Search for squarks and gluinos using machine learning at the ATLAS detector

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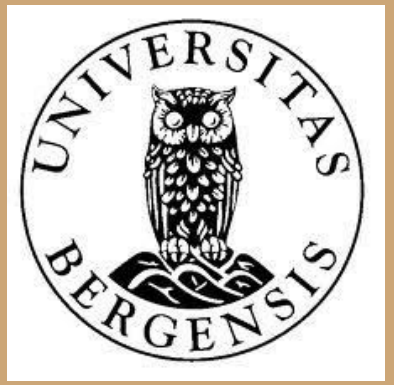
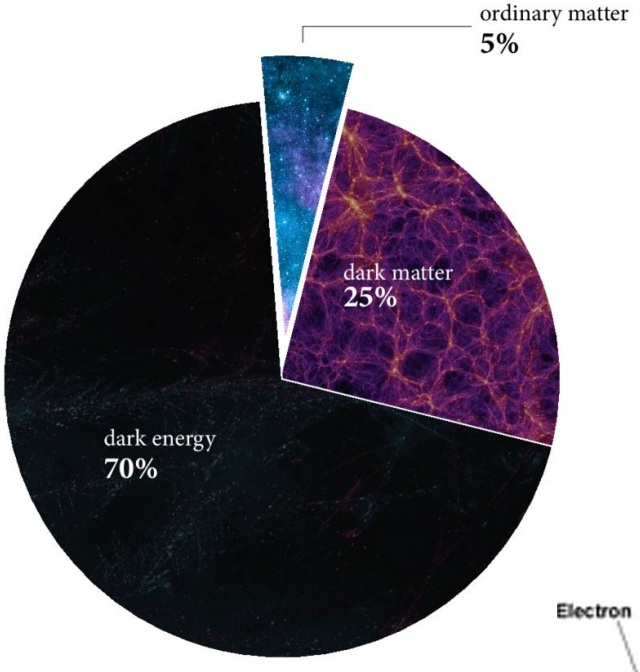


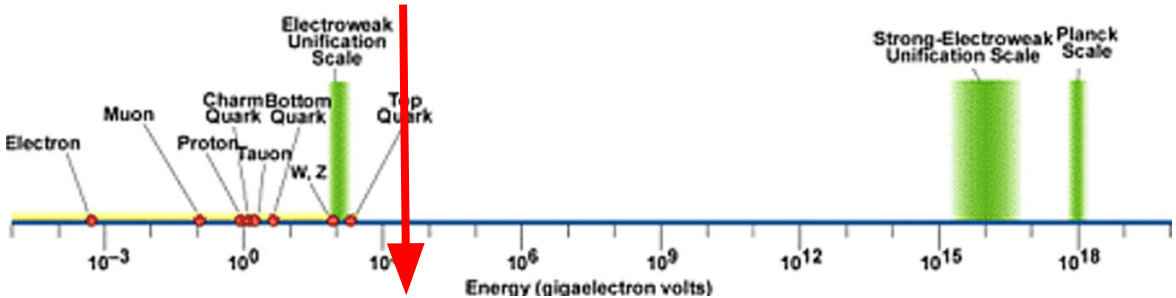
Overview

- Introduction
- Strong SUSY searches
- My analysis and methods
- Sample production
- Grid design and expected sensitivity
- Machine learning for the further analysis

