@hepic_ifusp

WORKSHOP
PROJETO TEMÁTICO

Application of Machine Learning Techniques to the Study of Jet Modification in Relativistic Heavy-Ion Collisions

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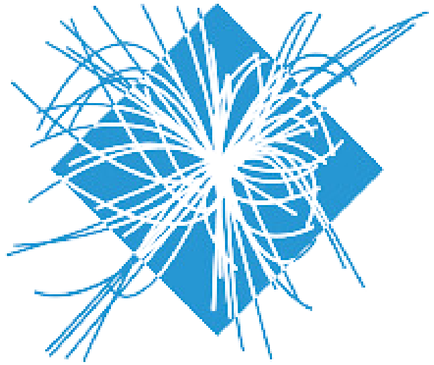

- INTRODUCTION
- OBJECTIVES & GOALS
- CASE STUDY
- RESULTS

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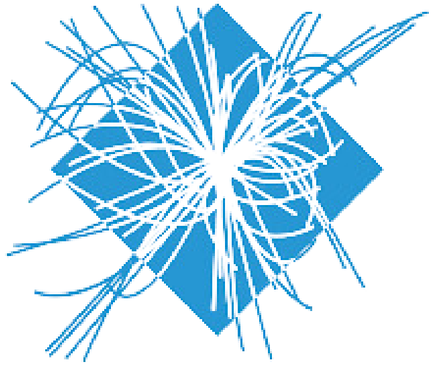

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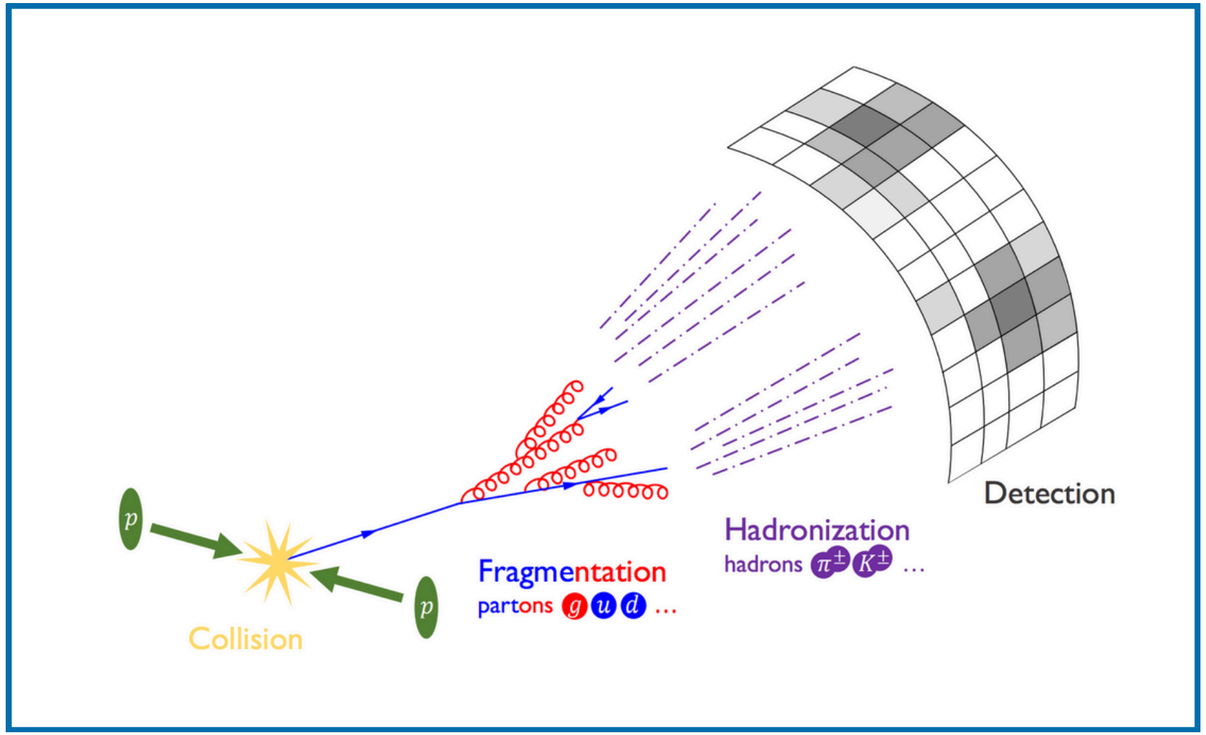
INTRODUCTION

