A Machine Learning Approach for Dark Matter Search Analysis: From Savitzky-Golay to Autoencoder

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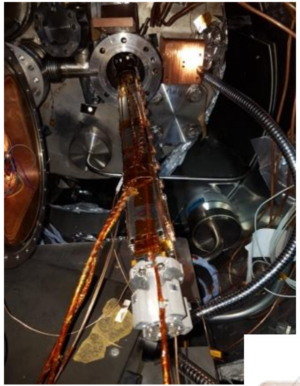
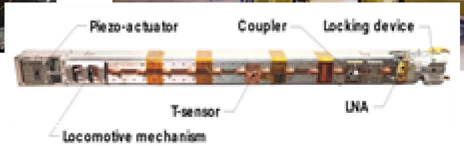
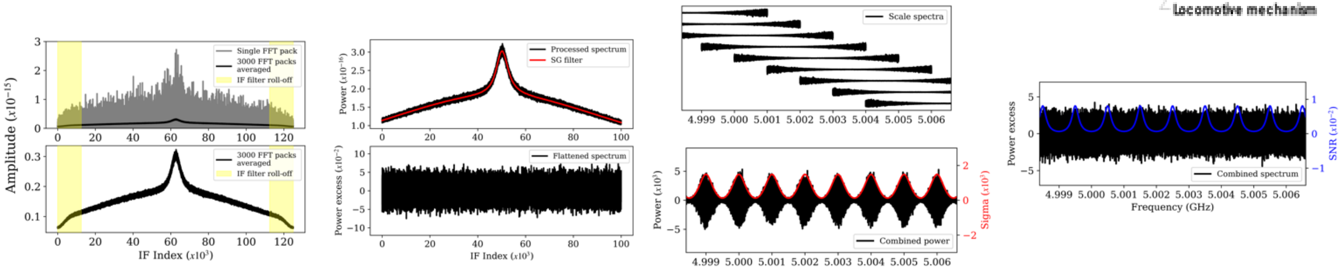
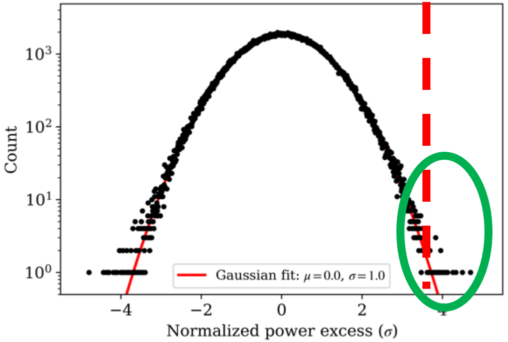
A new path for haloscope analysis?

- Conventional haloscope analysis: CAST-CAPP example.
- Can we increase SNR further with new methods?







