Introduction to LArSoft

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art/LArSoft Course

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Goals for this session

- Provide overview of LArSoft project, collaboration and software
- Introduce basic concepts and workflows
- Summarize primary LArSoft design principles
- Provide simple example of how to use LArSoft
- Summarize available resources and documentation

Outline

- What is LArSoft?
- Operation of single-phase LAr TPC
- Primary reconstruction overview
  - Workflow and data structures
- Secondary reconstruction
- Simulation overview
- LArSoft design principles
- Using LArSoft
- Resources

What is LArSoft?

- A project / collaboration
  - Provide an integrated, art-based, experiment-agnostic set of software tools for LAr neutrino experiments to perform simulation, reconstruction and analysis
    - The core LArSoft (“project”) team maintains infrastructure, architecture, interfaces, coordination, code management and distribution
    - Experiment partners provide technical requirements, development effort and coordination, required experiment-specific plug-ins and configuration
- A body of code
  - Core LArSoft products
    - Experiment-agnostic data structures, algorithms, interfaces, etc
    - Lives in a set of repositories managed by the core LArSoft team
  - Experiment-specific components
    - Detector-specific geometry descriptions, electronics response functions, calibration functions, etc.
    - Live in repositories managed by the experiments

What is LArSoft?

- The collaboration of experiments, Fermilab, other stakeholders in the project
  - DUNE/35T/LBNF
  - MicroBooNE
  - SBND
  - LArIAT
  - ArgoNeuT
  - NuTools
  - art
  - Pandora
  - Core LArSoft project
  - Future participating experiments, laboratories and projects

The experiments define requirements, schedules, priorities

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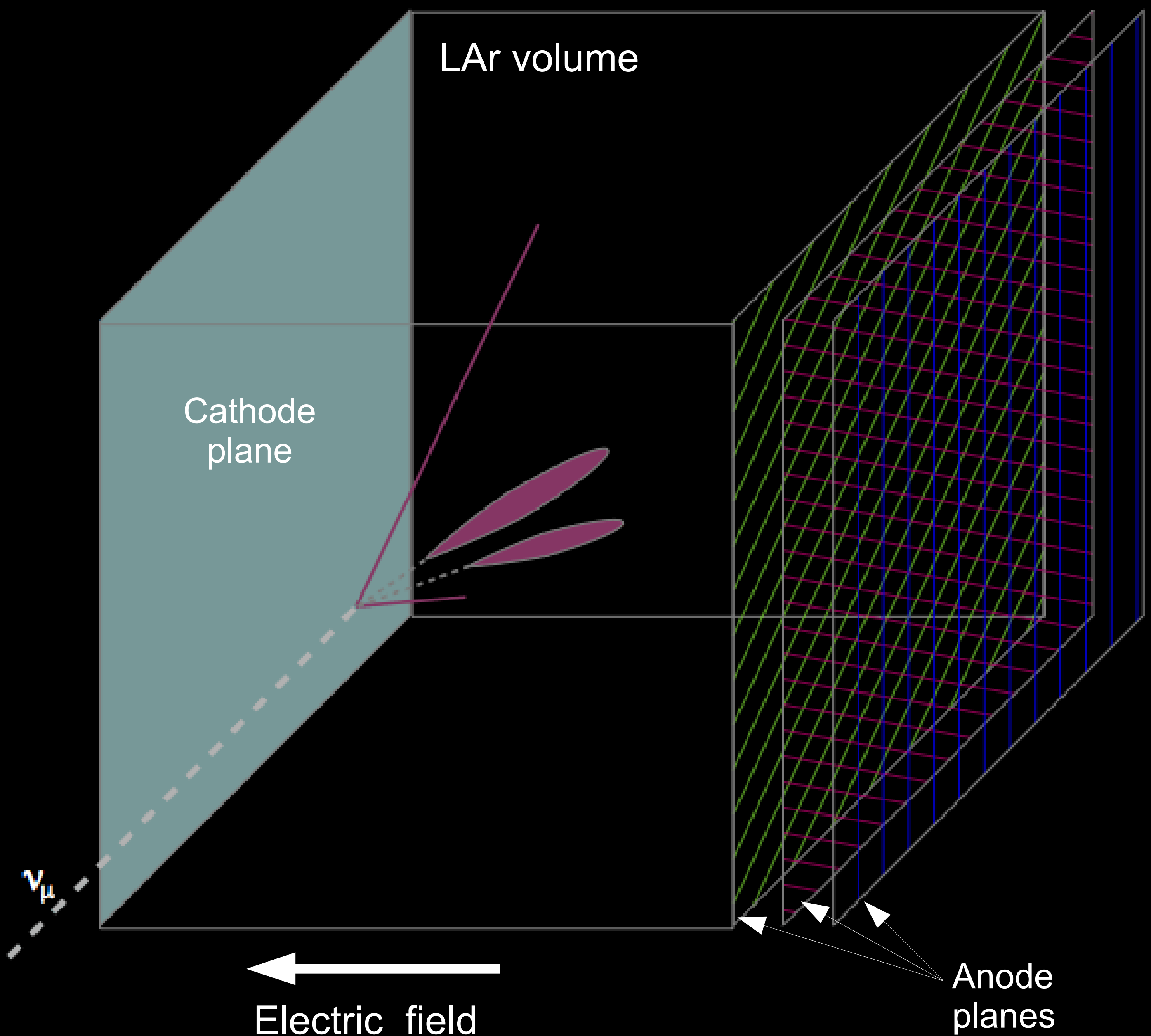
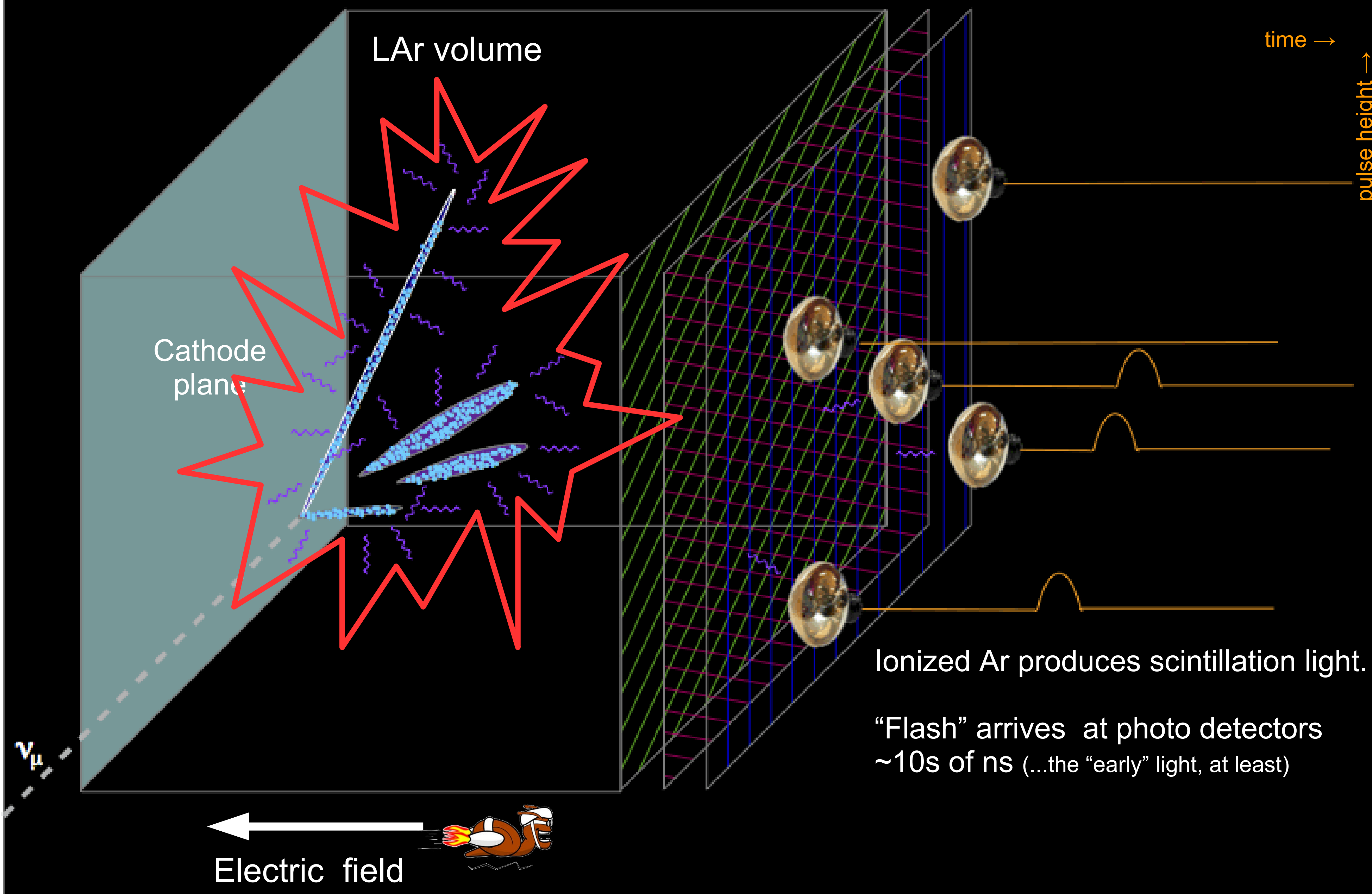
To understand the code and how it is made detector-agnostic, start with the operation of a LAr TPC

Operation of a single-phase LAr TPC

Operation of single-phase LAr TPC



Operation of single-phase LAr TPC



Ionized Ar produces scintillation light.

“Flash” arrives at photo detectors ~10s of ns (...the “early” light, at least)

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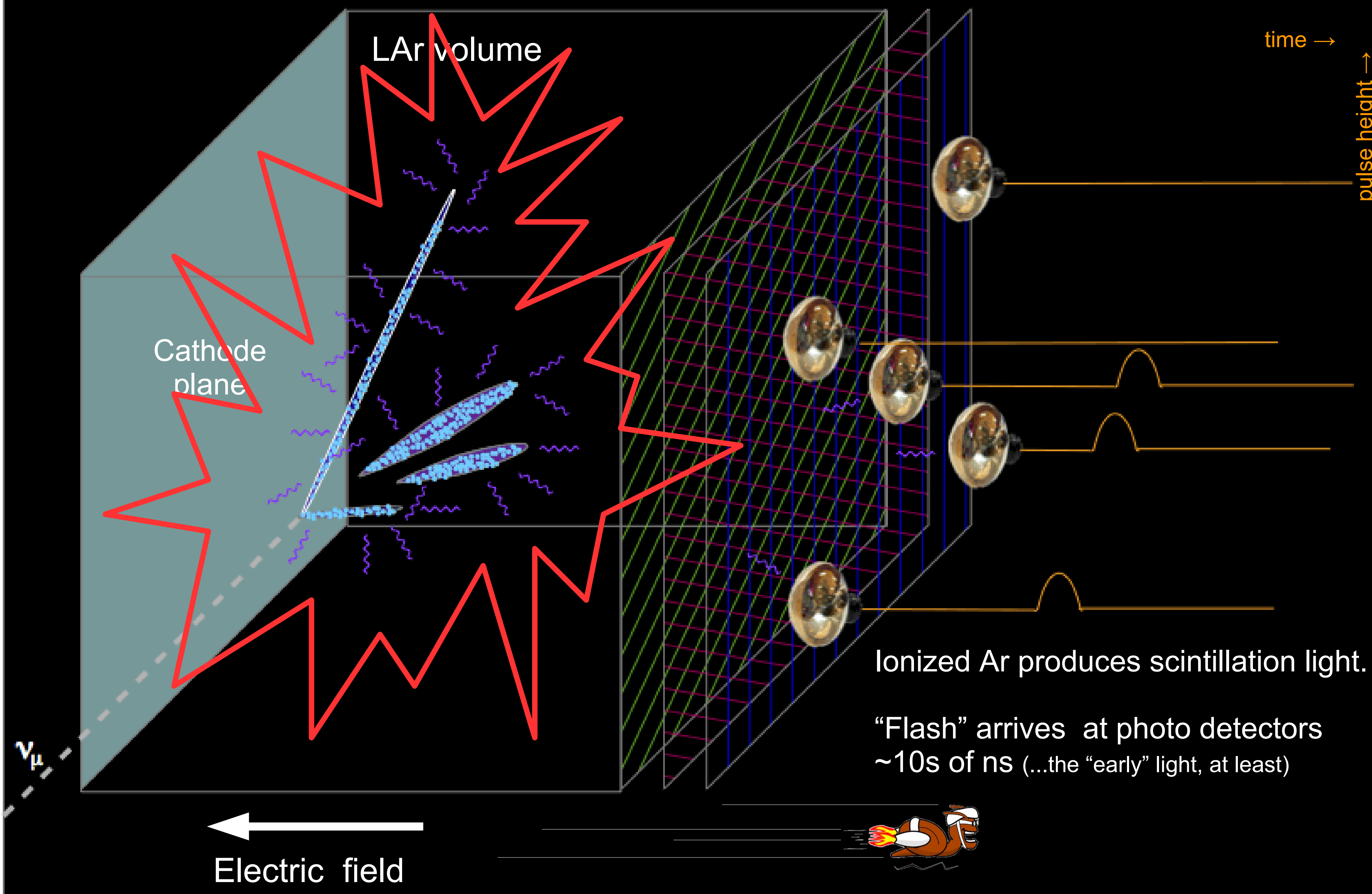

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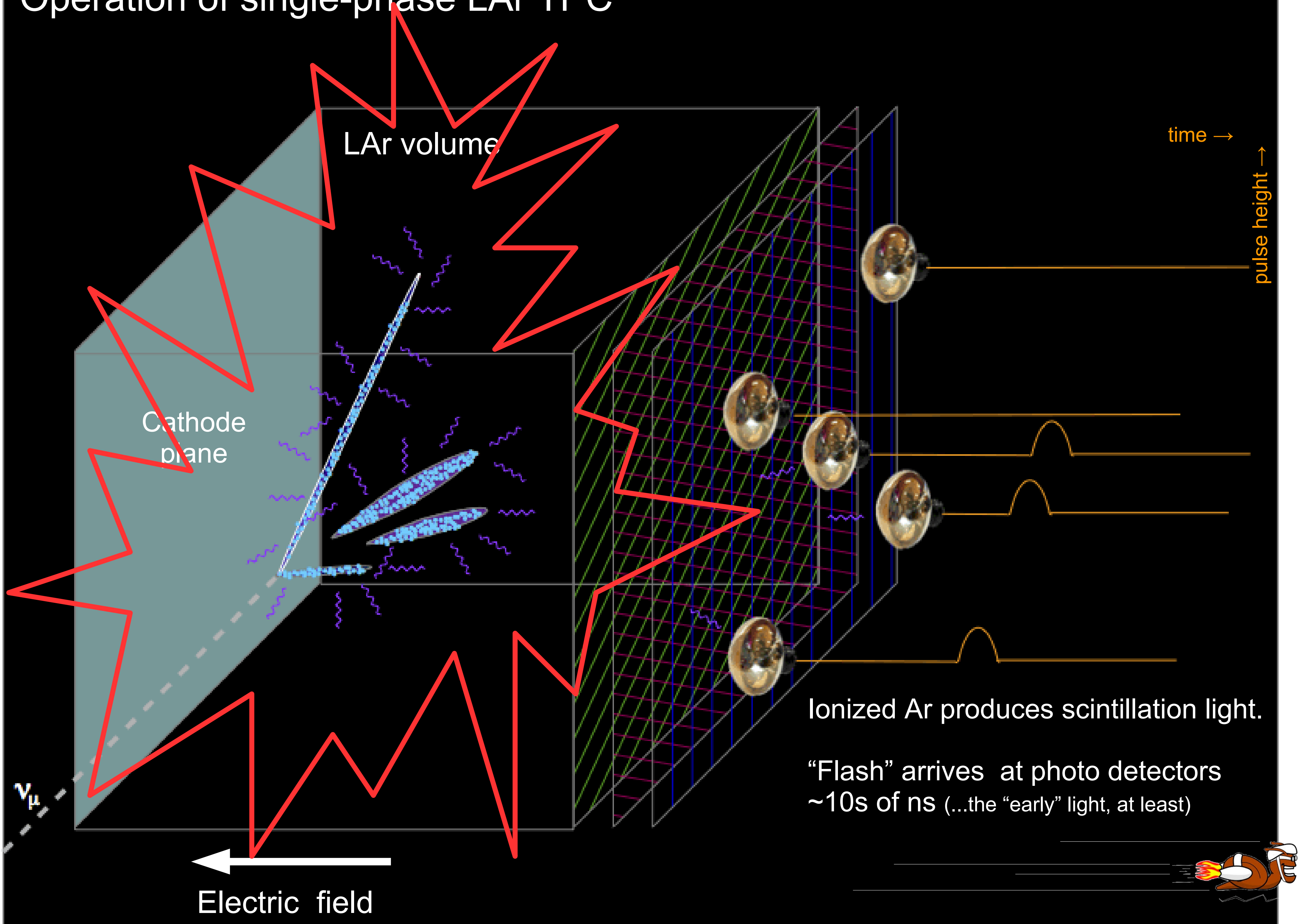

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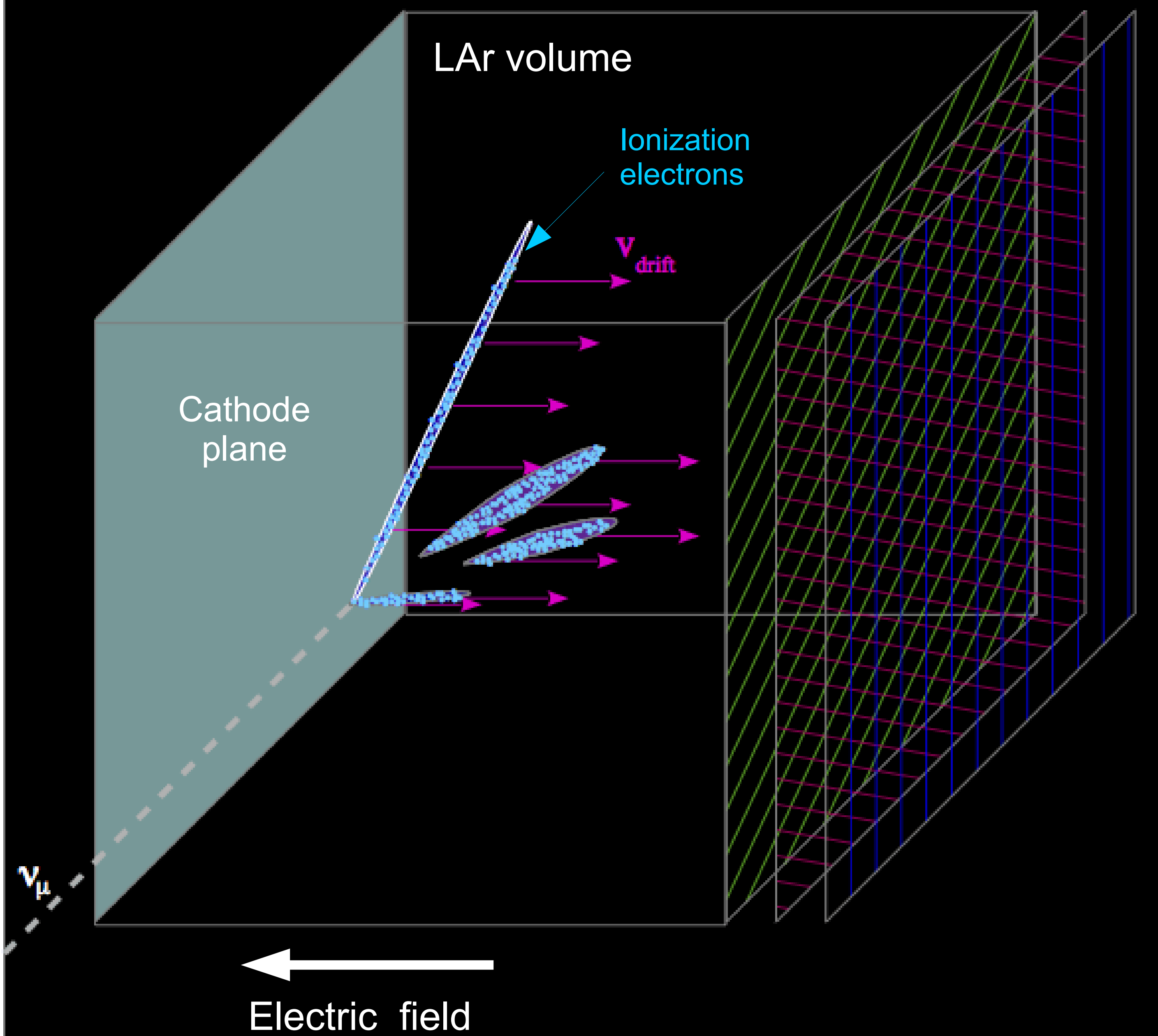


Neutrino interacts with Ar nucleus

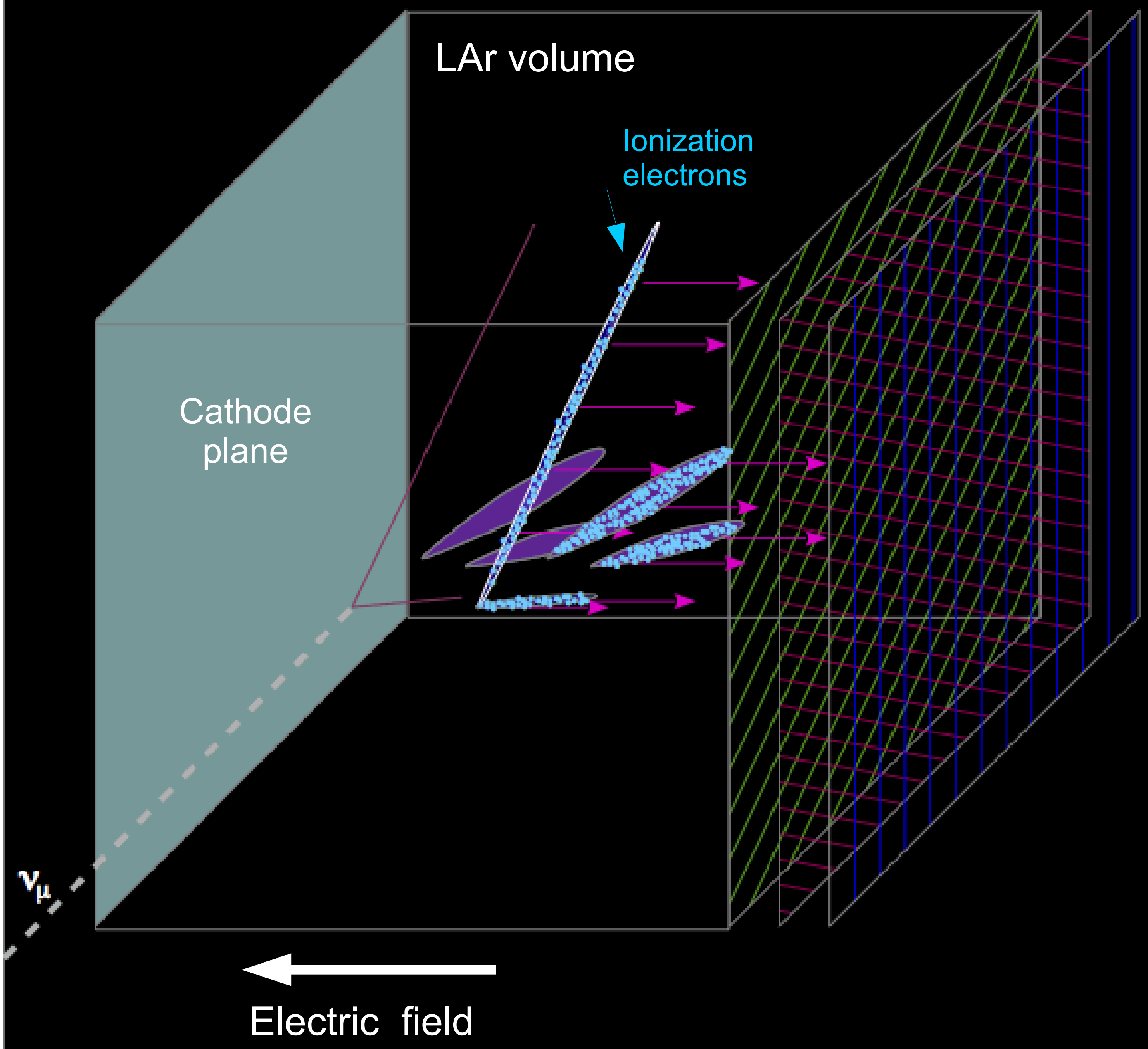
Charged secondaries ionize the Ar

Electrons drift in the electric field toward anode wires

$v_{drift} \approx 1$ – few mm/μs

Max drift time ~ ms!!

Operation of single-phase LAr TPC



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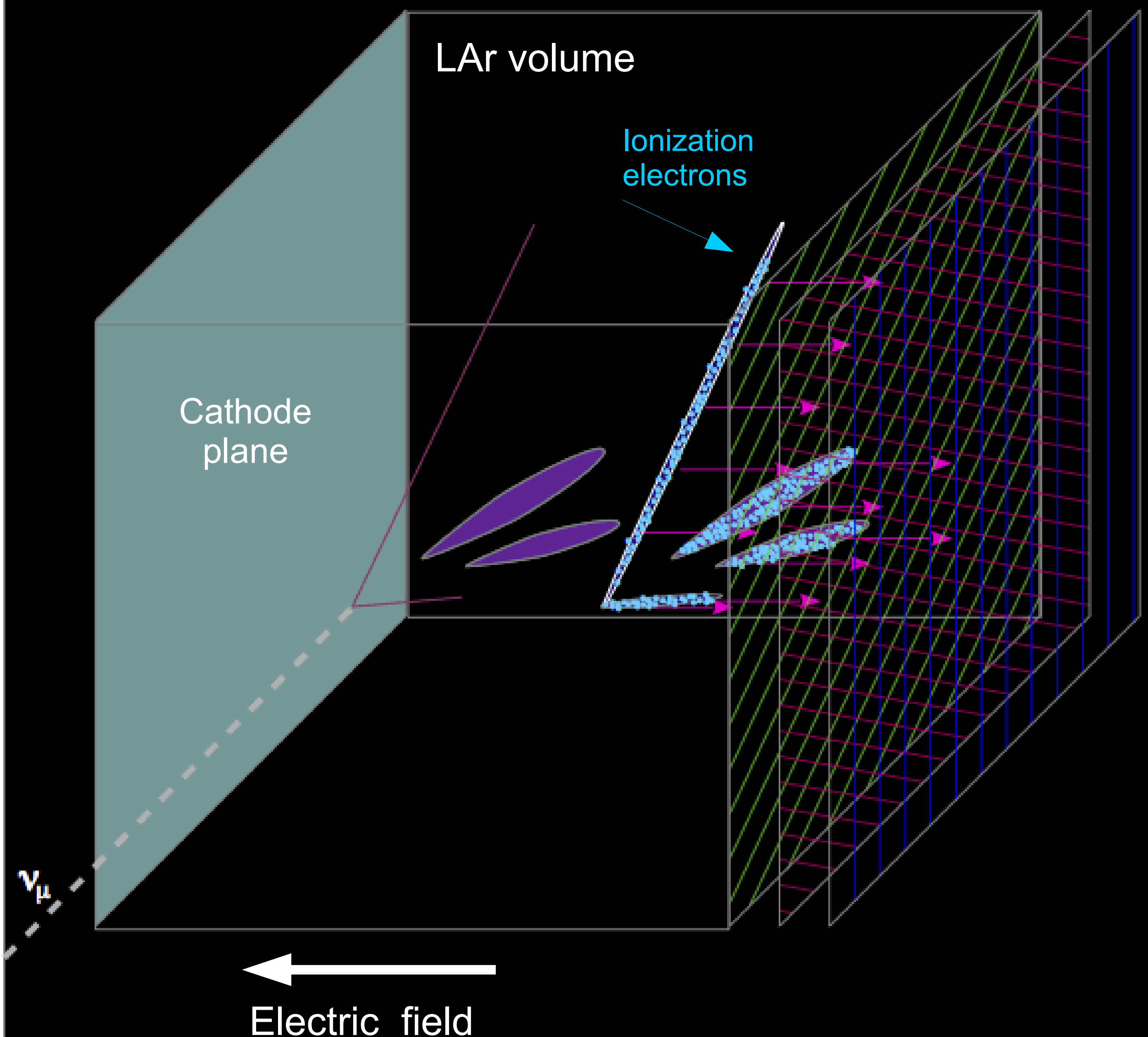

