

CMSPixel processors for the EUTelescope framework

Simon Spannagel

INSTITUTE OF EXPERIMENTAL NUCLEAR PHYSICS (IEKP)

```
// Now loop over all ROC chips to be read out:
do {
    TrackerDataImpl * sparse = new TrackerDataImpl;
    CellIDEncoder<TrackerDataImpl> sparseDataEncoder(EUTELESCOPE::ZSDATADEFAULTENCODING, sparseDataCollection);
    sparseDataEncoder["sensorID"] = iROC;
    sparseDataEncoder["sparsePixelType"] = static_cast<int> ( _pixelType );
    sparseDataEncoder.setCellID(sparse);

    EUTelSparseDataImpl<EUTelSimpleSparsePixel> sparseData( sparse );

    for (int ipx = 0; ipx < MAXEVENTS; ipx++) {
        // zero suppressed data:
        if ( event_data[iROC][ipx].raw != 0 ) {
            auto_ptr<EUTelSimpleSparsePixel> sparsePixel( new EUTelSimpleSparsePixel );

            sparsePixel->setXCoord( static_cast<int> (event_data[iROC][ipx].col ));
            sparsePixel->setYCoord( static_cast<int> (event_data[iROC][ipx].row ));
            sparsePixel->setSignal( static_cast<short> ( event_data[iROC][ipx].raw ));
            streamlog_out ( DEBUG0 ) << (*sparsePixel.get()) << endl;

            //fill histogramms if necessary:
            if ( _fillHistos ) fillHistos ( event_data[iROC][ipx].col, event_data[iROC][ipx].row, iROC );
            sparseData.addSparsePixel( sparsePixel.get() );
        }
    }

    sparseDataCollection->push_back( sparse );

    iROC++;
}
```

Viewing data: tools

- LCIO data format:
 - “dumpevent”
 - In LCIO installation binaries

dumpevent file.slcio evt#

- Prints all collections from the first run found in the file.

- PSI46 mtb binaries

- “raw”
- In offline analysis package of psi46expert

raw -r run# -d

- See source code for paths.

```

8008    0    3 1249 :201289
8010    0    3 125f :201311
8004    0    3 12ca :201418
8081    0    3 12dc :201436
      TBM   -750 -750 -750    0    0 186 374    0
      ROC 0   -748  20  344
      TBM   -750 -750    0    0 374 -188 186 -188
8008    0    3 3a49 :211529

```

- (later more on encoding)

LCIO: collections

- Contains one or more collections per event:
- Collections can be added or dropped by LCIOOutputProcessors
- e.g. after calibration it might be useful to have both
 - raw data and the calibrated data
- But after clustering we don't need raw anymore and drop it.

```
=====
Event   : 1 - run:  3 - timestamp 1333099906000000000 - weight 1
=====
date:      30.03.2012  09:31:46.000000000
detector : CMSPixelTelescope
event parameters:
parameter EventType [int]: 2,

collection name : cluster
parameters:

----- print out of TrackerPulse collection -----

[DATA]

collection name : original_zsdata
parameters:

----- print out of TrackerData collection -----

[DATA]
```

```
collection name : sparse
parameters:
```

```
----- print out of TrackerData collection -----
```

```
flag: 0x80000000
LCIO::TRAWBIT_ID1 : 1
parameter CellIDEncoding [string]: sensorID:5,xMin:12,xMax:12,
yMin:12,yMax:12,
```

[illegible]

4160 entries per ROC & event
135MB

```
----- print out of TrackerData collection -----
```

```
flag: 0x0
LCIO::TRAWBIT_ID1 : 0
parameter CellIDEncoding [string]:
sensorID:5,sparsePixelType:5,
```

[id]	cellid0	cellid1	time	cellid-fields
[00000004]	00000020	00000000	0	
sensorID:0,sparsePixelType:1chargeADC : 37,56,-164,				

only entries for pixel hits
15MB

CMSPixel Testboard data

```

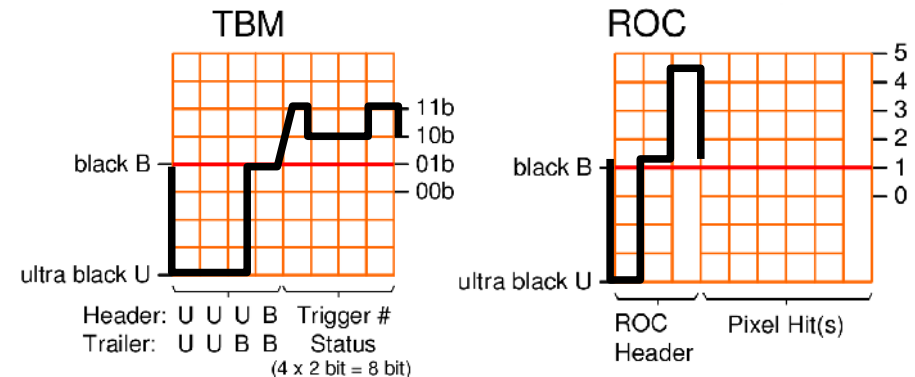
8008 0 3 1249 :201289
8010 0 3 125f :201311
8004 0 3 12ca :201418
8081 0 3 12dc :201436
TBM -750 -750 -750 0 0 186 374 0
ROC 0 -748 20 344
TBM -750 -750 0 0 374 -188 186 -188
8008 0 3 3a49 :211529
8010 0 3 3a5f :211551
8004 0 3 3aca :211658
8001 0 3 3adc :211676
TBM -750 -750 -750 0 0 374 -188 -188
ROC 0 -752 16 348
388 -196 4 200 4 -192
TBM -750 -750 0 0 374 -188 186 -188
8008 0 3 4449 :214089
8010 0 3 445f :214111
8004 0 3 44ca :214218
8001 0 3 44dc :214236
TBM -750 -750 -750 0 0 374 -188 0
ROC 0 -756 12 356
-196 776 380 196 584 -164
-188 772 188 -196 200 -188
396 -196 204 196 396 68
392 0 0 200 388 36
392 0 4 200 772 -180
392 -4 0 388 -4 -192
396 196 0 200 192 -172
392 196 -4 196 -192 696
TBM -750 -750 0 0 374 -188 186 -188
8008 0 3 4e49 :216649
8010 0 3 4e5f :216671
8004 0 3 4eca :216778

