30 May 2012

Searches for new physics:
Interpretation of LHC results

Sabine Kraml

Enigmass
The enigma of mass

LAPTH - LPSC collaboration

Motivation

- LHC is the high energy frontier machine to explore the TeV scale and provide answers to many key questions in particle physics.

- There are high hopes for groundbreaking discoveries shedding light on electroweak symmetry breaking (Higgs mechanism or some other new dynamics) and new physics beyond the Standard Model (BSM).

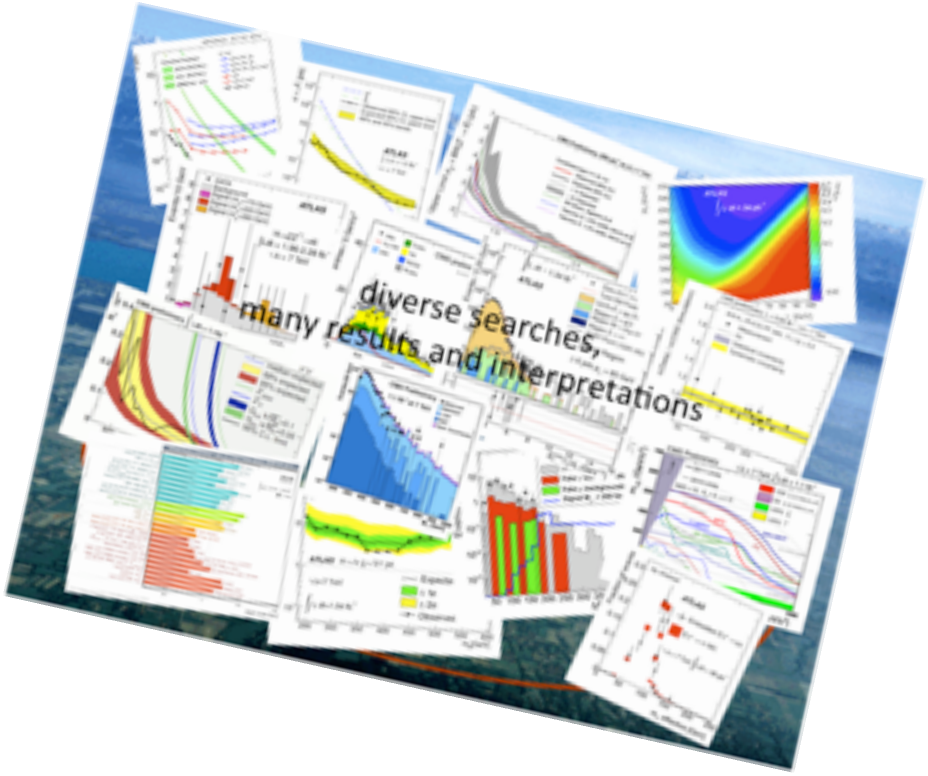
- Need to interpret LHC results in the contexts of all kinds of models of new physics; crucial if we are to unravel the correct theory and determine its parameters.

- The complexity of

  a) the experimental analyses and

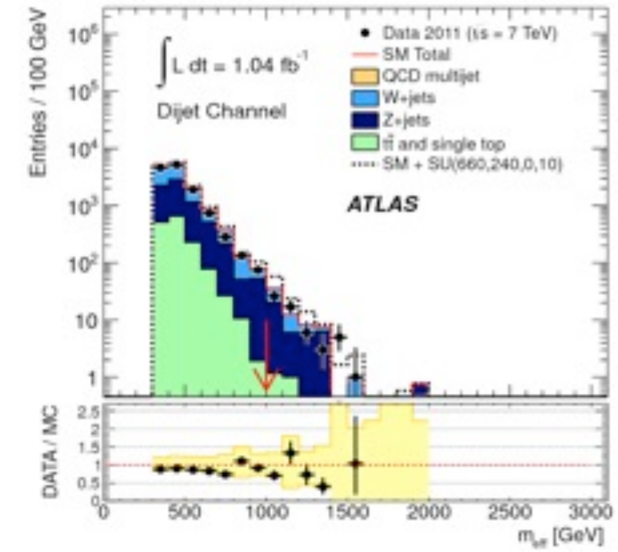
  b) the possible new physics models

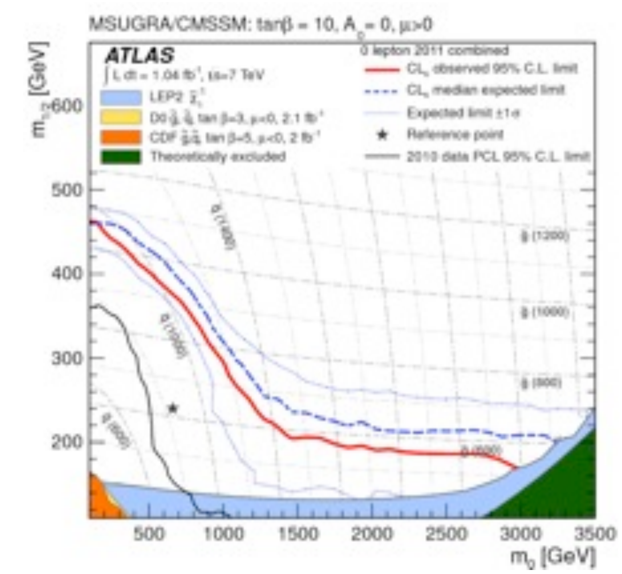
  requires active collaboration of experimentalists and theorists to fully exploit the LHC potential.

