Universidade do Minho
Escola de Ciências

LIP
LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

Competence Center on Simulation and Big Data

Jornadas Científicas do LIP

Coimbra, 9th July 2022

Nuno Castro, on behalf of the Competence Center

FCT Fundação para a Ciência e a Tecnologia

UIDP/50007/2020
LA/P/0016/2020
CERN/FIS-PAR/0010/2021
CERN/FIS-COM/0004/2021

Competence center
for Simulation and Big Data

- Aims to gather and expand LIP's competences on these areas
  - achieve critical mass
  - train students (and researchers)
  - explore the synergies between different LIP groups
  - leverage collaborations inside and outside LIP

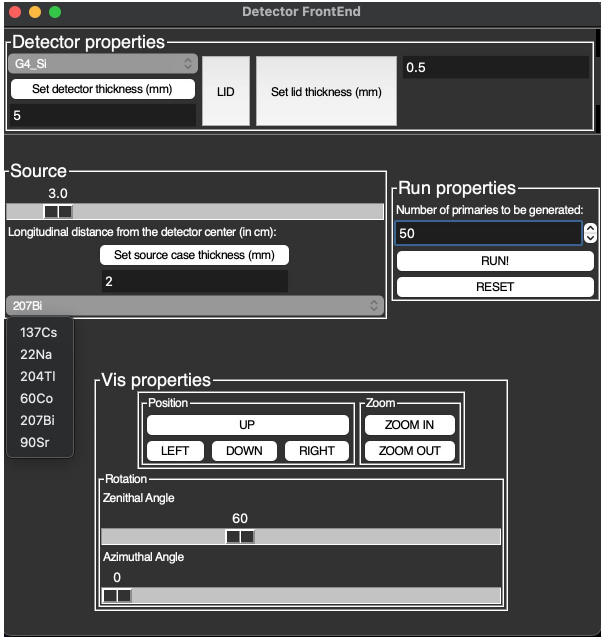
- Since the creation of the Competence Center (~ 2017):
  - new groups joined LIP - bringing new competences
  - explosion of the use of ML (and in particular deep learning)
  - new collaborations and resources

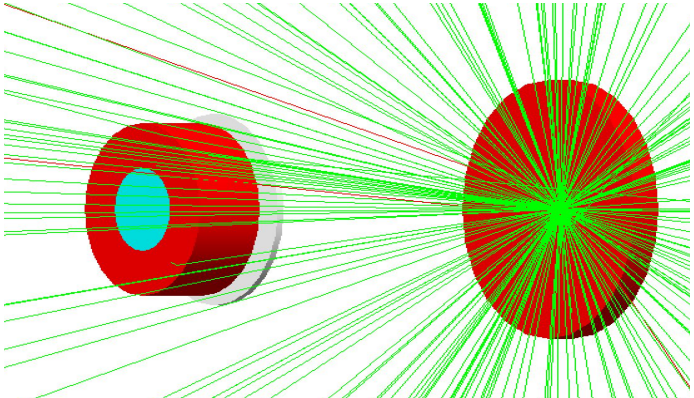
Simulation
VRLab recent developments

- VRLab is a Geant4+Python based virtual laboratory of experimental setups commonly used in radiation physics related teaching activities;
- First version in 2018 with students @ IST
    - Gamma spectroscopy, Geiger-Muller detector, PET system
- This tool proved quite useful as a way of complementing and helping the understanding of the results obtained in the lab

Simulation
Energy deposition

- Study of energy deposition in different materials, geometries, …
- Extensively used in the course on Radiation Physics at IST
- Allowed, in particular, an in-depth understanding of the β spectroscopy experiment



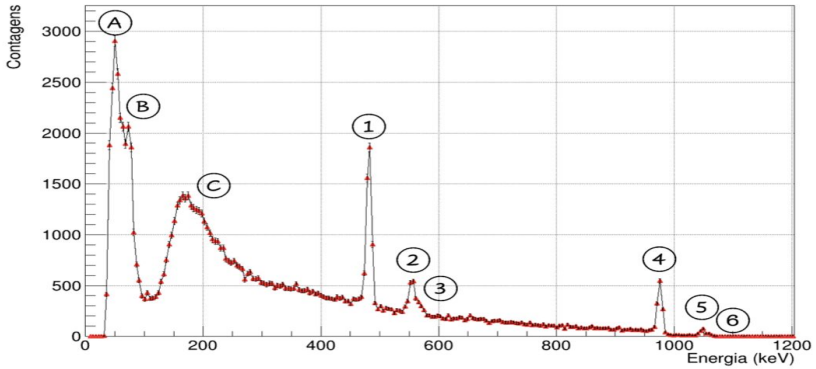


António Gomes, Francisca Santos, Sofia Cardoso
(Radiation Physics Course, MEFT 2021/2022)

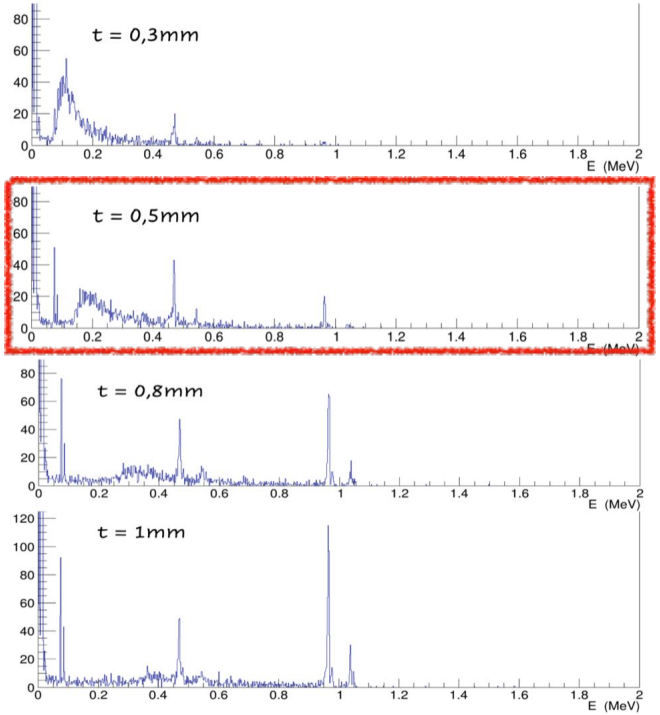
Simulation
β spectroscopy of ^{207}Bi

- Simulating the measured spectrum for different Si thickness, allowed to understand in detail its impact on:
  - the observed features of the spectrum
  - the detection efficiency vs energy

