Simulation of ν_τ

Jianming Bian, Wenjie Wu

University of California, Irvine

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UCIrvine

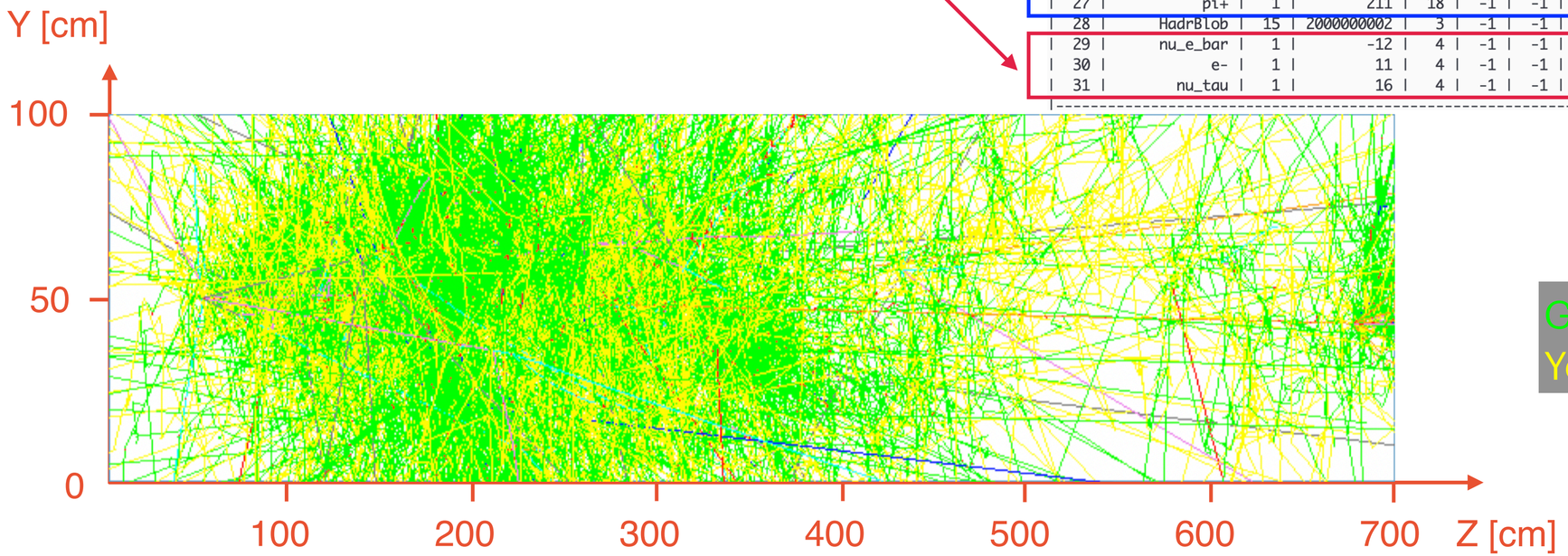
100 GeV ν_τ

- DIS CC
- $\nu_\tau + \mathrm{Ar40} \rightarrow \tau^- + \mathrm{Ar39} + \mathrm{hadrSyst}$

$$\tau^- \rightarrow \nu_\tau + \bar{\nu}_e + e^-$$

GENIE GHEP Event Record [print level: 3]

Idx	Name	Ist	PDG	Mother	Daughter	Px	Py	Pz	E	m
0	nu_tau	0	16	-1 -1	4 4	0.000	0.000	100.000	100.000	0.000
1	Ar40	0	1000180400	-1 -1	2 3	0.000	0.000	0.000	37.216	37.216
2	neutron	11	2112	1 -1	5 5	-0.068	0.054	0.167	0.929	**0.940
3	Ar39	2	1000180390	1 -1	28 28	0.068	-0.054	-0.167	36.286	36.286
4	tau-	3	15	0 -1	29 31	1.562	0.484	25.817	25.929	1.777
5	HadrSyst	12	2000000001	2 -1	6 7	-1.630	-0.430	74.350	75.000	**0.000
6	u	12	2	5 -1	8 8	-1.627	-0.429	74.193	74.213	0.330
7	ud_1	12	2103	5 -1	8 8	-0.003	-0.001	0.157	0.787	0.771
8	string	12	92	6 -1	9 14	-1.630	-0.430	74.350	75.000	**0.000
9	rho0	12	113	8 -1	15 16	-0.654	-0.116	33.267	33.282	**0.768
10	Delta++	12	2224	8 -1	17 18	-0.465	-0.306	31.178	31.202	**1.231
11	pi-	14	-211	8 -1	19 19	-0.282	-0.224	2.723	2.750	0.140
12	Lambda0_bar	14	-3122	8 -1	20 20	-0.157	0.659	5.247	5.407	1.116
13	Lambda0	14	3122	8 -1	21 21	-0.136	-0.396	1.732	2.102	1.116
14	pi0	14	111	8 -1	22 23	0.064	-0.048	0.203	0.257	0.135
15	pi-	14	-211	9 -1	24 24	0.052	0.119	10.504	10.506	0.140
16	pi+	14	211	9 -1	25 25	-0.705	-0.236	22.763	22.776	0.140
17	proton	14	2212	10 -1	26 26	-0.462	-0.332	27.597	27.619	0.938
18	pi+	14	211	10 -1	27 27	-0.003	0.026	3.581	3.584	0.140
19	pi-	1	-211	11 -1	-1 -1	-0.282	-0.224	2.723	2.750	0.140
20	Lambda0_bar	1	-3122	12 -1	-1 -1	-0.157	0.659	5.247	5.407	1.116
21	Lambda0	1	3122	13 -1	-1 -1	-0.136	-0.396	1.732	2.102	1.116
22	neutron	1	2112	14 -1	-1 -1	-0.441	0.263	-0.101	1.076	0.940
23	proton	1	2212	14 -1	-1 -1	0.417	-0.270	-0.038	1.062	0.938
24	pi-	1	-211	15 -1	-1 -1	0.052	0.119	10.504	10.506	0.140
25	pi+	1	211	16 -1	-1 -1	-0.705	-0.236	22.763	22.776	0.140
26	proton	1	2212	17 -1	-1 -1	-0.462	-0.332	27.597	27.619	0.938
27	pi+	1	211	18 -1	-1 -1	-0.003	0.026	3.581	3.584	0.140
28	HadrBlob	15	2000000002	3 -1	-1 -1	0.156	-0.095	0.176	34.405	**0.000
29	nu_e_bar	1	-12	4 -1	-1 -1	0.227	0.285	7.080	7.089	0.000
30	e-	1	11	4 -1	-1 -1	0.373	0.736	10.029	10.063	**0.001
31	nu_tau	1	16	4 -1	-1 -1	0.962	-0.537	8.708	8.777	**0.000



Green: Gamma
Yellow: Neutron

100 GeV ν_τ

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2	neutron	11	2112	1	-1	5	5	-0.068	0.054	0.167	0.929	**0.940
3	Ar39	2	1000180390	1	-1	28	28	0.068	-0.054	-0.167	36.286	36.286
4	tau-	3	15	0	-1	29	31	1.562	0.484	25.817	25.929	1.777
5	HadrSyst	12	2000000001	2	-1	6	7	-1.630	-0.430	74.350	75.000	**0.000
6	u	12	2	5	-1	8	8	-1.627	-0.429	74.193	74.213	0.330
7	ud_1	12	2103	5	-1	8	8	-0.003	-0.001	0.157	0.787	0.771
8	string	12	92	6	-1	9	14	-1.630	-0.430	74.350	75.000	**0.000
9	rho0	12	113	8	-1	15	16	-0.654	-0.116	33.267	33.282	**0.768
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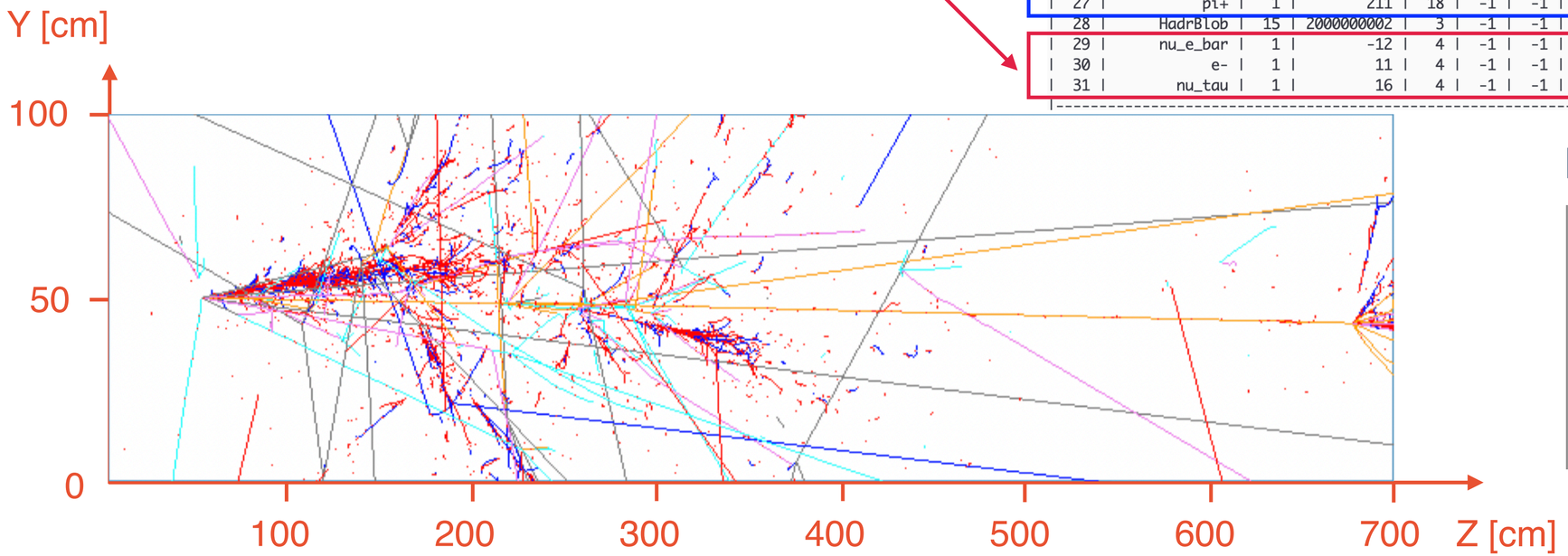

Exclude gamma/neutron

red: e-
blue: e+
cyan: proton
orange: pi+
violet: pi-

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100 GeV ν_τ

Energy deposition (MeV)

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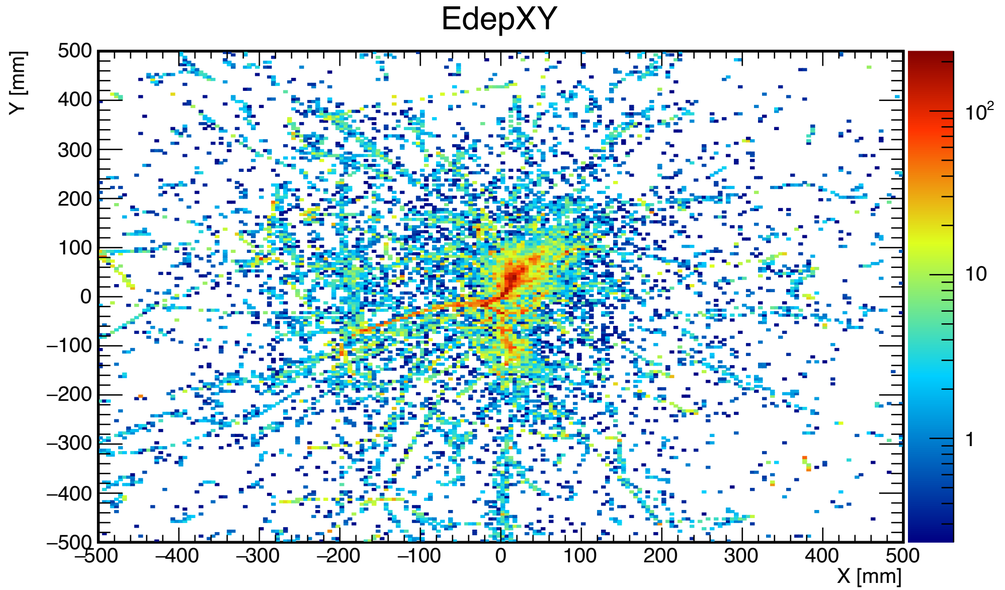
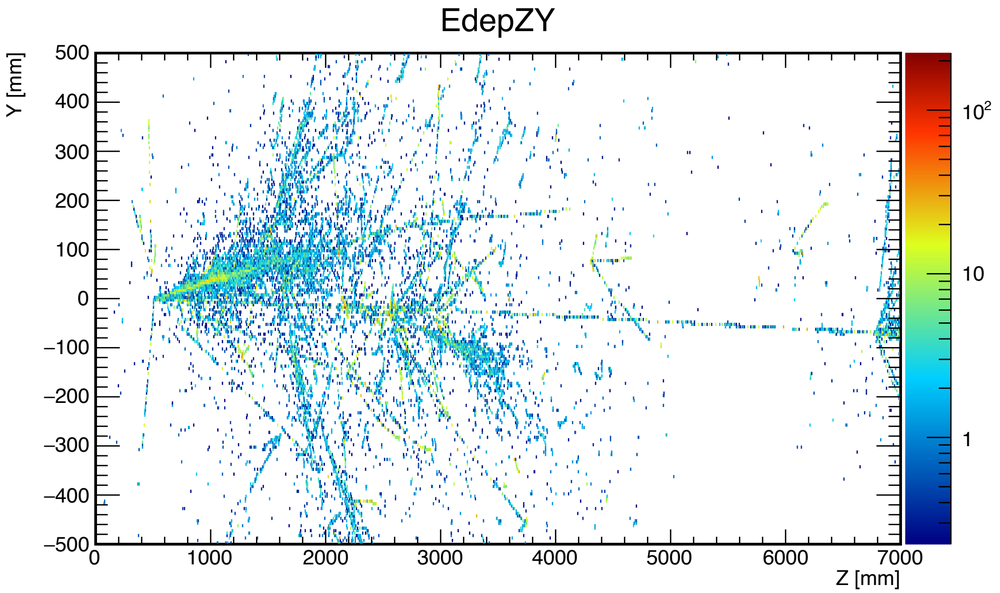
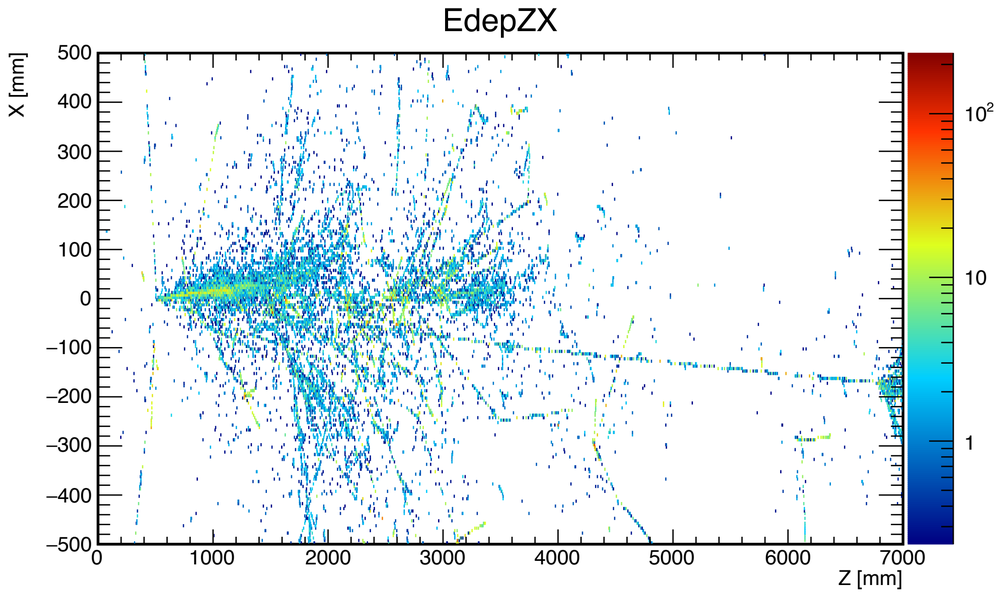
  $\tau^- \rightarrow \nu_\tau + \bar{\nu}_e + e^-$







100 GeV ν_τ

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$\tau^- \rightarrow \nu_\tau + \bar{\nu}_\mu + \mu^-$

