MarlinTPC

- A TPC simulation, reconstruction and analysis software (based on Marlin Framework) that uses LCIO as data format
- Before: individual software packages of the different TPC R&D groups worldwide (with more or less specific focus on different aspects)
  Disadvantages:
  - Work is being done twice
  - Results not totally comparable; many parts of the reconstruction chains do differ: difficult to compare differences of individual algorithms
  - No common data format (although LCIO was used often)
- Idea behind MarlinTPC:
  - Combine the efforts to work more effective
  - Combine experience and knowledge
  - Real comparison of single algorithms possible
  - Integration into a common ILC reconstruction framework: profit from developments there and test algorithms in a larger frame

MarlinTPC

- History
- Before 2005: individual reconstruction software by the different R&D groups worldwide
- Development started by Matthias E. Janssen in 2005 in close contact with other groups (1st version was called MatriX)
- 2006:
  Agreement of six TPC R&D groups on a common software standard
  Quiet phase for development of the reconstruction software
  But work being done on porting the Aachen TPC simulation to Marlin (no inclusion in MarlinTPC yet)
- Reviving in 2007 (Analysis Jamboree in Aachen):
  Lot of development since then and integration / reimplementation of existing software / algorithms
- Status 2007:
- Basic reconstruction chain ready, but there are still missing reconstruction parts
- Analysis processors mostly missing
- Testing with real measurement data sets to do

The Software Framework

- MARLIN (analysis and reconstruction framework):
- very modular with well defined interfaces between its modules: the modules are called processors
- this ensures that different developers can work on different processors in parallel without interference and to plug’n’play with processors to easily try out e. g. different algorithms.
- LCCD (Linear Collider Conditions Data):
- a common way to store conditions data: ranging from gas properties (pressure, water content, mixture) to voltages (drift, amplification) and other properties that are not stored in the actual measured data
- tag data sets for later easy reference and to request data valid at a particular point in time.
- GEAR (Geometry API for Reconstruction)
- allows to access geometry information needed for the simulation, digitization and reconstruction of events. Thereby it is made sure that consistent geometry information is used throughout MarlinTPC.

LCIO

- LCIO is a common data format to ensure persistency in the ILC software
- It contains classes for the needed reconstruction and analysis data
- Available in C++, Java and Fortran
- Also contains methods to write/read the data

- Tracker Objects in LCIO not limited to TPC but can also be used for other detector parts

LCIO

- Tracker classes in LCIO:
- TrackerRawData:
  Data as measured, right after the DAQ
- TrackerData:
  Measured data with applied electronic related corrections (pedestals, timeshift)
- TrackerPulse:
  Reconstructed data on a pad
- TrackerHit:
  Reconstructed data in a row
- Track:
  Track candidate and reconstructed track, collection of tracks

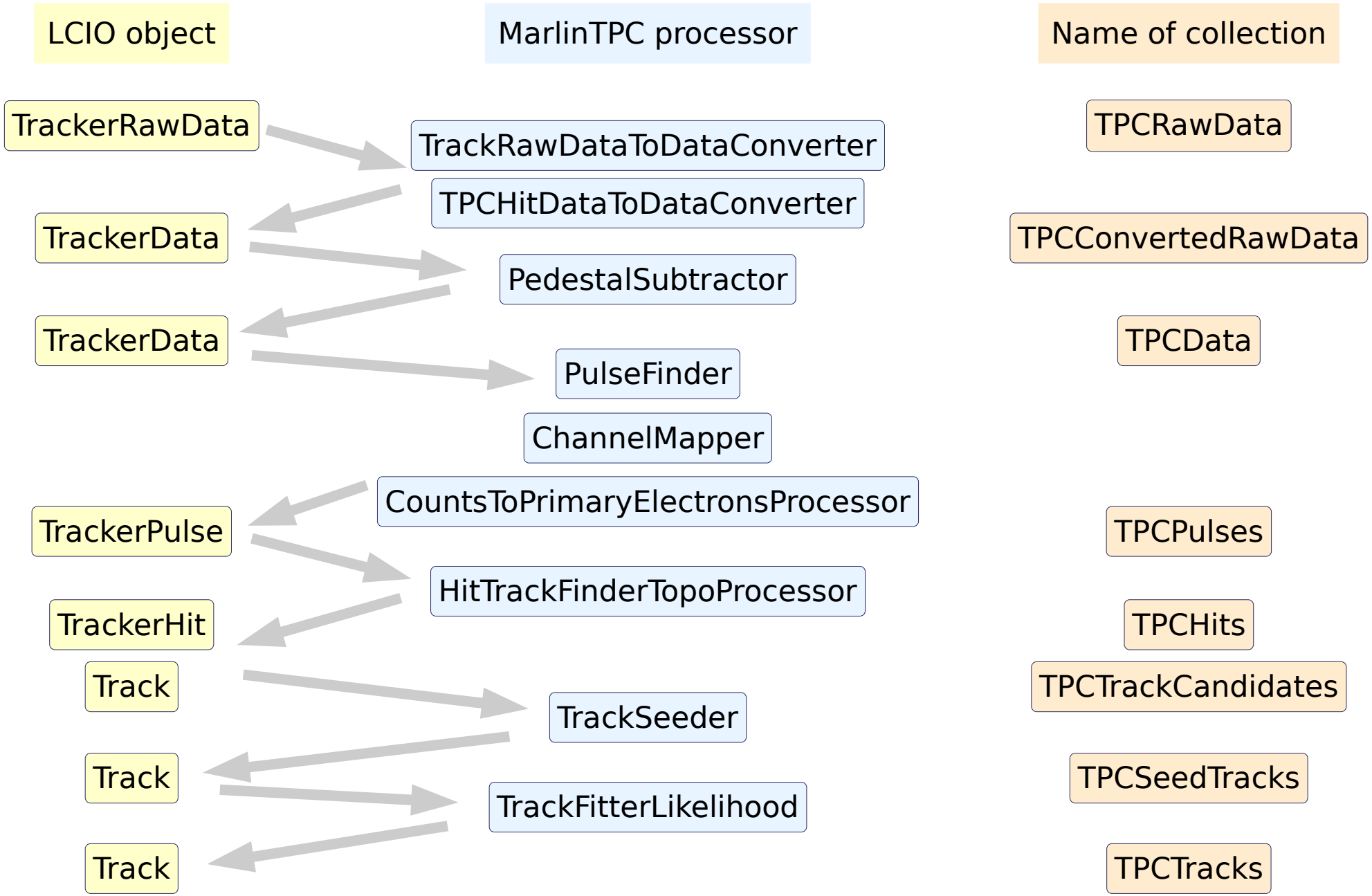
- More information (download and documentation): http://lcio.desy.de

MarlinTPC

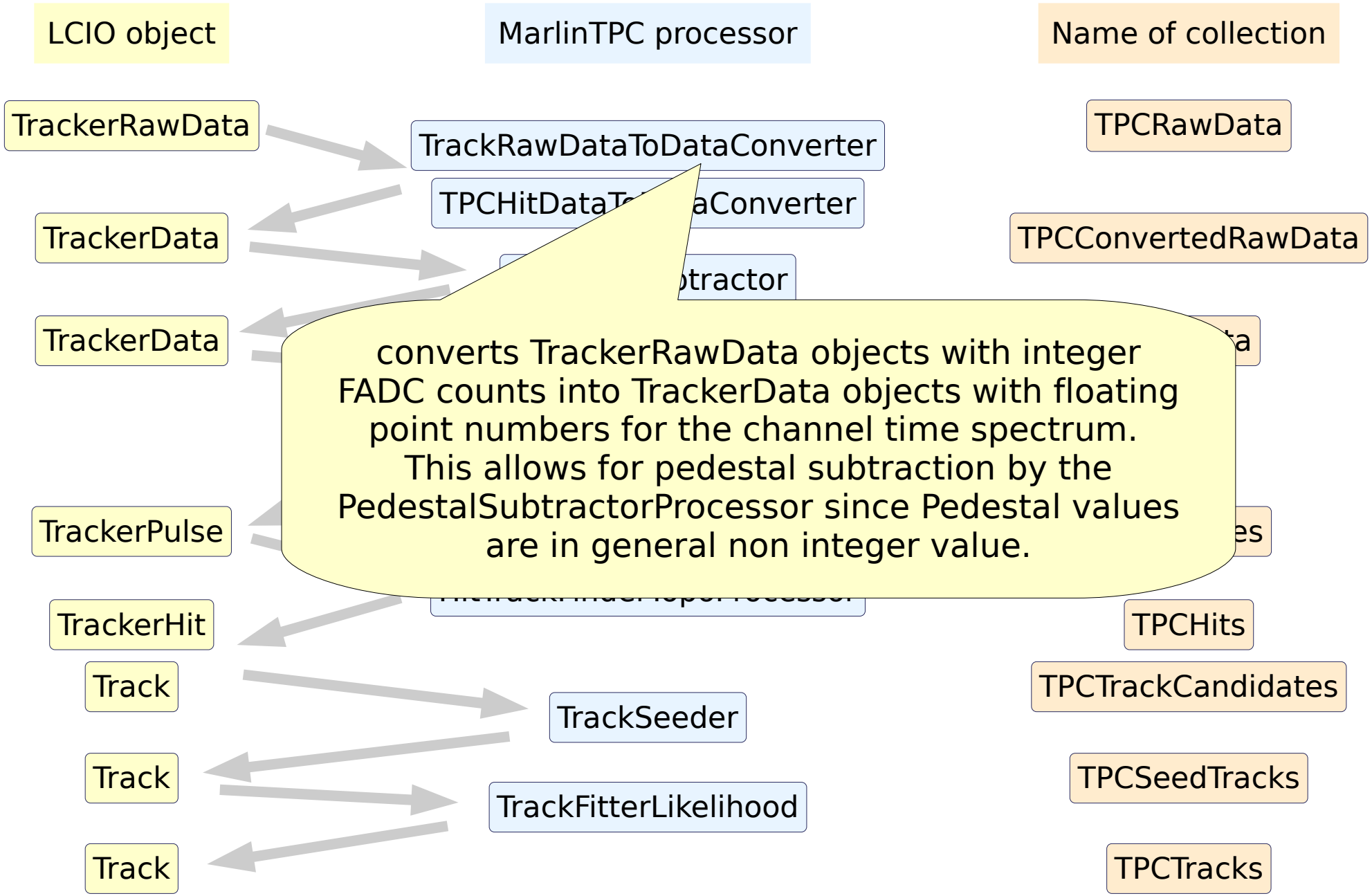
- Simulation (Astrid Münnich's TPC simulation package)
- Digitization (current development by Thorsten Krautscheid)
- Reconstruction
- Analysis

- Library for TPC conditions data based on LCCD
- Contains examples for testing and validation
- International effort:
  - Aachen (Germany): Astrid Münnich
  - Bonn (Germany): Martin Killenberg, Thorsten Krautscheid, Martin Ummenhofer, Peter Wienemann, Simone Zimmermann
  - DESY, University of Hamburg (Germany): Klaus Dehmelt, Ralf Diener, Matthias Enno Janssen, Adrian Vogel
  - Victoria, Canada: Jason Abernathy
  - Cornell, USA: Jim Hunt
- Still a lot of space to join :)

