



スーパージェット  
*Super-Kamiokande*

# fiTQun $\pi^+$ Reconstruction

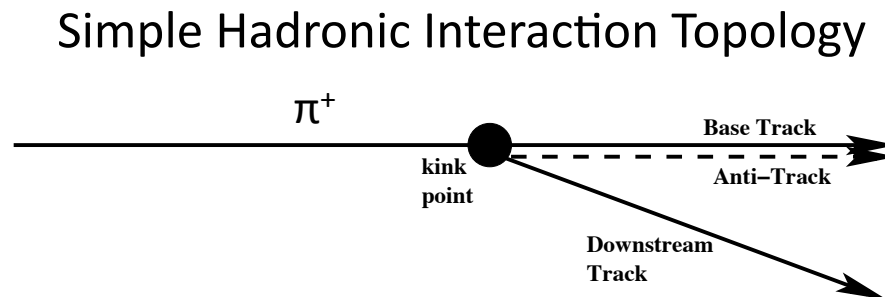
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fiTQun Workshop

# $\pi^+$ Reconstruction

- Current reconstruction includes a multi-ring fitter that separates rings into either e-like or  $\pi$ -like
  - Counts total number of rings
- Due to hadronic interactions pions may create more than one ring
- Want to understand the relationship between number of rings and number of pions



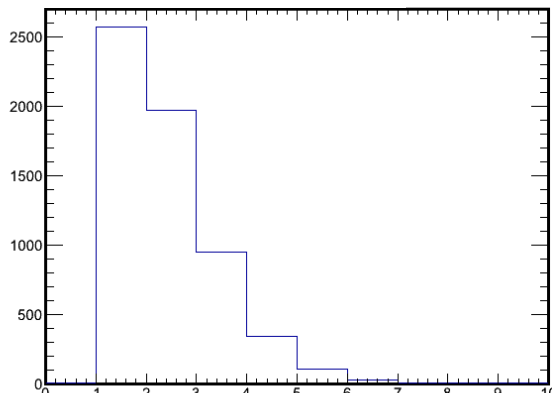
# Map Pion Interactions in SK

- Possible to trace all of the secondary interactions that particles undergo in SK
- Follow pions through the tank
  - Momentum before and after scattering
  - Distance travelled before scattering
  - Angle between initial and final direction
  - Count scatters
- Relate this information to the output of the reconstruction

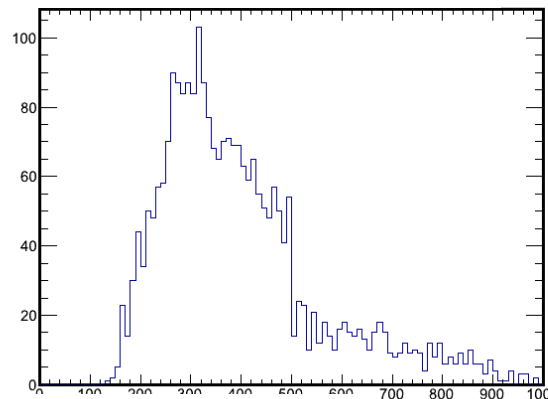
# Characterizing $\pi^+$

- “Scatter” means elastic or inelastic scatter, where the pion is above Cherenkov threshold after the interaction.
- Similar studies have been done with other types of hadronic interactions and multiple scatters. Focus on pions that scatter once here as it is the simplest topology.

