

Simulations and Analyses

Matteo Tenti

Meeting Annuale della Collaborazione Nazionale di DUNE

07/11/2022

Mailing lists & Meetings

- Mailing lists:

- DUNE-ND-SAND-PHYSICS@FNAL.GOV
- DUNE-ND-SAND-SOFTWARE@FNAL.GOV

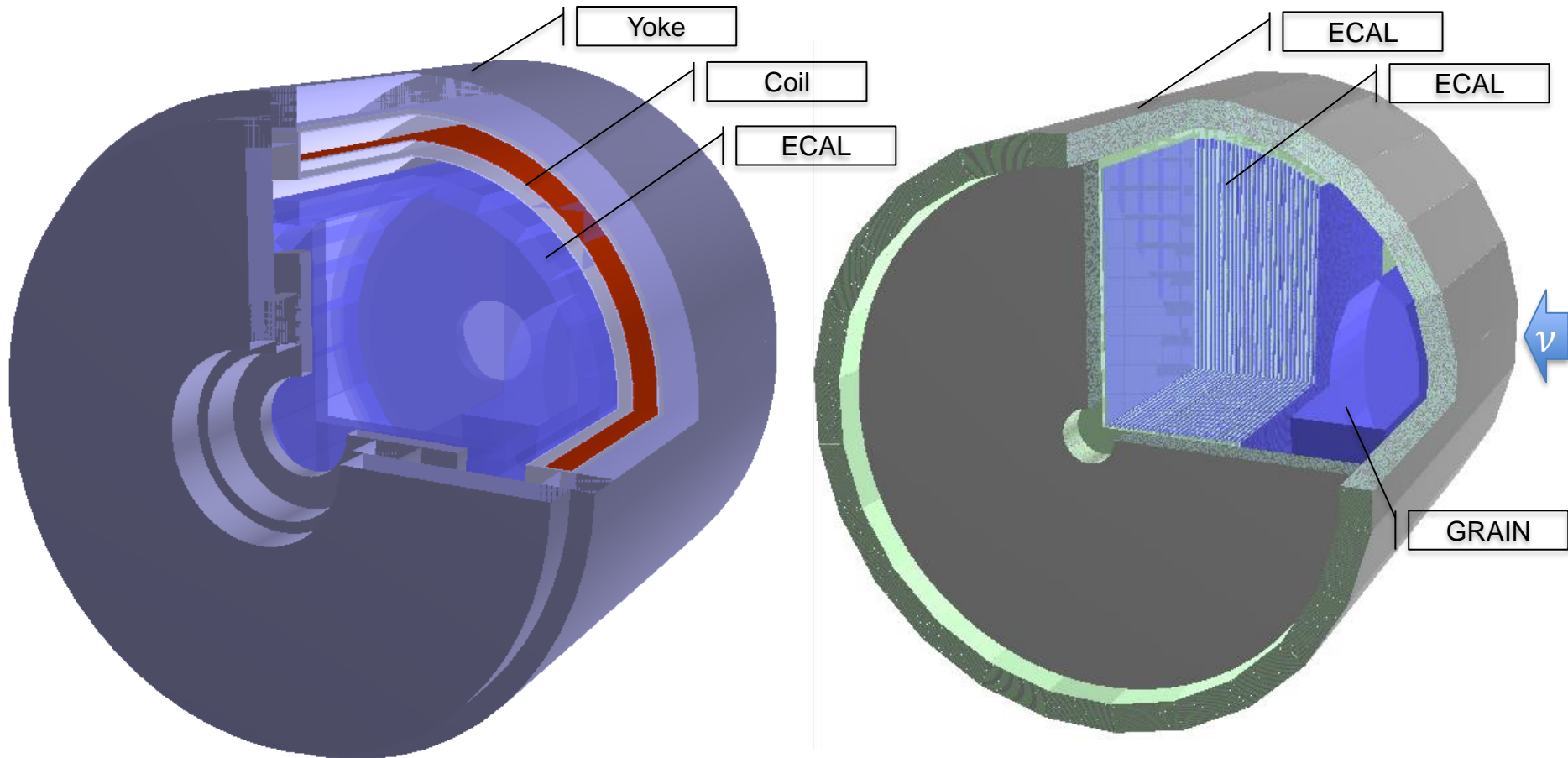
- Meetings:

- Friday at 14.15 [Weekly]
- Wednesday at 15:00 [Bi-Weekly]



Repositories

- github.com/DUNE/dunendggd:
geometry repository
- baltig.infn.it/dune:
simulation, reconstruction and analysis tools
- github.com/DUNE/ND_Production
ND «official production»
- github.com/DUNE/ND_CAFMaker
CAF maker

Geometry










































Baltig: overview

D dune  Group ID: 631  [Leave group](#)

🔔 New subgroup New project

Subgroups and projects Shared projects Archived projects Search by name Updated date

>	 A analyses  Owner	 0	 2	 1	
>	 S sand-optical 	 0	 12	 3	
	 S sand-reco  This project aims at developing tools to reconstruct neutrino interaction in the SAND ...	 1			1 week ago
	 S software-reference 	 0			3 weeks ago
	 S STTTrackReco 	 0			4 weeks ago
	 P prod-scripts 	 0			1 month ago
	 F FastReco 	 0			2 months ago
	 S sand-ci  Docker image to build SAND Reconstruction Software	 1			9 months ago
	 C cluster-analysis  The project aims to test and validate the SAND ECAL clustering algorithm.	 0			1 year ago
	 N nuev-generator  development of code, script and macros in order to generate neutrino event in a format...	 1			11 months ago
	 S sand-FLUKA  Codes for FLUKA simulations analysis	 0			10 months ago

Baltig: overview

The screenshot shows the GitHub group page for 'dune'. At the top, there are buttons for 'New subgroup' and 'New project'. Below, there are tabs for 'Subgroups and projects', 'Shared projects', and 'Archived projects'. A search bar and a dropdown for 'Updated date' are also present. The main content is a list of projects, each with a letter icon, a name, a description, a star count, and an update date. The 'sand-reco' project is highlighted with a box and the text 'Digitization and Reconstruction'.

