Digitization Simulation using DigiSim

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Talk Outline

- DigiSim: purpose and description
- Configuration
- An example: effects on hit energy distributions
- Usage instructions
- Current status

DigiSim

- Goal: a program to parametrically simulate the signal propagation and digitization processes for the ILC detector simulation
  ☞ an essential tool for comparing different detector technologies

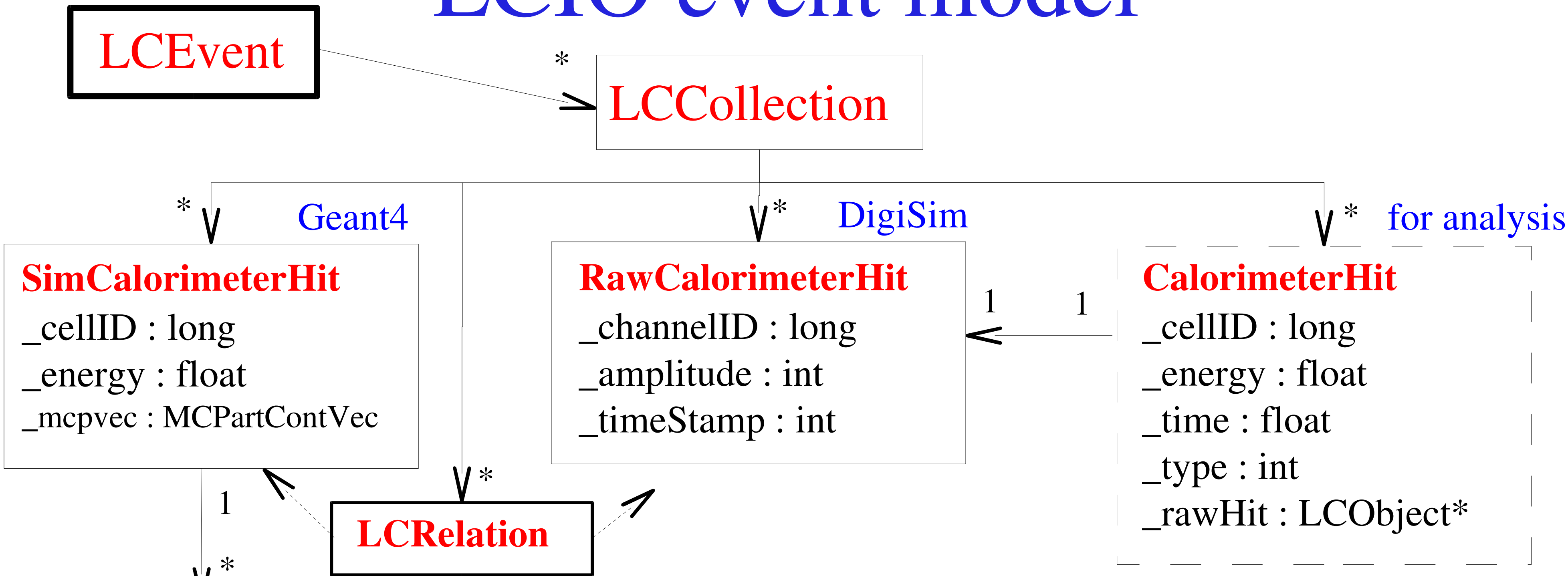
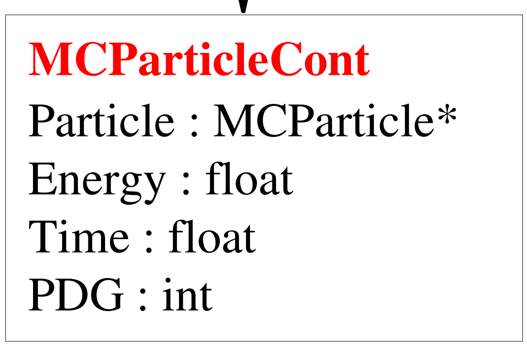
- DigiSim role is to convert the simulated data (energy depositions and hit timings) into the same format AND *as close as possible* to real data from readout channels, while preserving all MC information from input data files

  – *As close as possible* means that all known effects from digitization process should be taken into account, if possible: cell ganging, inefficiencies, noise, crosstalks, hot and dead channels, non-linearities, attenuation, etc.

- Same reco / analysis software can be used for MC and real data

- DigiSim produces RawHits and (Digi)CalorimeterHits from SimCalorimeterHits

LCIO event model

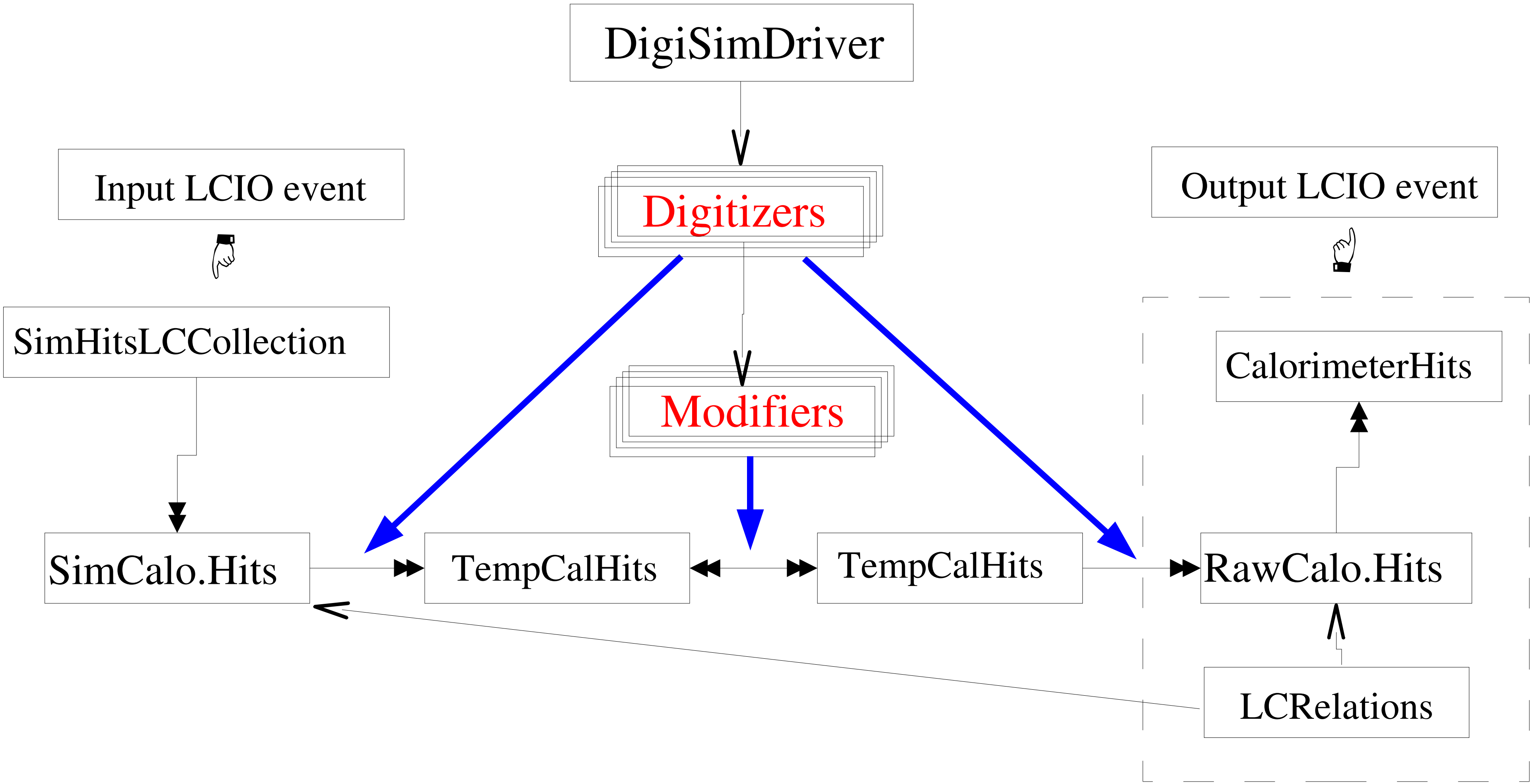
- DigiSim: SimCalorimeterHits --> RawCalorimeterHits
- Reco: RawCalorimeterHits --> CalorimeterHits (analysis)
- Note that _cellID and _energy access is identical for SimCalorimeterHit and CalorimeterHit

SimCalorimeterHits or CalorimeterHits?

