SEARCH FOR NEW PHYSICS AT LARGE HADRON COLLIDER (CMS)

(Hope not last hadron collider)

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> Nikolai Krasnikov, 12 May, Moscow

OUTLINE

- 1. Introduction
- 2. Standard Higgs boson
- 3. Supersymmetry(MSSM model)
- 4. New physics beyond the SM and the MSSM(EXOTICA)
- 4b. W_r boson and heavy neutrino
- 5. Conclusions

1.Introduction

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LHC(Large Hadron Collider)
              2010
Real start:
Two proton beams with total energy
F = 7 \text{ TeV}
Low luminosity stage with L_{low} = 4*10^{33} \text{ cm}^{-2} \text{s}^{-1}
                                               Remember: Nev = sigma Lt
with total luminosity L_t = 4.7 fb<sup>-1</sup> per 2011 year Remember: 1 fb = 10^{-39} cm<sup>2</sup>s<sup>-1</sup>
2012: Total energy 8 TeV and luminosity goal (15-20) fb<sup>-1</sup>
Two big detectors:
CMS(Compact Muon Solenoid)
ATLAS(A Toroidal LHC Apparatus)
In this talk we review
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- 1. The search for Standard Higgs boson
- 2. The search for supersymmetry
- 3. The search for new physics beyond SM and MSSM Nikolai Krasnikov, 12 May,

Perspective view of the LHC





ATLAS and CMS Experiments Large general-purpose particle physics detectors

A Large Toroidal LHC ApparatuS



Total weight	7000 t
Overall diameter	25 m
Barrel toroid length	26 m
End-cap end-wall chamber span	46 m
Magnetic field	2 Tesla

Compact Muon Solenoid



Total weight	12 500 t
Overall diameter	15.00 m
Overall length	21.6 m
Magnetic field	4 Tesla

Detector subsystems are designed to measure: energy and momentum of γ , e, μ , jets, missing E_T up to a few TeV

Compact Muon Solenoid (CMS) DETECTOR



A Toroidal LHC AppartuS (ATLAS) DETECTOR



Magnets: solenoid (Inner Detector) 2T, air-core toroids (Muon Spectrometer) ~0.5T

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Higgs boson search

 The existence of the Higgs boson is the direct consequence of the renormalizability of electroweak interactions and vice versa So the discovery of the Higgs boson last nondiscovered ingredient of Standard Model will be the triumph of the renormalizability approach which severely restricts the form of possible interactions and fixes Lagrangian up to several arbitrary terms with D = <4

2. Standard Higgs boson search

In $SU(3) \otimes SU(2) \otimes U(1)$ Standard Model $H(X) = (H_1(x), H_2(x))$ Higgs field is $SU(2)_L$ doublet In unitare gauge $H(x) = (0, \frac{v}{\sqrt{2}} + \frac{H(x)}{\sqrt{2}})$, v=242GeV

The most important interactions are:

$$\frac{2M_{W}^{2}}{v}HW_{\mu}^{+}W + \frac{M_{Z}^{2}}{v}Z_{\mu}Z^{\mu} - \frac{m_{t}}{v}H\overline{t}t - \frac{m_{\tau}}{v}\overline{\tau}\tau$$
Experimental bounds on the Higgs boson mass
$$M_{h} > 114.4 \text{ GeV} \qquad \text{LEP2 bound}$$

$$M_{h} < 162 \text{ GeV} \qquad \qquad \text{LEP1 + rad.cor.}$$
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Higgs boson mass bounds

Theoretical bounds :

- 1. Unitarity bound : $m_H < 700 \text{ GeV}$
- 2. Vacuum stability bound: $m_H > 135 \text{ GeV}$
- 3. Absence of Landau pole singularity:

m_H < 170 GeV

(for $\Lambda = 10^{12}$ GeV)

So there are several indications that the Higgs boson is relatively light . Moreover,

in the MSSM model the lightest Higgs boson

 $m_h < 140 \text{ GeV}$

Higgs boson decays

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The most important Higgs boson decays are:

 $H \rightarrow ZZ^*/ZZ \rightarrow l^+ l^- l^{+} l^{-}$

 $H \rightarrow WW^* / WW \rightarrow l^+ \upsilon l^- \upsilon$

 $H \rightarrow b\overline{b}$

 $H \rightarrow \tau \overline{\tau}$

 $H \rightarrow \gamma \gamma$

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Branching ratios and decay width of the SM Higgs boson



Branchings and cross sections



Higgs boson production mechanisms

1.Gluon fusion: $gg \rightarrow H$ (the main mechanism)

- 2. WW, ZZ fusion: W⁺ W⁻, ZZ \rightarrow H
- 3. Higgs-strahlung off W, Z : $qqW,Z \rightarrow W +H, Z +H$

4. Higgs bremsstrahlung off top quark: qq, gg \rightarrow tt +H

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For m_H = 120 GeV Higgs boson production cross section is around 45^{Nikolai Krasnikov, 12 May,}

Gluon fusion diagram



Weak boson fusion diagram



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Higgs-strahlung off W and Z



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Higgs bremsstrahlung off top quark



Higgs boson production cross section at the LHC



Signatures used for Higgs search

- H→WW* →2l2nu
- H→WW* →2l2q
- H→ZZ*→4I
- H--.ZZ*-.2l2q
- H→ZZ*→2l2tau
- H→ZZ*→2l2nu
- H→2l2jets
- H→gamma gamma
- H→bb

Higgs Search Channels in CMS

	Channel	m _H range	Luminosity	Sub-	щ _Н
		(GeV)	(fb ⁻¹)	channels	resolution
new	$H \rightarrow \gamma \gamma$	110 - 150	4.8	2	1-2%
	$H \rightarrow \tau \tau \rightarrow e\tau_h/\mu \tau_h/e\mu + X$	110-145	4.6	9	20%
new	$H \rightarrow \tau \tau \rightarrow \mu \mu + X$	110-140	4.5	3	20%
new	$WH \rightarrow e\mu\tau_k/\mu\mu\tau_h + \nu's$	100 - 140	4.7	2	20%
	$(W/Z)H \rightarrow (e\nu/\mu\nu/ee/\mu\mu/\nu\nu)(bb)$	110-135	4.7	5	10%
	$H \rightarrow WW^* \rightarrow 2\ell 2\nu$	110-600	4.6	5	20%
new	$WH \rightarrow W(WW^*) \rightarrow 3\ell 3v$	110-200	4.6	1	20%
	$H \rightarrow ZZ^{(*)} \rightarrow 4\ell$	110-600	4.7	3	1-2%
	${\rm H} \rightarrow {\rm ZZ}^{(*)} \rightarrow 2\ell 2q$	{ 130-164 200-600	4.6	6	3% 3%
	$H \rightarrow ZZ \rightarrow 2\ell 2\tau$	190-600	4.7	8	10-15%
	$H \rightarrow ZZ \rightarrow 2\ell 2\nu$	250-600	4.6	2	7%

H→WW*→2l2nu

For L =4.7fb^{-1}
 in SM at 95% C.L. Higgs boson is excluded
 In the mass range [129 – 270] GeV

ATLAS \rightarrow [130, 260] GeV are excluded

Distribution on dilepton angle



Limit on SM Higgs boson mass



$H \rightarrow ZZ^* \rightarrow 4I$

- Higgs in SM is excluded
- for [134 158], [180 305], [340 465]
- GeV mass region at 95% C.L. for
- L=4.7fb^{-1}
- Small excesses of events around 119, 126 and 320 GeV ATLAS \rightarrow [134,156], [182, 233], [256, 265], [268, 415] are excluded

Limit for SM Higgs



Limit for SM Higgs



M(4e) invariant mass distribution



M(4mu) invariant vass distribution



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P-values for Higgs to 4I mode



ATLAS 4I exclusion plot



$H \rightarrow ZZ^* \rightarrow 2l2nu$

For L=4.7fb^{-1} SM Higgs is excluded for [270 – 440] GeV region at 95% C.L.