Reconstruction Chain



Reconstruction Chain



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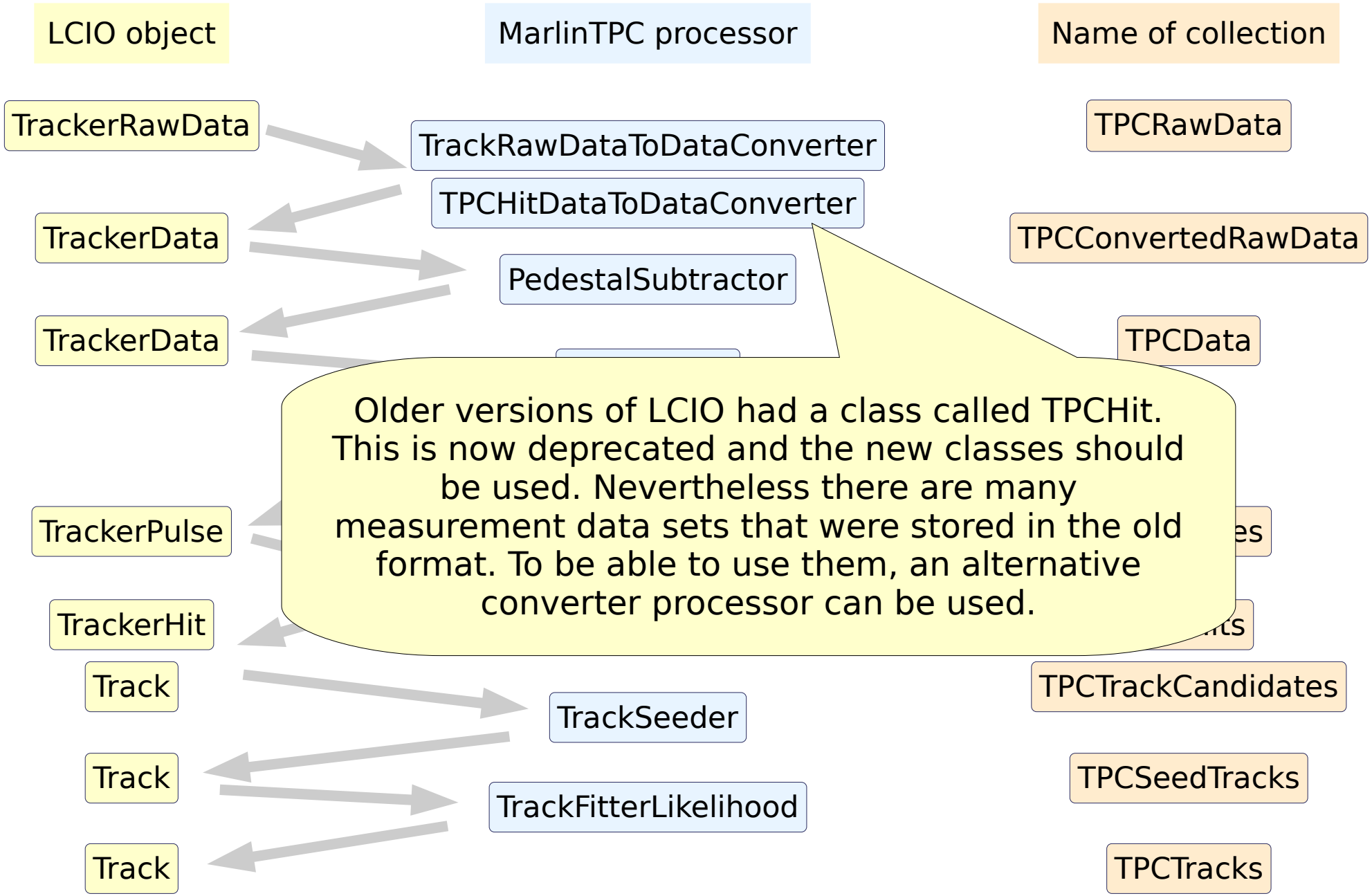

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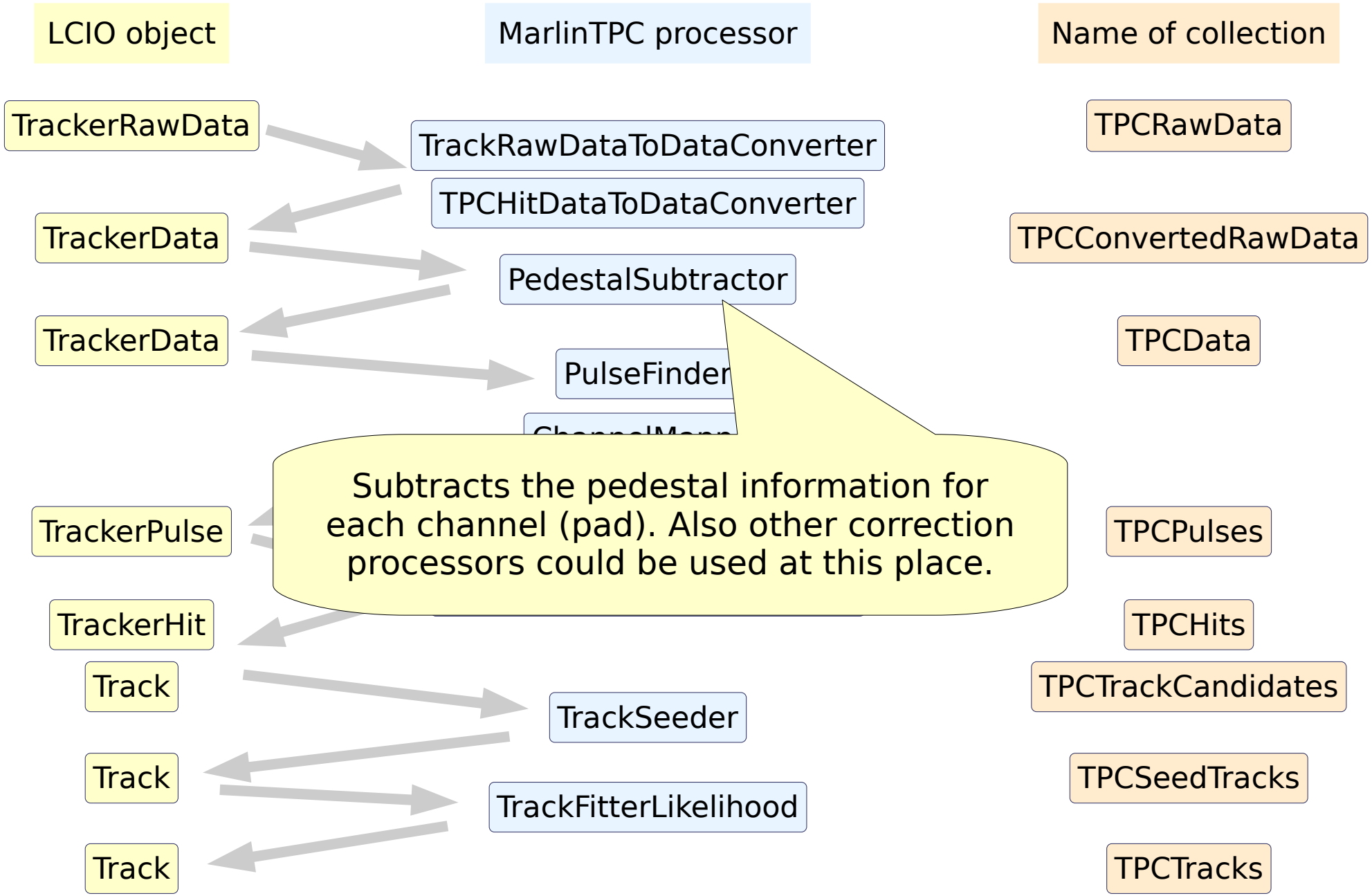

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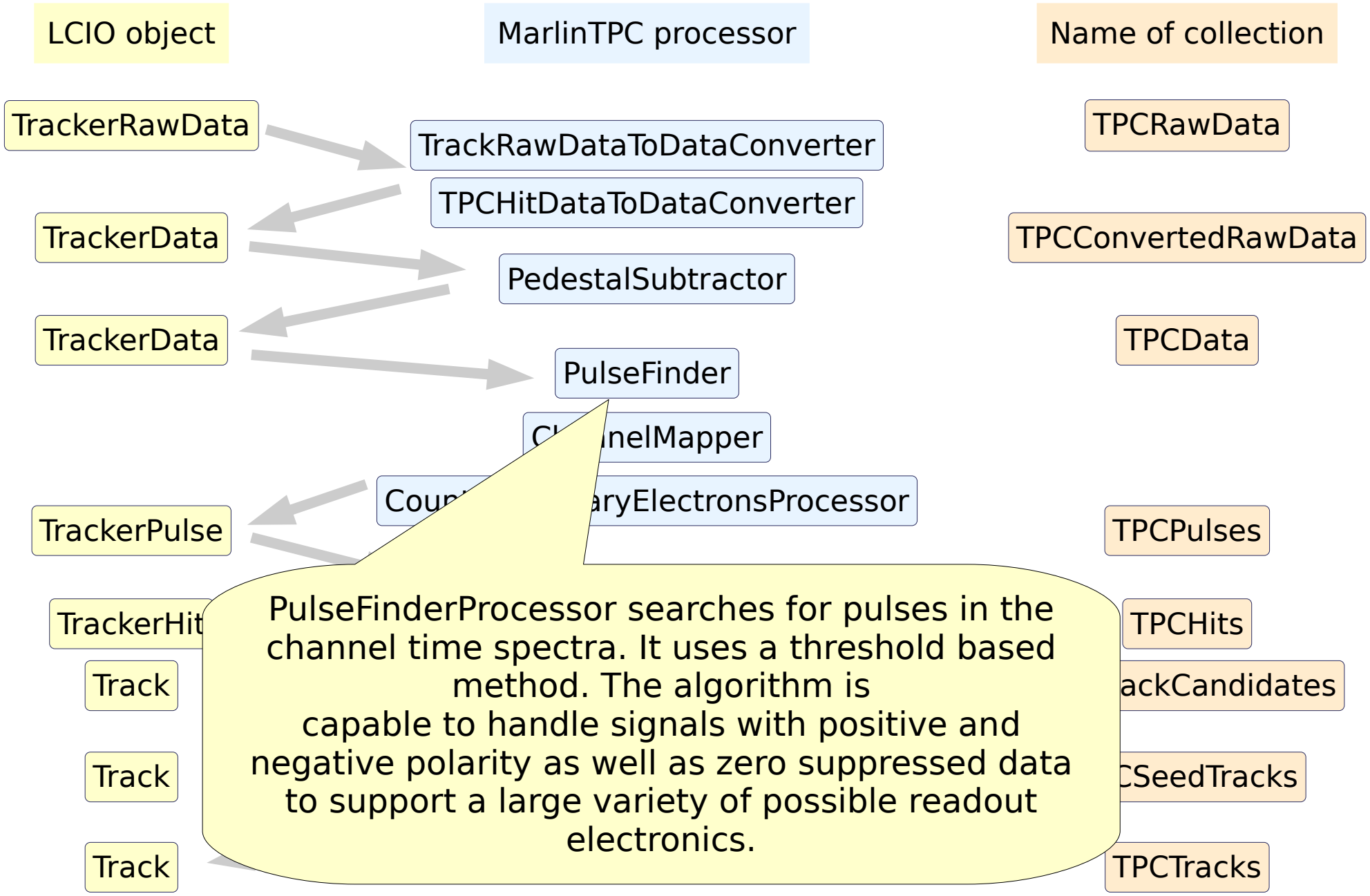

