Trigger algorithm based on image processing

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Summary

1. Introduction

Motivation

- One of the biggest challenges for the **CYGNO experiment** in the long term will be to manage and store all the data produced by the detector.
  - Each run containing **400 images** need **~1.36 Gb** to be stored.
  - A **single day** of acquisition may produce **~266 Gb** of data.

- The main objective of this work was to study algorithms capable of **distinguishing** which images contain any kind of **signal** or only **electronic noise.**

- This proposal was called **image-based trigger algorithm.**

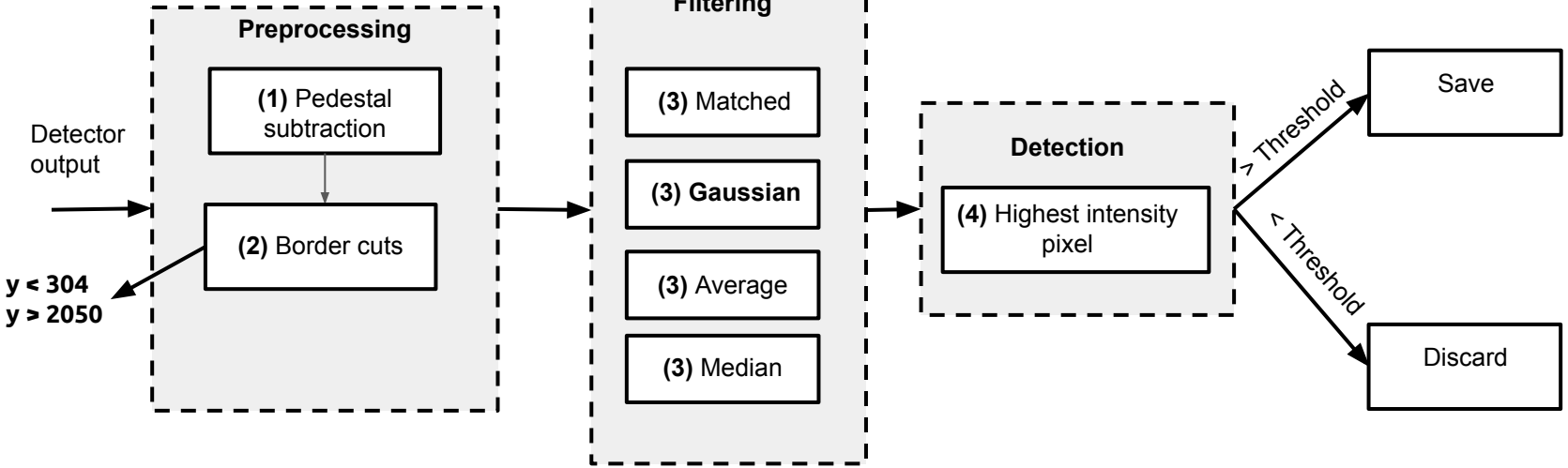
What was done

- **Two algorithms were proposed:**
  - Based on **filtering.**
  - Based on **CNN.**

- **Comparative analysis:**
  - **Detection performance** on low energy simulated signals.
  - **Time** analysis.
  - Comparison with the **reconstruction algorithm.**

