RICH AI

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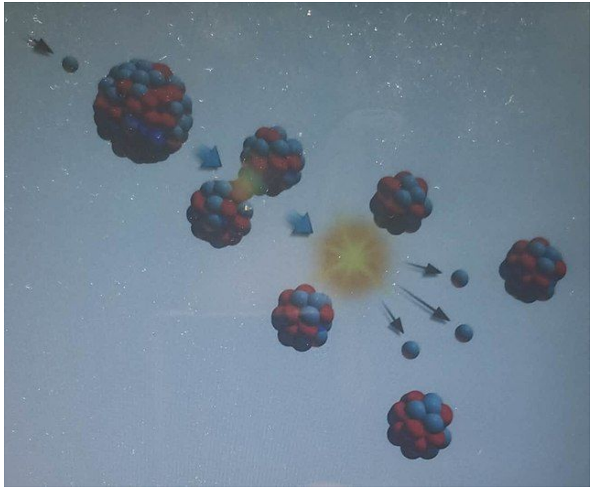
Agenda

1) Background and scope
2) Data
3) Machine learning approach
4) Evaluation metrics
5) Timelines

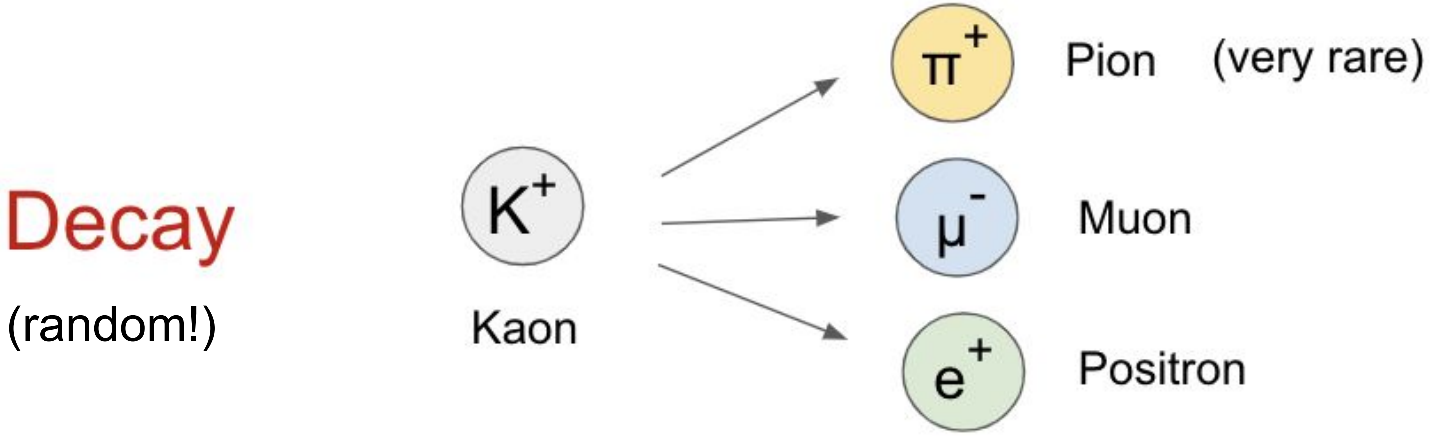
1. Background and scope

The NA62 particle physics experiment at CERN detects sub-atomic particles



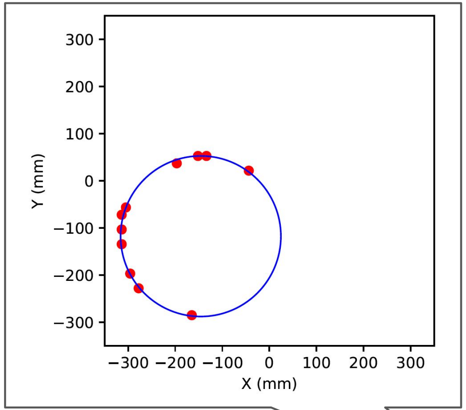
Geneva, Switzerland

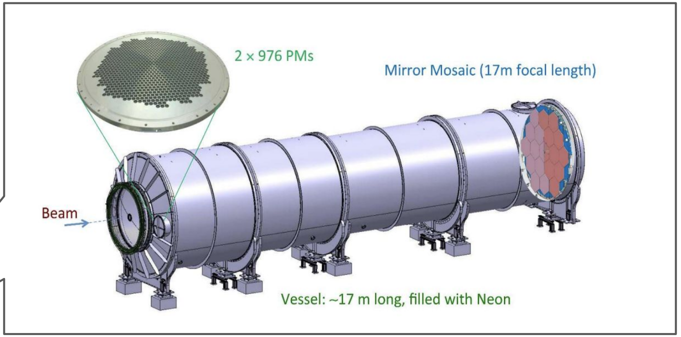
The challenge is to match the experimental results to the standard model



