



An analysis of air shower data using Neural Networks.

By Miro Joensuu

Contents

The Experiments

- Maket-Ani
- KASCADE
- Airshowers

Neural Networks

- Basic architecture
- Learning
- Feed forward network

My work so far

- Optimization of Network
- Preliminary training results
- Outlook

The Experiments

The background is a solid dark blue. It features several decorative elements: a vertical white line on the left side ending in a cyan square; a vertical white line in the upper center ending in a small orange square; a vertical white line on the right side ending in a cyan square; a vertical white line on the far right; a pink square in the upper right quadrant; a small orange square below it; and a cyan square on the right side.

Maket-Ani

- Decommissioned cosmic ray experiment in Armenia
- Open and reusable data on KCDC datacentre
- No available simulation data
- Small number of features



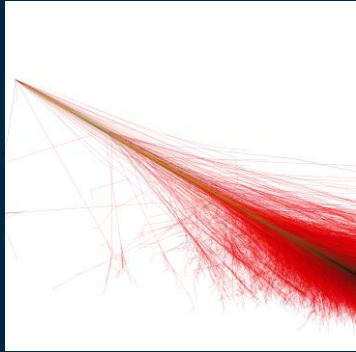
KASCADE

- Cosmic ray experiment in Karlsruhe, Germany
- Available simulation data to train network
- More measured features



Airshowers

Shower Simulation using CORSIKA

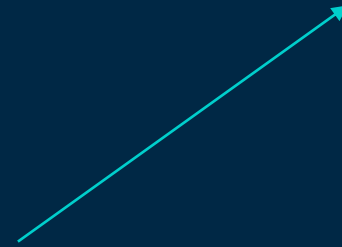


Detector simulation using CRES



Data reconstruction using KRETA

Experiment



Airshowers

Input (true shower information)

- Energy
- Particle mass
- X, Y
- Zenith, Azimuth
- N.o. different particles at observation level

Shower Simulation



Data reconstruction

Output (reconstructed information)

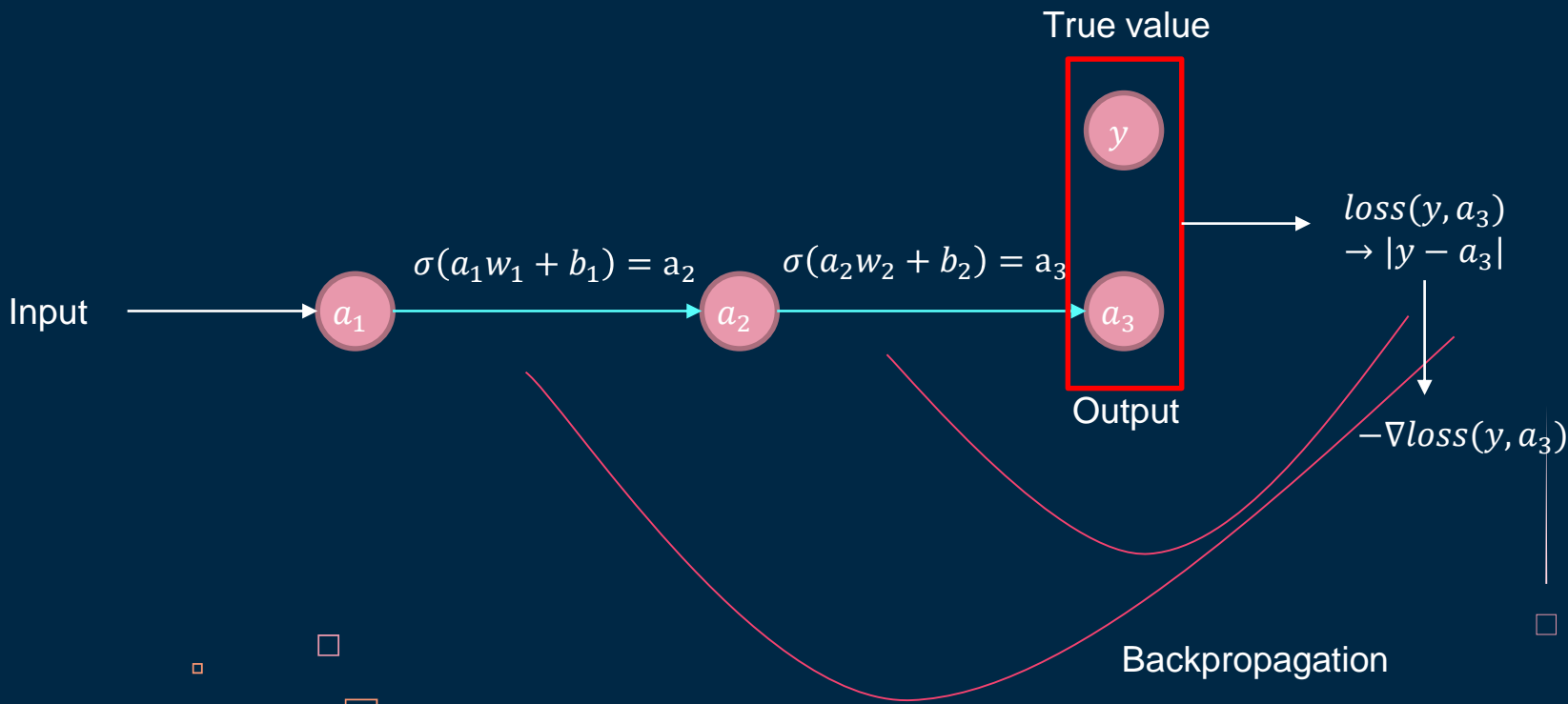
- Energy
- X, Y
- Zenith, Azimuth
- N.o. electrons, muons
- Age
- ...



