MINOS NEAR DETECTOR BEAM DECOMPOSITION

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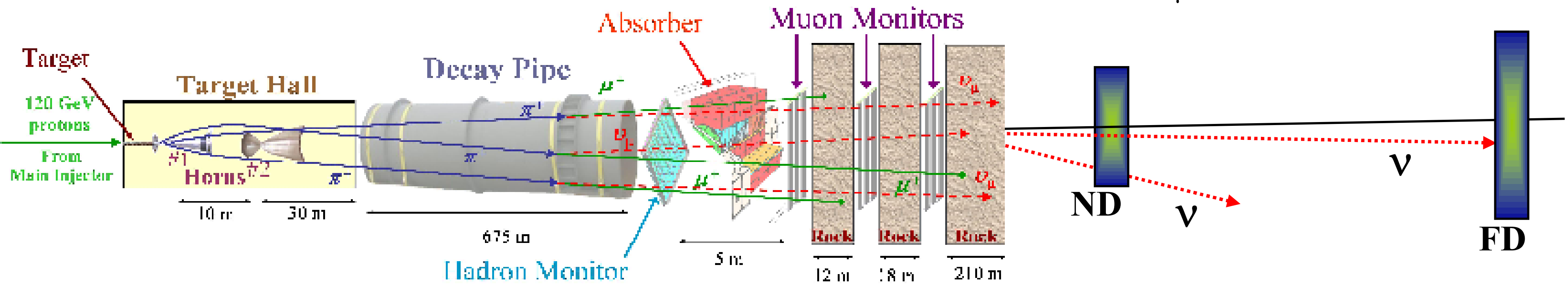
Outline

- Introduction to beam decomposition
- Why we need it ?
- Different methods of decomposition
  - Horn On/Off (HOO)
  - Muon Removed ν_μ CC (MRCC)
- Results
- Summary and conclusion

Introduction

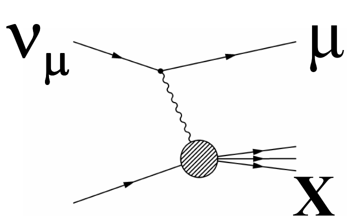
The ND detector beam decomposition in the context of search for ν_e appearance at the far detector.

MINOS neutrino beam production process: $[\pi\ (K) \to \mu + \nu_\mu$, $K \to \pi^0 e \nu_e]$

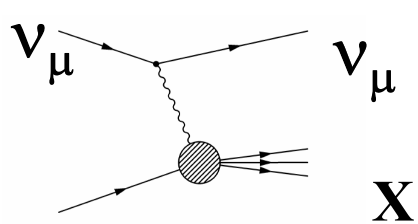


Neutrino Interaction

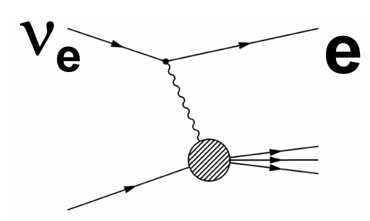
CC interaction



NC interaction



Beam-ν_e interaction



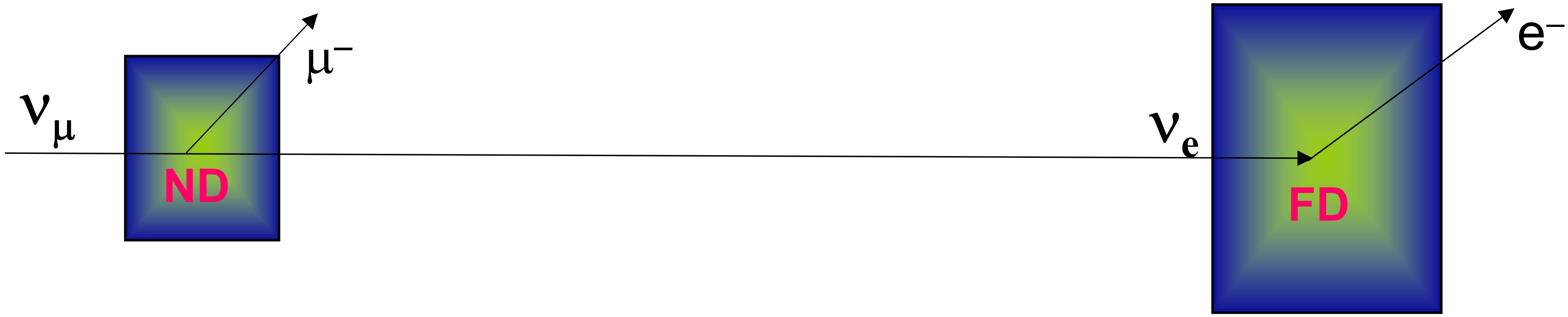
Total initial beam: CC fraction + NC fraction + beam-ν_e fraction

Why we need to decompose beam ?

