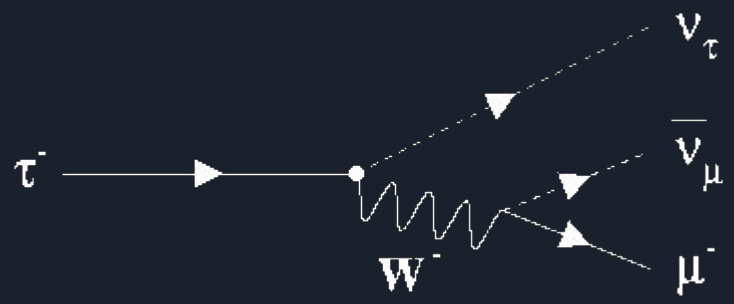
LBNF Tau Neutrino Optimization

Eric Leon

Motivation

- Least observed neutrino
- Great potential knowledge gap
- BSM and other interesting theories



Source: *Example Tau Pair Events*. (n.d.). Hep.uchicago.edu. Retrieved July 24, 2023, from https://hep.uchicago.edu/~oreglia/wyatt/tautau.html

LBNF Target Station

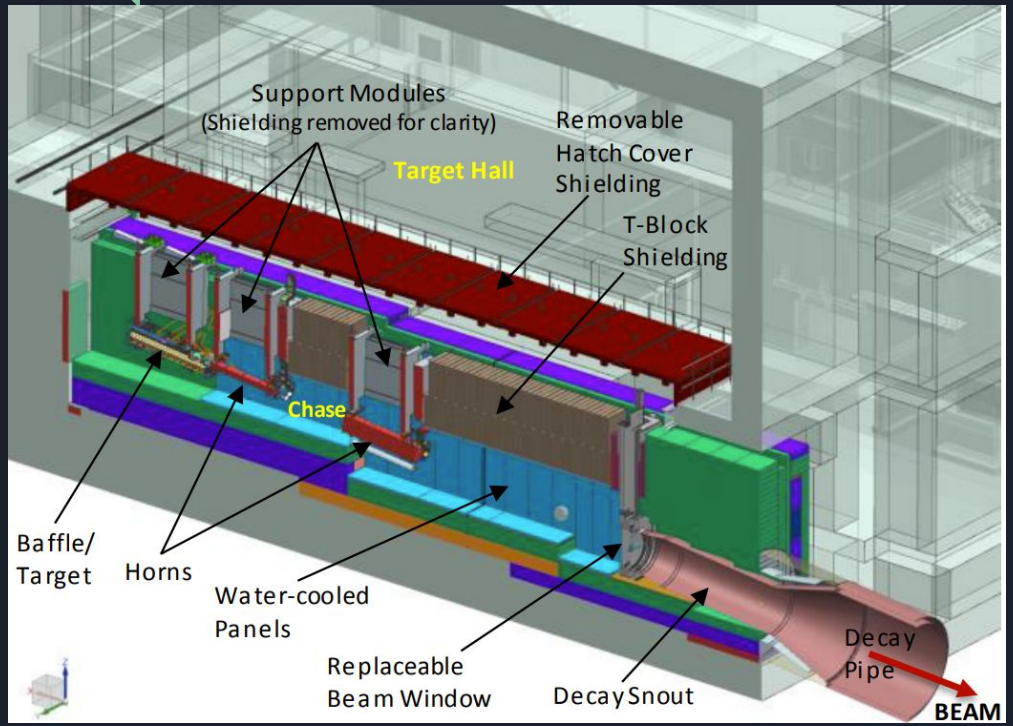
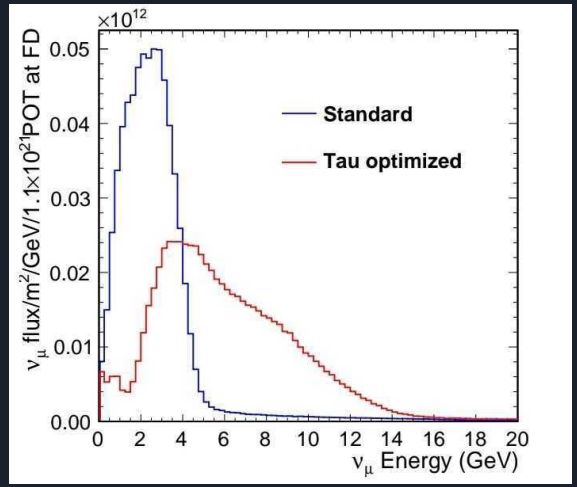


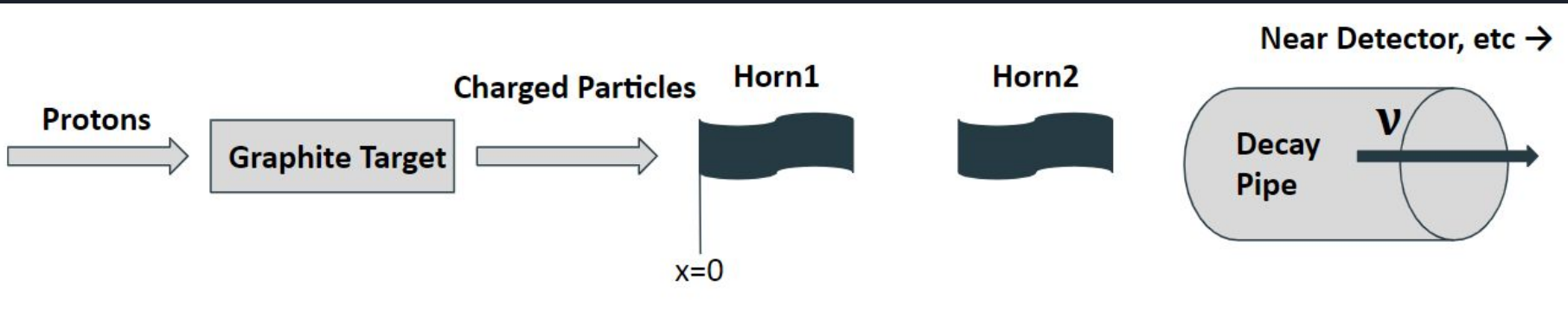
Image from: . Tariq, K. Ammigan, K. Anderson, et al., and C. Densham, Design of the lbnf

beamline target station (2016), arXiv:1612.07293 [physics.acc-ph] .

Original Tau Optimized Configuration

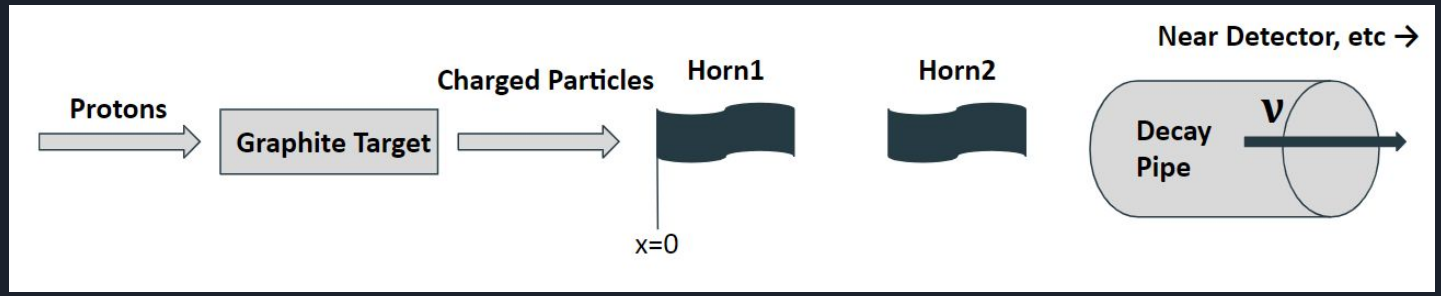


Abi, B., Acciarri, R., et al. (2020, March 25). *Deep Underground Neutrino Experiment (DUNE), Far Detector Technical Design Report, Volume II: DUNE Physics*. ArXiv.org. https://doi.org/10.48550/arXiv.2002.03005 pg 89



Beam Parameters

- Proton momentum (60GeV/c - 130Gev/c)
- Target Position (0.5m - 2.7m)
- Graphite Fin Width (5mm - 21mm)
- Horn Curent (200 kA- 300kA)
- Horn 2 Long Position (8m -20m)
- Horn 1 Radial Rescale (0.5 - 2.1)
- Horn 1 Longitudinal Rescale (0.5 - 2.1)
- Horn 2 Radial Rescale (0.5 - 2.1)
- Horn 2 Longitudinal Rescale (0.5 - 2.1)



