Prospects for the ATLAS upgrade for the high luminosity LHC

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- Motivation for high luminosity running and upgrade scenario
- Phase-0
- Phase-I
- Phase-II
- Summary
Motivation for high luminosity running of LHC (higher than LHC design luminosity)
Physics motivation for upgrading LHC in one plot

With constant luminosity, the statistical error on a measurement hardly decreases after a few years of running.

Courtesy: J. Strait, Fermilab 2003
Upgrade physics studies in ATLAS

ATLAS upgrade physics studies are collected in ATL-PHYS-PUB-2012-004 and were submitted to the European Strategy for Particle physics, Cracow Poland, September 2012.

The studies cover:

- Measurements of Higgs boson properties
  - Spin/CP nature
  - Couplings
  - Higgs self-coupling
- Measurements of weak boson scattering
- Supersymmetry measurements
- Exotics
  - $Z'$

→ dedicated talk by Victor Solovyev on present BSM searches
Higgs precision measurements

Current ATLAS result

- Good sensitivity to all final states important
- Good b-tagging if any chance for measurement of Higgs self coupling
- Crucial to keep low trigger thresholds to maintain high signal efficiency

→ dedicated talk by Makoto Tomoto
BSM: SUSY searches

- More statistics extend studies to corners of SUSY parameter space
- Searches extended by ~500GeV (squarks&gluino), ~200GeV (stop)
- MET performance crucial

**Current ATLAS result**

**Expected ATLAS performance**
BSM: Weak boson scattering

- VBS scattering is be enhanced by BSM processes such as Technicolor little Higgs.
- Fully leptonic decay $ZZjj \rightarrow lllljj$: measurement of forward jets crucial
c) The discovery of the Higgs boson is the start of a major programme of work to measure this particle’s properties with the highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier. The LHC is in a unique position to pursue this programme. *Europe’s top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.*
LHC upgrade plan

RUN 1
25fb⁻¹

RUN 2
Phase-0
100fb⁻¹

RUN 3
Phase-I
300fb⁻¹

RUN 4
Phase-II
HL-LHC
3000fb⁻¹

Year ending

Integrated luminosity [fb⁻¹]

Peak luminosity
Integrated luminosity

Luminosity [cm⁻² s⁻¹]
ATLAS upgrade plans
Phase-0
Phase-0 (currently ongoing)

- Small r Be beampipe
- Insertable pixel B-layer
- Improve coverage of muon spectrometer

+ consolidation of the existing detector
- New beampipe with smaller radius free space for an additional pixel layer
- First hit 33mm from IP (now 55mm)
- Smaller pixel size (100x250µm, now 100x400µm)
- 75% planar/25% 3D sensors
Figures of merit

- Significant improvement of the MS-term in impact parameter resolution
- Almost twice better rejection of light jets, important for H-\(\rightarrow\)bb
Muon system coverage - Endcap extension chambers

- At $\eta=0$ the Muon system only partially equipped
- In gap region $1.1<\eta<1.3$ only one layer is traversed.
- Endcap extension muon drift tubes will give precise muon track sagita with 45$\mu$m resolution in gap region
ATLAS upgrade plans
Phase-I

CERN-LHCC-2011-012 ; LHCC-I-020

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Phase-I

- Replace SW -> new forward muon wheels (NSW)
- Fast Track Trigger (FTK)
- High granularity, topological L1 trigger in calorimeters

(Possibly: New detectors at +/- 210m for Atlas Forward Physics program)
New muon small wheel - NSW

- Very high L1 muon trigger rate in forward ATLAS due to too few muon trigger layers
- Redo the forward detectors to get a layer at small $r$ to add one trigger hit → improved $p_T$ measurement due to long lever arm

**Current forward L1 muon Upgrade, NSW**

CERN-LHCC-2013-006 ; ATLAS-TDR-020
Fast TracKer (FTK)

- FTK does hardware based tracking of Si-tracking layers at "Level 1.5"
- Provides tracking information for full detector in ~25 µs to L2.
- Two steps
  - Pattern recognition \((10^9\) patterns)  
  - Track fitting

CERN-LHCC-2013-007 ; ATLAS-TDR-021
FTK performance

- FTK delivers almost offline quality data
- FTK works up to $L = 3 \cdot 10^{34} \text{ Hzcm}^{-2}$
- Latency keeps up with a 100kHz L1 trigger rate and delivers data in average 25$\mu$s
L1 calorimeter trigger

- Improve granularity of L1 calorimeter readout to improve e/jet discrimination
  - Upgrade of the calorimeter front-end
  - Shower shape algorithms already at L1
- Topological L1 trigger at CTP
- Compatibility with Phase-II upgrade
**Phase-2**

- New Inner Detector (strips and pixels only, TRT removed)
- New LAr front-end and back-end electronics
- New Tiles front-end and back-end electronics
- TDAQ upgrade
- TAS and shielding upgrade
- Various infrastructure upgrades
- Common activities (installation, safety, ...)
- New FCAL (if conditions require it)?
- LAr HEC cold electronics consolidation (radiation hardness)?
- L1 track trigger
- Muon Barrel and Large Wheel system electronics upgrade?
- Forward detectors upgrade?
• ATLAS Inner Detector has reached end of lifetime by end of decade due to radiation damage
• New detector need to cope with 5x design luminosity → 200 pile-up
• Replacement of entire Inner Detector necessary
Inner detector

- 4 pixel and 5 double sided silicon layers in Barrel
- 5 pixel and 7 silicon disks
- Much better X/X0 than present detector and excellent efficiency

![Pixel ladder (drawing)](image)

![Strip ladder (prototype)](image)

![Occupancy at 200 pileup](image)
**L1 track trigger**

- New trigger architecture@Phase-II
  - L0->500kHz, latency<6µs
  - L1->200kHz, latency<20µs

- Two options investigated
  - Data pull: ROI seeded L1track
  - Data push: self seeded L1track

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**Rejection of fakes in EM**

**Sharper turn-on for muons**
Summary
The luminosity of LHC need to continuously increase in order to improve measurements

The LHC will through the upgrade continue to be the main infrastructure for HEP experiments for the next decades

ATLAS will be upgraded in two steps to cope with the luminosity increase without loosing quality

Several upgrades are needed in the trigger system and in the associated detector systems

The tracker must be replaced by the end of the decade regardless if the expected Phase-II luminosity will be reached

The upgrade will keep the performance of the ATLAS detector even if the environment is much more difficult because of pile-up

We have interesting physics ahead!
Back-up
Trigger rates
Two technologies are developed in parallel and both have reached TDR: sTGC (Thin Gap Chambers) and MM (Micro Megas).

Rejection of fake muons significantly improves.
A topological trigger processor will be added to the Central Trigger Processor
FTK added to trigger chain
ATLAS Forward Proton (AFP) detectors

- Project not approved but considered
- New detectors at +/-210m for diffractive physics
- Radiation hard 3D silicon edgeless detectors for large acceptance close to beam and
- 10ps timing Cherenkov detectors for association with high pT primary
Thresholds acceptance and rates

ATLAS Simulation, 14 TeV

Acceptance fraction

true muon $p_T$ [GeV/c]

- WH (black)
- SUSY-direct-gaugino (blue)
- $t\bar{t}$ (red)

Rate [Hz]

- EM Trigger (blue)
- Isolated EM Trigger (EM_VH) (orange)

Threshold [GeV]

$L_{\text{inst}} = 4 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$

400 kHz

20 kHz

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