The ATLAS upgrade programme for LHC Run-3 and the HL-LHC

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On behalf of the ATLAS Collaboration

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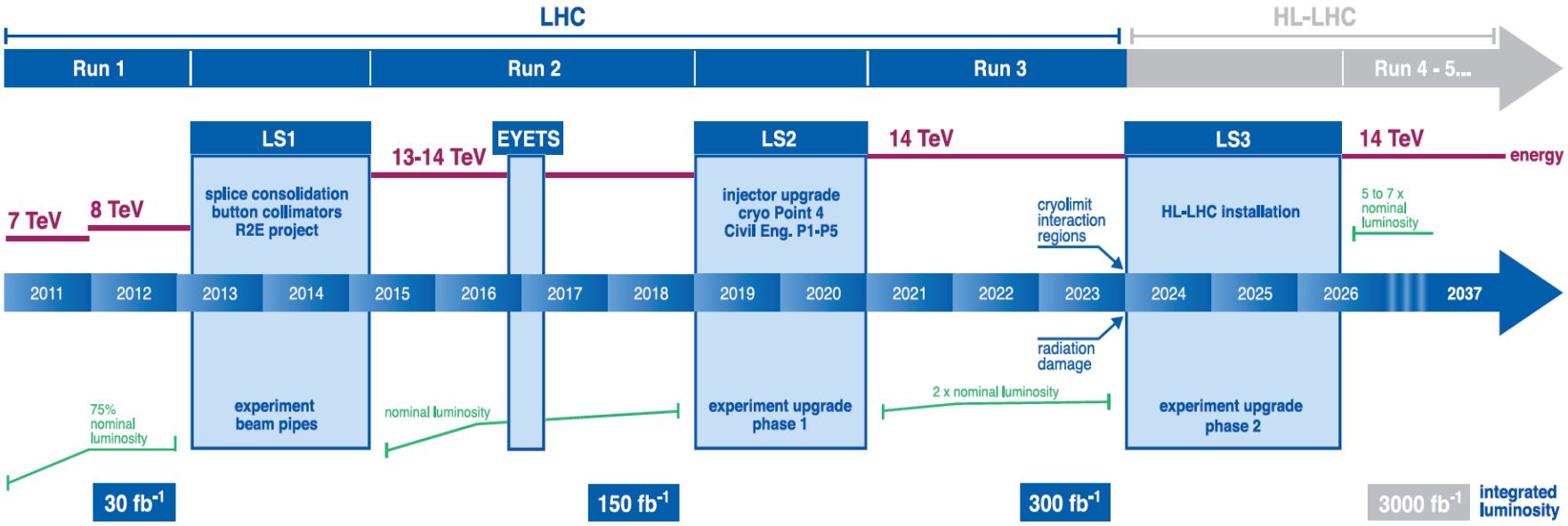
The LHC Operation time-line (updated)

LHC / HL-LHC Plan

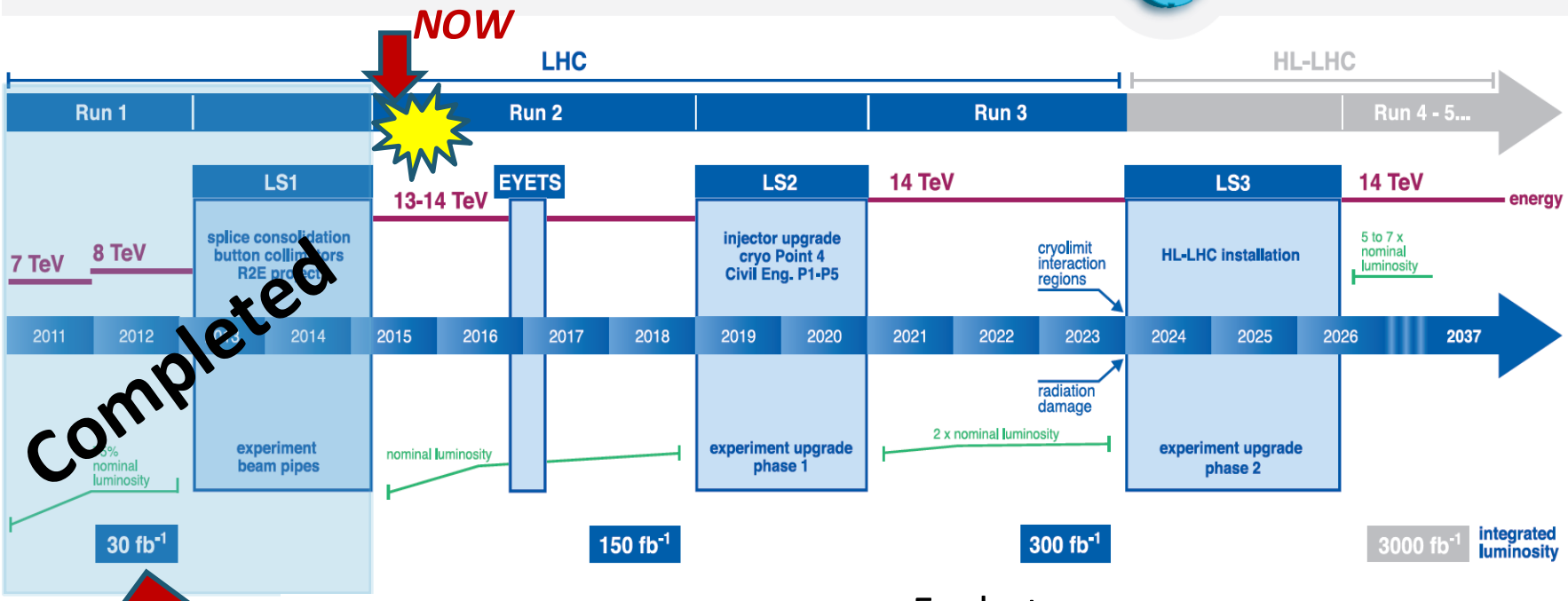


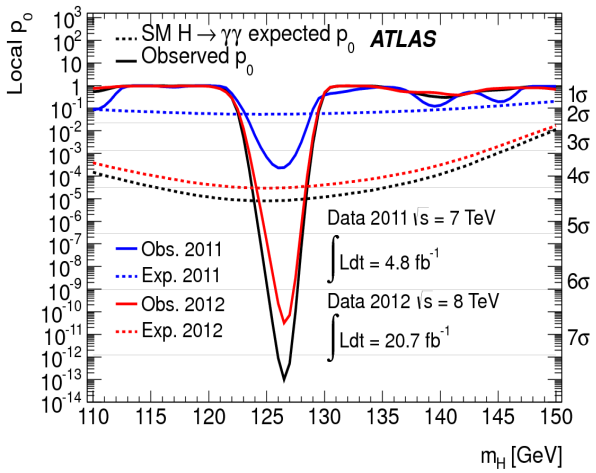
European Strategy for Particle Physics

"Europe's top priority should be the exploitation of the full potential of the LHC, including the high luminosity upgrade of the machine and the detectors with a view to collecting 10 times more data than in the initial design, by around 2030"

The LHC Operation time-line – Run 1 & 2

LHC / HL-LHC Plan





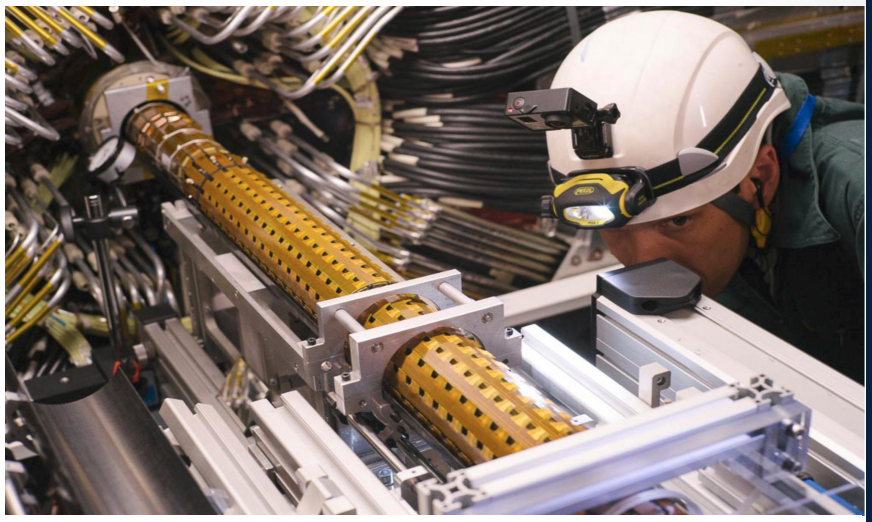
Englert & Higgs

Won the 2013 Nobel Prize

ATLAS UPGRADE

A flavour on the Run 2 (early physics & performance)