^{207}Bi spectrum measured with a Si solid-state detector

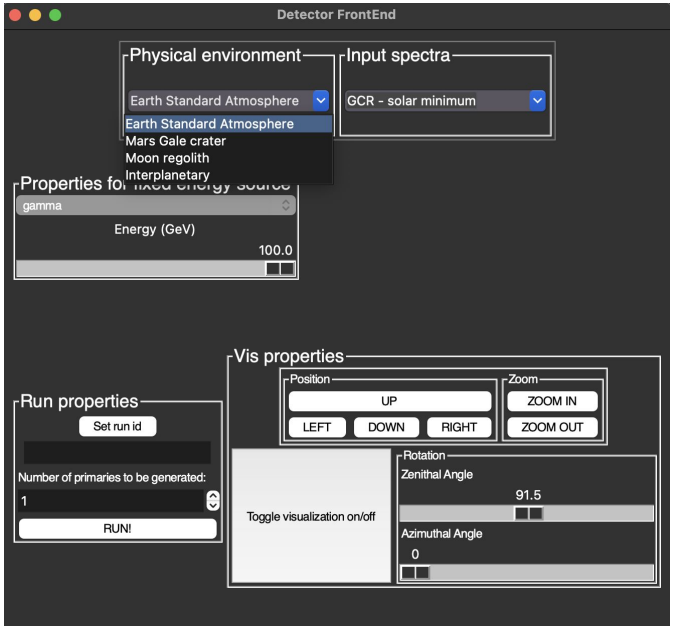


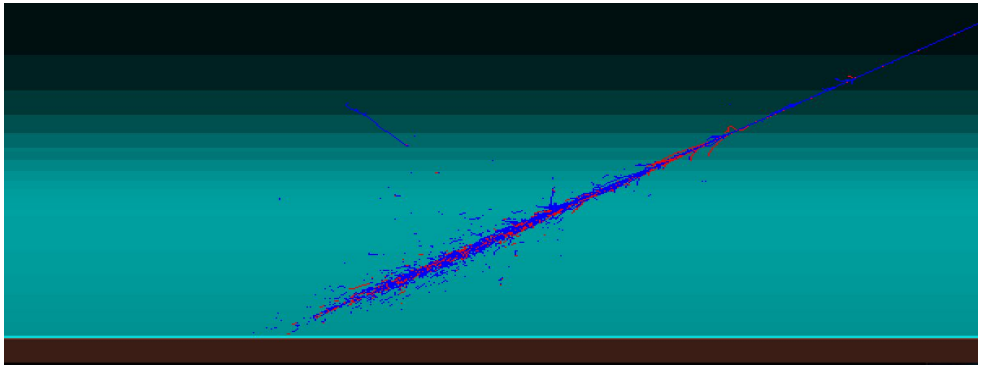
VRLab simulation for different Si thicknesses



Simulation
PlanetRAD

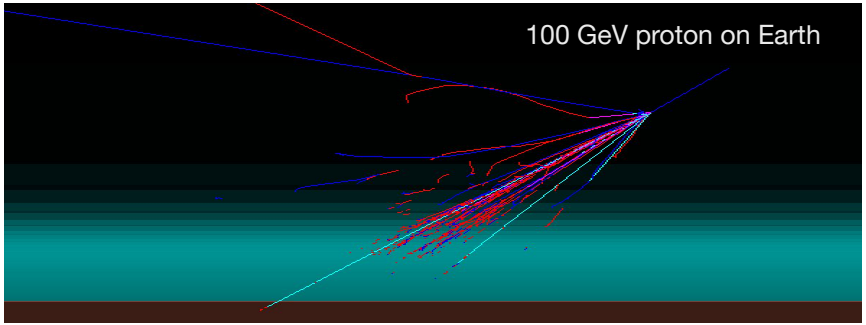
- Based on a simplified version of dMEREM (SpaceRad group)
- Different scenarios:
  - Earth, Mars, Moon, Interplanetary;
  - Cosmic ray flux (solar minimum/maximum), SEP spectra, fixed energy
- Used in the IST Minor in *Space Sciences & Technologies*

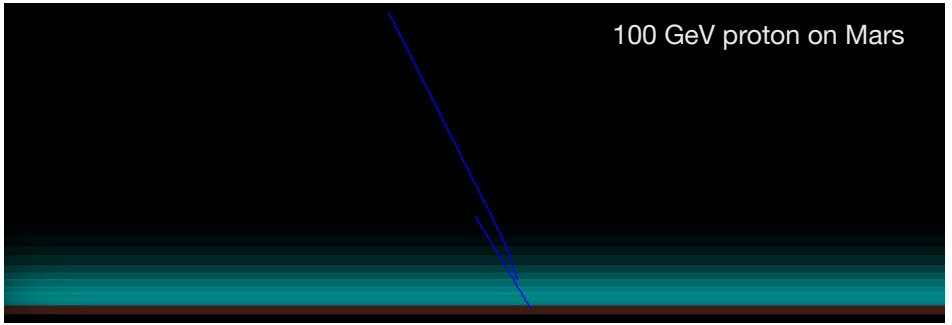




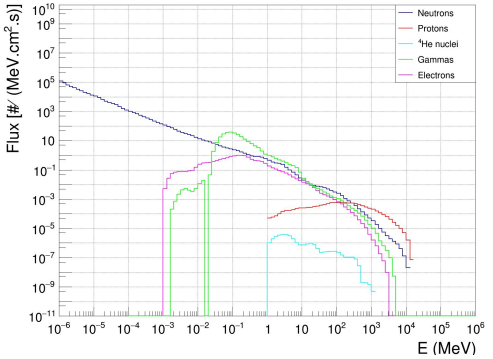
Simulation
PlanetRAD

- Visualisation of impact of different planetary scenarios:

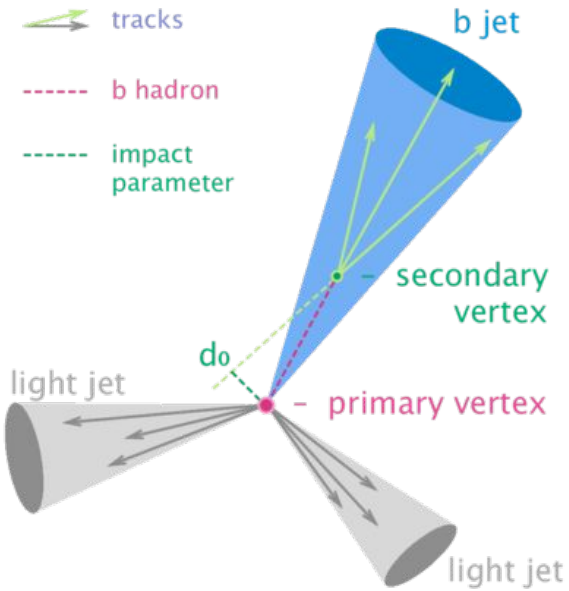


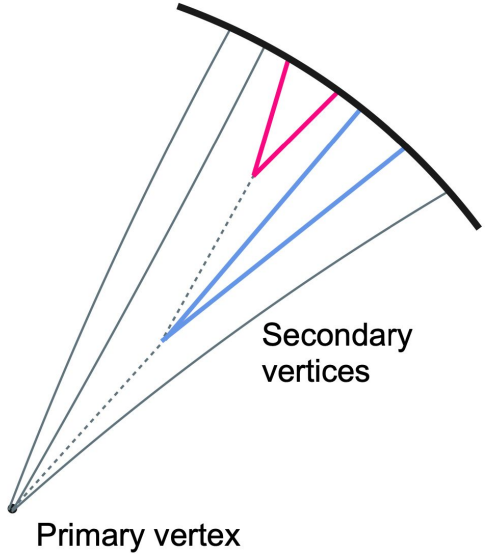


- Analysis tools to obtain :
  - Primary and secondary particle spectra;
  - Effective dose and ambient dose (total and per particle)



