LHC Status & Plans

Craig Buttar
PPAP community meeting
September 2015

2015: Re-commissioning the LHC

- Target energy: 6.5 TeV
  - looking good after a major effort
- Bunch spacing: 25 ns
  - strongly favored by experiments to reduce pile-up
- Increase luminosity β^* in ATLAS and CMS: reduce from 80 to 40 cm

Challenges to achieve 6.5TeV

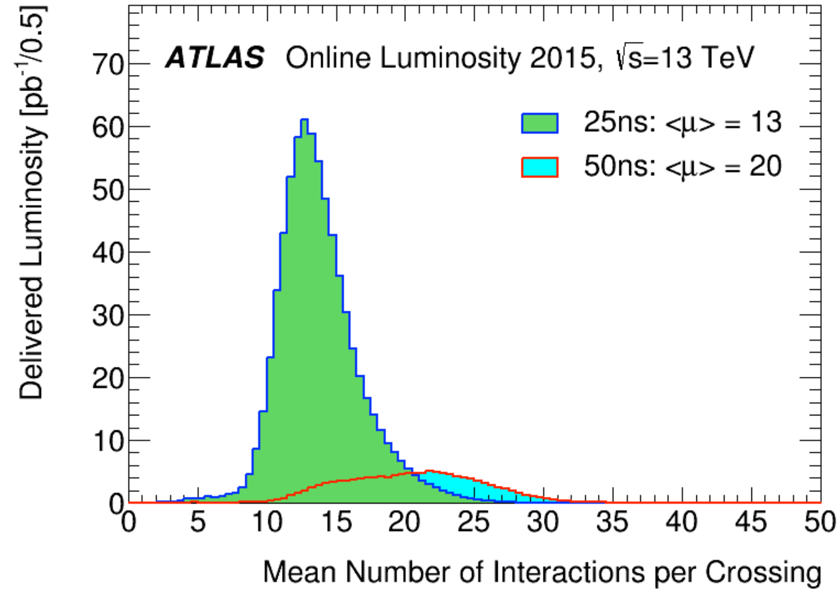
- Lower quench margins
- Lower tolerance to beam loss
- Hardware closer to maximum (beam dumps, power converters etc.)

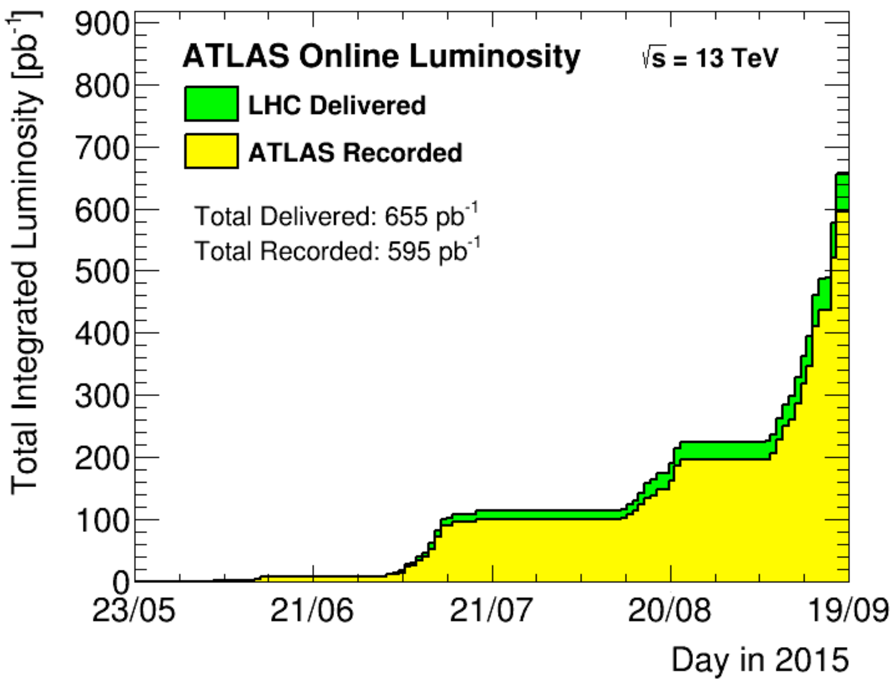
Challenges to achieve 25 ns bunch spacing

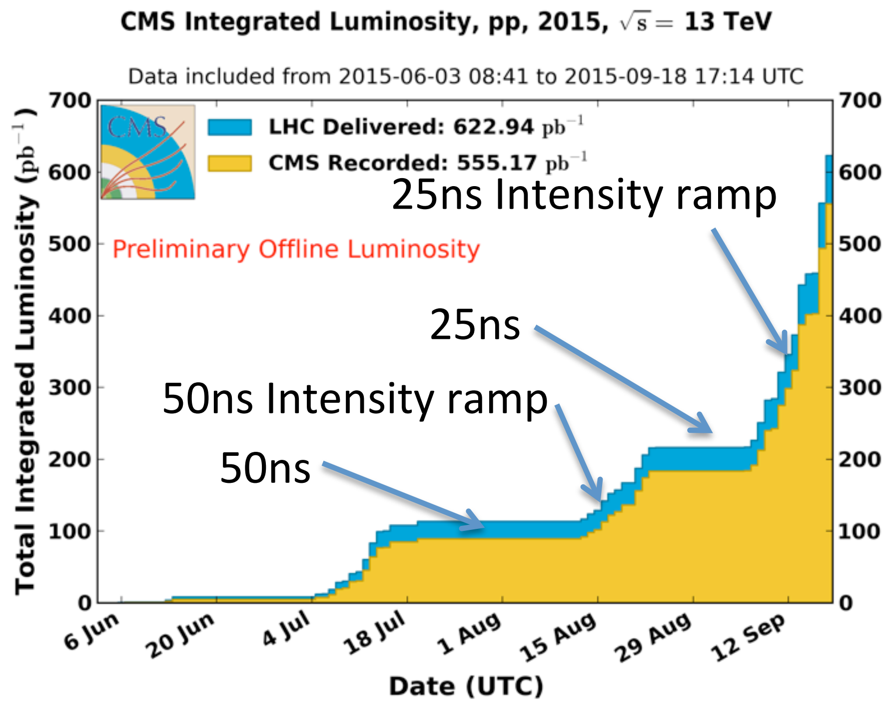
- Electron-cloud
- UFOs
- More long range collisions
- Higher total beam current
- Higher intensity per injection

Luminosity for 2015

- Experiments have ~0.9fb^{-1} luminosity
  - Pileup ~13 for 25ns at 1-2x10^{33}cm^{-2}s^{-1}



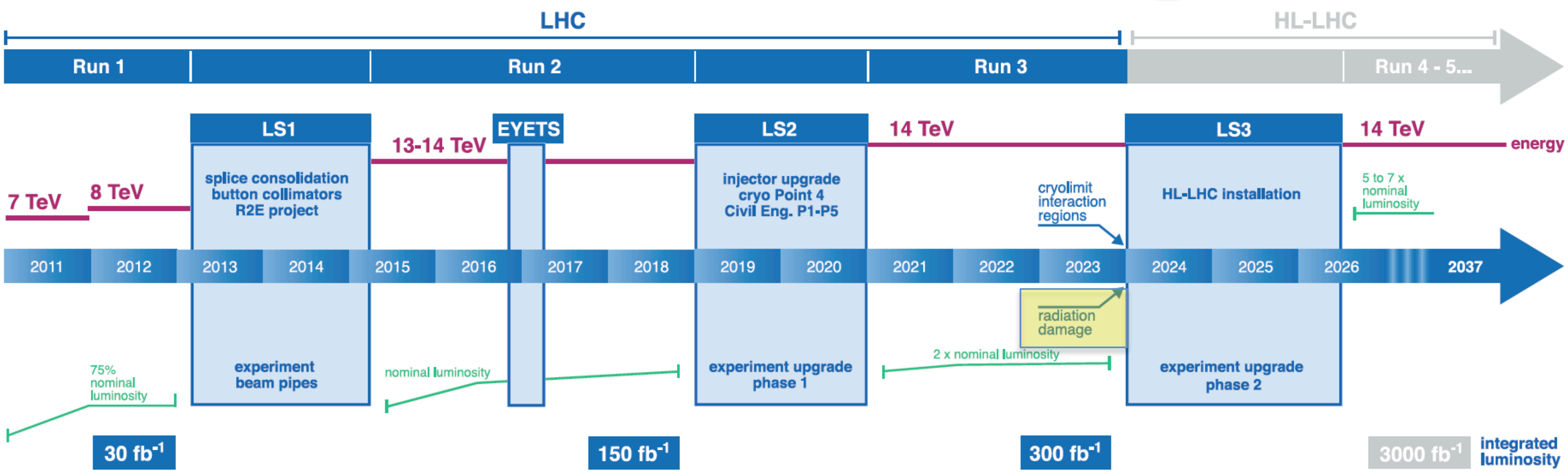




2015: Re-commissioning the LHC

- Achieved 6.5 TeV beam energy
- Luminosity delivered at 50ns and 25ns bunch spacing
- Working to increase luminosity
  - e-cloud: beam scrubbing
  - β^* currently at 80cm, working to reduce to 40cm
  - Try BCMS injection scheme, lower emittance and 30% high luminosity possible
- Due to some technical issues number of physics days reduced to 70d → target luminosity reduced to 3-5fb^{-1}
- The return of the LHC has been a great success, much experience gained that will be put into practice next year