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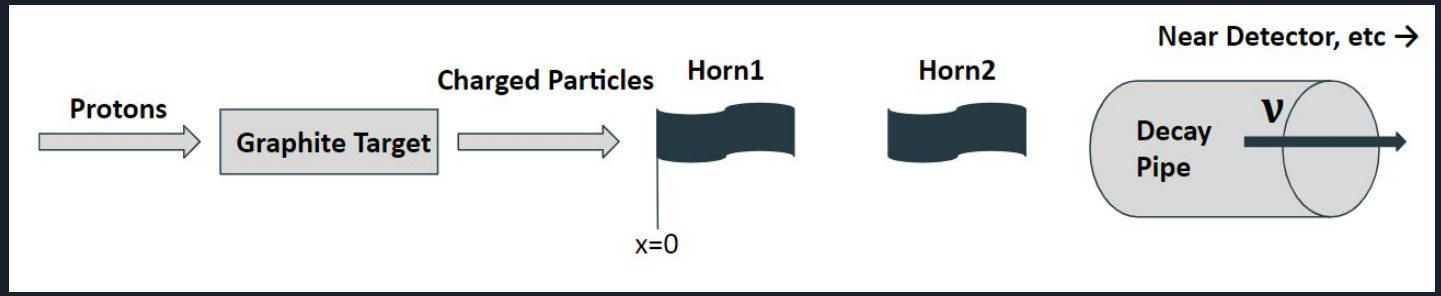
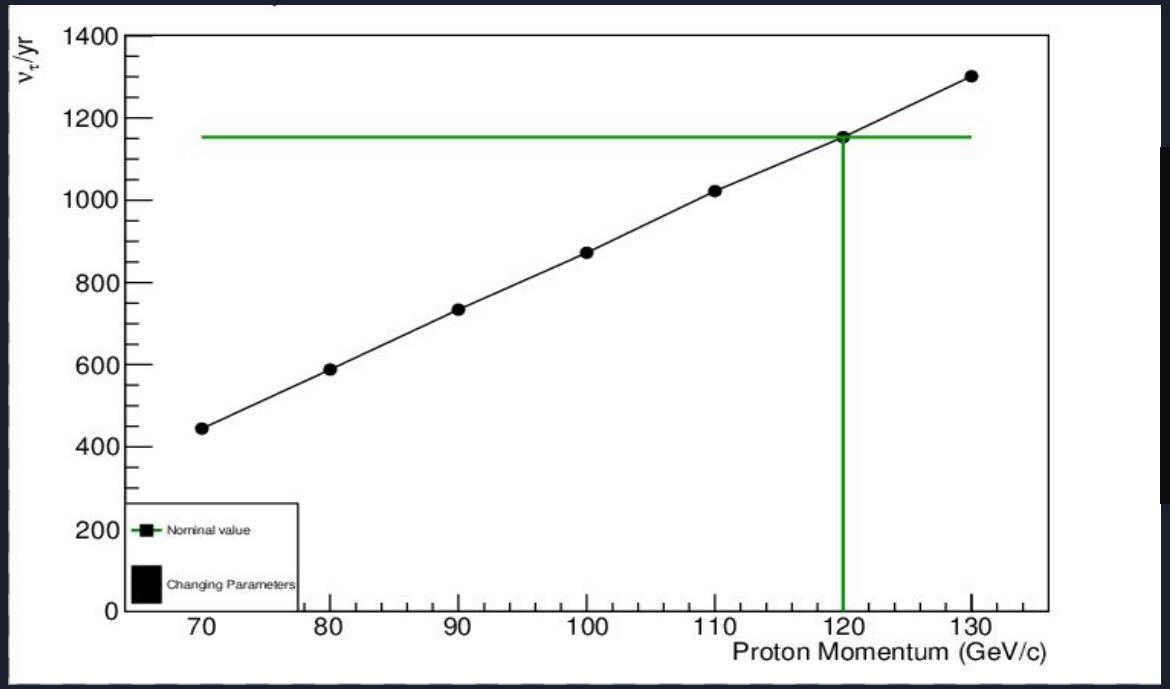
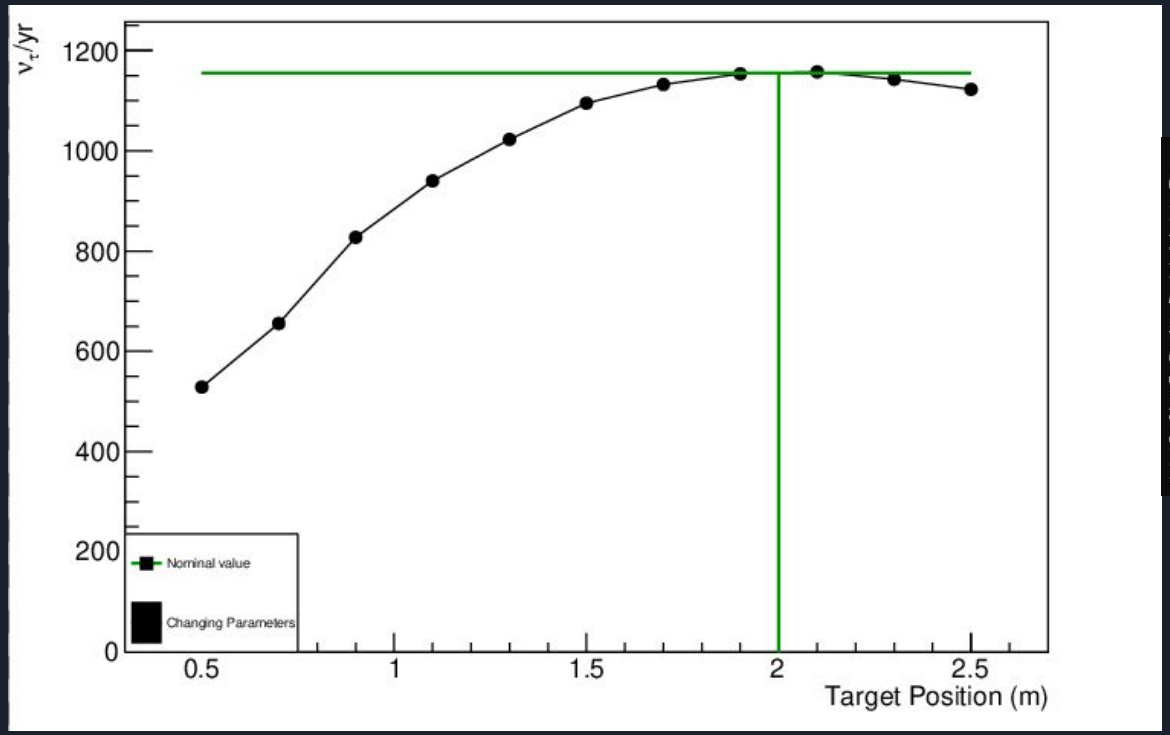


