Alma 9 Validation & ALPtrino Analysis

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Alma 9 Validation : Single Muon MC

Alma 9 Validation

Data Selection Criteria

- Fiducial truth in all 3 stations (& at vertex)
- r_atMaxRadius < 100
- Exactly one 1 Good Track
- Matching using:
  - PDG value [for truth]
  - Track charge [for reco]

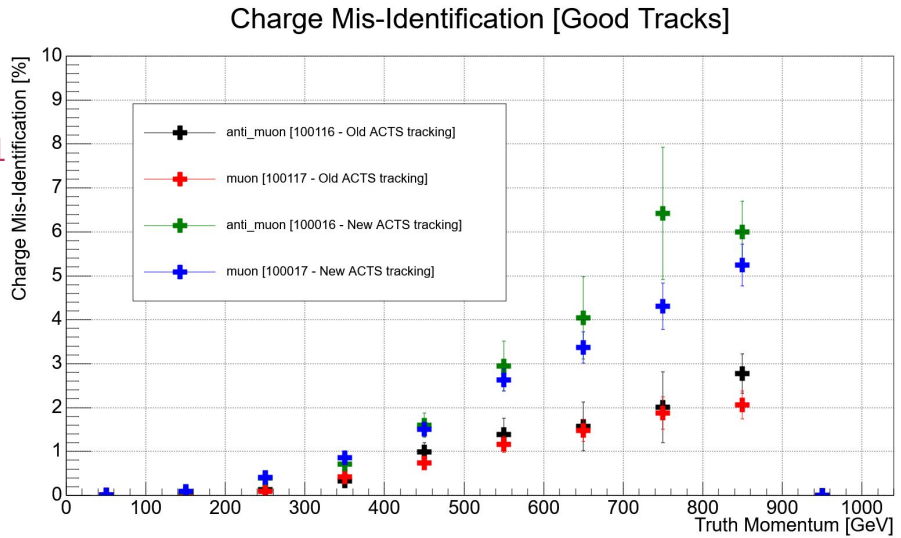
- As part of the migration of calypso to alma 9 - it is essential we validate the new build with both data and MC
- Samples looked at as part of this study are MC
  - Both samples are particle gun - single muon samples [one muon and the other anti-muon] produced for the FLUKA energy and angular spectra
    - 100117 (/eos/experiment/faser/data0/sim/mc24/particle_gun/100117/phy/s0012-dev)
    - 100116 (/eos/experiment/faser/data0/sim/mc24/particle_gun/100116/phy/s0012-dev)
- As part of the validation looking at :
  - Getting resolutions using residuals
  - Track efficiency
  - Charge misidentification etc.

Charge Misidentification

- Charge misidentification
  - Gives the percentage of events that have a incorrectly assigned charge
- Definition of charge mis-identification:
  - Track charge = -1 & PDG ≠ 13 OR Track charge ≠ -1 & PDG = 13 [Muons]
- Looked at this for the case of All tracks and Good Tracks
  - In both cases :
    - All tracks are required to be fiducial
    - Truth particles are required to be fiducial

Observations

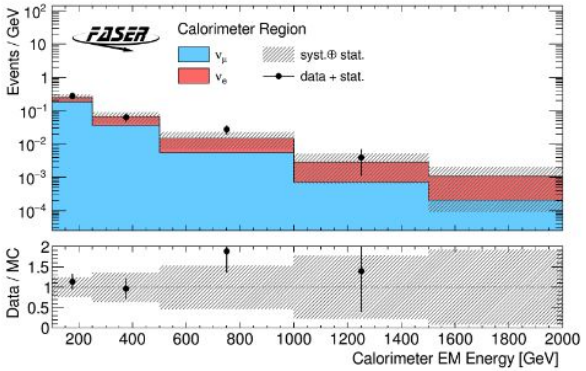
- Behaviour of the distribution of charge misid is as expected
  - At low momentum - percentage of charge misid is low
  - At high momentum - percentage of charge misid is high