ATLAS \rightarrow [320, 560] GeV Higgs boson exclusion region

SM boson Higgs mass limit



$H \rightarrow ZZ \rightarrow 2I2q$

Bound on Higgs boson cross section In [130 – 600] GeV mass region at 95%C.L. $ATLAS \rightarrow$ [300, 310], [360,400] are excluded



H→gamma gamma

- SM Higgs is excluded for [128, 132] GeV region. Excess of events at 124 GeV
- ATLAS → [113, 115],
- [134.5, 136] are excluded
- excess at 126.5 GeV



$H \rightarrow 2gamma limits$



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M(2photon) invariant mass distributions



CMS diphoton invariant mass distrbution



ATLAS diphoton mass distribution



Higgs boson combination

 The combination of the SM Higgs boson signatures for L = 4.6 fb^{{-1}} leads to Higgs exclusion for mass interval: [127, 600] GeV (95% C.L.) [129, 525] GeV (99% C.L.) $ATLAS(95\% C.L.) \rightarrow [110, 117.5],$ [118.5, 122.5], [129, 539] GeV are excluded

Exclusion region for SM Higgs



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The combined 95% upper limit



Combined p-values



Individual and combined Higgs boson limits



Individual and combined Higgs boson limits



Higgs boson(Conclusions)

- > CMS searched for the Higgs boson in 11 independent channels.
- > Expected 95% exclusion M_H in [114.5-543] GeV.
- > Observed 95% exclusion M_H in [127.5-600] GeV.
- If the Higgs boson exists, its mass is limited at 95% CL to the range [114.4 – 127.5] GeV.
- An excess around 125 GeV was observed with a local significance of 2.8 σ, corresponding to an global significance of 0.8 σ in the full search range (2.1 σ in the low mass range 110 - 145 GeV).
- The excess is consistent both with a fluctuation of the background and with a SM Higgs boson with a mass around 125 GeV.
- > More data is needed to resolve the origin of the excess.

Higgs boson (Conclusions)

- The most interesting (discovery) Higgs boson decay modes are:
- $H \rightarrow$ gamma gamma
- $H \rightarrow ZZ^*/ZZ \rightarrow 4I$

Weak boson fusion production mechanism is also very promising for Higss boson properties investigation

3. Search for supersymmetry

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- Y.A.Goldfarb and E.P.Likhtman
- D.V.Volkov and V.P.Akulov
- J.Wess and B.Zumino

- Why we like SUSY?
- elegant theory
- technical solution of the gauge hierarchy problem
- dark matter \rightarrow LSP is natural candidate
- consistent string theories are superstring
- theories

SUSY, rules of the game

MSSM – minimal supersymmetric standard model based on $SU_c(3) \otimes SU_L(2) \otimes U(1)$ gauge group. For each known particle \rightarrow superanalog superparticle (the same mass and internal quantum numbers, difference only in spin)

g (gluon, s = 1) \rightarrow $\mathcal{S}(gluino, s = \frac{1}{2})$ quarks (s = $\frac{1}{2}$) \rightarrow squarks (s = 0) leptons (s = $\frac{1}{2}$) \rightarrow sleptons (s = 0) gauge bosons (photon, Z- and W-bosons) (s =1) \rightarrow gaugino (s = $\frac{1}{2}$) SUSY, rules of the game

 H_1 , H_2 (two Higgs doublets) (s = 0) → Higgsino (s = 1/2)

As a result of gaugino and higgsino mixing In mass spectrum:

two chargino

 $\chi_1^{\pm}, \chi_2^{\pm}$ (S = $\frac{1}{2}$)

four neutralino χ_1^0 , χ_2^0 , χ_3^0 , χ_4^0 (s = $\frac{1}{2}$)

R-parity conservation postulate \rightarrow to get

rid of dangerous terms leading to fast proton decay.

For ordinary particles R = +1

SUSY, rules of the game

- For sparticles R = -1
- R-parity is conserved by construction
- Two important consequences:
- 1. At supercolliders sparticles are pair produced
- 2. The lightest sparticle (LSP) is stable: χ_1^0 \rightarrow dark matter candidate
- Note that SUSY models with R-parity violation are possible

MSUSGRA model

So SUSY has to be broken and in general masses of sparticles (squarks, sleptons, gluino, gaugino, Higgsino) are arbitrary that makes analysis extremely difficult For LHC most calculations were done within so called MSUGRA model \rightarrow Squark, slepton, higgsino masses are universal at GUT scale $\rightarrow m_0$ Gaugino masses also universal $\rightarrow m_{1/2}$

Sparticle production

• From cosmology and astrophysics \rightarrow LSP is weakly interacting neutral particle. As a result LSP escapes from detection (analog of neutrino) \rightarrow SUSY events are characterized by nonzero transverse missing momentum In real life SUSY has to be broken 1. gravity mediated SUSY breaking 2. gauge mediated SUSY breaking

Sparticle production

• At LHC sparticles can be produced via reactions:

 $gg, qq, qg \rightarrow \tilde{g}\tilde{g}, \tilde{q}\tilde{g}, \tilde{q}\tilde{q}$ $qq \rightarrow \chi_{i}^{\pm}\chi_{j}^{\mp}, \chi_{i}^{\pm}\chi_{j}^{0}, \chi_{i}^{0}\chi_{j}^{0}$ $qq, qg \rightarrow \tilde{g}\chi_{i}^{0}, \tilde{g}\chi_{i}^{\pm}, \tilde{q}\chi_{i}^{0}, \tilde{q}\chi_{i}^{\pm}$ $qq \rightarrow \tilde{l}\tilde{V}, \tilde{l}\tilde{l}, \tilde{V}\tilde{V}$

For squarks and gluino with masses O(1) TeV squark and gluino cross sections O(1) pb

The total SUSY cross sections



LHC SUSY Searches



- Strongly interacting sparticles (squarks, gluinos) dominate production.
- Heavier than sleptons, gauginos etc. g cascade decays to LSP.
- Potentially long decay chains and large mass differences
 - Many high p_T objects observed (leptons, jets, b-jets).
- If R-Parity conserved LSP (lightest neutraliño in mSUGRA) stable and sparticles pair produced.
 - Large E_T^{miss} signature (c.f. Wglv).

SUSY Searches

- Inclusive searches to detect SUSY with first data
- Exclusive studies performed with more data to determine model parameters Nikolai Krasnikov, 12 Mag.g. masses etc from 56 end point measurements...

Susy signatures

- As a result of squark, gluino decays and chargino and neutralino decays the most interesting signatures for the search for SUSY at LHC are:
- multijets plus E_T^{miss} events
- 11 plus jets plus E_T^{miss} events
- 2I plus jets plus E_T^{miss} events
- 3I plus jets plus E_T^{miss} events
- 4I plus jets plus E_T^{miss} events

CMS SUSY bounds for MSUGRA



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The use of razor variables



Figure 10: Observed (solid curve) and median expected (dot-dashed curve) 95% CL limits in the $(m_0, m_{1/2})$ CMSSM plane with $\tan \beta = 10$, $A_0 = 0$, $\operatorname{sgn}(\mu) = +1$ from the razor analysis. The \pm one standard deviation equivalent variations in the uncertainties are shown as a band around the median expected limit.

