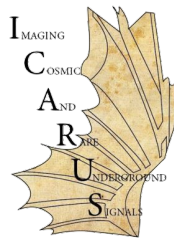


ν_e event selection with pandora

ICARUS Collaboration Meeting | October 16th 2024

Diana Mendez



Overview

— — —

Past efforts to develop the selection of BNB electron neutrino charge current (nue-cc) events at the ICARUS were made at the **beginning of 2021**.

A very preliminary selection followed at that time by SBND and it **wasn't optimised for the far detector**.

Work on the selection of BNB nue-cc interactions has been brought back in the **last couple of months using new MC and updated criteria**.



Current selection criteria

- ~~Pandora neutrino score~~
- Remove everything that is **pandora clear cosmic**.
- **Flash score** < 6.0
- **CRT veto**: remove events where there are CRT hits in the BNB window and above threshold: (-0.1, 1.8) micro seconds and hit PE > 100.
- **Barycenter**^{*}: Delta Z in (0.0, 100] *new*
- **Containment**^{*}: Longest shower and track start and end within the fiducial volume.
- **Reconstruction**^{**}: Slice with all the required variables reconstructed - See next slide.

Full selection = combine all the above cuts^{***}

* Not optimized ** Optimized for SBND *** Not in any specific order

Current selection criteria

Containment:

- Updated from 2021 to 2024

Reconstruction:

- One shower in the slice with energy > 200 MeV
- Longest shower $dE/dx < 3.625$ MeV/cm
- Largest shower conversion gap < 3.25 cm
- Largest shower density > 4.5 MeV/cm
- Largest shower energy > 200 MeV
- Longest track length < 110 cm

Specifications

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- Exposure:

Everything normalized to 6.6×10^{20} protons on target.

- Sample:

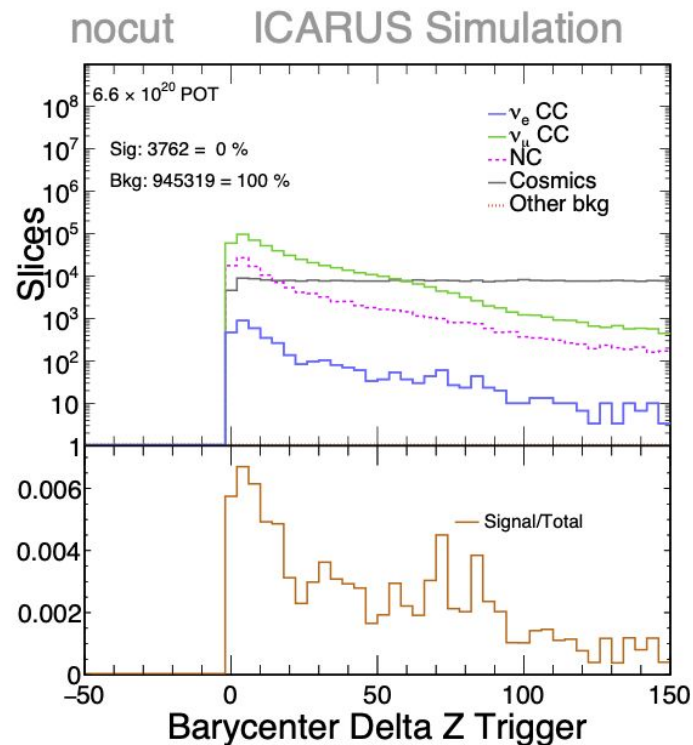
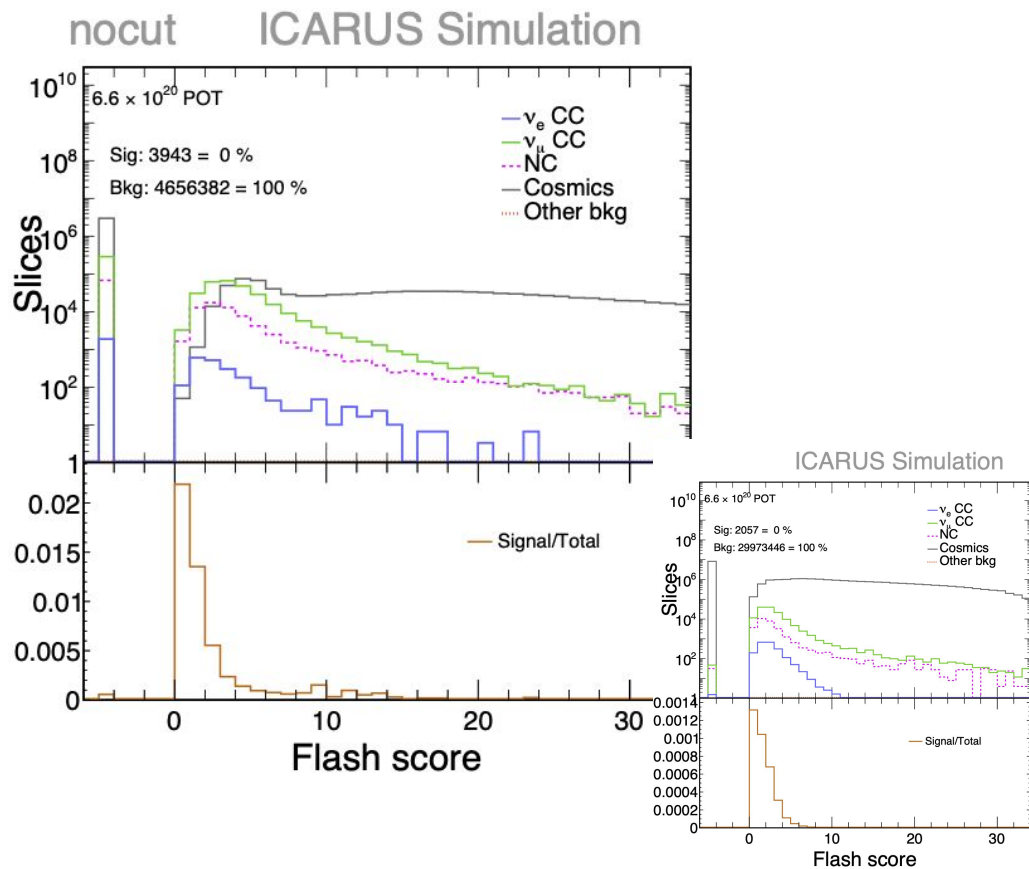
ν_x with out of time cosmics. No in-time cosmics/overlay.

