ND-GAr Acceptance Studies

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ND-GAr Meeting

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Imperial College London

DUNE

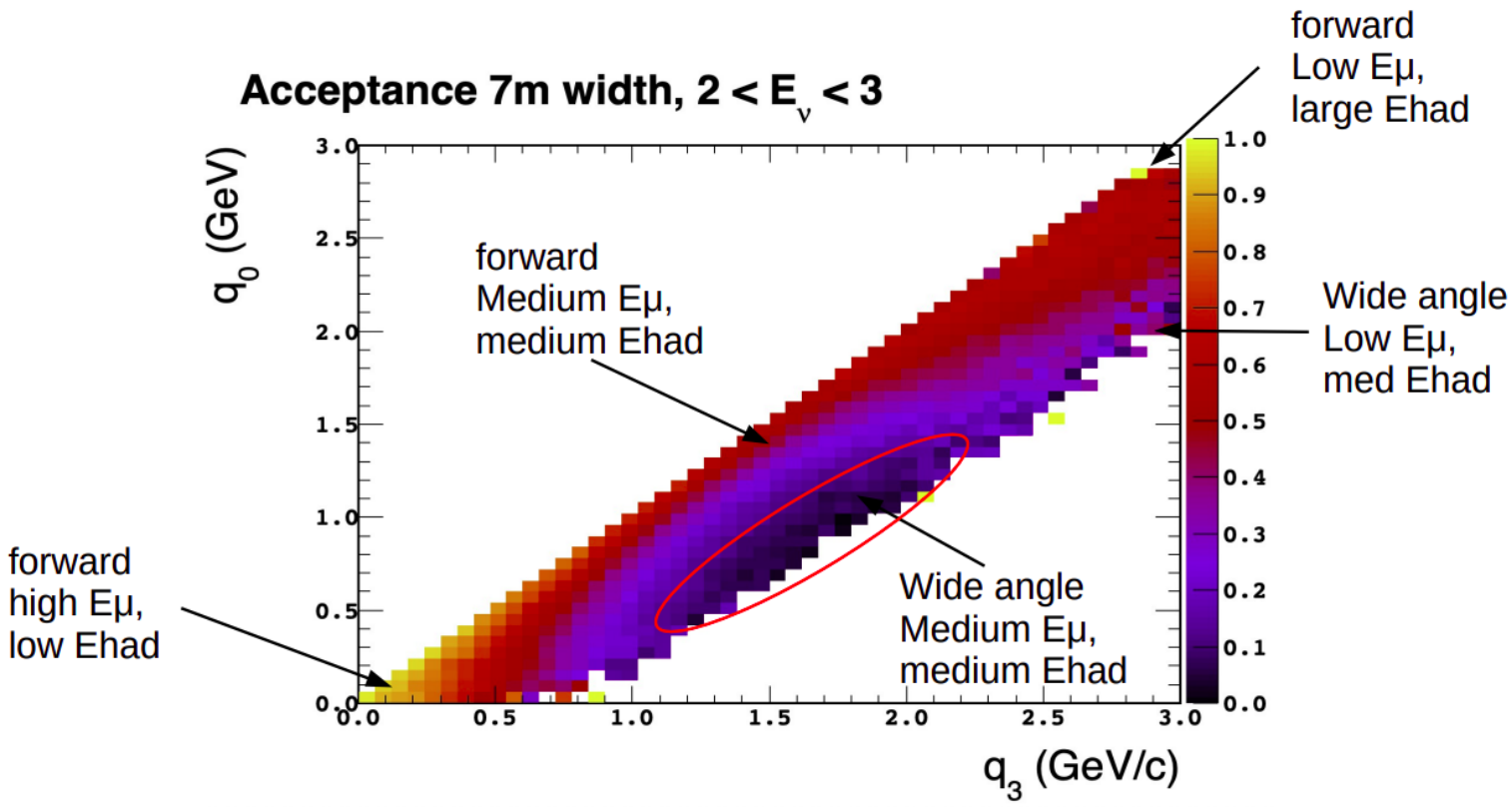
Motivation

- Chris Marshall's talk
  - FD has 4π acceptance, so ND needs to measure neutrino interactions over the full 4π to match the FD
  - Need to ensure the full phase space has good acceptance so that a reliable correction can be applied
  - However, some regions have very small, or zero, acceptance with ND-LAr + TMS.
  - Events are classed as "accepted" in ND-LAr+TMS if:
    - Hadrons are contained in ND-LAr
    - Muon stops in ND-LAr active volume or TMS instrumented region
  - Some events will be accepted if the vertex is in some region of ND-LAr but the same event can be rejected if it happens elsewhere
  - However, some events are not accepted no matter where the vertex is