ATLAS talks showing early Run 2 results

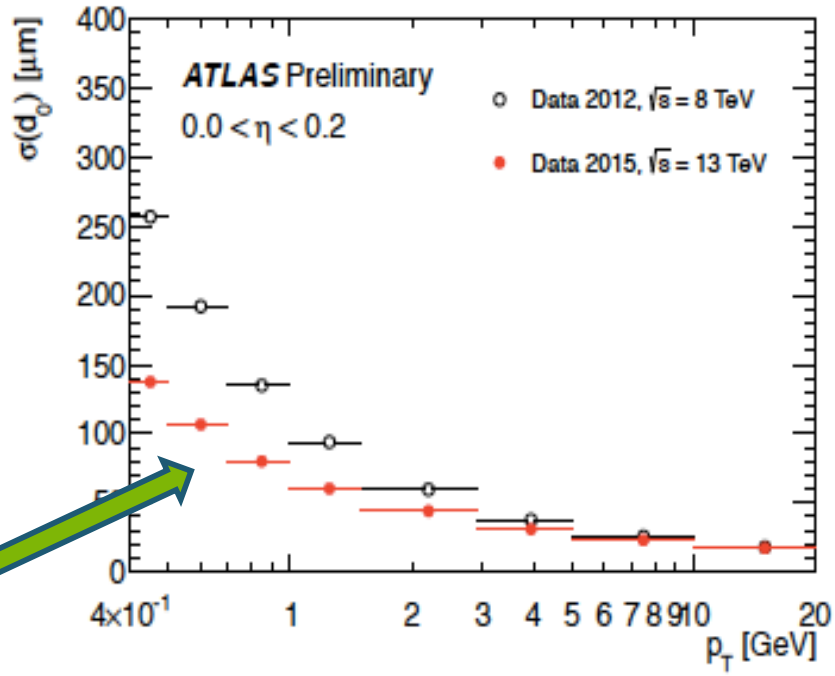


Physics

- ***ATLAS status and results in the dawn of Run-2***
- ***B-physics and quarkonia results from ATLAS***
- ***ATLAS results on top-quark physics***
- ***QCD and electroweak physics with ATLAS***
- ***Searches for supersymmetry with ATLAS***
- ***Searches for exotic new phenomena with ATLAS***

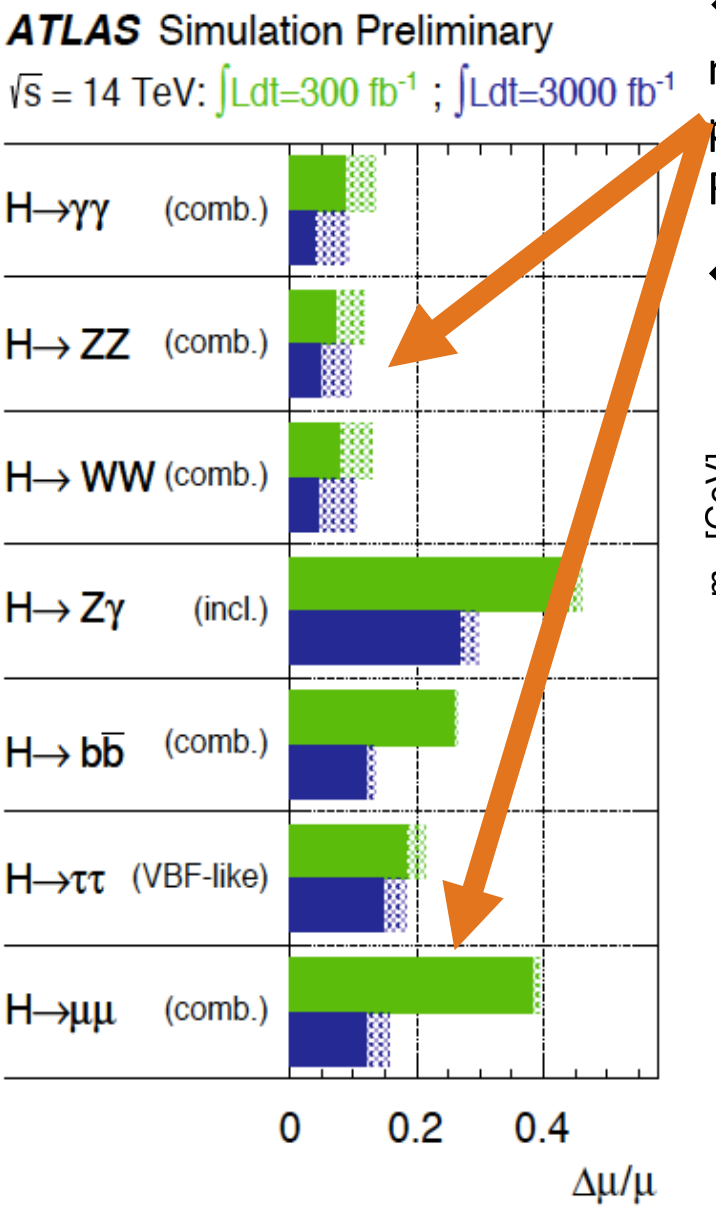
Performance

- ***The TileCal Energy Reconstruction for LHC Run2 and Future Perspectives***
- ***The ATLAS Trigger System: Ready for Run-2***
- ***The Upgrade of the ATLAS Electron and Photon Triggers towards LHC Run 2 and their Performance***

