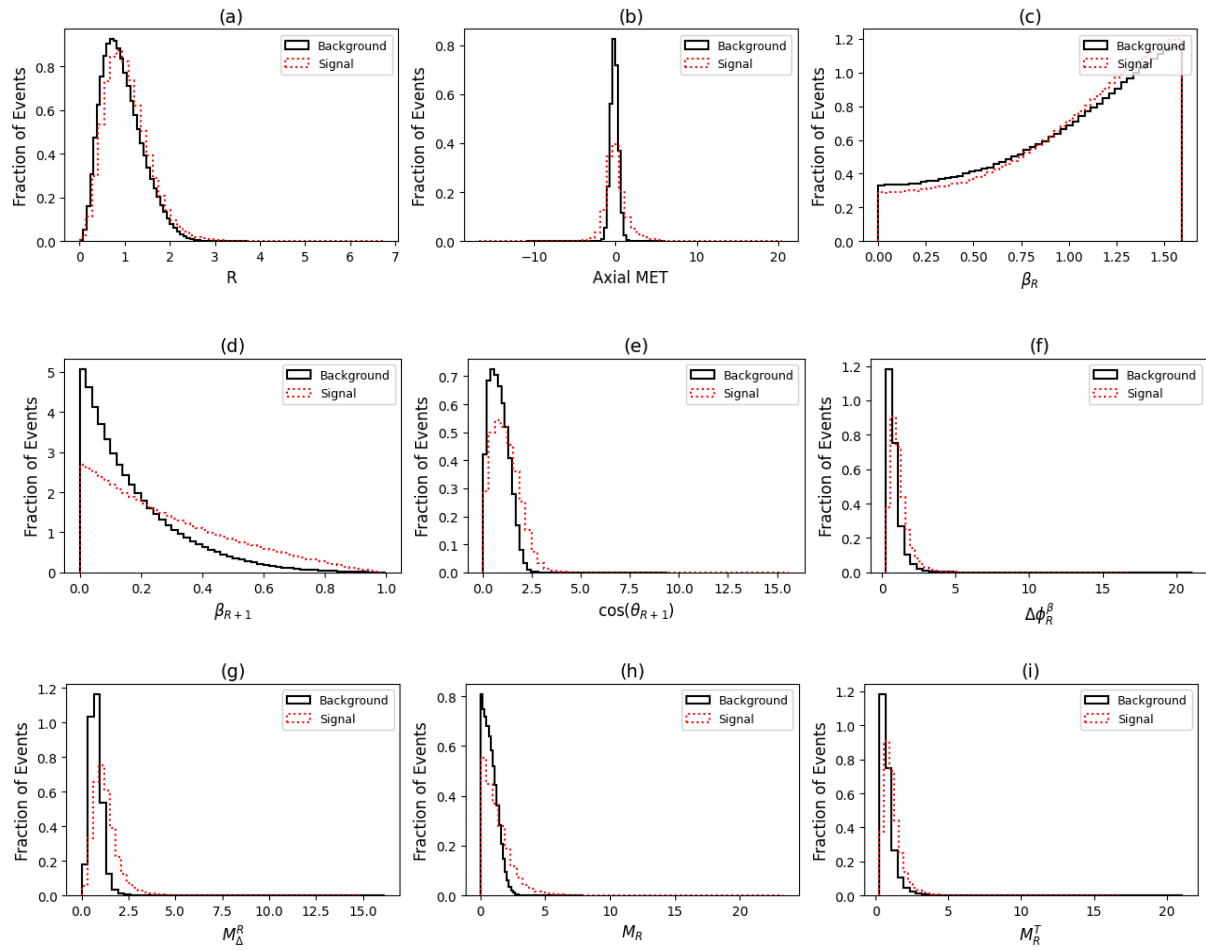# Lab7(Ex1~4) Result:

Exercise 1
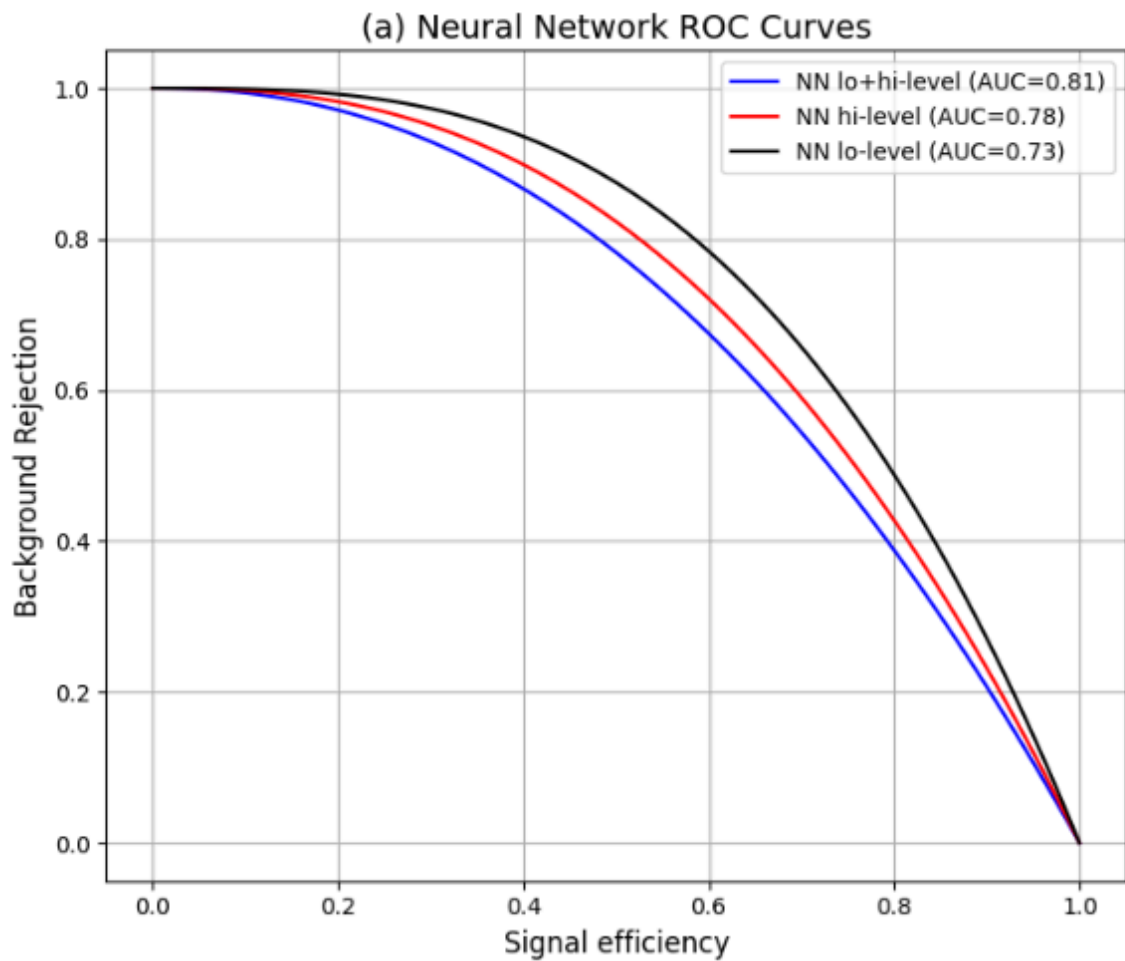(Already exist)

Exercise 2
(Already exist)

Exercise 3

(j)

(k)

(l)

(a) Neural Network ROC Curves

NN lo+hi-level (AUC=0.81)
NN hi-level (AUC=0.78)
NN lo-level (AUC=0.73)

(b) Deep Network ROC Curves

Legend:
- DN hi-level (AUC=0.80)
- DN lo-level (AUC=0.88)
- DN lo+hi-level (AUC=0.88)

