CNN For High Energy

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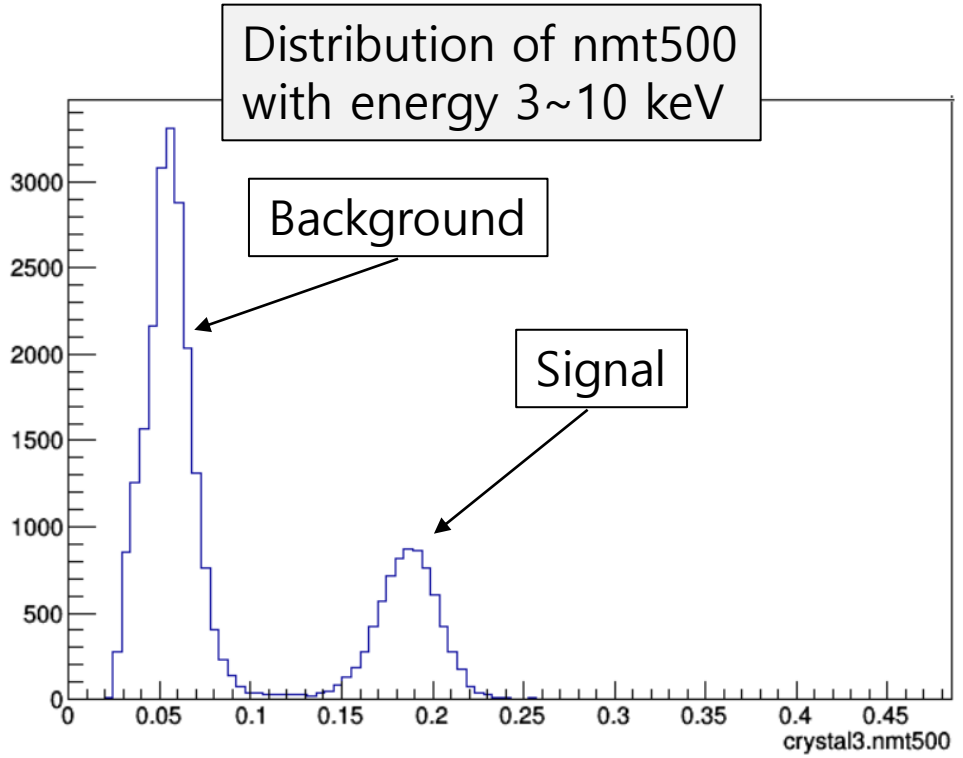
Seungmok Lee

Data Selection

- New data selection criteria for Cosine data was applied.
  - Signal tag
    - Runnum 1765, 1601 (Calibration run)
    - Have coincidence
    - Nmt500 > 0.12
  - Background tag
    - Runnum 1858, 1859 (Physics run)
    - No coincidence
    - Nmt500 < 0.12



Data Statistics

		Training data		Validation data		Test data	
		Background	Signal	Background	Signal	Background	Signal
Crystal 1	3~6 keV	146,089	414	18,264	47	18,273	38
	6~10 keV	62,381	452	7,805	48	7,806	47
Crystal 3	3~6 keV	142,487	1,367	17,815	164	17,792	187
	6~10 keV	50,477	1,909	6,322	226	6,326	222
Crystal 7	3~6 keV	146,834	1,892	18,365	224	18,371	218
	6~10 keV	63,592	2,761	7,959	333	7,980	312

CNN Structure

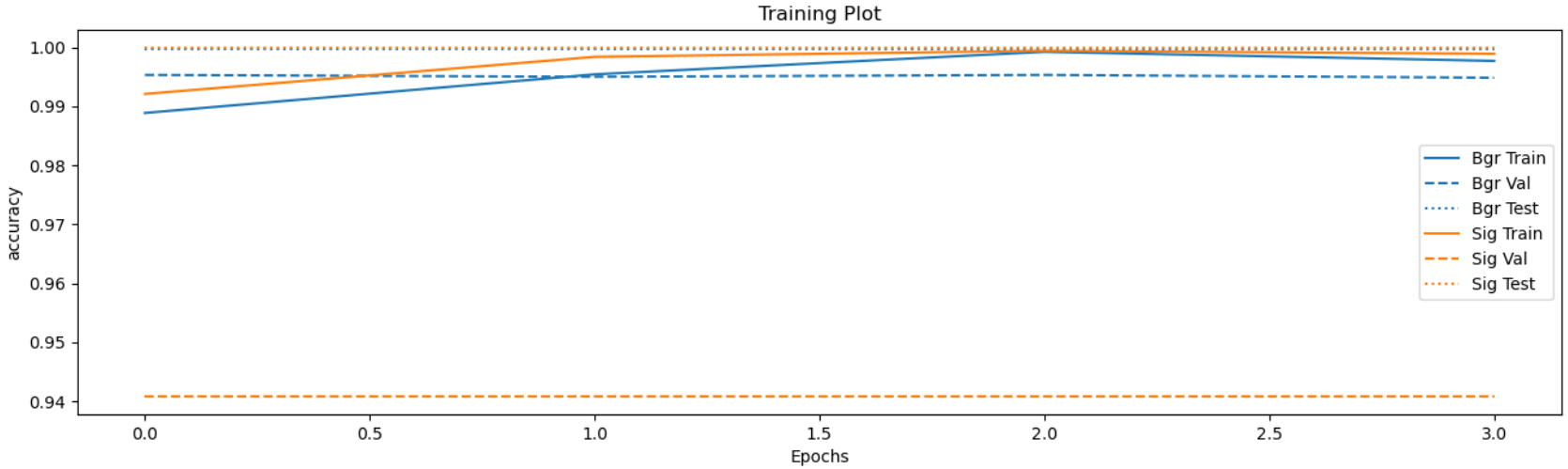
- 1dimensional CNN motivated by AlexNet was successful!
- Batch norm., ReLU activation applied.

