SAND Analysis Tools Overview

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DUNE Italia

Lecce, 07/11/2023

Summary

1. Framework
2. Sim/Reco Status
3. On Going Activities
4. To Do List
5. Conclusions

Mailing lists & Meetings

- SAND SOFTWARE & ANALYSIS:
  - DUNE-ND-SAND-SOFTWARE@FNAL.GOV
  - DUNE-ND-SAND-PHYSICS@FNAL.GOV
  - Wednesday at 15:00 CEST (08:00 CT) [Bi-Weekly]

Repositories

- github.com/DUNE/dunendggd:
  geometry repository

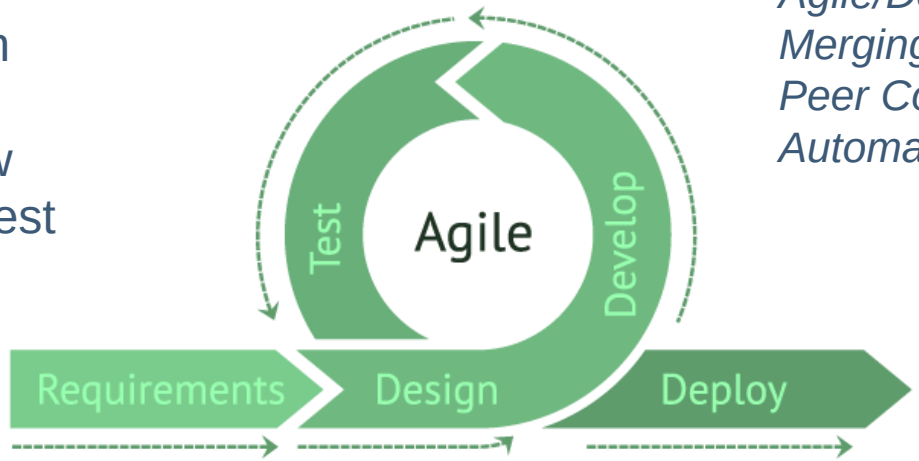
- baltig.infn.it/dune → github.com/DUNE/sandreco:
  simulation, reconstruction and analysis tools

- github.com/DUNE/ND_Production
  ND «official production»

- github.com/DUNE/ND_CAFMaker
  CAF maker

Coding and Development Workflow

- Language: C++11
- Code Format:
  - Based on Google C++ Style Guide
  - Proposal: *clang-format -style="{BasedOnStyle: Google, BreakBeforeBraces: Linux, DerivePointerAlignment: false}"*
- Project layout: pitchfork
- Development Workflow:
  1. Create Issue
  2. Open Branch
  3. Develop
  4. Test / Review
  5. Merge Request
  6. Release

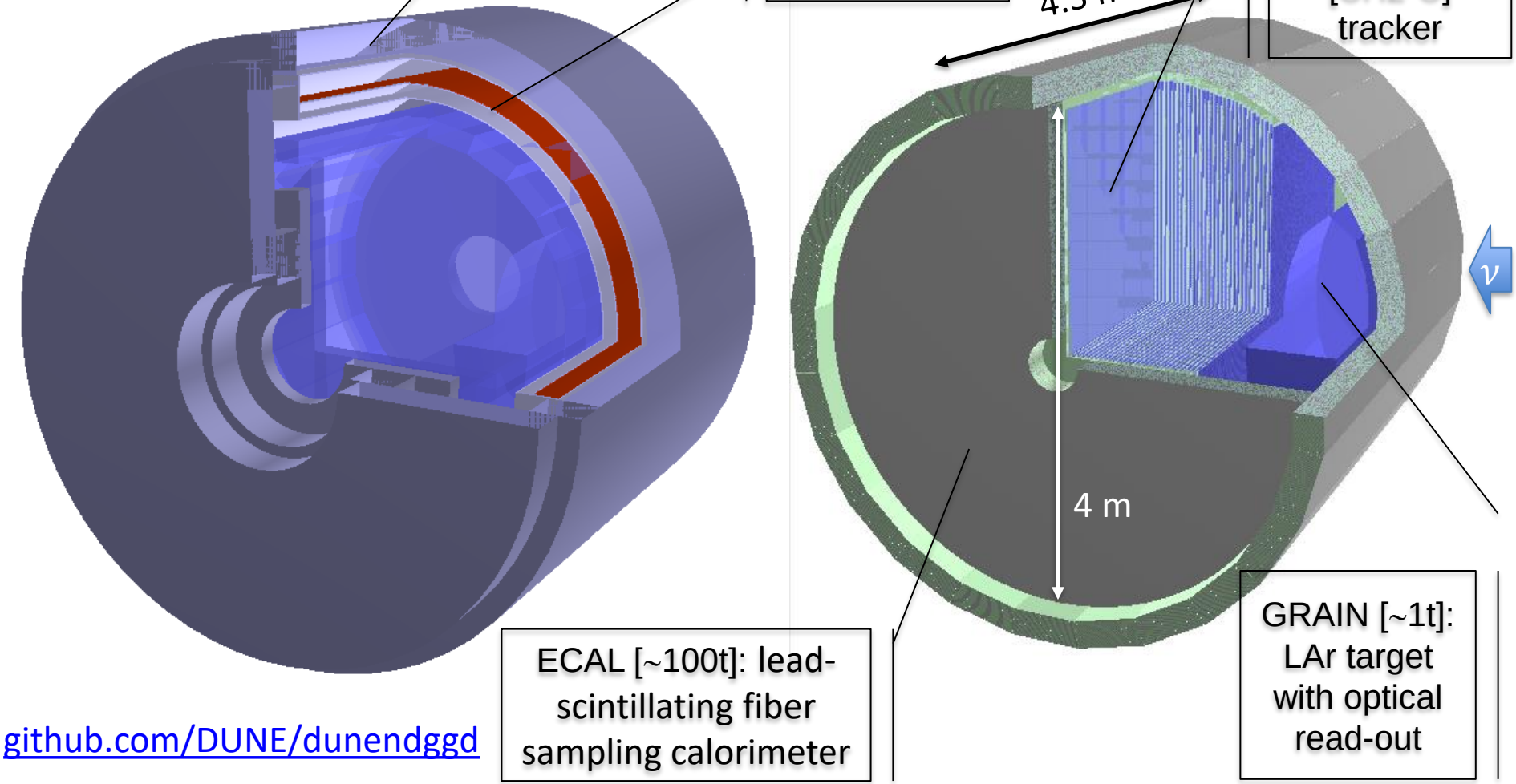


Exploits:
Agile/DevOps,
Merging by Pull Request
Peer Code Review,
Automated Tests,

