BCD Master Colloquium, May 27, 2014

A primer to (selected) winter conference'14 highlights in High Energy Physics

Outline: SM EWK precision tests, Higgs, Top Flavor & BSM Heavy Flavors Neutrinos & Cosmology Outlook

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SM: Standard Model of Particle Physics BSM: Beyond the SM

EWK: Electroweak (electromagnetic and weak forces)

- QFT: Quantum Field Theory
- FCNC: Flavor Changing Neutral Current
- GIM: Glashow-Iliopoulos-Maiani mechanism to suppress FCNCs by degeneracy
- LHC: Large Hadron Collider
- CKM: Cabibbo-Kobayashi-Maskawa quark mixing matrix
- BEH: Brout-Englert-Higgs mechanism of spontaneous breaking of EWK symmetry

renormalizable QFT in 3+1 Minkowski space w. local symmetry



fundamental degrees of freedom:

 ψ : fermions (quarks and leptons)

 $F_{\mu\nu}$: gauge bosons $g^a, a = 1, ..8$ plus 4 EWK ones

$$\mathcal{L}_{SM} = -\frac{1}{4}F^2 + \bar{\psi}i\not{D}\psi$$
 3 coupling constants

Known fundamental matter comes in generations $\psi \rightarrow \psi_i$, i = 1, 2, 3, subject to identical gauge transformations, e.g. for e^-, μ^-, τ^- .

The fundamental degrees of freedom are massless in this model.

renormalizable QFT in 3+1 Minkowski space w. local symmetry which spontaneously gets broken to QCD \times QED

$$SU(3)_C \times SU(2)_L \times U(1)_Y \to SU(3)_C \times U(1)_{em}$$

$$\mathcal{L}_{SM} = -\frac{1}{4}F^2 + \bar{\psi}i \not{D}\psi + \frac{1}{2}(D\Phi)^2 - \underbrace{\bar{\psi}Y\Phi\psi}_{Flavor\ physics} + \mu^2\Phi^{\dagger}\Phi - \lambda(\Phi^{\dagger}\Phi)^2$$

$$\underbrace{-\underbrace{\bar{\psi}Y\Phi\psi}_{Hiqgs\ physics}}_{Hiqgs\ physics}$$

 ψ : fermions (quarks and leptons) $F_{\mu\nu}$: gauge bosons $g^a, \gamma, Z^0, W^{\pm}$

 Φ : Higgs doublet (observation of *h* 2012 at LHC consistent with SM)

$$\Phi(x) = 1/\sqrt{2} \left(\begin{array}{c} \mathbf{0} \\ v + h(x) \end{array} \right)$$

renormalizable QFT in 3+1 Minkowski space w. local symmetry which spontaneously gets broken to QCD \times QED

 $SU(3)_C \times SU(2)_L \times U(1)_Y \to SU(3)_C \times U(1)_{em}$

$$\mathcal{L}_{SM} = -\frac{1}{4}F^2 + \bar{\psi}i \not\!\!D\psi + \frac{1}{2}(D\Phi)^2 - \bar{\psi}Y\Phi\psi + \mu^2\Phi^{\dagger}\Phi - \lambda(\Phi^{\dagger}\Phi)^2$$

A fundamental description of microscopic processes based on 3 coupling constants, α_s , α_e , $\sin^2 \vartheta_W$, $m_W = 80.4$ GeV, $m_h = 125$ GeV and O(10) masses and mixings from the flavor sector (generational structure $\psi \rightarrow \psi_i$, i = 1, 2, 3).

- 1. Experimental support of SM
- 2. Given the short-comings of the SM, whats next?

Exploring Fundamental Physics





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• Let's have an overview on the Conference contents.



Rencontres de Moriond EW 2014

15-22 mars 2014 Europe/Paris timezone

Overview

Scientific Programme

Preliminary Program [PDF]

Timetable with slides (slides visible only upon completion)

Timetable (compact version)

Preparing contributions to the proceedings (NEW)

Programme scientifique

Electroweak Interactions and Unified Theories.

The Standard Model: precision tests. Search for the Higgs Boson. Beyond the Standard Model: searches, supersymmetry, rare processes, extradimensions, ... Flavour physics and CP violation (in the hadronic and leptonic sectors). Neutrino physics. Axions. Dark matter searches and Dark energy candidates. Astroparticles and cosmological observations and their implications.



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Part I

Motivations



The detailed outline

- 1. Gauge bosons, Standard Model (SM) tests and beyond: Shaking the first pillar of the SM.
 - Introduction to the LHC Physics Case from previous machines.
 - The top quark properties.
 - The 126 GeV boson particle and its properties.
 - The searches for New Physics.
- 2. Quark Flavour Physics: Shaking the second pillar of the SM.
 - State of the art of the CKM matrix consistency checks.
 - Searches for rare and less rare processes.
- 3. The other frontiers: neutrinos, cosmology etc... What if the quake comes from them?



Motivation for Part I

• Any HEP physics summary talk contains the following figures:



• We'll try to undress these plots.



• The former main machines in question here are the TeVatron (Fermilab, US, 2011), SLC (SLAC, US, 1998) and LEP (CERN, EU, 2001), the B-factories KEKB (KEK, JP, 2011) and PEPII (SLAC, US, 2008), and the experiments are ALEPH, DELPHI, L3 and OPAL (LEP), SLD (SLC), CDF, D0 (TeVatron) and BaBar and Belle (B-factories). The results of this continuum of experiments drive the LHC (CERN, EU) Physics Case, explored by the experiments LHCb, ATLAS and CMS. This machine is currently unique (Very)HEP machine to be operated world-wide.

- KEKB: *e⁻/e⁺* asymmetric circular collider at ~10 GeV. 2 rings yet.
- PEPII: *e⁻/e⁺* asymmetric circular collider at ~10 GeV. 2 rings yet.
- SLC: *e⁻/e⁺* linear collider at ~ 90 GeV.
- LEP: *e⁻/e⁺* circular collider at 90-210 GeV.
- TeVatron: p^+/p^- circular collider at a center-of-mass energy of 2 TeV.
- LHC: *p/p* circular collider at ~7-8 TeV.
 - To be upgraded to 13 TeV in 2015.
 - Two rings.
 - A high luminosity program is considered at the horizon of 2022.



