LHC Highlights

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Key Questions



- What is the origin of Electroweak Symmetry Breaking? Origin of Mass?
- Where is all the Anti-Matter?
- Were the fundamental forces once unified?
- Are there extra dimensions? Dark Matter?

New particles should appear at the TeV scale, in reach of the LHC



CERN Accelerator Complex



Overall view of the LHC experiments.



LHC Experiments



- ATLAS/CMS :
 - Electroweak Symmetry Breaking
 - Supersymmetry
 - Extra Dimensions, Exotics
- LHCb :
 - CKM Measurements
 - (Matter/Anti-Matter Imbalance)
 - Precision tests of the standard model
- ALICE :
 - Properties of the Quark-Gluon Plasma

LHC Experiments



- ATLAS/CMS :
 - Electroweak Symmetry Breaking
 - Supersymmetry
 - Extra Dimensions, Exotics
 - Also smaller experiments:Totem,Alpha
 - CKM Measurements
 - (Matter/Anti-Matter Imbalance)
 - Precision tests of the standard model
- ALICE :
 - Properties of the Quark-Gluon Plasma

LHC Experiments



- ATLAS/CMS :
 - Electroweak Symmetry Breaking
 - Supersymmetry
 - Extra Dimensions, Exotics
- LHCb :
 - CKM Measurements
 - (Matter/Anti-Matter Imbalance)
 - Precision tests of the standard model
- ALICE :
 - Properties of the Quark-Gluon Plasma



LHC Beginning & Beyond



2009		LHC start up, √s = 900 GeV	
2010			
2011		$\sqrt{s} = 7-8 \text{ TeV}$, L = 6 to 8•10 ³³ cm ⁻² - ¹ , bunch spacing 50 ns	
2012			~25 fb ^{⁻1}
2013	LS1	Go to design energy, nominal luminosity	
2014			
2015		$\sqrt{s} = 13-14$ TeV/ $I = 1.10^{34}$ cm ⁻²⁻¹ bunch spacing 25 ns	
2016		(likely to be more)	
2017			~50 fb
2018	LS2	Injector & LHC Phase I upgrade to full design luminosity	/
2019		34 0.4	
2020		$\sqrt{s} = 14 \text{ TeV}, L = 2 \cdot 10^{37} \text{ cm}^2 \overline{s}, \text{ bunch spacing } 25 \text{ ns}$	
2021		(likely to be more)	~300 fb ⁻¹
2022	LS3	HL-LHC Phase-2 upgrade, crab cavities?, IR	
2023		34 2 1	
00000		$\sqrt{s} = 14 \text{ TeV}, L = 5.10^{\circ} \text{ cm}^2 \text{ s}, \text{ bunch spacing } 25 \text{ ns}$	~3000 fb ¹
2030?		Plan for 50% more	



- 2009-today: Run I : 7-8 TeV centre of mass energy. Peak Luminosity 6.66 x 10³³ cm⁻²s⁻¹
- 2013-2014 : Shut down to prepare machine for design energy (14 TeV) and nominal luminosity (10³⁴cm⁻²s⁻¹)
 2015-2016 : Operation at design

LHC Peak Luminosity



http://lpc.web.cern.ch/lpc/lumiplots.htm





Impressive Luminosity Race with an Amazing Finish!



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26 June 2012 Tuesday, 26 June 12 2 12

An extremely successful week 24

- Very stable operation with
 - ~6.5 e33
 - 1.5e11 ppb
- 1.33 fb-1 recorded in one week!!
- 51% of the time in stable beams
- Total 18.7% 'down time'
 - MKI waiting for cool down: 13h40'
 - Injectors: 6h30'
 - Waiting for experiments: 3h28'



Peak Stable Luminosity Delivered	6.76x10 ³³ cm ⁻² s ⁻¹	Fill 2710	12/06/06, 15:52
Maximum Luminosity Delivered in one fill	237.32 pb ⁻¹	Fill 2692	12/06/02, 01:55
Maximum Luminosity Delivered in one day	250.94 pb ⁻¹	Saturday 16 June, 2012	
Maximum Luminosity Delivered in 7 days	1350.14 pb ⁻¹	Sunday 10 June, 2012 - Saturday 16 June, 2012	
Maximum Colliding Bunches	1380	Fill 2660	12/05/24, 13:17
Maximum Peak Events per Bunch Crossing	43.81	Fill 2479	12/04/06, 10:22
Maximum Average Events per Bunch Crossing	31.87	Fill 2710	12/06/06, 15:52
Longest Time in Stable Beams for one fill	22.8 hours	Fill 2692	12/06/02, 05:10
Longest Time in Stable Beams for one day	20.5 hours (85.6%)	Saturday 02 June, 2012	
Longest Time in Stable Beams for 7 days	90.0 hours (53.6%)	Sunday 10 June, 2012 - Saturday 16 June, 2012	
Eastest Turnaround to Stable Beams	2 13 hours	Fill 2472	12/04/05 15:46