- The detection of ν_e events is very difficult due to granularity of the MINOS detectors which are designed for μ's from ν_μ CC events.
- Low purity ν_e CC events with large NC and high-Y CC event backgrounds
- Hadronic showers are not modeled well in MC. Difficult to estimate background at FD
- Use data-driven method to decompose ND beams and extrapolate to FD

$$FD_{data} = \frac{FD_{MC}}{ND_{MC}} \times ND_{data}$$

(for CC,NC and ν_e separately)

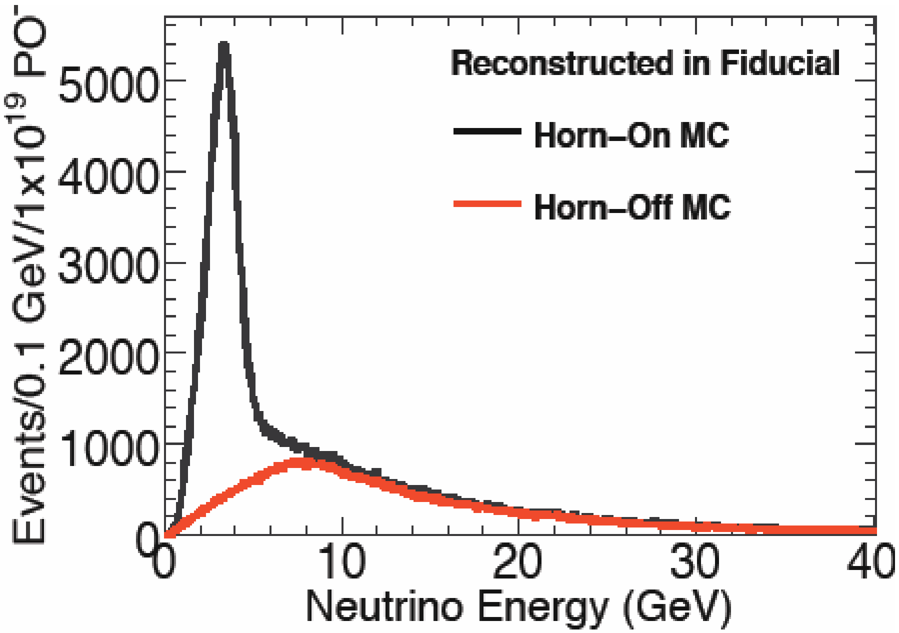


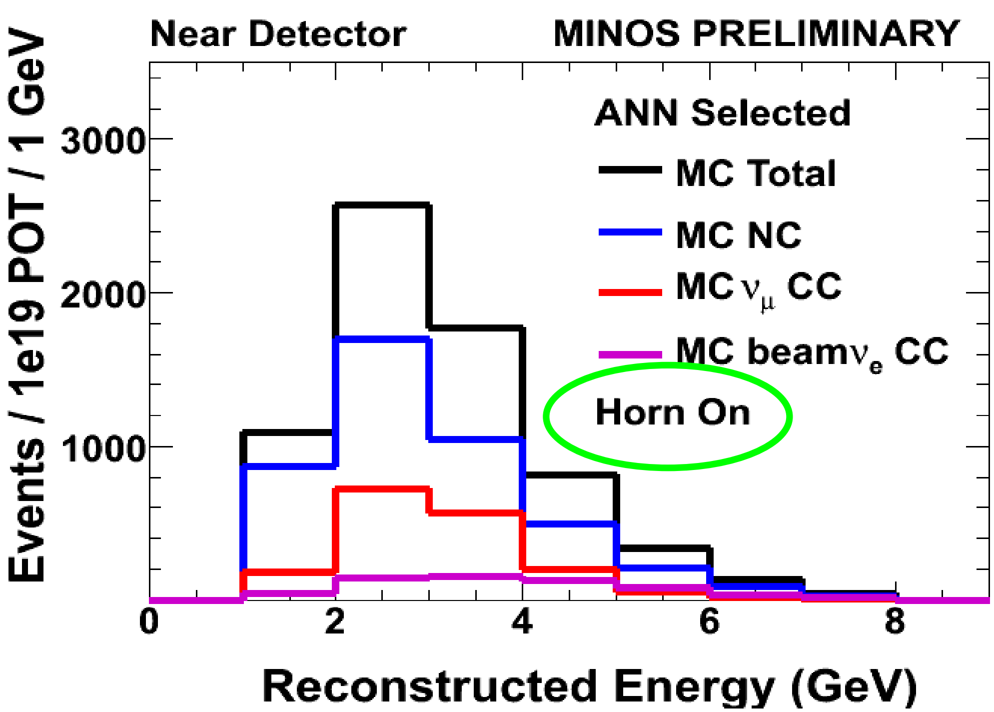
CC, NC, beam ν_e (CC oscillates) **CC, NC, beam ν_e**

