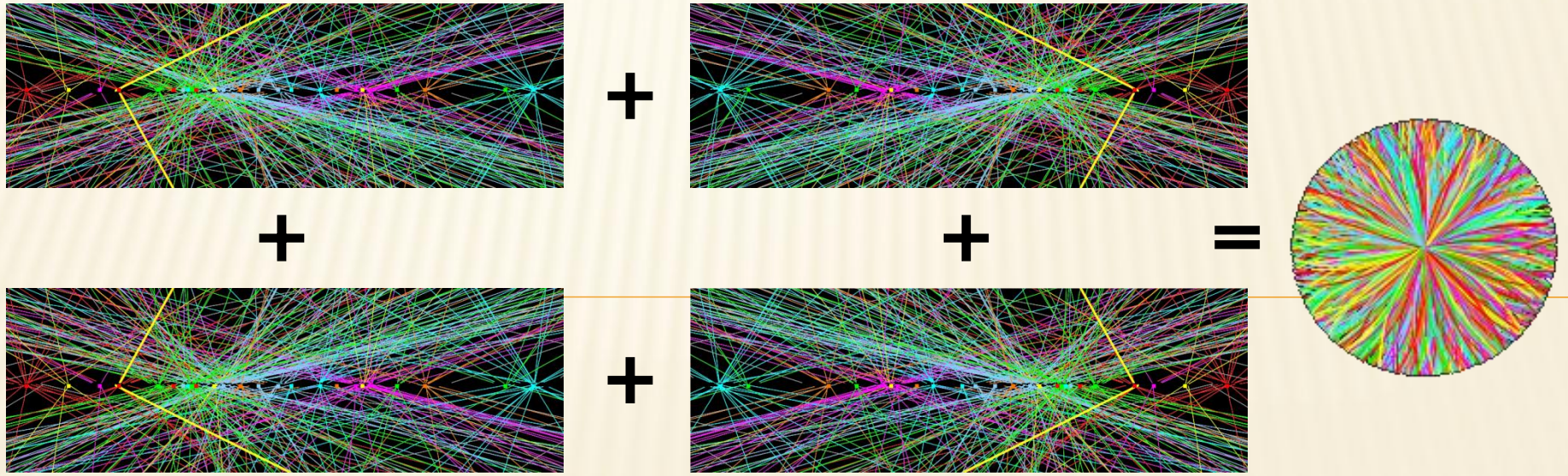
FUTURE PLANS AND UPGRADES OF THE ATLAS EXPERIMENT

Stephen Hillier, University of Birmingham
on behalf of the ATLAS Collaboration
ICFP 2012, Kolymbari, 15th June



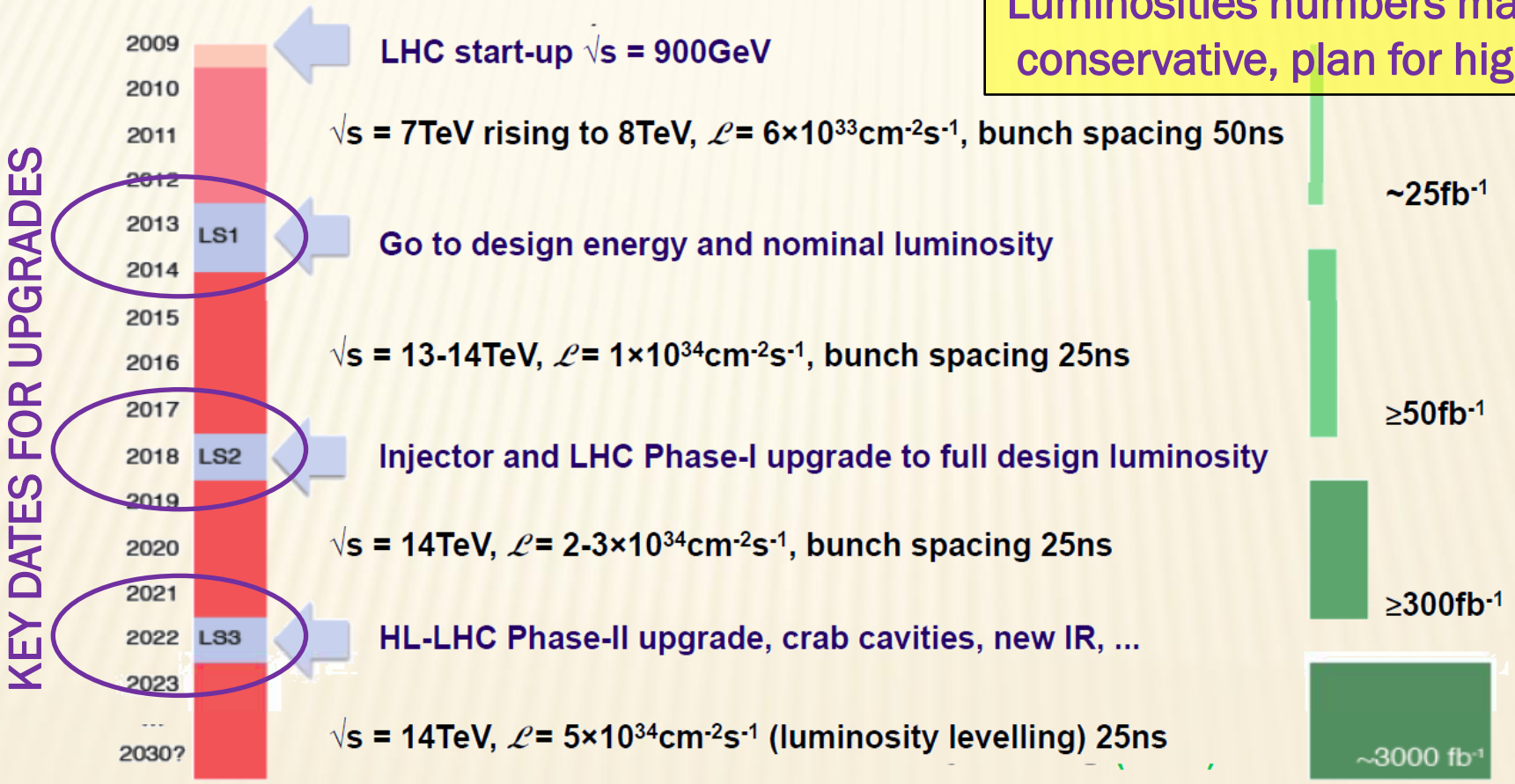
OUTLINE

- The high luminosity challenge
- Triggering
  - Enhanced Level-1, HLT and Dataflow
  - Muon Small Wheel
  - Increased Calorimeter Trigger Granularity
  - Strategy beyond 2022
- Tracking
  - Insertable B-Layer (IBL)
  - Fast Track Trigger (FTK)
  - Upgrade Inner Tracker (ITK)
- Upgrades in other areas

LHC LUMINOSITY FUTURE

- Future luminosity evolution not so dramatic
  - But it goes beyond design on a short time-scale

Luminosities numbers maybe conservative, plan for higher



LUMINOSITY CHALLENGE TO DETECTORS

- Radiation damage and ageing
  - Long-term replacement for Inner Detector always anticipated
  - Effect on other detectors to be studied with a view to replacement
    - Forward Calorimeters, Hadronic End-Cap
- High occupancy and particle flux
  - Up to 200 events per bunch crossing
  - Multiple hits reduce particle separation and resolution
  - Increased trigger and data rates
  - Calorimeter pulse shaping optimized for design pile-up
  - Cavern background in Muon detector
  - Increased activation of detector elements