Project Name	Description	Stars	Updated
analyses		0	2 weeks ago
sand-optical		0	12 weeks ago
sand-reco	This project aims at developing tools to...	1	1 week ago
software-reference		0	3 weeks ago
STTTrackReco		0	4 weeks ago
prod-scripts		0	1 month ago
FastReco		0	2 months ago
sand-ci	Docker image to build SAND Reconstruction Software	1	9 months ago
cluster-analysis	The project aims to test and validate the SAND ECAL clustering algorithm.	0	1 year ago
nuev-generator	development of code, script and macros in order to generate neutrino event in a format...	1	11 months ago
sand-FLUKA	Codes for FLUKA simulations analysis	0	10 months ago

Baltig: overview

The screenshot shows the 'dune' group page on baltig.infn.it. The group ID is 631. Under 'Subgroups and projects', several projects are listed, including 'software-reference'. A callout box highlights the 'software-reference' project and points to a detailed page titled 'Useful Information for SAND Developers'. This page contains sections for 'Collaborative Tools', 'Repositories', and 'References', each with a list of links and instructions.

dune Group ID: 631 [Leave group](#)

Subgroups and projects Shared projects Arch

- > **A** analyses Owner
- > **S** sand-optical
- S** sand-reco This project aims at developing tools to
- S** software-reference
- S** STTTrackReco
- P** prod-scripts
- F** FastReco
- S** sand-ci Docker image to build SAND Reconstruct
- C** cluster-analysis The project aims to test and validate the
- N** nuev-generator development of code, script and macros
- S** sand-FLUKA Codes for FLUKA simulations analysis

Useful Information for SAND Developers

- [Tools](#)
- [Repositories](#)
- [Reference](#)

Collaborative Tools

- **SAND Channel** in DUNE SLACK workspace. Click [here](#) to be invited in the channel. The DUNE SLACK workspace subscription will be accepted once verified the user is part of the DUNE Collaboration.
- **Github/Baltig Issues:**
 - Instructions on how to access GIT repositories at baltig.infn.it can be found in the section "BALTIG" [here](#)
- **Mailing List:** DUNE-ND-SAND-SOFTWARE@fnal.gov. Instructions on how to subscribe are [here](#)

Repositories

- Policy on how to develop code can be found [here](#)
- Repositories are both on github.com and baltig.infn.it:
 - [baltig repositories for DUNE](#)
 - [official ND geometry repository](#)
 - [CAF Maker](#)

References

- [Data Model](#)
- [Code Format](#)
- [wiki](#) page with some usefull info
- [A Proposal to enhance the DUNE Near-Detector Complex](#). Document with the expected performance of the SAND detector
- [DUNE NearDet Design Redmine Project](#). Page with the aim of facilitating the design of the near detector

Baltig: overview

The screenshot shows the Baltig group overview for 'dune'. At the top, there is a group header with the name 'dune', a globe icon, and the group ID '631'. There are buttons for 'New subgroup' and 'New project'. Below the header, there are tabs for 'Subgroups and projects', 'Shared projects', and 'Archived projects'. A search bar and a dropdown for 'Updated date' are also present. The main content is a list of subgroups and projects. The 'STTTrackReco' project is highlighted with a red box, and a callout box labeled 'Kalman Filter' points to it. Other projects include 'analyses', 'sand-optical', 'sand-reco', 'software-reference', 'prod-scripts', 'FastReco', 'sand-ci', 'cluster-analysis', 'nuev-generator', and 'sand-FLUKA'. Each project entry shows its name, a globe icon, a star icon, and the time since it was updated.

Project Name	Star Count	Updated
analyses	0	1 week ago
sand-optical	0	3 weeks ago
sand-reco	1	3 weeks ago
software-reference	0	4 weeks ago
STTTrackReco	0	1 month ago
prod-scripts	0	2 months ago
FastReco	0	9 months ago
sand-ci	1	1 year ago
cluster-analysis	0	11 months ago
nuev-generator	1	10 months ago
sand-FLUKA	0	

Baltig: overview

dune Group ID: 631 [Leave group](#)

[New subgroup](#) [New project](#)

Subgroups and projects Shared projects Archived projects

Search by name Updated date

Project Name	Stars	Updated
analyses (Owner)	0	2
sand-optical	0	3
sand-reco (This project aims at developing tools to reconstruct neutrino interaction in the SAND ...)	1	1 week ago
software-reference	0	3 weeks ago
STTTrackReco	0	4 weeks ago
prod-scripts (Scripts for MC production)	0	1 month ago
FastReco	0	2 months ago
sand-ci (Docker image to build SAND Reconstruction Software)	1	9 months ago
cluster-analysis (The project aims to test and validate the SAND ECAL clustering algorithm.)	0	1 year ago
nuev-generator (development of code, script and macros in order to generate neutrino event in a format...)	1	11 months ago
sand-FLUKA (Codes for FLUKA simulations analysis)	0	10 months ago

Baltig: overview

dune Group ID: 631 [Leave group](#)

[New subgroup](#) [New project](#)

