

# L2G FIRST STEPS: SAMPLE PRODUCTION AND ANALYSIS



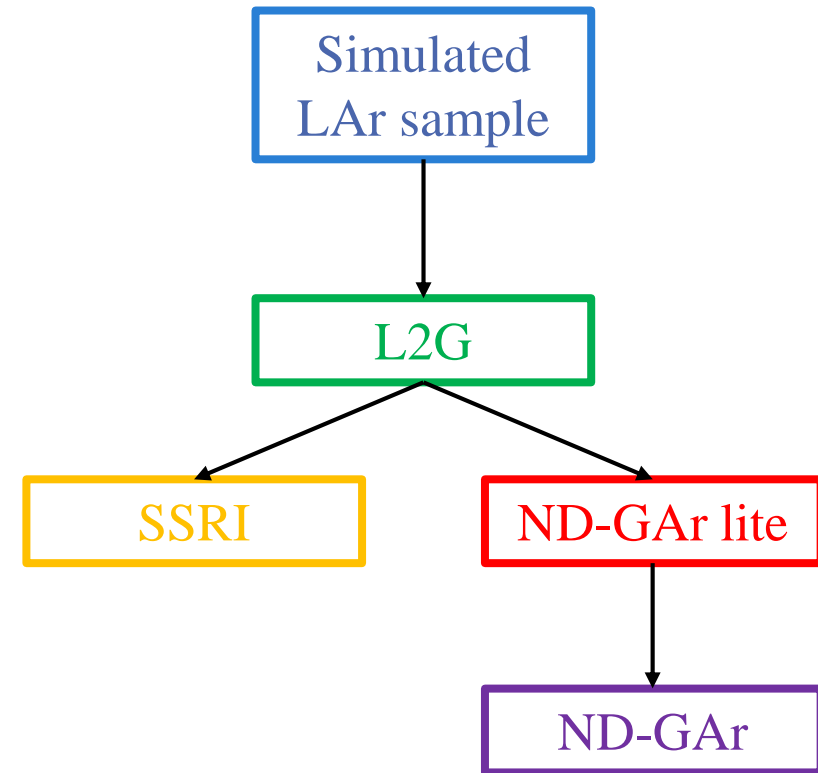
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# LAR TO GAR SAMPLE: L2G

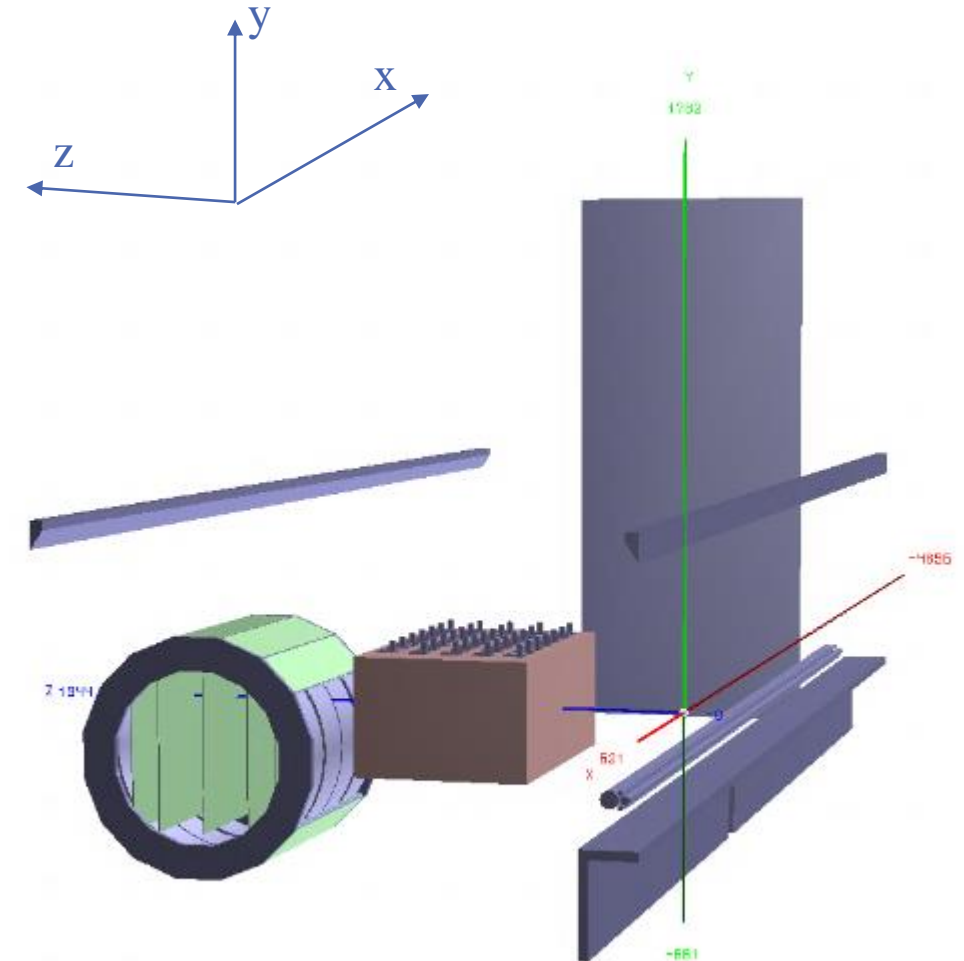
- Strong need for **large LAr samples** already propagated in edep-sim
- **L2G**: interface that takes outgoing LAr particles and feeds them to edep-sim with any TMS detector could simplify the sample simulation/reconstruction and standardize the procedure between detector designs (ND-GAr/TMS).
- As a first step Eldwan **produced a large sample of LAr interactions**, developed it up to reconstruction and anatreer production and we **started studying its properties focusing on the produced muons**



[https://indico.fnal.gov/event/44562/contributions/200915/attachments/136745/170170/DUNE\\_ND\\_Meeting\\_28.10.20.pdf](https://indico.fnal.gov/event/44562/contributions/200915/attachments/136745/170170/DUNE_ND_Meeting_28.10.20.pdf)