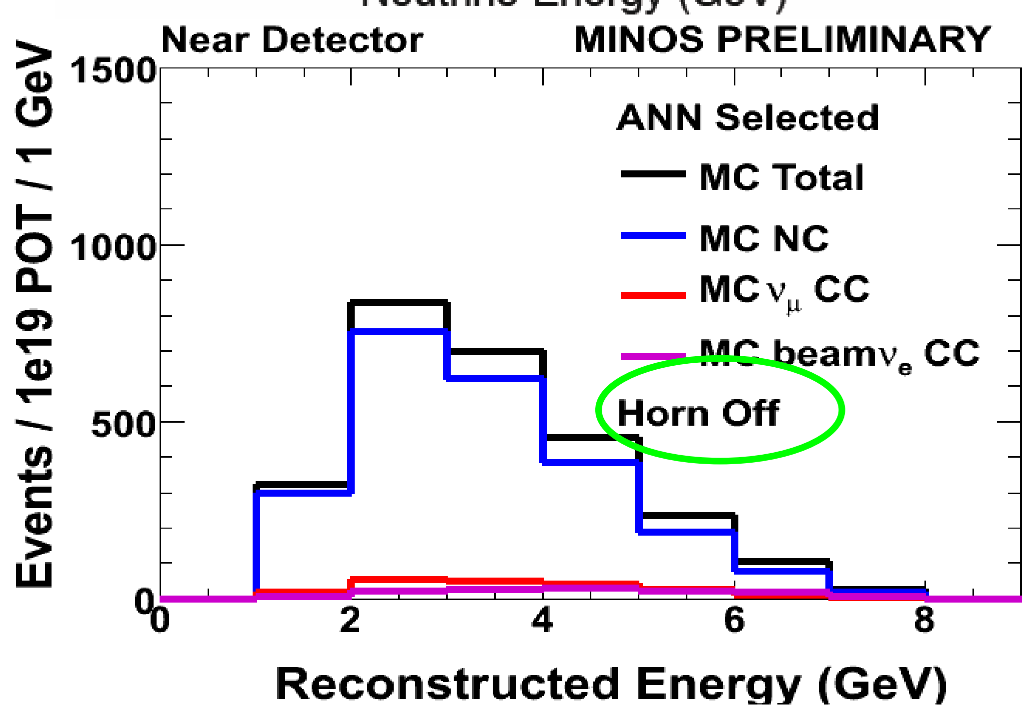
Data driven method#1: Horn on/off

Horn-on (off) method: When horns are off, the π's don't get focused resulting in disappearance of low energy peak in neutrino spectrum.

- NC events dominate horn off spectrum
- Use difference in background composition in horn-on and horn-off configuration







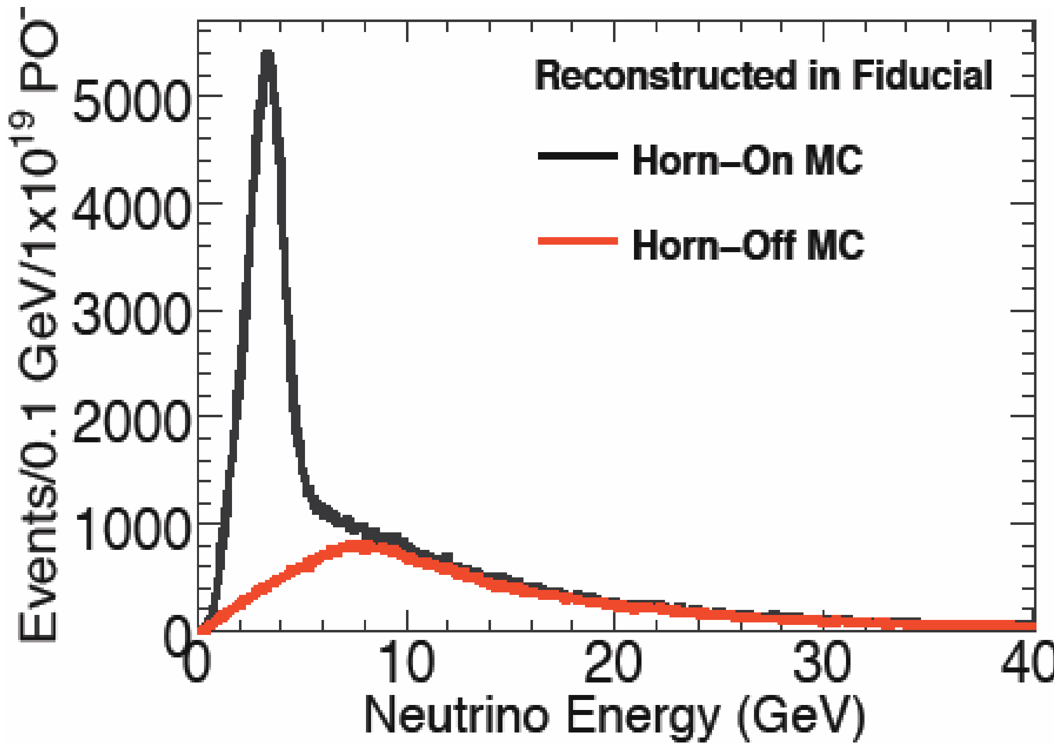
Horn-on (off) method

The Total Horn-on (N^{ON}) and Horn-off (N^{OFF}) data can be written as sum of CC , NC and n_e components:

$$N^{ON} = N_{NC}^{ON} + N_{CC}^{ON} + N_{\nu e}^{ON}$$

$$N^{OFF} = N_{NC}^{OFF} + N_{CC}^{OFF} + N_{\nu e}^{OFF}$$

$$= r_{NC} N_{NC}^{ON} + r_{CC} N_{CC}^{ON} + r_{\nu e} N_{\nu e}^{ON}$$



Solving the above two equations:

$$N_{CC}^{ON} = \frac{r_{NC} N^{ON} - N^{OFF} + (r_{\nu e} - r_{NC}) N_{\nu e}^{ON}}{r_{NC} - r_{CC}}$$