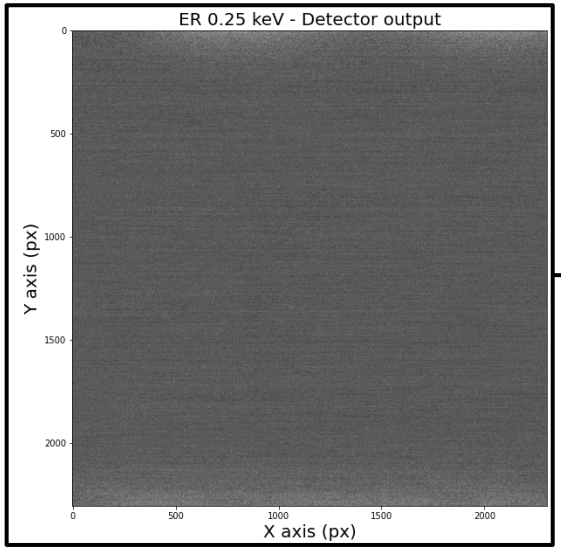
2. Algorithms

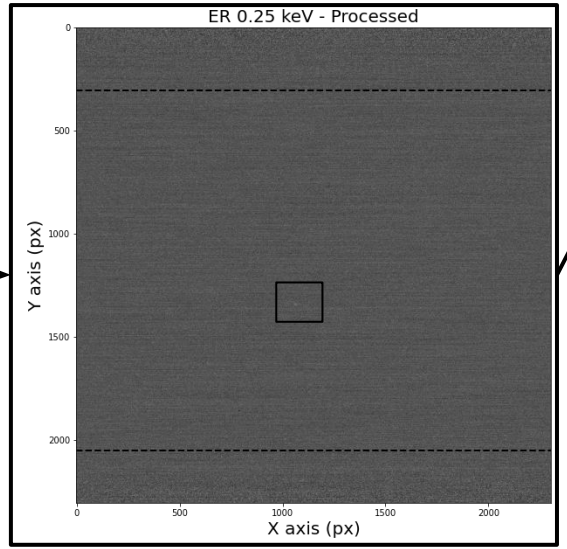
Trigger based on filtering

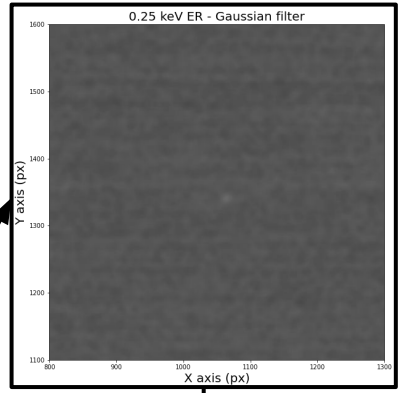


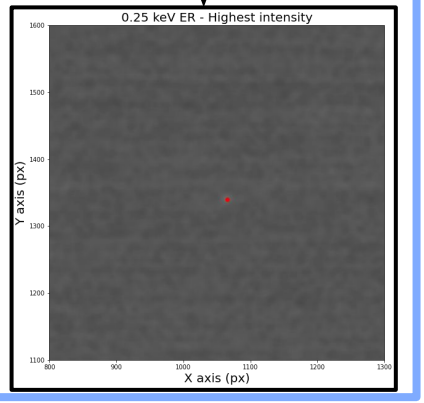
The optimal filter parameters should be selected
The optimal threshold should be selected