LHC / HL-LHC Plan



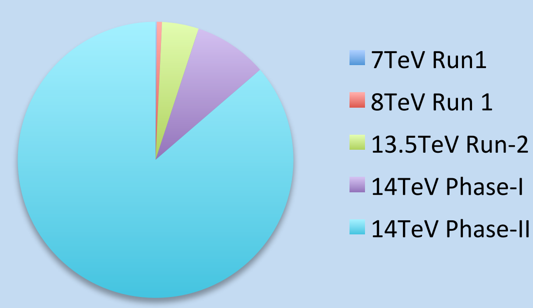
Run-3

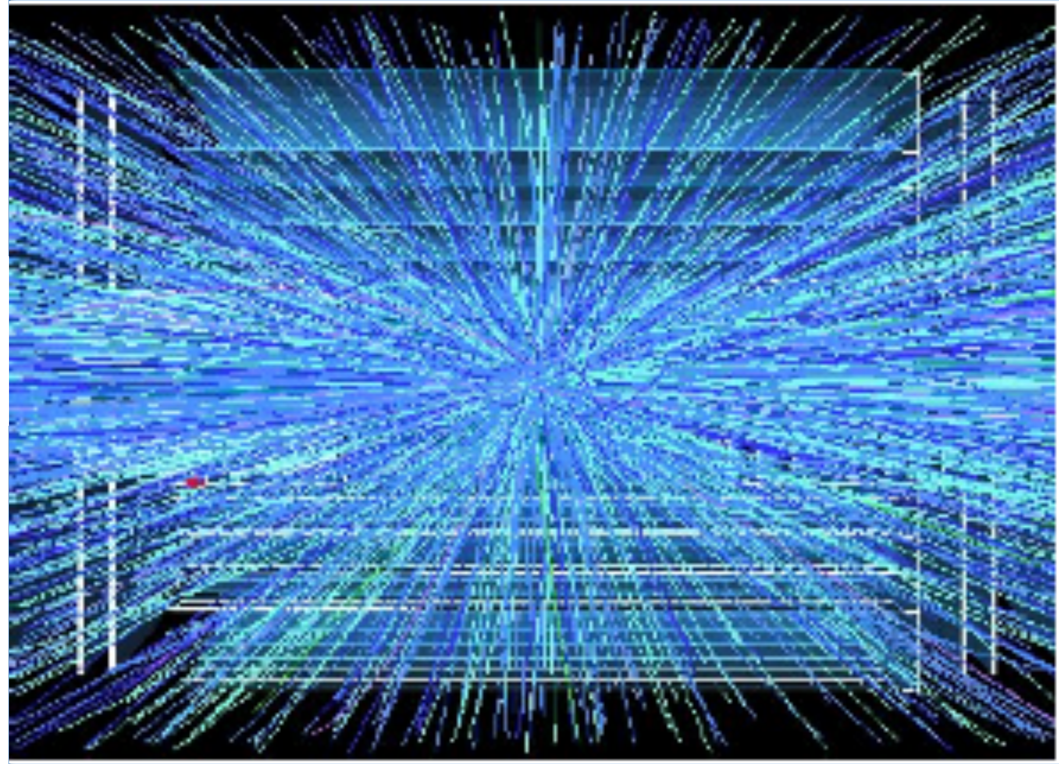
- LHC will increase to 2 x nominal luminosity, 2-3x10^{34}cm^{-2}s^{-1}
- Aim to provide 300fb^{-1} by end of 2023
- Pile-up = mean of ~55-80 soft pp collisions/event

HL-LHC

- HL-LHC will begin operation ~2026
- Aim to provide 3000fb^{-1} by 2035
- Instantaneous luminosity up to 7.5x10^{34}cm^{-2}s^{-1}
- Pile-up up to a mean of ~200 soft pp collisions/ event

LHC Luminosity





ATLAS report to Particle Physics community

Craig Buttar

on behalf of ATLAS-UK

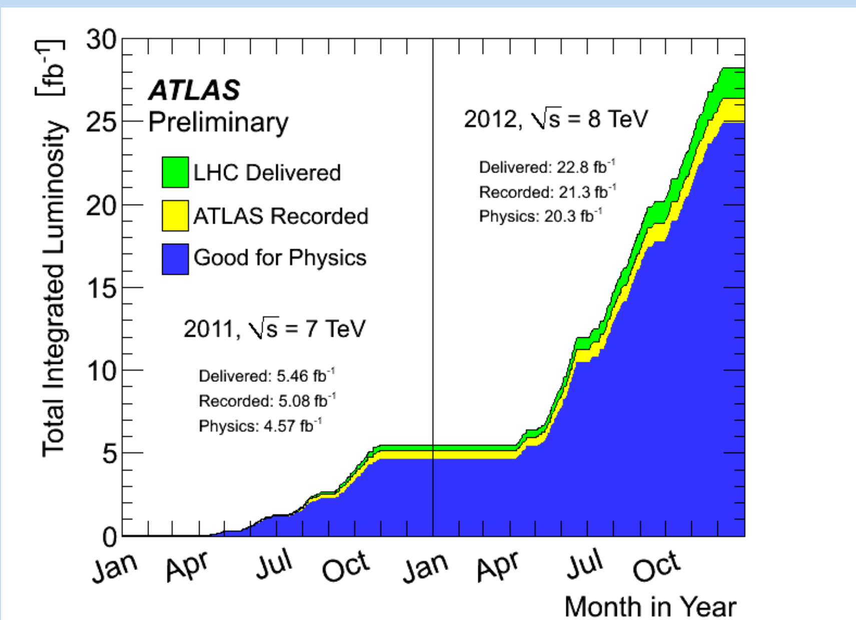
UK-ATLAS

- 14 Universities + STFC/RAL
- ~300 authors --> ~11% of ATLAS collaboration
- ~70 academics, ~33% of UK PP academic community
- Currently UK holds
  - ~20% of senior management positions:
    - Current spokesperson: Dave Charlton (2nd term)
    - Incoming Physics coordinator: Dan Tovey
    - Incoming Data Preparation coordinator: Paul Laycock
    - Incoming Run coordinator: Alex Cerri
    - Inner Detector Project Leader: Dave Robinson
  - 4 of 8 Physics groups have UK convenors
- Recent senior positions: Two physics coordinators, upgrade coordinator, publications committee chair, trigger coordinator
- UK played major roles in construction of ATLAS experiment: Silicon strip tracking detector (SCT), L1 calorimeter trigger, High Level Trigger (HLT), Computing & Software
  - UK continue to lead operation of key elements of ATLAS: Inner tracker (SCT), Trigger: Level-1 Calorimeter trigger & High Level Trigger, Computing & Software
- UK is taking forward its expertise and leadership in the detector construction into Phase-I and Phase-II Upgrades

Run-I

Summary of Run-1 Data Taking

- Run-1 data taking completed in Feb. 2013
  - Outstanding performance of LHC machine and ATLAS detector



ATLAS Run-1 Detector Status (from Oct. 2012)

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	95.0%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	97.5%
LAr EM Calorimeter	170 k	99.9%
Tile calorimeter	9800	98.3%
Hadronic endcap LAr calorimeter	5600	99.6%
Forward LAr calorimeter	3500	99.8%
LVL1 Calo trigger	7160	100%
LVL1 Muon RPC trigger	370 k	100%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	96.0%
RPC Barrel Muon Chambers	370 k	97.1%
TGC Endcap Muon Chambers	320 k	98.2%

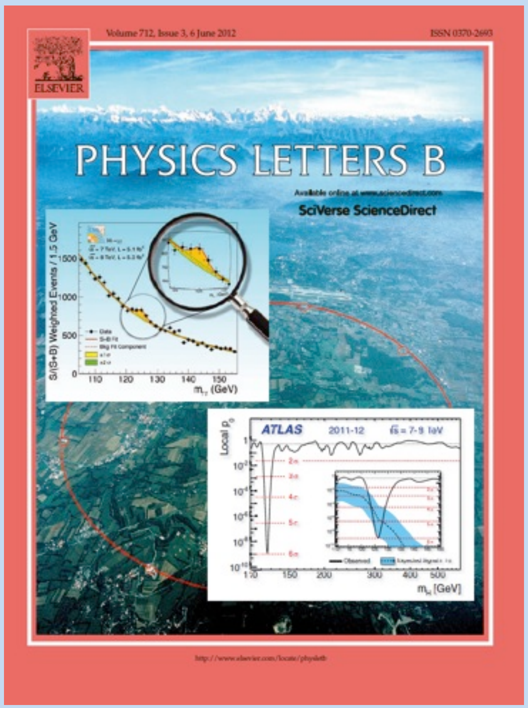
All good for physics **95.5%** of all data
89% of delivered luminosity is of physics quality
"Constant attention to detail by many people, at CERN and home institutes was essential to obtain such high efficiencies for data-taking and data quality." D.Charlton ATLAS spokesperson