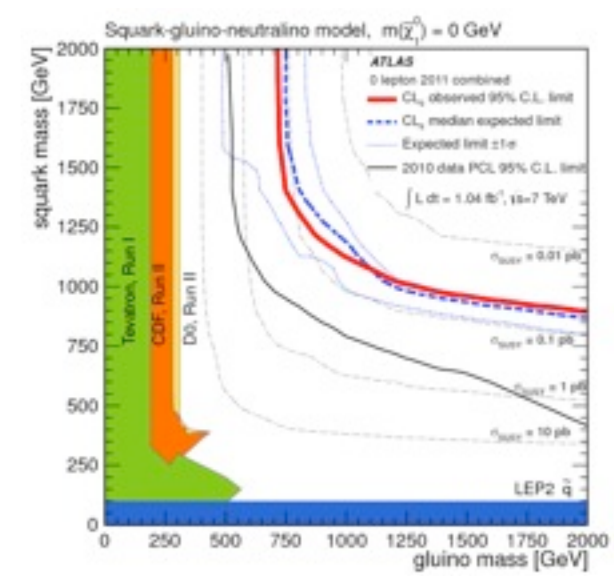


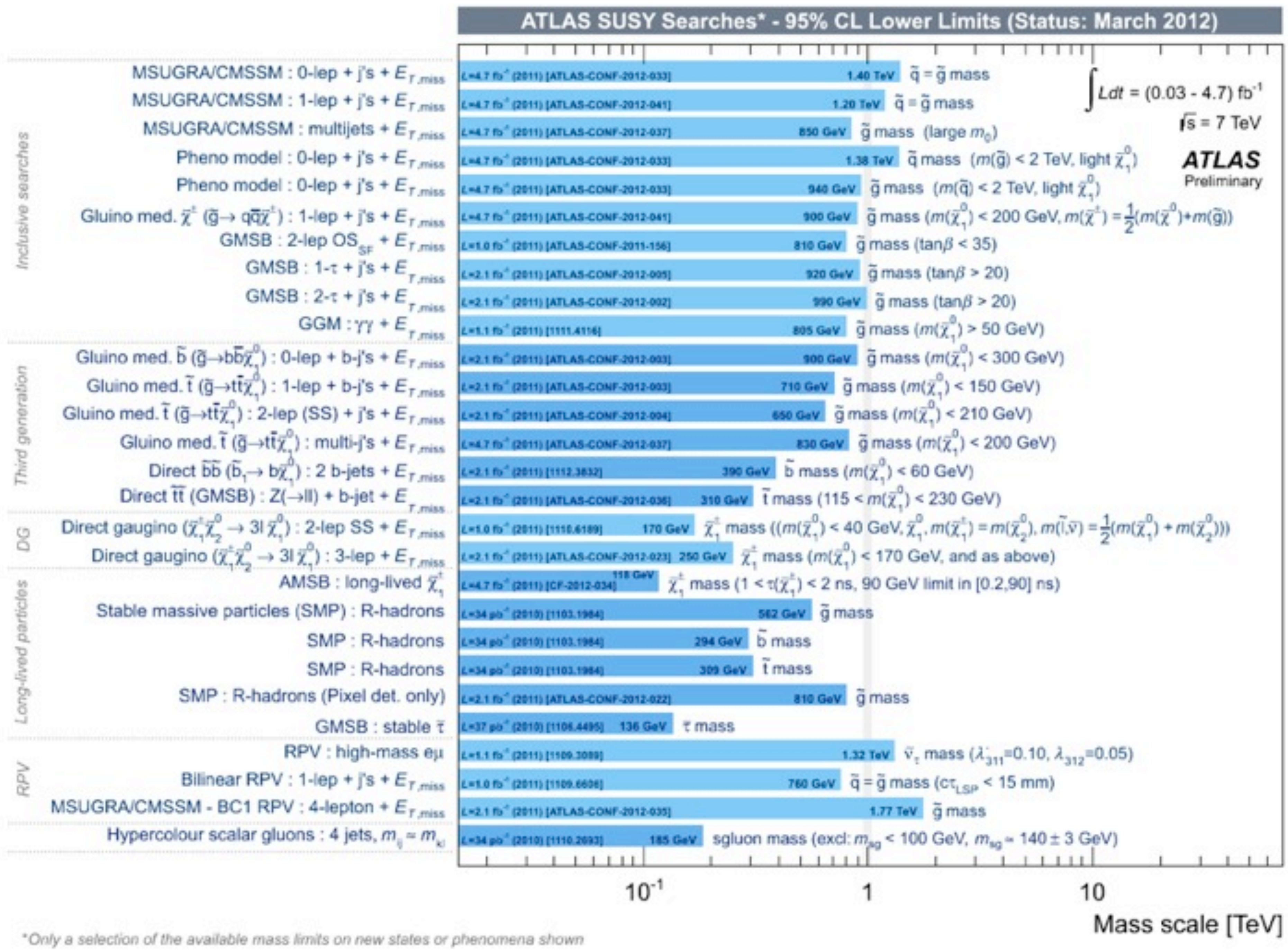
Experimental results

- The ATLAS and CMS collaborations are providing detailed results of searches in many different topologies and final states.
- The experimental groups typically interpret their results in the contexts of the most popular new physics scenarios; regarding supersymmetry, for instance, within the constrained minimal supersymmetric standard model (CMSSM).
- In addition, many analyses are interpreted within so-called Simplified Models, designed as an effective-Lagrangian description of a small number of new particles.
- However, there exists such a vast variety of BSM theories, that clearly a broad effort featuring close teamwork of theorists and experimentalists is required in order to carry out a sufficiently wide range of interpretation studies.