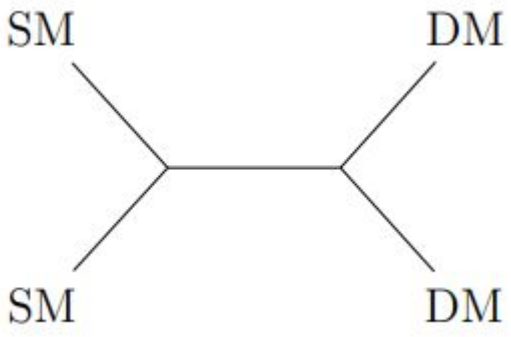
Introduction- Dark Matter



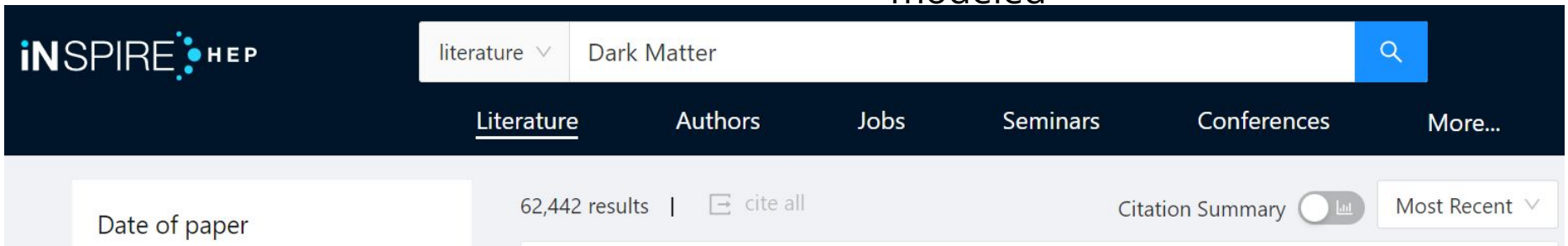
- As you probably know, we believe that baryonic matter only accounts for ~5% of the energy content of the Universe
- From null observations we can deduce that DM is weakly interacting



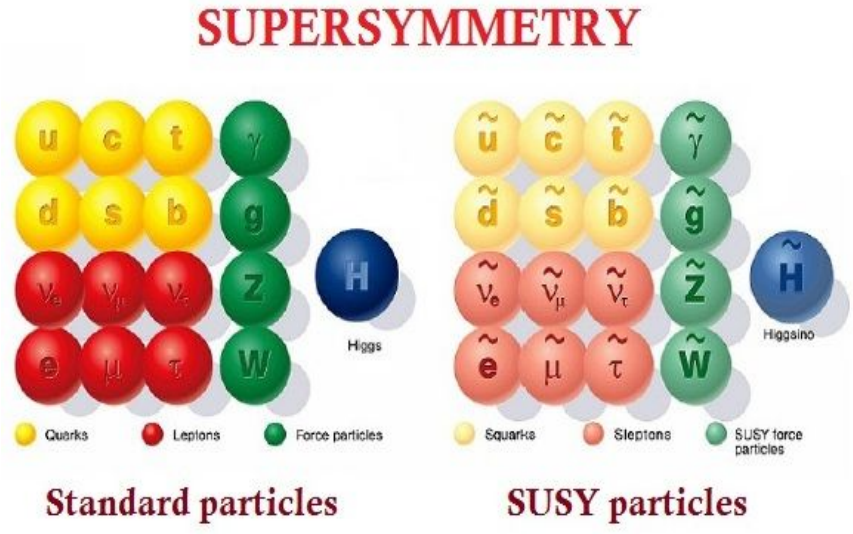
Introduction - Searching for BSM physics



- The list of BSM models is long and full of free parameters
- For searches it can be boiled down to a likelihood comparison between the SM and some BSM model
- First by comparing MC and then looking at data once the MC is well modeled



