# Neutrino Detection Using Machine Learning

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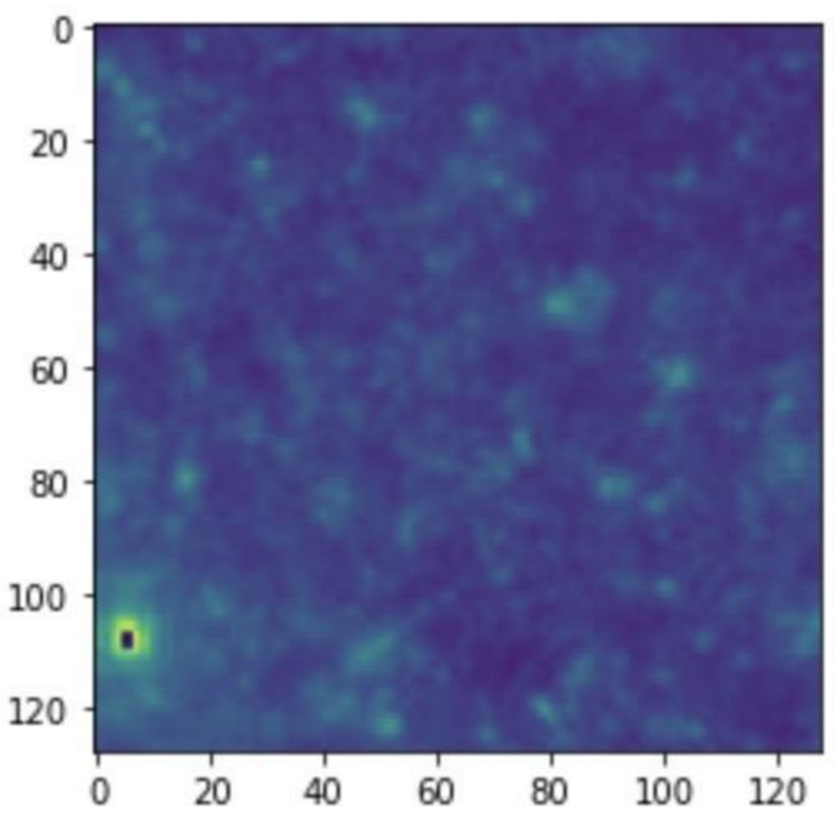
## Introduction

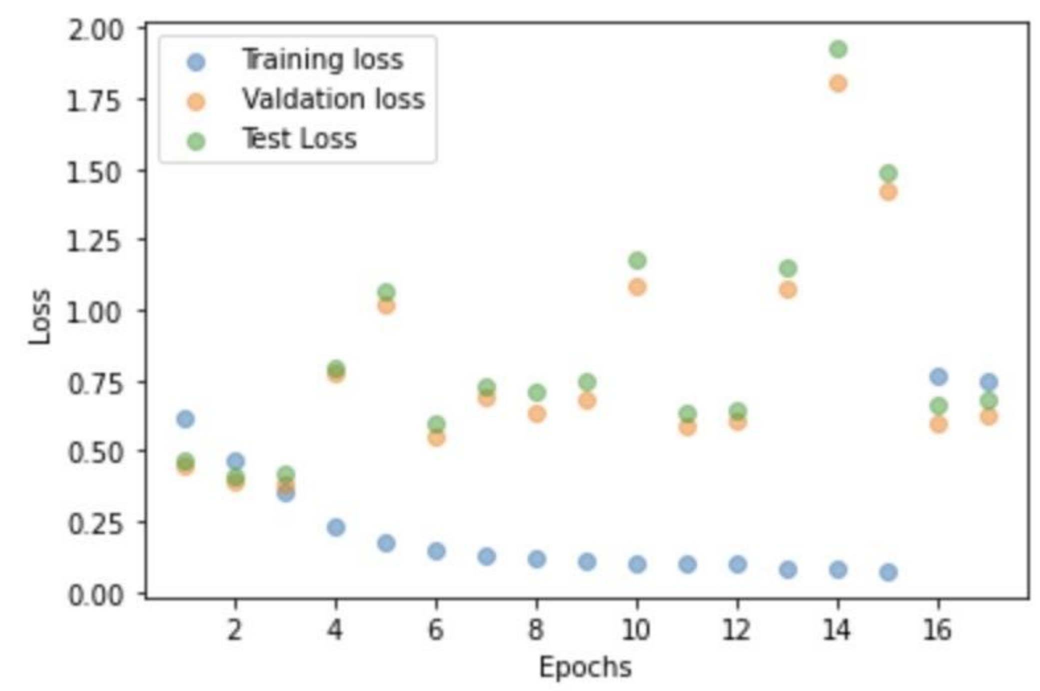
The neutrino is an elementary subatomic particle with no electric charge and spin of ½. The neutrino also has very little mass. In the standard model of particle physics they are even expected to be massless, but the observed flavor oscillations would not be possible without the neutrino having some mass.

