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# Study of muon&hadron acceptance in LAr+TMS

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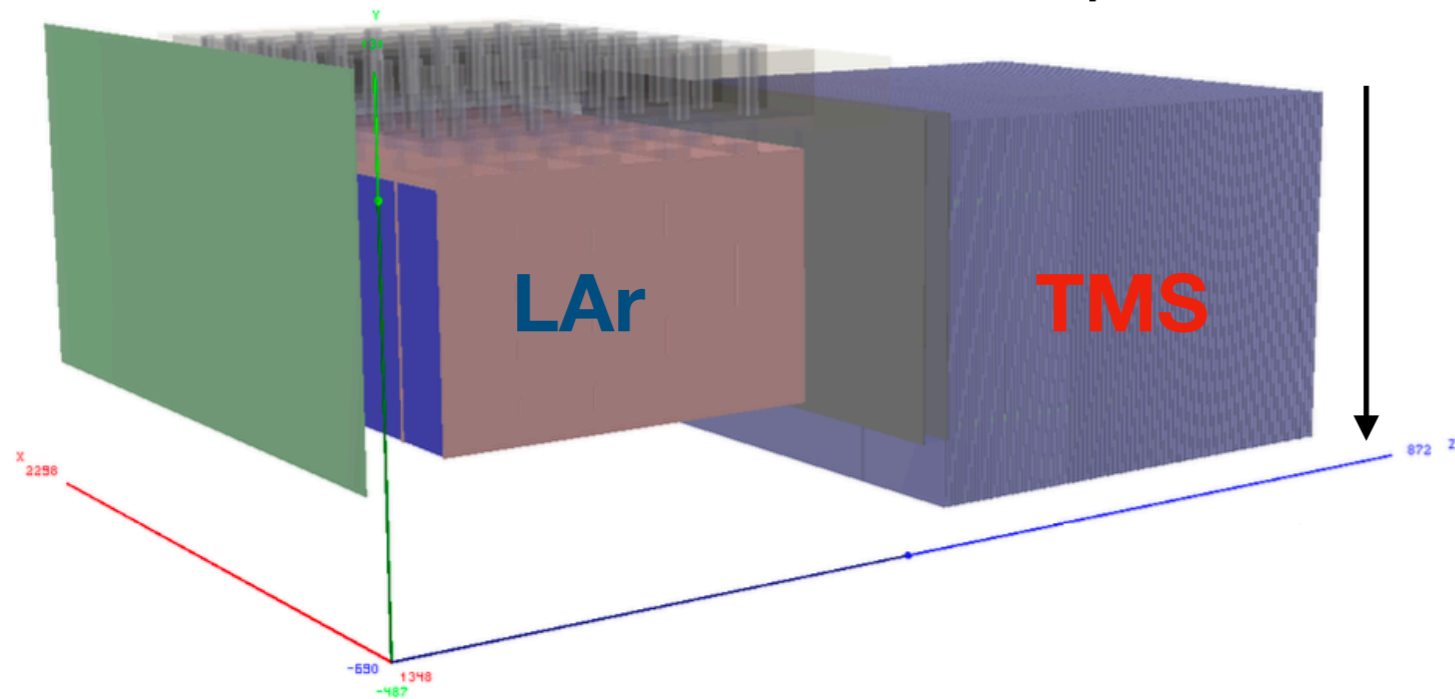
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Aug. 14, 2024

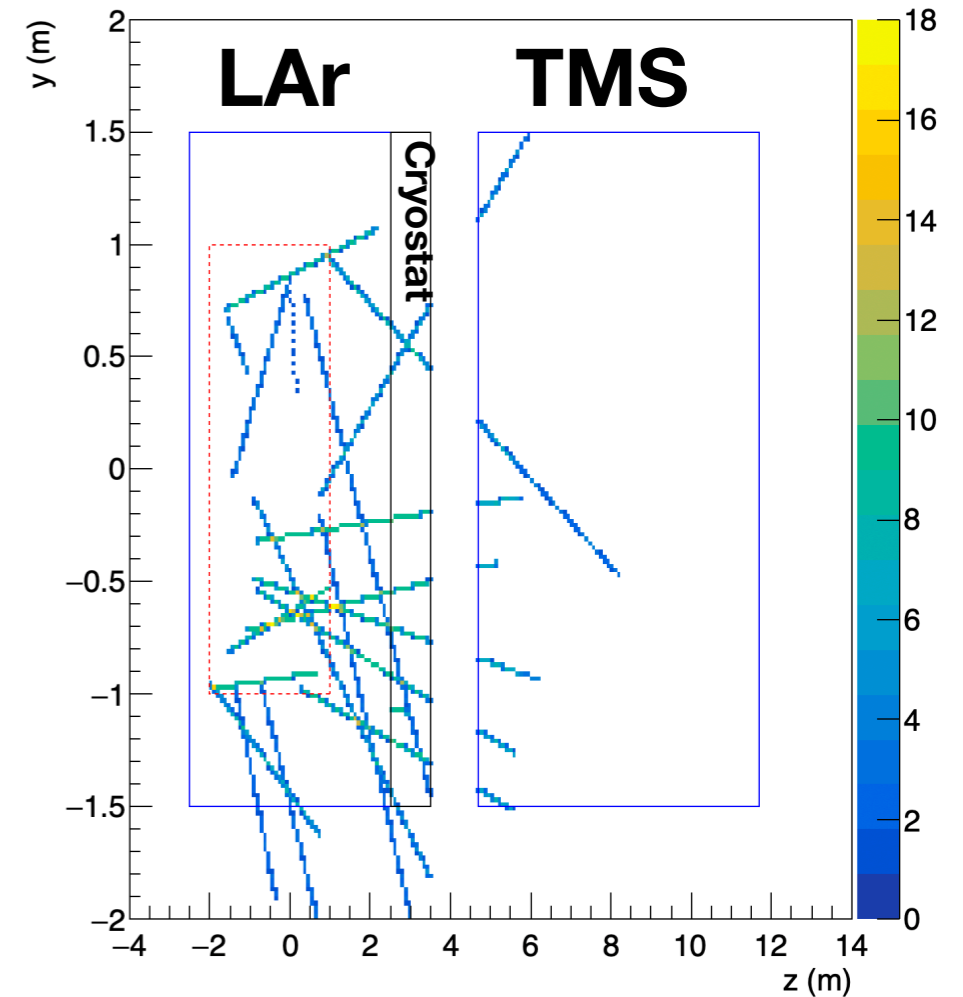
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# Introduction

- Beam angle: downward at 101 mrad.
- Change of muon acceptance in TMS by moving y position.
- Toy simulation:
  - Muon ( up to 5 GeV) vertex in LAr fiducial volume.
  - Pick  $\theta_{\nu,\mu}$  and kinetic energy of muon.
  - Random azimuthal angle between 0 and  $2\pi$ .
  - For the cryostat, assume 1m depth from active volume of LAr with 60g/cm<sup>2</sup>.
  - Check the where the muon stop.

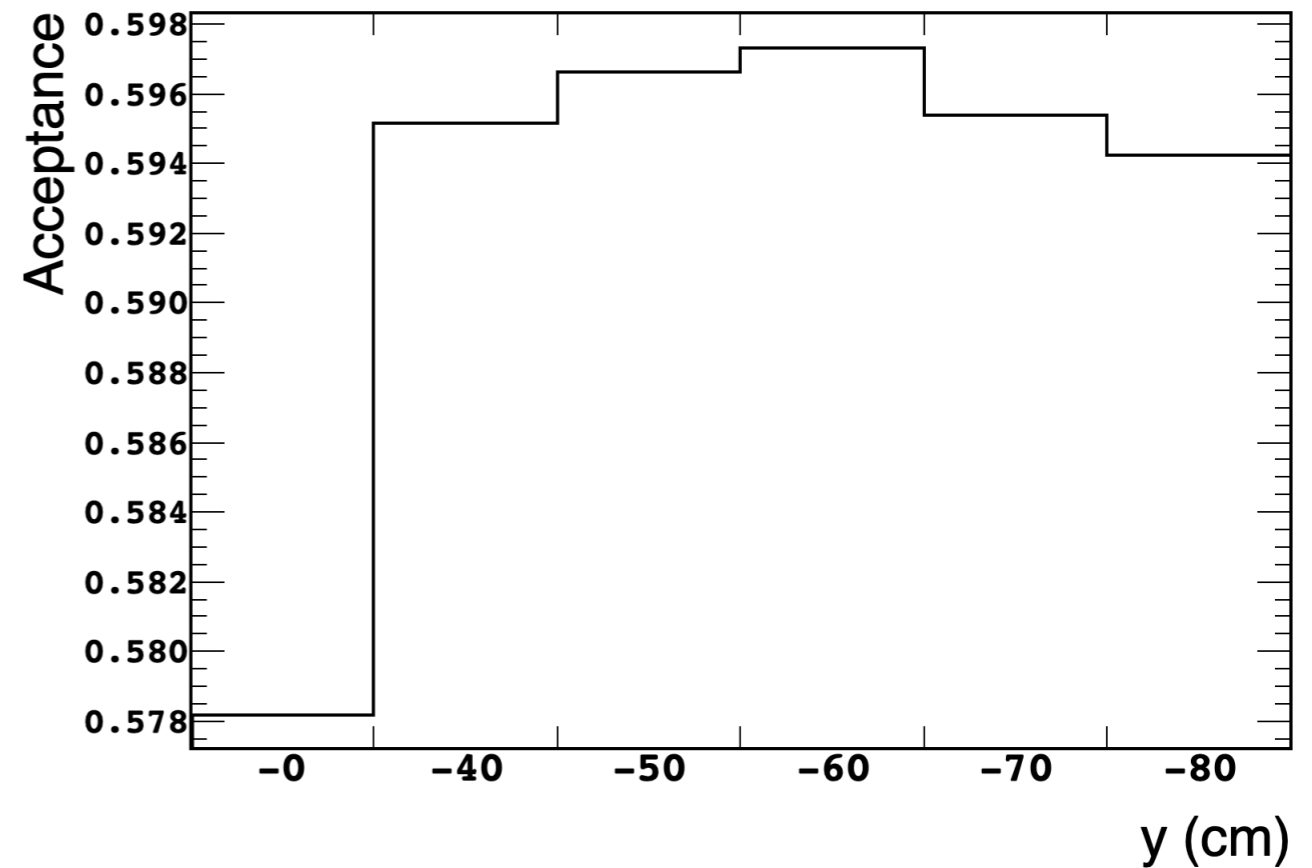
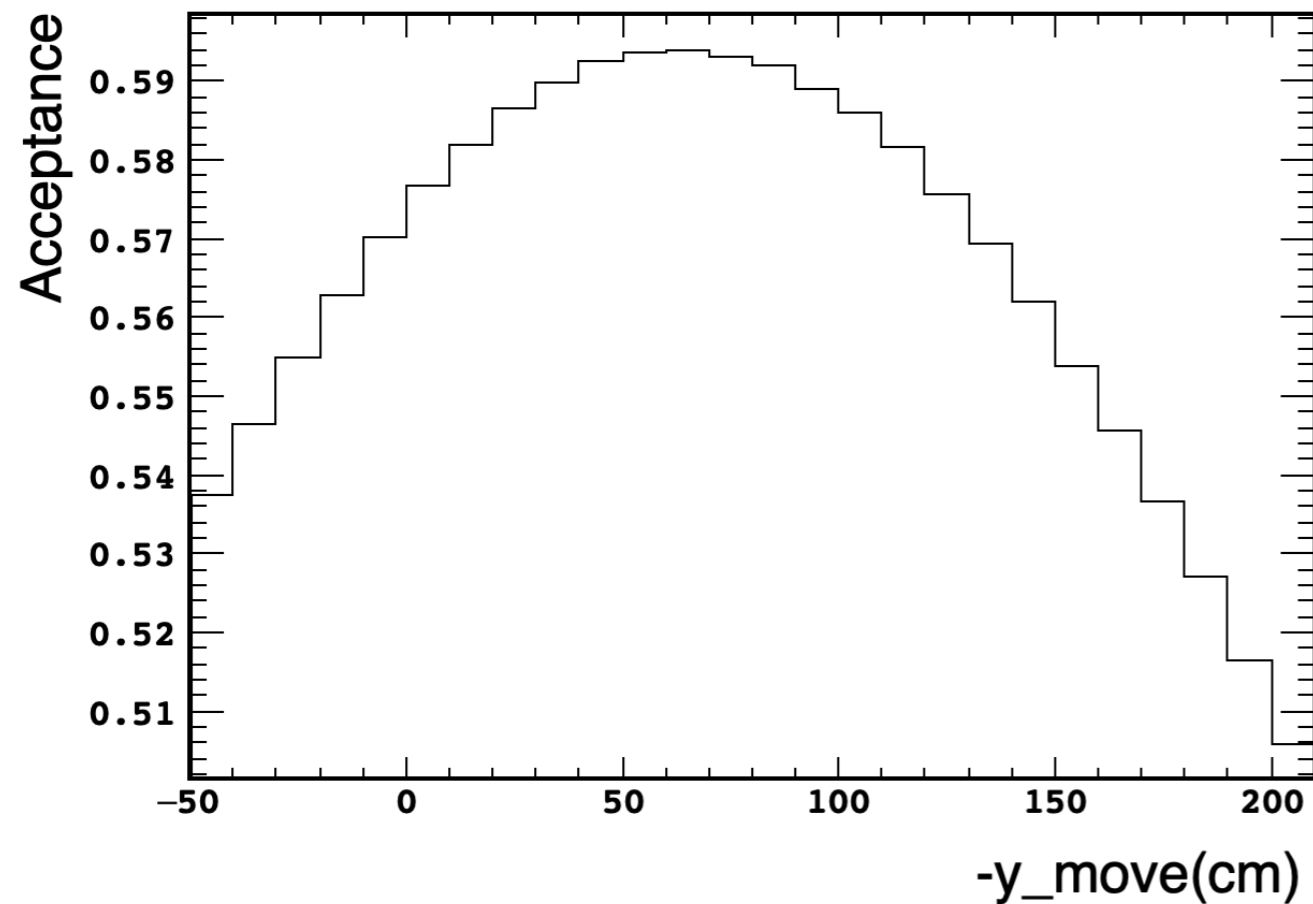


