LST T5 DNN

Successful integration of DNN into LST

May 26th, 2023

P. Chang, ***J. Guiang***

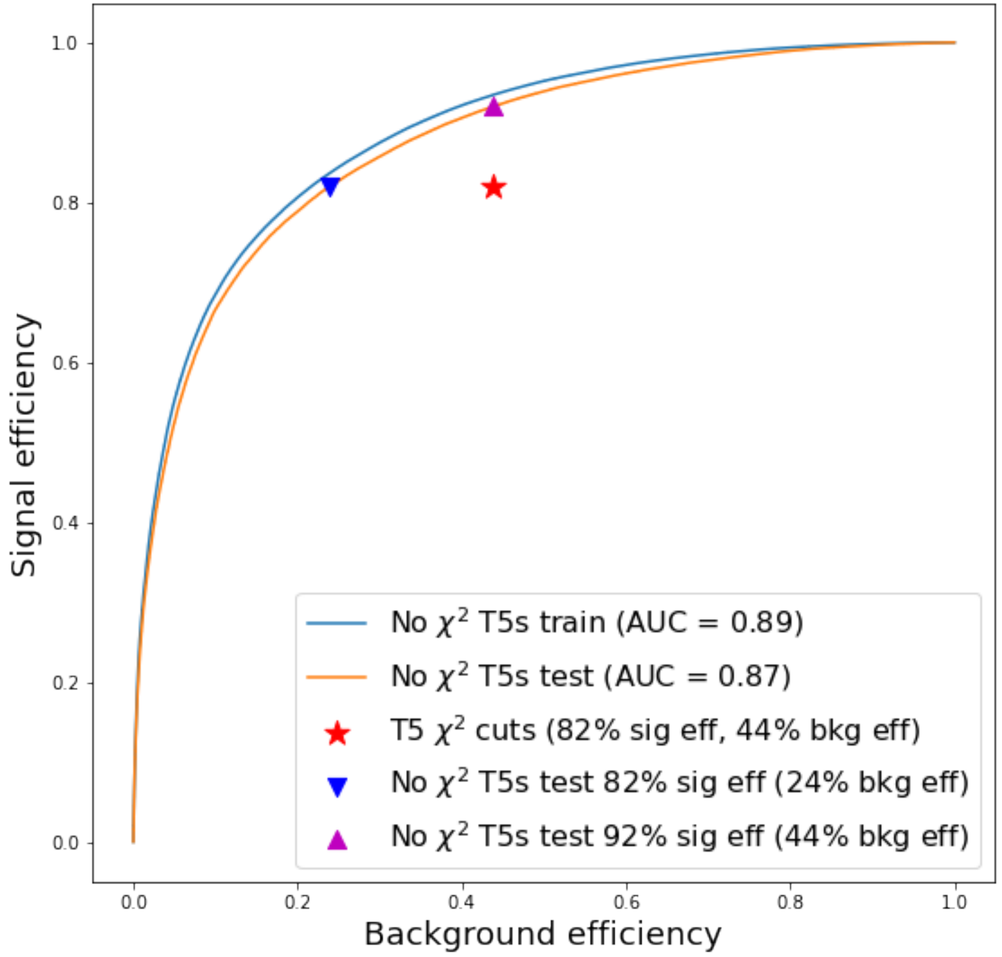
UC San Diego

UF UNIVERSITY of FLORIDA

Overview

- Last time, settled on using the ▲ working point
  - Match bkg eff, 10% better sig eff
- Next, show results for the following samples:
  - $t\bar{t}$ PU200 (sample used to train/test DNN)
  - 5cm cube
  - 50cm cube
  - Muon gun
  - Pion gun

2 hidden layers + no δr + p_T fix



UC San Diego

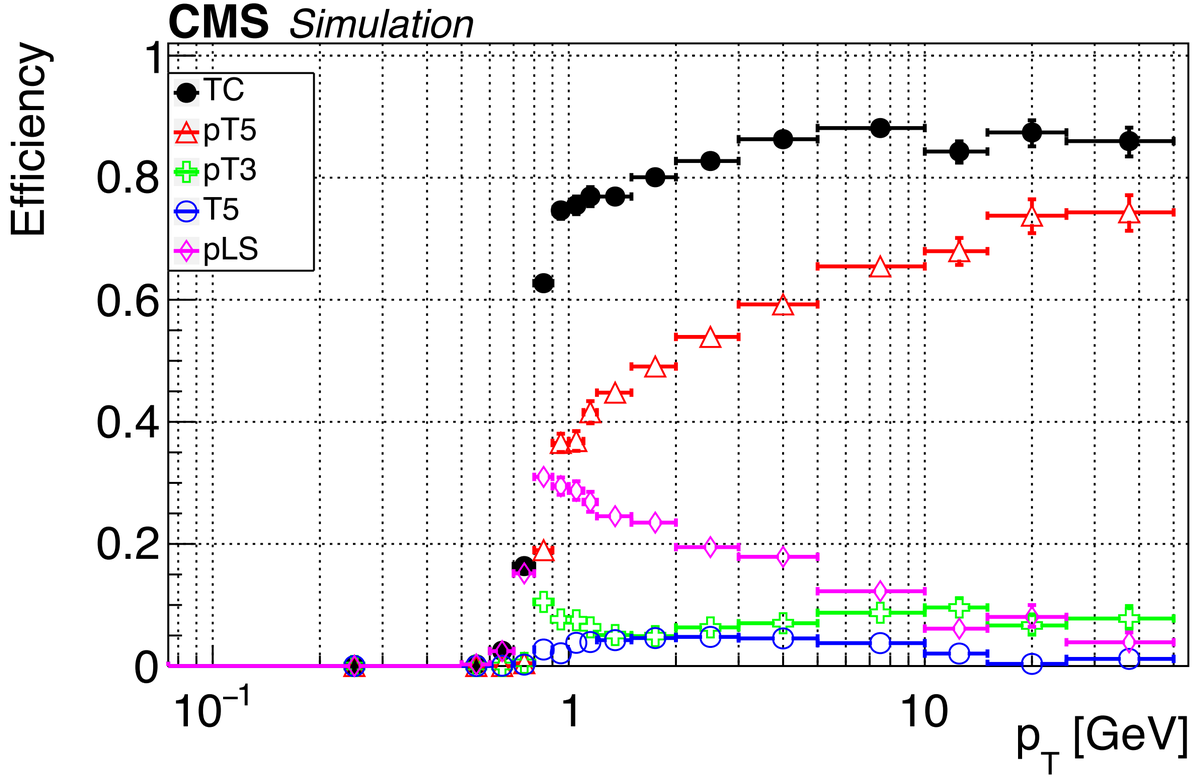
LST Master Efficiency Plots

$t\bar{t}$ PU200 sample

Efficiency of Track Candidate

Sample:PU200 Version tag:1b12eeD N_{evt}:175

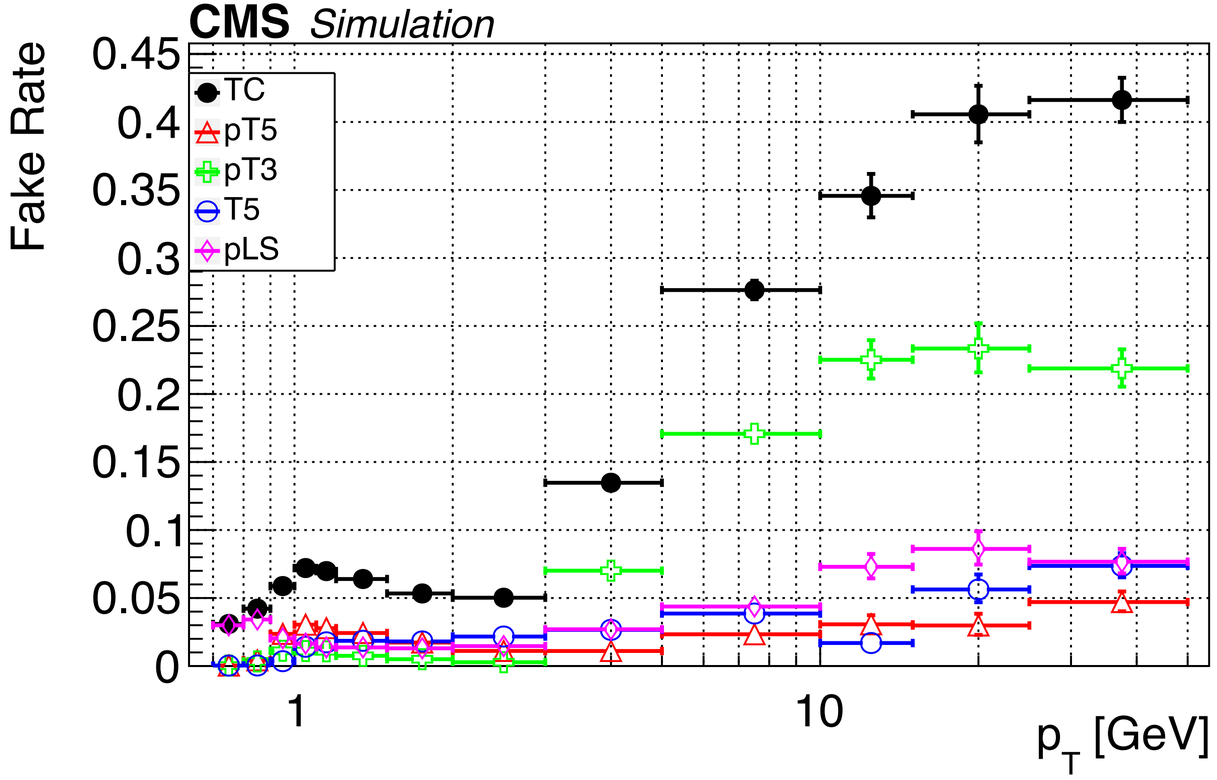
$|\eta| < 4.5$, $|Vtx_z| < 30$ cm, $|Vtx_{xy}| < 2.5$ cm, Particle:All, Charge:All



Fake Rate of Track Candidate

Sample:PU200 Version tag:1b12eeD N_{evt}:175

$|\eta| < 4.5$



https://uaf-10.t2.ucsd.edu/~jguiang/LSTMasterPerformance/Master_PU200_1b12eeD-PU200/

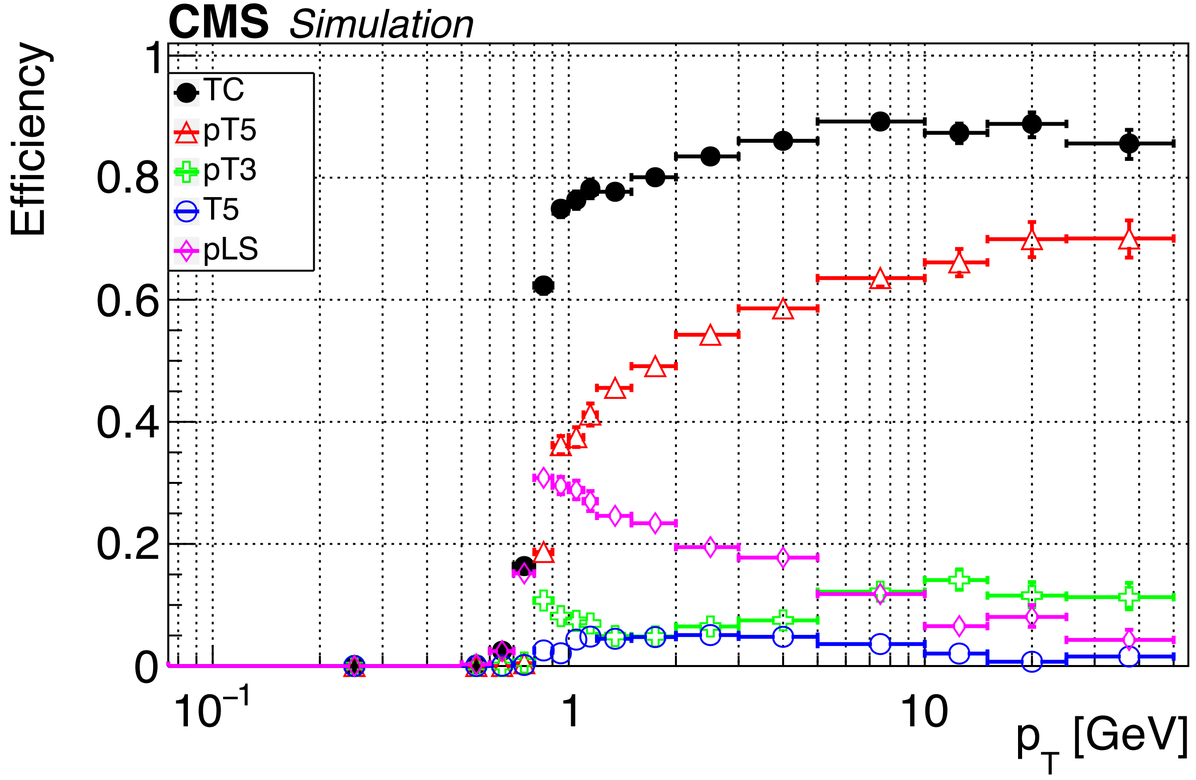
UC San Diego

LST DNN Efficiency Plots

$t\bar{t}$ PU200 sample (▲ WP)

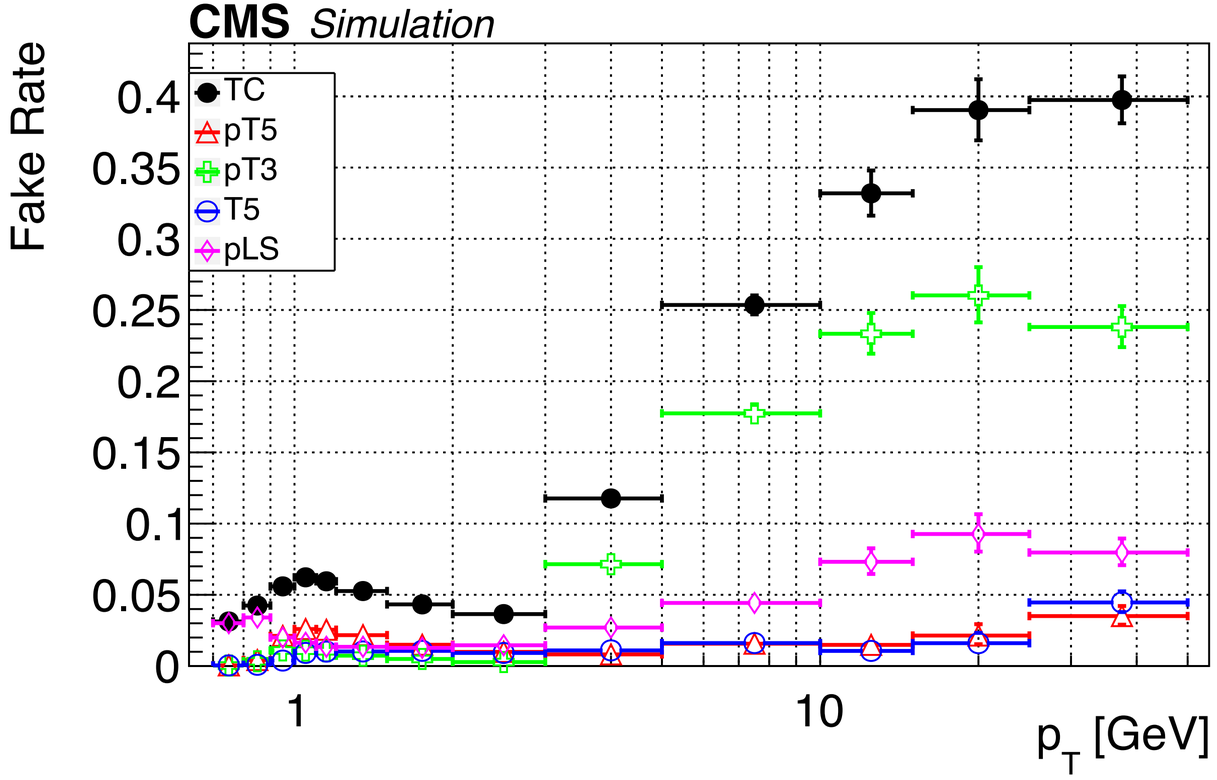
Efficiency of Track Candidate

Sample:PU200 Version tag:3b63fa N_{evt}:175
$|\eta| < 4.5$, $|Vtx_z| < 30$ cm, $|Vtx_{xy}| < 2.5$ cm, Particle:All, Charge:All



