Introduction to the Beyond the Standard Model session

Nikola Makovec

LABORATOIRE
DE L'ACCÉLÉRATEUR
LINÉAIRE

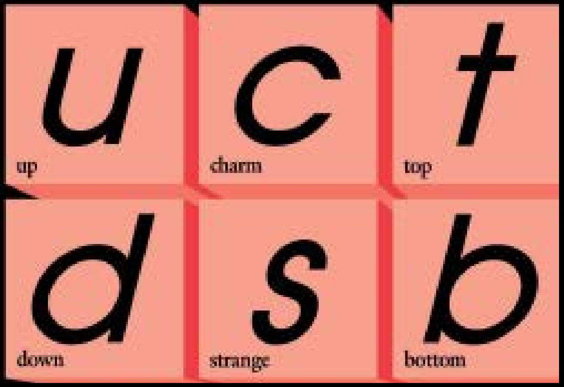
Les acteurs de la session BSM

Today

Tomorrow

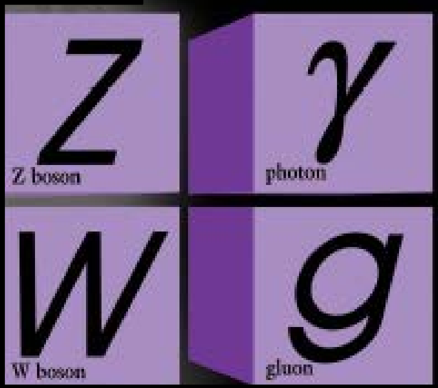
Speaker	Title
Ahmed BASSALAT	Overview of the Insertable B-Layer (IBL) Project of the ATLAS Experiment at the LHC
Zuzana BARNOVSKA	Search for a narrow resonance decaying to two photons with the ATLAS detector using 21 fb-1 of proton-proton collision data
Lucien HEURTIER	Extra U(1), effective operators, anomalies and dark matter
Vincent BIZOUARD	Desintegration du Higgs en Gamma Z dans le NMSSM
Marija MARJANOVIC	Analyse du canal SUSY-0lepton
Otilia Anamaria DUCU	Search for strongly-produced superpartners in final states with two same-sign leptons or three leptons with the ATLAS detector using 20 fb-1 of LHC pp collisions at 8 TeV
Alexandre Aubin	Recherche de stops dans l'experience CMS au LHC
Geoffroy Gilles	Recherche de nouveaux bosons de jauge lourds W' avec le détecteur ATLAS au LHC.
Mathieu Guigue	A la recherche de particules légères avec l'Hélium 3 polarisé
Yannick Stoll	Violation de saveur au delà du modèle minimal: Un tour d'horizon
Dorian Simon	Recherche de Nouvelle Physique dans les événements à quatre quarks top avec les détecteur ATLAS auprès du LHC

Quarks

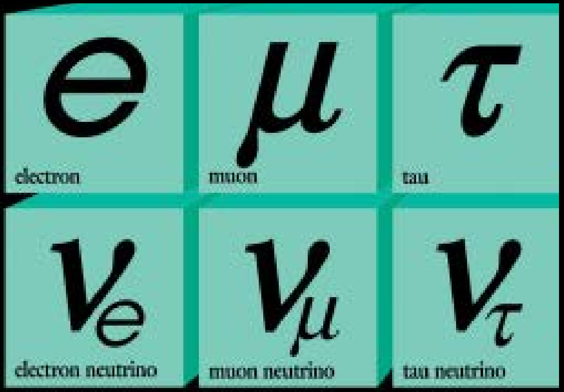


u up	c charm	t top
d down	s strange	b bottom

Forces

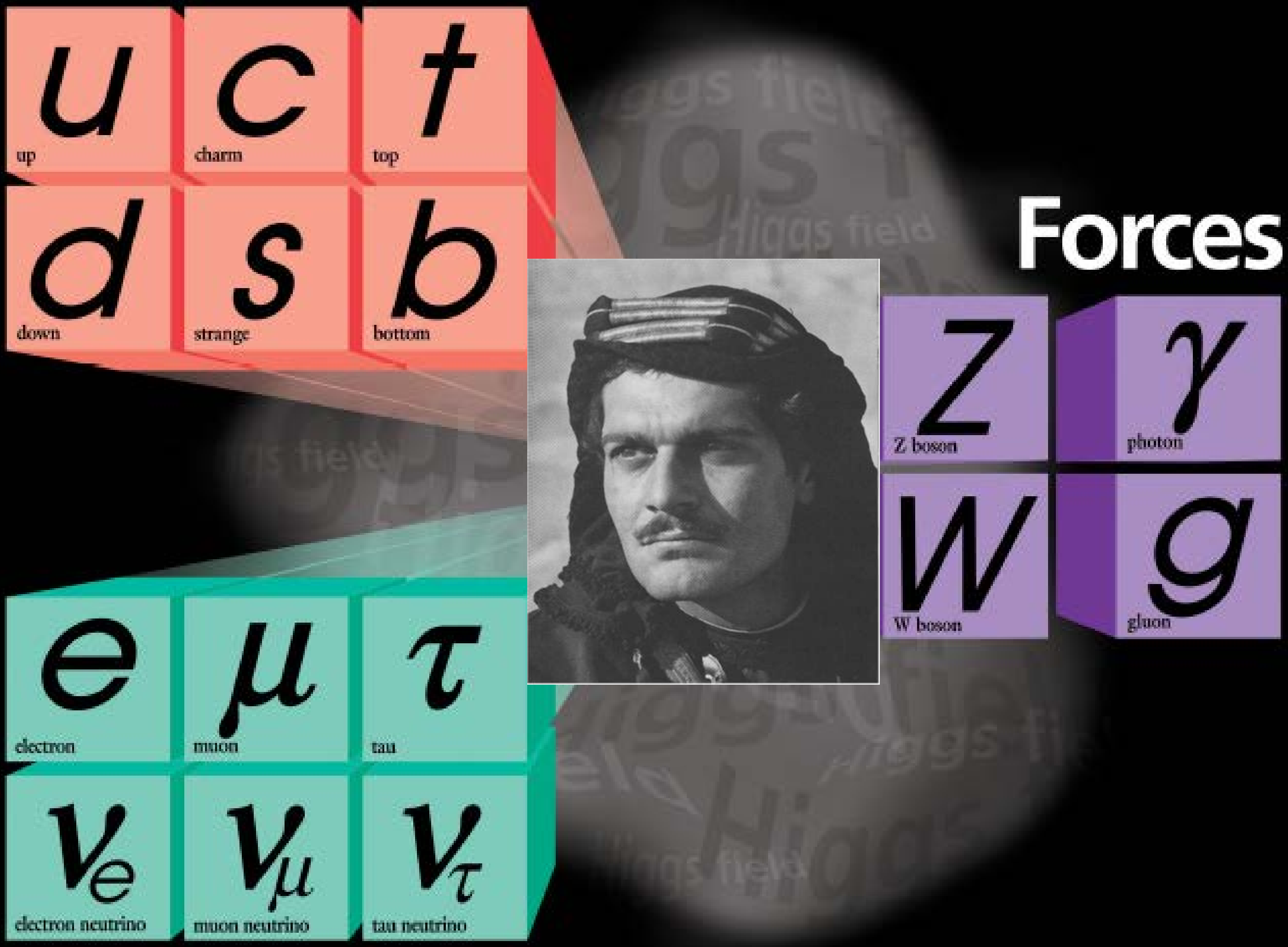


Z Z boson	γ photon
W W boson	g gluon



e electron	μ muon	τ tau
ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino

Leptons



Quarks

u up	c charm	t top
d down	s strange	b bottom

Forces

Z Z boson	γ photon
W W boson	g gluon

e electron	μ muon	τ tau
ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino

Leptons

The Standard Model of particle physics

Most general renormalizable lagrangian including all SM fields with $SU(3)_C \times SU(2)_L \times U(1)_Y$ gauge groups:

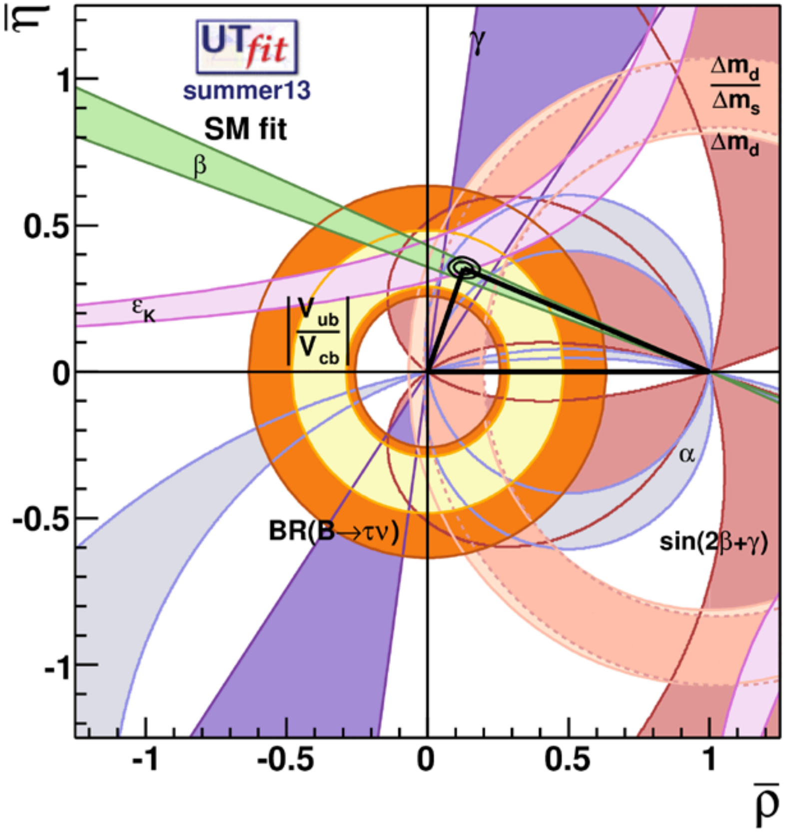
$$\begin{aligned}
\mathcal{L}_{SM} = & -\frac{1}{4g'^2}B_{\mu\nu}B^{\mu\nu} - \frac{1}{2g^2}\mathrm{Tr}(W_{\mu\nu}W^{\mu\nu}) - \frac{1}{2g_s^2}\mathrm{Tr}(G_{\mu\nu}G^{\mu\nu}) \\
& +\bar{Q}_i i\not{D} Q_i + \bar{L}_i i\not{D} L_i + \bar{u}_i i\not{D} u_i + \bar{d}_i i\not{D} d_i + \bar{e}_i i\not{D} e_i \\
& +(Y_u^{ij}\bar{Q}_i u_j \tilde{H} + Y_d^{ij}\bar{Q}_i d_j H + Y_l^{ij}\bar{L}_i e_j H + \mathrm{h.c.}) \\
& +(D_\mu H)^\dagger (D^\mu H) - \lambda(H^\dagger H)^2 - \boxed{\mu^2} H^\dagger H \\
& + \frac{\theta}{32\pi^2}\epsilon^{\mu\nu\rho\sigma}\mathrm{Tr}(G_{\mu\nu}G_{\rho\sigma})
\end{aligned}$$

