Making a Neutrino Beam

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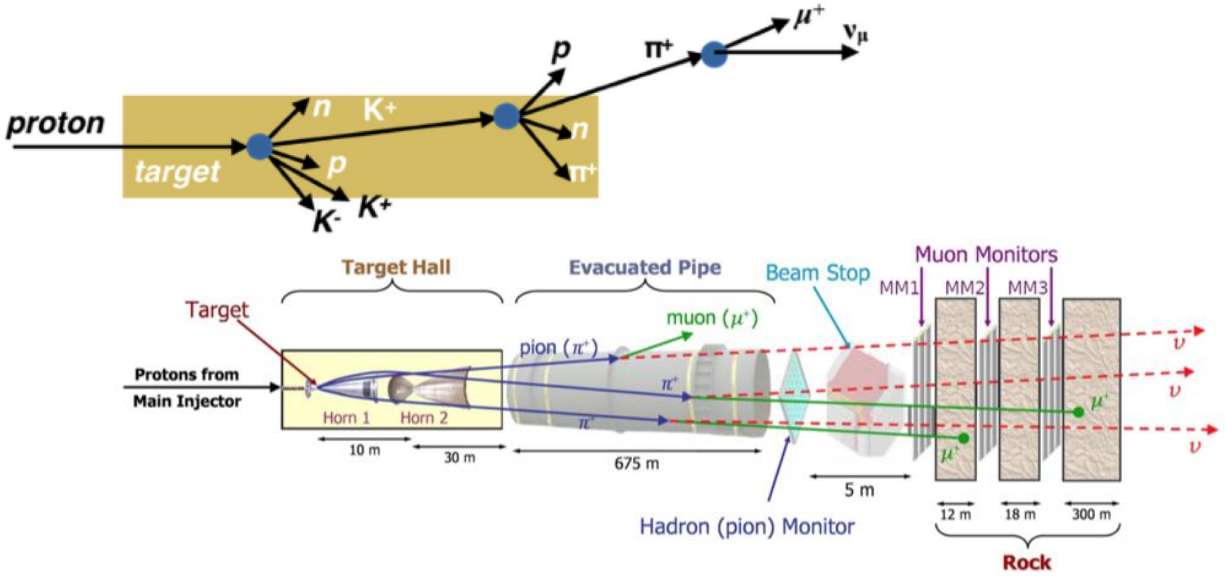
Simulations: NuMI target, FLUKA, Flair, GEANT4



Target features:
(Graphite 1.78 g/cm^3)

Fin dimension	Width (mm)	Height (mm)	Length (mm)	Beam power (kW)	RMS beam size (mm)
Present target (MET-05)	9.0	155.3	24.0	900	1.5
Previous target (MET-03)	7.4	143.0	24.0	700	1.3

Title of the project is “making a neutrino beam”. We have used following softwares/simulation packages to answer some questions like:
→ Composition of neutrino beam (by comparing pi+, pi-, K+, K-, K0 spectra)
→ Compare the hadron spectra in different angular bins etc.

A summary about the softwares used:

FLUKA (**FLU**ktuierende **KA**skade) is a fully integrated Monte Carlo simulation package for the interaction and transport of particles and nuclei in matter.