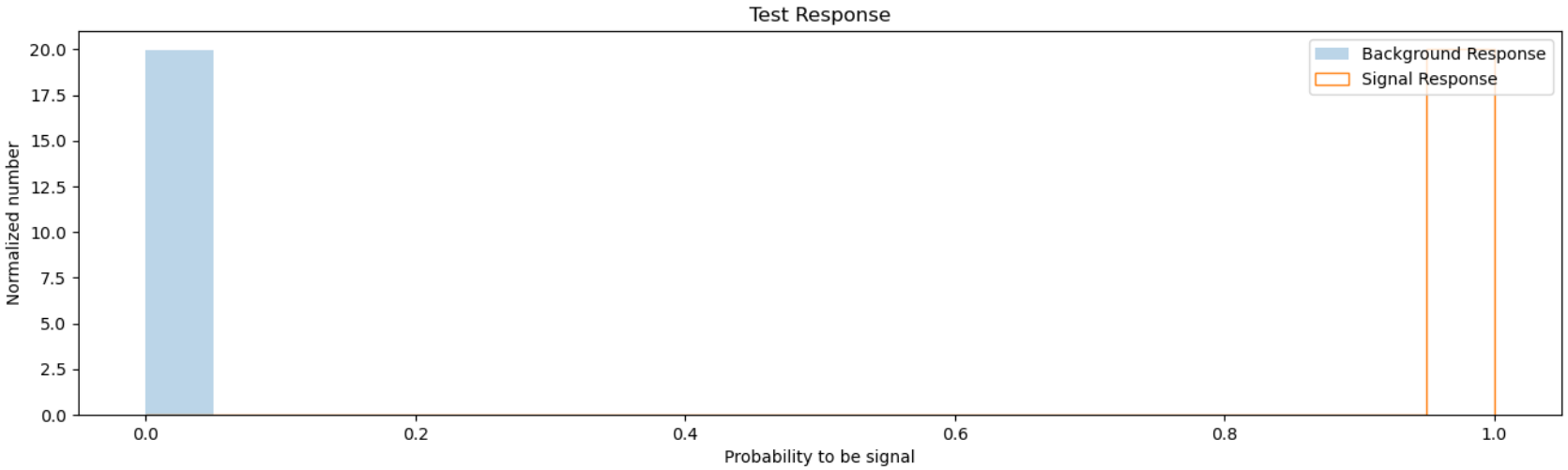
Input shape	Layer	Output shape
(4080, 2)	Conv1D(filters=96, kernel_size=39, strides=3)	(1348, 96)
(1348, 96)	MaxPool1D(pool_size=4)	(337, 96)
(337, 96)	Conv1D(filters=256, kernel_size=23)	(315, 256)
(315, 256)	MaxPool1D(pool_size=3)	(105, 256)
(105, 256)	Conv1D(filters=384, kernel_size=9)	(97, 384)
(97, 384)	Conv1D(filters=384, kernel_size=9)	(89, 384)
(89, 384)	Conv1D(filters=256, kernel_size=9)	(81, 256)
(81, 256)	MaxPool1D(pool_size=3, strides=2)	(40, 256)
(40, 256)	Flatten()	10240
10240	Dense(512)	512
512	Dense(512)	512
512	Dense(512)	512
512	Dense(512)	512
512	Dense(2)	2

Training Strategy

- Batch size = 64
  - Maximum value available in my laptop.
- Categorical crossentropy loss function
  - Weight applied using sig/bkg event number.
- Adam(lr=0.0015, beta_1=0.97)
  - A little high learning rate.
  - Train using latest ~30 batches.
  - 30 batches ≒ 2,000 events ≒ 5~80 signal events