```

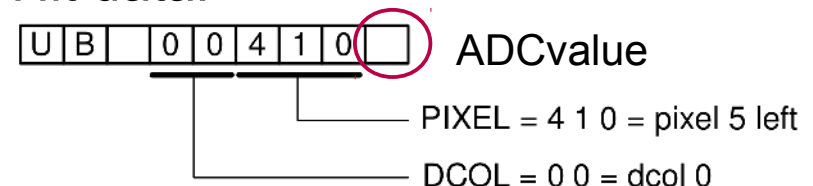
MTB headers:

- 0x8004, 0x8002 = trigger
- 0x8001, 0x8081 = data
- 0x8008 = reset
- 0x8010

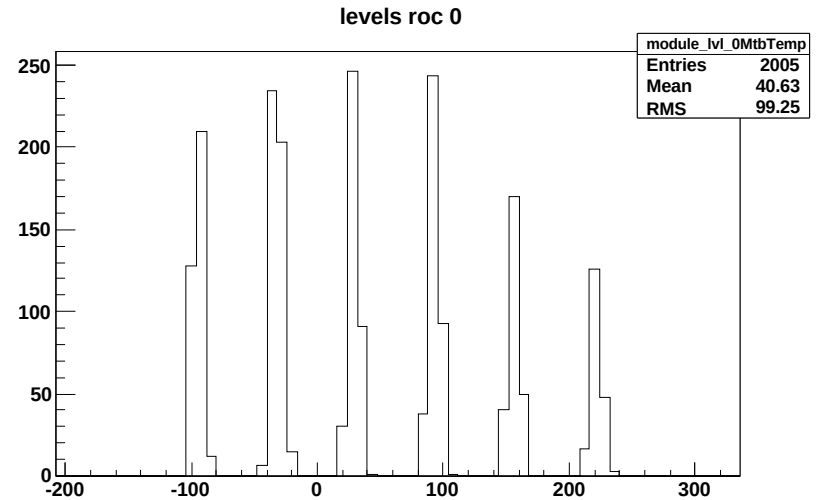
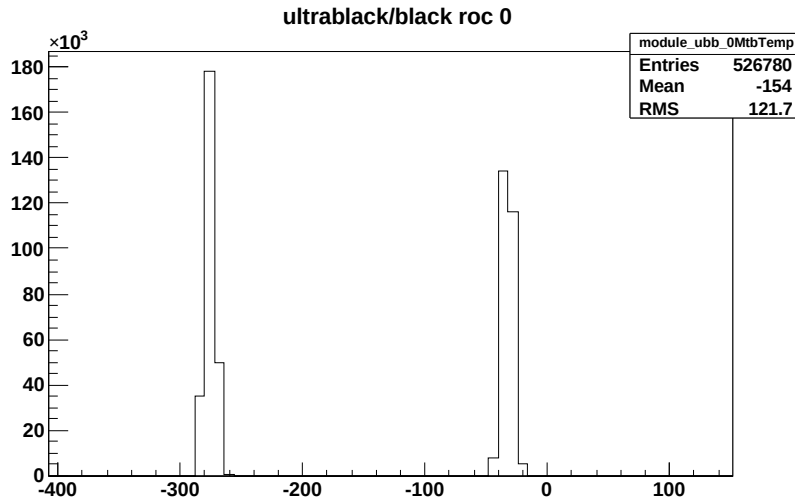
TBM and ROC headers:



Hit data:



Address levels encoding



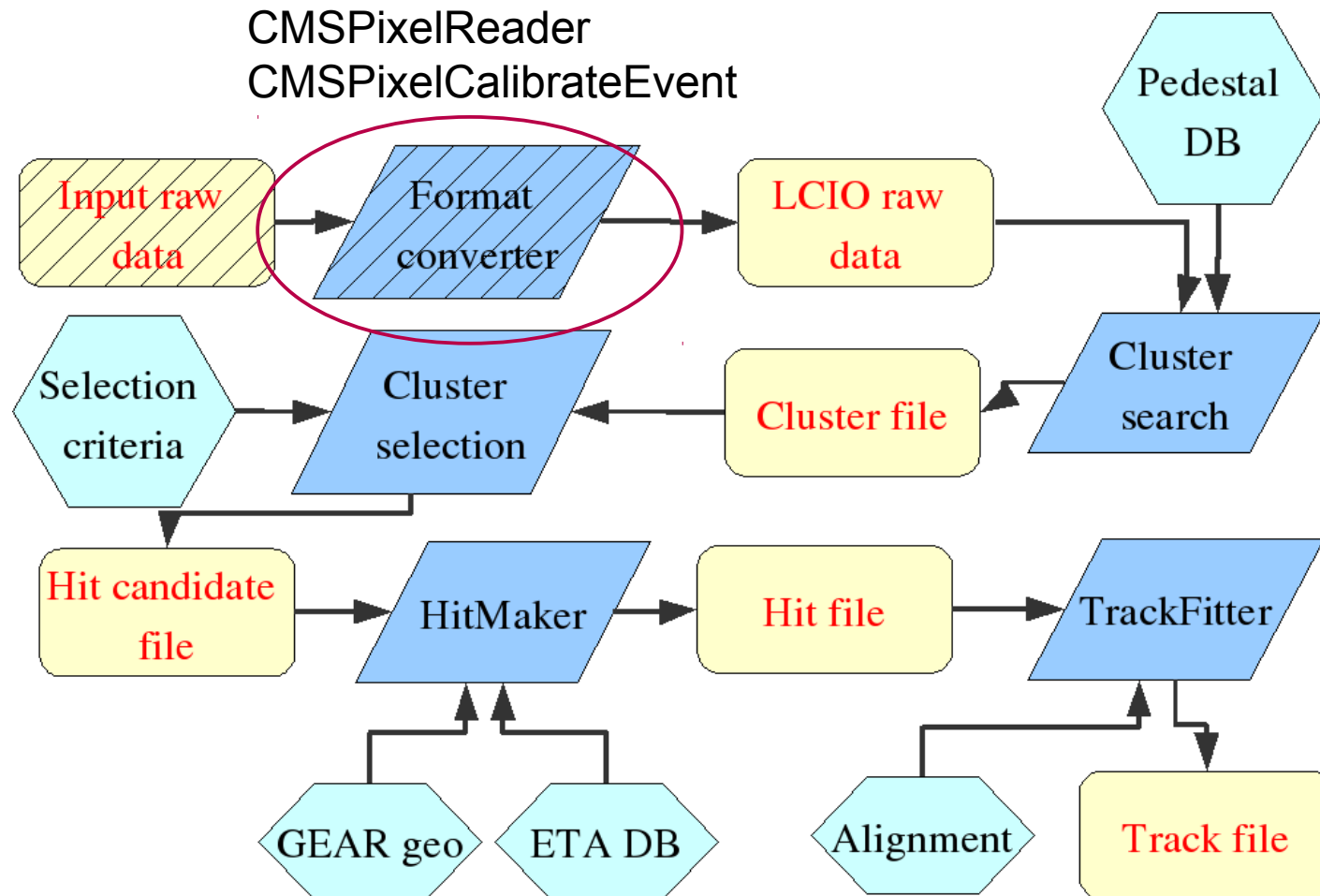
■ Address levels detected during module tests and saved in file:

Module Address Level Table:

=====										
	UB	B		Lev0	Lev1	Lev2	Lev3			
TBM	-2000	-468	300							
				-468	-94	93	280	2000		

	UB	B		Lev0	Lev1	Lev2	Lev3	Lev4	Lev5	
ROC0	-2000	-476	300							
				-476	-100	95	290	484	674	2000
=====										

CMSPixelTelescope analysis chain



CMSPixelReader: converting PSI46 mtb to LCIO

Processor parameters:

```

44
45 <processor name="MyCMSPixelReader" type="CMSPixelReader">
46   <!--Reads data files and creates LCEvent with TrackerRawData collection.
47   Make sure to not specify any LCIOInputFiles in the steering in order to read
48   CMSPixel files.-->
49   <!--Name of the output sparsified data collection-->
50   <parameter name="sparseDataCollectionName" type="string"
51   lcioOutType="TrackerData"> sparse </parameter>
52   <!--Input file-->
53   <parameter name="FileName" type="string" value="mtb.bin"/>
54   <!--Number of ROC single modules-->
55   <parameter name="NoOfROC" type="int" value="1"/>
56   <!--Number of pixels along X-->
57   <parameter name="NoOfXPixel" type="int" value="52"/>
58   <!--Number of pixels along Y-->
59   <parameter name="NoOfYPixel" type="int" value="80"/>
60   <!--Type of sparsified pixel data structure (use SparsePixelType enum)-->
61   <parameter name="SparsePixelType" type="int" value="1"/>
62   <!--verbosity level of this processor
63   ("DEBUG0-4, MESSAGE0-4, WARNING0-4, ERROR0-4, SILENT")-->
64   <!--parameter name="Verbosity" type="string" value=""/-->
65   <!--Calibration file for the TBM and ROC address encoding levels.-->
66   <parameter name="addressLevelsFile" type="string"
67   value="addressParameters.dat"/>
68   <!--Enable or disable DEBUG mode of the Decoder routine.-->
69   <parameter name="debugDecoder" type="bool" value="false"/>
70   <!-- Switch between strict and lazy decoding. Lazy decoding will not check for
71   correct TBM trailers and a valid data length. DO NOT USE unless you have a
72   binary file that can't be decoded using strict mode (e.g. corrupted TBM
73   trailers).-->
74   <parameter name="lazyDecoding" type="bool" value="false"/>
75   <!--RunNumber-->
76   <parameter name="runNumber" type="int" value="1"/>
77   <!--Enable or disable the writing of events with no hit in all ROCs.-->
78   <parameter name="writeEmptyEvents" type="bool" value="false"/>
79 </processor>

