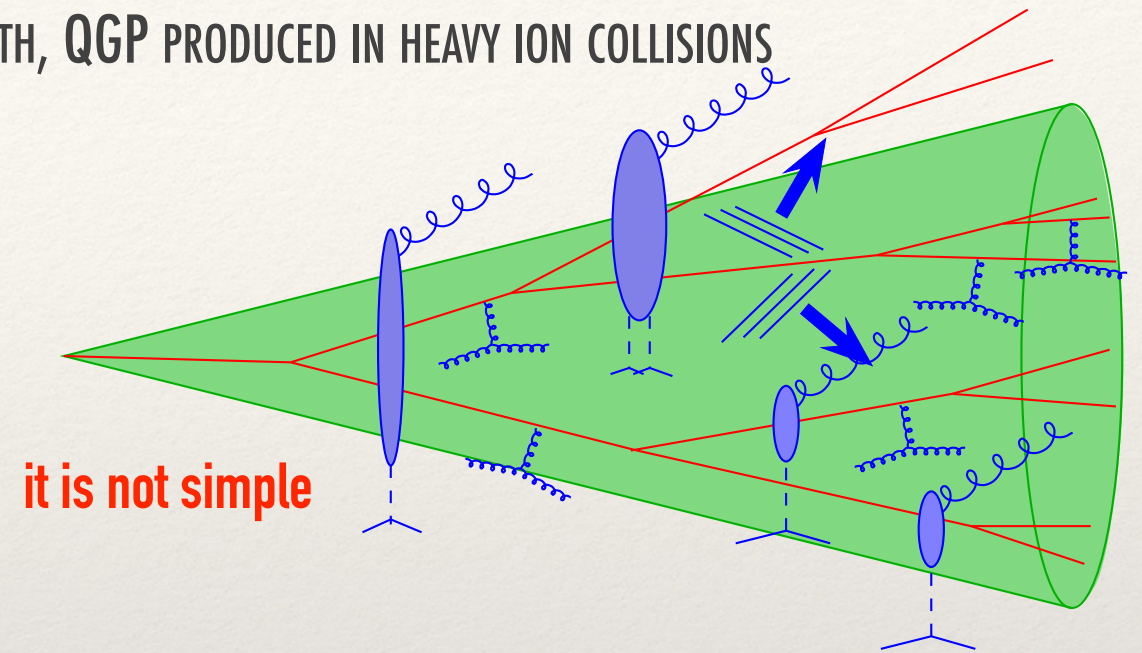# TASK 2

# Machine learning for LHC data: physics objects reconstruction and physics aware learning

Guilherme Milhano

jet quenching

MODIFICATION OF JET PROPERTIES DUE TO TRAVERSAL OF, AND INTERACTION WITH, QGP PRODUCED IN HEAVY ION COLLISIONS
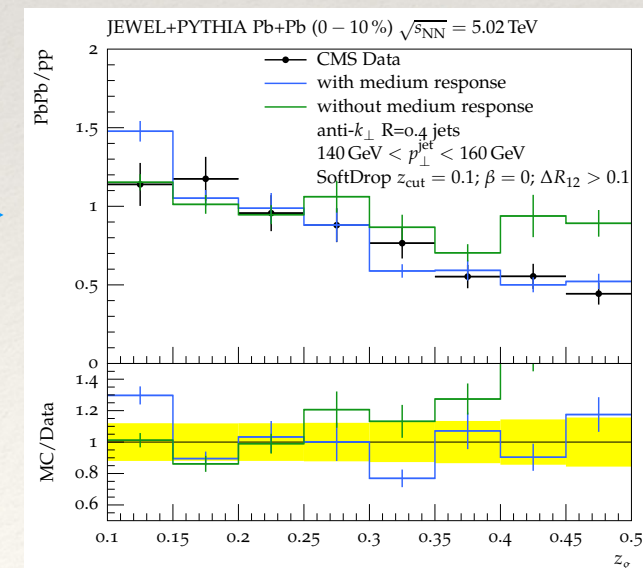
it is not simple