icaruspro_production_v09_89_01_01_

2024A_ICARUS_MC_Sys_NuCos_2024A_MC_Sys_NuCos_CV

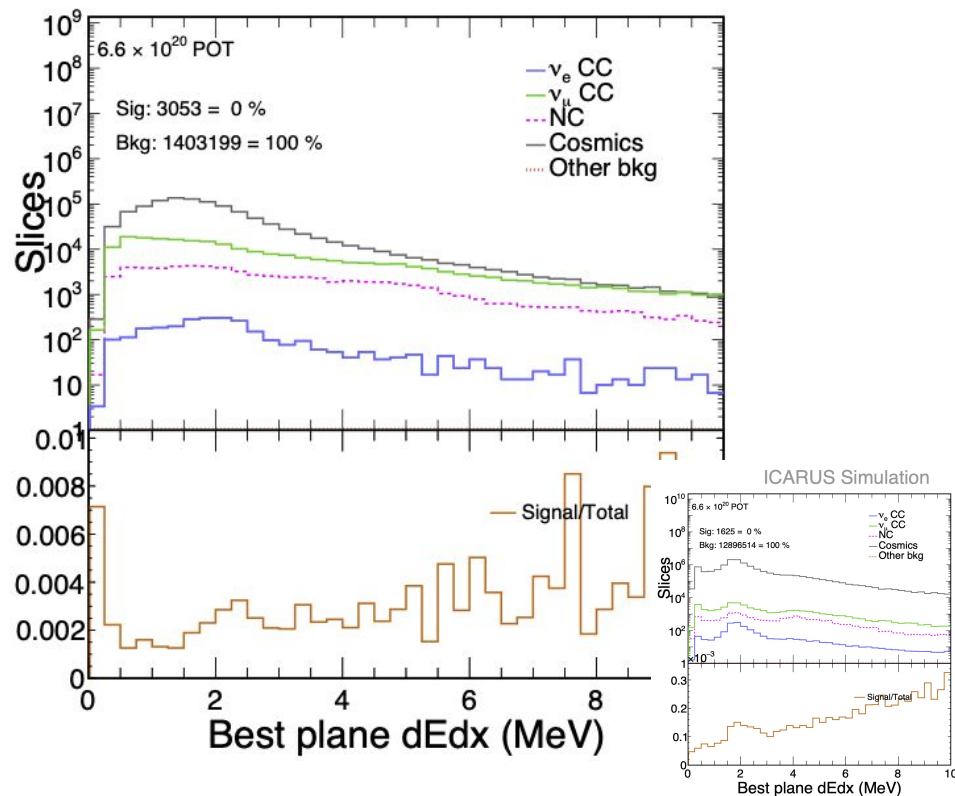
Flash score: Removes 90% of the background and preserves 46% of the signal.

