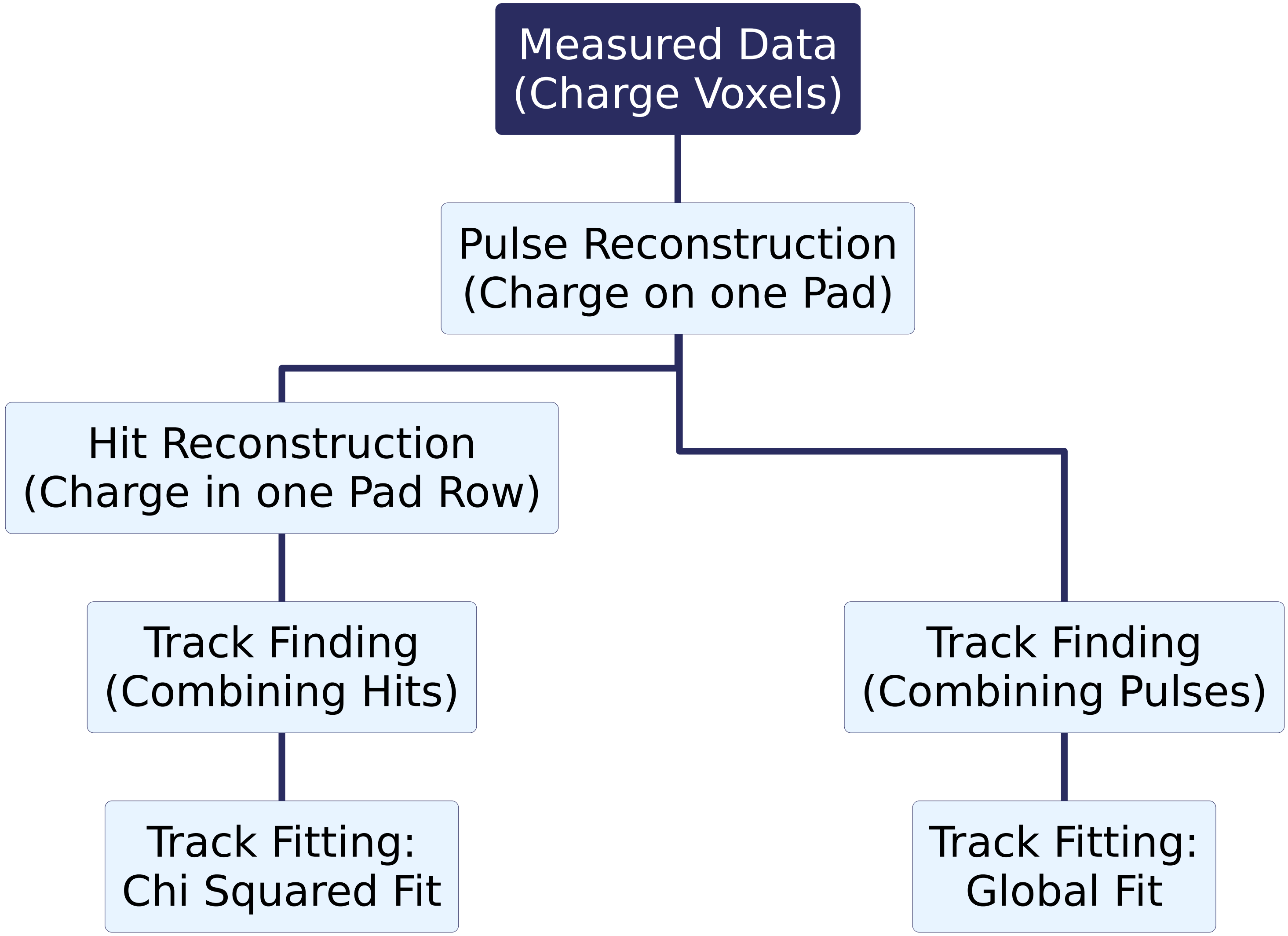
Measured Data



Measured Data Object

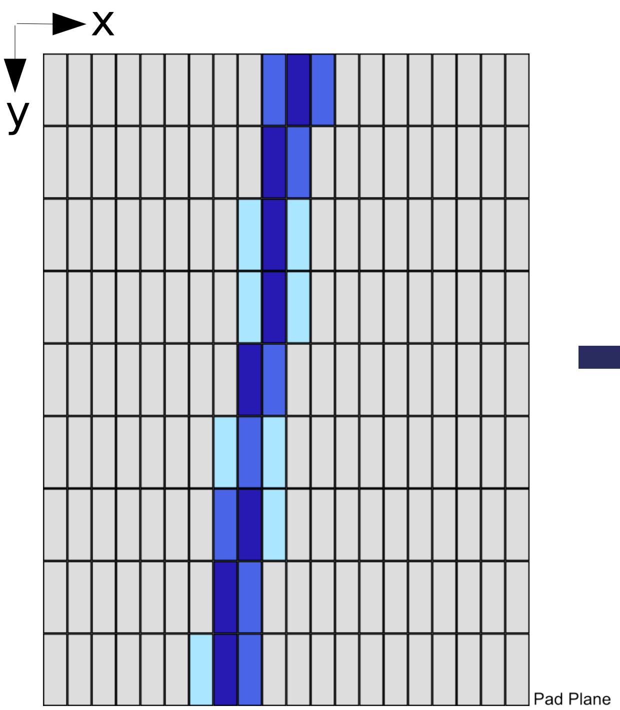
- Object Properties:

- Identification of the channel:
  Detector ID (and sub detector ID; for example: first ID for petal on a large readout plane, the second for the pad on this petal)
- Time:
  A time measurement associated with the ADC values
  (i.e. start of charge spectrum)
- Charge:
  ADC Values: The actual ADC spectrum (vector with ADC values)

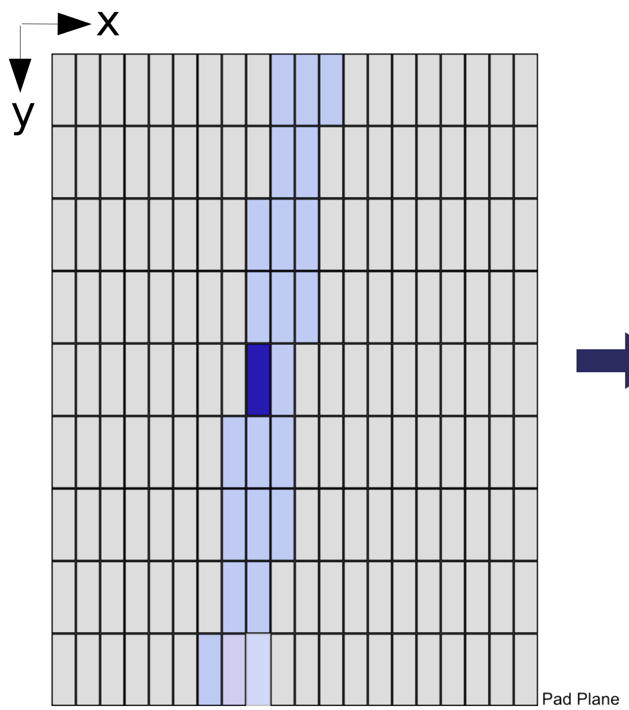
- A Pulse objects of an event (and all other objects in the reconstruction chain) should belong to a collection which contains information about the event
  (i.e run number, detector, maybe a comment, identification number of event, time of event)

