Machine learning triggers: feasibility study

status report, what did I do last month, 18.08.22
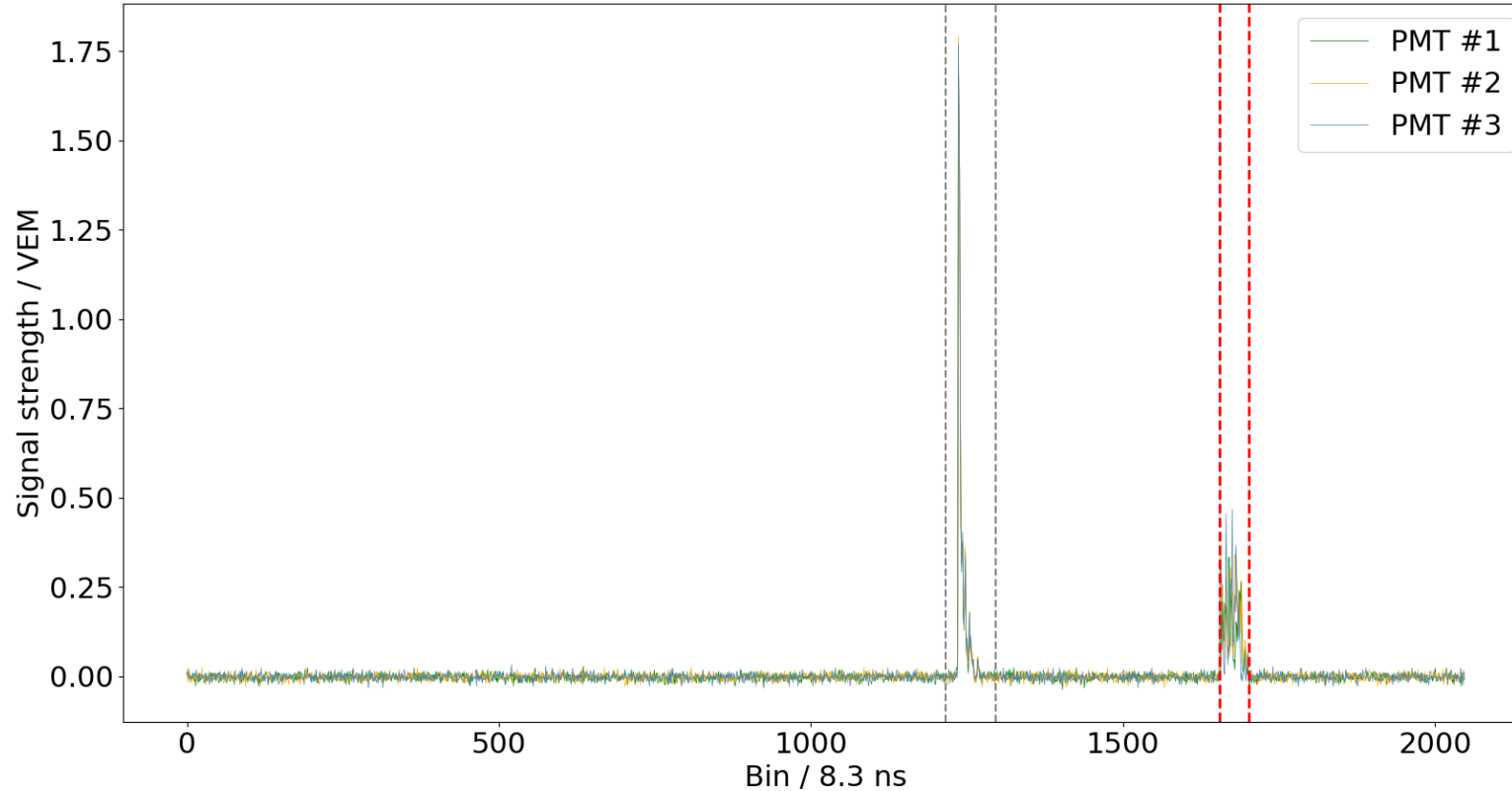
Recap from last KA / BsAs meeting

