

Quarks, Gluons, and Nuclei

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William & Mary Undergraduate Seminar

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had spec



U.S. DEPARTMENT OF
ENERGY

ExoHAD
EXOTIC HADRONS TOPICAL COLLABORATION



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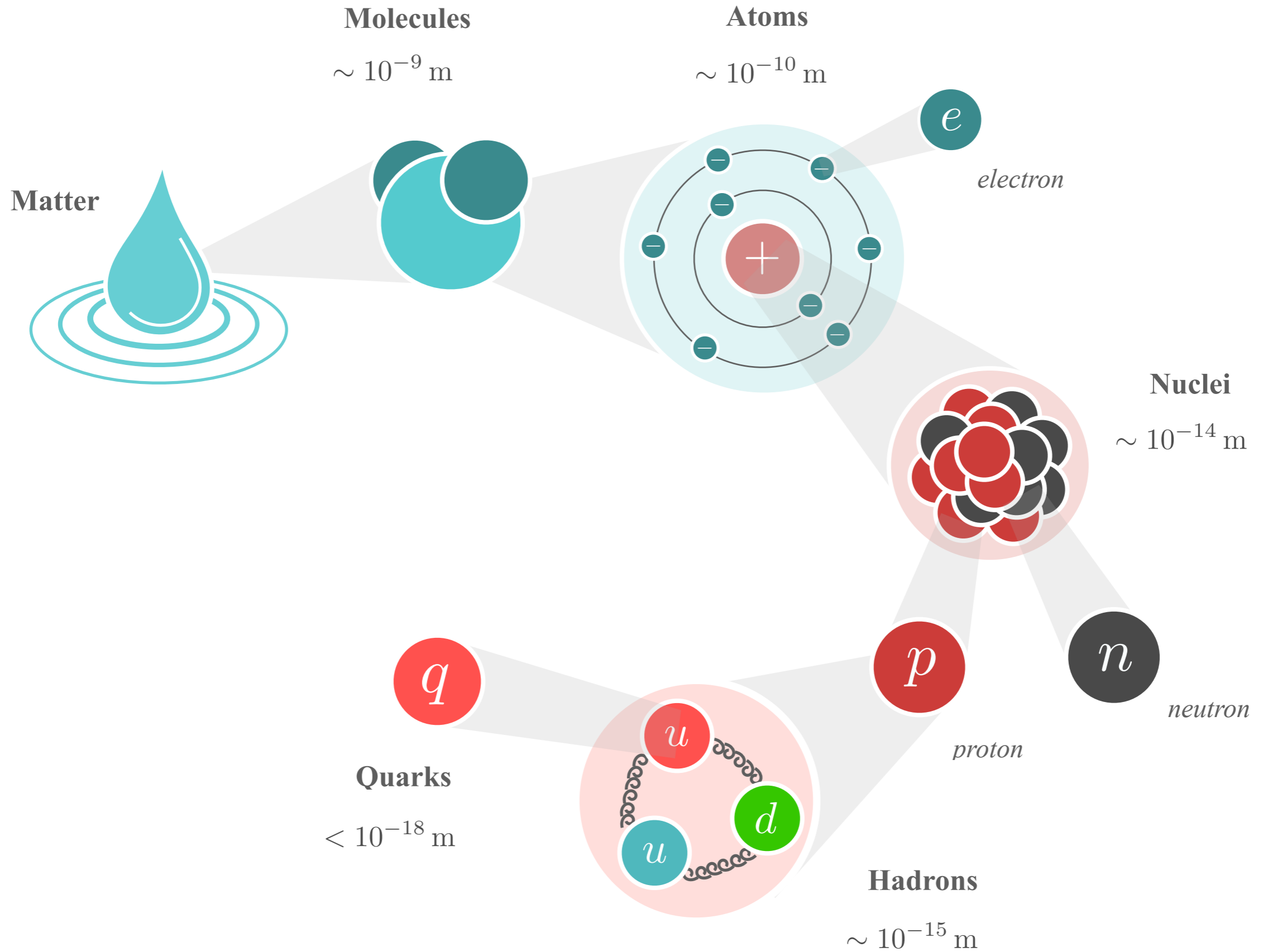
[ajackura.github.io](https://github.com/ajackura)



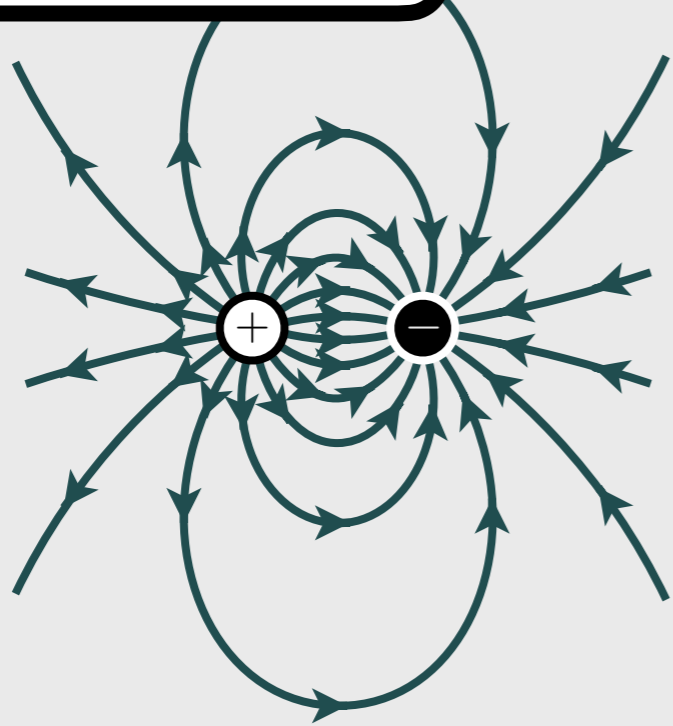
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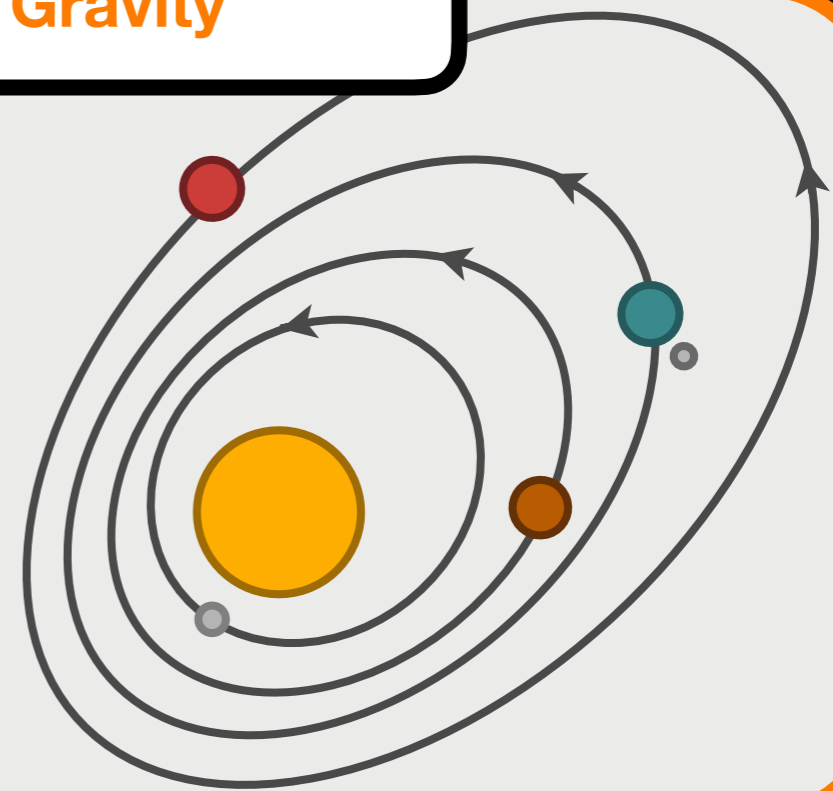
Matter