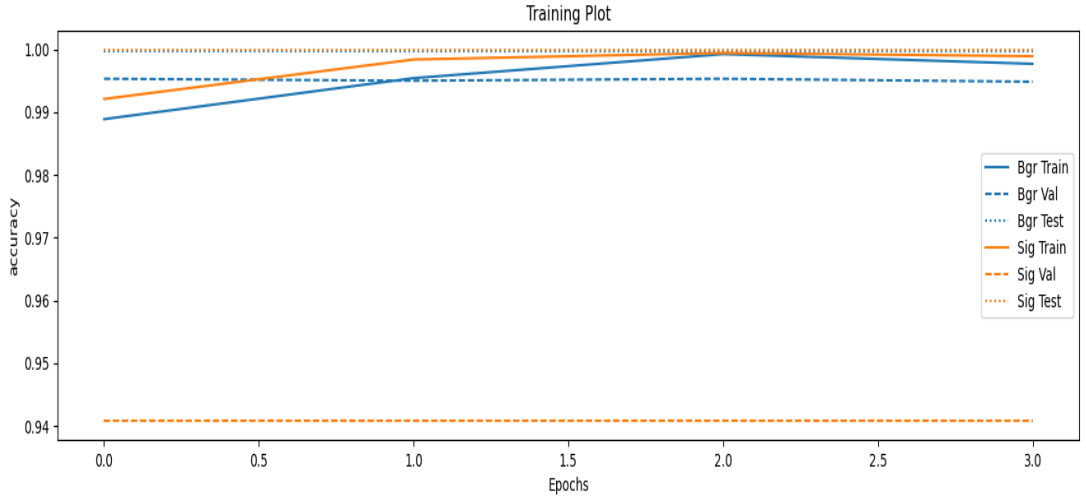
Crystal3, 6~10 keV

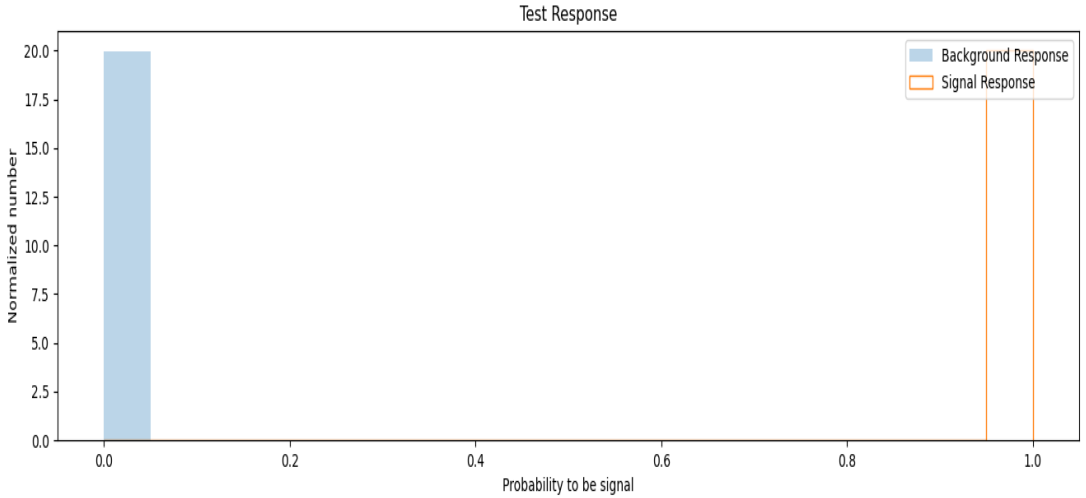




Crystal3, 6~10 keV

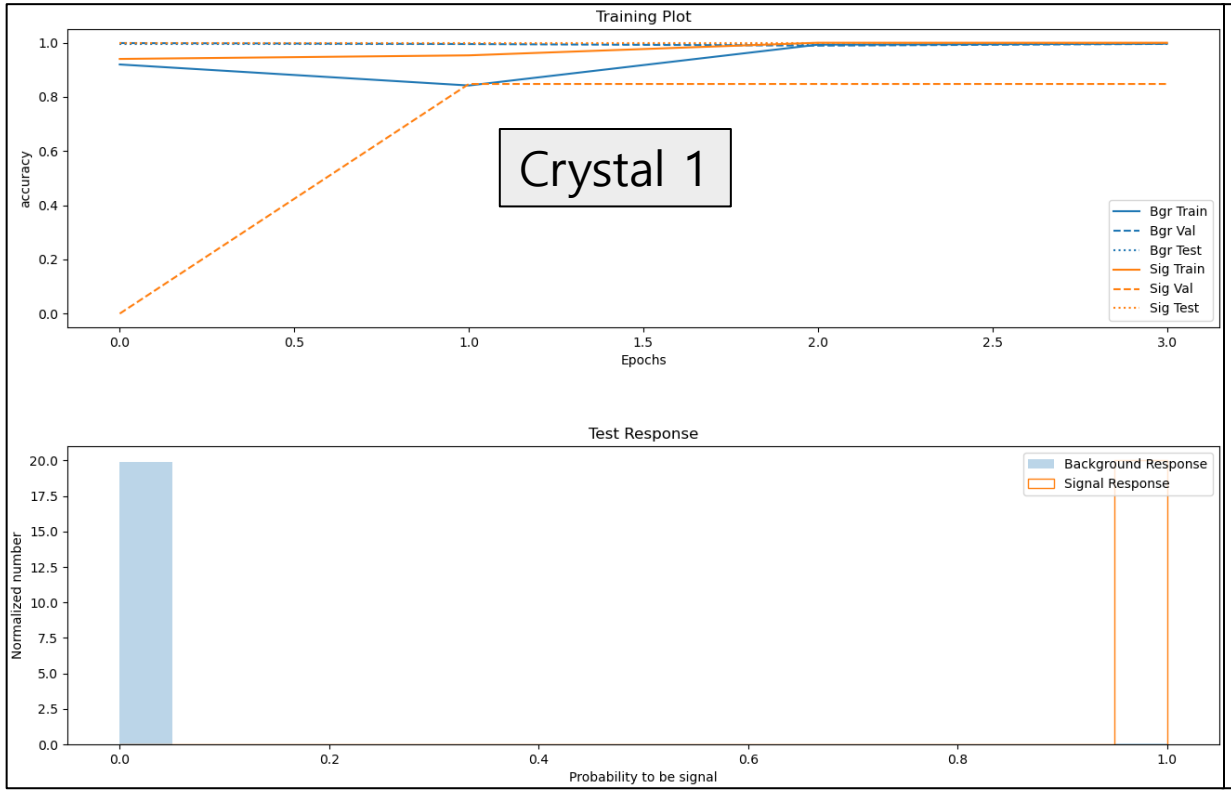
- 3~4 epochs were enough to train the network.
- Test passed!
  - Signal efficiency 100%
  - Background efficiency 99.97%