- **Random traces exist, but some issues in data**

- **Background model has stray muons, etc.**

- **Various testing on model background + randoms**

- **Standard input to NNs (3 (PMTs), 120 (bins))**
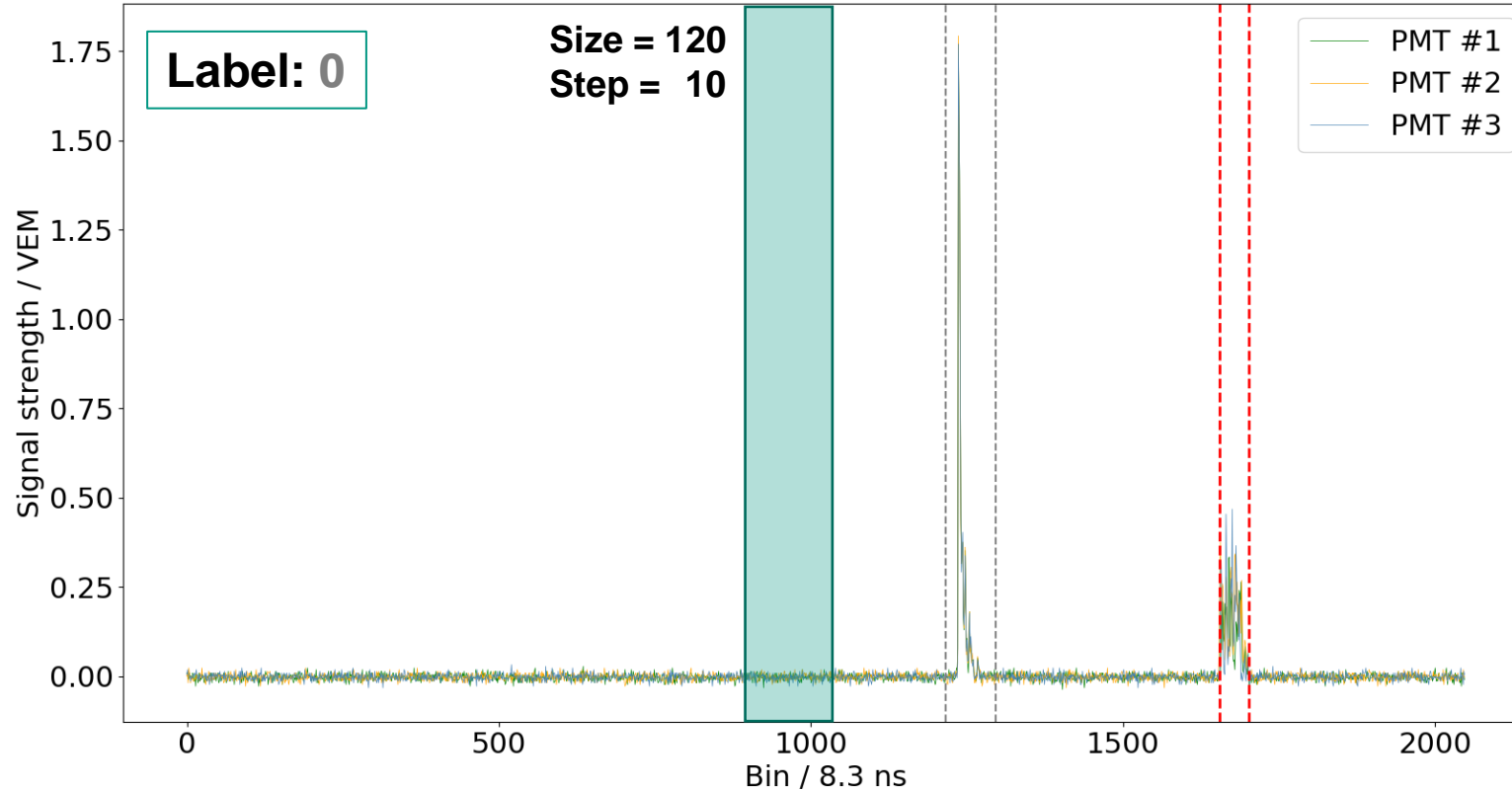
- **QoL code improvements, bug fixes, hyperparameters**

Outlook / Next steps

- ☑ **Build larger dataset of traces (espically for lower energies)**

- ☐ **Test NNs on random traces provided by David Nitz…**
- ☐ **… and improve background model accordingly**

- ☐ **Drastically reduce NN input size (20 000 bins currently)**
- ☐ **Aim for 120 bin window as CNN input (same as ToT, etc.)**

