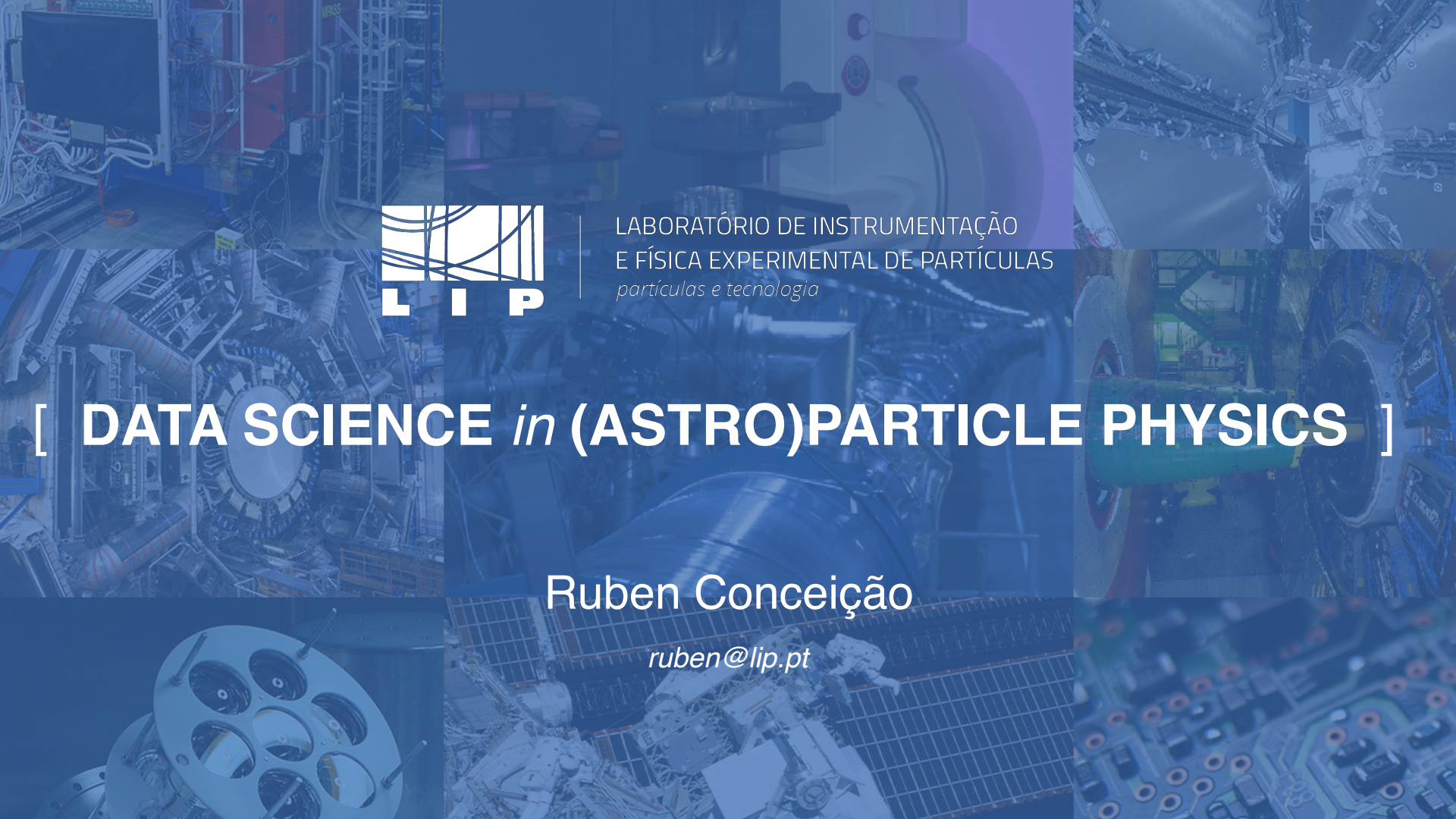


LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

[DATA SCIENCE *in* (ASTRO)PARTICLE PHYSICS]

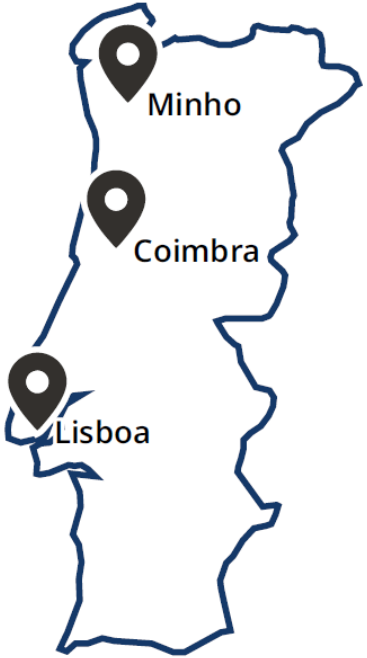
Ruben Conceição

ruben@lip.pt

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



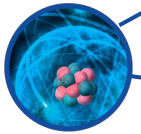
LIP

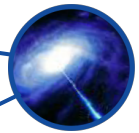
Laboratório de Instrumentação e Física Experimental de Partículas

Experimental particle and astroparticle Physics

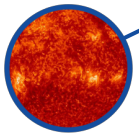
LHC experiments and phenomenology
- ATLAS
- CMS
- Phenomenology

Structure of matter
- COMPASS
- HADES
- NUC-RIA

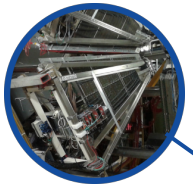




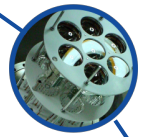
Cosmic Rays
- AMS
- Pierre Auger Observatory
- LATTES



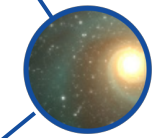
Dark Matter and neutrinos
- LUX/LZ
- SNO+
- SHIP



Development of new instruments and methods



Detectors for particles and nuclear physics
- Neutron detectors
- RPC R&D
- Gaseous Detectors R&D
- Liquid Xenon R&D



