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Projection of inclusive Search for Gluinos and Squarks at the HL-LHC ATLAS experiment

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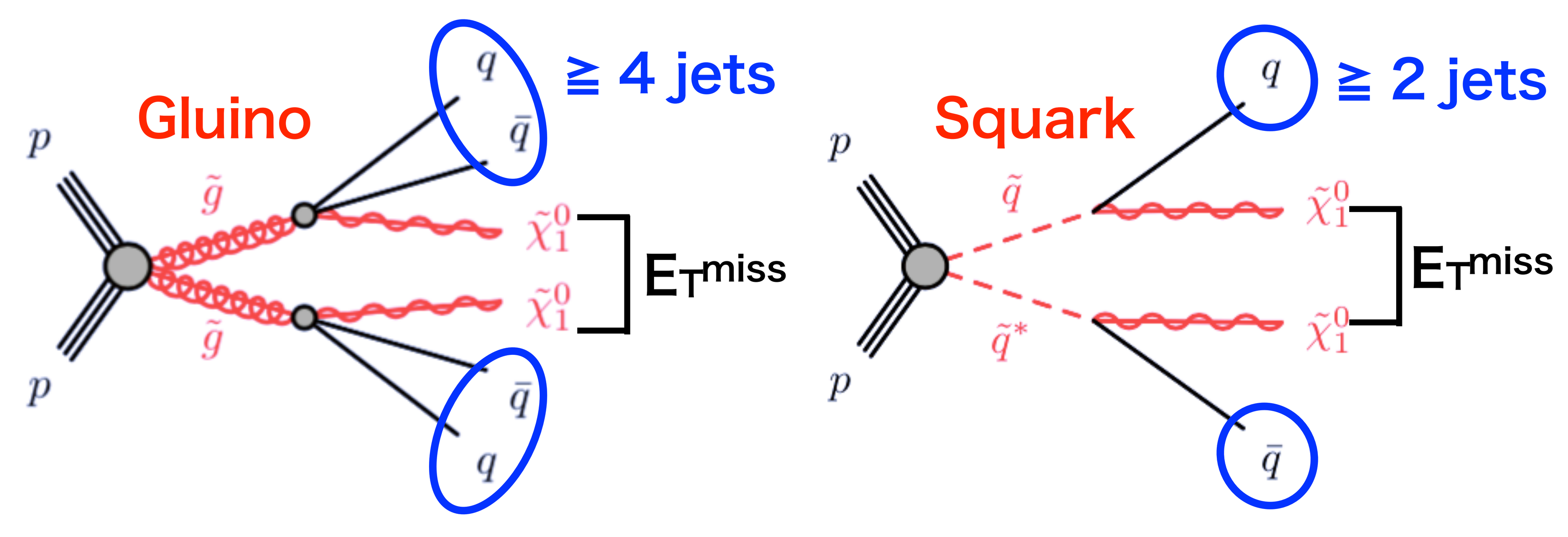
Supersymmetry is one of the most promising theories beyond the Standard Model and can solve the Hierarchy problem. For more sensitive searches of such New Physics and more precise measurements of Higgs couplings, the High Luminosity LHC (HL-LHC) experiment [1] is planned to start in 2026 which it is expected to acquire proton-proton collision data of 3000 fb^{-1} at a center-of-mass energy of 14 TeV. The ATLAS detector will be upgraded in order to cope with higher luminosities. In 2018, groups in the ATLAS and CMS experiments study projections of main physical analysis channels toward the HL-LHC experiment. In particular, we focus on strongly produced supersymmetric particles, gluinos and squarks.