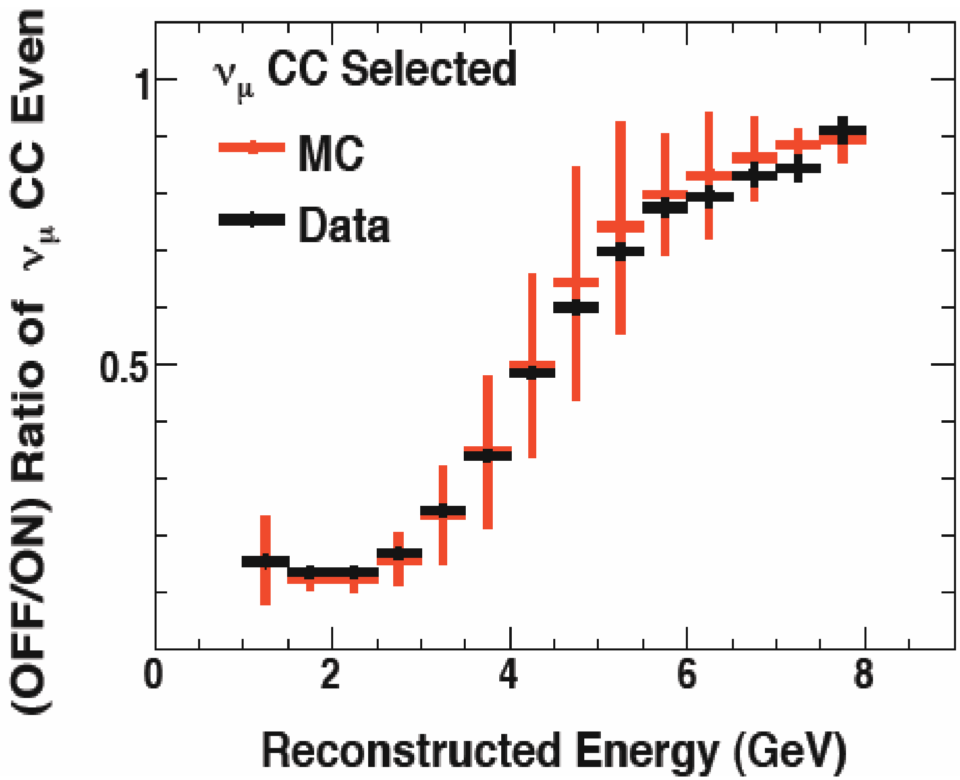
$$N_{NC}^{ON} = \frac{N^{OFF} - r_{CC} N^{ON} - (r_{\nu e} - r_{CC}) N_{\nu e}^{ON}}{r_{NC} - r_{CC}}$$

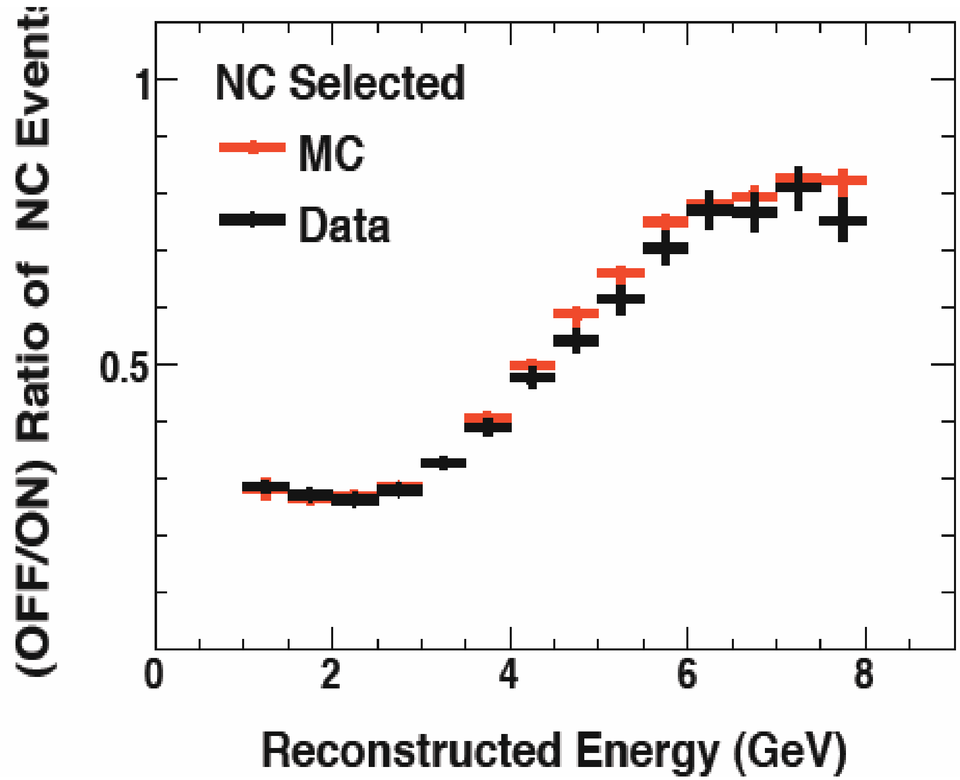
(solved in bins of energy)