Health and biomedical applications
- Dosimetry
- OR imaging
- Gamma Cameras

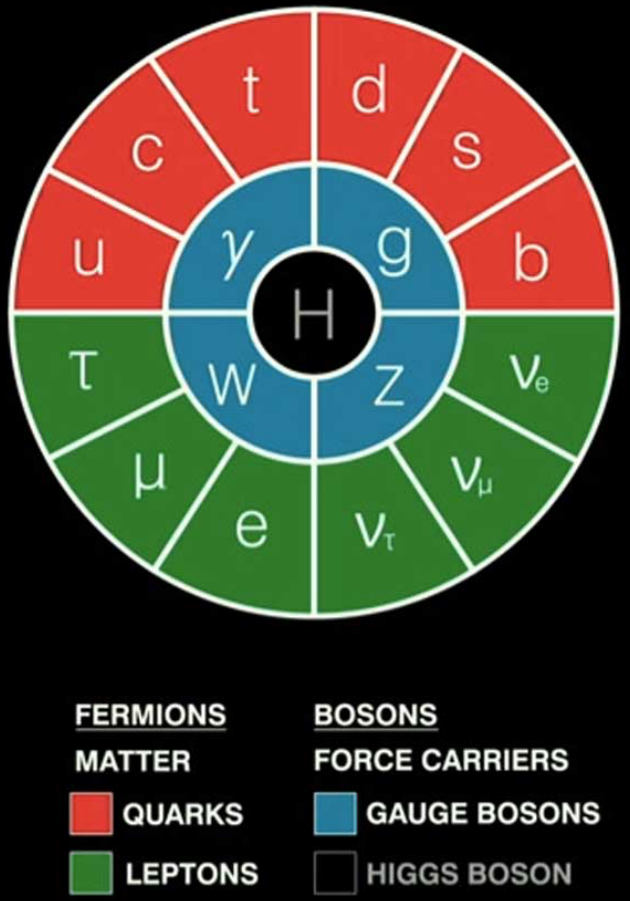
Space applications
- Space Rad
- I-Astro

Computing
- GRID
- Advanced Computing

R&D

Ultimate Goal

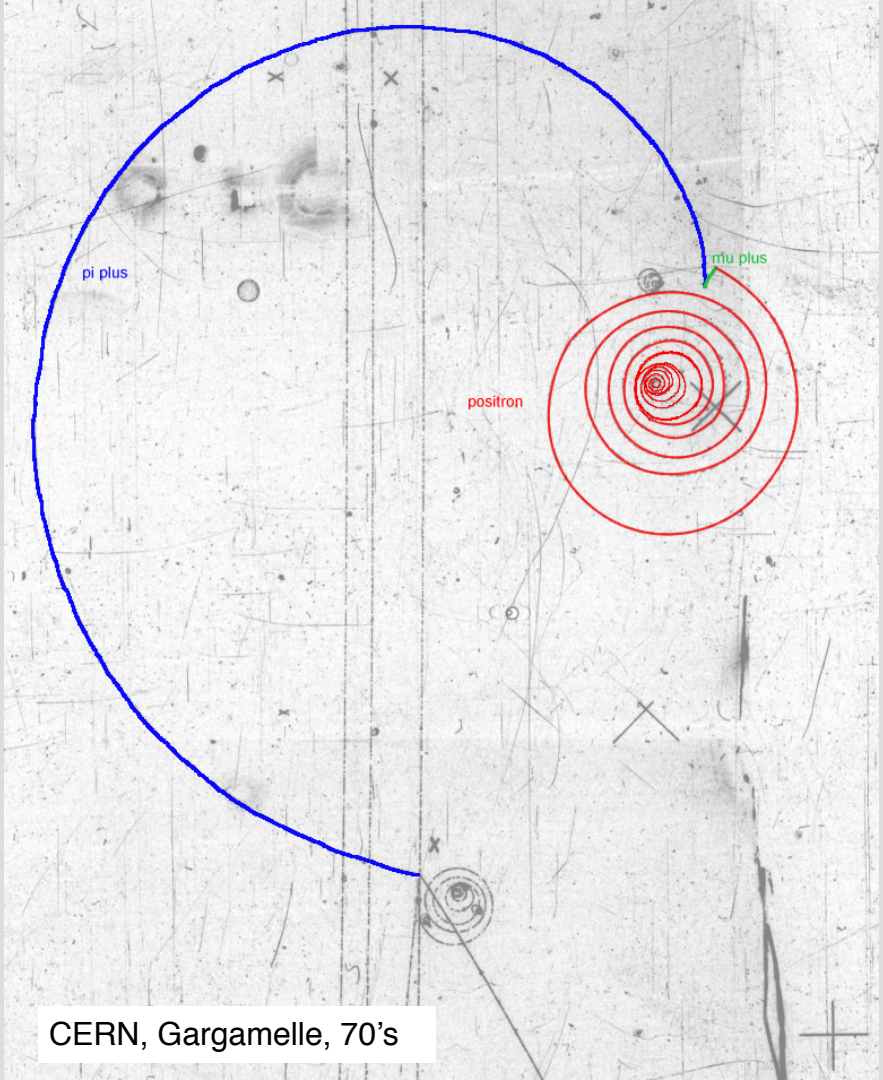
Understand the elementary blocks (particles) and interactions that compose and drive the dynamics of our Universe



Methodology

A highly simplified view of the observation of an interaction

- Create(collect) a beam of particles
- Make them to collide
- Collect the interaction products
- Model observations (Theory)



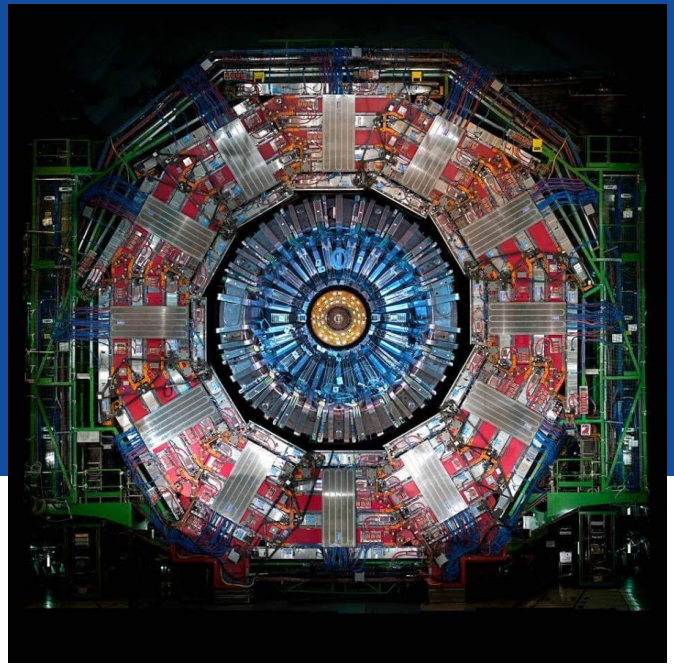
CERN, Gargamelle, 70's

The accelerators

LARGE HADRON COLLIDER (LHC)

