ATLAS UPGRADES FOR THE NEXT DECADES

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ON BEHALF OF THE ATLAS COLLABORATION

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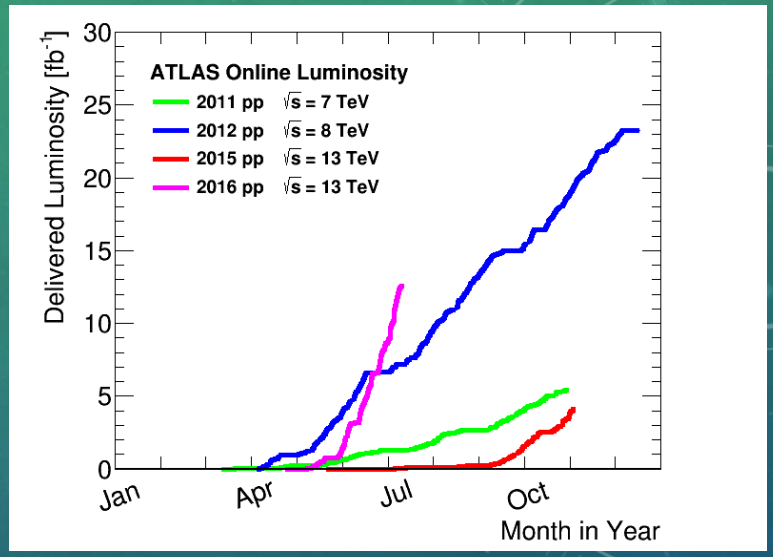
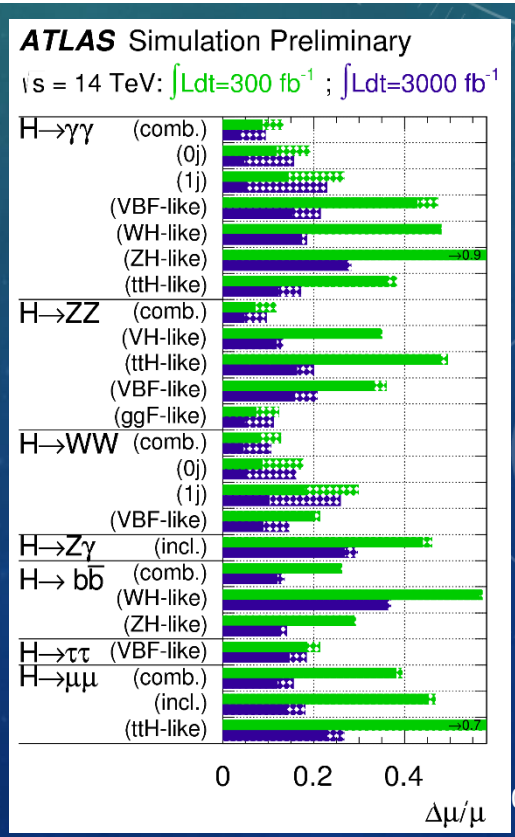
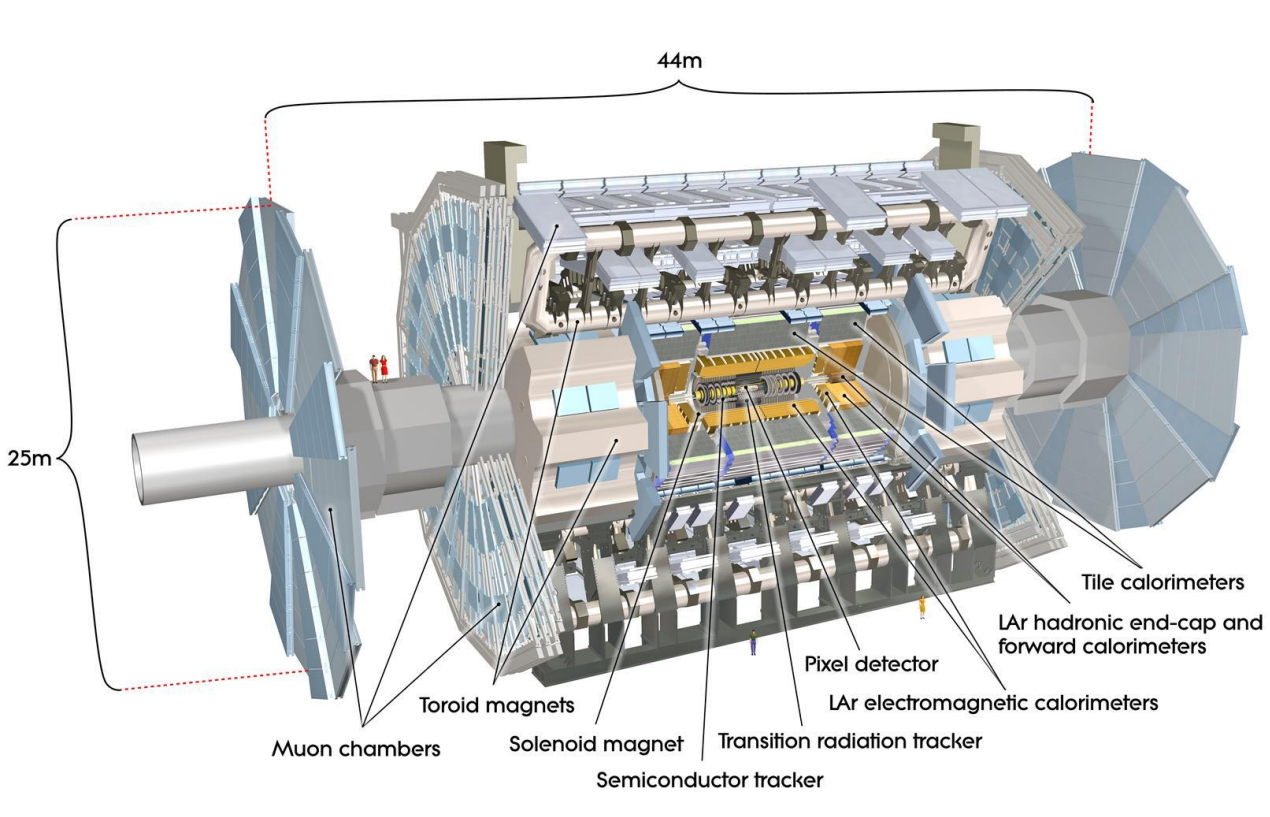
INTRODUCTION AND OUTLINE

