Expected Performance of the ATLAS Inner Tracker Upgrade

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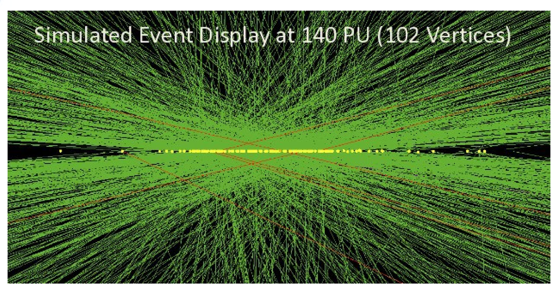
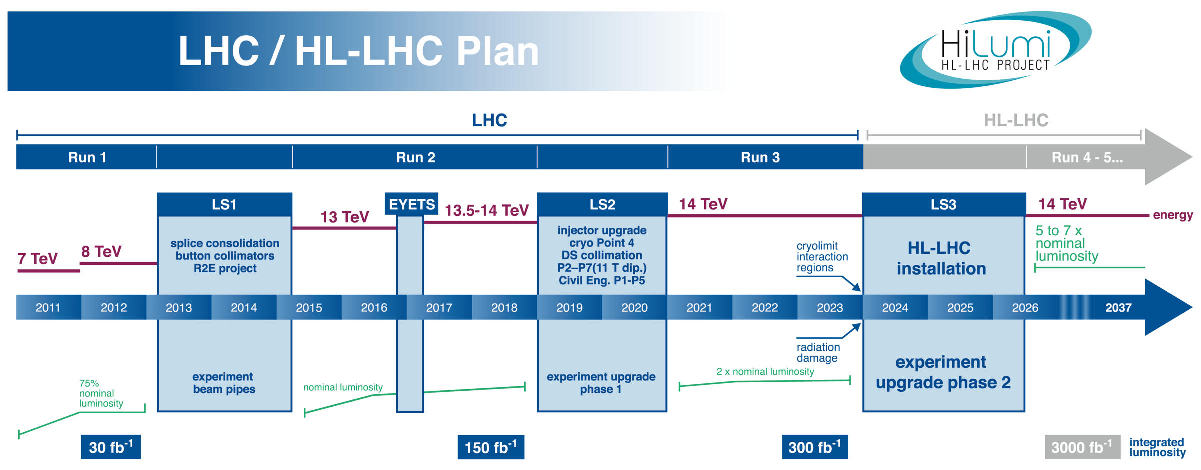


The High-Luminosity Large Hadron Collider is now foreseen to deliver an average of up to 200 collisions every 25 nanoseconds

