Simple charge diffusion model

Paul Dauncey, Anne-Marie Magnan

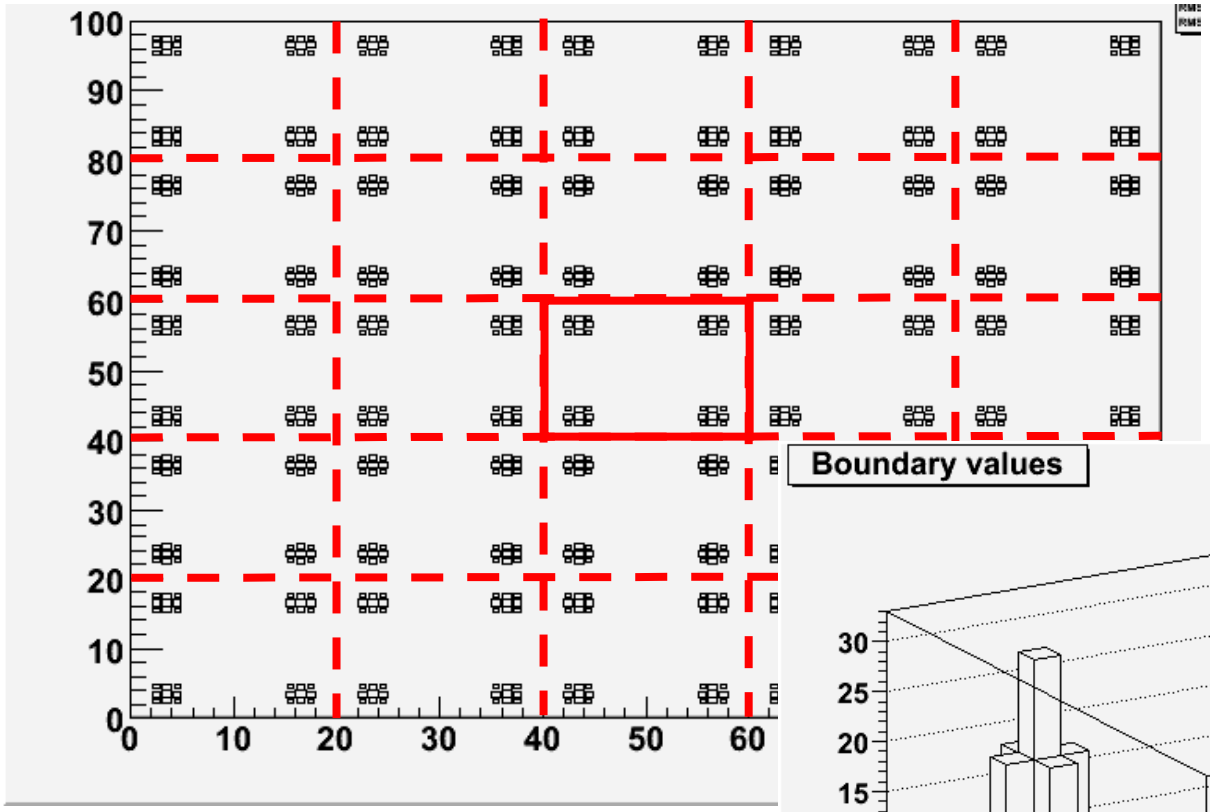
Epitaxial layer charge movement

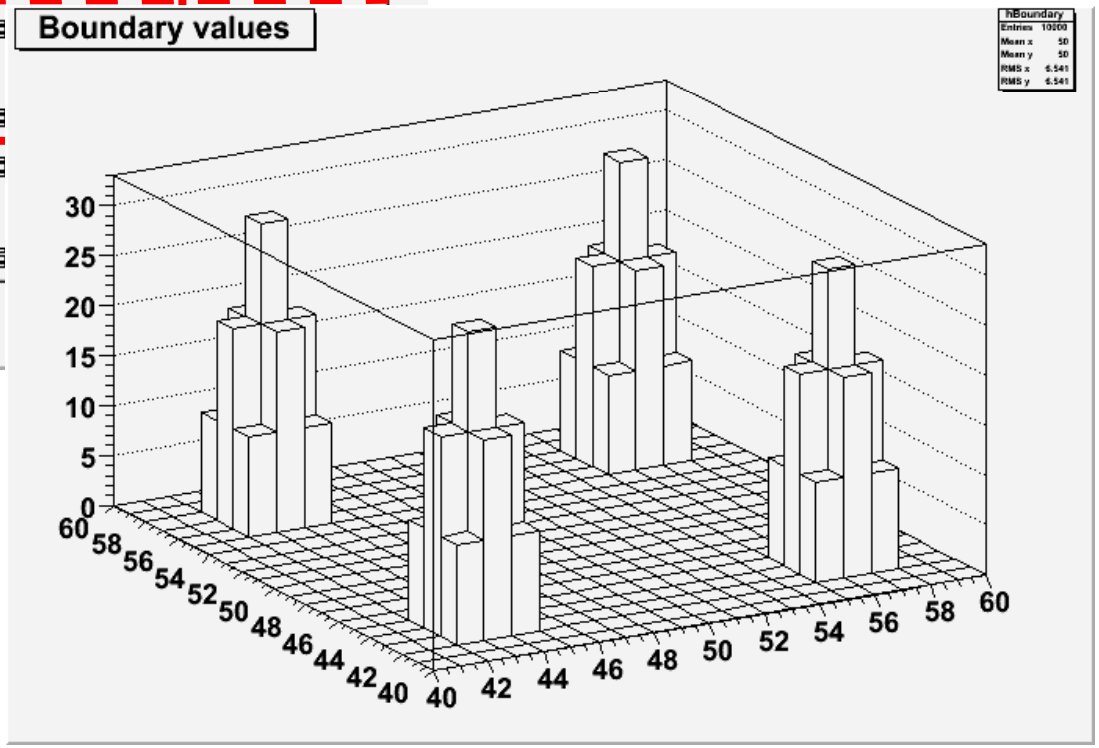
- Modelled in detail by Giulio
  - All effects included
  - Detailed geometry
- Hard to get intuitive feel for results
  - Difficult to run many variations due to speed restrictions
- Wanted to see how much due to diffusion
  - Assumption that this is dominant movement mechanism
- Make simple model for diffusion
  - Numerically solve and compare to Giulio's more detailed simulation
- NOT a replacement for Giulio's work
  - Need to calibrate to his results to set scale
  - But allows quick interpolation and test of other geometries, charge deposits, etc.