Pulse Reconstruction

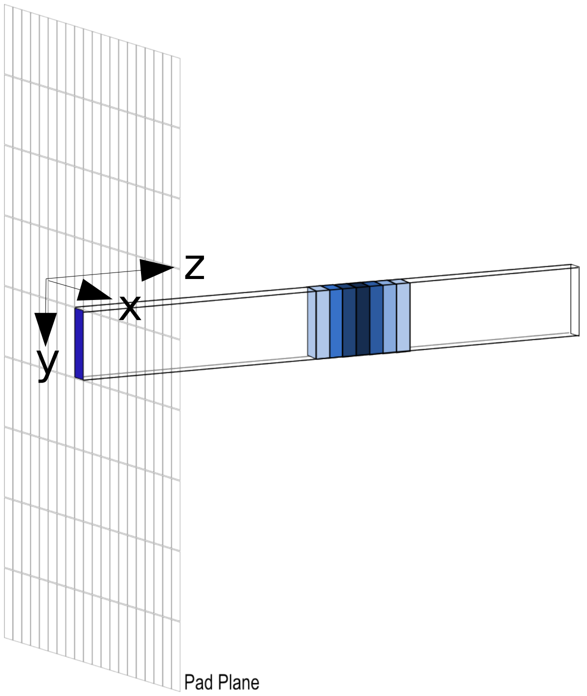
- First Step: Pulse reconstruction
- A ***Pulse*** is the charge deposition on a single pad that belongs to one track