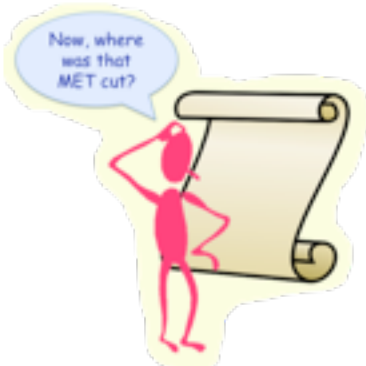







ATLAS SUSY Searches* - 95% CL Lower Limits (Status: March 2012)
Inclusive searches
MSUGRA/CMSSM : 0-lep + j's + $E_{T,miss}$
1.40 TeV $\tilde{q} = \tilde{g}$ mass
MSUGRA/CMSSM : 1-lep + j's + $E_{T,miss}$
1.20 TeV $\tilde{q} = \tilde{g}$ mass
MSUGRA/CMSSM : multijets + $E_{T,miss}$
850 GeV $\tilde{g}$ mass (large m_0)
Pheno model : 0-lep + j's + $E_{T,miss}$
1.38 TeV $\tilde{q}$ mass ($m(\tilde{g})$ < 2 TeV, light $\tilde{\chi}_1^0$)
Pheno model : 0-lep + j's + $E_{T,miss}$
940 GeV $\tilde{g}$ mass ($m(\tilde{q})$ < 2 TeV, light $\tilde{\chi}_1^0$)
Gluino med. $\tilde{\chi}^\pm$ ($\tilde{g} \to q\bar{q}\tilde{\chi}^\pm$) : 1-lep + j's + $E_{T,miss}$
900 GeV $\tilde{g}$ mass ($m(\tilde{\chi}_1^0)$ < 200 GeV, $m(\tilde{\chi}^\pm) = \frac{1}{2}(m(\tilde{\chi}^0)+m(\tilde{g}))$)
GMSB : 2-lep OS_{SF} + $E_{T,miss}$
810 GeV $\tilde{g}$ mass ($\tan\beta$ < 35)
GMSB : 1-τ + j's + $E_{T,miss}$
920 GeV $\tilde{g}$ mass ($\tan\beta$ > 20)
GMSB : 2-τ + j's + $E_{T,miss}$
990 GeV $\tilde{g}$ mass ($\tan\beta$ > 20)
GGM : $\gamma\gamma$ + $E_{T,miss}$
805 GeV $\tilde{g}$ mass ($m(\tilde{\chi}_1^0)$ > 50 GeV)
Third generation
Gluino med. $\tilde{b}$ ($\tilde{g} \to b\bar{b}\tilde{\chi}_1^0$) : 0-lep + b-j's + $E_{T,miss}$
900 GeV $\tilde{g}$ mass ($m(\tilde{\chi}_1^0)$ < 300 GeV)
Gluino med. $\tilde{t}$ ($\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$) : 1-lep + b-j's + $E_{T,miss}$
710 GeV $\tilde{g}$ mass ($m(\tilde{\chi}_1^0)$ < 150 GeV)
Gluino med. $\tilde{t}$ ($\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$) : 2-lep (SS) + j's + $E_{T,miss}$
650 GeV $\tilde{g}$ mass ($m(\tilde{\chi}_1^0)$ < 210 GeV)
Gluino med. $\tilde{t}$ ($\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$) : multi-j's + $E_{T,miss}$
830 GeV $\tilde{g}$ mass ($m(\tilde{\chi}_1^0)$ < 200 GeV)
Direct $\tilde{b}\tilde{b}$ ($\tilde{b}_1 \to b\tilde{\chi}_1^0$) : 2 b-jets + $E_{T,miss}$
390 GeV $\tilde{b}$ mass ($m(\tilde{\chi}_1^0)$ < 60 GeV)
Direct $\tilde{t}\tilde{t}$ (GMSB) : $Z(\to ll)$ + b-jet + $E_{T,miss}$
310 GeV $\tilde{t}$ mass (115 < $m(\tilde{\chi}_1^0)$ < 230 GeV)
DG
Direct gaugino ($\tilde{\chi}_1^\pm\tilde{\chi}_2^0 \to 3l\,\tilde{\chi}_1^0$) : 2-lep SS + $E_{T,miss}$
170 GeV $\tilde{\chi}_1^\pm$ mass (($m(\tilde{\chi}_1^0)$ < 40 GeV, $\tilde{\chi}_1^0$, $m(\tilde{\chi}_1^\pm) = m(\tilde{\chi}_2^0)$, $m(\tilde{l},\tilde{\nu}) = \frac{1}{2}(m(\tilde{\chi}_1^0)+m(\tilde{\chi}_2^0))$))
Direct gaugino ($\tilde{\chi}_1^\pm\tilde{\chi}_2^0 \to 3l\,\tilde{\chi}_1^0$) : 3-lep + $E_{T,miss}$
250 GeV $\tilde{\chi}_1^\pm$ mass ($m(\tilde{\chi}_1^0)$ < 170 GeV, and as above)
Long-lived particles
AMSB : long-lived $\tilde{\chi}_1^\pm$
118 GeV $\tilde{\chi}_1^\pm$ mass (1 < $\tau(\tilde{\chi}_1^\pm)$ < 2 ns, 90 GeV limit in [0.2,90] ns)
Stable massive particles (SMP) : R-hadrons
562 GeV $\tilde{g}$ mass
SMP : R-hadrons
294 GeV $\tilde{b}$ mass
SMP : R-hadrons
309 GeV $\tilde{t}$ mass
SMP : R-hadrons (Pixel det. only)
810 GeV $\tilde{g}$ mass
GMSB : stable $\tilde{\tau}$
136 GeV $\tilde{\tau}$ mass
RPV
RPV : high-mass $e\mu$
1.32 TeV $\tilde{\nu}_\tau$ mass (λ'_{311}=0.10, λ_{312}=0.05)
Bilinear RPV : 1-lep + j's + $E_{T,miss}$
760 GeV $\tilde{q} = \tilde{g}$ mass ($c\tau_{LSP}$ < 15 mm)
MSUGRA/CMSSM - BC1 RPV : 4-lepton + $E_{T,miss}$
1.77 TeV $\tilde{g}$ mass
Hypercolour scalar gluons : 4 jets, $m_{ij} \approx m_{kl}$
185 GeV sgluon mass (excl: m_{sg} < 100 GeV, $m_{sg} \approx 140 \pm 3$ GeV)
$\int L dt$ = (0.03 - 4.7) fb^{-1}
$\sqrt{s}$ = 7 TeV
ATLAS
Preliminary
10^{-1}
1
10
Mass scale [TeV]
*Only a selection of the available mass limits on new states or phenomena shown

