A digitization simulation package for the International Linear Collider

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Talk Outline

- Singletons!
- DigiSim: Purpose and requirements
- Package description
- Usage and configuration
- Developing new functionality
- Preliminary results
- Current status and summary

A typical clustering code

```
LCCollection* col = _event->getCollection("EMcalCollection");

SimCalorimeterHit *ihit, *jhit;
for( int i = 0; i < col->getNumberOfElements(); ++i ) {  // loop over EM hits
  ihit = (SimCalorimeterHit*)col->getElementAt(i);
  int icellID = ihit->getCellID0();

  // find a neighbor hit
  int neighID = findANeighborHit(icellID);

  for( int j = 0; j < col->getNumberOfElements(); ++j ) { // a nested loop!
    jhit = (SimCalorimeterHit*)col->getElementAt(j);
    int jcellID = jhit.getCellID0();

    if( jcellID == neighID ) {                            // neighbor hit found
      // ...do some processing here...
    }
  }
}
```

Better: use hit maps

```
LCCollection* col = _event->getCollection("EMcalCollection");

CalHitMap hitmap;                                          // Create a hit map
for( int i = 0; i<col->getNumberOfElements(); ++i ) {
  ihit = (SimCalorimeterHit*)col->getElementAt(i);
  int cellID = ihit->getCellID0();
  hitmap[cellID] = ihit;                                   // populate hit map
}

SimCalorimeterHit *ihit, *jhit;
CalHitMap::iterator iter, jter;
for( iter = hitmap.begin(); iter != hitmap.end(); ++iter) { // loop over hits
  ihit = *iter;
  int icellID = ihit->getCellID0();

  int neighID = findANeighborHit(icellID);                  // find a neighbor
  jter = find( hitmap.begin(); hitmap.end(), neighID );
  if( jter!=hitmap.end() ) {                                // neighbor found
    jhit = *jter;
    // ...do some processing here...
  }
}
```

Even better: use a singleton

```
// fetch the hit map filled by a singleton class
CalHitMapMgr* pHitMgr = CalHitMapMgr::getInstance();
CalHitMap& hitmap = pHitMgr->getCollHitMap("EMcalCollection");

for( int i = 0; i<col->getNumberOfElements(); ++i ) {
  ihit = (SimCalorimeterHit*)col->getElementAt(i);
  int cellID = ihit->getCellID0();

  // look for a neighbor
  int neigbID = getANeighbor();
  jhit = find( hitMap.begin(); hitMap.end(); neigbID );
  //... do some processing here ...
}
```

Remember: people out there are copying your code into their analysis/reconstruction code. It is up to you to give them good code to be copied!

Uh? What's a singleton?!

- Singleton:
  a class behavior to inforce that only a single instance of a given class will ever exist.
- Example: optimize data access (hit maps keyed by cellID)
- Other hit collections can also be made available in a similar optimized way

```
typedef map<int,SimCaloHit*> CalHitMap;

class CalHitMapMgr {
public:
  // To be used instead of constructor
  static CalHitMapMgr* getInstance() {
    if( !_me ) _me = new CalHitMapMgr();
    return _me;
  }

  static void destroy() {if(_me) delete _me;}
  CalHitMap& getCollHitMap(string& name);

private:
  CalHitMapMgr();   // constructor
  ~CalHitMapMgr();  // destructor

private:
  static CalHitMapMgr* _me;
}
```

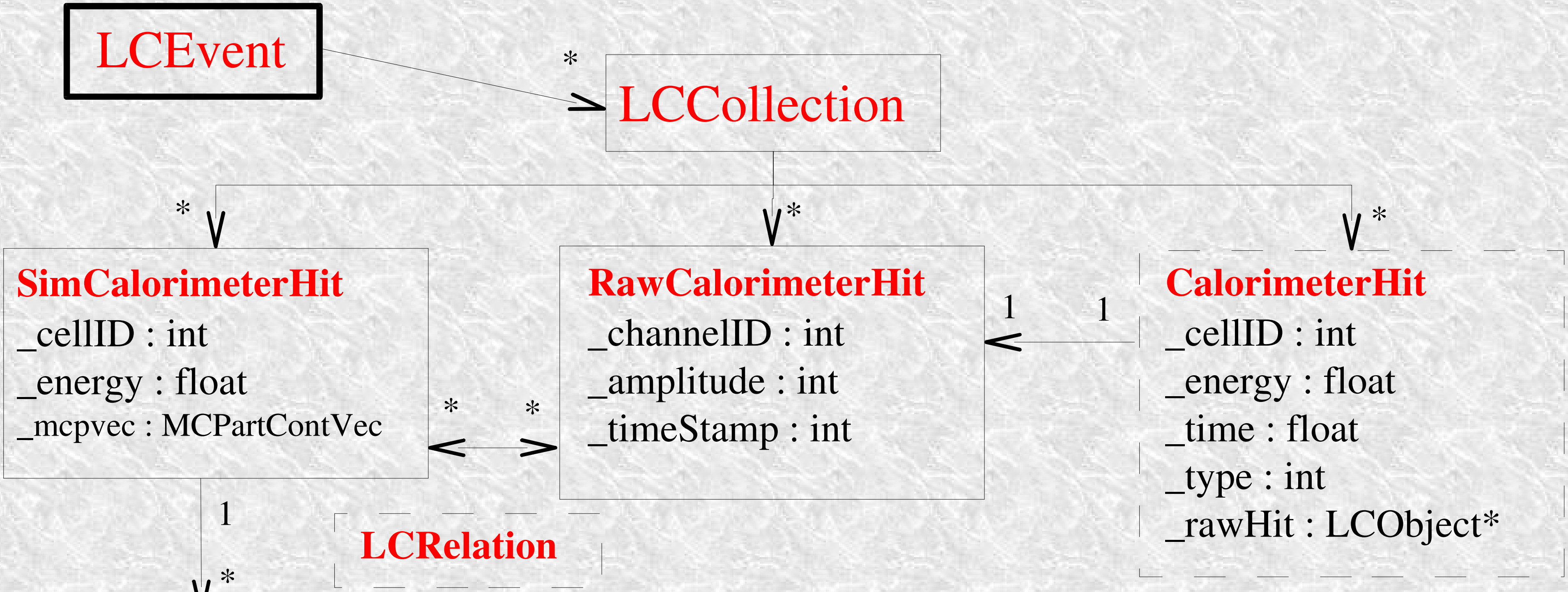
DigiSim

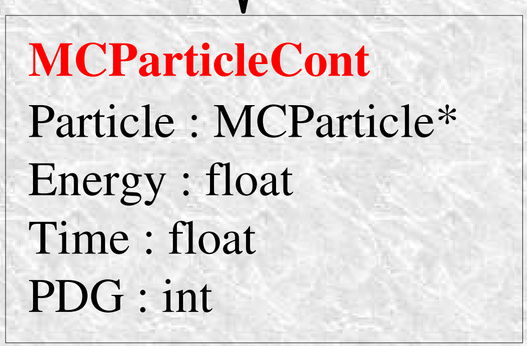
- Goal: a program to simulate the digitization process for the ILC detector simulation
- DigiSim role is to convert the simulated data (energy depositions and hit timings) into the same format AND *as close as possible* to real data from readout channels.
- Same reco / analysis software can be used for MC and real data.
- *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-uniformities, etc.