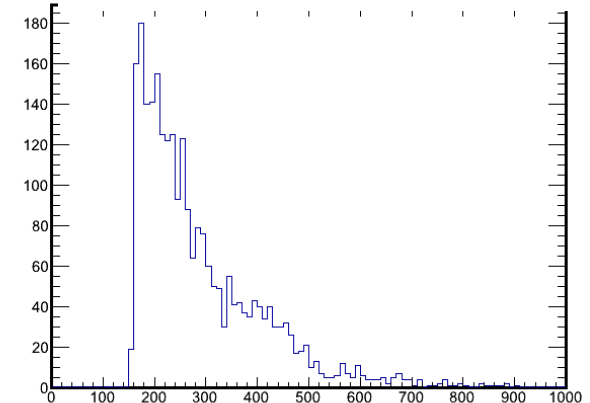
Number of scatters



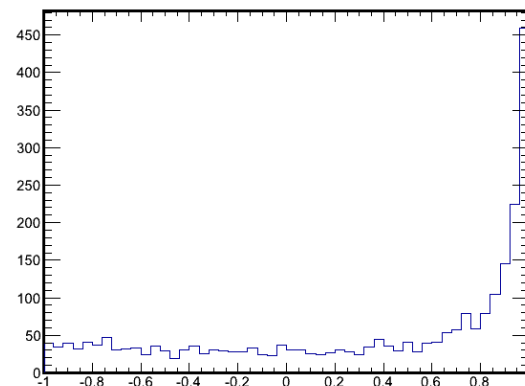
Momentum before scatter



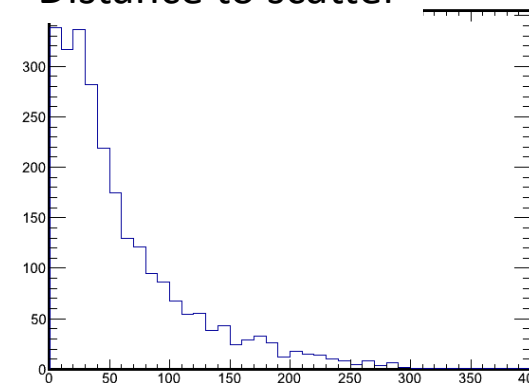
Momentum after scatter



Cos(t) between pre and post scatter directions



Distance to scatter

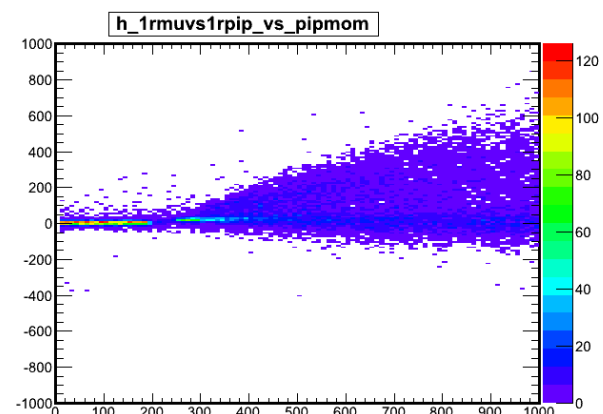
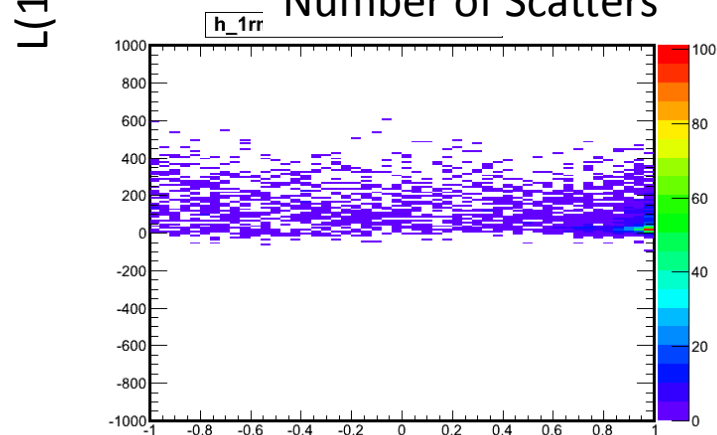
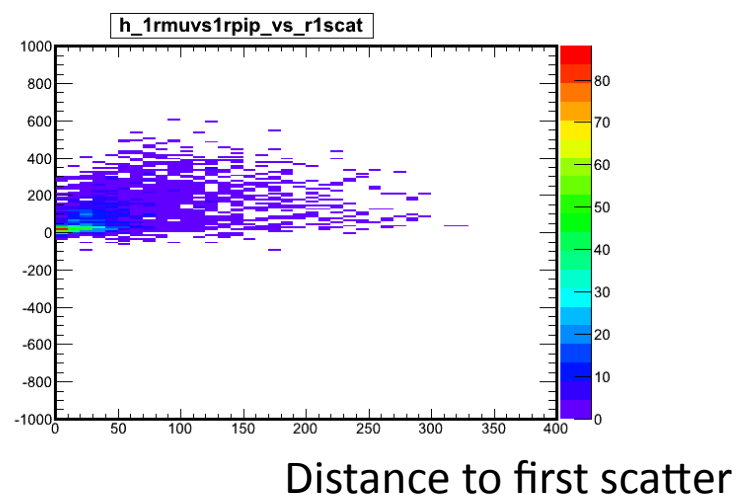
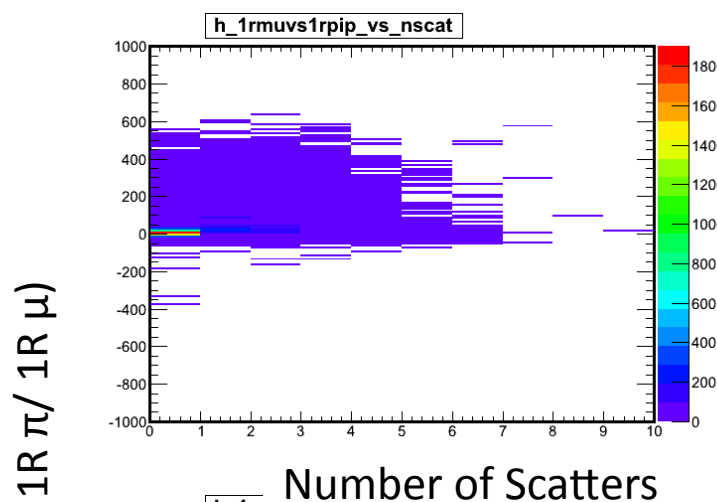