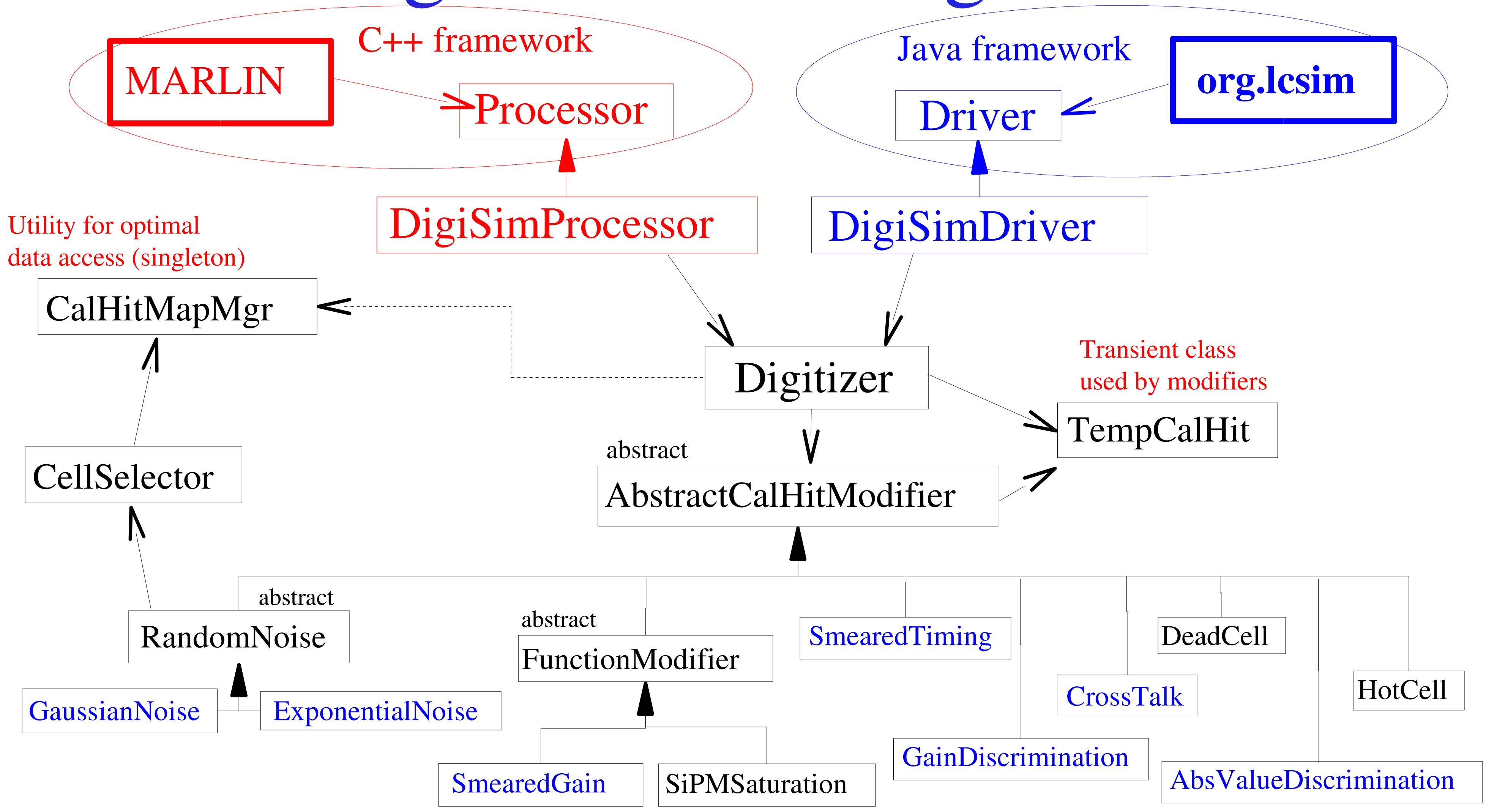
- Consider moving your reconstruction algorithms to use CalorimeterHits instead of SimCalorimeterHits

- How to do this:
  - All non-MC calls to SimCalorimeterHits (energy, position, time) can be transparently replaced with equivalent calls to CalorimeterHit objects.
    For MC-related values, use (same) cellid as a key to access SimCalorimeterHits.
  - Detector name is used to select the correct DigiSim configuration file.
  - Config files exist for all Snowmass detectors
    - All RPC-based have identity configurations
    - All scintillator-based: SDJan03, sidaug05_scint, cdcaug05* have non-identity configurations (see later)
  - Identity DigiSim config files are available for helping people to get started with DigiSim output