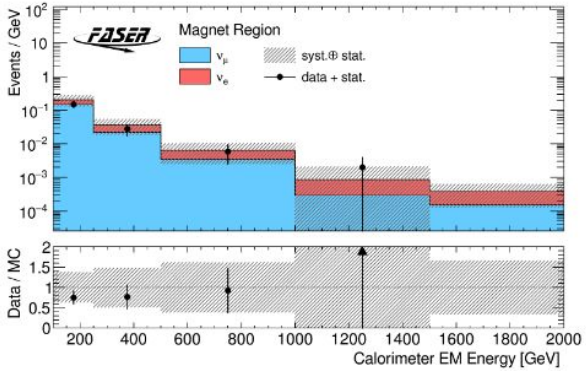


ALPtrino [Electronic Electron Neutrino] Analysis

Overview of Analysis

- The ALP analysis has observed a significant selection of neutrinos in the control region (CR).
  - CR is now our region of interest
- Uses RDF framework
  - Used in DP (2023) and ALP (2024) analyses.
- Utilises predefined neutrino regions
  - Identified in the ALPs background analysis
- Targets 2022–2024 data,
  - Totaling approximately 180 fb^{-1}.
- Goal:
  - Detect electron neutrinos using the FASER electronic detector.
- Signal is CC Electron Neutrinos (with NC Electron and Muon neutrinos both contributing to the background)





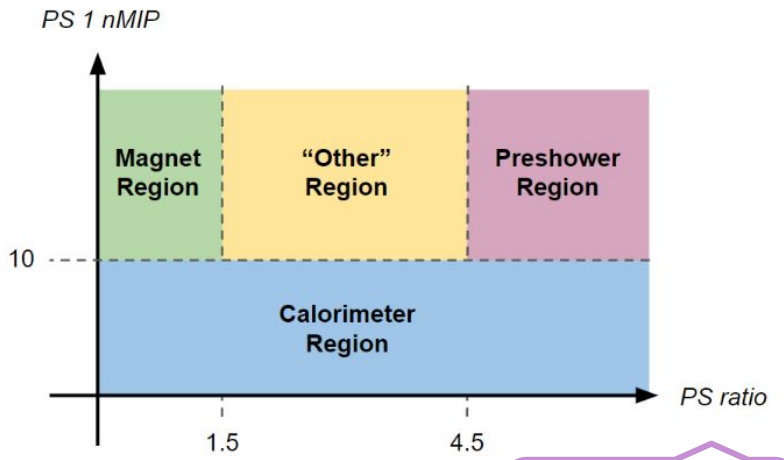
Baseline Cuts

- ➔ No signal in Veto or VetoNu
- ➔ Timing Signal < 40 pC

Overview of regions

- Utilising regions used for neutrino background in ALPs analysis
- Regions defined by PS ratio and PS1 nMIP (and utilising baseline cuts):
- **Magnet**:
  - PS1 nMIP >10
  - PS ratio < 1.5
- **Other**:
  - PS1 nMIP >10
  - PS ratio <4.5 & >1.5
- **PS**:
  - PS1 nMIP >10
  - PS ratio > 4.5
- **Calo**:
  - PS1 nMIP < 10

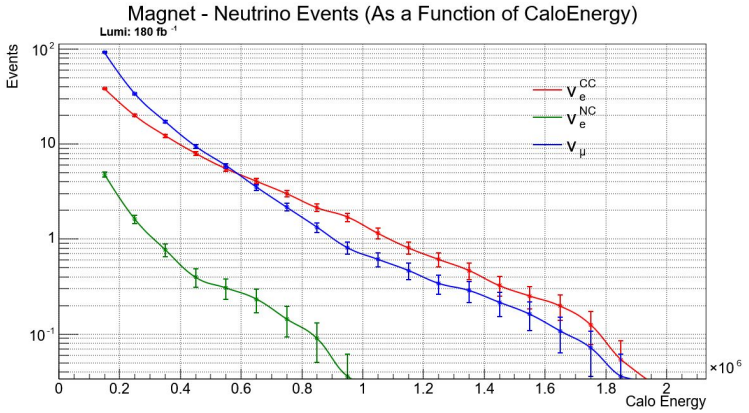
PS ratio
Ratio of MIPs in PS station 1 compared to station 10

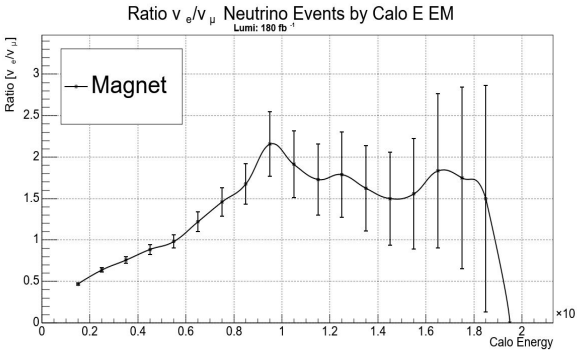


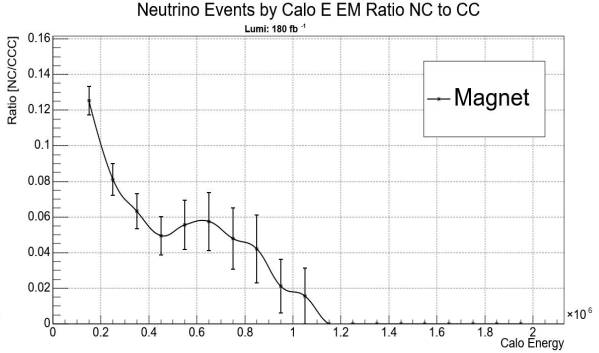
PS1 nMIP
Number of MIPs in preshower station 1

Magnet Region

- One focus has been on studying the magnet region
- There have been some investigations into the calo region done in parallel
  - Calo region provides the highest number of neutrino events and potential significance
- Good ratio of CC electron neutrinos to muon and NC electron neutrinos in magnet region

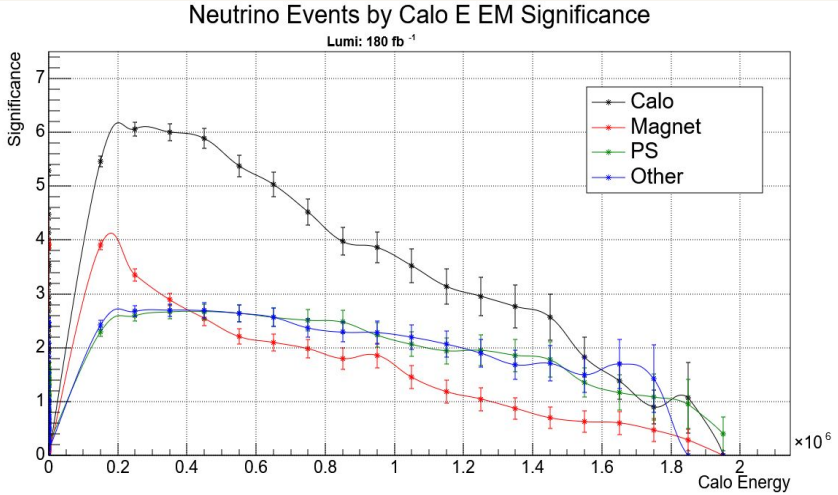


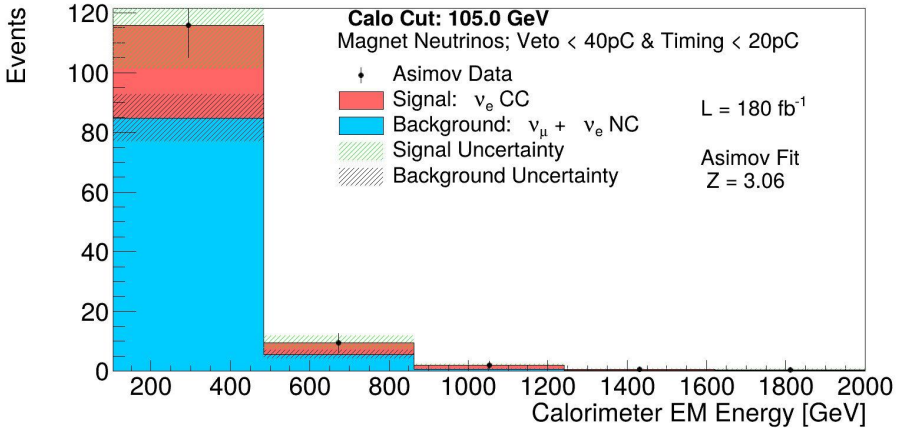


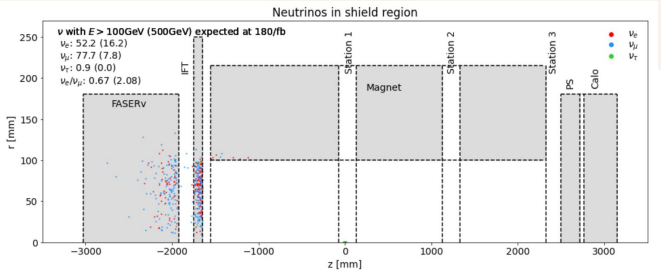


Magnet Region

- Significance studies showed magnet region would add a non negligible amount of significance to the cumulative significance
- Studies done using:
  - Basic significance formula: $\frac{\text{Signal}}{\sqrt{\text{Bkg}}} = \frac{\nu_e^{CC}}{\sqrt{\nu_e^{NC} + \nu_\mu}}$
  - Using asimov data to give a predicted significance
- Using basic significance method:
  - Found best cut for this region ~105 GeV
  - Magnet region gives a significance of 3.9
    - Calo region gives a higher significance but could be used in addition to this
- Using optimal cut found, asimov data is used to provide a prediction of significance for this region
  - Using 5 bins, significance is 3.06
    - Note: Using the same binning the Calo region gives a significance 5.00





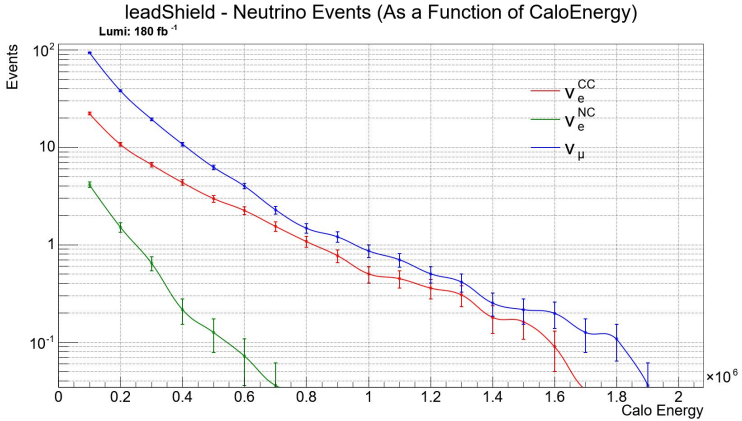


Lead Shield Cuts

- No Raw Veto Nu Signal
- Raw Veto Signal > 40
- Energy > 100 GeV

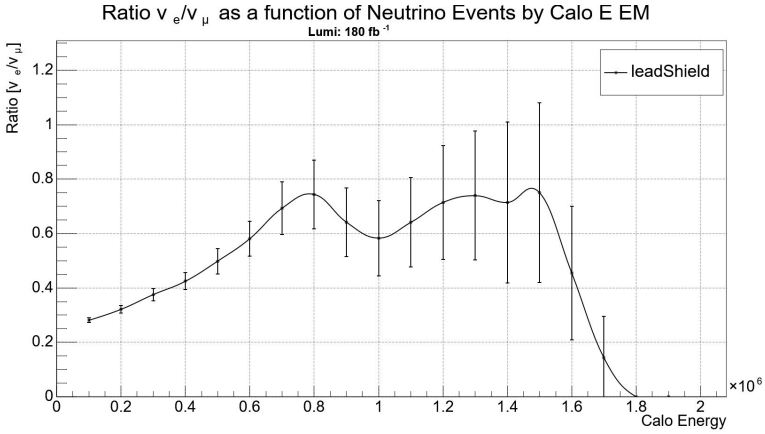
Lead Shield Region

- New region (Lead Shield Region) has been proposed
  - designed to encompass neutrinos that interact in the lead shield
  - These neutrinos could still leave a large a amount of energy in the calorimeter