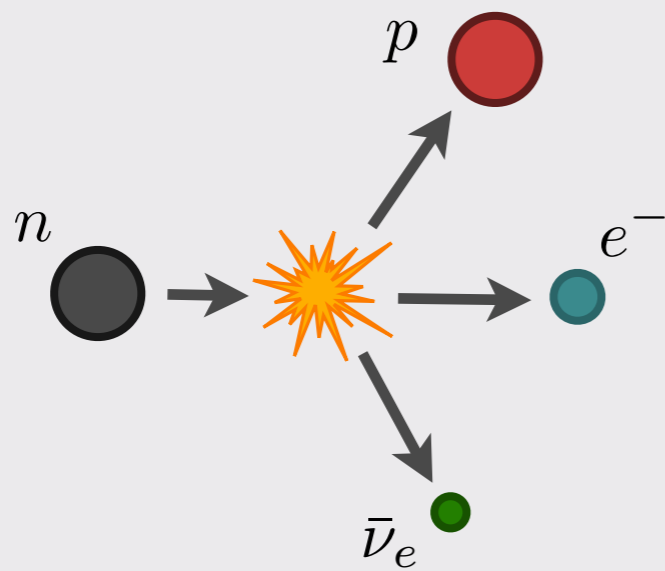
Electromagnetism



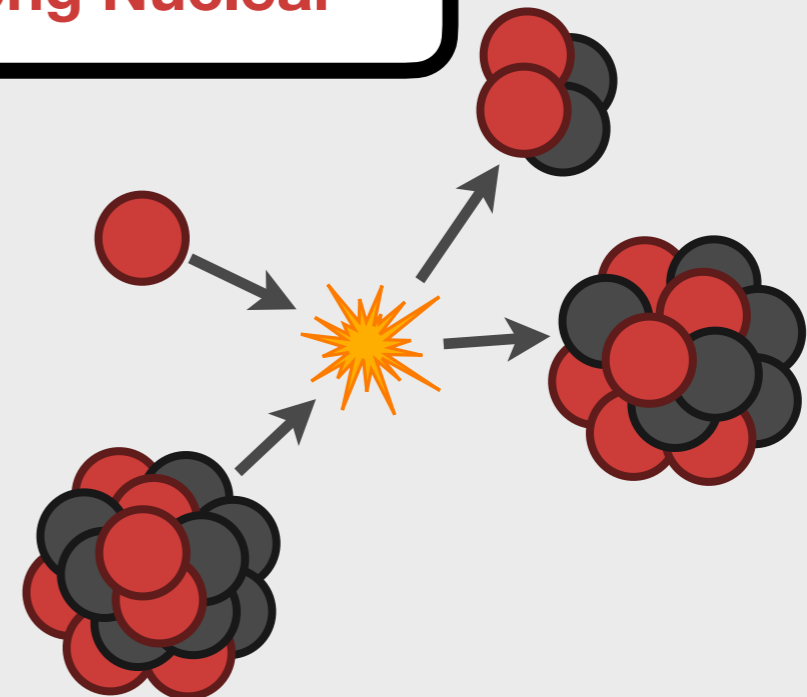
Gravity

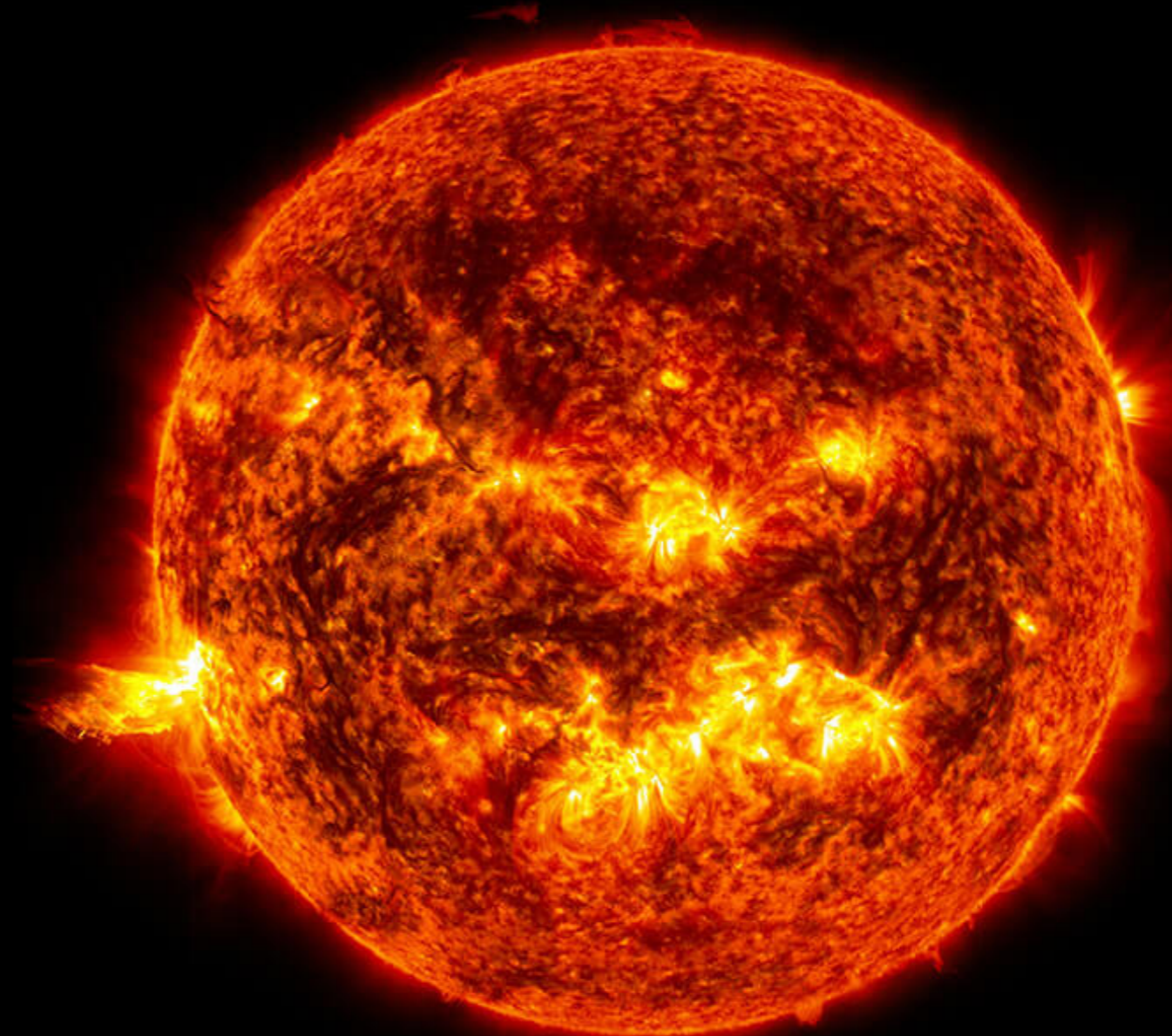