Barycenter: Removes 82% of the background and preserves 92% of the signal.

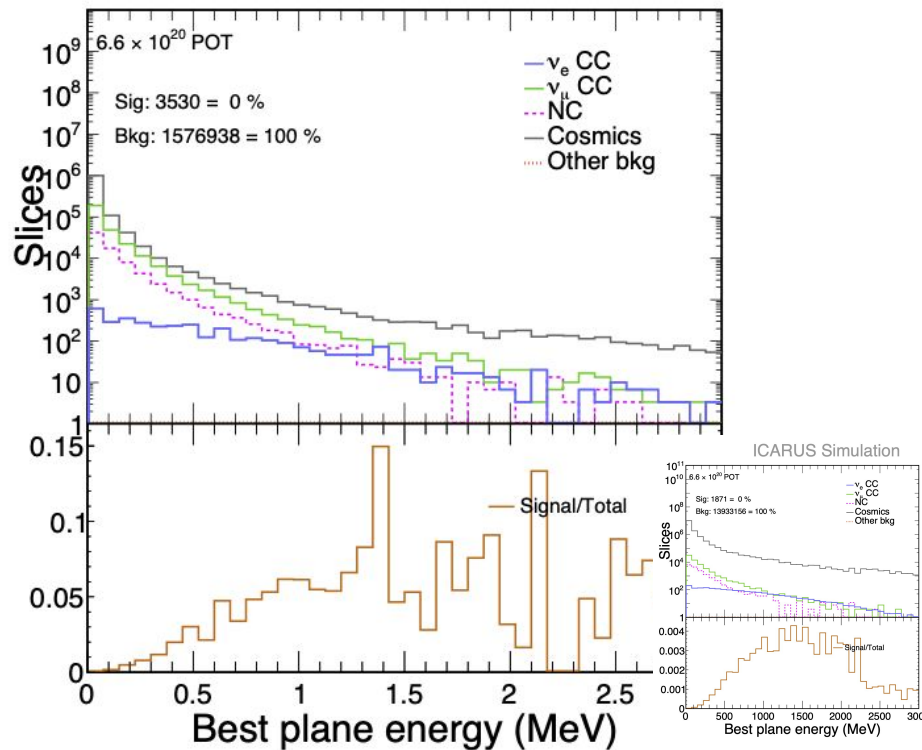


Reconstruction: multiple inputs used to reject long tracks - muons - and reduce the NC background. Removes 99% of the background, and preserves 21% of the signal

