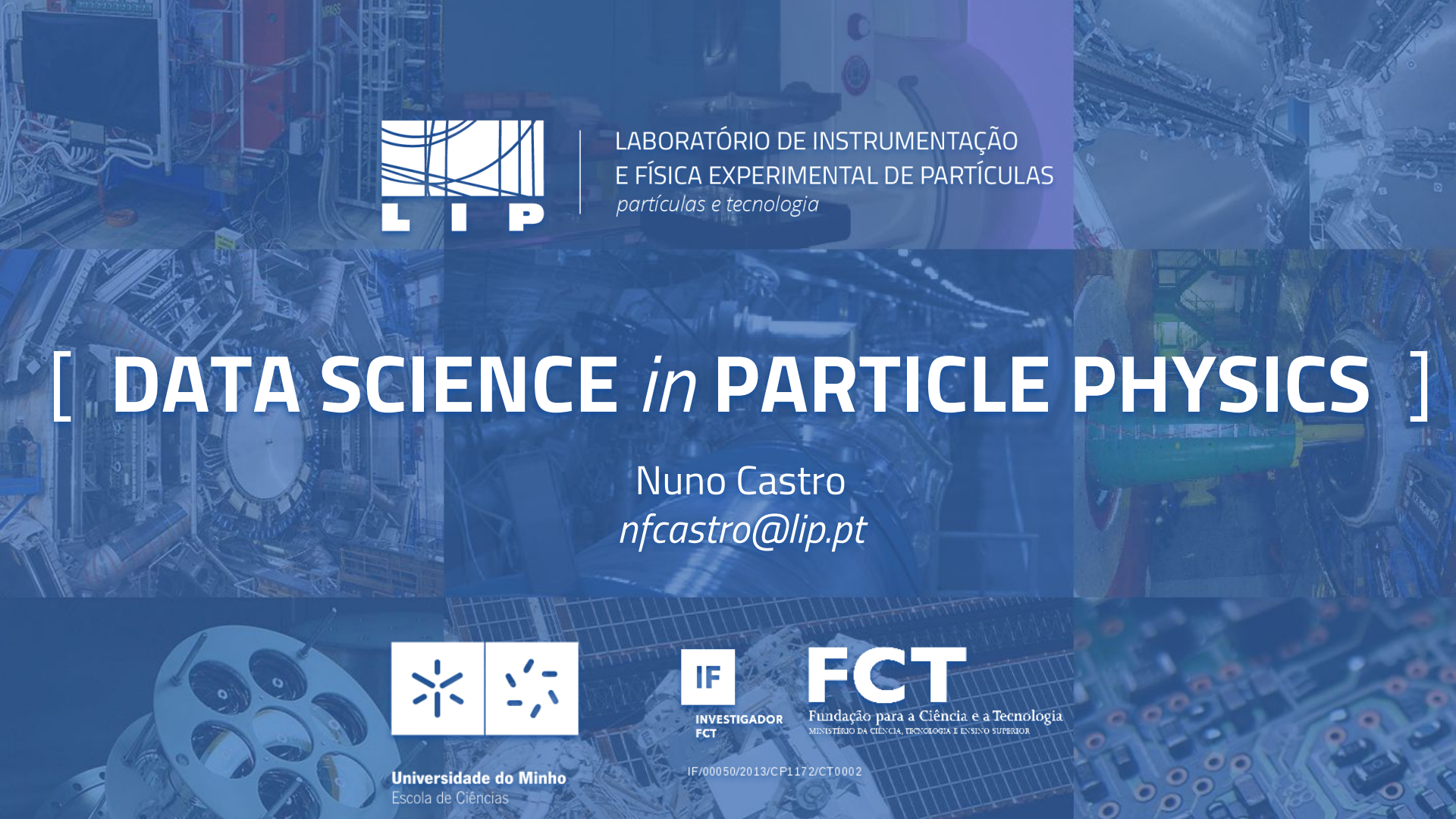

LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

[DATA SCIENCE *in* PARTICLE PHYSICS]

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Escola de Ciências

IF INVESTIGADOR FCT

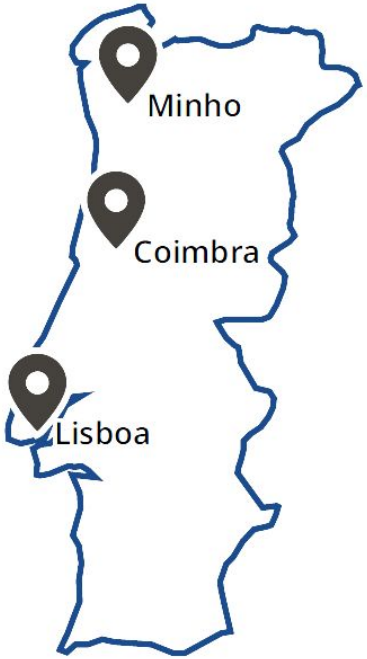
FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

IF/00050/2013/CP1172/CT0002

LIP

Laboratório de Instrumentação e Física Experimental de Partículas

- LIP is the reference laboratory for experimental particle physics and associated technologies in Portugal
- LIP exists for the discovery of the fundamental laws of the Universe, ensuring the full participation of the Portuguese scientific community in this endeavour, and to share this knowledge with society
- The laboratory is nation-wide, with nodes in Lisbon, Coimbra and Braga, in close collaboration with the local universities



LIP

Laboratório de Instrumentação e Física Experimental de Partículas

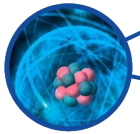
Experimental particle and **astroparticle Physics**