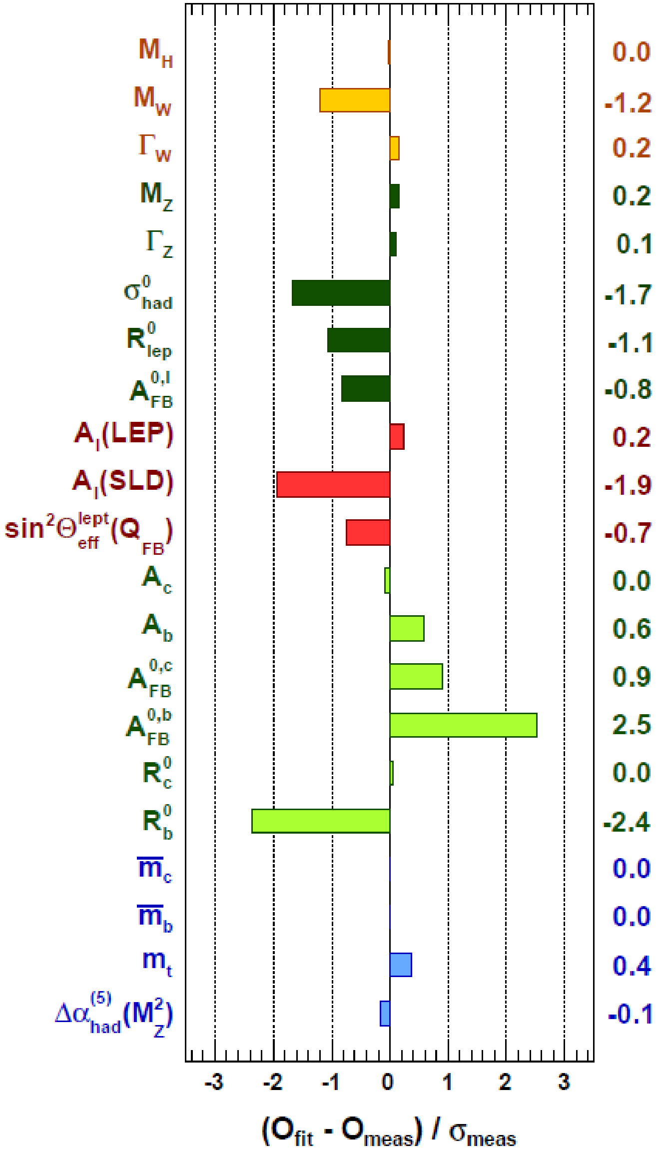
19 parameters:

- 3 gauge coupling constants
- 9 fermion Yukawa couplings
- 3 CKM mixing angles + 1 phase
- μ,λ or m_Z, m_H
- θ_{strong}

Success

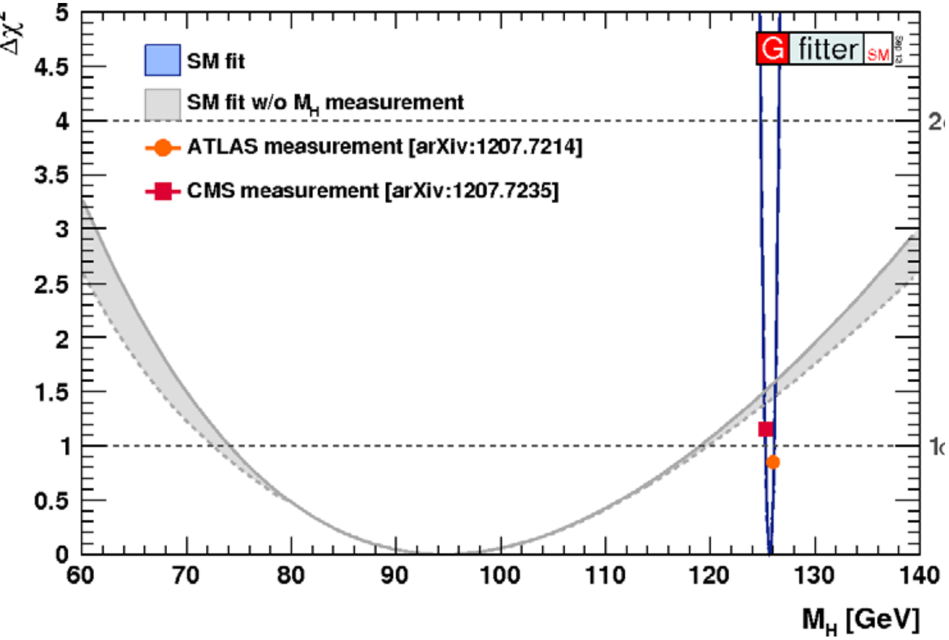
- Electroweak measurements at LEP, SLD, and Tevatron
- CP-violation at B-factories, K-factories

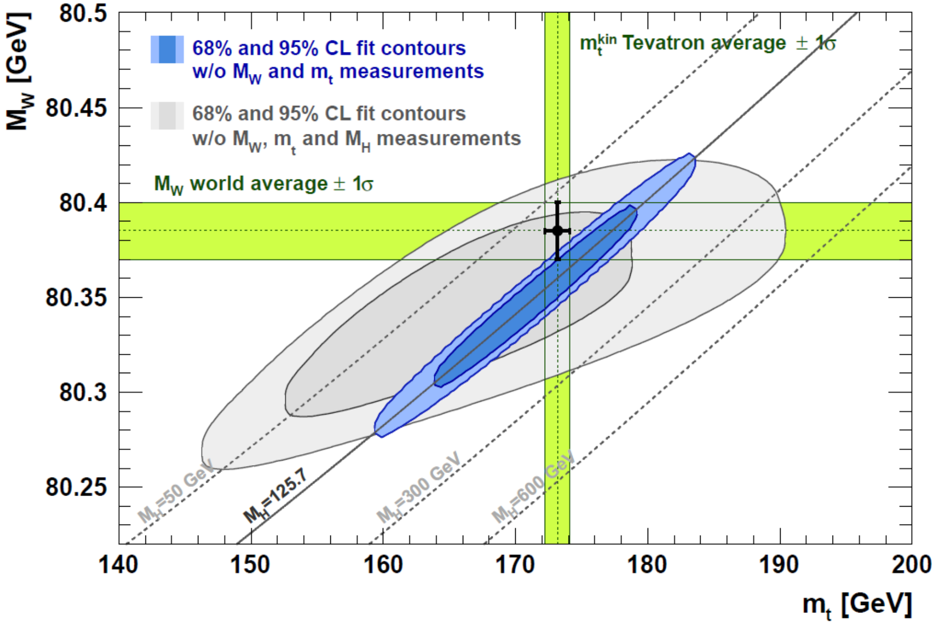


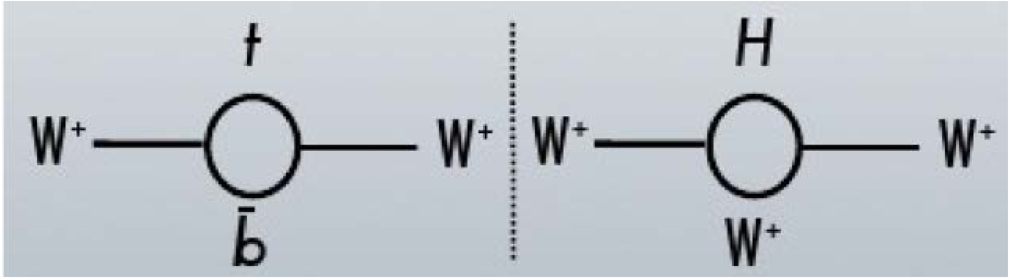


Latest success: Higgs discovery

- LHC Higgs boson discovery at ~126 GeV is compatible with precision measurements







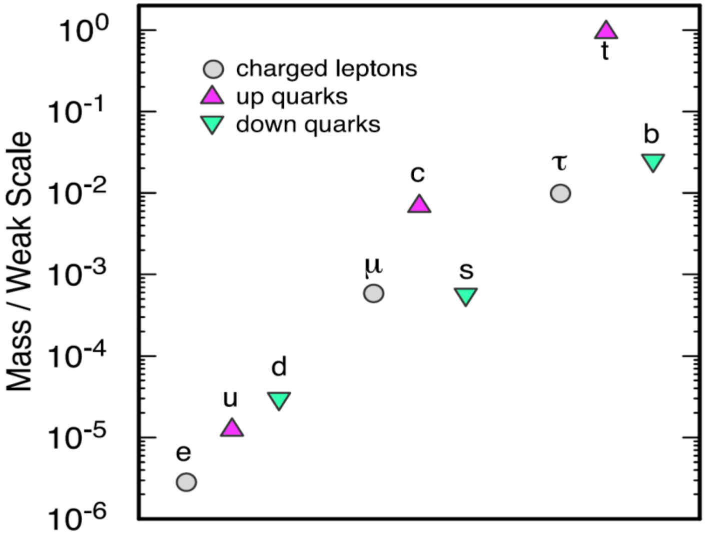
Unanswered questions?

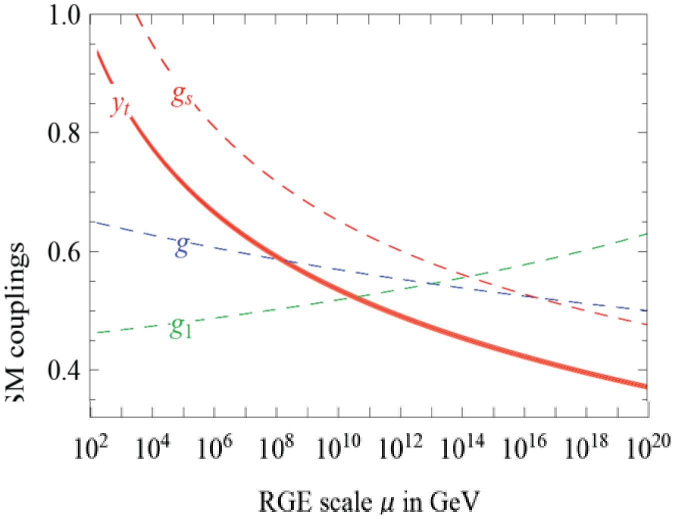
Experimental evidence not explained by SM

- **Why do neutrinos have mass yet so light?**
  - Observed neutrino masses imply new physics (at least, right-handed neutrinos) somewhere between 1 keV and 10^{15} GeV)
  - Add 7(+2) parameters to the SM
- **What is the origin of matter anti-matter asymmetry in Universe?**
  - Domination of matter over anti-matter requires new physics between 100 GeV and 10^{16} GeV
- **What is dark matter?**
  - Existence of dark matter requires new physics (at least one new stable particle) somewhere between sub-eV and 10^{19} GeV
  - What is the physics which reconciles gravity and quantum mechanics?
- **What is the physics which reconciles gravity and quantum mechanics?**
  - New physics expected (at least) at energies ~ 10^{19}GeV !

Why things are the way they are?

