Seaching for sgluons in the same-sign leptons final state at the LHC

Wojciech Kotlarski[2]

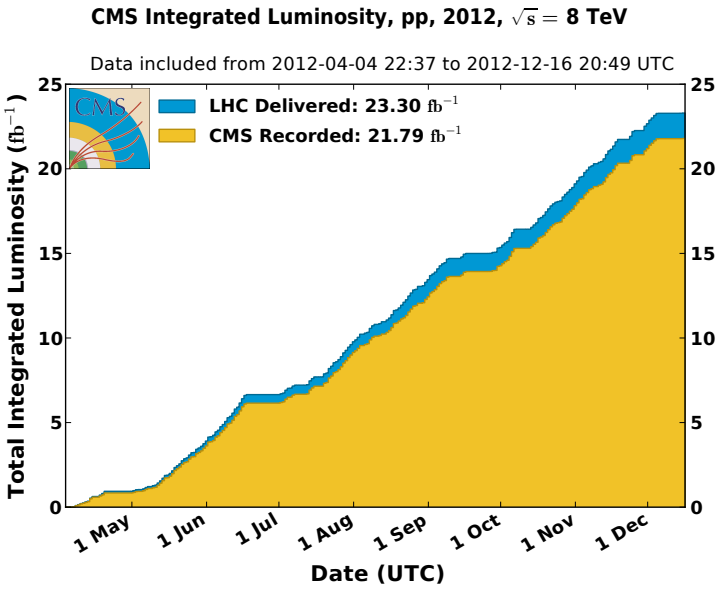
Faculty of Physics, University of Warsaw

Ustroń, September 4, 2013

[2]Work done with Artur Kalinowski and Jan Kalinowski

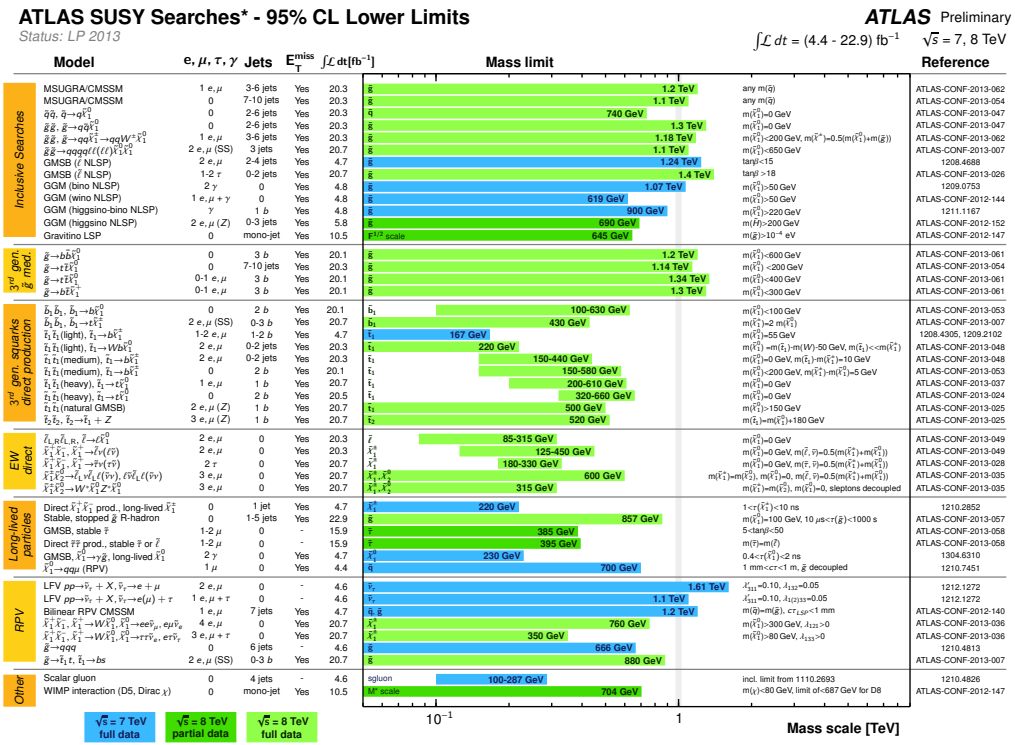
Motivation

- LHC has performed marvellously
- A Higgs-like particle of a mass around 125 GeV has been found