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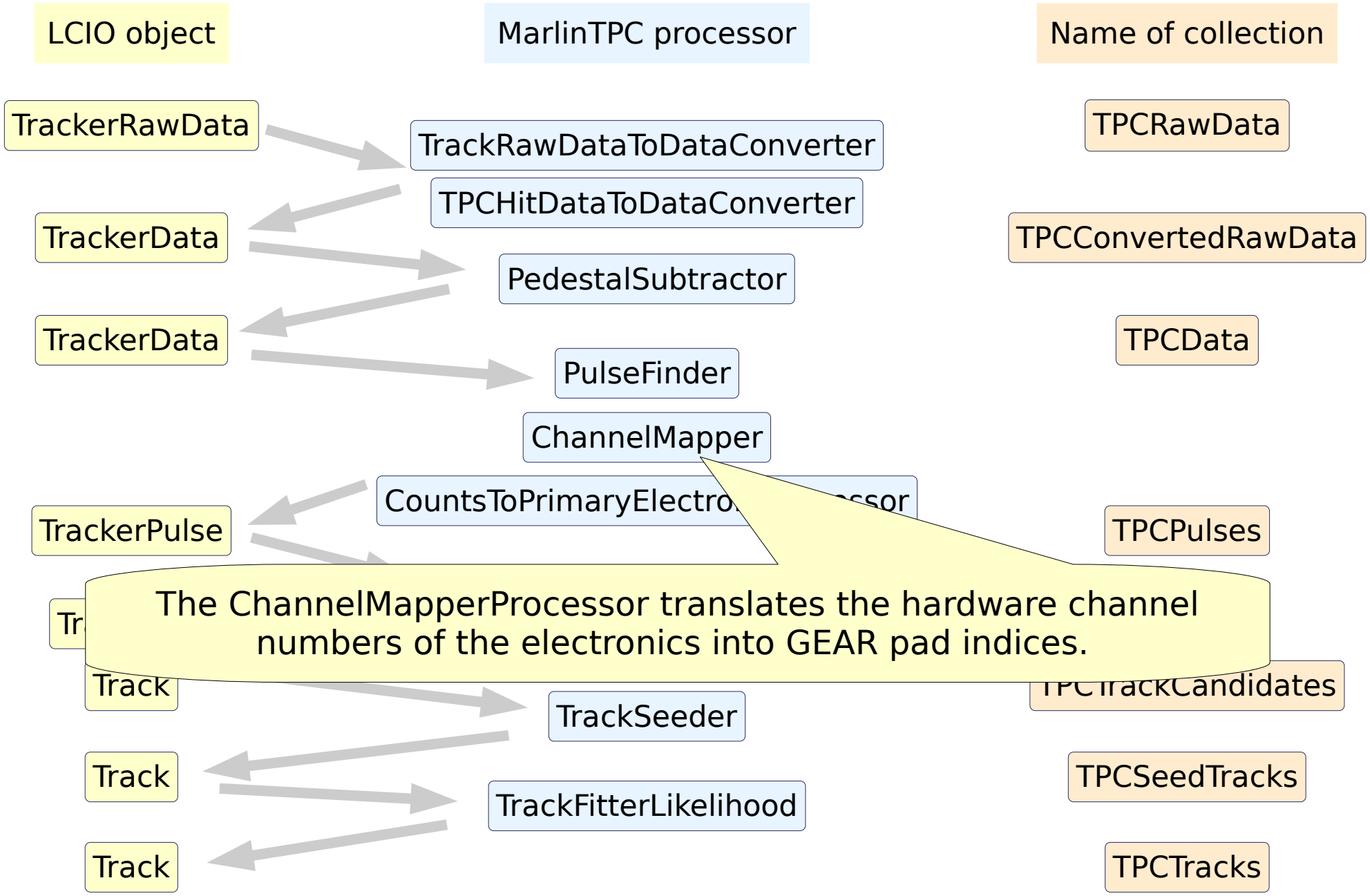

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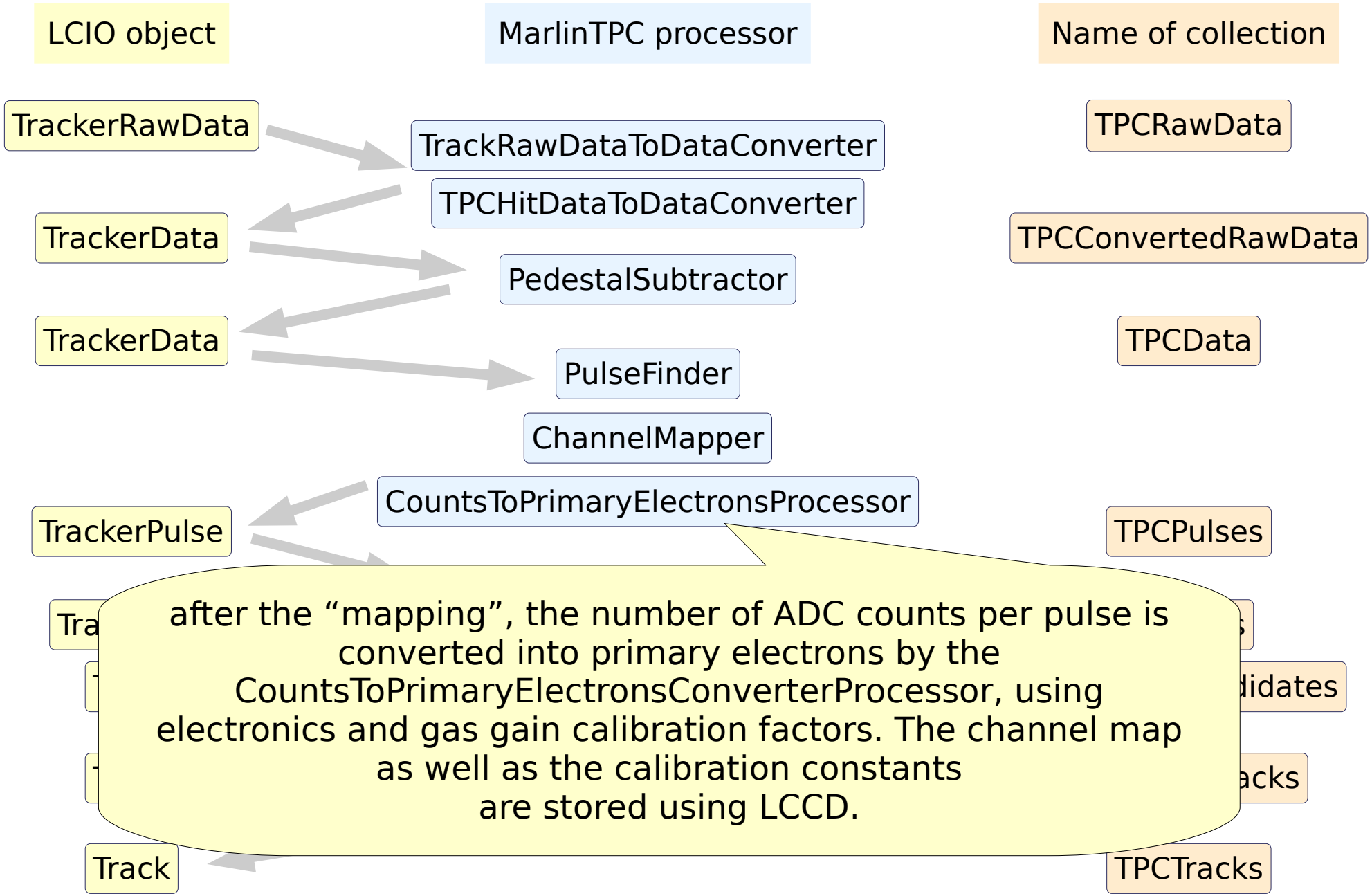

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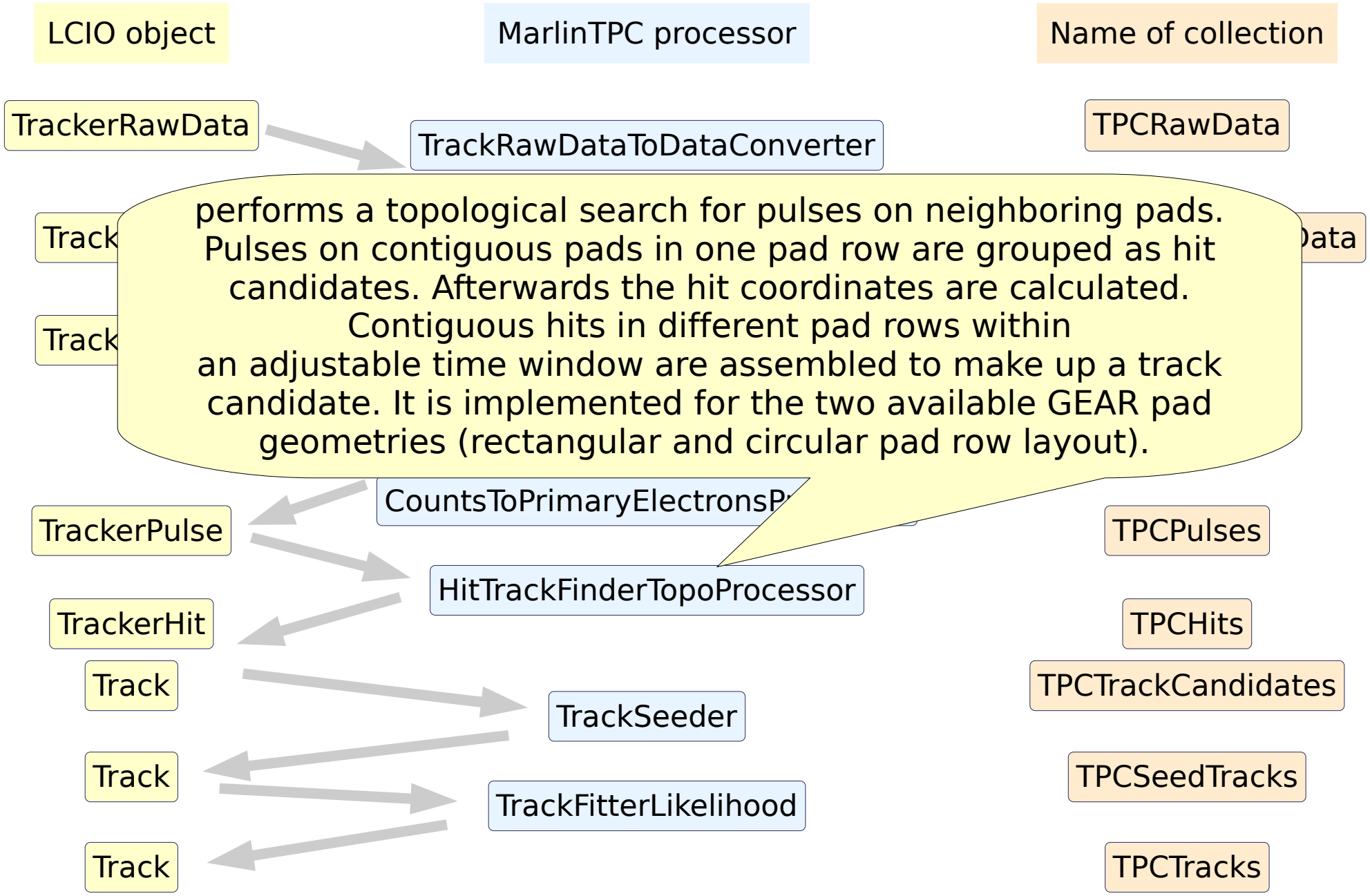