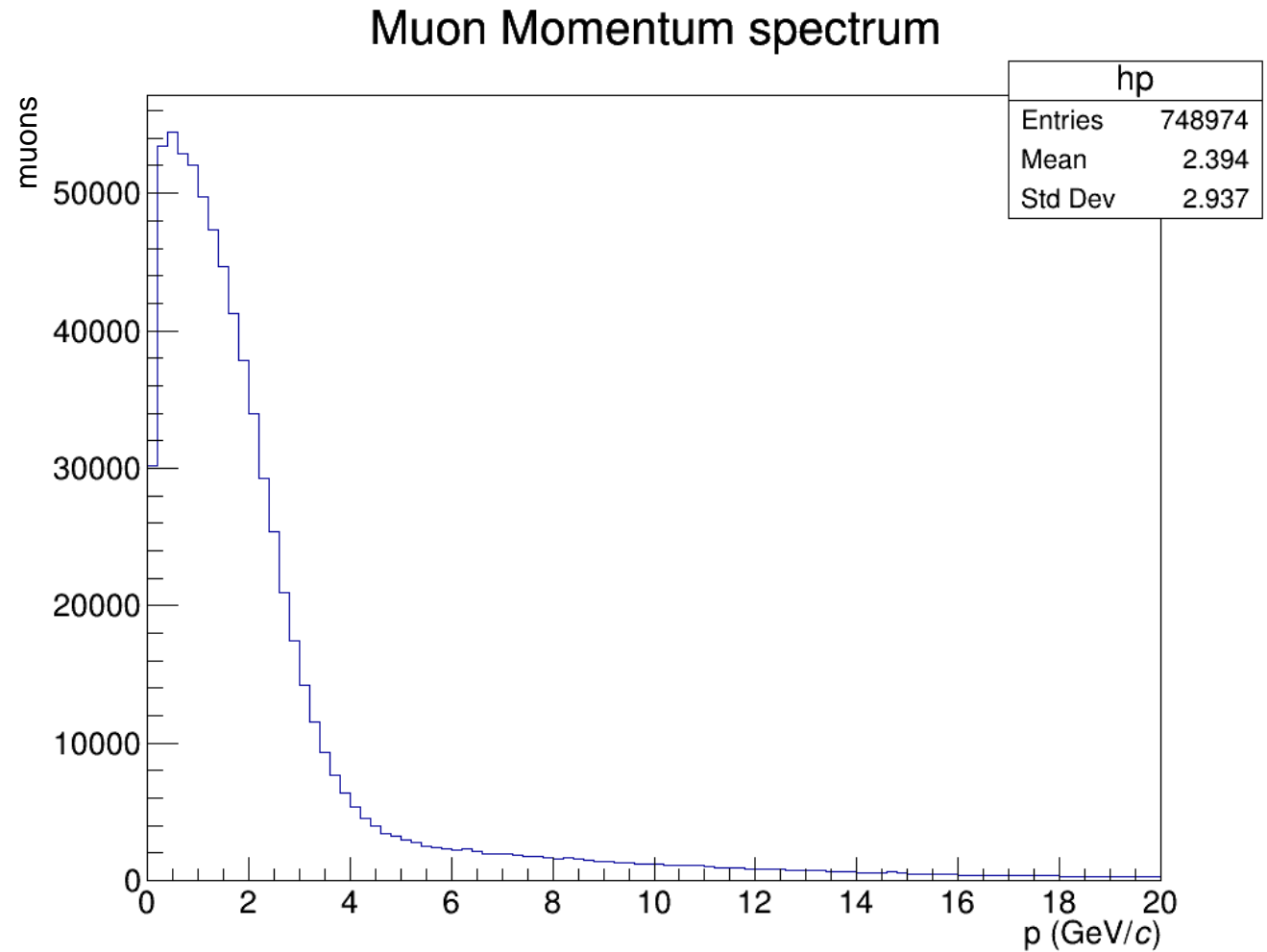
# GENERATED SAMPLE: NEUTRINO INTERACTIONS IN LAR

- Sample generated with GENIE v2
  - Gsimple flux in ND-Hall (from Tanaz)
  - 1M events in ND-LAr (volArgonCubeActive)
- Geometry used
  - Baseline ND-LAr from dunendggd (apparently some updates are needed but not pushed yet...)
  - ND-GAr-Lite detector with SPY magnet (not the latest one acting as PV)
    - 5 Scintillator planes (Minerva-like) of 6mx5mx4cm at (-240, -150, 0, 150, 240) //Not Optimized yet!
    - Segmented with triangular shapes strips in X/Y (2 cm triangle base)
  - Includes a muon detector (3 planes of Sc of 2 cm) with 2x7.5cm iron
- Got to test the full chain gen/sim/reco for ND-GAr-Lite without major hickups with edep-sim and GArSoft
- LAr digi/reco to be done standalone and merged back
- Note that in our coordinate sytem **z is the flux direction**, **y is the vertical direction** and **x is the drift direction** (i.e. the magnetic field direction)



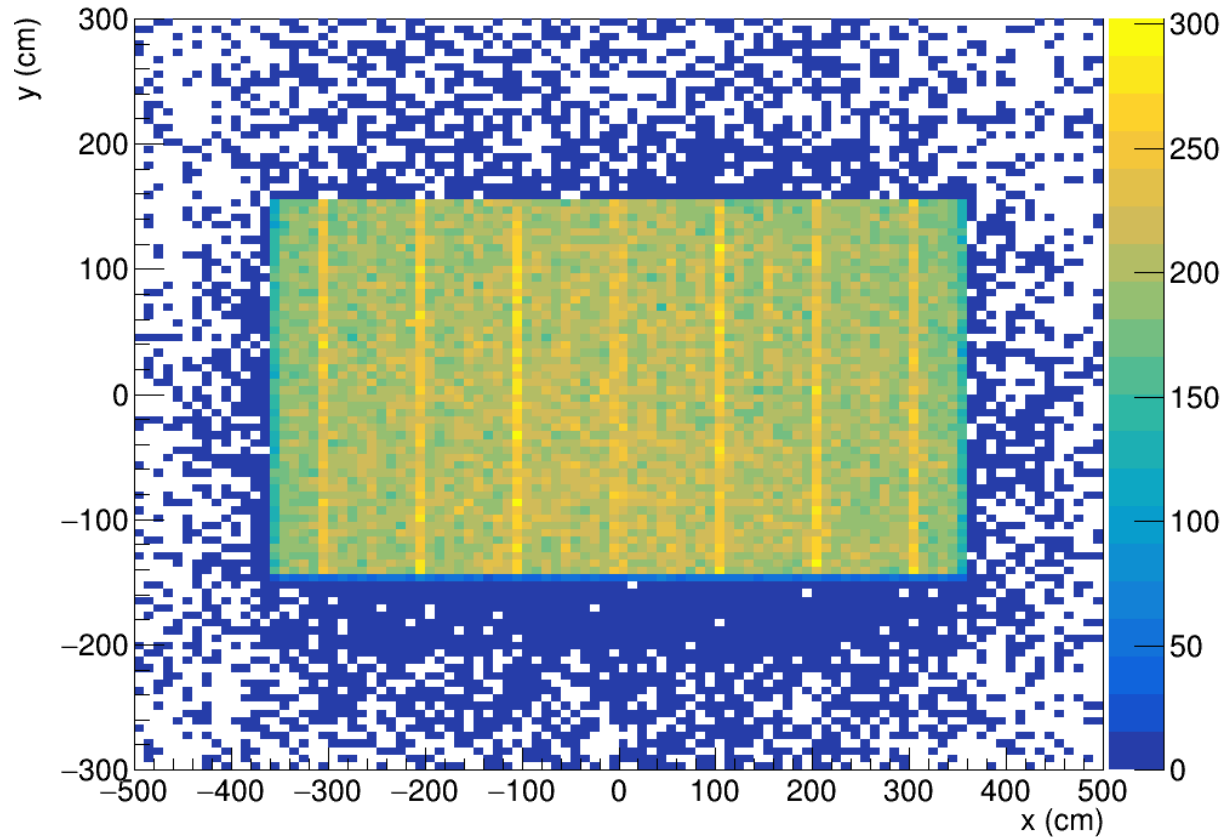
# MUON SPECTRUM

- As a first step we looked at the [muon spectrum](#)
- Here [all the muons present in the sample are considered](#), irregardeless of where and how they are produced
- Note that [all the neutrinos are set to interact in the liquid argon](#) volume, but not all the muons are produced directly in  $\nu_\mu(CC)$  interactions, some could be the product of  $\pi$  or  $K$  decay
- Also note that [roughly 3% of the events in the sample contain more than 1 muon track](#); in almost all of these cases the event contains one primary  $\mu$  and one or more secondary  $\mu$  from  $\pi$  or  $K$  decay

