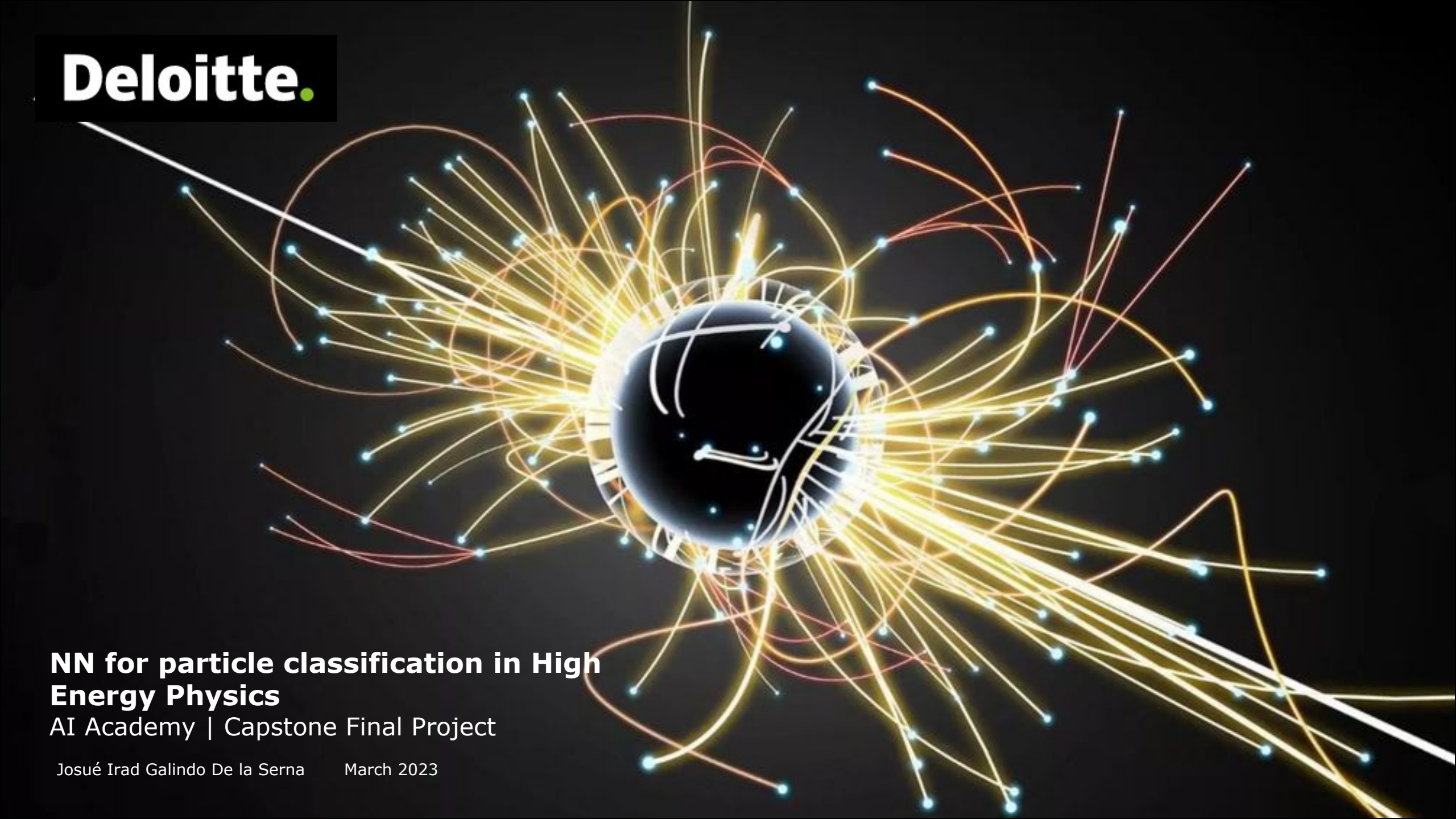
Deloitte.



NN for particle classification in High Energy Physics

AI Academy | Capstone Final Project

Josué Irad Galindo De la Serna March 2023

Contents

Project Overview

Business Understanding

What is the problem and why is it important? How are we addressing it?

Dataset Description

What is the target? What are the features? Where was the data taken from?

Proposed Model

Model description and validation. Model evaluation metrics and results.

