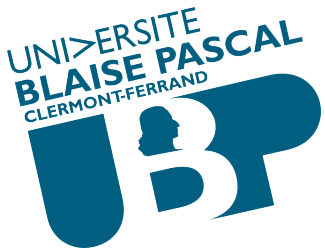

Search for sgluons in multitop final states at the LHC

Samuel CALVET[1], Benjamin FUKS[2], Philippe GRIS[1], Adrien RENAUD[3], Loïc VALÉRY[1], Dirk ZERWAS[3]

[1] : Laboratoire de Physique Corpusculaire (LPC) - Clermont-Ferrand
[2] : Institut Pluridisciplinaire Hubert Curien (IPHC) - Strasbourg
[3] : Laboratoire de l'Accélérateur Linéaire (LAL) - Orsay

GDR Terascale @ Clermont-Ferrand
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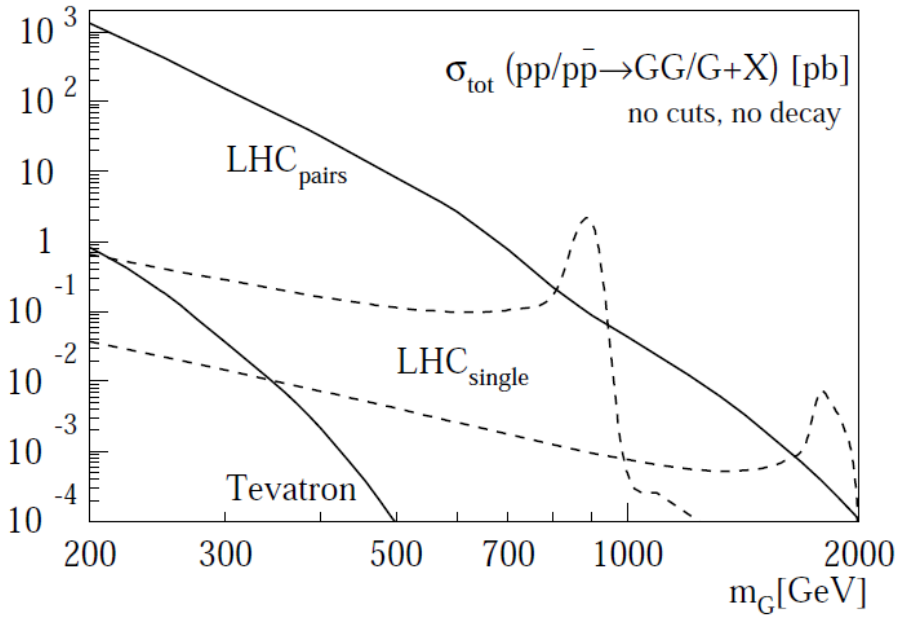
Outline

Theoretical context

- We consider an extension of the Minimal Supersymmetric Standard Model.
- By adding a new symmetry (R-symmetry), new particles are predicted.
- Among them, a new color-octet scalar field, named **sgluon**, partner of the the gluon and gluino, denoted σ in the next slides.

