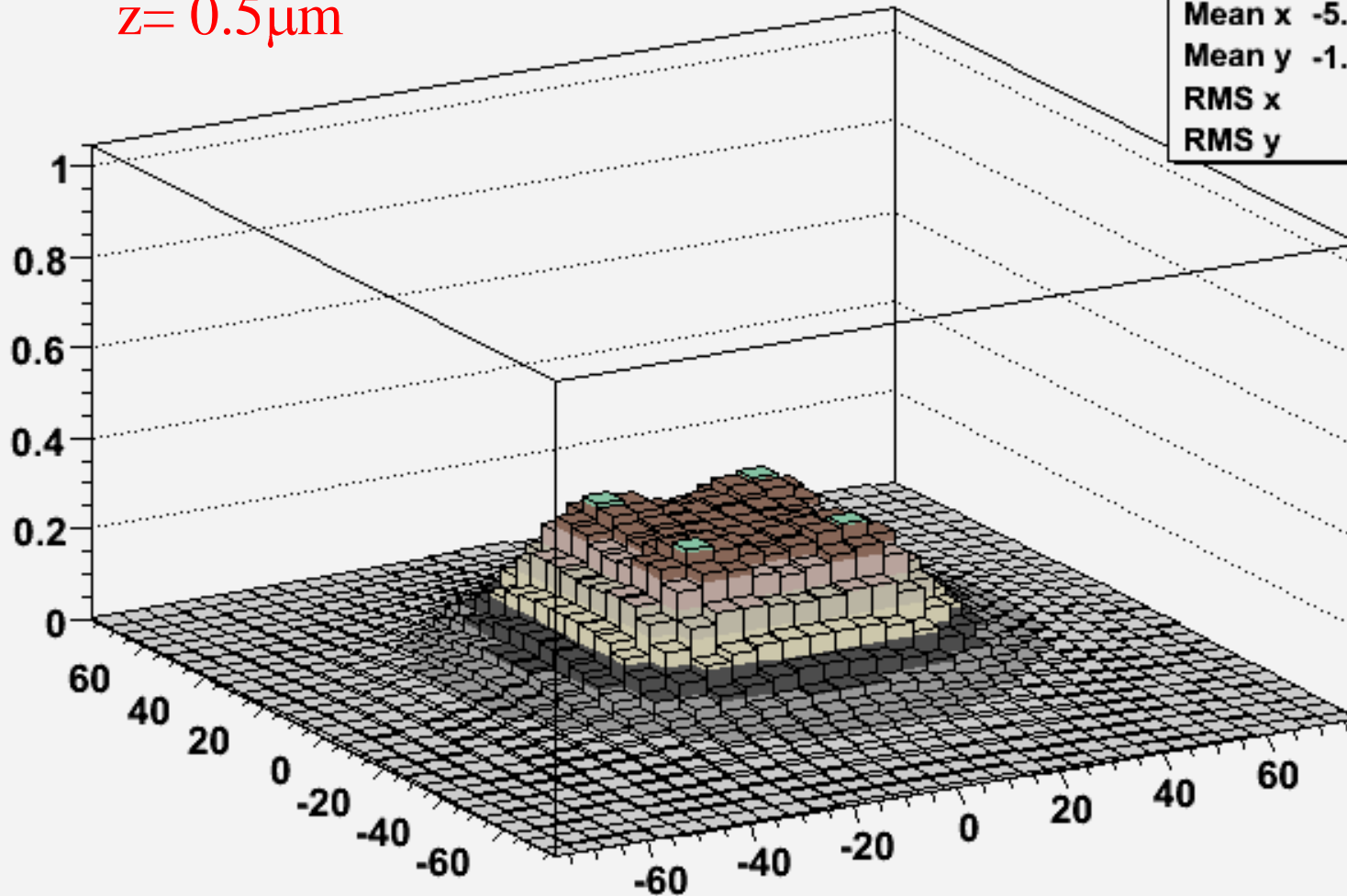


hAmm	
Entries	961
Mean x	1.659e-16
Mean y	1.288e-16
RMS x	26.17
RMS y	26.17

Depth dependence

AMM plot

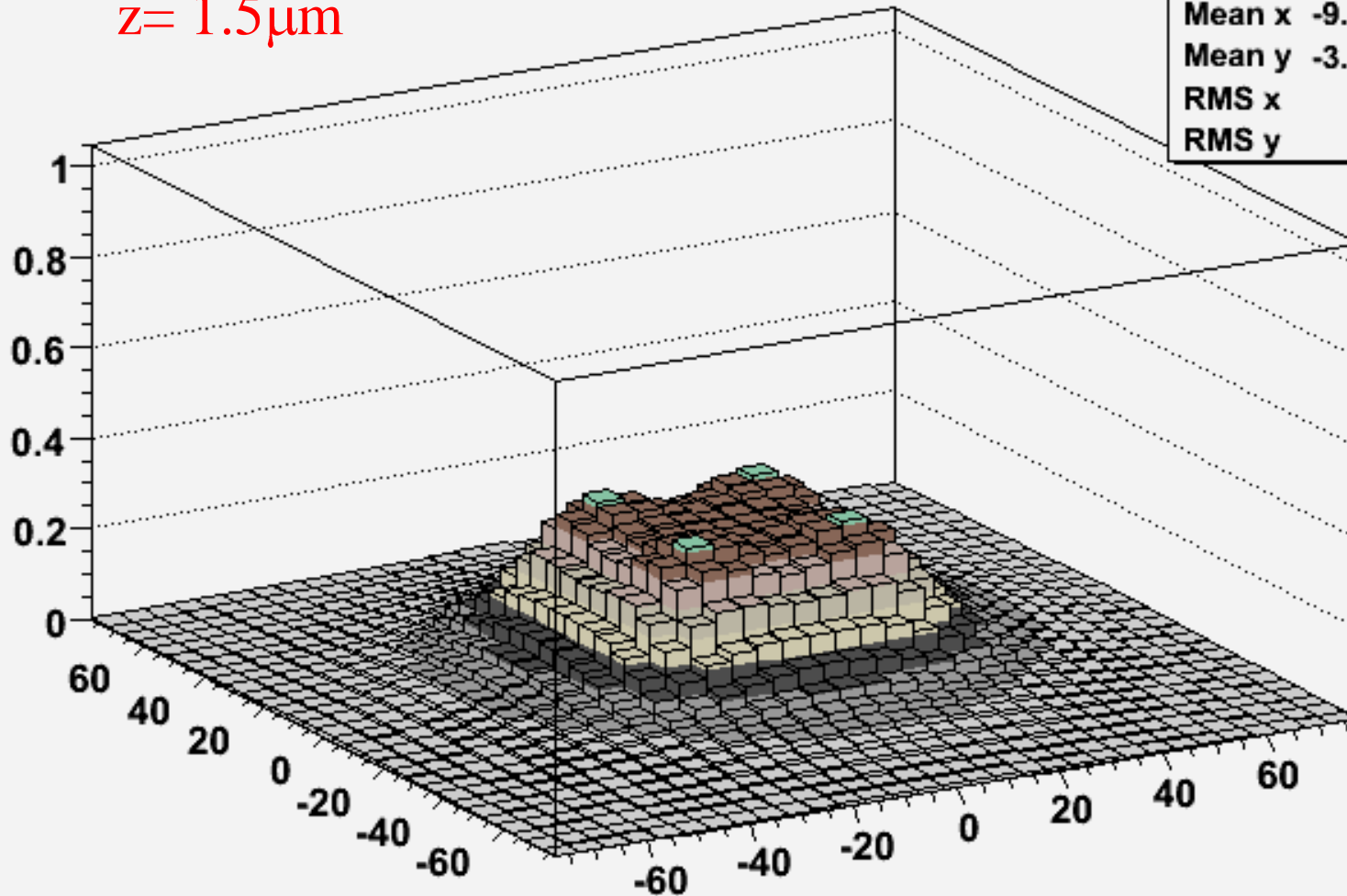
$z = 0.5\mu\text{m}$



Depth dependence

AMM plot

$z = 1.5\mu\text{m}$

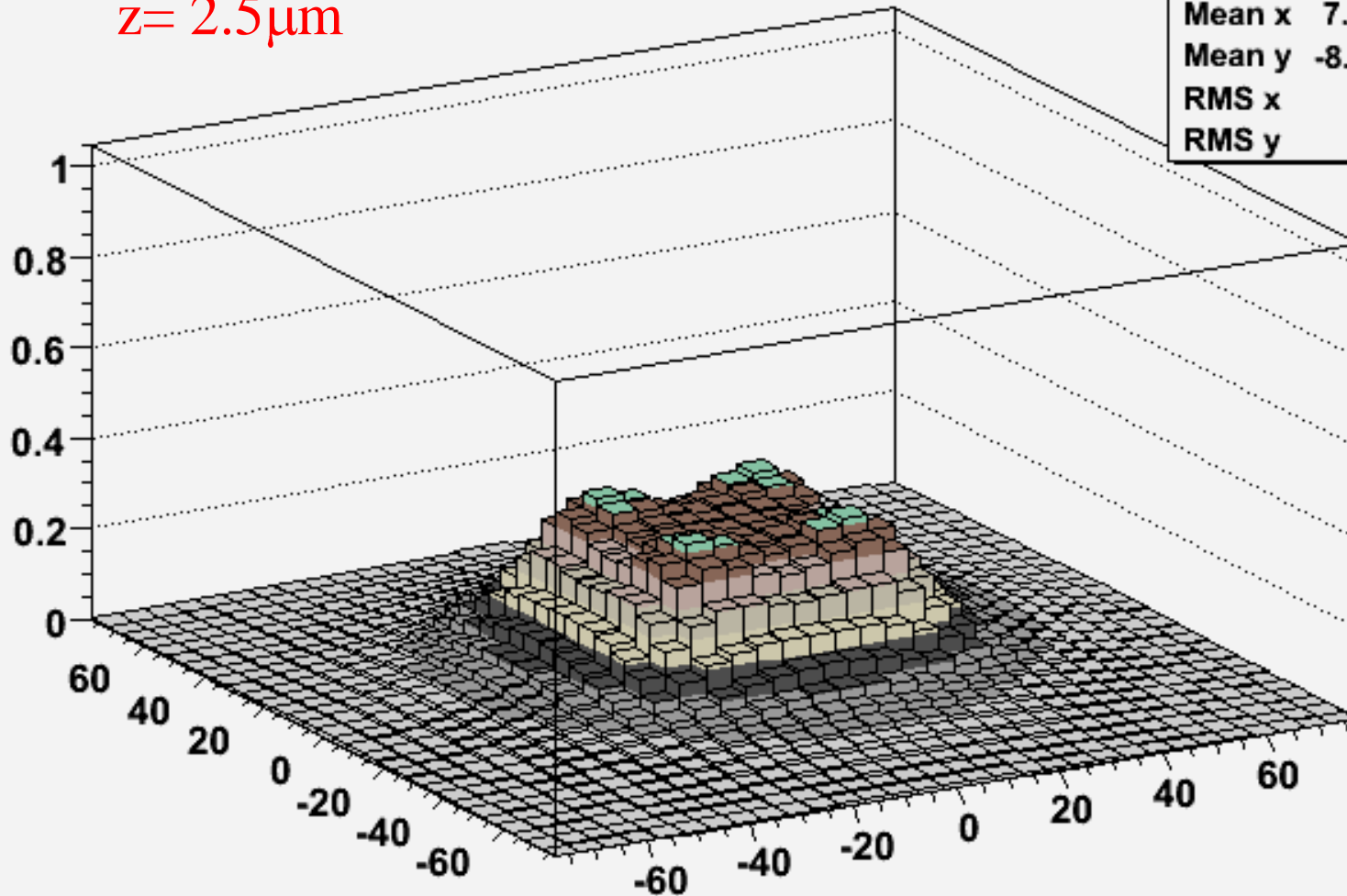


hAmm	
Entries	961
Mean x	-9.618e-16
Mean y	-3.187e-16