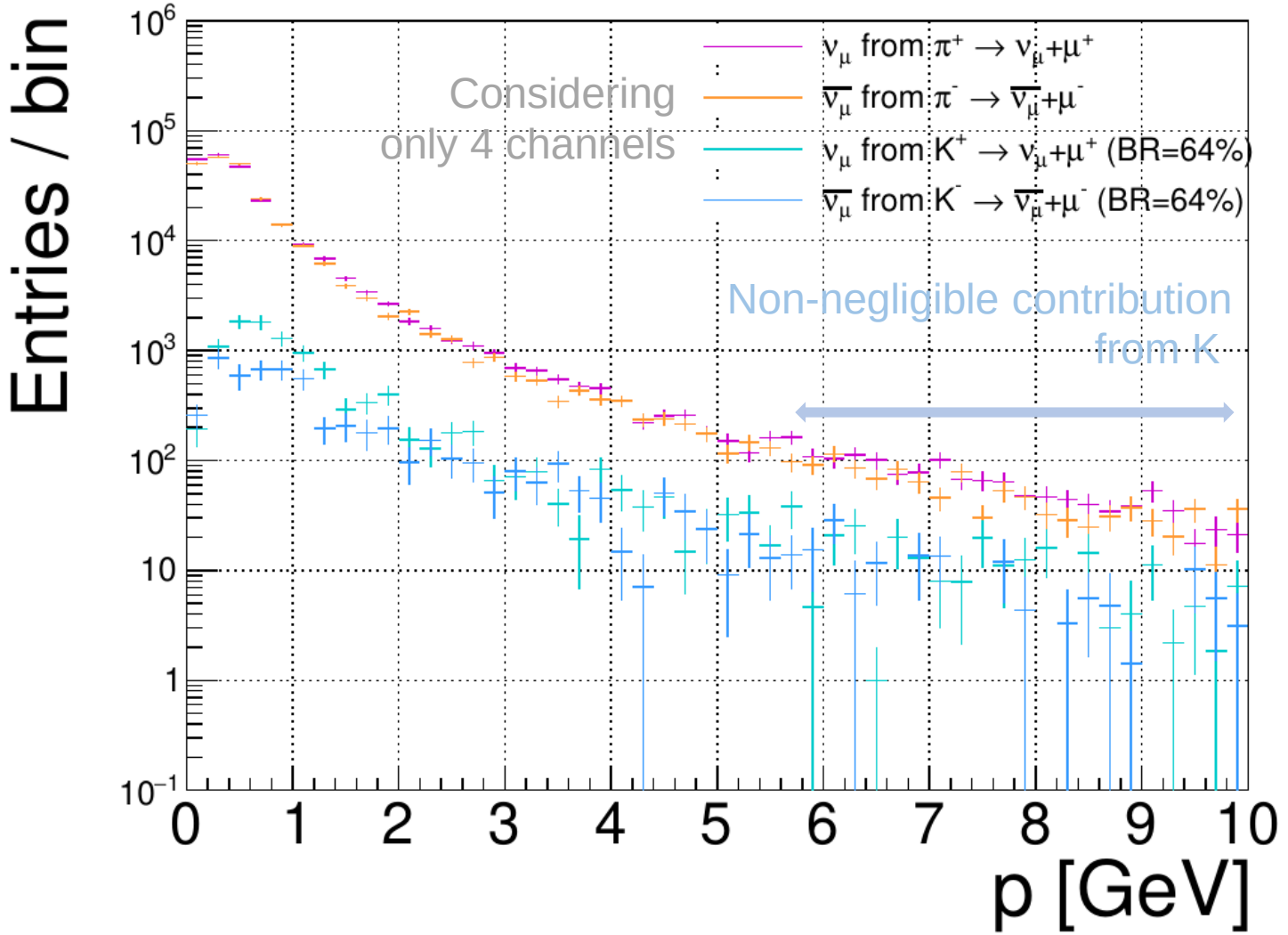
FLAIR (Fluka advanced user interface) is an all in one graphical interface, which provides an easy to interact front end for FLUKA and facilitates running and monitoring of the status of a run (runs).

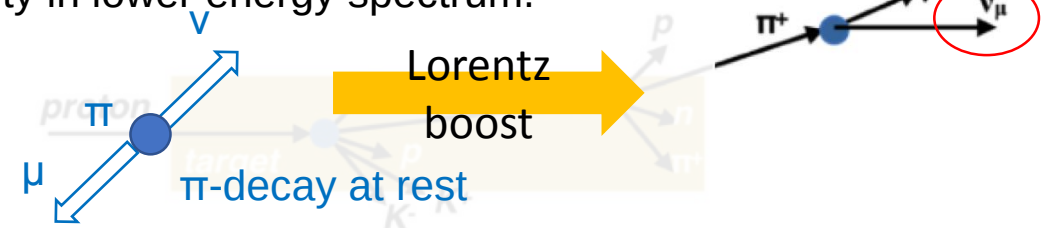
GEANT Geant4 is a toolkit for the simulation of particles passing through and interacting with matter. We used it as an alternative to Fluka, as the installation experience of FLUKA wasn’t exactly smooth.