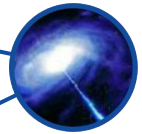
LHC experiments and **phenomenology**

- ATLAS
- CMS
- Phenomenology

Structure of **matter**

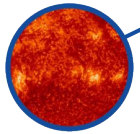
- COMPASS
- HADES





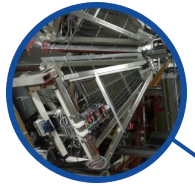
Cosmic Rays

- AMS
- Auger
- LATTES

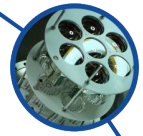


Dark Matter and **neutrinos**

- LUX/LZ
- SNO+
- NEXT

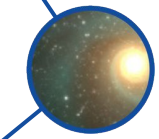


Development of **new instruments** and **methods**



Detectors for **particles** and **nuclear physics**

- Neutron detectors
- RPC R&D
- Liquid Xenon R&D
- NUC-RIA



Health and **biomedical applications**

- RPC-PET
- OR imaging
- Gamma Cameras
- STCD TagusLIP

Space applications

- Space Rad
- I-Astro

Computing

- GRID
- Advanced Computing

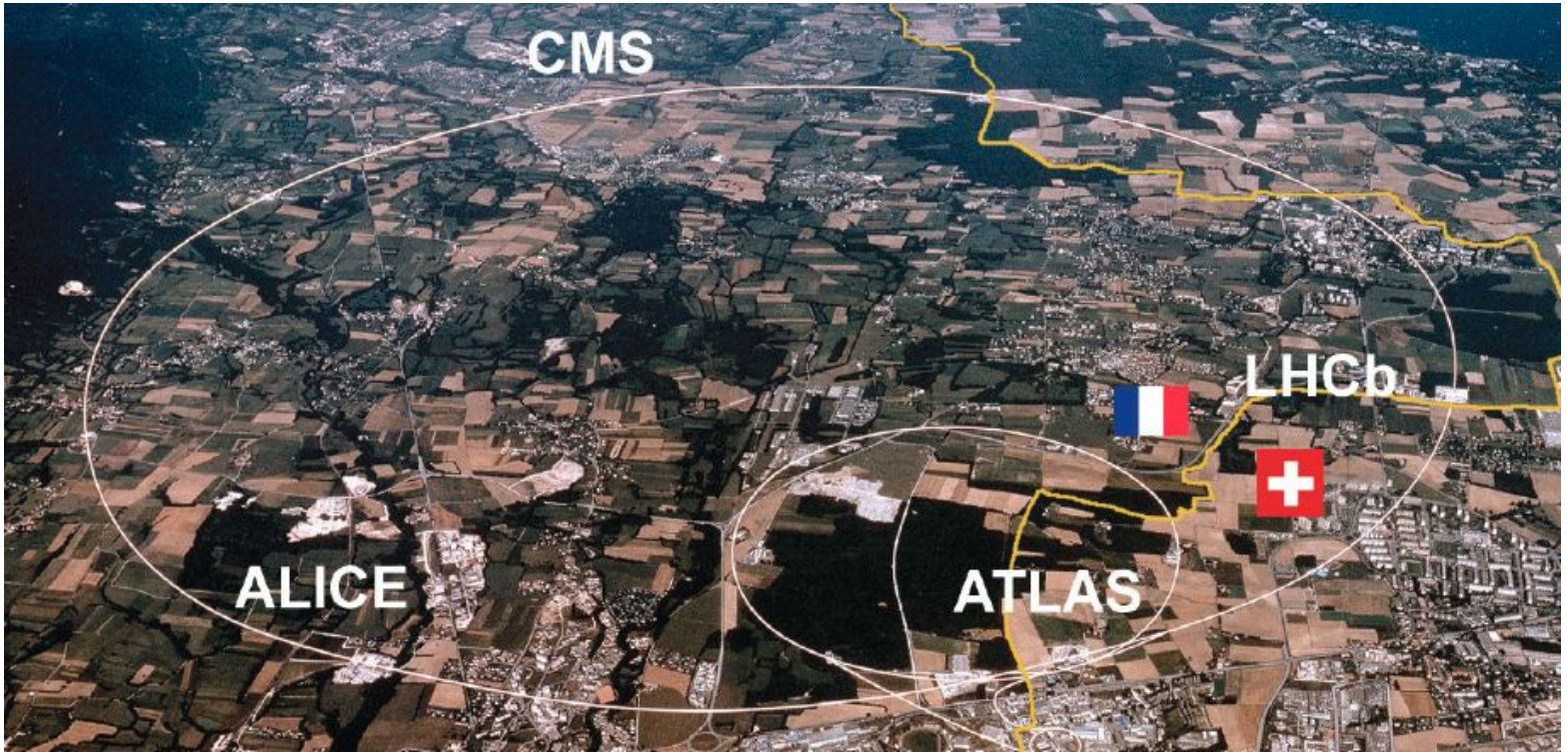
R&D

CERN

- The European Laboratory for Particle Physics
- Located in the franco-swiss border
- Portugal is a member since 1986, with LIP being the reference portuguese partner