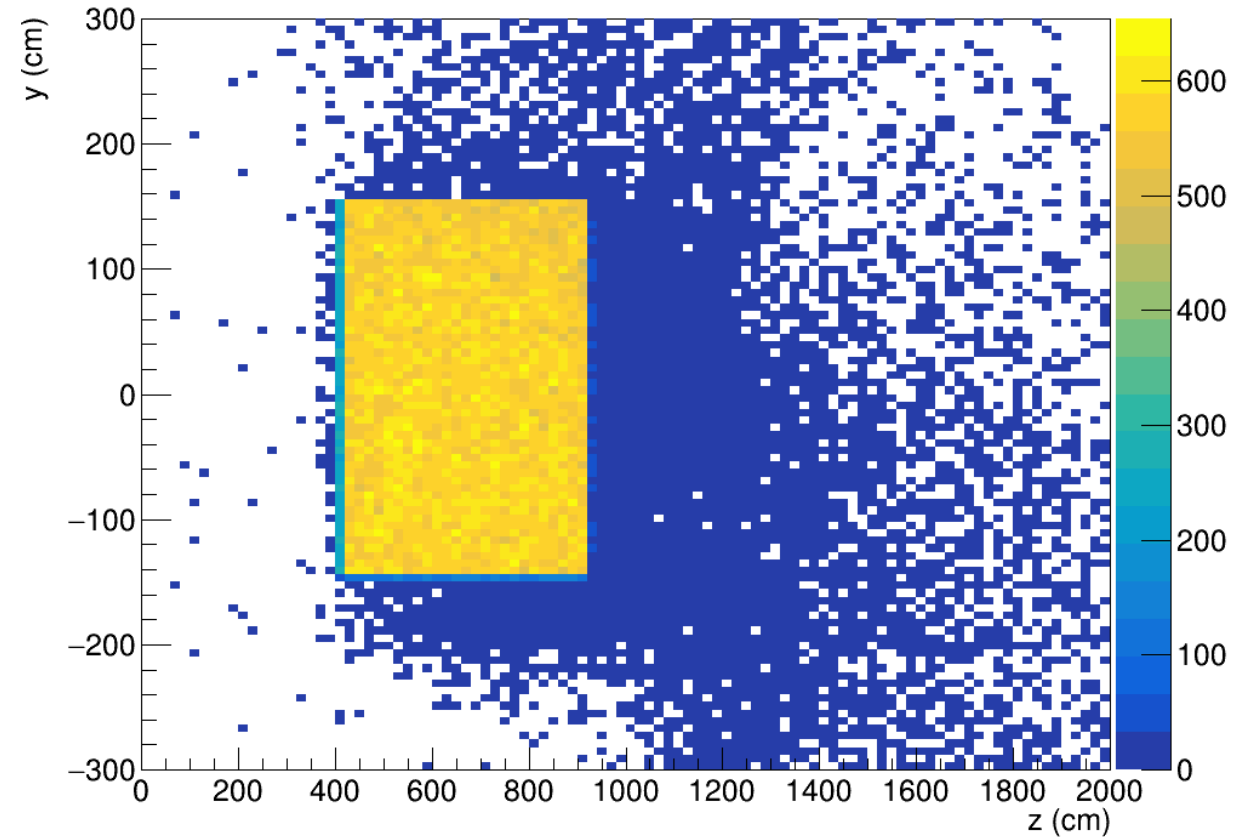


# MUON PRODUCTION VERTEX

Muon production vertex distribution



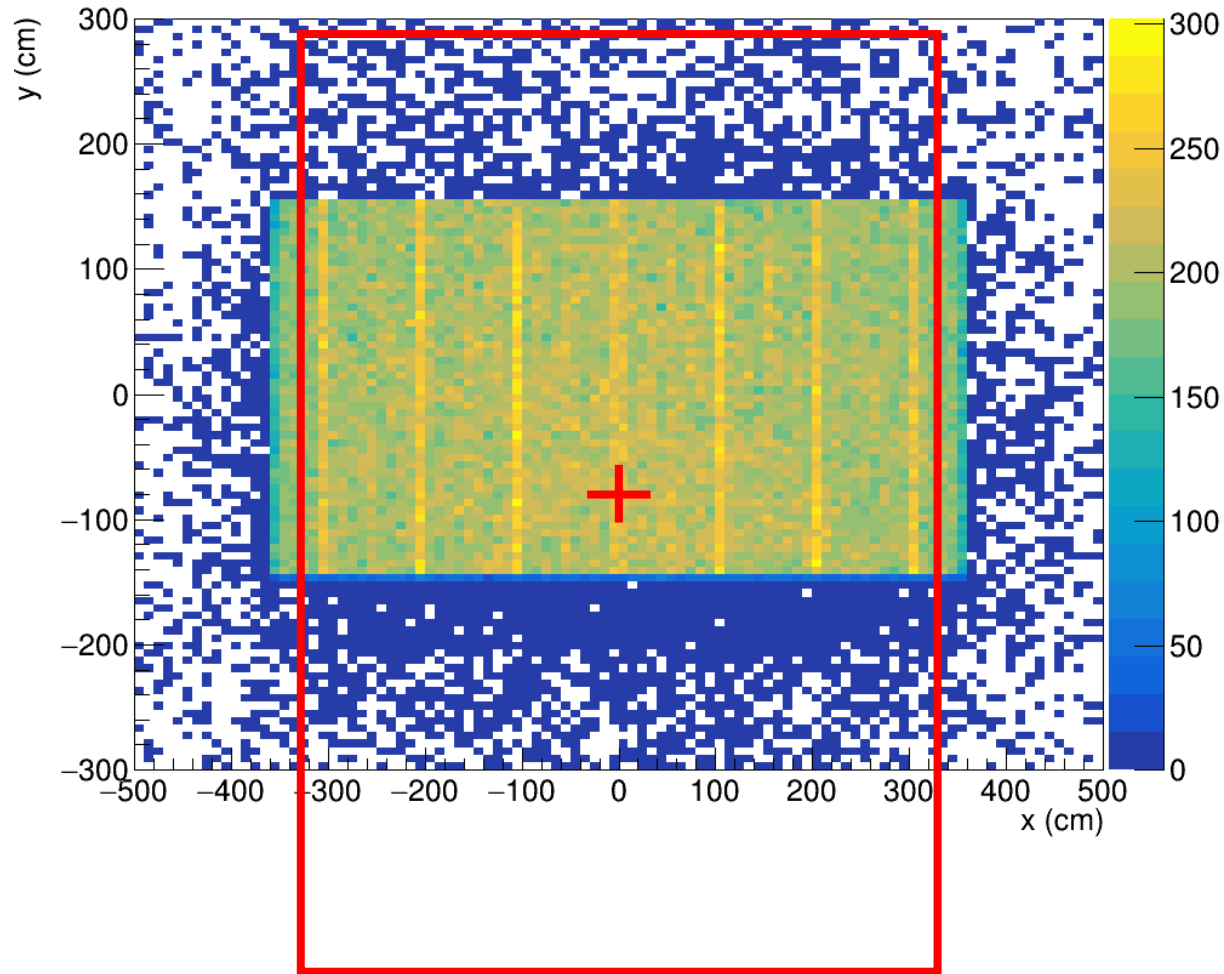
Muon production vertex distribution



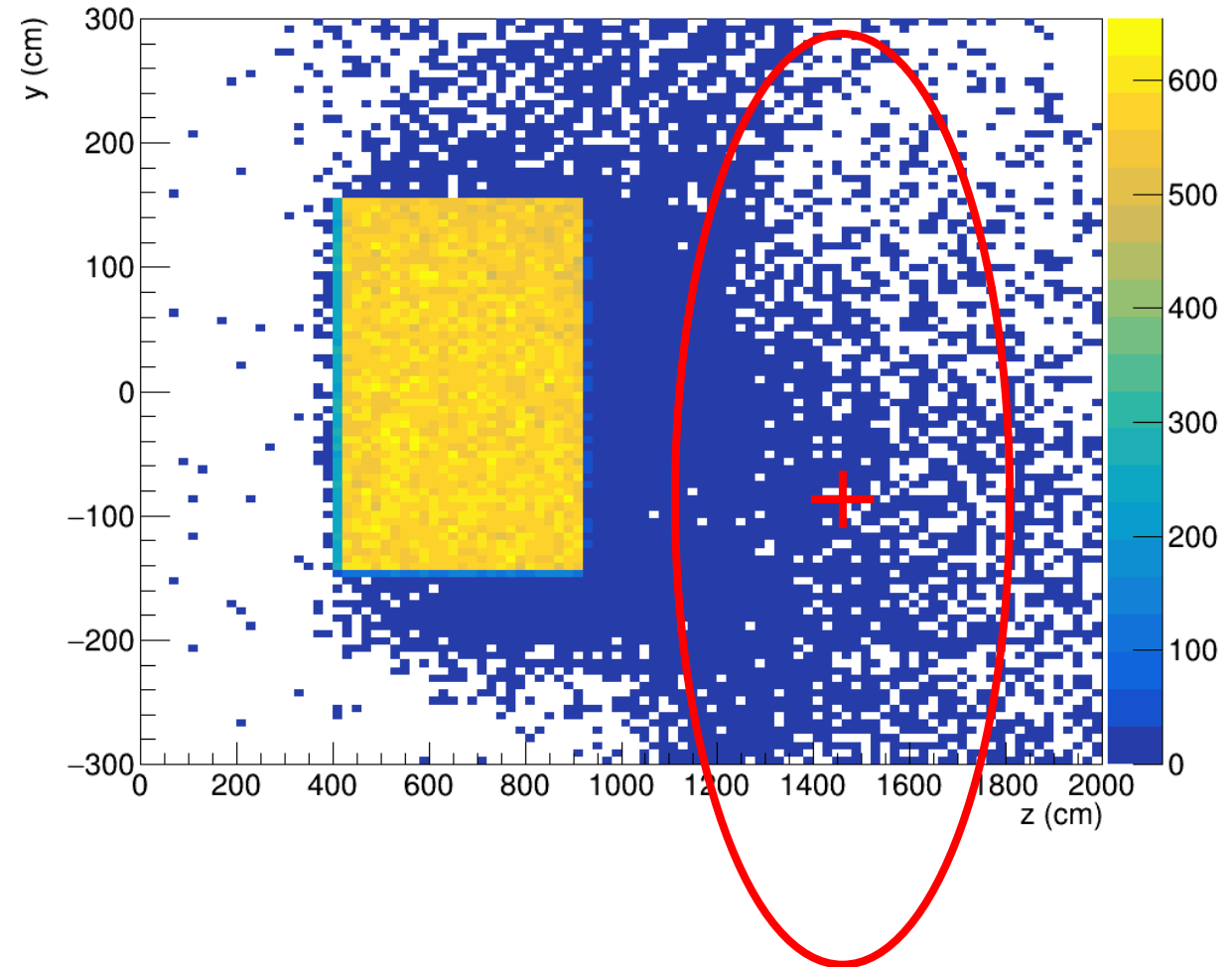
- Here we plot the spatial distribution of the points of production of the muons i.e. The first points registered in the muon trajectories.