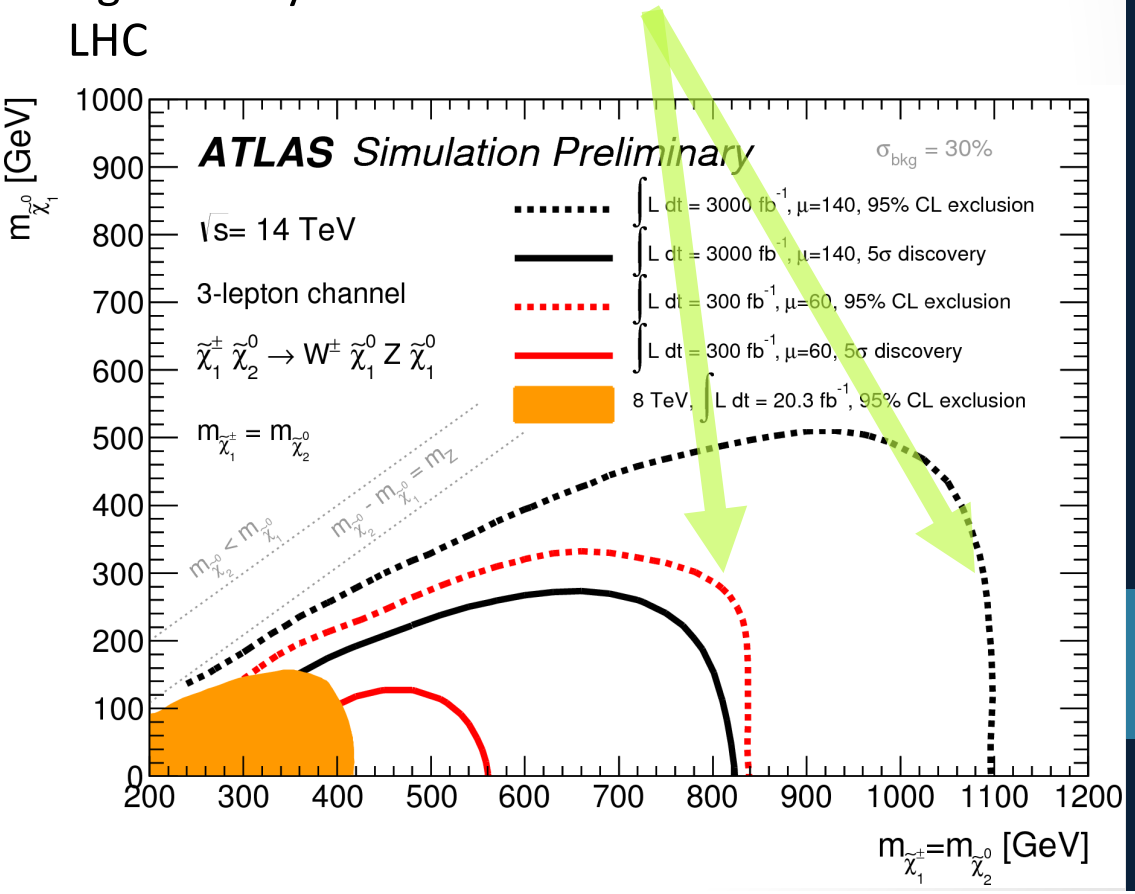


Improved track reconstruction with IBL

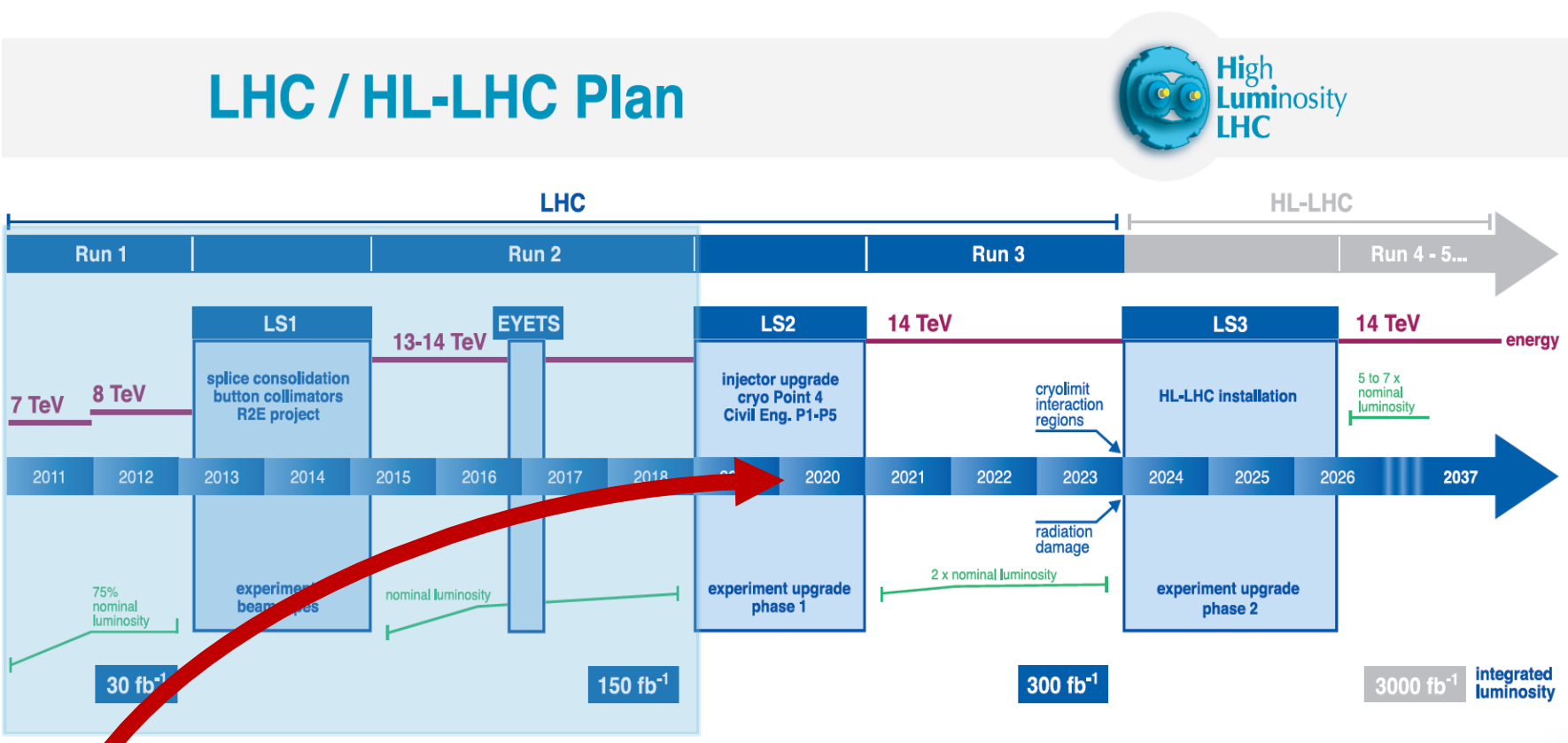
Main physics motivations for future LHC runs, beside many others…



- Significant improvements in Higgs precision measurements (maintaining good performance for low-pT objects crucial !), access to Rare processes (H→μμ, and HH)
- Reach in SUSY particles searches significantly extended in Run 3 and the HL-LHC



The LHC Operation time-line
LS2 & Run 3



Significant changes will be made to the LHC injector and the ATLAS detector during the LS2 in order to reach and to cope respectively with the ultimate design luminosity of Phase-I

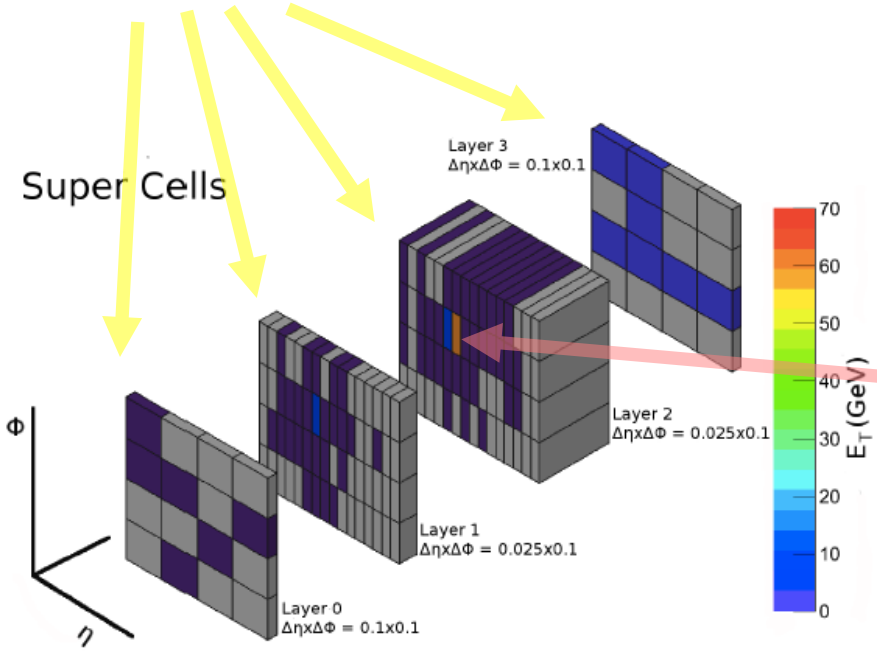
❑ Run 3 Main ATLAS Upgrades

- **L1Calor supercells & Improvement on the L1 Trigger architecture.**
- **Triggering Fast TracKing (FTK) – 1.5 Trigger level.**
- **New Small Wheels (NSW) detector installation.**

L1 Trigger – LAr Super cells

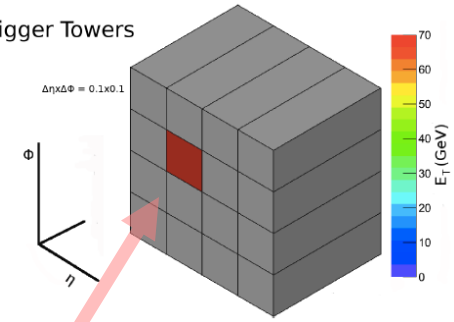
Improve the trigger energy resolution and efficiency for selecting electrons, photons, leptons, jets, and missing transverse momentum (E_T^{miss}), while enhancing discrimination against backgrounds and fakes in an environment with high instantaneous luminosity.

Exploiting the higher-resolution and longitudinal shower information from the calorimeter for being used in the Level-1 trigger processors.