There are 3 main particles generated in the NA62 experiment

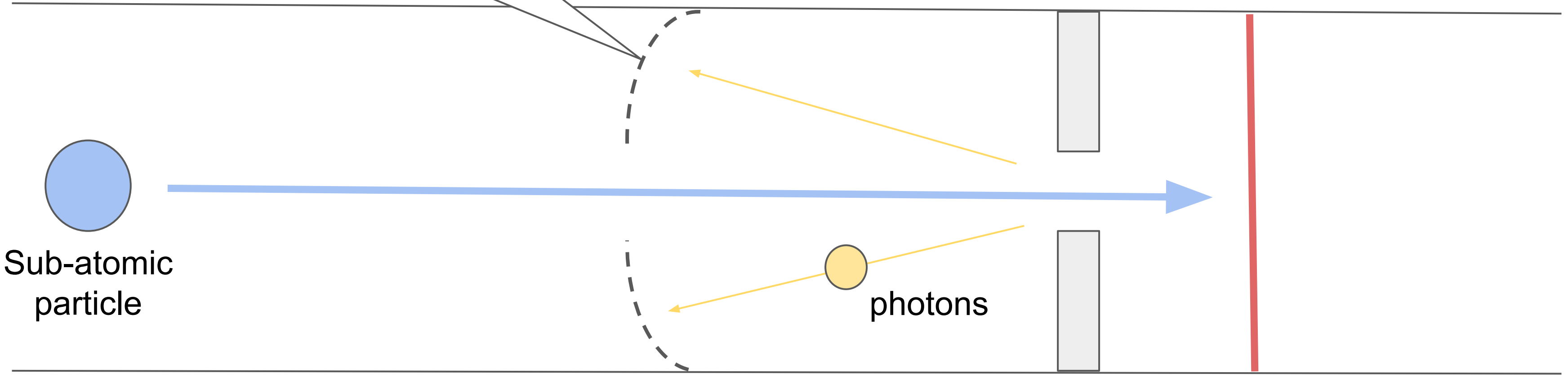
The RICH detector is used to produce light




2 × 976 PMs
Mirror Mosaic (17m focal length)
Beam
Vessel: ~17 m long, filled with Neon

RICH detector

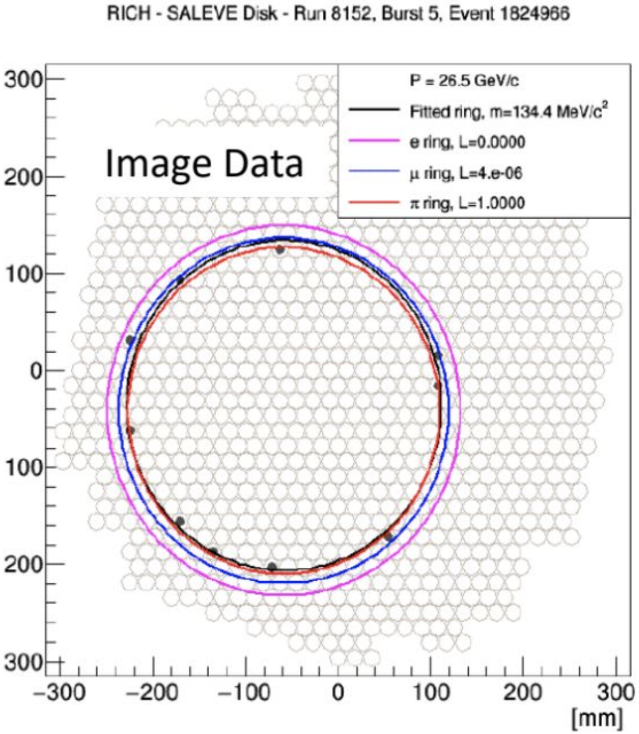
Hodoscope



Sub-atomic particle

photons

Each particle produces a different size ring.. image classification!



Current method

- MLE used to fit rings analytically

Challenges

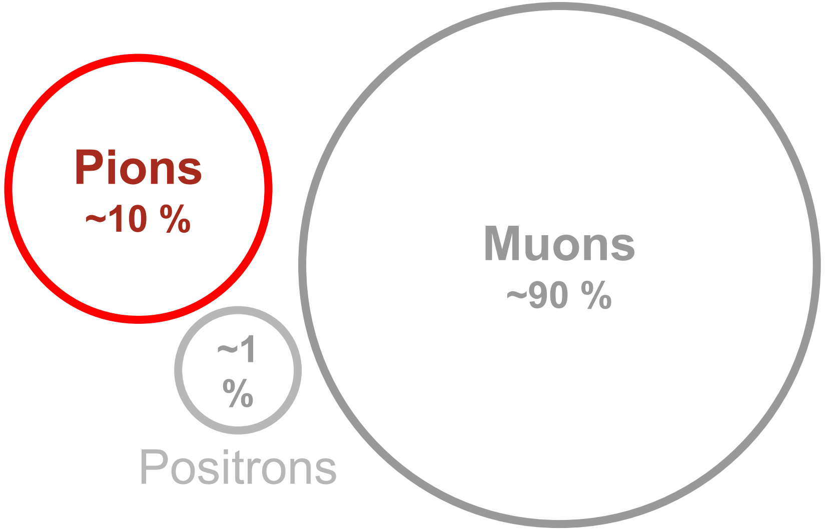
- Pion decay is very rare
- Capture as many pion decays as possible
- Reduce the number of incorrect classifications