DigiSim event loop



DigiSim class diagrams



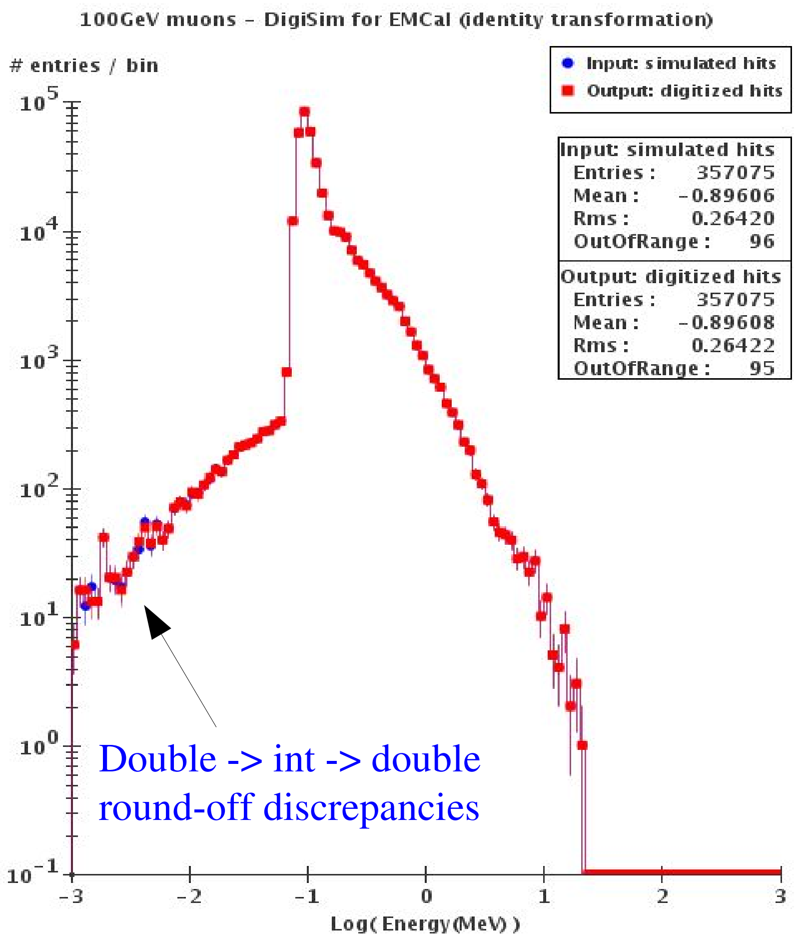
Setting up a configuration file

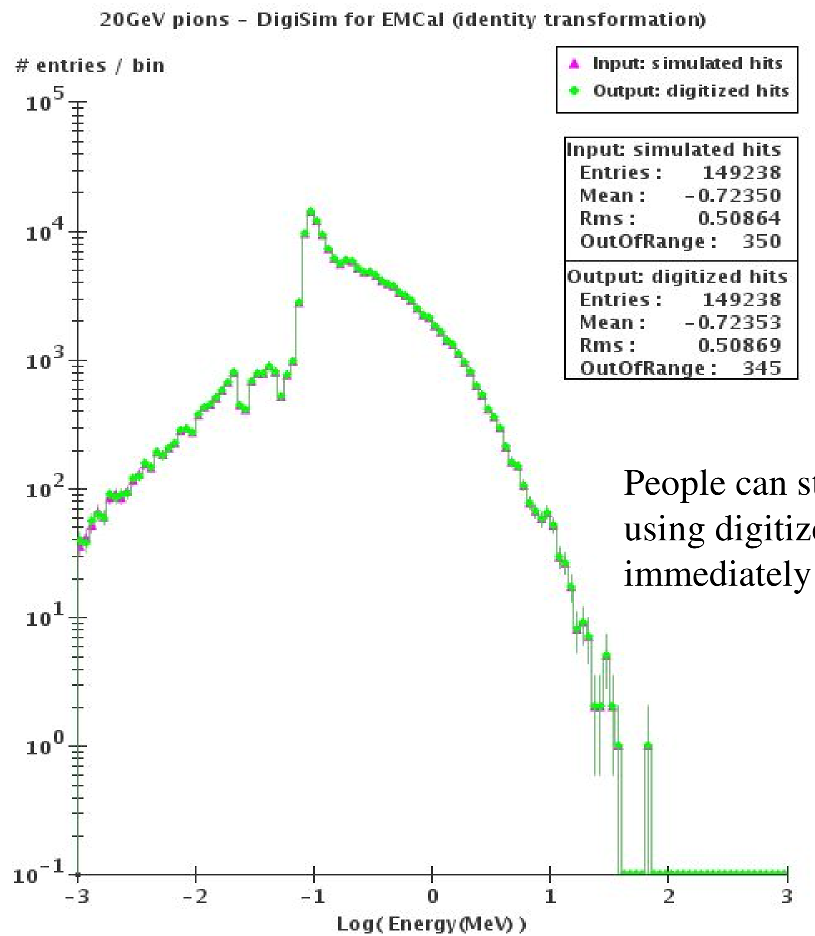
```
############################################
#  Example steering file for DigiSim
############################################
.begin Global  -----------------------------------------
# specify one or more input files (in one or more lines)
LCIOInputFiles inputfile

# the active processors that are called in the given order
ActiveProcessors CalHitMapProcessor
ActiveProcessors EcalBarrelDigitizer
ActiveProcessors EcalEndcapDigitizer
ActiveProcessors HcalBarrelDigitizer
ActiveProcessors HcalEndcapDigitizer
ActiveProcessors OutputProcessor

# limit the number of processed records (run+evt):
MaxRecordNumber 500
.end Global  ---------------------------------------------
############################################################
.begin EcalBarrDigitizer
ProcessorType DigiSimProcessor

InputCollection        EcalBarrHits
OutputCollection       EcalBarrRawHits
Raw2SimLinksCollection EcalBarrRaw2sim

ModifierNames    EMBDigiIdentity
# modifierName    Type                Parameters (floats)
EMBDigiIdentity    SmearedGain         100000000      0
.end ------------------------------------------------
```

One digitizer per subdetector

"Identity" factor 10^8 avoids precision loss in the conversion double -> int -> double

An identity transformation





People can start using digitized hits immediately!!

Simple example: configuration for the tile HCal

- Scintillation: 100 eV/photon , or 10^{+4} photons/MeV

  Ex: a MIP at normal incidence on 0.5cm-thick scintillator deposits ~ 0.9MeV, or 9000 photons

  ==> use GainDiscrimination modifier with 10^{+7} photons/GeV and a threshold at 1 photon

```
#modifierName   type                  gainNom   gainSig   thresh   thrSig
HBlightYield    GainDiscrimination   10000000         0        1        0
```

- Light crosstalk:

  first neighbors: 1.5% to 2% --> (2.0 +/- 0.5) %

```
HBcrosstalk      Crosstalk                     0.020     0.005
```

- Photon collection efficiency (QE~15%):

  9000 scint.photons/MIP --> 15 PE/MIP detected (cosmics measurements at NICADD)

  15 / 0.15 = 100 incident photons => Eff_{coll} = 100 inc. / 9000 tot.scint. = 0.0111

  Variance (Poisson): $sigma_N^2 = <N>$ → for $<N_{PE}> = 15$, $(sigma_N / N) \sim 26\%$

  Therefore: $Eff_{coll} = 0.0111 \pm 0.0029$ => use GainDiscrimination with smearing

```
HBlightCollEff GainDiscrimination    0.0111   0.0020       1        0
```

Simple example: numbers from the tile HCal

- Photosensor detection efficiency: QE ~ 15 %

```
HBPDQuEffic      GainDiscrimination    0.15          0       1        0
```

- Noise simulation:
  - Photosensor noise: exponential distribution (guess: mean 0.6)
  - Electronics noise: gaussian distribution (guess: mean 0, sigma 1.6, keep +/- tails)

```
# GaussNoise parameters:        sys    be    Ecut    TimeNom  TSig   Mean  Sigma
# Note: sigma<0 means that threshold acts on absolute value only
HBGaussNoise   GaussianNoise      3     0    2.5        100   100     0.0  -0.58
# ExponentialNoise parameters:  sys     be   Ecut    TimeNom  TSig   Mean
HBExpoNoise    ExponentialNoise   3     0    2.5        100   100    0.23
```

- Discrimination: ¼ MIP cut ~ 4 PEs: threshold at 4 +/- 0.25 (on abs value)

```
# Discrimination                                       threshold     sigma
HBdiscrim    AbsValueDiscrimination                            4       0.25
###HBdiscrim GainDiscrimination    1        0        4       0.25
```

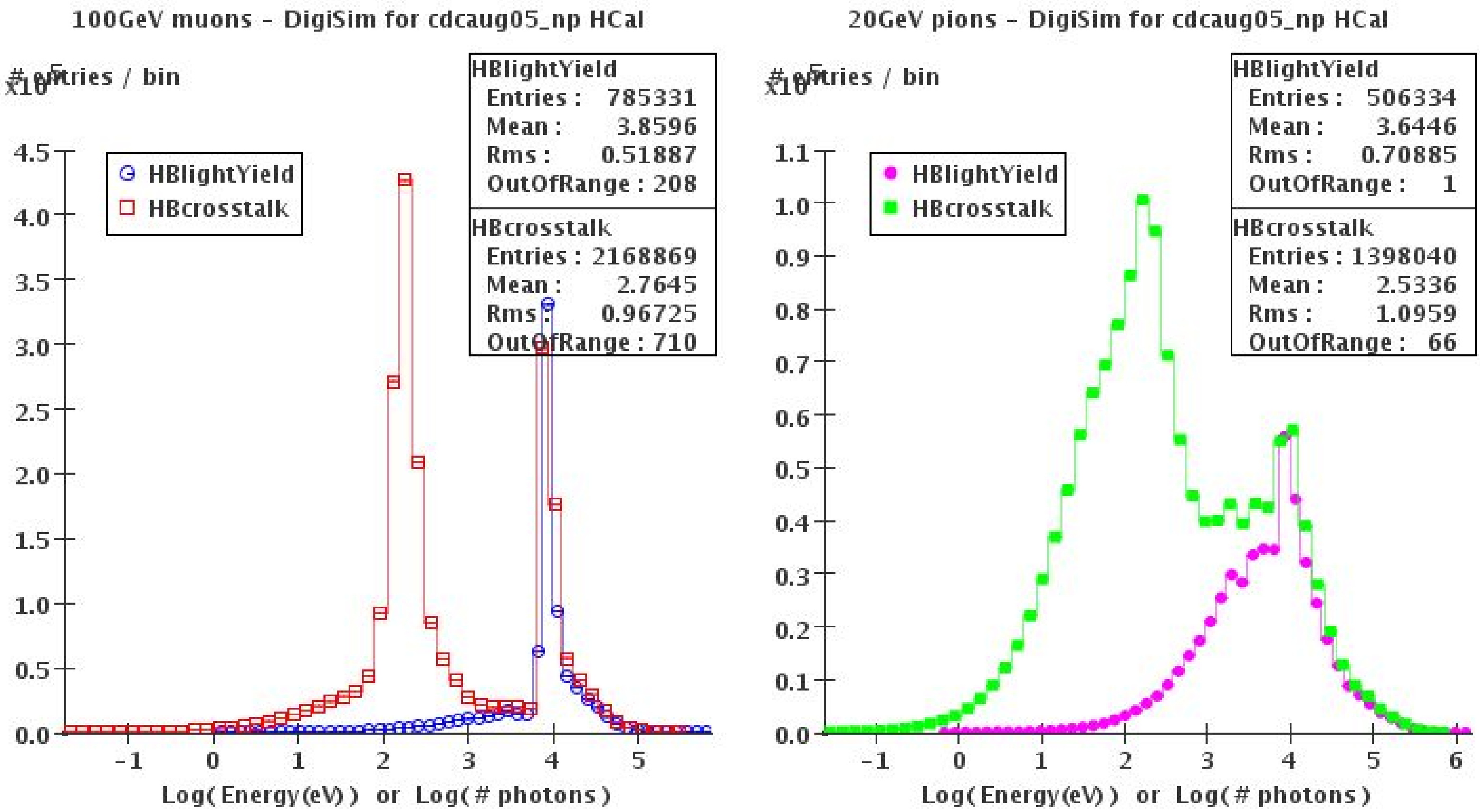
Configuring processors and modifiers

```
############################################################
# A subdetector digitizer.  It instantiates one or more calorimeter hit
#  "modifiers", which together represent the full digitization process
.begin HcalBarrDigitizer

ProcessorType DigiSimProcessor

InputCollection  HcalBarrHits
OutputCollection HcalBarrRawHits
Raw2SimLinksCollection HcalBarrRaw2sim
```