X-axis: Signal efficiency

Y-axis: Background Rejection
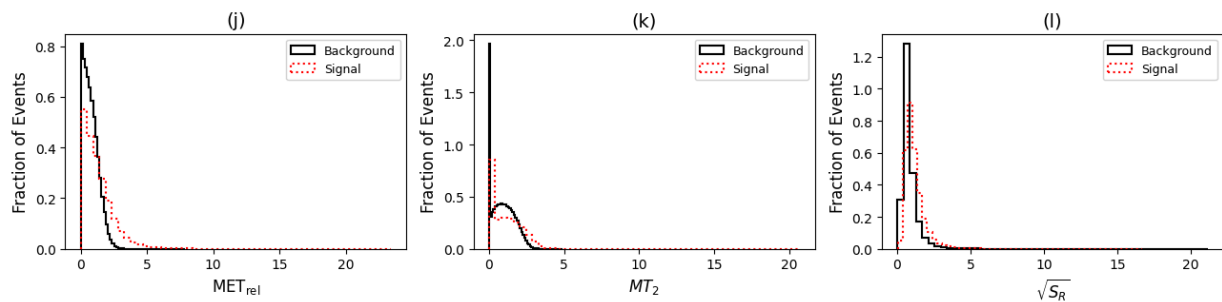
Exercise 4.1
(Part a)
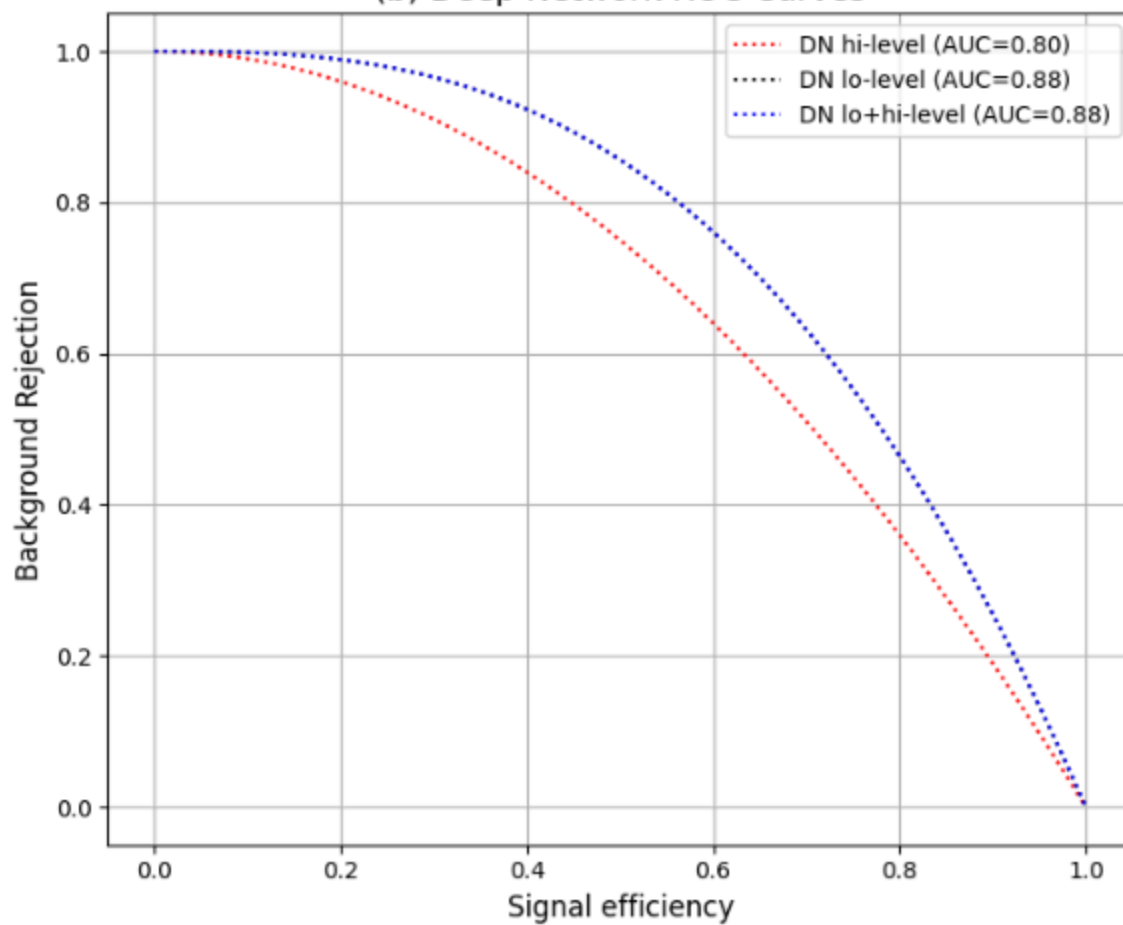
Low-Level Features (Subset)
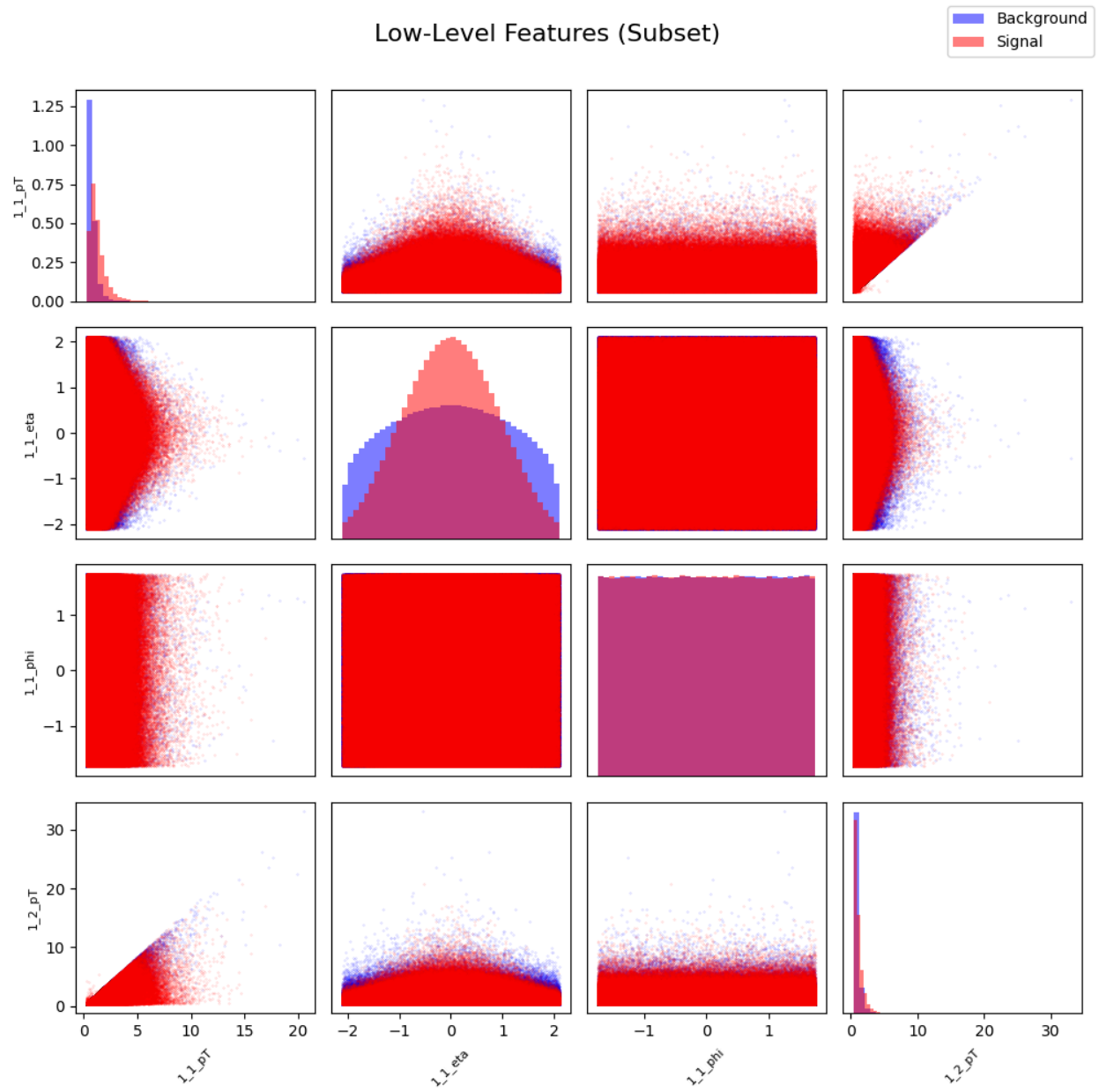
High-Level Features (Subset)

