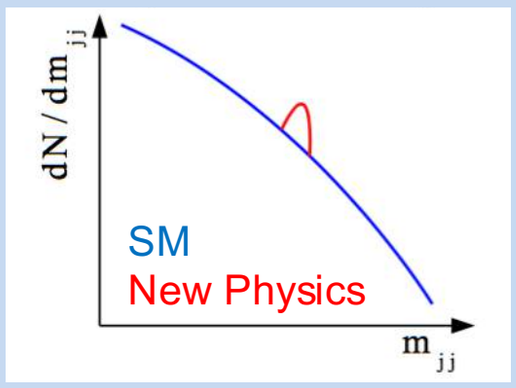
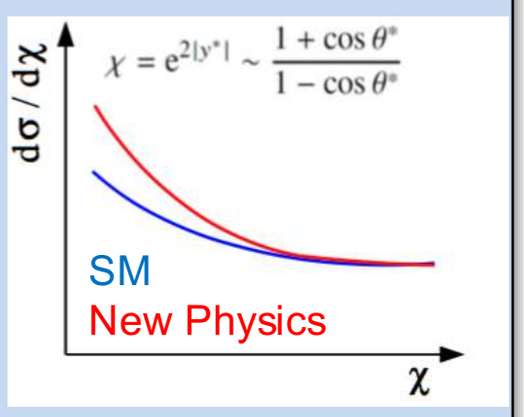
# Z' searches in supersymmetric and leptophobic scenarios at (HL-)LHC

Searching for heavy vector bosons Z′, predicted in models inspired by Grand Unification Theories (GUT),is among the challenging objectives of the LHC. Current experiments have focused on Standard Model final states and set exclusion limits on the Z' mass in the TeV range. However, possible Z' bosons may well decay into novel states, such as supersymmetric (SUSY) particles, eventually leading to leptons and missing energy (neutrinos and neutralinos). Furthermore, there exist realizations of the GUT models, the so-called leptophobic scenarios, wherein leptons in Z' events can originate only through supersymmetric cascades, the direct coupling being suppressed.
The High Luminosity-Large Hadron Collider (HL-LHC) is expected to start in 2026 and to provide an integrated luminosity of 3000 $fb^{-1}$ in ten years, a factor 10 more than what will be collected by 2023. This large amount of data will both improve existing searches for new physics at the TeV scale and open the possibility to search for new signatures. The Z'→invisible particles + leptons channel is a new topology, not yet fully investigated with the current data of the LHC nor with a realistic simulation at HL-LHC. We propose a mixed theoretical/experimental study on the significance reach for this channel at HL-LHC, based on simulated data from the ATLAS detector. The student will have the opportunity to understand all the steps of a complex analysis, from the theory models to be tested, to the event reconstruction up to the analysis for the signal extraction.

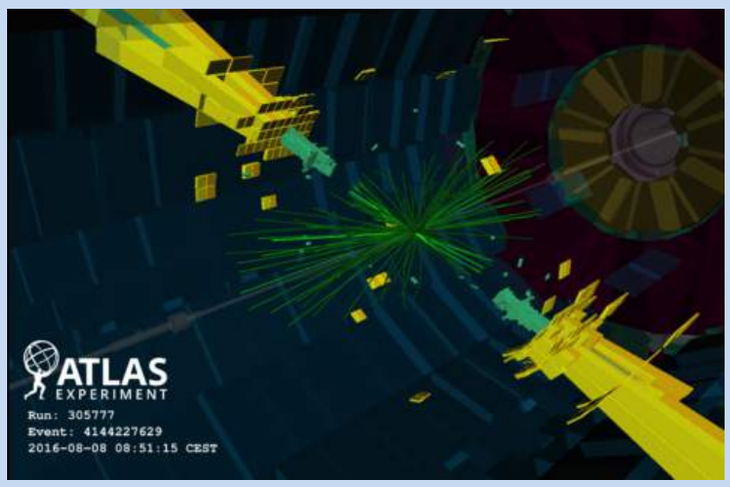
## *Searching for novel high-mass resonances at HL-LHC*

Hunting for new particles not predicted by the Standard Model (SM) is of high priority for the LHC program.
Heavy resonances can be detected as bumps in the invariant-mass spectra or as anomalies in other final-state distributions.
The searching strategy depends on the theoretical model and, above all, on the resonance decay modes.
The LHC experiments have been extensively searching for heavy neutral gauge bosons, yet considering only SM decay channels.