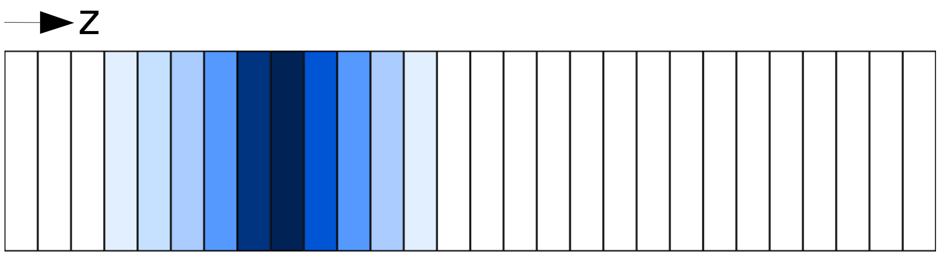
Track on pad plane



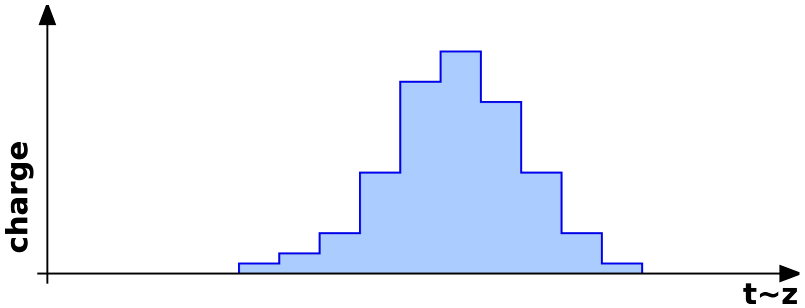
Signal on single pad



Coordinate of a single pad in Z

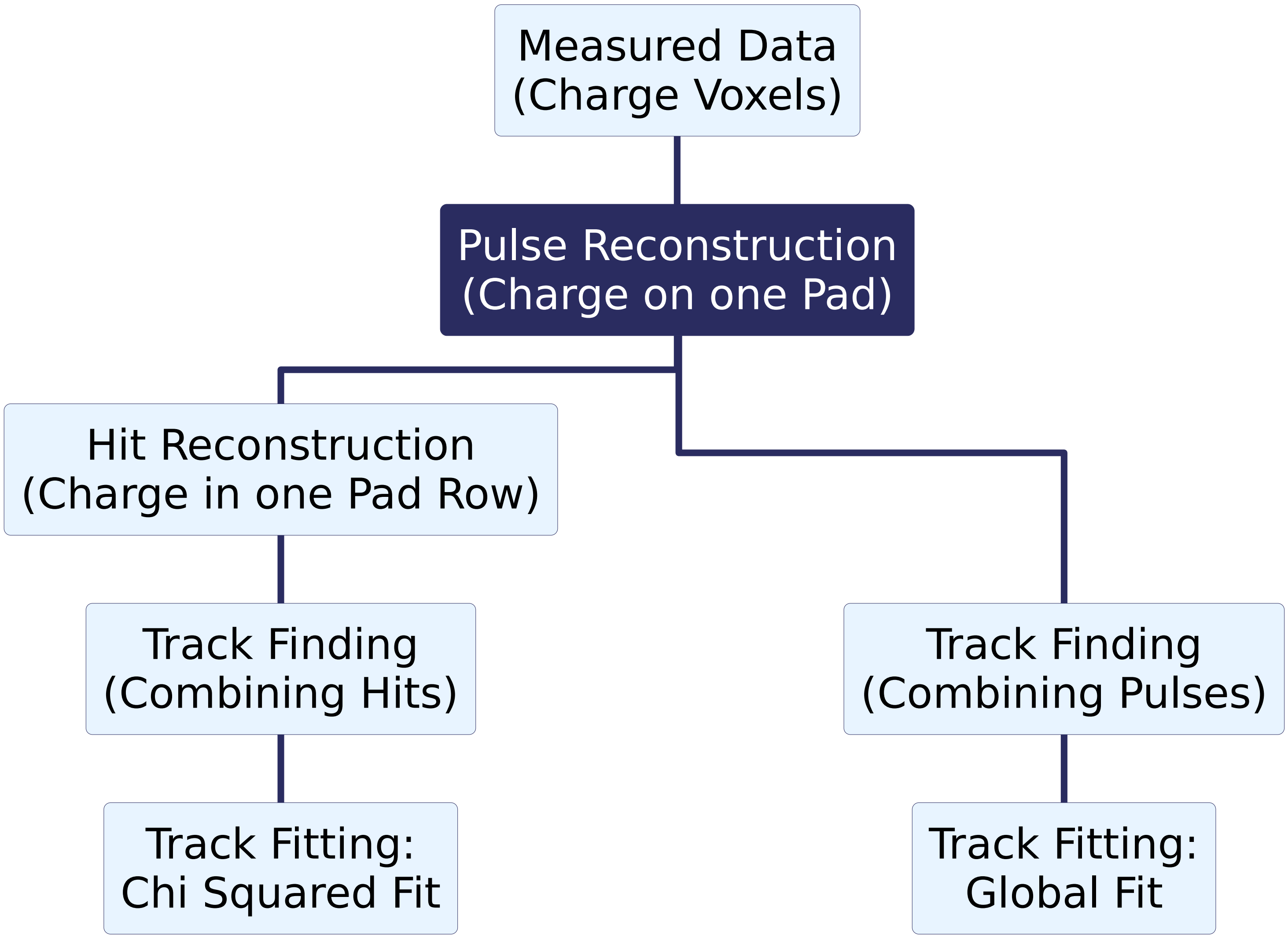


Charge deposition in time bins on a single pad = Pulse



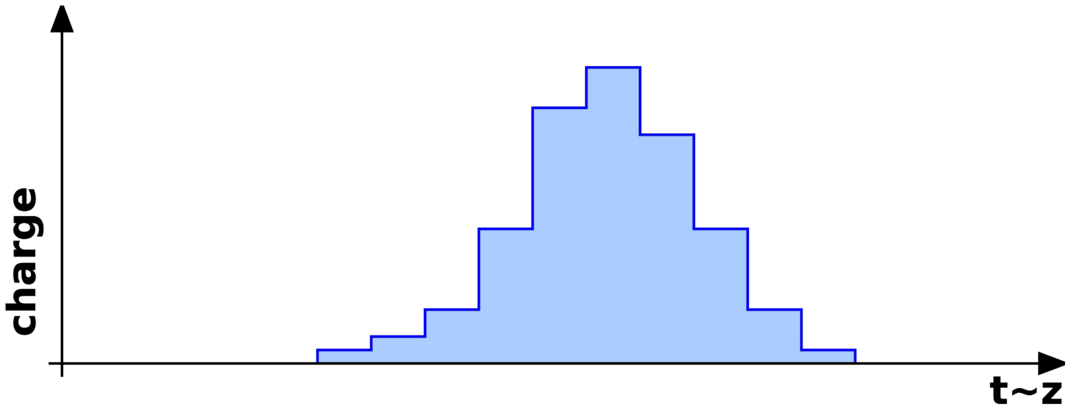
Pulse charge histogram in time (z)

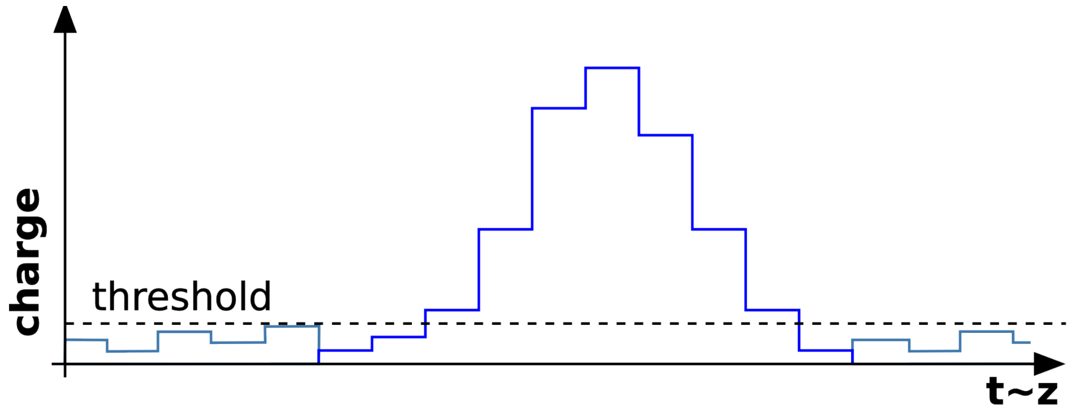
Pulse Reconstruction

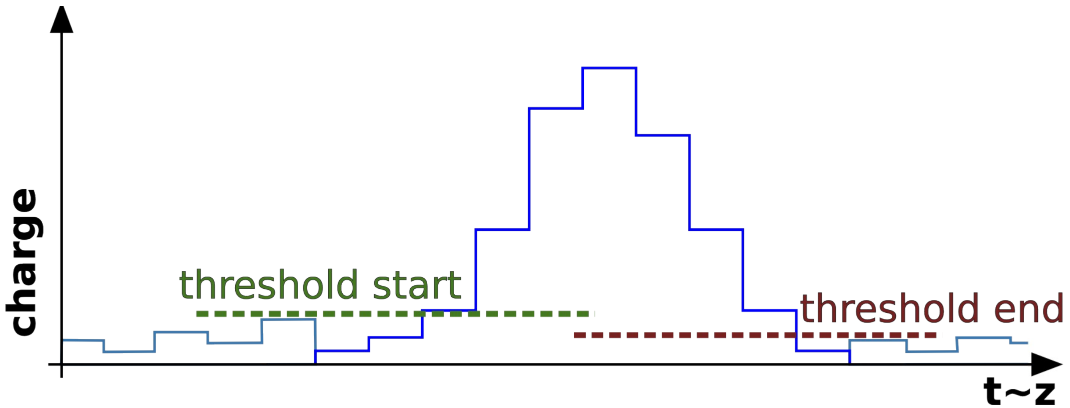


Pulse Reconstruction

- Pulse signal:
  continuous (in time) charge deposition on a pad
- Need to apply a threshold to filter out noise signals:
  Signal over threshold belongs to one Pulse
- In Practice: Better to apply different thresholds for start and end of Pulse detection:
  - At the start: make sure that only real signals start a Pulse, that are surely over the noise level
  - At the end: make sure not to miss charge deposition that belongs to the pulse