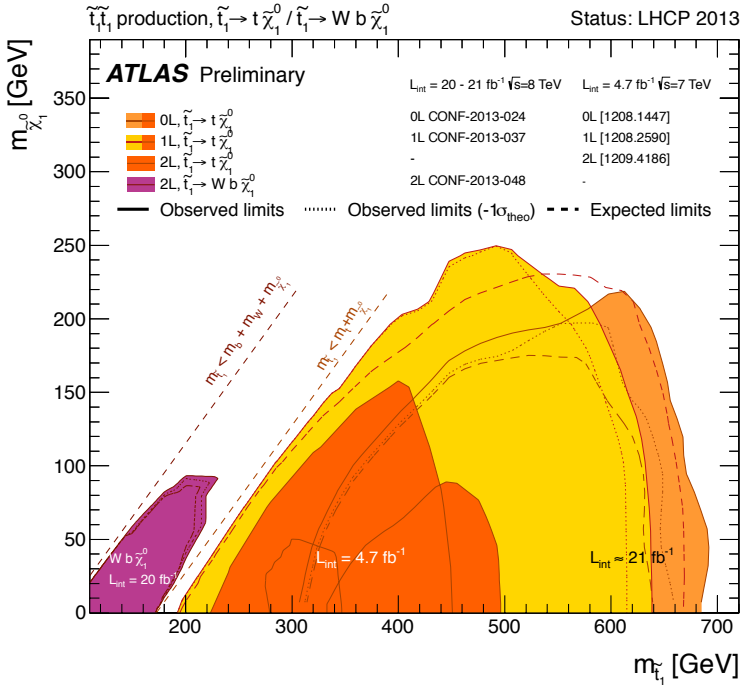


- $\approx$ 20/fb of integrated luminosity has been gathered per experiment
- Long shut down in progress - time to analyse gathered data in the context of your favourite model

SUSY searches



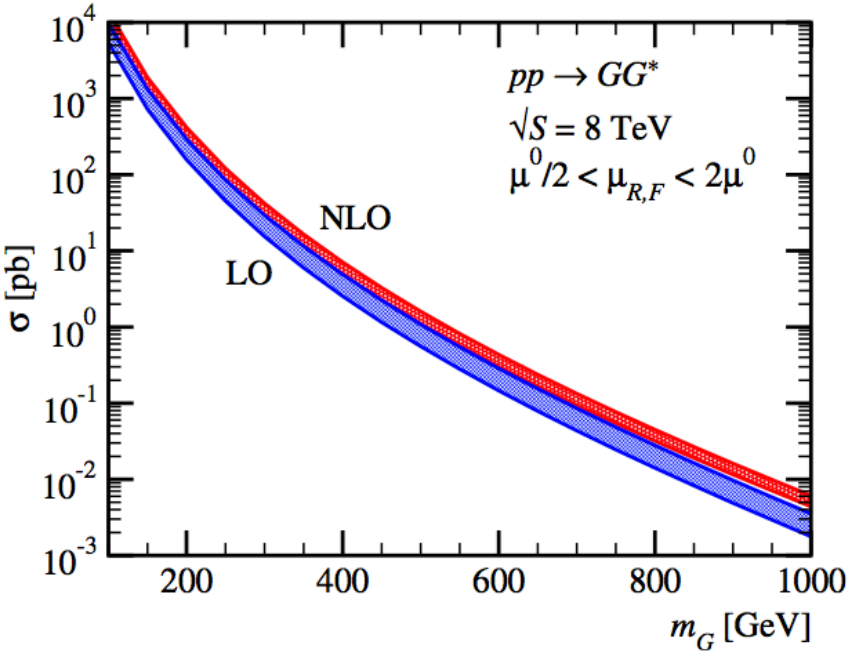
*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.



New limits on "new physics" but SUSY is still alive

Color octet scalars

- Lorentz-scalars in the adjoint representation of $SU(3)_C$ appear in many different models
  - R-symmetric and $\mathcal{N} = 1/\mathcal{N} = 2$ hybrid SUSY models
  - technicolor
  - ...
- Can have distinct experimental signature
- Pair production is model independent [Phys. Rev. D 85.114024]



	$\sqrt{S} = 8$ TeV			$\sqrt{S} = 14$ TeV		
m_G [GeV]	σ^{LO}[pb]	σ^{NLO}[pb]	K	σ^{LO}[pb]	σ^{NLO}[pb]	K
200	2.12×10^{2}	3.36×10^{2}	1.58	9.77×10^{2}	1.48×10^{3}	1.52
350	8.16×10^{0}	1.36×10^{1}	1.66	5.44×10^{1}	8.46×10^{1}	1.56
500	7.64×10^{-1}	1.34×10^{0}	1.75	7.14×10^{0}	1.14×10^{1}	1.60
750	3.40×10^{-2}	6.54×10^{-2}	1.93	5.56×10^{-1}	9.29×10^{-1}	1.67
1000	2.47×10^{-3}	5.29×10^{-3}	2.15	7.31×10^{-2}	1.28×10^{-1}	1.75