Analysis and results

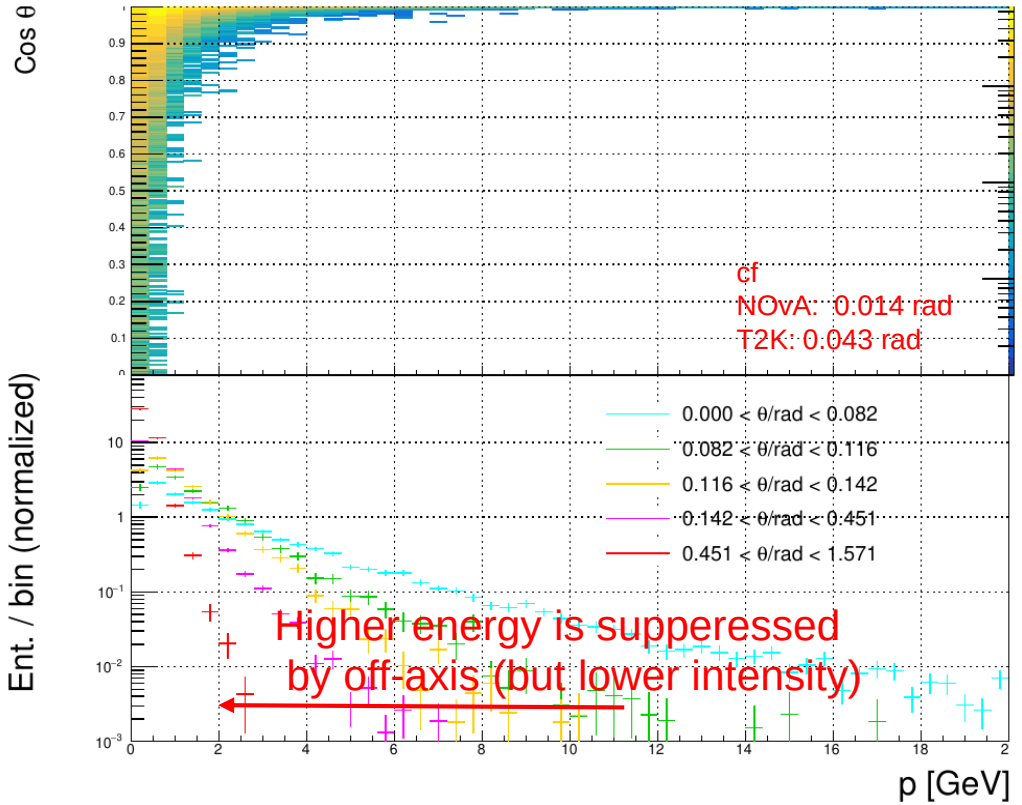
- FLUKA -> only hadron production
- Considered ν spectrum is only came from π/K-decay, not μ-decay
  - *This is not a perfect simulation
- More density in lower energy spectrum.