# MUON PRODUCTION VERTEX

Muon production vertex distribution



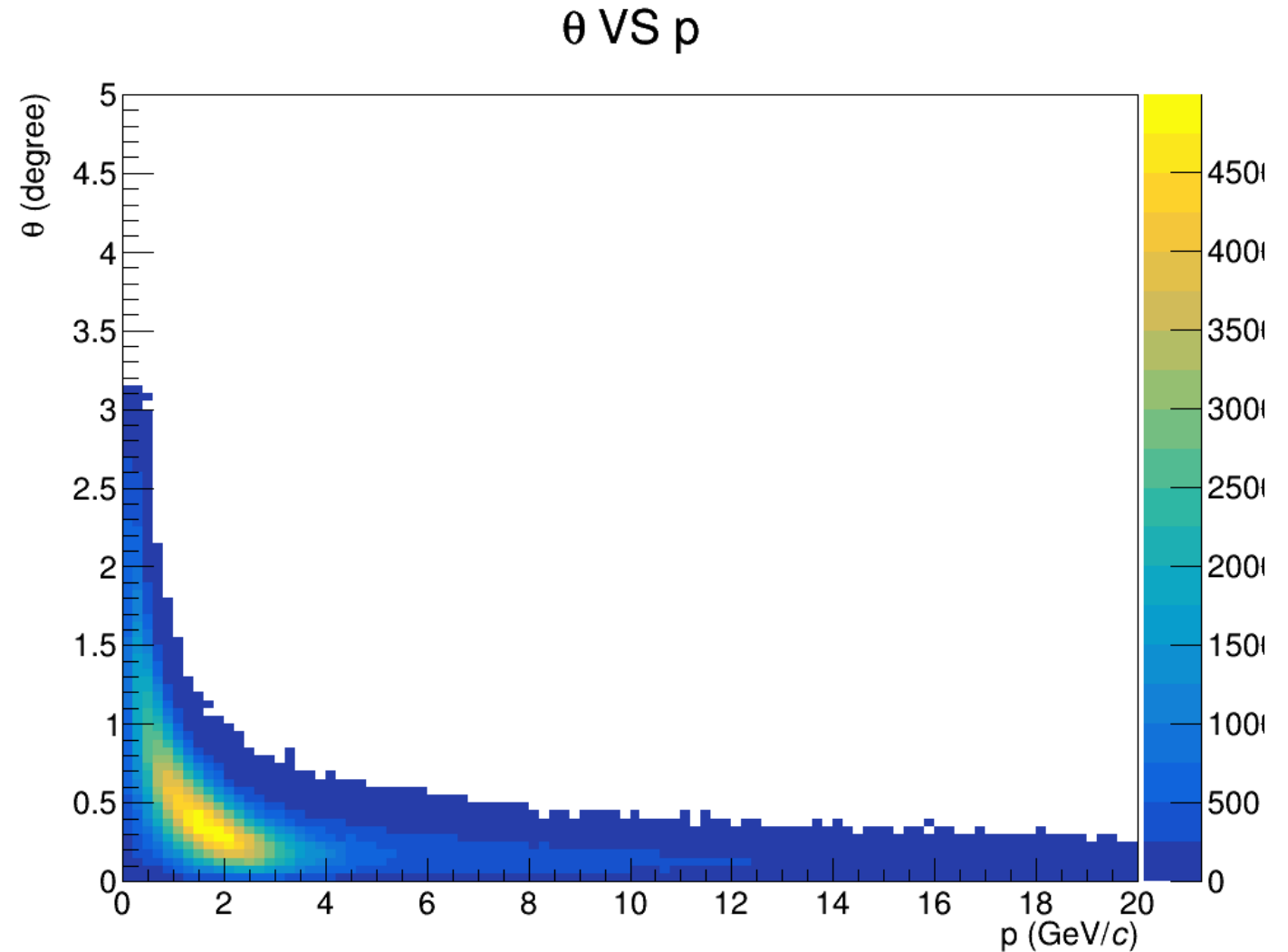
Muon production vertex distribution



- Here we plot the spatial distribution of the points of production of the muons i.e. The first points registered in the muon trajectories. The ND-GAr tracker volume is outlined in red

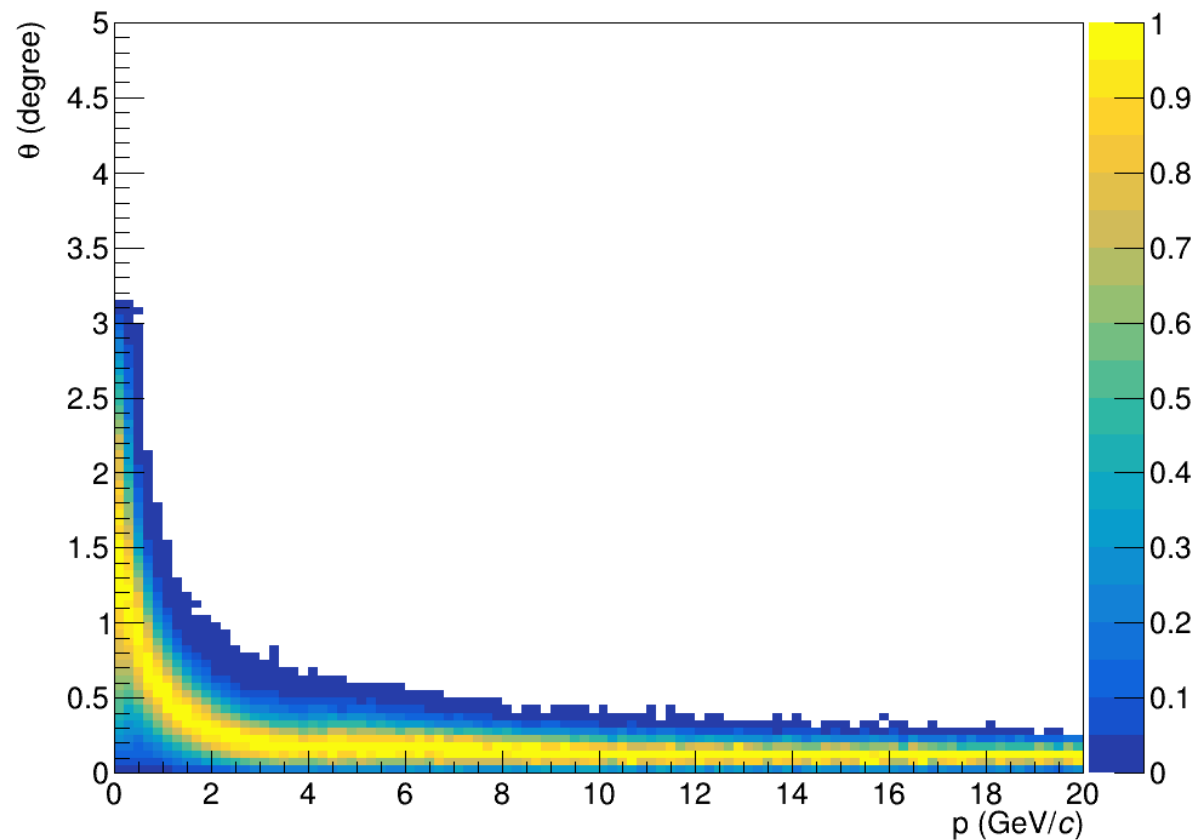
# THETA VS P

- Here we analyze the distribution of the angle between the muon initial trajectory and the z axis,  $\theta$  and the muon initial momentum
- We note that, as expected most of the sample is concentrated at low angles and an initial momentum between 0 and 5 GeV/c
- We also note that the more energetic the muons are the more they tend to be produced at low angles

