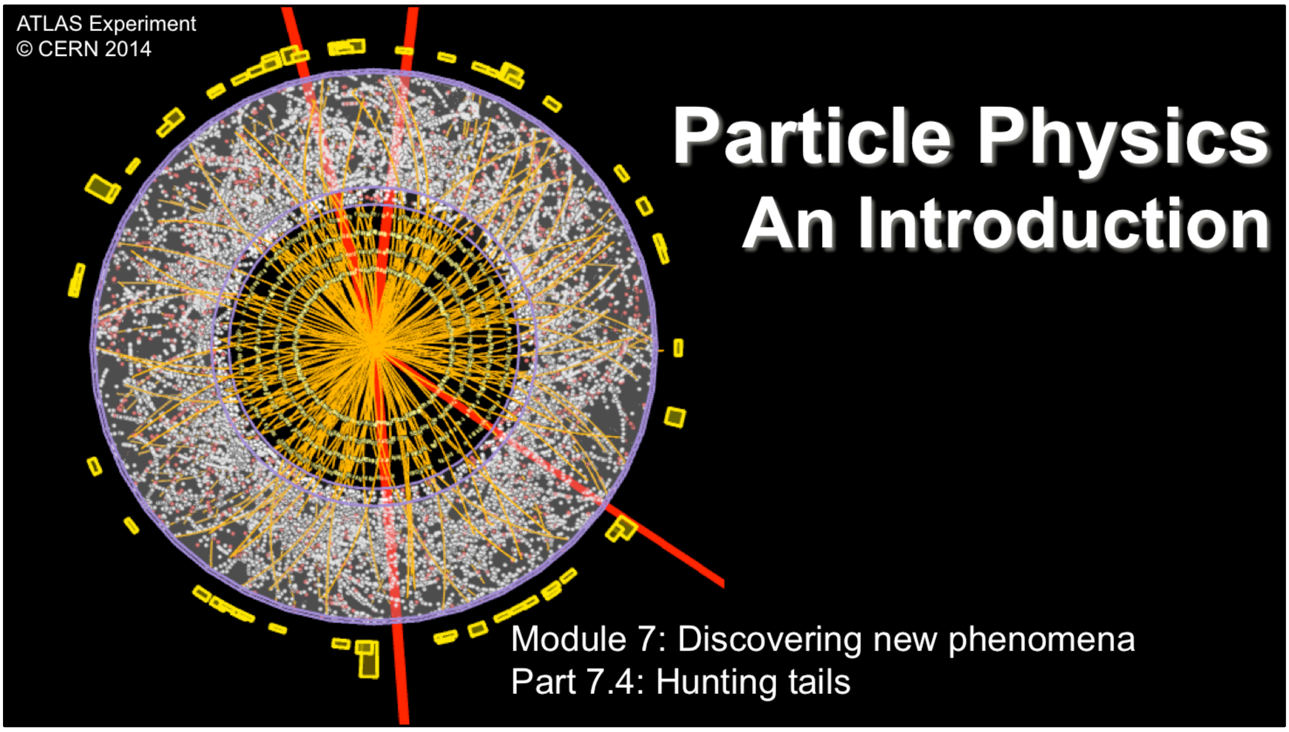
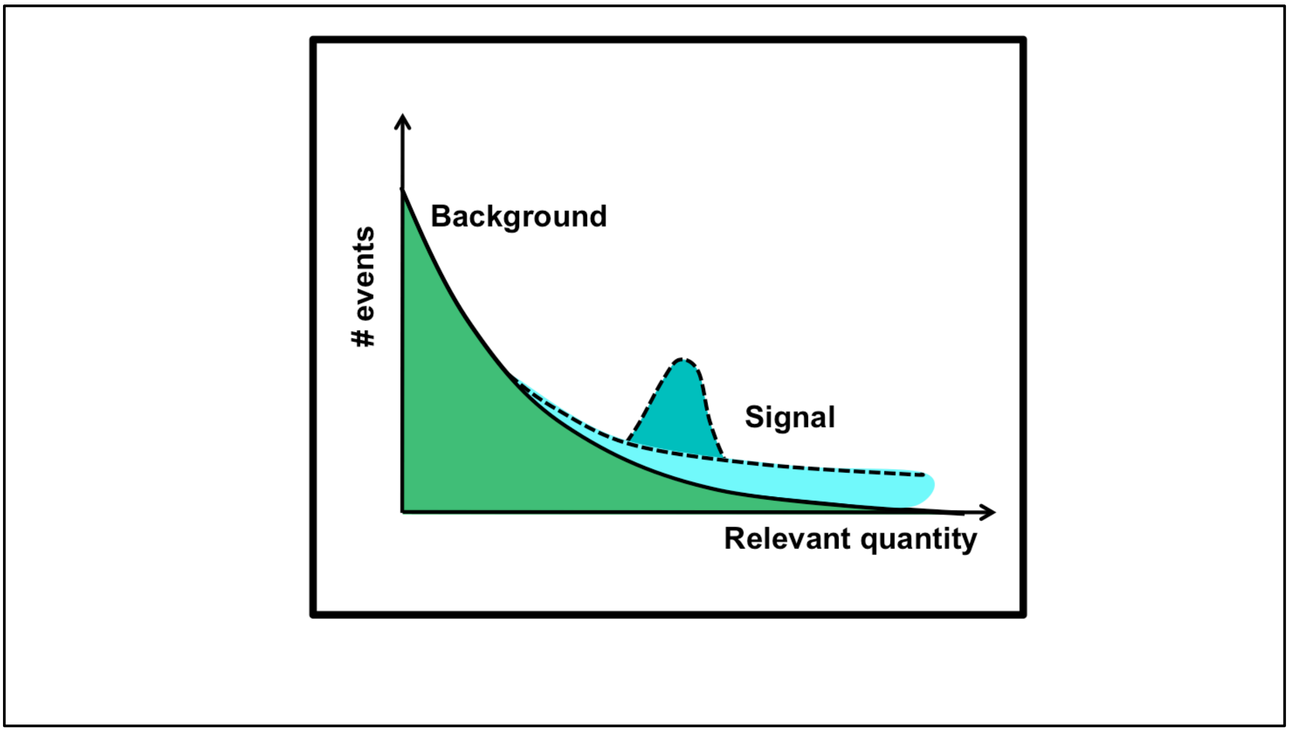