26 June 2012

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LHC Collision Conditions



Re-discovery of the SM





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A Higgs Search (H->WW*) @ ATLAS



A Higgs Search (H->YY) @ CMS



Discovery?



- Finding the Higgs is a discovery!
- Not finding the SM Higgs is a discovery!

 LHC will elucidate spontaneous symmetry breaking. How do the W and Z get their mass? Let alone all other elementary particles?

Higgs Search Limits



It took ~30 years to experimentally restrict the SM Higgs mass to be above 114 GeV CMS and ATLAS independently eliminated another ~475 GeV of the range in 2011

"Expected" exclusion 114.5 - 543 GeV Observed exclusion 127.5 - 600 GeV

Higgs Search Limits: ATLAS Coeffections of Excellence of E



Excluded at 95% CL

Expected if no signal 120-555 GeV

||0 < mH < |22.5 GeV (except ||7.5-||8.5) |29 < mH < 539 GeV

One window left open? Have a new peak at ICHEP 2012

A standard model Higgs?

- Is the particle we are calling a Higgs, a real Higgs? A real Higgs would decay to WW* much more often than it decays to γγ
- Decay to two photons proceeds via indirect decay. If it happens more often than expected
 - Higgs couplings to top and W don't match prediction OR
 - Unknown heavy particles are mediating the decay
- Must proceed to measure decays to fermions: leptons and quarks (H → TT & H→bb)

Retrospective



- In 2008 ATLAS performed studies involving state of the art simulations in a rigorous effort to prepare for the start of data taking at the LHC
- Culminated in a ~1850 page document it reported what was expected to be searched for or measured and to what exclusion or precision at collision energy of 14 TeV
 - (arXiv:0901.0512 citations > 700)
- In 2012 we can look back and measure our progress with respect to expectation
 - (Higgs is the best case study)





· 사회 관계 1979년 전 관계 전 1971년 1971년 1971년 1971년 1971			
√s (TeV)	σ(gg→H) (pb) m(H) = 125 GeV		
7	15		
8	20		
14	50		





 $H \rightarrow \gamma \gamma$

 $H \rightarrow ZZ'$

→ 41



9

8

7

6

5

4

3

2

120

140

160



significance ATLAS $H \rightarrow \gamma\gamma$ $H \rightarrow ZZ^{*} \rightarrow 4I$ $H \rightarrow \tau\tau$ $H \rightarrow WW \rightarrow ev\mu\nu$ 8 7

Factor 2.5-3 less Higgs events at 7-8 TeV than at 14 TeV - at 125 GeV expected significance was 4 sigma with luminosity of 10/ fb.

With ~15/fb at 7-8 TeV, the significance is greater than 5 sigma. Basically in three years of data-taking analyses have improved by a factor of 2. Remarkable achievement!





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7	15		
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 $H \rightarrow \gamma \gamma$

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→ 41

Physics Beyond the SM

- Has the LHC ...
 - made dark matter?
 - made weird heavy particles? Black holes?
 - found sources of CP asymmetry that help bridge the gap between the minuscule amount in the SM and that observed in the Universe
- No evidence for any of it yet, but as David Gross said at EPS2011 "we're only at the beginning of a long journey". We expect to accumulate 100 times more data, so let's be optimistic.