Diffusion model

- 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
  - 20×20 points per pixel, each 2.5×2.5μm^2
- Divide epitaxial depth with same cell size
  - 15μm/2.5μm = 6 cells
- Use very simple numerics
  - Three-point $O(\Delta x^2)$ for ∇^2
  - Forward (Newton) $O(k\Delta t)$ time step
- Boundary conditions a bit tricky
  - Perfect boundary at bottom of epitaxial layer
  - Fraction of charge removed for some cells at top of epitaxial layer
  - Exponential falloff through 5×5 pixel grid edges

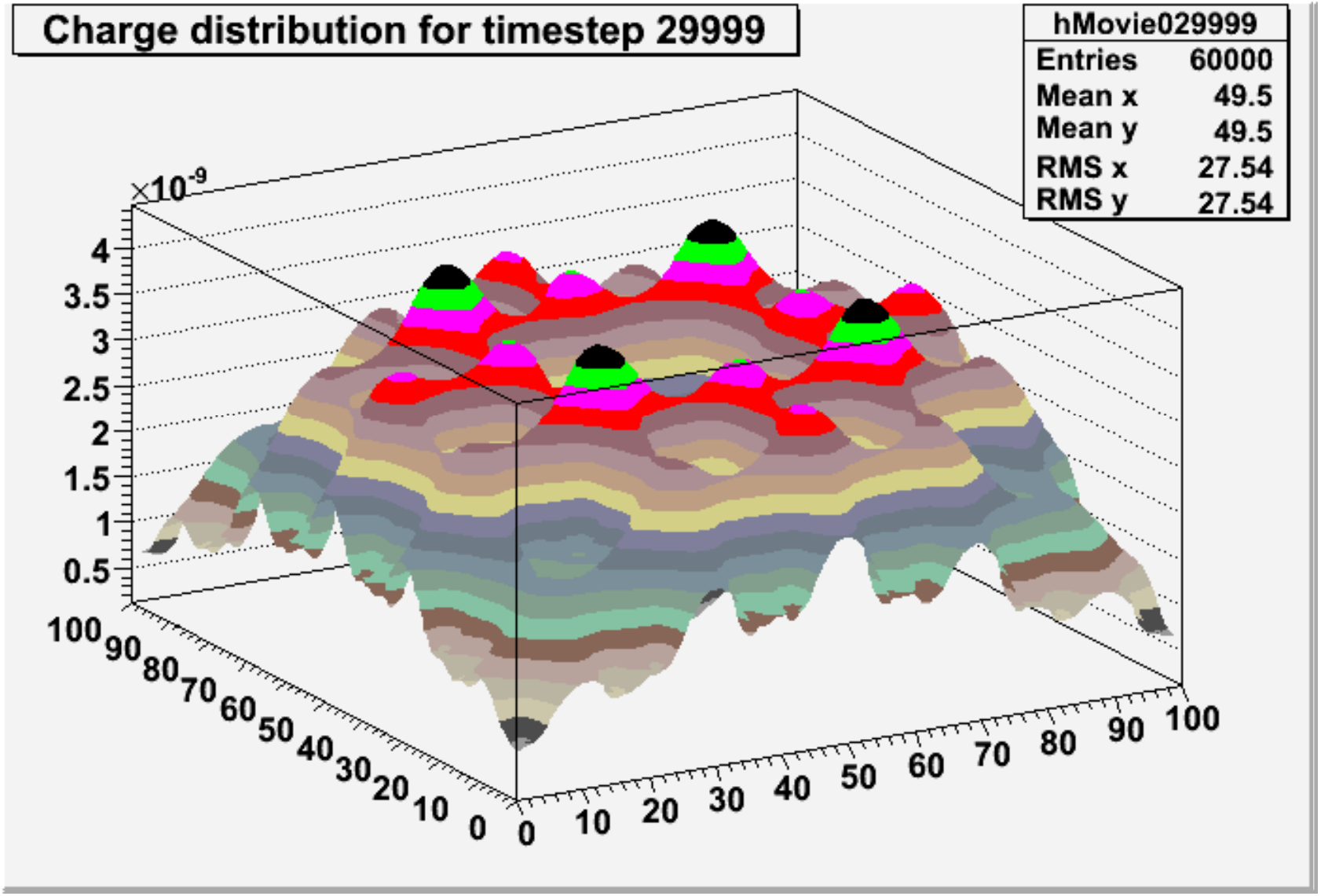
First run with no n-well





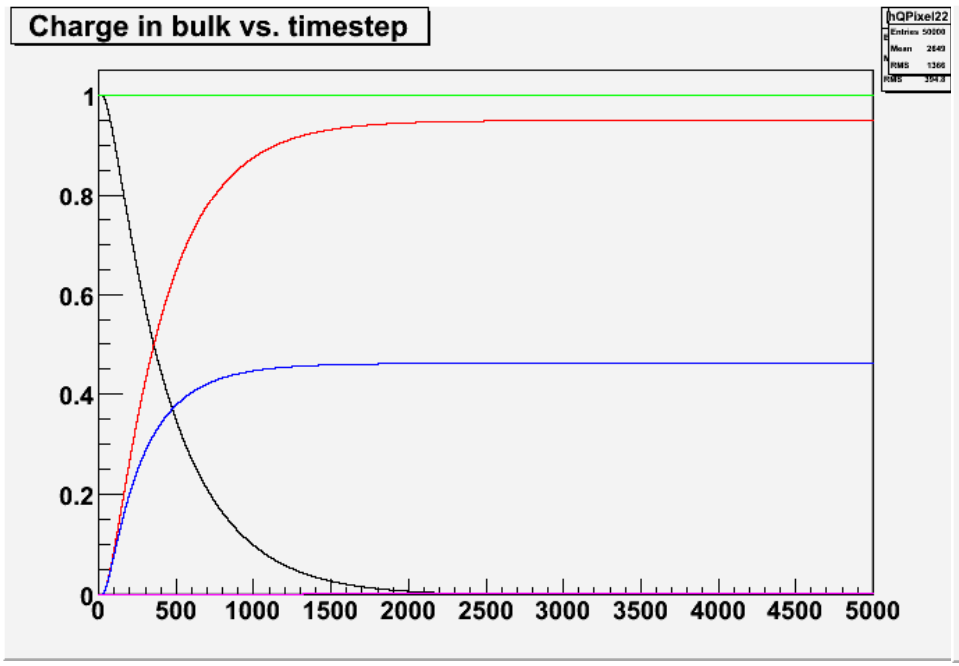
Magnitude is rate of charge absorbed in top cells; values chosen by comparing with Giulio's results