Weak Nuclear



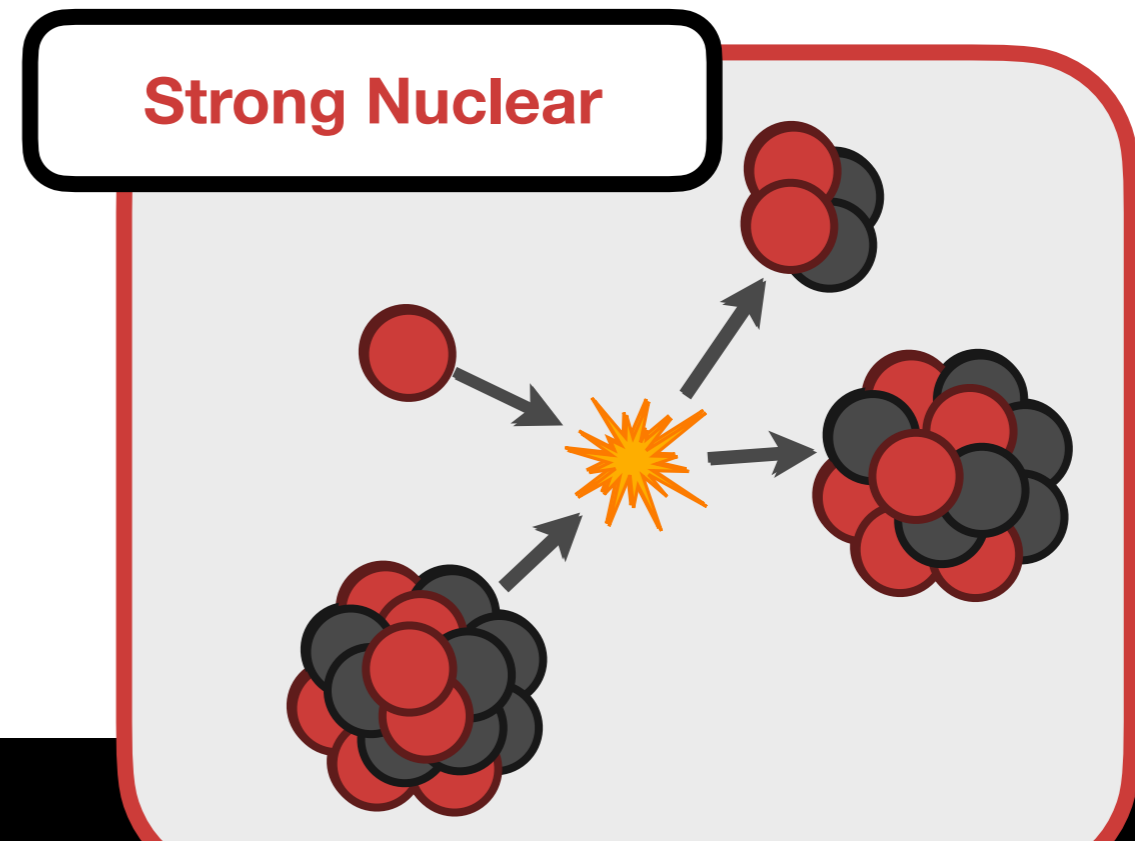
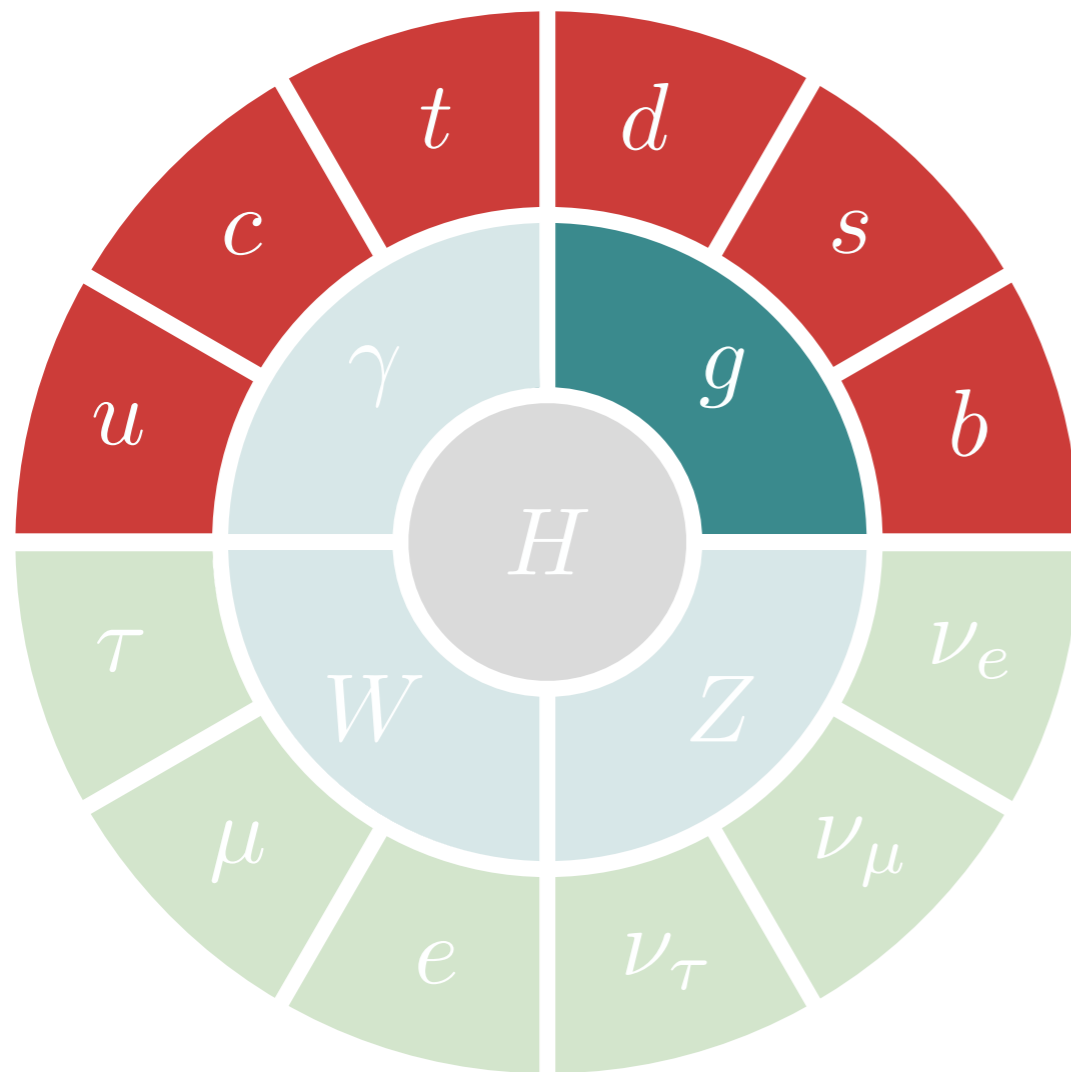
Strong Nuclear





