### ATLAS Run 2 – Higgs Prospects



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# on behalf of The ATLAS Collaboration

### Outline

- ATLAS Upgrades during LS1
- ATLAS readiness
  - First physics results with Run 2 data
- Higgs Road Map for Run 2
  - Early searches
  - Prospects with 2015 dataset (Moriond 2016)
  - Hints for improvements on precision measurements (mass, cross-sections & couplings)

Note : Prospects with full Run 2 dataset (100 fb<sup>-1</sup>) and beyond will be mostly covered in CMS talk

### LHC Run 2 planning



• 5 to 10 fb<sup>-1</sup> expected at the end of 2015 (Moriond 2016)

→ Expected sensivity comparable to full Run 1 dataset (or better)

## ATLAS Upgrades during LS1

#### Detector consolidation :

- Muon chamber completion and replacement (1.0 <  $|\eta|$  < 1.3)
- Calorimeter electronics repair
- Improved inner detector readout to cope with 100 kHz L1 rate
- New Topological L1 trigger and Central Trigger Processor, restructured HLT
- New Insertable B-Layer
  - 4<sup>th</sup> pixel layer at 3.3 cm from the beam
  - Planar and 3D sensors (forward region)
  - Smaller pixels

**ATLAS Prospects** 

- New beam pipe r =2.5 cm
- New software with improved reconstruction
  - Tau, b-tagging, MET...





### 13 TeV Data Summary in ATLAS



#### New Insertable B Layer





First hits in IBL with Cosmic data and minimum bias events

#### **ATLAS Prospects**

# IBL alignement and IP resolution in Run 2 data (min bias)



- IBL alignement getting close to the simulation expected performance
- Up to 40% improvement on the impact parameters resolutions w.r.t Run 1

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/IDTR-2015-007/ https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2015-031/

**ATLAS Prospects** 

# Improved b-tagging performance in Run 2



- New IBL layer + offline b-tagging algorithm optimization
- Expect light jet rejection increase by a factor 4 and by 50 % for c-jet for the same efficiency as Run 1

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2015-022/

# Improved performance of b-jet and tau triggers in Run 2



- New IBL layer + online online b-tagging optimization
- Expect light jet rejection increase by a factor 100 for the same efficiency as Run 1
- Increased  $\tau$  trigger efficiency from 70 % to 90 %

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TauTriggerPublicResults https://twiki.cern.ch/twiki/bin/view/AtlasPublic/BJetTriggerPublicResults

#### **ATLAS Prospects**

#### Cross-Sections @ 13 TeV



**ATLAS Prospects** 

### Higgs Road Map for Run 2

- With early 2015 dataset (5 to 10 fb<sup>-1</sup>) :
  - High Priority for BSM Higgs Searches
  - High priority for ttH
- With full 2015 dataset (10 to 15 fb<sup>-1</sup>) :
  - Higgs « rediscovery » in  $\gamma\gamma$  and ZZ\* channels
  - Mass and couplings measurements
  - Higgs Cross-section measurements in all channels
  - Combination with Run 1
- With Full run 2 dataset (100 fb-1)
  - Precision gain for SM Higgs measurements of 3.5 over Run 1

 $\rightarrow$  at this point, the systematic uncertainties will be dominant for most of the measurements (covered in CMS talk)

## Early BSM searches (5 to $10 \text{ fb}^{-1}$ )

- Heavy Neutral Higgs decaying to fermions
  - $H/A \rightarrow t\bar{t}, b\bar{b}, \tau\tau$
- Charged Higgs
  - $H^+ \rightarrow \tau v + jets$ , tb
- Heavy Neutral Higgs
  - $H \rightarrow WW, ZZ, \gamma\gamma$
- Di-Higgs searches
  - $H \rightarrow hh \rightarrow \gamma \gamma b \overline{b}$

 → Many channels can reach the Run 1 sensitivity with only a few fb<sup>-1</sup> of 13 TeV data