- LAr dimensions (cm): X (-350, 350), Y: (-150, 150), Z: (-250, 250).
- Fiducial volume of LAr : X (-300, 300), Y: (-100, 100), Z: (-200, 100).
- Cryostat dimension= (X: (-500, 500), Y: (-340, 340), Z: (250, 350).
- TMS dimensions (cm) : X: (-350, 350), Y: (-150, 150), Z: (500, 1140).



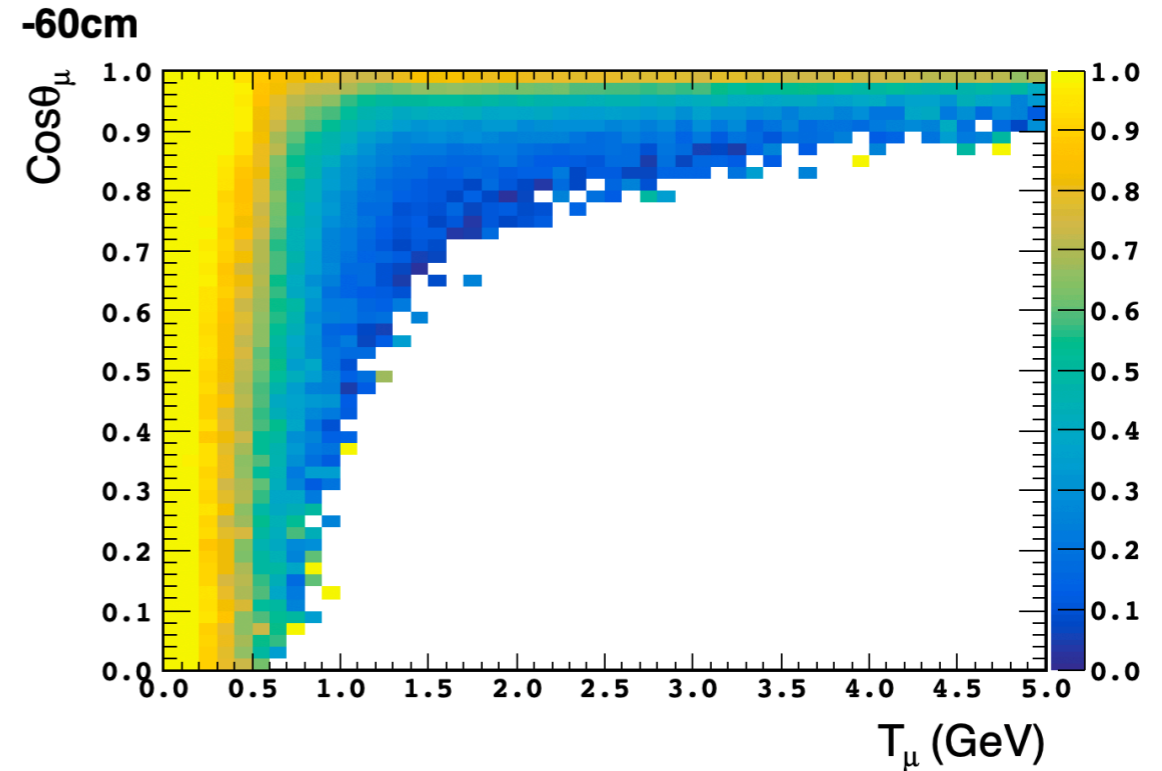
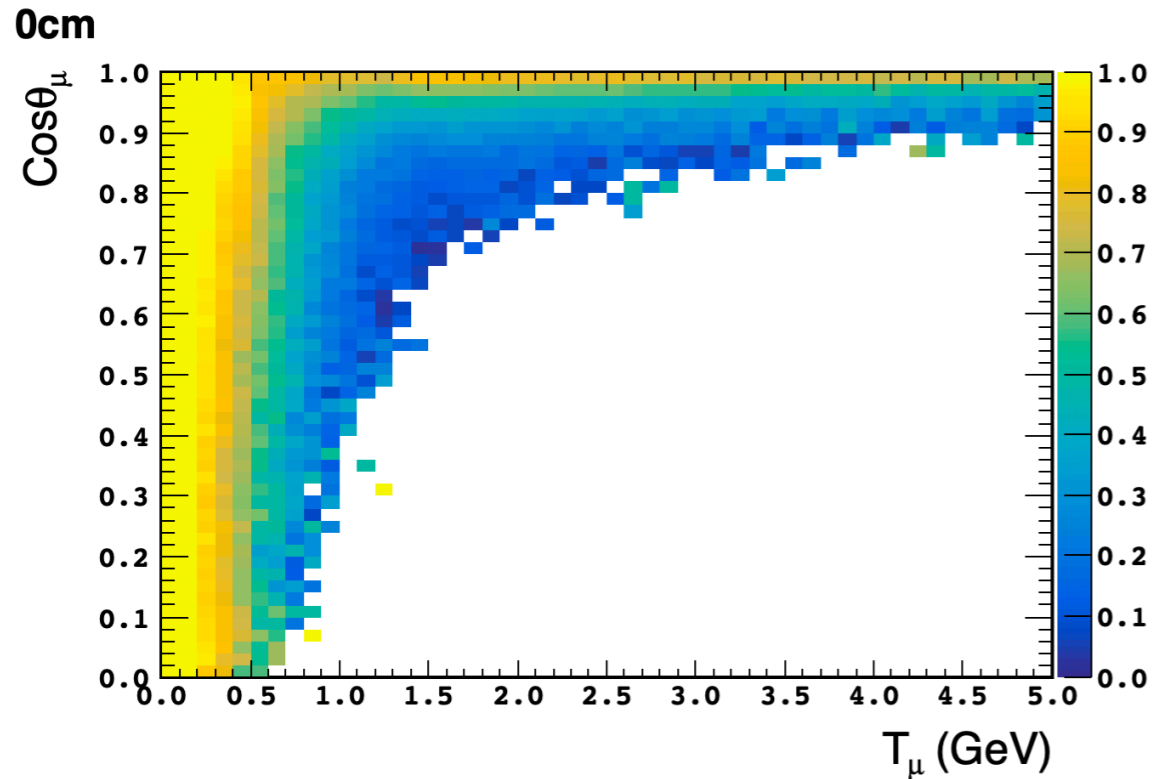
# Acceptance in TMS+LAr

## LAr+TMS Muon Acceptance

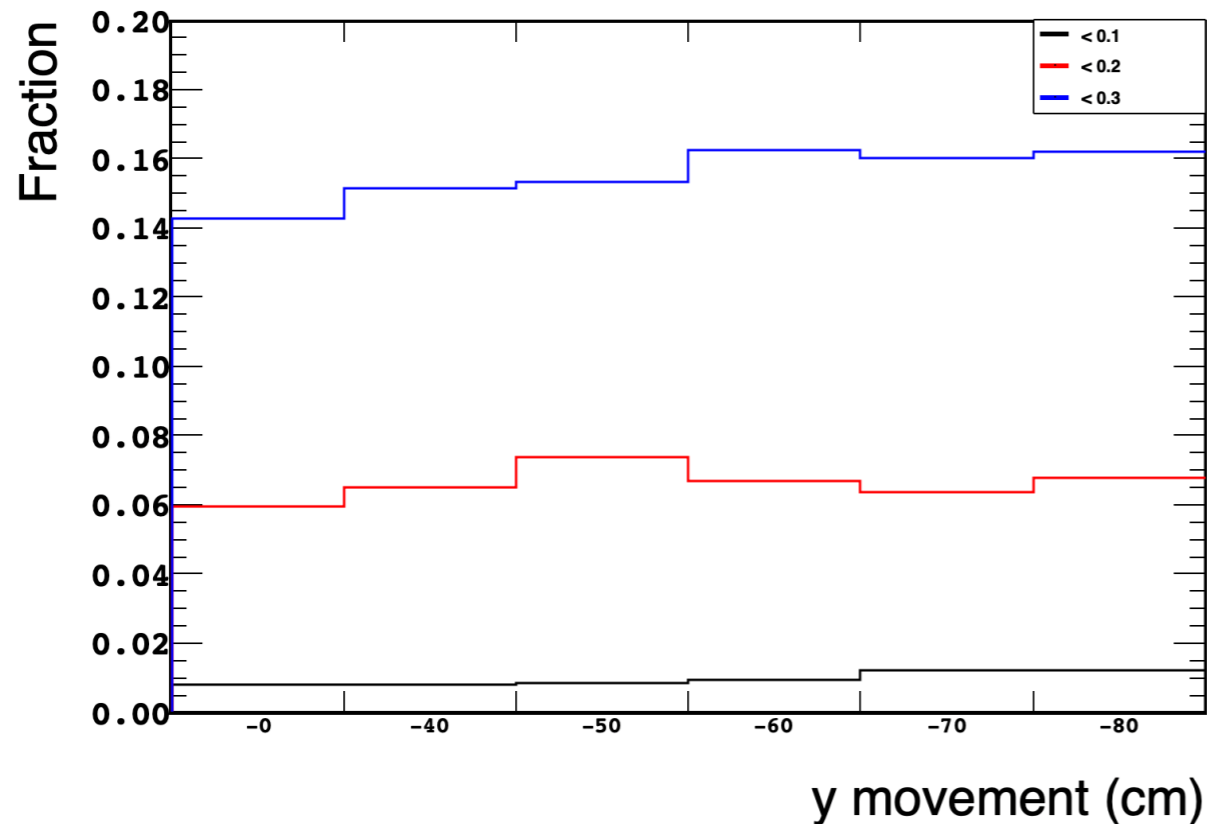


- 0cm means the center of the TMS lines the LAr's center on the y-axis.
- Moving TMS around -60cm increases the acceptance by about 2% more.
- Now, in TMS.gdml, the y position difference between the center of TMS's scintillator and the active LAr is around -1m.