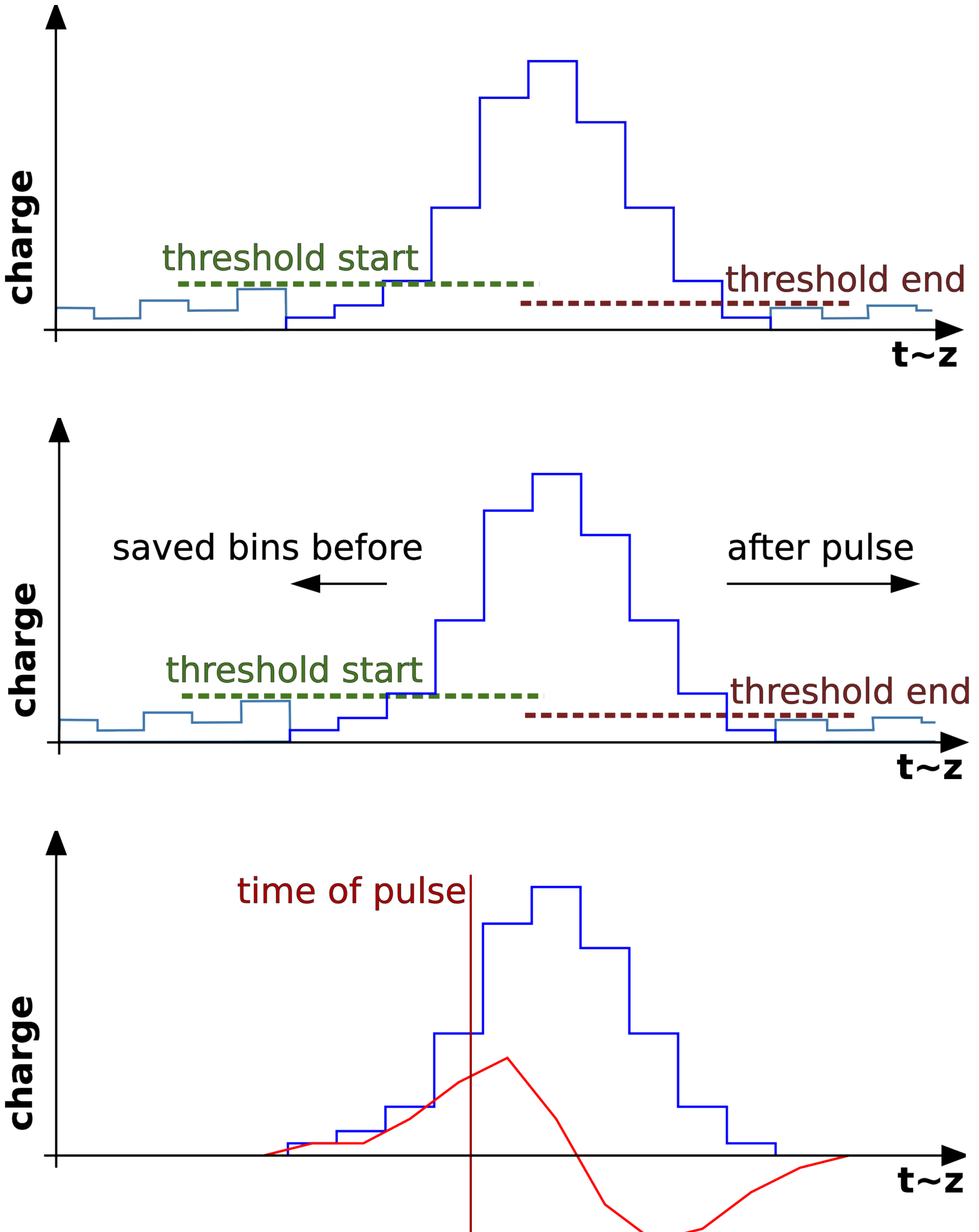
Pulse Reconstruction

- Some charge of the Pulse is missed due to the thresholds

- Add the charge information of some bins before and after the threshold cuts to get the complete charge

- Now the time of the pulse is determined:

  - Short signal on pad plane and long shaping time
  - Determine the derivative of the histogram
  - Mean of the positive derivative is a good measure of the time of the pulse



Pulse Reconstruction

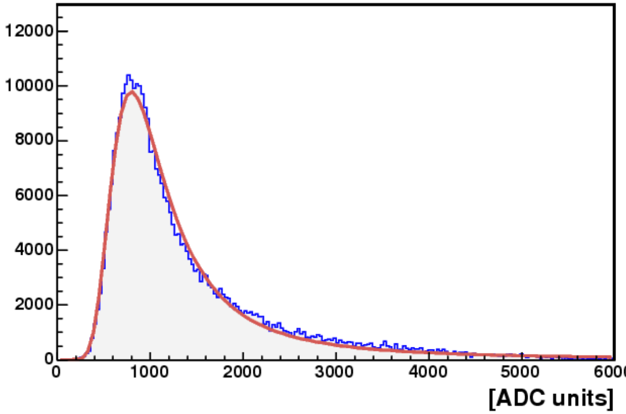
- Now we have the 3D coordinates of the Pulses:
  - X and Y are defined by the center of the pad:
    this information comes from a pad mapping (is used later on)
  - Z is defined by the time information: $z = v_{Drift} * t$
- The charge of the Pulse is determined by integrating over the histogra:

$$Q_{Pulse} = \sum_{all\,Voxels\,of\,the\,Pulse} Q_{Voxel}$$

- Additionally a *Quality* can be assigned to mark non-perfect Pulses with:
  - Pulse is in overflow
  - Pulse has a very long tail
  - Pulse has a “strange” shape
  - etc.

Pulse Reconstruction

- Error of the Pulse charge:
  - Assume a Poisson distribution of primary electrons, therefore: $\sigma_{charge}=\sqrt{\mu}$
  - Here: μ is the number of primary electrons n_e
  - We need a conversion factor C to convert ADC counts to primary electrons:
    - this is best to be measured
    - assume a Landau distribution of the primary ionization
    - the charge Q per row is measured in ADC values
    - make a row of measurements to get a distribution of the number of primary electrons n_e
    - the most probable value (MPV_Q) of the distribution is taken to be the value of expected electrons per row N_t (this value is a gas property)
    - Conversion factor: $C=\frac{N_t}{MPV_Q}$



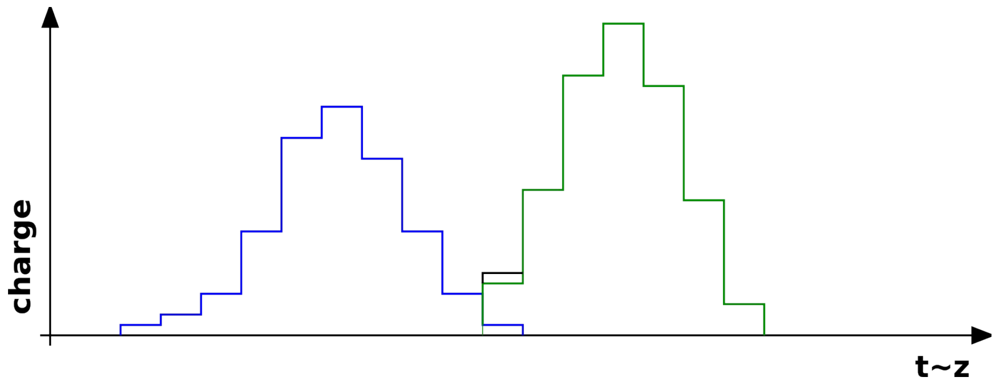
Gas	$X_0[m]$	$N_t[\frac{1}{cm}]$	$\sigma_n[barn]$
He	5299	8	1.34
Ne	345	43	2.628
Ar	110	94	0.683
CO_2	183	91	14.015
CH_4	646	53	333.631
C_2H_6	340	111	503.222
iC_4H_{10}	169	195	842.404

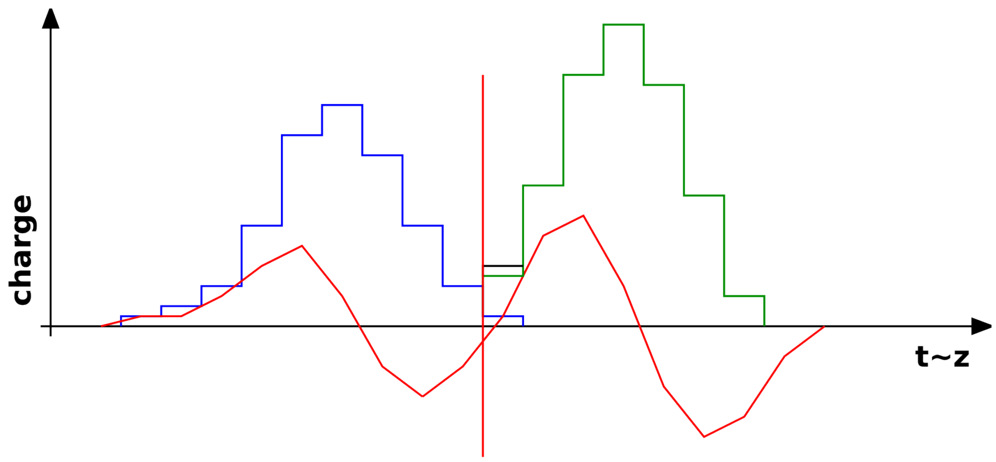
- So the error is: $\sigma_{charge}=\sqrt{C*Q_{[ADC\,counts]}}$