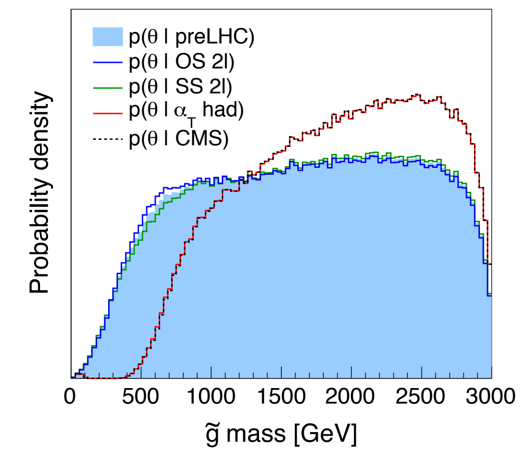
Our aim



- Develop and maintain a coherent analysis framework

  - based on fast simulation, that
  - collects all public LHC results on searches for new physics
    (includes of course also all available information on the Higgs)
  - allows for testing of a large variety of BSM scenarios.

arXiv:1109.5119



- Include in addition all relevant data from other sectors:

  - flavor physics,
  - direct dark matter searches,
  - cosmological observations, etc..

see also ANR project presented by Genevieve

- Investigate implications for SUSY and non-SUSY models

- LPSC - LAPTH - CERN collaboration involving theorists & experimentalists

PEPS-PTI project "*Tools for presentation, preservation and interpretation of LHC results*" with G. Belanger, C. Diaconnu (Marseille), B. Fuks (Strasbourg), F. Mahmoudi (Clermont): 6000 Euro in 2012.

Pioneering study

Interpreting LHC SUSY searches in the "phenomenological MSSM" (pMSSM)

S. Sekmen, SK, et al., arXiv:1109.5119

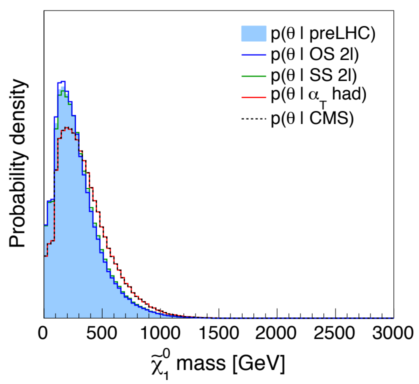
- Sample the pMSSM parameter space by a Markov-Chain Monte Carlo (MCMC) technique which through a likelihood function incorporates various pre-LHC measurements ($b \to s\gamma$, $B \to \mu^+\mu^-$, g-2, LEP mass limits, ...).