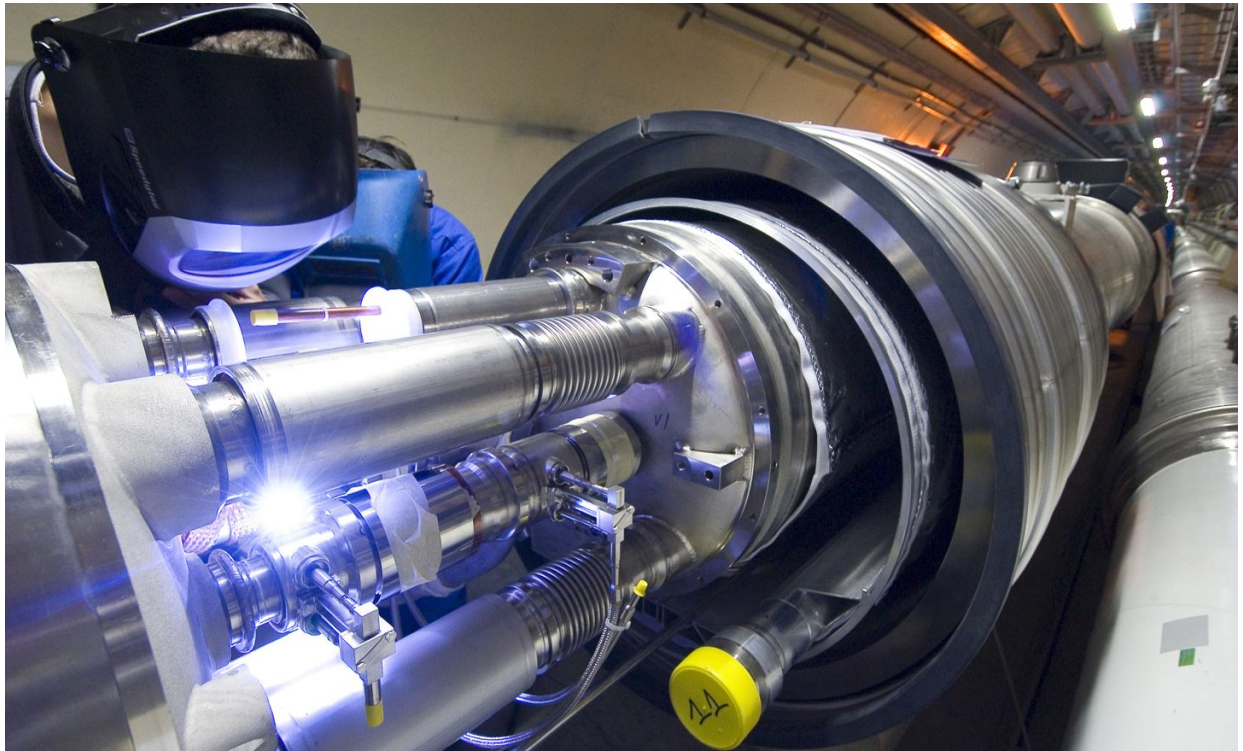
CERN

one of the fastest race tracks on the planet



CERN

the emptiest space in the solar system

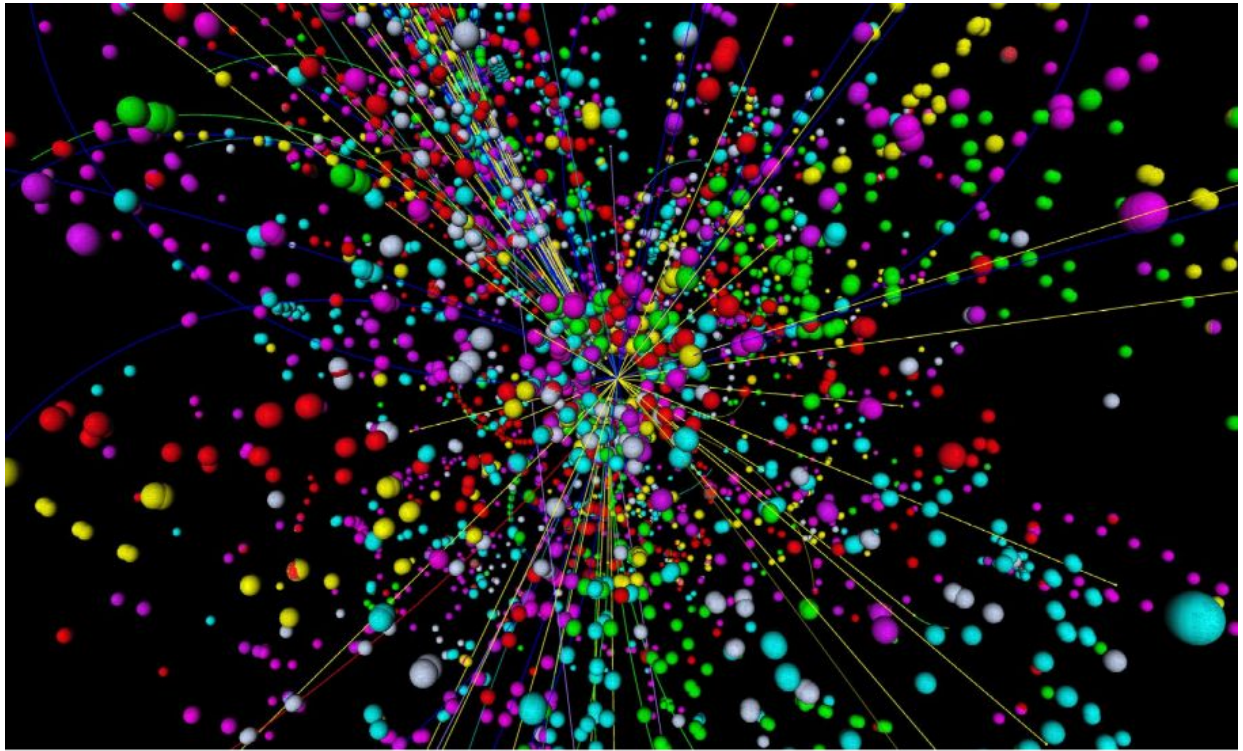


CERN

one of the coldest places in the Universe

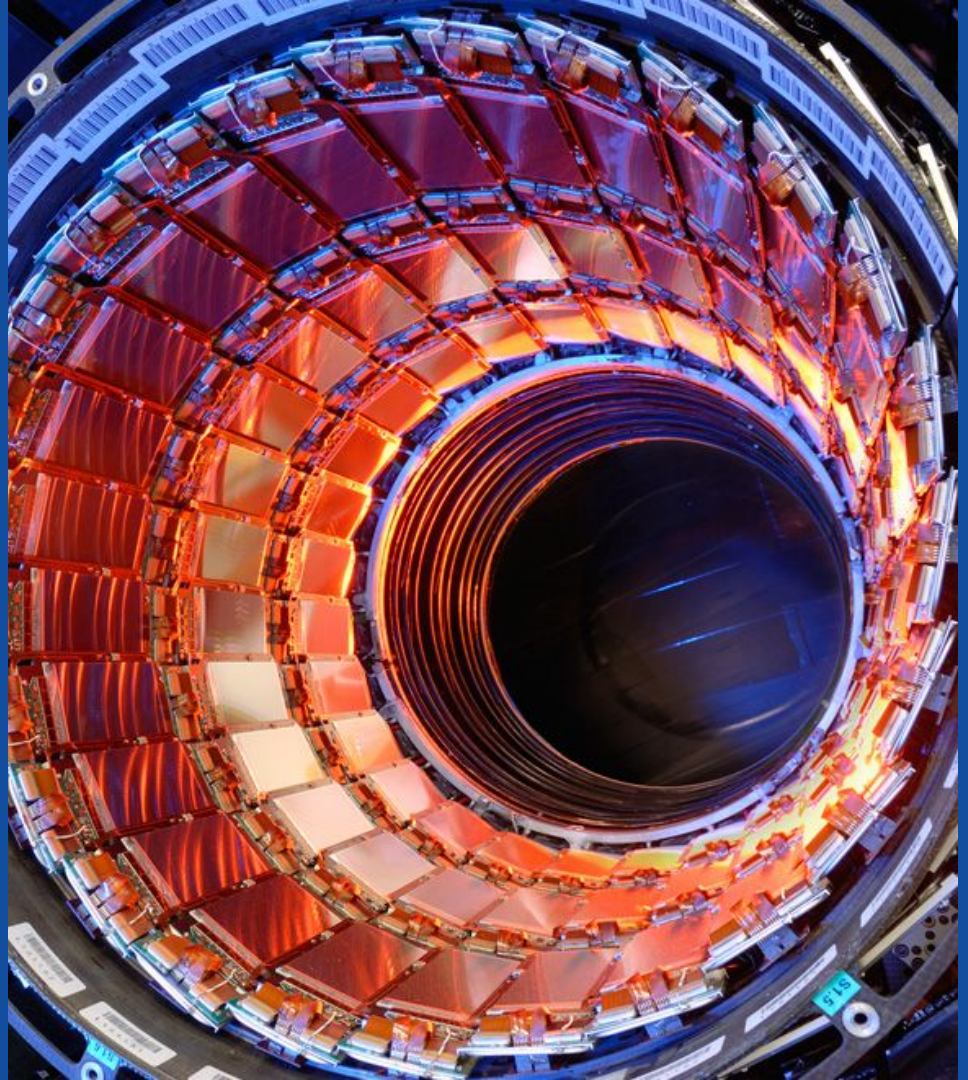
CERN

one of the hottest places in the Galaxy



In the frontier of the technology

- Particle physics accelerators and detectors are amongst the most complex devices built by the humankind
- Being on the edge of the technology is required

