IN2P3, Conseil Scientifique 23 juin 2021
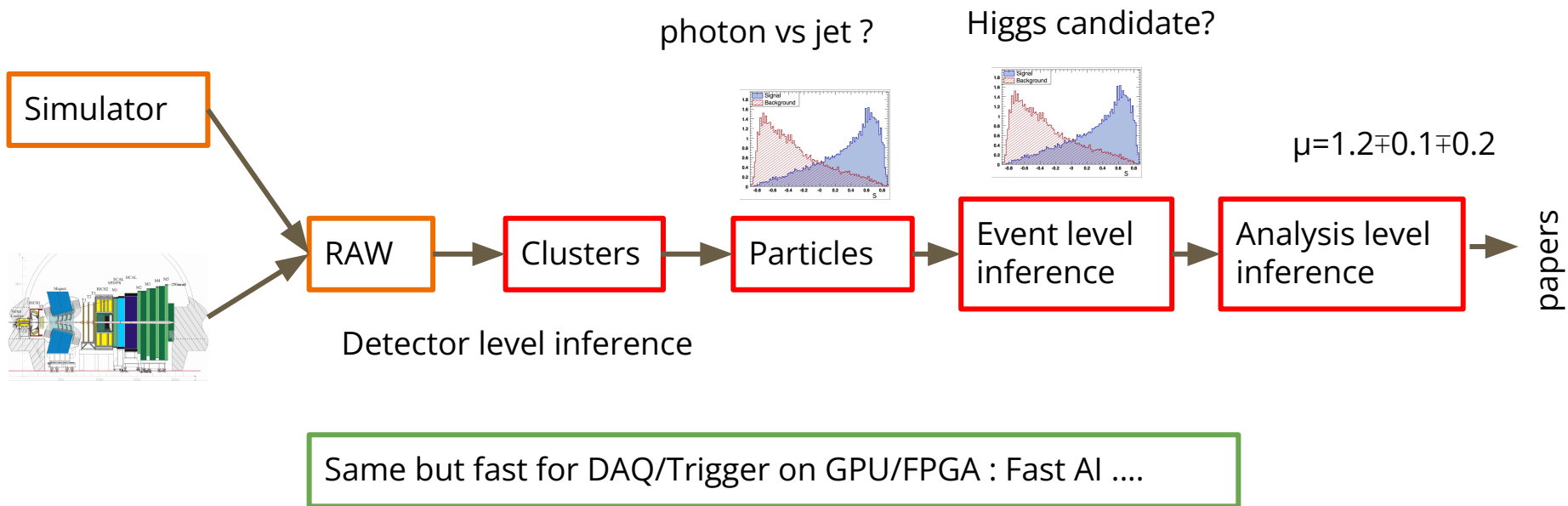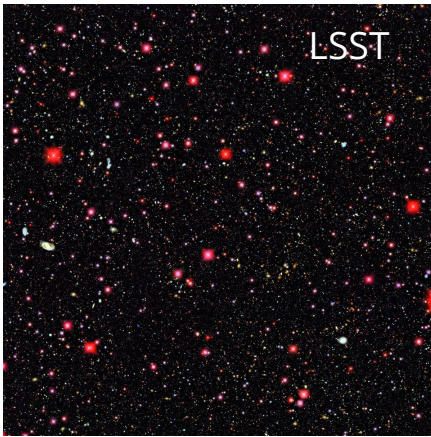
AI at IN2P3

David Rousseau (IJCLab), Alexandre Boucaud (APC) with inputs from the IN2P3 AI community
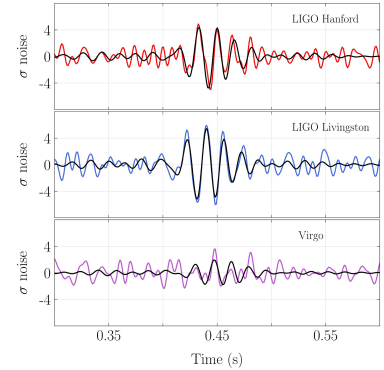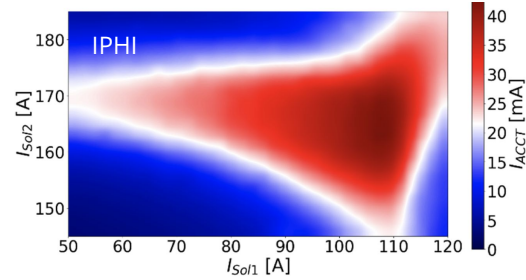
Disclaimer

- Overview of AI activity at IN2P3
  - based on May 2022 survey of projects : 55 answers !
  - not claiming to be exhaustive

- 1st part : broad overview with a few typical **examples** from IN2P3
- 2nd part : survey answers and remarks
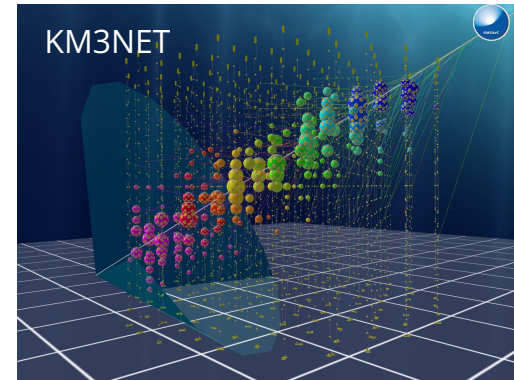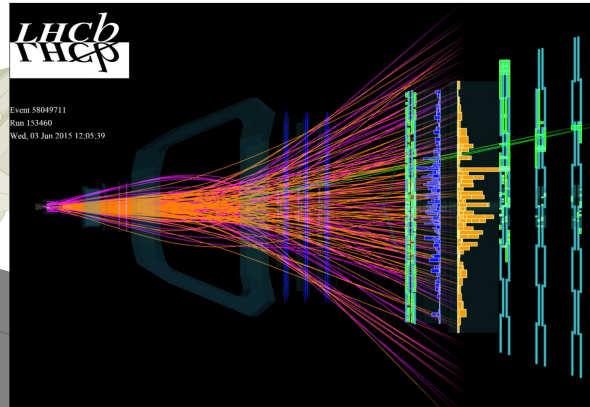
Typical analysis pipeline

photon vs jet ?

Higgs candidate?

$\mu=1.2 \mp 0.1 \mp 0.2$

Simulator

RAW → Clusters → Particles → Event level inference → Analysis level inference → papers

Detector level inference

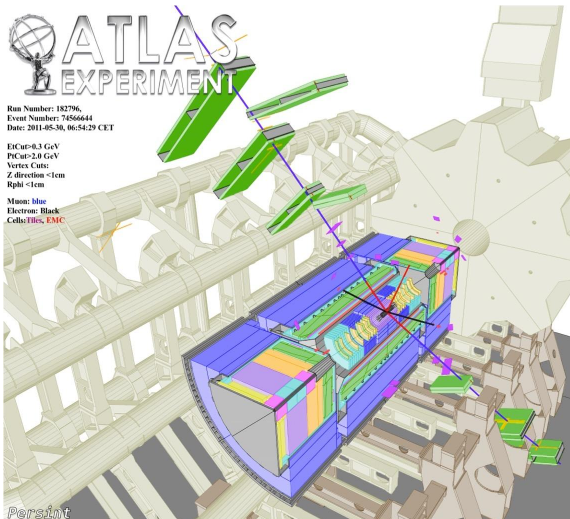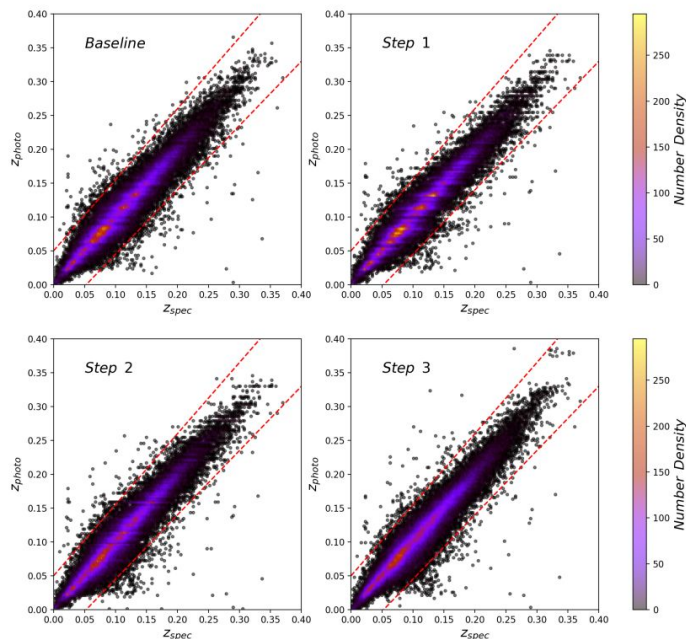Same but fast for DAQ/Trigger on GPU/FPGA : Fast AI ....