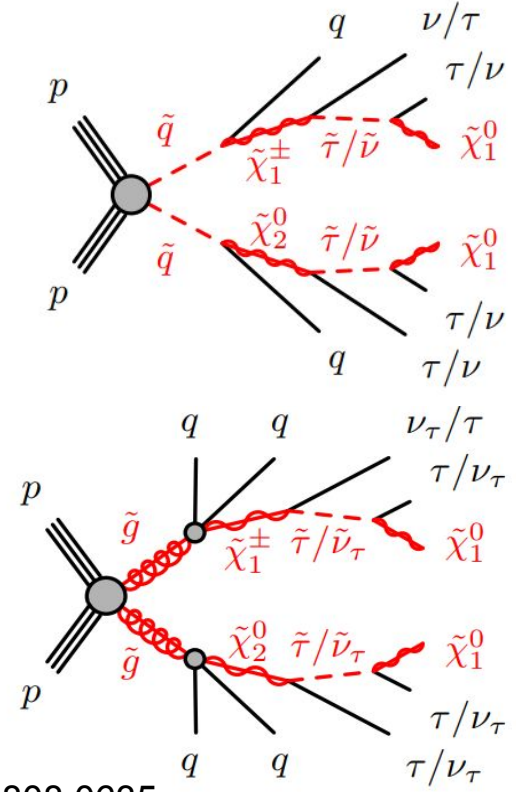
SUSY searches at ATLAS



- Supersymmetry is a well-known framework invented to (in-part) solve the hierarchy problem
- Offers a candidate for dark matter
- SUSY has 100+ free parameters
- Reduced to 20 by imposing R-parity (to prevent proton decay)
- Still way too much for an exhaustive parameter scan
- Leads to simplified models where we only consider a few degrees of freedom

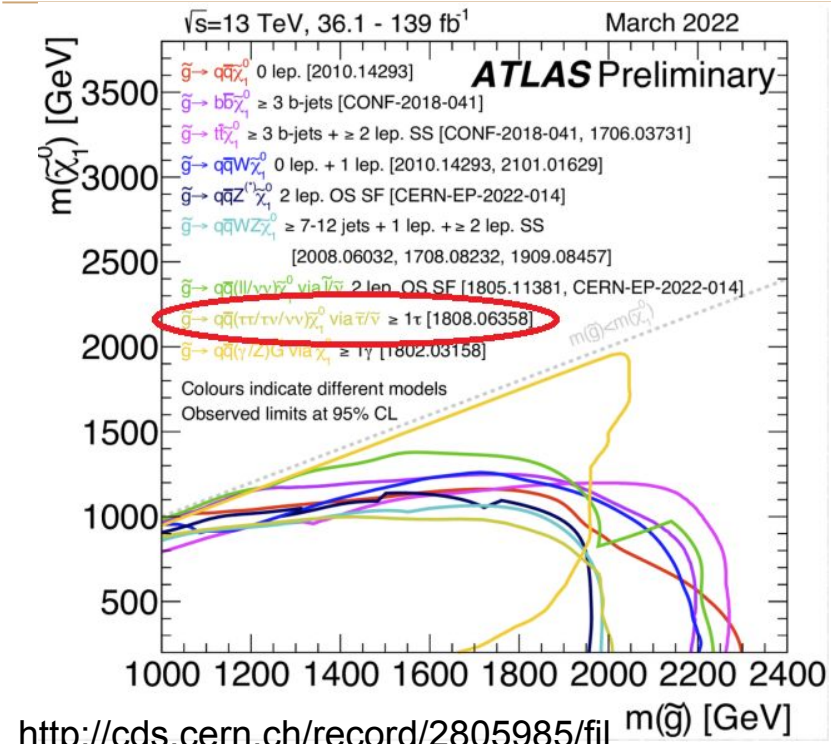
My current analysis - SUSY strong with taus

- Searching for pair production of squarks and gluinos decaying to jets, taus and missing transverse energy
- Simplified model where most SUSY particles are decoupled
- Branching ratios are assumed in the simplified models
- The free parameters are the gluino(squark) masses and the neutralino mass
- In these simplified models the neutralino is a DM candidate and is stable due to R-parity
- This analysis follows up on a partial Run 2 analysis