RMS x	26.83
RMS y	26.83

Depth dependence

AMM plot

$z = 2.5\mu\text{m}$

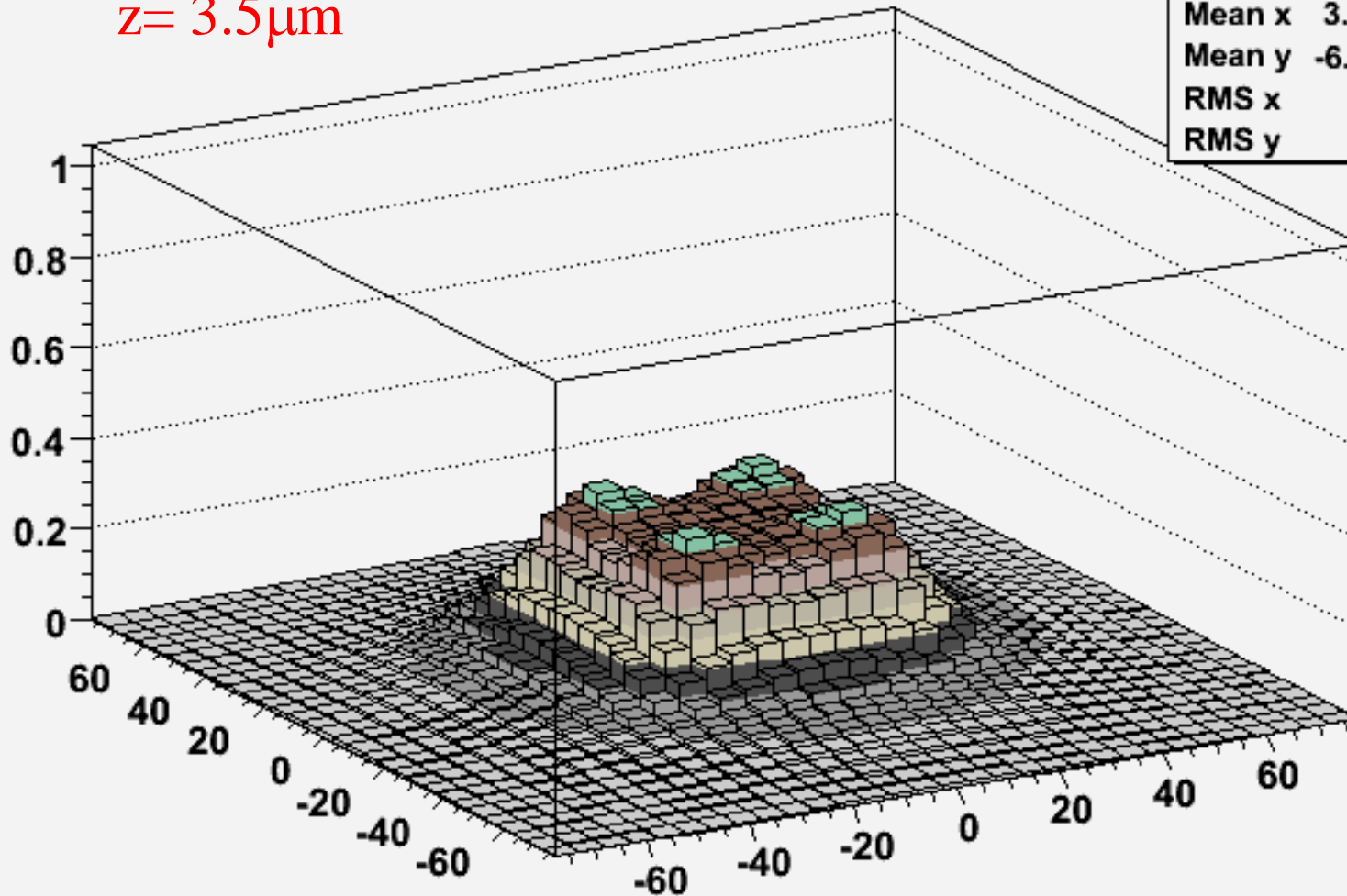


hAmm	
Entries	961
Mean x	7.382e-16
Mean y	-8.986e-17
RMS x	26.77
RMS y	26.77

Depth dependence

AMM plot

$z = 3.5\mu\text{m}$

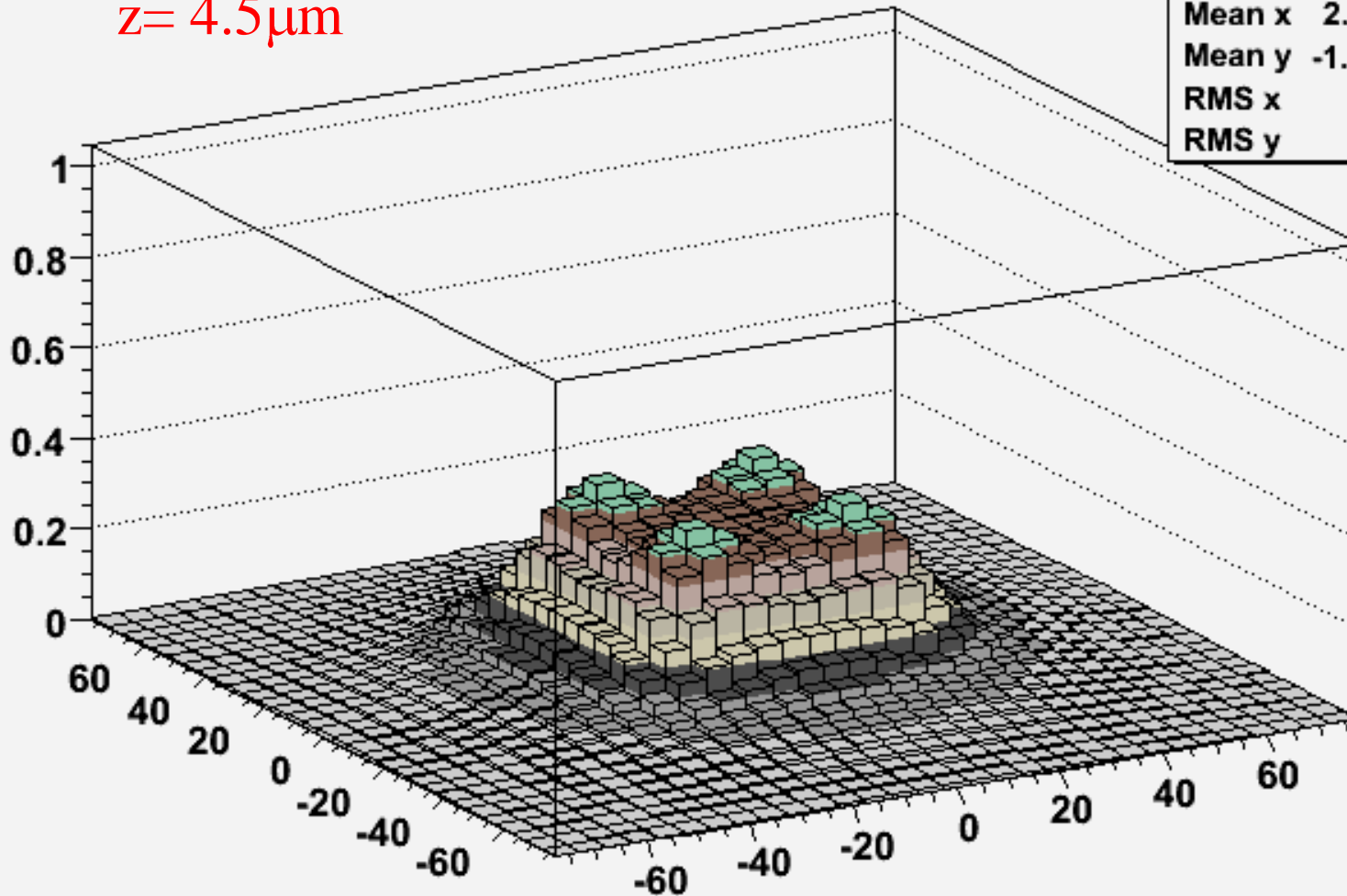


hAmm	
Entries	961
Mean x	3.577e-16
Mean y	-6.056e-17
RMS x	26.69