(Exercise 4.1 Part b)
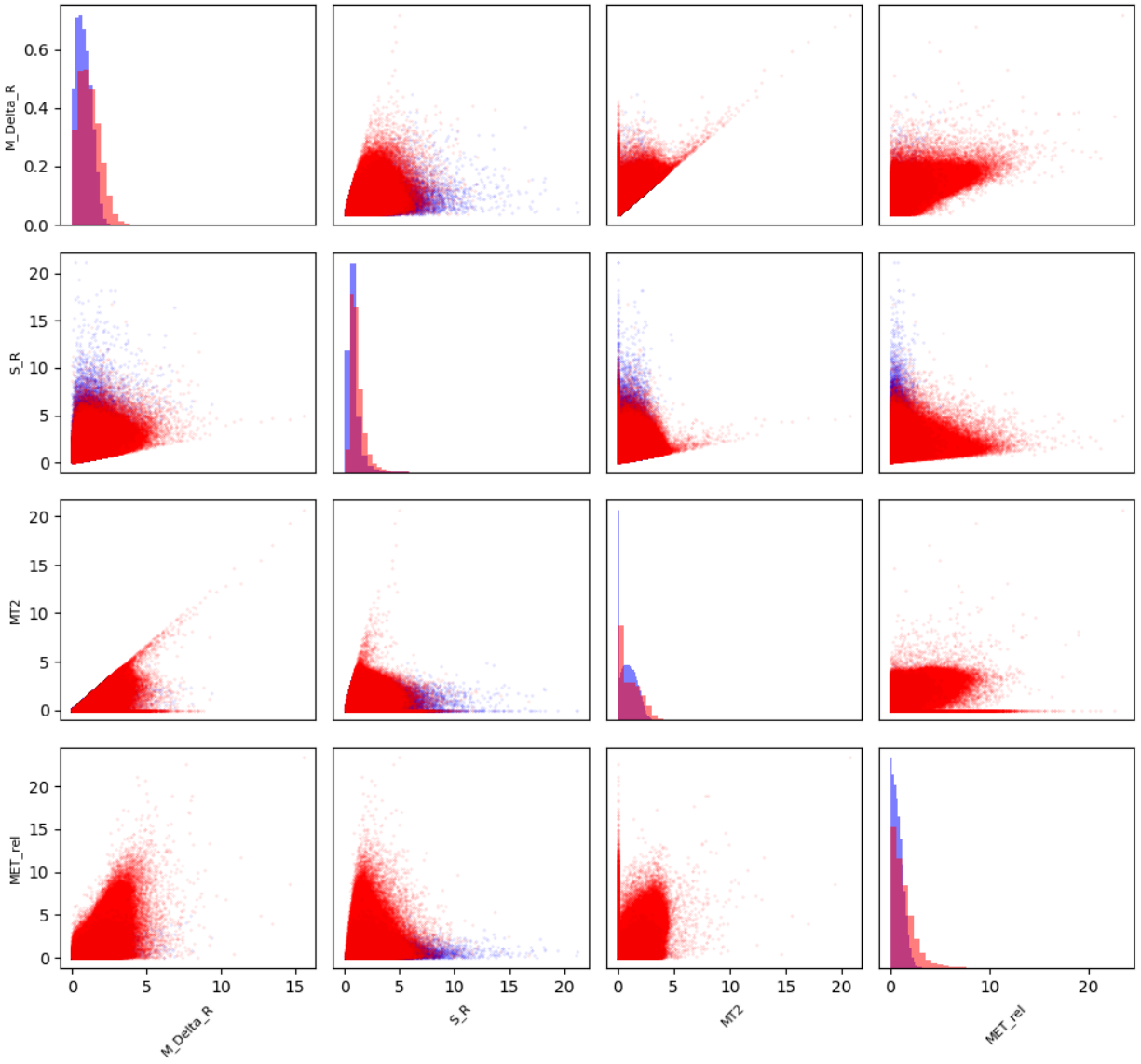
Low-Level Features (Sampled)
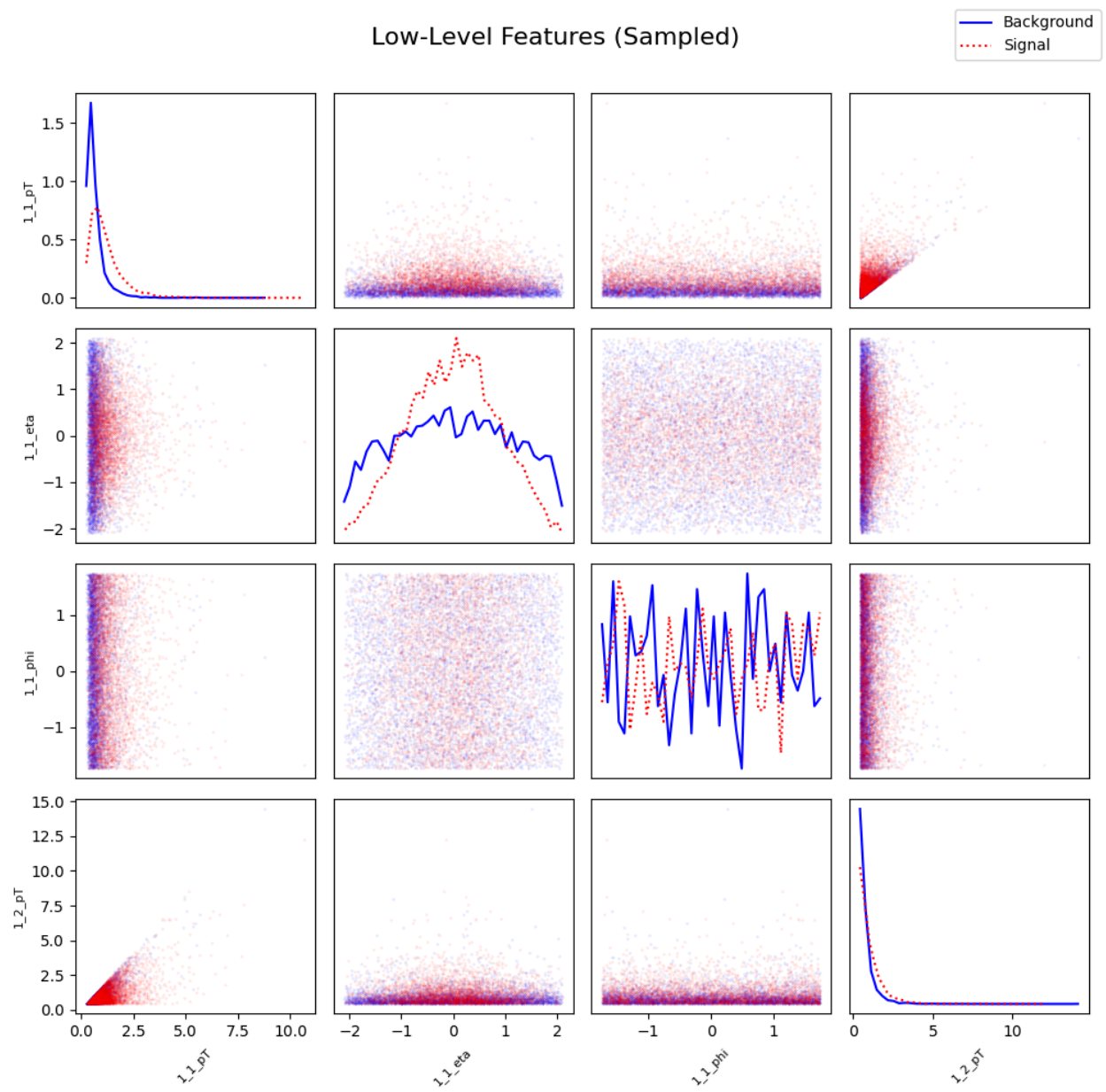
High-Level Features (Sampled)
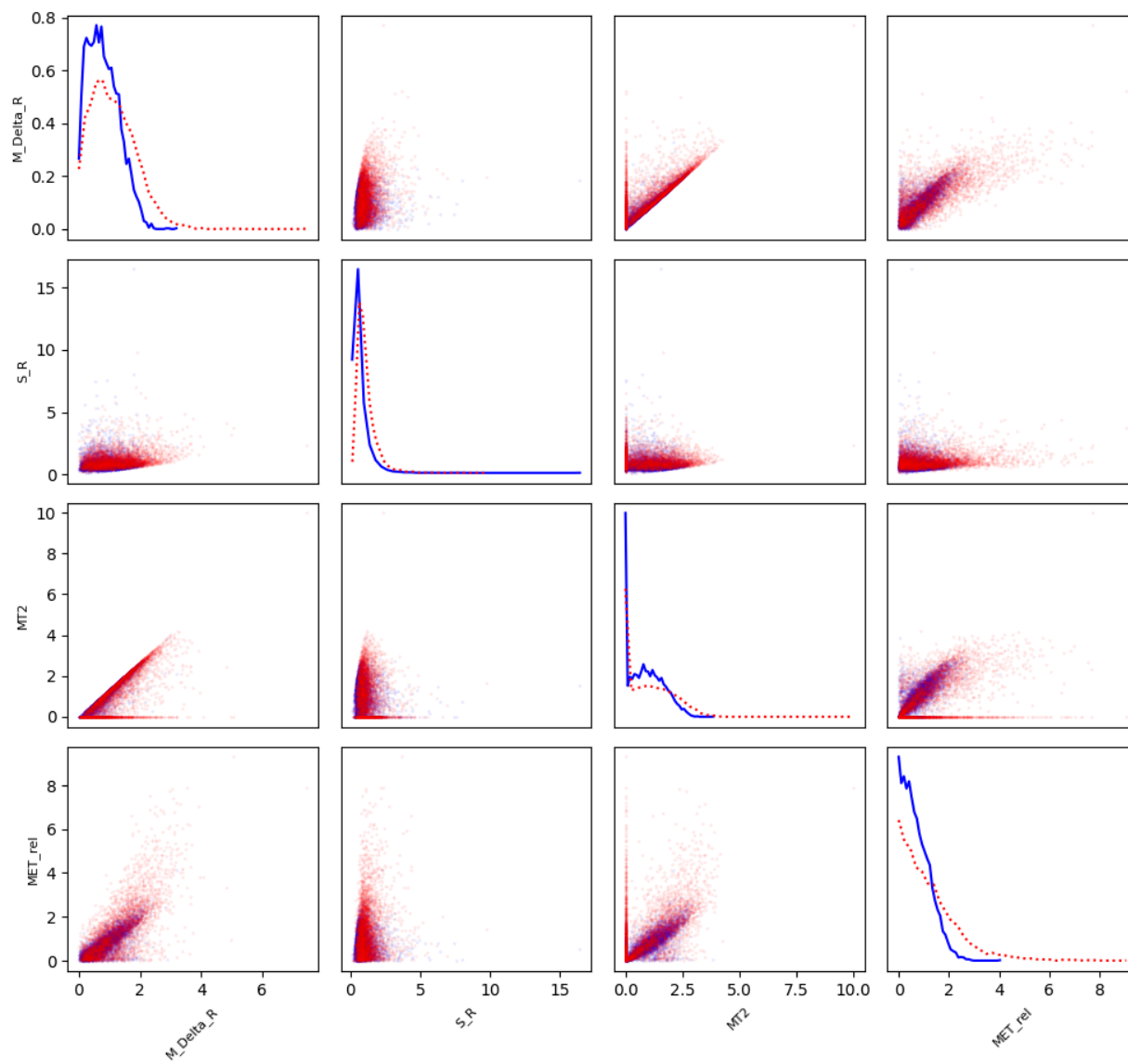
(Exercise 4.1 part c)

```
Top 10 discriminative variables based on mean difference:

MET           0.768857
1_1_pT        0.534471
MET_rel       0.505263
M_TR_2        0.495986
M_Delta_R     0.341800
M_R           0.336500
S_R           0.321856
1_2_pT        0.255800
axial_MET     0.154960
MT2           0.136978
dtype: float32
```