Pulse Reconstruction

- Two Pulses following each other closely: need to be separated

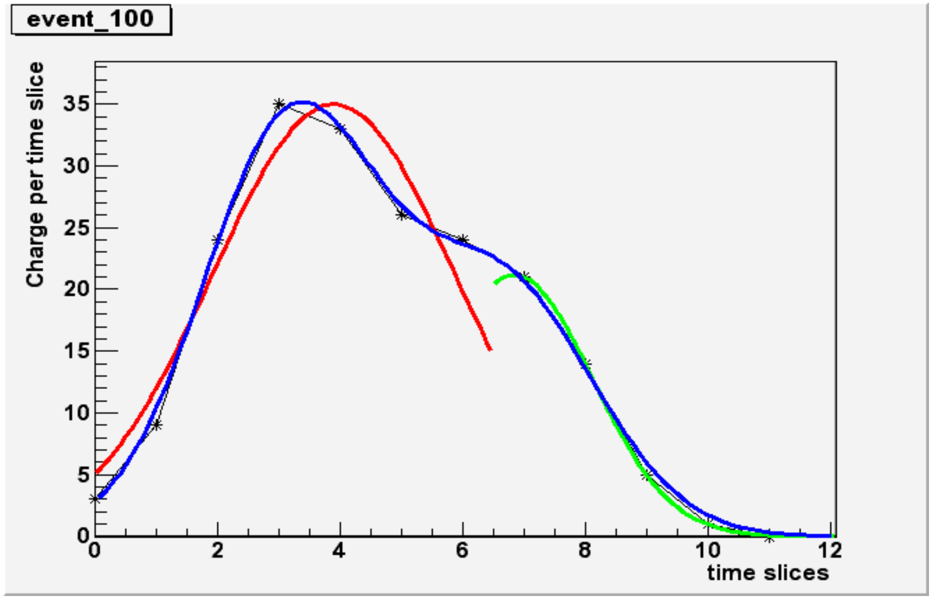
- Calculate the derivative D (gives value D_i for every time bin)
- Detect change in the sign of the derivative from negative to positive
- Zero crossing is taken to be the Z coordinate of the separation
- Charge C_i of this time bin ***i*** is splitted between pulses by assigning: $$F = C_i * \frac{D_i}{D_{i-1} - D_i}$$ to first Pulse, the rest to the second Pulse
- In this case no adding of bins before/after this bin to other pulse
- Ignore variations in the order of noise in this process!

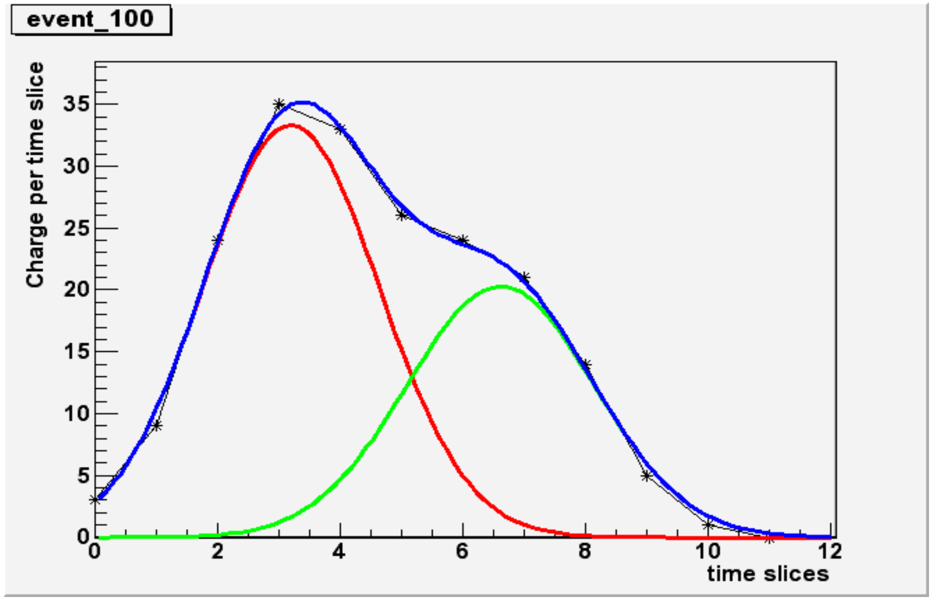




Pulse Reconstruction

- Idea to improve Pulse separation: Use a double Gaussian fit





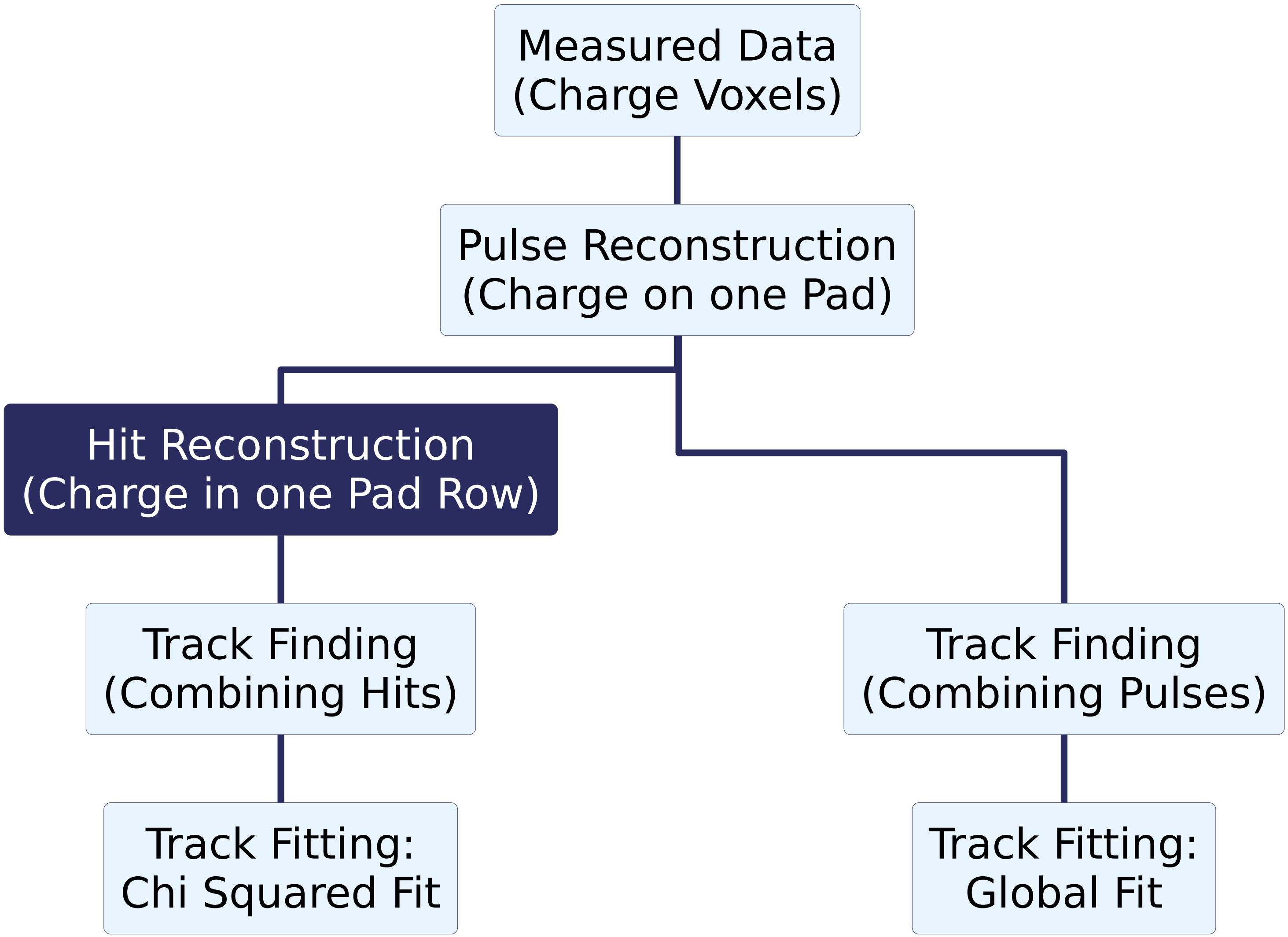
- Maybe not a very good idea:
  - Needs outside input when to apply the separation algorithm (length of Pulse)
  - Gaussian Fit is time consuming
- Depends much on setup (electronics) and is very sensitive to fluctuations (gain, noise etc.)