1.Target signals



Gluino and squark pair production.
Decay mode : direct $\tilde{g} \rightarrow qq\tilde{\chi}_1^0$ decay of gluinos
direct $\tilde{q} \rightarrow q\tilde{\chi}_1^0$ decay of squarks
Final state : 0 lepton + ≧2 − 4 jets + missing transverse energy(E_T^{miss})

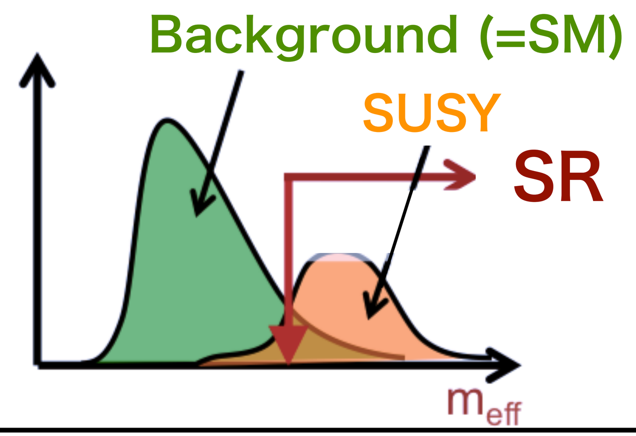
2. Technical setup

- Based on method of Run-2 analysis with 36 fb^{-1} [2].
- Used truth MC samples smeared with reconstruction information in the average pileup of 200.
- Cross section are reweighed from 13 TeV to14 TeV considering to increase parton luminosities.
- Number of MC events is scaled to number of events with 3000 fb^{-1}.
- Follow Recommendation for treatment of systematics uncertainty at the HL-LHC
  - Data-based statistics-driven source : scaled with sqrt{L} (L : Integrated luminosity)
  - Theory modeling uncertainties : halved
  - Method uncertainties : kept the same value as Run-2 analysis

3. Event selection

Main discriminating variables

- Number of jets (p_T > 50 GeV)
- m_{eff}(incl.) : the scalar sum of E_T^{miss} and transverse momenta of jets (p_T > 50 GeV)
  -> corresponded to mass of produced particle (i.e gluino pairs and squark pairs)



SUSY is searched by judging whether or not number of data events are more than SM prediction in Signal Region (SR).

The other variables

- ΔΦ(j_i, E_T^{miss}) : Angle between jets (p_T > 50 Gev) and E_T^{miss}
- E_T^{miss}/m_{eff} , $E_T^{miss}/\sqrt{H_T}$
  (H_T is scalar sum of the transverse momenta of all jets.)

-> reduce the background from multi-jet process

One of the SRs for high mass region of gluinos

- Number of jets ≧ 4, m_{eff}(incl.) ≧ 3000 GeV
- ΔΦ(j_i, E_T^{miss}) ≧ 0.4, E_T^{miss}/m_{eff} ≧ 0.2