ACTIVE GALAXY NUCLEI (AGN)

The detectors



CMS experiment

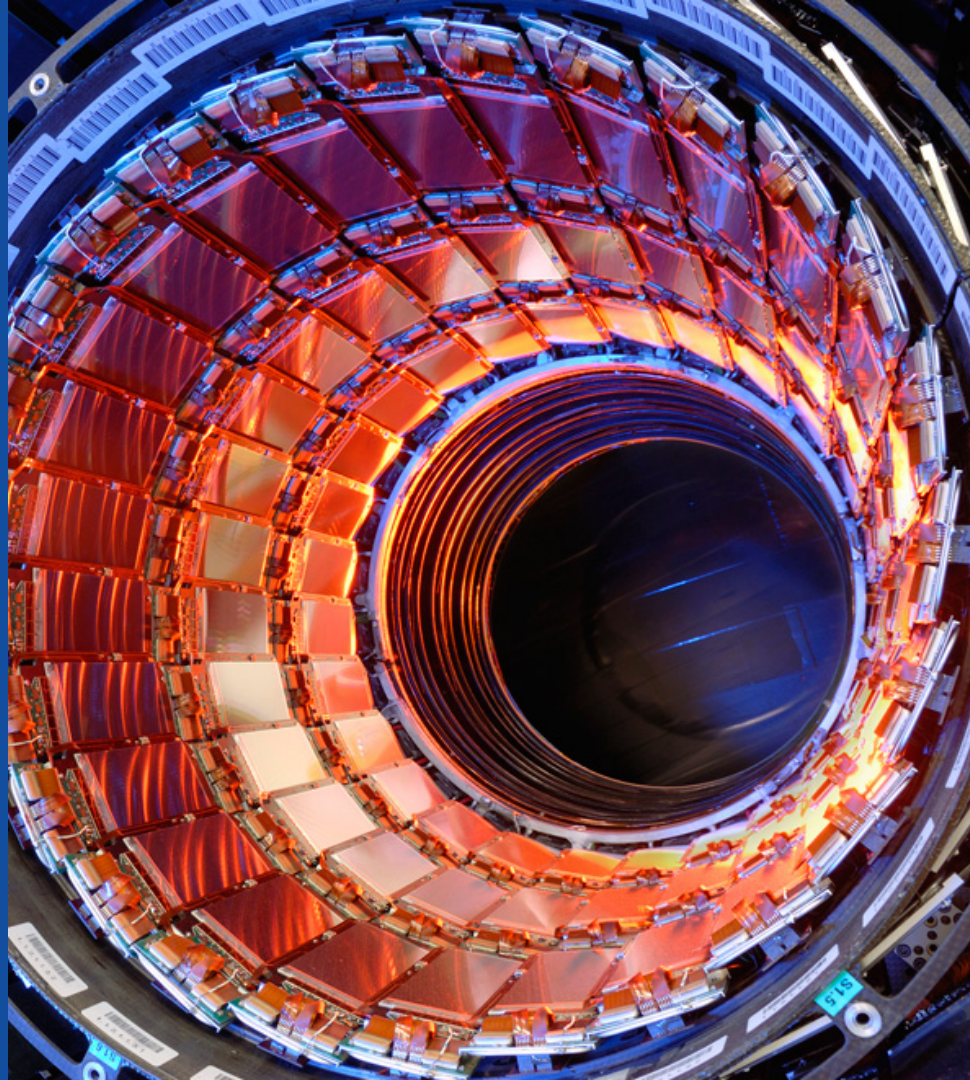
Pierre Auger Observatory

In the frontier of the technology

- Particle physics accelerators and detectors are amongst the most complex devices built by the human-kind

- Being on the edge of the technology is required

  - Fast-timing response
  - High-efficiency



In the frontier of the technology

- Particle physics accelerators and detectors are amongst the most complex devices built by the human-kind
- Being on the edge of the technology is required
  - Ability to work under harsh outdoor conditions (temperature, humidity)
  - Low price