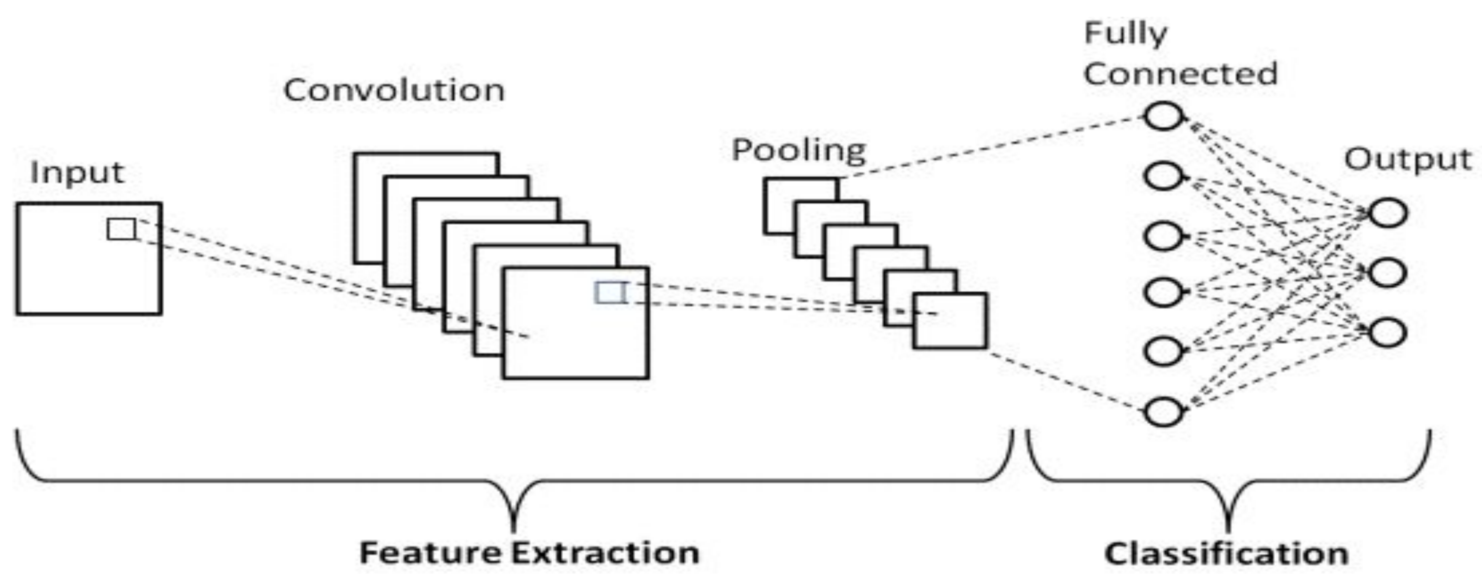
Due to the nature of neutrinos particle physics experiments have a hard time accurately measuring neutrino mass. Currently the upper bound of the neutrino mass in particle experiments is M < 0.8eV and the lower bound is M > 0.6eV. On the other hand using cosmological methods has allowed the upper bound mass to be measured at 0.12 eV and it is believed that we can go even lower.

Currently what we are hoping to do is to see if whether machine learning can be used to accurately to detect massive and non-massive neutrinos, in the hope that we can demonstrate that machine learning techniques can be used to aid in better measuring neutrino mass.