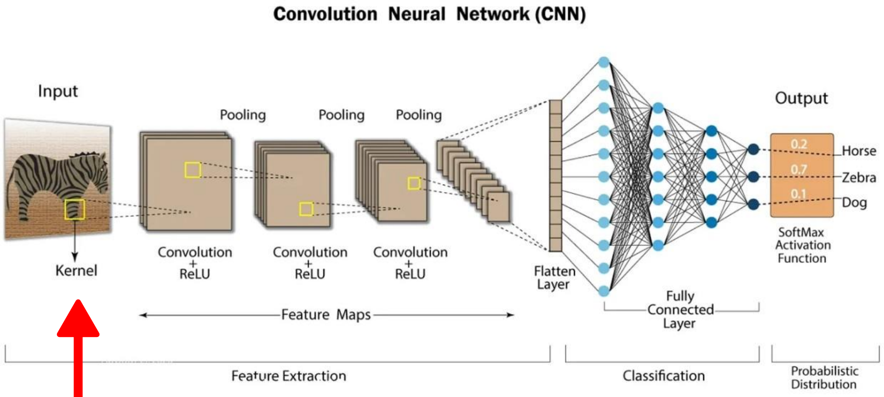


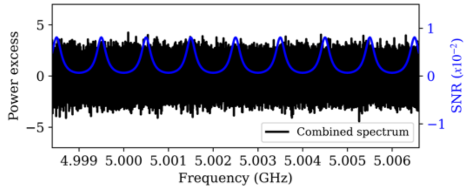
Conventional analysis path

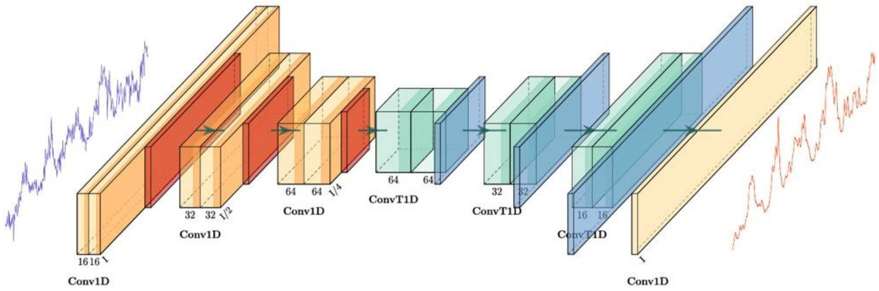
Deep learning architectures

Deep learning (DL) have revolutionized the field by a wide spectrum of new techniques:

- Convolutional neural networks (CNNs) → image recognition
- Transformers → ChatGPT
- Autoencoders → This work







Can Autoencoders replace Savitzky-Golay filtering?

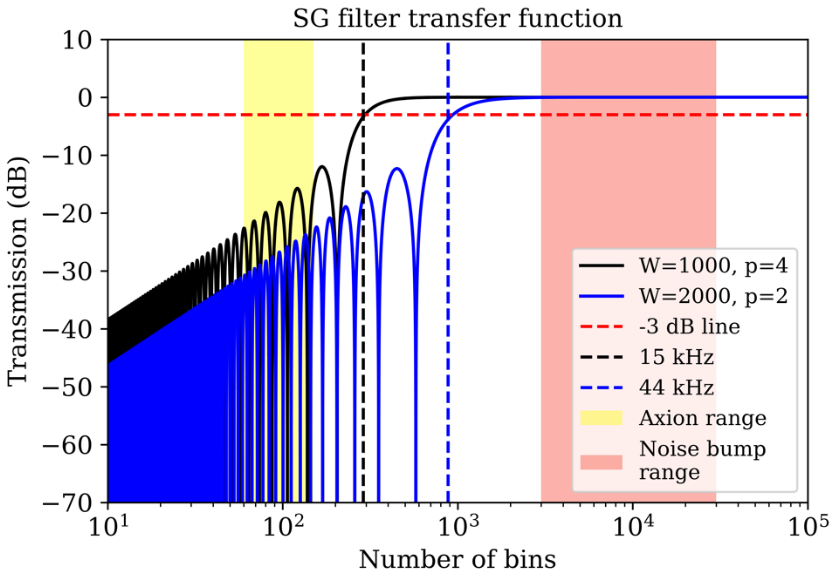
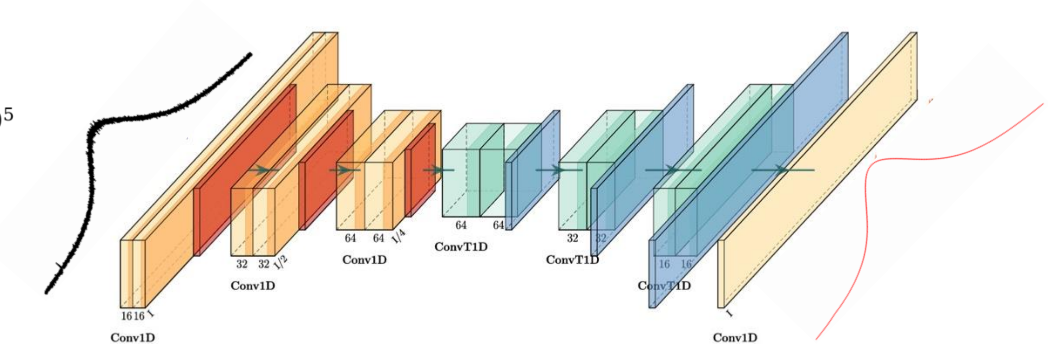