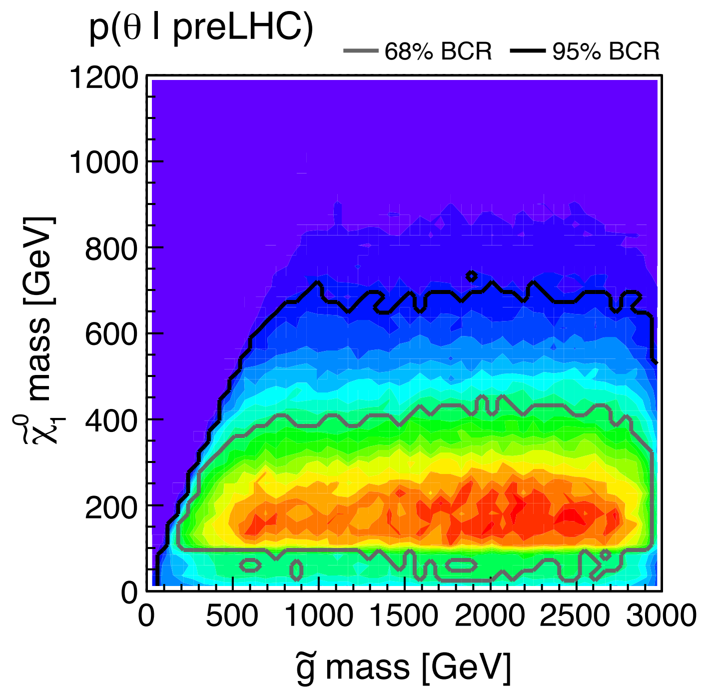
neutralino LSP, no long-lived sparticles

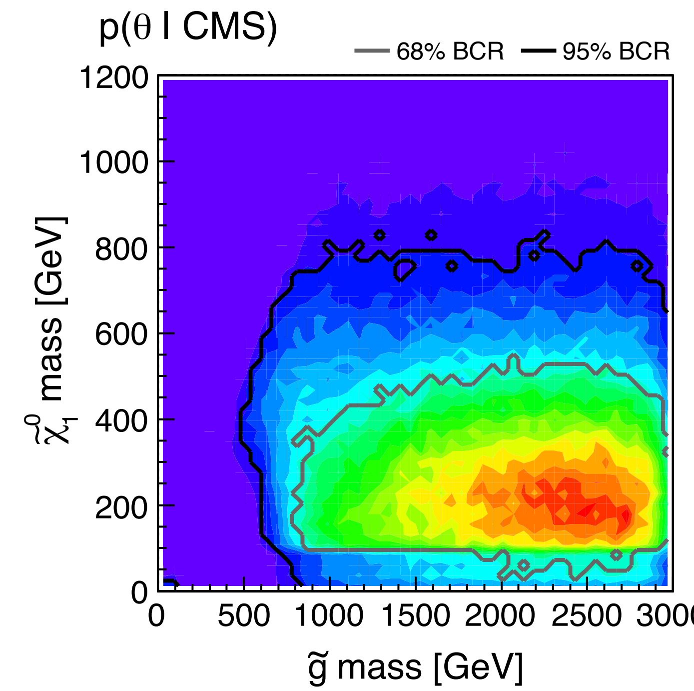
- For a random subset of 500K points, simulate 10K events per point and calculate the signal yields for 3 disjoint CMS SUSY analyses for ~1fb^{-1} of data (α_T hadronic, same-sign dilepton, opposite-sign dilepton)
- In practice: re-weight the pre-LHC likelihood of these 500K points with the "CMS likelihood" (since the analyses are disjoint, the total likelihood is the product of the individual L's).
- Performing a global Bayesian analysis, we obtain posterior probability densities of parameters, masses and derived observables.
- In contrast to constraints derived for particular SUSY breaking schemes, such as the CMSSM, our results provide more generic conclusions on how the current data constrain the MSSM.