Minimal R-symmetric Supersymmetry

- Symmetry of the every SUSY algebra, discussed already by Fayet in '75
- Global continuous $U(1)$ symmetry under which $\theta \to e^{\imath\alpha}\theta$. Convention $R(\theta) = 1$ implies that $R(d\theta) = -1$, $R(\bar{\theta}) = -1$, $R(d\bar{\theta}) = 1$
- Gauge invariance requires that gauge fields have $R(\hat{G}) = 0$
- Kähler potential invariant by default
- $V = \int d^2\theta W(\{\Phi_i\}) \Rightarrow$ superpotential have R-charge 2.
- Transformation of superfield with charge ξ_i

$$\hat{\Phi}_i(x^\mu, \theta, \bar{\theta}) = e^{\imath\xi_i\alpha}\hat{\Phi}_i(x^\mu, e^{\imath\alpha}\theta, e^{-\imath\alpha}\bar{\theta})$$

- For chiral supermultiplet different spin component must have different R-charges. One of possible choices
  - chiral (matter) $\hat{q}$: $R(\hat{q}) = 1 \Rightarrow R(\tilde{q}) = +1, R(q) = 0$
  - chiral (Higgs) $\hat{H}$: $R(\hat{H}) = 0 \Rightarrow R(H) = 0, R(\tilde{H}) = 1$
- Allowed terms: Yukawa, soft-scalar masses
- Forbidden terms: μ-term, L- and B- violating terms, trilinear scalar couplings, Majorana gaugino masses
- No trilinear couplings minimizes flavour violation

MRSSM field content

- chiral superfield in the adjoint of $SU(3)_C$: $\hat{\Sigma} = \{\sigma^a, \tilde{G}'^a\}$ to build a Dirac gluino

$$R(\hat{\Sigma}) = 0 \Rightarrow R(\sigma) = 0, R(\tilde{G}') = -1$$

  and the same for other gauginos

- two chiral iso-dublets with R-charge $+2$ to build a μ-term:

$$W \ni \mu_D \hat{H}_D \hat{R}_D + \mu_U \hat{H}_U \hat{R}_U$$

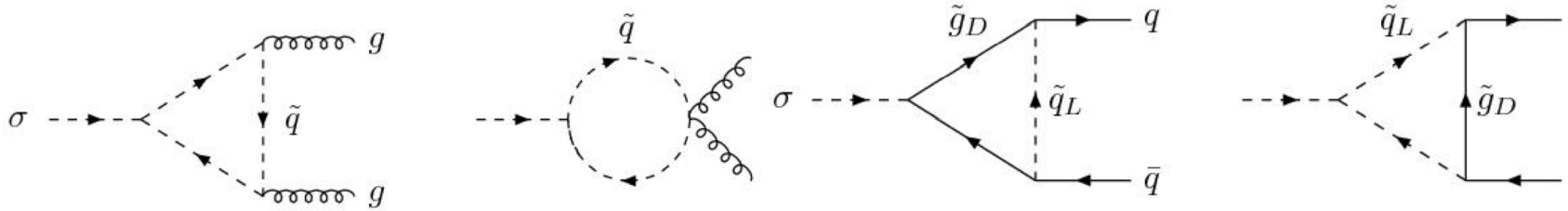
Field	Superfield		Boson		Fermion	
Matter	$\hat{Q}, \hat{D}^c, \hat{U}^c$	$+1$	$\tilde{Q}, \tilde{D}^c, \tilde{U}^c$	$+1$	Q, D^c, U^c	0
Higgs	$\hat{H}_{d,u}$	0	$H_{d,u}$	0	$\tilde{H}_{d,u}$	-1
	$\hat{R}_{d,u}$	$+2$	$R_{d,u}$	$+2$	$\tilde{R}_{d,u}$	$+1$
Gauge Vector	$\hat{G}$	0	G_μ	0	$\tilde{G}$	$+1$
Gauge Chiral	$\hat{\Sigma}$	0	σ	0	$\tilde{G}'$	-1

