Status of simulation and reconstruction of fine-grained tracker SFGD

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on behalf of Sofia's group

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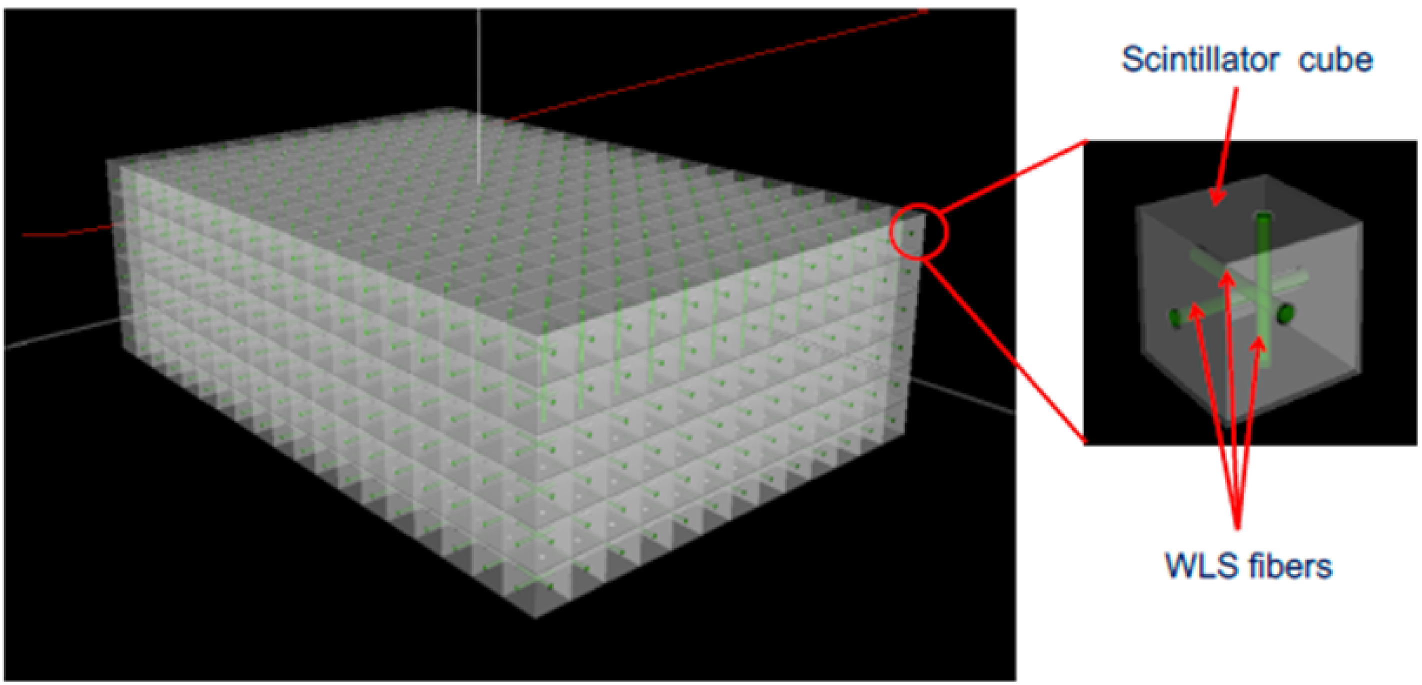
Super Fine-Grained Detector

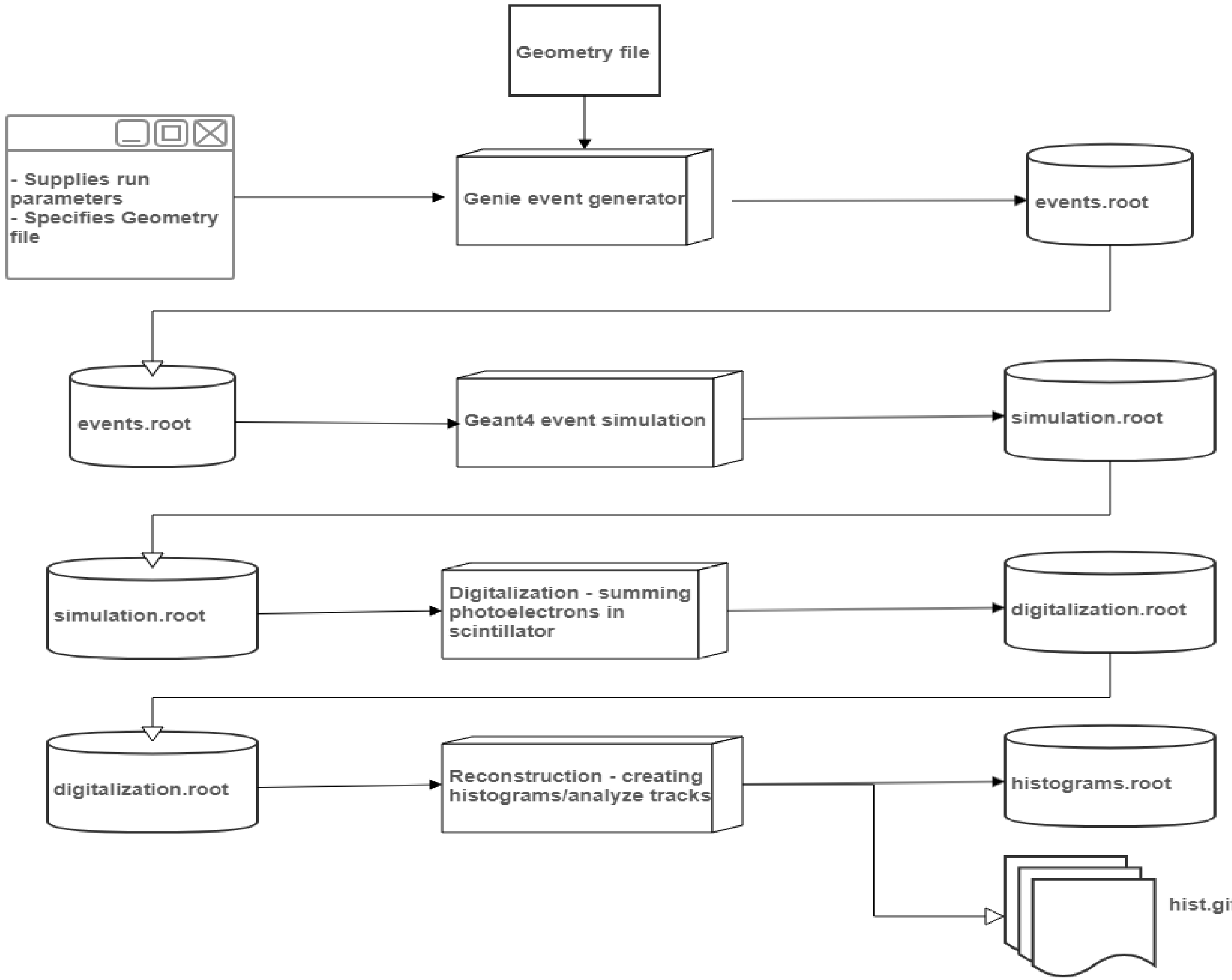
(T2K- ND280 upgrade type)



Cube size: 1x1x1 cm
sfgd size: 100x100x100 cubes

Parameter	Value
Coating thickness	50 μm
Hole diameter	1.5 mm
WLS fiber diameter	1.0 mm

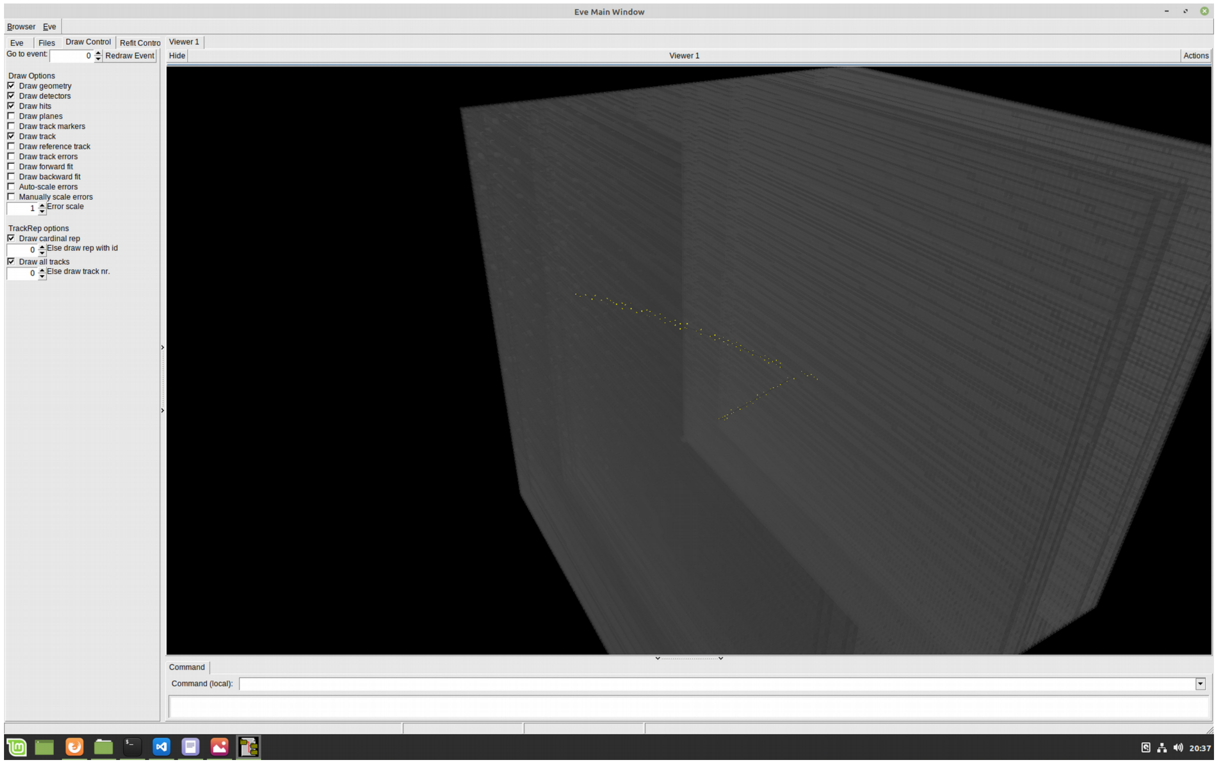
Data flow



Geometry file
- Supplies run parameters
- Specifies Geometry file
Genie event generator
events.root
events.root
Geant4 event simulation
simulation.root
simulation.root
Digitalization - summing photoelectrons in scintillator
digitalization.root
digitalization.root
Reconstruction - creating histograms/analyze tracks
histograms.root
hist.gif

Geometry

- Dimensions:
  - cube size and number of cubes can be easily manipulate in a text file
- Materials of scintillating cubes, WLS fibers and corresponding coating:
  - based on T2K SFGD prototype
- Magnetic field:
  - change direction and magnitude from text file
- Optical photons on/off.