Requirements and choices

- Basic requirements:
  - Object oriented design to simplify maintenance and implementation of new functionality
  - Should be used within the CALICE test beam project, as a testbed for the reconstruction framework
  - All test beam code based on C++ and LCIO
- Gaede's Marlin (v0.6) chosen as the C++ framework

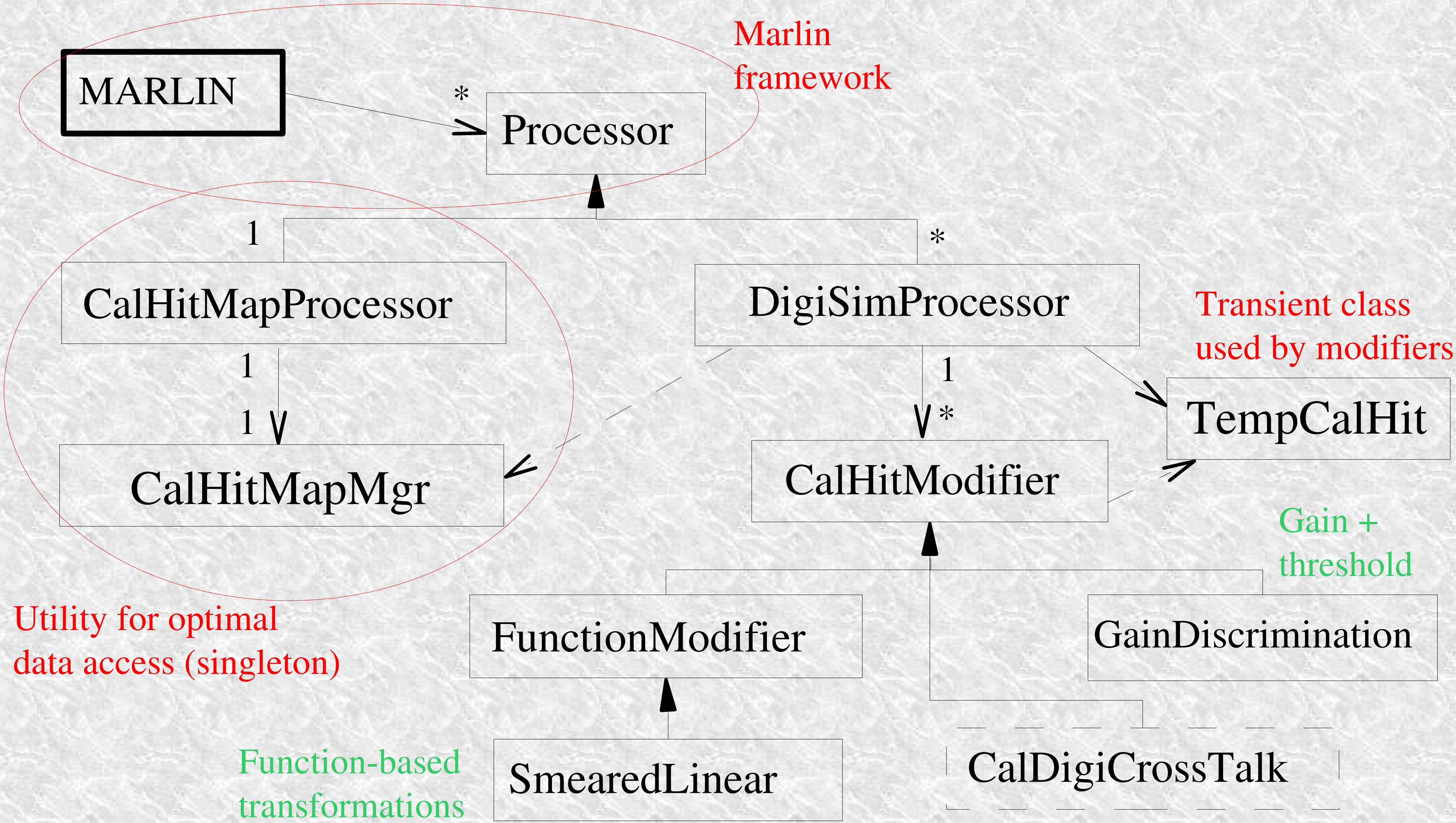
LCIO event model



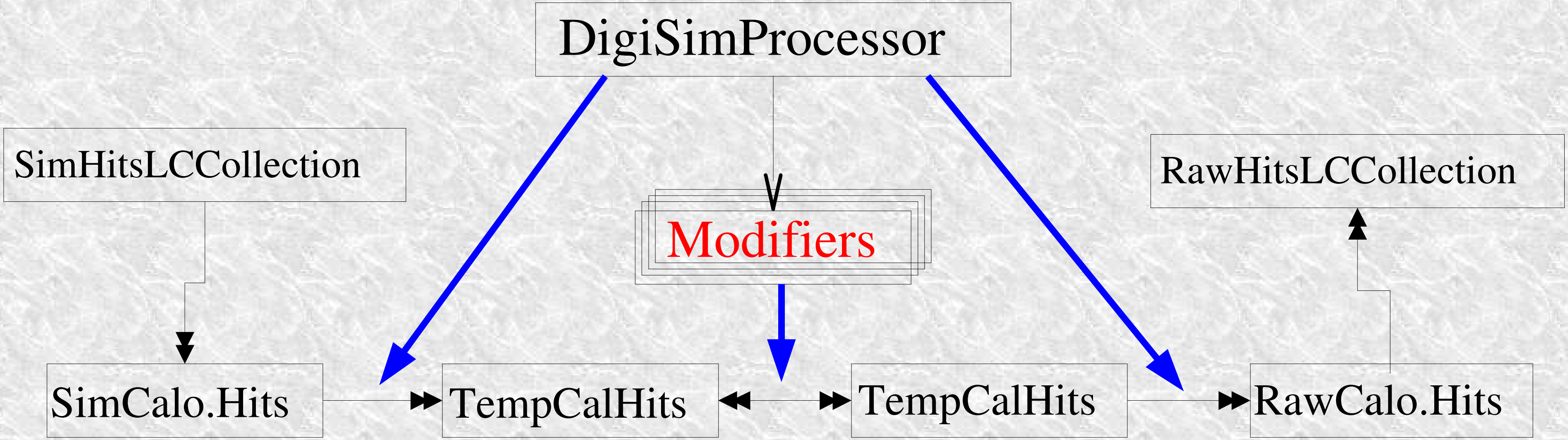


- DigiSim: SimCalorimeterHits --> RawCalorimeterHits
- Reco: RawCalorimeterHits --> CalorimeterHits
- LCRelations associating SimHits to RawHits have not yet been implemented