ν momentum

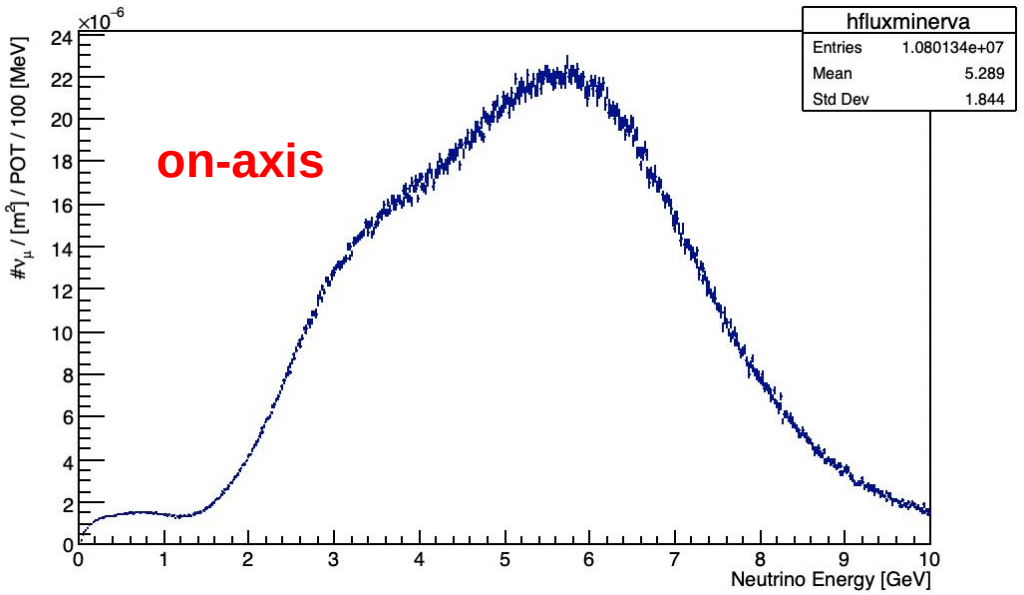


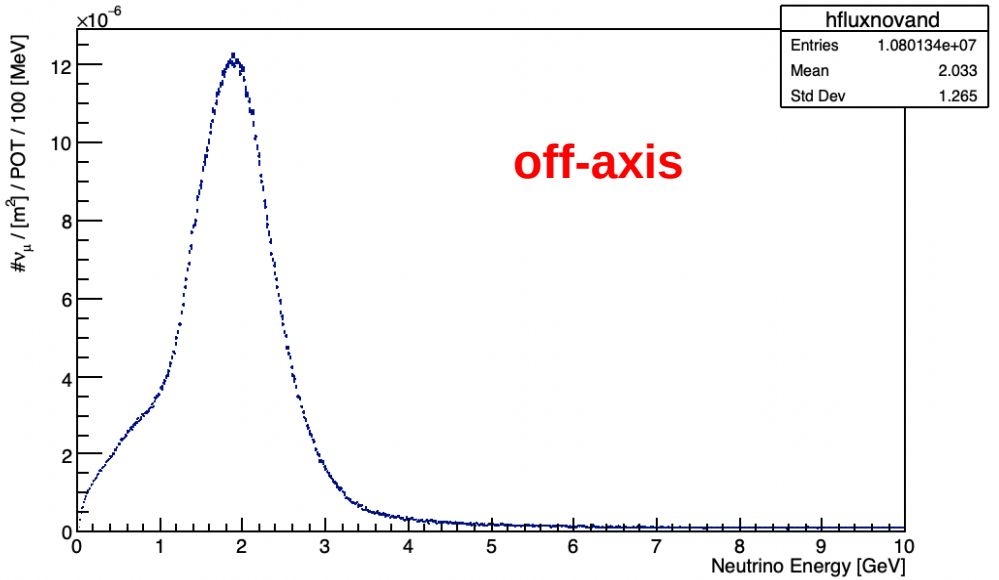


ν angle v.s. momentum



Analysis and results



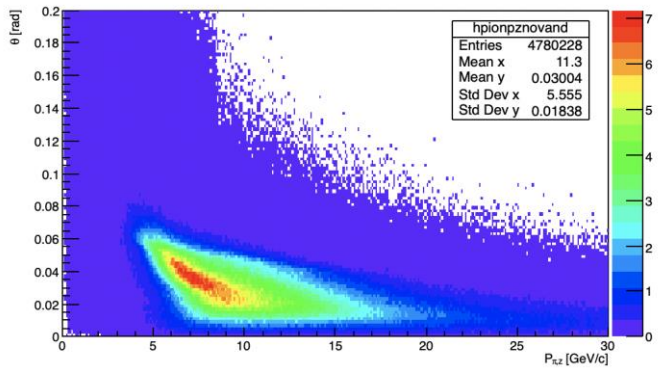


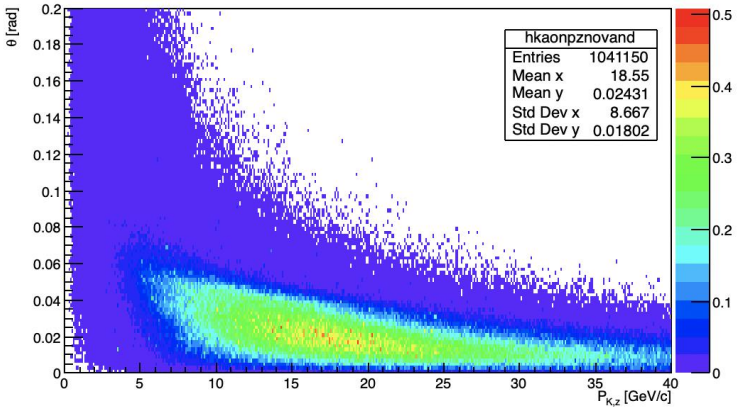
Comparison between energy spectra versus neutrino flux at the **on-axis** detectors (**MINERvA**) and **off-axis** detectors (**NOvA**):

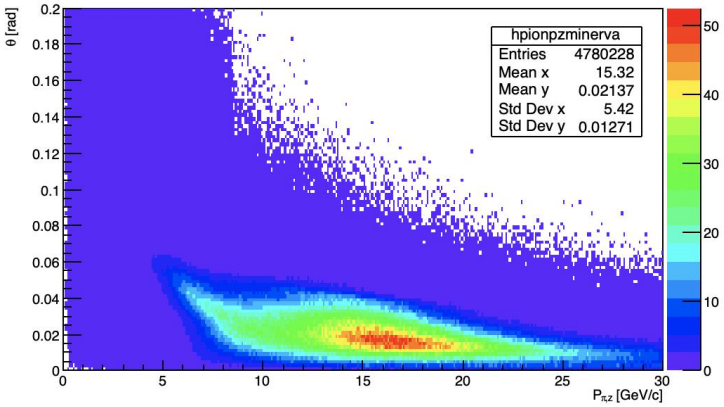
- The ν_μ flux spectrum for the MINERvA location shows the energy peak is around 