Motivation

- Chris Marshall's talk
- Study by KiYoung Jung
  - Uses a full Geant4 Simulation of ND-LAr+TMS
  - Region in Q3 vs Q0 phase space that has very low acceptance
    - This is a "blind spot" for the ND

Looking at acceptance vs. q0/q3



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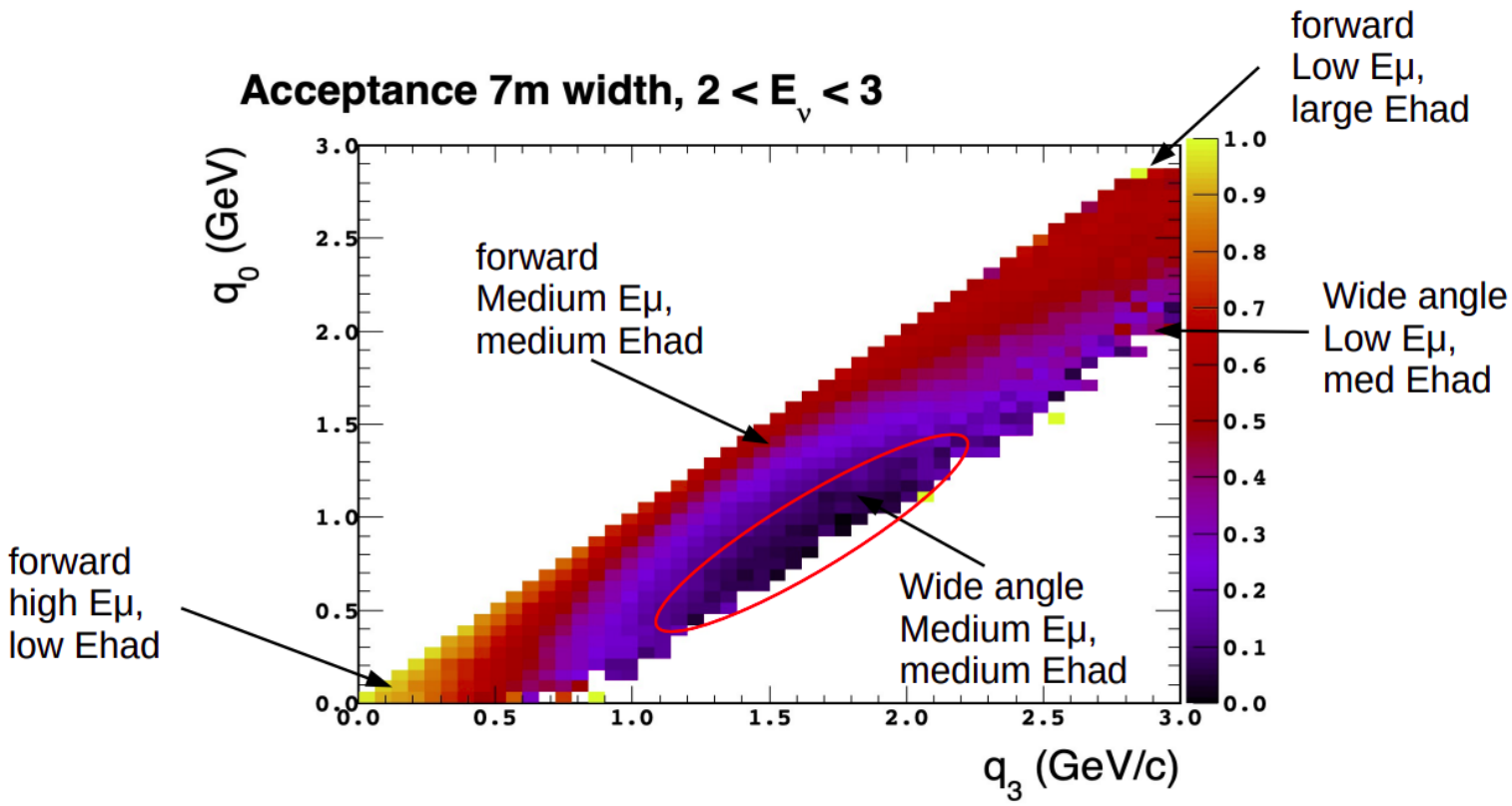
- Chris Marshall's talk
- Study by KiYoung Jung
  - Uses a full Geant4 Simulation of ND-LAr+TMS
  - Region in Q3 vs Q0 phase space that has very low acceptance
    - This is a "blind spot" for the ND
- **ND-GAr will have full 4π coverage**