DigiSim class diagrams



DigiSim event loop



- Calorimeter hits are shown here, but the same structure could also be used for tracker hits
- TempCalHits are both input and output to each modifier
- All processing is controlled by a DigiSimProcessor (one per subdetector)
- Modifiers are configured at run time, via the Marlin steering file
- New modifiers can be easily created for new functionality (more info later)

Steering file example

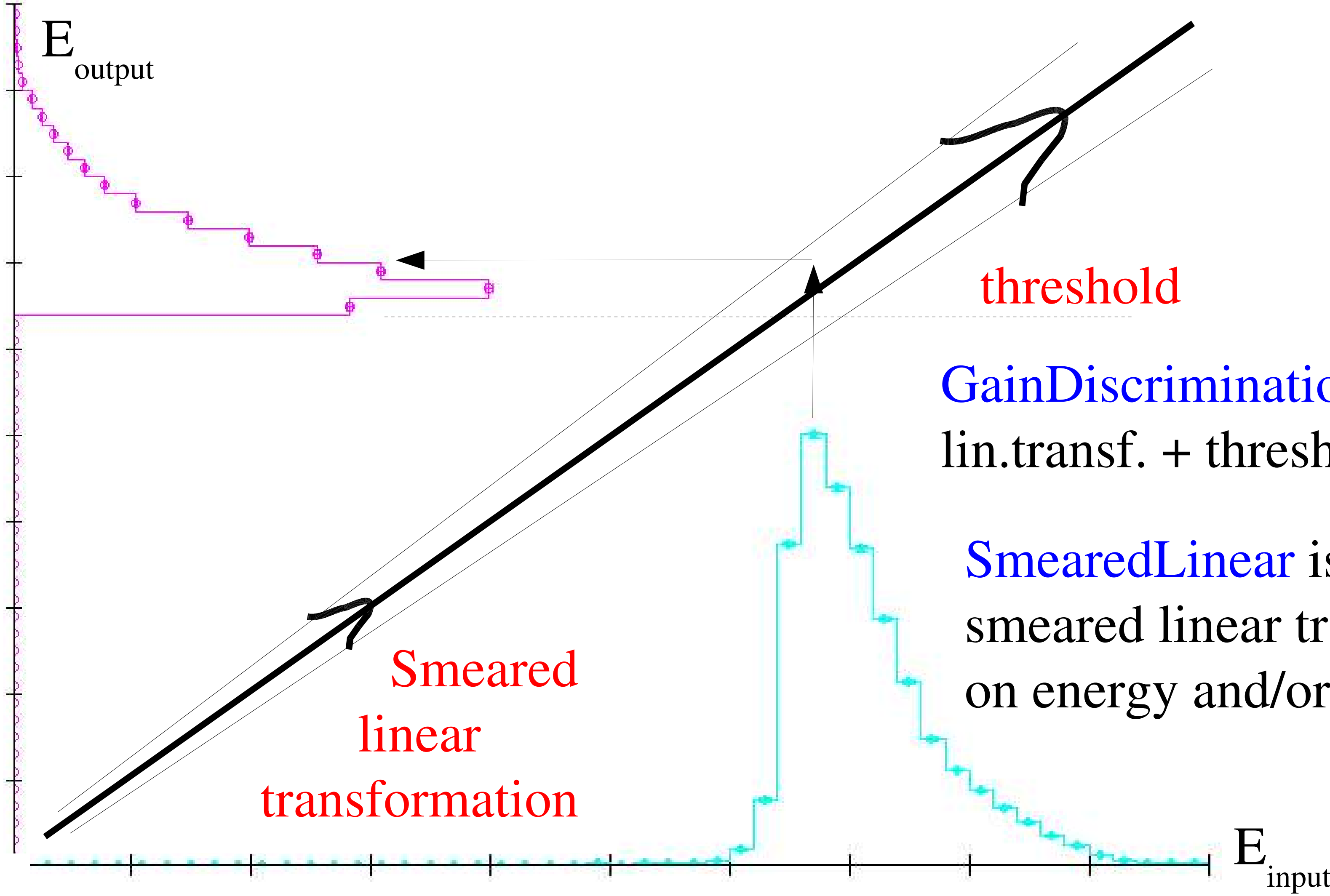
```
############################################
#  Example steering file for DigiSim
############################################
.begin Global  ------------------------------------
# specify one or more input files (in one or more lines)
LCIOInputFiles inputfile

# the active processors that are called in the given order
ActiveProcessors CalHitMapProcessor
ActiveProcessors EMDigiSimProcessor
ActiveProcessors HADDigiSimProcessor
ActiveProcessors TCDigiSimProcessor
ActiveProcessors OutputProcessor

# limit the number of processed records (run+evt):
MaxRecordNumber 500
.end Global  -------------------------------------
```

Configuring processors and modifiers

```
#############################################################
# A DigiSim processor.  It instantiates one or more calorimeter hit
#  "modifiers", which together represent the full digitization process
.begin EMDigiSimProcessor ---------------------------------------
ProcessorType    DigiSimProcessor
InputCollection  EMcalCollection
OutputCollection EMrawCollection

ModifierNames    EMFixedGain EMThreshOnly EMDigiIdent

# Parameters:  type                gainNom gainSig  thresh   thrSig
EMFixedGain    GainDiscrimination  1000000       0       0        0
EMThreshOnly   GainDiscrimination        1       0      30        0
EMGainThresh   GainDiscrimination  1000000   50000      30      1.5

# A function-based modifier        ElinNom ElinSig TlinNom  TlinSig
EMDigiIdent    SmearedLinear             1       0       1        0
.end ------------------------------------------------------------
```

(As many as needed)

