

### ATLAS in Run2 and in the future



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#### Scrubbing for 25 ns operation

July				Aug				Sep							
Wk	27	28	29	30	31		32	33	34	35		36	37	38	39
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## Inner Detector



- Pixel/IBL operational since Week1
- IBL significantly improves the performance of the Pixel
- **IBL** = the 4<sup>th</sup> and innermost Pixel layer installed in LS1
- operational stability thanks to firmware upgrades and mainly before 25 ns runs (3 order of magnitude less errors)





SCT and TRT are operating smoothly and are preparing for high  $\mu$ runs



IBL Hits



# Calorimetry

• very smooth operations for 50 and 25ns

### • LAr:

- noise burst flagging running @ HLT level (very energetic with high Q factor over a few μs, looked up in a 100ms sliding window)
- LAr Phase-I trigger upgrade demonstrator
   boards (1.767 < φ < 2.160, |η| < 1.4, super</li>
   cells record data) installed

### • Tile:

- no LVPS trips (unlike in Run1), 2 dead modules
- Using all calibration systems to preserve the scale
- new MBTS counters were inter-calibrated based on the minimum bias current measurements from Tile





### Muons

- alignment performed with toroid magnet off
  - 30M muon tracks collected (target resolution of 10% @ 1 TeV)
  - initial alignment from July available
- overall performance of the muon systems is very good, operational teams are focusing on troubleshooting of small issues
- TGC deployed the inner coincidence (reduction of muon trigger rates in the ECs.)
  - additional Tile-muon coincidence under commissioning









## Object performance



- Prepared so-called 'pre-recommendations' for physics object calibrations based on MC and Run-1 data. These pre-recommendations, verified with early 13 TeV data, were used in initial physics analyses presented at EPS-HEP in July.
- Since then, data driven recommendations were determined for electron and muon identification efficiencies and calibrations, as well as jet calibrations (insitu corrections). The calibrations of the other physics objects are ongoing

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### Electrons and Photons

- Data/MC disagreement in Electron ID is due to (known) GEANT mismodelling of shower shapes
- quite flat as a function of in-time pile up
- scale factors from data applied to MC



## Muon reconstruction



based on 50 ns data (85 pb<sup>-1</sup>)

- ATL-PHYS-PUB-2015-037
- improved acceptance (1.0 <  $|\eta|$  < 1.4) and reconstruction algorithm





# Jets (I)



- jet cleaning selection of good jets based on calorimeter criteria (beam background, noise, cosmics)
  - criteria for analyses defined
- JES and JER preliminary recommendations (based on simulations) delivered for early analyses, AntiKt4TopoEM





#### ATL-PHYS-PUB-2015-036



# Jets (II)



- preliminarily calibrated jets
- MC normalised to data
- good shape agreement -> validated inputs to more sophisticated methods (GSC, substructure...)





# Flavour Tagging



- Several enhancements between Run-1 and 2 will impact flavour tagging
  - Improved tracking (including IBL) and flavour tagging algorithms
- Significant improvement predicted in both light-flavour (factor ~4!) and c-jet rejection (~1.6)









#### ATL-PHYS-PUB-2015-023



#### performance plot from mono-iet search



- new techniques developed during LS1, use tracking information
  - TST (track soft term), Track MET
  - reduces pile up sensitivity
- systematics derived from MC, will be updated soon
- validated against data in <u>ATL-PHYS-PUB-2015-027</u>

### Physics – Measurements and Searches

First Stable Beams at 13 TeV



THE DEPOSIT







Run: 266904 Event: 25855182 2015-06-03 13:41:48 CEST

> Run: 267639 Event: 9576943 2015-06-14 08:51:30 CEST

> > J/Ψ candidate









Event: 876578955 2015-08-22 07:43:18 CEST







ATLAS-CONF-2015-038

• MBTS triggers (counting experiment, highly efficient) runs taken in June

• fiducial volume: 2.08< $|\eta|$ <3.86 <-> Mx > 13 GeV -> extrapolation

 $\sigma_{\text{inel}} = \sigma_{\text{SingleDiff}} + \sigma_{\text{DoubleDiss}} + \sigma_{\text{CentralDiff}} + \sigma_{\text{NonDiff}}$ 



constraints on diffractive dissociative component through single sided event vs inclusive selection (25–30% depending on model)