Looking at acceptance vs. q0/q3



ND-GAr Acceptance Studies

- We want to know what requirements we can put on the design of ND-GAr in order to have a good acceptance in this region that ND-LAr will miss
- We will use the same assumptions as ND-LAr+TMS studies so it is a fair comparison
  - Use the Geant4 Simulation of ND-GAr with GENIE events
  - Using the 100k event sample
  - Using the G18 tune of GENIE

ND-GAr Acceptance Studies

- Define Acceptance as all tracks are either:
  - Contained
  - Better momentum resolution than 5% for any charged particles leaving the TPC
  - Assume Neutral Pions/Photons will be well reco'd in the ECAL
  - Ignore neutrons (as ND-LAr study has ignored these)
- Not accounting for any misreconstruction at the moment

Momentum Resolution Calculation

- For particles that do not stop in the fiducial volume, we can determine their momentum from track curvature
- Track must be long enough and curved enough to measure momentum with a 5% uncertainty
- Assuming a helix with fixed radius of curvature

$$\left(\frac{\sigma_p}{p}\right)^2 = \left(\frac{\sigma_{p_T}}{p_T}\right)^2 + \left(\tan(\lambda)\sigma_\lambda\right)^2$$

R. Kogler

- p is Total Momentum
- pT is Transverse Momentum
- λ is the dip angle of the helix

Momentum Resolution Calculation

- Transverse momentum resolution estimated from the Gluckstern Formula

$$\frac{\sigma_{p_T}}{p_T} \approx \sqrt{\frac{720}{N+4}} \left(\frac{\sigma_y p_T}{0.3 B L^2} \right)$$

C. Young

- N is the number of pixels a track goes through.
  - This is estimated using a pixel grid of 6mm x 6mm pixels.
- B is the magnetic field.
  - Set to 0.5 T , but will be varied and studied
- L is the length of the track in the transverse plane
  - Estimate the track as a circle in the transverse plane
- σy is the spatial resolution in the transverse plane (pixel spacing)