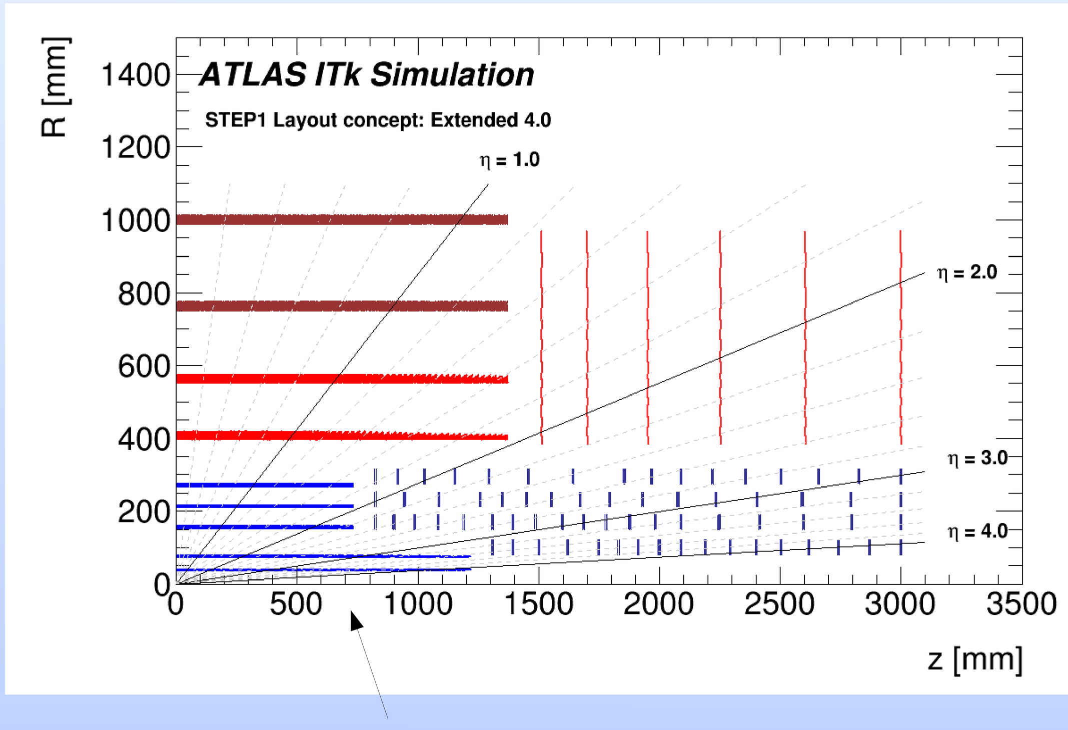
Introduction

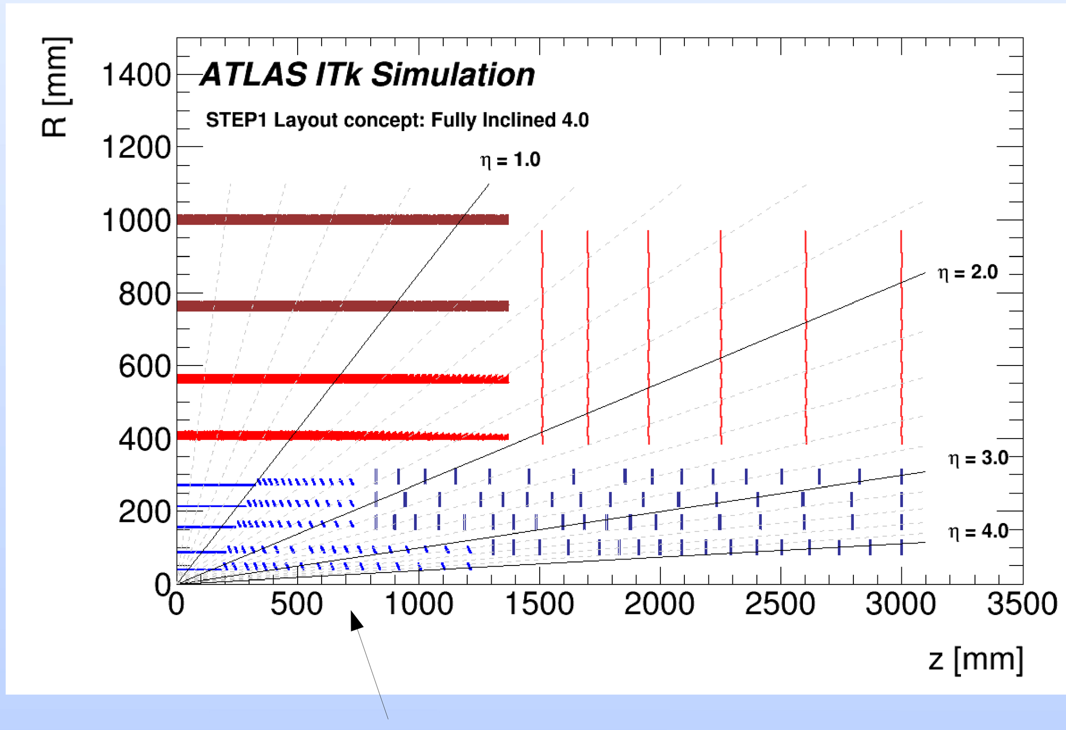
The design of the **ATLAS Inner Tracker (ITk)** upgrade is underway. This tracking detector, consisting of silicon **pixel and strip modules**, will replace the current ATLAS Inner Detector to reconstruct tracks from charged particles produced at the very high collision rate expected from the **High-Luminosity Large Hadron Collider (HL-LHC)**.