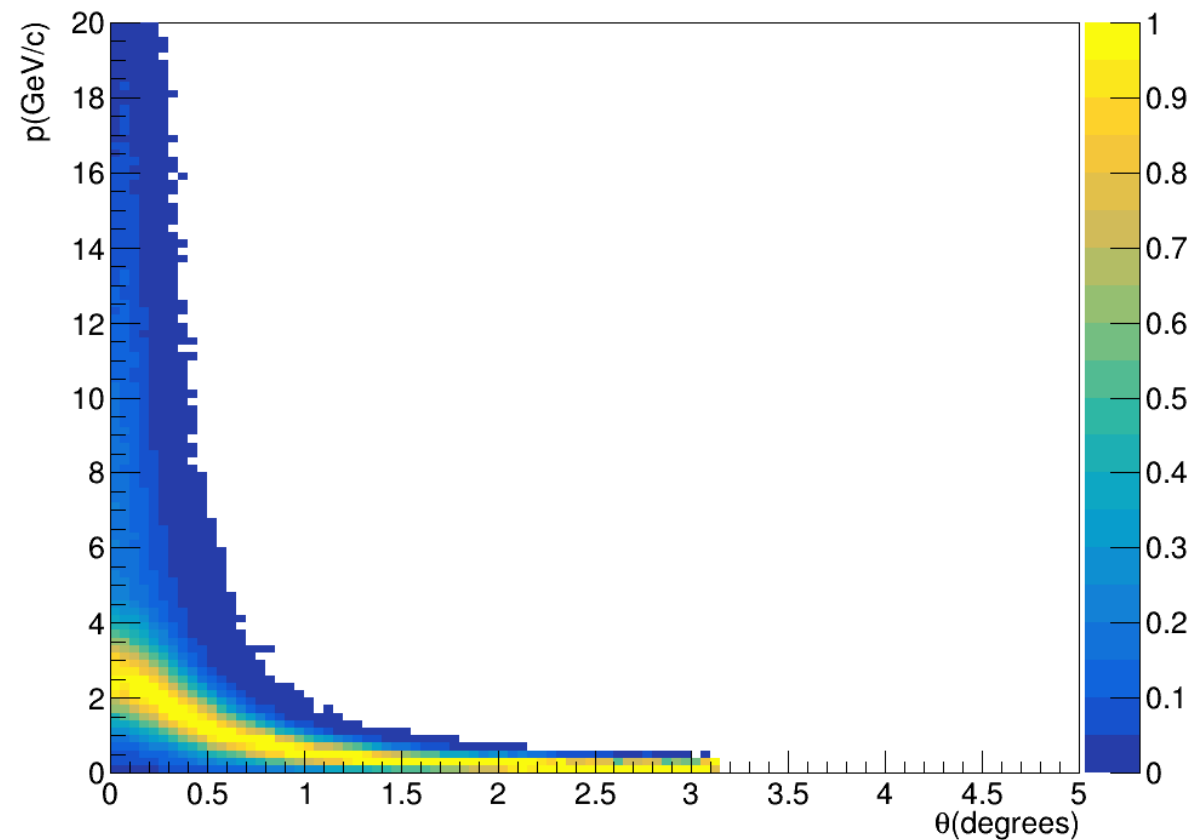


# $P(\theta|p)$ AND $P(p|\theta)$

$P(\theta|p)$



$P(p|\theta)$

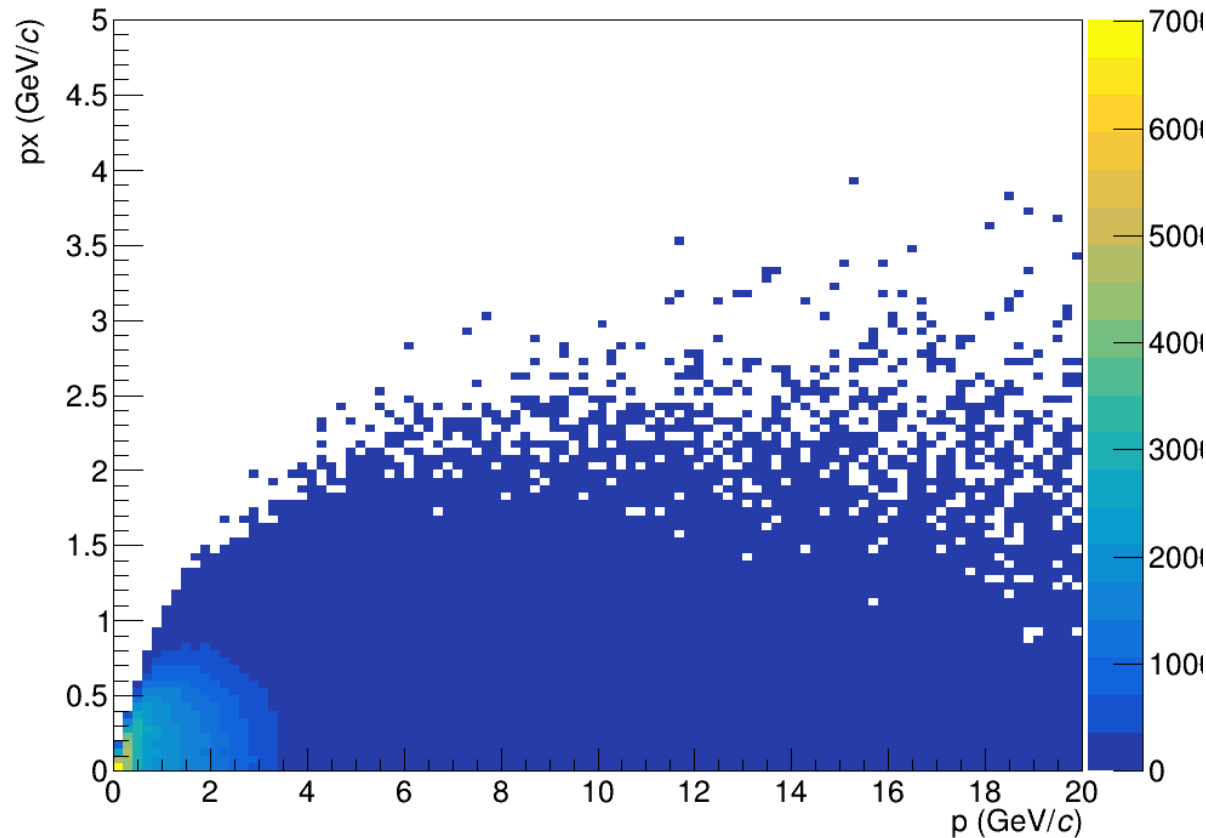


- Conditional probabilities  $P(\theta|p)$  and  $P(p|\theta)$  normalized so that the points with maximum probability in each slice are assigned the value 1