Simulation

Two options:

- Monoenergetic neutrinos at a given flavor are forced to interact somewhere in the detector (e.g. at center)
  - Can change energy, flavor, direction and interaction point via job macro file
- Real neutrino flux illuminates entire detector
  - Neutrino direction is parallel to z-axis
  - Distribution in (x,y) is flat

Digitization

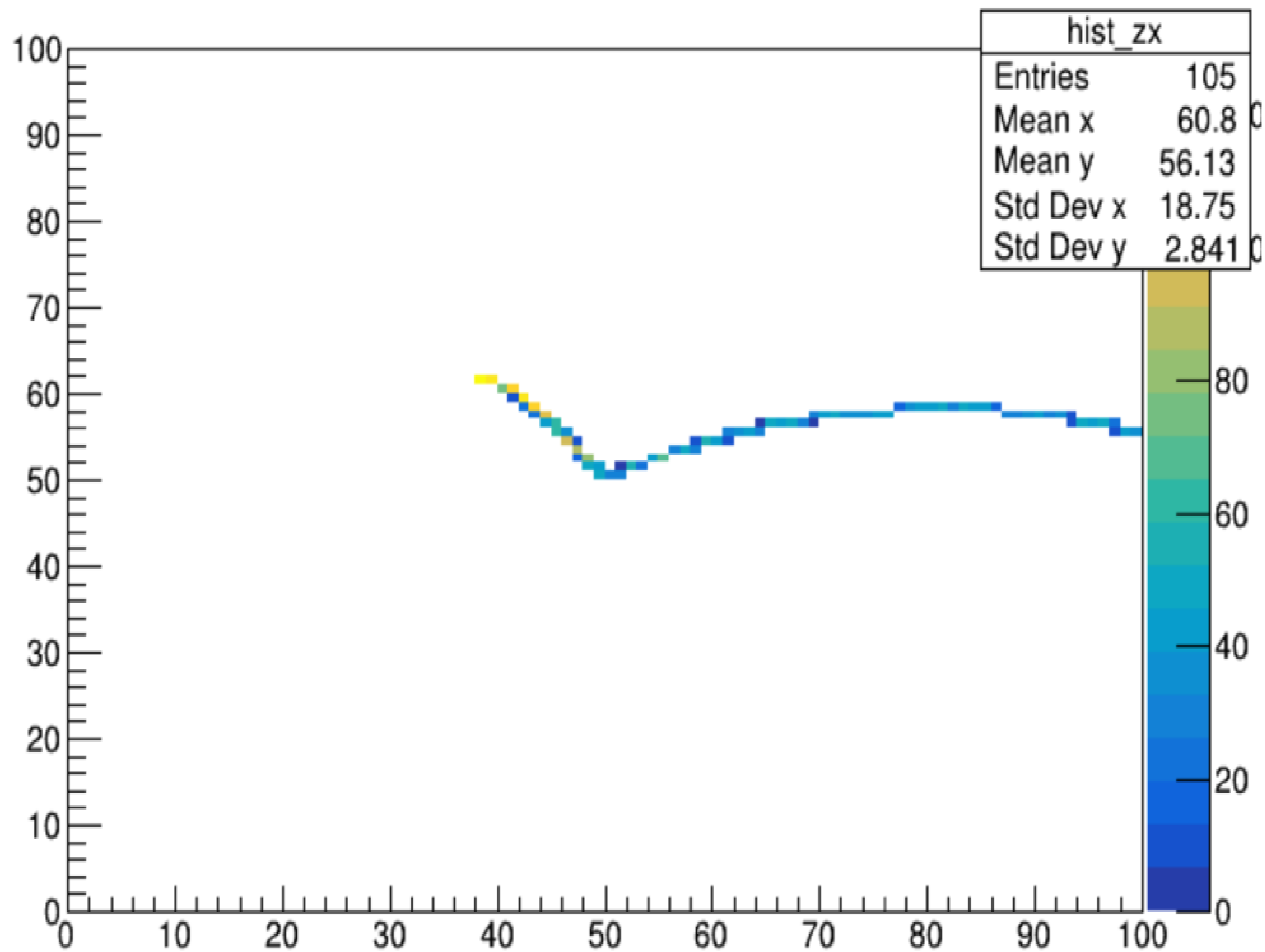
(from dE/dx to photoelectrons)

For every cube is performed following:

- Produced light yield via Birks' law.
- Conversion from photons to photoelectrons (from experimental data).
- Light attenuation in fibers.
- MPPC efficiency (from experimental data).

For every axis (X, Y, Z) is performed photon summation.

Digitization



Reconstruction

Reconstruction consists (in our minds) from two major sub-tasks:

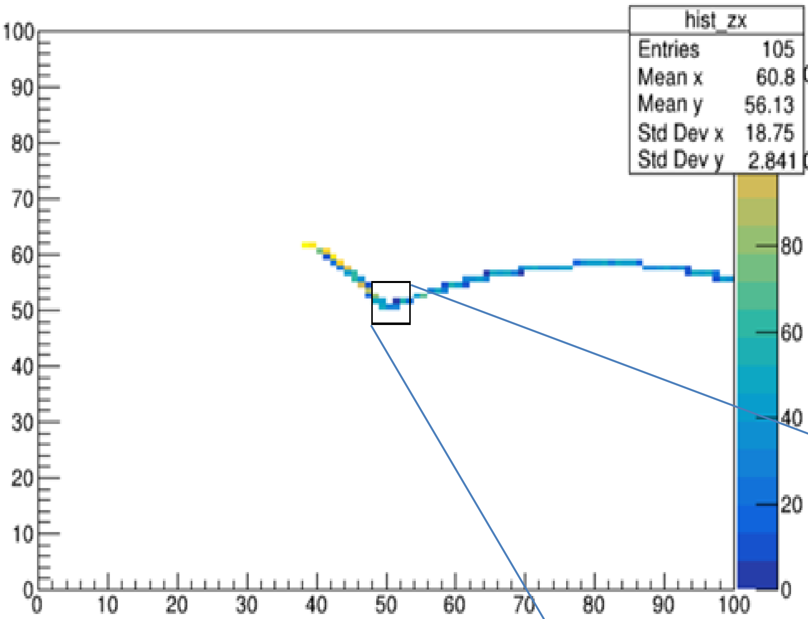
- pattern recognition (the most difficult one);
- fitting tracks

Initial investigations:

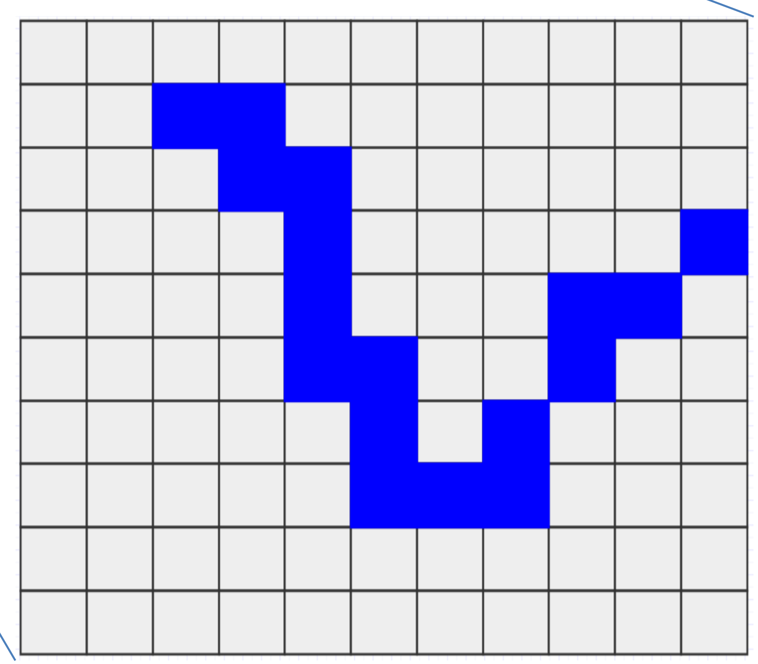
- Hough transform – integrated PATHFINDER (DESY framework)
- From FairSHiP – investigated Artificial Retina, Template matching
- Cellular Automata