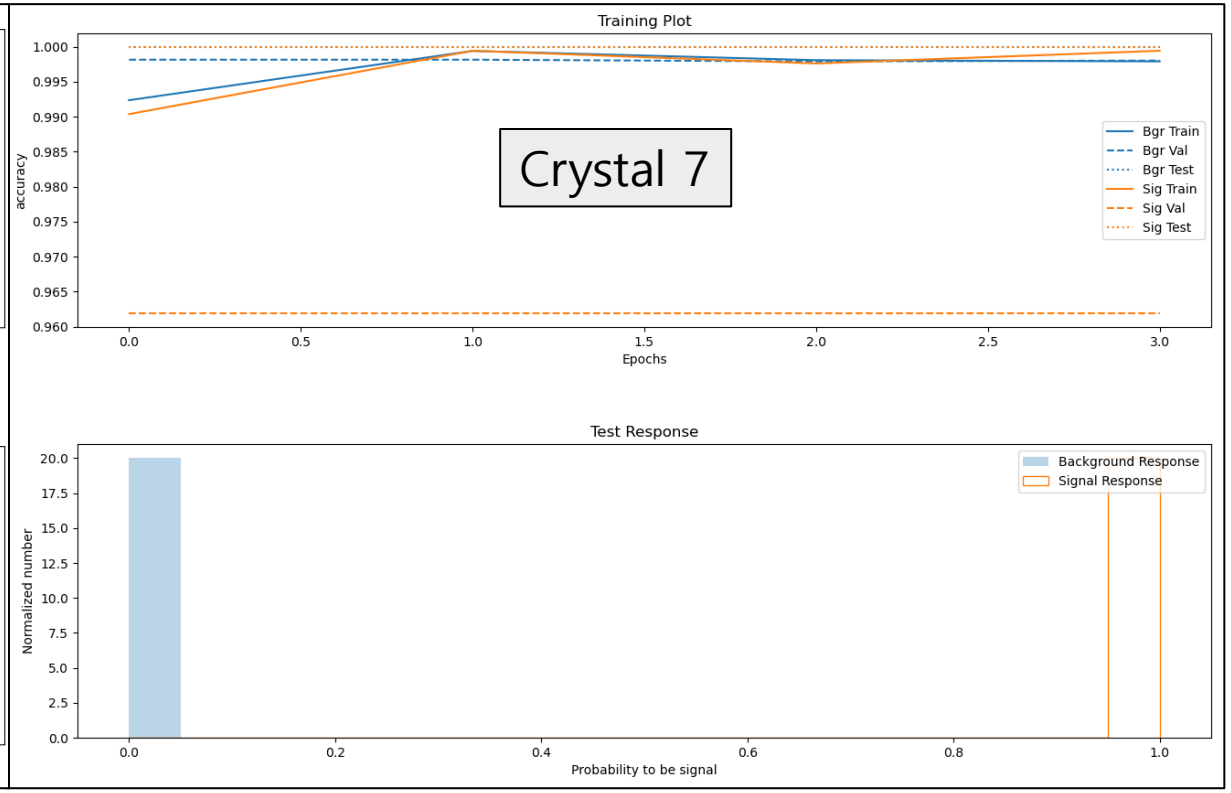




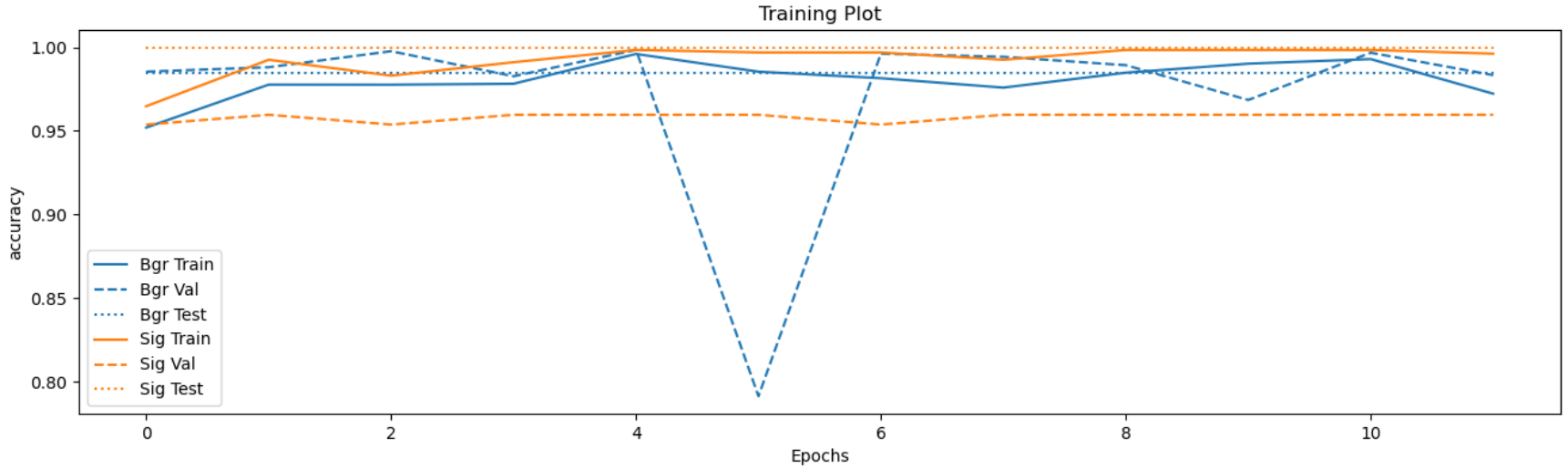
Crystal1 and 7, 6~10 keV

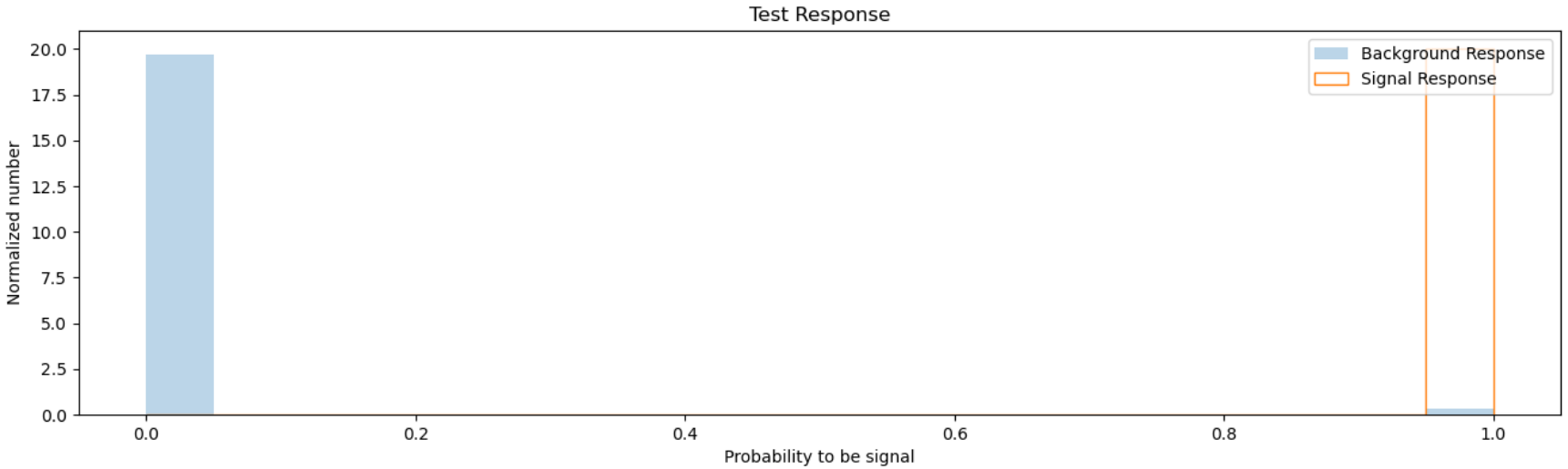
Test Efficiency	Crystal 1	Crystal 7
Signal [%]	100	100
Background [%]	99.62	100