Exercise 4.2
(part a~c no need)

(part d)

Low-Level Features Covariance Matrix

	1_1_pT	1_1_eta	1_1_phi	1_2_pT	1_2_eta	1_2_phi	MET	MET_phi
1_1_pT	0.472	-0	-0	0.308	-0	0	0.231	-0.001
1_1_eta	-0	1.006	0	-0	0.406	0	-0.001	-0.001
1_1_phi	-0	0	1.003	-0	0.001	-0.268	0.001	-0.184
1_2_pT	0.308	-0	-0	0.428	-0	0	0.08	-0.001
1_2_eta	-0	0.406	0.001	-0	1.006	-0	0	-0
1_2_phi	0	0	-0.268	0	-0	1.003	0	-0.034
MET	0.231	-0.001	0.001	0.08	0	0	0.762	-0.002
MET_phi	-0.001	-0.001	-0.184	-0.001	-0	-0.034	-0.002	1.003

Low-Level Features Correlation Matrix

	1_1_pT	1_1_eta	1_1_phi	1_2_pT	1_2_eta	1_2_phi	MET	MET_phi
1_1_pT	1	-0	-0	0.685	-0	0	0.385	-0.001
1_1_eta	-0	1	0	-0.001	0.403	0	-0.001	-0.001
1_1_phi	-0	0	1	-0	0.001	-0.267	0.001	-0.184
1_2_pT	0.685	-0.001	-0	1	-0.001	0	0.14	-0.002
1_2_eta	-0	0.403	0.001	-0.001	1	-0	0	-0
1_2_phi	0	0	-0.267	0	-0	1	0	-0.034
MET	0.385	-0.001	0.001	0.14	0	0	1	-0.002
MET_phi	-0.001	-0.001	-0.184	-0.002	-0	-0.034	-0.002	1