slguon production

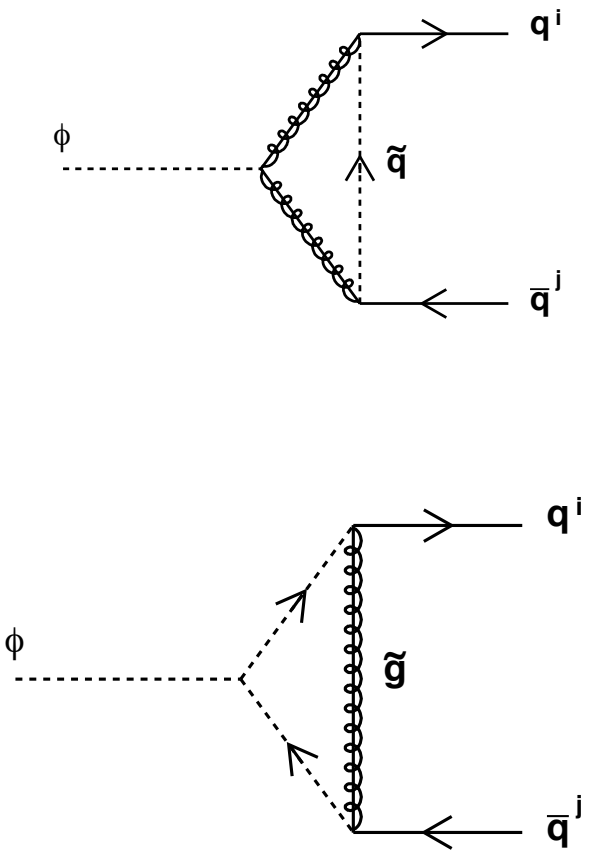


Cross section of sgluon [pb] vs mass of sgluon [GeV].

- Sgluon sensitive to strong interaction : large coupling to quarks and gluons. Important production at the LHC.
- The pair production is always the main way to produce sgluons.
- The cross section is quite important for low masses, but decreases quickly.

arXiv :0810.3919v2 [hep-ph]

sgluon decays



- The coupling between sgluon and quarks is mediated by squarks and gluinos.
- Assuming a maximal mixing between the up-type squarks.
- Final states with at least one top quark are equiprobable.

Summary

Production

The sgluon pair production is the most favoured one.

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tjtj topology

Each sgluon decays into one top quark and a up-type ligh quark (u or c).

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tjtj topology

Each sgluon decays into one top quark and a up-type ligh quark (u or c).

4-top topology

Each sgluon decays into two top quarks.

In this study, we consider an integrated luminosity of 10 fb $^{-1}$ at 7 TeV using pp collisions.

Framework

- Parton level : MadGraph 5.1.2/5.1.3.
- Parton showering + hadronization : Pythia 6.
- Detector simulation : DELPHES with ATLAS card.
  - Fast simulation of ATLAS and CMS detectors
  - Smearing and reconstruction of objects (electron, jets, ...)
  - Using a *b*-tagging efficiency of 60%.

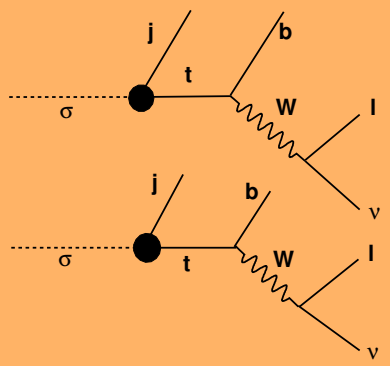
Signal

- Model generated by FeynRules 1.6. for the 2 topologies. Test for each topology : BR($\sigma \to t\bar{t}$)=100% and BR($\sigma \to tq'$)=100% with $q' = u, c$.
- Two mass points : 400 and 1000 GeV.

Cross sections

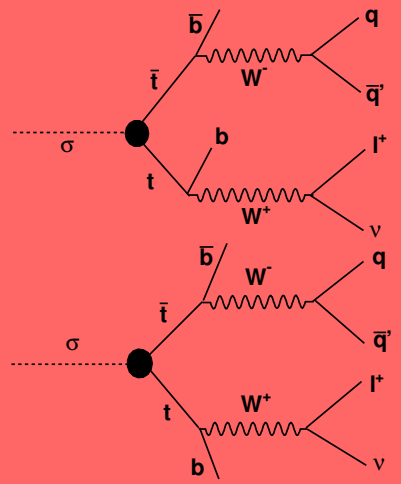
Sample	Cross section [pb]
σ (M=400 GeV)	1.86
σ (M=1000 GeV)	8.2×10^{-4}
W+jets	14350
γ/Z+jets	1672
$t\bar{t}$	20.3
single top	13.91
Dibosons	12.28
$t\bar{t}X$+jets	0.26
$t\bar{t}t\bar{t}$	3.7×10^{-4}