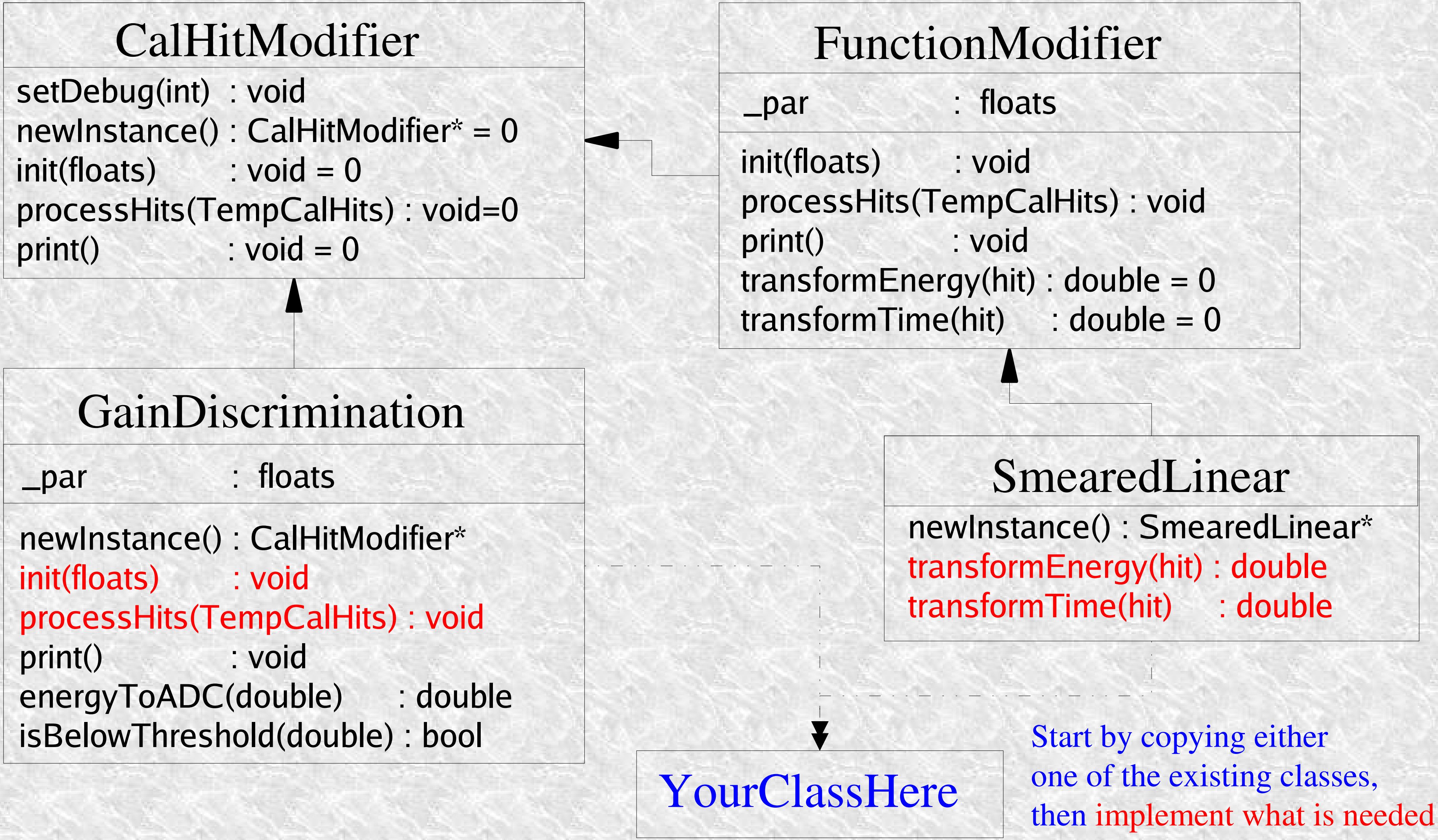
Existing modifiers



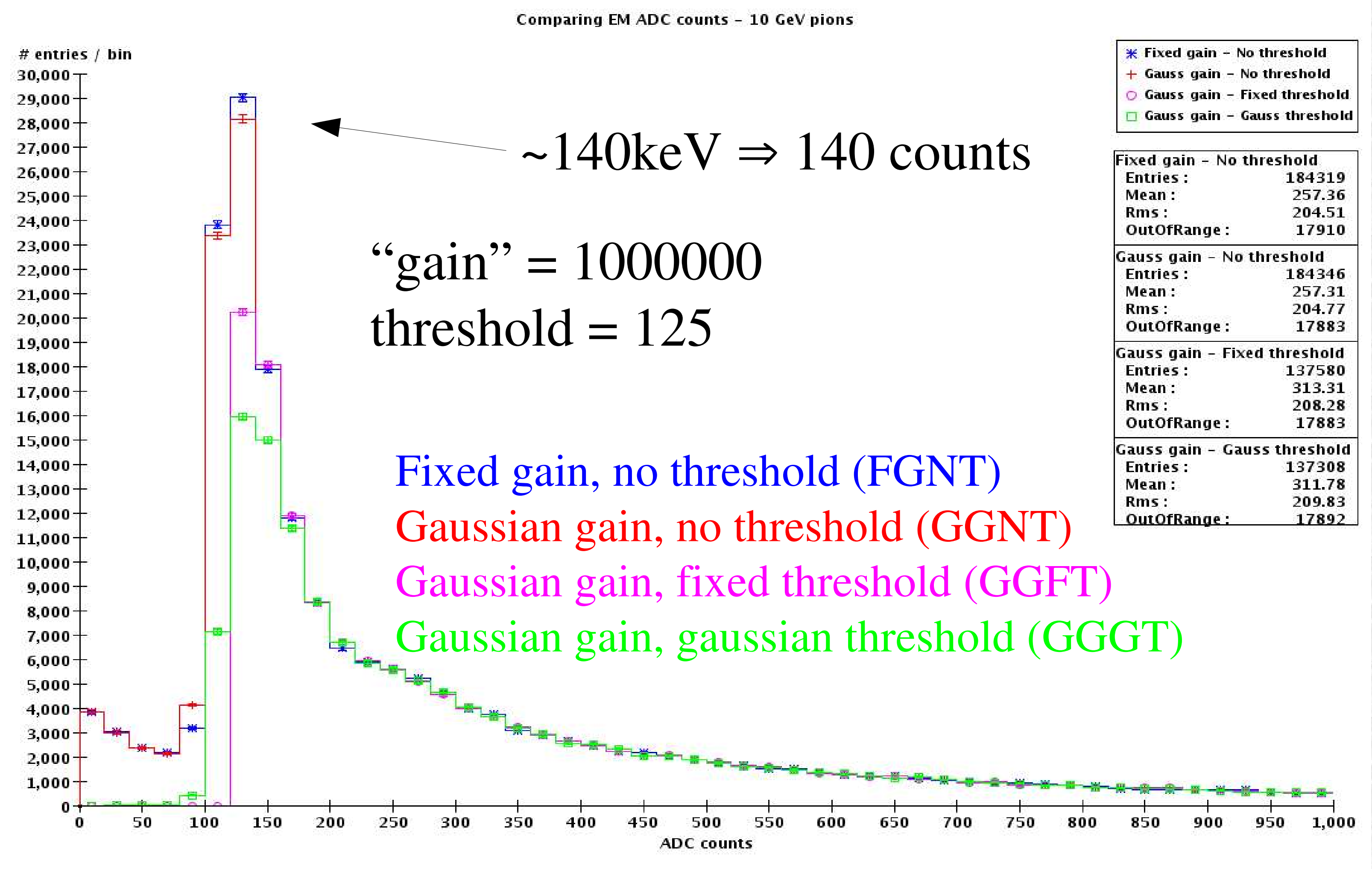
GainDiscrimination is a smeared lin.transf. + threshold on energy

