Status of Digitisation

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Introduction

- To optimise a detector design by firstly investigating the parameter space between GLD and LDC
- For this we need to form a single set of digitisers to use for the reconstruction
- Here I will only concentrate on LDC, and more specifically only software available in Marlin

Tracking Detectors

- Silicon
  - Simple Gaussian Smearing
  - Sophisticated Hit Reconstruction

    Three instances in Marlin(Reco):
    - VTXDigitizer, SiliconDigi, CCDDigitizer
- TPC
  - Simple Gaussian Smearing
  - Marlin TPC

Simple Gaussian Smearing in Si

- Gaussian Smearing based on measurements at fixed R or Z -- VTX, SIT, FTD
- Smearing performed according to single point resolution supplied by the user
- Geometric information taken from GEAR
- Ladder construction recently added
- Strip ambiguities not considered
- No Electronics effects considered
- Problems seen of hits outside of active region

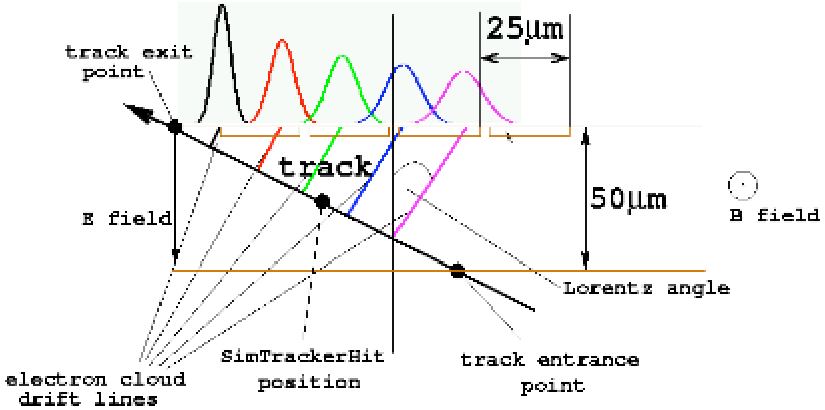
VertexDigi: Raspereza et al

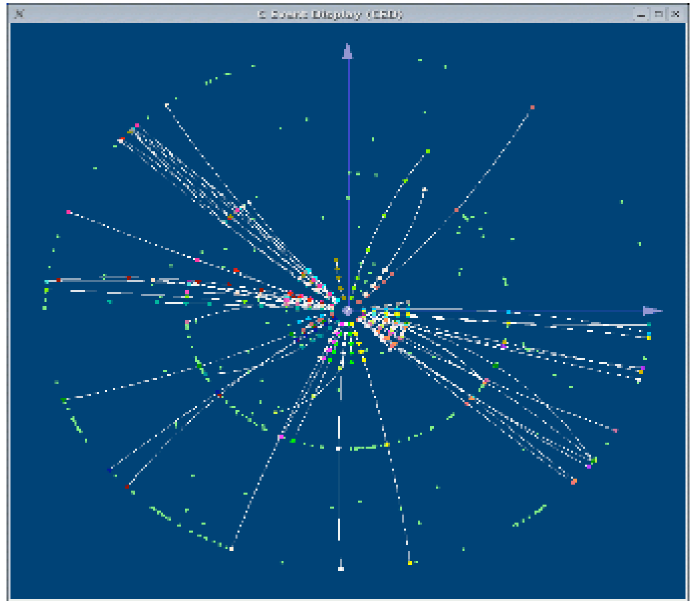
- create ionisation points along the track among a certain distance (this processor parameter is chosen to 5µm)

- ionisation point has random energy according to distribution of MyG4UniversalFluctuationForSi class, mean energy of ionisation point depends on energy loss of particle per tracklength (chosen to 280 keV/mm)

- Diffusion of charge of each ionisation point according to Gaussian distribution width proportional to root of distance between ionisation point and collection plane

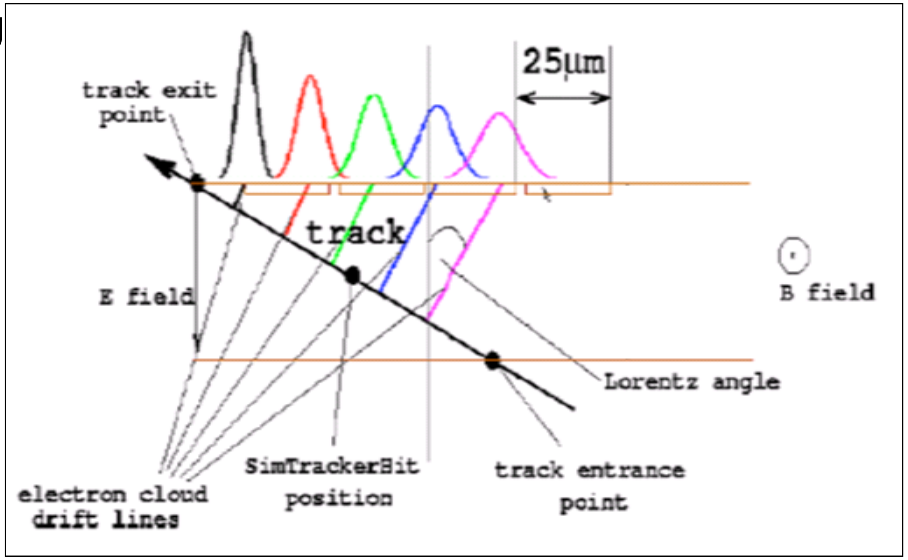
- shift caused by magnetic field is taken into account





VertexDigi: Raspereza et al

Signal for each pixel: random number according to Poisson distribution with mean value of electron number in pixel calculated above



Electronic noise for each pixel: adds a random number according to gauss distribution with mean 0, and width 100 electrons

Reconstruction:
-every hit is reconstructed separately: no hit is missed, no cluster finding algorithm is needed

There is a background generator: creates Poisson- distributed number of additional signals in each ladderSignal

VertexDigi: Raspereza et al

Simulation of DEPFET sensor has been tuned & validated with testbeam data in e- beam & DESY

– DEPFET sensor thickness = 450um
– Pixel size : 36×22 μm^2

Parameters steering the simulation has been readjusted to ensure good description of testbeam data

– Diffusion coefficient:

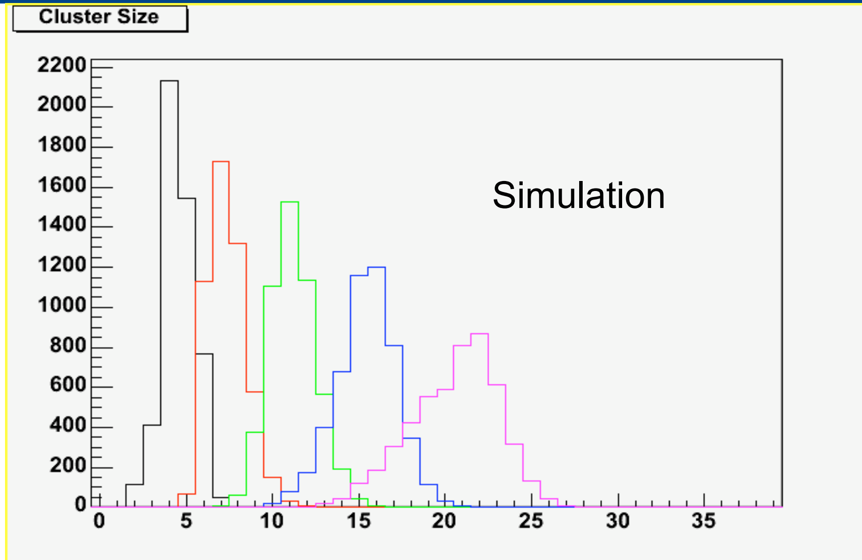
$$\sigma^2_D = D \cdot L_{drift}, \quad D = 3.2 \cdot 10^{-4} \mu m$$

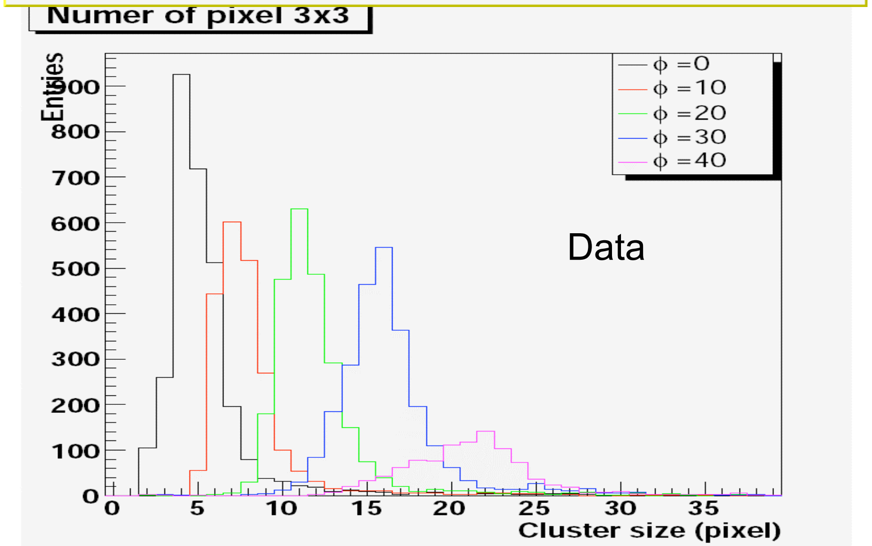
– Factor converting deposited energy into produced electrons:

Yield = 270 e-/keV

– Energy loss per unit of length

dE/dx = 330 keV/mm





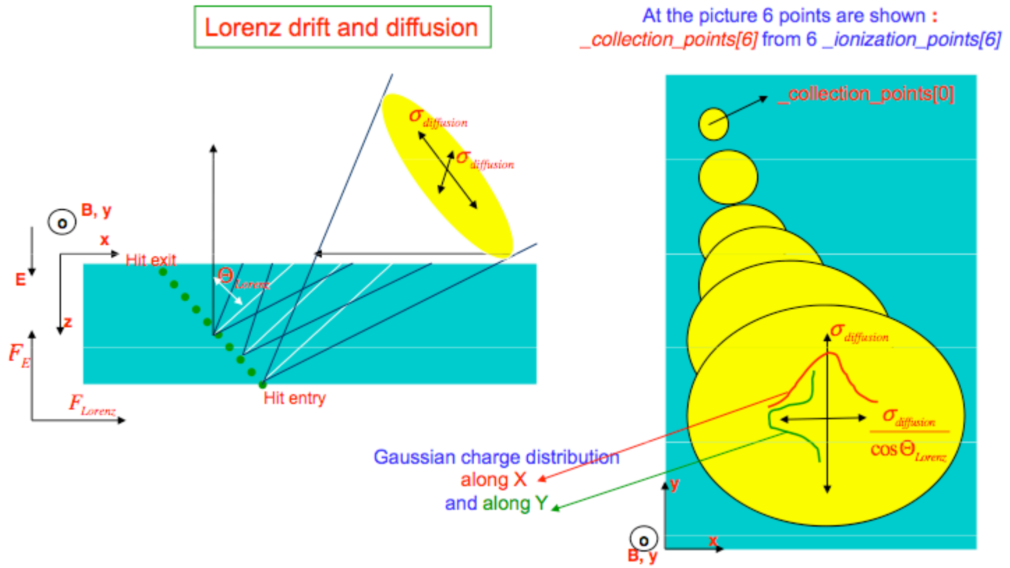
SiliconDigi: Shulga et al

SiDigiProcessor transforms input SimHit collection to output TrackerRawData;

SiClusteringProcessor transforms input TrackerRawData to output TrackerHit.

SiTracker : - main element of the digi/clustering processors
- defines subdetector (VXD/SIT/FTD) as a container of layers and SiDetUnit's using GEAR information (xml)
- digitizes DetUnits
- clusterizes DetUnits.

Based on algorithms developed in CMS (ORCA, COBRA)



SiliconDigi: Shulga et al

Digitizer input: DetUnit with collection of sim.hits (TrackerSimHit) in event
and geometrical information: pixel X,Y sizes, thickness,
and number of pixels in DetUnit along X (row) and Y (column).

Digitizer output: DetUnit with collection of fired pixels which are collected in map < int channel, double amplitude > _signal, where channel is packed 2-dimensional pixel number,
amplitude contains total charge (in electrons) from all sim.hits in event and vector of contributing sim.hits.

The clusterization is performed on a matrix with size equal to the size of the pixel detector, taking into account thresholds and noise

Clusterizer input: DetUnit with collection of raw.hit (TrackerRawData) in event
and geometrical information: number of pixels in DetUnit along X (row) and Y (column).

