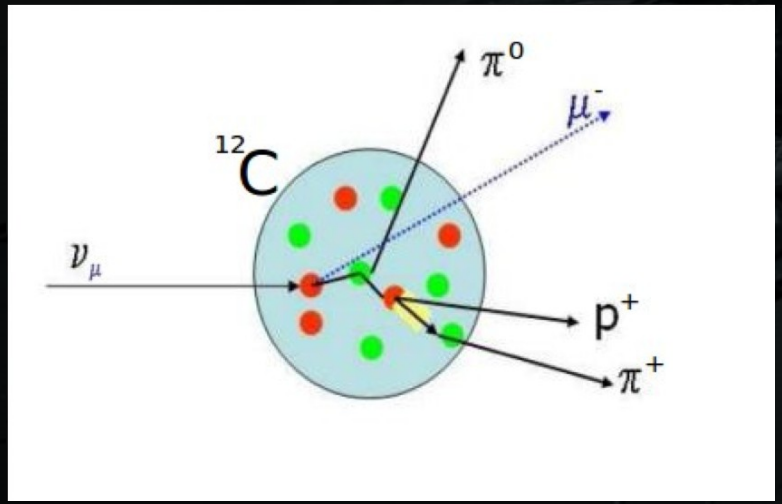
Analysis of the Inclusive $\nu_\mu + C \rightarrow \mu^- + \pi^+ + \pi^0 + N$ Cross Section in the T2K Near Detector

