# Simulation of RPC avalanche signal for a Digital Hadron Calorimeter (DHCAL)

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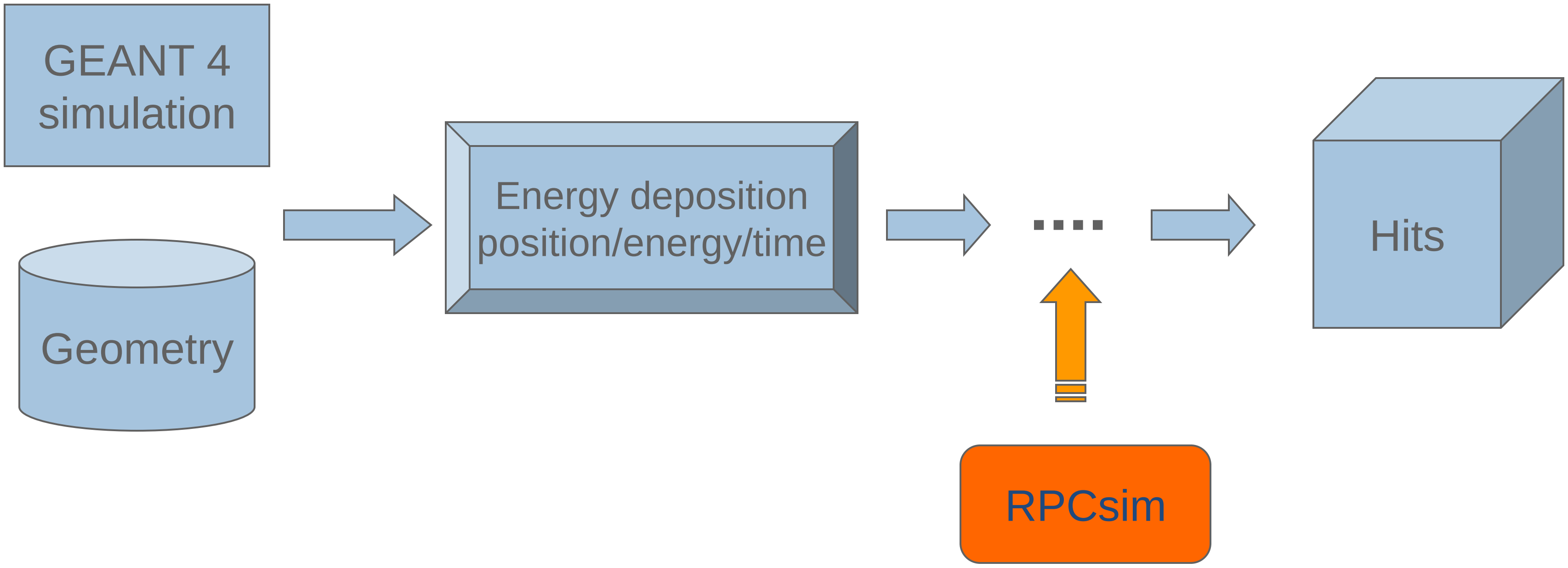
# Outline