• If you want to introduce color to your friends, pick up this plot:



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- SU(2)_L \otimes U(1)_Y unification: the coupling constants G_F/g_W and α_{EM} .
- Spontaneous breaking of the symmetry: fermions masses m_f , electroweak gauge bosons m_Z and m_W (also θ_W), and the scalar sector parameters, v (the v.e.v) and m_{H^*} $V(\phi) = \mu^2 \phi^{\dagger} \phi + \lambda (\phi^{\dagger} \phi)^2$
- CKM matrix elements: 3x3 complex and unitary matrix, **4 independent parameters.** As fermion masses, decoupled from the rest of the theory.
- If you like QCD in (and you do), just add α_s (and $\theta_s CP$).
- Neutrino oscillations are implying neutrinos to be massive and to mix → 7 more parameters [This is SM as far as they are Dirac neutrinos].
- The number of parameters amounts to 20 (28 w/ neutrinos and strong CP). Not all of them are independent though... How do we know what we know then? At the *Z* energy the non-decoupled free parameters can be seen through loop processes.

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Universal corrections to propagators (self energy)



The form of the self-energy correction, when $m_H (>) > m_W$:

$$\Delta \rho_{\rm se} = \frac{3G_F m_W^2}{8\sqrt{2}\pi^2} \left[\frac{m_t^2}{m_W^2} - \frac{\sin^2 \theta_W}{\cos^2 \theta_W} \left(\ln \frac{m_H^2}{m_W^2} - \frac{5}{6}\right)\right] + \dots \,,$$

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2.1 universal corrections to propagators (self energy) :

- They do not depend on the final state. But sensitivity depends upon observables.
- Basically all Z pole observables are sensitive to these selfenergy corrections. Parity-violating observables at first.
- Yet, they are suppressed in ratio of widths such as: $R_b = \frac{\Gamma(Z \to b\bar{b})}{\Gamma(Z \to had)} \quad \sigma_{had}^0 = \frac{12\pi\Gamma_{e^+e^-}\Gamma_{had}}{m_Z^2\Gamma_Z^2}$
- The mass of the W boson is a good laboratory too.
- Homework 1: Draw the one loop self-energy of the W boson.



- In the SM, these corrections are proportional to the CKM matrix elements V_{tq} .
- The current experimental determination of these elements presents the following hierarchy (within the SM):

 $|V_{tb}| \approx 1 \gg |V_{ts}| \approx 0.04 \gg |V_{td}| \approx 0.008$

- Vertex corrections are only relevant for b quarks: $\Delta \kappa_b = rac{G_F m_t^2}{4\sqrt{2}\pi^2} +$
- A unique observable of interest there: R_b .

2.5 Summary for the radiative corrections at *Z* energy :

• In addition to the tree-level process:

 And beyond the standard QED and QCD radiative corrections, one must consider the electroweak radiative correction to the Z propagator:

• And last but not least the electroweak radiative corrections at the *Zbb* vertex:



2.5 Summary for the radiative corrections with LEP/SLC at Z energy :

- The different games we can play:
 - $R_b \rightarrow$ testing the vertex corrections.
 - $R_{l} \rightarrow$ testing lepton universality.
 - All Z pole observables treated globally. If the agreement is good, perform the metrology of the free parameters:
 - The ρ parameter to measure genuine weak corrections
 - Predicting *m*_{top}
 - Predicting m_W
 - Add up the direct measurements: m_{top} (TeVatron) and m_W (LEP/TeVatron) \rightarrow Predict the Higgs mass.





• The SM EW global fit has a remarkable $\chi^2_{min}/d.o.f = 1.40$ (p-value=15%).

• The SM hypothesis passes the test. It does not mean that SM IS the Nature. In Science, one can usually only say NO...

• 2 observables depart « with some significance » from their prediction. It happens they are the two most important for the constraint on the Higgs boson.

• One can go one step further and make the metrology of the parameters.

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• The information on the top quark is basically brought by $\sin^2\theta_{eff}$ $(A_{IB} \text{ and } A_{FB} - \text{propagator corrections}), m_W (again propagator)$ corrections) and R_b (vertex corrections).





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• The information on the top quark is basically brought by $\sin^2\theta_{eff}$ (A_{LR} and A_{FB} – propagator corrections), m_W (again propagator corrections) and R_b (vertex corrections).

• Putting all these observables together (and some others) yields a top quark mass prediction of :

$$m_{\rm top} = 172.6 + \frac{13.3}{-10.2} \, \text{GeV}/c^2 \, [(\text{indirect} - \text{LEP1})].$$

• basically obtained (w/ three times the current uncertainty) from 1993.

• Bottomline: if the SM is correct, there should exist an isospin partner to the *b* quark, sitting in the Nature at a mass ~ 175 times the one of the proton. The observation of a candidate at TeVatron was a tremendous success of the SM.



The top properties as of Moriond 2014.



CERN/FNAL Press Release:

A total of more than six thousand scientists from more than 50 countries participate in the four experimental collaborations. The CDF and DZero experiments discovered the top quark in 1995, and the Tevatron produced about 300,000 top quark events during its 25-year lifetime, completed in 2011. Since it started collider physics operations in 2009, the LHC has produced close to 18 million events with top quarks, making it the world's leading top quark factory.

- What do we want to know about the top beyond its existence?
 - Production cross-sections.
 - Its mass: invaluable input to constrain the free parameters of the SM.
 - Single top productions.
 - And much more as a New Physics laboratory...



0.72

1.7

3.6

2.9

2.6

0.7

0.9

0.4

1.7

1.0

0.1

0.1

1.1

3.4

0.1

1.2

0.4

1.2

1.4

0.1

1.0

0.7

0.9

7.4

7.4

4.0

top pairs production cross-sections:

Results for ttbar: precision cross-sections, differential ulletdistributions, ttbar+HF, ttbar+ γ /W/Z. Uncertainty $\Delta \sigma_{t\bar{t}} / \sigma_{t\bar{t}}$ $\Delta \sigma_{t\bar{t}}$ (%) (pb)

