HGC Beamtest Analysis Meeting

CERN TB October 2018

Ntuples & event synchronisation

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III. Physikalisches Institut | RWTH AACHEN UNIVERSITY

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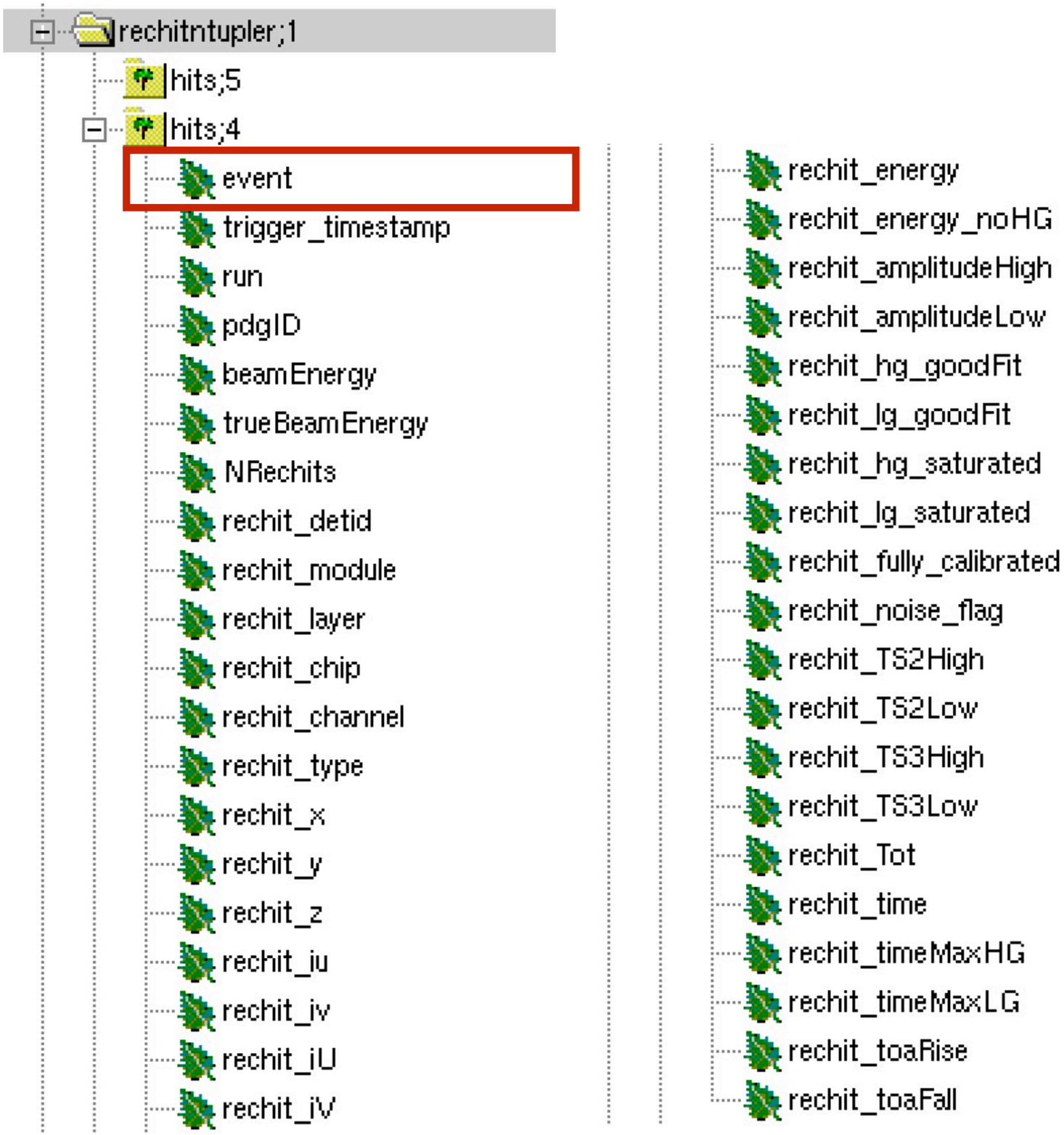
HGCal

“Rechits” = reconstructed HGCal hits

- rechitntupler;1
  - hits;5
  - hits;4
    - event
    - trigger_timestamp
    - run
    - pdgID
    - beamEnergy
    - trueBeamEnergy
    - NRechits
    - rechit_detid
    - rechit_module
    - rechit_layer
    - rechit_chip
    - rechit_channel
    - rechit_type
    - rechit_x
    - rechit_y
    - rechit_z
    - rechit_iu
    - rechit_iv
    - rechit_iU
    - rechit_iV
    - rechit_energy
    - rechit_energy_noHG
    - rechit_amplitudeHigh
    - rechit_amplitudeLow
    - rechit_hg_goodFit
    - rechit_lg_goodFit
    - rechit_hg_saturated
    - rechit_lg_saturated
    - rechit_fully_calibrated
    - rechit_noise_flag
    - rechit_TS2High
    - rechit_TS2Low
    - rechit_TS3High
    - rechit_TS3Low
    - rechit_Tot
    - rechit_time
    - rechit_timeMaxHG
    - rechit_timeMaxLG
    - rechit_toaRise
    - rechit_toaFall

Content: Event



type:
uint

<u>description:</u>
trigger index in run

Content: Trigger timestamp

type:

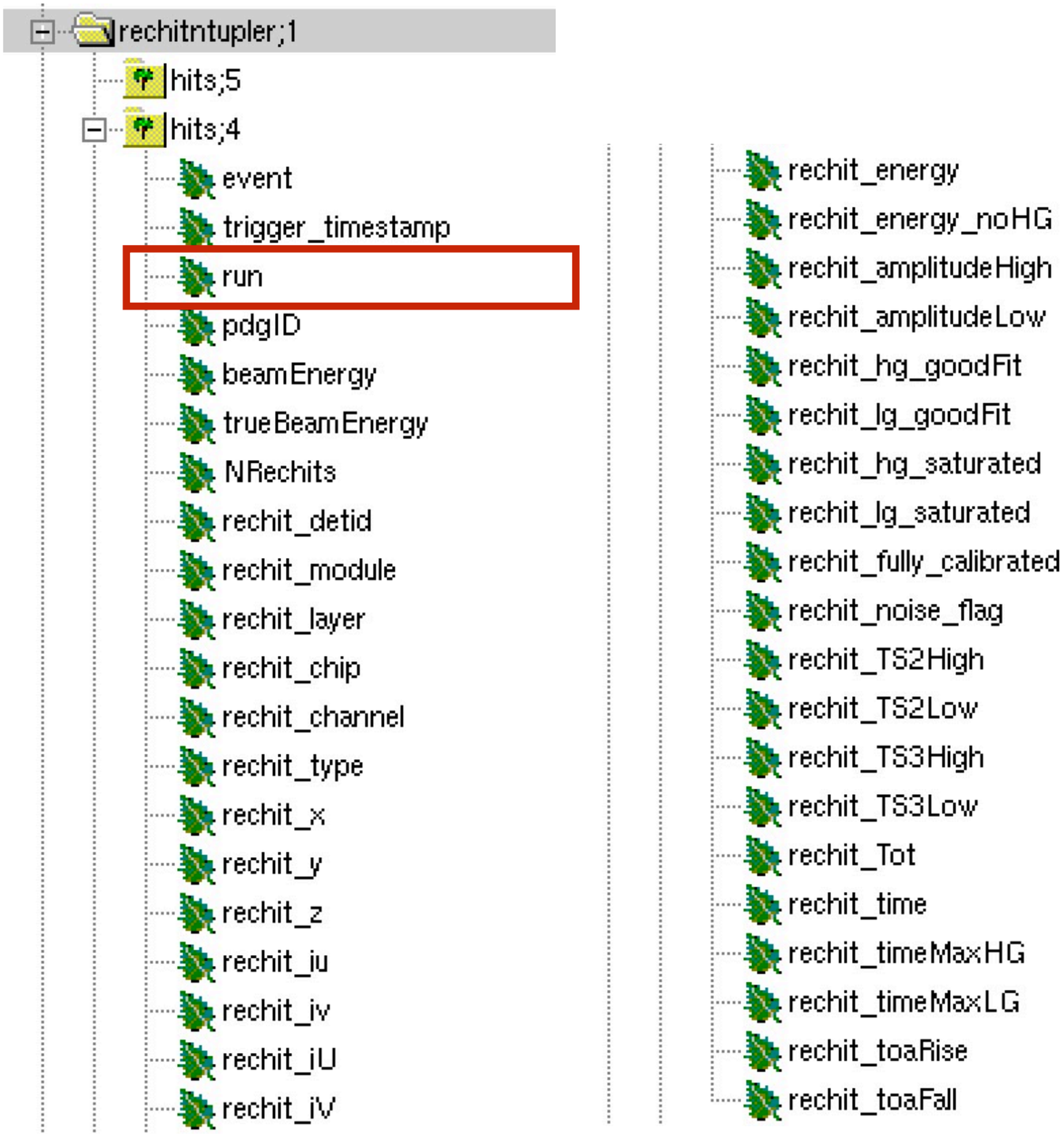
Long64_t

<u>description:</u>

trigger timestamp from ORMs

unit: 25ns

Content: Run



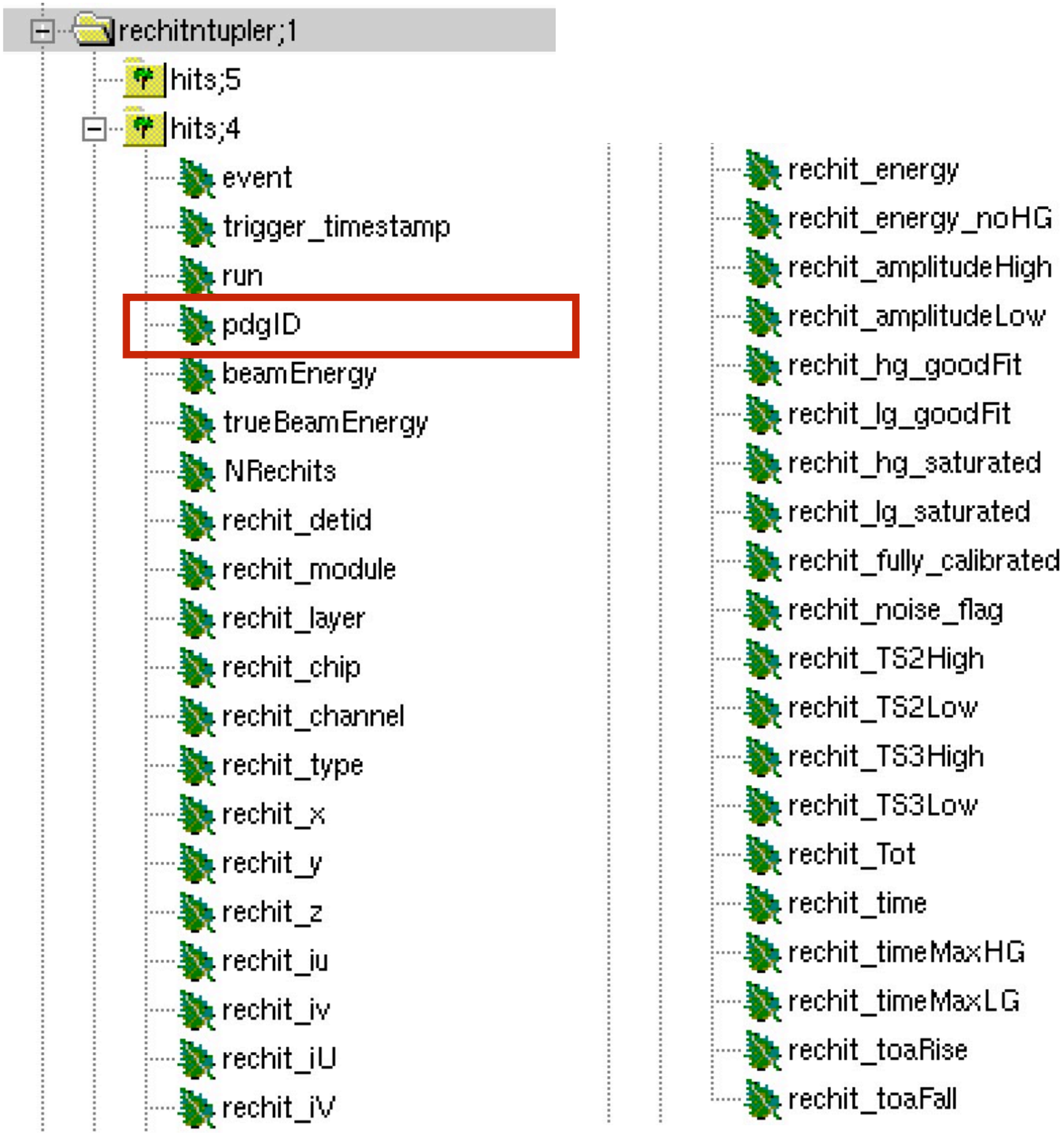
type:

uint

<u>description:</u>

run number

Content: Particle ID



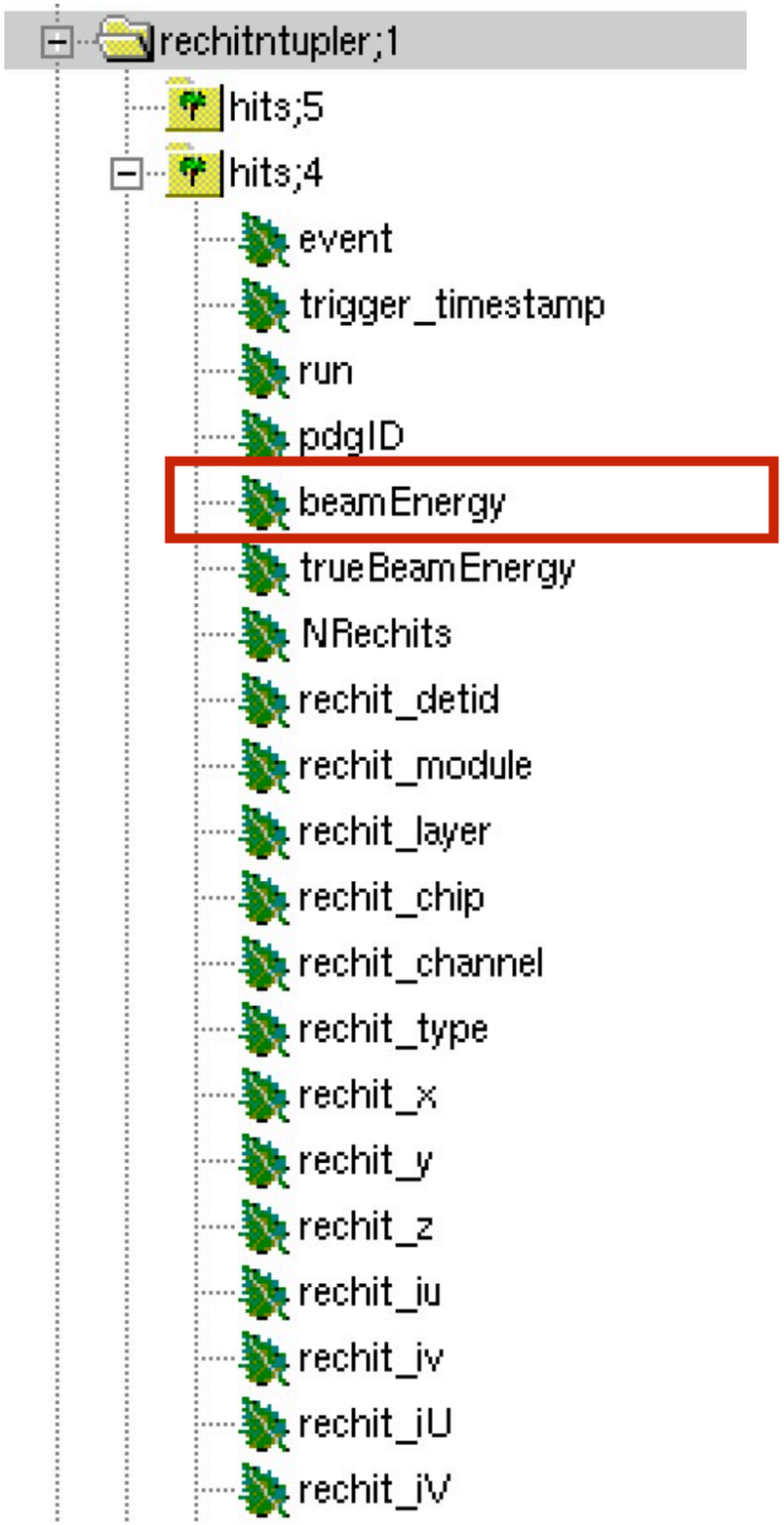
type:

int

<u>description:</u>

particle ID (PDG) indicated by beam file

Content: Beam momentum



type:

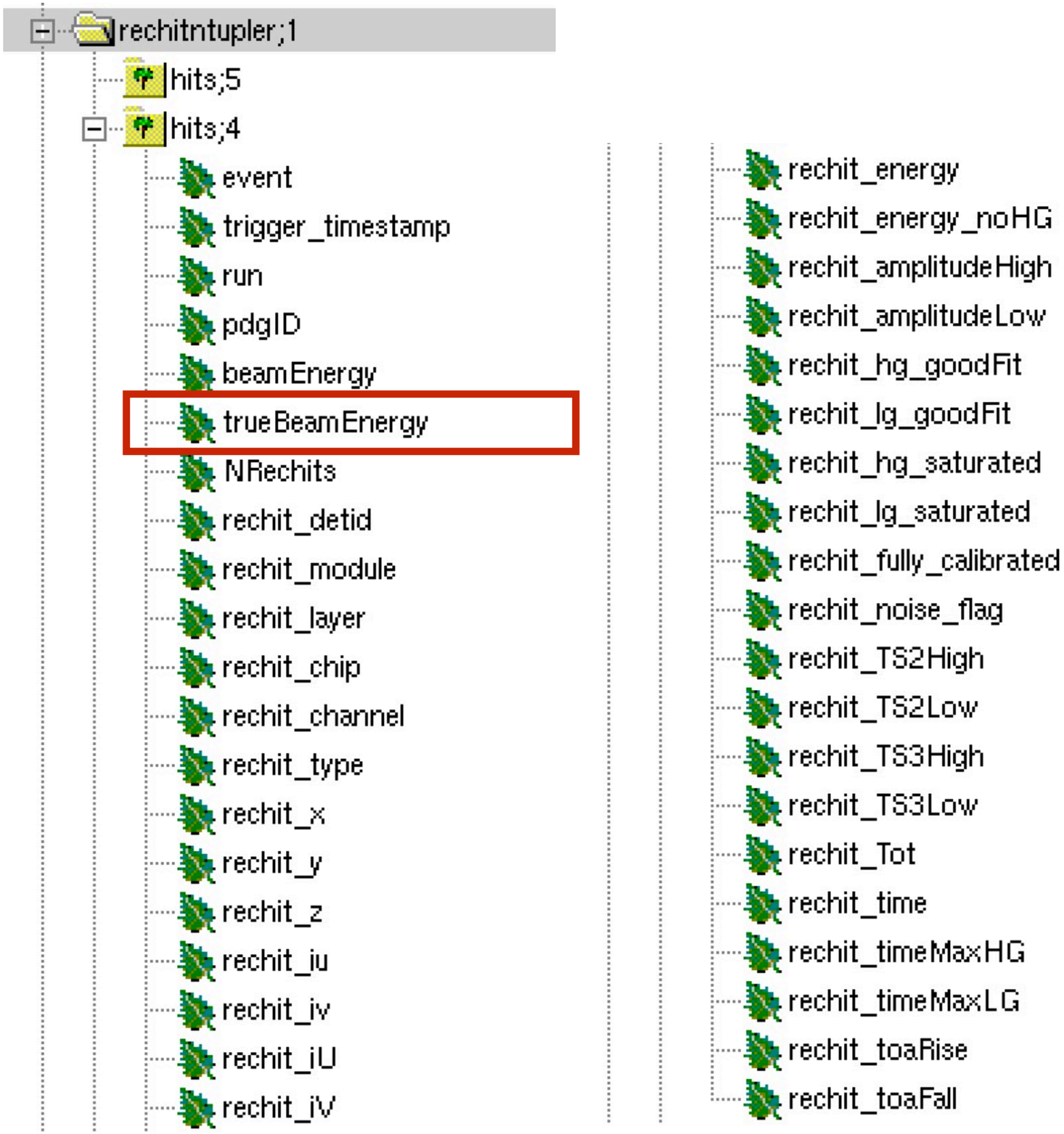
float

<u>description:</u>

beam momentum (=energy) indicated by beam file

unit: GeV

Content: True particle momentum



type:

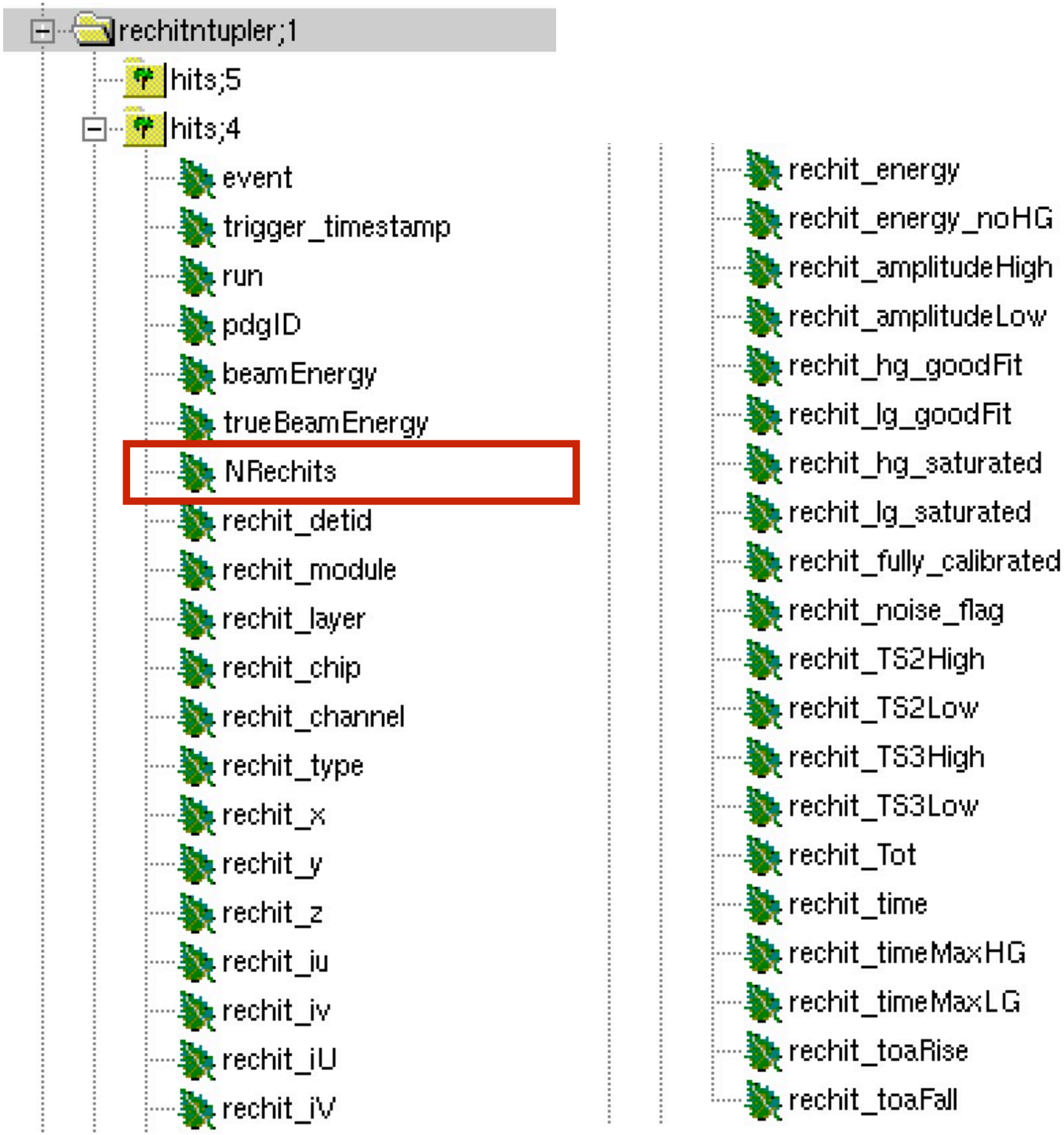
float

<u>description:</u>

true particle momentum, *simulation-only*

unit: GeV

Content: Number of hits



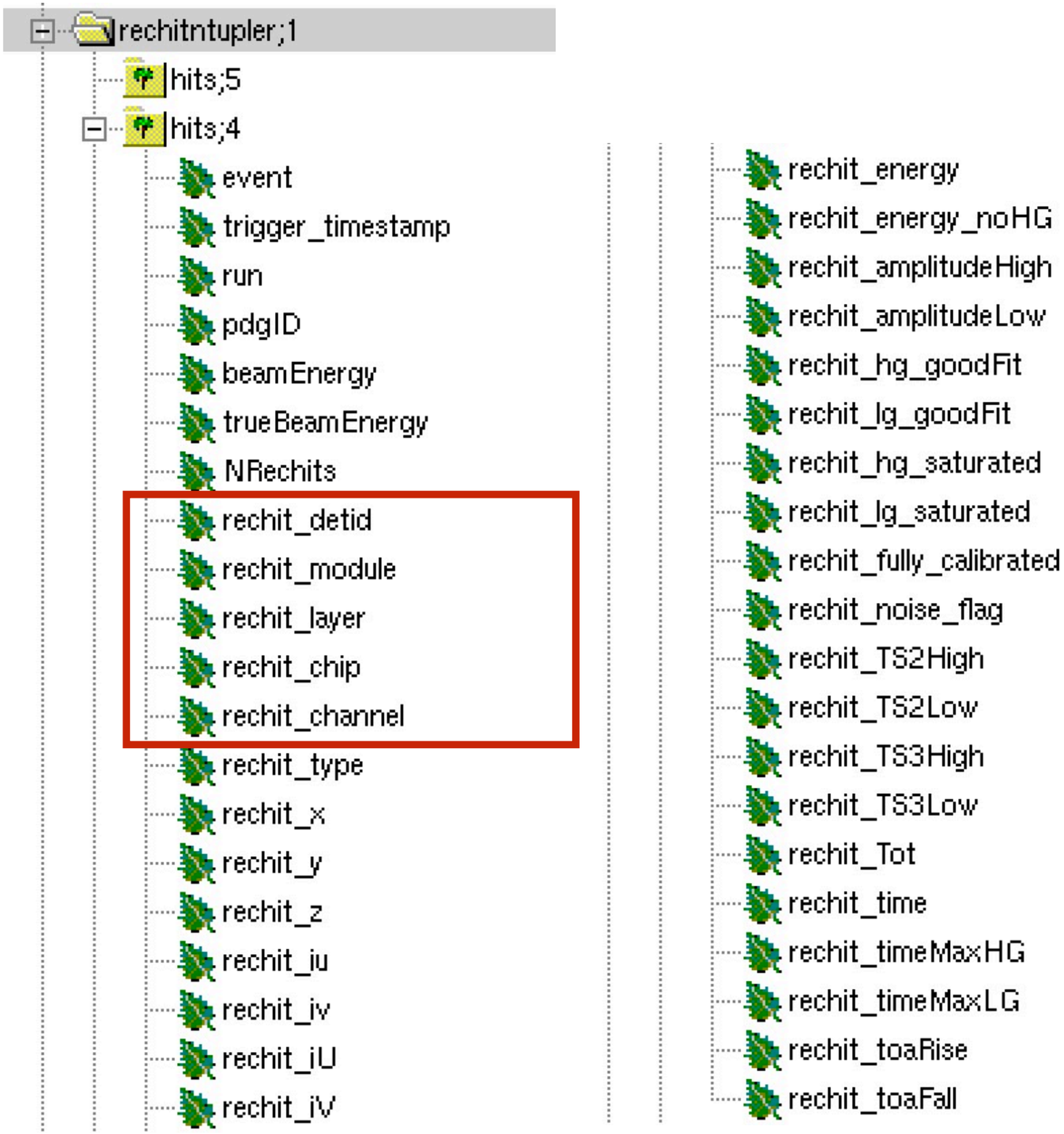
type:

int

<u>description:</u>

number of reconstructed hits

Content: Physical location in detector

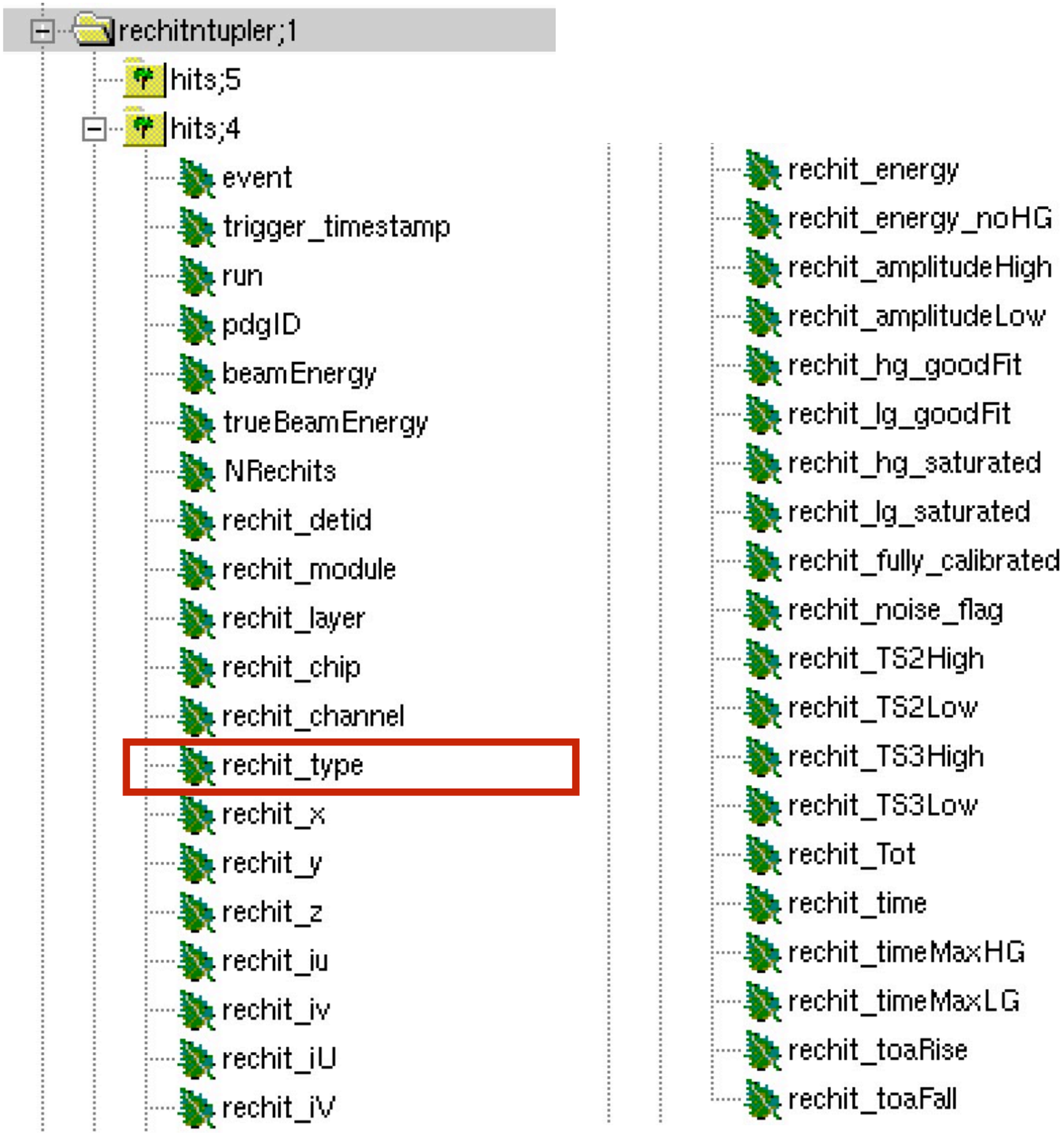


type:
vector<uint>

<u>description:</u>
physical location of the rechits in terms of

- Module
- Layer
- Chip (0-3)
- Channel (0-62)

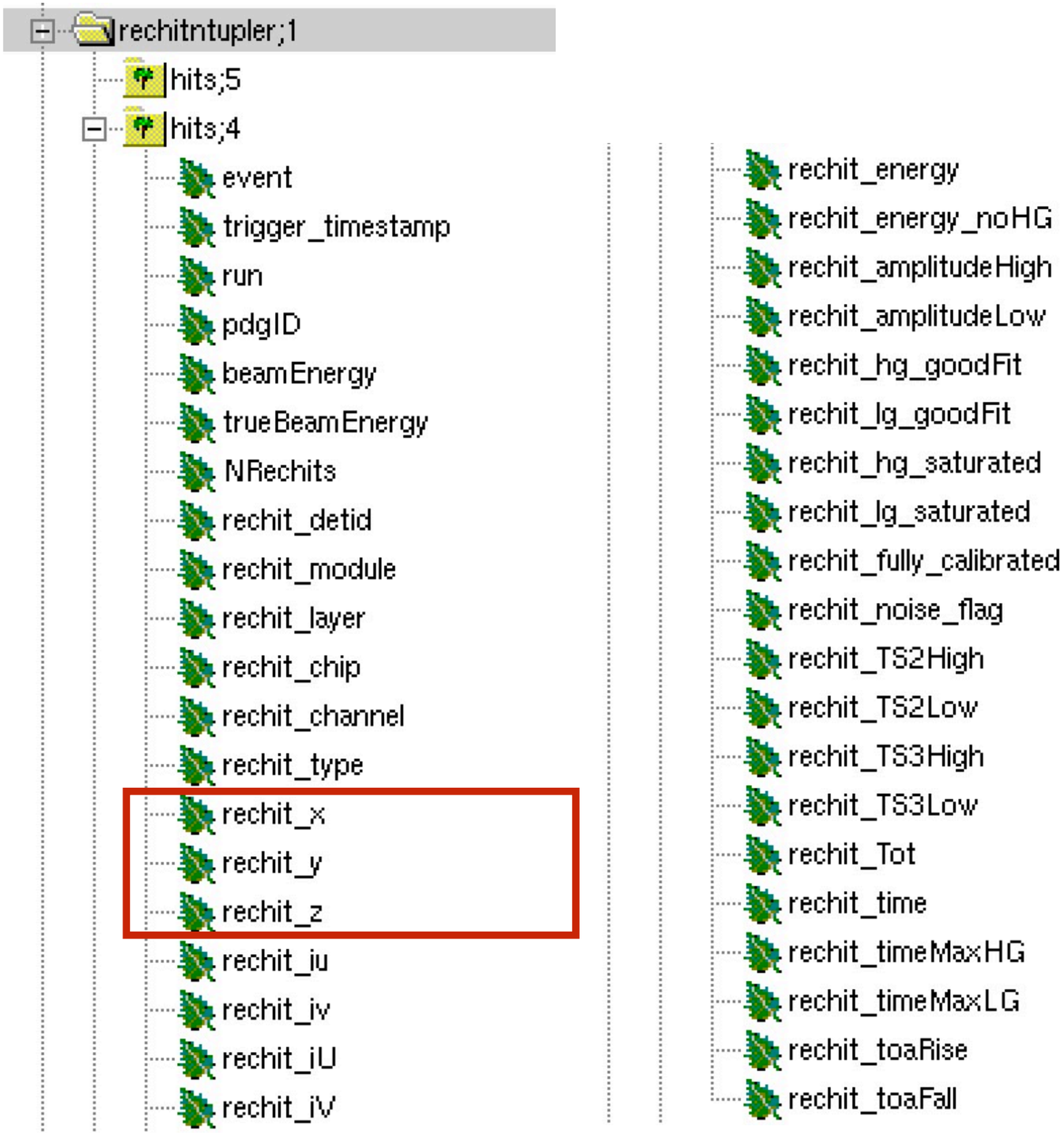
Content: Physical cell type



type:
vector<uint>

<u>description:</u>
shape type of the physical cell
-0: full cell
-1: calibration pad
-2: half cell
-3: mouse bite
-4: outer calib. pad
-5: merged cell