STANDARD APPROACH IS DEVISE INCREASINGLY SOPHISTICATED OBSERVABLES THAT CAN BE ARGUED TO BE SENSITIVE TO SPECIFIC ASPECTS OF JET-QGP INTERACTION AND, IF JET DYNAMICS WERE FULLY UNDERSTOOD, TO THE EXTRACTION OF QGP PROPERTIES
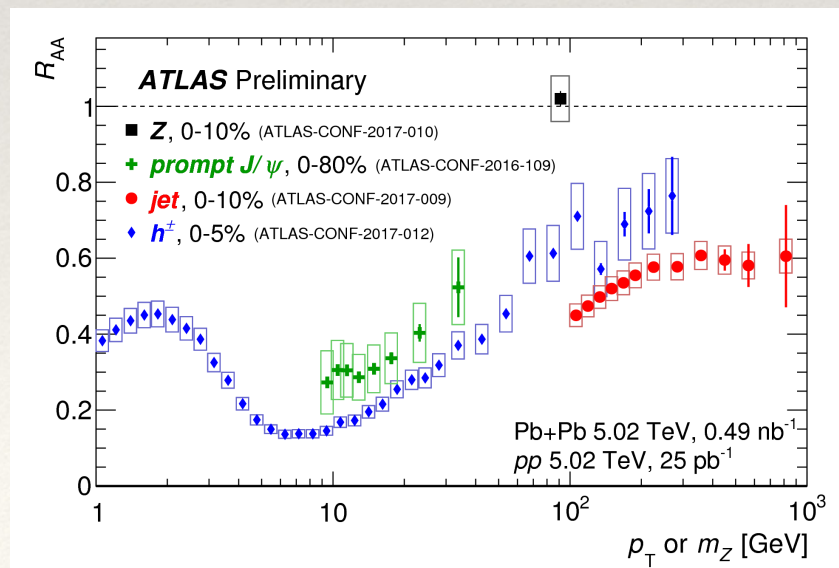
observable complexity

increased sensitivity

$$R_{AA} = \frac{\sigma_{AA}^{eff}}{\sigma_{pp}^{eff}}\bigg|_{p_T}$$

$$z_g \equiv \frac{\min(p_{\perp,1}, p_{\perp,2})}{p_{\perp,1} + p_{\perp,2}} > z_{cut}\left(\frac{\Delta R_{12}}{R}\right)^{\beta}$$

jet quenching

However, no criterium to separate samples of strongly and weakly modified jets :: effects are diluted in sample

Choices of sensitive observables strongly biased by prejudice and lack of imagination [often imported from quark/gluon jet discrimination and W-tagger studies in vacuum]

ML offers tools to separate samples on a statistical basis [classification]

ML offers an agnostic approach :: let the machine learn and learn the physics [best observables] from the machine

a brief summary

- *2 MSc theses concluded*
  - *João Gonçalves [IST]*
  - *Filipa Peres [UMinho]*
- *1 MSc on-going ,*
  - *João Silva [IST]*

- work involving Liliana, Miguel and myself

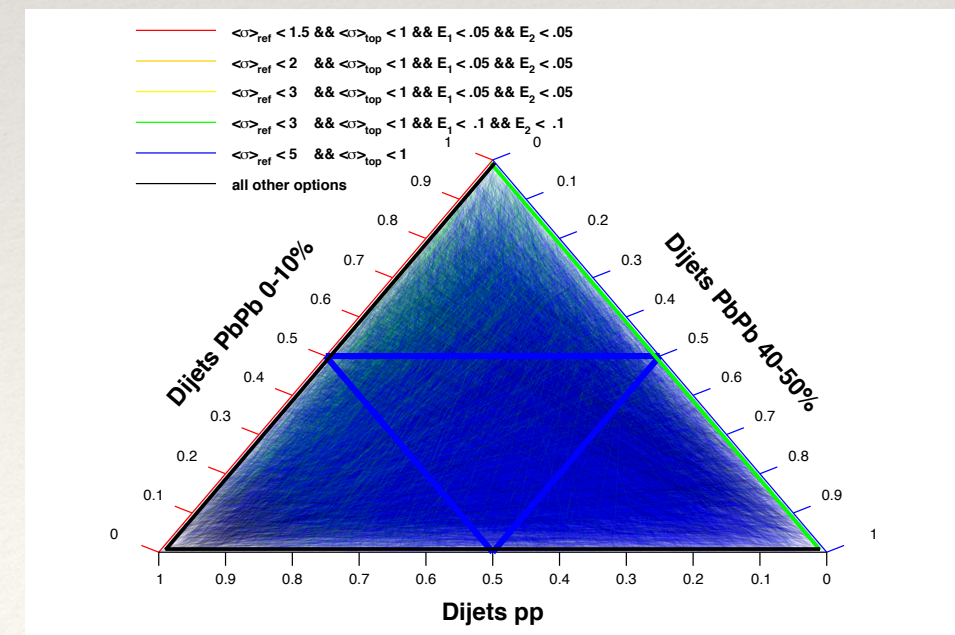- *some of the very first works in ML for jets in HI*
  - *expect to publish soon*
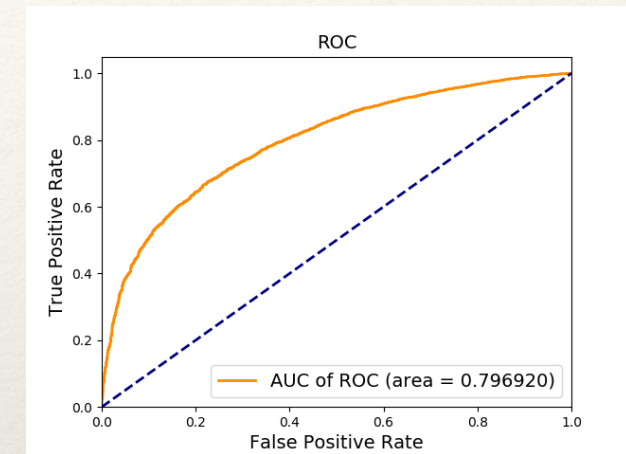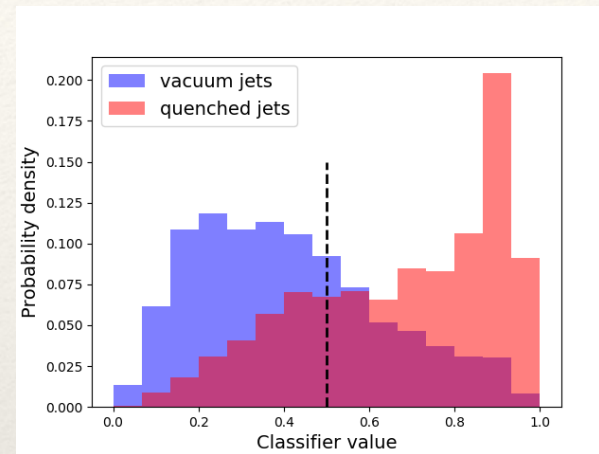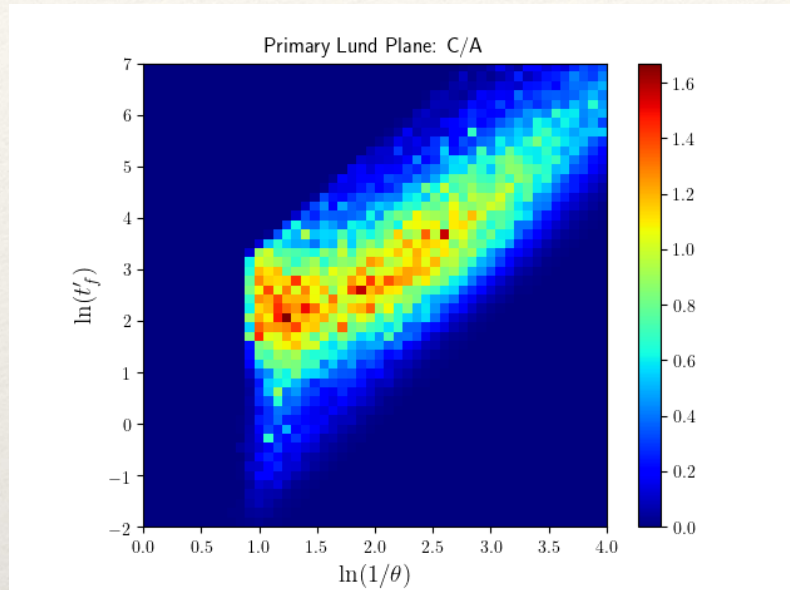
topic modelling

João Gonçalves [MSc IST]
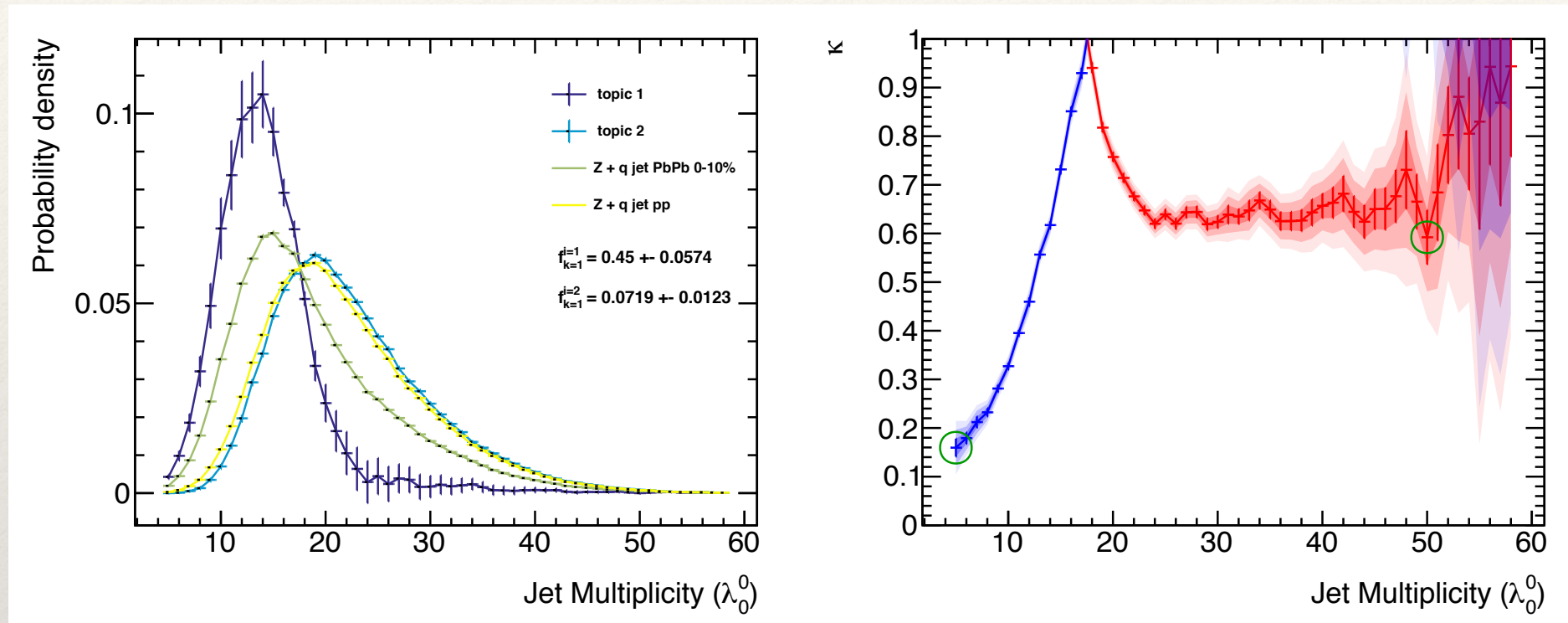
techniques from document classification perform well in separating jets in pp and AA