Sim/Reco Status

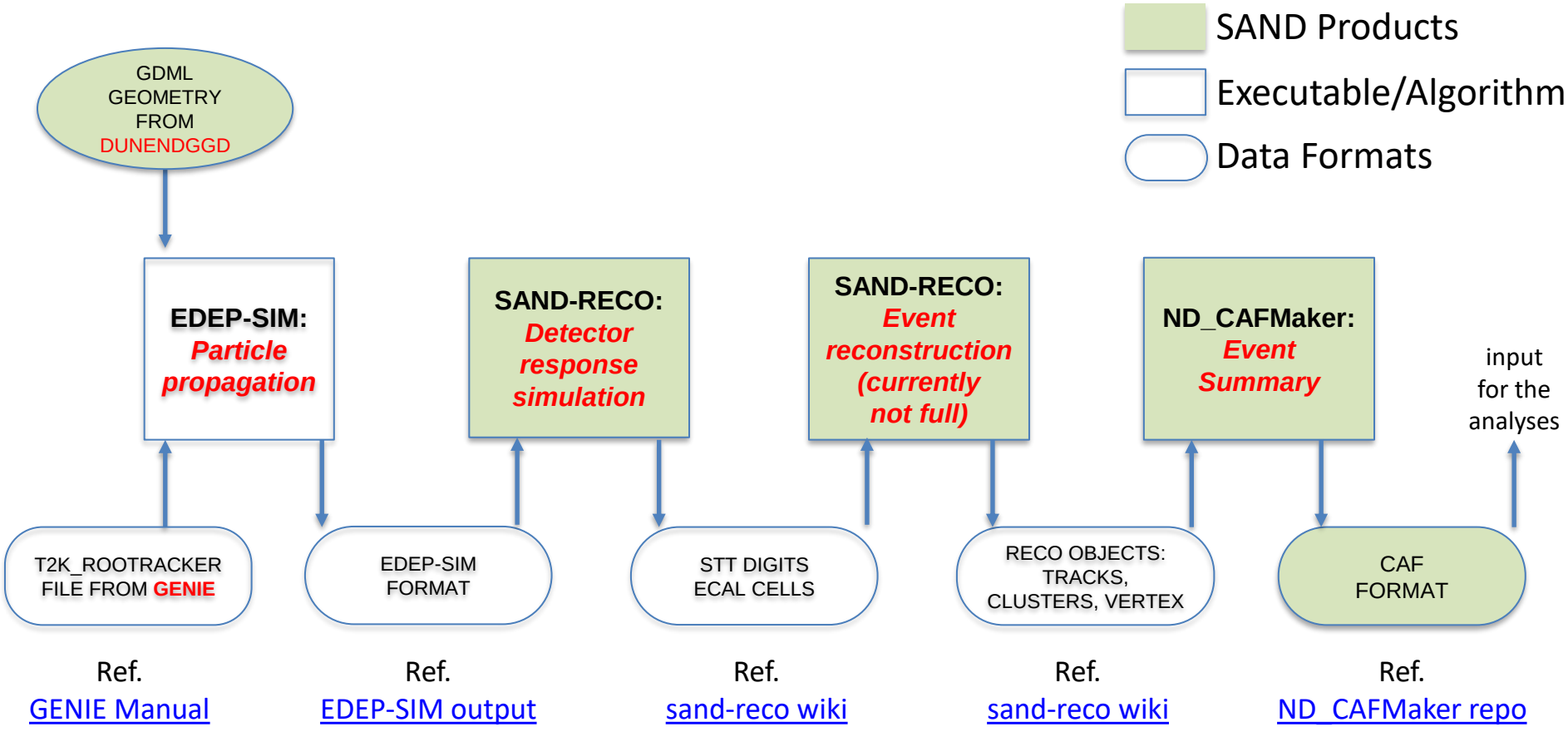
Geometry

- SANDGeoManager
- Easy tool to build geometry w/ gegede

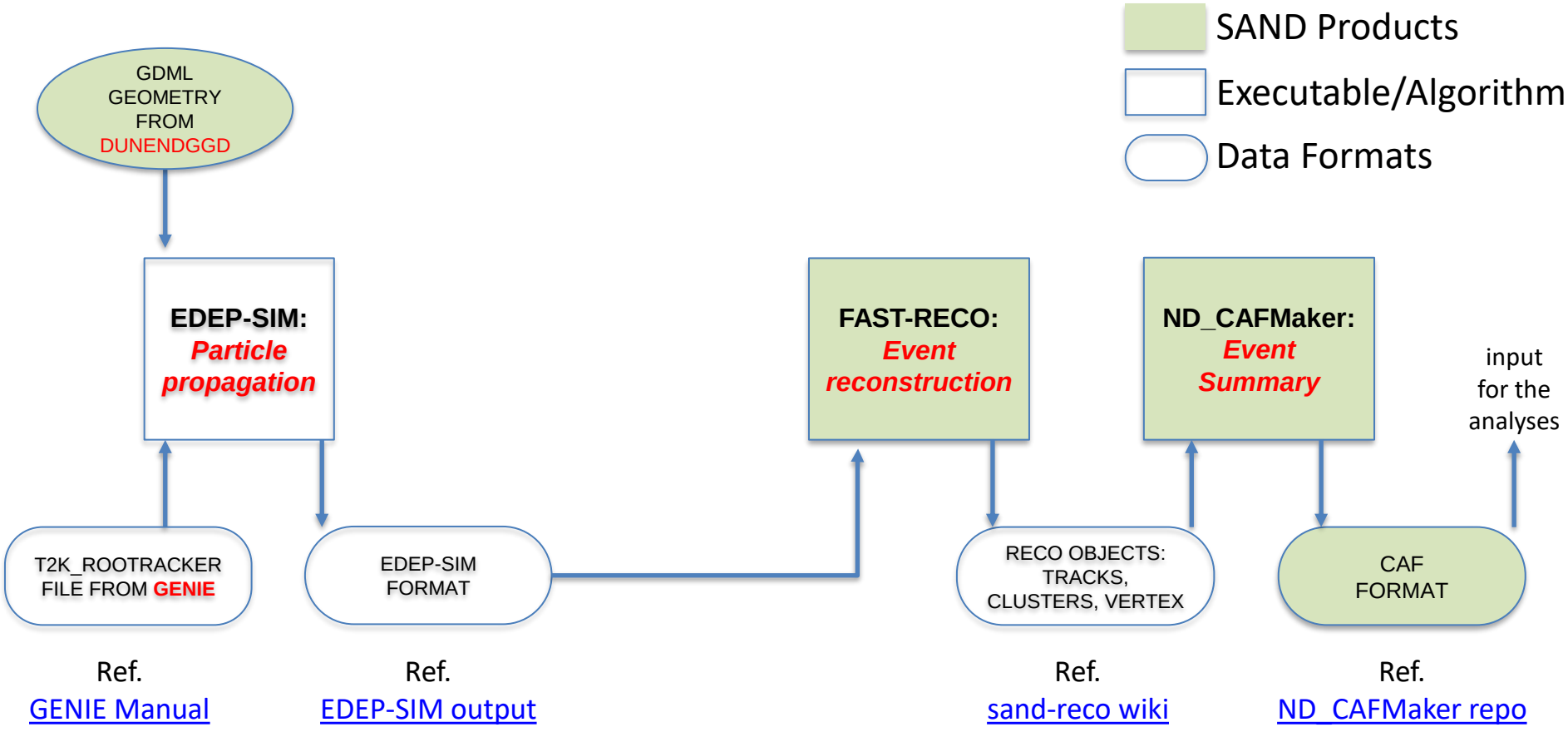


github.com/DUNE/dunendggd

Reconstruction Chain: Full



Reconstruction Chain: Fast



Reconstruction Chain: Fast

ducts

e/Algorithm

nats

input
for the
analyses

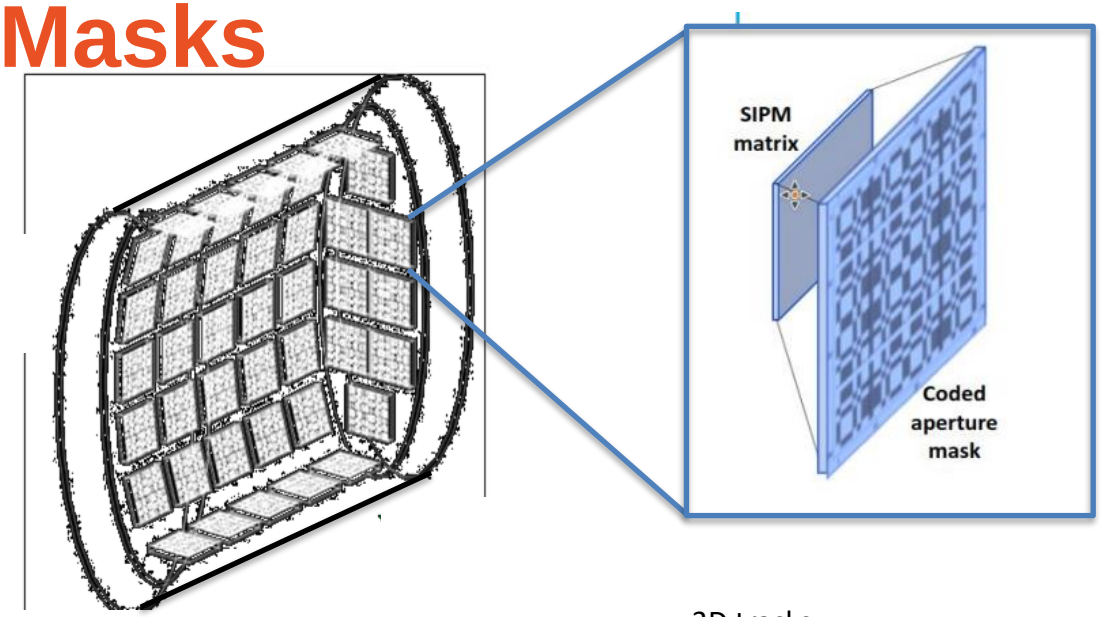
T2K_ROOTR
FILE FROM