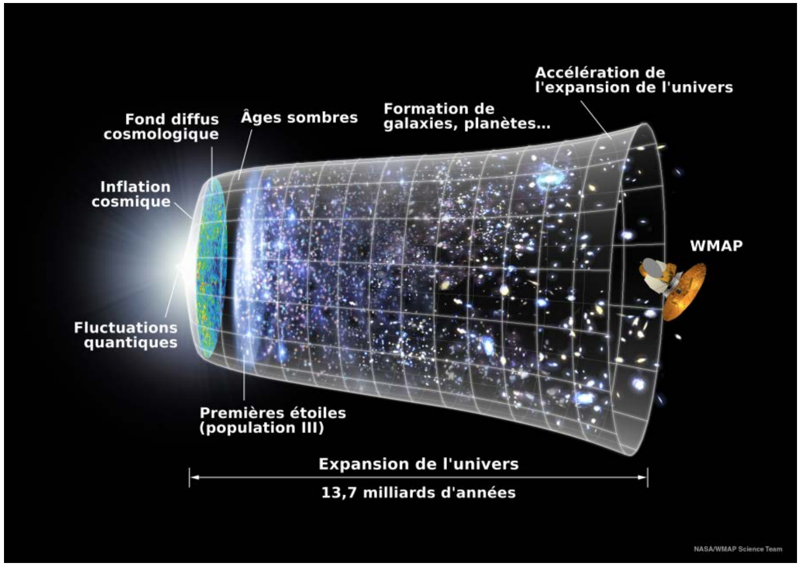
- **The Higgs mass term:**
  - Why the gravity is so weak?
  - $M_{EW}^2 \sim 10^4 GeV^2 << M_P^2 \sim 10^{38}\ GeV^2$
- **Charge quantization:**
  - Why $|Q_p + Q_e| < 10^{-21} Q_e$?
- **The strong CP problem:**
  - Why $\theta_{strong} < 10^{-13}$
- **Number of families:**
  - Why are there three families?
- **Fermion masses:**
  - Why $m_{top}/m_e \sim 3 \times 10^5$?
- **Gauge coupling unification:**
  - Is there a unified description of all forces at higher energy?



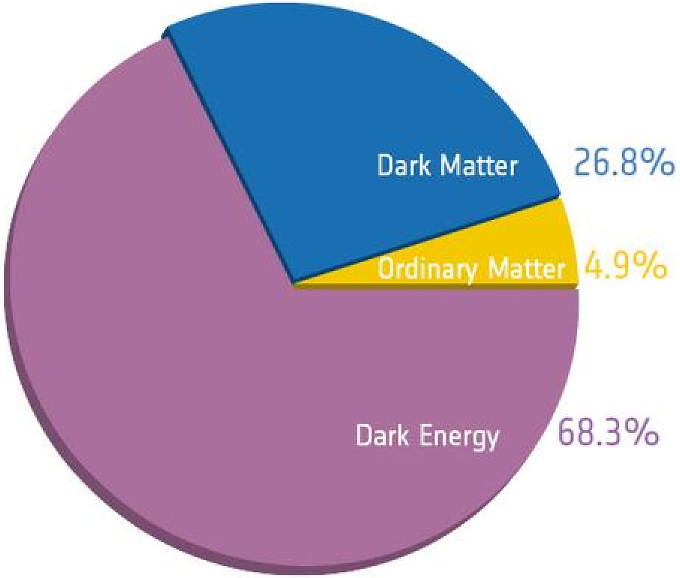


Cosmology and particle physics

- What is the **dark energy**?
- Why is the **cosmological constant** small but non zero ?
- Why now? (**Cosmic coincidence problem**)
- Why is the Universe so big? (**flatness problem, horizon problem**)
- What is the physics which underlies **inflation**?
  - Link with **Higgs**?

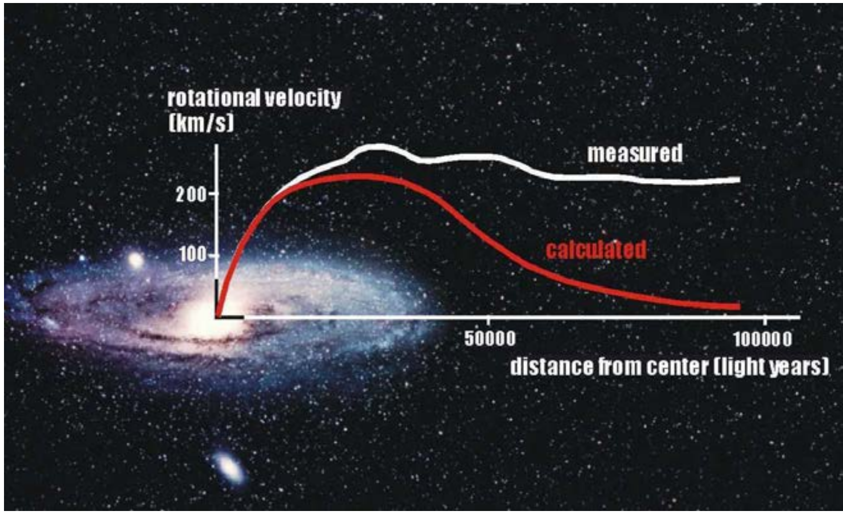


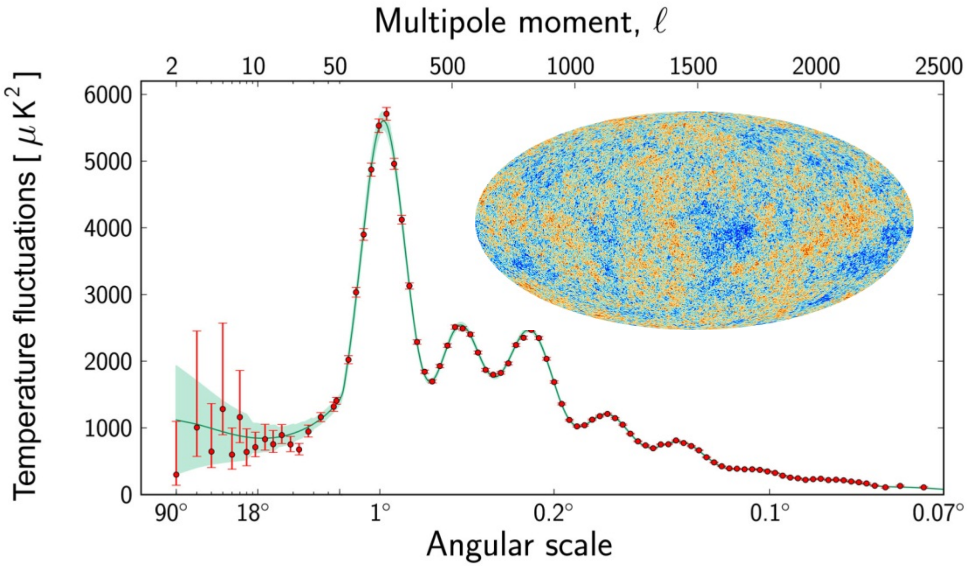
NASA/WMAP Science Team



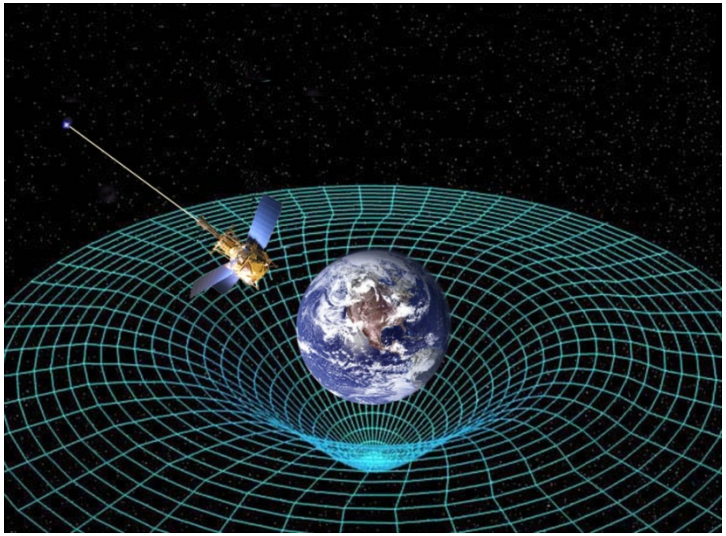
Dark matter

- Dark matter does not emit or reflect sufficient electromagnetic radiation to be detected.
- ~ 80% of matter is Dark Matter
- The most compelling candidate is a WIMP for Weakly Interacting Massive Particle

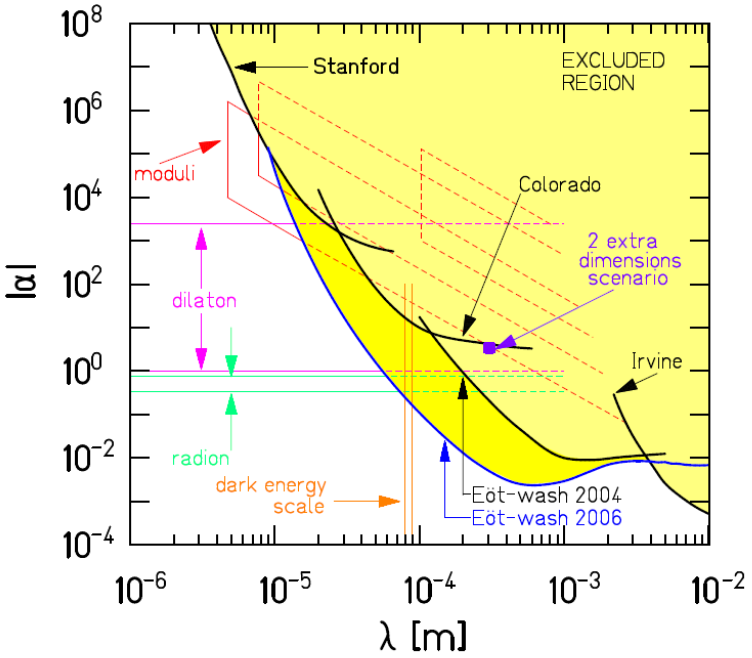




Gravity



- Described successfully by the **General relativity** but:
  - **No acceptable quantum theory of gravity**
  - Inverse-square law of gravity only down to distances just **shorter than 0.1 mm**, corresponding to energies of 0.01eV



- Associated with a dynamical symmetry group (symmetry of the spacetime), other gauge theories are built on internal symmetries.