Electron (70 GeV E_T) seeing with finer granularity

Current Trigger Cell



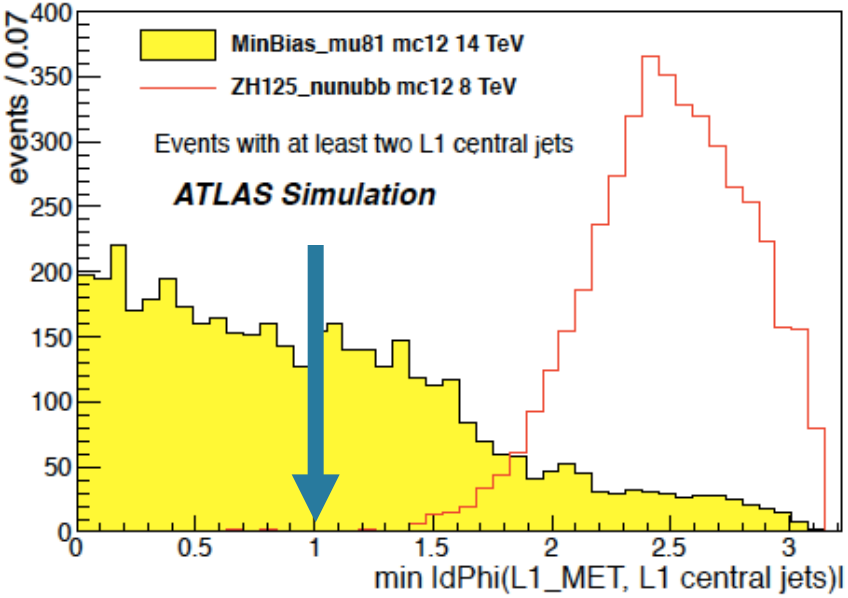
Electron (70 GeV E_T) at current L1 read-out

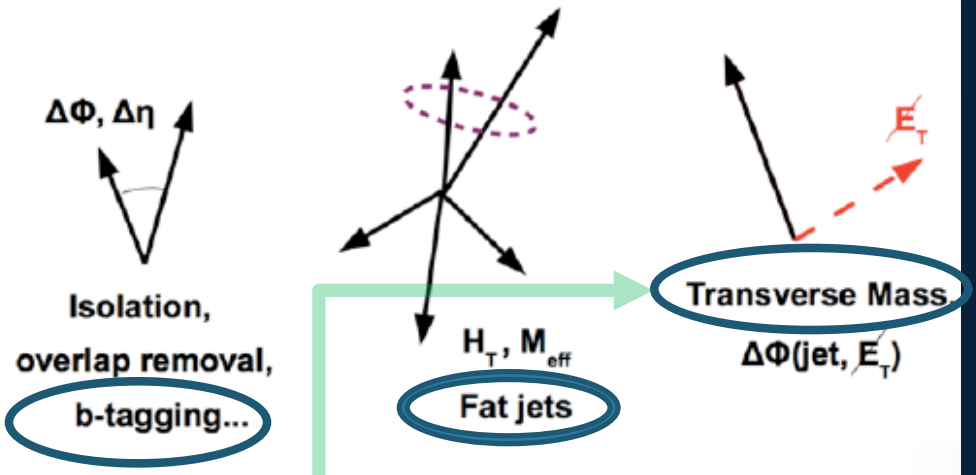
Allowing largest Jet rejection, crucial for efficient electron identification

ATLAS UPGRADE

L1Calo trigger read-out evolution

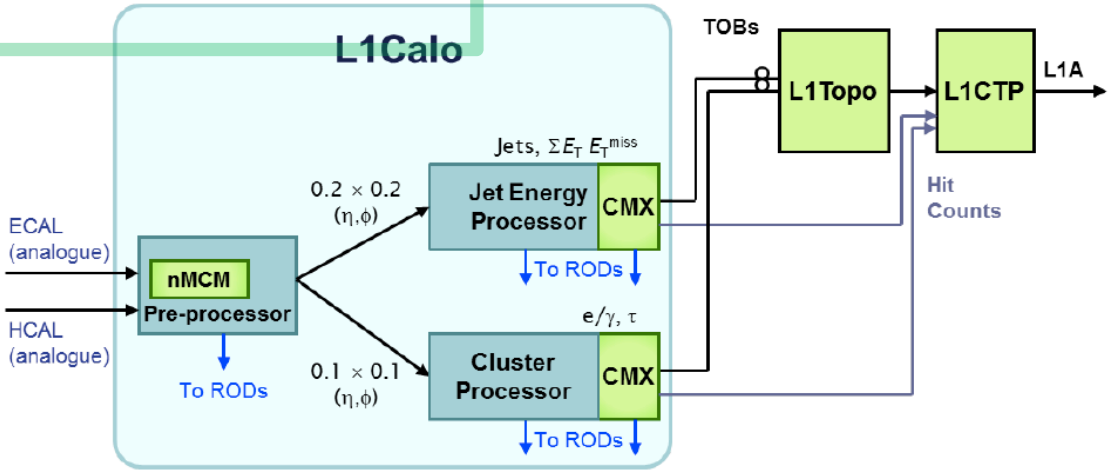
Significant improvements in the L1 trigger architecture already in place for the current ***Run 2.***





Allow a variety of topological cuts already at the L1 and a better control of pile-up.

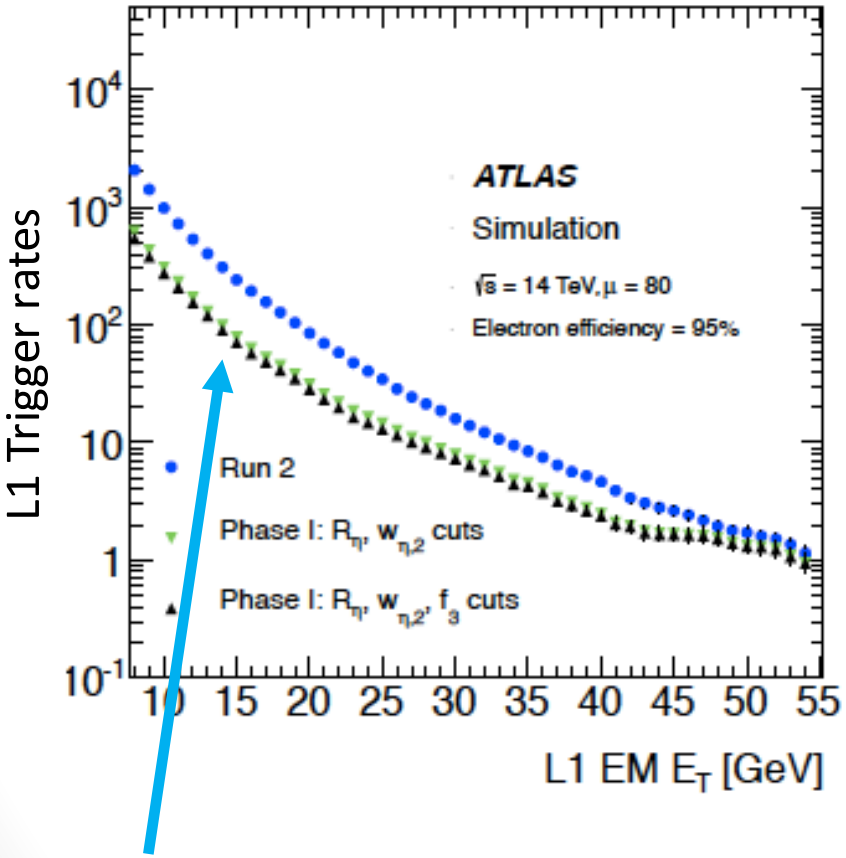
Topological cuts provide good rejection agains pile-up and a significat L1 rate reduction.