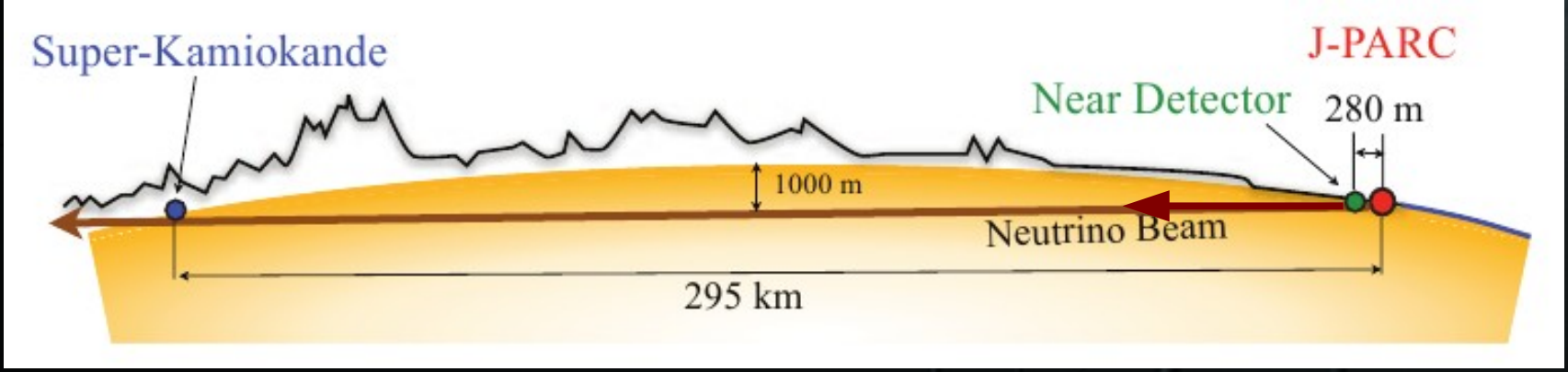
Steven William Bentham



IOP HEPP/APP Annual Meeting 2012

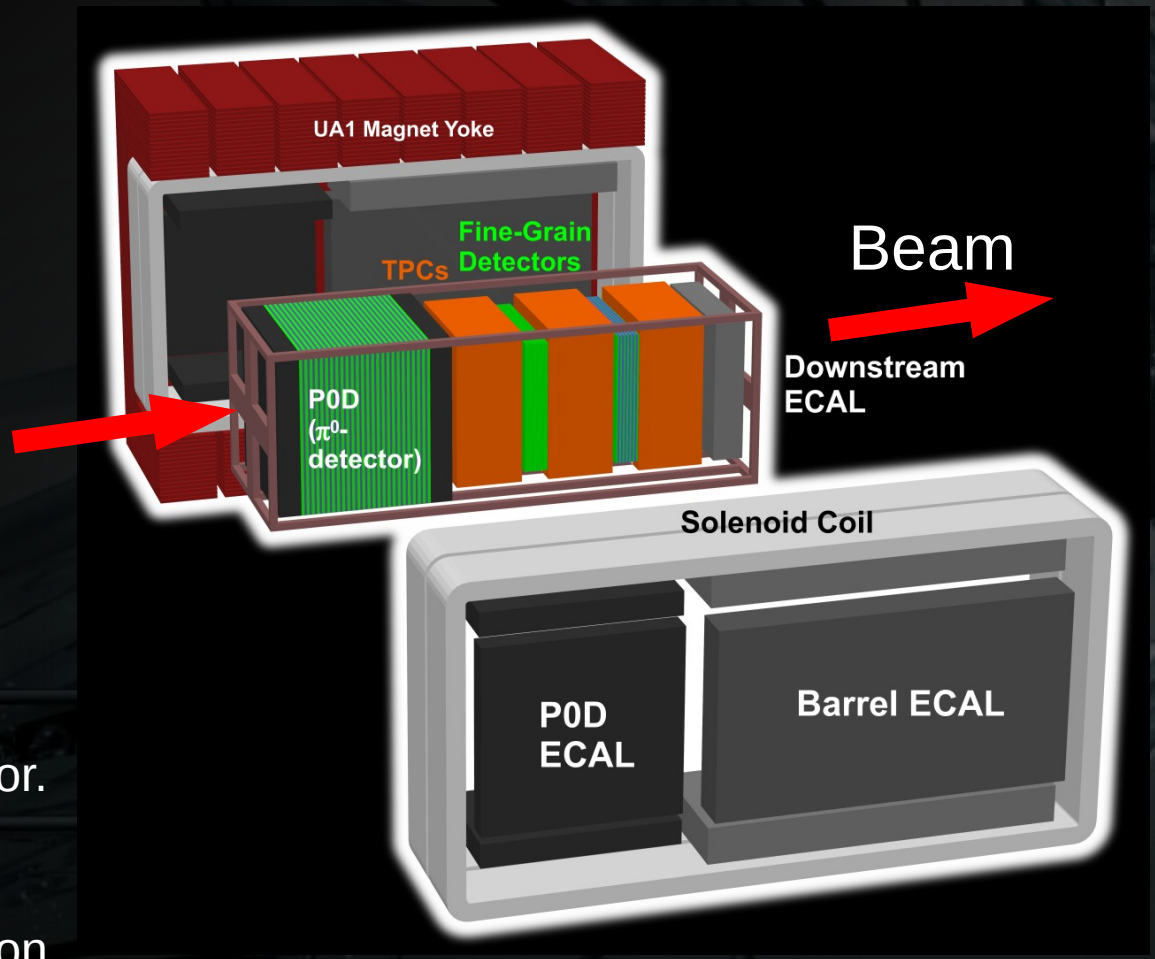
T2K

- Tokai to Kamioka.
- Off axis long-baseline neutrino experiment.
- Muon neutrino beam.
  - Starting in J-PARC.
  - Through the Near Detector at 280 m from target.
  - To Super Kamiokande at 295 km from target.
- T2K is looking at ν_μ disappearance to measure θ_{23} and Δm^2_{32} and ν_e appearance to measure θ_{13}.



ND280

- P0D (π^0 Detector)
  - Layers of lead/water and plastic scintillator.
- 3 TPCs (Time Projection Chambers)
  - High-resolution tracking chambers with Micromegas readout.
- 2 FGDs (Fine-Grained Detectors)
  - High-Granularity layers.
    FGD1: Scintillator.
    FGD2: Scintillator and water.
- ECAL (Electromagnetic Calorimter)
  - Layers of lead and plastic scintillator.
- SMRD (Side Muon Range Detector)
  - Slabs of plastic scintillator inside iron magnet yoke.



Definitions

Exclusive:

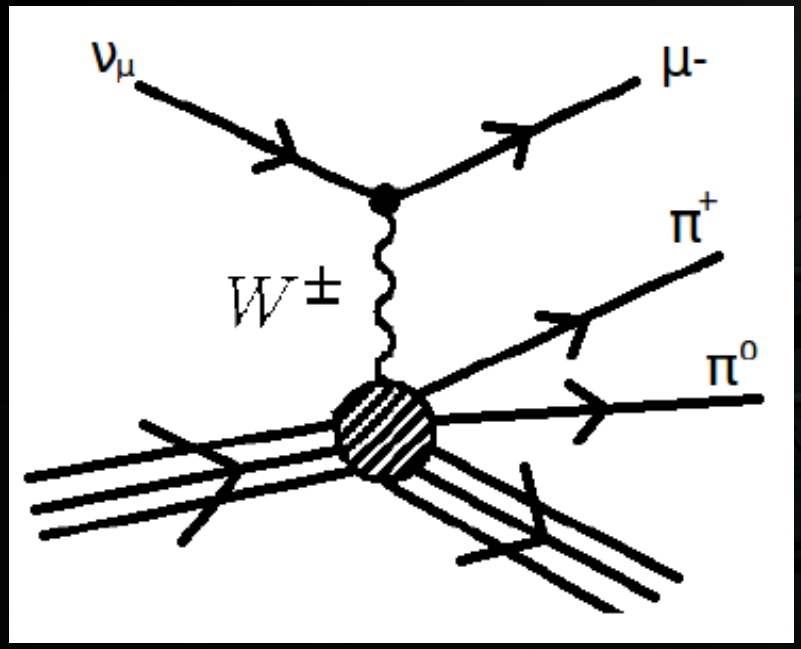
$\nu_\mu + C \rightarrow \mu^- + \pi^+ + \pi^0 + N$