- Very weak compared to the three other forces
  - Suppressed E/M_{planck} with M_{planck}=1.22 10^{19}GeV

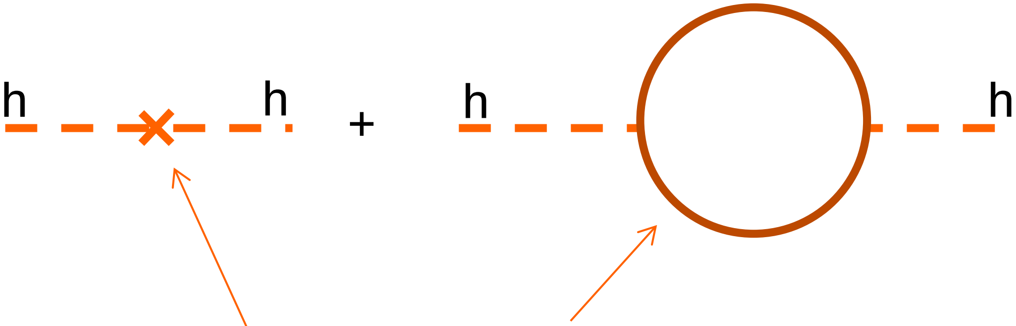
- **New physics expected at least at energies ~ 10^{19}GeV !**

Hierarchy problem

$m_{\rm P} = \sqrt{\frac{\hbar c}{G}}$

- Why the gravity is so weak?
  - $M_{EW}^2 \sim 10^4 \mathrm{GeV}^2 << M_P^2 \sim 10^{38}\ \mathrm{GeV}^2$
- At the quantum level, scalar masses are extremely sensitive to heavy states

$$m_H^2 =$$



$$m_H^2 = m_{bare}^2 + c.M_p^2$$

- Strong dependence of physics at the electroweak scale on the physics at the Planck scale
  - It’s like saying that to describe the rotation of the moon around the earth one needs to know about the quarks inside the proton

Hierarchy problem

$$m_H^2 = m_{bare}^2 + c.M_p^2$$

Hierarchy problem

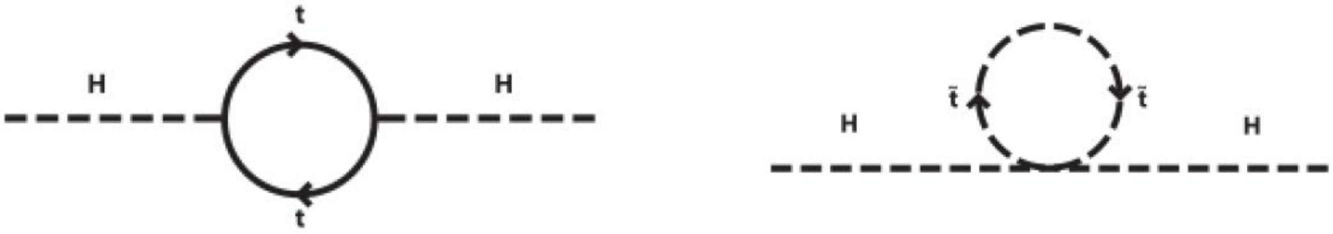
$$m_H^2 = 125^2 = 36{,}127{,}890{,}984{,}789{,}307{,}394{,}520{,}932{,}878{,}928{,}933{,}023$$
$$- 36{,}127{,}890{,}984{,}789{,}307{,}394{,}520{,}932{,}878{,}928{,}917{,}398$$

Hierarchy problem

$$m_H^2 = 125^2 = 36,127,890,984,789,307,394,520,932,878,928,933,023$$

$$-\,36,127,890,984,789,307,394,520,932,878,928,917,398$$

- Extreme fine tuning of parameters!!!!
- Different situation for fermions or gauge bosons $\Rightarrow$ gauge symmetries protect them
- **Solution to the hierarchy problem lead to new physics at the weak scale**

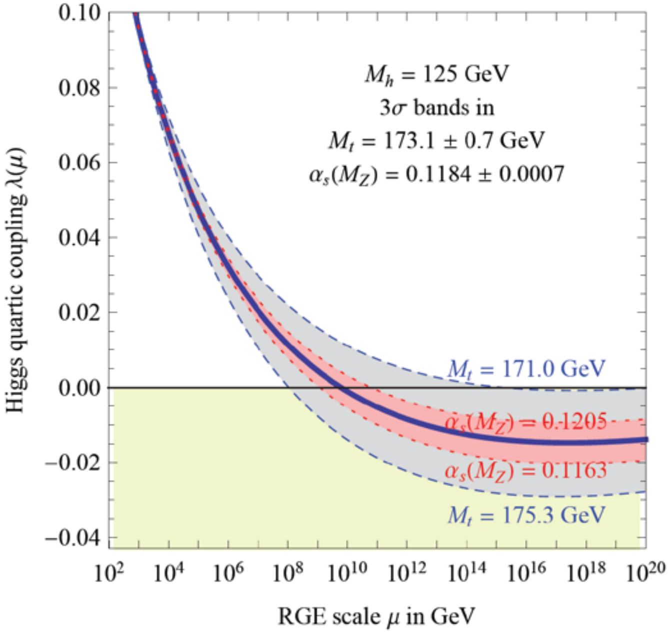


Fate of the EW vacuum

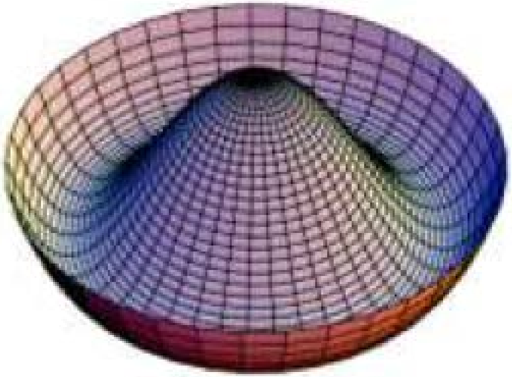
- Higgs self-coupling (λ) energy variation deduces from renormalization group evolution

- EW vacuum unstable if λ <0

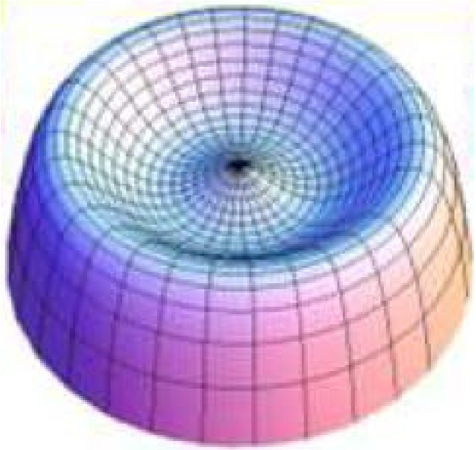
$$V(\phi) = \mu^2 |\phi|^2 + \lambda |\phi|^4$$

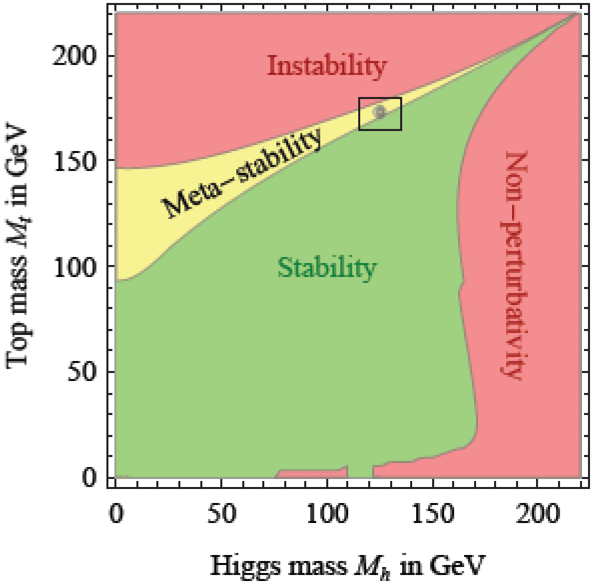


λ>0



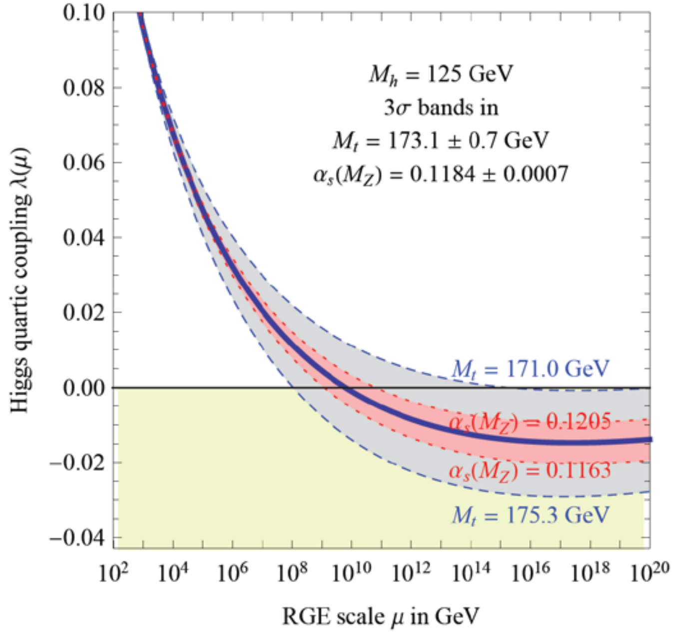
λ<0

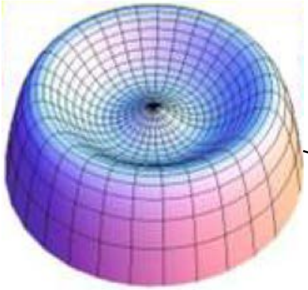


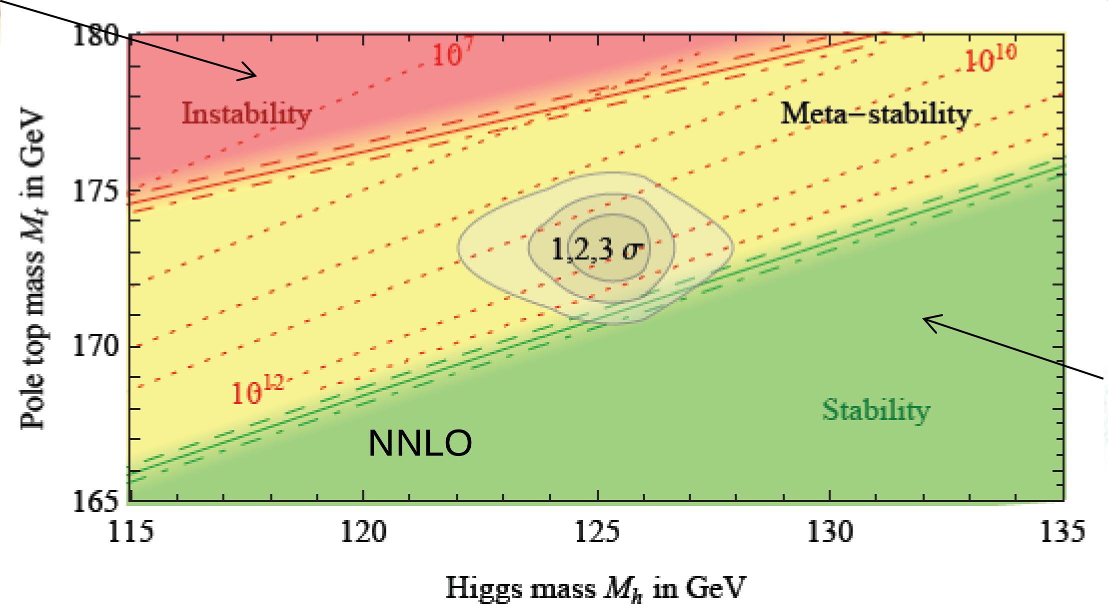


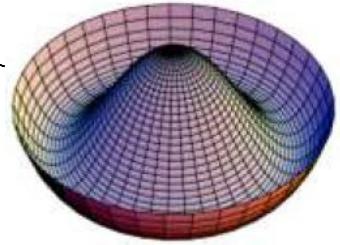
Fate of the EW vacuum

- Assuming SM valid up to M_p
  $\Rightarrow$ meta stable @ 2σ
- Or stable vacuum if new physics appears $\Lambda = 10^{10}$GeV…