Dileptonic tjtj signature



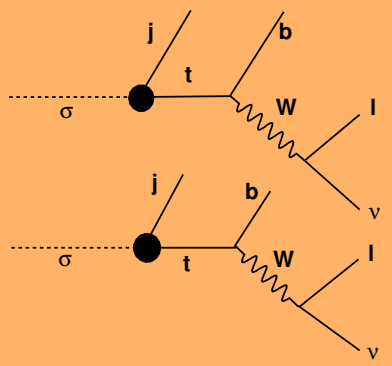
- 4 jets (2 *b*-jets and two high-P_T jets)
- 2 charged leptons
- Missing transverse energy (neutrinos)

Dileptonic 4-top signature



- 8 jets (2 *b*-jets and two high-P_T jets)
- 2 charged leptons
- Missing transverse energy

Dileptonic tjtj signature



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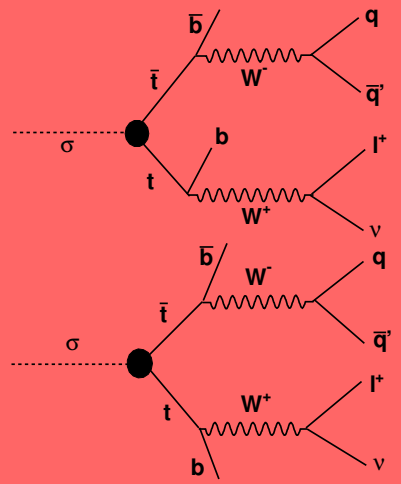


- 8 jets (2 *b*-jets and two high-P_T jets)
- 2 charged leptons
- Missing transverse energy

In both cases, both leptons can have the same sign.

Selection criteria

Common selection

- 2 same-sign leptons (ee, $\mu\mu$ and $e\mu$)
- $M(lepton, lepton) \geq 20\ GeV$
- $\not{E}_T \geq 40$ GeV

Dileptonic tjtj signature

- At least 4 jets with $P_T \geq 25$ GeV
- At least 1 b-jet

Results (for 400 GeV sgluon)

- Exp. signal events : 150 (eff : 2%)
- Exp. $t\bar{t}$ events : 348 (eff : 0.02%)

Dileptonic 4-top signature

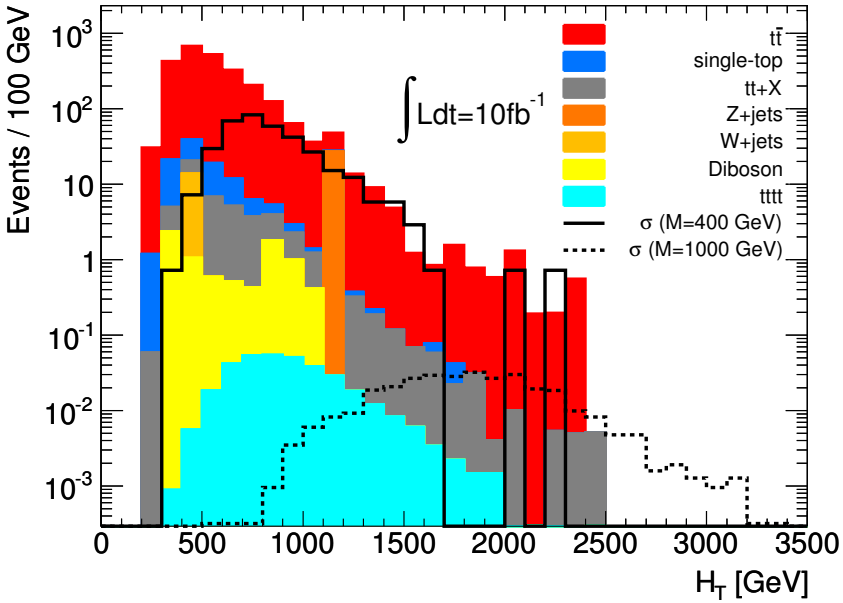
- At least 8 jets with $P_T \geq 25$ GeV
- At least 2 b-jets

Results (for 400 GeV sgluon)

- Exp. signal events : 144 (eff : 2%)
- Exp. $t\bar{t}$ events : 0.57 (eff : 10^{-5}%)

Backgrounds

- After the selection, essentially SM $t\bar{t}$, single top and SM $t\bar{t}t\bar{t}$ backgrounds.
- $t\bar{t}$ and single top backgrounds : lower activity than the signal. This activity can be described by H_T.