Trigger based on filtering

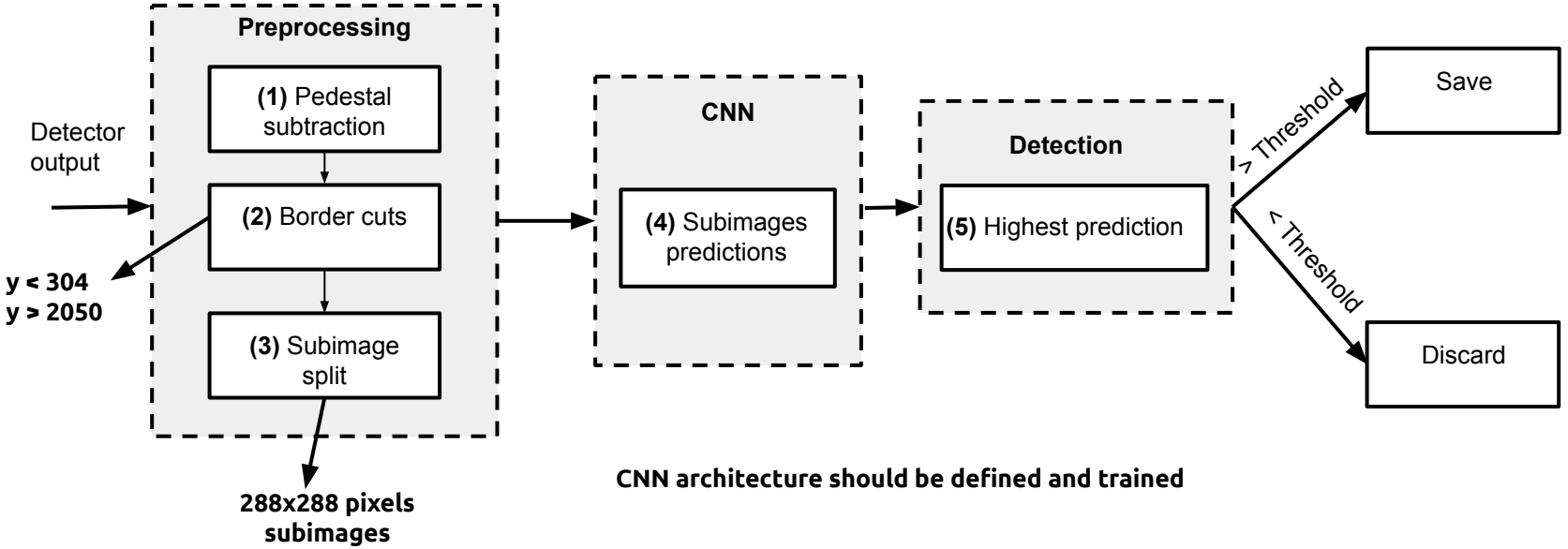






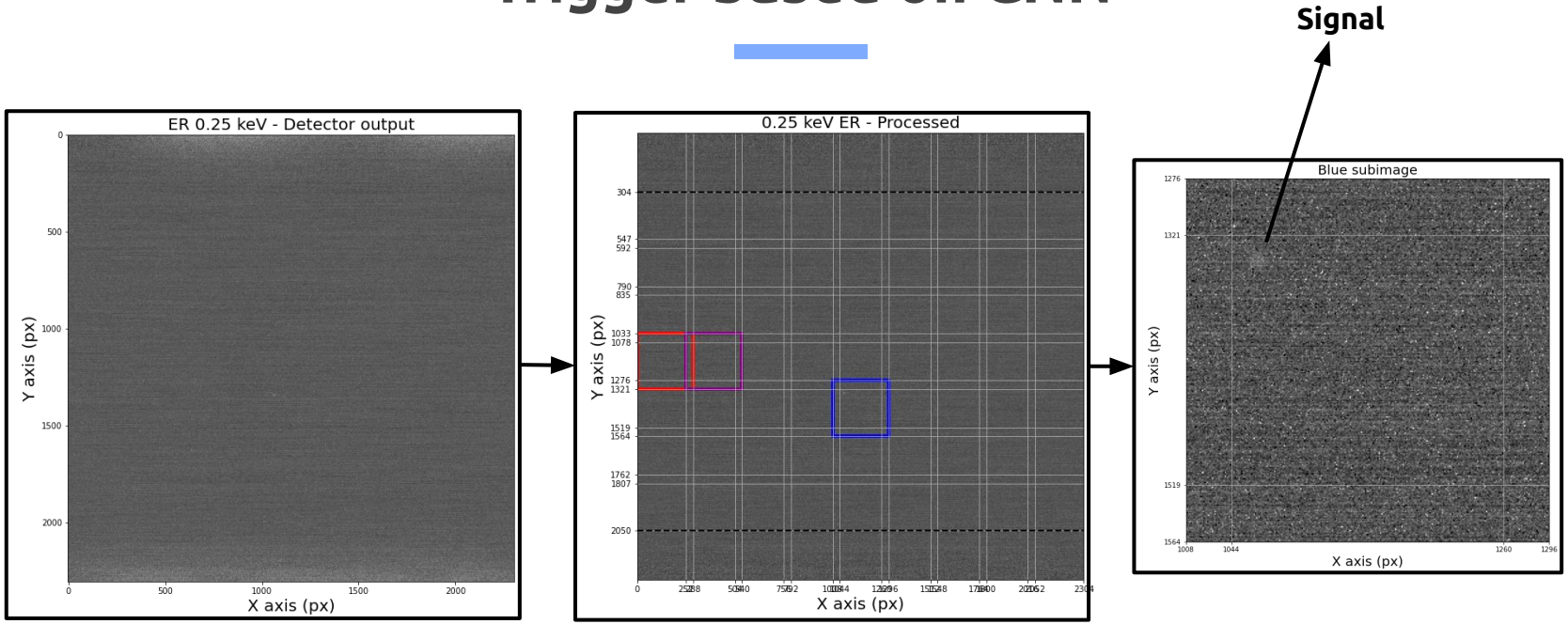


Trigger based on CNN

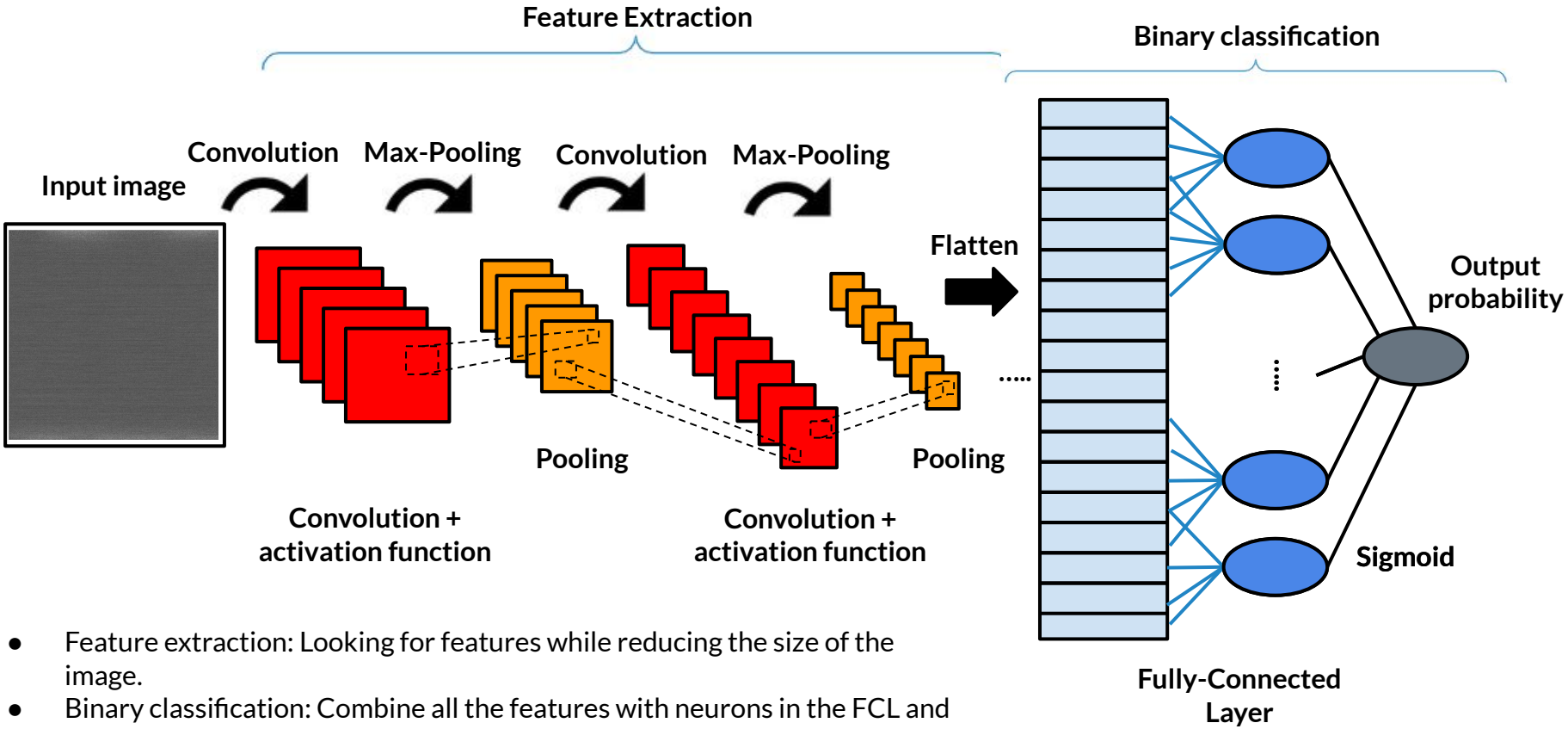


CNN architecture should be defined and trained

Trigger based on CNN



CNN architecture



- Feature extraction: Looking for features while reducing the size of the image.