JETS

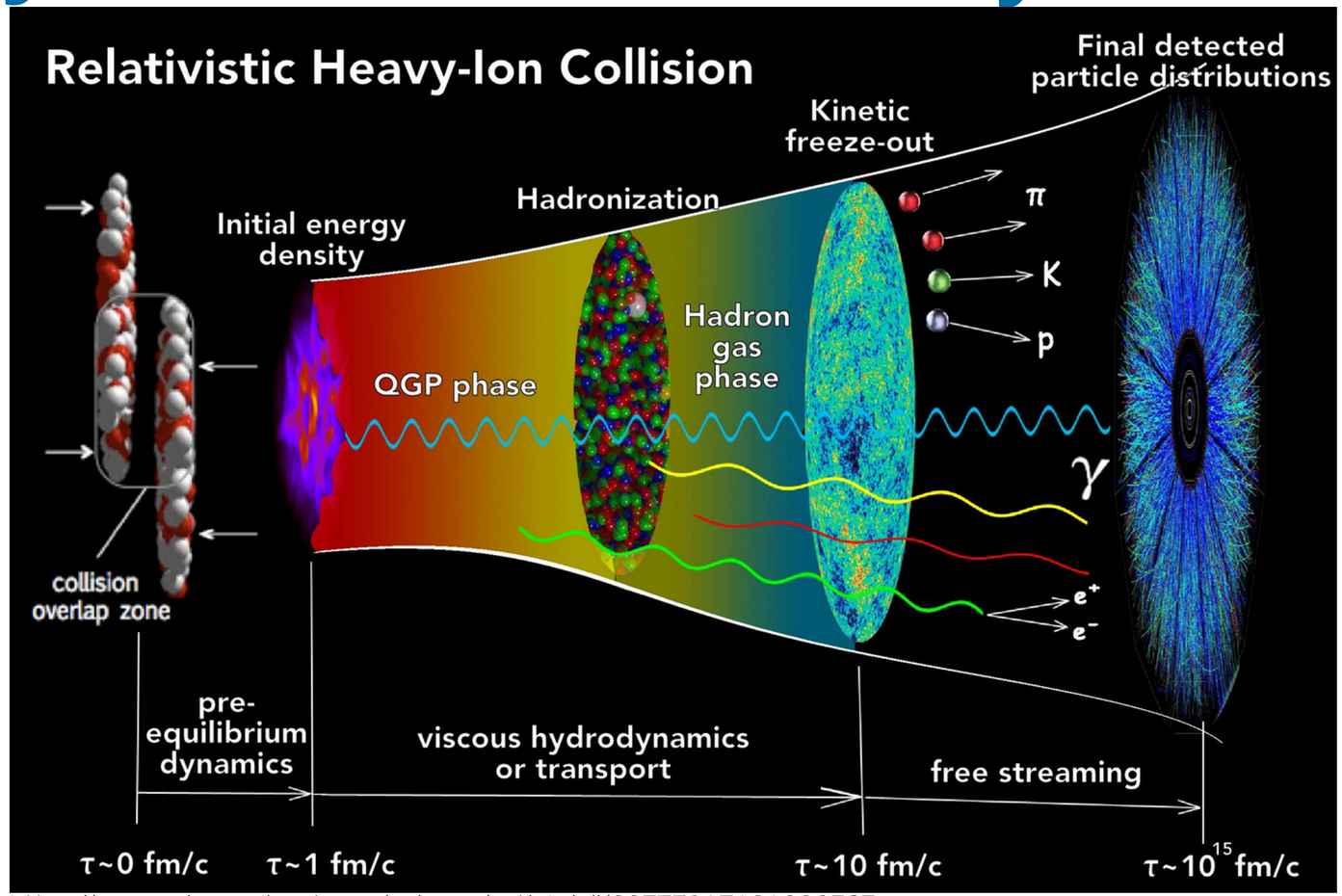
- QCD - hard scattering
- Energy clusters in the detectors
- "Spray" of particles collimated in one direction