```

- FileName: input mtb data
- addressLevelsFile: input file with address levels of all ROCs
- runNumber
- lazyDecoding (see later)
- NoOfROC
- NoOfXPixel = 52
- NoOfYPixel = 80
- debugDecoder
- writeEmptyEvents
- SparsePixelType

CMSPixelReader: converting PSI46 mtb to LCIO

Decoding one event:

```

READ_CMSPIXEL_ADDRESS_LEVELS::STATUS TBM header: -2000 -468 300 -468 -94 93 280 2000
READ_CMSPIXEL_ADDRESS_LEVELS::STATUS ROC 0 header: -2000 -476 300
READ_CMSPIXEL_ADDRESS_LEVELS::STATUS ROC 0 addresses: -476 -100 95 290 484 674 2000

READ_CMSPIXEL_EVENT::STATUS header detected: 8008 0 3 1249
READ_CMSPIXEL_EVENT::STATUS header detected: 8010 0 3 125f
READ_CMSPIXEL_EVENT::STATUS header detected: 8004 0 3 12ca
READ_CMSPIXEL_EVENT::TBM_HEADER
READ_CMSPIXEL_EVENT::STATUS event was empty, 19 words. Skipped.
READ_CMSPIXEL_EVENT::STATUS header detected: 8008 0 3 26dd
READ_CMSPIXEL_EVENT::STATUS header detected: 8008 0 3 3049
READ_CMSPIXEL_EVENT::STATUS header detected: 8010 0 3 305f
READ_CMSPIXEL_EVENT::STATUS header detected: 8004 0 3 30ca
READ_CMSPIXEL_EVENT::TBM_HEADER
READ_CMSPIXEL_EVENT::STATUS event: 48 data words.
READ_CMSPIXEL_EVENT::HIT ROC 0 ipx 0 | pix 10 18, raw -164
READ_CMSPIXEL_EVENT::HIT ROC 0 ipx 1 | pix 10 43, raw -188
READ_CMSPIXEL_EVENT::HIT ROC 0 ipx 2 | pix 37 43, raw 68
READ_CMSPIXEL_EVENT::HIT ROC 0 ipx 3 | pix 39 55, raw 36
READ_CMSPIXEL_EVENT::HIT ROC 0 ipx 4 | pix 39 54, raw -180
READ_CMSPIXEL_EVENT::HIT ROC 0 ipx 5 | pix 39 53, raw -192
READ_CMSPIXEL_EVENT::HIT ROC 0 ipx 6 | pix 40 55, raw -172
READ_CMSPIXEL_EVENT::HIT ROC 0 ipx 7 | pix 40 56, raw 696
READ_CMSPIXEL_EVENT::TBM_TRAILER
READ_CMSPIXEL_EVENT::STATUS noOfROC: 1 ROCs detected: 1.
READ_CMSPIXEL_EVENT::STATUS end of data reading.

```

CMSPixelReader: converting PSI46 mtb to LCIO

Decoding one event from a full module (16ROCs):

```

READ_CMSPIXEL_ADDRESS_LEVELS::STATUS TBM header: -2000 -187 300 -187 -66 -6 54 2000
READ_CMSPIXEL_ADDRESS_LEVELS::STATUS ROC 0 header: -2000 -183 300
READ_CMSPIXEL_ADDRESS_LEVELS::STATUS ROC 0 addresses: -183 -63 -2 62 125 187 2000
READ_CMSPIXEL_ADDRESS_LEVELS::STATUS ROC 1 header: -2000 -186 300
READ_CMSPIXEL_ADDRESS_LEVELS::STATUS ROC 1 addresses: -186 -62 1 64 129 194 2000
[...]
READ_CMSPIXEL_ADDRESS_LEVELS::STATUS ROC15 header: -2000 -165 300
READ_CMSPIXEL_ADDRESS_LEVELS::STATUS ROC15 addresses: -165 -20 54 129 202 276 2000

READ_CMSPIXEL_EVENT::STATUS header detected: 8008 0 1 4a0f
READ_CMSPIXEL_EVENT::STATUS header detected: 8010 0 1 4a25
READ_CMSPIXEL_EVENT::STATUS header detected: 8004 0 1 4a90
READ_CMSPIXEL_EVENT::TBM_HEADER
READ_CMSPIXEL_EVENT::STATUS event: 87 data words.
READ_CMSPIXEL_EVENT::HIT ROC 5 ipx 0 | pix 45 26, raw 823
READ_CMSPIXEL_EVENT::HIT ROC 5 ipx 1 | pix 45 25, raw 954
READ_CMSPIXEL_EVENT::HIT ROC 5 ipx 2 | pix 47 26, raw 1141
READ_CMSPIXEL_EVENT::HIT ROC 5 ipx 3 | pix 48 27, raw 881
READ_CMSPIXEL_EVENT::HIT ROC 5 ipx 4 | pix 48 28, raw 1002
READ_CMSPIXEL_EVENT::HIT ROC 5 ipx 5 | pix 49 29, raw 207
READ_CMSPIXEL_EVENT::HIT ROC 5 ipx 6 | pix 49 28, raw 324
READ_CMSPIXEL_EVENT::TBM_TRAILER
READ_CMSPIXEL_EVENT::STATUS noOfROC: 16 ROCs detected: 16.
READ_CMSPIXEL_EVENT::STATUS end of data reading.