- Binary classification: Combine all the features with neurons in the FCL and classify the input image.

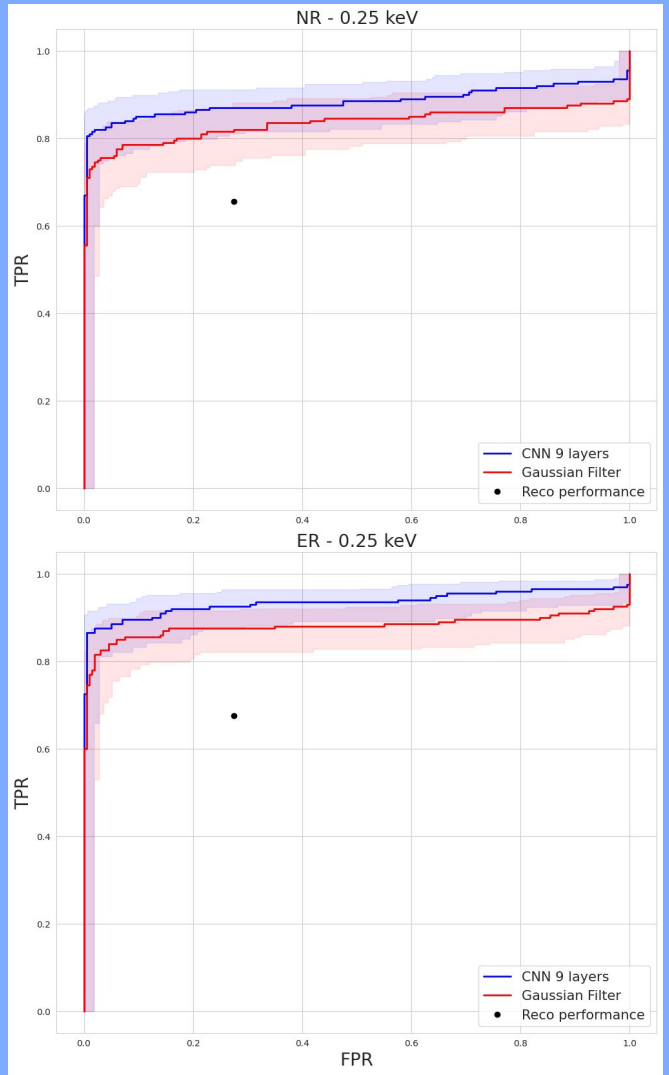
3. Results

Datasets

- **Training:**
  - **Noise dataset:** 600 images from pedestal runs (Run 4 underground).
  - **ER and NR signal simulation:** 600 images each containing 0.25-1 keV signals added to pedestal runs (different from noise dataset).
- **Validation:**
  - **Noise dataset:** 200 images from pedestal runs.
  - **ER and NR signal simulation:** 200 images each containing 0.25-1 keV signals.
- **Test:**
  - Same configuration as validation.

