GNN's with PyTorch

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Results from ParticleNet with ORCA4

- Task: classify neutrino (1) vs background (0) muon events
- $\sim$2.4 million samples (approximately balanced, 60/40 ratio)
- ParticleNet architecture
- Now with fully dynamic EdgeConvolution (compute KNN every block $\mathcal{O}(N^2)$)
- training took approximately 7 days (20 epochs of the 2.4 million samples $\rightarrow \sim$ 80 events per second)

Results from ParticleNet with ORCA4

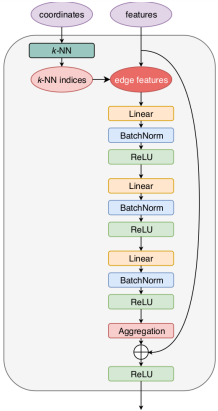
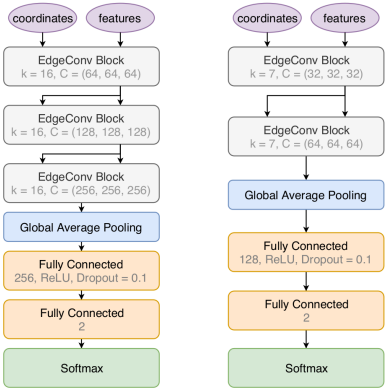
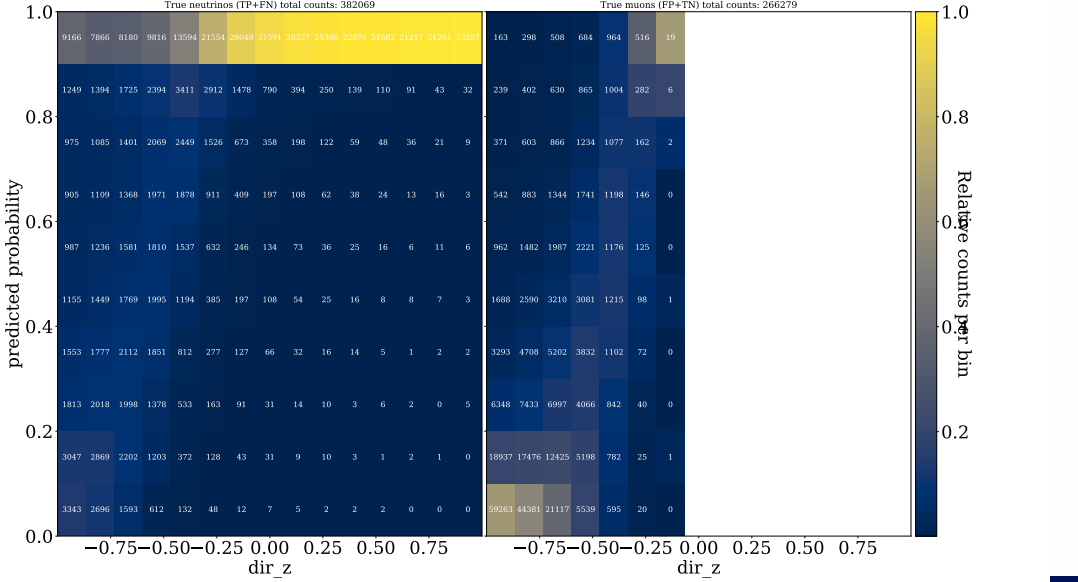