Next Steps

How to improve. What can be accomplished next?

Business Understanding

Problem and Solution Proposal

Problem and Solution | Particle collision products identification

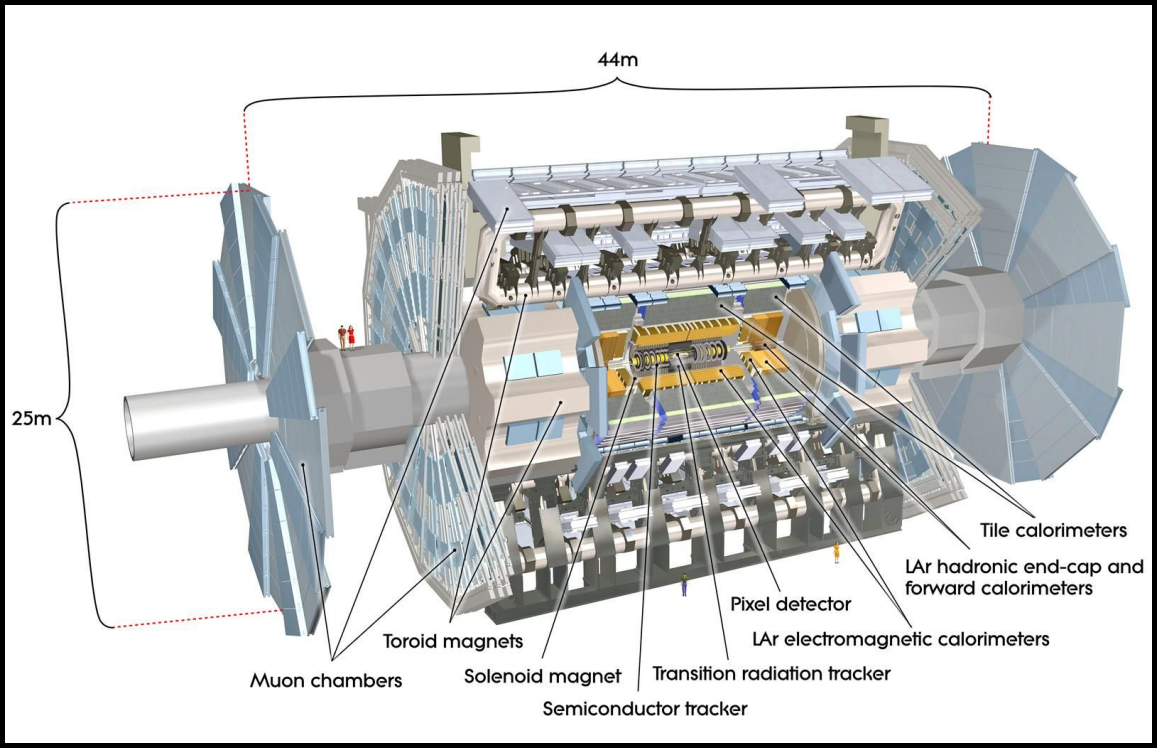
Particle identification is a fundamental task in high energy physics, where scientists study the properties and behavior of subatomic particles.

Challenge:

- Datasets are very large and complex
- They contain noise, background events, and multiple particle interactions
- Current statistical methods are slow and inaccurate

Approach:

- Automate the process using AI



The Dataset

Features and Target

Dataset | Electron-Proton scattering simulation detector response

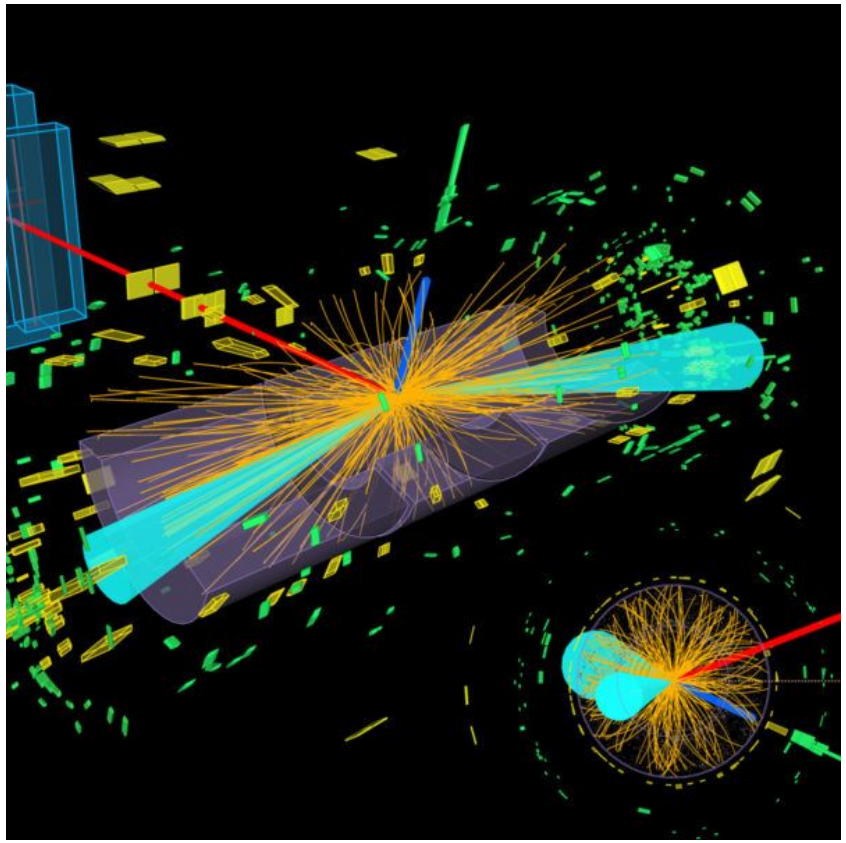


Fig 1. Scattering event 3D reconstruction inside Atlas detector at LHC CERN laboratory.

- Nuclear reactions rom a highly energetic collision between an electron and a proton produce numerous particles
- Particle products depend on the energy
- Physical properties of product particles are obtained through detectors (such as “Atlas”)

About the Dataset

GEANT simulation for detector measurements (position, direction, energy, etc) in a highly energetic electron-proton collision.

Total records: 5,000,000

Dataset | Electron-Proton scattering simulation detector response

Features

P	Particle Momentum (GeV/c)
θ (theta)	Scattering angle (radians)
β (beta)	Position angle (radians)
Nγ (nphi)	Number of photoelectrons produced in the photomultiplier
E_in	Total initial energy
E_out	Total final energy