The Standard Model of Particle Physics

Nature can be described by a remarkably *simple** theory

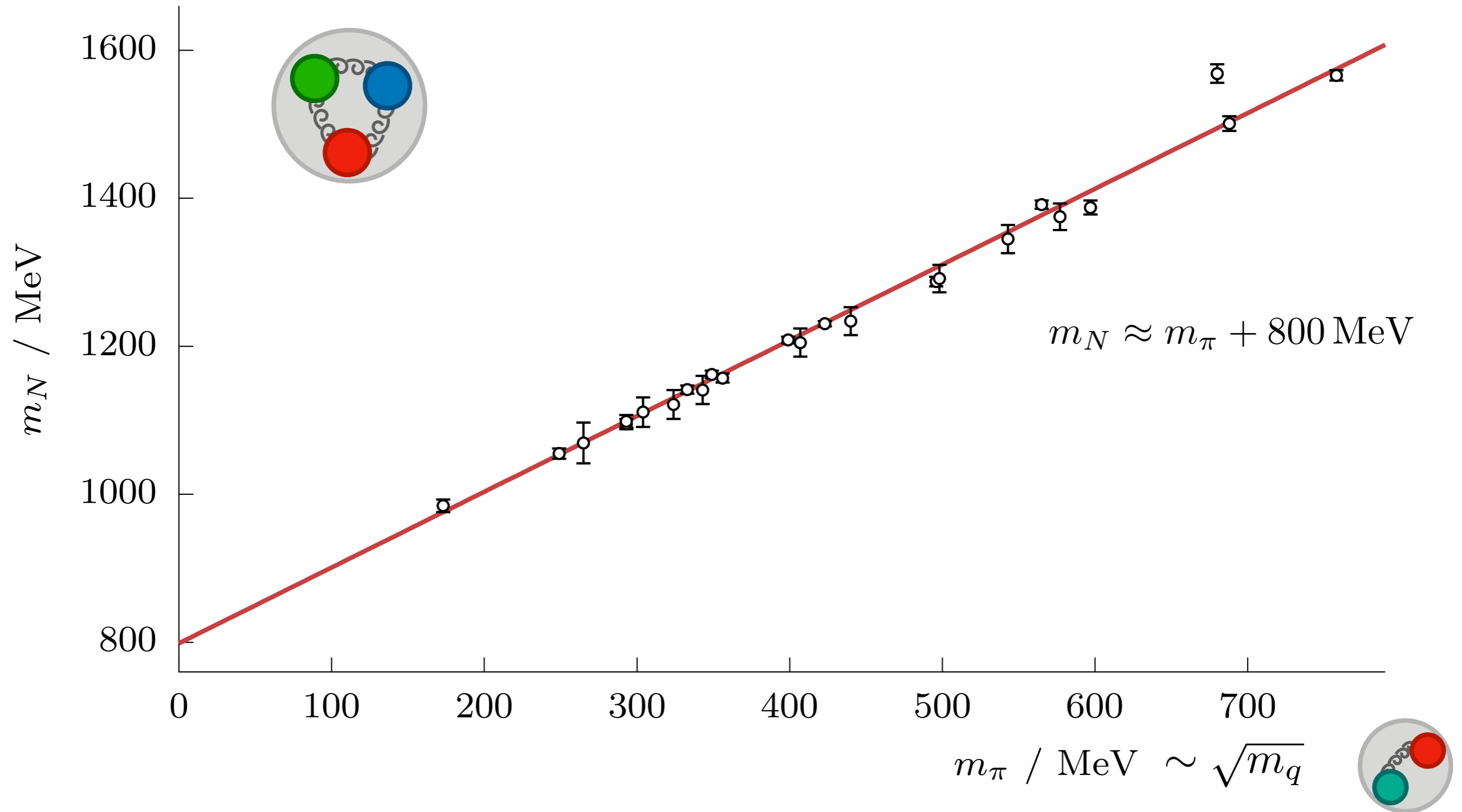


Quantum ChromoDynamics (QCD)

* *simple* = An a
invariant under the gauge group $SU(3)_C \otimes SU(2)_L \otimes U(1)_Y$
which spontaneously breaks via a scalar field to $SU(3)_C \otimes U(1)_Q$

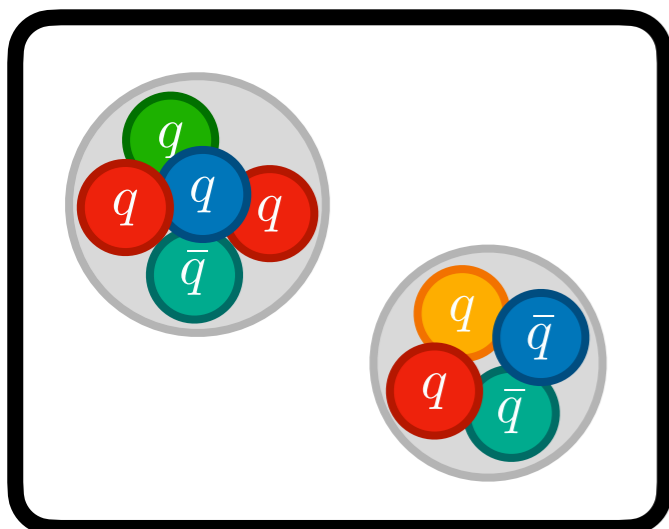
Nuclear Forces

Most of our mass comes from nuclear forces!