Pulse Object

- Object Properties:

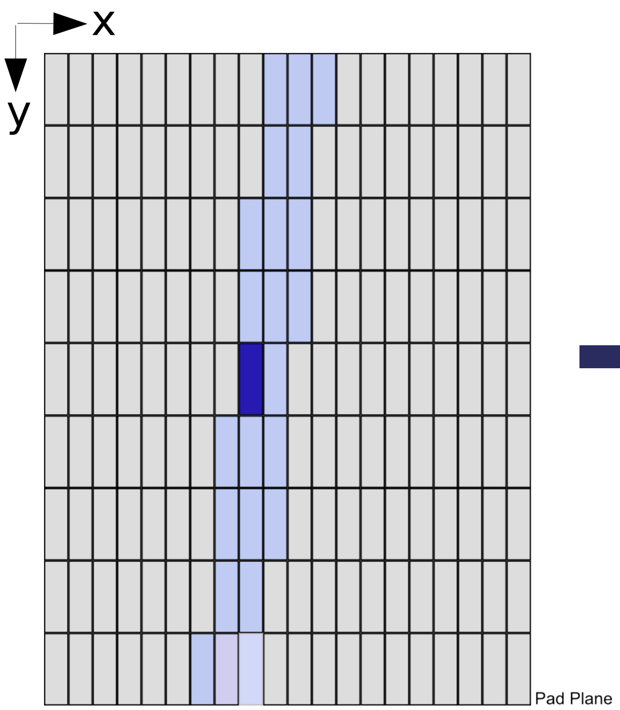
- Identification of the channel:
  Detector ID (and sub detector ID; for example: first ID for petal on a large readout plane, the second for the pad on this petal)
- Time:
  A time value.
- Charge:
  The integrated charge of the pulse (arbitrary units; i.e. ADC counts)
- Quality:
  The quality bit flag of the pulse
- *optionally:* Measured Data:
  Spectrum of the Pulse
- *optionally*: Error of the charge information:
  Can be calculated easily, so no real need to store it

Hit Reconstruction

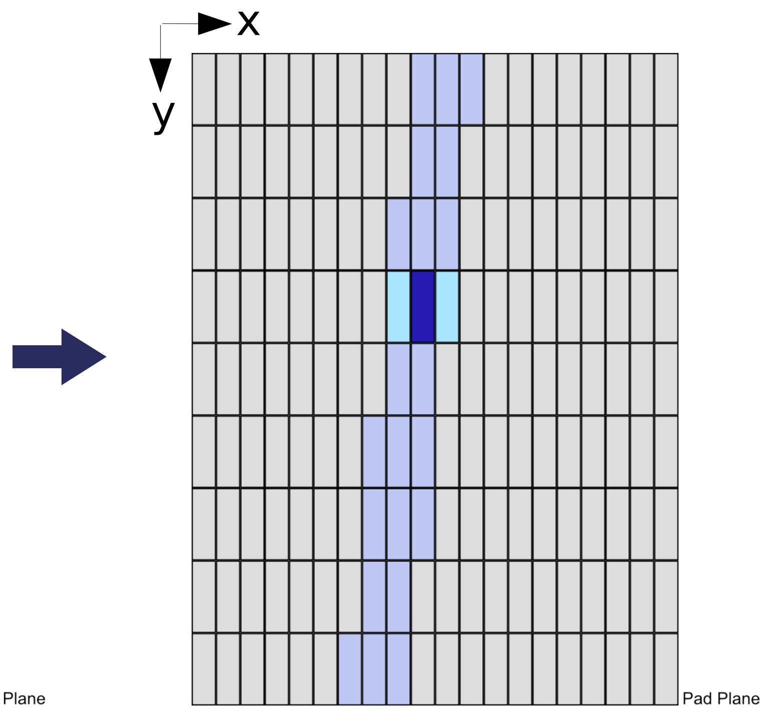


Hit Reconstruction

- Hit Reconstruction
  - A ***Hit*** is the charge deposition in a single row that belongs to one track
  - Gets reconstructed by combining pulses of one row