# Some Details

- All of the studies that use the MR fitter, not a  $\pi^+$  fitter with hadronic interactions included
- Preliminary studies
- $\pi^+$  particle gun from 0-1GeV

# Likelihood Ratios

- What variables have separation power for charged pions? How much power for different hypotheses?

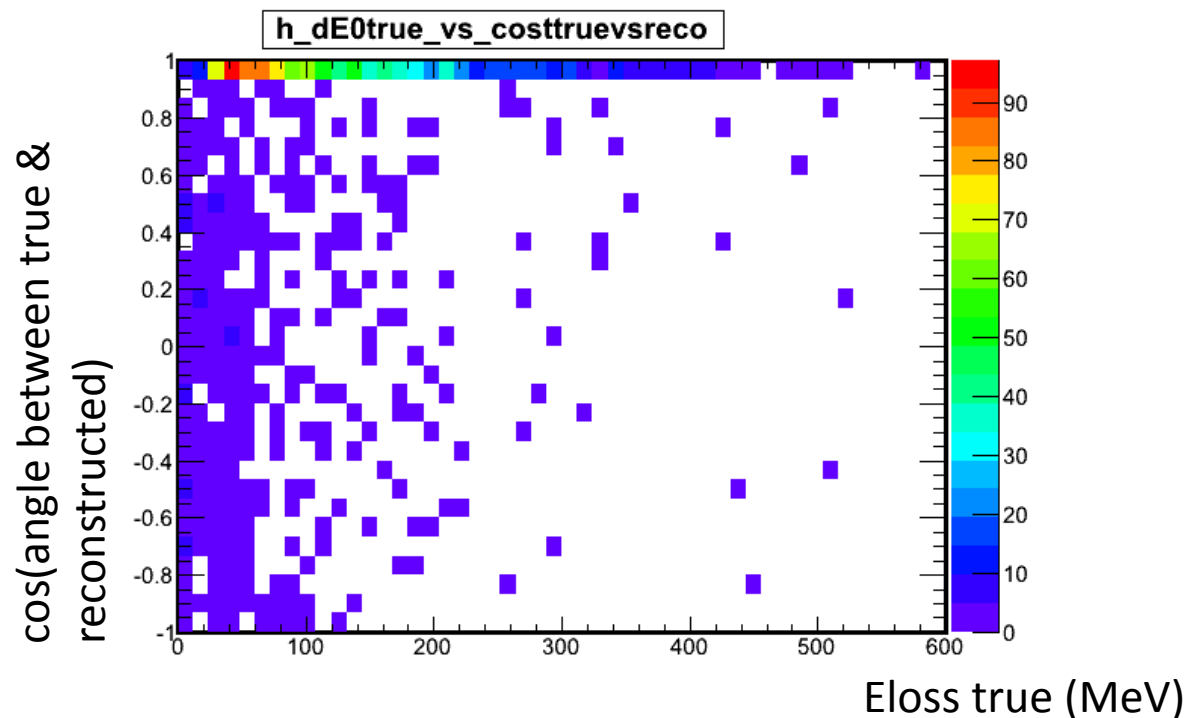


Angle between initial and scattered direction

True Momentum

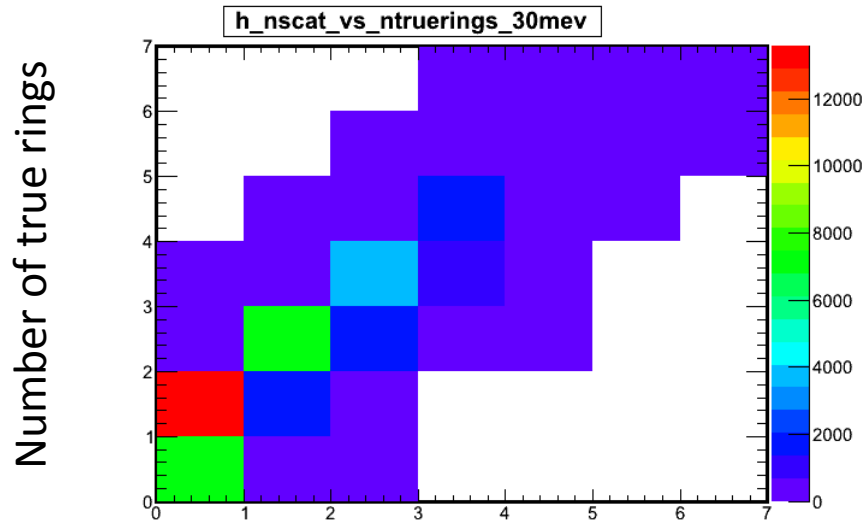
# True Ring Cut

- At what energy above Cherenkov threshold is it possible to resolve a pion ring? ( $T > T_{\min} + x$ )
