Istituto Nazionale di Fisica Nucleare

Update on dRICH DAQ & Data Reduction

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for
INFN Roma1&2

dRICH Meeting - Updates for PID Review
March 19 2025

Realistic Noise Model

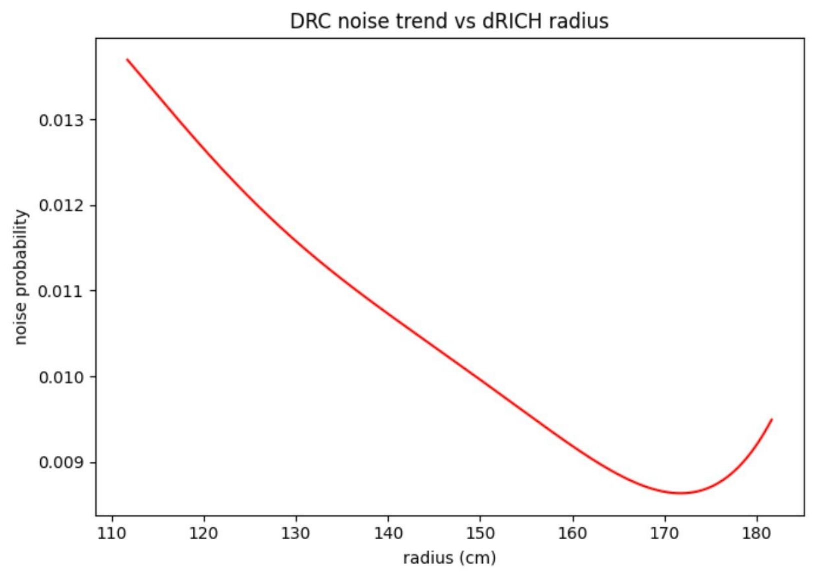
Thanks to R. Preghenella's contribution , we added to the toy noise model ("gaussian") a new "realistic" one in which the Dark Count probability of a certain dRICH SiPM is dependent on its radial distance from the detector z-axis and on the integrated luminosity

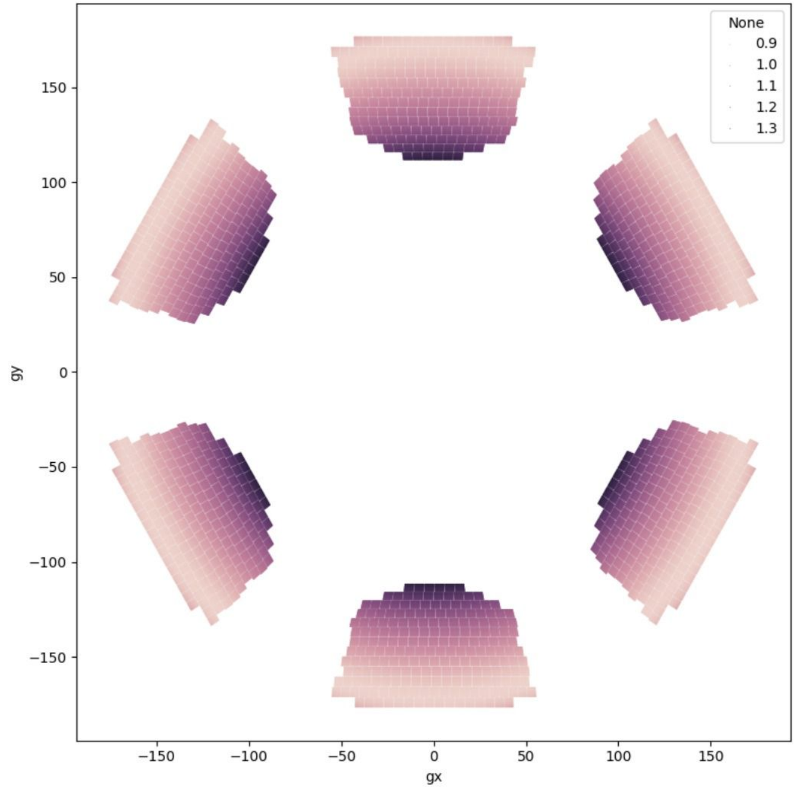
⇒ Implemented in EICRecon digitization step (new flag to enable new model noise)

```
const float baseline_dcr = 3.e3; // [Hz] new sensors at T = -30 C and Vover = 4V
const float dcr_increase = 300.e3 / 1.e9; // [Hz/neq]
float neq_radius_params[6] = { -3.27029e+09, 1.26055e+08, -1.88568e+06, 13929.1, -50.9931, 0.0741068 };

float neq_radius(float radius /* cm */)
{
  float neq = 0.;
  for (int ipar = 0; ipar < 6; ++ipar)
    neq += neq_radius_params[ipar] * std::pow(radius, ipar);
  return neq;
}

float
noise_probability(float radius = 150. /* cm */, float window = 10. /* ns */, float luminosity = 100. /* fb-1 */)
{
  float neq = neq_radius(radius) * luminosity;
  float dcr = baseline_dcr + dcr_increase * neq;
  float pro = dcr * window; //* 1.e-9;
  return pro;
}
```

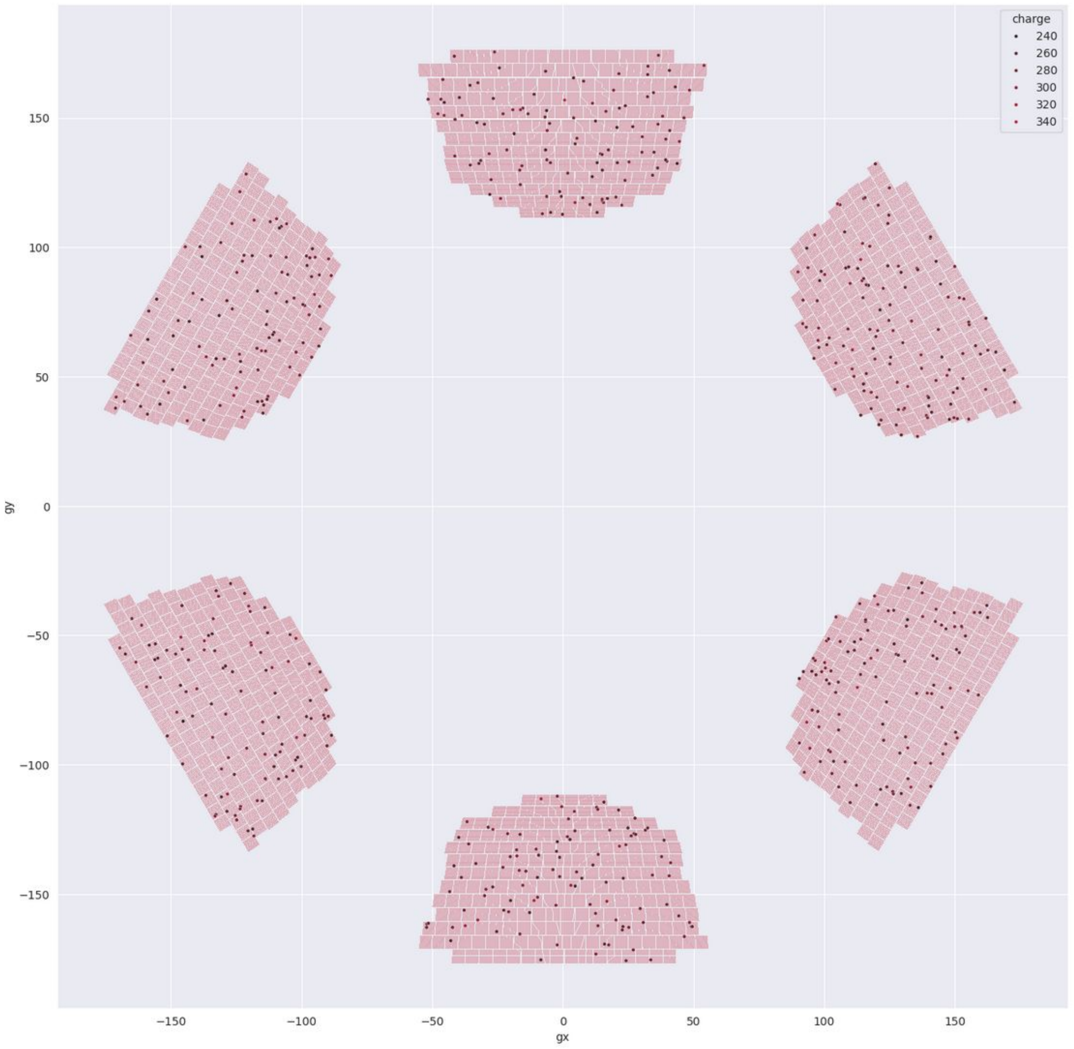
Reconfigurable parameters, used for the new dataset:

- **(Noise) Time window = 10 ns**
- **(Integrated) Luminosity = 20 fb-1**

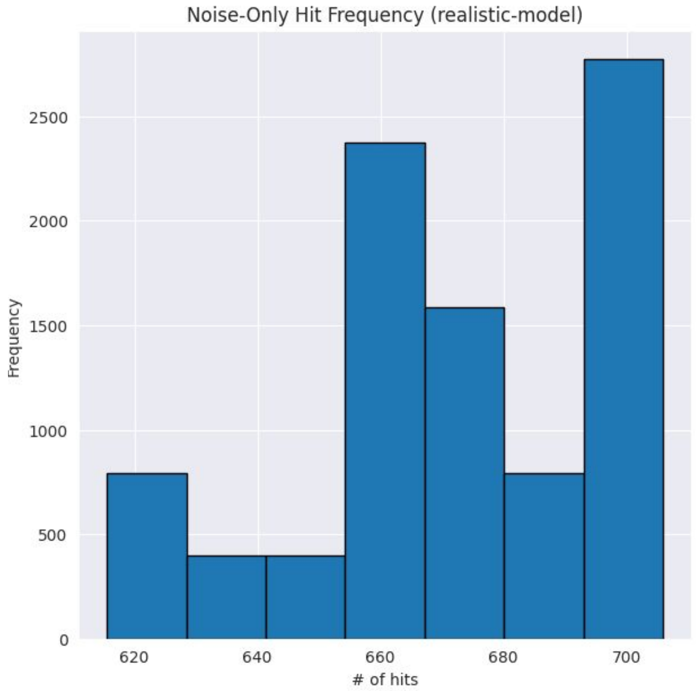


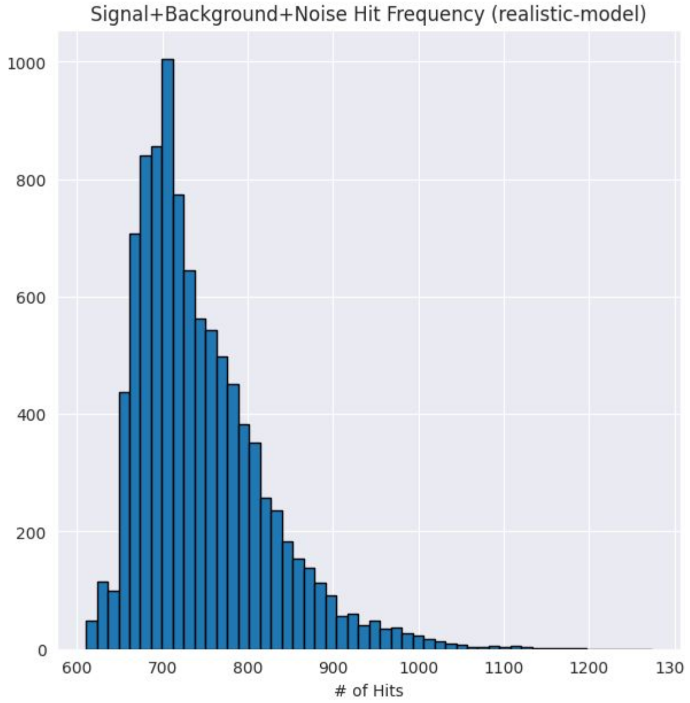


Updates to the Data Reduction Pipeline



With the new “realistic” noise model, the **global density of dark count noise hits** within the selected events has increased with respect to the previous dataset used for training and testing.
⇒ we decided to maintain the same NN model architecture (in order to cope with the hardware constraints) and to re-train the whole model with the new dataset





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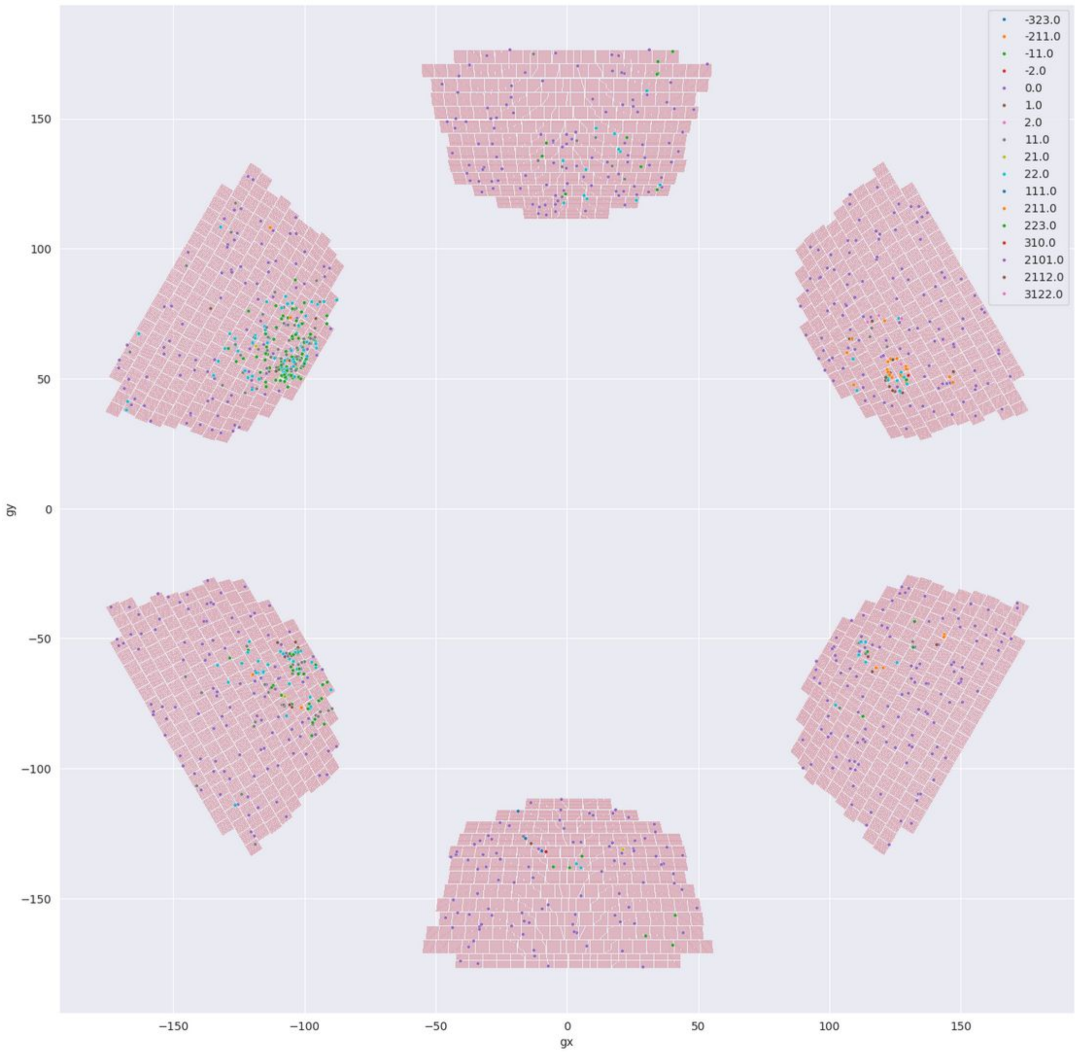
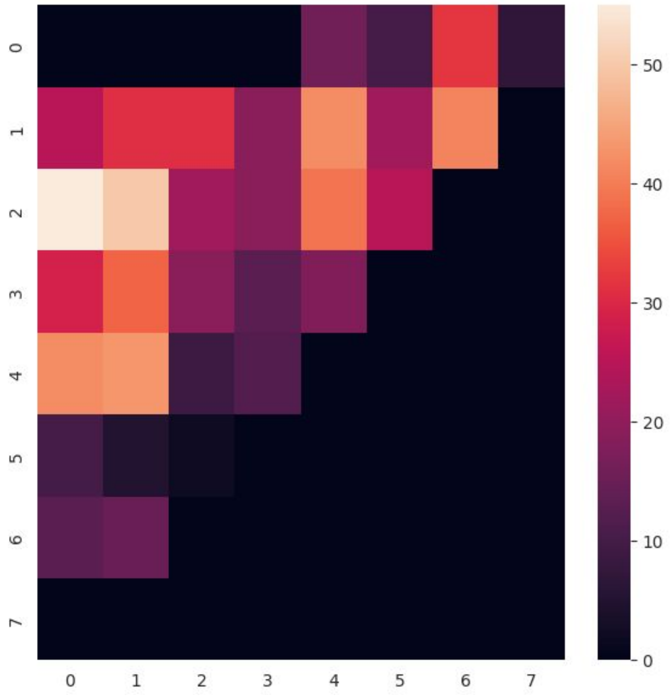
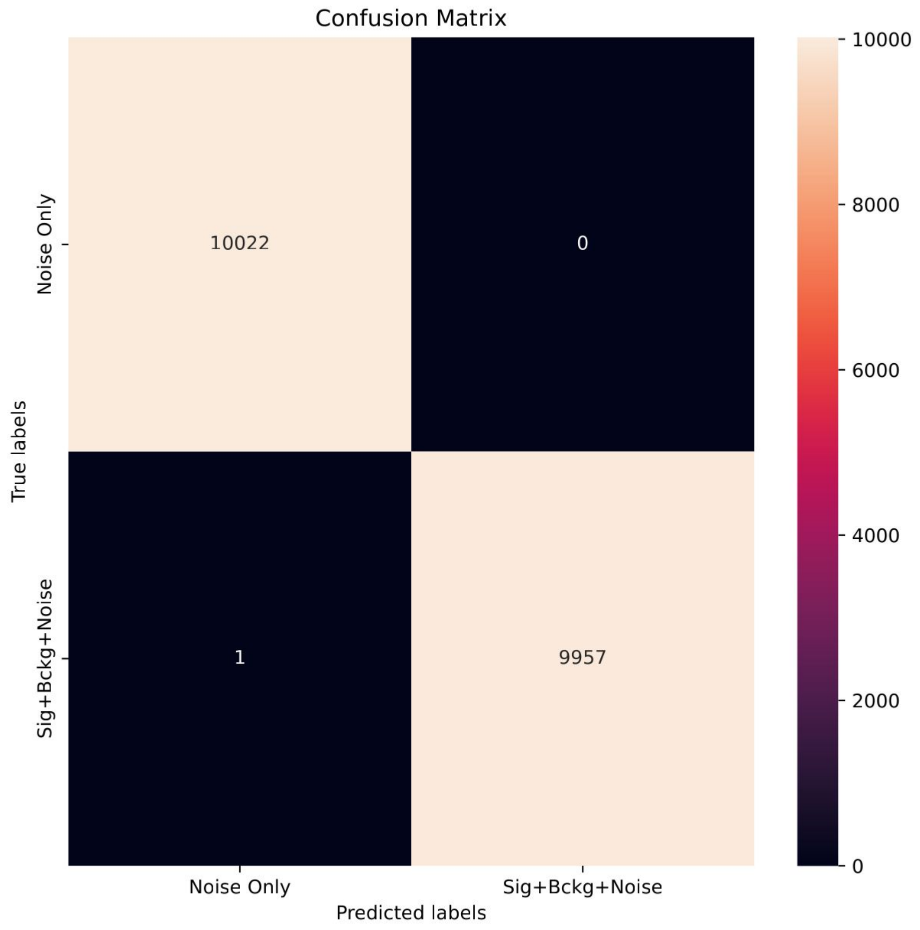


⇒ taking as example a **background event**, we can see how the **pixel intensity in input to the MLP_DAM NN** has increased wrt to the previous cases

