New ways to understand the strong force

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1. Introduction

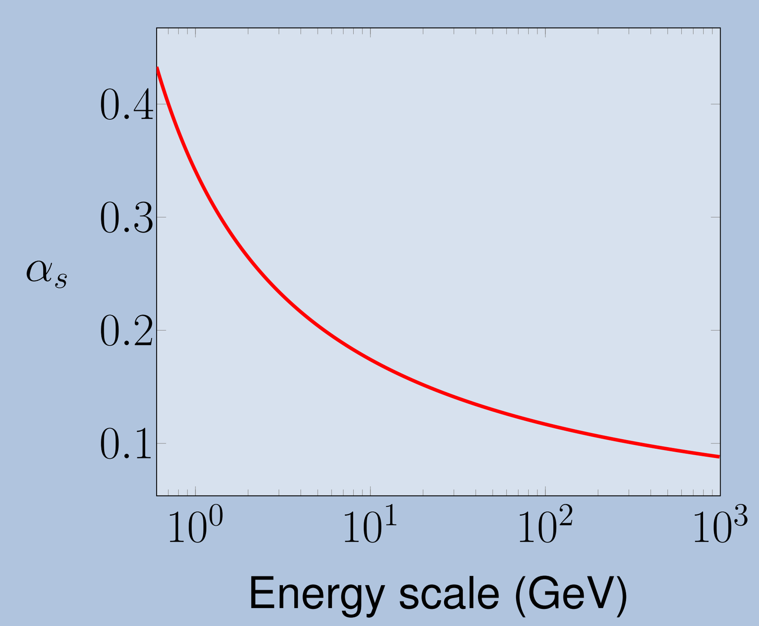
Theoretical physicists try to understand the world using **mathematical models** (also called theories). By making calculations with these models we can make predictions for what we can see in the real world, these can then be compared to experiments such as at the LHC (pictured below). Sometimes these models are too mathematically complicated, and it is very difficult to make these calculations. An example is the theory of the **strong force**, which is what binds **quarks** together to form protons and neutrons. Calculations involving the strong force often take months running on supercomputers.

2. Holography

Sometimes the models of two different physical systems are **equivalent**. This means that we can do calculations in one model to learn things about the other. This is called **holography** because the two systems have a different number of dimensions, similar to how a hologram contains a 3D image on a 2D surface.

If we can find a theory equivalent to the strong force, but easier to use, then we can work with that theory and use holography to translate the results to find things such as the masses of protons and other particles.

3. An example



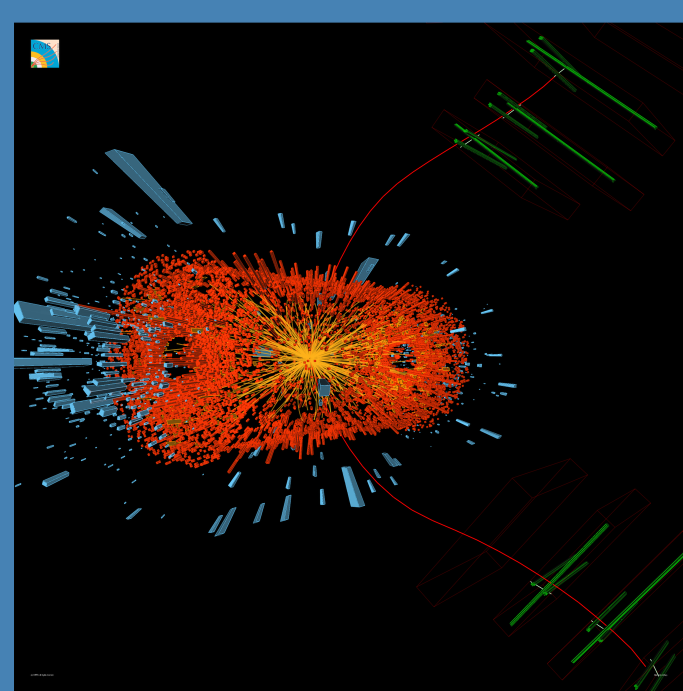
The **coupling constant** of the strong force determines how strongly quarks interact. It depends on the energies of these quarks.

In holography, this energy scale is thought of as a **new dimension**, and the coupling constant becomes a **field** similar to an electric or magnetic field. This new field has equations determining the value that this field takes at a given point along the new dimension. Solving these equations tells us how the coupling constant depends on the energy scale.

4. The QCD Kondo effect

I'm studying a particular effect involving the strong force. When there is a large density of one type of quark and a smaller density of a heavier type of quark, the two types can interact very strongly with each other. This is called the **QCD Kondo effect**.

QCD is the technical name for the theory of the strong force. It stands for "quantum chromodynamics".

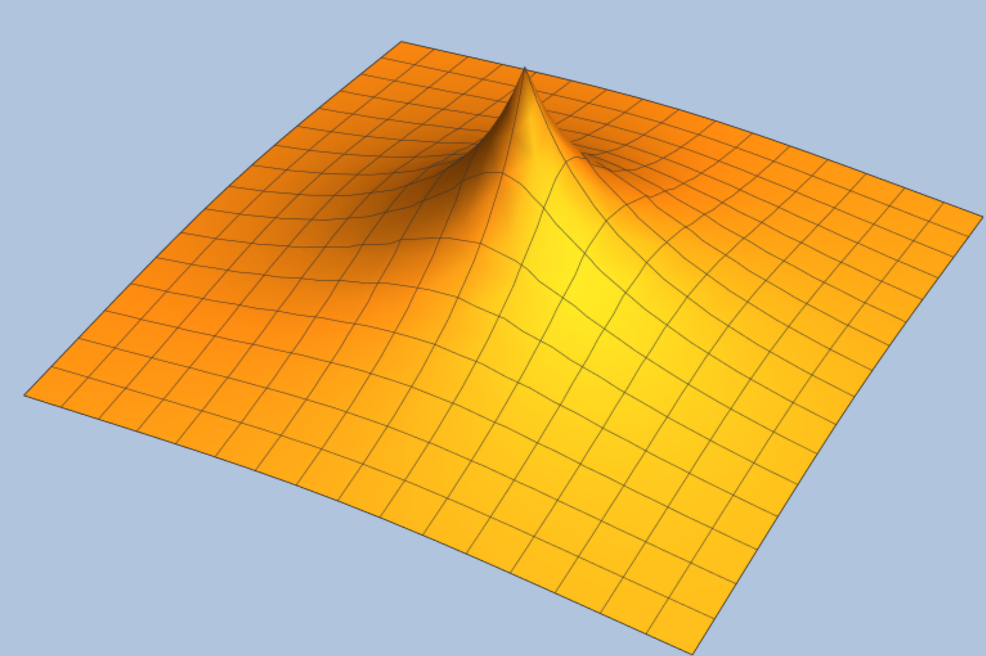


Collisions of heavy ions such as gold or lead may create the right conditions for the QCD Kondo effect to occur.
Pictured left: a simulated heavy ion collision at the LHC.[1]

5. D-branes

D-branes are used to build holographic models of quarks. These are membrane-like objects from string theory, similar to the head of a drum. The D-branes are included in the higher dimensional theory, and their behaviour directly determines the properties of quarks in the equivalent theory. For example, the distance between the D-branes can be used to calculate the mass of the quarks.

I am building models with D-branes to learn about the QCD Kondo effect. By studying the properties of these D-branes, such as how ripples travel across them, I aim to learn about how the quarks behave. Pictured right: Our model of how a D-brane bends in curved spacetime. The sharp point represents a heavy quark.



[1] Image from CMS, cms.web.cern.ch/tags/heavy-ions