The latest Inner Tracker designs considered, and the most recent expected performance results from simulation are presented.



Inner Tracker Layout: Latest Design Options





Extended pixel barrel layers

- Well-established design with pixel modules placed in a cylinder around the beam pipe, with innermost layer covering **|η| < 4**
- Measurement of **long pixel clusters** in the forward barrel region brings new capabilities:
  - **Pattern recognition** for track reconstruction and pileup jet rejection at very high pileup
  - **Particle identification** using cluster shapes and dE/dX
  - **Luminosity** measurement

Inclined pixel barrel layers

- Innovative design with pixel modules at an angle with respect to the beam pipe in the forward barrel region; also covers **|η| < 4**
- **Higher number of space-points** measured, with tracks from the luminous region crossing the sensors at ~ normal incidence
- **Reduced number of modules** required, especially in outer layers
- Slight **reduction in material** in the forward region

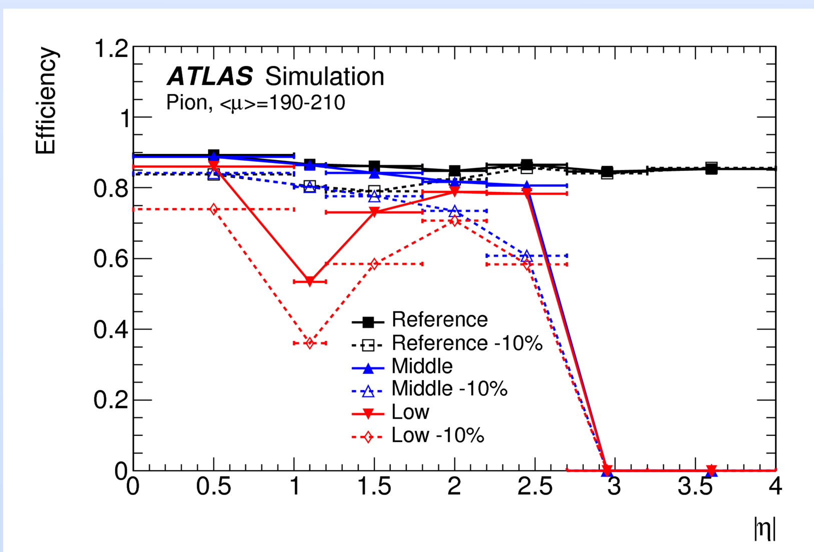
A decision between these two options is expected in early 2017

ATLAS Phase-II Upgrade Scoping Document Results

Increasing the **tracking coverage up to |η| = 4** significantly improves vertex identification, pileup jet rejection, electron and photon identification, muon acceptance, missing transverse momentum resolution, b-tagging performance.

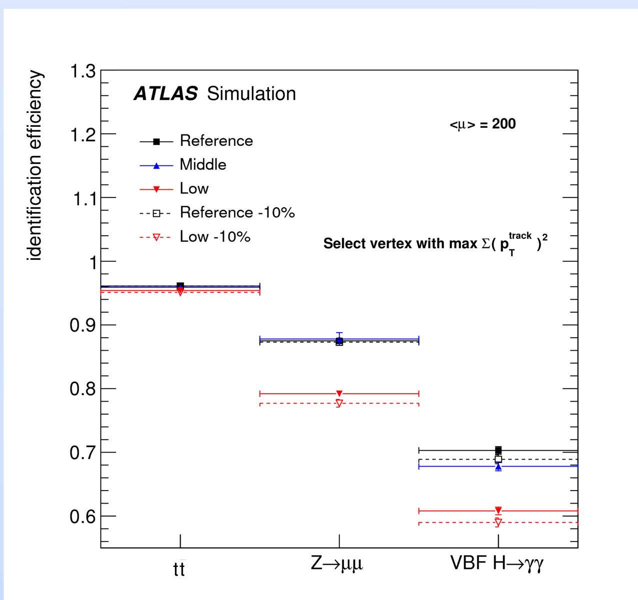
These studies are based on three ATLAS upgrade scenarios (Reference, Middle and Low), corresponding to older Inner Tracker layout designs presented below