- At what energy loss threshold are the true and reconstructed directions the same?
- For pions that absorb, so only a true upstream portion of the track
- Conservative cut for next plots, true ring = 30MeV over Cherenkov Threshold (also done with 10MeV and 20MeV)

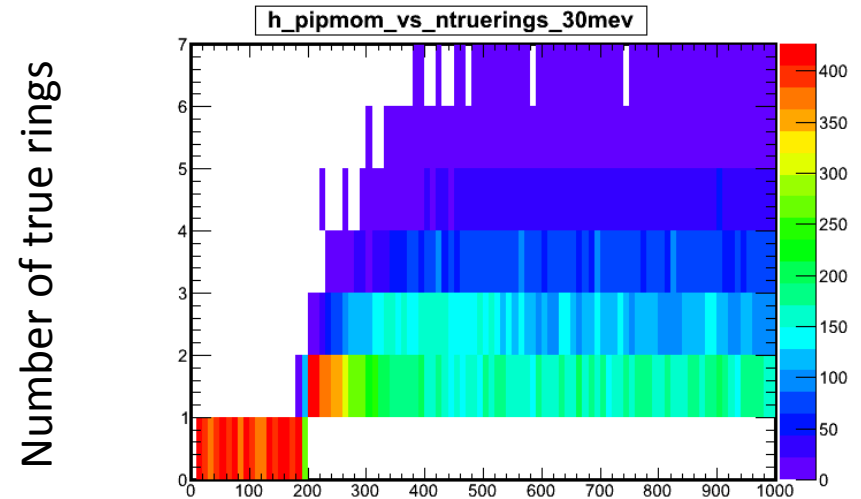


# Number of True Rings

- Correlate number of true rings with true variables (number of scatters, pion momenta)
- True ring:  $T > T_{\min} + x$ . Here assume  $x=30$  MeV as a conservative true ring from previous slide (Also done with  $x=10$  MeV and 20 MeV, but features are the same)
- All particles in primary and secondary stack