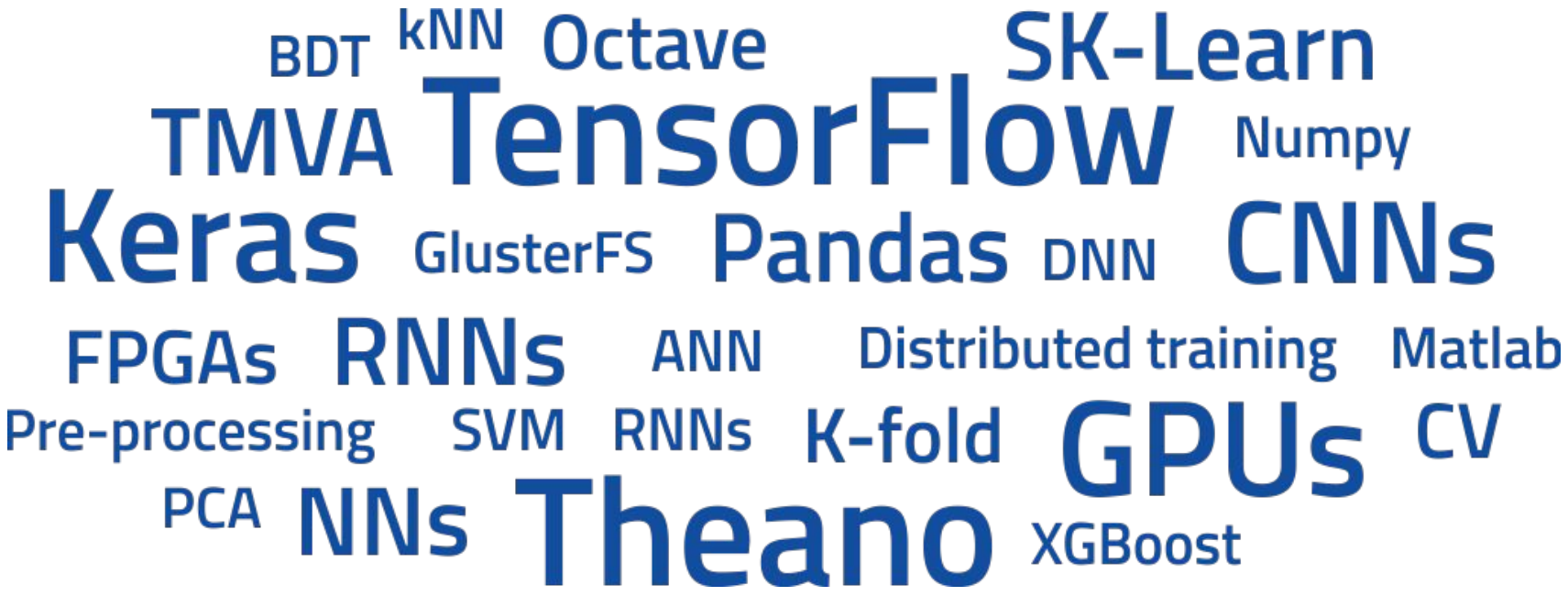


LIP competences
data analysis and processing in particle physics

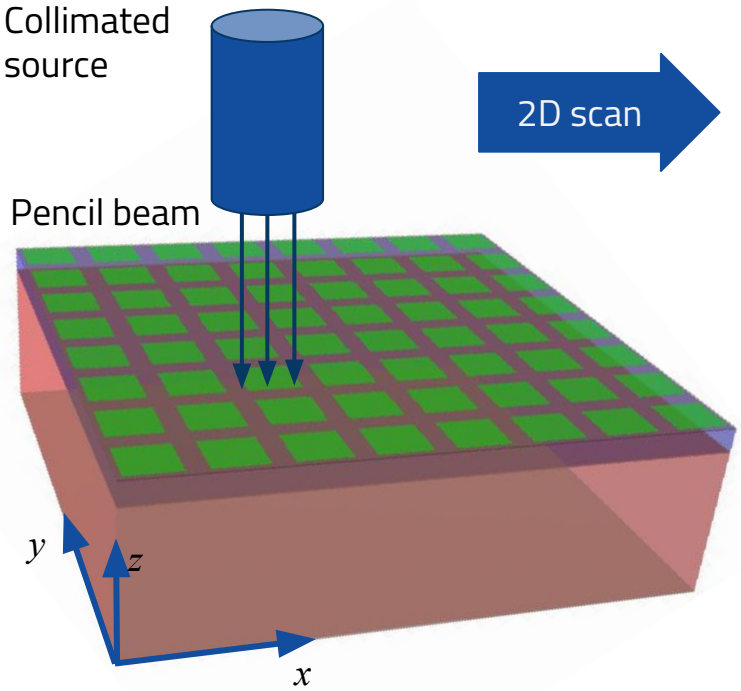
- LIP has been involved in the analysis of extremely large amounts of data produced by different experiments in High Energy Physics for a long time
- Expertise on the implementation and development of elaborate multivariate techniques aiming at a vast range of applications
- Competence in efficient data processing to better use the available computing resources

LIP competences

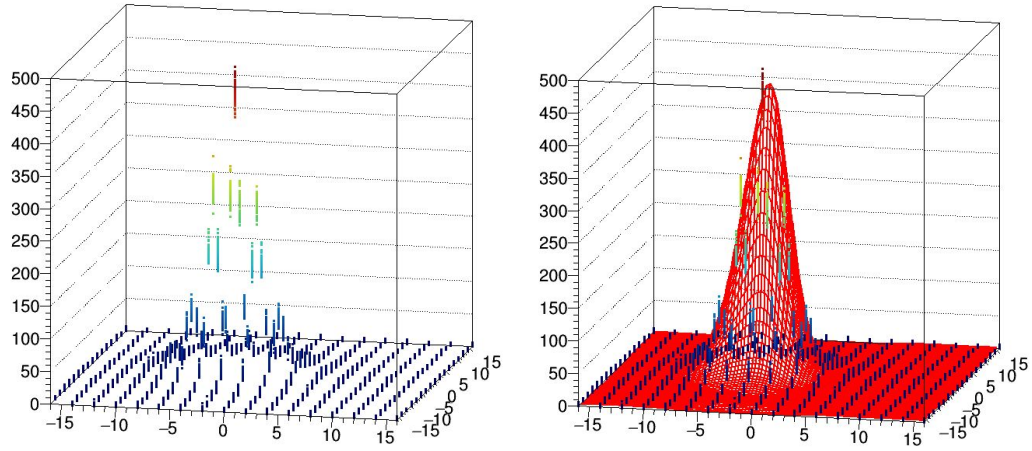
data analysis and processing in particle physics