Various input data type

⇒diversity of AI techniques

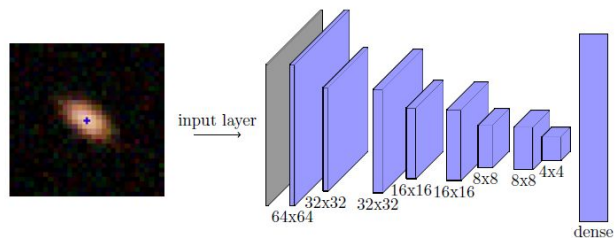# Detector level inference on images

Rubin/LSST
Euclid

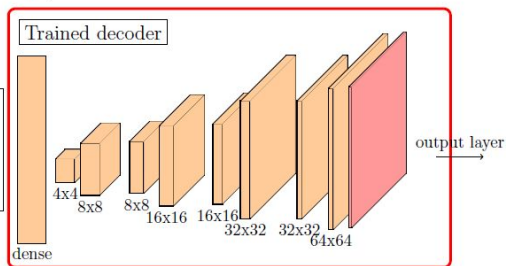Photometric redshift estimation with Convolutional Neural Networks and galaxy images

Detector level inference on images

Rubin/LSST

Normalising Flows

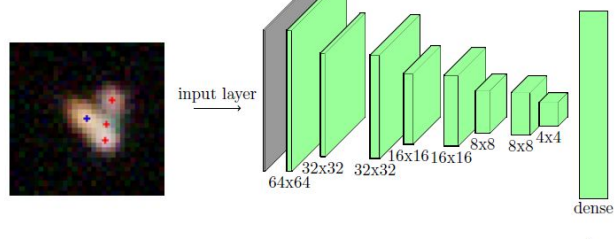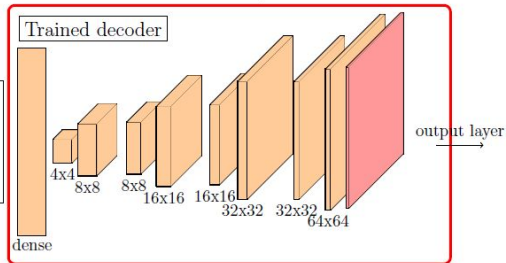*Variational Auto Encoders*

MADNESS (Maximum-A-posteriori solution
with Deep generative NEtworks for Source Separation)

deep generative model that performs deblending: it **isolates** galaxies from overlapping projections to enable accurate shape measurement

Detector level inference on images

CTA

LAPP
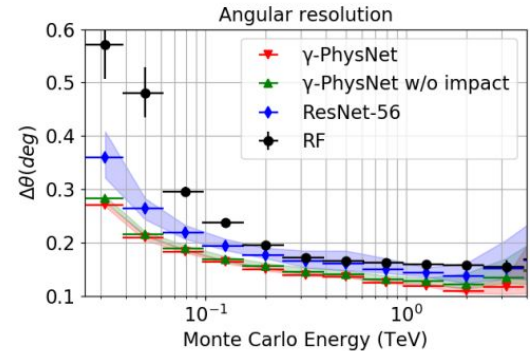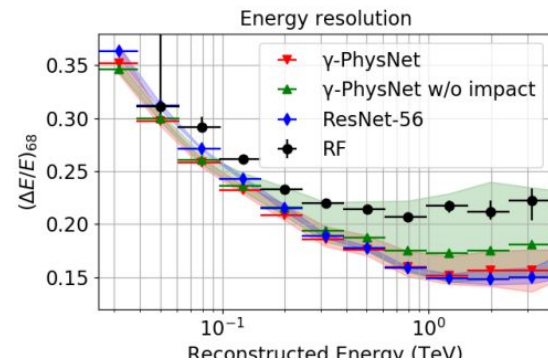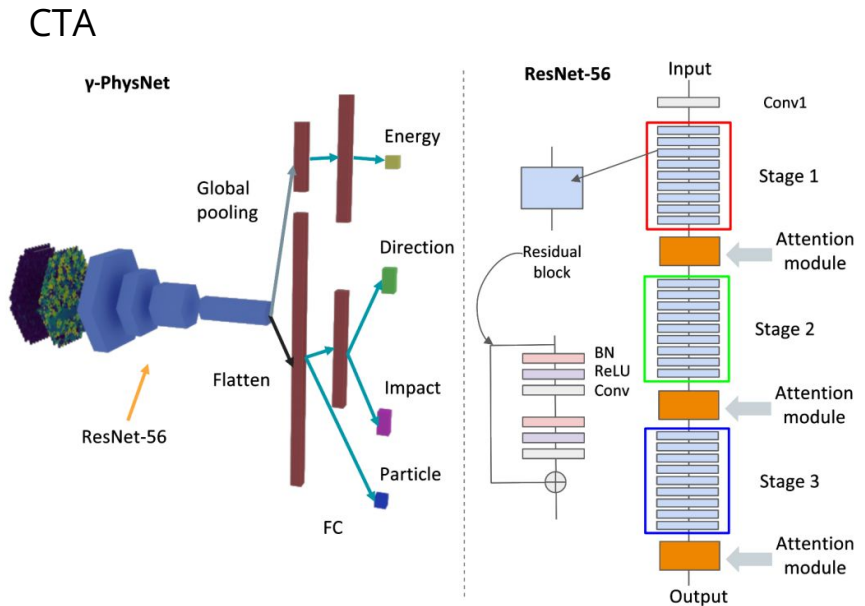
Multi-head convolutional neural network with attention mechanism
and novel kernel design for dealing with hexagonal pixels

Detector level inference on semi-structured data

tracking at the LHC   L2IT

Graph Neural Networks

Detector level inference

Calorimetry at the LHC   *Convolutional Neural Network*
(with depth⇒color trick)

LLR

CMS HGCAL
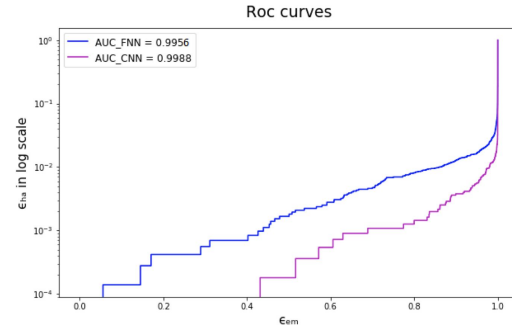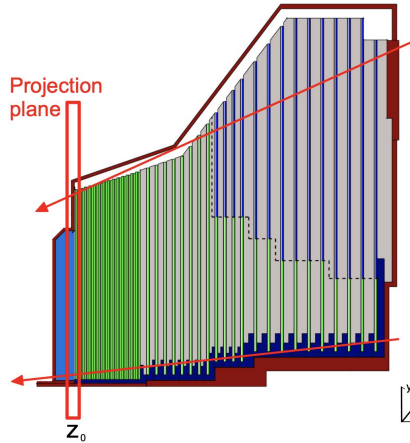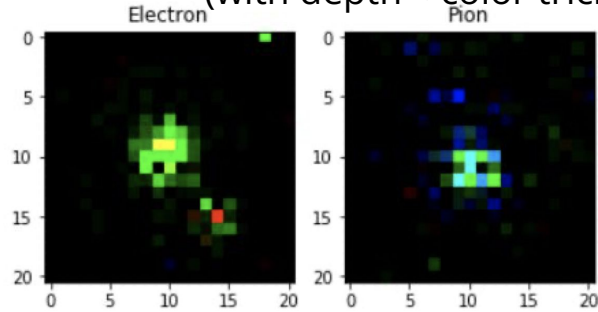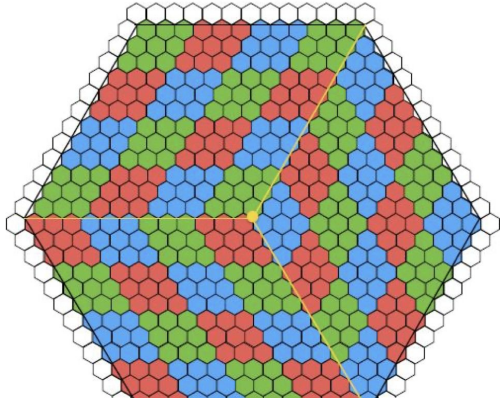
- Fast AI (DAQ, Trigger) covered by D von Bruch