RMS y	26.69

Depth dependence

AMM plot

$z = 4.5\mu\text{m}$



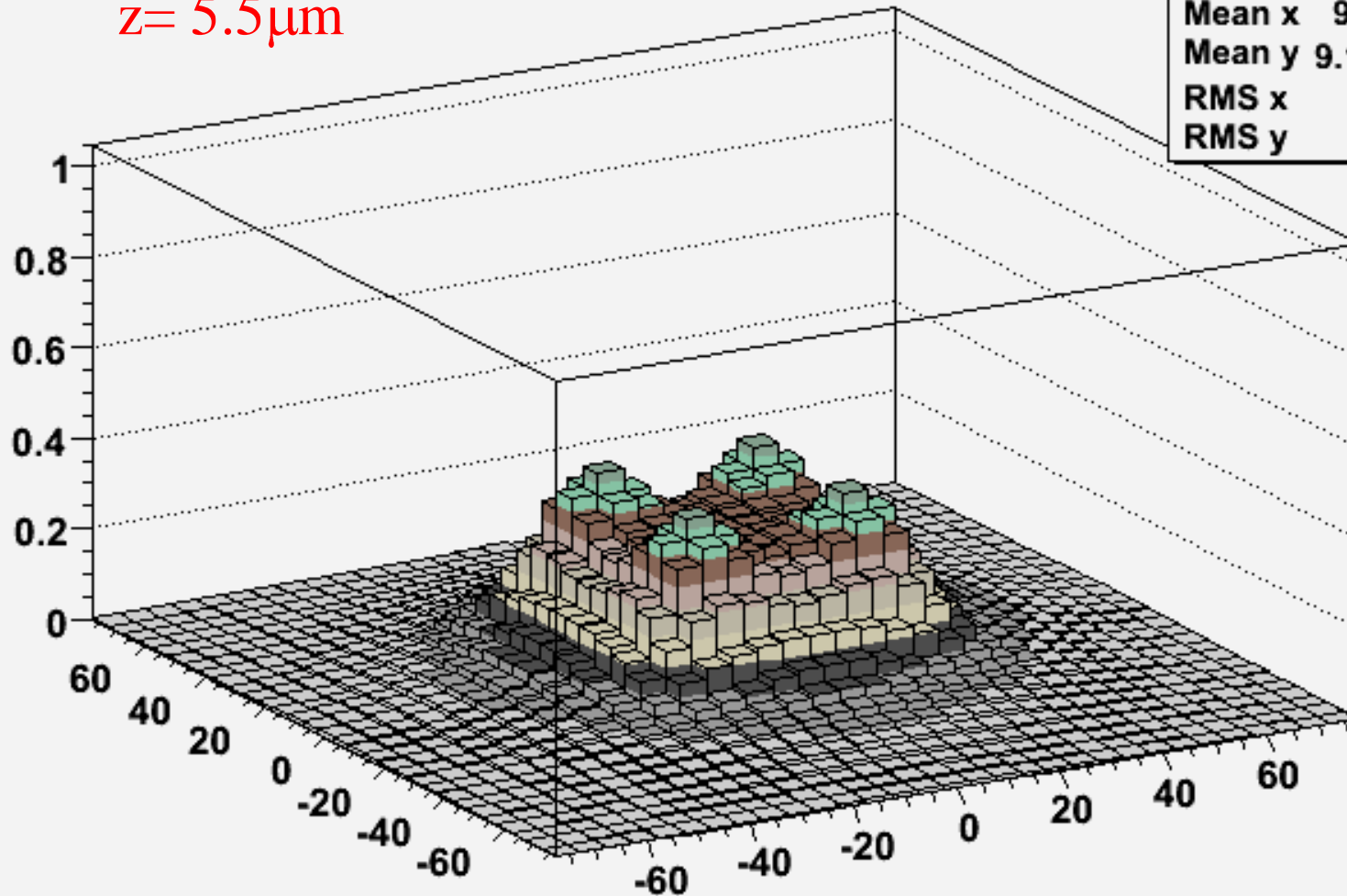
hAmm	
Entries	961
Mean x	2.958e-17
Mean y	-1.966e-16
RMS x	26.57
RMS y	26.57

Depth dependence

AMM plot

$z = 5.5\mu\text{m}$

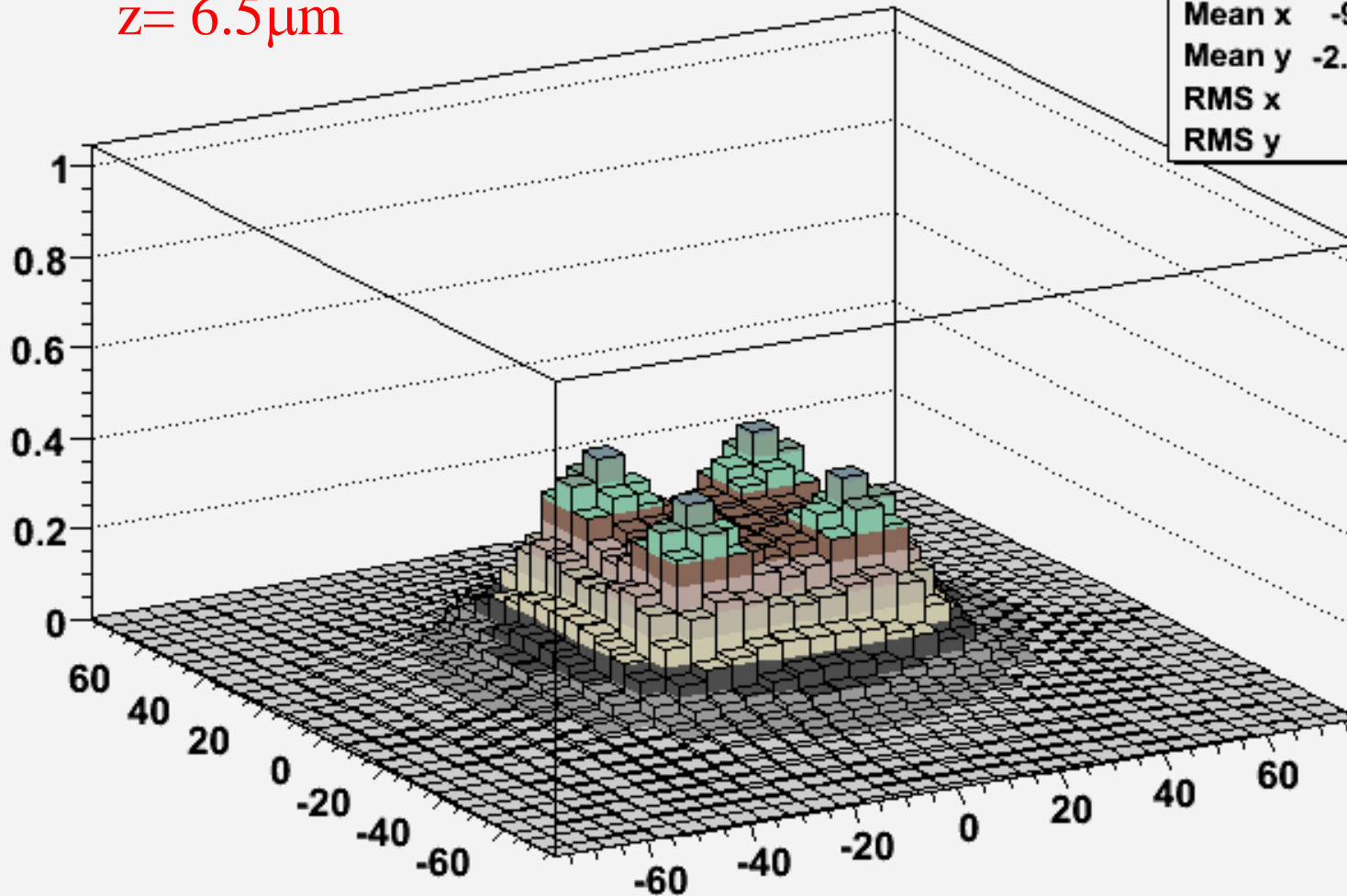
hAmm	
Entries	961
Mean x	9.87e-16
Mean y	9.113e-17
RMS x	26.43
RMS y	26.43