Data statistics

tī modelling 1.52 $\sigma_{tt^{-}} = 237.7 \pm 1.7 \text{ (stat)} \pm 7.4 \text{ (syst)} \pm 7.4 \text{ (lumi)}$ Initial/final state radiation 1.23 1.09 \pm 4.0 (beam energy) pb Parton density functions 0.30 QCD scale choices Single-top modelling 0.38 Events Single-top/tī interference 0.15 ATLAS Preliminary 14000 Single-top Wt cross-section 0.70 vs=8 TeV L=20.3 fb Diboson modelling 0.42 12000 Data 2012 World's most precise Diboson cross-sections 0.03 📺 tī Powheg+PY 0.05 Z+jets extrapolation Wt 10000 Z+jets Electron energy scale/resolution 0.48 ttbar cross-section: Diboson Electron identification/isolation 1.42 8000 Fake lepton Muon momentum scale/resolution 0.05 total uncert = 4.8% Powhea+PY 6000 Muon identification/isolation 0.52 MC@NLO+HW Lepton trigger 0.16 Alpgen+HW 4000 Jet energy scale 0.49 Jet energy resolution 0.59 2000 Jet reconstruction/vertex fraction 0.04 0.42 b-tagging 0 0.28 Data/MC Pileup modelling 1.3F 1.2 Misidentified leptons 0.38 Total systematic 3.12 0.9 0.8 Integrated luminosity 3.11 0 2 3 4 5 6 LHC beam energy 1.70 $\mathsf{N}_{\mathsf{jet}}$ 4.77 Total uncertainty 11.3

• Notes: systematics limited. SM prediction (embodied w/ the generators) is nice.

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The top properties as of Moriond 2014.

- Top level results of the LHC/Tevatron combination: 173.34 +/- 0.76 GeV (Tevatron +/- 0.87, LHC +/- 0.95)



Notes: dominated by the systematics. Very consistent among machines.
 A concern comes from the top mass definition. Realm of future electron machines.

$$m_{\text{top}} = 173.26 \pm 0.95 \text{ GeV}/c^2$$
, [direct - Moriond2014]
 $m_{\text{top}} = 172.6^{+13.2}_{-10.2} \text{ GeV}/c^2$, [indirect - LEP1]

• top mass

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• Single top production:



• Combined discriminant for CDF+D0, and combined result for cross-section, result 6.3 σ ! σ = 1.29 + 0.26 - 0.24 pb⁻¹



• Notes: signal established in most channels. Useful for polarization, SM tests, NP searches ...

Global interp. of the LEP/TeVatron results: the scalar

• the BEH particle is the only piece of the SM which escaped to experiments prior to LHC (Limits on direct searches are the yellow bands (Left band: LEP; Right band: TeVatron, LHC 2010))

• If one adds the top and *W* mass measurements to the EW precision measurements at the *Z* pole, one is able to get information on *H* mass. Here, the main actors at the *Z* pole are $\sin^2\theta_{\text{eff}}$ (A_{LR} and A_{FB} – propagator corrections).



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- We can bound the mass of the SM Brout-Englert-Higgs boson.
- A central part of the physics at the LHC is about the gauge scalar search. Was mostly driven by EW precision measurements.



• Bottomline: if the SM is correct, there should exist an isospin partner to the *b* quark, sitting in the Nature at a mass ~ 175 times the one of the proton and a fundamental scalar boson with:

 $m_{\rm BEH} < 152 \; {\rm GeV}/c^2 \; 95\% \; {\rm CL}.$



• There is very much something around: $H \rightarrow \gamma \gamma$



• Note: it's a boson and it's not a spin 1 (Landau theorem).



• There is very much something around: $H \rightarrow ZZ$.



• Evidence also observed in $H \rightarrow WW$ (gauge couplings most likely there) but also in heavy fermions $H \rightarrow bb$, $\tau\tau$.

The (scalar?) boson properties as of Moriond 2014



• The mass:



• Notes: the two main modes for Atlas slightly discrepant. Very much OK for CMS. Likely that nothing is to be dug further there.





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• Note: the $J^P = O^+$ hypothesis is so far preferred by the data.

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• The couplings: each of the SM couplings of *H* to fermions or bosons can be quit accurately calculated. Measuring all (most) of them is the next global consistency check in the field.

PUTTING ALTOGETHER : $(H \to ff) = \frac{1}{8\pi}(1 - 4\frac{mf^2}{M_H^2})$ = 1 gw². m²_H 16TT Mu² PART FROM COMES FROM THE SE SPACE DYNAMICS OF THE DECLY Lec X mg/10 DRIVES THE BI

• top quarks dominate ... [When a guy weighing 100 kg is saying some things, the 60 kg guys do listen ... M. Audiard,]

... if you can afford twice its mass...Higgstrahlung.

- If not, beauty quarks dominate.
- The lepton tau is very appealing ...

• The couplings: each of the SM couplings of H to fermions or bosons can be quit accurately calculated. Measuring all (most) of them is the next global consistency check in the field.









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• The couplings: though LHC is at the level of evidence for the channels (when accessible), significant constraints can be strength is defeind as σ_{obs}/σ_{SM}



• Note: it's amazing that LHC brought so much with Run I.





• The couplings: a closer look to fermions



• Note: TeVatron results on bbbar still dominating.





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• Outlook: we know so far that an overall 20% agreement w.r.t. the SM expectations is achieved. The LHC Run II will bring these studies at a mature stage. A breakthrough will come from the *ttbar* coupling, which can be accessed from top pair production with a Higgsstrahlung (remember LHC is a top factory. . Already a hint for this:



• Note: To be compared with the $H \rightarrow \gamma \gamma$ proceeding with a top loop.





• To my knowledge, the existence of the fundamental scalar particle sitting in the Nature at a mass below 130 GeV/ c^2 is/was the uniquely testable prediction of the SuperSymmetry (well, there should as well be a Lightest Supersymmetric Particle if *R* parity is conserved...)

• This is met.

• The consistency with the SM couplings though might be an indication that the higher fields are strongly decoupled (hence at much higher masses).

• Still, the experimentalist's honor and duty is to complete the landscape understanding. And set a/the (direct searches/ precision measurements) scale for New Physics.

• Let's examine in a glance the LHC searches.