Fake Rate of Track Candidate

Sample:PU200 Version tag:3b63fa N_{evt}:175
$|\eta| < 4.5$



http://uaf-10.t2.ucsd.edu/~jguiang/LSTDNNPerformance/T5_DNN_consistentPT_matchBkgEff_PU200_3b63fa-PU200/

UC San Diego

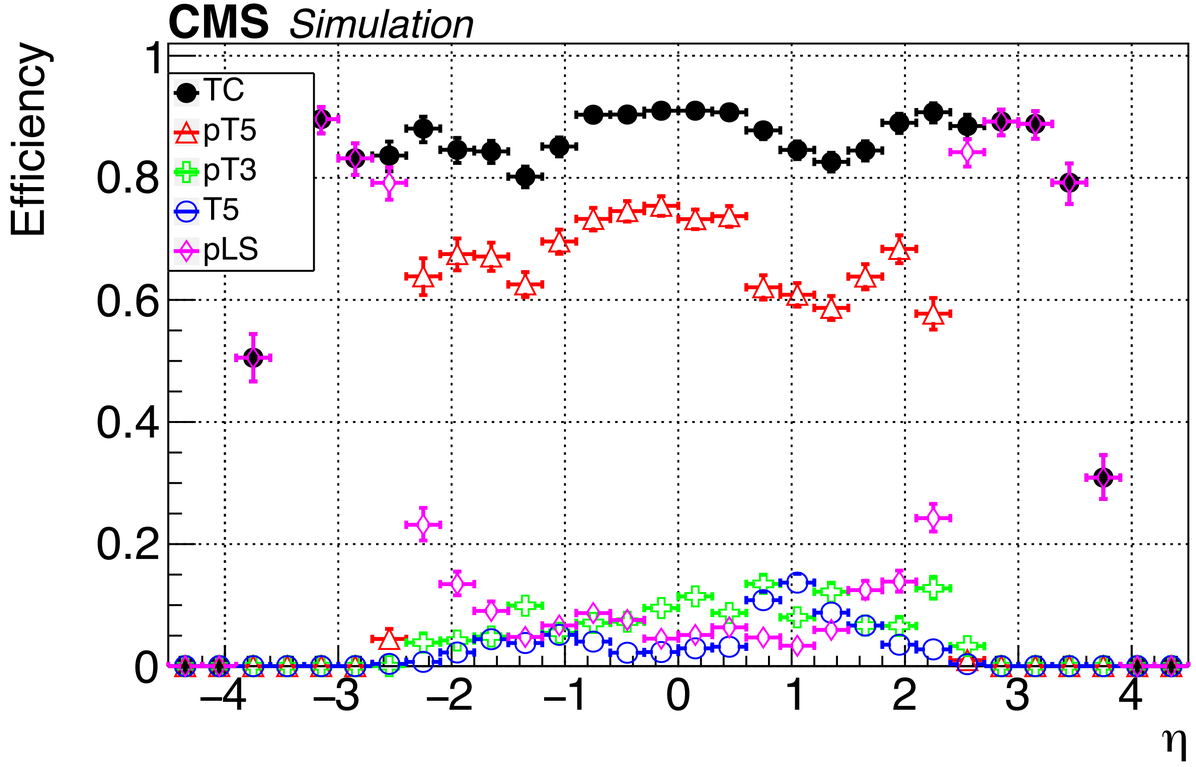
LST Master Efficiency Plots

$t\bar{t}$ PU200 sample

Efficiency of Track Candidate

Sample:PU200 Version tag:1b12eeD N_{evt}:175

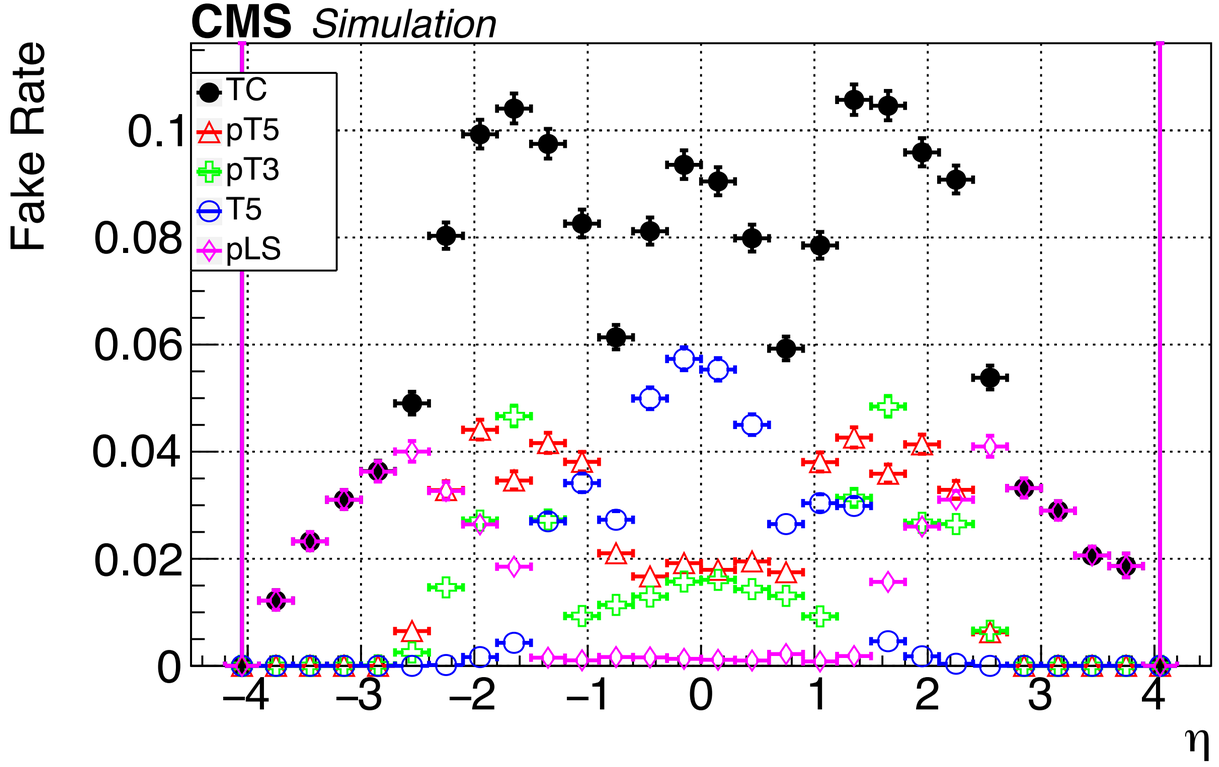
$p_T > 0.9$ GeV, $|Vtx_z| < 30$ cm, $|Vtx_{xy}| < 2.5$ cm, Particle:All, Charge:All



Fake Rate of Track Candidate

Sample:PU200 Version tag:1b12eeD N_{evt}:175

$p_T > 0.9$ GeV

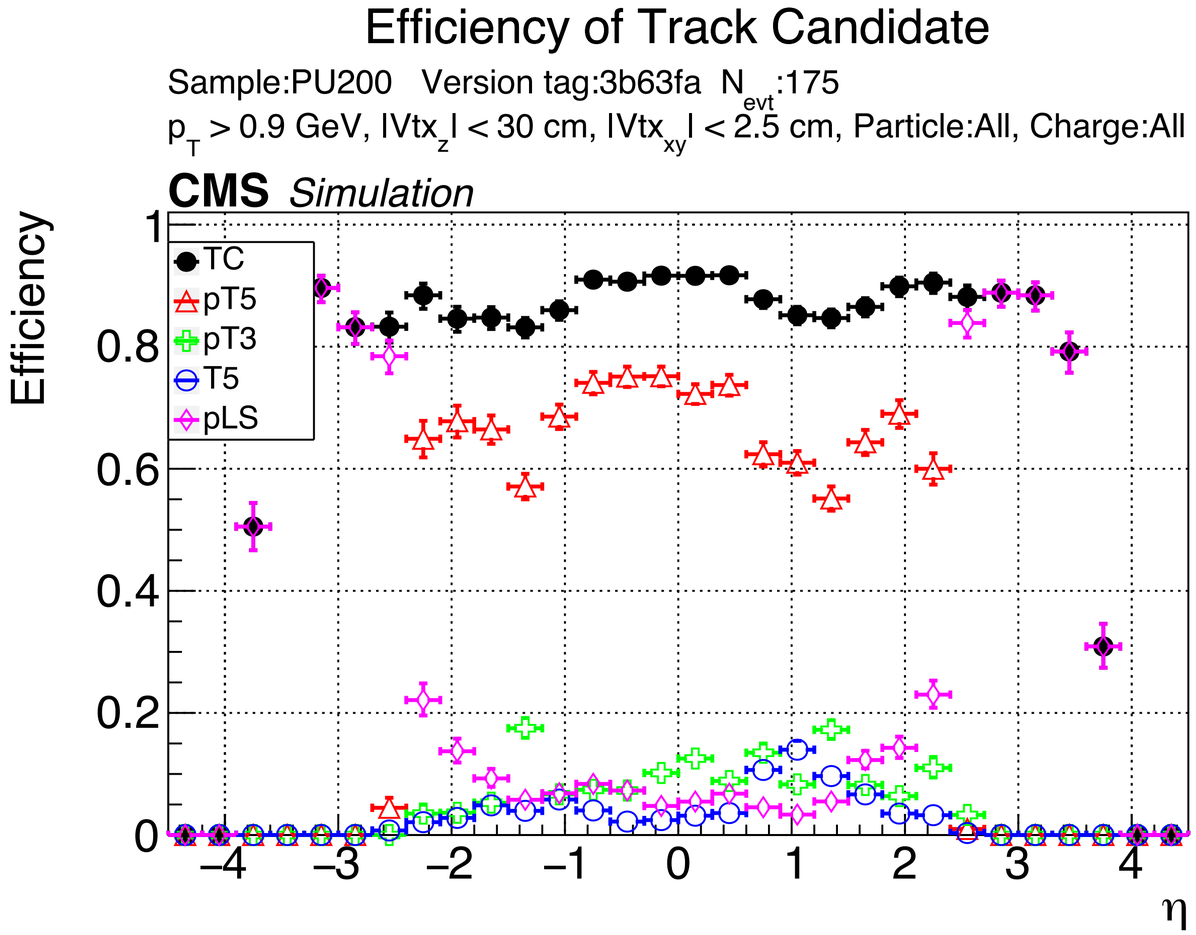


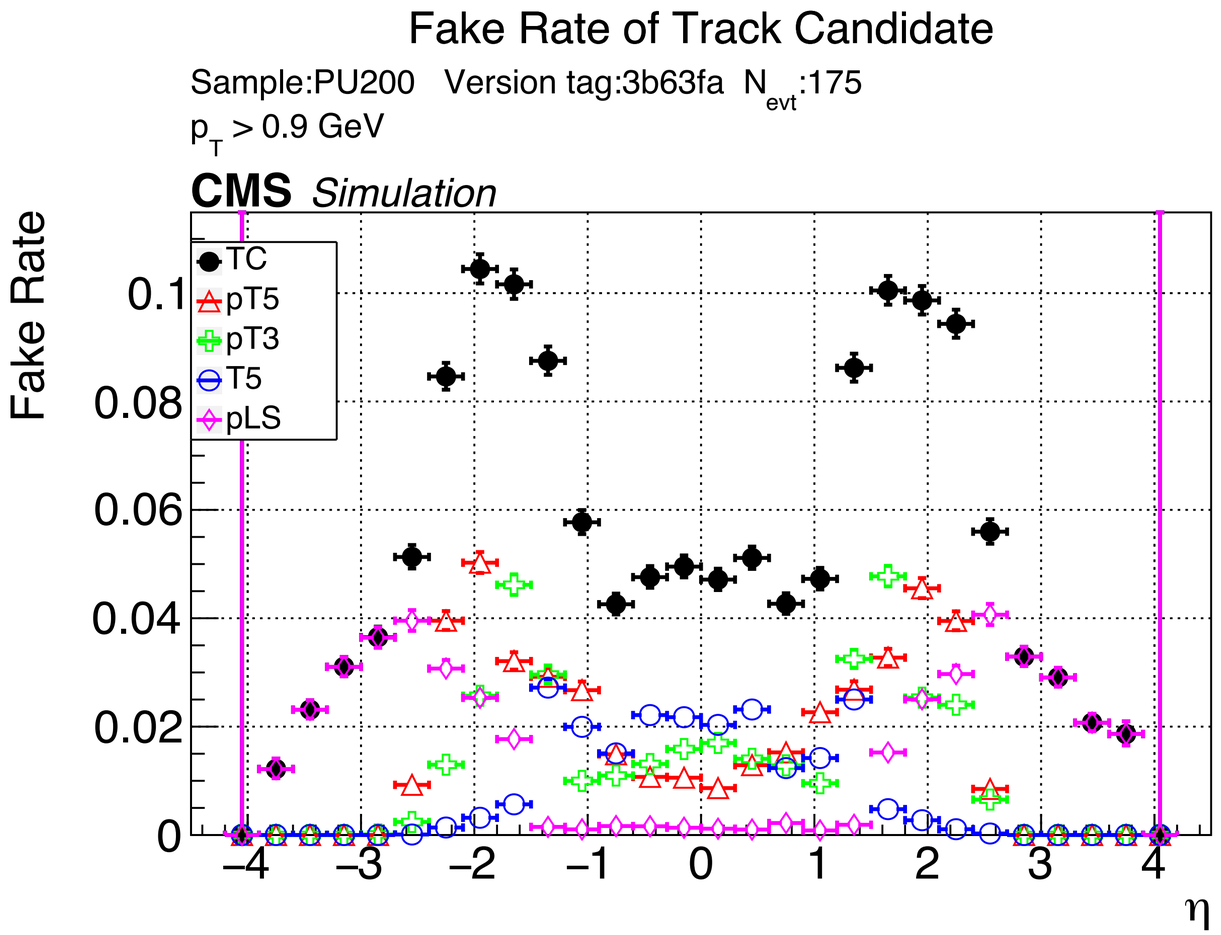
https://uaf-10.t2.ucsd.edu/~jguiang/LSTMasterPerformance/Master_PU200_1b12eeD-PU200/

UC San Diego

LST DNN Efficiency Plots

$t\bar{t}$ PU200 sample (▲ WP)