nocut ICARUS Simulation

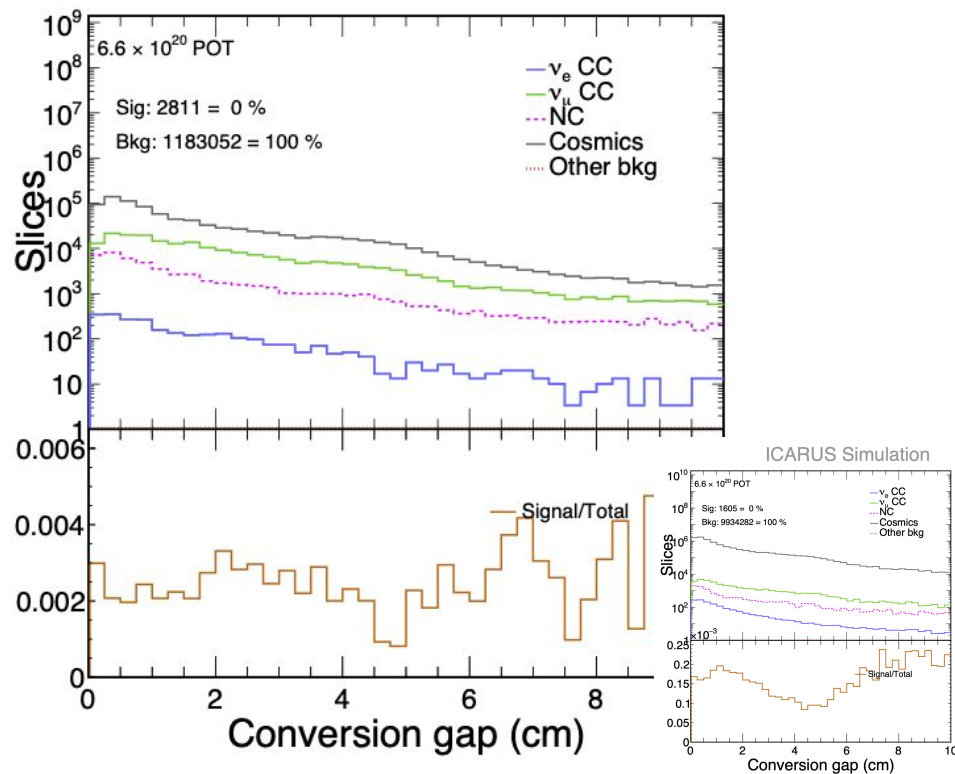


nocut ICARUS Simulation

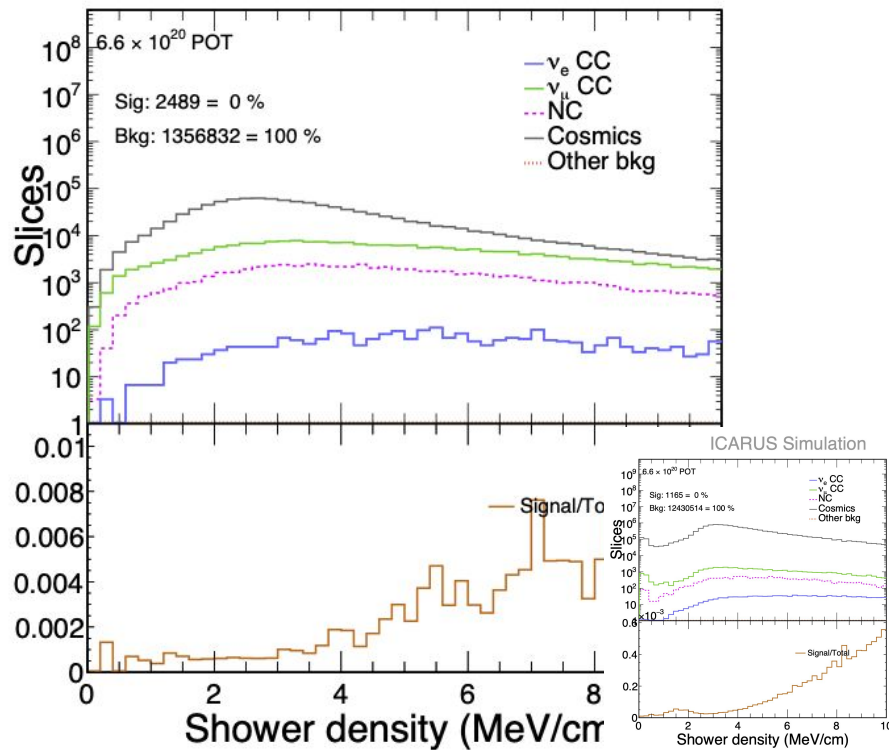


Reconstruction: multiple inputs used to reject long tracks - muons - and reduce the NC background. Removes 99% of the background, and preserves 21% of the signal