Crystal3, 3~6 keV

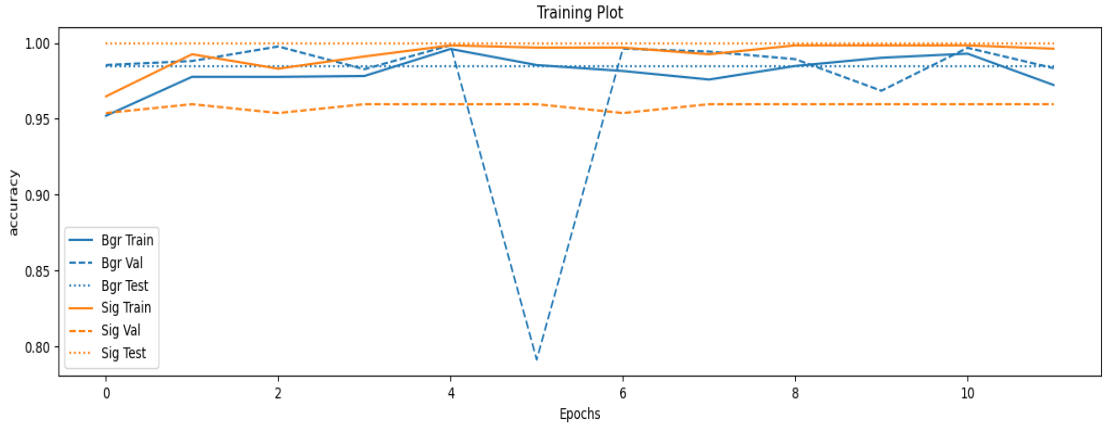


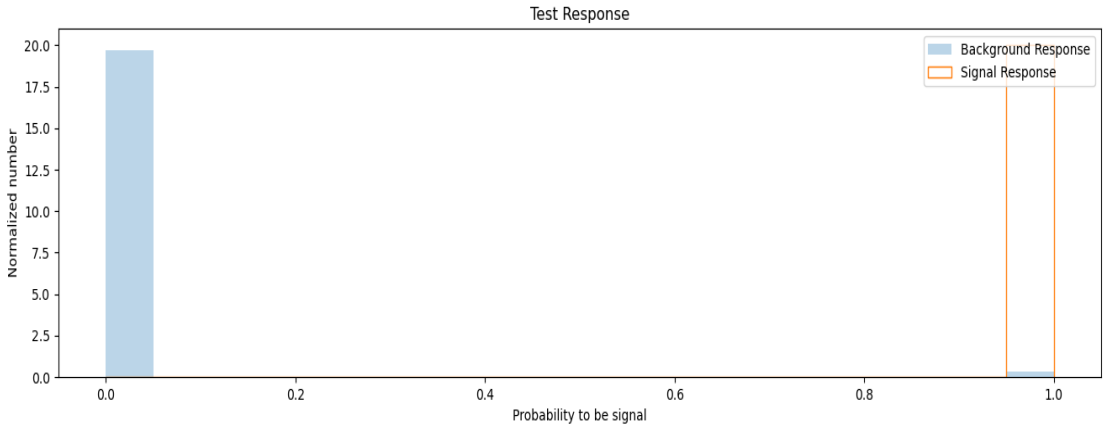


Crystal3, 3~6 keV

- More (6~12) epochs were needed for training.
- Test passed!
  - Signal efficiency 100%
  - Background efficiency 98.47%
- Also successful for crystal 1 and 7.

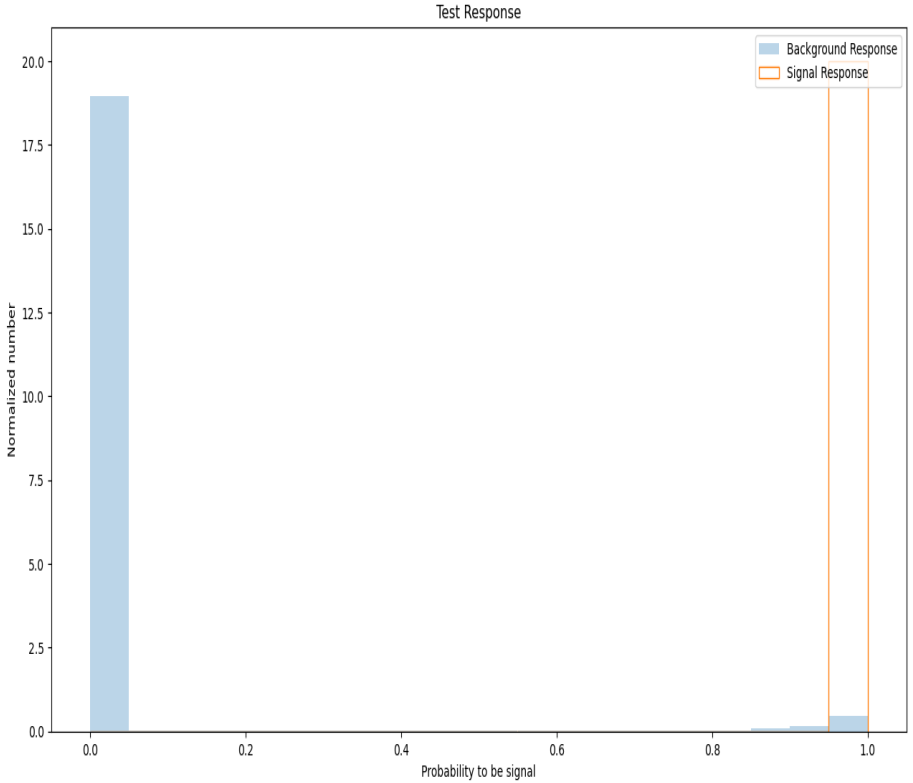
Test Efficiency	Crystal 1	Crystal 7
Signal [%]	100	100
Background [%]	99.21	99.96