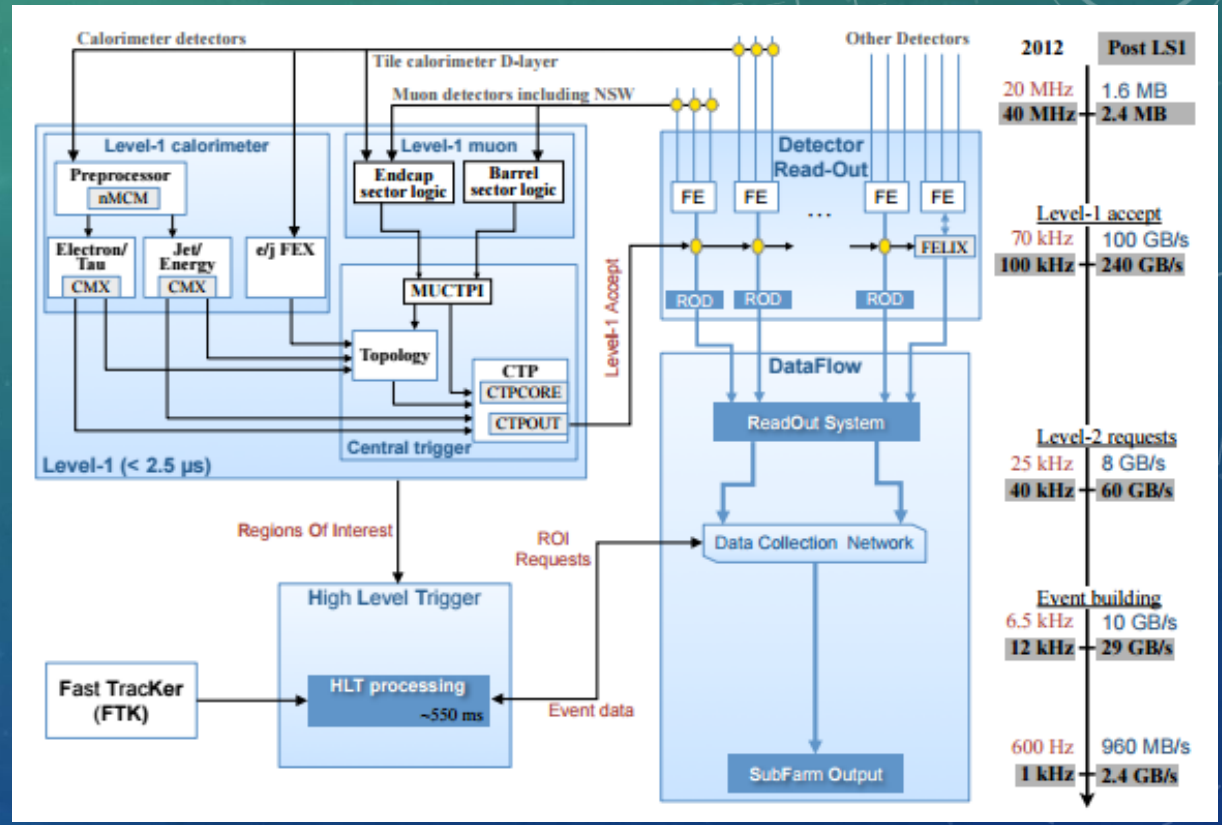
- ATLAS is a multipurpose experiment designed for 14 TeV collisions and a peak luminosity up to 10^{34} $cm^{-2}s^{-1}$,
  - Equivalent to 25 simultaneous collisions (pileup) per bunch crossing
- The sub-systems have performed as expected, allowing to collect large data sample and allow important discoveries
- The Large Hadron Collider has reached the design level or overcome them
  - Luminosity can stably overcome the design value already this year, with pileup higher than expected
- Improvements to the accelerator are continuously deployed but big leap is expected in the decades with the High Luminosity LHC programs
  - HL-LHC is expected to provide 3000 fb^{-1} at the end of the program
  - Unprecedented density for p-p collisions will provide huge data samples
  - The detector and the DAQ system need to improve to face new challenges
  - The enormous data sample will guarantee precise measurements in the Higgs sector, explore beyond SM theories and search for new phenomena





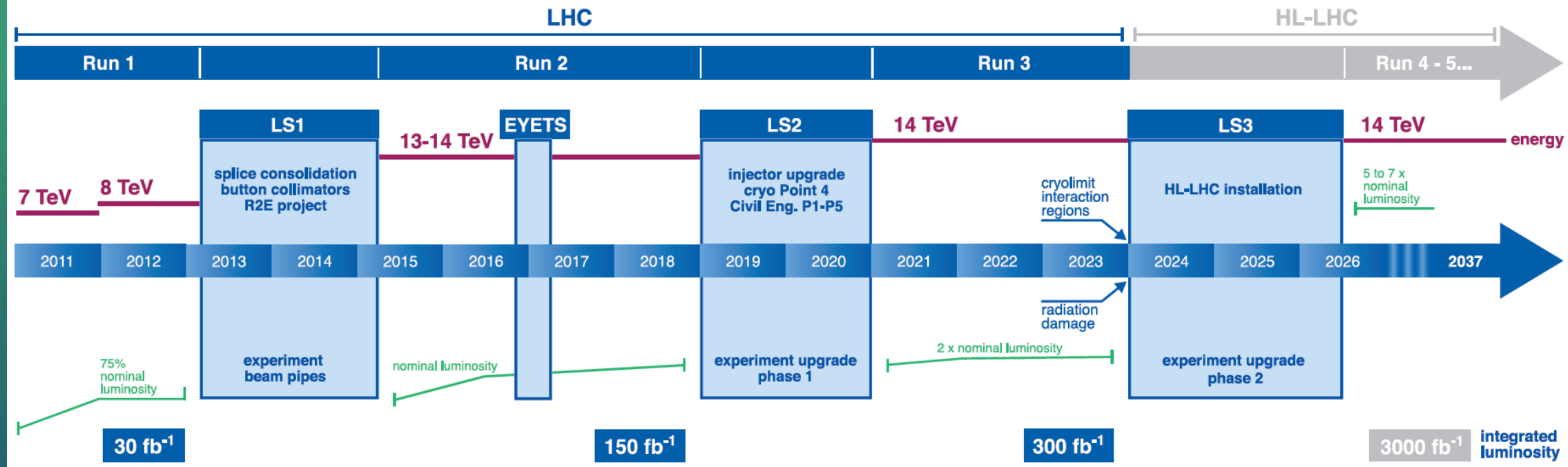
THE ATLAS DETECTOR AND TDAQ





The current detector allows full tracking up to eta 2.5, with calorimeter coverage up to $|\eta|<5$.
The overall structure will remain unchanged for the HL-LHC