2. Data

Data: *description*

Source	NA62 datasets from RICH detector
Type	Labelled datasets
Format	HDF5
Volume	~11.5 million examples*

Class Imbalance*



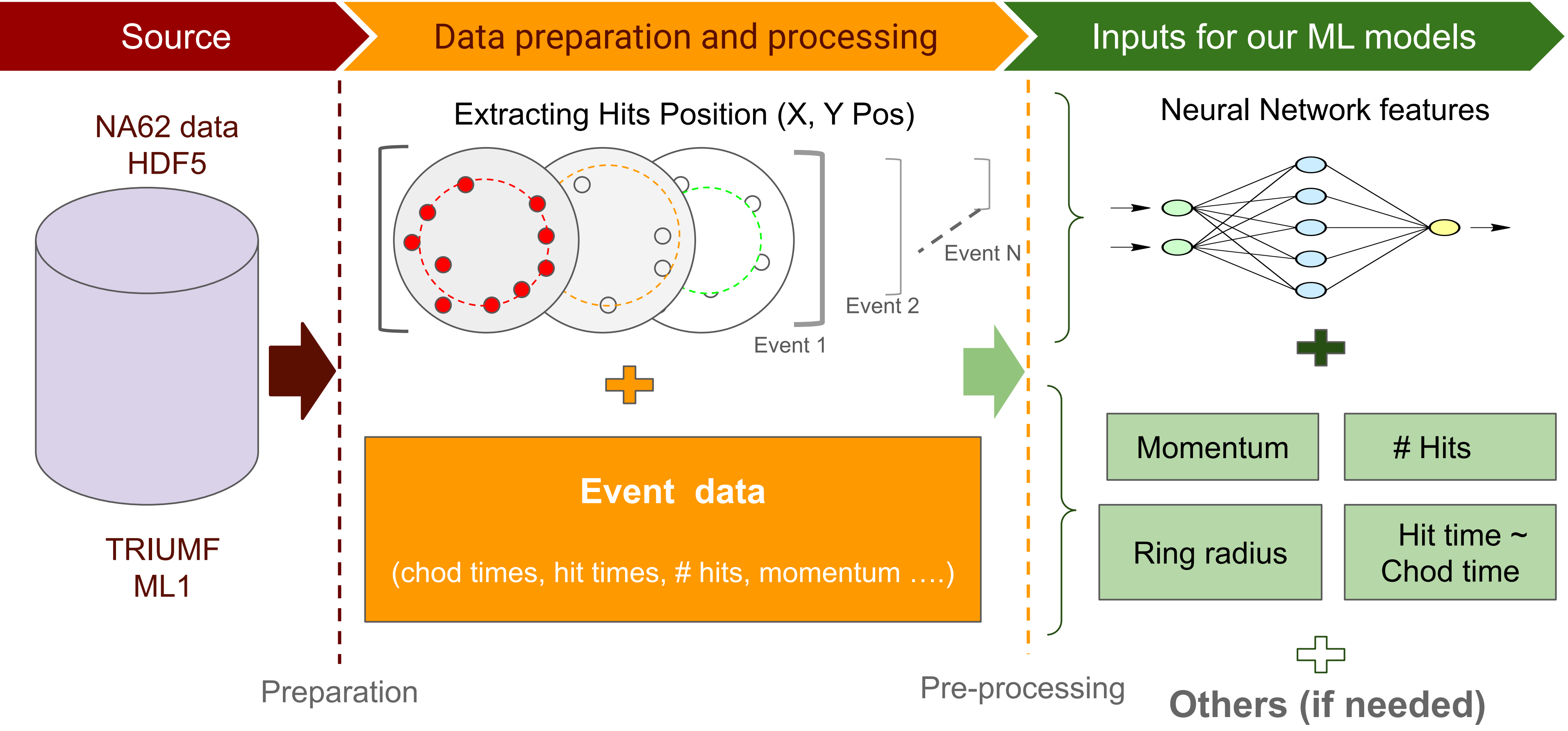
Pions
~10 %

Muons
~90 %

~1 %
Positrons

*Source: As per the initial datasets shared by TRIUMF for 2018 (B & E); Other 4 years data would be shared on need basis
https://github.com/TRIUMF-Capstone2022/RICHPID/tree/main/docs

Data: *flow*



Source

Data preparation and processing

Inputs for our ML models

NA62 data
HDF5

TRIUMF
ML1

Extracting Hits Position (X, Y Pos)

Event data

(chod times, hit times, # hits, momentum ….)