Sgluons in MRSSM

- Lagrangian for the sgluon sector

$$\mathcal{L} = -\sqrt{2}\imath g_s f^{abc}\overline{\tilde{g}^a_{D,L}}\tilde{g}^b_{D,R}\sigma^c - g_s M^D_G \sigma^a \frac{\lambda^a_{ij}}{\sqrt{2}} \sum_q \left(\tilde{q}^*_{i,L}\tilde{q}_{j,L} - \tilde{q}^*_{i,R}\tilde{q}_{j,R}\right) +$$
$$-\sqrt{2}g_s\left(\overline{q_L}\frac{\lambda^a}{2}\tilde{g}^a_R\tilde{q}_L - \overline{q_R}\frac{\lambda^a}{2}\tilde{g}^a_L\tilde{q}_R\right) + \text{h.c.}$$

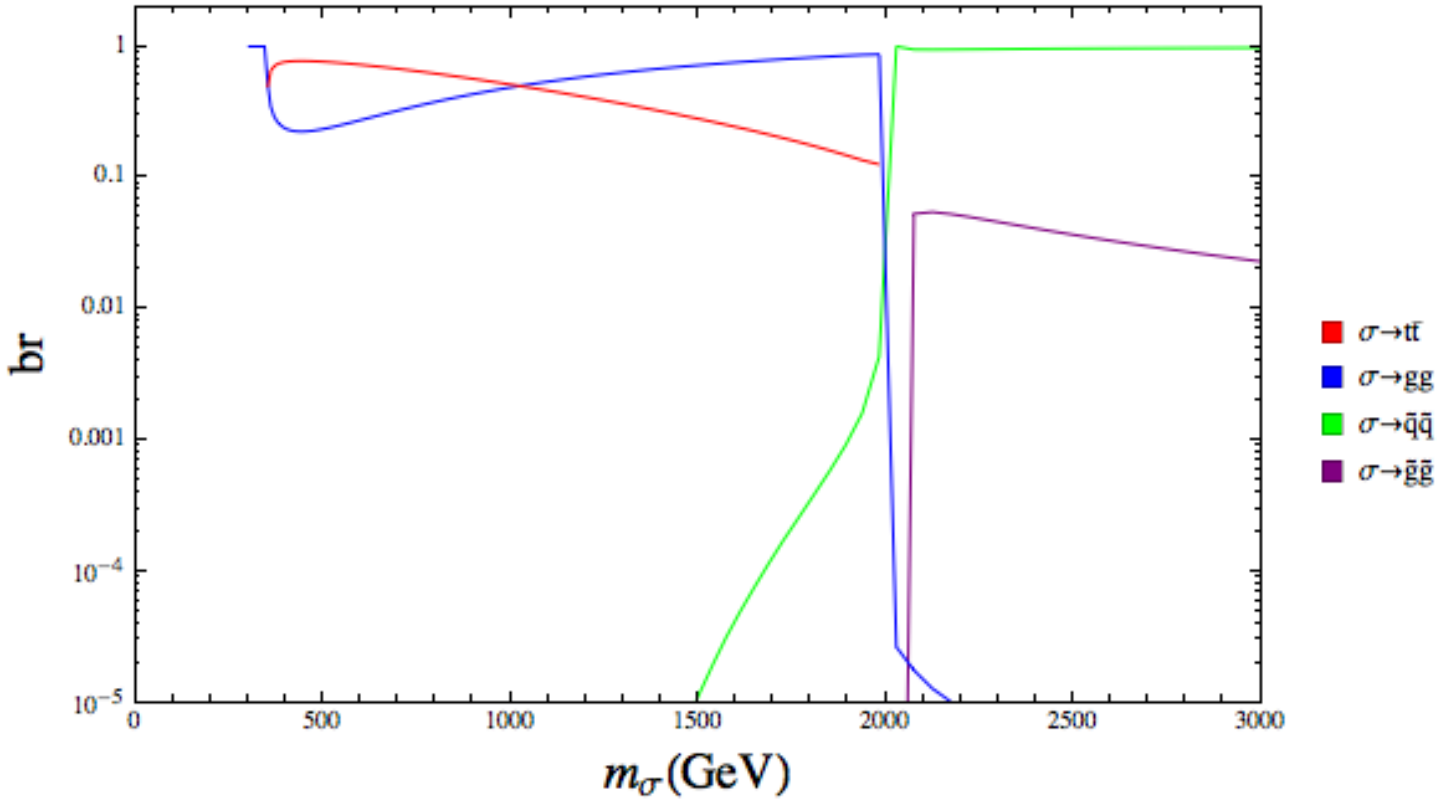
- R-charge of sgluon is the same as that of SM particles
- Loop induced couplings to gluons and quarks



