Search for the lightest MSSM Higgs boson in a cascade of supersymmetric particles in ATLAS

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Outline

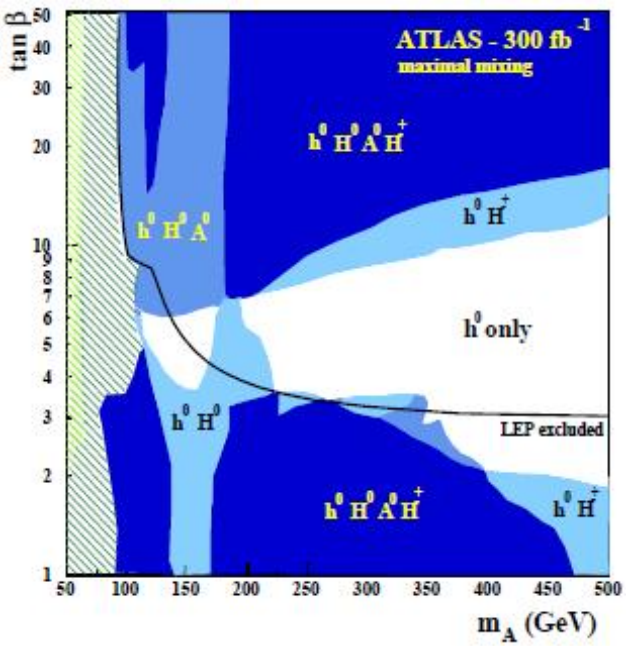
- Introduction
- Why a SUSY cascade?
- Background studies
- B-tagging
- Summary and outlook

Introduction

- Supersymmetry (SUSY) is one of the most believed *new physics* phenomena
- Need two Higgs doublets:

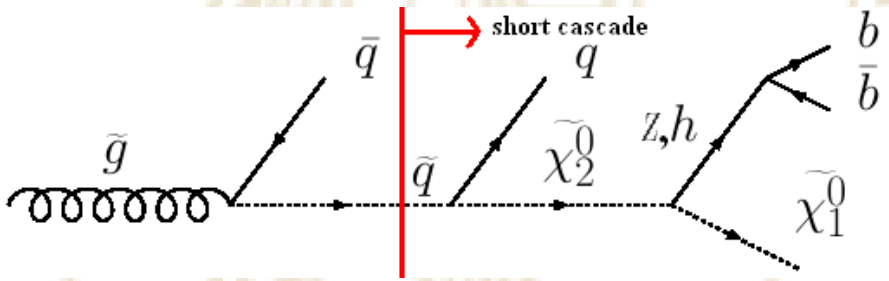
$$H_u = \begin{pmatrix} h_u^+ \\ h_u^0 \end{pmatrix}, \qquad H_d = \begin{pmatrix} h_d^- \\ h_d^0 \end{pmatrix},$$

  to give mass to up and down type fermions
- 8^o of freedom, so SUSY predicts 5 Higgs bosons
  - The lightest Higgs, h. $m_h < 135$GeV
  - Heavy, CP-even, Higgs, H
  - Charged Higgs, $H^{\pm}$
  - CP-odd Higgs, A
- the lightest Higgs (if it exists) should be discovered at the LHC
- Ratio of vacuum expectation values (vev) of up and down field: $\tan\beta = v_u/v_d$



Why SUSY cascade?

- The lightest Higgs, h, can be produced either through
  1. direct interaction of SM particles (e.g.: gluon-gluon fusion)
  2. cascade of SUSY particles
- In a cascade of SUSY particles you will have (together with h):
  - Missing transverse energy ($\not{E}_T$) from LSP (Lightest Supersymmetric Particle) (if R-parity conservation)
  - two or three hard jets