(As many as needed)

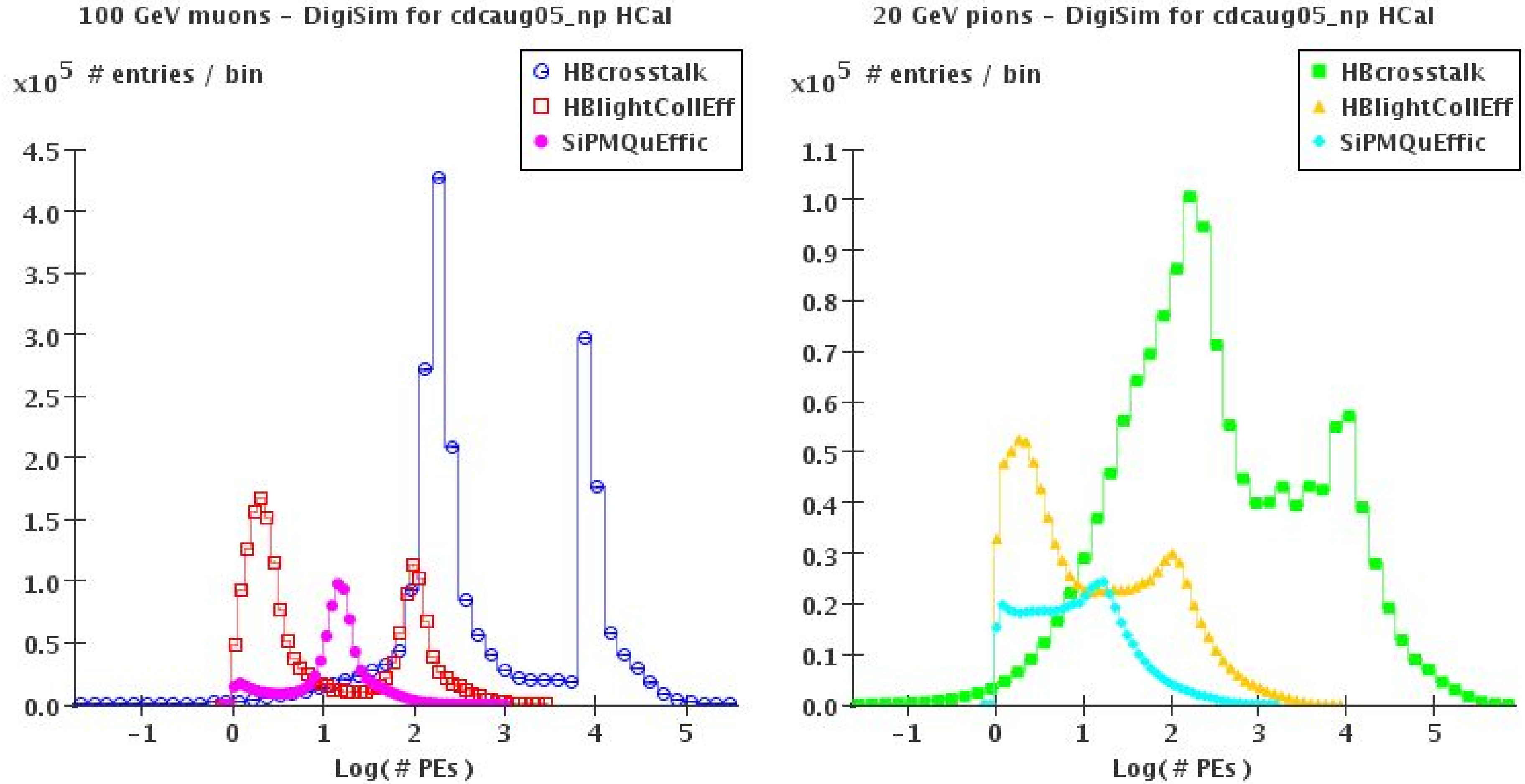
```
ModifierNames HBlightYield HBcrosstalk HBlightCollEff HBPDQuEffic HBExpoNoise  HBGaussNoise
HBdiscrim HBGain

# Parameters:
# modifierName    Type                gainNom  gainSig  thresh   thrSig
HBlightYield      GainDiscrimination  10000000        0       1        0

# Crosstalk                                 mean     sigma
HBcrosstalk       Crosstalk                 0.020     0.005

# Smeared gain parameters:                gain   gainSigma  thresh   thrSig
HBlightCollEff    GainDiscrimination  0.0111     0.0029       1        0
HBPDQuEffic       GainDiscrimination    0.15          0       1        0

(...Truncated... see file cdcaug05_np.steer in DigiSim area)
.end ----------------------------------------------------------------
```