Sliding window analysis - principle

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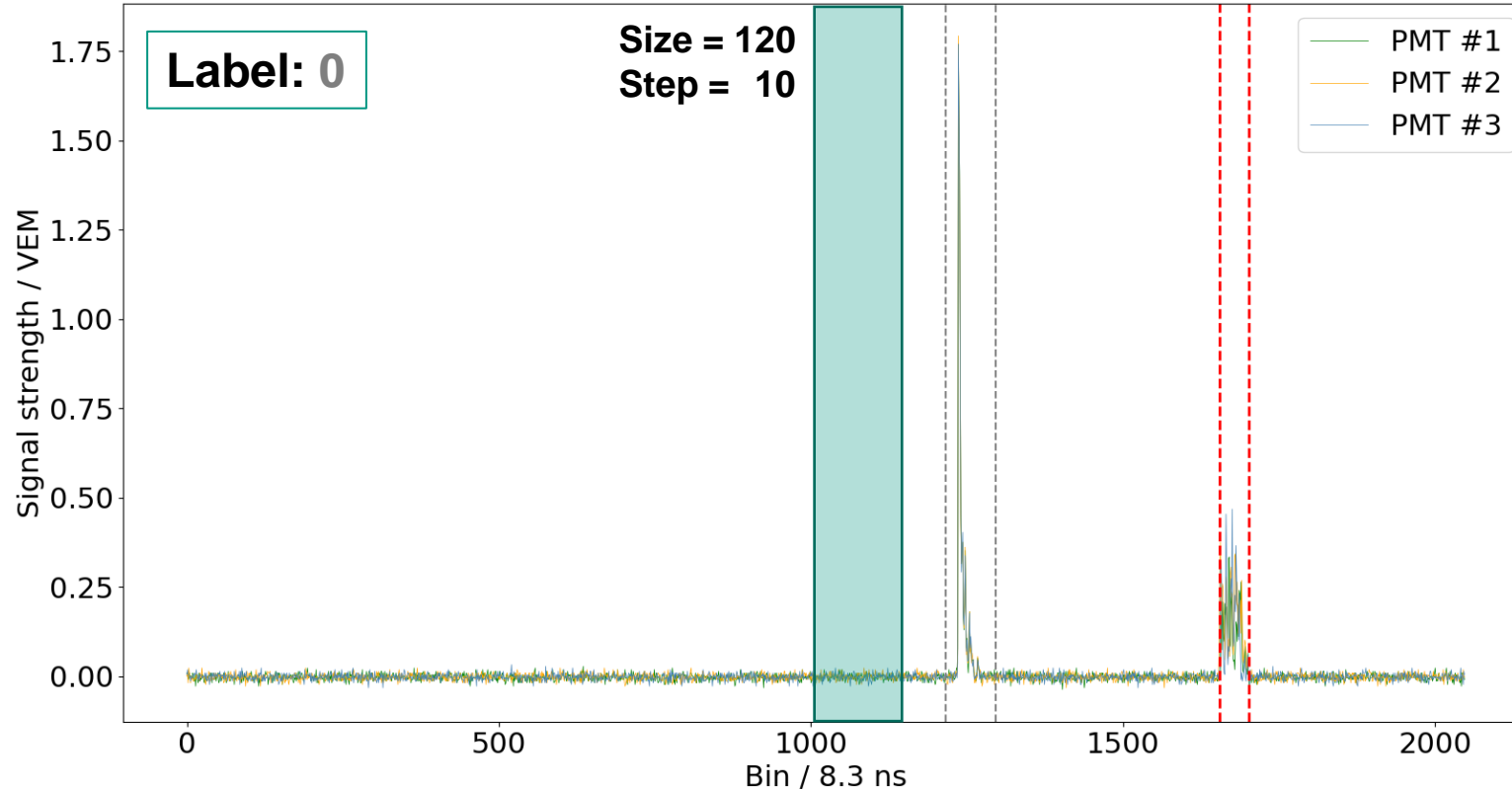