Tracking efficiency



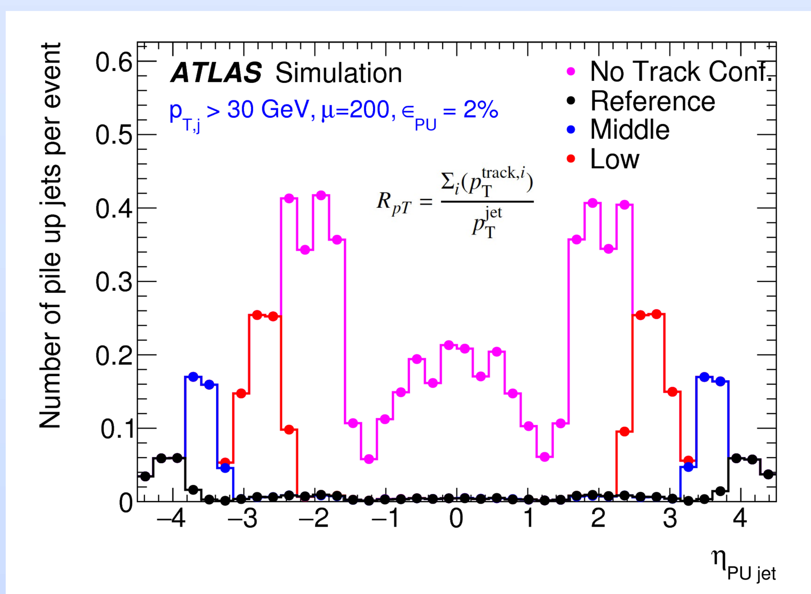
Efficiency for reconstructing pion tracks in the 3 scenarios considered. The Reference scenario achieves the highest efficiency with the lowest mis-reconstructed track fraction for the whole pseudorapidity range, and is robust against disabling 10% of modules.

Vertex identification efficiency



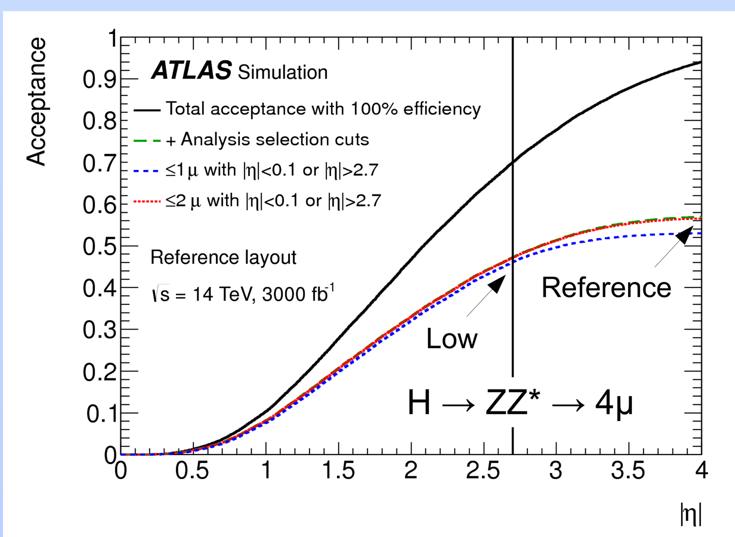
The primary vertex identification efficiency improves when forward tracks are measured, and is robust against disabling 10% of modules

Pileup jet rejection



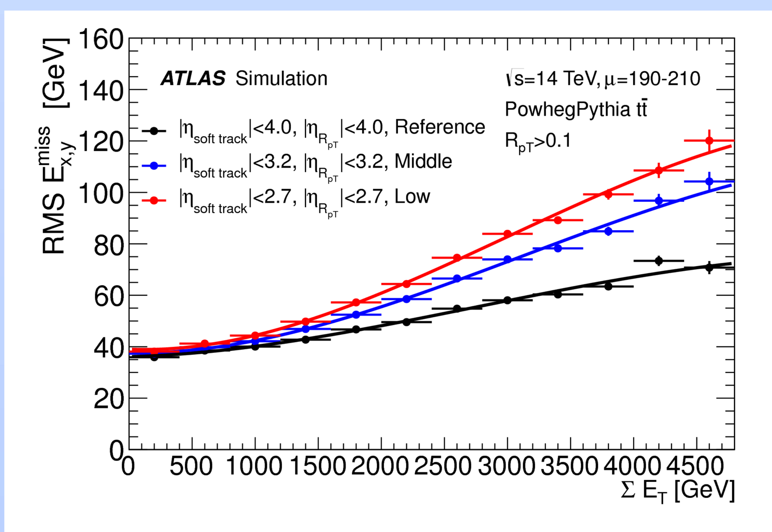
Pileup jets are rejected based on the momentum of tracks within a jet which are associated with the primary vertex: measuring tracks at high η extends the range of this technique

Muon acceptance



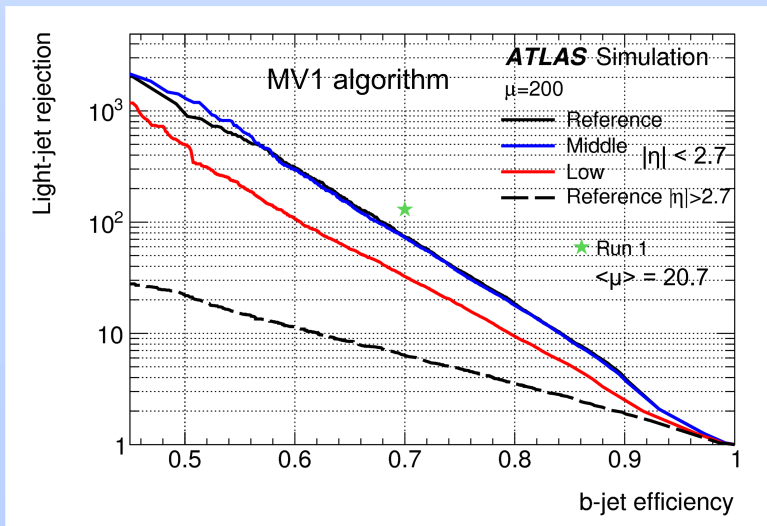
Forward tracking along with a forward muon tagger extends the muon acceptance up to |η| < 4

Missing transverse momentum resolution



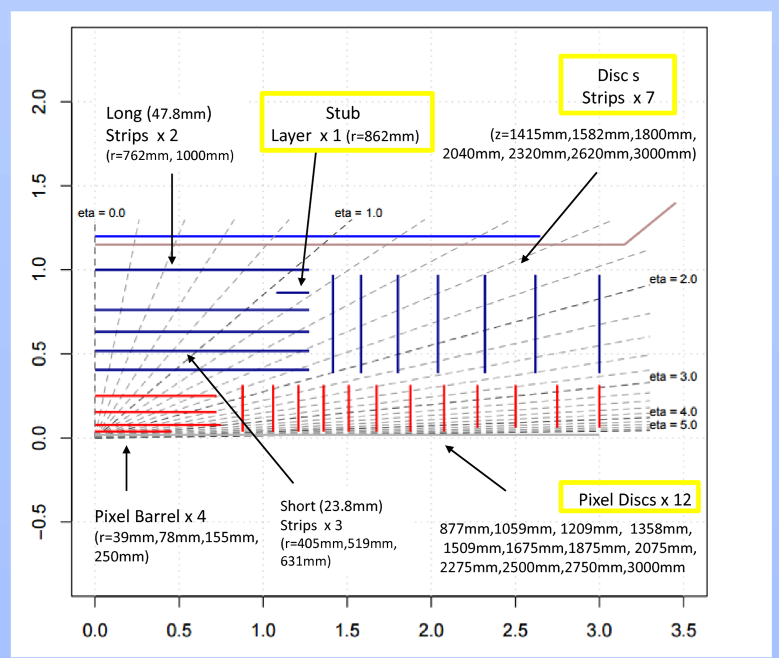
Pileup jet rejection allows to improve the missing transverse momentum resolution. The forward calorimeter is upgraded in the Reference scenario. Best improvements are observed for the most energetic events