Momentum Resolution Calculation

- Dip Angle Resolution Estimation

$$\tan(\lambda) = \frac{L_x}{L_T} \qquad L_T = \frac{L_x}{pitch} 2\pi R$$

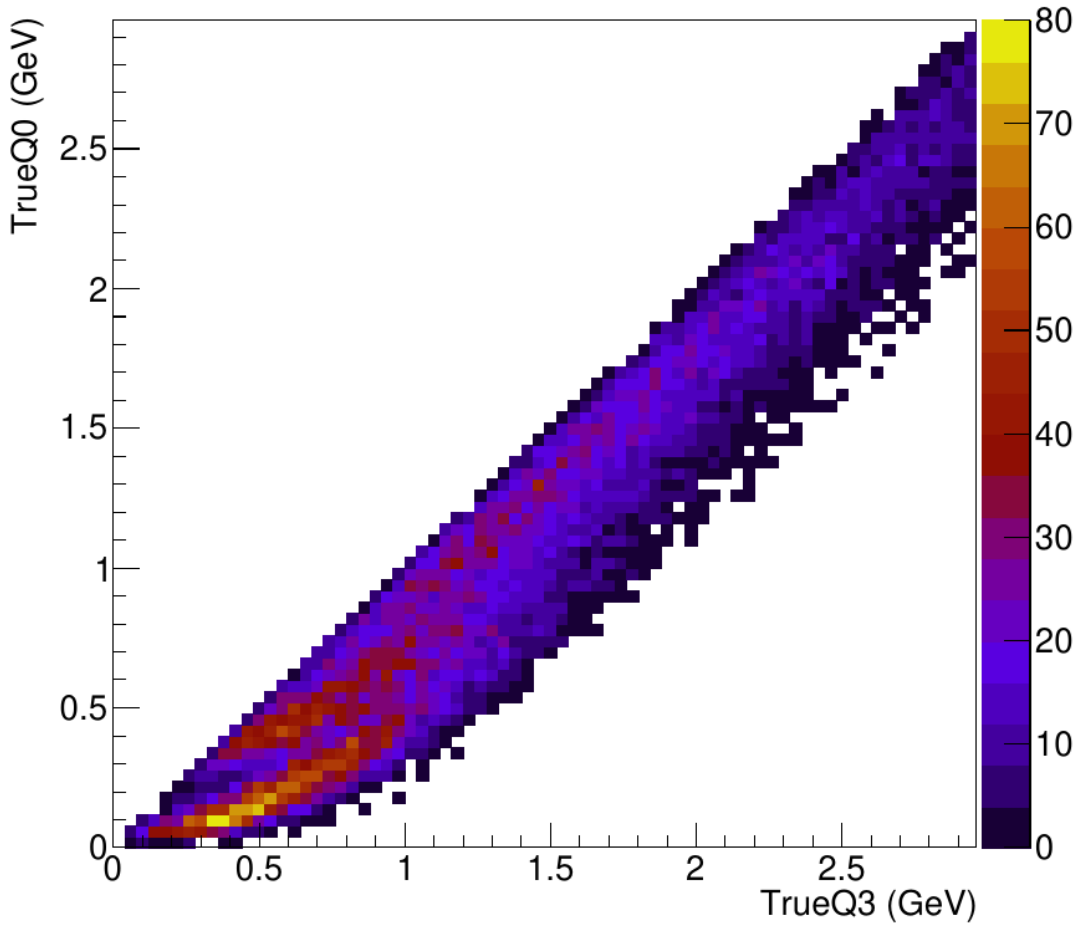
- Lx is the track length in the X-direction (direction of the B-field)
- This gives:

$$\tan(\lambda)\sigma_\lambda = \tan^3(\lambda)\left(\frac{\sigma_x}{L_x} - \frac{\sigma_{p_T}}{p_T}\right)$$