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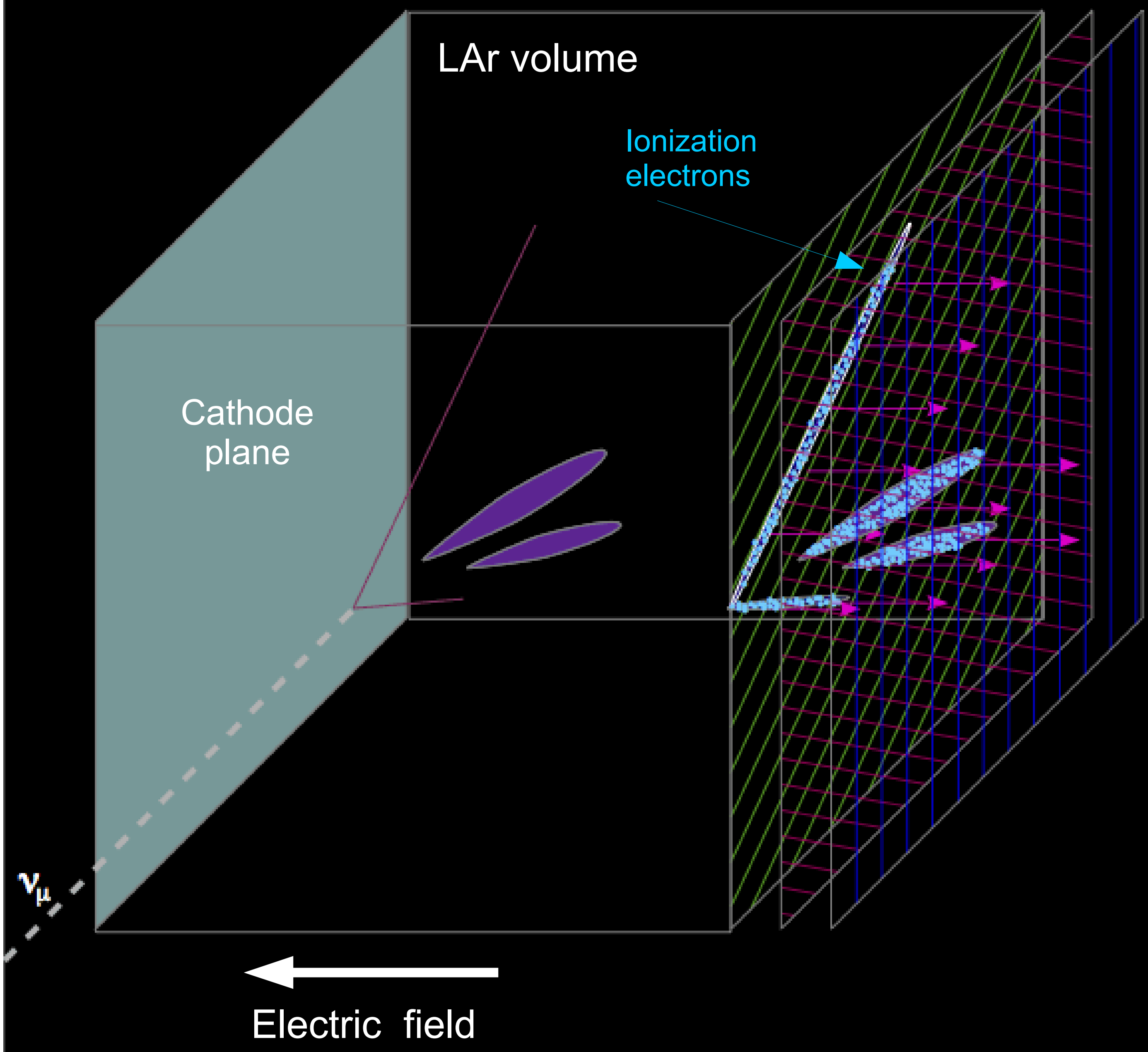

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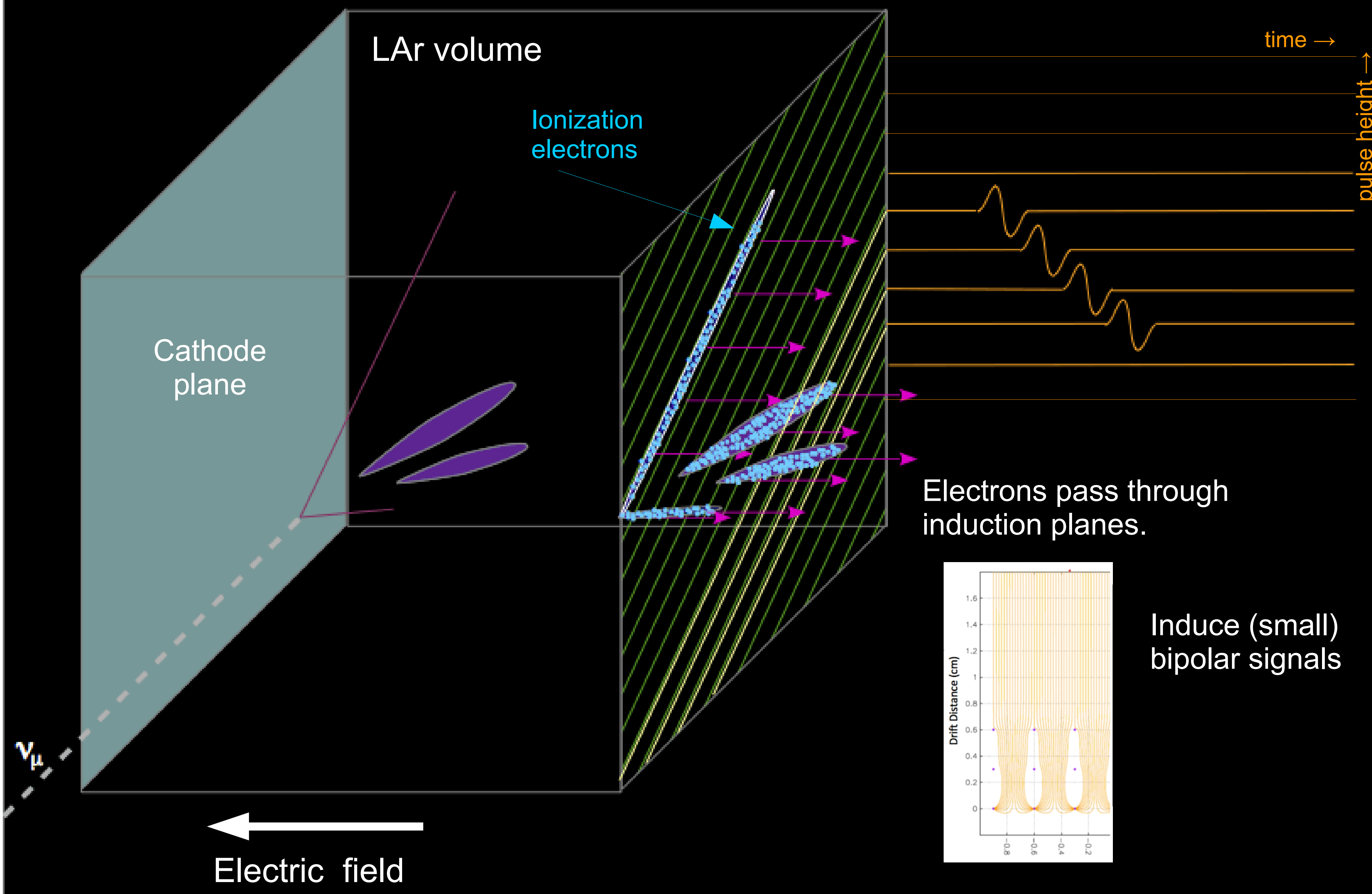

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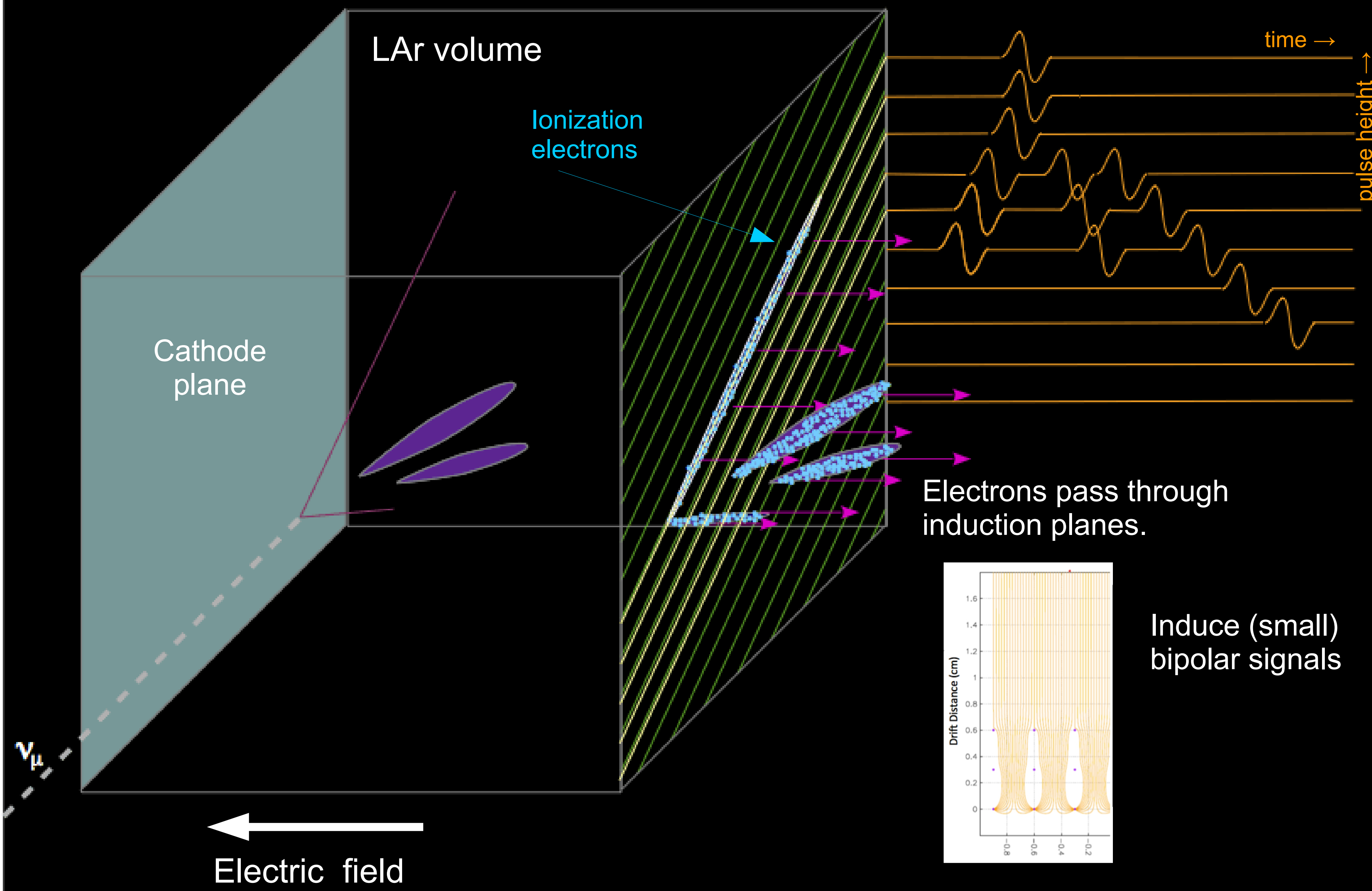

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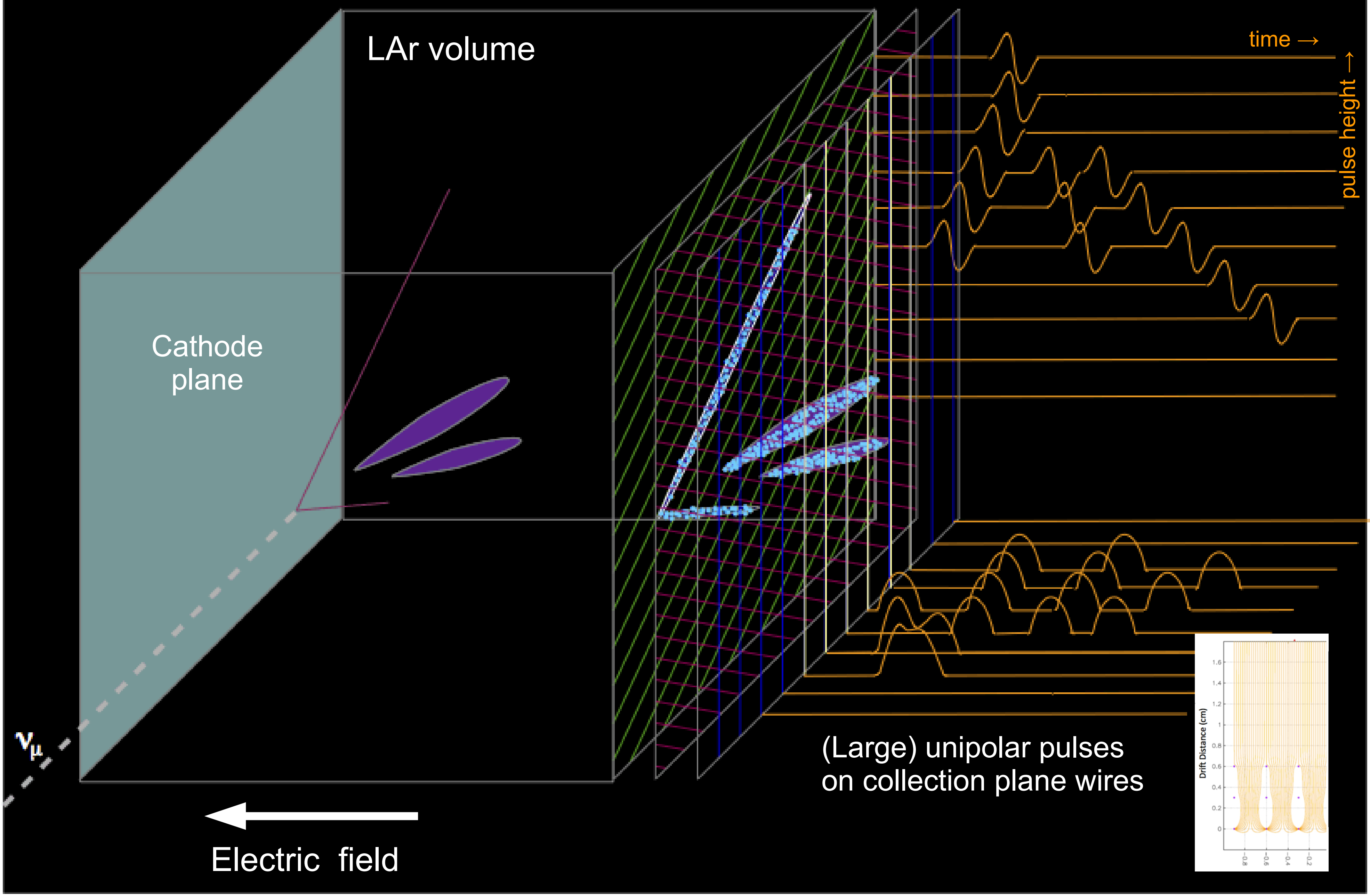
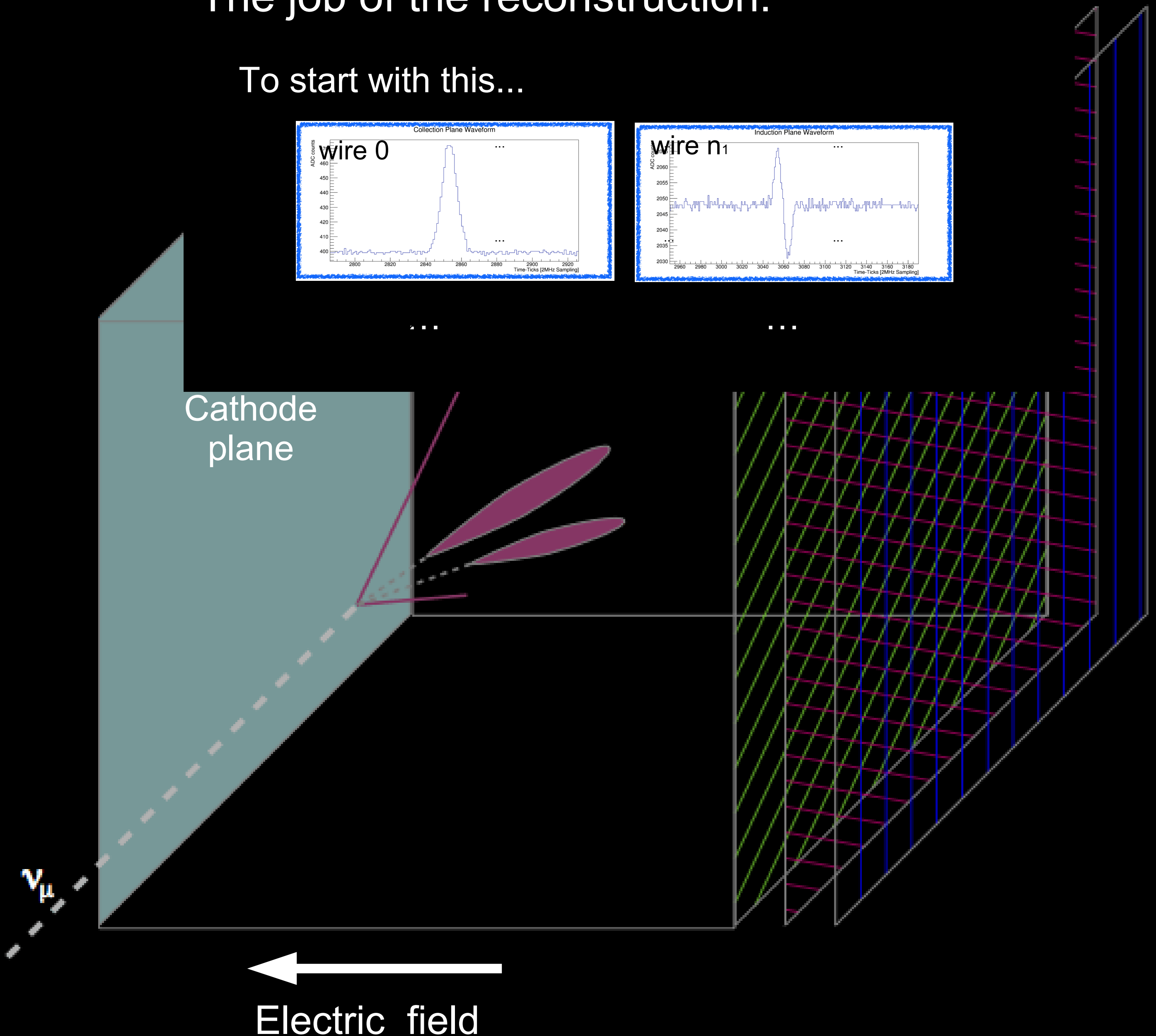


Operation of single-phase LAr TPC

The job of the reconstruction:

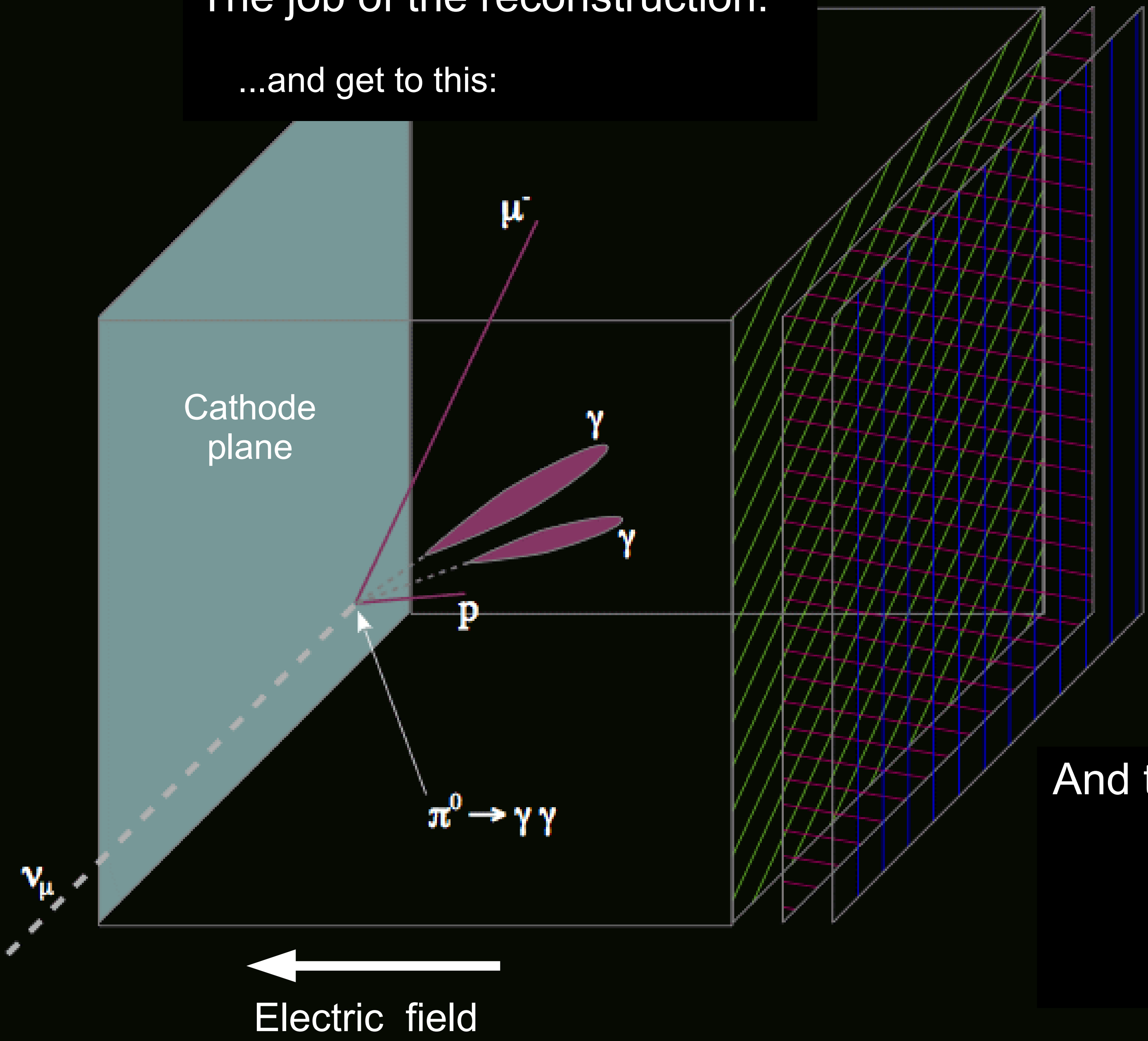
To start with this...



Operation of single-phase LAr TPC

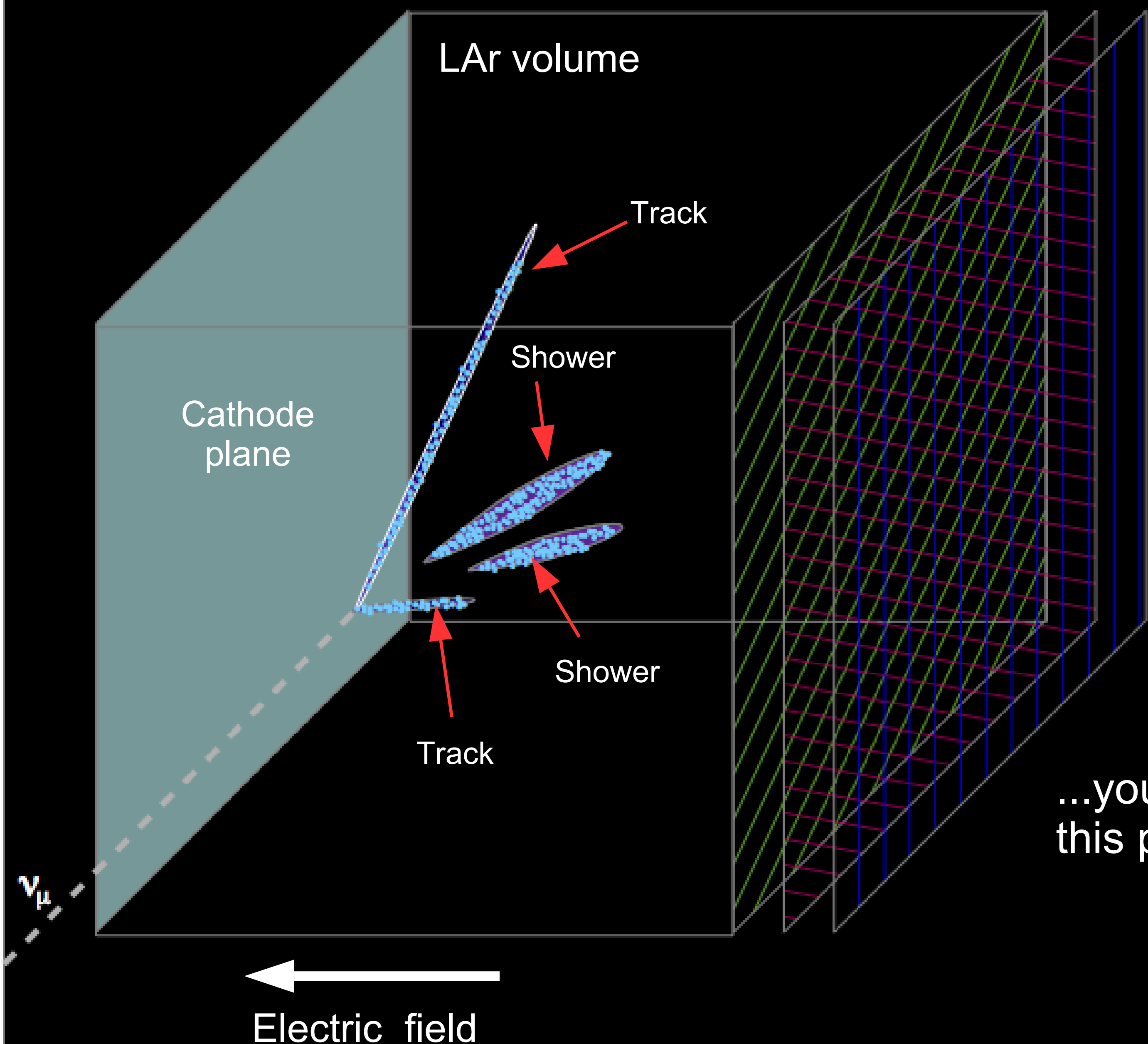
The job of the reconstruction:

...and get to this:



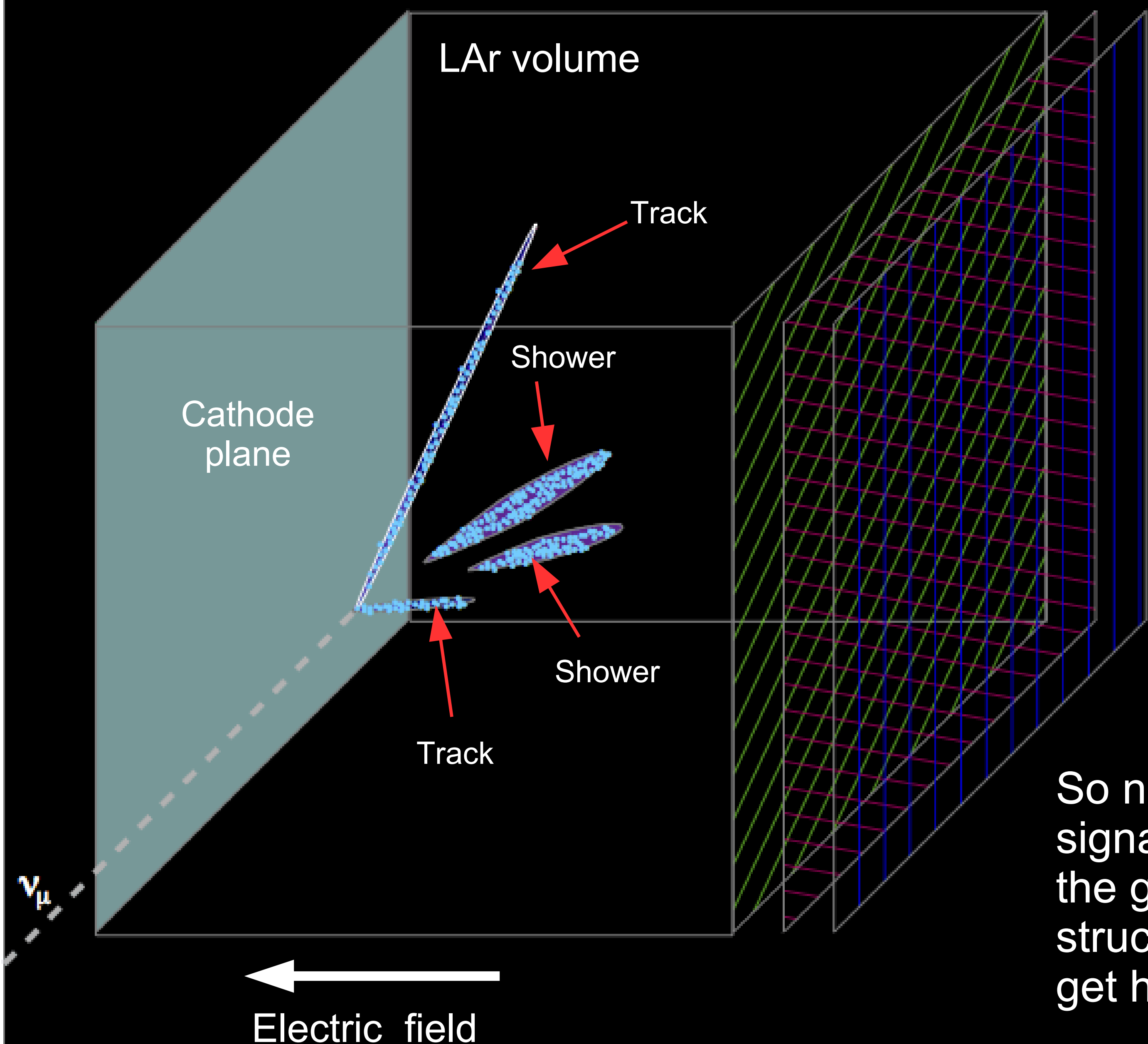
And to get here...

Operation of single-phase LAr TPC



...you need to reconstruct this picture.