Content: Cartesian coordinates



type:
vector<Float16_t>

<u>description:</u>
cartesian coord-inates of the phys-ical cell

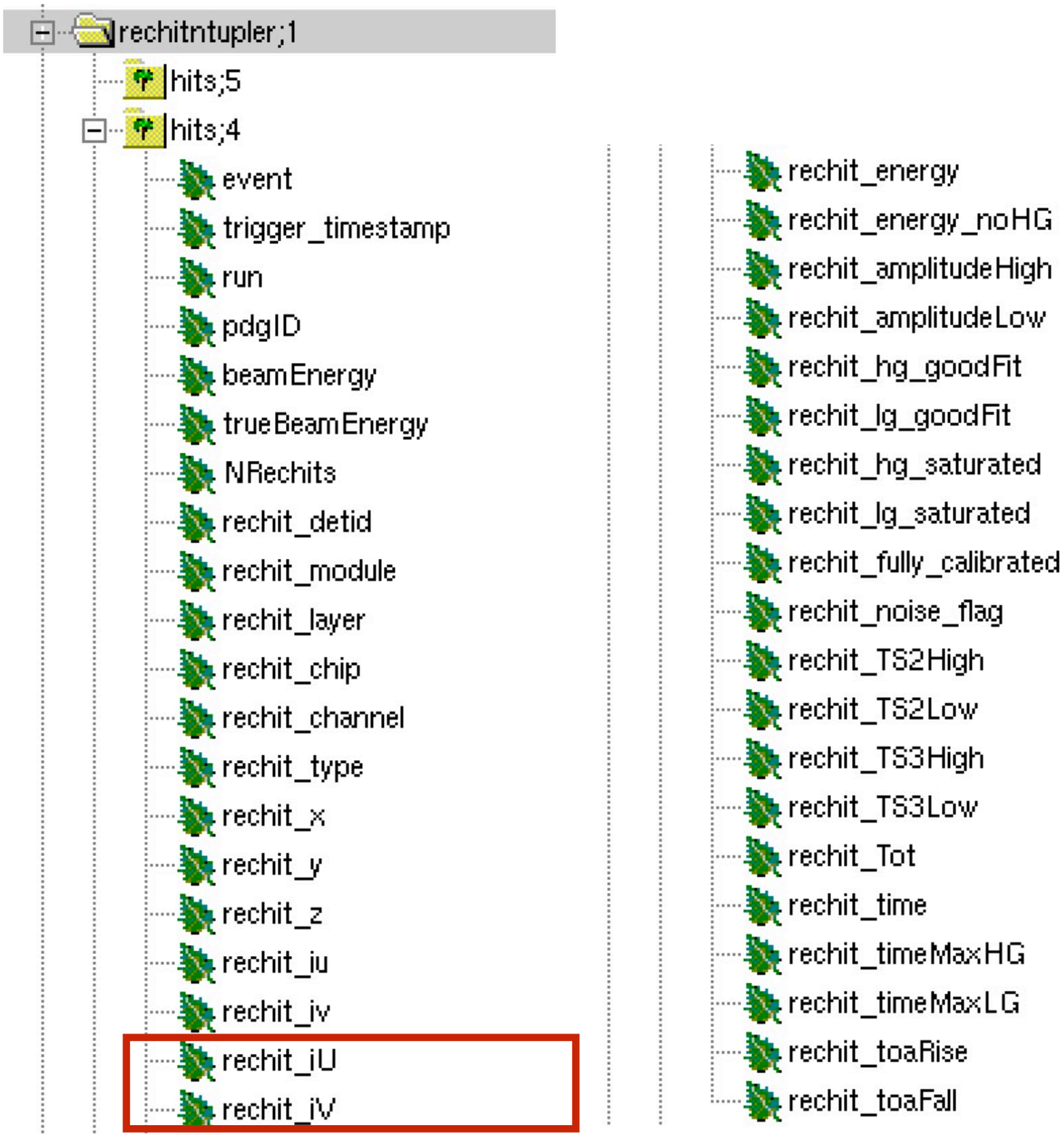
unit: cm

Content: Hexagonal coordinates on module

type:
vector<short>

<u>description:</u>
hexagonal coordinates of the physical cell

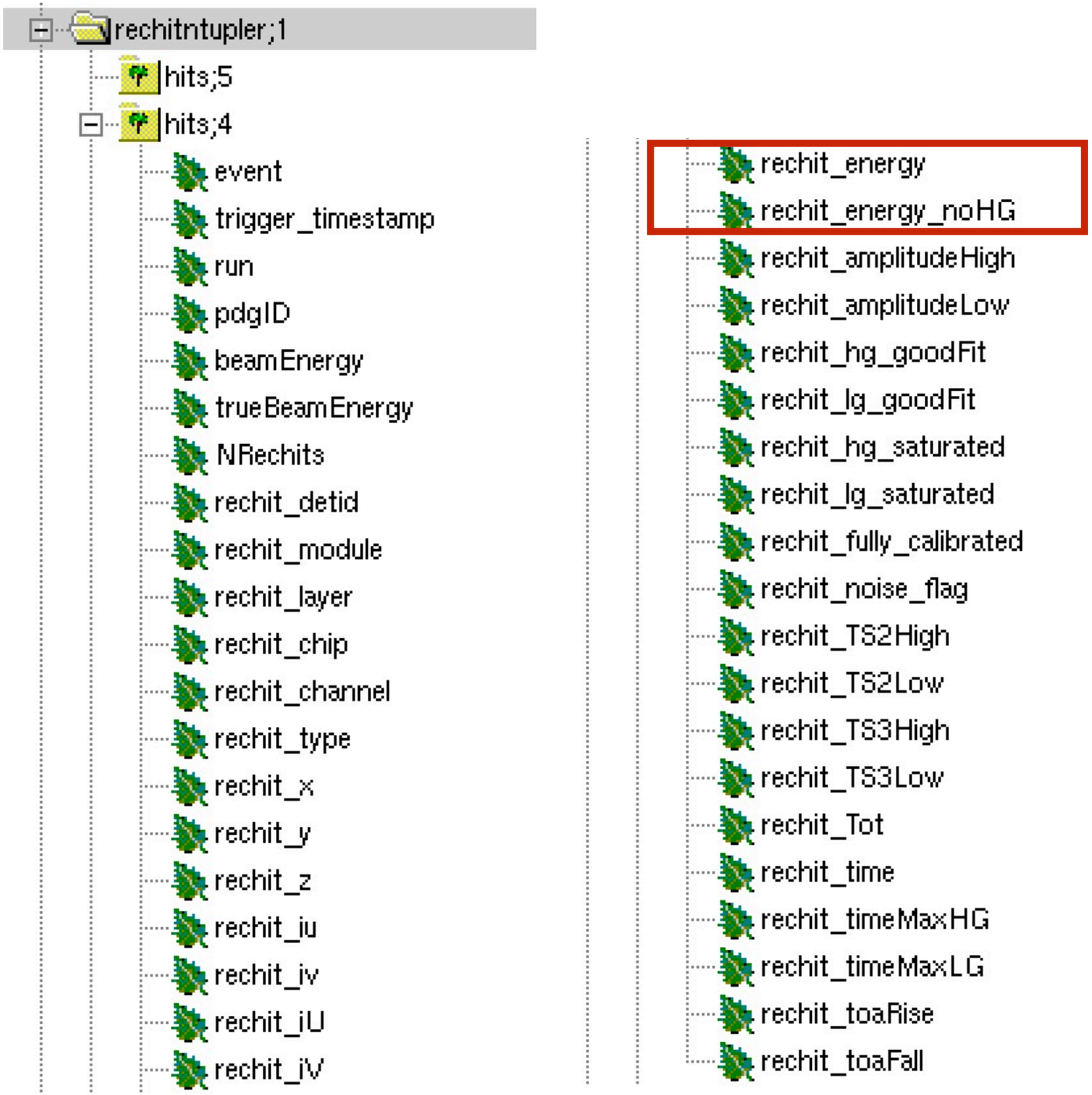
Content: Hexagonal coordinates of the module



type:
vector<short>

<u>description:</u>
hexagonal coordinates of the physical module, relevant for daisies

Content: Reconstructed energy

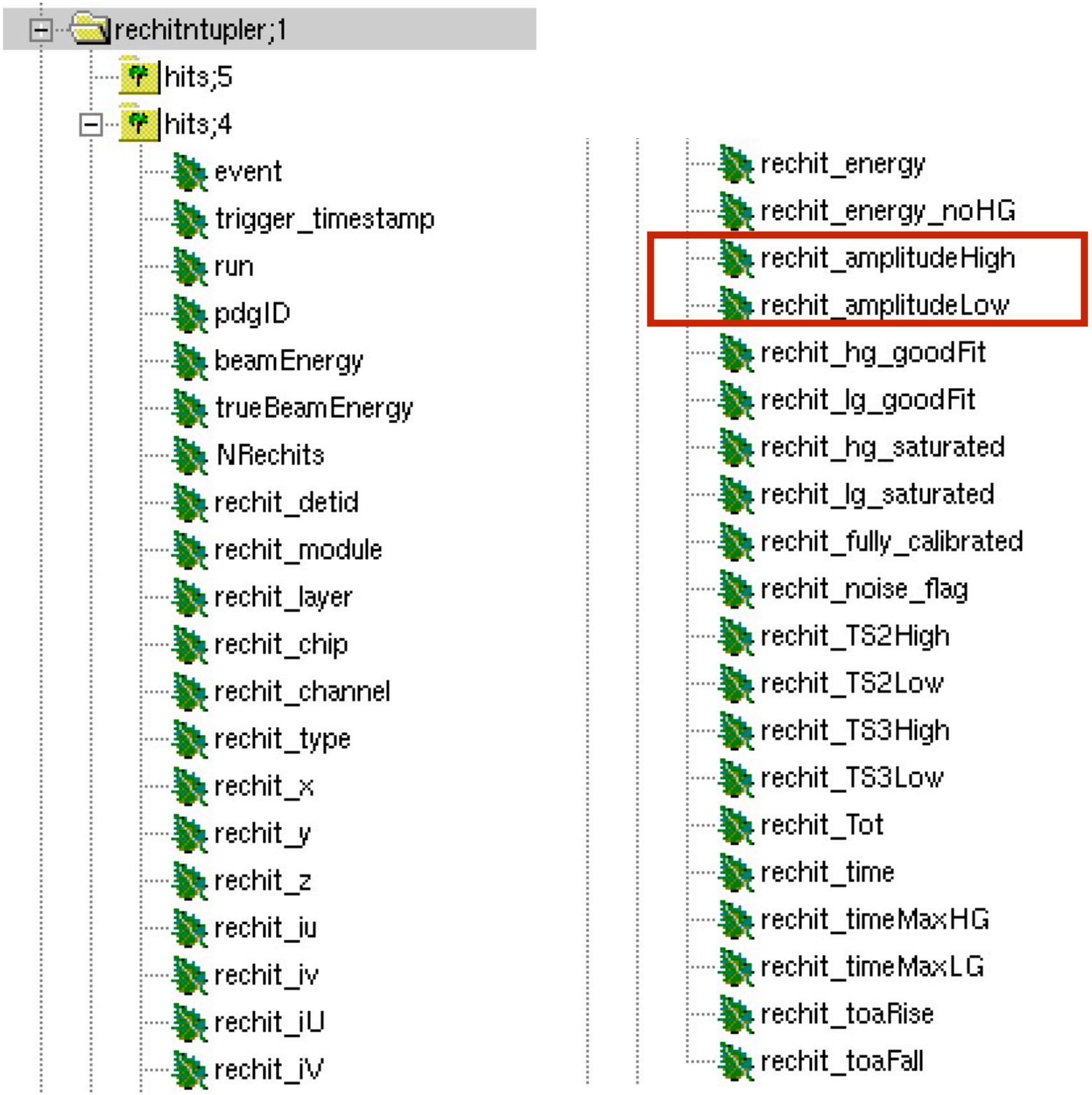


type:
vector<Float16_t>

<u>description:</u>
reconstructed energy incl. pulse fit, gain switching, …
with and without use of High Gain