ATLAS UPGRADE STRATEGY

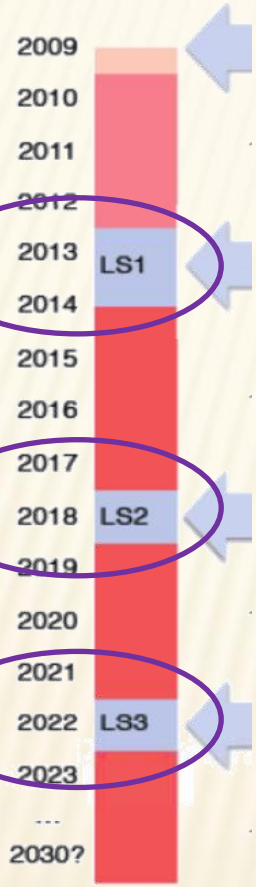
- Objective: maintain physics sensitivity at current level
  - Detailed investigation of Higgs sector, if Higgs found
  - Careful study of rare processes (WW scattering) if no Higgs
  - Continue search for new phenomenon at edge of mass range
- ATLAS plan a staged series of upgrades
  - Incrementally evolve in step in with LHC upgrades
  - New elements commissioned during each major shutdown
  - More radical overhaul of trigger and detectors in 2022
    - Required to cope with increased data bandwidth
    - Take advantage of new technologies and ideas
    - Increase flexibility and capacity to cope with new physics landscape

Trigger Priority: retain single lepton trigger with low threshold

Tracking Goals: increase momentum, vertex and double track resolution in the face of increasing occupancy

UPGRADES TIMELINE

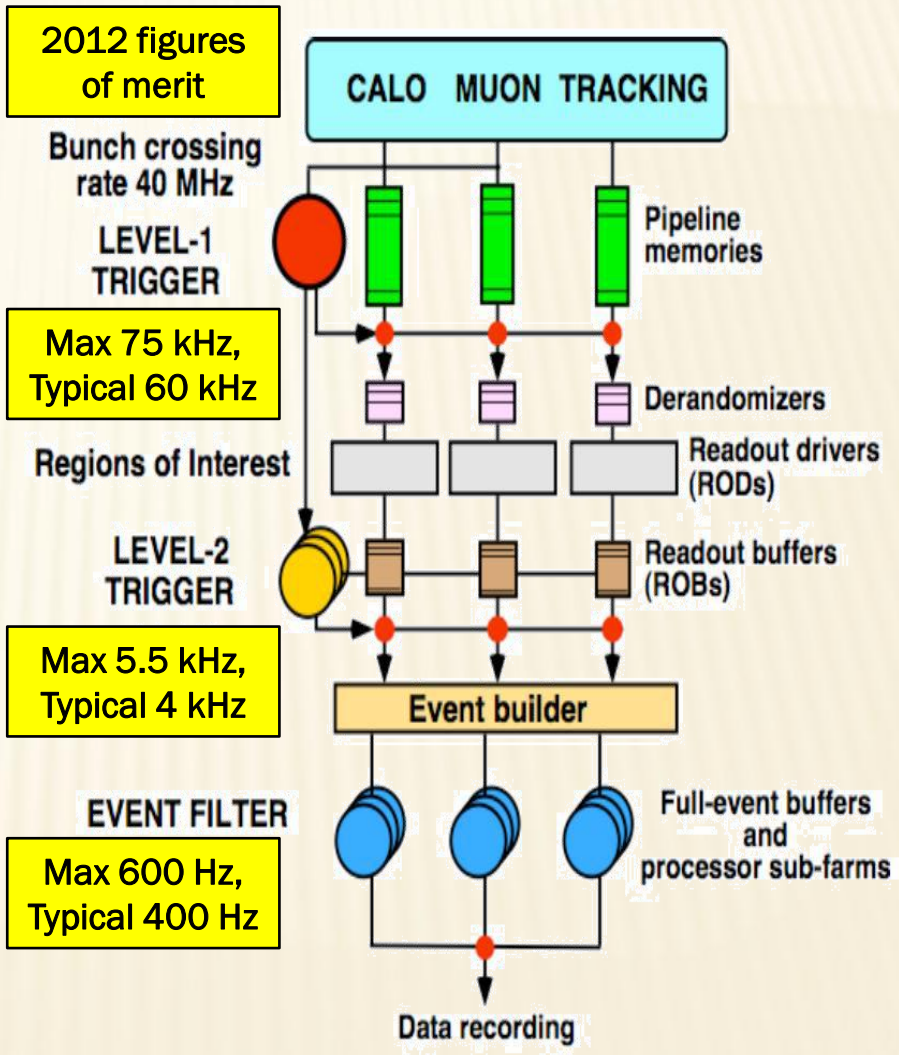
KEY DATES FOR UPGRADES



Triggering	Tracking	Other
bandwidth enhancements	Insertable B Layer	diamond beam monitor, consolidation
	Fast Track Trigger	
level-1 lepton trigger sharpening		ATLAS Forward Physics detectors
new level-1 and DAQ infrastructure	complete replacement of inner detector	calorimeter and readout upgrades

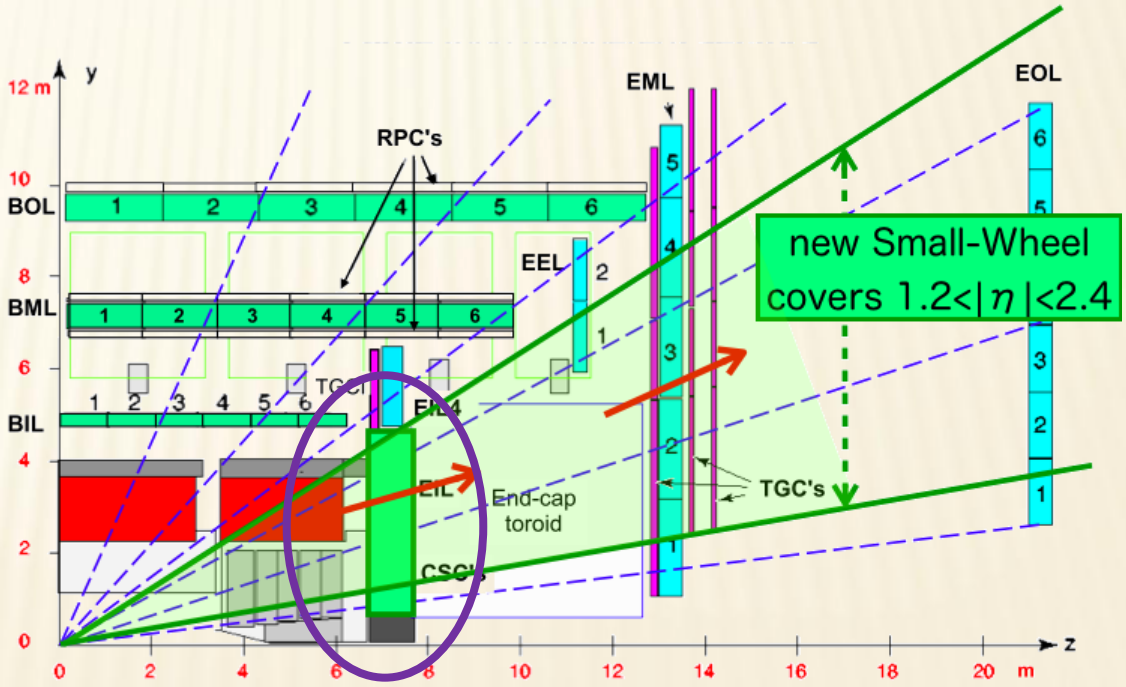
TRIGGER ENHANCEMENTS 2014+

- Level-1
  - Add topological functionality and extra flexibility
  - Move to 100 kHz L1A rate
    - Requires detector readout upgrades
- High Level Trigger
  - Integrated Level-2/Event Filter processing
  - Interface with FTK
- Dataflow
  - Longer term move to new readout links
  - More event building and recording capacity
    - In parallel with detector upgrades