- H_T : scalar sum of the P_T of all objects (leptons, jets, MET).
- Further discrimination is provided by an additional selection wrt H_T.

← H_T distribution after *tjtj* selection

Sensitivity & Results

Sensitivity : minimal cross section that can be excluded at 95% CL taking into account the fluctuations of the background.

$$s = \frac{\sqrt{N_b} \times 1.64}{\epsilon \times \mathcal{L}}$$

where N_b is the number of expected background events, ϵ the efficiency of the signal selection and $\mathcal{L}$ is the integrated luminosity.

Dileptonic tjtj topology

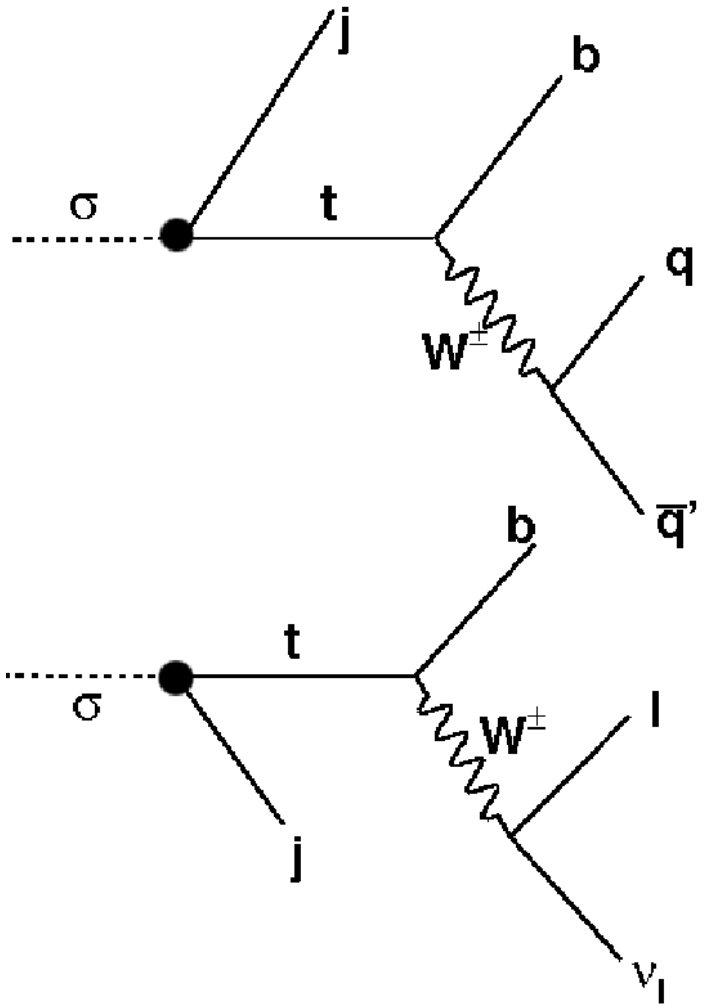
- **Without additional selection**
  - 400 GeV : 380 fb
  - 1 TeV : 209 fb
- **With a selection wrt/ H_T**
  - 400 GeV : 216 fb ($H_T \geq 650 GeV$)
  - 1 TeV : 15 fb ($H_T \geq 1550 GeV$)

Dileptonic 4-top topology

- **Without additional selection**
  - 400 GeV : 17 fb
  - 1 TeV : 6 fb
- **With a selection wrt/ H_T**
  - 400 GeV : 11.8 fb ($H_T \geq 850 GeV$)
  - 1 TeV : 0.5 fb ($H_T \geq 1650 GeV$)