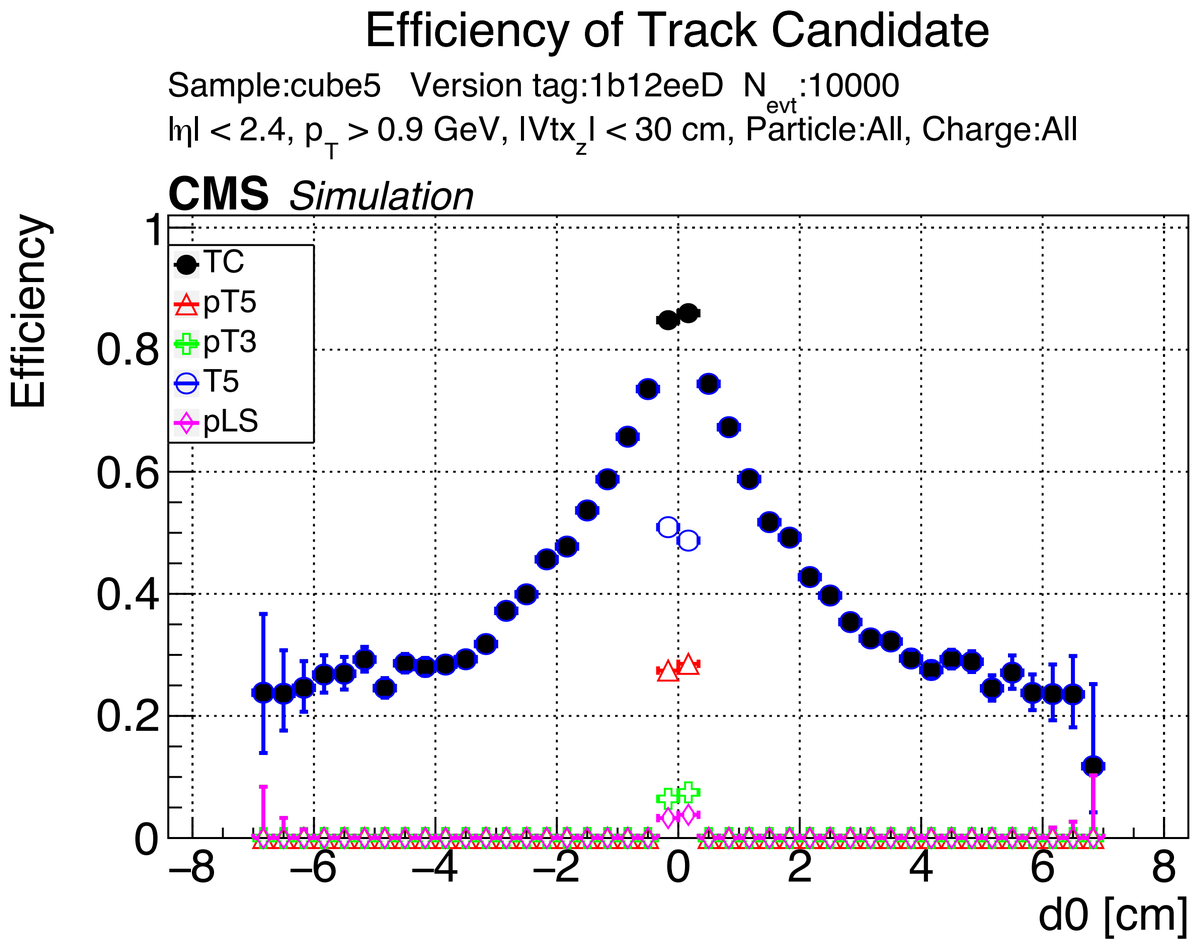


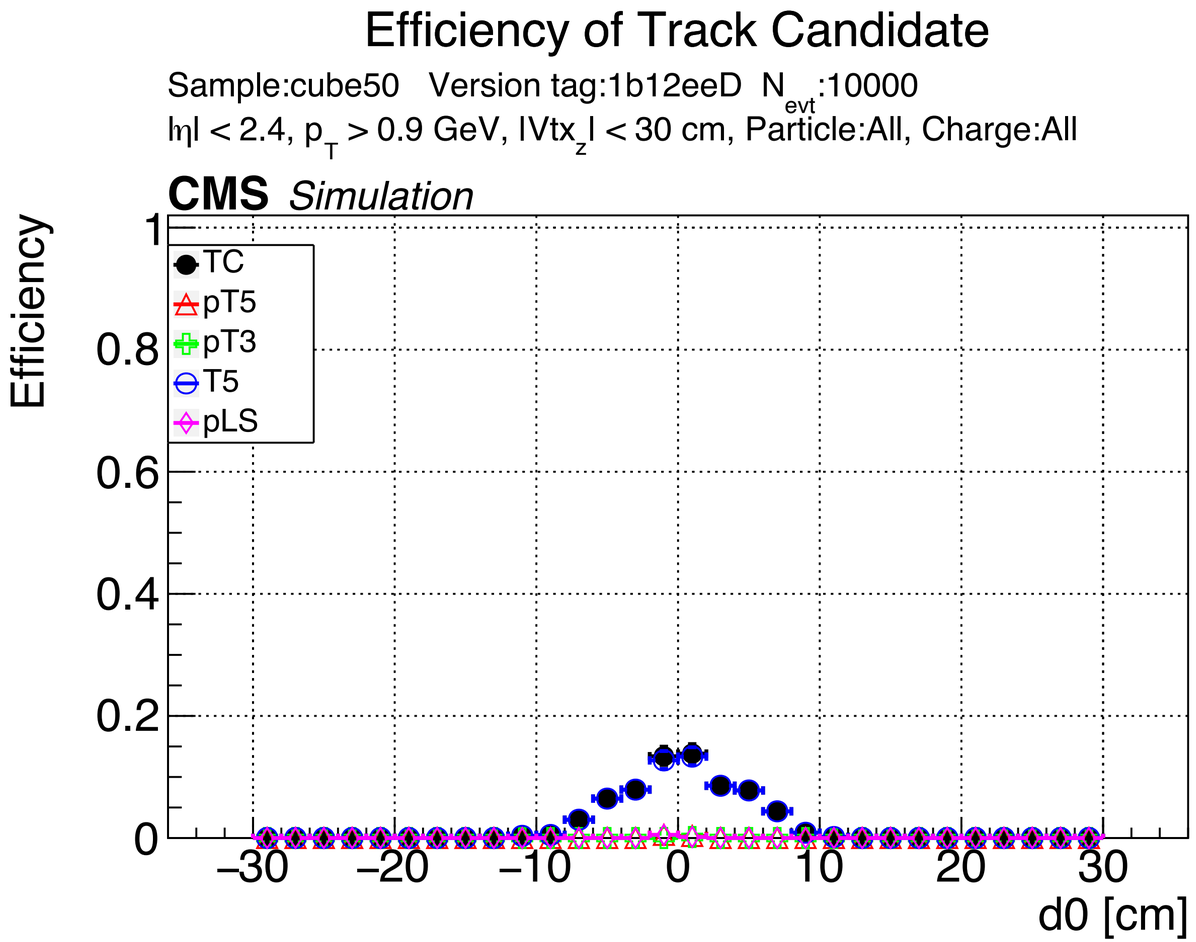
http://uaf-10.t2.ucsd.edu/~jguiang/LSTDNNPerformance/T5_DNN_consistentPT_matchBkgEff_PU200_3b63fa-PU200/

UC San Diego

LST Master Efficiency Plots

5cm (left) and 50cm (right) cube sample with $|\eta| < 2.7$



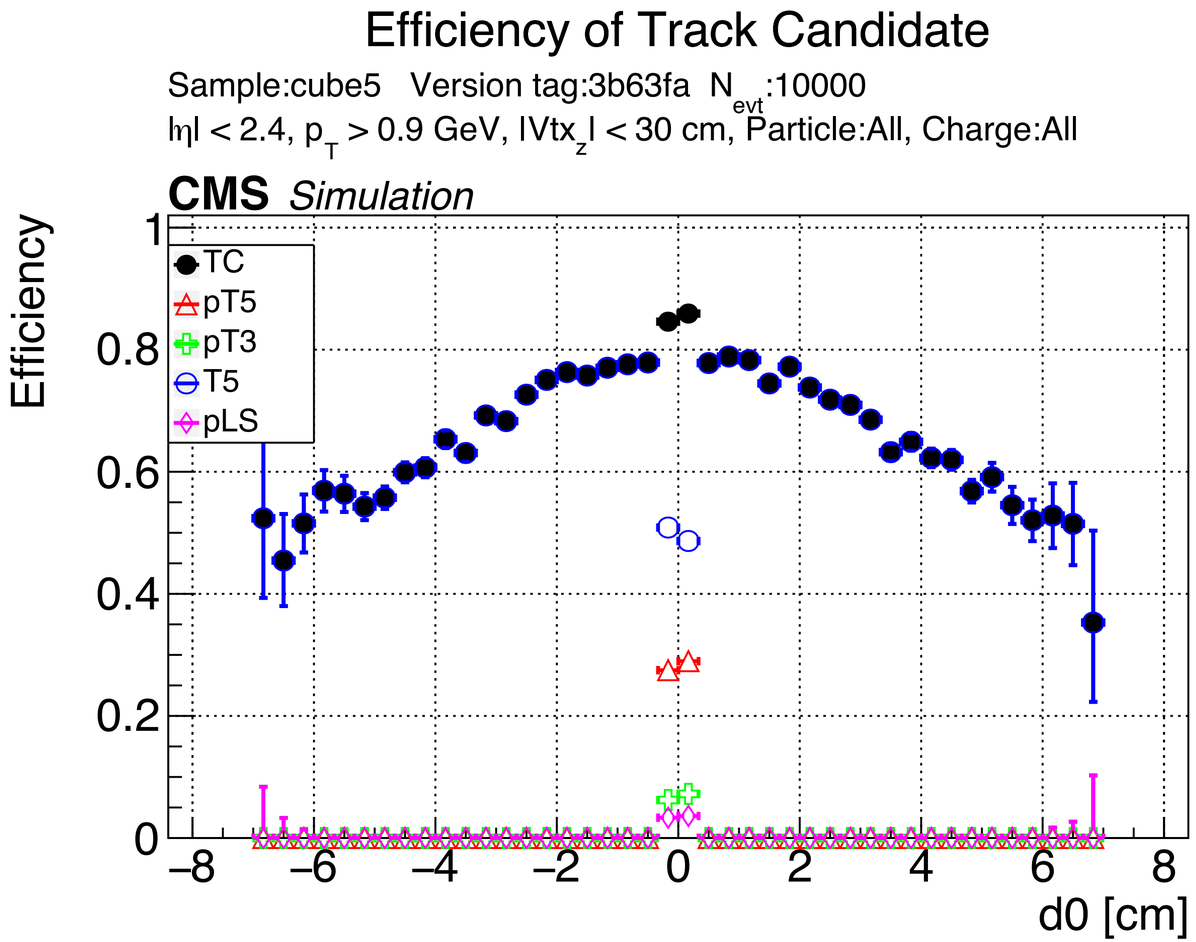


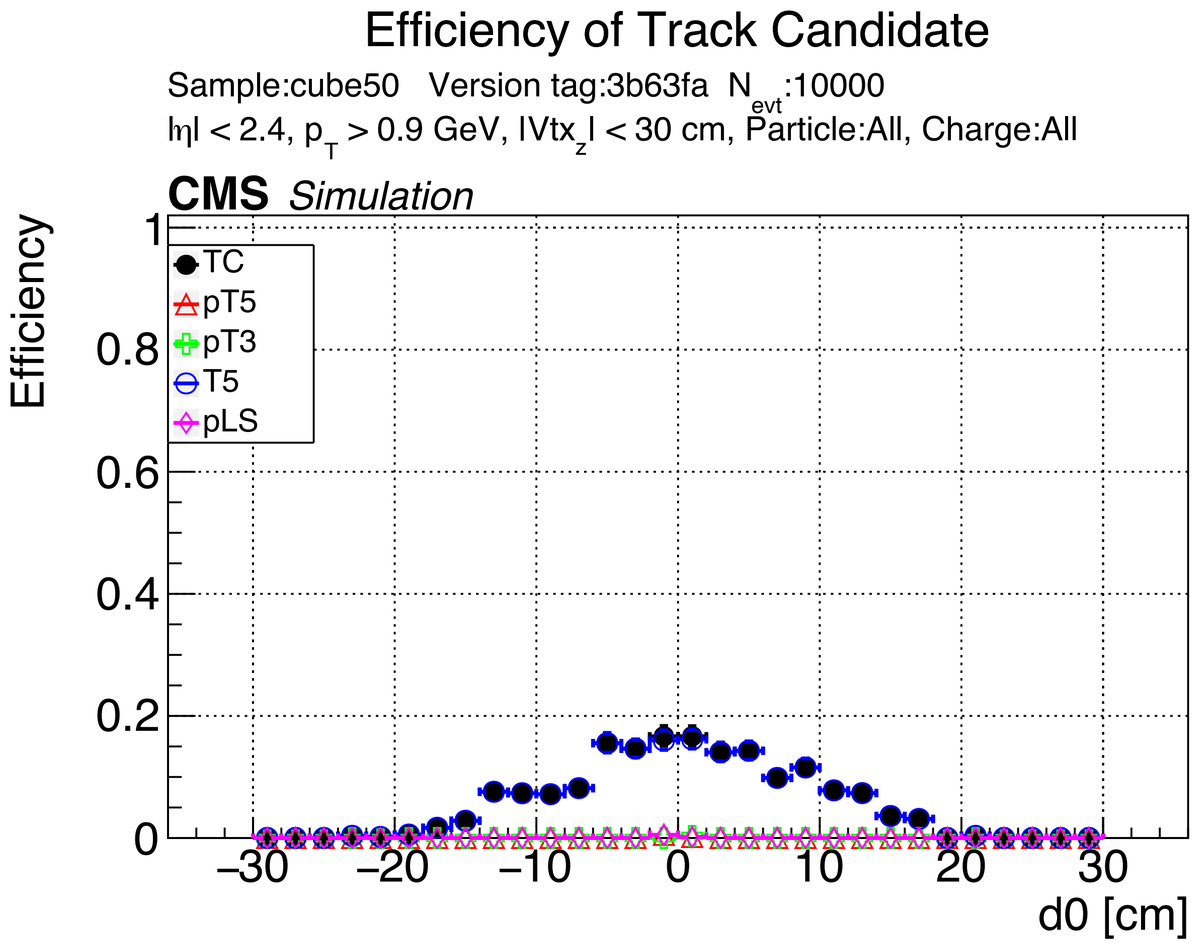
http://uaf-10.t2.ucsd.edu/~jguiang/LSTMasterPerformance/Master_cube5_1b12eeD-cube5/
http://uaf-10.t2.ucsd.edu/~jguiang/LSTMasterPerformance/Master_cube50_1b12eeD-cube50/