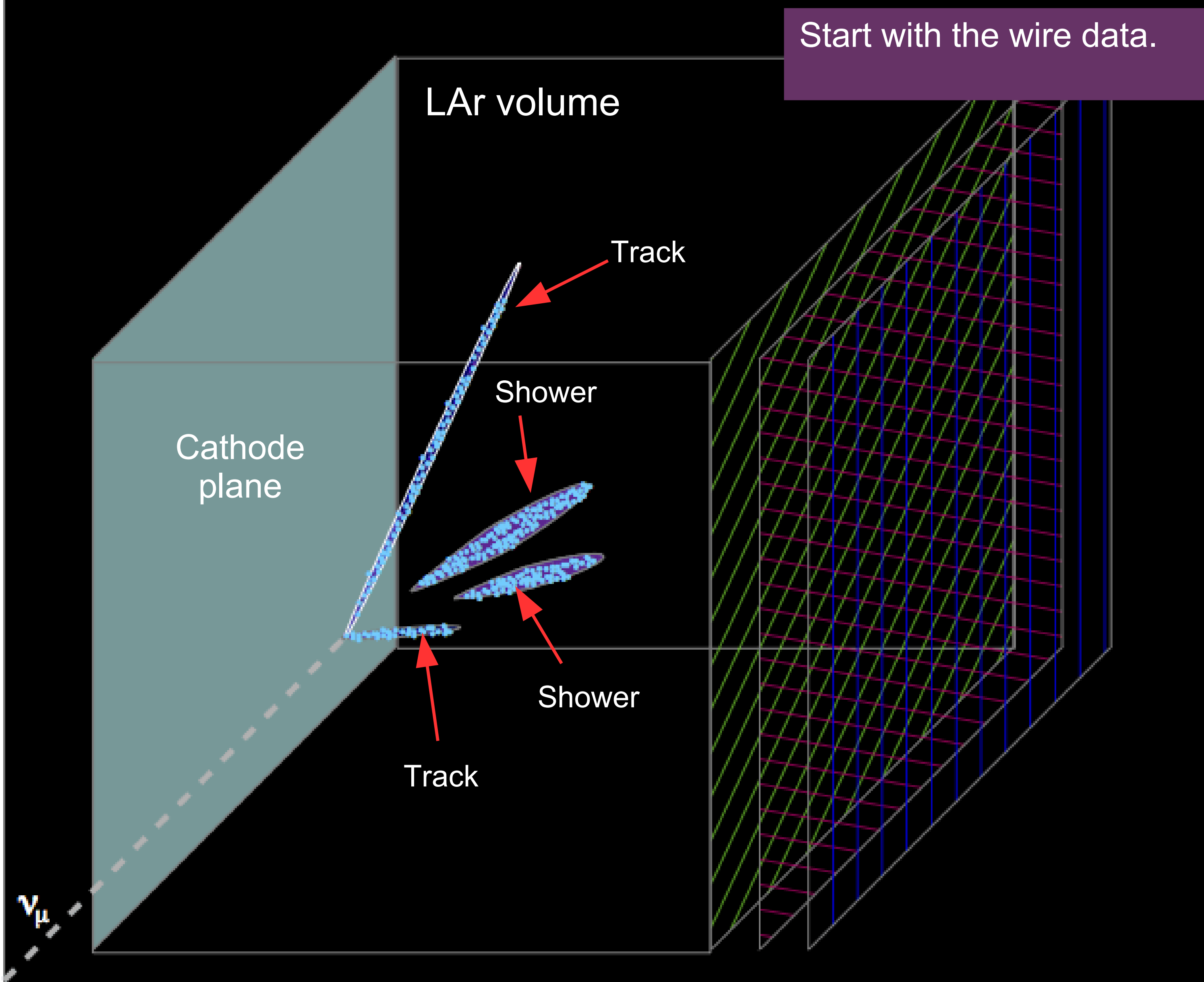
Operation of single-phase LAr TPC



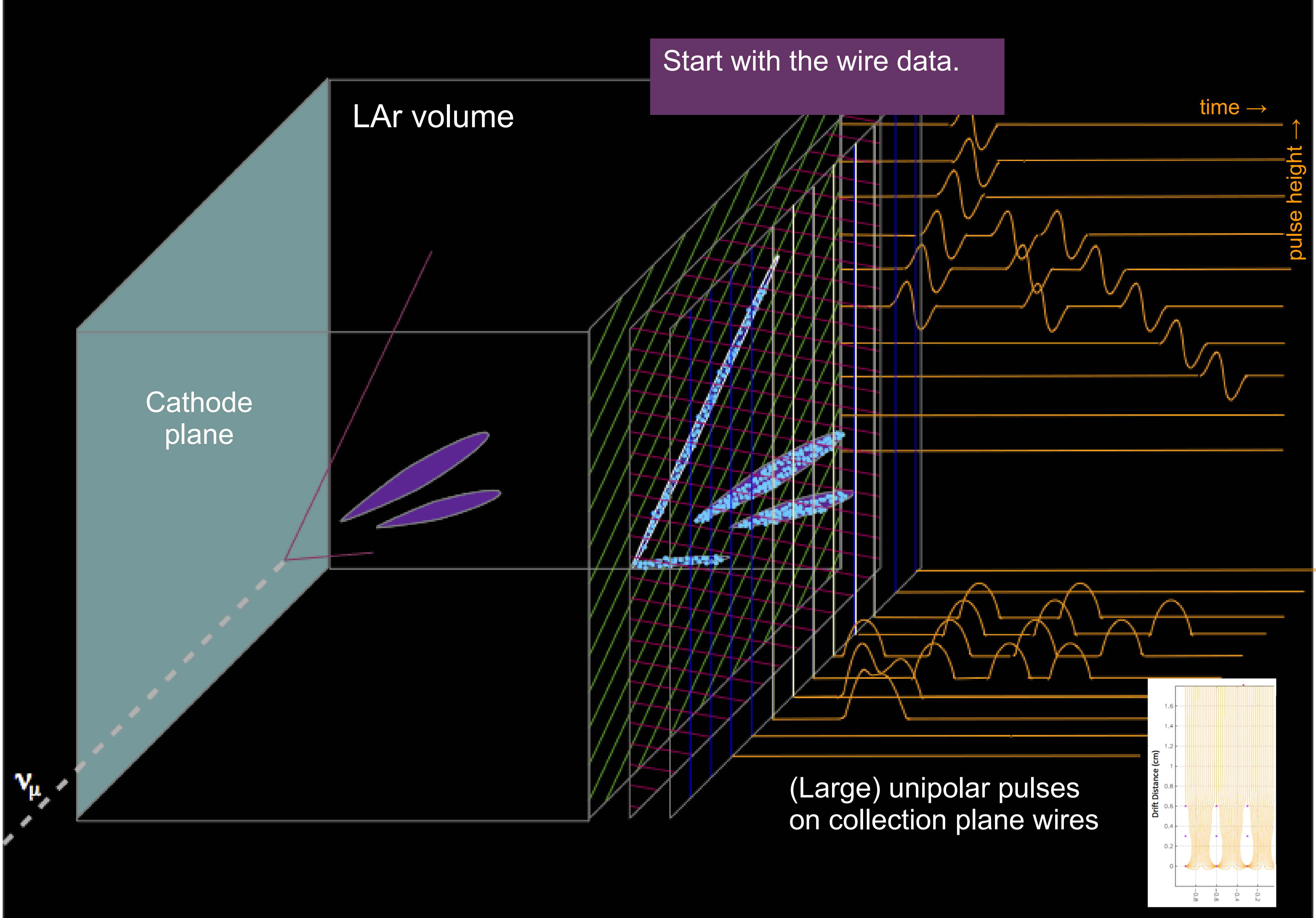
So now start from the raw signals, and walk through the general process, data structures needed to get here.

Primary reconstruction workflow and data structures

Reconstruction workflow and data structures



Reconstruction workflow and data structures



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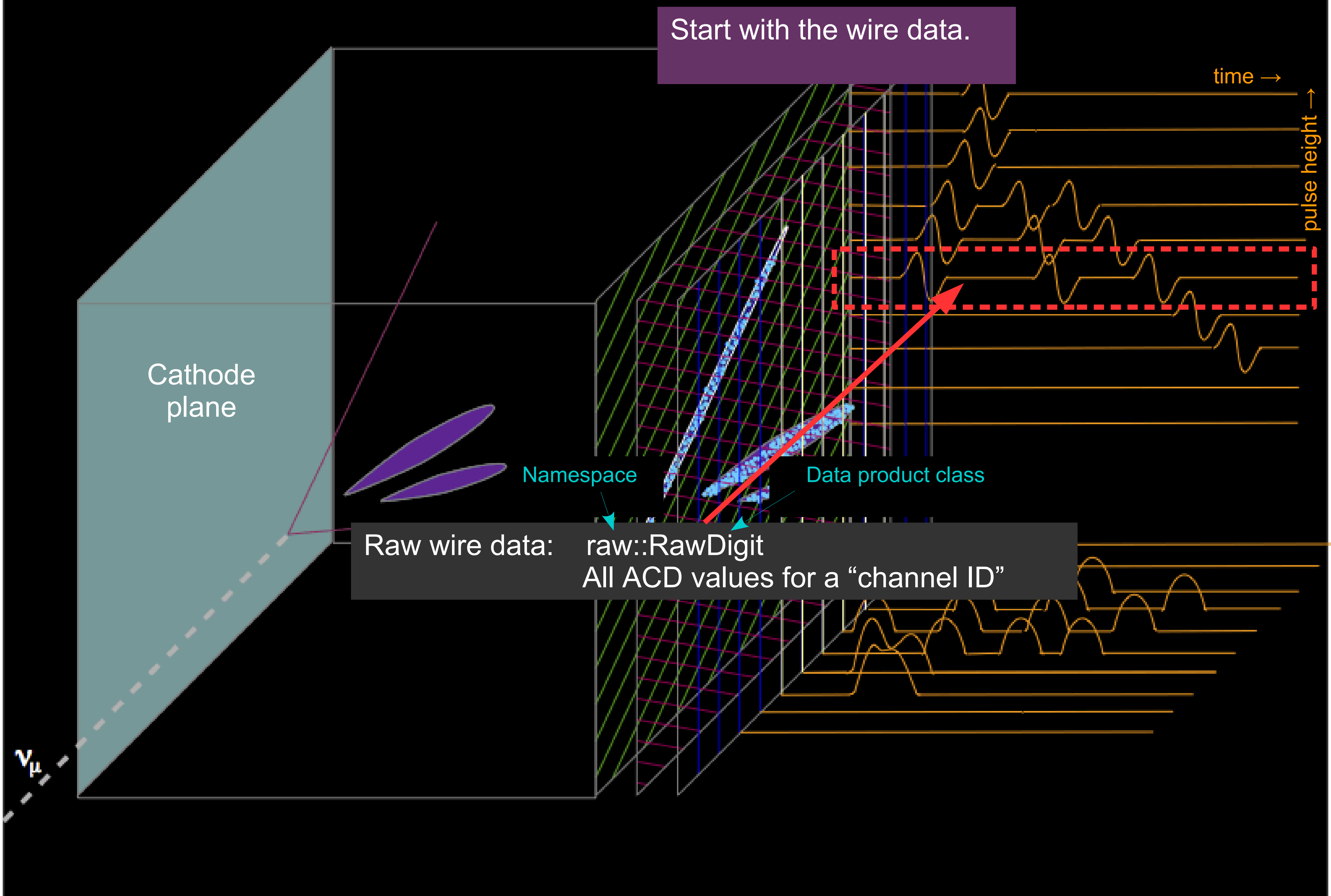

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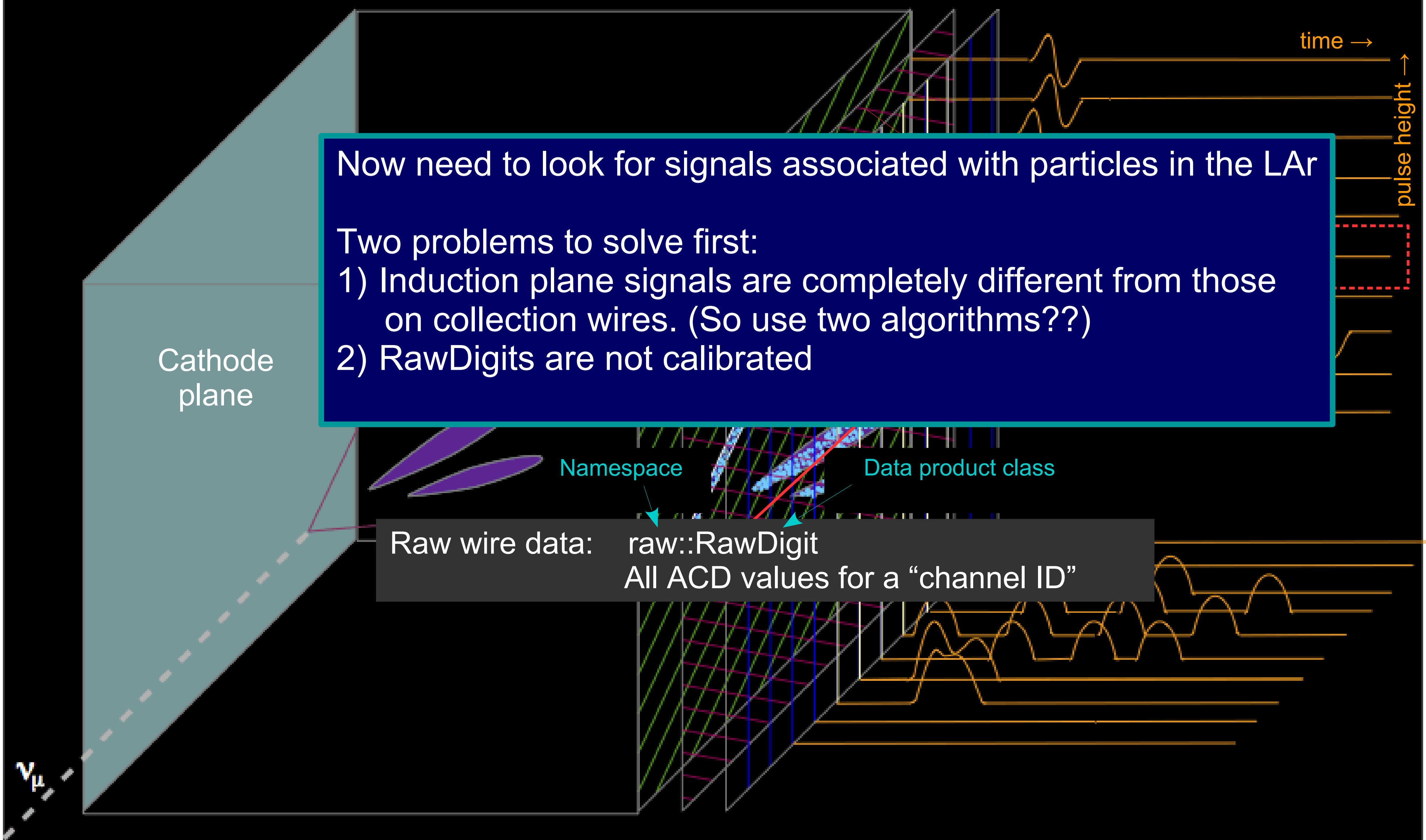


Now need to look for signals associated with particles in the LAr

Two problems to solve first:

1) Induction plane signals are completely different from those on collection wires. (So use two algorithms??)
2) RawDigits are not calibrated

Raw wire data: raw::RawDigit
All ACD values for a “channel ID”

Wire calibration and deconvolution

Performed by a number of classes

CalWire ...
CalROI ...
SignalShapingService ...
SignalShaping
LArFFT

(Experiment-specific)

- Calibration
  - Only pedestal subtraction at this phase.
    (Channel gains come later...)
- Deconvolution
  - The inverse of the following problem

    $$y(t)=(h*x)(t)+n(t)$$

    - where $y(t)$ = measured output signal (raw digits)

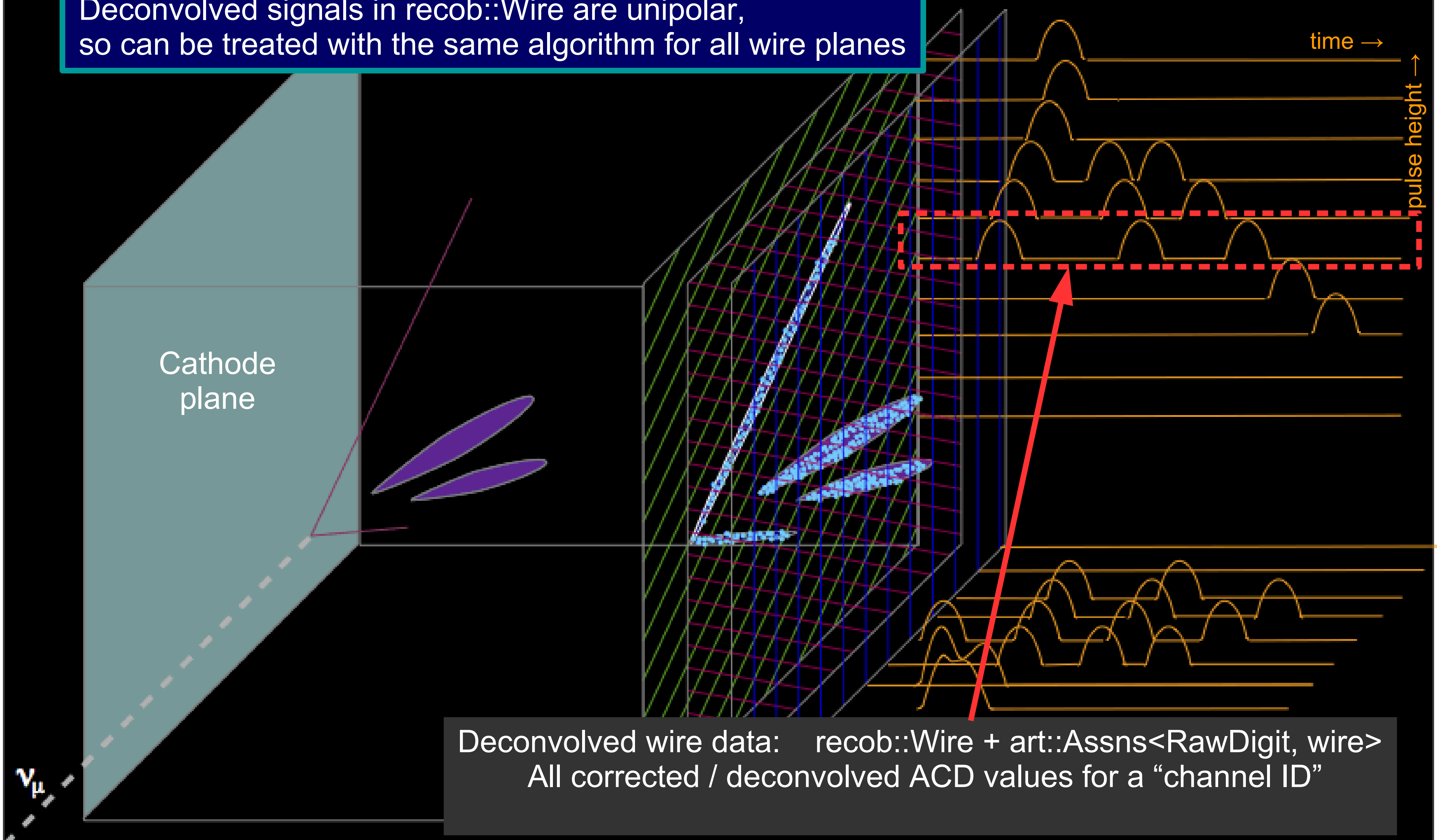
      $(h*x)(t)$ = convolution of impulse response $h(t)$ and (unknown) input signal $x(t)$

      $n(t)$ = noise (unknown)
  - Can extract an optimal estimate of the signal given:
    - impulse response of the front-end electronics
    - estimated mean power spectrum for the signal and the noise
      (i.e., the signal-to-noise ratio)

  Perform the calculation in the frequency domain

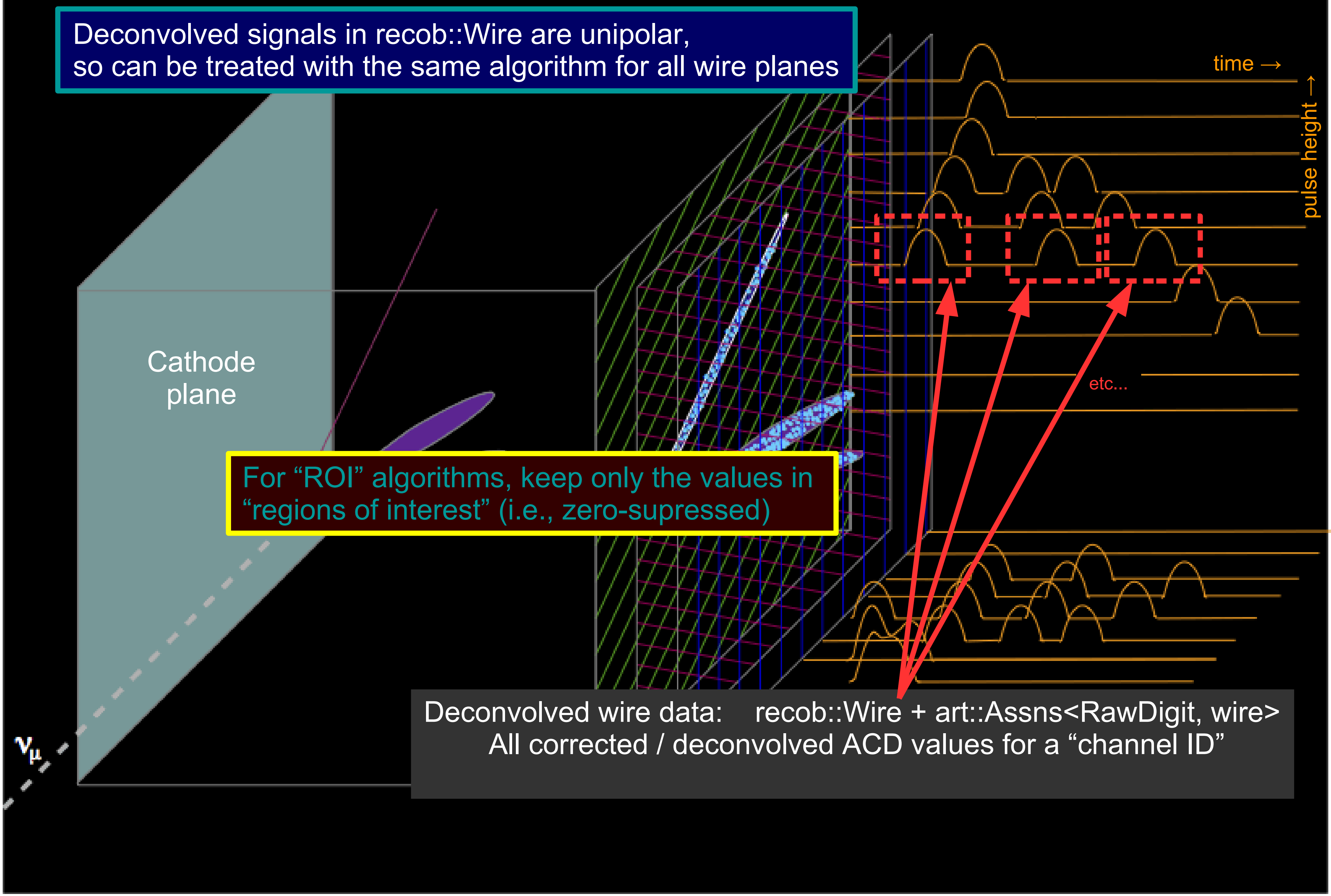
Reconstruction workflow and data structures

Deconvolved signals in recob::Wire are unipolar,
so can be treated with the same algorithm for all wire planes



Deconvolved wire data: recob::Wire + art::Assns<RawDigit, wire>
All corrected / deconvolved ACD values for a “channel ID”

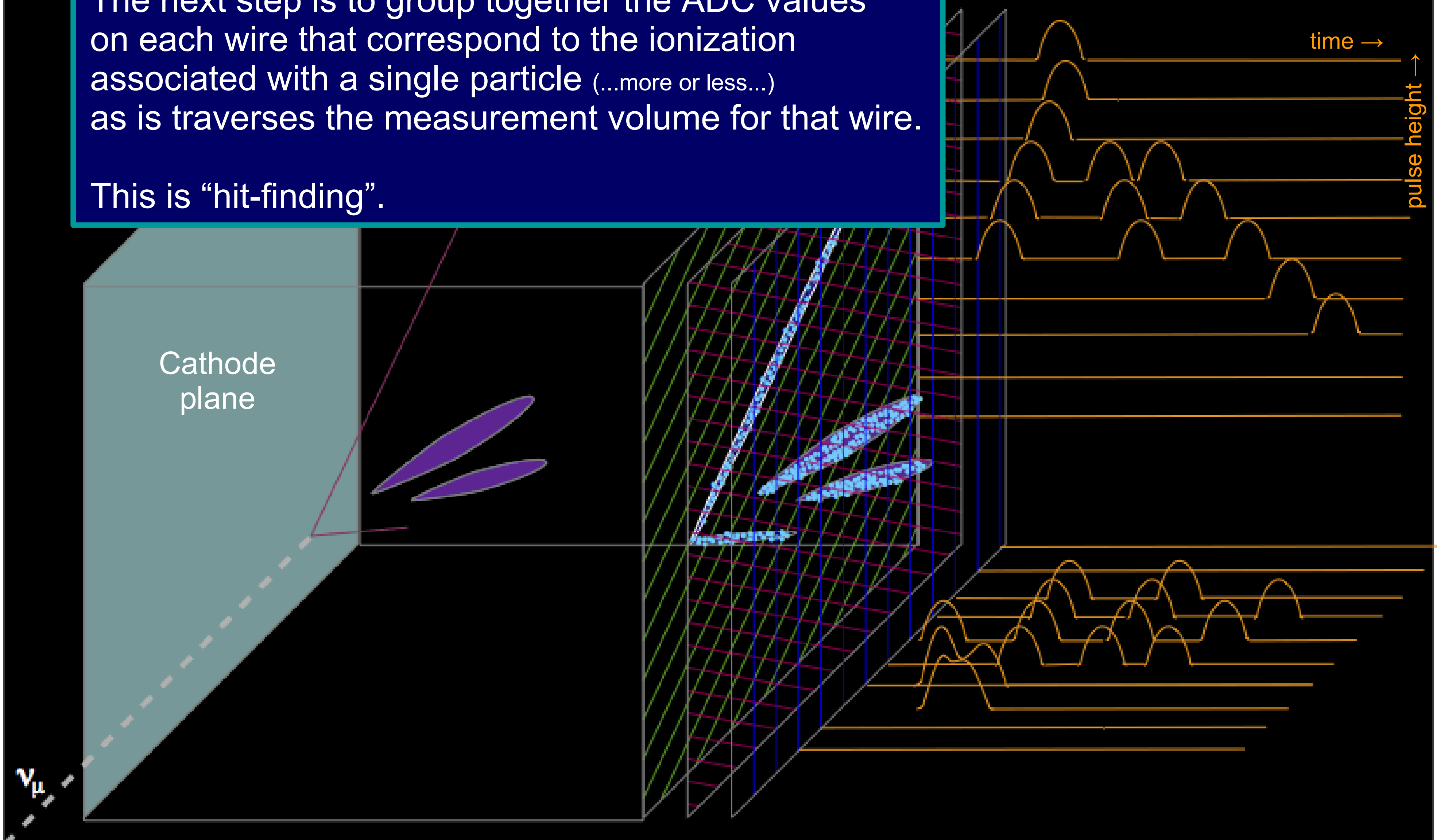
Reconstruction workflow and data structures



Reconstruction workflow and data structures

The next step is to group together the ADC values on each wire that correspond to the ionization associated with a single particle (...more or less...) as is traverses the measurement volume for that wire.

This is “hit-finding”.