LHC / HL-LHC Plan



0.75 10^{34} $cm^{-2}s^{-1}$
50 ns bunch
high pile up ~40

50 ⇒ 25 ns

1.5 10^{34} $cm^{-2}s^{-1}$
25 ns bunch
pile up ~40

1.7-2.2 10^{34} $cm^{-2}s^{-1}$
25 ns bunch
pile up ~60

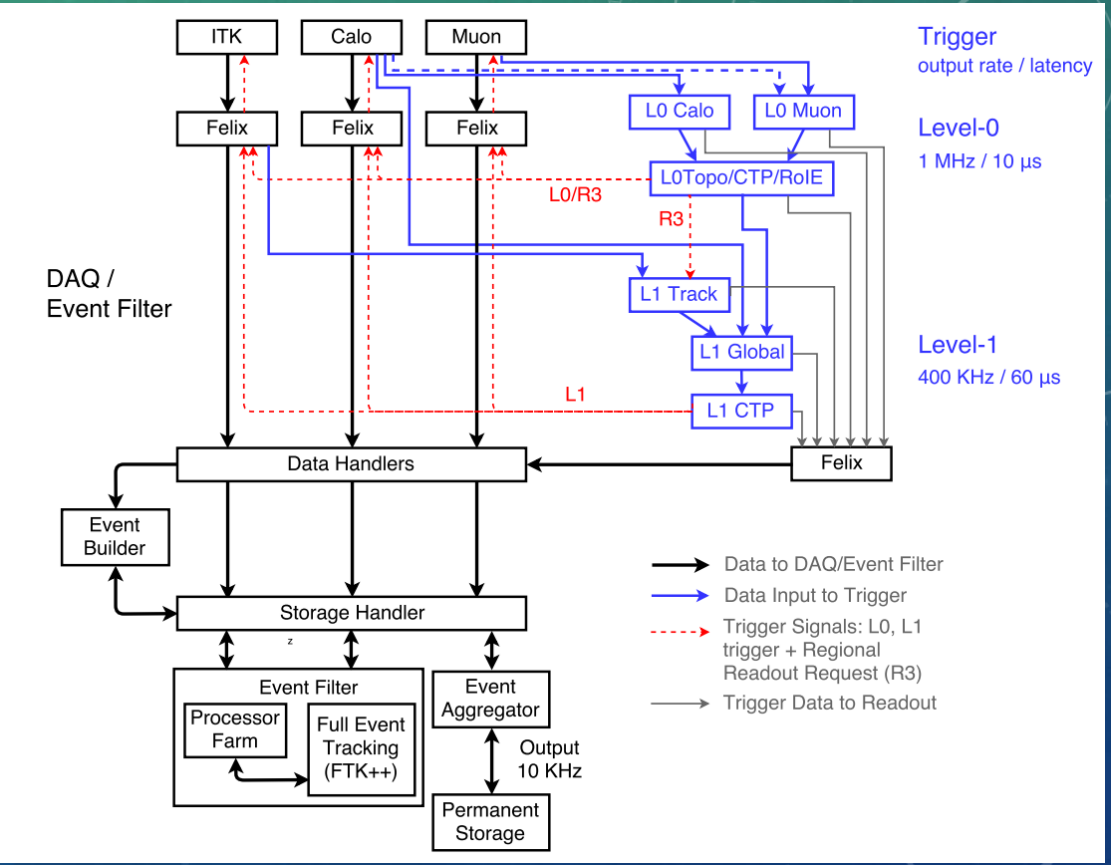
25 ns bunch
pile up 140-200

ATLAS UPGRADES' OVERVIEW

- Many sub-detectors would benefit from an upgrade of the system or require improvements
  - Inner detector wont be able to survive to the total dose of HL-LHC, replacement is required
  - The Forward liquid argon calorimeter (FCal) may have boiling LAr, intervention would be beneficial
  - Innermost layers of the muon endcap system need to be upgraded to cope with the higher density
- The goal is to maintain (or improve) the current performance, despite the most challenging environment
- Some upgrades were done during LS1
  - Inclusion an additional pixel layer Insertable B-Layer and new beam pipe
  - TDAQ improvements: Level-1 trigger topo processor, new multi chip modules (nMCM)
  - many others will be spread in the different shutdowns
- Detector electronic and Trigger and Data-acquisition would require major updates
  - The HLT would require more bandwidth and computing power
  - Detector front ends will be updated in (almost) all sub-systems
  - DAQ system will be redesigned to benefit of newer technology
- Different upgrades scenario have been studied for the LS3 interventions, reflecting different funding scenario and risks associated to specific interventions

TRIGGER AND DAQ

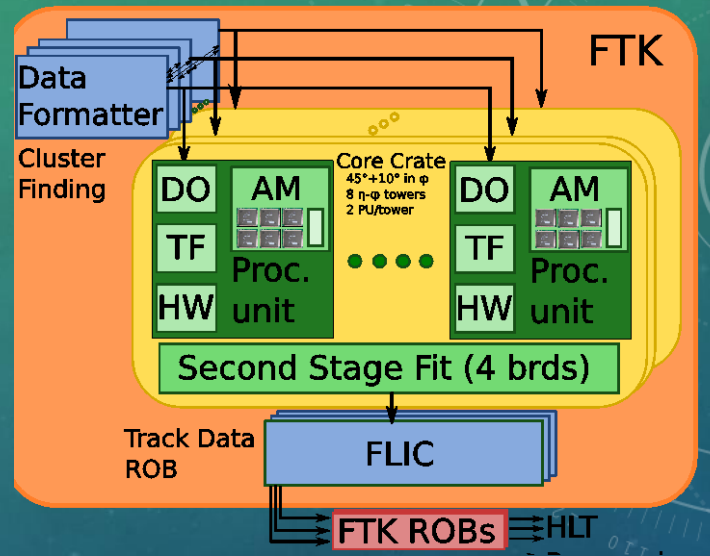
- The trigger and DAQ infrastructure will undergo a major update
  - Almost all the front-end electronics will be upgraded
  - Allowing larger read-out rates and more bandwidth
  - Most of the ASICs will migrate to powerful FPGAs
    - Exploiting the greater flexibility of this solution
- The goal of the design is to maintain low thresholds to avoid to reduce efficiency on important selections
- A multilevel TDAQ architecture will be exploited
  - A Level-0 trigger, with accept rate up to 1 MHz will receive data from calorimeters and muon detectors
  - A Level-1 trigger, up to 400 KHz, will be implemented using the full muon information and the tracker
  - Exploring the impact a Level-0 only infrastructure
- Some technologies will be tested during the current run and incoming shutdowns

