

How Neutrino Event Generator Works ? Ex : GENIE

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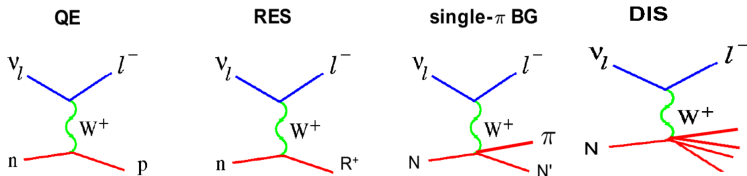
Understanding The Universe Through Neutrinos



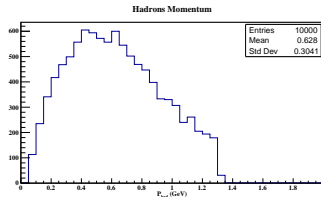
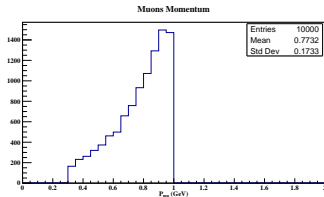
Plan for today's session :

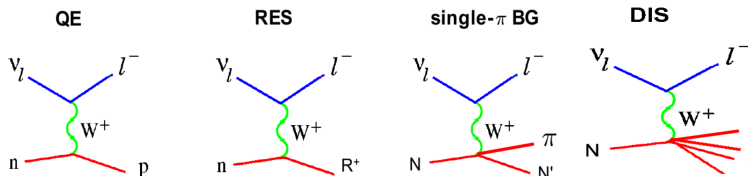
- Model tuning and detector effects simulation.
- See the parameters in the file "/opt/Gene.....config/CommonParam.xml" , discussed in the morning lectures(Sajjad).
- Today, we will also perform more basics simulation and more realistic simulation.
- Define your own flux spectrum: Ex : Dark-matter flux, Supernova-flux, Solar-Neutrino flux and some new physics flux?

Pre-school example (Day-1):



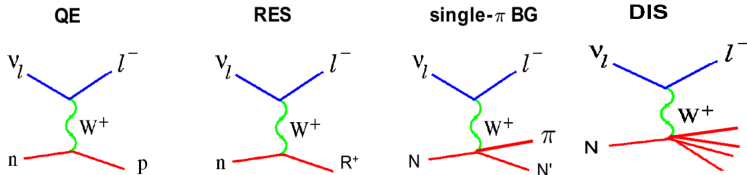
- What is the muon and hadrons momentum for 1 GeV neutrino beam for CCQE ?



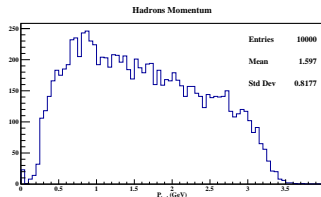
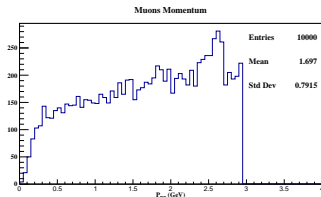


- Is that will be same for anti-neutrino; $\bar{\nu}_\mu$, 1 GeV neutrino beam for CCQE process ?
- Is there any other process at 1 GeV neutrino events, like : RES, MEC and DIS process ?
- Is it same for other nuclear target material Ar, Ca, C, Fe, H ?
- What are the list of parameters that can affect this final states particles kinematics ?

Day-2 Session



- What is the muon and hadrons momentum for 3 GeV neutrino beam for CC (QE, RES, DIS and MEC) ?
- Generate the 10000 event using argon target for 3 GeV neutrino energy and count the number of interaction process RES, QE and DIS.