Pattern recognition

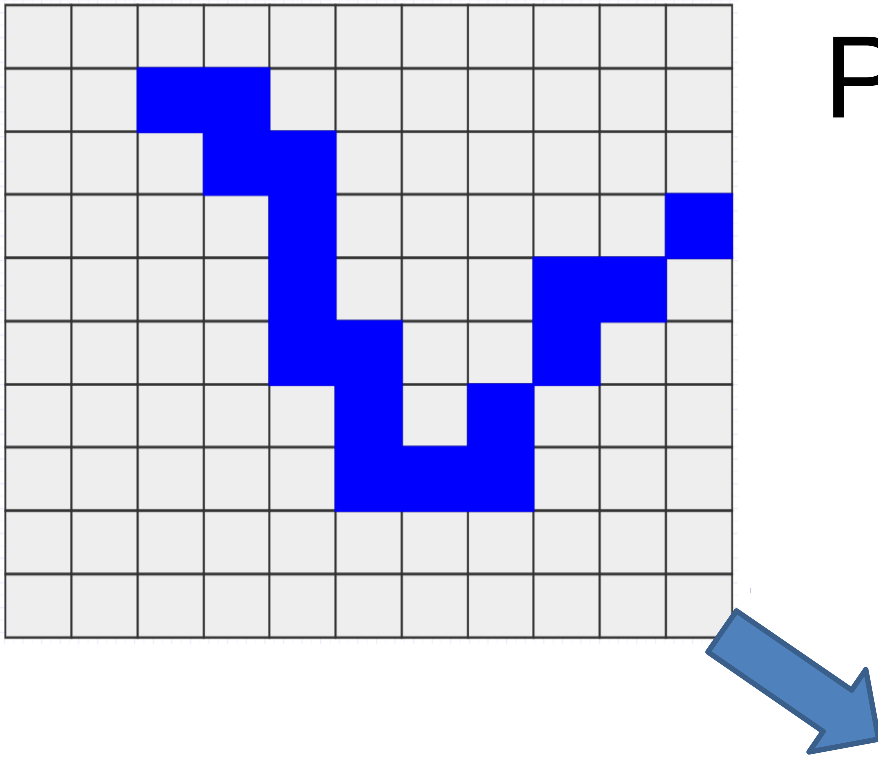
or track finding using graph traversal



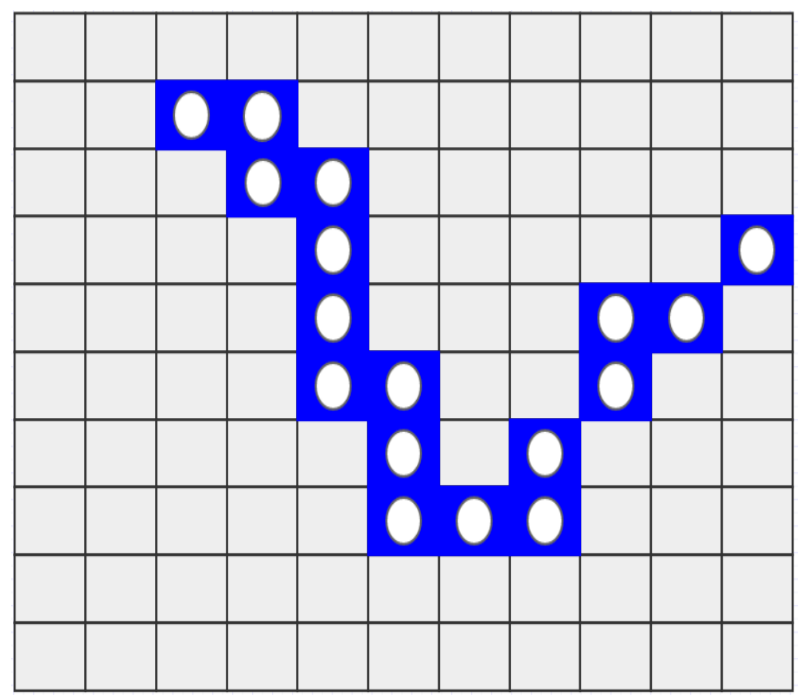
Initial Projection in two axis



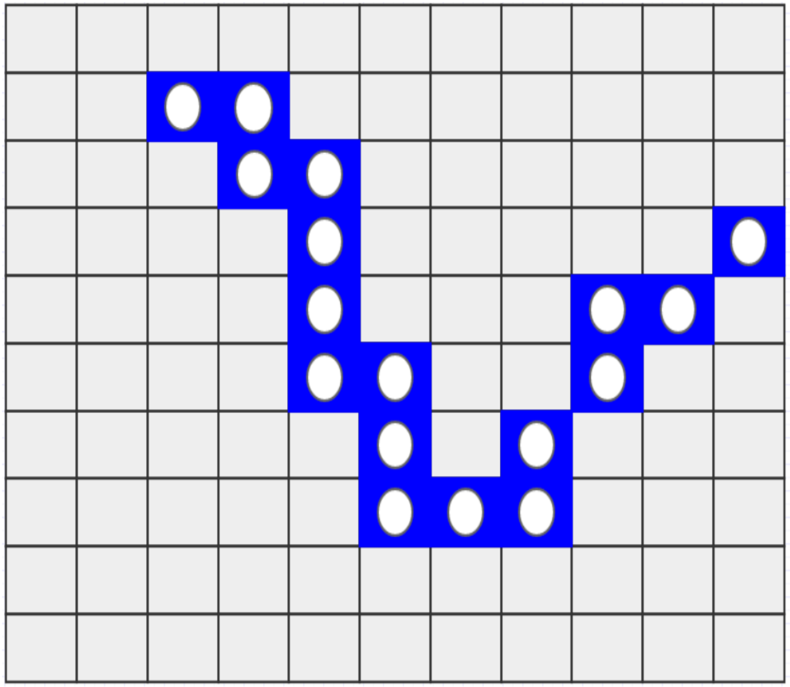
Pattern recognition



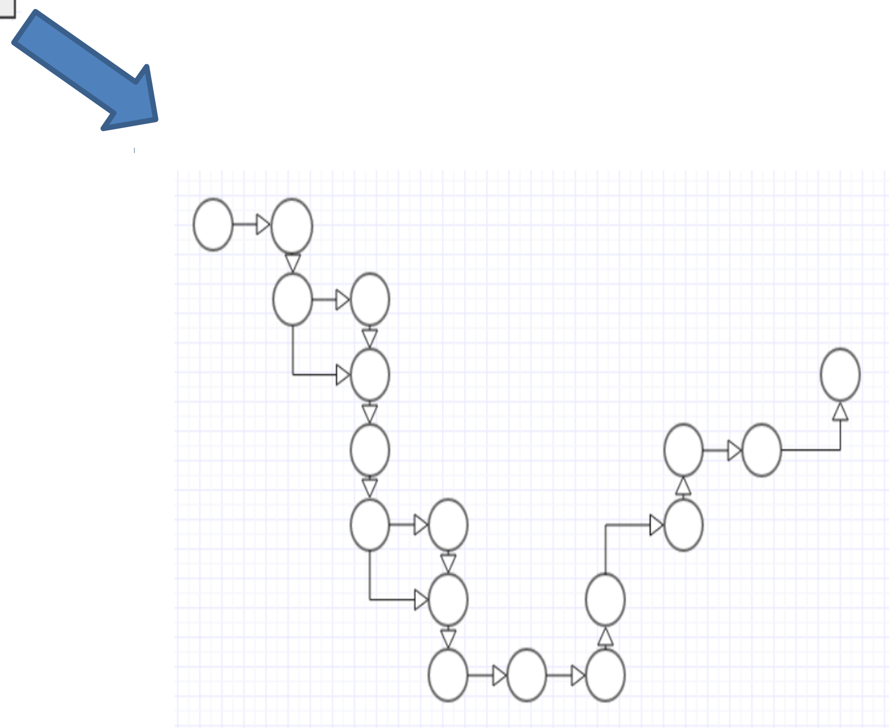
Convert to graph from local hits



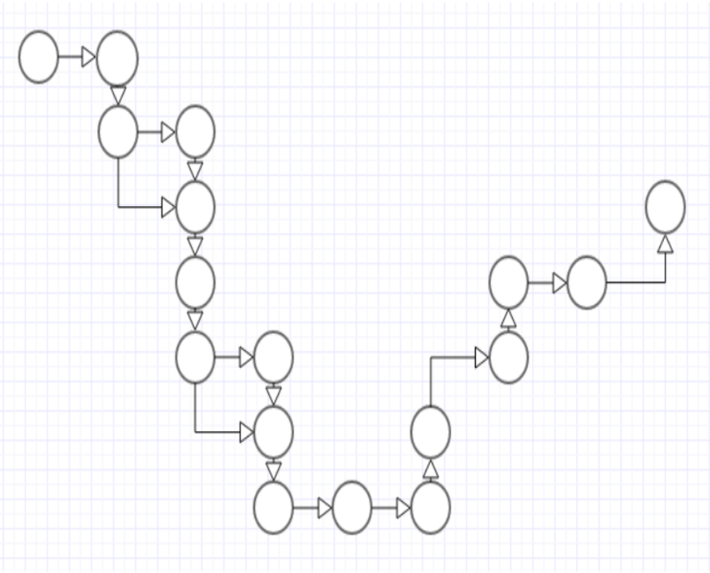
Pattern recognition



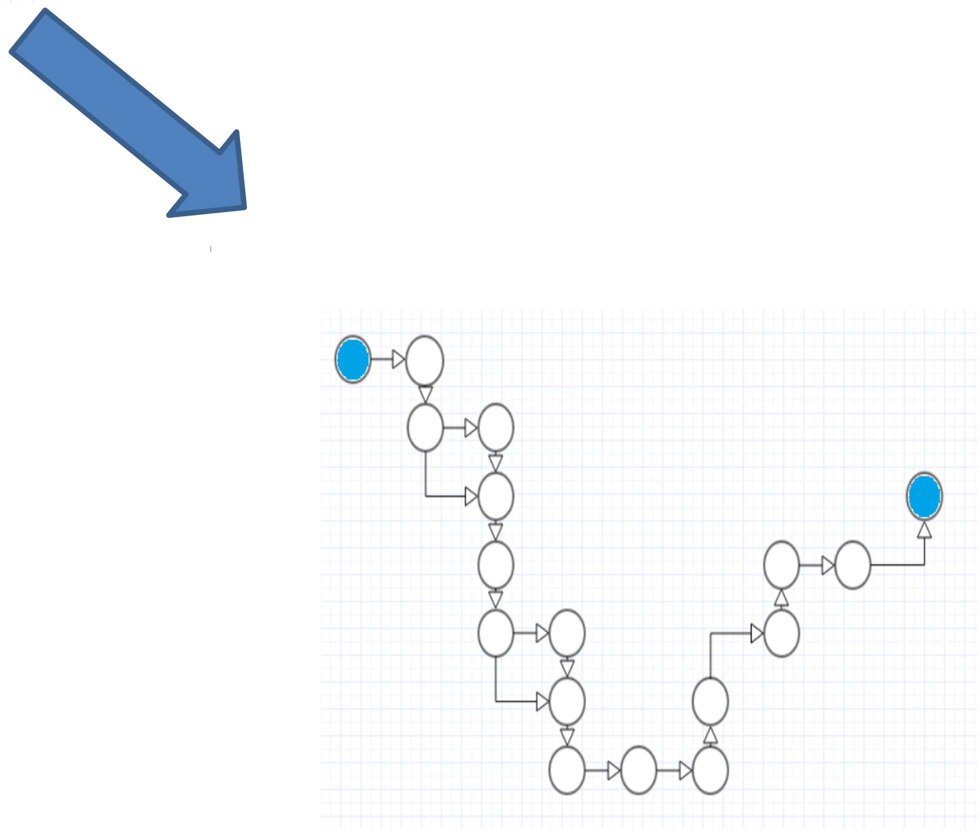
Connect graph to only local cubes
– those which have a common face, edge of corner



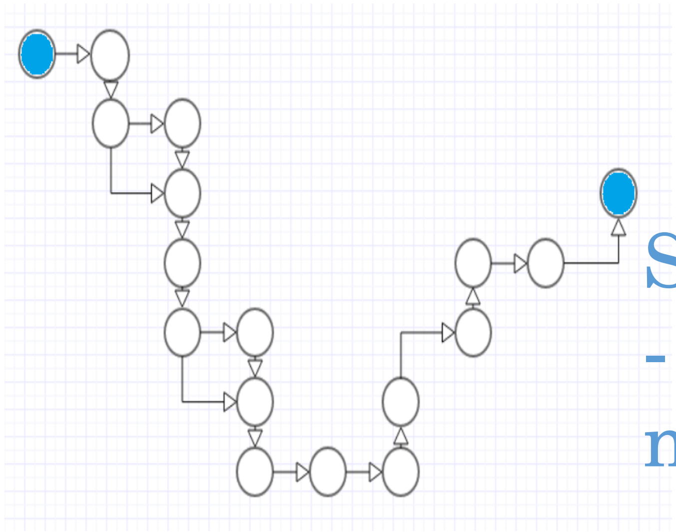
Pattern recognition



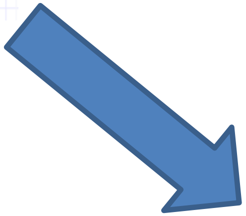
Identify leaf – those who have only one neighbor (also a few templates are defined for 2 and 3 neighbors)