Depth dependence

AMM plot

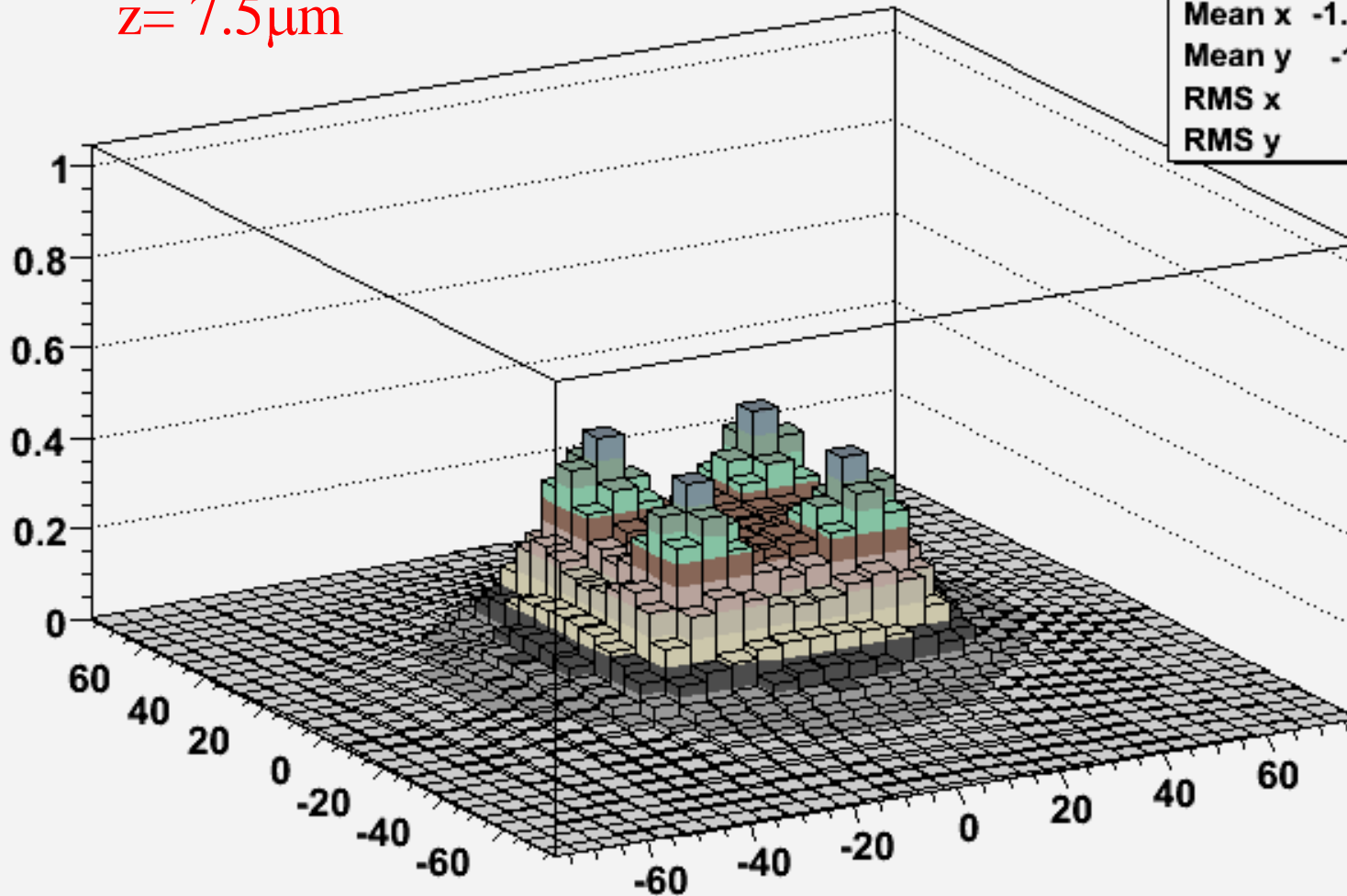
$z = 6.5\mu\text{m}$



Depth dependence

AMM plot

$z = 7.5\mu\text{m}$



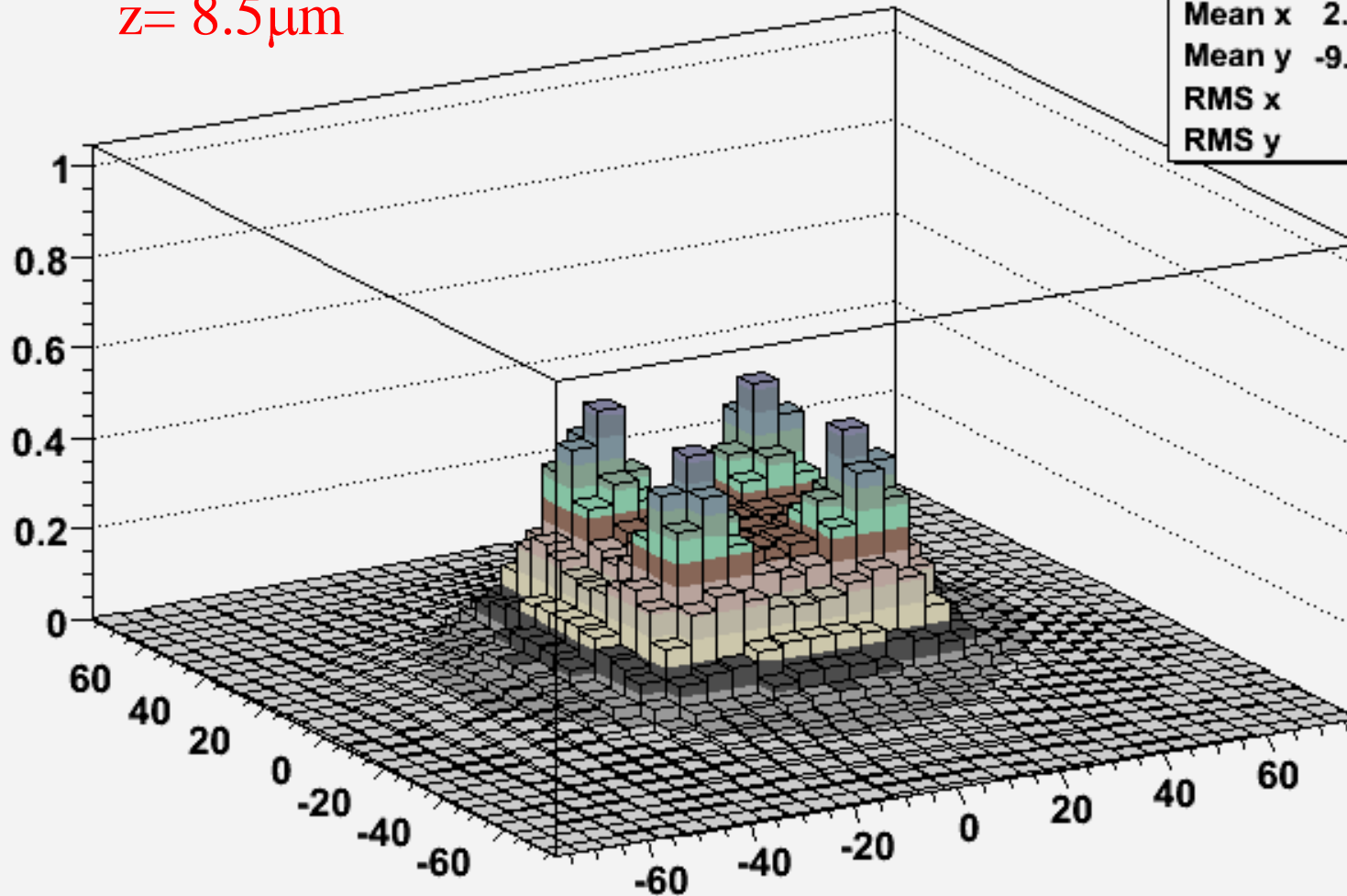
hAmm	
Entries	961
Mean x	-1.149e-16
Mean y	-1.85e-17
RMS x	26.05
RMS y	26.05