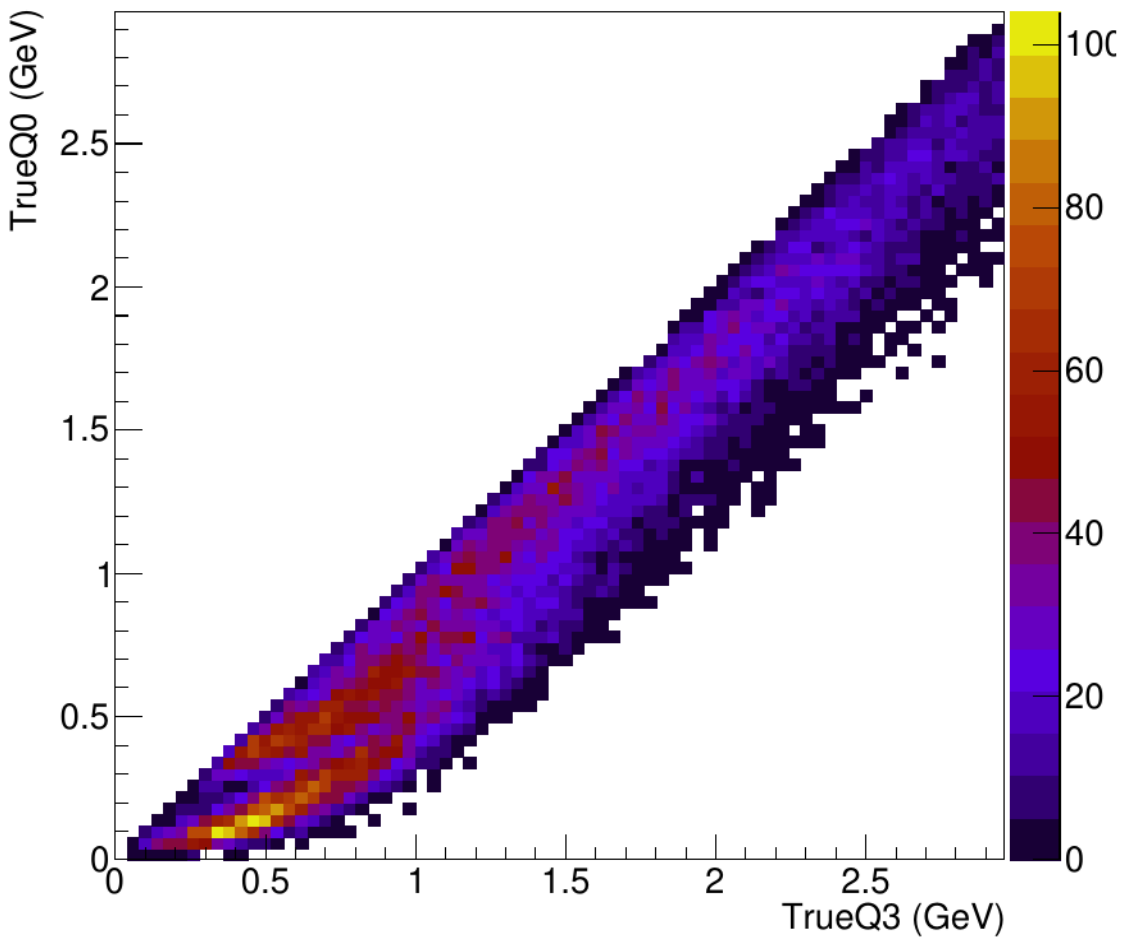
- We take σx to be the spatial resolution in the x-direction (assuming a drift velocity of ~3.011 cm/μs and a Sampling frequency of 20 MHz)