Clusterizer output: DetUnit with collection of reconstructed hits (TrackerHit)

SiliconDigi: Shulga et al

Parameters	default
• Pixel sizes	0,150 x 0,150 mm
• DetUnit thickness	0,282 mm
• Ionization segment length	0.01 mm
• Angle of Lorenz drift	$\tan\Theta_{Lorenz} = 0.106 * B$, B = 4 Tesla
• $\sigma_{diffusion}$ for drift length 0.3 mm	0.007 [mm]
• Fired cluster widths: $\sigma_X, \sigma_Y = f(\Theta_{Lorenz}, \sigma_{diffusion})$	$[3*\sigma_X, 3*\sigma_Y]$,
• RMS of gaussian distribution of pixel noise	500 electrons
• Pixel threshold in units of noise RMS for pixels 0,150 x 0,150 [mm]	4 (2000 electrons)
• Efficiency for single pixel	99%
• Efficiency for pixel double column	99%
• Readout Chip efficiency	99.75%
• Readout Chip sizes (in units of pixels)	20 x 52

Plans: Strip digitizers and clusterizers for SIT (rectangular strip topology) and FTD (trapezoidal strip topology) will be included in common framework described above

CCDDigi: Uebelacker et al

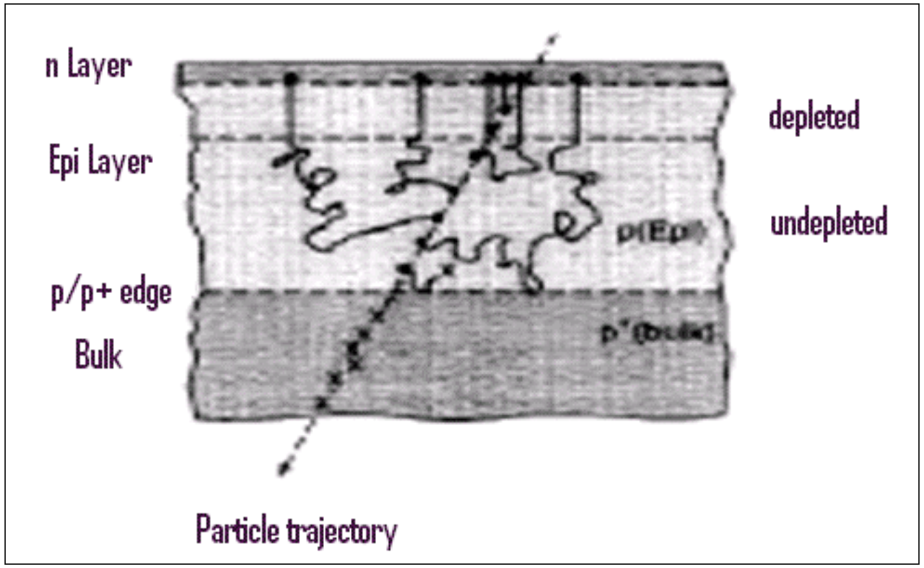
Creation of ionisation- points as VTXDigitizer

But: different treatment, depending on depth of the ionisation- point

1. Ionisation- points in the bulk do not contribute (electrons recombine immediately)

2. Epitaxial layer: charge distribution in pixels proportional to

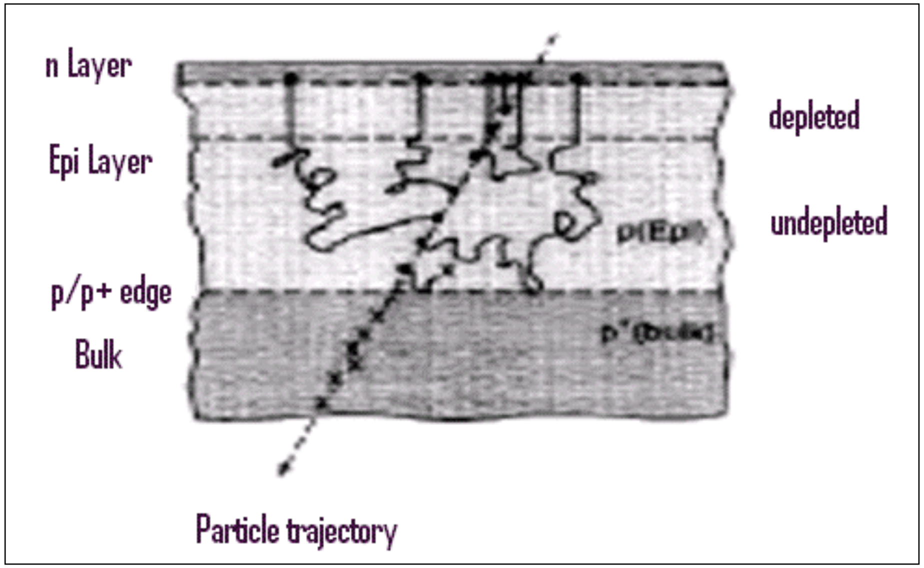
$$\sim \frac{exp(\frac{-d^2}{2\sigma^2})}{d}$$



d : lateral distance between ionisation point and considered pixel
σ : width depends on depth of the ionisation point

The calculation is divided in two cases
A: ionisation point is in undepleted zone
B: ionisation point is in depleted zone

CCDDigi: Uebelacker et al



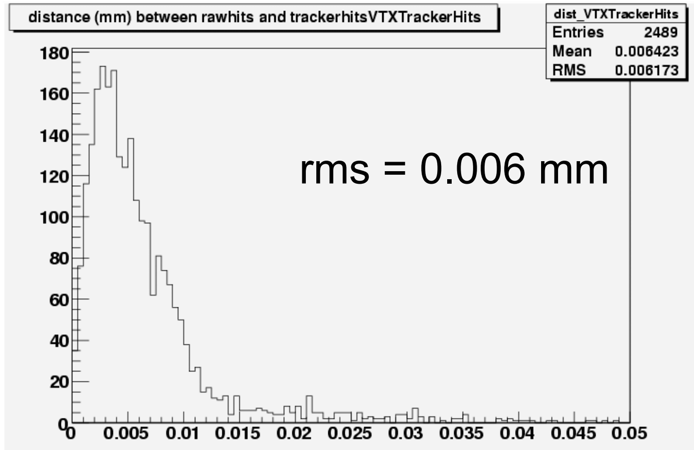
σ in depleted zone is smaller than in undepleted zone