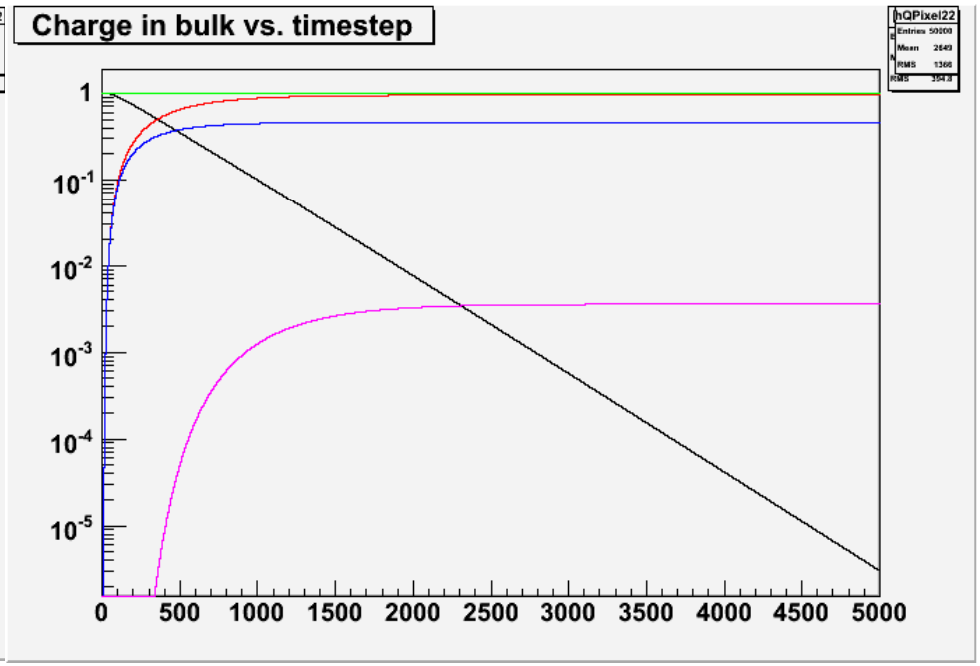
Charge diffusion movie



Time dependence

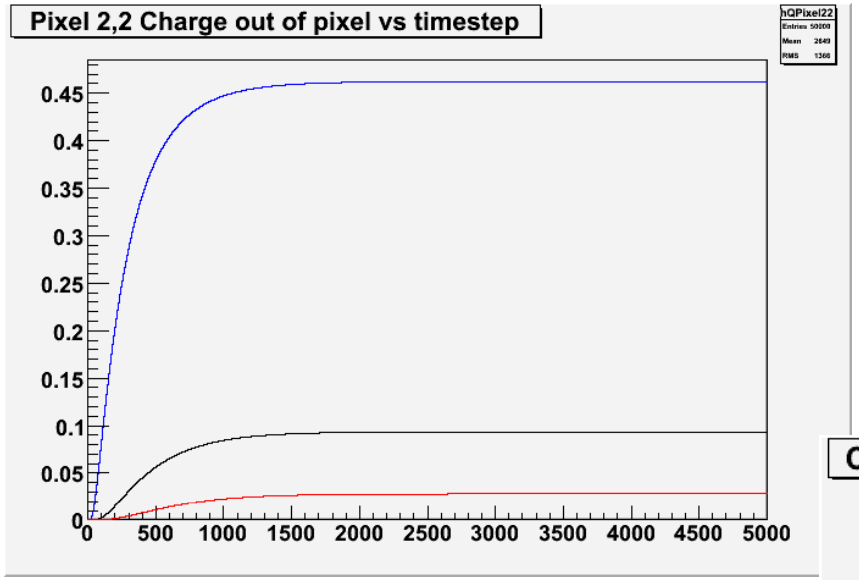
- Want final results after charge has been collected/diffused out
  - Note, Giulio reports 90% charge levels so some differences
  - Worst-case for time as least charge absorbed by pixels



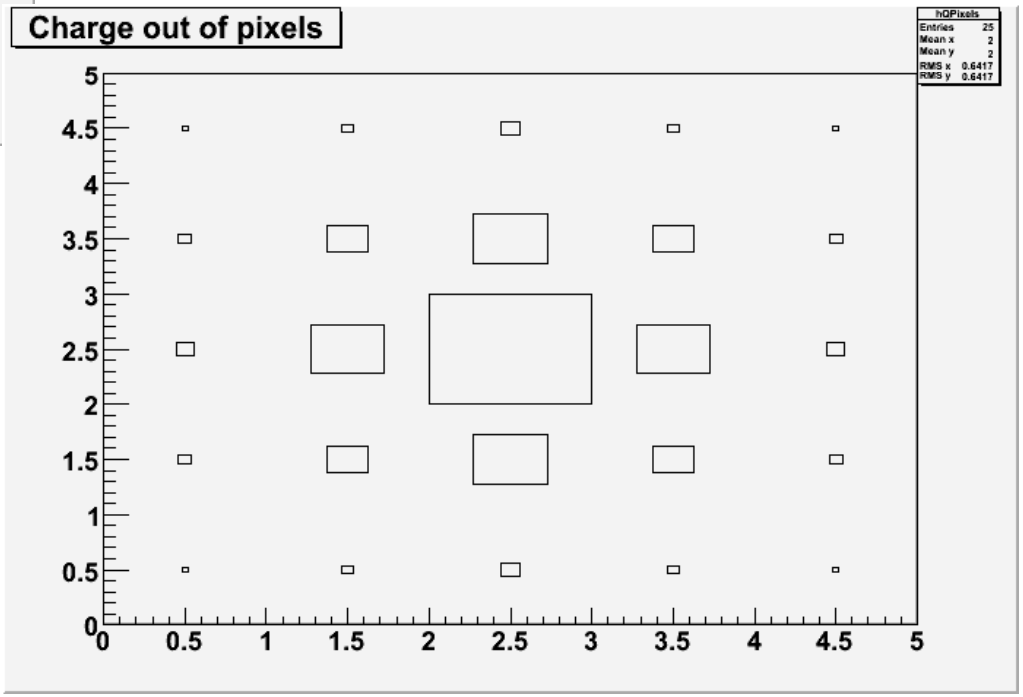


- Total = 1.0, Bulk → 0.0, 3×3 pixels ~ 0.95, Central pixel ~ 0.45, Outside 5×5 < 0.01