Neutralino/chargino versus gluino mass

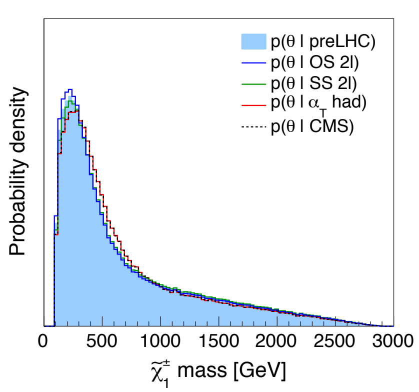
1/fb

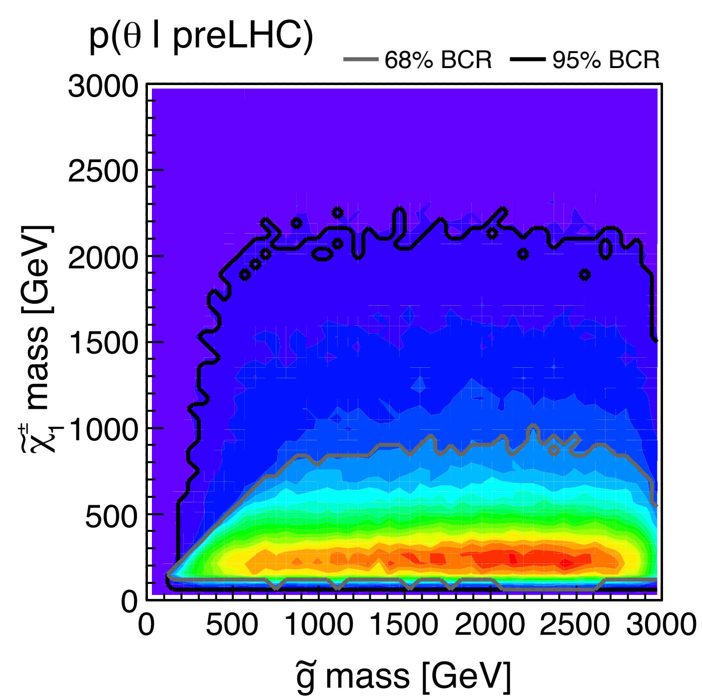


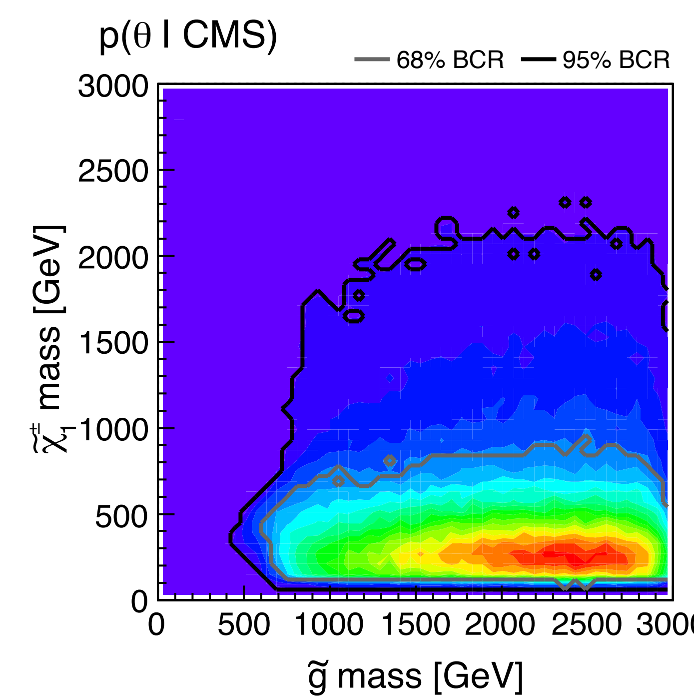




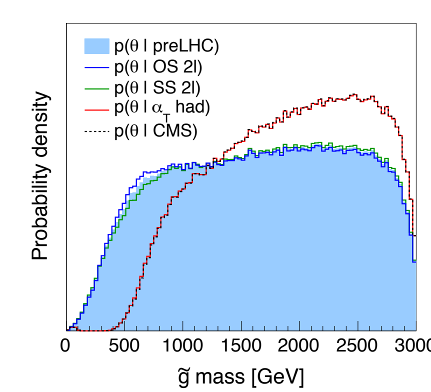
neutralino vs. gluino







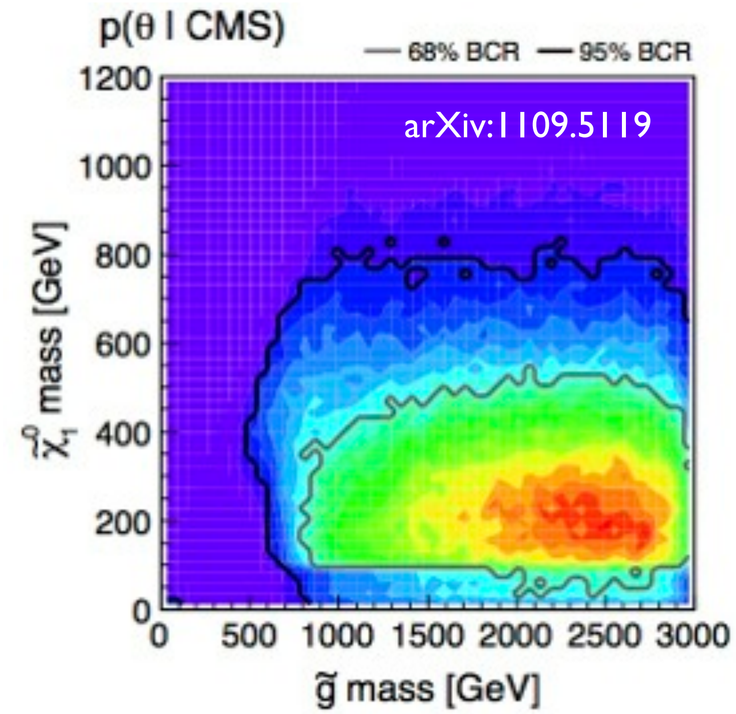
chargino vs. gluino



BCR: Bayesian credible region − these are not exclusion curves!

