Searching for supersymmetry in the 3 lepton channel at the HL-LHC

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Overview

- Supersymmetry $\rightarrow$ direct gaugino production
- HL-LHC
- Background processes
- Implementing a boosted decision tree
- LHC and HL-LHC sensitivity

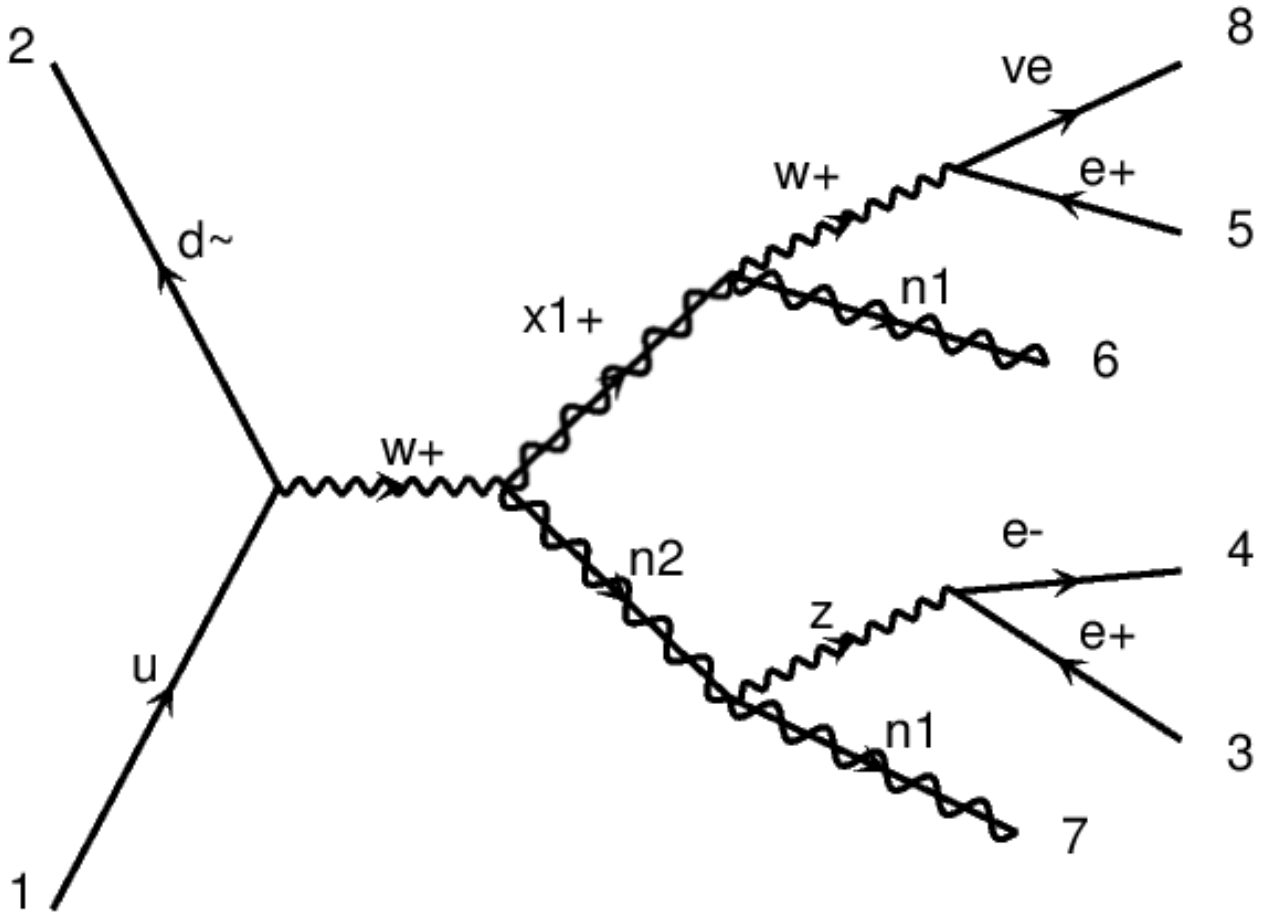
Supersymmetry

- Supersymmetry (SUSY) is one of the promising theories for physics beyond the standard model.
- In SUSY models, each standard model particle has a supersymmetric pair particle.
- Current searches have placed strong limits on squark and gluino masses.
- In scenarios with very heavy squarks and gluinos, weak production of charginos and neutralinos can dominate the SUSY production.