Neural Network features

Momentum

Hits

Ring radius

Hit time ~
Chod time

Others (if needed)

Preparation

Pre-processing

3. Machine Learning Approach

Machine learning approach

Task	Build a **classification** model: pions, muons, positrons
Goals	*Goal 1*: **Maintain** pion efficiency of **95%** (TP rate) *Goal 2*: **Reduce** pion/muon misclassification by **10x**
Baseline	Gradient Boosted Tree (XGBoost or LightGBM)
Deep Learning	*Model 1*: PointNet or PointNet++ *Model 2*: Graph CNNs
Deep Learning Implementation	PyTorch Geometric

4. Evaluation metrics

Evaluation: ROC curve to compare classifiers

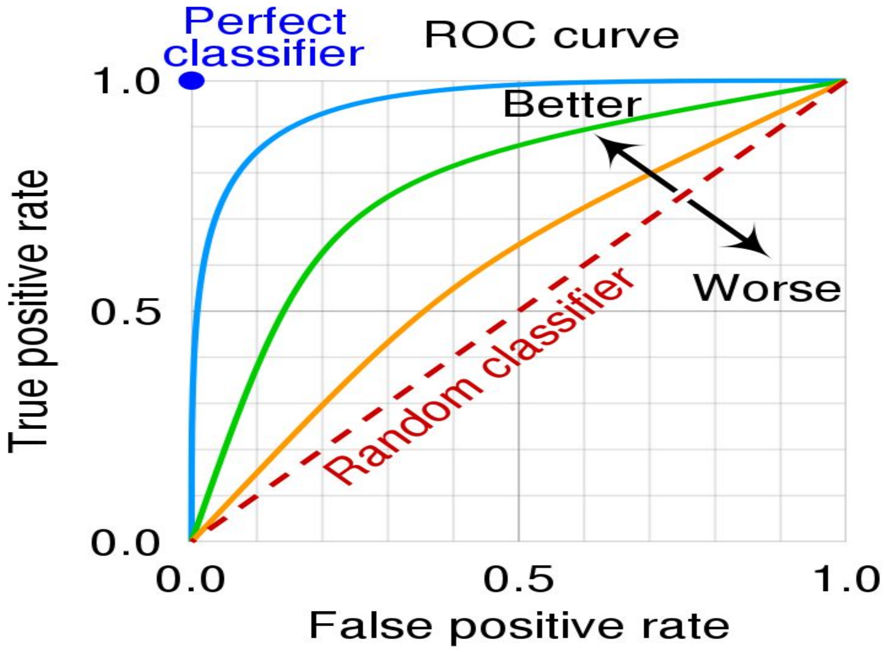


**Image source: wikipedia

ROC Curve

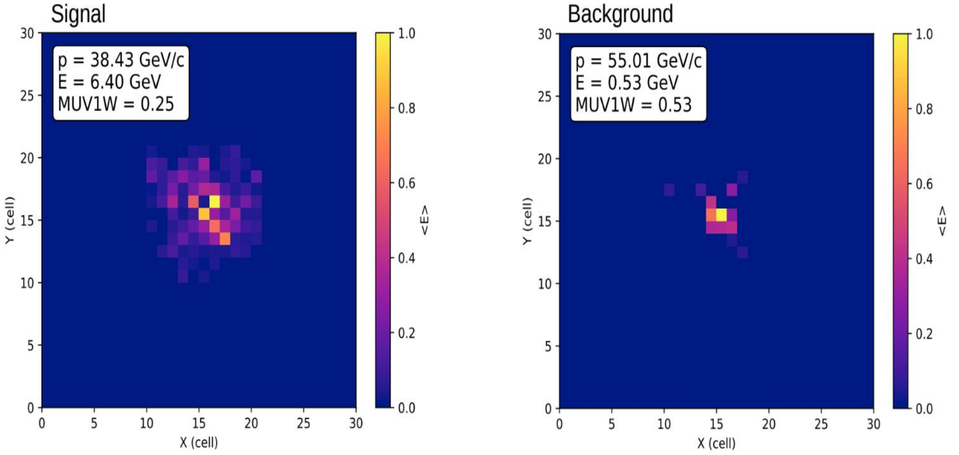
- Useful in comparing different classifiers
- Diagonal line represents random classifier
- Models below diagonal lines are worse than random classifier
- Area under ROC curve (AOC) - ability of a classifier to distinguish between classes

Evaluation: Pion efficiency

Fraction of matched detected pions out of the all the pion particles.