Calibrating detectors in particle physics
an example



2D scan



Scan the detector with a pencil beam of monoenergetic γ-rays on a fine grid and then fit the obtained data with the appropriate smooth function

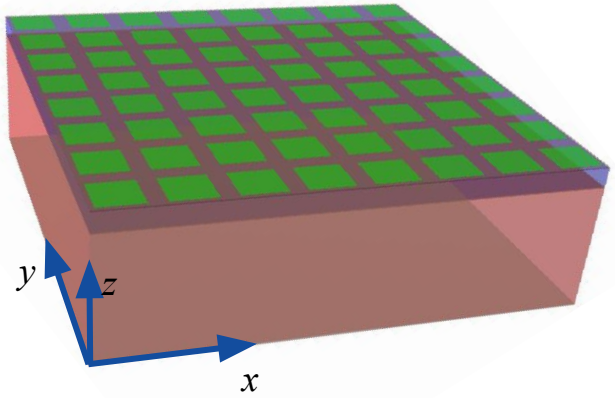
Calibrating detectors in particle physics
an example

This standard calibration procedure has some important limitations:

- Time consuming (N_{steps}^{2})
- 3D is feasible (scan at different angles and solve a linear system) but cumbersome and even more time consuming (N_{steps}^{3})

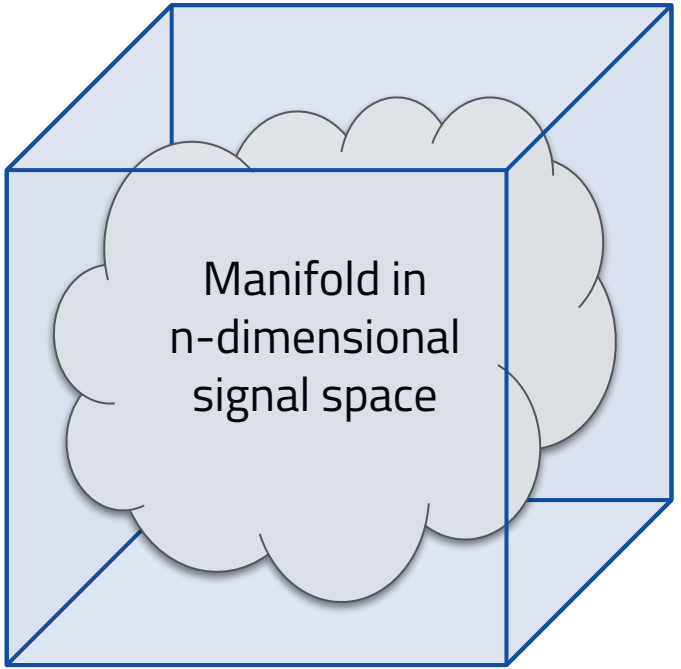
A machine learning approach can be the solution

Calibrating detectors in particle physics
an example

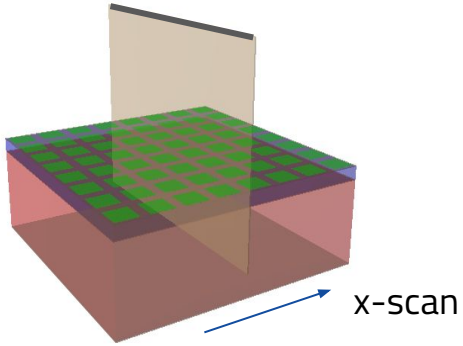


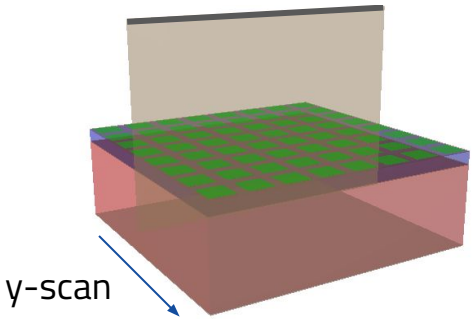
Event parameter space
e.g. x, y, z

n measured signals

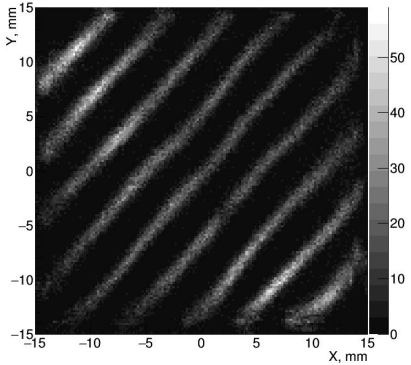


Calibrating detectors in particle physics
an example

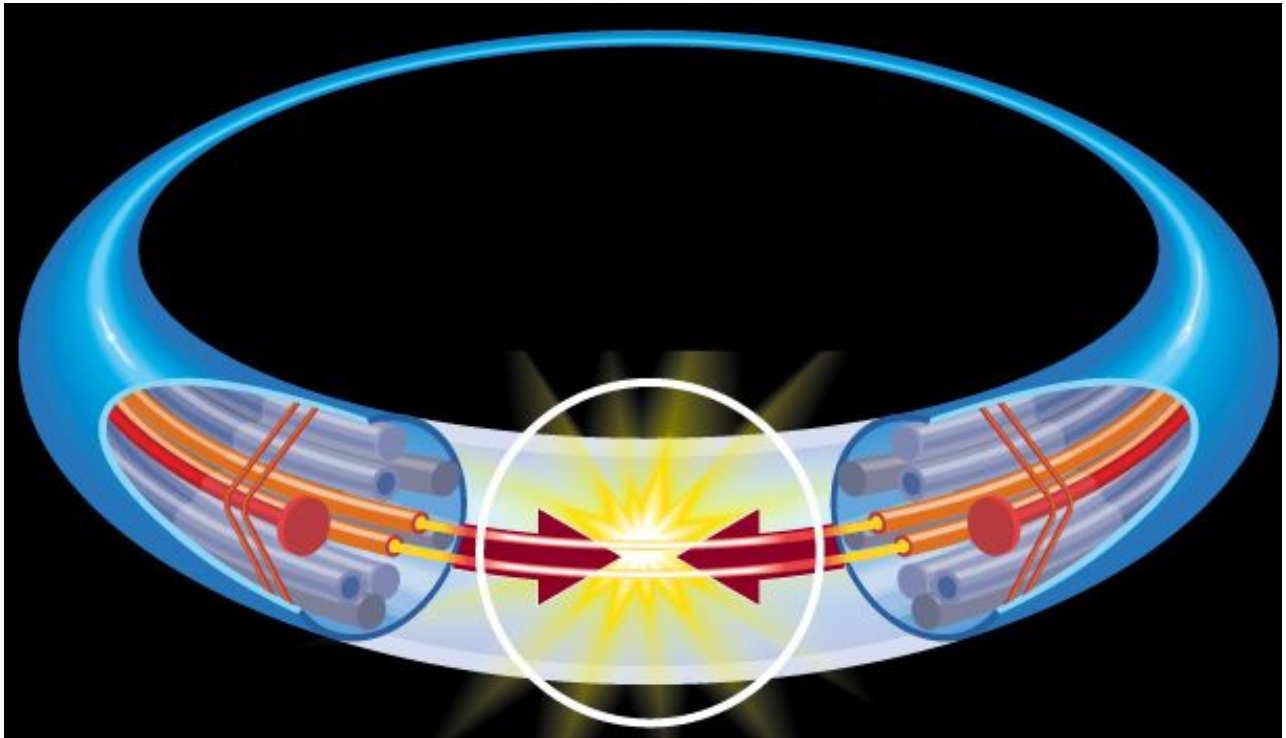




- Pencil beam -> knife-edge beam
- 2D scan -> 2 x 1D scans (N_{steps}^{2} -> 2 x N_{steps})
- 3D scan -> 3 x 1D scans (N_{steps}^{3} -> 3 x N_{steps})
- Use nearest neighbour (kNN) to find the points on the intersection between the scan lines/planes
- Then proceed as in the standard calibration