Particles decaying to Top



Kaluza-Klein gluon excitation in the Randall-

Sundrum model



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Di-jet Resonance Searches



- Test of QCD & Large sensitivity to new physics
- Resonances decaying into two quarks or gluons, excited quarks
- ATLAS 36/pb. Exclude 95% C.L. 0.60 < m(q*) < 2.64 TeV. CMS similar analysis with 2.9/pb



0-lepton jet+MET channels most sensitive to gluino and squark production (Simplified Model - assumes only squarks gluino & LSP) Changing neutralino mass and allowing for richer SUSY particle content weakens constraints (more room to search)

ATLAS Mass Reach for SUSY COEPP

	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		
S	MSUGRA/CMSSM : 1-lep + j's + E _{7,miss}	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-041] 1.20 TeV $\tilde{q} = \tilde{g}$ mass		
	MSUGRA/CMSSM : multijets + E _{T,miss}	$L=4.7 \text{ fb}^{-1} (2011) [ATLAS-CONF-2012-037] 850 \text{ GeV} $		
rch	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 \tilde{g} mass $(m(\tilde{q}) < 2 \text{ TeV}, \text{ light } \tilde{\chi}_1^0)$ 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 $(m(\bar{\chi}_1^0) < 200 \text{ GeV}, m(\bar{\chi}^{\pm}) = \frac{1}{2}(m(\bar{\chi}^0) + m(\tilde{g}))$		
clus	GMSB : 2-lep OS _{SF} + E _{T,miss}	L=1.0 fb ⁻¹ (2011) [ATLAS-CONF-2011-156] 810 GeV g̃ mass (tanβ < 35)		
4	GMSB : $1-\tau + j's + E_{\tau,miss}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-005] 920 GeV g̃ mass (tanβ > 20)		
	GMSB : $2-\tau + j's + E_{\tau,miss}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-002] 990 GeV g̃ mass (tanβ > 20)		
	$GGM: \gamma\gamma + E_{\tau, miss}$	L=1.1 fb ⁻¹ (2011) [1111.4116] 805 GeV \tilde{g} mass ($m(\bar{\chi}_1^0) > 50$ GeV)		
~	Gluino med. \tilde{b} ($\tilde{g} \rightarrow b \bar{b} \bar{\chi}_1^0$) : 0-lep + b-j's + $E_{\tau,miss}$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-003] 900 GeV g mass (m(χ_1^0) < 300 GeV)		
atior	Gluino med. t̃ (ğ→tt̄χ̃¹) : 1-lep + b-j's + E _{7,miss}	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-003] 710 GeV \tilde{g} mass ($m(\bar{\chi}_1^0) < 150$ GeV)		
Gluino med. \tilde{t} ($\tilde{g} \rightarrow t\bar{t}\chi_1^0$): 2-lep (SS) + j's + $E_{T,miss}$ L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-004] 650 GeV \tilde{g} mass ($m(\bar{\chi}_1^0)$ < 210 GeV)				
d ge	Gluino med. \tilde{t} ($\tilde{g} \rightarrow t\bar{t} \chi^0$) : multi-j's + $E_{T,miss}$	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-037] 830 GeV g mass (m(χ_1^0) < 200 GeV)		
Thin	Direct $\tilde{b}\tilde{b}$ ($\tilde{b}_1 \rightarrow b \tilde{\chi}_1^0$) : 2 b-jets + $E_{T,miss}$	L=2.1 fb ⁻¹ (2011) [1112.3832] 390 GeV \tilde{b} mass ($m(\chi_1^0) < 60$ 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)		
C	Direct gaugino $(\bar{\chi}_1^{\pm} \bar{\chi}_2^0 \rightarrow 3 \bar{\chi}_1^0)$: 2-lep SS + $E_{\tau,miss}$	$L=1.0 \text{ fb}^{-1}(2011)[1110.6189] \qquad 170 \text{ GeV} \bar{\chi}_{1}^{\pm} \text{ mass} ((m(\bar{\chi}_{1}^{0}) < 40 \text{ GeV}, \bar{\chi}_{1}^{0}, m(\bar{\chi}_{1}^{\pm}) = m(\bar{\chi}_{2}^{0}), m(\bar{l}, \bar{v}) = \frac{1}{2}(m(\bar{\chi}_{1}^{0}) + m(\bar{\chi}_{2}^{0})))$		
Q	Direct gaugino $(\overline{\chi}_{1}^{\pm}\overline{\chi}_{2}^{0} \rightarrow 3I \overline{\chi}_{1}^{0})$: 3-lep + $E_{\tau, miss}$	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)		
Se	AMSB : long-lived $\bar{\chi}_1^{\pm}$	L=4.7 fb ⁻¹ [2011] [CF-2012-034] $\vec{\chi}_1^{\pm}$ mass (1 < $\tau(\vec{\chi}_1^{\pm})$ < 2 ns, 90 GeV limit in [0.2,90] ns)		
rticl	Stable massive particles (SMP) : R-hadrons	L=34 pb ⁻¹ (2010) [1103.1984] 562 GeV g mass		
d pa	SMP : R-hadrons	L=34 pb ⁻¹ (2010) [1103.1984] 294 GeV b mass		
live	SMP : R-hadrons	L=34 pb ⁻¹ (2010) [1103.1984] 309 GeV T mass		
-buo	SMP : R-hadrons (Pixel det. only)	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-022] 810 GeV g mass		
Ľ	GMSB : stable ∓	L=37 pb ⁻¹ (2010) [1106.4495] 136 GeV T MASS		
~	RPV : high-mass eµ	L=1.1 fb ⁻¹ (2011) [1109.3089] 1.32 TeV \bar{v}_{τ} mass (λ_{311}^{2} =0.10, λ_{312} =0.05)		
PU A	Bilinear RPV : 1-lep + j's + E _{T,miss}	L=1.0 fb ⁻¹ (2011) [1109.6606] 760 GeV q = g mass (CT _{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} = m _{kl}	L=34 pb ⁻¹ (2010) [1110.2693] 185 GeV sgluon mass (excl: m _{sg} < 100 GeV, m _{sg} = 140 ± 3 GeV)		
		10 ⁻¹ 1 10		
		Mass scale [TeV]		