- $\sigma q\bar{q}$ coupling proportional to $m_q \Rightarrow$ decay channel only relevant for top quarks
- couplings vanish for degenerate squarks

Sgluon's branching ratios

- Exemplary MRSSM parameter point[10]:

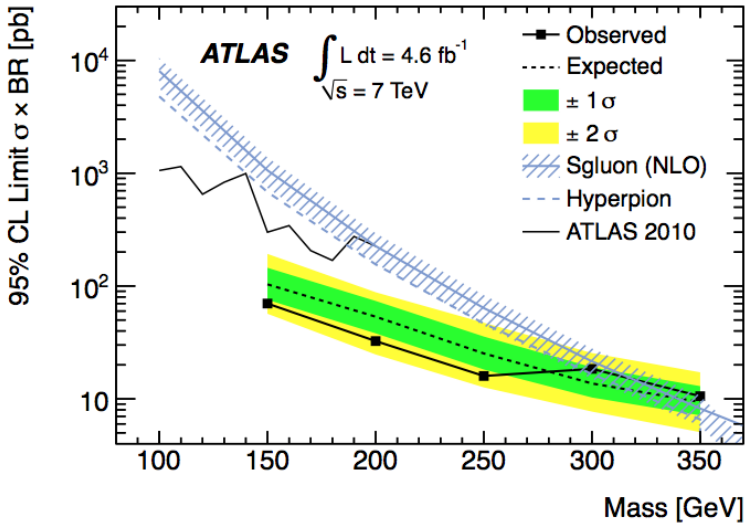


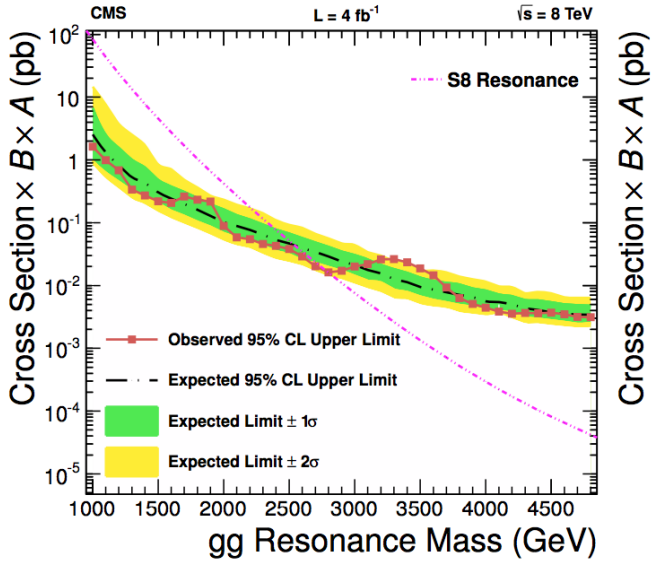
- Easy to arrange a scenario in which bellow 1 TeV sgluons decay mainly to $t\bar{t}$ pairs

[10] $m_{\tilde{g}} = 1$ TeV, $m_{\tilde{q}_L} = 4$ TeV, $m_{\tilde{q}_R} = 0.95 m_{\tilde{q}_L}$, $m_{\tilde{b}_R} = 0.35 m_{\tilde{q}_L}$, $m_{\tilde{b}_L} = 0.4 m_{\tilde{q}_L}$, $m_{\tilde{t}_R} = 0.25 m_{\tilde{q}_L}$, $m_{\tilde{t}_R} = 0.25 m_{\tilde{q}_L}$

Possible experimental signatures

- di-jet signature for $m_\sigma < 2m_t$: dedicated ATLAS search for colored scalars in 4-jet final states and CMS search for di-jet events [Eur. Phys. J. C (2013) 73:2263, arXiv:1302.4794]





- 2 $t\bar{t}$ pairs as a possible signature for $m_\sigma > 2m_t$
  - SM cross section for $t\bar{t}t\bar{t}$ production is 0.91 fb [MC@NLO]
  - observed upper limit on the SM $t\bar{t}t\bar{t}$ production is 49 fb [CMS PAS SUS-13-013]
  - sgluons with mass below 0.8 TeV are excluded [ATLAS-CONF-2013-051]
- chain decay though SUSY particles for heavy sgluons also possible