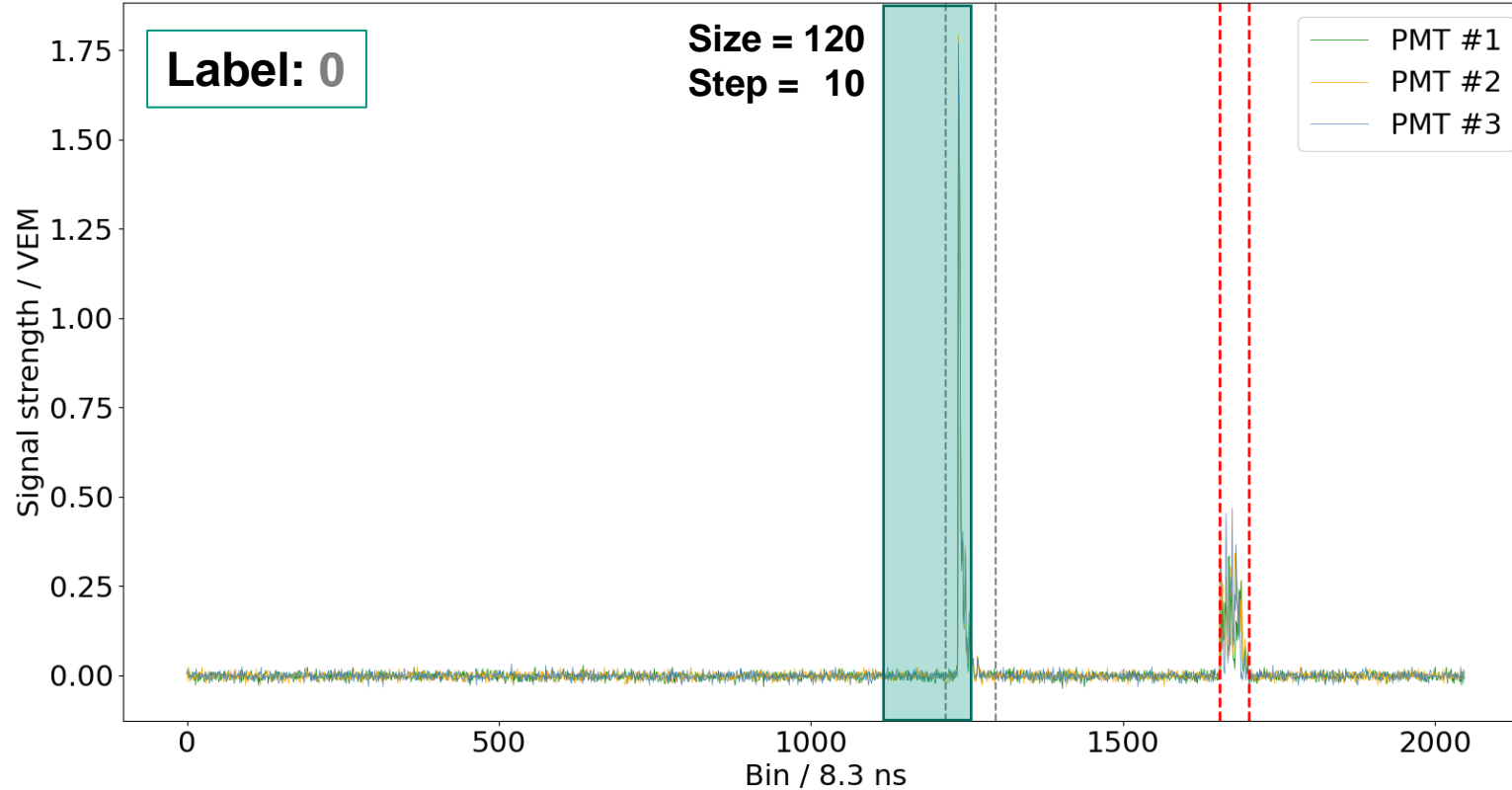
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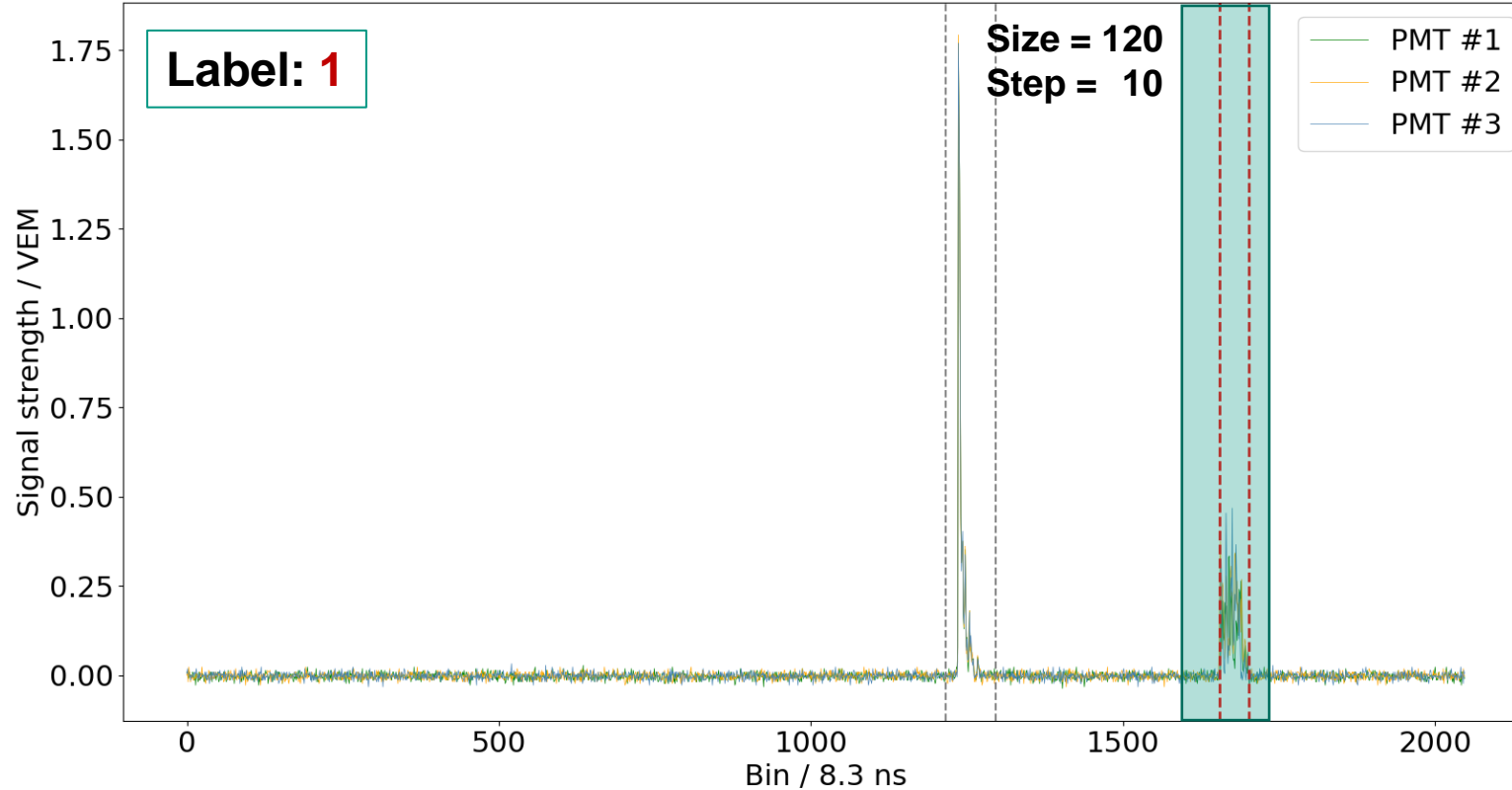