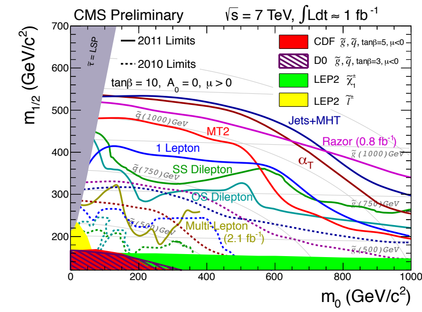
The team (so far)

- LAPTH:
  - Genevieve Belanger (CNRS)
  - Jonathan da Silva (PhD student)
- LPSC:
  - Marie-Helene Genest (CNRS)
  - Sabine Kraml (CNRS)
  - Suchita Kulkarni (postdoc)
  - Beranger Dumont (PhD student)
- Very time-consuming work, more manpower needed → the project would highly benefit from a postdoctoral researcher who works 100% on this.
- Interested people at LAPP, LAPTH, LPSC are welcome to join

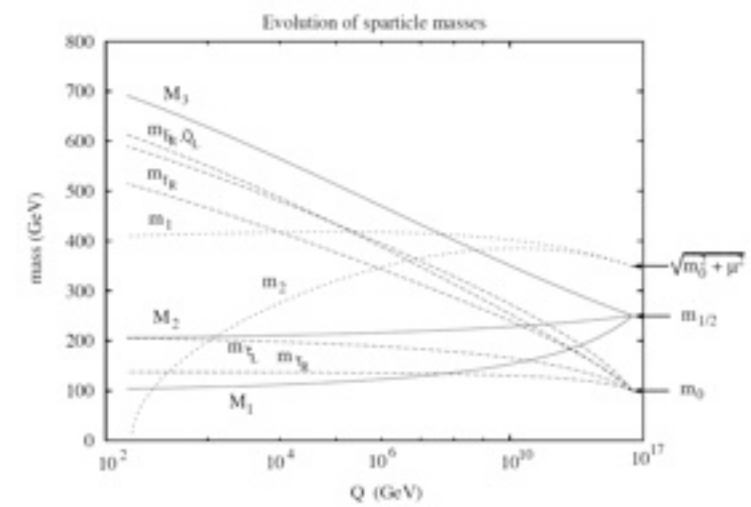


Additional material

Beware the CMSSM



- CMSSM: Constrained Minimal Supersymmetric Standard Model
- Assumes rather ad-hoc boundary conditions at the GUT scale
  - universal gaugino mass $m_{1/2}$
  - universal scalar mass parameter m_0
  - universal trilinear coupling A_0