Only magnetic effects in undepleted zone are taken into account

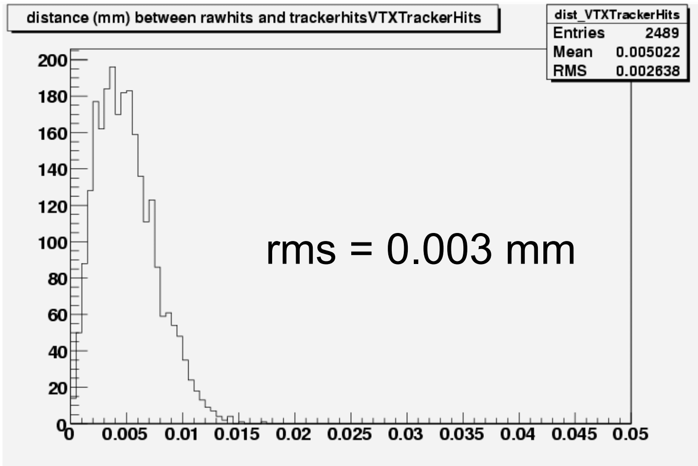
Reconstruction:
- every hit is still reconstructed separately
- the algorithm is now a generic centre of gravity finder
- due to fact that the charge deposited in the bulk is not stored in pixels, the interaction plane (average radial coordinate during interaction) has changed (the thickness of the active layer has effectively changed therefore the radial coordinate needs to be corrected
- function, which computes Lorentz angle in undepleted zone dependent on bias voltage, magnetic field, mobility of electrons and temperature

Different Models

Hit Position Residuals
Sim - Rec

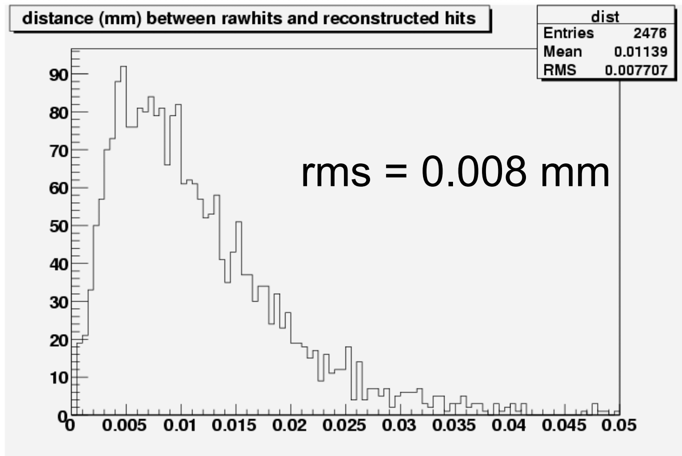


VTXDigitizer



VTXDigiProcessor

20 events of the Sample 90GeV_Z_to_qq



CCDDigitizer

Simple Gaussian Smearing in TPC

- Default Approach gives priority to ensuring stiff tracks produce hits with well understood resolution
- Gaussian Smearing based on measurements at fixed R

$$\sigma_{r\text{-}\varphi}^2 = \sigma_0^2 + \sigma_D^2 \cdot L_{drift}$$

σ_0 = 55 μm, σ^2_D = 3 μm

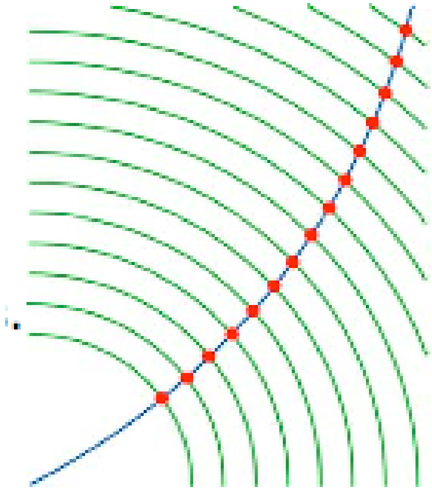
- Currently σ_z = 0.5 mm fixed over the entire drift length
- Smearing performed according to single point resolution supplied by the user
- Geometry information taken from GEAR
- No Electronics effects considered

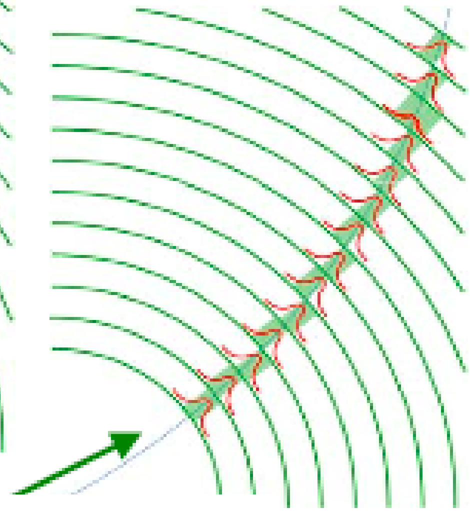
Three Different Cases

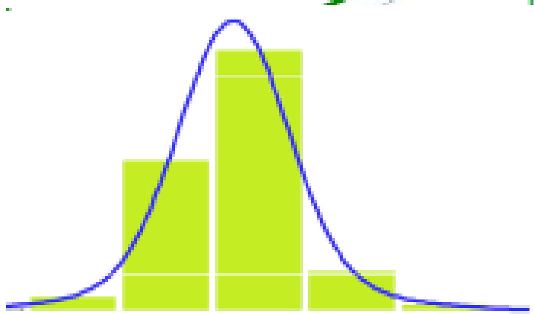
- Almost all high Pt tracks cross through pad rings close to normal in r-phi
- Low Pt tracks (Loopers) can travel substantial distances within one pad ring
- Extremely low Pt tracks can travel completely within one pad ring due due to the very high B-Field