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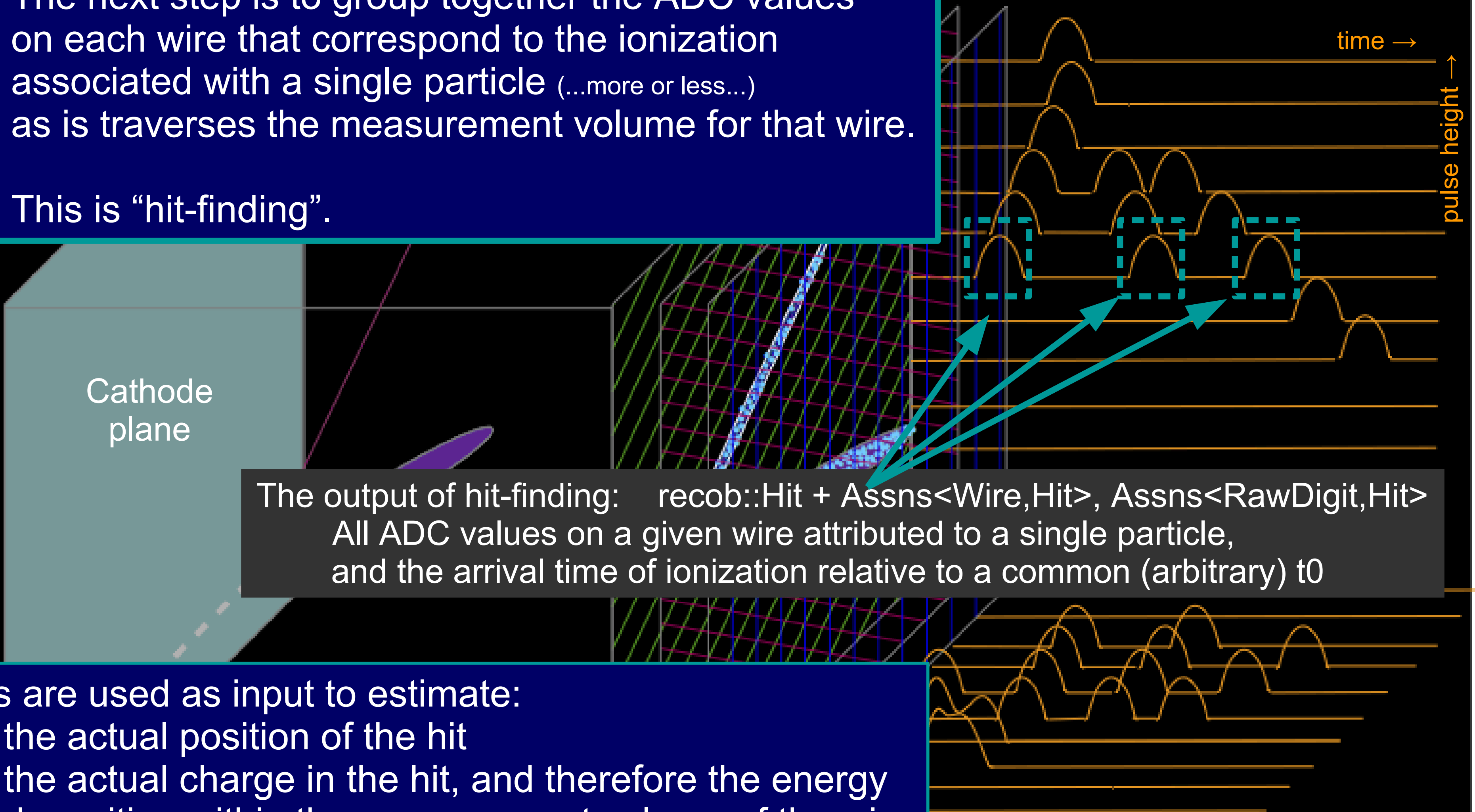

The output of hit-finding: recob::Hit + Assns<Wire,Hit>, Assns<RawDigit,Hit>
All ADC values on a given wire attributed to a single particle,
and the arrival time of ionization relative to a common (arbitrary) t0

Hits are used as input to estimate:

1) the actual position of the hit
2) the actual charge in the hit, and therefore the energy deposition within the measurement volume of the wire

Reconstruction workflow and data structures

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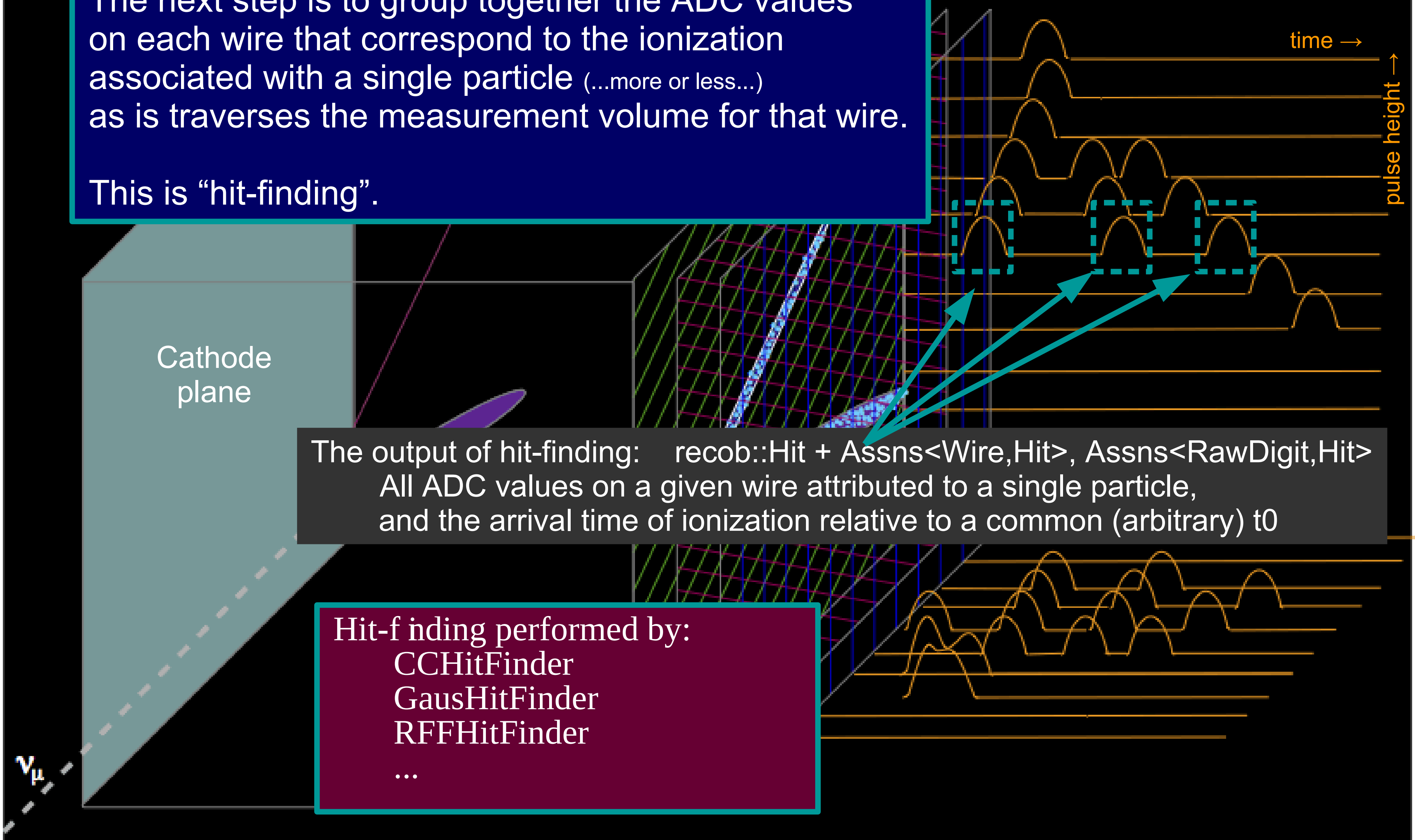

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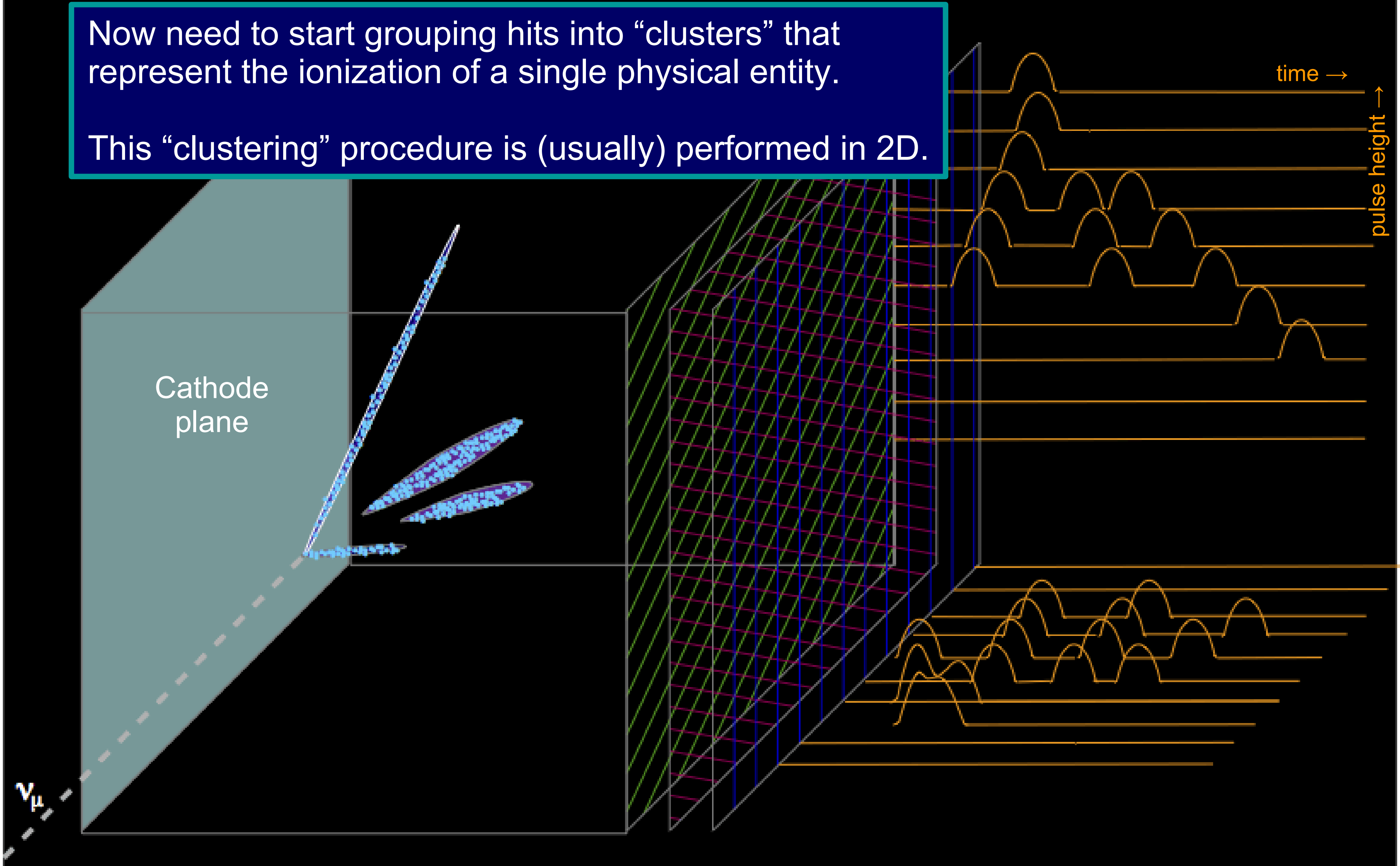
Hit-f inding performed by:

- CCHitFinder
- GausHitFinder
- RFFHitFinder
- ...

Reconstruction workflow and data structures

Now need to start grouping hits into “clusters” that represent the ionization of a single physical entity.

This “clustering” procedure is (usually) performed in 2D.



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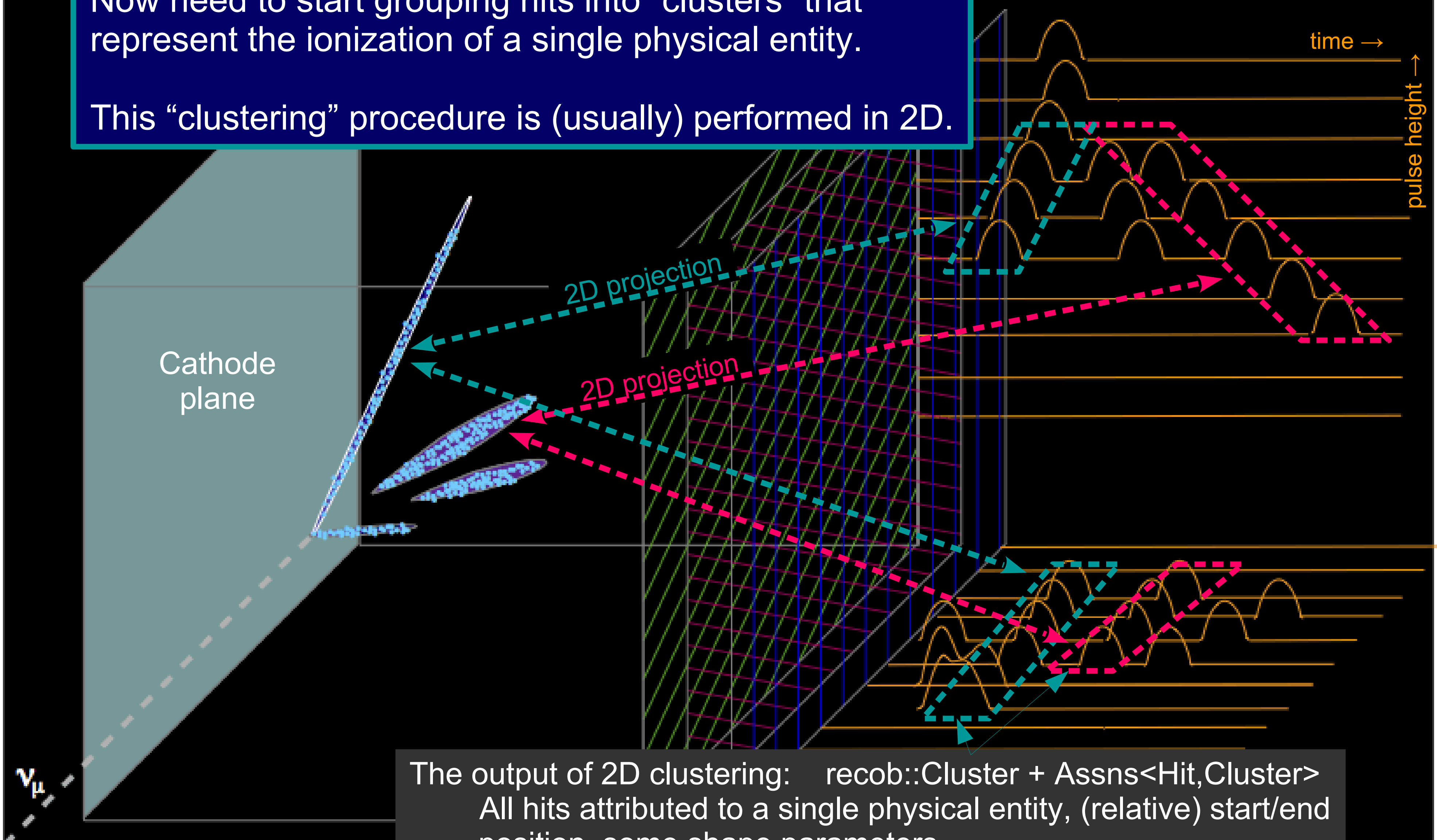

The output of 2D clustering: recob::Cluster + Assns<Hit,Cluster>
All hits attributed to a single physical entity, (relative) start/end position, some shape parameters

Reconstruction workflow and data structures

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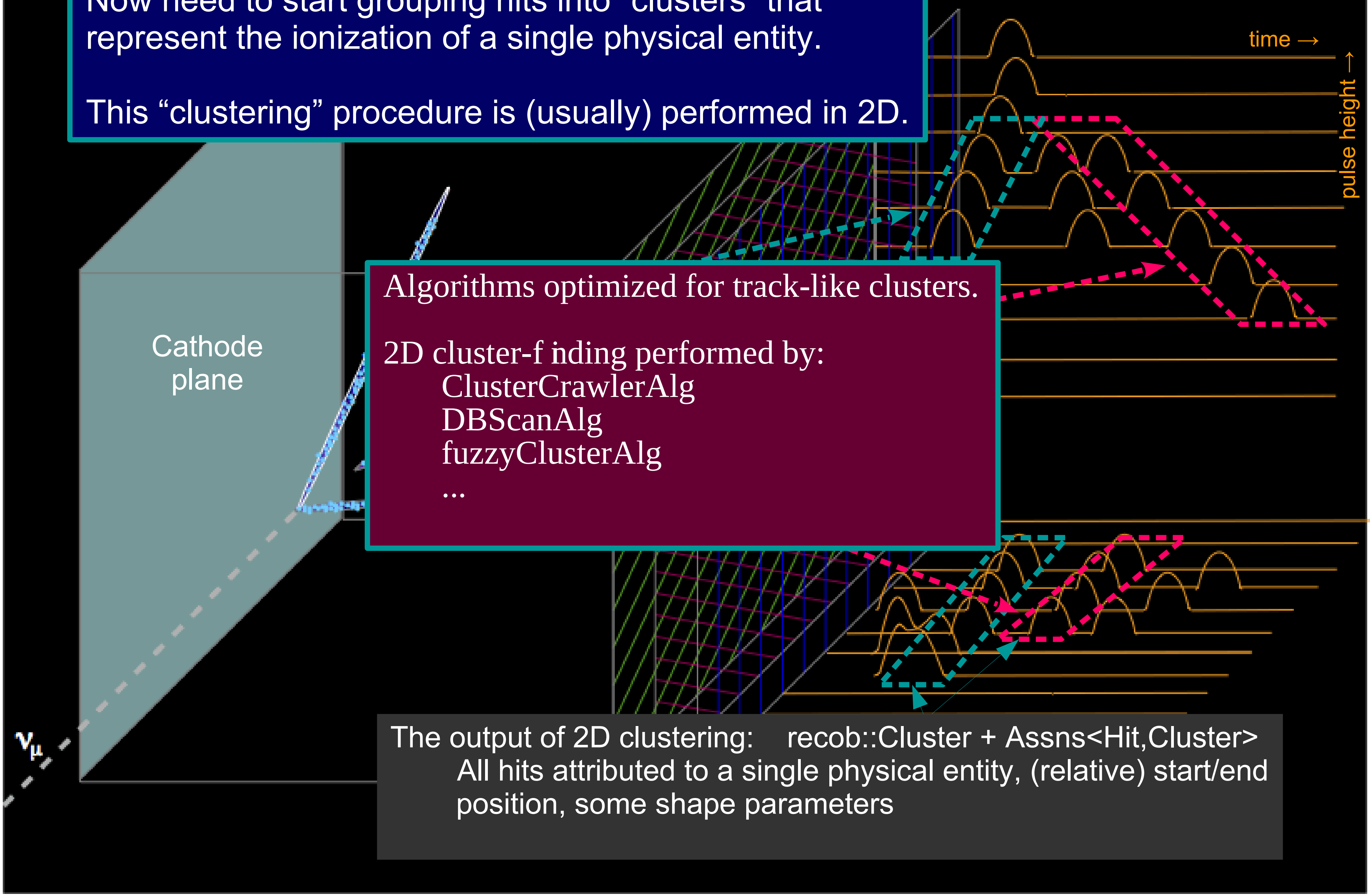

Algorithms optimized for track-like clusters.

2D cluster-finding performed by:

- ClusterCrawlerAlg
- DBScanAlg
- fuzzyClusterAlg
- ...

The output of 2D clustering: recob::Cluster + Assns<Hit,Cluster>

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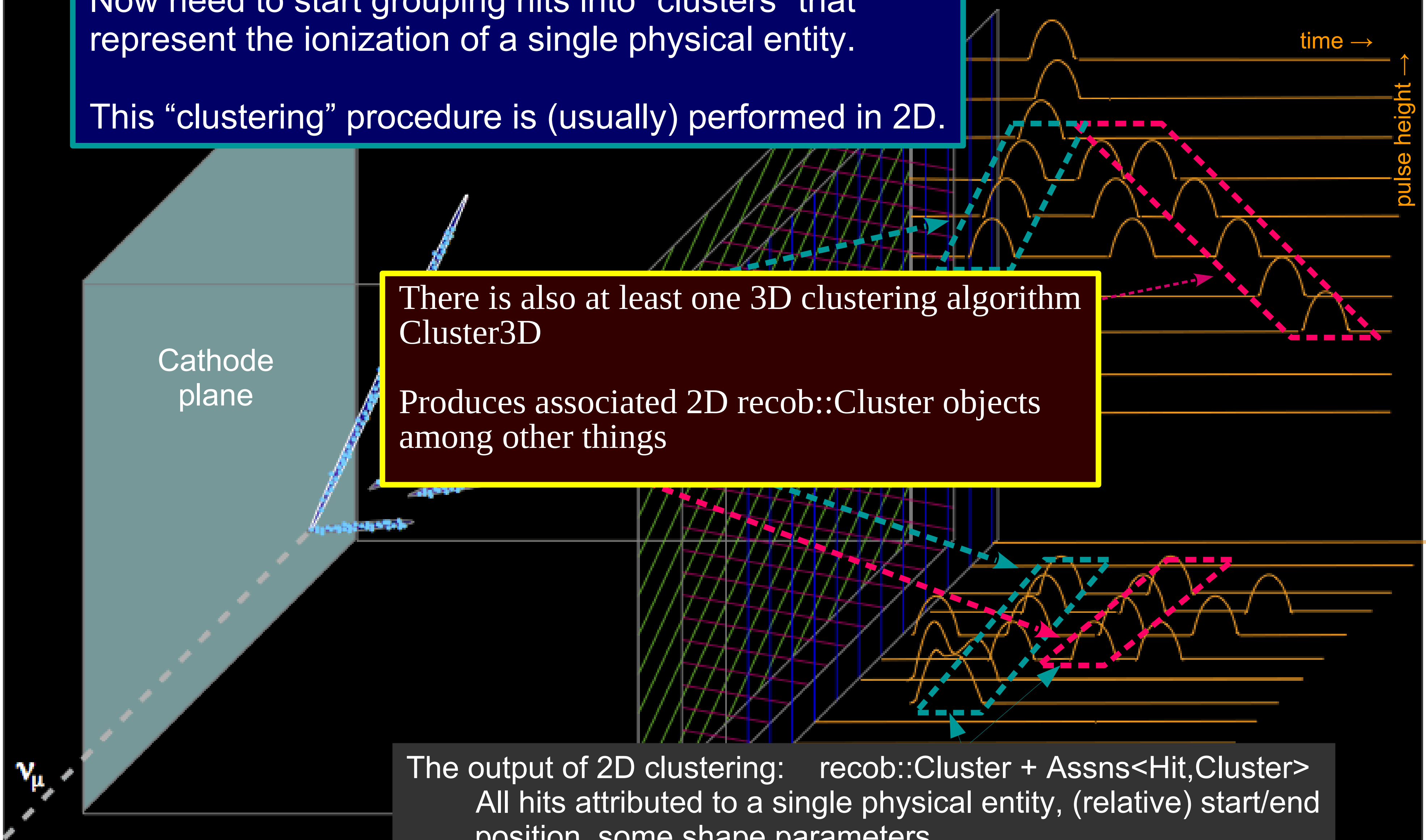


There is also at least one 3D clustering algorithm Cluster3D

Produces associated 2D recob::Cluster objects among other things

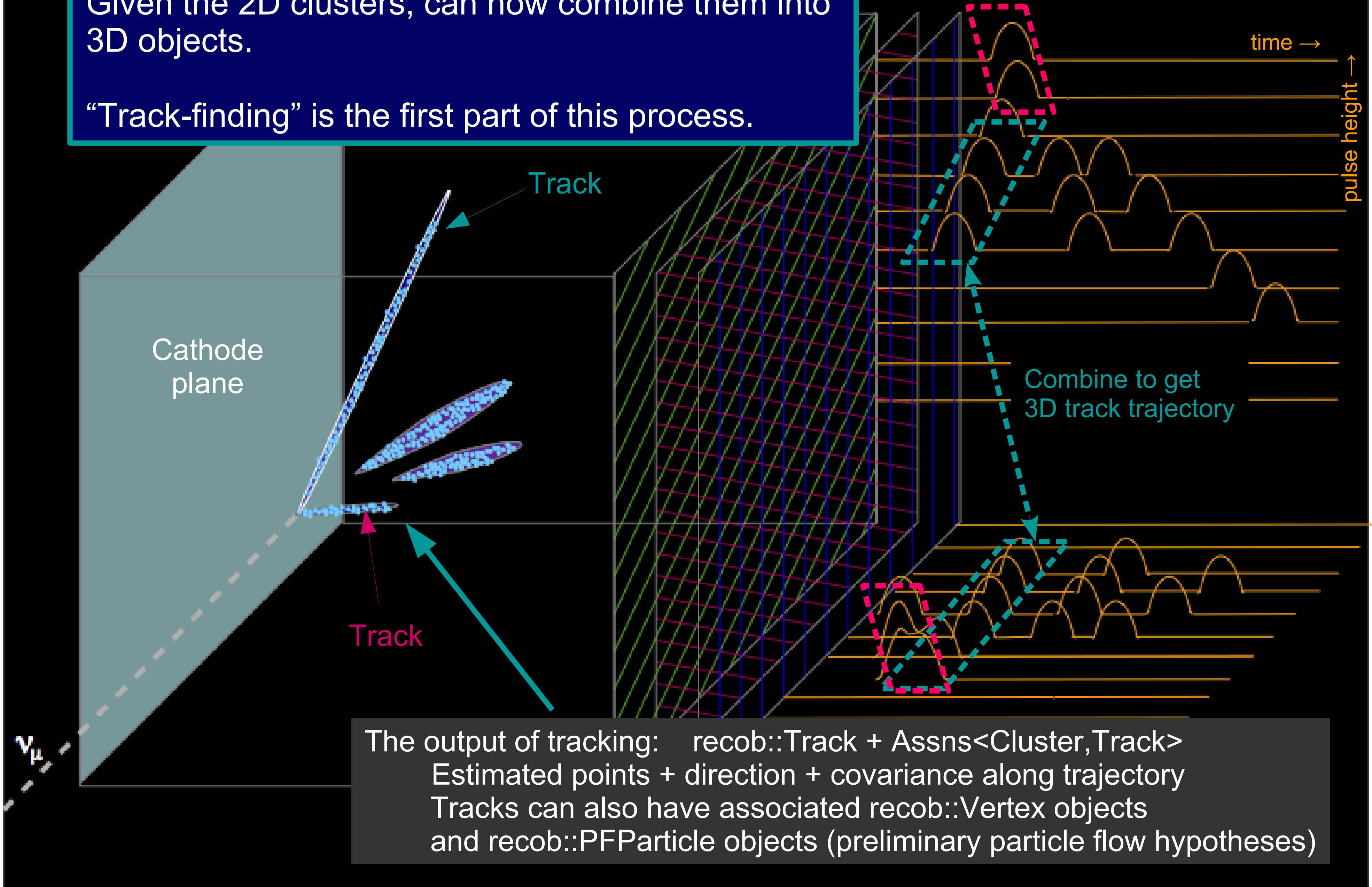
The output of 2D clustering: recob::Cluster + Assns<Hit,Cluster>

All hits attributed to a single physical entity, (relative) start/end position, some shape parameters

Reconstruction workflow and data structures

Given the 2D clusters, can now combine them into 3D objects.

"Track-finding" is the first part of this process.



The output of tracking: recob::Track + Assns<Cluster,Track>

Estimated points + direction + covariance along trajectory

Tracks can also have associated recob::Vertex objects and recob::PFParticle objects (preliminary particle flow hypotheses)

Reconstruction workflow and data structures

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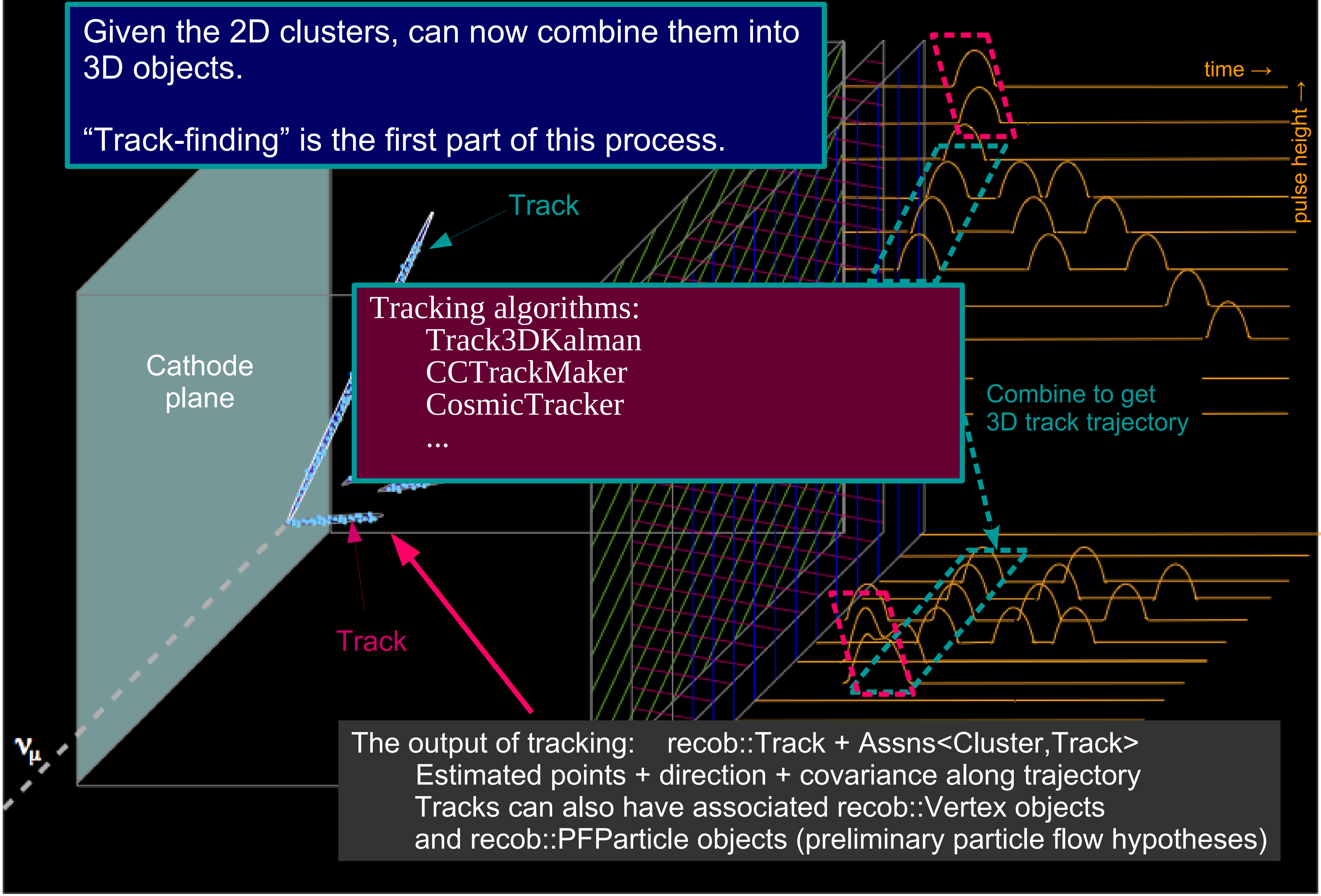


Tracking algorithms:

- Track3DKalman
- CCTrackMaker
- CosmicTracker
- ...