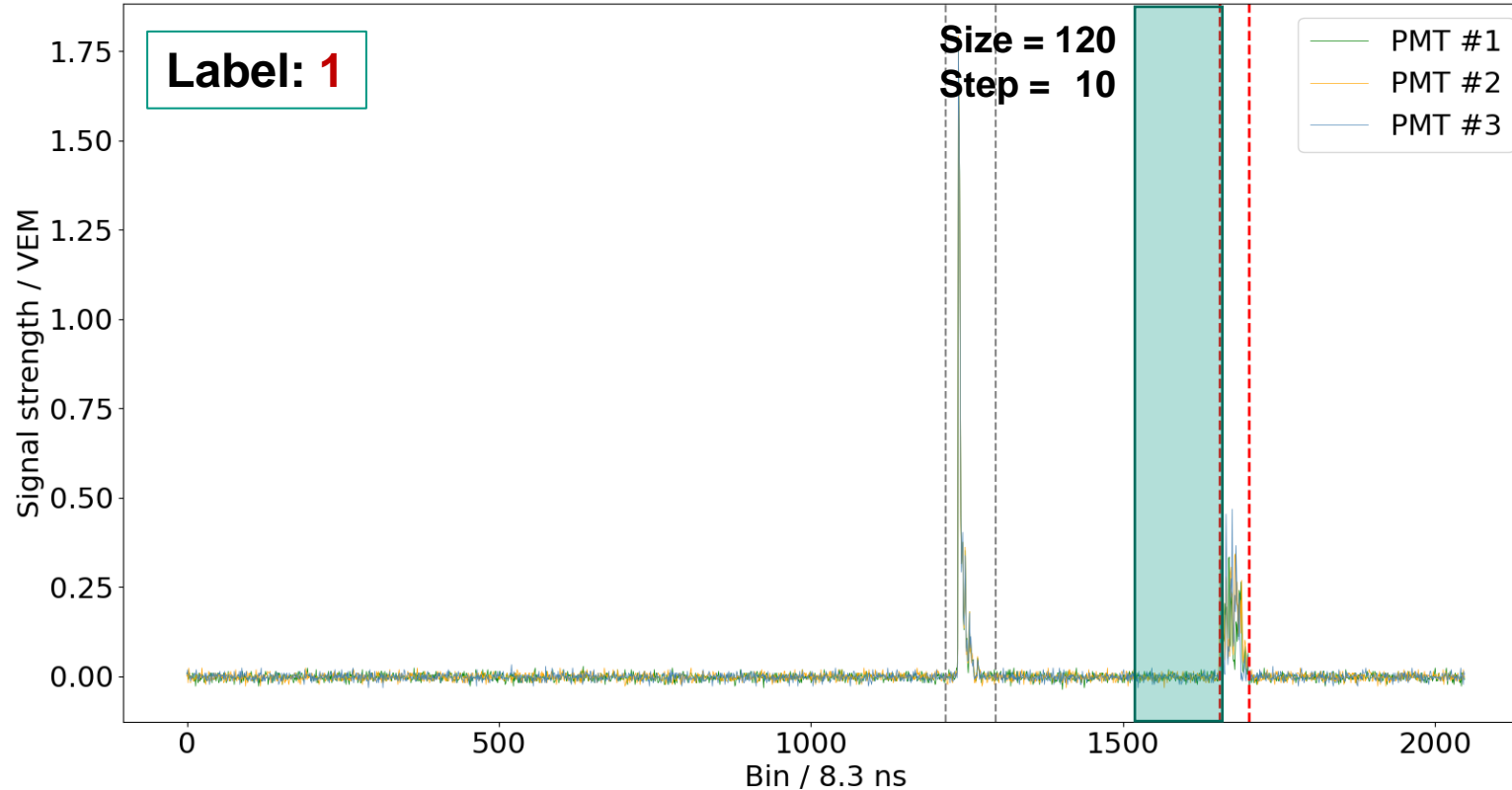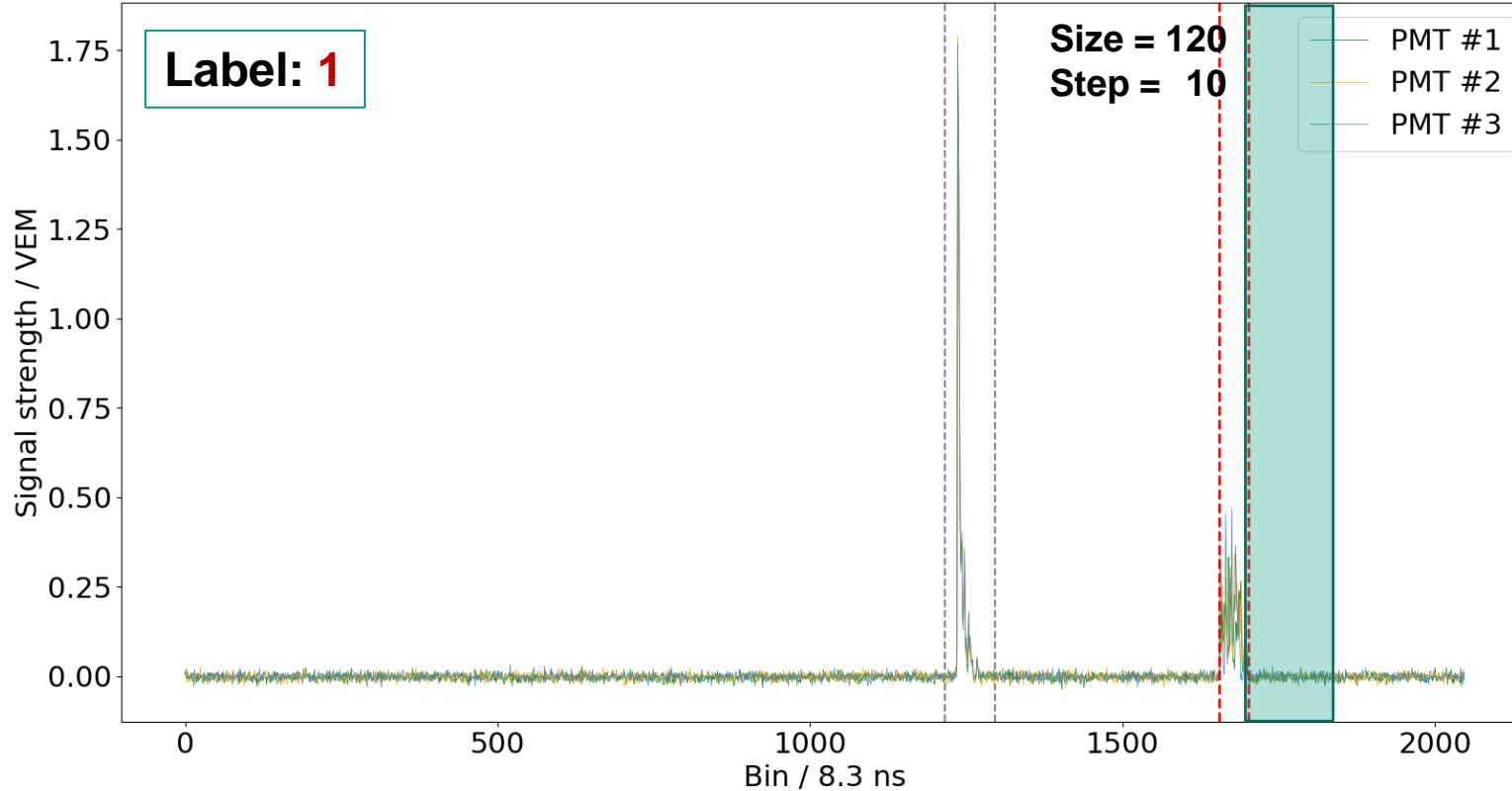
Sliding window analysis - performance