# Phase space check



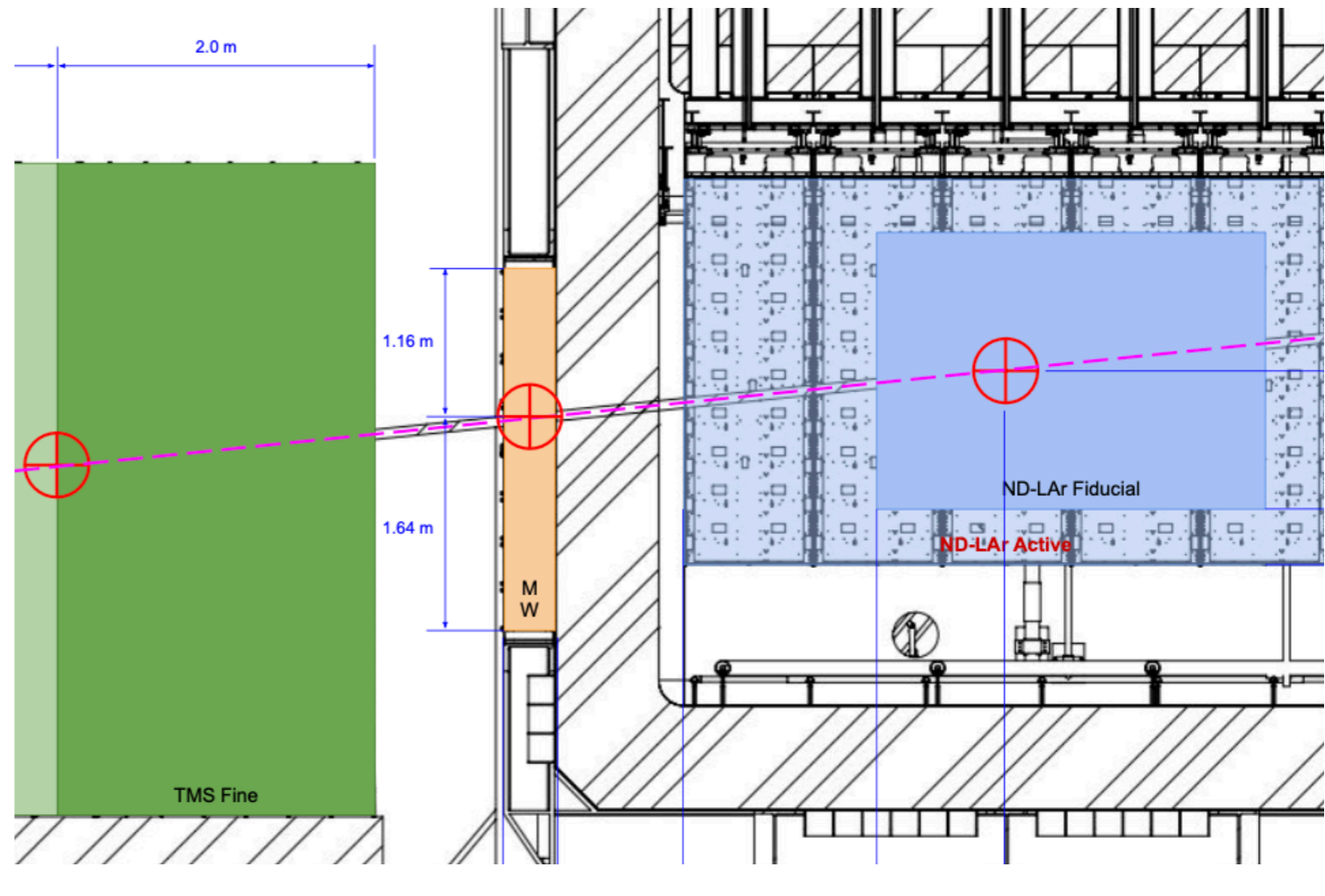
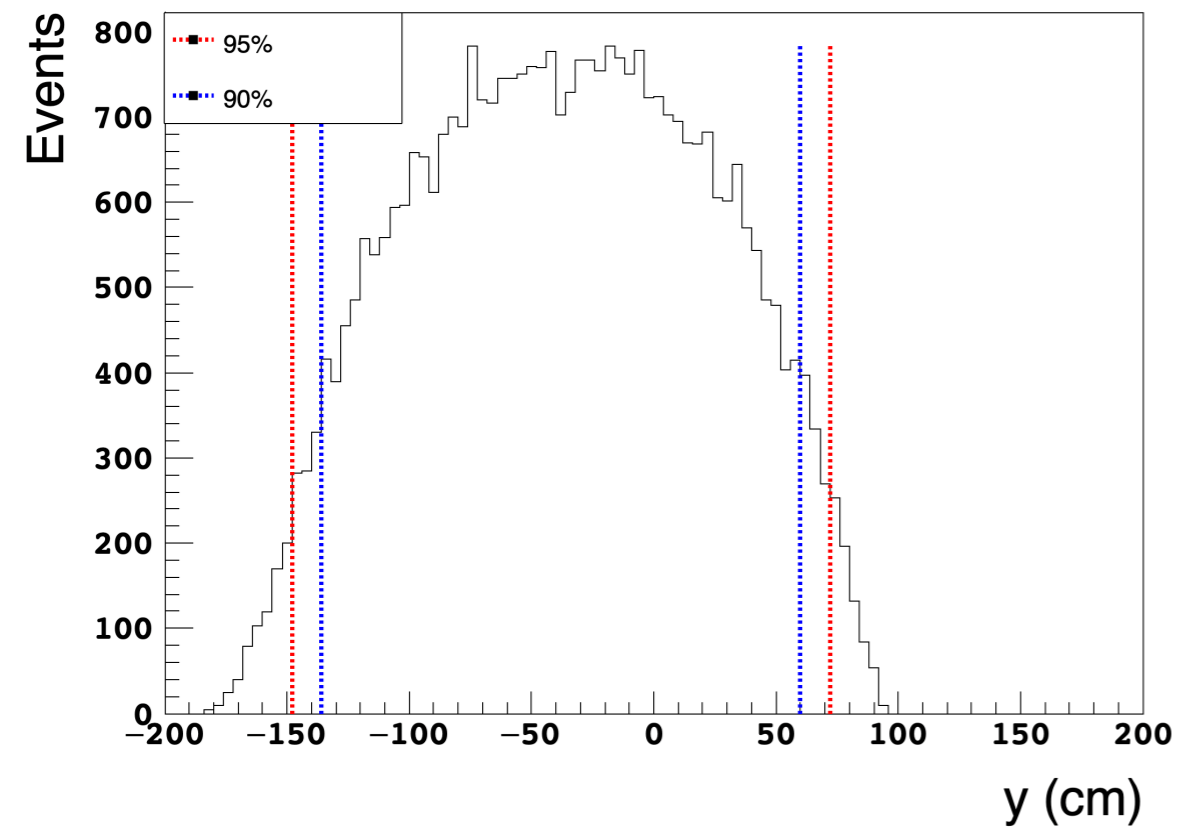
## Muon fraction, acceptance <



- We scanned all the bins that have acceptance below 0.1, 0.2, 0.3 in angle vs E. The muon fraction difference between 0 cm and -60cm is ~2% for the bin which has acceptance < 0.3.

# $\mu$ stopped in TMS through the window

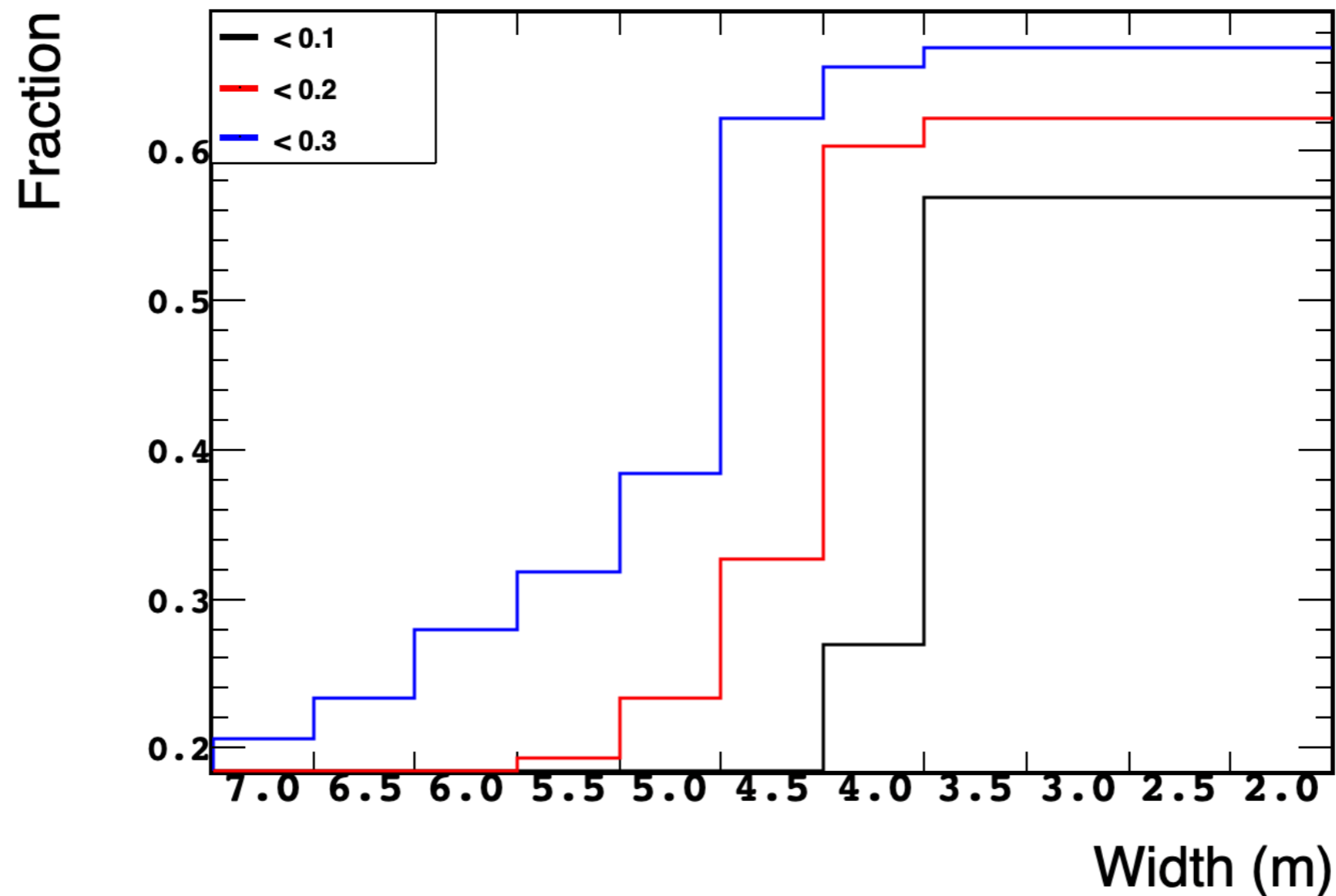
- TMS's center on -60 cm



- Muon window (-2.0 m, 1m) can cover the whole of muon stopped in TMS when the TMS's y position is on -60cm, which is consistent with design.