Big Data
tagging long-lived particles at the LHC

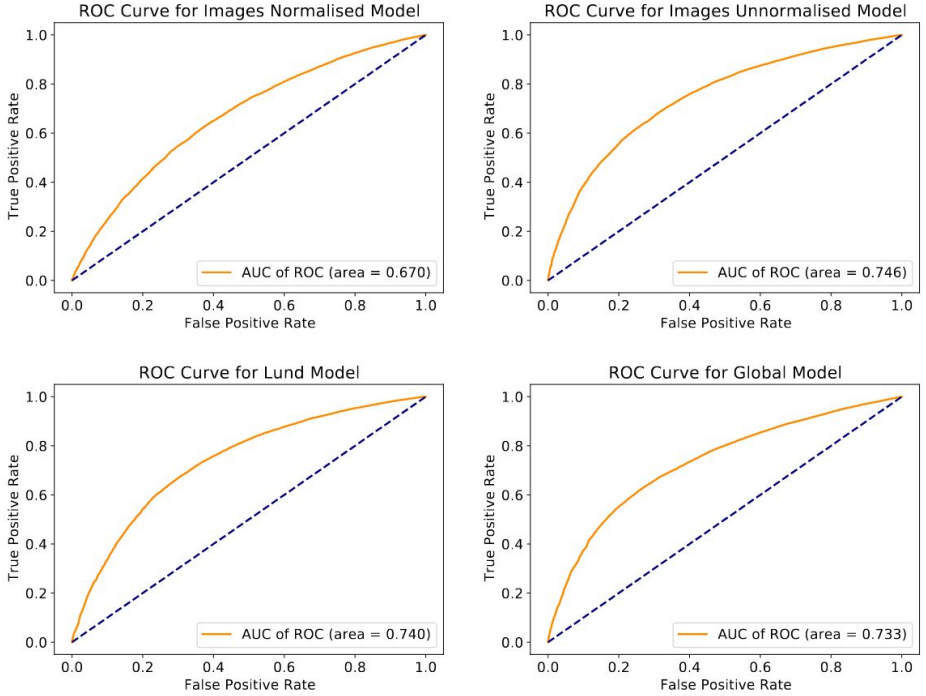




Exploring **graph-neural-networks** for b-tagging, via improved secondary vertexing finding
(very preliminary)

Big Data
tagging new phenomena: the quark gluon plasma

Model Type		Hyperparameter	Value
CNN (Images)	Normalised	Number of Filters	104
		Spatial Dropout Rate	0.3
		Gamma	0.925
	Unnormalised	Number of Filters	88
		Spatial Dropout Rate	0.0
		Gamma	0.970
RNN (Lund)		Number of Layers	2
		Number of Units	15
		Gamma	0.935
DNN (Global)		Number of Layers	6
		Number of Units	116
		Dropout Rate	0.1
		Gamma	0.93



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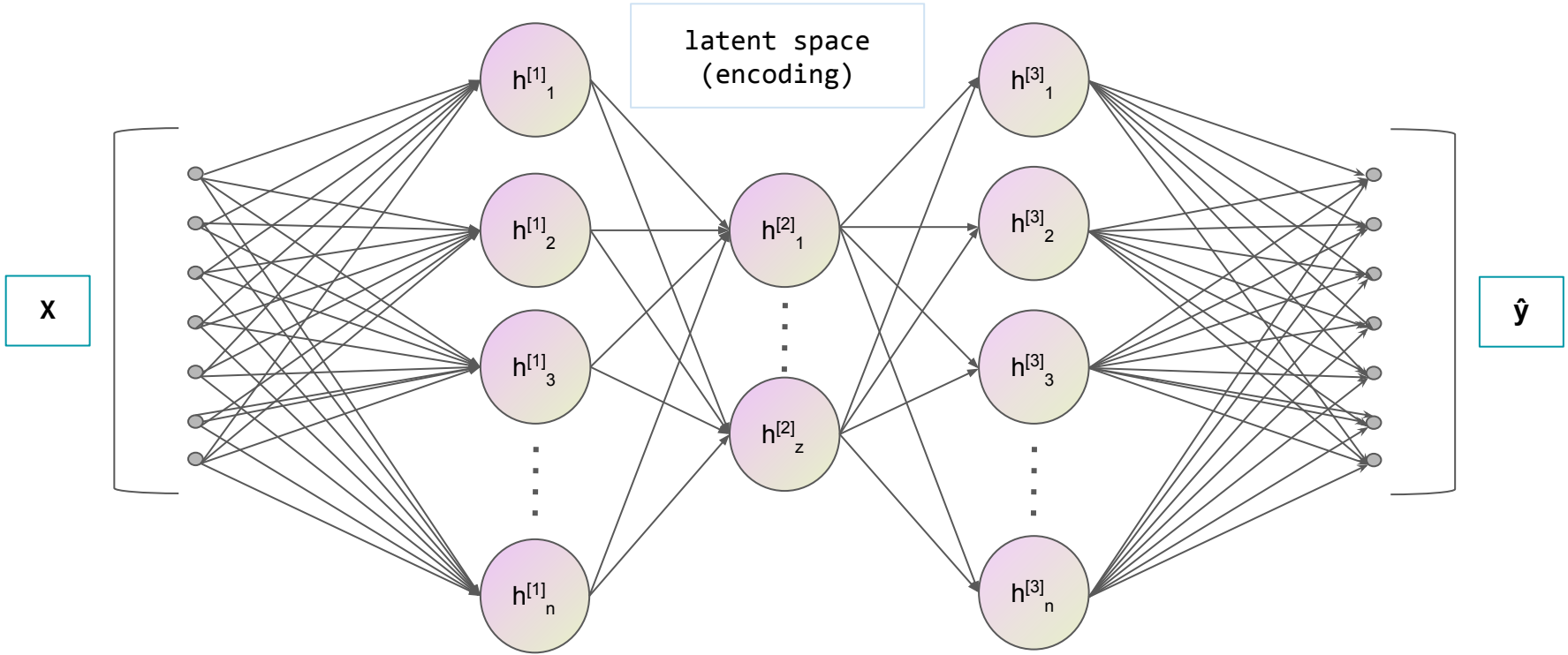
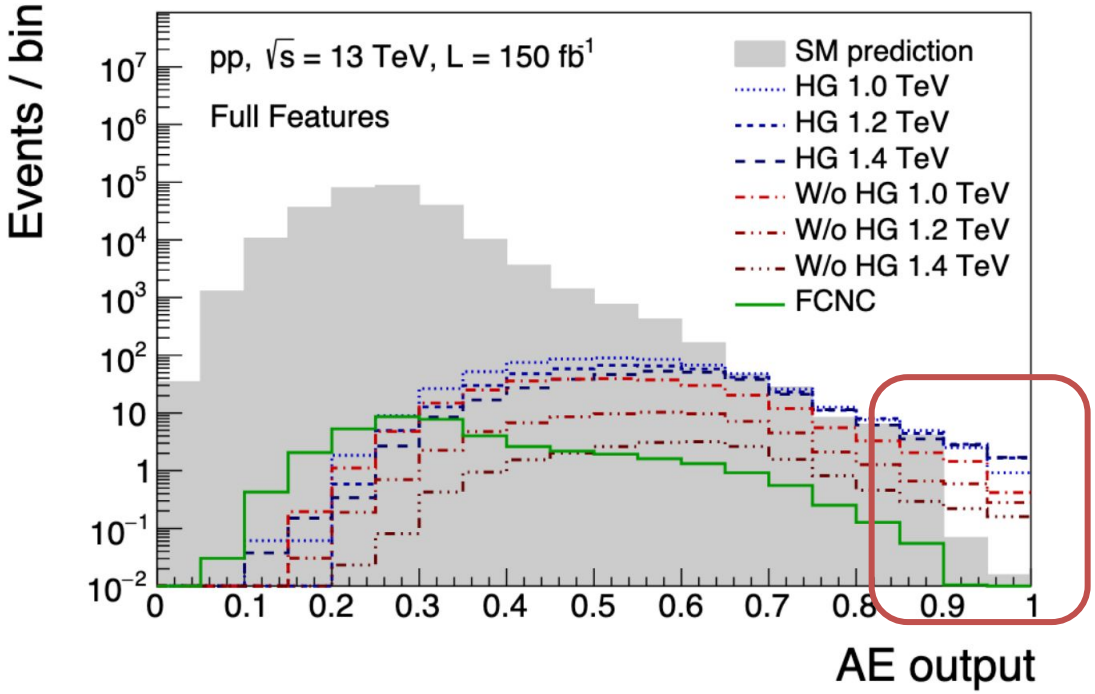
Searching for new phenomena
autoencoders