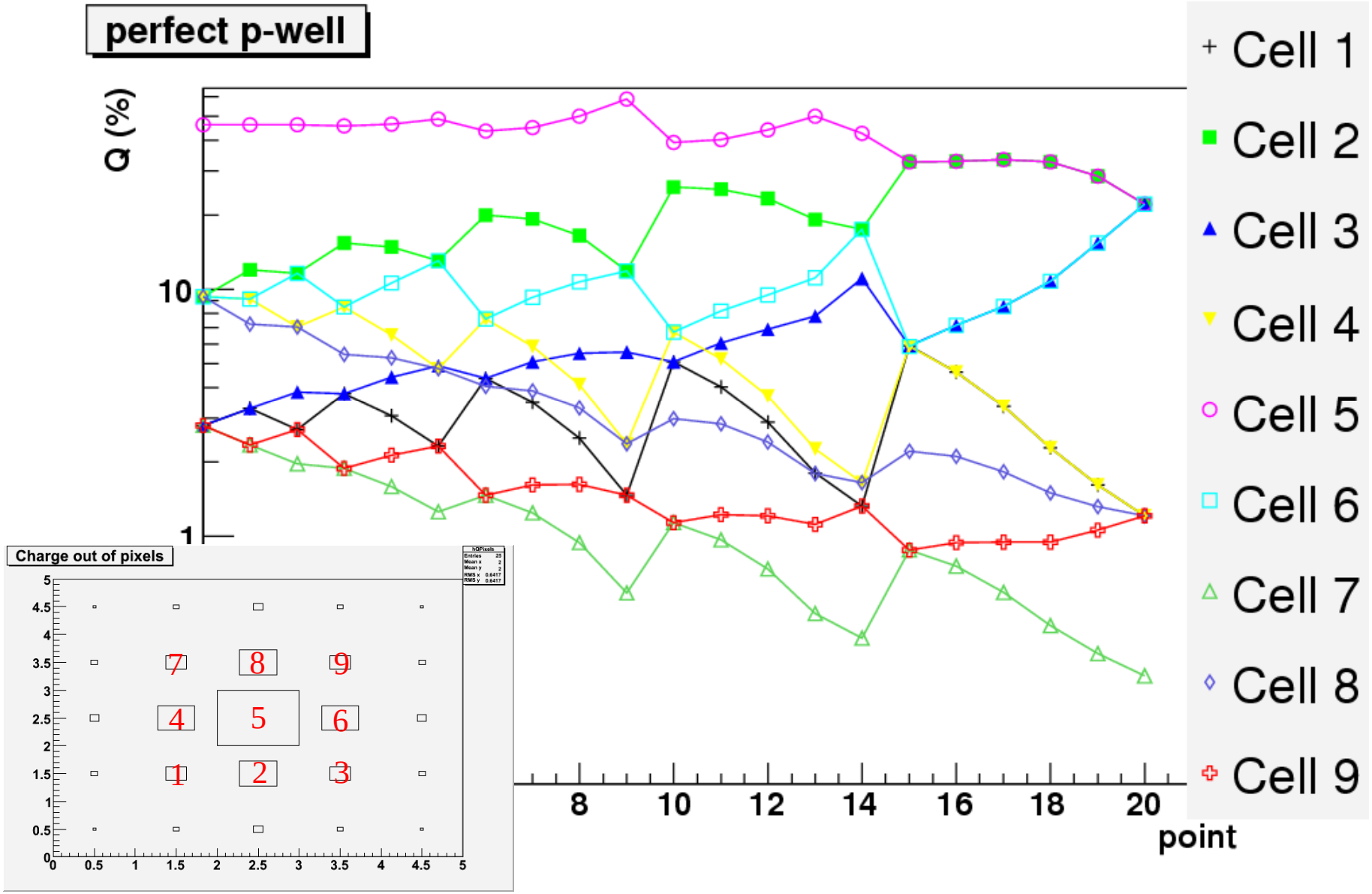
Overall final distribution



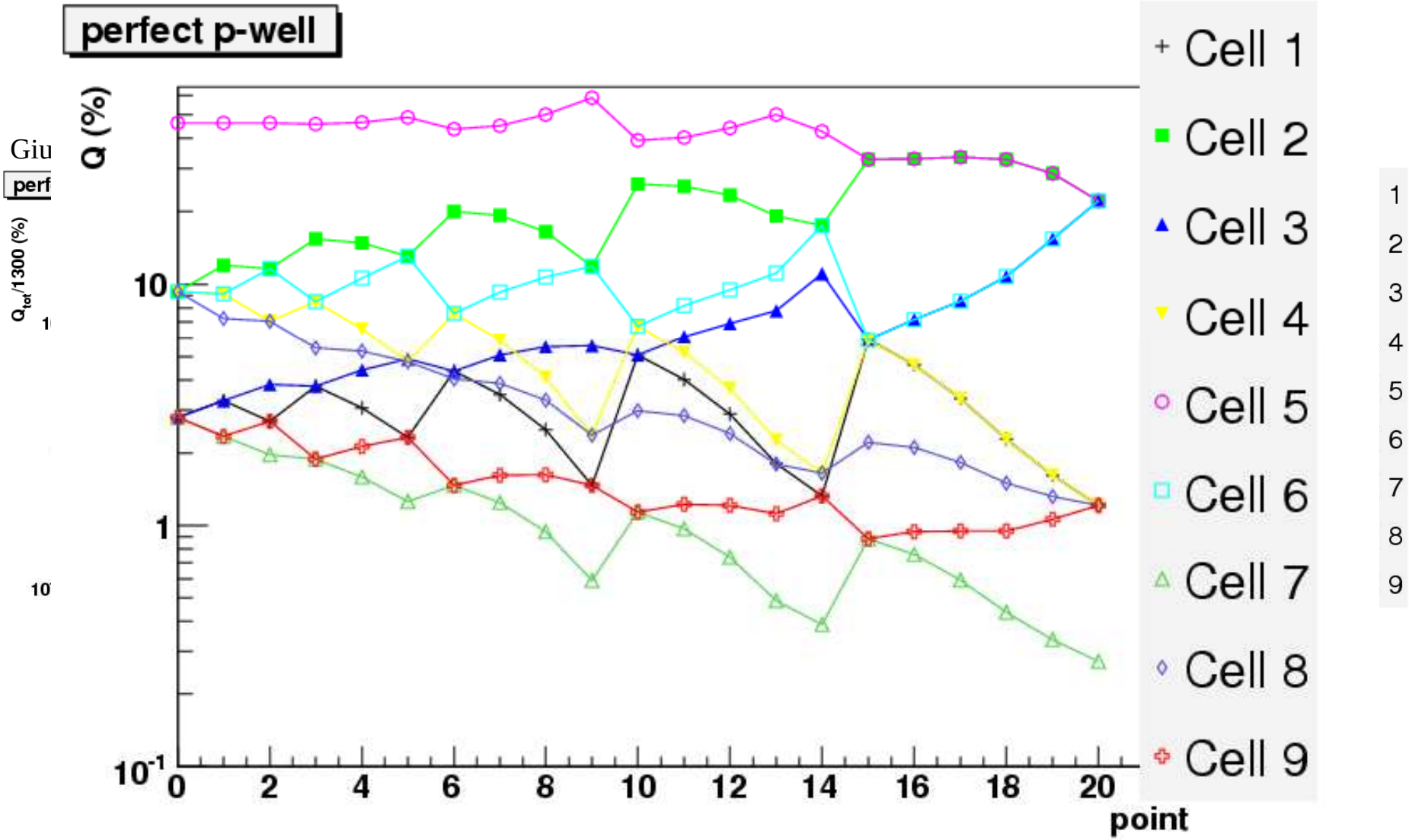
- Central pixel ~ 0.45
- Side pixel ~ 0.1
- Corner pixel ~ 0.03