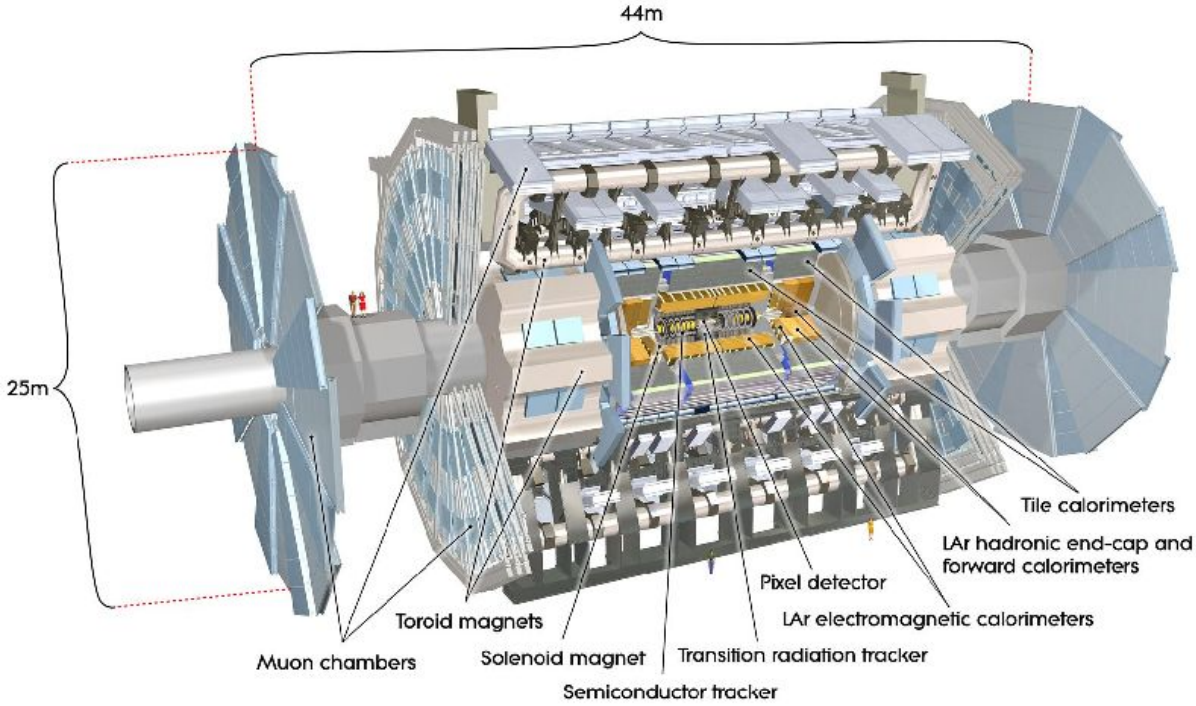


From data to physics at the Large Hadron Collider
a long and complex path



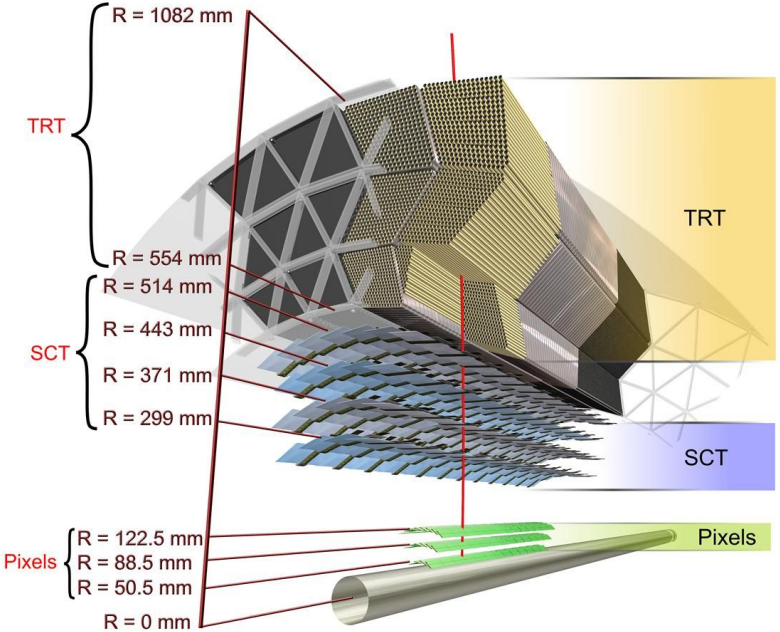
~1 billion collisions per second

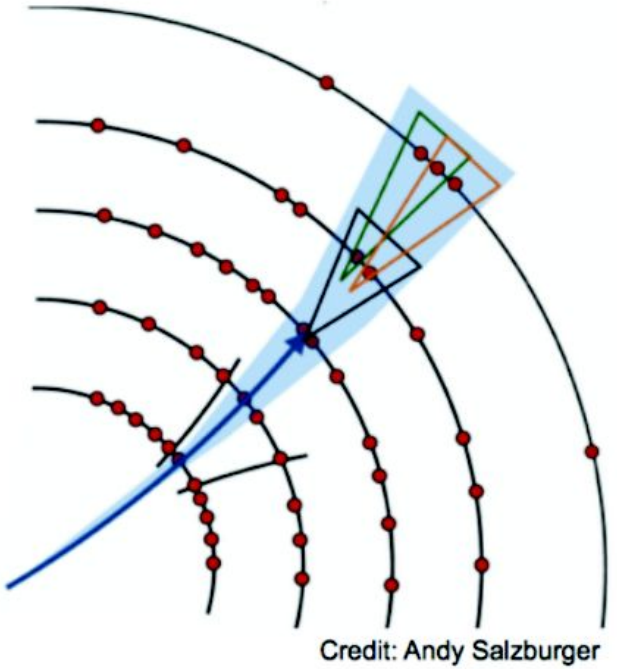
From data to physics at the Large Hadron Collider
a long and complex path



Hundreds of millions of readout channels

Tracking in particle physics
connecting the dots...



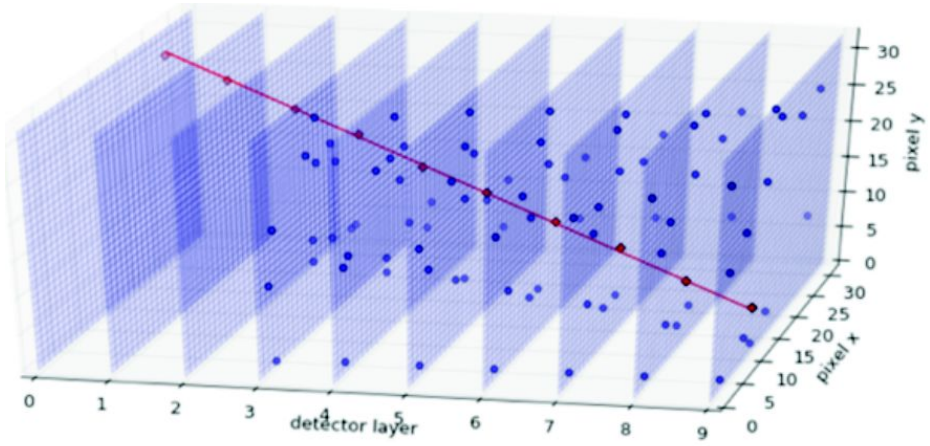


Tracking in particle physics
connecting the dots…

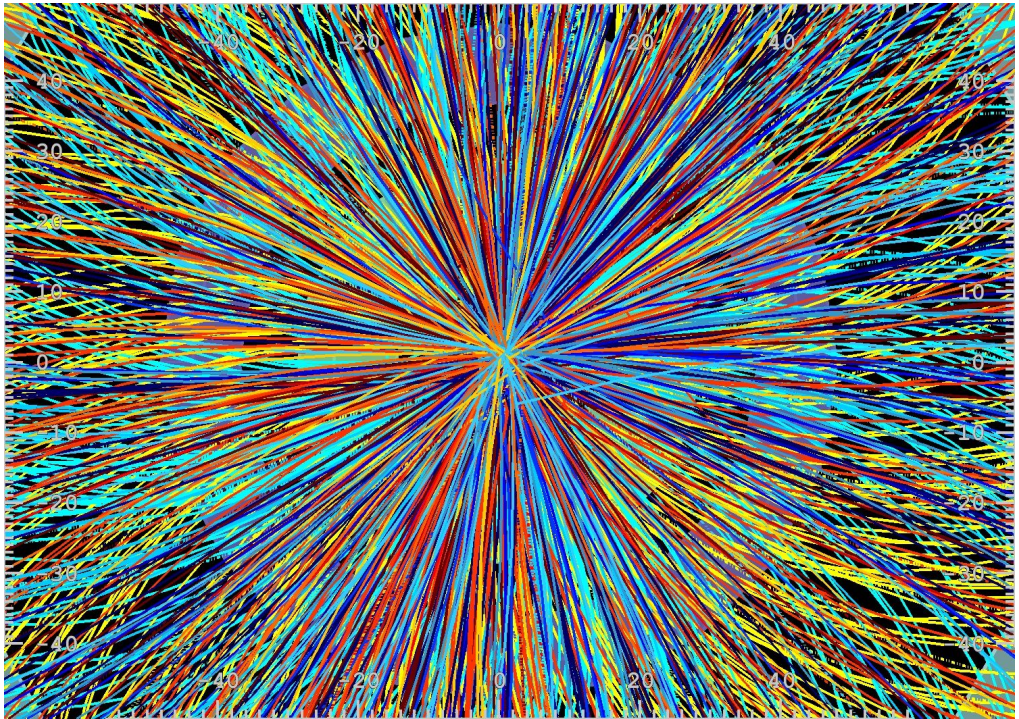
Tracking algorithms in particle physics have been quite successful so far

In a nutshell:

- *Track seeding:* combinatorial search
- *Track building:* combinatorial Kalma Filter (time consuming)
- *Track fitting:* final parameter estimation



Tracking in particle physics
connecting the dots...

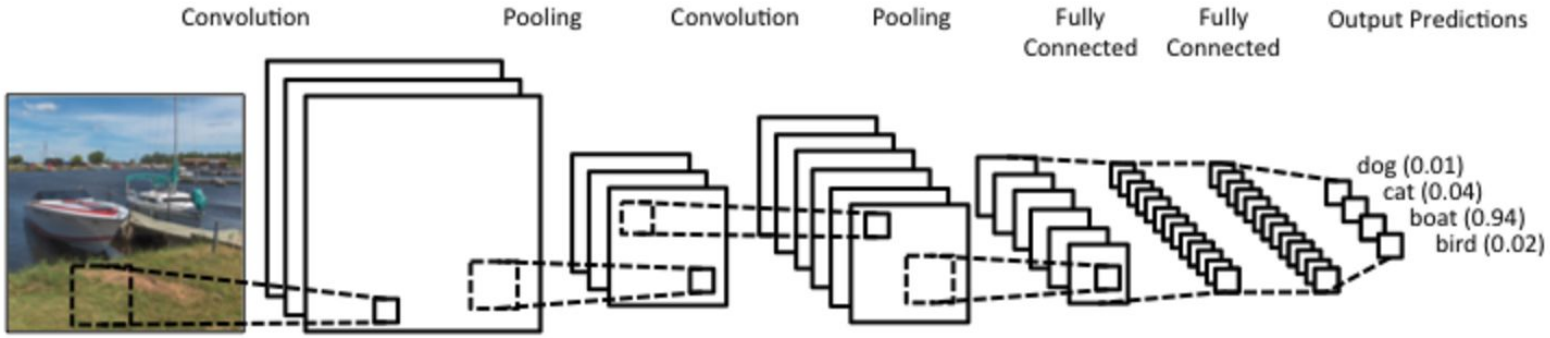


But with more data, the problem can become much more complex....