# TMS width

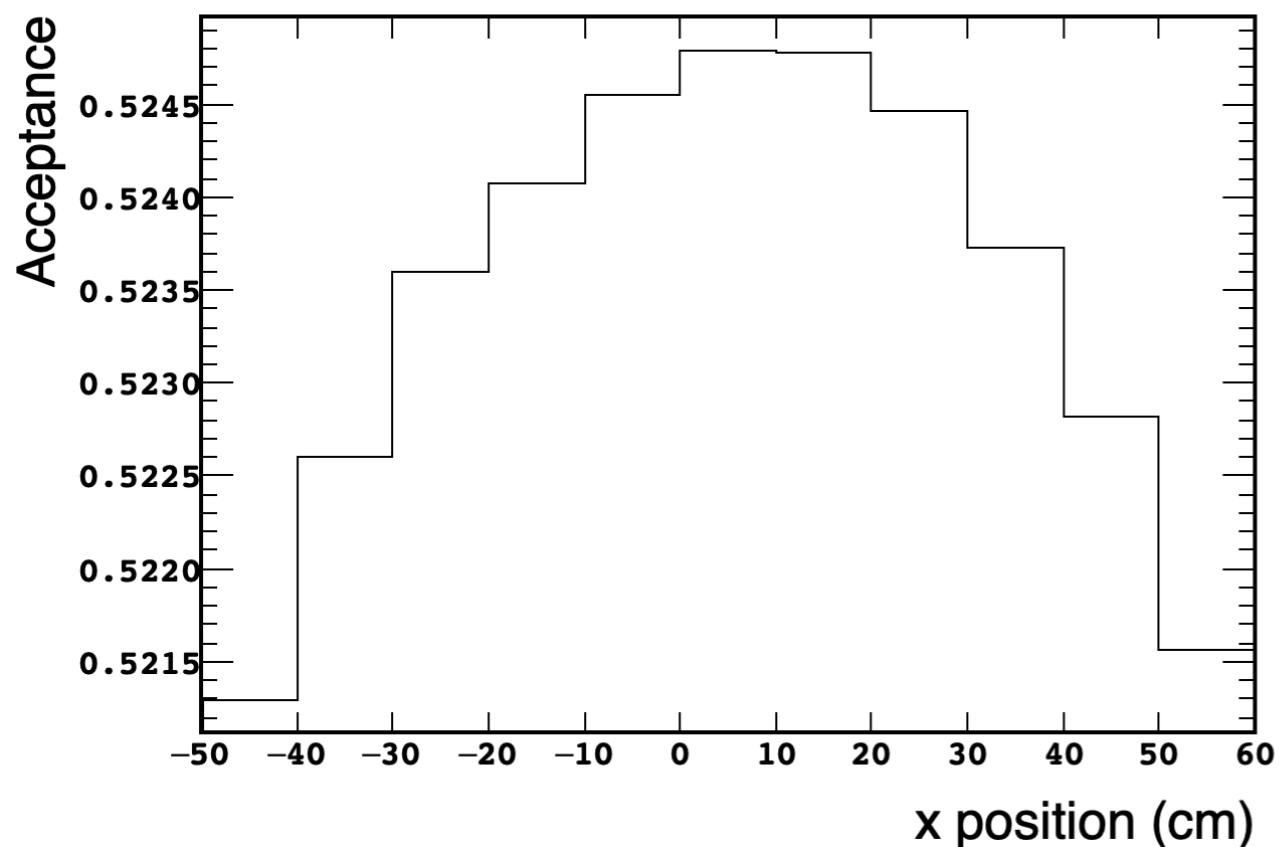
Muon fraction, acceptance  $\leq$ , w/ width



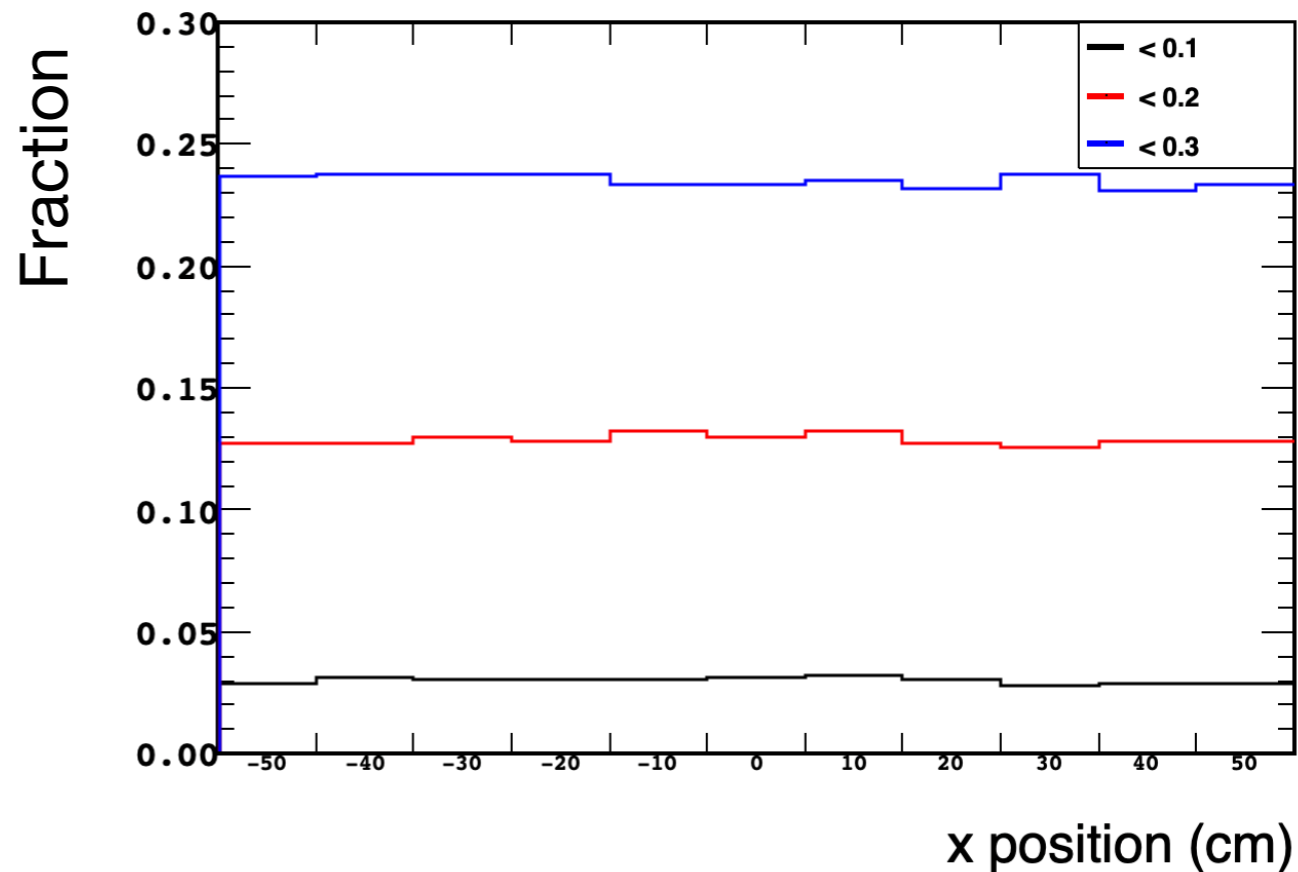
- Phase loss is significant when the TMS width is reduced to 4m and 5m.
- After 3.5m width, the phase loss is flat.

