Event reconstruction in SAND with sandreco

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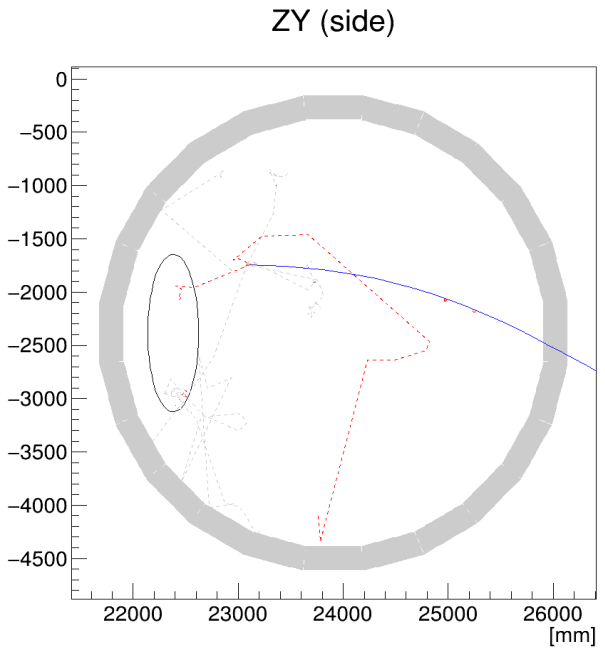
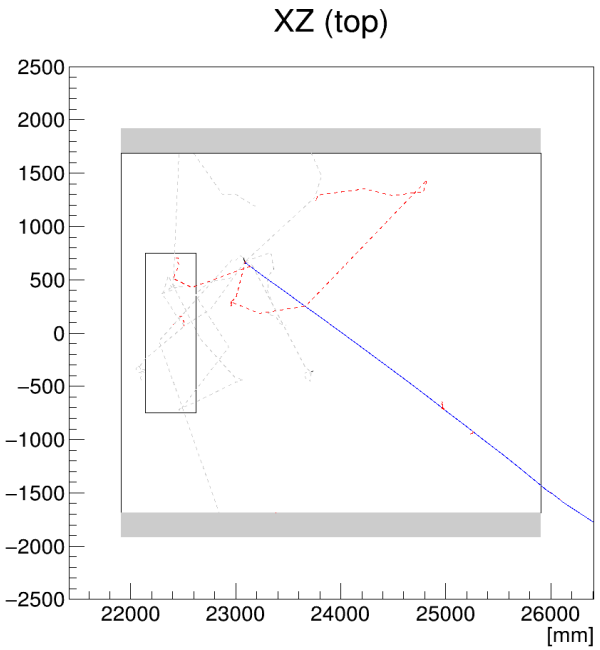
Introduction

- **Aim of the work: full event reconstruction in SAND with sandreco**
  - GENIE + EDepSim
  - Latest detector geometry
  - Digitized events (in sandreco)
  - Neutrino interaction vertex
  - Primary identification: tracks and particles
  - Neutrino energy reconstruction





Introduction

- **Starting point: analysis performed for gobal event reconstruction in SAND**
  https://agenda.infn.it/event/32953/contributions/184143/attachments/98921/137065/SAND_Ev_Reco_Surdo.pdf
  - Based on FLUKA as ν interaction generator
  - A previous geometry, different from the latest one
- **Neutrino interactions in GRAIN or STT**
- **Results:**
  - Primaries classification (number, type, energy, …)
  - Energy reconstruction (from tracked particles, ECAL clusters, scintillation in GRAIN)
  - Others
- **Ongoing work: reconstruction in sandreco**
  - Characterization of events using MC information – I part
  - Prelimary study of event reconstruction without MC information – II part

MonteCarlo Production

- **Geometry: SAND_opt3_STT1.gdml** (*https://web.infn.it/nu_at_fnal/wp-content/uploads/2023/11/recap_info_geo.pdf*)

  GRAIN has realistic dimensions (902 mm thickness) and also the clearances are reasonable

- **Interactions:** *GEO_VOLUMES= "STTtracker"* , *"GRAIN_LAr_lv"* and *"sand_inner_volume"*

  interactions in STT, GRAIN, Inner volume (STT+GRAIN)

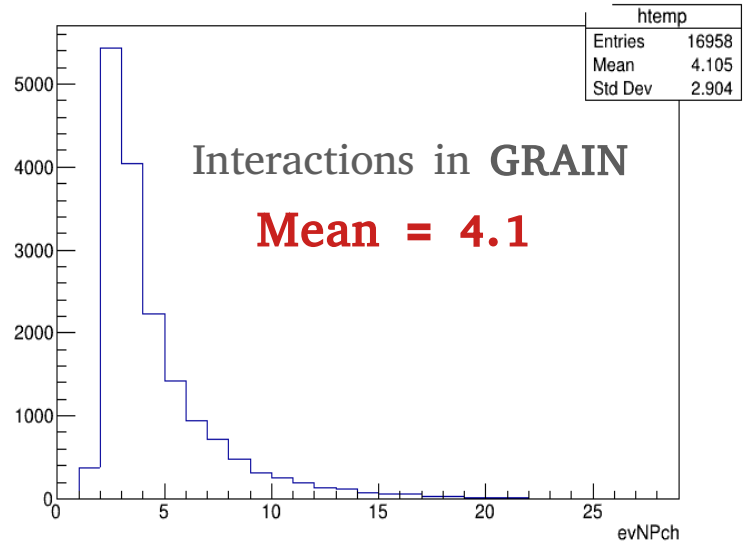
- **Type of event:** *OVERLAY="no"*

  single event (alternative: *"yes"*-> beam spill)

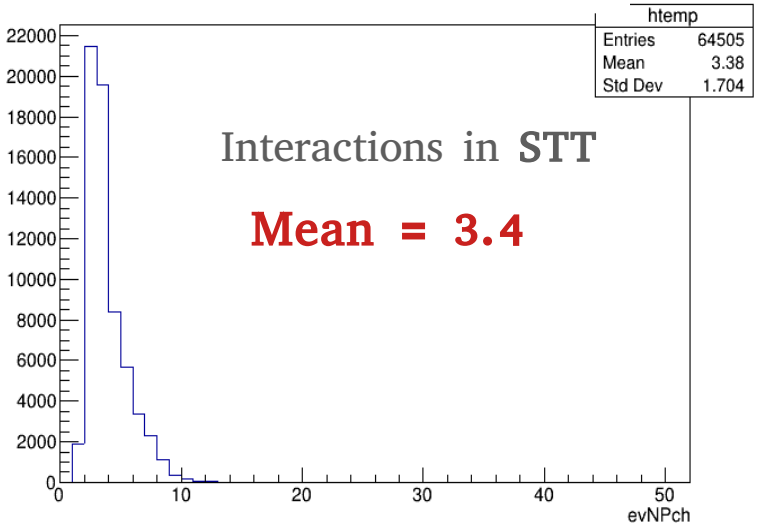
- **Particle:**
  - *MODE="neutrino"* (alternative: *"antineutrino"*)
  - *NU_FLAVORS="14,-14"* ($\overline{\nu}_\mu$, ν_μ)