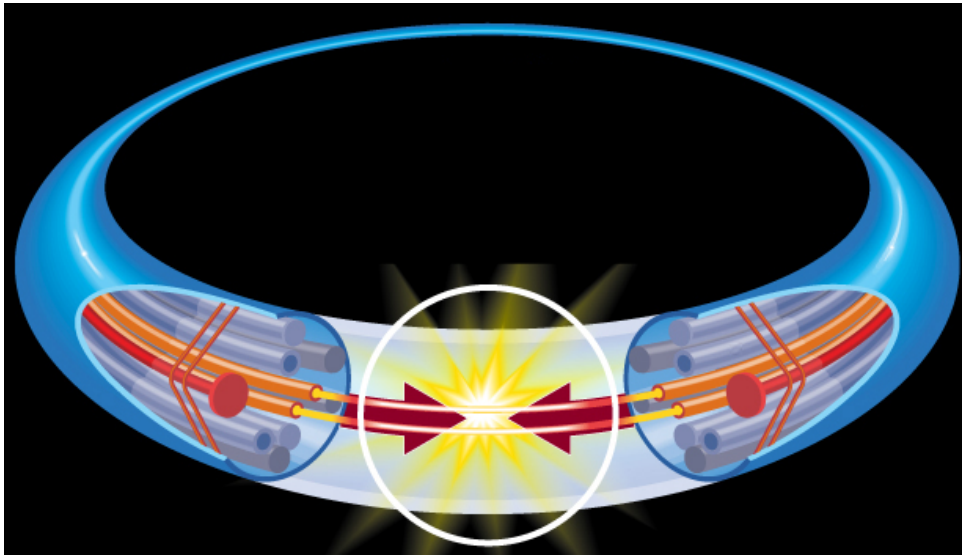
The long chain from

Data *to* Physics

a practical example:
the Large Hadron Collider

From data to physics at the LHC
A long and complex path

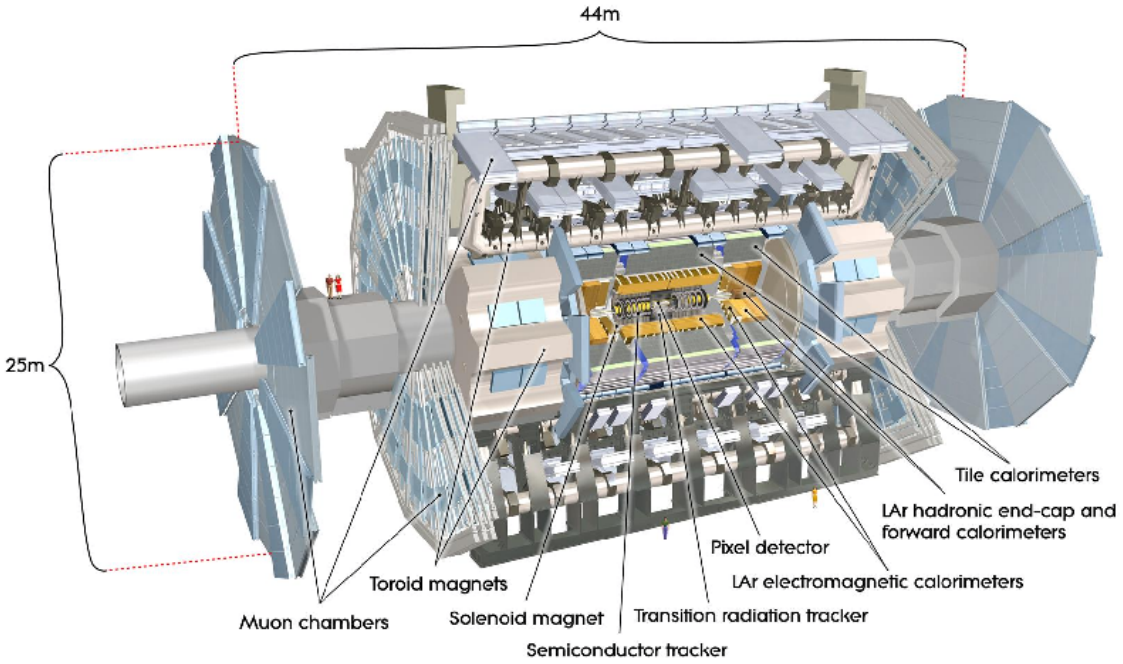
- 40 million proton-proton collisions per second



From data to physics at the LHC
A long and complex path

- Hundreds of millions of readout channels
- CERN has stored more than passed the **200 PetaBytes** of data in tape
- Need to (inter-)calibrate detectors

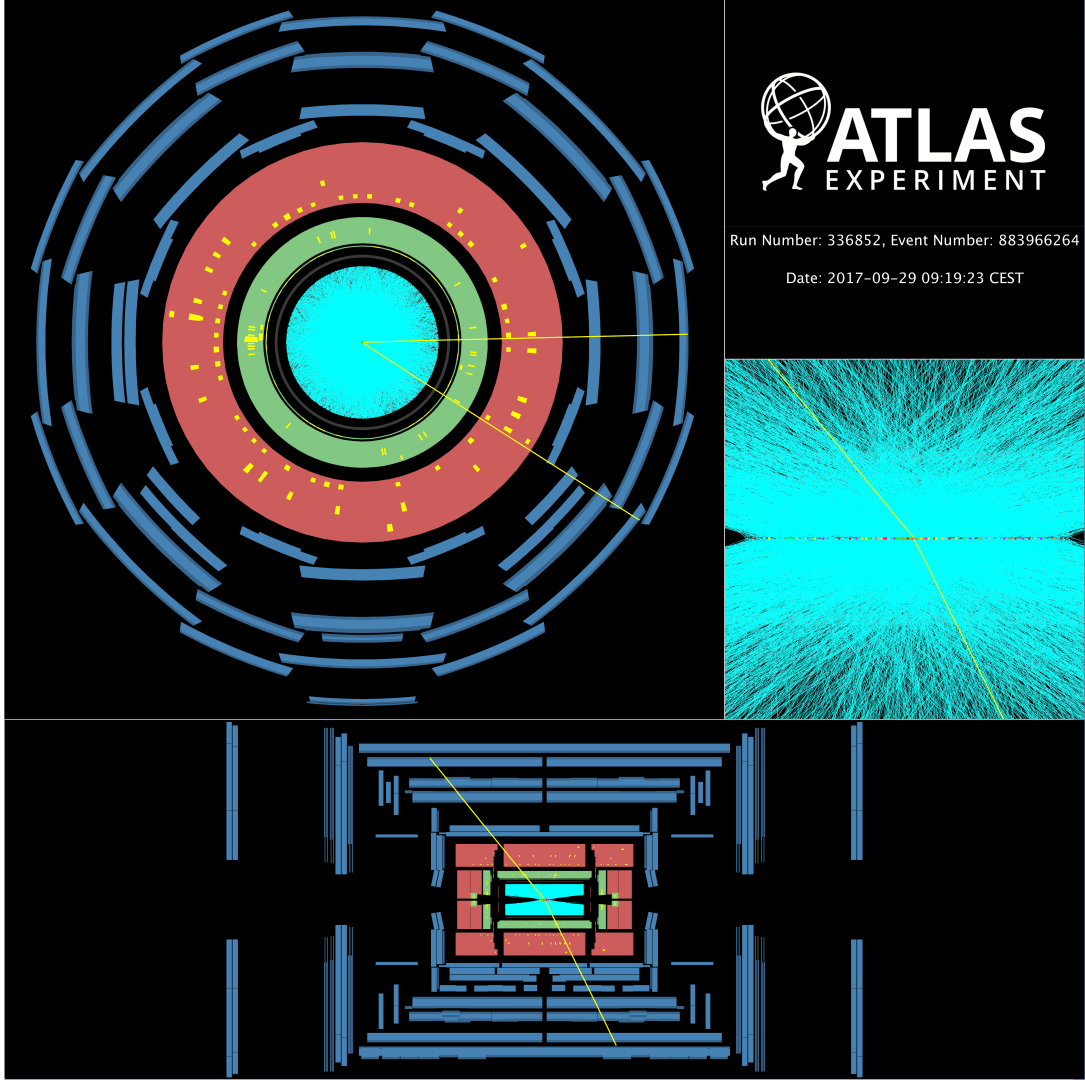
ATLAS experiment @ CERN



LHC events
p-p collisions

- Several collisions at the same time
- Big data problem
- Need to **select interaction of interest** with 65 reconstructed vertexes