The output of tracking: recob::Track + Assns<Cluster,Track>

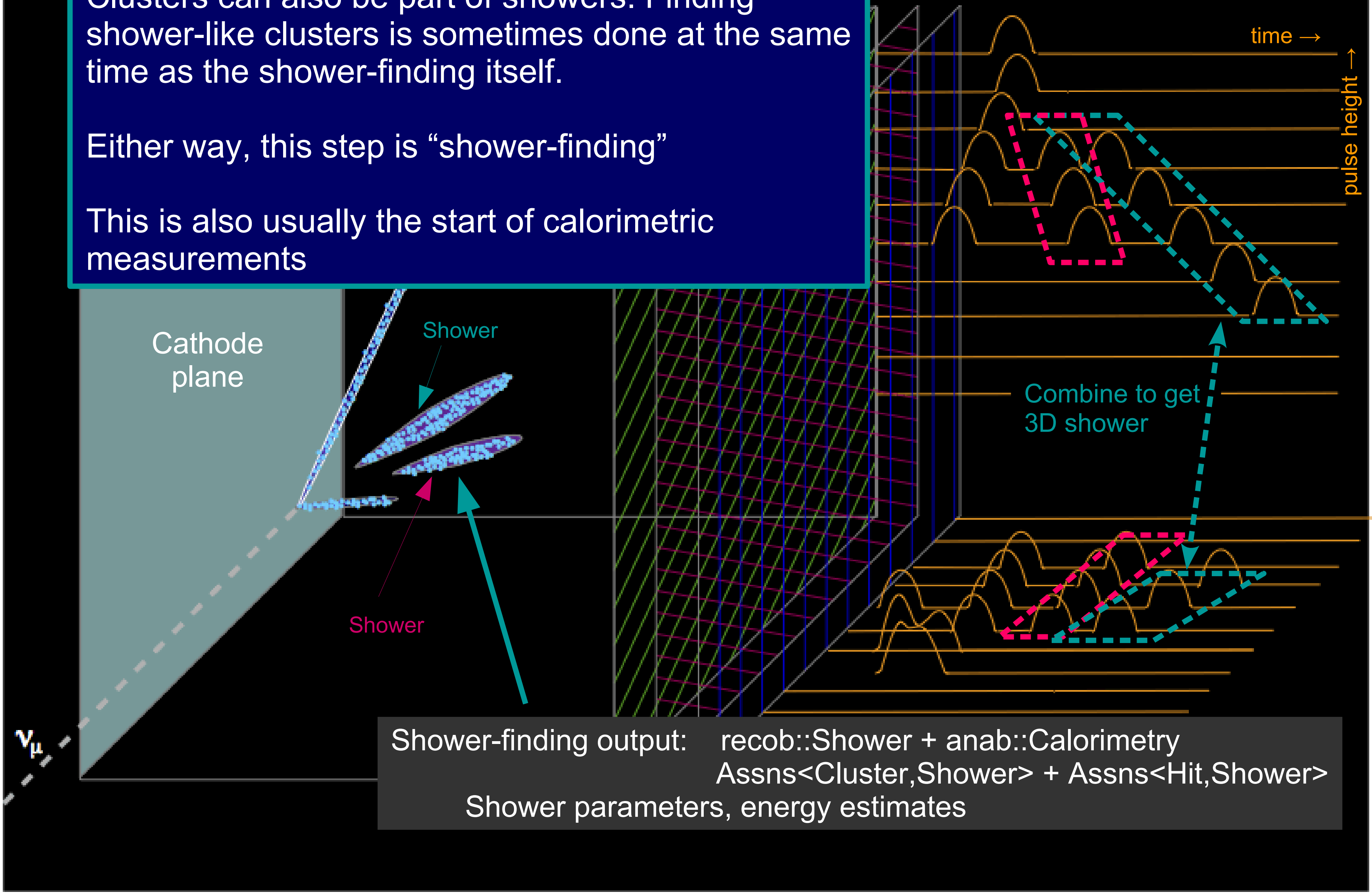
- Estimated points + direction + covariance along trajectory
- Tracks can also have associated recob::Vertex objects and recob::PFParticle objects (preliminary particle flow hypotheses)

Reconstruction workflow and data structures

Clusters can also be part of showers. Finding shower-like clusters is sometimes done at the same time as the shower-finding itself.

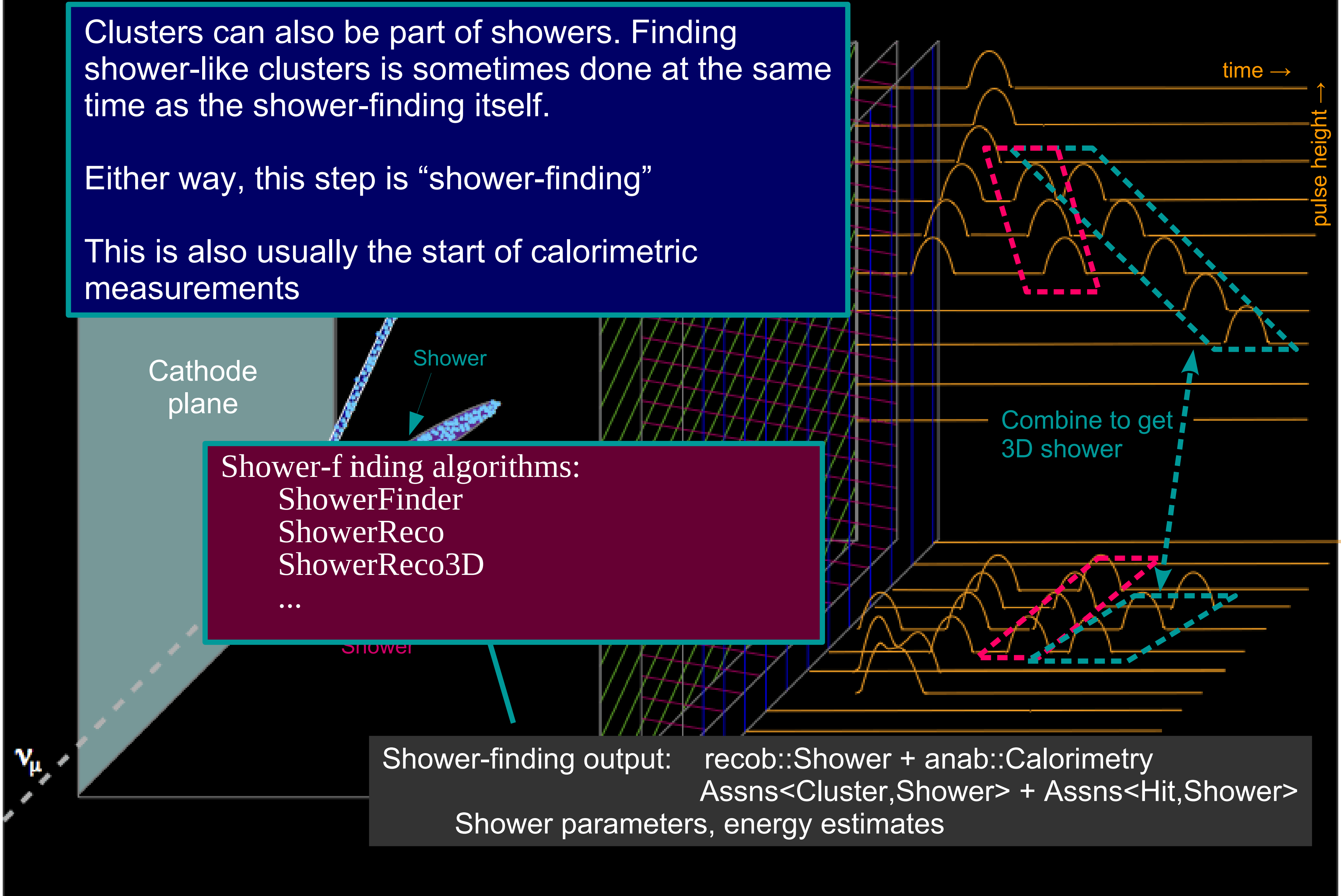
Either way, this step is “shower-finding”

This is also usually the start of calorimetric measurements



Shower-finding output: recob::Shower + anab::Calorimetry
Assns<Cluster,Shower> + Assns<Hit,Shower>
Shower parameters, energy estimates

Reconstruction workflow and data structures



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Shower-finding algorithms:
- ShowerFinder
- ShowerReco
- ShowerReco3D
- ...

Shower-finding output: recob::Shower + anab::Calorimetry
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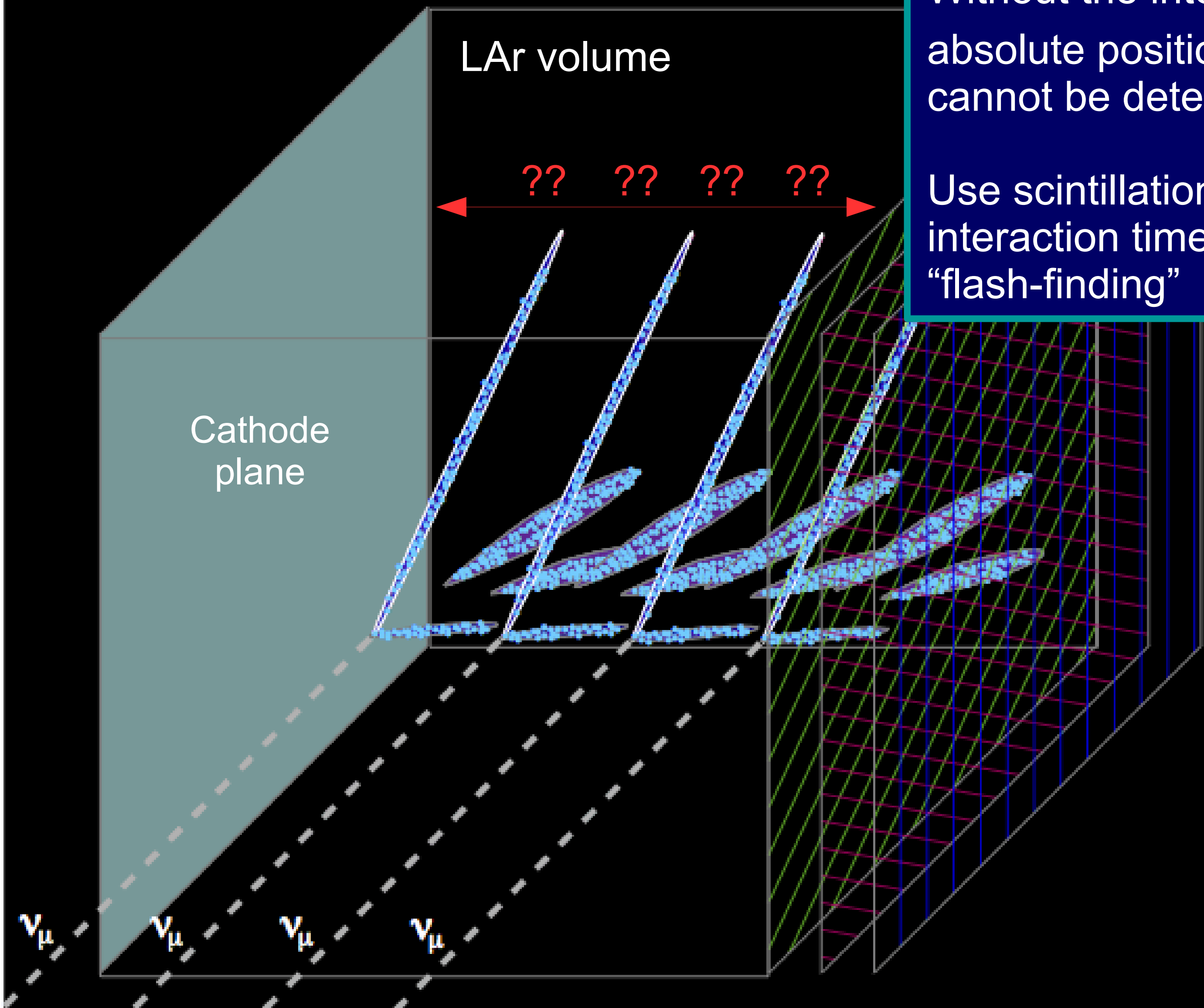
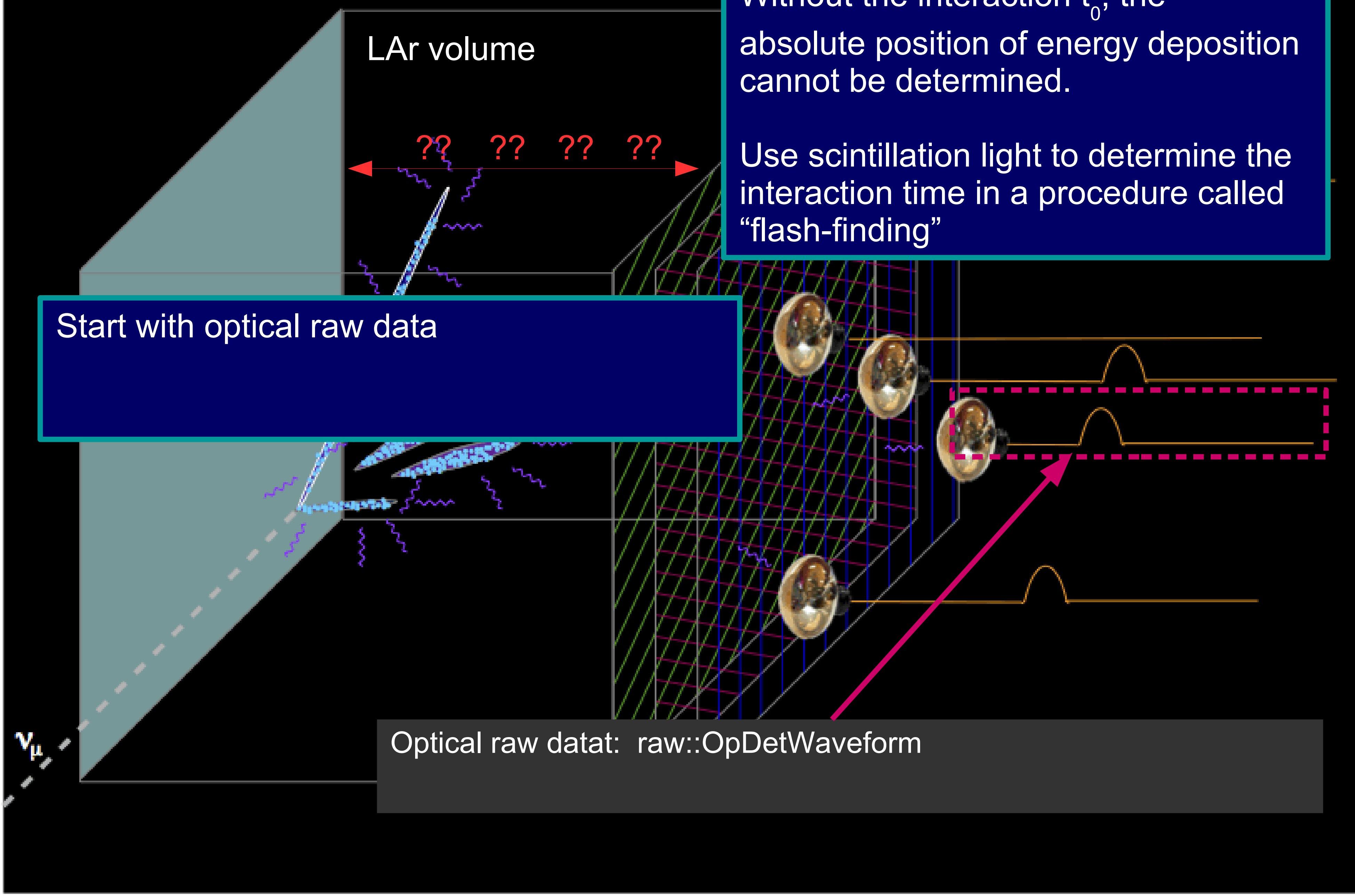
Reconstruction workflow and data structures



Without the interaction t_0, the absolute position of energy deposition cannot be determined.

Use scintillation light to determine the interaction time in a procedure called "flash-finding"

Reconstruction workflow and data structures



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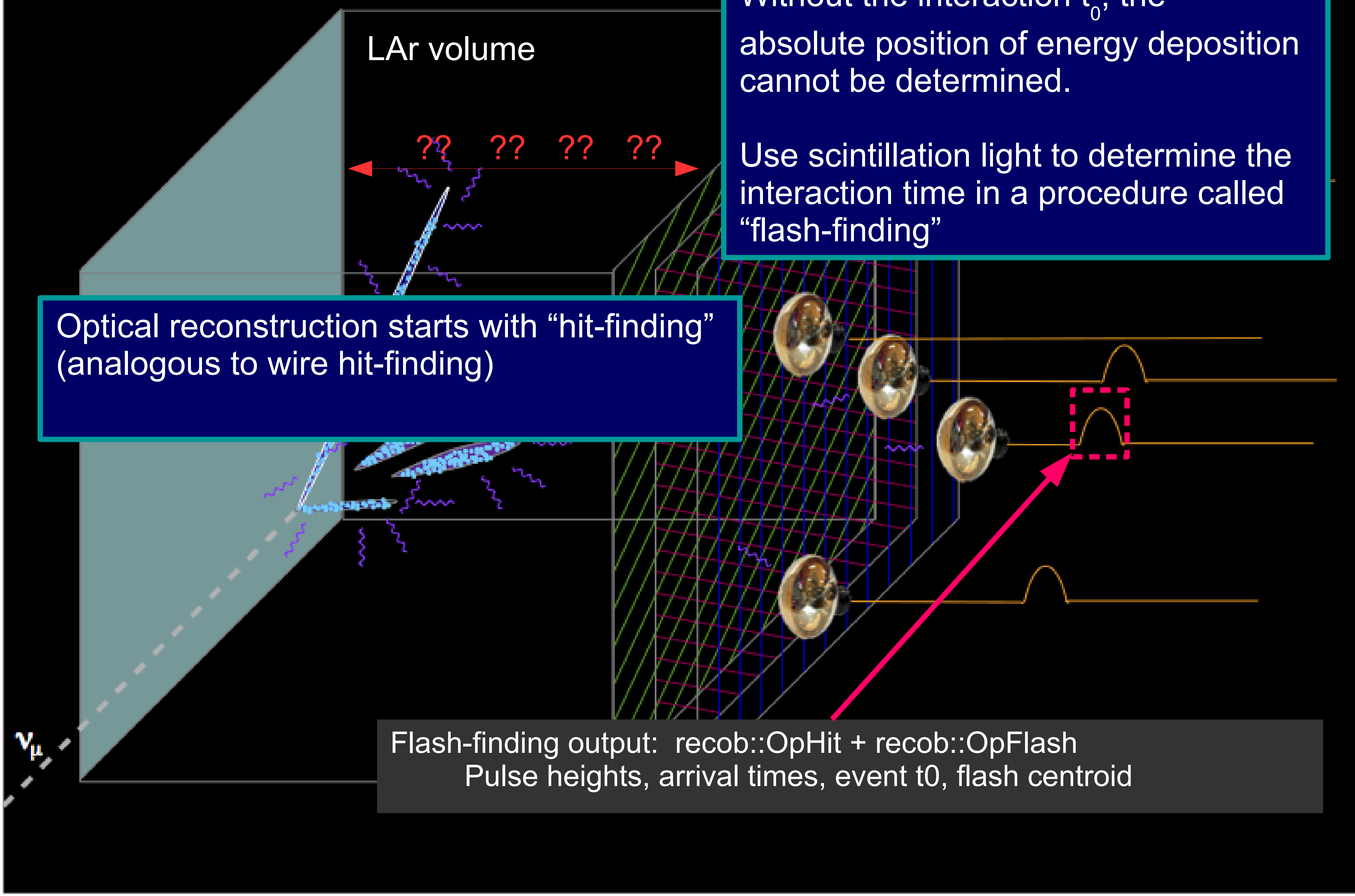
Start with optical raw data

Optical raw datat: raw::OpDetWaveform

Reconstruction workflow and data structures



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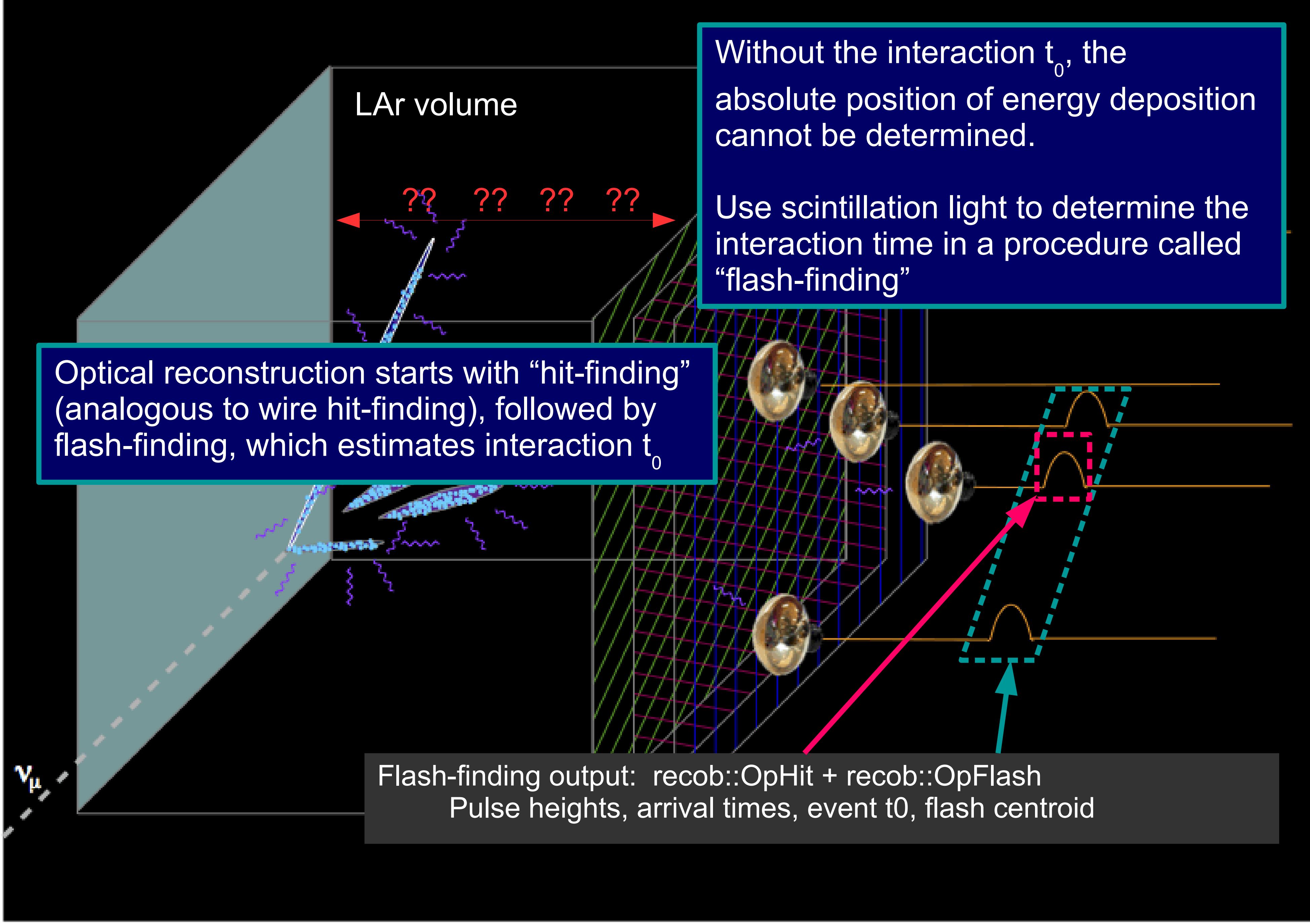
Optical reconstruction starts with “hit-finding” (analogous to wire hit-finding)

Flash-finding output: recob::OpHit + recob::OpFlash
Pulse heights, arrival times, event t0, flash centroid

Reconstruction workflow and data structures



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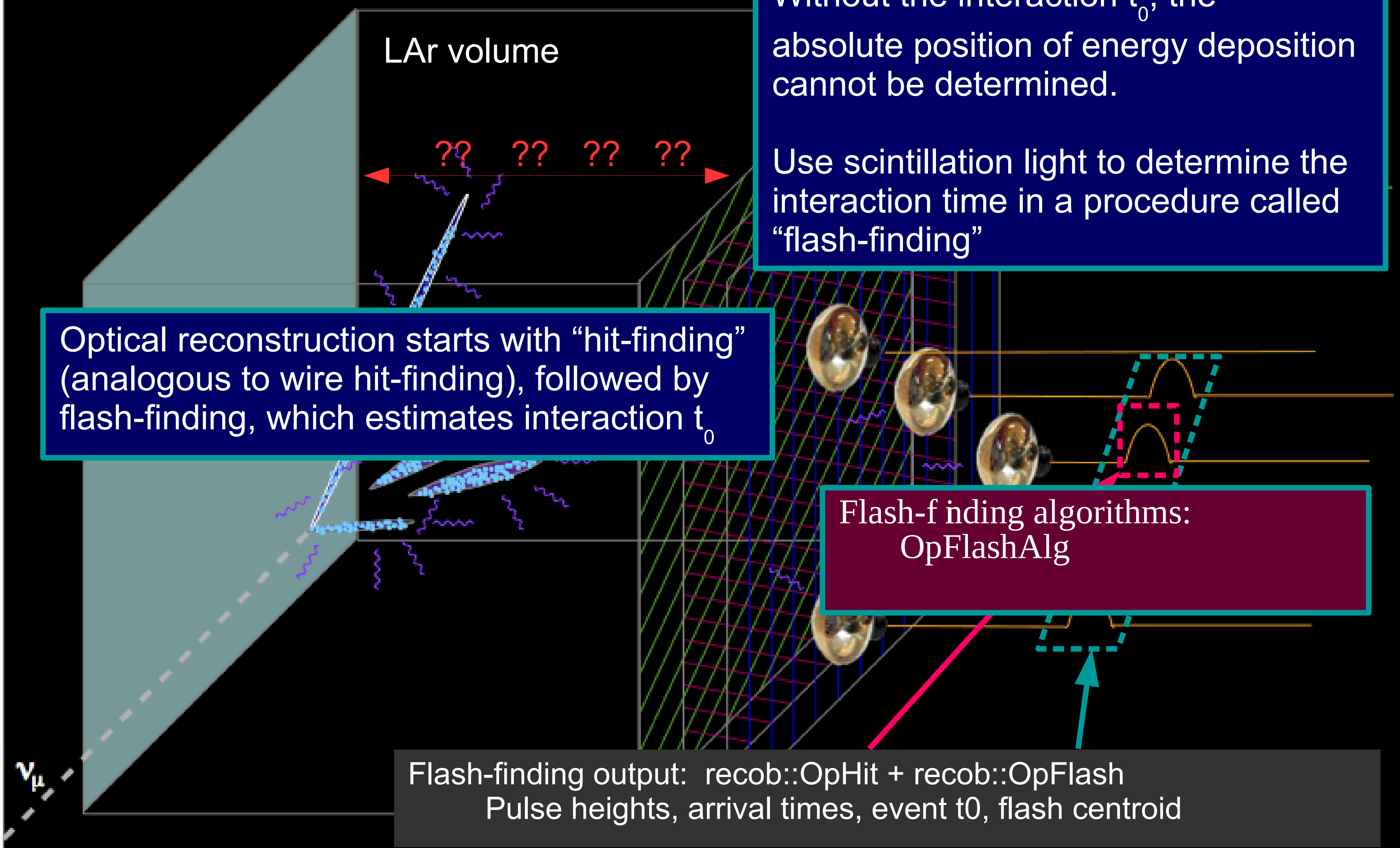

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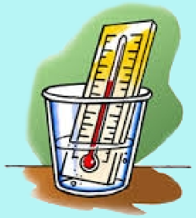
Flash-finding algorithms:
OpFlashAlg

Flash-finding output: recob::OpHit + recob::OpFlash
Pulse heights, arrival times, event t0, flash centroid

Secondary reconstruction

“Analysis-phase” reconstruction

- Cosmic ray removal
  - Particularly important for surface detectors
    - SBN detectors at Fermilab
    - Test beam detectors
  - Employs track-finding, clustering, flash-track and flash-cluster matching
  - Representative algorithms: CosmicTrackTagger, BeamFlashTrackMatchTagger...
  - Output: anab::CosmicTag

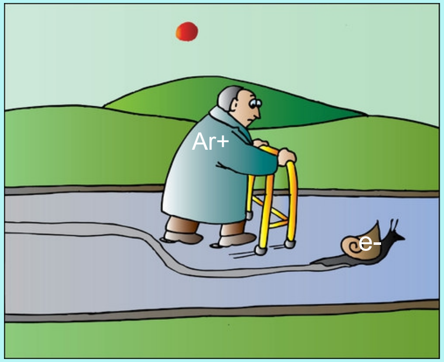


- Calorimetric measurements
  - Energy and dE/dx estimates for Tracks
  - Representative algorithms: CalorimetryAlg, TrackCalorimetryAlg
  - Output: anab::Calorimetry

“Analysis-phase” reconstruction

- Momentum estimation and particle identification
  - Use range, dE/dx and multiple Coulomb scattering of tracks
  - Representative algorithms: Chi2PIDAlg, PIDAAlg
  - Output: anab::ParticleID, Assns<Track, ParticlePID>, or TTree