Proton Momentum



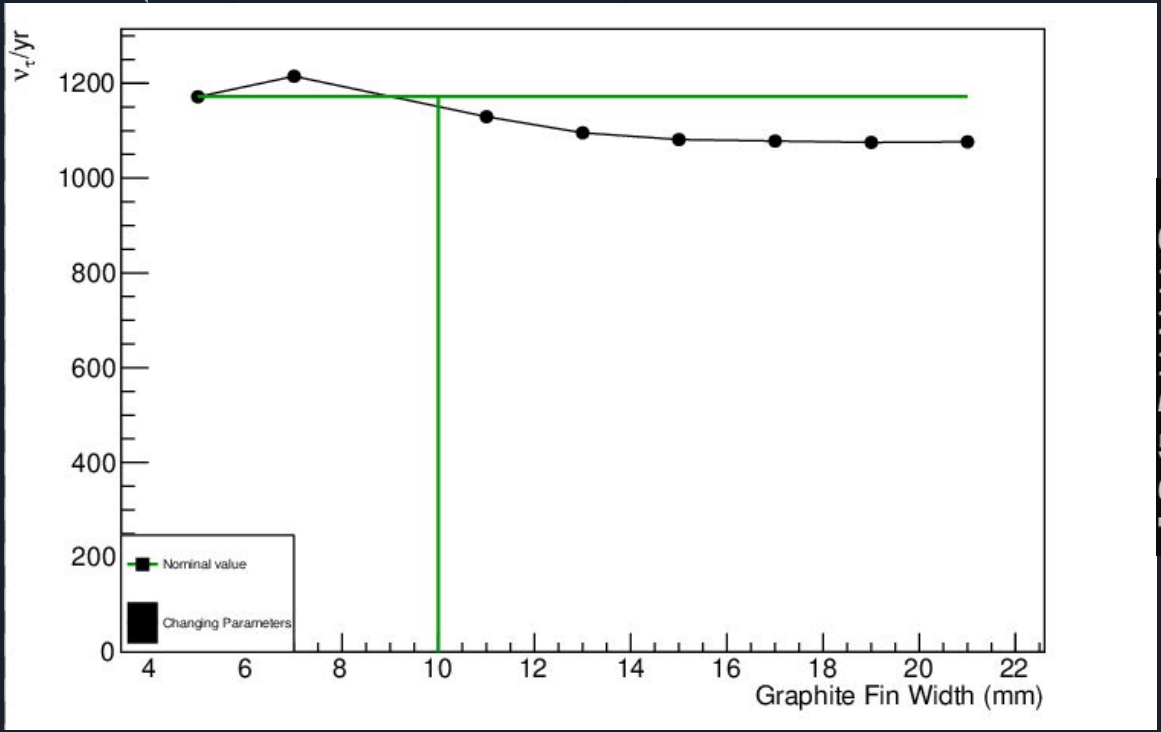
	Proton Momentum	taus/yr
0	70	444.653954
1	80	588.348318
2	90	734.037186
3	100	872.224520
4	110	1022.254309
5	120	1153.369511
6	130	1301.600972

Target Position



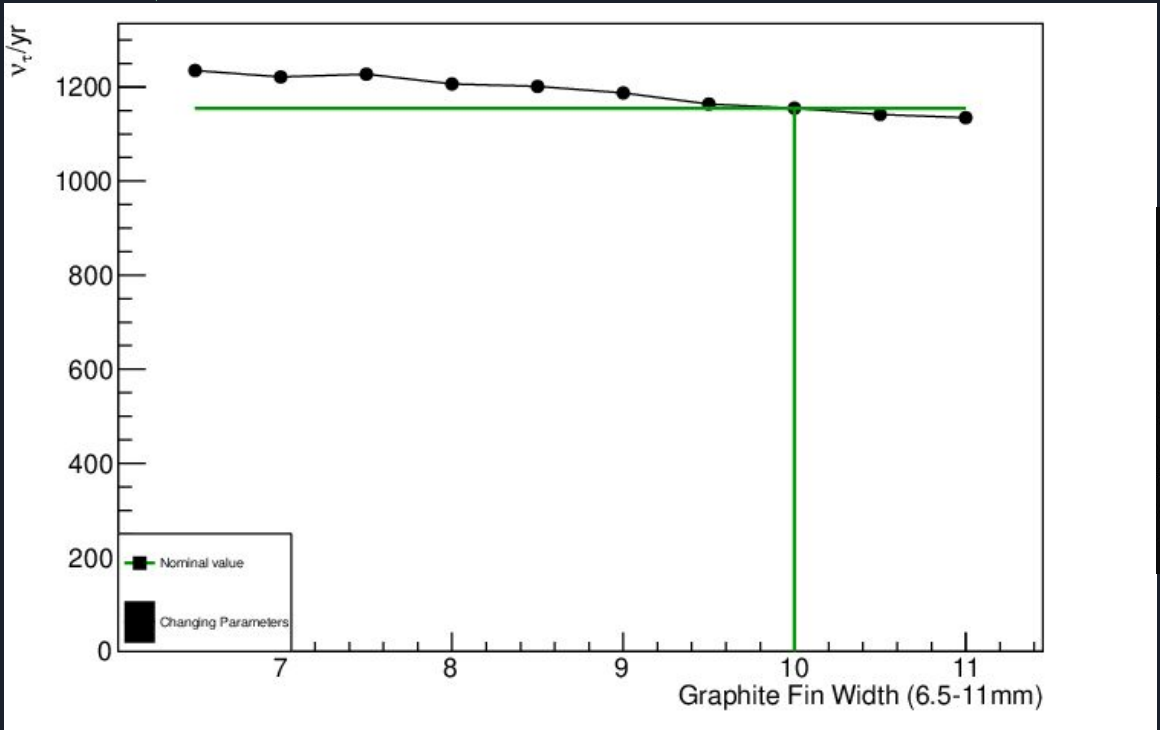
	target positions (m)	taus/yr
0	0.5	528.646913
1	0.7	655.494950
2	0.9	827.375053
3	1.1	940.043273
4	1.3	1022.725149
5	1.5	1095.034681
6	1.7	1132.290946
7	1.9	1153.556636
8	2.1	1157.467360
9	2.3	1142.691941
10	2.5	1122.587004

Graphite Fin Width



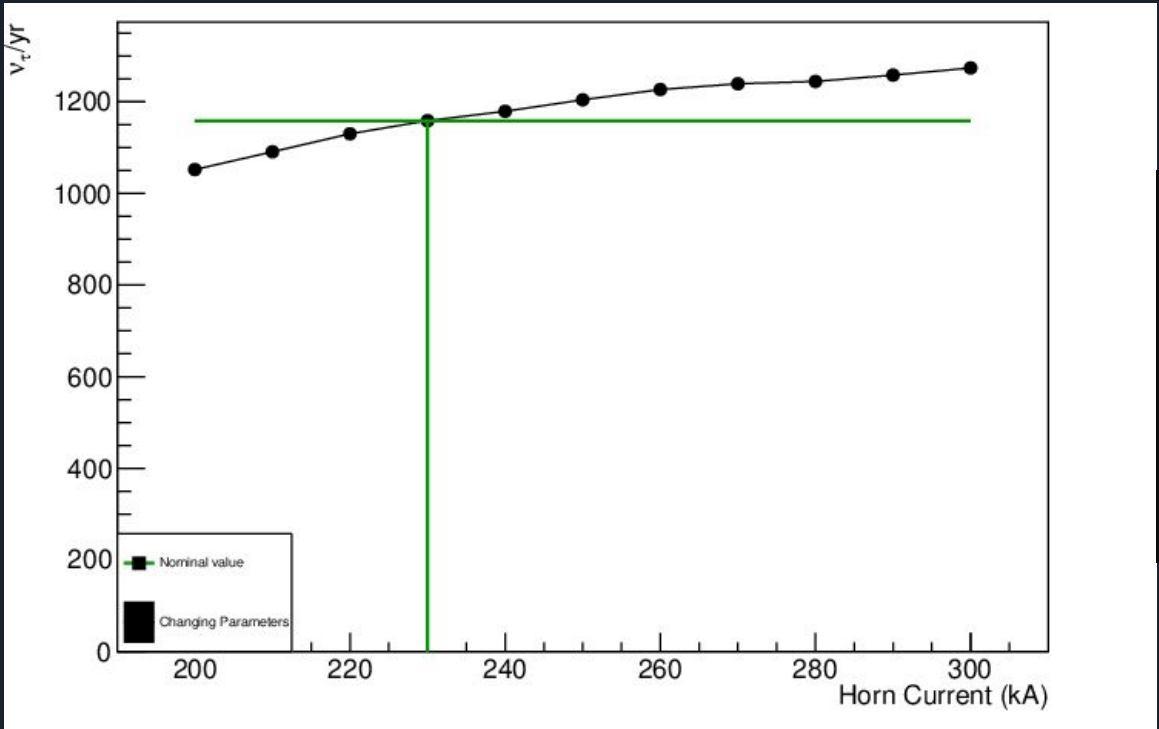
	Graphite Fin Width (mm)	taus/yr
0	5	1171.594547
1	7	1214.924481
2	11	1129.528487
3	13	1095.566489
4	15	1081.314539
5	17	1078.236247
6	19	1075.265462
7	21	1076.562127