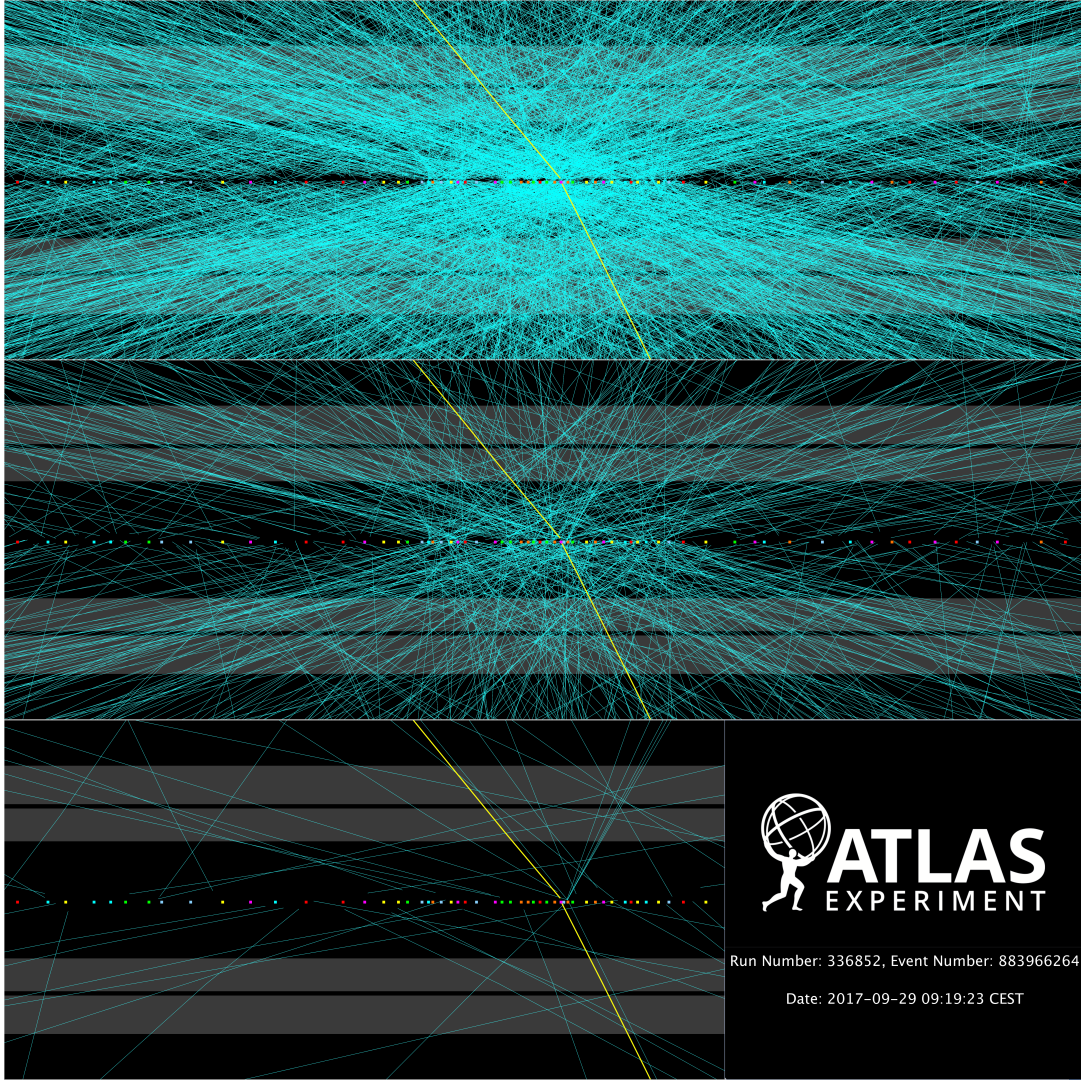
$$Z^0 \rightarrow \mu^+\mu^-$$



LHC events
p-p collisions

- Several collisions at the same time
- Big data problem
- Need to **select interaction of interest** with 65 reconstructed vertexes

$$Z^0 \rightarrow \mu^+\mu^-$$

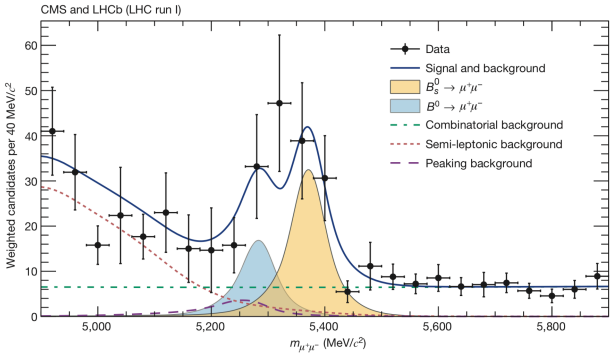


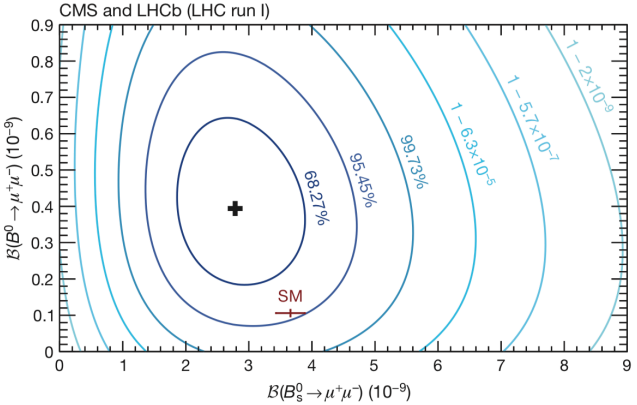
Data Analysis

Some Data Science examples applied to physics

Observation of a Standard Model rare decay
Probing new physics

- The decay **$B_s \rightarrow \mu\mu$** is extremely rare (about **1 per billion**) in the Standard Model (SM)
- Its observation requires:
  - **Monte Carlo simulation** to describe Physical mechanism + detector+ performance + event geometry + …
  - **Boosted Decision Tree** (BDT) to make a selection
  - **Likelihood methods** to quantify expectation (SM) deviations