So far the ATLAS Collaboration has looked for Z' bosons by exploring dilepton and dijet final states, and assuming that they can only decay according to SM modes, namely quark and lepton pairs. The exclusion limits on the Z' mass have thus been set to about 4.5 TeV and 2.1-2.9 TeV, for decays into dileptons and dijets, respectively.

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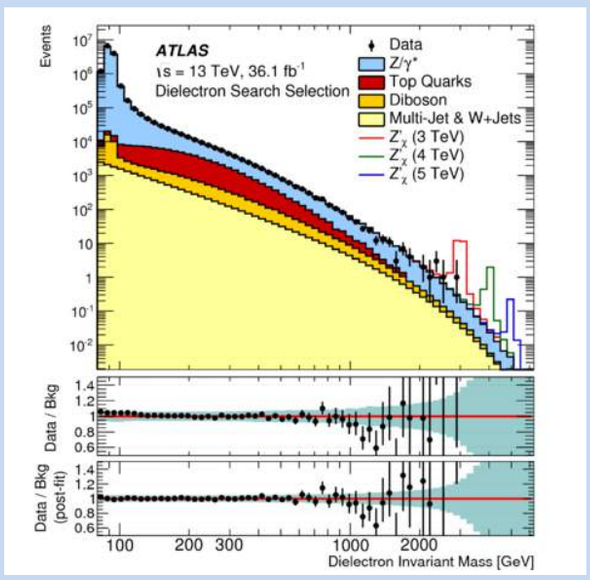


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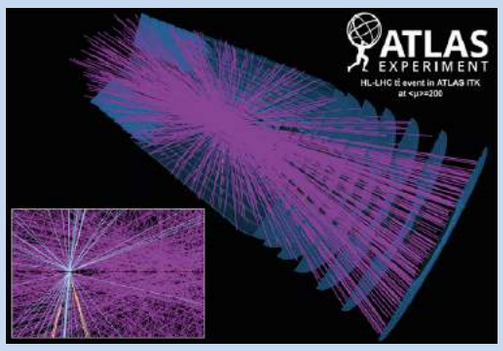
## *Challenges at HL-LHC*

- High Luminosity HL- LHC will start in 2026
- 3000 $fb^{-1}$ in ten years (ten times the data collected by 2023)

Improved sensitivity to searches for New Physics at the TeV scale

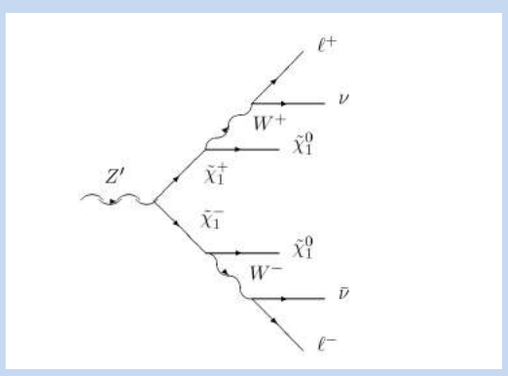
But unprecedented number of pile-up collisions: up to 200 per bunch crossing,
→**harsh environment** for event reconstruction

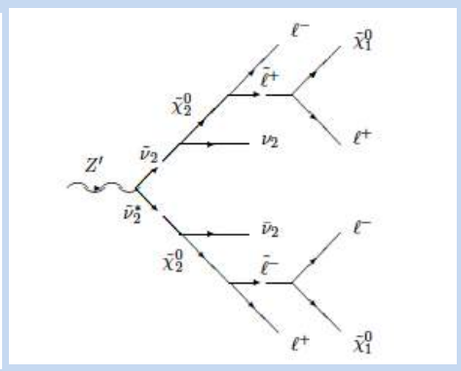



→Need **realistic simulation** to evaluate the reach in new physics

## *Z' in* supersymmetric and leptophobic scenarios

Loopholes in the existing Z' searches have been recently explored by studying supersymmetric (SUSY) decays, as well as leptophobic scenarios, where the Z' coupling to leptons is suppressed.
In this framework, the Z' evades the current bounds from dilepton final states.