Crosstalk

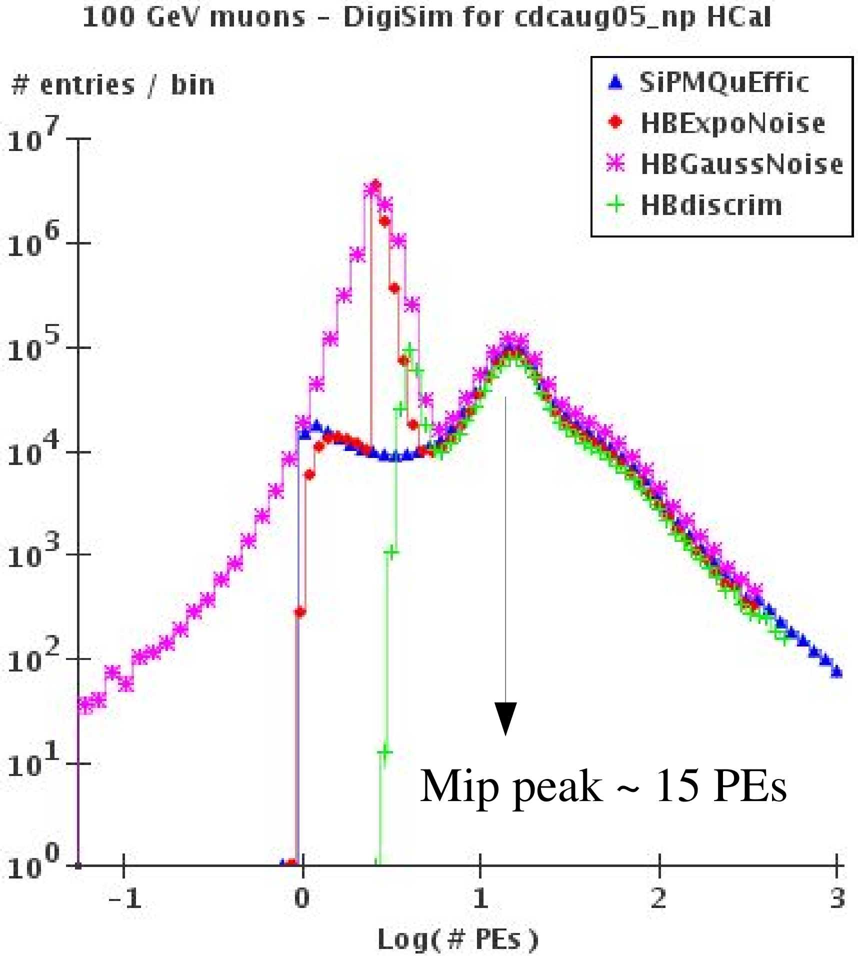


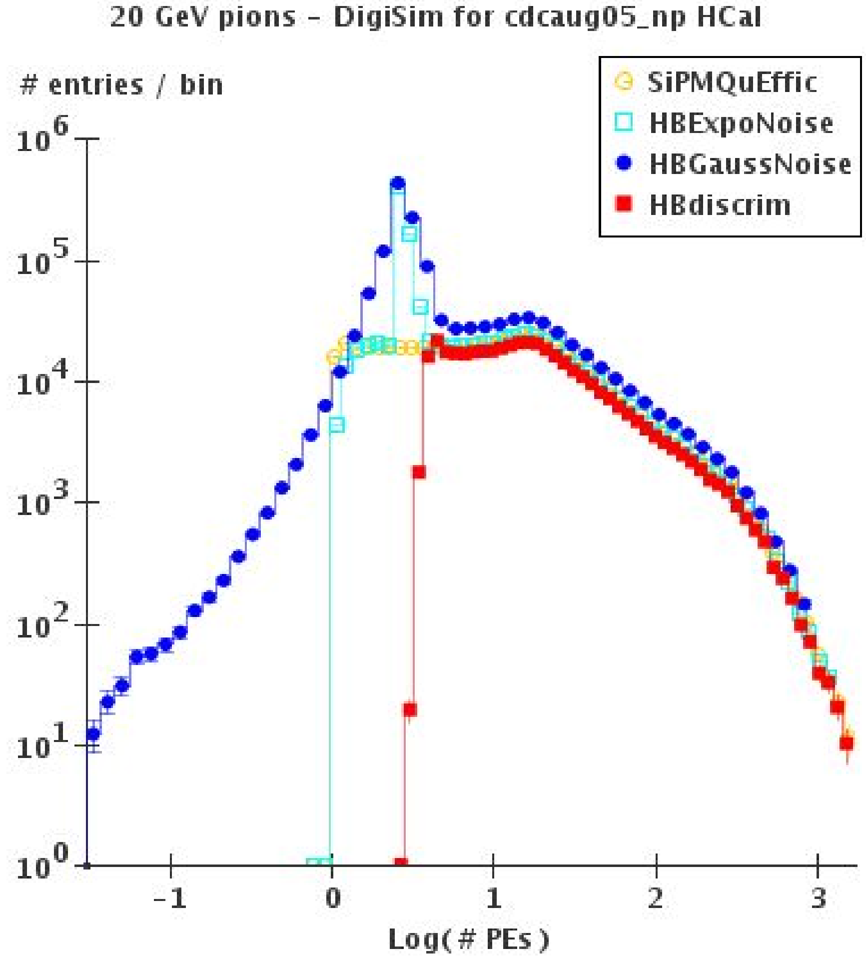
100GeV muons - DigiSim for cdcaug05_np HCal
entries / bin
x10^5
HBlightYield
Entries : 785331
Mean : 3.8596
Rms : 0.51887
OutOfRange : 208
HBcrosstalk
Entries : 2168869
Mean : 2.7645
Rms : 0.96725
OutOfRange : 710
HBlightYield
HBcrosstalk
Log(Energy(eV)) or Log(# photons)
20GeV pions - DigiSim for cdcaug05_np HCal
entries / bin
x10^5
HBlightYield
Entries : 506334
Mean : 3.6446
Rms : 0.70885
OutOfRange : 1
HBcrosstalk
Entries : 1398040
Mean : 2.5336
Rms : 1.0959
OutOfRange : 66
HBlightYield
HBcrosstalk
Log(Energy(eV)) or Log(# photons)