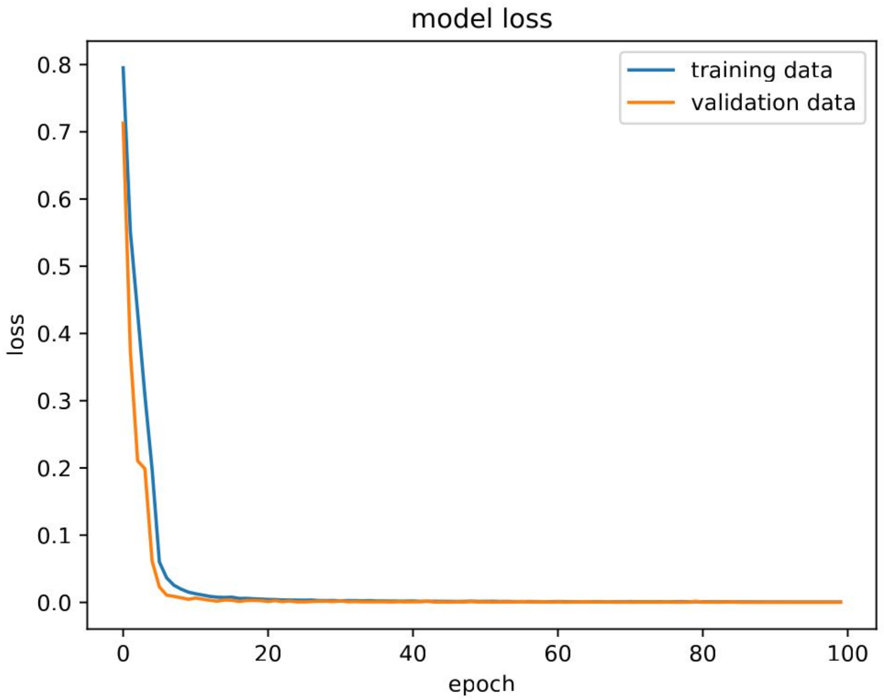


⇒ we explore several new preprocessing steps (rescaling, normalization,...) to take care about this new feature in the data

Results with the new noise model & pipeline



- **Accuracy =** (TP+TN)/(TP+TN+FP+FN) = **0.9999**
- **Purity =** TP/(TP+FP) = **0.9999**
- **Efficiency =** TP/(TP+FN) = **1.0000**



- (Noise) Time window = 10 ns
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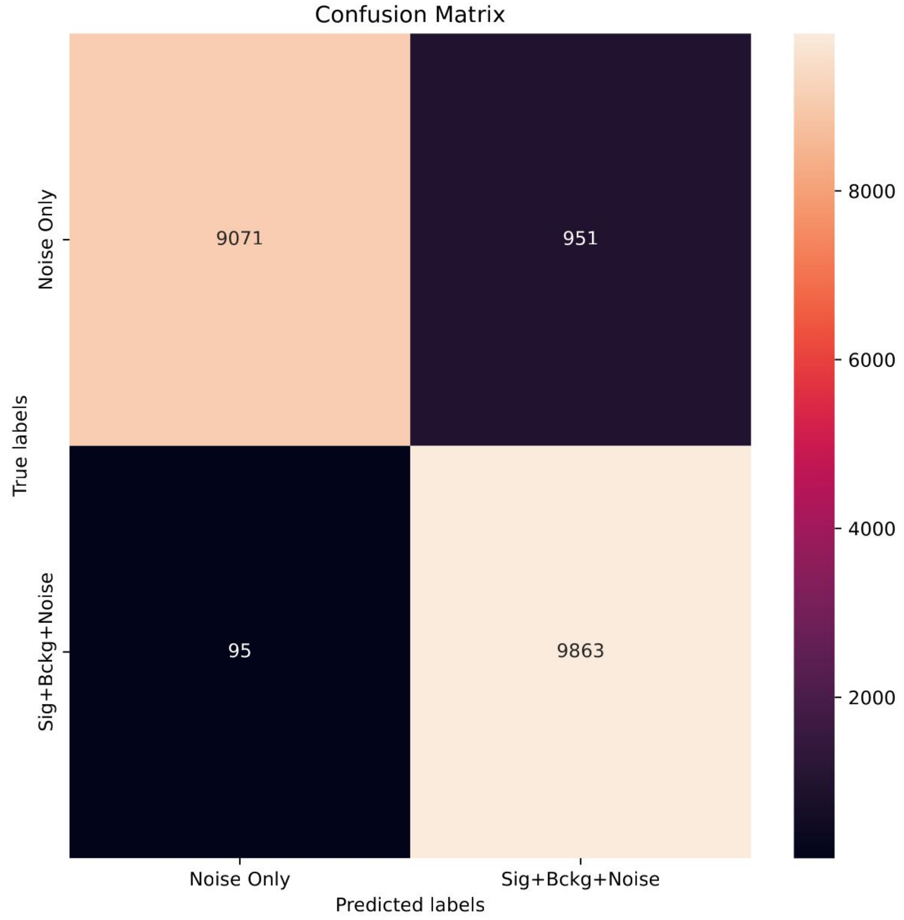
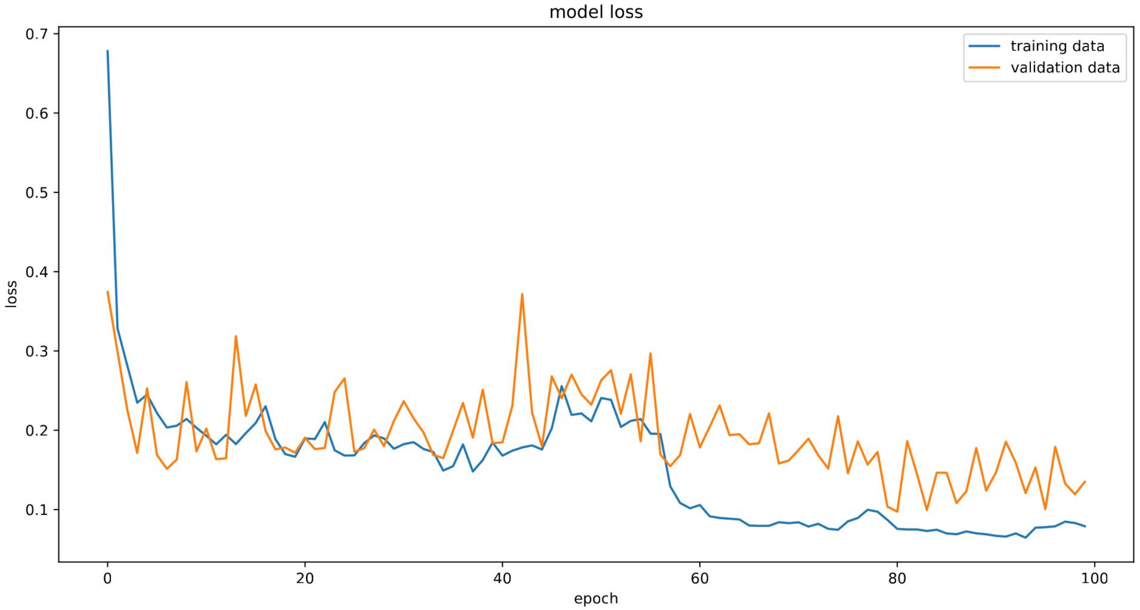


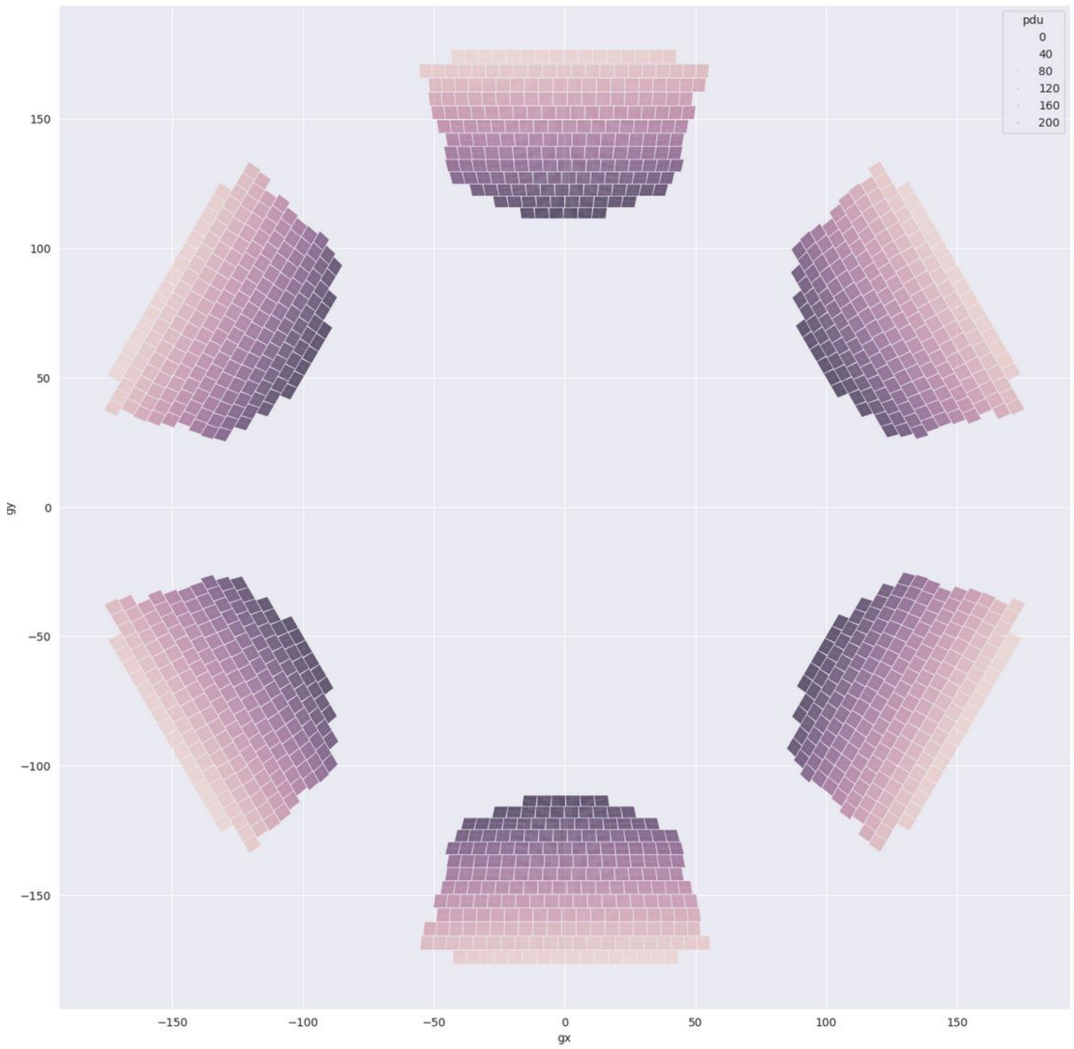
- **Accuracy =** (TP+TN)/(TP+TN+FP+FN) = **0.9476**
- **Purity =** TP/(TP+FP) = **0.9896**
- **Efficiency =** TP/(TP+FN) = **0.9051**



