Summary of the timebased EMC simulation and reconstruction chain in PandaRoot

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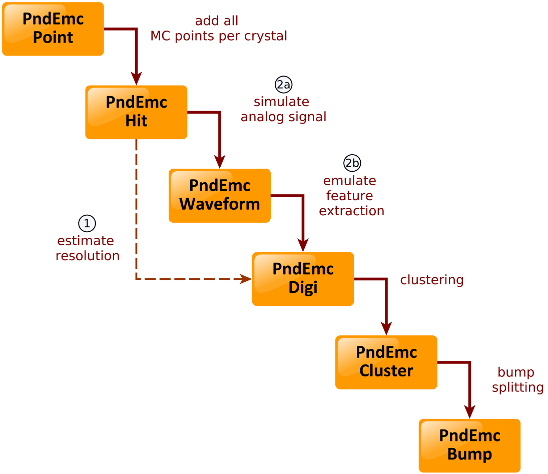
17.03.2015

EMC simulation and reconstruction chain



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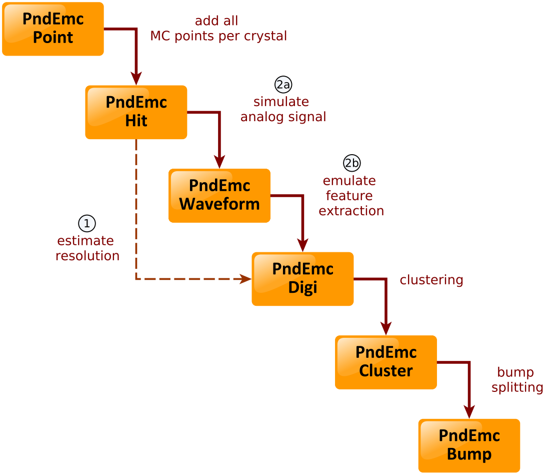
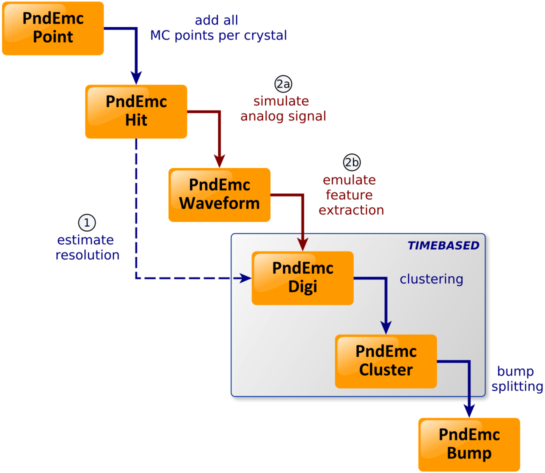


two ways of generating EmcDigis:

1. directly out of corresponding EmcHit
2. impose intermediate step: waveform simulation

→ "hardware-based" description

EMC simulation and reconstruction chain

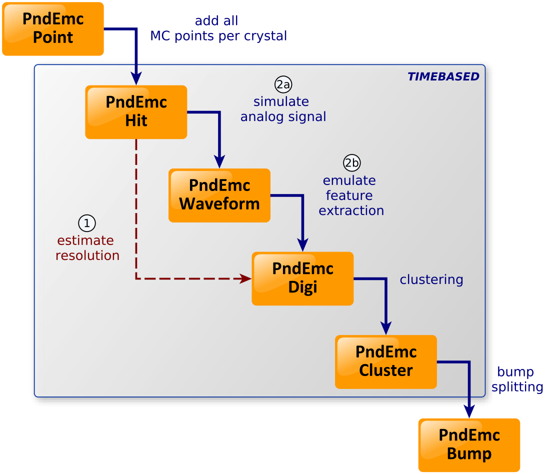


. . . and making things timebased

"classical" timebased approach:

- rearrange and sort digis in time
- use smeared (or even exact) information of EmcHits ①