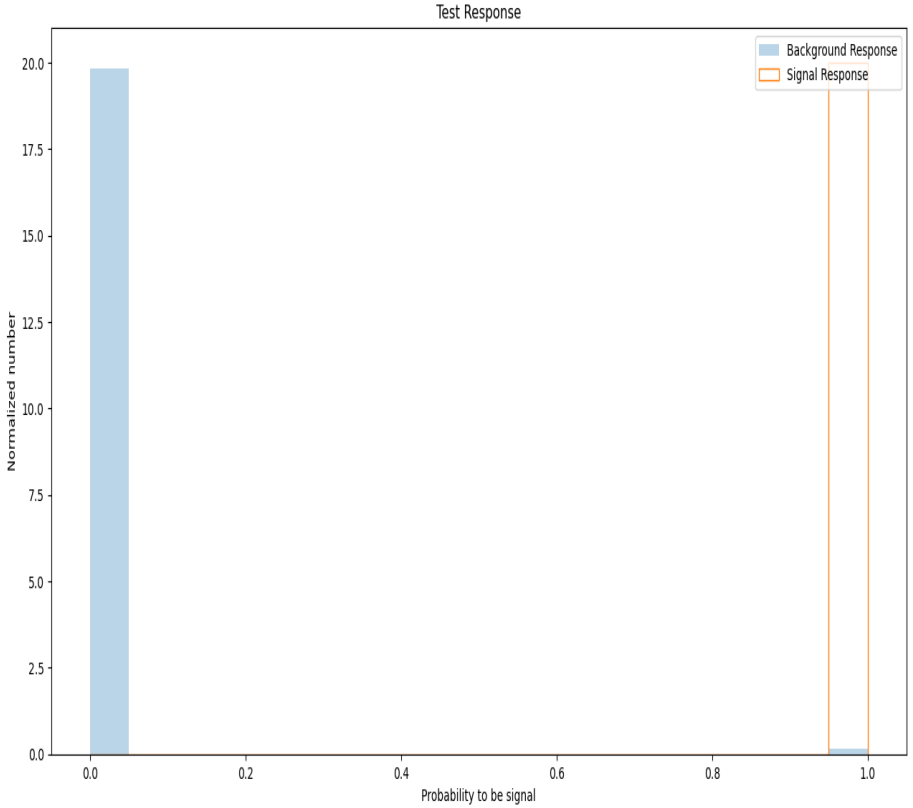
Compatibility

- Training
  - crystal 3, 6~10 keV data.
- Test
  - crystal 3, 3~6 keV data.
- Result
  - Signal efficiency 100%
  - Background efficiency 95.48%



Compatibility

- Training
  - crystal 3, 3~6 keV data.
- Test
  - crystal 3, 6~10 keV data.
- Result
  - Signal efficiency 100%
  - Background efficiency 99.21%