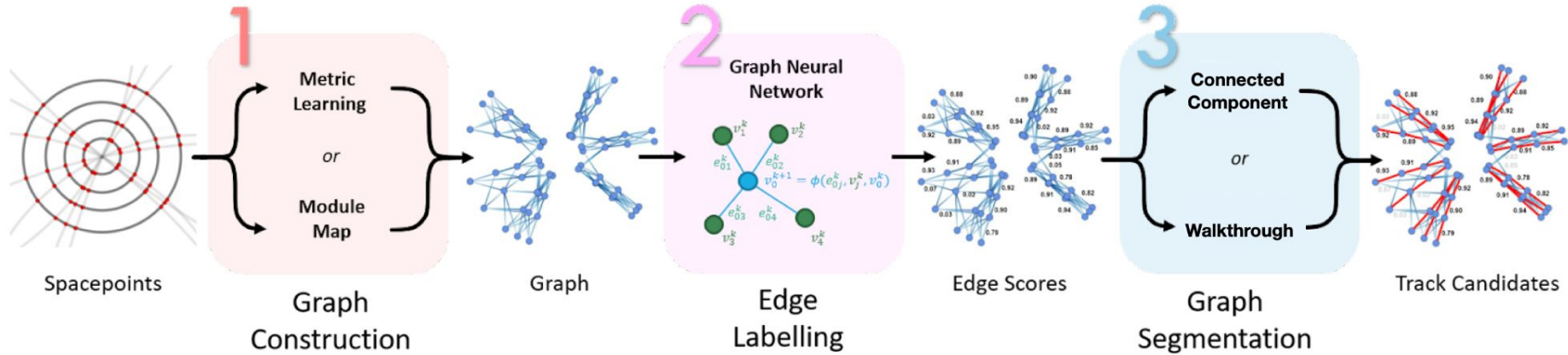# Detector level inference jet calibration

ATLAS : E and M jet calibration from 21 characteristics variable using *DNN with attention layer* ....
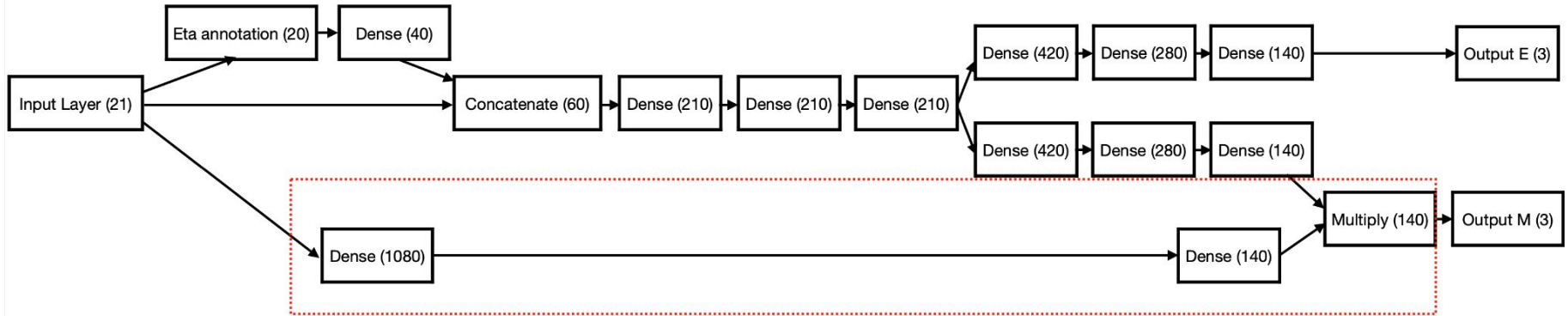
Energy R(pt GeV) with m ∈ [40,80] GeV eta ∈ [-0.6,-0.4]

- uncal Atlas
- cal Atlas
- dnn batchSequenceMix_att_tail6
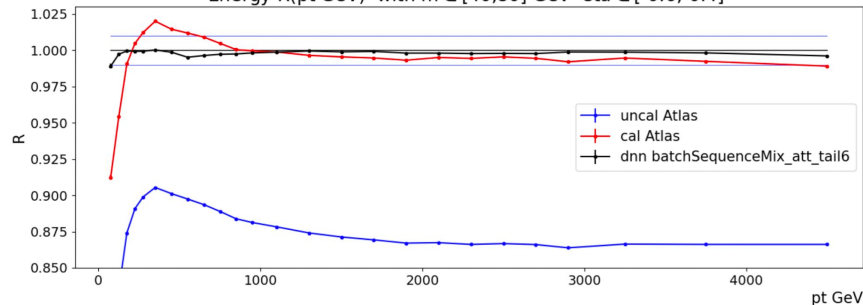
Energy σ(eta) with pt ∈ [400.0,500.0] GeV m ∈ [80,100] GeV

- uncal Atlas
- cal Atlas
- dnn batchSequenceMix_att_tail6

10
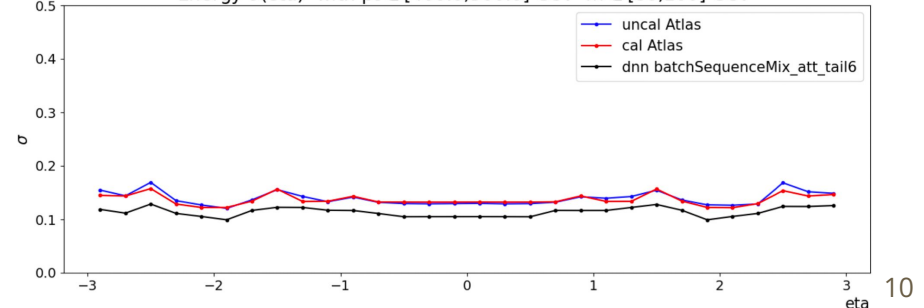
Event level inference

- ttH event identification
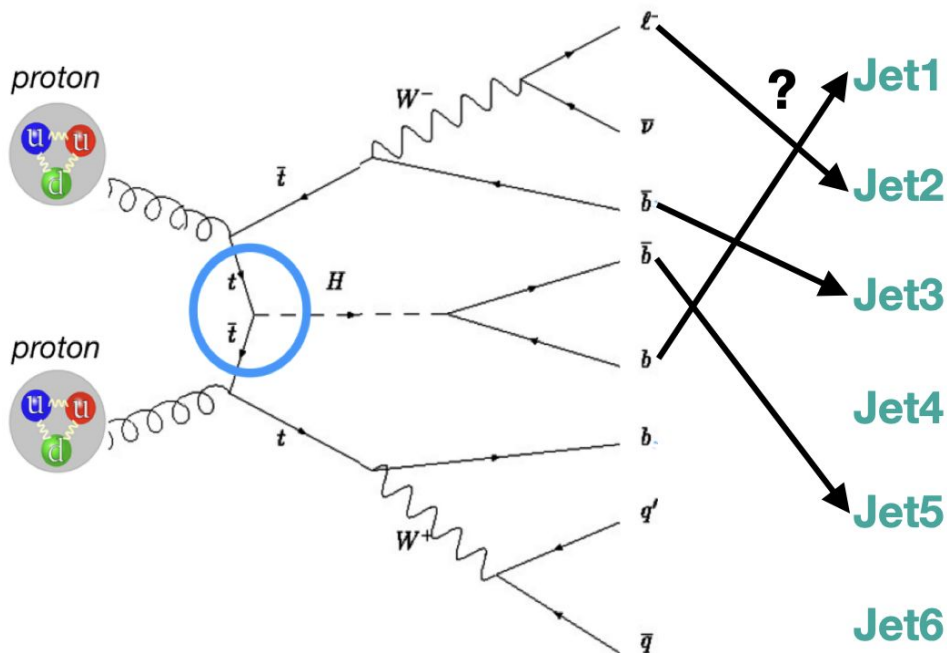
DeepSet architecture

Event level inference

Convolution NN
Graph NN

APC

KM3NeT

Virgo/LIGO

GeV-TeV Neutrino event   CNN

Graph NN

Wish List
- **Nu flavour**
- **Energy**
- **Direction**
- **Resolution**
- Inelasticity
- EM vs Had.