EMC simulation and reconstruction chain



. . . and making things timebased

include waveform simulation:

- simulate important parts of continuous waveform stream (2a)
- to be processed by free-running ADC (2b)

⟶ preserve realistic signal signature

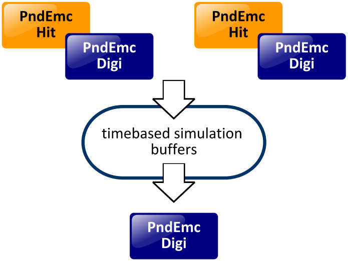
Timebased waveform simulation

Decouple hit grouping and waveform simulation:

- PndEmcWaveformData stores hit(s) information (energy, time)

→ closer to digi object than waveform

- PndEmcAbsWaveformSimulator simulates PndEmcWaveform based on PndEmcWaveformData
  (**1** *data object yields* **1** *waveform, including* **n** *hits)*
- PndEmcAbsPSA scans single waveforms, producing PndEmcDigi objects
  (**n** *simulated hits,* **m** *recovered digis)*
- Call PndEmcDigiRingSorter ...



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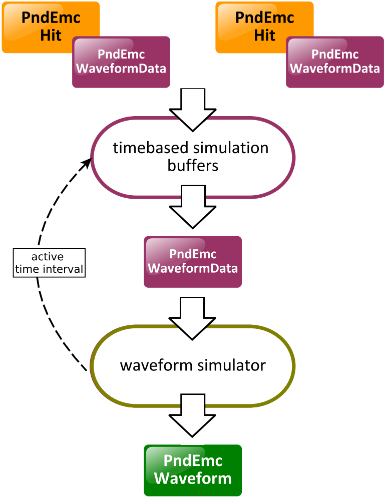

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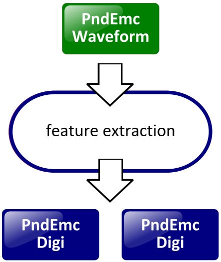
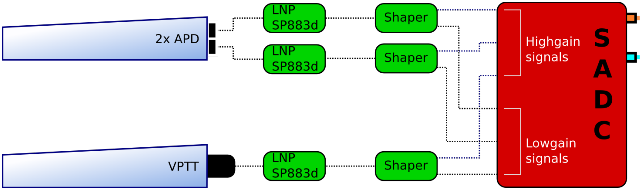


Match experimental conditions

readout chain in the Forward Endcap:



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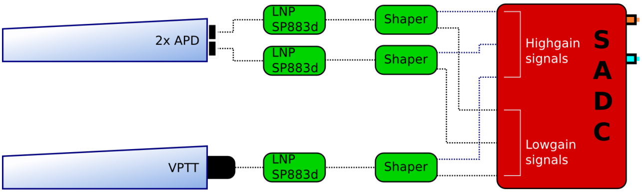

classes in PandaRoot:

`WaveformSimulator`

$\Downarrow$

`ShapingNoiseAdder`

$\Downarrow$

`WaveformDigitizer`

$\Downarrow$

`FeatureExtraction`

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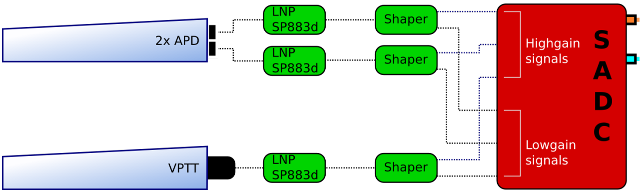

classes in PandaRoot:

WaveformSimulator
⇓
ShapingNoiseAdder
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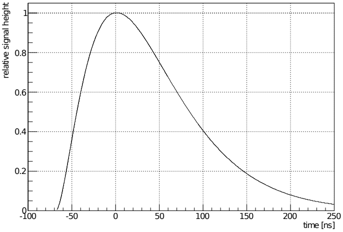
FeatureExtraction

fitted pulseshape:



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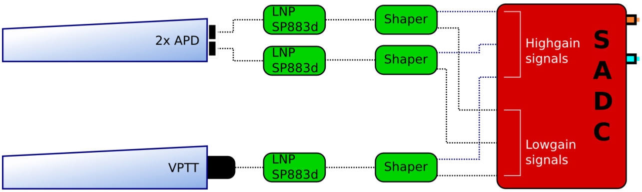

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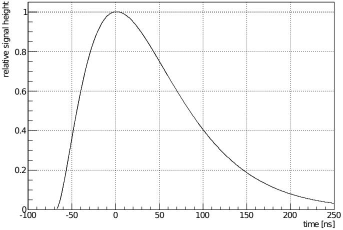
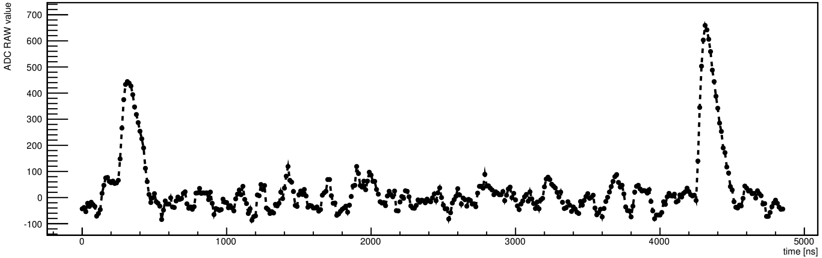


readout parameters for APD channel:

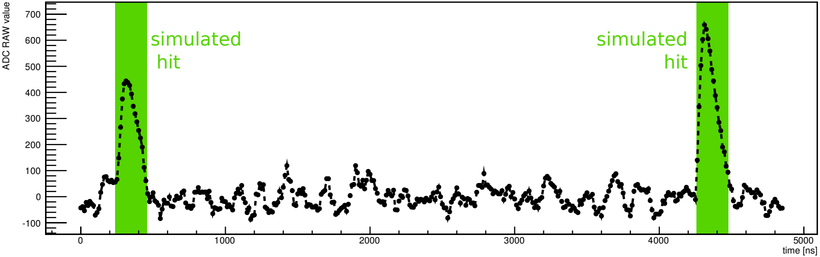
	high gain	low gain
multiplicity	$2\times$	$2\times$
sampling rate	80 MHz	80 MHz
channels	2^{14}	2^{14}
energy range	1 GeV	15 GeV
noise width	2.3 MeV	3.5 MeV

Invoke feature extraction



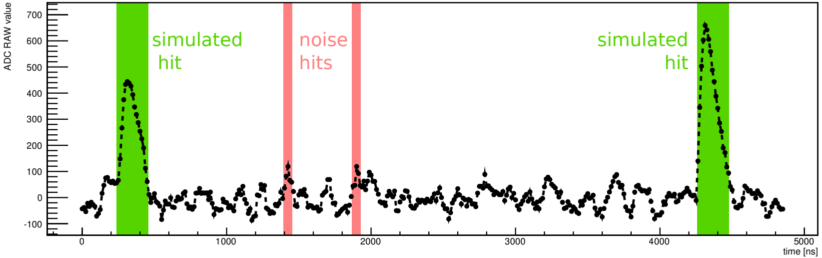
- resulting waveforms $\longrightarrow$ close to hardware signal

Invoke feature extraction



- resulting waveforms $\longrightarrow$ close to hardware signal
- next step: process them by feature extraction
    - as intermediate step in simulation chain
    - to study its performance (testing, optimization)