```

CMSPixelReader: converting PSI46 mtb to LCIO

lazyDecoding

corrupted TBM trailer:

```

8001  0  d 971d :890653
      TBM -750 -750 -750  0 186  0  0 374
      ROC 0 -744  8 -12
      TBM -750 -750  0  0 374 -188 186 -188
8008  0  d a08a :893066
8010  0  d a0a0 :893088
8004  0  d a10b :893195
8001  0  d a11d :893213
      TBM -750 -750 -750  0 186  0 186 -188
      ROC 0 -748  8 -20
           0 756 -16 -192 -188 -156
           -750 -750 -188  0 374 -188
8008  0  d aa8a :895626
  
```

sane event:

```

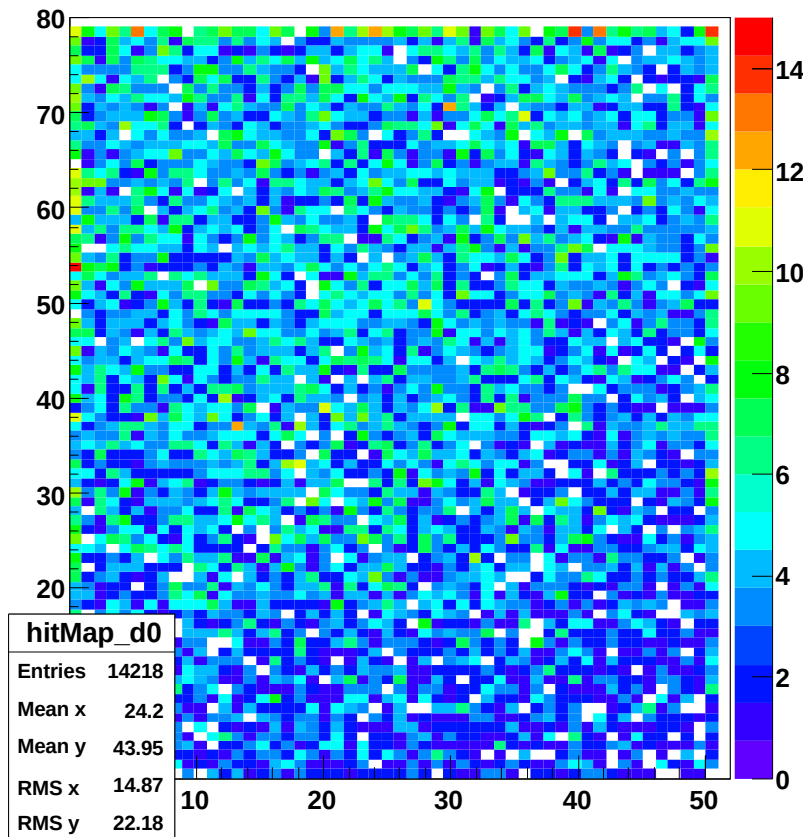
8001  0  d 971d :890653
      TBM -750 -750 -750  0 186  0  0 374
      ROC 0 -744  8 -12
      TBM -750 -750  0  0 374 -188 186 -188
8008  0  d a08a :893066
8010  0  d a0a0 :893088
8004  0  d a10b :893195
8001  0  d a11d :893213
      TBM -750 -750 -750  0 186  0 186 -188
      ROC 0 -748  8 -20
           0 756 -16 -192 -188 -156
           -750 -750 -188  0 374 -188 186 -188
8008  0  d aa8a :895626
  
```

- Introduced parameter to skip all checks for sane events:
 - Checking of data length (always bunches of 6 data words)
 - Checking for TBM trailer absence
 - Checking for huge events
- Do only use if you really have a mtb file with slightly corrupted events!