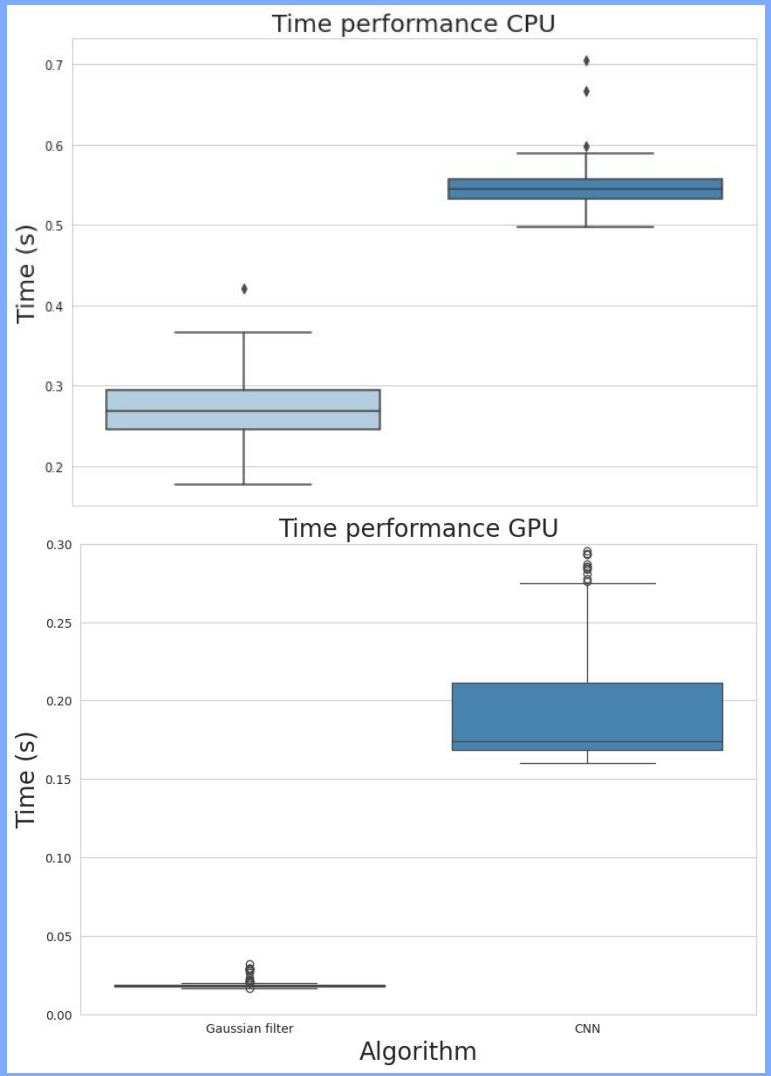
Trigger performance

- The **CNN** can **detect 80%** of the 0.25 keV NR and ER from the test dataset with a **~0.5% false alarm.**
- The Gaussian filter would have **~10% false alarm** to have the same detection performance.
- Both methods **outperforms** the **reconstruction** code in detecting **0.25 keV** signals.
- All methods can **easily detect** signals with energies above **0.5 keV.**



Processing time

- The **Gaussian filter** needs **~0.25** and **~0.02 s** per event using **CPU[1]** and **GPU[2]** respectively.
- The **CNN** needs **~0.55** and **~0.2 s** per event using **CPU** and **GPU** respectively.
- A **higher detection** performance is **compensated** with a **slower processing time.**



[1]CPU: Notebook01 cloud
[2]GPU: Tesla T4 Google Collab

4. Conclusions

Conclusions

- The results show that the **trigger algorithms** based on the **Gaussian filter** and **CNN** can achieve a **80% signal detection** rate on **0.25 keV ER** and **NR** simulated events with a **10%** and **0.5% false alarm** rate respectively.

- The **CNN algorithm** needs a **GPU** to have a **proper time margin** to predict the data, whereas the **Gaussian filter** may be used with a **CPU.**

- **All the signals** detected by the **reconstruction algorithm** were detected by the **trigger algorithms.**

Next steps

- Study methods to simplify a trained CNN model: Bit reduction, weight combination, pruning and vectorization.
  - First attempt did not work, on going.
- Apply the CNN on the DAQ machine.
  - GPU: Quadro RTX 5000
- Test popular CNN architectures such as AlexNET, GoogleLeNet, Unet with necessary adaptations.
- Write a paper based on these results.

Thank you

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