Graphite Fin Width ZOOM



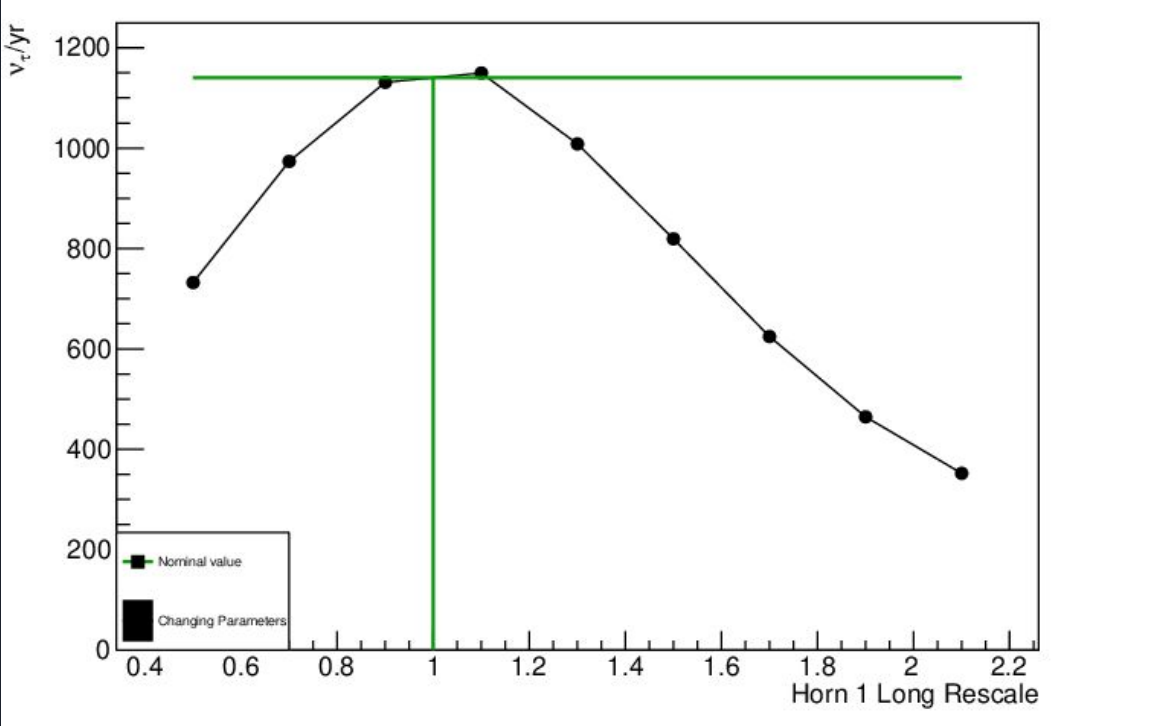
	Graphite Fin Width (mm)	taus/yr
0	6.5	1235.131128
1	7.0	1221.358848
2	7.5	1227.316091
3	8.0	1206.440258
4	8.5	1201.273254
5	9.0	1187.393092
6	9.5	1163.727583
7	10.0	1154.948368
8	10.5	1141.608542
9	11.0	1134.744383

Horn Current



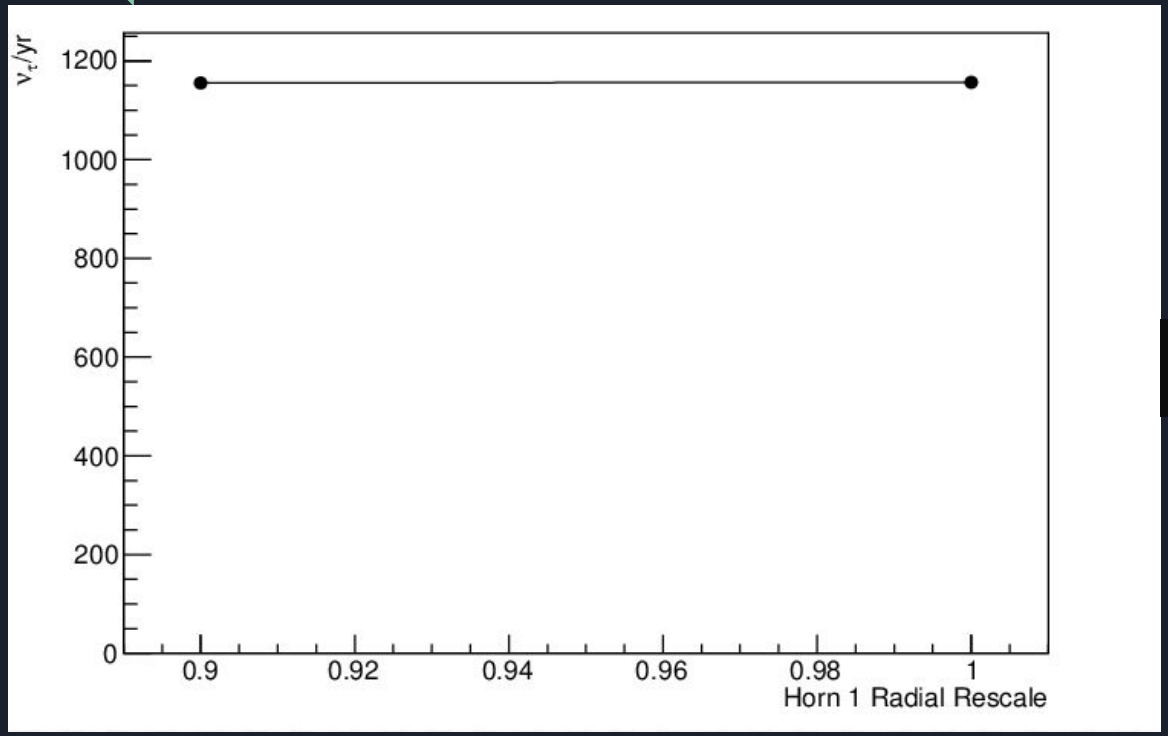
	Horn Current (kA)	taus/yr
0	200	1051.956823
1	210	1090.742587
2	220	1130.016593
3	230	1158.588226
4	240	1179.103502
5	250	1204.172319
6	260	1226.615860
7	270	1239.146584
8	280	1244.278907
9	290	1258.138250
10	300	1273.611681

Horn 1 Longitudinal Rescale



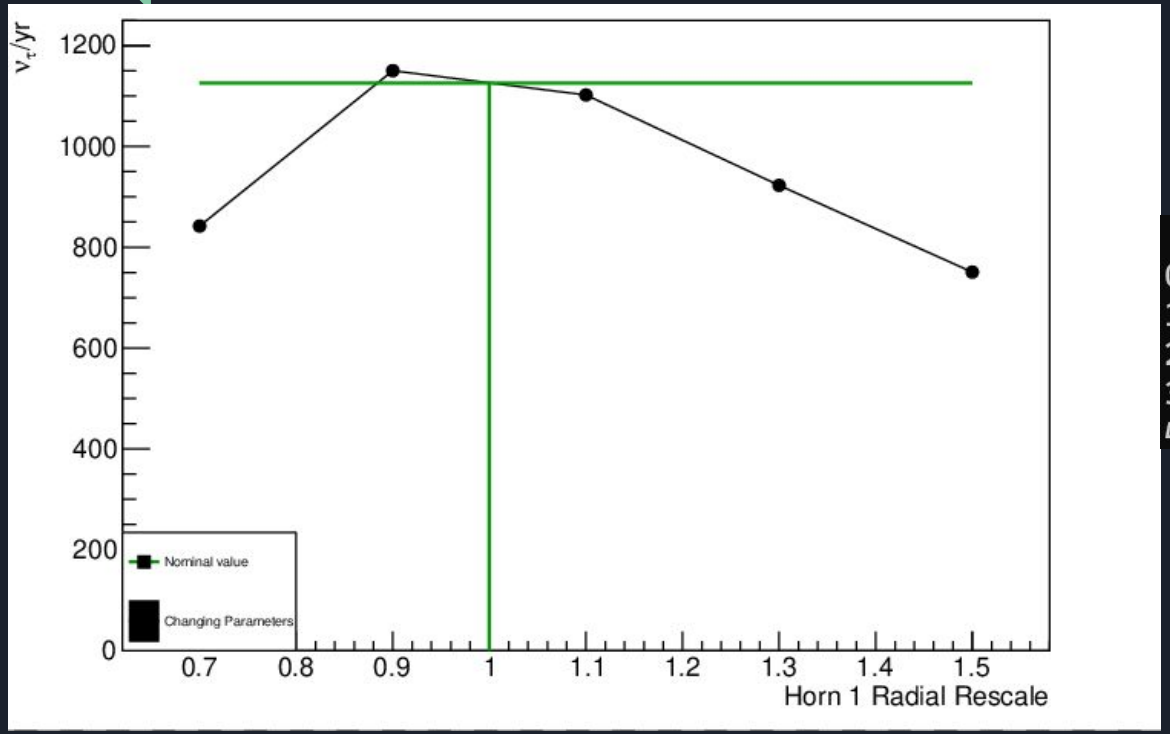
	Horn1LongRescale	taus/yr
0	0.5	732.206307
1	0.7	973.628204
2	0.9	1131.102441
3	1.1	1149.692988
4	1.3	1008.421213
5	1.5	819.228726
6	1.7	624.590224
7	1.9	464.613305
8	2.1	352.028688