ATLAS Mass Reach for Exotics

			lysics at the Terascale
		ATLAS Exotics Searches* - 95% CL Lower Limits (Status: March 2012)	
	Large ED (ADD) : monojet	L=1.0 fb ⁻¹ (2011) [ATLAS-CONF-2011-096] 3.2 TeV M _D (δ=2)	
	Large ED (ADD) : diphoton	L=2.1 fb ⁻¹ (2011) [1112.2194] 3.0 TeV M _S (GRW cut-off) ATLAS	
63	UED : $\gamma\gamma + E_{T miss}$	L=1.1 fb ⁻¹ (2011) [1111.4116] 1.23 TeV Compact. scale 1/R (SPS8) Preliminary	
ON	RS with $k/M_{\rm Pl} = 0.1$: diphoton, $m_{\gamma\gamma}$	L=2.1 fb ⁻¹ (2011) [1112.2194] 1.85 TeV Graviton mass	
1DSI	RS with $k/M_{\rm Pl} = 0.1$: dilepton, $m_{\rm H}$	L=4.9-5.0 fb ⁻¹ (2011) [ATLAS-CONF-2012-007] 2.16 TeV Graviton mass	
me	RS with k/M _{Pl} = 0.1 : ZZ resonance, m	L=1.0 fb ⁻¹ (2011) [1203.0718] 845 GeV Graviton mass	
8	RS with $g = -0.20$: $t\bar{t} \rightarrow l+jets, m$	L=2.1 fb ⁻¹ (2011) [ATLAS-CONF-2012-029] 1.03 TeV KK gluon mass	
XIX	ADD BH $(M_{TH}^{qgr})M_{p}^{*}=3)$: multijet, Σp_{τ} , N_{iets}^{it}	L=35 pb ⁻¹ (2010) [ATLAS-CONF-2011-068] 1.37 TeV M _D (δ=6)	
Ц	ADD BH (M _{TH} /M _D =3) : SS dimuon, N _{ch. part.}	L=1.3 fb ⁻¹ (2011) [1111.0080] 1.25 TeV M _D (δ=6)	
	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)	
	Quantum black hole : dijet, F ₂ (m _{ij})	L=4.7 fb ⁻¹ (2011) [ATLAS-CONF-2012-038] 4.11 TeV M _D (δ=6)	
	qqqq contact interaction : $\hat{\chi}(m_{\perp})$	L=4.8 fb ⁻¹ (2011) [ATLAS-CONF-2012-038] 7.8 TeV	
C	qqll Cl : ee, μμ combined, m [*]	L=1.1-1.2 fb ⁻¹ (2011) [1112.4462] 10.2 TeV A (constructive int.)	Statio Sin
	uutt CI : SS dilepton + jets + E _{T.miss}	L=1.0 fb ⁻¹ (2011) [1202.5520] 1.7 TeV Λ	
2	SSM Z' : m _{eeluu}	L=4.9-5.0 fb ⁻¹ (2011) [ATLAS-CONF-2012-007] 2.21 TeV Z' mass	
>	SSM W': m _{T.e/µ}	L=1.0 fb ⁻¹ (2011) [1108.1316] 2.15 TeV W mass	للكته فأسبت فاستحت
3	Scalar LQ pairs (β=1) : kin. vars. in eejj, evjj	L=1.0 fb ⁻¹ (2011) [1112.4828] 660 GeV 1 st gen. LQ mass	
_	Scalar LQ pairs (β=1) : kin. vars. in μμjj, μvjj	L=1.0 fb ⁻¹ (2011) [Preliminary] 685 GeV 2 nd gen. LQ mass	an and a start
50	4^{th} generation : Q $\overline{Q}_{4} \rightarrow WqWq$	L=1.0 fb ⁻¹ (2011) [1202.3389] 350 GeV Q ₄ mass	
e e	4 th generation : uᢆ,u੍ਰੋ→ WbWb	L=1.0 fb ⁻¹ (2011) [1202.3076] 404 GeV U ₄ mass	