Invoke feature extraction



- resulting waveforms $\longrightarrow$ close to hardware signal
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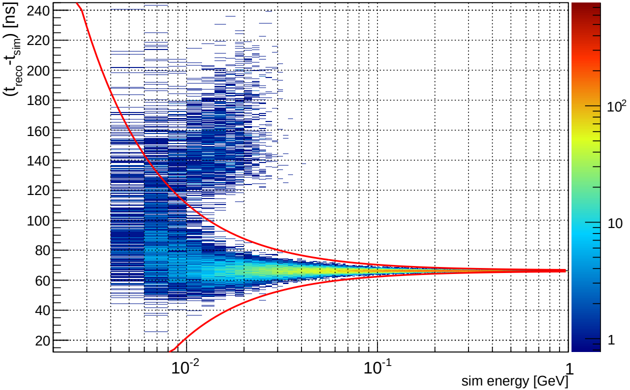
- include relevant noise (false posivite) hits in simulation: enlarge simulation window

Timing of reconstructed hits

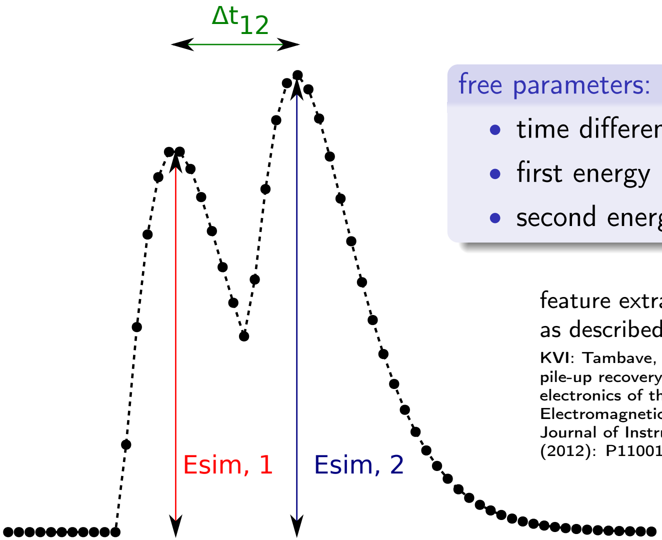


- 1×10^6 simulated pulses
- single hit with $E_{sim} \sim \mathcal{U}(5\,\text{MeV}, 1\,\text{GeV})$
- only waveforms with 1 reconstructed hit selected

Triggerless concept demands proper hit timing:

- $\lesssim 20\,\text{MeV}$: hit detection uncertain
- $\lesssim 10\,\text{MeV}$: hit detection fails

Testing pileup recovery capabilities



free parameters:

- time difference Δt_{12}
- first energy $E_{\text{sim, 1}}$
- second energy $E_{\text{sim, 1}}$

feature extraction
as described in:

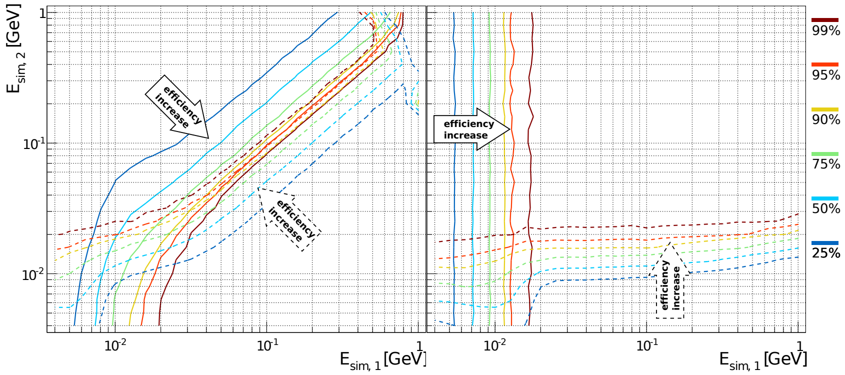
KVI: Tambave, G., et al. "Pulse pile-up recovery for the front-end electronics of the PANDA Electromagnetic Calorimeter." Journal of Instrumentation 7.11 (2012): P11001.