Other complications



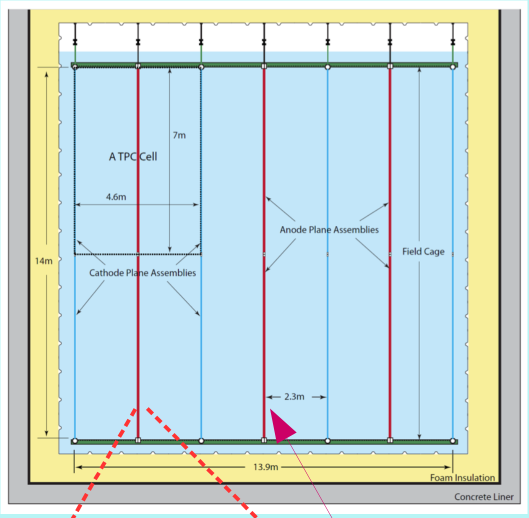
Alexei Talimonov, used w/o permission

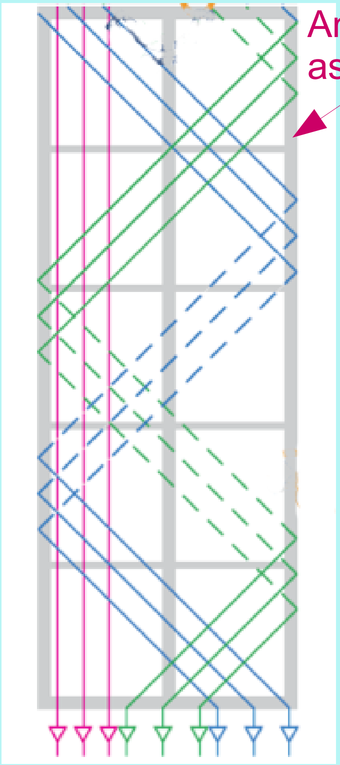
- Space-charge distortions
  - Ion drift mobilities are about $10^6\times$ smaller than that of electrons
    - Cation drift velocities are ~nm / μs !!
  - High cosmic ray rate for surface detectors introduces significant positive ion load
    - At MicroBooNE, field distortions could reach cm scales
  - Need to map and correct for these
  - A common service exists to access the offsets
- Charge attenuation
  - Electron lifetime can be comparable to maximum drift time
  - Effective gain will be drift-length dependent
  - Expect to see significant reduction in SNR with drift distance

Other complications

- Hit disambiguation
  - DUNE TPCs have wrapped induction wires
    - See signals in two TPCs, and in many cases, multiple places within the same TPC
  - Some LArSoft nomenclature:
    - “Wire”: a segment of a physical wire in an anode plane
      - A geometric concept
    - “Channel”: a readout channel connected to one or more “wires”
      - A DAQ concept

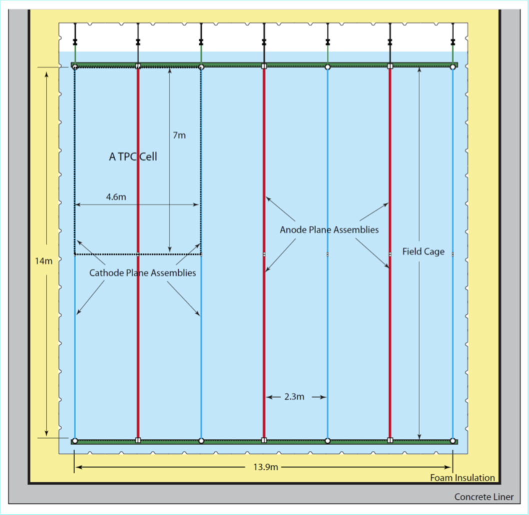
Sectional view of TPCs



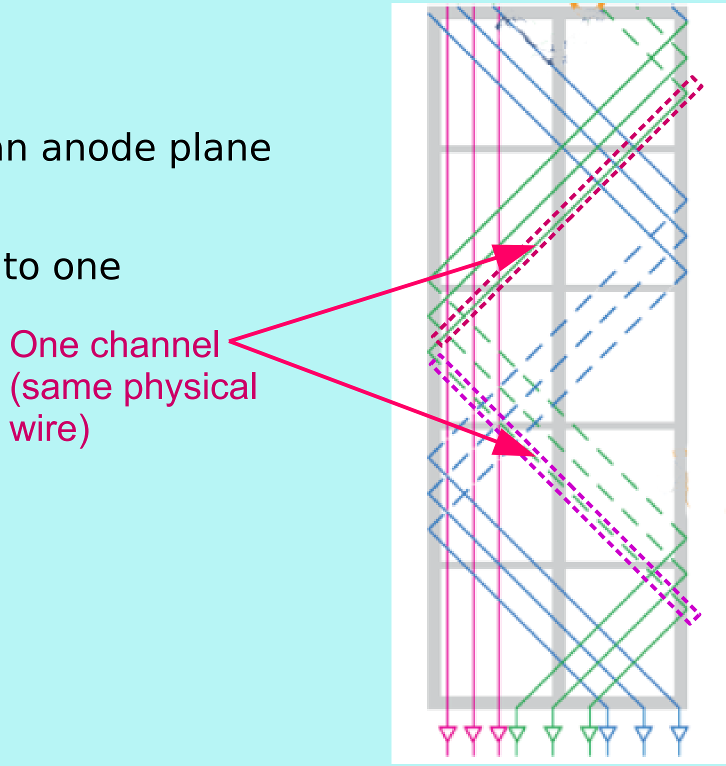


Anode plane assemblies

Other complications



- Hit disambiguation
  - DUNE TPCs have wrapped induction wires
    - See signals in two TPCs, and in many cases, multiple places within the same TPC
  - Some LArSoft nomenclature:
    - "Wire": a segment of a physical wire in an anode plane
      - A geometric concept
    - "Channel": a readout channel connected to one or more "wires"
      - A DAQ concept



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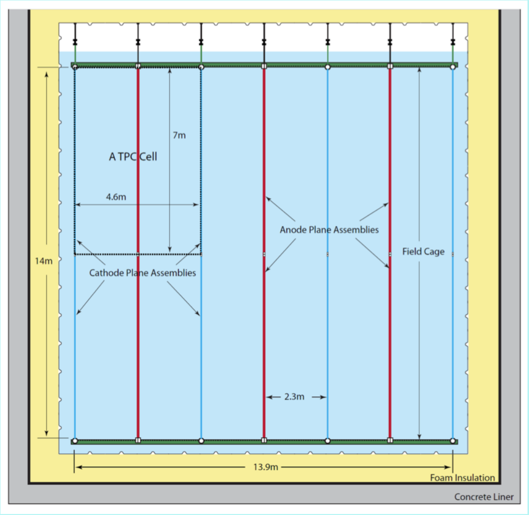
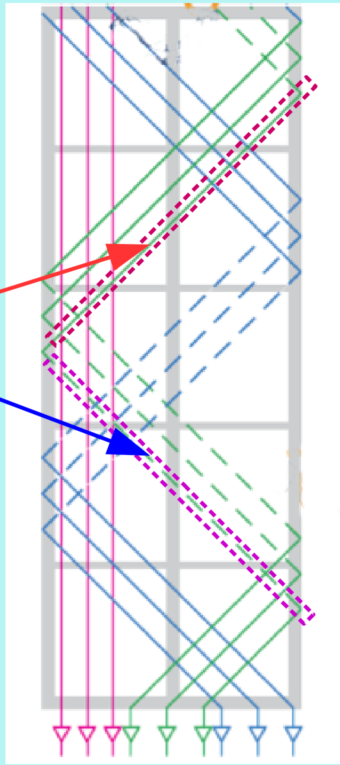
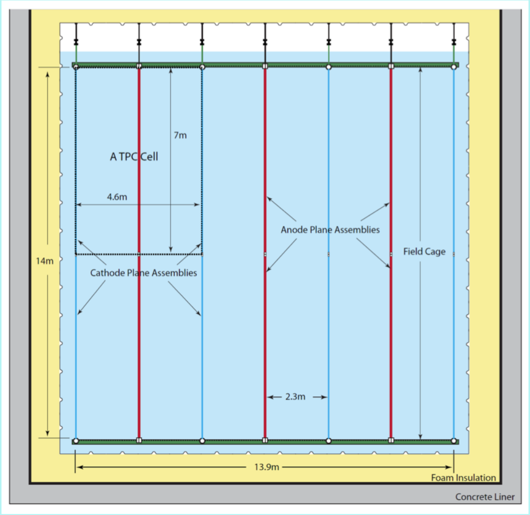


Two “wires”



Other complications

- Hit disambiguation
  - DUNE TPCs have wrapped induction wires
    - See signals in two TPCs, and in many cases, multiple places within the same TPC
  - Introduce a disambiguation step to deal with this
    - Resolves the TPC ambiguity of each induction hit
    - Currently performed after hit-finding
      - Existing algorithms use timing information and neighboring activity



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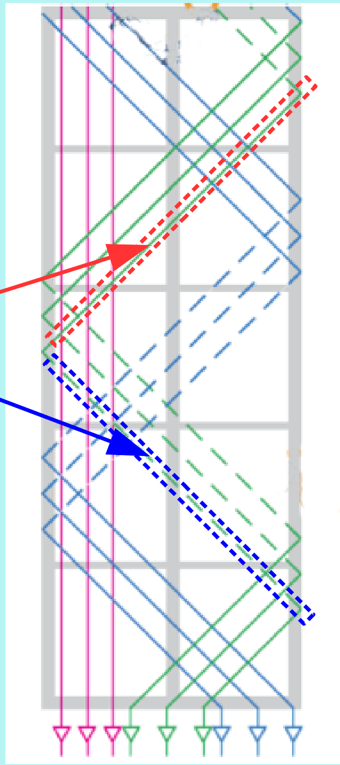


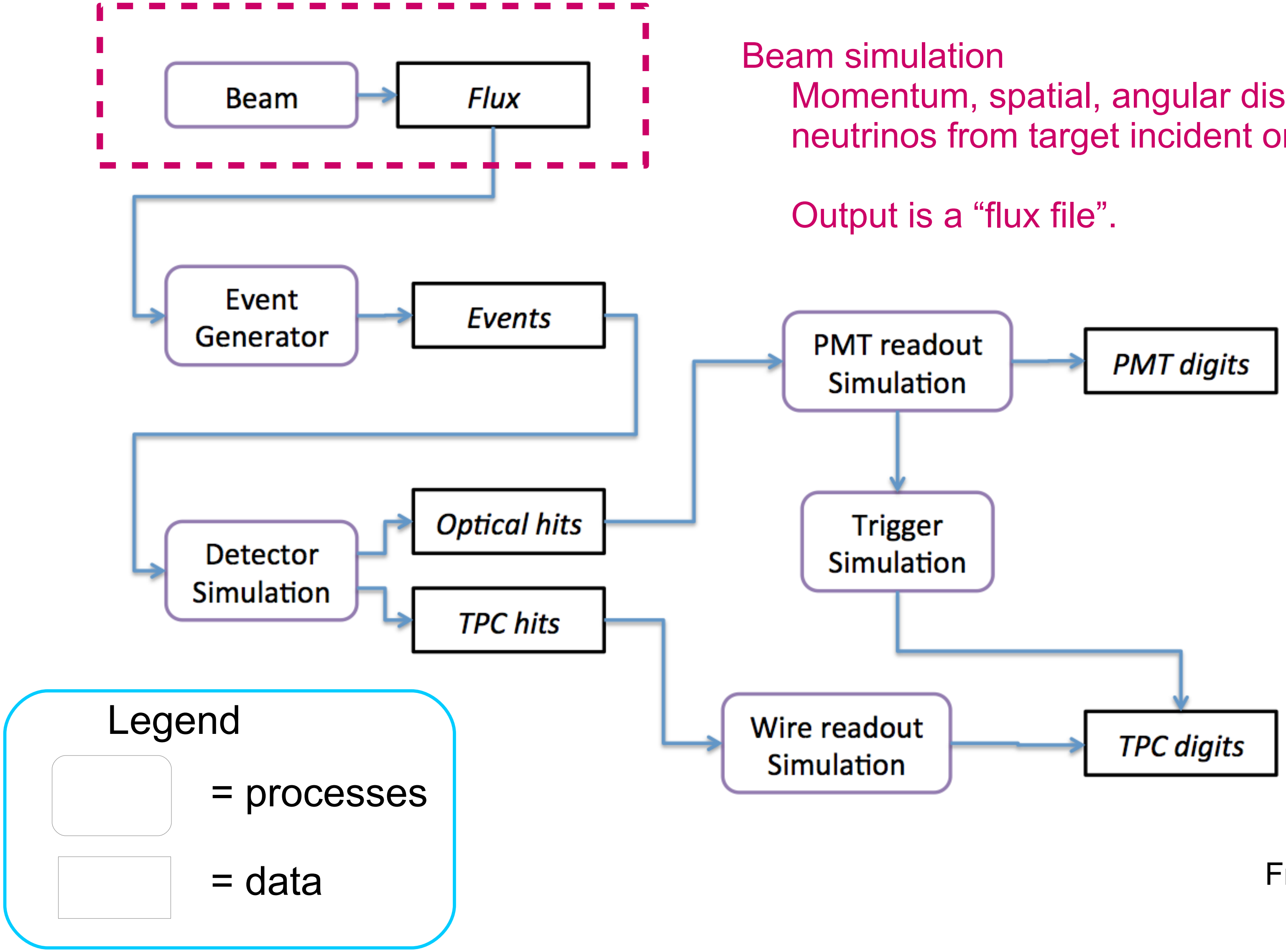
Other complications

- Dual-phase LAr TPCs
  - Under development / consideration by DUNE
  - Do not yet understand potential implications for LArSoft

Detector simulation in LArSoft

Simulation workflow

Three phases, typically run separately



Beam simulation

Momentum, spatial, angular distribution of neutrinos from target incident on detector

Output is a “flux file”.

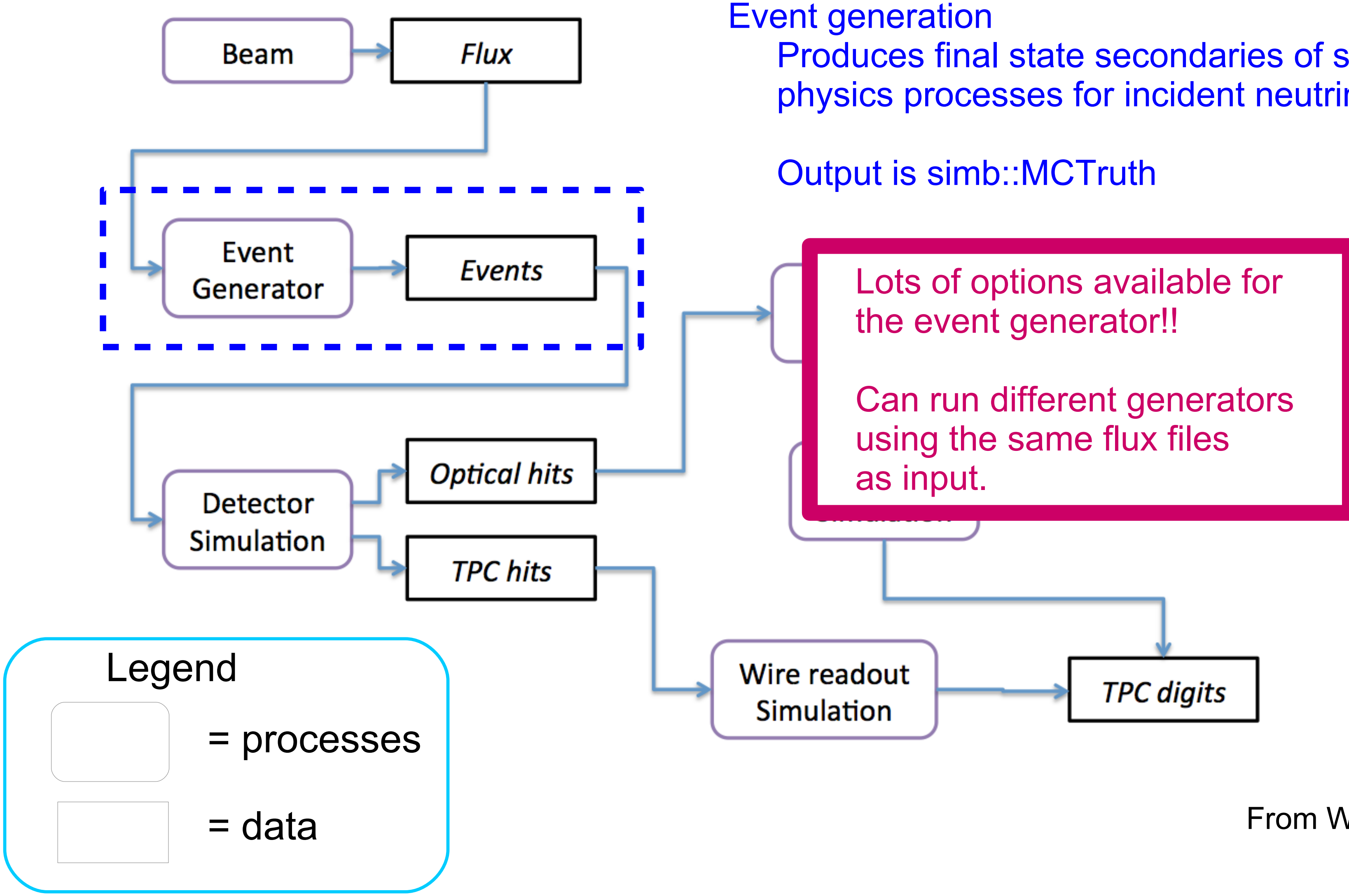
From W Seligman

Simulation workflow

Three phases, typically run separately

Event generation
Produces final state secondaries of selected physics processes for incident neutrinos.

Output is simb::MCTruth



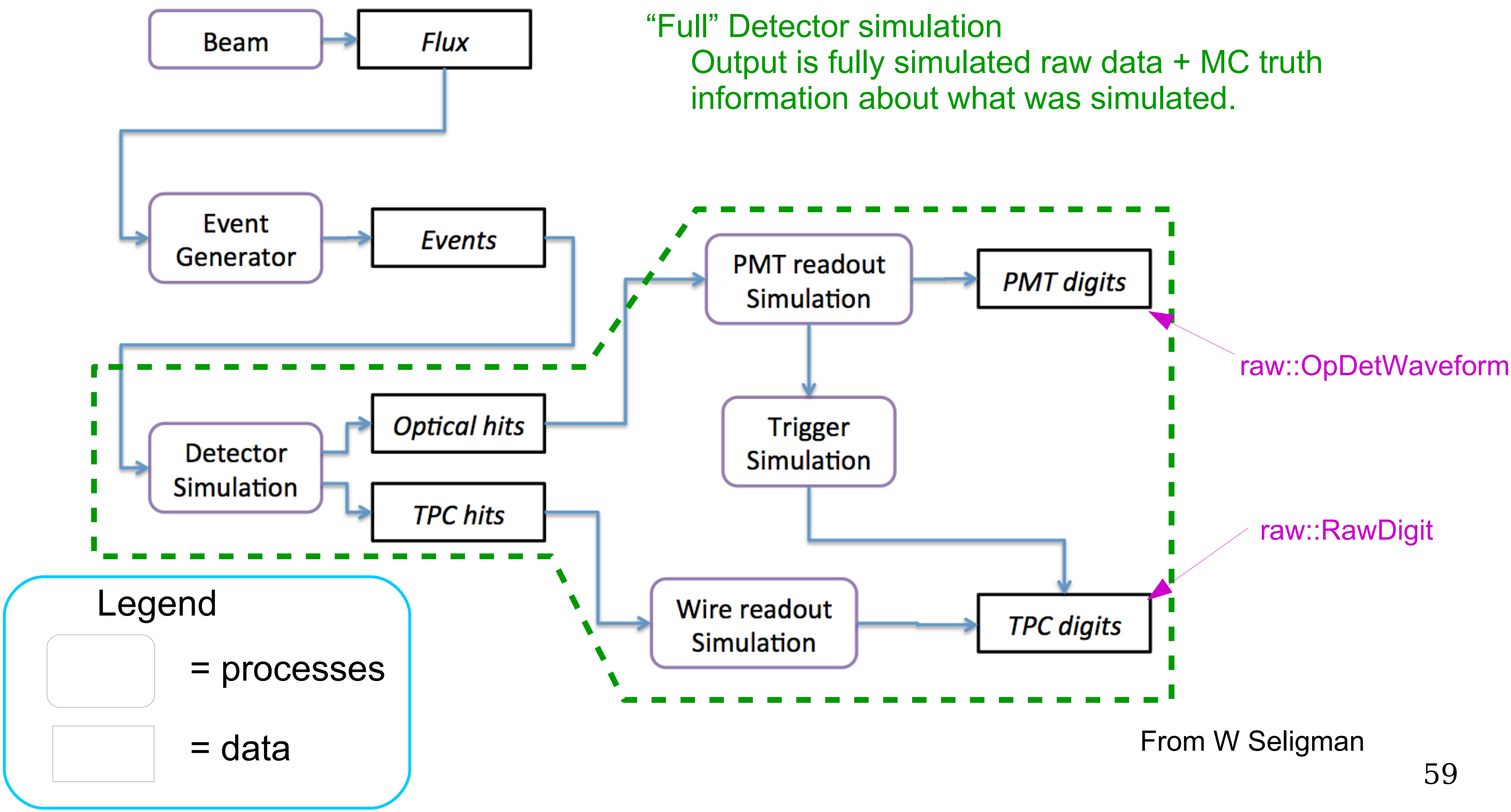
Lots of options available for the event generator!!

Can run different generators using the same flux files as input.

From W Seligman

Simulation workflow

Three phases, typically run separately

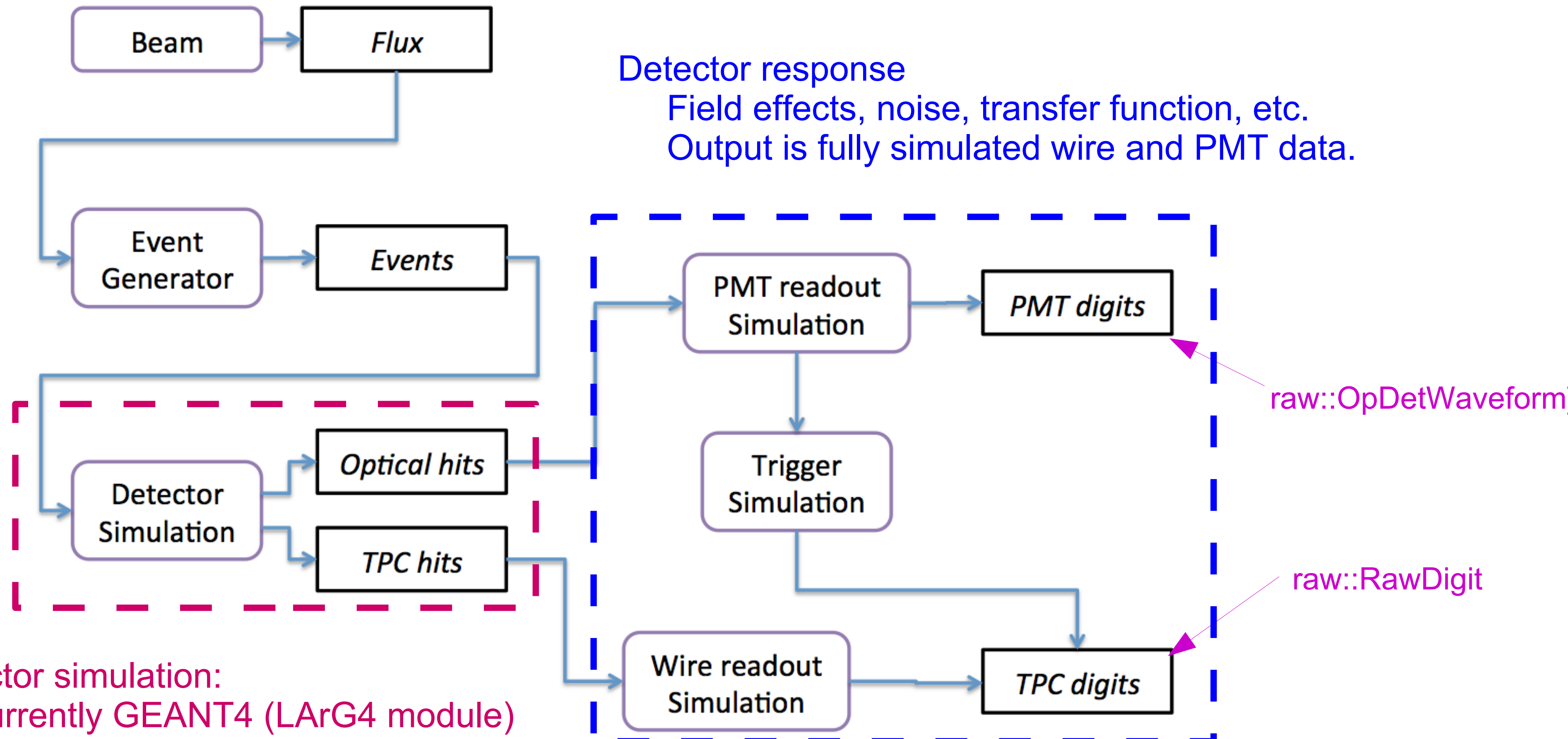


From W Seligman

Simulation workflow

The full detector simulation includes two separable sub-phases

Detector response
- Field effects, noise, transfer function, etc.
- Output is fully simulated wire and PMT data.

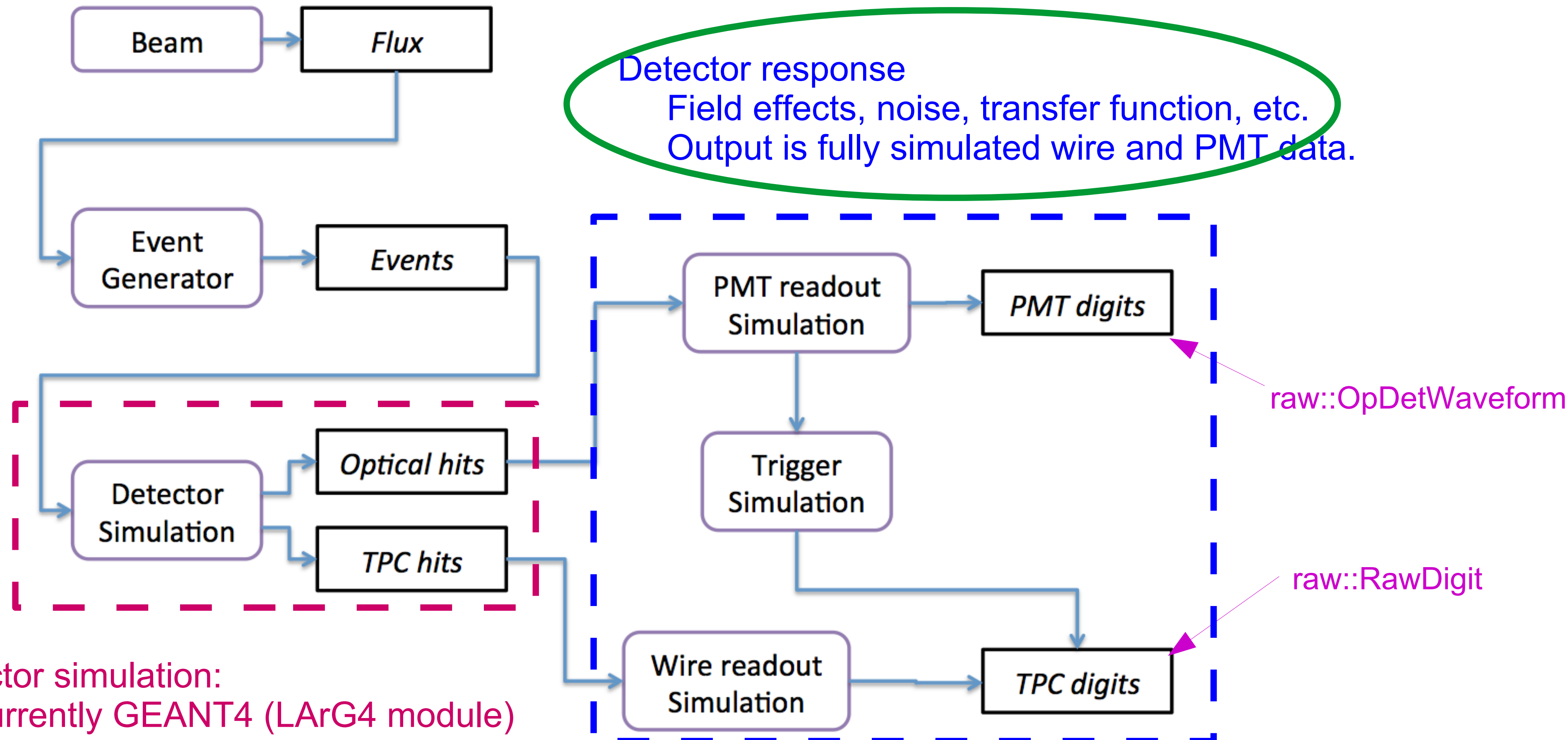


Detector simulation:
- Currently GEANT4 (LArG4 module)
- Particle propagation/interactions, charge/photon transport.
- Output is MC truth information in simb::MCParticle, sim::SimPhoton, sim::SimChannel, sim::AuxDetSimChannel,

From W Seligman

Simulation workflow

Most detect-specific customizations go into the detector response



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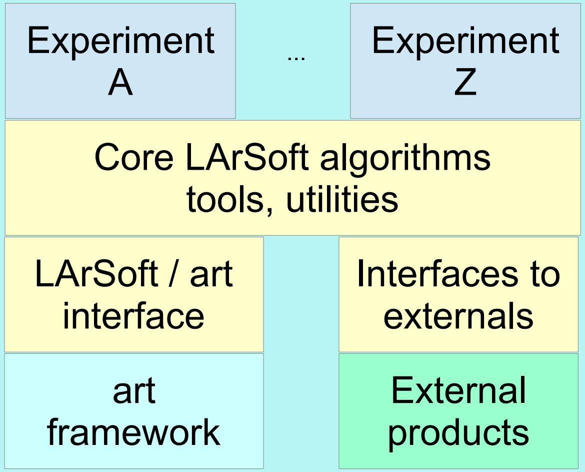
From W Seligman

LArSoft design principles

LArSoft design principles and practices

- Detector interoperability
  - The most important design objective for the LArSoft project
  - Define (and use!!) common interfaces for accessing detector-specific configuration information and functionality
  - Applies to geometry, channel mappings, LAr properties, E-field map...
- Separation of framework and algorithm code
  - Encapsulate algorithms, configuration, tools and utilities into a layer that is independent of the art framework
  - Will describe reasons and techniques to achieve this later in the course



General disclaimer:

In examining the code, you may note that only a portion currently adheres to these principles.