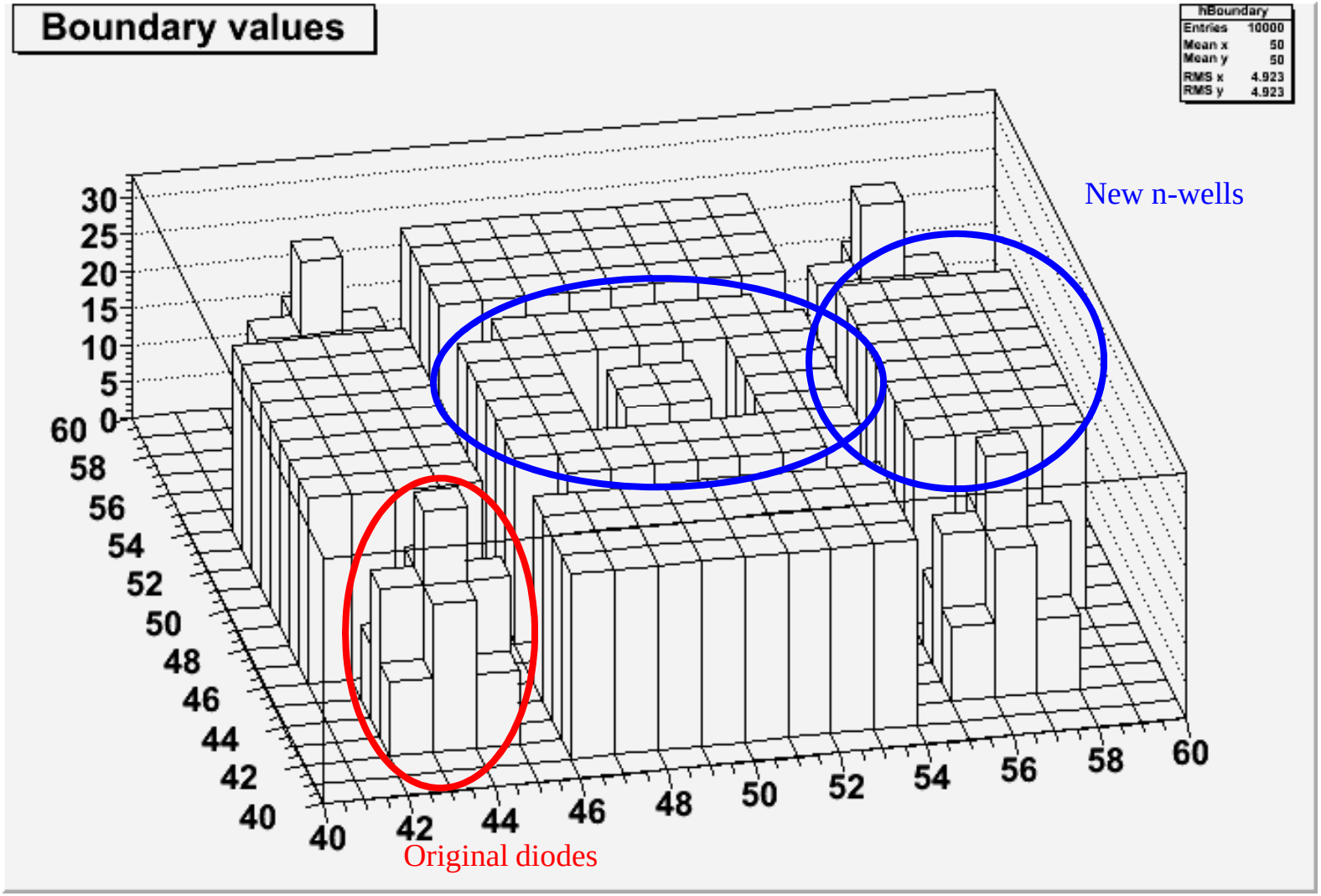
Repeat for the usual 21 points



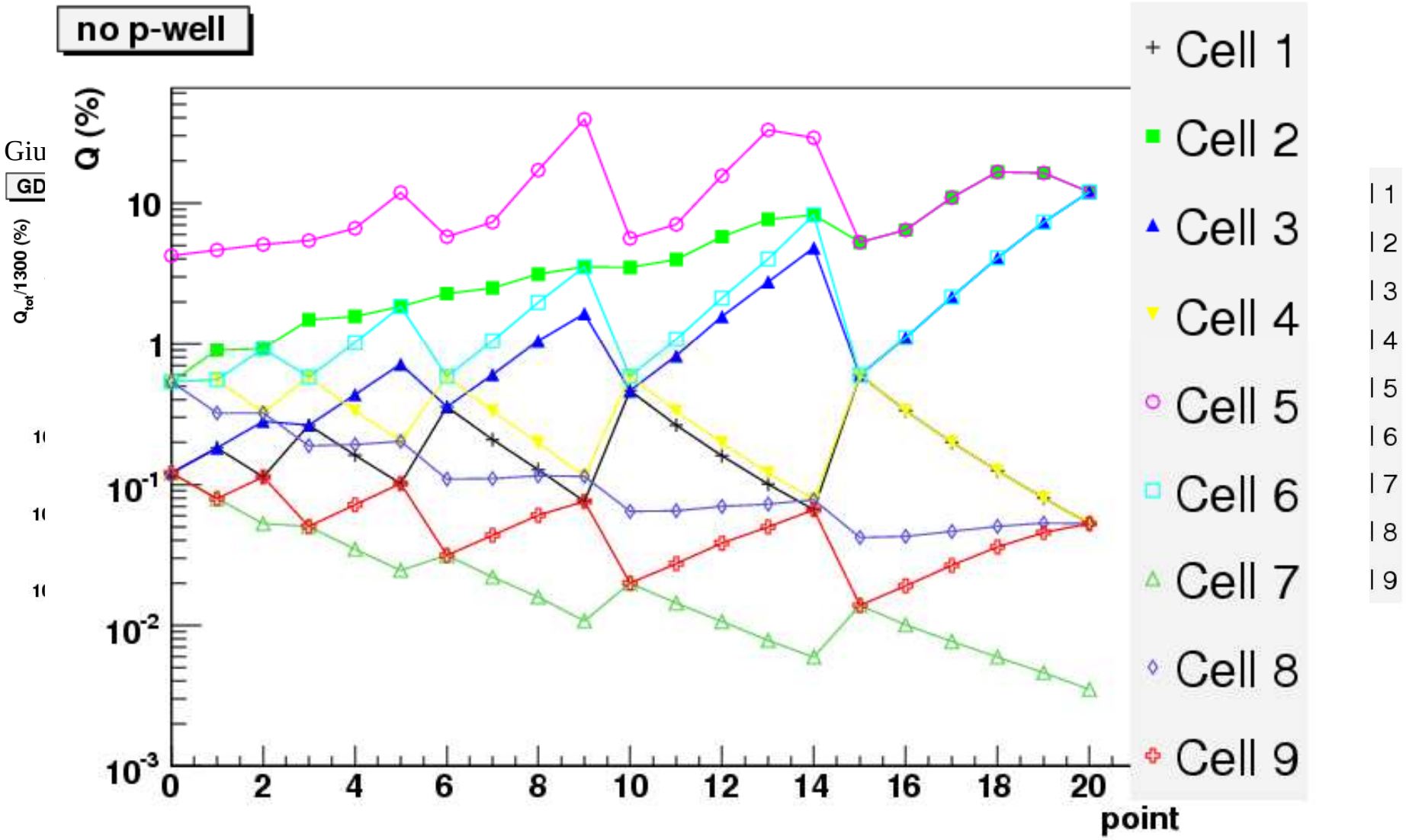
Comparison with Giulio's results



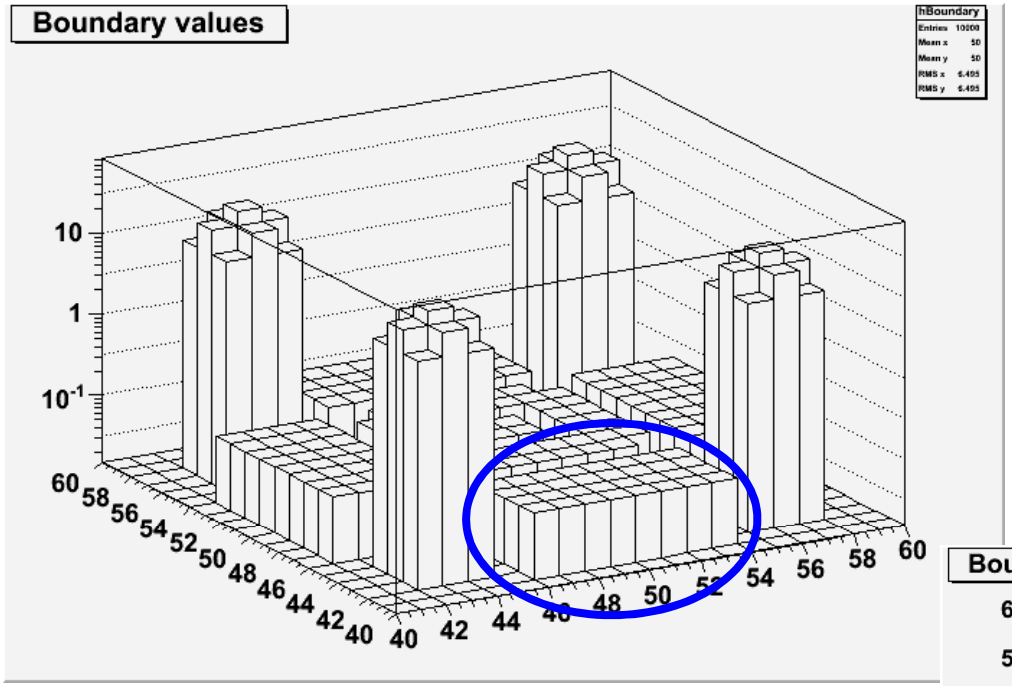
Add n-well with no deep p-well



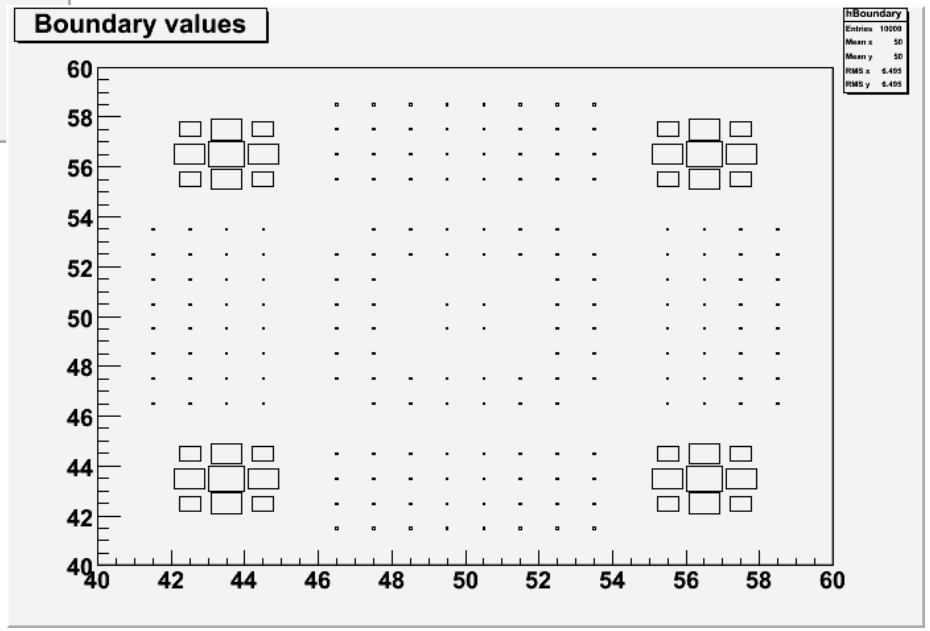