Searching for new phenomena
anomaly detection



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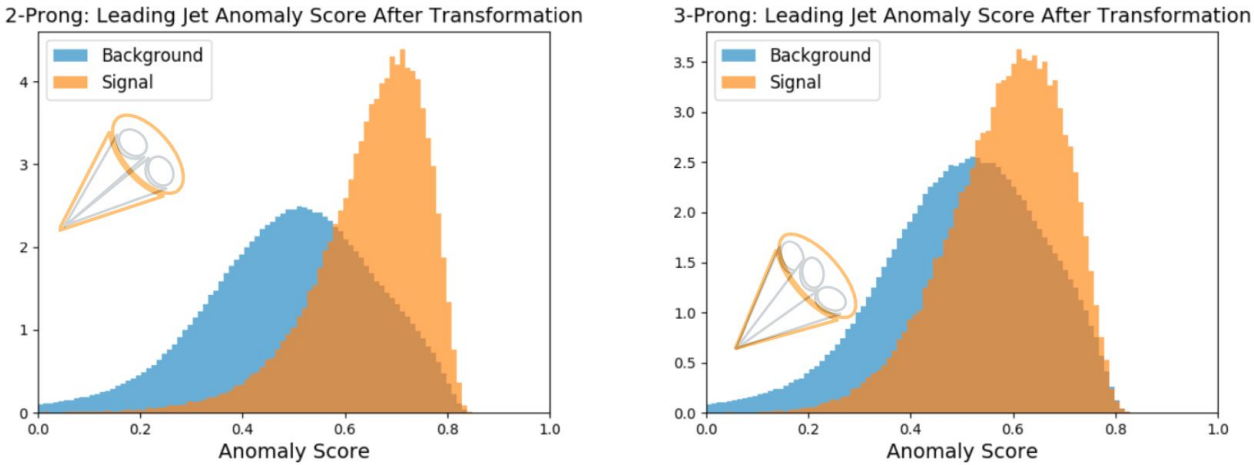
Searching for new phenomena
anomaly detection

Detecting “anomalous” jets via sequence modeling



Using a variational recurrent neural network to assign an “anomaly score” to each jet

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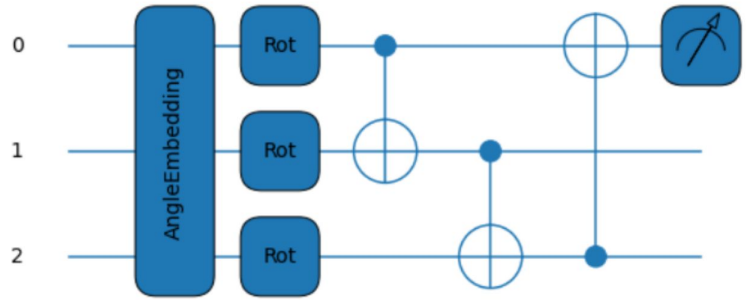
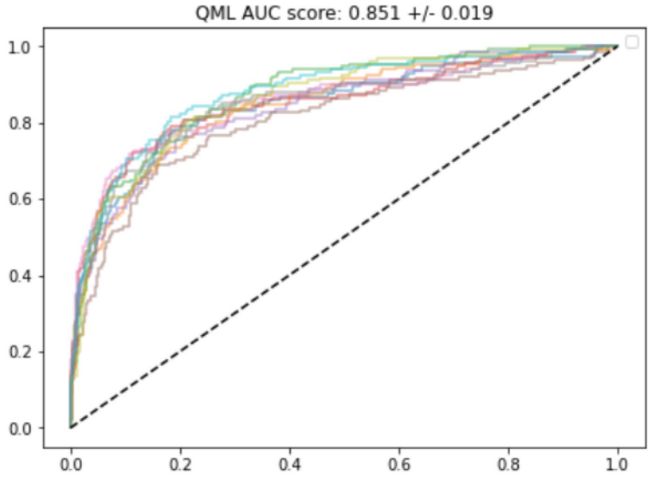
Quantum computing in particle physics: QML

Variational Quantum Classifier



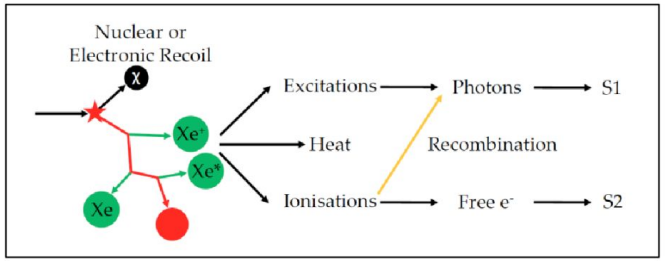
$$|\psi'_x\rangle = U(\theta)\,|\psi_x\rangle$$

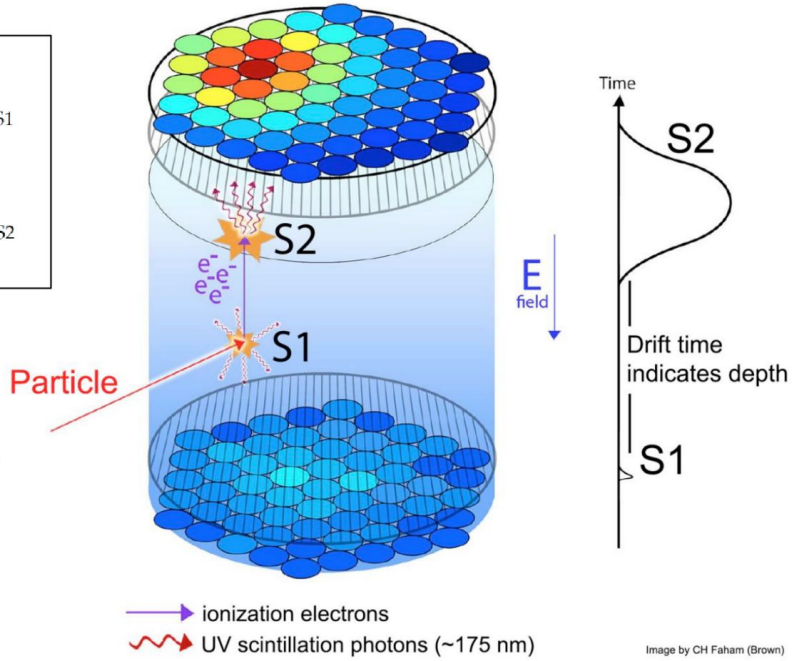
parameterized by a set of learnable parameters