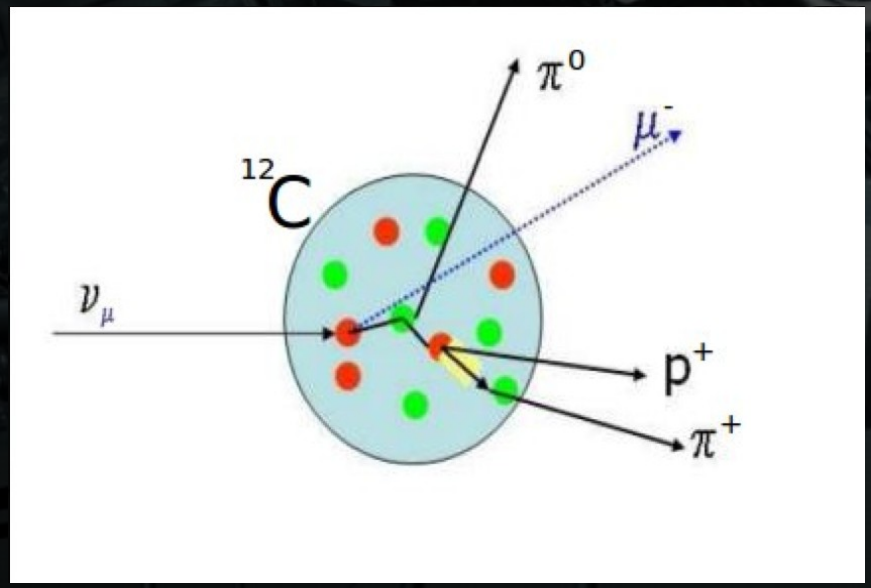
Inclusive:

$\nu_\mu + C \rightarrow \mu^- + \pi^+ + \pi^0 + N + X$

Where N=Nucleus.

X=Any number of other particles.





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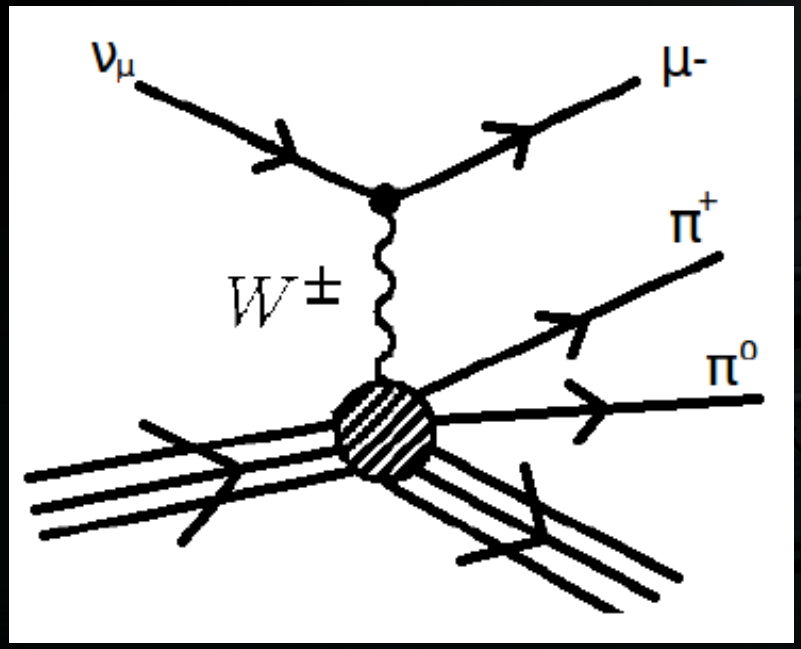