Subgroups and projects | [Shared projects](#) | [Archived projects](#) | |

Subgroup/Project	Stars	Updated
A analyses Owner	0	
S sand-optical	0	
S sand-reco This project aims at developing tools to reconstruct neutrino interaction in the SAND ...	★ 1	1 week ago
S software-reference	★ 0	3 weeks ago
S STTTrackReco	★ 0	4 weeks ago
P prod-scripts	★ 0	1 month ago
F FastReco	★ 0	2 months ago
S sand-ci Docker image to build SAND Reconstruction Software	★ 1	9 months ago
C cluster-analysis The project aims to test and validate the SAND ECAL clustering algorithm.	★ 0	1 year ago
N nuev-generator development of code, script and macros in order to generate neutrino event in a format...	★ 1	11 months ago
S sand-FLUKA Codes for FLUKA simulations analysis	★ 0	10 months ago

Baltig: overview

The screenshot shows the Baltig project overview for the 'dune' group. At the top, there's a group header with 'dune' and 'Group ID: 631'. Below that, there are tabs for 'Subgroups and projects', 'Shared projects', and 'Archived projects'. A search bar and a dropdown for 'Updated date' are also present. The main content is a list of projects, each with a letter icon, a name, a description, a star rating, and a date. A callout box highlights the 'sand-reco' project with the text 'sand-reco continuous integration'.

Project Name	Description	Stars	Last Updated
analyses		0	2 weeks ago
sand-optical		0	3 weeks ago
sand-reco	This project aims at developing tools to reconstruct neutrino interaction in the SAND ...	1	1 week ago
software-reference		0	3 weeks ago
STTTrackReco		0	4 weeks ago
prod-scripts		0	1 month ago
FastReco		0	2 months ago
sand-ci	Docker image to build SAND Reconstruct...	1	9 months ago
cluster-analysis	The project aims to test and validate the SAND ECAL clustering algorithm.	0	1 year ago
nuev-generator	development of code, script and macros in order to generate neutrino event in a format...	1	11 months ago
sand-FLUKA	Codes for FLUKA simulations analysis	0	10 months ago

Baltig: overview

The screenshot shows the Baltig group overview for 'dune'. At the top, there is a group header with the name 'dune', a globe icon, and the Group ID: 631. There are buttons for 'New subgroup' and 'New project'. Below the header, there are tabs for 'Subgroups and projects', 'Shared projects', and 'Archived projects'. A search bar and a dropdown for 'Updated date' are also present. The main content is a list of subgroups and projects. The 'cluster-analysis' project is highlighted with a red box and a callout box that says 'ECAL clustering validation'. The list includes projects like 'analyses', 'sand-optical', 'sand-reco', 'software-reference', 'STTTrackReco', 'prod-scripts', 'FastReco', 'sand-ci', 'cluster-analysis', 'nuev-generator', and 'sand-FLUKA'. Each project entry shows a star icon for favorites and a date indicating when it was last updated.

Project Name	Favorites	Last Updated
analyses	0	1 week ago
sand-optical	0	3 weeks ago
sand-reco	1	4 weeks ago
software-reference	0	1 month ago
STTTrackReco	0	2 months ago
prod-scripts	0	9 months ago
FastReco	0	1 year ago
sand-ci	1	11 months ago
cluster-analysis	0	10 months ago
nuev-generator	1	
sand-FLUKA	0	

Baltig: overview

The screenshot shows the GitHub interface for the 'dune' group. At the top, there's a group header with 'dune' and 'Group ID: 631'. Below that, there are tabs for 'Subgroups and projects', 'Shared projects', and 'Archived projects'. A search bar and a dropdown for 'Updated date' are also visible. The main content is a list of projects, each with a colored icon, name, description, star count, and update date. The 'nuev-generator' project is highlighted with a red box, and a callout box points to it with the text 'Simple neutrino event generator'.

Project Name	Description	Stars	Updated
analyses		0	2 weeks ago
sand-optical		0	12 weeks ago
sand-reco	This project aims at developing tools to reconstruct neutrino interaction in the SAND ...	1	1 week ago
software-reference		0	3 weeks ago
STTTrackReco		0	4 weeks ago
prod-scripts		0	1 month ago
FastReco		0	2 months ago
sand-ci	Docker image to build SAND Reconstruction Software	1	9 months ago
cluster-analysis	The project aims to test and validate the SAND FCML ...	0	1 year ago
nuev-generator	development of code, script and macro at...	1	11 months ago
sand-FLUKA	Codes for FLUKA simulations analysis	0	10 months ago

Baltig: overview

The screenshot shows the Baltig interface for the 'dune' group. At the top, there are buttons for 'New subgroup' and 'New project'. Below, there are tabs for 'Subgroups and projects', 'Shared projects', and 'Archived projects'. A search bar and a dropdown for 'Updated date' are also present. The main content is a list of projects, each with a letter icon, a name, a description, a star rating, and a date. The 'sand-FLUKA' project is highlighted with a red box and a callout box that reads 'FLUKA-to-edepsim converter'.

Project Name	Description	Stars	Updated
analyses		0	2 weeks ago
sand-optical		0	12 weeks ago
sand-reco	This project aims at developing tools to reconstruct neutrino interaction in the SAND ...	1	1 week ago
software-reference		0	3 weeks ago
STTTrackReco		0	4 weeks ago
prod-scripts		0	1 month ago
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sand-ci	Docker image to build SAND Reconstruction Software	1	9 months ago
cluster-analysis	The project aims to test and validate the SAND ECAL clustering algorithm.	0	1 year ago
nuev-generator	development of code, script and macros in order to generate neutrino event in a format...	1	11 months ago
sand-FLUKA	Codes for FLUKA simulations analysis FLUKA-to-edepsim converter	0	10 months ago

Baltig: GRAIN sim/reco

baltig.infn.it/dune

The screenshot displays the Baltig web interface. On the left, the 'dune' group is shown with a 'sand-optical' project highlighted. On the right, the 'sand-optical' project page is expanded, showing a list of sub-projects with their descriptions, star counts, and last update times.