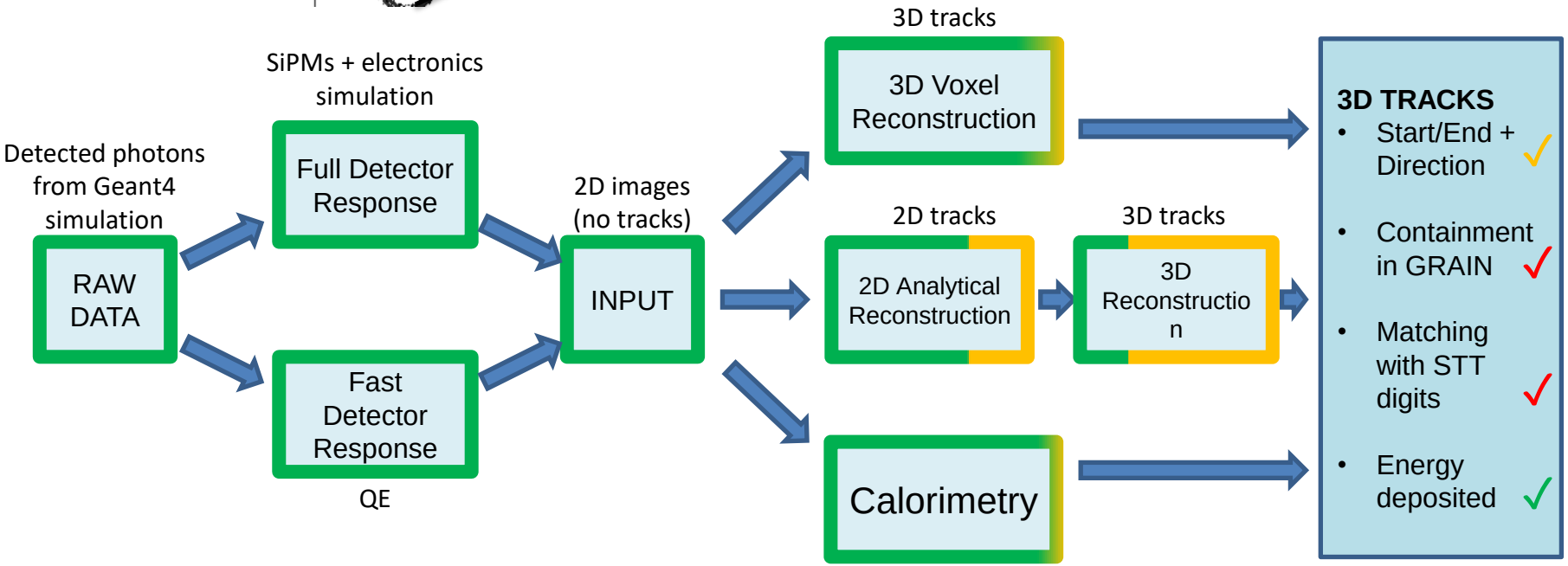
CAF
ORMAT

Ref.
GENIE Ma

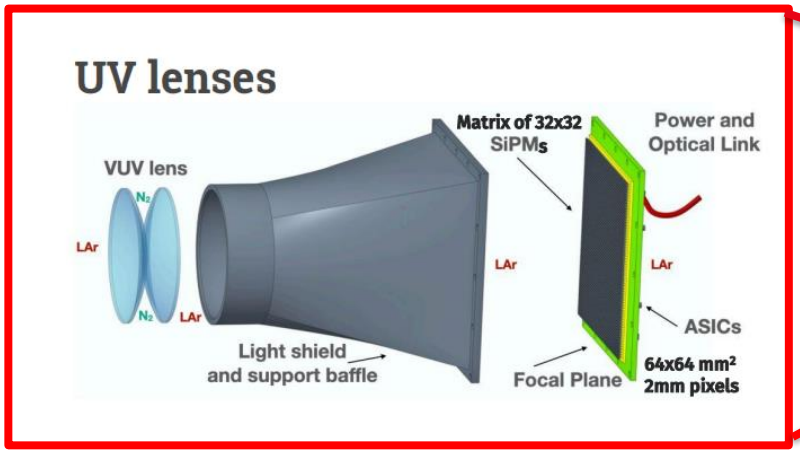
Ref.
Maker repo

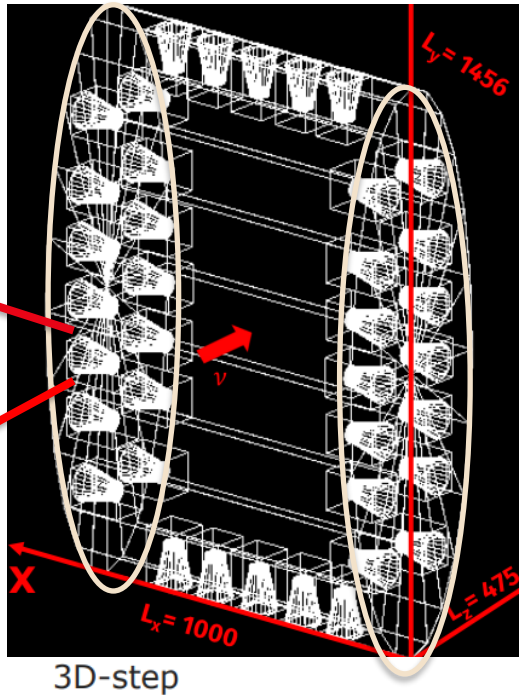
GRAIN: Masks

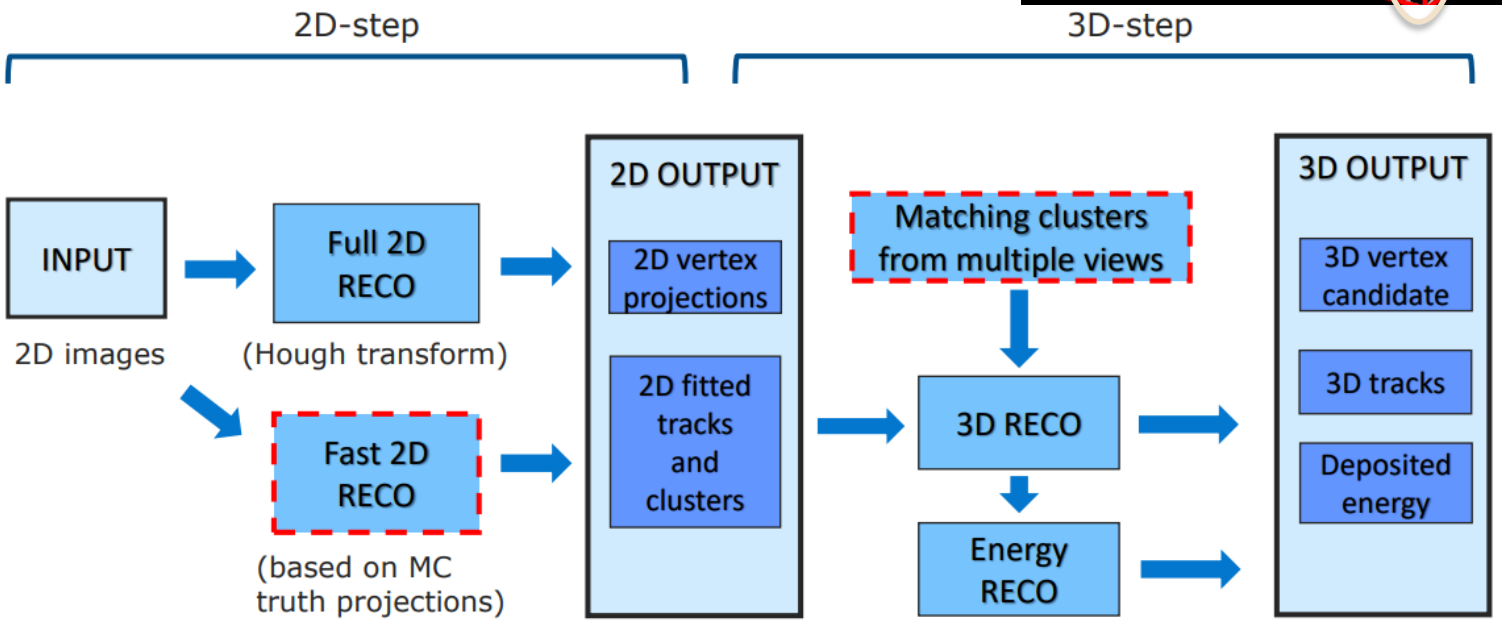

SIPM
matrix
Coded
aperture
mask


Detected photons
from Geant4
simulation
RAW
DATA
SiPMs + electronics
simulation
Full Detector
Response
Fast
Detector
Response
QE
2D images
(no tracks)