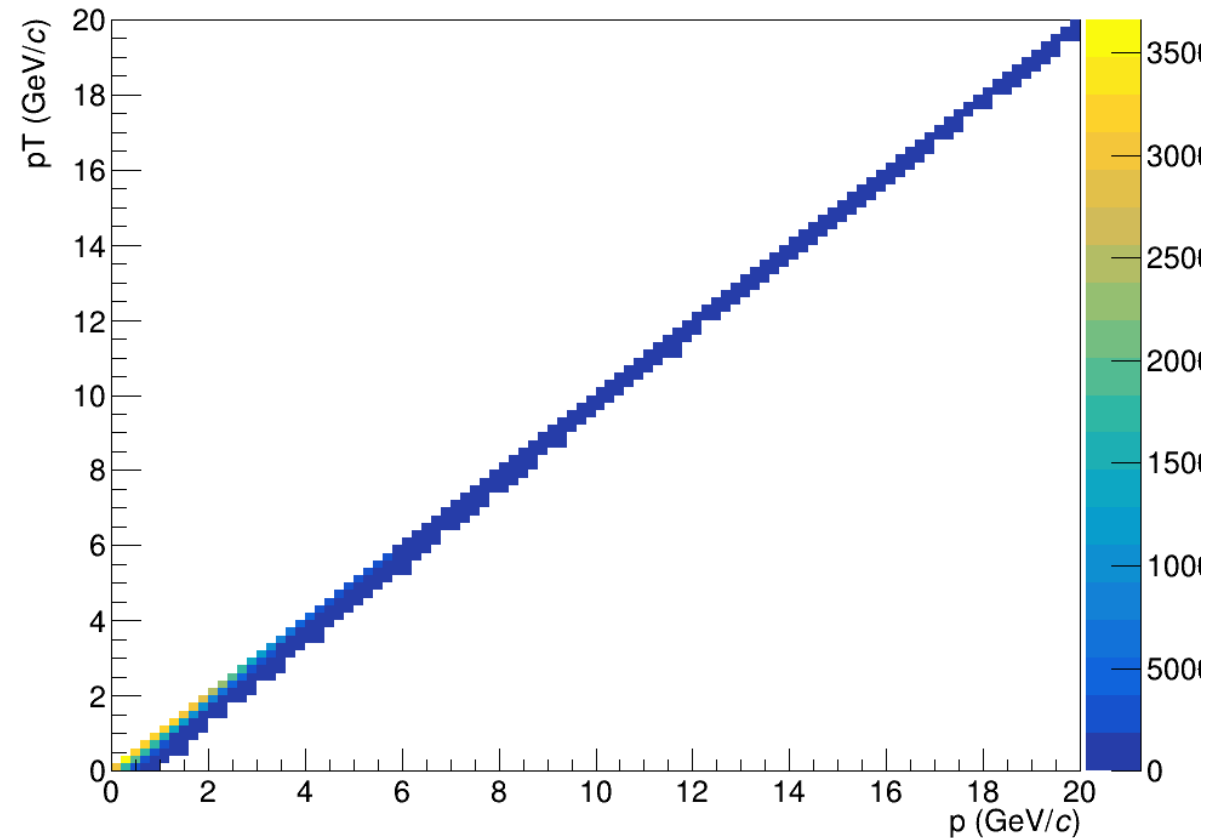


## $(p_x \text{ VS } p)$ AND $(p_T \text{ VS } p)$

$p_x \text{ VS } p$



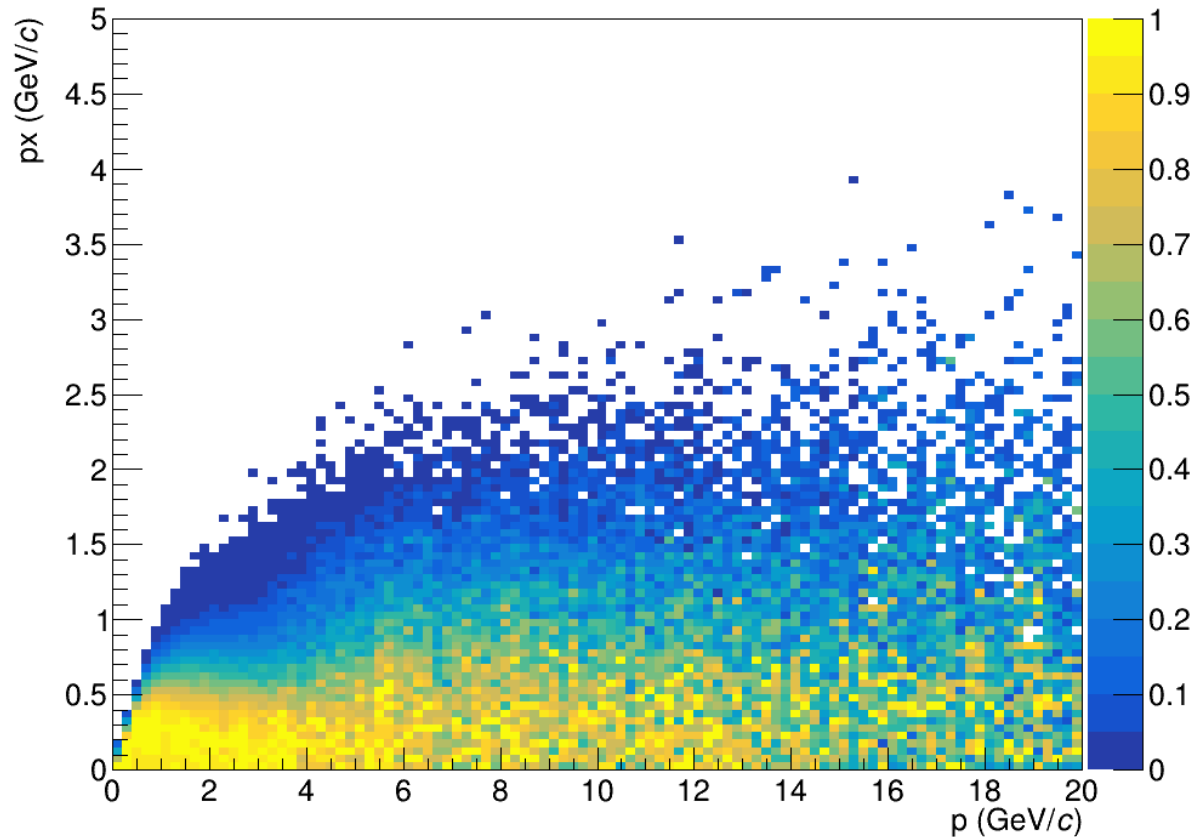
$p_T \text{ VS } p$



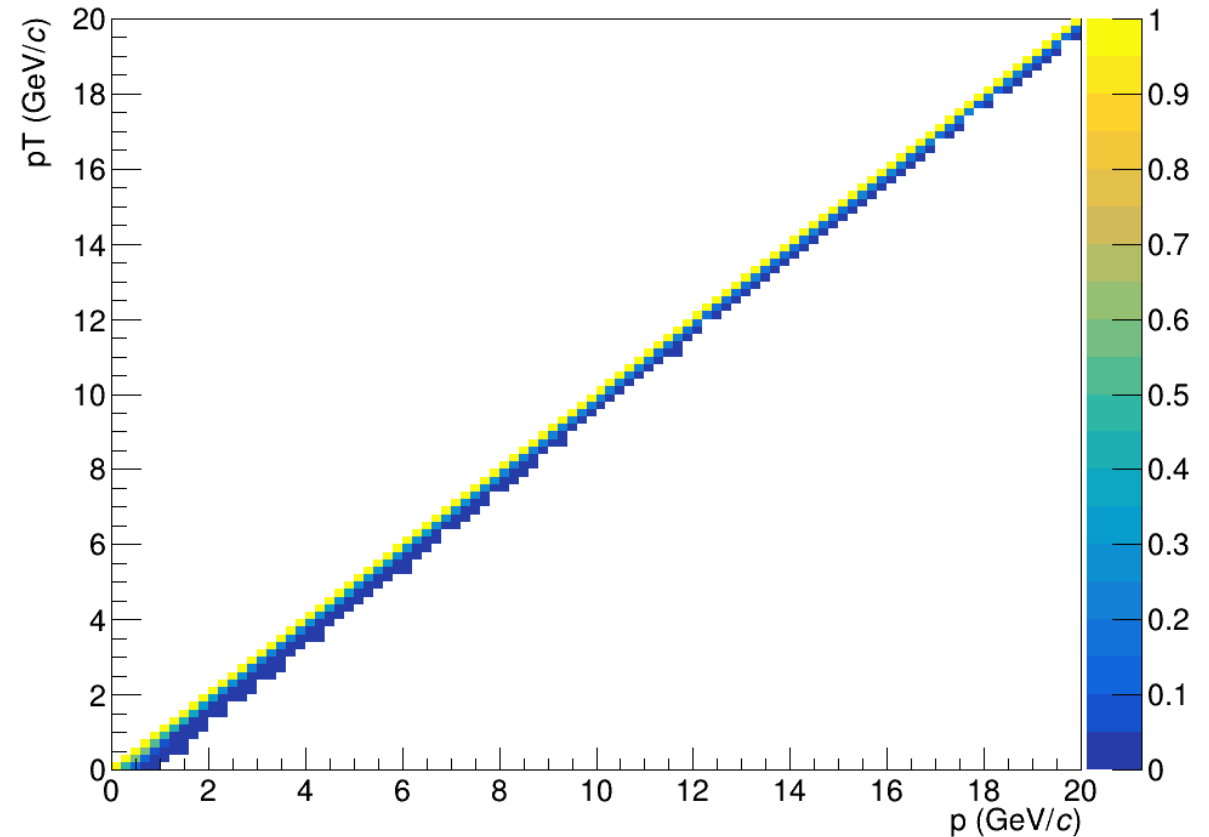
- Distributions of the momentum components along the drift direction  $p_x$  and on the transverse plane  $yz$   $p_T$  as a function of the total momentum  $p$ . The transverse momentum largely dominates, especially at low momenta