UC San Diego

LST DNN Efficiency Plots

5cm (left) and 50cm (right) cube sample (▲ WP) with |η| < 2.7

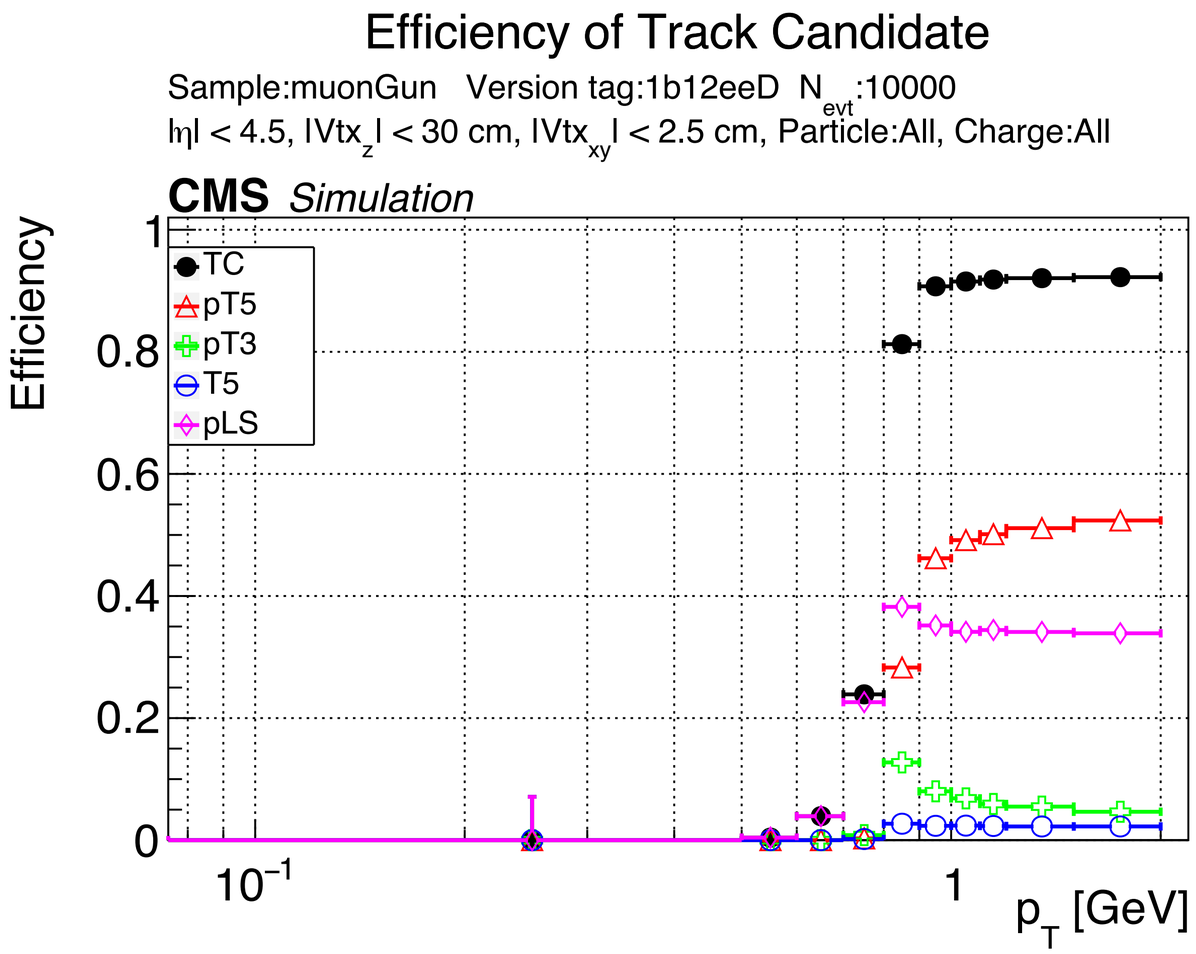


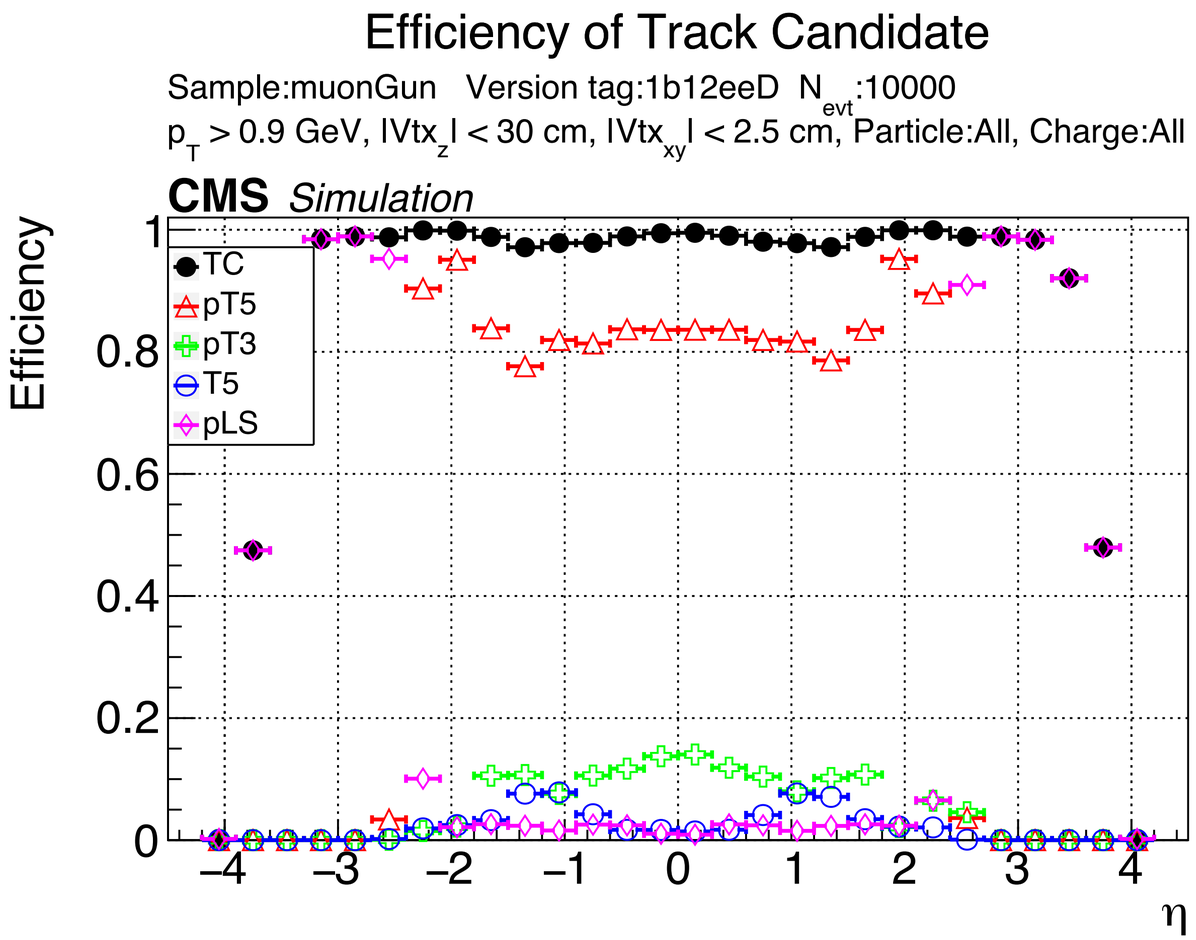


http://uaf-10.t2.ucsd.edu/~jguiang/LSTDNNPerformance/T5_DNN_consistentPT_matchBkgEff_cube5_3b63fa-cube5/
http://uaf-10.t2.ucsd.edu/~jguiang/LSTDNNPerformance/T5_DNN_consistentPT_matchBkgEff_cube50_3b63fa-cube50/

LST Master Efficiency Plots

Muon gun sample



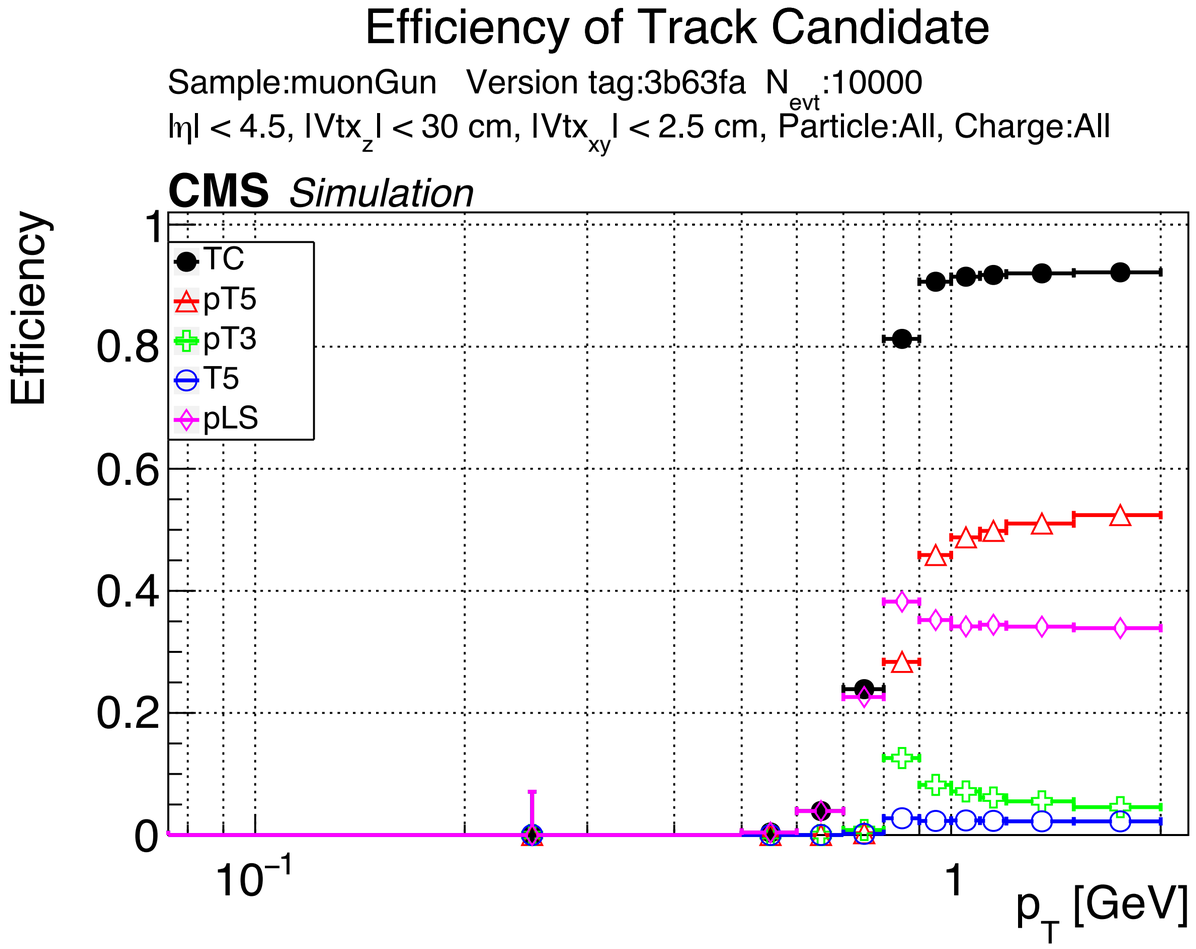


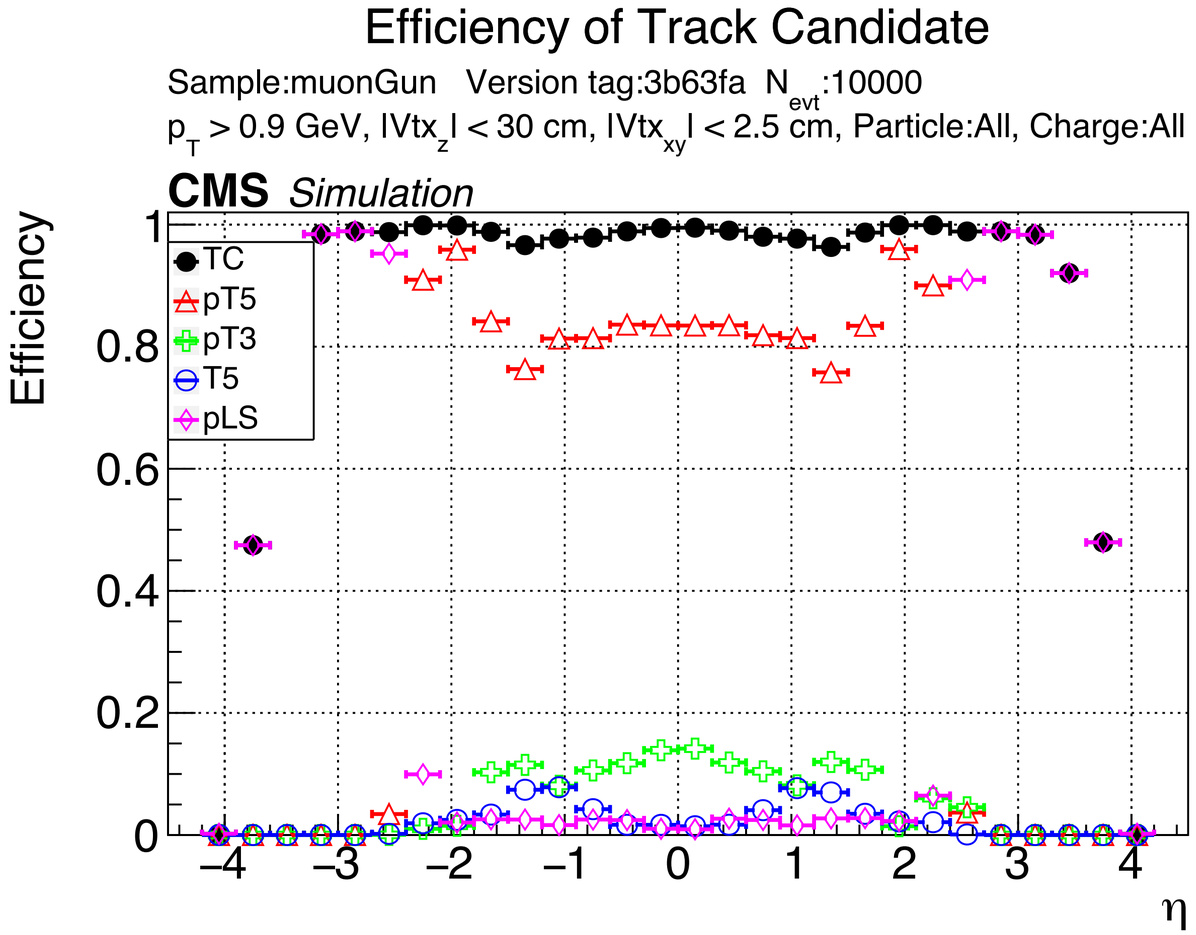
http://uaf-10.t2.ucsd.edu/~jguiang/LSTMasterPerformance/Master_muonGun_1b12eeD-muonGun/

UC San Diego

LST DNN Efficiency Plots

Muon gun sample (▲ WP)





http://uaf-10.t2.ucsd.edu/~jguiang/LSTDNNPerformance/T5_DNN_consistentPT_matchBkgEff_muonGun_3b63fa-muonGun/

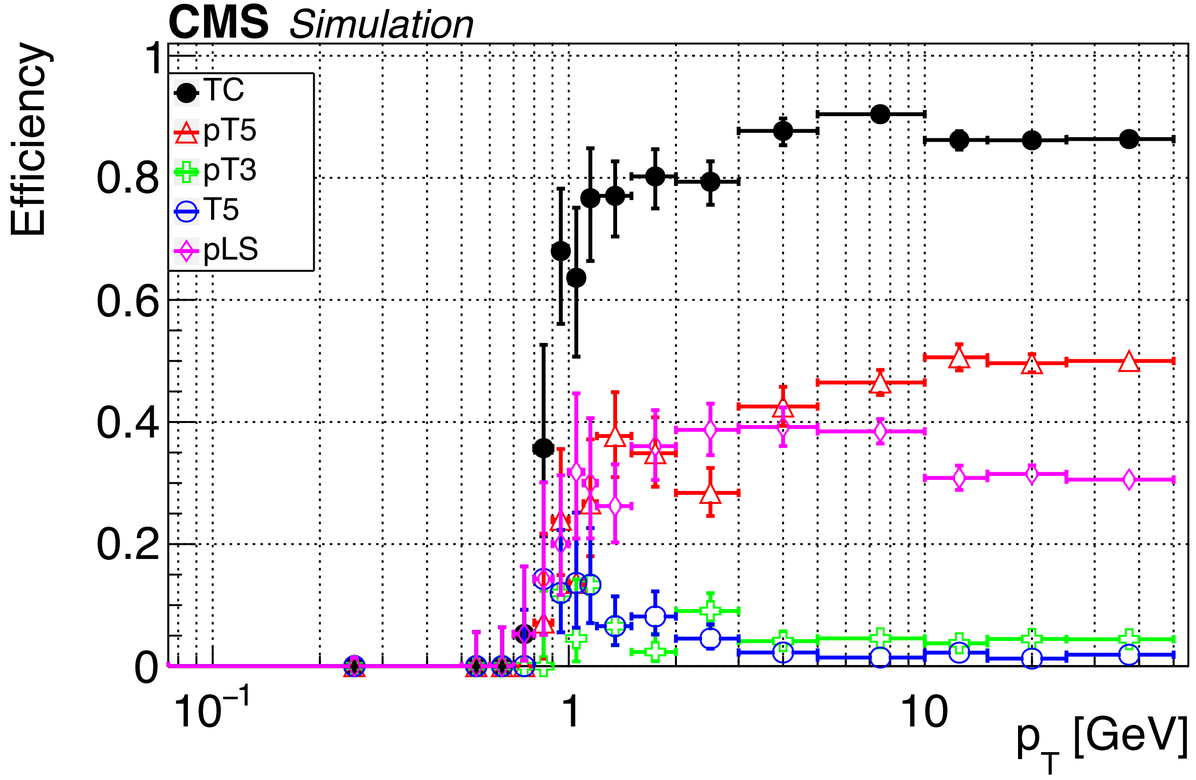
UC San Diego

LST Master Efficiency Plots

Pion gun sample

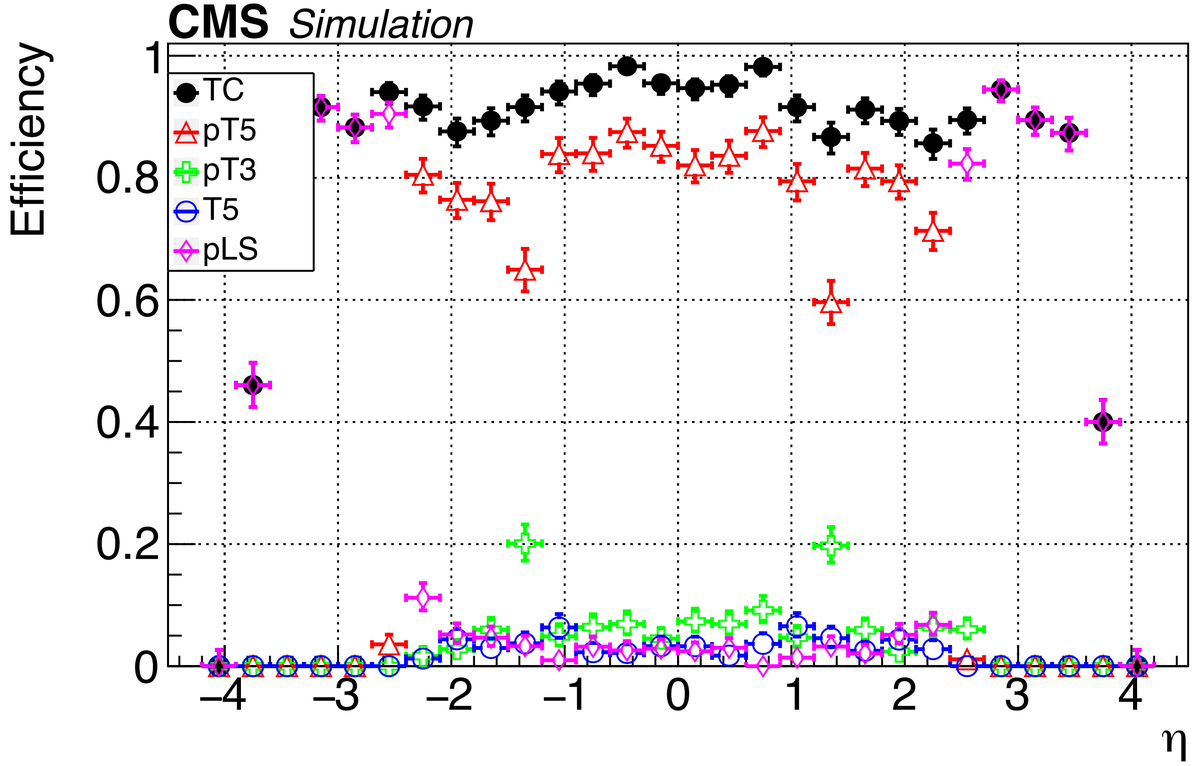
Efficiency of Track Candidate

Sample:pionGun Version tag:1b12eeD N_{evt}:1000
$|\eta| < 4.5$, $|Vtx_z| < 30$ cm, $|Vtx_{xy}| < 2.5$ cm, Particle:All, Charge:All