Summary

- These signatures could **lead to a discovery**. But **few information on the nature of the excess** (no visible resonance).
- One can look at the lepton+jets signature : **possible** (and easier than in dilepton signature) **reconstruction**.
- Can test whether the excess comes from a $\sigma \rightarrow tj$ resonance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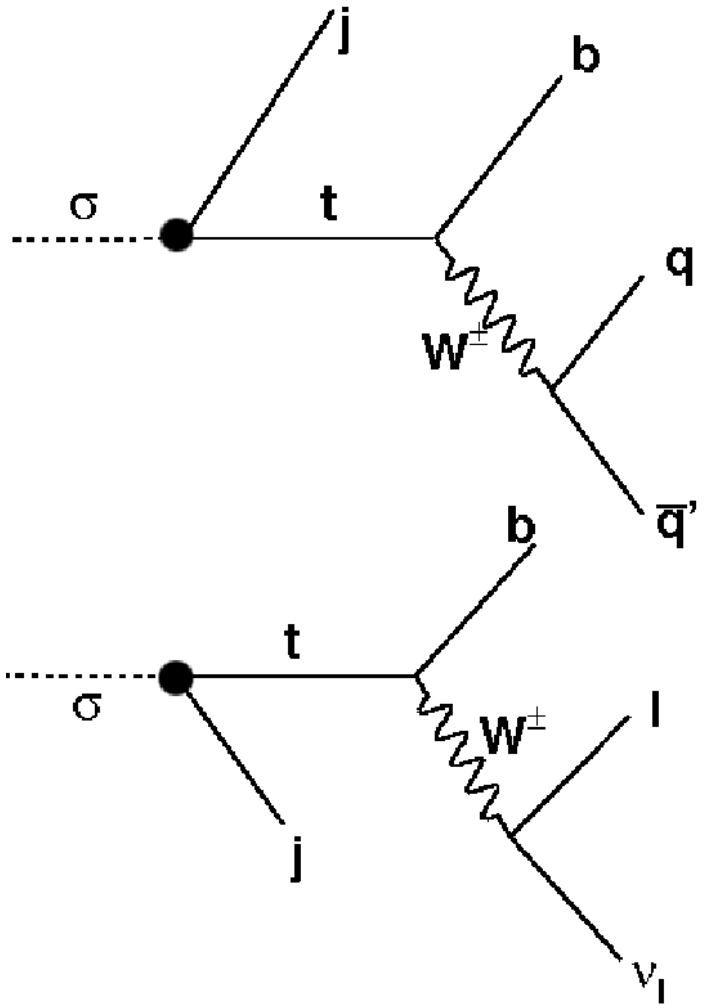


If one W boson decays leptonically and the other one hadronically, the final state contains :

- 1 charged lepton (electron or muon).
- Missing transverse momentum (associated to the neutrino).
- 6 jets (2 b-jets and 2 jets with high P_T).

Selection criteria

To suppress the physical backgrounds, each event is required to contain :

- Exactly one lepton (electron or muon) with $P_T \geq 25 GeV$.
- At least 6 jets with $P_T \geq 25 GeV$.
- $\not{E}_T \geq 40$ GeV.
- $M_T(W) = \sqrt{2P_T^{lept}.\not{E}_T \left[1 - \cos\left(\Delta\varphi(lept, \not{E}_T)\right)\right]} \geq 25$ GeV.

Sample	Before selection	After selection	Efficiency
σ ($M = 400$ GeV)	18 050	792	4.4%
σ ($M = 1000$ GeV)	7.93	1.07	6.75%
Backgrounds	5.15×10^8	7870	0.02%

Reconstruction algorithm

- One can also compute the sensitivity by 2 methods.
- Like for the 2^{nd} method, we need a discriminant variable.
- As the sgluon can be reconstructed in this final state, the **mass** should be a good discriminant variable.