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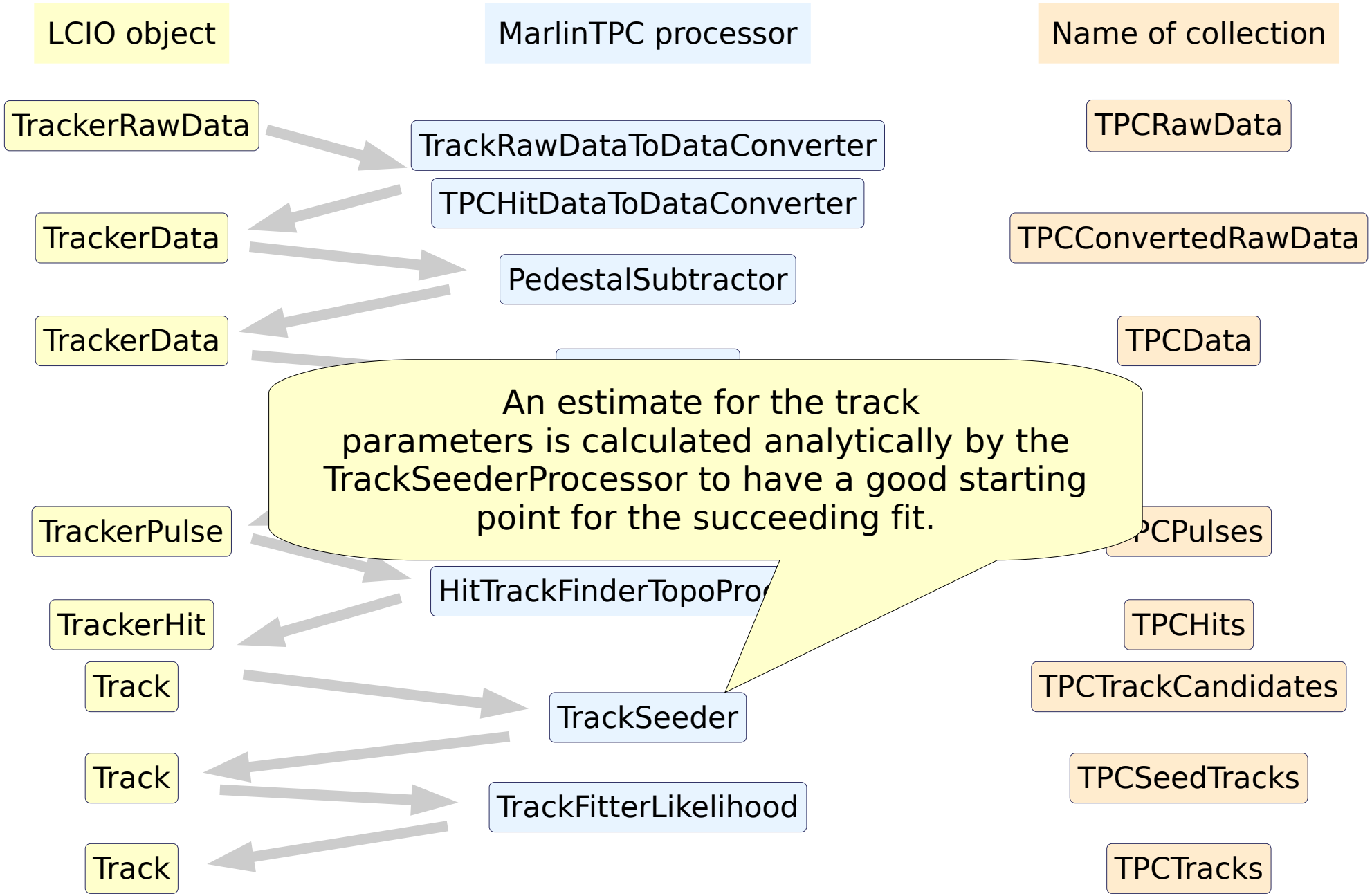

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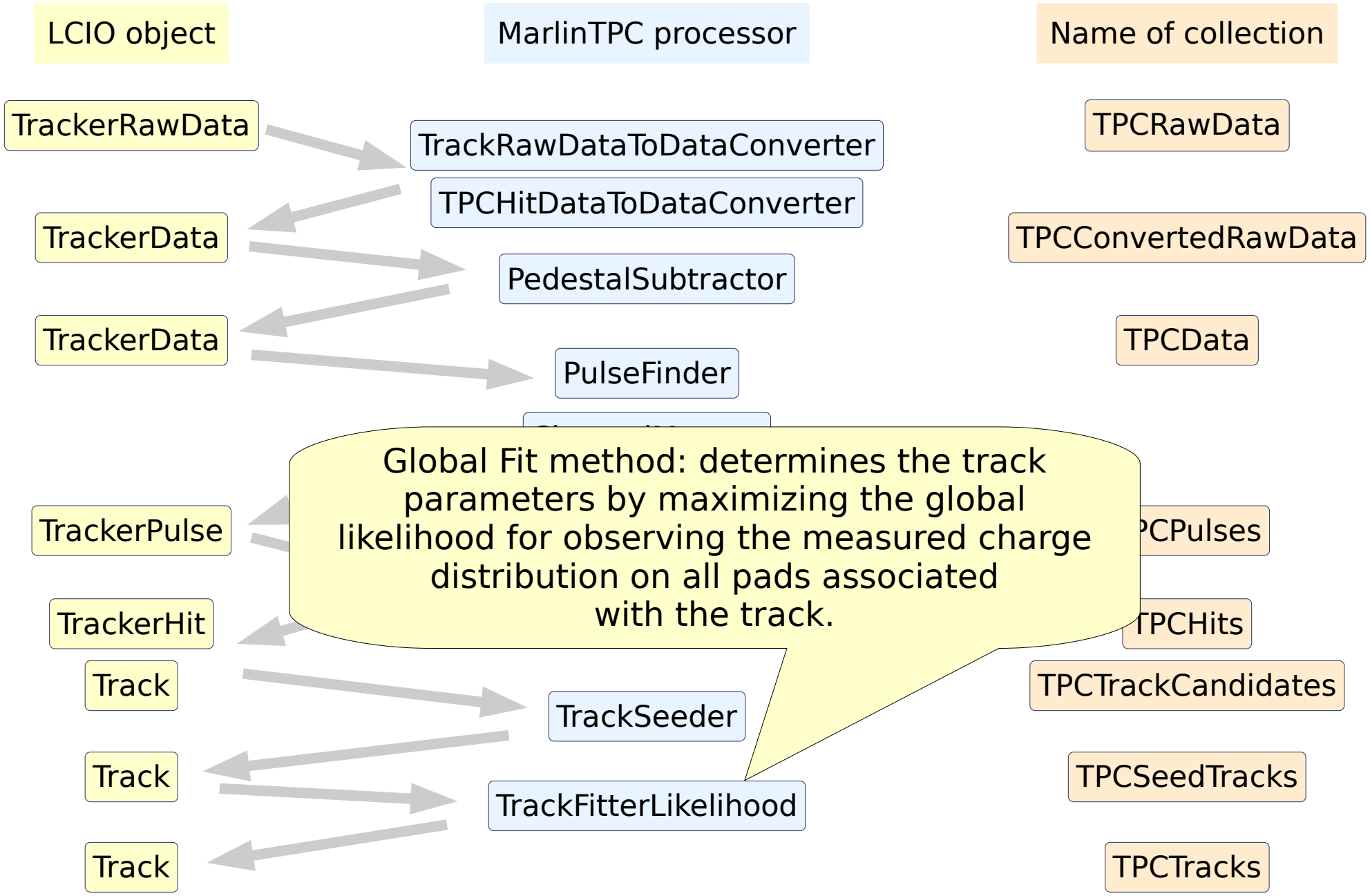
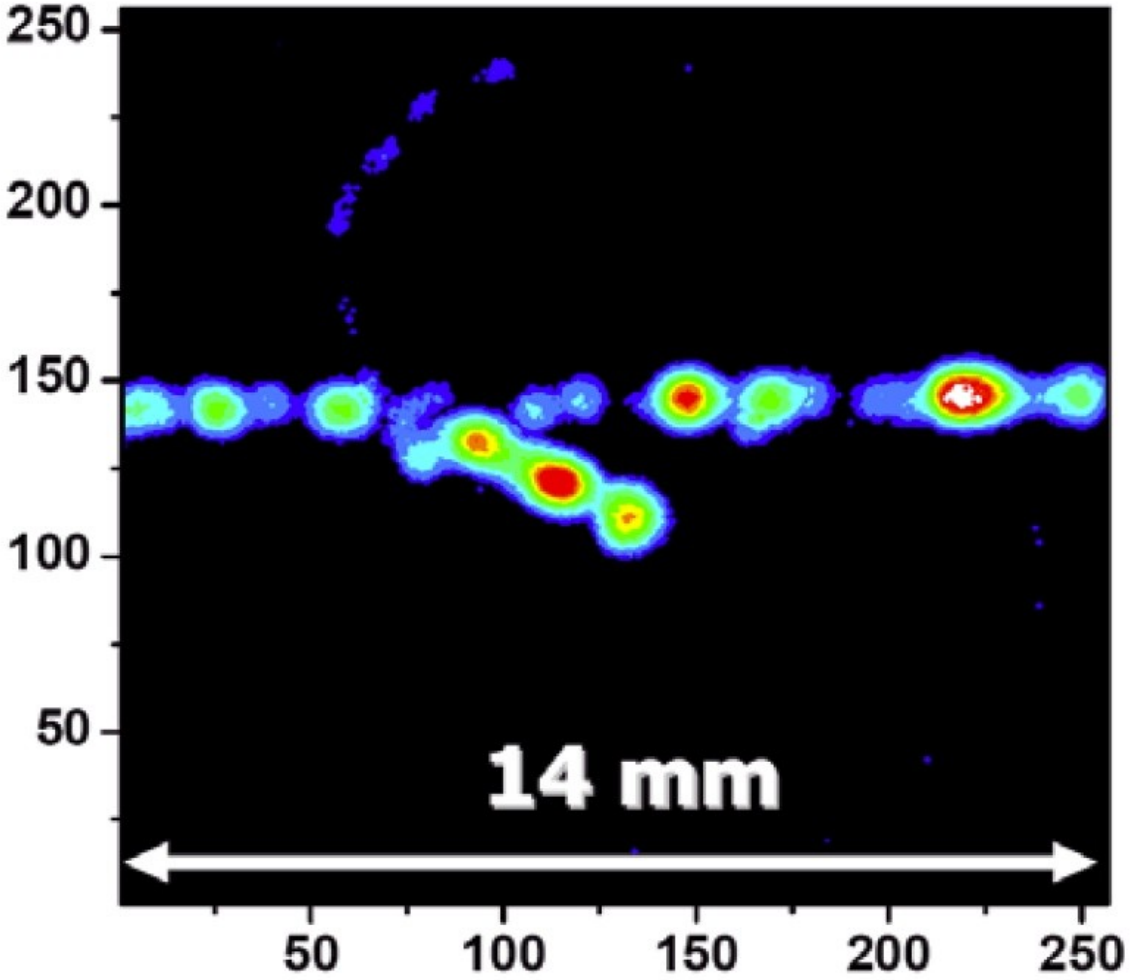