	Predicted PION	Predicted NOT PION
IS a PION	True Positives	False Negatives
NOT a PION	False Positives	True Negatives

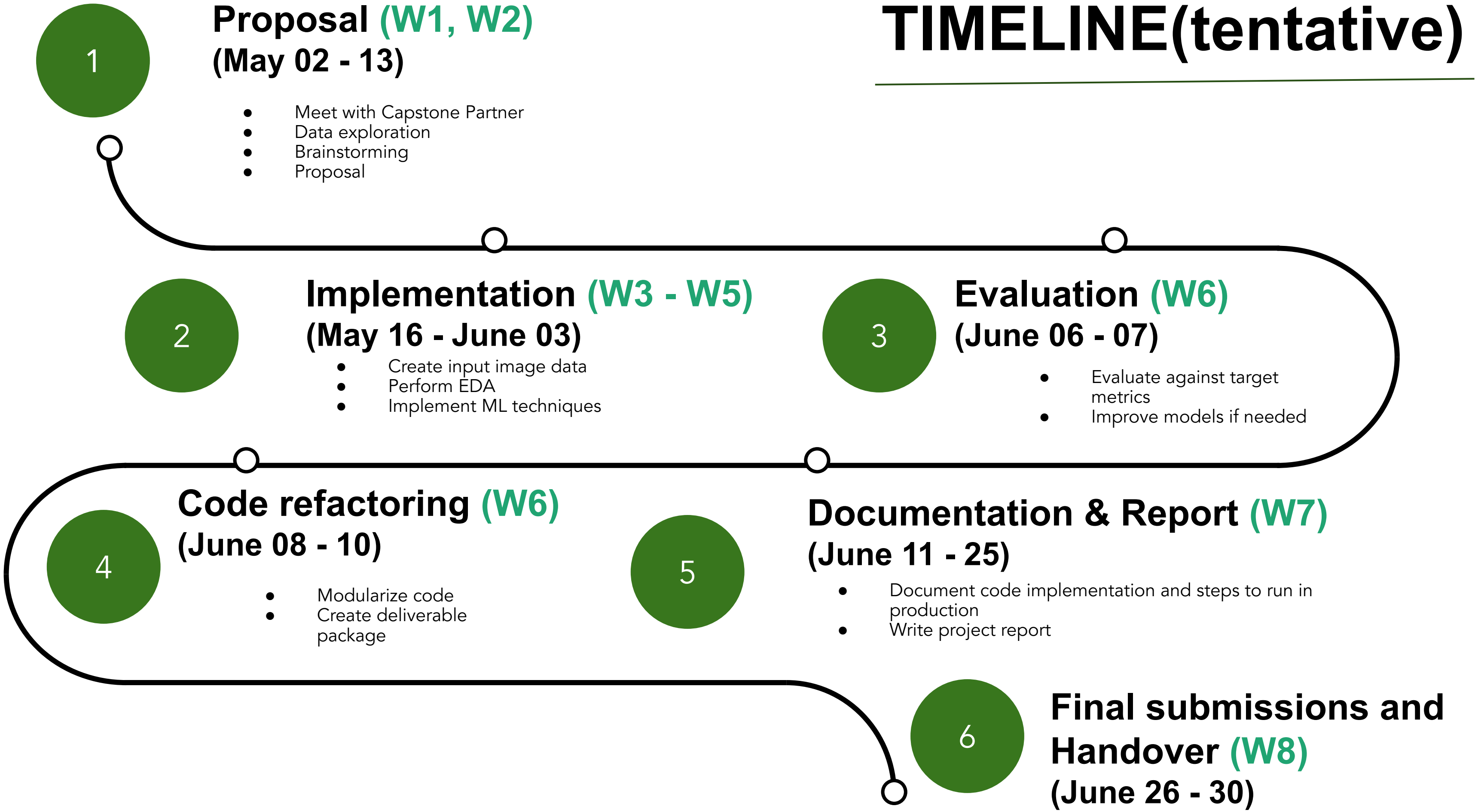
$$\text{Pion efficiency} = \frac{\text{\#pions detected}}{\text{\#pions}}$$



- Need 95% efficiency for the signal

5. Timelines

TIMELINE(tentative)



1

Proposal (W1, W2)
(May 02 - 13)

- Meet with Capstone Partner
- Data exploration
- Brainstorming
- Proposal

2

Implementation (W3 - W5)
(May 16 - June 03)

- Create input image data
- Perform EDA
- Implement ML techniques

3

Evaluation (W6)
(June 06 - 07)

- Evaluate against target metrics
- Improve models if needed

4

Code refactoring (W6)
(June 08 - 10)

- Modularize code
- Create deliverable package

5

Documentation & Report (W7)
(June 11 - 25)

- Document code implementation and steps to run in production
- Write project report