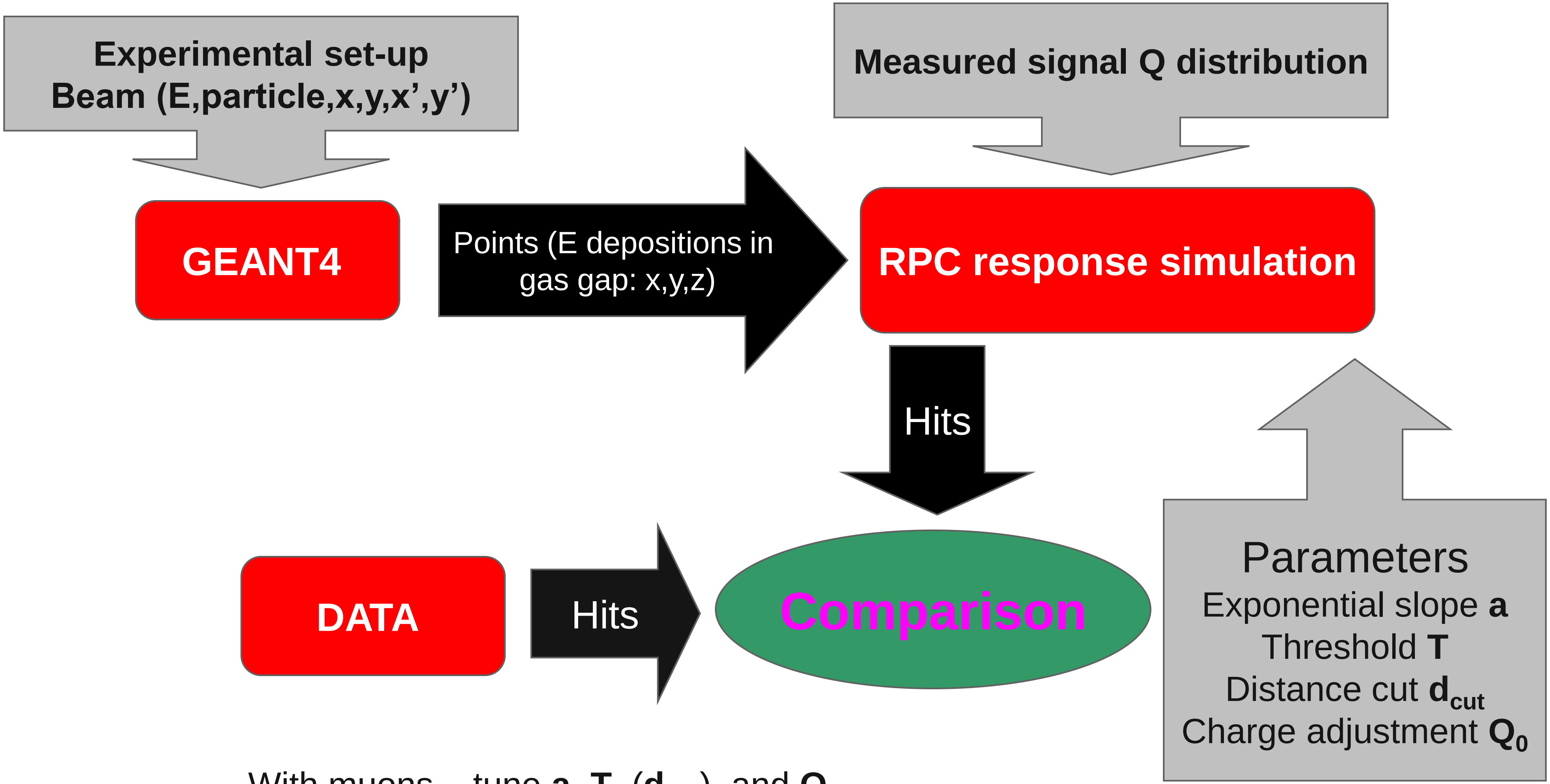
- Why do we need an RPC response simulation
- Implementation details
- Recent development
- SiD/lcsim implementation

# Purpose of RPCsim

- DHCAL: energy is measured with number of hits (to first order), no energy deposition information within each cell
- Digitization: RPC response simulation that convert energy deposition points into detector hits