Photodetection

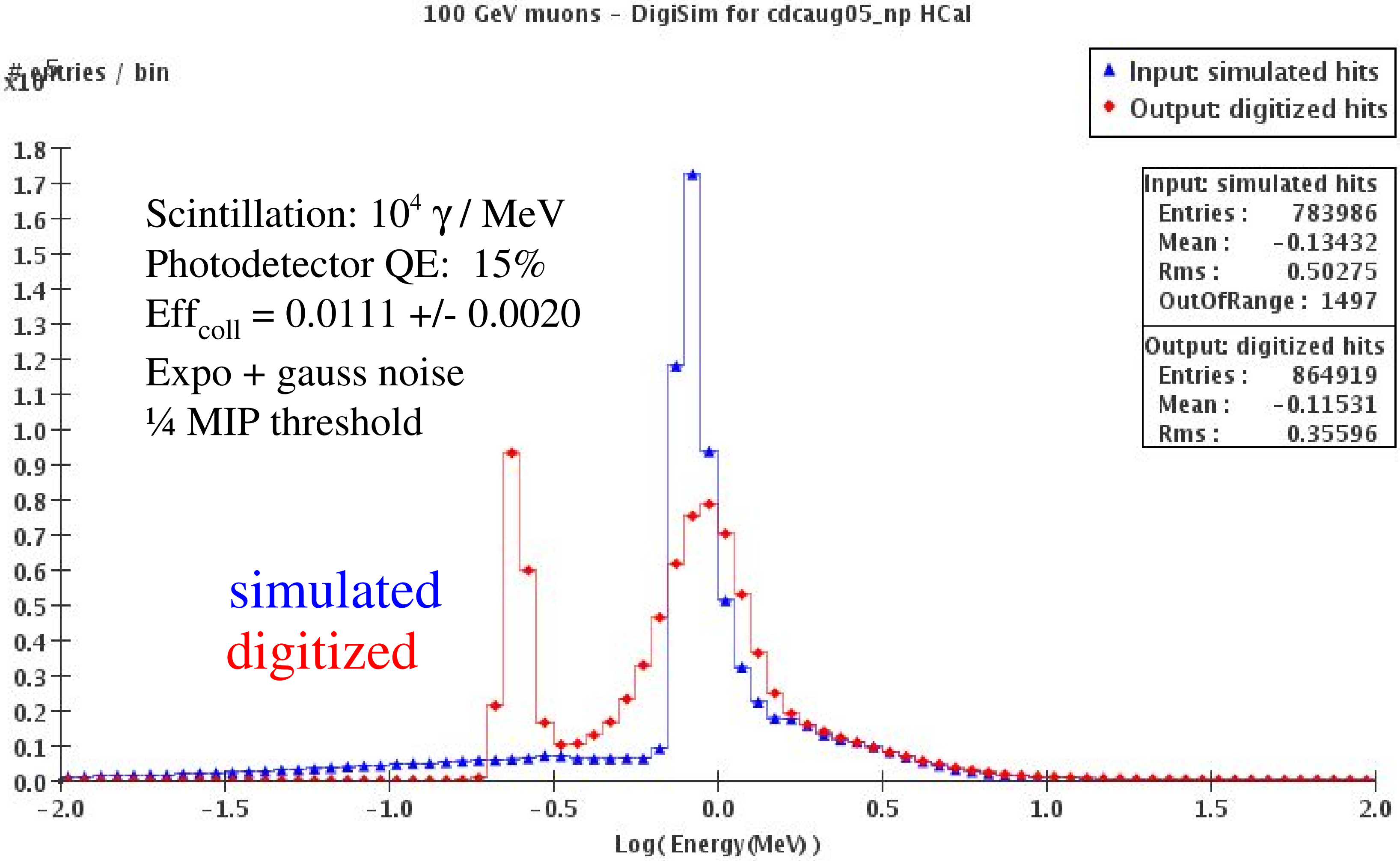


Noise and discrimination

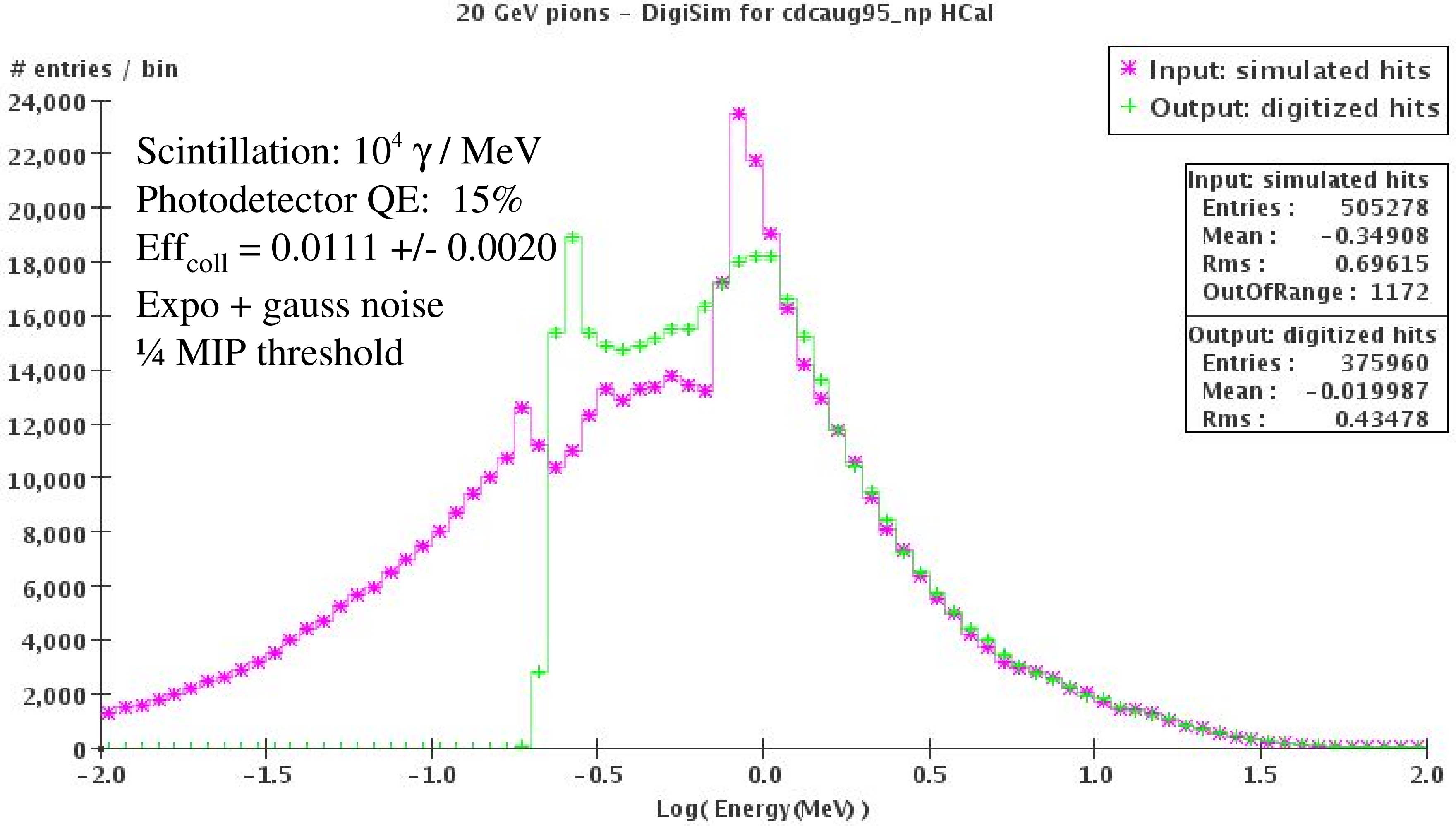




HCal scintillator digitization (preliminary)



HCal scintillator digitization (preliminary)



DigiSim usage instructions

- Download/install/build java 1.5, Maven, org.lcsim
  (see http://www.lcsim.org for details)

- Drivers needed: (all available from org.lcsim.digisim)
  CalHitMapDriver, DigiSimDriver and CalorimeterHitsDriver,
  plus LCIODriver (for standalone run, saving output file)
  or YourAnalysisDrivers (as an on-the-fly preprocessor)

- DigiSim configuration file stored on LCDetectors: digisim/digisim.steer

- Run it:

  - From command line: after setting the CLASSPATH (see docs for details)
    java org.lcsim.digisim.DigiSimMain <inputfile>
    an output file ./digisim.slcio will be produced, to be used for analysis or reconstruction

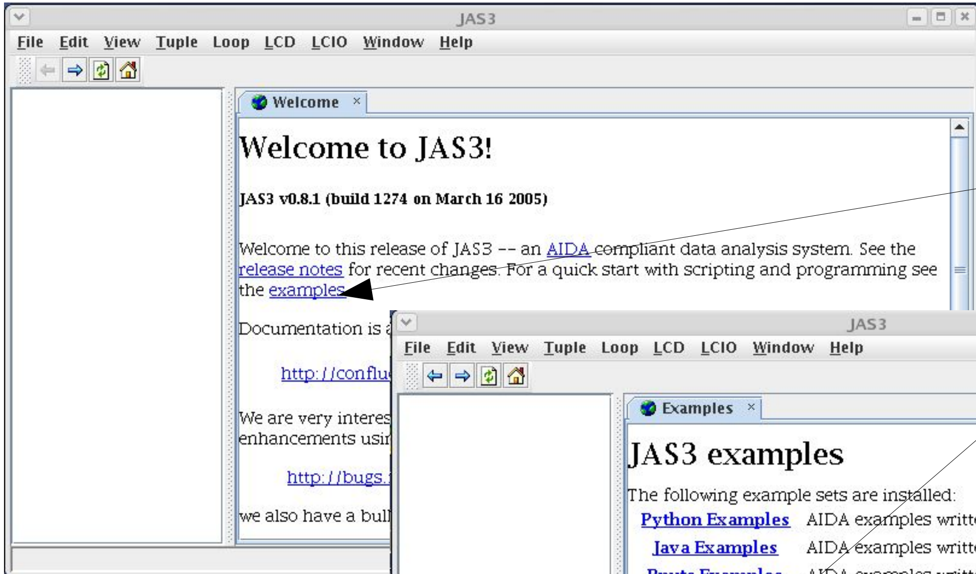
  - From inside JAS:
    DigiSimExample is available from Examples -> org.lcsim examples