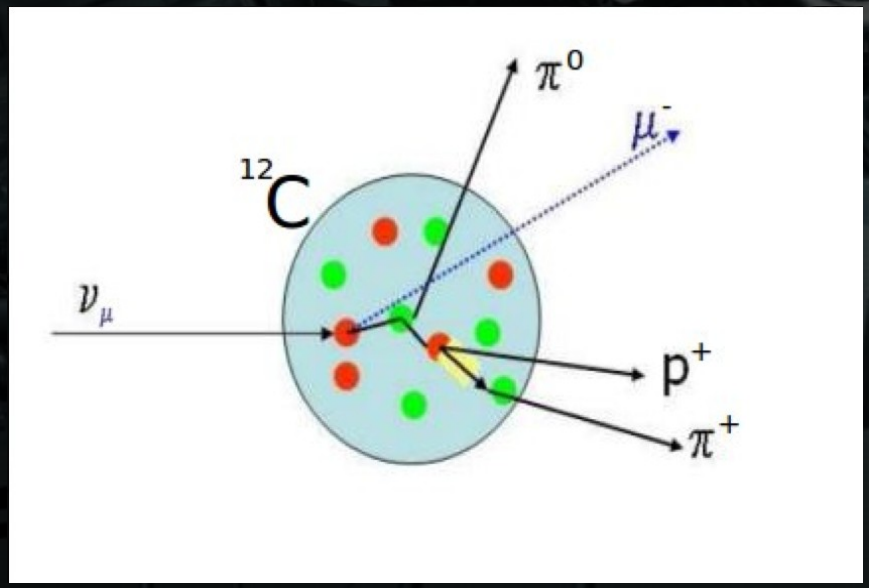

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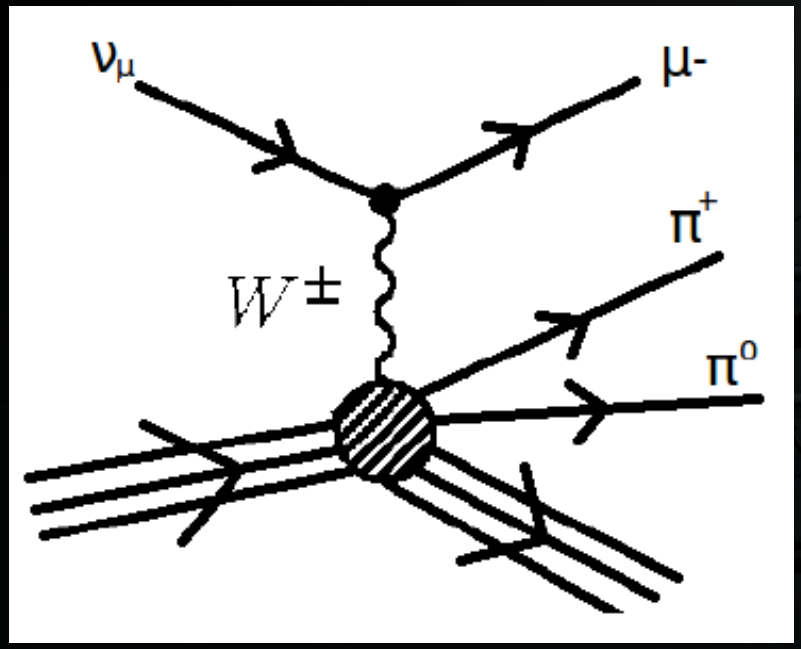
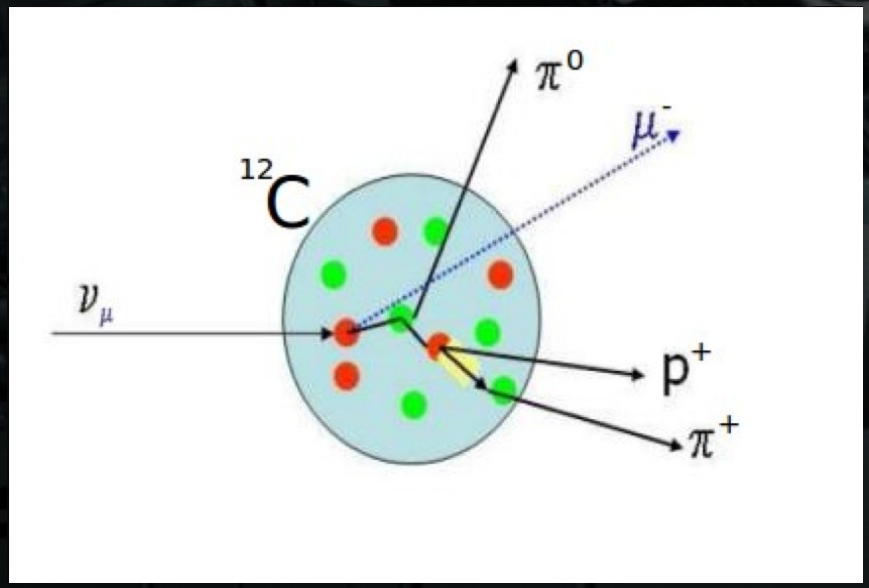