First part: Characterization of interactions in SAND

- **MC events**
- Digitization in sandreco
- Characterization of neutrino interactions in GRAIN or STT
- **Benchmark results,** reference for the full reconstruction

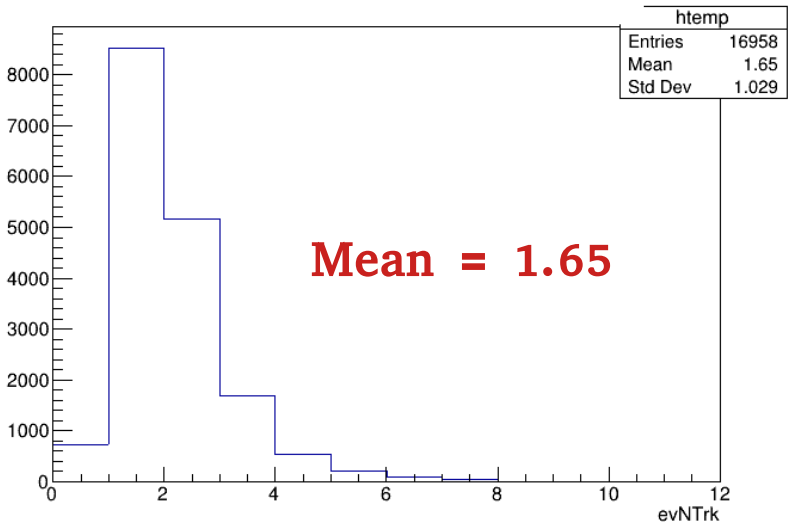


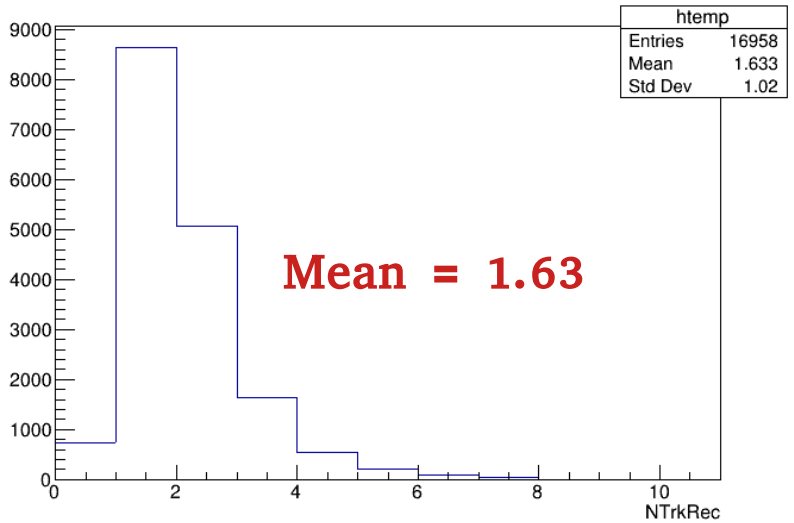
- Mean number of **charged particles** produced per interaction
- The higher charged particle multiplicity in GRAIN reflects the nu interaction with heavier nuclei (Ar) than in the STT



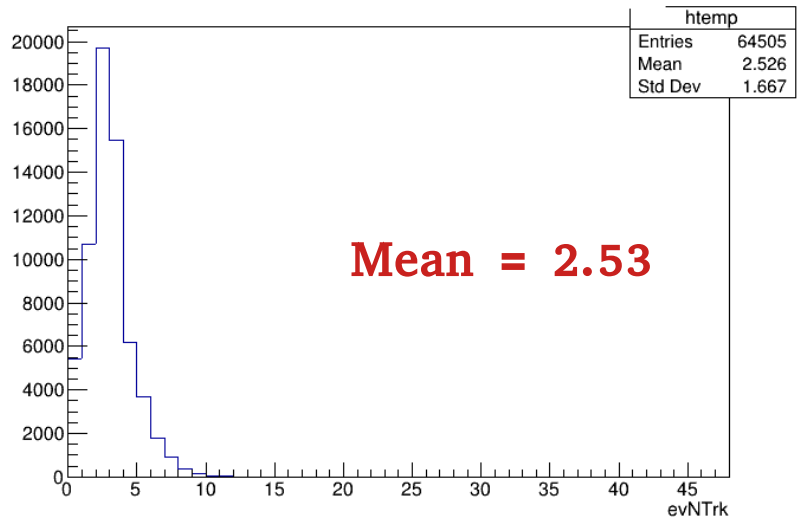
Characterization of interactions in SAND: tracks

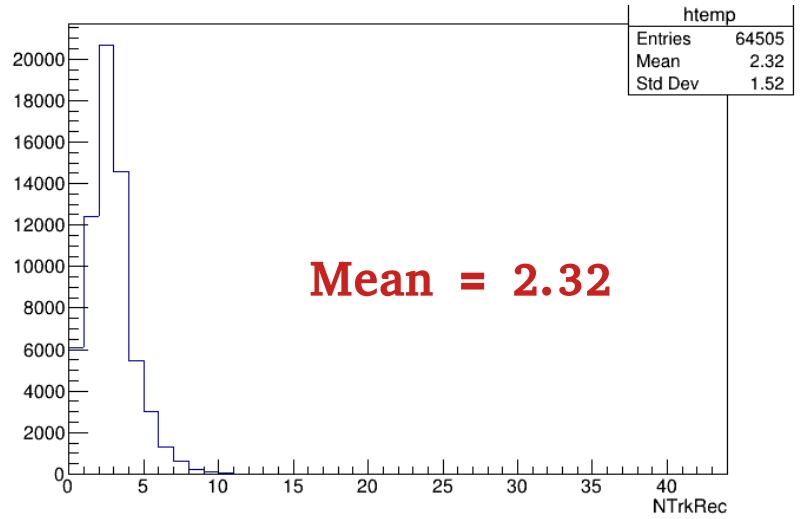
Interactions in **GRAIN**





Interactions in **STT**





Total number of primary tracks (in the STT) generated in the ν_μ-CC interactions *without any request on the number of hits*

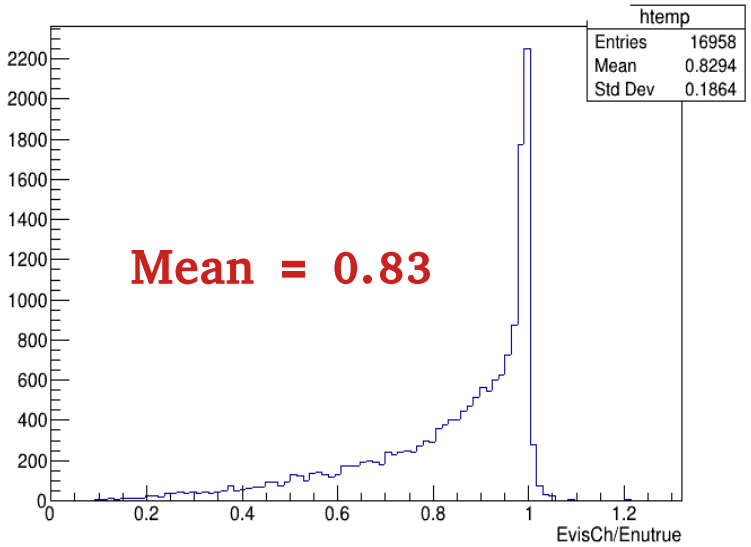
Mean number of primary tracks with **at least 3 hits** in X and Y view