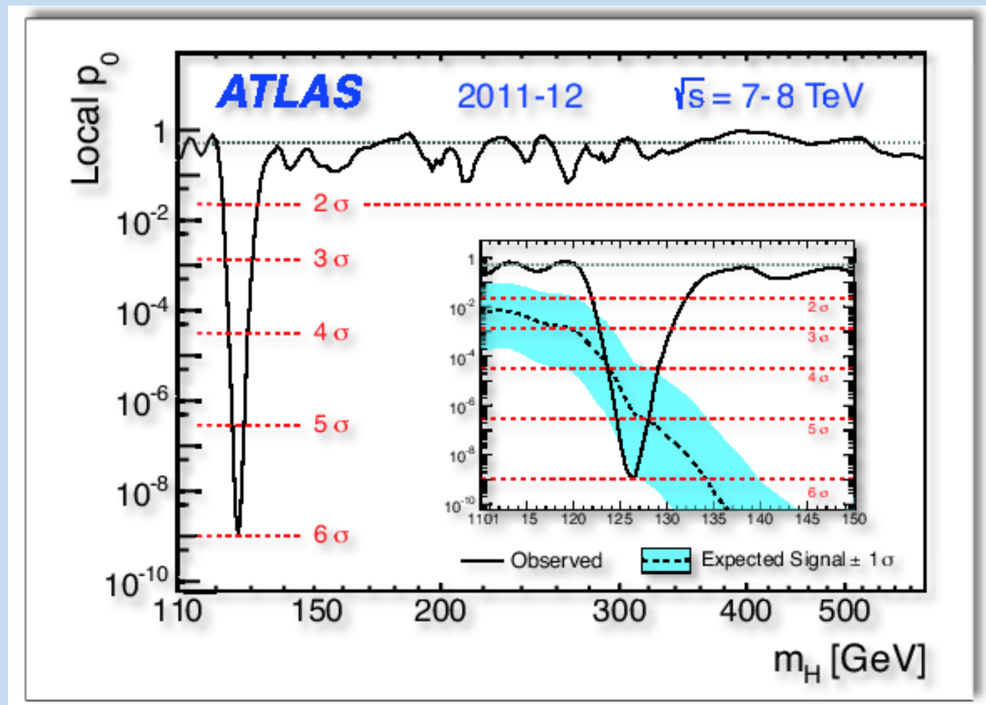
Summary: The Discovery of the Higgs Boson

Dec. 2013

JULY REVOLUTION (2012)

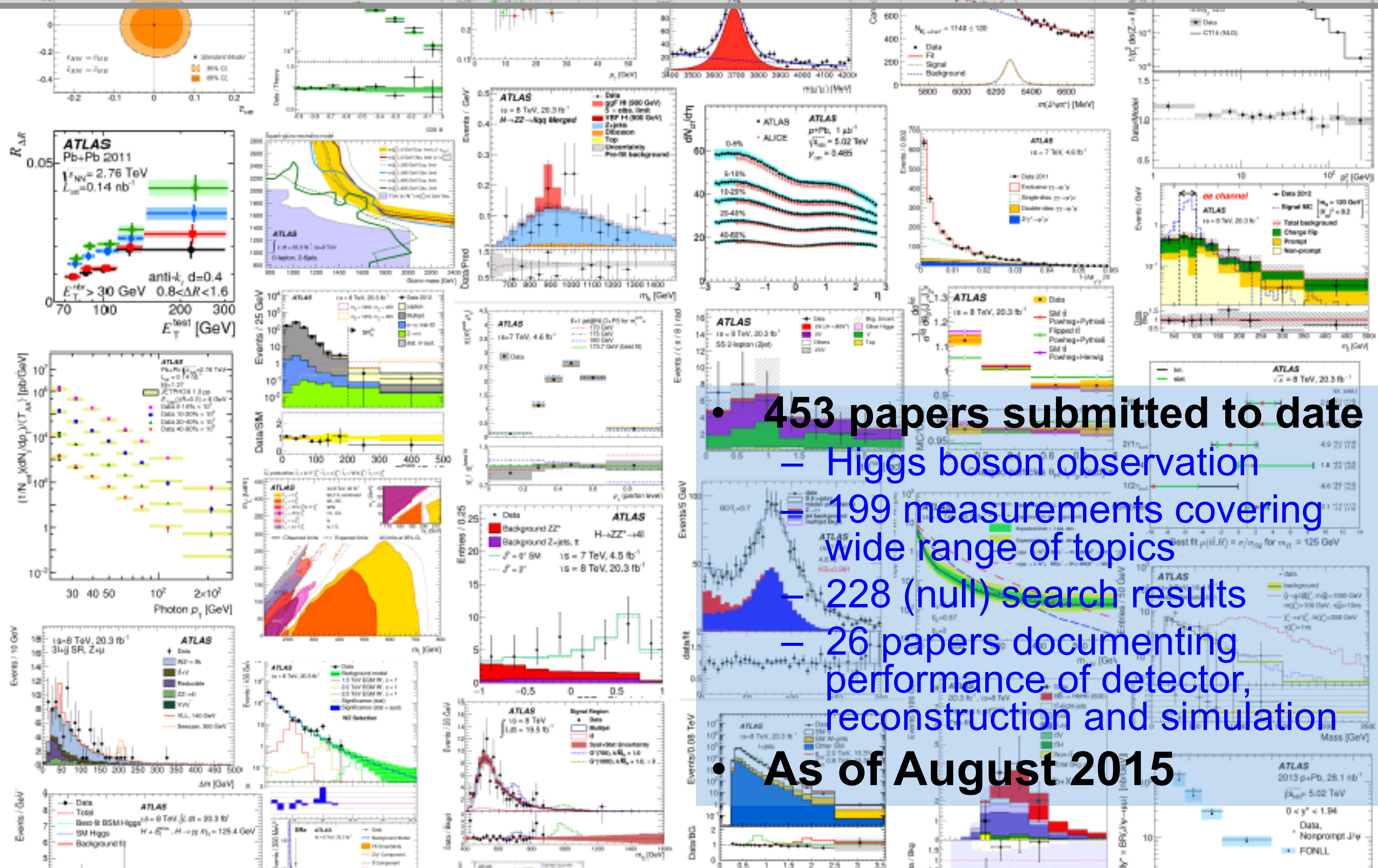
A new particle is discovered





This opens a new window on particle physics
And raises more questions!

One plot each from 32 most recent Run-1 papers



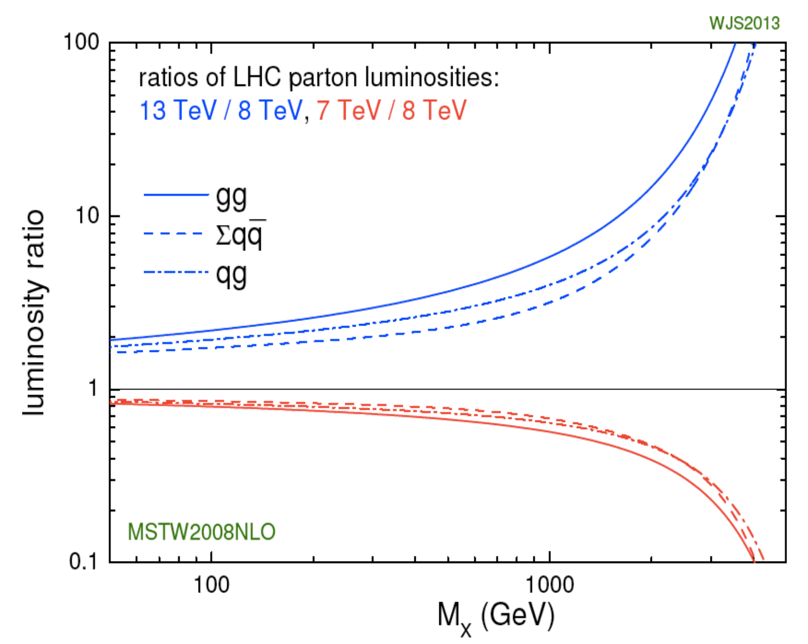
- **453 papers submitted to date**
  - Higgs boson observation
  - 199 measurements covering wide range of topics
  - 228 (null) search results
  - 26 papers documenting performance of detector, reconstruction and simulation
- **As of August 2015**

Run-1 dataset unique & still being analysed actively

Run-2

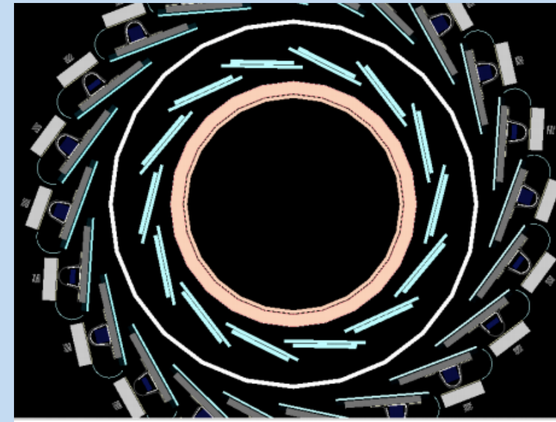
Run-2

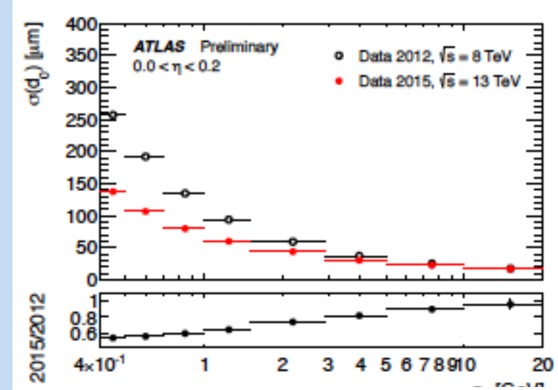
- Improved LHC
  - Higher √s
    - Large increase in cross sections
  - Reduced bunch spacing: 25 ns
  - Higher integrated luminosity
    - More than 100 fb^{-1} by end of 2018
- Improved ATLAS experiment
- Improved discovery potential
  - SUSY, Z', black holes,…
- Observation and study of rare processes
  - ttH, VBS, 3-boson,…
- Higher precision measurements
  - Higgs, top, W/Z, B, …