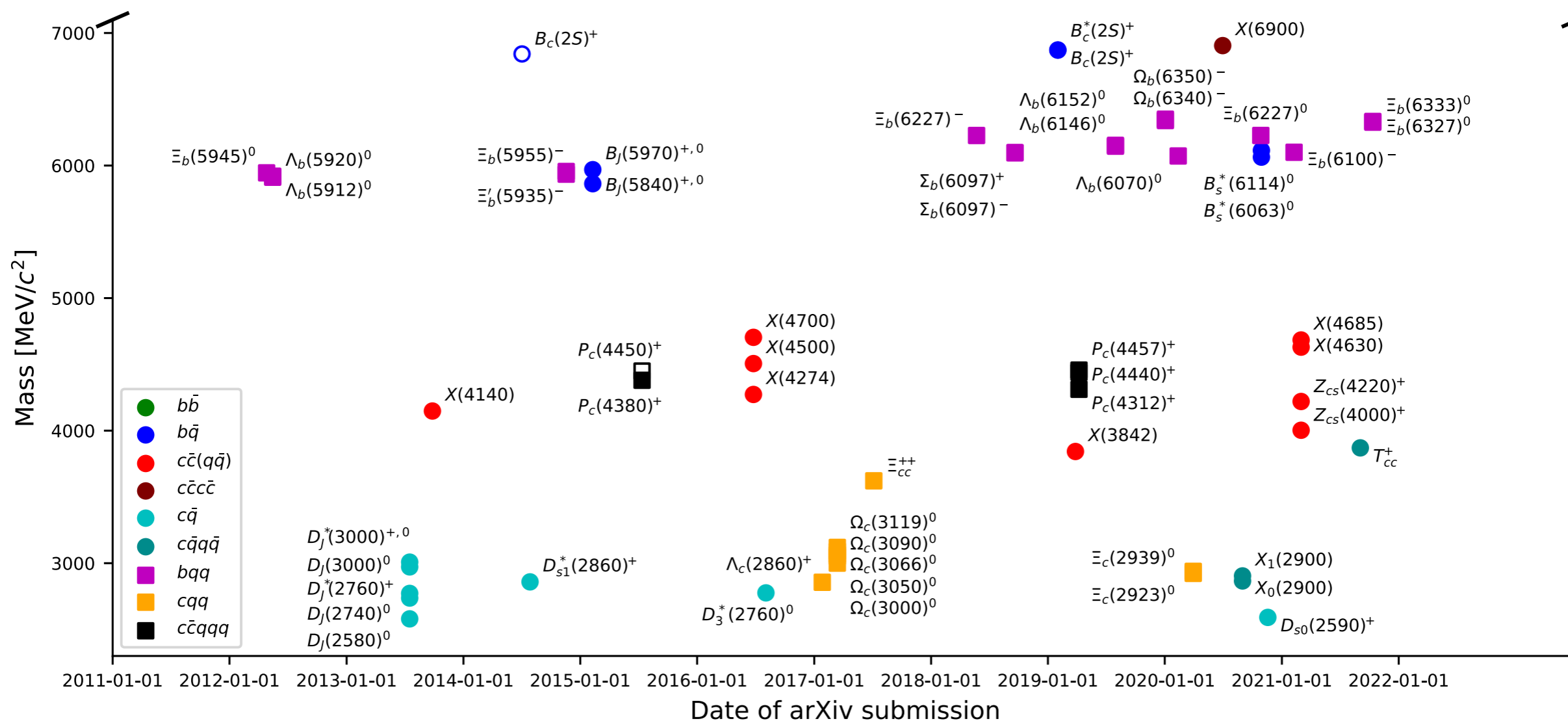


New discoveries in Nuclear Physics

Zoo of *exotic* quark configurations discovered



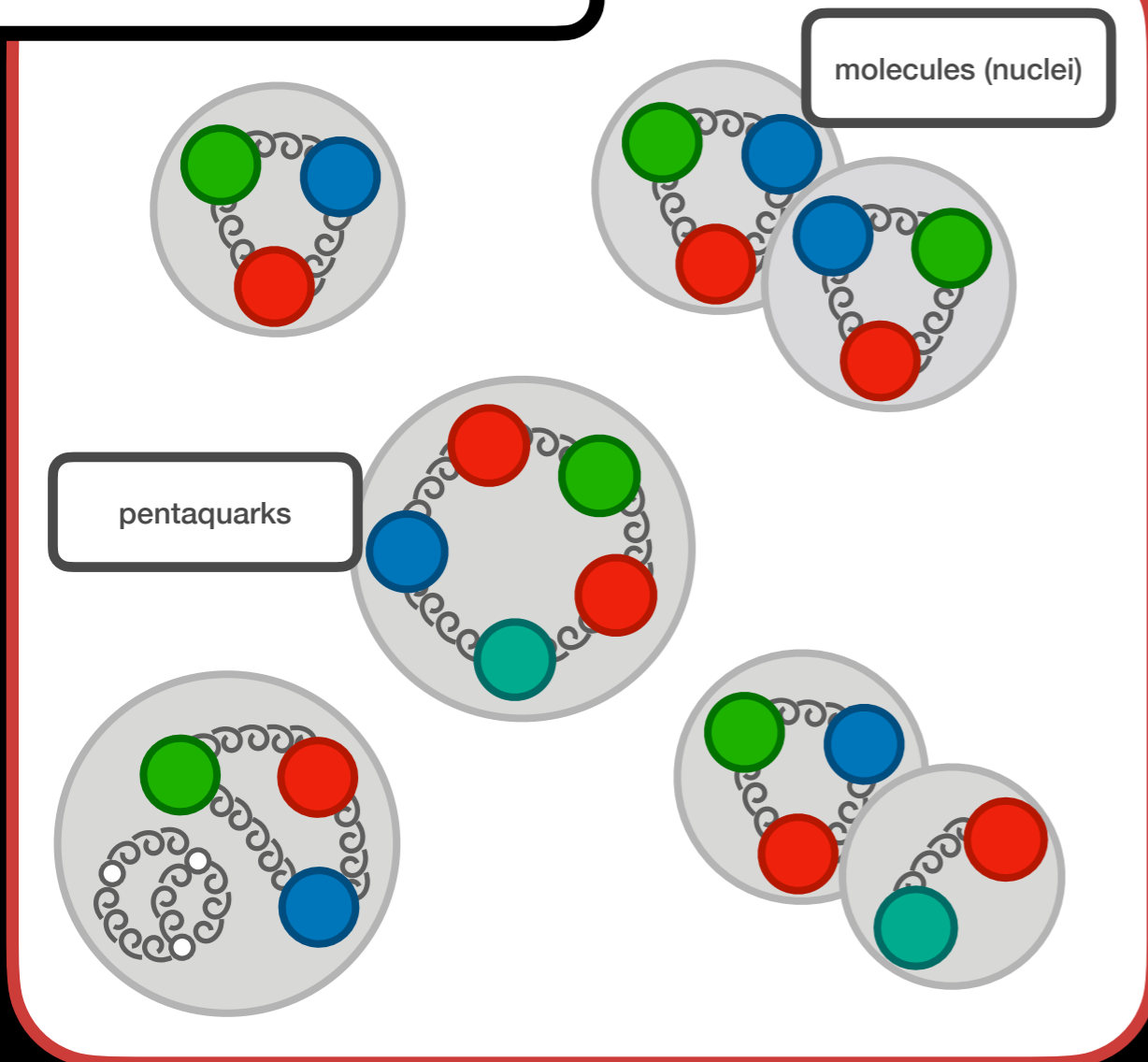
62 new hadrons at the LHC



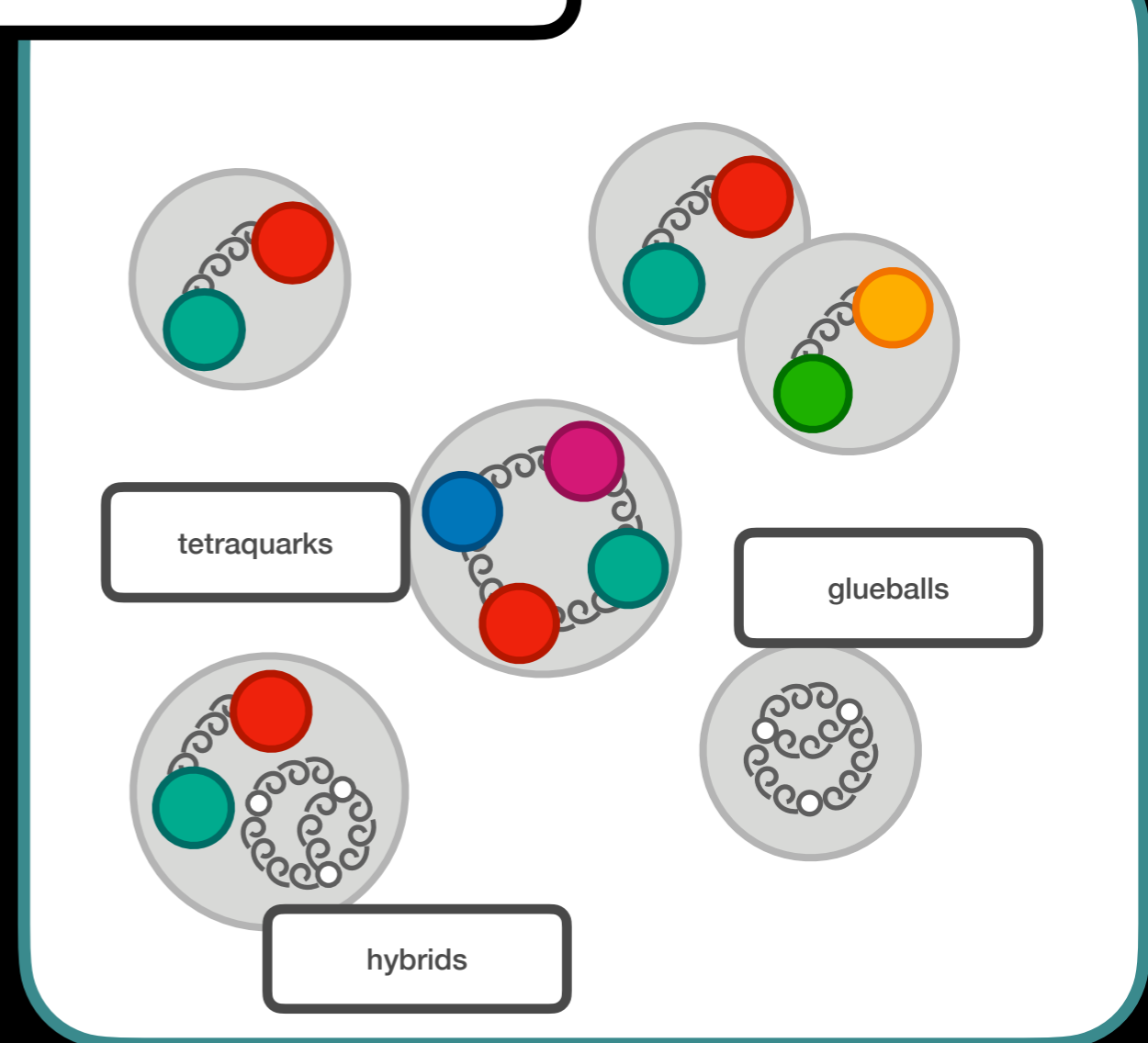
Many types of nuclear particles

A zoo of particles — How to understand?

Baryons (fermions)