Horn 1 Longitudinal Rescale ZOOM



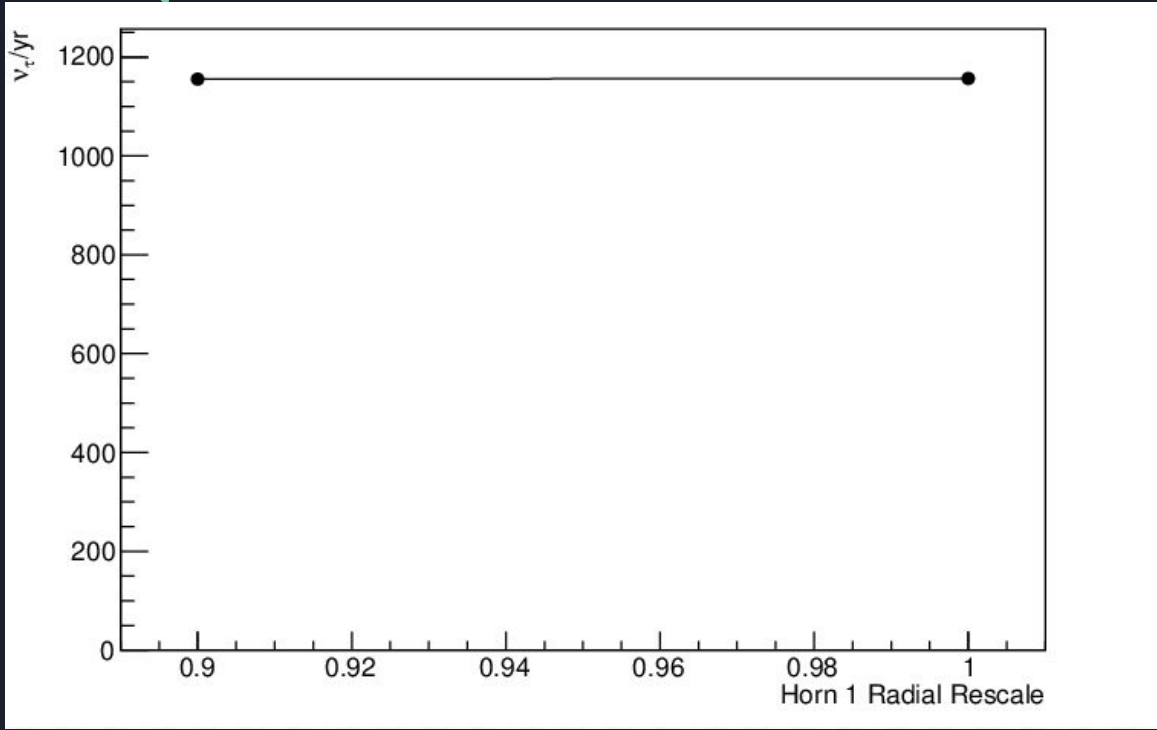
	Horn1RadialRescale	taus/yr
0	0.9	1155.277354
1	1.0	1156.601761

Horn 1 Radial Rescale



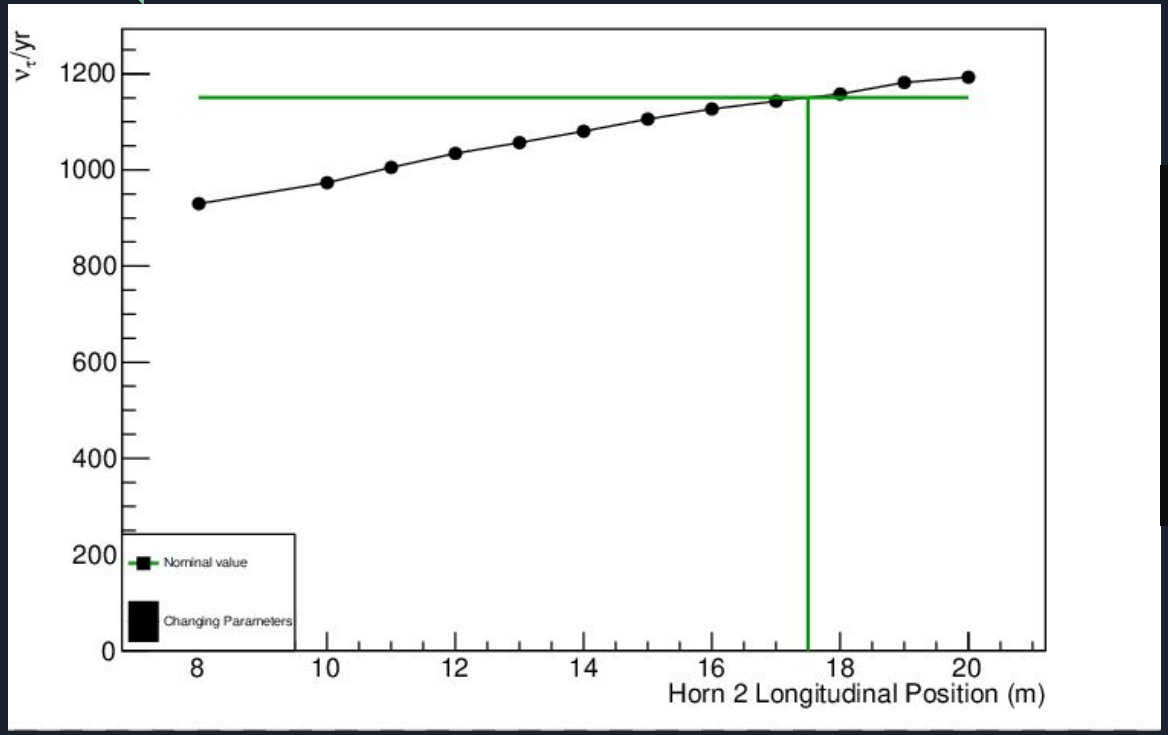
	Horn1RadialRescale	taus/yr
0	0.7	842.049969
1	0.9	1150.245742
2	1.1	1102.069930
3	1.3	922.788051
4	1.5	750.726383

Horn 1 Radial Rescale ZOOM



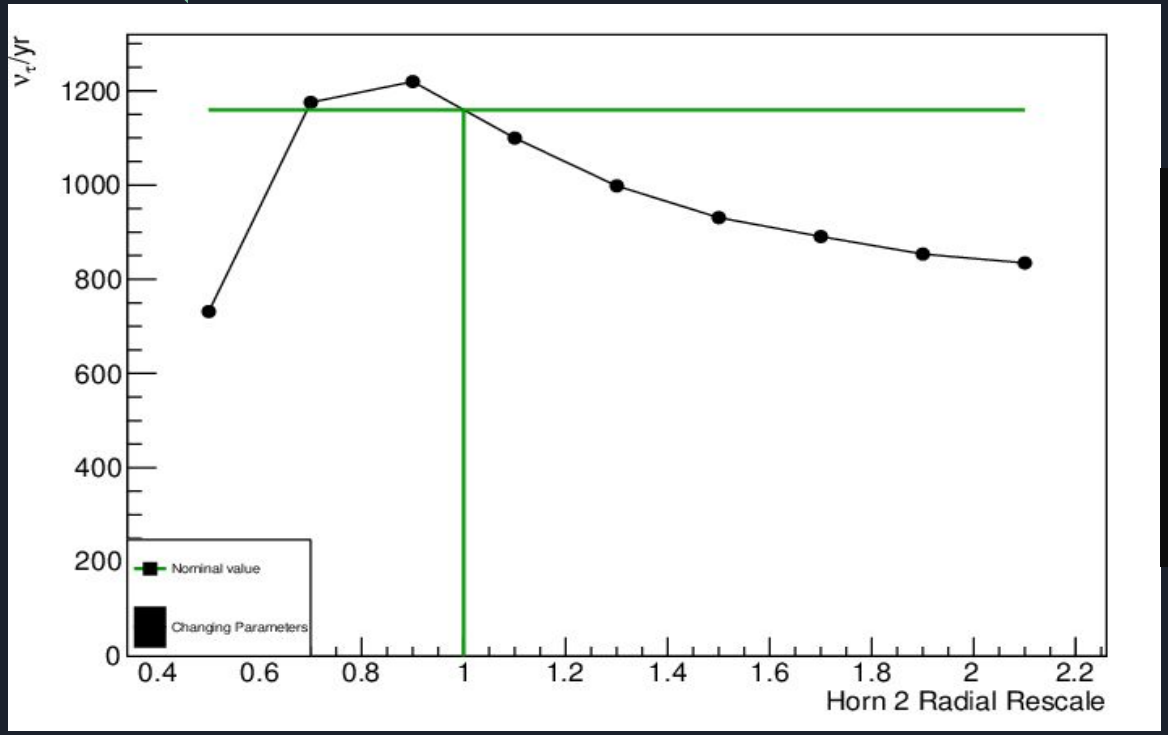
	Horn1RadialRescale	taus/yr
0	0.9	1155.277354
1	1.0	1156.601761