Supersymmetry model

- Searching for "direct gaugino production"
- The "neutralino-1" (χ_1^0 or n1) is a neutral particle and is assumed to be the lightest SUSY particle (LSP).
- The "neutralino-2" (χ_2^0 or n2) and "chargino-1" ($\chi_1^\pm$ or x1$\pm$) are heavier SUSY particles and are assumed to have the same masses.
- R-parity is a property of SUSY particles which is conserved so the lightest SUSY particle (χ_1^0 in our case) is stable.
- All other SUSY particles are assumed to be very heavy and are ignored for this analysis.

Supersymmetry model - Feynman diagram of signal

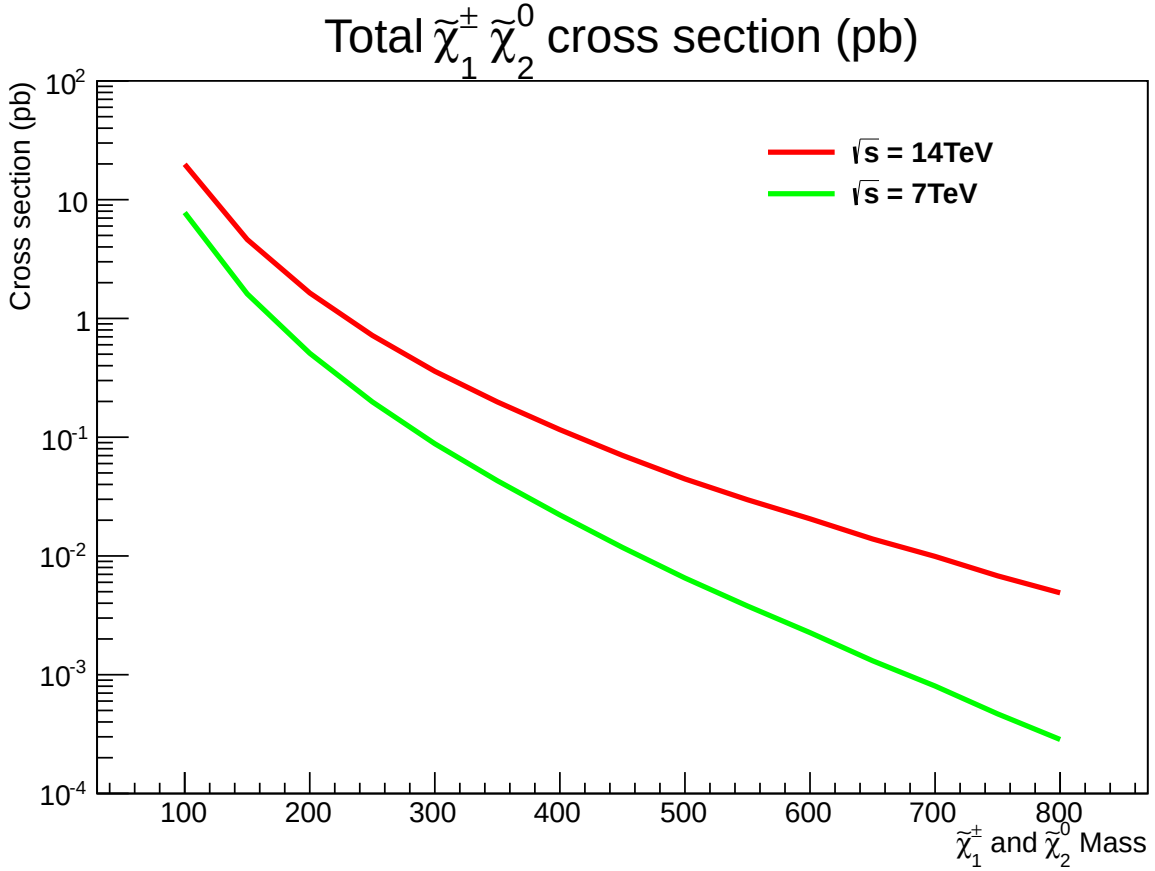


HL-LHC

- The HL-LHC is the proposed successor to the LHC and is designed to collect 3000 fb^{-1} of data at 14 TeV.
- If an excess is observed in the 20 fb^{-1} (2012, 8 TeV) or 300 fb^{-1} (full LHC, 14 TeV) runs, the HL-LHC will be able to measure properties of the excess.
- If no excess is seen, the HL-LHC will be able to extend the reach to larger masses.