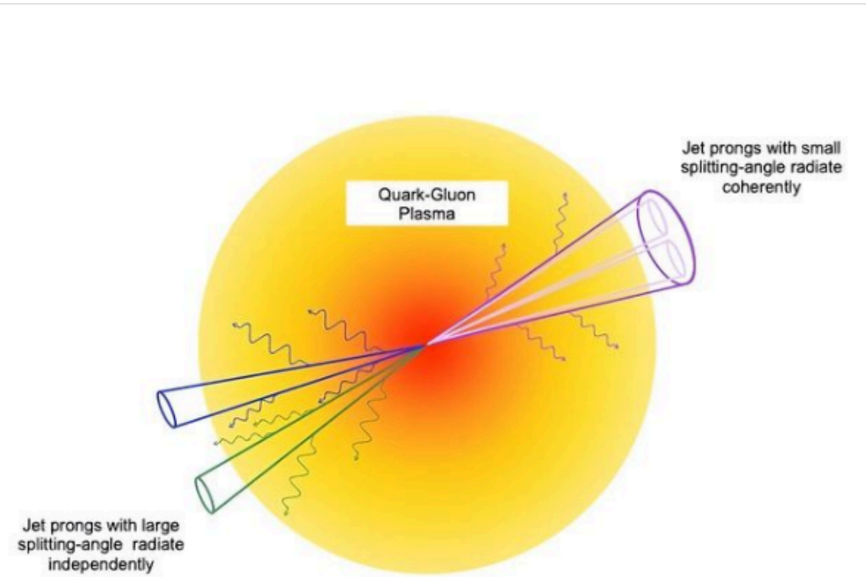
https://www.ericmetodiev.com/files/slides/CERN2019_Metodiev.pd

QUENCHED JETS

Jets can be modified by the medium



https://www.sciencedirect.com/science/article/pii/S0375947424000563



Not all jets radiate equally in quark-gluon plasma, study finds

Studying nuclear matter under extreme conditions allows scientists to better understand how the universe might have looked right after its creation. Scientists at the Large Hadron Collider achieve the ...

Phys.org / Dec. 7, 2023

https://phys.org/news/2023-12-jets-equally-quark-gluon-plasma.html

MACHINE LEARNING

A subfield of artificial intelligence that teaches computers to learn from data and make decisions or predictions without being explicitly programmed

- Supervised
- Unsupervised

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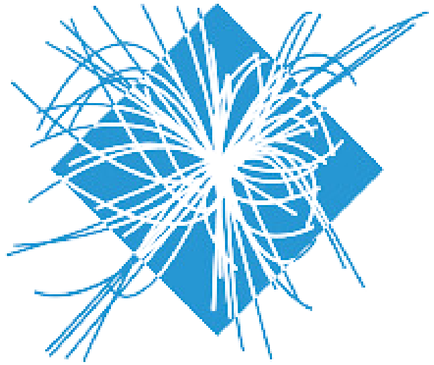