### $\mathsf{BSM} \mathsf{H} \to \mathsf{ZZ}^*$

- Run 1 searches from 200 GeV to 1 TeV
- Scale 8 TeV → 13 TeV
  - Bkg Z(W) + jets \* 1.6 (1.7)
  - Bkg tt \* 3.3
  - Bkg diboson \* 2
  - Signal \* 4
- Run 1 significance reached with ~5 fb<sup>-1</sup> of Run 2 data



https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2013-20/

#### BSM H/h/A $\rightarrow \tau \tau$

- Run 1 searches from 100 GeV to 1 TeV
- Better significance at high mass and high tan β with 5 to 10 fb<sup>-1</sup> @13 TeV





https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2013-31/

## $H \rightarrow b\overline{b} \gamma\gamma$



https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2013-29/

# SM Higgs diboson with 2015 data : back-of the envelop estimates

- Going from 8  $\rightarrow$  13 TeV
  - Higgs signal increases by factor 2.3
  - Background typically increases by factor 1.9 (3.3 for tt)
  - Significance scales as  $S/\sqrt{B}$ 
    - → Sensitivity gain : **1.6**
- Sensitivity scales with  $\sqrt{L}$ 
  - √(25 fb<sup>-1</sup>/ 10 fb<sup>-1</sup>) = **1.6**
- Sensitivity for 10 fb<sup>-1</sup> @ 13 TeV corresponds to full Run 1 dataset (25 fb<sup>-1</sup> @ 7/8 TeV)



Combination of full Run 1 + 10 fb<sup>-1</sup> of Run 2 will increase the sensitivity by 40 % w.r.t Run 2 data alone

## SM Higgs Diboson Fiducial/Differential cross-sections

#### Statistics dominated

 Early fiducial cross-sections might be measured with less than 10 fb<sup>-1</sup>
 @13 TeV for γγ and ZZ channels





- Differential distributions
  - Expected to have similar precision with 10 fb<sup>-1</sup> @13 TeV data than published 8 TeV data

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2013-10/

## SM Higgs Strength & Couplings

Xsec (pb)	ggF	VBF	WH	ZH	ttH	bbH
8 TeV	19.27	1.578	0.7046	0.4153	0.1293	0.2106
13 TeV	43.92	3.748	1.380	0.8696	0.5085	0.5116
Ratio	2.28	2.38	1.96	2.09	3.93	2.43

- Statistical uncertainty ~ 2.5 times larger than systematics
  - 10 fb<sup>-1</sup> @13 TeV to reach same precision as full Run 1 dataset
  - Except for ttH : +45 %
  - Statistics and systematics will become equivalent with the full Run 2 dataset (100 fb<sup>-1</sup>)



### Higgs Boson Mass



- Still statistically dominated with 2015 dataset. Assume same systematics as Run 1.
- $H \rightarrow \gamma \gamma$  extrapolation with Run 1 systematics :
  - 10 fb<sup>-1</sup> : stat 0.43 GeV, syst 0.27 GeV
  - Statistical and systematic uncertainties become equal with ~ 30 fb<sup>-1</sup>
- H → ZZ\* with 10 fb<sup>-1</sup> @13 TeV expected to match Run 1 precision
  - Small systematics, statistical uncertainty reduces with luminosity
  - Expect better precision in H  $\rightarrow$  ZZ than H  $\rightarrow \gamma\gamma$  with ~50 fb<sup>-1</sup>

# SM Higgs to fermions with 2015 data

#### Run 1 legacy

• Observed H  $\rightarrow \tau\tau$  (ggH and VBF)

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2012-07/

• Limit on  $H \rightarrow b\overline{b}$ 

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2013-23/

• Limit on H  $\rightarrow \mu\mu$ 

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2013-07/

- Run 2 expectations
  - Update couplings measurements in  $\tau\tau$ ,  $b\overline{b}$ ,  $\mu\mu$  with 10 fb<sup>-1</sup>@13 TeV
  - Longer term : observation of VH,  $t\bar{t}H$  with  $H \rightarrow$  fermions
  - Improvement expected from b-tagging performance





## SM Higgs couplings to fermions $H \rightarrow \tau \tau, b\overline{b}$



- Improvement in H  $\rightarrow \tau \tau$  and bb channels :
  - Objet identification and detector upgrade
  - Increased selection efficiency from VBF topology and boosted Higgs
- Expect to be at least as good as Run 1 with 10 fb<sup>-1</sup> @13TeV, probably better



### **Summary & Conclusions**

#### Very good restart of the ATLAS detector

- First physics results with ~80 pb<sup>-1</sup> show the readiness of the detector
- First tracking performance plots show that the new IBL pixel layer is operating properly
- More Run 2 results in Andreas Hoecker's talk @ EPS
  https://indico.cern.ch/event/356420/session/18/contribution/6

#### Higgs prospects in early Run 2 data

- Run 1 precision should be reached with ~10 fb<sup>-1</sup> of Run 2 data @13 TeV
- BSM Higgs could be observed with a bit less (5 to 10 pb<sup>-1</sup>)
- Combination between Run 1 and Run 2 will bring significant improvement
- Nest step : improved precision measurements with the full Run 2 dataset (100 pb<sup>-1</sup>). See CMS talk.