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Idx	Name	Ist	PDG	Mother		Daughter		Px	Py	Pz	E	m
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1	Ar40	0	1000180400	-1	-1	2	3	0.000	0.000	0.000	37.216	37.216
2	neutron	11	2112	1	-1	5	5	0.056	-0.181	-0.037	0.929	**0.940
3	Ar39	2	1000180390	1	-1	26	26	-0.056	0.181	0.037	36.286	36.286
4	tau-	3	15	0	-1	27	29	2.517	-0.454	17.142	17.423	1.777
5	HadrSyst	12	2000000001	2	-1	6	7	-2.460	0.273	82.821	83.506	**0.000
6	u	12	2	5	-1	8	8	-2.456	0.273	82.686	82.723	0.330
7	ud_1	12	2103	5	-1	8	8	-0.004	0.000	0.135	0.783	0.771
8	string	12	92	6	-1	9	13	-2.460	0.273	82.821	83.506	**0.000
9	pi0	14	111	8	-1	18	18	-0.444	0.231	12.471	12.482	0.135
10	pi+	14	211	8	-1	19	19	-0.903	-0.083	41.362	41.372	0.140
11	K*0	12	313	8	-1	14	15	-0.200	0.473	24.983	25.004	**0.896
12	Sigma*-	12	3114	8	-1	16	17	-1.061	0.032	3.766	4.157	**1.387
13	pi+	14	211	8	-1	20	20	0.146	-0.380	0.239	0.492	0.140
14	K+	14	321	11	-1	21	21	-0.164	0.544	14.397	14.416	0.494
15	pi-	14	-211	11	-1	22	22	-0.035	-0.072	10.587	10.588	0.140
16	Lambda0	14	3122	12	-1	23	23	-0.810	-0.014	3.504	3.766	1.116
17	pi-	14	-211	12	-1	24	25	-0.250	0.046	0.262	0.391	0.140
18	pi0	1	111	9	-1	-1	-1	-0.444	0.231	12.471	12.482	0.135
19	pi+	1	211	10	-1	-1	-1	-0.903	-0.083	41.362	41.372	0.140
20	pi+	1	211	13	-1	-1	-1	0.146	-0.380	0.239	0.492	0.140
21	K+	1	321	14	-1	-1	-1	-0.164	0.544	14.397	14.416	0.494
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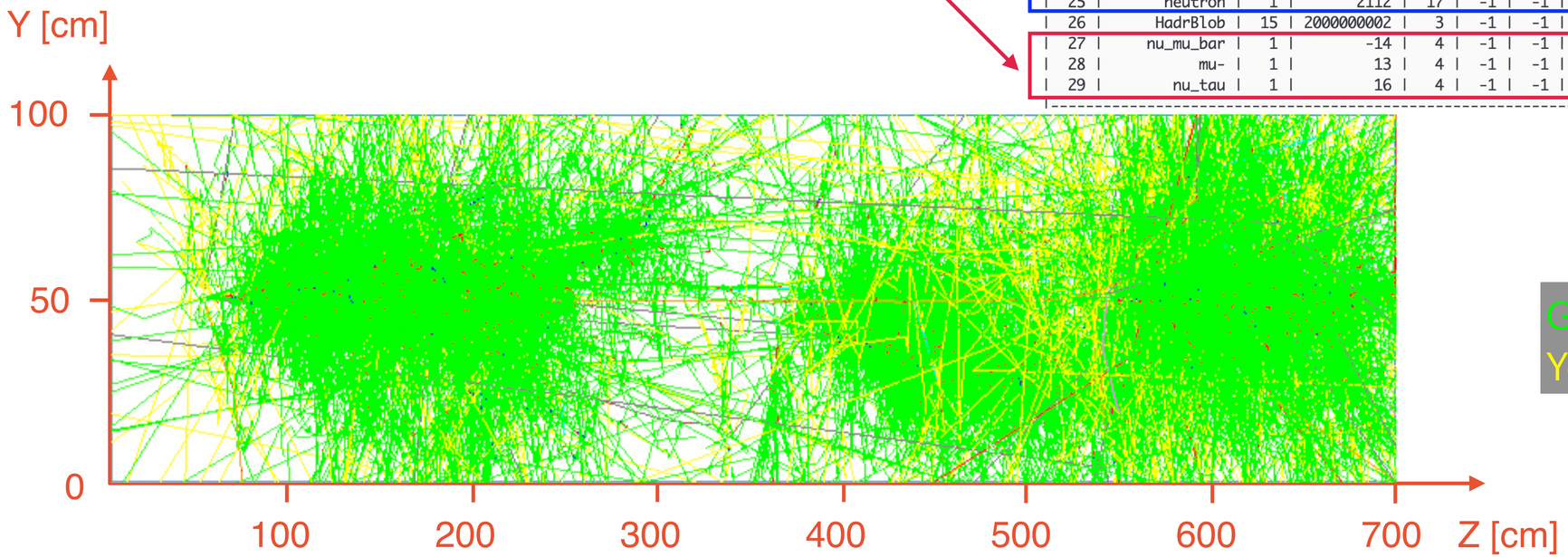
24	neutron	1	2112	17	-1	-1	-1	0.121	-0.468	0.363	1.117	0.940
25	neutron	1	2112	17	-1	-1	-1	-0.565	0.320	0.013	1.142	0.940
26	HadrBlob	15	2000000002	3	-1	-1	-1	0.138	0.374	-0.077	34.418	**0.000
27	nu_mu_bar	1	-14	4	-1	-1	-1	-0.019	0.103	0.036	0.111	0.000
28	mu-	1	13	4	-1	-1	-1	0.112	-0.052	0.639	0.659	0.106
29	nu_tau	1	16	4	-1	-1	-1	2.424	-0.505	16.467	16.652	**0.000



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5	HadrSyst	12	2000000001	2 | -1	6 | 7	-2.460	0.273	82.821	83.506	**0.000
6	u	12	2	5 | -1	8 | 8	-2.456	0.273	82.686	82.723	0.330
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8	string	12	92	6 | -1	9 | 13	-2.460	0.273	82.821	83.506	**0.000
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11	K*0	12	313	8 | -1	14 | 15	-0.200	0.473	24.983	25.004	**0.896
12	Sigma*-	12	3114	8 | -1	16 | 17	-1.061	0.032	3.766	4.157	**1.387
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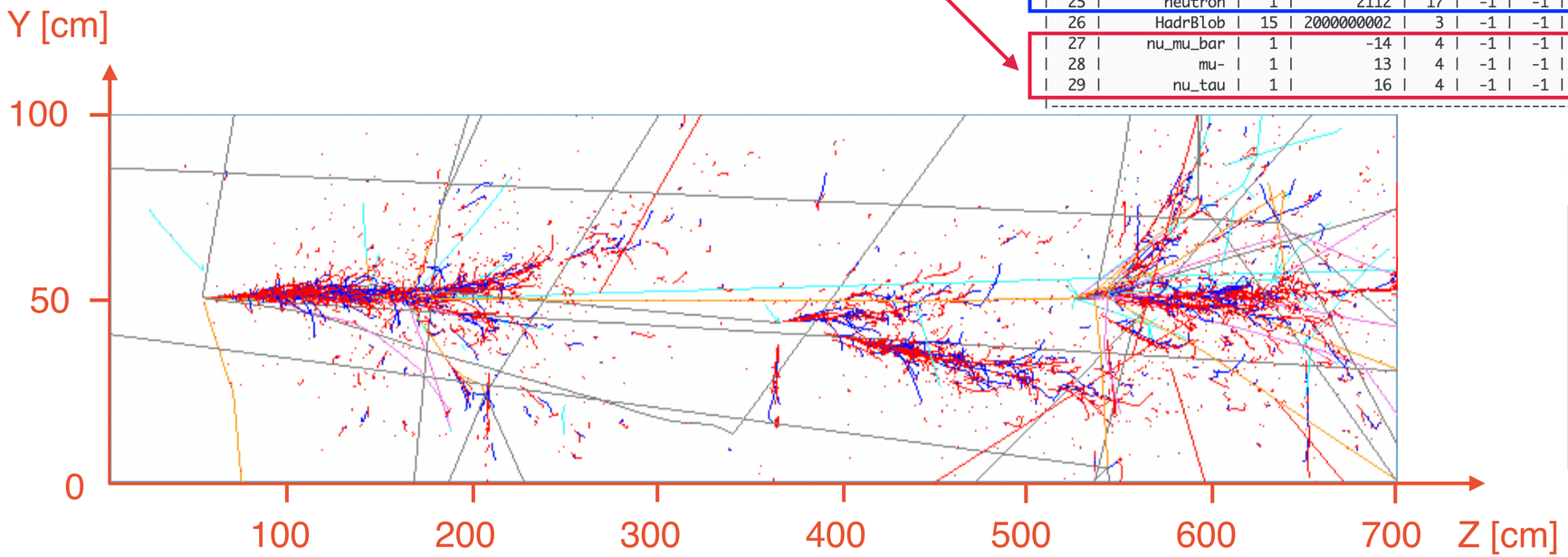
29	nu_tau	1	16	4 | -1	-1 | -1	2.424	-0.505	16.467	16.652	**0.000



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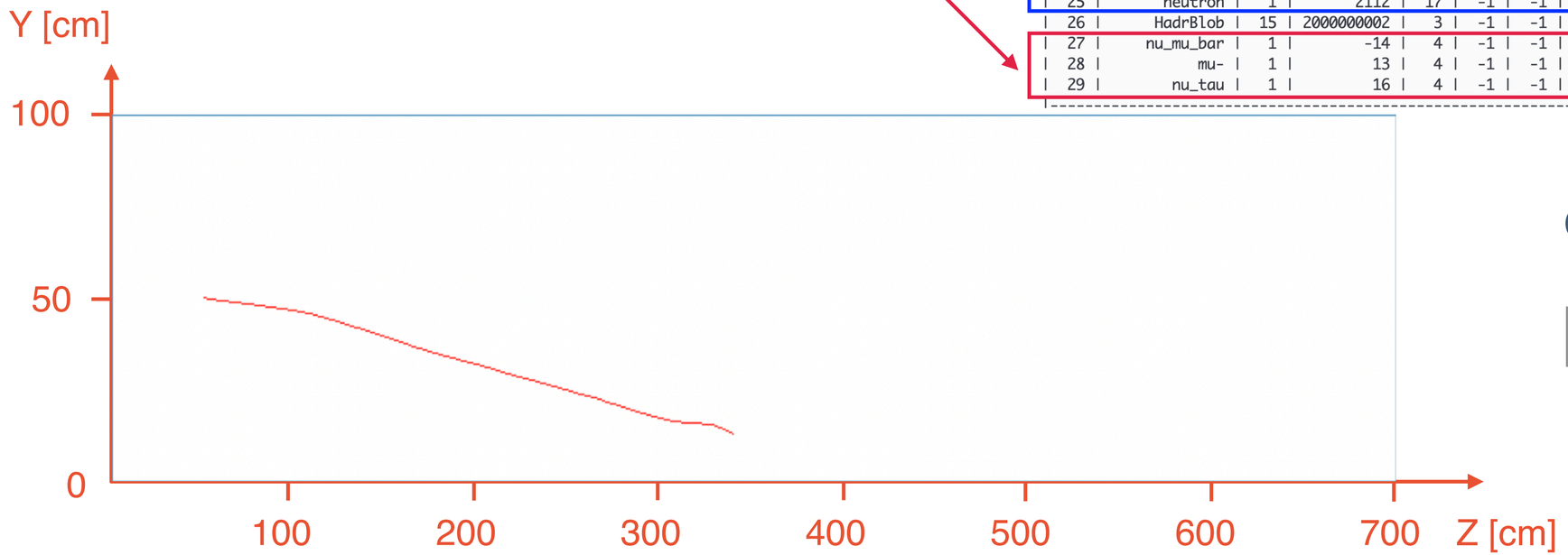
25	neutron	1	2112	17 | -1	-1 | -1	-0.565	0.320	0.013	1.142	0.940
26	HadrBlob	15	2000000002	3 | -1	-1 | -1	0.138	0.374	-0.077	34.418	**0.000
27	nu_mu_bar	1	-14	4 | -1	-1 | -1	-0.019	0.103	0.036	0.111	0.000
28	mu-	1	13	4 | -1	-1 | -1	0.112	-0.052	0.639	0.659	0.106
29	nu_tau	1	16	4 | -1	-1 | -1	2.424	-0.505	16.467	16.652	**0.000



Only draw mu-

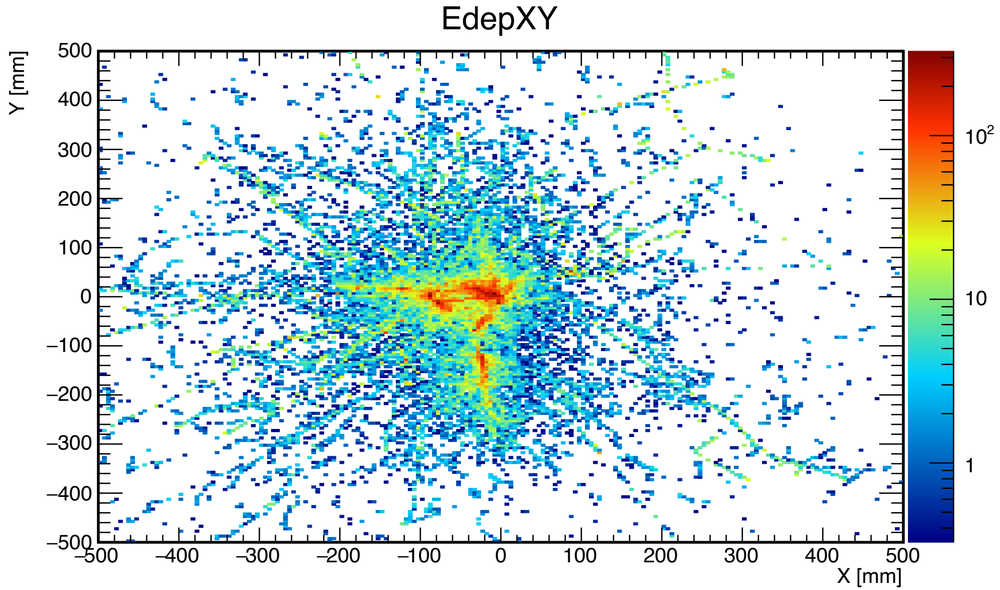
red: mu-

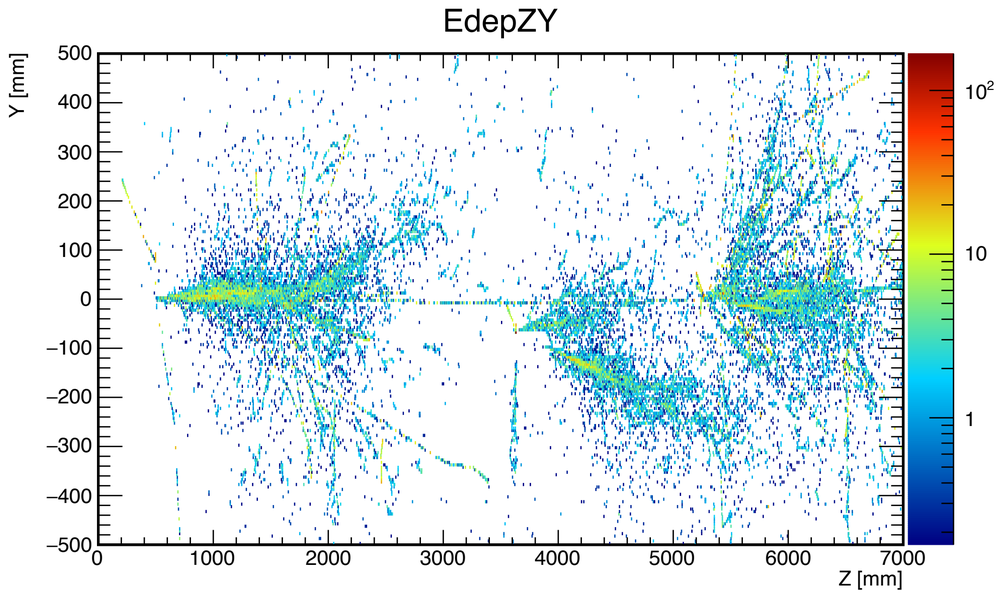
100 GeV ν_τ

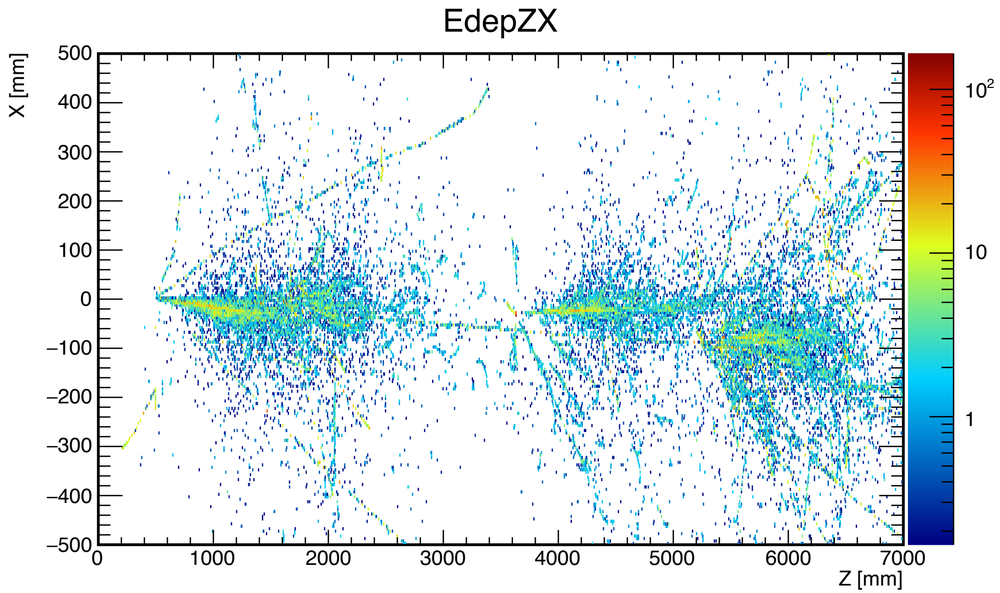
Energy deposition (MeV)