Searches tous azimuts at LHC (SuSy for illustrati

BERKELEY

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: SUSY 2013

ATLAS Preliminary $\int \mathcal{L} dt = (4.6 - 22.9) \text{ fb}^{-1} \quad \sqrt{s} = 7, 8 \text{ TeV}$

	Model	e, μ, τ, γ	Jets	ET	JL dt[fb	[*]] Mass limit	Reference
Inclusive Searches	$ \begin{array}{l} MSUGRA/CMSSM \\ MSUGRA/CMSSM \\ MSUGRA/CMSSM \\ \overline{MSUGRA/CMSSM} \\ \overline{g}\overline{q}, \overline{q} \rightarrow q \overline{x}_1^{H} \\ \overline{g}\overline{s}, \overline{g} \rightarrow q \overline{x}_1^{H} \\ \overline{g}\overline{s}, \overline{g} \rightarrow q \overline{x}_1^{H} \\ \overline{g}\overline{g}, \overline{g} \rightarrow q \overline{x}_1^{H} \rightarrow q W^+ \overline{y}_1^{H} \\ \overline{g}\overline{g}, \overline{g} \rightarrow q \overline{x}_1^{H} \rightarrow q W^+ \overline{y}_1^{H} \\ \overline{g}\overline{g}, \overline{g} \rightarrow q \overline{x}_1^{H} \rightarrow q W^+ \overline{y}_1^{H} \\ \overline{g}\overline{g}, \overline{g} \rightarrow q \overline{g}(L/(\nu/\nu)^{H}) \overline{x}_1^{H} \\ \overline{G}M(bino NLSP) \\ \overline{G}M(bino NLSP) \\ \overline{G}GM(bino NLSP) \\ \overline{G}GM(higgsino-bino NLSP) \\ \overline{G}GM(higgsino NLSP) \\ \overline{G}farvitino LSP \end{array} $	$\begin{array}{c} 0 \\ 1 \ e, \mu \\ 0 \\ 0 \\ 1 \ e, \mu \\ 2 \ e, \mu \\ 2 \ e, \mu \\ 1 \ 2 \ \tau \\ 2 \ \gamma \\ 1 \ e, \mu + \gamma \\ 2 \ e, \mu (Z) \\ 0 \end{array}$	2-6 jets 3-6 jets 2-6 jets 2-6 jets 2-6 jets 3-6 jets 0-3 jets 2-4 jets 0-2 jets - 1 <i>b</i> 0-3 jets mono-jet	Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes	20.3 20.3 20.3 20.3 20.3 20.3 20.3 20.3	q_{E} 1.7 TeV $m(\tilde{q})=m(\tilde{g})$ \tilde{g} 1.2 TeV $any m(\tilde{q})$ \tilde{g} 1.2 TeV $any m(\tilde{q})$ \tilde{g} 1.1 TeV $any m(\tilde{q})$ \tilde{g} 1.1 TeV $m(\tilde{\chi}_1^0)=0 \text{ GeV}$ \tilde{g} 1.1 TeV $m(\tilde{\chi}_1^0)=0 \text{ GeV}$ \tilde{g} 1.18 TeV $m(\tilde{\chi}_1^0)=0 \text{ GeV}$ \tilde{g} 1.12 TeV $m(\tilde{\chi}_1^0)=0 \text{ GeV}$ \tilde{g} 1.24 TeV $m(\tilde{\chi}_1^0)=0 \text{ GeV}$ \tilde{g} 1.27 TeV $m(\tilde{\chi}_1^0)=0 \text{ GeV}$ \tilde{g} 1.27 TeV $m(\tilde{\chi}_1^0)=0 \text{ GeV}$ \tilde{g} 1.07 TeV $m(\tilde{\chi}_1^0)=0 \text{ GeV}$ \tilde{g} 0.00 GeV $m(\tilde{\chi}_1^0)=220 \text{ GeV}$ \tilde{g} 900 GeV $m(\tilde{\chi}_1^0)=220 \text{ GeV}$ \tilde{g} 690 GeV $m(\tilde{\chi}_1^0)=200 \text{ GeV}$ $m(\tilde{g})$ \tilde{g} 0.00 GeV $m(\tilde{g}) > 10^4 \text{ eV}$	ATLAS-CONF-2013-047 ATLAS-CONF-2013-062 1308.1841 ATLAS-CONF-2013-047 ATLAS-CONF-2013-047 ATLAS-CONF-2013-069 1208.4688 ATLAS-CONF-2013-069 1209.0753 ATLAS-CONF-2012-162 ATLAS-CONF-2012-162 ATLAS-CONF-2012-152
3 rd gen. ĝ med.	$\begin{array}{c} \bar{g} \rightarrow b \bar{b} \tilde{V}_{1}^{0} \\ \bar{g} \rightarrow t \bar{t} \tilde{V}_{1}^{0} \\ \bar{g} \rightarrow t \bar{t} \tilde{V}_{1} \\ \bar{g} \rightarrow b \bar{t} \tilde{V}_{1} \end{array}$	0 0 0-1 <i>e</i> ,μ 0-1 <i>e</i> ,μ	3 b 7-10 jets 3 b 3 b	Yes Yes Yes Yes	20.1 20.3 20.1 20.1	Î Î.2 TeV m(t ² ₁) < 600 GeV Î Î.1 TeV m(t ² ₁) < 600 GeV	ATLAS-CONF-2013-061 1308.1841 ATLAS-CONF-2013-061 ATLAS-CONF-2013-061
3rd gen. squarks direct production	$ \begin{array}{c} \overline{b}, \overline{b}_1, \overline{b}_1 \rightarrow b\overline{x}_1^n \\ \overline{b}, \overline{b}_1, \overline{b}_1 \rightarrow b\overline{x}_1^n \\ \overline{b}, \overline{b}_1, \overline{b}_1 \rightarrow c\overline{x}_1^n \\ \overline{t}_1, \overline{t}_1(\text{light}), \overline{t}_1 \rightarrow b\overline{x}_1^n \\ \overline{t}_1, \overline{t}_1(\text{light}), \overline{t}_1 \rightarrow b\overline{x}_1^n \\ \overline{t}_1, \overline{t}_1(\text{indum}), \overline{t}_1 \rightarrow b\overline{x}_1^n \\ \overline{t}_1, \overline{t}_1(\text{measury}), \overline{t}_1 \rightarrow c\overline{x}_1^n \\ \overline{t}_1, \overline{t}_1(\text{measury}), \overline{t}_1 \rightarrow c\overline{x}_1^n \\ \overline{t}_1, \overline{t}_1, \overline{t}_1 \rightarrow c\overline{x}_1^n \\ \overline{t}_1, \overline{t}_1 \rightarrow c\overline{x}_1^n \\ \overline{t}_1, \overline{t}_1, \overline{t}_1, \overline{t}_1(\text{matural GMSB}) \\ \overline{t}_1, \overline{t}_1(\text{matural GMSB}) \\ \overline{t}_1, \overline{t}_2, \overline{t}_2, \overline{t}_2 \rightarrow \overline{t} + Z \end{array} $	$\begin{array}{c} 0 \\ 2 e, \mu (\mathrm{SS}) \\ 1 - 2 e, \mu \\ 2 e, \mu \\ 2 e, \mu \\ 0 \\ 1 e, \mu \\ 0 \\ 0 \\ 0 \\ 3 e, \mu (Z) \end{array}$	2 b 0-3 b 1-2 b 0-2 jets 2 jets 2 b 1 b 2 b cono-jet/c-t 1 b 1 b	Yes Yes Yes Yes Yes Yes Yes ag Yes Yes	20.1 20.7 4.7 20.3 20.3 20.1 20.7 20.5 20.3 20.7 20.7	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	1308.2631 ATLAS-CONF-2013-007 1208.4305,1209.2102 ATLAS-CONF-2013-048 ATLAS-CONF-2013-048 ATLAS-CONF-2013-037 ATLAS-CONF-2013-028 ATLAS-CONF-2013-028 ATLAS-CONF-2013-025 ATLAS-CONF-2013-025