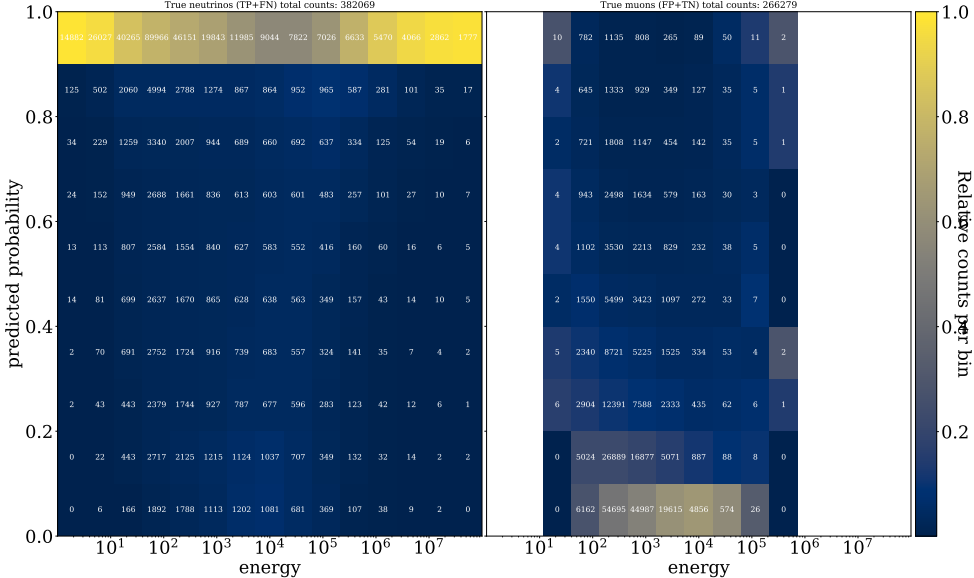
FIG. 1: The structure of the EdgeConv block.

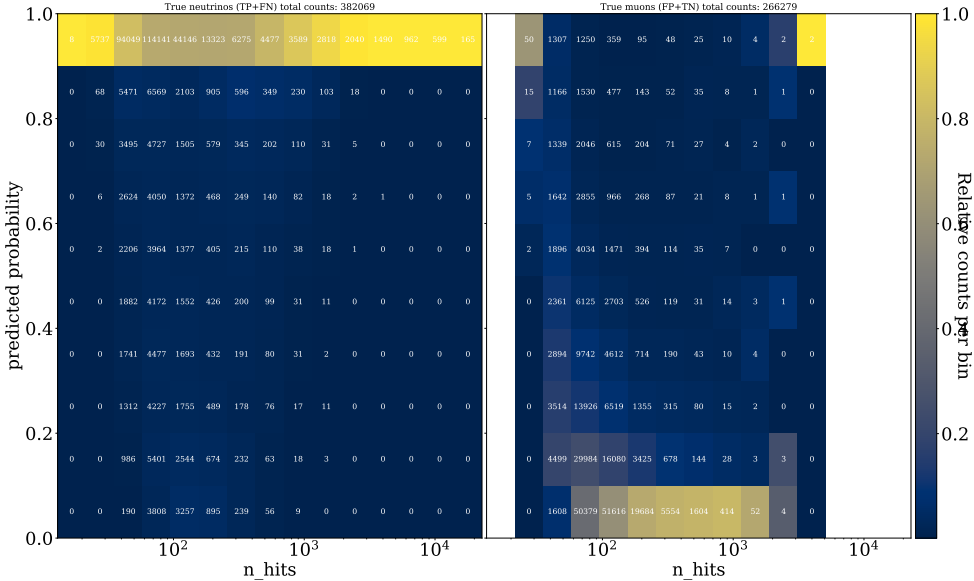


(a) ParticleNet (b) ParticleNet-Lite

FIG. 2: The architectures of the ParticleNet and the ParticleNet-Lite networks.


True neutrinos (TP+FN) total counts: 382069
True muons (FP+TN) total counts: 266279
predicted probability
dir_z
dir_z
Relative counts per bin
1.0
0.8
0.6
0.4
0.2
0.0
−0.75 −0.50 −0.25 0.00 0.25 0.50 0.75
9166 7866 8180 9816 13594 21554 28049 31591 28327 25380 22879 21682 21217 21261 23257
1249 1394 1725 2394 3411 2912 1478 790 394 250 139 110 91 43 32
975 1085 1401 2069 2449 1526 673 358 198 122 59 48 36 21 9
905 1109 1368 1971 1878 911 409 197 108 62 38 24 13 16 3
987 1236 1581 1810 1537 632 246 134 73 36 25 16 6 11 6
1155 1449 1769 1995 1194 385 197 108 54 25 16 8 8 7 3
1553 1777 2112 1851 812 277 127 66 32 16 14 5 1 2 2
1813 2018 1998 1378 533 163 91 31 14 10 3 6 2 0 5
3047 2869 2202 1203 372 128 43 31 9 10 3 1 2 1 0
3343 2696 1593 612 132 48 12 7 5 2 2 2 0 0 0
163 298 508 684 964 516 19
239 402 630 865 1004 282 6
371 603 866 1234 1077 162 2
542 883 1344 1741 1198 146 0
962 1482 1987 2221 1176 125 0
1688 2590 3210 3081 1215 98 1
3293 4708 5202 3832 1102 72 0
6348 7433 6997 4066 842 40 0
18937 17476 12425 5198 782 25 1
59263 44381 21117 5539 595 20 0