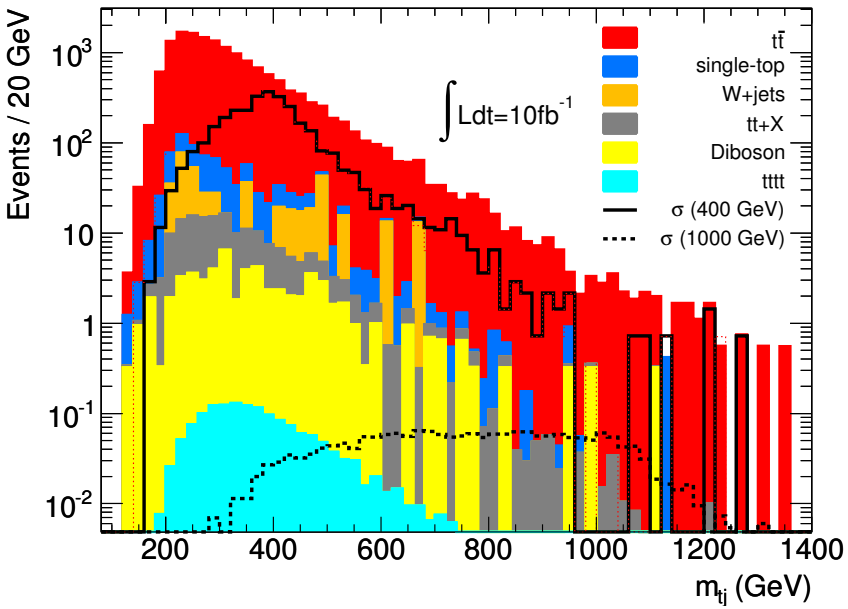
The χ^2 algorithm

- We want to find the combination of jets, lepton and MET that comes from the sgluon decay.
- For each event, we can estimate the χ^2 given by :

$$\chi^2(j_1, j_2, b_1, b_2, q_1, q_2, l, MET) =$$
$$\left[\frac{m_{jj} - m_W}{\sigma_W}\right]^2 + \left[\frac{m_{jjb} - m_{jj} - m_{th-W}}{\sigma_{th-W}}\right]^2 + \left[\frac{m_{jl\nu} - m_{tl}}{\sigma_{tl}}\right]^2 +$$
$$\left[\frac{(M(\sigma_{lep}) - M(t_{lep})) - (M(\sigma_{had}) - M(t_{had}))}{(M(\sigma_{lep}) - M(t_{lep})) + (M(\sigma_{had}) - M(t_{had}))} \times \frac{1}{\sigma_{sgluon}}\right]^2$$

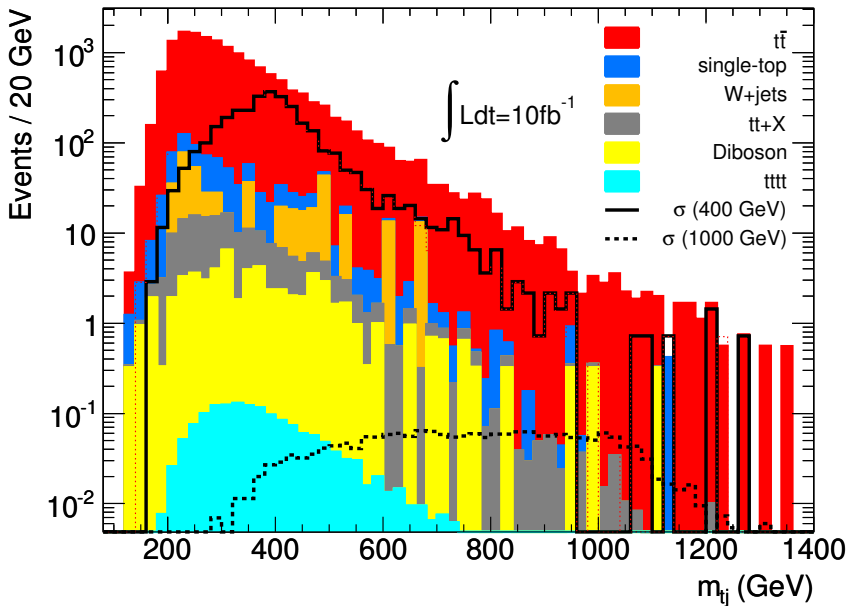
- All possible combinations (jets, lepton, $\not{E}_T$) are estimated.
- The combination that minimizes the χ^2 is chosen.