SmearedLinear is a func-based smeared linear transformation on energy and/or timing

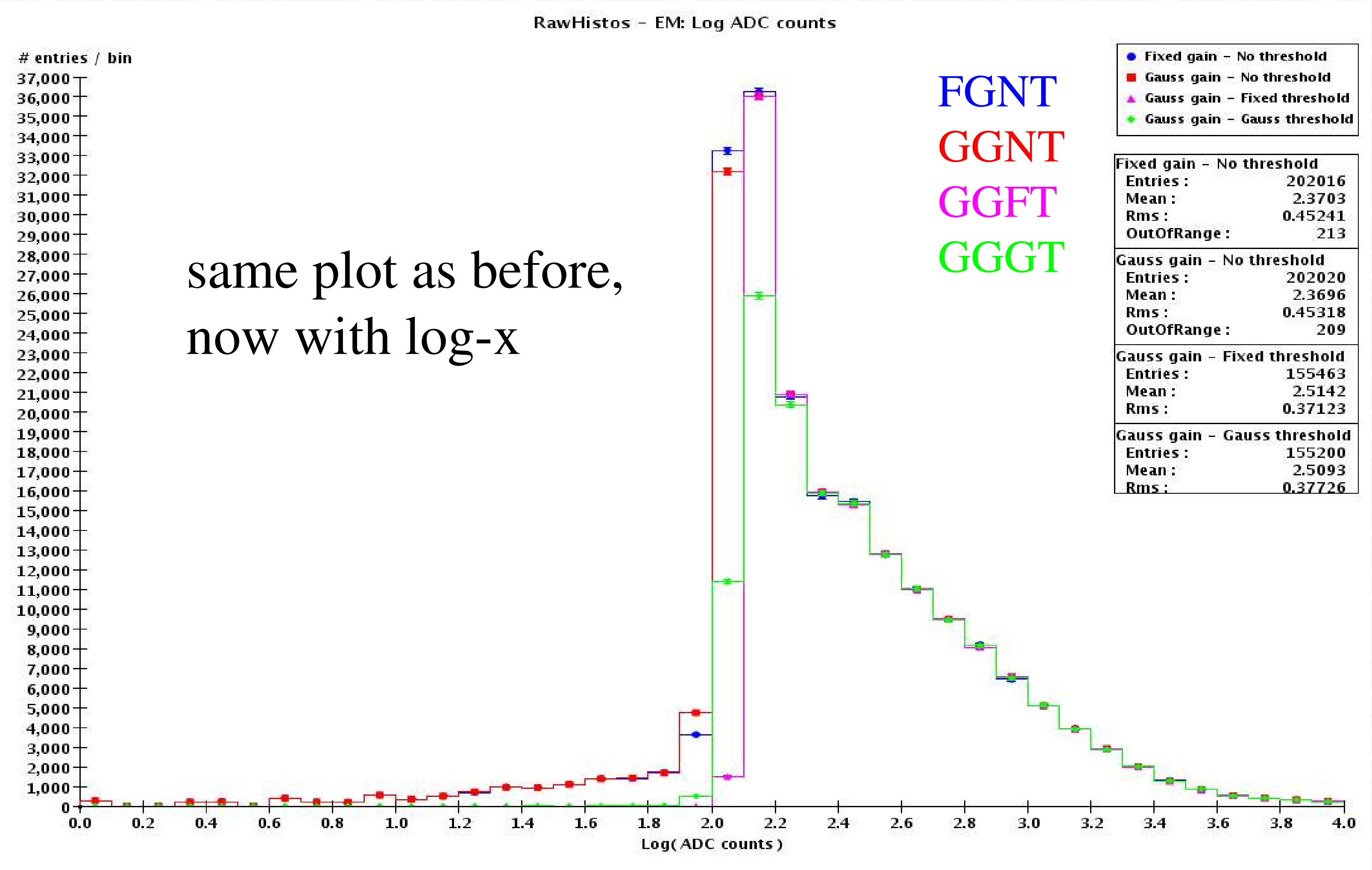
Creating new modifiers