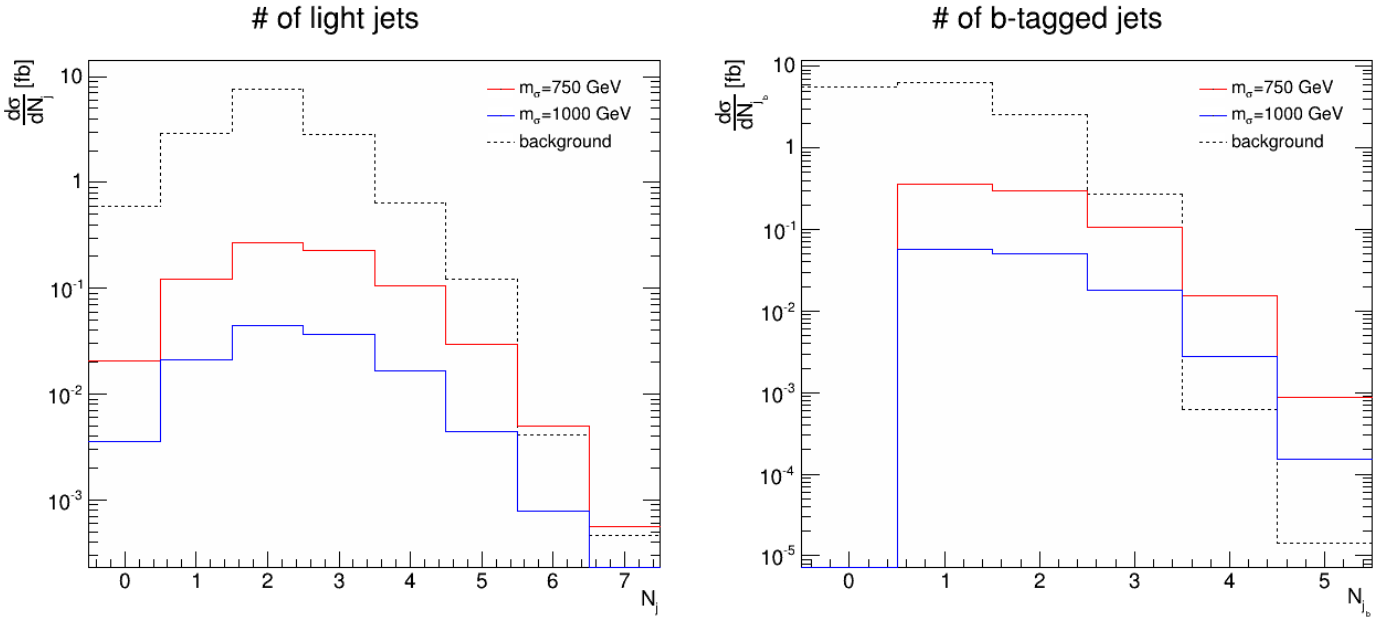
Event preselection

- Preselection: 2 same-sign isolated muons with $p_\perp > 20$ GeV and $|\eta_{\mu^\pm}| < 2.1$. Enough to cut out most of the SM background. All shown plots are done **after** the preselection.
- Relevant background processes
  - Rare SM processes with at least two same-sign prompt leptons: $W^\pm Z$, ZZ, $W^\pm W^\pm jj$, $t\bar{t}W^\pm$, $t\bar{t}Z$, $t\bar{t}t\bar{t}$
  - High cross section processes with 1 prompt lepton: Z,$W^\pm$, di- and semi-leptonic $t\bar{t}$,

process	σ [fb]	$\sigma \cdot$ BR [fb]
$W^\pm Z / ZZ$	-	96.28
$W^\pm W^\pm jj$	-	1.87
$t\bar{t}W^\pm$	203.1	8.45
$t\bar{t}Z$	205.7	2.13
$W^\pm$	-	11.2×10^6
Z/γ^*	-	1.81×10^6
$t\bar{t}$	240×10^3	50.2×10^3
$m_\sigma = 750$ GeV	65.4	2.73
$m_\sigma = 1000$ GeV	5.29	0.221