Exclusion limits for squrk and gluino

Ranges of exclusion limits for gluinos and squarks, varying m($\tilde{\chi}^0$) CMS preliminary



Exclusion limits for squarks and gluino

Ranges of exclusion limits for gluinos and squarks, varying $m(\tilde{\chi}^0)$ CMS preliminary



 $m(\tilde{\chi}^0)$ is varied from 0 GeV/c² (dark blue) to $m(\tilde{g})$ -200 GeV/c² (light blue).

Single lepton bounds



Opposite-sign dileptons bounds



Same-sigh dileptons



3 leptons +E^T_miss signature



3 leptons +E^T_miss signature



Multilepton bound



Multilepton bound



- LSP decays (within detector) into photon and gravitino
- Signature:
- Jets + E^T-miss + >1 photons



1γ, >=3 jets, MET> 200 GeV



1γ, >=3 jets, MET> 200 GeV


At present: No SUSY at LHC

• Can we forget it?

At present: No SUSY at LHC

То, о чем писал поэт – это бред?
 В. Высоцкий
 Как много красивых теорий уродуют
 ужасные факты

At present: No SUSY at LHC

Or: Let us wait and see? Your opinion?

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SUSY mass reach of ATLAS

		ATLAS SUSY Searches* - 95% CL Lower Limits (Status: March 2012)
	MSUGRA/CMSSM : 0-lep + j's + E _{T,miss}	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-033] 1.40 TeV $\tilde{q} = \tilde{g}$ mass
	MSUGRA/CMSSM : 1-lep + j's + E _{T,miss}	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-041] 1.20 TeV $\vec{q} = \vec{g}$ mass
Se	MSUGRA/CMSSM : multijets + E _{T,miss}	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-037] 850 GeV \tilde{g} mass (large m_0) [S = 7 IeV
rche	Pheno model : 0-lep + j's + $E_{T,miss}$	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-033] 1.38 TeV \tilde{q} mass $(m(\tilde{g}) < 2$ TeV, light $\tilde{\chi}_1^0$) ATLAS
sea	Pheno model : 0-lep + j's + $E_{T,miss}$	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-033] 940 GeV \widetilde{g} mass $(m(\widetilde{q}) < 2$ TeV, light $\widetilde{\chi}_1^0$) Preliminary
sive	Gluino med. $\tilde{\chi}^{\pm}$ ($\tilde{g} \rightarrow q \overline{q} \tilde{\chi}^{\pm}$) : 1-lep + j's + $E_{T,miss}$	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-041] 900 GeV \tilde{g} mass $(m(\tilde{\chi}_1^0) < 200 \text{ GeV}, m(\tilde{\chi}^{\pm}) = \frac{1}{2}(m(\tilde{\chi}^0) + m(\tilde{g}))$
Inclus	GMSB : 2-lep OS _{SF} + $E_{T,miss}$	L=1.0 fb ⁻¹ (2011) [ATLAS-CONF-2011-156] 810 GeV g̃ mass (tanβ < 35)
	$GMSB: 1-\tau + j's + E_{\tau,miss}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-005] 920 GeV \tilde{g} mass (tan β > 20)
	GMSB : $2-\tau + j's + E_{\tau,miss}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-002] 990 GeV \tilde{g} mass (tan β > 20)
	$GGM: \gamma\gamma + E_{\tau,miss}$	L=1.1 fb ⁻¹ (2011) [1111.4116] 805 GeV \tilde{g} mass ($m(\chi_1^0) > 50$ GeV)
d generation	Gluino med. \tilde{b} ($\tilde{g} \rightarrow b \bar{b} \bar{\chi}_{1}^{0}$) : 0-lep + b-j's + $E_{T,miss}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-003] 900 GeV \tilde{g} mass ($m(\chi_1^0) < 300$ GeV)
	Gluino med. \tilde{t} ($\tilde{g} \rightarrow t \bar{t} \tilde{\chi}_{1}^{0}$) : 1-lep + b-j's + $E_{T,miss}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-003] 710 GeV \tilde{g} mass ($m(\tilde{\chi}_1^0) < 150$ GeV)
	Gluino med. \tilde{t} ($\tilde{g} \rightarrow t \bar{t} \tilde{\chi}_{1}^{0}$) : 2-lep (SS) + j's + $E_{T,miss}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-004] 650 GeV ĝ mass (m(χ̃ ₁ ⁰) < 210 GeV)
	Gluino med. \tilde{t} ($\tilde{g} \rightarrow t\bar{t} \tilde{\chi}_1^0$) : multi-j's + $E_{T,miss}$	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-037] 830 GeV \tilde{g} mass ($m(\tilde{\chi}_1^0) < 200 \text{ GeV}$)
Thin	Direct $\widetilde{b}\widetilde{b}$ ($\widetilde{b}_1 \rightarrow b \widetilde{\chi}_1^0$) : 2 b-jets + $E_{T,miss}$	L=2.1 m ⁻¹ (2011) [1112.3832] 390 GeV Ď mass (m(χ̃ ₁ ⁰) < 60 GeV)
	Direct $\tilde{t}\tilde{t}$ (GMSB) : Z(\rightarrow II) + b-jet + E	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-036] 310 GeV \tilde{t} mass (115 < $m(\tilde{\chi}_1^0)$ < 230 GeV)
DG	Direct gaugino $(\tilde{\chi}_1^{\pm} \tilde{\chi}_2^0 \rightarrow 3 I \tilde{\chi}_1^0)$: 2-lep SS + $E_{T,miss}$	$ L=1.0 \text{ fb}^{-1}(2011) [1110.6189] \qquad 170 \text{ GeV} \tilde{\chi}_{1}^{\pm} \text{ mass} ((m(\tilde{\chi}_{1}^{0}) < 40 \text{ GeV}, \tilde{\chi}_{1}^{0}, m(\tilde{\chi}_{1}^{\pm}) = m(\tilde{\chi}_{2}^{0}), m(\tilde{l}, \tilde{v}) = \frac{1}{2} (m(\tilde{\chi}_{1}^{0}) + m(\tilde{\chi}_{2}^{0}))) $
	Direct gaugino $(\overline{\chi}_1^{\pm} \overline{\chi}_2^0 \rightarrow 3 \overline{\chi}_1^0)$: 3-lep + $E_{T,\text{miss}}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-023] 250 GeV $\tilde{\chi}_1^{\pm}$ mass ($m(\tilde{\chi}_1^0) < 170$ GeV, and as above)
ong-lived particles	AMSB : long-lived $\tilde{\chi}_1^{\pm}$	$L=4.7 \text{ fb}^{-1} (2011) [\text{CF-2012-034}]^{\frac{118 \text{ GeV}}{2}} \tilde{\chi}_{1}^{\pm} \text{ mass } (1 < \tau(\tilde{\chi}_{1}^{\pm}) < 2 \text{ ns}, 90 \text{ GeV limit in } [0.2,90] \text{ ns})$
	Stable massive particles (SMP) : R-hadrons	L=34 pb ⁻¹ (2010) [1103.1984] 562 GeV ĝ mass
	SMP : R-hadrons	L=34 pb ⁻¹ (2010) [1103.1984] 294 GeV Ď mass
	SMP : R-hadrons	L=34 pb ⁻¹ (2010) [1103.1984] 309 GeV t mass
	SMP : R-hadrons (Pixel det. only)	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-022] 810 GeV ĝ mass
Ę	GMSB : stable τ	L=37 pb ⁻¹ (2010) [1106.4495] 136 GeV 7 mass
RPV	RPV : high-mass eµ	L=1.1 fb ⁻¹ (2011) [1109.3089] 1.32 TeV $\tilde{v_{\tau}}$ mass ($\lambda_{311}^{-}=0.10, \lambda_{312}^{-}=0.05$)
	Bilinear RPV : 1-lep + j's + $E_{T,miss}$	L=1.0 /b ⁻¹ (2011) [1109.6606] 760 GeV q̃ = g̃ mass (cτ _{LSP} < 15 mm)
	MSUGRA/CMSSM - BC1 RPV : 4-lepton + E _{T,miss}	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-035] 1.77 TeV ĝ mass
	Hypercolour scalar gluons : 4 jets, $m_{ij} \approx m_{kl}$	L=34 pb ⁻¹ (2010) [1110.2693] 185 GeV sgluon mass (excl: $m_{sg} < 100$ GeV, $m_{sg} \approx 140 \pm 3$ GeV)
		10 ⁻ ' 1 10
		Mass scale [TeV]