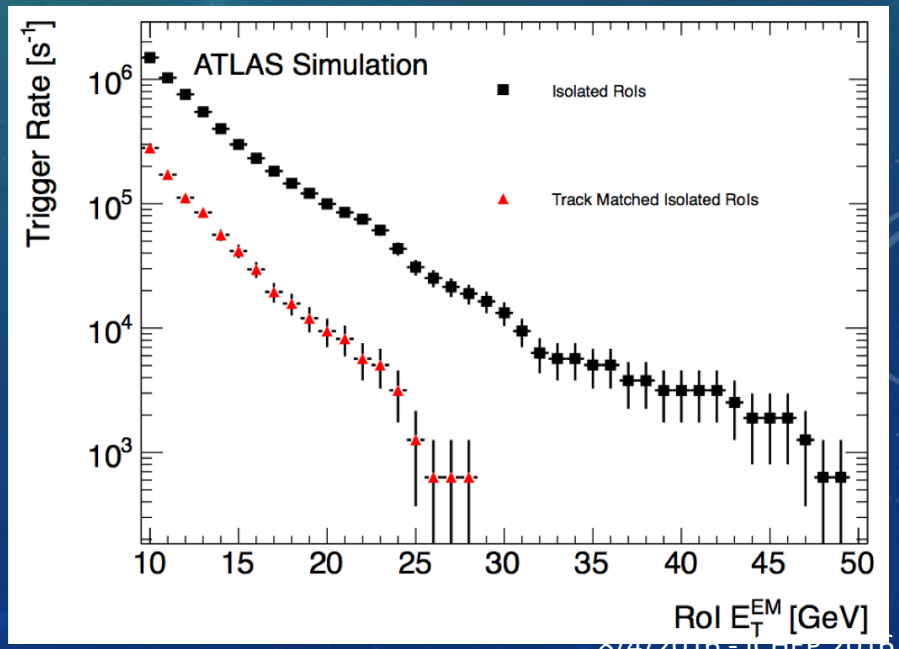


Multi levels scenario

TRACK RECONSTRUCTION AT TRIGGER LEVEL

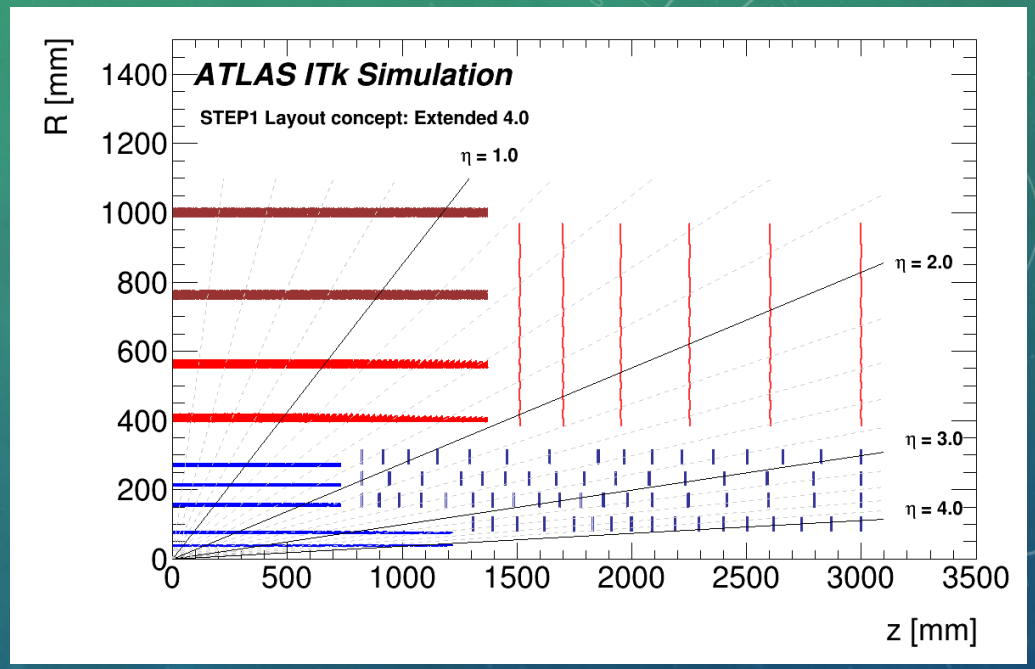
- The use of tracks allows to increase the rejection against the pileup
  - Most of tracking currently performed in regions of interest
- With Run II ATLAS is installing an hardware tracking processor
  - The ATLAS Fast Tracker, designed to allow 100 KHz full track reconstruction for the HLT
    - Exploits associative memory (AM) chips and FPGAs to achieve full tracking for p_T>1GeV track within tens of micro-seconds
    - Within the HL-LHC scenario the ability to have tracking will be even more important
  - In both possible TDAQ architectures 2 independent tracking processors are expected: L1Track and FTK++
- L1Track will provide regional tracking a high rate and low latency (6 us latency) on the Level-0 input
  - Based on AM chips and FPGAs, as current FTK
  - Main goal to reduce the 1 MHz L0 accept of a factor 2-4 basing the decision on tracks
    - Main focus single leptons triggers
- The FTK++ will provide full scan tracking at 100 KHz rate
  - Two possible technological choices: CPU+GPU or other accelerators, AM+FPGAs as in L1Track