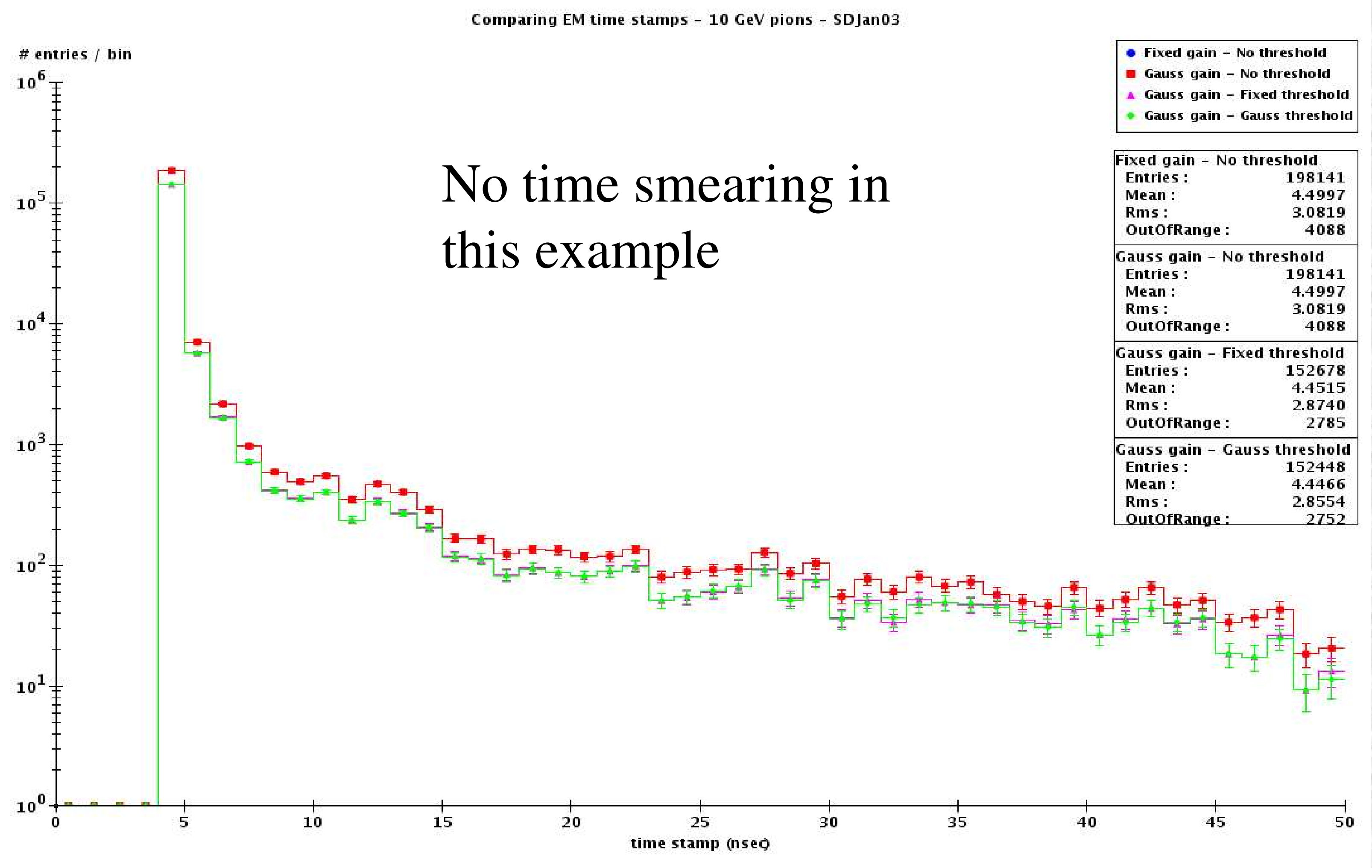
10 GeV π± on EM: gain + threshold



10 GeV ± on EM: gain + threshold

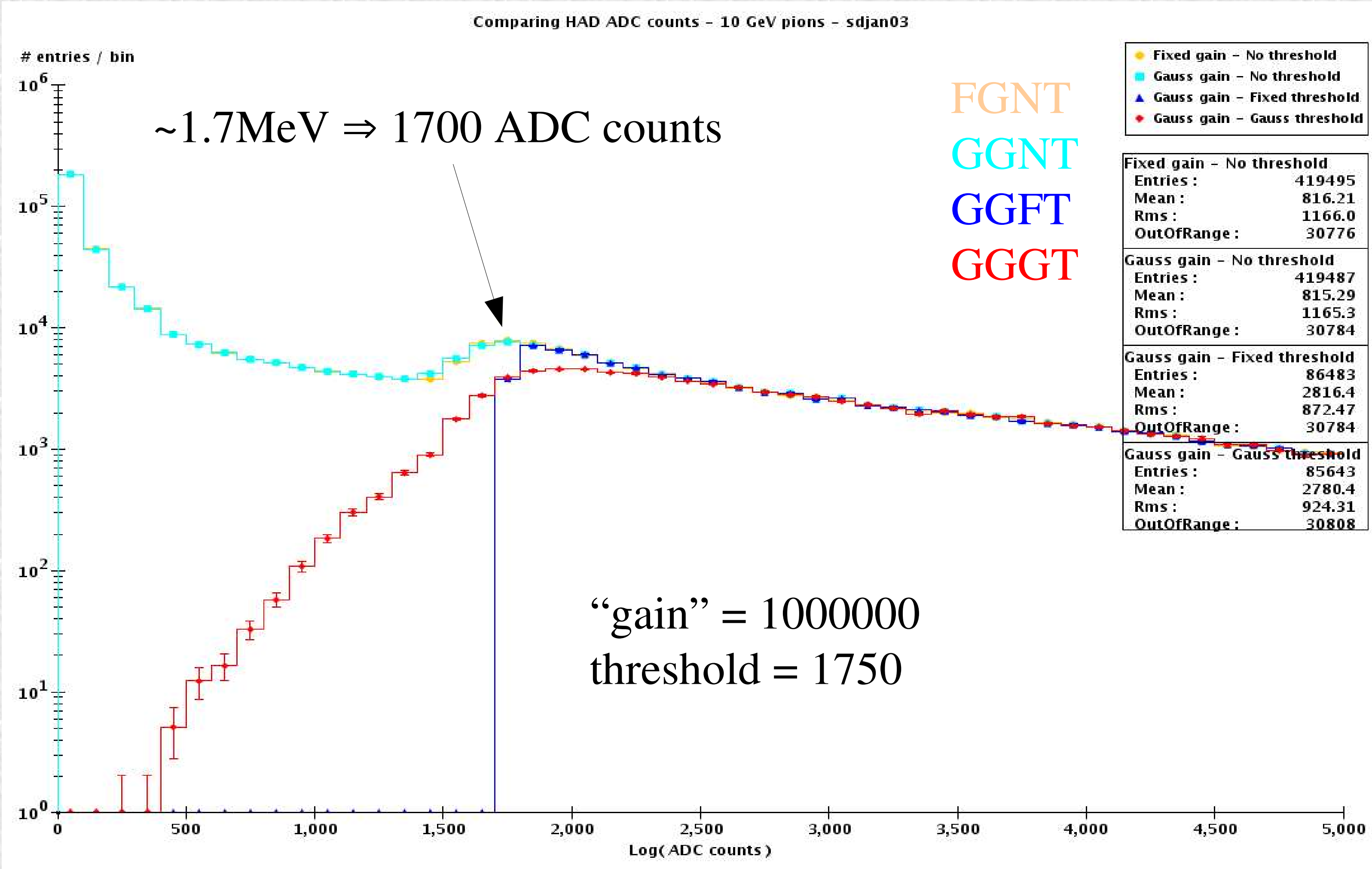


10 GeV $\pi^{\pm}$ on EM: time stamps