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

Mass scale [TeV]

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MSSM Higgs boson searches

- In the MSSM there are 4 Higgs bosons
 h, H, A, H^{+/-} the lightest scalar h for
 - m_A > m_h^{max} (decoupling regime) is
 - SM-like Higgs boson.
 - The production of H and A proceeds mainly through $gg \rightarrow H/A$ and $gg/qq \rightarrow bbH/A$
- At large tan(beta) bbH/A production dominates and it is ~90% for tan(beta) >10 and $m_A > 300$ (Fig. Trasnikov, 12 May, Moscow 12 May, 77

The cross sections of light h and heavy H as a function of their masses



The MSSM Higgs boson signatures

- Light charged Higgs boson m_{H+/} < m_{top} is produced in tt events with t→H^{+/}b
- The most important production mechanisms for m_{H+/}>m_{top} are gb →tH⁺, gg→tbH^{+/}, qqbar →H^{+/} with cross sections ~tan²(beta)
- The H,A \rightarrow b,bbar decay dominates at large tan(beta). The branching to $\tau^+\tau^-$ is ~10% and to $\mu^+\mu^-$ is about 3*10⁻⁴

H→tau tau signature



H→tau tau signature



MSSM Higgs bound



MuMu bound



Charged MSSM Higgs boson bound



Mass bounds for doubly charged Higgs boson



Nikolai Krasnikov, 12 May, Moscow 4.Search for new physics beyond SM and MSSM(Exotica)

- There are a lot of models:
- Additional dimensions
- Additional gauge bosons
- Heavy neutrino
- Scalar leptoquarks
- Compositeness



Additional dimensions

 In ADD(Arkani-Hamed, Dimopoulos, Dvali) model gravity lives in (4+d) -space-time, observable world lives on 4-brane. After compactification on torus of d additional dimensions

$$\begin{split} \mathsf{M}^{2}_{\mathsf{PL}} &= \mathsf{V}_{\mathsf{d}}\mathsf{M}_{\mathsf{D}}^{2+\mathsf{d}}, \qquad \mathsf{V}_{\mathsf{d}} &= (2\pi R_{c})^{\mathsf{d}} \\ \text{If } \mathsf{M}_{\mathsf{D}} \sim 1 \; \mathsf{TeV} \xrightarrow{} \mathsf{R}_{\mathsf{c}}^{-1} &= (10^{-3} \; \mathsf{eV} - 10 \; \mathsf{MeV}) \; \mathsf{for} \\ \mathsf{d} &= 2 - 6 \; . \quad \mathsf{The \ masses \ of \ KK \ gravitons} \\ \mathsf{m}_{\mathsf{n}} \sim (\mathsf{n}^{\mathsf{a}}\mathsf{n}^{\mathsf{a}})^{1/2} \mathsf{R}_{\mathsf{c}}^{-1}, \quad \mathsf{n}^{\mathsf{a}} = (\mathsf{n}_{\mathsf{1}}, \dots \mathsf{n}_{\mathsf{d}}) \end{split}$$

• Graviton mass splitting Nikolai Krasnikov, 12 May, Moscow

ADD model

- We have an almost continuous spectrum of gravitons which behave as massive stable noninteracting spin 2 particle
- Supercollider signature
 qg → q G⁽ⁿ⁾ at parton level and
 pp → jet + E_T^{miss} at particle level.

 For d = 2 R_c⁻¹ can be probed up to

10 TeV. The contribution of ADD massive gravitons contributes into DY cross section that allow to restricts Roy, 12 Nov, 8 TeV 88

Distributions for missing transverse energy for ADD model



ADD bound for delta =2



ADD bound for delta =4



Photon +E^miss_T ADD bound



RS model

 In RS model (Randall-Sundrum) gravity lives in a 5-dimensional Anti-de Sitter space with a single extra dimension compactified to the orbifold S¹/Z₂ The metric is

$$ds^{2} = e^{-2k[y]} \eta_{\mu\nu} dx^{\mu} dx^{\nu} + dy^{2} ..., y = r_{c}\theta$$
$$M_{PL}^{2} = \frac{M_{5}^{3}}{k} (1 - e^{-2kr_{c}\pi})$$

There are two 3-dimensional branes (TeV brane,our world) and Planck brane

RS model predictions

- The main prediction of the RS model KK excitations with $m_{gr}(1) \sim O(1)$ TeV The most promising signature is $q\bar{q}, gg \rightarrow G_{res,1} \rightarrow e^+e^-, \mu^+\mu^-$
- The graviton resonance can be detected for M_{gr}(1) <4 TeV(14 TeV)
- Other consequence → radion field (similar to Higgs boson, couples with trace of energy-momentum)

Diphoton mass spectrum



RS graviton resonance bound for k/Mpl=0.01(diphoton mode)



RS graviton resonance bound for k/Mpl=0.1(diphoton mode)



Additional neutral gauge bosons

 Additional gauge bosons arise in many extensions of SM containing additional U(1) gauge group. Such extensions arise in the context of SO(10) and E(6) gauge groups. The most promising way to discover Z'-boson is to use its leptonic modes $Z' \rightarrow e^+e^-, \mu^+\mu^-$ The manifestation of the Z' boson is the resonance structure in DY process. It is possible to discover Z⁴ with a mass up to 4.3 TeV for $L_{tot} = 100 \text{ fb}^{-1} \text{ using dimuon mode}$

Distribution on (mu mu) invariant mass



(Mu Mu) mass limit for different models



(e e) mass limit gor different models



(e e) + (mu mu) limit for different models



Additional W` bosons

- For model with heavy W` boson with decay modes as SM W boson
- W→l nu,
- W→ qq`
- The signature is isolated electron or muon plus missing transverse energy
- Backrounds: W-production and ttbarproduction

Distribution on transverse mass



CMS limit on W` mass



Heavy neutrino and right W boson

 Left-right symmetric models based on $SU_{c}(3) \otimes SU_{I}(2) \otimes SU_{R}(2) \otimes U(1)$ gauge group naturally include heavy Majorana neutrino. For heavy neutrino lighter than W_{R} -boson it is possible to look for heavy neutrino in W_R decay using the signature $pp \rightarrow W_R + ... \rightarrow e(v_{R,I} \rightarrow ejj) + ...$ Due to Majorana nature of neutrino halph of events will be with the same sign leptons. Signature-2 is.leptons +two jets