Cross section

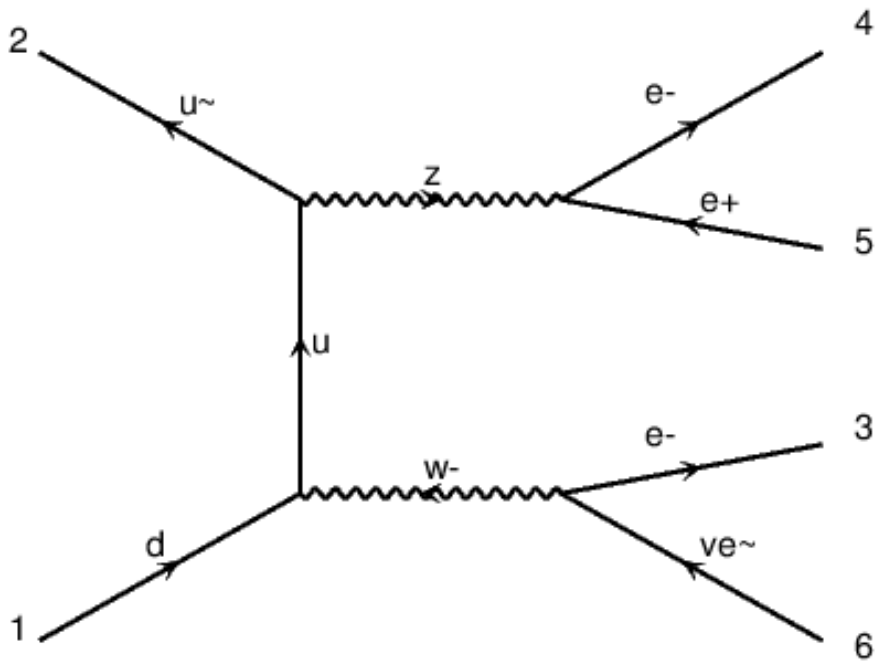
- The cross section of $\chi_2^0\chi_1^\pm$ production is 0.01-10 pb for the 100-800 GeV mass range.
- Only $\sim$1% of $\chi_2^0\chi_1^\pm$ pairs decay to 3 leptons $\rightarrow$ **need to suppress background!**



Background

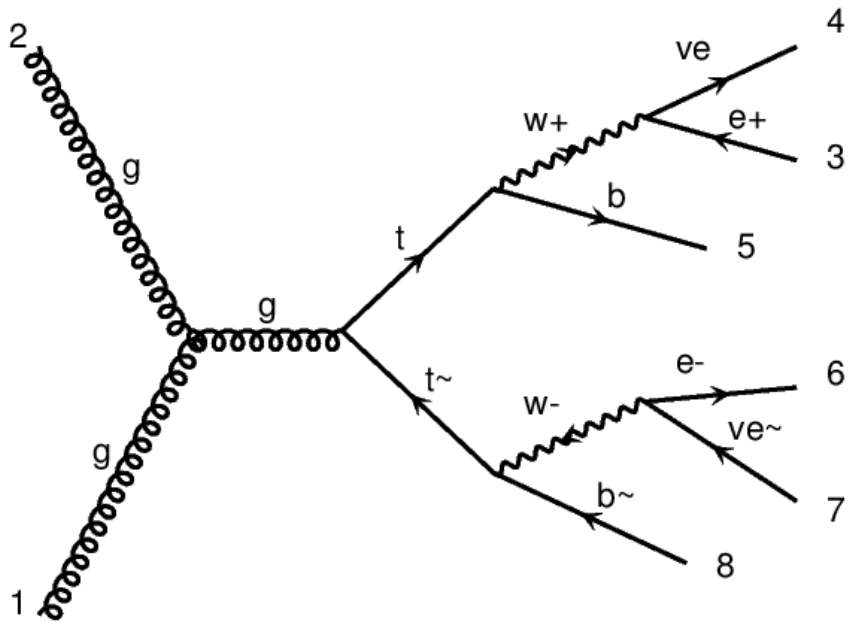
Two main sources of background:

1. *WZ* production
   - Cross section: $\sim$50 pb
   - Only invisible particle in the final state is a single neutrino $\rightarrow$ **cut on missing transverse energy.**



