HadronColliderPhysics Symposium 2011

STANDARD MODEL HIGGS COMBINATION AT ATLAS

FABIEN TARRADE CARLETON UNIVERSITY ON BEHALF THE ATLAS COLLABORATION

NOVEMBER 16TH



ATLAS DATA TAKING IN 2011

A huge amount of data collected in 2011 :

- Thanks to the LHC teams for this great job
- ATLAS data taking in 2011:
 - p-p collision at $\sqrt{s}=7$ TeV
 - peak luminosity : ~3.65x10³³ cm⁻² s⁻¹
 - O(5) fb⁻¹ for analysis
 - data taking efficiency : ~93.5%

Pile-up challenge :

- 50 ns bunch train for ~all 2011 data in-and out-of-time pile up :
 <µ>~6 for 2.47 fb⁻¹ of the data collected
 <µ>~12 for 2.78 fb⁻¹ of the data collected
- Continuing details performances studies in presence of "high" pile-up





HIGGS BOSON CROSS-SECTION



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STATISTICAL PROCEDURE

Used for individual channels and S 🅢 ggs combination at ATLAS :

- Common parameters of interest is I ss-section scale factor : $\mu = \sigma/\sigma^{SM}$ $\mu = 0$ is the background only model $\mu = 1$ correspond to the nominal signal model
- Combined probability model is formed by identifying nuisance parameters v associated to common systematic effects
- The profile likelihood ratio is used as a test statistics :

 $\lambda(\mu) = L_{s+b}(\mu, \hat{\nu}) / L_{s+b}(\hat{\mu}, \hat{\nu})$

one-sided variants of the test statistic are used for the upper-limits and discovery

- Nuisance parameters are "profiles" based on the data
- The distribution of the test statistic is obtained in two way :
 - ensemble tests with with Toy Monte Carlo using a fully frequentist procedure
 - using asymptotic distribution of likelihood ratio (improved χ^2 method)
- Primary results based on CLs
 - more relevant to protect against downward fluctuations
 - additional comparison with Bayesian procedure with a uniform prior on $\mu {=} \sigma / \sigma^{\text{SM}}$

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Use RooFit/RooStats

UNDERSTANDING OF THE BAND

Understanding of the Yellow and Green bands :

 Upper limit on the Standard Model (SM) Higgs Boson production cross section divided by the Standard Model expectation as a function of m_{Higgs}



CHANNELS INCLUDED

channels used in the SM Higgs combination at ATLAS :

- Low mass searches : $m_{Higgs} < 140 \text{ GeV}$ W/ZH with H \rightarrow bb, H $\rightarrow \tau\tau$, H $\rightarrow \gamma\gamma$
- Intermediate mass searches : 120 GeV < m_{Higgs} < 180 GeV H \rightarrow WW^(*) \rightarrow IvIv
- Higgs mass searches : 180 GeV < m_{Higgs} < 600 GeV H \rightarrow WW \rightarrow Ivqq, H \rightarrow ZZ^(*) \rightarrow IIII, H \rightarrow ZZ \rightarrow IIvv, H \rightarrow ZZ \rightarrow IIqq

Channel	Mass range (GeV)	Integrated Luminosity (fb ⁻¹)
Η → γγ	110 – 150	1.08
$H \rightarrow bb (WH,ZH)$	110 - 150	1.04
Η → ττ	110 - 150	1.06
$H \to WW^{(*)} \to I_{V}I_{V}$	110 - 300	1.70
$H \rightarrow WW \rightarrow I_V qq$	240 - 600	1.04 *(<i>NOT</i> in this version of the combination)
$H \to ZZ^{(*)} \to IIII$	110 - 600	~2.10
$H \rightarrow ZZ \rightarrow II_{VV}$	200 - 600	1.04 *(2.05 NEW and not in the combination)
H → ZZ → llqq	200 - 600	1.04 *(2.05 NEW and not in the combination)

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DETAILS PRESENTATION

More detailed presentations on the channels during this conference :

 SM Higgs Boson Searches at Low mass in ATLAS presentation by Michael Duehrssen

 ATLAS Higgs searches in WW and ZZ channels presentation by Lydia Iconomidou-Fayard