Distribution of eejj invariant mass



Distribution of (mu mu jet jet) invariant mass


Bounds for heavy electron neutrino for 240 pb^-1 luminosity



Bounds on heavy electron neutrino and W_R boson



Bounds on heavy muon neutrino and W_R boson **2D Model Exclusion** 2000 CMS 5.0 fb⁻¹ at 7 TeV M² 18∟ M^{2[±]1600} $M_N > M_{W_n}$ Observed ···· Expected 1400 1200 1000 800 600 400 200 PAPER 0 2000 2500 M_{W_R} [GeV] 1000 1500

Scalar leptoquarks

- Scalar leptoquarks (LQ) are particles having lepton,colour and baryon numbers different from zero. At LHC both single and pair leptoquark productions are possible
- $g + g \rightarrow LQ + I \rightarrow 2I + q$
- g +g \rightarrow LQ + LG \rightarrow 2l + 2q

Scalar leptoquarks

For pair leptoquark production the main signature are events with
 2 jets and 2 isolated leptons

1 st generation leptoquark bound



1 st generation leptoquark bound



2 nd generation leptoquark bound



2 nd generation leptoquark bound



Search for dijet resonances

- A lot of models
- At quark gluon level
- qq \rightarrow Resonance \rightarrow 2 jets
- qg \rightarrow Resonance \rightarrow 2 jets
- gg→Resonance→2 jets
- Signature: resonance structure in dijet mass distribution

Search for resonances in dijet mass spectrum



Dijet mass cross section distribution



The ratio of jet cross sections for different eta regions



Cross section resonances bounds



qg resonance bounds



Mass bounds for some models

Model	Excluded N	Mass (TeV)
	Observed	Expected
String Resonances	4.00	3.90
E ₆ Diquarks	3.52	3.28
Excited Quarks	2.49	2.68
Axigluons/Colorons	2.47	2.66
W' Bosons	1.51	1.40

Compositeness

 If squarks and leptons are composite particles made from "preons" we can expect deviations from SM predictions for high p_{T} cross sections (Drell-Yan, jet cross sections). At $L_{tot} = 100 \text{ fb}^{-1} \text{ LHC will}$ be able to probe point like stucture of quarks with a scale up to 20 TeV