↓

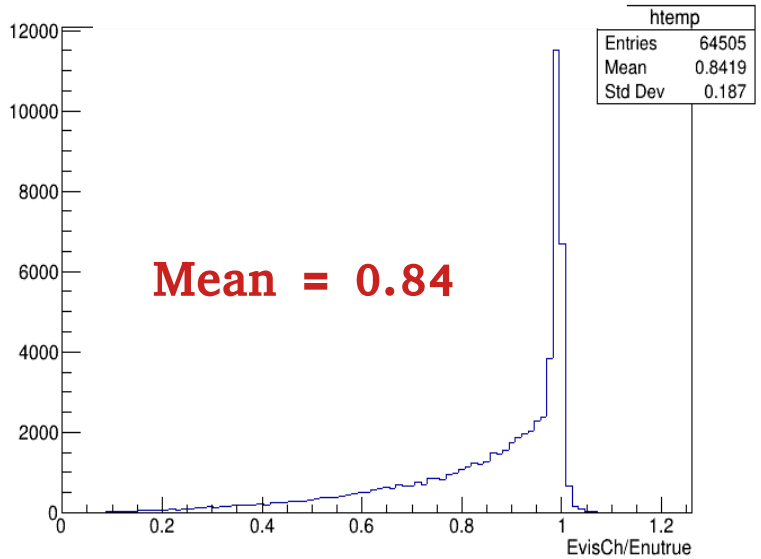
Mean number of primary tracks that can be reconstructed in the STT

Energy of charged particles and energy estimated from tracks

Interactions in **GRAIN**

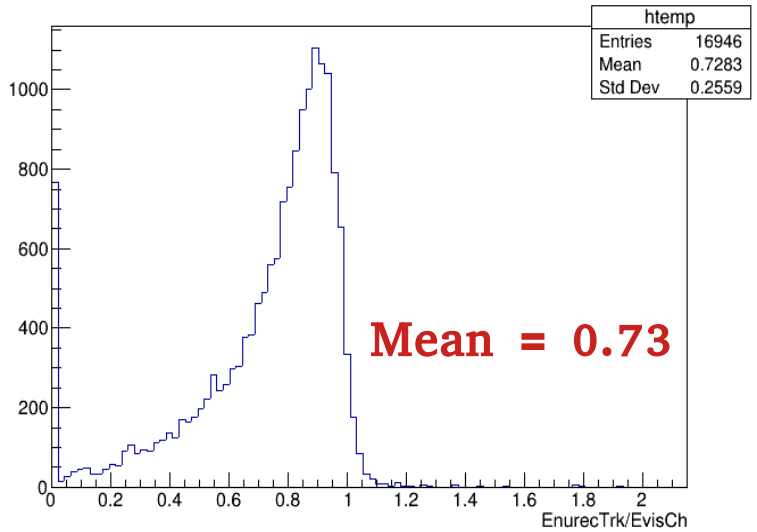


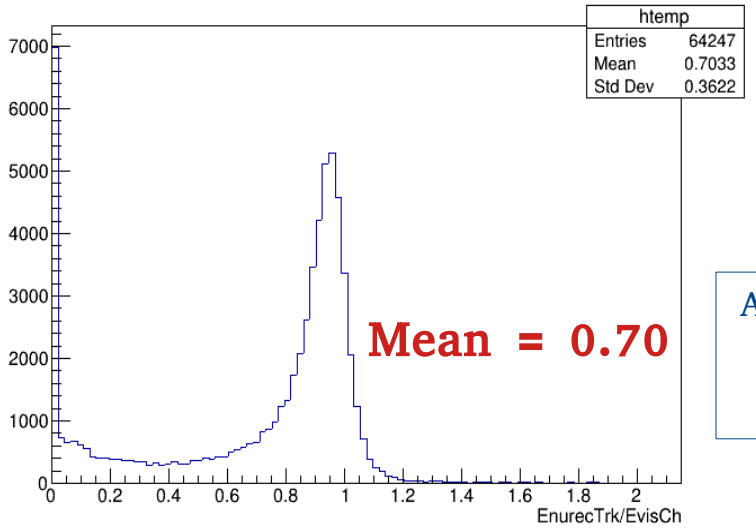
Interactions in **STT**



$E_{visCh} = E_{\mu} + E_{mesons+-} + E_{kin,protons\&baryons+-}$

EvisCh is the part of neutrino **energy** carried by **charged particles** (that could be reconstructed if every charged particle can generate a visible track)



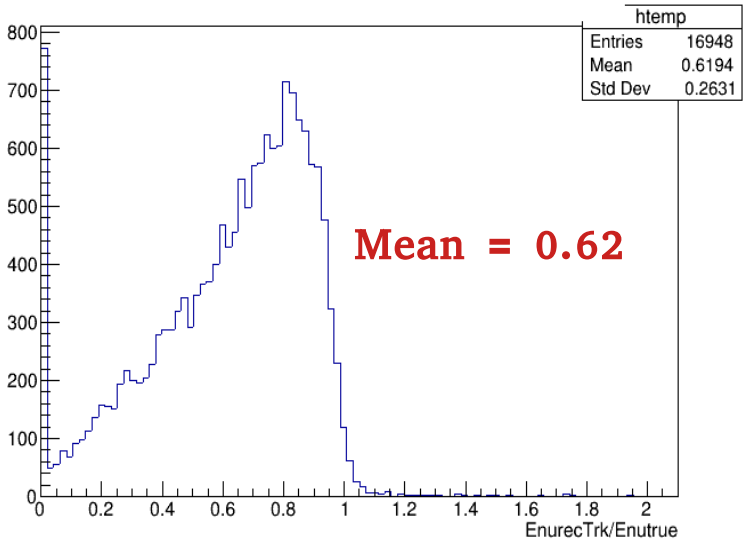


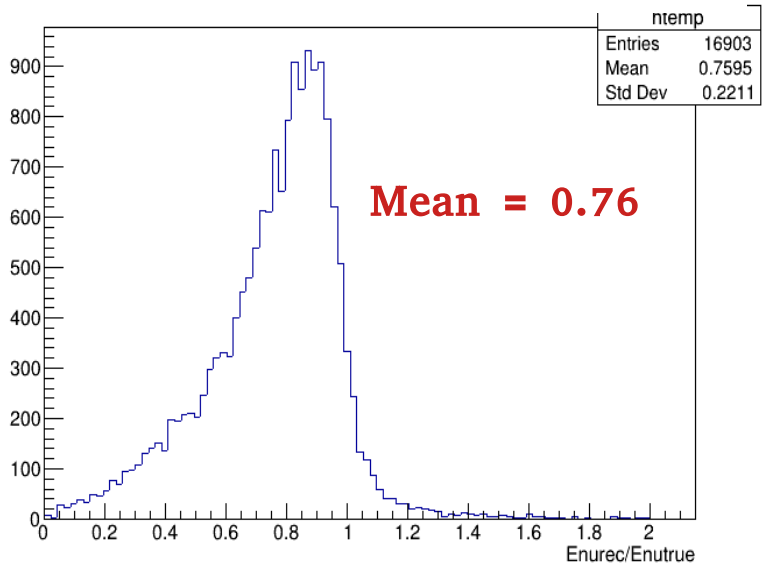
EnurecTrk/EvisCh is the **fraction** of EvisCh estimated **from** reconstructed **tracks**