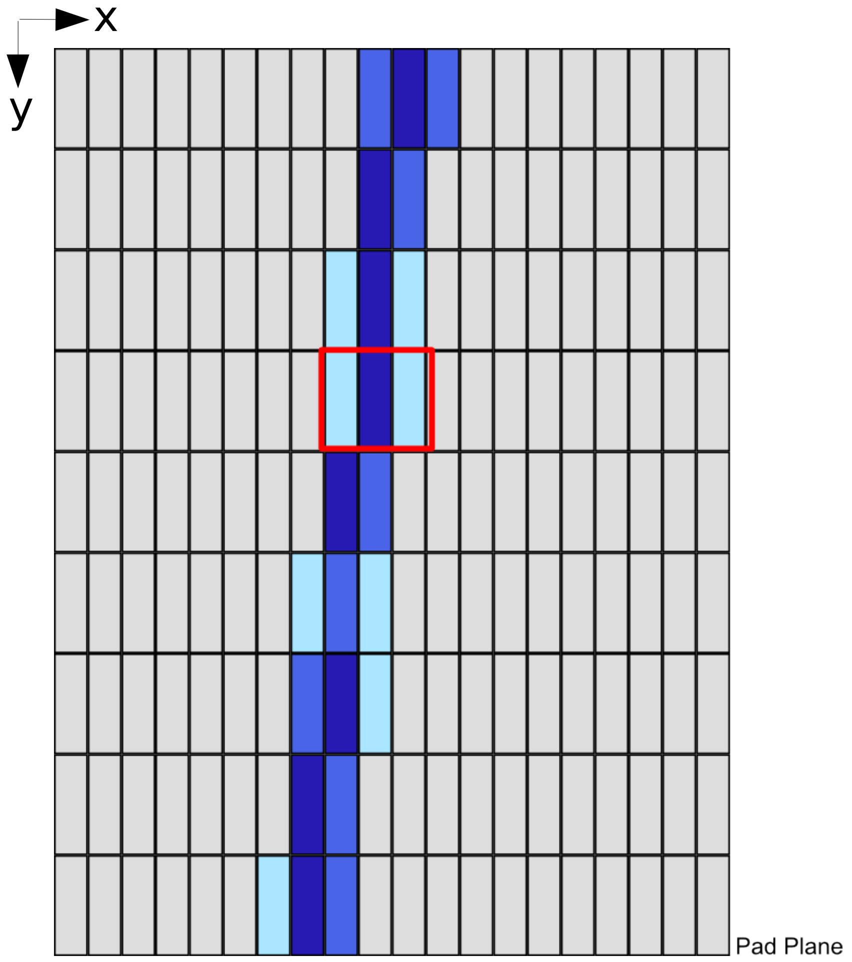
Pulse



Hit: Signal in one Row

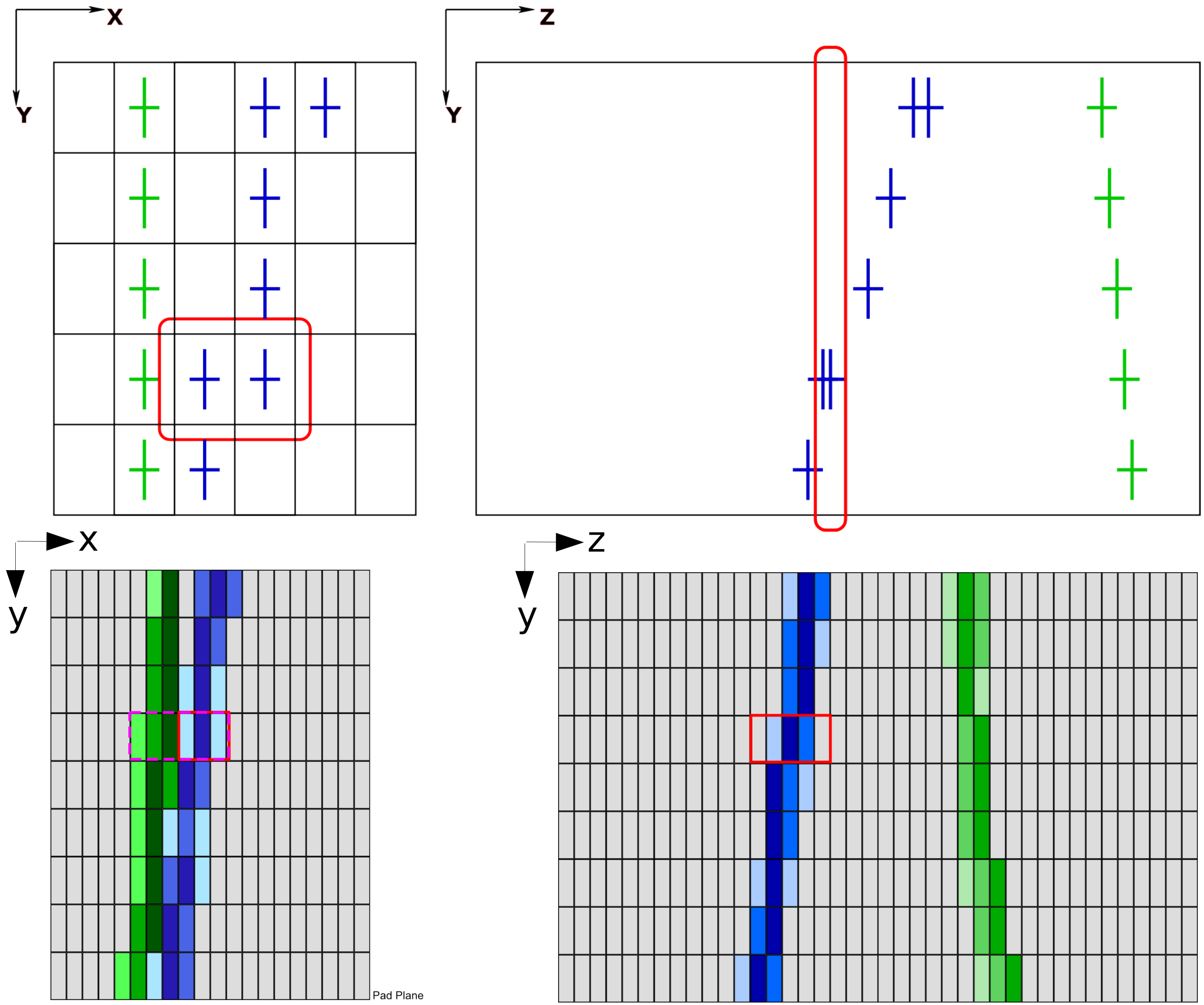
Hit Reconstruction

- Find adjacent Pulses in a row:
- Start with the pulse with the highest charge in a row and add it as first Pulse to the Hit
- Search on both sides Pulses that are adjacent and add them to the Hit
- If a pad has been marked as damaged continue search next to this pad (avoids accidental splitting of Hit)
- After search ended on pads without signal “remove” these Pulses from the row and start a new search with the Pulse, that is now the highest
- Repeat this procedure until no Pulses are left in the row
- Repeat this procedure in all rows



Hit Reconstruction

- To avoid false combinations: define search window in Z around the Pulse with the highest charge (starting point for search)