Number of scatters (pion above threshold)

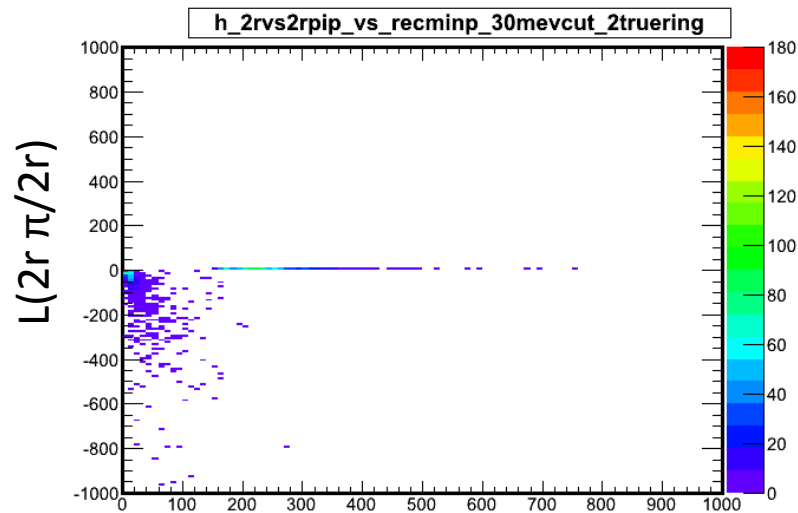


Pion Momentum

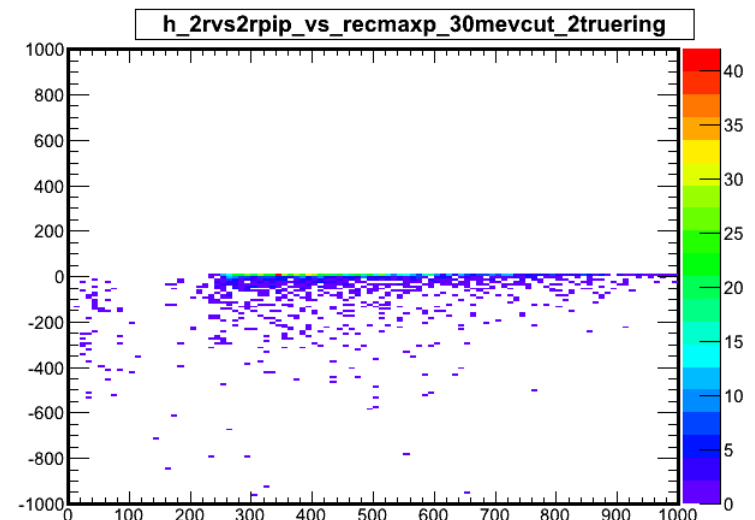


# Likelihoods ( $2r \pi/2r$ )

- True 2 ring pions (True ring:  $T > T_{\min} + x$ . Here  $x=30$  MeV)
- Best fit is not always 2 pion rings, especially for low reconstructed momentum of the second ring



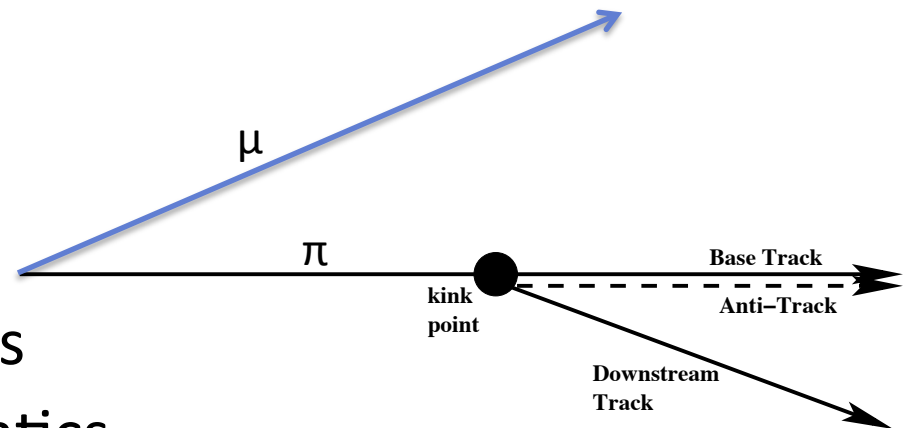
Reconstructed momentum (p1 for  $p1 < p2$ )