(very preliminary studies)

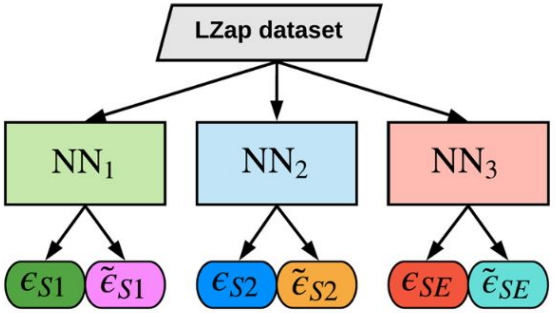
Underground experiments
search for very rare events





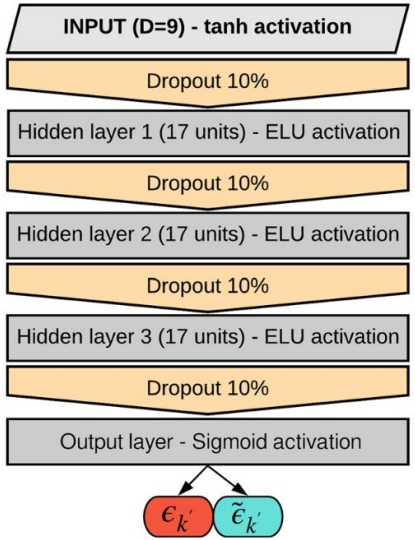
- Single photon and electron sensitivity
- Z position from S1-S2 timing
- X-Y position from S2 signal pattern
- ER/NR discrimination by charge to light ratio (S2/S1)

Underground experiments
search for very rare events



- pulse classification

Name [unit]	Type	Description
pA [phd]	Float	Total integrated area from the start to the end of the pulse
pH [phd/ns]	Float	Pulse maximum amplitude
pHTL	Float	Fraction of pulse length time at which the pulse reaches maximum amplitude
pL90 [ns]	Int	Pulse length time at 90% area, from 5 to 95% integrated area time
pRMSW [ns]	Int	Pulse root mean square (RMS) width
pF50	Float	Fraction of the pulse area integrated in a 50 ns time window starting 10 ns before the 5% integrated area time
pF100	Float	Same as *pF50* but for a 100 ns integration window
pF200	Float	Same as *pF50* but for a 200 ns integration window
pF1k	Float	Same as *pF50* but for a 1 μs integration window
TBA	Float	Top-bottom asymmetry: difference between the top PMT area fraction and bottom PMT area fraction
Coincidence	Int	Number of PMT channels that record signal within pulse boundaries



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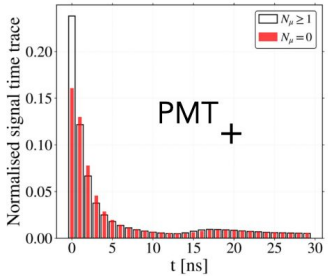
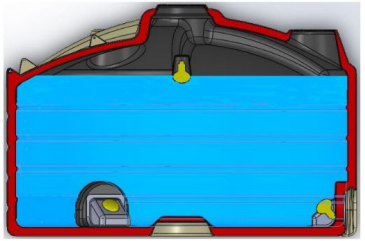
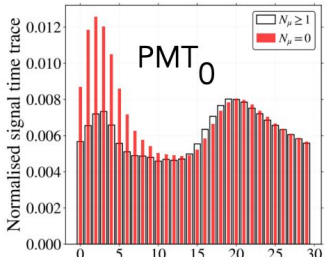
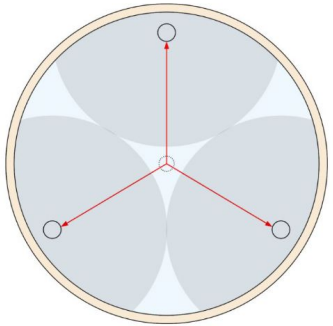
SWGO
Simulation and ML model

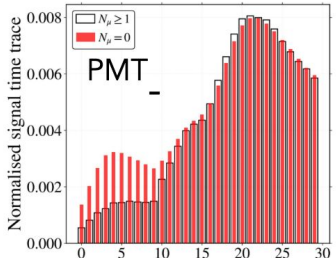
CNN to get the probability that a muon has passed through the WCD











arXiv:2203.08782

[credit: Borja Gonzalez]

Social Physics and Complexity

- SPAC uses large scale computational tools to study societal challenges, especially in disease forecasting, human behavior and public policy

Social Physics & Complexity

erc

summary

- Exploring the different competences across LIP's groups
- synergies with other fields and activities
- We need you!