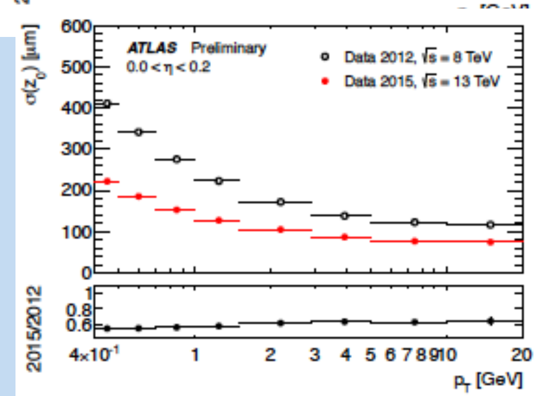


Upgrades to ATLAS during LS1

- Infrastructure:
  - New beampipe, improvements to magnet & cryogenic system
- Detector consolidation
  - Muon chambers completion (|η|=1.1-1.3) and repairs, improved readout of various systems (L1 rate 100 kHz), repair of pixel modules and calorimeter electronics, new pixel services, new luminosity detectors, new MBTS detector
- 4th silicon pixel detector layer (IBL)
  - Innermost Pixel detector layer at R=3.3 cm from beam
- Trigger & DAQ improvements
  - Topological L1 trigger, new central trigger processor, coincidence between Tile and muons, restructuring of high-level trigger, new Fast TracK Trigger (FTK), improved L1 calorimeter trigger, upgrade ROS
- Software
  - Many improvements to simulation, reconstruction, grid and analysis software







ATLAS Detector Status

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	92 M	99.0%
SCT Silicon Strips	6.3 M	98.9%
TRT Transition Radiation Tracker	350 k	97.3%
LAr EM Calorimeter	170 k	100%
Tile calorimeter	4900	99.2%
Hadronic endcap LAr calorimeter	5600	99.6%
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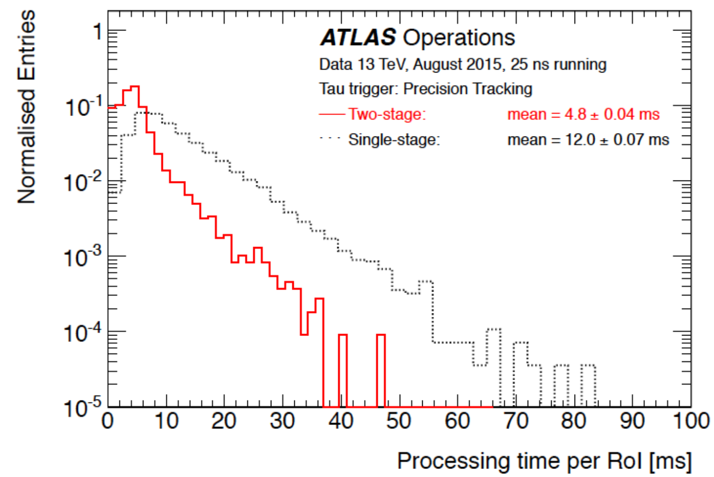
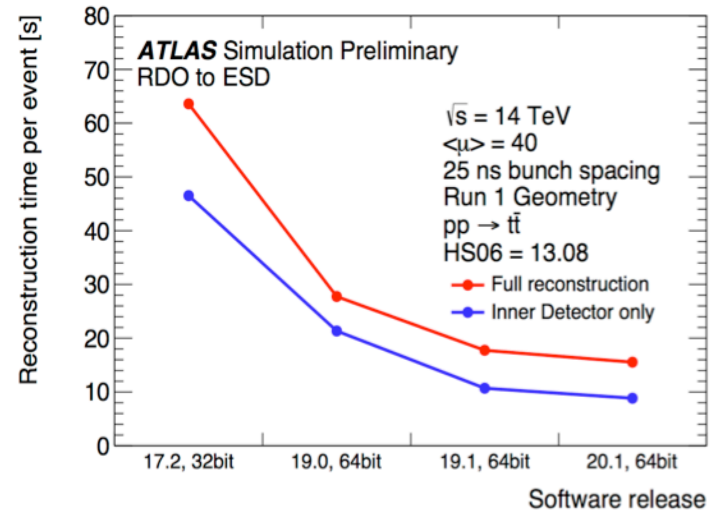
ATLAS pp run: June-July 2015

Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
97.3	99.6	100	98.4	100	100	100	100	100	100	99.3

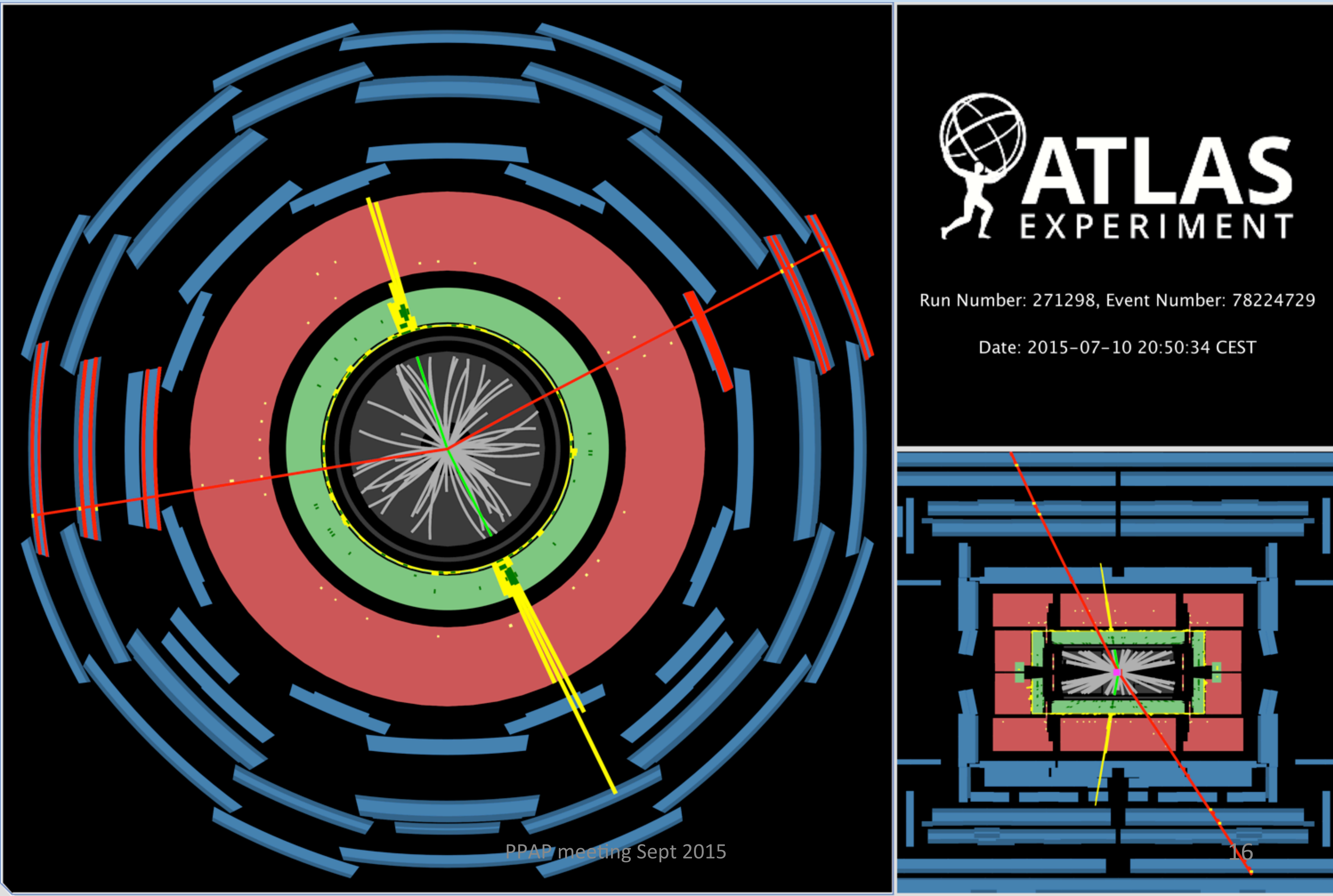
All good for physics: 93.3%

Luminosity weighted relative detector uptime (in percent) and good quality data delivery during 2015 stable beams in pp collisions at $\sqrt{s}$ = 13 TeV between 3 June and 16 July – corresponding to 91 pb^{-1} of recorded data.