Model Quantization:

- **Inputs, Activations: fixed point<16,6>**
- **Weights, Biases: fixed point<8,1>**

Evaluation for HW implementation



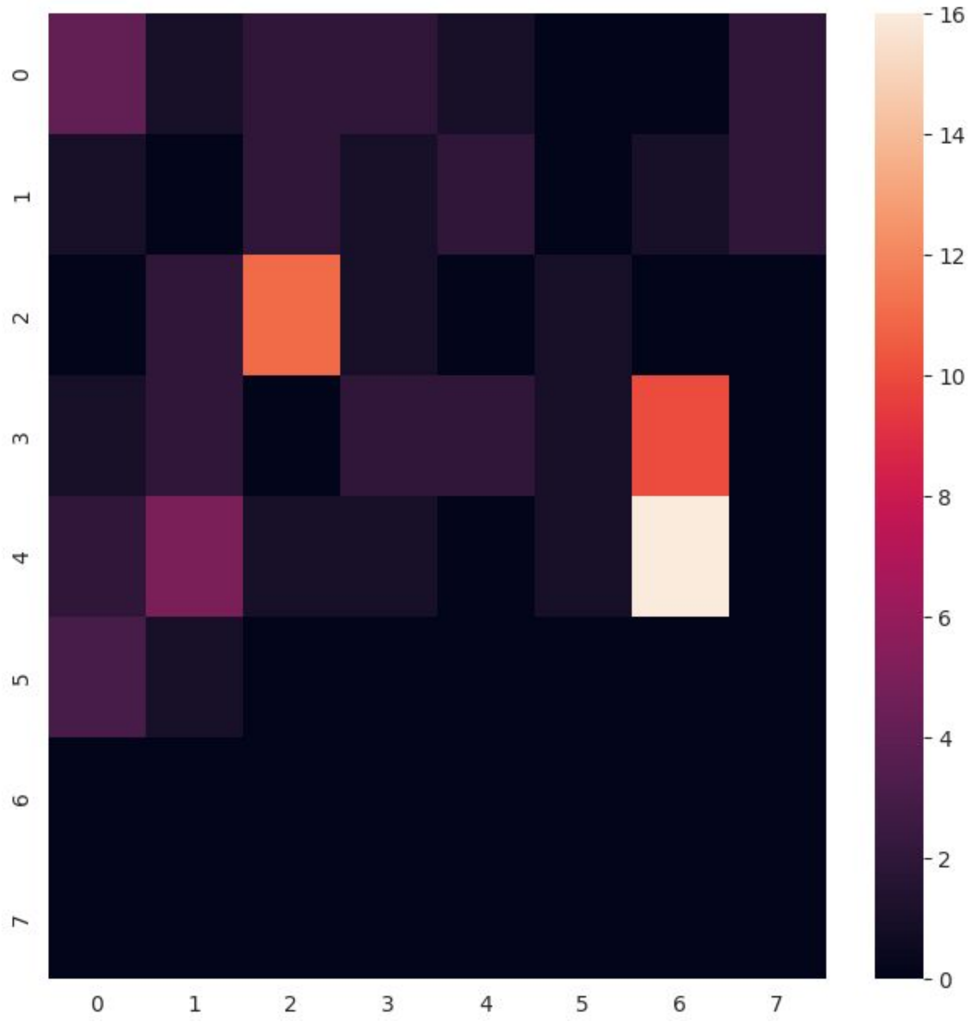
From our design proposal, we indicate **42 input links for each DAM** occurring into the streaming readout data reduction computation.
This number (42) is coherent with the number of expected PDUs per subsector (~210/5 = 42).

Thus, to cope with the realistic composition of the dRICH hardware readout, we explore the possibility of taking the **information of each PDU as input** for the respective subsector MLP NN model

⇒ each pixel of the MLP input grid now corresponds to a single PDU

⇒ **42 SiPM/pixel**

Evaluation for HW implementation ⇒ PDUs as input



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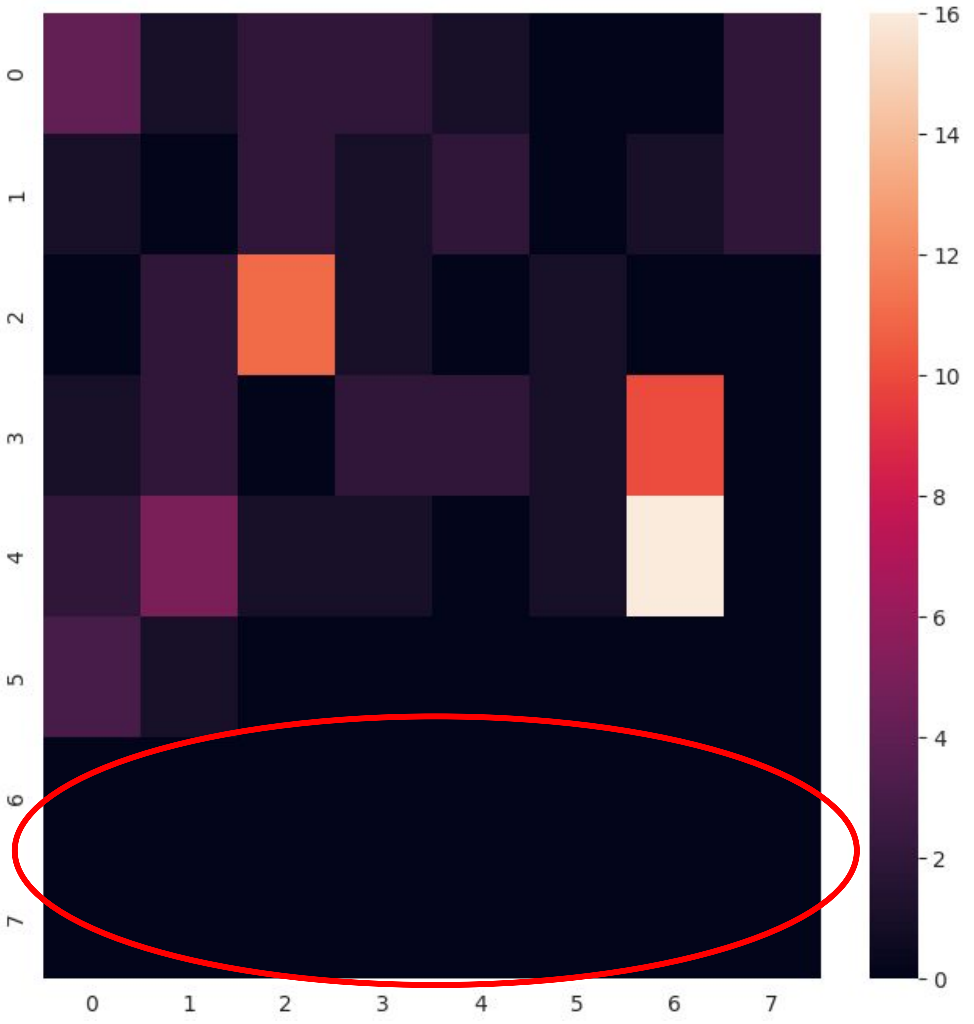

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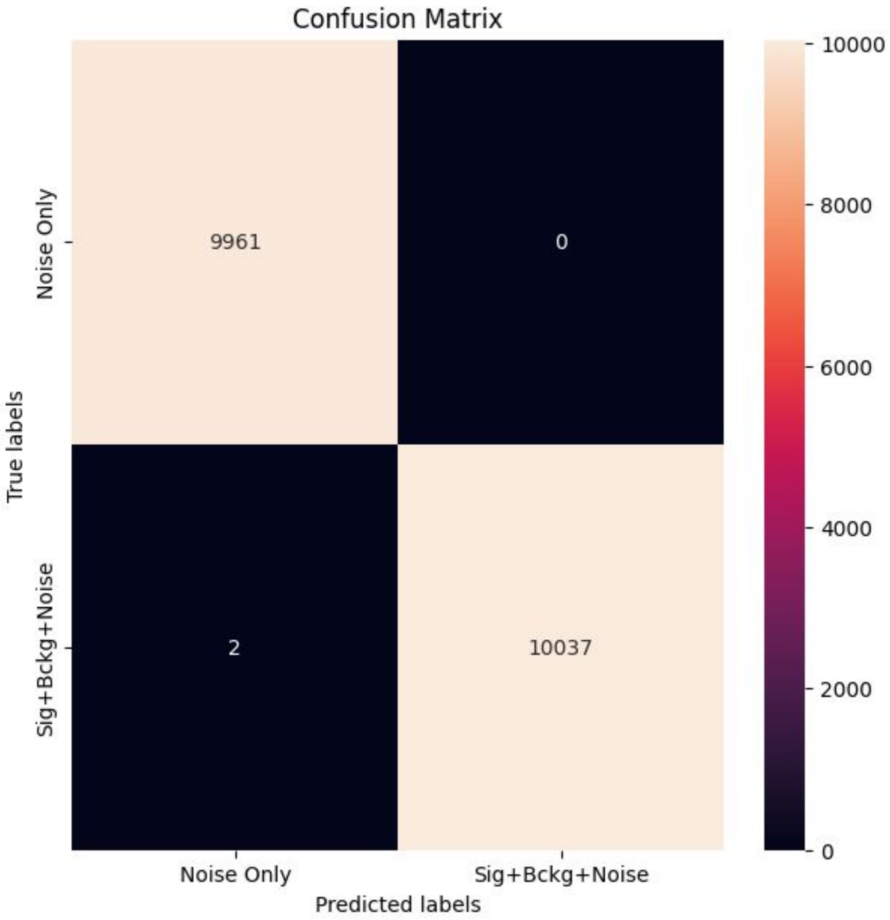
PDUs as input ⇒ Results with realistic noise