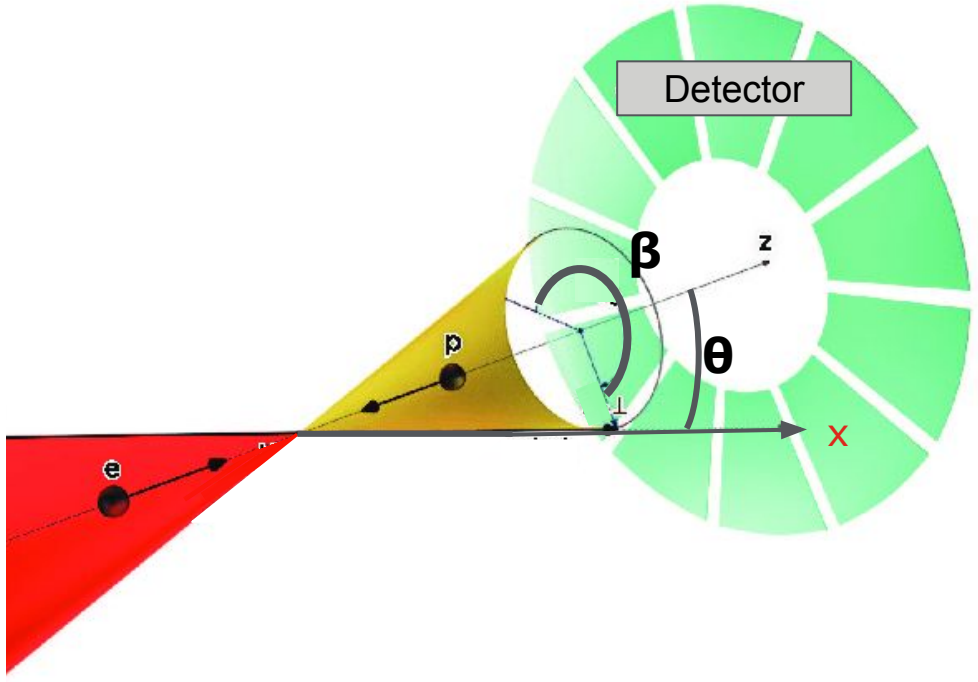
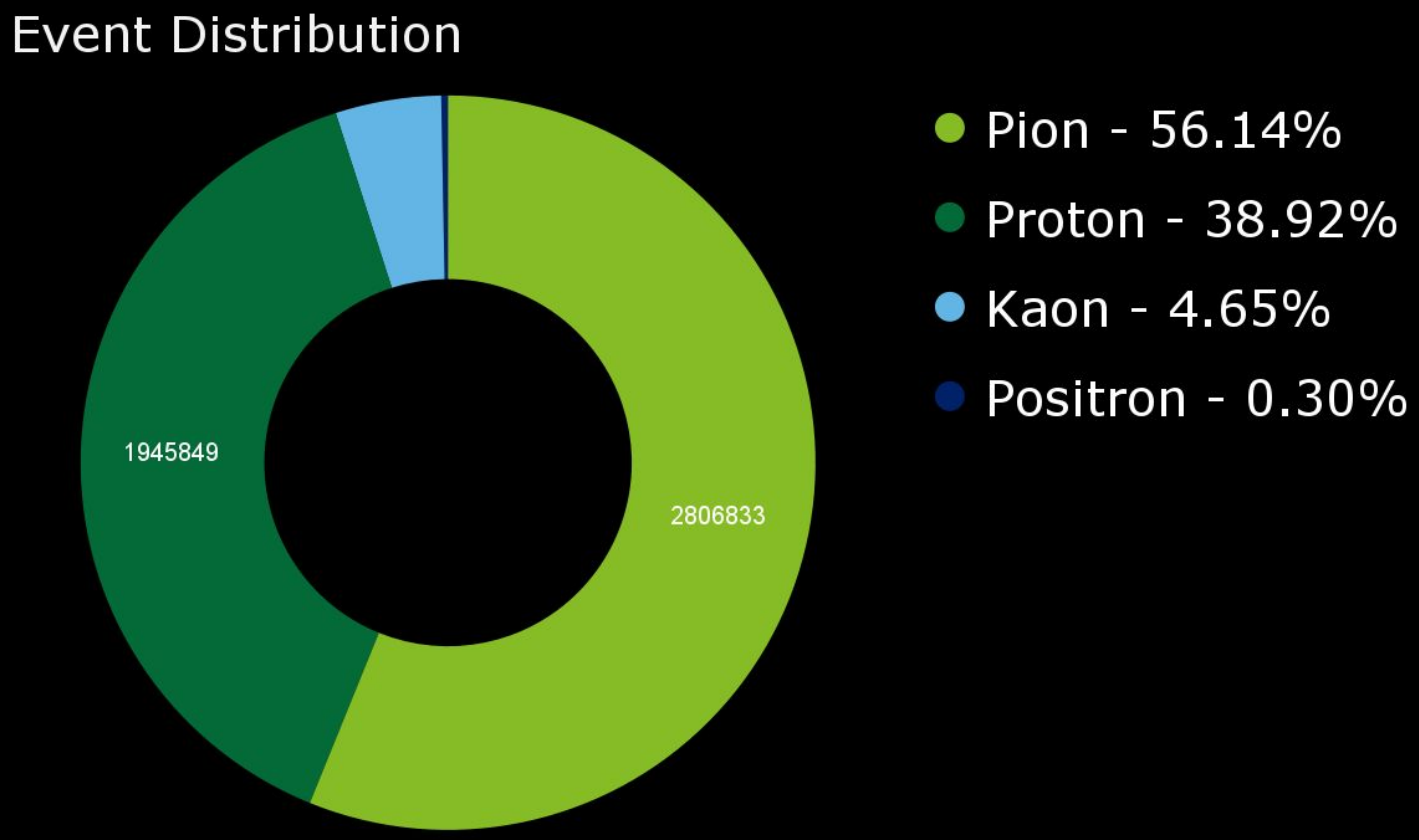


Fig 2. Particle detector arrangement diagram

Dataset | Electron-Proton scattering simulation detector response

Target

Product particle (proton, kaon, pion, positron)



