We address **discrepancies between Theory and Experiments** in the **bottom quark** sector of **Particle Physics** through simulations on **Supercomputers**.

Lattice Simulations in Particle Physics: the b-quark Decay

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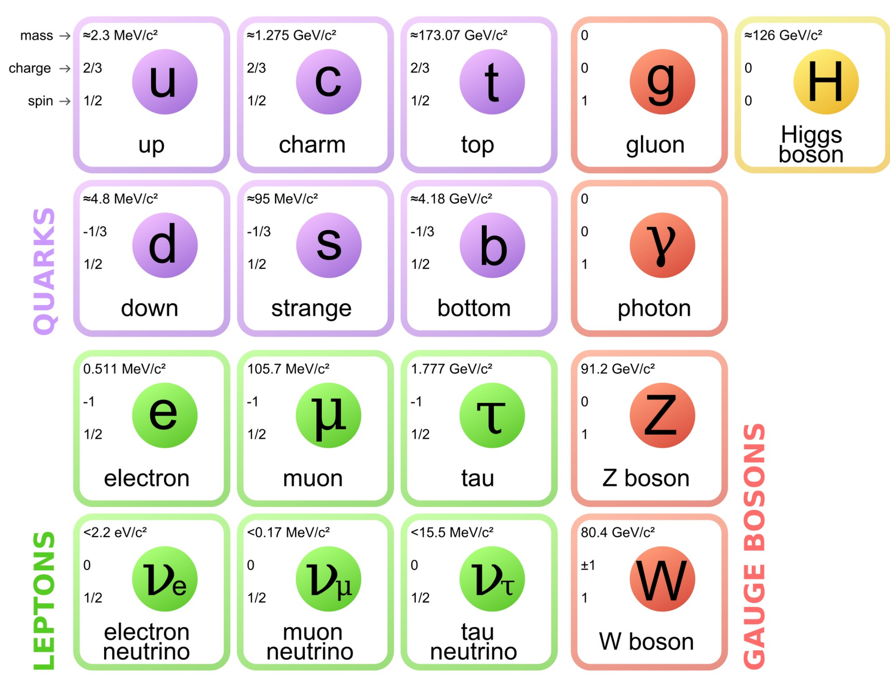
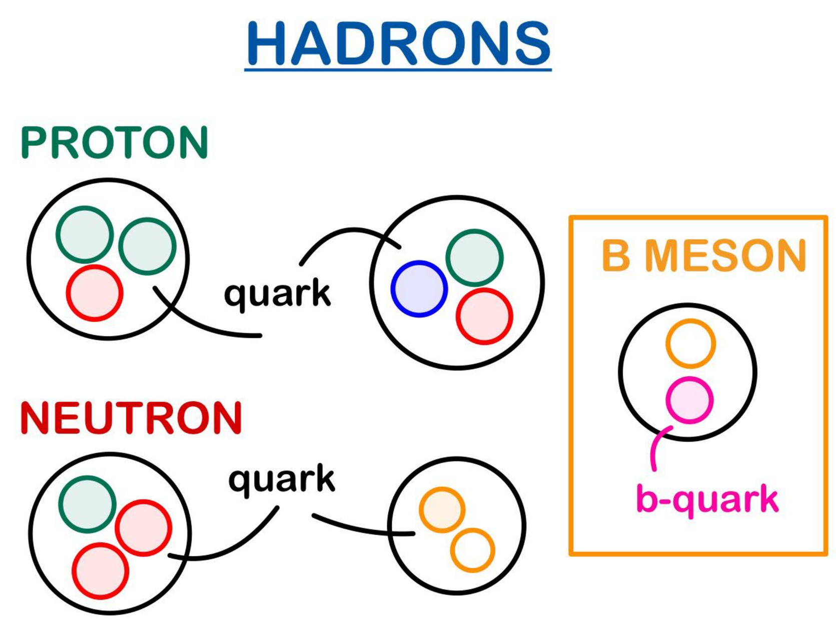
Introduction



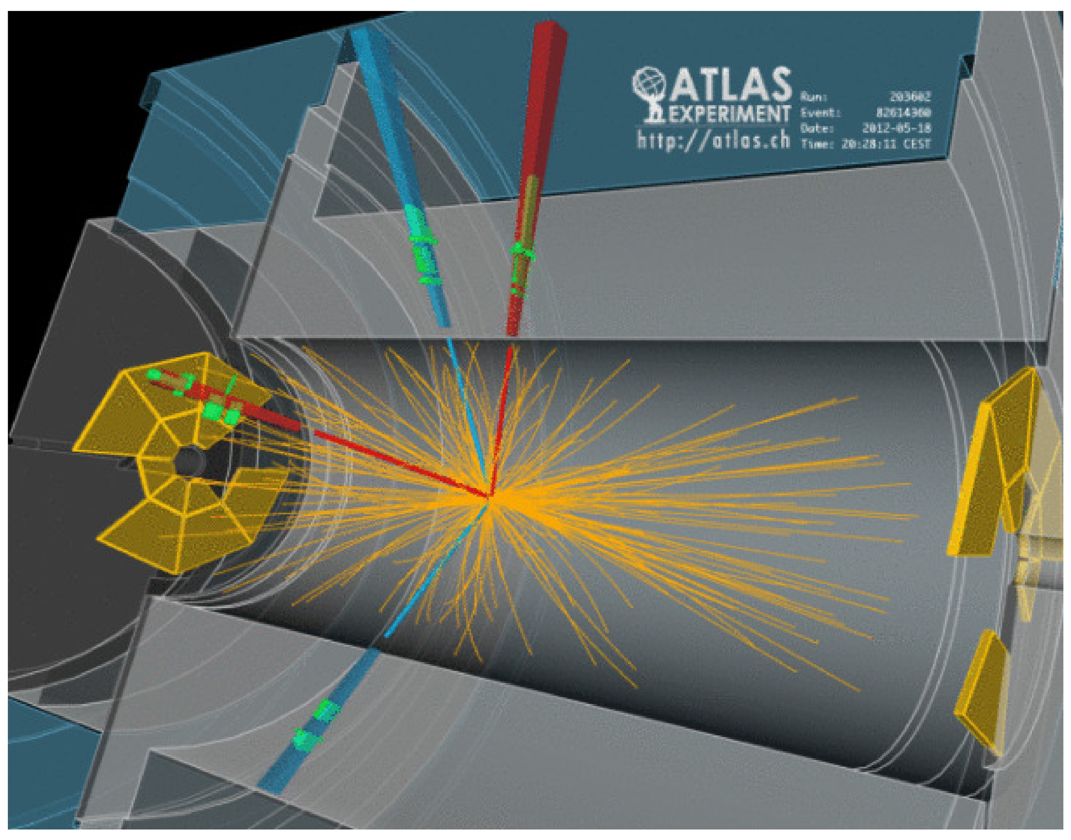
Standard Model Table

Particle physics is the study of the tiniest elements in the whole Universe and is key to unravelling its mysteries. All the particles are described through a mathematical model known as **Standard Model**. In this work, we are interested in a set of particles called **quarks**. There are in total six quarks, which can bind together very strongly to form **hadrons**, i.e. heavier particles such as protons and neutrons. We focus on a set of hadrons containing a **bottom quark** (or **b-quark**) called **B mesons** and address some discrepancies between theory and experiments that recently came to light.



Example of hadrons, i.e. particles made by quarks

The background



Particles collision at the ATLAS detector (CERN)

Quarks interact with each other via the **strong force**: the theory that governs it is known as **QCD** (**Quantum Chromodynamics**). It is an essential building block of the Standard Model. While this model is very robust, it is not sufficient to explain all the natural phenomena. Physicists are looking for a hint of new physics using the following recipe.

Experiments:
- smash proton-proton at supercolliders;
- track the products of collisions in detectors;
- measure properties of the detected particles.

Theory:
- build mathematical models;
- compute theoretical predictions for physics observables for each model.

3 scenarios:

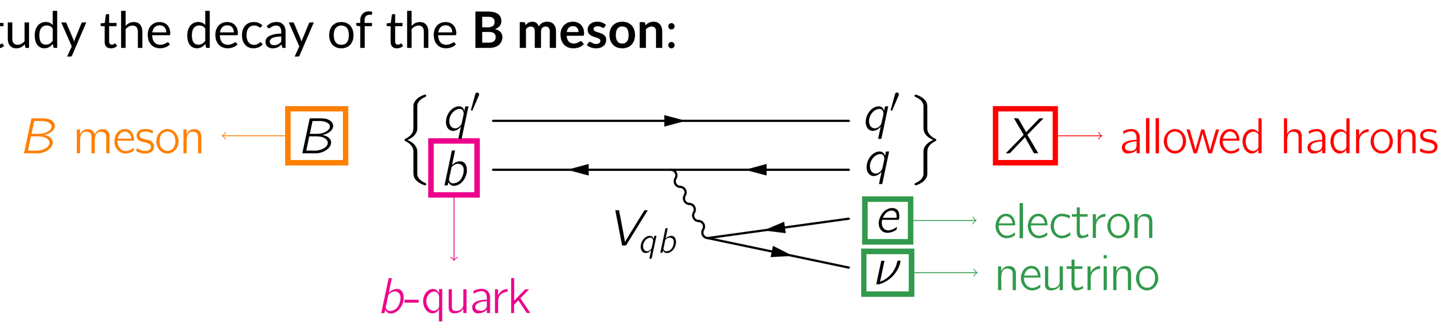
✓ theory and experiments agree: our model is a good description of Nature;

• theory and experiments are in tension: we need to investigate more;

✗ theory and experiments do not agree: we identified sources of new physics!

The problem

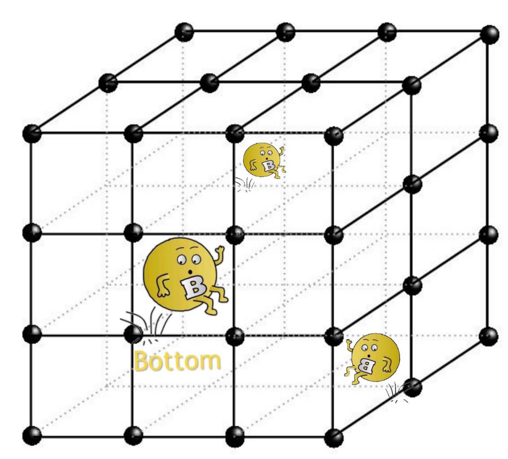
We study the decay of the **B meson**:



V_{qb} is a parameter that controls the interaction between the quark b and the generic quark q: this is the quantity that is currently showing discrepancies. To address this, we calculate the decay rate $\Gamma/|V_{qb}|^2$, which tells us about how often the particles decay under certain conditions.

How we address it

We rely on numerical simulations on supercomputers. Instead of dealing with a continuous and infinite space, we pretend that our quarks live in a finite 4D cubic lattice, where they can jump from one site to the other.



Steps of the calculation:
- discretise the spacetime;
- simulate the system on supercomputers;
- extrapolate to the physical world:
  - lattice volume goes to infinity;
  - lattice spacing goes to zero.

Conclusions and outlook

The interplay of theory and experiments in Particle Physics is essential to push forward our understanding of Nature. Discrepancies between the two may be indications of new physics and could potentially lead to new discoveries. To investigate tensions in the b-quark sector we address theoretical calculations of B mesons with the help of supercomputers. We are setting up the optimal environment to perform this task: the final result may eventually shed some light on these anomalies and lead the path to the extension of the Standard Model.

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References
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