Multi-tasking
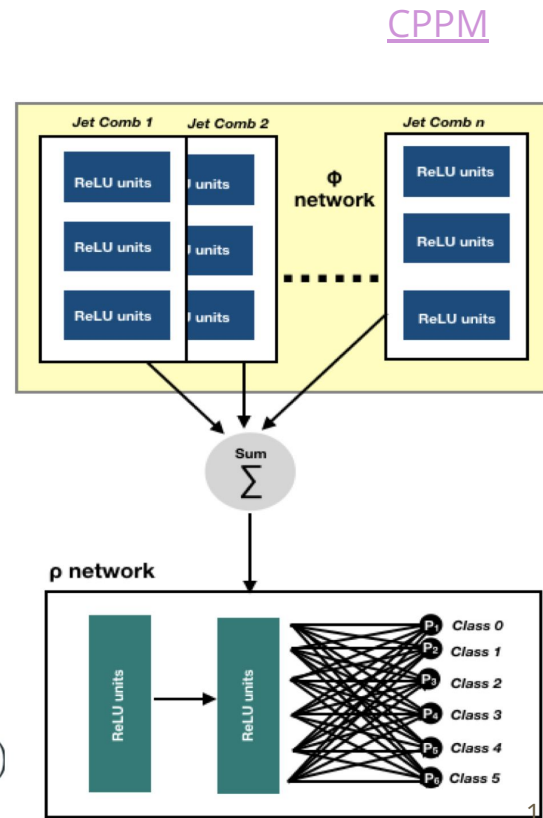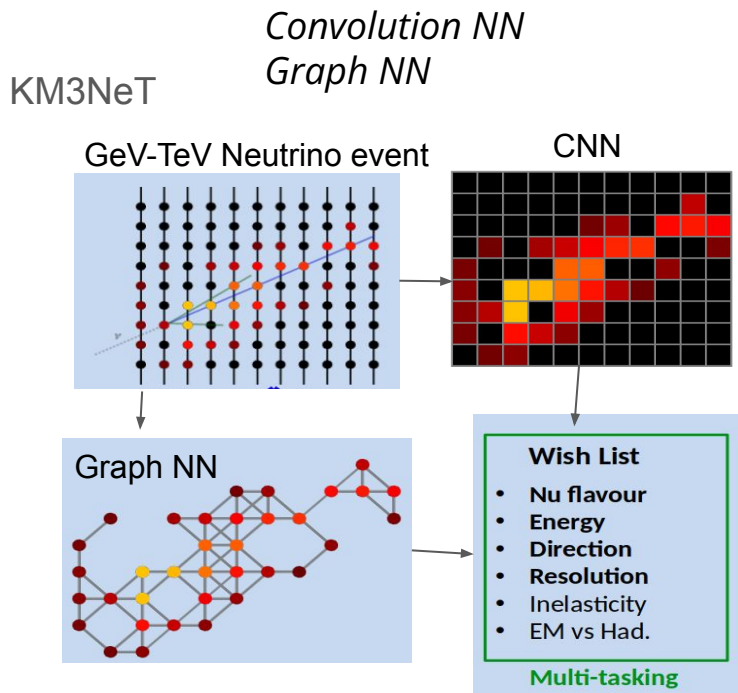
- Background characterization and single DOM / multiple DOM analysis of MeV neutrinos from supernovae
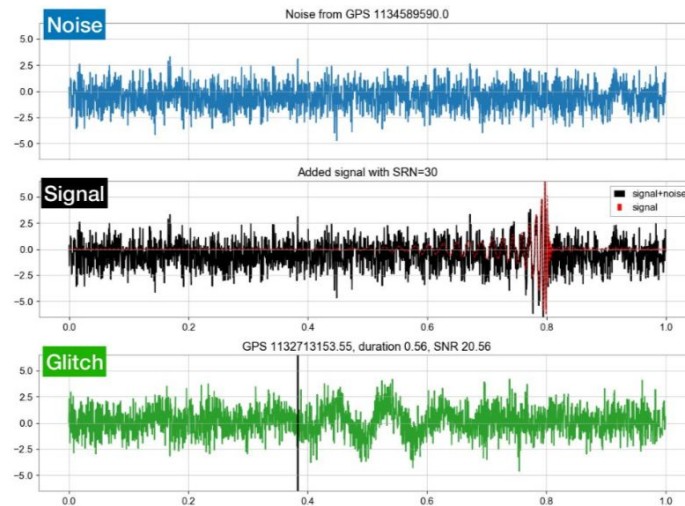
- Gravitational wave signal classification and extraction