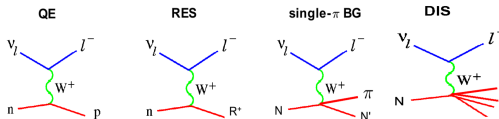
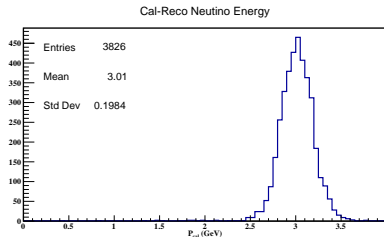
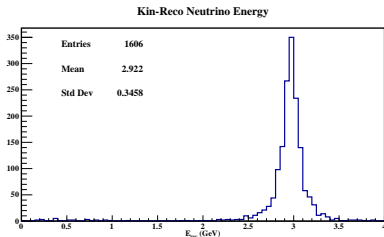
- Calorimetric approach : summing up all the outgoing particles

$$E_{\nu}^{Calor} = E_{lep} + \sum_i T_i^{nuc} + \epsilon_{nuc} + \sum_m E_m \quad (1)$$

- Kinematics approach : neutrino with an energy < 1 GeV, CCQE interaction is the dominant interaction mode, the angle and energy of the outgoing muon.

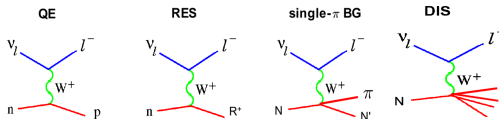
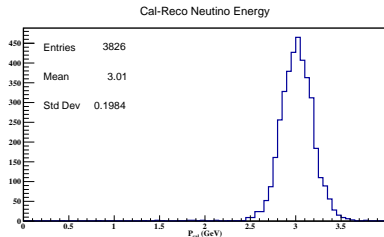
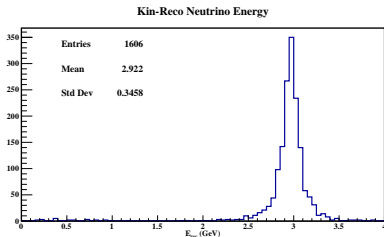
$$E_{rec}^{\nu} = \frac{2(M - E_b)E_{\mu} - (E_b^2 - 2ME_b + m_{\mu}^2 + \Delta M^2)}{2(M - E_b - E_{\mu} + |\vec{p}_{\mu}| \cos \theta_{\mu})} \quad (2)$$

Day-2 Session : Event Selection CCQE and CCRES



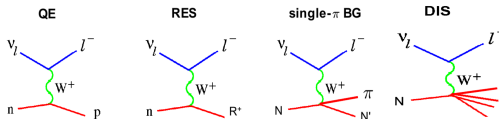
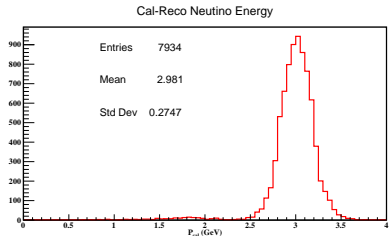
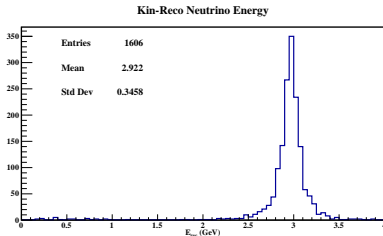
- What is the muon and hadrons momentum for 3 GeV neutrino beam for CC (QE, RES, DIS and MEC) ?

Day-2 Session : Event Selection CCQE and CCRES



- What is the muon and hadrons momentum for 3 GeV neutrino beam for CC (QE, RES, DIS and MEC) ?