High class Imbalance can bias the model

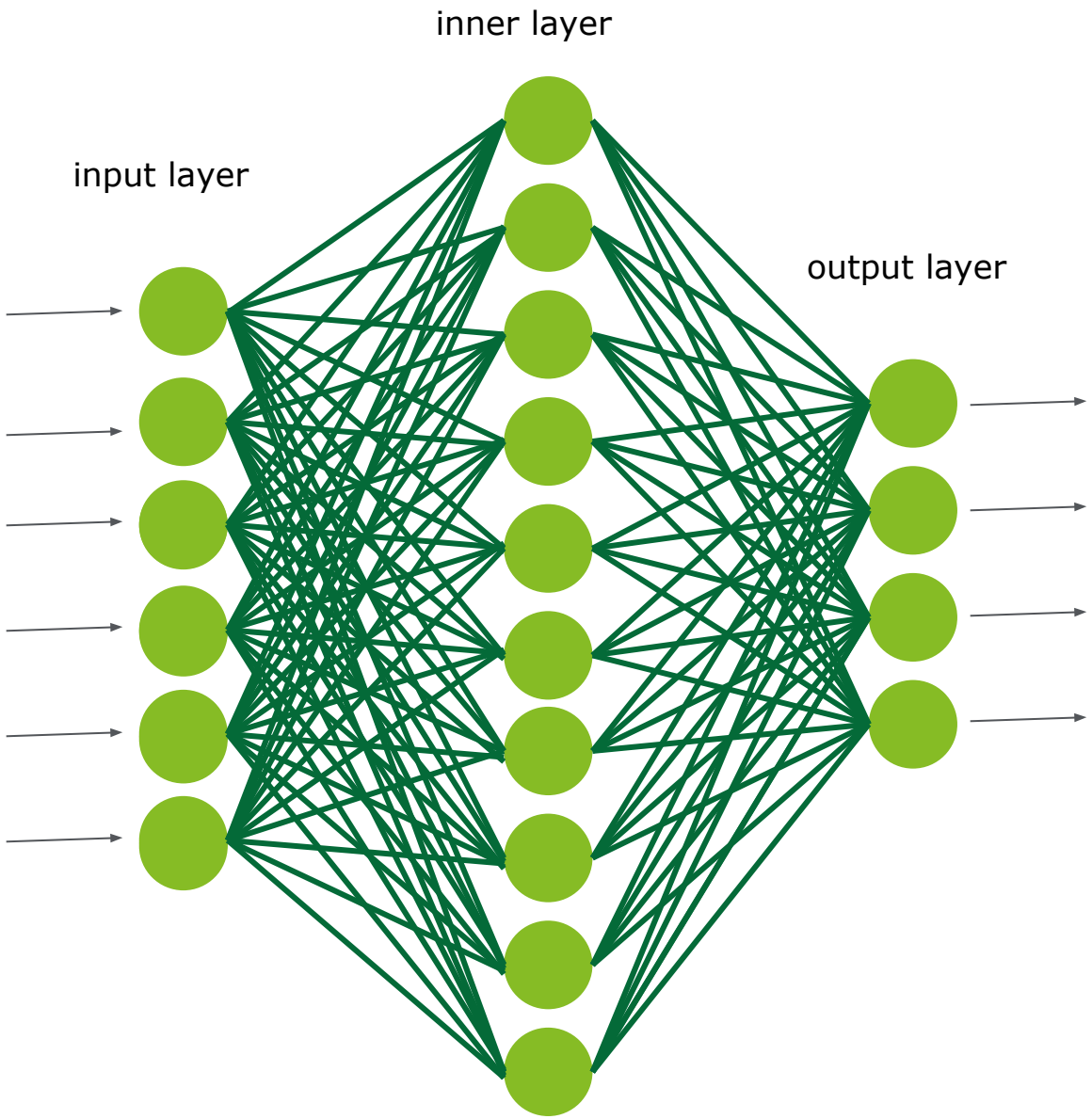
What can we do?