Reconstructed momentum (p2 for  $p1 < p2$ )

# CC1 $\pi^+$ Fitter Structure

- 16 parameter fit:
  - Vertex
  - Muon kinematics
  - Upstream pion kinematics
  - Downstream pion kinematics
- Require downstream momentum to be some fraction of the upstream pion momentum; float the fraction
- Calculate the scatter point using the kinematics of the up stream track portion



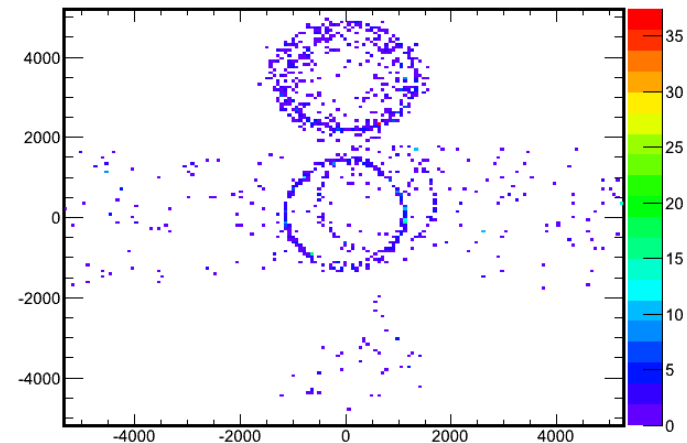
# CC1 $\pi^+$ Fitter Seeding

- Truth:
  - All secondary information is accessible within fitQun
  - Use this to seed the fitter
  - Best case scenario for the fitter
- Reconstructed (output of MR fit):
  - If 3 rings:
    - Require common vertex for two of the 3 rings (one e/ $\mu$ -like, one  $\pi$ -like)
    - The third ring should be consistent with downstream segment of one of the other rings, and be  $\pi$ -like
    - Fit all combinations (that are kinematically allowed)
    - Best is fit result
  - If 2 rings:
    - Should share a common vertex
    - One e/ $\mu$ -like, one  $\pi$ -like
    - Look for a downstream segment multi-ring fit may have missed

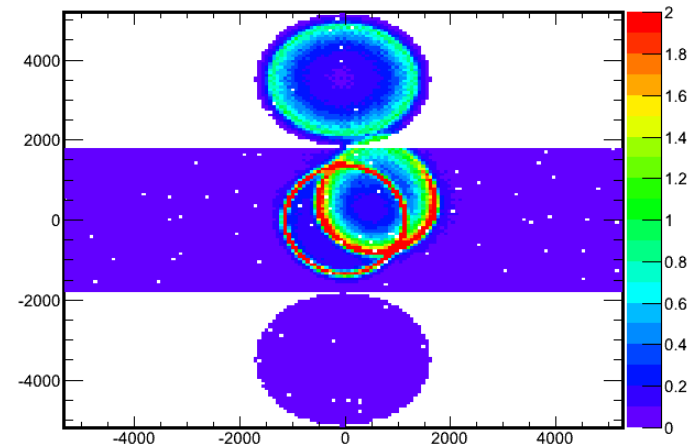
# CC1 $\pi^+$ Fitter Status

- Still resolving some issues with downstream ring
- Validating the truth fits before looking into reconstructed seeding in more detail.

PMT Hit Distribution



Predicted Charge



# Backup

# $\pi^+$ Hadronic Interactions

- $\pi^+$  can create multi-ring topologies in SK water
  - Main distinction between  $\mu^-$  and  $\pi^+$  at SK
- Hadronic interactions:

