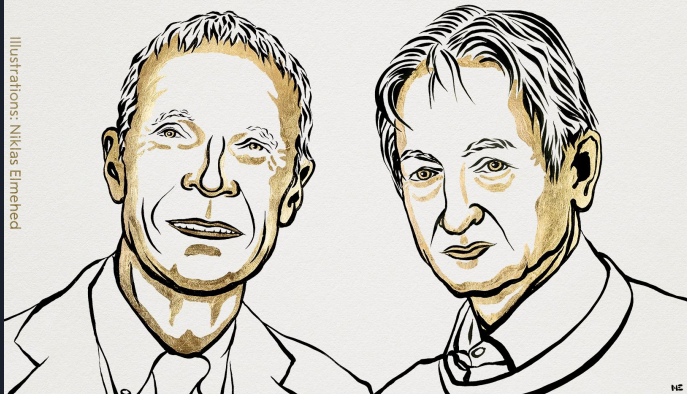


Uso de machine learning no estudo de jatos e suas propriedades

Palestrante: J. G. Arneiro

THE NOBEL PRIZE
IN PHYSICS 2024

Illustrations: Niklas Elmehed



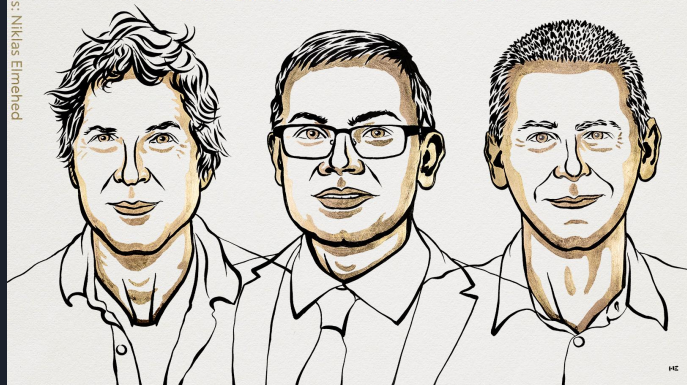
John J. Hopfield Geoffrey E. Hinton

"for foundational discoveries and inventions
that enable machine learning
with artificial neural networks"

THE ROYAL SWEDISH ACADEMY OF SCIENCES

THE NOBEL PRIZE
IN CHEMISTRY 2024

Illustrations: Niklas Elmehed



David
Baker

"for computational
protein design"

Demis
Hassabis

"for protein structure prediction"

John M.
Jumper

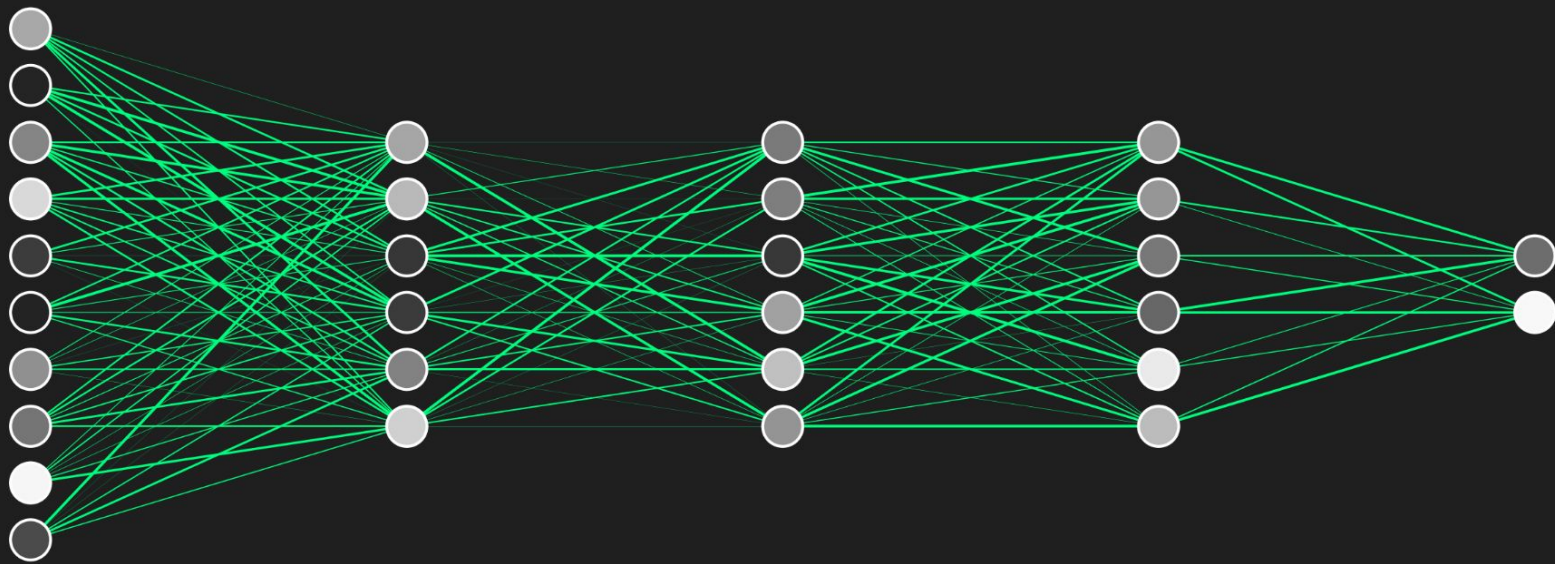
THE ROYAL SWEDISH ACADEMY OF SCIENCES

Uso de IA!

Tudo não passa de uma
“caixa preta”?

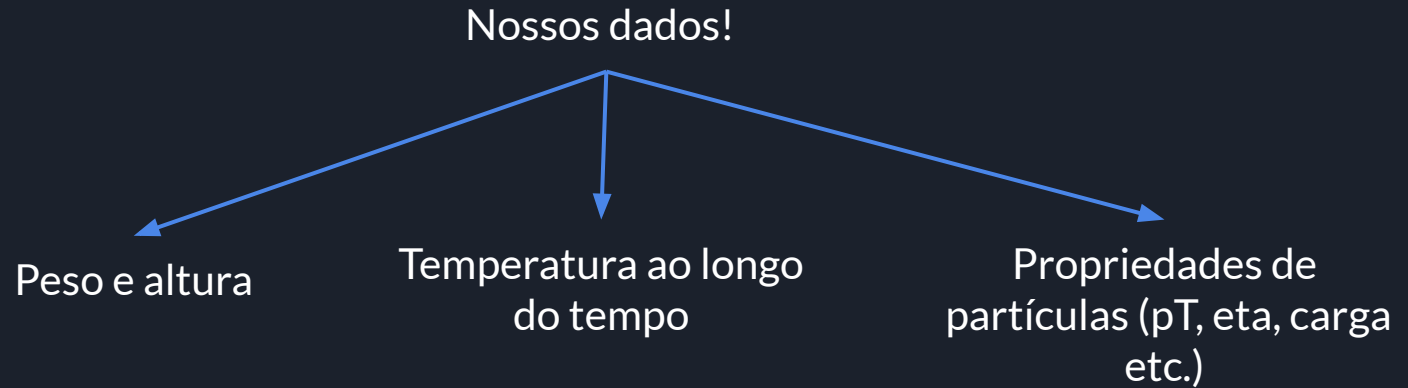
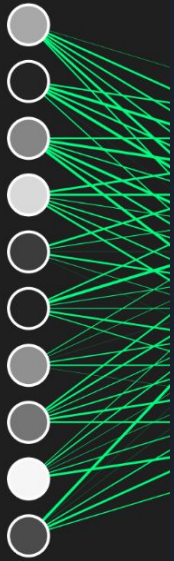


A estrutura de uma rede neural



A estrutura de uma rede neural

Camada de entrada



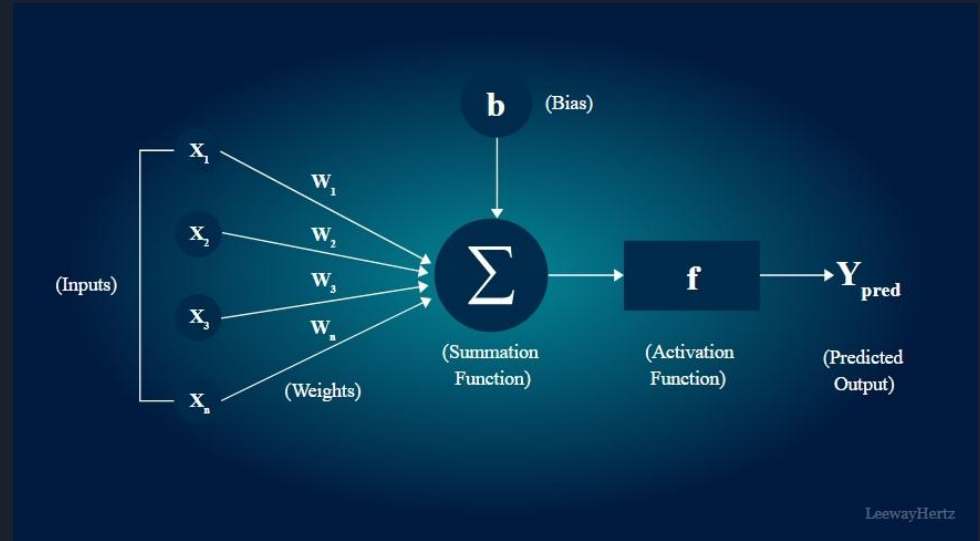
A estrutura de uma rede neural

Camadas escondidas

Onde a “mágica” acontece!

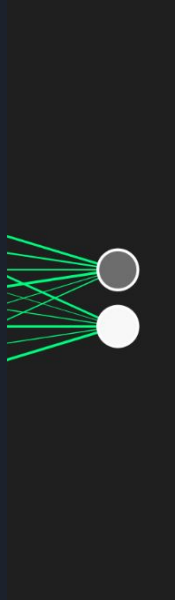


$$x_i = f \left(\sum_{n=1}^N w_n x_n + b_n \right)$$



A estrutura de uma rede neural

Camada de saída



A informação que nós buscamos!

Probabilidade de cada classe

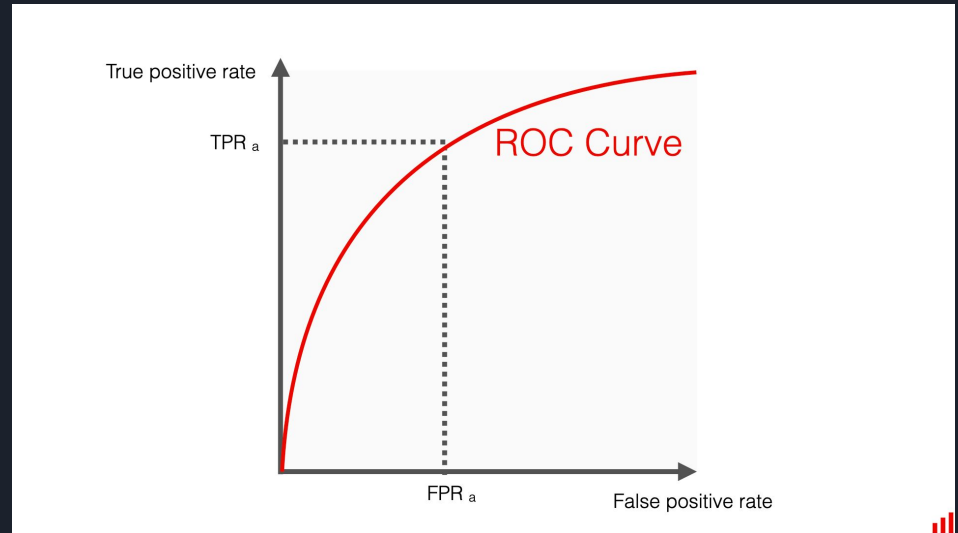
Valor da variável

Avaliação de performance

Como saber se a rede é boa ou não?

Métricas de performance:

- Acurácia
- Falso positivo
- Falso negativo
- Verdadeiro Positivo
- Verdadeiro Negativo
- Curva ROC e AUC





Motivação

Projeto final da disciplina de ML e IA em física



Classificação de jatos em colisões p+p no LHC

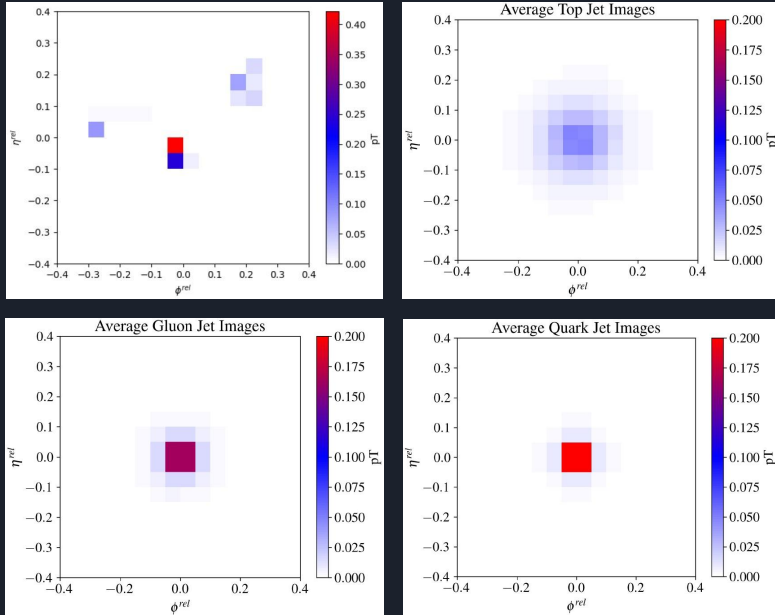


Aplicar algoritmos para tentar classificar jatos como sendo originados por quarks pesados, leves ou glúons

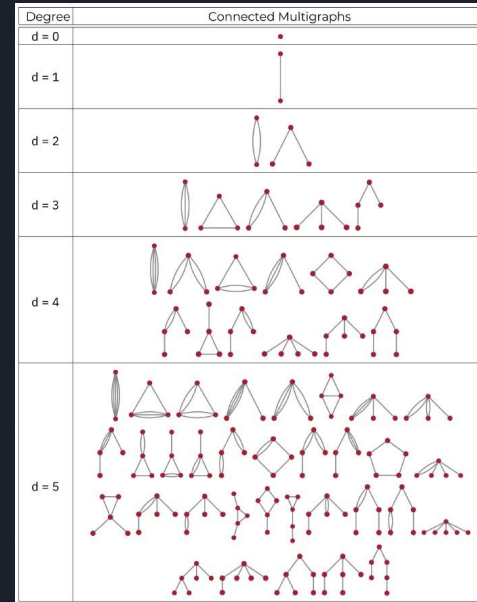
Motivação

Projeto de classificação de jatos

Imagens de jatos



Energy Flow Polynomials (EFPs)



Motivação

Projeto de classificação de jatos

Da literatura^{[1],[2]}

Modelo	AUC	Background Rejection ($1 - \varepsilon_b$)		Quantidade de parâmetros
		$\varepsilon_s = 0.3$	$\varepsilon_s = 0.5$	
Logistic Regression EFPs	0.848	0.98	0.93	55
Discriminat Analysis EFPs	0.856	0.98	0.95	55
CNN JetImages	0.863	0.98	0.95	520.002
Decision Tree	0.864	0.98	0.95	-
Boosted DT EFPs	0.867	0.98	0.95	-
Random Forests EFPs	0.867	0.98	0.96	-
Point Net	0.872	0.99	0.96	16.066
Particle Cloud	0.880	0.99	0.96	3.842
CNN EFPs + mean ΔR_{ij}	0.892	0.99	0.97	584.267

Modelo	AUC	Background Rejection ($1 - \varepsilon_b$)		Quantidade de parâmetros
		$\varepsilon_s = 0.3$	$\varepsilon_s = 0.5$	
Logistic Regression EFPs	0.949	0.996	0.984	55
Decision Tree	0.950	0.996	0.984	-
Discriminat Analysis EFPs	0.950	0.994	0.985	55
Point Net	0.950	0.995	0.983	16.066
Boosted DT EFPs	0.952	0.997	0.987	-
CNN JetImages	0.952	0.997	0.987	593.218
Random Forests EFPs	0.954	0.997	0.987	-
Particle Cloud	0.954	0.997	0.987	6.306
CNN EFPs + mean ΔR_{ij}	0.973	0.999	0.995	584.257

Quark-gluon
tagging

AUC: 0.91

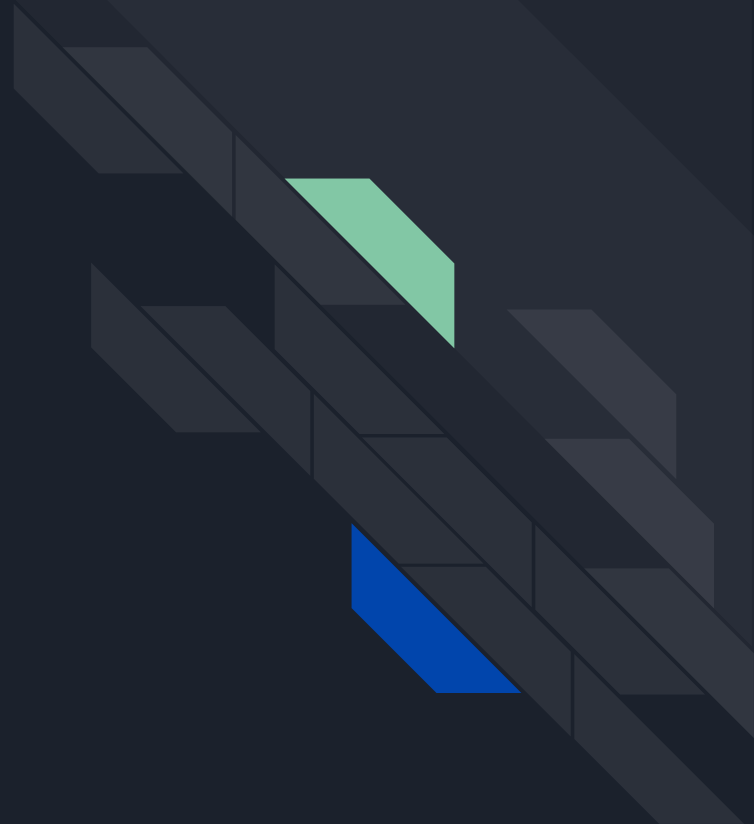
Top tagging

AUC: 0.98

[1] Gregor Kasieczka et al. "The Machine Learning landscape of top taggers". Em: *SciPost Physics* 7.1 (2019). ISSN: 2542-4653. DOI: 10.21468/scipostphys.7.1.014. URL: <http://dx.doi.org/10.21468/SciPostPhys.7.1.014>.

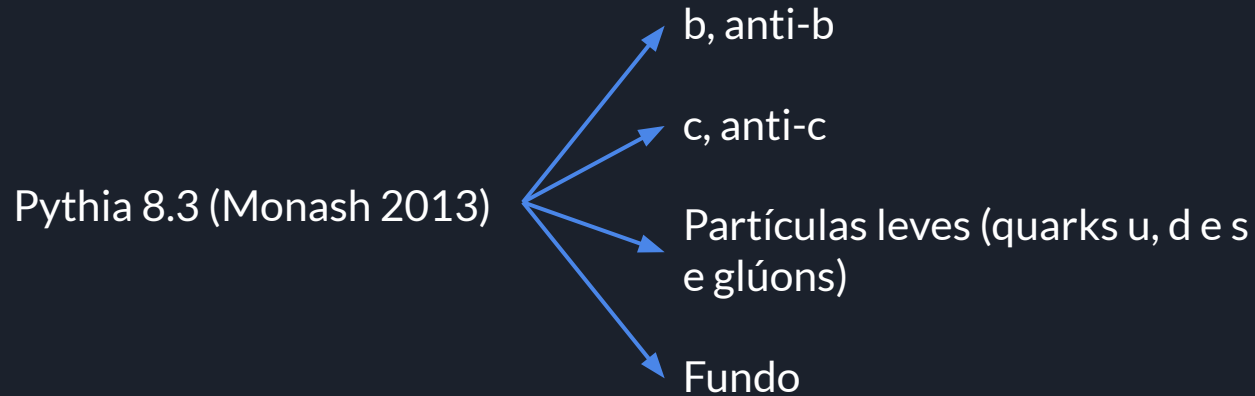
[2] Huilin Qu e Loukas Gouskos. "ParticleNet: Jet Tagging via Particle Clouds". Em: *Phys. Rev. D* 101.5 (2020), p. 056019. DOI: 10.1103/PhysRevD.101.056019. arXiv: 1902.08570 [hep-ph].

E agora?





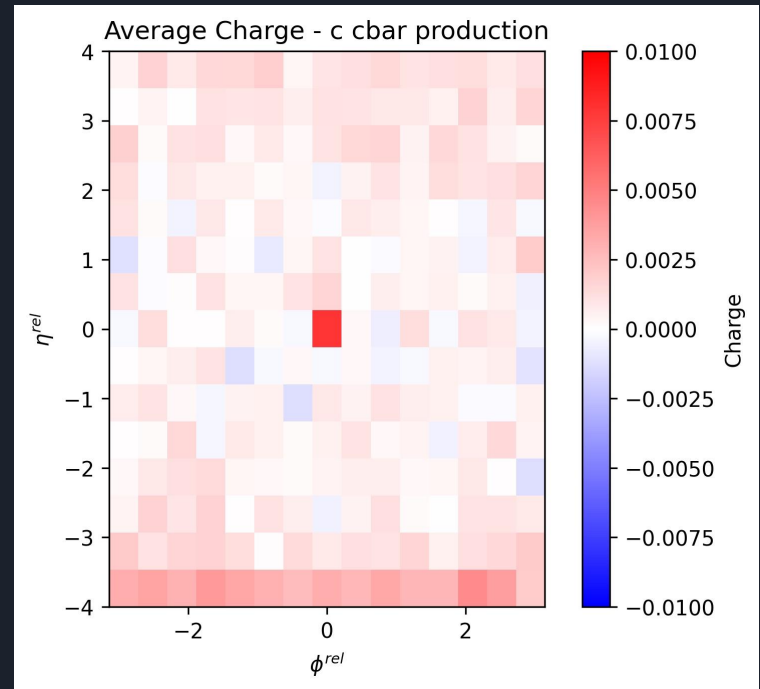
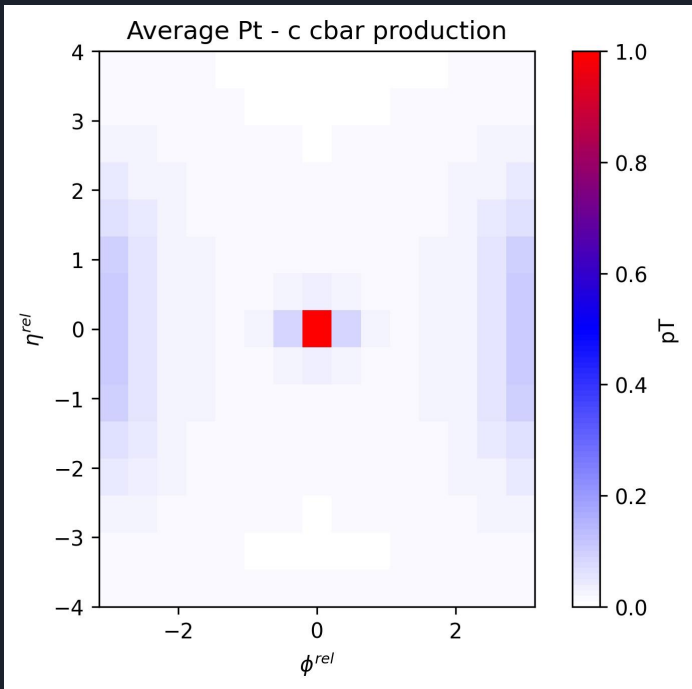
Geração de dados



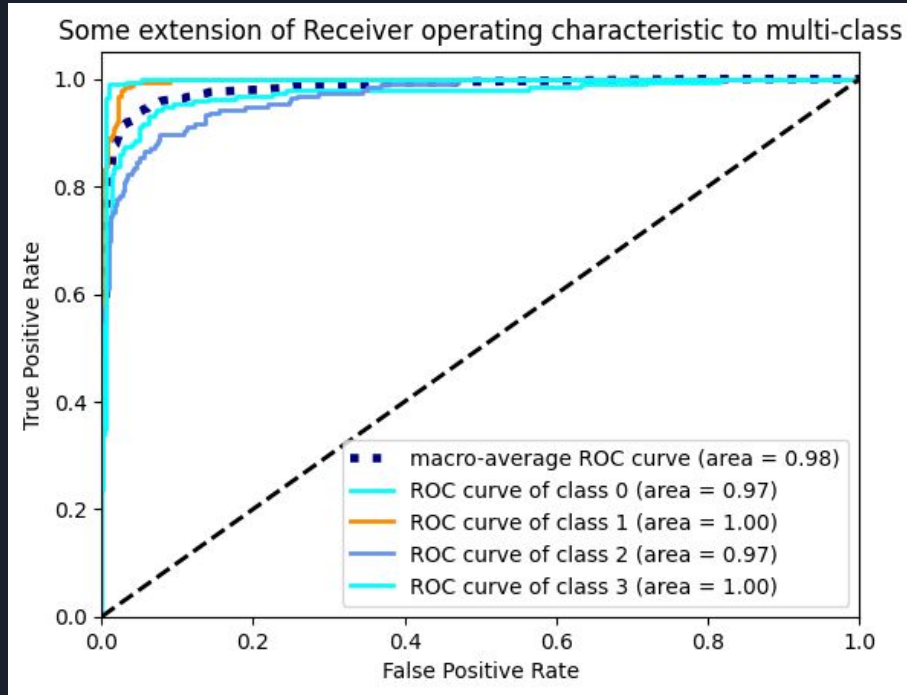
Cortes no espaço de fase (hard process): 10 a 30 GeV, 40 a 60 GeV e 90 a 110 GeV