In this module we discuss searches for new phenomena, beyond the known ones described by the standard model.

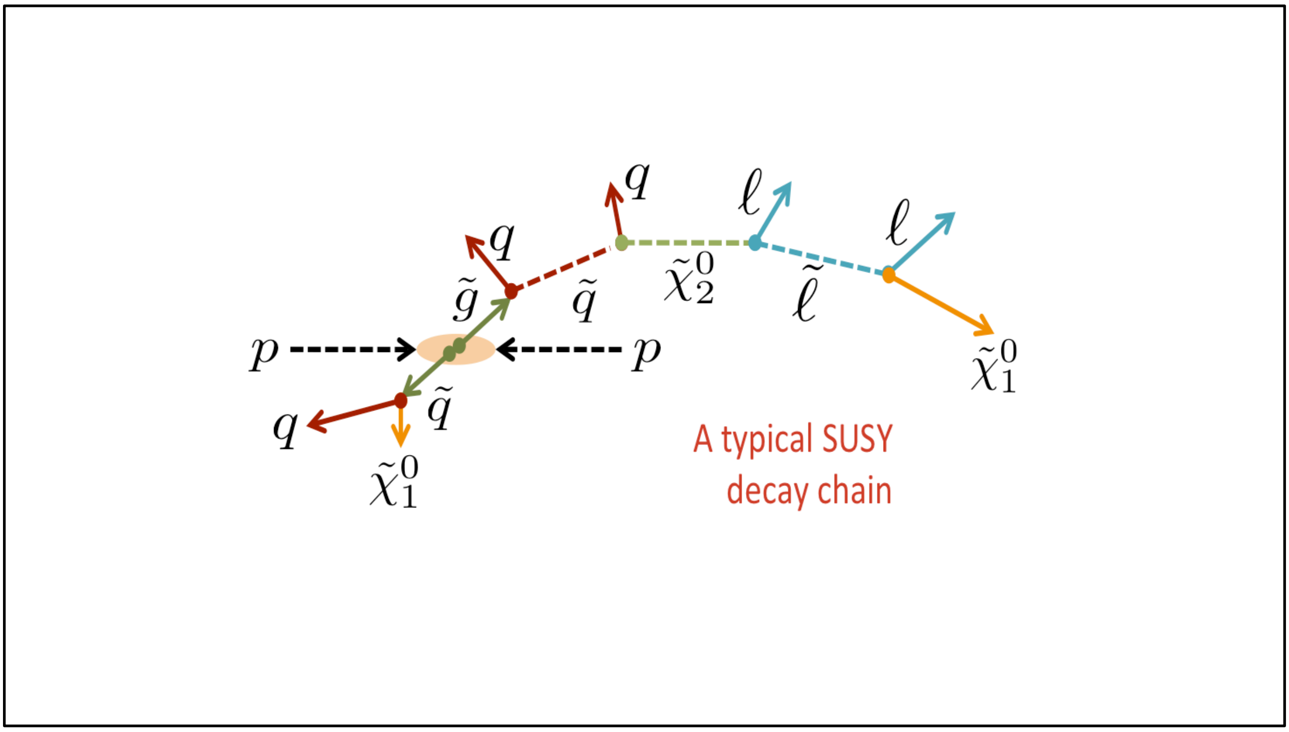
In this video we will discuss searches for tails in characteristic event distributions. This type of searches are, for example, typically used in the searches for supersymmetry.

After watching this video you will know:

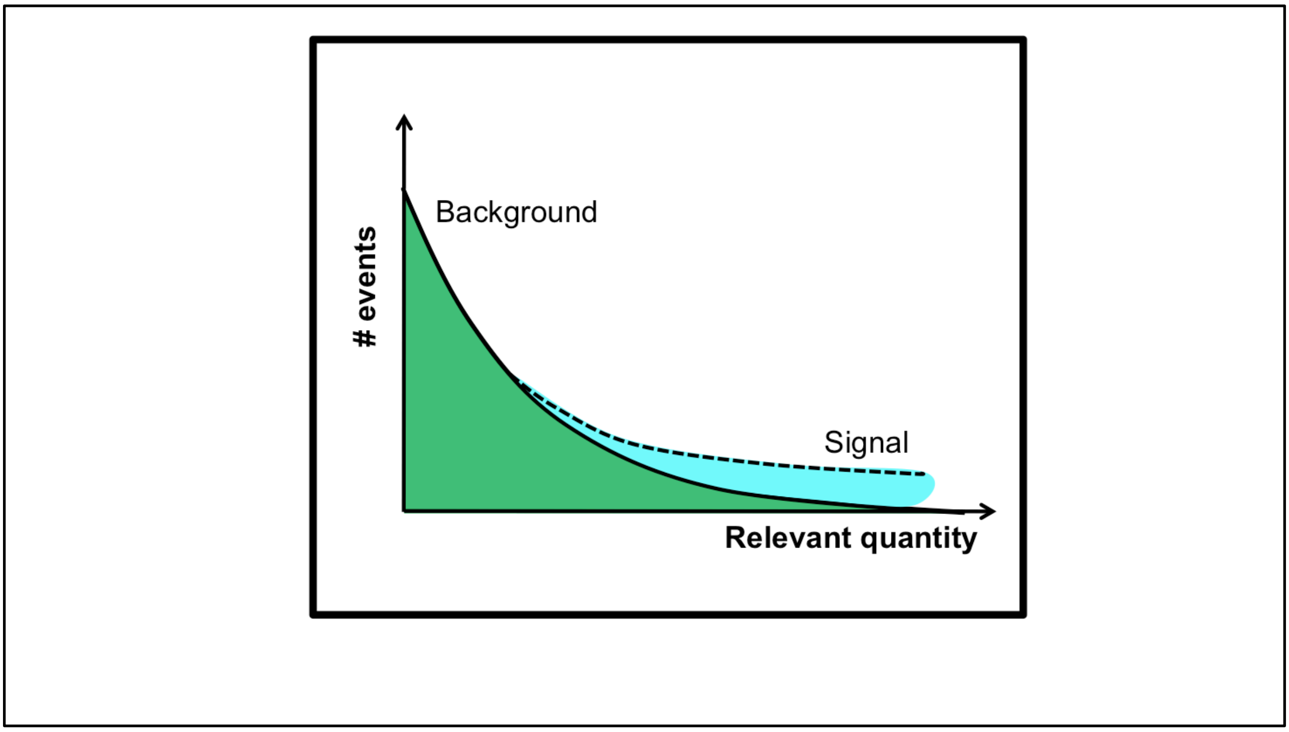
- How we typically search for supersymmetry in hadron collider data;
- What is the main challenge of these searches in the busy proton-proton collision environment; and
- Where we stand in our searches for supersymmetry and new physics in general, using the ATLAS experiment as an example.



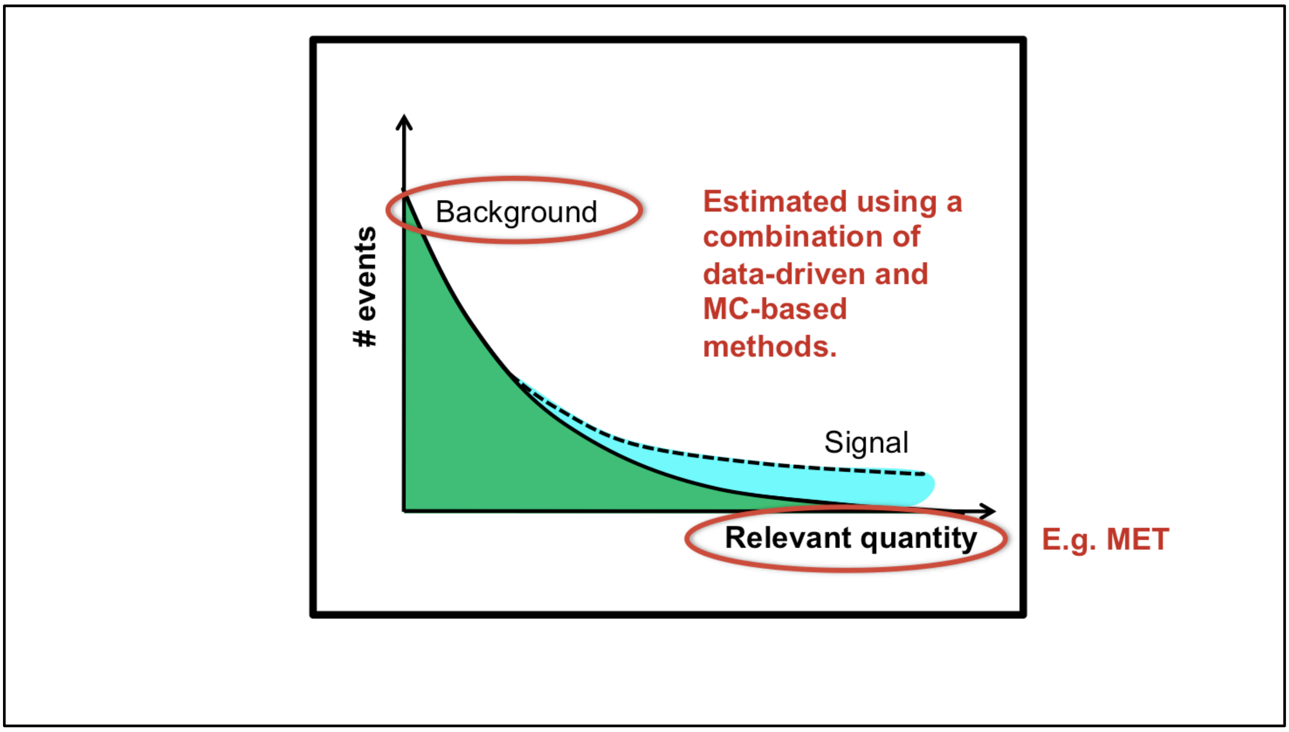
We are typically searching for new physics looking for bumps on a steep falling spectrum, or looking for enhanced tails in the distribution of a relevant quantity. We already talked in the previous video about bump searches, using the heavy Z boson search as an example. While this type of searches is very intuitive and convincing in case of a positive result, such bumps are not easy to identify in decays of supersymmetric particles.