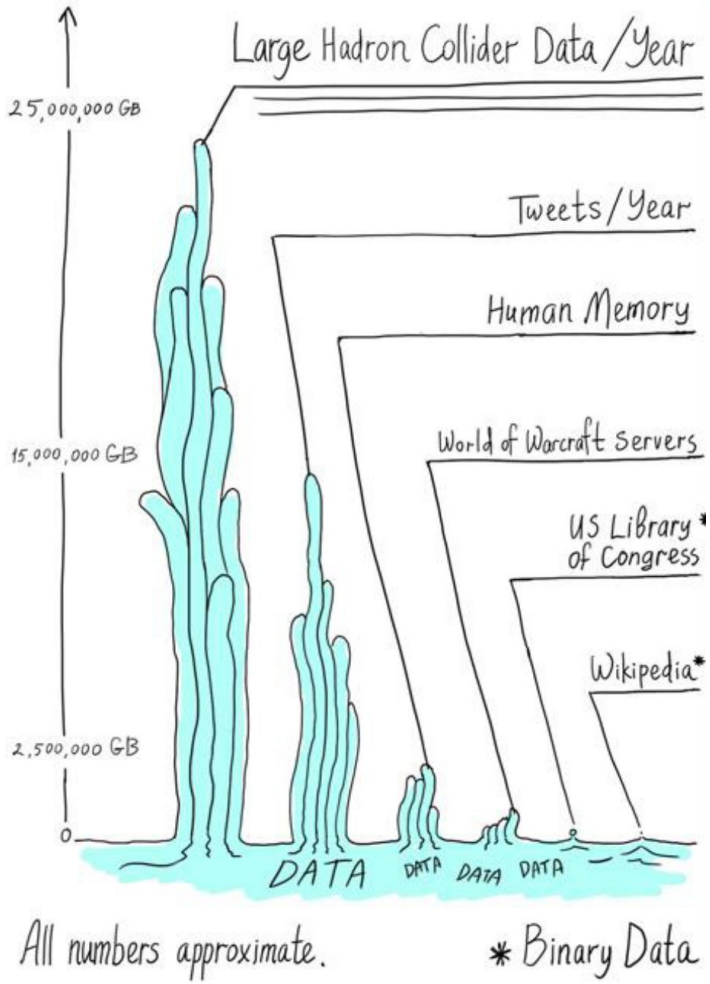
JORNADAS CIENTÍFICAS

Competence Center on Simulation and Big Data

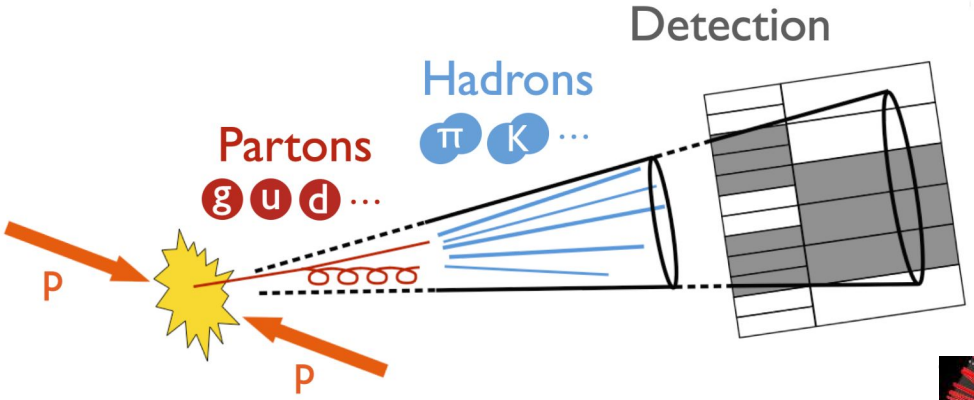
big-data@lip.pt [N. Castro and G. Milhano]
geant4@lip.pt [B. Tomé and P. Gonçalves]

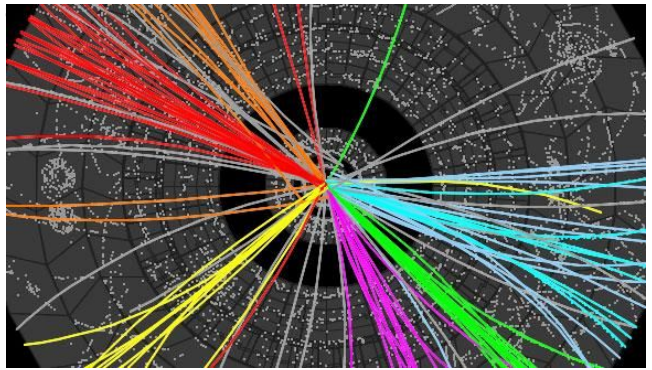
Large Hadron Collider

data, data, data, ...