Project Name	Description	Stars	Last Update
geometry	GDML geometry description	0	20 hours ago
LAr Lenses	Reconstruction and analysis code for LAr lenses	0	3 days ago
VolumeReco	Voxel based event reconstruction	0	2 weeks ago
FastElectronics	Simple converter from OptMen output to TH2	0	1 month ago
Tools	Miscellaneous tools and utilities	0	1 month ago
drdf	Detector Response Data Format libraries and tools	0	2 months ago
Detector Response GPU		0	2 months ago
ProdScripts	Scripts for Simulation Production	0	3 months ago
OpticalMeniscus		0	4 months ago
Optical to Full		0	6 months ago
gdmlParser		0	6 months ago
Detector Response		0	1 year ago

Baltig: analyses

The screenshot displays the Baltig web interface for the 'dune' group. At the top, the group name 'dune' is shown with a globe icon, Group ID: 631, and a 'Leave group' link. There are buttons for 'New subgroup' and 'New project'. Below this, there are tabs for 'Subgroups and projects', 'Shared projects', and 'Archived'. A callout box highlights the 'analyses' subgroup, which is the 'Owner'. Inside this callout, a project 'grain-physics-case' is shown with a description: 'Studiare la sensitività di SAND a differenti modelli di interazioni di neutrino in LAr c...'. The main list of projects includes:

Project Name	Description	Stars	Last Update
sand-reco	This project aims at developing tools to reconstruct neutrino interaction in the SAND ...	★ 1	1 week ago
software-reference		★ 0	3 weeks ago
STTTrackReco		★ 0	4 weeks ago
prod-scripts		★ 0	1 month ago
FastReco		★ 0	2 months ago
sand-ci	Docker image to build SAND Reconstruction Software	★ 1	9 months ago
cluster-analysis	The project aims to test and validate the SAND ECAL clustering algorithm.	★ 0	1 year ago
nuev-generator	development of code, script and macros in order to generate neutrino event in a format...	★ 1	11 months ago
sand-FLUKA	Codes for FLUKA simulations analysis	★ 0	10 months ago

ND sim/reco «official ND production»

- Infrastructure for production chain:
 - Event generator, detector response simulation, digitization, reconstruction

DUNE / ND_Production Public

Notifications Fork 4 Star 0

<> Code Issues 1 Pull requests 2 Actions Projects Security Insights

main ND_Production / scripts / Go to file

Jeffrey Kleykamp Fixed typo in overlay code. Previous overlay using this script was 1 ... 56810a2 on 8 Jul History

..

CMaakeLists.txt	make a UPS product with mrb	17 months ago
ProcessND.py	Fixed typo in overlay code. Previous overlay using this script was 1 ...	4 months ago
template.sh	fix line 60, add comma	13 months ago

master ND_CAFMaker / src / reco /

chenel whoops, don't be lazy. put implementation in .cxx

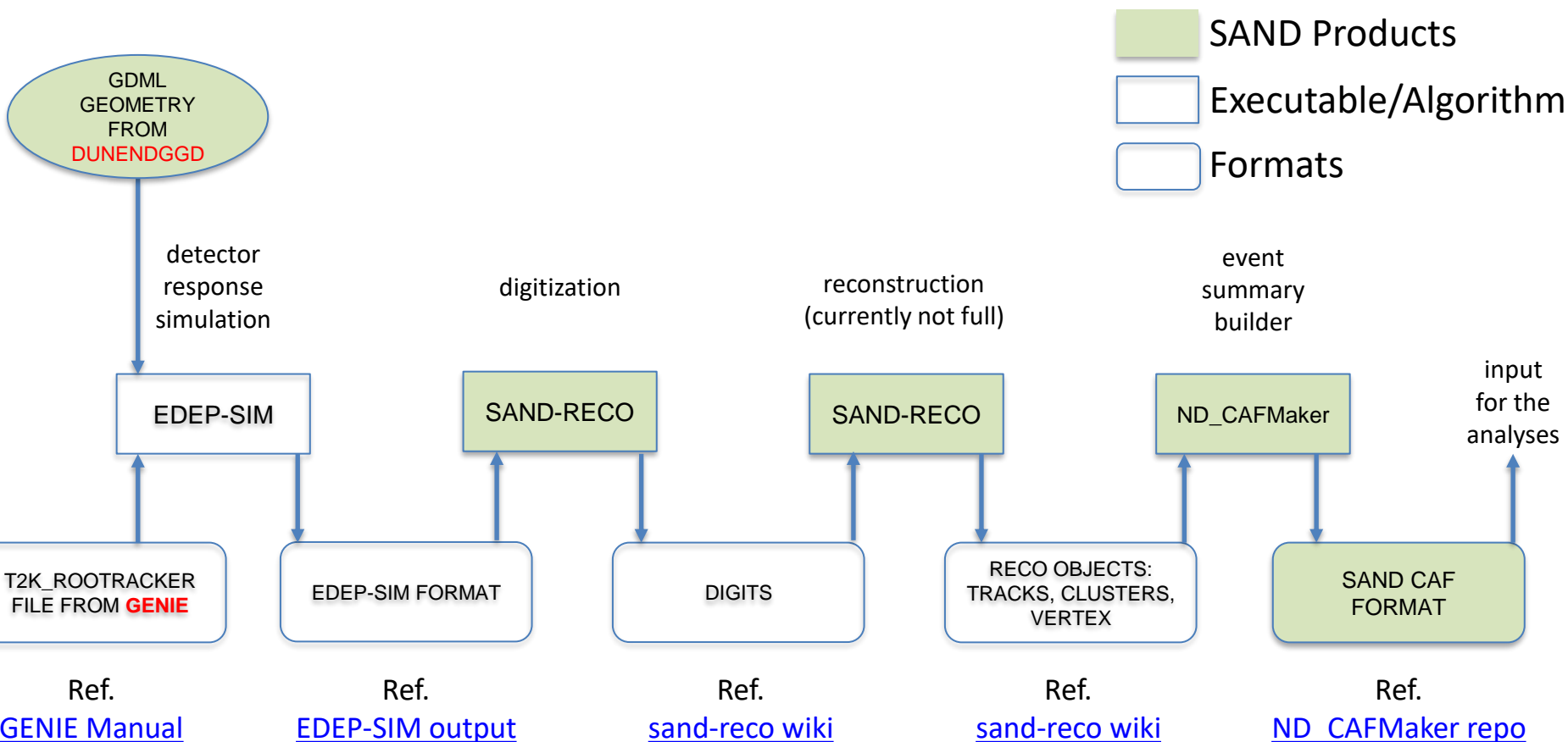
..