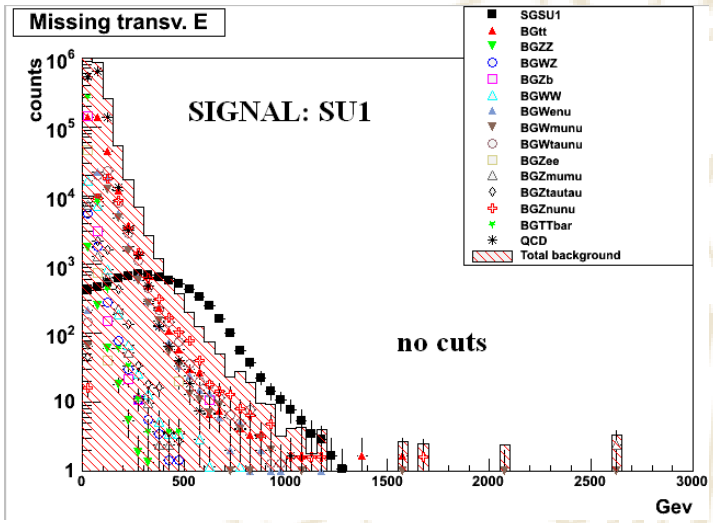
- When (if) a Higgs is discovered: nearly impossible to determine if it is a SUSY or a SM Higgs...., but
  - a SUSY cascade will have different signature than an ordinary SM cascade, a way to distinguish between them
- also a way to remove dominant SM background, which makes it possible to study the decay $h \longrightarrow b\bar{b}$

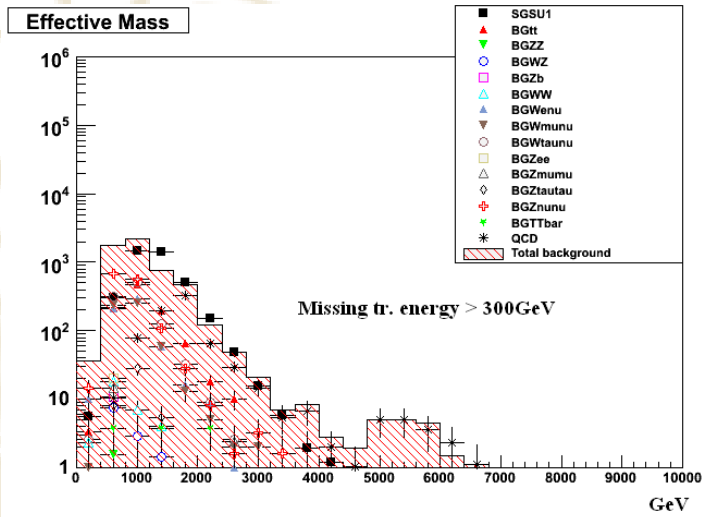
Background Studies

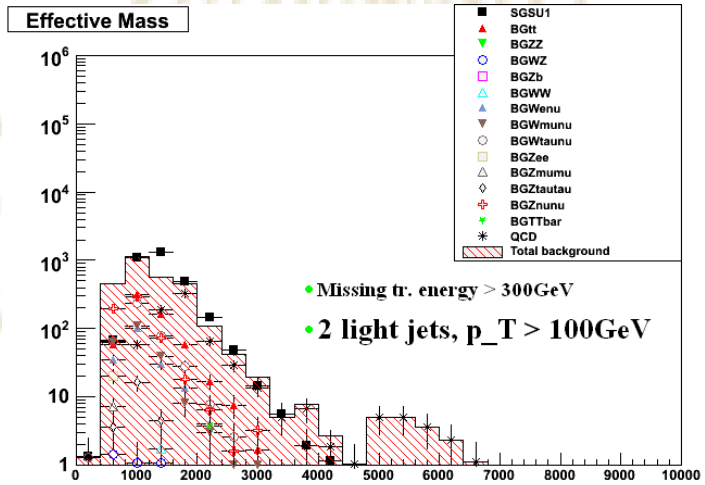
- Looking at two of the ATLAS mSUGRA benchmark points, the Co-annihilation (SU1) and Focus Point region (SU2)