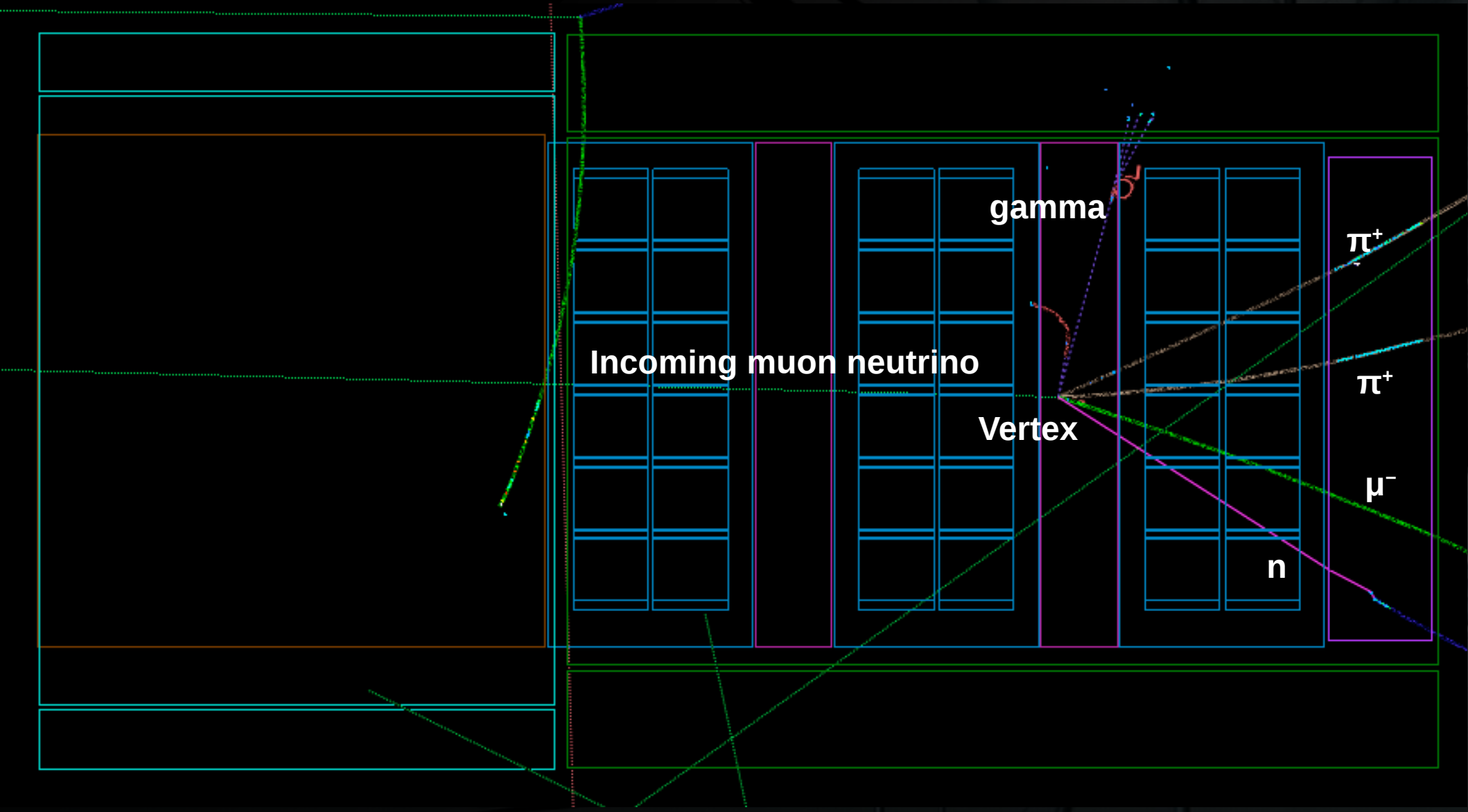
- Typical ν_μ energy ~ 600 MeV.
- This analysis based upon T2K protons on target (PoT) ~3×10^{20} by summer 2012.
- Using NEUT event generator.