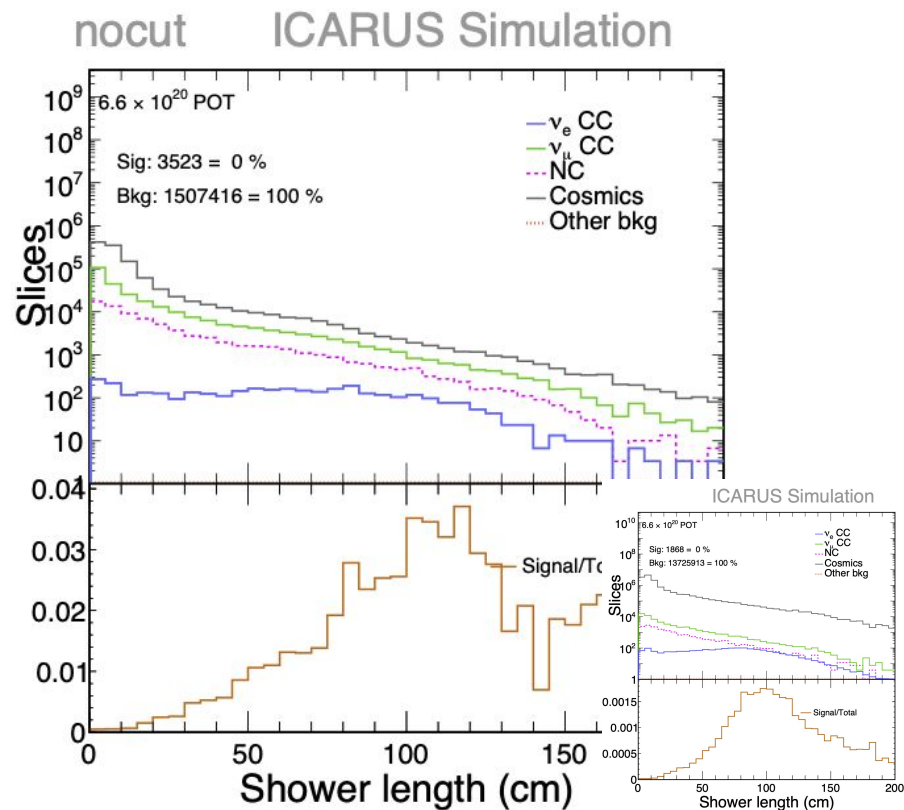
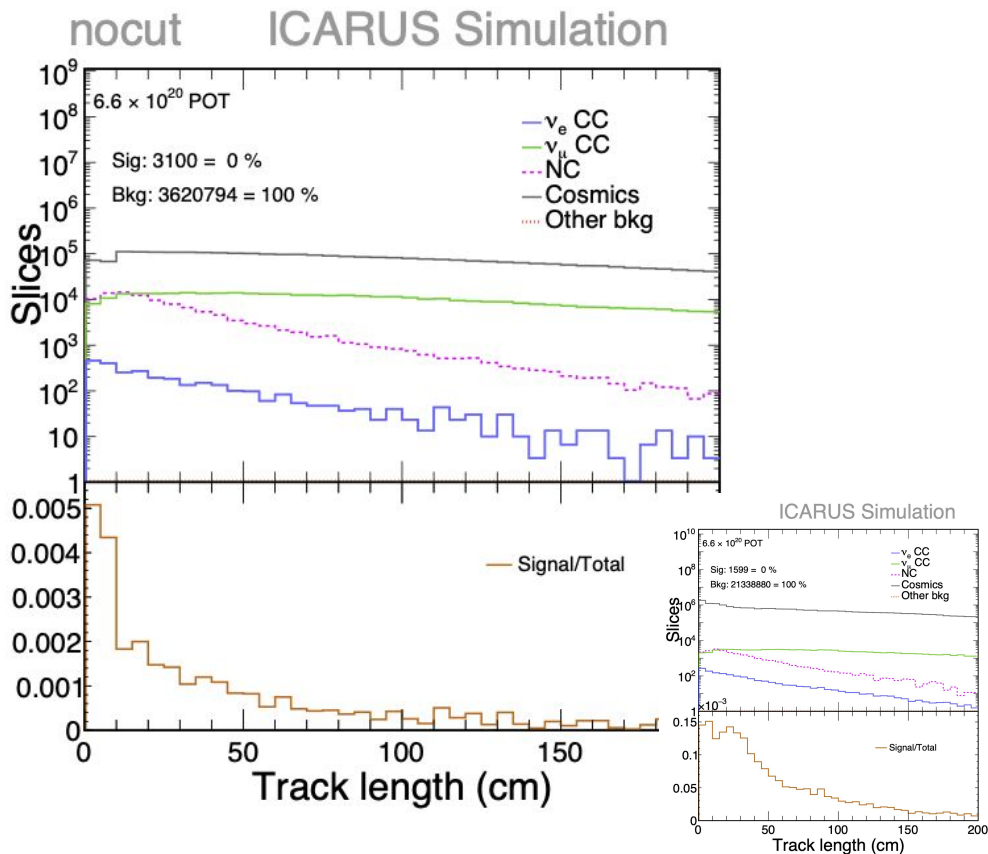
nocut ICARUS Simulation