Pulse detection efficiency

- define successful detection: ± 15 ns around expected time

____ : recovery efficiency of 1. pulse **- - - : recovery efficiency of 2. pulse**

$\Delta t_{12} = 75$ ns $\Delta t_{12} = 150$ ns



Pulse detection efficiency

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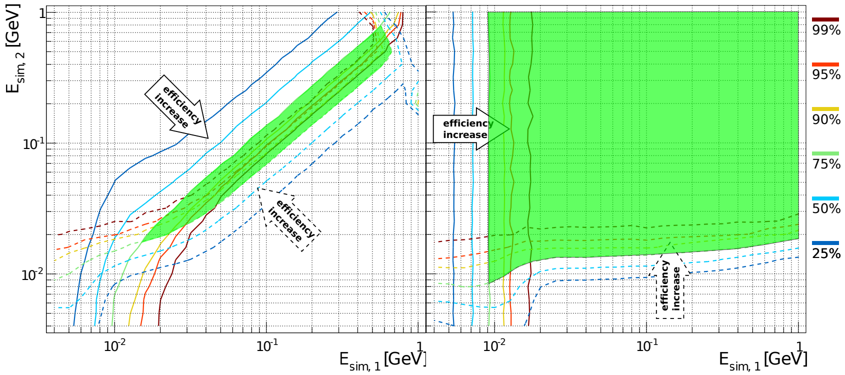
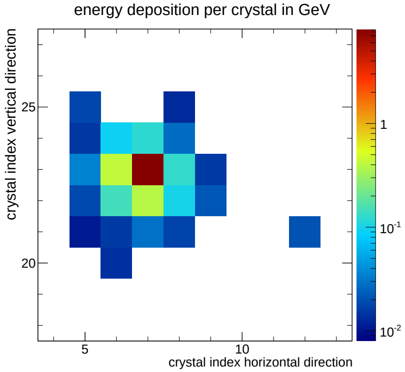
$\Delta t_{12} = 75$ ns **detection efficiency $> 75\,\%$** $\Delta t_{12} = 150$ ns



- $\Delta t_{12} > 100$ ns **for almost always successfuly detection**

Eventbased clustering algorithm in PandaRoot . . .



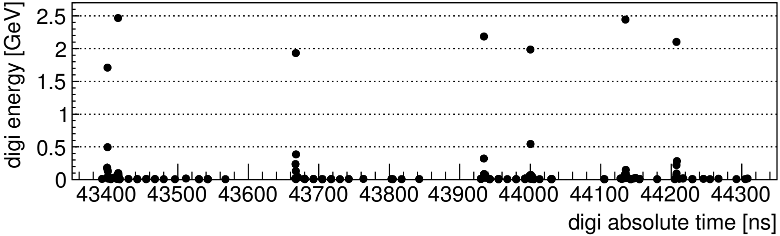
simulation of a 10 GeV photon cluster in the Forward Endcap with split-off

1. main clustering:
   - group all fired neighboring crystals into one cluster

   ⇔ two distinct clusters are separated by inactive crystals
2. subsequent tasks:
   - detect local maxima within clusters
   - bump splitting

. . . and its timebased continuation

1. group incoming digi stream into *pseudo events*
   $\longrightarrow$ search for gaps $\geq t_{\text{active}}$



2. perform spacial clustering on pseudo events
3. reimpose timing condition (*defined by* t_{active})

$\Rightarrow$ overall clustering conditions:

$$\begin{cases} \text{space}: & \text{direct neighbor} \\ \text{time}: & \Delta t < t_{\text{active}} \end{cases} \quad \text{to any crystal already in cluster}$$

- still use of solely energy based bumpsplitting methods

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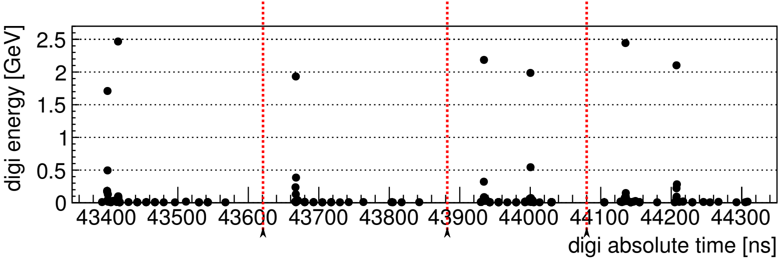