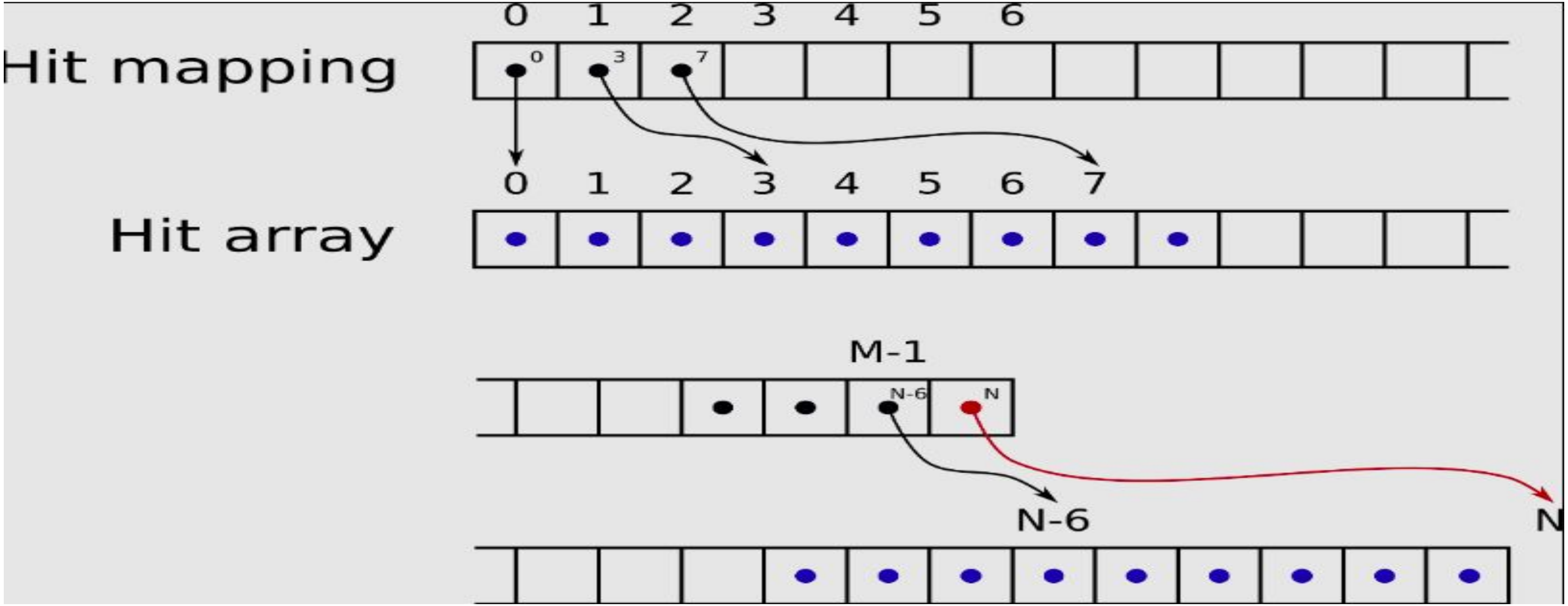
6

Final submissions and Handover (W8)
(June 26 - 30)