Depth dependence

AMM plot

$z = 8.5\mu\text{m}$

hAmm	
Entries	961
Mean x	2.664e-16
Mean y	-9.681e-18
RMS x	25.81
RMS y	25.81

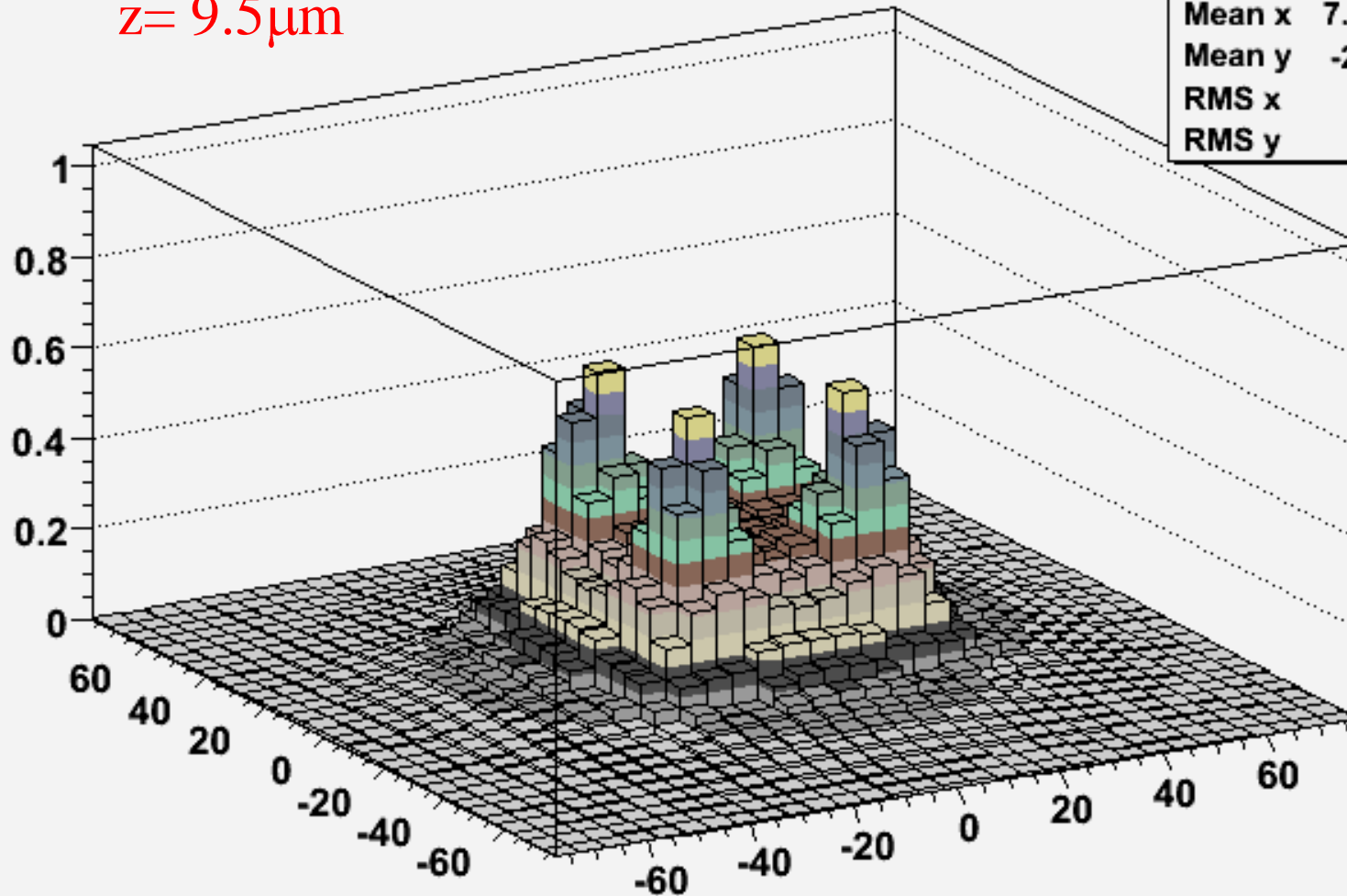


Depth dependence

AMM plot

$z = 9.5\mu\text{m}$

hAmm	
Entries	961
Mean x	7.561e-16
Mean y	-2.65e-16