## $P(p_x|p)$ AND $P(p_T|p)$

$P(p_x|p)$



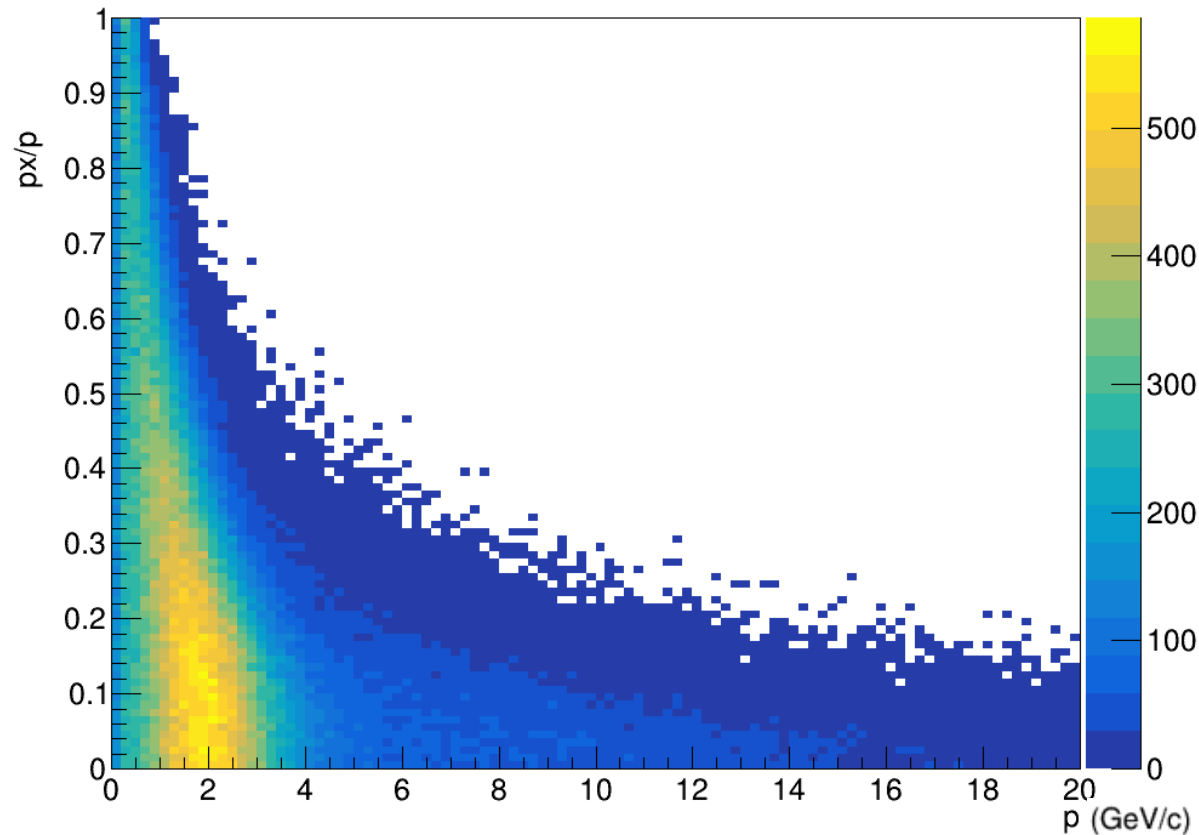
$P(p_T|p)$



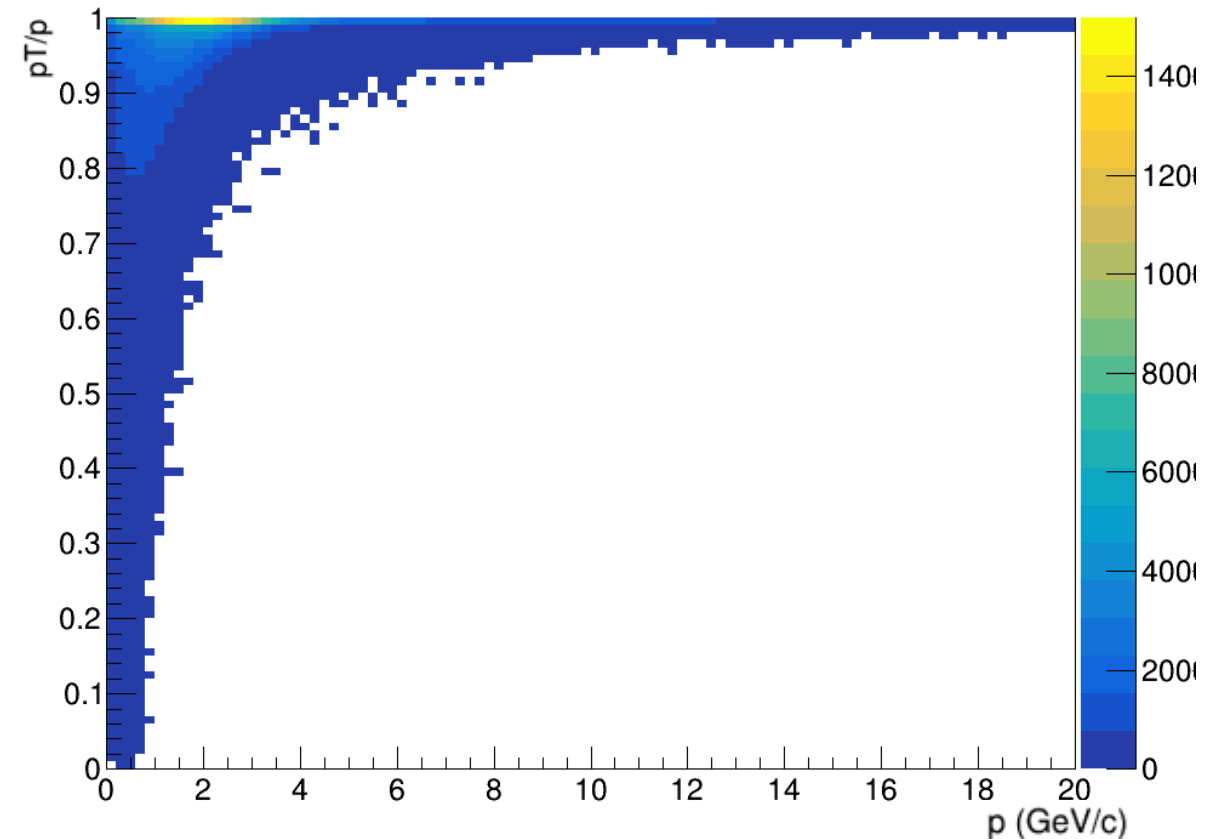
- Same information expressed in the form of conditional probabilities  $P(p_x|p)$  and  $P(p_T|p)$  once again normalized with the maxima at 1