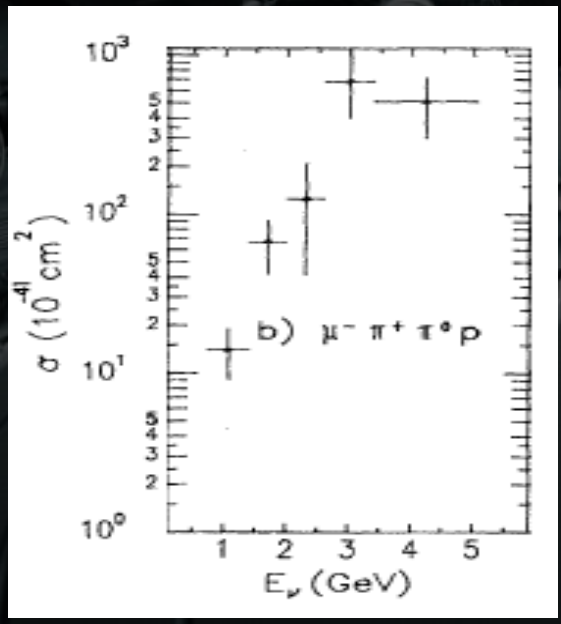


Event Display (MC Truth)



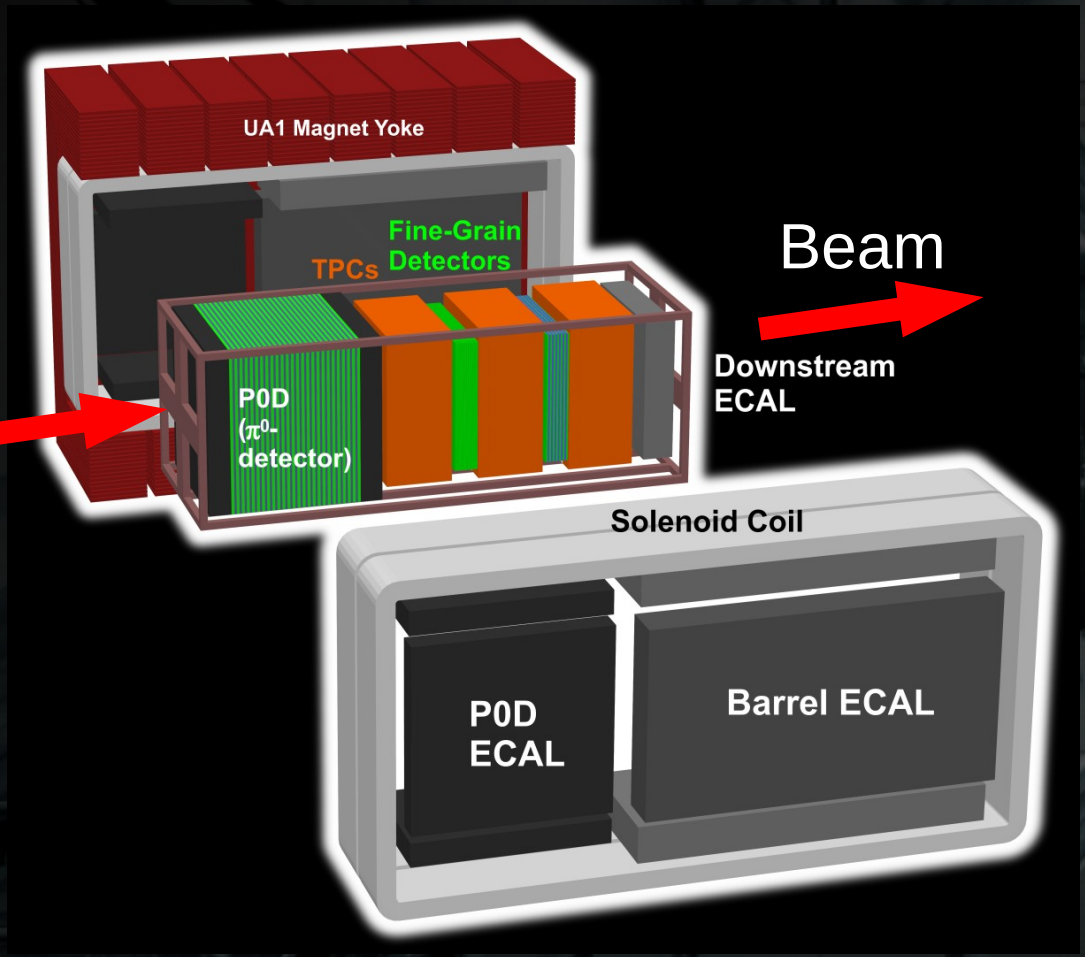
Why measure $\nu_\mu + C \rightarrow \mu^- + \pi^+ + \pi^0 + N + X$ cross section

- Helps constrain final-state nuclear interactions.
- Can be used to tune our two event generators, GENIE and NEUT.
- Important to understand T2K flux.
- Few previous measurements of the cross section.
  - Argonne bubble chamber.
    - E=0.5 GeV
    - Deuterium target.
    - D. Day et al., Phys. Rev. D 28, 2714 (1983).
  - Brookhaven bubble chamber.
    - E=1.6 GeV
    - Deuterium target.
    - T. Kitagaki et al., Phys. Rev. D 34, 2554 (1986).



Detectors Used

- Fine-grained detectors (FGD)
  - FGD1 Carbon target
  - FGD2 Carbon and oxygen target
  - Detect proton recoil
- Time projection chambers (TPC)
  - Particle identification based on dE/dx
  - Measure momentum and charge
- ECALs
  - Detect electromagnetic showers



Check Criteria using Monte Carlo

Feasibility study with no detector effects
Assuming ideal detector

Criteria Number	Criteria name	Expected number of vertices (NEUT)	% of expected vertices remaining
0	Use Truth to select inclusive sample with a vertex in the fiducial volume of FGD1.	619	100
1	At least one negatively charged particle with p>100MeV in TPC2.	587	94.8
2	At least one positively charged particle with p>100MeV in TPC2.	476	76.9
3	At least two photons with E>100MeV each, in the ECAL.	273	44.1

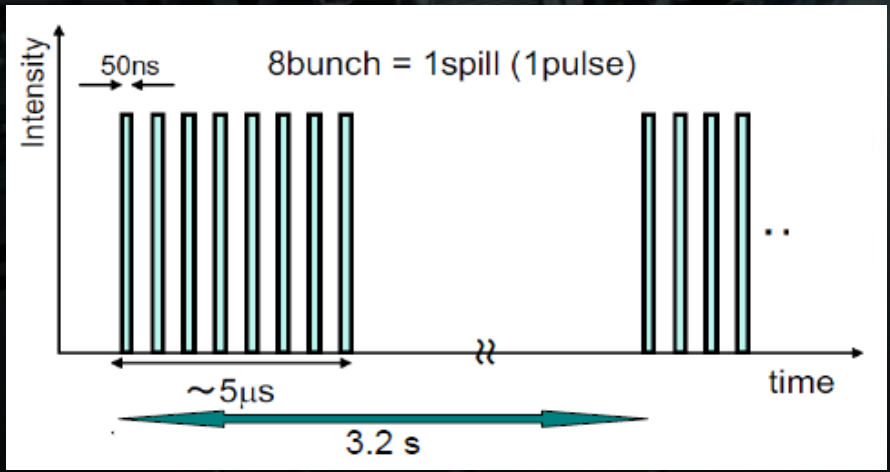
Expected number of vertices is scaled to the amount of data expected by summer 2012

Future cuts to be applied to reconstructed MC and data

Charged Current Inclusive cuts

Cut Number	Cut name
1	Data quality and timing cut.
2	At least one negative particle originating from a vertex in FGD1. (muon candidate)
3	No tracks in TPC1.
4	Highest energy other particle must start no more than 150 mm upstream from the muon candidate's starting point.
5	At least one positively charged particle with p>100MeV in TPC2.
6	At least two photons with a reconstructed invariant mass consistent with π^0 or one photon and e^+e^- pair.