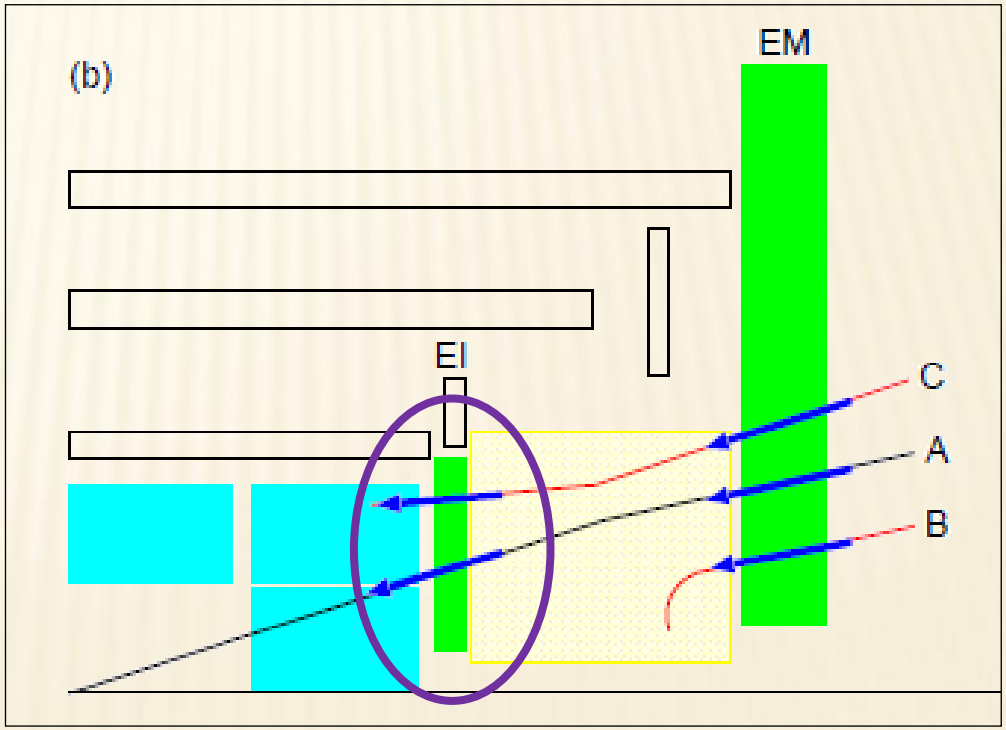
NEW MUON SMALL WHEELS 2018

- Motivation - Muon trigger rates at high eta escalate:
  - High cavern background
  - Coincidence triggers with high multiplicity
- Solution:
  - New small wheels which also form a new trigger station
  - Technology likely to combine TGC and Micromegas
  - Improved shielding
  - Future-proofed for HL-LHC operation



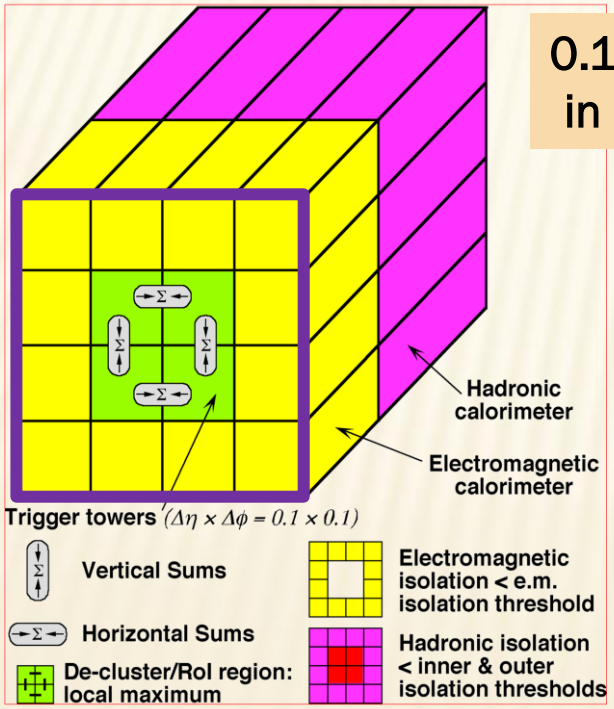
NEW MUON SMALL WHEELS 2018

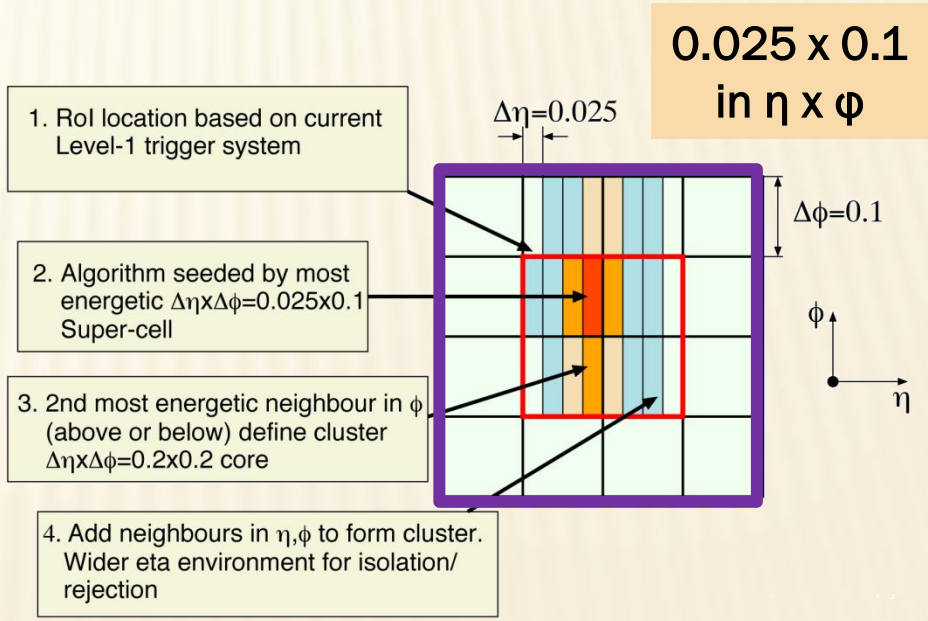
- Motivation - Muon trigger rates at high eta escalate:
  - High cavern background
  - Coincidence triggers with high multiplicity
- Detector resolution
  - Position < 100 μm
  - Angular ~ 1 mrad
- Trigger rate reduction
  - 20% of current
  - Small reduction in efficiency
- Additional logic required for Level-1 muon trigger



HIGH GRANULARITY CALORIMETER TRIGGER 2018

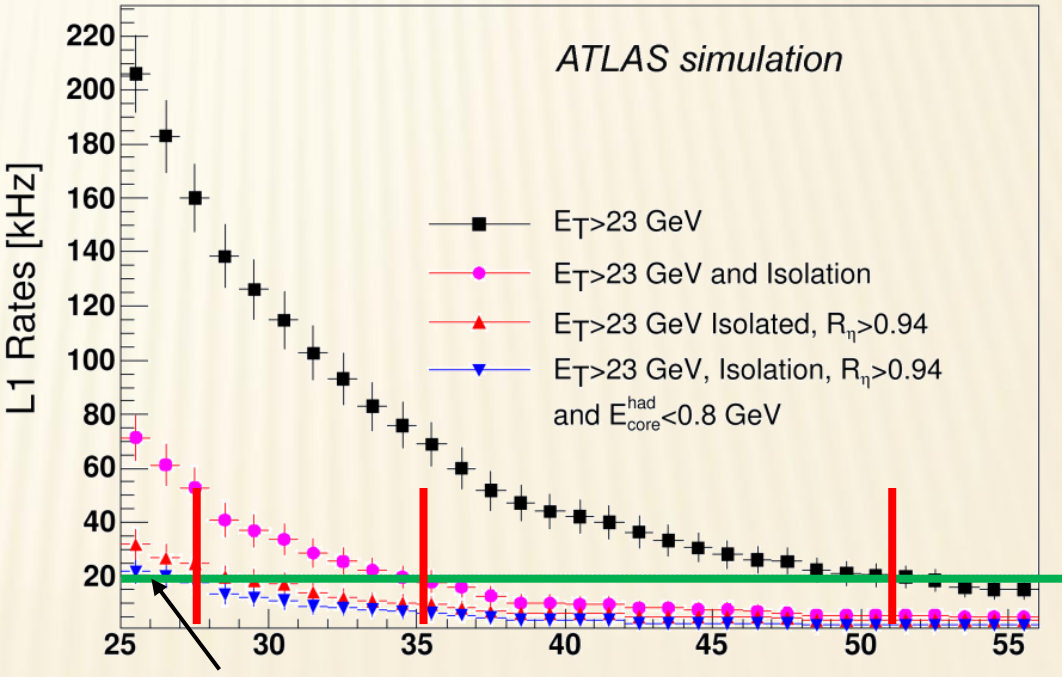
- Motivation - Electron trigger rates escalate:
  - Jet background
  - Pile-up makes isolation cuts less attractive
- Solution:
  - Higher granularity trigger towers