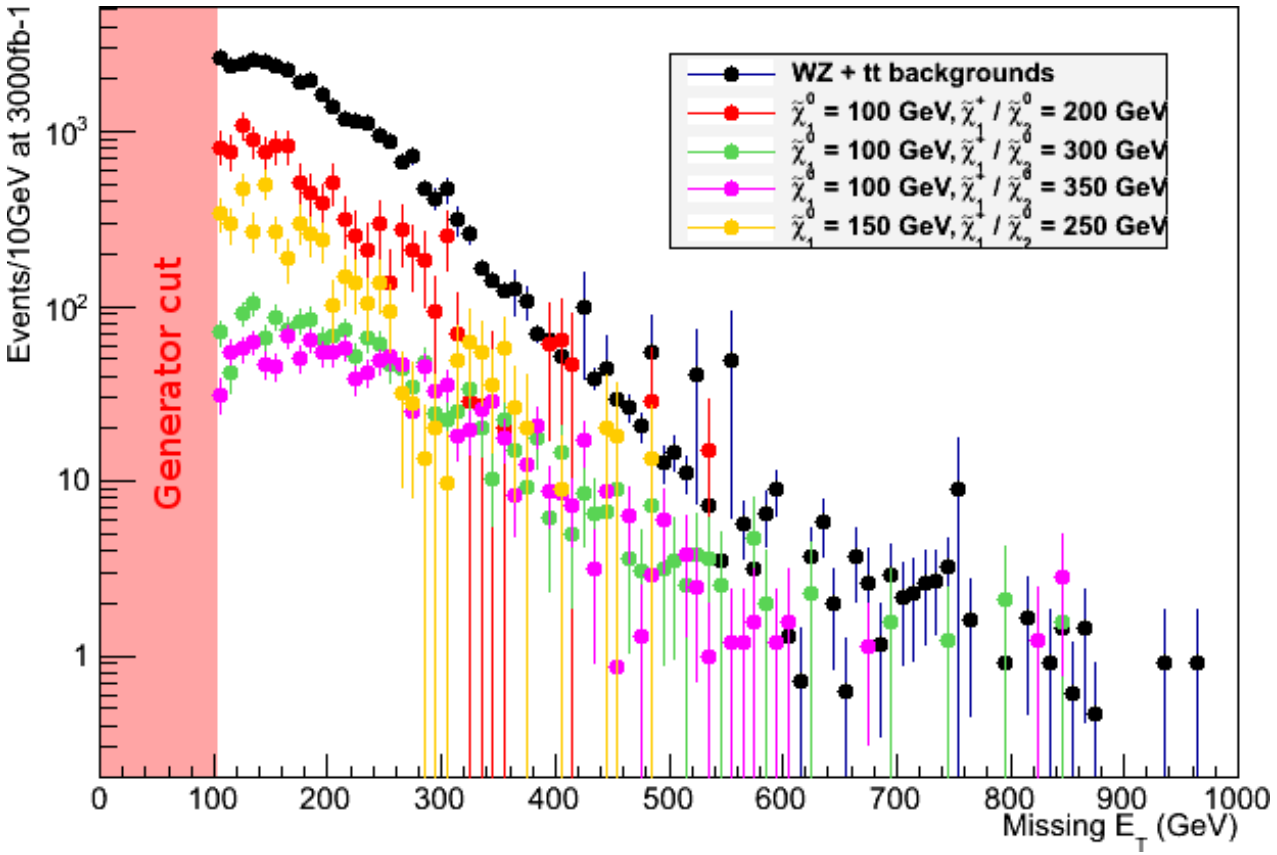
Background

2. $t\bar{t}$ production
   - Cross section: $\sim$1000 pb
   - In the SUSY scenario, there is a Z-boson $\rightarrow$ **cut on reconstructed Z-boson mass.**
   - 2 b-quarks are present in a $t\bar{t}$ event. Often one b-quark decays leptonically (3 leptons) and the other one forms a b-jet. $\rightarrow$ **veto events with b-jets.**