6 GeV with a small bump at around 3 GeV because of over-focused pions for MINERvA flux

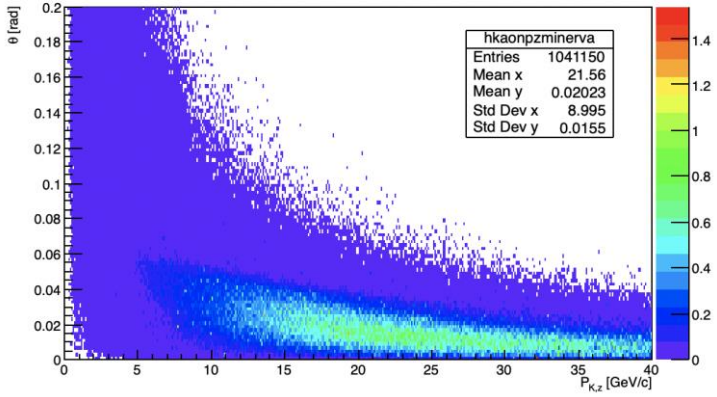
- In the **off-axis** (14.6 mrad) near detector case, the spectrum of neutrino energy for ν_μ flux has a peak at lower energy than in the **on-axis** case (MINERvA), the neutrino flux for NOvA has an energy peak at approximately 2 GeV. In addition, the energy peak for NOvA is narrower enough than the energy peak prediction for on-axis experiments like MINERvA.