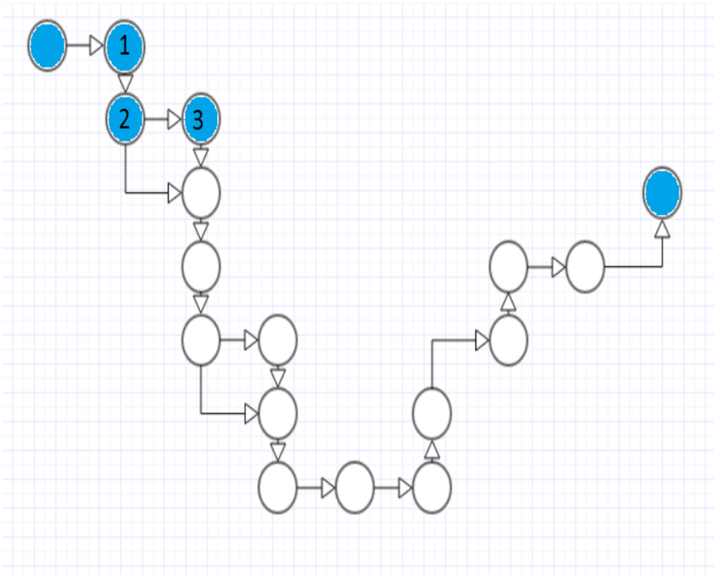


Pattern recognition

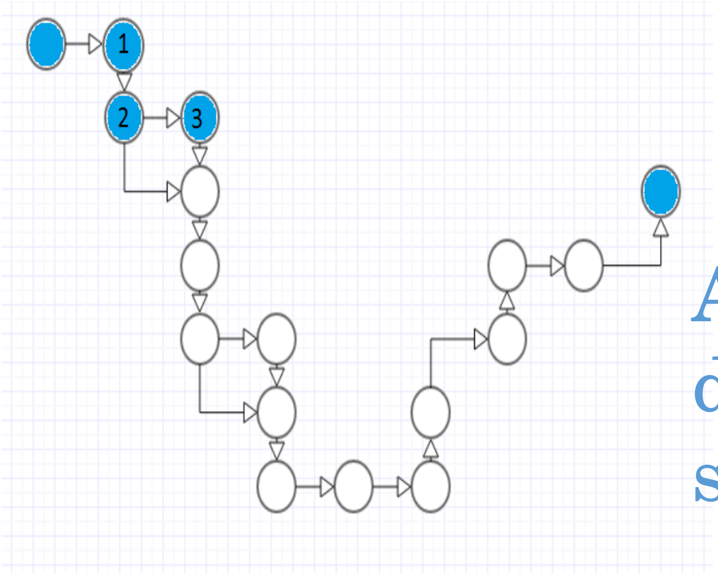


Start traversing graph from the leaves - Go to the next nearest neighbor, do not go to visited nodes

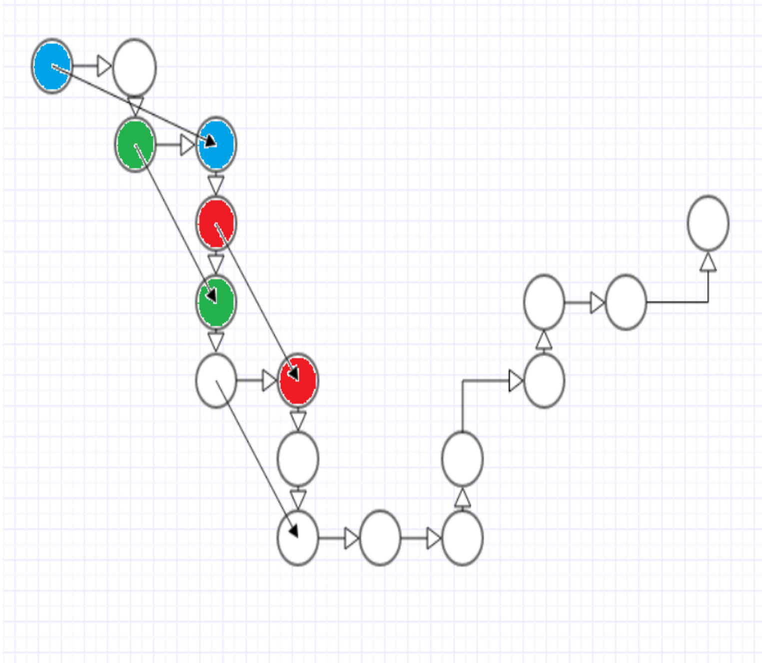




Pattern recognition

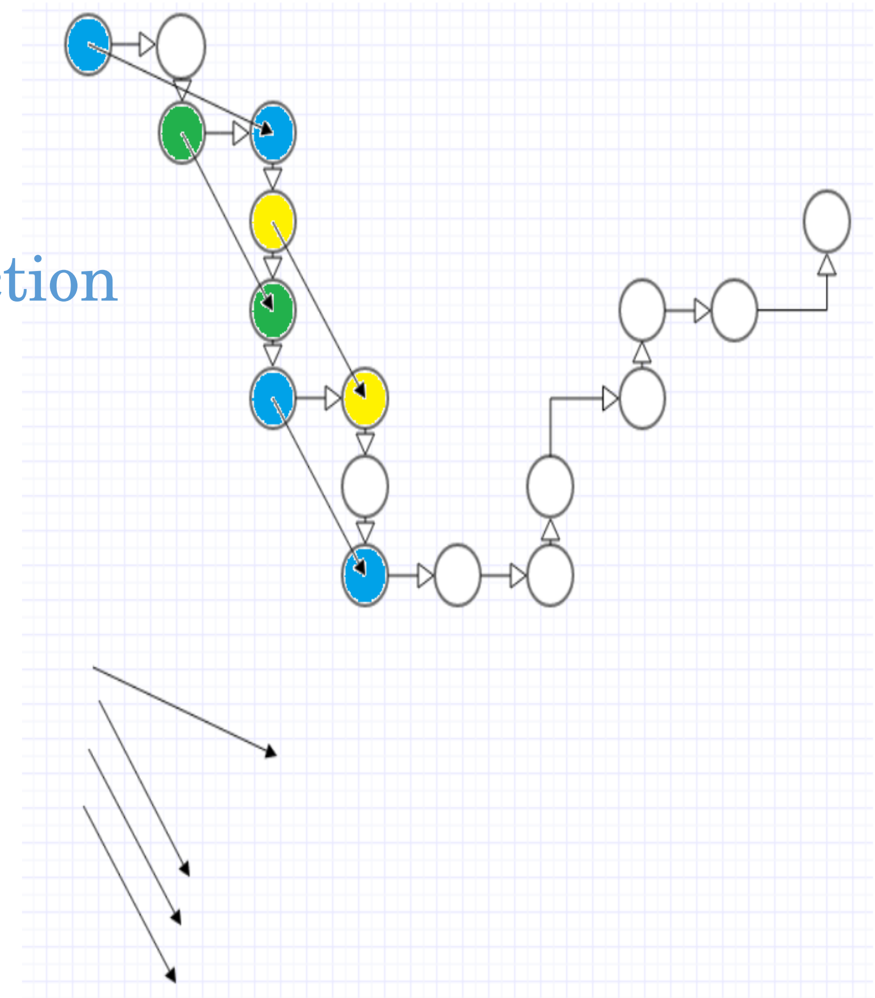


After traversal is done, calculate direction vectors between two cubes some distance apart



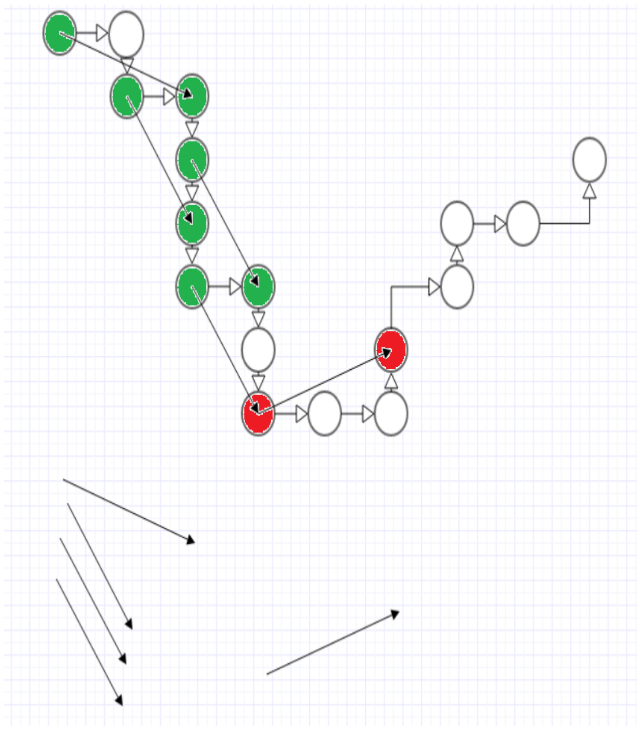
Pattern recognition

If it is a one track, then the direction vectors will points more or less in the same direction



Pattern recognition

However, if it is a different track, then there is an expectation for bigger change in the direction vector. This is then a different track.



List of tracks with corresponding digits is given as an input for track fitting algorithm GENFIT.

Track Fitting with GENFIT

GENFIT package:

- GENFIT is an experiment-independent framework for track reconstruction for particle and nuclear physics;
- GENFIT has been developed in the framework of the PANDA experiment at FAIR, Darmstadt, Germany;
- GENFIT is open source;

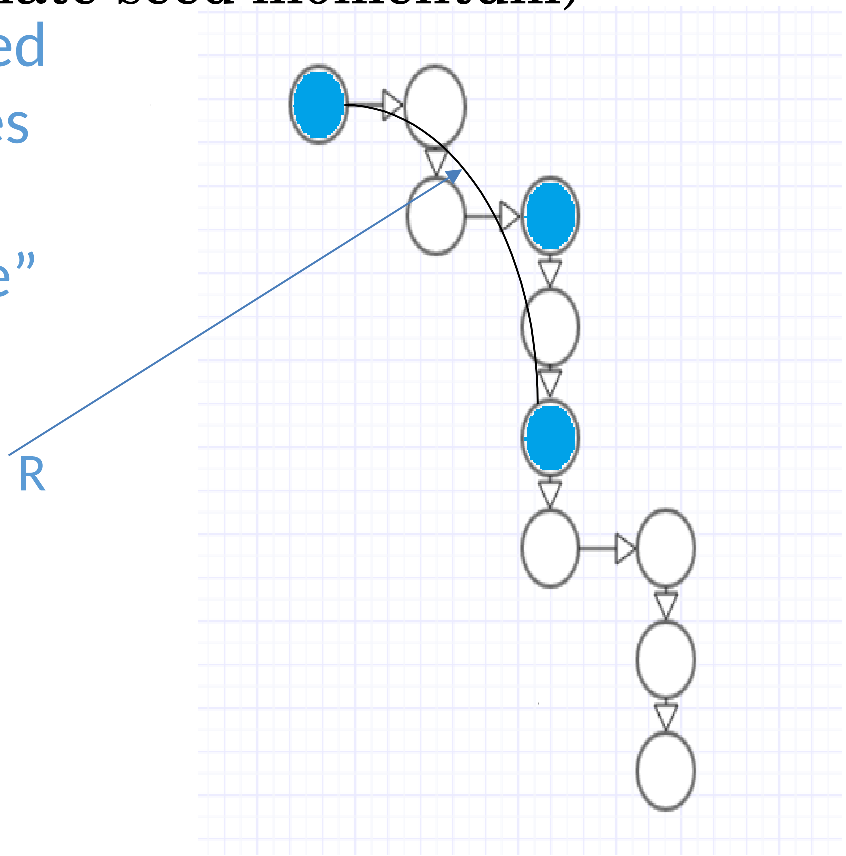
GENFIT package requires as seed:

- rough particle momentum (see next page)
- rough vertex position (under study, fixed now)
- particle type (under study; for time being set to muon)

Track Fitting

(estimate seed momentum)

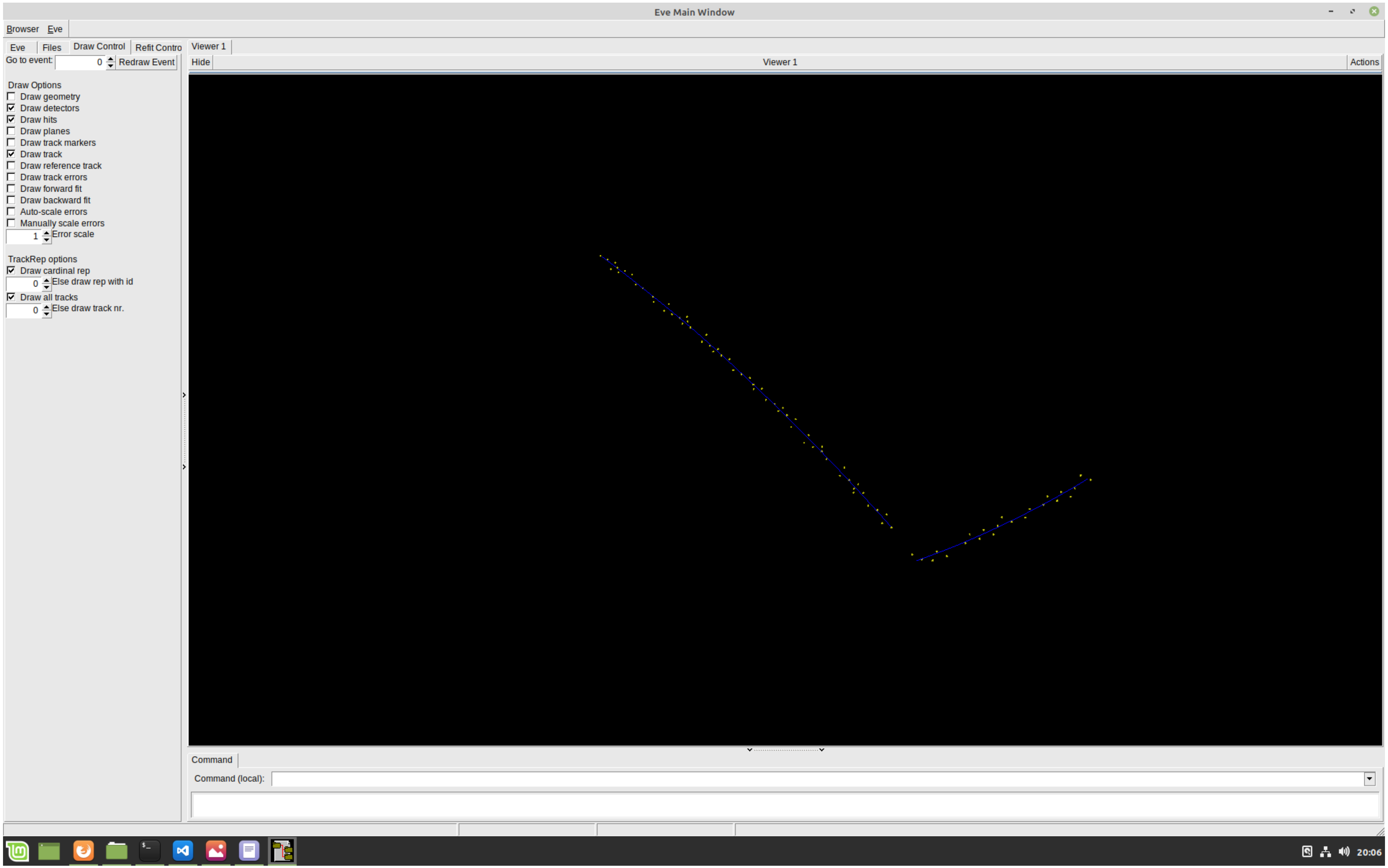
After track has been identified
extract a radius from 3 cubes
some distance apart
using the “Menger Curvature”
theorem



Then make an estimate
of the momentum
p = e[C] *R [m] * B [T]

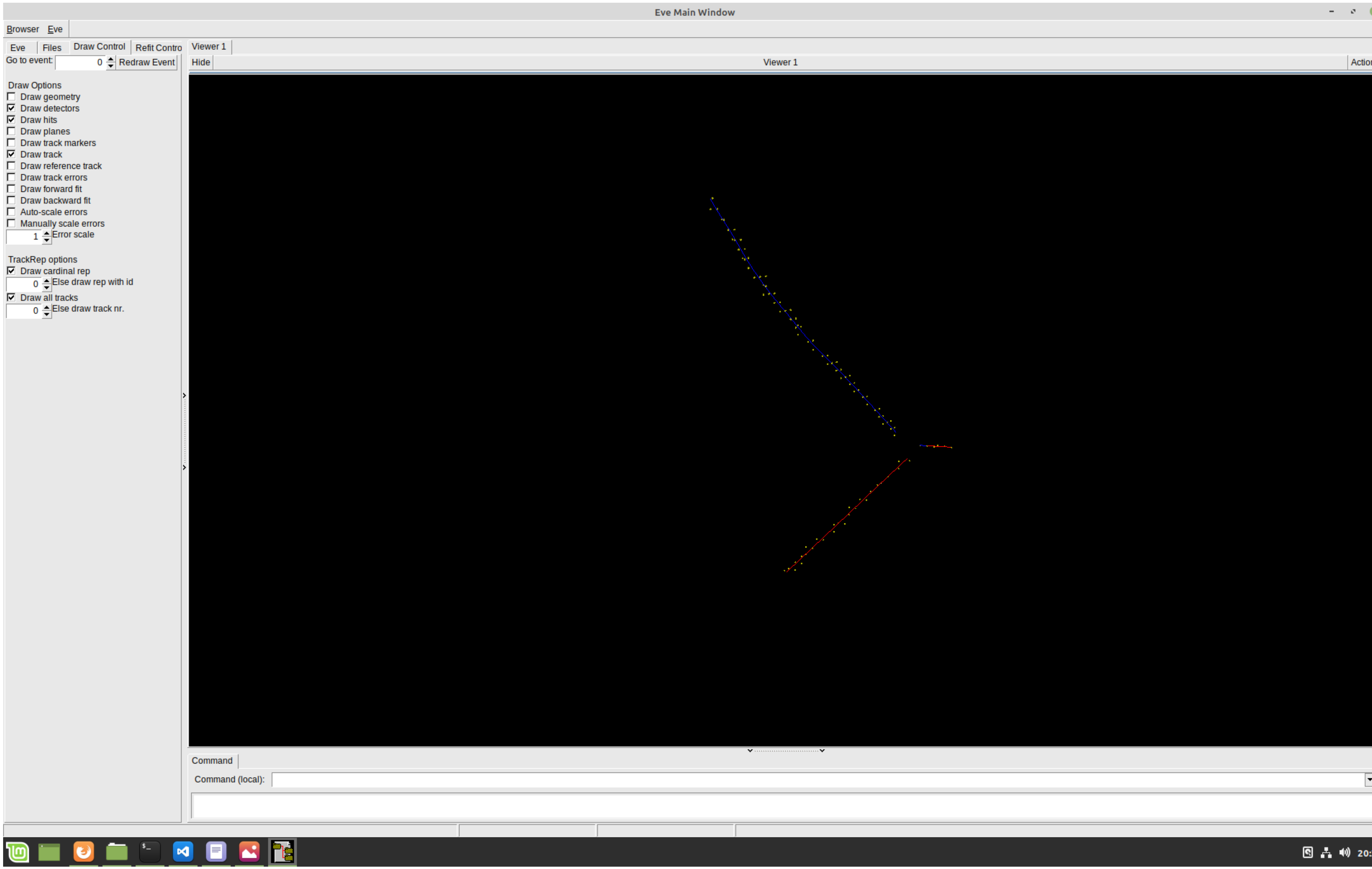
Make an average of the estimated
momenta for different points.

Example 1



Fitted muon and proton tracks at B=0.5T, B||Y, Enu=0.6GeV

Example 2



Fitted muon and 2 proton tracks at B=0.5T, B||Y, Enu=0.6GeV

Can we reconstruct neutrino energy?

(following results are very preliminary)

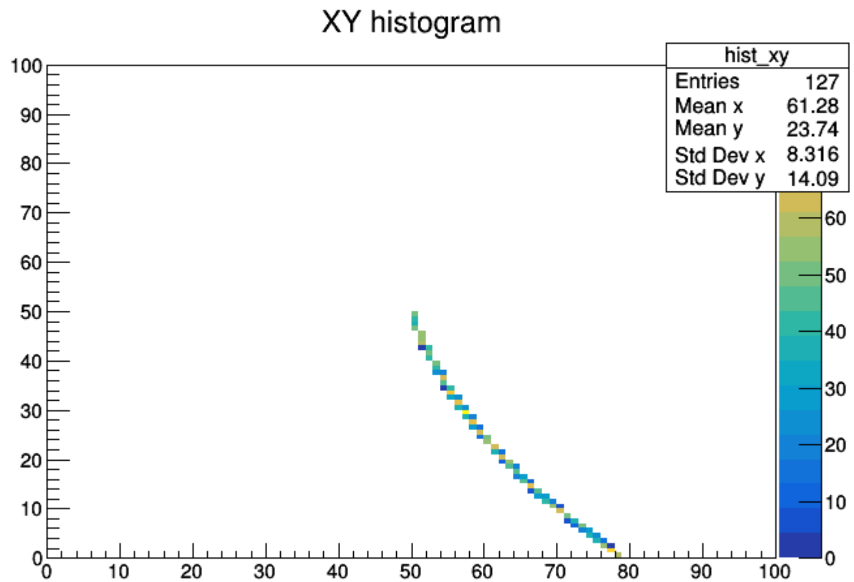
- Generated 1000 monoenergetic quasielastic muon neutrino interactions at SFGD center.
  - - Enu = {0.2, 0.3, 0.4, 0.5} GeV;
  - - B = {1, 2} T; B | | Z and B | | Y ;
  - νμ + n → μ- + p (+ hadrons)
- Take only digits belonging to muon track (no pattern recognition) and supply fitting alg.
- Calculate muon track momentum using GenFit package
- Reconstruct neutrino energy kinematically based only on muon momentum (and energy) and assuming proton (and other hadrons) energy is missing:

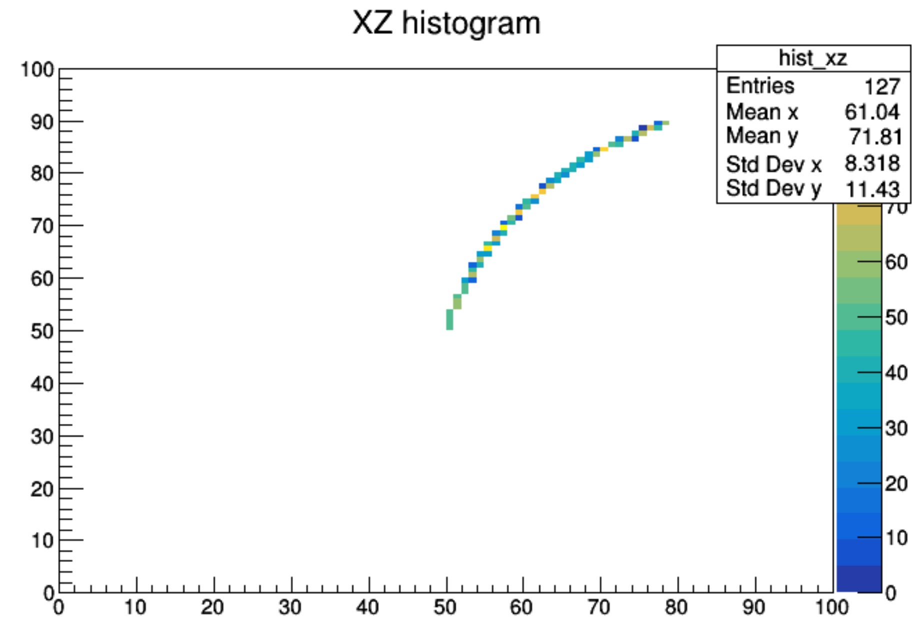
$$\overline{E_\nu} = \frac{E_\mu - m_\mu^2/(2M)}{1 - (E_\mu - P_\mu \cos\theta)/M}.$$

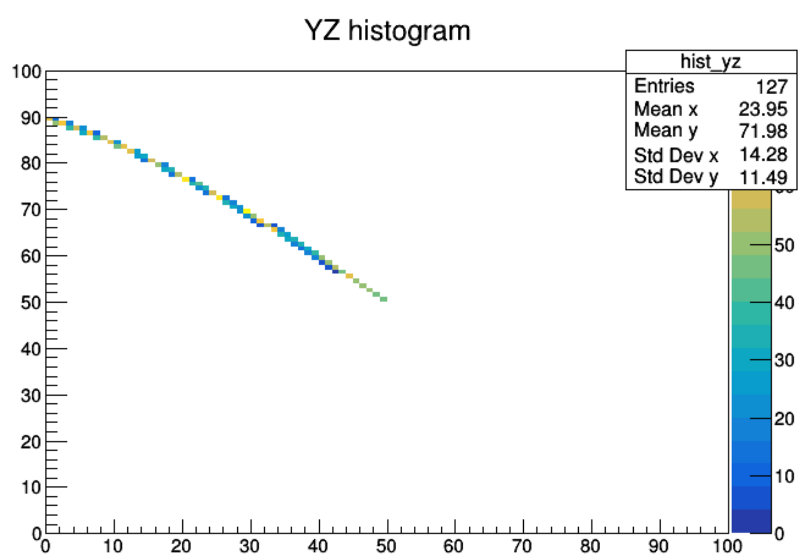
Θ – muon angle with respect to νμ

M – neutron mass

Muon track

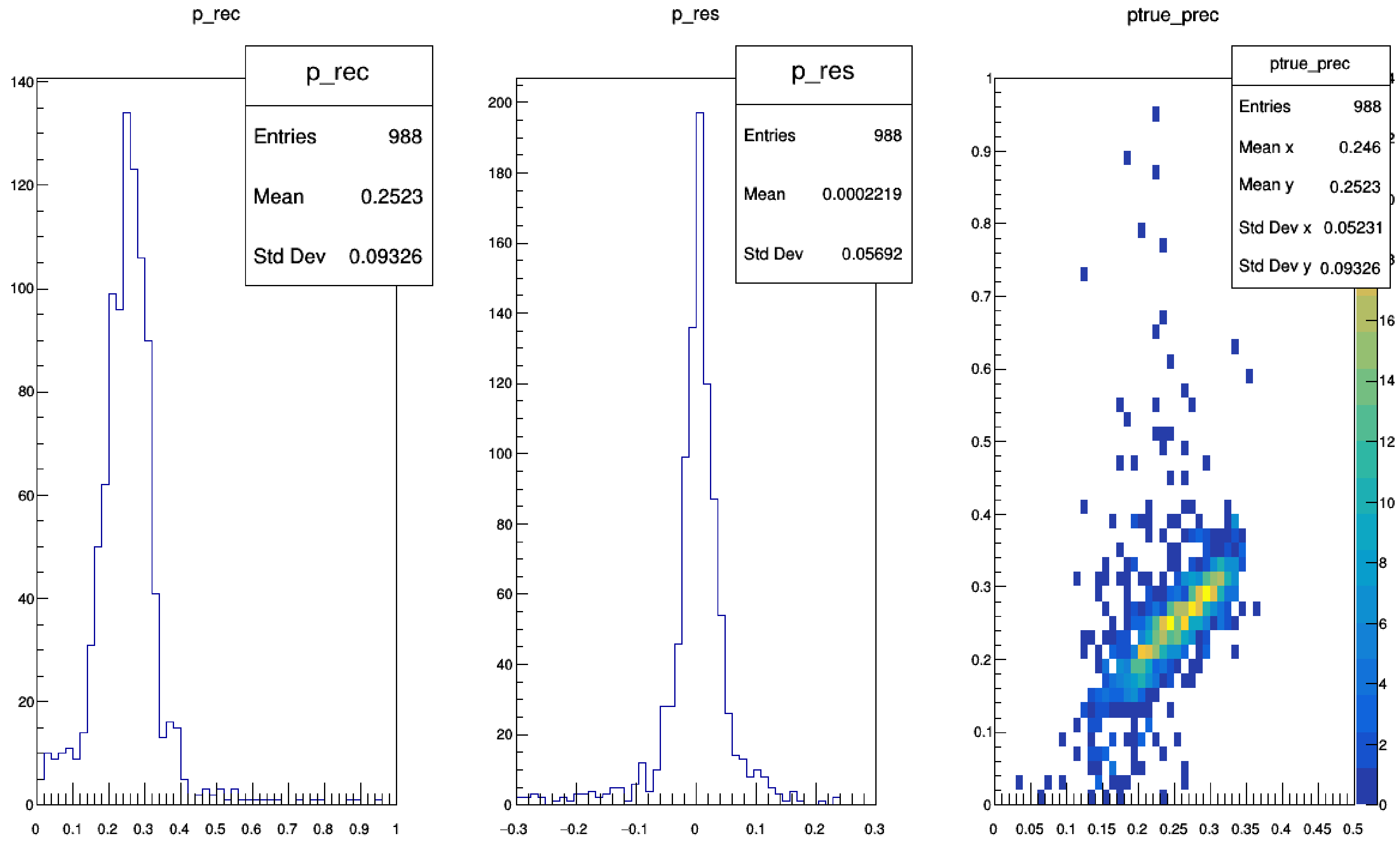

XY histogram
hist_xy
Entries 127
Mean x 61.28
Mean y 23.74
Std Dev x 8.316
Std Dev y 14.09


XZ histogram
hist_xz
Entries 127
Mean x 61.04
Mean y 71.81
Std Dev x 8.318
Std Dev y 11.43


YZ histogram
hist_yz
Entries 127
Mean x 23.95
Mean y 71.98
Std Dev x 14.28
Std Dev y 11.49

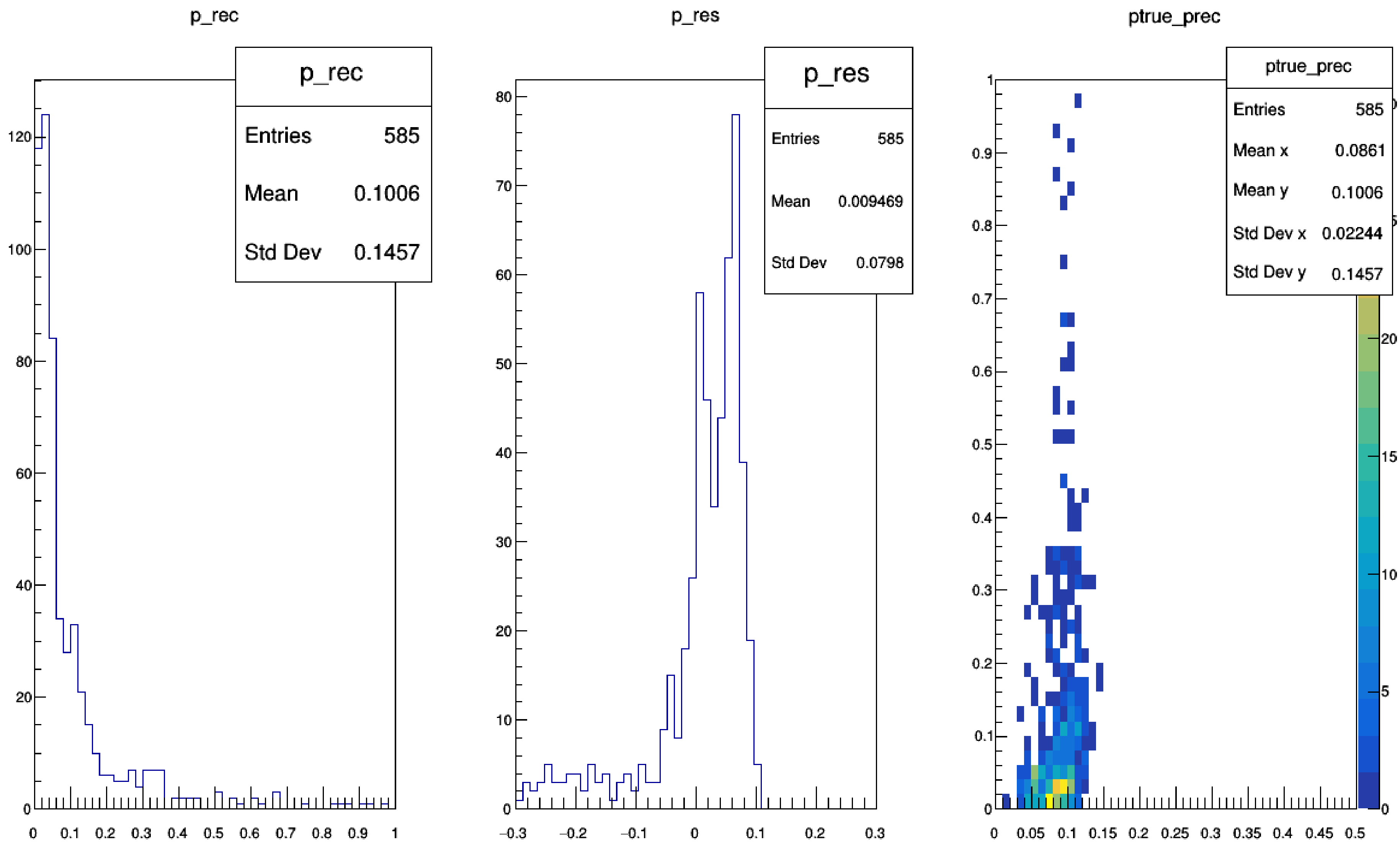
Rec.vs.True muon momentum

(ex. 400 MeV, 2T, B||Z)