b-tagging performance

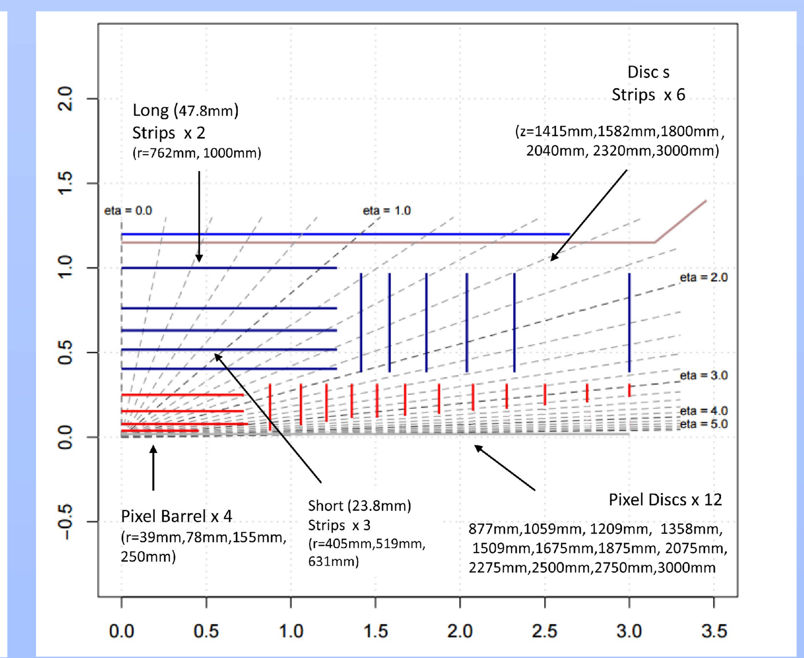


Forward b-tagging becomes a possibility with a forward tracker. These studies are based on Run-1 algorithms which will certainly be improved and optimized for high pileup

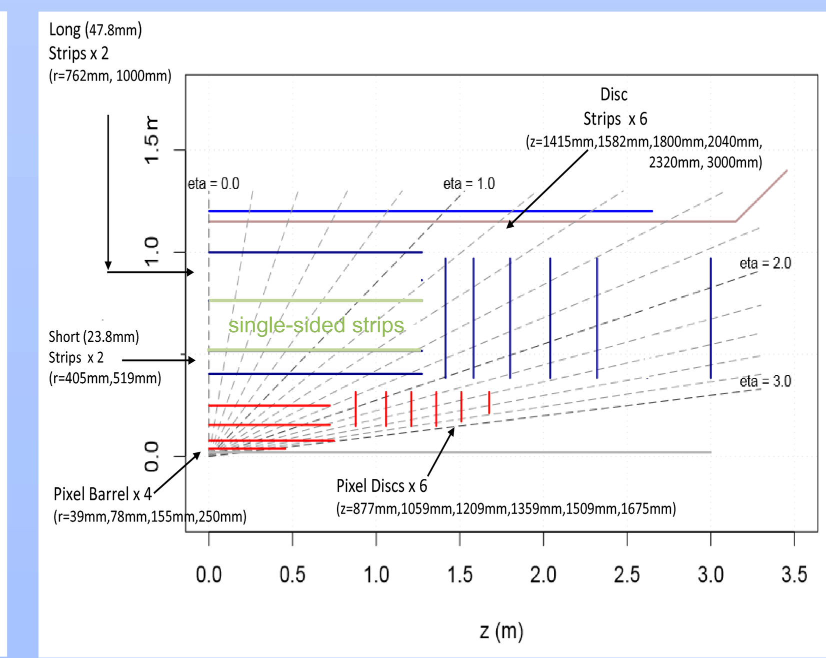
Reference scenario



Middle scenario



Low scenario



Three scenarios were evaluated at the time of the Scoping Document: the Reference scenario for |η| < 4, the Middle scenario for |η| < 3.2 and the Low scenario for |η| < 2.7