Pixel Reconstruction

- Chip of 256x256 pixels

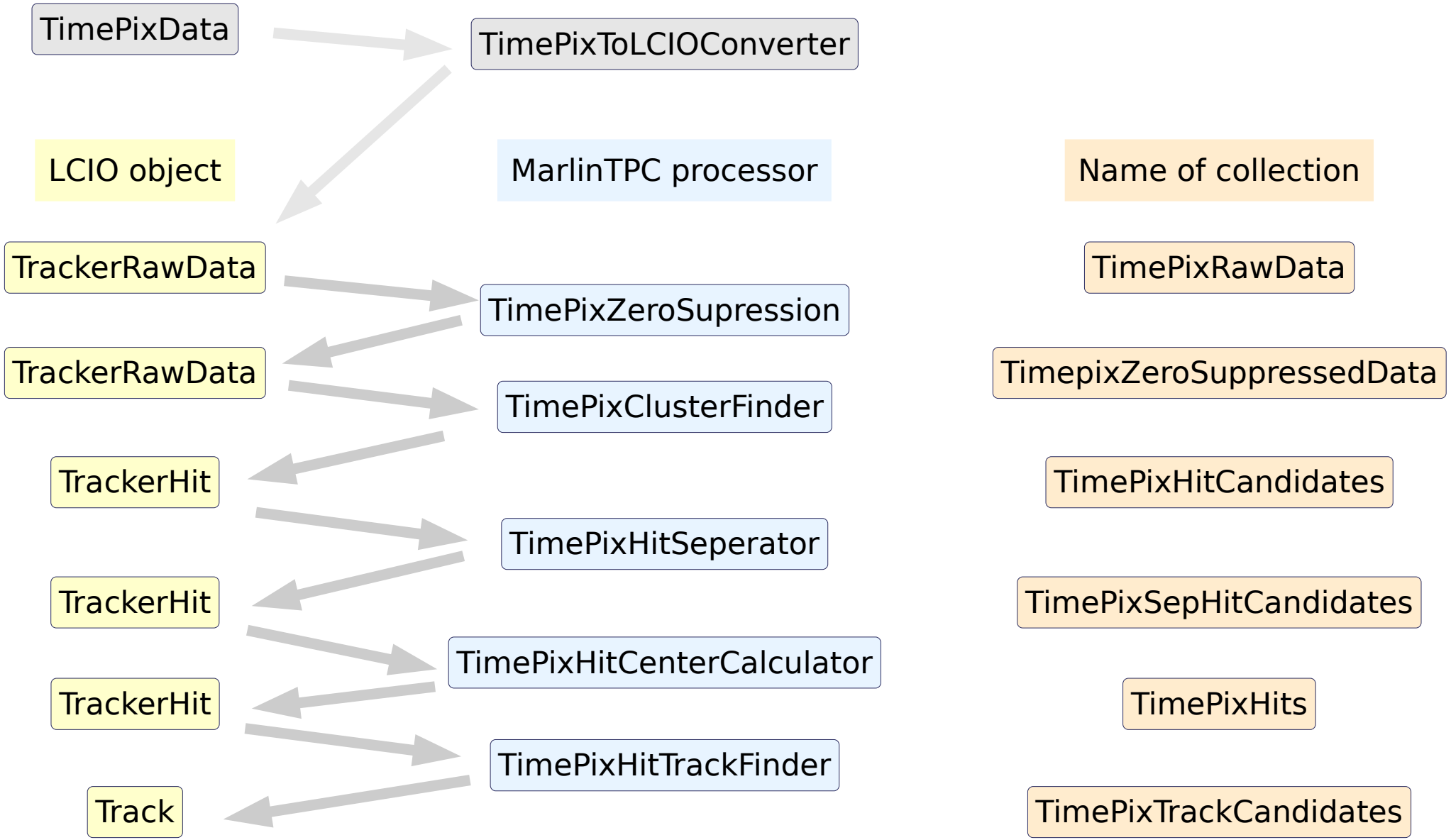
- Each pixel is 55x55μm^2

- Each pixel can operate in two modes:
  - TOT (“time over threshold”) gives measure of the charge
  - TIME gives measure of the drift time => drift length



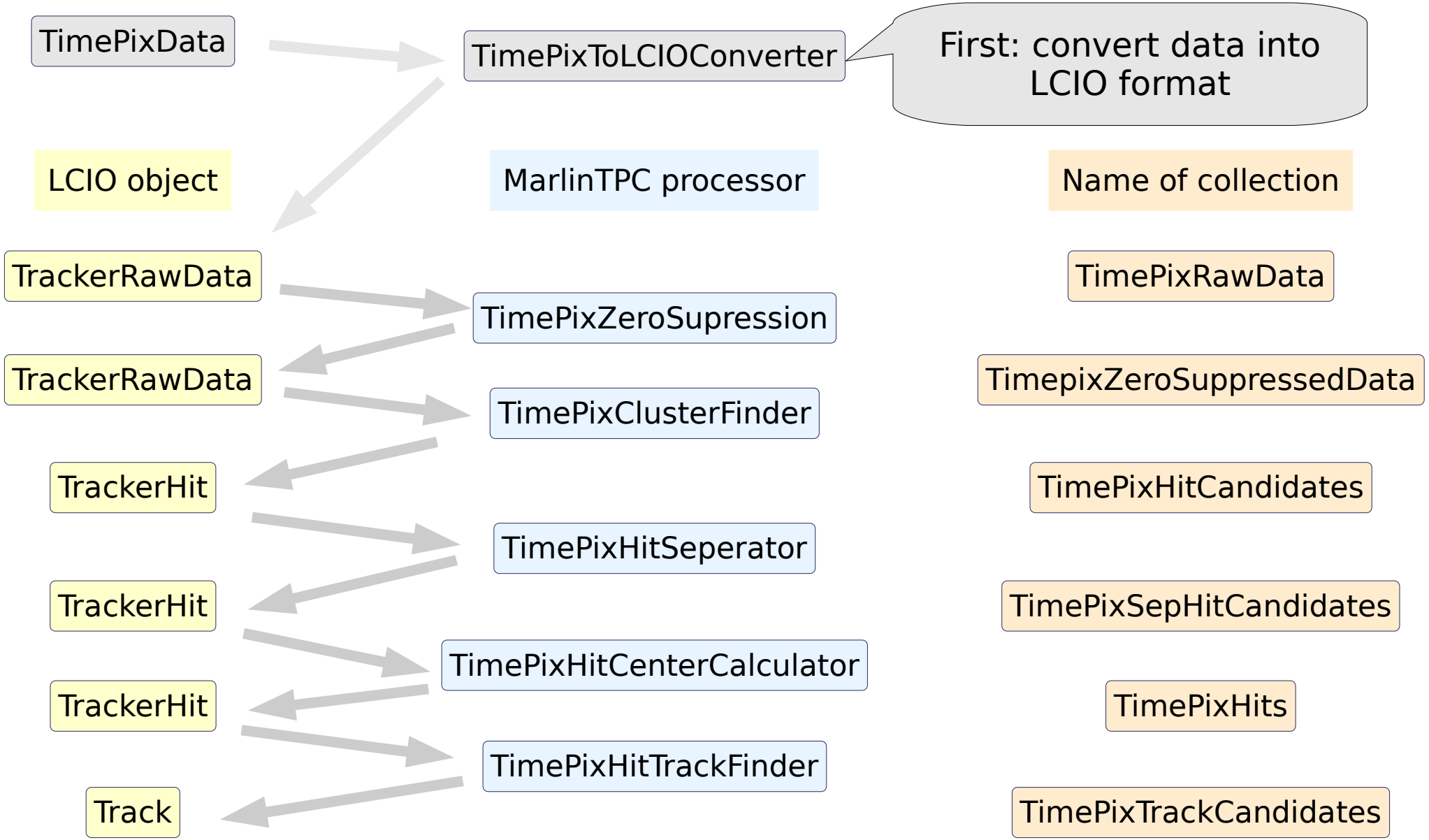
Pixel Reconstruction

- Reconstruction Chain



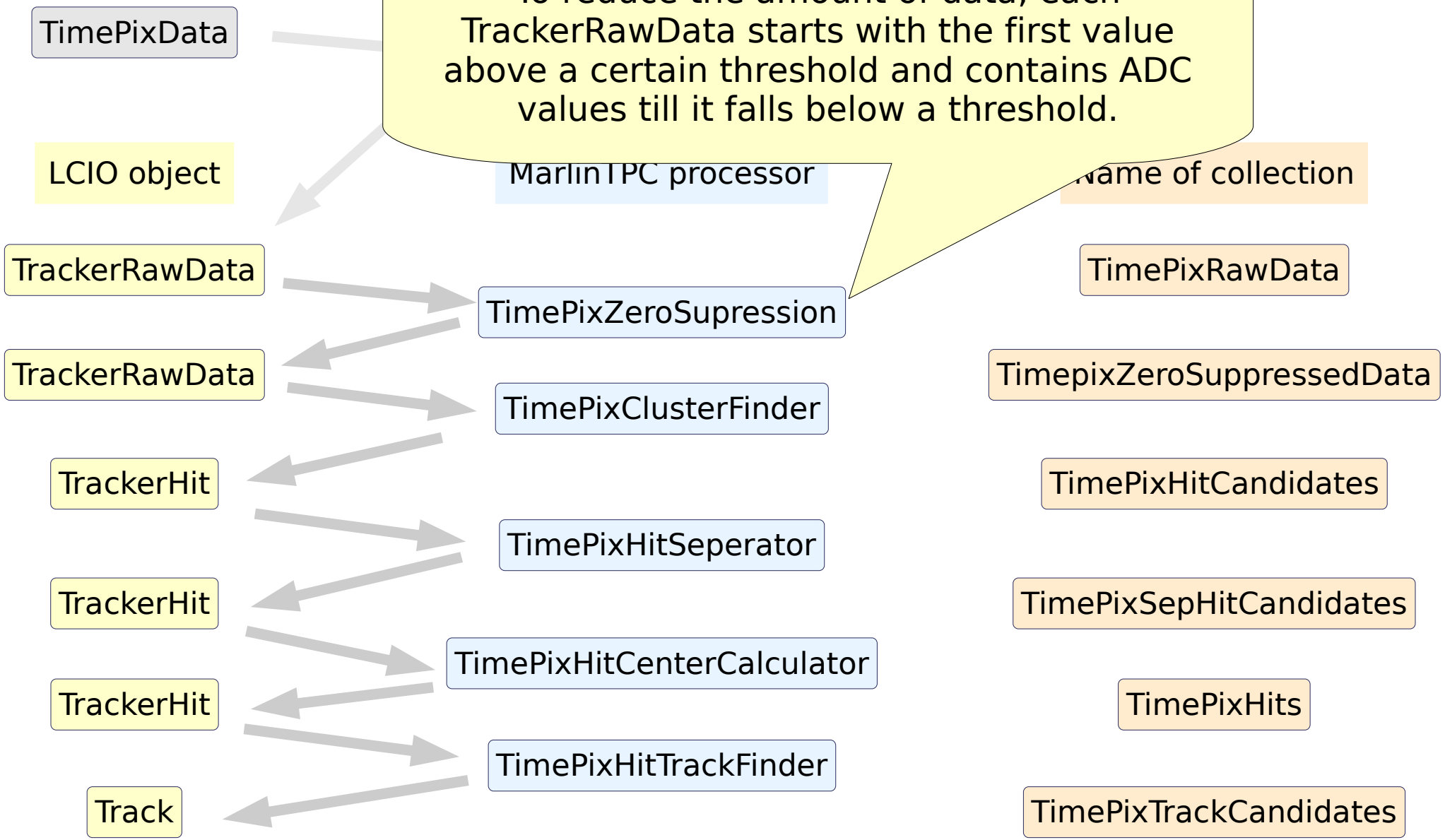
Pixel Reconstruction

- Reconstruction Chain



Pixel Reconstruction

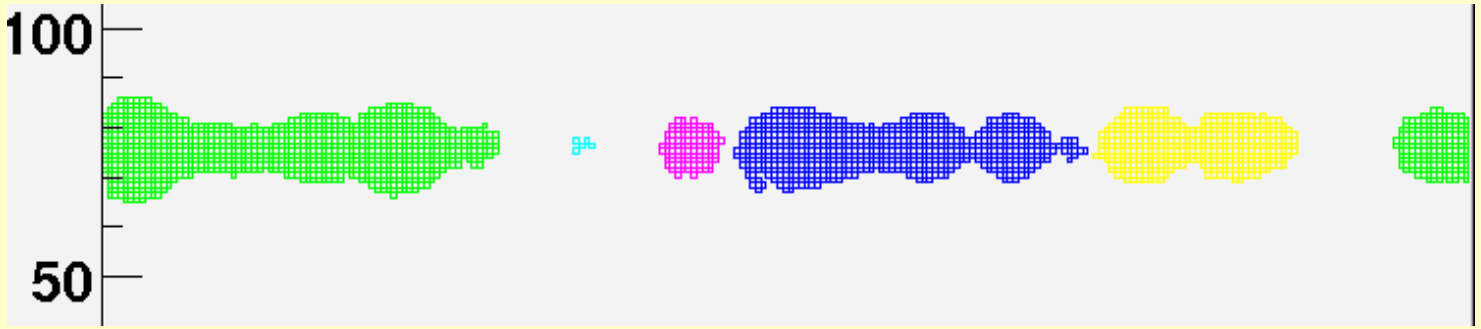
- Reconstruction Ch



Pixel Reconstruction

- Reconstruction Chain

Here adjacent pixels are arranged to clusters. Each cluster is one TrackerHit.