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- still use of solely energy based bumpsplitting methods

The PndEmcClusterObject

```
class PndEmcCluster {
    ...
    std::vector<Int_t> fDigiList;
    std::map<Int_t, Int_t> fMemberDigiMap;
    std::map<Int_t, Int_t> fMcMap;
    ...
};
```

digi's index in TClonesArray

digi's detectorID (crystal index)

MC trackID

count

- cluster stores reference to incorporated digis

⟶ objects relay on (eventbased) digi grouping

- same for MC track information handling

- detectorID serves as key

⟶ detectorID must be unique

⟹ **conflicts with idea of timebased reconstruction**

Timebased clustering in PandaRoot

the best future solution: ...

cleanest solution

Rewrite cluster class, make heavy use of `FairLinks`

$\longrightarrow$ *still reasonably performant?*

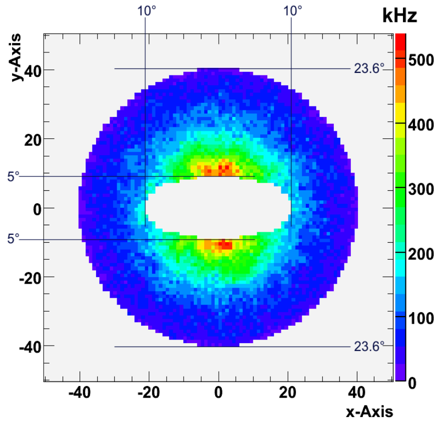
Timebased clustering in PandaRoot

needed to do full physics simulations timebased:

MC backpropagation

- available backpropagation broken in timebased runs
- chain of `FairLinks` considered to be continuous
- but `PndEmcMatchTasks` did not work either??

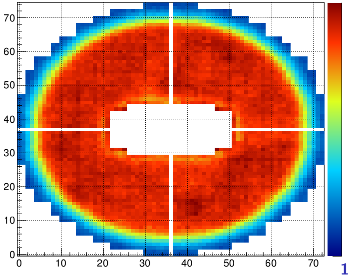
probably fixed with new version of FairLinks



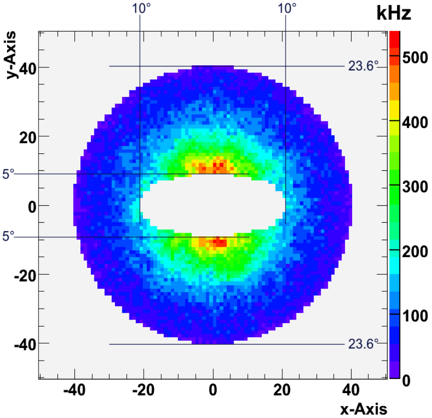
TDR:
expected hit rate on Forward Endcap
($E_{\text{hit}} \geq 3\,\text{MeV}$) @ $p_{\bar{p}} = 14\,\text{GeV}$

simulation:

- photons with fixed energy (*no need for backpropagation*)
- time between events: Poisson-distributed, characterized by τ