unit: MIPs

Content: Pulse fit amplitudes

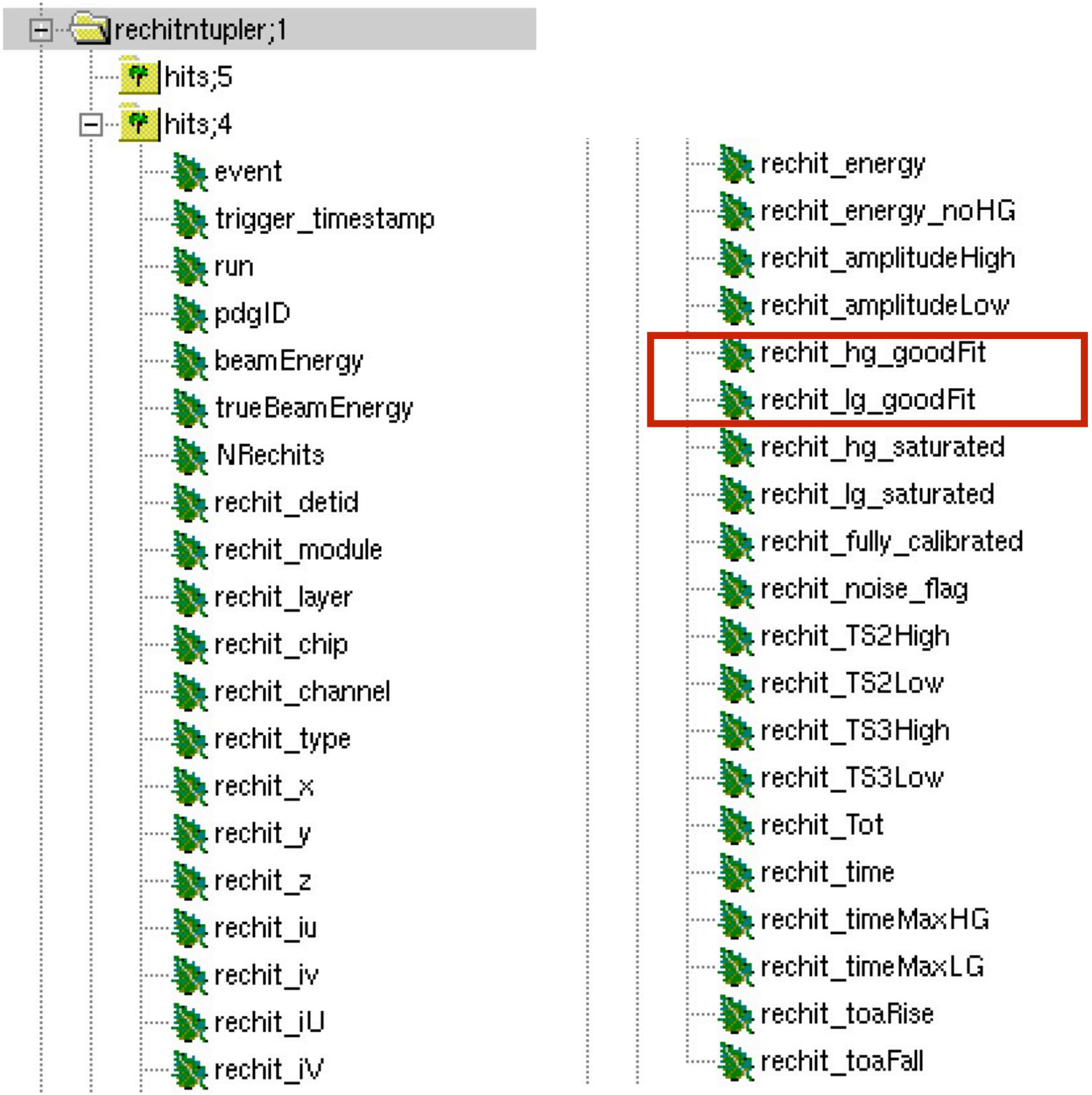


type: vector<Float16_t>

<u>description:</u> reconstructed amplitude in High- and Low-gain

unit: ADC

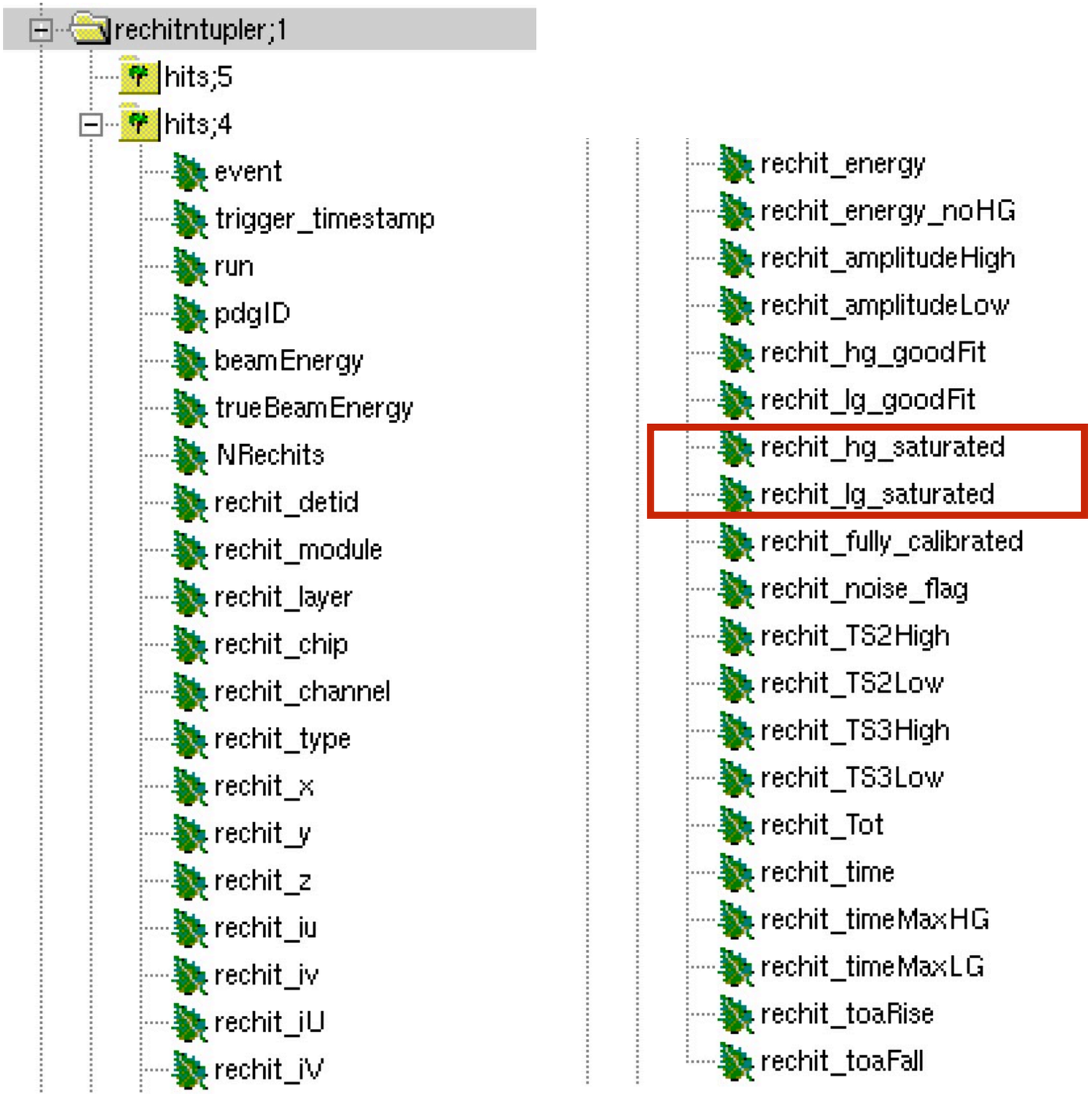
Content: Goodness of amplitude fitting



type:
vector<bool>

<u>description:</u>
status of pulse fits
good=true
fail=false

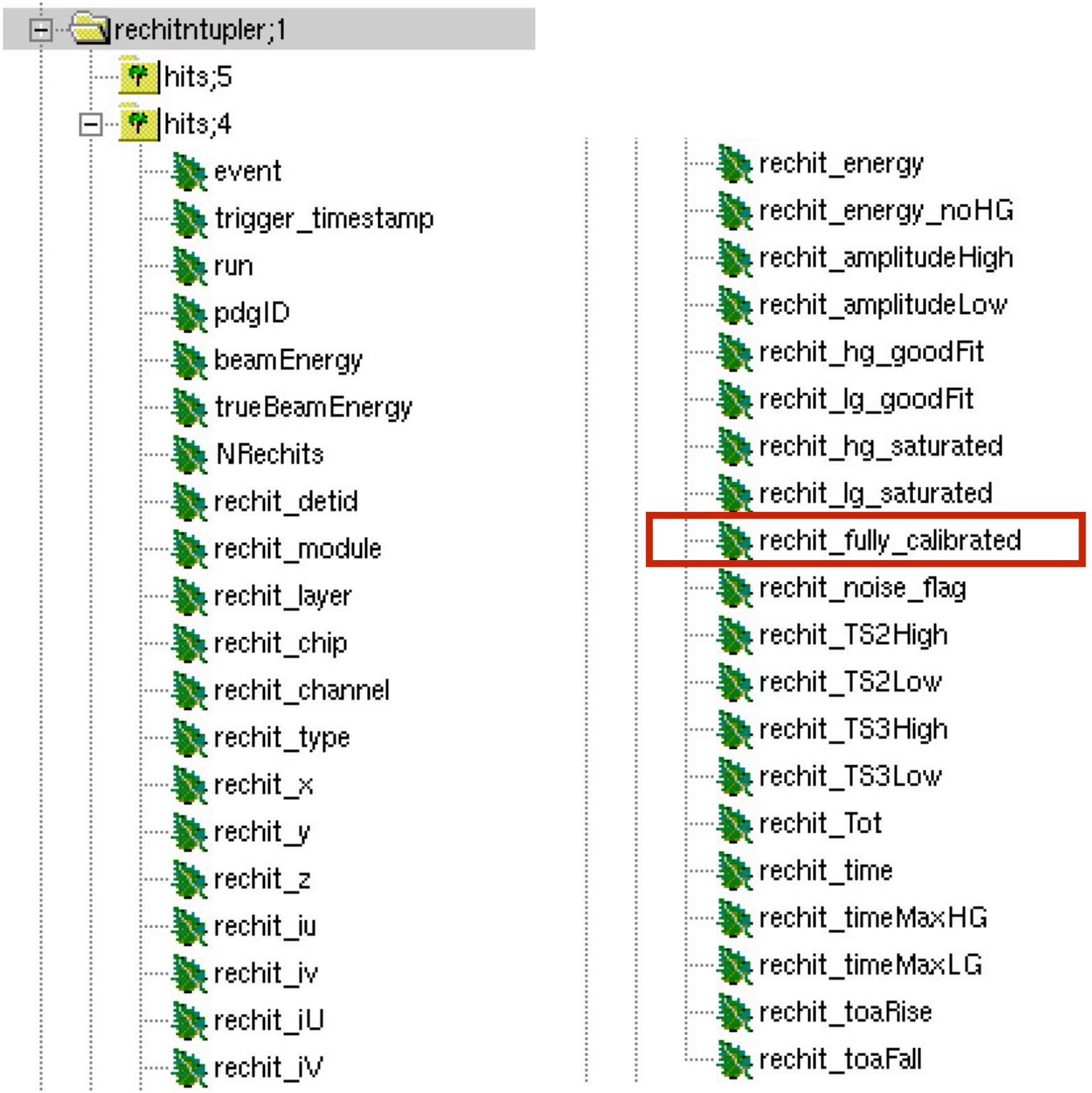
Content: Gain saturation



type:
vector<bool>

<u>description:</u>
reconstructed amplitude above saturation threshold (true) or below (false)

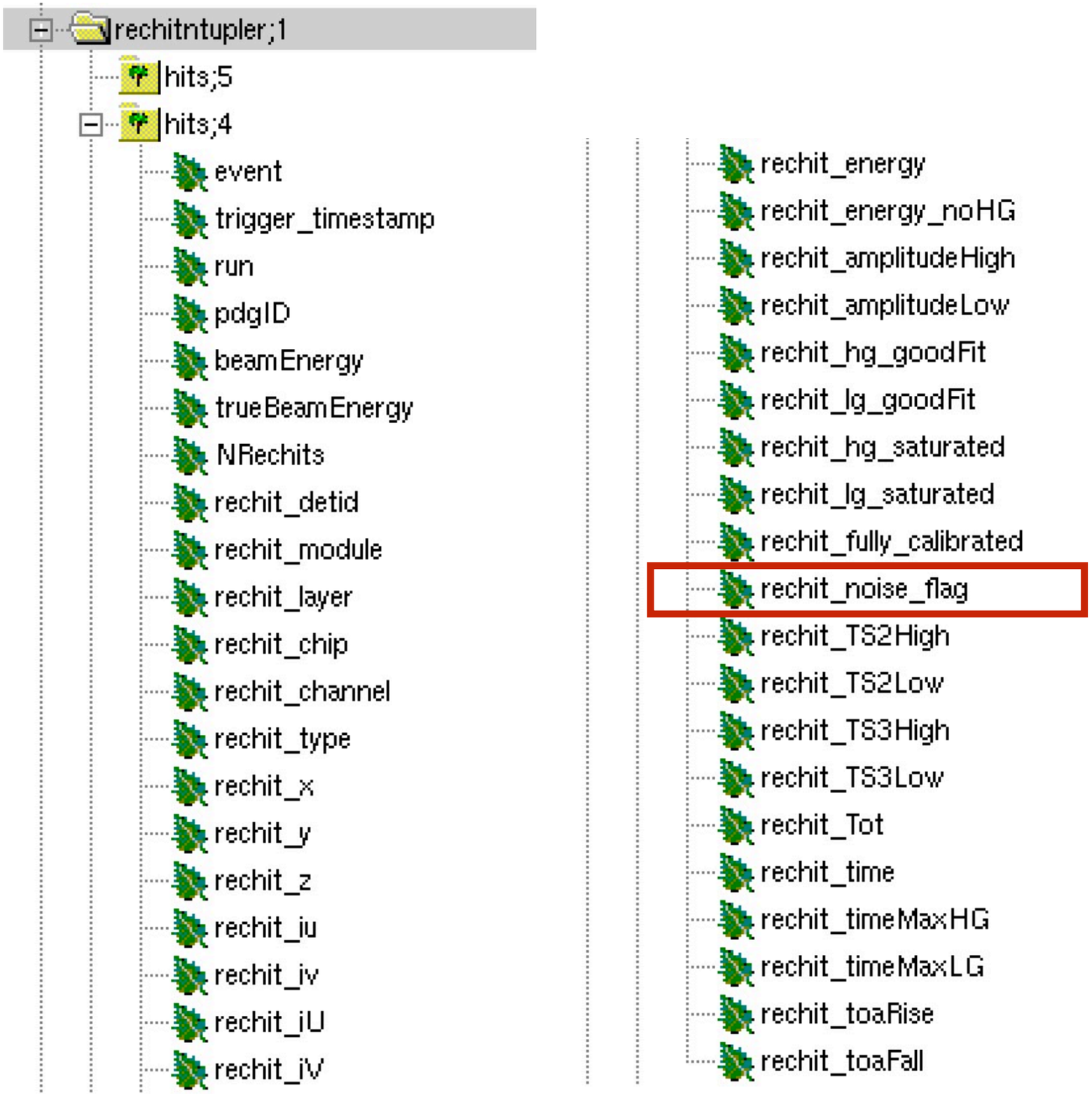
Content: Calibration



type:
vector<bool>

<u>description:</u>
true: underlying cell has been fully calibrated, i.e.
- MIP-HG
- HG-LG
- LG-TOT