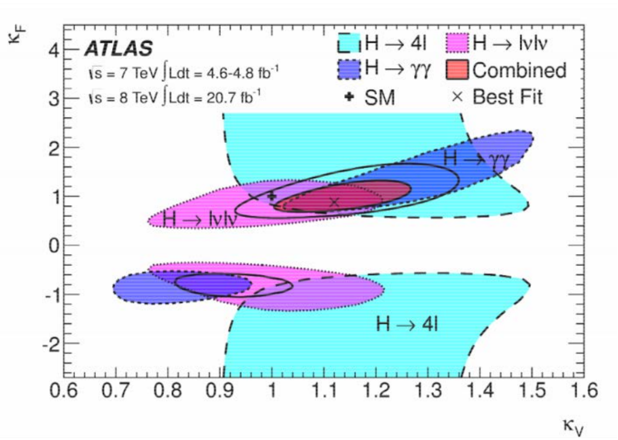


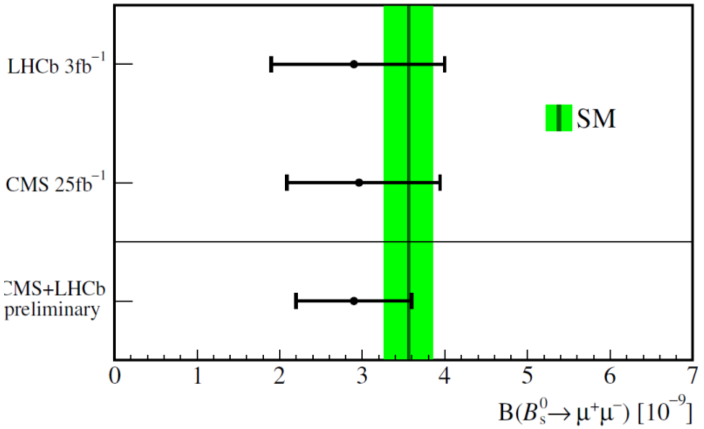
BSM models

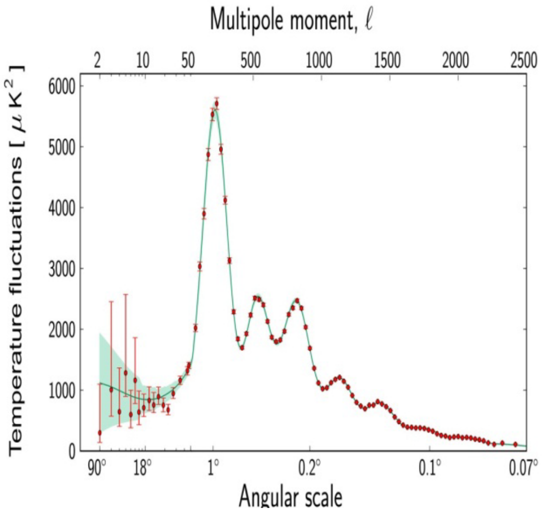
- Many BSM models developed to answer Standard Model limitations. For instance:
  - Supersymmetry:
    - Add a new broken symmetry to SM to protect Higgs mass
  - Composite Higgs:
    - The Higgs is not elementary, first manifestation of a new strong force
  - Large extra dimensions:
    - addresses Hierarchy Problem by bringing the Plank scale down to TeV

Various strategies to track new physics

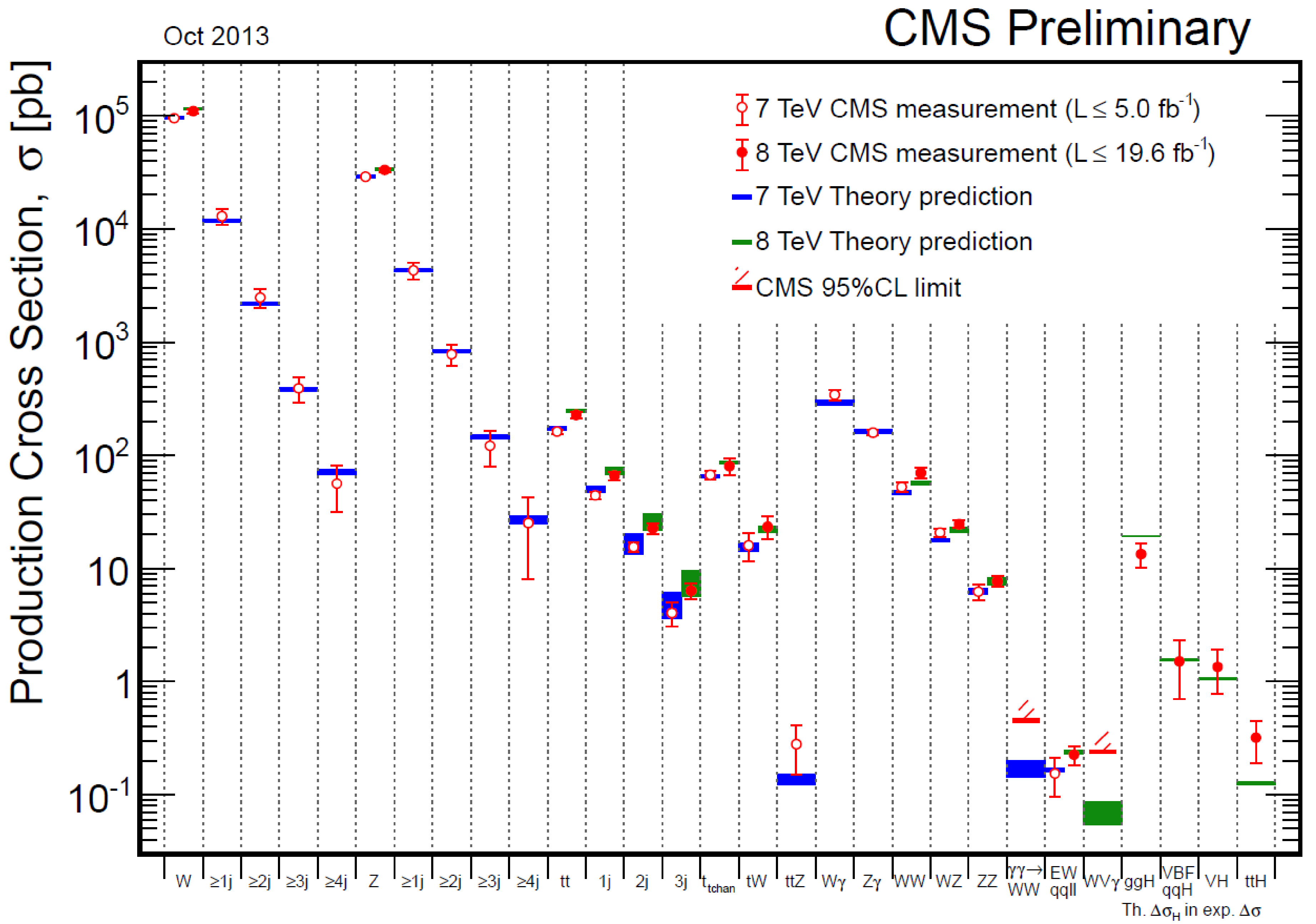
- **Multi-pronged approach to search for new physics**
  - **Direct Searches** at high energy colliders
  - **Precision Measurements** (need good theoretical control)
  - **Rare decays** (K & B) **and Forbidden Processes**
  - **Neutrino physics**
  - **Cosmological observations**
- **Beyond Standard Model physics not only in this session!!!**