# TMS x position

y at -60.0 cm with 6m width

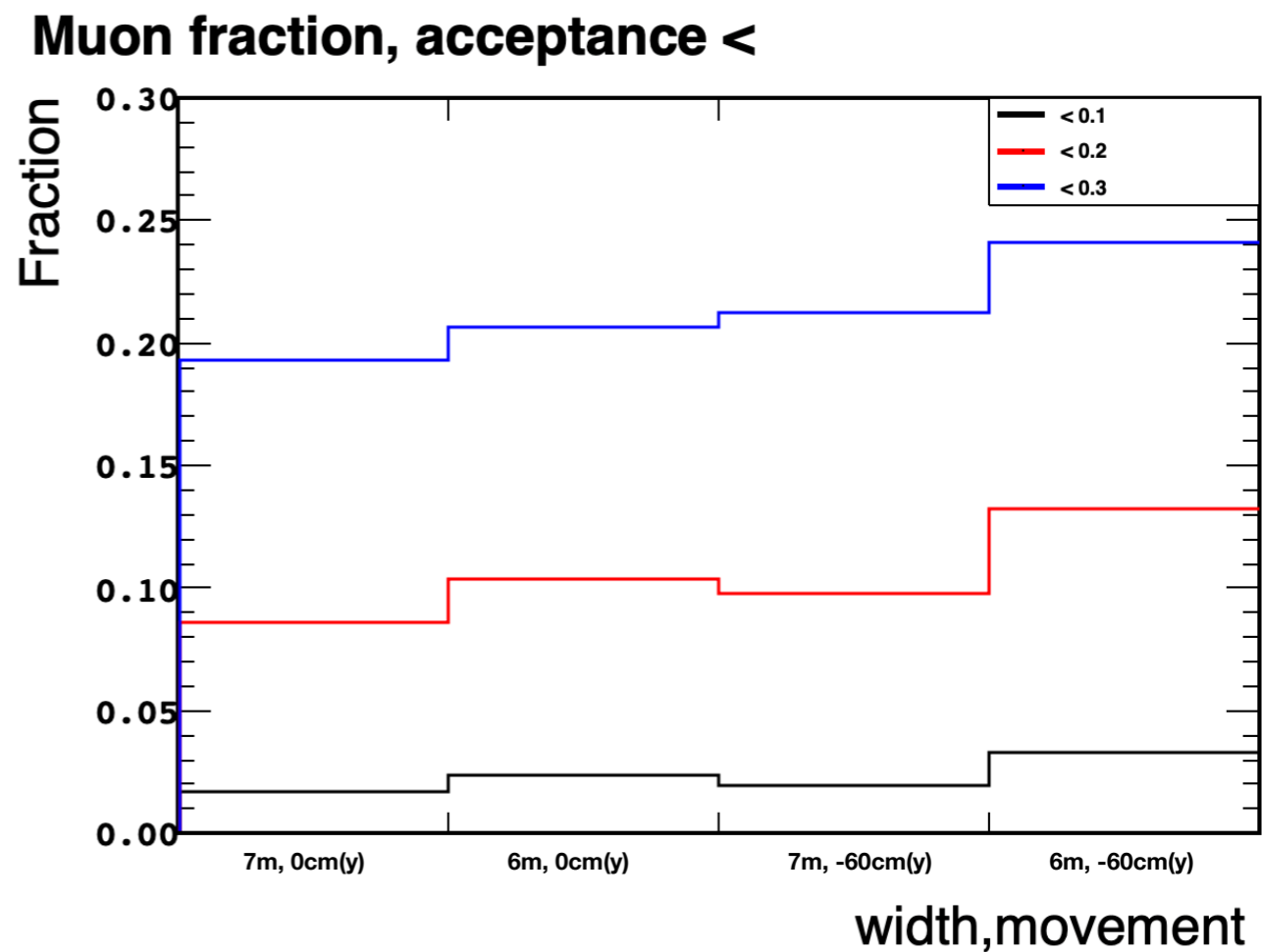
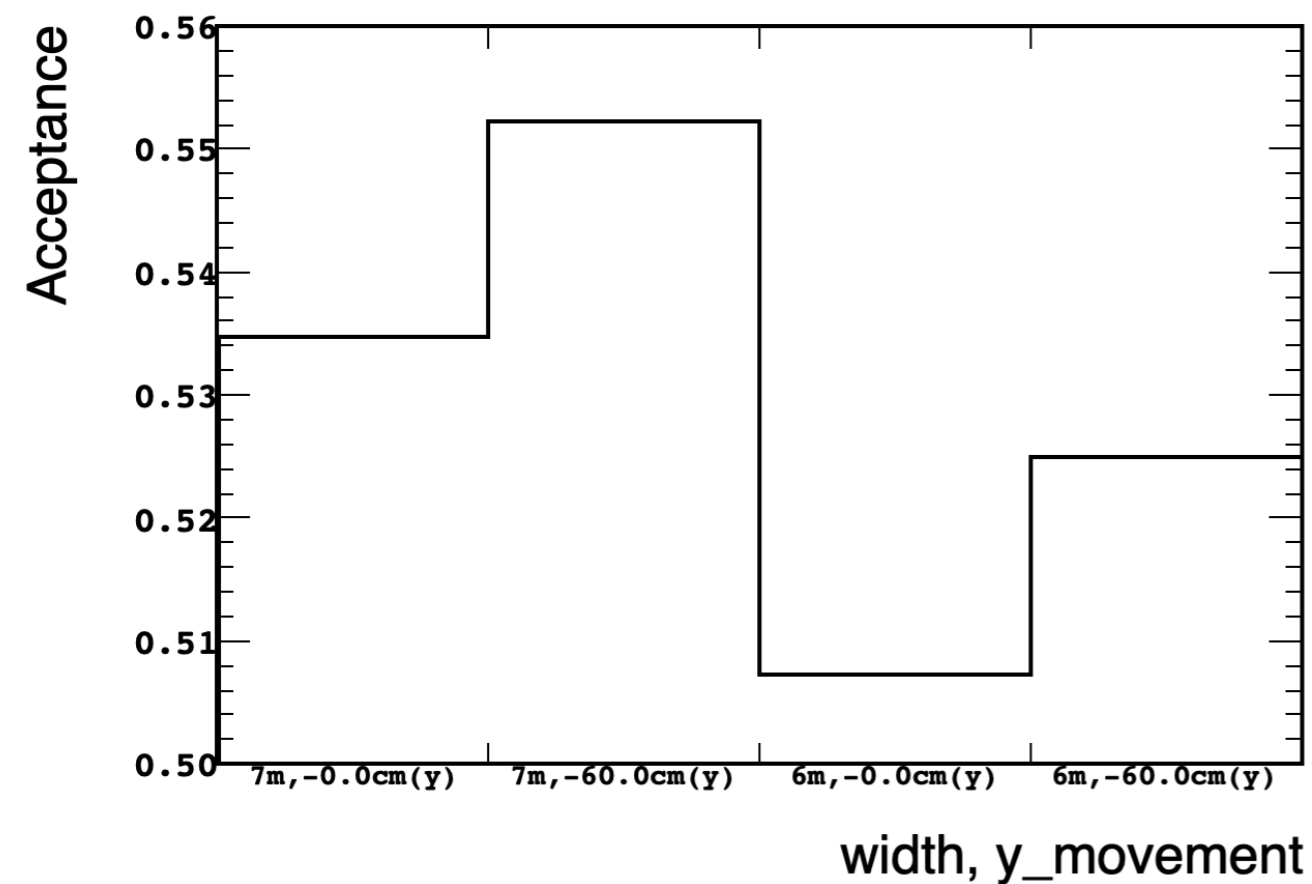


Muon fraction, acceptance < y at -60.0 cm w/ 6m width



- X position of TMS doesn't give any change in acceptance and muon fraction loss.

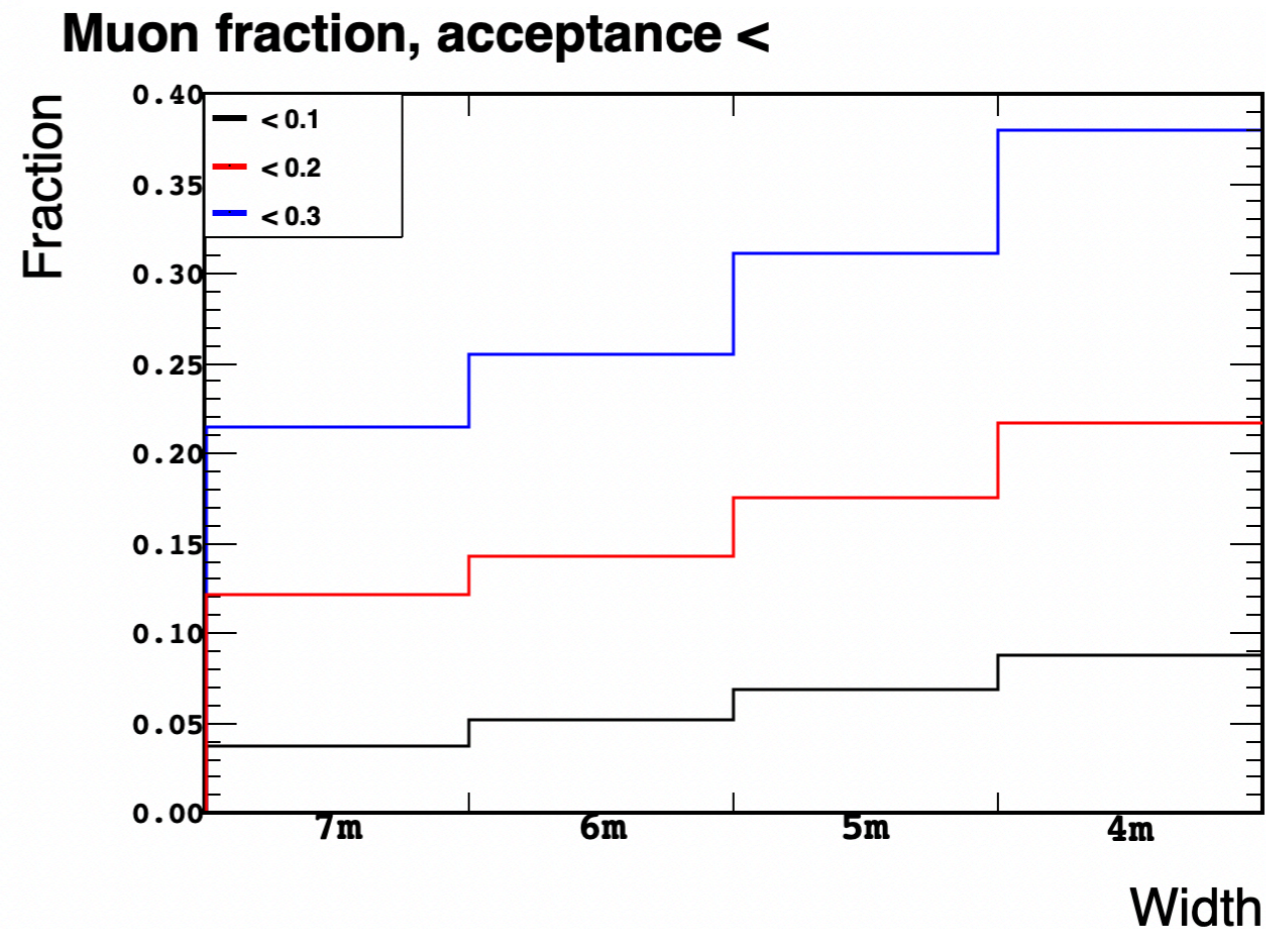
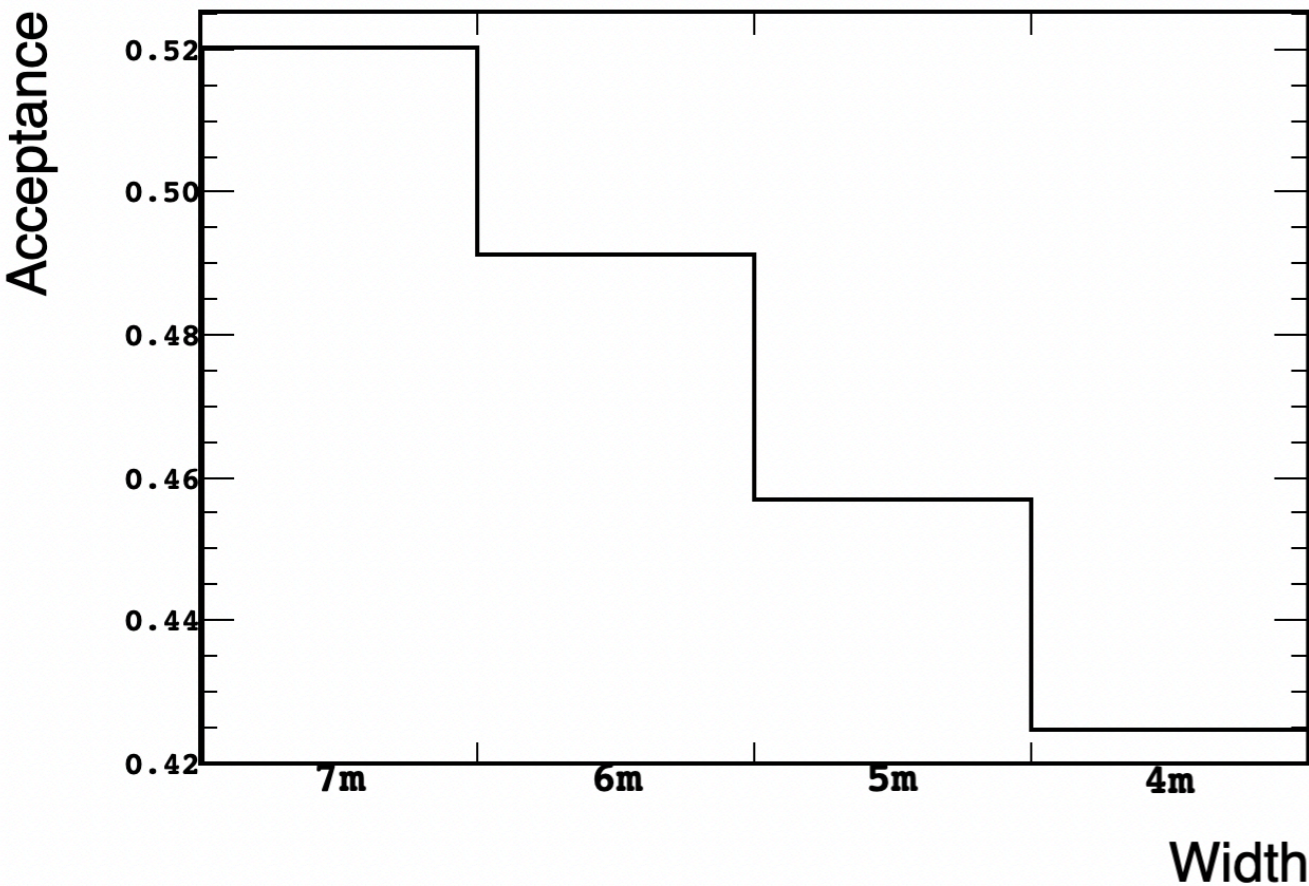
# TMS's width and height