- An on-going architecture review project is intended to address this

Strongly encourage people to adopt these practices for all new code

LArSoft design principles and practices

- Use of standardized algorithm interfaces
  - Define standard interfaces for well-defined steps in the workflow to promote modularity, layering of algorithms
- Modularity
  - Build sophistication by applying algorithms in a layered, iterative structure
- Design / write testable units of code
  - Include unit and integration testing in the development process
  - Follow the practice of continuous integration
    - Perform automated, broad-scale testing at frequent intervals in order to catch unintended side-effects quickly

LArSoft design principles and practices

- Document code in the source files
  - See many files with no comments at all
  - At very least, need the purpose of the file, how it is used, pre-requisites, assumptions,

Using LArSoft

Supported platforms

- Scientific Linux
  - SLF6
  - Have also installed / run this code under:
    - SLC6 (CERN)
    - Redhat 6 (SLAC)
- Mac OSX
  - Mavericks and Yosemite
    - ups qualifiers d13:noifdh and d14:noifdh respectively
- Installation instructions
  - See links in release notes available at https://cdcvs.fnal.gov/redmine/projects/larsoft/wiki/LArSoft_release_list

Releases

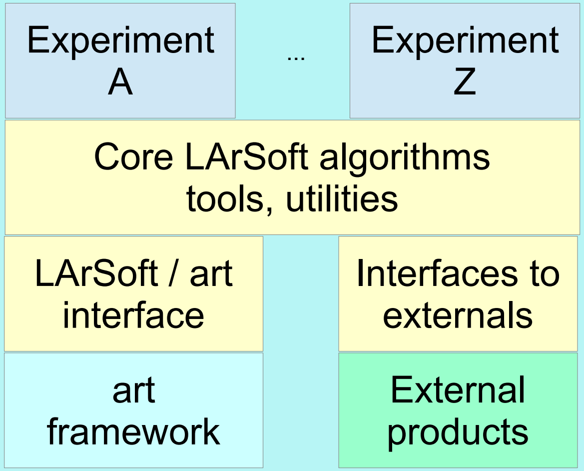
- Two types of releases
  - Integration
    - Created weekly or on demand for special purposes
    - Contents approved at Coordination Meetings
      - Head of develop + additional branches approved at a CM or via email
    - May be removed without notice after about a month
      - In practice, we announce our intentions in advance
  - Production
    - Any release designated as “production” by an experiment
    - Created on demand (but usually on the weekly schedule)
    - Contents approved by the experiment declaring production
      - Typically also coordinated through the CM to keep other experiments informed
    - Production releases are retained on disk indefinitely
- List of all available tagged releases
  - https://cdcvs.fnal.gov/redmine/projects/larsoft/wiki/LArSoft_release_list

How to set up and run art/LArSoft

- First point to note
  - LArSoft is designed to be run by experiments
    - Need detector-specific parts to run it
    - So start with the code of your experiment

MicroBooNE	uboonecode
DUNE	lbnecode (changing name soon!!)
SBND	lar1ndcode (changing??)
LArIAT	lariatsoft

The setup procedures for each are different
so refer to the setup relevant setup instructions



- Second point to note
  - Do not need a “working area” to run LArSoft. Just need to set up the appropriate products + a fcl file

How to set up and run art/LArSoft

- The most simple scenario: run from a tagged LArSoft release
  - First, set up the working environment:

```
# Set up ups
source <ups location>/setup
#
# Set up the working environment
# for your experiment
<the setup procedure for your experiment here>

# Set up a LArSoft release
setup larsoft v04_16_00 -q e7:<prof|debug>
```

    - In most cases, experiment-specific setup scripts will include all of the above
    - Note that setting up for development requires additional steps
  - Now run art (the LArSoft version is called `lar`)

```
# List art command-line options
lar --help
#
# Now run LArSoft
#
lar -c <some fcl file>.fcl [-i <input file>]
```

That's it! ...if you have a fcl file and have no code to change

Setting up and running LArSoft as a developer

- This is the second case of running LArSoft,
  - Applies to people developing LArSoft, or writing analysis software using art
  - Will defer this to the next session, when Saba will talk about how to contribute to LArSoft and use the build tools

Getting LArSoft to work with a new detector

- LArSoft is really a toolkit
  - It requires a certain amount of detector-specific information and plug-in functionality in order to work
- The minimum needed to run LArSoft for a new detector
  - Define the geometry for the new detector in a GDML file
  - Customize E-field, drift velocity, readout parameters, etc, as needed
  - Customize digitization for simulation, as needed
  - Write a fcl file
  - lar -c sim_new_det.fcl → simulated data; lar -c <reco...>.fcl → results!!

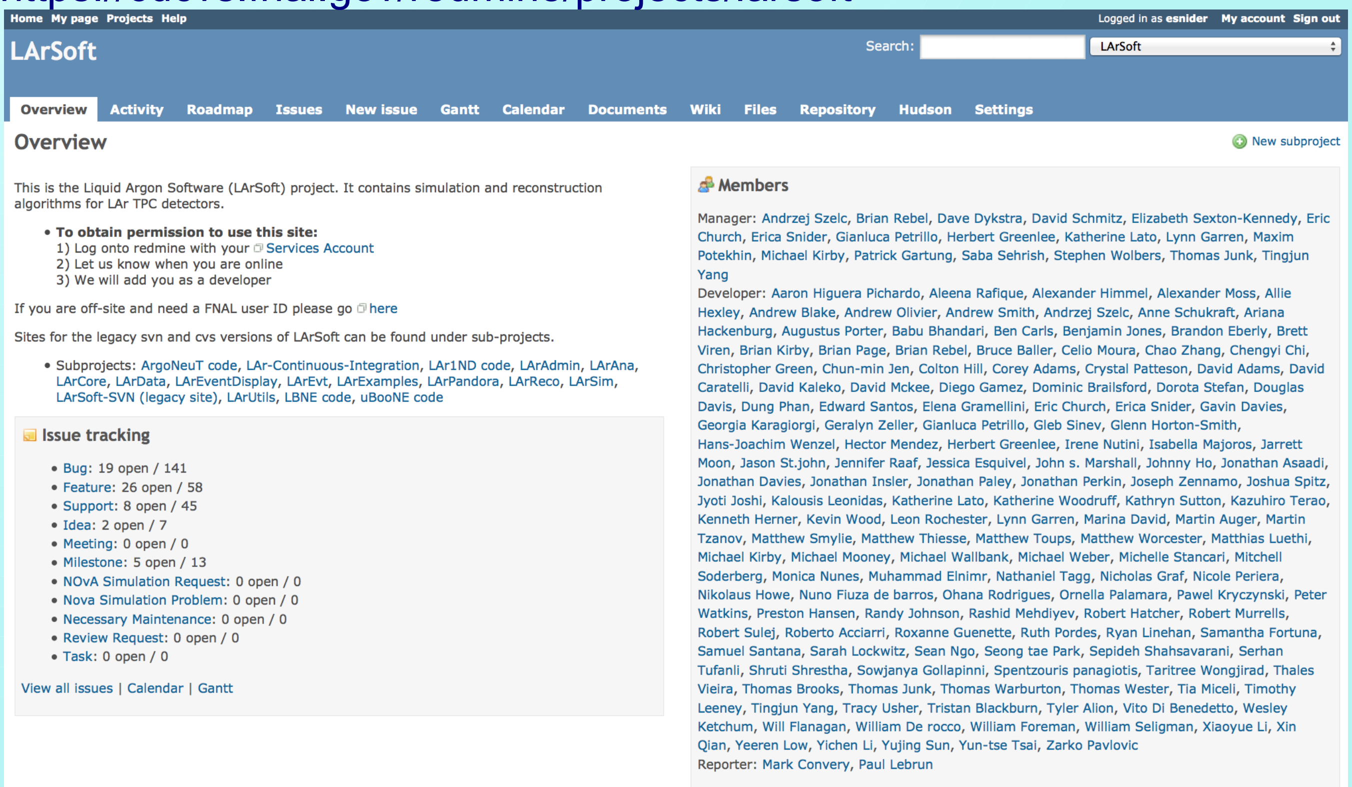
...A bit over-simplified, but this is basically what happens

Resources

LArSoft Redmine site

Redmine sites are called “projects”

https://cdcvs.fnal.gov/redmine/projects/larsoft



This is the home page for the LArSoft Redmine project

Tabs across the top link to different types of content

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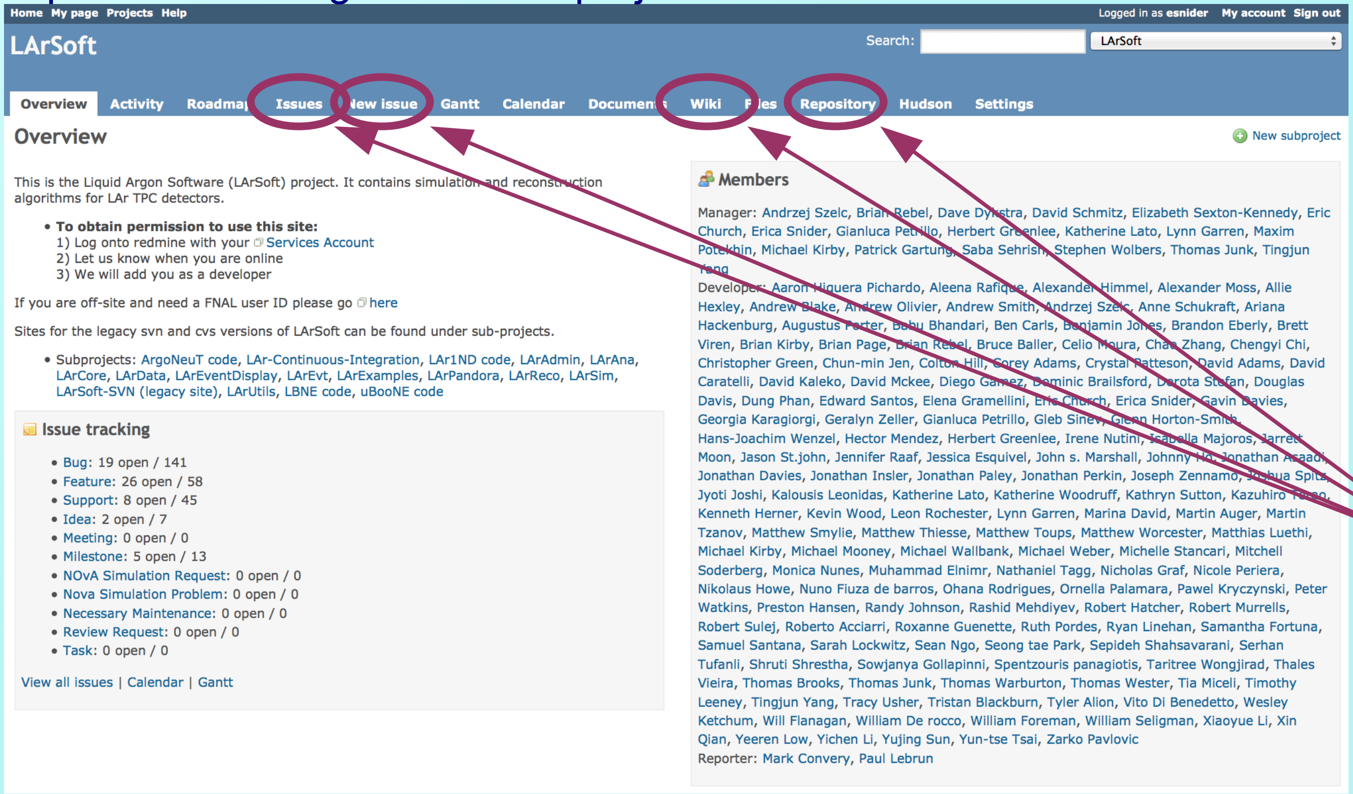


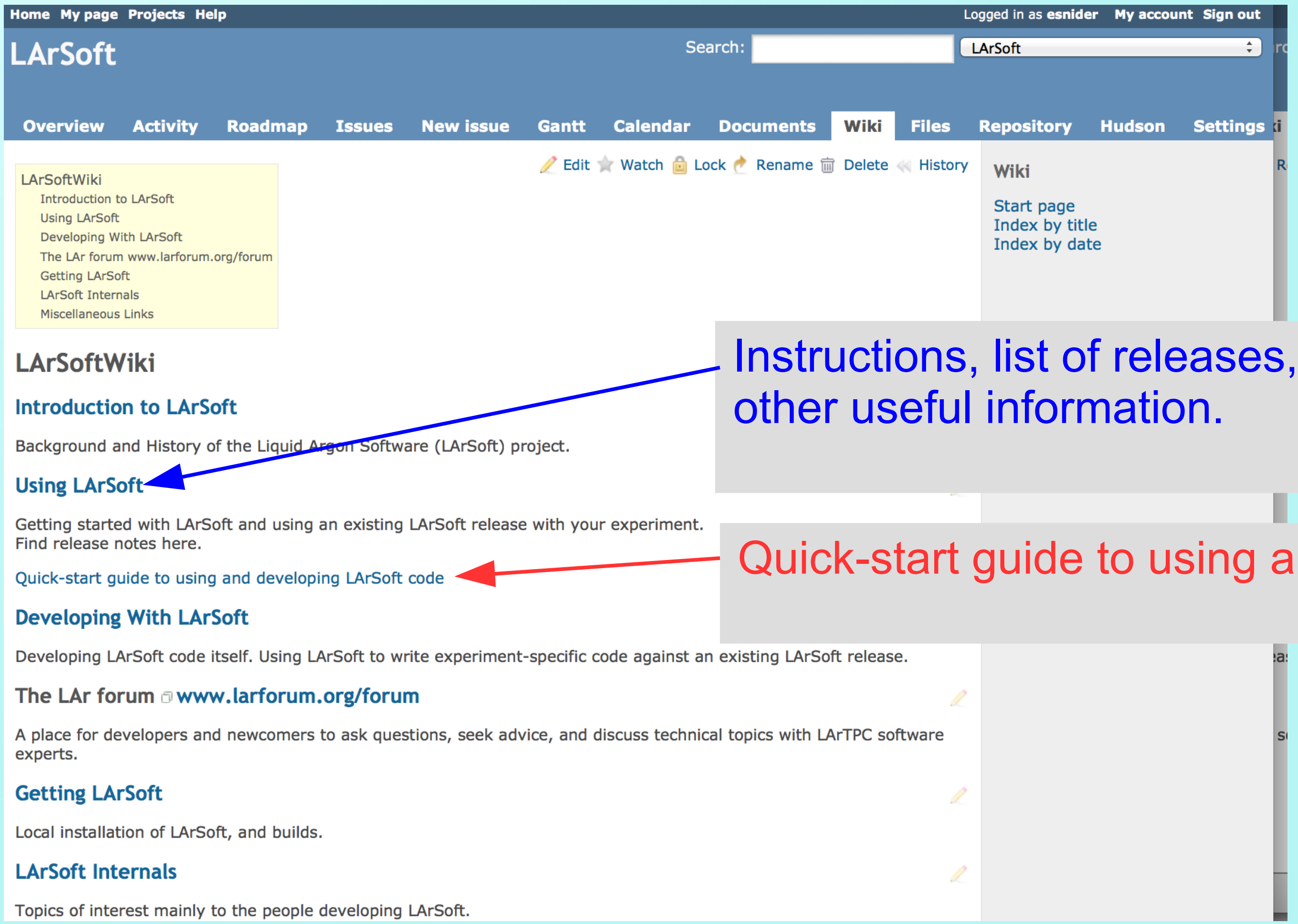
This is the home page for the LArSoft Redmine project

Tabs across the top link to different types of content

The most useful tabs:
- Wiki
- Issues
- New Issues
- Repository

LArSoft wiki

https://cdcvs.fnal.gov/redmine/projects/larsoft/wiki



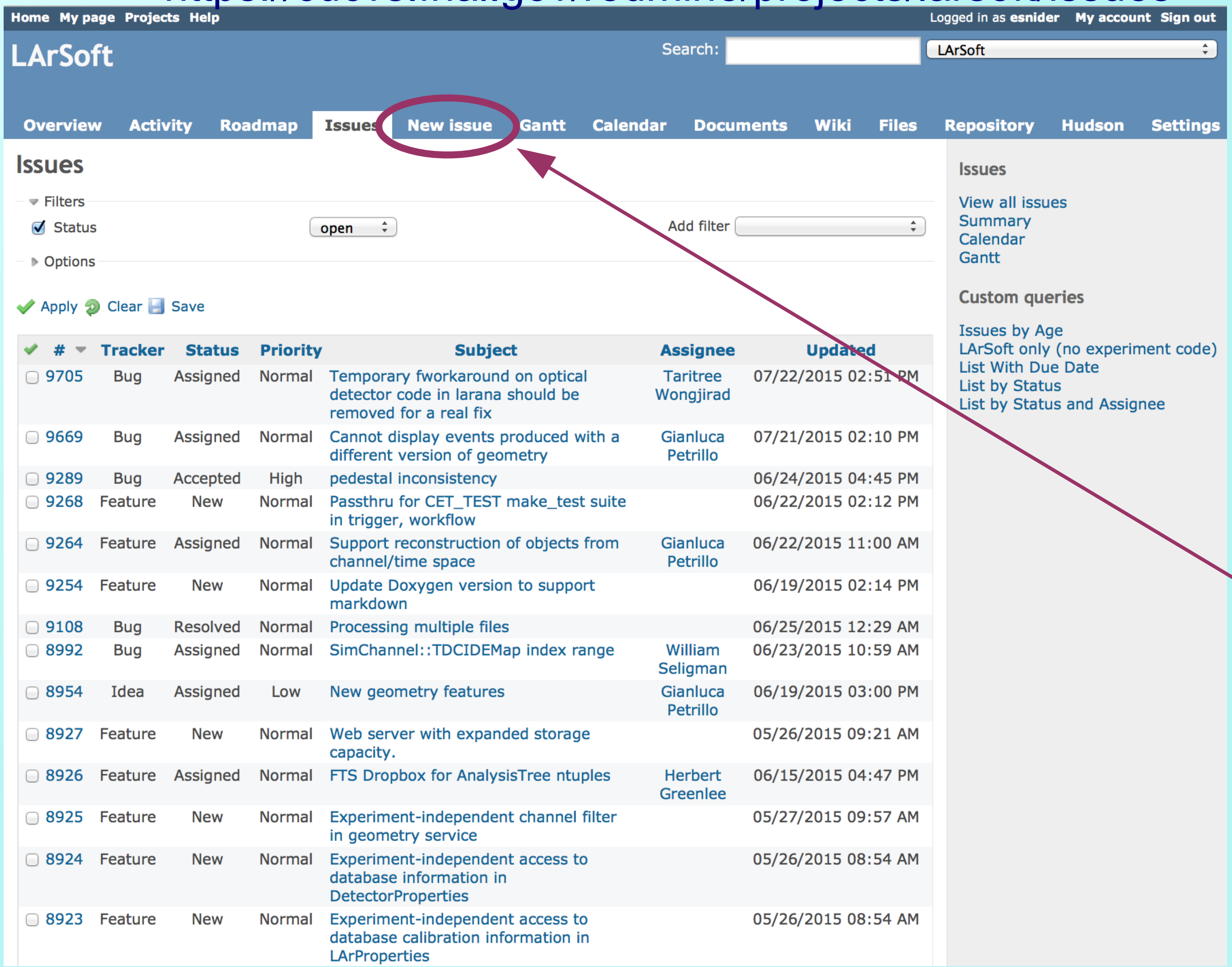
General information and documentation

Instructions, list of releases, and other useful information.

Quick-start guide to using and developing LArSoft code

LArSoft issue tracker

https://cdcvs.fnal.gov/redmine/projects/larsoft/issues



We track bugs, problems with LArSoft-related infrastructure, requests for support and new features, questions...

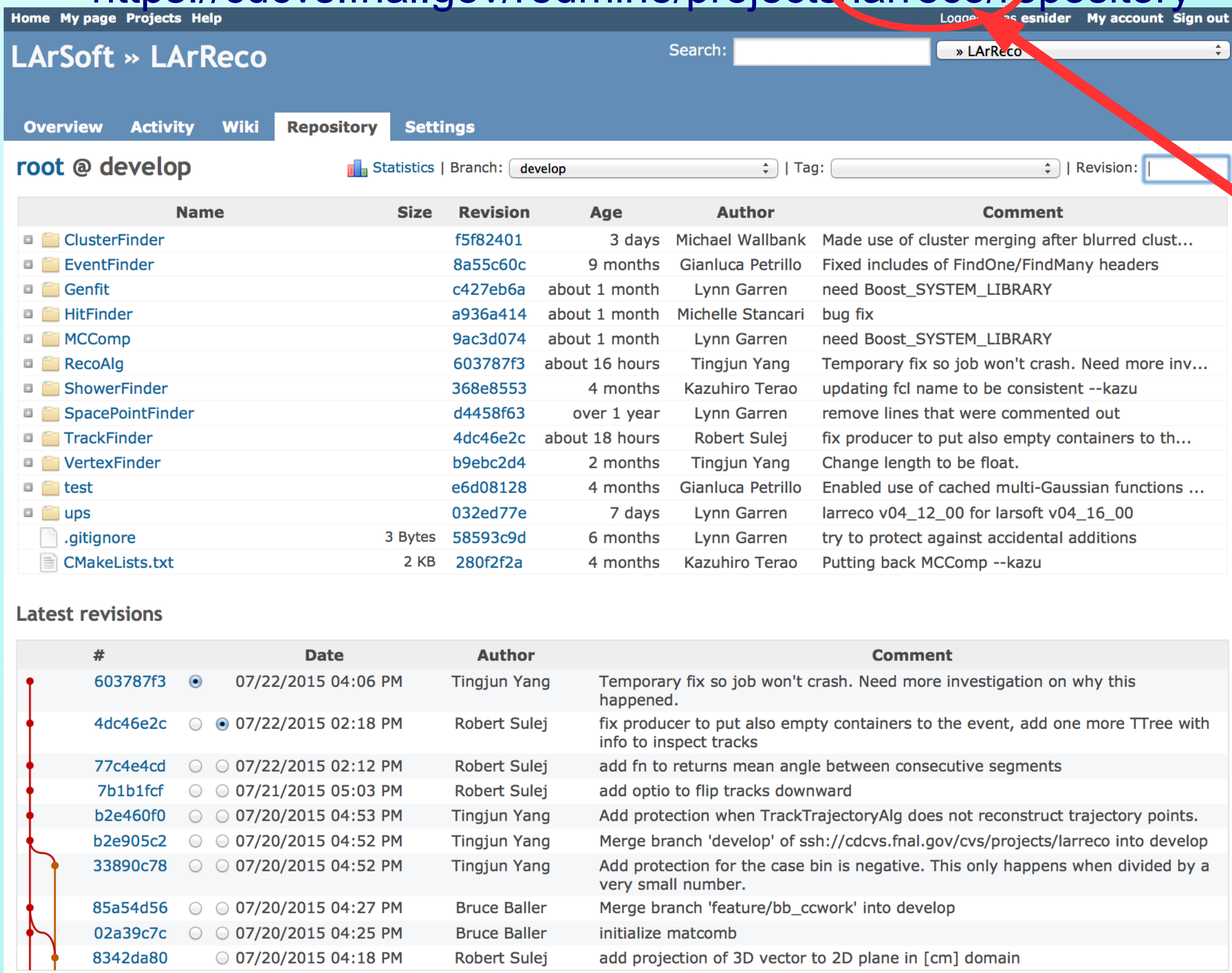
Open a new ticket using the “New Issue” tab if you have any of the above

Create a new issue using this tab.

Must be logged into Redmine using your Fermilab **services account** and password

LArSoft Redmine code browser …

https://cdcvs.fnal.gov/redmine/projects/larreco/repository



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LArSoft » LArReco

Search: | » LArReco

Overview Activity Wiki Repository Settings

root @ develop | Statistics | Branch: develop | Tag: | Revision:

Name	Size	Revision	Age	Author	Comment
ClusterFinder		f5f82401	3 days	Michael Wallbank	Made use of cluster merging after blurred clust…
EventFinder		8a55c60c	9 months	Gianluca Petrillo	Fixed includes of FindOne/FindMany headers
Genfit		c427eb6a	about 1 month	Lynn Garren	need Boost_SYSTEM_LIBRARY
HitFinder		a936a414	about 1 month	Michelle Stancari	bug fix
MCComp		9ac3d074	about 1 month	Lynn Garren	need Boost_SYSTEM_LIBRARY
RecoAlg		603787f3	about 16 hours	Tingjun Yang	Temporary fix so job won't crash. Need more inv…
ShowerFinder		368e8553	4 months	Kazuhiro Terao	updating fcl name to be consistent --kazu
SpacePointFinder		d4458f63	over 1 year	Lynn Garren	remove lines that were commented out
TrackFinder		4dc46e2c	about 18 hours	Robert Sulej	fix producer to put also empty containers to th…
VertexFinder		b9ebc2d4	2 months	Tingjun Yang	Change length to be float.
test		e6d08128	4 months	Gianluca Petrillo	Enabled use of cached multi-Gaussian functions …
ups		032ed77e	7 days	Lynn Garren	larreco v04_12_00 for larsoft v04_16_00
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CMakeLists.txt	2 KB	280f2f2a	4 months	Kazuhiro Terao	Putting back MCComp --kazu

Latest revisions

#	Date	Author	Comment
603787f3	07/22/2015 04:06 PM	Tingjun Yang	Temporary fix so job won't crash. Need more investigation on why this happened.
4dc46e2c	07/22/2015 02:18 PM	Robert Sulej	fix producer to put also empty containers to the event, add one more TTree with info to inspect tracks
77c4e4cd	07/22/2015 02:12 PM	Robert Sulej	add fn to returns mean angle between consecutive segments
7b1b1fcf	07/21/2015 05:03 PM	Robert Sulej	add optio to flip tracks downward
b2e460f0	07/20/2015 04:53 PM	Tingjun Yang	Add protection when TrackTrajectoryAlg does not reconstruct trajectory points.
b2e905c2	07/20/2015 04:52 PM	Tingjun Yang	Merge branch 'develop' of ssh://cdcvs.fnal.gov/cvs/projects/larreco into develop
33890c78	07/20/2015 04:52 PM	Tingjun Yang	Add protection for the case bin is negative. This only happens when divided by a very small number.
85a54d56	07/20/2015 04:27 PM	Bruce Baller	Merge branch 'feature/bb_ccwork' into develop
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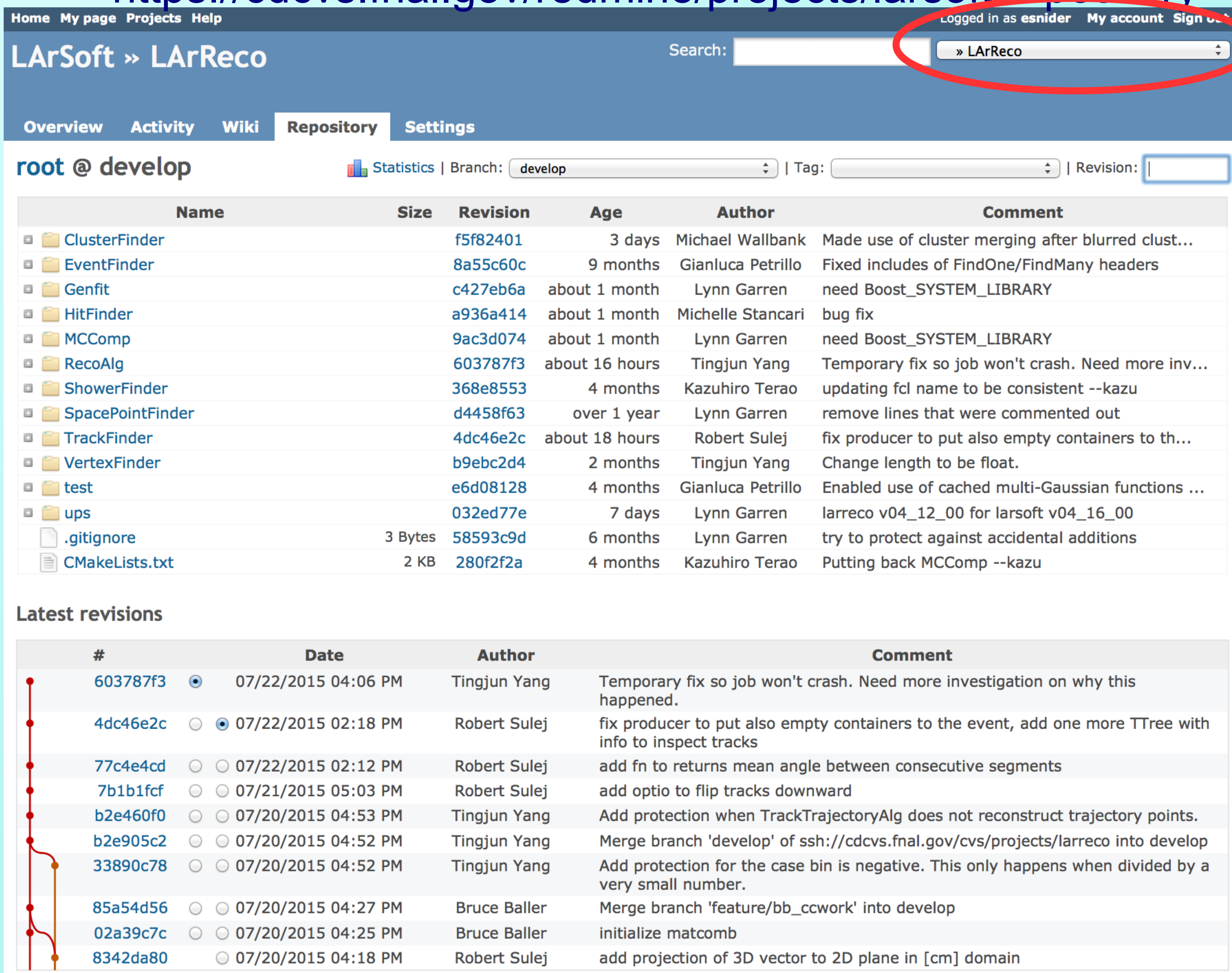
8342da80	07/20/2015 04:18 PM	Robert Sulej	add projection of 3D vector to 2D plane in [cm] domain

Each LArSoft repository lives in a separate Redmine project which is specified here.