INPUT
3D tracks
3D Voxel
Reconstruction
2D tracks
2D Analytical
Reconstruction
3D tracks
3D
Reconstructio
n
Calorimetry
3D TRACKS
• Start/End +
Direction
• Containment
in GRAIN
• Matching
with STT
digits
• Energy
deposited

GRAIN: Lenses

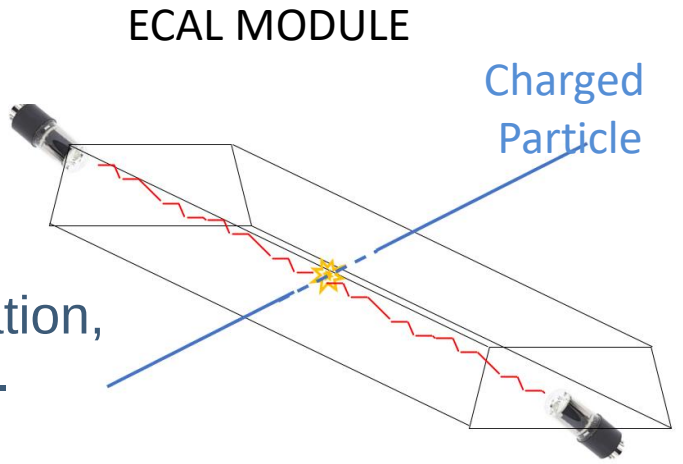




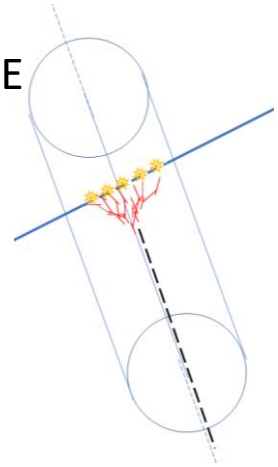


Detector Simulation

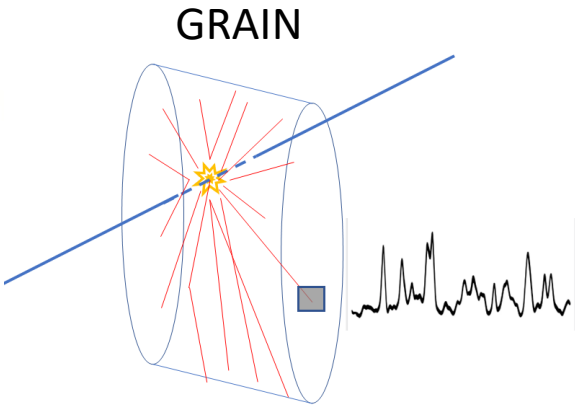
- ECAL:
  - Light yield, scintillation decay time, attenuation, photon propagation, segmentation, PMT response and front-end [ADC & TDC].



- STT:
  - drift towards wire, electric signal propagation and front-end [ADC & TDC]



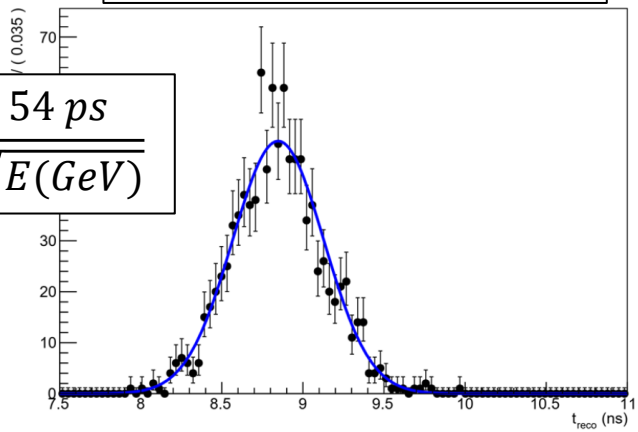
- GRAIN:
  - LAr : Rayleigh scattering, absorption
    SiPM : PDE, cross-talk, after-pulse
    front-end : waveform with electronic noise