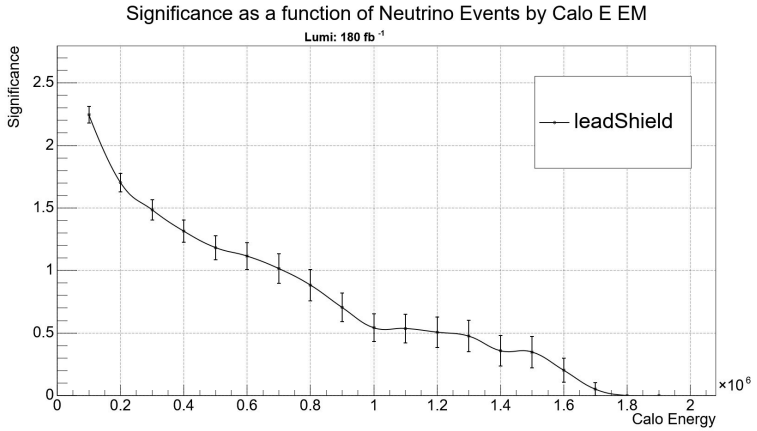
Signal and background events for leadShield region with $\mathcal{L} = 180$ fb^{-1}.

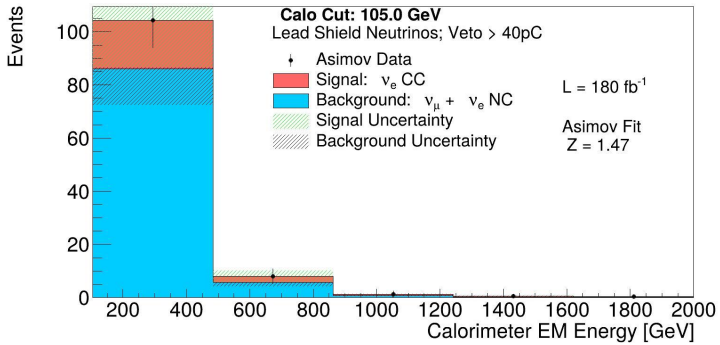
Calo Energy [GeV]	Signal [ν_e^{CC}] Events	Background [$\nu_e^{NC} + \nu_\mu$] Events
100.00	22.19	97.72
200.00	10.71	39.55
300.00	6.66	20.11
400.00	4.36	10.98
500.00	2.99	6.37
600.00	2.25	4.07
700.00	1.55	2.32
800.00	1.08	1.49
900.00	0.77	1.21
1000.00	0.50	0.86
1100.00	0.45	0.70
1200.00	0.36	0.50
1300.00	0.31	0.41
1400.00	0.18	0.25
1500.00	0.16	0.22
1600.00	0.09	0.20
1700.00	0.02	0.13
1800.00	0.00	0.11
1900.00	0.00	0.04



Lead Shield : Significance

- Lead shield region doesn't add as much potential significance as other regions
  - Likely due to the low ratio of electron neutrinos to muon neutrinos
  - At high calo energy cut >9oo GeV
    - Number of events drop below 1 signal event
- Using Asimov data - this predicts a significance of only 1.47 for the lead shield region when using 5 bins





Background Considerations

- In the ALPs analysis background studies were done for:
  - Cosmics & Beam 1 Background
  - Neutral hadrons (Calo E > 500 GeV)
  - Geometric Background (Calo E > 500 GeV)
- ALPs analysis only used 22/23 data, we need to also consider 2024 data
  - Background likely a little bit more complex in 2024 due to:
    - Increased muon flux due to change in optics
    - Periods of time with replacement in FaserNu box:
      - Just tungsten
      - CaloNu
    - See talk from Brian here, covers background test around 1st beam of 2024 …
- Need to also look at background for Calo E < 500 GeV for 22/23 data
  - Should be able to rework existing background studies for this (hopefully)
- Next steps:
  - Consider what samples are needed (e.g. Simulations with CaloNu installed)
  - Potentially split up 2024 into runs with FaserNu, runs without, runs with another installation (CaloNu etc)

Summary & Next Steps

Alma 9 Validation

- Alma 9 seems to have good performance in reconstructing MC samples
- Charge misid seems to be slightly worse for alma9 compared to centos7
  - Currently trying to understand why this is occurring
    - Potential point of discussion at the offline sw meeting