Analysis and results





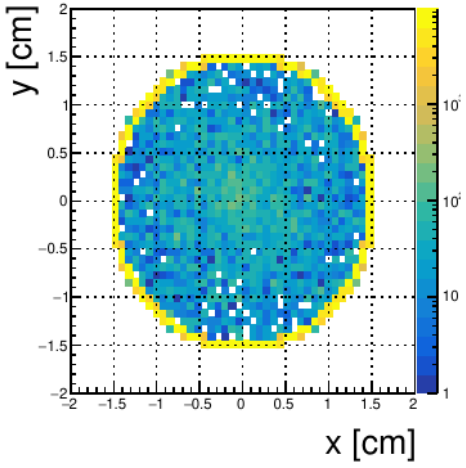


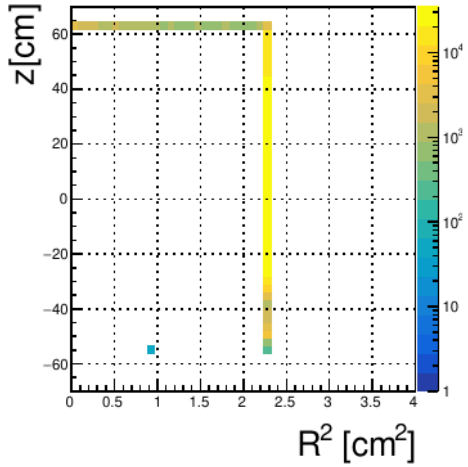


Phase-spaces with NOvA ND and MINERvA detector weights for pion and kaon production

Exiting points of hadron

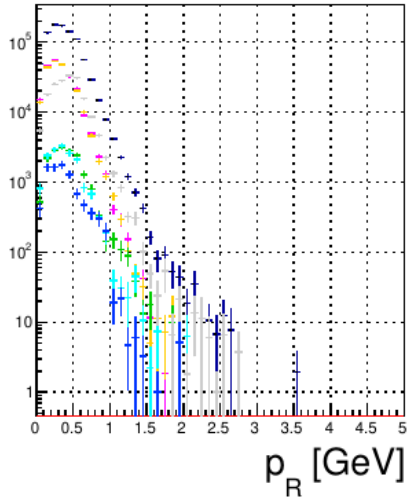
Target is simple one: cylindrical shape

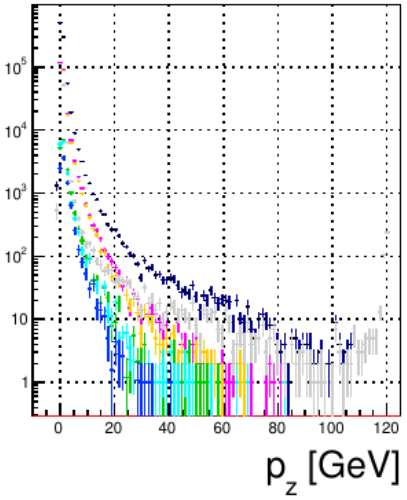




Transverse/z momentum

Black: all
Magenta/orange: pion
Cyan/green/blue: kaon





Summary and learnings

- Simulated hadron production with simple target of NuMI
  -> Cylinder of graphite (radius = 30mm, length ~ 1200 mm ~ 2 interaction length)

- Momentum spectrum
  -> Almost same amount of π+ / π- → de-focusing with horn is essensial for ν / anti-ν discrimination
  -> K amount ~ 1/7 of π, but non neglible contribution to neutrino in higher momentum (> 5 GeV)

- Momentum v.s. outgoing angle
  -> off axis technique reduces higher energy composition in hadron level