Reconstruction

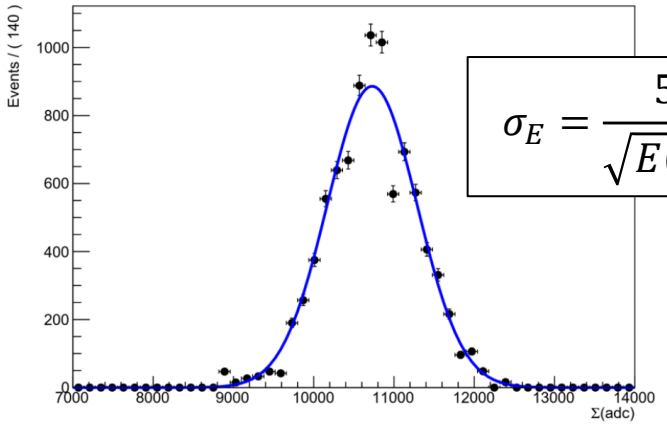
- ECAL:
  - CELL: Energy, position and time of energy deposits in ECAL are reconstructed using signals of PMTs on both ends.
  - PATTERN RECOGNITION: CELLS are grouped in CLUSTERS using MC truth.
  - FIT: Energy, position, time and direction of the track/shower are then reconstructed using energy deposit topologie

t_{cell} for 10 GeV muons



$$\sigma_t = \frac{54\ ps}{\sqrt{E(GeV)}}$$

adc_{cell} for 1 GeV e^-

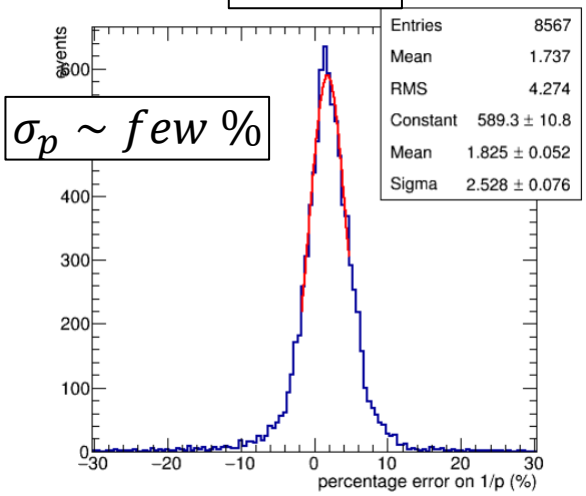


$$\sigma_E = \frac{5\ \%}{\sqrt{E(GeV)}}$$

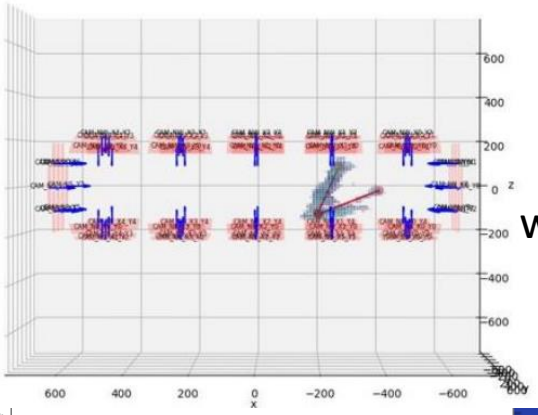
Reconstruction

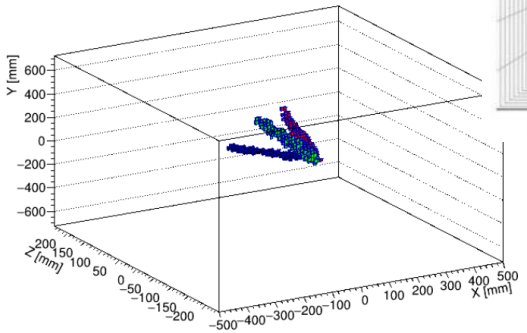
- STT
  - PATTERN RECOGNITION: TUBES are grouped in TRACKS using MC truth.
  - FIT: hits from vertical and horizontal tubes are fitted separately to obtain position direction and momentum of the TRACK
- GRAIN

muons



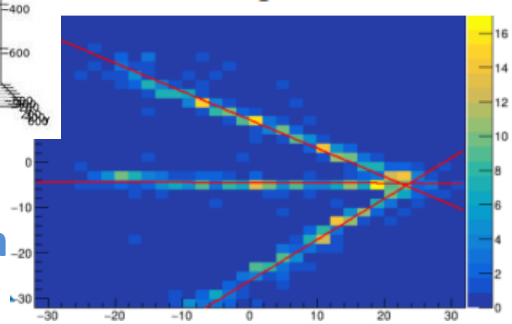
3D reconstruction with **Multiple View**

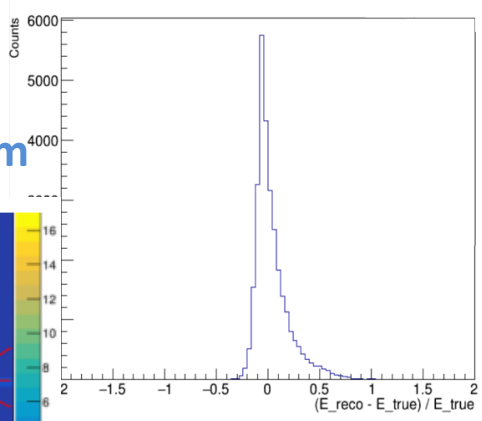




3D reconstruction with **Back Propagation**

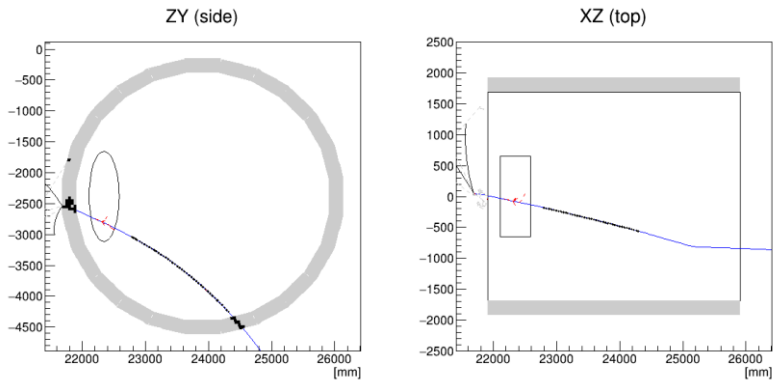
2D reconstruction with **Hough Transform**