Three Different Cases

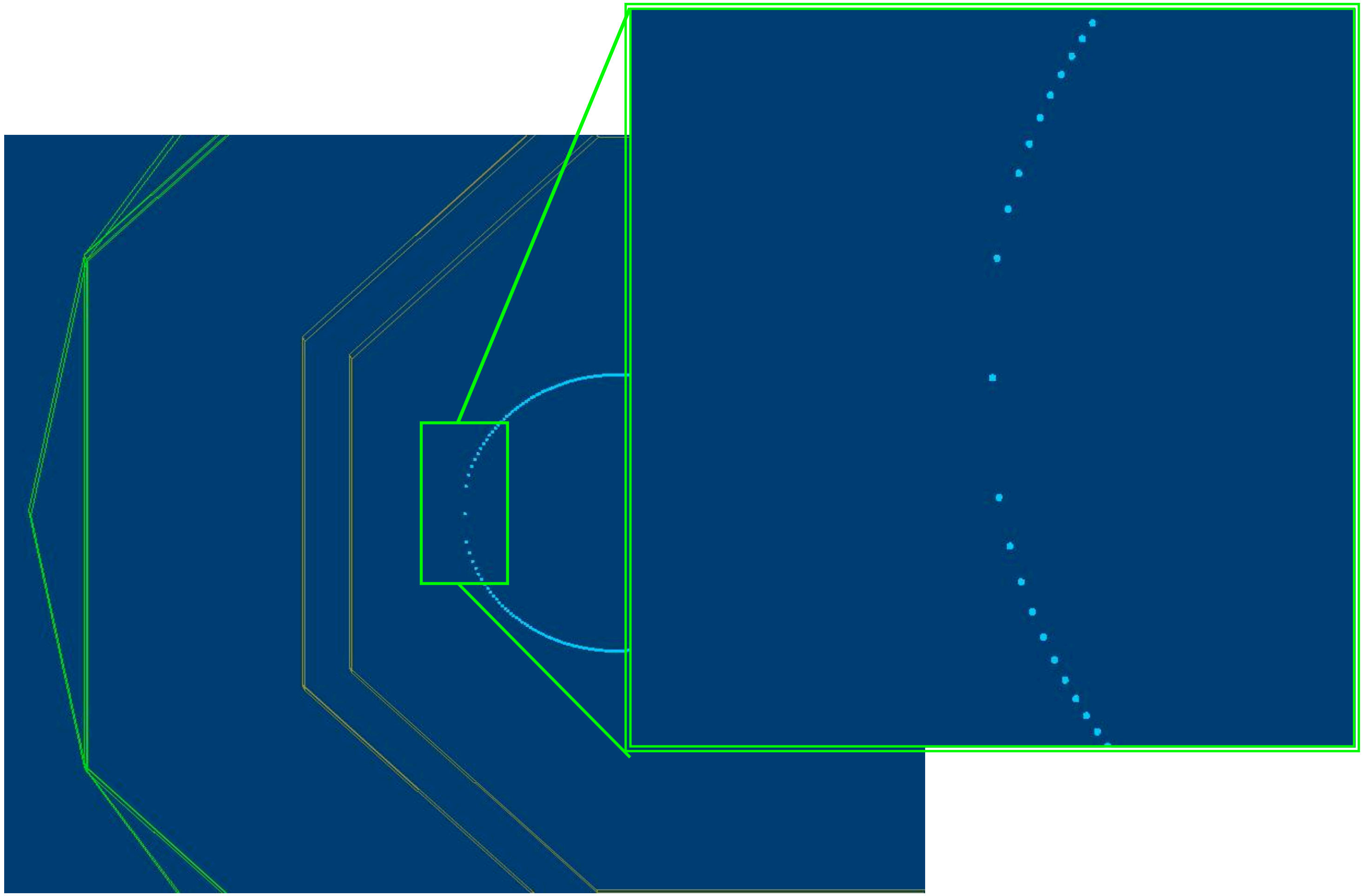
- Hits will be determined from charge sharing between adjacent pads in the same pad ring
  - Accurate determination of phi at fixed r
- Large number of consecutive pads in one pad ring will record the same average charge
  - difficult to reconstruct, probably go to pixel approach
- Continuous arrival of charge on a few pads
  - background, will knock-out pads over period of time