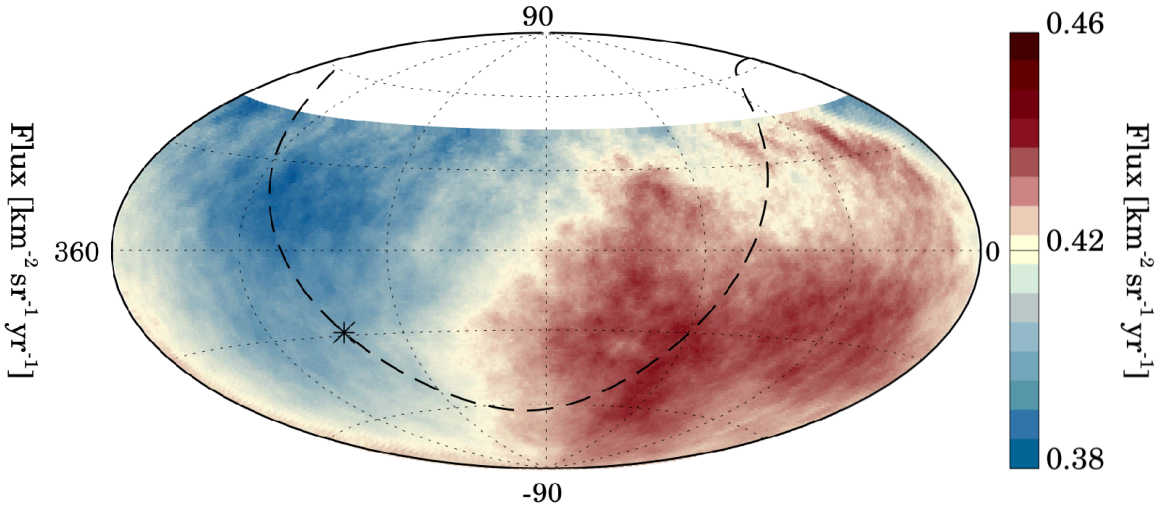




Nature 522 (2015) 68-72

Extreme energy cosmic rays anisotropy
Decisions with very low statistics

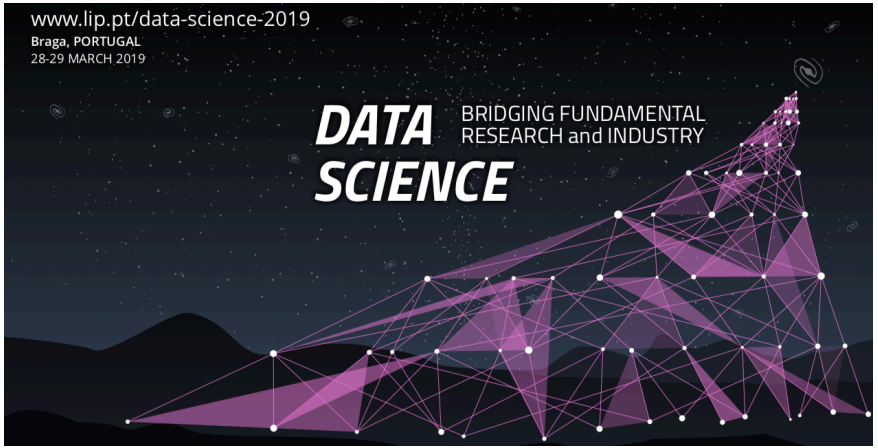
- At the highest energy there is a few tenths of events per year
- Define an hypothesis and perform a statistical test to conclude about its veracity

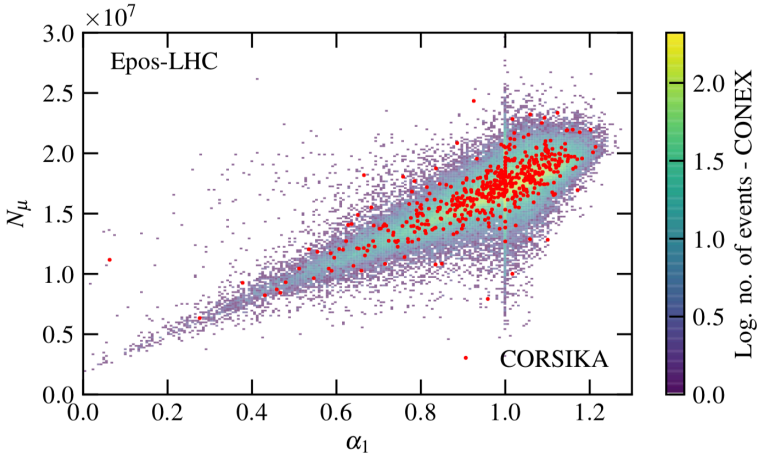


Science 357 (2017) no.6537, 1266-1270

Muons and Shower Physics
Access the first interaction

- Fluctuations of the number of muons at ground connected with first interaction properties
- Able to extract relevant/accurate information even though the description of the shower is incomplete