TrackerRawData

TimePixClusterFinder

TrackerHit

TimePixHitCandidates

TimePixHitSeperator

TrackerHit

TimePixSepHitCandidates

TimePixHitCenterCalculator

TrackerHit

TimePixHits

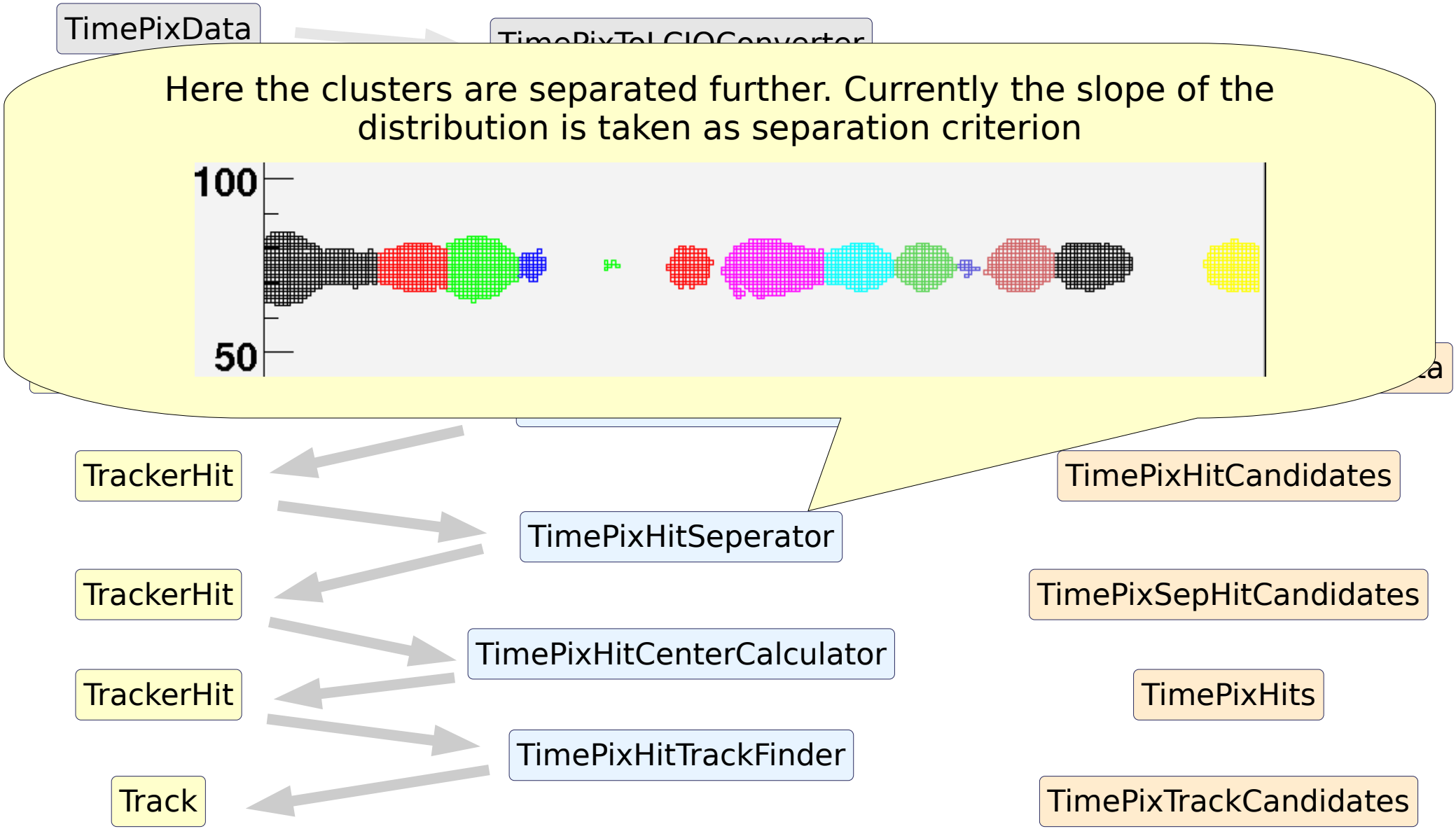
TimePixHitTrackFinder

Track

TimePixTrackCandidates

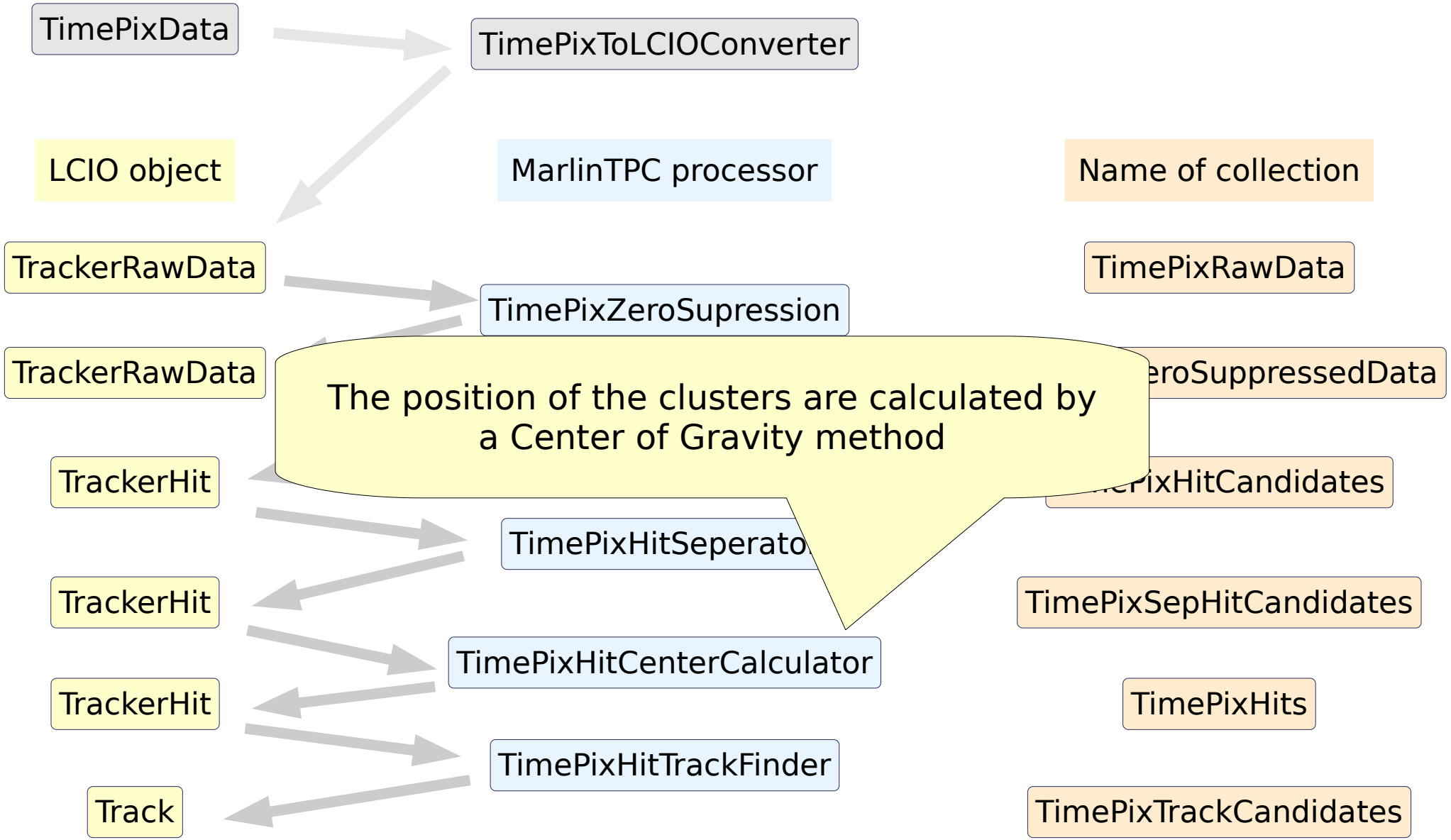
Pixel Reconstruction

- Reconstruction Chain



Pixel Reconstruction

- Reconstruction Chain



Simulation

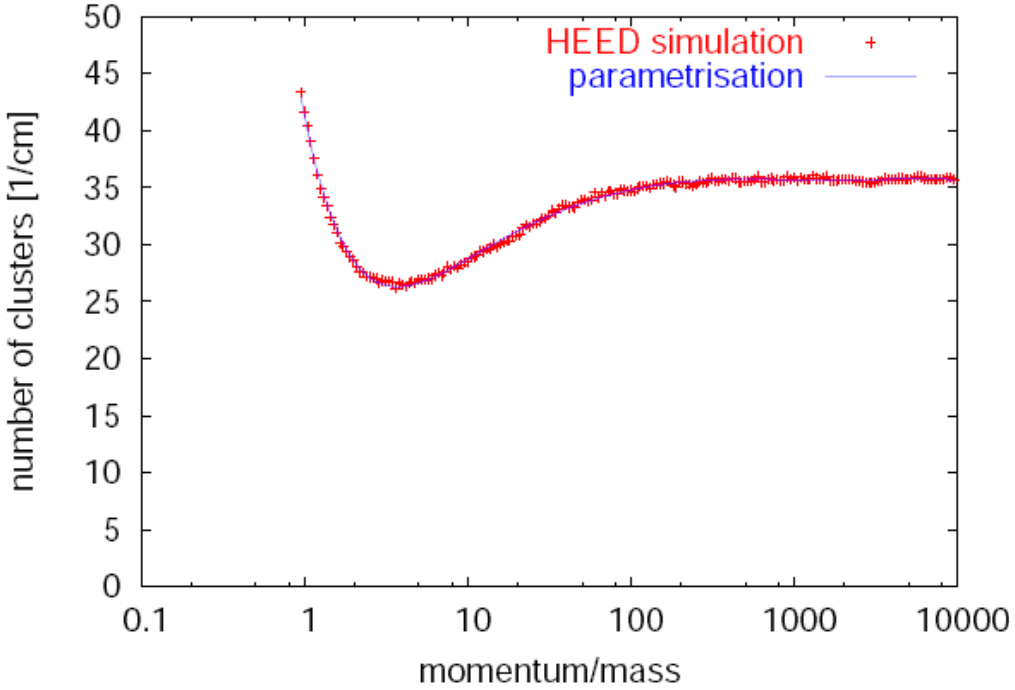
- Simulation package for detailed studies of a TPC.