THANK YOU

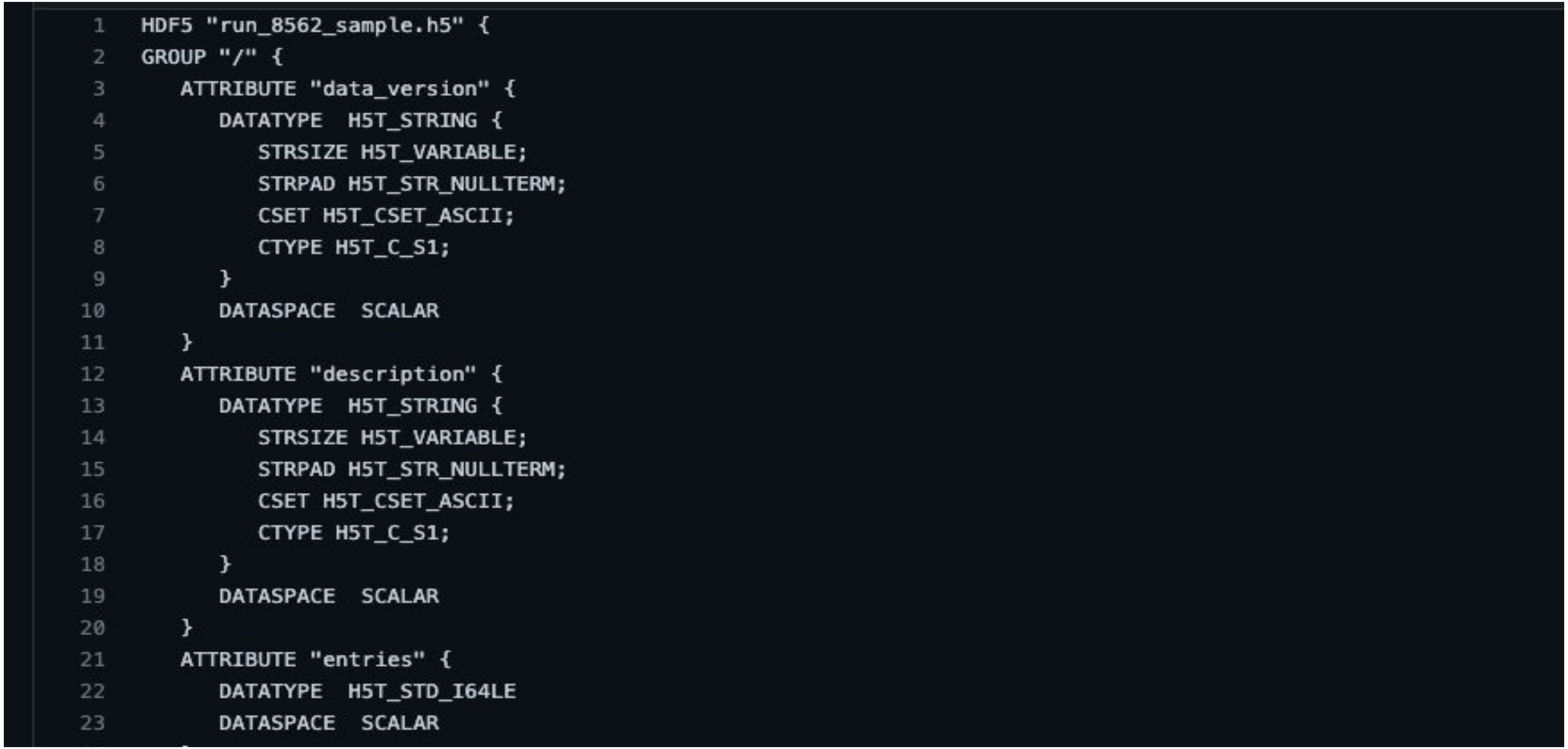
APPENDIX

Data - structure and *indexing*



*Source: https://github.com/TRIUMF-Capstone2022/RICHPID/tree/main/docs

HDF5 format



```
HDF5 "run_8562_sample.h5" {
GROUP "/" {
   ATTRIBUTE "data_version" {
      DATATYPE  H5T_STRING {
         STRSIZE H5T_VARIABLE;
         STRPAD H5T_STR_NULLTERM;
         CSET H5T_CSET_ASCII;
         CTYPE H5T_C_S1;
      }
      DATASPACE  SCALAR
   }
   ATTRIBUTE "description" {
      DATATYPE  H5T_STRING {
         STRSIZE H5T_VARIABLE;
         STRPAD H5T_STR_NULLTERM;
         CSET H5T_CSET_ASCII;
         CTYPE H5T_C_S1;
      }
      DATASPACE  SCALAR
   }
   ATTRIBUTE "entries" {
      DATATYPE  H5T_STD_I64LE
      DATASPACE  SCALAR
```

*Source: As per TRIUMF RICHPID docs
https://github.com/TRIUMF-Capstone2022/RICHPID/blob/86a82e48ec32cad9fdf6bed99a57cfe8e1c0f024/docs/hdf5_format.txt

Data

Description: Large particle-tagged data sets for training

Data source: NA65 datasets generated from light sensing RICH detector (~2000 pixels) for 2016, 2017, 2018 and 2021
We would be using 2018 data (2 periods)

Data Format:
-HDF5 (File directory structured array data)

Number of training examples:
~ 11.5 Million from 2018 B and 2018 E periods

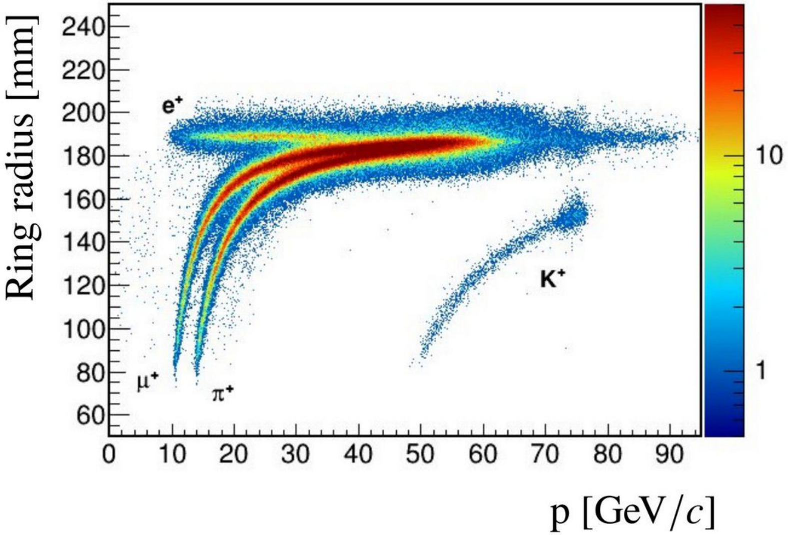
Class Imbalance

Particle * (Class)	**N***	**%**
Pion	**1,169,556**	**10 %**
Muon	10,281,301	89%
Positron	113,112	1 %
Total	11,563,969	