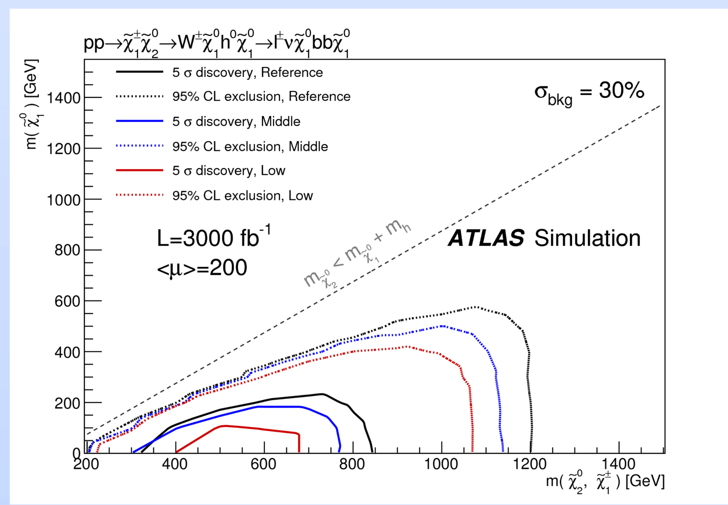
Physics Program

HL-LHC physics program with 3000 fb^{-1} at $\sqrt{s}$ = 14 TeV:

Discovery reach for searches **beyond the Standard Model**, especially for processes with small production cross-sections, for example due to small couplings

Measurements with **new particles** potentially discovered by the LHC !

Ability to distinguish between different models of SUSY, or extended gauge and scalar sectors



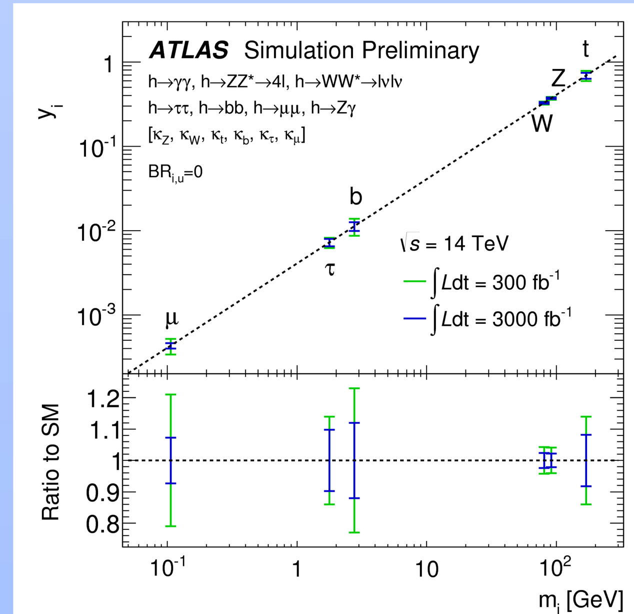
Sensitivity of the search for SUSY with W → lν and H → bb in the final state

Standard Model differential cross-section measurements: Higgs boson, same-sign WW ...

Precision measurements of **Higgs boson couplings**, including rare decays: H → Zγ, H → μμ, perhaps H → cc

Measurements in all major production modes: gluon fusion, vector boson fusion, VH, ttH, tH, bbH

Di-Higgs production: searches for physics beyond the Standard Model, sensitivity to the triple-Higgs self-coupling



Sensitivity to the Higgs coupling scale factors $y_i = \sqrt{\kappa_i}\, m_i / v$ as a function of m_i

Conclusions

Two design concepts for the **ATLAS Inner Tracker upgrade** towards the HL-LHC are considered, with different module orientation choices in the forward pixel barrel.

Both latest options offer hermetic **tracking coverage up to |η| = 4**, motivated by the improved vertex identification, pileup jet rejection, as well as the identification, acceptance and resolution capabilities for physics objects. This choice maximizes the expected performance of the upgraded ATLAS detector at the HL-LHC.

38th International Conference on High-Energy Physics, Chicago, August 3-10 2016

References: ATLAS Collaboration (2016) Step1 ITk Layouts. ITK-2016-001
ATLAS Collaboration (2015) ATLAS Phase-II Upgrade Scoping Document. CERN-LHCC-2015-020
ATLAS Collaboration (2014) Projections for measurements of Higgs boson signal strengths and coupling parameters with the ATLAS detector at the HL-LHC. ATL-PHYS-PUB-2014-016