Limits on parameters of contact interactions



New long-lived particles photon decays





Nikolai Krasnikov, 12 May, Moscow











ATLAS exotica summary plot

$ \begin{array}{c c c c c c c c c c c c c c c c c c c $			ATLAS Exotics Searches* - 95% CL Lower Limits (Status: March 2012)
Large ED (ADD): monojet Large ED (ADD): monojet UED: $YT + E_{n,max}$ RS with $K/M_{n} = 0.1$: diheton M_{n} (Secondard Compact. scale 1/R (SPS8) RS with $K/M_{n} = 0.1$: diheton M_{n} ($K = 0.0$): $K = 0.0$ RS with $K/M_{n} = 0.1$: diheton M_{n} ($K = 0.0$): $K = 0.0$ RS with $K/M_{n} = 0.1$: diheton M_{n} ($K = 0.0$): $K = 0.0$ RS with $K/M_{n} = 0.1$: diheton M_{n} ($K = 0.0$): $K = 0.0$ RS with $K/M_{n} = 0.1$: diheton M_{n} ($K = 0.0$): $K = 0.0$ RS with $K/M_{n} = 0.1$: diheton M_{n} ($K = 0.0$): $K = 0.0$ RS with $K/M_{n} = 0.0$: $K = 0.0$ RS with $K/M_{n} = 0.0$: $K = 0.0$ RS with $K/M_{n} = 0.0$: $K = 0.0$ M = 0.0 ADD BH ($M_{n}, (M_{n} = 3)$): Sc dimon. M_{n} ($M = 0.0$ ADD BH ($M_{n}, (M_{n} = 3)$): Sc dimon. M_{n} ($M = 0.0$ M = 0.0 M = 0.0			
Large ED (ADD): diphoton, RS with $k/M_{m} = 0.1$: diphoton, ADD BH ($M_{m_{m}} M_{m} = 0.1$: diphoton, diphoton diphoton,		Large ED (ADD) : monojet	L=1.0 fb ⁻¹ (2011) [ATLAS-CONF-2011-096] 3.2 TeV M_D (δ =2)
$ \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} U = D \cdot T + E \\ R & \text{with } M_{m} = 0.1 : \text{dilepton, } m_{n} \\ R & \text{with } M_{m} = 0.1 : \text{dilepton, } m_{n} \\ R & \text{with } M_{m} = 0.1 : \text{dilepton, } m_{n} \\ R & \text{with } M_{m} = 0.1 : \text{dilepton, } m_{n} \\ R & \text{with } M_{m} = 0.1 : \text{dilepton, } m_{n} \\ R & \text{with } M_{m} = 0.1 : \text{dilepton, } m_{n} \\ R & \text{with } M_{m} = 0.1 : \text{dilepton, } m_{n} \\ R & \text{with } M_{m} = 0.1 : \text{dilepton, } m_{n} \\ R & \text{with } M_{m} = 0.1 : \text{dilepton, } m_{n} \\ R & \text{with } M_{m} = 0.1 : \text{dilepton, } m_{n} \\ R & \text{with } M_{m} = 0.1 : \text{dilepton, } M_{n} \\ R & \text{with } M_{m} = 0.1 : \text{dilepton, } M_{n} \\ R & \text{with } M_{m} = 0.1 : \text{dilepton, } M_{n} \\ R & \text{with } M_{m} = 0.1 : \text{dilepton, } M_{n} \\ R & \text{with } M_{m} = 0.1 : \text{dilepton, } M_{n} \\ R & \text{dile } (0.04 - 5.0) \text{ fb}^{-1} \\ R & \text{dile } (0.04 - 5.0) \text{ fb}$		Large ED (ADD) : diphoton	<u>L=2.1 fb⁻¹ (2011) [1112.2194]</u> 3.0 TeV M _S (GRW cut-off) ATLAS
$ \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \\ \\ \\ \\ \\ \\ \end{array} \end{array} \\ \begin{array}{c} \\ \end{array} \end{array} \\ \begin{array}{c} \\ \\ \end{array} \end{array} \\ \begin{array}{c} \\ \end{array} \end{array} \\ \begin{array}{c} \\ \\ \end{array} \end{array} \\ \begin{array}{c} \\ \end{array} \end{array} \\ \begin{array}{c} \\ \\ \end{array} \end{array} \\ \begin{array}{c} \\ \end{array} \end{array} \\ \end{array} \\ \begin{array}{c} \\ \end{array} \end{array} \\ \begin{array}{c} \\ \end{array} \end{array} \\ \begin{array}{c} \\ \end{array} \end{array} \\ \end{array} \\ \begin{array}{c} \\ \end{array} \end{array} \\ \end{array} \end{array} \\ \begin{array}{c} \\ \end{array} \end{array} \\ \begin{array}{c} \\ \end{array} \end{array} \\ \end{array} \end{array} \\ \begin{array}{c} \\ \end{array} \end{array} \\ \end{array} \end{array} \\ \begin{array}{c} \end{array} \end{array} \\ \end{array} \\ \begin{array}{c} \end{array} \end{array} \\ \end{array} \\ \end{array} \end{array} \\ \begin{array}{c} \end{array} \end{array} \\ \end{array} \\ \end{array} \end{array} \\ \begin{array}{c} \end{array} \end{array} \\ \end{array} \\ \end{array} \end{array} \\ \end{array} \end{array} \\ \end{array} \end{array} \\ \begin{array}{c} \end{array} \end{array} \\ \end{array} \\ \end{array} \end{array} \\ \end{array} \end{array} \\ \end{array} \\ \end{array} \end{array} \end{array} \\ \end{array} \end{array} \end{array} \\ \end{array} \end{array} \end{array} \end{array} \\ \end{array} \end{array} \end{array} \\ \end{array} \\ \end{array} \end{array} \\ \end{array} \end{array} \\ \end{array} \\ \end{array} \end{array} \end{array} \\ \end{array} \\ \end{array} \end{array} \\ \end{array} \end{array} \\ \end{array} \\ \end{array} \end{array} \\ \end{array} \\ \end{array} \\ \end{array} \\ \end{array} \end{array} \\ \end{array} \\ \end{array} \end{array} \\ \end{array} \end{array} \\ \end{array} \\ \end{array} \\ \end{array} \end{array} \\ \end{array} \\ \end{array} \end{array} \\ \end{array} \end{array} \\ \end{array} \\ \end{array} \\ \end{array} \end{array} \\ \end{array} \\ \end{array} \\ \end{array} \end{array} \\ \end{array} \\ \end{array} \\ \end{array} \\ \end{array} \end{array} \\ \\ \end{array} \\ \end{array} \\ \end{array} \\ \end{array} \\ \\ \\ \end{array} \\ \end{array} \\ \\ \end{array} \\ \end{array} \\ \end{array} \\ \end{array} \\ \\ \end{array} \\ \end{array} \\ \end{array} \\ \\ \end{array} \\ \\ \end{array} \\ \end{array} \\ \\ \end{array} \\ \\ \end{array} \\ \end{array} \\ \end{array} \\ \\ \end{array} \\ \\ \end{array} \\ \end{array} \\ \\ \end{array} \\ \\ \end{array} \\ \end{array} \\ \\ \end{array} \\ \\ \end{array} \\ \end{array} \\ \end{array} \\ \end{array} \\ \\ \end{array} $ \\ \end{array} \\ \\ \end{array} \\ \end{array}	60	$UED: \gamma\gamma + E_{\tau,miss}$	L=1.1 fb ⁻¹ (2011) [1111.4116] 1.23 TeV Compact. scale 1/R (SPS8) Preliminary
$ \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c}$	ion	RS with $k/M_{Pl} = 0.1$: diphoton, $m_{\gamma\gamma}$	L=2.1 fb ⁺ (2011) [1112.2194] 1.85 TeV Graviton mass
$ \begin{array}{c} \label{eq:result} \\ \begin{tabular}{lllllllllllllllllllllllllllllllllll$	sue	RS with $k/M_{Pl} = 0.1$: dilepton, m_{\parallel}	L=4.9-5.0 fb ⁻¹ (2011) (ATLAS-CONF-2012-007) 2.16 TeV Graviton mass
$ \begin{array}{c} \text{RS with } g_{\text{eq}} / (q = 0.20: \text{t}^{1}_{\text{e}} \rightarrow \text{He}; \text{R}, m_{\text{e}}, m_$	ime	RS with k/M _{PI} = 0.1 : ZZ resonance, m _{III / III}	$L = 1.0 \text{ fb}^{-1} (2011) [1203.0718] \qquad 845 \text{ GeV} \text{Graviton mass} \qquad \int Lat = (0.04 - 5.0) \text{ fb}$
$ \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c}$	a d	RS with $g_{g} = -0.20$: $t\bar{t} \rightarrow l+jets, m_{g}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-029] 1.03 TeV KK gluon mass Is = 7 TeV
$ \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c}$	Xtr	ADD BH $(M_{TH}^{qgr})M_{D}^{=3}$: multijet, $\Sigma p_{T}, N_{jets}^{t}$	L=35 pb ⁻¹ (2010) [ATLAS-CONF-2011-068] 1.37 TeV $M_{\rm D} (\delta=6)$
ADD BH (M_{11} , M_0 -3): leptons + jets, Σ_p Quantum black hole : dijet, F_1 , m_1^{11} qqq contact interaction : (m_1) qqq contact interaction : (m_1) qqq contact interaction : (m_1) qql IC : ee, $\mu\mu$ combined, m_1 uutt CI : SS dilepton + jets + E_7 , m_1^{11} SSM Z': m_2^{11} SSM Z': m_2^{11} SSM Z': m_2^{11} Scalar LQ pairs (β =1): kin. vars. in µujj, µvj Scalar LQ pairs (β =1): kin. vars. in µujj, µvj 4^{10} generation : $(1, 1, -)^{11}$ New quark b': bD -2 bD × M_2 4^{10} generation : $(1, 1, -)^{11}$ Excited quarks: 'y jet resonance, m_1^{11} Excited quarks: 'g jet resonance, m_1^{11} Excited quark	ш	ADD BH ($M_{TH}/M_D=3$) : SS dimuon, $\dot{N}_{ch. part.}$	L=1.3 fb ⁻¹ (2011) [1111.0080] 1.25 TeV M _D (δ=6)
$ \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c}$		ADD BH ($M_{TH}/M_{D}=3$) : leptons + jets, Σp_{T}	L=1.0 fb ⁻¹ (2011) [ATLAS-CONF-2011-147] 1.5 TeV M _D (δ=6)
$ \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c}$		Quantum black hole : dijet, F, (mij)	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-038] 4.11 TeV $M_D(\delta=6)$
$\frac{1}{100} \qquad $		qqqq contact interaction : $\hat{\chi}(m_{\mu})$	L=4.8 fb ⁻¹ (2011) [ATLAS-CONF-2012-038] 7.8 TeV A
$ \begin{array}{c} \text{uutt Cl : SS dilepton + jets + E_{T,mix} \\ SSM W : m_{Tabular} \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar LQ pairs (\beta=1) : kin, vars. in egij, evij \\ Scalar Product (log log log log log log log log log log $	5	qqll Cl : ee, μμ combined, m	L=1.1-1.2 fb ⁻¹ (2011) [1112.4462] 10.2 TeV A (constructive int.)
$ \begin{array}{c} \text{SSM } V: m_{\text{respin}} \\ \text{SSC } V: M_{\text{respin}} \\ \text{SSM } V: m_{\text{respin}} \\ \text{SSC } V: M_{\text{respin}} \\ \text{SSM } V: m_{\text{respin}} \\ \text{SSC } V: M_{\text{respin}} \\ \text{SSM } V: m_$		uutt CI : SS dilepton + jets + E _{7 miss}	L=1.0 fb ^{-*} (2011) [1202.5520] 1.7 TeV
$\frac{1}{10^{1}}$ $\frac{1}{1}$	5	SSM Z' : m _{ee/uu}	L=4.9-5.0 fb ⁻¹ (2011) [ATLAS-CONF-2012-007] 2.21 TeV Z' MASS
Scalar LQ pairs $(\beta=1)$: kin. vars. in µµji, µvji Scalar LQ pairs $(\beta=1)$: kin. vars. in µµji, µvji 4^{en} generation : Q $\overline{Q}_{a} \rightarrow WqW_{a}$ 4^{en} g	\geq	SSM W': mTelu	L=1.0 fb ⁻¹ (2011) (1108.1316) 2.15 TeV W' mass
$\frac{1}{10^{-1}}$ Scalar LQ pairs $(\beta = 1)$: kin. vars. in µµµµ µµ	α	Scalar LQ pairs (β =1) : kin. vars. in eeji, evji	L=1.0 fb ⁻² (2011) [1112.4828] 660 GeV 1 st gen. LQ mass
$\frac{4^{m}}{2} generation : (1, 1, \rightarrow) W W W W W W W W W W W W W W W W W W $	Ľ	Scalar LQ pairs (β =1) : kin, vars, in uuii, uvii	L=1.0 fb ⁻¹ (2011) [Preliminary] 685 GeV 2 nd gen, LQ mass
$ \begin{array}{c} 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}} \text{ generation }: 4 \text{ T}_{4}^{\text{th}} \text{ yebp} \\ 4^{\text{th}$	60	4^{th} generation : Q $\overline{Q} \rightarrow WgWg$	L=1.0 fb ⁻¹ (2011) [1202.3389] 350 GeV Q, mass