ALPtrino analysis

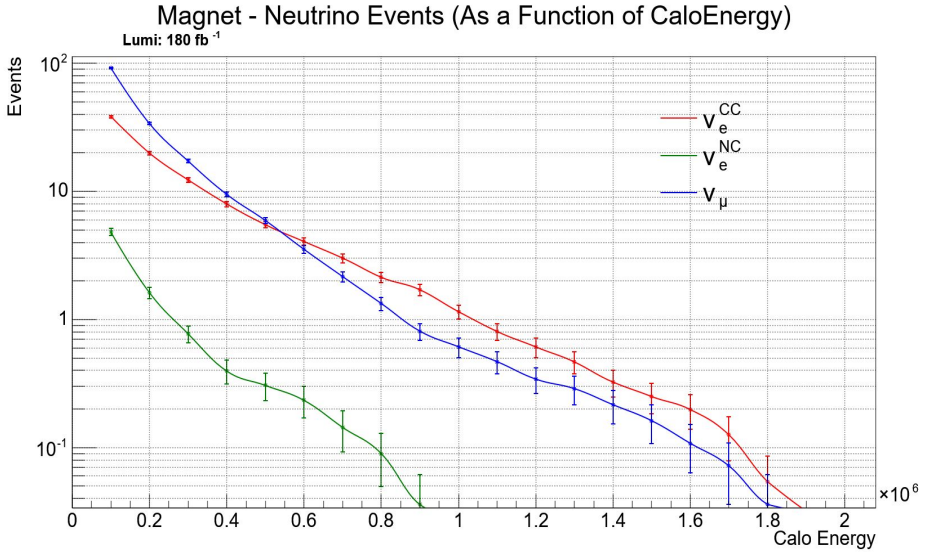
- Magnet region seems very promising in adding further significance alongside the Calo region
- Lead shield region seems to have a high background and doesn't seem to add much to the end result
  - Need to consider whether this is a region used in the analysis or not
- Background studies need to be done
  - Some of the background studies done for the ALPs analysis will need to be revisited and calo cut decreased
  - For 2024 data:
    - Muon background needs to be studied as saw a higher flux of muons due to the LHC optics
    - Neutral Hadron, Beam 1 Bkg and cosmics need to be analysed to give an accurate background prediction

Back Up

Magnet Region

Signal and background events for Magnet region with $\mathcal{L} = 180$ fb^{-1}.

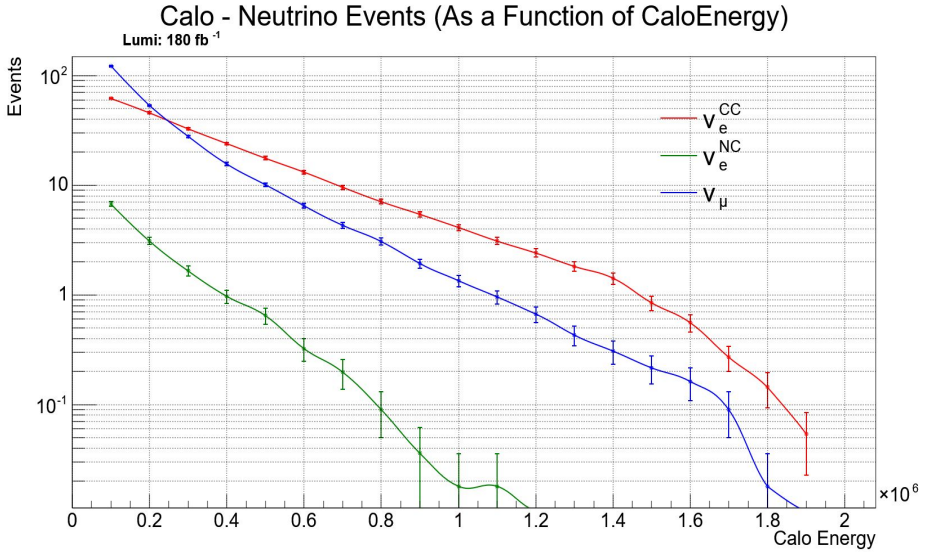
Calo Energy [GeV]	Signal [ν_e^{CC}] Events	Background [$\nu_e^{NC} + \nu_\mu$] Events
100.00	38.34	96.62
200.00	19.94	35.41
300.00	12.26	17.98
400.00	7.99	9.86
500.00	5.51	6.23
600.00	4.07	3.76
700.00	3.01	2.30
800.00	2.14	1.42
900.00	1.71	0.85
1000.00	1.15	0.63
1100.00	0.81	0.47
1200.00	0.61	0.34
1300.00	0.47	0.29
1400.00	0.32	0.22
1500.00	0.25	0.16
1600.00	0.20	0.11
1700.00	0.13	0.07
1800.00	0.05	0.04
1900.00	0.00	0.00



Calo Region

Signal and background events for Calo region with $\mathcal{L} = 180$ fb^{-1}.

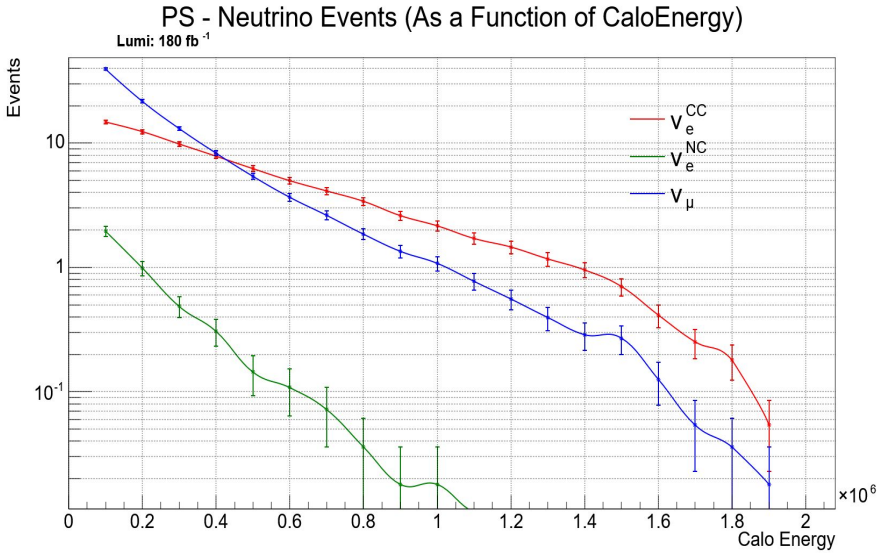
Calo Energy [GeV]	Signal $[\nu_e^{CC}]$ Events	Background $[\nu_e^{NC} + \nu_\mu]$ Events
150.00	61.88	128.38
250.00	45.67	56.68
350.00	32.69	29.63
450.00	23.99	16.61
550.00	17.64	10.75
650.00	13.18	6.86
750.00	9.59	4.50
850.00	7.07	3.17
950.00	5.44	1.98
1050.00	4.12	1.37
1150.00	3.10	0.97
1250.00	2.41	0.67
1350.00	1.82	0.43
1450.00	1.42	0.31
1550.00	0.85	0.22
1650.00	0.56	0.16
1750.00	0.27	0.09
1850.00	0.14	0.02
1950.00	0.05	0.00



PS Region

Signal and background events for PS region with $\mathcal{L} = 180$ fb^{-1}.

Calo Energy [GeV]	Signal [ν_e^{CC}] Events	Background [$\nu_e^{NC} + \nu_\mu$] Events
150.00	14.78	41.42
250.00	12.37	22.70
350.00	9.83	13.59
450.00	7.85	8.62
550.00	6.23	5.56
650.00	4.99	3.78
750.00	4.12	2.70
850.00	3.40	1.89
950.00	2.61	1.37
1050.00	2.16	1.10
1150.00	1.71	0.77
1250.00	1.46	0.56
1350.00	1.17	0.40
1450.00	0.95	0.29
1550.00	0.70	0.27
1650.00	0.41	0.13
1750.00	0.25	0.05
1850.00	0.18	0.04
1950.00	0.05	0.02



Other Region

Signal and background events for Other region with $\mathcal{L} = 180$ fb^{-1}.

Calo Energy [GeV]	Signal [ν_e^{CC}] Events	Background [$\nu_e^{NC} + \nu_\mu$] Events
150.00	16.94	48.83
250.00	13.46	25.33
350.00	10.53	15.21
450.00	8.32	9.56
550.00	6.73	6.50
650.00	5.45	4.52
750.00	4.36	3.38
850.00	3.53	2.38
950.00	2.95	1.67
1050.00	2.43	1.22
1150.00	1.96	0.90
1250.00	1.53	0.65
1350.00	1.15	0.47
1450.00	0.92	0.29
1550.00	0.67	0.20
1650.00	0.56	0.11
1750.00	0.27	0.04
1850.00	0.22	0.00
1950.00	0.05	0.00