- **Accuracy =** (TP+TN)/(TP+TN+FP+FN) = **0.9999**
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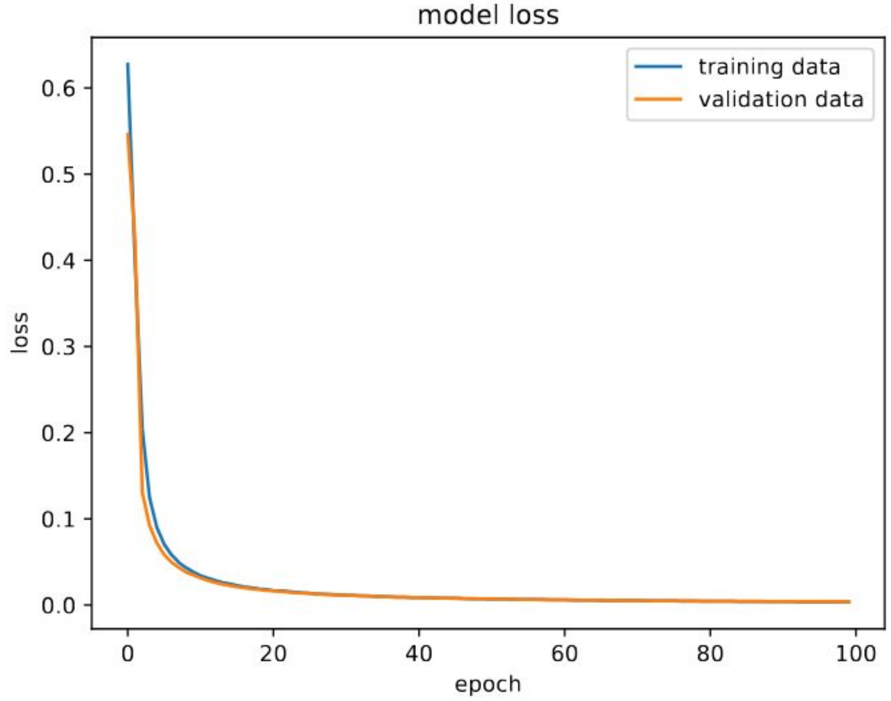

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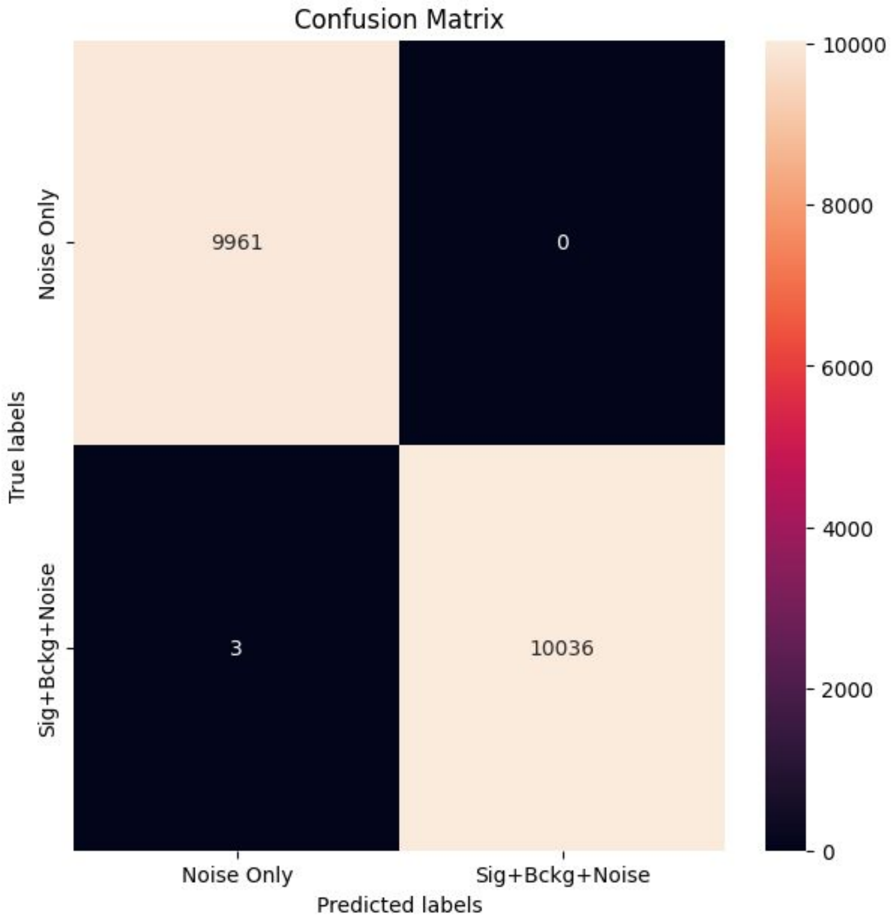

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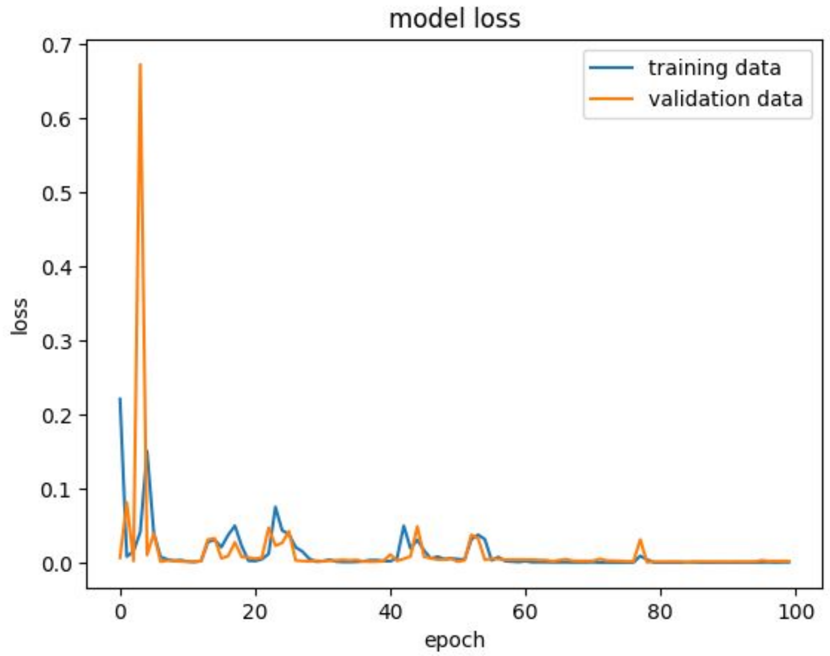

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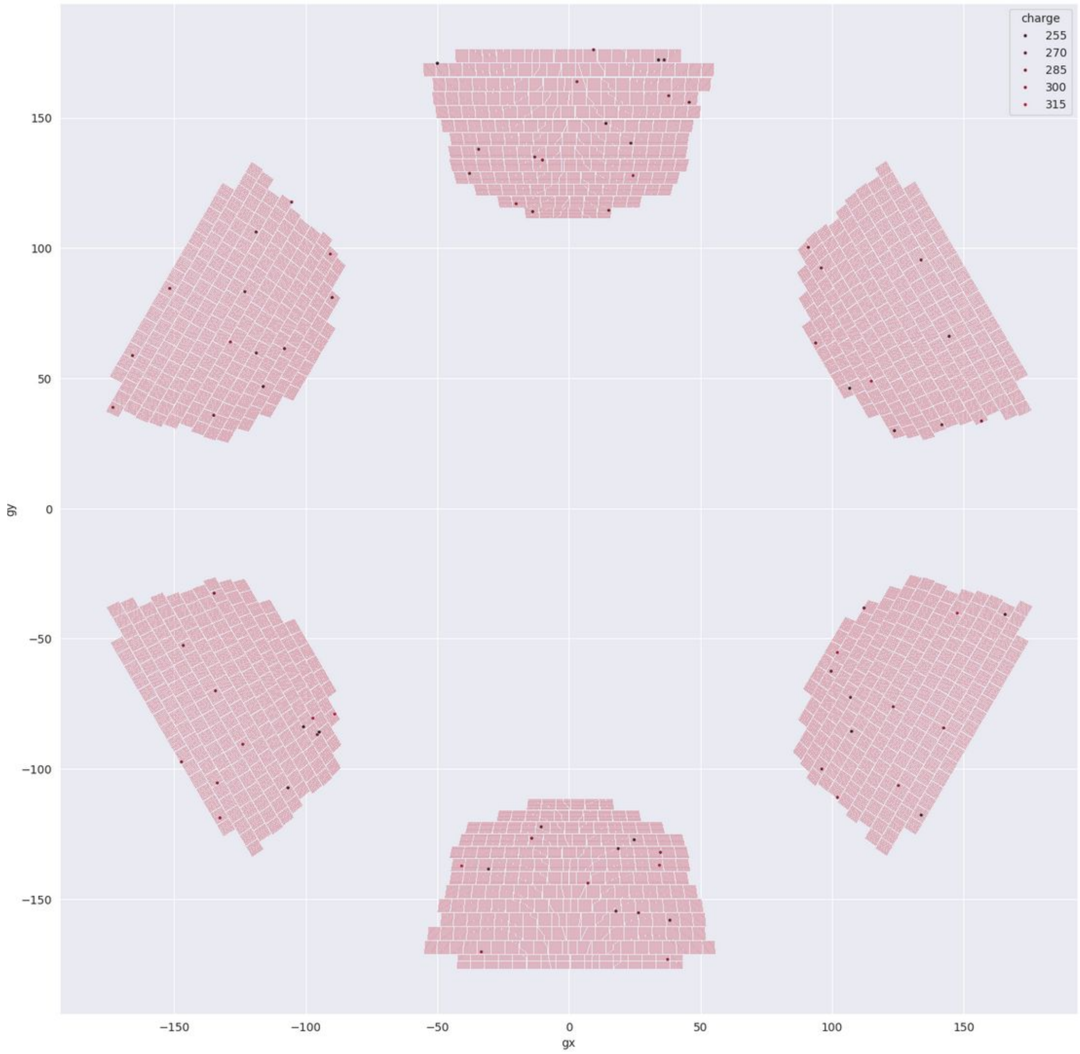
Realistic-Model + PDUasInput ⇒ Luminosity = 2fb-1