Width, height	7m, 0cm	7m, -60cm	6m, 0cm	6m, -60cm
Acceptance	53.5%	55.2%	50.7%	52.5%
$\mu$ Fraction (0.1, 0.2, 0.3)	(1.8%,8%,19%)	(1.9%,9%,21%)	(2.1%,11%,20%)	(3.5%,13%, 24%)

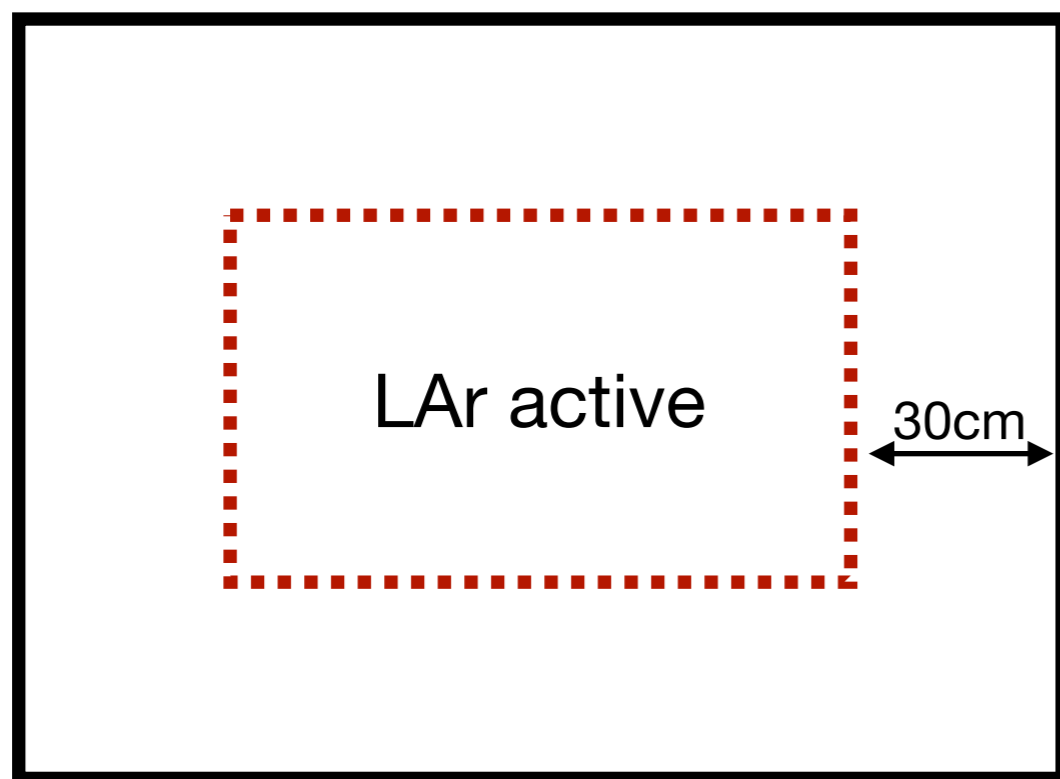


# TMS width result from edepsim

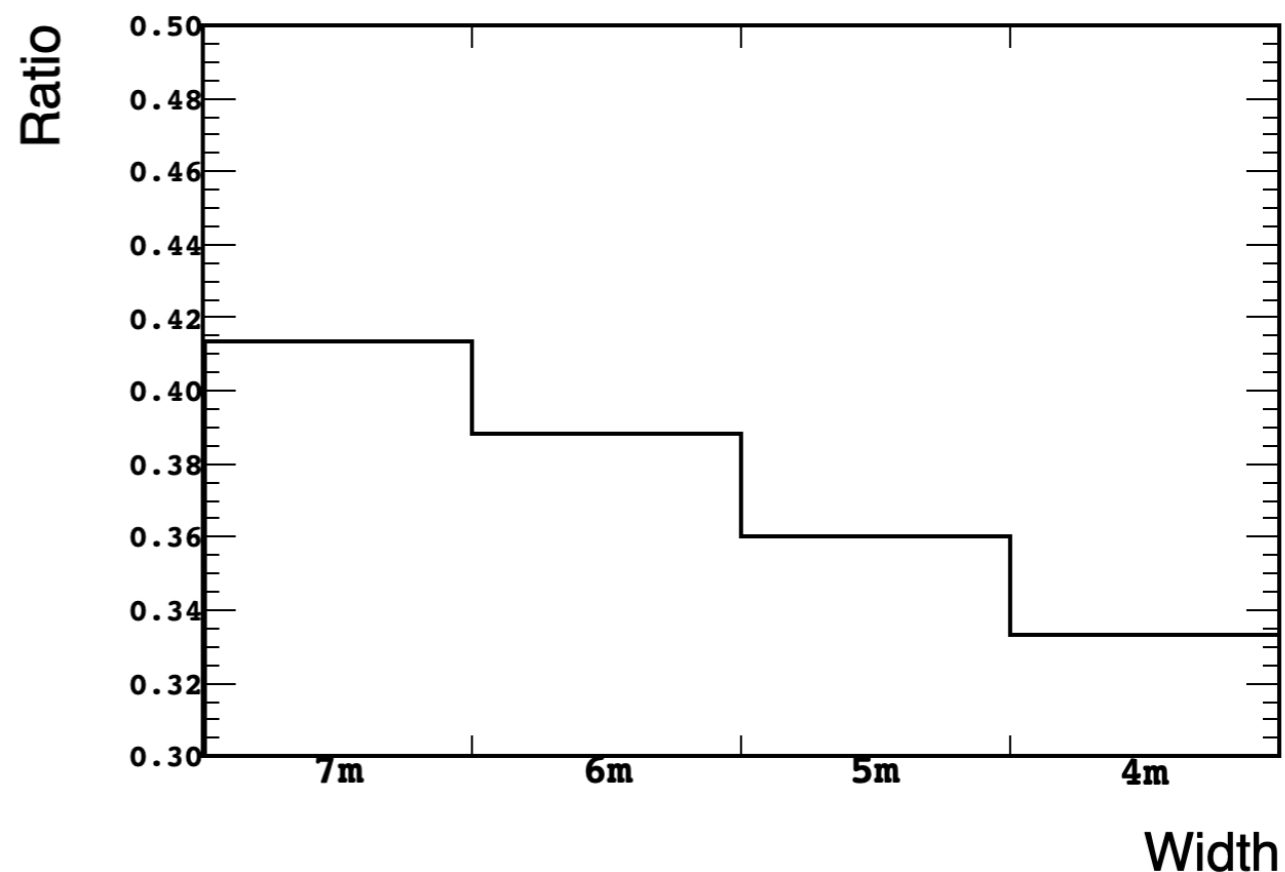


Width	7m	6m	5m	4m
Acceptance	52%	49%	45%	42%
$\mu$ Fraction (0.1, 0.2, 0.3)	(4%,12%,21%)	(5%,14%,26%)	(7%,18%,31%)	(8%,22%,38%)

# Hadron & muon acceptance



Hadron containment when the muon accepted

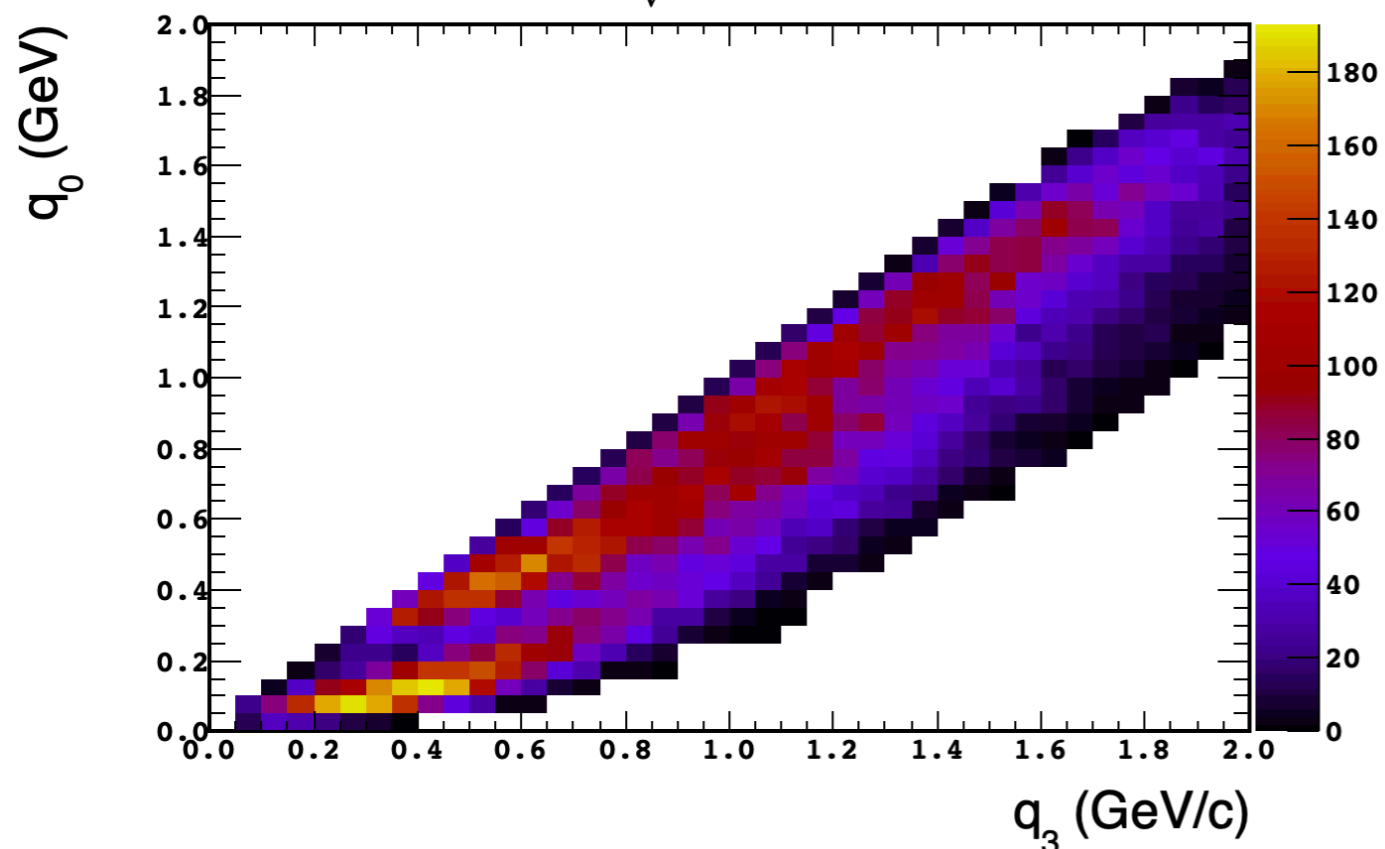


- Collect the hadron's deposit energy in outmost 30cm of active LAr region.  
if E deposit <30 MeV, hadron is contained in LAr.