$$r_{xx} = \left(\frac{N_{xx}^{OFF}}{N_{xx}^{ON}} \right)_{MC}$$

where r_{xx} is obtained from MC

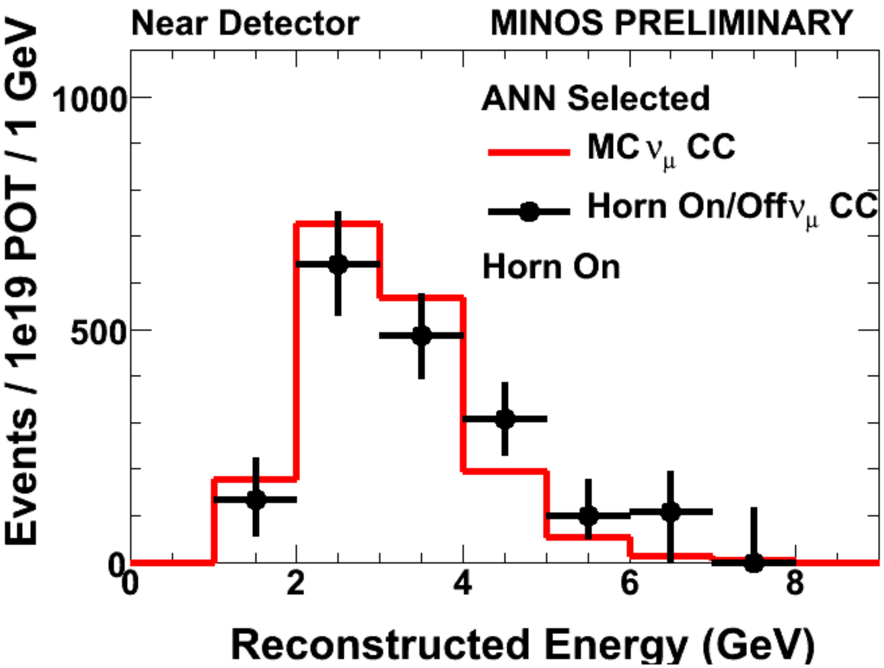
Data-Monte Carlo comparison of "r"



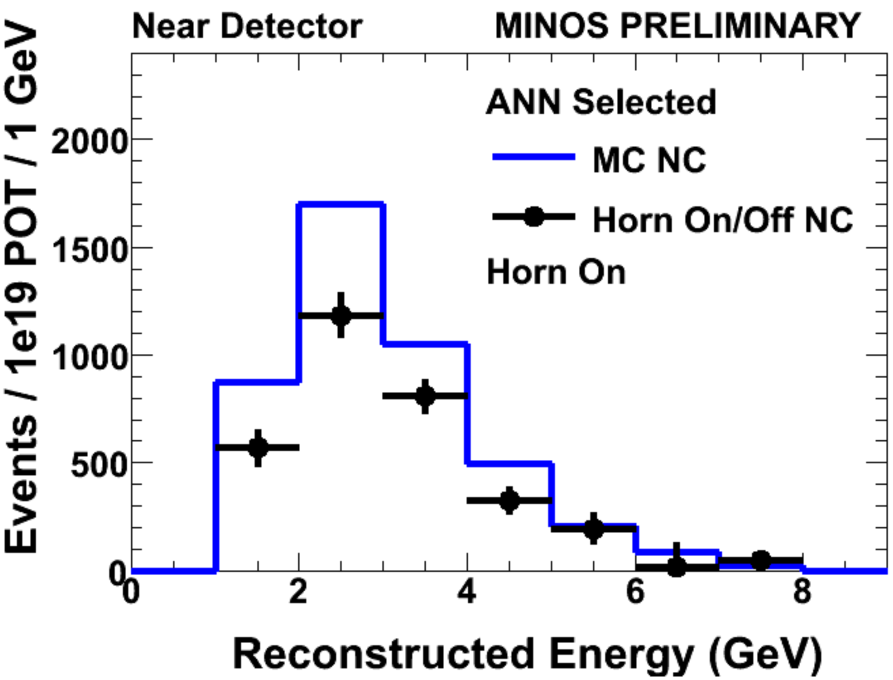


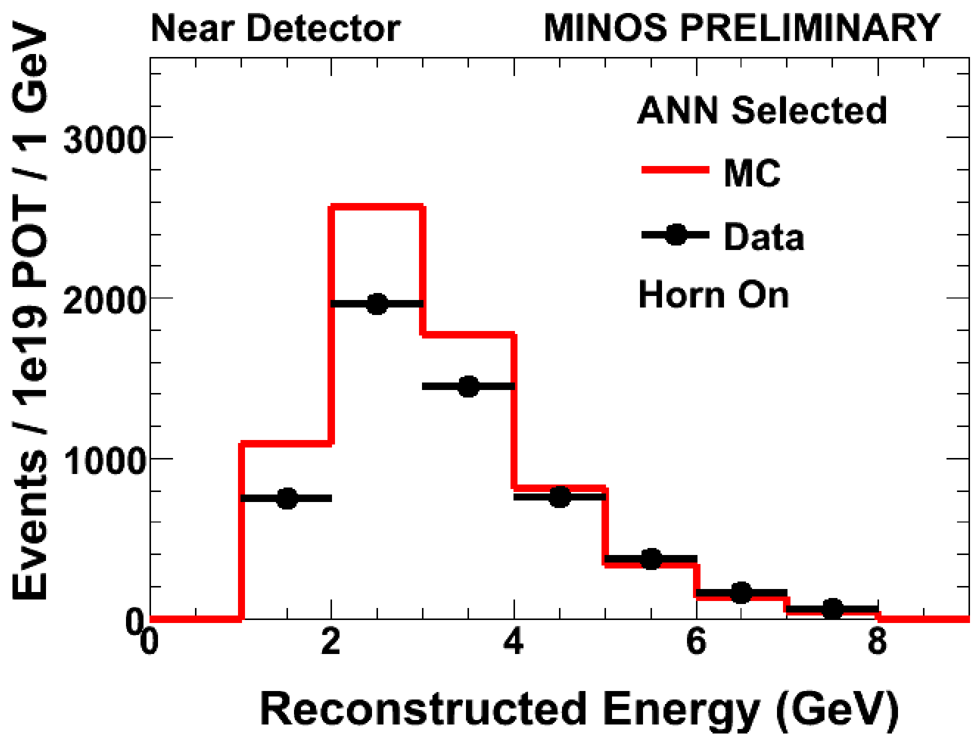
- The Horn off/on ratios for ν_μ CC and NC selected events match very well between the data and Monte Carlo after fiducial requirements.
- These ratios are inputs to Horn on/off equations which are solved simultaneously