HIGH GRANULARITY CALORIMETER TRIGGER 2018

- Motivation - Electron trigger rates escalate:
  - Jet background
  - Pile-up makes isolation cuts less attractive
- Requires several new components
  - Front-end digitizers
  - Off detector processor
  - Latency unchanged
- Gain is ~3 times rate reduction for single electron trigger
- Legacy hardware initially run in parallel



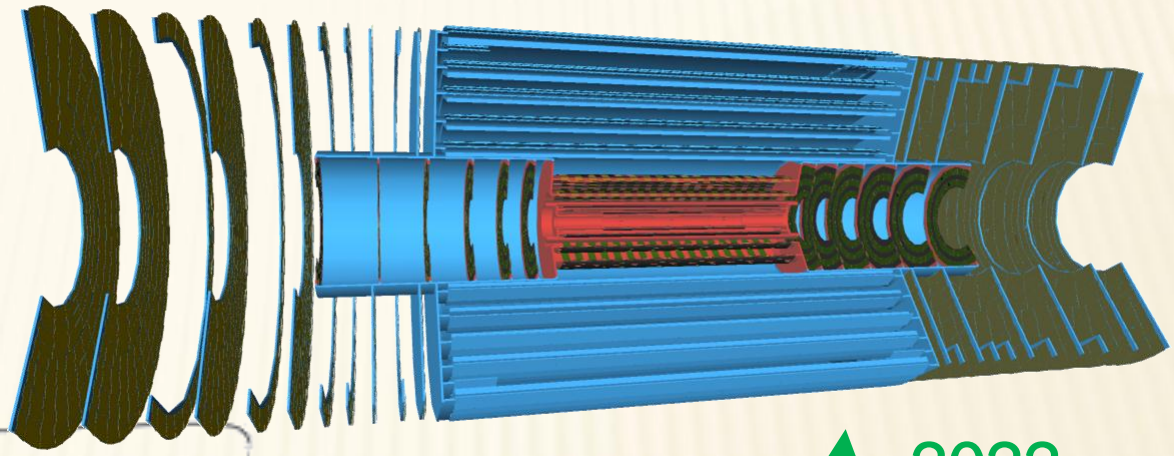
Electron trigger rate budget ~ 20 kHz

TRIGGER STRATEGY BEYOND 2022

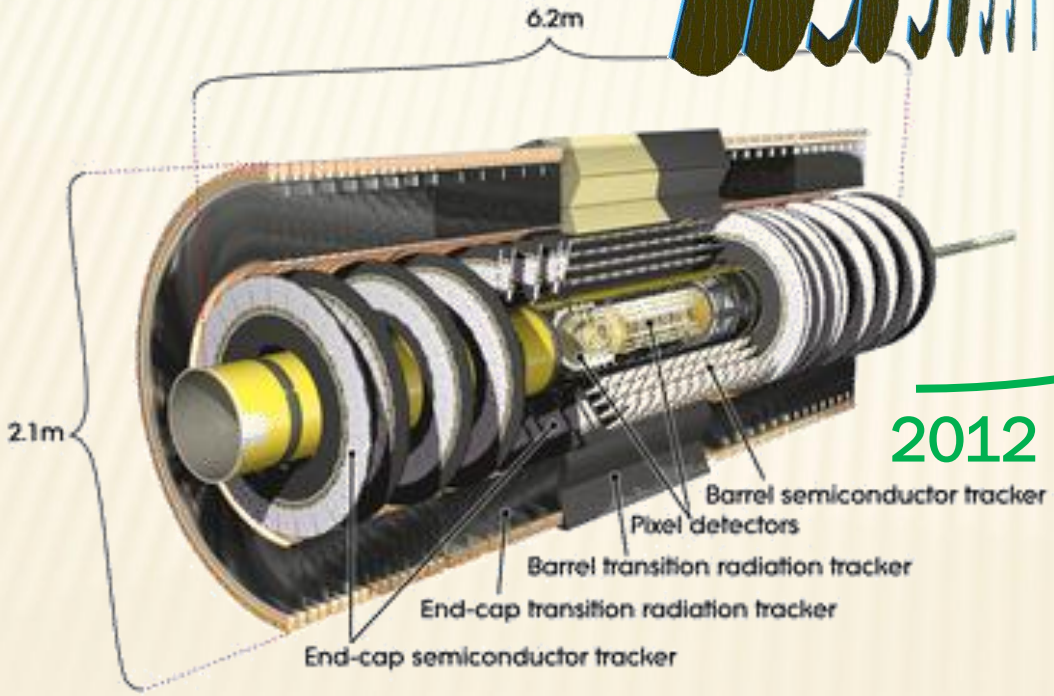
- Important that all short-term upgrades compatible with future strategy
- Concern that 100 kHz Level-1 rate too restrictive
- Two options
  - Increase Level-1 rate
  - Introduce a new stage - Level-0 and Level-1
    - Level-0 500 kHz, latency 5 μs
    - Level-1 200 kHz, latency 20 μs
- Second option allows for a Level-1 Track Trigger
  - RoI Based or self-seeded
- Trigger, DAQ and detector readout infrastructure will require a large over-haul