Main Background after event selection

- Z + jets, W + jets, ttbar, single top, di/tri boson

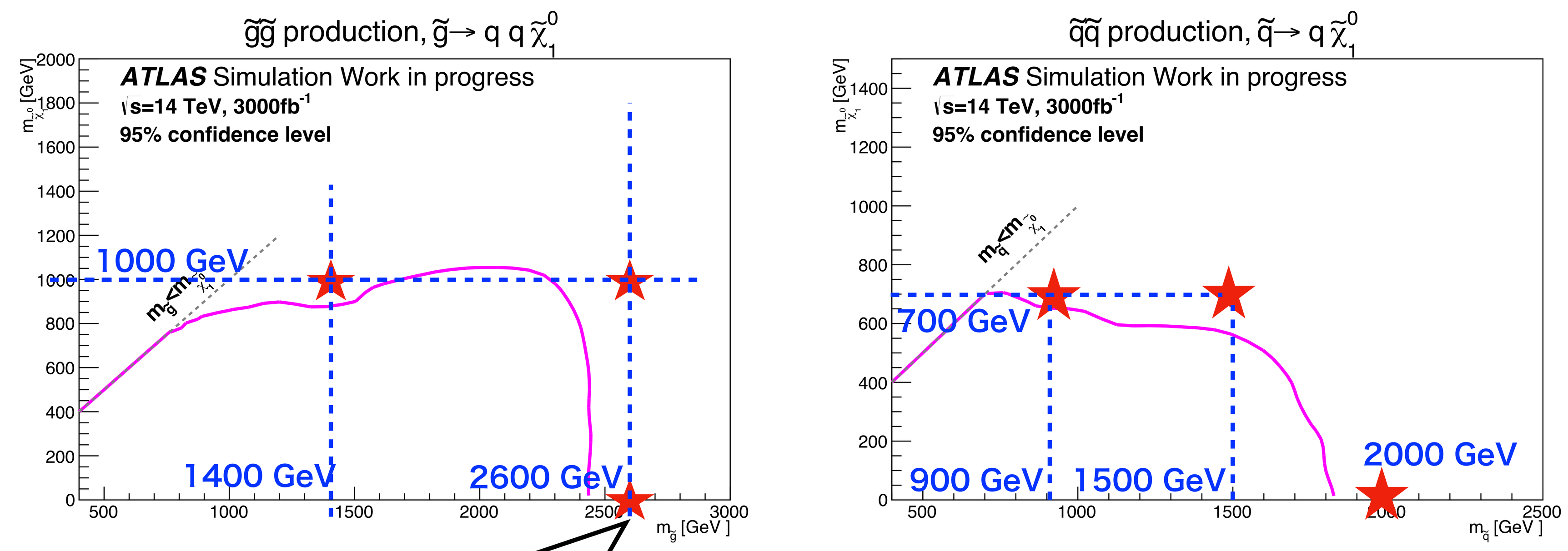
4. SR optimization

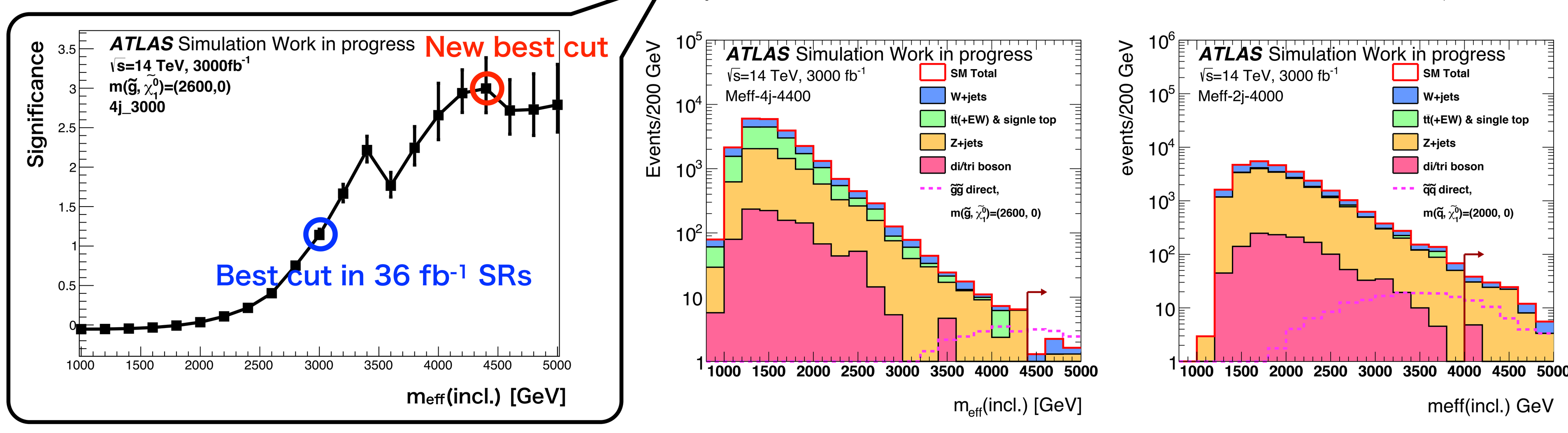
Why optimization need?

Cut should be tighter to improve significance because of high statistics at the HL-LHC experiment. In particular, optimization of m_{eff}(incl.) cut is effective for high mass region of gluinos and squarks.

Method

1. Draw expected limits using SRs of Run-2 analysis with 36 fb^{-1}.
2. Choose benchmark points(★) from out of limits.





3. Make the m_{eff}(incl.) cut tighter by 200 GeV step in each benchmark point and adopt the m_{eff}(incl.) cuts which are the highest significance as new SRs.