Figure. Transmission plot of the Savitzky-Golay filter. The spectral shape (red band) corresponds to a nearly perfect passband while the axion signal shape (yellow band) corresponds to an imperfect stopband leading to an axion signal attenuation.

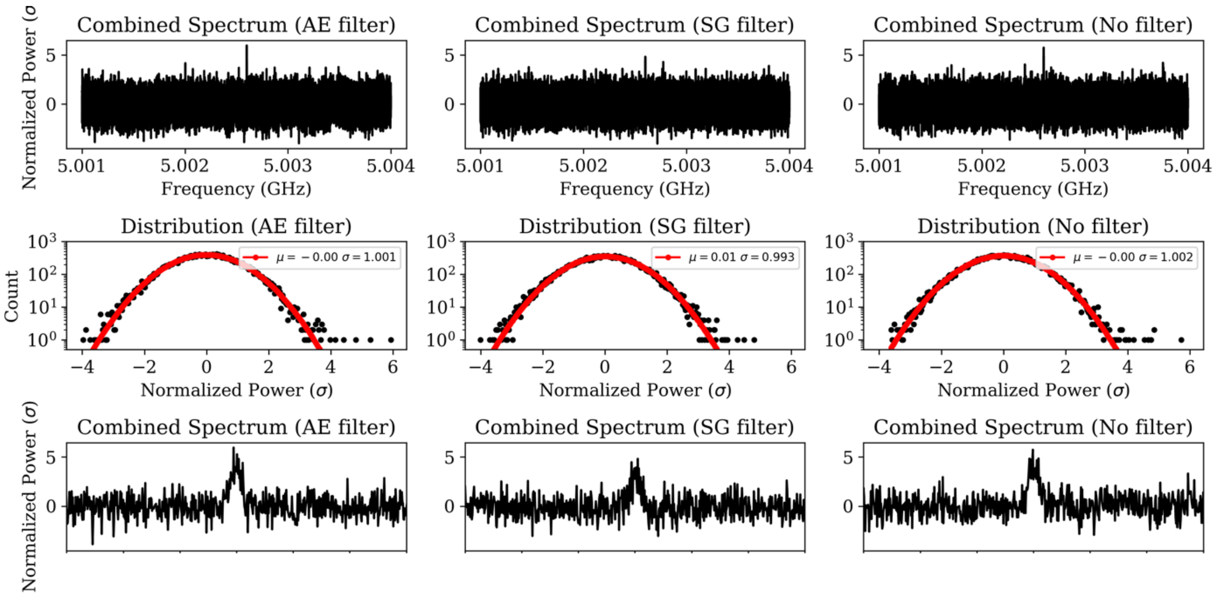
As a first step towards full DL integration...

- Savitzky-Golay attenuates the Axion signal
- Autoencoders may perform better.