TRACKING UPGRADES

Upgrade of Inner Tracker is the main activity for 2022



2022

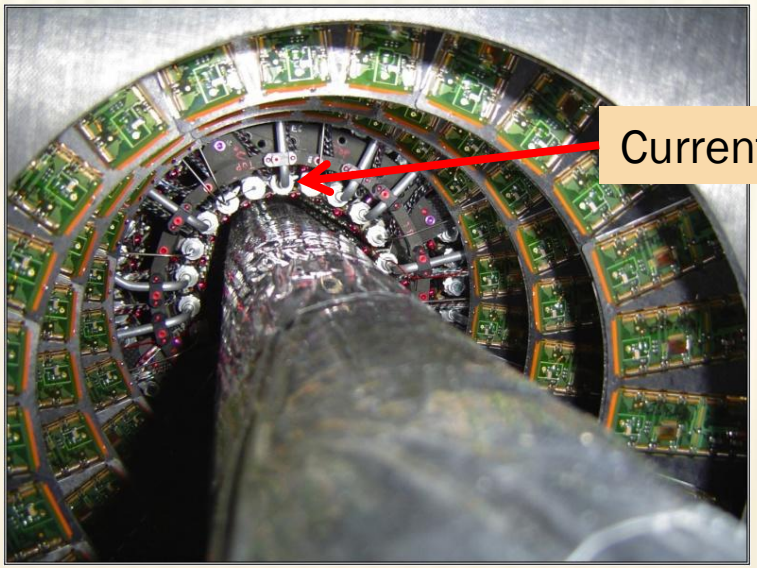


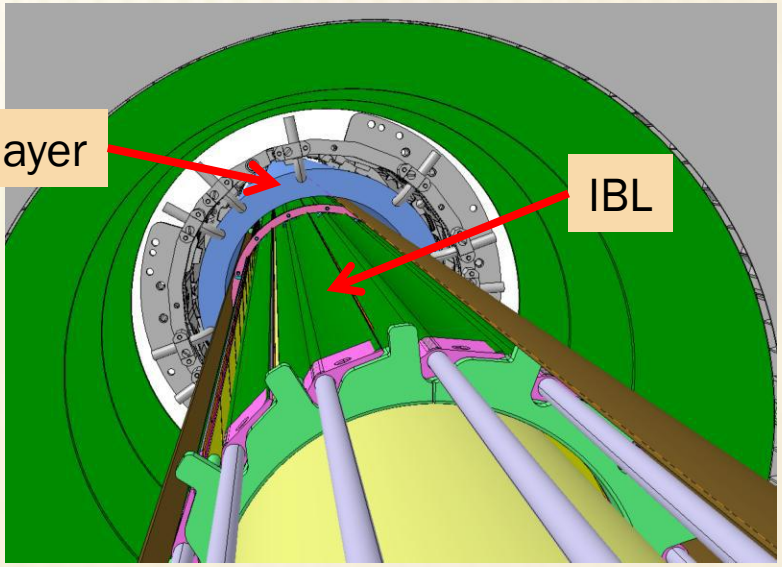
2012

There are also some smaller steps en-route

INSERTABLE B-LAYER (IBL) 2013/14

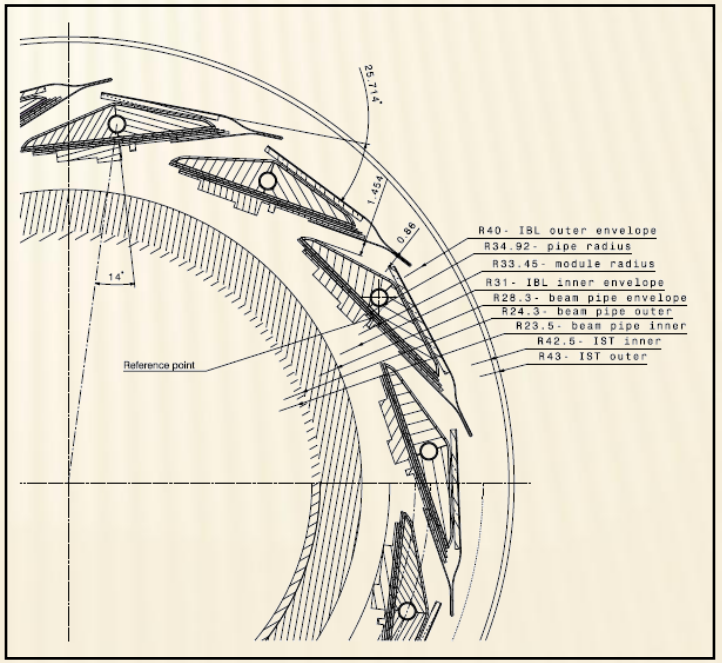
- Extra layer of pixel detectors inside current ID volume
  - Made possible by smaller beam-pipe (29 mm → 25 mm)
  - Can be installed in-situ without interference to current system
  - Integration also possible on surface with removal of pixel volume





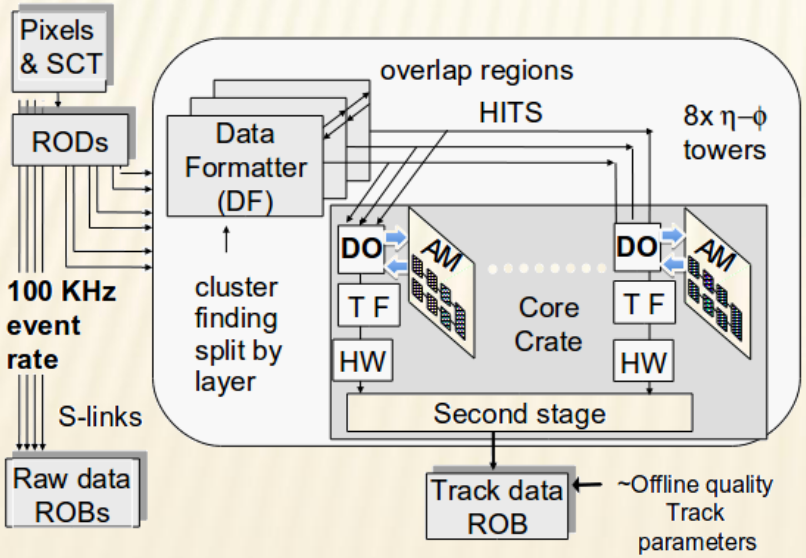
INSERTABLE B-LAYER (IBL) 2013/14

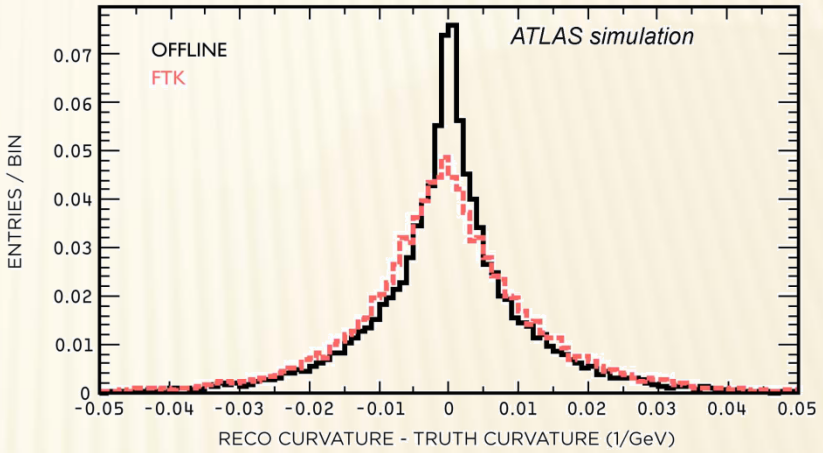
- Motivation
  - High Occupancy in current Pixel leads to inefficiency
    - Double hits, bandwidth limitations
  - Smaller pixels and smaller radius gives better resolution
    - Vertexing, tracking and b-tagging
  - Improved radiation tolerance
- Layout
  - Average radius 33mm
  - Length 60 cm covering $\eta<2.5$
  - 14 planes with overlap in φ

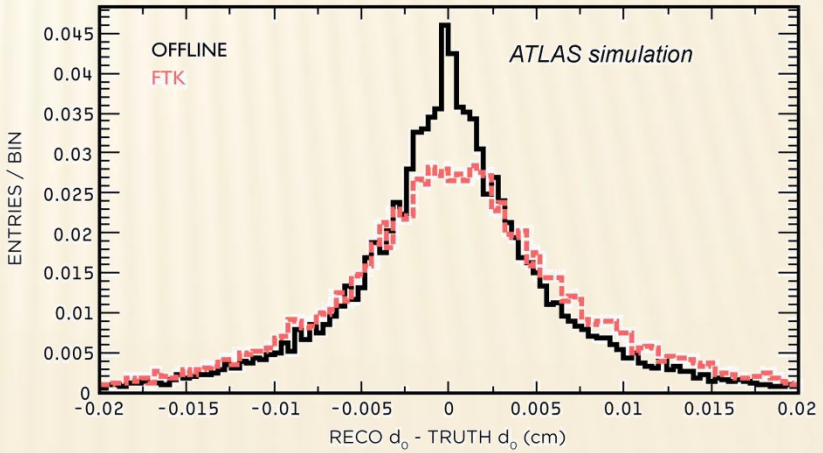


FAST TRACK TRIGGER (FTK) 2014 ONWARDS

- Hardware Trigger Processor
  - Global scope for Pixels and Silicon Tracker (SCT)
- Acts as pre-processor to Level-2 algorithms
  - Hence speed-up for Level-2 processing
- Provides offline-like track information
- Barrel coverage expected in 2014
  - Full coverage will follow soon afterwards