Efficiency of Track Candidate

Sample:pionGun Version tag:1b12eeD N_{evt}:1000
$p_T > 0.9$ GeV, $|Vtx_z| < 30$ cm, $|Vtx_{xy}| < 2.5$ cm, Particle:All, Charge:All



http://uaf-10.t2.ucsd.edu/~jguiang/LSTMasterPerformance/Master_pionGun_1b12eeD-pionGun/

UC San Diego

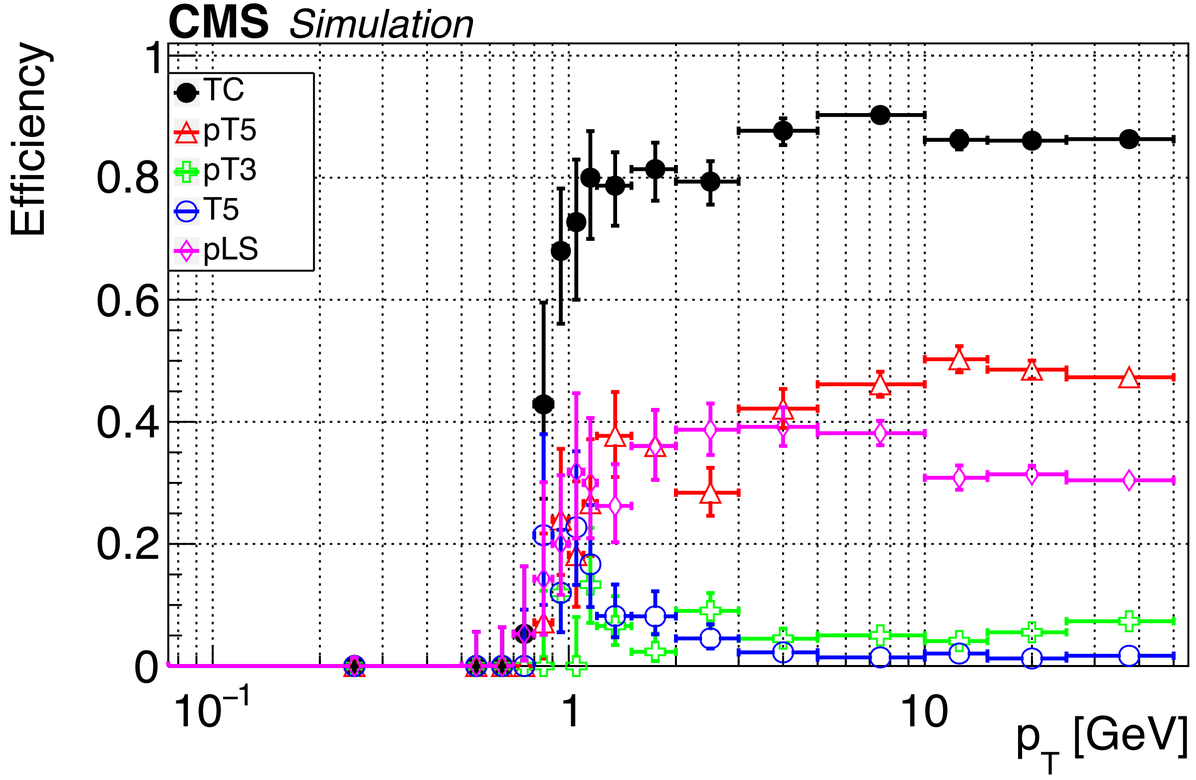
LST DNN Efficiency Plots

Pion gun sample (▲ WP)

Efficiency of Track Candidate

Sample:pionGun Version tag:3b63fa N_{evt}:1000

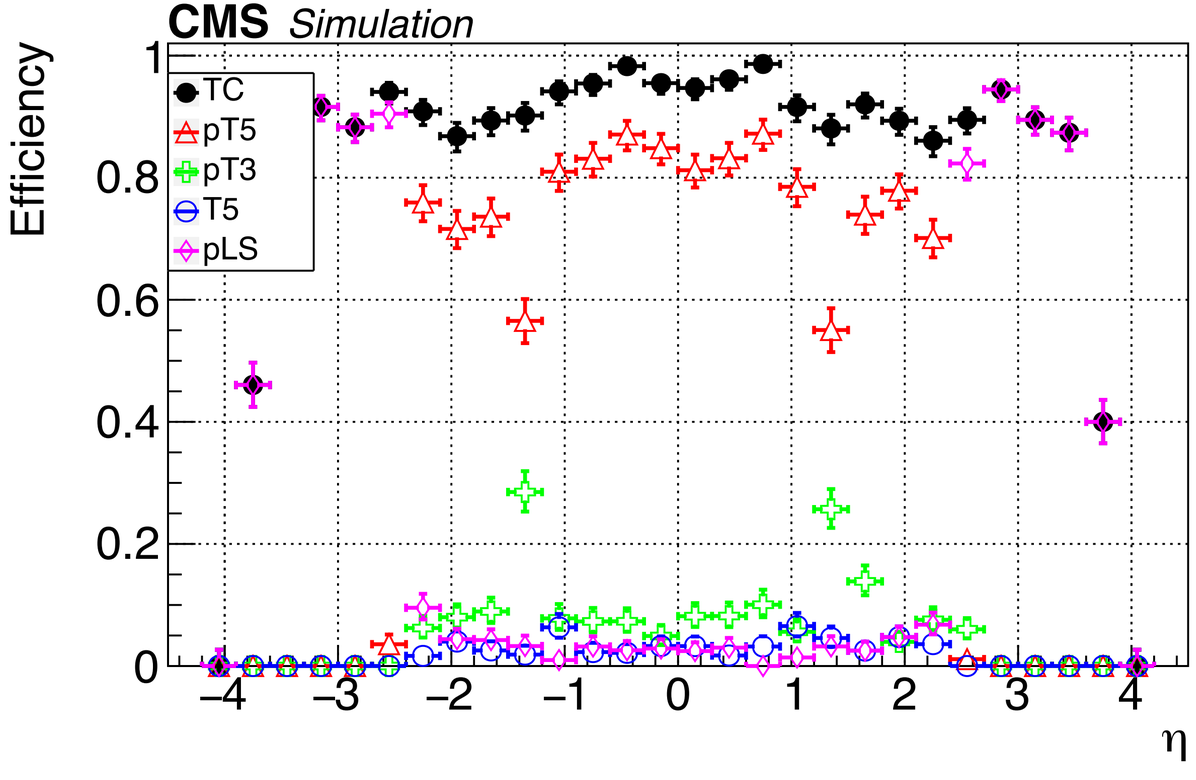
$|\eta| < 4.5$, $|Vtx_z| < 30$ cm, $|Vtx_{xy}| < 2.5$ cm, Particle:All, Charge:All



Efficiency of Track Candidate

Sample:pionGun Version tag:3b63fa N_{evt}:1000

$p_T > 0.9$ GeV, $|Vtx_z| < 30$ cm, $|Vtx_{xy}| < 2.5$ cm, Particle:All, Charge:All



http://uaf-10.t2.ucsd.edu/~jguiang/LSTDNNPerformance/T5_DNN_consistentPT_matchBkgEff_pionGun_3b63fa-pionGun/

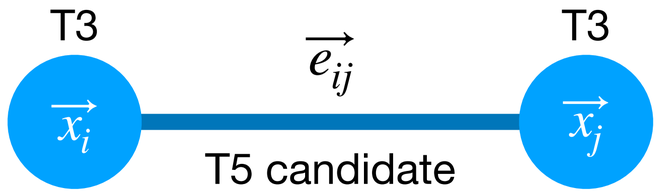
UC San Diego

Summary

- Significant performance improvement across various samples:
  - $t\bar{t}$ PU200: fake rate greatly reduced
  - 5/50cm cube: efficiency greatly increased
  - Muon/pion guns: efficiency slightly decreased
- Next steps:
  - Get PR #291 approved
  - Add Δr information to DNN input features
  - If performance improves, try removing a hidden layer

Backup

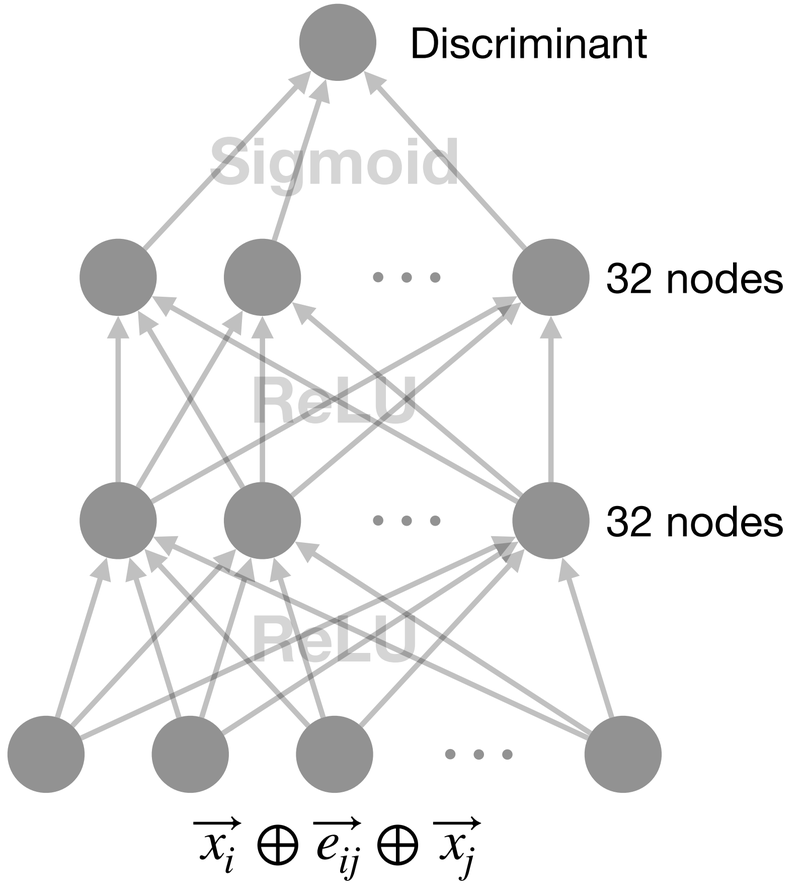
T5 DNN Configuration



Object	Feature
T3	p_T
	Inner anchor hit r, z, ϕ, η, layer
	Middle anchor hit r, z, ϕ, η, layer
	Outer anchor hit r, z, ϕ, η, layer
T5 candidate	p_T, η, ϕ
	Inner T3 radius
	Bridge T3 radius
	Outer T3 radius

Scaled such that all features ∈ [0, 1]

2 hidden layers

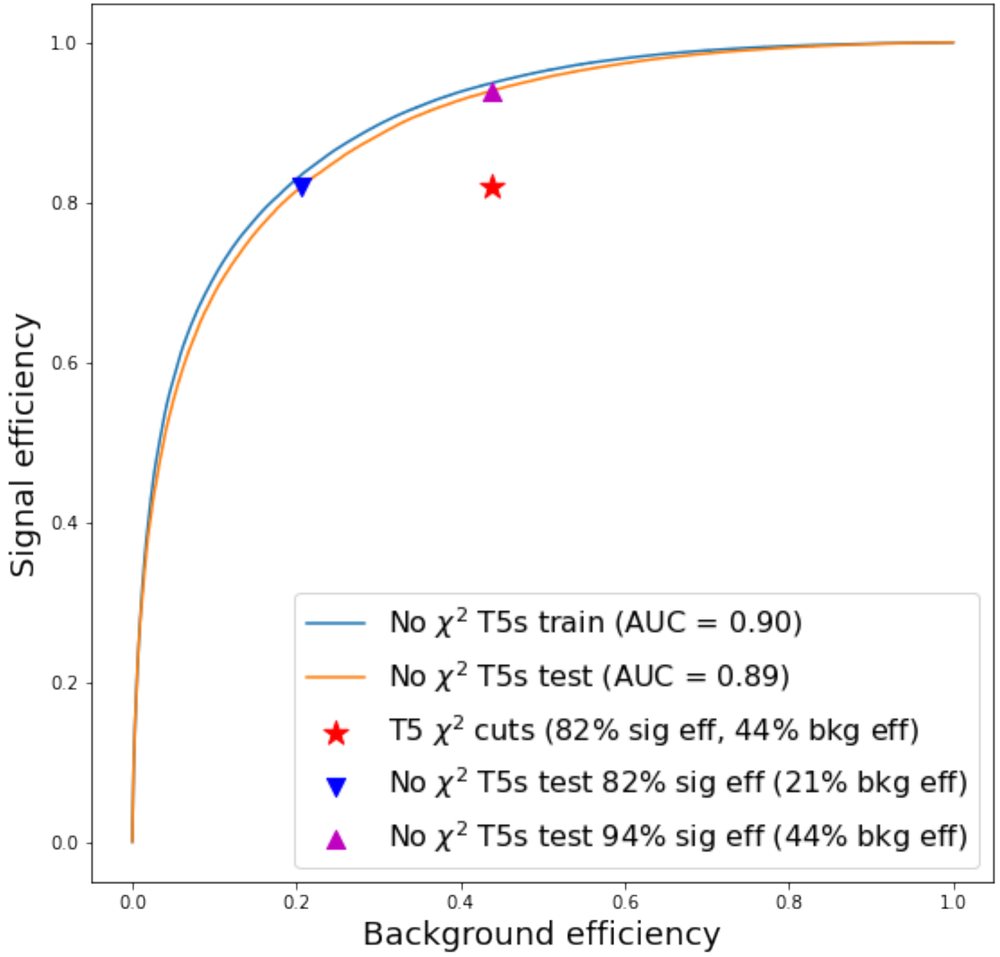


UC San Diego

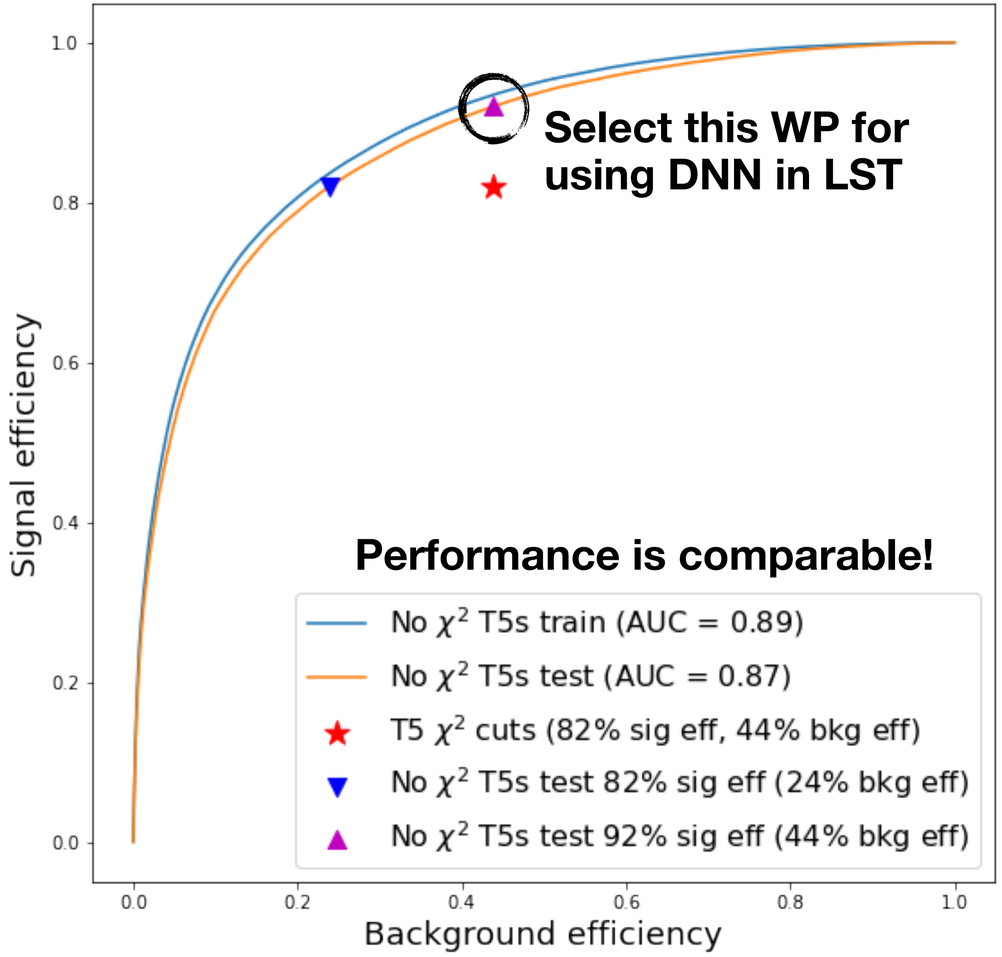
T5 DNN Performance

Performance is comparable to previous results

2 hidden layers (old result)