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The presence of neutral supersymmetric particles (neutralinos), in addition to leptons, leads to topologies `leptons + missing transverse energy ($\not{E}_T$)', not yet explored.
The production of an intermediate Z' with a given mass can be inferred from features of $\not{E}_T$ and lepton transverse-momentum and angular spectra.
At HL-LHC, with 3000 $fb^{-1}$ of data, this signal can be observed with a significance of 4-7 standard deviations.
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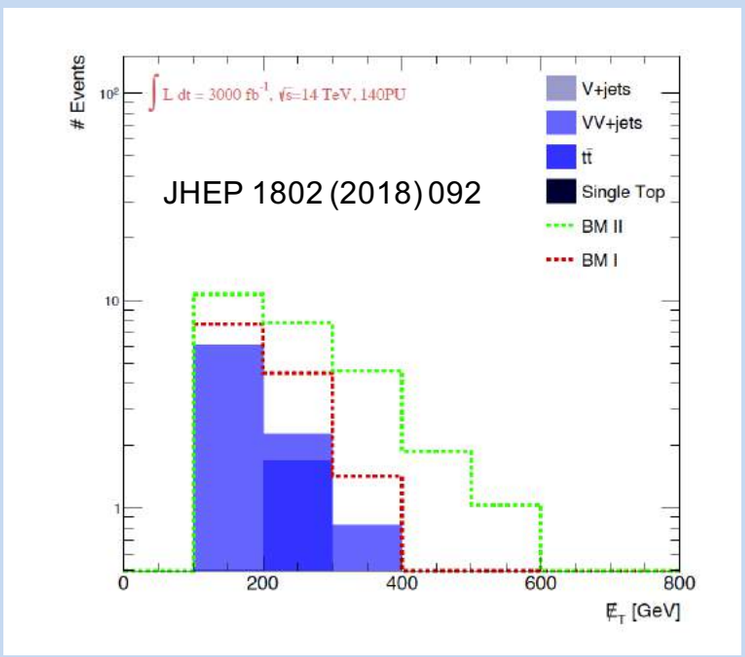
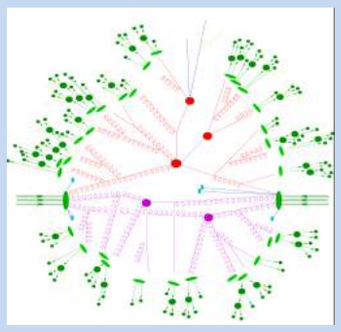



The $\not{E}_T$ is the missing transverse energy due to the production invisible particles (neutrinos and possibly neutralinos) in the event.

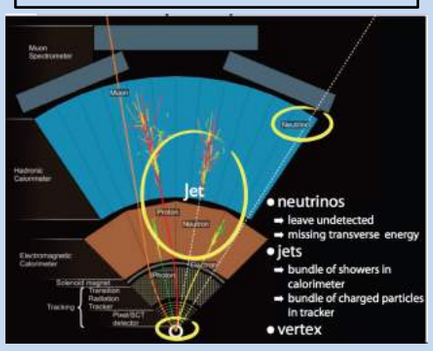
## *Proposal*

We propose a study of the significance reach of the Z' in SUSY and leptophobic models at HL-LHC. The student will use data samples from the most updated simulation of the ATLAS detector, including upgrades and pile-up effects. She/he will first generate the event samples and then reconstruct them applying the parametrization of the detector performance. Throughout the thesis work, the student will have the opportunity to understand and have under control all the steps of the experimental analysis This aspect is not common in the analysis on real data from the LHC experiments, due to the complexity of analysis and software. In particular, she/he will get acquainted with the new Inner Tracker (ITk) to improve the $\not{E}_T$ reconstruction. From the theory viewpoint, she/he will learn about Standard Model, supersymmetry, Grand Unification Theories and physics of Monte Carlo event generators (hard scattering, QCD parton showers, hadronization and underlying event). Also, she/he will have to optimize the choice of benchmark points in the SUSY/GUT parameter space to respect the current LHC exclusion limits and enhance the signal with respect to the background. The student will be supervised by an ATLAS experimental physicist and by a theorist with expertise in LHC phenomenology from LNF.

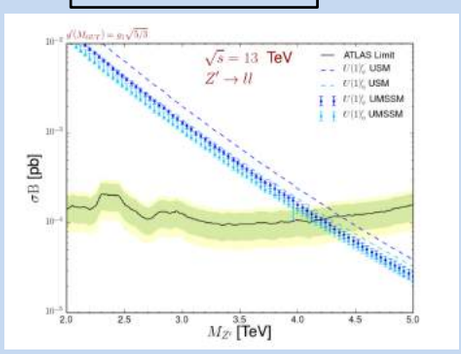
**Generation of events**



**Reconstruction**




**Analysis**




Gennaro Corcella (LNF-INFN), Marianna Testa (LNF-INFN)