- DIS CC
- ν_τ + Ar40 → τ^- + Ar39 + hadrSyst

  → $\tau^- \rightarrow \nu_\tau + \bar{\nu}_\mu + \mu^-$





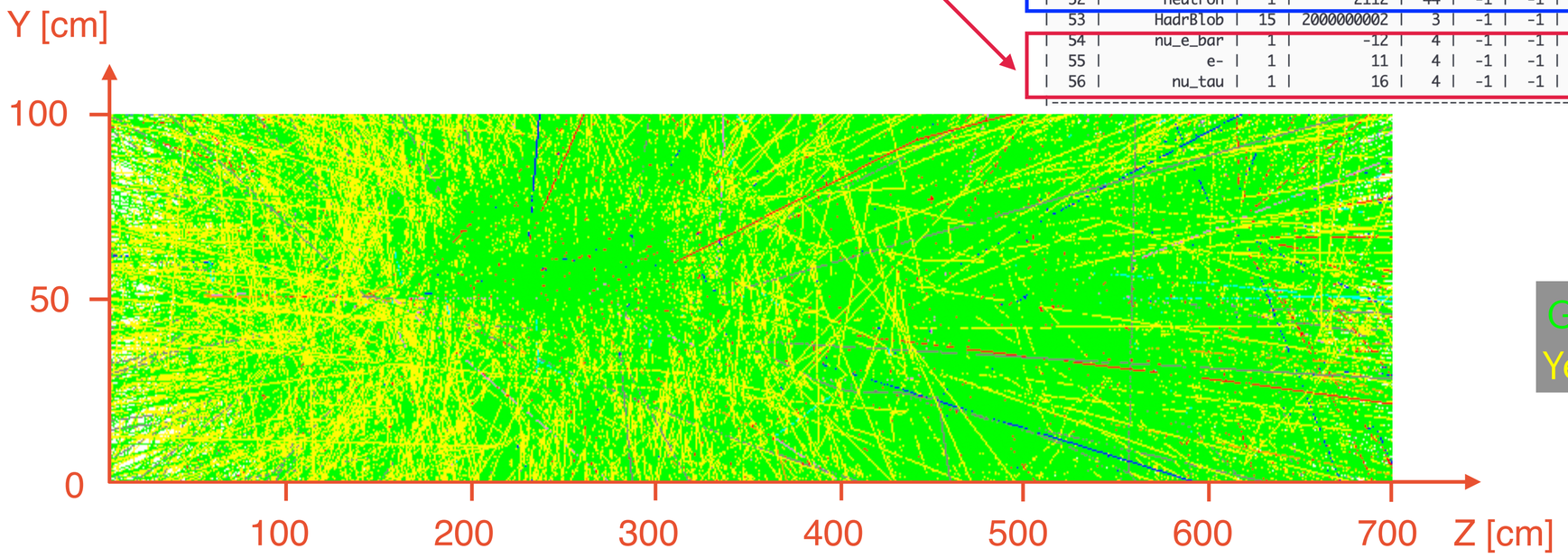


999 GeV ν_τ

- DIS CC
- $\nu_\tau + \mathrm{Ar40} \rightarrow \tau^- + \mathrm{Ar39} + \mathrm{hadrSyst}$

$$\tau^- \rightarrow \nu_\tau + \bar{\nu}_e + e^-$$

21	pi0	14	111	11	-1	37	37	-0.928	-0.417	179.820	179.823	0.135
22	pi-	14	-211	12	-1	38	38	0.001	0.091	0.810	0.827	0.140
23	pi+	14	211	12	-1	39	39	0.003	-0.083	0.558	0.581	0.140
24	pi0	14	111	12	-1	40	40	-0.149	0.038	1.678	1.691	0.135
25	K0	14	311	16	-1	41	41	-0.041	-0.500	2.120	2.234	0.498
26	pi+	14	211	16	-1	42	42	-0.227	-0.339	2.554	2.590	0.140
27	Lambda0	14	3122	17	-1	43	43	-0.448	-0.138	2.863	3.108	1.116
28	pi-	14	-211	17	-1	44	44	-0.292	-0.017	0.452	0.556	0.140
29	pi+	1	211	9	-1	-1	-1	-0.964	-0.450	178.059	178.062	0.140
30	pi-	1	-211	10	-1	-1	-1	-1.235	-0.128	139.149	139.155	0.140
31	pi+	1	211	13	-1	-1	-1	-0.827	-0.773	21.983	22.013	0.140
32	pi-	1	-211	14	-1	-1	-1	0.114	0.274	16.783	16.786	0.140
33	pi0	1	111	15	-1	-1	-1	0.590	0.515	12.751	12.776	0.135
34	pi+	1	211	18	-1	-1	-1	0.475	0.444	2.749	2.828	0.140
35	pi-	1	-211	19	-1	-1	-1	-0.930	-0.584	157.487	157.491	0.140
36	pi+	1	211	20	-1	-1	-1	-0.709	-0.251	184.004	184.006	0.140
37	pi0	1	111	21	-1	-1	-1	-0.928	-0.417	179.820	179.823	0.135
38	pi-	1	-211	22	-1	-1	-1	0.001	0.091	0.810	0.827	0.140
39	pi+	1	211	23	-1	-1	-1	0.003	-0.083	0.558	0.581	0.140
40	pi0	1	111	24	-1	-1	-1	-0.149	0.038	1.678	1.691	0.135
41	K0	1	311	25	-1	-1	-1	-0.041	-0.500	2.120	2.234	0.498
42	pi+	1	211	26	-1	-1	-1	-0.227	-0.339	2.554	2.590	0.140
43	Lambda0	1	3122	27	-1	-1	-1	-0.448	-0.138	2.863	3.108	1.116
44	HadrClus	16	2000000300	28	-1	45	52	-0.292	-0.017	0.452	0.457	**0.000
45	proton	1	2212	44	-1	-1	-1	-0.289	0.120	-0.115	0.996	0.938
46	proton	1	2212	44	-1	-1	-1	-0.287	0.020	0.081	0.985	0.938
47	neutron	1	2112	44	-1	-1	-1	0.167	-0.121	-0.258	0.996	0.940
48	neutron	1	2112	44	-1	-1	-1	0.117	0.022	-0.118	0.954	0.940
49	neutron	1	2112	44	-1	-1	-1	-0.147	0.071	0.267	0.990	0.940
50	neutron	1	2112	44	-1	-1	-1	0.216	-0.092	0.377	1.039	0.940
51	neutron	1	2112	44	-1	-1	-1	0.173	-0.249	0.244	1.017	0.940
52	neutron	1	2112	44	-1	-1	-1	-0.243	0.212	-0.025	0.994	0.940
53	HadrBlob	15	2000000002	3	-1	-1	-1	0.024	-0.059	-0.015	28.872	**0.000
54	nu_e_bar	1	-12	4	-1	-1	-1	1.146	0.968	26.180	26.223	**0.000
55	e-	1	11	4	-1	-1	-1	4.446	1.466	67.138	67.301	**0.001
56	nu_tau	1	16	4	-1	-1	-1	-0.049	-0.057	1.876	1.878	0.000



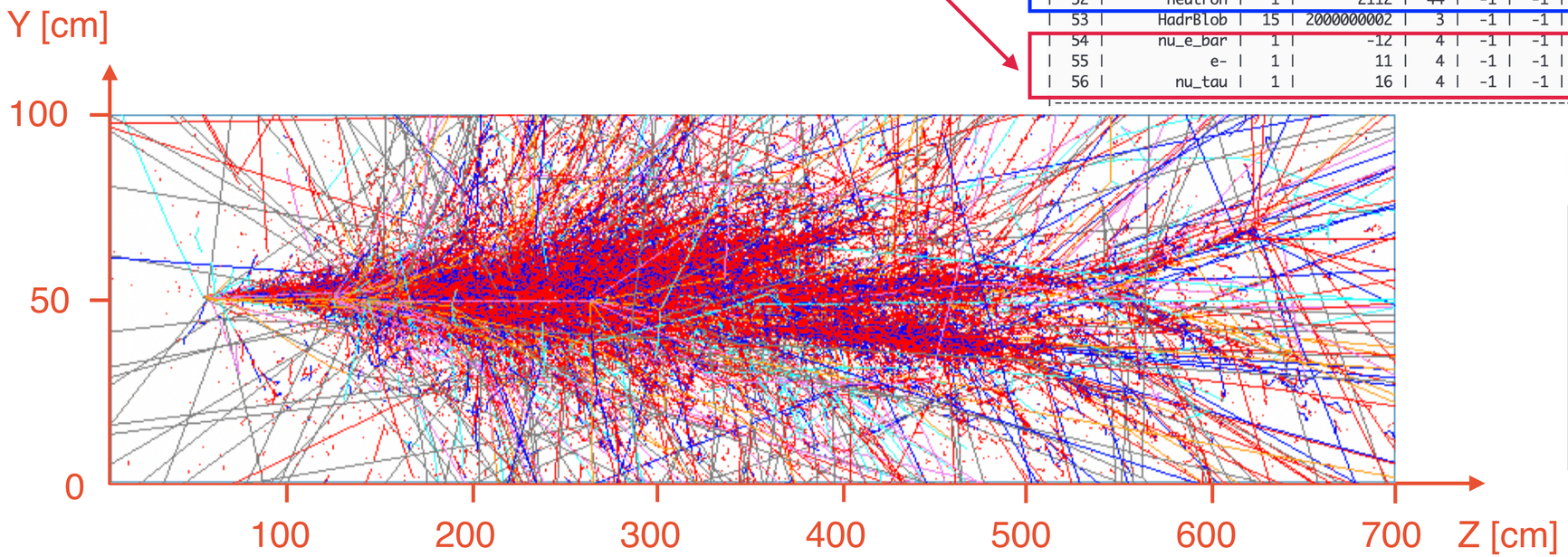
Green: Gamma
Yellow: Neutron

999 GeV ν_τ

- DIS CC
- ν_τ + Ar40 → τ^- + Ar39 + hadrSyst

  → $\tau^- \rightarrow \nu_\tau + \bar{\nu}_e + e^-$

21	pi0	14	111	11	-1	37	37	-0.928	-0.417	179.820	179.823	0.135
22	pi-	14	-211	12	-1	38	38	0.001	0.091	0.810	0.827	0.140
23	pi+	14	211	12	-1	39	39	0.003	-0.083	0.558	0.581	0.140
24	pi0	14	111	12	-1	40	40	-0.149	0.038	1.678	1.691	0.135
25	K0	14	311	16	-1	41	41	-0.041	-0.500	2.120	2.234	0.498
26	pi+	14	211	16	-1	42	42	-0.227	-0.339	2.554	2.590	0.140
27	Lambda0	14	3122	17	-1	43	43	-0.448	-0.138	2.863	3.108	1.116
28	pi-	14	-211	17	-1	44	44	-0.292	-0.017	0.452	0.556	0.140
29	pi+	1	211	9	-1	-1	-1	-0.964	-0.450	178.059	178.062	0.140
30	pi-	1	-211	10	-1	-1	-1	-1.235	-0.128	139.149	139.155	0.140
31	pi+	1	211	13	-1	-1	-1	-0.827	-0.773	21.983	22.013	0.140
32	pi-	1	-211	14	-1	-1	-1	0.114	0.274	16.783	16.786	0.140
33	pi0	1	111	15	-1	-1	-1	0.590	0.515	12.751	12.776	0.135
34	pi+	1	211	18	-1	-1	-1	0.475	0.444	2.749	2.828	0.140
35	pi-	1	-211	19	-1	-1	-1	-0.930	-0.584	157.487	157.491	0.140
36	pi+	1	211	20	-1	-1	-1	-0.709	-0.251	184.004	184.006	0.140
37	pi0	1	111	21	-1	-1	-1	-0.928	-0.417	179.820	179.823	0.135
38	pi-	1	-211	22	-1	-1	-1	0.001	0.091	0.810	0.827	0.140
39	pi+	1	211	23	-1	-1	-1	0.003	-0.083	0.558	0.581	0.140
40	pi0	1	111	24	-1	-1	-1	-0.149	0.038	1.678	1.691	0.135
41	K0	1	311	25	-1	-1	-1	-0.041	-0.500	2.120	2.234	0.498
42	pi+	1	211	26	-1	-1	-1	-0.227	-0.339	2.554	2.590	0.140
43	Lambda0	1	3122	27	-1	-1	-1	-0.448	-0.138	2.863	3.108	1.116
44	HadrClus	16	2000000300	28	-1	45	52	-0.292	-0.017	0.452	0.457	**0.000
45	proton	1	2212	44	-1	-1	-1	-0.289	0.120	-0.115	0.996	0.938
46	proton	1	2212	44	-1	-1	-1	-0.287	0.020	0.081	0.985	0.938
47	neutron	1	2112	44	-1	-1	-1	0.167	-0.121	-0.258	0.996	0.940
48	neutron	1	2112	44	-1	-1	-1	0.117	0.022	-0.118	0.954	0.940
49	neutron	1	2112	44	-1	-1	-1	-0.147	0.071	0.267	0.990	0.940
50	neutron	1	2112	44	-1	-1	-1	0.216	-0.092	0.377	1.039	0.940
51	neutron	1	2112	44	-1	-1	-1	0.173	-0.249	0.244	1.017	0.940
52	neutron	1	2112	44	-1	-1	-1	-0.243	0.212	-0.025	0.994	0.940
53	HadrBlob	15	2000000002	3	-1	-1	-1	0.024	-0.059	-0.015	28.872	**0.000
54	nu_e_bar	1	-12	4	-1	-1	-1	1.146	0.968	26.180	26.223	**0.000
55	e-	1	11	4	-1	-1	-1	4.446	1.466	67.138	67.301	**0.001
56	nu_tau	1	16	4	-1	-1	-1	-0.049	-0.057	1.876	1.878	0.000



Exclude gamma/neutron

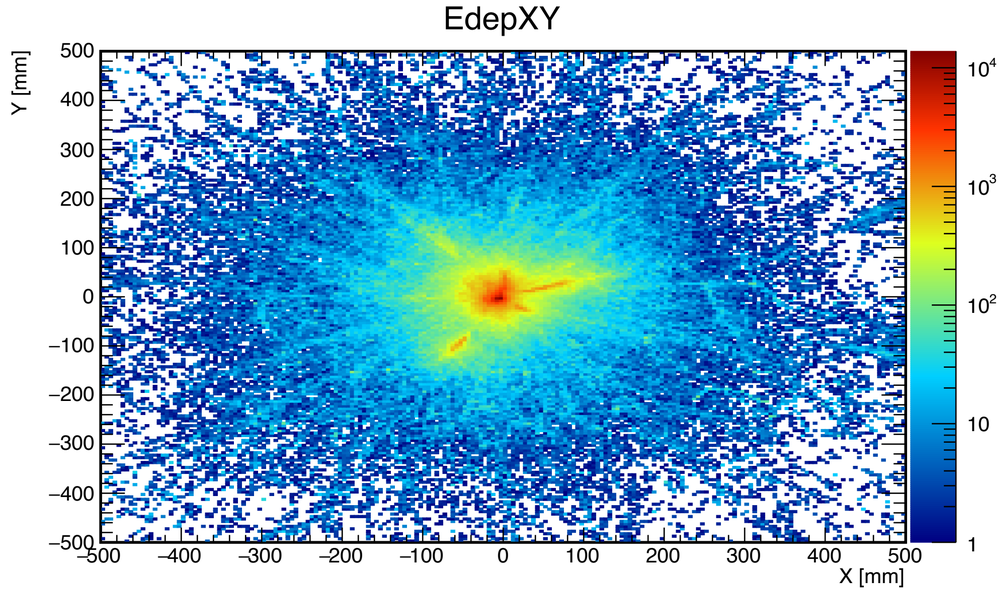
red: e-
blue: e+
cyan: proton
orange: pi+
violet: pi-