■ **Current triggers (Th, ToT)**

```
DATASET                                TP      FP      TN      FN
current trigger validation data        350736  571     562338  172183   -> Acc = 84.09%, TPR = 99.8375%




















(base) filip@iklx288:~/Trigger$ ▌
```

Sliding window analysis - performance

■ **Current triggers (Th, ToT)**

■ **One layer Conv2D, 92 parameters**

■ **Way higher accuracy, but also FPR**

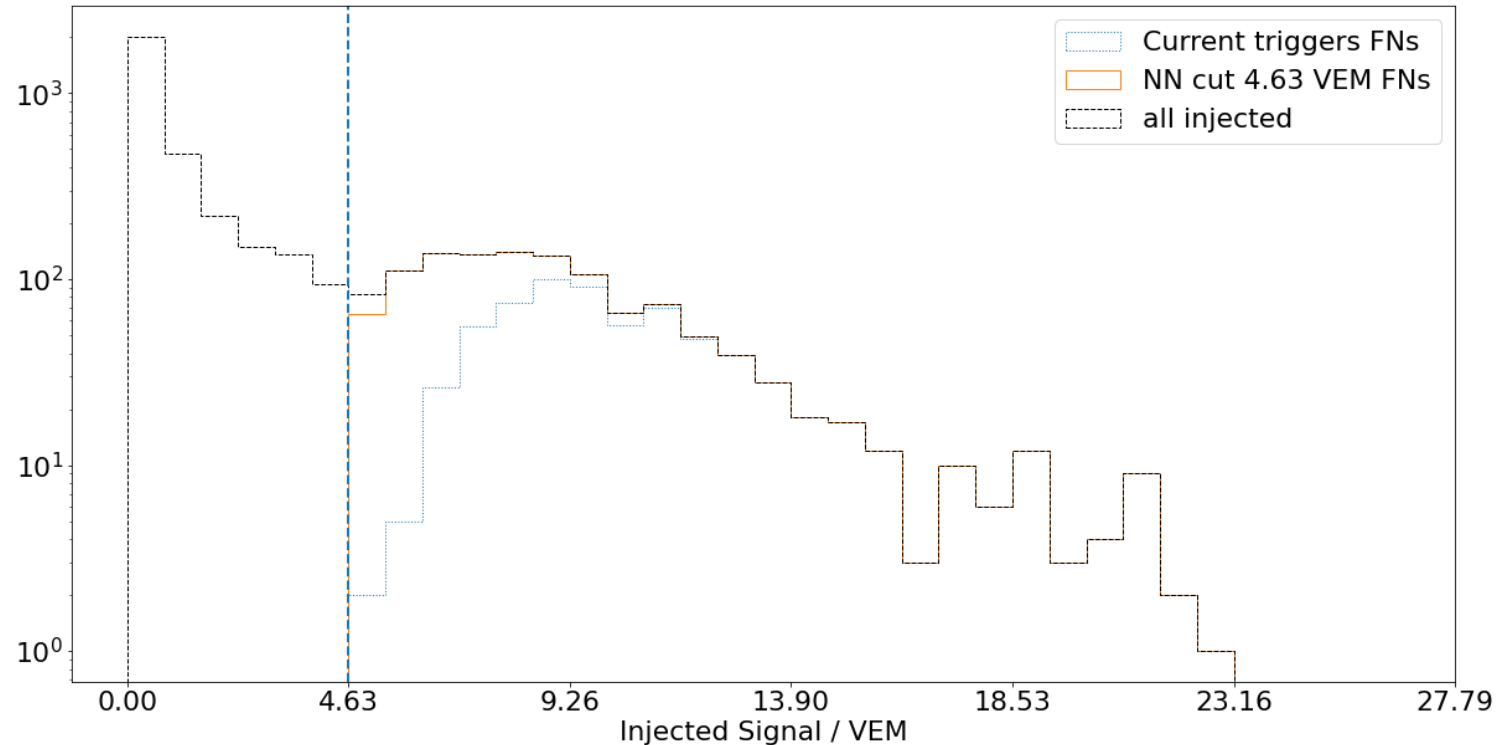| Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 1, 40, 1)	10
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dense (Dense)	(None, 2)	82

Total params: 92
Trainable params: 92

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current_trigger_validation_data                  350736   571    562338   172183   -> Acc = 84.09%, TPR = 99.8375%
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```

Sliding window analysis - performance

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Sliding window analysis - performance

- **Current triggers (Th, ToT)**
- **One layer Conv2D, 92 parameters**
- **Improve TPR by cutting on sum of signal**


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one_layer_conv2d_cut_0.50VEM_validation_data    493014   1481    561156   30177   -> Acc = 97.08%, TPR = 99.7005%
one_layer_conv2d_cut_1.00VEM_validation_data    479109   1283    560510   44926   -> Acc = 95.74%, TPR = 99.7329%
one_layer_conv2d_cut_2.00VEM_validation_data    451829   1008    561348   71643   -> Acc = 93.31%, TPR = 99.7774%
one_layer_conv2d_cut_4.63VEM_validation_data    401690   658     561498   121982  -> Acc = 88.71%, TPR = 99.8365%

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```

Sliding window analysis - performance

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- **Improve TPR by cutting on sum of signal**

BUT!!!