Supersymmetric particles decay in cascades, generating long decay chains, which make it difficult to identify a resonant signature. Given the large multiplicity (and variety) of particles in the final state, we are typically looking for an enhancement in the tail of a distribution. Relevant distributions can be related to the multiplicity of a given type of object, for example jets, or to missing transverse momentum, which in many variants of supersymmetry is enhanced by the emission of neutralinos. These are the lightest supersymmetric particles, neutral and weakly interacting, escaping the detector just like neutrinos do.

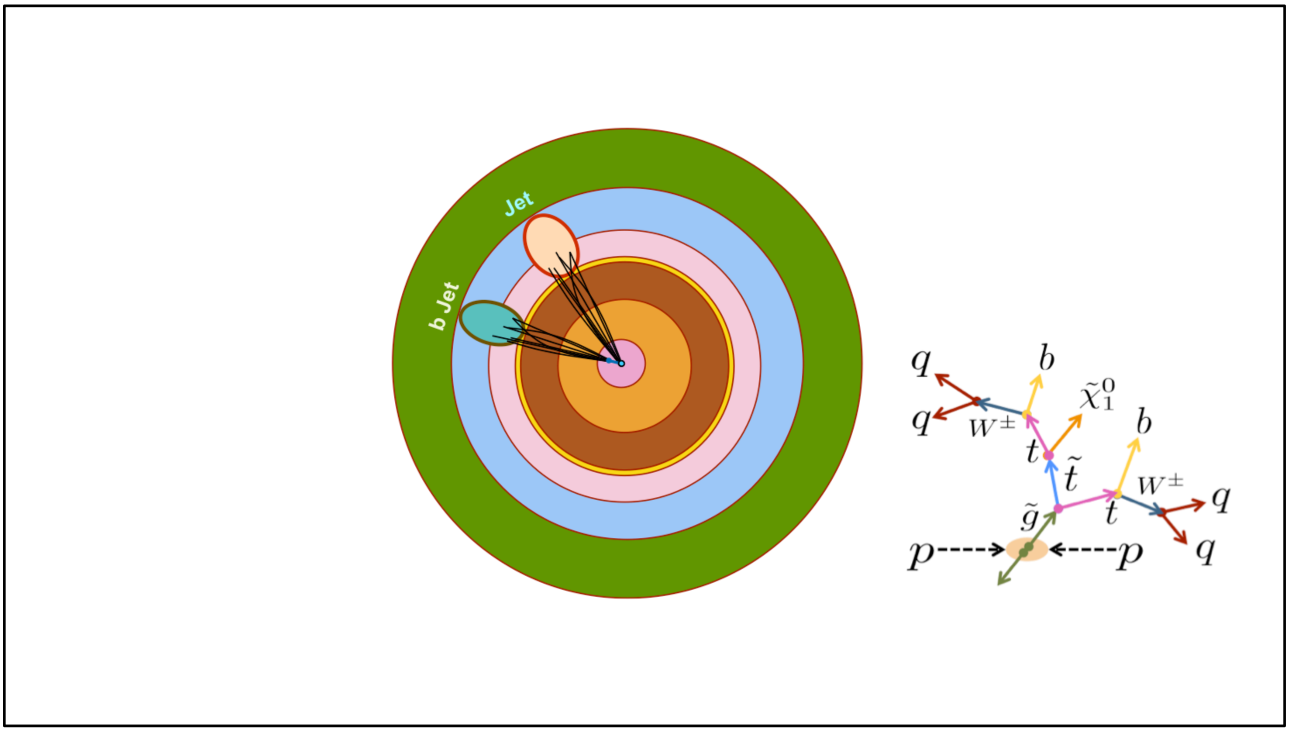


In a SUSY search we are therefore looking for signals that way,



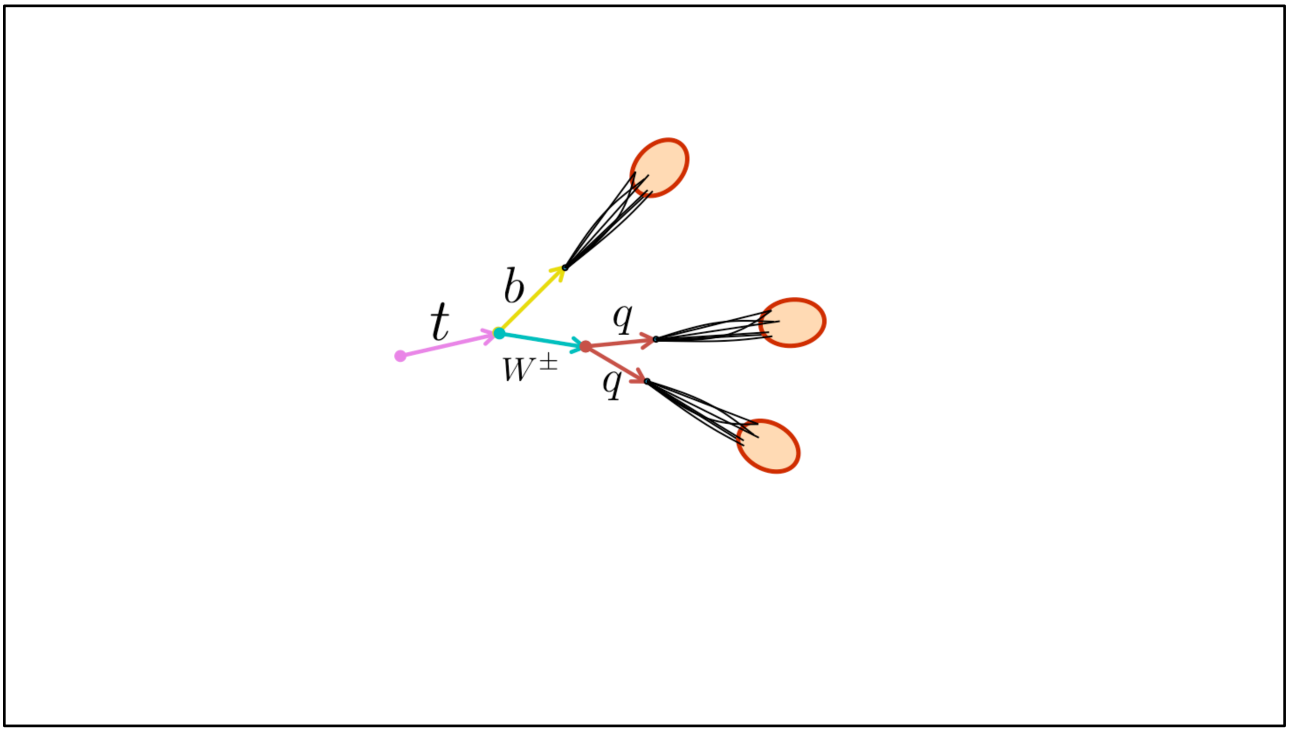
… where the relevant quantity can be the Missing Transverse Momentum. The Standard Model backgrounds, given the large number and variety of objects involved in these searches, are very complicated to estimate. For