EW direct	$ \begin{array}{l} \tilde{\mathcal{L}}_{1} = \tilde{\mathcal{K}}_{1} = \tilde{\mathcal{K}}_{1} \tilde{\mathcal{K}}_{1}^{0} \\ \tilde{\mathcal{K}}_{1} = \tilde{\mathcal{K}}_{1} = \tilde{\mathcal{K}}_{1} \to \tilde{\mathcal{K}}_{1} \tilde{\mathcal{K}}_{1}^{0} \\ \tilde{\mathcal{K}}_{1} = \tilde{\mathcal{K}}_{1} = \tilde{\mathcal{K}}_{1} \to \tilde{\mathcal{T}}_{1} (\ell \tilde{\nu}) \\ \tilde{\mathcal{K}}_{1} = \tilde{\mathcal{K}}_{1} = \tilde{\mathcal{K}}_{1} (\ell \tilde{\nu}), \ell \tilde{\nu} \tilde{\mathcal{K}}_{1} \ell (\tilde{\nu}) \\ \tilde{\mathcal{K}}_{1} = \tilde{\mathcal{K}}_{2} \to \tilde{\mathcal{K}}_{1} \tilde{\mathcal{K}}_{1} \\ \tilde{\mathcal{K}}_{2} \to \mathcal{K}_{1} \\ \tilde{\mathcal{K}}_{1} = \mathcal{K}_{2} \to \mathcal{K}_{1} \\ \tilde{\mathcal{K}}_{1} = \mathcal{K}_{2} \to \mathcal{K}_{1} \\ \tilde{\mathcal{K}}_{1} = \mathcal{K}_{2} \to \mathcal{K}_{1} \\ \tilde{\mathcal{K}}_{1} \to \mathcal{K}_{1} \\ \tilde{\mathcal{K}}_{1} \to \mathcal{K}_{1} \\ \tilde{\mathcal{K}}_{2} \to \mathcal{K}_{1} \\ \tilde{\mathcal{K}}_{1} \to \mathcal{K}_{1} \\ \tilde$	$\begin{array}{c} 2 \ e, \mu \\ 2 \ e, \mu \\ 2 \ \tau \\ 3 \ e, \mu \\ 3 \ e, \mu \\ 1 \ e, \mu \end{array}$	0 0 0 0 2 b	Yes Yes Yes Yes Yes Yes	20.3 20.3 20.7 20.7 20.7 20.7 20.3	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	ATLAS-CONF-2013-049 ATLAS-CONF-2013-049 ATLAS-CONF-2013-028 ATLAS-CONF-2013-035 ATLAS-CONF-2013-035 ATLAS-CONF-2013-035 ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^+$ Stable, stopped \tilde{g} R-hadron GMSB, stable $\hat{\tau}, \tilde{\chi}_1^0 \rightarrow \tau(\tilde{e}, \tilde{\mu})_+ \tau(e$ GMSB, $\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$, long-lived $\tilde{\chi}_1^0$ $\tilde{q}\tilde{q}, \tilde{\chi}_1^0 \rightarrow q q \mu$ (RPV)	Disapp. trk 0 $(\mu) 1-2 \mu$ 2γ 1μ , displ. vtx	1 jet 1-5 jets -	Yes Yes Yes	20.3 22.9 15.9 4.7 20.3	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	ATLAS-CONF-2013-069 ATLAS-CONF-2013-057 ATLAS-CONF-2013-058 1304.6310 ATLAS-CONF-2013-092
RPV	$ \begin{array}{l} LFV pp \rightarrow \widetilde{v}_{\tau} + X, \widetilde{v}_{\tau} \rightarrow e + \mu \\ LFV pp \rightarrow \widetilde{v}_{\tau} + X, \widetilde{v}_{\tau} \rightarrow e(\mu) + \tau \\ Bilinear RPV CMSSM \\ \widetilde{x}_1^+ \widetilde{x}_1^- \widetilde{x}_1^+ \rightarrow W \widetilde{v}_1^0, \widetilde{x}_1^0 \rightarrow e \widetilde{v}_{\mu}, e \mu \widetilde{v}, \\ \widetilde{x}_1^+ \widetilde{x}_1^- \widetilde{x}_1^+ \rightarrow W \widetilde{v}_1^0, \widetilde{x}_1^0 \rightarrow \tau \tau \widetilde{v}_e, e r \widetilde{v}, \\ \widetilde{x}_2^+ \widetilde{x}_1^- \widetilde{x}_1^- \rightarrow W \widetilde{v}_1^0, \widetilde{x}_1^0 \rightarrow \tau \tau \widetilde{v}_e, e r \widetilde{v}, \\ \widetilde{g} \rightarrow \widetilde{q} q 1 \\ \widetilde{g} \rightarrow \widetilde{q}_1 t, \ \widetilde{t}_1 \rightarrow b s \end{array} $	$2 e, \mu 1 e, \mu + \tau 1 e, \mu e 4 e, \mu 3 e, \mu + \tau 0 2 e, \mu (SS)$	7 jets 6-7 jets 0-3 <i>b</i>	Yes Yes Yes Yes	4.6 4.6 4.7 20.7 20.7 20.3 20.7	P. 1.61 TeV l_{311}^{i} -0.10, l_{322} -0.05 F. 1.1 TeV l_{311}^{i} -0.10, l_{322} -0.05 G. 1.1 TeV l_{311}^{i} -0.10, l_{322} -0.05 G. 1.2 TeV $m(\tilde{q})=m(\tilde{g}), ct_{15}v<1$ mm R_1^4 760 GeV $m(\tilde{q})=m(\tilde{g}), ct_{15}v<1$ mm R_1^4 350 GeV $m(\tilde{r}_1^{i})>80 GeV, l_{335}>0$ B 916 GeV BR(t)=BR(b)=BR(c)=0% g 880 GeV 880 GeV	1212.1272 1212.1272 ATLAS-CONF-2012-140 ATLAS-CONF-2013-036 ATLAS-CONF-2013-036 ATLAS-CONF-2013-091 ATLAS-CONF-2013-097
Other	Scalar gluon pair, sgluon $\rightarrow q\bar{q}$ Scalar gluon pair, sgluon $\rightarrow t\bar{t}$ WIMP interaction (D5, Dirac χ)	0 2 e, µ (SS) 0	4 jets 1 b mono-jet	Yes Yes	4.6 14.3 10.5	sgluon 100-287 GeV ind. limit from 1110.2693 sgluon 800 GeV m(χ)<80 GeV, limit of<687 GeV for D8	1210.4826 ATLAS-CONF-2013-051 ATLAS-CONF-2012-147
	vs = / lev	vs = 8 Tev	VS =	olev		10 ⁻¹ 1 Mass scale [ToV]	