Event level inference

- Belle2 Graph Full Event Interpretation
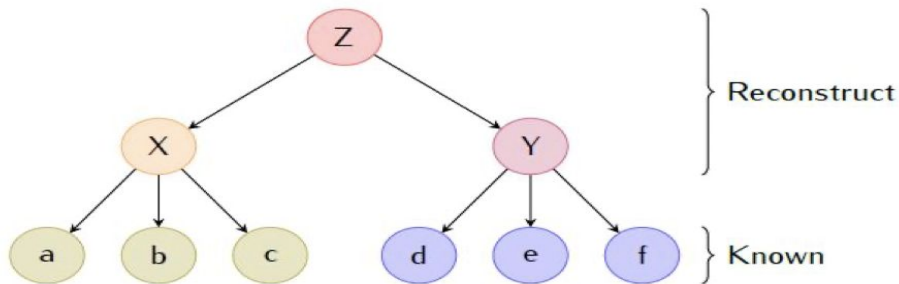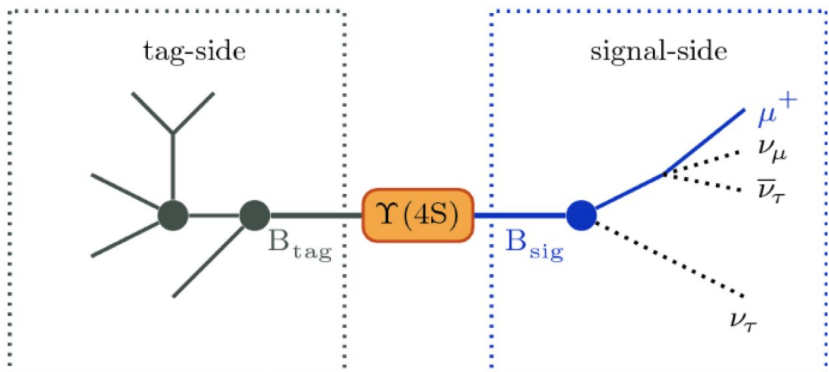
Graph Neural Networks
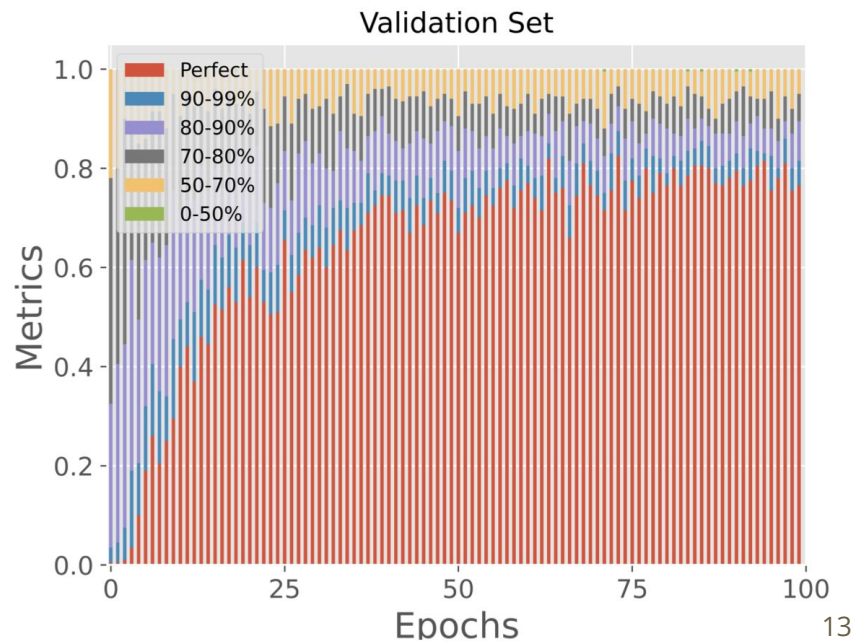
Generator Models for Simulation
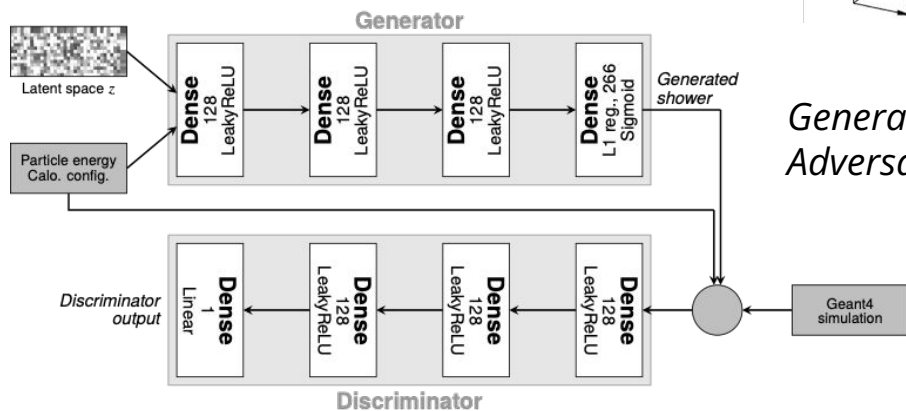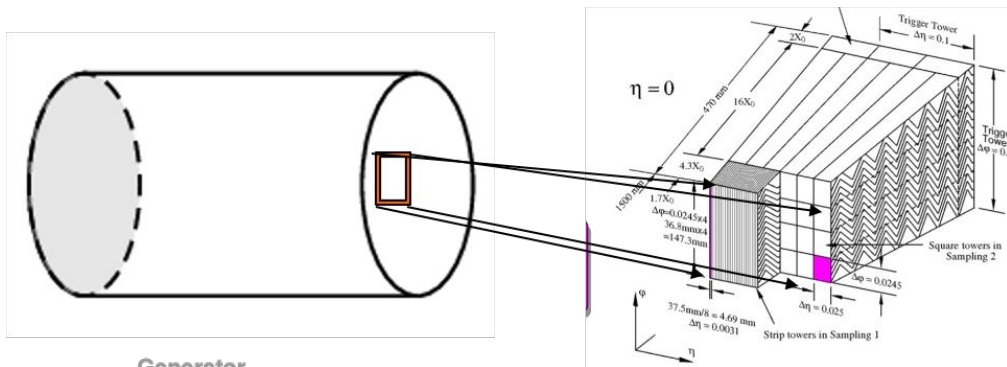
Generative Adversarial Network
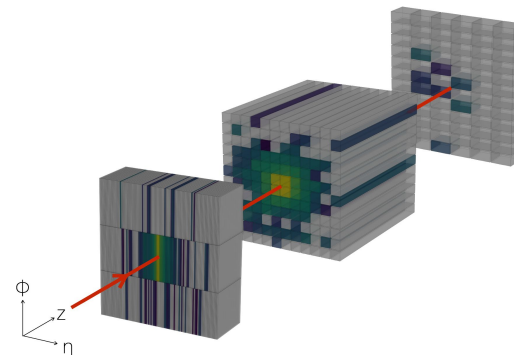
Generator Models for Simulation

Variational Autoencoders

Euclid
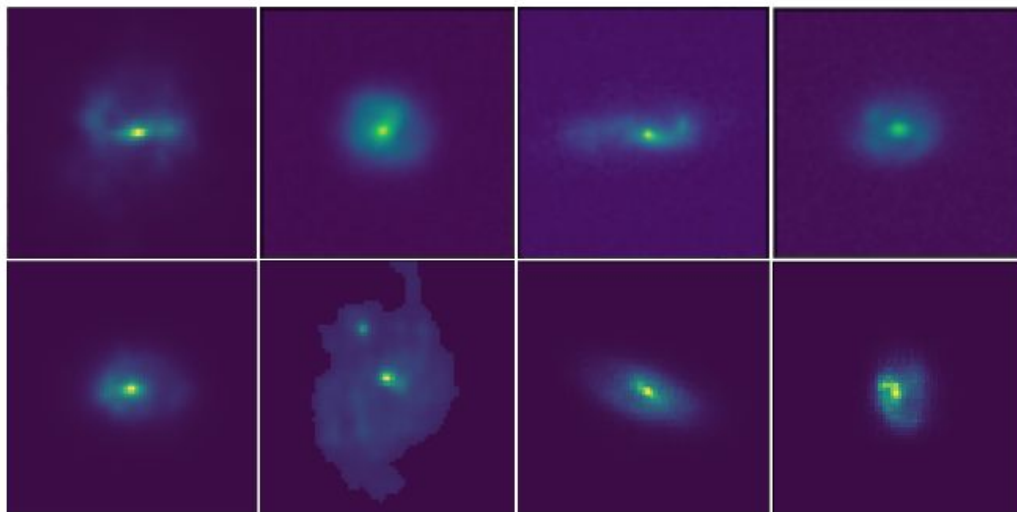
deep generative model conditioned to physical galaxy parameters,
able to **generate galaxies given input properties** (e.g. size, flux, bulge to disk ratio)
taken from real distributions (catalogues)

arXiv:2105.12149 with contrib. from APC

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Accelerator physics

Dense Neural Networks

	Name	Symbol
Inputs	First solenoid setpoint	I_1^{sol}
	Second solenoid setpoint	I_2^{sol}
	Iris position	r_{col}
Outputs	Beam current	$I_{RFQ,out}^b$
	Transmission of the RFQ	t_{RFQ}
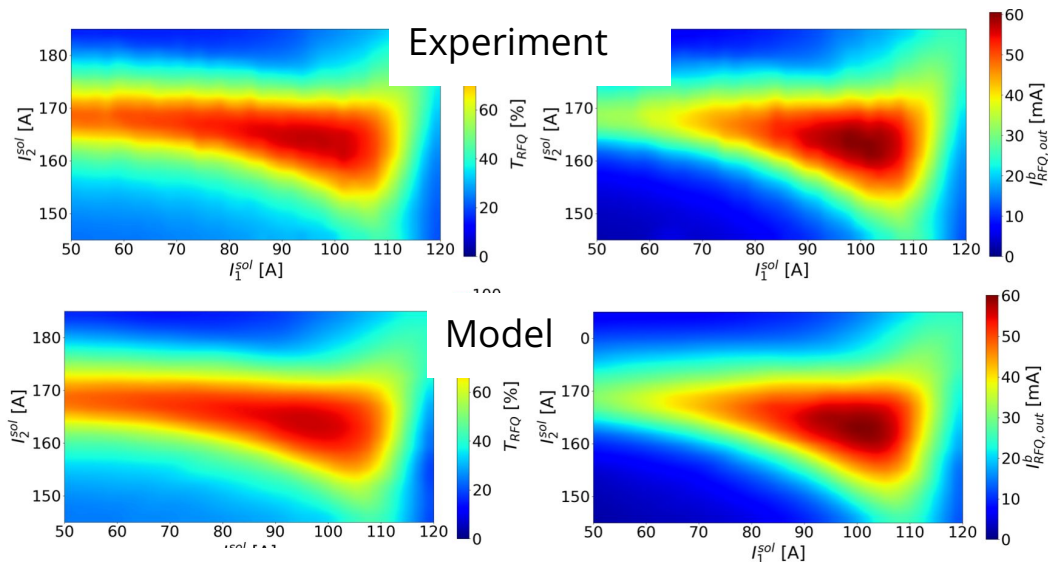
Experiment

Model

Train a surrogate model to interpolate between experimental scans
⇒then use the model to optimise working point

also : Advanced Accelerator Control Day @ IJCLab June 21 2022

Aparté: the very first AI HEP paper was @ IN2P3!