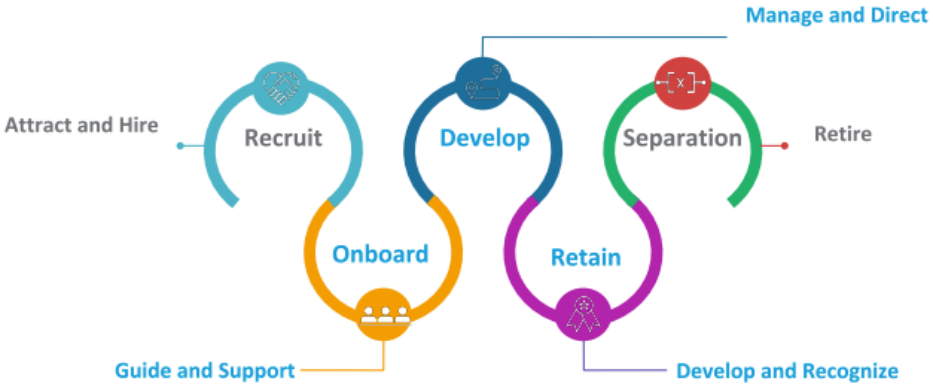
Phys.Lett. B784 (2018) 68-76

Synergies

- **LIP competence center on simulation and big data**
- One of the goals of this symposium is to look for possible **synergies between Academia and Industry**
- New joint-project between LIP and Nielsen was initiated some time after last event edition

Joint-project between LIP and Nielsen

- How to predict Auditors attrition?



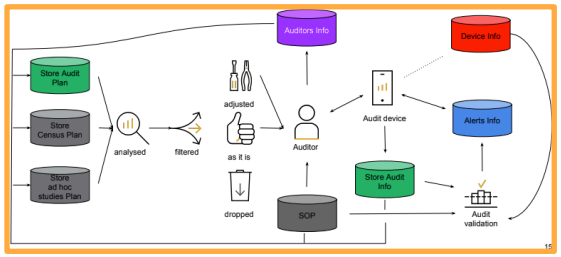
- Try to predict probability of an auditor to leave the company based on data related with his activities

Joint-project* between LIP and Nielsen

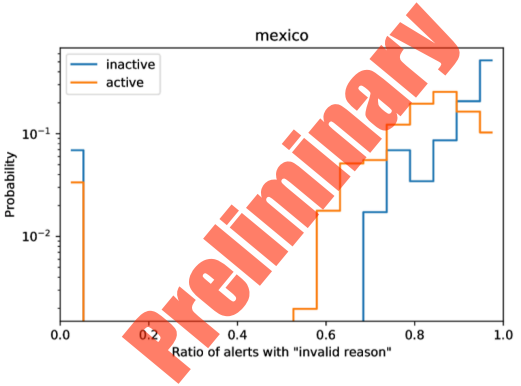
***opening Research position**
Please contact us if interested

- On-going work…

AUDITORS WORK MAP



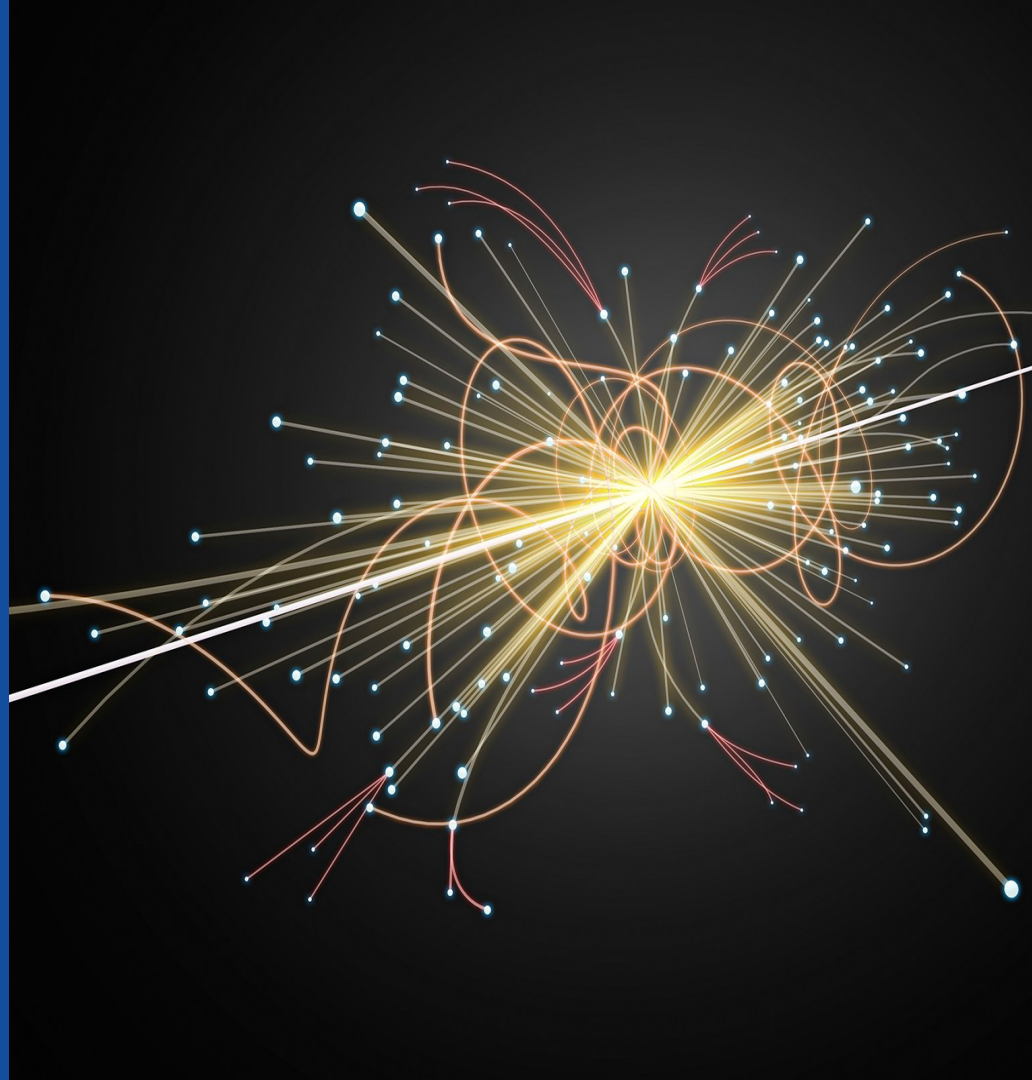
- Clean Data (make it trustworthy)
- Identify most sensitive quantities
  - 1st level: direct correlations
  - 2nd level: building up complex variables