- **two topics accurately reconstructed from two enriched samples**
- **extensive studies of performance improvement with additional samples**
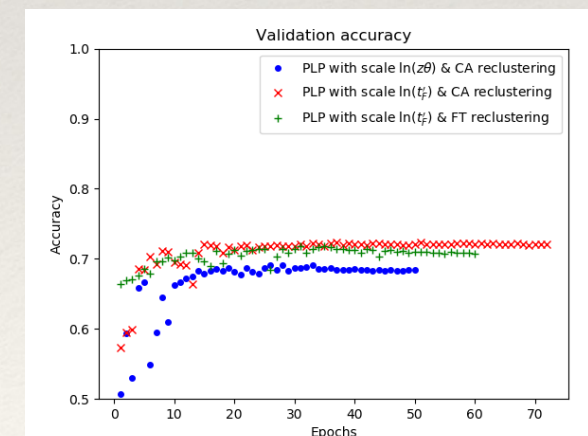
lund planes

FILIPA PERES [MSc UMINHO]

Lund plane :: information on jet history via decluttering algorithm

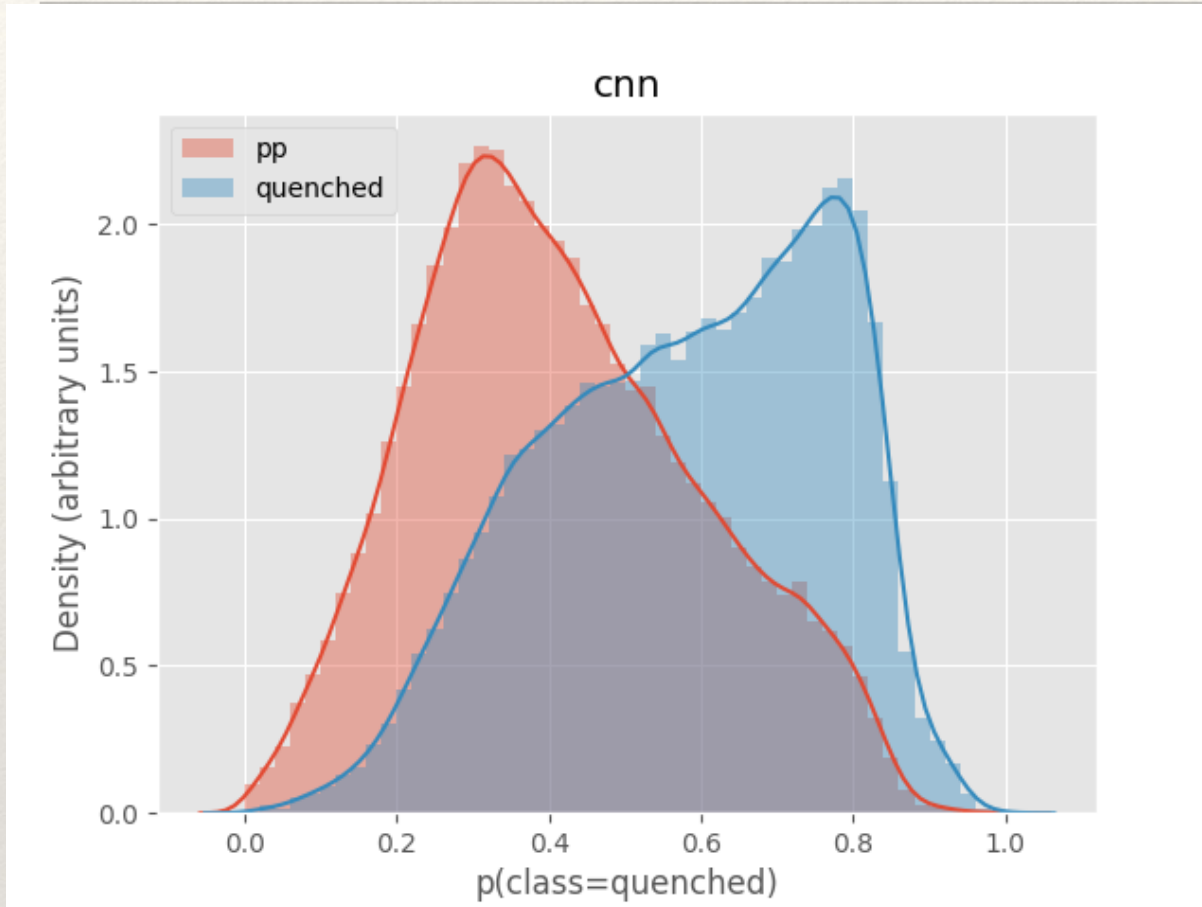**per jet sequence os splittings as input to NN**

$$\left[\left[\ln(1/\theta_1), \ln(t'_{F,1})\right], \left[\ln(1/\theta_2), \ln(t'_{F,2})\right], ..., \left[\ln(1/\theta_n), \ln(t'_{F,n})\right]\right]$$

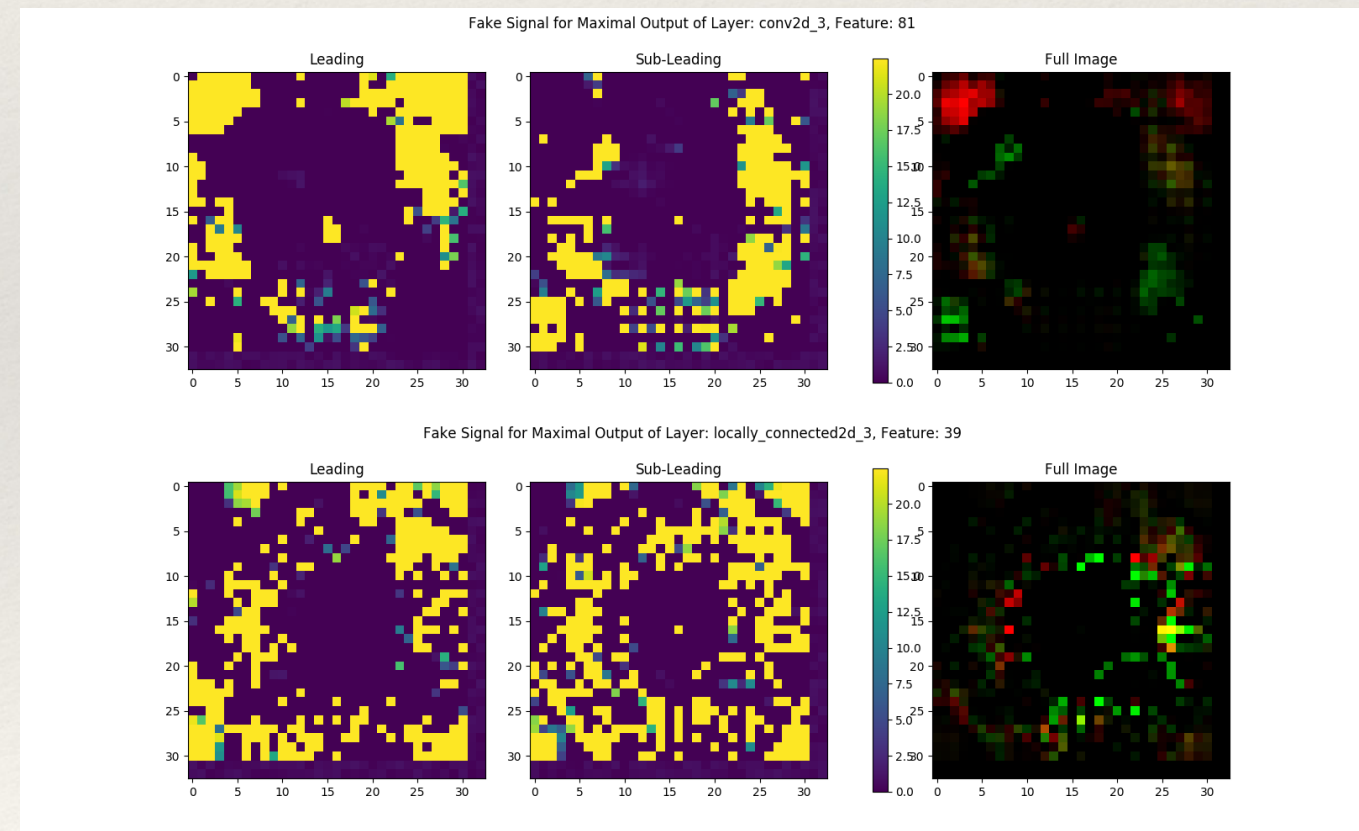**further discrimination power needs grooming of jets**

on going – jet images

Liliana Apolinário, Guilherme Milhano, Miguel Romão

very promising first results

jets as images [from calorimetric energy depositions] to train CNN

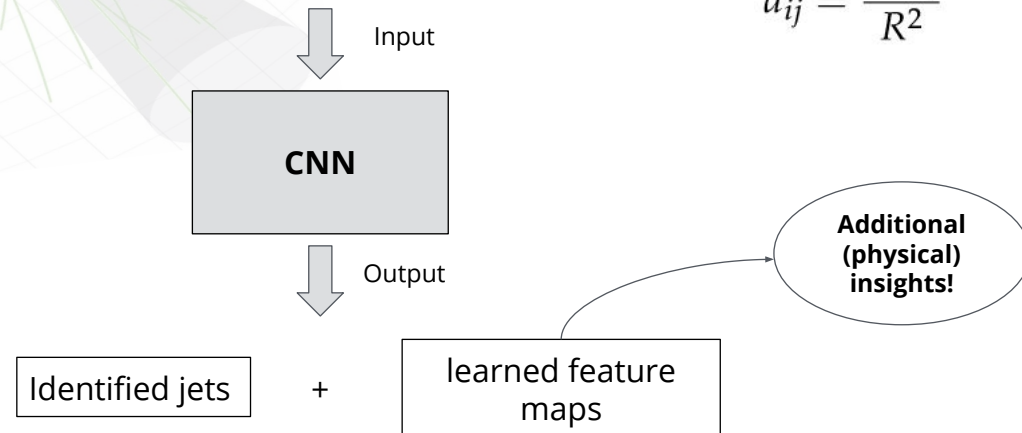

read off features identified by CNN

jet evolution history

João Silva [MSc IST, on-going]

Convolutional Neural Networks (CNN)

Construct jet's evolution history with C/A algorithm

$$d_{ij} = \frac{\Delta R_{ij}^2}{R^2}$$

Input

CNN

Output

Identified jets + learned feature maps → Additional (physical) insights!

G. Kasieczka et al. "Deep-learning Top Taggers or The End of QCD?"
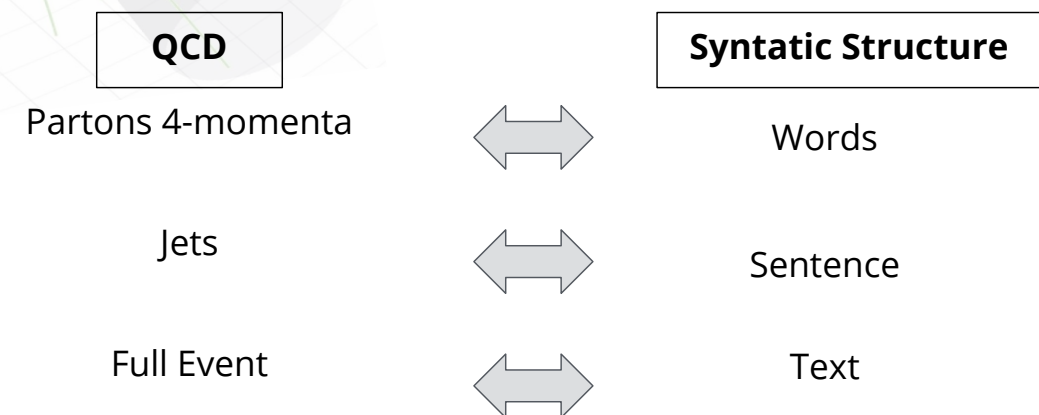
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- **jet evolution formulated in momentum space**
- **recover space–time picture [needed for interaction with time evolving QGP] from multi–observable consistency**
- **analogous to learning a grammar from texts**

:: Just Started ::

Recursive Neural Networks (RNN)

➢ Recursive Neural Networks (RNNs) with **topology** defined by a jet's **evolution history**

QCD		Syntatic Structure
Partons 4-momenta	⬌	Words
Jets	⬌	Sentence
Full Event	⬌	Text

Gilles Louppe et al. "QCD-Aware Recursive Neural Networks for Jet Physics"

Jan 2020   23/35   Machine Learning in Heavy-Ion Jets / João Silva