Horn 2 Long Position



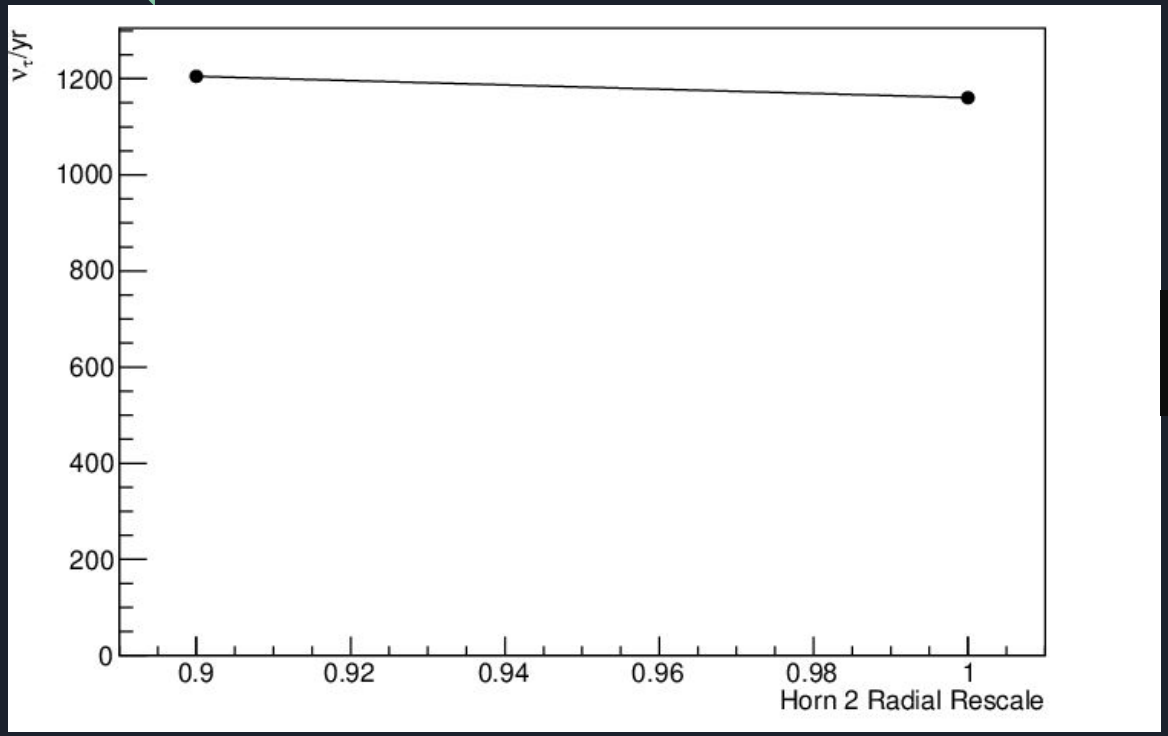
	Horn2LongitudinalPosition (m)	taus/yr
0	8	929.720826
1	10	973.316354
2	11	1005.193432
3	12	1034.344020
4	13	1056.694437
5	14	1080.394040
6	15	1105.710451
7	16	1126.692847
8	17	1143.000366
9	18	1157.745810
10	19	1181.880094
11	20	1192.823272

Horn 2 Radial Rescale



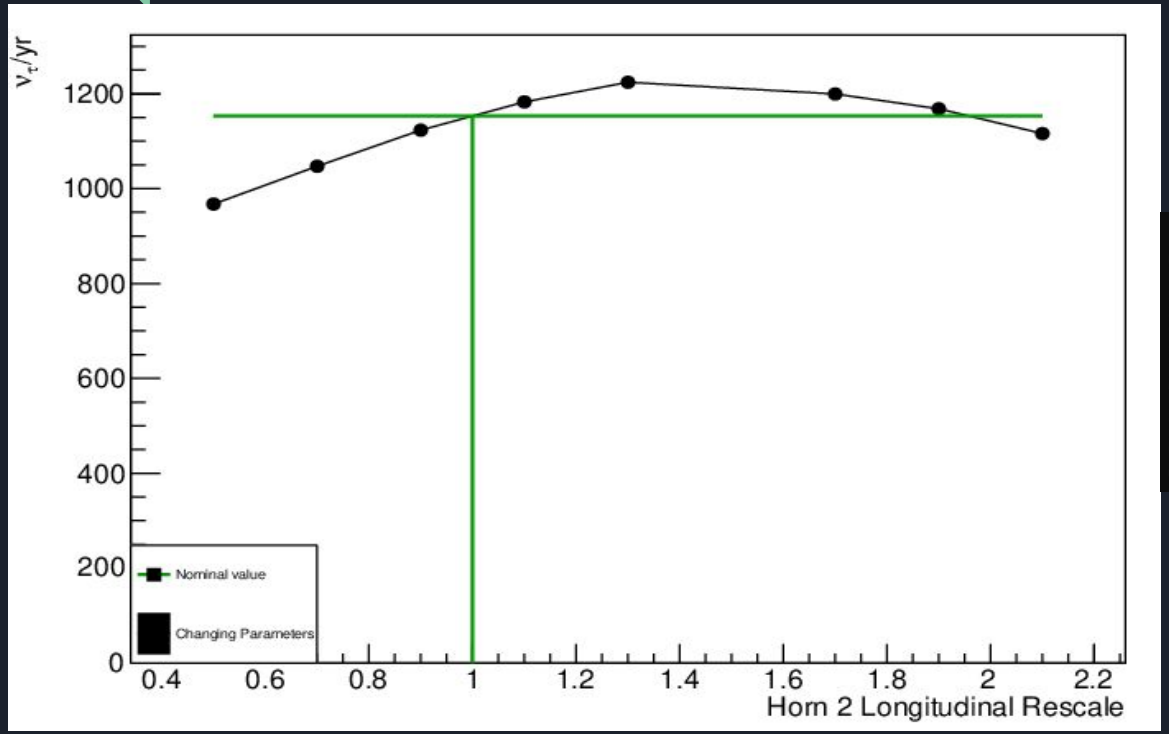
	Horn2RadialRescale	taus/yr
0	0.5	731.441989
1	0.7	1175.324719
2	0.9	1219.494011
3	1.1	1099.649114
4	1.3	998.198955
5	1.5	930.783450
6	1.7	890.665393
7	1.9	853.457881
8	2.1	834.552254