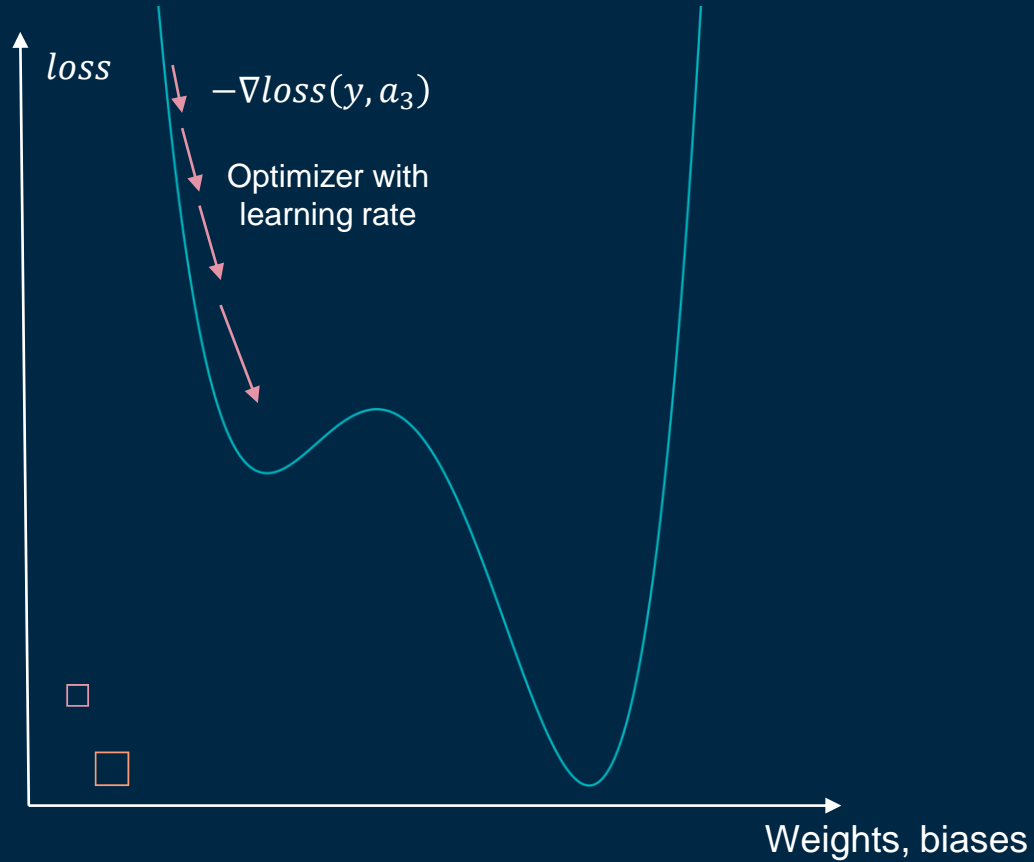
Neural Networks



Basic architecture

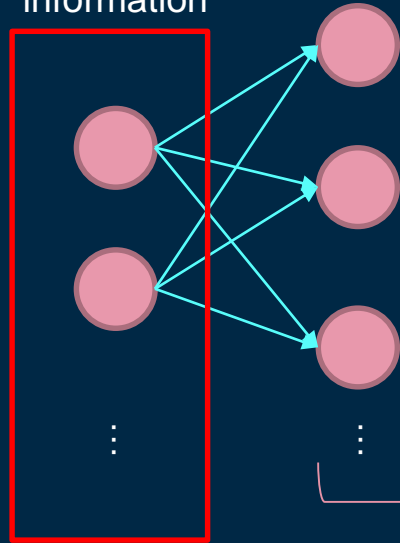


Learning

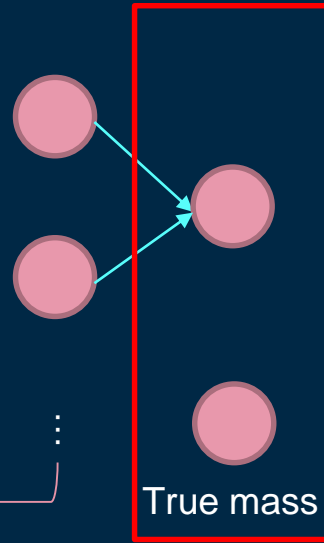


Feed forward network

Reconstructed information



Predicted mass



→ Complex Tool for fitting predicted mass to reconstructed information

Hidden layers



My work

The image features a dark blue background with several abstract geometric elements. A large white text 'My work' is centered. Surrounding the text are various shapes: a teal square at the bottom left, a teal square at the bottom right, a pink square at the top right, and an orange square at the top right. There are also several white lines of varying lengths and orientations, some ending in small squares of the same color as the shapes mentioned.