 $\sigma_{fid} = 65.2$ ±0.8 (exp.)±5.9 (lum.) mb

 $\sigma_{tot} = 73.1 \pm 0.9(exp.)$ ±6.6(lum.)±3.8(extr.) mb



 $\langle p_{\mathrm{T}} 
angle$  [ GeV

1.8

1.6

1.4

1.2

0.8

0.6

0.4

0.2

1.2

1.1⊧

0.9

0.8

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MC / Data

### Charged Particle spectra and UE $n_{ch} \ge 1, \ p_{_{T}} > 500 \text{ MeV}, \ \mid \eta \mid < 2.5$ **ATLAS** Preliminary $\sqrt{s} = 13 \text{ TeV}$ 🗕 Data PYTHIA 8 A2 PYTHIA 8 Monash HERWIG++ UE-EE5 ---- EPOS LHC ----- QGSJET II-04

80

60

40

100

120

140

n<sub>ch</sub>



- $\bullet$  measurement of unfolded spectra of charge particle multiplicity, also differentially in  $\eta$  and pT
  - comparison to model prediction
- allowed to validate the tune (Pythia A2) used for the pileup modelling in the 13 TeV MC that was derived from Run-1 data
- `leading track underlying event' analysis (<u>ATL-PHYS-PUB-2015-019</u>) has allowed to validate the underlying event tune (Pythia A14) used in the simulation of hard scattering processes, also derived from Run-1 data





# Inclusive jet measurement



#### ATLAS-CONF-2015-034

- lacksim lowest p\_ unprescaled trigger (346 < p\_ < 838 GeV) in central region |y| < 0.5
- cross section compared to fixed order NLO (NLOJET++) with several PDFs CT10, NNPDF3, MMHT





## W/Z Boson Cross Sections

ATLAS-CONF-2015-039



- 50 ns run, L =  $85 \text{pb}^{-1}$
- single lepton triggers with  $p_T > 24$  (20) GeV for e ( $\mu$ ) -> final selection  $p_T^{lep} > 25$ GeV
- W: MET > 25 GeV,  $m_T$  > 50 GeV ~1 M evts
- Z: 66 < mll < 116 GeV ~80K evts







# W/Z Boson Cross Sections





top cross section



200





top cross section



#### ATLAS-CONF-2015-049



agreement within uncertainties

σ<sub>tt</sub> = 829 ± 50 (stat) ± 56 (syst) ± 83 (lumi) pb.

R<sub>tt/z</sub> = 0.445 ± 0.027 (stat) ± 0.028 (syst) = 0.445 ± 0.039



# Dijet searches



ATLAS-CONF-2015-042

lacksim High-p $_{ au}$  searches do not use July data due to a s = 13 TeV, 80 pb<sup>-1</sup> ATLAS Preliminary trigger problem Data SM QBH, M<sub>th</sub>= 6.5 TeV Theoretical uncert. • central production, highest  $p_{\tau}$  ( > 360 GeV) Total uncertainties |y<sup>\*</sup>| < 1.7, |y<sub>B</sub>| < 1.1 di-jet invariant mass spectrum ( > 1.1 TeV) (N dN/d m<sub>ii</sub> > 3.4 TeV 0.06 Quantum Black Holes models 0.04 0.02 Events **ATLAS** Preliminary 3.1 < m<sub>ii</sub> < 3.4 TeV 0.1 √s=13 TeV, 80 pb<sup>-1</sup> —— Data 10 0.05 Background fit BumpHunter interval BlackMax, m = 4.0 TeV 10<sup>2</sup> BlackMax, m = 5.0 TeV 2.8 < m<sub>ii</sub> < 3.1 TeV 0.1 0.05 **10** ⊨ p-value = 0.79 2.5 < m<sub>ii</sub> < 2.8 TeV Fit Range: 1.1 - 5.3 TeV 0.1 ly\*l < 0.6 14111111 0.05 Signif.  $^{20} \gamma ^{30}$ 2 З 6 5 78 10 2 3 5 6 4 difference in rapidities m<sub>ii</sub> [TeV] no significant deviations observed, limit extended to 6.5 TeV (+1TeV wrt Run1)



## Multijet searches



#### ATLAS-CONF-2015-043

- at least 3 jets,  $H_T > 1$  TeV
- Control (fitted) -> Validation -> Signal region
- models with additional space-time dimensions



Lepton+jet searches - <u>ATLAS-</u> <u>CONF-2015-046</u> - show also consistency with SM



Limits are significantly extended wrt Run1, yet no evidence for deviations from SM was observed

# Brief selection of latest Run1 Highlights



- ATLAS-CONF-2015-047
- 8 TeV analysis (20.3fb), single lepton triggers
- single top s-channel production, leptonic W decays, Matrix element method