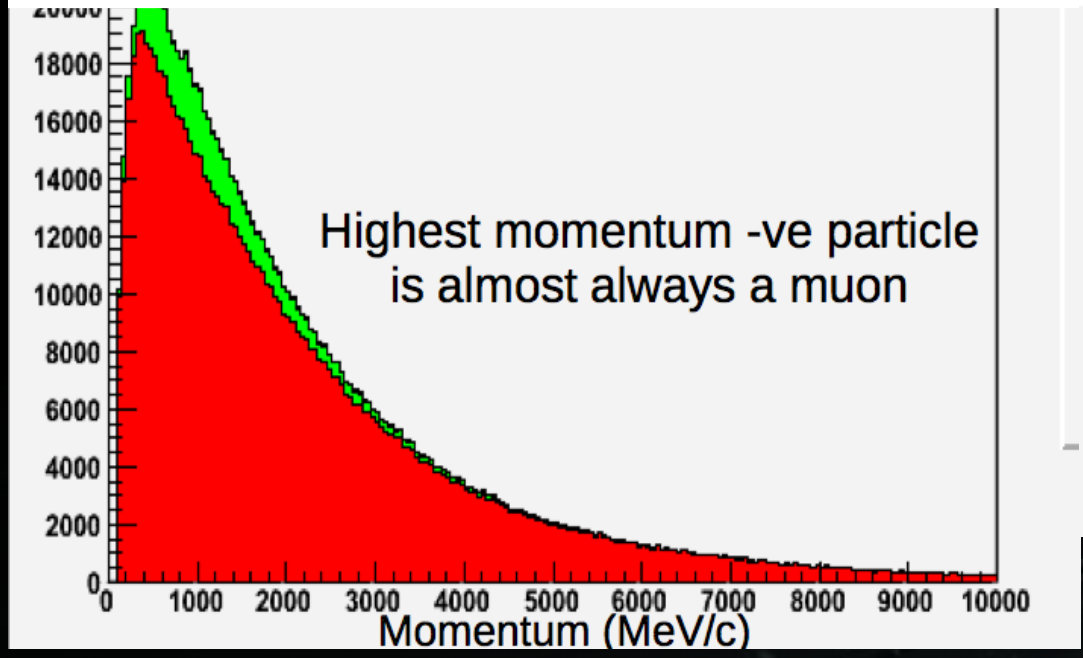
Using selection efficiency from other T2K analyses, we estimate of order ~50 signal candidates after cuts.