- 1987 : NN for tracking and calo clustering in Delphi @ LEP
- Bruce Denby still active (not HEP, professor at U Sorbonne, Institut Langevin Ondes et Images): "silent speech" (analysis of ultrasonic video of the tongue)
- 1992 JetNet Peterson, Rognvaldsson (Lund), Lonnblad (CERN) (~500 citations) really started NN use in HEP

- End of 90ies : AI winter

NEURAL NETWORKS AND CELLULAR AUTOMATA IN EXPERIMENTAL HIGH ENERGY PHYSICS

B. DENBY

Laboratoire de l'Accélérateur Linéaire, Orsay, France
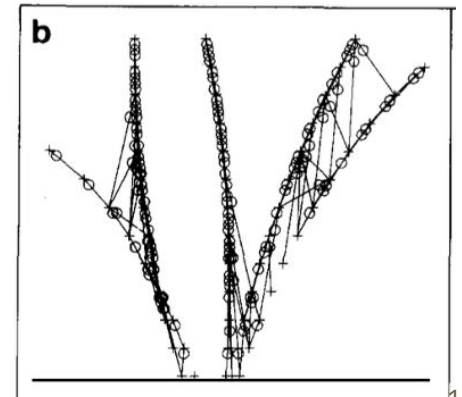
AI at IN2P3 overview

IN2P3 ML Survey

- Survey ran end of May 2022
- Expected one answer per "project"
- 55 answers
- Not quite exhaustive, but provides input for a cartography to be detailed in the future
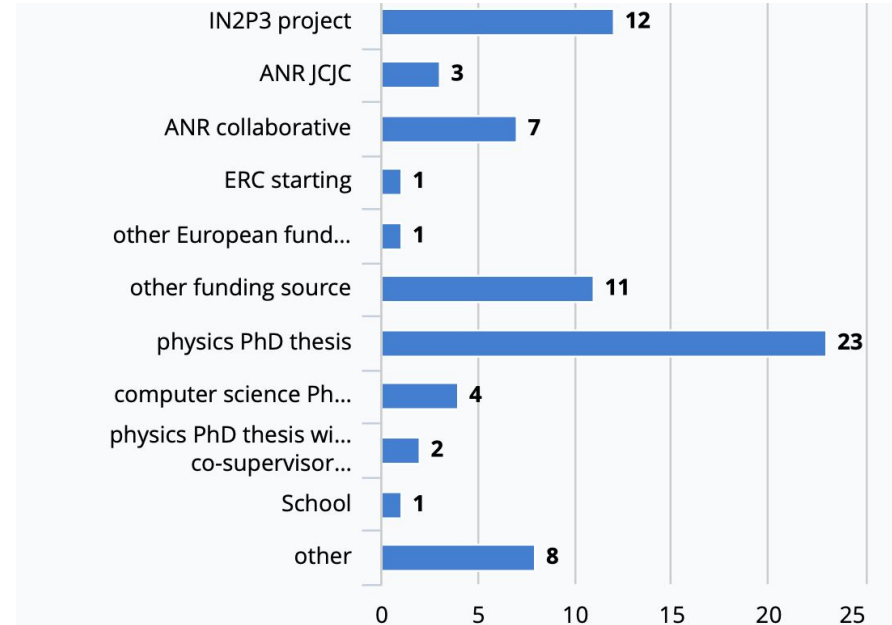
Physics topics
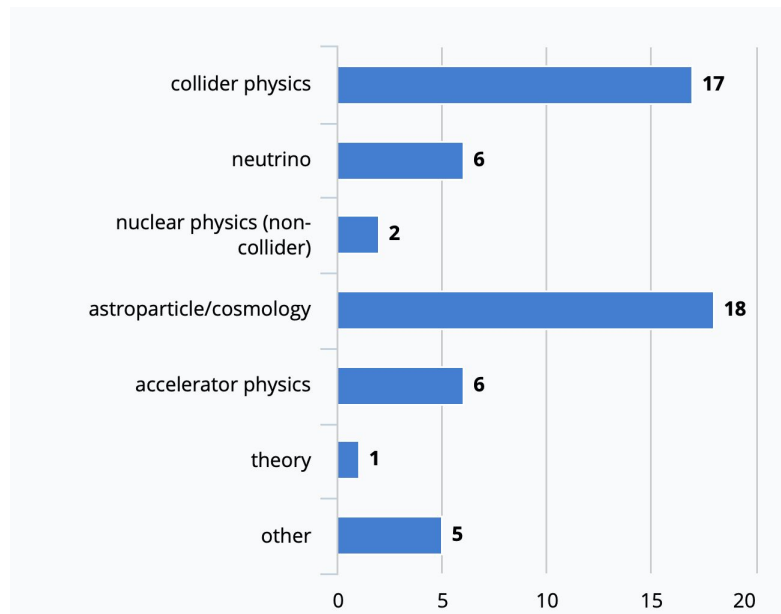
Main AI themes
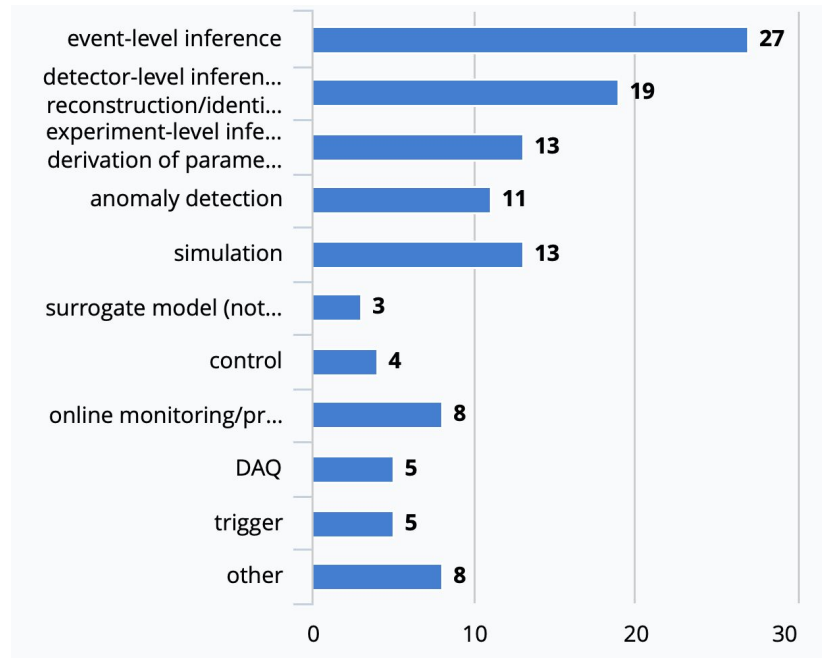
Input data type
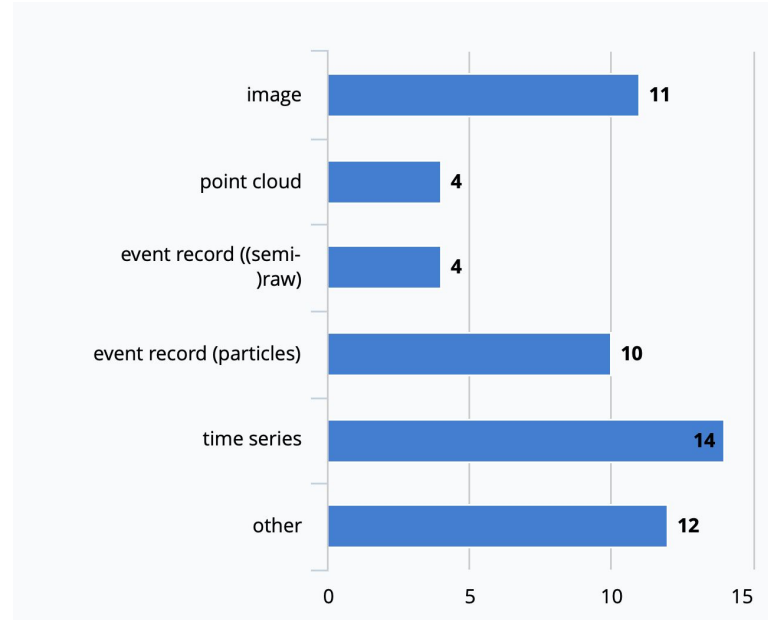
AI techniques