σ=4.8<sup>+2.5</sup>-2.2 pb

arXiv:1508.06608

- SUSY Run1 summary on phenomenological MSSM (19 parameteres)
- 22 ATLAS searches considered (Inclusive,
  - generation of squarks, EW produced,...) 3

- Run1 ATLAS+CMS coupling combinations
- **Η-> ZZ,WW,γγ,ττ,bb &** μμ





### Run1 Searches for new heavy bosons

### ATLAS-CONF-2015-045

- Ivl'l', Ilqq, Ivqq and JJ final states
  - J ... CA R=1.2 jets -> groomed (mass drop)
- Extended Gauge Model (EGM, W')
- bulk-Randall-Sundrum (RS, G\*)



EGW min. mass limit = 1.81 TeV (exp = obs)





# Into the future...

- ATLAS Phase-II Upgrade Scoping Document
- High Luminosity LHC (HL-LHC) 2026++
- 14 TeV, instantaneous luminosity up to  $7.5 \times 10^{34}$  cm<sup>-2</sup> s<sup>-1</sup>  $\rightarrow \langle \mu \rangle \sim 200!!$  (~20 in Run1, up to 60 in Run2+3)  $\rightarrow$  $L_{HL-LHC} = 3000 \text{ fb}^{-1}$





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# Scoping Scenarios



#### • 275MCHF - "Reference"

• ITk up to  $|\eta|$  = 4.0, sFCAL, HGTD...

#### 235MCHF - "Middle"

• ITk up to  $|\eta|$  = 3.2, central region degradation

#### • 200MCHF - "Low"

 $\bullet$  ITk up to  $|\eta|$  = 2.7, significant central region degradation



Trigger and Data Acquisition	Reference	Scoping Scenarios Middle	Low
	(275 MCHF)	(235 MCHF)	(200 MCHF)
Level-0 Trigger System			
Central Trigger	1	1	1
Calorimeter Trigger (e/y)	$ \eta  < 4.0$	$ \eta  < 3.2$	$ \eta  < 2.5$
Muon Barrel Trigger	MDT everywhere RPC-BI Tile-µ	MDT (BM & BO only) Partial η coverage RPC-BI Tile-μ	MDT (BM & BO only) No RPC-BI Tile-µ
Muon End-cap Trigger	MDT everywhere	MDT (EE&EM only)	MDT (EE&EM only)
Level-1 Trigger System			
Output Rate [kHz]	400	200	200
Central Trigger	1	1	1
Global Trigger	1	1	1
Level-1 Track Trigger (Rol based tracking)	$p_{\mathrm{T}} > 4 \text{ GeV}$ $ \eta  \le 4.0$	$p_{\rm T} > 4 \text{ GeV}$ $ \eta  \le 3.2$	$p_{\rm T} > 8 ~{\rm GeV}$ $ \eta  \le 2.7$
High-Level Trigger			
FTK++ (Full tracking)	$p_{\rm T} > 1  { m GeV}$ 100 kHz	$p_{\rm T} > 1 \text{ GeV}$ 50 kHz	$p_{\rm T} > 2  { m GeV}$ 50 kHz
Event Filter	10 kHz output	5 kHz	5 kHz
DAQ			
Detector Readout	✓ [400 kHz L1 rate]	✓ [200 kHz L1 rate]	✓ [200 kHz L1 rate]
DataFlow	√ [400 kHz L1 rate]	[200 kHz L1 rate]	[200 kHz L1 rate]

### LO up to 40 MHz, L1 up to 400 kHz, HLT up to 10 kHz (100 kHz L1 and ~1kHz HLT in Run2)



# Calorimetry upgrade



- deterioration of signal in the forward region due to ion buildup in the LAr (269  $\mu$ m)
- possibility of the LAr boiling from increased beam heating
- FCAL channels: 1008 (FCAL1) 500 (FCAL2) 254 (FCAL3)
  - sFCAL upgrade: 4x more cells in FCAL1 and 100  $\mu$ m gaps <sup>2</sup>
  - necessity to open the cryostat to remove the summing boards (risky)
- possibility of MiniFCAL to absorb the flux (~30  $X_0$ )







not mentioning the read-out upgrade which is necessary no matter what

 $|\tan(\theta)| \times \cos(\phi)$ 

 $|\tan(\theta)| \times \cos(\phi)$ 



pile-up

- Run1:  $\langle \mu \rangle = 20$  for  $p_{Tj} > 30$  GeV ...  $\langle n_j \rangle \sim 0.04$
- HL-LHC:  $\langle \mu \rangle = 200$  for  $p_T > 30$  GeV ...  $\langle n_j \rangle \sim 7.4$ 
  - pile-up mitigation most important!
  - offline and online the more the better (tracking volume, timing)