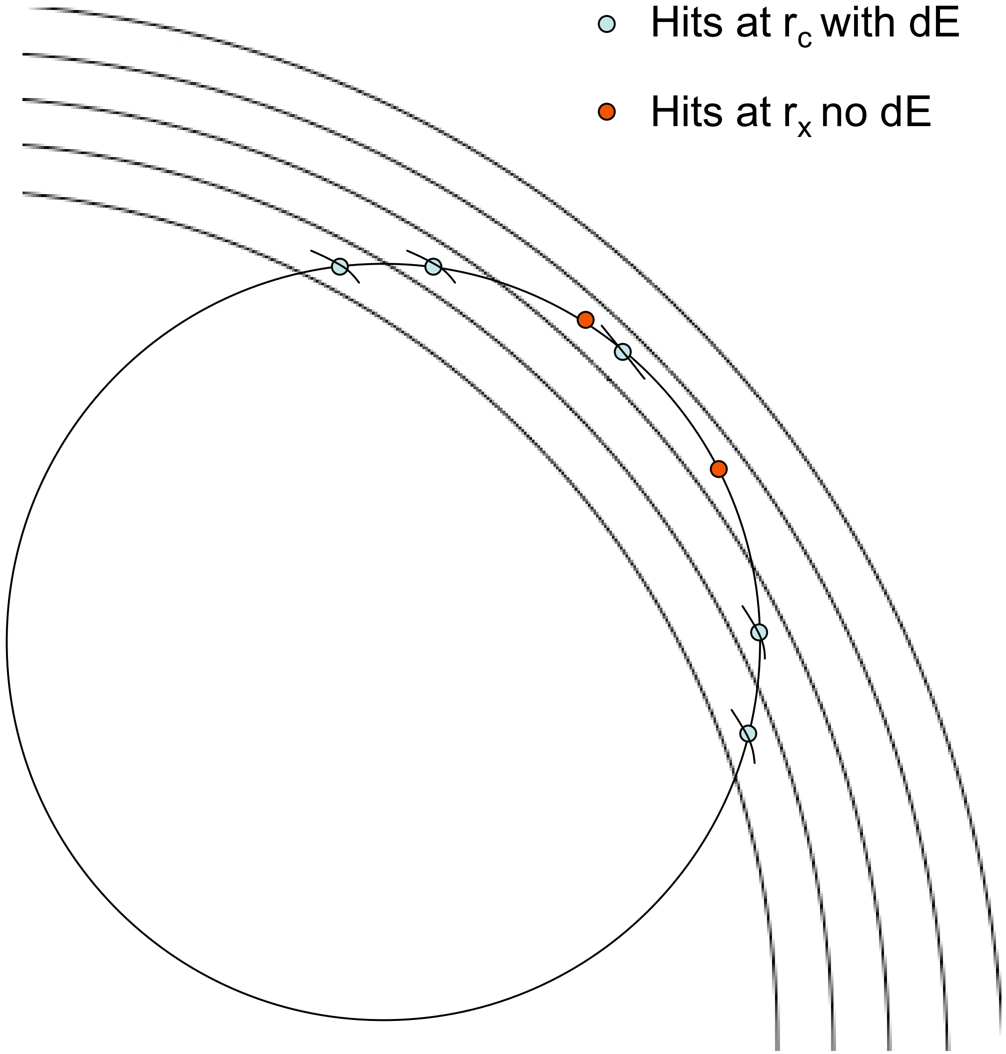
Known Problem



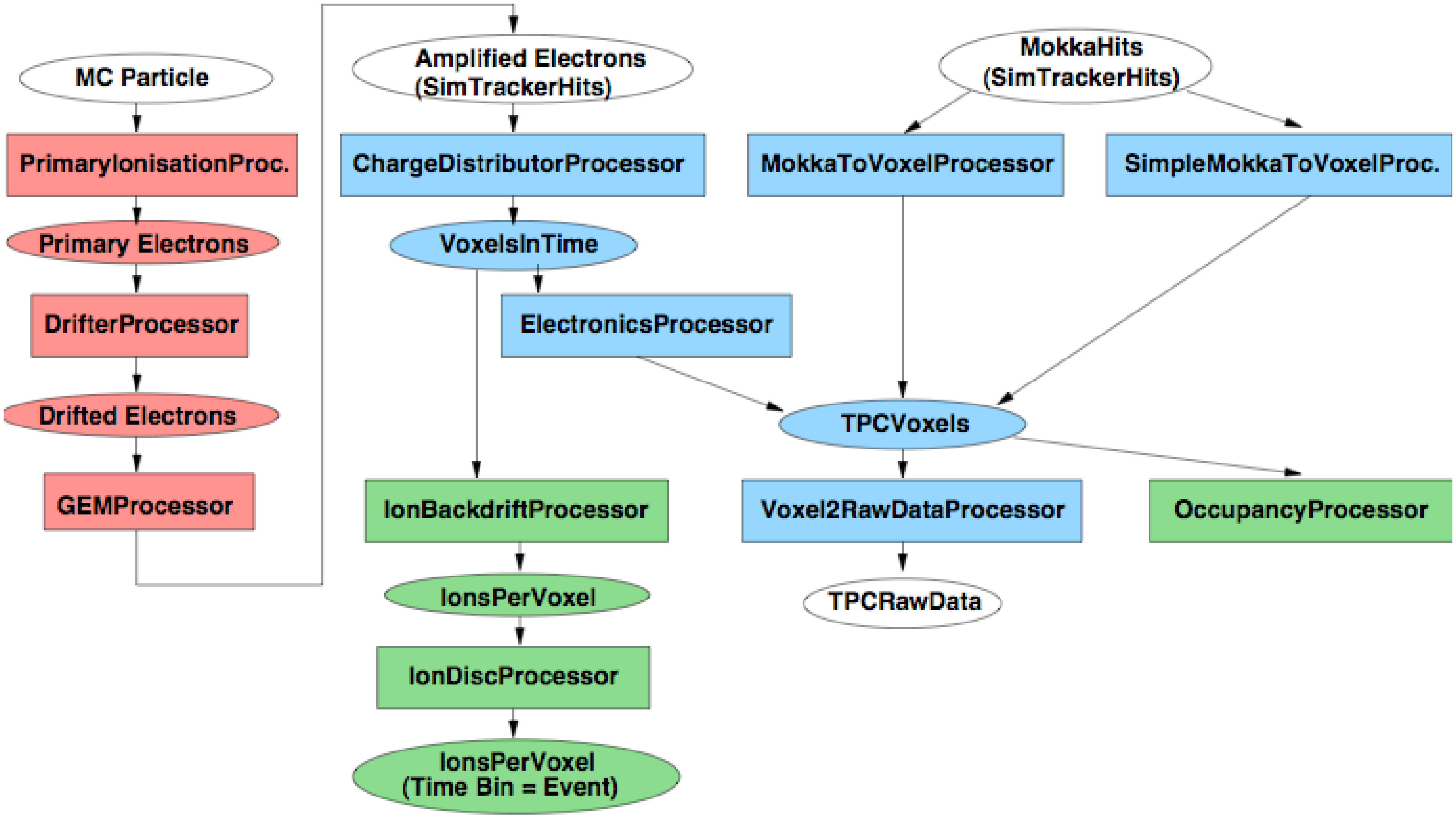
Partial Solution

Two collections of hits created, those on the measurement planes (shown in blue) and those in between (shown in red)

The extra hits need to be implemented to aid pattern recognition



MarlinTPC: LC-TPC



MarlinTPC: LC-TPC

The pads are sampled with a given frequency, which results in a 3D binning of the TPC (voxels).

To have a realistic digitisation a **voxel map** has been introduced which represents the (binned) **status of charge in the TPC at every moment in time**. This also handles pile-up naturally, since every event deposits charge in the TPC which is stored in the map, until it is drifted to the pad plane and read out.

MarlinTPC: LC-TPC

VoxelTPC

- interface class for management of TPCVoxels
- contains map of TPCVoxels
- handles the mapping of the charges into voxels
- distributes charge onto pads (according to transversal and longitudinal diffusion) with correct pad response
- does pile-up of charges (intrinsically)

MarlinTPC: LC-TPC

Processors using VoxelTPC:

- IonsInVoxelsProcessor
  uses VoxelTPC to fill voxel with primary ions over several events
- ChargeDistributionProcessor
  uses VoxelTPC to distribute the amplified electrons on pads
- IonBackdriftProcessor
  uses VoxelTPC for the built up of an ion disc during one bunch train

MarlinTPC: LC-TPC

Data Structure	Processor Name	Collection Name
`TrackerRawData`		TPCRawData
	TrackerRawDataToDataConverter	
`TrackerData`		TPCConvertedRawData
	PedestalSubtractor	
`TrackerData`		TPCData
	PulseFinder	
	ChannelMapper	
	CountsToPrimaryElectronsProcessor	
`TrackerPulse`		TPCPulses
	HitTrackFinderTopoProcessor	
`TrackerHit`		TPCHits