- SM search in VH, H → bb searches in ATLAS poster by Alberto Palma
- Search for SM Higgs boson in the two-photon in ATLAS poster by Olivier Andre Davignon
- Search for SM Higgs H→WW→IvIv in ATLAS poster by Xiao Meng
- SM Higgs H→ZZ→4I in ATLAS poster by Jerome Odier





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LOW MASS CHANNELS

Key points of the analysis :



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LOW MASS CHANNELS

Key points of the analysis :

 H → bb (1.04 fb⁻¹) Associated production WH/ZH inclusive analysis m_{bb} shape bkg : W+(b)jets, Z+(b)jets, QCD jets





INTERMEDIATE MASS CHANNELS



HIGH MASS CHANNELS

Key points of the analysis :

• $H \rightarrow ZZ^{(*)} \rightarrow IIII (1.96-2.28 \text{ fb}^{-1})$ m₄₁ shape bkg : ZZ (mainly), Zbb, Z+jets, Top



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HIGH MASS CHANNELS

Key points of the analysis :



combined results : tagged and untagged

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SUMMARY OF THE CHANNELS

Summary of the individual channels :



Observed limit : ——

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SYSTEMATIC UNCERTAINTIES

Treatment of the systematic uncertainties between the different channels :

	H – $ au_\ell au_{had}$	$ au au^+ au^- \ au_\ell au_\ell + jet$	$H ightarrow \gamma \gamma$	$H ightarrow bar{b}$	$ \begin{array}{c} H \to WW^{(*)} \\ \ell \nu \ell \nu \end{array} $	H. LLLL	$H \rightarrow ZZ^{(l)}$ $\ell\ell\nu\nu$	*) llqq
Luminosity	±3.7	±3.7	±3.7	±3.7	±3.7	±3.7	±3.7	±3.7
e/γ eff.	±3.5	$^{+2.0}_{-2.1}$	$^{+11.6}_{-10.4}$	±2.3	±2.2	±3.3	± 1.2	±1.1
e/γ E. scale	$^{+1.3}_{-0.1}$	$^{+0.2}_{-0.5}$	-	$^{+1.5}_{-1.6}$	± 0.1	-	$^{+0.8}_{-1.1}$	-
e/γ res.	-	± 3.7	-	$^{+2.1}_{-1.5}$	± 0.1	-	-	-
μ eff.	±1.0	$^{+2.0}_{-2.1}$	-	$^{+1.1}_{-2.0}$	±0.6	±1.2	$^{+0.8}_{-0.7}$	±0.6
μ res.	-	$^{+0.4}_{-0.6}$	-	± 5.8	±1.6	-	-	-
Jet/ τ /MET E. scale	$^{+19}_{-16}$	$+3.3 \\ -10.0$	-	$^{+21}_{-17}$	±6.1	-	$^{+5.9}_{-4.0}$	$+3.7 \\ -10.4$
JER	•	± 2.0	-	±2.5	$^{+2.2}_{-1.8}$	-	-	$^{+2.1}_{-0.0}$
MET	-	$+4.4 \\ -5.3$	-	$+5.5 \\ -6.1$	-	± 0.6	+6.6 -4.2	-
<i>b</i> -tag eff.	-	-	-	$+37 \\ -33$	± 0.1	-	$^{+4.3}_{-4.4}$	-

• Correlated systematic uncertainties (Jet Energy Scale, Luminosity, ...)

- For background estimated with data-driven, systematic uncertainties are uncorrelated
- Careful treatment of theory uncertainties (ATLAS-CMS LHC combination working group)

Production Mode	QCD Scale	PDF+α _s	Total	
ggF	+12/-7 %	±8 %	+20/-15 %	
VBF	±1 %	±4 %	±5 %	change with m _{Higgs}
WH/ZH	±1 %	±4 %	±5 %	
ttH	±4 %	±8 %	±12 %	

SM Higgs Combination at ATLAS with 2010 and 2011 data :





LOCAL P-VALUES

Local p-value of the SM Higgs combination at ATLAS :