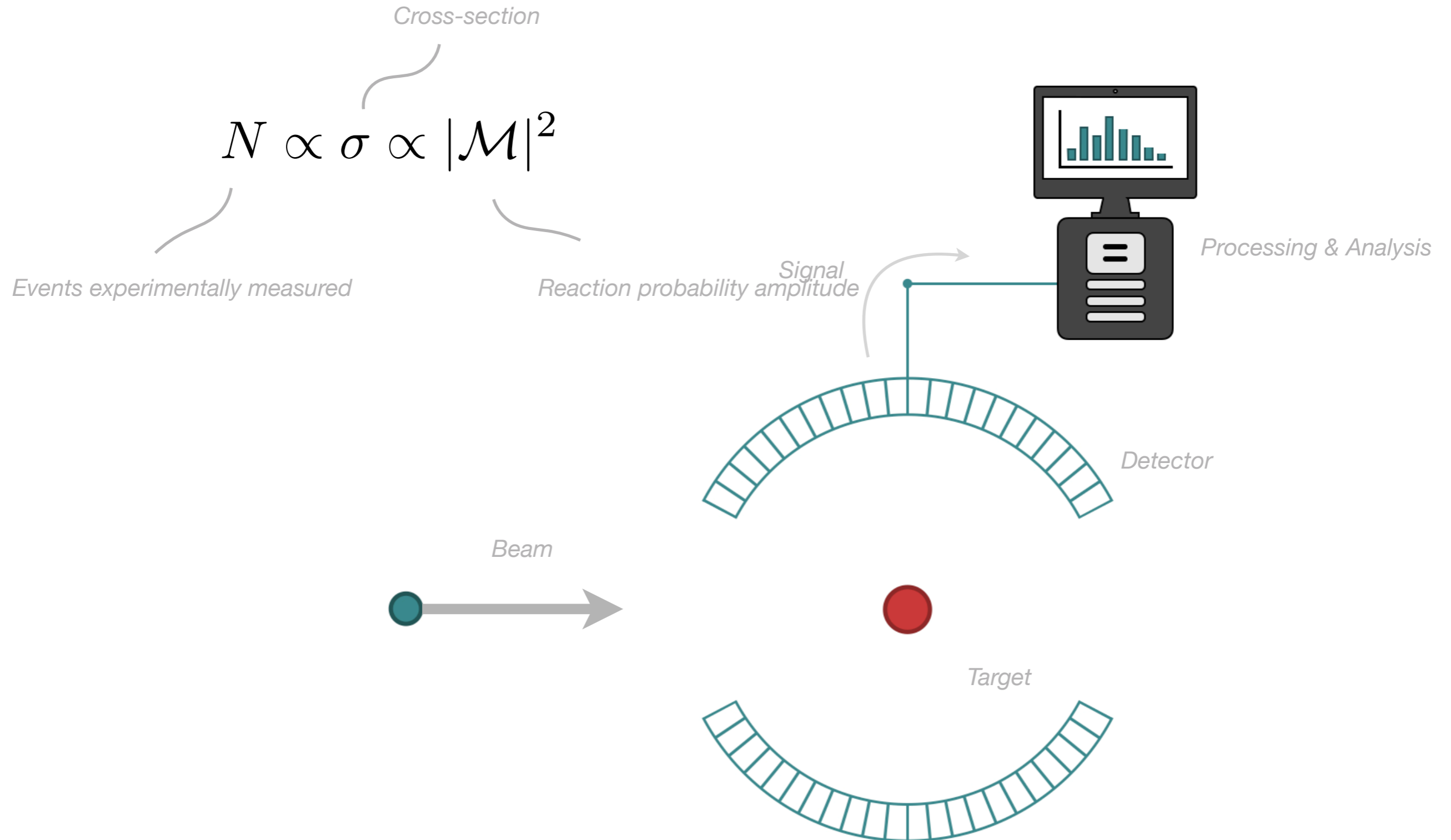


Mesons (bosons)



Observing Hadrons

We observe strongly interacting hadrons through reactions in accelerators/colliders



Observing Hadrons

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- If the interaction is sufficiently attractive, particles can form a **resonance**