See Rita Lima's talk, tomorrow

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

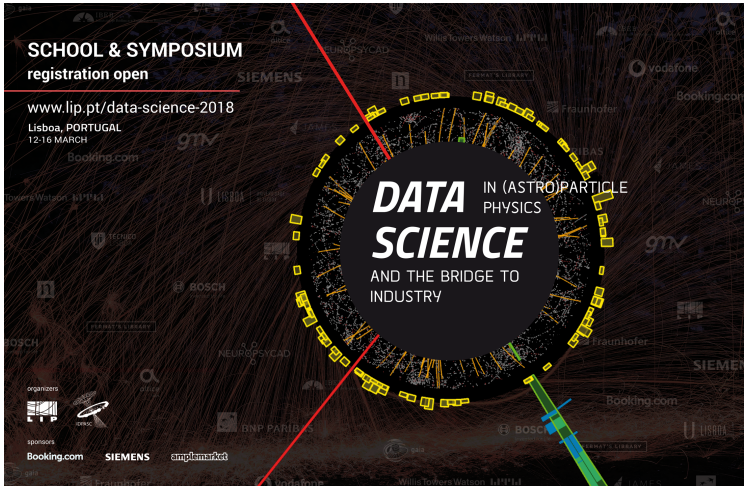


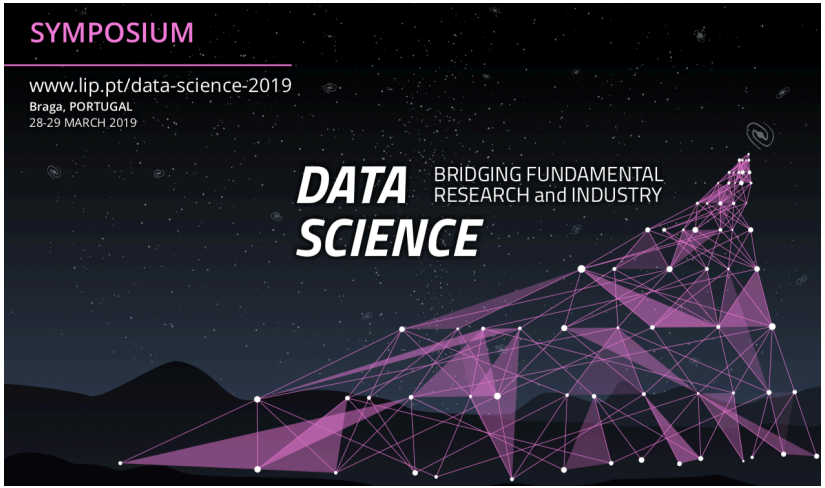
Thanks

Any questions?

You can also find me at ruben@lip.pt

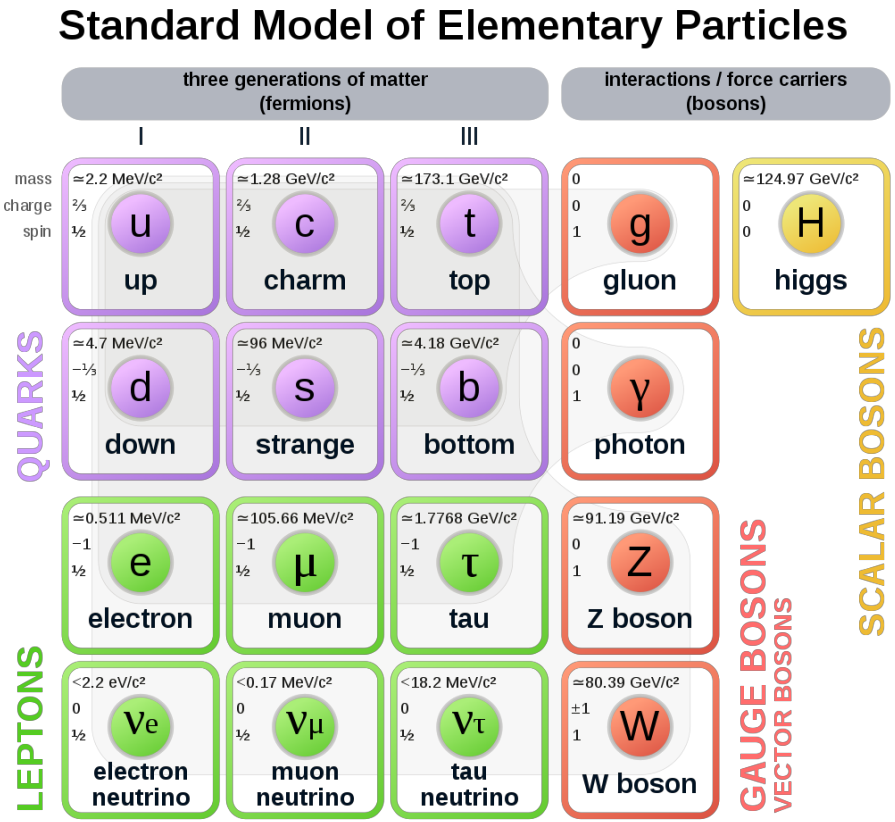
Data science
Symposium

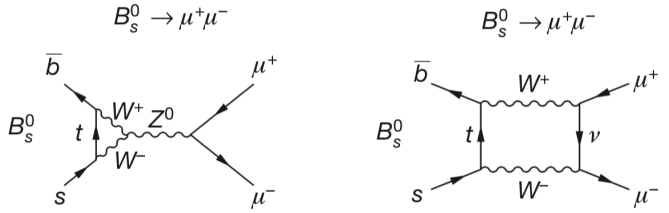




Ultimate Goal

Understand the elementary blocks (particles) and interactions that compose and drive the dynamics of our Universe




$B_s^0 \to \mu^+\mu^-$
$\overline{b}$
B_s^0
t
s
W^+
Z^0
W^-
μ^+
μ^-
$B_s^0 \to \mu^+\mu^-$
$\overline{b}$
B_s^0
t
s
W^+
ν
W^-
μ^+
μ^-