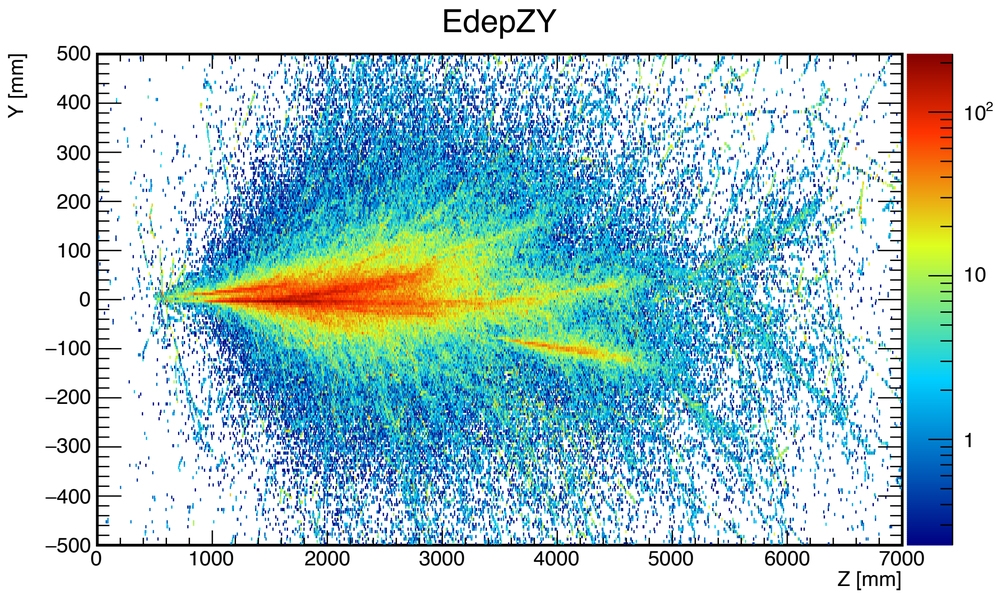
999 GeV ν_τ

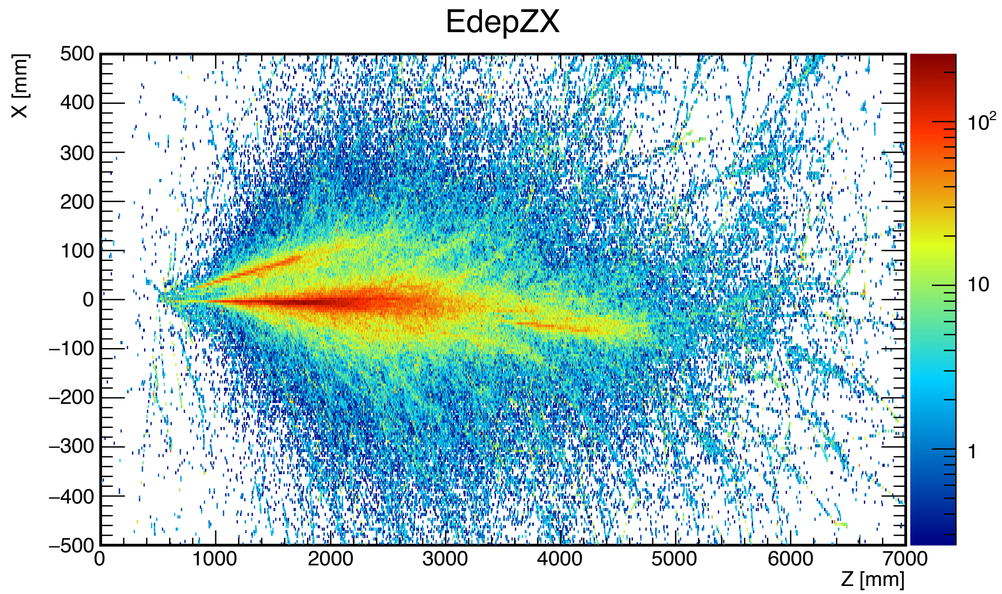
Energy deposition (MeV)

- DIS CC
- ν_τ + Ar40 → τ^- + Ar39 + hadrSyst

  → $\tau^- \rightarrow \nu_\tau + \bar{\nu}_e + e^-$





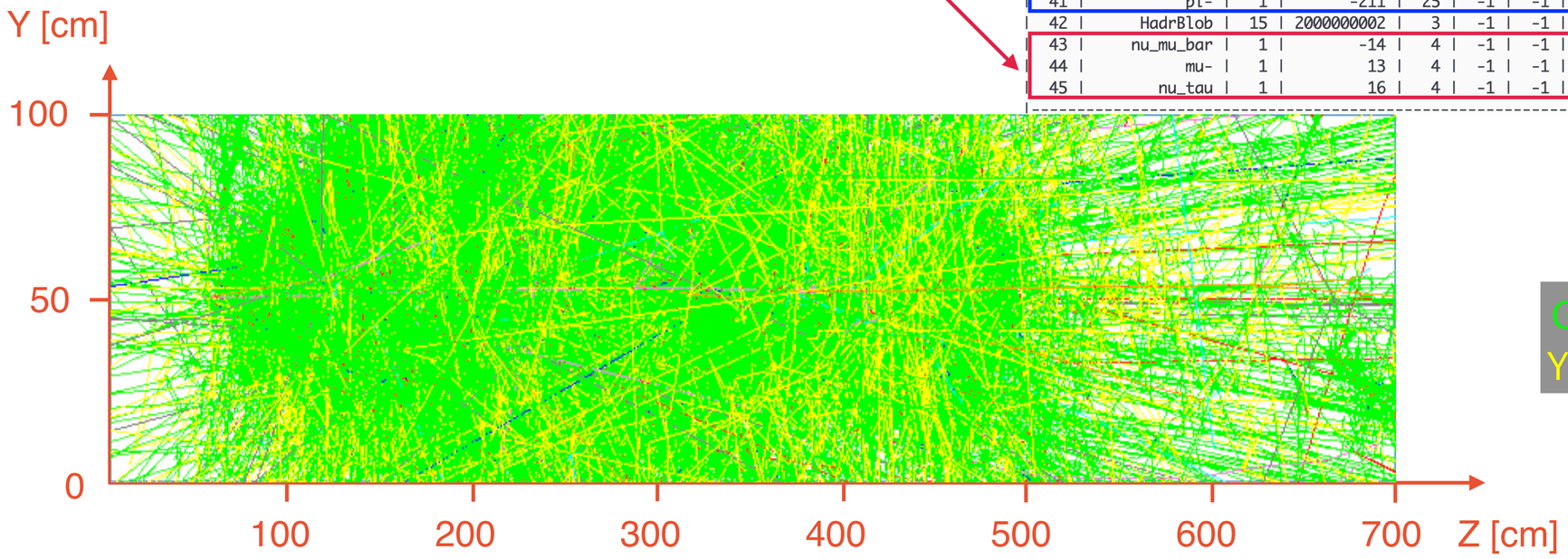


999 GeV ν_τ

- DIS CC
- $\nu_\tau + \mathrm{Ar40} \rightarrow \tau^- + \mathrm{Ar39} + \mathrm{hadrSyst}$

  $\tau^- \rightarrow \nu_\tau + \bar{\nu}_\mu + \mu^-$

11	pi+	14	211	8	-1	28	28	0.050	0.348	4.181	4.198	0.140
12	pi-	14	-211	8	-1	29	29	1.896	0.577	41.522	41.569	0.140
13	eta	12	221	8	-1	21	23	0.477	-0.498	23.286	23.302	0.547
14	pi0	14	111	8	-1	30	30	0.617	0.896	2.376	2.617	0.135
15	Delta+	12	2214	8	-1	24	25	0.079	-0.103	5.730	5.860	**1.232
16	eta'	12	331	8	-1	26	27	0.106	-0.101	1.771	2.018	0.958
17	K0	14	311	9	-1	31	31	5.838	1.078	131.432	131.567	0.498
18	pi+	14	211	9	-1	32	32	1.343	0.538	30.323	30.358	0.140
19	K0_bar	14	-311	10	-1	33	33	0.660	-0.148	15.299	15.322	0.498
20	pi-	14	-211	10	-1	34	34	0.161	0.126	13.195	13.197	0.140
21	pi0	14	111	13	-1	35	35	0.168	-0.026	5.143	5.148	0.135
22	pi0	14	111	13	-1	36	36	0.144	-0.076	5.890	5.894	0.135
23	pi0	14	111	13	-1	37	37	0.165	-0.396	12.252	12.260	0.135
24	proton	14	2212	15	-1	38	38	0.160	0.111	4.444	4.546	0.938
25	pi0	14	111	15	-1	39	41	-0.081	-0.214	1.287	1.314	0.135
26	gamma	1	22	16	-1	-1	-1	-0.060	0.285	0.122	0.316	0.000
27	gamma	1	22	16	-1	-1	-1	0.166	-0.386	1.649	1.702	0.000
28	pi+	1	211	11	-1	-1	-1	0.050	0.348	4.181	4.198	0.140
29	pi-	1	-211	12	-1	-1	-1	1.896	0.577	41.522	41.569	0.140
30	pi0	1	111	14	-1	-1	-1	0.617	0.896	2.376	2.617	0.135
31	K0	1	311	17	-1	-1	-1	5.838	1.078	131.432	131.567	0.498
32	pi+	1	211	18	-1	-1	-1	1.343	0.538	30.323	30.358	0.140
33	K0_bar	1	-311	19	-1	-1	-1	0.660	-0.148	15.299	15.322	0.498
34	pi-	1	-211	20	-1	-1	-1	0.161	0.126	13.195	13.197	0.140
35	pi0	1	111	21	-1	-1	-1	0.168	-0.026	5.143	5.148	0.135
36	pi0	1	111	22	-1	-1	-1	0.144	-0.076	5.890	5.894	0.135
37	pi0	1	111	23	-1	-1	-1	0.165	-0.396	12.252	12.260	0.135
38	proton	1	2212	24	-1	-1	-1	0.160	0.111	4.444	4.546	0.938
39	neutron	1	2112	25	-1	-1	-1	0.247	-0.526	0.640	1.277	0.940
40	pi+	1	211	25	-1	-1	-1	-0.202	-0.060	0.433	0.501	0.140
41	pi-	1	-211	25	-1	-1	-1	0.031	0.465	0.112	0.499	0.140
42	HadrBlob	15	2000000002	3	-1	-1	-1	-0.189	-0.027	0.159	35.323	**0.000
43	nu_mu_bar	1	-14	4	-1	-1	-1	-7.353	-1.568	485.926	485.984	**0.000
44	mu-	1	13	4	-1	-1	-1	-1.785	-0.273	131.151	131.163	0.106
45	nu_tau	1	16	4	-1	-1	-1	-2.060	-0.939	112.751	112.774	**0.000



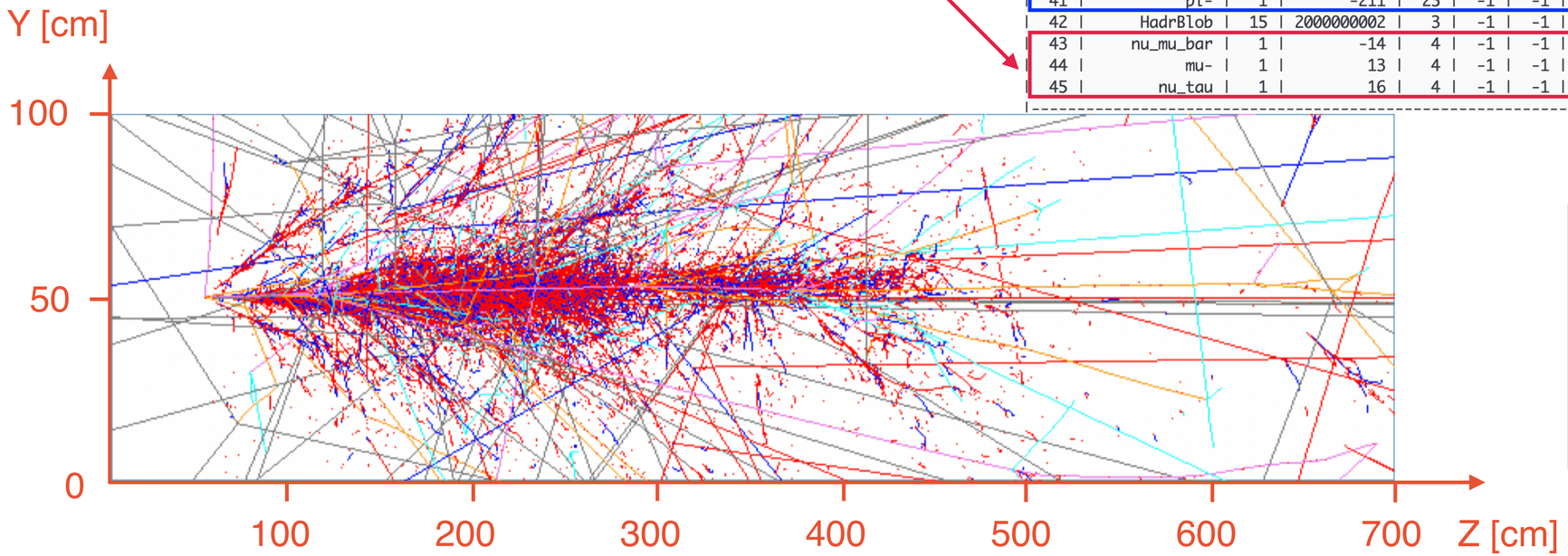
Green: Gamma
Yellow: Neutron

999 GeV ν_τ

- DIS CC
- $\nu_\tau + \mathrm{Ar40} \rightarrow \tau^- + \mathrm{Ar39} + \mathrm{hadrSyst}$

$\tau^- \rightarrow \nu_\tau + \bar{\nu}_\mu + \mu^-$

11	pi+	14	211	8	-1	28	28	0.050	0.348	4.181	4.198	0.140
12	pi-	14	-211	8	-1	29	29	1.896	0.577	41.522	41.569	0.140
13	eta	12	221	8	-1	21	23	0.477	-0.498	23.286	23.302	0.547
14	pi0	14	111	8	-1	30	30	0.617	0.896	2.376	2.617	0.135
15	Delta+	12	2214	8	-1	24	25	0.079	-0.103	5.730	5.860	**1.232
16	eta'	12	331	8	-1	26	27	0.106	-0.101	1.771	2.018	0.958
17	K0	14	311	9	-1	31	31	5.838	1.078	131.432	131.567	0.498
18	pi+	14	211	9	-1	32	32	1.343	0.538	30.323	30.358	0.140
19	K0_bar	14	-311	10	-1	33	33	0.660	-0.148	15.299	15.322	0.498
20	pi-	14	-211	10	-1	34	34	0.161	0.126	13.195	13.197	0.140
21	pi0	14	111	13	-1	35	35	0.168	-0.026	5.143	5.148	0.135
22	pi0	14	111	13	-1	36	36	0.144	-0.076	5.890	5.894	0.135
23	pi0	14	111	13	-1	37	37	0.165	-0.396	12.252	12.260	0.135
24	proton	14	2212	15	-1	38	38	0.160	0.111	4.444	4.546	0.938
25	pi0	14	111	15	-1	39	41	-0.081	-0.214	1.287	1.314	0.135
26	gamma	1	22	16	-1	-1	-1	-0.060	0.285	0.122	0.316	0.000
27	gamma	1	22	16	-1	-1	-1	0.166	-0.386	1.649	1.702	0.000
28	pi+	1	211	11	-1	-1	-1	0.050	0.348	4.181	4.198	0.140
29	pi-	1	-211	12	-1	-1	-1	1.896	0.577	41.522	41.569	0.140
30	pi0	1	111	14	-1	-1	-1	0.617	0.896	2.376	2.617	0.135
31	K0	1	311	17	-1	-1	-1	5.838	1.078	131.432	131.567	0.498
32	pi+	1	211	18	-1	-1	-1	1.343	0.538	30.323	30.358	0.140
33	K0_bar	1	-311	19	-1	-1	-1	0.660	-0.148	15.299	15.322	0.498
34	pi-	1	-211	20	-1	-1	-1	0.161	0.126	13.195	13.197	0.140
35	pi0	1	111	21	-1	-1	-1	0.168	-0.026	5.143	5.148	0.135
36	pi0	1	111	22	-1	-1	-1	0.144	-0.076	5.890	5.894	0.135
37	pi0	1	111	23	-1	-1	-1	0.165	-0.396	12.252	12.260	0.135
38	proton	1	2212	24	-1	-1	-1	0.160	0.111	4.444	4.546	0.938
39	neutron	1	2112	25	-1	-1	-1	0.247	-0.526	0.640	1.277	0.940
40	pi+	1	211	25	-1	-1	-1	-0.202	-0.060	0.433	0.501	0.140
41	pi-	1	-211	25	-1	-1	-1	0.031	0.465	0.112	0.499	0.140
42	HadrBlob	15	2000000002	3	-1	-1	-1	-0.189	-0.027	0.159	35.323	**0.000
43	nu_mu_bar	1	-14	4	-1	-1	-1	-7.353	-1.568	485.926	485.984	**0.000
44	mu-	1	13	4	-1	-1	-1	-1.785	-0.273	131.151	131.163	0.106
45	nu_tau	1	16	4	-1	-1	-1	-2.060	-0.939	112.751	112.774	**0.000