The Standard Model @ LHC



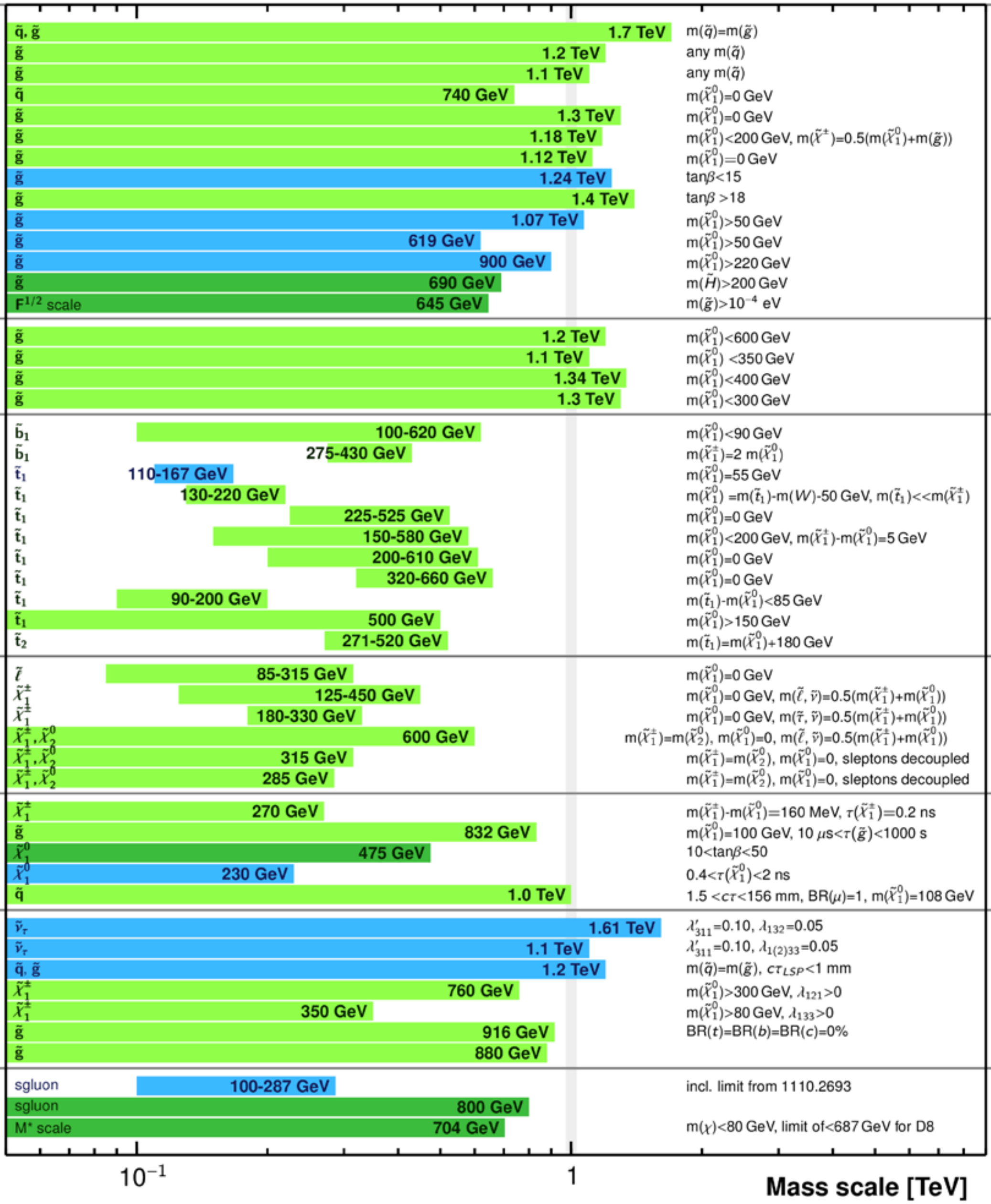
Limits, limits, limits

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: SUSY 2013

ATLAS Preliminary

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

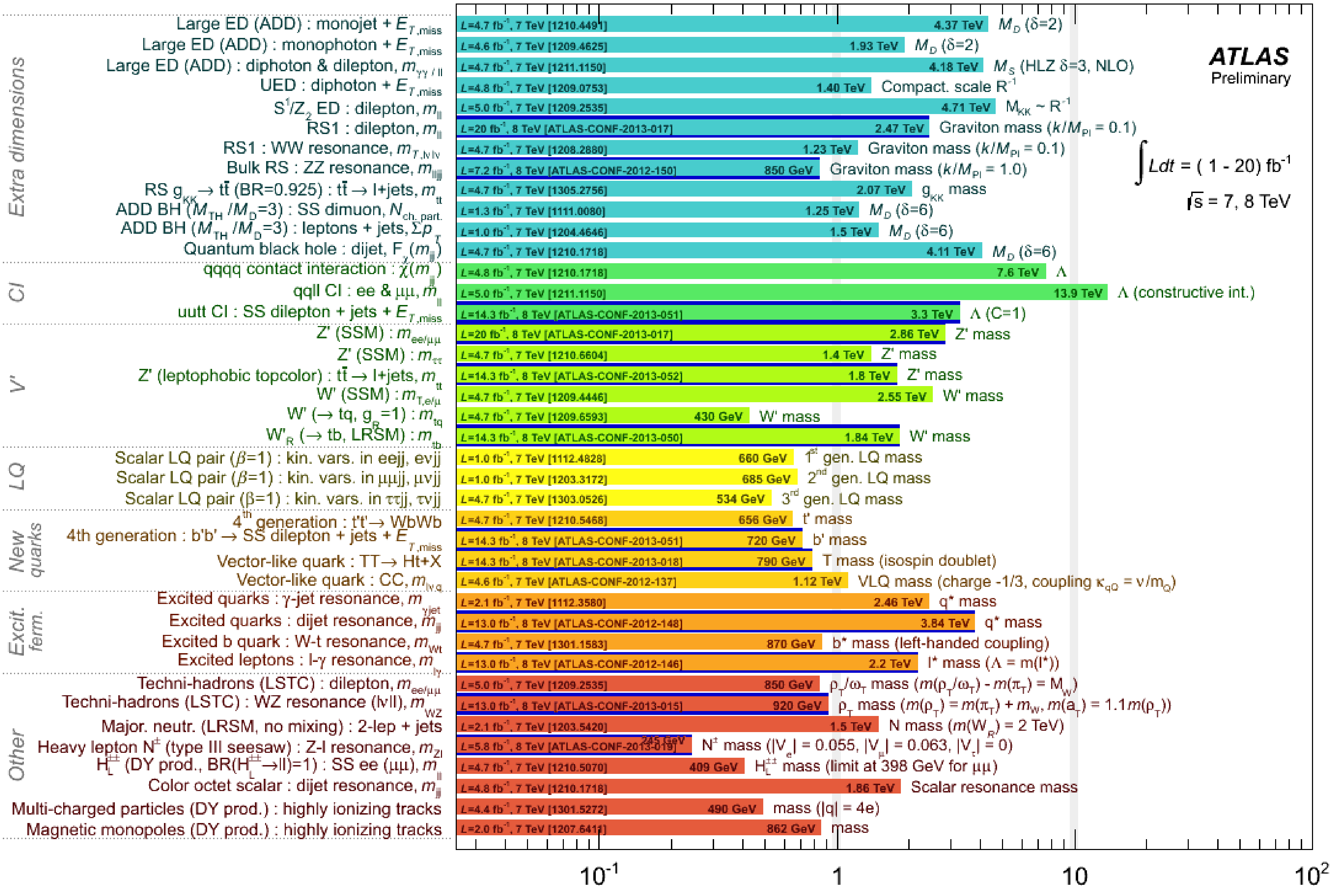


	Model	e,μ,τ,γ	Jets	E_T^{miss}	$\int\mathcal{L}\,dt[\text{fb}^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q},\tilde{g}$ 1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	any $m(\tilde{q})$	1308.1841
	$\tilde{q}\tilde{q},\ \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 740 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g},\ \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g},\ \tilde{g}\to qq\tilde{\chi}_1^{\pm}\to qqW^{\pm}\tilde{\chi}_1^0$	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.18 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}^{\pm})$=0.5($m(\tilde{\chi}_1^0)$+$m(\tilde{g})$)	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g},\ \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ	0-3 jets	-	20.3	$\tilde{g}$ 1.12 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e,μ	2-4 jets	Yes	4.7	$\tilde{g}$ 1.24 TeV	$\tan\beta$<15	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$ 1.4 TeV	$\tan\beta$ >18	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	-	Yes	4.8	$\tilde{g}$ 1.07 TeV	$m(\tilde{\chi}_1^0)$>50 GeV	1209.0753
	GGM (wino NLSP)	1 $e,\mu+\gamma$	-	Yes	4.8	$\tilde{g}$ 619 GeV	$m(\tilde{\chi}_1^0)$>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$ 900 GeV	$m(\tilde{\chi}_1^0)$>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e,μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$ 690 GeV	$m(\tilde{H})$>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale 645 GeV	$m(\tilde{g})>10^{-4}$ eV	ATLAS-CONF-2012-147
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$ 1.2 TeV	$m(\tilde{\chi}_1^0)$<600 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	$m(\tilde{\chi}_1^0)$ <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.34 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	ATLAS-CONF-2013-061
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1,\ \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$ 100-620 GeV	$m(\tilde{\chi}_1^0)$<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1,\ \tilde{b}_1\to t\tilde{\chi}_1^{\pm}$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$ 275-430 GeV	$m(\tilde{\chi}_1^{\pm})$=2 $m(\tilde{\chi}_1^0)$	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}_1^{\pm}$	1-2 e,μ	1-2 b	Yes	4.7	$\tilde{t}_1$ 110-167 GeV	$m(\tilde{\chi}_1^0)$=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e,μ	0-2 jets	Yes	20.3	$\tilde{t}_1$ 130-220 GeV	$m(\tilde{\chi}_1^0)$ =$m(\tilde{t}_1)$-$m(W)$-50 GeV, $m(\tilde{t}_1)$<<$m(\tilde{\chi}_1^{\pm})$	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e,μ	2 jets	Yes	20.3	$\tilde{t}_1$ 225-525 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-065
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}_1^{\pm}$	0	2 b	Yes	20.1	$\tilde{t}_1$ 150-580 GeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}_1^{\pm})$-$m(\tilde{\chi}_1^0)$=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e,μ	1 b	Yes	20.7	$\tilde{t}_1$ 200-610 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$ 320-660 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$ 90-200 GeV	$m(\tilde{t}_1)$-$m(\tilde{\chi}_1^0)$<85 GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_1$ 500 GeV	$m(\tilde{\chi}_1^0)$>150 GeV	ATLAS-CONF-2013-025
	$\tilde{t}_2\tilde{t}_2,\ \tilde{t}_2\to\tilde{t}_1+Z$	3 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_2$ 271-520 GeV	$m(\tilde{t}_1)$=$m(\tilde{\chi}_1^0)$+180 GeV	ATLAS-CONF-2013-025
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R},\ \tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$ 85-315 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-,\ \tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 125-450 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})$=0.5($m(\tilde{\chi}_1^{\pm})$+$m(\tilde{\chi}_1^0)$)	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-,\ \tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.7	$\tilde{\chi}_1^{\pm}$ 180-330 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})$=0.5($m(\tilde{\chi}_1^{\pm})$+$m(\tilde{\chi}_1^0)$)	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu),\ \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.7	$\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$ 600 GeV	$m(\tilde{\chi}_1^{\pm})$=$m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})$=0.5($m(\tilde{\chi}_1^{\pm})$+$m(\tilde{\chi}_1^0)$)	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0Z\tilde{\chi}_1^0$	3 e,μ	0	Yes	20.7	$\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$ 315 GeV	$m(\tilde{\chi}_1^{\pm})$=$m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0h\tilde{\chi}_1^0$	1 e,μ	2 b	Yes	20.3	$\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$ 285 GeV	$m(\tilde{\chi}_1^{\pm})$=$m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 270 GeV	$m(\tilde{\chi}_1^{\pm})$-$m(\tilde{\chi}_1^0)$=160 MeV, $\tau(\tilde{\chi}_1^{\pm})$=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$ 832 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau},\ \tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$ 475 GeV	10<$\tan\beta$<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$ 230 GeV	0.4<$\tau(\tilde{\chi}_1^0)$<2 ns	1304.6310
	$\tilde{q}\tilde{q},\ \tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$ 1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, $m(\tilde{\chi}_1^0)$=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau+X,\ \tilde{\nu}_\tau\to e+\mu$	2 e,μ	-	-	4.6	$\tilde{\nu}_\tau$ 1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X,\ \tilde{\nu}_\tau\to e(\mu)+\tau$	1 $e,\mu+\tau$	-	-	4.6	$\tilde{\nu}_\tau$ 1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	1 e,μ	7 jets	Yes	4.7	$\tilde{q},\tilde{g}$ 1.2 TeV	$m(\tilde{q})$=$m(\tilde{g})$, $c\tau_{LSP}$<1 mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-,\ \tilde{\chi}_1^+\to W\tilde{\chi}_1^0,\ \tilde{\chi}_1^0\to ee\tilde{\nu}_\mu,\ e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.7	$\tilde{\chi}_1^{\pm}$ 760 GeV	$m(\tilde{\chi}_1^0)$>300 GeV, λ_{121}>0	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-,\ \tilde{\chi}_1^+\to W\tilde{\chi}_1^0,\ \tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e,\ e\tau\tilde{\nu}_\tau$	3 $e,\mu+\tau$	-	Yes	20.7	$\tilde{\chi}_1^{\pm}$ 350 GeV	$m(\tilde{\chi}_1^0)$>80 GeV, λ_{133}>0	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1t,\ \tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$ 880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon 100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e,μ (SS)	1 b	Yes	14.3	sgluon 800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale 704 GeV	$m(\chi)$<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

🟦 $\sqrt{s}$ = 7 TeV full data	🟩 $\sqrt{s}$ = 8 TeV partial data	🟩 $\sqrt{s}$ = 8 TeV full data