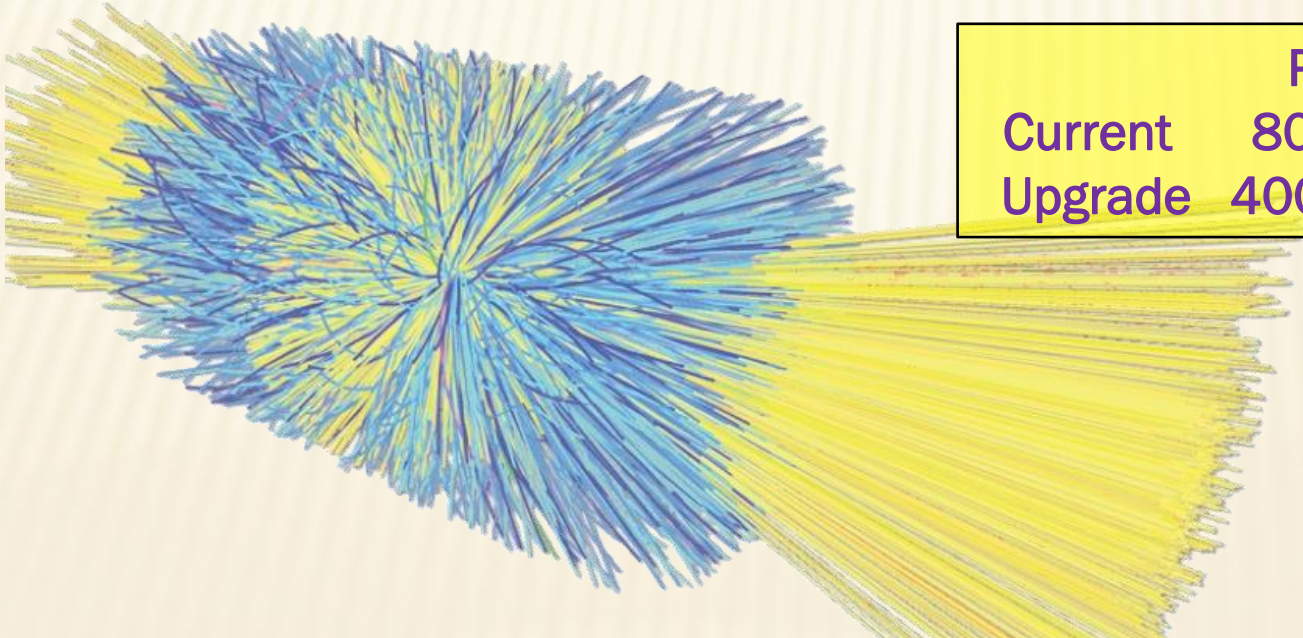






UPGRADE INNER TRACKER (ITK) 2022

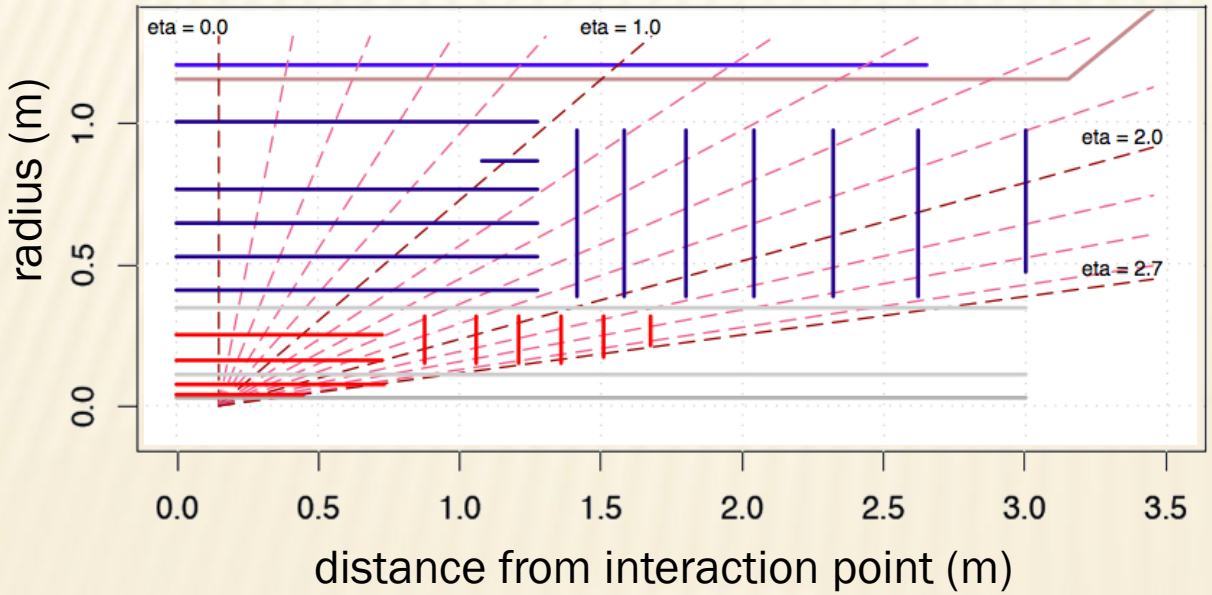
- Tracker Upgrade foreseen for many years
  - Pixel/SCT degradation expected with radiation dose
  - Occupancy and readout bandwidth limitations, also affecting TRT
- Upgrade planning already well advanced
  - Full silicon replacement for all of Inner Tracker
  - 4 pixel layers, 5 double sided strips in barrel plus disks in endcap
  - Shorter strips to compensate for higher occupancy

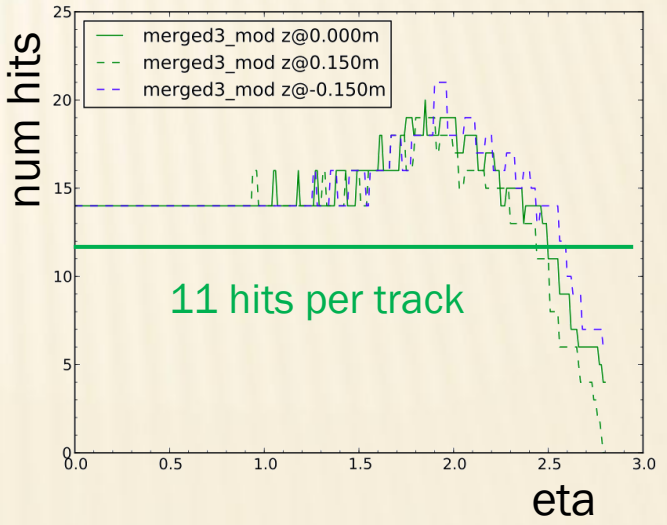


	Pixels	Strips
Current	80 million	6 million
Upgrade	400 million	45 million

UPGRADE INNER TRACKER (ITK) 2022

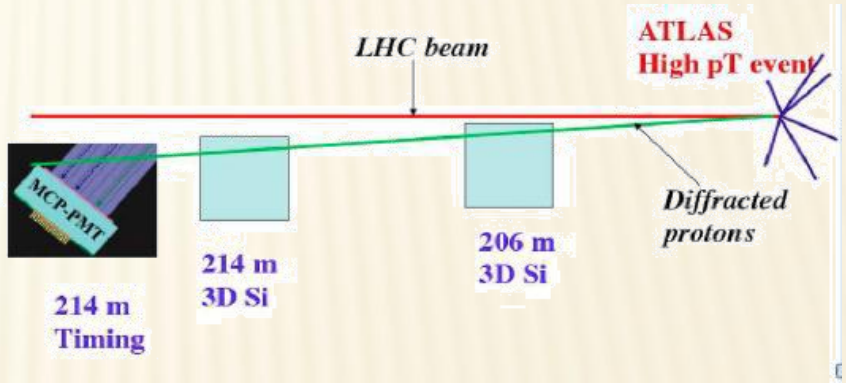
- Necessary enhancements for high luminosities
  - Better radiation tolerance
  - Minimum number of space points: 11 up to η of 2.5
    - Increases ability to resolve hits in high occupancy environment
    - Includes small layer in barrel/endcap transition to maintain coverage
  - Utilize full envelope to maximize momentum resolution
- Latest Layout:





UPGRADES IN OTHER AREAS

- During 2013/2014 shutdown
  - Numerous consolidations
    - Shielding, power supplies, magnet systems, cooling, pixel services and diamond beam monitor
- During 2018 shutdown
  - ATLAS Forward Physics
    - Enhance diffractive physics
- During 2022 shutdown
  - Possible replacement of some calorimeter systems
    - Requires opening of end-cap cryostat, need being assessed
  - Numerous electronics/readout upgrades

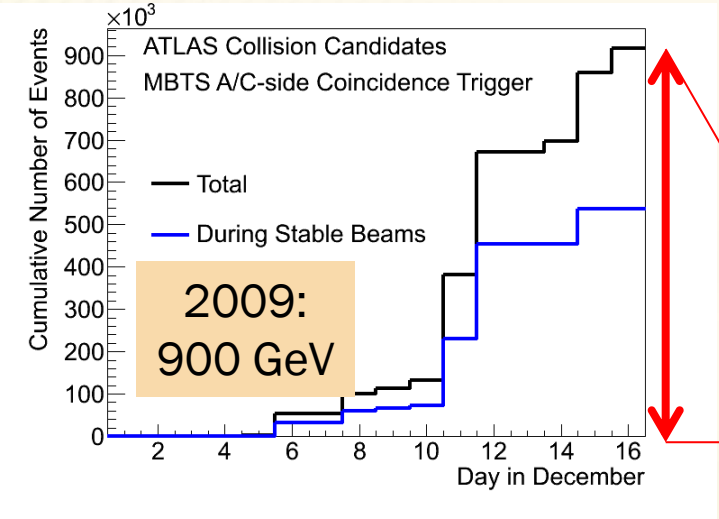


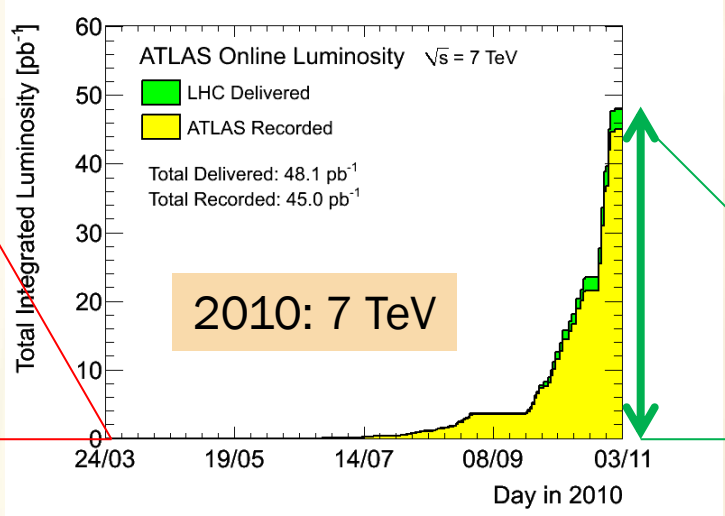
CONCLUSIONS

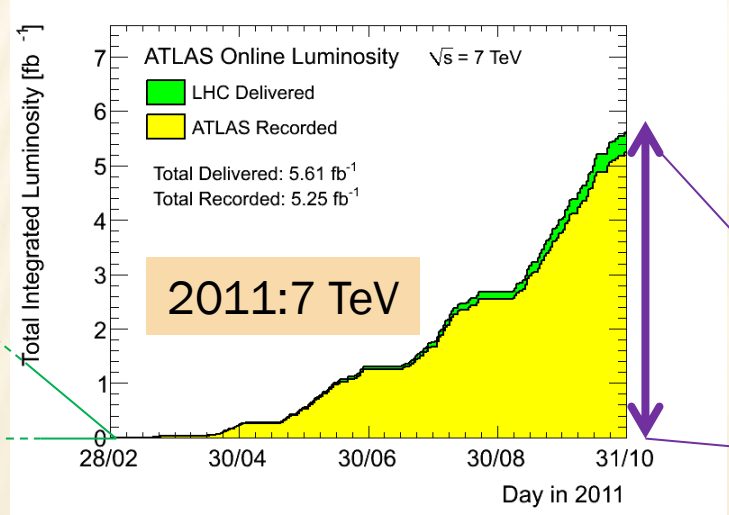
- ATLAS has a diverse set of upgrade projects
  - Many are already rather mature
  - Ambitious plans with plenty of technological challenges
- Require constant evolution of ideas and techniques to keep pace with LHC
  - Many people also still heavily involved with Operation
- We can't afford to relax and just watch the data roll in!