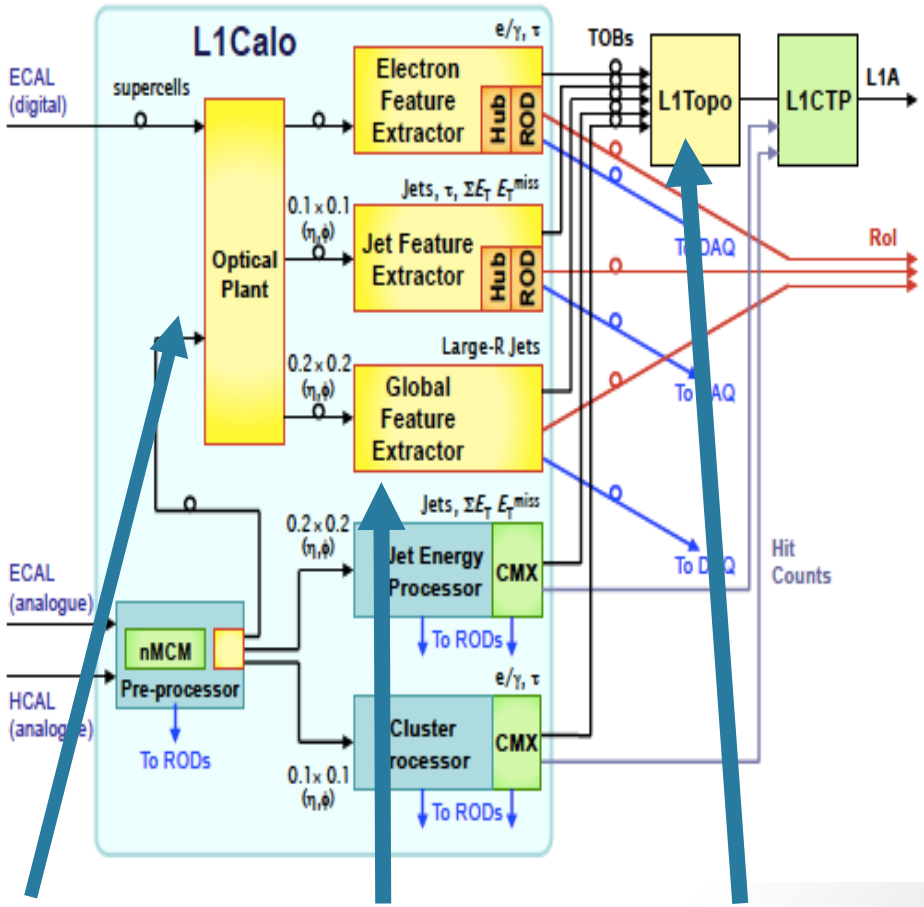


Run 2 upgrades in green.

L1Calo trigger read-out evolution

In addition, for the upcoming Run 3 there will be major upgrades in L1Calo, which will include the Electron, Jet and global FEXs, taking full advantage of the longitudinal shower shape information.





Significant reduction for low-pT particles compared with ***Run-2.***

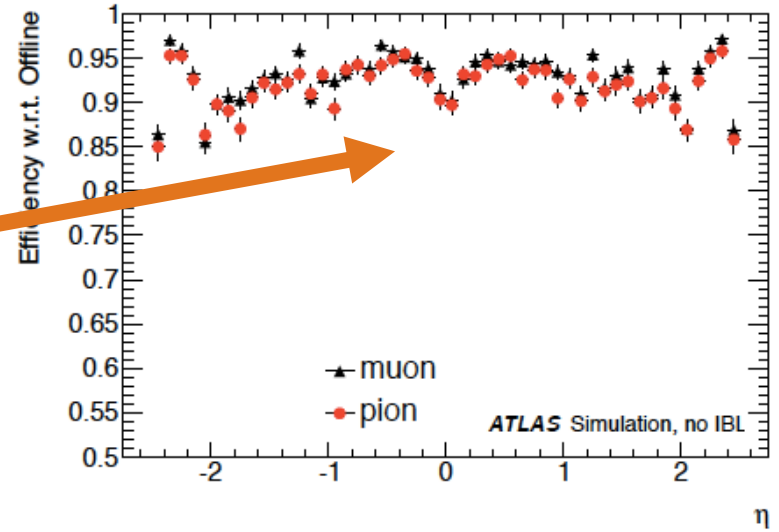
Run 3 upgrades, needed for taking full advantage of detailed information at the L1 Trigger level.

ATLAS UPGRADE

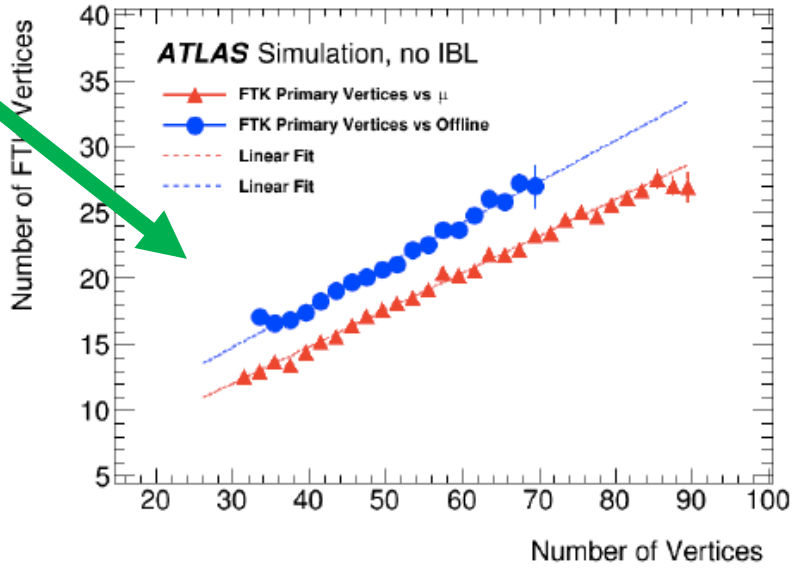
Triggering with Fast TracKing (FTK)

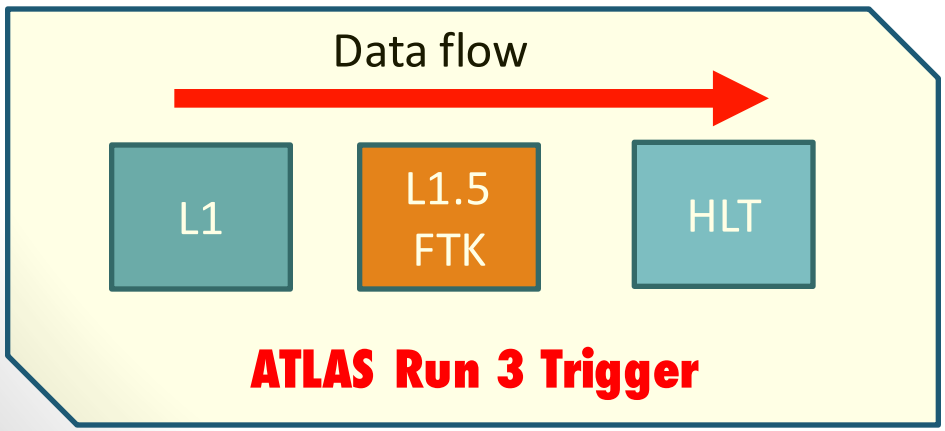
Dedicated FAST hardware-based track finder (~ 25 μs) acting after L1 and providing full event tracking information for the HLT.

- FTK will take information from the ID silicon detectors, allowing an offline quality track reconstruction

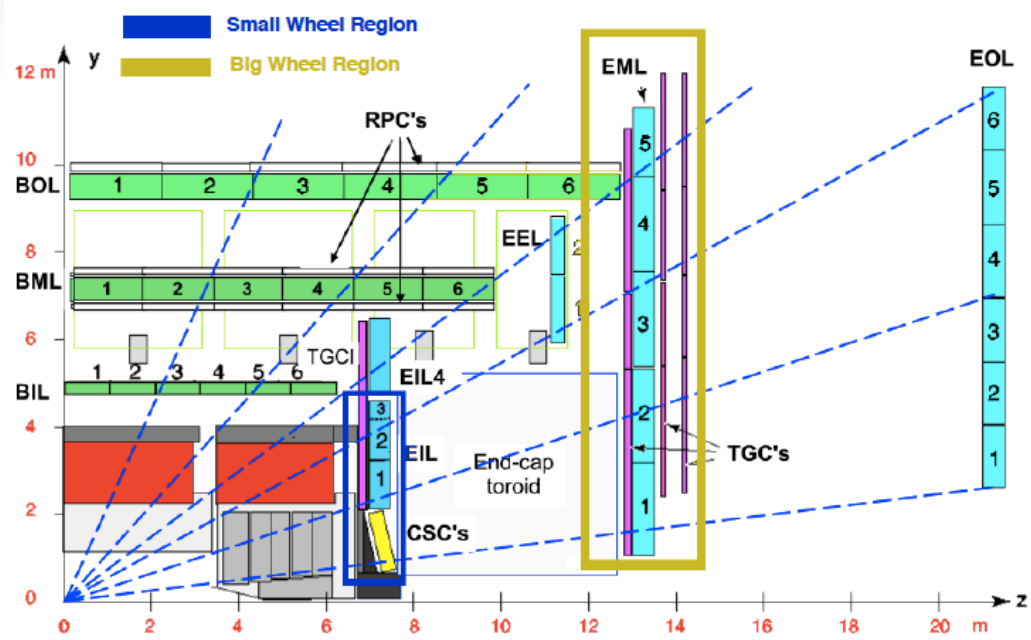


- Additional tracking and vertexing information at the start of the HLT, good for handle pile-up.