Ъ	4^{th} generation : $d_1 d_4 \rightarrow WtWt$	L=1.0 fb ⁻¹ (2011) [Preliminary] 480 GeV d ₄ mass	
80	New quark b' : b' $\overline{b}' \rightarrow Zb+X, m_{Tb}$	L=2.0 fb ⁻¹ (2011) [Preliminary] 400 GeV b' mass	
<	$T\overline{T}_{exp, 4th pen} \rightarrow t\overline{t} + A_0A_0$: 1-lep + jets + $E_{T, miss}$	L=1.0 fb ⁻¹ (2011) [1109.4725] 420 GeV T mass (m(A ₀) < 140 GeV)	
Ë	Excited quarks : y-jet resonance, m	L=2.1 fb ⁻¹ (2011) [1112.3580] 2.46 TeV q ⁺ mass	THERE
10	Excited quarks : dijet resonance, m	L=4.8 fb ⁻¹ (2011) [ATLAS-CONF-2012-038] 3.35 TeV q* mass	
CC/L	Excited electron : e-y resonance, m	L=4.9 fb ⁻¹ (2011) [ATLAS-CONF-2012-023] 2.0 TeV e* mass ($\Lambda = m(e^*)$)	
£	Excited muon : µ-y resonance, m	L=4.8 fb ⁻¹ (2011) [ATLAS-CONF-2012-023] 1.9 TeV μ* mass (Λ = m(μ*))	Children Hal
	Techni-hadrons : dilepton, m _{ee/µµ}	L=1.1-1.2 (m^{+} (2011) [ATLAS-CONF-2011-125] 470 GeV ρ_{T}/ω_{T} mass ($m(\rho_{T}/\omega_{T}) - m(\pi_{T}) = 100$ GeV)	
	Techni-hadrons : WZ resonance (vIII), m	L=1.0 fb ⁻¹ (2011) [Preliminary] 483 GeV ρ_{T} mass $(m(\rho_{T}) = m(\pi_{T}) + m_{W}, m(a_{T}) = 1.1 m(\rho_{T}))$	
	Major. neutr. (LRSM, no mixing) : 2-lep + jets	L=2.1 fb ⁻¹ (2011) [Preliminary] 1.5 TeV N mass $(m(W_R) = 2 \text{ TeV})$	
101	W _R (LRSM, no mixing) : 2-lep + jets	L=2.1 fb ⁻¹ (2011) [Preliminary] 2.4 TeV W _R mass (m(N) < 1.4 GeV)	
5	H_{L}^{Ex} (DY prod., BR($H_{L}^{\text{Ex}} \rightarrow \mu\mu$)=1): SS dimuon, $m_{\mu\mu}$	L=1.6 fb ⁻¹ (2011) [1201.1091] 355 GeV H ¹¹ _L mass	
	Color octet scalar : dijet resonance, m	L=4.8 fb ⁻¹ (2011) [ATLAS-CONF-2012-038] 1.94 TeV Scalar resonance mass	
	Vector-like quark : CC, mivg	$L=1.0 \text{ fb}^{-1} (2011) [1112.5755]$ 900 GeV Q mass (coupling $\kappa_{qQ} = \nu/m_Q$)	
	Vector-like quark : NC, m _{ilq}	L=1.0 fb ⁻¹ (2011) [1112.5755] 760 GeV Q mass (coupling $\kappa_{qQ} = v/m_Q$)	
		10^{-1} 1 10 10^{2}	
m	ilar results for CMS for SUSY and Ex	Mass scale [TeV]	
ttp	os://twiki.cern.ch/twiki/bin/view/CMS	SPublic/PhysicsResultsSUS	
ttr	os://twiki.cern.ch/twiki/bin/view/CMS	SPublic/PhysicsResultsEXO 2 - Geoffrey Taylor	2

Tuesday, 26 June 12

S

Centre of Excellence for

Is SUSY beyond reach?