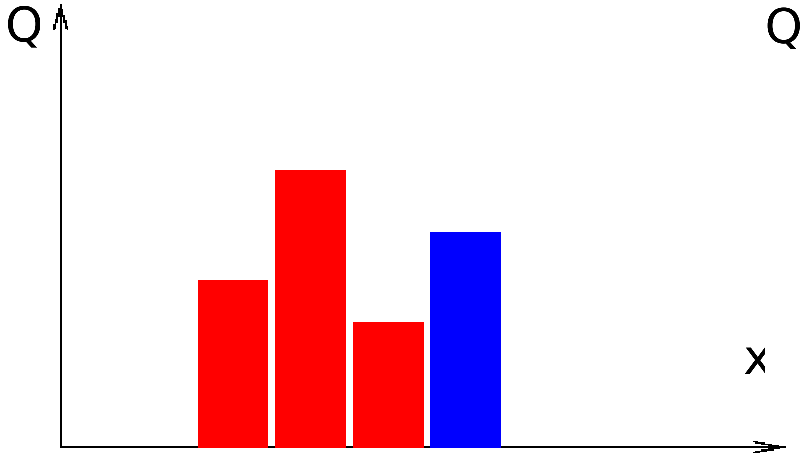


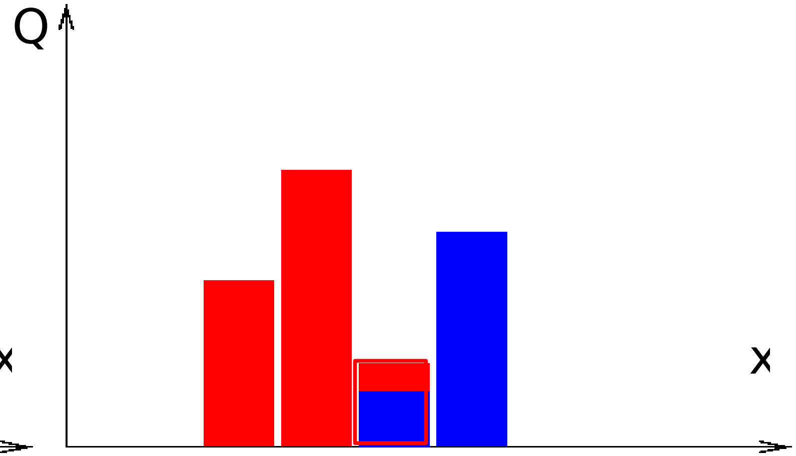
Hit Separation

- Hit separation: If 2 Pulses lie next to each other **and** in the same time window, they have to be splitted

- Similar to Pulse separation: Go through Pulses and detect changes in the slope

- Find the first local minimum by calculating the derivative of the pulses (ignore changes in the order of noise)





- To get a good charge assignment, calculate charge depending weight: $x = Q_1 / (Q_1+Q_2)$ resp. $1-x = Q_2 / (Q_1+Q_2)$; default value x = 1

- Produce two Pulse collections (=Hits): first store pulses before minimum + minimum, second erase pulses before minimum (to repeat the method)

Hit Reconstruction

- Now we have Hits:
  the 3D position and the charge deposition of a track in every row

- The X position is determined by a center of gravity method:

$$x_{Hit} = \frac{\sum_{Pulses} Q_{i,Pulse} * x_i}{\sum_{Pulses} Q_{i,Pulse}}$$

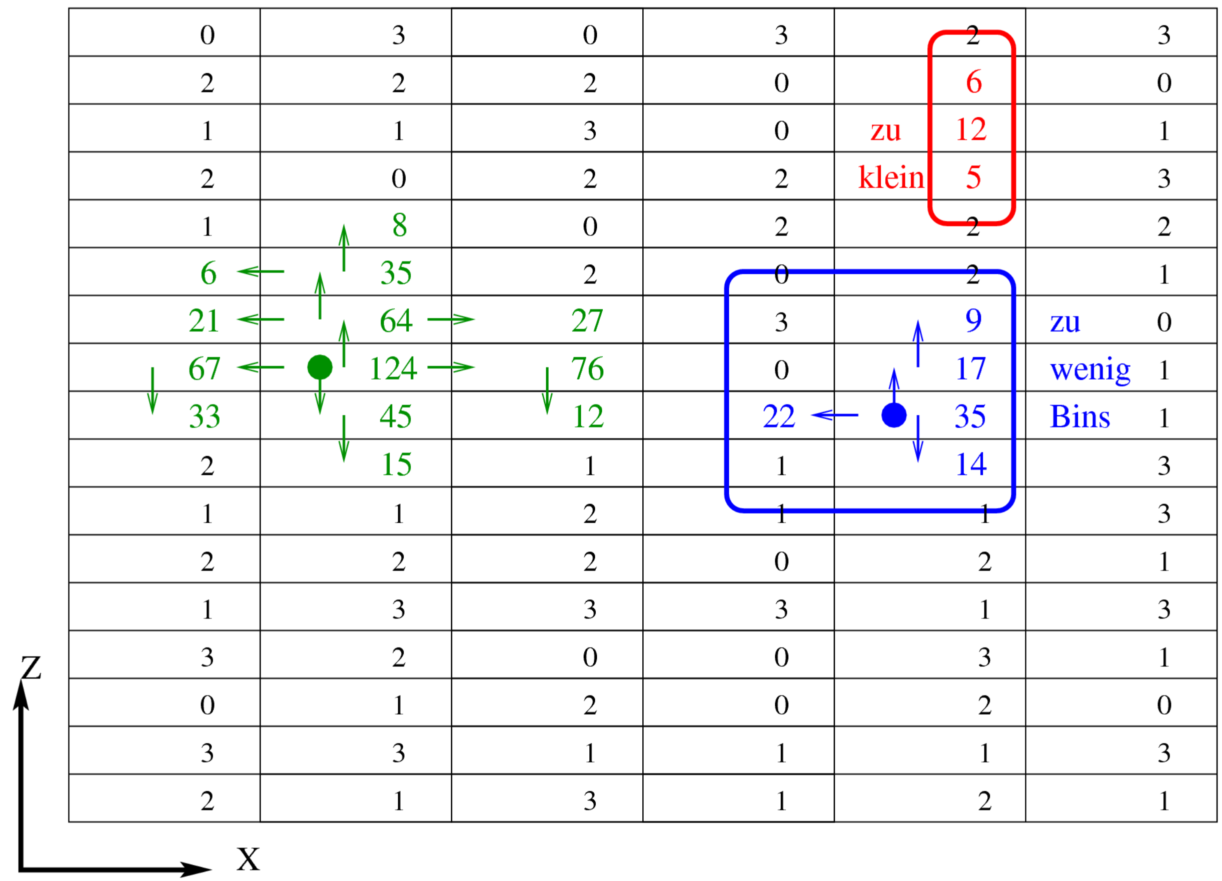
- The Y position is given by the vertical center of the pad row
- The Z position is calculated by:
  - The Z position of the Pulse with the highest charge

    or

  - The Z position is calculated from the error weighted mean of the Z coordinates of the Pulses belonging to the Hit

- The charge is given by the sum over the charge of the Pulses

- An idea that didn’t work out: search hits in complete XZ plane:
  - Start with highest Voxel
  - Search Voxels which are smaller but larger than a threshold next to it
  - Repeat this with every new found Voxel
  - When no new Voxels can be added: remove information and start again
- Too CPU intensive
- Z information worse than with previous method



Hit Object

- Object Properties:

- Position
  The position: 3 Parameters for the 3 dimensions
- Time:
  The time of the hit.
- Errors of the Hit:
  Error of the position values
- Charge:
  The charge sum of the Pulses belonging to the Hit
- *optionally*: dEdx:
  The dE/dx of the hit in [GeV]
  proportional to the deposited charge: $n_e(x) = dE/dx * W^{-1}$
  (W is a factor which depends on the gas mixture)
  The number of primary electrons can be transformed
  into ADC counts
- RawHits:
  The Pulses that make up the Hit (→ Charge Information)