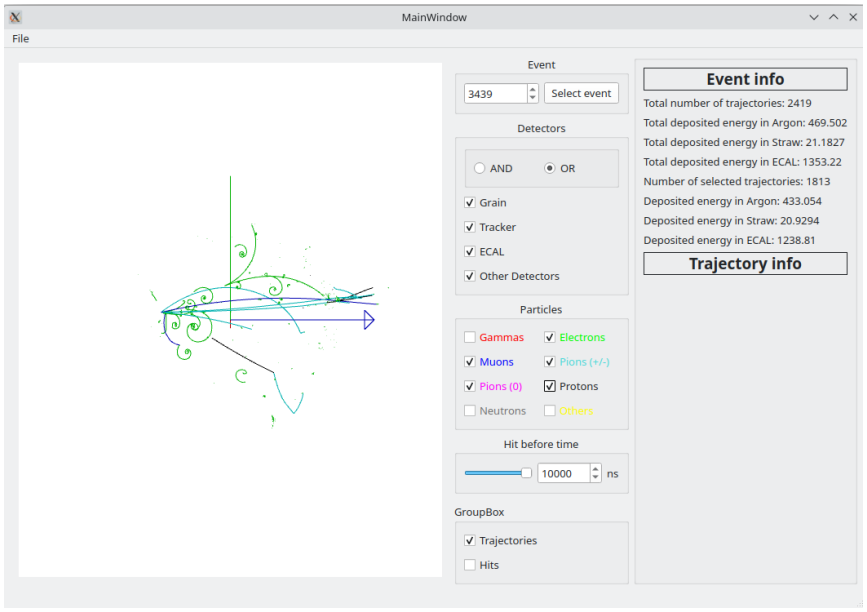
Calorimetry

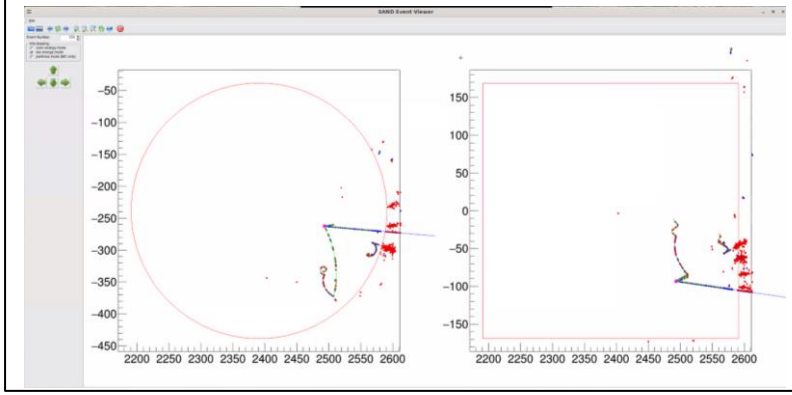
Event Viewers



Simple single event display based on ROOT 2D basic graphics

Interactive display based **Qt** libraries



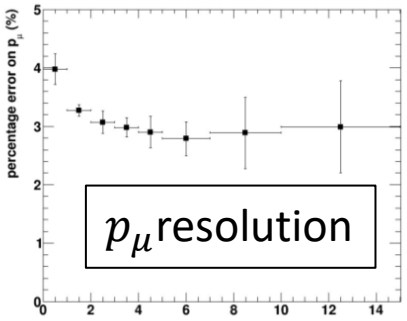


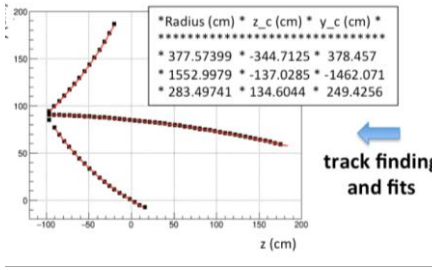
Interactive display based on **ROOT Graphical User Interface**

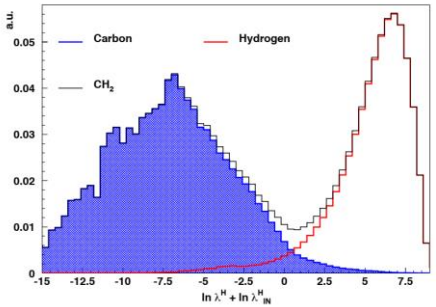
Analyses

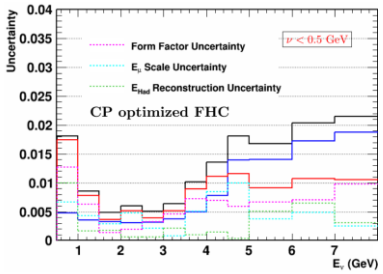
docdb-13262

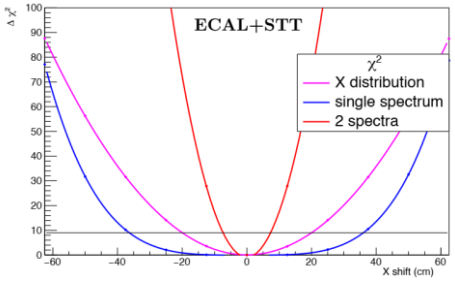
- Particle Reconstruction
- Particle Identification
- Demonstration of Full Event Reconstruction
- Event Classification
- νH samples
- Flux measurements
- Beam monitoring
- External Background
- CCQE Event Selection w/ GRAIN

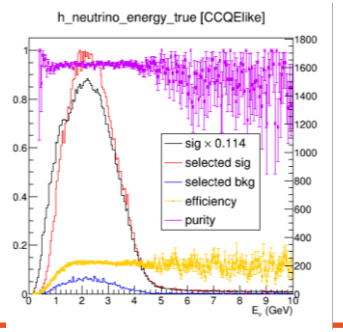












On Going Activities

Simulation and Reconstruction

- Study of **alternative designs** for the tracker
  [see Alessandro & Gianfranco's talk]

- Development of a reliable **track reconstruction** for the tracker:
  - Fit of reco circles w/ simplified track model (helix: i.e. ignore energy loss) for a fast comparison between tracker designs [see Gianfranco's talk]
  - Extended Kalman Filter Algorithm [see Valerio's talk]