CMSPixelReader: converting PSI46 mtb to LCIO

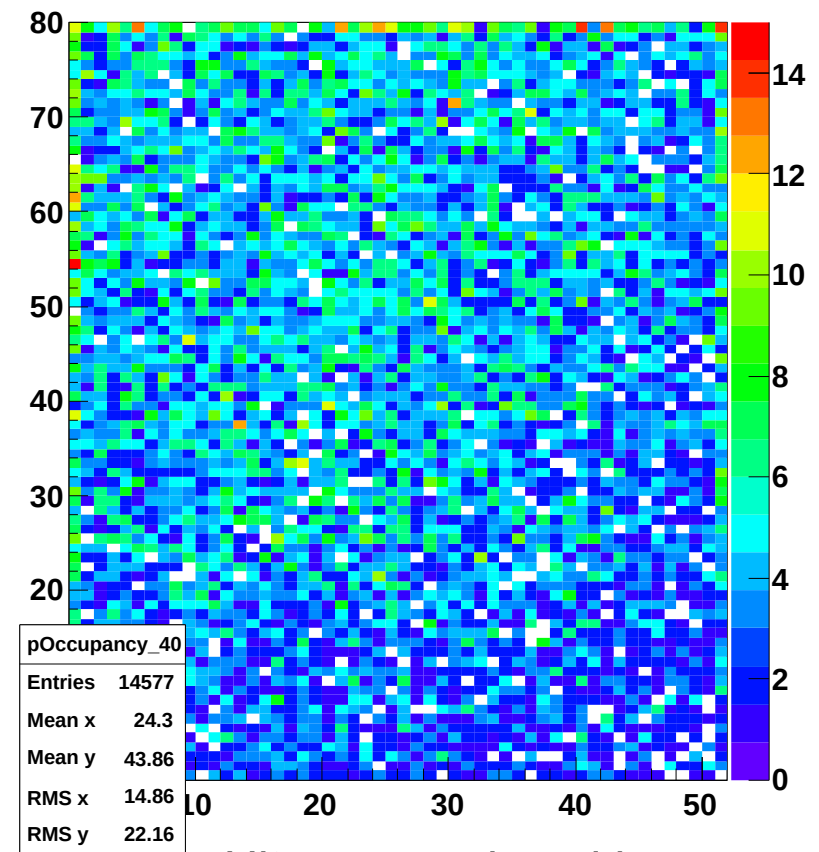
Hit map

Hit map



Hit map produced by
CMSPixelReader

Number of Hit in Pixel



Hit map produced by
"converttotree" (offline tools)

CMSPixelReader: converting PSI46 mtb to LCIO

Statistics

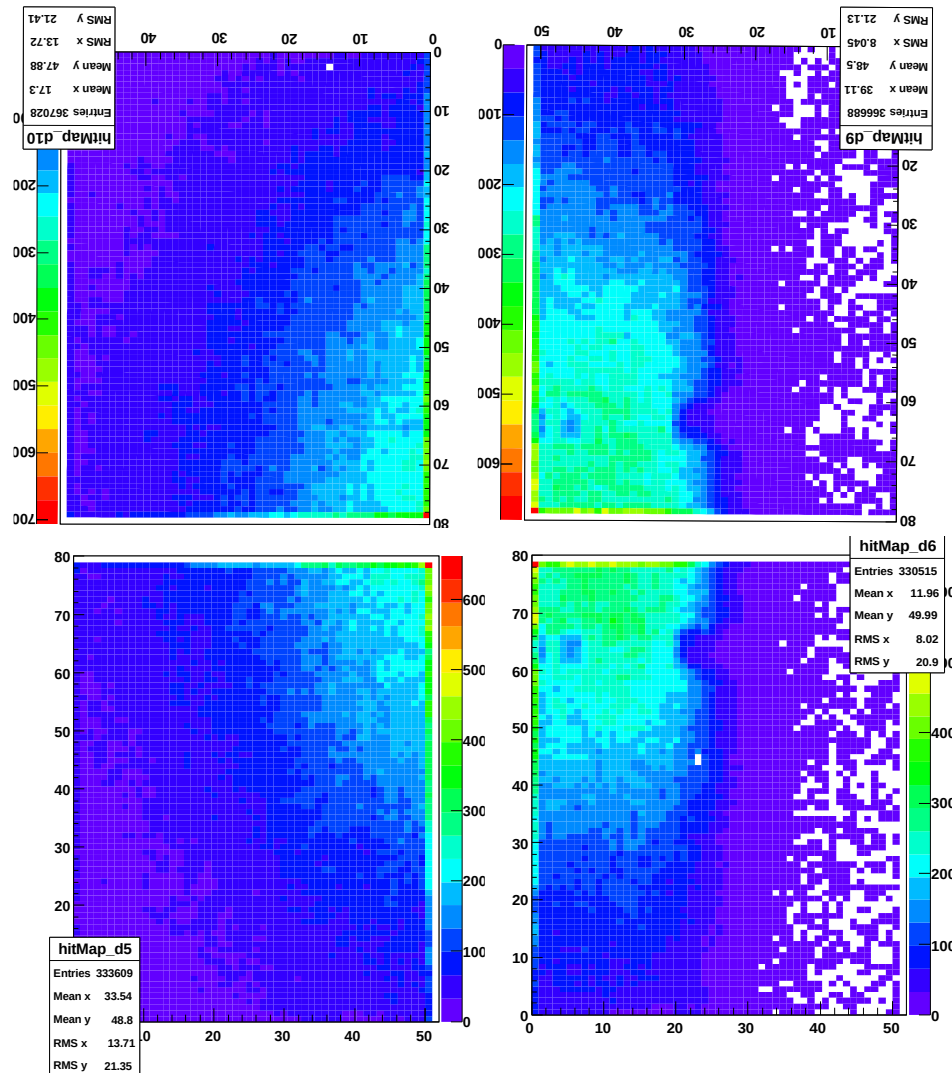
```
-----  
Processor statistics:  
Detected data headers: 642123  
Sane events: 305798  
    with 1253824 sane pixel hits in total.  
    failed to convert 0 pixel addresses.  
Empty events: 336192  
Events without TBM trailer: 34  
Events with wrong data length: 98  
Huge events: 0  
Dropped headers: 54 (no trigger/data/reset)
```

```
-----  
Total events written to LCIO file: 305798  
-----
```

```
-----  
Processor statistics:  
Detected data headers: 856203  
Sane events: 14234  
    with 14287 sane pixel hits in total.  
    failed to convert 1 pixel addresses.  
Empty events: 841968  
THIS FILE WAS DECODED USING THE lazyDecoding SWITCH!  
NO DETECTION OF CORRUPT EVENTS!  
Dropped headers: 0 (no trigger/data/reset)
```

```
-----  
Total events written to LCIO file: 14234  
-----
```