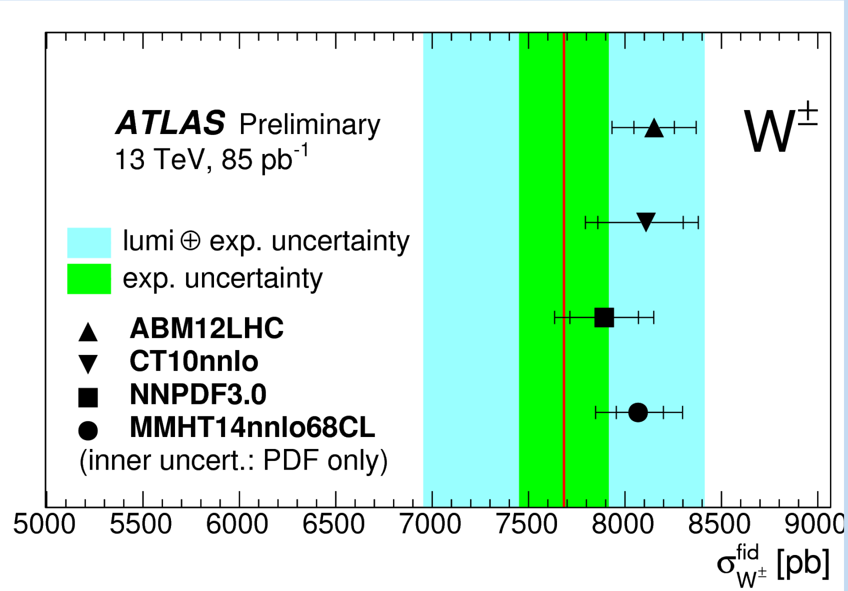


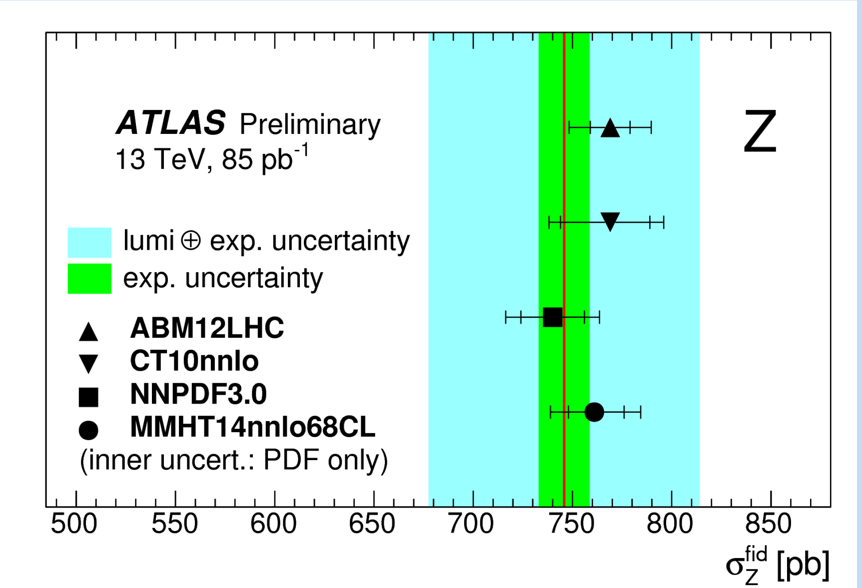


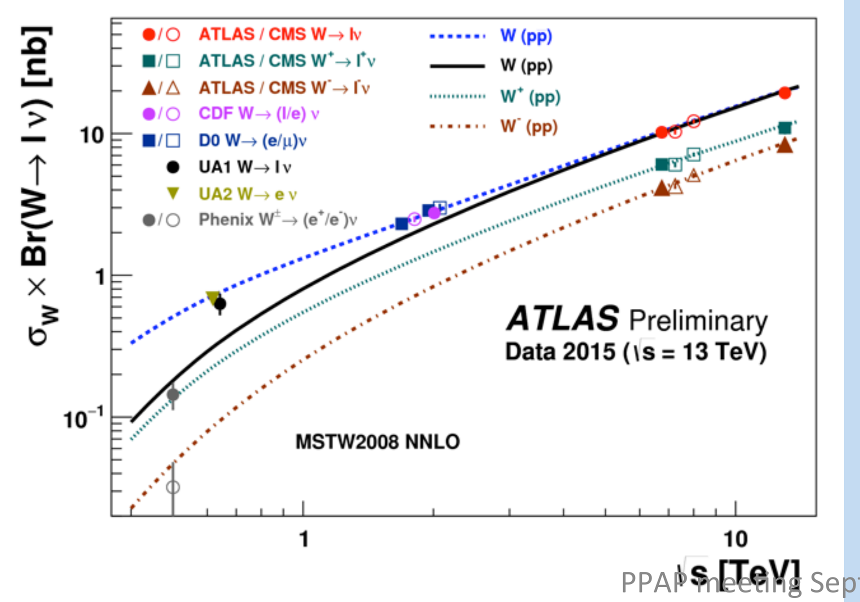
Run-2 Physics

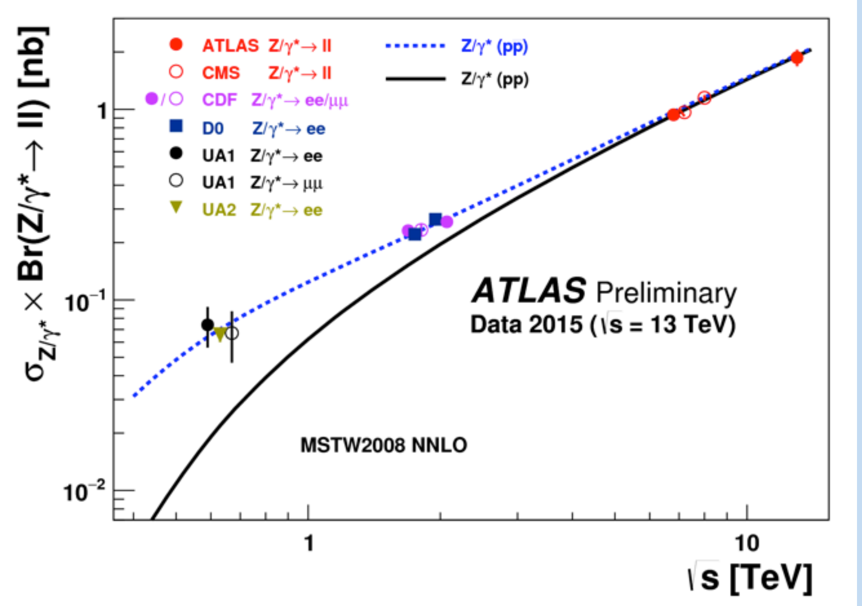


Inclusive W and Z Cross Sections



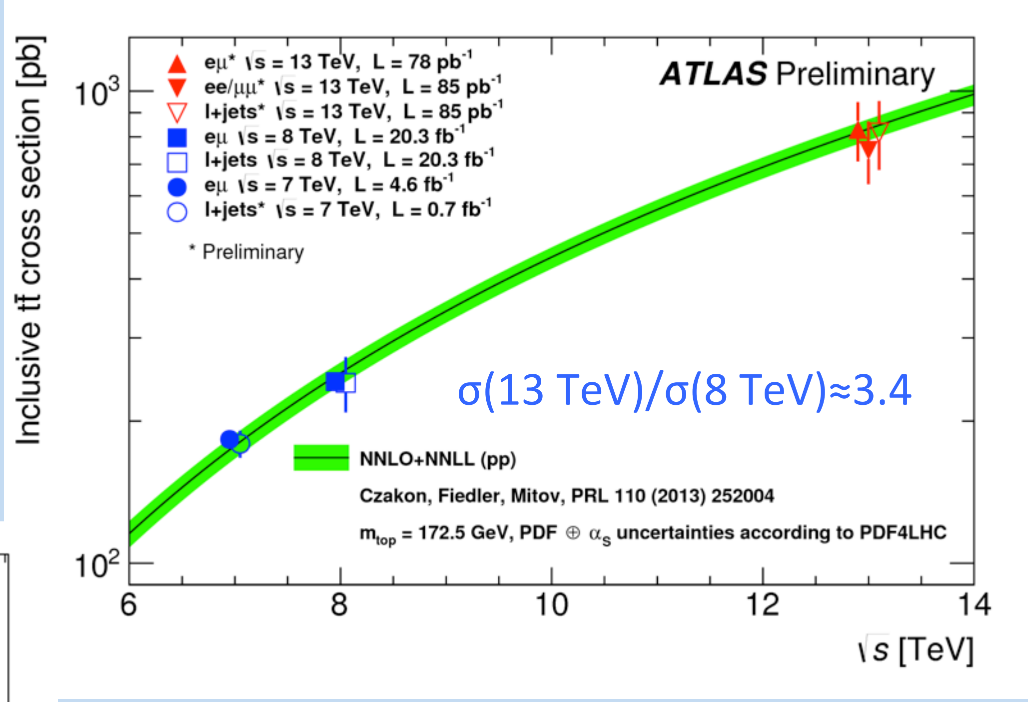


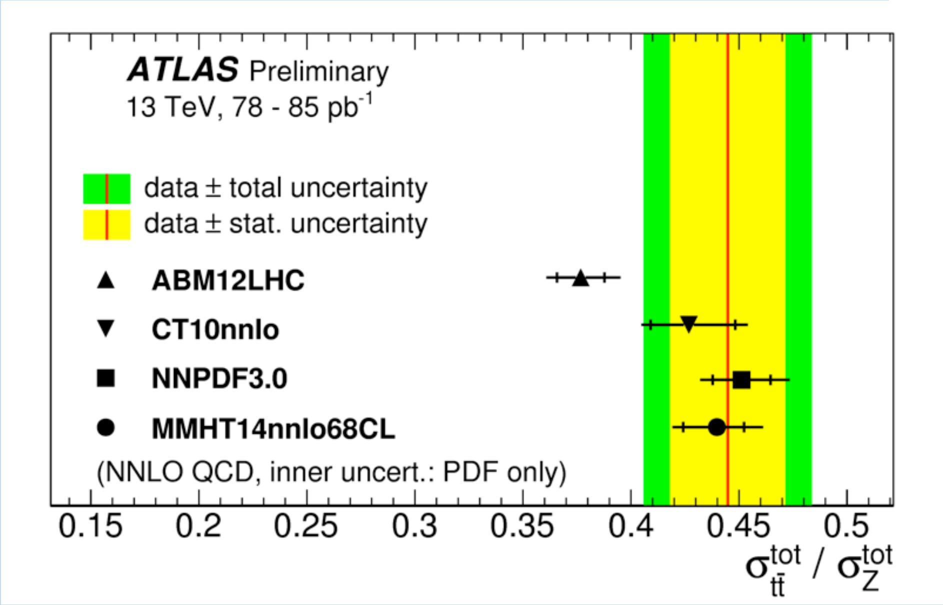




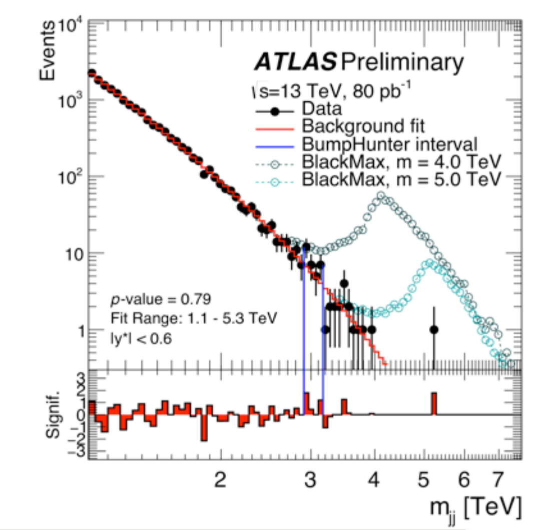
Top quark physics

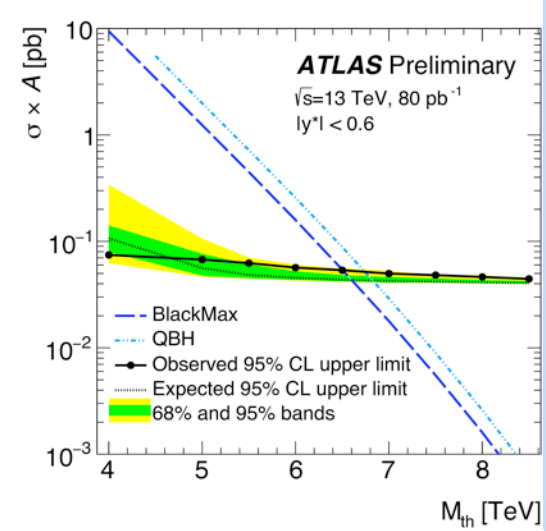
- Top cross-section measurements for dilepton and single lepton events events