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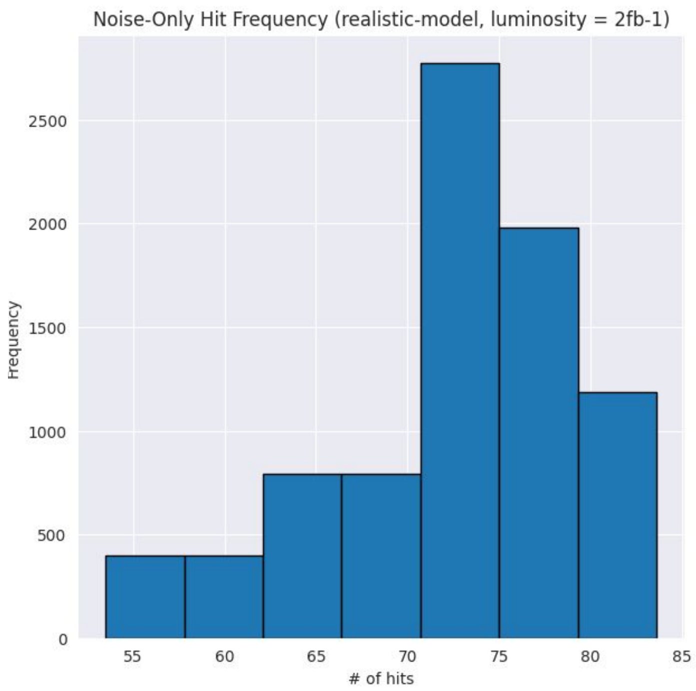

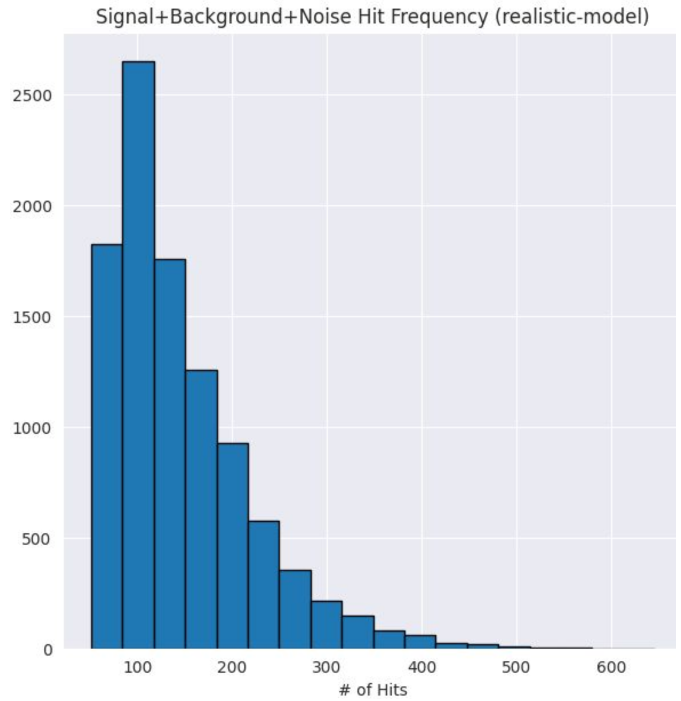

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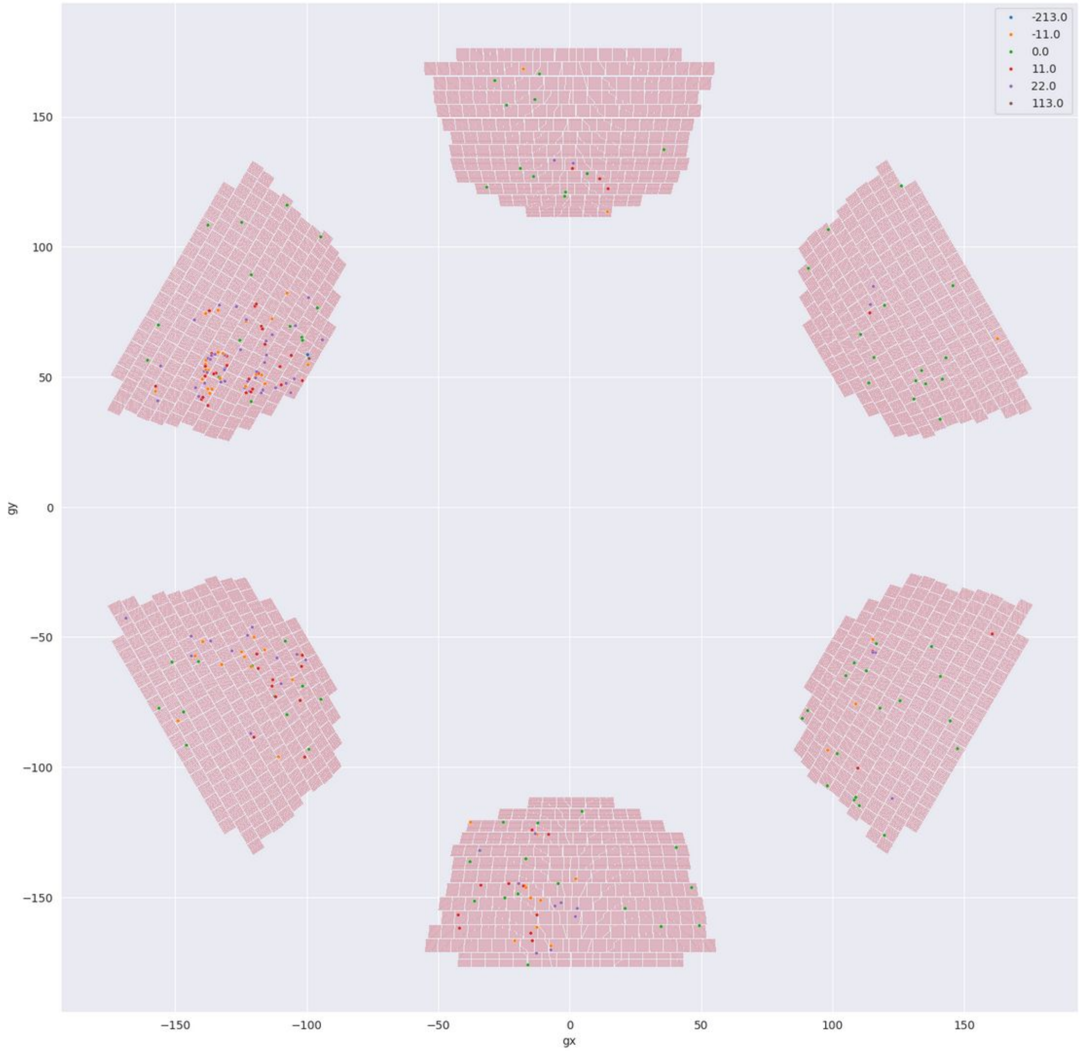

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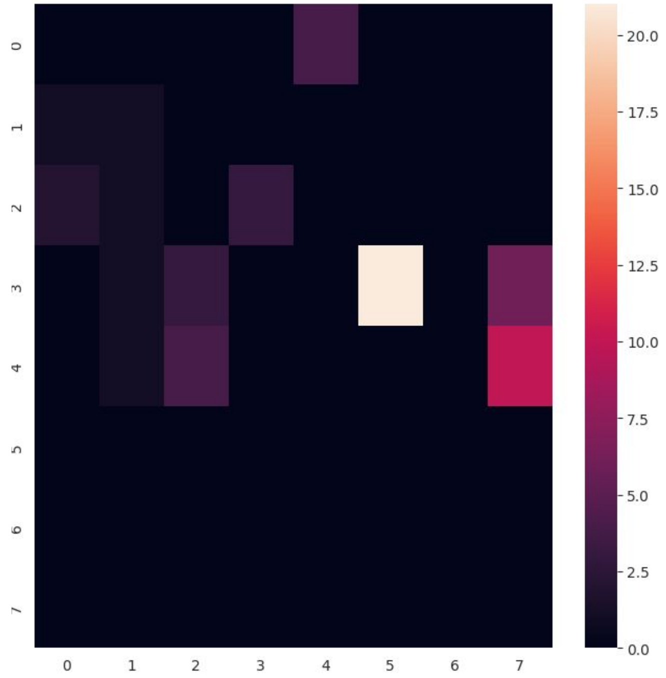

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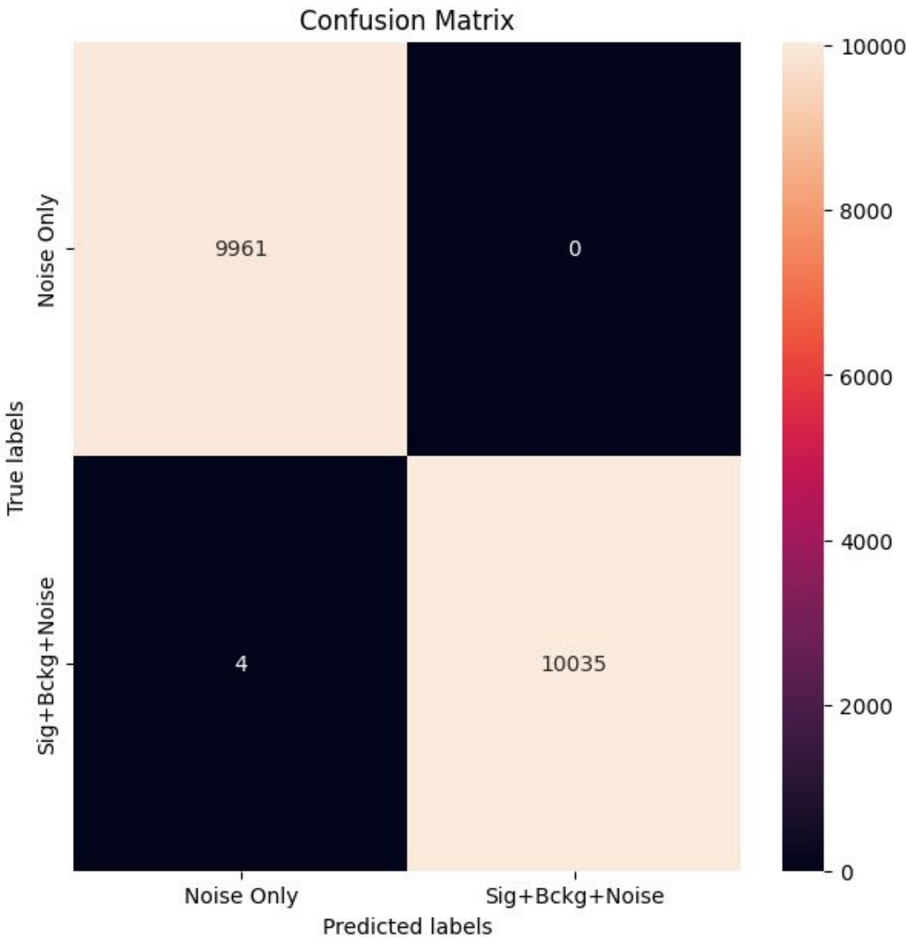
PDUs as input ⇒ Results with Luminosity = 2fb-1