Exclude gamma/neutron

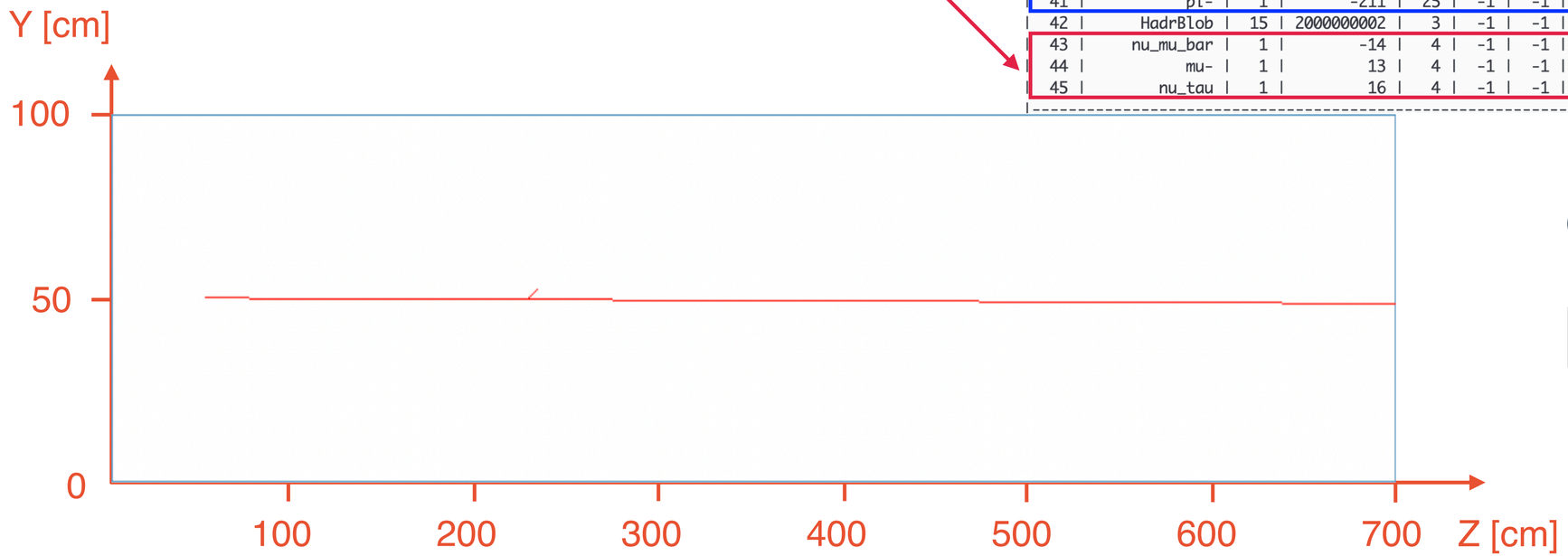
red: e-
blue: e+
cyan: proton
orange: pi+
violet: pi-

999 GeV ν_τ

- DIS CC
- $\nu_\tau + \mathrm{Ar40} \rightarrow \tau^- + \mathrm{Ar39} + \mathrm{hadrSyst}$

$\tau^- \rightarrow \nu_\tau + \bar{\nu}_\mu + \mu^-$

11	pi+	14	211	8	-1	28	28	0.050	0.348	4.181	4.198	0.140
12	pi-	14	-211	8	-1	29	29	1.896	0.577	41.522	41.569	0.140
13	eta	12	221	8	-1	21	23	0.477	-0.498	23.286	23.302	0.547
14	pi0	14	111	8	-1	30	30	0.617	0.896	2.376	2.617	0.135
15	Delta+	12	2214	8	-1	24	25	0.079	-0.103	5.730	5.860	**1.232
16	eta'	12	331	8	-1	26	27	0.106	-0.101	1.771	2.018	0.958
17	K0	14	311	9	-1	31	31	5.838	1.078	131.432	131.567	0.498
18	pi+	14	211	9	-1	32	32	1.343	0.538	30.323	30.358	0.140
19	K0_bar	14	-311	10	-1	33	33	0.660	-0.148	15.299	15.322	0.498
20	pi-	14	-211	10	-1	34	34	0.161	0.126	13.195	13.197	0.140
21	pi0	14	111	13	-1	35	35	0.168	-0.026	5.143	5.148	0.135
22	pi0	14	111	13	-1	36	36	0.144	-0.076	5.890	5.894	0.135
23	pi0	14	111	13	-1	37	37	0.165	-0.396	12.252	12.260	0.135
24	proton	14	2212	15	-1	38	38	0.160	0.111	4.444	4.546	0.938
25	pi0	14	111	15	-1	39	41	-0.081	-0.214	1.287	1.314	0.135
26	gamma	1	22	16	-1	-1	-1	-0.060	0.285	0.122	0.316	0.000
27	gamma	1	22	16	-1	-1	-1	0.166	-0.386	1.649	1.702	0.000
28	pi+	1	211	11	-1	-1	-1	0.050	0.348	4.181	4.198	0.140
29	pi-	1	-211	12	-1	-1	-1	1.896	0.577	41.522	41.569	0.140
30	pi0	1	111	14	-1	-1	-1	0.617	0.896	2.376	2.617	0.135
31	K0	1	311	17	-1	-1	-1	5.838	1.078	131.432	131.567	0.498
32	pi+	1	211	18	-1	-1	-1	1.343	0.538	30.323	30.358	0.140
33	K0_bar	1	-311	19	-1	-1	-1	0.660	-0.148	15.299	15.322	0.498
34	pi-	1	-211	20	-1	-1	-1	0.161	0.126	13.195	13.197	0.140
35	pi0	1	111	21	-1	-1	-1	0.168	-0.026	5.143	5.148	0.135
36	pi0	1	111	22	-1	-1	-1	0.144	-0.076	5.890	5.894	0.135
37	pi0	1	111	23	-1	-1	-1	0.165	-0.396	12.252	12.260	0.135
38	proton	1	2212	24	-1	-1	-1	0.160	0.111	4.444	4.546	0.938
39	neutron	1	2112	25	-1	-1	-1	0.247	-0.526	0.640	1.277	0.940
40	pi+	1	211	25	-1	-1	-1	-0.202	-0.060	0.433	0.501	0.140
41	pi-	1	-211	25	-1	-1	-1	0.031	0.465	0.112	0.499	0.140
42	HadrBlob	15	2000000002	3	-1	-1	-1	-0.189	-0.027	0.159	35.323	**0.000
43	nu_mu_bar	1	-14	4	-1	-1	-1	-7.353	-1.568	485.926	485.984	**0.000
44	mu-	1	13	4	-1	-1	-1	-1.785	-0.273	131.151	131.163	0.106
45	nu_tau	1	16	4	-1	-1	-1	-2.060	-0.939	112.751	112.774	**0.000



Only draw mu-

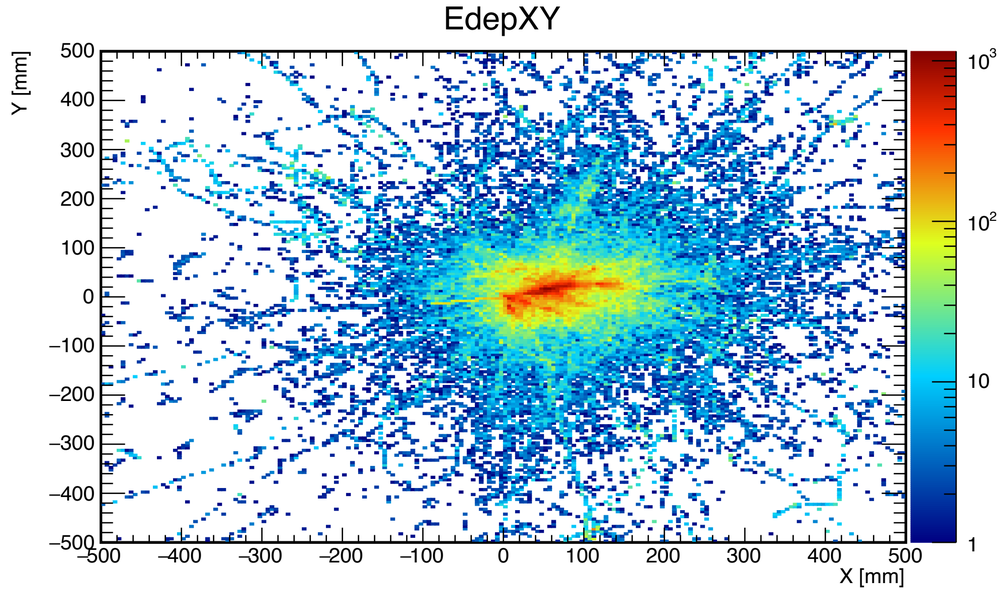
red: mu-

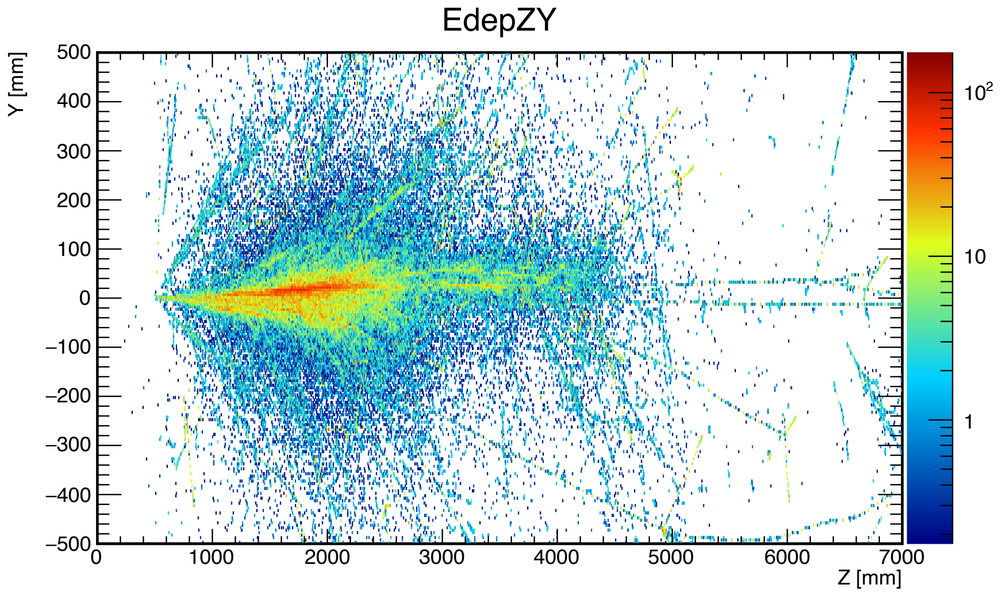
999 GeV ν_τ

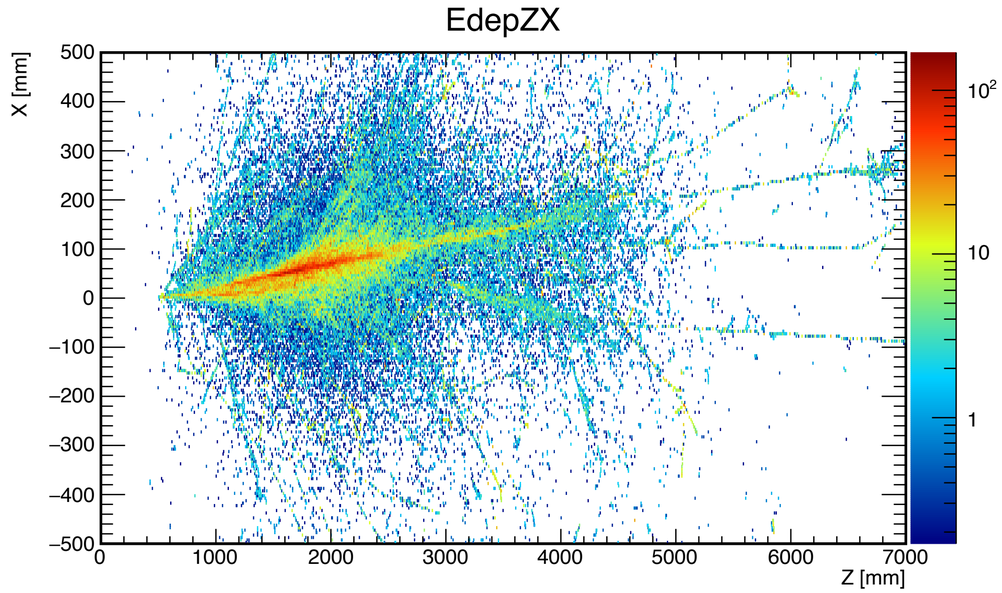
Energy deposition (MeV)

- DIS CC
- ν_τ + Ar40 → τ^- + Ar39 + hadrSyst

  → $\tau^- \rightarrow \nu_\tau + \bar{\nu}_\mu + \mu^-$





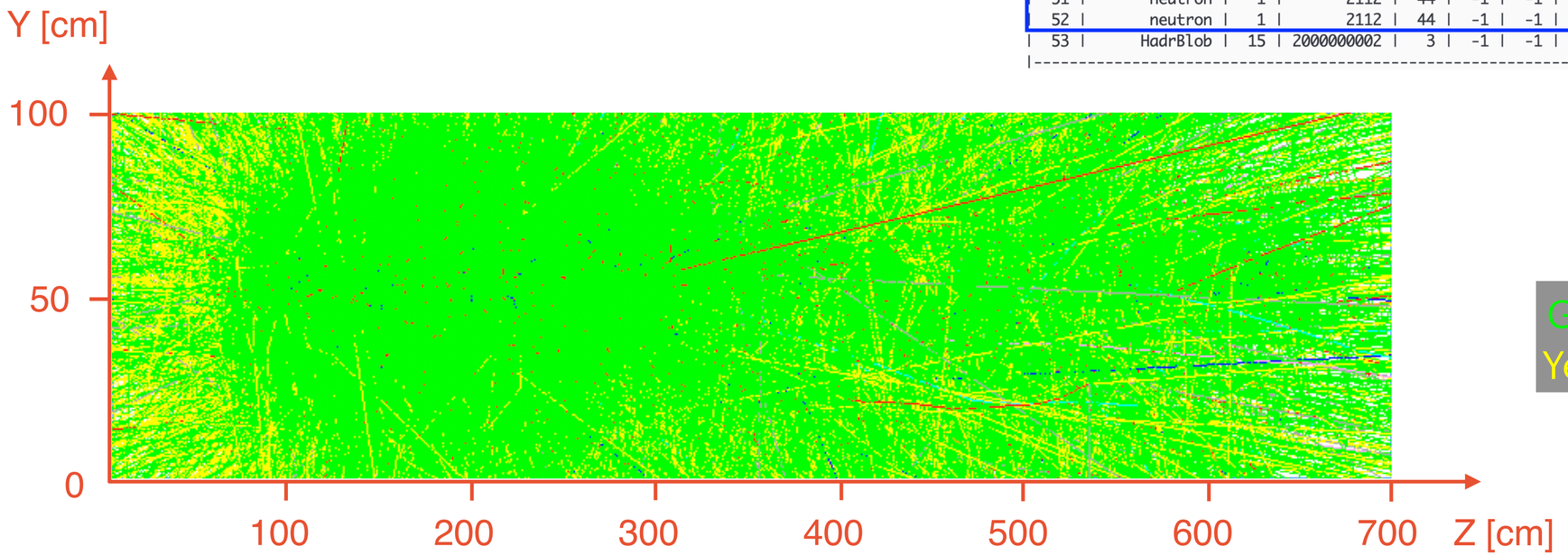


999 GeV ν_e

- DIS CC
- ν_e + Ar40 → e^- + Ar39 + hadrSyst

  → (E_k = 93.411 GeV)