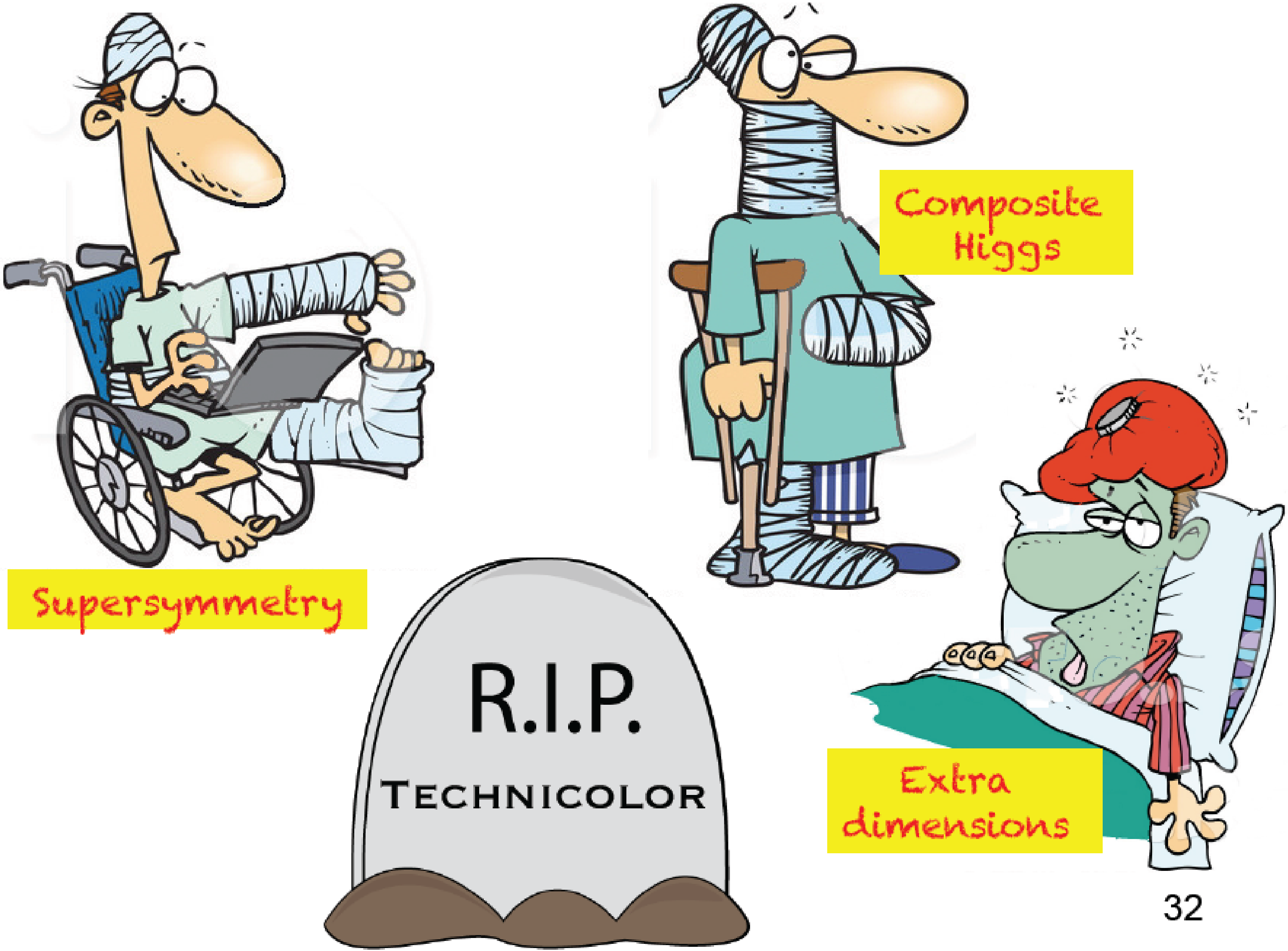
*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

ATLAS Exotics Searches* - 95% CL Lower Limits (Status: May 2013)



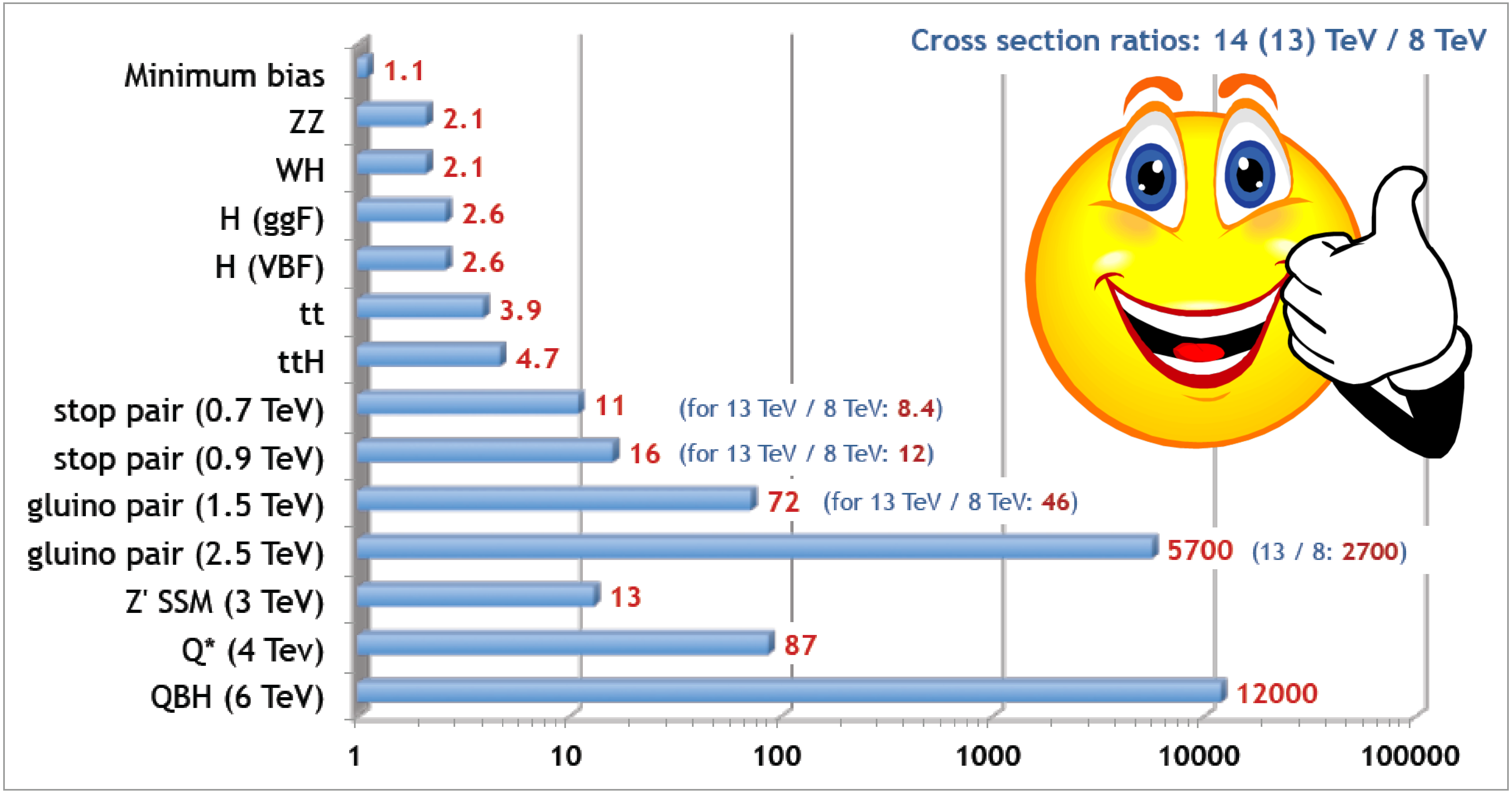
*Only a selection of the available mass limits on new states or phenomena shown

LHC run I summary



G.F. Giudice

LHC run II perspective

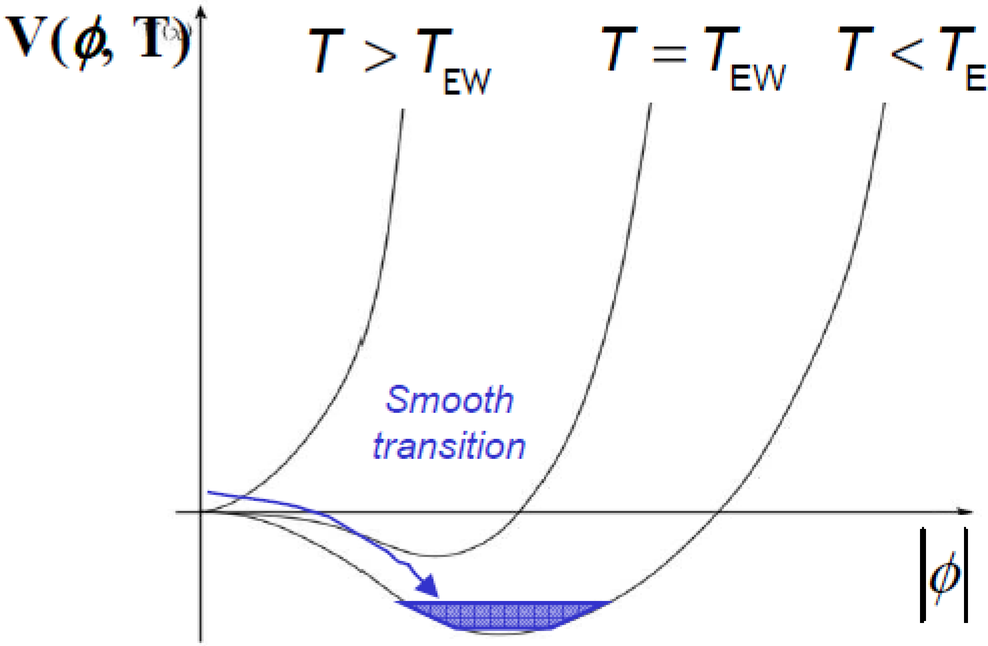


Sources of inspiration

- *Unanswered Questions in the Electroweak Theory*, C. Quigg, hep-ph/0905.3187
- *Beyond the Standard Model*, A. Pomarol, hep-ph/1202.1391
- *Physics Beyond the Standard Model and Dark Matter*, H. Murayama, hep-ph/0704.2276
- *Nouvelles Physiques* by Henri Bachacou and Adam Falkowski, Lecture @ Ecole de Gif 2012 (slides only)

Backup

Second order phase transition or cross-over



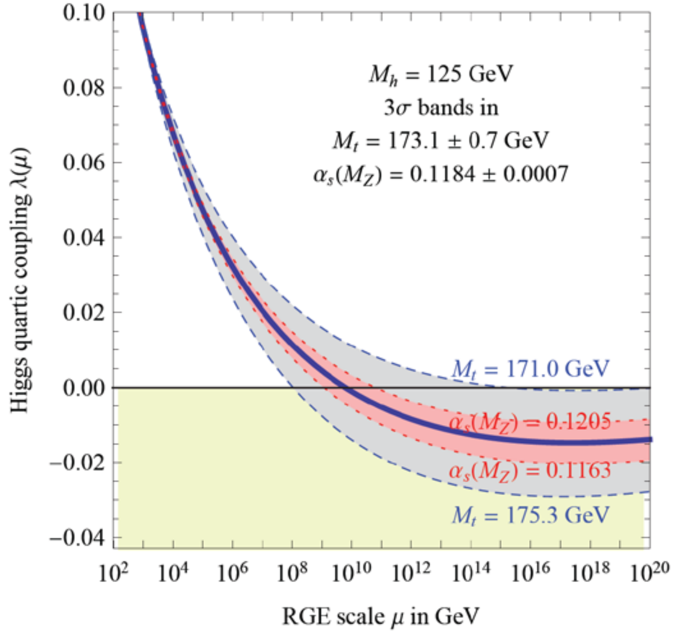
EW Vacuum (ϕ_{min}=v for T≈0)