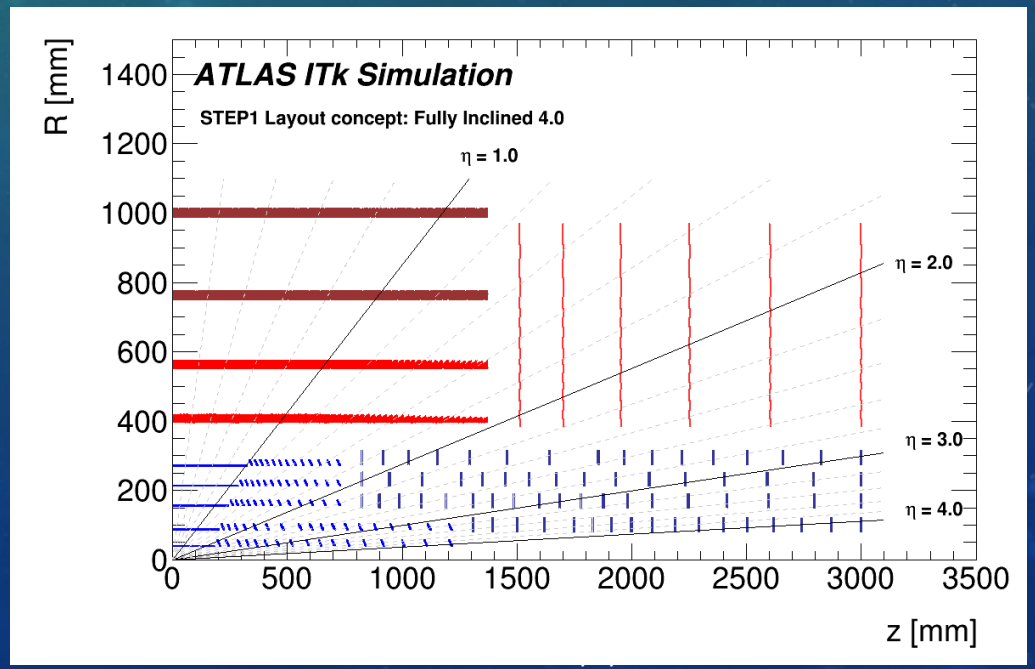




NEW INNER TRACKER DESIGN

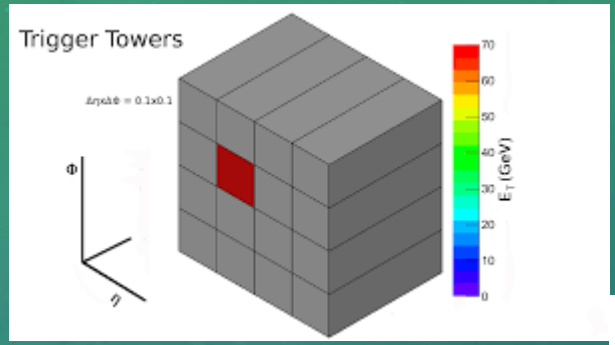
- In the HL-LHC scenario (pileup 140-200) the total dose of 700 Mrad for the innermost detector, exceeding the original design
  - A completely new design of the inner detector is under development
- The new Inner Tracker (ITK) will use only silicon technology
  - 5 pixel layers and 4 layers of strip sensors
  - Need high granularity to limit the effect of pileup
- Strip layout is almost finalized, TDR at the end of 2016
- Pixel layout exploring different solutions for the modules
  - Latest efforts in evaluating the pro and cons of inclined modules in the transition region
  - TDR for the pixel system in 2017
- Final decision on the possible scenarios under finalization
  - ITK coverages can reach $|\eta|<4$ in some of scenario
  - The coverage and number of layer can change in the alternative ATLAS upgrade scenarios

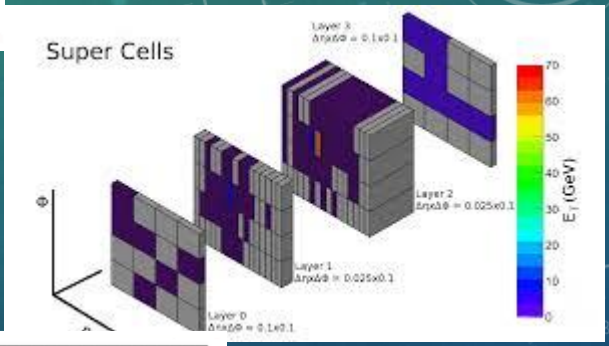


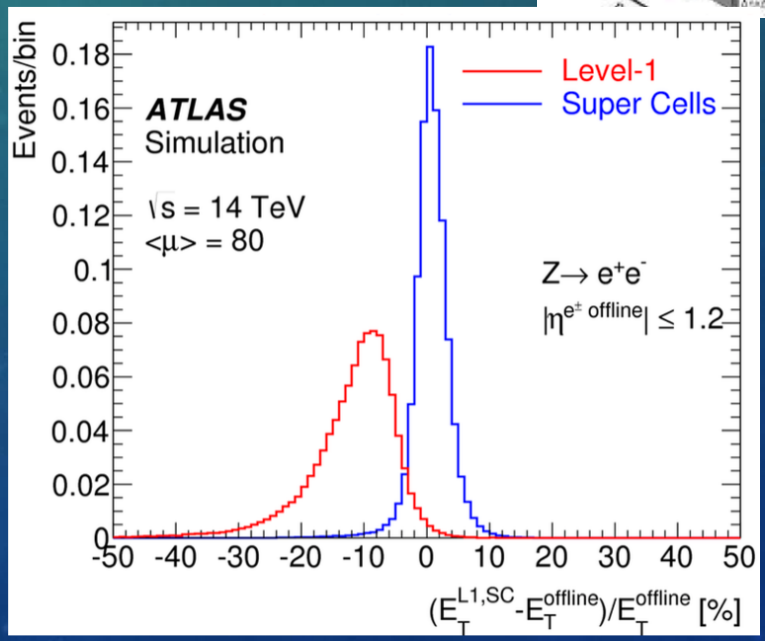


CALORIMETER UPGRADES

- The goal of the calorimeter upgrades is to improve the pileup rejection and maintain (or improve) the current performance
- The hardware for the central LAr and Tile calorimeters will not have major hardware upgrades
  - Most changes related to the read-out electronics
- Full redesign of the detector electronics required
- New front-end able to increase the granularity installed in LS1
- During HL-LHC the calorimeters will be read the full detector granularity at 40 MHz
  - Data processing should be performed within 1.5 us
  - Processing done outside detector with custom electronic boards
- Installation of the demonstrator expected during LS2