21	pi0	14	111	11	-1	37	37	-0.957	-0.429	180.228	180.231	0.135
22	pi-	14	-211	12	-1	38	38	0.000	0.091	0.805	0.822	0.140
23	pi+	14	211	12	-1	39	39	0.003	-0.083	0.554	0.578	0.140
24	pi0	14	111	12	-1	40	40	-0.150	0.038	1.668	1.680	0.135
25	K0	14	311	16	-1	41	41	-0.041	-0.500	2.116	2.231	0.498
26	pi+	14	211	16	-1	42	42	-0.227	-0.339	2.550	2.586	0.140
27	Lambda0	14	3122	17	-1	43	43	-0.449	-0.138	2.857	3.103	1.116
28	pi-	14	-211	17	-1	44	44	-0.292	-0.018	0.451	0.556	0.140
29	pi+	1	211	9	-1	-1	-1	-0.993	-0.462	178.459	178.462	0.140
30	pi-	1	-211	10	-1	-1	-1	-1.257	-0.138	139.462	139.468	0.140
31	pi+	1	211	13	-1	-1	-1	-0.831	-0.775	22.179	22.208	0.140
32	pi-	1	-211	14	-1	-1	-1	0.111	0.273	16.753	16.756	0.140
33	pi0	1	111	15	-1	-1	-1	0.589	0.514	12.729	12.753	0.135
34	pi+	1	211	18	-1	-1	-1	0.475	0.444	2.744	2.824	0.140
35	pi-	1	-211	19	-1	-1	-1	-0.955	-0.595	157.855	157.859	0.140
36	pi+	1	211	20	-1	-1	-1	-0.739	-0.263	184.401	184.402	0.140
37	pi0	1	111	21	-1	-1	-1	-0.957	-0.429	180.228	180.231	0.135
38	pi-	1	-211	22	-1	-1	-1	0.000	0.091	0.805	0.822	0.140
39	pi+	1	211	23	-1	-1	-1	0.003	-0.083	0.554	0.578	0.140
40	pi0	1	111	24	-1	-1	-1	-0.150	0.038	1.668	1.680	0.135
41	K0	1	311	25	-1	-1	-1	-0.041	-0.500	2.116	2.231	0.498
42	pi+	1	211	26	-1	-1	-1	-0.227	-0.339	2.550	2.586	0.140
43	Lambda0	1	3122	27	-1	-1	-1	-0.449	-0.138	2.857	3.103	1.116
44	HadrClus	16	2000000300	28	-1	45	52	-0.292	-0.018	0.451	0.456	**0.000
45	proton	1	2212	44	-1	-1	-1	-0.289	0.120	-0.115	0.996	0.938
46	proton	1	2212	44	-1	-1	-1	-0.287	0.020	0.081	0.985	0.938
47	neutron	1	2112	44	-1	-1	-1	0.167	-0.121	-0.258	0.996	0.940
48	neutron	1	2112	44	-1	-1	-1	0.117	0.022	-0.118	0.954	0.940
49	neutron	1	2112	44	-1	-1	-1	-0.147	0.071	0.266	0.990	0.940
50	neutron	1	2112	44	-1	-1	-1	0.216	-0.092	0.376	1.039	0.940
51	neutron	1	2112	44	-1	-1	-1	0.173	-0.249	0.244	1.017	0.940
52	neutron	1	2112	44	-1	-1	-1	-0.243	0.212	-0.025	0.994	0.940
53	HadrBlob	15	2000000002	3	-1	-1	-1	0.024	-0.059	-0.015	28.872	**0.000



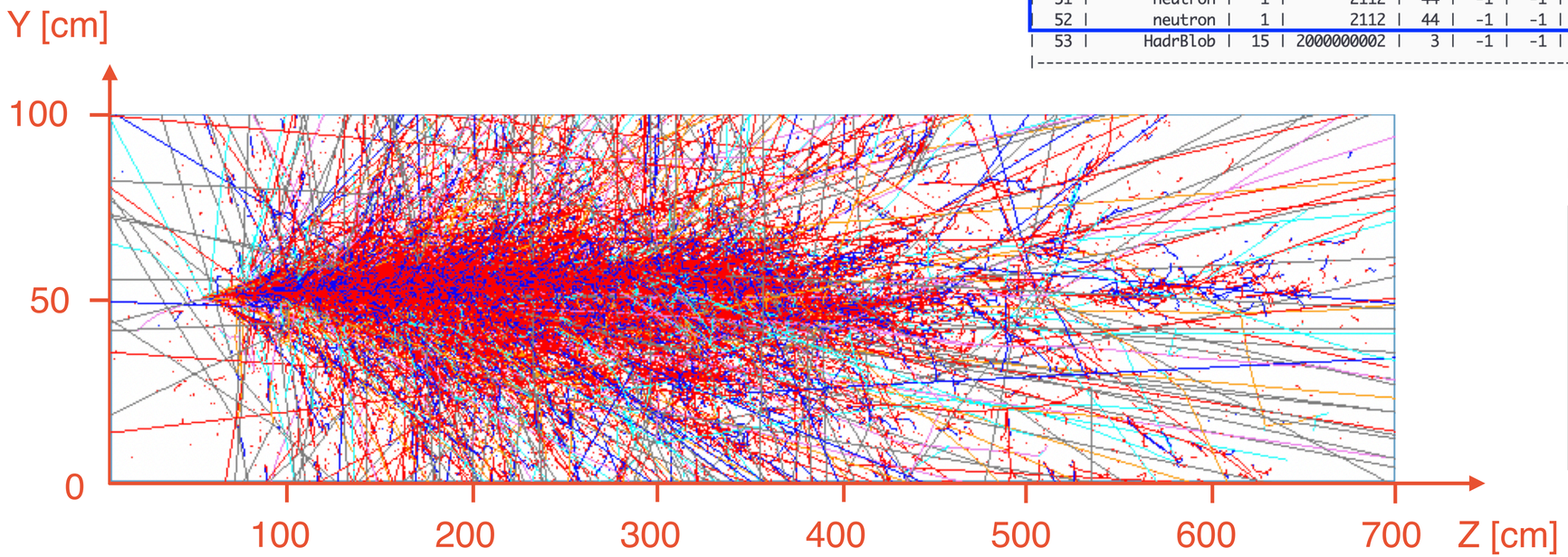
Green: Gamma
Yellow: Neutron

999 GeV ν_e

- DIS CC
- ν_e + Ar40 → e^- + Ar39 + hadrSyst

  → (E_k = 93.411 GeV)

21	pi0	14	111	11	-1	37	37	-0.957	-0.429	180.228	180.231	0.135
22	pi-	14	-211	12	-1	38	38	0.000	0.091	0.805	0.822	0.140
23	pi+	14	211	12	-1	39	39	0.003	-0.083	0.554	0.578	0.140
24	pi0	14	111	12	-1	40	40	-0.150	0.038	1.668	1.680	0.135
25	K0	14	311	16	-1	41	41	-0.041	-0.500	2.116	2.231	0.498
26	pi+	14	211	16	-1	42	42	-0.227	-0.339	2.550	2.586	0.140
27	Lambda0	14	3122	17	-1	43	43	-0.449	-0.138	2.857	3.103	1.116
28	pi-	14	-211	17	-1	44	44	-0.292	-0.018	0.451	0.556	0.140
29	pi+	1	211	9	-1	-1	-1	-0.993	-0.462	178.459	178.462	0.140
30	pi-	1	-211	10	-1	-1	-1	-1.257	-0.138	139.462	139.468	0.140
31	pi+	1	211	13	-1	-1	-1	-0.831	-0.775	22.179	22.208	0.140
32	pi-	1	-211	14	-1	-1	-1	0.111	0.273	16.753	16.756	0.140
33	pi0	1	111	15	-1	-1	-1	0.589	0.514	12.729	12.753	0.135
34	pi+	1	211	18	-1	-1	-1	0.475	0.444	2.744	2.824	0.140
35	pi-	1	-211	19	-1	-1	-1	-0.955	-0.595	157.855	157.859	0.140
36	pi+	1	211	20	-1	-1	-1	-0.739	-0.263	184.401	184.402	0.140
37	pi0	1	111	21	-1	-1	-1	-0.957	-0.429	180.228	180.231	0.135
38	pi-	1	-211	22	-1	-1	-1	0.000	0.091	0.805	0.822	0.140
39	pi+	1	211	23	-1	-1	-1	0.003	-0.083	0.554	0.578	0.140
40	pi0	1	111	24	-1	-1	-1	-0.150	0.038	1.668	1.680	0.135
41	K0	1	311	25	-1	-1	-1	-0.041	-0.500	2.116	2.231	0.498
42	pi+	1	211	26	-1	-1	-1	-0.227	-0.339	2.550	2.586	0.140
43	Lambda0	1	3122	27	-1	-1	-1	-0.449	-0.138	2.857	3.103	1.116
44	HadrClus	16	2000000300	28	-1	45	52	-0.292	-0.018	0.451	0.456	**0.000
45	proton	1	2212	44	-1	-1	-1	-0.289	0.120	-0.115	0.996	0.938
46	proton	1	2212	44	-1	-1	-1	-0.287	0.020	0.081	0.985	0.938
47	neutron	1	2112	44	-1	-1	-1	0.167	-0.121	-0.258	0.996	0.940
48	neutron	1	2112	44	-1	-1	-1	0.117	0.022	-0.118	0.954	0.940
49	neutron	1	2112	44	-1	-1	-1	-0.147	0.071	0.266	0.990	0.940
50	neutron	1	2112	44	-1	-1	-1	0.216	-0.092	0.376	1.039	0.940
51	neutron	1	2112	44	-1	-1	-1	0.173	-0.249	0.244	1.017	0.940
52	neutron	1	2112	44	-1	-1	-1	-0.243	0.212	-0.025	0.994	0.940
53	HadrBlob	15	2000000002	3	-1	-1	-1	0.024	-0.059	-0.015	28.872	**0.000



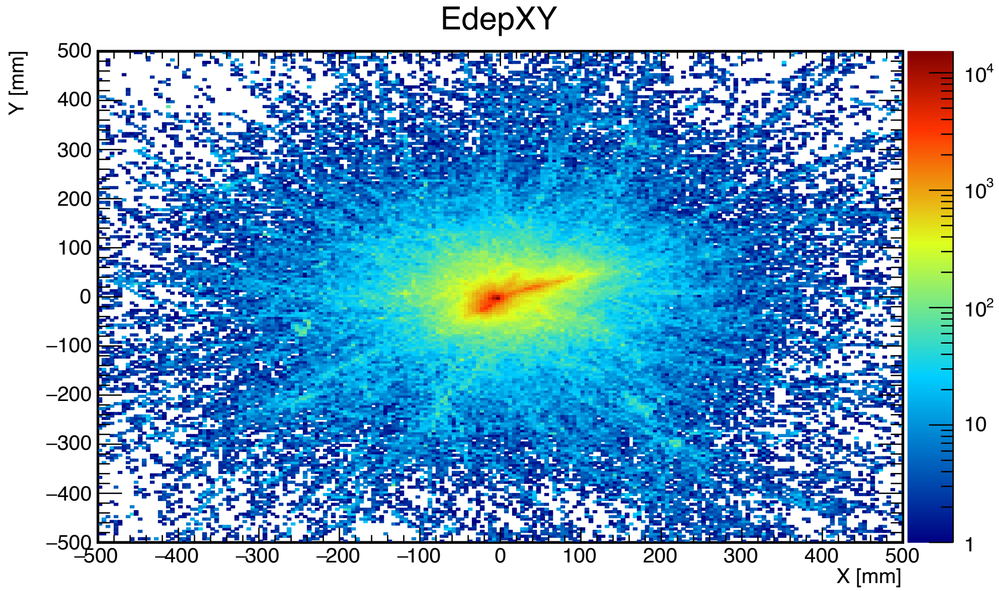
Exclude gamma/neutron

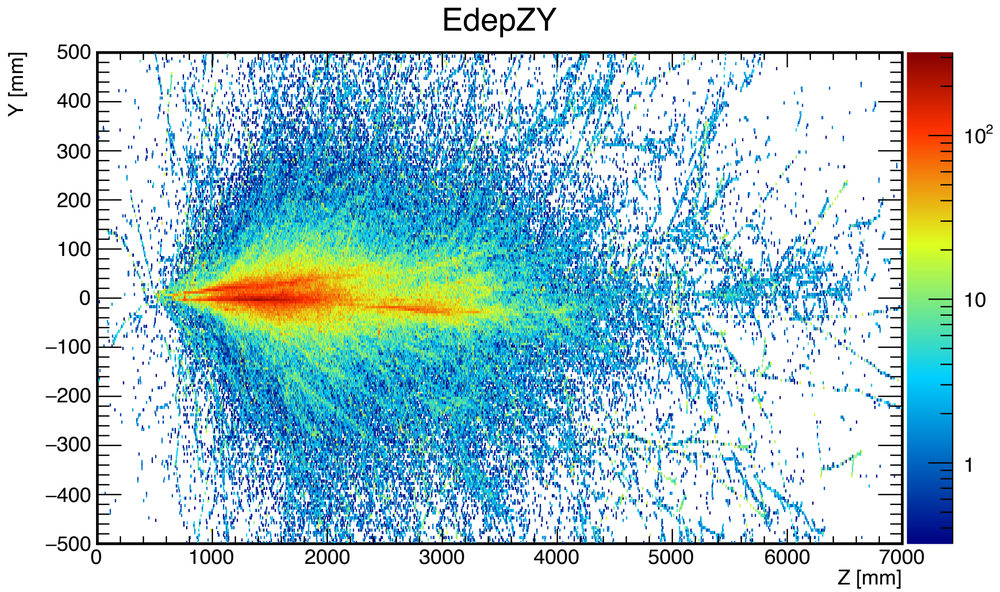
red: e-
blue: e+
cyan: proton
orange: pi+
violet: pi-

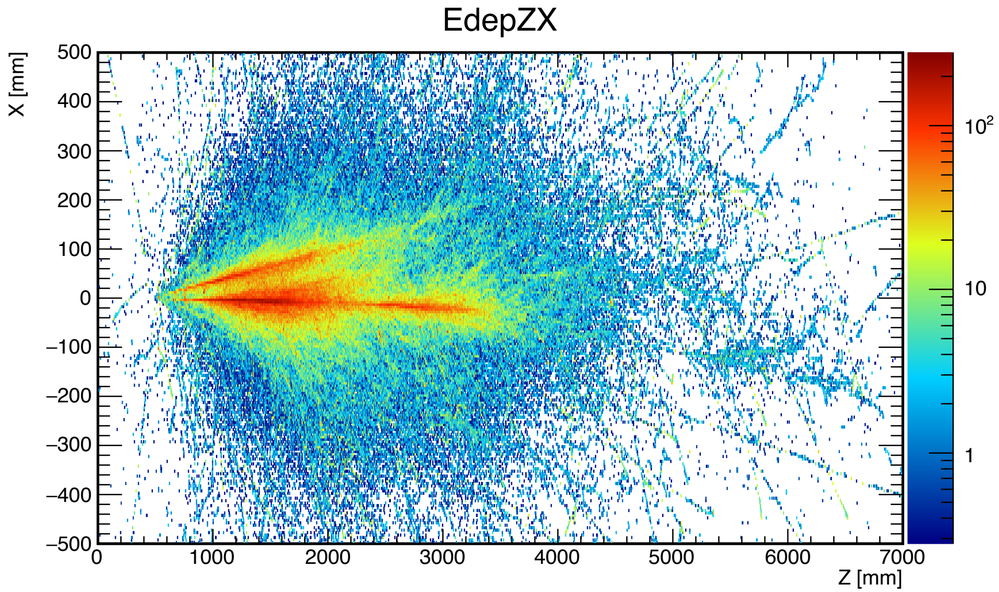
999 GeV ν_e

Energy deposition (MeV)

- DIS CC
- ν_e + Ar40 → e^- + Ar39 + hadrSyst
  - (E_k = 93.411 GeV)





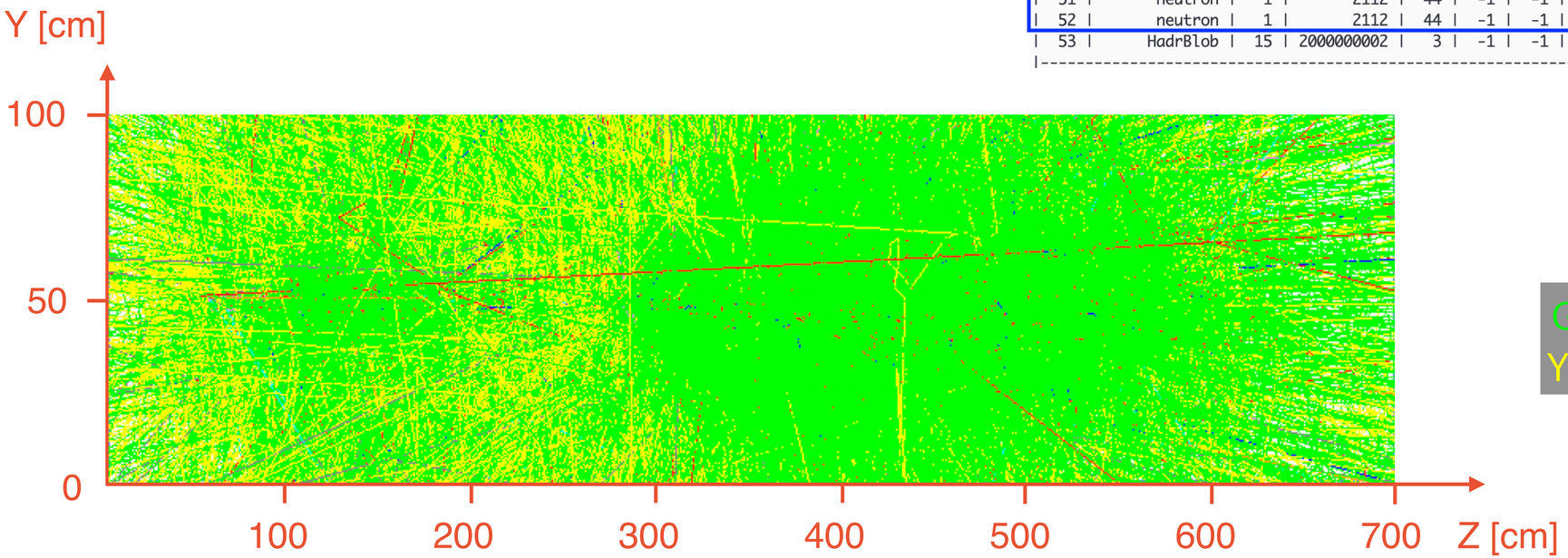


999 GeV ν_μ

- DIS CC
- ν_μ + Ar40 → μ^- + Ar39 + hadrSyst

  → (E_k = 93.508 GeV)