IRecoBranchFiller.h	Merge branch 'master' into feature/TMSconverer to pick up cl
MLNDLArRecoBranchFiller.cxx	Merge branch 'master' into feature/TMSconverer to pick up cl
MLNDLArRecoBranchFiller.h	getting rid of dt + parametrized reco
NDLArProductFiller.cxx	whoops, don't be lazy. put implementation in .cxx
NDLArProductFiller.h	whoops, don't be lazy. put implementation in .cxx
NDLArSummaryH5DatasetReader.cxx	quiet print statements in NDLAr fillers
NDLArSummaryH5DatasetReader.h	once again, don't set a size_t to -1 (eyeroll)
NDLArTMSMatchRecoFiller.cxx	Update matcher to use TMS distances in cm units, and not to convert L...
NDLArTMSMatchRecoFiller.h	Update matcher to slightly different method (propagate the LAr track ...
SANDRecoBranchFiller.cxx	Automatically enable or disable compilation of sand reco based on exi...
SANDRecoBranchFiller.h	Automatically enable or disable compilation of sand reco based on exi...
TMSRecoBranchFiller.cxx	Move TMS reco branches to have lengths in cm, not mm, as to match LAr...
TMSRecoBranchFiller.h	Merge branch 'master' into feature/TMSconverer to pick up changes due...

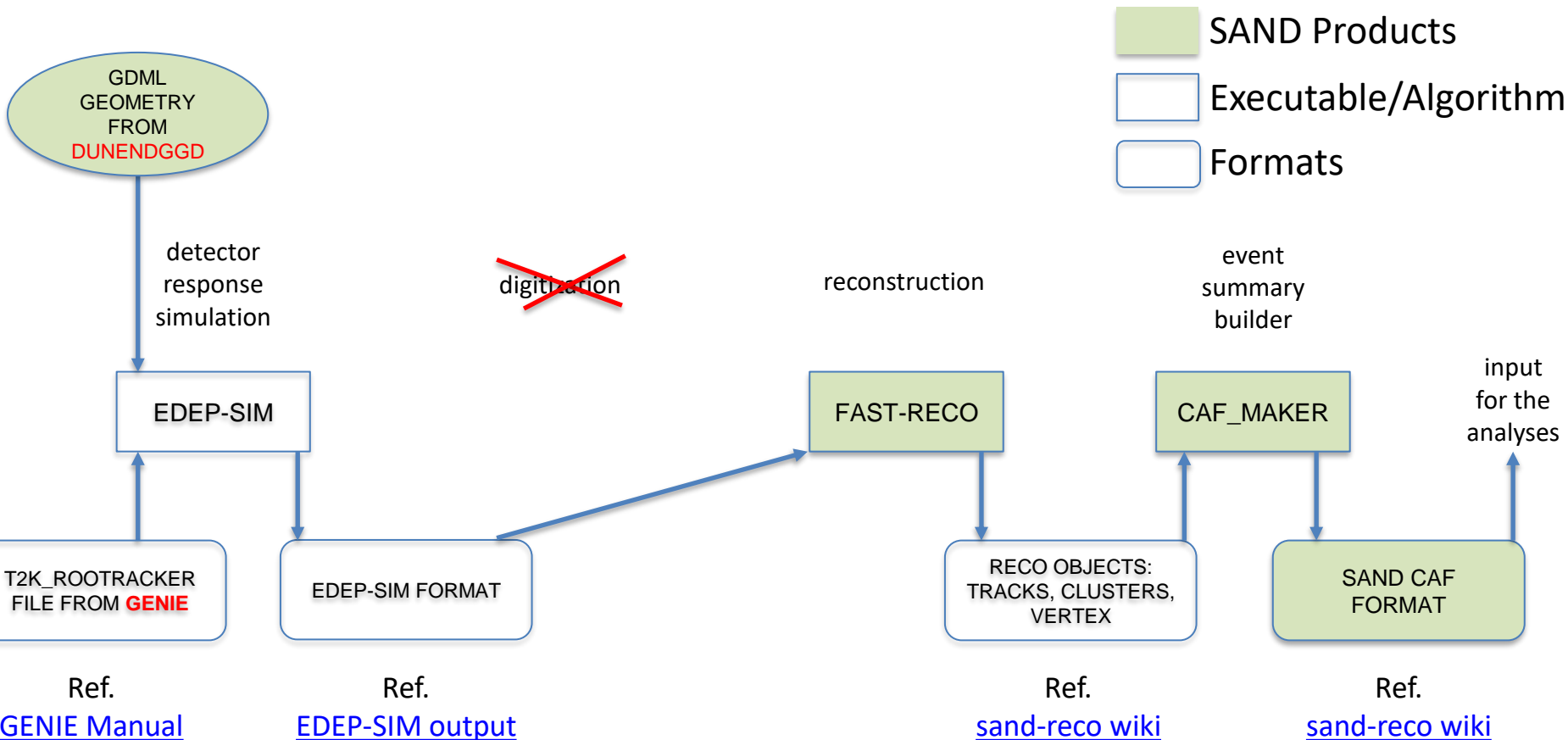
CAF Maker

- Common Analysis File
- Event Summary
- Input for Analyses
- SAND CAF implemented
- Content to be defined