### Upgrade Physics Analyses

- Upgrade physics community is small and deals with future scenarios --> it is not possible to request FullSim samples for all analyses (1 ttbar events FullSim = 10.6 mins @  $\mu$ =200!)
  - -> concept of work based on truth-level objects and applying Smearing Functions (parametrisation, mostly  $p_T/E$ , of future detector performance)
  - this approach does not take into account additional PU jet activity -> additional overlay of truth-level event with a representative PU jet distribution (PU Library)
- future JVT (aka Tracking Confirmation) is taken into account through HS/PU rates obtained from ROC curves





### Higgs Analyses

- Le vector boson fusion (VBF) with characteristic two forward jet topology (high energy and large rapidity separation) is an ideal benchmark process for SD
  - vector boson fusion is also very important process 2nd most probable and theoretically very well understood (theoretical uncertainties generally by a factor of 10 smaller than for gluon-gluon fusion) – due to EWK nature of the process and missing QCD calculation
  - so far low statistics, but at HL-LHC it will become a high precision tool for measuring Higgs couplings and search for new physics, in SD H->WW->lvlv and H->ZZ->llll





	Pile-u	Pile-up impurity				
Scoping scenario	Bin 1	Bin 2	Bin 3			
VBF	Sample					
Reference	2.0	4.6	13.1			
Middle	3.0	6.4	23.6			
Low	5.2	12.0	38.7			
99F	Sample					
Reference	23.2	37.9	52.1			
Middle	24.0	43.4	65.0			
Low	41.2	59.4	76.2			



Scoping Scenario	without theo. unc.						
	$\Delta \mu / \mu$	$\Delta I$ (fb <sup>-1</sup> )	$Z_0$ -value ( $\sigma$ )				
Reference scenario	0.134	-	11.41				
Middle scenario	0.137	125	10.86				
Low scenario	0.142	425	9.84				

H->WW->lvlv VBF, ~100% degradation from Ref->Low





<sup>34</sup> Low scenario dramatically reduces potencial for SUSY searches



- Higgs decaying to invisible particles is therefore an ideal tool for probing both (yet B.r. for H->ZZ->4v is ~0.1% and H->vv is ~m, ), signature: two VBF jets and large missing transverse energy
- 8 TeV Run1 analyses: MET > 150 GeV trigger (@L2), p<sub>T1</sub> > 75(120) GeV, p<sub>T2</sub> > 50(35) GeV, m<sub>jj</sub> > 0.5
   (1) TeV



upper limit on B.R.(H->inv.) = 0.28



Q: Can we effectively trigger on VBF+MET?



# High Granularity Timing Detector



### • Q: what if there is a high granularity detector for $|\eta| > 2.4$ ?

excellent timing resolution could distinguish place of origin through ToF





concept by Ariel Schwarzman (SLAC)



# pile up mitigation







H->WW->lvlv VBF @ 8 TeV

Run 214680, Event 271333760 17 Nov 2012 07:42:05 CET





### electron/ $\gamma$ reconstruction



- excellent performance of the EM calorimeter due to high granularity strip layer
- missing in ElectroMagnetic EndCap
- processes such as ssWW could benefit from forward electrons





current forward resolution poor (wrt central region) between 20 and 40% -> adding fine "strip-like" granularity to region 2.4 <  $|\eta| < 4.0$ 

# ATLAS

# HGTD technology

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- challenging spatial requirements:  $\Delta z = 70$ mm, R: 90 ( $\eta$ =4.3)-600mm ( $\eta$ =2.4)
  - R=50mm ( $\eta$ =5.0) possible
- surface ~9m , cells 5x5mm
- 4 layers with possible Pb/W-absorbers
- technologies:
  - sensor: silicon-based option synergy with ID, CMSand CALICE- like (re-)design
  - sensor: Low-Gain Avalanche Detectors
    - so far best precision, but not enough rad. hard so far
  - sensor+readout: High Voltage CMOS (not sure if fast enough)





technology and concept of the detector to be decided in ~a year







• ATLAS has restarted successfully the Run2

- Detector is in good shape and running quite smoothly
- recorded now ~2.5 fb<sup>-1</sup> with a data-taking efficiency of 91%
- Detailed performance studies ongoing, demonstrating already a good understanding of the 2015 data
- Exploring the landscape of physics at 13 TeV with measurements of inclusive, jet, W, Z and top production processes, sensitivity to beyond-the-SM physics starts to extend beyond Run-1
- ATLAS Phase-II Scoping Document delivered with a convincing preference for the Reference scenario
- High Granularity Timing Detector will improve the forward pile up rejection and electron-photon identification as well as triggering capabilities for physics beyond standard model