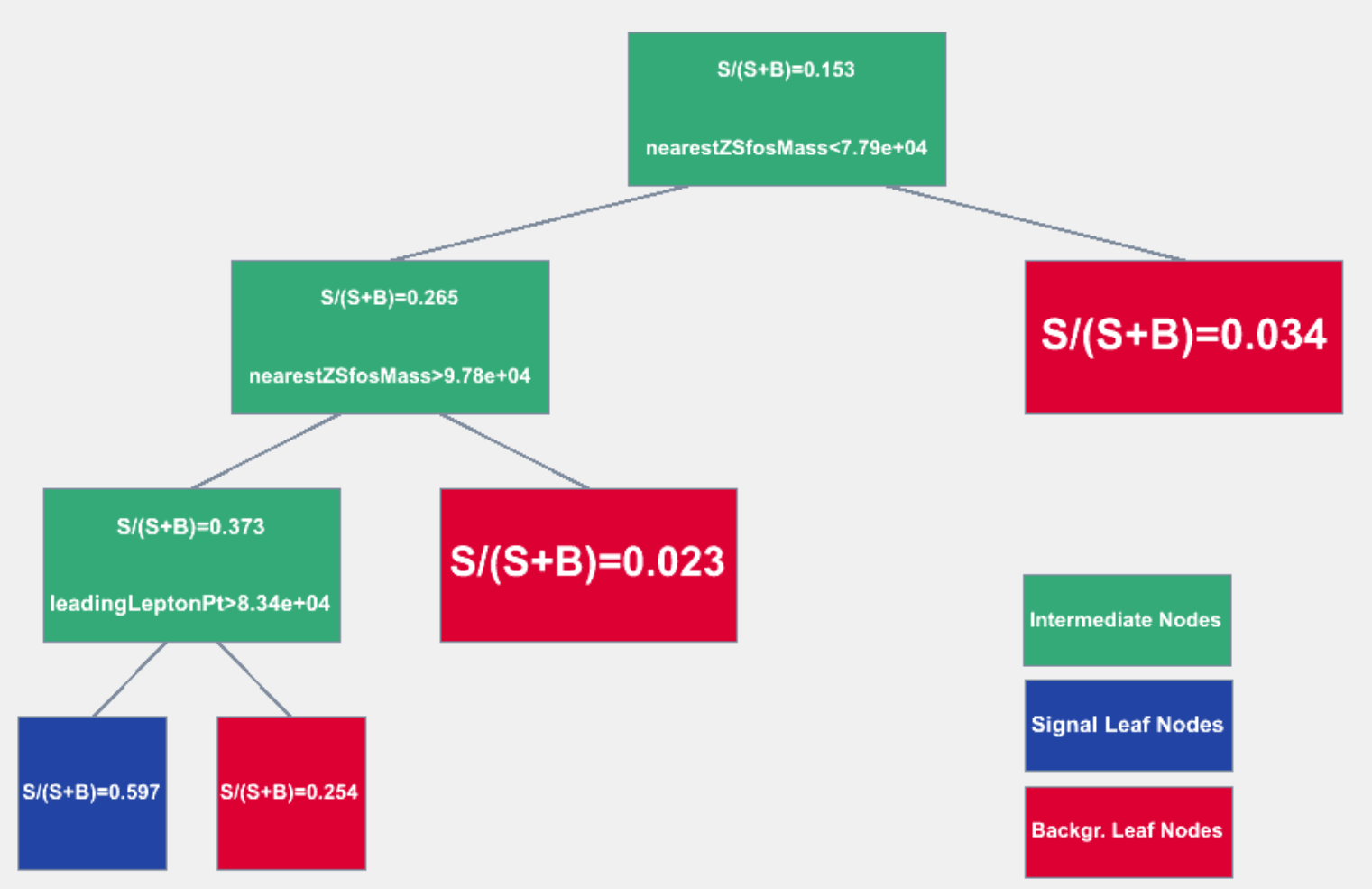
Background - Missing Transverse Energy Distribution

- Truth level samples were generated for the background and signal.
- The momenta of generated particles were adjusted to account for detector resolution.
- Background is huge compared to signal, no "easy" cuts on a single variable. $\rightarrow$ **use a Boosted Decision Tree**