2 hidden layers + no δr + p_T fix

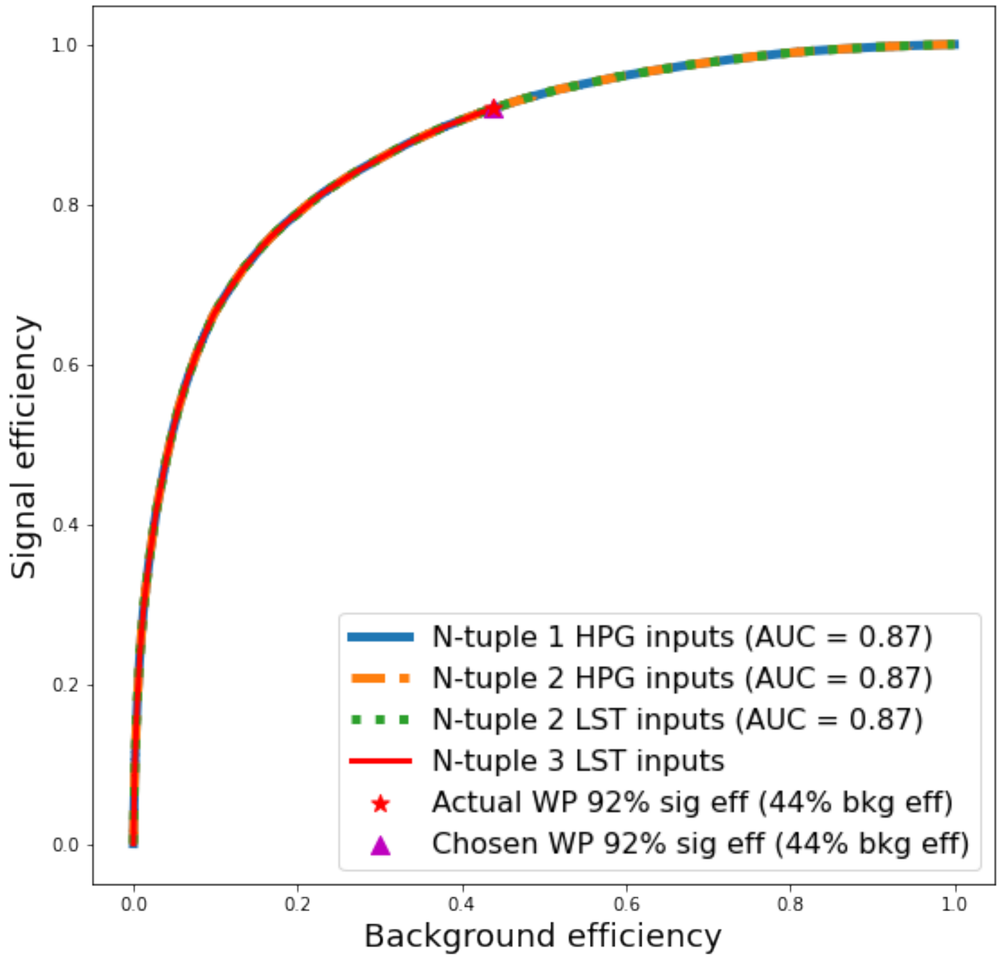


T5 DNN Results

It works…?

- — curve: $FPR_3 \times (N_3/N_2)$ vs. $TPR_3 \times (P_3/P_2)$
- ★ point: N_3/N_2 vs. P_3/P_2
- $FPR_i = FP_i/N_i$
  - FP_i = # false positives for DNN > X (N-tuple i)
  - N_i = # total negatives in N-tuple i
- $TPR_i = TP_i/P_i$
  - TP_i = # true positives for DNN > X (N-tuple i)
  - P_i = # total positives in N-tuple i

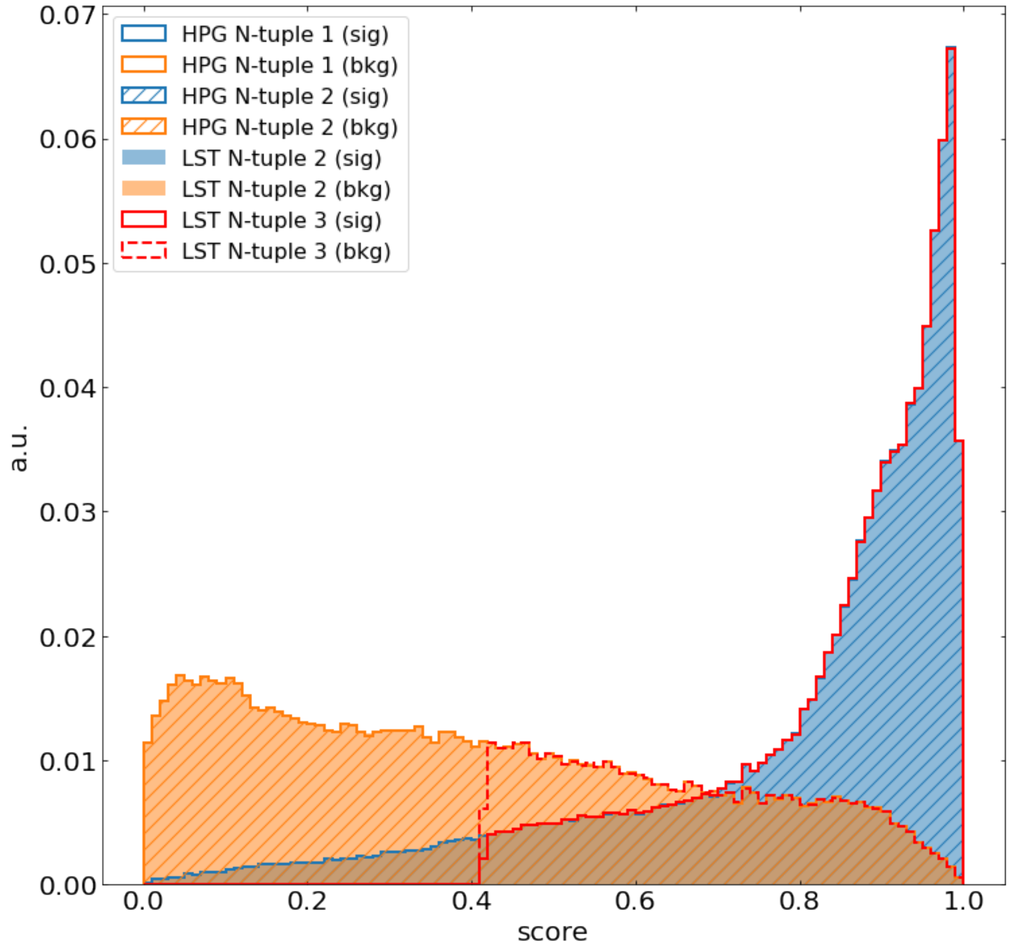
2 hidden layers + no δr + p_T fix



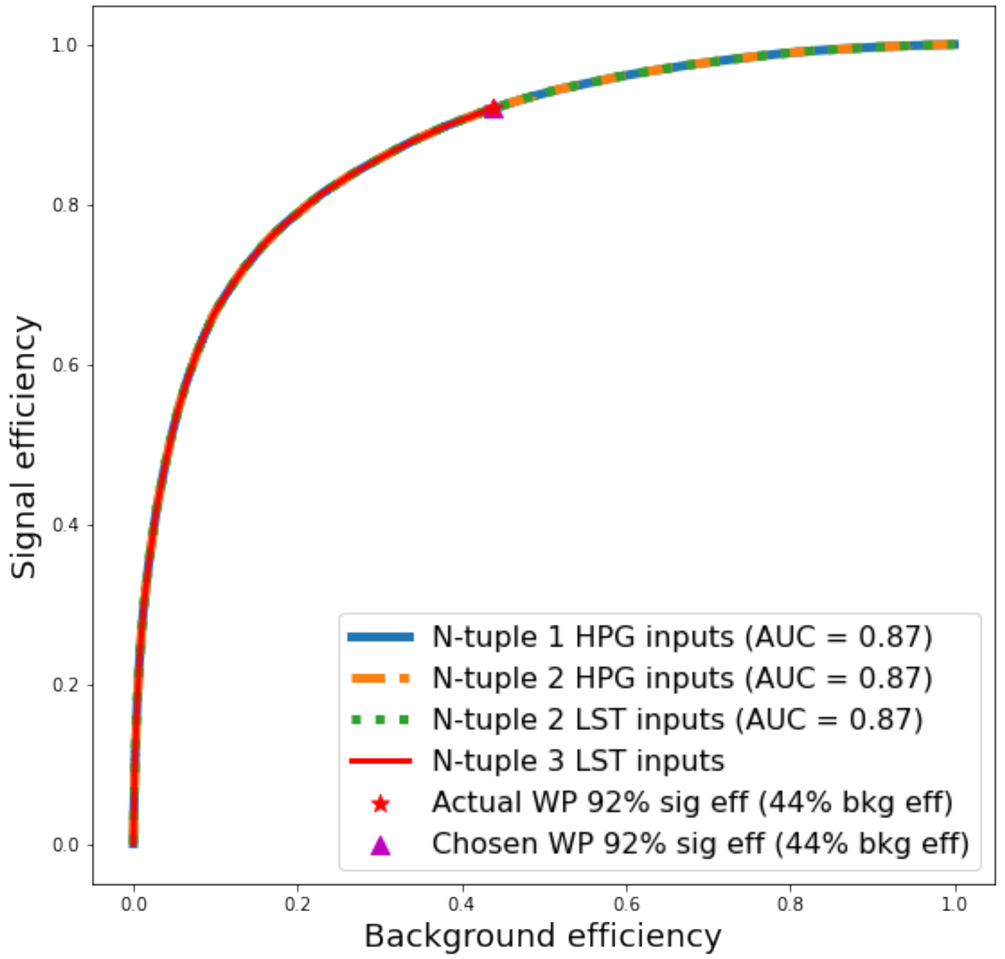
UC San Diego

T5 DNN Results

It works!