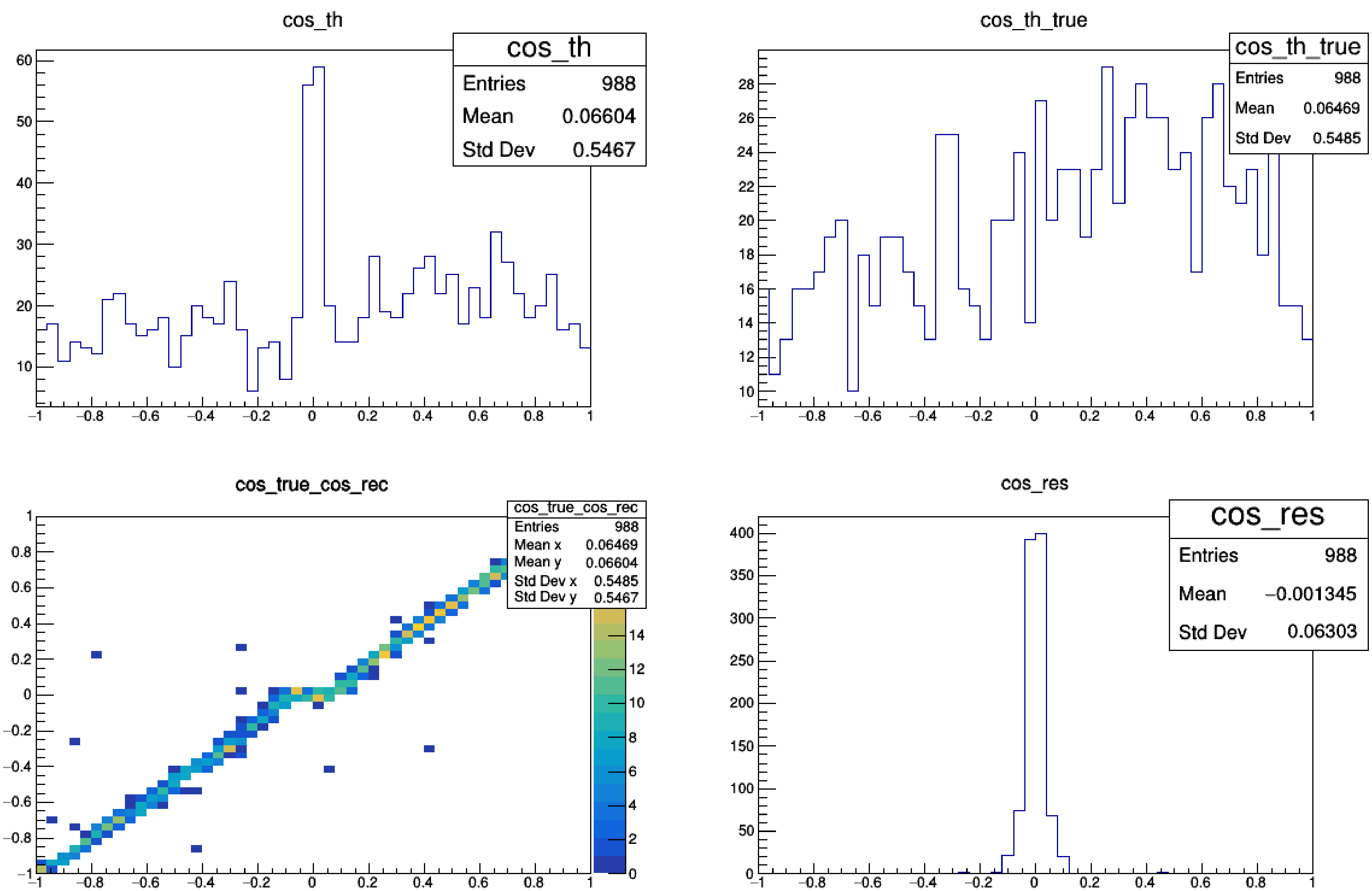
Rec.vs.True muon momentum

(ex. 200 MeV, 2T, B||Z)

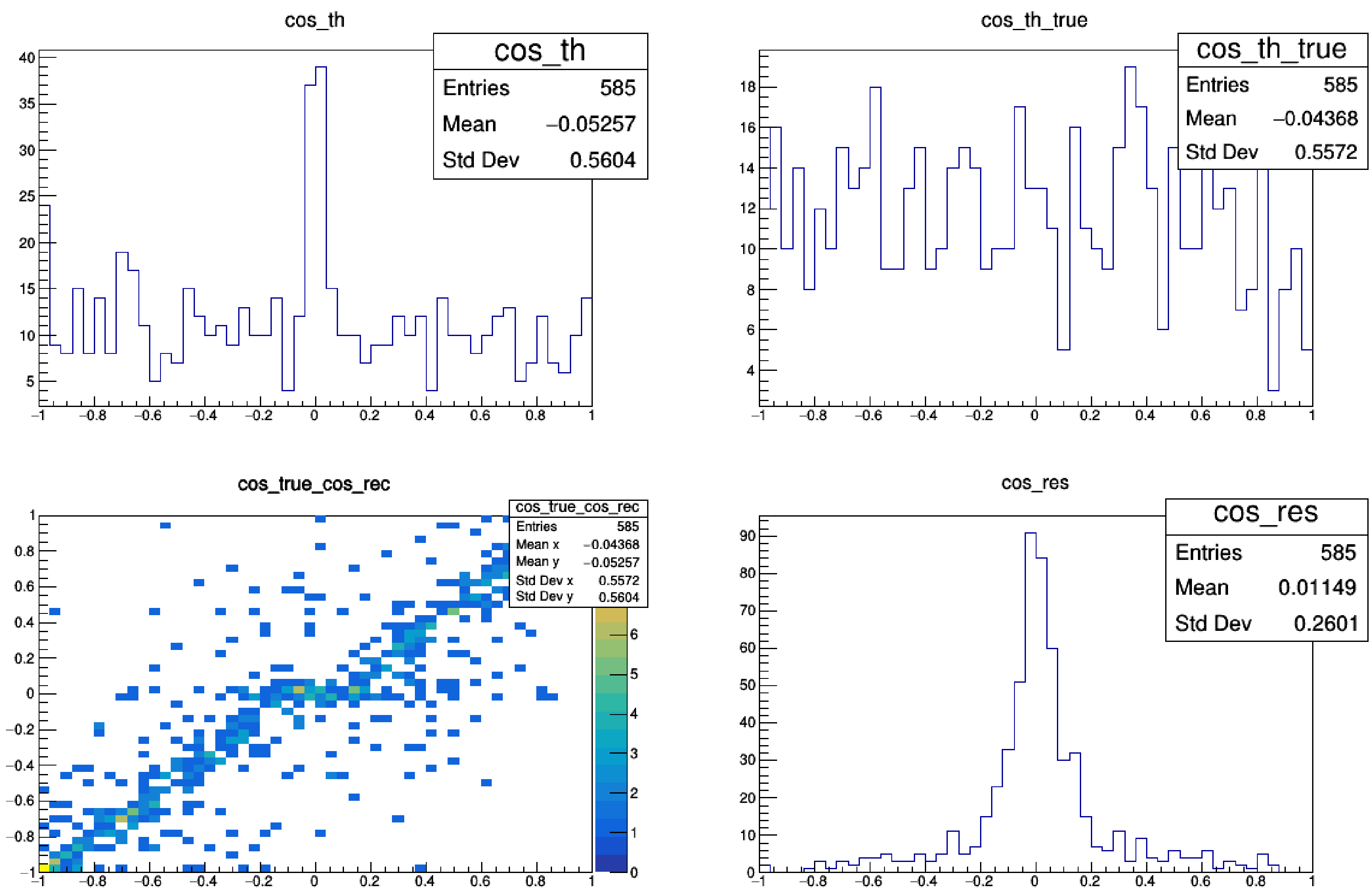


Rec.vs.True muon angle

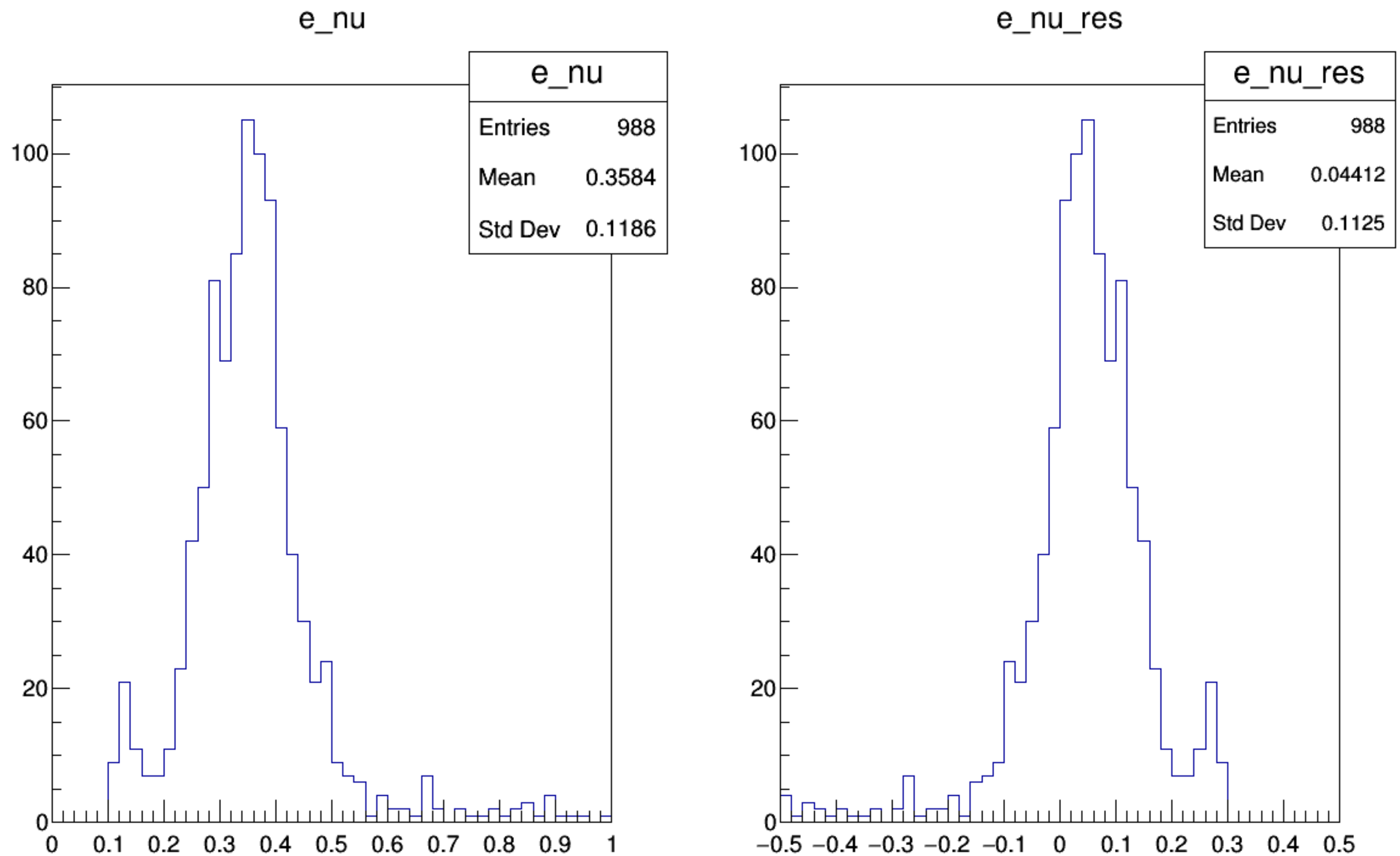
(ex. 400 MeV, 2T, B||Z)