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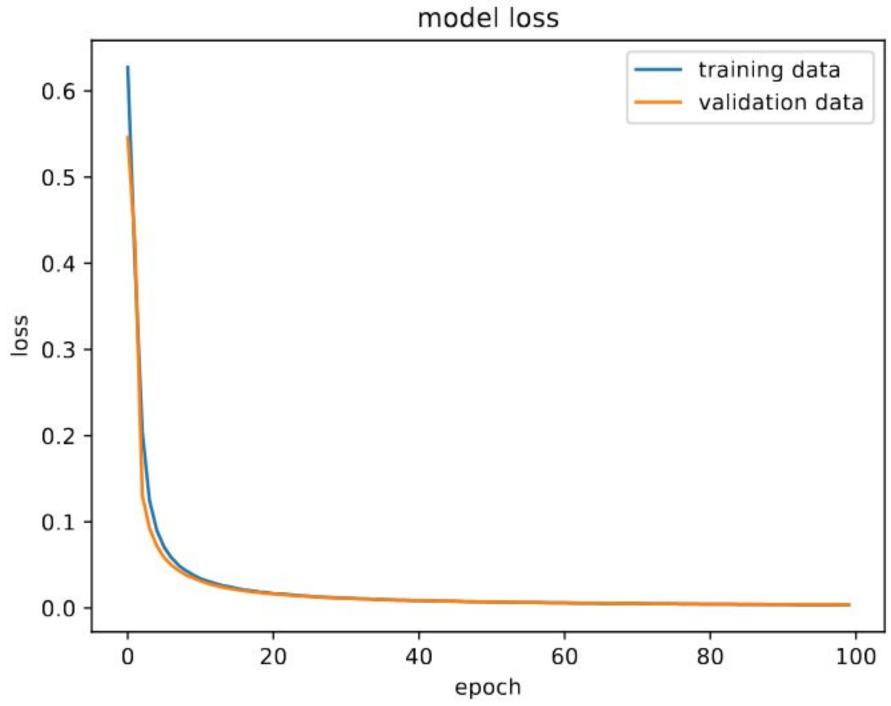

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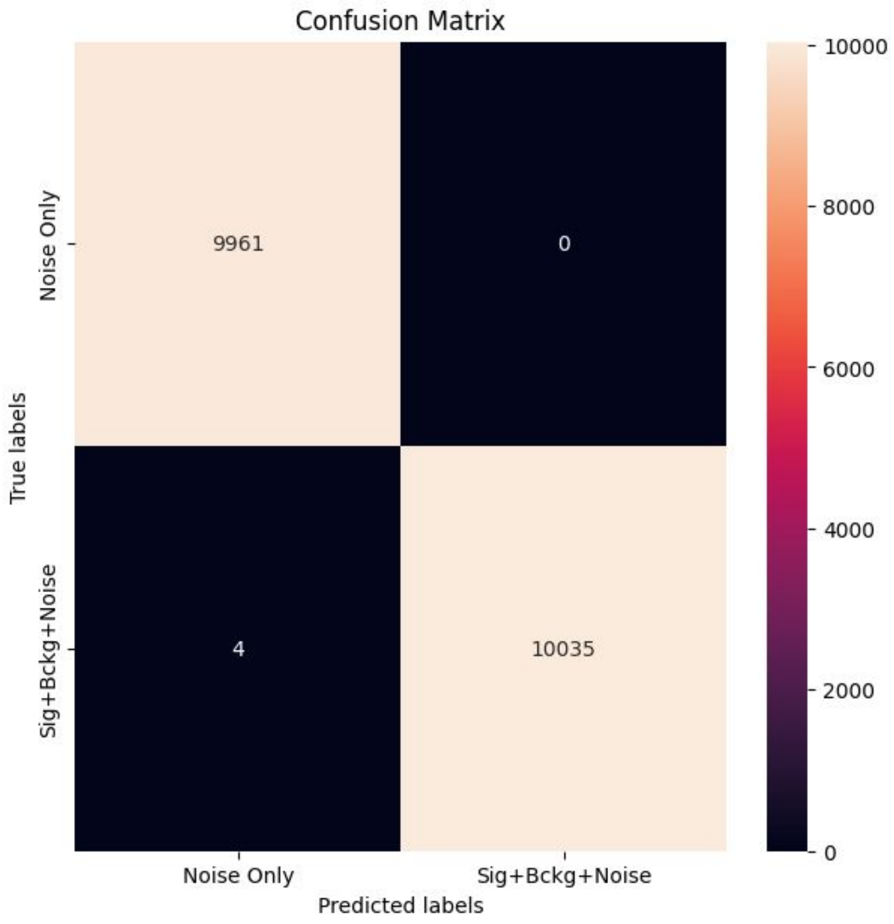

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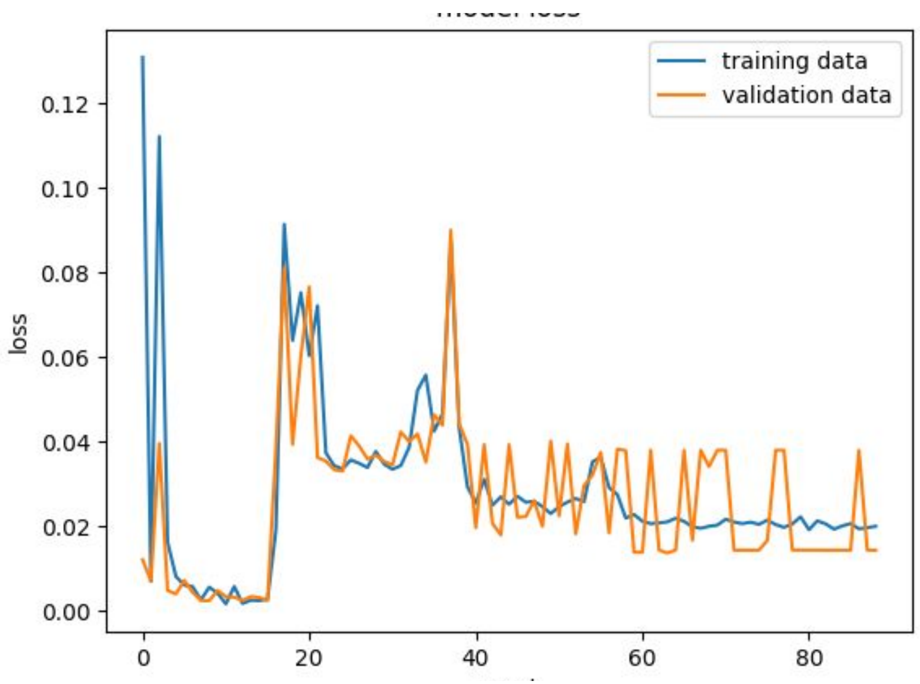

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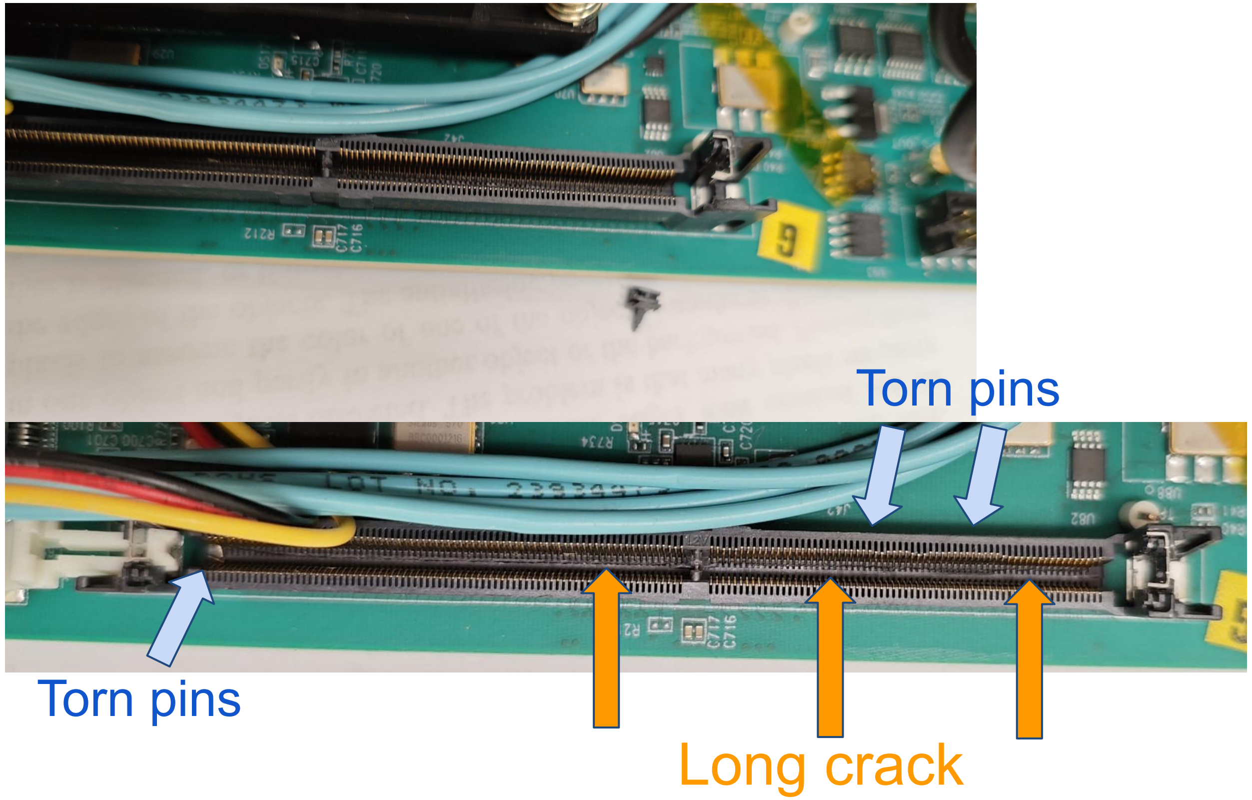
Procurement of one Felix-182 Card



Felix-182 board arrived from JLab in Rome end of December '24

Unfortunately it showed damages to the DRAM slot:

- **torn contact pins**
- **a crack along the inner side of the slot toward the FPGA**

Maybe they occurred due to the pressure of a DRAM module left in the slot during the delivery (bad packaging).