High-Level Features Covariance Matrix

	M_Delta_R	S_R	MT2	MET_rel	axial_MET	R	M_R	M_TR_2	dPhi_r_b	cos_theta_r1
M_Delta_R	0.389	0.096	0.433	0.416	-0.234	0.166	0.074	0.242	0.042	0.039
S_R	0.096	0.385	-0.011	0.082	-0.043	-0.083	0.383	0.23	-0.004	-0.01
MT2	0.433	-0.011	0.738	0.41	-0.46	0.232	-0.037	0.189	0.021	0.045
MET_rel	0.416	0.082	0.41	0.792	-0.125	0.25	0.044	0.303	0.147	0.056
axial_MET	-0.234	-0.043	-0.46	-0.125	1.003	-0.182	0.015	-0.189	-0.026	-0.054
R	0.166	-0.083	0.232	0.25	-0.182	0.222	-0.113	0.104	0.087	0.058
M_R	0.074	0.383	-0.037	0.044	0.015	-0.113	0.395	0.212	-0.029	-0.014
M_TR_2	0.242	0.23	0.189	0.303	-0.189	0.104	0.212	0.341	0.058	0.052
dPhi_r_b	0.042	-0.004	0.021	0.147	-0.026	0.087	-0.029	0.058	0.19	0.009
cos_theta_r1	0.039	-0.01	0.045	0.056	-0.054	0.058	-0.014	0.052	0.009	0.039

High-Level Features Correlation Matrix

	M_Delta_R	S_R	MT2	MET_rel	axial_MET	R	M_R	M_TR_2	dPhi_r_b	cos_theta_r1
M_Delta_R	1	0.248	0.808	0.749	-0.375	0.564	0.189	0.666	0.156	0.319
S_R	0.248	1	-0.021	0.149	-0.07	-0.285	0.981	0.636	-0.013	-0.084
MT2	0.808	-0.021	1	0.536	-0.535	0.574	-0.068	0.378	0.056	0.263
MET_rel	0.749	0.149	0.536	1	-0.141	0.595	0.078	0.583	0.378	0.317
axial_MET	-0.375	-0.07	-0.535	-0.141	1	-0.385	0.024	-0.323	-0.06	-0.274
R	0.564	-0.285	0.574	0.595	-0.385	1	-0.381	0.38	0.424	0.627
M_R	0.189	0.981	-0.068	0.078	0.024	-0.381	1	0.578	-0.106	-0.115
M_TR_2	0.666	0.636	0.378	0.583	-0.323	0.38	0.578	1	0.228	0.451
dPhi_r_b	0.156	-0.013	0.056	0.378	-0.06	0.424	-0.106	0.228	1	0.106
cos_theta_r1	0.319	-0.084	0.263	0.317	-0.274	0.627	-0.115	0.451	0.106	1

All Features Covariance Matrix

	1_1_pT	1_1_eta	1_1_phi	1_2_pT	1_2_eta	1_2_phi	MET	MET_phi	MET_rel	axial_MET	M_R	M_TR_2	R	MT2	S_R	M_Delta_R	dPhi_r_b	cos_theta_r1
1_1_pT	0.472	-0	-0	0.308	-0	0	0.231	-0.001	0.099	-0.013	0.368	0.291	-0.059	-0.013	0.346	0.098	-0.047	0.023
1_1_eta	-0	1.006	0	-0	0.406	0	-0.001	-0.001	-0	-0	-0	-0	0	-0	-0	-0.001	0	0
1_1_phi	-0	0	1.003	-0	0.001	-0.268	0.001	-0.184	0.002	-0.002	-0	0.001	0.001	0.002	0	0.001	0.001	0
1_2_pT	0.308	-0	-0	0.428	-0	0	0.08	-0.001	-0.002	0.05	0.328	0.164	-0.099	-0.069	0.325	0.006	-0.004	-0.028
1_2_eta	-0	0.406	0.001	-0	1.006	-0	0	-0	0	-0	-0.001	-0	0	0	-0.001	-0	-0	0
1_2_phi	0	0	-0.268	0	-0	1.003	-0	-0.034	0	-0	-0	0	0	0.001	0	0	0	-0
MET	0.231	-0.001	0.001	0.08	0	0	0.762	-0.002	0.548	0.145	0.146	0.368	0.189	0.156	0.167	0.317	0.145	0.073
MET_phi	-0.001	-0.001	-0.184	-0.001	-0	-0.034	-0.002	1.003	-0.003	-0.001	-0.001	-0.001	-0	0.001	-0.001	-0	-0.001	0
MET_rel	0.099	-0	0.002	-0.002	0	0	0.548	-0.003	0.792	-0.125	0.044	0.303	0.25	0.41	0.082	0.416	0.147	0.056
axial_MET	-0.013	-0	-0.002	0.05	-0	-0	0.145	-0.001	-0.125	1.003	0.015	-0.189	-0.182	-0.46	-0.043	-0.234	-0.026	-0.054
M_R	0.368	-0	-0	0.328	-0.001	0	0.146	-0.001	0.044	0.015	0.395	0.212	-0.113	-0.037	0.383	0.074	-0.029	-0.014
M_TR_2	0.291	-0	0.001	0.164	-0	0	0.368	-0.001	0.303	-0.189	0.212	0.341	0.104	0.189	0.23	0.242	0.058	0.052
R	-0.059	0	0.001	-0.099	0	0	0.189	-0	0.25	-0.182	-0.113	0.104	0.222	0.232	-0.083	0.166	0.087	0.058
MT2	-0.013	0	0.002	-0.069	0	0.001	0.156	0.001	0.41	-0.46	-0.037	0.189	0.232	0.738	-0.011	0.433	0.021	0.045
S_R	0.346	-0	0	0.325	-0.001	0	0.167	-0.001	0.082	-0.043	0.383	0.23	-0.083	-0.011	0.385	0.096	-0.004	-0.01
M_Delta_R	0.098	-0.001	0.001	0.006	-0	0	0.317	-0	0.416	-0.234	0.074	0.242	0.166	0.433	0.096	0.389	0.042	0.039
dPhi_r_b	-0.047	0	0.001	-0.004	-0	0	0.145	-0.001	0.147	-0.026	-0.029	0.058	0.087	0.021	-0.004	0.042	0.19	0.009
cos_theta_r1	0.023	0	0	-0.028	0	-0	0.073	0	0.056	-0.054	-0.014	0.052	0.058	0.045	-0.01	0.039	0.009	0.039