nocut ICARUS Simulation



Reconstruction: multiple inputs used to reject long tracks - muons - and reduce the NC background. Removes 99% of the background, and preserves 21% of the signal



Result summary

Individual cuts performance

Efficiency = selected signal / all signal

Purity = selected signal / (selected signal + selected background)

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Cut	Number of interactions (% total)				Integrated	
	ν_e CC	ν_μ CC	NC	Cosmic	Efficiency	Purity
No cut	3946.485(0.081)	570708.750(11.738)	134570.094(2.768)	4151299.000(85.383)	0.000	0.000
Containment	1283.027(0.577)	79430.148(35.745)	29056.205(13.076)	112348.867(50.559)	0.493	0.006
Flash score	1817.062(0.362)	237669.078(47.302)	56392.750(11.224)	205905.750(40.981)	0.437	0.004
Reconstructed shower	3304.971(0.227)	262997.125(18.038)	73455.000(5.038)	1117140.750(76.619)	0.813	0.002
Number of showers	2293.999(1.758)	36149.801(27.707)	13475.146(10.328)	77834.758(59.656)	0.595	0.018
Shower dE/dx	2525.750(0.193)	194227.516(14.839)	49453.652(3.778)	1061826.125(81.126)	0.640	0.002
Conversion gap	2273.847(0.226)	180520.609(17.944)	46561.805(4.628)	775899.062(77.125)	0.566	0.002
Track length	3657.636(0.132)	292516.812(10.592)	129280.125(4.681)	2334790.750(84.545)	0.876	0.001
Shower density	2693.686(0.469)	159068.531(27.722)	43720.336(7.619)	367402.625(64.029)	0.670	0.005
Shower energy	2428.348(1.970)	36096.062(29.279)	13827.812(11.216)	70183.617(56.928)	0.635	0.020
Reconstruction (all)	846.395(5.622)	2408.196(15.997)	1440.887(9.572)	10139.947(67.358)	0.237	0.057
Barycenter	3650.918(0.434)	521486.844(62.045)	116476.727(13.858)	197603.016(23.510)	0.896	0.004
CRT veto	3946.485(0.081)	570698.688(11.738)	134570.094(2.768)	4151258.750(85.383)	0.951	0.001
Everything (incl. CRT veto)	194.805(27.103)	312.360(43.458)	194.805(27.103)	6.717(0.935)	0.077	0.275

Background by contribution: cosmics (~4M), numu (~135k) CC and NC (~58k).

Barycenter and CRT veto provide most of the background reduction.

Reconstruction cut (including more than one variable) performs best at increasing the signal percentage.

N-1 cuts performance

Efficiency = selected signal / all signal

Purity = selected signal / (selected signal + selected background)