Reconstruction Chain: Full



Reconstruction Chain: Fast



FAST-RECO

- Parameterized reconstruction
- Repository: baltig.infn.it/dune/FastReco
- Last commit: 10/05/2022
- Input: edep-sim format
- Output: tracks
- Only primary particles
- Straw Tube threshold: 250 eV
- ECAL Cell threshold: 100 keV
- Visible track: digits > 4
- Pattern recognition by MC truth
- Particle ID by MC truth
- Charged particles' momentum: Gluckstern formula based on number of STT digits
- Gammas' energy: $\frac{5.6\%}{\sqrt{E/GeV}}$ on visible energy in ECAL
- Neutrons' energy: TOF

SAND-RECO

- STT and ECAL Digitization
- STT tracks and ECAL clusters Reconstruction
- Repository: baltig.infn.it/dune/sand-reco
- Last commit: 26/10/2022

SAND-RECO Digitization

- Input: edep-sim format
- Output: [STT digits](#) + [ECAL digits](#)
- Simulation of detector response:
 - ECAL: light yield, scintillation decay time, attenuation, propagation to PMT
 - Straw Tube: drift towards wire, signal propagation along wire
- Digitization:

Straw Tube:

No threshold

TDC: arrival time of the earliest signal
at wire end + smearing

ADC: equals to total energy deposit

Integration window: 200 ns

ECAL Cell:

2.5 pe threshold

TDC: 2 options (fixed threshold
or constant fraction)

ADC: equals to sum of pe

Integration window: 30 ns

SAND-RECO Reconstruction

- Input: edep-sim format
- Output: reco objects
(i.e. [STT tracks](#) and [ECAL clusters](#))
- STT Track:
 - Pattern recognition: 2 options w/ or w/o using MC truth
 - Particle momentum: circular fit in YZ + linear fit on transformed ZX coord.
 - Particle ID by MC truth
- ECAL Cluster:
 - Pattern recognition: MC truth
 - Direction, position and «size» based on energy deposit in cells
 - Energy equals to sum of cells' energy

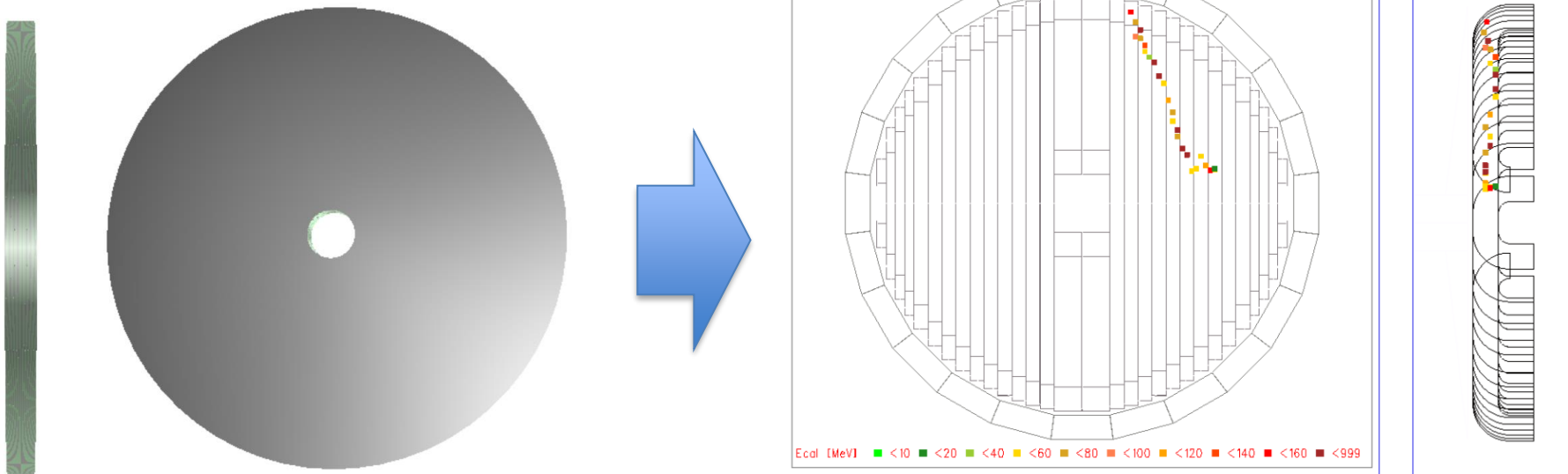
Analyses

- Detector performances:
 - Muon charge mis-ID
 - Muon and electron momentum resolution
 - Neutrino energy
 - Neutron detection efficiency
- External background rejection
- Beam monitoring
- $\nu - H$ interaction:
 - Relative and absolute fluxes
 - Nuclear smearing in Ar
- $\nu - e$ Interaction
- Ar Cross Section
- GRAIN physics case
- ...
- See: docdb-13262

What is missing?

To Do: Geometry

- Implement a realistic design for ECAL endcaps



- Implement a SAND «geometry manager»

To Do: Digitization

WHO?

- Implement Trigger or Full Spill Acquisition
 - Discussion with DAQ WG
- Implement time reference
 - Discussion with DAQ WG
- Define details of subdetector DAQ
 - Discussion with DAQ WG

To Do: Full Event Reconstruction

- Event Builder
- STT Kalman Filter
- ECAL Clustering
- GRAIN + STT+ ECAL matching
- Particle ID:
 - e- ID in ECAL
 - μ/π separation:
need for downstream μ catcher?
- Vertexing
- Integration with PANDORA
- Event classification
- Neutrino Energy Reconstruction
- Event Display
- ...