background determination we are often using data-driven methods, combined with simulation-based techniques. We use Standard Model processes with similar characteristics to verify that the detector response to an assumed signal, properly simulated, is indeed as expected.

In this type of searches the usage of multivariate discriminants is not uncommon, and attempts to achieve a more powerful discrimination of the signal with respect to the background.

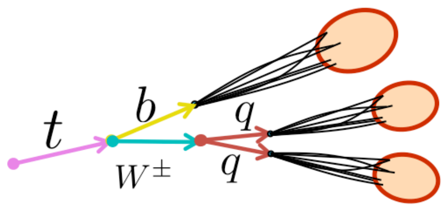


To increase sensitivity in models that involve large multiplicity of b-quarks in the final state, like the one shown in this page, we reconstruct jets originating from a b-quark. We use the knowledge that hadrons containing b-quarks travel a short distance inside the detector before decaying. Stable hadrons, on the contrary, come directly from the proton-proton vertex.

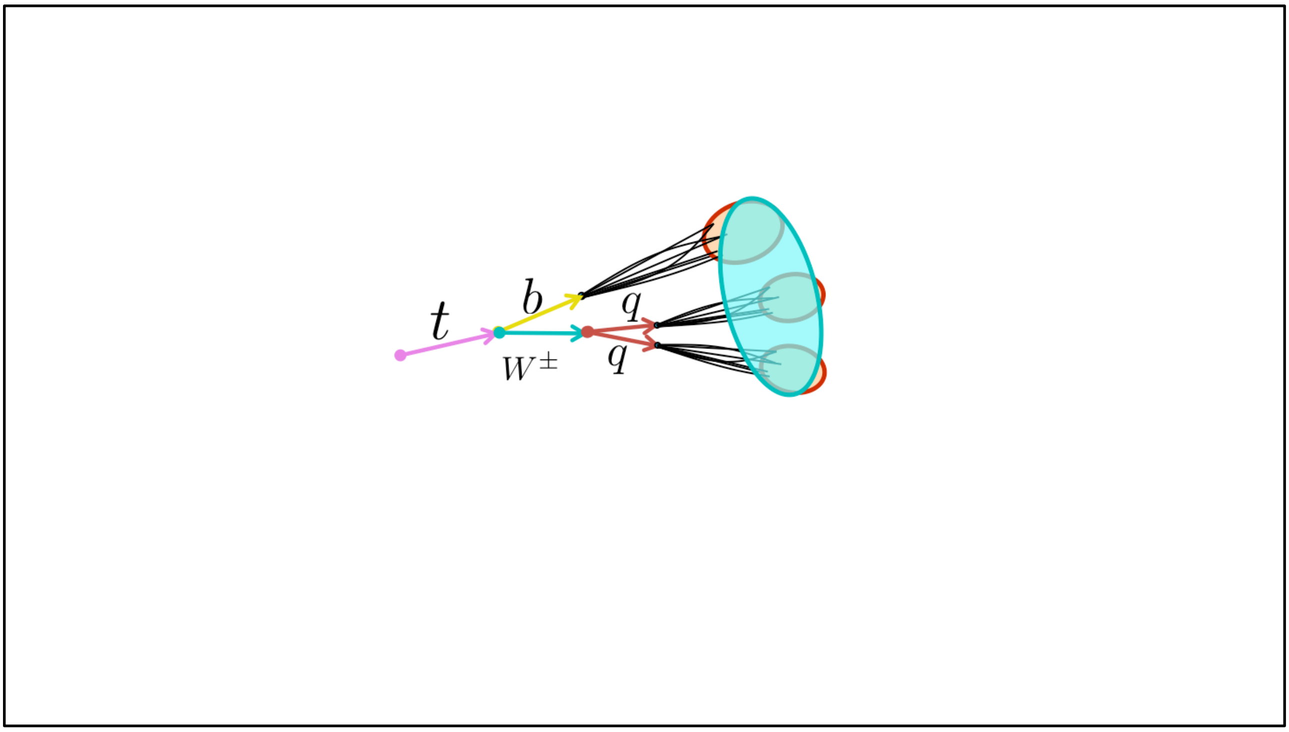
We also reconstruct top quarks from their decays, using their kinematic properties.