$\frac{4^{\text{m}} \text{generation}}{100} \frac{4^{\text{m}} \frac{1}{3} \rightarrow \text{WW}}{\text{New quark b': b'b' } \frac{4^{\text{m}} 2\text{D} $	arka	4 th generation : u u → WbWb	L=1.0 fb ⁻¹ (2011) [1202.3076] 404 GeV U, MASS
$\begin{array}{c} \begin{array}{c} \begin{array}{c} \text{New quark b': b'\overline{b} \rightarrow 4Zb+X, m_{D_{1}} \\ \text{TT}_{axo, 4th}_{qen} \rightarrow t\overline{t} + A_{Q}A_{0}: 1-lep + jets + E_{T} \\ \text{Excited quarks: '} + jet resonance, m_{1} \\ \text{Excited quarks: '} + jet resonance, m_{1} \\ \text{Excited quarks: '} + jet resonance, m_{1} \\ \text{Excited quarks: i} \\ \text{Excited quark: i} \\ Excited quark: i$	dns	4 th generation : d d,→ WtWt	L=1.0 fb ⁻¹ (2011) [Preliminary] 480 GeV d, mass
$T_{\text{avo. 4th}\underline{\rho_{\text{cons}}} \rightarrow t\bar{t} + A_{\text{cons}}^{\text{c}} : 1 - lep + jets + E_{\text{cons}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} T \text{ mass} (m(A_{\text{cons}}) < 140 \text{ GeV}) $ $Excited quarks : djet resonance, m_{\text{prive}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} q^{\text{cons}} mass $ $Excited quarks : djet resonance, m_{\text{prive}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} q^{\text{cons}} mass $ $Excited quarks : djet resonance, m_{\text{prive}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} Q_{\text{cons}}^{\text{cons}} Z_{\text{cons}}^{\text{cons}} q^{\text{cons}} q^{\text{cons}} Z_{\text{cons}}^{\text{cons}} Q_{\text{cons}}^{\text{cons}} Q_{\text{cons}}^{con$	MG	New quark b' : b' $\overline{b}' \rightarrow Z \overline{b} + X, m$	L=2.0 fb ⁻¹ (2011) [Preliminary] 400 GeV b ⁺ mass
$\frac{1}{10^{-1}} \frac{1}{1} \frac{1}{1} \frac{1}{10} \frac{1}{10$	Ž	$T\overline{T}$ $\rightarrow t\overline{t} + A_{a}A_{a}$: 1-lep + jets + E_{-}	L=1.0 fb ⁻³ (2011) [1109.4725] 420 GeV T mass ($m(A_{-}) < 140$ GeV)
$\frac{1}{10^{-1}}$ Excited quarks : dijet resonance, $m_{\mu\nu}$ Excited electron : e- γ resonance, $m_{\mu\nu}$ Excited quarks : dijet resonance, $m_{\mu\nu}$ Excited quarks : dijet resonance, $m_{\mu\nu}$ Excited quarks : dilepton, m_{eelpu} Techni-hadrons : WZ resonance (VIII), $m_{\tau,WZ}$ Major. neutr. (LRSM, no mixing) : 2-lep + jets W _R (LRSM, no mixing) : 2-lep + jets H ^{±+} _L (DY prod., BR(H ^{±+} →µµ)=1) : SS dimuon, $m_{\mu\mu}$ Color octet scalar : dijet resonance, $m_{\mu\mu}$ Vector-like quark : NC, $m_{\mu\mu}$ 10^{-1} 1 1 1 1 1 1 1 1 1 1	Ë.	exo. 4th gen Excited quarks : γ-jet resonance, m	L=2.1 fb ⁻¹ (2011) (1112.3580) 2.46 TeV g ⁺ mass
$\frac{1}{249} \frac{1}{10} $	fen	Excited quarks : dijet resonance, $m_{\rm e}^{\gamma \rm per}$	L=4.8 fb ⁻² (2011) [ATLAS-CONF-2012-038] 3.35 TeV g ⁺ mass
$ \begin{array}{c} \underbrace{1}{10^{-1}} \\ \underbrace{1}{10^{-1}} \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 $	cit.	Excited electron : e-y resonance, m	L=4.9 fb ⁻¹ (2011) [ATLAS-CONF-2012-023] 2.0 TeV e^* mass ($\Lambda = m(e^*)$)
$\begin{array}{c} \text{Techni-hadrons : dilepton, } m_{equival rates conservations results resonance (vill), } m_{T,WZ} \\ \text{Techni-hadrons : WZ resonance (vill), } m_{T,WZ} \\ \text{Major. neutr. (LRSM, no mixing) : 2-lep + jets } \\ \mathbb{W}_{R} (\text{LRSM, no mixing) : 2-lep + jets } \\ \mathbb{W}_{R} (\text{LRSM, no mixing) : 2-lep + jets } \\ \text{Mit (DY prod., BR(H_{L}^{\pm} \rightarrow \mu) = 1) : SS dimon, } m_{\mu\mu} \\ \text{Color octet scalar : dijet resonance, } m_{ij} \\ \text{Vector-like quark : CC, } m_{ij} \\ \text{Vector-like quark : NC, } m_{$	Ě	Excited muon : μ-γ resonance, m	L=4.8 fb ⁻² (2011) IATLAS-CONF-2012-023) 1.9 TeV μ^* mass ($\Lambda = m(\mu^*)$)
Techni-hadrons : WZ resonance (vIII), $m_{T,WZ}^{\text{despty}}$ Major. neutr. (LRSM, no mixing) : 2-lep + jets W_R (LRSM, no mixing) : 2-lep + jets Color octet scalar : dijet resonance, m_{jij} Vector-like quark : CC, m_{jij} $Vector-like quark : NC, m_{jij}10^{-1}10^{-1}10^{-1}10^{-1}10^{-1}10^{-1}10^{-1}$		Techni-hadrons : dilepton, manual	$(=1,1,1,2)$ (2011) IATLAS-CONF-2011-1251 470 GeV, ρ/ω_{-} mass $(m(\rho/\omega_{-}) - m(\pi_{-}) = 100$ GeV)
$\begin{array}{c} \text{Major. neutr. (LRSM, no mixing): 2-lep + jets} \\ \text{W}_{R} (LRSM, no mixing): 2-lep + jets} \\ \text{H}_{L}^{\pm \pm} (DY \text{ prod., } BR(H_{L}^{\pm \rightarrow} \mu\mu)=1): SS \text{ dimuon, } m_{\mu\mu} \\ \text{Color octet scalar : dijet resonance, } m_{jj} \\ \text{Vector-like quark : CC, } m_{Veq} \\ \text{Vector-like quark : NC, } m_{iiq} \\ \end{array} $		Techni-hadrons : WZ resonance (vIII), m	$483 \text{ GeV} \qquad \qquad$
$\begin{array}{c} W_{R} (LRSM, no mixing): 2-lep + jets \\ W_{R} (LRSM, no mixing): 2-lep + jets \\ H_{L}^{\pm 2} (DY \text{ prod.}, BR(H^{\pm} \rightarrow \mu\mu)=1): SS dimuon, m_{\mu\mu} \\ Color octet scalar : dijet resonance, m_{jj} \\ Vector-like quark : CC, m_{Nq} \\ Vector-like quark : NC, m_{ilq} \\ \end{array}$		Major, neutr. (LRSM, no mixing) : 2-lep + jets	$1 = 2.1 \text{ (b)}^2 (2011) (Preliminary) $ 15 TeV N mass (m(W) = 2 TeV)
$ \begin{array}{c} \begin{array}{c} \begin{array}{c} H_{L}^{\pm\pm}\left(\text{DY prod., BR}(H^{\pm\pm}\rightarrow\mu\mu)=1\right):\text{SS dimuon, }m_{\mu\mu}\\ \text{Color octet scalar: dijet resonance, }m_{\mu\mu}\\ \text{Color octet scalar: dijet resonance, }m_{\mu\mu}\\ \text{Vector-like quark: CC, }m_{\nu q}\\ \text{Vector-like quark: NC, }m_{\mu q}\\ \end{array} \right _{\substack{\textbf{t=16.16}} \begin{array}{c} (2011) (221.1021) \\ \textbf{t=16.16} \end{array}} \begin{array}{c} 355 \text{ GeV} \\ \textbf{t=16.16} \end{array} \right _{\substack{\textbf{t=16.16}} \begin{array}{c} 1.94 \text{ TeV}\\ \textbf{t=16.16} \end{array}} \begin{array}{c} \text{Scalar resonance mass}\\ \textbf{t=16.16} \end{array} \right _{\substack{\textbf{t=16.16}} \begin{array}{c} (2011) (211.021) \\ \textbf{t=16.16} \end{array}} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \right _{\substack{\textbf{t=16.16}} \begin{array}{c} 1.94 \text{ TeV}\\ \textbf{t=16.16} \end{array}} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \right _{\substack{\textbf{t=16.16}} \begin{array}{c} 1.94 \text{ TeV}\\ \textbf{t=16.16} \end{array}} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \right _{\substack{\textbf{t=16.16}} \begin{array}{c} \textbf{t=16.16} \end{array}} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \right _{\substack{\textbf{t=16.16}} \begin{array}{c} \textbf{t=16.16} \end{array}} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \right _{\substack{\textbf{t=16.16}} \begin{array}{c} \textbf{t=16.16} \end{array}} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \right _{\substack{\textbf{t=16.16}} \begin{array}{c} \textbf{t=16.16} \end{array}} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \right _{\substack{\textbf{t=16.16}} \begin{array}{c} \textbf{t=16.16} \end{array}} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \right _{\substack{\textbf{t=16.16}} \begin{array}{c} \textbf{t=16.16} \end{array}} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \right _{\substack{\textbf{t=16.16}} \begin{array}{c} \textbf{t=16.16} \end{array}} \\ \begin{array}{c} \textbf{t=16.16} \end{array}} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \right _{\substack{\textbf{t=16.16}} \begin{array}{c} \textbf{t=16.16} \end{array}} \\ \begin{array}{c} \textbf{t=16.16} \end{array}} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \right _{\substack{\textbf{t=16.16}} \begin{array}{c} \textbf{t=16.16} \end{array}} \\ \begin{array}{c} \textbf{t=16.16} \end{array}} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \end{array} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \end{array} \right \right $ \\ \begin{array}{c} \textbf{t=16.16} \end{array} \end{array} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \end{array} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \end{array} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \end{array} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \end{array} \end{array} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \end{array} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \end{array} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \end{array} \\ \end{array} \end{array} \\ \begin{array}{c} \textbf{t=16.16} \end{array} \end{array} \\	θĽ	W _n (LRSM, no mixing) : 2-lep + jets	(m, R) (2011) [Preliminary] 2.4 TeV W _C mass (m(N) < 1.4 GeV)
Color octet scalar : dijet resonance, $m_{ij}^{\mu\mu}$ Vector-like quark : CC, m_{ijq} Vector-like quark : NC, m_{ijq} 10^{-1} 10^{-1} 10^{-1} 10^{-1} 10^{-1} 10^{-1}	CH-	$H_{\pm}^{\pm\pm}$ (DY prod., BR($H^{\pm\pm} \rightarrow \mu\mu$)=1) : SS dimuon, m	$r_{1} = 1.6 \text{ m}^{-1} (2014) (12014) (100$
Vector-like quark : NC, m_{ilq} Vector-like quark : NC, m_{ilq} 10^{-1} 1 10 10 10	0	Color octet scalar : dijet resonance, m	1 = 4 8 fb ⁻¹ (2011) (ATLAS-CONE-2012-038) 194 TeV Scalar resonance mass
Vector-like quark : NC, m_{liq} 10^{-1} 1 10 10 10 10 10 10 10 10 10 10 10 10 1		Vector-like guark : CC. m.	$L=1.0 \text{ fb}^{-1}(2011) [1112.5755]$ 900 GeV Q mass (coupling x $_{-2} = y/m_{-1}$)
10 ⁻¹ 1 10 10	Vector-like quark: NC. m_{i_0}		$L=1.0 \text{ fb}^{-1}(2011) [1112.5755]$ 760 GeV Q mass (coupling $\kappa_{qQ} = v/m_{q}$)
10^{-1} 1 10 10			
			10^{-1} 1 10 10
			National IV-