- INTRODUCTION
- **OBJECTIVES & GOALS**
- CASE STUDY
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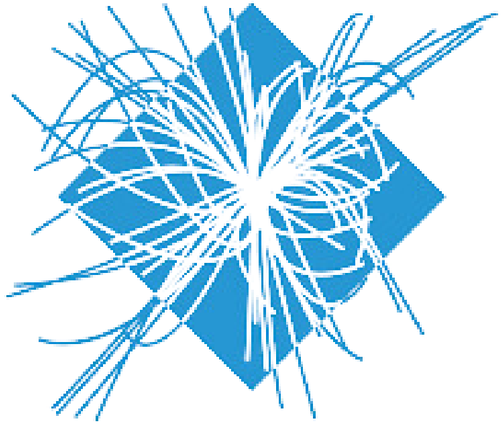
OBJECTIVES & GOALS

This work will investigate the use of different Artificial Intelligence methods and will utilize the JEWEL [1, 2] and v-USPhydro [3, 4] models to study jet modifications in heavy-ion collisions.



01

PYTHIA + JEWEL

Understand the Mechanism of Event Generators

02

RECONSTRUCT JETS

Apply Event Generator Output to Reconstruction Algorithms, such as FastJet

03

AI TECHNIQUES

Apply Different Machine Learning Techniques to the Dataset

04

CHOOSE TECHNIQUE

Based on the Metrics of Different Models, Choose the One that Best Classifies the Data

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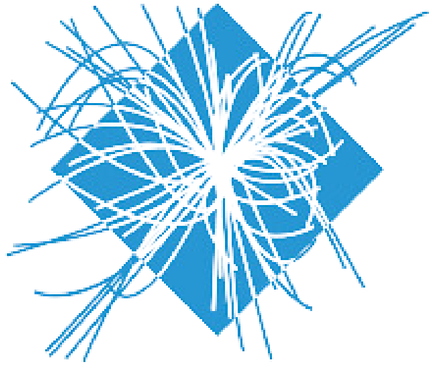

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CASE STUDY

ENCODER LSTM - LONG SHORT-TERM MEMORY [5]

01	02	03	04	05
PROBLEM	**ANALYSIS**	**CURRENT STATE**	**PROPOSED SOLUTION**	**IMPLEMENTATION**
Distinguish between non-quenched jets and quenched jets.	Jet Substructure Analysis	Reproduce the results from the article 'Identifying quenched jets in heavy ion collisions with machine learning' [5]	Use of LSTM neural networks	Python

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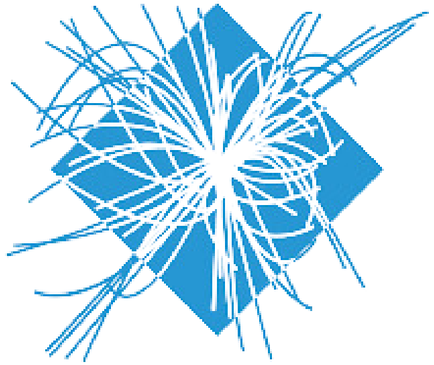


- INTRODUCTION
- OBJECTIVES & GOALS
- CASE STUDY
- **RESULTS**

SOME RESULTS

$$z = \frac{\min(p_{\mathrm{T,i}}, p_{\mathrm{T,j}})}{p_{\mathrm{T,i}} + p_{\mathrm{T,j}}},$$

$$\Delta R = \sqrt{(\phi_{\mathrm{i}} - \phi_{\mathrm{j}})^2 + (\eta_{\mathrm{i}} - \eta_{\mathrm{j}})^2},$$