	SU1	SU2	SU3	SU4	SU6	SU8.1
Region	Co-annihil.	Focus P.	Bulk	Low mass	Funnel	Co-annihil.
σ [pb]	7.43	4.86	18.59	262		6.44
sparticle	**mass [GeV]**					
h^0	113	118	113	110	114	114
squarks	≈ 730	≈ 3500	≈ 1200	≈ 400	≈ 850	≈ 800
gluino	829	857	775	410	892	850
$\widetilde{\chi}_1^0$ (LSP)	140	99	123	61	153	146
$\widetilde{\chi}_2^0$	262	155	233	113	287	274
A_0	513	3507	1101	369	402	439
decay	**Branching Ratio [%]**					
$\widetilde{\chi}_2^0 \rightarrow \widetilde{\chi}_1^0 h$	5	37	0	0	4	3
$\widetilde{\chi}_2^0 \rightarrow \widetilde{\chi}_1^0 Z$	1	63	100	0	1	1
$h \rightarrow b\bar{b}$	75	66	73	77	66	69

Background Studies

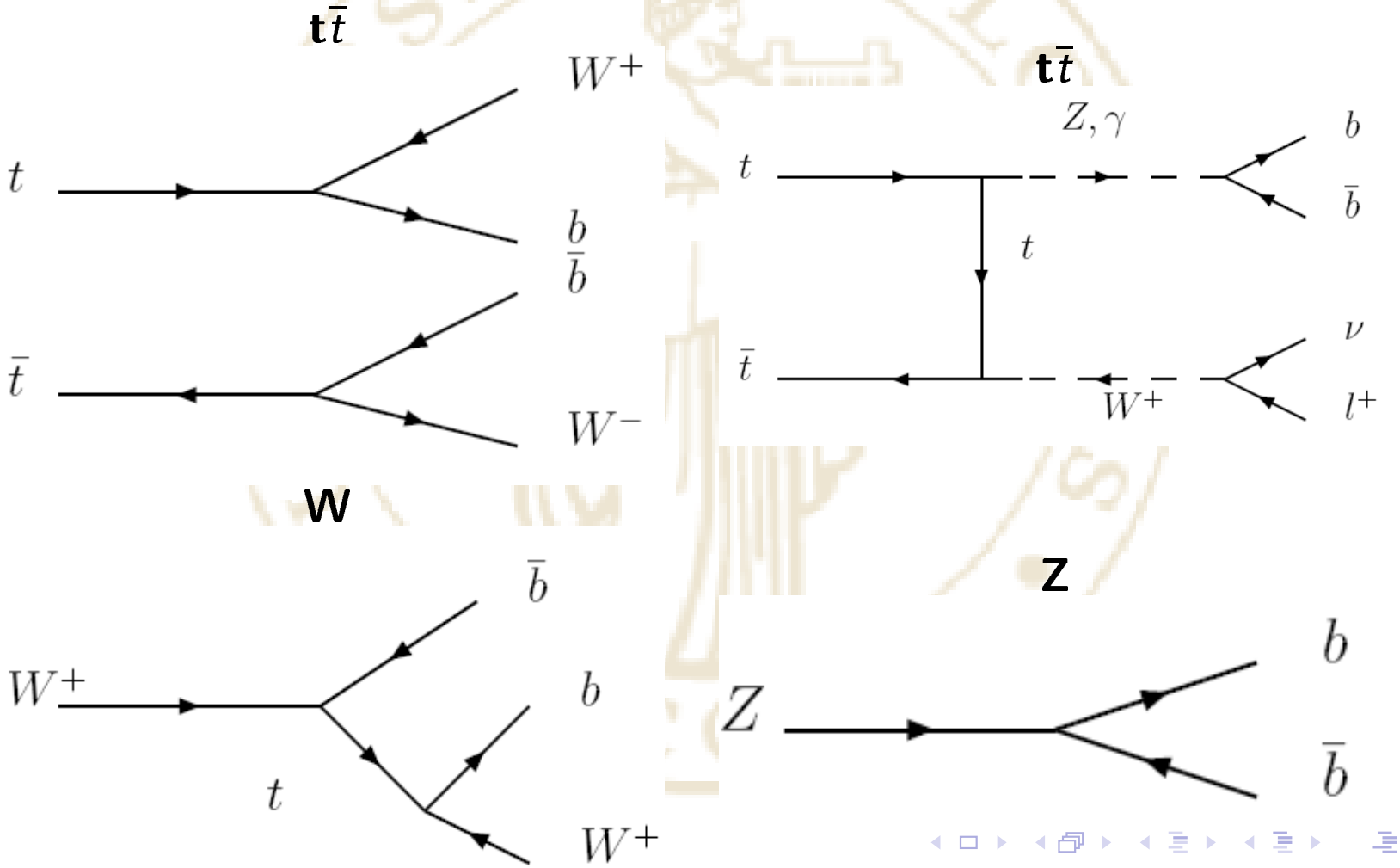






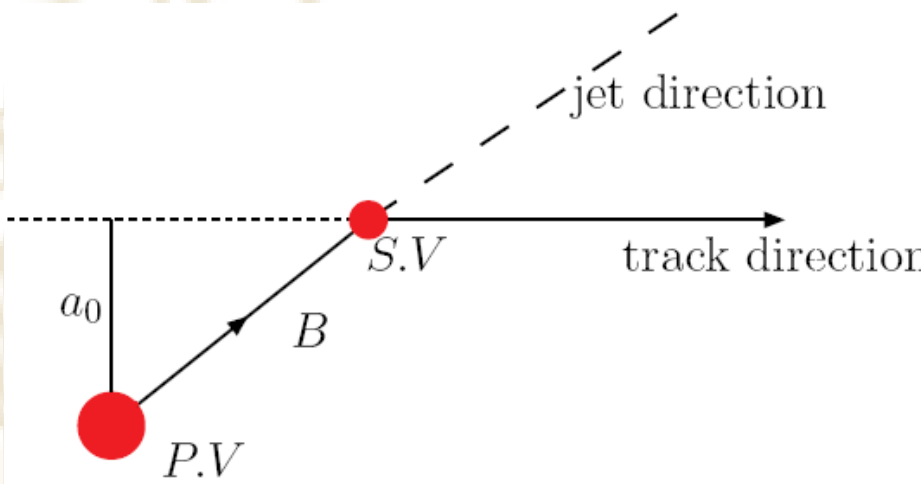
Background Studies