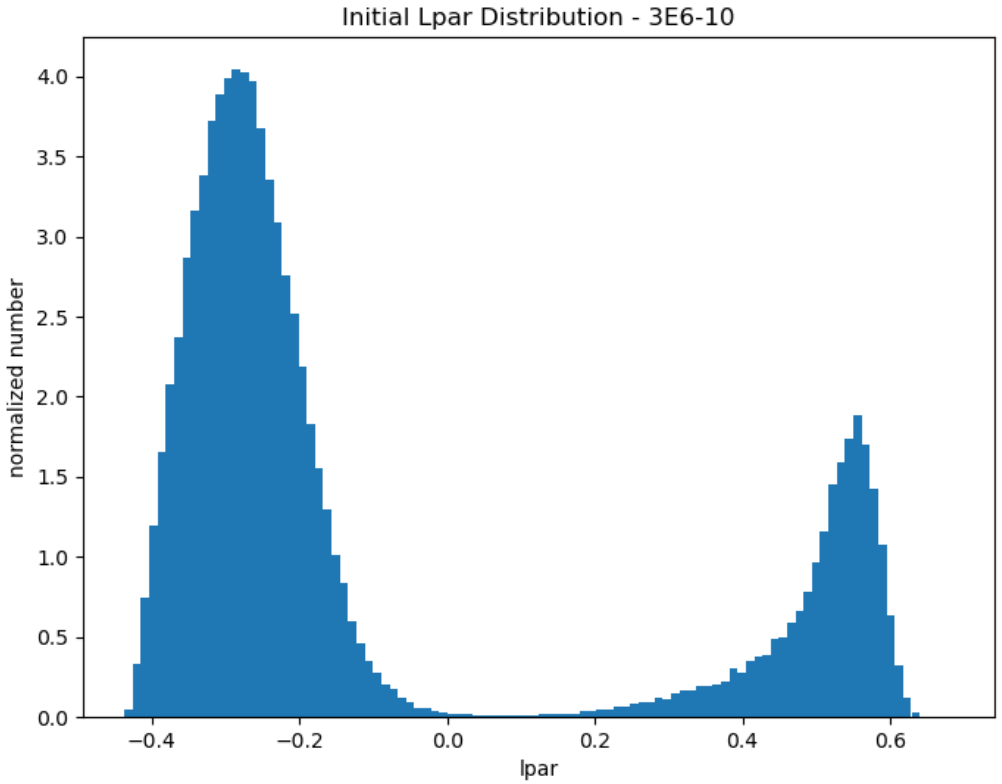


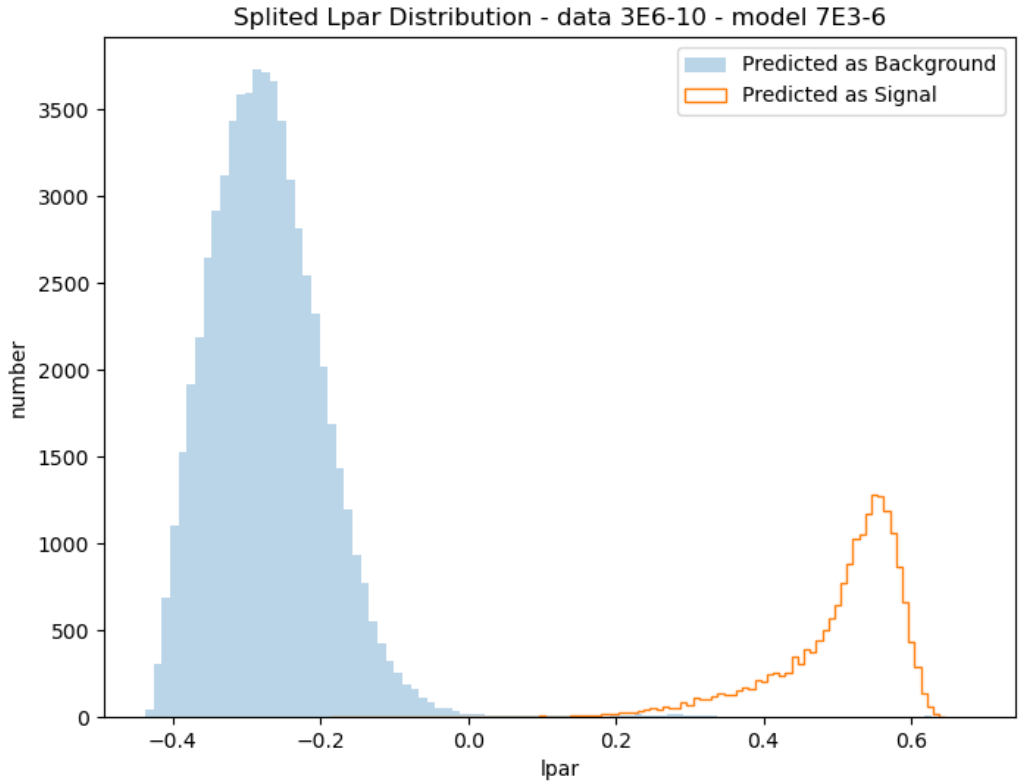
Compatibility

Trained Using		Tested on		Signal Eff. [%]	Background Eff. [%]	F1 Score [%]
Crystal	Energy [keV]	Crystal	Energy [keV]			
3	6~10	3	3~6	100	95.48	**97.69**
3	3~6	3	6~10	100	99.21	**99.60**
7	6~10	3	6~10	100	99.18	**99.59**
7	6~10	3	3~6	100	94.22	**97.03**
7	3~6	3	6~10	100	100	**100**
7	3~6	1	6~10	100	99.69	**99.84**
7	3~6	1	3~6	100	99.64	**99.82**
3	6~10	1	6~10	100	99.69	**99.84**
1	3~6	7	6~10	99.68	100	**99.84**

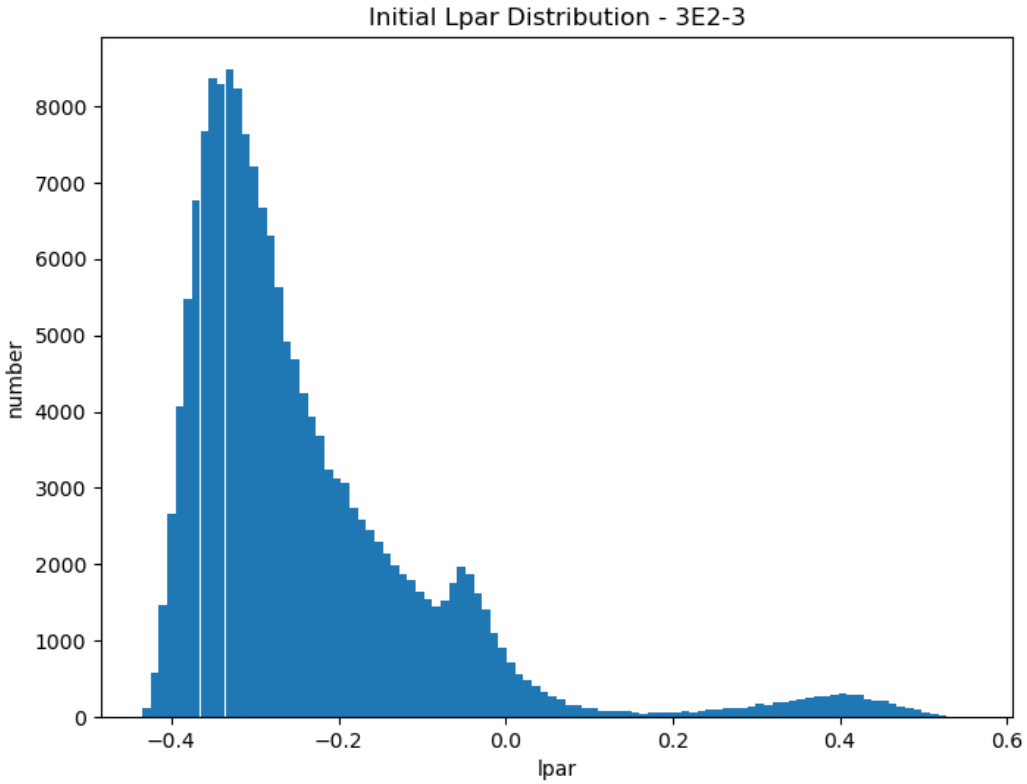
※ $\mathrm{F}_1\ \mathrm{score} = \dfrac{2}{\dfrac{1}{\text{Signal eff.}} + \dfrac{1}{\text{Background eff.}}}$