Preliminary Plots

- Accepted Events

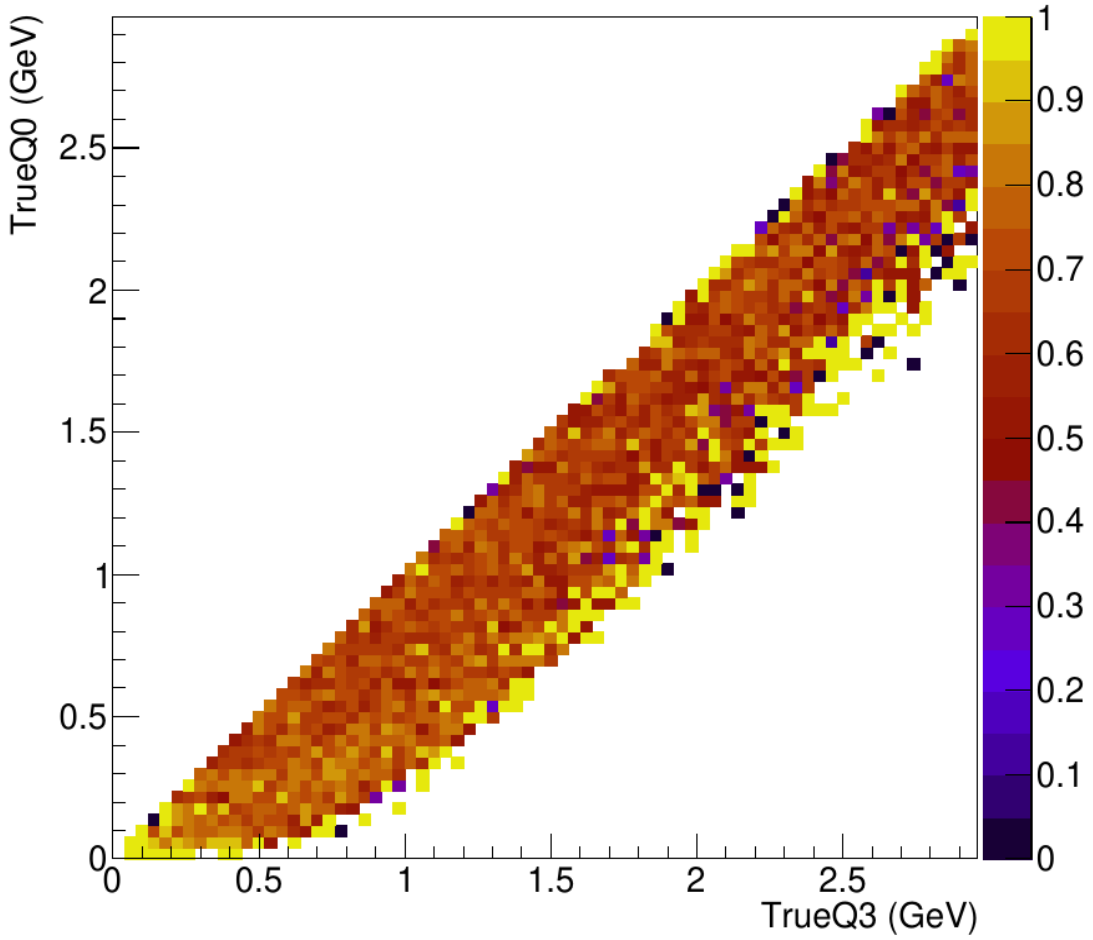


- All Events

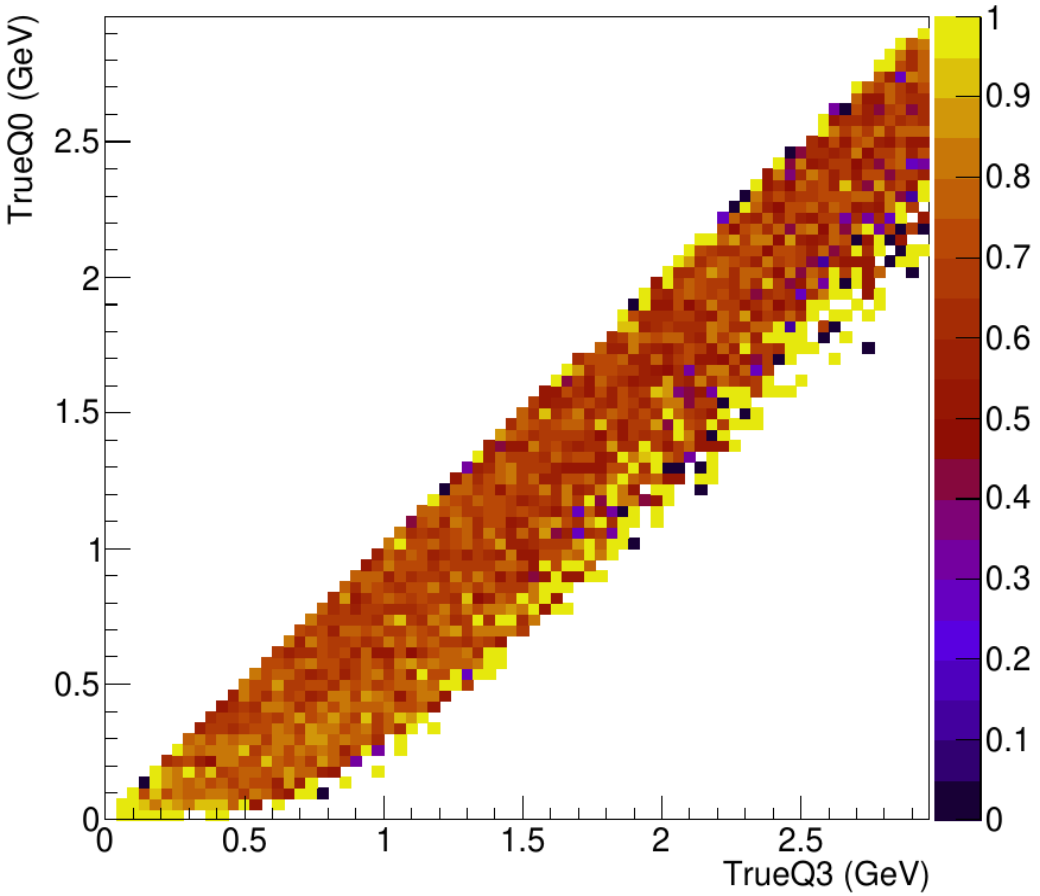


Preliminary Plots

- Accepted Events



Preliminary Plots - Acceptance



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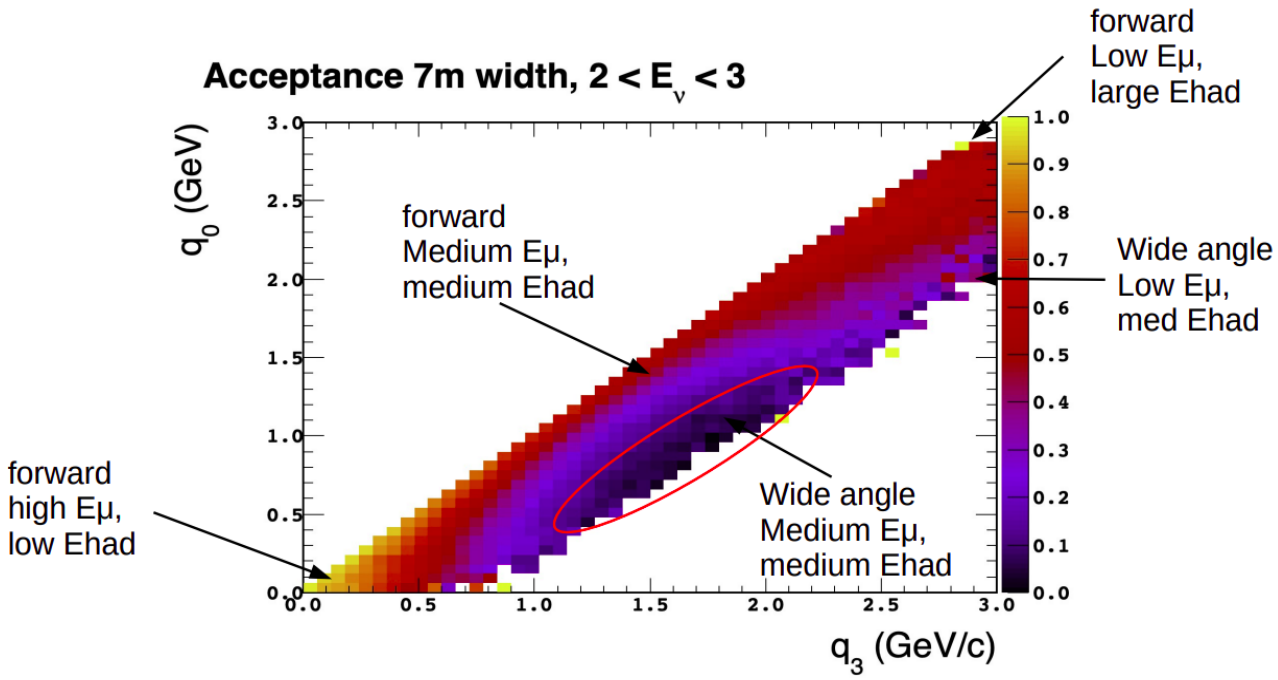

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Conclusions

- These early studies are aiming to determine the impact ND-GAr will have on the ND acceptance correction.
- Want to reach a good acceptance in the low acceptance regions of ND-LAr
- Can then vary fiducial volume, pixel spacing, B-field etc. and see what we **require** for ND-GAr to see enough events in this region of phase space
  - Written in an easily configurable way
- As this still uses 100k events, we should confirm if the plots show the same thing with a larger sample
- We have tried to keep the assumptions similar to those used in the ND-LAr+TMS study so we can make fair comparisons
  - Plan to show these studies to wider audiences e.g. LBL, ND-Sim/Reco for input