As a consequence, DRAM is not detected by the system.

We tried to load some standard fw to the board but it was not possible because the DRAM check failed.

We consulted with:

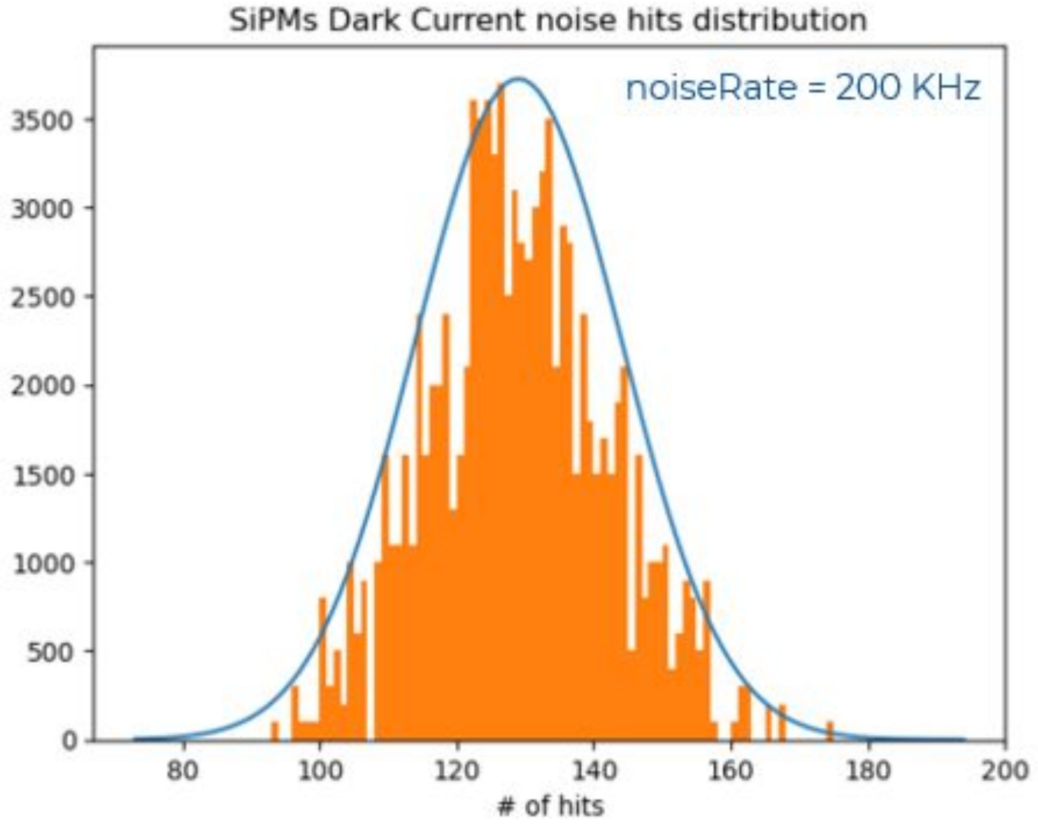
- the INFN Electronics Laboratory in Rome
- CERN EP-ESE Electronic Systems for Experiments (thanks to Markus Joos)

Both concur that is extremely difficult to repair the DRAM slot and not worth the effort considering the costs and the likely not optimal result, we are sending it back.

Backup Slides

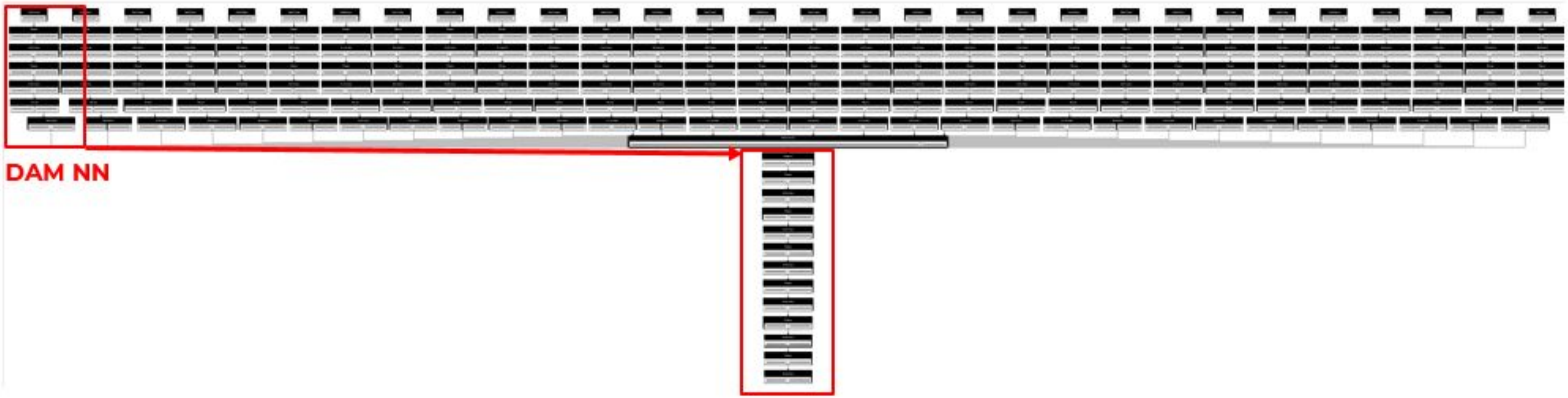
dRICH Data reduction: Input Data (Features Definition)

- **Gaussian** dark current SiPM **noise hits distribution,** obtained by modifying EICRecon source:
- avg = noiseRate*noiseTimeWindow
- sigma = 0.1*avg
- noiseTimeWindow = 2 ns



dRICH Data Reduction: Tensorflow Model

- Coherently with the hardware design composition of the proposed system, we trained **30** (# of subsectors x #number of sectors) **concatenated MLP networks** into a single MLP model to be deployed on 30 DAM FPGAs + 1 TP FPGA

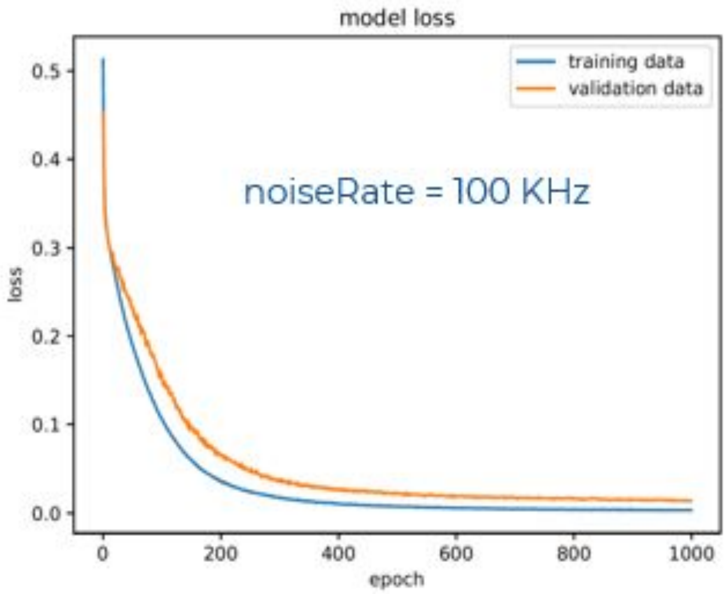


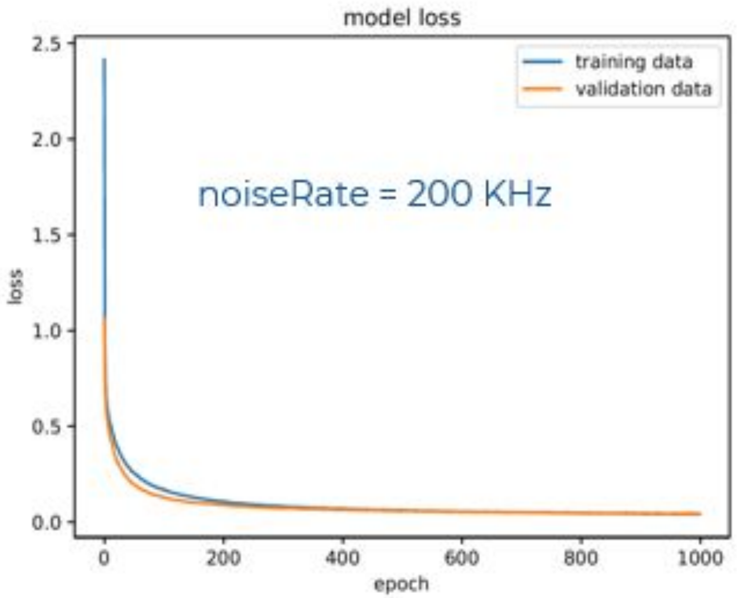
DAM NN

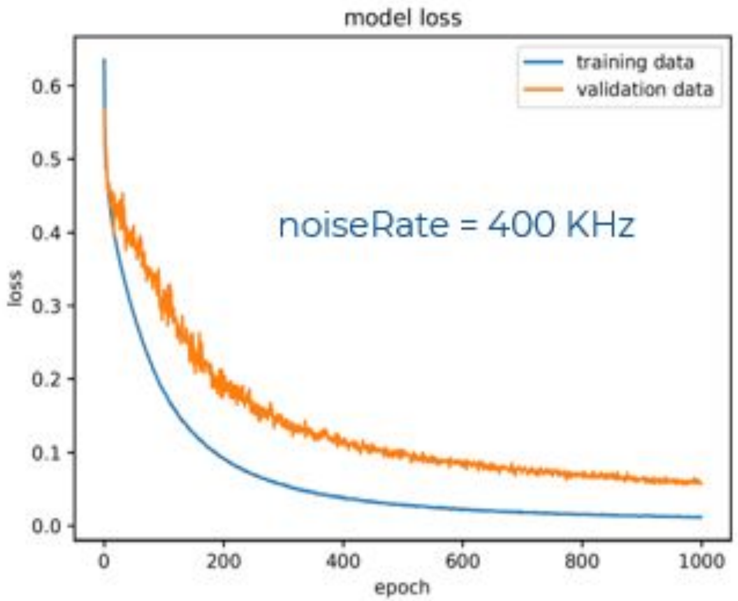
Trigger Processor NN

«Distributed MLP Model»

Model training & validation: Loss







Summary of Distributed MLP Performance