WHO?

To Do: CAF

- Currently only basic info:
 - i.e. E_ν , E_l , lepton PDG, event class
- Define content:
 - input from analyses

Genova

```
void SANDRecoBranchFiller::_FillRecoBranches(std::size_t ii,
                                             caf::StandardRecord &sr,
                                             const cafmaker::Params &par) const
{
    fTree->GetEntry(ii);

    //todo: currently filling simple variables
    //rewrite once sr.nd.sand exists in StandardRecord

    // neutrino energy
    sr.Ev_reco = fEvent->Enureco*0.001; //GeV

    std::vector<particle> particle_event = fEvent->particles;
    bool foundLepton = false;
    for ( auto it = particle_event.begin(); it != particle_event.end(); ++it){

        // primary lepton
        if( abs((*it).pdg) == 13 || abs((*it).pdg) == 11) && (*it).primary == 1){
            sr.reco_lepton_pdg = (*it).pdg;
            sr.Elep_reco = (*it).Ereco*0.001; //GeV
            foundLepton = true;
        }

        // other species
        // ...

    }

    // event flags
    if(!foundLepton){ //flags as nc
        sr.reco_numu = 0; sr.reco_nue=0; sr.reco_nc=1;
        sr.reco_lepton_pdg = -1;
        sr.Elep_reco = -1;
    }else if(sr.reco_lepton_pdg == 13){ //numu
        sr.reco_numu = 1; sr.reco_nue = 0; sr.reco_nc = 0;
    }else if(sr.reco_lepton_pdg == 11){ //nue
        sr.reco_numu = 0; sr.reco_nue = 1; sr.reco_nc = 0;
    }

}
}
```

To Do: ND Sim/Reco Integration

- Currently SAND is integrated into [ND Sim/Reco production chain](#) up to edep-sim step

WHO?

INTEGRATION WITH PRODUCTION	Stage 1 Geo + GENIE	Stage 2 GEANT	Stage 3 Detector Response	Stage 4 Detector Reco	Stage 5 Analysis files
ND-LAr	done	done	full	ML-Reco	CAFs
ND-LAr + TMS	done	done	partial	ML-Reco + Hough/A*	CAFs
TMS Only	done	done	cheated	Hough/A*	CAFs
ND-GAr	done	done	full	GArSoft	CAFs + GArAna
SAND+STT+GRAIN	done	done	full/fast		CAFs

- Finalize integration of the SAND reconstruction chain into [ND Sim/Reco production chain](#)

To Do: Analyses

- Produce analyses we claimed we can perform:
see [docdb-13262](#)
- Use CAF as input for the analyses
 - Update old analyses
- Share codes through our repositories
- Setup automatic end-to-end chain from MC production to analysis result

WHO?

Conclusions

We have done a lot of work:

- A detector geometry
- A detailed digitization and a working reconstruction
- A fast reconstruction
- Detector performance studies
- Several physics analyses

We have a lot of work in front of us

- More realistic detector geometry and digitization
- Full event reconstruction
- SAND CAF
- Physics studies we claimed to be able to do
- Integration with ND sim/reco
- Full analysis chain