21	pi0	14	111	11	-1	37	37	-0.957	-0.429	180.208	180.211	0.135
22	pi-	14	-211	12	-1	38	38	0.000	0.091	0.805	0.822	0.140
23	pi+	14	211	12	-1	39	39	0.003	-0.083	0.554	0.578	0.140
24	pi0	14	111	12	-1	40	40	-0.150	0.038	1.668	1.680	0.135
25	K0	14	311	16	-1	41	41	-0.041	-0.500	2.116	2.231	0.498
26	pi+	14	211	16	-1	42	42	-0.227	-0.339	2.550	2.586	0.140
27	Lambda0	14	3122	17	-1	43	43	-0.449	-0.138	2.857	3.103	1.116
28	pi-	14	-211	17	-1	44	44	-0.292	-0.018	0.451	0.556	0.140
29	pi+	1	211	9	-1	-1	-1	-0.993	-0.463	178.440	178.443	0.140
30	pi-	1	-211	10	-1	-1	-1	-1.258	-0.138	139.447	139.453	0.140
31	pi+	1	211	13	-1	-1	-1	-0.831	-0.775	22.172	22.202	0.140
32	pi-	1	-211	14	-1	-1	-1	0.111	0.273	16.753	16.756	0.140
33	pi0	1	111	15	-1	-1	-1	0.588	0.514	12.729	12.753	0.135
34	pi+	1	211	18	-1	-1	-1	0.475	0.444	2.744	2.824	0.140
35	pi-	1	-211	19	-1	-1	-1	-0.956	-0.595	157.838	157.842	0.140
36	pi+	1	211	20	-1	-1	-1	-0.739	-0.263	184.381	184.383	0.140
37	pi0	1	111	21	-1	-1	-1	-0.957	-0.429	180.208	180.211	0.135
38	pi-	1	-211	22	-1	-1	-1	0.000	0.091	0.805	0.822	0.140
39	pi+	1	211	23	-1	-1	-1	0.003	-0.083	0.554	0.578	0.140
40	pi0	1	111	24	-1	-1	-1	-0.150	0.038	1.668	1.680	0.135
41	K0	1	311	25	-1	-1	-1	-0.041	-0.500	2.116	2.231	0.498
42	pi+	1	211	26	-1	-1	-1	-0.227	-0.339	2.550	2.586	0.140
43	Lambda0	1	3122	27	-1	-1	-1	-0.449	-0.138	2.857	3.103	1.116
44	HadrClus	16	2000000300	28	-1	45	52	-0.292	-0.018	0.451	0.456	**0.000
45	proton	1	2212	44	-1	-1	-1	-0.289	0.120	-0.115	0.996	0.938
46	proton	1	2212	44	-1	-1	-1	-0.287	0.020	0.081	0.985	0.938
47	neutron	1	2112	44	-1	-1	-1	0.167	-0.121	-0.258	0.996	0.940
48	neutron	1	2112	44	-1	-1	-1	0.117	0.022	-0.118	0.954	0.940
49	neutron	1	2112	44	-1	-1	-1	-0.147	0.071	0.266	0.990	0.940
50	neutron	1	2112	44	-1	-1	-1	0.216	-0.092	0.376	1.039	0.940
51	neutron	1	2112	44	-1	-1	-1	0.173	-0.249	0.244	1.017	0.940
52	neutron	1	2112	44	-1	-1	-1	-0.243	0.212	-0.025	0.994	0.940
53	HadrBlob	15	2000000002	3	-1	-1	-1	0.024	-0.059	-0.015	28.872	**0.000



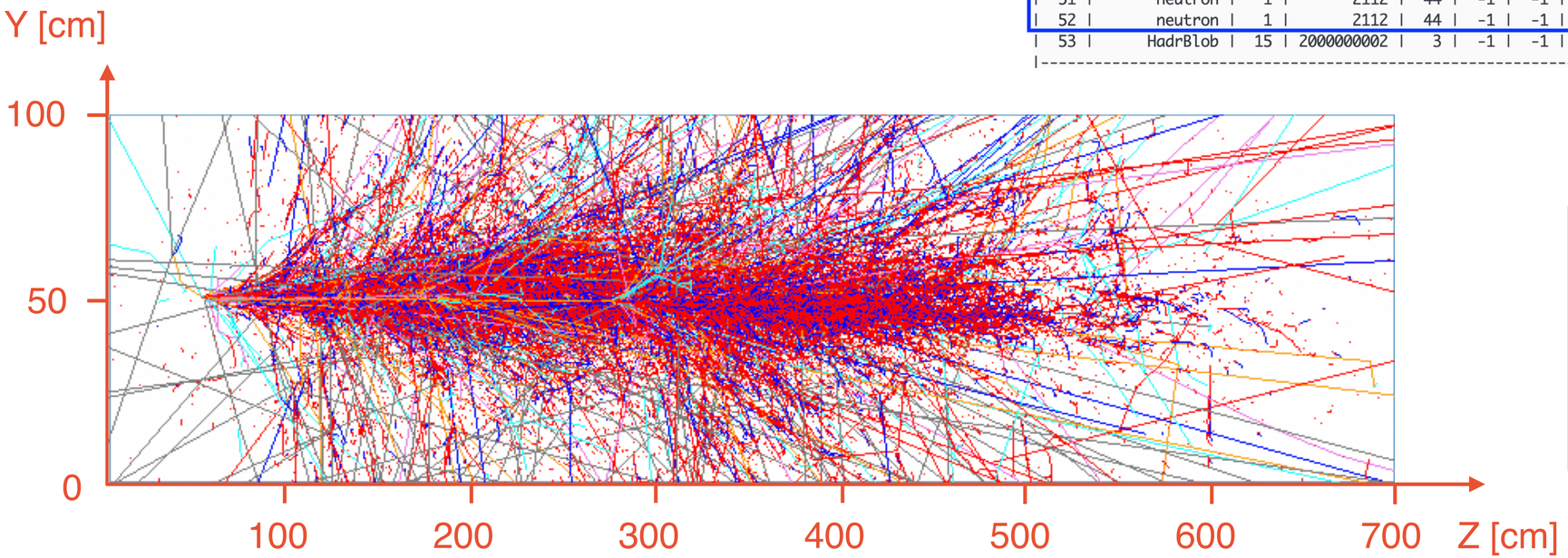
Green: Gamma
Yellow: Neutron

999 GeV ν_μ

- DIS CC
- ν_μ + Ar40 → μ^- + Ar39 + hadrSyst

  → (E_k = 93.508 GeV)

21	pi0	14	111	11	-1	37	37	-0.957	-0.429	180.208	180.211	0.135
22	pi-	14	-211	12	-1	38	38	0.000	0.091	0.805	0.822	0.140
23	pi+	14	211	12	-1	39	39	0.003	-0.083	0.554	0.578	0.140
24	pi0	14	111	12	-1	40	40	-0.150	0.038	1.668	1.680	0.135
25	K0	14	311	16	-1	41	41	-0.041	-0.500	2.116	2.231	0.498
26	pi+	14	211	16	-1	42	42	-0.227	-0.339	2.550	2.586	0.140
27	Lambda0	14	3122	17	-1	43	43	-0.449	-0.138	2.857	3.103	1.116
28	pi-	14	-211	17	-1	44	44	-0.292	-0.018	0.451	0.556	0.140
29	pi+	1	211	9	-1	-1	-1	-0.993	-0.463	178.440	178.443	0.140
30	pi-	1	-211	10	-1	-1	-1	-1.258	-0.138	139.447	139.453	0.140
31	pi+	1	211	13	-1	-1	-1	-0.831	-0.775	22.172	22.202	0.140
32	pi-	1	-211	14	-1	-1	-1	0.111	0.273	16.753	16.756	0.140
33	pi0	1	111	15	-1	-1	-1	0.588	0.514	12.729	12.753	0.135
34	pi+	1	211	18	-1	-1	-1	0.475	0.444	2.744	2.824	0.140
35	pi-	1	-211	19	-1	-1	-1	-0.956	-0.595	157.838	157.842	0.140
36	pi+	1	211	20	-1	-1	-1	-0.739	-0.263	184.381	184.383	0.140
37	pi0	1	111	21	-1	-1	-1	-0.957	-0.429	180.208	180.211	0.135
38	pi-	1	-211	22	-1	-1	-1	0.000	0.091	0.805	0.822	0.140
39	pi+	1	211	23	-1	-1	-1	0.003	-0.083	0.554	0.578	0.140
40	pi0	1	111	24	-1	-1	-1	-0.150	0.038	1.668	1.680	0.135
41	K0	1	311	25	-1	-1	-1	-0.041	-0.500	2.116	2.231	0.498
42	pi+	1	211	26	-1	-1	-1	-0.227	-0.339	2.550	2.586	0.140
43	Lambda0	1	3122	27	-1	-1	-1	-0.449	-0.138	2.857	3.103	1.116
44	HadrClus	16	2000000300	28	-1	45	52	-0.292	-0.018	0.451	0.456	**0.000
45	proton	1	2212	44	-1	-1	-1	-0.289	0.120	-0.115	0.996	0.938
46	proton	1	2212	44	-1	-1	-1	-0.287	0.020	0.081	0.985	0.938
47	neutron	1	2112	44	-1	-1	-1	0.167	-0.121	-0.258	0.996	0.940
48	neutron	1	2112	44	-1	-1	-1	0.117	0.022	-0.118	0.954	0.940
49	neutron	1	2112	44	-1	-1	-1	-0.147	0.071	0.266	0.990	0.940
50	neutron	1	2112	44	-1	-1	-1	0.216	-0.092	0.376	1.039	0.940
51	neutron	1	2112	44	-1	-1	-1	0.173	-0.249	0.244	1.017	0.940
52	neutron	1	2112	44	-1	-1	-1	-0.243	0.212	-0.025	0.994	0.940
53	HadrBlob	15	2000000002	3	-1	-1	-1	0.024	-0.059	-0.015	28.872	**0.000



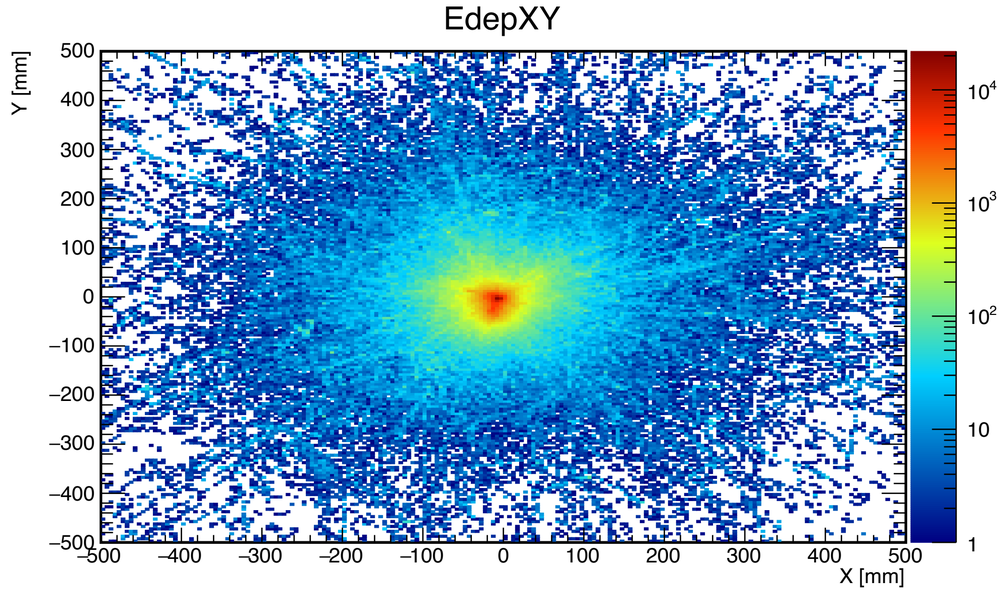
Exclude gamma/neutron

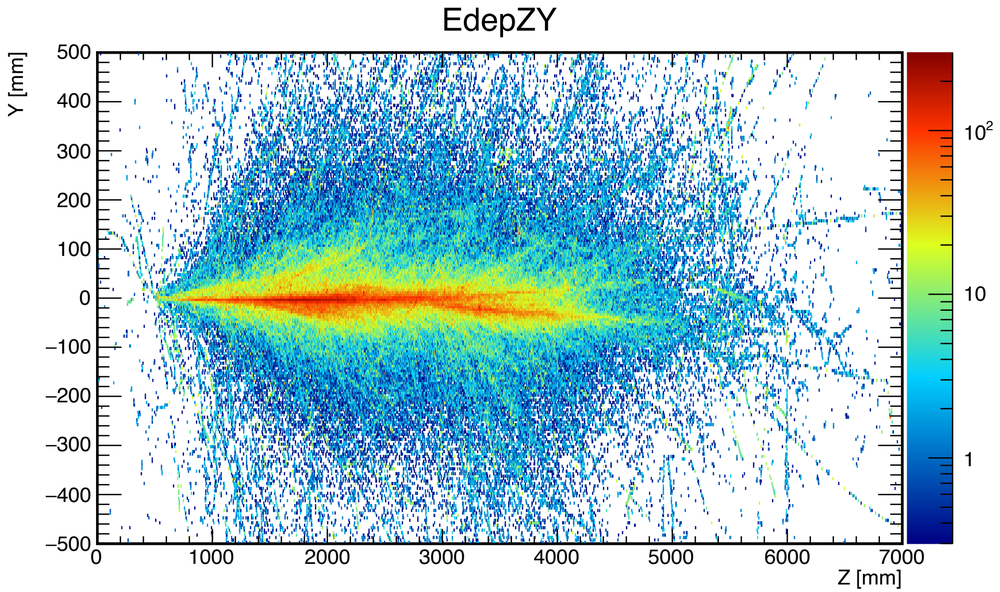
red: e-
blue: e+
cyan: proton
orange: pi+
violet: pi-

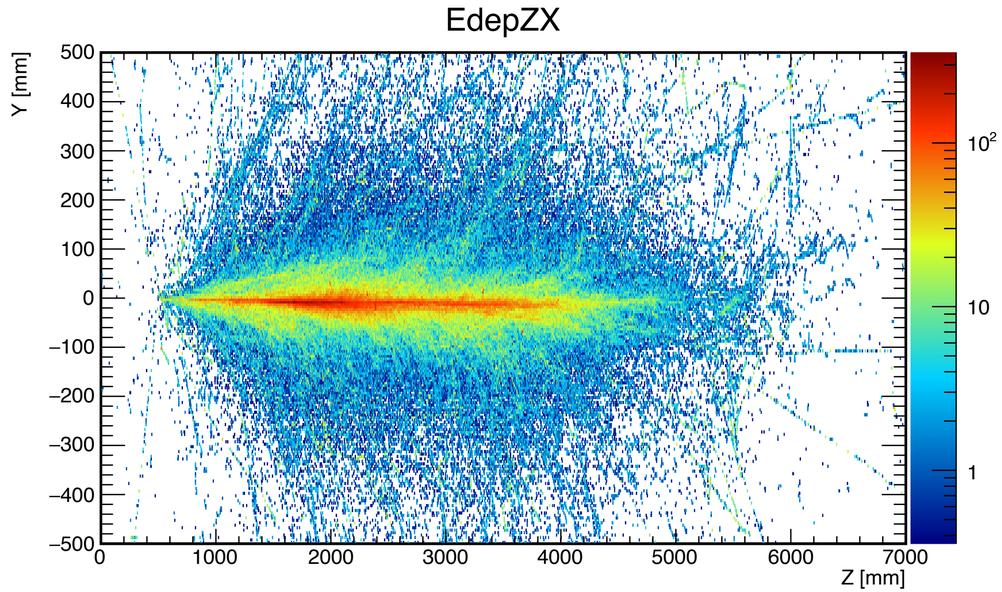
999 GeV ν_μ

Energy deposition (MeV)

- DIS CC
- ν_μ + Ar40 → μ^- + Ar39 + hadrSyst
  - → (E_k = 93.508 GeV)