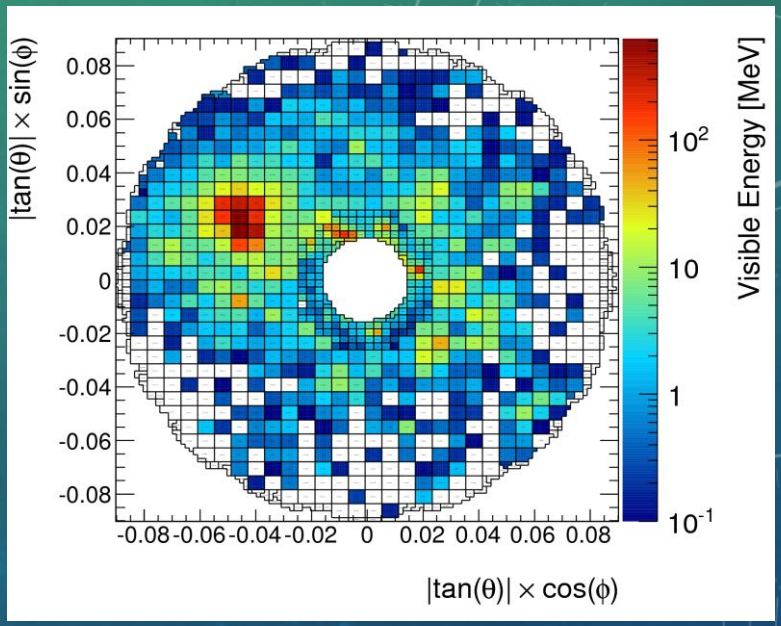


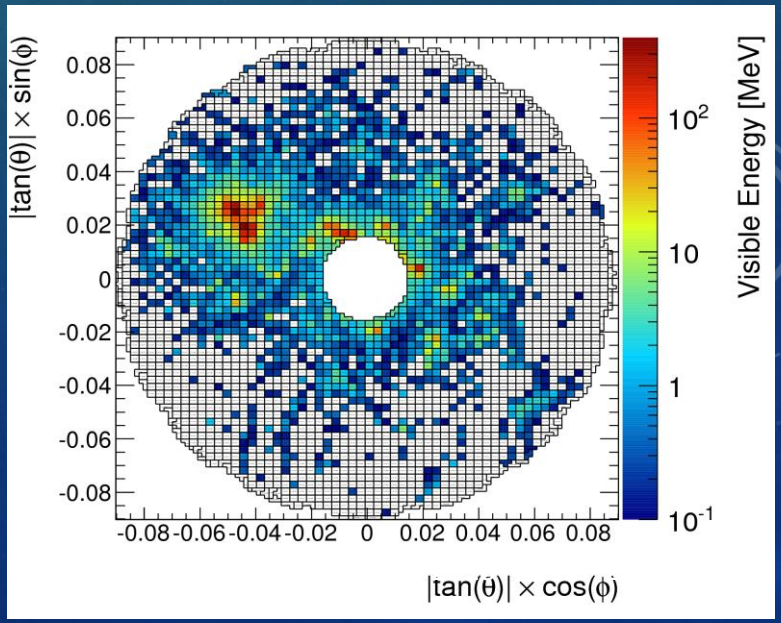




FORWARD CALORIMETER UPGRADE

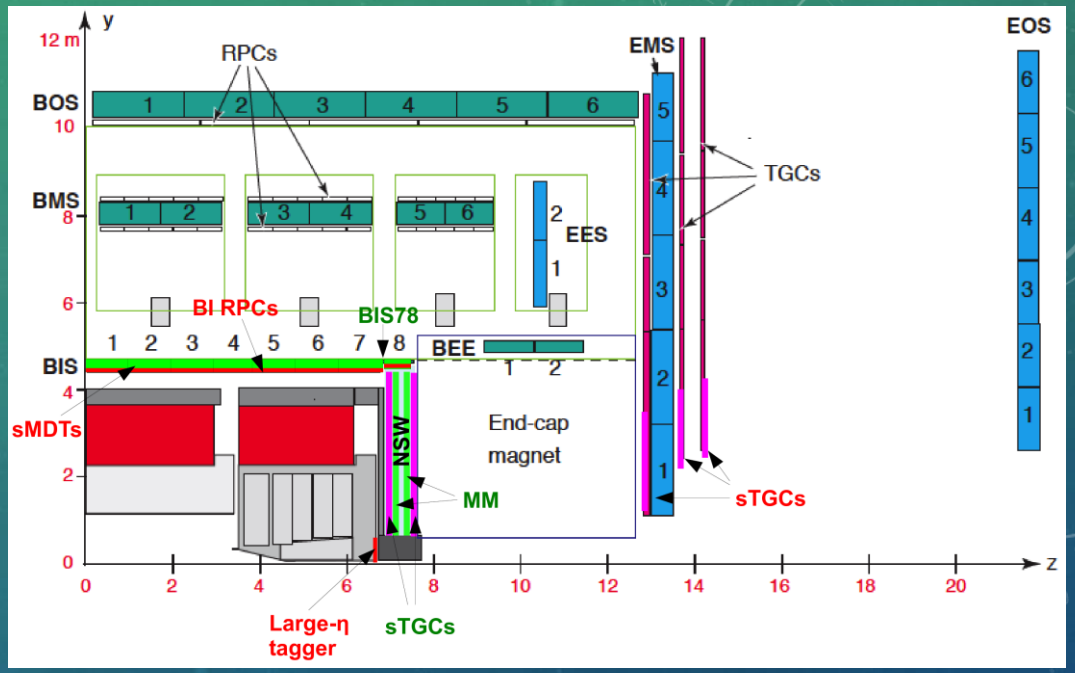
- Most delicate part for the calorimetry system in the HL-LHC scenario is forward LAr section (FCAL)
  - Given the expected high flux of particles the LAr can produce bubbles
  - Different options to mitigate it, need a careful risk analysis
- In the option of installing sFCal, a newer forward calorimeter detector, the segmentation should be increased
  - Better granularity will increase the jet properties determination, improving pileup rejection
- Possibility to have a High Granularity Time Detector under consideration
  - It can be placed between barrel and end-cape cryostats
  - Based low gain avalanche detectors
  - Expected to provide a <50ps for single particle timing can allow rejection power of factor 10 for pileup jets