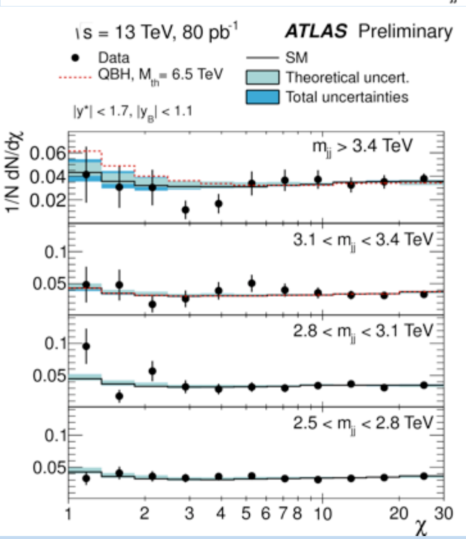


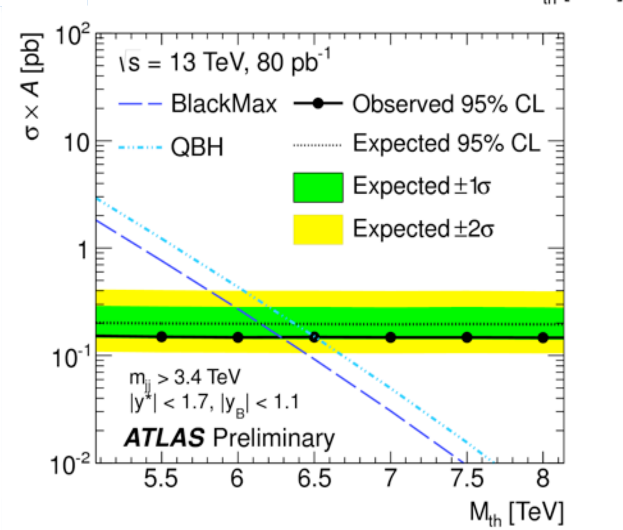


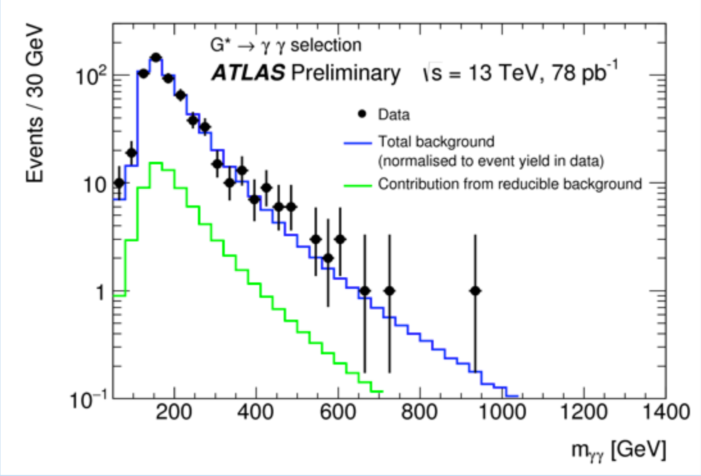
Searches for new phenomena



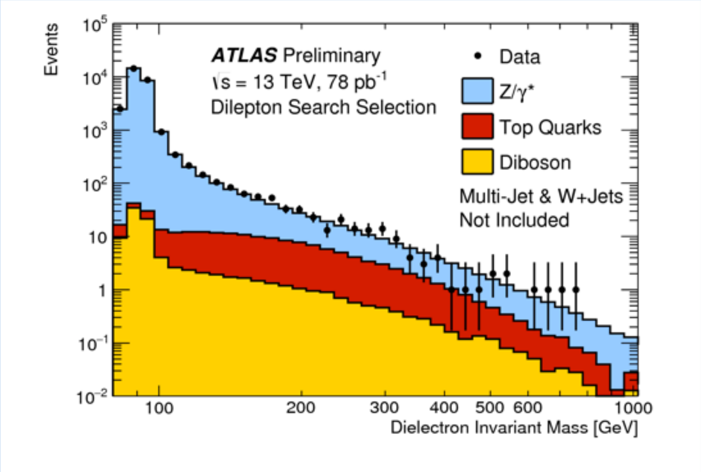








Searches now starting to go beyond Run-1 sensitivity

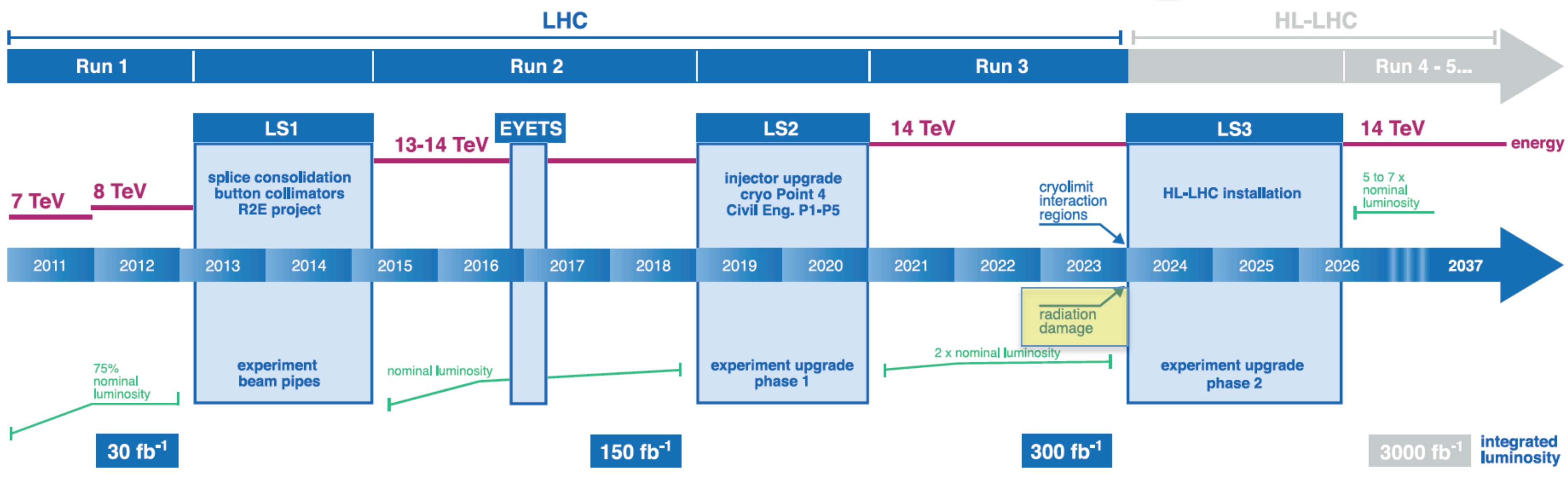


- New phenomena in di-jet mass and chi (angular) distribution

ATLAS Phase-I and Phase-II Upgrade

LHC / HL-LHC Plan

High Luminosity LHC



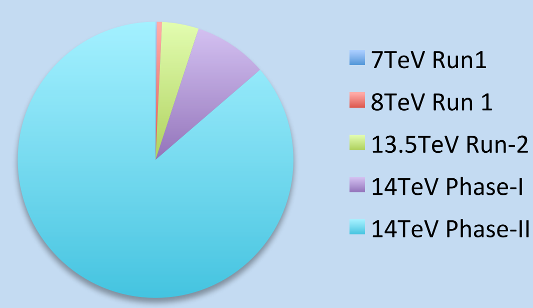
Run-3

- LHC will increase to 2 x nominal luminosity, 2-3x10^{34}cm^{-2}s^{-1}
- Aim to provide 300fb^{-1} by end of 2023
- Pile-up = mean of ~55-80 soft pp collisions/event

HL-LHC

- HL-LHC will begin operation ~2026
- Aim to provide 3000fb^{-1} by ~2035
- Instantaneous luminosity up to 7.5x10^{34}cm^{-2}s^{-1}
- Pile-up up to a mean of ~200 soft pp collisions/ event

LHC Luminosity



ATLAS Upgrade Programme

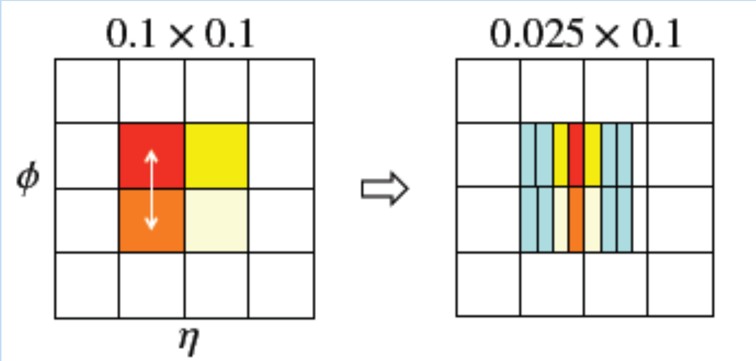
- Phase-I
  (up to and including LS2: 2019)
  - *Upgrade TDAQ*
    - *L1 calorimeter trigger*
    - FTK
    - Topological triggers
    - *High Level Trigger*
    - *ROS*
  - LAr readout electronics
  - New small muon wheel in forward region
  - Forward detector system
  - Install scintillators in gap