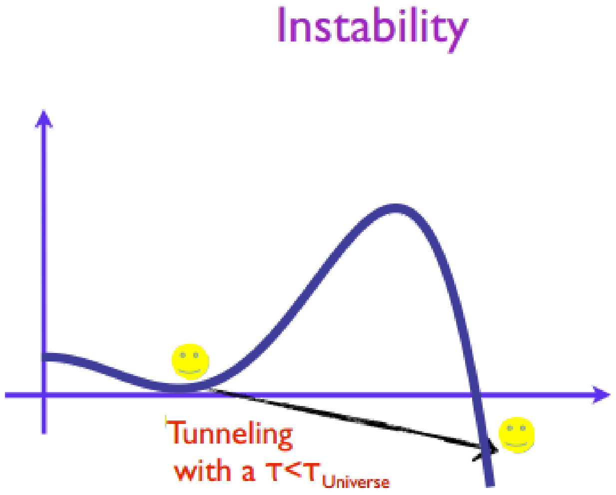
No role in baryogenesis

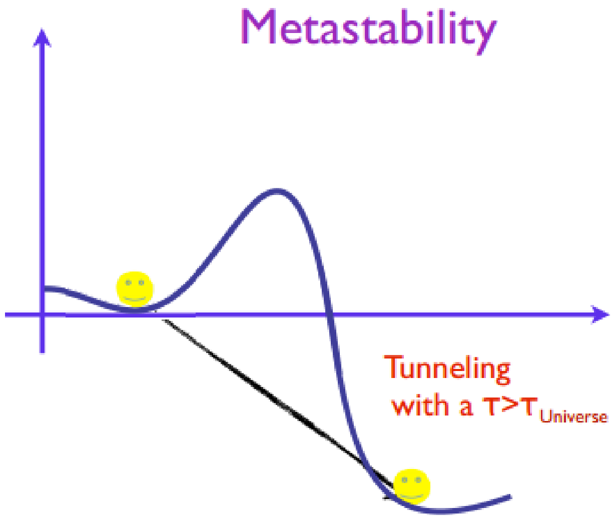
Fate of the EW vacuum

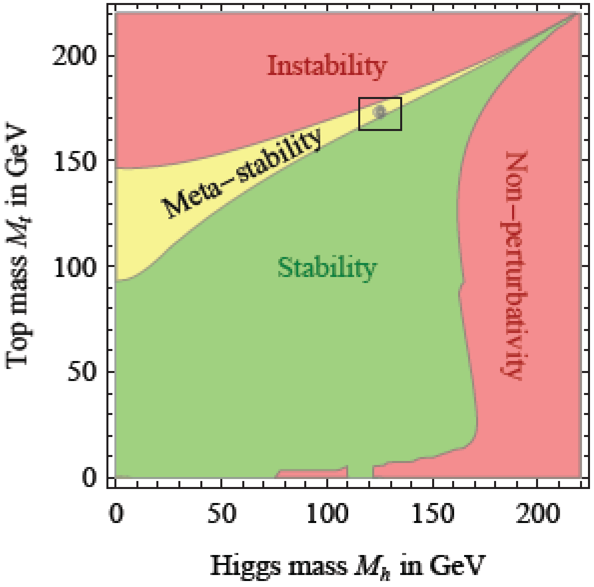
- Higgs self-coupling (λ) energy variation deduces from renormalization group evolution

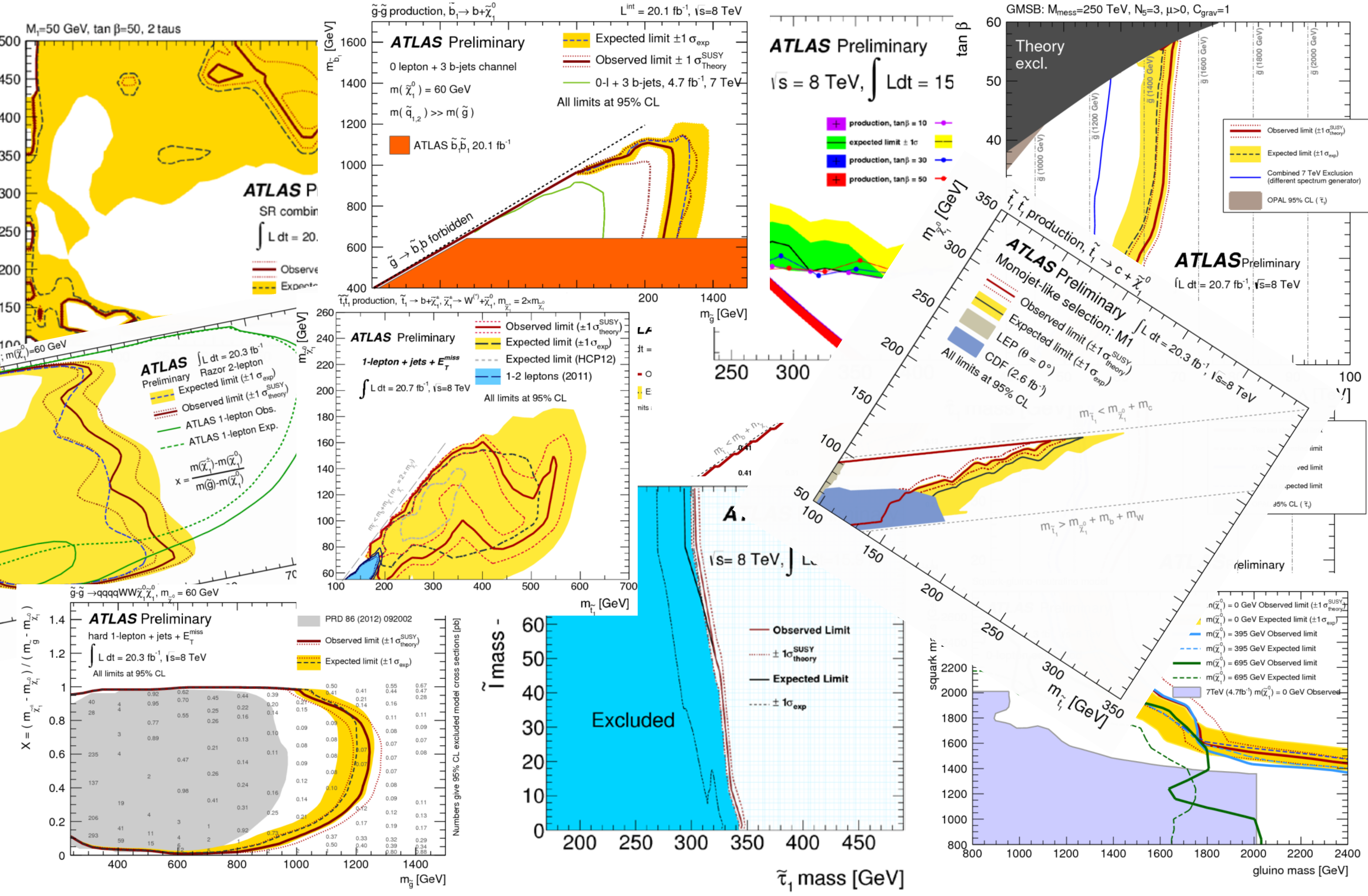
- EW vacuum unstable if λ <0










M1=50 GeV, tan β=50, 2 taus
ATLAS Preliminary
SR combin
Observe
Expecte
g̃-g̃ production, b̃1→ b+χ̃⁰1
Lint = 20.1 fb⁻¹, √s=8 TeV
ATLAS Preliminary
0 lepton + 3 b-jets channel
m(χ̃⁰1) = 60 GeV
m(q̃1,2) >> m(g̃)
ATLAS b̃1b̃1 20.1 fb⁻¹
Expected limit ±1 σexp
Observed limit ± 1 σSUSYTheory
0-l + 3 b-jets, 4.7 fb⁻¹, 7 TeV
All limits at 95% CL
g̃ → b̃b forbidden
mb̃1 [GeV]
mg̃ [GeV]
ATLAS Preliminary
√s = 8 TeV, ∫ Ldt = 15
production, tanβ = 10
expected limit ± 1σ
production, tanβ = 30
production, tanβ = 50
GMSB: Mmess=250 TeV, N5=3, μ>0, Cgrav=1
Theory excl.
tan β
Observed limit (±1 σSUSYtheory)
Expected limit (±1 σexp)
Combined 7 TeV Exclusion (different spectrum generator)
OPAL 95% CL (τ̃1)
ATLAS Preliminary
∫L dt = 20.7 fb⁻¹, √s=8 TeV
t̃1t̃1 production, t̃1 → c + χ̃⁰1
ATLAS Preliminary
Monojet-like selection: M1
∫L dt = 20.3 fb⁻¹, √s=8 TeV
Observed limit (±1 σSUSYtheory)
Expected limit (±1 σexp)
LEP (θ = 0°)
CDF (2.6 fb⁻¹)
All limits at 95% CL
mt̃1 < mχ̃⁰1 + mc
mt̃1 > mχ̃⁰1 + mb + mW
mχ̃⁰1 [GeV]
mt̃1 [GeV]
m(χ̃⁰1)=60 GeV
ATLAS Preliminary
∫L dt = 20.3 fb⁻¹
Razor 2-lepton
Expected limit (±1 σexp)
Observed limit (±1 σSUSYtheory)
ATLAS 1-lepton Obs.
ATLAS 1-lepton Exp.
x = (m(χ̃±1)-m(χ̃⁰1)) / (m(g̃)-m(χ̃⁰1))
t̃1t̃1 production, t̃1 → b+χ̃±1, χ̃±1→ W(*)+χ̃⁰1, mχ̃±1 = 2×mχ̃⁰1
ATLAS Preliminary
1-lepton + jets + ETmiss
∫L dt = 20.7 fb⁻¹, √s=8 TeV
Observed limit (±1 σSUSYtheory)
Expected limit (±1 σexp)
Expected limit (HCP12)
1-2 leptons (2011)
All limits at 95% CL
mχ̃⁰1 [GeV]
mt̃1 [GeV]
g̃-g̃ →qqqqWWχ̃⁰1χ̃⁰1, mχ̃⁰1 = 60 GeV
ATLAS Preliminary
hard 1-lepton + jets + ETmiss
∫L dt = 20.3 fb⁻¹, √s=8 TeV
All limits at 95% CL
PRD 86 (2012) 092002
Observed limit (±1 σSUSYtheory)
Expected limit (±1 σexp)
X = (mχ̃±1 - mχ̃⁰1) / (mg̃ - mχ̃⁰1)
Numbers give 95% CL excluded model cross sections [pb]
mg̃ [GeV]
√s= 8 TeV, ∫ L
Excluded
Observed Limit
± 1σSUSYtheory
Expected Limit
± 1σexp
l̃ mass
τ̃1 mass [GeV]
m(χ̃⁰1) = 0 GeV Observed limit (±1 σSUSYtheory)
m(χ̃⁰1) = 0 GeV Expected limit (±1 σexp)
m(χ̃⁰1) = 395 GeV Observed limit
m(χ̃⁰1) = 395 GeV Expected limit
m(χ̃⁰1) = 695 GeV Observed limit
m(χ̃⁰1) = 695 GeV Expected limit
7TeV (4.7fb⁻¹) m(χ̃⁰1) = 0 GeV Observed
squark m
gluino mass [GeV]