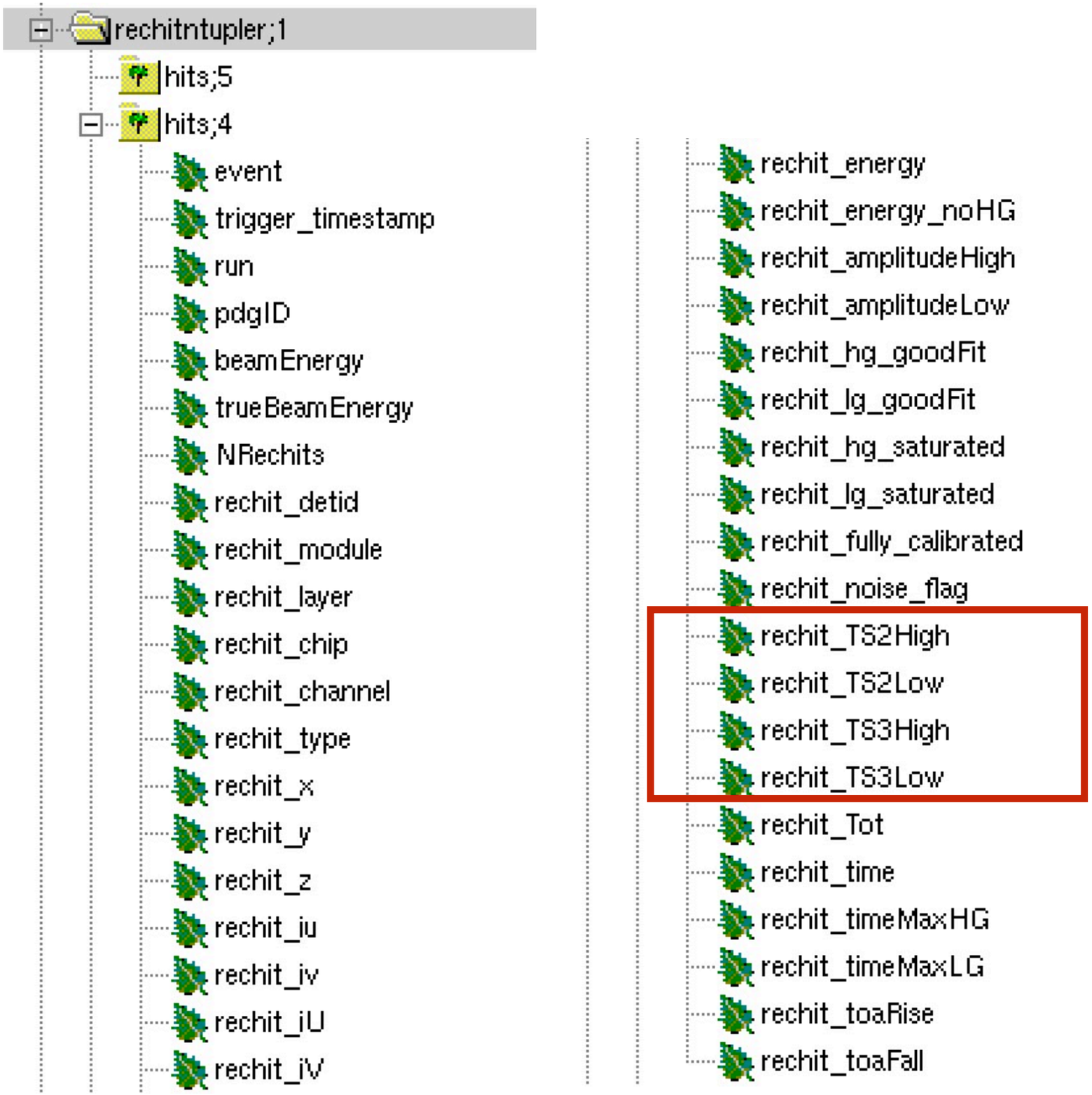
Content: Noise flag



type:
vector<bool>

<u>description:</u>
true: cell is labeled noise based on its pedestal width

Content: Timesamples 2 & 3

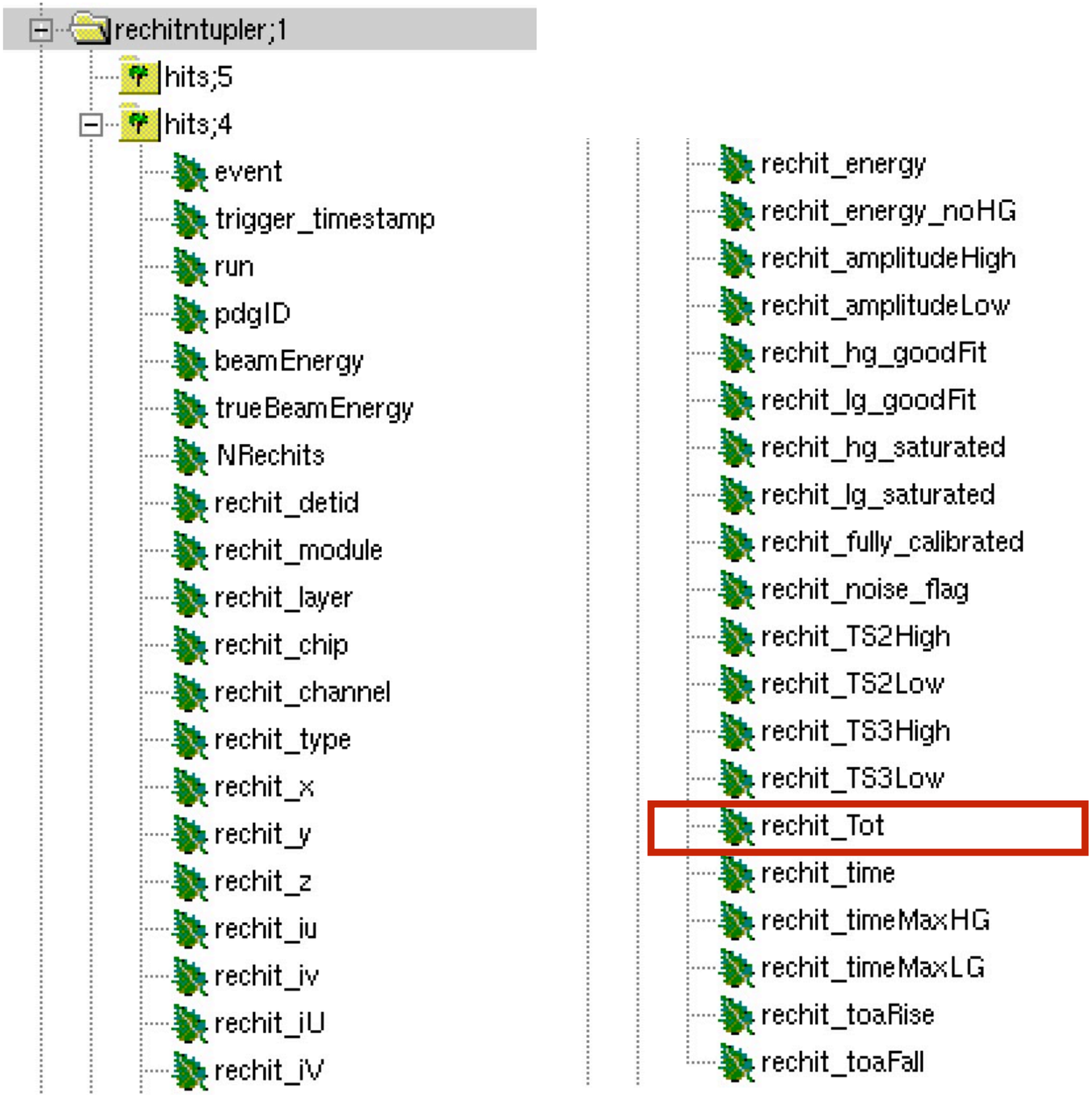


type:
vector<Float16_t>

<u>description:</u>
pedestal &
common mode
noise subtracted
HG&LG samples
2 & 3

unit: ADC

Content: TOT

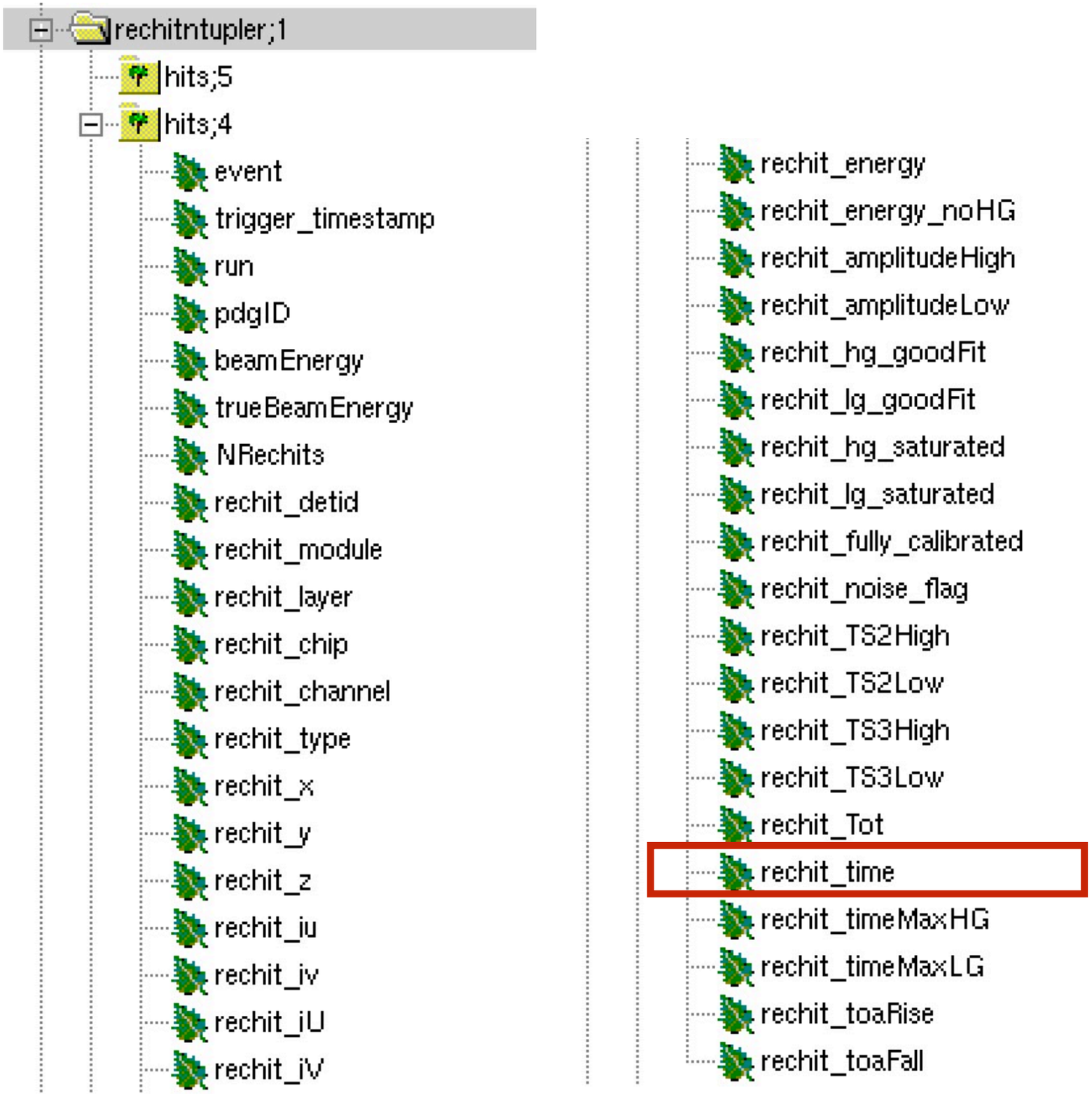


type:
vector<ushort>

<u>description:</u>
Time over threshold from readout ASIC

unit: ADC

Content: (Calibrated) Time

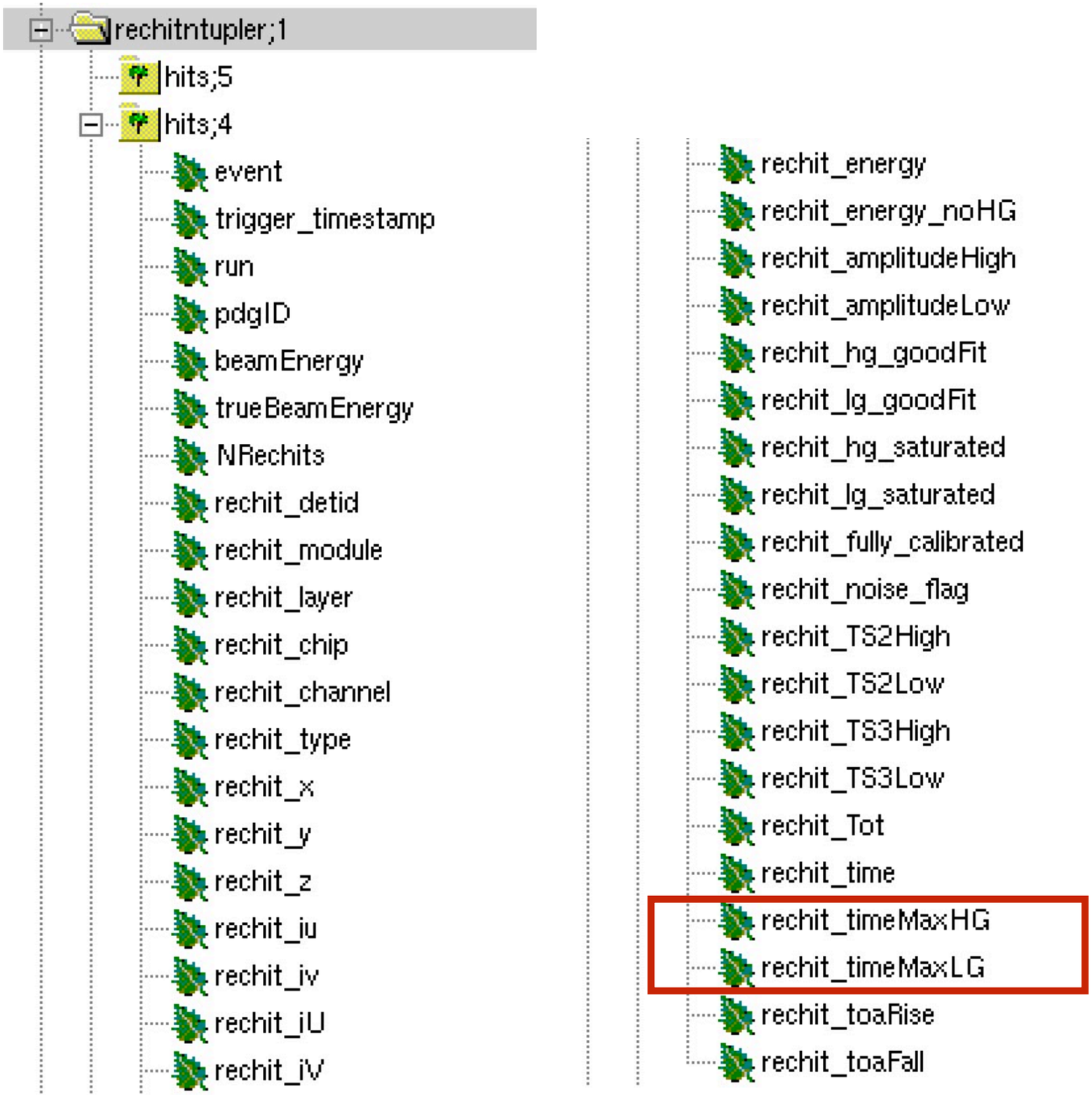


type:
vector<Float16_t>

<u>description:</u>
(will be) calibrated time of arrival reconstructed from TOA

not filled yet!!!

Content: Peak time of pulses



type:
vector<Float16_t>

<u>description:</u>
peak time
of pulse fitted to
High- and Low
gain samples

unit: ns

Content: TOA

- rechitntupler;1
  - hits;5
  - hits;4
    - event
    - trigger_timestamp
    - run
    - pdgID
    - beamEnergy
    - trueBeamEnergy
    - NRechits
    - rechit_detid
    - rechit_module
    - rechit_layer
    - rechit_chip
    - rechit_channel
    - rechit_type
    - rechit_x
    - rechit_y
    - rechit_z
    - rechit_iu
    - rechit_iv
    - rechit_iU
    - rechit_iV
    - rechit_energy
    - rechit_energy_noHG
    - rechit_amplitudeHigh
    - rechit_amplitudeLow
    - rechit_hg_goodFit
    - rechit_lg_goodFit
    - rechit_hg_saturated
    - rechit_lg_saturated
    - rechit_fully_calibrated
    - rechit_noise_flag
    - rechit_TS2High
    - rechit_TS2Low
    - rechit_TS3High
    - rechit_TS3Low
    - rechit_Tot
    - rechit_time
    - rechit_timeMaxHG
    - rechit_timeMaxLG
    - rechit_toaRise
    - rechit_toaFall

type:
vector<ushort>

<u>description:</u>
Time of arrival
from readout ASIC

unit: ADC

Location of files

/eos/cms/store/group/dpg_hgcal/tb_hgcal/2018/cern_h2_october/offline_analysis/ntuples/v1

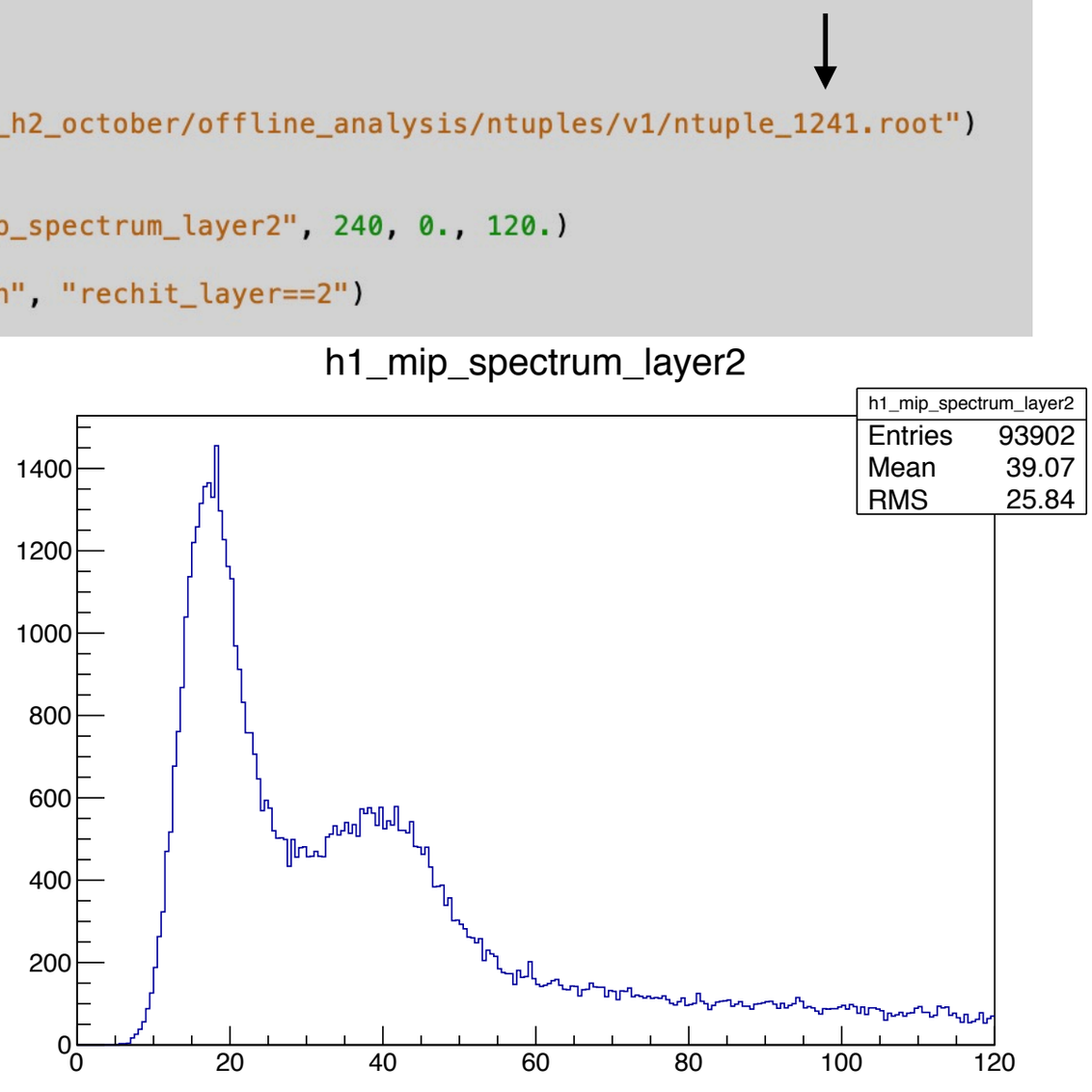
6 million events = 190 GB (“*du -sh*”)

dedicated README.txt for each version to document:
changes
dependencies
software tag
…

Example: MIP spectra

```
[pclcd37:~ > ipython
Python 2.7.5 (default, Jul 13 2018, 13:06:57)
Type "copyright", "credits" or "license" for more information.

IPython 5.7.0 -- An enhanced Interactive Python.
?         -> Introduction and overview of IPython's features.
%quickref -> Quick reference.
help      -> Python's own help system.
object?   -> Details about 'object', use 'object??' for extra details.

[In [1]: import ROOT

[In [2]: tree_rechits = ROOT.TChain('rechitntupler/hits','hits')

[In [3]: tree_rechits.Add("/eos/cms/store/group/dpg_hgcal/tb_hgcal/2018/cern_h2_october/offline_analysis/ntuples/v1/ntuple_1241.root")
 Out[3]: 1

[In [4]: h1_mip_spectrum_layer2 = ROOT.TH1F("h1_mip_spectrum_layer2", "h1_mip_spectrum_layer2", 240, 0., 120.)

[In [5]: tree_rechits.Project("h1_mip_spectrum_layer2", "rechit_amplitudeHigh", "rechit_layer==2")
 Out[5]: 93902L

[In [6]: h1_mip_spectrum_layer2.Draw()
 Info in <TCanvas::MakeDefCanvas>:  created default TCanvas with name c1
```

muon run



➡7 quick steps for MIP spectra

➡ROOT only!

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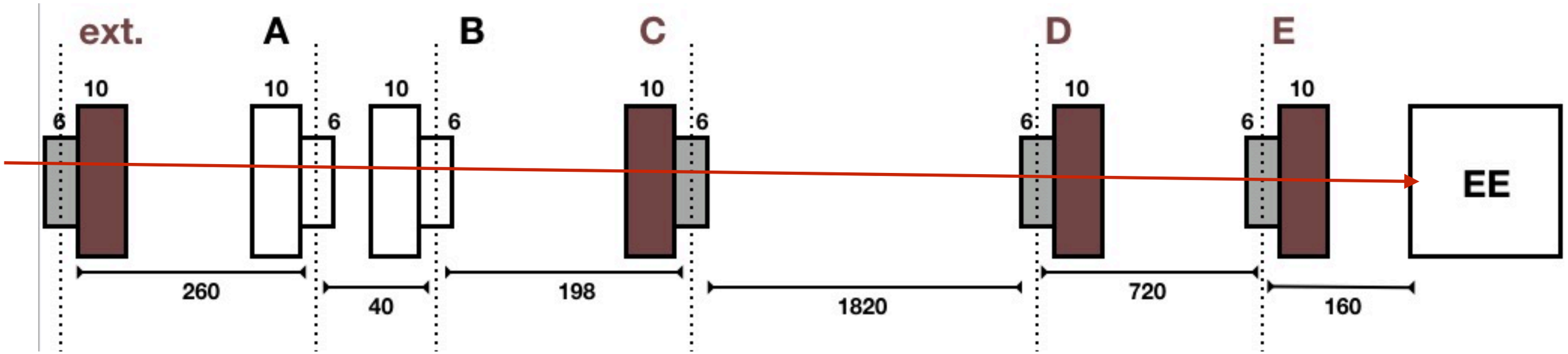
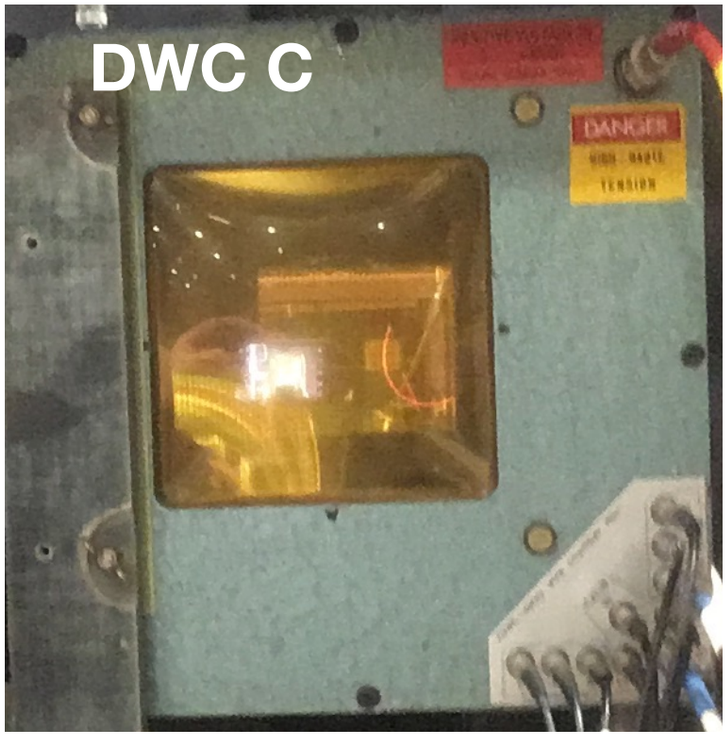
Delay Wire Chambers

Delay wire chambers = Tracking





- Straight-forward reconstruction
- Software alignment

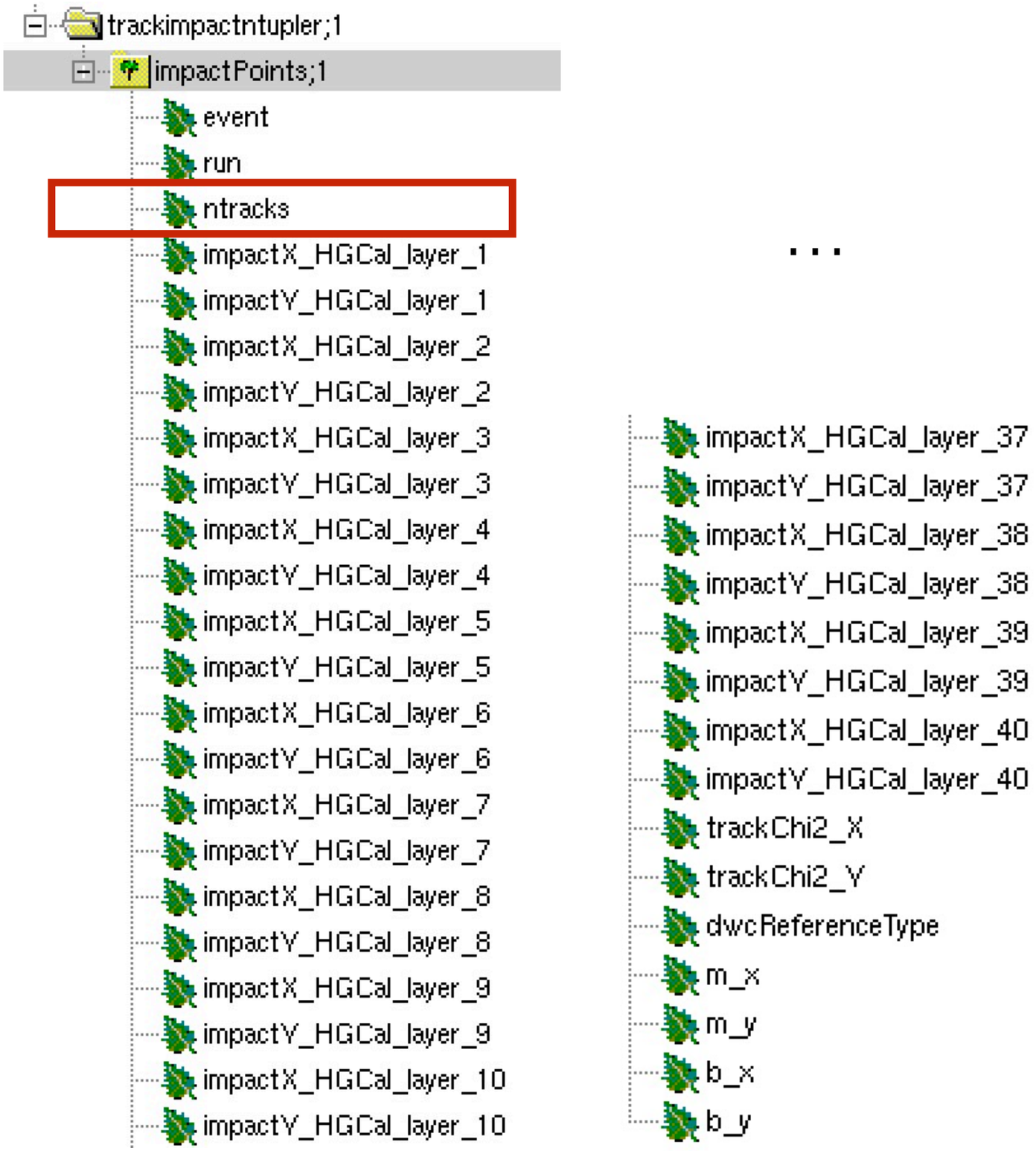
Impact position resolution on EE ~ 0.6 - 0.8 mm.