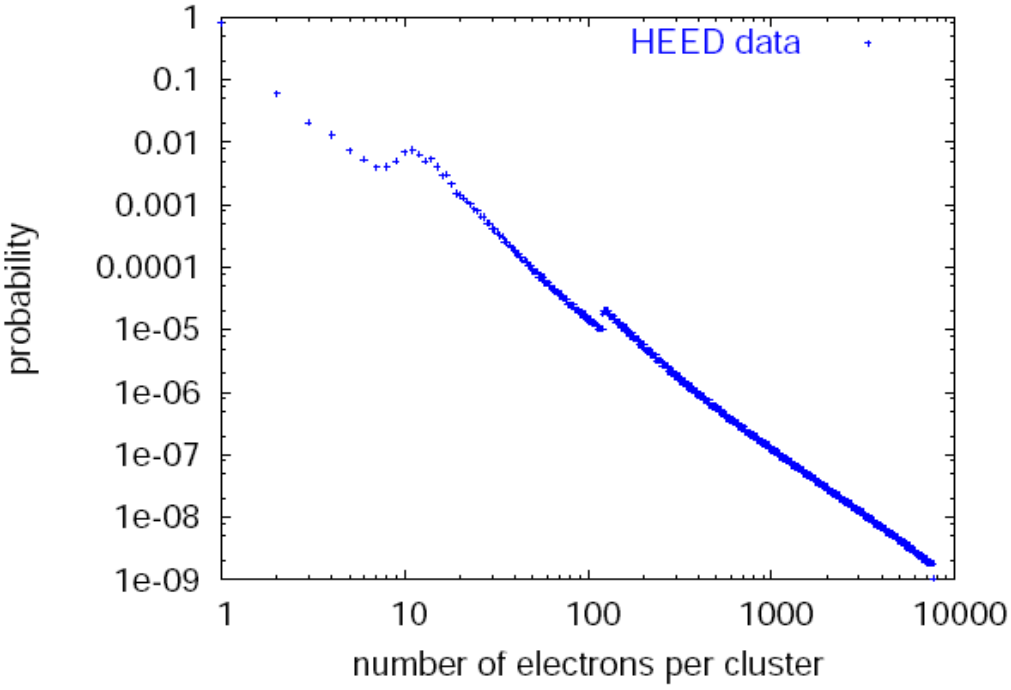
- Started off with TPCGEMSimulation (Astrid Münnich, Aachen) and separated the simulation and the digitization:
  - Parameterized deposition of primary electrons, realistic clusters, delta electrons...
  - Drift of electrons incl. diffusion
  - Detailed simulation of amplification and charge transfer in a GEM stack, incl. gain fluctuations and collection / extraction efficiencies: only for specific gas mixtures. Currently: P5 (Ar:CH_4/95:5), P10 (Ar:CH_4/90:10) and TDR (Ar:CH_4,CO_2/93:5:2)
  - MICROMEGAS amplification simulation still missing

- Every single primary electron is tracked in the TPC. This should provide data realistic enough for a silicon pixel readout.

Simulation: Ionization

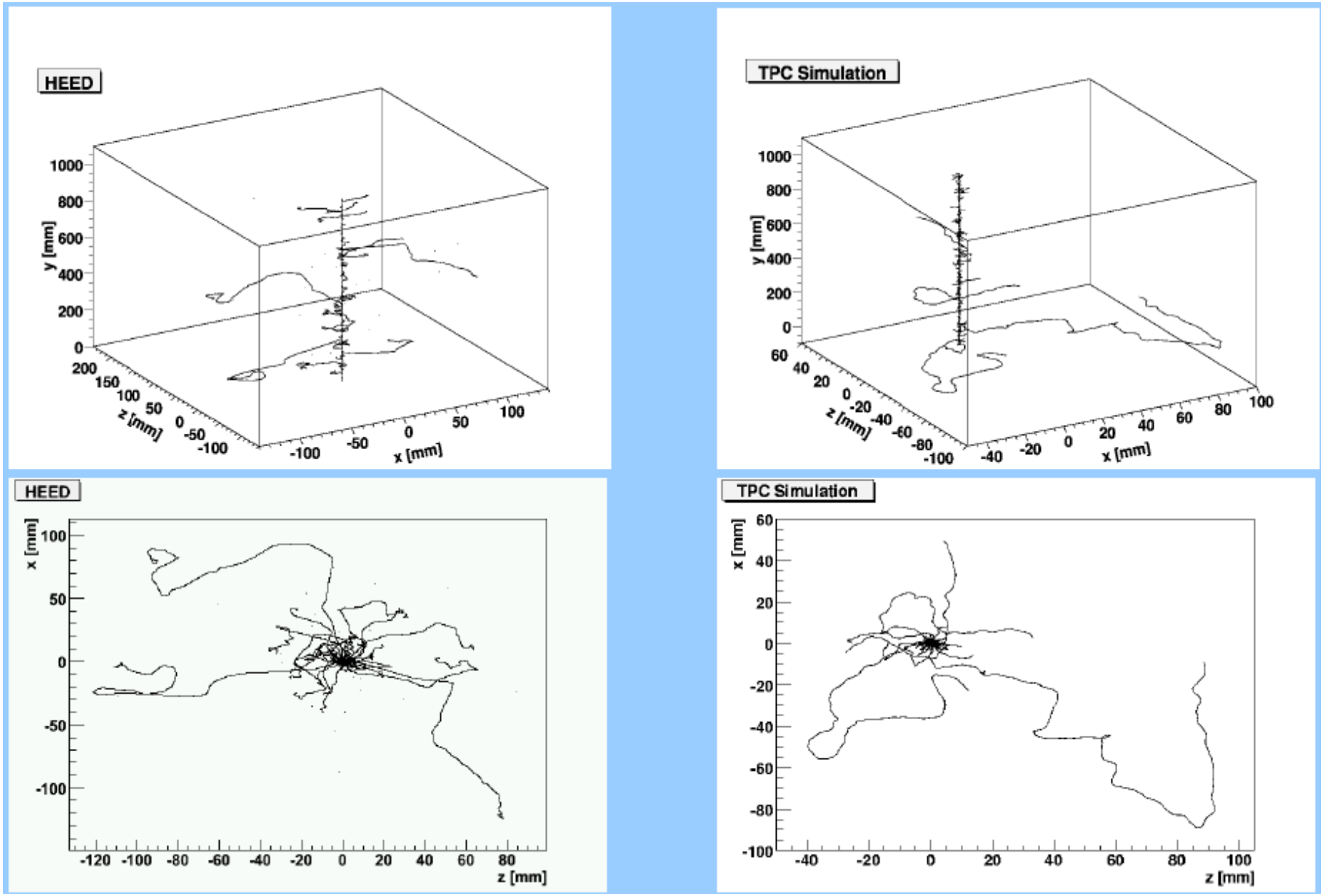
- HEED: Simulation tool for primary ionization:
  → Parametrization of:
- Number of cluster per cm
- Number of electrons per cluster
- Range and energy of delta electrons





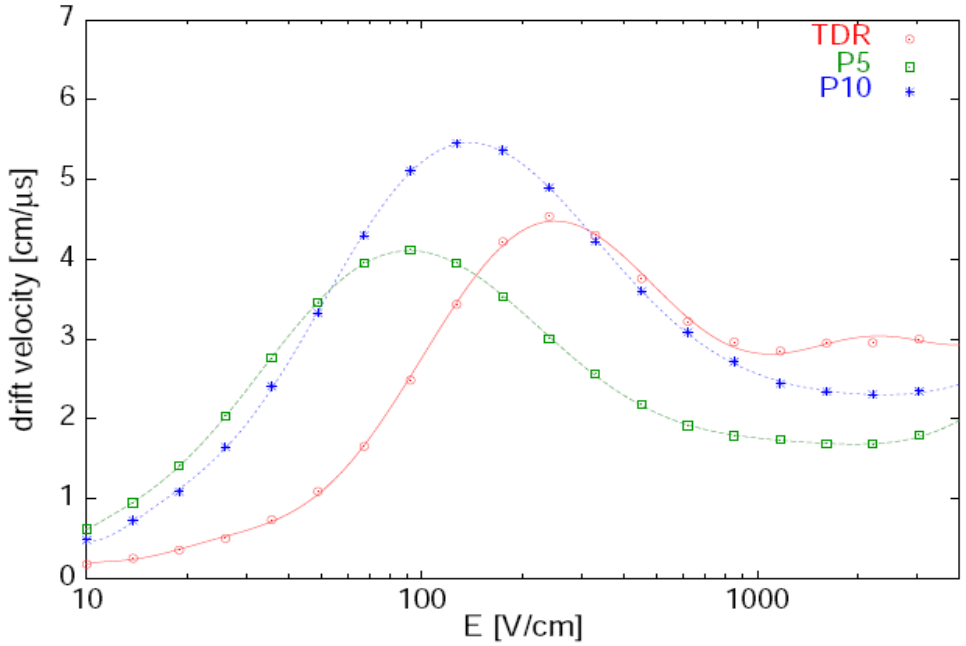
Simulation: Delta Electrons

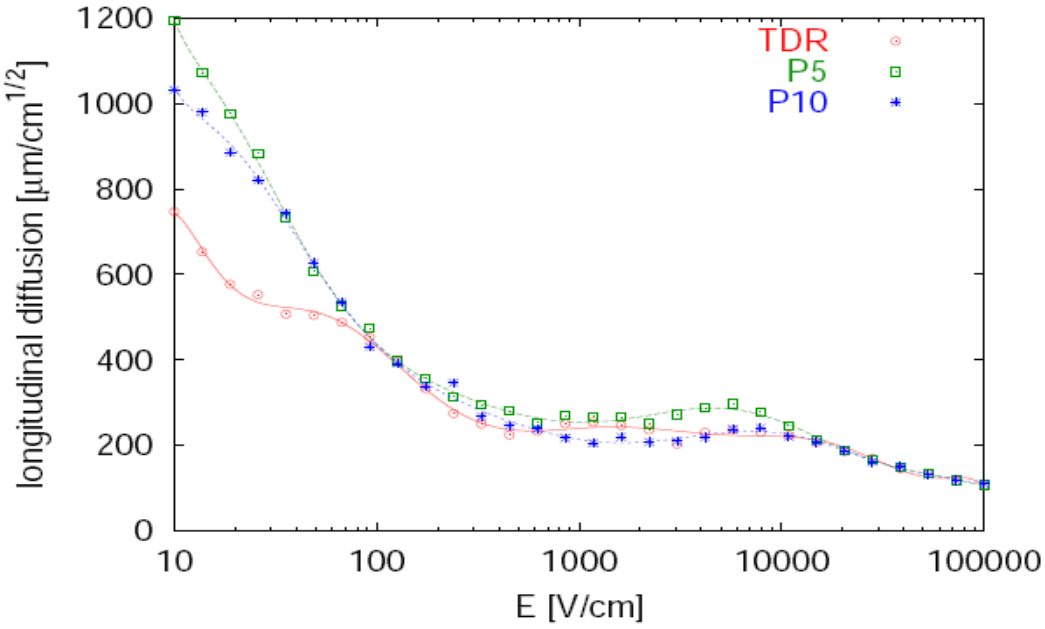
- Multiple scattering of delta electrons