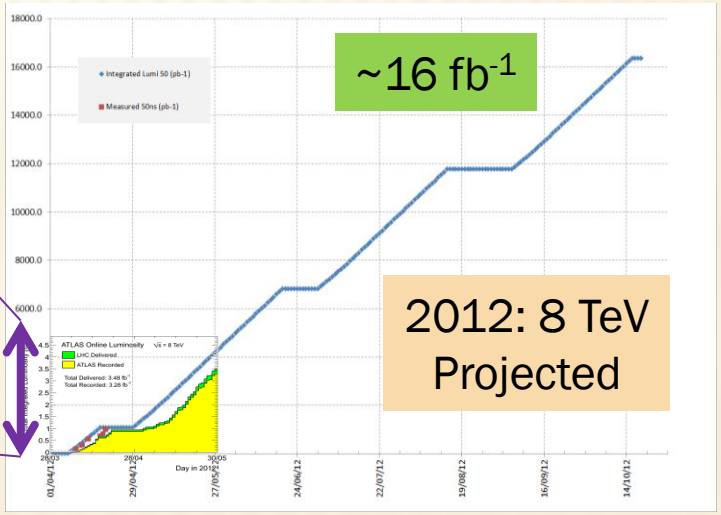
EXTRAS

LHC LUMINOSITY HISTORY



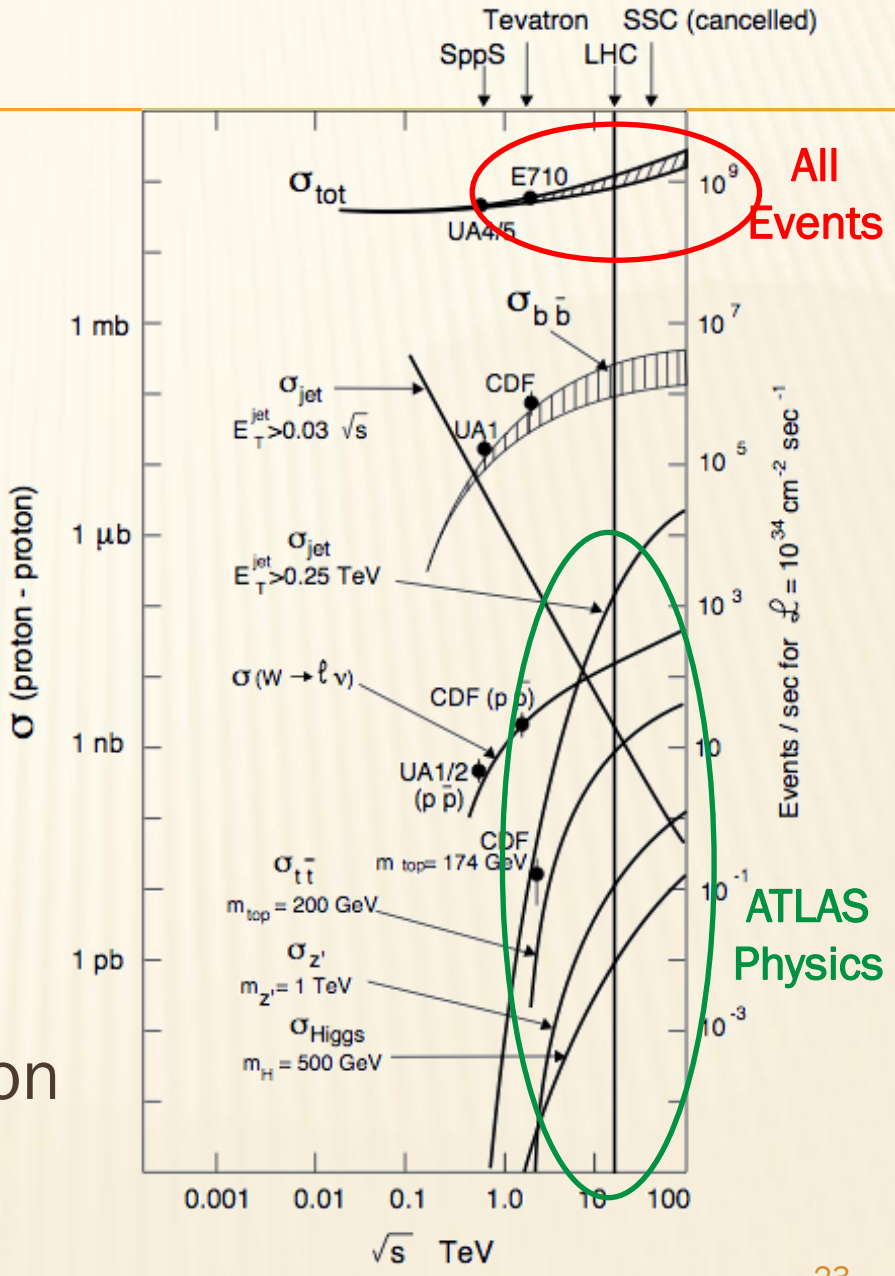






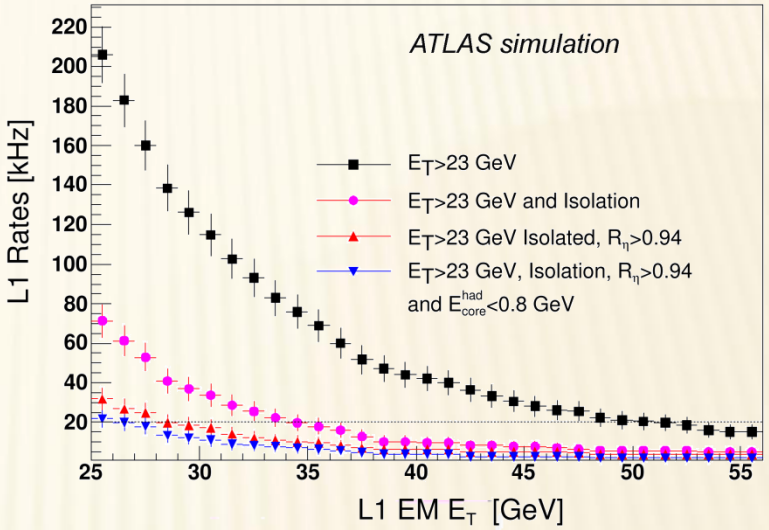
TRIGGER UPGRADES

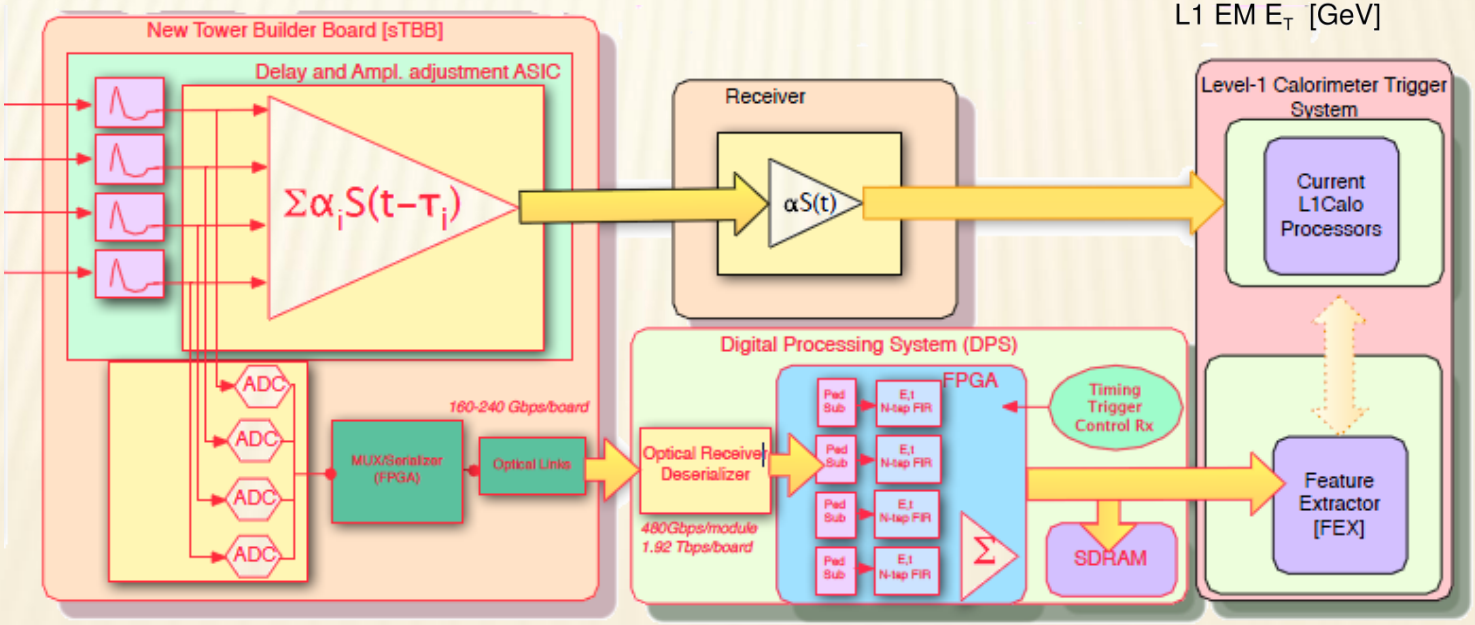
- LHC at 5 x 10^{34} means
- In one second:
  - 5 x 10^{9} collisions
  - 20 top pair events
  - <1 Higgs or exotic events
- We need to pick carefully
- Priority: maintain single lepton trigger with low threshold



HIGH GRANULARITY CALORIMETER TRIGGER

- Requires several new components
  - Calorimeter Front End digitizers
  - Off detector trigger processing
  - Must fit within current latency
- Gain is ~3 times rate reduction for single electron trigger
- Legacy hardware run in parallel





LEVEL-1 TRACK TRIGGER 2022

- New tracker gives potential for a track trigger
  - Combined with Level-0/Level-1 trigger architecture
- Vital to keep single lepton thresholds low
  - Higgs sector and W/Z mass range
- Decisions needed soon for ITK design
  - RoI based: uses Level-0 electron and muon information
  - Self-seeded: locally formed tracks read out when required
- Assessments still ongoing
  - Comes at a price: higher power and material budget, increased triggering complexity