A fraction of the neutrino energy is lost because of:
- Absorption of low energy particles in LAr
- Tracks not reconstructed on the STT borders

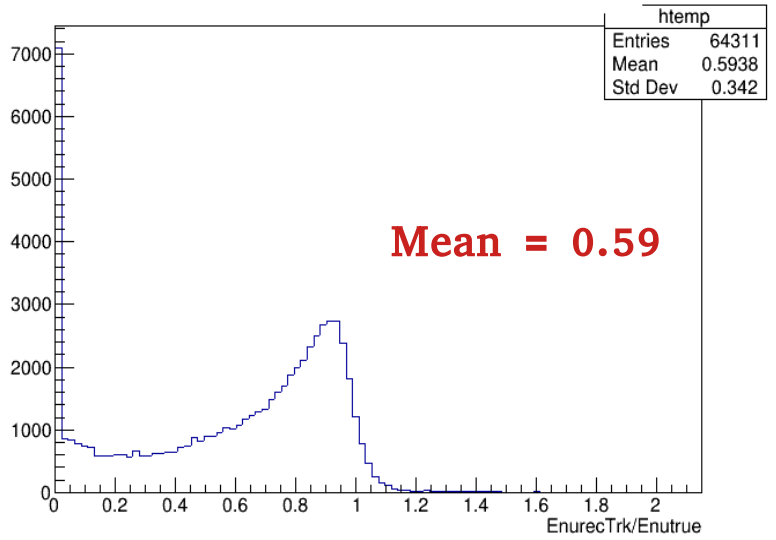
Characterization of interactions in SAND: reconstructed energy

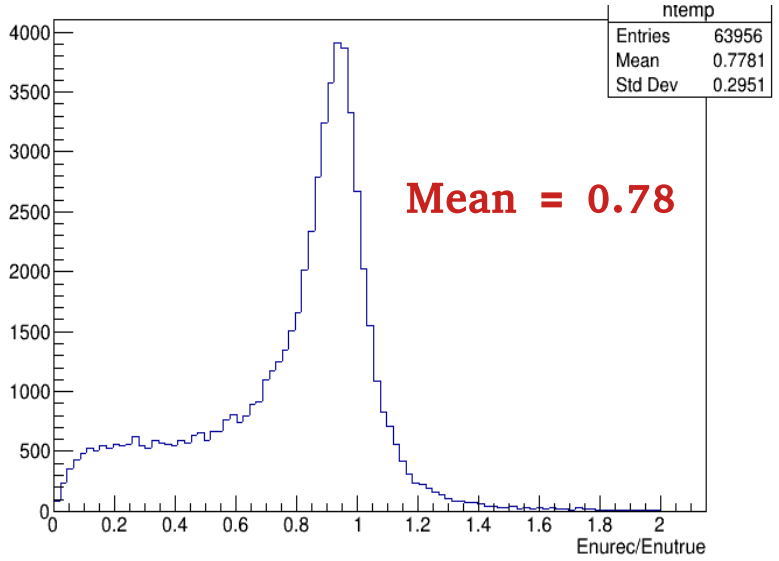
Interactions in **GRAIN**





Interactions in **STT**





Fraction of **neutrino energy** estimated **from** reconstructed **tracks** in the STT

Fraction of reconstructed neutrino energy

Second part: full event reconstruction

Motivation:

So far we used **MC information** for reconstruction in sandreco → **benchmark results** representing the ideal case

More realistic scenario: no MC truth but only **output of the digitization**

Method:

Interaction **vertex** estimation based on **STT-hit** topology (STEP 0)

Track finding (Global transform method)

Linear or circle **fits** to the tracks (to be integrated with the Kalman filter)

Vertex reconstruction from crossing the 2 most rigid tracks (STEP 1)

Possible procedure iteration

Matching of tracks in the two views → **track in 3D** space

Momentum evaluation

Combine with information from **GRAIN** and **ECAL**

Vertex reconstruction (step 0)

Interactions in the STT

Digitized events

A primary vertex finding algorithm is applied,

based on simple topological criteria (preliminary)

Digit spread profile on STT planes (x-z, y-z views) vs z coordinate

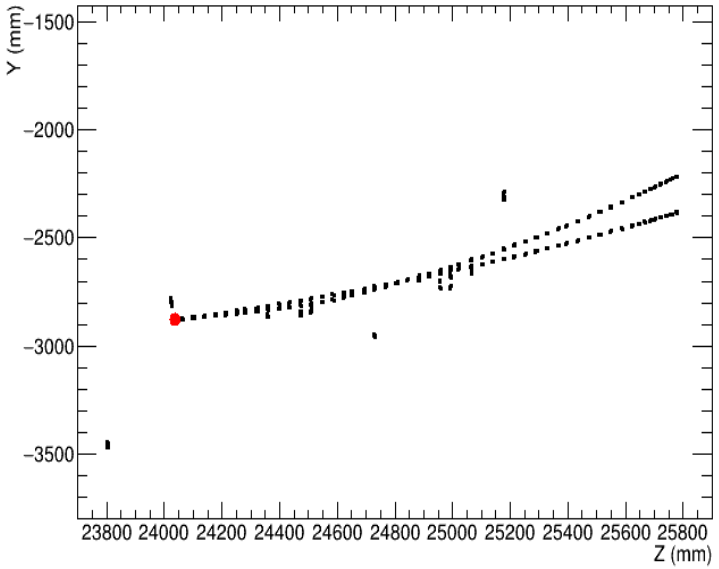
Vertex in the point of **minimum spread**