- Pre-LHC : SUSY predicted particles at the Terascale
- Today : SUSY is directly being pushed beyond the Terascale > I TeV
- Precision flavor physics e.g LHCb (Belle, Babar elsewhere) > 10 TeV
- Naturalness requires SUSY to have fairly light stops to cancel "un-naturally" large corrections to the Higgs mass



Precision Tests of the Standard Model

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LHCb

- Sensitive probe of new physics.
 Virtual loops
- Measurement of the Isospin asymmetry in B->K µµ turned up an asymmetry which no one expected
- arXiv:1205.3422 [hep-ex]
- Awaiting SM prediction

More on LHCb results in upcoming talk



Heavy Ion Physics





Exact mechanism that causes confinement remains unknown Is the mechanism that confines

quarks inside protons responsible for most of the mass in matter?

Properties of qg-Plasma

- QCD predicts the existence of quarkgluon plasma at high energy density
- Azimuthal distribution of particles in the plane perpendicular to the beam direction (azimuthal anisotropy)
- Higher Harmonic Anisotropic Flow Measurements of Charged Particles in Pb-Pb collitions at sqrt(s)= 2.76 TeV
- Fourier coefficients

 $\boldsymbol{v}_n = \langle \cos[n(\boldsymbol{\phi} - \boldsymbol{\Psi}_n)] \rangle$

- First measurements of particle flow v3, v4 and v5!
- PRL 107, 032301 (2011)



Jet Quenching @ ATLAS



Ultra-relativistic heavy ion collisions are expected to produce hot and dense QCD matter.

High pT quarks or gluons are expected lose energy or have their parton shower modified in the medium of high color-charge density.

May lead to modified jet yields or structure, phenomenon known as "jet quenching"



2012 LHC Goals



- Allow ATLAS and CMS to independently discover the Higgs before the shutdown (LSI)
- Run with Pb-p collisions at the end of 2012
- Machine studies with 25 ns bunch spacing and pileup to ensure smooth operation after LSI
- Data needed for Higgs discovery

Year	Data(/fb)/Beam E(TeV)	Significance (σ)
2011	5 / 3.5	2.5
2012	11.5 /4.0	5

Impressive Luminosity Race with an Amazing Finish!



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LHC Lowlights



Summary



2009		LHC start up, √s = 900 GeV	
2010			
2011		$\sqrt{s} = 7-8 \text{ TeV}$, L = 6 to 8•10 ³³ cm ⁻² s ⁻¹ , bunch spacing 50 ns	
2012			~25 fb ^{⁻1}
2013	LS1	Go to design energy, nominal luminosity	-1
2014			
2015		$\sqrt{s} = 13-14$ TeV. L = 1.10 ³⁴ cm ⁻²⁻¹ bunch spacing 25 ns	
2016		(likely to be more)	
2017			~50 fb ⁻¹
2018	LS2	Injector & LHC Phase I upgrade to full design luminosit	y
2019		34 0.4	
2020		$\sqrt{s} = 14 \text{ TeV}, L = 2.10^{34} \text{ cm}^2 \text{ s}^3, \text{ bunch spacing } 25 \text{ ns}$	
2021		(likely to be more)	~300 fb ⁻¹
2022	LS3	HL-LHC Phase-2 upgrade, crab cavities?, IR	
2023		-34 - 2 - 1	4
2030?		$\sqrt{s} = 14$ leV, L = 5.10 cm ^{-s} , bunch spacing 25 ns	~3000 fb



- Remarkable that with ~1/2 design energy (but with great progress on the luminosity front) the LHC has achieved so already.
- With plans for massive increases in data at higher energies in the future the LHC will without doubt be extremely productive

last word from CERN DG

Nevertheless, at less than two weeks from the start of the ICHEP conference, the news from the experiments is exciting. As I reported to Council, the hints that were reported in the 2011 data last December are still present in the 2012 data. Furthermore, refinements of the analysis of the 2011 data have confirmed the hints reported in December. It is too early for the experiments to say whether the significance is enough to claim a discovery, but whatever the news, it will be reported at CERN on Wednesday 4 July with a live two-way video link to the scientists gathering in Melbourne for ICHEP2012.