- Most important SM background: $t\bar{t}$ and vector boson production



B-tagging

- since $m_h < 135\text{GeV}$, the decay $h \to b\bar{b}$ is dominant $(60 - 70\%)$. Therefor: need to tag the b-quarks coming from the Higgs
- B-mesons have long lifetime, so they travel a distance before decaying
- identified to not come from the primary vertex



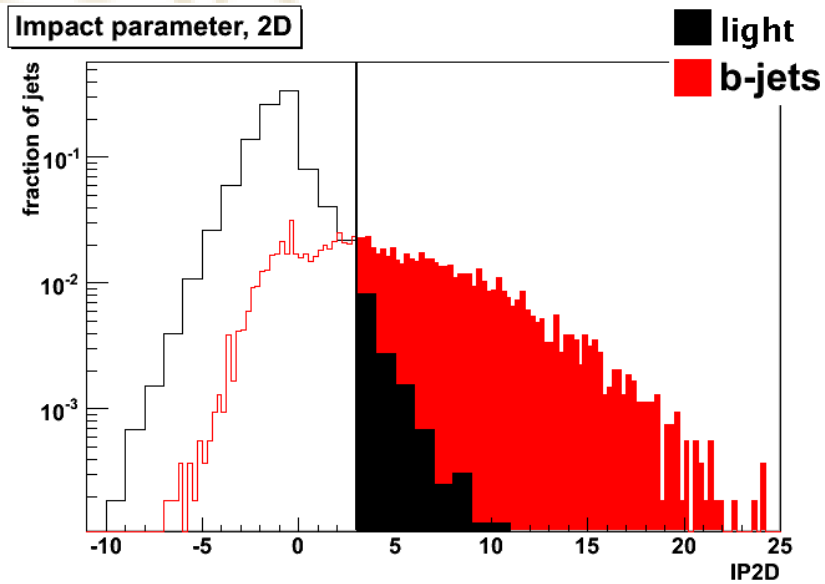
- the Impact Parameter (IP) is the distance the projected track from the decay of the B meson is from primary vertex (a_0)
- define track significance: $S_{track} = a_0/\sigma_{a_0}$.
- normalize distributions of S_{track} for different hypotheses, i.e: b-quarks and light quarks or gluons (l: u,d,s,g)
- define track weight as $b(S_i)/l(S_i)$