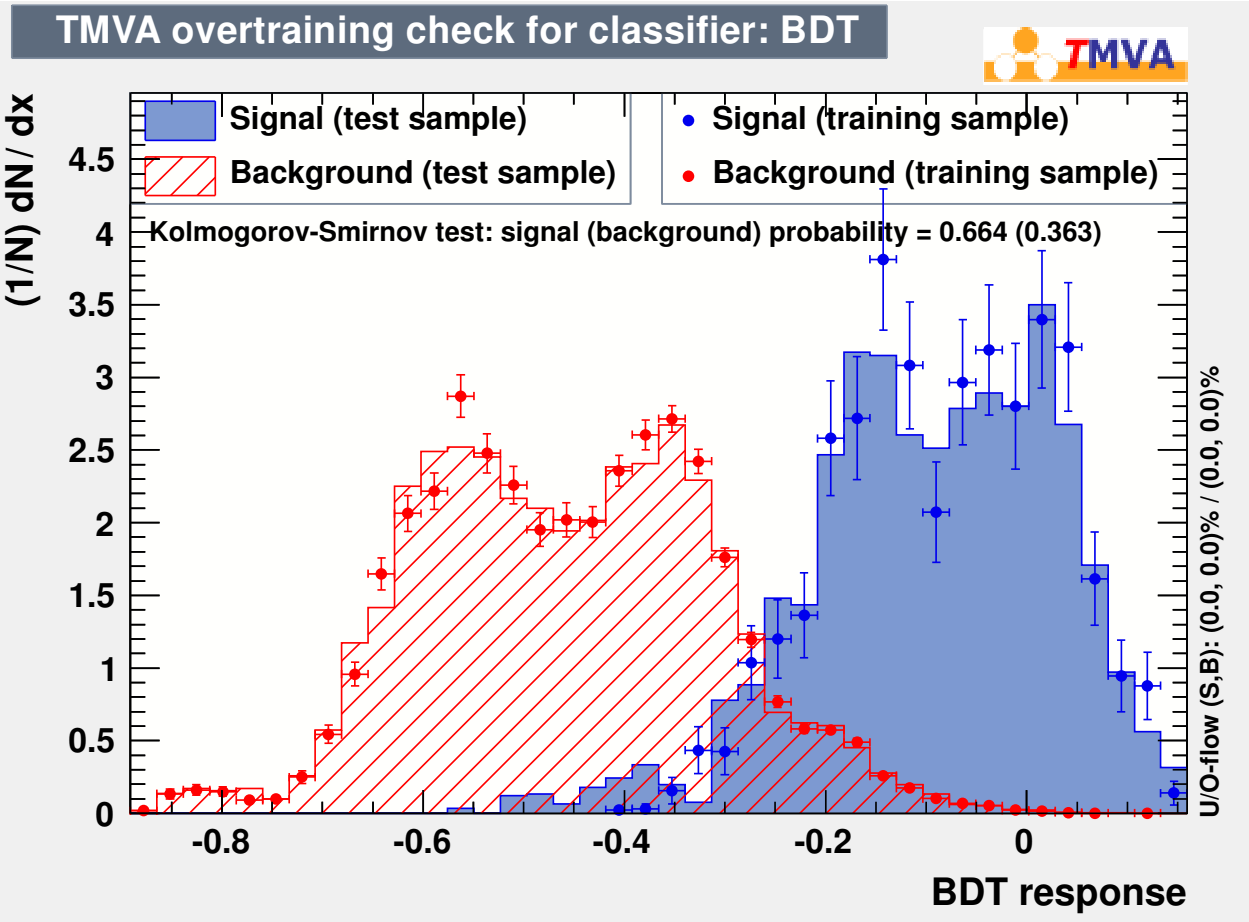
Boosted Decision Tree

- Train a BDT using the ROOT TMVA package to optimize cuts.
- BDT consists of many weighted trees, each with a few different cuts.