Results from Horn on (off) method



- Large data/MC difference primarily coming from hadronic shower modeling
- The beam ν_e component is taken from MC (very small fraction of total beam and, also, the MC models ν_e component very well)





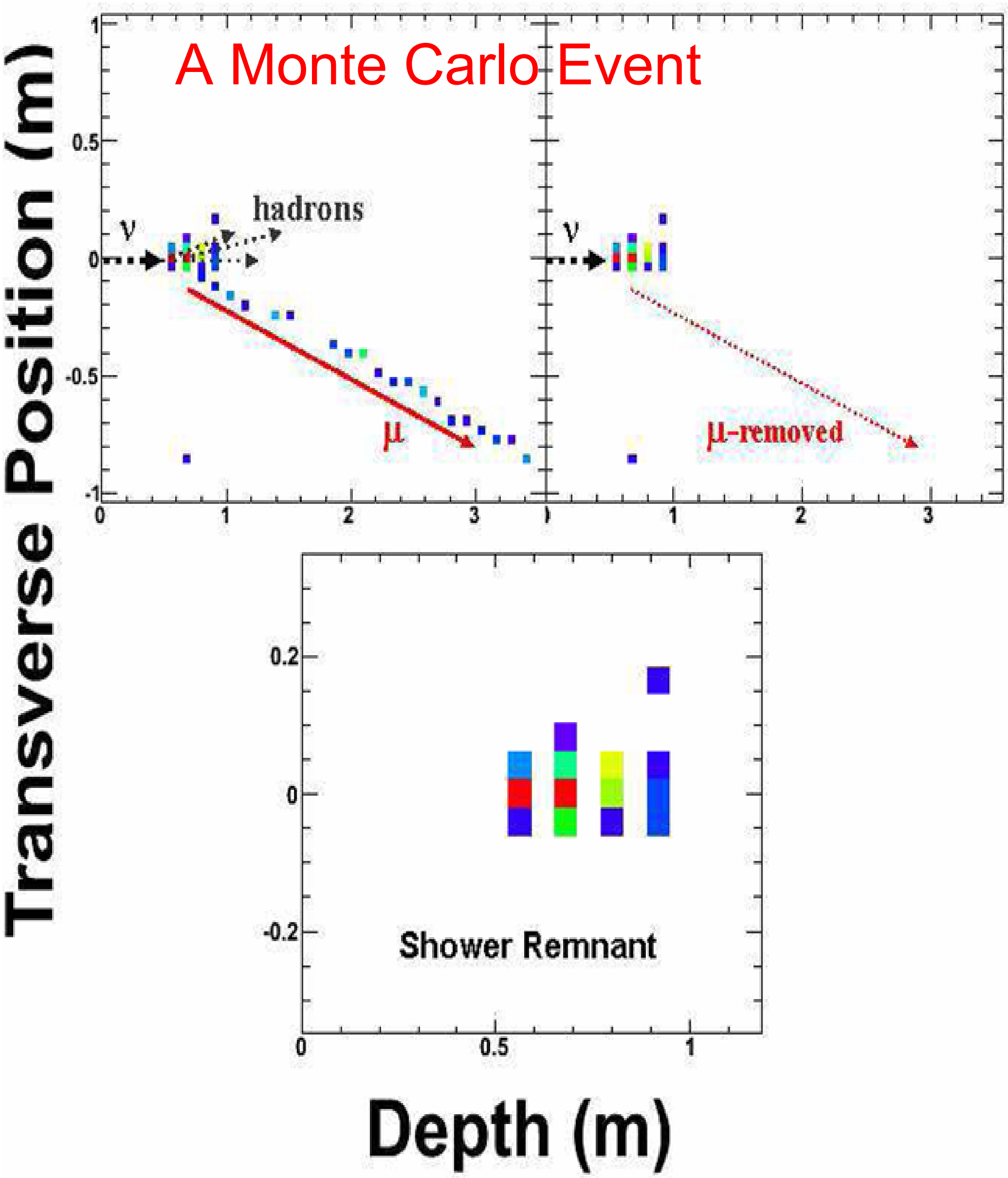
Method#2: MRCC (Muon Removed ν_μ CC)

This method uses muon removed ν_μ CC to study the hadronic showers and correct MC.