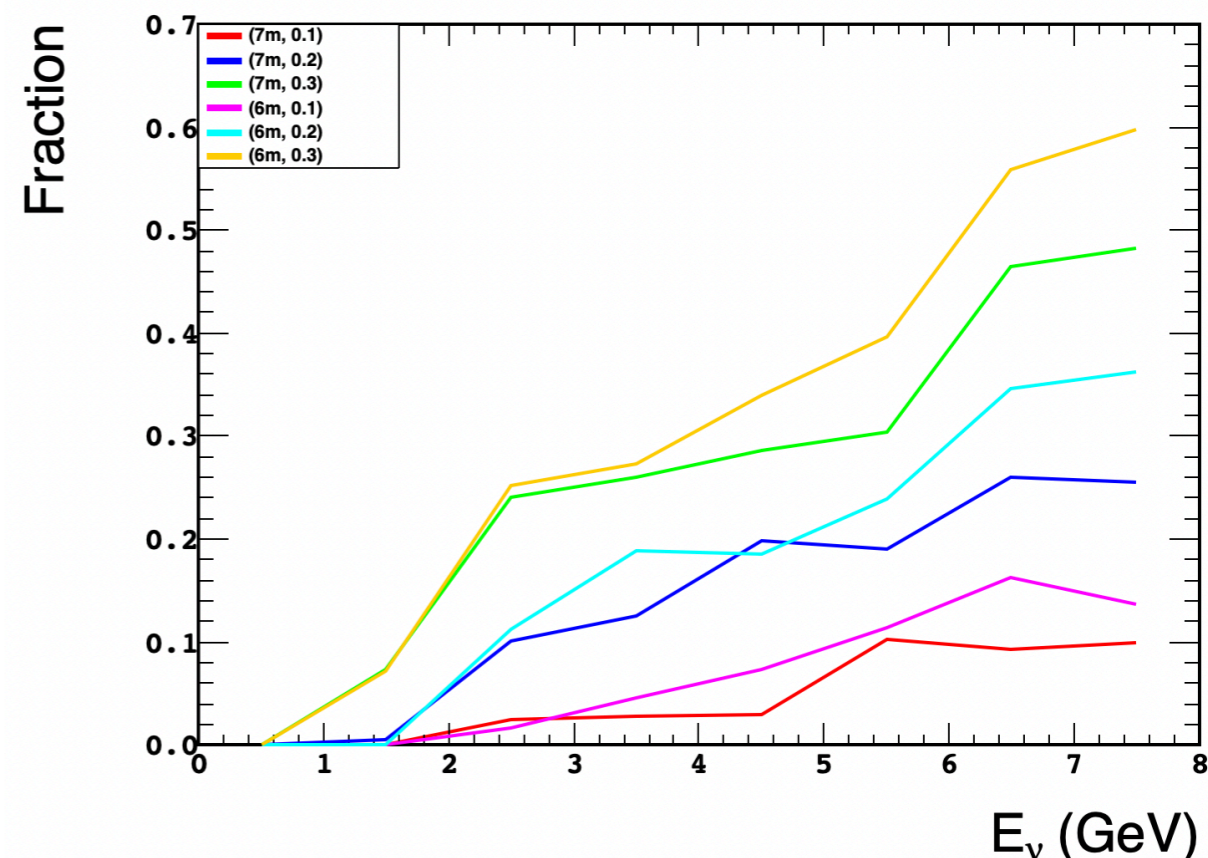
Width	7m	6m	5m	4m
Hadron acceptance ratio	41%	38%	36%	33%

# Phase space check for hadron & muon acceptance

Events 7m width,  $1 < E_\nu < 2$



Hadron fraction, acceptance  $\leq$ , 7m and 6m Width



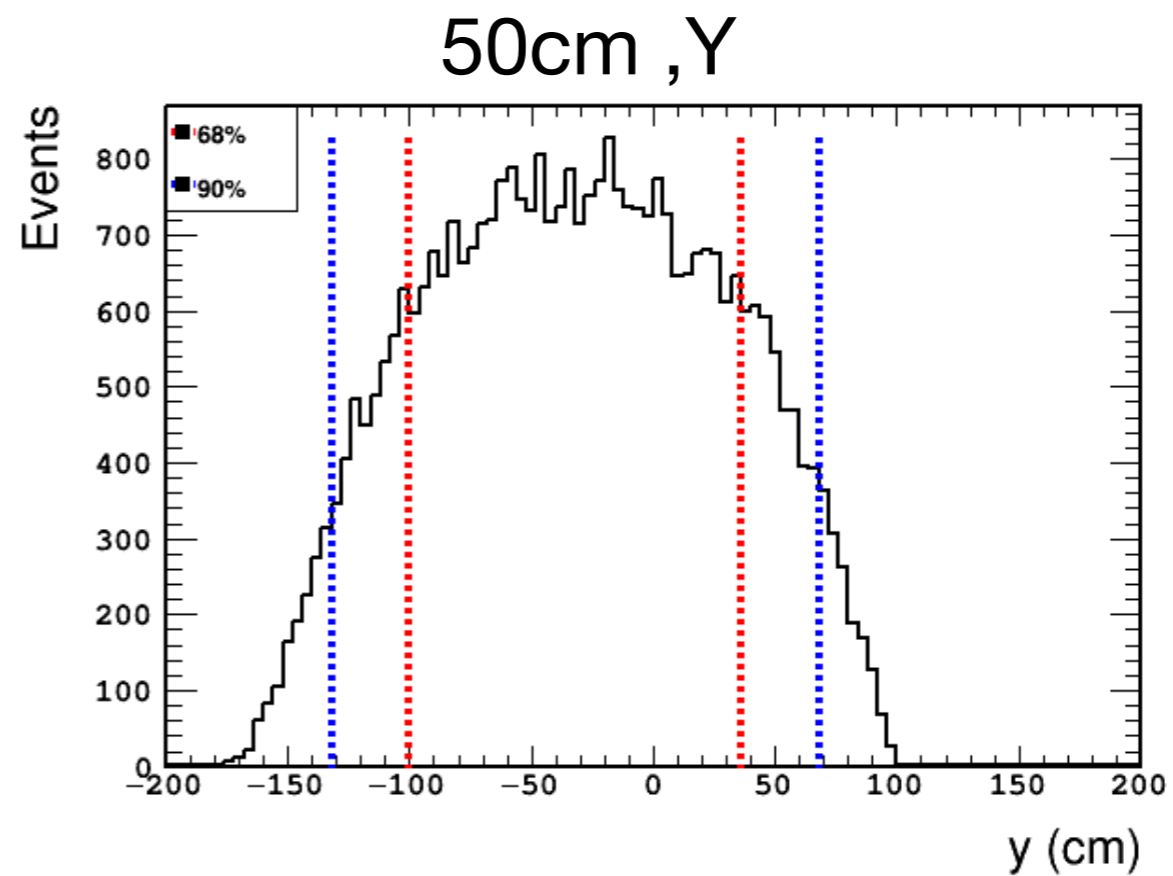
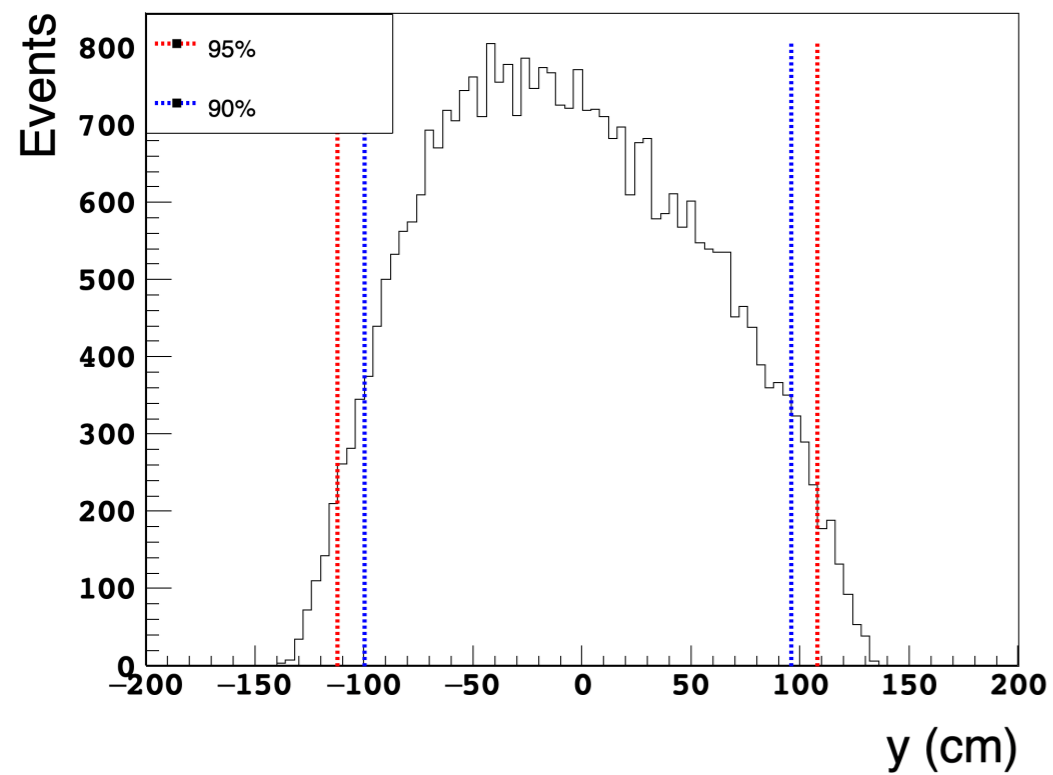
- Like before, we scanned all bins in  $q_3$  vs  $q_0$  region.
- At the neutrino energy (2 GeV, 3 GeV), the hadron fraction is less than 1% difference for every acceptance.

# Summary

- We can get the muon 2% more comparing the position at 0 cm by adjusting the y position around -50~80 cm.
- The Muon window from -2m to 1m can cover the whole muon from LAr.
- Phase loss gets severe when TMS's width shrinks from 5m.
- The muon acceptance and muon fraction are steady after moving TMS' x position.
- The phase loss of Hadron and muon containment between 7m and 6m width doesn't have a big difference at the neutrino peak region.