True neutrinos (TP+FN) total counts: 382069
True muons (FP+TN) total counts: 266279
predicted probability
energy
energy
Relative counts per bin
1.0
0.8
0.6
0.4
0.2
0.0
10^1 10^2 10^3 10^4 10^5 10^6 10^7
14882 26027 40265 89966 46151 19843 11985 9044 7822 7026 6633 5470 4066 2862 1777
125 502 2060 4994 2788 1274 867 864 952 965 587 281 101 35 17
34 229 1259 3340 2007 944 689 660 692 637 334 125 54 19 6
24 152 949 2688 1661 836 613 603 601 483 257 101 27 10 7
13 113 807 2584 1554 840 627 583 552 416 160 60 16 6 5
14 81 699 2637 1670 865 628 638 563 349 157 43 14 10 5
2 70 691 2752 1724 916 739 683 557 324 141 35 7 4 2
2 43 443 2379 1744 927 787 677 596 283 123 42 12 6 1
0 22 443 2717 2125 1215 1124 1037 707 349 132 32 14 2 2
0 6 166 1892 1788 1113 1202 1081 681 369 107 38 9 2 0
10 782 1135 808 265 89 50 11 2
4 645 1333 929 349 127 35 5 1
2 721 1808 1147 454 142 35 5 1
4 943 2498 1634 579 163 30 3 0
4 1102 3530 2213 829 232 38 5 0
2 1550 5499 3423 1097 272 33 7 0
5 2340 8721 5225 1525 334 53 4 2
6 2904 12391 7588 2333 435 62 6 1
0 5024 26889 16877 5071 887 88 8 0
0 6162 54695 44987 19615 4856 574 26 0


True neutrinos (TP+FN) total counts: 382069
True muons (FP+TN) total counts: 266279
predicted probability
n_hits
n_hits
Relative counts per bin
1.0
0.8
0.6
0.4
0.2
0.0
10^2
10^3
10^4
8 5737 94049 114141 44146 13323 6275 4477 3589 2818 2040 1490 962 599 165
0 68 5471 6569 2103 905 596 349 230 103 18 0 0 0 0
0 30 3495 4727 1505 579 345 202 110 31 5 0 0 0 0
0 6 2624 4050 1372 468 249 140 82 18 2 1 0 0 0
0 2 2206 3964 1377 405 215 110 38 18 1 0 0 0 0
0 0 1882 4172 1552 426 200 99 31 11 0 0 0 0 0
0 0 1741 4477 1693 432 191 80 31 2 0 0 0 0 0
0 0 1312 4227 1755 489 178 76 17 11 0 0 0 0 0
0 0 986 5401 2544 674 232 63 18 3 0 0 0 0 0
0 0 190 3808 3257 895 239 56 9 0 0 0 0 0 0
50 1307 1250 359 95 48 25 10 4 2 2
15 1166 1530 477 143 52 35 8 1 1 0
7 1339 2046 615 204 71 27 4 2 0 0
5 1642 2855 966 268 87 21 8 1 1 0
2 1896 4034 1471 394 114 35 7 0 0 0
0 2361 6125 2703 526 119 31 14 3 1 0
0 2894 9742 4612 714 190 43 10 4 0 0
0 3514 13926 6519 1355 315 80 15 2 0 0
0 4499 29984 16080 3425 678 144 28 3 3 0
0 1608 50379 51616 19684 5554 1604 414 52 4 0

Next step

Implement and test different architectures that do not dynamically compute the graph, such that we can either get better performance on ORCA4 data or even use ARCA data (with up to 5000 events per graph)