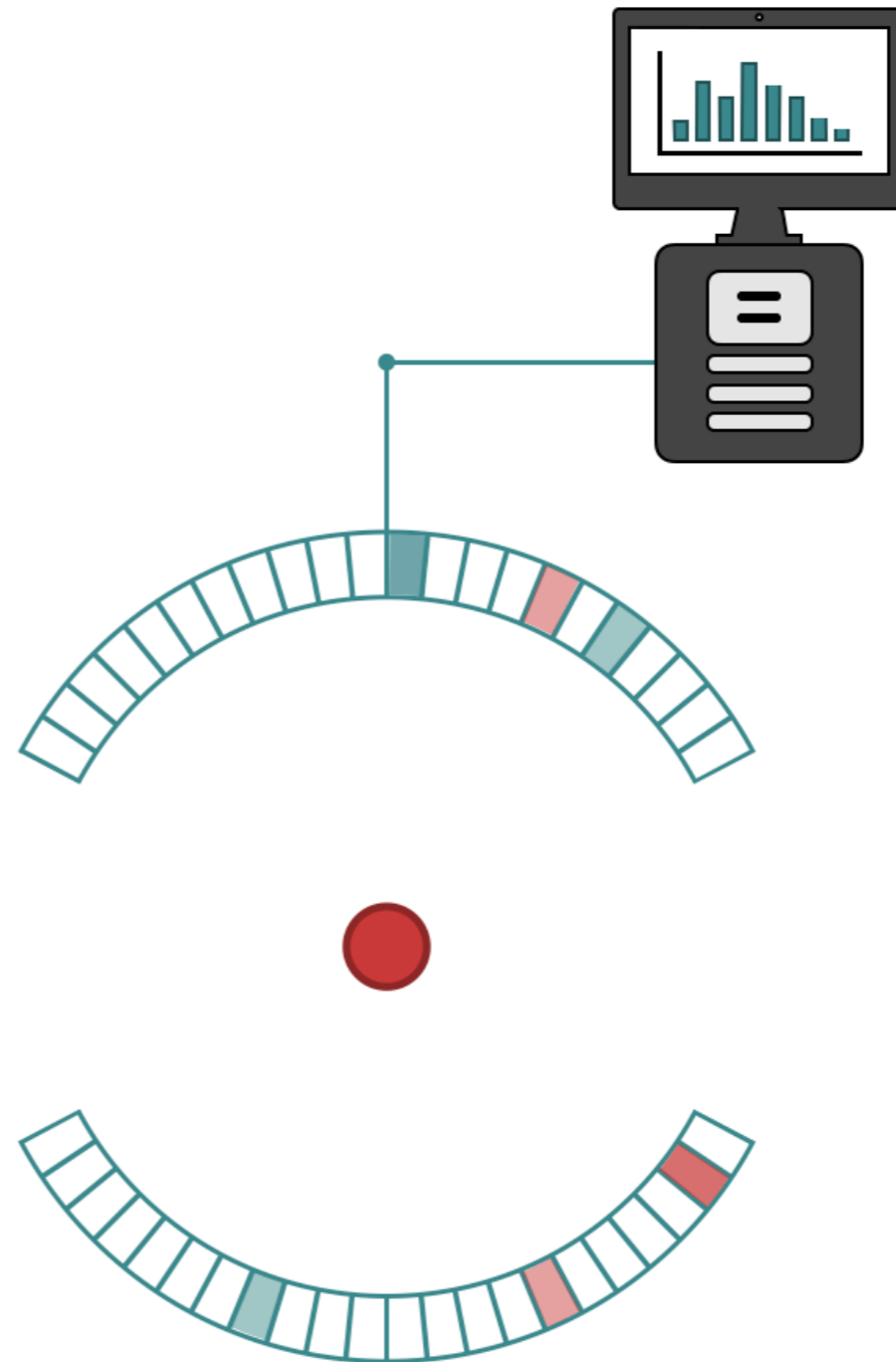
Resonance

Unstable hadron which decays via strong nuclear interaction

Has a mass *and* finite lifetime

$$\tau \sim 10^{-23} \text{ sec}$$

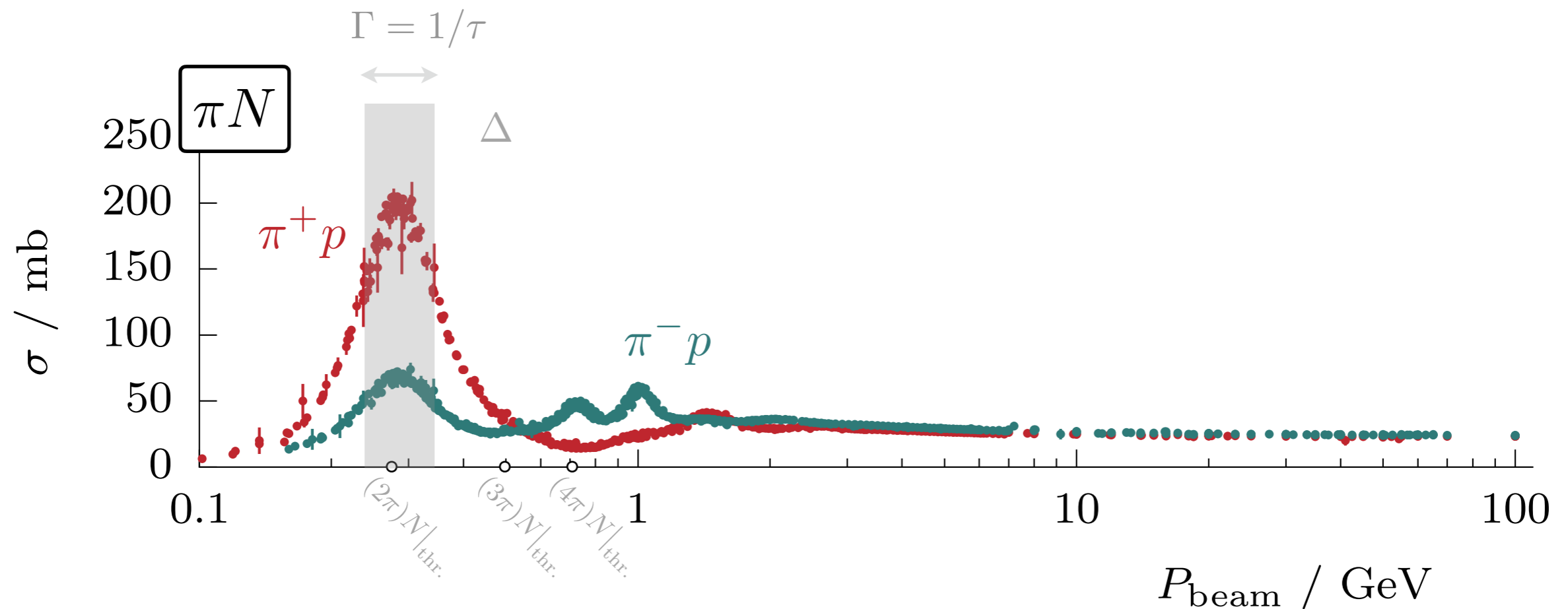
Most hadrons are resonances



Observing Hadrons

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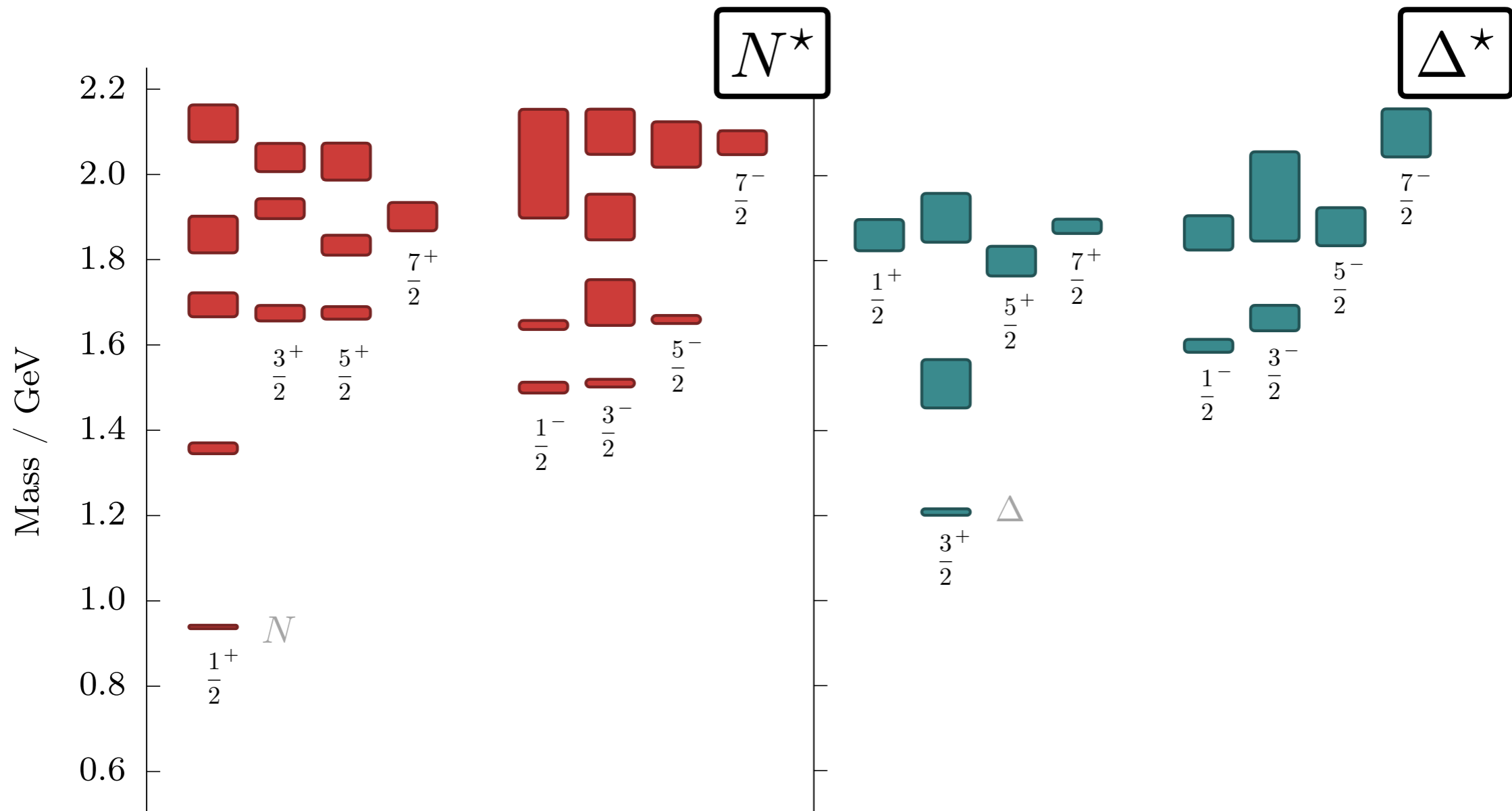
- If the interaction is sufficiently attractive, particles can form a **resonance**
- Resonances can appear as enhancements in the cross-section / amplitude



Observing Hadrons

We observe strongly interacting hadrons, through reactions in accelerators/colliders

- If the interaction is sufficiently attractive, particles can form a *resonance*
- Resonances can appear as enhancements in the cross-section / amplitude



Modern Nuclear Physics

Connect low-energy hadron & nuclear physics to **QCD**

- Quantitatively describe few-body reactions and their impact on observables