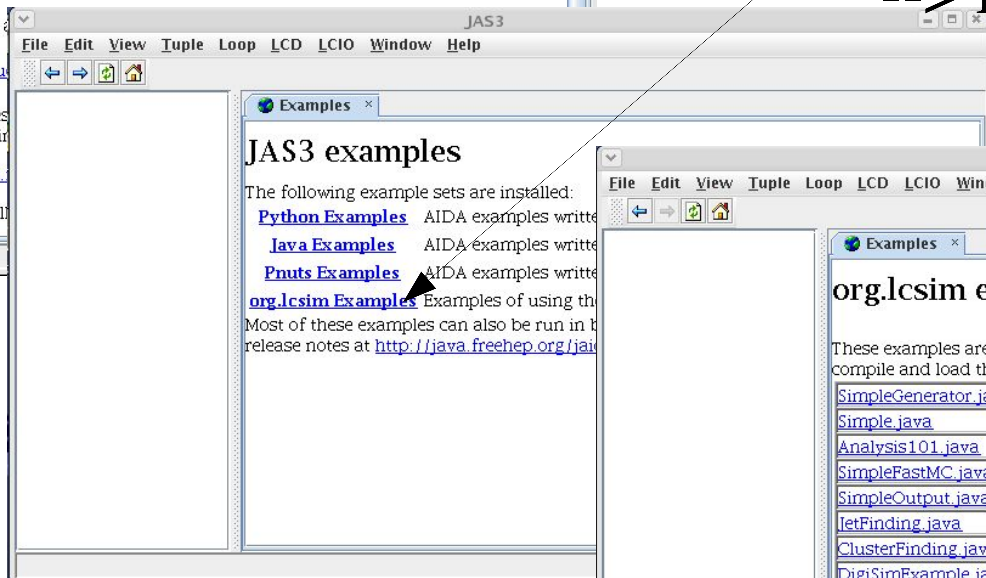
Running DigiSim inside JAS3

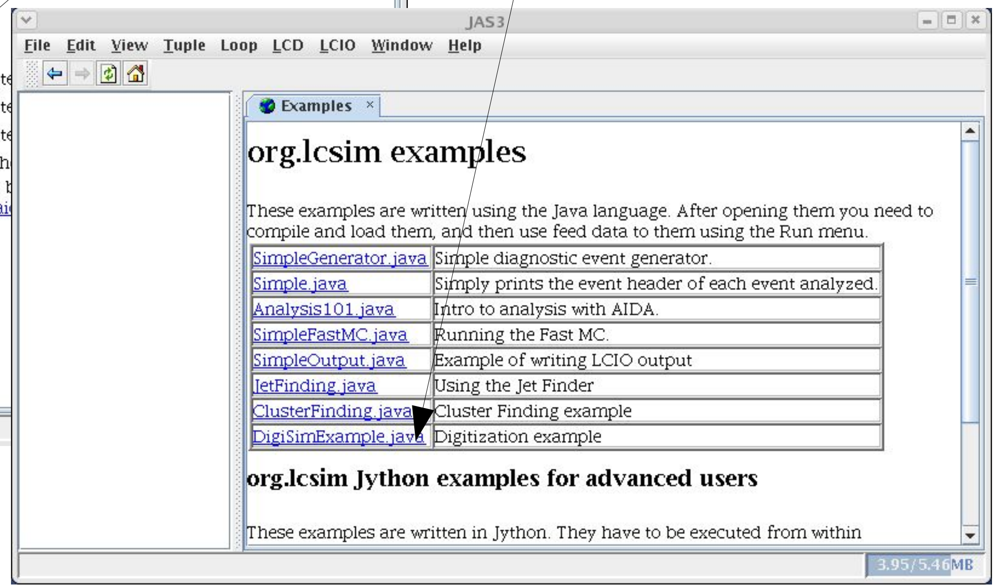
From starting page, click on examples

--> org.lcsim examples

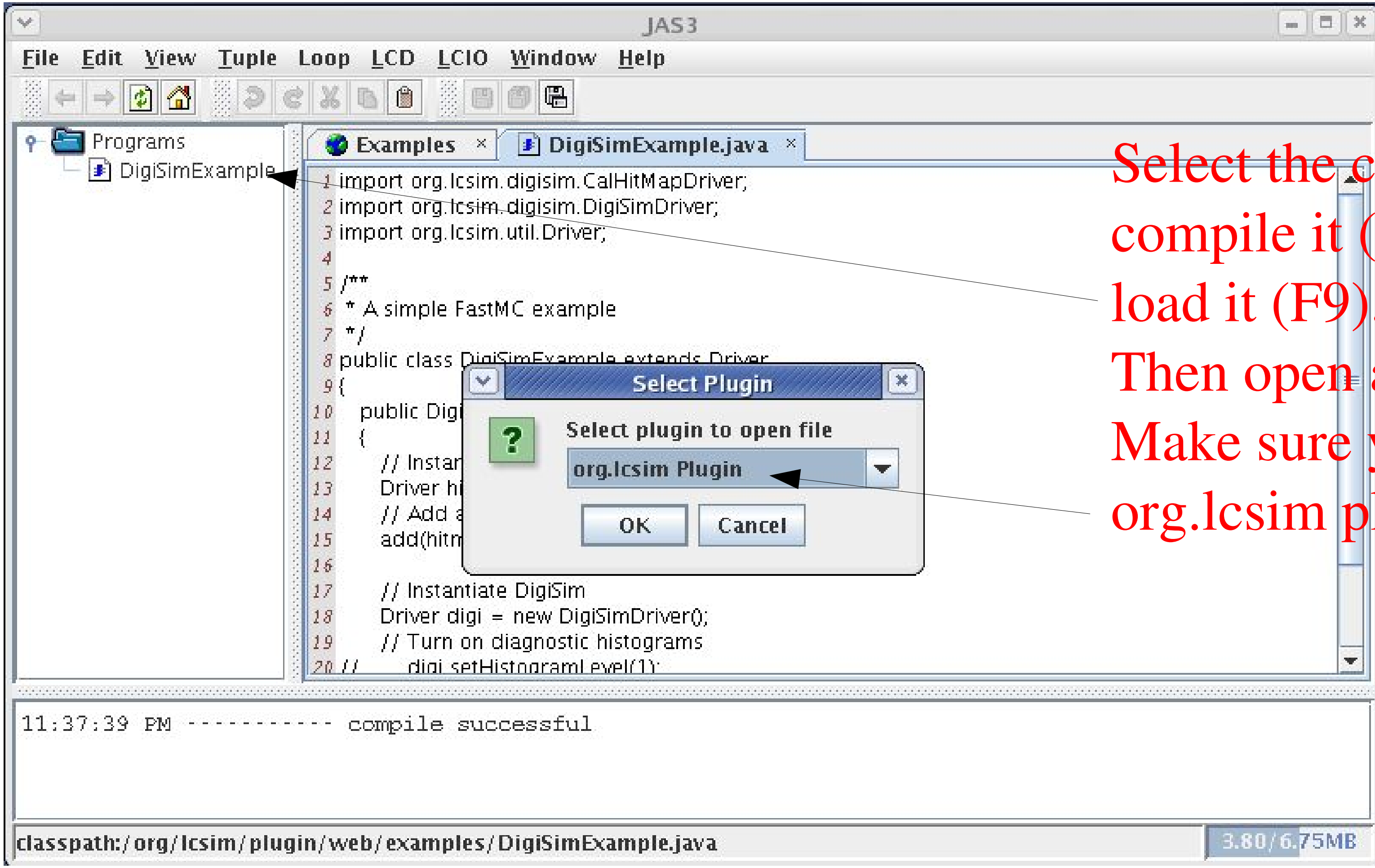
--> DigiSimExample.java





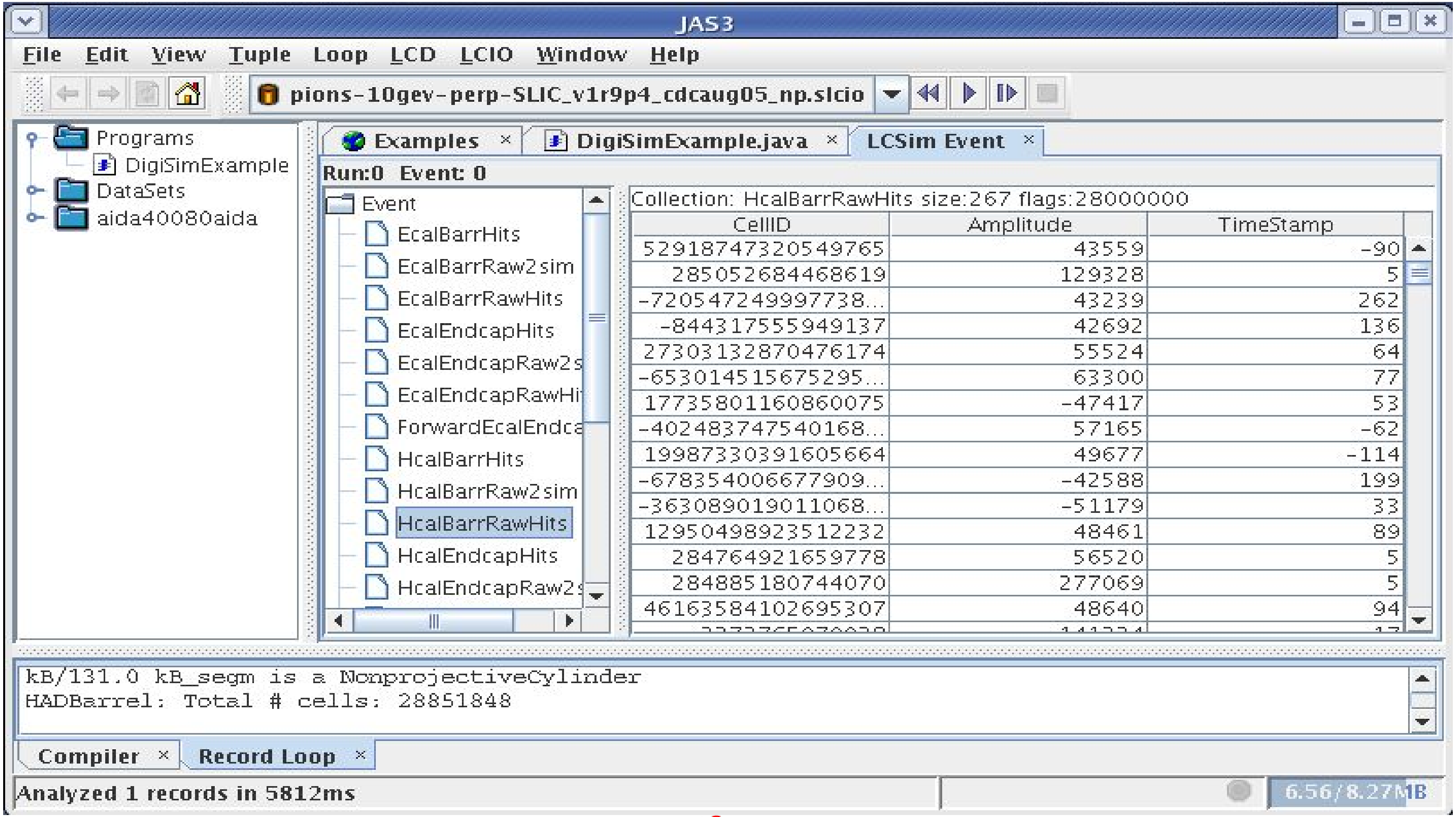


Loading driver(s) and data

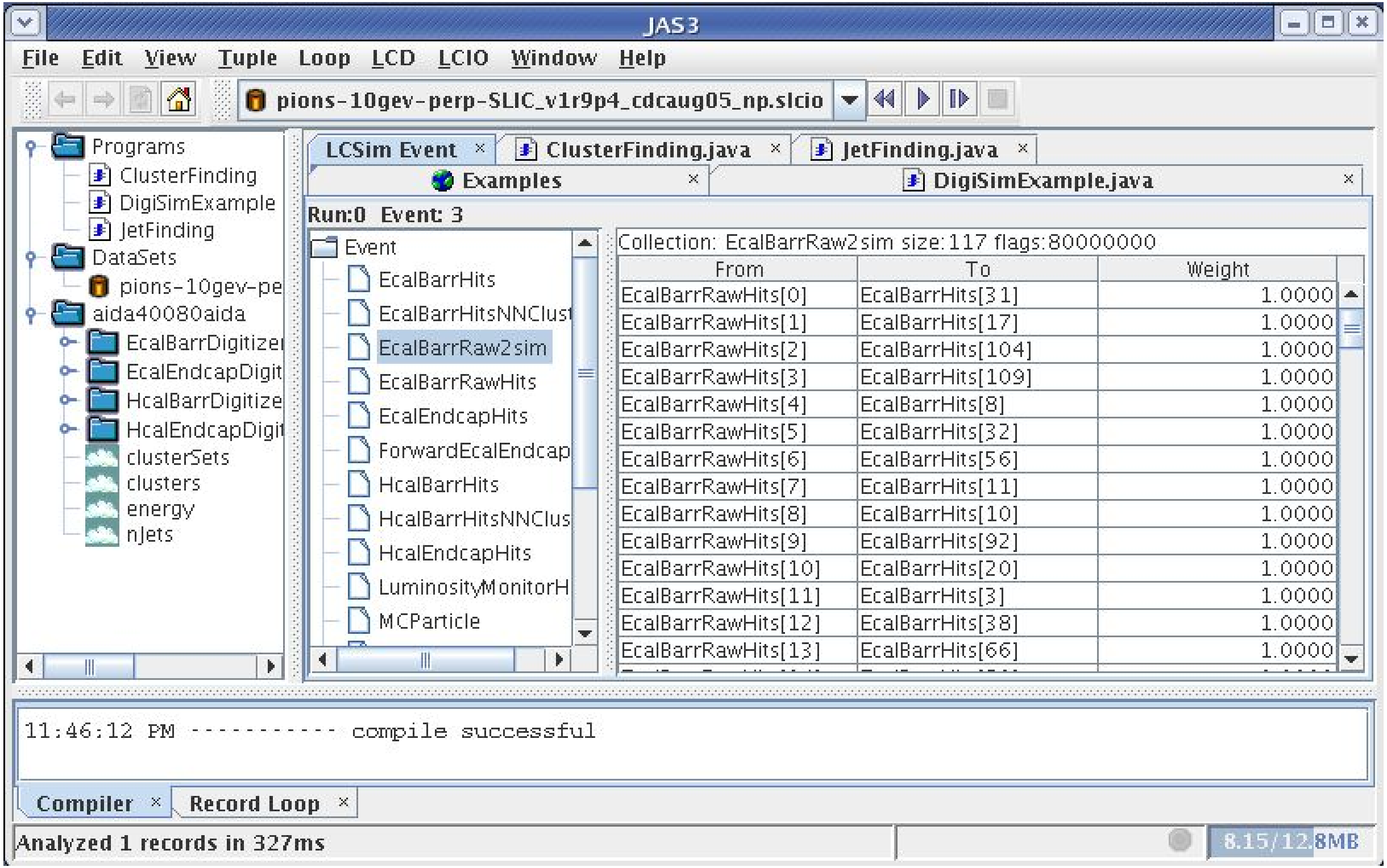


Select the code window, compile it (F2) and load it (F9).
Then open an LCIO file.
Make sure you select the org.lcsim plugin.

Looking at raw hits...



...and raw -> sim links



DigiSim Status

- A digitization simulation package, DigiSim, has been developed at NICADD/NIU
  - Java version released is full featured. Same configuration file as C++ (Marlin steering file)
  - C++ version partly available. Same basic structure, missing are crosstalks and noise modeling, as they depend on geometry-aware classes (CGA?)
  - Several generic modifiers are available (smeared linear transforms, crosstalk, noise, discrimination, etc. (Note: crosstalk and noise modifiers are not available in C++ version)
  - LCRelations implemented to associate raw hits to one or more corresponding simulated hits
- DigiSim can be run in either a stand-alone mode to produce persistent lcio output, or as an on-the-fly preprocessor to reconstruction/analysis.