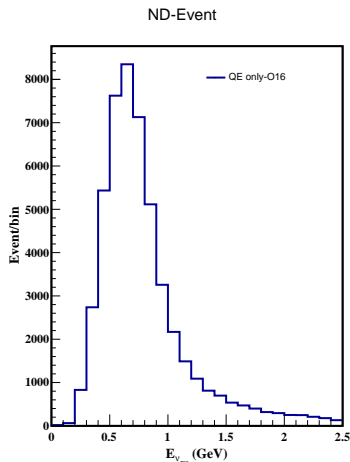
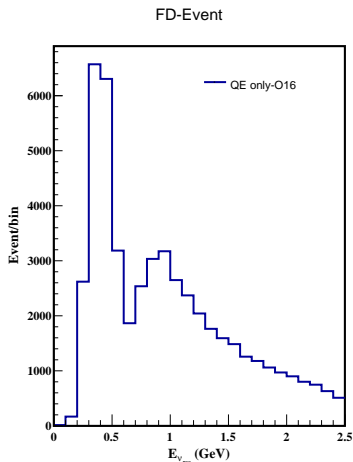
Day-2 Session : Event Selection CCQE and RES + DIS



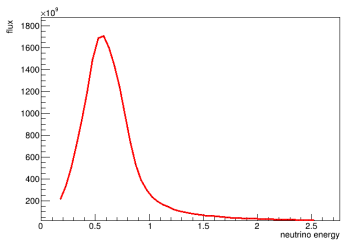
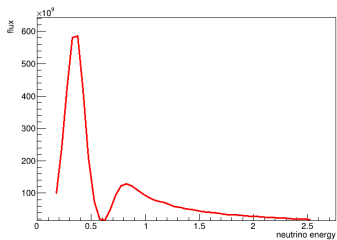
- What is the muon and hadrons momentum for 3 GeV neutrino beam for CC (QE, RES, DIS and MEC) ?

Event distribution for CC : Assignment-3

- Repeat the simulation for liquid argon target (1000180400) and includes all the CC process (QE, RES, DIS, COH, MEC...).
- See the list of process defined for your simulation in the file
"/opt/Gene...../config/EventGeneratorListAssembler.xml".

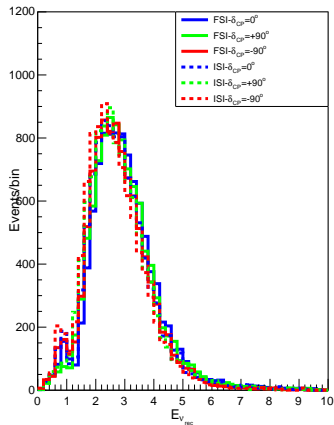


T2K Flux used : Assignment-1

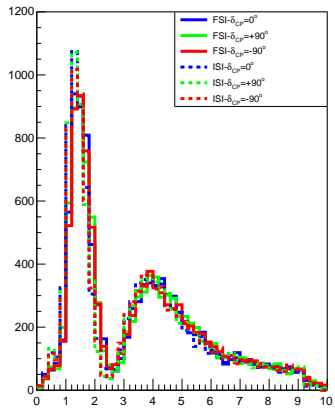


DUNE flux used : Assignment-1

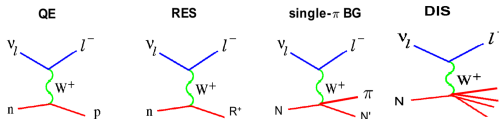
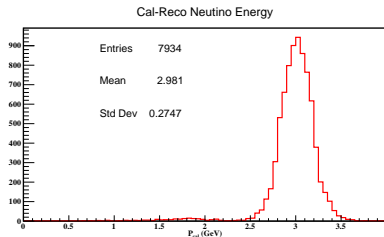
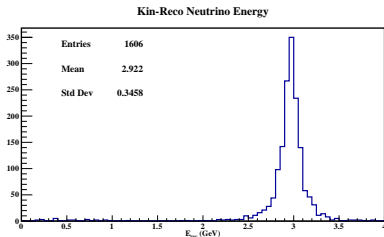
FD-Event for ν_e appearance