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

Nikolai Krasnikov, 12 May, Moscow

Conclusions

- CMS & ATLAS have significant discovery potential
- LHC will be able to discover Higgs boson and to check its basic properties
- LHC will be able to discover SUSY with squark and gluino masses up to 2.5 TeV.
 There is nonzero probability to find something beyond SM or MSSM(extra dimensions, Z'-boson, compositeness ...)
- ✓ Heavy gauge bosons up to ~5-6 TeV
- ✓ Heavy neutrino up to 2.6 TeV
- ✓ RS model ED up to ~4 TeV

Conclusions

 At any rate after LHC we will know the mechanism of electroweak symmetry breaking (Higgs boson or something more exotic?) and the basic properties of the matter structure at TeV scale.

Backup slides

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Higgs boson production cross section at the LHC



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Other mass measurements



Using the $e^{\pm}m^{-}+E^{+}m_{iss}$ signature in the search for Supersymmetry and lepton flavour violation in neutralino decay

A search was performed using the CMS detector simulation. The optimal cut set was found to be:

Isolated leptons with $p_t > 20$ GeV

EtMiss > 300 GeV



$$\mathsf{BR}(\ell_i \ell_j) \equiv \mathrm{BR}(\tilde{\chi}_2^0 \to \ell_i \ell_j \tilde{\chi}_1^0).$$

$$\begin{split} \kappa &= 2x \sin^2\theta \cos^2\theta, \\ x &= \frac{\Delta m_{\tilde{e}\tilde{\mu}}^2}{\Delta m_{\tilde{e}\tilde{\mu}}^2 + \Gamma^2}, \end{split}$$



SUSY (s)lepton flavour studies with ATLAS