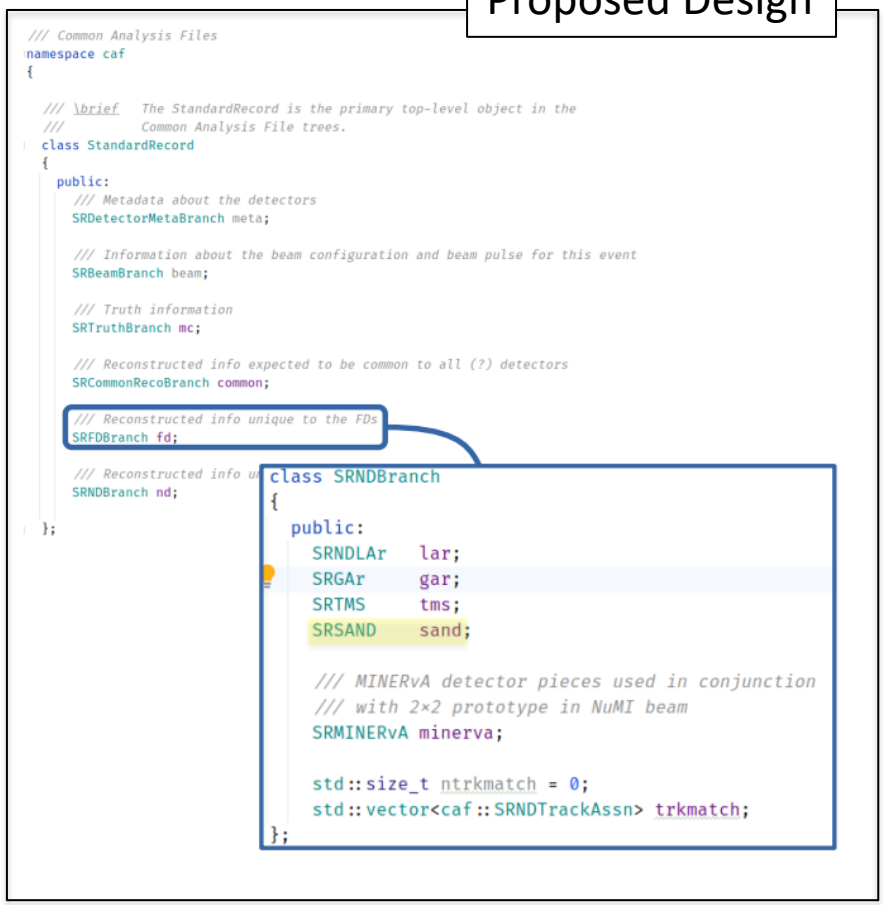
- ECAL: [see Denise's talk]
  - Improve endcaps **design and digitization**
  - Implement reliable **clustering**
  - **PID**

- Optimization of **GRAIN reconstruction** [reported by Valentina & Giovanni]

CAF Updates Highlights

- **Common Analysis Files** are the input for high-level analysis (used for TDR LBL analysis and by CAFAna, Mach3, etc…)
- Event Summary format is **StandardRecord** object
- It contains **SAND-related** objects and info
- CAF Taskforce (identified to improve StandardRecord format) made a proposal
- A SAND **liaison person** is part of Taskforce

Proposed Design



ND Sim/Reco Integration

- Motivation:
  - Build **`sandreco`** sw against tagged release in DUNE accessible repository
  - Run **`sandreco`** sw (det-sim and reco) on the Fermi grid
- In contact w/ Jake Calcutt and Tom Junk since beginning of August. Thank you both!!
- 02/08 First meeting: definition of a todo list
- 23/08 SAND repository moved to github/sandreco. baltig/sand-reco archieved
- 25/08 sandreco tadded o the scisoft web distribution server list RITM1843346
- Next step: build script for mrb
  - …support from Jake and Tom will be appreciated

DUNE Software Architecture Meeting 03/11/2023

sand-reco

- Matteo Tenti has copied sand-reco from SAND's gitlab instance to DUNE's github organization as sand-reco
- Additions to make it UPS-comptible – a UPS directory with product_deps based on other DUNE products, and enough CMakeLists.txt file changes to get mrb to run.
- mrb does not build sand-reco products however – no libraries or executables in localProducts when mrb is run on it
- Tom has been experimenting with a private copy, getting mrb to build the executables inside of it, and found that there are a lot of compiler warnings which are treated as errors.

CNAF Integration

- 17/07/23 zoom meeting:
  CNAF [Carmelo Pellegrino], DUNE [Steven Timm, Michael Kirby]
  - Summary: here
  - Topics: protocols to access (copy/stream) data; authentication/authorization policy for Storage and Computing Elements, resources @ CNAF, next steps
- 06/11/2023 Ticket with OSG factory to add DUNE as supported VO to CNAF
- 31/10/2023 Successful test jobs at CNAF
- 03/11/2023 CNAF: *the WebDAV Storage Area is set up*

What is missing?

To Do

- Detector response:
  - Implement simulation of subdetector DAQ
- Reconstruction:
  - Event Builder
  - STT Kalman Filter, ECAL Clustering, Tracking and Calorimetry from GRAIN: comparison of tracker solutions
  - GRAIN + STT+ ECAL matching
  - Particle ID:
    - e- ID in ECAL: need for TR?
    - μ/π separation: need for downstream μ catcher?
  - Vertexing
  - Integration with PANDORA

To Do: Analyses

- Reproduce analyses w/ full reconstruction:
  see docdb-13262

- Use CAF as input for the analyses
  - Update analyses

- Setup automatic end-to-end chain from MC production to analysis result

+ finalize **integration** with DUNE «infrastructure»

Conclusions

We have done a lot of work:

- A detailed detector geometry
- A detailed digitization and a working reconstruction
- A fast reconstruction
- Detector performance studies
- Several physics analyses
- Integration with ND sim/reco

We have a lot of work in front of us

- Full event reconstruction
- SAND CAF
- Physics studies w/ full reco and CAF
- Automated end-to-end analysis chain

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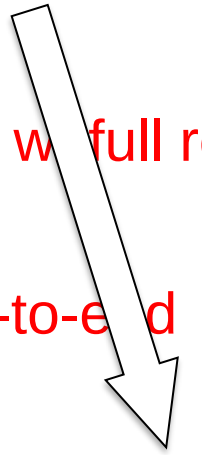

it is becoming more and more urgent

Conclusions

I WANT YOU
FOR SAND
RECONSTRUCTION
AND ANALYSES