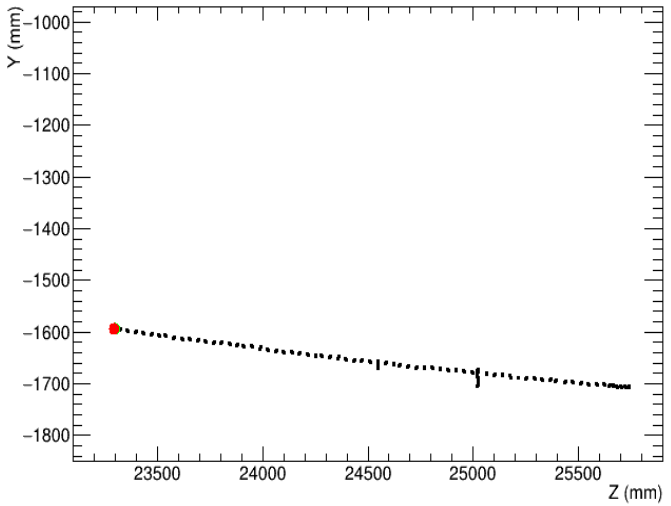
The red point represents

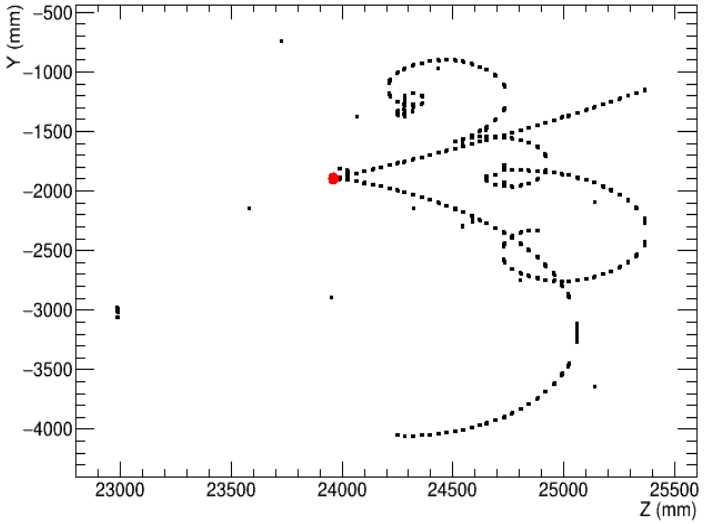
the **reconstructed vertex,**

superimposed with the true vertex

(**good reconstruction**)







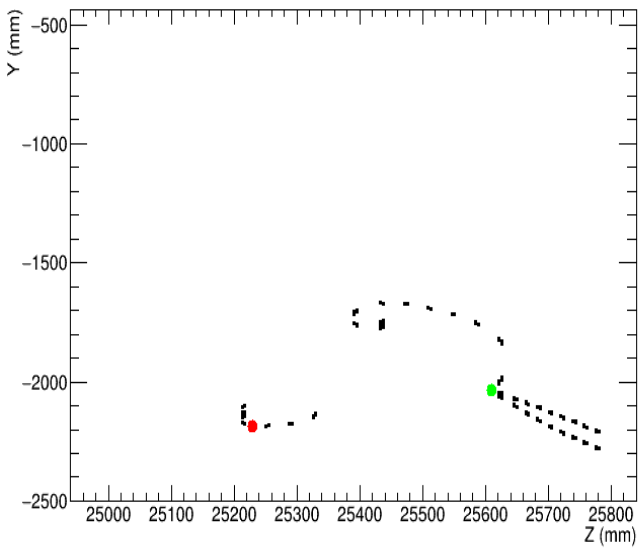
Some examples of not good reconstruction

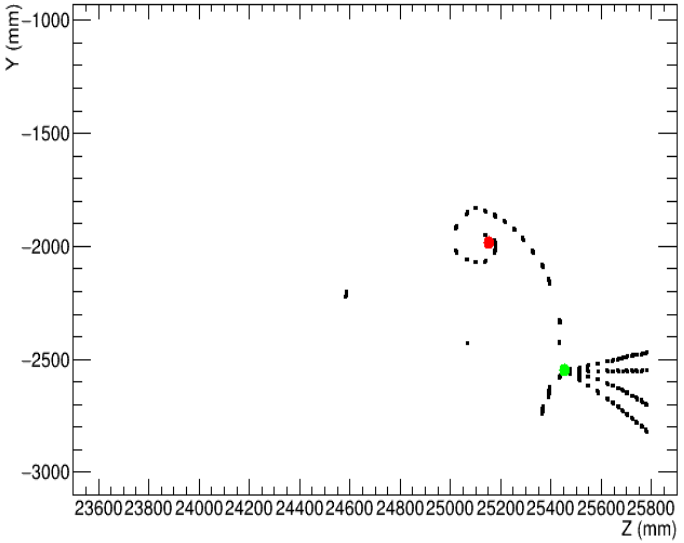
At this step (**step 0**) the vertex reconstruction is not always well performed

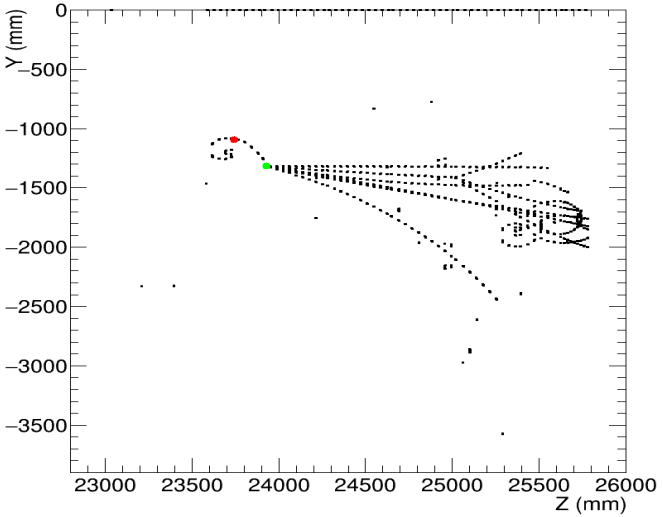
In green the true vertex (MC)

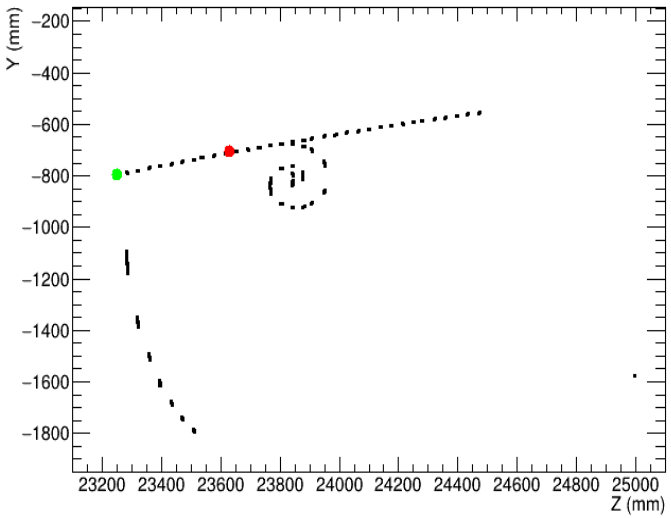
In red the reconstructed vertex

- More **studies on the event topology** are ongoing to improve the reconstruction
- **At least one more iteration is needed** (improvement from previous studies with FLUKA)