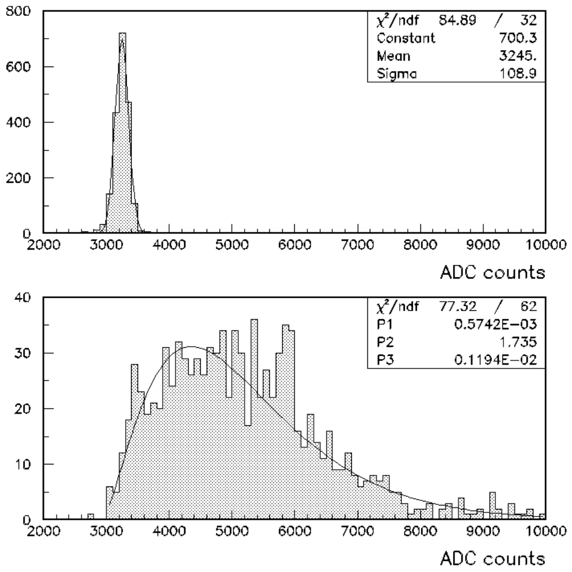
# Detailed implementation



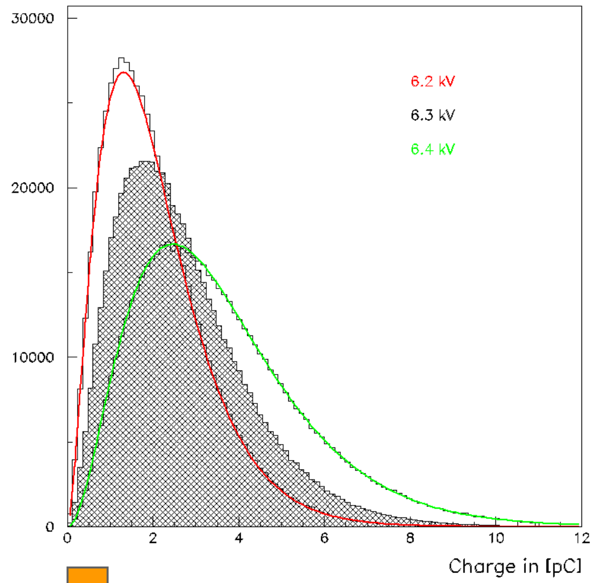

With muons – tune **a**, **T**, (**$d_{cut}$**), and **$Q_0$**
With positrons – tune **$d_{cut}$**
Pions – no additional tuning

# Detailed implementation: avalanche charge

Measured charge distribution
for HV = 6.2 kV




Generated charge distributions
for different HV settings

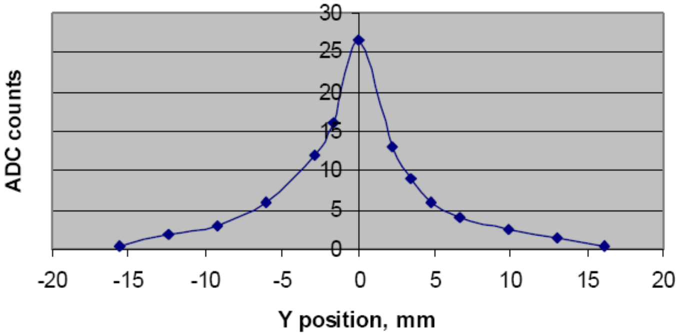



Randomly sampling the charge distribution

Total charge

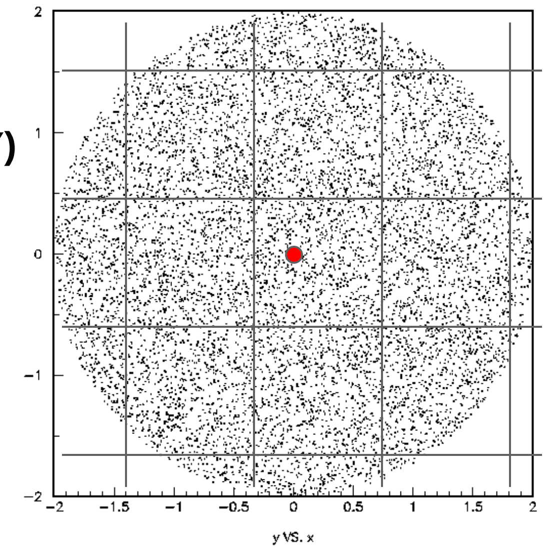
# Detailed implementation: charge distribution

Measured charge distribution as function of y in the pick-up plane




**Assume exponential drop in R (even though the measurement was in Y)**

Throw 10,000 points in x,y plane, calculate charge Q(r), sum up charge on 1 x 1 $cm^2$ pads