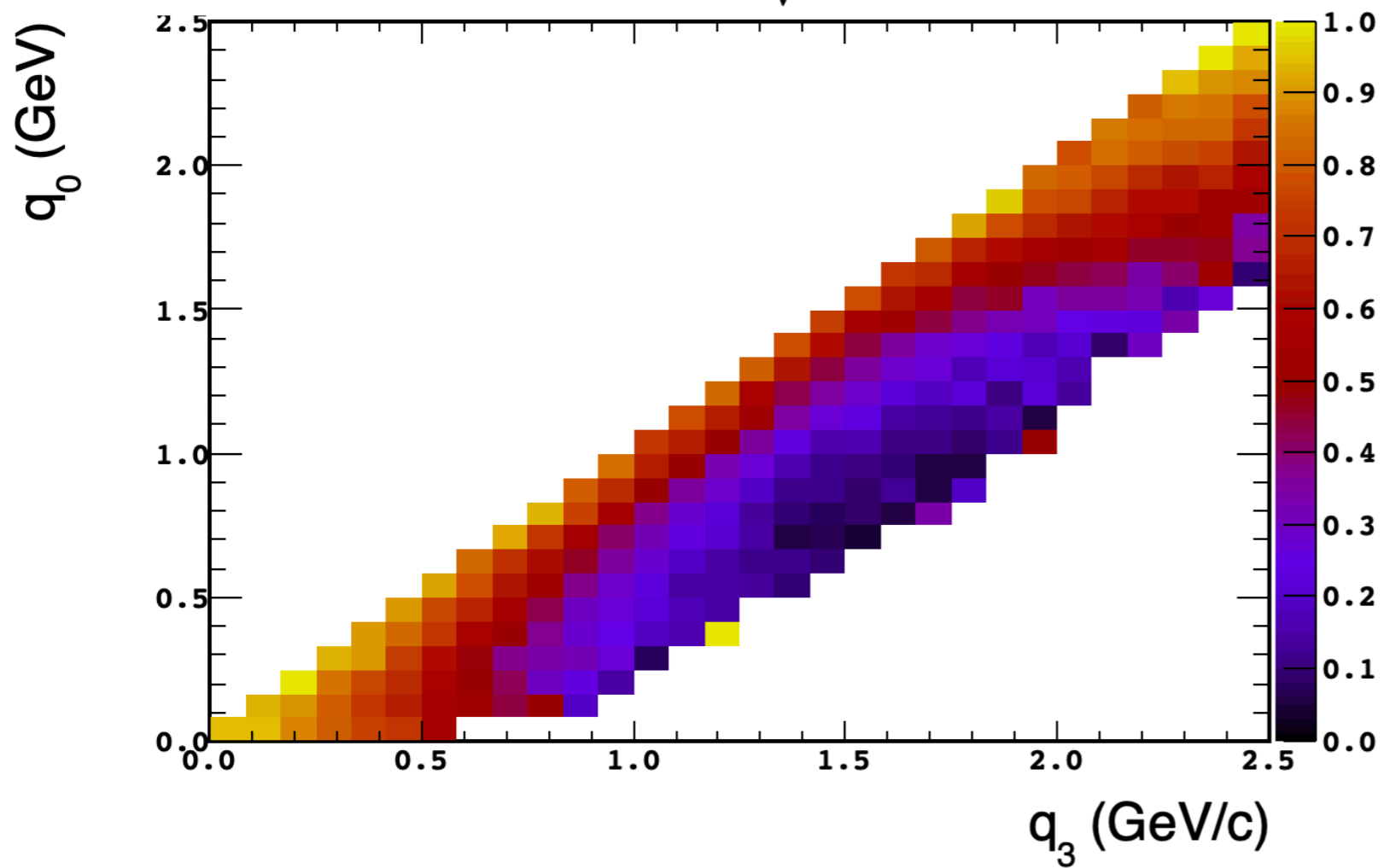
# Backup

- TMS'center on 0 cm



# Backup

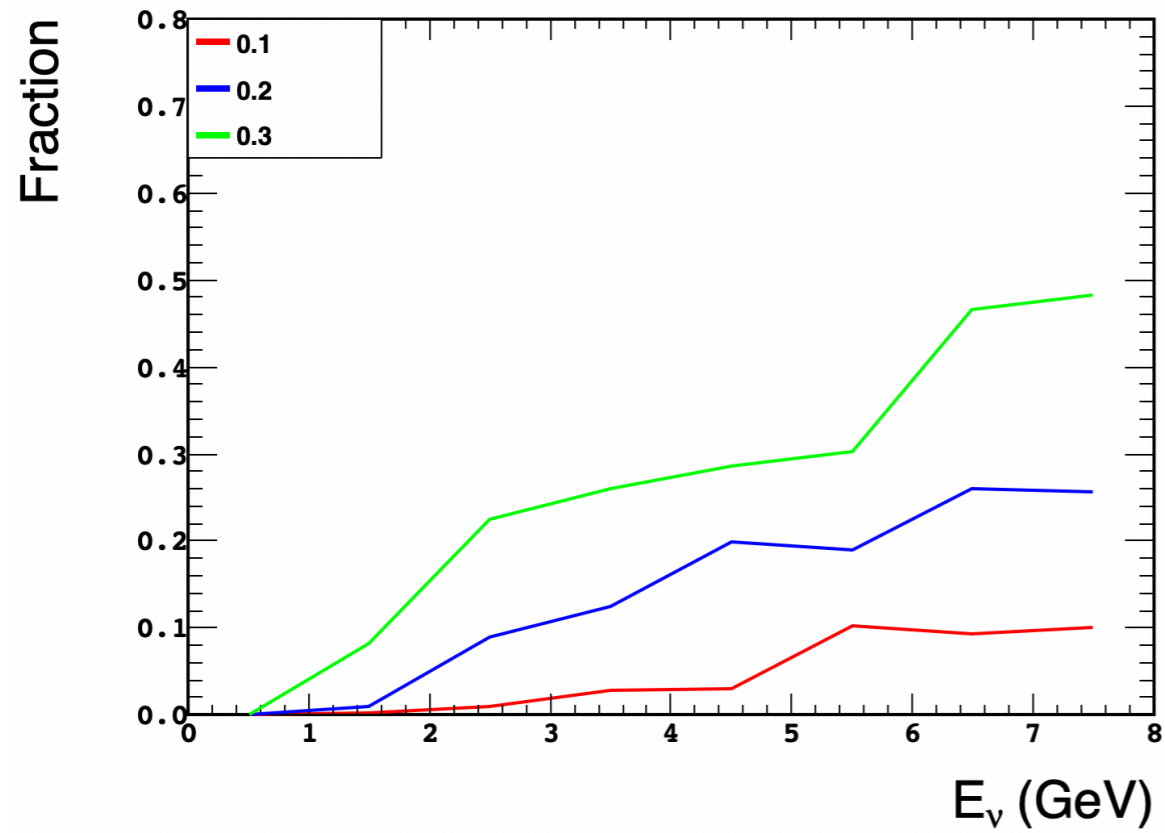
Acceptance 7m width,  $2 < E_\nu < 3$



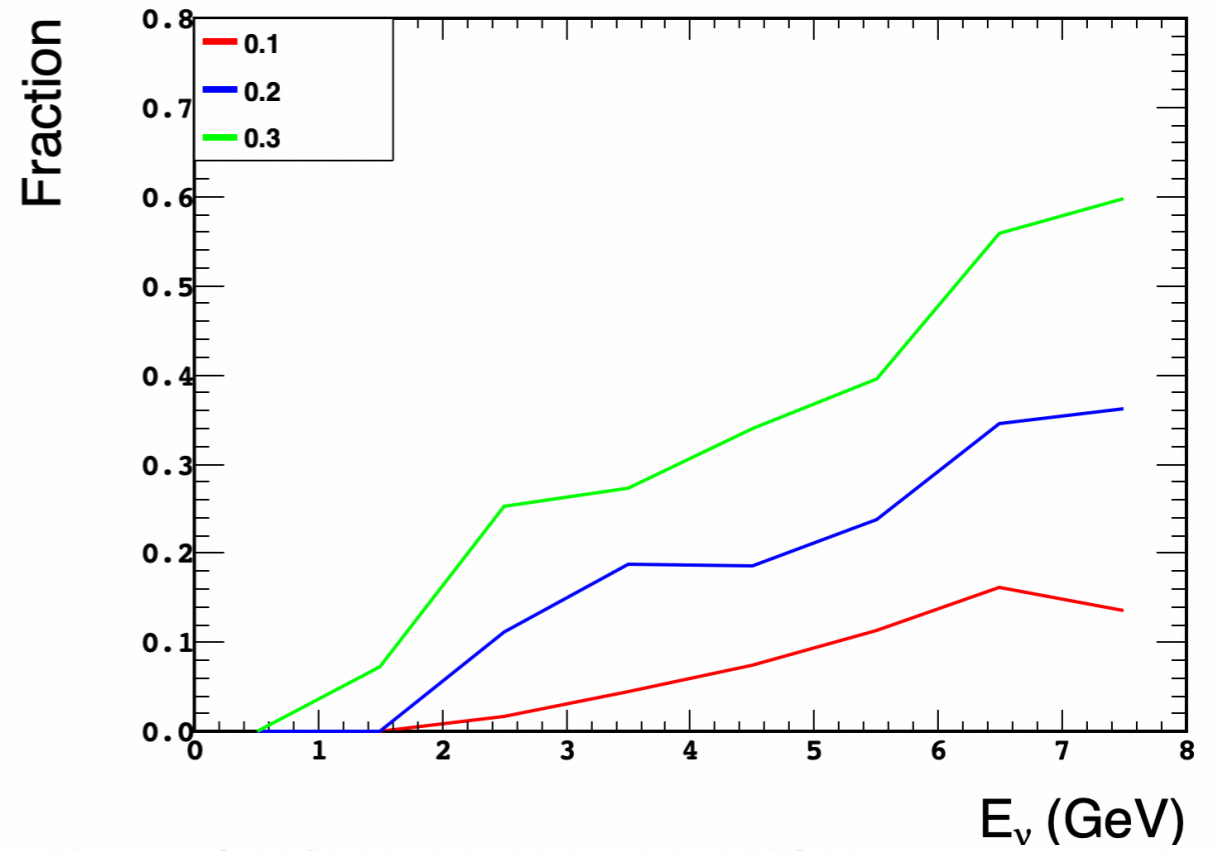


# Backup

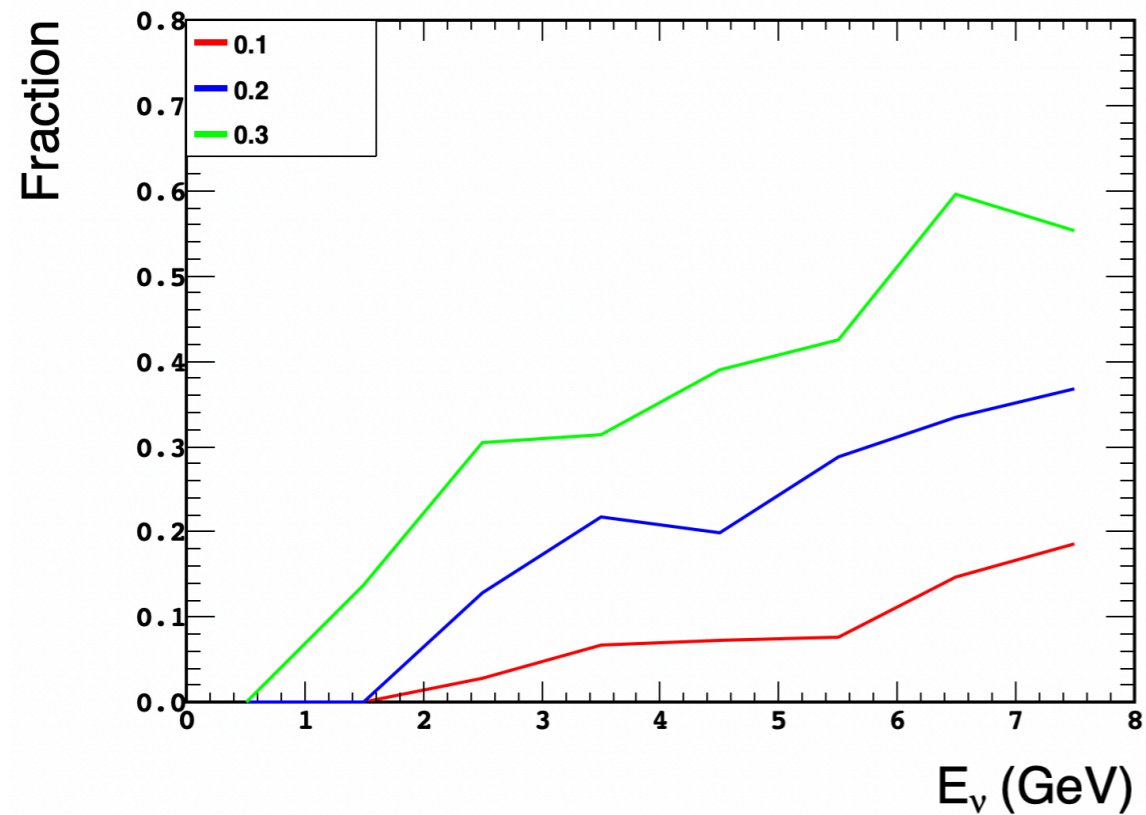
Hadron fraction, acceptance  $\leq$ , 7m Width



Hadron fraction, acceptance  $\leq$ , 6m Width



Hadron fraction, acceptance  $\leq$ , 5m Width



Hadron fraction, acceptance  $\leq$ , 4m Width