Strategy:

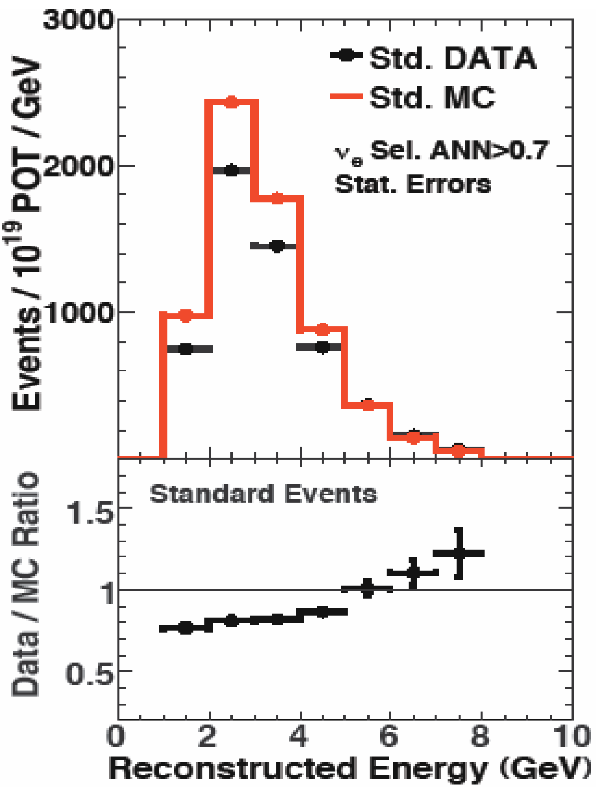
- We use events that pass our ν_μ CC event selection, i.e. that have a well defined track
- Remove the muon track in this ν_μ CC event by removing the hits associated with the track and use the rest as hadronic shower only event
- We apply the same procedure to both data and MC.

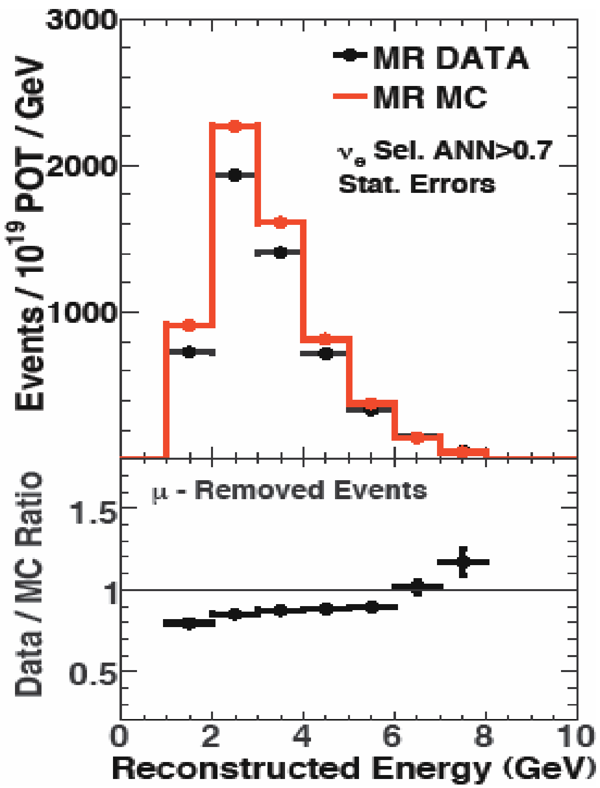
$$NC_i^{corr} = \frac{MRCC_i^{data}}{MRCC_i^{MC}} \times NC_i^{MC}$$

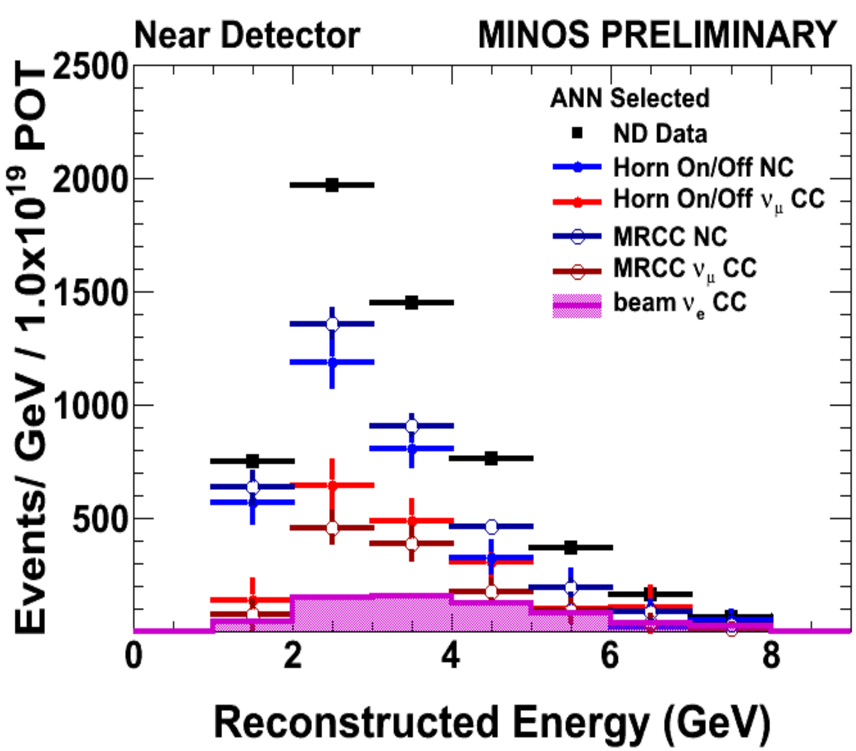


MRCC (Muon Removed ν_μ CC) cont…

- ν_e selection is applied to standard data/mc as well as MRCC data/MC
- The data/MC ratio from the MRCC is used to obtain a data driven correction that is applied to the standard NC, CC events as a function of energy.
- Discrepancy with the models show the same trend in both standard data/MC and MRCC data/MC –> Hadronic shower is the main source of discrepancy.