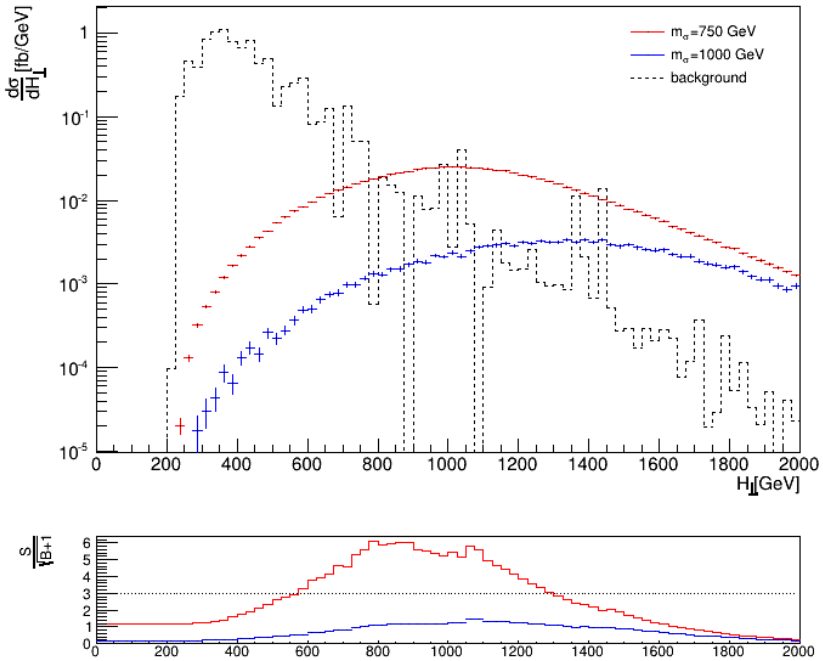
"fat"-jet analysis

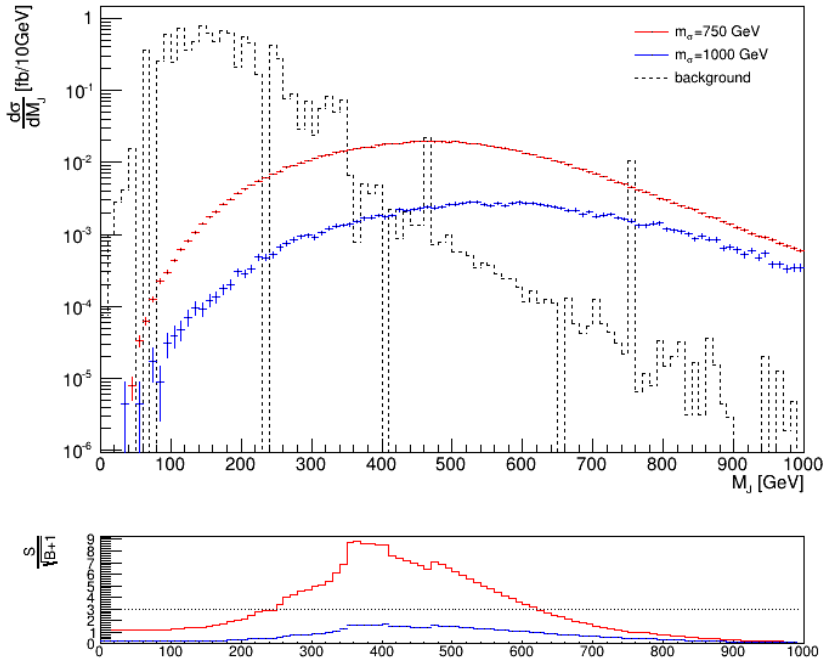
- "Fat" jets as an observable [Phys. Rev. D 85, 055029]
- b-tagging working point (default Delphes 3.0.10 CMS run card):
  - maximal b-tagging efficiency 50-40%
  - maximal c misidentification rate 20-10%
  - light jet mistag rate 0%
- Number of light and b-tagged "fat"-jets with $\Delta R = 1.2$ clustered with `anti-kt` algorithm, $p_\perp^j > 50$ GeV