RMS x	25.54
RMS y	25.54

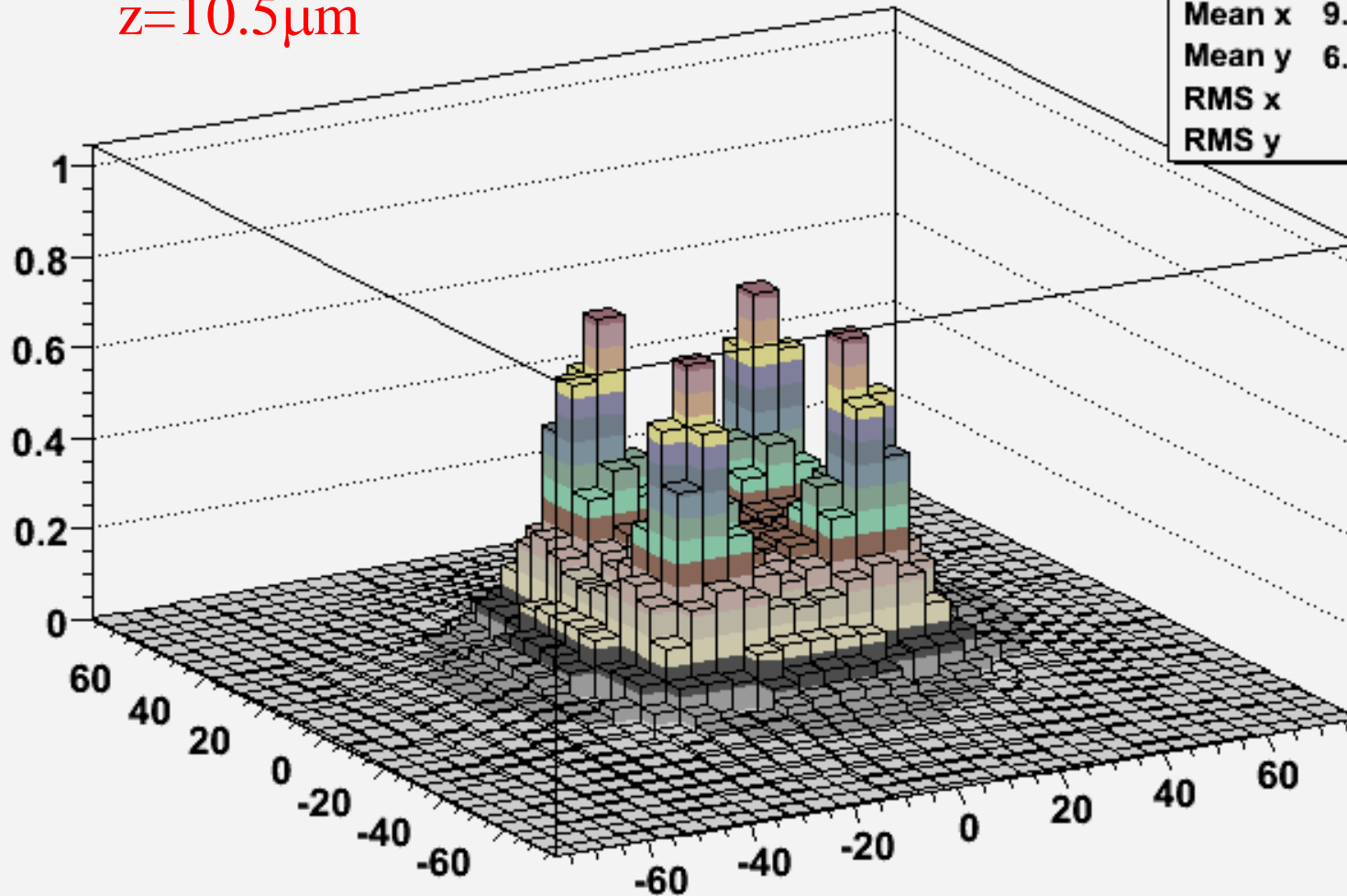


Depth dependence

AMM plot

$z=10.5\mu\text{m}$

hAmm	
Entries	961
Mean x	9.949e-16
Mean y	6.895e-17
RMS x	25.24
RMS y	25.24

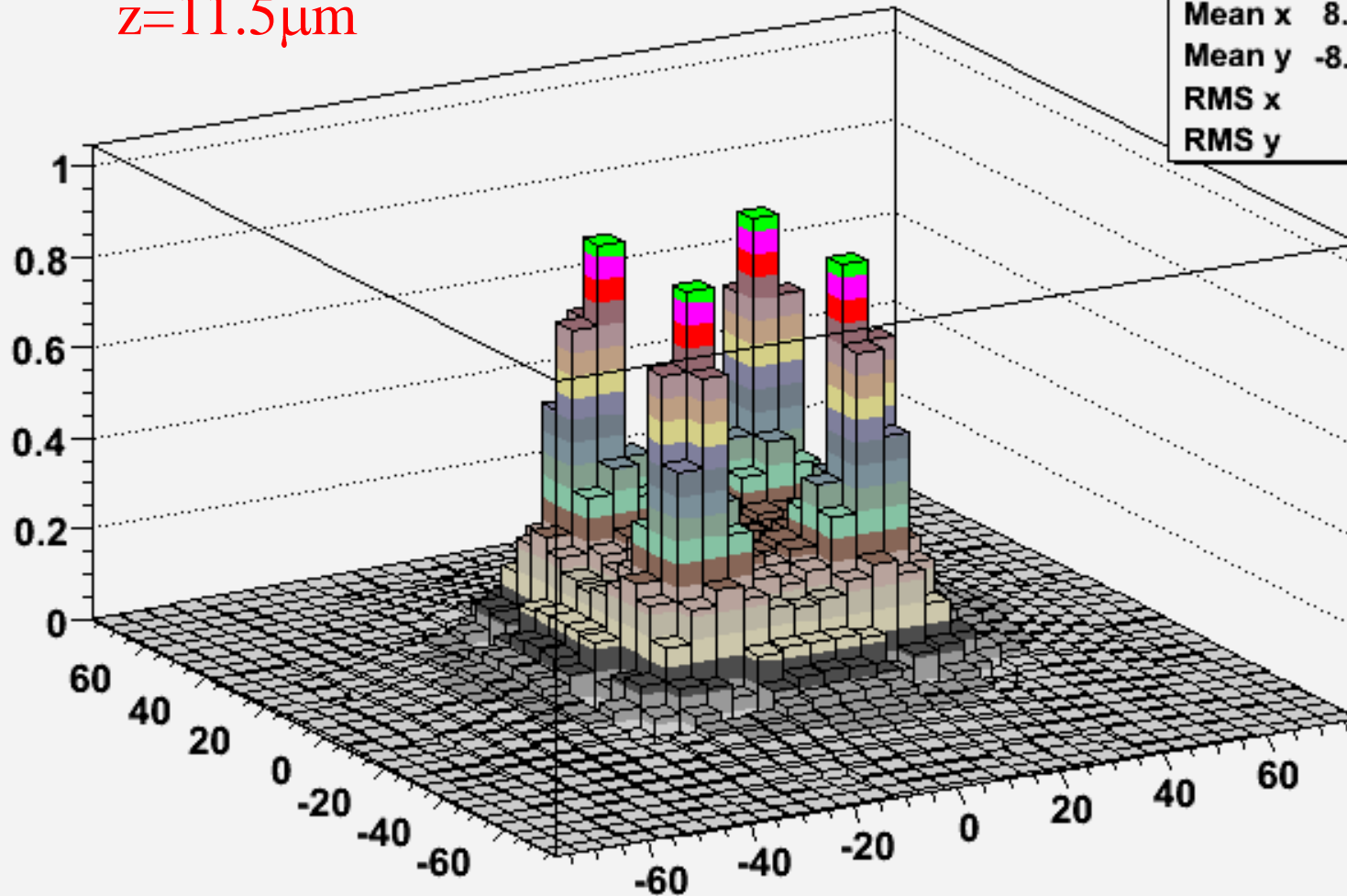


Depth dependence