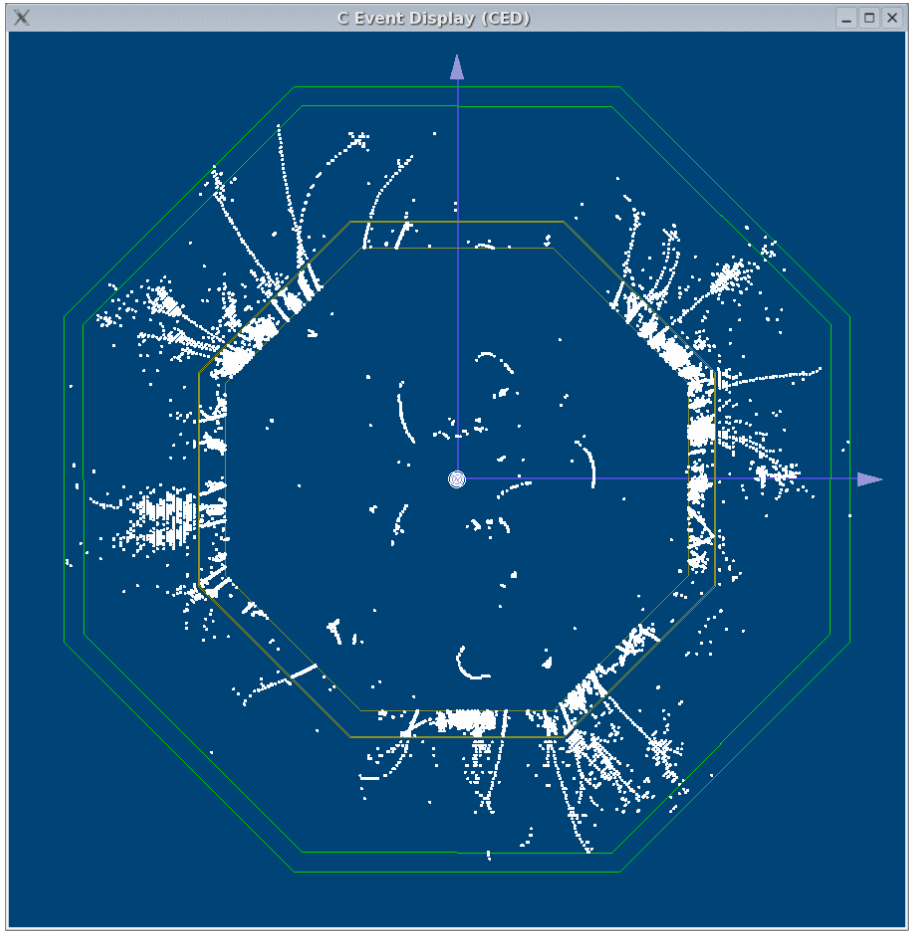
Calorimeters

- ECAL, HCAL, LCAL and Muon
  - SimpleCaloDigi
    - Rejects hits below 1/2 MIP
    - Converts remaining hits into physical energy deposited in a given cell taking into account absorber etc. using a single calibration constant
  - MokkaCaloDigi (HCAL Only)
    - Additionally hits can be ganged together from 1x1cm to provide a more coarse granulation

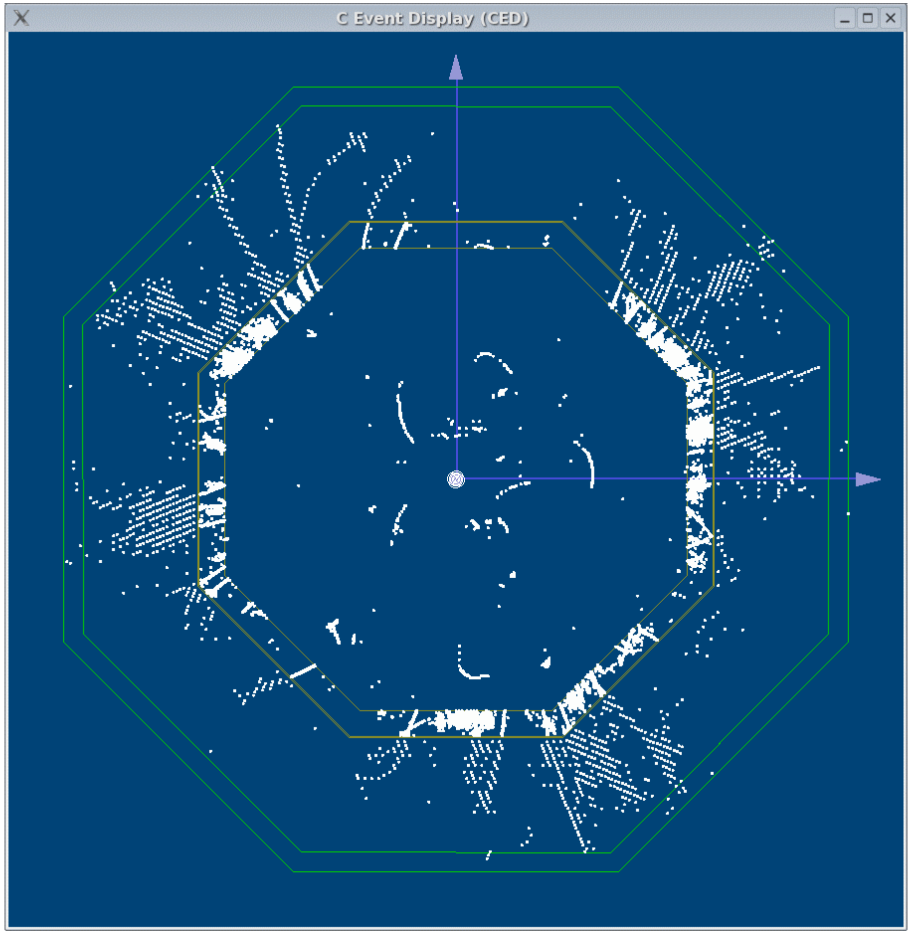
Calorimeters

- Calibration Constants are derived from dedicated MC studies
- Default parameters are supplied but can be specified by the user at run time
- Readout effects are not currently considered

HCAL Ganging: Help or Hindrance



1 x 1 cm



5 x 5 cm

Calorimeter R+D

Calorimeter for LC

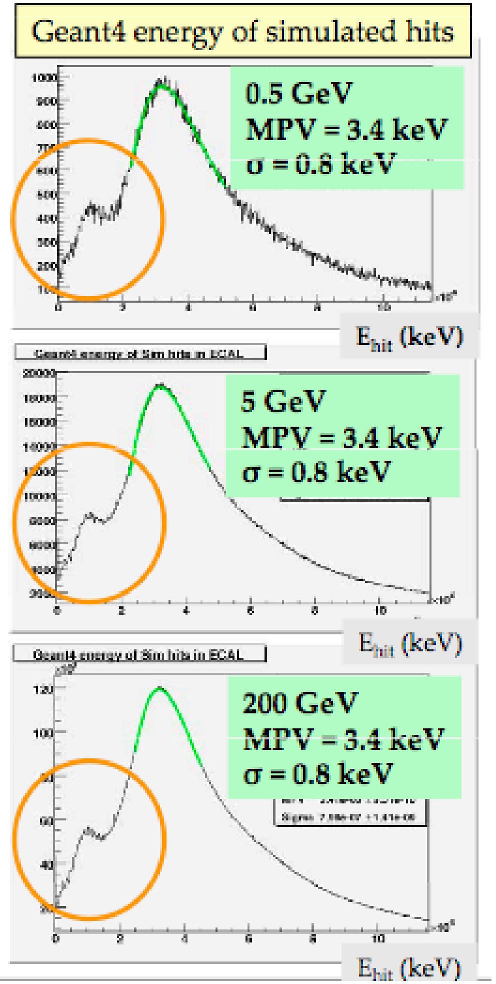
Physics simulation

- MAPS Simulation implemented in MOKKA, with LDC01 for now on.
- MIP landau MPV stable vs energy @ Geant4 level
  ➔ Assumption of 1 MIP per cell checked up to 200 GeV,
- Definition of energy : E α N_{MIPS}.
- Binary readout : need to find the optimal threshold, taking into account a 10^{-6} probability for the noise to fluctuate above threshold.