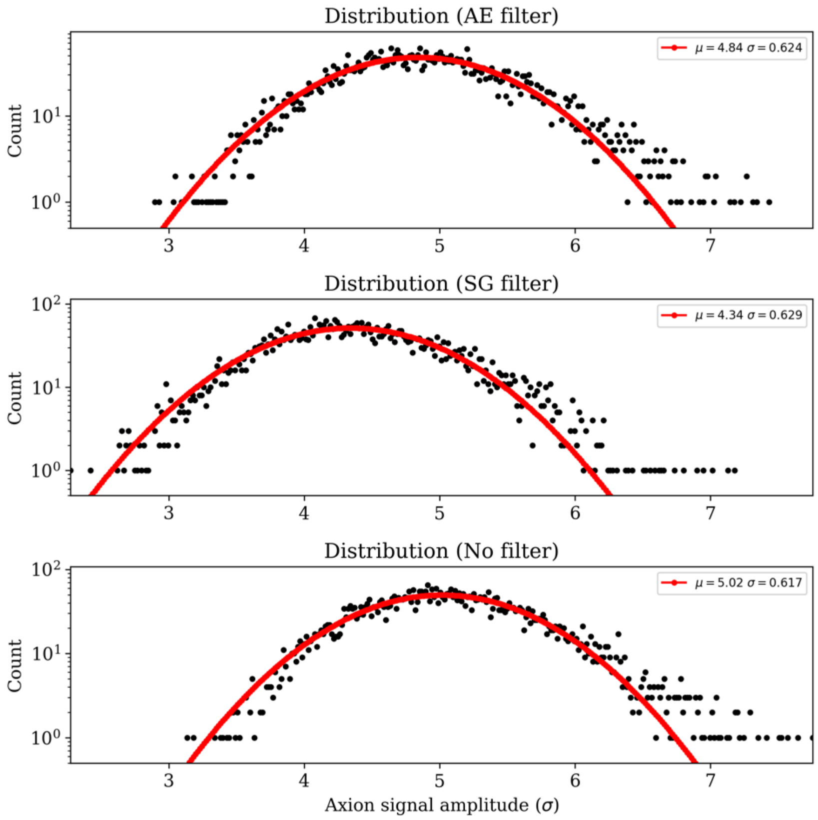


Preliminary Results

- Preliminary results of a Monte Carlo simulation comparing the autoencoder (AE) and Savitzky-Golay (SG) filters against the non-filtered case for a single spectrum.



Preliminary Results

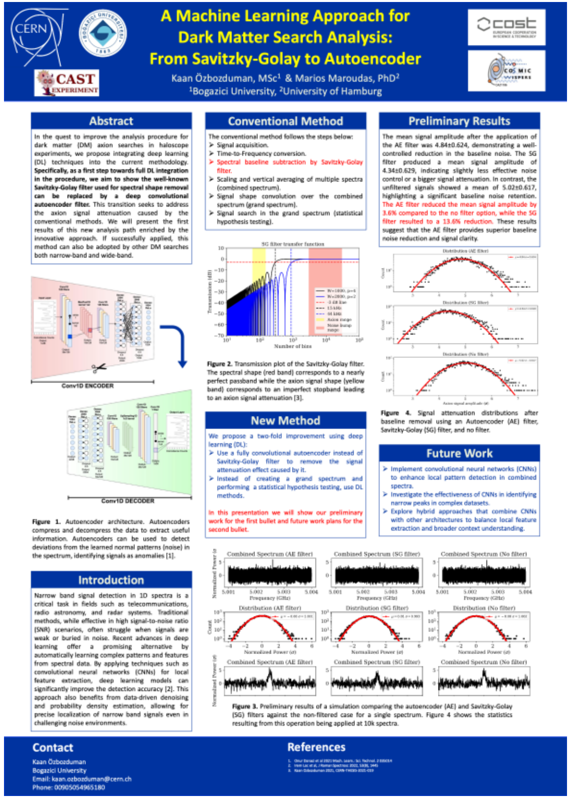


- Signal amplitude distributions after baseline removal using an Autoencoder (AE) filter, Savitzky-Golay (SG) filter, and no filter. Simulation of the previous slide was repeated 10k times.

- The AE filter reduced the mean signal amplitude by 3.6% compared to the no filter option, while the SG filter resulted to a 13.6% reduction.

- These results suggest that the AE filter may increase the signal sensitivity by up to 10%.

Future Work



- Implement convolutional neural networks (CNNs) to enhance local pattern detection in combined spectra.
- Investigate the effectiveness of a variety of DL architectures on Axion searches.
- Applications on **real data**.

Thank you!