DWC ntuples

- trackimpactntupler;1
  - impactPoints;1
    - event
    - run
    - ntracks
    - impactX_HGCal_layer_1
    - impactY_HGCal_layer_1
    - impactX_HGCal_layer_2
    - impactY_HGCal_layer_2
    - impactX_HGCal_layer_3
    - impactY_HGCal_layer_3
    - impactX_HGCal_layer_4
    - impactY_HGCal_layer_4
    - impactX_HGCal_layer_5
    - impactY_HGCal_layer_5
    - impactX_HGCal_layer_6
    - impactY_HGCal_layer_6
    - impactX_HGCal_layer_7
    - impactY_HGCal_layer_7
    - impactX_HGCal_layer_8
    - impactY_HGCal_layer_8
    - impactX_HGCal_layer_9
    - impactY_HGCal_layer_9
    - impactX_HGCal_layer_10
    - impactY_HGCal_layer_10
    - ...
    - impactX_HGCal_layer_37
    - impactY_HGCal_layer_37
    - impactX_HGCal_layer_38
    - impactY_HGCal_layer_38
    - impactX_HGCal_layer_39
    - impactY_HGCal_layer_39
    - impactX_HGCal_layer_40
    - impactY_HGCal_layer_40
    - trackChi2_X
    - trackChi2_Y
    - dwcReferenceType
    - m_x
    - m_y
    - b_x
    - b_y

Available from **run 381 onward**

Content: Number of tracks



type:
vector<int>

<u>description:</u>
number of reconstructed DWC tracks
range: 0, 1

Content: Impact points

type:
float

<u>description:</u>
extrapolated impact positions onto HGCal layers

unit: cm

Content: Track quality

type:
float

<u>description:</u>
chi^2 of extrapolated tracks

straight line model

Content: Contributing DWCs

type:
int

<u>description:</u>
indicator for contributing DWCs to the track

DWC E —> +8
DWC D —> +4
DWC C —> +2
DWC ext —> +1

Content: Track angles / slopes

type:
float

<u>description:</u>
track slopes
~particle angle

unit: 1 [rad]

Content: Track offsets

type:
float

<u>description:</u>
track offsets
= impact onto EE

unit: cm

Example: DWC profile & coordinate x-check

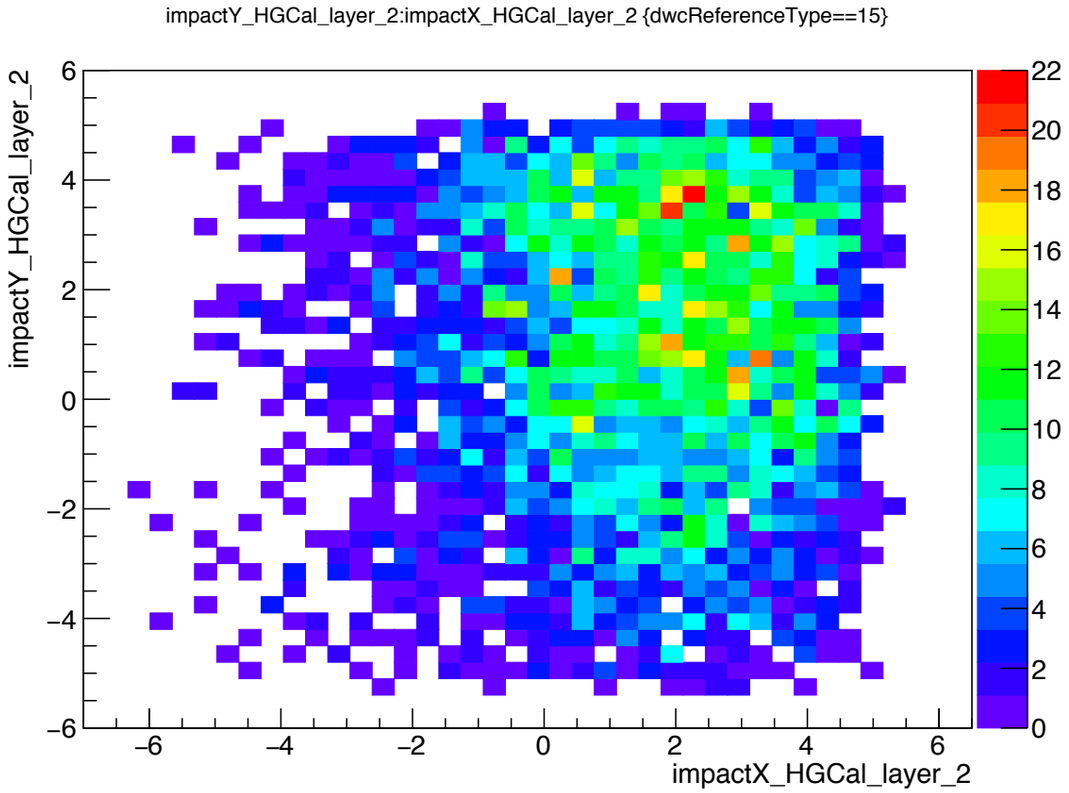
```
[In [1]: import ROOT

[In [2]: tree_tracks = ROOT.TChain('trackimpactntupler/impactPoints','dwcs')

[In [3]: tree_tracks.Add("/eos/cms/store/group/dpg_hgcal/tb_hgcal/2018/cern_h2_october/offline_analysis/ntuples/v1/ntuple_700.root")
 Out[3]: 1

[In [4]: tree_tracks.Draw("impactY_HGCal_layer_2:impactX_HGCal_layer_2", "dwcReferenceType==15", "COLZ")
 Info in <TCanvas::MakeDefCanvas>:  created default TCanvas with name c1
 Out[4]: 4410L
```

muon run



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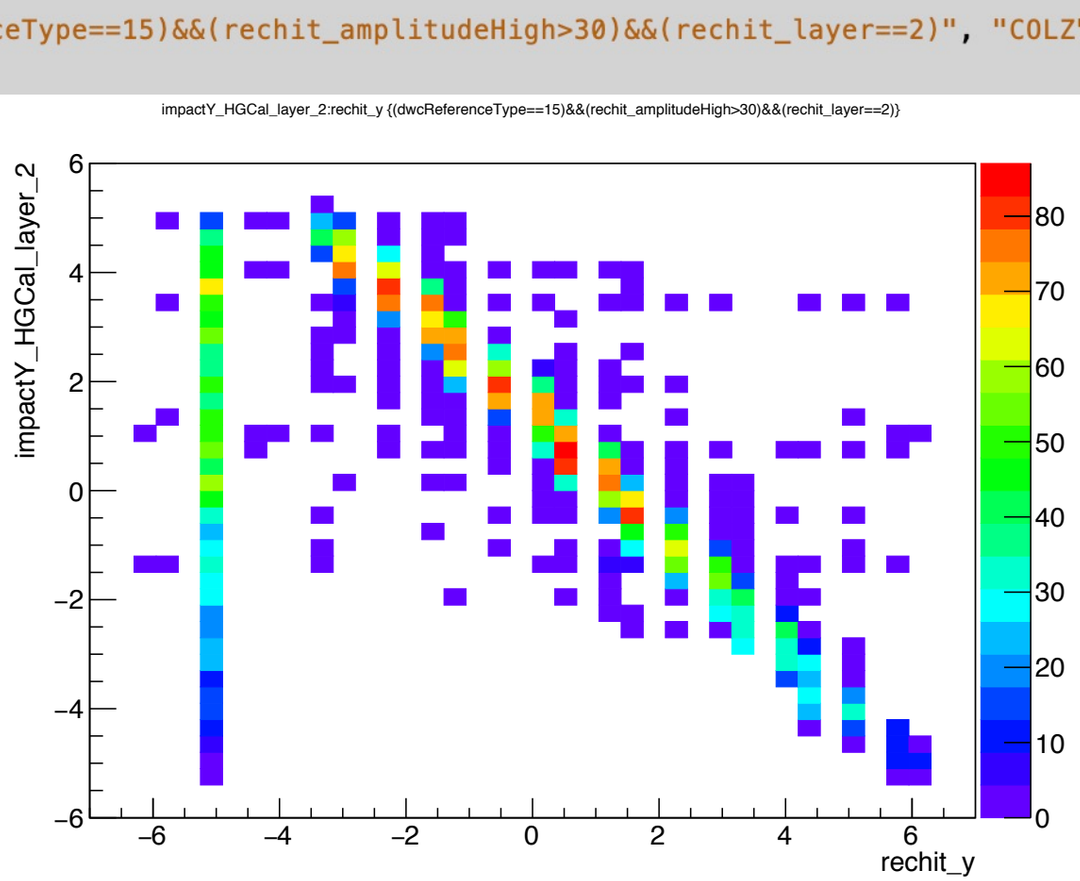
Example: DWC profile & coordinate x-check

muon run

```
[In [1]: import ROOT

[In [2]: tree_tracks = ROOT.TChain('trackimpactntupler/impactPoints','dwcs')

[In [3]: tree_tracks.Add("/eos/cms/store/group/dpg_hgcal/tb_hgcal/2018/cern_h2_october/offline_analysis/ntuples/v1/ntuple_700.root")
 Out[3]: 1

[In [4]: tree_tracks.Draw("impactY_HGCal_layer_2:impactX_HGCal_layer_2", "dwcReferenceType==15", "COLZ")
 Info in <TCanvas::MakeDefCanvas>:  created default TCanvas with name c1
 Out[4]: 4410L
```

```
[In [5]: tree_rechits = ROOT.TChain('rechitntupler/hits','hits')

[In [6]: tree_rechits.Add("/eos/cms/store/group/dpg_hgcal/tb_hgcal/2018/cern_h2_october/offline_analysis/ntuples/v1/ntuple_700.root")
 Out[6]: 1

[In [7]: tree_tracks.AddFriend(tree_rechits)
 Out[7]: <ROOT.TFriendElement object ("rechitntupler/hits") at 0x3a7b250>
```

```
[In [9]: tree_tracks.Draw("impactY_HGCal_layer_2:rechit_y", "(dwcReferenceType==15)&&(rechit_amplitudeHigh>30)&&(rechit_layer==2)", "COLZ")
 Out[9]: 4763L
```



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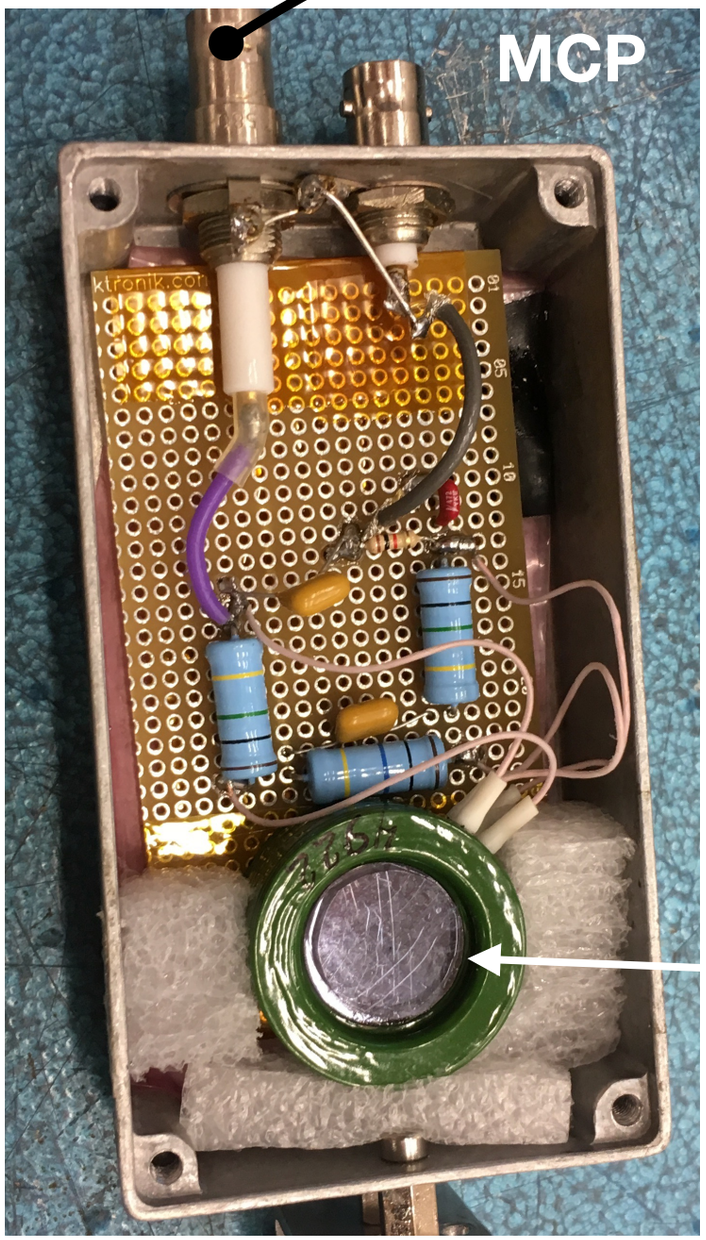
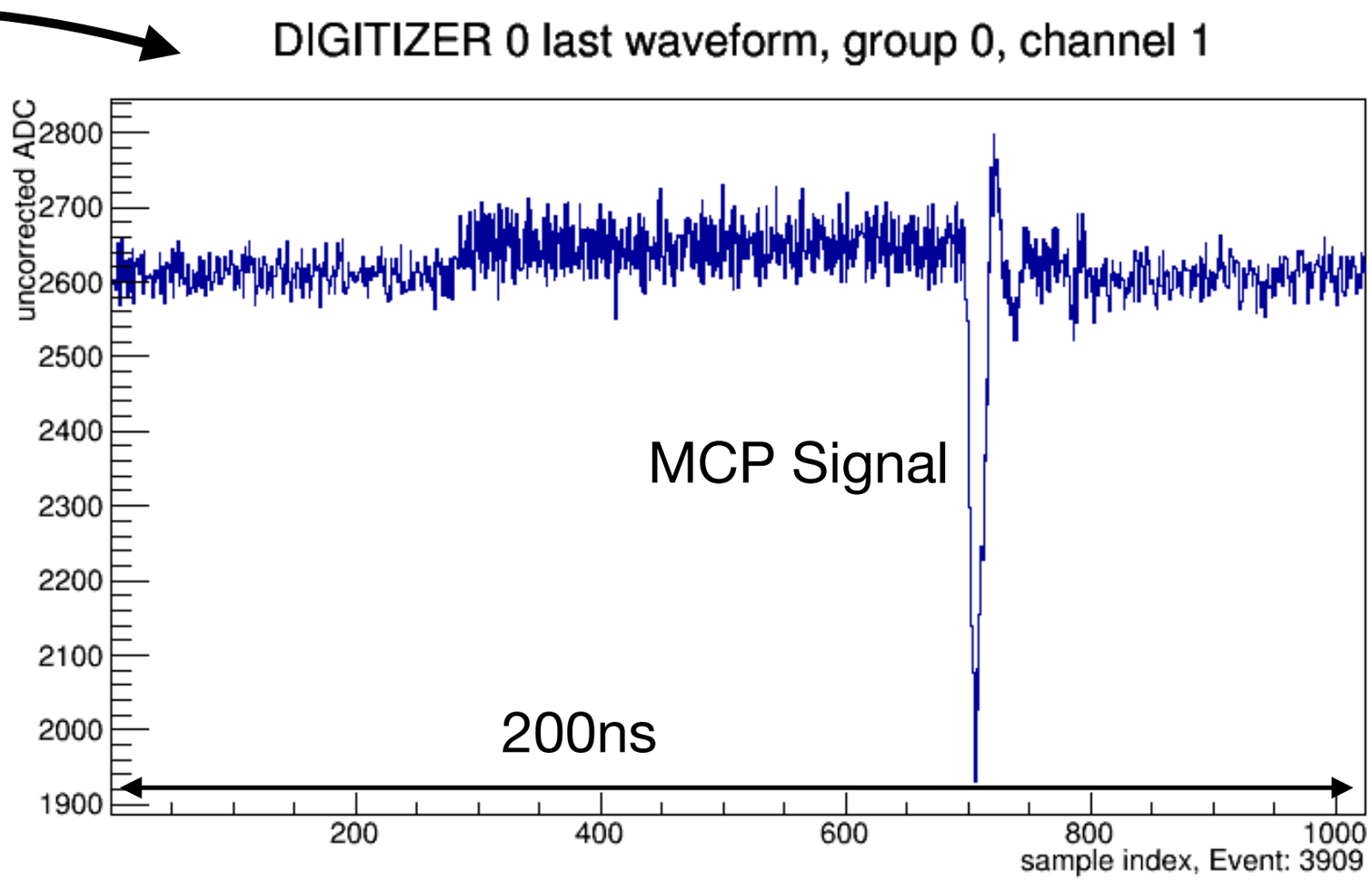
MCP (time reference)

(2x) MCP = Fast timing reference O(30ps)

NEW



sensitive area (~1cm²)



Achieved by other groups:

30ps timing resolution

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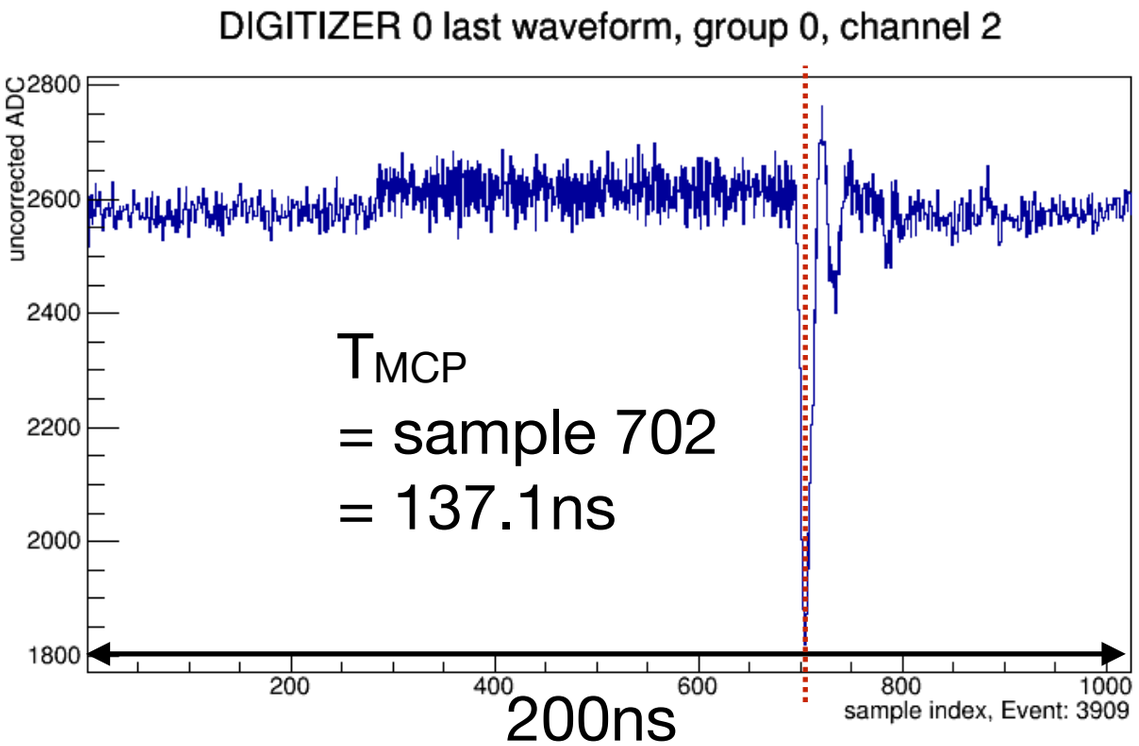
Preliminary time signal reconstruction



MCP:

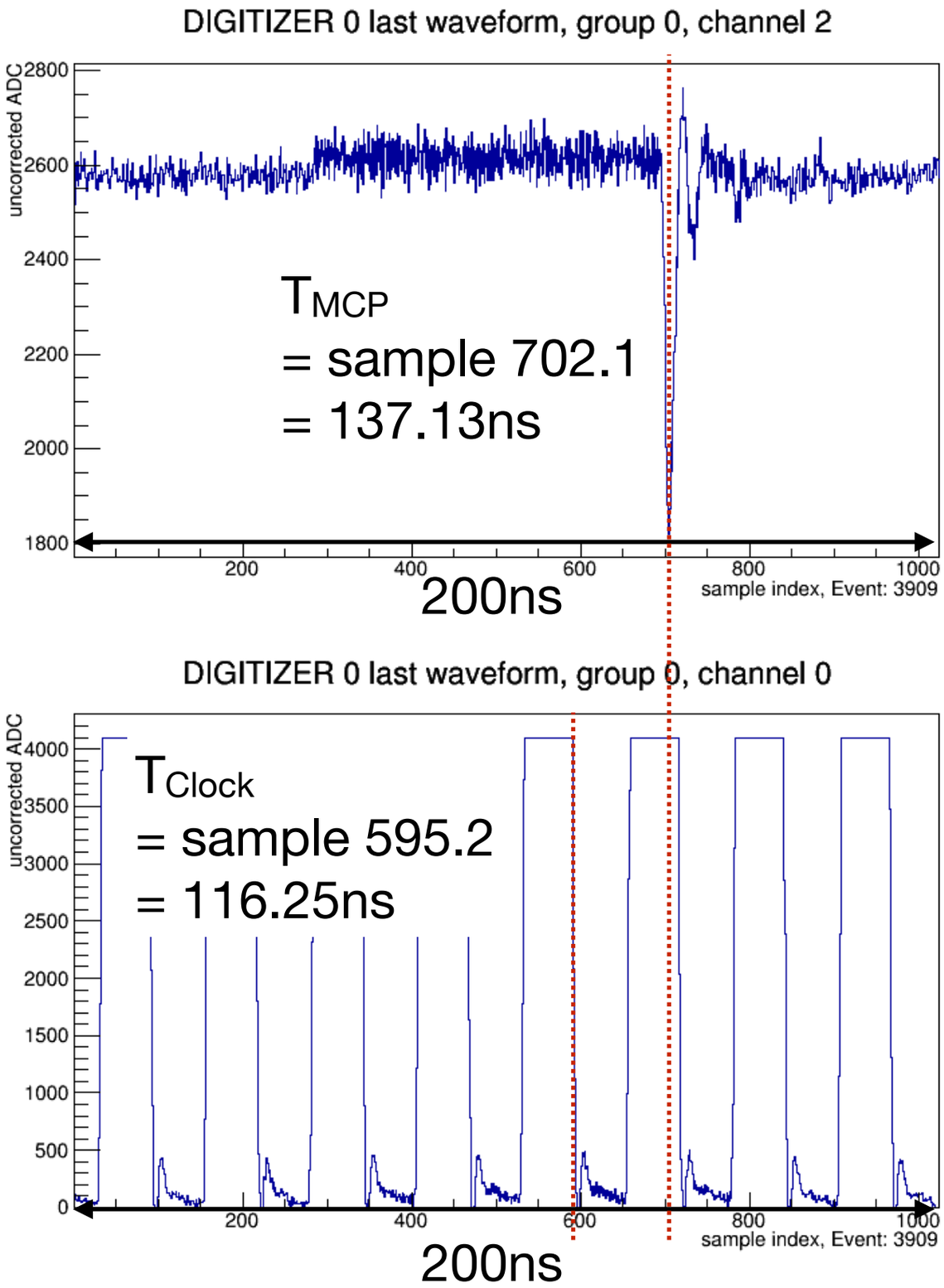
Baseline subtraction

Noise from unconnected chs.

Require ΔADC > 150

Gaussian around max

Preliminary time signal reconstruction



<u>MCP:</u>

Baseline subtraction

Noise from unconnected chs.

Require ΔADC > 150

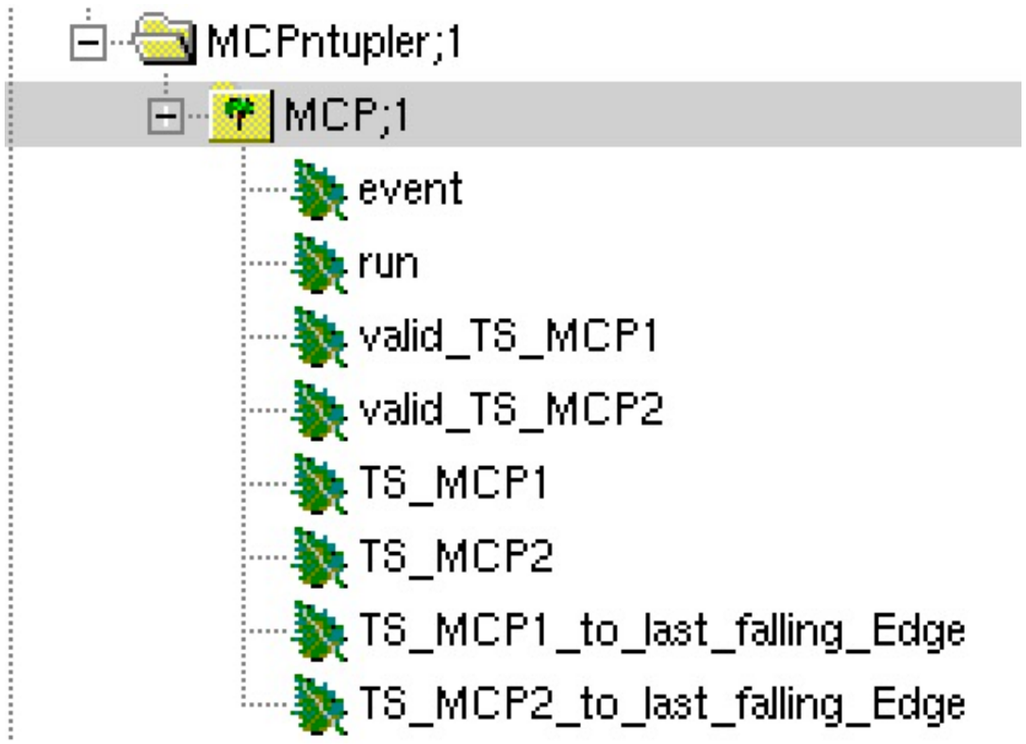
Gaussian around max

<u>Clock:</u>

Last falling edge passing 3200 ADC counts before MCP signal

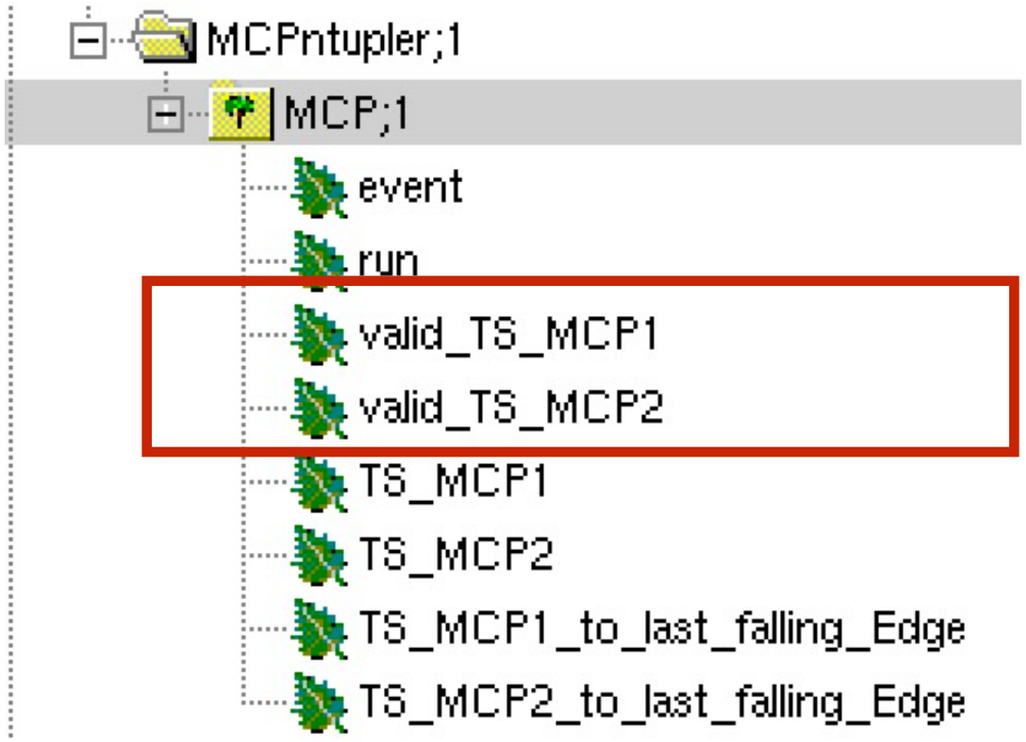
MCP ntuples

Available from **run 912 onward**



Content: MCP signal flag

Available from **run 912 onward**

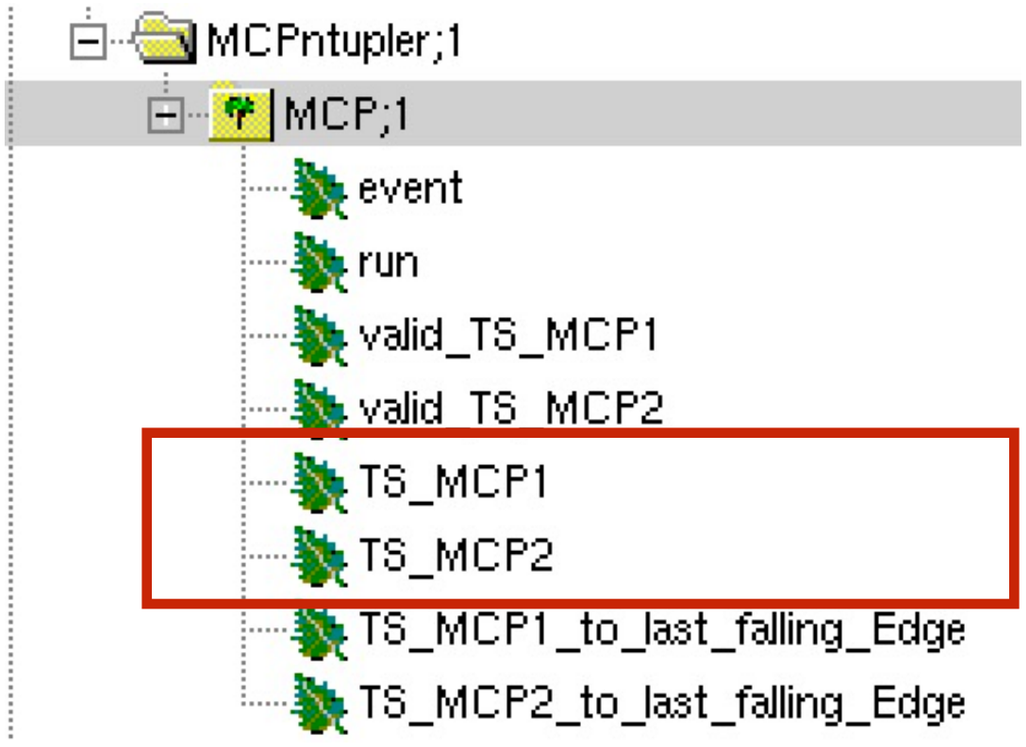


type:
short

<u>description:</u>
1=MCP signal reconstructed
0=no MCP signal

Content: MCP timestamps

Available from **run 912 onward**



type:
float

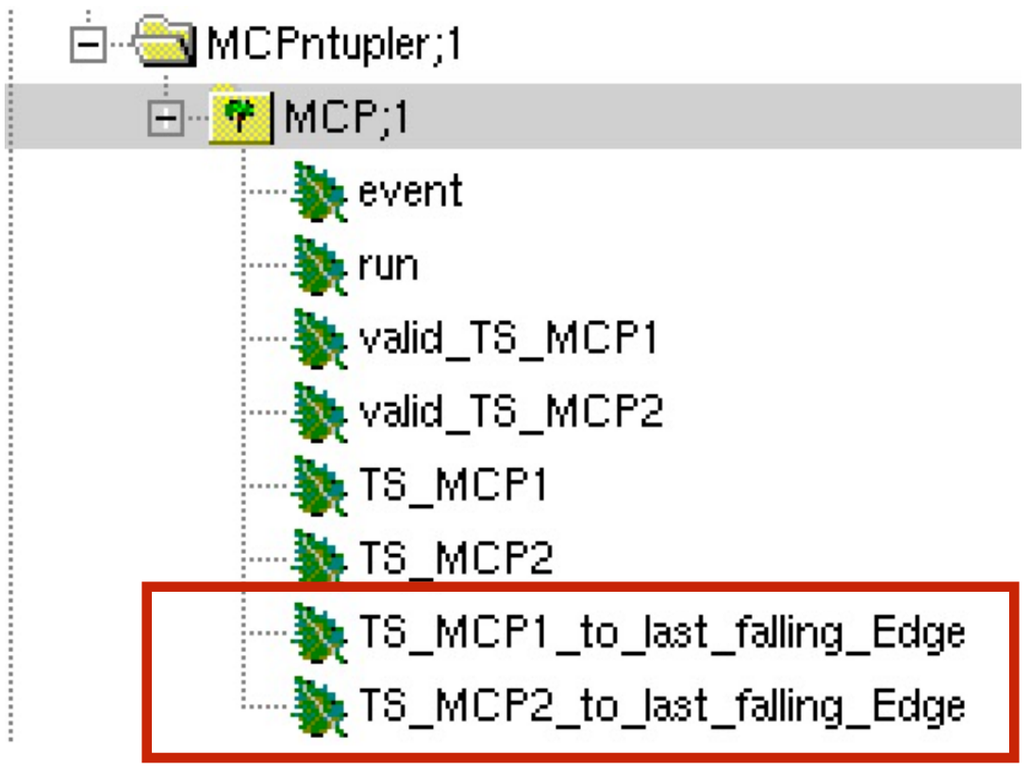
<u>description:</u>
time stamp from gaussian fit to maximum

also set if valid=0

unit: ns

Content: MCP timestamps - clock falling edge

Available from **run 912 onward**



type:
float

<u>description:</u>
time stamp from gaussian fit to maximum w.r.t. last falling clock edge

also set if valid=0

unit: ns

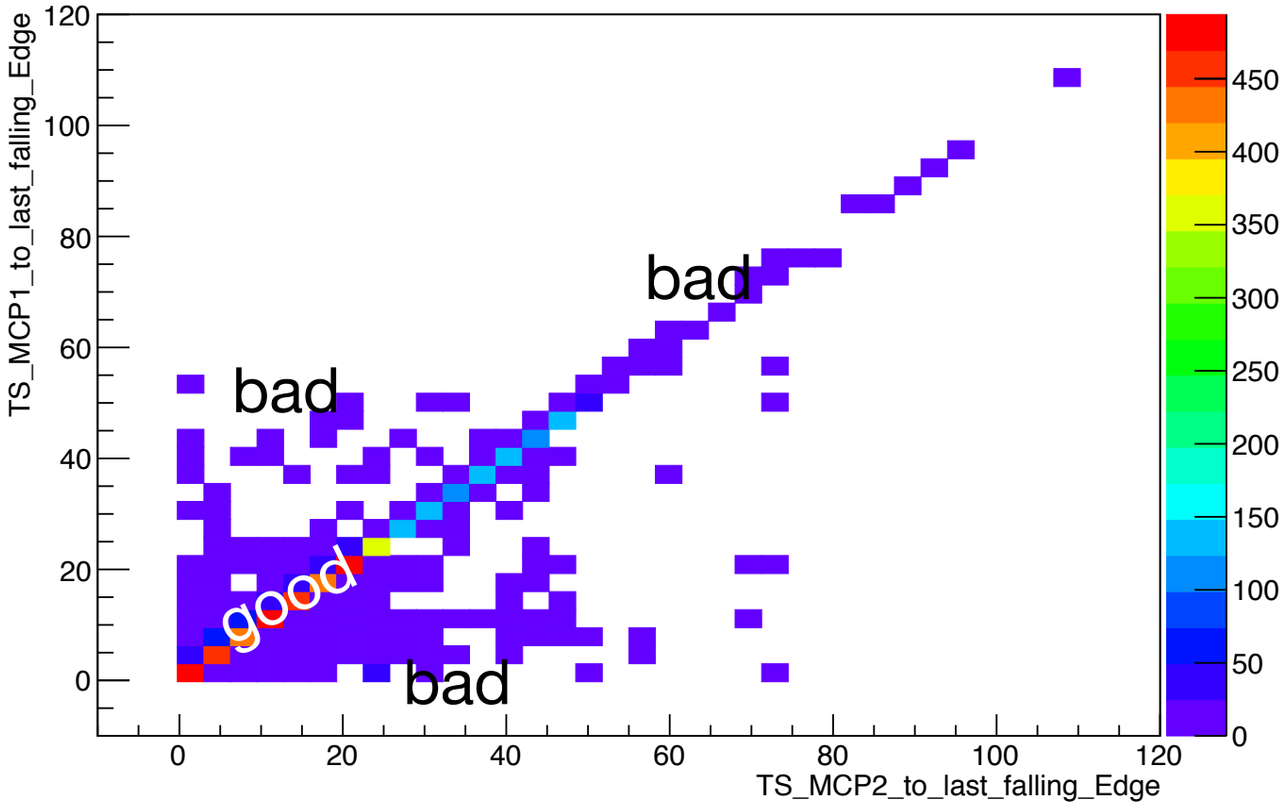
Example: MCPs timing correlation

```
[In [1]: import ROOT

[In [2]: tree_mcp = ROOT.TChain('MCPntupler/MCP','MCP')
 ^[[A
[In [3]: tree_mcp.Add("/eos/cms/store/group/dpg_hgcal/tb_hgcal/2018/cern_h2_october/offline_analysis/ntuples/v1/ntuple_965.root")
 Out[3]: 1

[In [4]: tree_mcp.Draw("TS_MCP1_to_last_falling_Edge:TS_MCP2_to_last_falling_Edge", "valid_TS_MCP1*valid_TS_MCP2==1", "COLZ")
 Info in <TCanvas::MakeDefCanvas>:  created default TCanvas with name c1
 Out[4]: 5378L
```

300 GeV e run



Further effort on MCP timing reconstruction necessary!