Undersampling or Oversampling (SMOTE)

The Model

Design, results and evaluation

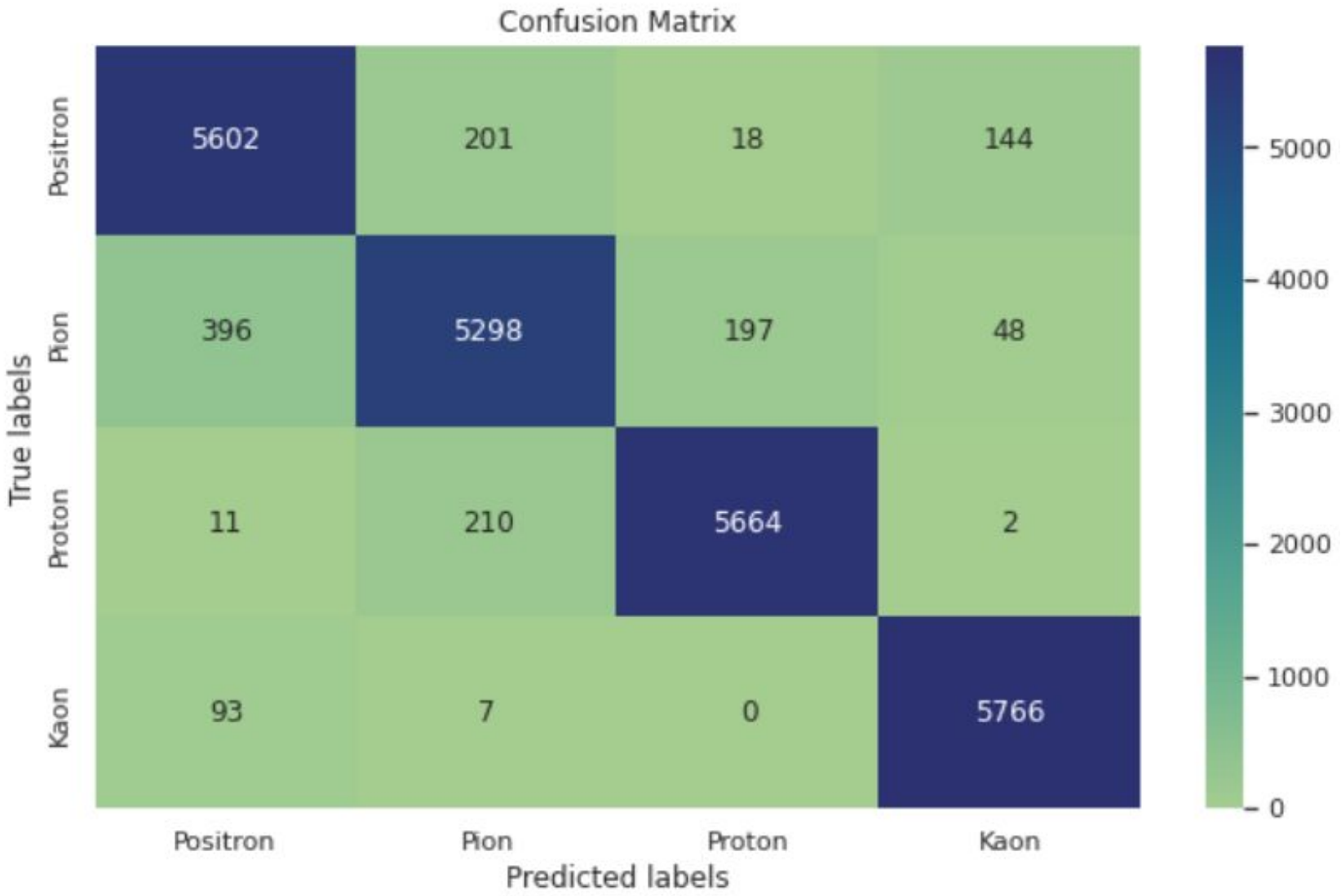
Model | Simple sequential Neural Network



WHY?

- Neural networks are computer programs inspired by the human brain.
- They solve complex problems that traditional algorithms can't. In this case, particle identification
- Neurons are interconnected nodes that learn from input data during training.
- Once trained, the network can make predictions or classify new data.

Model Evaluation| Evaluation metrics per class



What is next?

Conclusion and next steps

Conclusion | Model insights and next steps

.

- Precise particle classification can revolutionize particle physics research, potentially leading to the discovery of new particles and phenomena.

- Practical applications include medical imaging, where accurate particle classification is essential for diagnosis and treatment.

- The technology can have a profound impact on our understanding of the universe's fundamental building blocks and can lead to advances in various fields.

- This technology can be further developed to

Q&A

Thank you!