  - *Computing*
  - *UK construction project funded to 2019*

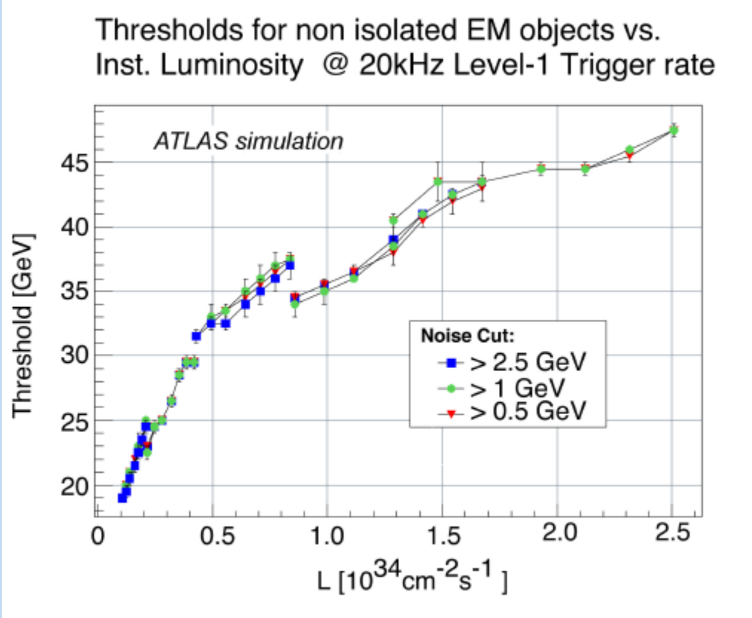
- Phase-II
  (LS3: 2024-2026)
  - *Replace tracking system*
  - Replace calorimeter and muon detector readout electronics
  - *Upgrade TDAQ*
    - New trigger architecture
    - *L1 Calorimeter trigger*
    - *New L1 track trigger*
    - *Event Filter (HLT)*
  - *Computing*
  - *UK for Tracker and L1 Track Trigger R&D funded to April 2016*

ATLAS-UK upgrade projects, building on construction experience

UK Phase I: L1 Calorimeter trigger upgrade

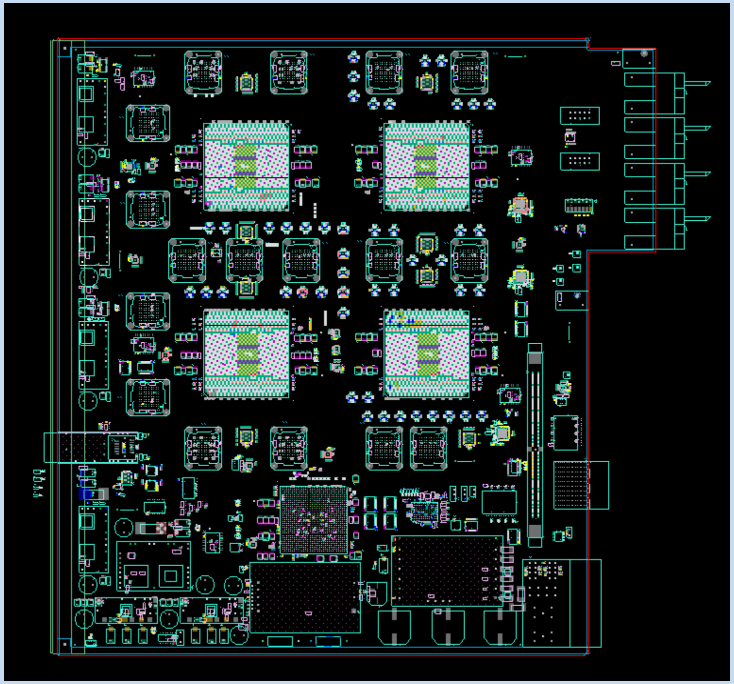
- LAr calorimeter upgrade will provide finer granularity data to L1 trigger
- Preserve un-prescaled L1 thresholds for single electron trigger at P_T ~ 25 GeV for LHC luminosity increasing to ~2-3x nominal
- UK to develop and construct electron feature extractor (eFEX), and associated readout



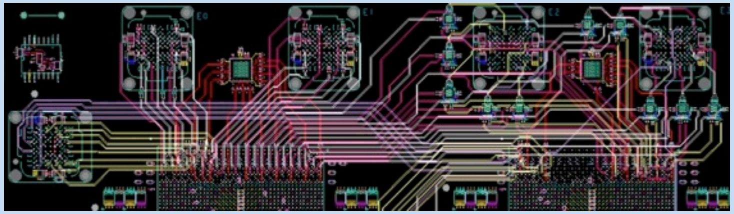


UK Phase-I: Electron feature extractor

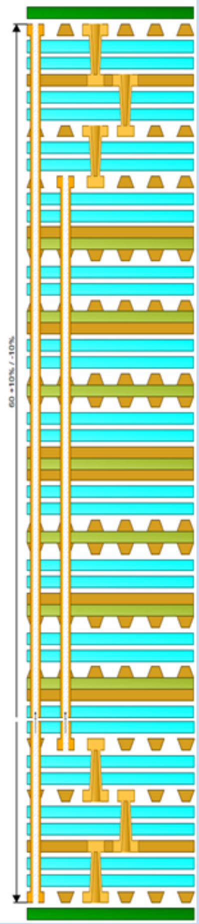
- Current status
- 3189 Components
  - 4 × XC7VX550T
  - 1 × XC7VX330T
  - 17 Minipods
  - 19 clock buffers
- 4 clock domains
- 3942 nets
  - 424 multi-Gb/s pairs
  - 362 LVDS pairs
- 13,142 connections
- ~350W/module