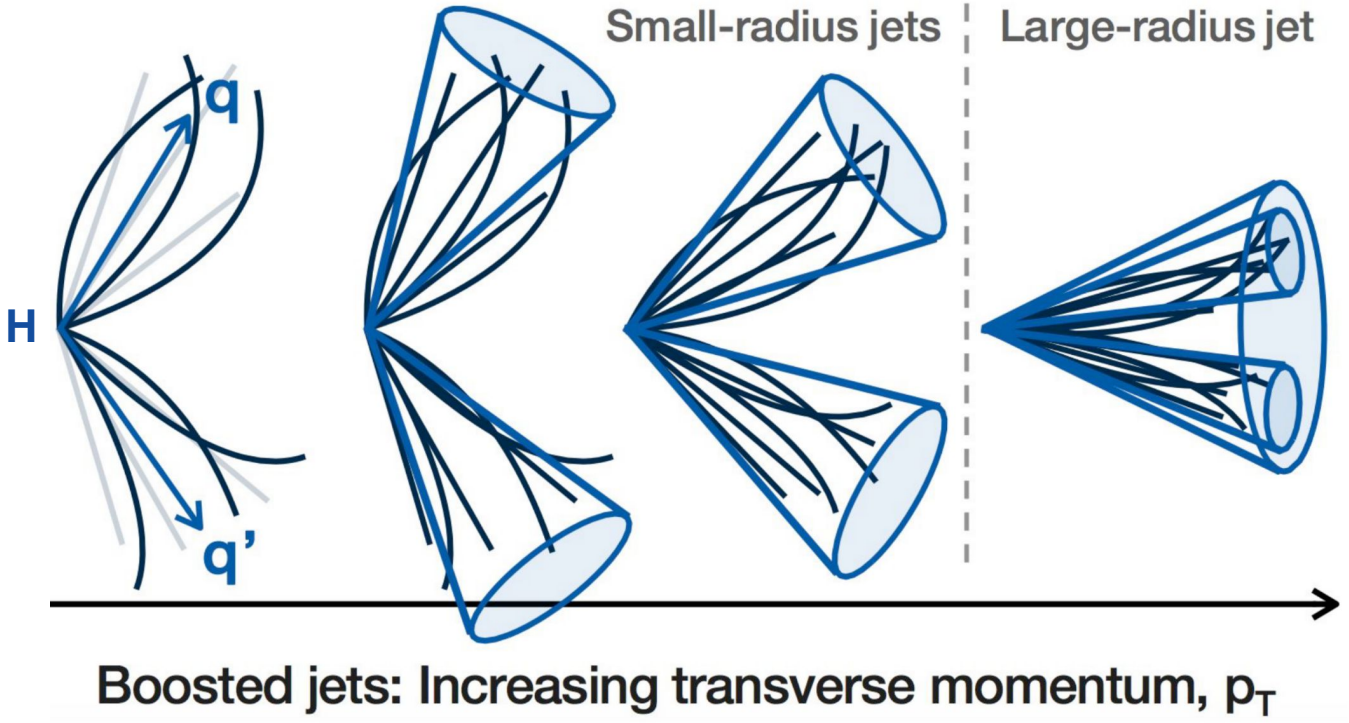
tagging special objects in collisions





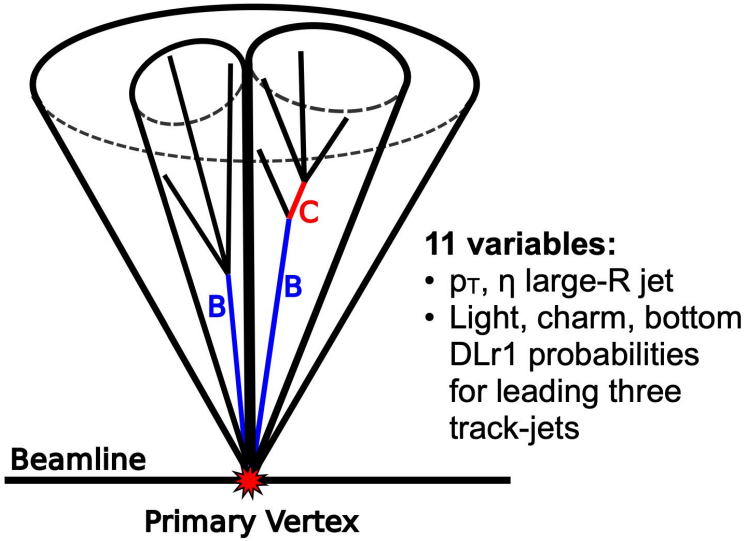
tagging special objects in collisions

tagging the Higgs boson



tagging special objects in collisions
tagging the Higgs boson

- Deep neural networks for supervised classification



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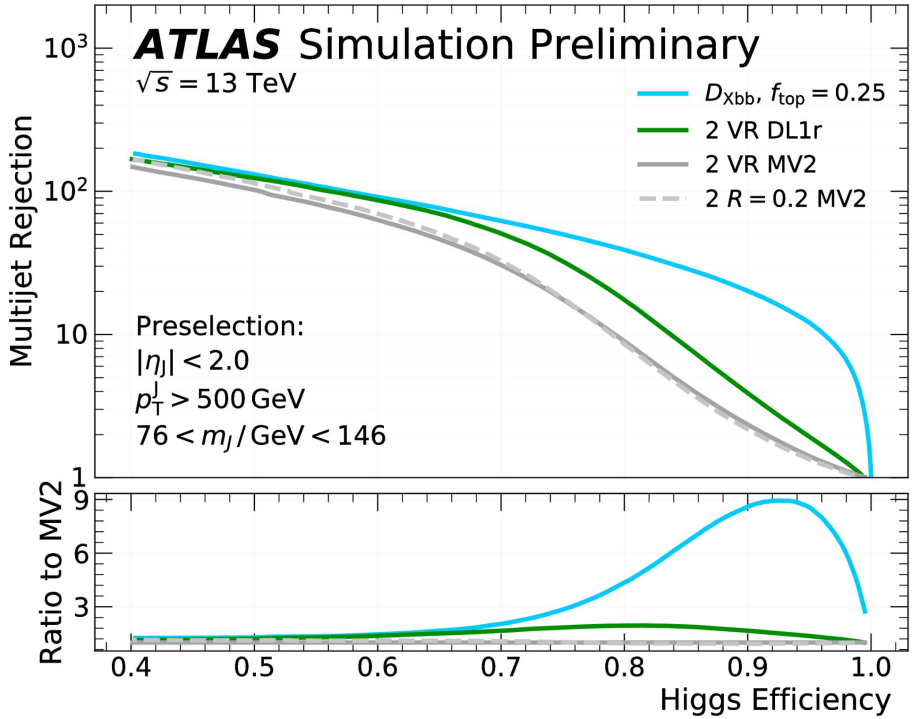
tagging special objects in collisions
tagging the Higgs boson



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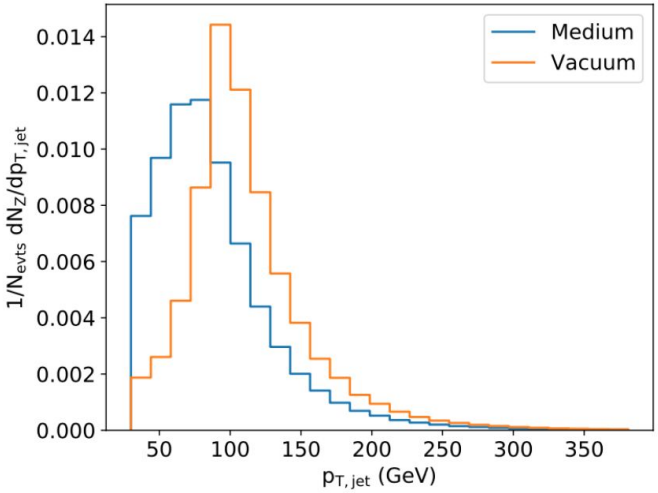
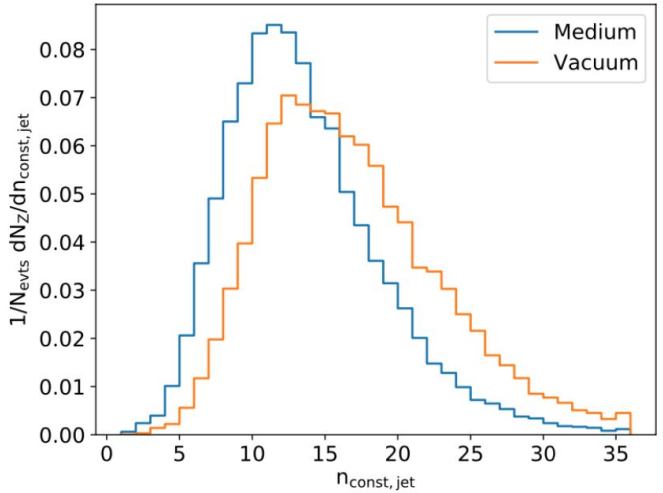
tagging special objects in collisions

tagging new phenomena: the quark gluon plasma





tabular data: use of a supervised dNN

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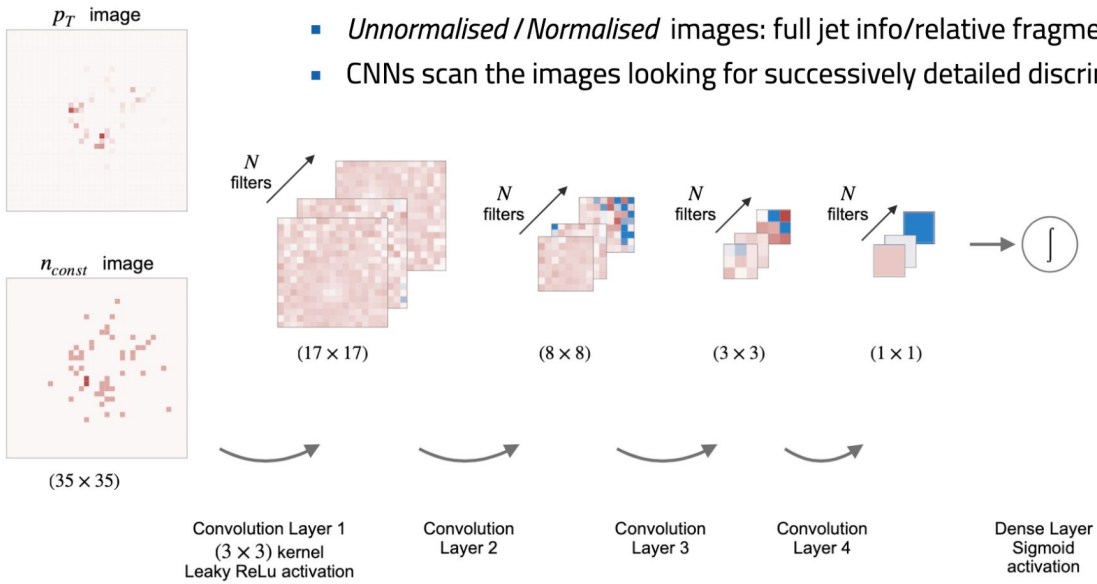
tagging special objects in collisions
tagging new phenomena: the quark gluon plasma

- 2 $\Delta\eta, \Delta\phi$ grids centred in the jet axis with jet pT and *n* constituents
- *Unnormalised / Normalised* images: full jet info/relative fragmentation pattern
- CNNs scan the images looking for successively detailed discriminant patterns



jet images: Convolutional Neural Networks (CNN)