Full list of 13 TeV results can be found here











## Datasets



period	date	bunch spacing	<b>µ</b> Мах	L <sub>peak</sub> [10 <sup>32</sup> cm <sup>-2</sup> s <sup>-1</sup> ]	L <sub>recorded</sub> [pb <sup>-1</sup> ]	L <sub>total</sub> [pb <sup>-1</sup> ]	
Α	3.614.6.	50ns	27.6	1.4	7.9	7.9	
В	9.613.6.	2000ns	0.3	4.5x10 <sup>-3</sup>	0.0145	7.9	
С	4.720.7.	50ns	27.4	16.0	101	109	EPS datase
D	12.823.8.	25ns	29.4	10.5	105	214	LHCP datas



# Inner Detector (II)

 SCT - Noise, gain and operating voltage comparable to Run1 conditions, set Excellent data taking efficiency

- SCT vetoing signals from "previous" BX causes inefficiencies during 25 ns running (negligible effect on the data)
- TRT operates smoothly and provides high DQ, preparing HW and SW tools to run with high  $\mu$  and 25ns
  - HV Protection system against overshoot at the beam dump implemented.
    - No discharges in the detector since
  - Significant ROD repair effort and ROD FW upgrade made. (10% spares, able to operate @ 100kHz)
    - due to leaks in exit pipes (50-701/day, no new ones in Run2), Ar is used in parts of the detector instead of Xe, Kr is under testing



### Muons

- alignment performed in July and August runs with toroid magnet off
  - resolution of 10% @ 1 TeV needs resolution 20-80µm
     (10 scale!), ~30M muon tracks ~collected
- overall performance of the muon systems is very good, operational teams are focusing on troubleshooting of small issues
- CSC two planes OFF, 5 reduced HV
- MDT noise burst study ongoing (origin in one chamber)
- RPC new chambers installed in LS1 and equipped with electronics in LS1; still need some development and commissioning work
- TGC are ready to deploy the inner coincidence (reduction of muon trigger rates in the ECs.); timing verified (scan), Tile-muon coincidence under commissioning









 ALFA – will be used in the special ß\*=90m run; elastic and diffractive physics



- LUCID newly installed, very well performing is and providing online and offline luminosity for ATLAS
- ZDC test beam (SPS) showed need for refurbishment of EM modules; will take part in the next LHC Heavy Ion run (installation during TS3) - centrality measurement
- AFP Roman Pot installation approved by LMC on August 26th. Aiming to install infrastructures and possibly two stations in the Year End Technical Stop 2015/2016, soft QCD, hard diffraction



# Computing



### • Grid utilisation at full

- MC simulation:
  - 2.8B simulated events produced
  - 5B events reconstructed for 50 ns &
     25 ns conditions
- No issue with data transfer and data processing
- parts of 2015 data have been reprocessed twice
- Major software update for summer 2016 only.
- New analysis model: group data format DxAOD made using a train model
  - Production of 83 DxAOD species on the grid via 17 trains
  - Within 24h after data reconstruction at Tier-0
  - Successful and popular







# Trigger Performance



- L1 trigger menu ~500 items, HLT ~2000 items
- pedestal correction minimising pile up effects and linearising trigger rate for the L1Calo MET > 35 GeV trigger shows dramatic improvement for the rate







## Muon reconstruction



ATL-PHYS-PUB-2015-037

- based on 50 ns data (85 pb<sup>-1</sup>)
- improved acceptance (1.0 <  $|\eta|$  < 1.4) and reco algorithm



### Efficiencies of the combined trackbased and calorimeter-based isolation for the Gradient working point



#### excellent agreement, but large $\delta_{\text{stat}}$



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taus

### ATL-PHYS-PUB-2015-025

- identification based on BDT
- data samples: low μ runs
   (MBTS trigger) and high μ (e,μ and τ triggers)





good modelling by MC and understanding of the detector





# Lepton+jet searches



ATLAS-CONF-2015-046

- single lepton trigger  $p_T > 50$  GeV
- $\bullet$  SRs: p\_T > 100 GeV + additional l/j with p\_T > 100 GeV,  $\sum p_T$  > 2 TeV/3TeV
- bkg: W+j, Z+j, ttbar -> CRs





ROC curve w/o CK