$$k_{\perp} = \min(p_{\mathrm{T,i}}, p_{\mathrm{T,j}}) * \Delta R,$$

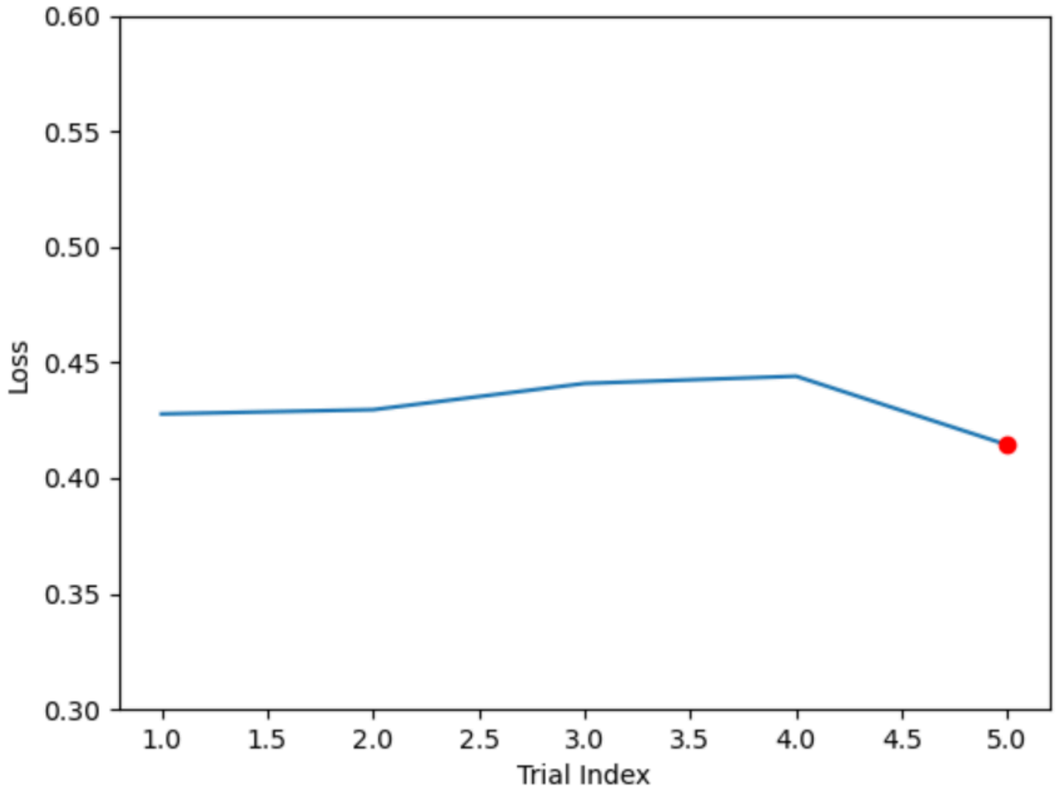
$$m_{\mathrm{inv}} = \sqrt{(E_{\mathrm{i}} + E_{\mathrm{j}})^2 - (\mathbf{p}_{\mathrm{i}} + \mathbf{p}_{\mathrm{j}})^2},$$