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

Hiller, Monteil

Searches tous azimuts at LHC (SuSy for illustrati

BERKELEY

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: SUSY 2013

ATLAS Preliminary $\int \mathcal{L} dt = (4.6 - 22.9) \text{ fb}^{-1}$ $\sqrt{s} = 7, 8 \text{ TeV}$

	Model	e, μ, τ, γ	Jets	ET	∫£ dt[fb	1] Mass limit	A	Reference
Inclusive Searches	$ \begin{array}{l} MSUGRA/CMSSM \\ MSUGRA/CMSSM \\ MSUGRA/CMSSM \\ \overline{qq}, \overline{q} \rightarrow q \overline{k}_1^0 \\ \overline{gz}, \overline{z} \rightarrow q \overline{k}_1^0 \\ \overline{zz}, \overline{z} \rightarrow q q \overline{k}_1^0 \\ \overline{zz}, \overline{z} \rightarrow q q \overline{k}_1^{-1} \rightarrow q W^+ \overline{k}_1^0 \\ \overline{zz}, \overline{z} \rightarrow q q (f/(\nu/\nu\nu) \overline{k}_1^0 \\ GMSB (\overline{c} \ NLSP) \\ GGM (bino \ NLSP) \\ GGM (wino \ NLSP) \\ GGM (miggsino-bino \ NLSP) \\ GGM (higgsino-bino \ NLSP) \\ GGM (higgsino-bino \ NLSP) \\ Gravitino \ LSP \end{array} $	$\begin{array}{c} 0 \\ 1 \ e, \mu \\ 0 \\ 0 \\ 1 \ e, \mu \\ 2 \ e, \mu \\ 1 \ c \ r \\ 2 \ \gamma \\ 1 \ e, \mu + \gamma \\ 2 \ e, \mu (Z) \\ 0 \end{array}$	2-6 jets 3-6 jets 2-6 jets 2-6 jets 3-6 jets 3-6 jets 0-3 jets 2-4 jets 0-2 jets 	Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes	20.3 20.3 20.3 20.3 20.3 20.3 20.3 4.7 20.7 4.8 4.8 4.8 5.8 10.5	9.8 1.7 TeV 8 1.2 TeV 8 1.2 TeV 9 1.1 TeV 9 1.1 TeV 9 1.1 TeV 9 1.3 TeV 8 1.18 TeV 9 1.18 TeV 8 1.12 TeV 8 1.2 TeV 8 1.2 TeV 9 1.24 TeV 8 1.2 TeV 8 519 GeV 900 GeV 590 GeV 8 690 GeV 8 690 GeV	$\begin{array}{l} \mathfrak{m}(\tilde{q})\!=\!\mathfrak{m}(\tilde{g}) \\ \mbox{any }\mathfrak{m}(\tilde{q}) \\ \mbox{any }\mathfrak{m}(\tilde{q}) \\ \mbox{m}(\tilde{r}_1^3)\!=\!0 \mbox{GeV} \\ \mbox{m}(\tilde{r}_1^3)\!=\!0 \mbox{GeV} \\ \mbox{m}(\tilde{r}_1^3)\!=\!0 \mbox{GeV} \\ \mbox{m}(\tilde{r}_1^3)\!=\!0 \mbox{GeV} \\ \mbox{m}(\tilde{r}_1^3)\!=\!50 \mbox{GeV} \\ \mbox{m}(\tilde{r}_1^3)\!\!>\!\!50 \mbox{GeV} \\ \mbox{m}(\tilde{r}_1^3)\!\!>\!\!200 \mbox{GeV} \\ \mbox{m}(\tilde{r}_1^3)\!\!>\!\!200 \mbox{GeV} \\ \mbox{m}(\tilde{r}_1^3)\!\!>\!\!200 \mbox{GeV} \\ \mbox{m}(\tilde{r}_1^3)\!\!>\!\!200 \mbox{GeV} \\ \mbox{m}(\tilde{r}_1)\!\!>\!\!200 \mbox{GeV} \\ \mbox{m}(\tilde{r}_1)\!\!>\!\!20$	ATLAS-CONF-2013-047 ATLAS-CONF-2013-062 1308.1841 ATLAS-CONF-2013-047 ATLAS-CONF-2013-067 ATLAS-CONF-2013-062 ATLAS-CONF-2013-026 1208.4688 ATLAS-CONF-2013-026 1208.0758 ATLAS-CONF-2012-147 ATLAS-CONF-2012-152 ATLAS-CONF-2012-152
3 rd gen. ĝ med.	$ \begin{split} \tilde{g} &\to b \bar{b} \tilde{k}_{1}^{0} \\ \tilde{g} &\to t \bar{t} \tilde{k}_{1}^{0} \\ \tilde{g} &\to t \bar{t} \tilde{k}_{1} \\ \tilde{g} &\to b \bar{t} \tilde{k}_{1}^{\prime} \\ \tilde{g} &\to b \bar{t} \tilde{k}_{1}^{\prime} \end{split} $	0 0 0-1 e, μ 0-1 e, μ	3 b 7-10 jets 3 b 3 b	Yes Yes Yes Yes	20.1 20.3 20.1 20.1	g 1.2 TeV g 1.1 ToV g 1.34 TeV g 1.3 TeV	$m(\tilde{k}_1^0) < 600 \text{ GeV}$ $m(\tilde{k}_2^0) < 350 \text{ GeV}$ $m(\tilde{k}_1^0) < 400 \text{ GeV}$ $m(\tilde{k}_2^0) < 300 \text{ GeV}$	ATLAS-CONF-2013-061 1308.1841 ATLAS-CONF-2013-061 ATLAS-CONF-2013-061