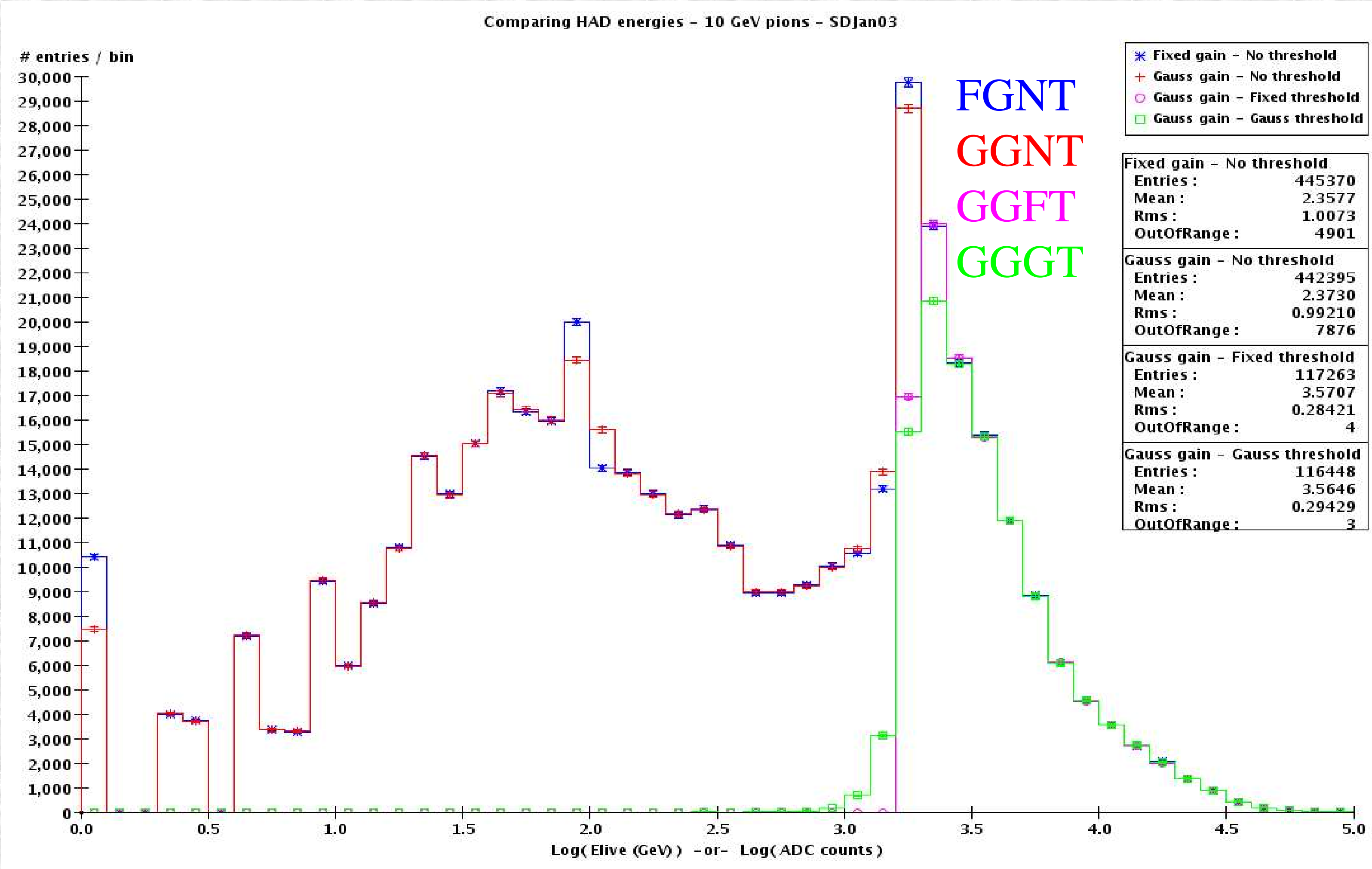


No time smearing in this example

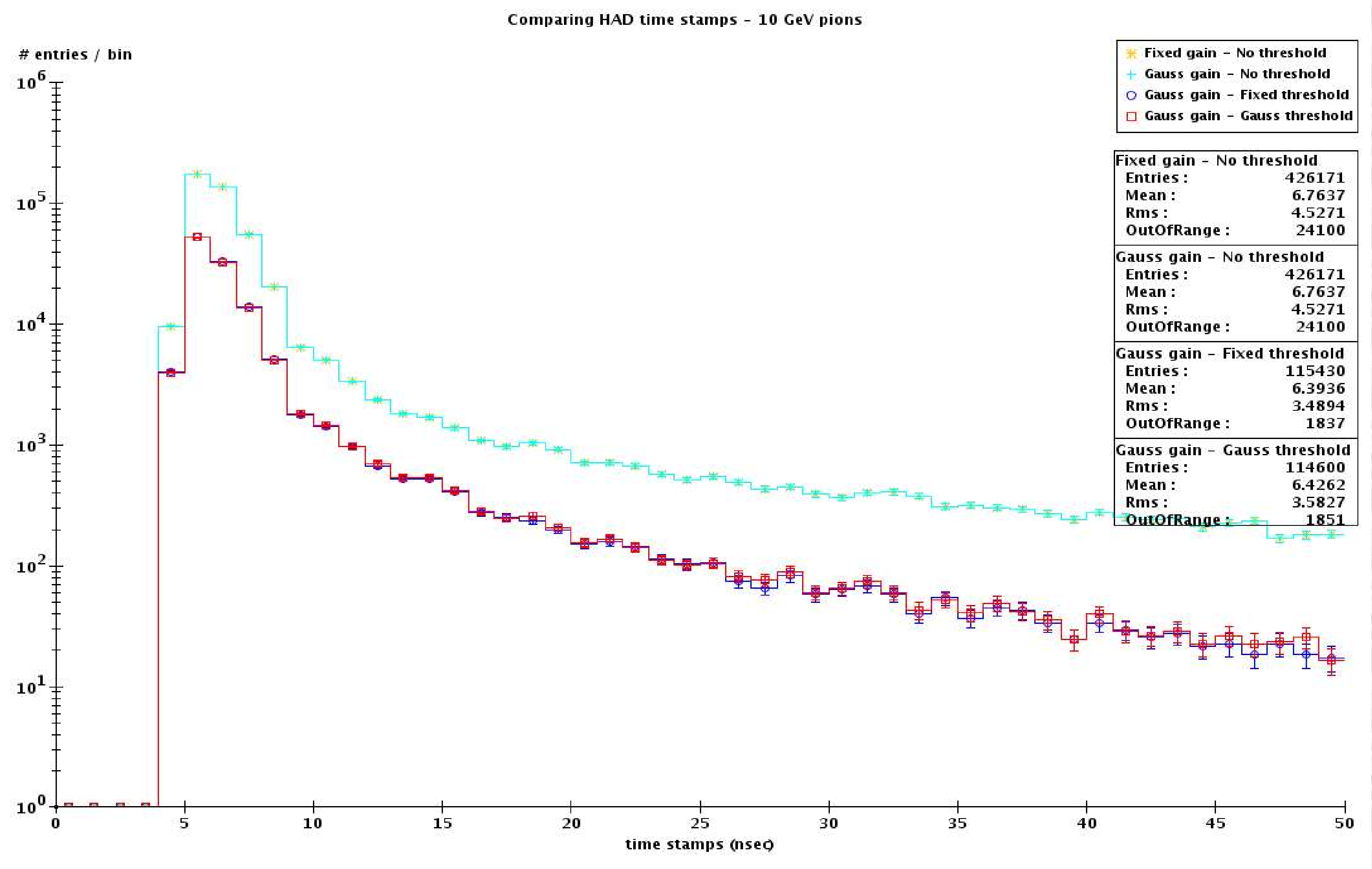
10 GeV $^{\pm}$ on HAD: gain + threshold