B-tagging

- For each jet, build a jet weight:

$$W_{jet} = \sum_{i=1}^{N_{track}} \ln \frac{b(S_i)}{l(S_i)}.$$

- The jet weigh is a probability of a jet being a b-jet



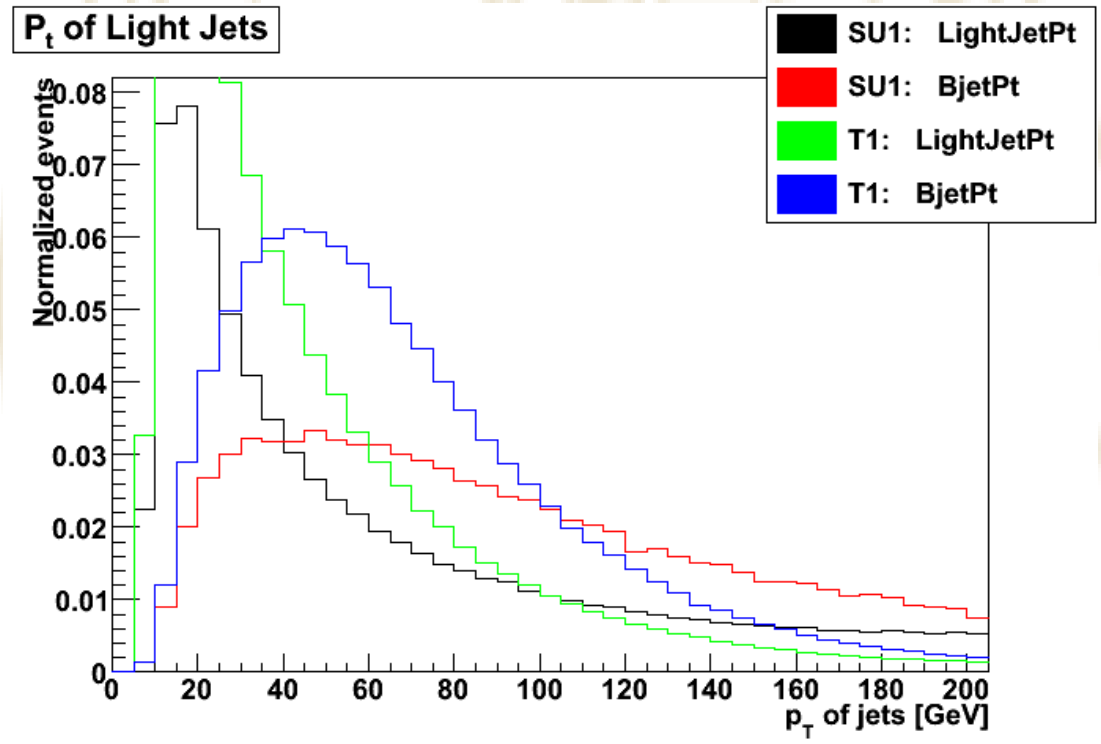
Dataset: SU1, $\varepsilon_b = 0.6$

- Define efficiency and rejection as

$$\varepsilon_b = \frac{b_{tagged}}{b_{all}} \quad R_l = \frac{l_{all}}{l_{mistagged}}$$