Horn 2 Radial Rescale ZOOM



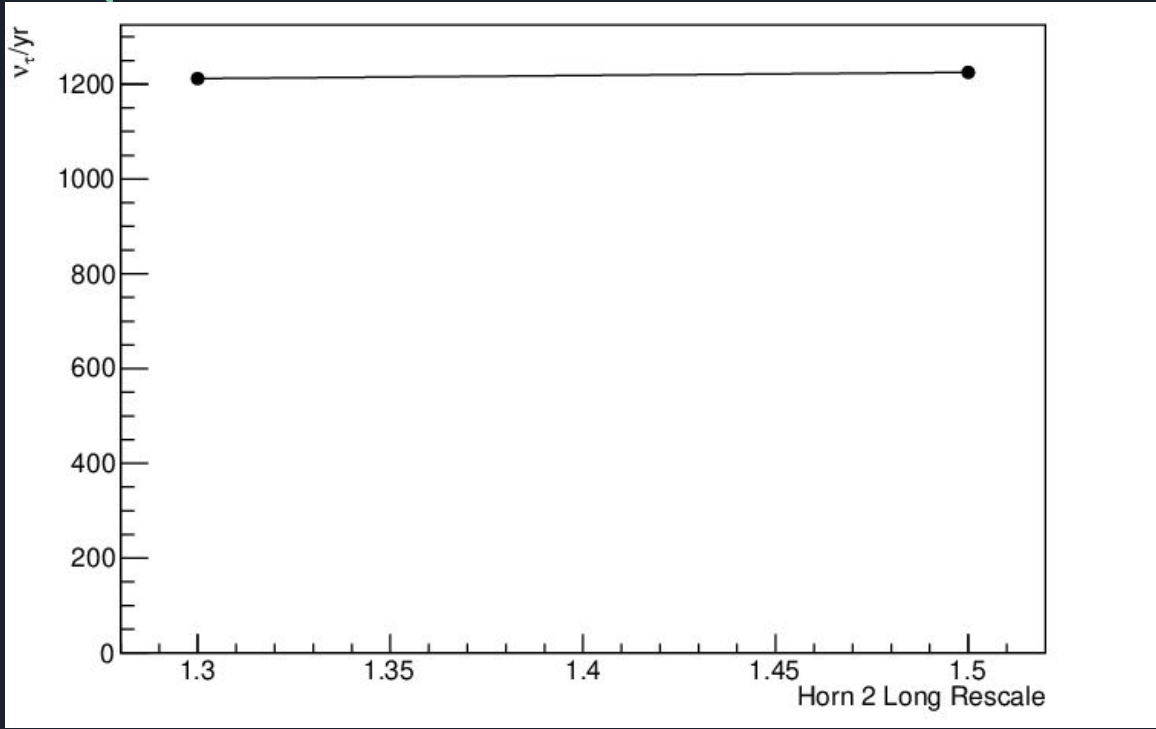
	Horn2RadialRescale	taus/yr
0	0.9	1205.103154
1	1.0	1160.561734

Horn 2 Longitudinal Rescale



	Horn2LongitudinalRescale	taus/yr
0	0.5	967.427592
1	0.7	1047.153627
2	0.9	1123.245424
3	1.1	1182.690657
4	1.3	1224.189208
5	1.7	1199.462197
6	1.9	1168.216495
7	2.1	1115.950054

Horn 2 Longitudinal Rescale ZOOM



	Horn2LongRescale	taus/yr
0	1.3	1211.862811
1	1.5	1224.906579

Most Effective Changes

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Total neutrino flux is  1162
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+5%