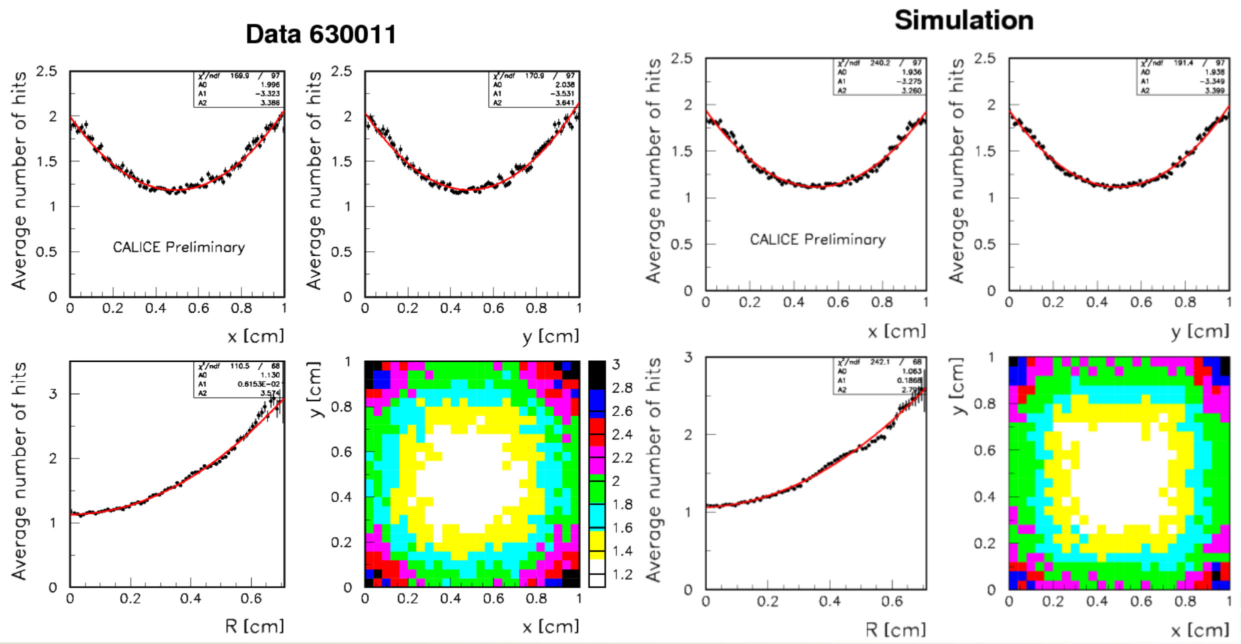



Energy deposition point (x,y,z) [from Geant 4]

Charge on each readout pad

# Detailed implementation: parameters and tuning

- There are 4 tunable parameters in the simulation
  - Overall charge offset: $\mathbf{Q_0}$
  - Charge threshold for each readout pad: **T**
  - Charge spread parameter (slope of the exponential): **a**
  - Distance cut (within which, only one avalanche is generated): **D**
- Parameter tuning
  - Muon data: $\mathbf{Q_0}$ **, T , a**
  - **Positron data: D**
  - Pion data: absolute prediction




Scan across pad

x scan:

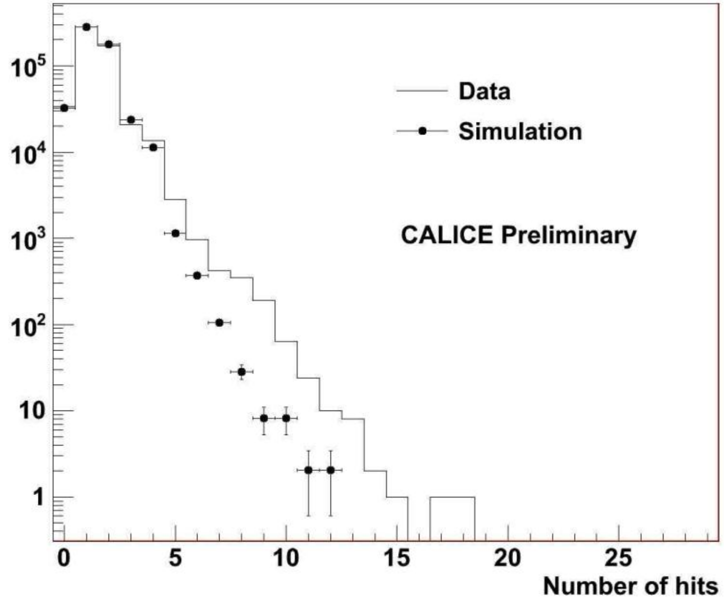
y constrained to (0.25, 0.75)

y scan:

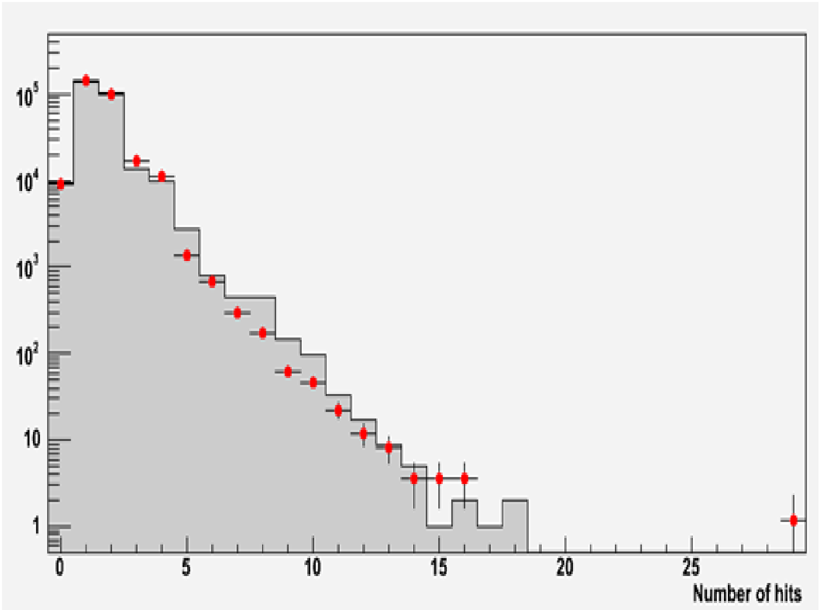
x constrained to (0.25, 0.75)

# Recent development: 2nd exponential

- For muon data taken at Fermilab test beam, we saw an larger than expected tail on the high end of the number of hits distribution
- Adding a 2nd exponential with wider charge distribution can match the simulation to data
  - Two more tunable parameters: **a'** (slope of 2nd exp), **R** (ratio of the two exp's)
- Systematic comparison using electrons/pions ongoing




Simulation with 1 exp




Simulation with 2 exp's

# Recent development: look-up table

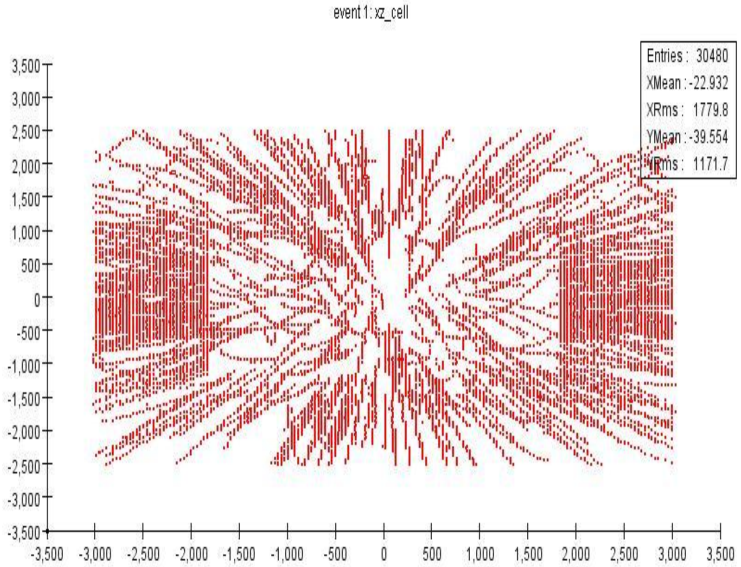
- Original RPCsim is relatively slow
  - Throw 10k points for each avalanche, in order to estimate charge on each pad
  - Randomly sample total charge distribution, to get charge for each avalanche
  - Both are essentially doing numerical integration → potential to save run time
- Implementation of pre-calculated look-up tables
  - Avalanche charge generation is straight-forward:
    - Numerically integrate the charge distribution to high precision
    - Map the integration to [0, 1] and generate look-up table
    - Generate single random number in [0,1], and lookup/interpolate to get charge
  - Charge distribution is more complicated, need 2-D lookup table
    - Calculate in a single pad (only 1/8 are needed due to symmetry) with very fine grid (200x200 points on 1cm x 1cm pad, which is also the look up coordinates)
    - For each grid point, perform precision numerical integrate to calculate fraction of charges in nearby 3x3 or 5x5 pads (table entries)
    - Lookup/interpolate to get fraction of charge on each pad, according to in-pad position
- Using the look-up tables is much faster, but generating the distribution table is not
  - Original RPCsim is used in the parameter tuning
  - Look-up table will be used in production, once the parameters are fixed