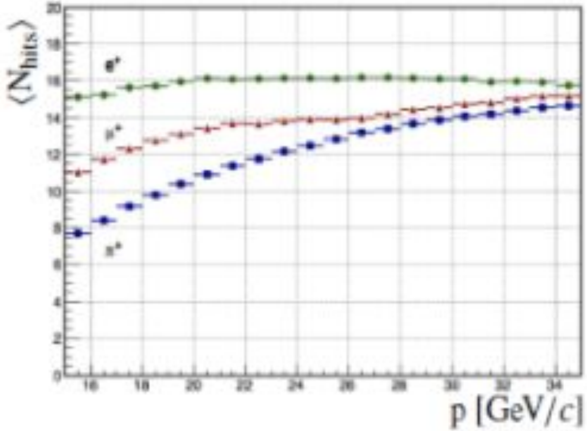
*Source: As per the initial datasets shared by TRIUMF for 2018 (B & E); Other 4 years data would be shared on need basis
https://github.com/TRIUMF-Capstone2022/RICHPID/tree/main/docs

Machine learning - key features

Ring radius vs. Momentum

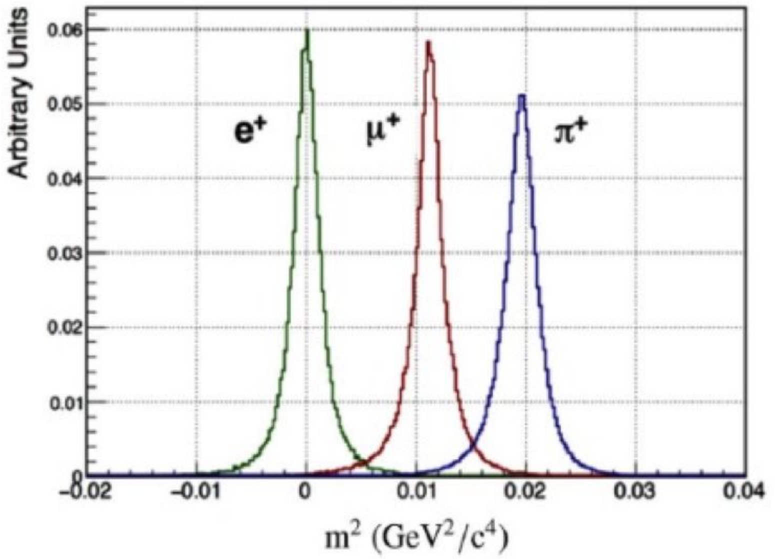


Hits vs. Momentum

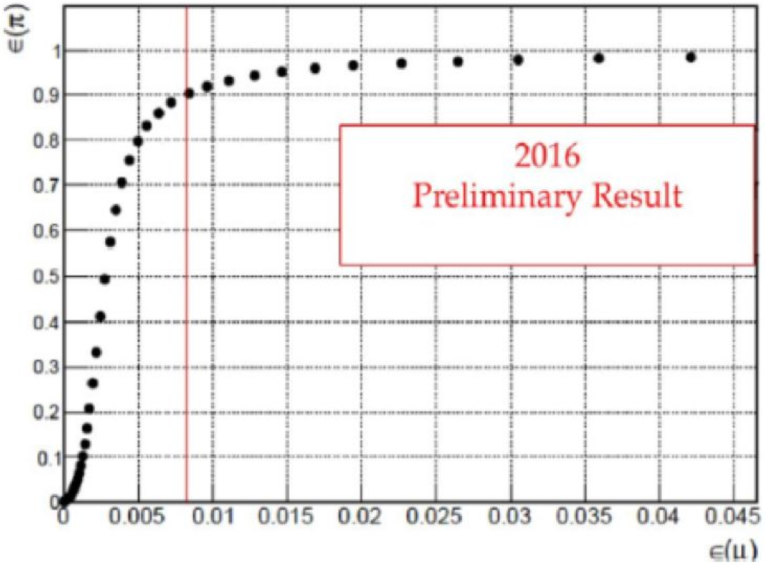


Machine learning - current analytical performance

Current Classification Results



Current ROC Curve


$\epsilon(\pi)$
$\epsilon(\mu)$
Preliminary Result