Main ideas

- Optimize network architecture
- Distinguish between proton and iron
- Quantify accuracy of network



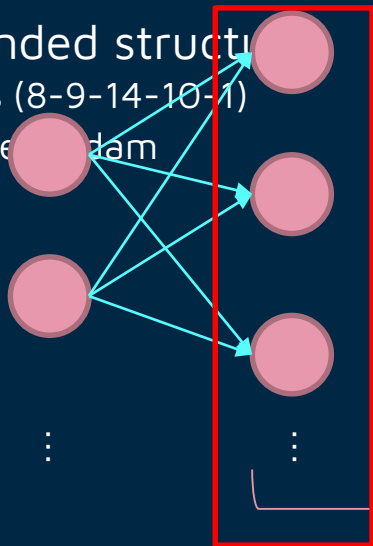
Network architecture

- Desired output $\rightarrow \ln(M_{H,He,C,Si,Fe})$
 - Distance between possible outputs $\rightarrow 1$
- Loss function \rightarrow SmoothL1Loss
 - Increases punishment after ± 0.5
- Network with 2 hidden layers
 - 8 – 10 – 5 – 1
- Optimizer \rightarrow Adam
 - Adaptive learning rate



Optimization of architecture

- Hyperparameter optimization
 - Where does the loss function converge fastest
- Recommended structure
 - 3 layers (8-9-14-10-1)
 - Optimizer Adam
- Not tested