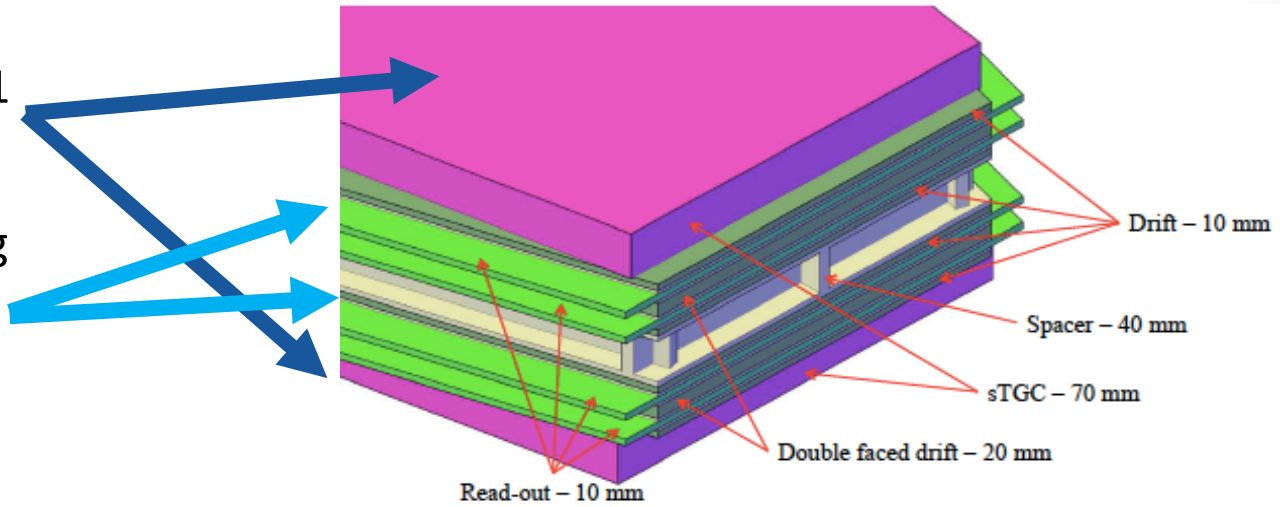
New S wheels for muon spectrometer



- After Run 2 will have to replace current muon system SW, due to radiation damage.
- New detector will help reducing the large background rate suffered in the muon detector end-caps.

TGC-MM-MM-TGC detector Sandwich

- Trigger chambers with angular resolution of ~ 1 mrad
- Precision offline tracking chambers with spatial resolution of ~ 100 µm
- Results in a very precise redundant system



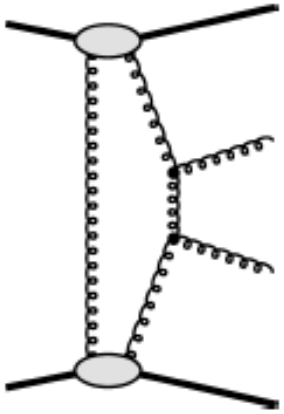
The new detector design satisfies the Phase-II requirements !

ATLAS UPGRADE

Forward Physics for ATLAS (AFP) at Run-2 and 3.

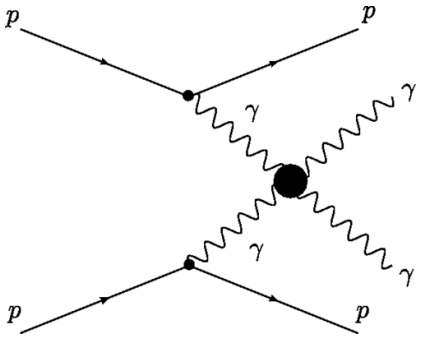
Physics with tagged forward protons @ ± 212 m from the IP.

- Primary goal is to study high rate diffactive physics in special low-μ runs.

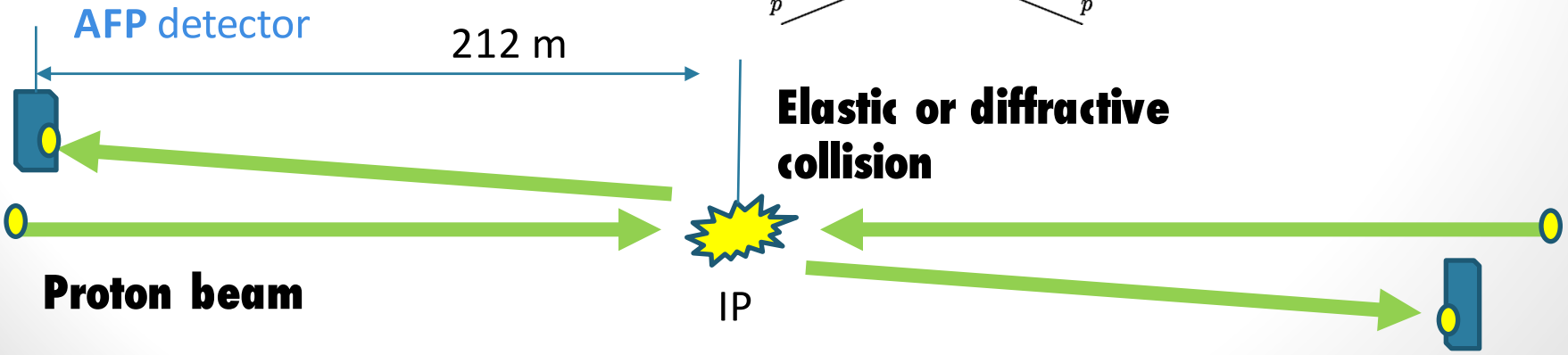


Central exclusive production (CEP)