Data/MC beam decomposition in two methods

Method -1 (called HOO):

	Total	NC	CC	Beam ν_e
HOO	5524±35	3150^{+292}_{-273}	1781^{+366}_{-302}	593±178
MC	6764±21	4429±17	1742±10	593±6
Difference	-18%	-29%	+2%	

Statistical error on NC ~9% and on CC~21%

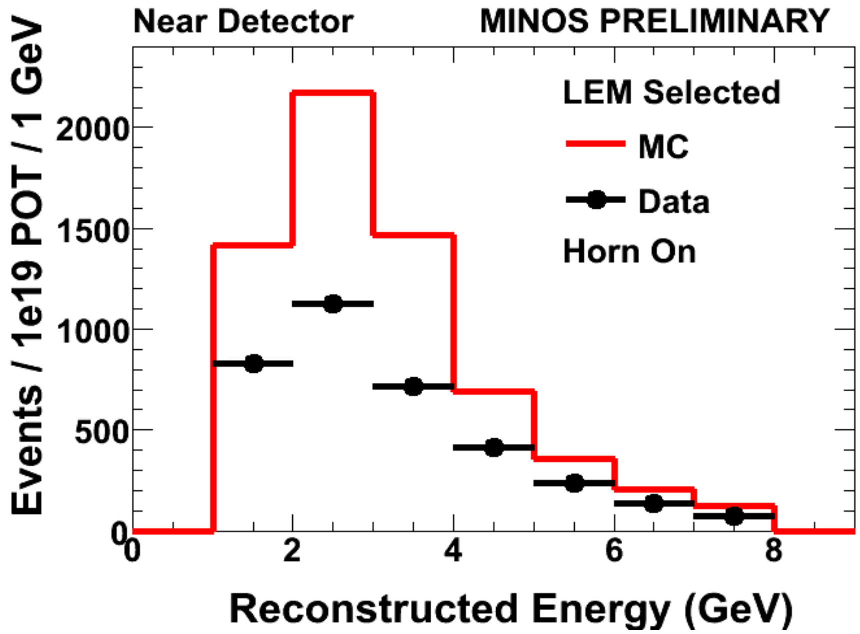
Method -2 (called MRCC):

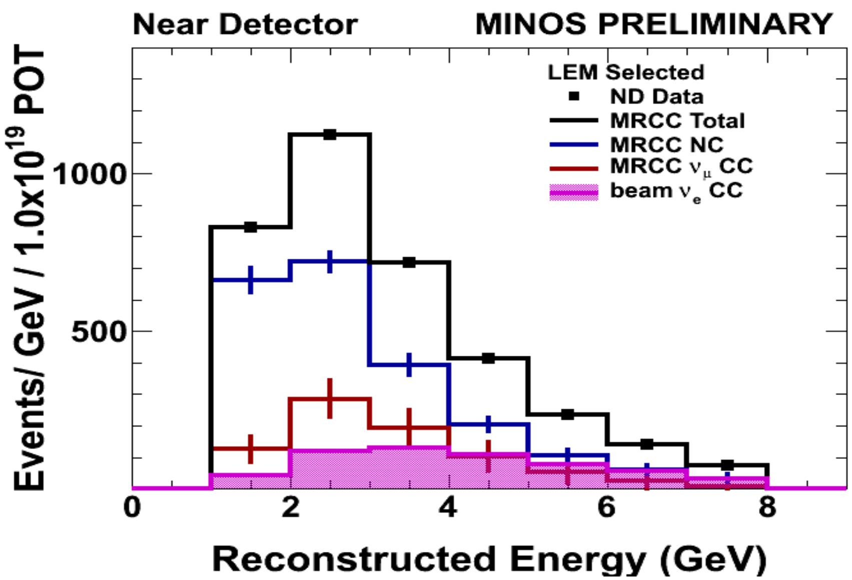
	Total	NC	CC	Beam ν_e
MRCC	5524±35	3674±192	1236±281	614±185
MC	6726±61	4285±49	1727±31	614±18
Difference	-18%	-14%	-28%	

Statistical error on NC ~5% and on CC~23%

Alternative Particle Identification (LEM)

- Different and complementary approach to ANN





	Total	NC	CC	Beam ν_e
HOO LEM MRCC LEM	3528±28 3528±28	2073^{+260}_{-258} 2170±136	865^{+351}_{-216} 789±244	590±177 570±172
HOO MC MRCC MC	6432±20 5860±57	4017±16 3640±45	1825±10 1650±30	590±6 570±18

Summary and Conclusion

- MINOS uses data driven method to decompose the background components at the near detector (because the hadronic shower is not well modeled in MC) and extrapolate to the FD
- Horn on/off method is used as the primary method estimate the NC, CC and ν_e backgrounds at the near detector.
- The ratios of off/on determined from Monte Carlo are quite robust against physics simulation uncertainties.
- The MRCC method of background estimation is robust in a sense that it corrects the nominal MC to much more closely to resemble the data but it is secondary method used as cross-check.
- The MC has been improved with new intra-nuke model (neutrino-nucleus interaction). In principle it should improve modeling hadronic shower.

Stay tuned !