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Horn2RadialRescale      taus/yr
0.9   1219
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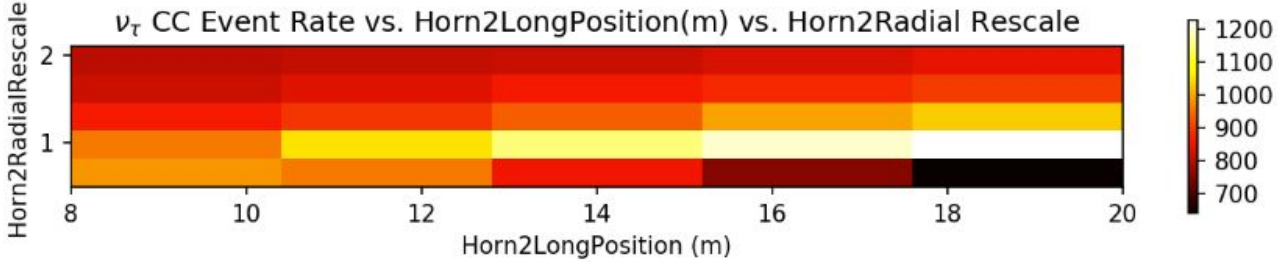
Horn2LongitudinalRescale      taus/yr
1.5   1224
```

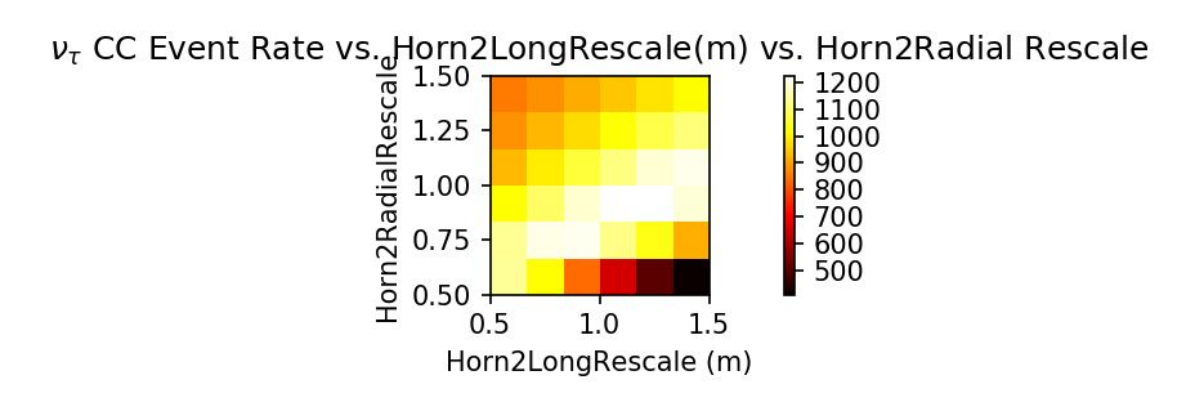
Horn2LongPosition vs Horn2RadialRescale



H2l position

H2RR	8m	11m	14m	17m	20m
0.5	984.85	960.61	852.79	754.83	641.01
0.9	961.16	1054.16	1150.19	1198.43	1227.21
1.3	862.13	897.33	936.24	996.08	1034.22
1.7	819.37	837.72	859.73	881.59	902.55
2.1	803.9	810.14	816.99	830.85	842.59

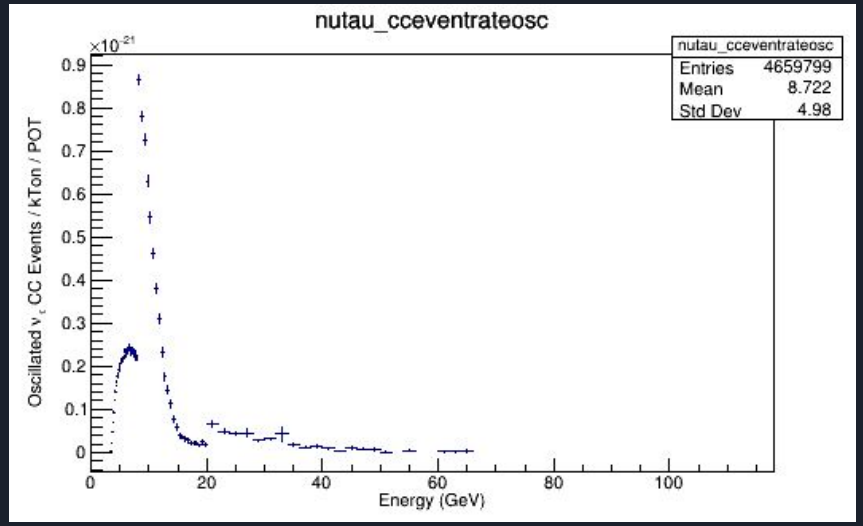
Horn2LongitudinalRescale vs Horn2RadialRescale



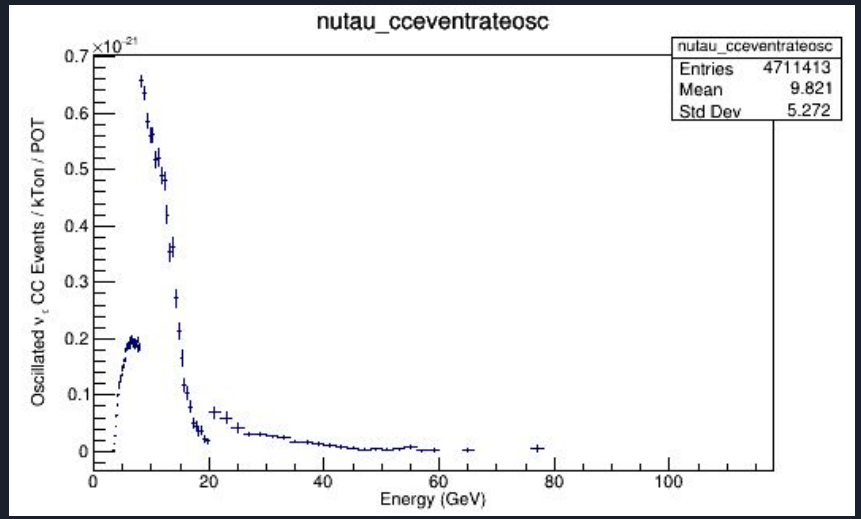
	0.5l	0.7l	0.9l	1.1l	1.3l	1.5l
0.5r	1137.93	1019.03	835.92	655.65	508.5	408.81
0.7r	1136.4	1201.9	1207.13	1126.2	1034.15	918.58
0.9r	1018.92	1097.73	1182.27	1221.82	1222.89	1188.89
1.1r	930.59	996.75	1062.31	1120.84	1186.61	1204.96
1.3r	883.61	929.44	973.33	1021.95	1076.13	1113.47
1.5r	854.94	881.25	915.38	947.33	982.21	1015.67

Original to Re-Optimized Comparison

Original Tau Optimization



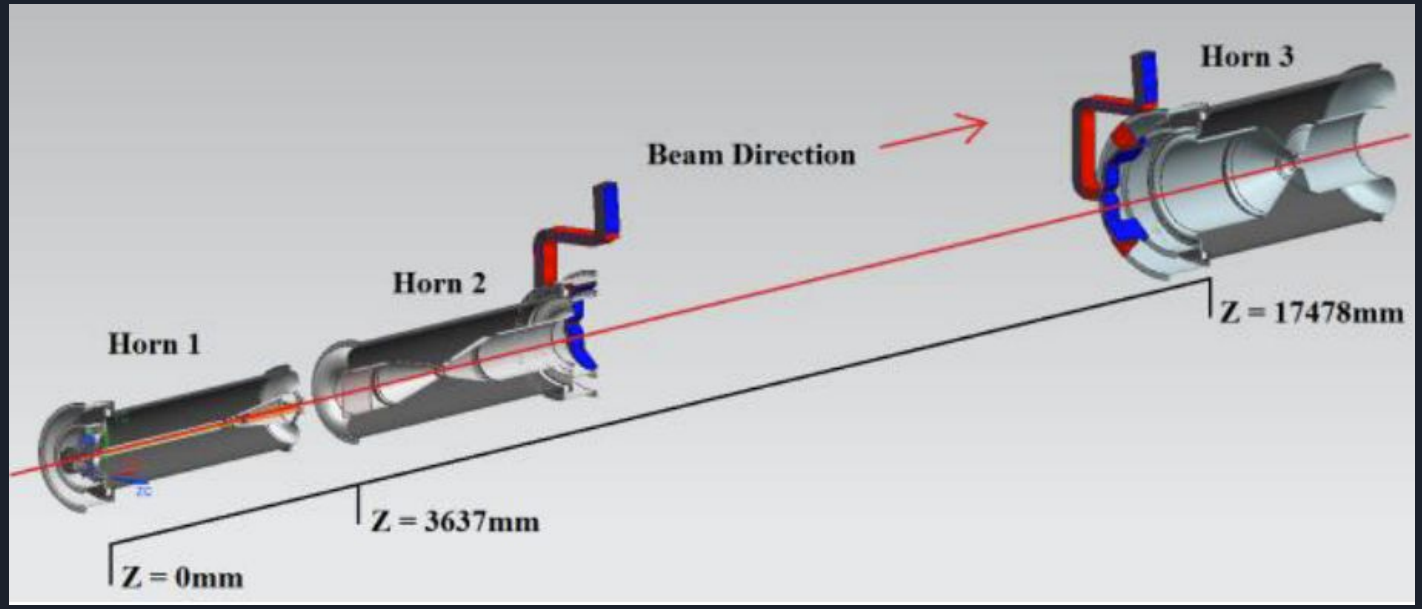
Tau Re-Optimization



Total neutrino flux is 1162.59667927

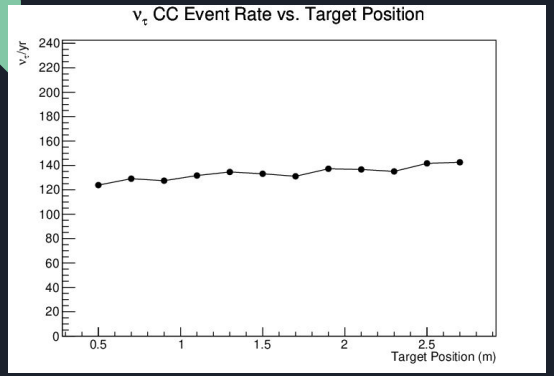
Total neutrino flux is 1164.47261665

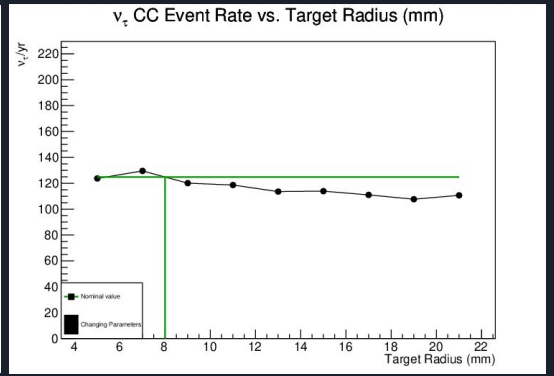
CP Optimized Configuration - A beginning

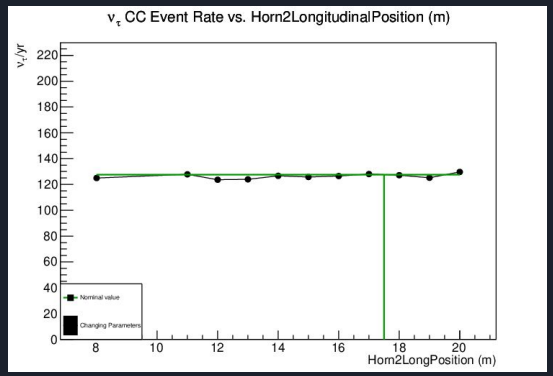


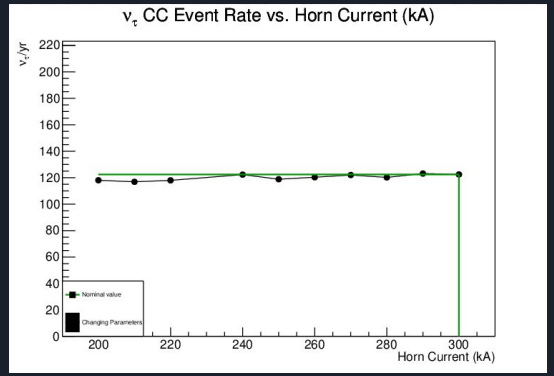
Source: Tariq, K. Ammigan, et al. Design of the lbnf beamline target station (2016), arXiv:1612.07293 [physics.acc-ph] .

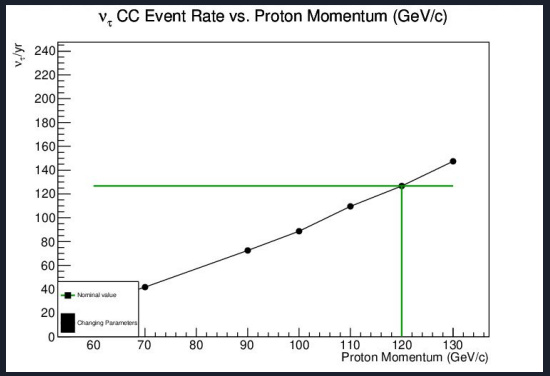
CP Optimized Plots - Horns B and C











Future Research

- Multi-dimensional optimization
- Try different horn configurations for CP-Optimized
- Employ machine learning algorithms to facilitate optimization