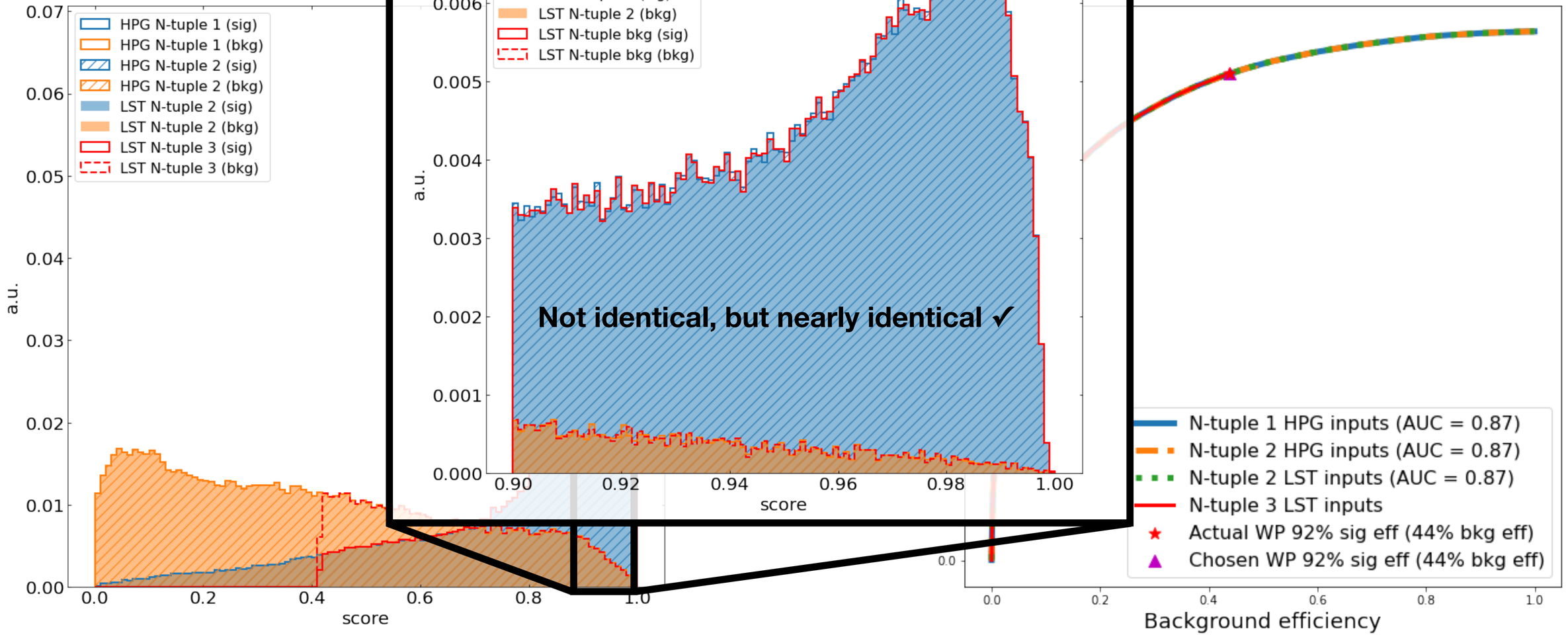


2 hidden layers + no δr + p_T fix



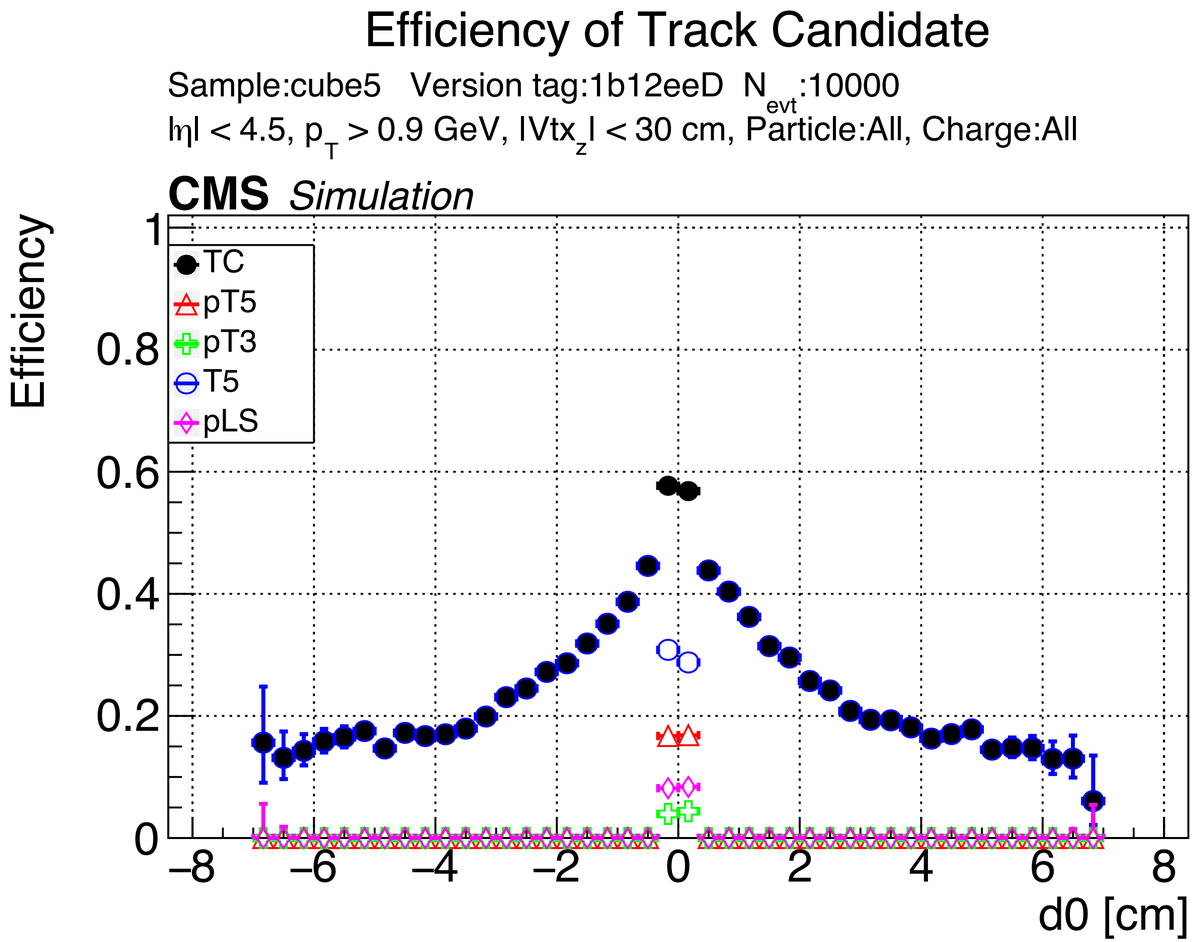
T5 DNN Results

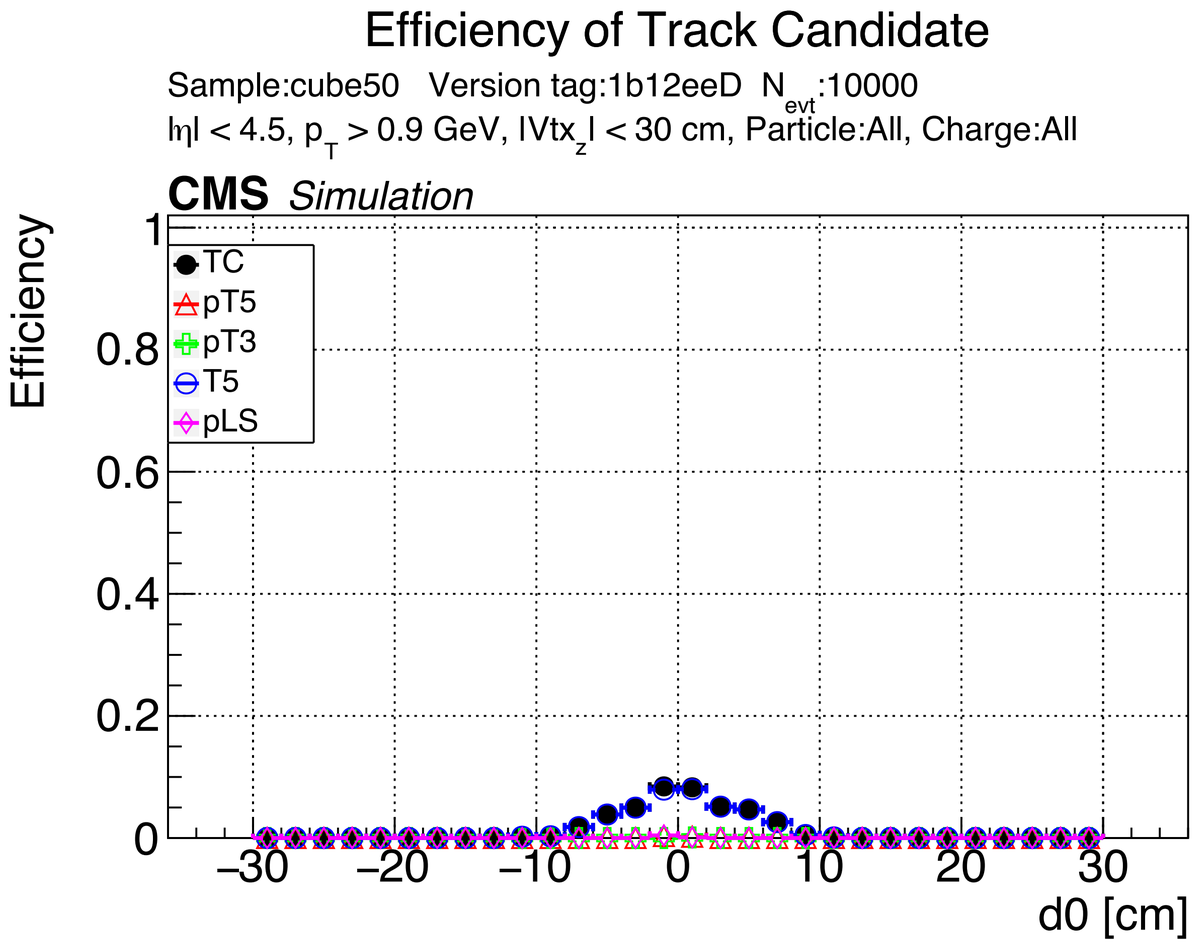
layers + no δr + p_T fix



LST Master Efficiency Plots

5cm (left) and 50cm (right) cube sample with $|\eta| < 4.5$



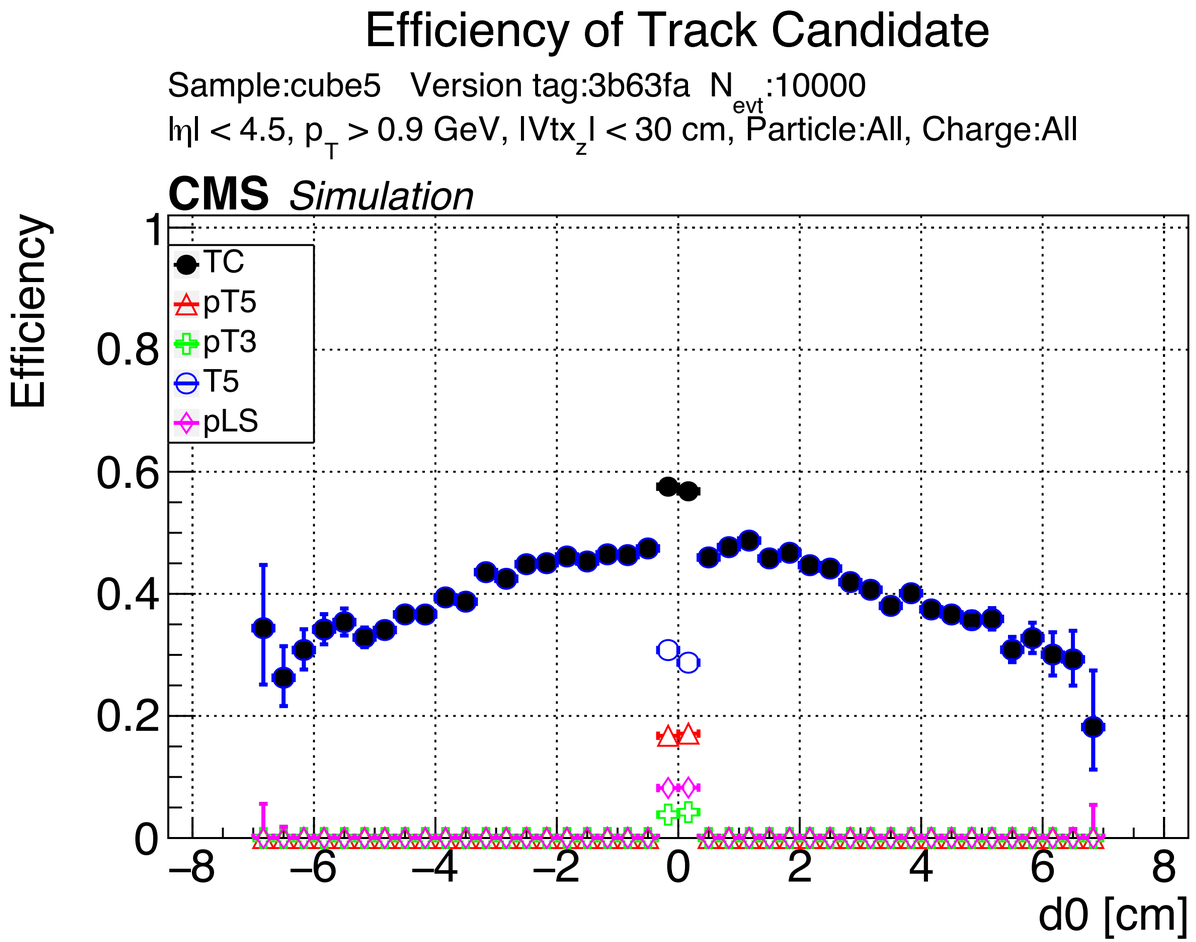


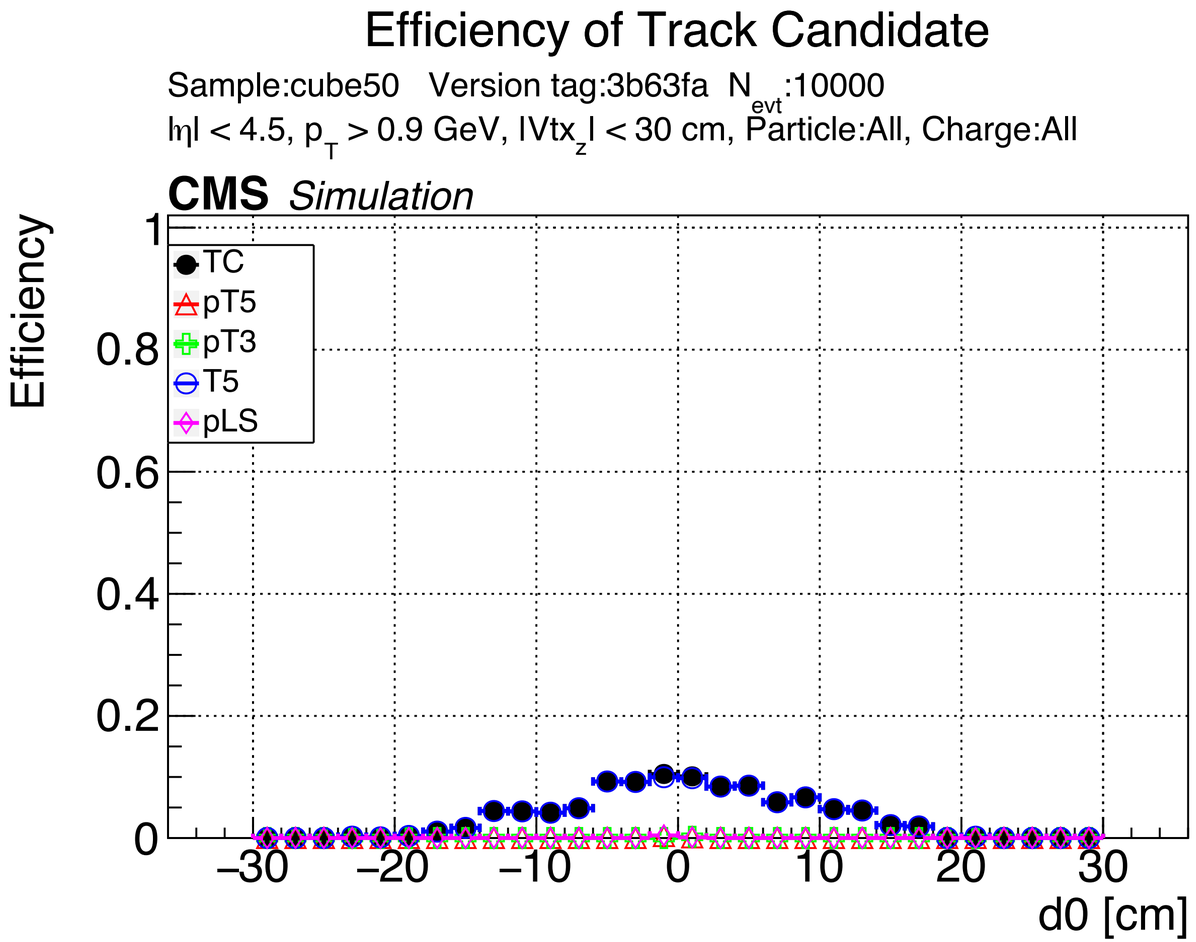
http://uaf-10.t2.ucsd.edu/~jguiang/LSTMasterPerformance/Master_cube5_1b12eeD-cube5/
http://uaf-10.t2.ucsd.edu/~jguiang/LSTMasterPerformance/Master_cube50_1b12eeD-cube50/