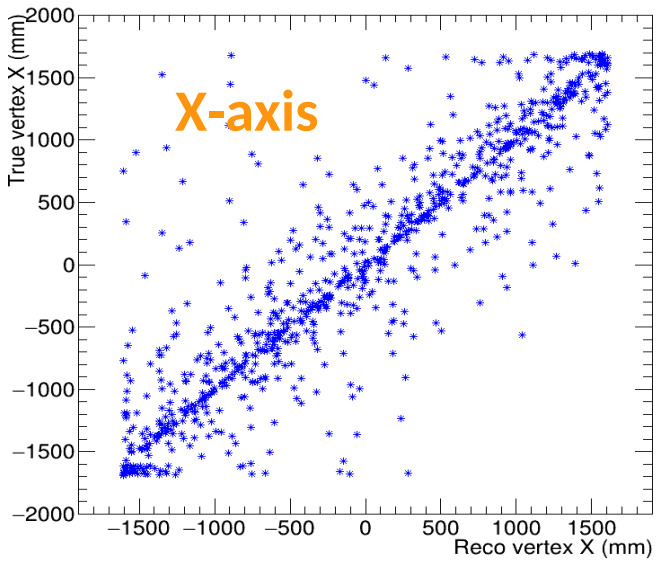


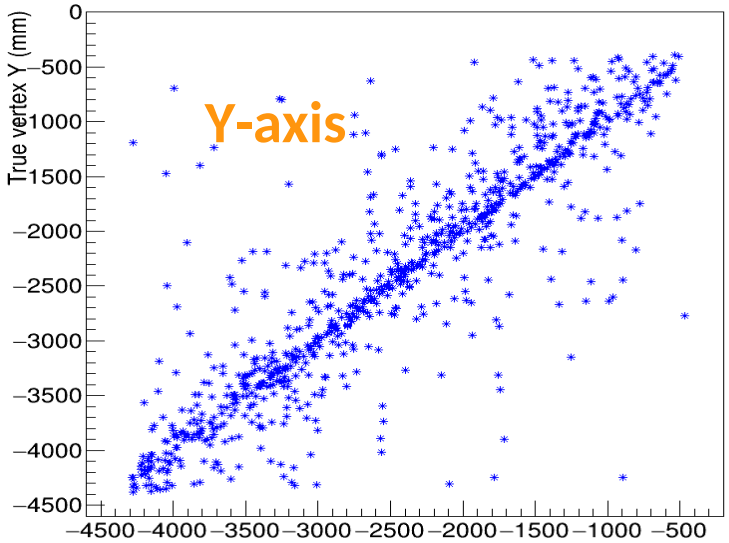


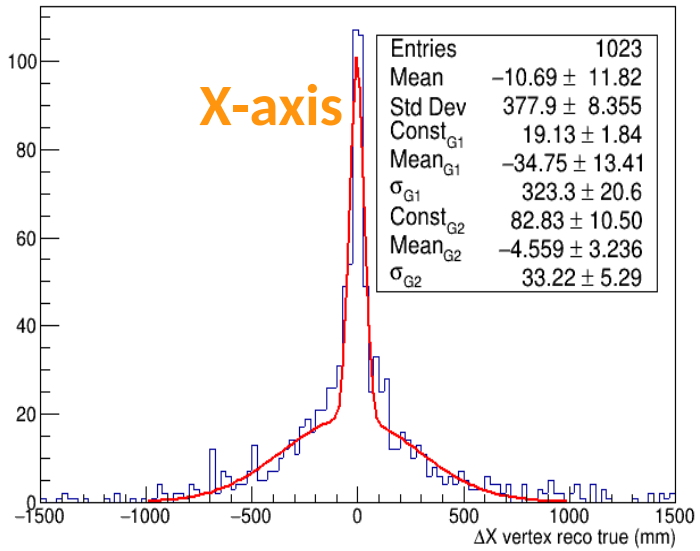


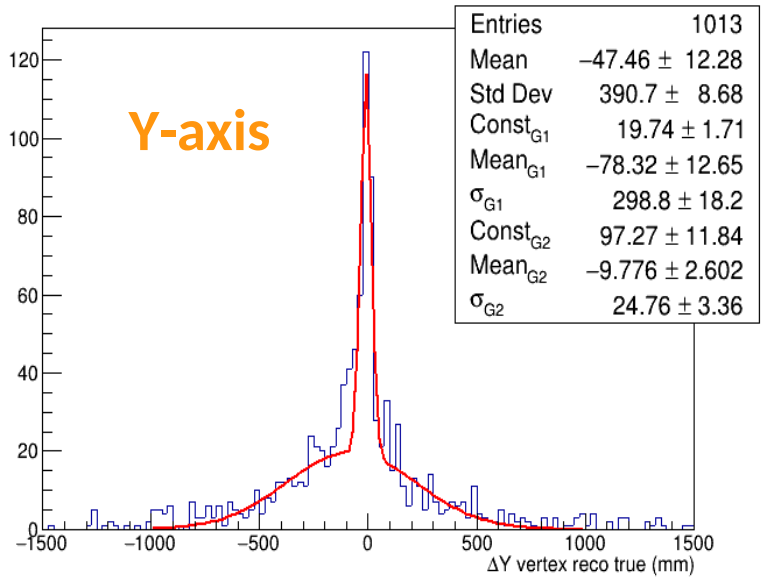


Vertex reconstruction - STEP 0 (vertex in STT)