B-tagging

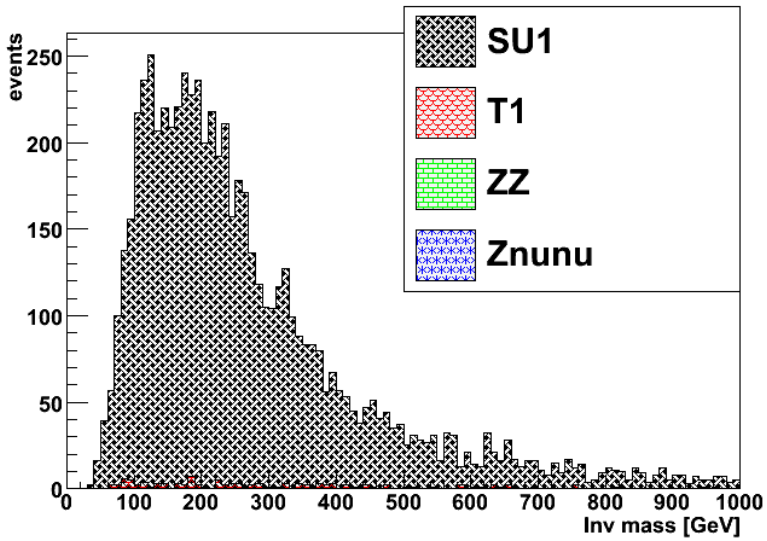
- we see that the b-jets in a SUSY sample are harder then in a SM sample.



p_T of the tagged b-jets in the $t\bar{t}$ sample and the SU1 sample. Tagging efficency is 0.6

A starting point for further analysis

- SM background is not a big problem
- signal is buried under a lot of SUSY background
- need to do more detailed studies:
  - optimize the b-tagging
  - reject the b-jets coming from other sources (e.g: sbottom decay)
  - more optimized and model independent cuts
  - search in other mSUGRA scenarios



- $\not{E}_T > 300\text{GeV}$
- at least 2 light flavoured jets with $p_T > 100\,GeV$
- B-tagging: IP$>$ 2 and $p_T > 50\text{GeV}$

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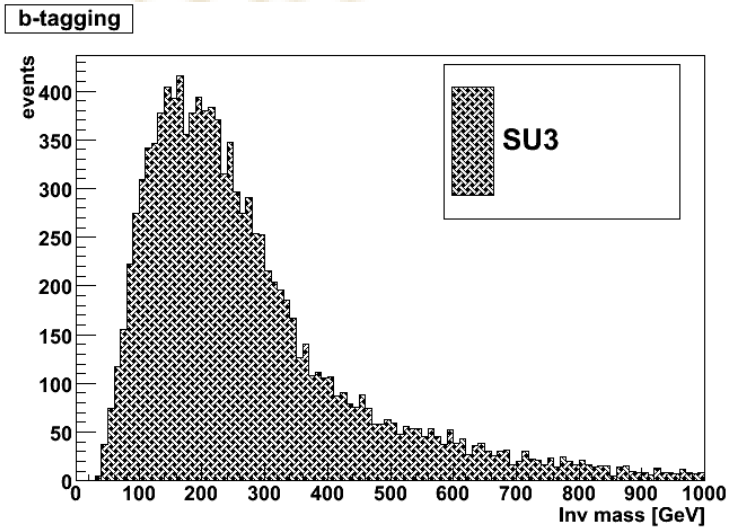

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Summary and Outlook

- SUSY predicts 5 Higgs bosons
- since the mass of the lightest Higgs, m_h, is believed to be below 135GeV, $b\bar{b}$ is the most interesting channel
- in SM: this channel is buried under huge QCD background
- in SUSY cascade: can use the $\not{E}_T$ signature to remove dominant SM background, the dominant background is then other SUSY events
- since B mesons have a long lifetime, there is possible to distinguish b-jets from other jets using Impact Parameter.
- SM background not a big problem, the challenge is to remove the SUSY background