10 GeV $^{\pm}$ on HAD: gain + threshold



10 GeV π± on HAD: time stamps



Status

- A first version of DigiSim (proof of concept) is implemented
  - Two real modifiers implemented:
    GainDiscrimination and function-based SmearedLinear
  - LCRelation: to be used (soon?), example code at hand (thanks to F.Gaede)
- Output LCIO files contain EM and HAD RawCalorimeterHit collections, while keeping simulation collections untouched.
- Analysis code for plotting raw hits, plots confirm expected behavior.
- Creation of new (simple) modifiers is quite easy, by just copying one of the existing modifier classes and implementing the desired transformation.
- Some complicated ones: crosstalk and cell ganging require neighborhood information, from geometry-aware classes. NonProj code exists (java and C++), but projective geometry only available in java.

Summary

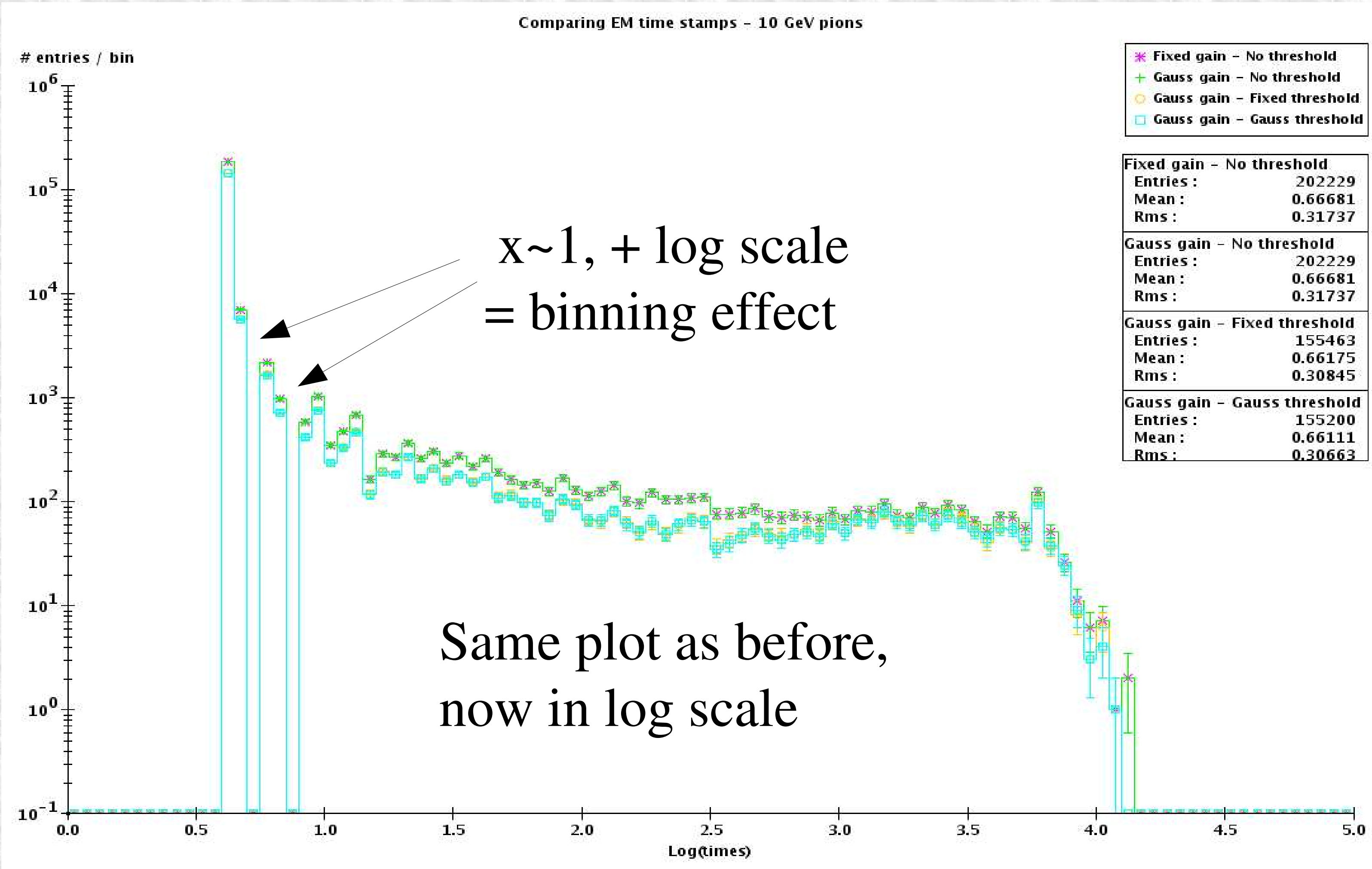
- A first version of a digitization simulation program, DigiSim, has been developed at NIU, aiming at full digitization of ILC detector simulations
- DigiSim is object-oriented, powerful, extensible, yet very simple implementation using C++
- Digitization of tracking detectors can probably be implemented as easily as the calorimeter hits
- CALICE test beam can use DigiSim as a testbed, for evaluation and improvement suggestions. Please use it for your digitization studies.
- Send any questions or comments to me: lima at nicadd.niu.edu
- Documentation available at http://nicadd.niu.edu/digisim/DigiSim.html, including download and building instructions

Hier heute zu sein ist nett.
Ich hofft bald zurückzukommen!

Danke!

Disclaimer: grammatical errors are google's, not mine!

10 GeV $^{\pm}$ on EM: time stamps



x~1, + log scale
= binning effect

Same plot as before,
now in log scale

10 GeV $^{\pm}$ on HAD: time stamps