## $(p_x/p \text{ VS } p)$ AND $(p_T/p \text{ VS } p)$

$p_x/p \text{ VS } p$



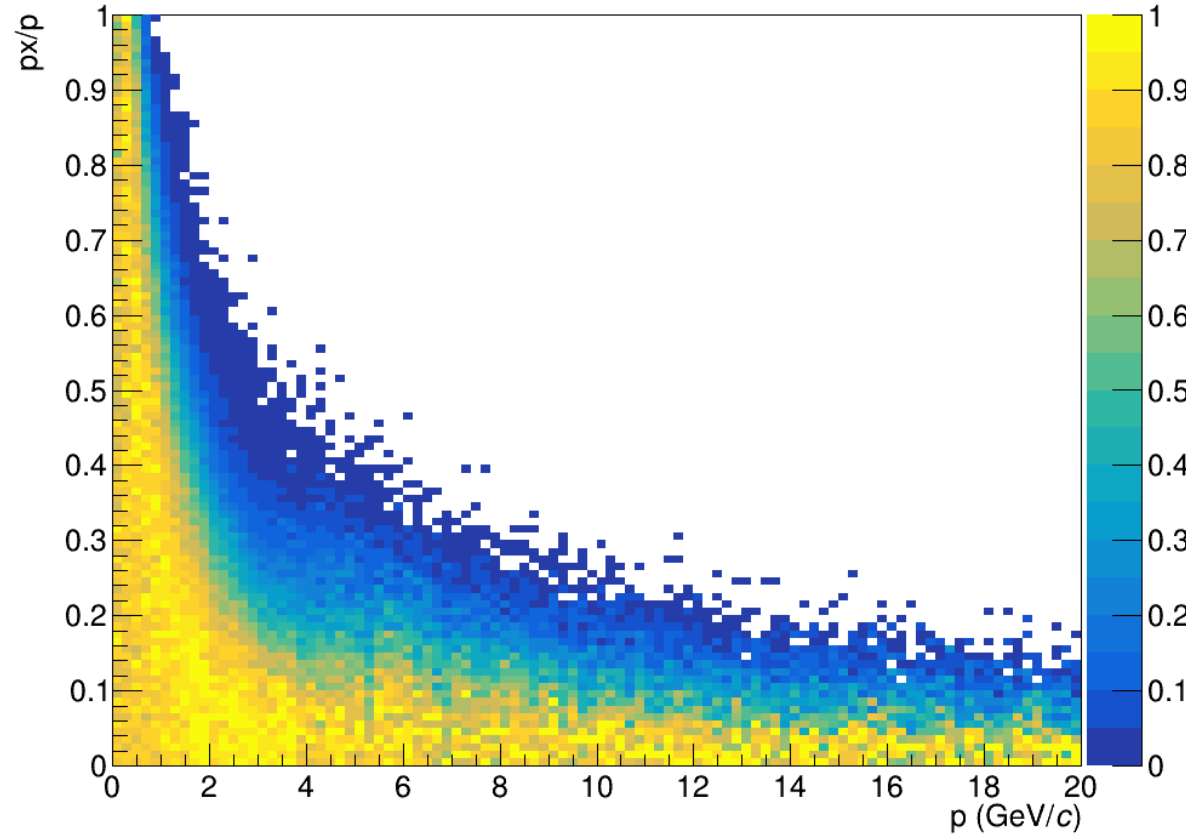
$p_T/p \text{ VS } p$



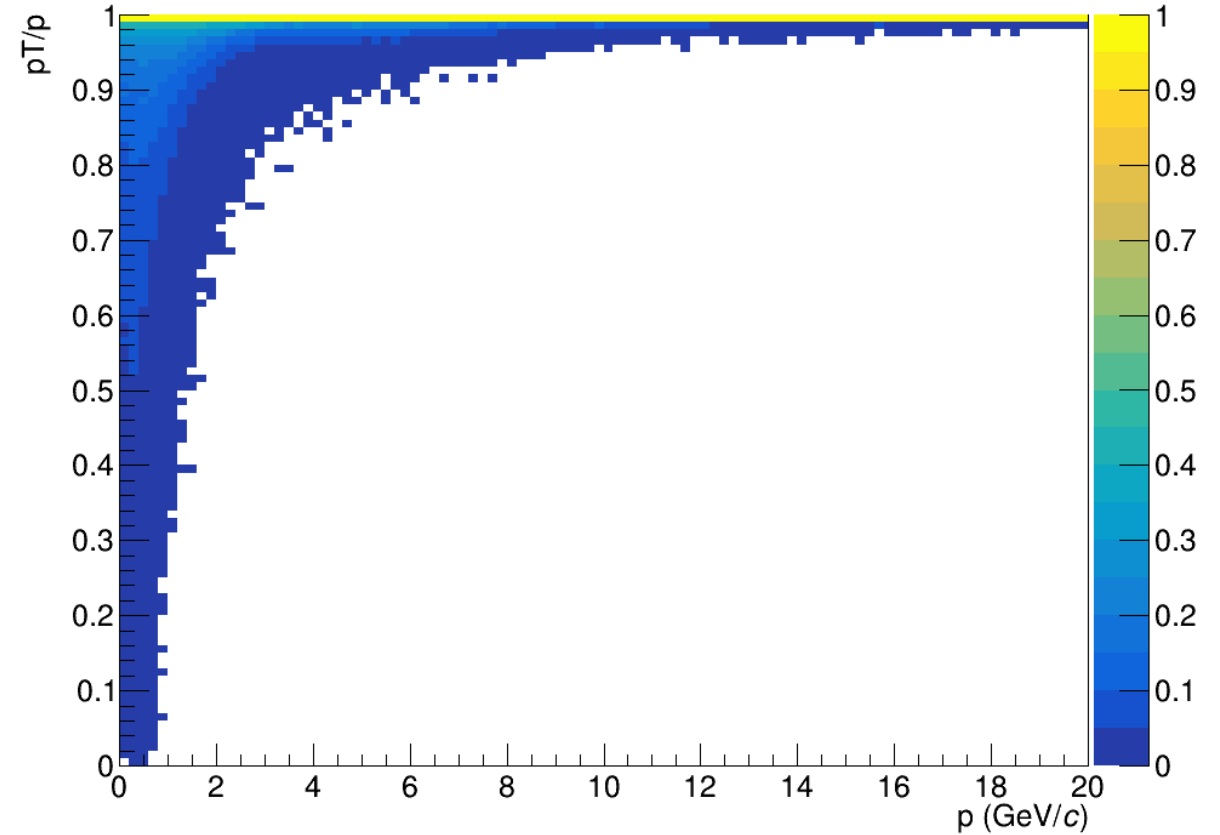
- Distributions of the momentum components fractions along the drift direction  $p_x/p$  and on the transverse plane  $p_T/p$  as a function of the total momentum  $p$ . Once again it is clear that the transverse momentum largely dominates, especially at low momenta

# $P(p_x/p|p)$ AND $P(p_T/p|p)$

$P(p_x/p|p)$



$P(p_T/p|p)$



- Conditional probabilities  $P(p_x|p)$  and  $P(p_T|p)$  once again normalized with the maxima at 1.
- Note that according to  $p_T/p$  and  $p_x/p$ , almost all L2G muons are inside the perpendicular plane to the B-field. This means that as a spectrometer, we need to optimize (y,z) space point resolution and can relax on drift dimension (i.e. use large sigma in KF)

# SUMMARY AND FUTURE STEPS

- The sample of muons produced directly indirectly by neutrino interactions in the Liquid Argon is largely forward going with initial momenta mostly concentrated between 0 and 5 GeV/c
- Roughly 3% of the events in the sample contain more than 1 muon track; in almost all of these cases the event contains one primary  $\mu$  and one or more secondary  $\mu$  from  $\pi$  or  $K$  decay
- The next immediate steps in the sample study would be to:
  - Apply fiducial cuts to the sample, for example considering just muon having their start point in the XY window defined by the LAr detector
  - Study how many muons reach the ND-GAr TPC and how many of them fully traverse it
- Once the sample is well understood we can start tagging the produced muons and develop the l2g interface. Any suggestions are welcomed, thanks!

# LAR TO GAR RATIO

- Here we plot the ratio of muons at the exit of the Lar active volume with the number of muons at the entrance of the Gar as a function of  $x$  and  $y$