$$x_{\mathrm{t}} = [z, \Delta R, k_{\perp}, m_{\mathrm{inv}}],$$

substructures

SOME RESULTS

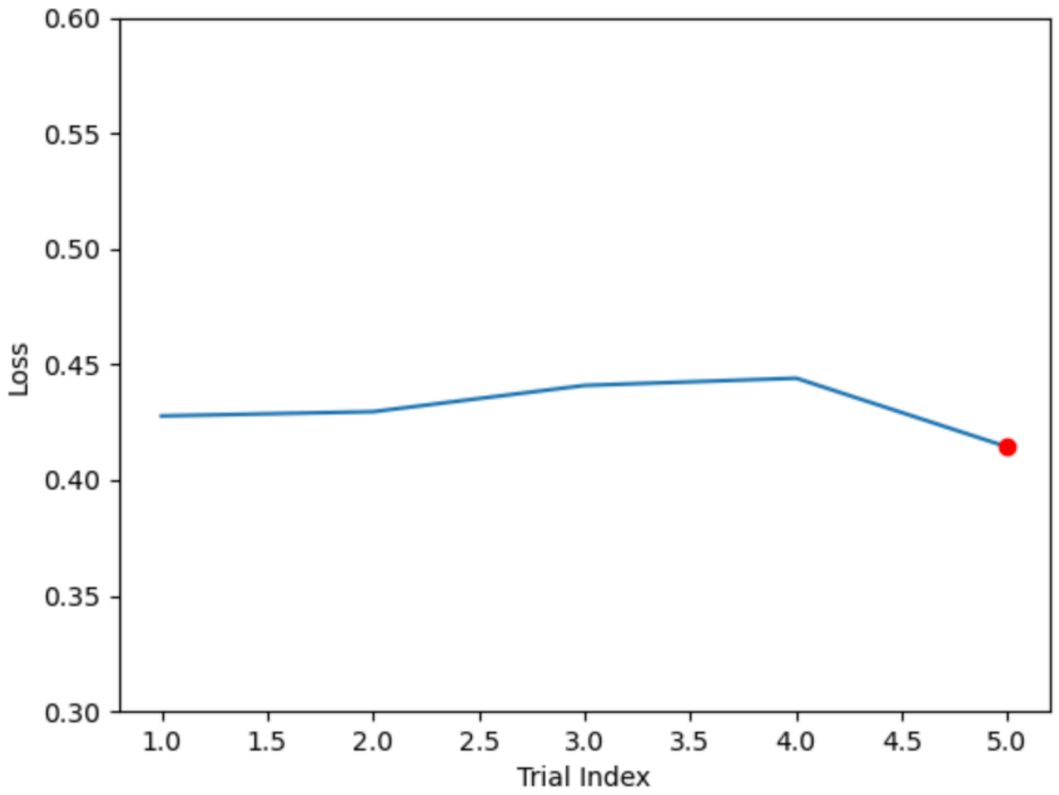
Hyperparameter tuning



▼ root
decay_factor 0.9612290185137162
hidden_size0 18
hidden_size1 4
learning_rate 0.032628487202416935
loss_func "mse"
num_batch 10000
num_epochs 50
num_layers 3

SOME RESULTS

Hyperparameter tuning



- **root**
  - **decay_factor** 0.9612290185137162
  - **hidden_size0** 18
  - **hidden_size1** 4
  - **learning_rate** 0.032628487202416935
  - **loss_func** "mse"
  - **num_batch** 10000
  - **num_epochs** 50
  - **num_layers** 3