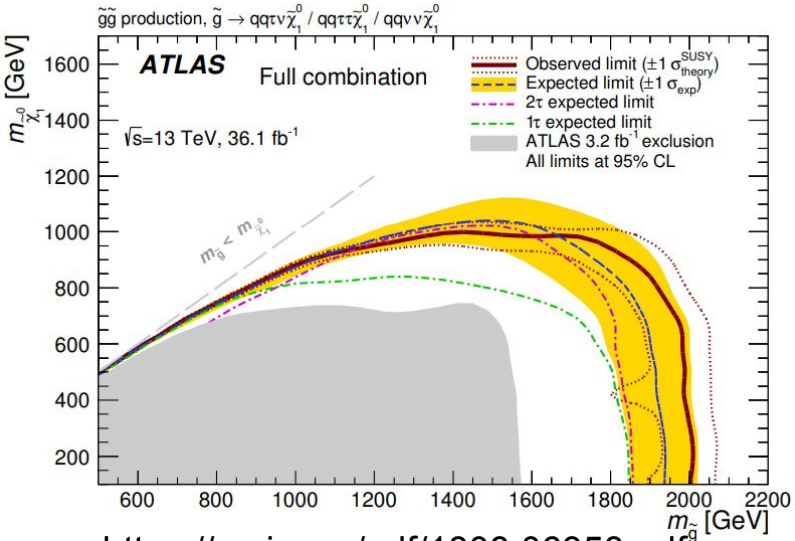


https://arxiv.org/pdf/1808.06358.pdf

Status of SUSY strong searches



http://cds.cern.ch/record/2805985/files/ATL-PHYS-PUB-2022-013.pdf



https://arxiv.org/pdf/1808.06358.pdf

- Left: Combination of all SUSY strong exclusion limits
- Right: Previous tauX analysis

Sample Productions and software

- In developing Run 3 ATLAS has undergone major upgrades
- A lot of validation between Run 2 and Run 3 software for
  - Athena
  - MadGraph
  - SimpleAnalysis
  - Pythia
- Overall good agreement between MC across versions
- Samples are then created for the squark-LSP (lightest SUSY particle) and gluino-LSP grids
- Allows for sensitivity estimation

Unfortunately no plots as they are ATLAS internal at this point

Grid design

- To perform an official ATLAS analysis we require official samples produced centrally
- Requires an estimate of the expected significance across the grid to launch
- The samples produced locally by us are not as detailed official samples → No ML optimization performed in this step
- For signal regions we used the following cuts from the previous partial Run 2 analysis
- Yields a very conservative estimate of the sensitivity
- Will be (hopefully) be improved quite significantly by using ML (XGBoost + Neural nets)

Subject of selection	1τ channel	2τ channel
Trigger	$E_{\mathrm{T}}^{\mathrm{miss}} > 180\,\mathrm{GeV}$, $p_{\mathrm{T}}^{\mathrm{jet}_1} > 120\,\mathrm{GeV}$	
Jets	$N_{\mathrm{jet}} \geq 2$, $p_{\mathrm{T}}^{\mathrm{jet}_2} > 25\,\mathrm{GeV}$	
Multijet events	$\Delta\phi(\boldsymbol{p}_{\mathrm{T}}^{\mathrm{jet}_{1,2}}, \boldsymbol{p}_{\mathrm{T}}^{\mathrm{miss}}) > 0.4$	
τ-leptons	$N_\tau = 1$	$N_\tau \geq 2$

2τ SRs	
High-mass	Multibin
$m_{\mathrm{T}}^{\tau_1} + m_{\mathrm{T}}^{\tau_2} > 350\,\mathrm{GeV}$ $H_{\mathrm{T}} > 1100\,\mathrm{GeV}$ —	$m_{\mathrm{T}}^{\tau_1} + m_{\mathrm{T}}^{\tau_2} > 150\,\mathrm{GeV}$ $H_{\mathrm{T}} > 800\,\mathrm{GeV}$ $N_{\mathrm{jet}} \geq 3$ 7 bins in $m_{\mathrm{T}}^{\tau_1} + m_{\mathrm{T}}^{\tau_2}$

The LSP - Gluino grid

- For each point in the grid I have simulated 10k events
- Total of O(2M) events
- Gluino masses up to 2200 GeV can be reached
- LSP masses of 1200 GeV can be reached
- Expected improvement b about 200 GeV in both axes
- Will be even further improved by ML

$$Z_A = \left[2\left((s+b)\ln\left[\frac{(s+b)(b+\sigma_b^2)}{b^2+(s+b)\sigma_b^2}\right] - \frac{b^2}{\sigma_b^2}\ln\left[1+\frac{\sigma_b^2 s}{b(b+\sigma_b^2)}\right]\right)\right]^{1/2}$$

Unfortunately no plots as they are ATLAS internal at this point

Plans for Machine learning

- Once official samples are received -> start the ML optimization
- Framework ready for XGBoost and Neural Networks
- In addition I'm also working on tau identification using RNNs as a qualification task
- New RNN algorithm for tauID is very promising (Interal for now)
- With ML and full Run 2 + developing Run 3 I hope to reach 2400 GeV gluino masses for LSP masses up to 1200 GeV