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Example: MCPs timing correlation & -to HGCal

```
[In [1]: import ROOT

[In [2]: tree_mcp = ROOT.TChain('MCPntupler/MCP','MCP')
 ^[[A
[In [3]: tree_mcp.Add("/eos/cms/store/group/dpg_hgcal/tb_hgcal/2018/cern_h2_october/offline_analysis/ntuples/v1/ntuple_965.root")
 Out[3]: 1

[In [4]: tree_mcp.Draw("TS_MCP1_to_last_falling_Edge:TS_MCP2_to_last_falling_Edge", "valid_TS_MCP1*valid_TS_MCP2==1", "COLZ")
 Info in <TCanvas::MakeDefCanvas>:  created default TCanvas with name c1
 Out[4]: 5378L
```

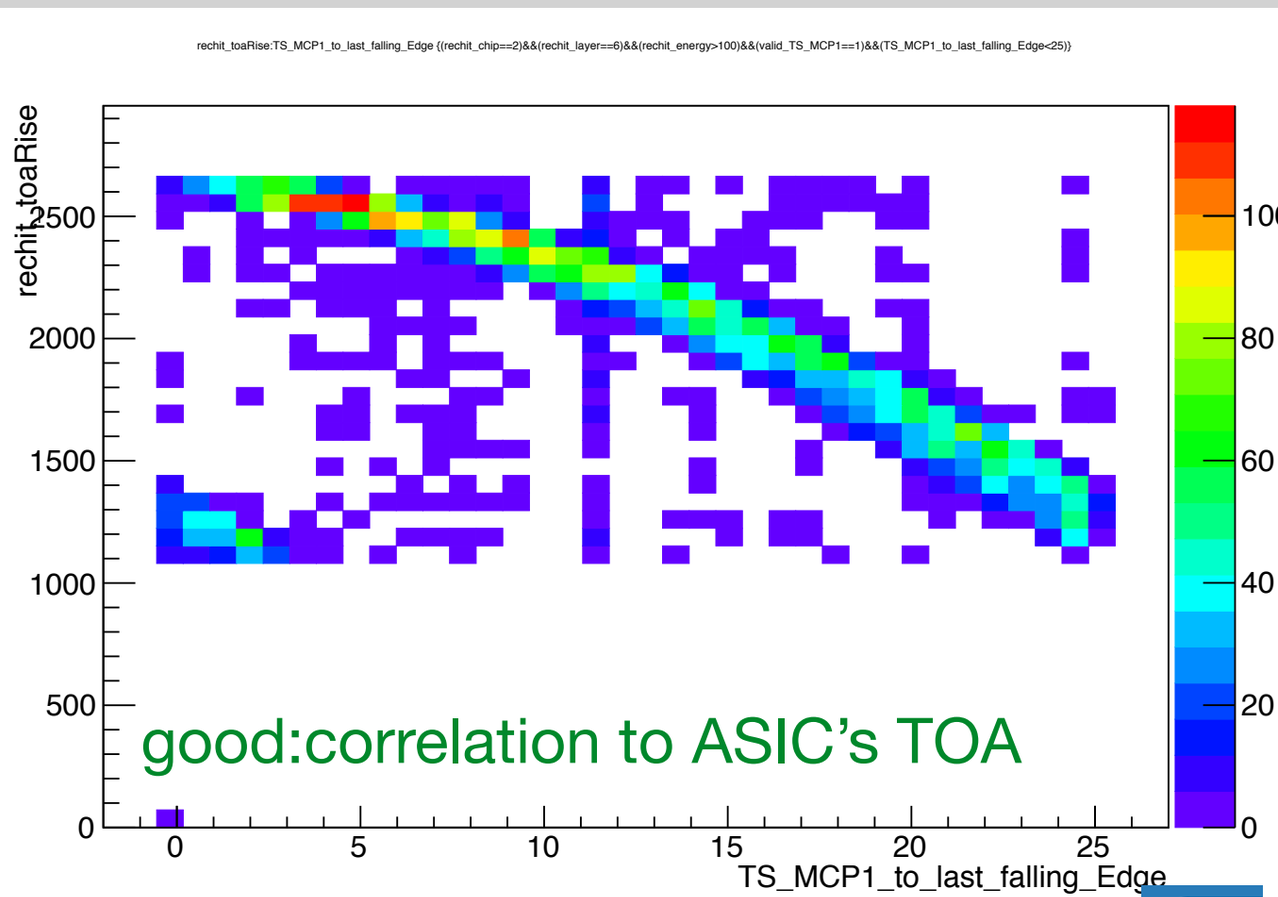
300 GeV e run

```
[In [5]: tree_rechits = ROOT.TChain('rechitntupler/hits','hits')

[In [6]: tree_rechits.Add("/eos/cms/store/group/dpg_hgcal/tb_hgcal/2018/cern_h2_october/offline_analysis/ntuples/v1/ntuple_965.root")
 Out[6]: 1

[In [7]: tree_mcp.AddFriend(tree_rechits)
 Out[7]: <ROOT.TFriendElement object ("rechitntupler/hits") at 0x4044760>

[In [8]: tree_mcp.Draw("rechit_toaRise:TS_MCP1_to_last_falling_Edge", "(rechit_chip==2)&&(rechit_layer==6)&&(rechit_energy>100)&&(valid_TS_MCP1==1)&&(TS_MCP1_to_last_falling_Edge<25)", "COLZ")
 Out[8]: 6223L
```



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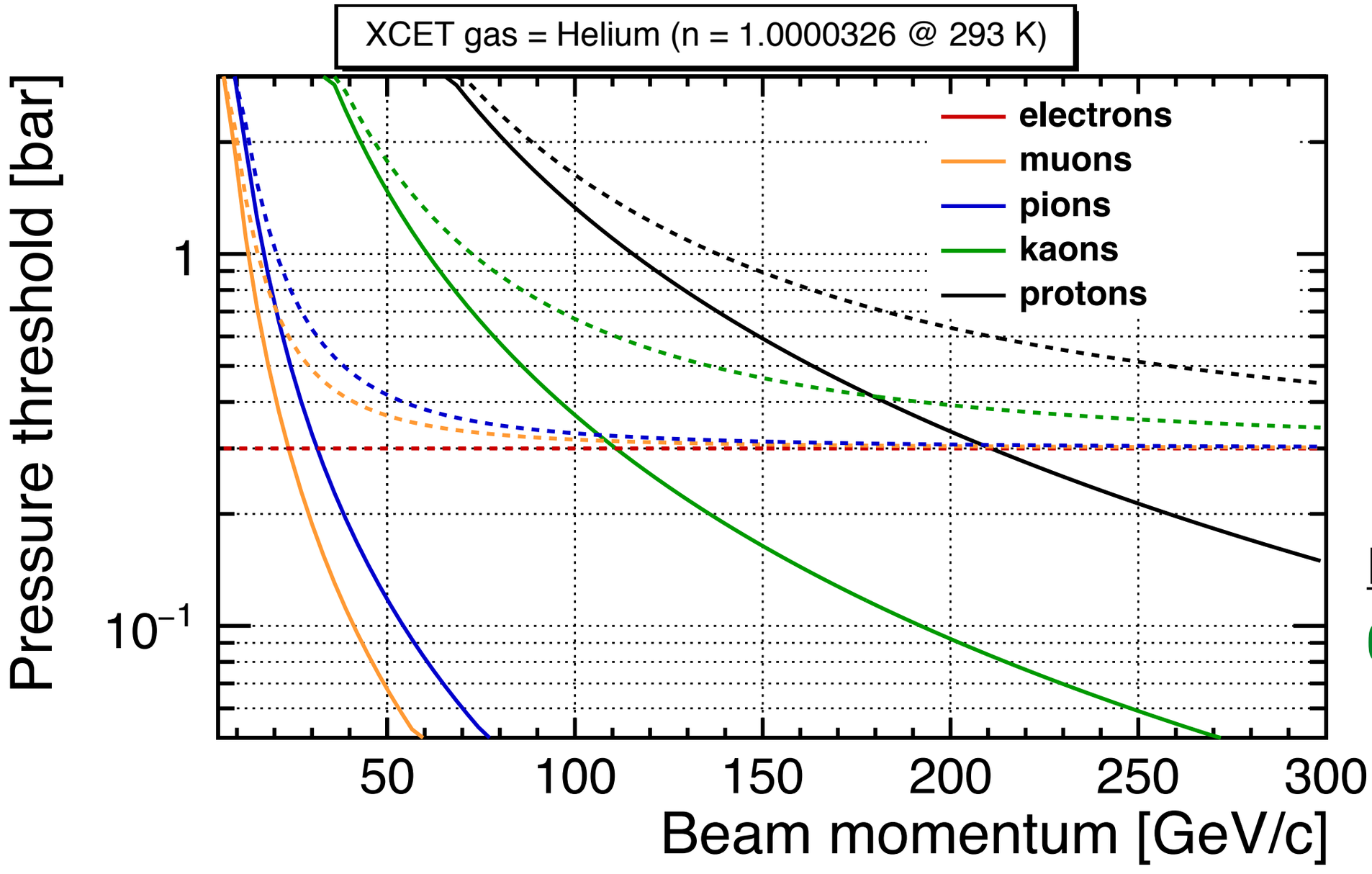
Cherenkov threshold detectors aka. XCET (hadron ID)

2x He-filled Cherenkov detectors = Hadron ID

NEW



Below threshold:

Quasi 0 fake-rate :)

XCET only 2m long

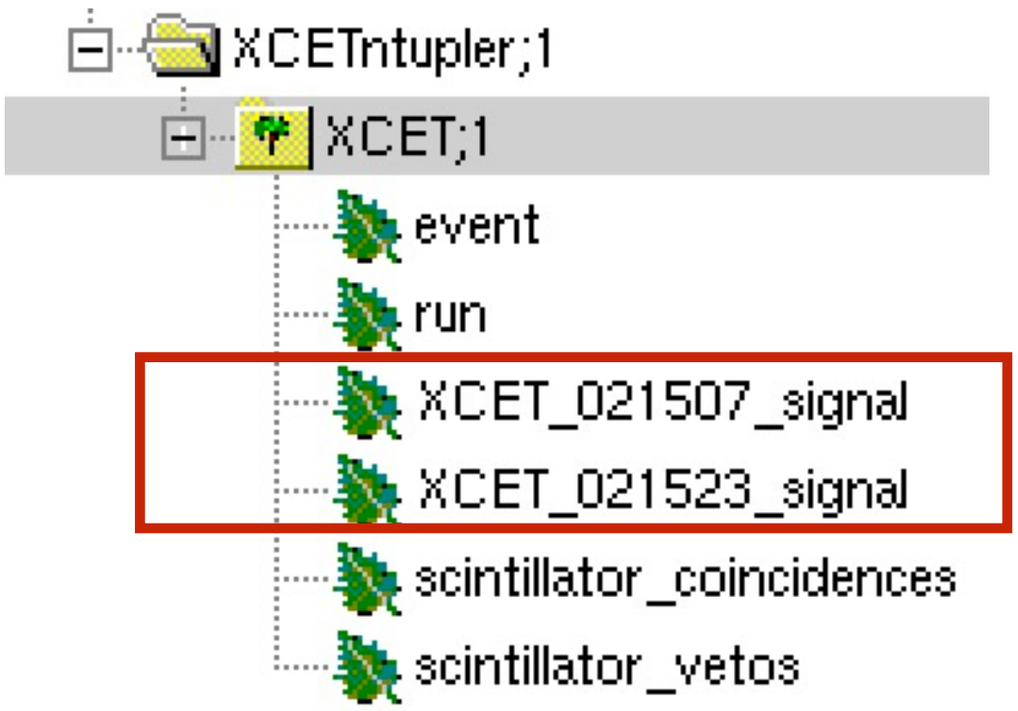
—> average #photo-electrons < 1

expect low efficiency :(

2-10%, ΔP=0.3 bar

XCET ntuples

Available from **run 435 onward**



type:
short

description:
1=XCET signal
0=no XCET signal

Check pressure settings in the spreadsheet for each run!

Outlook:

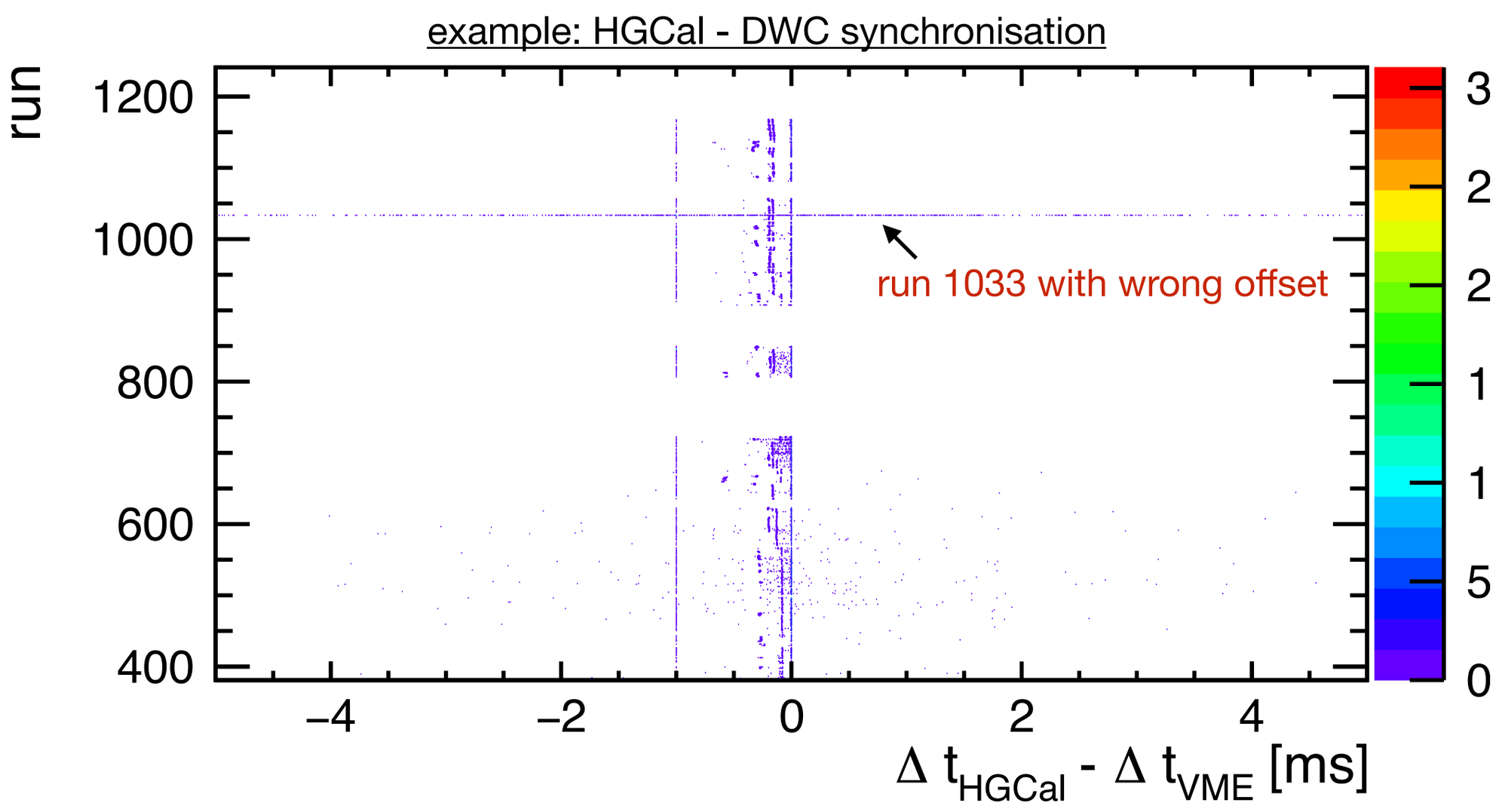
Synchronisation with AHCAL

Synchronisation based on event timestamps

Δ t := time between two events

Data streams are synchronised —> $(\Delta t_1 - \Delta t_2) \sim 0$

HGCal vs. DWC (etc.): offset at beginning of each run

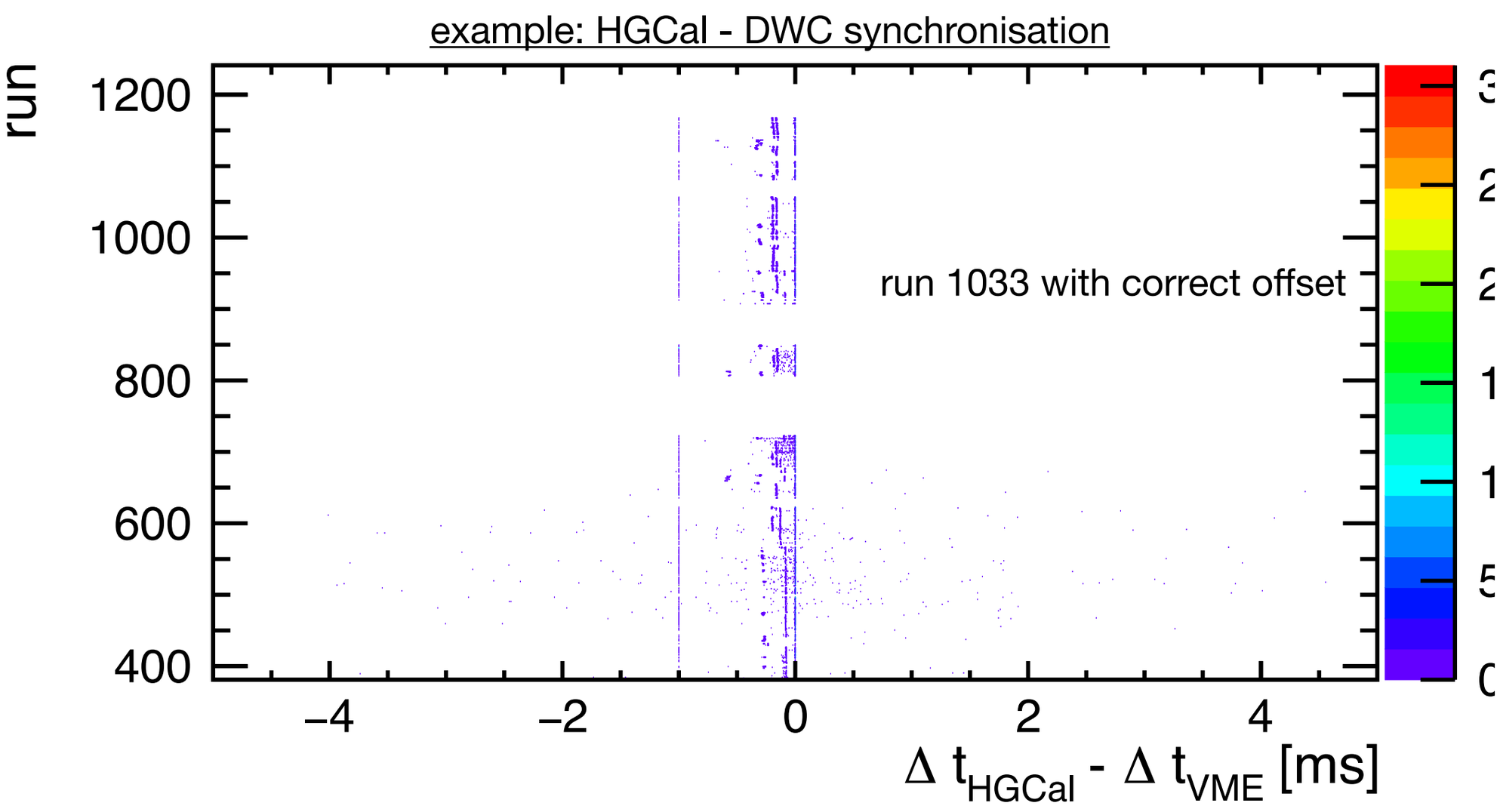


Synchronisation based on event timestamps

Δ t := time between two events

Data streams are synchronised —> $(\Delta t_1 - \Delta t_2) \sim 0$

HGCal vs. DWC (etc.): offset at beginning of each run



Application for HGCal-AHCAL

AHCAL & DWCs with identical trigger signal.

—> Same offsets should apply for HGCal synch.

HGCal-AHCAL synchronisation looks promising.