3rd gen. squarks direct production	$ \begin{array}{c} \overbrace{b_1 b_1, \overleftarrow{b_1} \rightarrow b \widetilde{\chi}_1^0} \\ \overbrace{b_1 b_1, \overleftarrow{b_1} \rightarrow b \widetilde{\chi}_1^0} \\ \overbrace{b_1 b_1, \overleftarrow{b_1} \rightarrow b \widetilde{\chi}_1^-} \\ \overbrace{f_1 f_1}^+ ([ight), \overleftarrow{t_1} \rightarrow b \widetilde{\chi}_1^- \\ \overbrace{f_1 f_2}^+ ([ight), \overleftarrow{t_1} \rightarrow b V \widetilde{h}_1^- \\ \overbrace{f_1 f_2}^+ (medium), \overleftarrow{t_1} \rightarrow b \widetilde{\chi}_1^- \\ \overbrace{f_1 f_2}^+ (medium), \overleftarrow{t_1} \rightarrow b \widetilde{\chi}_1^- \\ \overbrace{f_1 f_1}^+ (heavy), \overleftarrow{t_1} \rightarrow t \widetilde{\chi}_1^0 \\ \overbrace{f_1 f_2}^+ \overbrace{f_1} \rightarrow c \widetilde{\chi}_1^- \\ \overbrace{f_1 f_2}^+ \overbrace{f_1} \rightarrow c \widetilde{\chi}_1^- \\ \overbrace{f_1 f_2}^+ \overbrace{f_2} \rightarrow \widetilde{t_1} + Z \end{array} $	$\begin{matrix} 0 \\ 2 \ e, \mu \ (SS) \\ 1-2 \ e, \mu \\ 2 \ e, \mu \\ 2 \ e, \mu \\ 0 \\ 1 \ e, \mu \\ 0 \\ 0 \\ 3 \ e, \mu \ (Z) \end{matrix}$	2 b 0-3 b 1-2 b 0-2 jets 2 jets 2 b 1 b 2 b cono-jet/c-1 1 b 1 b	Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes	20.1 20.7 4.7 20.3 20.3 20.1 20.7 20.5 20.3 20.7 20.7	b₁ 100-620 GeV b₁ 275-430 GeV b₁ 110-167 GeV b₁ 110-200 GeV b₁ 130-220 GeV b₁ 130-220 GeV b₁ 100-580 GeV b₁ 150-580 GeV b₁ 200-610 GeV b₁ 200-610 GeV b₁ 90-200 GeV b₁ 500 GeV b₁ 271-520 GeV	$\begin{split} m(\tilde{k}_{1}^{0}) &<\!$	1308.2831 ATLAS-CONF-2013.007 1208.4305,1209.2102 ATLAS-CONF-2013.048 ATLAS-CONF-2013.048 ATLAS-CONF-2013.027 ATLAS-CONF-2013.028 ATLAS-CONF-2013.028 ATLAS-CONF-2013.025 ATLAS-CONF-2013.025
EW direct	$ \begin{split} \widetilde{\mathcal{L}}_{1-\mathcal{R}} \widetilde{\mathcal{L}}_{1-\mathcal{R}}, \widetilde{\ell} \to \ell \widetilde{\chi}_{1}^{0} \\ \widetilde{\mathcal{X}}_{1-\mathcal{X}}^{-1}, \widetilde{\mathcal{X}}_{1-\mathcal{X}}^{-1} \to \ell v(\ell \widetilde{r}) \\ \widetilde{\mathcal{X}}_{1-\mathcal{X}}^{-1}, \widetilde{\mathcal{X}}_{1-\mathcal{X}}^{-1} \to \overline{\tau} v(\tau \widetilde{r}) \\ \widetilde{\mathcal{X}}_{1-\mathcal{X}}^{-1}, \widetilde{\mathcal{X}}_{1-\mathcal{X}}^{-1} \to \overline{\tau} v(\tau \widetilde{r}) \\ \widetilde{\mathcal{X}}_{1+\mathcal{X}}^{-1} \to \ell v \widetilde{\mathcal{X}}_{1-\mathcal{X}}^{-1} \\ \widetilde{\mathcal{X}}_{1+\mathcal{X}}^{-1} \to \ell v \widetilde{\mathcal{X}}_{1-\mathcal{X}}^{-1} \\ \widetilde{\mathcal{X}}_{1+\mathcal{X}}^{-1} \to W \widetilde{\mathcal{X}}_{1-\mathcal{X}}^{-1} \\ \widetilde{\mathcal{X}}_{1+\mathcal{X}}^{-1} \to W \widetilde{\mathcal{X}}_{1-\mathcal{X}}^{-1} \\ \end{split} $	2 e, µ 2 e, µ 2 r 3 e, µ 3 e, µ 1 e, µ	0 0 0 2 b	Yes Yes Yes Yes Yes Yes	20.3 20.3 20.7 20.7 20.7 20.7 20.3	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{split} m(\tilde{t}_{1}^{0}) = & O GeV \\ m(\tilde{t}_{1}^{0}) = & O GeV, \ m(\tilde{t}, \widetilde{\gamma}) = 0.5(m(\tilde{t}_{1}^{0}) + m(\tilde{t}_{1}^{0})) \\ m(\tilde{t}_{1}^{0}) = & O GeV, \ m(\tilde{t}, \widetilde{\gamma}) = 0.5(m(\tilde{t}_{1}^{0}) + m(\tilde{t}_{1}^{0})) \\ (\tilde{t}_{2}^{0}), \ m(\tilde{t}_{1}^{0}) = & O, \ m(\tilde{t}, \widetilde{\gamma}) = 0.5(m(\tilde{t}_{1}^{0}) + m(\tilde{t}_{1}^{0})) \\ m(\tilde{t}_{1}^{0}) = m(\tilde{t}_{2}^{0}), \ m(\tilde{t}_{1}^{0}) = 0.5(pol (\tilde{t}_{1}^{0}) + m(\tilde{t}_{1}^{0})) \\ m(\tilde{t}_{1}^{0}) = m(\tilde{t}_{2}^{0}), \ m(\tilde{t}_{1}^{0}) = 0.5(pol (\tilde{t}_{1}^{0}) + m(\tilde{t}_{1}^{0})) \\ \end{split}$	ATLAS-CONF-2013-049 ATLAS-CONF-2013-049 ATLAS-CONF-2013-028 ATLAS-CONF-2013-035 ATLAS-CONF-2013-035 ATLAS-CONF-2013-035 ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^+$ Stable, stopped \tilde{g} R-hadron GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0 \rightarrow \tilde{\tau}(\tilde{e}, \tilde{\mu}) + \tau$ GMSB, $\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$, long-lived $\tilde{\chi}_1^0$ $\tilde{q}\tilde{q}, \tilde{\chi}_1^0 \rightarrow q q \mu$ (RPV)	Disapp. trk 0 (e, μ) 1-2 μ 2 γ 1 μ , displ. vtx	1 jet 1-5 jets -	Yes Yes Yes	20.3 22.9 15.9 4.7 20.3	X [±] 270 GeV 832 GeV g 832 GeV 832 GeV X [±] 475 GeV 832 GeV X [±] 230 GeV 1.0 TeV	$\begin{array}{l} \mathfrak{m}(\tilde{k}_1^*)\!