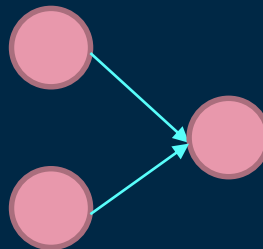
n.o. neurons

n.o. hidden layers

Type of optimizer

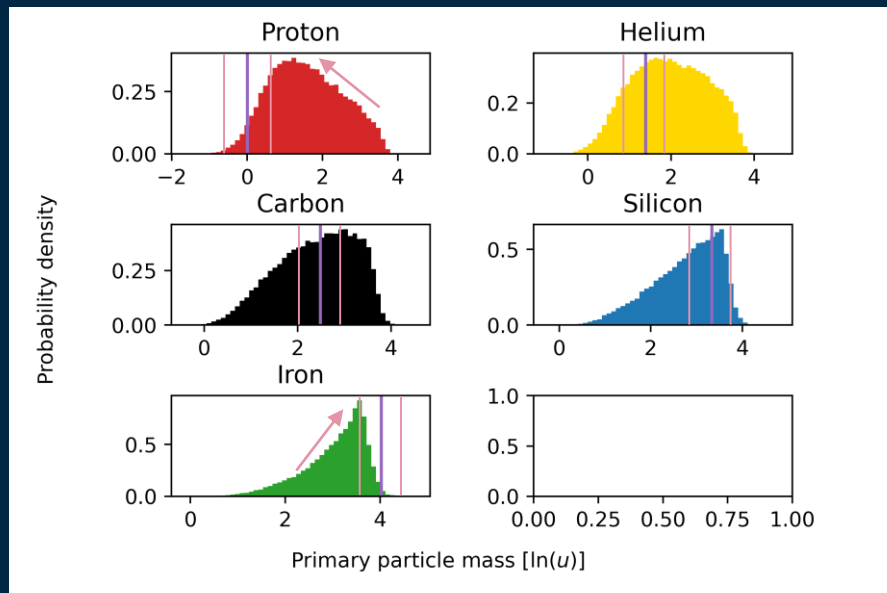


OPTUNA



Results

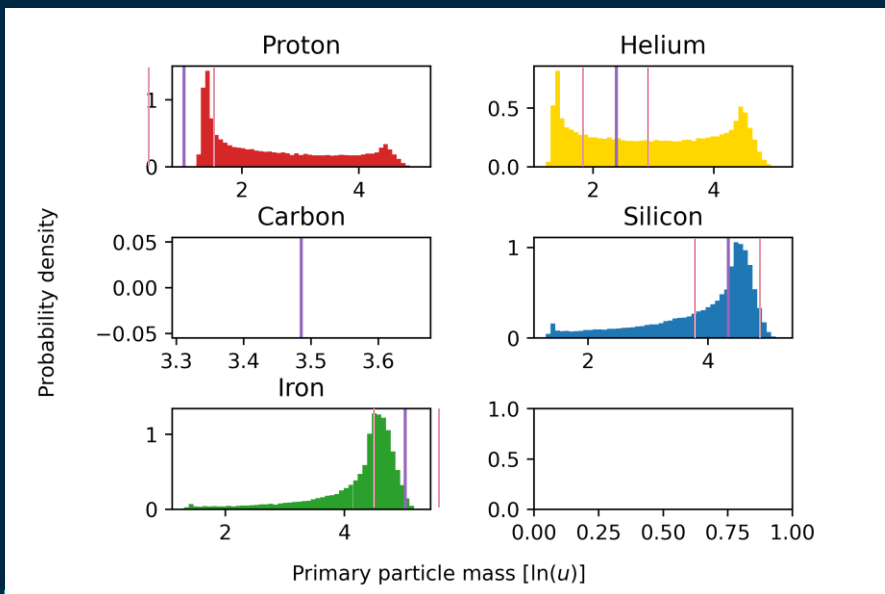
- Quantify using element plots
 - Probability to predict a certain mass for each element
- So far best model using all elements



33% accuracy
1.35 nats Kullback-Leibler
divergence between Proton
and Iron

Removing carbon from training set

- Clearer distinction between Proton and Iron
- Worse prediction for Helium



39% accuracy
13.99 nats Kullback-Leibler
divergence between Proton
and Iron

Outlook

- Use network on experimental data & compare with literature
- Implement network optimized by optuna
- Implement support vector regression
- See how well network performs on reduced data set (Maket-Ani)



References

Thank you to Paras Koundal from the KIT for tutoring & to Wladyslaw Trzaska for the support at CERN

<https://pytorch.org>

<https://optuna.org>

<https://www.kaggle.com>

<https://scikit-learn.org/stable/index.html>

https://kcdc.i kp.kit.edu/static/pdf/kcdc_mainpage/Maket-Ani-Manual.pdf

https://kcdc.i kp.kit.edu/static/pdf/kcdc_mainpage/kcdc-Simulation-Manual.pdf

<https://machinelearningmastery.com/divergence-between-probability-distributions/>

<https://machinelearningmastery.com/adam-optimization-algorithm-for-deep-learning/>

<https://www.iap.kit.edu/kascade/english/index.php>