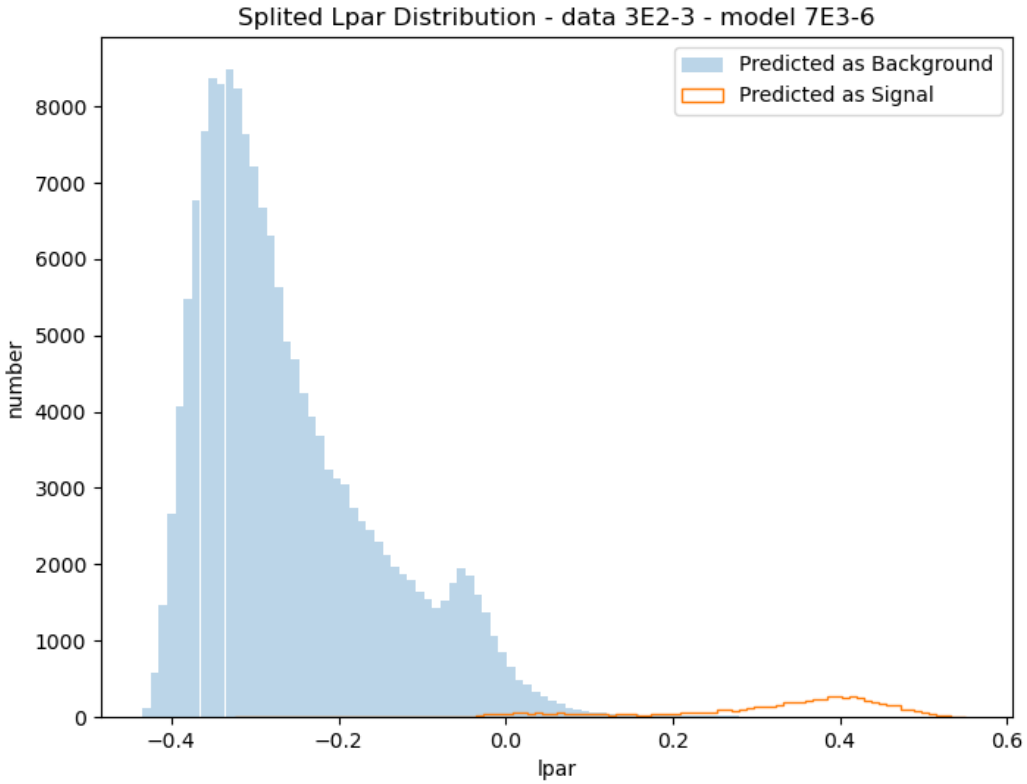
Compatibility



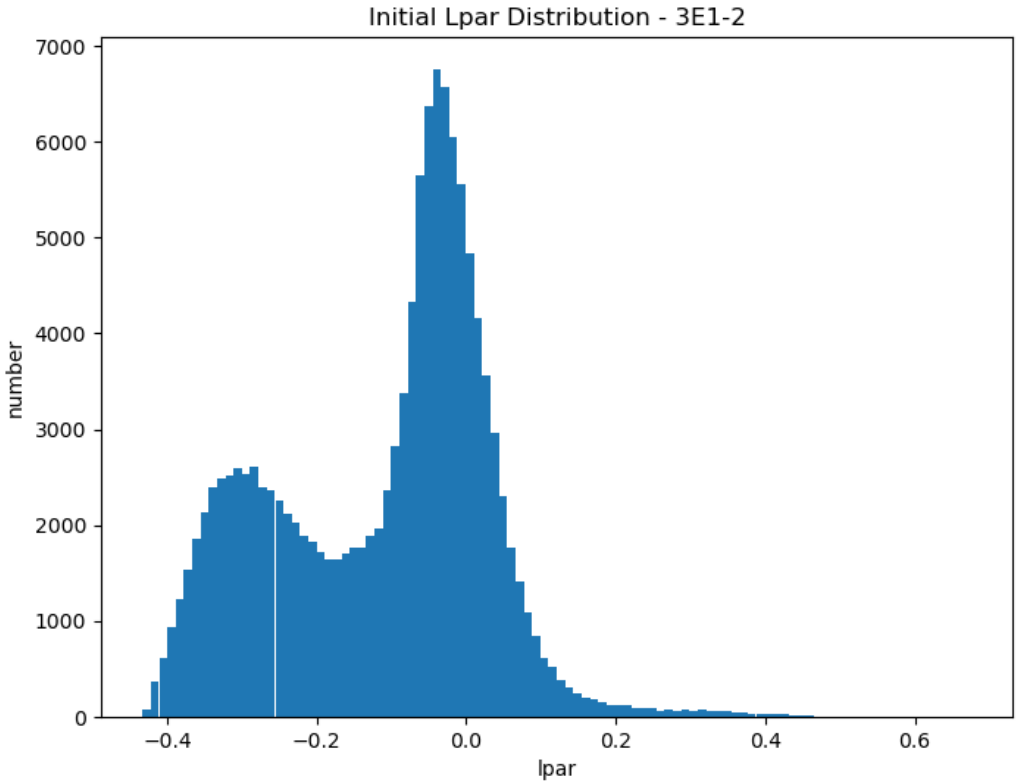


Compatibility – Low Energy

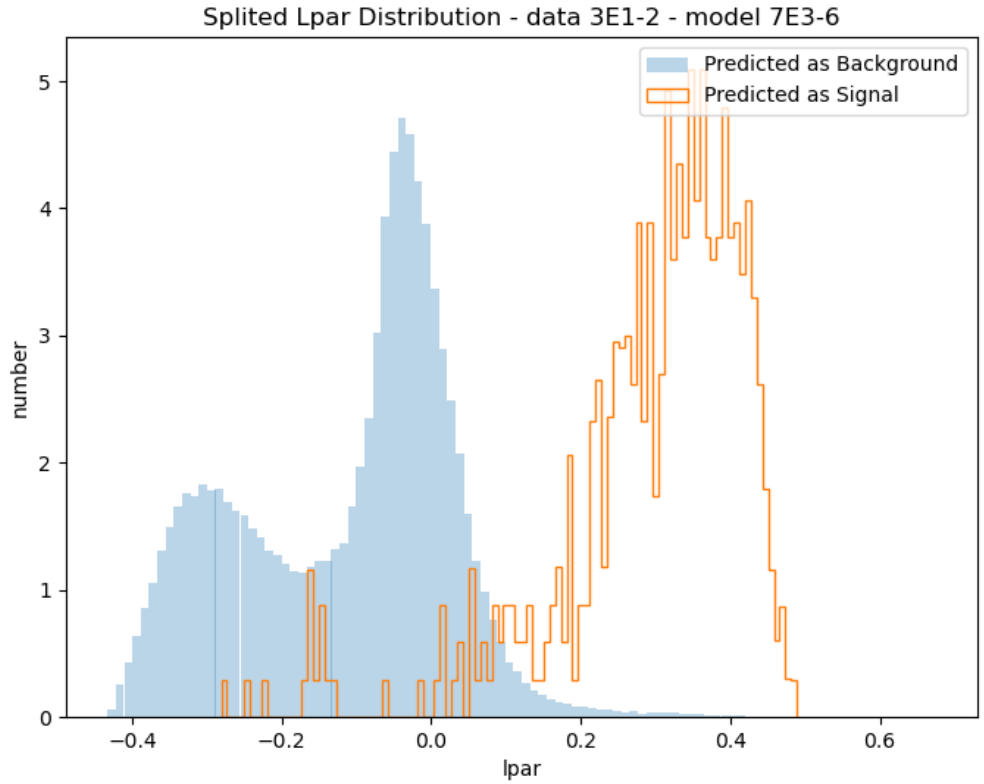




Compatibility – Low Energy



(normalized)



To Do List

- Determine how well my network is doing on low energy region.
- Prepare pure low energy data sample.
  - Study more about cuts, such as lpar, dpar and nmt.
  - Study trigger simulation.