-\!\mathfrak{m}(\tilde{k}_1^0)\!=\!160~\mathrm{MeV},~\tau(\tilde{k}_1^*)\!=\!0.2~\mathrm{ns}\\ \mathfrak{m}(\tilde{k}_1^0)\!=\!100~\mathrm{GeV},~10~\mu\mathrm{s}\!<\!\tau(\tilde{g})\!<\!1000~\mathrm{s}\\ 10\!<\!\mathrm{tar}(\pi/5^0)\\ 0.4\!<\!\tau(\tilde{k}_1^0)\!<\!2~\mathrm{ns}\\ 1.5<\!<\!\tau\!<\!\tau\!<\!156~\mathrm{nm},~\mathrm{BR}(\mu)\!=\!1,~\mathfrak{m}(\tilde{k}_1^0)\!=\!108~\mathrm{GeV} \end{array}$	ATLAS-CONF-2013-069 ATLAS-CONF-2013-057 ATLAS-CONF-2013-058 1304.6310 ATLAS-CONF-2013-092
RPV	$ \begin{array}{l} LFV pp \rightarrow \tilde{v}_{\tau} + X, \tilde{v}_{\tau} \rightarrow e + \mu \\ LFV pp \rightarrow \tilde{v}_{\tau} + X, \tilde{v}_{\tau} \rightarrow e(\mu) + \tau \\ Bilinear \ RPV \ CMSSM \\ \tilde{x}_1 \times \tilde{x}_1, \tilde{x}_1^+ \rightarrow W \tilde{x}_1^0, \tilde{x}_1^0 \rightarrow e \tilde{v}_{\mu}, e \mu \\ \tilde{x}_1 \times \tilde{x}_1, \tilde{x}_1^+ \rightarrow W \tilde{x}_1^0, \tilde{x}_1^0 \rightarrow e \tilde{v}_{\mu}, e \mu \\ \tilde{x}_1 \times \tilde{x}_1, \tilde{x}_1^+ \rightarrow W \tilde{x}_1^0, \tilde{v}_1^0 \rightarrow e \tilde{v}_{\mu}, e \mu \\ \tilde{g} \rightarrow q q q \\ \tilde{g} \rightarrow \tilde{q} \tau_1, \tilde{t}_1 \rightarrow b s \end{array} $	$\begin{array}{c} 2 \ e, \mu \\ 1 \ e, \mu + \tau \\ 1 \ e, \mu \\ \tilde{v}_e \ 4 \ e, \mu \\ \tilde{v}_\tau \ 3 \ e, \mu + \tau \\ 0 \\ 2 \ e, \mu \left(\mathrm{SS} \right) \end{array}$	7 jets 6-7 jets 0-3 <i>b</i>	Yes Yes Yes Yes	4.6 4.6 4.7 20.7 20.7 20.3 20.7	P. 1.61 TeV \$\vec{v}_{-}\$ 1.1 TeV \$\vec{v}_{-}\$ 1.2 TeV \$\vec{v}_{-}\$ 760 GeV \$\vec{v}_{-}\$ 350 GeV \$\vec{v}_{-}\$ 916 GeV \$\vec{v}_{-}\$ 880 GeV	$\begin{array}{l} A_{111}^{*}=0.10, \ A_{132}=0.05\\ A_{131}^{*}=0.10, \ A_{1}(c)_{12}=0.05\\ m(\vec{q})=m(\vec{g}), \ ct_{LSP}<1 \ mm\\ m(\vec{t}_{1}^{*})>80 \ GeV, \ A_{121}>0\\ m(\vec{t}_{1}^{*})>80 \ GeV, \ A_{133}>0\\ BR(c)=BR(c)=0\% \end{array}$	1212.1272 1212.1272 ATLAS-CONF-2012-140 ATLAS-CONF-2013-036 ATLAS-CONF-2013-036 ATLAS-CONF-2013-091 ATLAS-CONF-2013-097
Other	Scalar gluon pair, sgluon $\rightarrow q\bar{q}$ Scalar gluon pair, sgluon $\rightarrow t\bar{t}$ WIMP interaction (D5, Dirac χ)	0 2 e,μ(SS) 0	4 jets 1 <i>b</i> mono-jet	Yes Yes	4.6 14.3 10.5	sgluon 100-287 GeV 800 GeV 800 GeV 80 6 6 7 04 GeV	incl. limit from 1110.2693 m(γ)<80 GeV, limit of<687 GeV for D8	1210.4826 ATLAS-CONF-2013-051 ATLAS-CONF-2012-147
	√s = 7 TeV full data	Vs = 8 TeV partial data	√s = full	8 TeV data		10 ⁻¹ 1	Mass scale [TeV]	

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

• Note: no note.





• A continuum of ambitious and beautiful experiments in the past thirty years brought the Standard Model to the level of a theory.

• The observation of a possibly scalar particle at the LHC consecrates a daunting (collective) intellectual approach.

• You are entering the field at a time where we lost the *No-Loose theorem: Either the BEH or another source of EWK symmetry breaking below the TeV.*

- And these can be fascinating times.
- Starting by LHC Run II, approaching fast.
- Let's examine now precision physics, in the quark flavours at first.