FD-Event for ν_μ disappearance



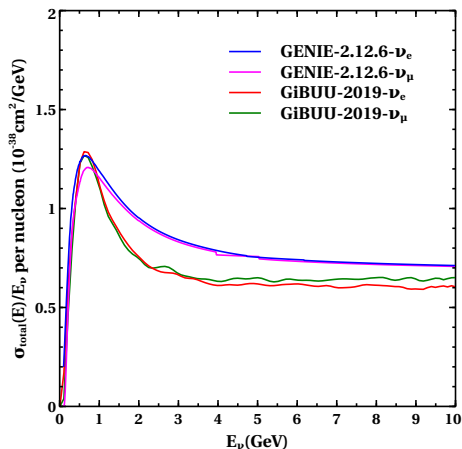
Day-3 : Detectors Effects + event selection ($\mu + \pi$) events selection)



- What is the muon and hadrons momentum for 3 GeV neutrino beam for CC (QE, RES, DIS and MEC) ?

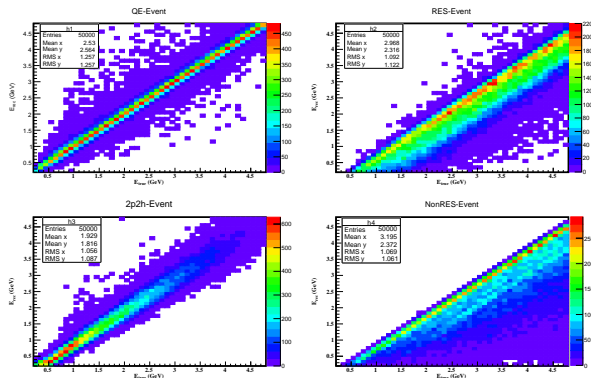
- Model tuning , parameters setting and the detector effect will be discuss tomorrow.
- Use the real detector geometry for realistic simulation, also neede for your Geant4 simulation.
- Define your own flux spectrum: Ex : Dark-matter flux, Supernova-flux, Solar-Neutrino flux and some new physics flux?

Furure Studies : Cross-sections data generation



- We have considered the QE, RES from Δ resonant decay and contribution from higher resonances, 2p2h/MEC and DIS interaction processes.

Furure Studies : Migration Matrix data generation



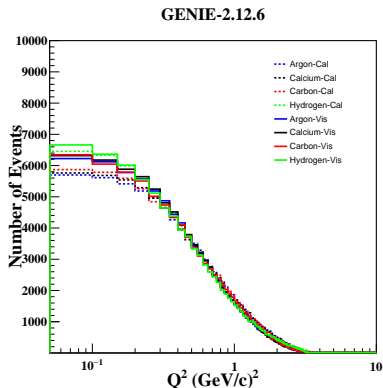
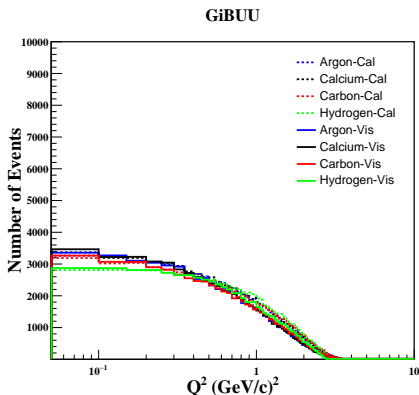
- Generate migration Matrix for performing analysis using globes package.

Future Studies : Q^2 Estimation

- Q^2 is calculated as-

$$Q^2 = 2E_{rec}^\nu(E_\mu - p_\mu \cos\theta_\mu) - M_\mu^2 \quad (3)$$

where M_μ , p_μ , E_μ and θ_μ are the mass, momentum, energy and angle of the outgoing muon.



Future Studies : Missing Hadrons Analysis

- **RNeutNu** = KE-Neutron/EnuTrue

This ratio defines the fraction of kinetic energy of neutrons with respect to the true neutrino energy.

- **RNHadNu** = KE-NeutralHadrons/EnuTrue

This ratio defines kinetic energy of neutral hadrons with respect to the true neutrino energy.