This is heavily dependant on the baseline parametrization

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current_trigger_random_traces	353635	496	561810	169887	-> Acc = 84.31%,	TPR = 99.8599%
one_layer_conv2d_cut_0.00VEM_random_traces	521655	192585	369787	1801	-> Acc = 82.10%,	TPR = 73.0364%
one_layer_conv2d_cut_0.20VEM_random_traces	510064	3541	558848	13375	-> Acc = 98.44%,	TPR = 99.3106%
one_layer_conv2d_cut_0.50VEM_random_traces	505383	3124	559179	18142	-> Acc = 98.04%,	TPR = 99.3857%
one_layer_conv2d_cut_1.00VEM_random_traces	491789	1734	560595	31710	-> Acc = 96.92%,	TPR = 99.6486%
one_layer_conv2d_cut_2.00VEM_random_traces	464368	1451	560927	59082	-> Acc = 94.43%,	TPR = 99.6885%
one_layer_conv2d_cut_4.63VEM_random_traces	524807	1171	712837	144989	-> Acc = 89.44%,	TPR = 99.7774%

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Baseline model comparison
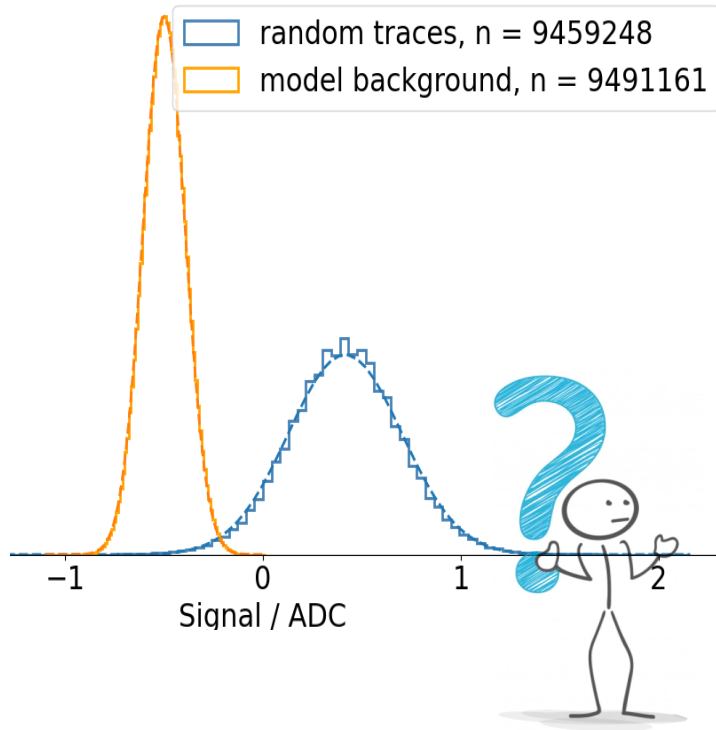
- **Model background:**
  - **Gaussian, $\mu = 0$ ADC $\sigma = 2$ ADC**
  - **Flooring causes mean $\mu = -0.5$ ADC**
  - **I.e. baseline assumed to be substracted**

- **Random traces:**
  - **Running estimate of baseline by FPGA**
  - **Baseline estimate substracted from trace**
  - **Different results from model background**

- **How to fix this?**

Baseline model comparison

legend: random traces, n = 9459248; model background, n = 9491161

x-axis: Signal / ADC
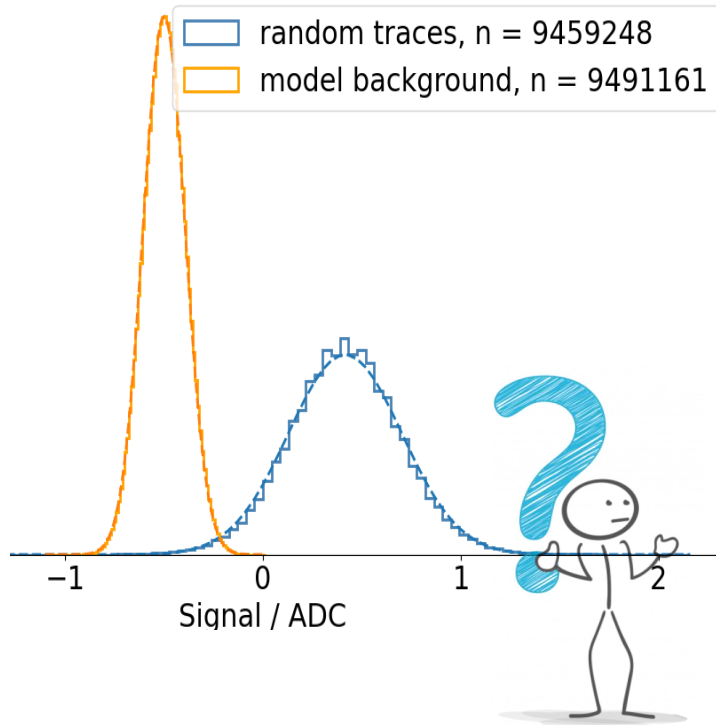
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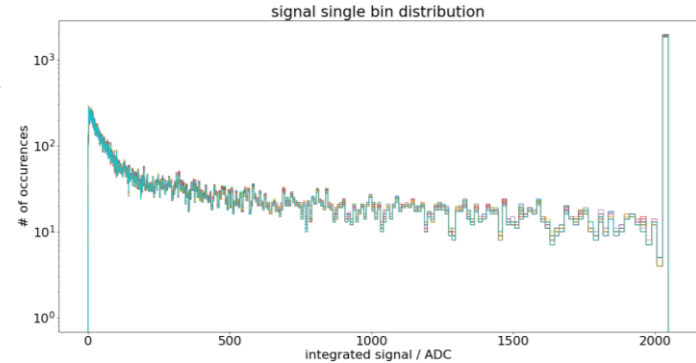 - **I.e. baseline assumed to be substracted**
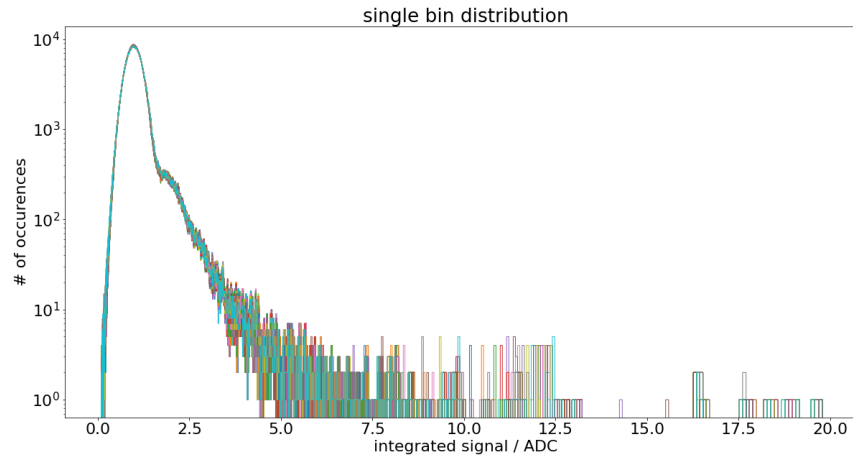
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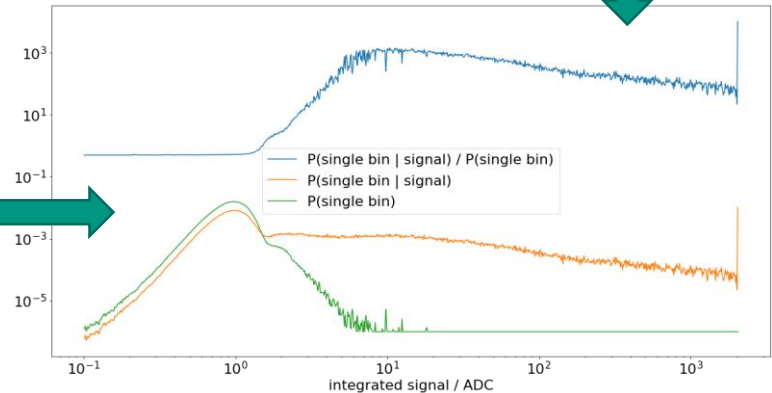WHY DONT WE TAKE THE TRACE