Navigating between LArSoft sub-projects

https://cdcvs.fnal.gov/redmine/projects/larsoft/repository



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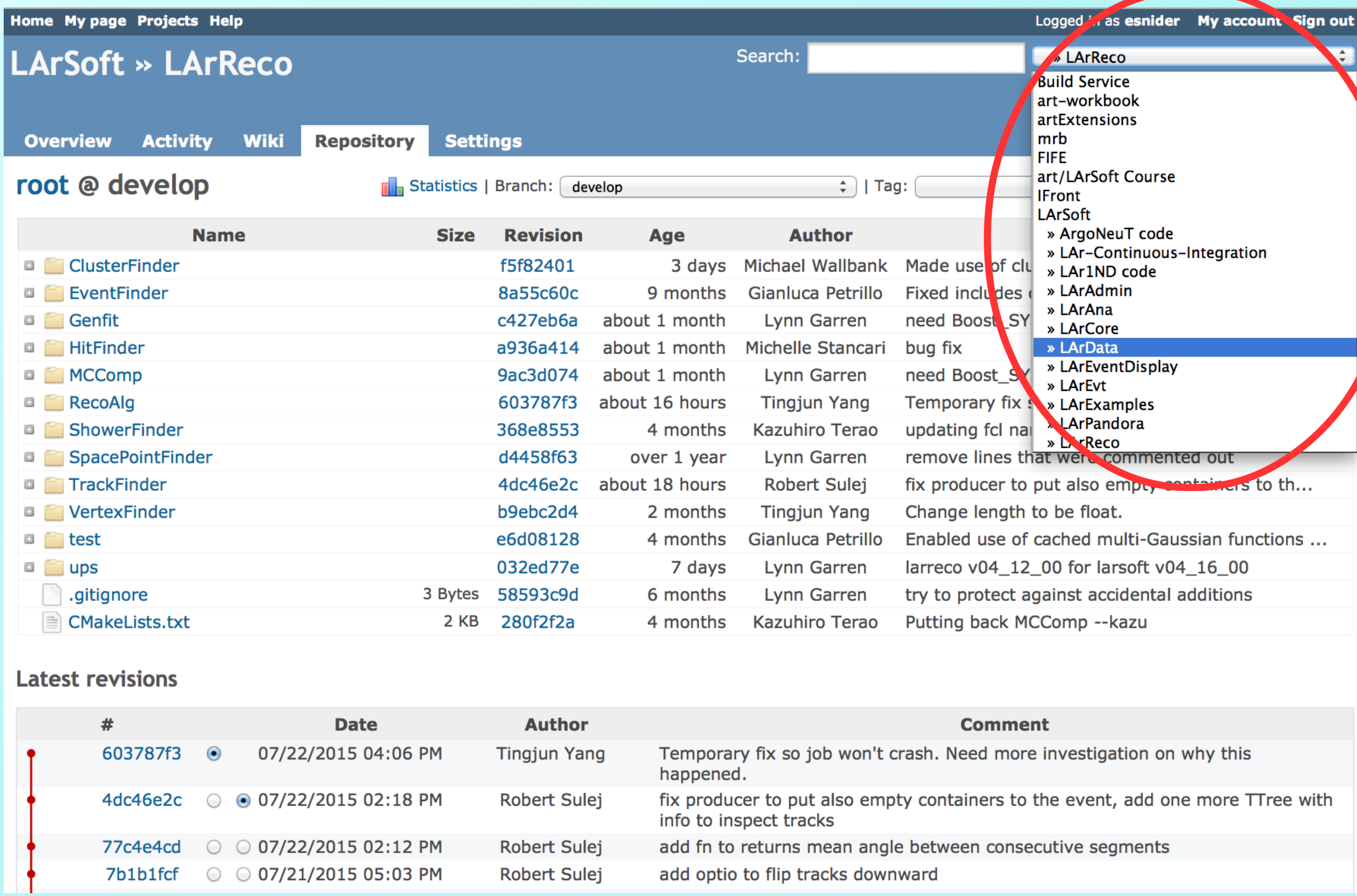
Navigating between LArSoft sub-projects



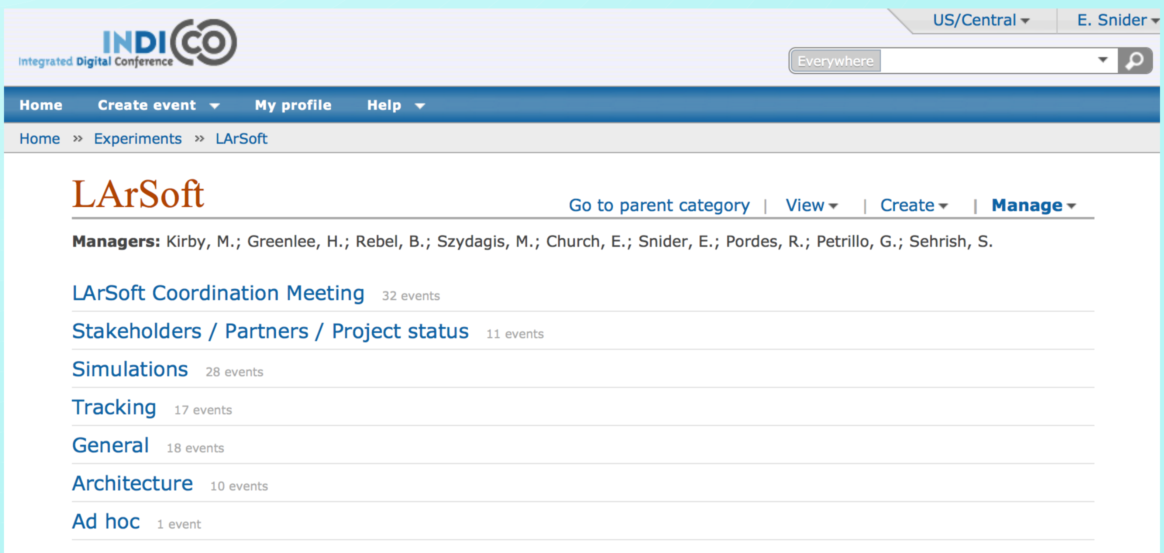
Can use the project navigation pull-down to get to the desired project.

LArSoft Indico site

- Slides and documents from meetings are posted to Indico

  https://indico.fnal.gov/categoryDisplay.py?categId=233

  - Or from the Indico home page: https://indico.fnal.gov/index.py, follow "Experiments", then "LArSoft" links to arrive at the LArSoft page



Can upload slides on the page for the particular meeting...

...but, must be logged in using your **Indico account** and password

Resources

- LArSoft dOxygen documentation system:
  - http://nusoft.fnal.gov/larsoft/doxsvn/html/index.html
- LAr reconstruction software forum: http://www.larforum.org/forum
  - Help with general problems in LAr software
  - So far almost entirely focused on LArSoft...
- LArSoft email list: larsoft@fnal.gov
  - General announcements. Often technical questions also.
  - Can self-subscribe. See http://listserv.fnal.gov/ for instructions.
- LArSoft Coordination Meeting
  - Bi-weekly at 13:00 Central Time. July 28 is the next one.
  - Remote connections via ReadyTalk. Slides posted to LArSoft Indico site.
- LArSoft wiki: https://cdcvs.fnal.gov/redmine/projects/larsoft/wiki
  - Quick-start guide to using and developing LArSoft code
  - See also https://cdcvs.fnal.gov/redmine/projects/uboonecode/wiki
- LArSoft issue tracker
  - https://cdcvs.fnal.gov/redmine/projects/larsoft/issues/new

Core LArSoft support team

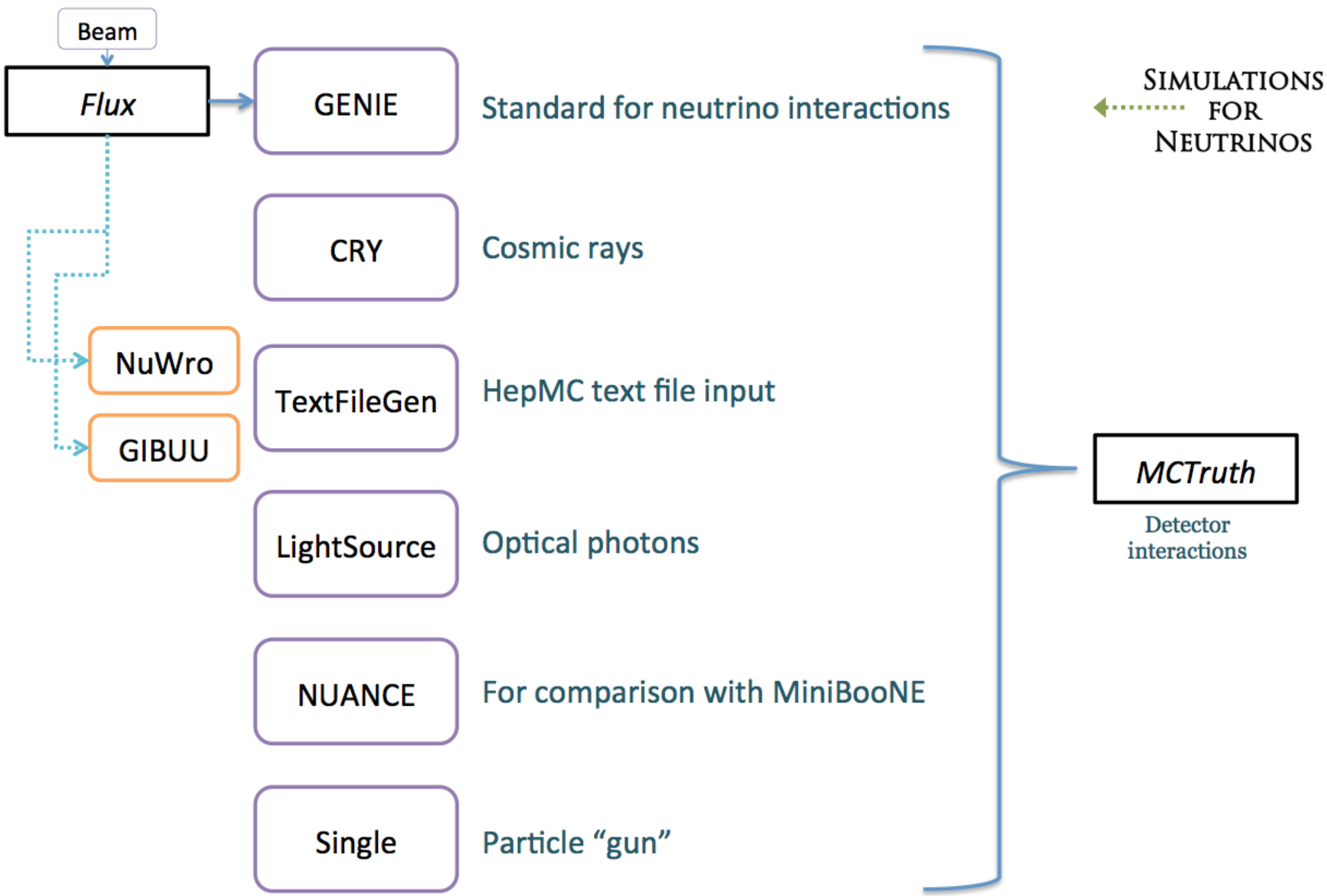
- Core team members
  - Technical lead: Erica Snider
    erica@fnal.gov
  - Project manager: Ruth Pordes
    ruth@fnal.gov
  - Lead developer: Gianluca Petrillo
    petrillo@fnal.gov
  - Developer: Saba Sehrish
    ssehrish@fnal.gov
  - Code management and distribution: Lynn Garren
    garren@fnal.gov
  - CI operations and testing support: Vito di Benedetto
    vito@fnal.gov

Email / visit any of the project team!!

The end

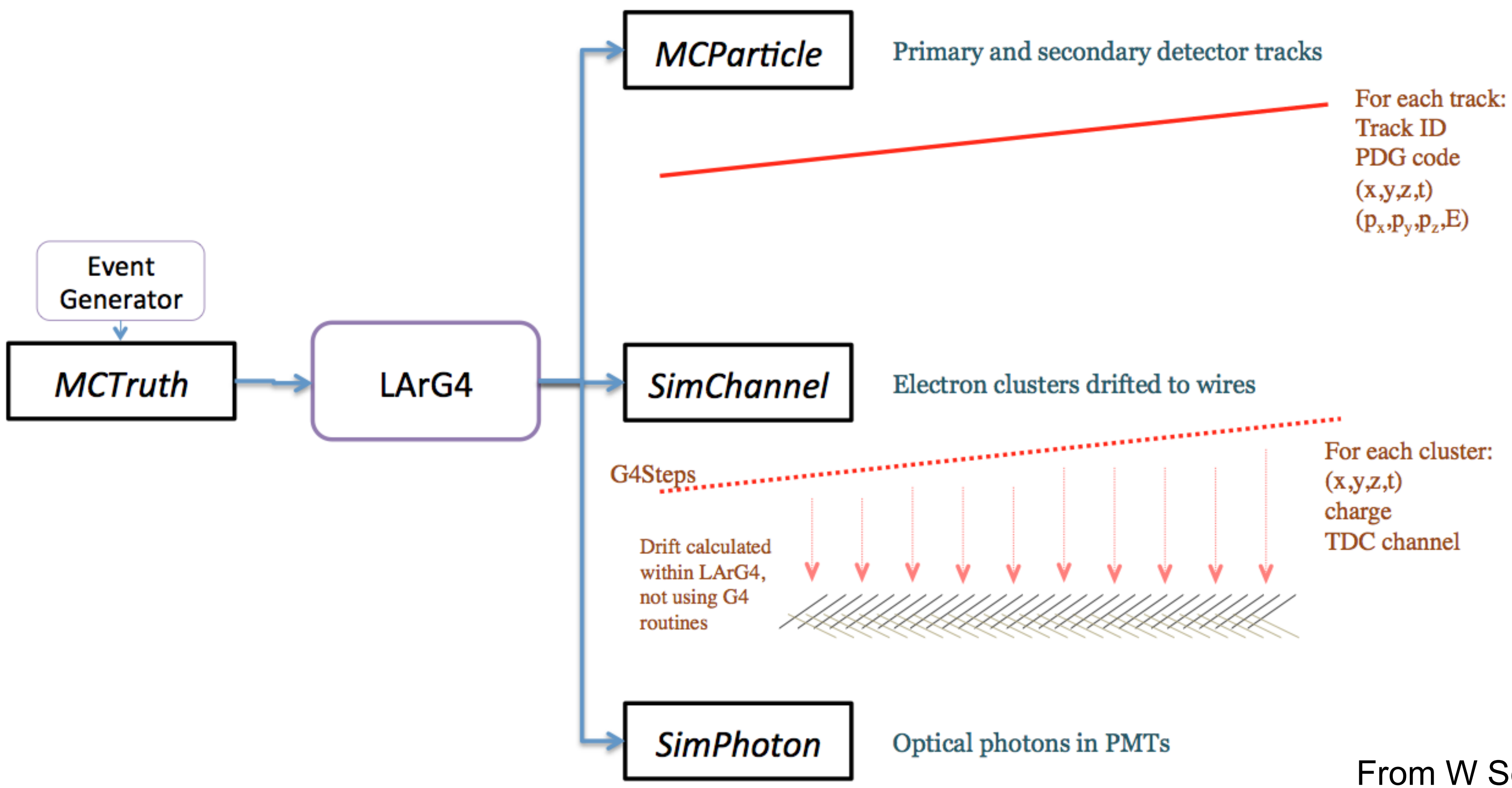
Backup

Event generators



From W Seligman

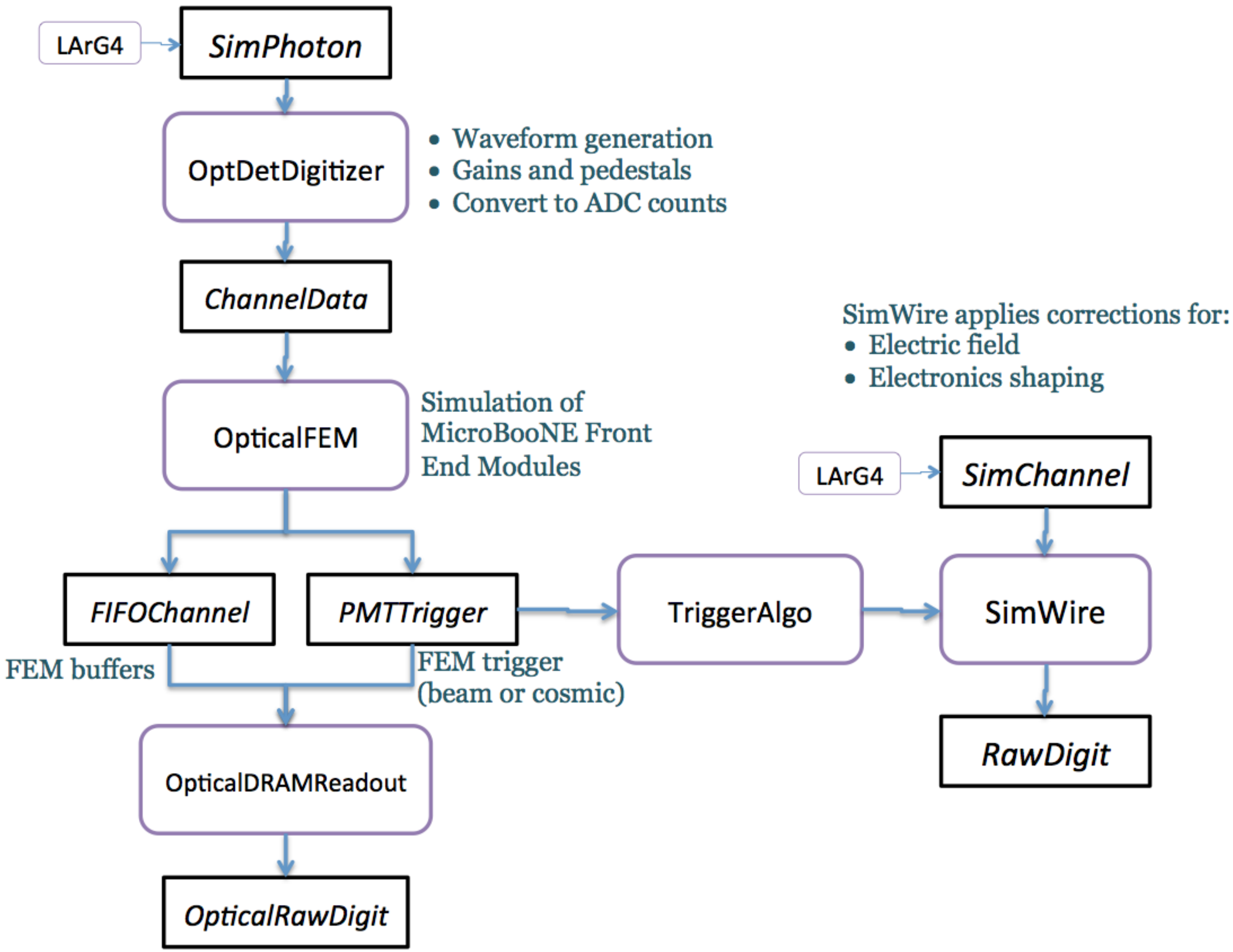
Detector simulation



From W Seligman

Simulation task workflow

Detector response and digitization



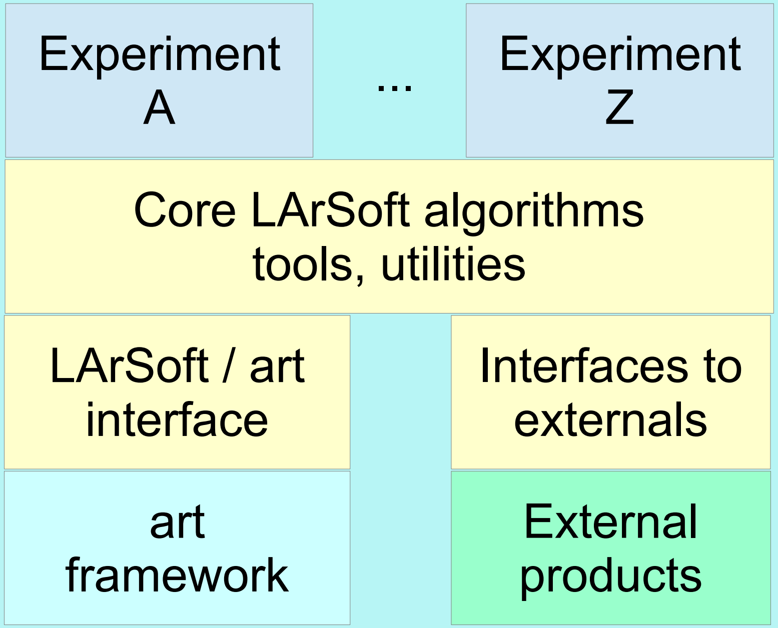
LArSoft design principles and objectives

- Detector interoperability
  - The most important design objective for the LArSoft project
  - Requires care to define (and use!!) common interfaces for accessing detector-specific configuration information
  - Good example: access to detector geometry information
    - A single interface that accommodates different (albeit very similar) geometries
      - Most differences a matter of configuration only
      - Also have detector-specific implementations of the interface where needed
    - Carefully avoid implied geometrical assumptions in algorithms
      - Position of the first plane or wire, the wire spacing, etc.
    - Introduced structures to facilitate generic loops over geometrical elements
      - Define detector / DAQ element IDs at all levels of detector geometry hierarchy
      - Can thereby avoid explicit reference to indices for loops, etc.
  - Also applies to
    - Access to calibration data, LAr properties, detector properties, E-field map, handling of common metadata for data files...
  - Have compiled a long list of do's and don'ts to ensure interoperability

LArSoft design principles and objectives

- Separation of framework and algorithm code
  - Encapsulate algorithms, configuration, tools and utilities into a layer that is independent of the framework
  - Why??
    - Allow testing of small units of algorithm code outside the framework
    - Provide greater flexibility in using algorithms
    - To provide a means of integrating LArSoft code (data products and algorithms) with external frameworks
      - e.g., LArLite used by MicroBooNE for algorithm development, testing

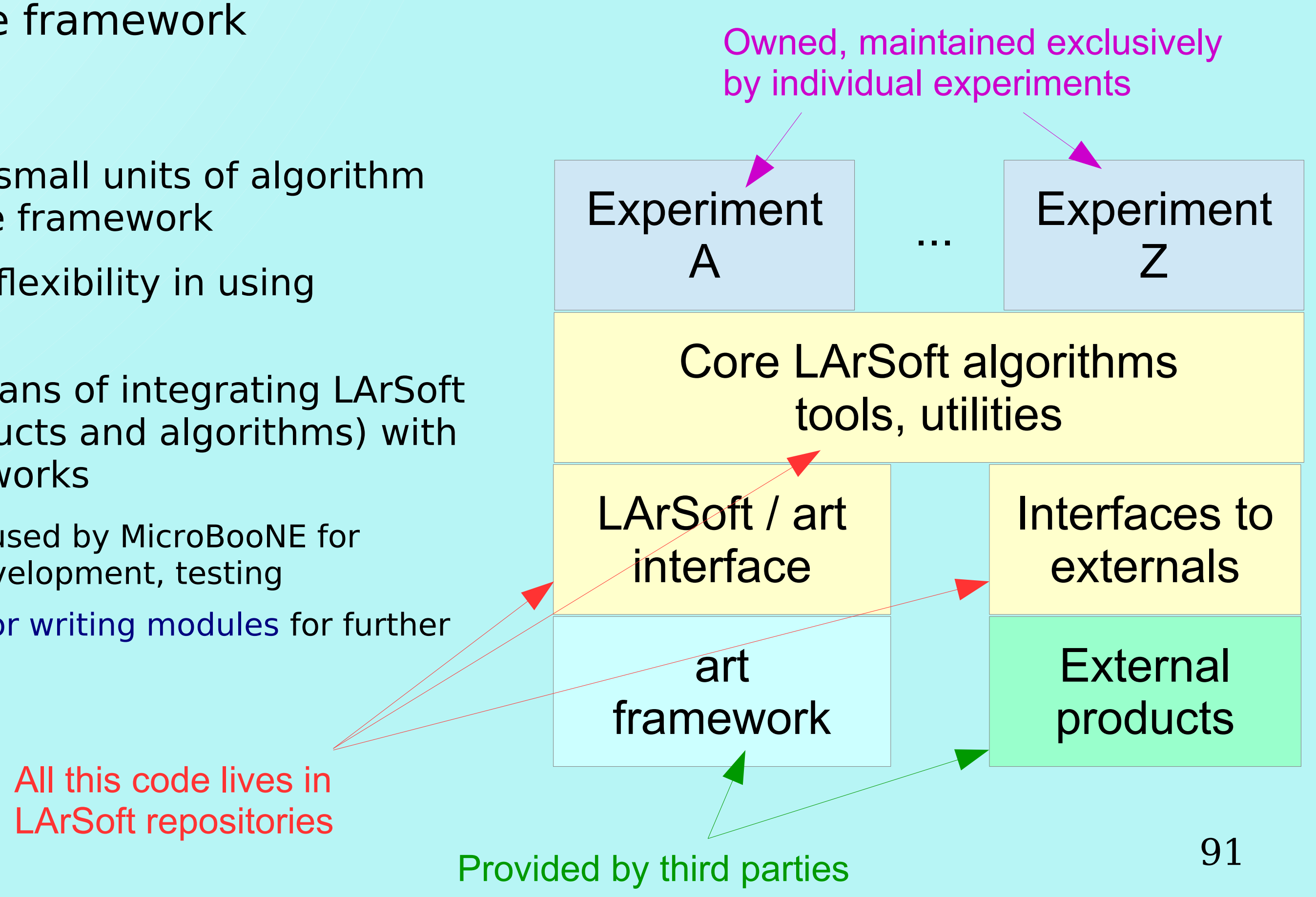
    See art guidance for writing modules for further discussion



LArSoft design principles and objectives

- Separation of framework and algorithm code
  - Encapsulate algorithms, configuration, tools and utilities into a layer that is independent of the framework
  - Why??
    - Allow testing of small units of algorithm code outside the framework
    - Provide greater flexibility in using algorithms
    - To provide a means of integrating LArSoft code (data products and algorithms) with external frameworks
      - e.g., LArLite used by MicroBooNE for algorithm development, testing

    See art guidance for writing modules for further discussion



LArSoft design principles and objectives

- Separation of framework and algorithm code (cont'd)
  - How??
    - Adhere to particular design patterns for the “LArSoft / art interface” code
      - I.e, art modules and services (to be discussed later)
    - Access framework functionality only within the interface code
      - Includes finding input data, writing output data, retrieving any required services, making filter decision calls, etc.
    - Pass all required data, utility classes into algorithms, and all output data back out

General disclaimer: In examining the code, you may note that only a portion of the existing code adheres to this an the other design principles.

- The on-going architecture review project is intended to address this

Strongly encouraging people to adopt this practice for new code.

LArSoft design principles and objectives

- Standardized algorithm interfaces
  - Define standard interfaces for well-defined steps in the workflow so that:
    - Multiple algorithms that address specific problems can share interfaces
  - Promote greater modularity, layering of algorithms
  - Generally enhances flexibility of the code
- Modularity
  - Build sophistication by applying small, targeted algorithms in a layered, iterative structure
  - Leads to code that is more easily tested, more maintainable, more flexible

LArSoft design principles and objectives

- Continuous integration
  - A development scheme in which changes to the main branch of development are integrated and tested frequently
    - At every push to the develop branch
    - Every night
    - At every release

Requires that code authors write tests!

  - Primary LArSoft goals
    - Ensure that code performs as intended
    - Facilitate early detection of problems created in one experiment due to changes introduced by another experiment
    - Ensure that all major features in the develop branch work at all times
  - Are now operating a continuous integration system for LArSoft
    - Currently runs at every push to develop branch
    - Can be triggered manually to run on a non-develop branch of a user's choosing

  See https://cdcvs.fnal.gov/redmine/projects/lar-ci/wiki for details