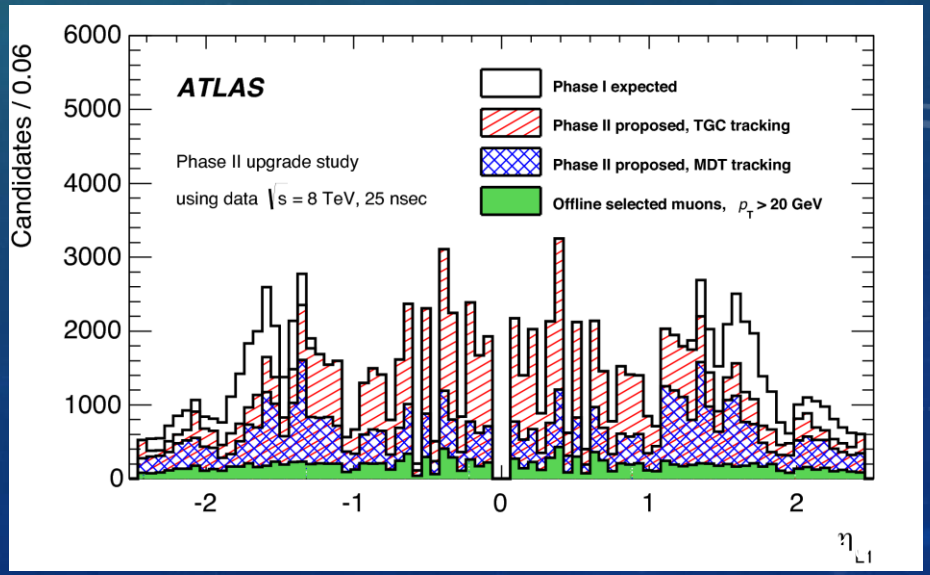




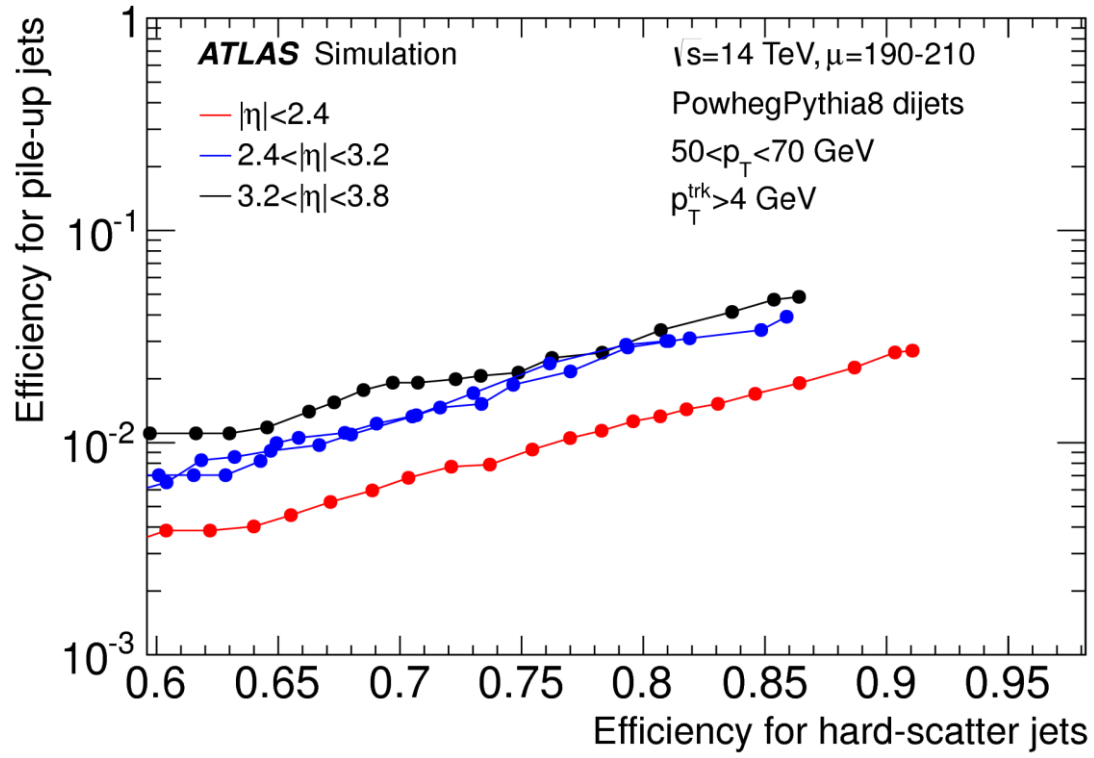
MUON UPGRADES

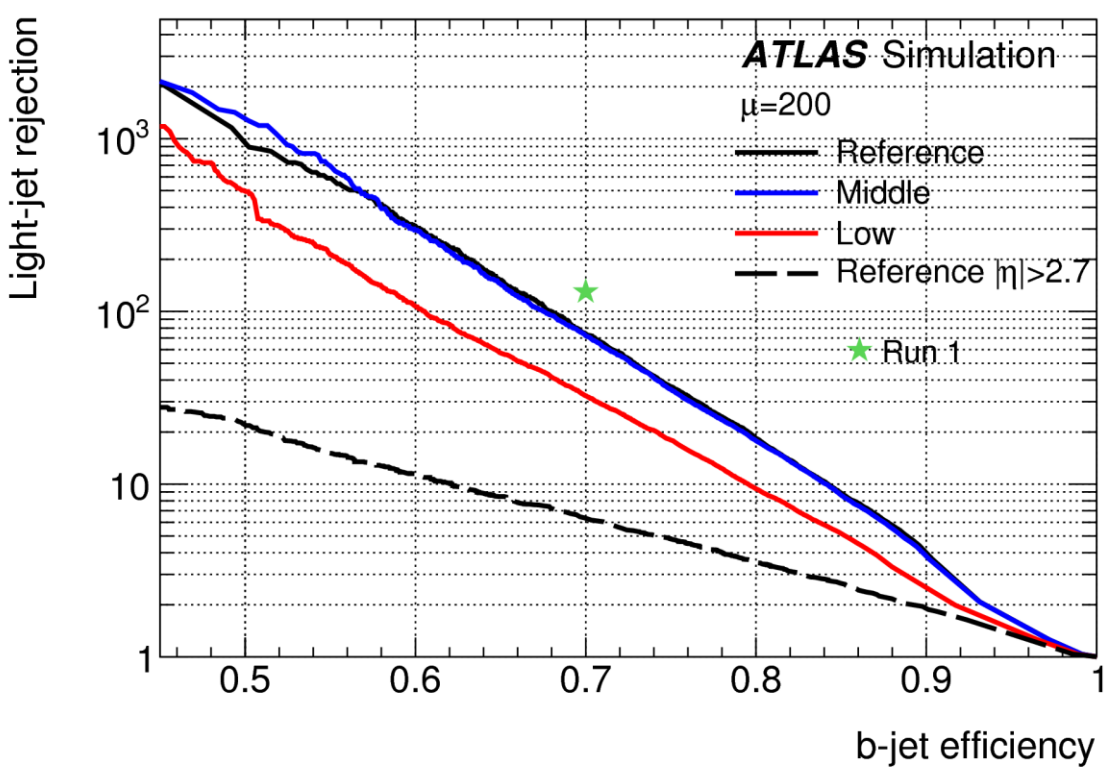
- The muon system upgrade will involve a new forward detector and replace of most of the electronic
  - The New Small Wheel will be installed during LS2 shutdown
  - The update on the electronics will happen during LS3
- The NSW will replace the existing detector
  - Using Micro-mega and sTGC stations, allowing precise tracking and trigger capability
- The newer detector provide a more robust solution to fight the greater event rate, with large fake reduction
  - The readout electronic will be compatible with the HL-LHC TDAQ design or upgradable
- Design will be finalized during the 2016
- More trigger stations in the innermost muons layers will be added in LS3 to improve fake rejection and increase trigger efficiency





UPGRADED ATLAS PERFORMANCE ON PHYSICS OBJECTS





Combining tracking and calorimeter information will be possible to guarantee a large rejection of pileup jets. Required tracking performance match the L1Track capabilities.

The upgrades will allow to maintain the b-tagging performance during HI-LHC at the same level of the Run-I. The proposed reference scenario guarantee a rejection also in the forward rejoin.