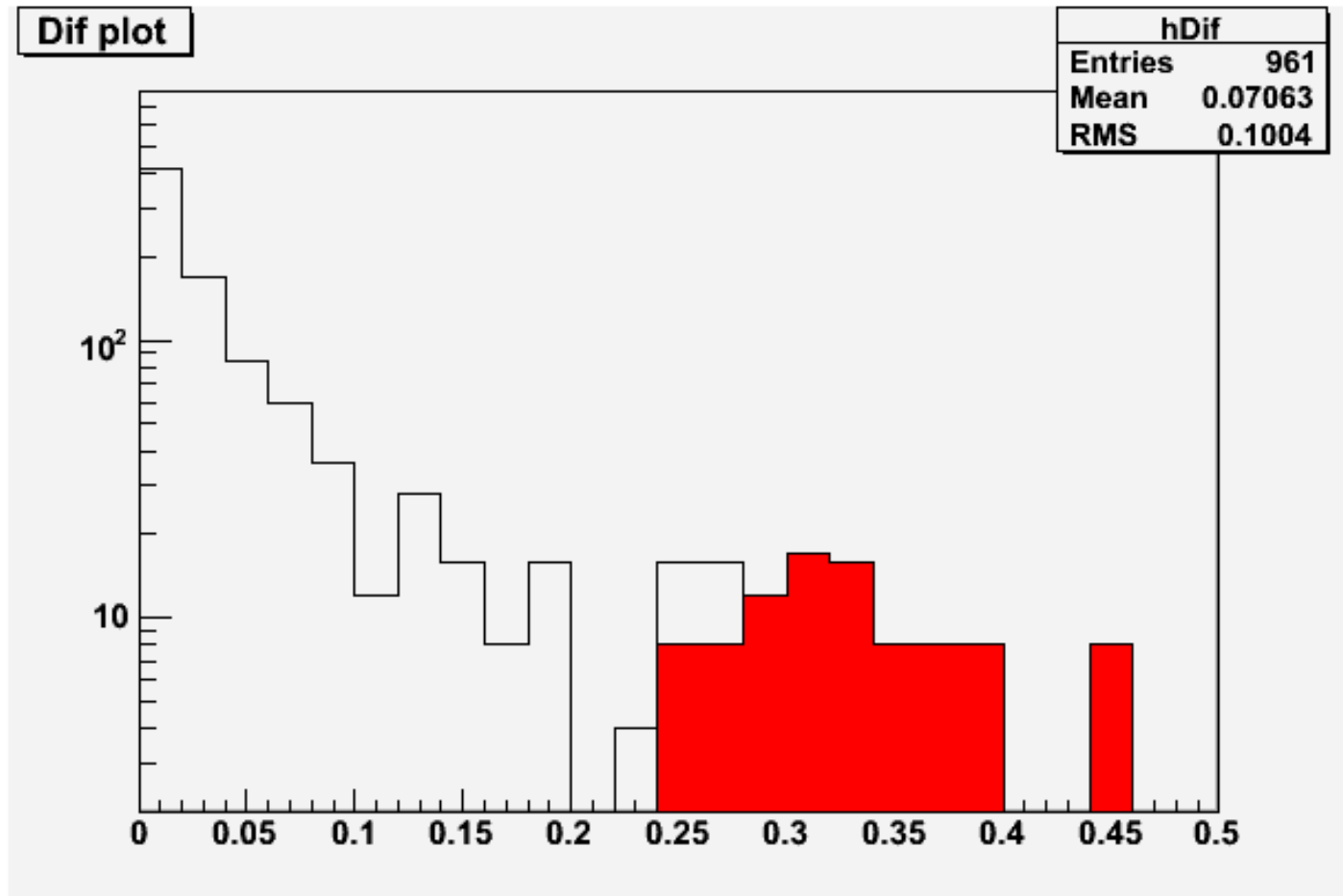
AMM plot

$z=11.5\mu\text{m}$

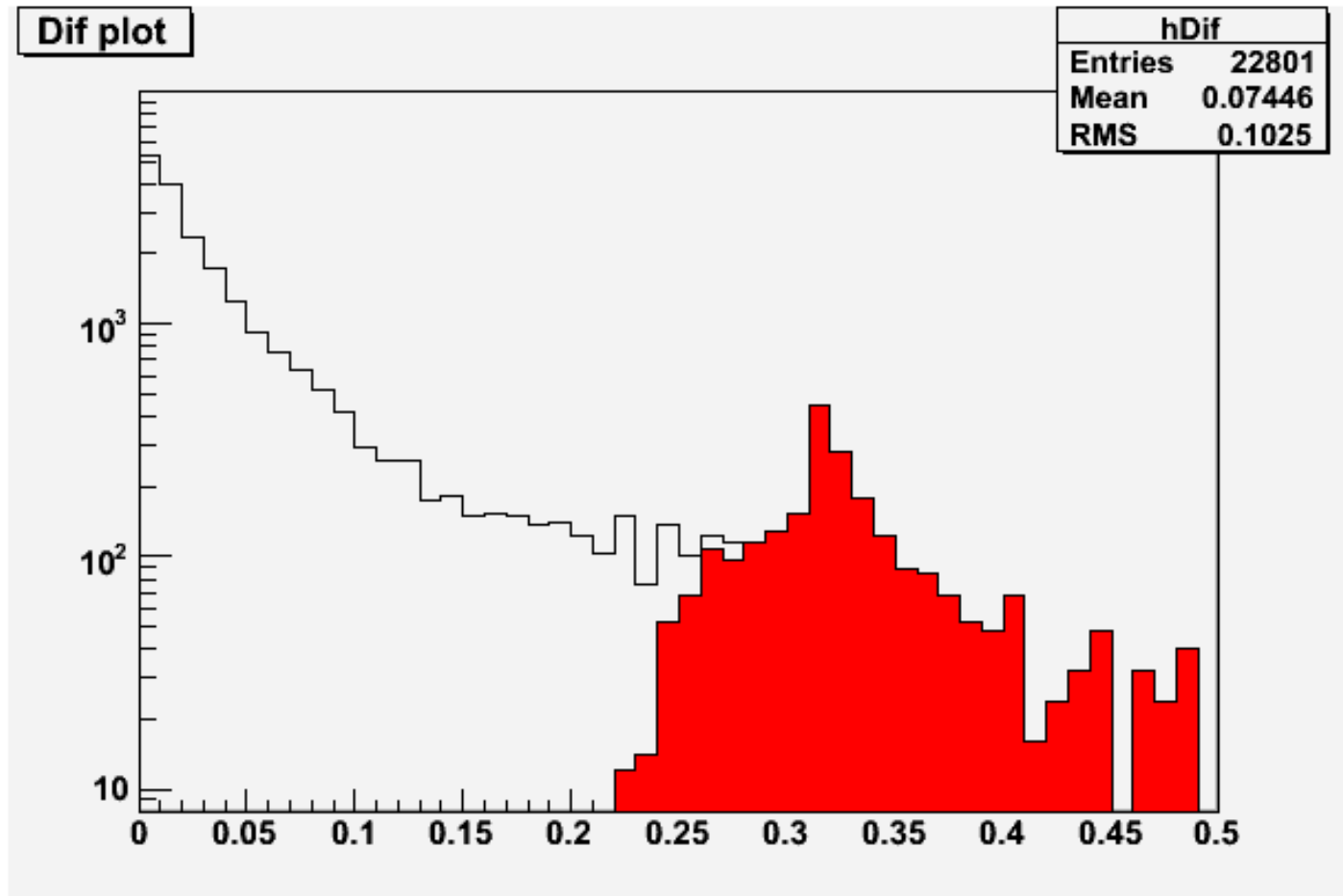
hAmm	
Entries	961
Mean x	8.814e-17
Mean y	-8.762e-17
RMS x	24.88
RMS y	24.88



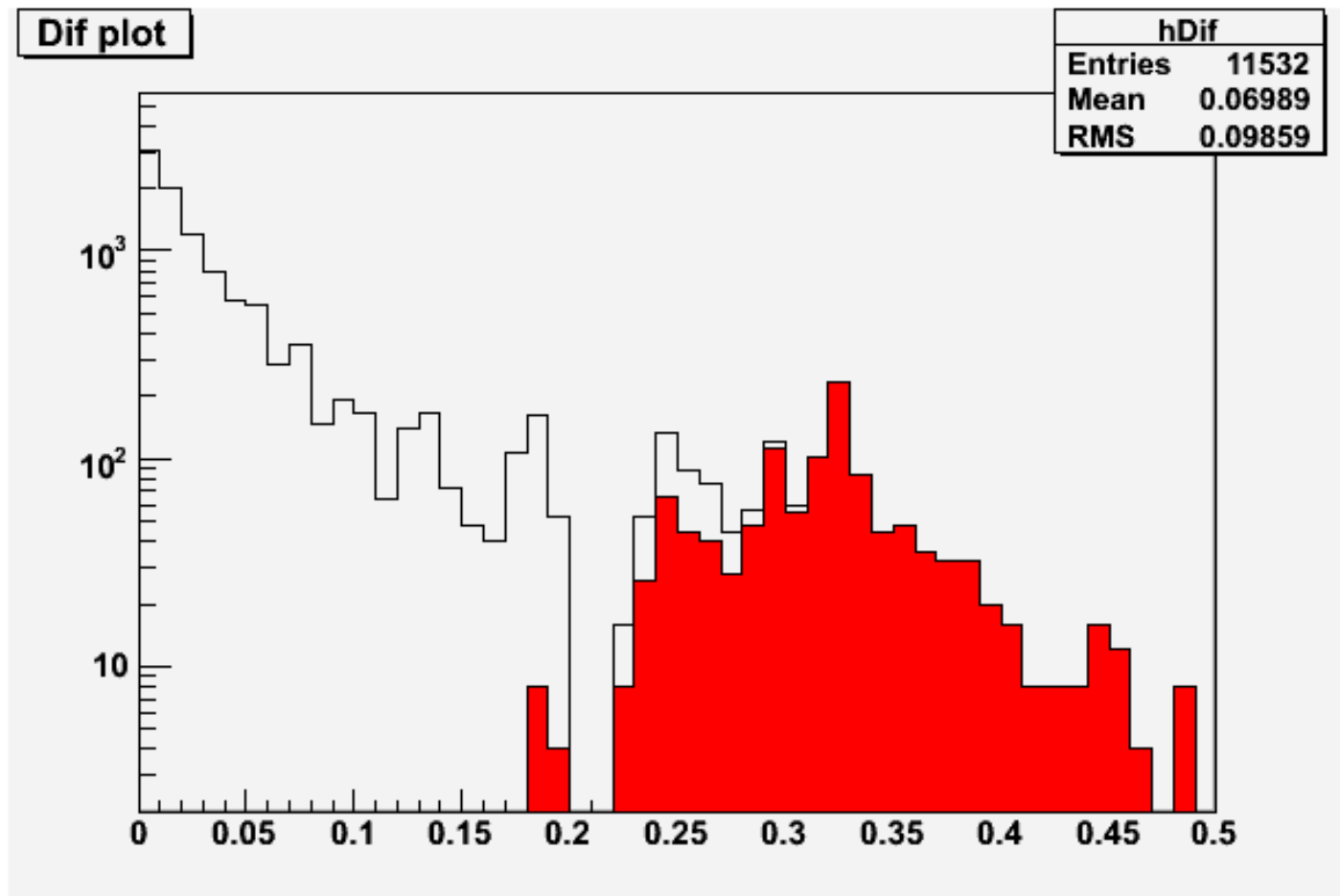
Fractional spectrum $5\mu\text{m}$ with MIP-like z