- Wide range of expertise in the diversity of ML techniques used at IN2P3, with an accent on deep learning

- Boosted Decision Trees is commonly used in particle physics and underrepresented here
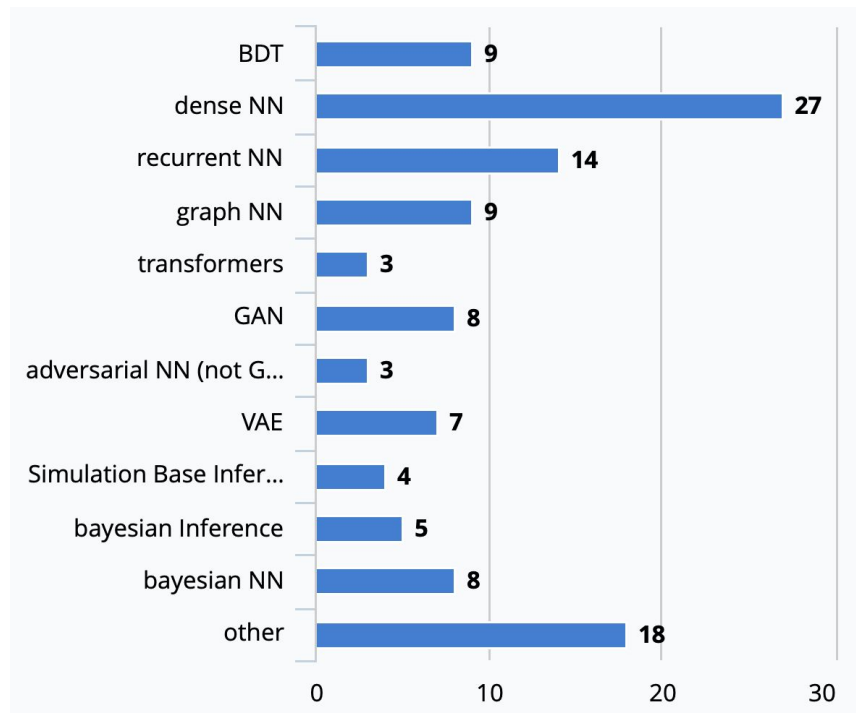
Resources

Computing resources

- Whole range of resources used, from local to national
- "Other" represents the other data centers (Fr or international) and cloud resources such as AWS or Azure
- Expected evolution
  - more projects
  - more detector level inference (more channels⇒more complex models)
  - more complex models (on same kind of input data, general AI trend)
  - ⇒ more resources needed in the future (still hard to quantify)
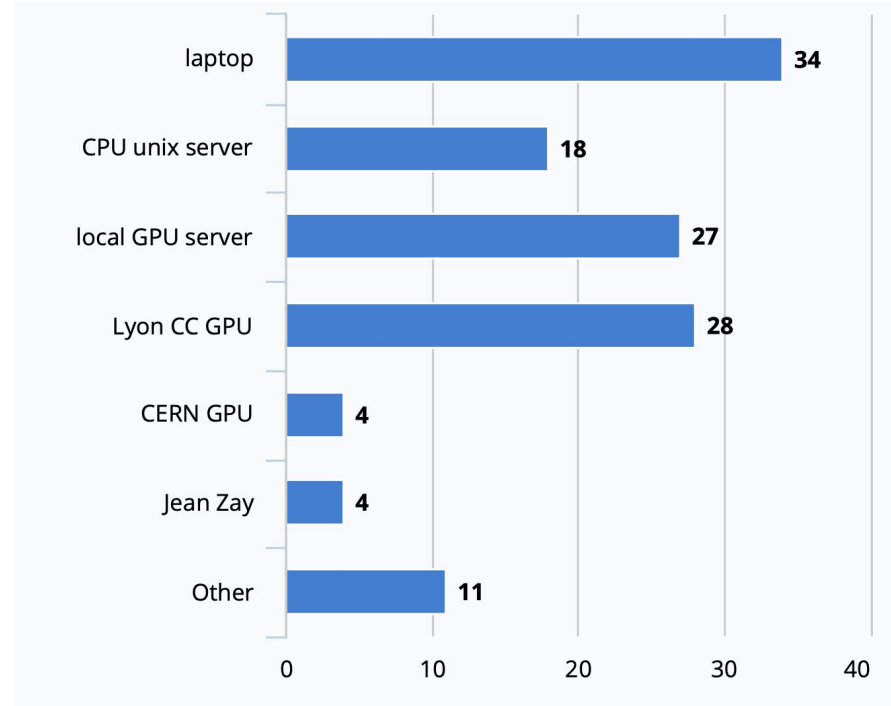
ML frameworks

Note : TMVA (ML package in Root) is still widely used, underrepresented here)
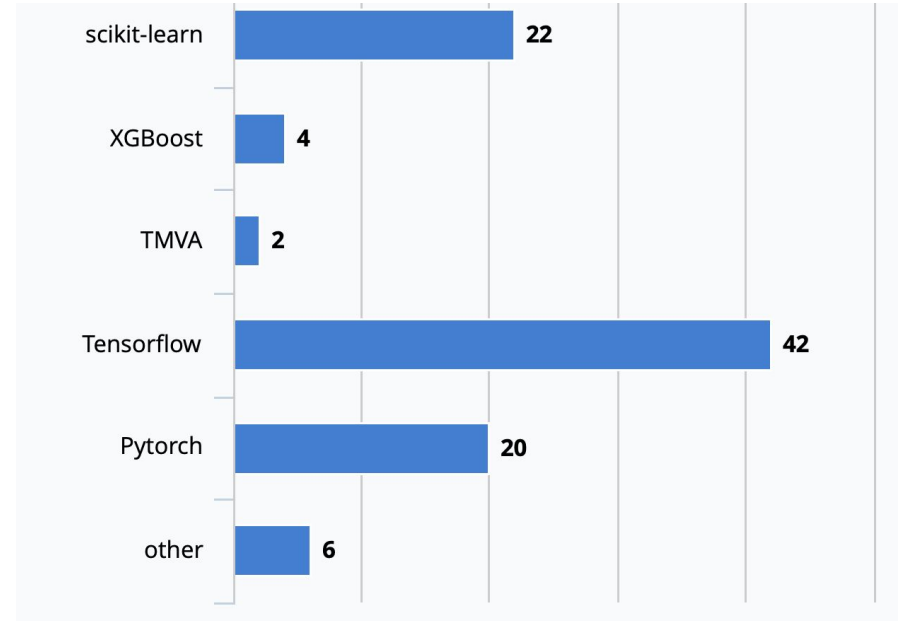
Preferred "cheap" action

- Compstat IN2P3 project
  - has **15k€** to support training and networking actions
  - paused during pandemic