# SiD/lcsim implementation

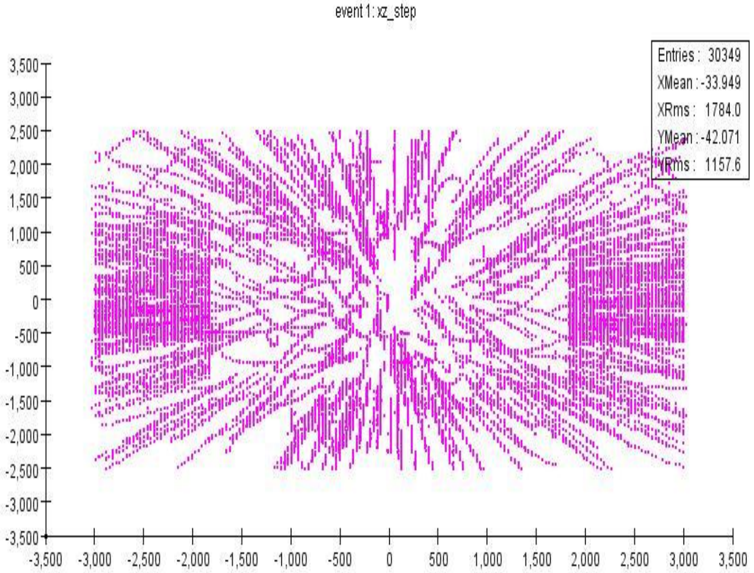
- So far the RPCsim has been used as a stand alone step in test beam simulation
- Recently made an effort to make it available for detector/physics studies
  - People would like to (at least) see if there's a significant difference between RPCsim and a much more simplified version used in the physics studies
  - RPCsim parameters still need some fine tuning, but are already good enough for detector/physics studies
  - Would require additional simulation information that was not in the standard SiD simulation output: position of all energy deposition points in RPC gas
- Norman Graf / Jeremy McCormick kindly provided new data samples that has the required information
- Jan Strube helped with setting up latest lcsim

# SiD/lcsim implementation

- SiD/lcsim implementation is basically a rewrite of the look-up table version
  - Most part is relatively straight forward
  - Some complication with the geometry, finding neighboring cells and local coordinate
  - Generated hits are currently stored in a self-defined simple hit class
- My part of job is considered done
  - Output hits need to be stored into more appropriate data structure: expect experts (Norman/Jeremy) to take over and finish it
- Did very limited/simple check: looks OK




Before RPC simulation:
only energy deposition points




After RPC simulation:
digital hits

# Summary

- RPC response simulation has been developed based on total charge and charge distribution measurements, with a few tuning parameters
- Parameters are being tuned according to test beam data
- Several improvement of the simulation implemented to improve data/simulation agreement and running speed
- Implementation in SiD/lcsim is (almost) done