Imagens de jatos

Dois canais de “cores”



Treino das redes



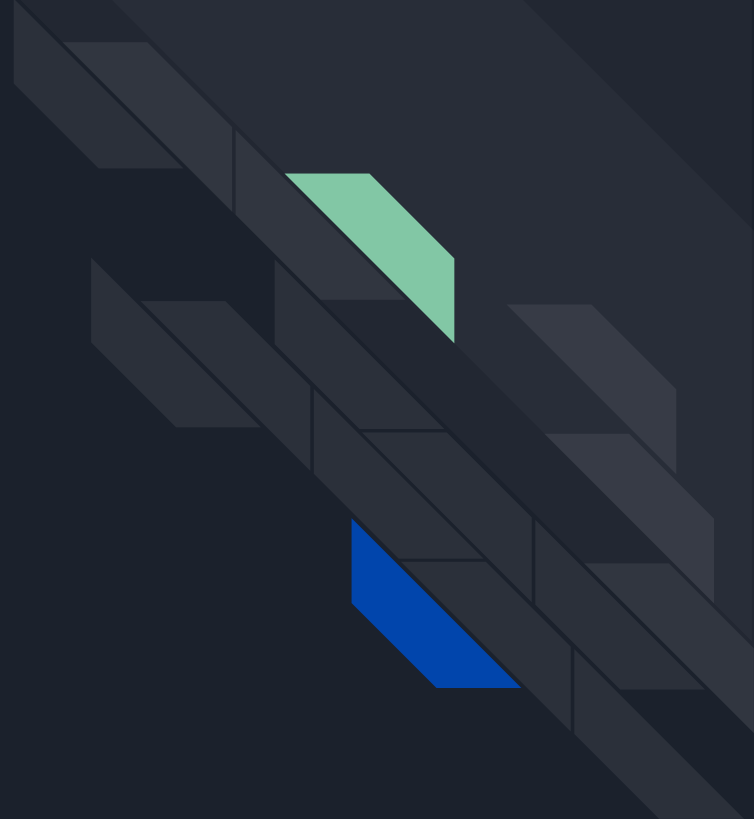
Bom demais pra ser verdade...



Próximos passos

- Funções de ativação
- Rever o que é considerado um sinal
- Geração de dados (parte 2)
- Aplicação de outros métodos

Obrigado!



Apêndice



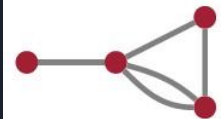
EFPs (a matemática por trás)

$$EFP_G = \sum_{i_1=1}^M \cdots \sum_{i_N=1}^M z_{i_1} \cdots z_{i_N} \prod_{(k,l \in G)} \theta_{i_k, i_l}$$

$$z_i = \frac{p_{T,i}}{p_{T,J}}, \quad p_{T,J} \equiv \sum_{i=1}^M p_{T,i}$$

$$\theta_{ij} = (\Delta y_{ij}^2 + \Delta \phi_{ij}^2)^{\beta/2}$$

$$\bullet_j \iff \sum_{i_j=1}^M z_{i_j}, \quad k \text{ --- } l \iff \theta_{ij}$$



$$= \sum_{i_1=1}^M \sum_{i_2=1}^M \sum_{i_3=1}^M \sum_{i_4=1}^M z_{i_1} z_{i_2} z_{i_3} z_{i_4} \theta_{i_1 i_2} \theta_{i_2 i_3} \theta_{i_2 i_4}^2 \theta_{i_3 i_4}$$