Conclusions

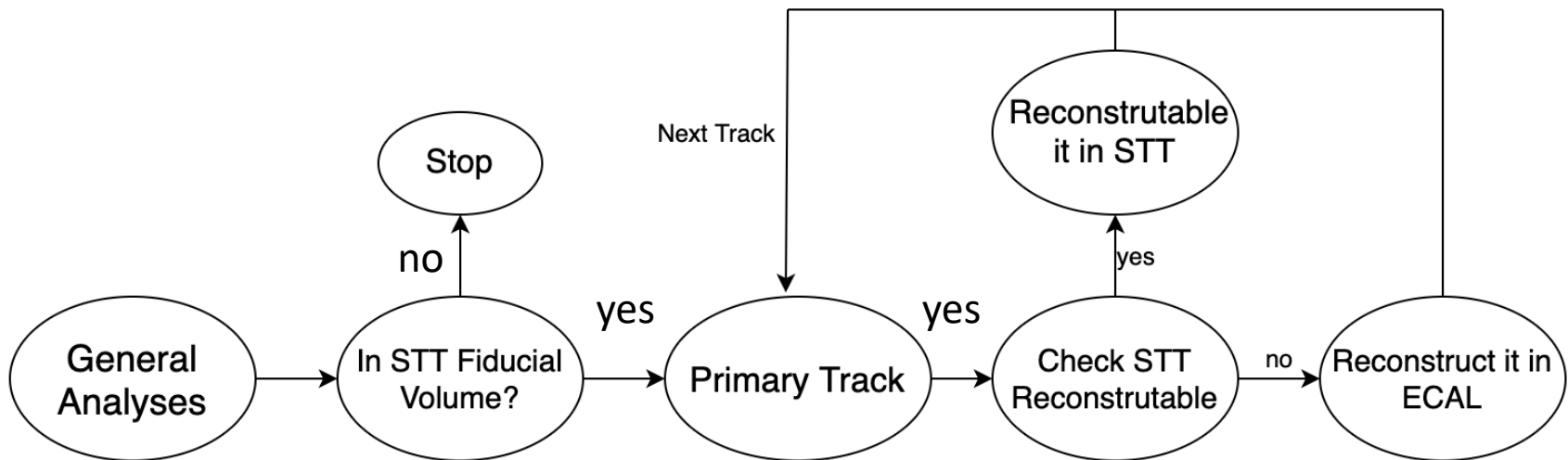


**I WANT YOU
FOR SAND
RECONSTRUCTION
AND ANALYSES**

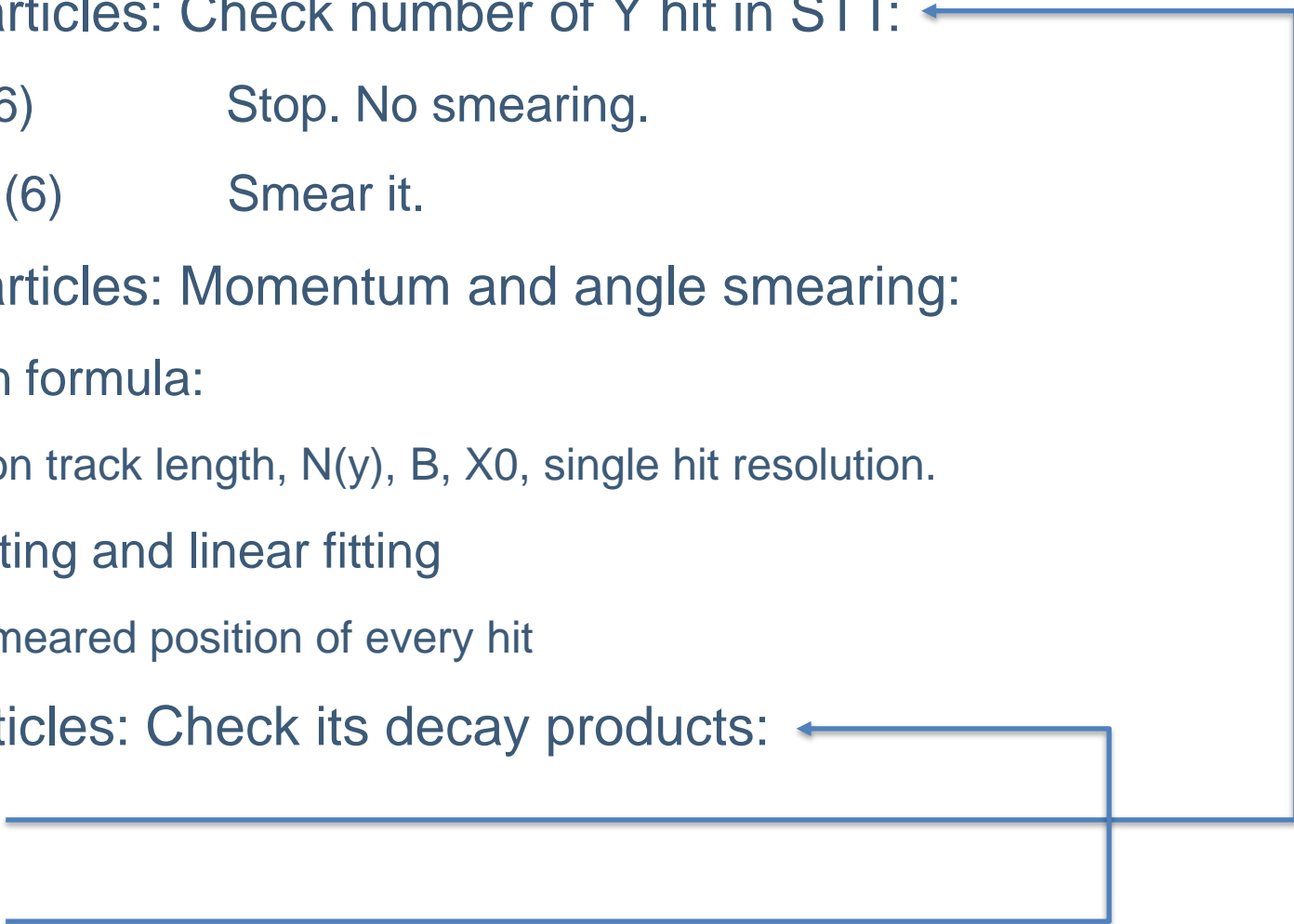
Backup

Fast Reconstruction

- Based on full detector simulation edep-sim (GEANT4)
- Treat events originating in different detector region differently
- Algorithm depends on specific analysis considered
- Single-particle smearing based on dedicated analysis/reconstruction



Fast Reconstruction in STT

- Charged particles: Check number of Y hit in STT:
 - $N(Y) < 4$ (6) Stop. No smearing.
 - $N(Y) \geq 4$ (6) Smear it.
 - Charged particles: Momentum and angle smearing:
 - Gluckstern formula:
 - Based on track length, $N(y)$, B , X_0 , single hit resolution.
 - Circular fitting and linear fitting
 - Need smeared position of every hit
 - Neutral particles: Check its decay products:
 - Charged
 - Neutral
- 

Neutral Particles Reconstruction

- $\pi^0 \rightarrow 2\gamma$ or $\pi^0 \rightarrow \gamma + e^-e^+$
 - Reconstruct each daughter particle's momentum separately then summing up.
- γ : e^-e^+ pair in STT or e.m. shower in ECAL.
 - Convert in STT: Reconstruct e^-e^+ track in STT
 - Convert in ECAL: find calibrated energy deposition of the e.m. shower
 - Smear earliest hit position by its resolution, connecting with vertex gives momentum direction
- Neutron: hits/cells detached from primary vertex.
 - Interaction in STT: connecting first hit (smeared) to vertex (or first hit for single track) gives direction, reconstructing the daughter tracks gives momentum.
 - Interaction in ECAL: detached cells are used to define neutral clusters, calibrated energy deposition in the cluster is summed up, connecting earliest cell to the vertex (or first hit for single track) gives momentum direction.
 - Neutron energy in CC: time-of-flight from smeared timing at primary vertex (or first hit) and earliest hit of detected neutron candidate and reconstructed direction.
 - Neutron energy in CC on Hydrogen: calculated analytically from energy-momentum conservation.