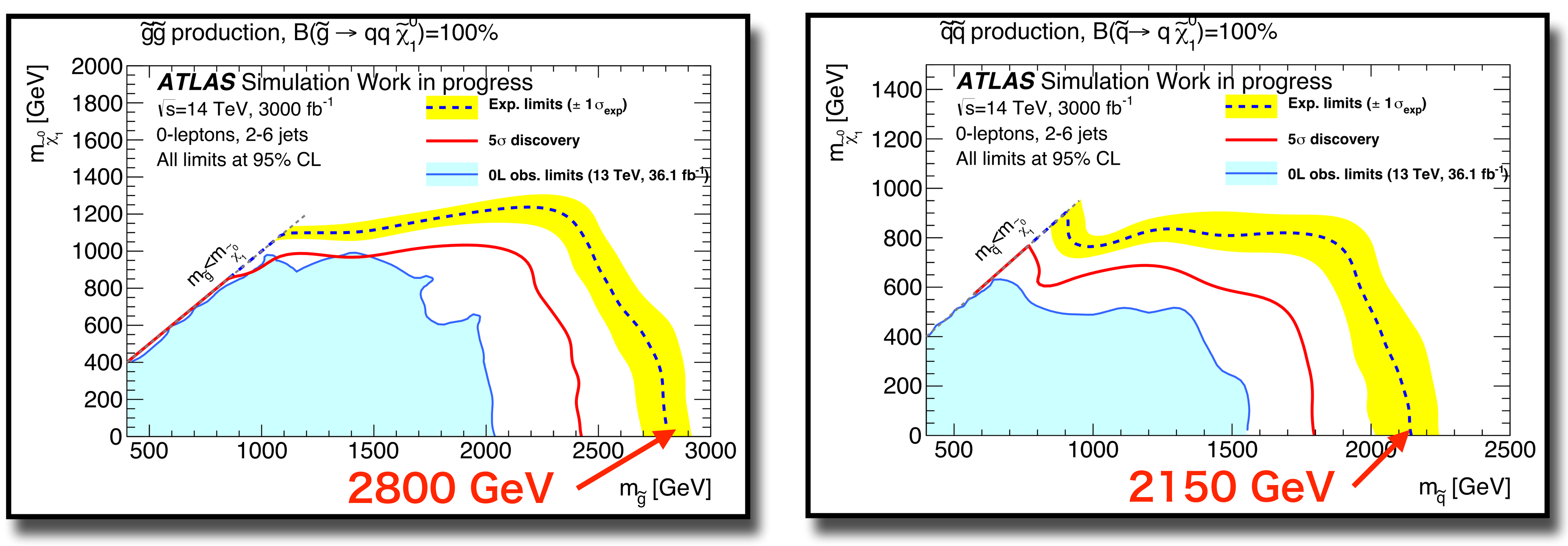
- Exclude m_{eff}(incl.) cuts that number of signal MC events is less than 10 in order not to overestimate significance.

optimized m_{eff}(incl.)

- for high mass region of gluinos : 3000 GeV —> 4400 GeV
- for high mass region of squarks : 3600 GeV —> 4000 GeV

5. Results of expected limits at the HL-LHC

- The expected exclusion sensitivity evaluation is done by performing a profile-likelihood fit.
- For each signal point, calculate p-value for the background only hypothesis(p_b) and for the signal + background hypothesis(p_{s+b}) from expected number of background and signal events.
- The ratio of p_b and p_{s+b} < 0.05 -> excluded at 95% confidence level.
- Follow recommendation for systematics uncertainty at the HL-LHC.
  -> 2−14% systematics uncertainties in each SR background yield.



- 95% confidence level expected limits for direct production of gluino pairs up to 2800 GeV and squark pairs up to 2150 GeV at the HL-LHC ATLAS experiment with 3000 fb^{-1}.

6. Conclusion

We studied projection of inclusive search for gluinos and squarks in final states with jets and missing transverse momentum at the HL-LHC. We optimized SRs due to increasing statistics at the HL-LHC. Expected limits for direct production of gluino pairs up to 2800 GeV and squark pairs up to 2150 GeV with 3000 fb^{-1}.

Reference
[1] Expected performance of the ATLAS detector at the High-Luminosity LHC, ATL-PHYS-PUB-2019-005,ATLAS collaboration; [2] Search for squarks and gluinos in final states with jets and missing transverse momentum using 36 fb^{-1} of √s = 13 TeV pp collision data with the ATLAS detector, Phys. Rev. D 97,112001, ATLAS collaboration