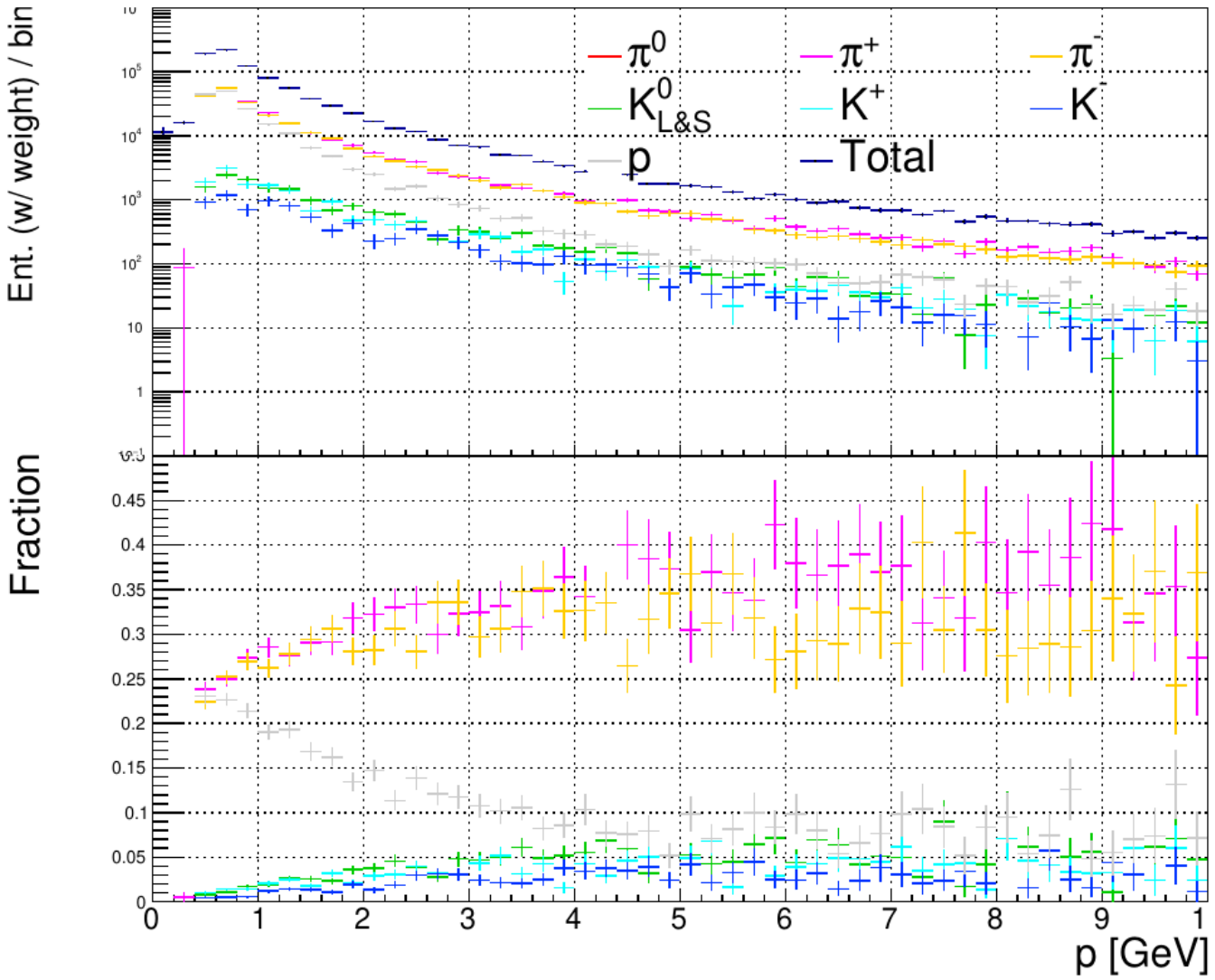
  - The detectors are situated on-axis like MINERvA experiment, the decay angle is zero. The relation between the neutrino energy and pion (kaon) parents are $E_\nu \approx 0.43\, E_\pi$ ($E_\nu \approx 0.95\, E_k$) for the on-axis location experiments.

  - For off-axis location experiments, θ_ν is different from 0, for instance, θ_ν = 14.6 mrad for NOvA experiment. As a result, unlike the on-axis, for off-axis location, the relation between the energy of neutrino and its parent is non-linear due to the Lorentz boost factor in the definition depending on parent energy.

  - In the Medium Energy run, the target is pulled away from the horn to produce the neutrino flux peaking at ~ 6 GeV for MINERvA and ~ 2 GeV for NOvA.

Backup

Hadron momentum



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