Rec.vs.True muon angle
(ex. 200 MeV, 2T, B||Z)

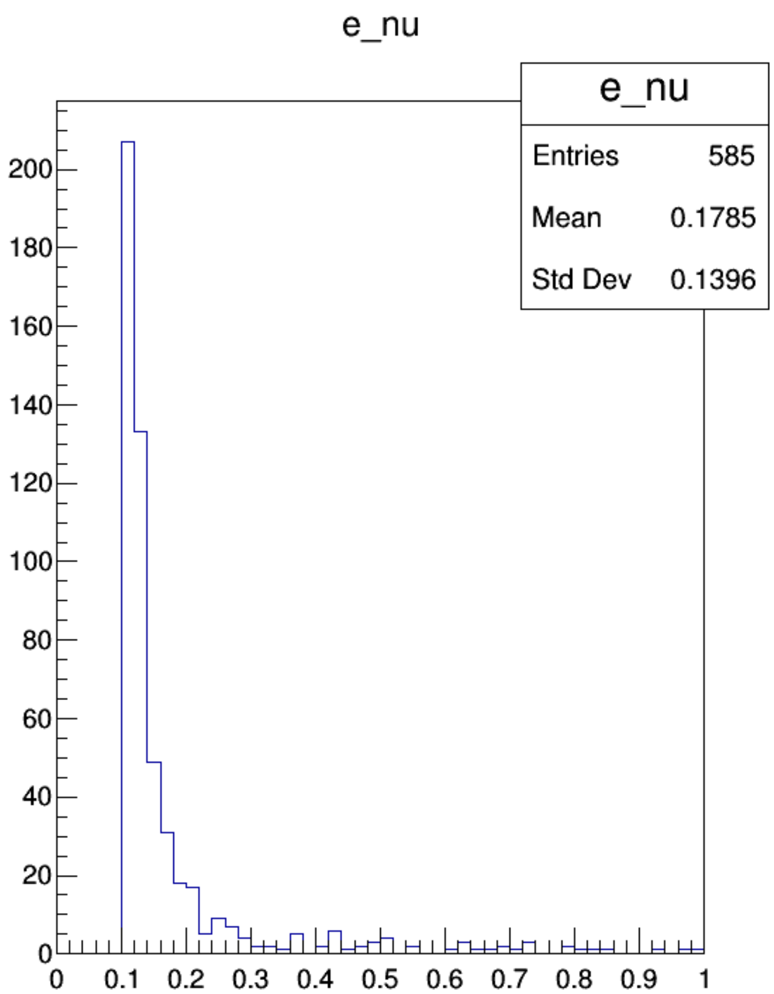


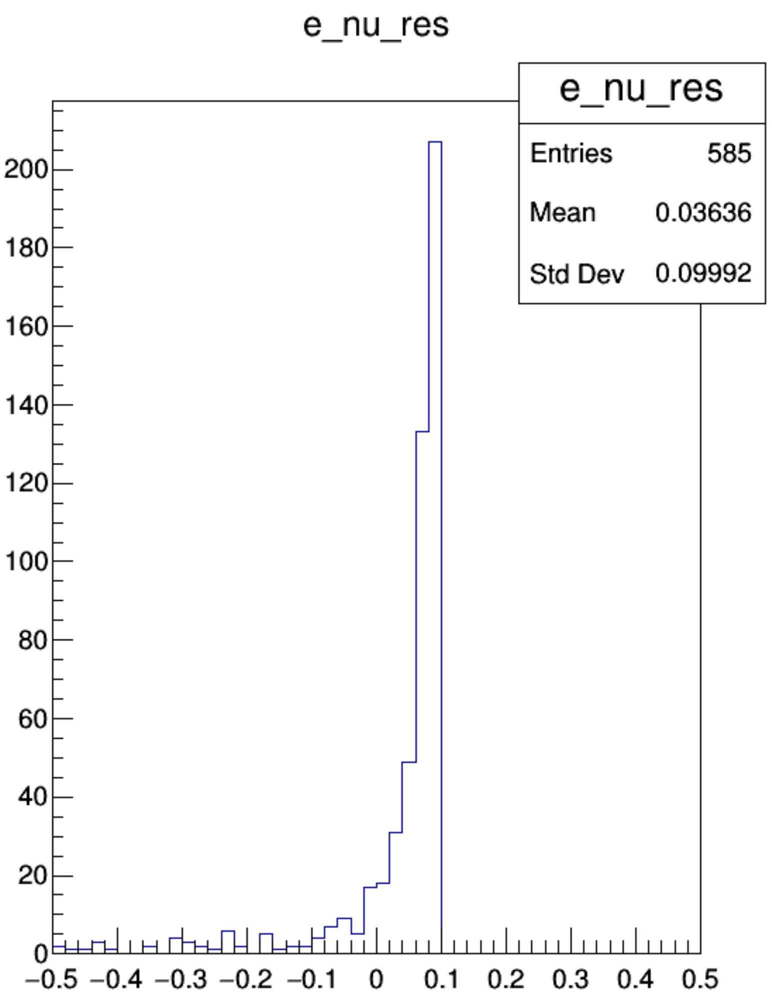
Reconstructed neutrino energy
(ex. 400 MeV, 2T, B||Z)



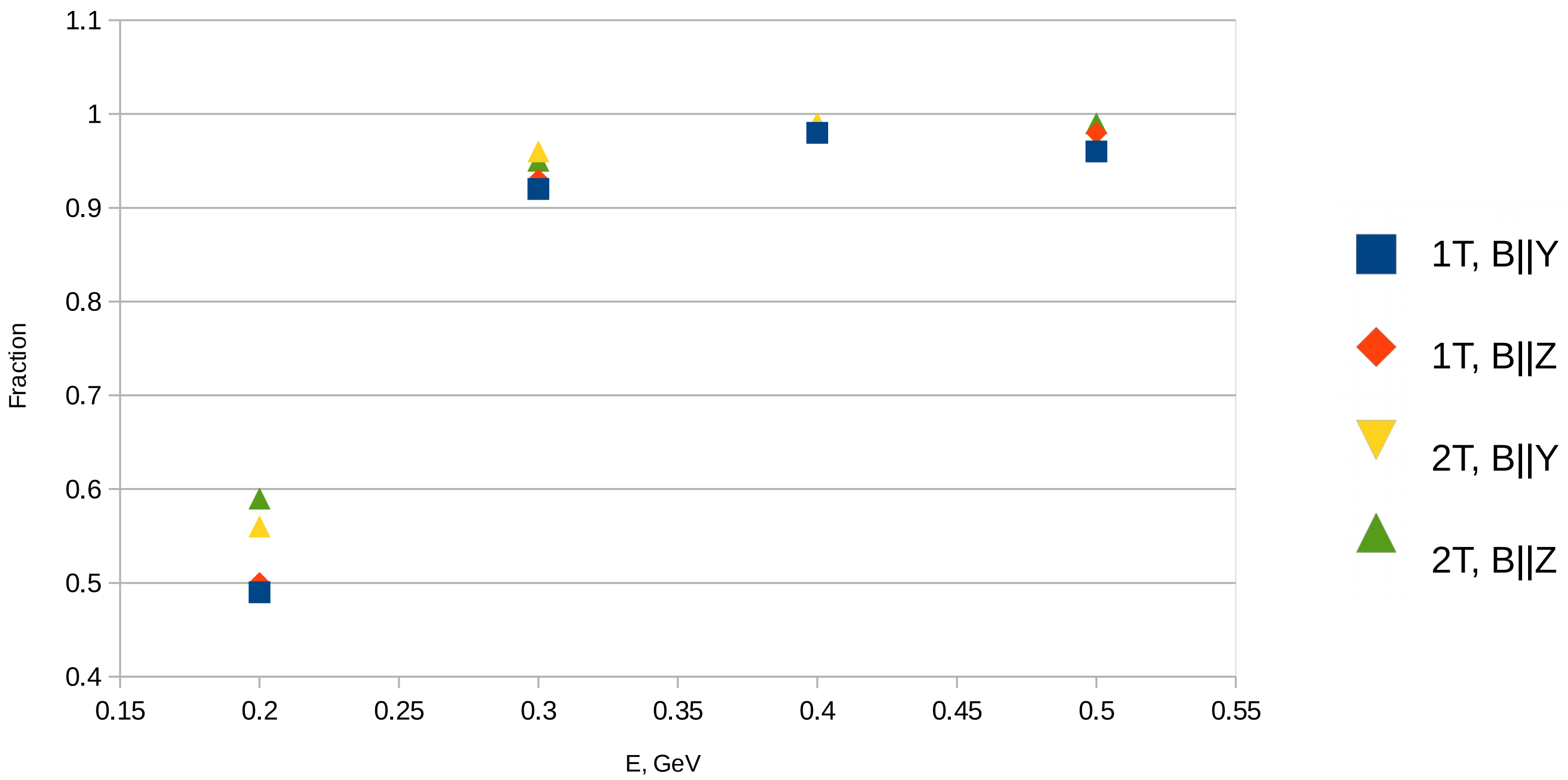
Reconstructed neutrino energy

(ex. 200 MeV, 2T, B||Z)





Track fitting efficiency



Not yet clear whether efficiency at low energy can be improved by tunning some parameters, cuts etc., or the algorithm is not capable to cope with.

To make the case more physical

- To implement the real neutrino spectrum
- To add missing energy:
  - by applying a fit on proton tracks if possible (long enough), or
  - to add deposited energy around the vertex to muon energy (therefore a trial for mixing kinematical and calorimetry energy reconstruction)
- To remove constrain of centered vertex
  - check what is going on around detector edges
  - find a way to supply rough vertex

ToDo List

- Finish the “muon” task
- Define optimal magnetic field
- Tune, optimize and qualify Graph algorithm for pattern recognition
- Optimize GenFit algorithm for track fitting
  - Need work on how to give initial seed to algorithm
  - Understand parameters, cuts,...
- Study detector response to electrons.

Conclusions

- SFGD integrated in EsbRoot framework.
- Geometry construction – done.
- Simulation in monoenergetic and flux modes – done.
- Digitization – done.
- Pattern recognition using graphs – promising, need a lot more digging.
- Fitting – done, but not fully understood.

- First attempt to characterize detector capabilities to reconstruct muon neutrino energy in QE scattering.