- at least 1 b-tagged jet, at least 3 in total, leading jet $p_\perp > 120$ GeV

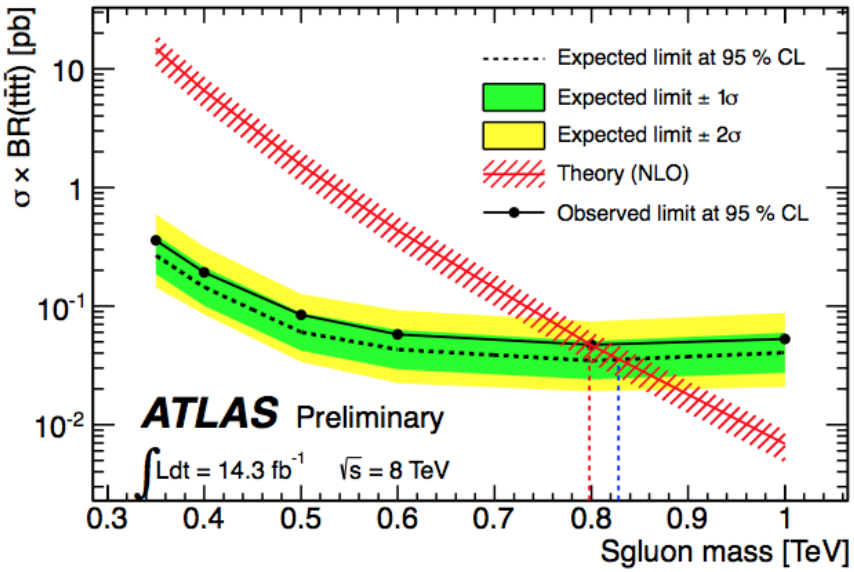
Comparison of M_J and $H_\perp$ as a discriminating variable

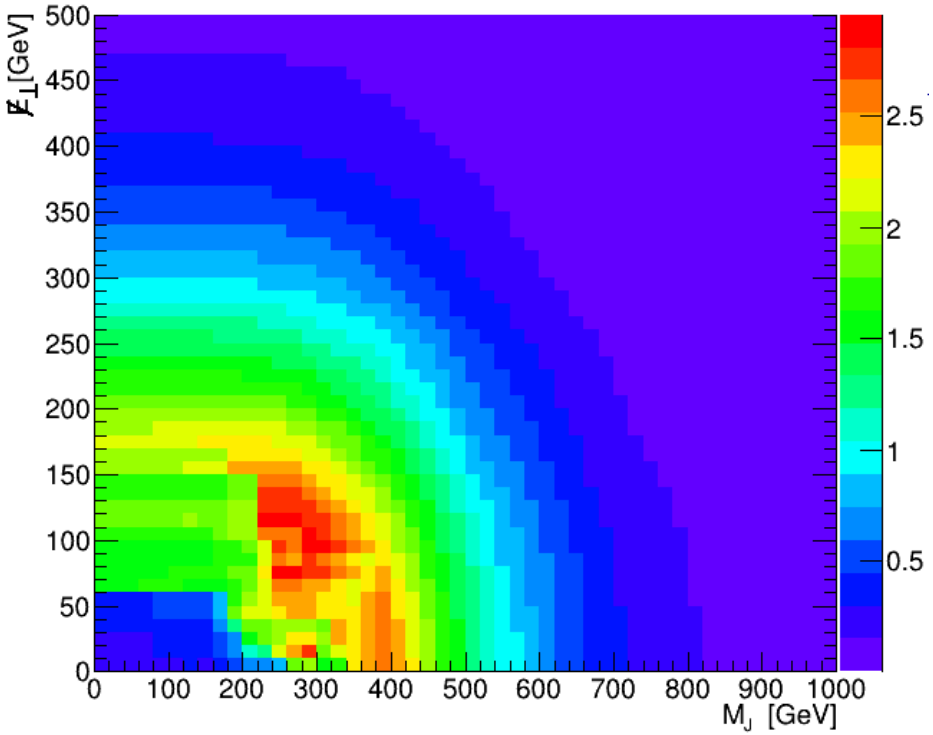




Plots made after previous cuts.

Selection in M_J vs. $\not{E}_\perp$ for 1 TeV sgluon





- Question: "What is the the value of the $S/\sqrt{B+1}$ ratio for a given choice of M_J and $\not{E}_\perp$ cut?"
- Selection in M_J vs. $\not{E}_\perp$ plane to maximize $S/\sqrt{B+1}$
- $\max(S/\sqrt{B+1}) \approx 3$ for the cut $\{M_J, \not{E}_\perp\} \geq \{290, 95\}$

Conclusions and outlook

- Theoretically well motivated R-symmetric model discussed
- Analysis (basically) model independent
- Sgluons can be relatively light, $\gtrsim 0.8$ TeV
- Specialised analysis of $\sigma \to t\bar{t}$ performed at $\sqrt{s}$=8 TeV could be sensitivity to $\sim$1 TeV sgluons
- Reconstruction of sgluon's mass in boosted topology?
- Large $\tilde{t}_R - \tilde{c}_R$ not excluded - can look at the $\sigma \to t\bar{c}$
- Projection study for 14 TeV is ongoing
- No pile up included. Importance of pile up for 14 TeV study?