- These are the preferred actions ⇒
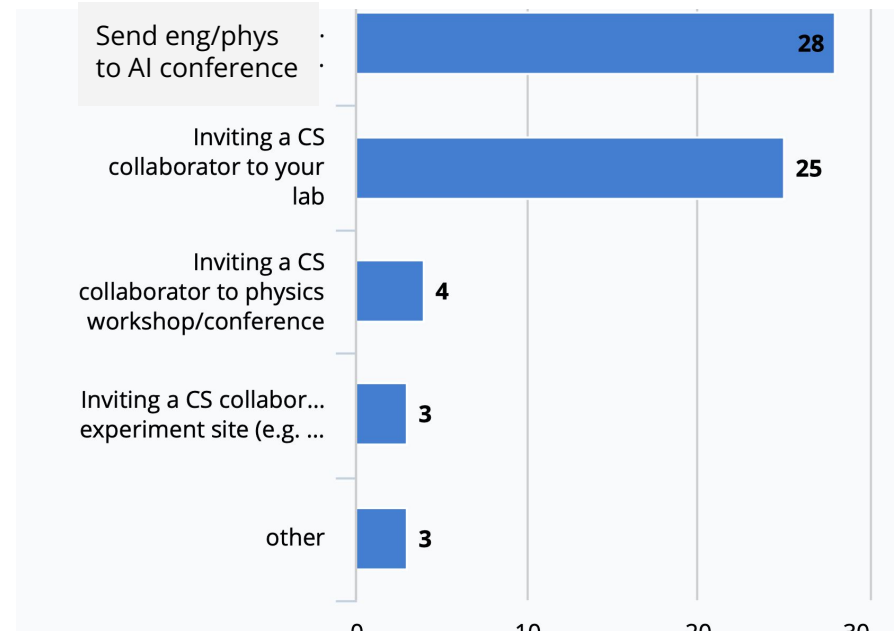
Publications

- Physics paper (with AI technique) in physics journal / conference (a few paragraph on the AI technique)
- Book contrib
- Methodology papers (about the AI technique) :
  - in physics journal/conference
  - in dedicated journal (Computing and Software for the Big Science, Machine Learning Science and Technology)
  - in dedicated AI (or computing) and HEP conferences (Advanced Computing and Analysis Techniques, Connecting The Dots, CHEP,), or parallel session of usual physics conference (ICHEP, EPS)
  - in "pure" AI journal/conference (NeurIPS, ICML,ICLR): very difficult
- Difficult to have an overview of IN2P3 production, would be useful for a **cartography** of AI at IN2P3
  - Maybe have the equivalent of https://iml-wg.github.io/HEPML-LivingReview/ for IN2P3 authors ?
- Lack of public datasets (slowly changing) hampers publication of methodology papers (especially true for PP, less for cosmology)
- Lack of incentive w.r.t. other countries
  - non-negligible work to write/produce the methodological paper in addition of the physics one
- Hopefully changing with more PhD and postdocs (next slide)

Human resources

- Recent increase of manpower (see full list of ANR and PhDs in the report)
- 26 recent or on-going ML PhDs reported
  - start date : 1 in 2017, 3 in 2018, 4 in 2019, 5 in 2020, 8 in 2021, 5 in 2022
  - including 4 Computer Science PhD, and 2 physics PhD with CS co-supervision
- 9 ANR JCJC and PRC (=>post-docs) :
  - 1 in 2018, 3 in 2019, 1 in 2021 4 in 2022
- 1 ERC Starting
- other calls (local or experiment)
- ⇒ former PhD students with a deep experience in AI "on the market", however may be deterred by **salary gap with industry** and the **winding path to permanent position** in academia
- CPJ with AI emphasis
- CNRS/IN2P3 CR recruitment (CID 55 sciences et données)

Workshops organisation

IN2P3/IRFU Machine Learning workshop

26–28 sept. 2022
APC, Paris
Fuseau horaire Europe/Paris

16–17 mars 2021
Remote only
Fuseau horaire Europe/Paris

22–23 janv. 2020
CC-IN2P3
Fuseau horaire Europe/Paris

https://astrodeep.net/workshop2022/

- French AI workshops
- International AI workshops in France

- International Workshops outside of France :
- IN2P3 participation not as high as it should be
  - lack of incentive?

30
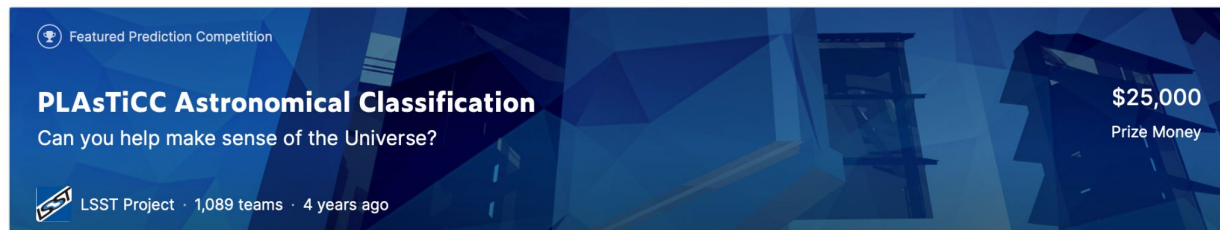
Schools

Preferred "free" action

- (sorry hardly readable : for each topic the lower the bar the more important)

- Most requests
  - website listing available resources (computing resources, tutorials, etc...) (to be done)
  - several day school (done)
  - tutorials (some exist, by product of schools)
  - several day in-person workshop (done)
  - one day topical workshop (starting)
- Spontaneous suggestion (several times)
  - expert helpdesk ...
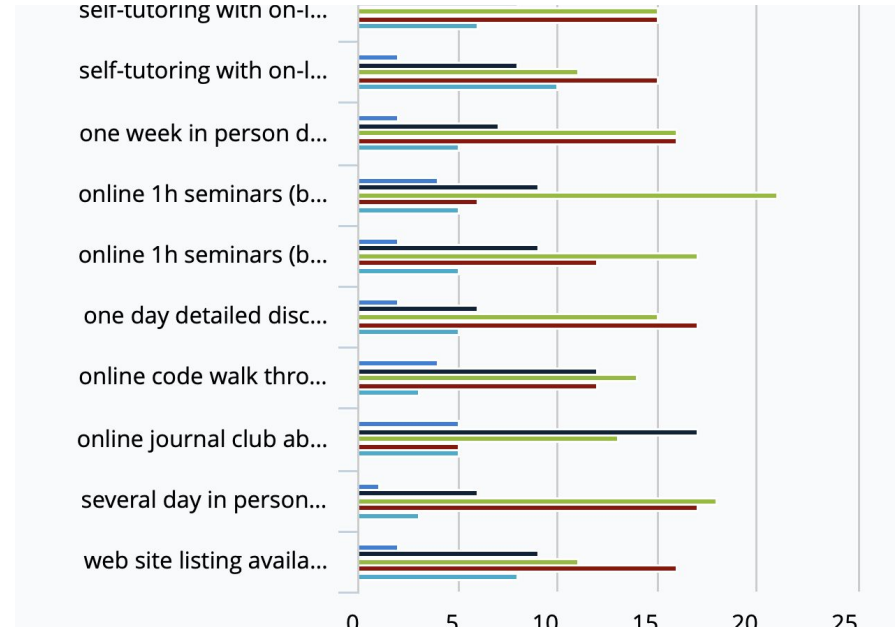
Challenge, Open Data

- PLastiCC (LSST Supernova luminosity curve classification)
- TrackML (particle tracking at LHC)
- spur attention of data scientists worldwide
- long lasting dataset and evaluation metric

SWOT

- **Strength**
  - data science is at the core of IN2P3
  - large labelled datasets
  - accurate simulators
  - relatively easy access to computing resources for training
- **Weakness**
  - AI competence is not easy to acquire
  - specific semi-structured data not suitable for off-the-shelf tools
  - difficulty to recruit AI-capable post-docs or engineers
- **Opportunities**
  - HEP specificities mean opportunities for specific AI developments, potentially interesting for other science
  - HEP « prestige » helps to attract Computer Science collaborators
- **Threats**
  - publication pace slow/difficult in HEP big collaborations compared to AI world (and smaller collaborations)
  - lack of incentive at IN2P3 for dedicated publication/workshop contributions

Conclusion

- Diversity of AI activity at IN2P3

- [IN2P3/CEA ML workshop @APC](), 26-28 Sept 2022 registration and call for contribution are opened

BACKUPS