Tracking in particle physics
connecting the dots...

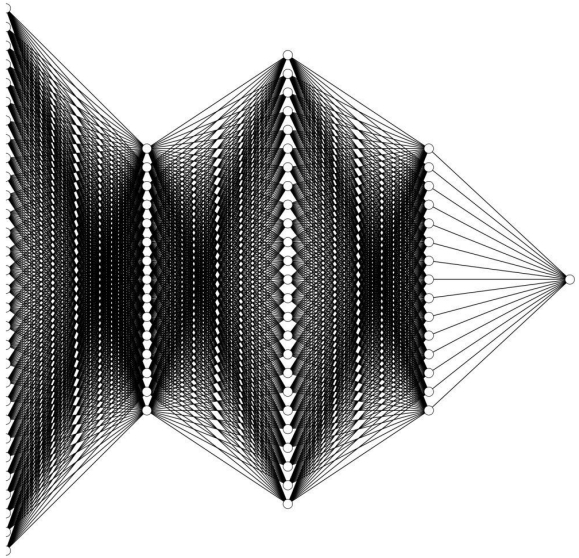
Use of sophisticated machine learning techniques is required

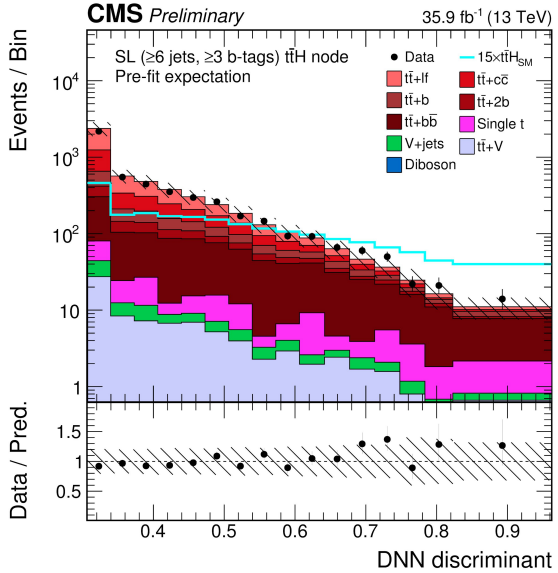
- we need to be able to run tracking faster and in parallel
- convolutional neural networks have great success in image classification and can be used as track finders
- treating track finding as an image recognition problem



Searching for rare events
finding a needle in many haystacks

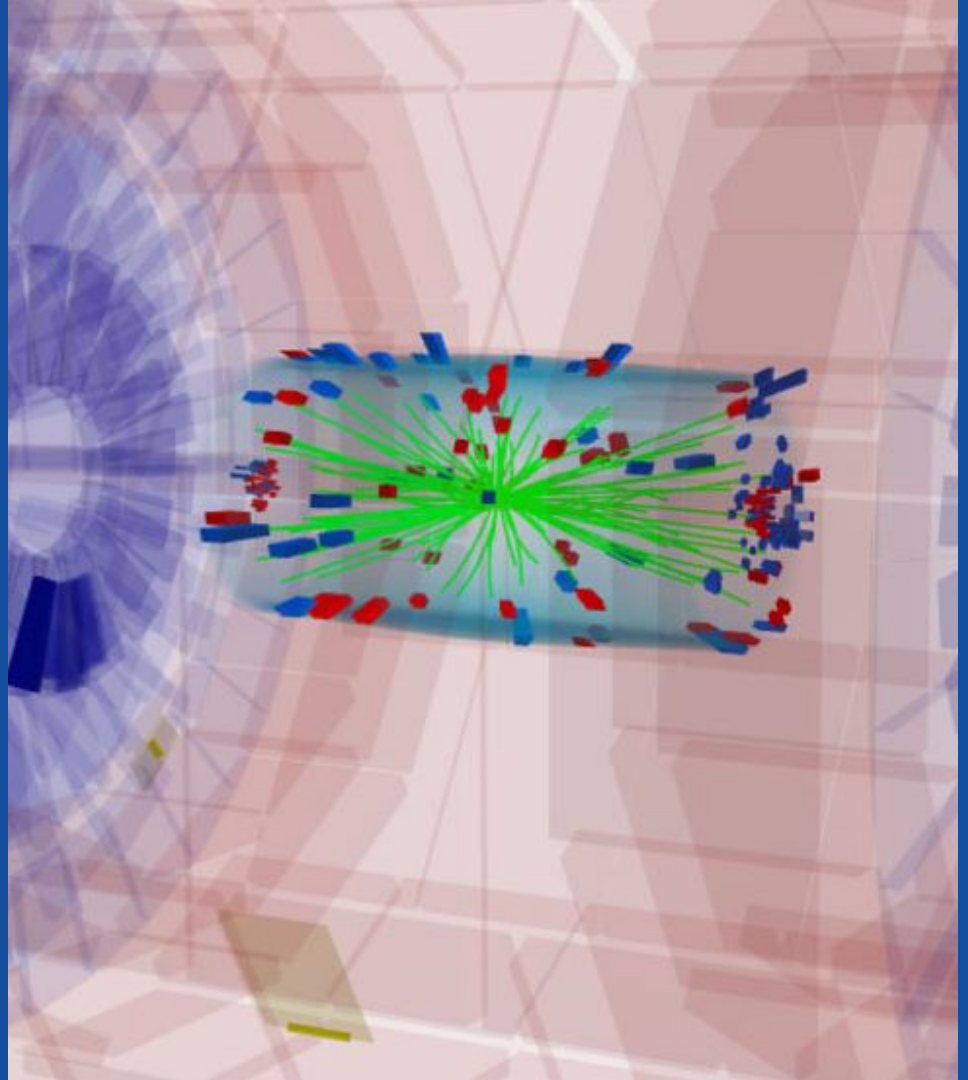
The interesting collisions at the Large Hadron Collider are extremely rare so advanced multivariate techniques are required





Summary

- at LIP we have more than 30 years of expertise in the analysis of large and complex data
- the most suitable technique has to be chosen for each problem
  - uncertainties and imperfect datasets
- possible synergies with other fields and activities



Thanks!

Any questions?

You can also find me at nfcastro@lip.pt