Results



tj invariant mass

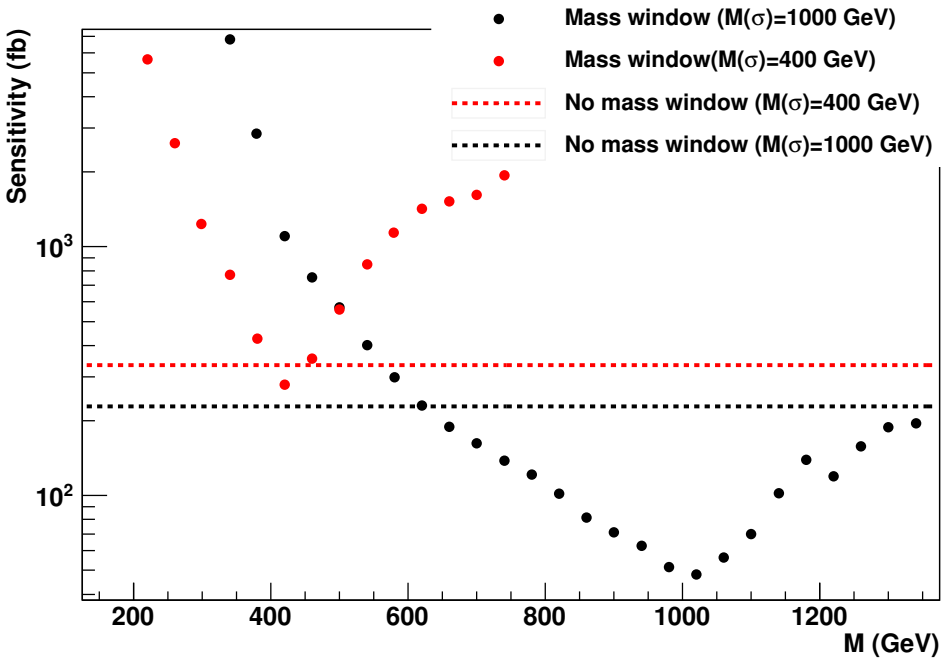
Results



tj invariant mass

- Quite clear peak for the 400 GeV sgluon.
- Broader one for the 1000 GeV (due to combinatorial background).

Results



- Sensitivity computable by 2 methods.
- 2^{nd} method : the mass is chosen as discriminant variable. Test mass M, sensitivity in the window $[M - 10\%; M + 10\%]$.

The optimal sensitivity in the semileptonic signature is :

- **278 fb** for the 400 GeV sgluon (compared to the cross section of 1.86 pb for the same sgluon mass).
- **48 fb** for the 1 TeV sgluon (compared to the cross section of 0.82 fb for the same sgluon mass).

Conclusions - Outlooks

- Two different final states studied : a same-sign dilepton final state and a semileptonic one.
- Dileptonic final states allow to exclude cross sections higher than :
  - 216 fb (resp. 15 fb) in the *tjtj* topology for a 400 (resp. 1000) GeV sgluon (the cross sections considered in this model are 1.86 pb (resp. 0.82 fb)).
  - 11.8 fb (resp. 0.5 fb) in the 4-top topology for a 400 (resp. 1000) GeV sgluon.
- Semileptonic signature allows to reconstruct the mass of the slguons and to probe the *tj* nature of the resonance.
- Up to now, semileptonic channel is sensitive to low mass sgluons but not yet for high masses.
- Work still ongoing to improve the selection efficiency (ex : using multivariate methods).

References

Phenomenological papers

- *Hadronically decaying color-adjoint scalars at the LHC*
  S. Schumann, A. Renaud, D. Zerwas
  `http://dx.doi.org/10.1007/JHEP09(2011)074`
- *Searching for sgluons in multitop production at the LHC*
  S. Calvet, B. Fuks, P. Gris, A. Renaud, L. Valéry, D. Zerwas
  `http://arxiv.org/abs/1203.1488`

Experimental paper

- *Search for Massive Colored Scalars in Four-Jet Final States in sqrts=7 TeV proton-proton collisions with the ATLAS Detector.*
  The ATLAS Collaboration
  `http://arxiv.org/pdf/1110.2693`