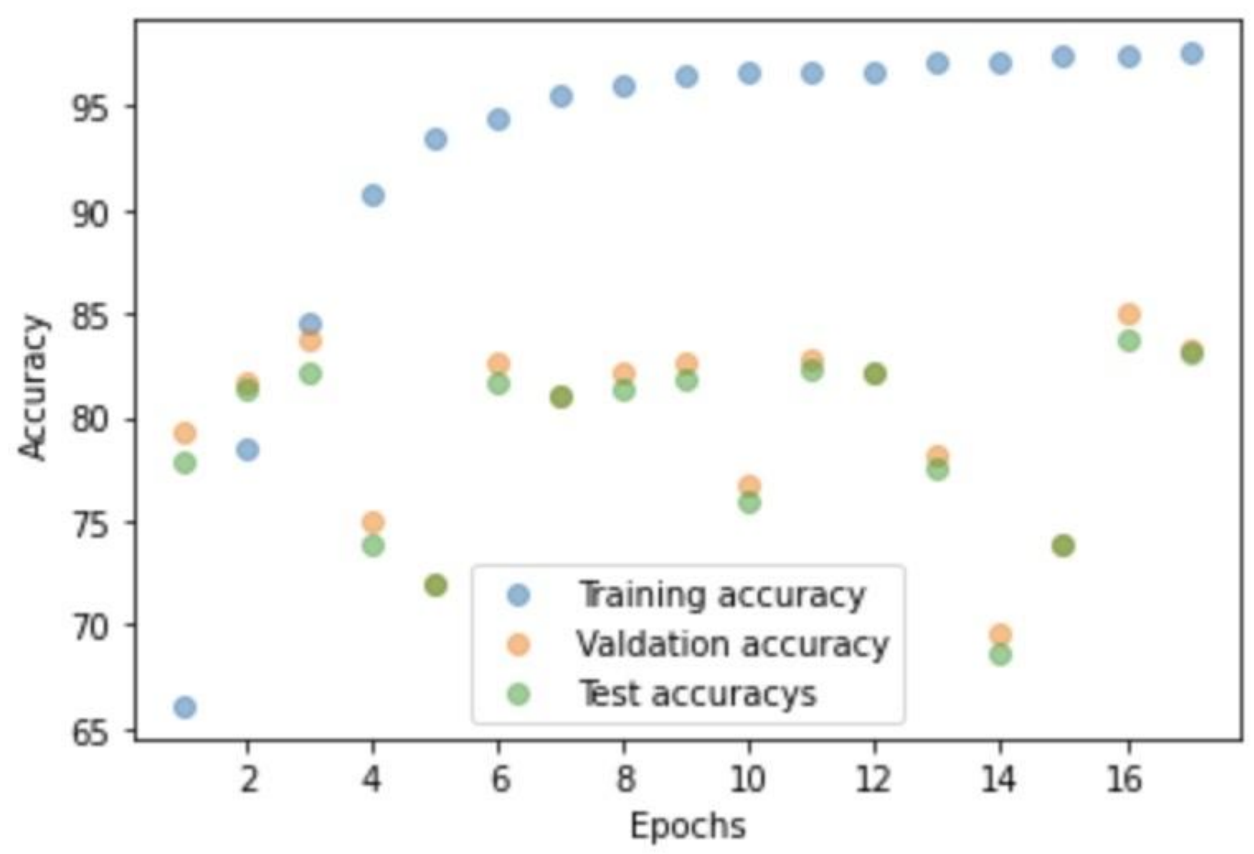


Simulated weak lensing map




Basic outline of cnn [3]




## Results

So far we have constantly been able to get an accuracy in the mid 80s for our model. These results have been possible through the method of exceptional lowering the learning rate. In the near future we would like to fine tune our model to give us a better accuracy but computing

## Future Plans

Futures planas are first to produce saliency maps for the model that we have to see what exactly the model is picking up on. Hopefully by having a better understanding of what the machine "sees" we can gain more understanding of what is going on in the black box.

We would also like to fine tune our model further. This includes simples doing more optuna runs with more fine tuned ranges for parameter settings and maybe looking pretrained models to see if they offer better accuracy.

Further into the future we would like to use regression instead of classification to measure the masses of neutrinos.

## Method

The first that is done is that data is simulated to that resembles weak lensing imaps. After we have attained our maps we create a machine learning model specifically a Convolutional Neural Networks (CNN) which is a type of classification model. To better fine tune our model we use a program called optuna that allows the user to run many trials with that use parameters from a range specified by the user.

## References

[1] Dvorkin, C., Gerbino, M., Alonso, D., Battaglia, N., Bird, S., Rivero, A. D., Fuller, G., Lattanzi, M., Loverde, M., Muñoz, J. B., Sherwin, B., & Slosar, A. (2019). Neutrino Mass from Cosmology: Probing Physics Beyond the Standard Model. *arXiv.* https://doi.org/10.48550/arXiv.1903.03689

[2]The KATRIN Collaboration. Direct neutrino-mass measurement with sub-electronvolt sensitivity. *Nat. Phys.* 18, 160–166 (2022). https://doi.org/10.1038/s41567-021-01463-1

[3] Balaji, S. (2020, August 29). *Binary image classifier CNN using tensorflow*. Medium. Retrieved March 7, 2023, from https://medium.com/techiepedia/binary-image-classifier-cnn-using-tensorflow-a3f5d6746697