Fractional spectrum $1\mu\text{m}$ with MIP-like z

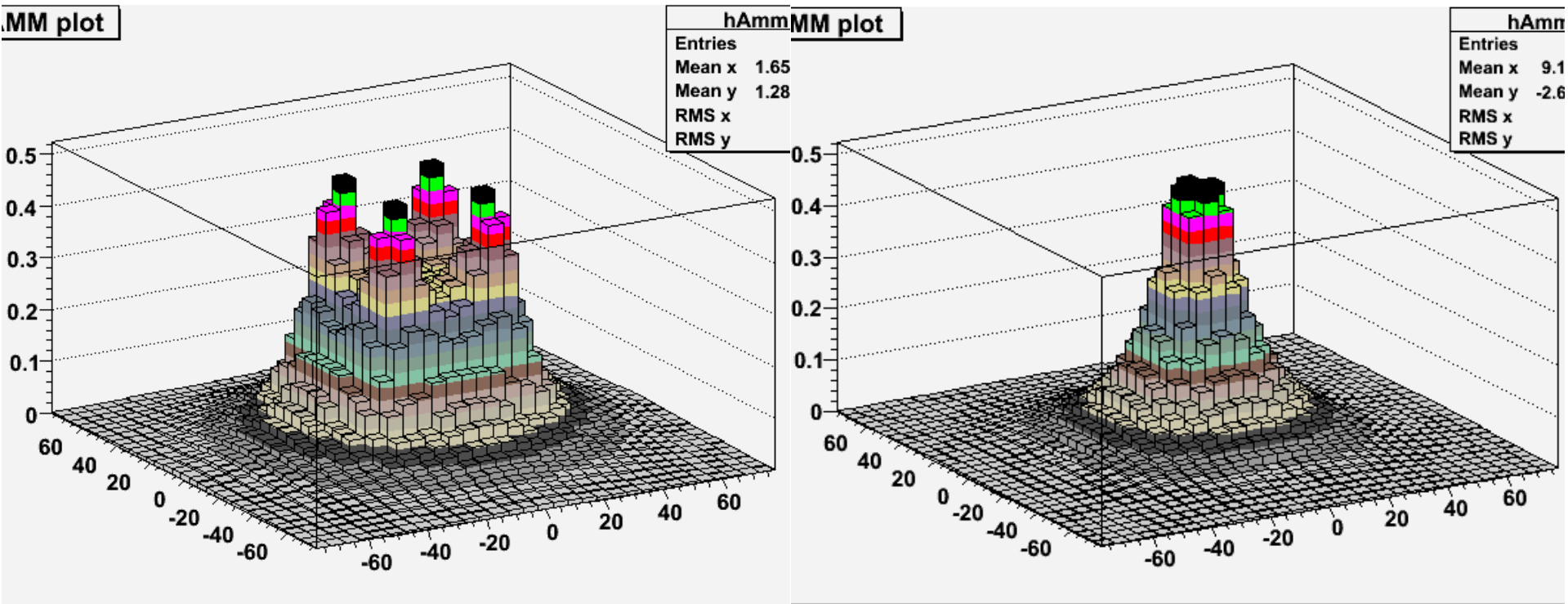


Fractional spectrum $5\mu\text{m}$ with ^{55}Fe -like z



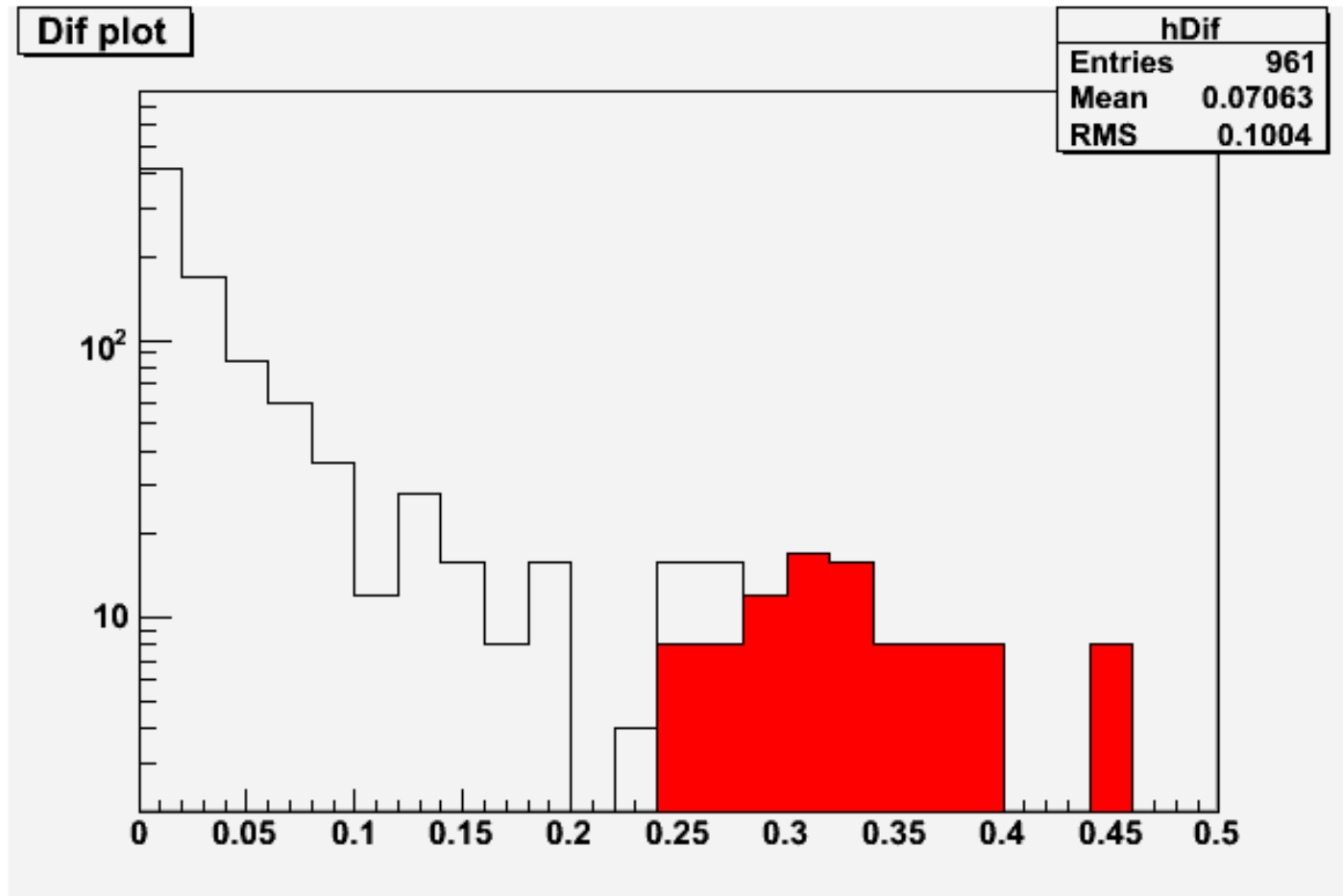
- Still shows peak but details differ
- Need to do 351 points in $xy \times 12$ points in z
 - Around ~ 2 weeks saturated running

Comparison with single diode

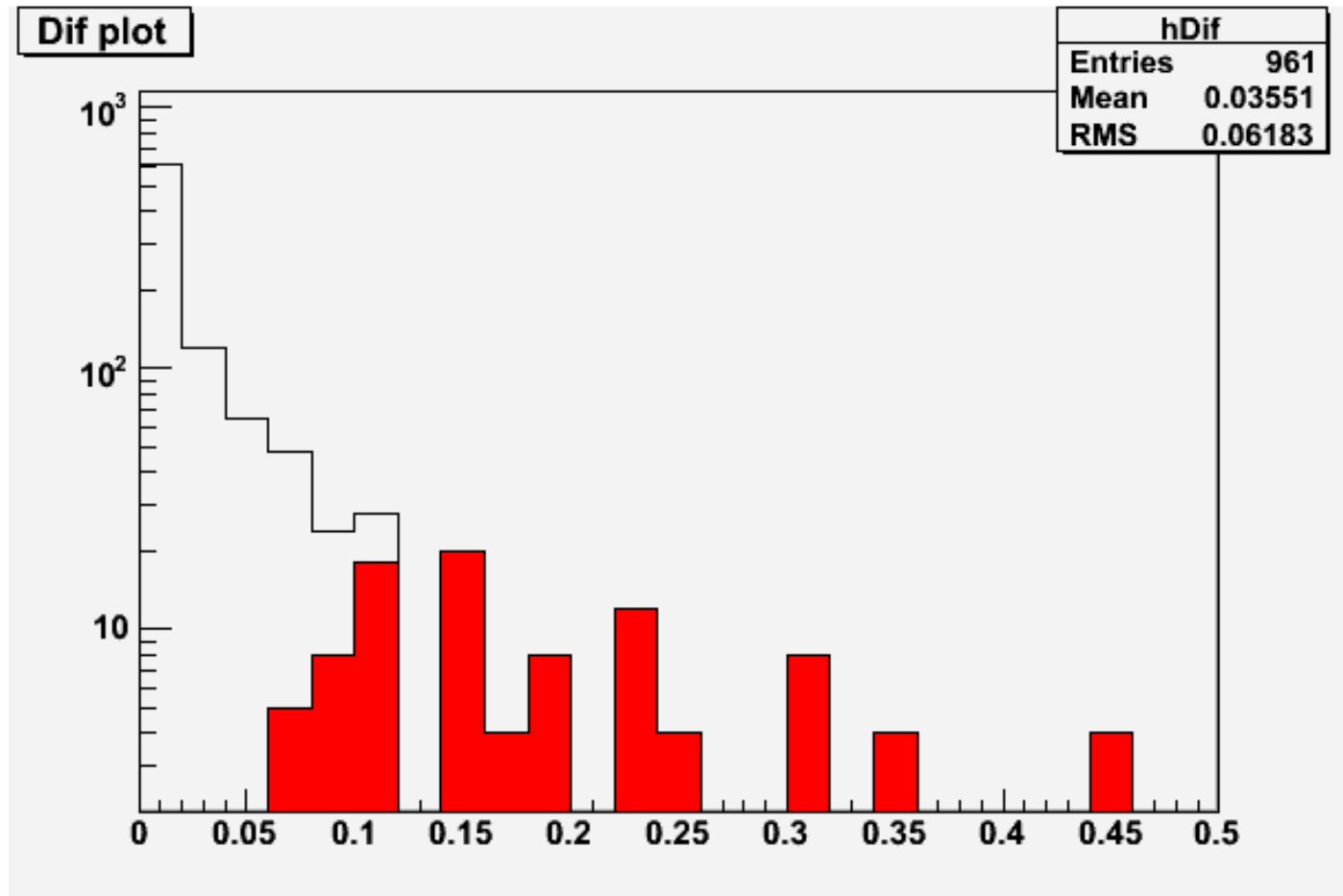


- Simple model; $6 \times 6 \mu\text{m}^2$ diode in centre of $50 \times 50 \mu\text{m}^2$ pixel
- Most of the rest of the pixel is n-well with deep p-well
 - Absorption parameters have same values

Fractional spectrum $5\mu\text{m}$ for four diodes



Fractional spectrum $5\mu\text{m}$ for single diode



- Average fraction seen in centre pixel \sim 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