Backup

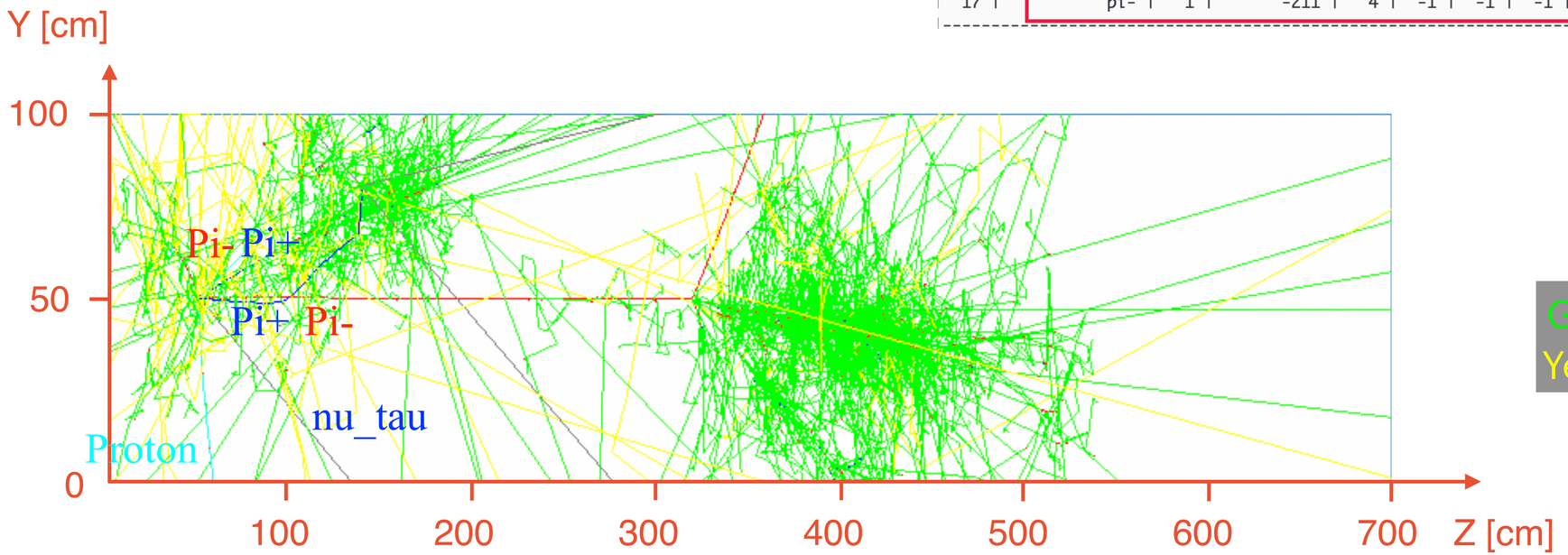
10 GeV ν_τ

- DIS CC
- $\nu_\tau + \mathrm{Ar40} \rightarrow \tau^- + \mathrm{Ar39} + \mathrm{hadrSyst}$

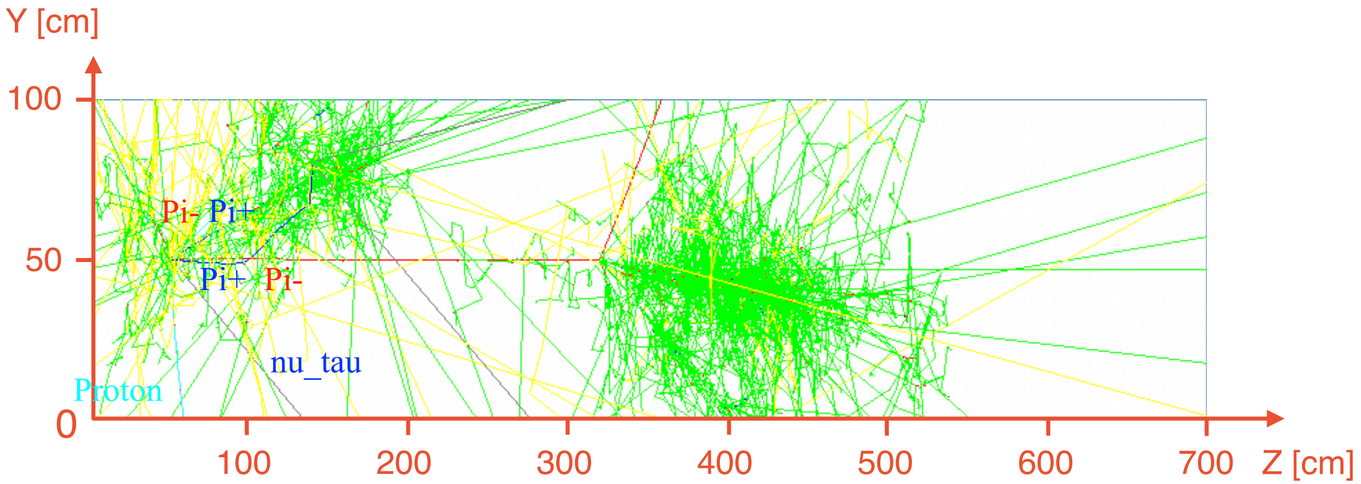
$$\tau^- \rightarrow \nu_\tau + \pi^-$$

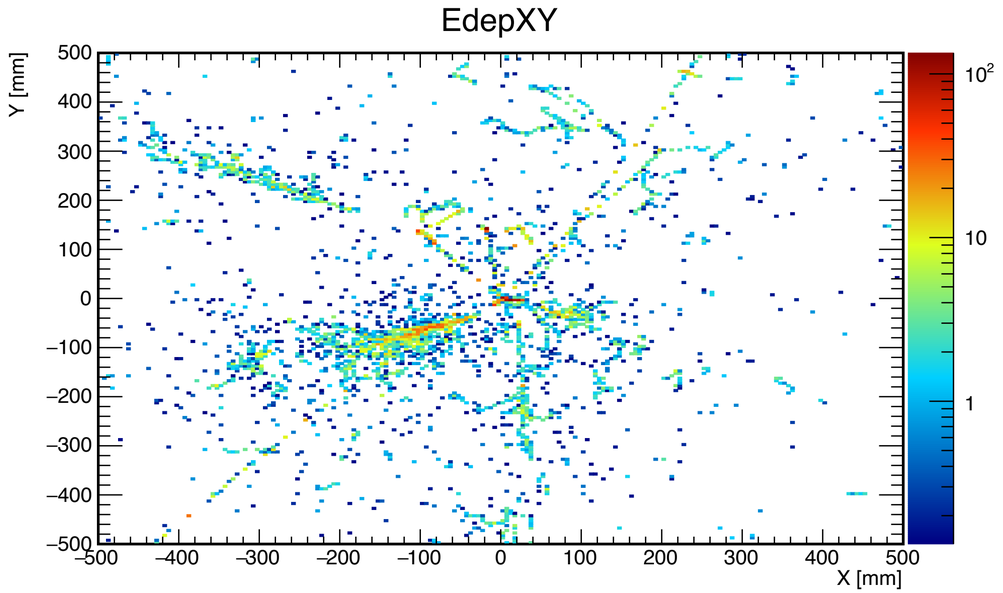
GENIE GHEP Event Record [print level: 3]

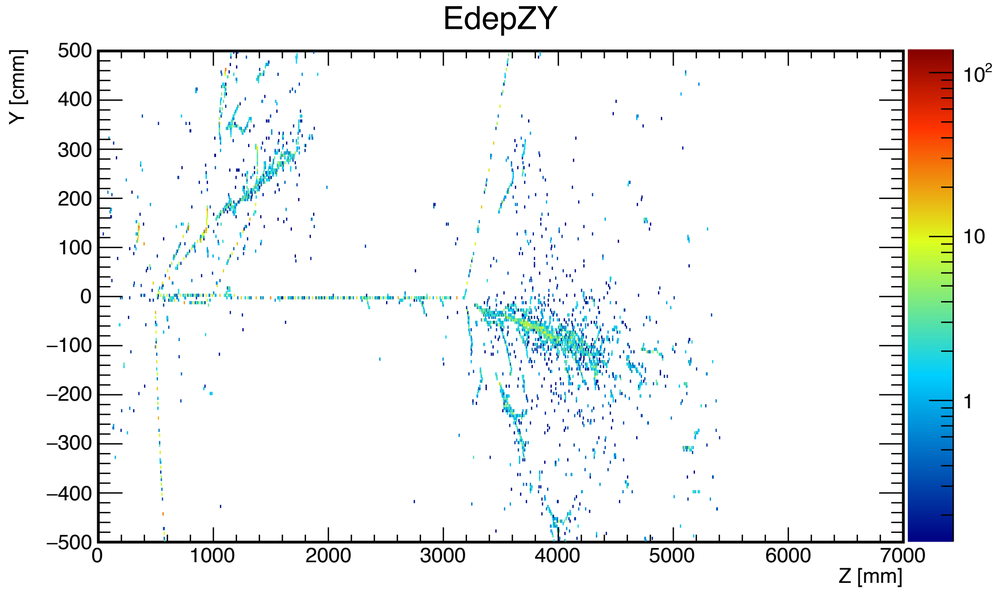
Idx	Name	Ist	PDG	Mother	Daughter	Px	Py	Pz	E	m
0	nu_tau	0	16	-1 -1	4 4	0.000	0.000	10.000	10.000	0.000
1	Ar40	0	1000180400	-1 -1	2 3	0.000	0.000	0.000	37.216	37.216
2	neutron	11	2112	1 -1	5 5	0.040	0.220	-0.079	0.929	**0.940
3	Ar39	2	1000180390	1 -1	15 15	-0.040	-0.220	0.079	36.287	36.286
4	tau-	3	15	0 -1	16 17	0.374	-0.802	7.364	7.627	1.777
5	HadrSyst	12	2000000001	2 -1	6 8	-0.334	1.022	2.557	3.302	**0.000
6	proton	14	2212	5 -1	9 9	-0.098	0.398	0.840	1.324	0.938
7	pi+	14	211	5 -1	10 11	-0.089	-0.121	0.282	0.349	0.140
8	pi-	14	-211	5 -1	12 14	-0.147	0.744	1.434	1.629	0.140
9	proton	1	2212	6 -1	-1 -1	-0.098	0.398	0.840	1.324	0.938
10	pi+	1	211	7 -1	-1 -1	-0.008	-0.016	0.260	0.295	0.140
11	neutron	1	2112	7 -1	-1 -1	-0.271	-0.148	-0.019	0.989	0.940
12	neutron	1	2112	8 -1	-1 -1	0.036	0.199	0.194	0.981	0.940
13	pi-	1	-211	8 -1	-1 -1	0.020	0.176	-0.156	0.275	0.140
14	pi+	1	211	8 -1	-1 -1	-0.285	0.396	1.230	1.330	0.140
15	HadrBlob	15	2000000002	3 -1	-1 -1	0.232	-0.204	0.287	34.394	**0.000
16	nu_tau	1	16	4 -1	-1 -1	0.339	-0.804	1.329	1.590	0.000
17	pi-	1	-211	4 -1	-1 -1	0.035	0.003	6.036	6.037	0.140

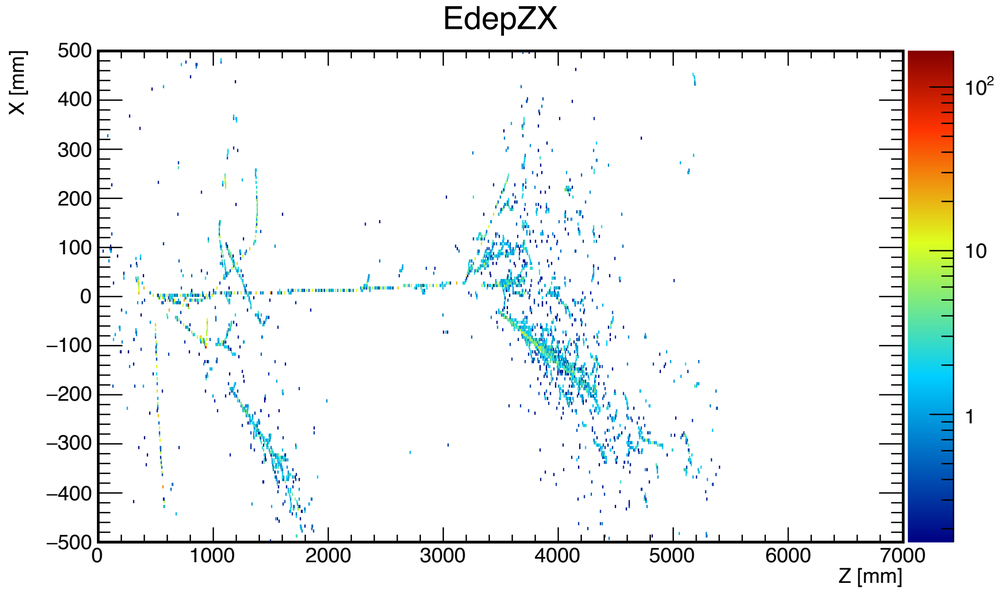


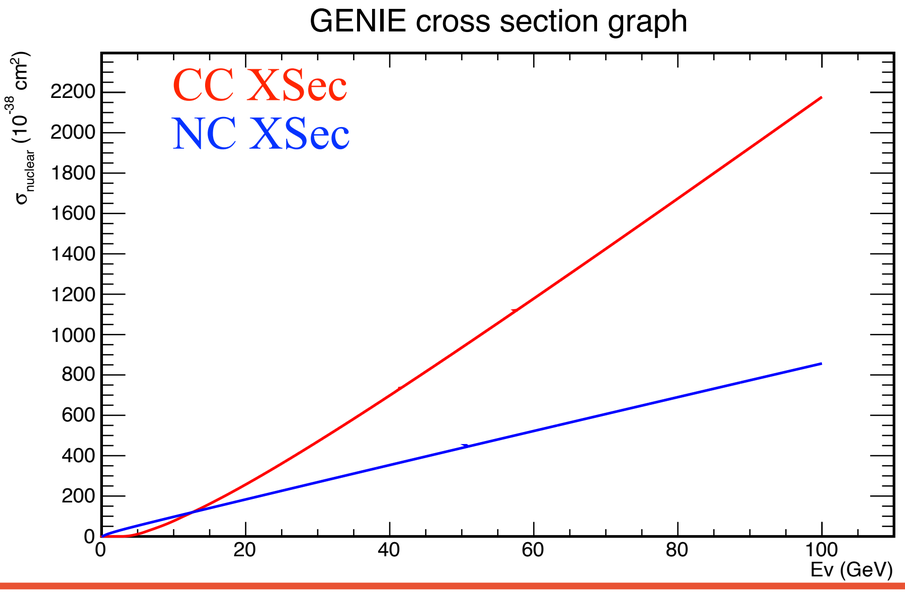
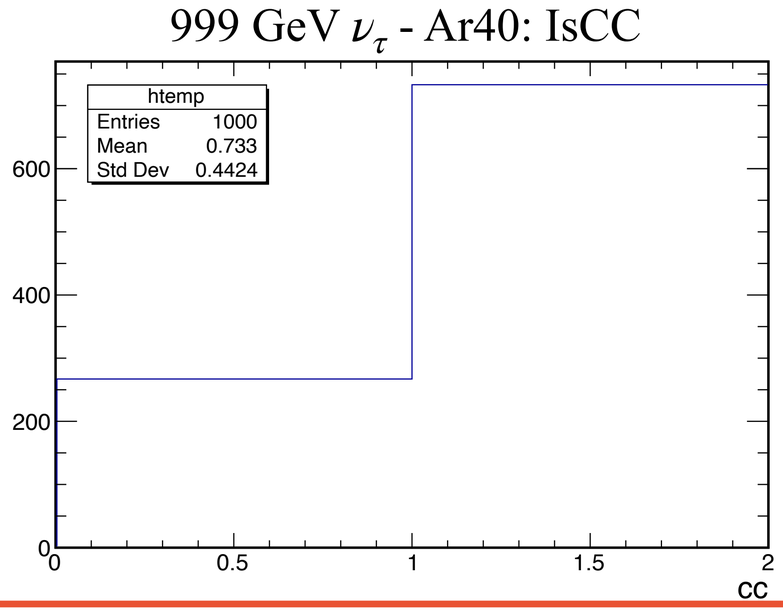
Green: Gamma
Yellow: Neutron


Y [cm]
100
50
0
Pi-
Pi+
Pi+
Pi-
nu_tau
Proton
100
200
300
400
500
600
700
Z [cm]


EdepXY
Y [mm]
X [mm]


EdepZY
Y [cmm]
Z [mm]


EdepZX
X [mm]
Z [mm]

ν_τ-Ar interactions in GENIE

- Found a pre-calculated spline for ν_τ-Ar interactions, with energy up to 999 GeV
  - Will use this spline for now, as the placeholder to develop the interface in Geant4 application to read GENIE results
- As pointed out by Felix, there is a new dedicated interaction model for high energy neutrino interactions in GENIE called HEDIS (high energy DIS): https://arxiv.org/abs/2106.09381
  - It's available in the GENIE repository (master branch), but not a released version of GENIE
  - Consider to move to the newer version of GENIE in the future, need more understanding on the simulation results