SOME RESULTS

Weighted mean squared error (MSE) loss function

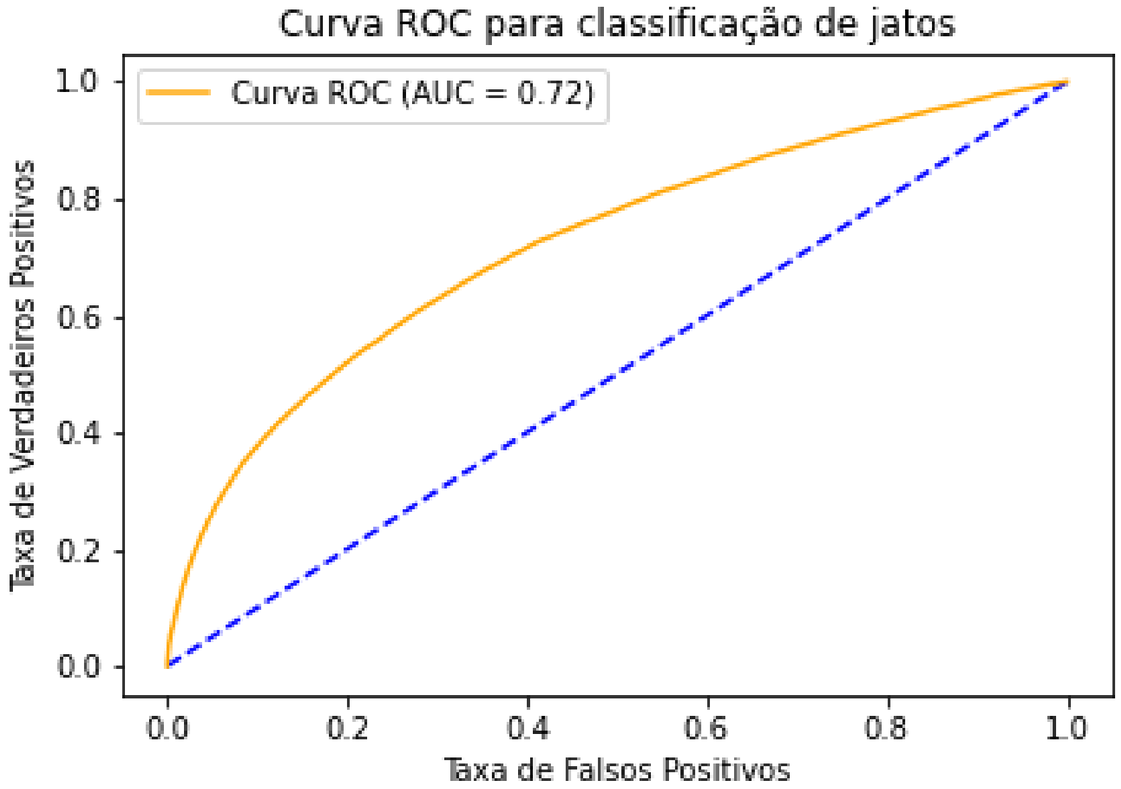
$$l_{\mathrm{MSE}} = \frac{\sum_{\mathrm{batch}} \omega_{\mathrm{i}} * (x_{\mathrm{i}} - y_{\mathrm{i}})^2}{\sum_{\mathrm{batch}} \omega_{\mathrm{i}}}$$

predictive label and the truth label of the *ith* jet

weight

SOME RESULTS

graphical tool used to evaluate the performance of a binary classification model



AUC score = 0.722

AUC score = 0.748 (Article [5])

REFERENCES

[1] K. Zapp, G. Ingelman, J. Rathsman, J. Stachel and U. A. Wiedemann: "A Monte Carlo Model for 'Jet Quenching'", Eur. Phys. J. C 60 (2009) 617

[2] Raghav Kunnawalkam Elayavalli and Korinna Christine Zapp: "Medium response in JEWEL and its impact on jet shape observables in heavy ion collisions", JHEP 07 (2017) 141

[3] J. Noronha-Hostler, G. S. Denicol, J. Noronha, R. P. G. Andrade and F. Grassi, Phys. Rev. C 88, (2013) 044916

[4] J. Noronha-Hostler, J. Noronha and F. Grassi, Phys. Rev. C 90, no. 3, (2014) 034907

[5] Liu, L., Velkovska, J., Wu, Y., & Verweij, M. (2023). Identifying quenched jets in heavy ion collisions with machine learning. Journal of High Energy Physics, 2023(4), 1-23.

THANK YOU

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BACKUP

AGENDA

PROJECT PLANNING

2024

1º Semester	2º Semester
• Obtaining Credits; • Hard Processes in QCD; • PYTHIA+JEWEL; • Jet Reconstruction Algorithms.	• Obtaining Credits; • Artificial Intelligence Techniques.

AGENDA

PROJECT PLANNING

2025

1º Semester	2º Semester
• Implementation of the AI Approach; • Validation Using Simulations (JEWEL+vUSPhydro).	• Completion of Simulated Data Analysis; • Writing of the Dissertation.

OUR TEAM

PhD students

Fabio de Moraes Canedo

Leopoldo Abranches de Carvalho

Leonardo Barreto

M. Monalisa de Melo Paulino

Lucas Ferrandi de Oliveira

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Masters students

Leonardo Lima da Silva

Lucas José Franco da Silva

João Costa

OUR TEAM

PostDoc

Geovane Grossi
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OUR TEAM

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