  In the former case, raw/digi hits and LCRelations are saved into the output LCIO files, in addition to all the (untouched) MC information present at DigiSim input.
- A test version of a digitizer for a tile HCal barrel currently exists
  It can be used as an example to implement other subdetectors, like endcaps, ECal, RPCs, GEMs, tracker detectors. See example presented in this talk.

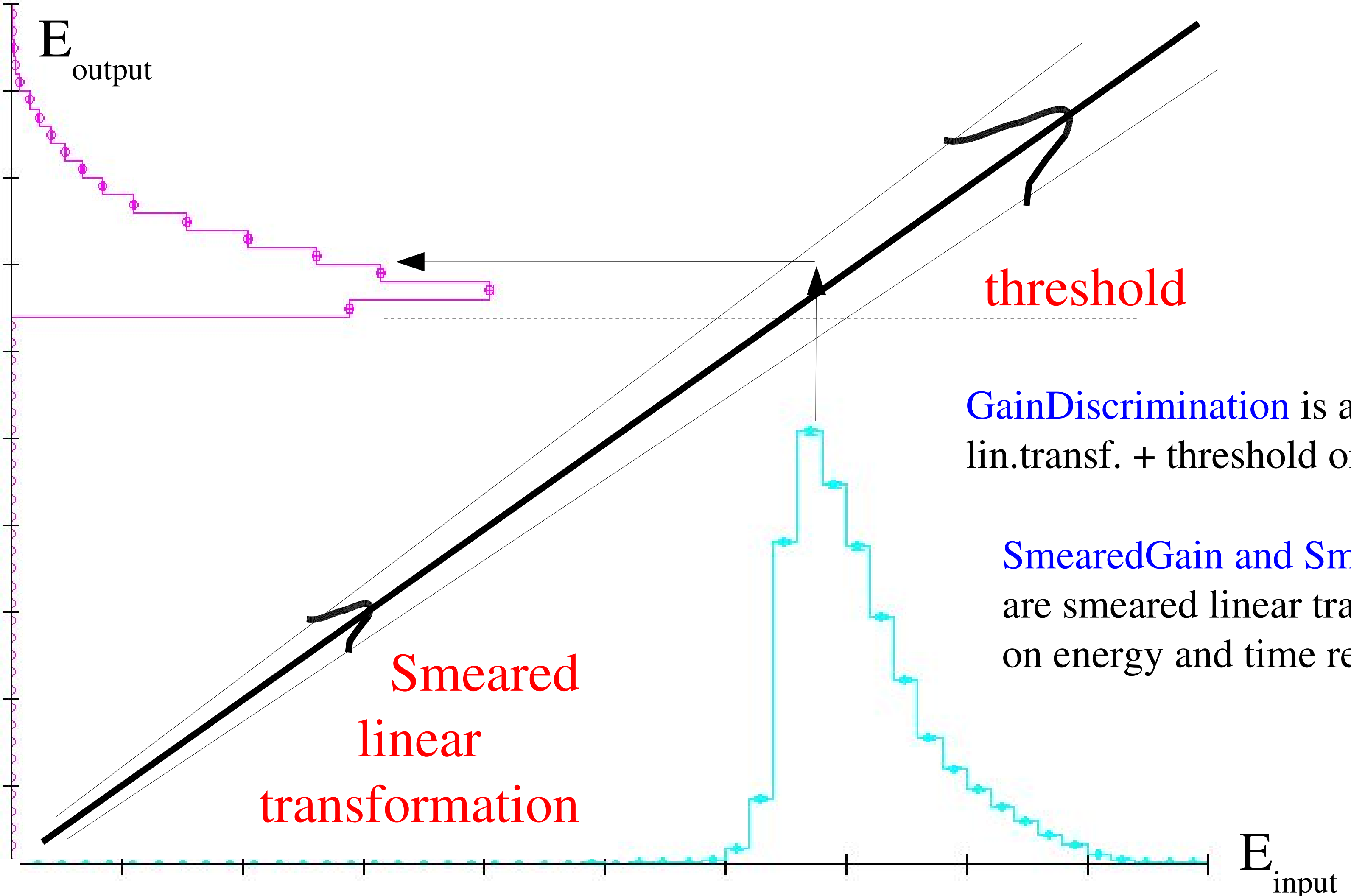
DigiSim status (cont.)

Other people are encouraged to add DigiSim configurators for RPCs, GEMs, trackers, and to make sure their algorithms can easily make the switch to use digitized data.

- Both C++ and Java versions are available through official CVS servers
  C++: released in the Calice CVS repository
  Java: released in the LCSim CVS repository. Download instructions from the confluence pages
- Documentation available from http://nicadd.niu.edu/digisim, including downloading and building instructions
- Send any questions or comments to: lima at nicadd.niu.edu

Thanks!

A common transformation



GainDiscrimination is a smeared lin.transf. + threshold on energy

SmearedGain and SmearedTiming are smeared linear transformations on energy and time respectively