•**MIP crossing boundaries** : effect can be reduced by clustering

•So energy resolution is given by the distribution of hits/clusters above threshold:

$$\frac{\sigma_E}{E} \propto \frac{\sqrt{\sigma_{N_{pixels}}{}^2 + N_{noise}}}{N_{pixels}}$$



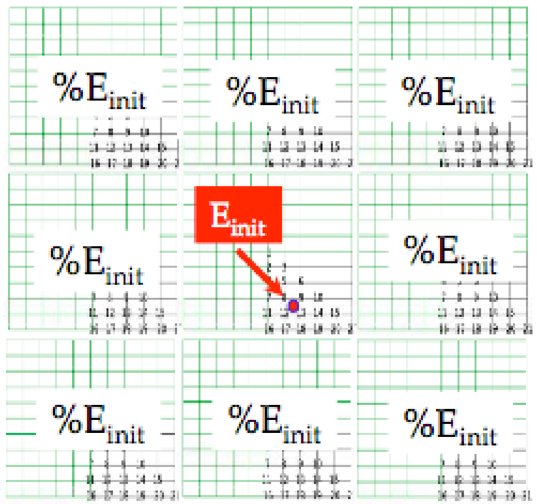
Calorimeter R+D

CALICE Calorimeter for LC

Digitisation procedure

Geant4 E_{init} in 5x5 μm² cells

Apply charge spread $E_{after\ charge\ spread}$



Importance of the charge spread :

$$\sum E_{neighbours} \sim (50\% - 80\%) \times E_{init}$$

Sum energy in 50x50 μm² cells E_{sum}

Add noise to signal hits with σ = 100 eV (1 e- ~ 3 eV ➔ 30 e- noise)

+ noise only hits : proba 10^{-6} ➔ ~ 10^{6} hits in the whole detector BUT in a 1.5*1.5 cm² tower : ~3 hits.

Register the position and the number of hits above threshold

Conclusion

- We need to build on what we have and make a concerted effort to take the very good work being in done in the R+D groups and put it into the simulation in a well parameterized and understood way
- To do this we need more interaction between the people doing the simulation and those doing the R+D
- We have some time before we start mass reconstruction: but not much

Conclusion

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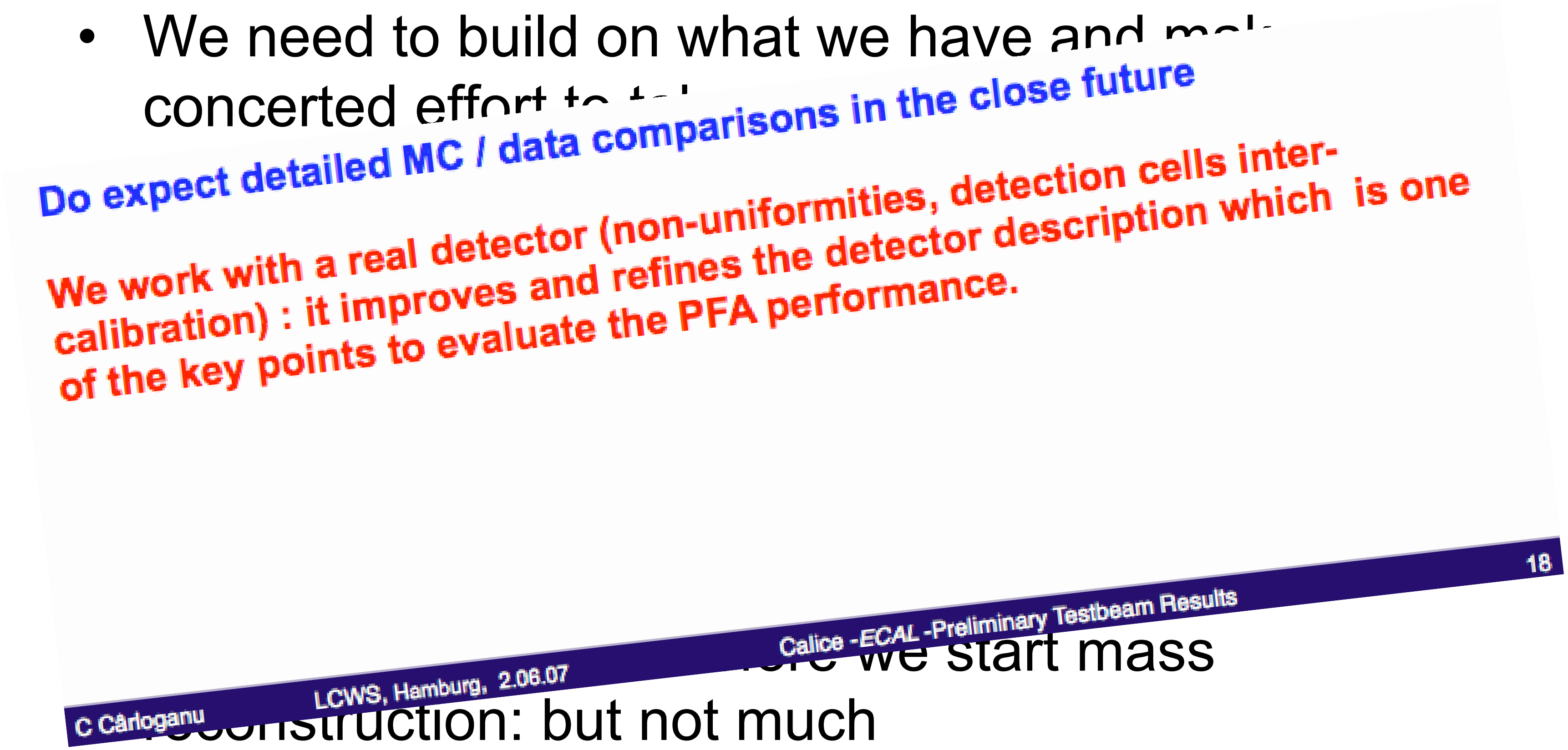

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