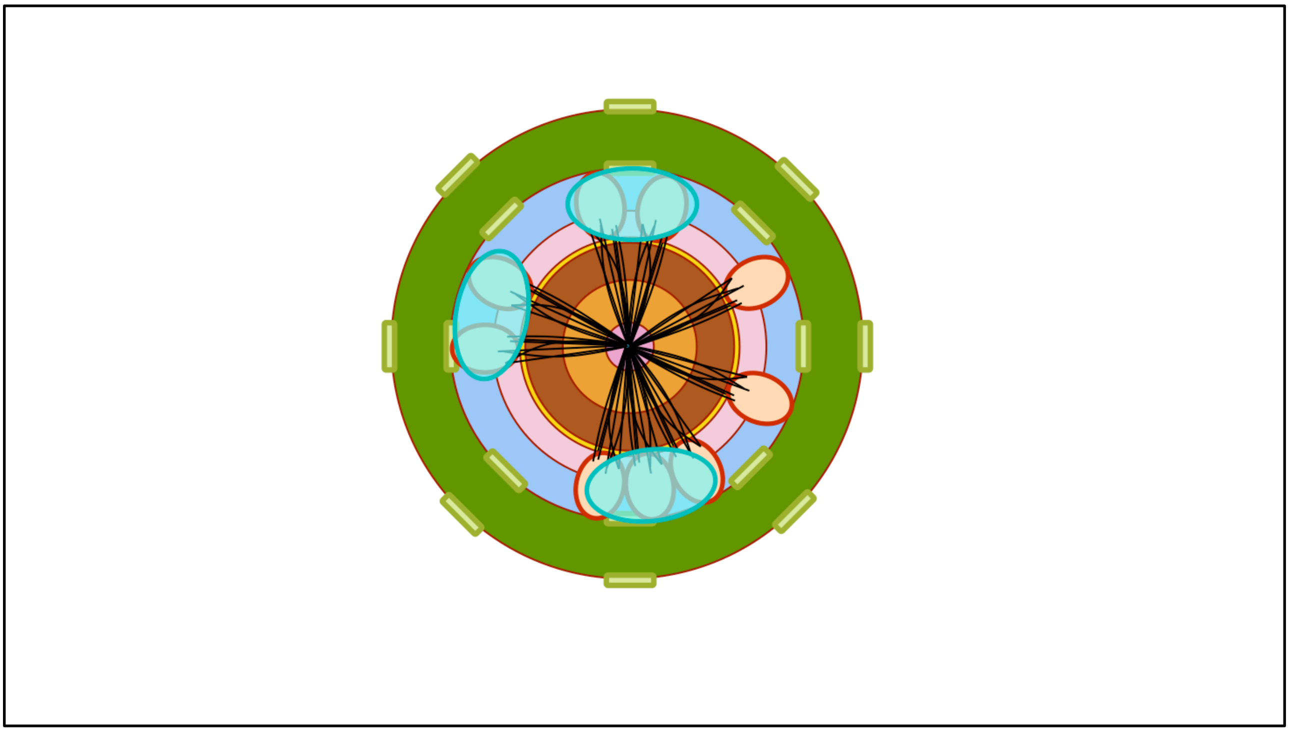
The top quark decays to a b-quark and a W boson, before forming a hadron and with a branching ratio close to 100%. The W boson decays most often to a quark pair. When the top quark has a large momentum, its decay products are more collimated, …