N-1 cut = all cuts except the specified cut

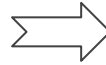
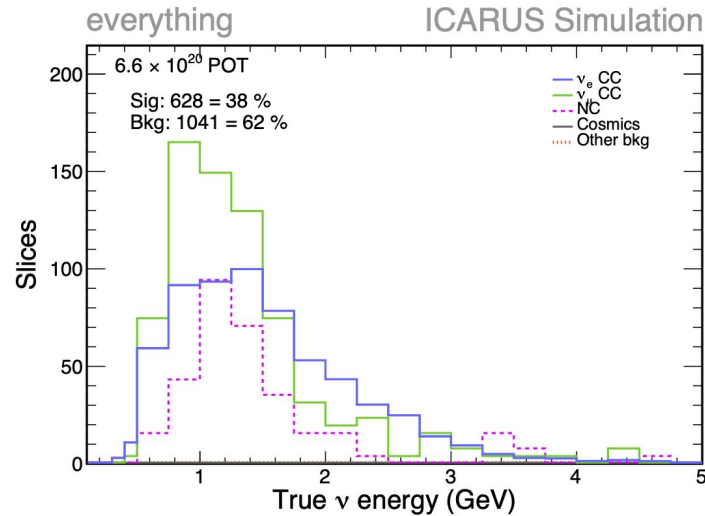
Cut	Number of interactions (% total)				Integrated	
	ν_e CC	ν_μ CC	NC	Cosmic	Efficiency	Purity
No cut	3946.485(0.081)	570708.750(11.738)	134570.094(2.768)	4151299.000(85.383)	0.000	0.000
Everything (incl. CRT veto)	194.805(27.103)	312.360(43.458)	194.805(27.103)	6.717(0.935)	0.077	0.275
N1 Containment	429.915(18.338)	1111.733(47.421)	668.383(28.510)	40.305(1.719)	0.127	0.191
N1 Flash score	342.588(22.517)	732.199(48.124)	389.610(25.607)	47.022(3.091)	0.138	0.227
N1 Reconstructed shower	194.805(24.893)	345.947(44.206)	221.675(28.326)	10.076(1.288)	0.077	0.252
N1 Number of showers	204.881(26.522)	342.588(44.348)	208.240(26.957)	6.717(0.870)	0.081	0.269
N1 Shower dE/dx	241.827(15.158)	769.145(48.211)	557.546(34.947)	10.076(0.632)	0.093	0.153
N1 Conversion gap	272.056(16.910)	809.449(50.313)	503.807(31.315)	10.076(0.626)	0.107	0.171
N1 Track length	194.805(22.568)	439.991(50.973)	208.240(24.125)	10.076(1.167)	0.077	0.228
N1 Shower density	228.392(19.048)	648.231(54.062)	302.284(25.210)	10.076(0.840)	0.091	0.192
N1 Shower energy	194.805(25.778)	342.588(45.333)	201.523(26.667)	6.717(0.889)	0.077	0.261
N1 Barycenter	198.164(25.877)	322.436(42.105)	198.164(25.877)	36.946(4.825)	0.078	0.262
N1 Reconstruction (all)	587.774(1.230)	33953.203(71.070)	12695.926(26.575)	493.730(1.033)	0.226	0.012
N1 CRT veto	194.805(27.103)	312.360(43.458)	194.805(27.103)	6.717(0.935)	0.077	0.275

Containment and flash score are the least efficient.

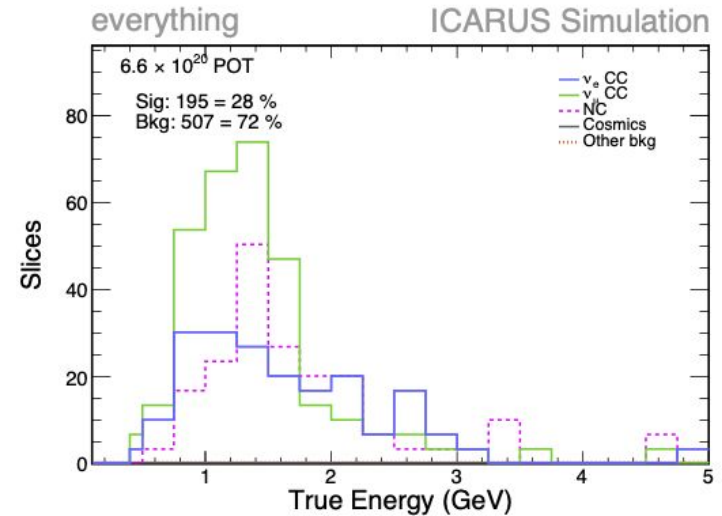
Full selection

Removes 99% of the background but only preserves 3% of the signal. This results on the selected nue CC interactions accounting for only 27% of the total selected events.

2021



2024



Distributions of only true neutrino energy: no cosmics shown.

Summary

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- Selection of BNB electron neutrinos based on Pandora is moving forward with fiducial volume update, addition of barycenter and removal of neutrino score.
- First study with new MC sample shows decreased performance when compared to the previous selection results.
 - Current selection removes 99% of background but only keeps 5% of signal.
 - Muon neutrino make up more than 40% of the selected events.
 - Essential to optimise cuts in each variable.
 - Further studies should provide feedback for reconstruction group.