ABSENT OF THE COMBINATION

> 3500

ର୍ ରୁ 3000

2500 Events

2000

Signal (x 100) ́т_н = 400 ĠeV

Data

Multi-jet Dibosons

 $H \rightarrow hv ii + 0 jet$

top W/Z+jets

Key points of the analysis :

• $H \rightarrow WW \rightarrow I_V qq (1.04 \text{ fb}^{-1})$ m_{lvqq} shape 0 jet, 1 jet bkg: W+jets, Top



UPDATED RESULTS

Key points of the analysis :



PROJECTION FOR THE FULL 2011 DATASET

What we can expect with the full 2011 dataset :



• Exclusion or evidence at 3σ : almost for the whole mass range



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Conclusion :

- Thanks to the excellent LHC operations, ATLAS has collected more than 5 fb⁻¹ of data (p-p collision at 7 TeV)
- The LHC dominates the SM Higgs with few fb⁻¹
- ATLAS has performed a Higgs Boson search corresponding to and integrated luminosity between 1.0 and 2.3 fb⁻¹ using several channels
- No significant excess (< 2.1 σ) is found in the mass range 110-600 GeV
- Exclusion limits at 95% C.L are set for a SM-like Higgs boson in the mass region : 146 < m_{Higgs} < 230 GeV 256 < m_{Higgs} < 282 GeV 296 < m_{Higgs} < 459 GeV with 1-2.3 fb⁻¹
- Interesting hints emerge





Outlook :

- Wait for the first ATLAS + CMS SM Higgs combination (presentation by Gigi Rolandi)
- With O(5 fb⁻¹) of data (full 2011 dataset), more than 2σ sensitivity in entire mass range with ATLAS
- Limits can be improved by optimizing the object performances (e, μ, τ, ...), by reducing the systematic and optimizing the selections
- We congratulate the LHC for terrific performances and look forward to more successful running in 2012!
- By the end of 2012 with O(10 fb⁻¹) a conclusive answer on the Standard Model Higgs should be obtained
- Very exiting times ahead ...

STAY TUNED

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DOCUMENTATIONS

ATLAS Public Documents :

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults

- ATLAS Luminosity and pile-up <u>https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResults</u>
- LHC Higgs Cross-section working group <u>https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CrossSections</u>
- Handbook of LHC Higgs Cross Sections: 1. Inclusive Observables CERN-2011-002, arXiv:1101.0593 <u>http://cdsweb.cern.ch/record/1318996</u>
- Search for the Standard Model Higgs boson in the decay mode H -> tau+ tau- -> II + 4 neutrinos in Association with jets in Proton-Proton Collisions at √s =7 TeV with the ATLAS detector ATLAS-CONF-2011-133 <u>http://cdsweb.cern.ch/record/1383836</u>
- Search for the Higgs boson in the two photon decay channel with the ATLAS detector at the LHC arXiv:1108.5895 <u>http://arxiv.org/abs/1108.5895</u>
- Search for the Standard Model Higgs boson produced in association with a vector boson and decaying to a b-quark pair with the ATLAS detector at the LHC ATLAS-CONF-2011-103 http://cdsweb.cern.ch/record/1369826

DOCUMENTATIONS

ATLAS Public Documents :

- Search for the Standard Model Higgs boson in the H->WW->Ilnunu decay mode using 1.7 fb⁻¹ of data collected with the ATLAS detector at √s=7 TeV ATLAS-CONF-2011-134 <u>http://cdsweb.cern.ch/record/1383837</u>
- Search for the Higgs boson in the H → ZZ → IIII decay channel with the ATLAS detector arXiv:1109.3615 http://arxiv.org/abs/1109.5945
- Search for a Standard Model Higgs boson in the H->ZZ->IInunu decay channel with the ATLAS detector arXiv:1109.3357 http://arxiv.org/abs/1109.3357
- Search for a heavy Standard Model Higgs boson in the channel H->ZZ->IIqq using the ATLAS detector arXiv:1108.5064 http://arxiv.org/abs/1108.5064
- Update of the Combination of Higgs Boson Searches in 1.0 to 2.3 fb⁻¹ of pp Collisions Data Taken at √s = 7 TeV with the ATLAS Experiment at the LHC ATLAS-CONF-2011-135 <u>http://cdsweb.cern.ch/record/1383838</u>