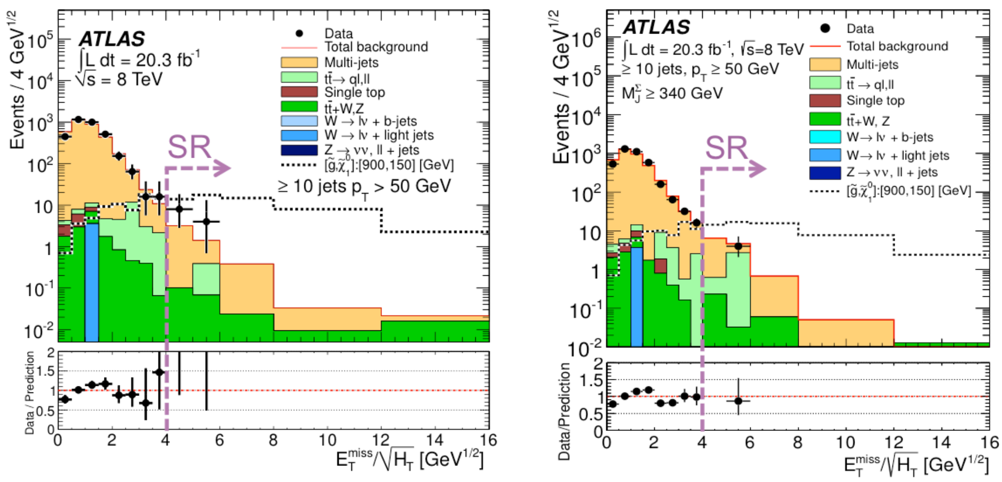
…as shown in this picture. At high t-quark momenta, some of the jets can't be disentangled from each other.



It is therefore common to define wider jets, called "fat jets", which capture the products of the decay of a high momentum top quark.

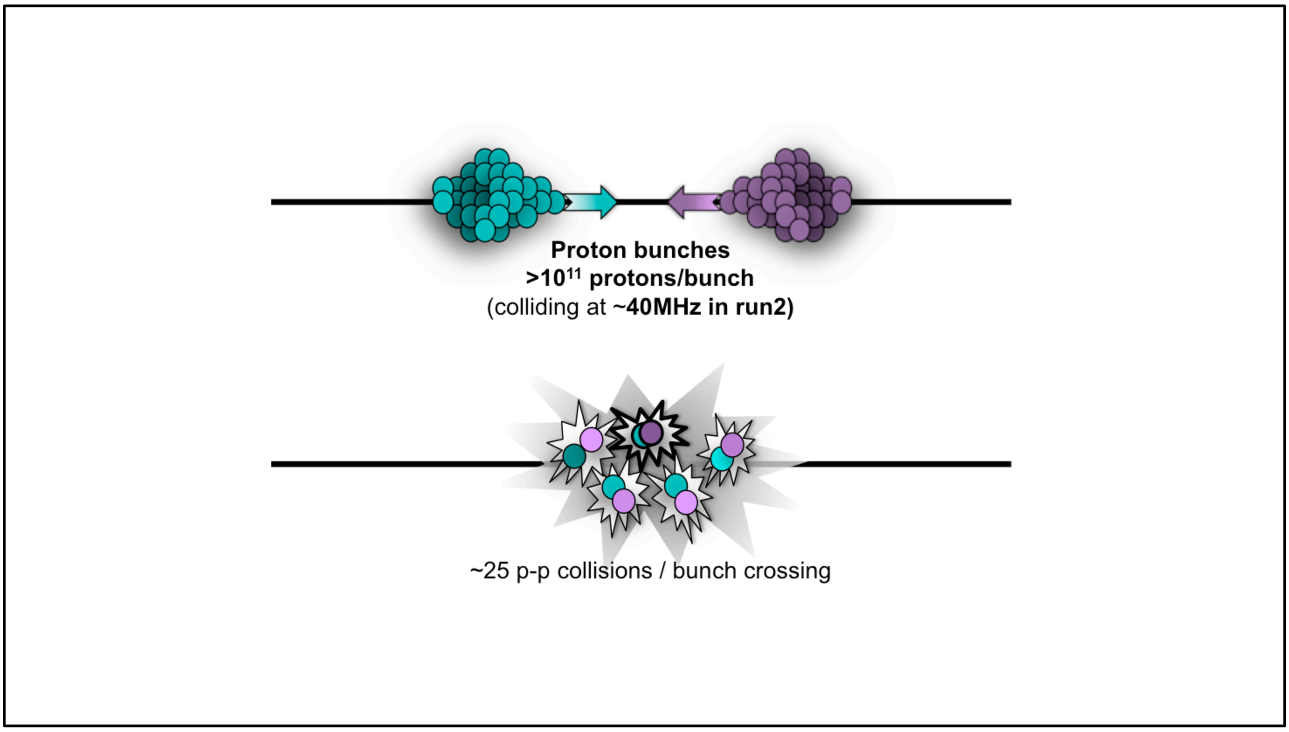


We can therefore require, for example, the presence of multiple fat jets in collision events, a requirement that can improve the signal to background discrimination, compared to an event selection that doesn't include such requirements.