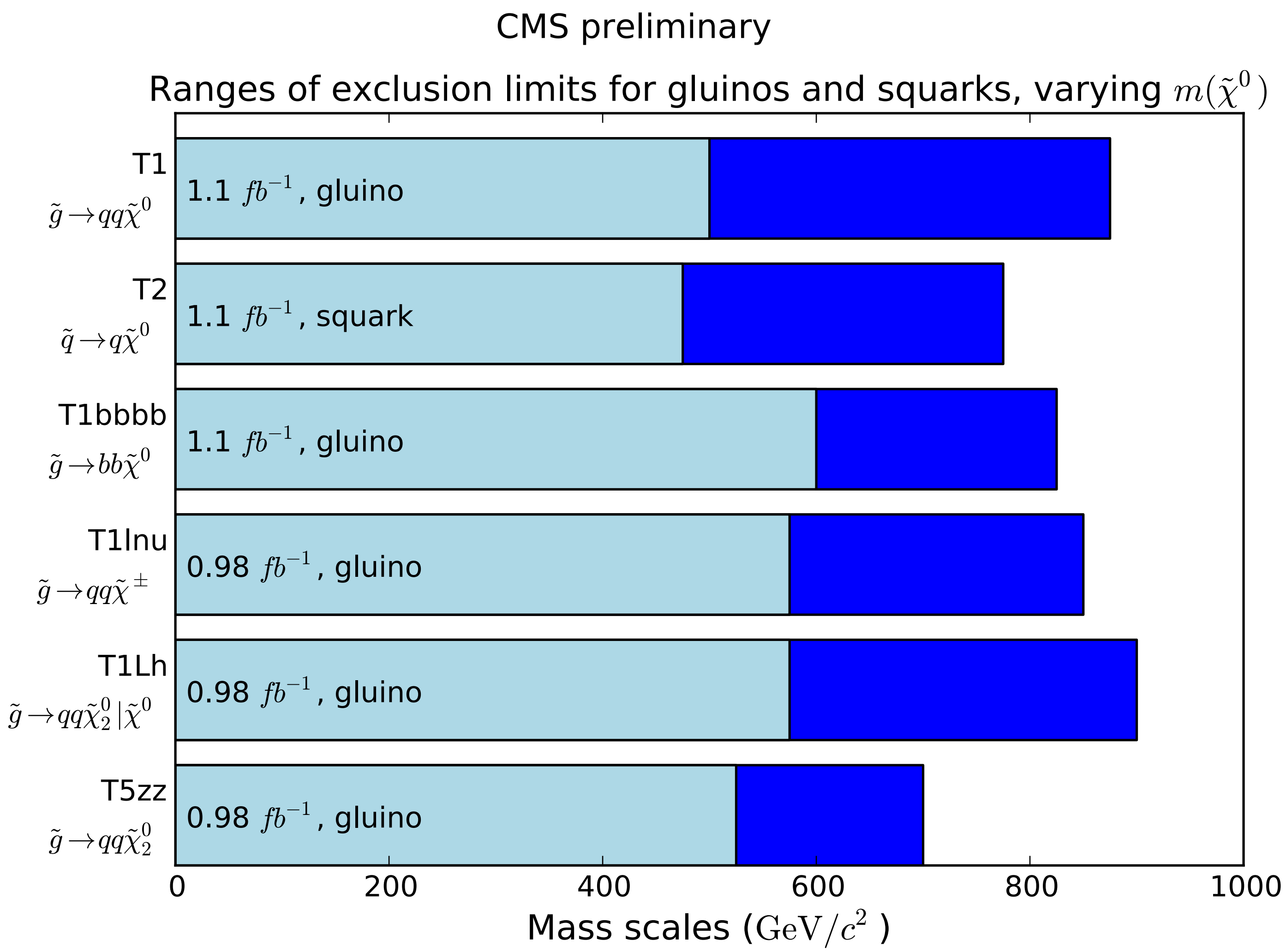


- Consequences:
  - Gluino : wino : bino (LSP) mass roughly 7 : 2 : 1 $\quad m^2_{\tilde\chi^0_1} \sim 0.4\, m_{1/2}, \quad m^2_{\tilde g} \sim 2.8\, m_{1/2}$
  - Squark masses related to gluino mass $\quad m^2_{\tilde Q} \approx m_0^2 + (5 \to 7) m^2_{1/2} \qquad m^2_{\tilde q} \sim m_0^2 + m^2_{\tilde g}$
  - Slepton masses related to gaugino and squark masses
  $$m^2_{\tilde R} \approx m_0^2 + 0.15\, m^2_{1/2}$$
  $$m^2_{\tilde L} \approx m_0^2 + 0.5\, m^2_{1/2}$$
- Convenient toy model for benchmark studies, but need to keep in mind that a constrained model gives a constrained phenomenology.

in particular if A0 and tanβ are fixed !

Beyond the CMSSM

Simplified Models



For limits on $m(\tilde{g}), m(\tilde{q}) >> m(\tilde{g})$ (and vice versa). $\sigma^{\mathrm{prod}} = \sigma^{\mathrm{NLO-QCD}}$.

$m(\tilde{\chi}^{\pm}), m(\tilde{\chi}_2^0) \equiv \frac{m(\tilde{g}) + m(\tilde{\chi}^0)}{2}$.

$m(\tilde{\chi}^0)$ is varied from 0 GeV/c^2 (dark blue) to $m(\tilde{g}) - 200$ GeV/c^2 (light blue).

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

A simplified model is defined by an effective Lagrangian describing the interactions of a small number of new particles. Simplified models can equally well be described by a small number of masses and cross-sections. These parameters are directly related to collider physics observables, making simplified models a particularly effective framework for evaluating searches and a useful starting point for characterizing positive signals of new physics.

D. Alves et al., arXiv:1105.2838

THE EUROPEAN PHYSICAL JOURNAL C - PARTICLES AND FIELDS
Volume 72, Number 4 (2012), 1976

SPECIAL ARTICLE - TOOLS FOR EXPERIMENT AND THEORY

arXiv:1203:2489

Searches for New Physics: Les Houches Recommendations for the Presentation of LHC Results

S. Kraml[1], B.C. Allanach[2], M. Mangano[3], H.B. Prosper[4], S. Sekmen[3,4] (editors), C. Balazs[5], A. Barr[6], P. Bechtle[7], G. Belanger[8], A. Belyaev[9,10], K. Benslama[11], M. Campanelli[12], K. Cranmer[13], A. De Roeck[3], M.J. Dolan[14], T. Eifert[15], J.R. Ellis[16,3], M. Felcini[17], B. Fuks[18], D. Guadagnoli[8,19], J.F. Gunion[20], S. Heinemeyer[17], J. Hewett[15], A. Ismail[15], M. Kadastik[21], M. Krämer[22], J. Lykken[23] F. Mahmoudi[3,24], S.P. Martin[25,26,27], T. Rizzo[15], T. Robens[28], M. Tytgat[29], A. Weiler[30]

Abstract

We present a set of recommendations for the presentation of LHC results on searches for new physics, which are aimed at providing a more efficient flow of scientific information between the experimental collaborations and the rest of the high energy physics community, and at facilitating the interpretation of the results in a wide class of models. Implementing these recommendations would aid the full exploitation of the physics potential of the LHC.

Fast Simulators for the LHC

11-12 June 2012 *CERN*
Europe/Zurich timezone

Search

Overview
Timetable
Registration
Registration Form
List of registrants
LH Recommendations

Dates: from 11 June 2012 09:00 to 12 June 2012 18:00

Timezone: Europe/Zurich

Location: *CERN*
Room: TH Conference Room

Chairs: Mangano, Michelangelo
Kraml, Sabine
Sekmen, Sezen

Additional info: This workshop has been motivated by the recently published "Les Houches Recommendations for the presentation of LHC results", arXiv:1203.2489, which emphasize the important role of public fast detector simulators in maximizing the use of LHC results, and suggest the HEP community to take responsibility for providing, validating and maintaining tools for fast simulation.

The workshop aims to bring together the developers of the existing and upcoming tools, the experts from experiments, and the current and potential users in order to thoroughly discuss fast simulators, and address topics such as:

- current status and shortcomings
- object implementation, difficult topologies
- validation
- input/output formats, common analysis tools

June 11-12