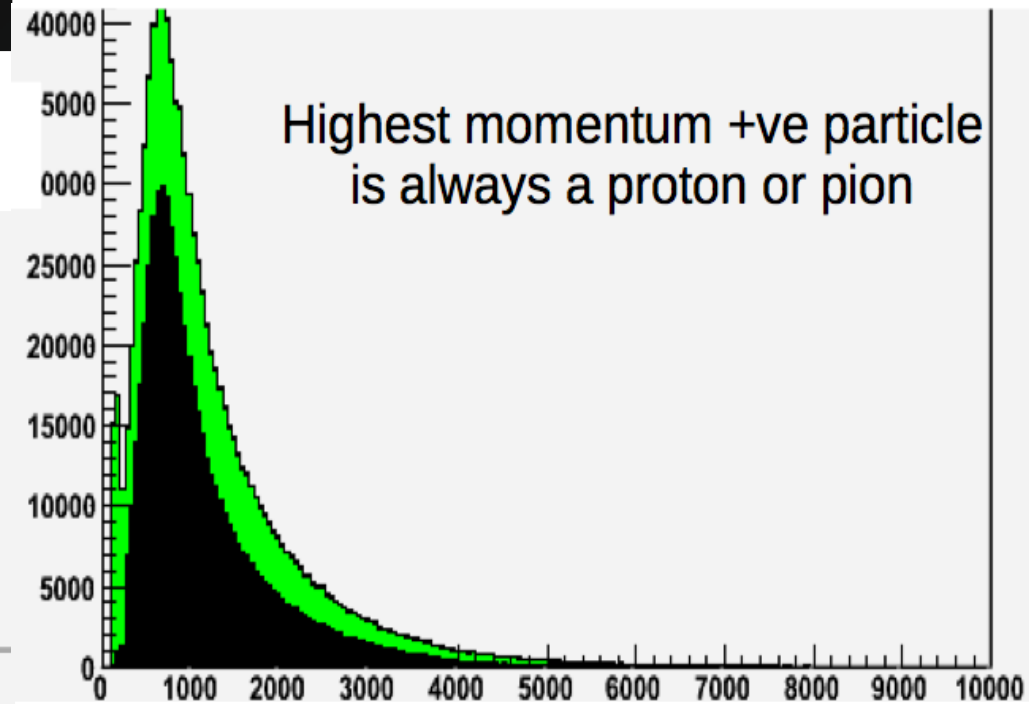
Particle momentum

Pion
Proton
Muon
Other

True momentum of the highest energy, negatively charged particle



True momentum of the highest energy, positively charged particle



Particle momentum

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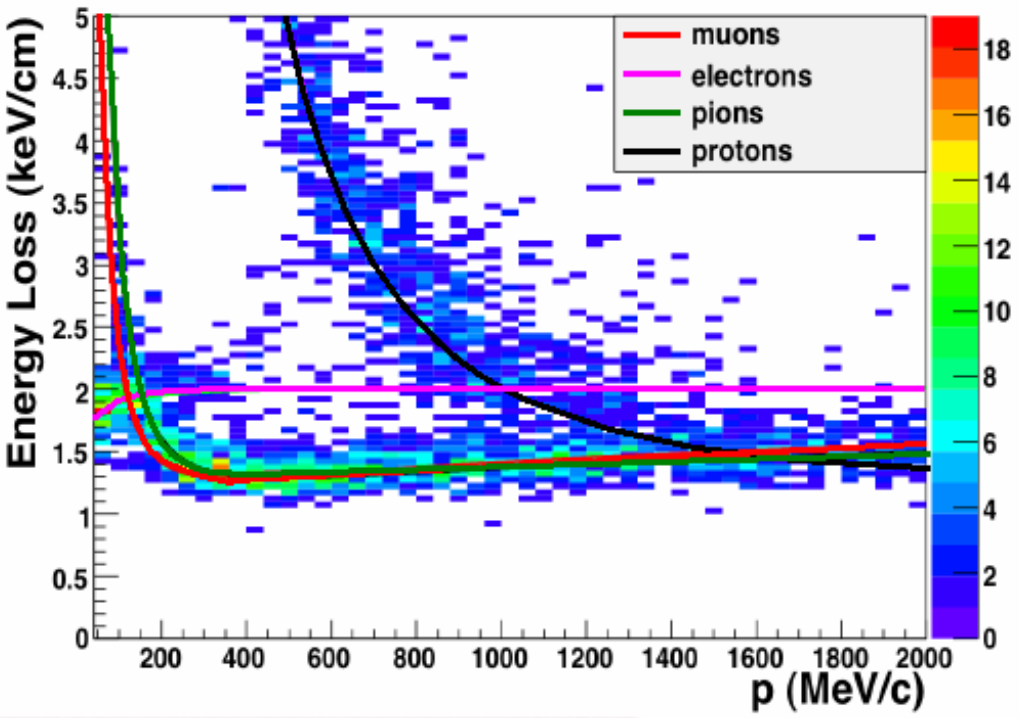
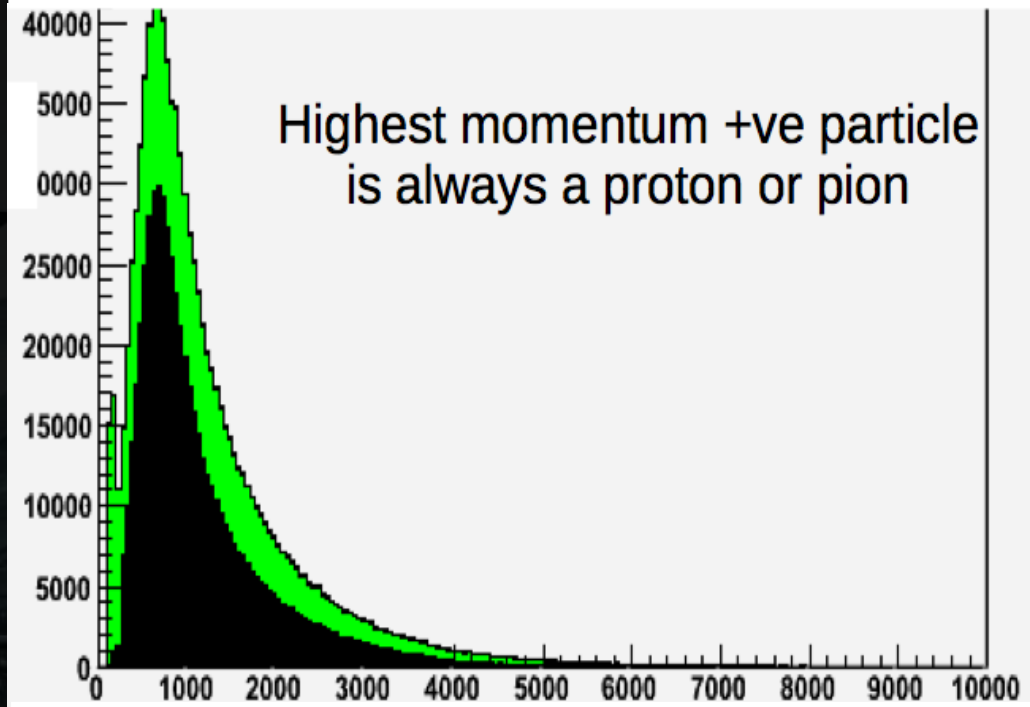
TPC data and theory curves: dE/dx



True momentum of the highest energy, positively charged particle



Future Work

- Finish optimising selection.
- Check consistency between data and our event generators.
- Make a cross-section measurement.

Summary

- Expect to get ~600 $\nu_\mu + C \rightarrow \mu^- + \pi^+ + \pi^0 + N + X$ interactions in FGD1 fiducial volume by summer 2012.
- Based upon selection efficiencies from other T2K analyses, we expect to see ~50 reconstructed signal candidates.