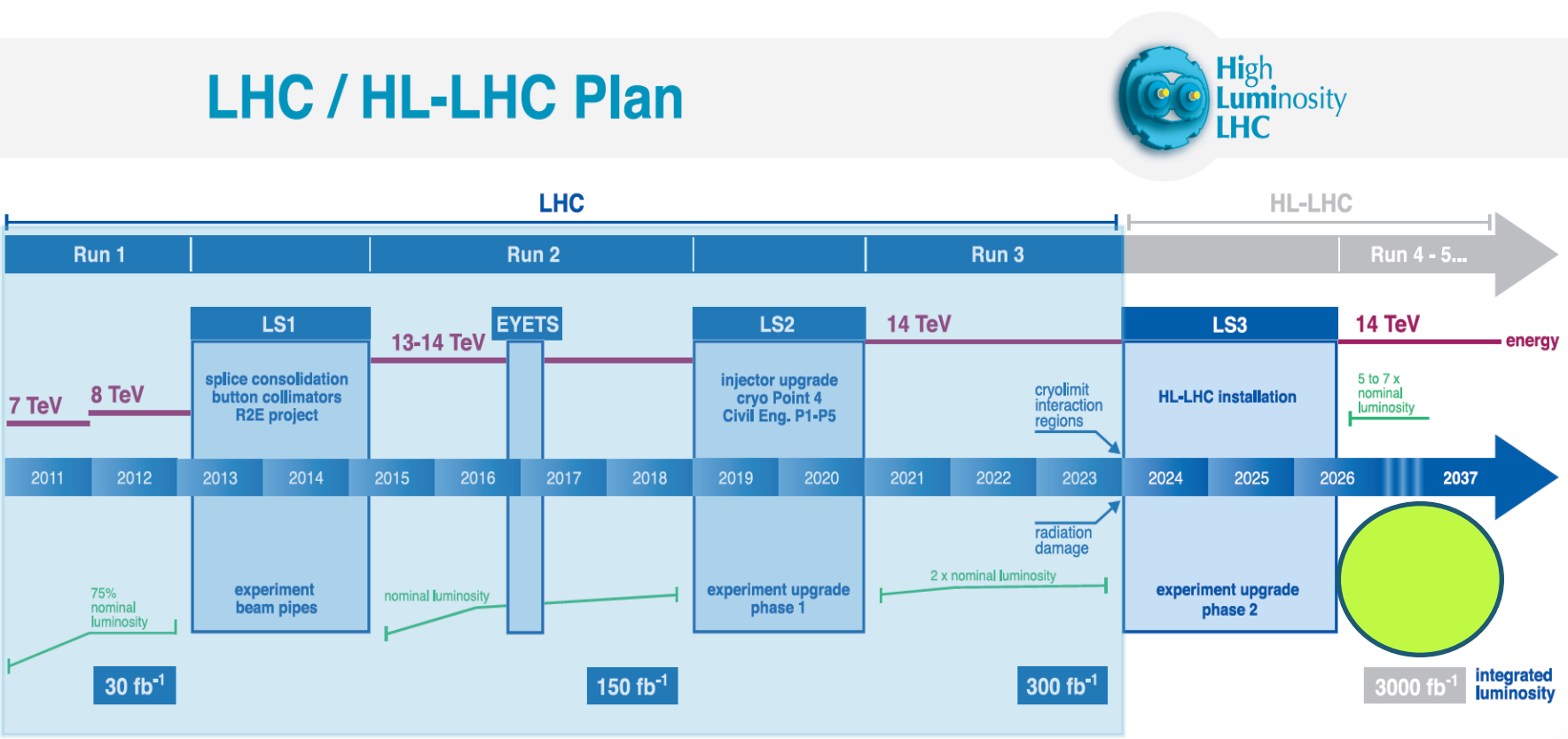
- Eventually, the detector could work also on high <μ> as an useful tool for searching new physics, but this option is still under investigation.



4-photon couplings are absent in the SM



The LHC Operation time-line
LS3 & HL-LHC stage after 2024..

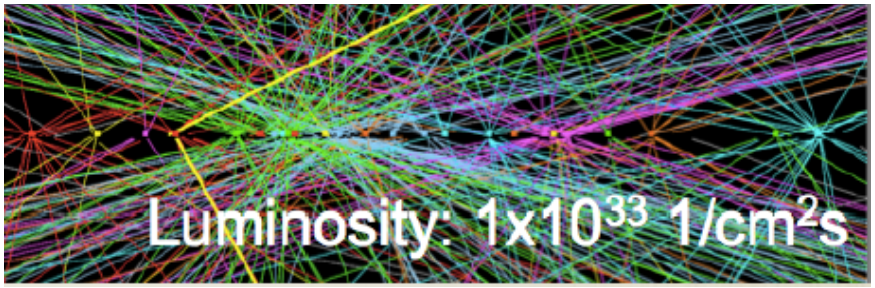


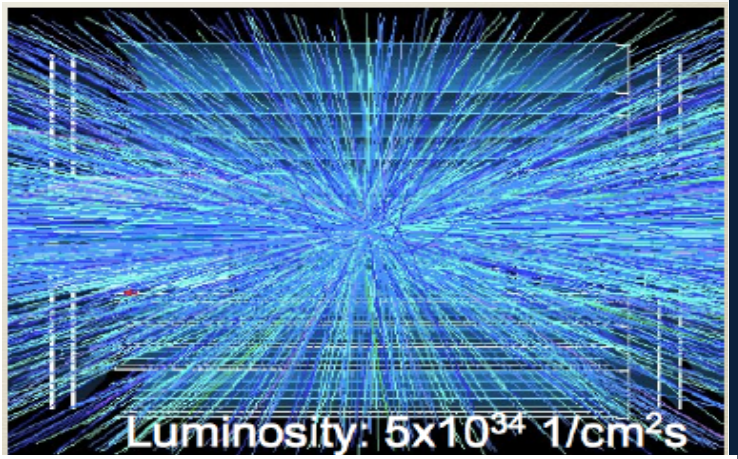
❑ HL-LHC Main ATLAS Upgrades

- **New all silicon inner tracking detector ITK.**
- **New trigger L0/L1 system architecture**
- **New Calorimeter and muon system electronics**

The busy HL-LHC environment

The HL-LHC detector and trigger upgrades in phase II will have to deal with a very hostile environment while maintaining good performance and efficiency.