Comparison with Giulio's results



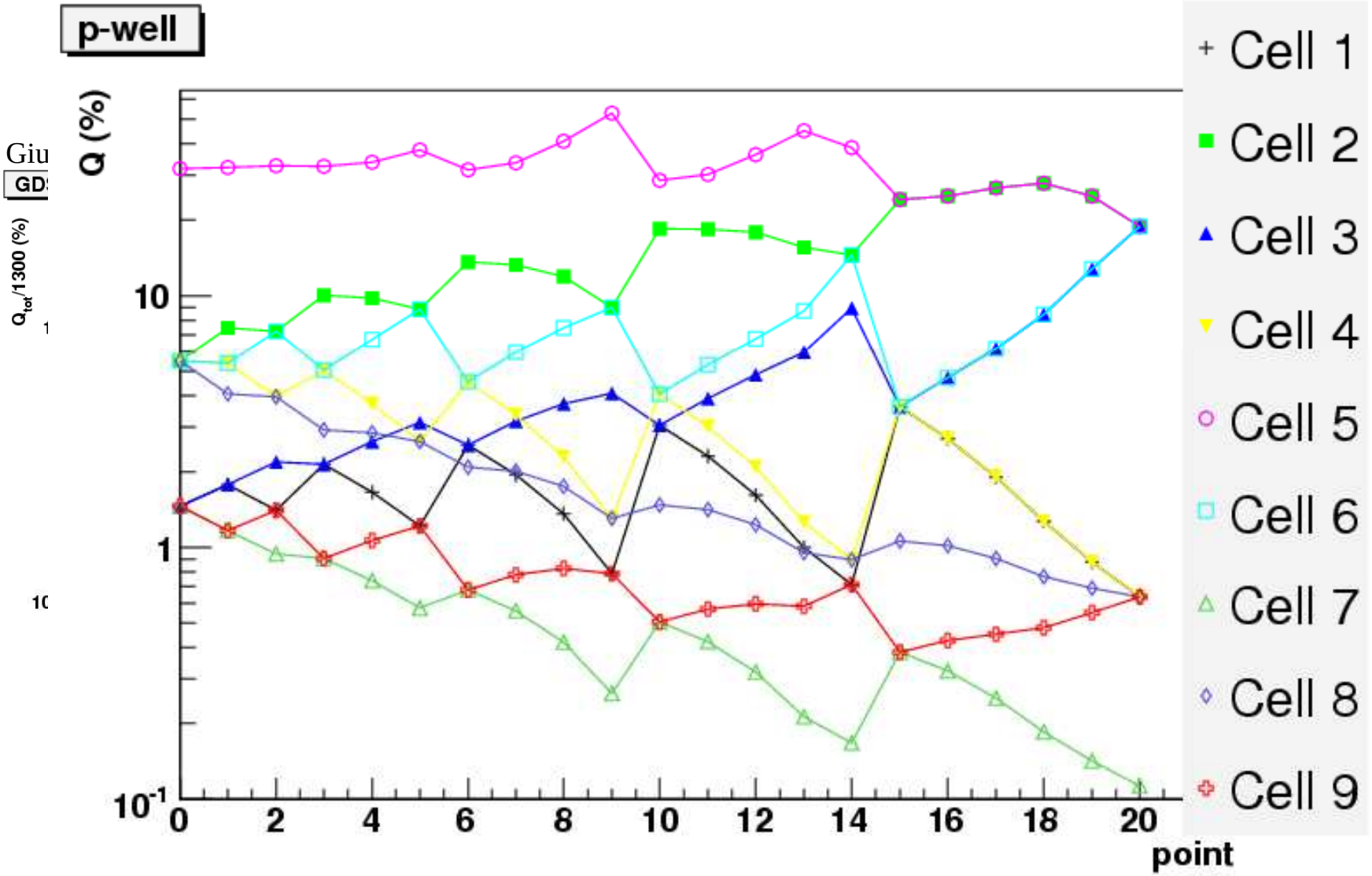
Add deep p-well



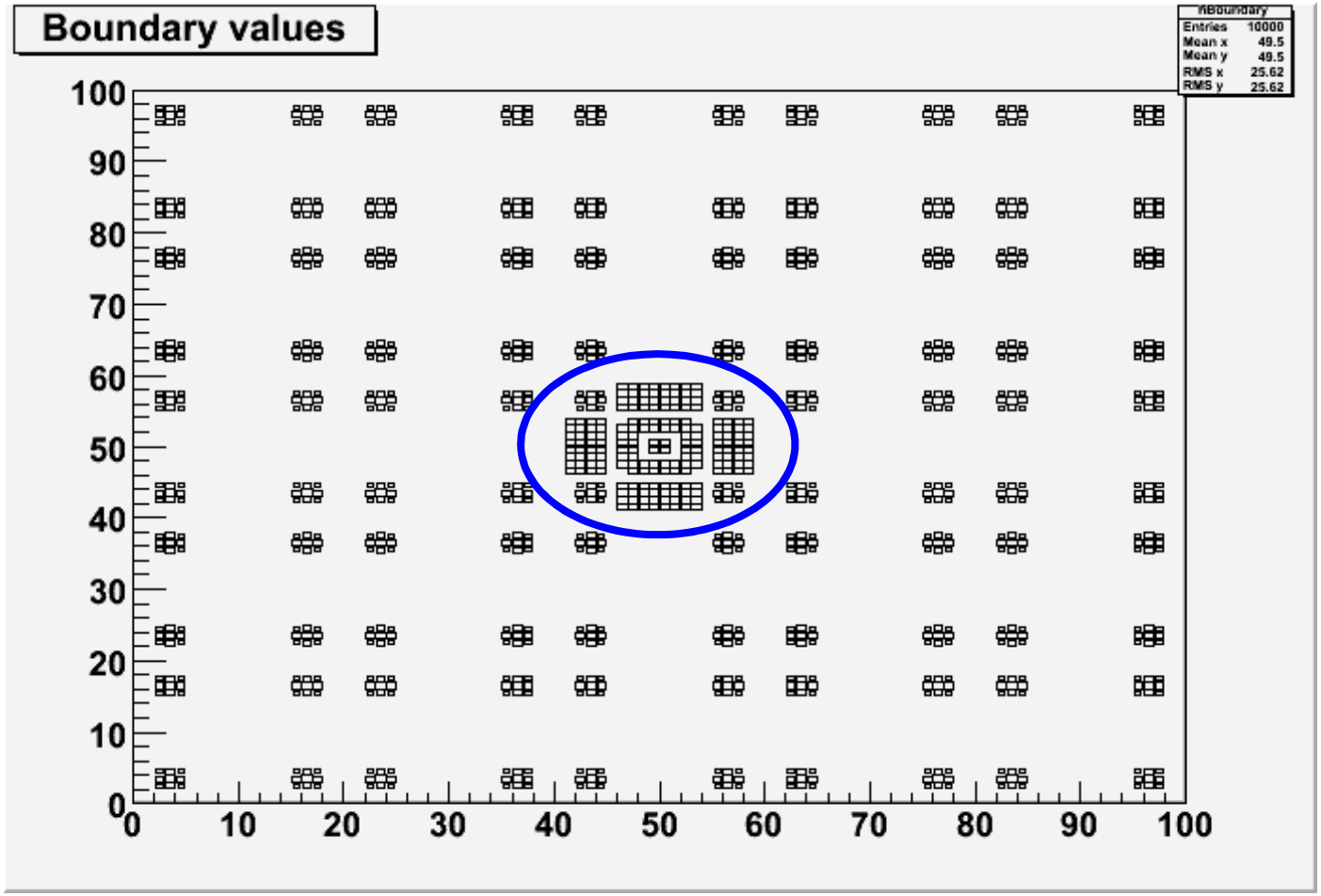
N-wells absorption reduced
by a factor of 250



Comparison with Giulio's results

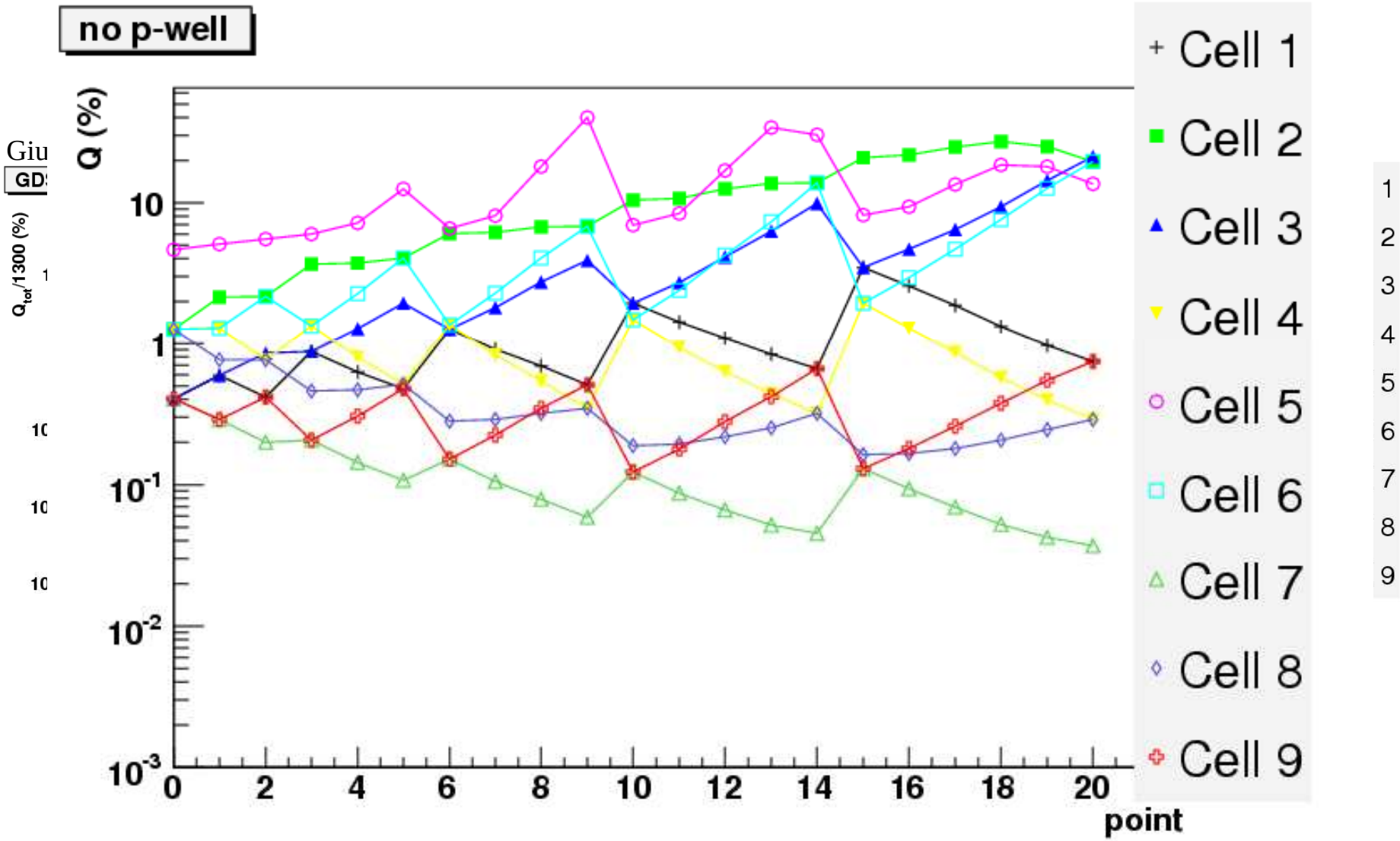


Just model central n-wells



N-wells without deep p-well but only in central pixel

Comparison with Giulio's results



Conclusions

- Main effect seems to be diffusion
- Modelling with simple simulation is reasonable but quantitatively there is disagreement
  - Ideal or realistic deep p-well agrees to within ~50%
  - No deep p-well differs by order of magnitude in tails
- Can help quickly to quantify differences
  - Missing n-wells outside central pixel
  - Charge lost outside 3×3 pixels, etc.
- Not a substitute for full simulation