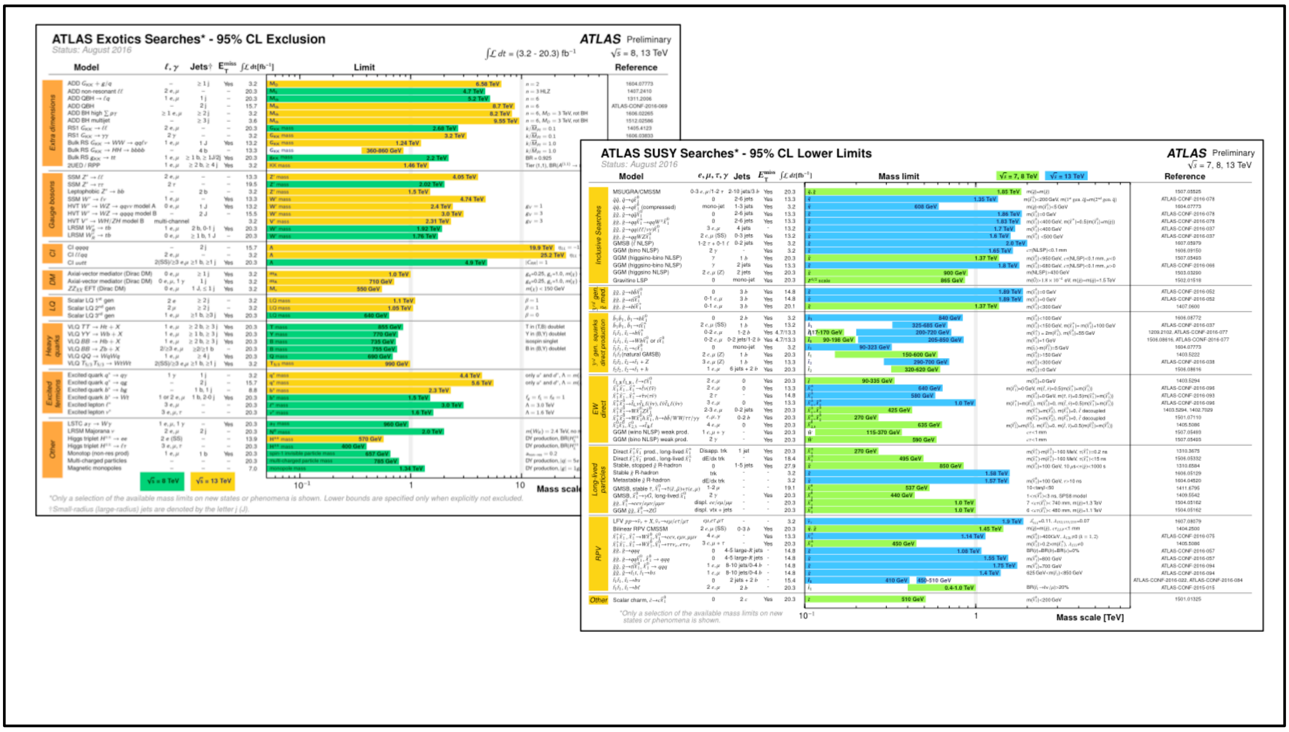
You can see in these figures examples of how final distributions look like; the filled areas show the Standard Model prediction while the dashed line shows how supersymmetry would manifest itself. The black points show the observed distributions, which agree very well with the Standard Model prediction. What is shown here were in fact the two signal regions with the largest excess (on the left) and largest deficit (on the right) of a specific search; the agreement with the Standard Model predictions is usually even better than what is demonstrated in these examples.

Getting the tails of a distribution right in hadron collider data is a very significant challenge. Many experimental factors can alter the expected distributions, therefore careful study goes to distributions with similar properties but coming from well known processes; this ensures an excellent understanding of those factors and the associated systematic uncertainties.



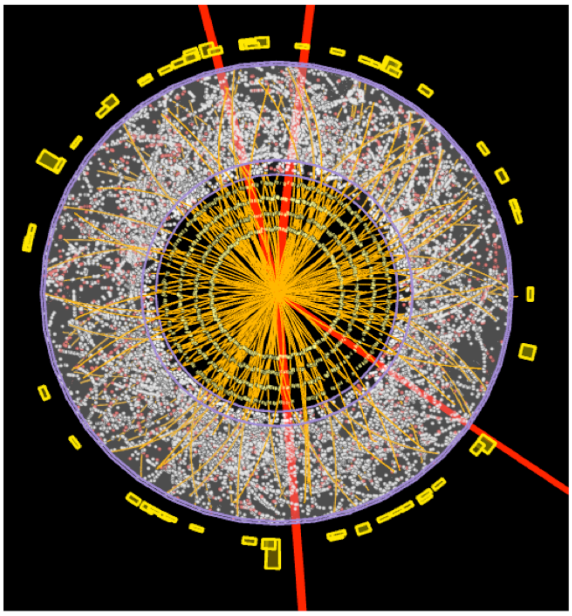
One of the most significant challenges comes from what we call “pile-up”. At the LHC, protons don’t collide individually but in bunches of hundreds of billions of protons. This results in multiple collisions in a bunch crossing, leading to several low q^2 reactions. Distinguishing the hard-scattering process from the rest, and understanding how pile-up affects the distributions of interest, are both very difficult tasks.

In the hadron colliders, we have achieved a significant level of understanding having thoroughly studied the LHC data collected so far. Having looked at a very broad spectrum of signatures, we have not yet found any significant excesses that could hint to new physics.



In lack of excesses, we put limits to the theories and models that have motivated our searches; that way we can obtain a global view of where we stand with our searches, and ask theorists about their advice on which direction to take in our future searches.

The figures in this slide give the current picture for all ATLAS searches for supersymmetry and other new phenomena. They are all expressed as lower limits on the mass scale that characterizes the process. You can see that we are close to excluding supersymmetric particles up to 2TeV in mass.



SuperSymmetry and other theories Beyond the Standard Model remain elusive so far...

A unique chance for a unique discovery!

Despite the fact that supersymmetry and other theories beyond the Standard Model remain elusive so far, the open questions of the Standard Model are so pressing that it's certain there is something beyond. With the increasing amount of available LHC data, we are on the right track to find what that is.

We are faced with a unique chance to make a unique discovery at the LHC, and history has taught us it may be unexpected. At the LHC experiments, we are looking forward to it.