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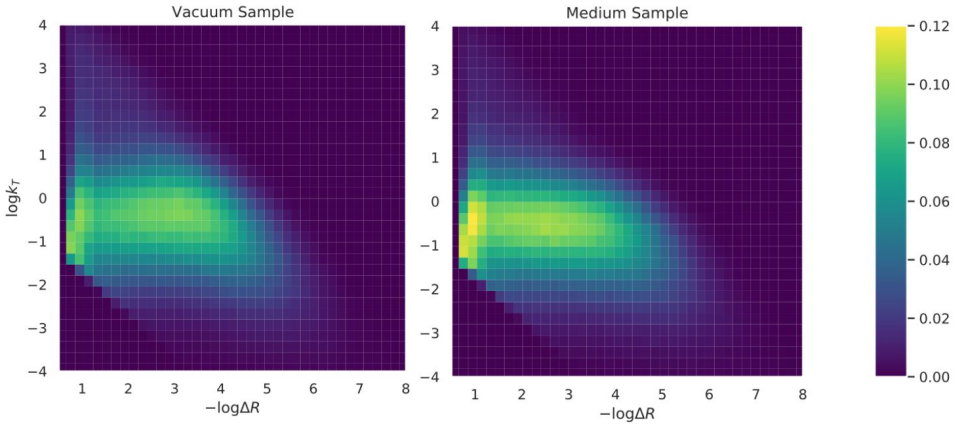
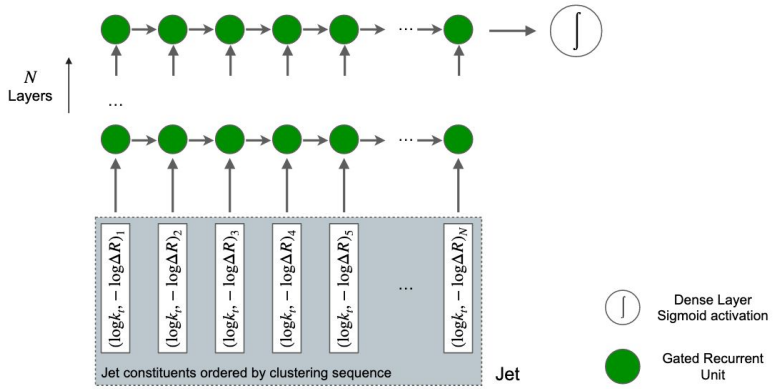
tagging special objects in collisions

tagging new phenomena: the quark gluon plasma





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Lund planes: Recurrent Neural Networks (RNN)

Underground experiments
search for very rare events

GMM class	TriNet predicted class				Total	
	S1	S2	SE	Other		
S1	11,571	0	0	280	11,851	5.9%
S2	0	51,001	444	10	51,455	25.7%
SE	0	380	128,211	8	128,599	64.4%
Other	698	38	28	7331	8095	4.0%
Total	12,269	51,419	128,683	7629	200,000	

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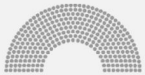
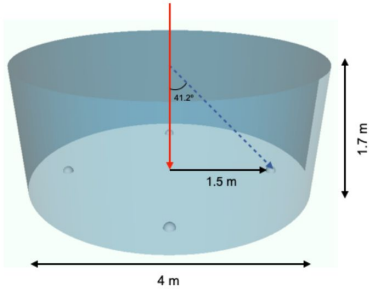
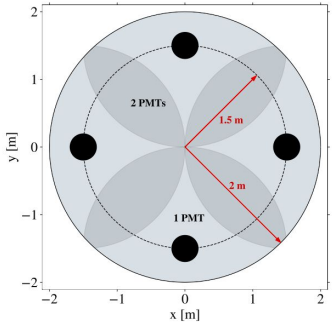
Social Physics and Complexity

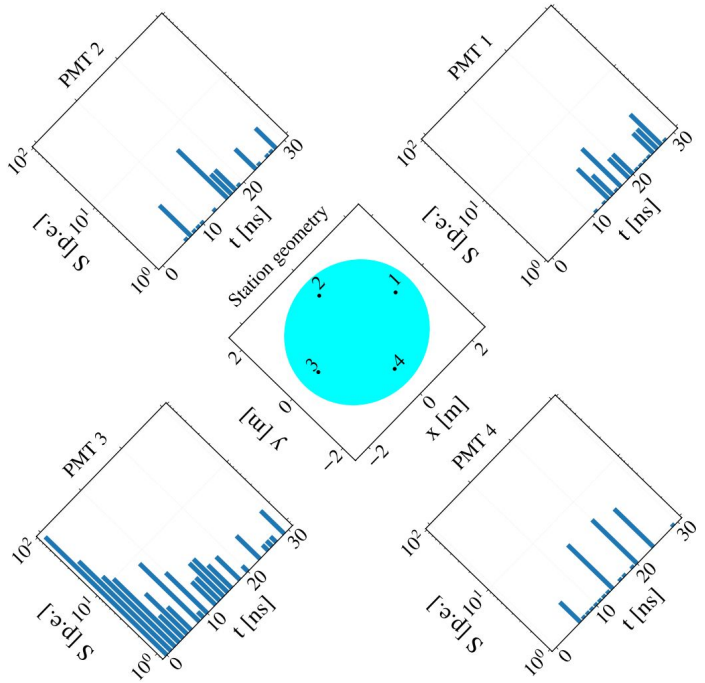
Social Physics and Complexity

		QUESTIONS	DATA	TOOLS
HEALTH		Online vs. Offline Patterns Emergency Now-casting Antibiotic Over-prescription	Google Trends SNS24 Twitter ER waiting times E-prescriptions Weather	**Math Modelling** **ML** **Epidemiology**
POLICY		Political Decisions Gender Differences Agenda Setting Voting vs. Discourse	Media records Twitter Parliament data Surveys	**NLP** **Networks** **Math Modelling** **Complex Systems**
BEHAVIOUR		Cognitive Biases Attitudes Towards Science Fake News Sharing	Large scale surveys Behavioral experiments Twitter Economic databases...	**Networks** **Math Modelling** **Psychology** **Information**

Gamma/hadron discrimination with ML







Top view of the WCD station and the signal detected in each PMT

(Single 2 GeV muon injected)

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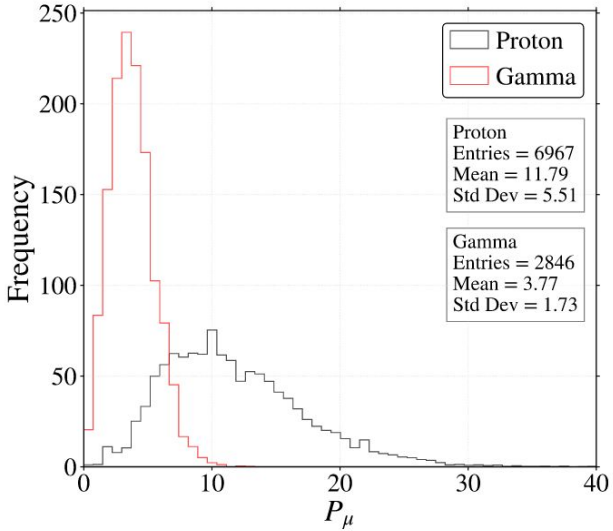
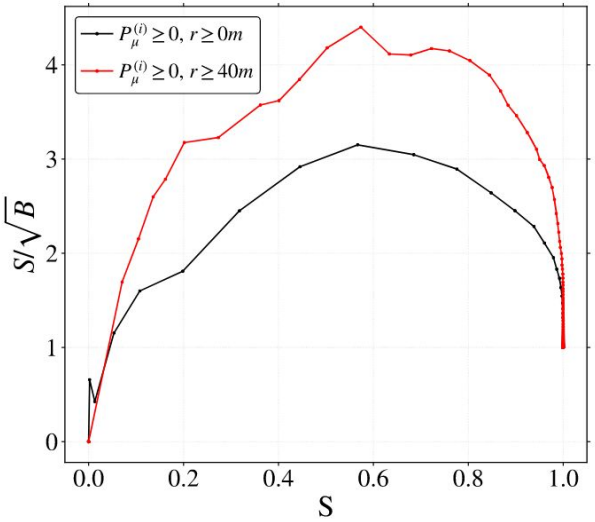
Gamma/proton discrimination with ML

- 1-D convolutional neural network





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