UC San Diego

LST DNN Efficiency Plots

5cm (left) and 50cm (right) cube sample (▲ WP) with |η| < 4.5



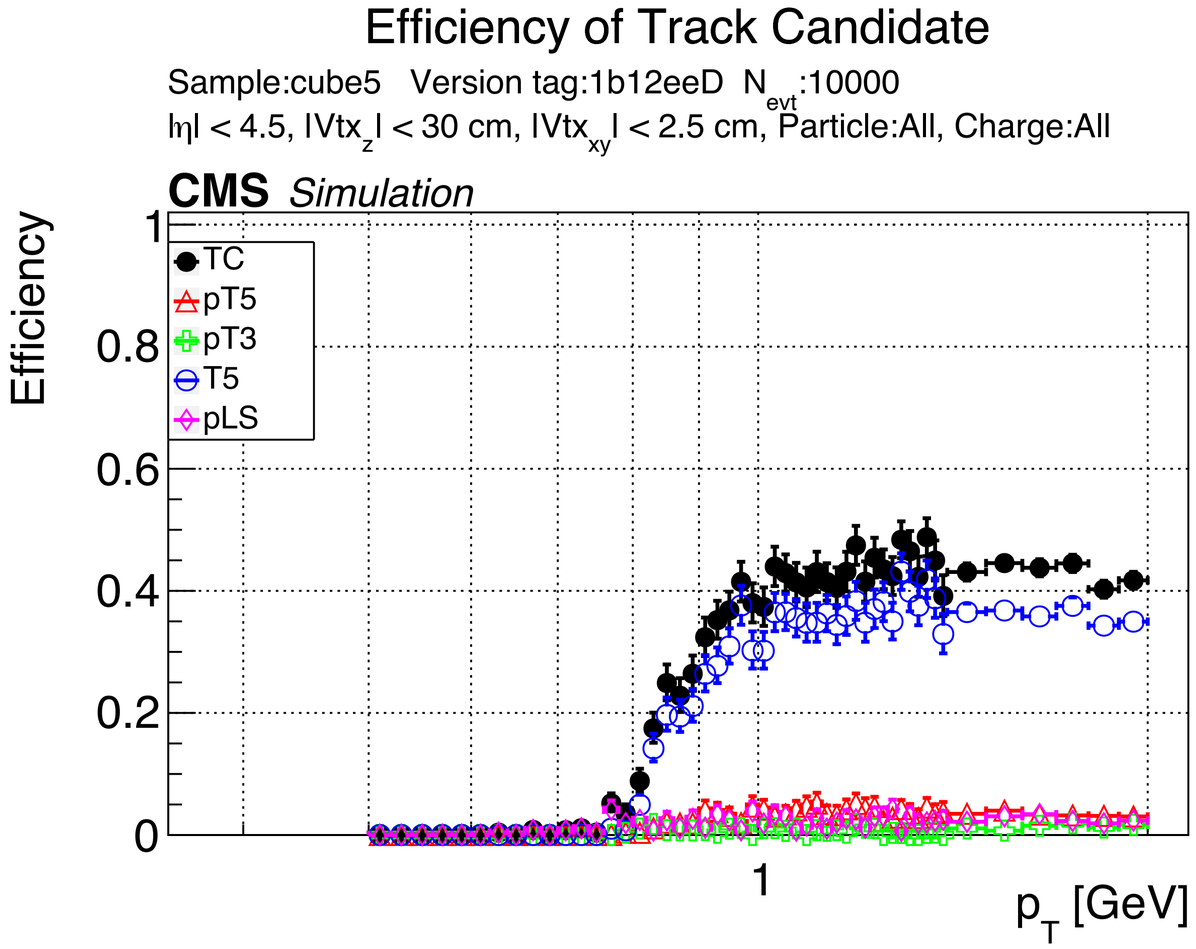


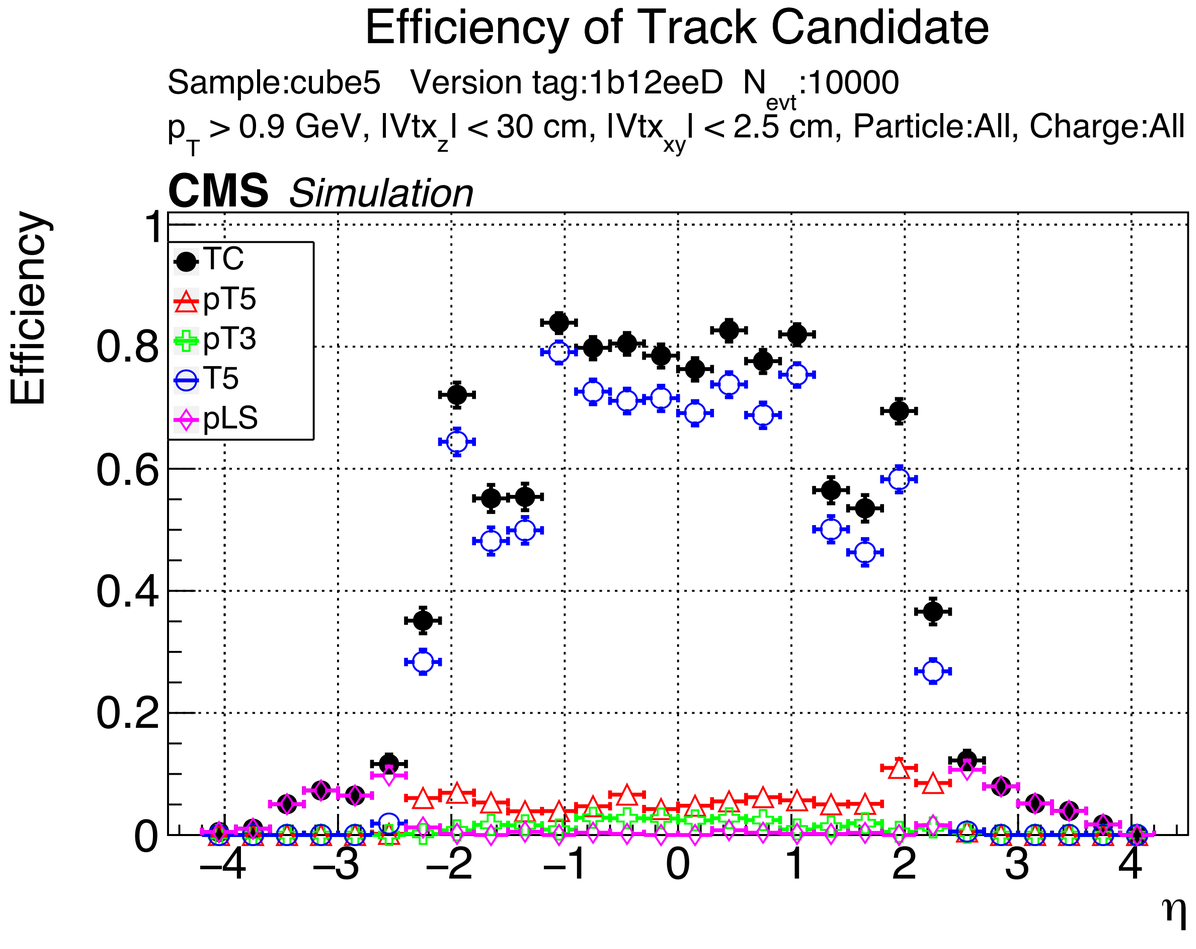
http://uaf-10.t2.ucsd.edu/~jguiang/LSTDNNPerformance/T5_DNN_consistentPT_matchBkgEff_cube5_3b63fa-cube5/
http://uaf-10.t2.ucsd.edu/~jguiang/LSTDNNPerformance/T5_DNN_consistentPT_matchBkgEff_cube50_3b63fa-cube50/

UC San Diego

LST Master Efficiency Plots

5cm cube sample



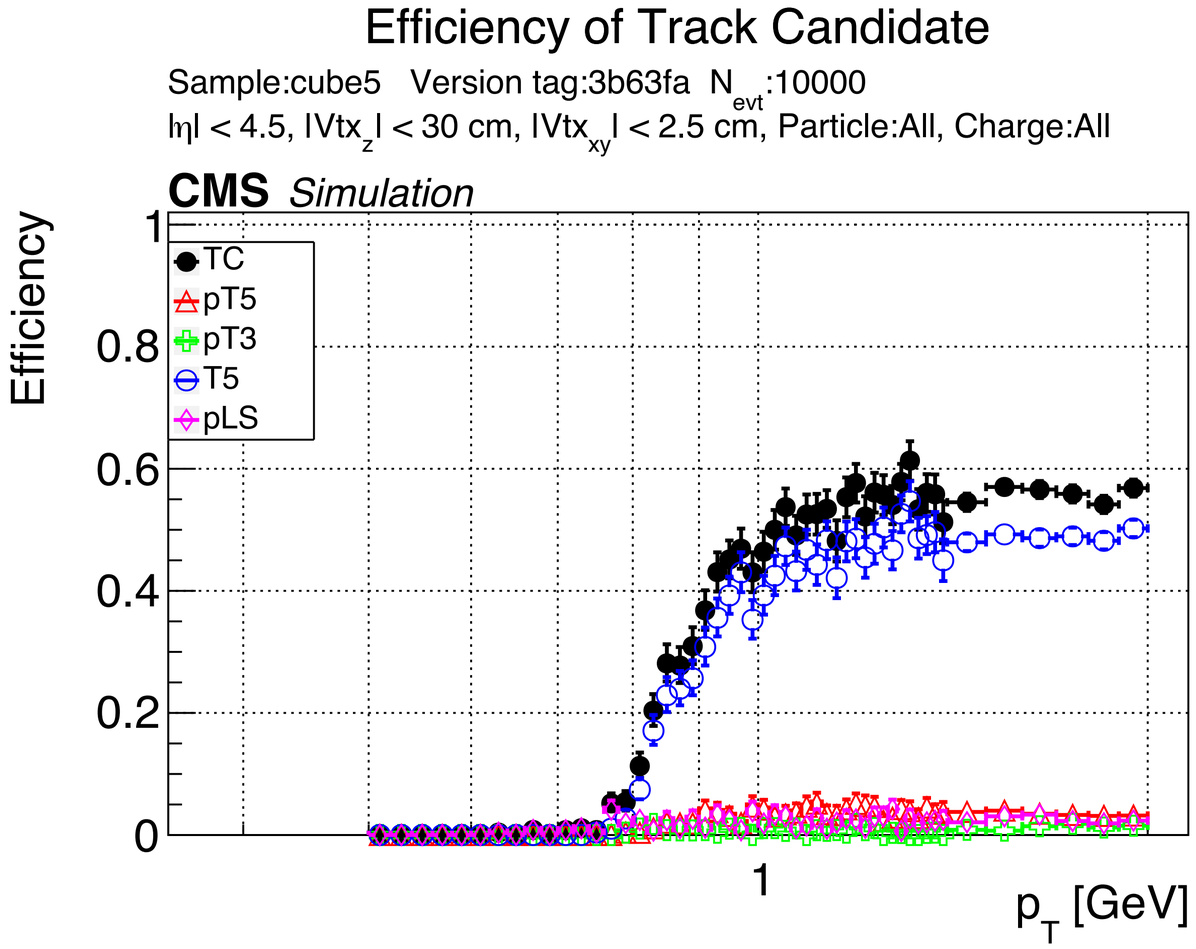


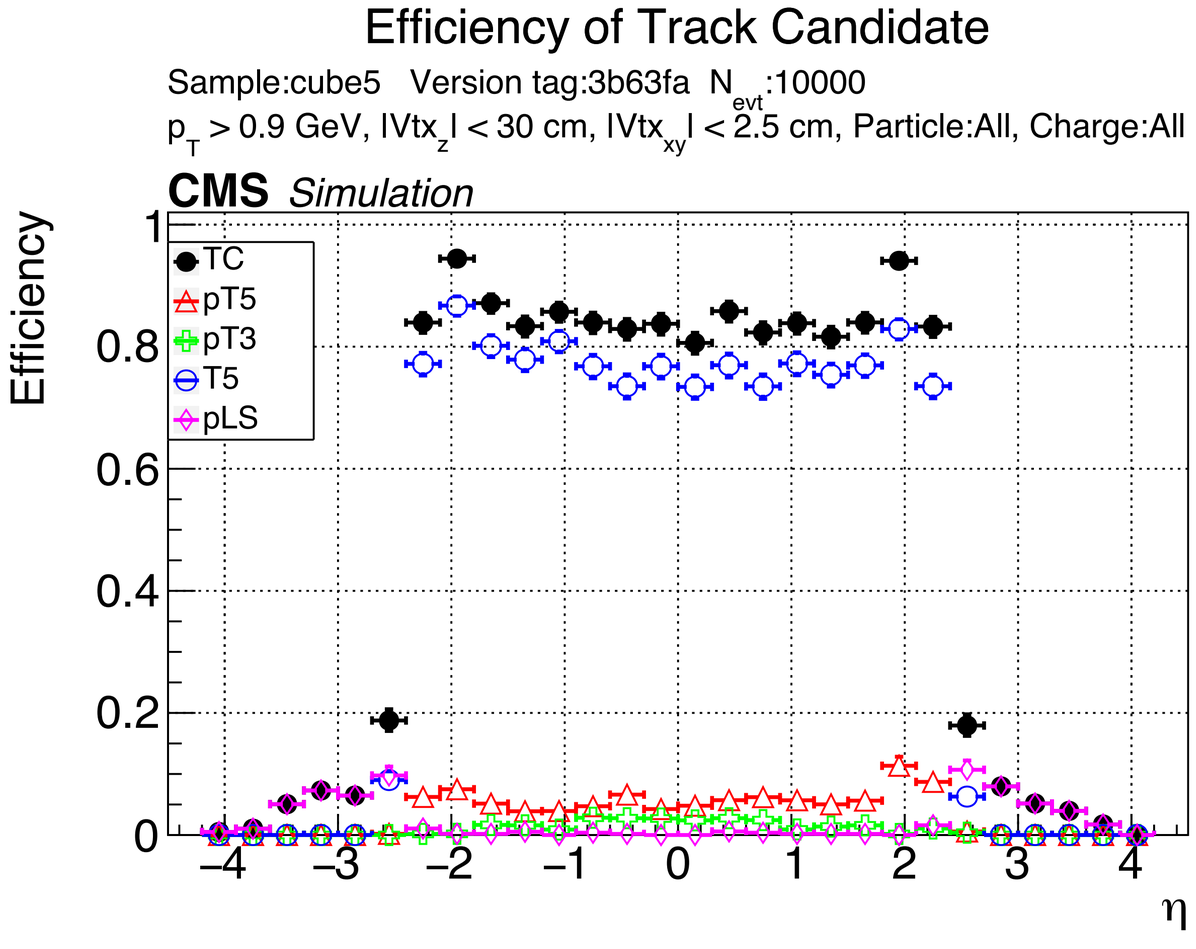
http://uaf-10.t2.ucsd.edu/~jguiang/LSTMasterPerformance/Master_cube5_1b12eeD-cube5/
http://uaf-10.t2.ucsd.edu/~jguiang/LSTMasterPerformance/Master_cube50_1b12eeD-cube50/

UC San Diego

LST DNN Efficiency Plots

5cm cube sample (▲ WP)





http://uaf-10.t2.ucsd.edu/~jguiang/LSTDNNPerformance/T5_DNN_consistentPT_matchBkgEff_cube5_3b63fa-cube5/
http://uaf-10.t2.ucsd.edu/~jguiang/LSTDNNPerformance/T5_DNN_consistentPT_matchBkgEff_cube50_3b63fa-cube50/

UC San Diego

LST Timing

LST does run slower with the DNN

Evt	Hits	MD	LS	T3	T5	pLS	pT5	pT3	TC	Event	Short		Rate	
avg	8.5	2.0	1.4	3.7	6.7	1.4	1.5	1.1	2.1	28.5	18.6+/-	3.9	32.1	explicit[s=1]
avg	12.5	3.3	1.8	6.2	10.0	1.5	4.0	2.5	3.4	45.3	31.3+/-	6.6	27.2	explicit[s=2]
avg	25.1	4.6	2.7	10.2	16.2	1.7	9.5	5.1	5.0	80.0	53.3+/-	10.3	28.8	explicit[s=4]
avg	34.9	4.5	2.7	13.7	22.6	1.9	17.3	8.1	5.8	111.6	74.9+/-	18.3	27.7	explicit[s=6]
avg	56.1	4.6	2.5	17.5	30.8	1.7	25.5	13.6	5.8	158.1	100.3+/-	27.9	29.1	explicit[s=8]
avg	1.6	2.0	1.4	3.3	6.1	1.4	1.3	1.0	2.1	20.3	17.3+/-	3.9	21.9	explicit_cache[s=1]
avg	4.7	3.7	2.0	5.4	8.1	1.5	3.0	1.9	3.6	33.8	27.7+/-	6.4	19.5	explicit_cache[s=2]
avg	5.5	5.4	3.3	10.5	12.8	1.7	7.0	3.3	6.3	55.8	48.5+/-	10.2	15.1	explicit_cache[s=4]
avg	11.6	7.3	4.7	14.9	17.8	2.2	11.0	5.4	9.6	84.5	70.7+/-	15.8	15.1	explicit_cache[s=6]
avg	17.1	8.7	5.9	20.0	24.0	2.8	15.1	7.5	12.9	114.1	94.2+/-	18.8	15.1	explicit_cache[s=8]

Evt	Hits	MD	LS	T3	T5	pLS	pT5	pT3	TC	Event	Short		Rate	
avg	8.9	2.0	1.4	3.7	4.1	1.4	1.5	1.1	2.2	26.2	15.9+/-	3.3	29.4	explicit[s=1]
avg	13.6	3.5	1.9	6.3	6.3	1.5	3.6	2.5	3.7	43.0	27.9+/-	5.7	27.1	explicit[s=2]
avg	20.2	3.7	2.3	10.0	12.2	1.5	8.8	5.1	4.6	68.4	46.6+/-	10.2	25.8	explicit[s=4]
avg	31.1	5.1	2.9	12.9	15.6	1.8	14.1	7.8	5.9	97.2	64.3+/-	16.4	24.6	explicit[s=6]
avg	49.5	4.1	2.5	16.5	26.5	1.7	23.3	12.9	5.6	142.5	91.3+/-	27.1	26.3	explicit[s=8]
avg	1.6	2.0	1.5	3.4	3.4	1.4	1.4	1.0	2.2	17.9	14.9+/-	3.5	19.1	explicit_cache[s=1]
avg	3.4	3.1	1.8	4.9	4.6	1.5	2.7	1.7	3.5	27.2	22.3+/-	5.9	16.2	explicit_cache[s=2]
avg	5.8	5.1	3.0	8.9	8.3	1.8	5.8	3.0	6.3	47.9	40.4+/-	7.8	12.9	explicit_cache[s=4]
avg	10.8	6.3	3.9	12.2	11.6	2.1	8.7	4.7	9.1	69.5	56.5+/-	12.2	12.6	explicit_cache[s=6]
avg	15.2	8.3	5.3	16.6	16.6	2.3	12.7	6.1	12.1	95.1	77.6+/-	11.1	12.3	explicit_cache[s=8]

ΔT5 = (1-DNN/master)
63%
59%
33%
45%
16%
79%
76%
54%
53%
45%