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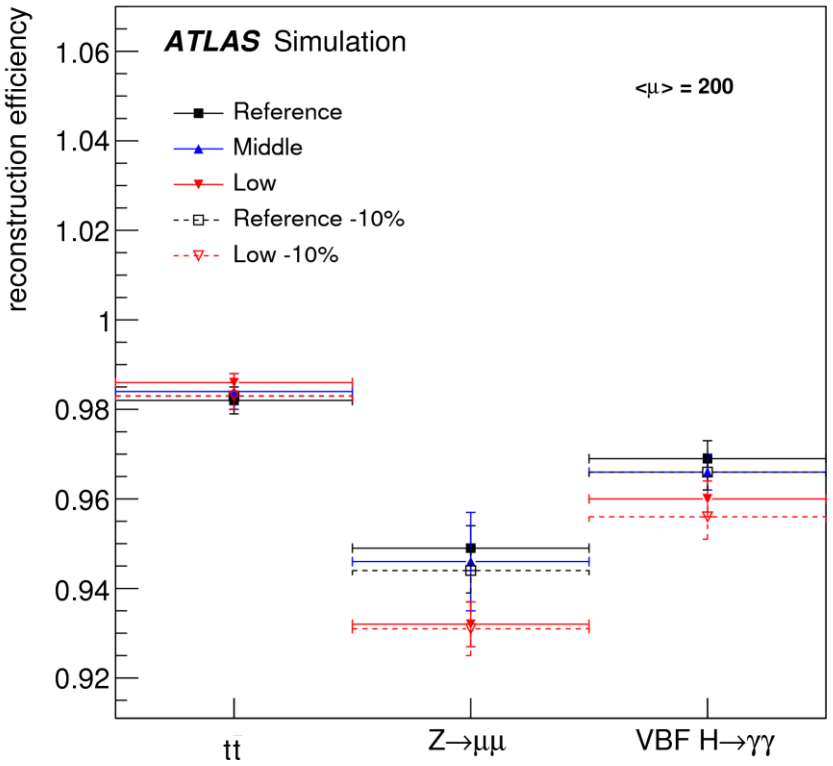
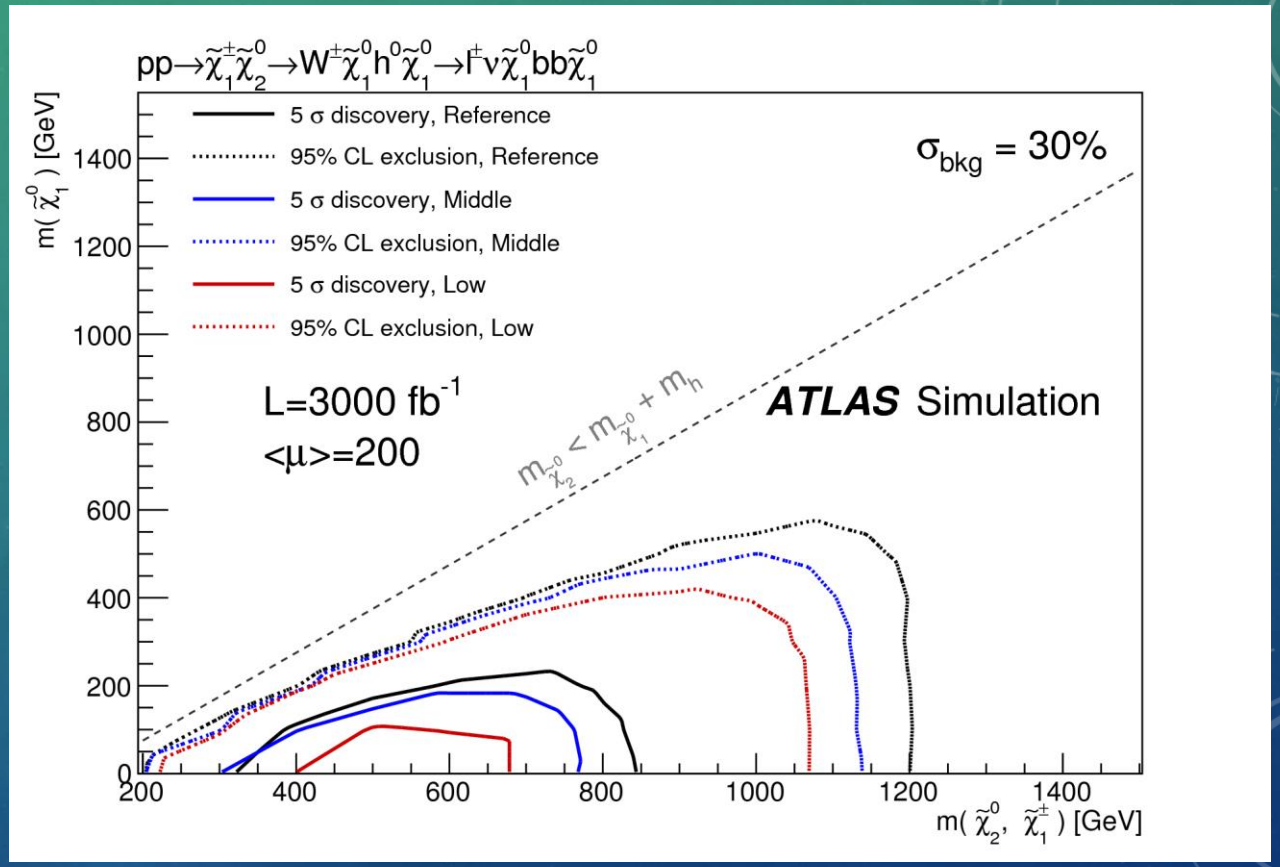
UPGRADED ATLAS PERFORMANCE ON PHYSICS CHANNELS





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Overall the ATLAS experiment will guarantee high efficiency on the interesting final states.
The reference scenario will guarantee a larger discovery power, compared to the low and middle ones.

OTHER RELATED ATLAS TALKS AT ICHEP

- The ATLAS Dataflow system in Run-2: Design and Performance, Othmane Rifk
  - http://indico.cern.ch/event/432527/contributions/1072204/
- Overview of the ATLAS Fast Tracker Project, Lucian Stefan Ancu
  - http://indico.cern.ch/event/432527/contributions/1072437/
- First testbeam results of prototype modules for the upgrade of the ATLAS strip tracking detector, Susanne Kuehn
  - http://indico.cern.ch/event/432527/contributions/1072342/
- The upgraded Pixel Detector of the ATLAS experiment for Run-2 at the Large Hadron collider, Mapo Giordani
  - http://indico.cern.ch/event/432527/contributions/1072151/
- Upgrade of the ATLAS Calorimeters for Higher LHC Luminosities, Ryne Michael Carbone
  - http://indico.cern.ch/event/432527/contributions/1071472/
- Resistive Micromegas for the Muon Spectrometer Upgrade of the ATLAS Experiment, Mauro Iodice
  - http://indico.cern.ch/event/432527/contributions/1071669/
- Small-Strip Thin Gap Chambers for the Muon Spectrometer Upgrade of the ATLAS Experiment, Bernd Stelzer
  - http://indico.cern.ch/event/432527/contributions/1071667/
- New developments in track reconstruction for the ATLAS experiment for Run-2 of the LHC, Simone Pagan Griso
  - http://indico.cern.ch/event/432527/contributions/1072353/

CONCLUSIONS

- The ATLAS detector has achieved tremendous results so far
- The LHC conditions however are in continuous change and a big jump is expected in 10 years
  - The HL-LHC will provide hundreds of fb-1 per year, allowing to explorer extremely rare processes
  - Unprecedented precision measurements of Higgs properties and an unique windows on supersymmetry or beyond standard model physics
- The experimental condition will be extremely challenging, with a pileup level of 200 contemporary collisions
  - The ATLAS detector started to plan upgrades in many of its system to allow to account for the increase in occupancy
- For the HL-LHC period a new all silicon inner tracker system will replace the current tracking system
- Better readout and partial detector replacement are also foreseen for the muon and calorimetric system
- The trigger and data acquisition will have an important redesign, studying a single or two levels systems under discussion
  - Higher bandwidth will be available from all detectors, with L0 readout up to 1 MHz
  - More granularity from most of the detector, particularly from the calorimetric system
  - Resources dedicated to real-time tracking will be available at early trigger levels

Thanks!!!