All Features Correlation Matrix

	1_1_pT	1_1_eta	1_1_phi	1_2_pT	1_2_eta	1_2_phi	MET	MET_phi	MET_rel	axial_MET	M_R	M_TR_2	R	MT2	S_R	M_Delta_R	dPhi_r_b	cos_theta_r1
1_1_pT	1	-0	-0	0.685	-0	0	0.385	-0.001	0.161	-0.018	0.852	0.724	-0.183	-0.022	0.812	0.229	-0.157	0.166
1_1_eta	-0	1	0	-0.001	0.403	0	-0.001	-0.001	-0.001	-0	-0	-0	0	-0	-0	-0.001	0	0.001
1_1_phi	-0	0	1	-0	0.001	-0.267	0.001	-0.184	0.002	-0.002	-0	0.001	0.002	0.002	0	0.002	0.002	0.002
1_2_pT	0.685	-0.001	-0	1	-0.001	0	0.14	-0.002	-0.004	0.076	0.798	0.43	-0.322	-0.123	0.799	0.014	-0.014	-0.216
1_2_eta	-0	0.403	0.001	-0.001	1	-0	0	-0	0	-0	-0.001	-0	0	0.001	-0.001	-0	-0	0.001
1_2_phi	0	0	-0.267	0	-0	1	0	-0.034	0	-0	-0	0	0	0.001	0.001	0.001	0.001	-0.001
MET	0.385	-0.001	0.001	0.14	0	0	1	-0.002	0.706	0.166	0.266	0.722	0.459	0.209	0.309	0.581	0.382	0.426
MET_phi	-0.001	-0.001	-0.184	-0.002	-0	-0.034	-0.002	1	-0.003	-0.001	-0.002	-0.001	-0	0.001	-0.002	-0.001	-0.003	0
MET_rel	0.161	-0.001	0.002	-0.004	0	0	0.706	-0.003	1	-0.141	0.078	0.583	0.595	0.536	0.149	0.749	0.378	0.317
axial_MET	-0.018	-0	-0.002	0.076	-0	-0	0.166	-0.001	-0.141	1	0.024	-0.323	-0.385	-0.535	-0.07	-0.375	-0.06	-0.274
M_R	0.852	-0	-0	0.798	-0.001	0	0.266	-0.002	0.078	0.024	1	0.578	-0.381	-0.068	0.981	0.189	-0.106	-0.115
M_TR_2	0.724	-0	0.001	0.43	-0	0	0.722	-0.001	0.583	-0.323	0.578	1	0.38	0.378	0.636	0.666	0.228	0.451
R	-0.183	-0	0.002	-0.322	0.001	0	0.459	-0	0.595	-0.385	-0.381	0.38	1	0.574	-0.285	0.564	0.424	0.627
MT2	-0.022	-0	0.002	-0.123	-0	0.001	0.209	0.001	0.536	-0.535	-0.068	0.378	0.574	1	-0.021	0.808	0.056	0.263
S_R	0.812	-0	0	0.799	-0.001	0.001	0.309	-0.002	0.149	-0.07	0.981	0.636	-0.285	-0.021	1	0.248	-0.013	-0.084
M_Delta_R	0.229	-0.001	0.002	0.014	-0	0.001	0.581	-0.001	0.749	-0.375	0.189	0.666	0.564	0.808	0.248	1	0.156	0.319
dPhi_r_b	-0.157	0	0.002	-0.014	-0	0.001	0.382	-0.003	0.378	-0.06	-0.106	0.228	0.424	0.056	-0.013	0.156	1	0.106
cos_theta_r1	0.166	0.001	0.002	-0.216	0.001	-0.001	0.426	0	0.317	-0.274	-0.115	0.451	0.627	0.263	-0.084	0.319	0.106	1