Full module with source



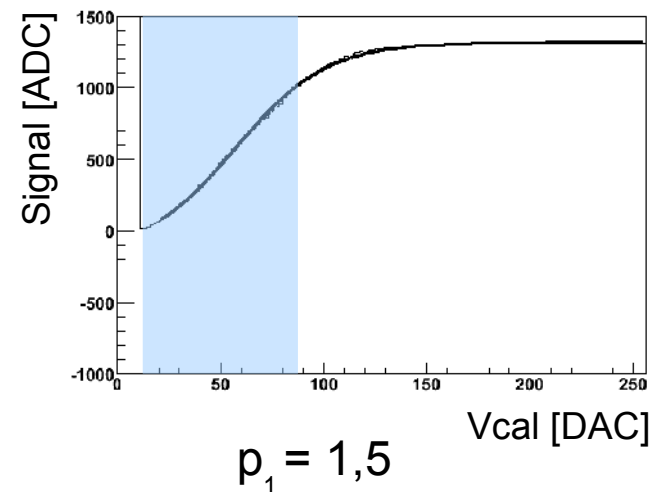
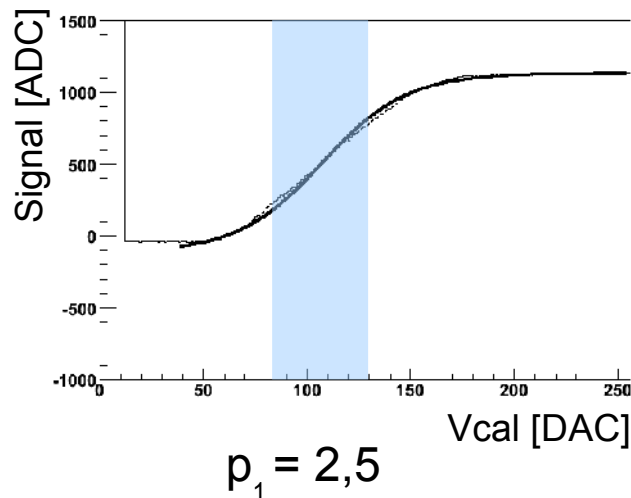
CMSPixelCalibrateEvent

pixel by pixel calibration of the ADC values

- We need to calibrate each pixel individually to get comparable values
- Calibrate measured ADC values to Vcal units
 - Vcal is a DAC to inject charge into a pixel
- In a module test different Vcal are injected into one pixel, the resulting curve is **hyperbolic**:

$$y = p_3 + p_2 \cdot \tanh(p_0 \cdot x - p_1)$$

- The parameters are tuned to extend the linear range of the curve:



CMSPixelCalibrateEvent

pixel by pixel calibration of the ADC values

- Module test: we get one calibration file per ROC
 - from the psi46expert module full test and calibration
 - This is usually done only once per module in the qualification process

Parameters of the vcal vs. pulse height fits

`par[3] + par[2] * TMath::TanH(par[0]*x[0] - par[1])`

+2.748700e-03	+1.233506e+00	+8.277028e+02	+4.596696e+02	Pix	0	0
+2.774166e-03	+1.241543e+00	+8.097066e+02	+4.840283e+02	Pix	0	1
+2.736101e-03	+1.271147e+00	+8.221820e+02	+4.731362e+02	Pix	0	2
[...]						
+2.894871e-03	+1.166067e+00	+8.590807e+02	+4.017648e+02	Pix	51	78
+2.570606e-03	+1.160969e+00	+8.509865e+02	+4.144082e+02	Pix	51	79

- Analysis: for each pixel hit we now calculate the Vcal value:

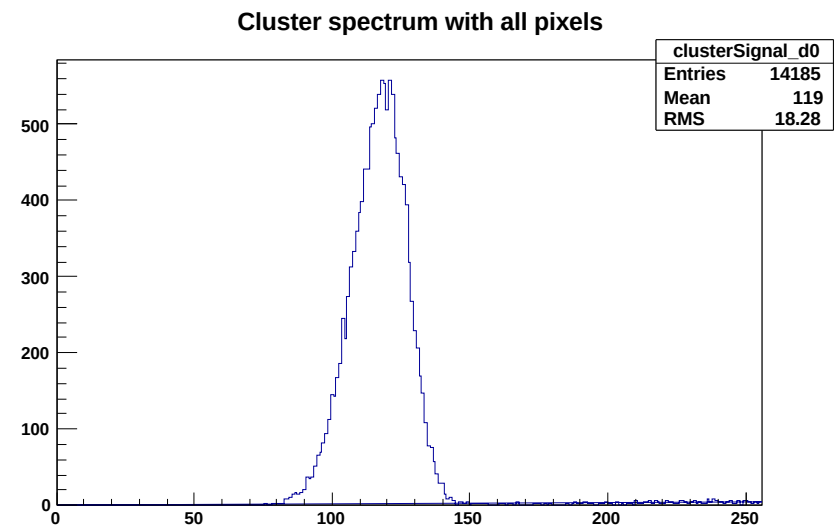
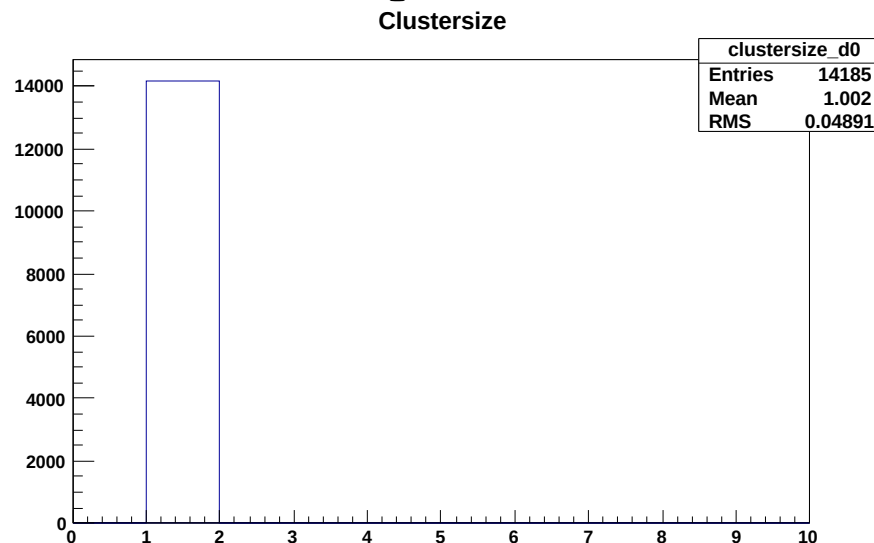
$$x = (\operatorname{atanh}((y - p_3) / p_2) + p_1) / p_0$$