AND PUSH IT SOMEWHERE ELSE

Other idea – Bayesian/Likelihood classifier

$$\frac{P(\text{signal} \mid \text{bin})}{P(\text{signal})} = \frac{P(\text{bin} \mid \text{signal})}{P(\text{bin})}$$

signal single bin distribution

single bin distribution

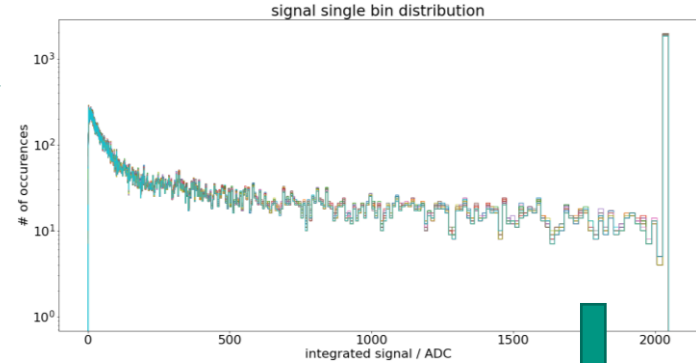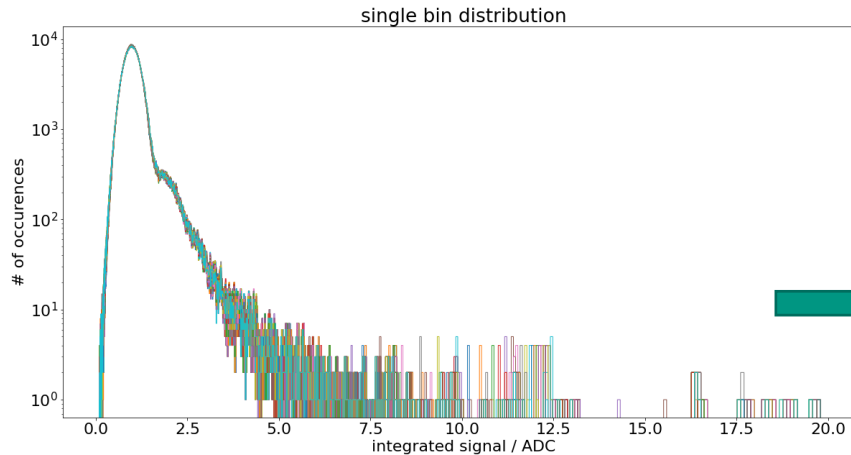Paul Filip – Machine learning triggers: a feasibility study   IAP, KIT Faculty for Physics

Other idea – Bayesian/Likelihood classifier

$$\frac{P(signal \mid bin)}{P(signal)} = \frac{P(bin \mid signal)}{P(bin)}$$

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bayes_m249_validation_data                 364932  590     562087  159570   -> Acc = 85.27%, TPR = 99.8386%
bayes_m244_validation_data                 266671  225     561764  257168   -> Acc = 76.30%, TPR = 99.9157%

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bayes_m249_random_traces                   365671  1104    561202  157851   -> Acc = 85.36%, TPR = 99.6990%
bayes_m244_random_traces                   267310  351     562021  256146   -> Acc = 76.38%, TPR = 99.8689%
(base) filip@iklx288:~/Trigger$
```

- **Fast and easy to implement**
- **Check full potential by tweaking hyper-parameters**