DOCUMENTATIONS

ATLAS Public Documents :

- Combination of the Searches for the Higgs Boson in ~1 fb⁻¹ of Data Taken with the ATLAS Detector at 7 TeV Center-of-Mass Energy ATLAS-CONF-2011-112 <u>http://cdsweb.cern.ch/record/1375549</u>
- Search for the Higgs boson in the H → WW → I nu jj decay channel in pp collisions at √s = 7 TeV with the ATLAS detector arXiv:1109.3615 <u>http://arxiv.org/abs/1109.3615</u>
- Search for a Standard Model Higgs boson in the H -> ZZ -> Ilnunu decay channel with 2.05 fb⁻¹ of ATLAS data ATLAS-CONF-2011-148 <u>http://cdsweb.cern.ch/record/1392668</u>
- Search for a Standard Model Higgs Boson in the mass range 200-600 GeV in the channel H -> ZZ -> Ilqq using the ATLAS Detector. ATLAS-CONF-2011-150 <u>http://cdsweb.cern.ch/record/1397901</u>
- Further investigations of ATLAS Sensitivity to Higgs Boson Production in different assumed LHC scenarios ATL-PHYS-PUB-2011-001 <u>http://cdsweb.cern.ch/record/1323856/</u>

COMMON LING STOLLMATICS

Theoretical Systematics

$\mathbf{PDF} + \alpha_s$ uncertainties

nuisance	groups of physics processes
$\mathrm{pdf}_{-}\mathrm{gg}$	$gg \to H, t\bar{t}H, VQQ, t\bar{t}, tW, tb \text{ (s-channel)}, gg \to VV$
pdf_qqbar	VBF $H, VH, V, VV, \gamma\gamma$
pdf_qg	tbq (t-channel), γ +jets

QCD scale uncertainties

nuisance	groups of physics processes
${ m QCDscale_ggH}$	total inclusive $gg \to H$
${ m QCDscale_ggH1in}$	inclusive $gg/qg \to H+ \ge 1$ jets
${ m QCDscale_ggH2in}$	inclusive $gg/qg \to H+ \ge 2$ jets
$\mathbf{QCDscale_qqH}$	VBF H
$\mathbf{QCDscale}_{\mathbf{VH}}$	associate VH
${f QCDscale_ttH}$	$t\bar{t}H$
$\mathbf{QCDscale}_{-}\mathbf{V}$	W and Z
$\mathbf{QCDscale}_{-}\mathbf{VV}$	WW, WZ, and ZZ up to NLO
${ m QCDscale_ggVV}$	$gg \to WW$ and $gg \to ZZ$
$\mathbf{QCDscale}_{\mathbf{Z}}\mathbf{QQ}$	Z with heavy flavor $q\bar{q}$ -pair
$\mathbf{QCDscale_WQQ}$	W with heavy flavor $q\bar{q}$ -pair
$\mathbf{QCDscale}_{ ext{tbar}}$	$t\bar{t}$, single top productions are lumped here for simplicity

Phenomenological uncertainties

nuisance	groups of physics processes
UEPS	all processes sensitive to modeling of UE and PS

Acceptance uncertainties

nuisance	comments
$QCDscale_WW_EXTRAP$	extrap. factor α for deriving WW bkgd in HWW analysis
$QCDscale_ttbar_EXTRAP$	extrap. factor α for deriving $t\bar{t}$ bkgd in HWW analysis

Instrumental Systematics Instrumental uncertainties

moti amentar ancer tampies	
nuisance	comments
lumi	uncertainties in luminosities

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MASS SIEPS

Higgs Decay Width and Mass Resolution :

Prepared for the LHC combination (ATLAS+CMS)



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SM Higgs Combination at ATLAS with 2011 data :



SM Higgs Combination at ATLAS with 2011 data :



SM Higgs Combination at ATLAS with 2011 data :



HEAVY FOURTH GENERATION

ATLAS SM Higgs Combination with the addition of a 4th generation of fermions :

- Expected exclusion : 116 600 GeV
- Observed exclusion : 119 593 GeV