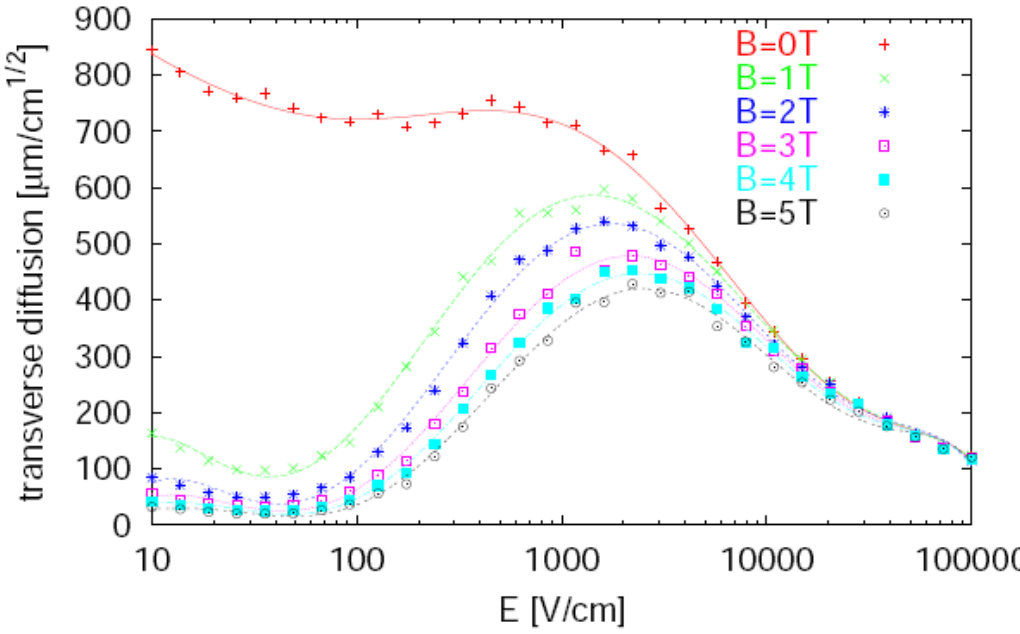


Simulation: Drift

- Values for drift velocity, longitudinal and transverse diffusion from MAGBOLTZ are parametrized



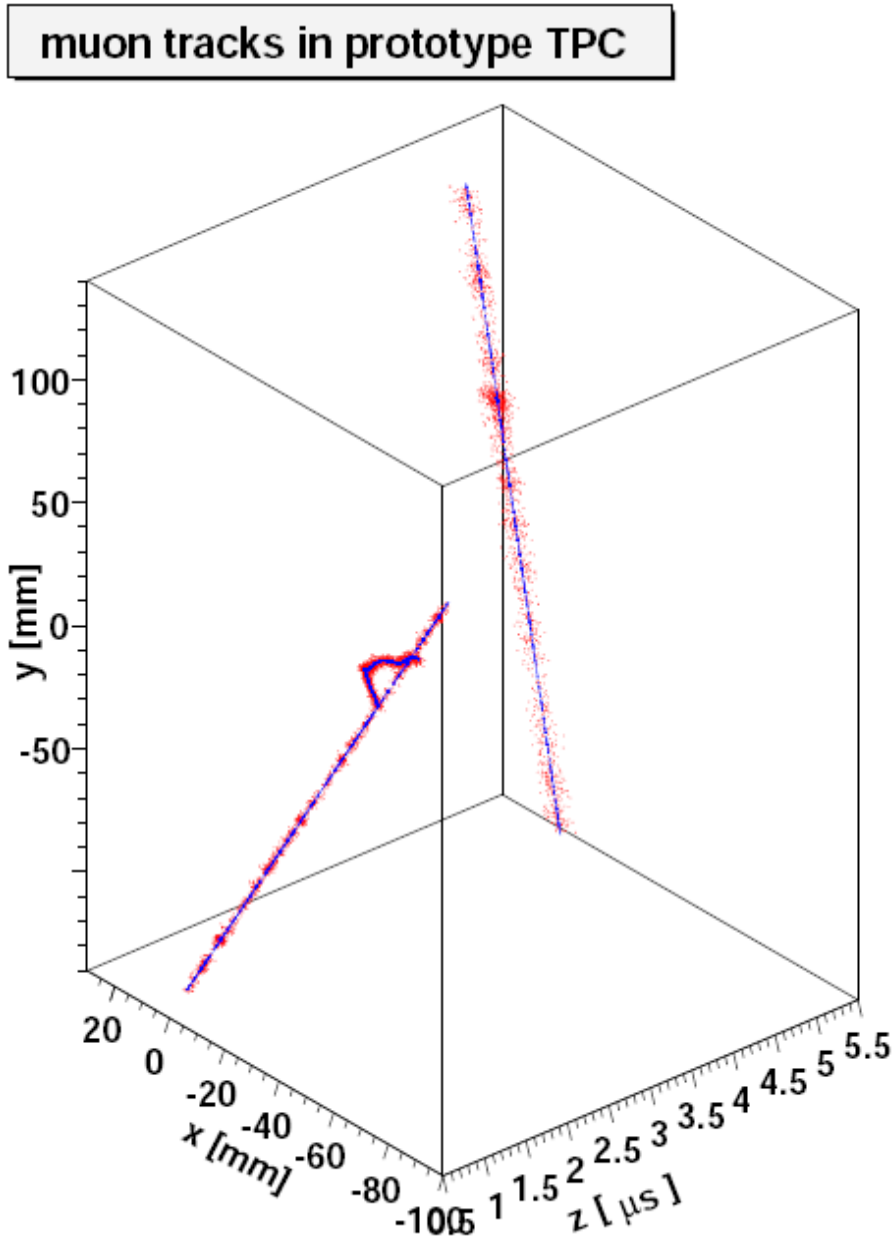




Simulation: Drift

- Example:
  two muon tracks in a TPC

- The primary ionization forms a straight line of electrons (blue) and the propagated electrons are scattered due to diffusion (red).
  The clustering process along the track is now visible for the drifted electrons.



Simulation: GEM Amplification

- Parameters derived from measurements
- Parametrization of charge transfer in triple GEM structure: collection, gain, extraction
- Charge broadening only due to diffusion between GEMs
  → Simulate diffusion with Magboltz values
- To limit the computing time:
  Electrons produced in the amplification process are not tracked individually, but:
- For each electron entering the GEM structure the number of secondary electrons reaching the anode is calculated.
- The distribution on the pad plane is assumed to be two dimensional Gaussian. The width given by the diffusion between the GEMs.

Simulation: GEM Amplification

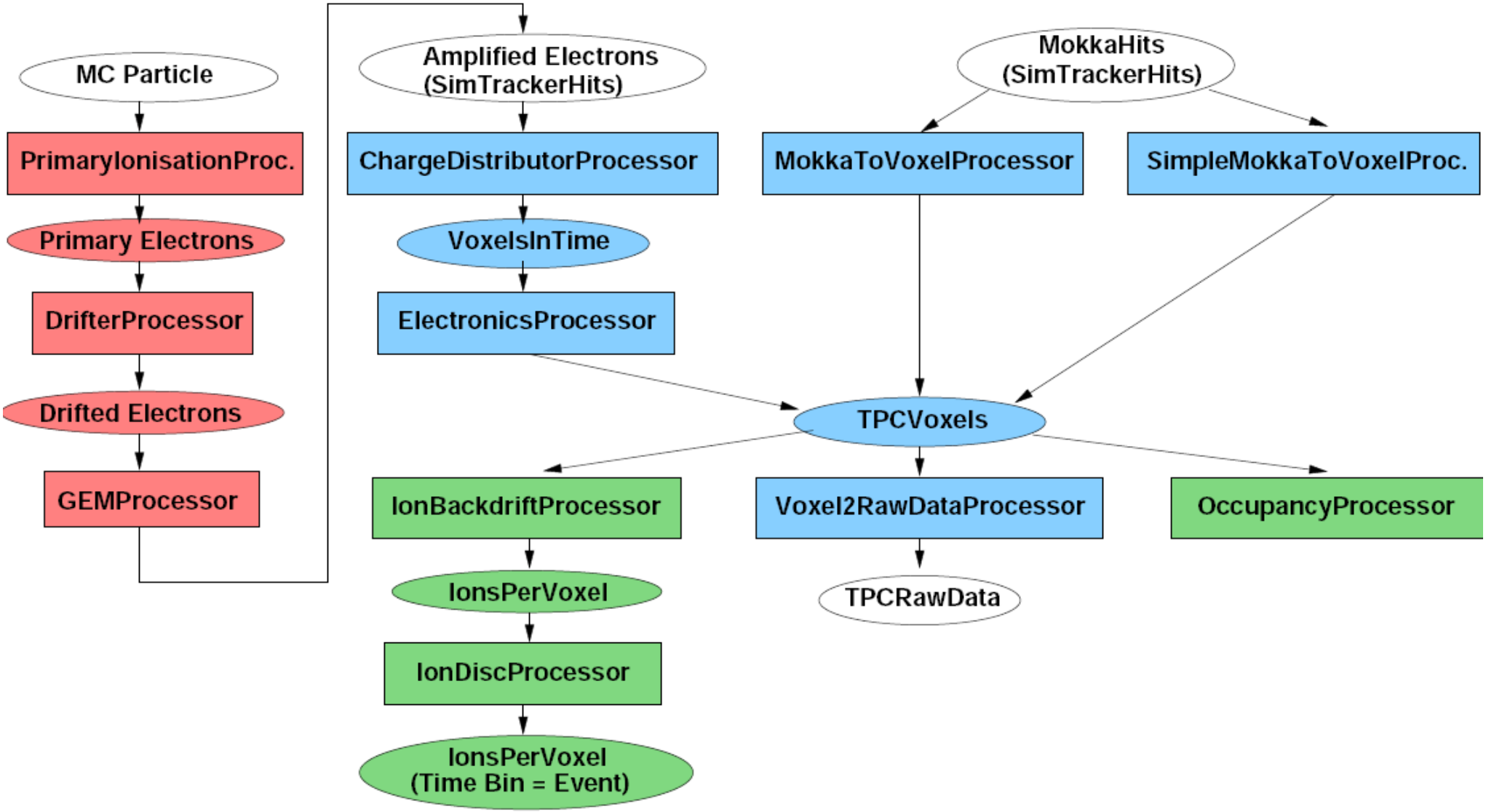
- Example of the statistic processes for one specific electron at each step in the GEM structure. The number of electrons given represents one example of random numbers generated according to the corresponding distribution in each step.

	after step	number of electrons	average efficiency or gain
GEM 1	collection	1	1
	gain	70	65
	extraction	24	0.35
	attachment	22	0.921
GEM 2	collection	14	0.66
	gain	1165	66
	extraction	389	0.35
	attachment	358	0.921
GEM 3	collection	245	0.66
	gain	17255	68
	extraction	9202	0.54
	attachment	7322	0.796

Simulation

- More information about the simulation principles and performance:
  “Simulation Studies for a High Resolution Time Projection Chamber at the International Linear Collider”, PhD thesis of Astrid Münnich (Aachen), 2007
  (most of the plots were “*borrowed*” from there)
  http://web.physik.rwth-aachen.de/~tpcmgr/en/index.html

Simulation and Digitization



Analysis

- Planned:
  - Provide a set of processors implementing the default analyses agreed on at first TPC Analysis Jamboree 2006 in Hamburg.
  - Resolution using geometric mean of fits with and without the test row
  - Resolution using external reference track (hodoscope or MC truth)
  - Resolution in dependence on the drift distance
  - Distribution showing number of 1-pad, 2-pad, 3-pad hits
  - Bias plots (residuals vs. position on the pad)
  - ...

MarlinTPC

- More information can be found on the MarlinTPC webpage on the http://ilcsoft.desy.de portal:
  http://ilcsoft.desy.de/portal/software_packages/marlintpc

- Help when using (developing) MarlinTPC is best searched in the linearcollider forum:
  http://forum.linearcollider.org/
  (here you can also find help regarding other software for the Linear Collider like LCIO etc.)
  There are also irregular phone meetings (EVO) for the developers

- It is now integrated in the ilcinstaller, which makes it easy to install:
  http://ilcsoft.desy.de/portal/software_packages/ilcinstall