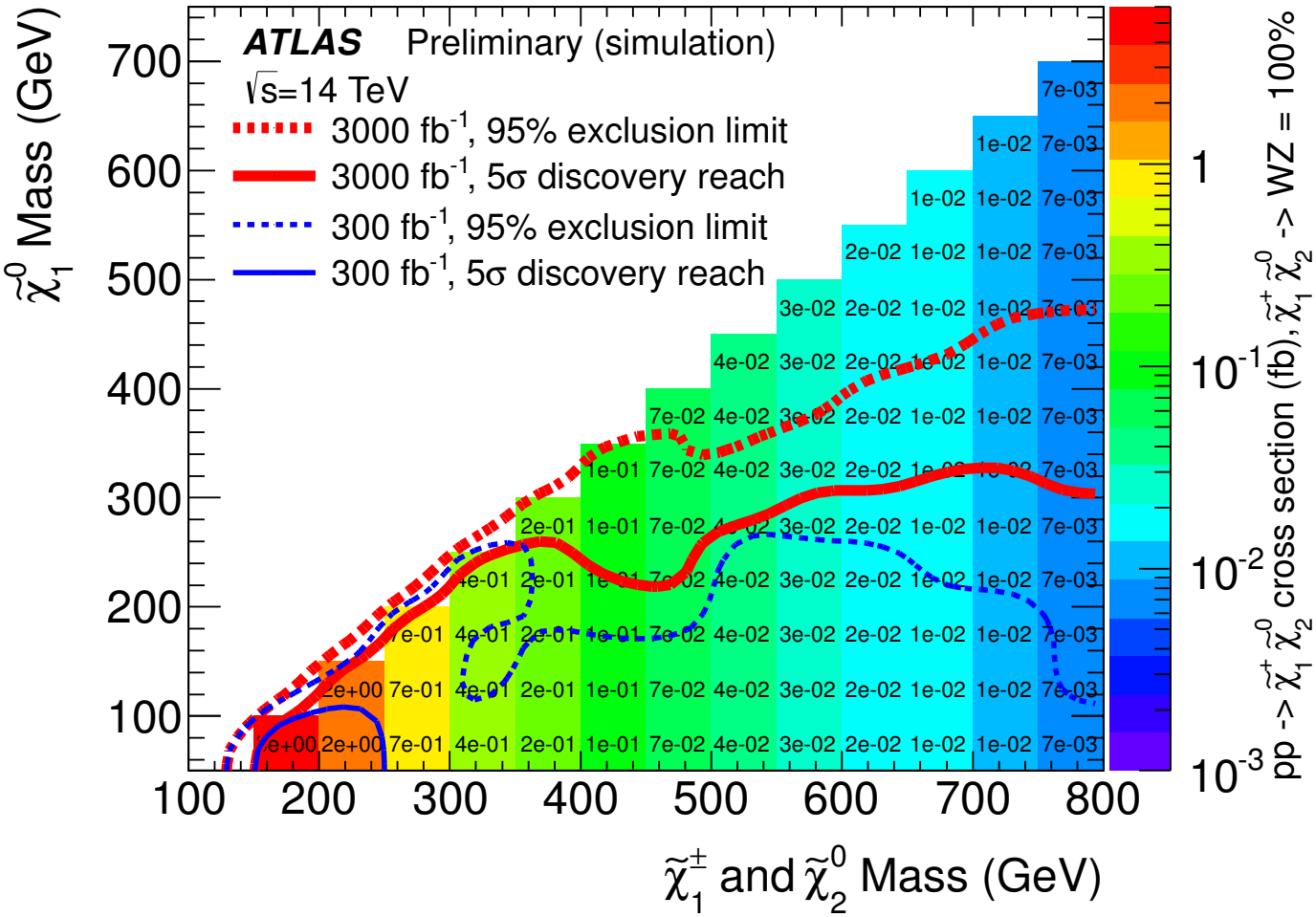
Boosted Decision Tree

- Each data point is assigned a score by the BDT.
- Cut on the BDT score to maximize the significance (roughly $S/\sqrt{B}$).



LHC and HL-LHC Sensitivity

- Run the BDT on each point in a signal grid.
- Interpret results as 95% exclusion limits and 5σ discovery reaches for LHC and HL-LHC.



Conclusion

- A SUSY model was investigated with low χ_1^0, χ_2^0 and $\chi_1^\pm$ masses and high masses for all other sparticles.
- Samples were generated and a BDT was used to select signal from background.
- The HL-LHC will be able to exclude this model for masses of χ_1^0 up to $\sim$400-500 GeV or discover it for masses of χ_1^0 up to $\sim$300 GeV.
- The results of this project are public and can be found in ATL-PHYS-PUB-2012-001.

References

ATLAS Collaboration (2012)

Search for supersymmetry in events with three leptons and missing transverse momentum in sqrt(s) = 7 TeV pp collisions with the ATLAS detector

arXiv:1204.5638

Baer et al. (2012)

WZ plus missing-E_T signal from gaugino pair production at LHC7

arXiv:1201.5382

ATLAS Collaboartion (2012)

Physics at a High-Luminosity LHC with ATLAS

ATL-PHYS-PUB-2012-001