Results



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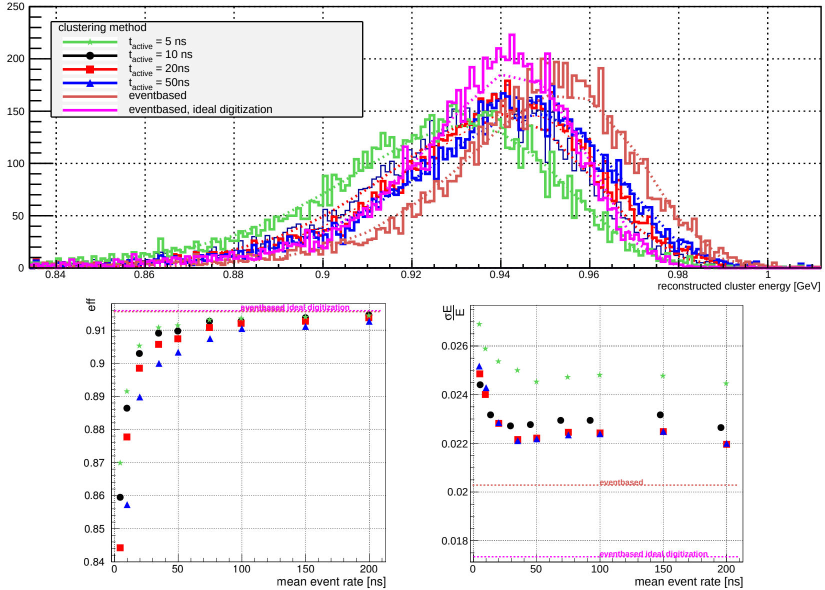
($E_{hit} \geq 3$ MeV) @ $p_{\bar{p}} = 14$ GeV

simulation:

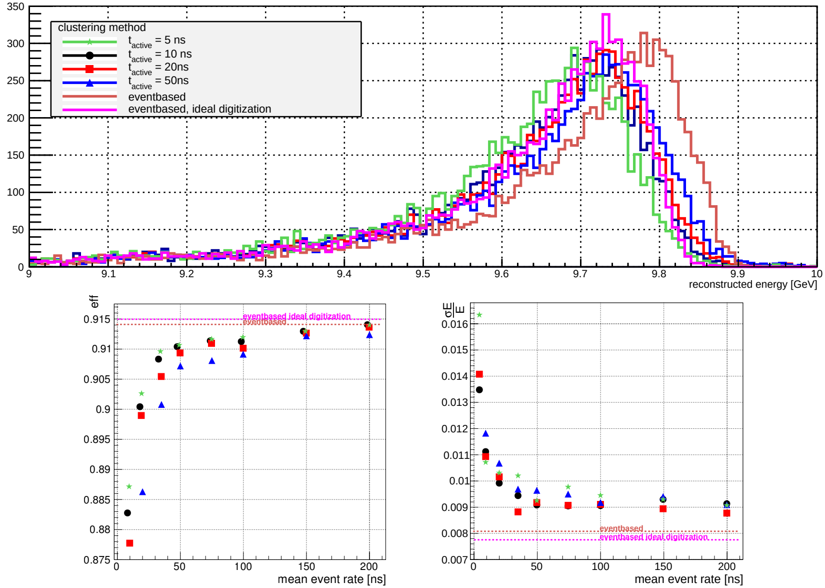
- photons with fixed energy (*no need for backpropagation*)
- time between events: Poisson-distributed, characterized by τ

τ	E_γ 1 GeV	E_γ 10 GeV
hit rate 100 kHz	30 ns	100 ns
hit rate 500 kHz	6 ns	20 ns

γ with 1 GeV on Forward Endcap (N=10^4)



γ with 10 GeV on Forward Endcap ($N=10^4$)



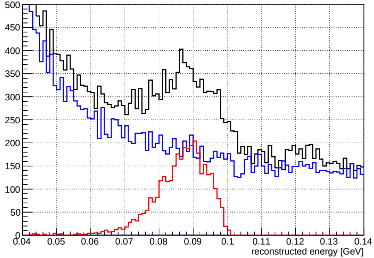
Timebased clustering: γ on DPM background

scenario:

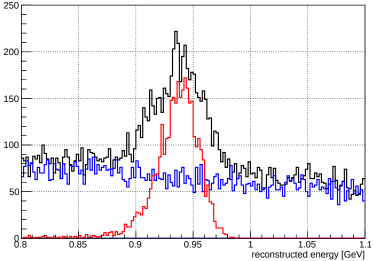
- DPM generator background
  $p_{\overline{p}} = 14\,\text{GeV}, \tau = 50\,\text{ns}$
- mixed with single photons:
  ratio Signal/BG: 1/10

—— event mixing
—— only DPM background
—— only photon events
(eventbased, ideal digitization)

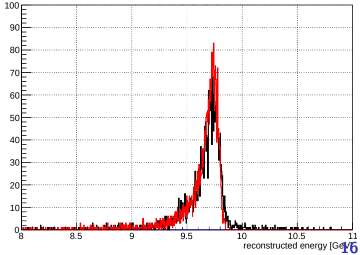
$E\gamma = 0.1$ GeV



$E\gamma = 1$ GeV



$E\gamma = 10$ GeV



Conclusion

- EMC simluation and reconstruction chain has been adapted to allow for timebased simulations of:

  `PndEmcDigis` via generation of timebased `PndEmcWaveforms` and usage of experimental feature extraction

  `PndEmcClusters` by applying extended clustering methods: considering energy **and** time

- tasks to do:
  - review simulation parameters
  - conform and improve clustering stage towards timebased needs

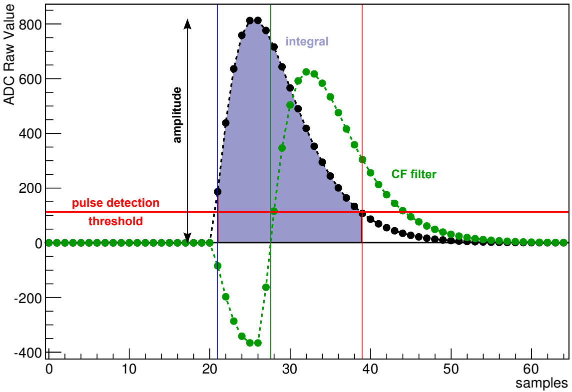
  ⟶ make MC backpropagation possible

Backup slides

Feature extraction

- experiment: FPGA based feature extraction (designed by KVI, Groningen)

⟶ reproduce its behavior in simulation



pulse detection:

- rigid threshold

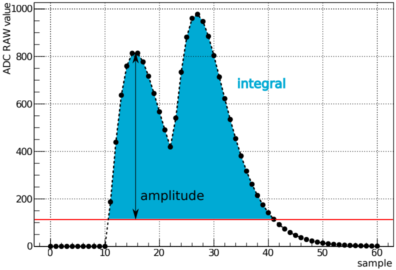
energy features:

- amplitude
- integral

timing features:

- zero crossing of CF-filter value

Foreseen pileup treatment of the feature extraction:



Pileup detection & recovery of E_2:

- define ratio $R = \frac{integral}{amplitude}$
- assumptions made:
  - amplitude not affected $\Rightarrow E_1$
  - $R = const$ for single pulses
- pileup detected:
  $R > R_{thres}$
- recover E_2 as a function of:
  amplitude, integral, R_{mean}

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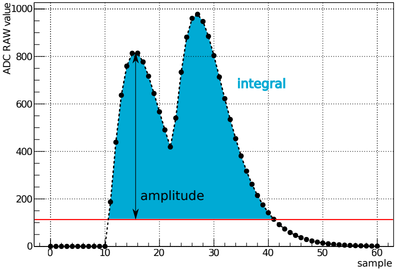

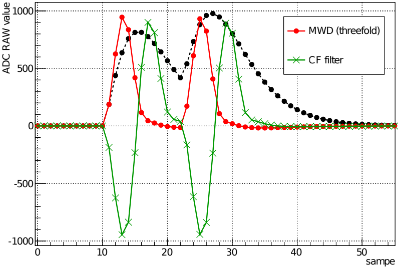

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Recovery of T_1, T_2:

- shorten pulses by means of threefold MWD filter