...and write the new value into the calibrated collection.

- Parameter: “calibrationFile”, default: “phCalibrationFit60_C%i.dat”

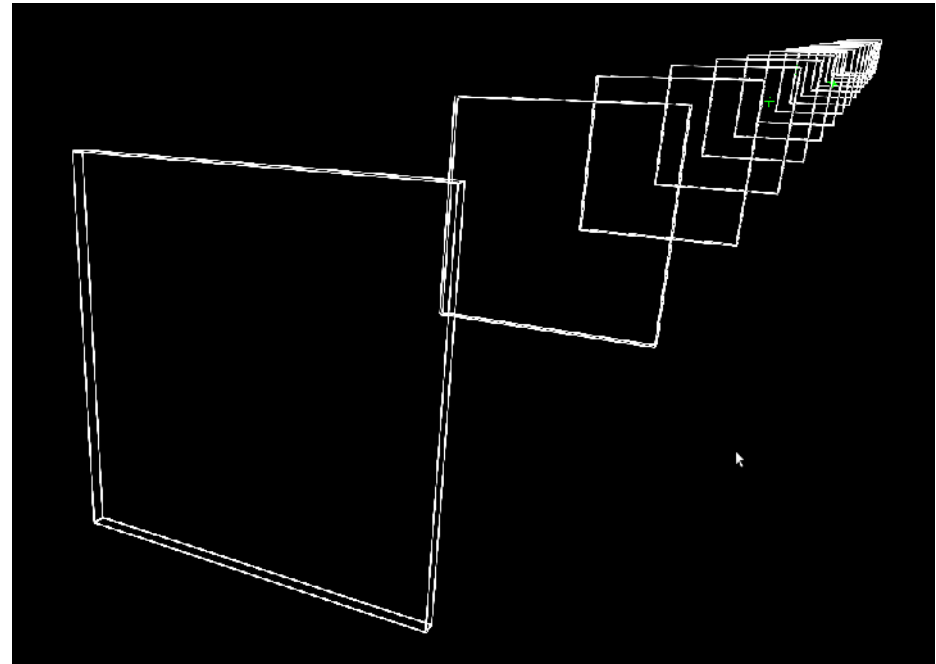
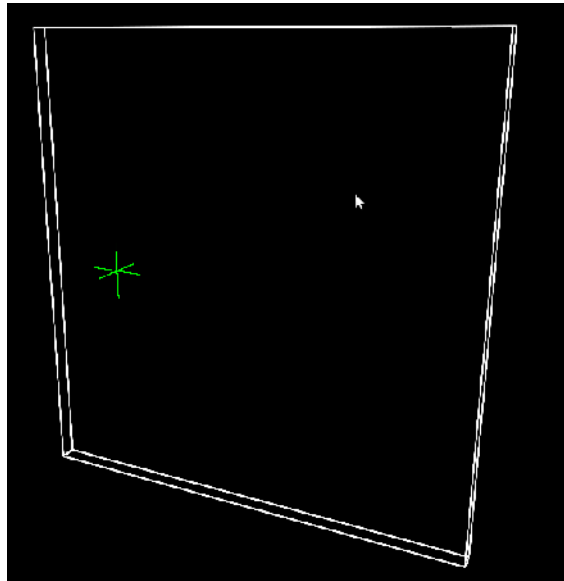
CMSPixelClusteringProcessor

- Based on the EUTelAPIXClusteringProcessor for sparse pixels
- Parameters:
 - "MinCharge" – minimum charge to accept cluster
 - "MinDiagonalDistance" – min. diagonal distance for pixels to build a cluster
 - "MinNumberOfPixels" – minimum number of Pixels to build a cluster
 - "MinXDistance", "MinYDistance" – minimum distance in X, Y
- Produces histograms with cluster size, charge



Further steps:

■ EUTelHitmaker:



■ Alignment (Millepede II with EUTelMille)

■ Track fitting:

- using EUTelMultilineFit (straight line fit for multiple tracks)
- or EUTelTestFitter (analytical track fitting taking multiple scattering into account)