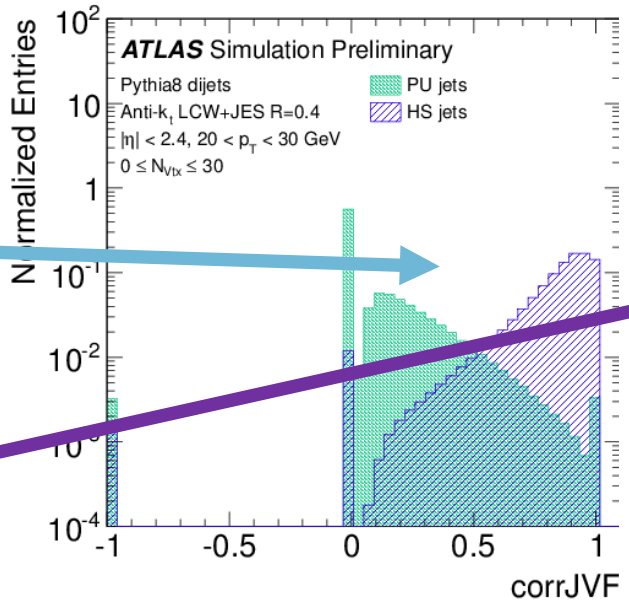


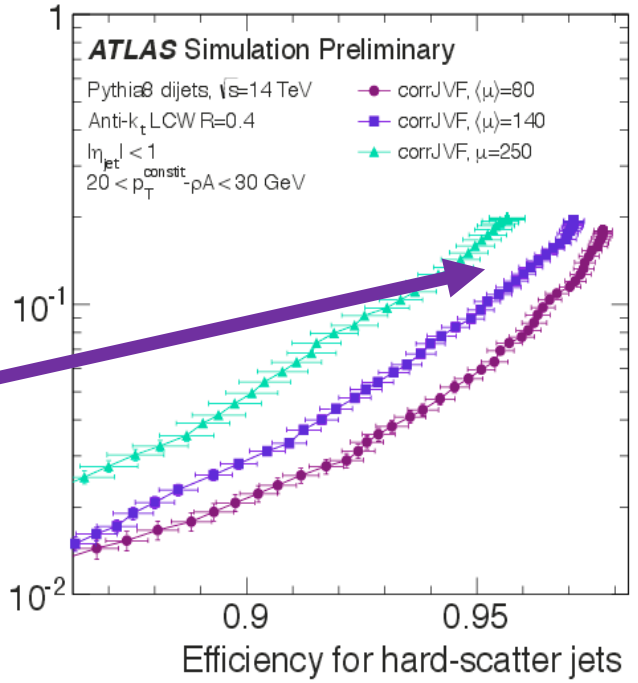


Run I -<μ> ~ 25

Run IV…<μ> ~ 200

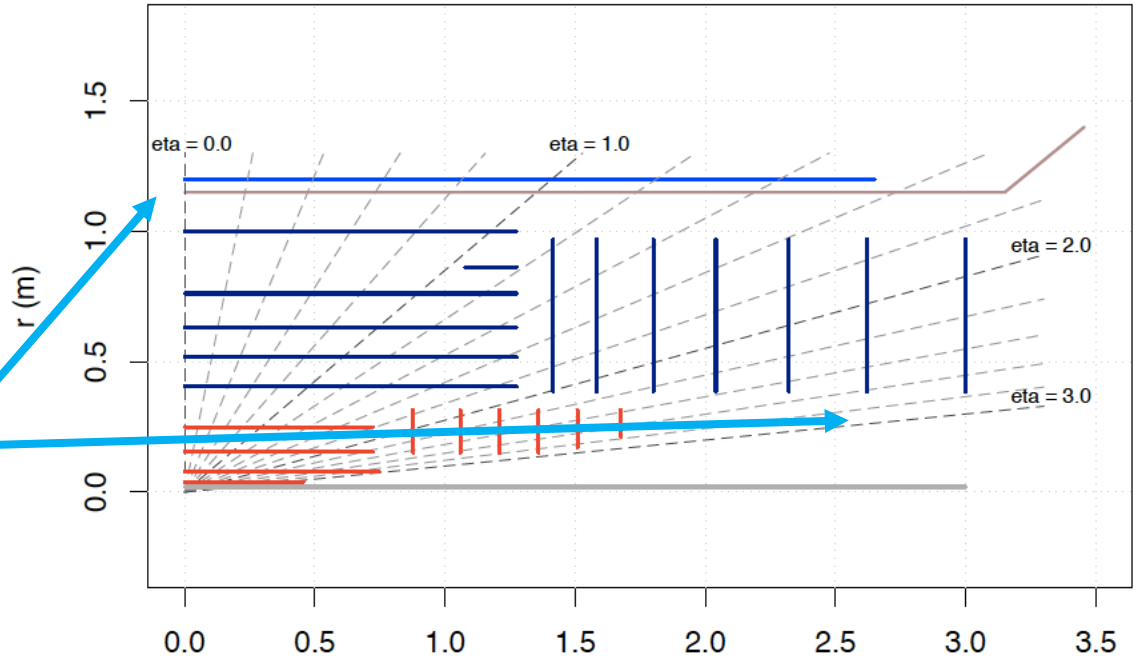
- corrJVF variable used to discriminate between PU and HS jets.
- Good rejection against PU jets for area corrected HS jets, at High mu.

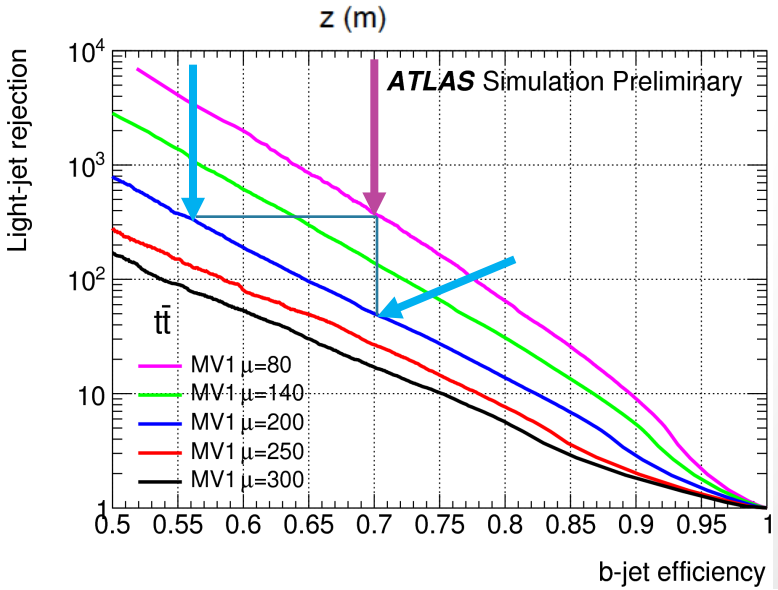




A fully new inner tracking detector (ITK)

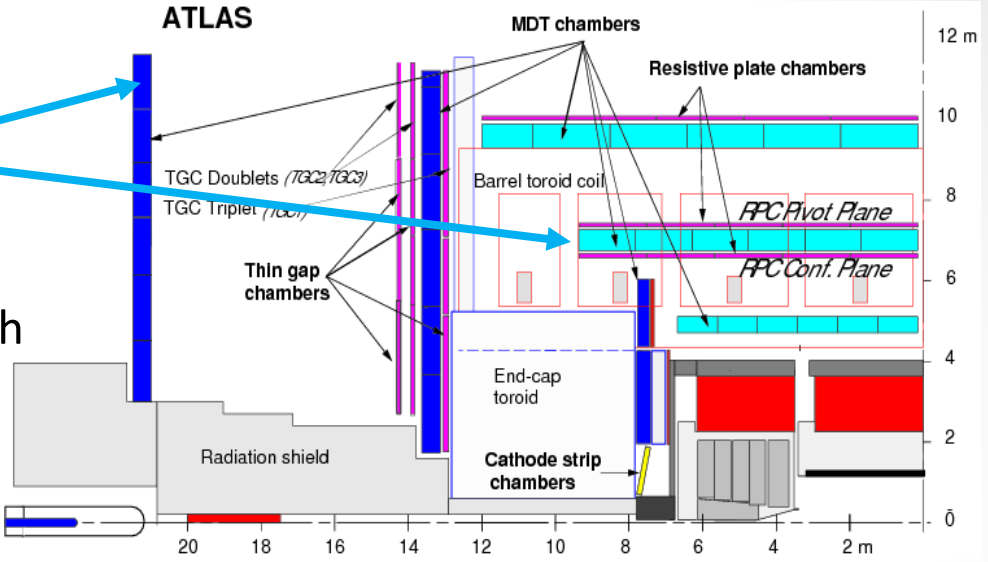
- Current ID will be replaced by the ITK after Run 3.
- Fully silicon detector will be built extending significantly current pixel+SCT radial and high-eta coverage and the detector performance by increasing the pixel density.
- A number of around 1000 tracks are expected per unit of rapidity, and an even larger track density is expected inside jets at the HL-LHC.
- B-tagging performance will be keept to good level using new multi-variate tagger, but new techniques will be needed to recover Run 3 (or better) performance.



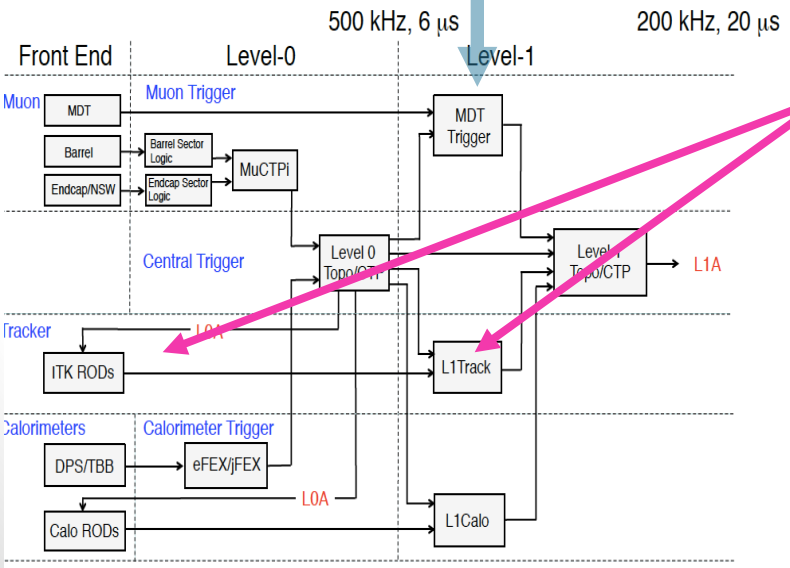


Split ATLAS hardware trigger system L0/L1 @ HL-LHC

- MDT chambers will be part of the L1-trigger at the HL-LHC, providing extra low-pT background reduction
- Current L1 trigger rate and latency is constrained by the MDT read out, which would be difficult to access/change



Detector	Max. Rate	Max. Latency
MDT	$\sim 200\,\text{kHz}$	$\sim 20\,\mu\text{s}$
LAr	any	any
TileCal	$> 300\,\text{kHz}$	any
ITK	$> 200\,\text{kHz}$	$< 500\,\mu\text{s}$



- L0/L1 Tracking will take information from the new ITK detector proving new triggering options at hardware level and better background/rate reductions, allowing a L1 output rate of 200 kHZ.
- This new trigger rates will demand the replacement of the calorimeters and muon system front and back-end electronics.

ATLAS UPGRADE

Summary

The ATLAS collaboration have developed an ambitious and detailed upgrade program for fulfilling the stringent luminosity conditions of the HL-LHC, while maintaining or improving the current detector performance.

❑ Run 2

- New innermost pixel layer (IBL).
- L1 topo-clustering.
- Detector consolidation.

❑ Run 3

- Improve of the L1 Trigger architecture, to cope with the high rate.
- Forward TracKing (FTK) Trigger
- NSW detector installation.

❑ HL-LHC

- New all silicon inner tracking detector.
- New trigger L0/L1 system architecture
- New Calorimeter and muon system electronics