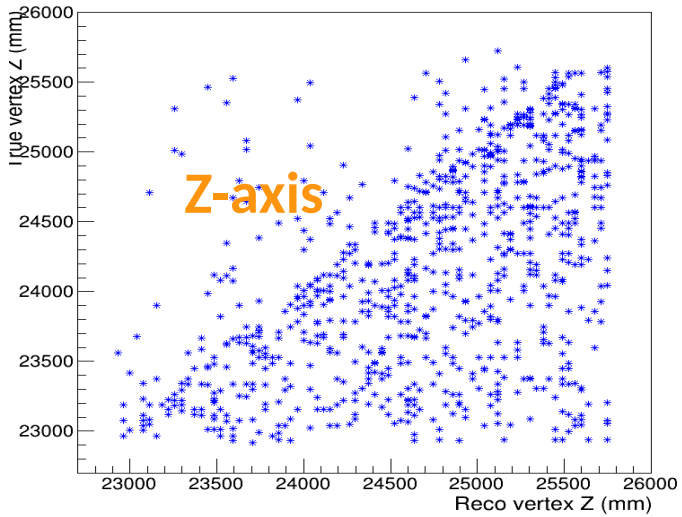


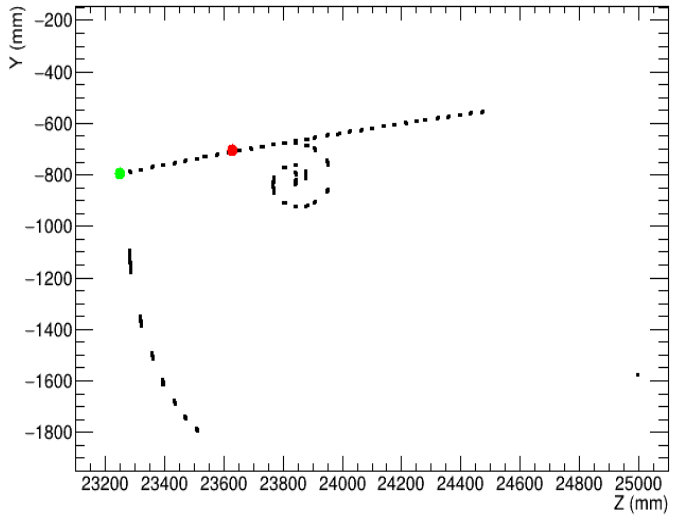




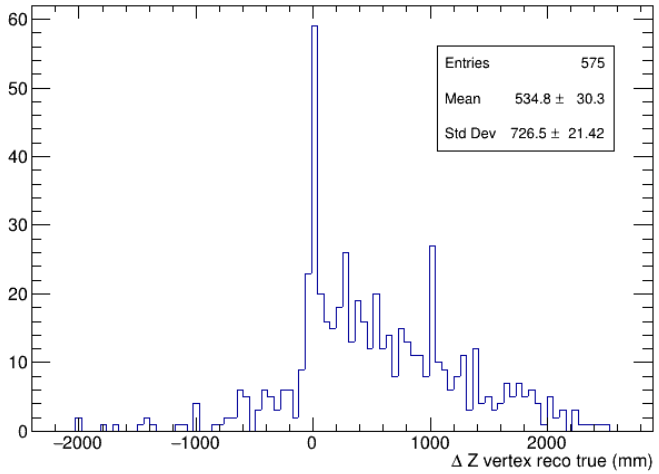
- Sum of two distributions: well-reconstructed events **+** a large distribution
- **At least one more iteration is needed** (improvement from previous studies with FLUKA)

Vertex reconstruction - STEP 0 (vertex in STT)





The bad reconstructed events have the maximum error on the **z axis**



- **At least one more iteration is needed** (improvement from previous studies with FLUKA)
- Investigation on the event topology to improve the reconstruction

Conclusion and future plans

Characterization of interactions in GRAIN and STT in sandreco using MC information

Estimation of the neutrino energy that can be reconstructed by using the tracks in the STT

Vertex reconstruction in sandreco without MC information

Only for the case of **neutrino interactions in the STT**

Next steps:

1) Further investigation on the bad reconstructed events to improve the reconstruction already at the step 0
2) Continue with the **track reconstruction**
3) **Iterative method** for vertex reconstruction in STT
4) Implement the vertex and track reconstruction in **GRAIN** and in the **ECAL,** using an iterative method

Backup

From DUNE Italian Meeting 2022

Track reconstruction (transform method)

Track-finding: global transform method → Vertex needed

- Use of Vertex position (from MC hits) reconstructed in LAr
- "Reconstructed" Vertex used for coordinate transformation:

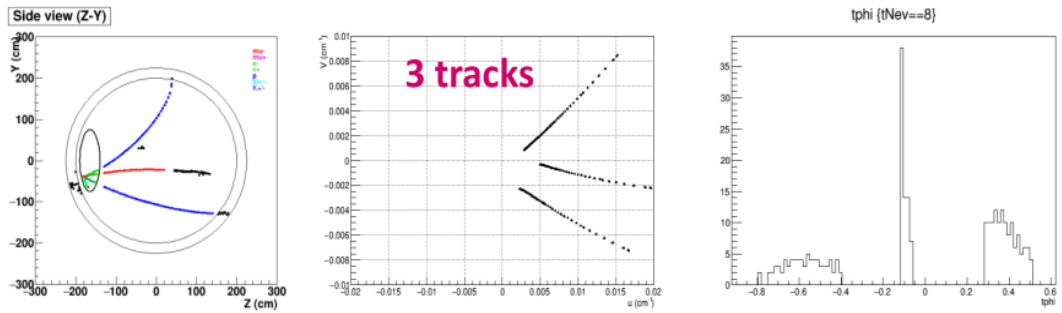
  $x \rightarrow u \qquad y \rightarrow v$

$$u = +(z-z_V) / [(z-z_V)^2 + (y-y_V)^2]$$
$$v = -(y-y_V) / [(z-z_V)^2 + (y-y_V)^2]$$

Vertex: (z_V, y_V)

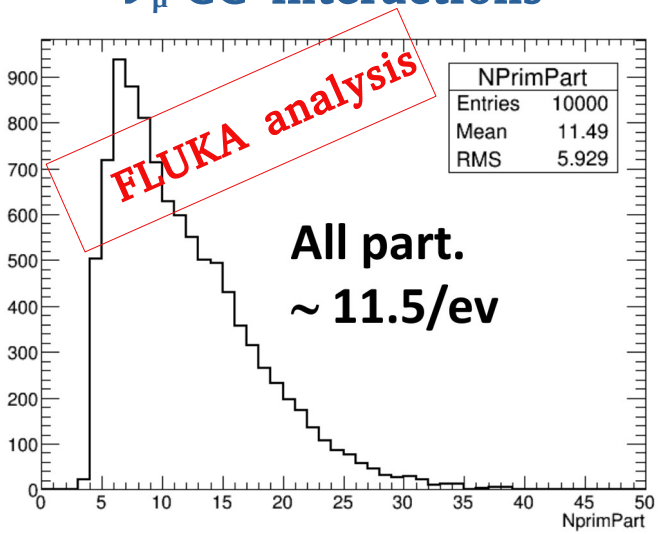
- Search for peaks in distribution of $\phi = \arctan(v/u)$
- Associate digits to tracks (without MC info!) and perform a circular fit

Example:

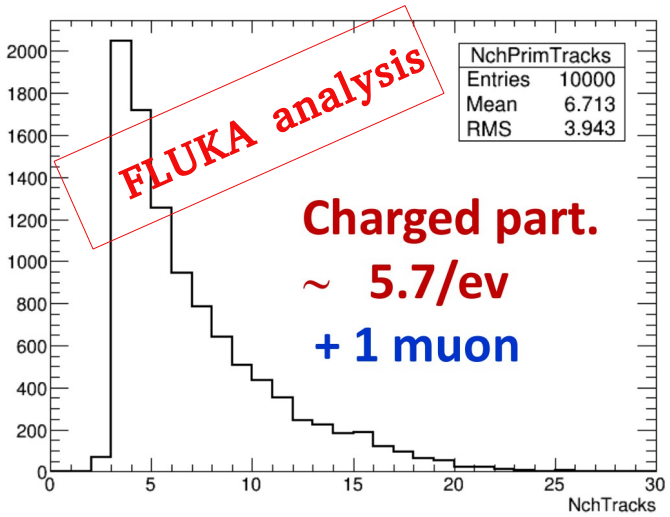


Primaries

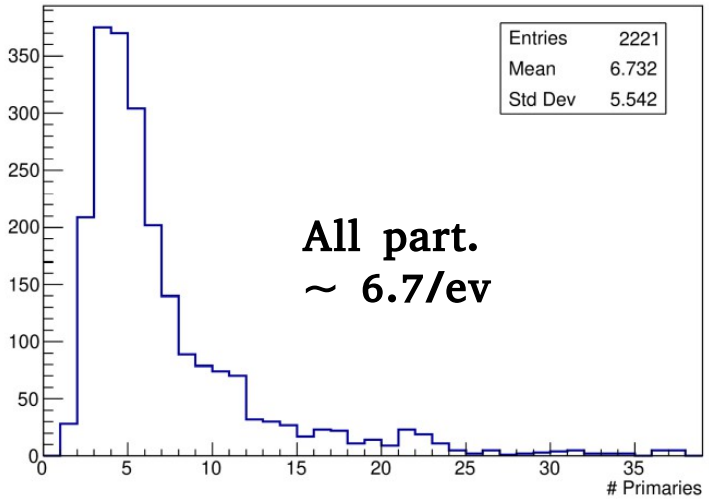
ν_μ-CC interactions



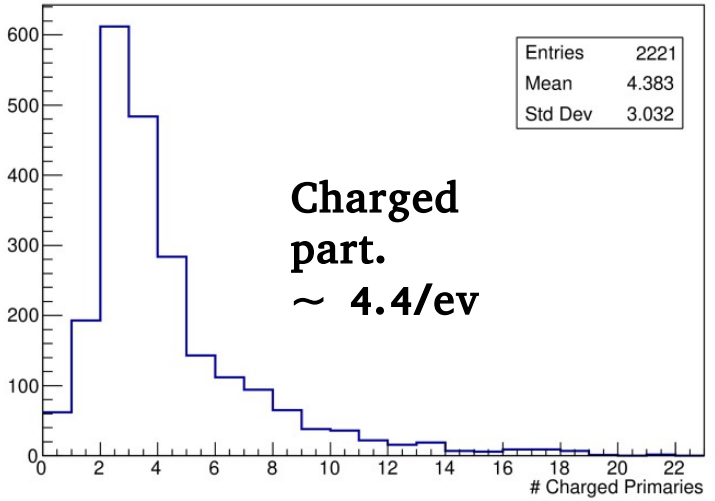
Vertex charged tracks (nu_mu-CC in LAr)



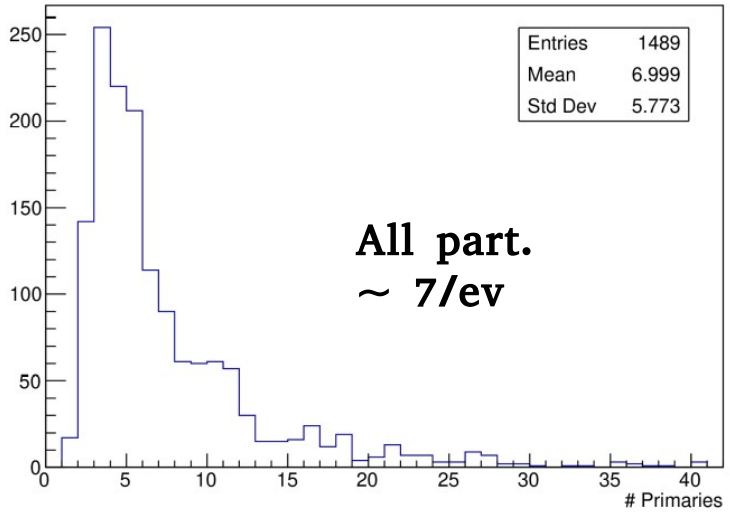
ν_μ, ν_e, CC and NC



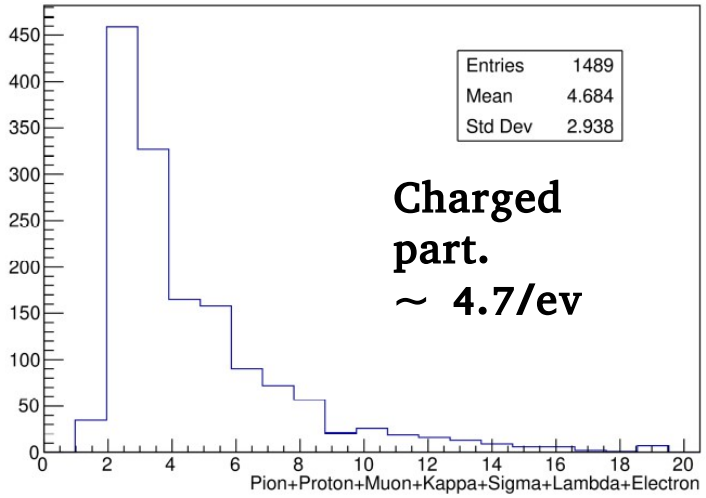
Pion+Proton+Muon+Kappa+Sigma+Lambda+Electron



ν_μ-CC interactions

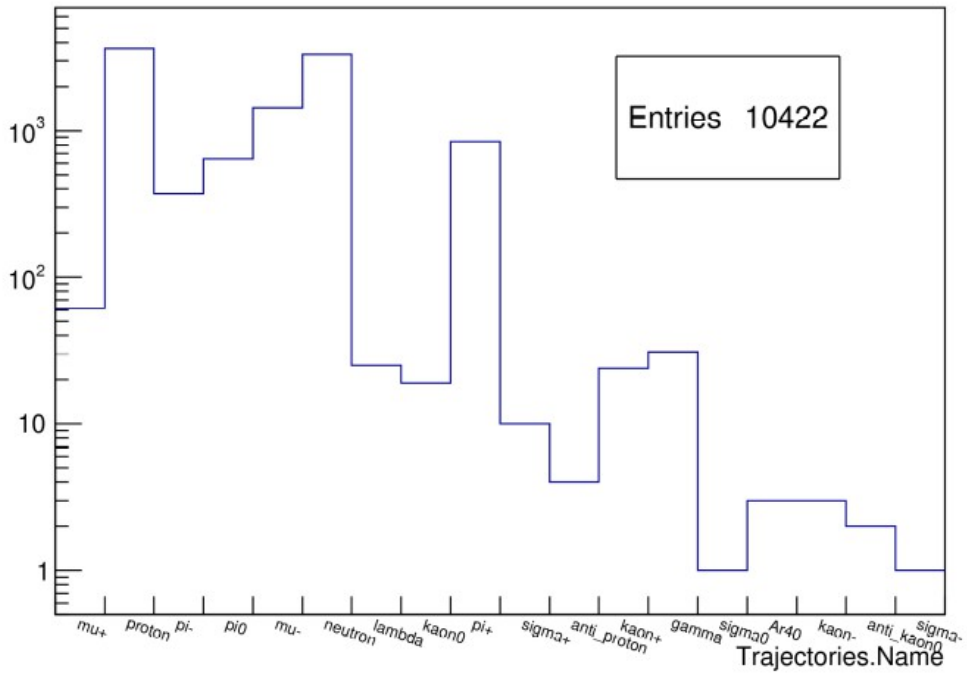


Pion+Proton+Muon+Kappa+Sigma+Lambda+Electron {isCC==1}



Primaries

ν_μ-CC interactions



Particles	FLUKA	sandreco	sandreco ν_μ-CC
Pions	~1.4/ev	~1.8/ev	~1.7/ev
Protons	~2.1/ev	~2.3/ev	~2.4/ev
Neutrons	~2.9/ev	~2.1/ev	~2.2/ev
Nuclei	~2.6/ev (various nuclear fragments)	~0.003/ev (only Ar40)	~0.002/ev (only Ar40)
Photons	~1.4/ev	~0.02/ev	~0.02/ev

Main difference: Number and type of nuclei (dependence on the set threshold in FLUKA or GENIE