eFEX Layout



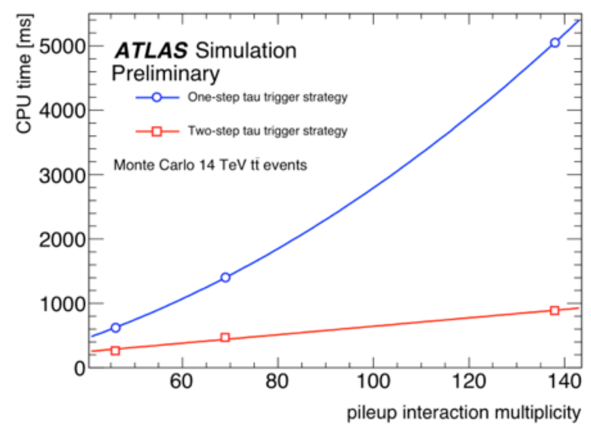
Detail of eFEX ~10G routing

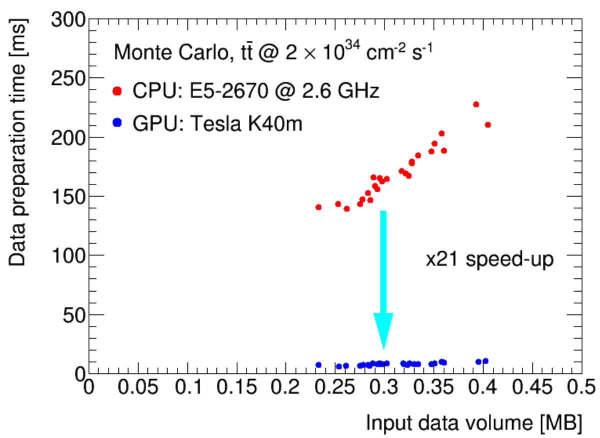


eFEX & FTM PCB Stack-Up

UK Phase-I: High Level Trigger

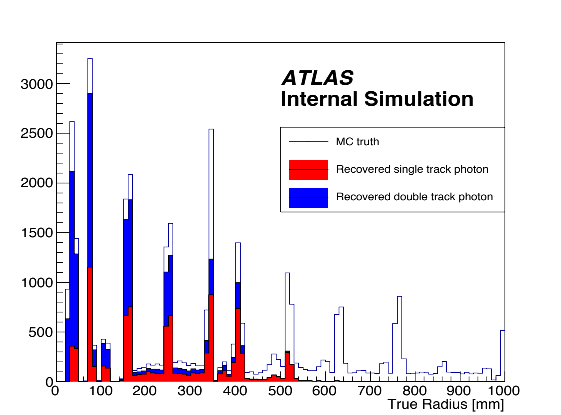
- ROS installation completed
  - Hardware, firmware and software all performing well at 100kHz
- Run-2 Menu complete,
  - Menu and signatures completed for Run 2 start, working well with 50ns and 25ns data
- New Inner Detector Trigger software completed
  - Higher efficiency and factor of 3 speed-up c.f. Run-1 trigger
  - New two-step strategy for tau trigger dramatically reduces cpu time and pileup dependency
- Core software:
  - Cost monitoring and rate prediction tools being used to estimate trigger rates and HLT farm resource requirements as function of luminosity
- GPU demonstrator on track under UK leadership
  - Factor 21x speed up shown for conversion of raw ID data to input format of tracking algorithms

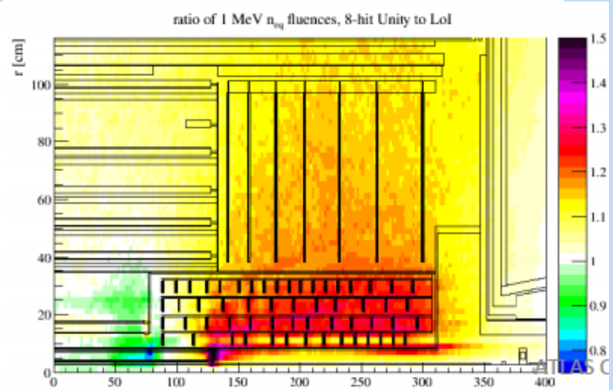


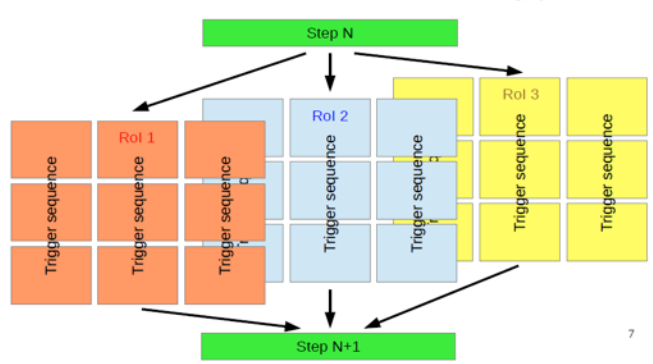


UK Phase-I: Computing and software

- Itk performance studied
  - E.g. photon reconstruction performance ITK layout
- Progress made on radiation simulation for various layouts
  - New 13/14TeV background predictions to be verified in Run2
- Software framework
  - Towards a single framework for online and offline processing
  - Demonstrators being developed for HLT use cases
  - need to adapt to many core architectures and reduce memory footprint with parallel scheduling of algorithms and events
  - prototype based on Gaudi Hive (common with LHCb and FCC)

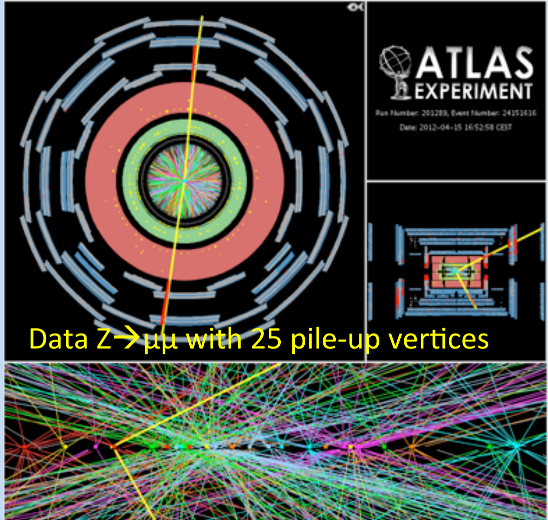


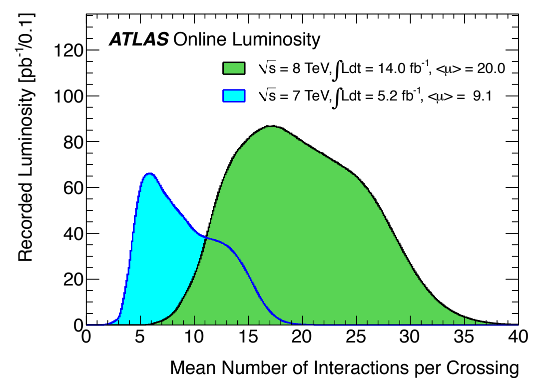


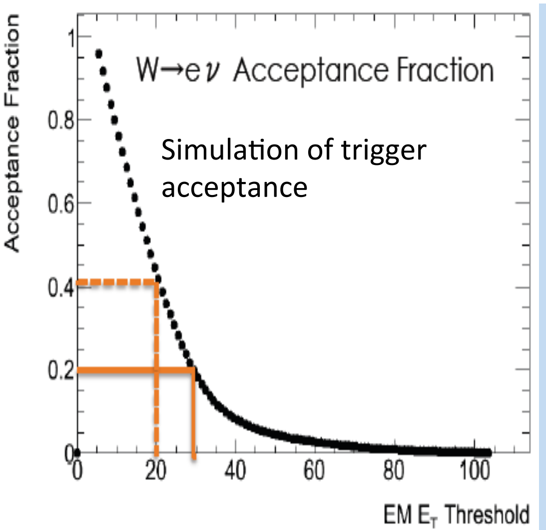


Phase-II: What is the problem?

- Increased luminosity → Increased pile-up:
  - Pile-up is the number of additional pp interactions per beam crossing
  - Phase-I: 55-80; Phase-II: up tp 200 pile-up events c.f. up to 35 in Run-I data
  - Increased pile-up compromises pattern recognition in the trigger and tracker
  - Increased readout rates
- Increased luminosity → Increased radiation damage
  - Damage scales approximately linearly with luminosity ~x10 increase
- End of life issues
  - Components ~20 years old by 2020
- Computer architectures changing
  - Many cores, low memory/core
  - Existing software approach inefficient & bloats memory
  - New framework & algorithms/codes needed







Probing physics at the TeV scale with increased luminosity

- A broad and exciting physics programme at the HL-LHC addressing the key questions in particle physics:
- Understanding electroweak symmetry breaking
  - 125GeV mass boson, is it the Standard Model Higgs?
  - Measure couplings
  - Measure vector-vector scattering to probe EWSB at high masses – strong vs weak coupling measurement of HH
- Is the standard model the whole story?
  - What protects the Higgs mass?
  - Is there a DM candidate?
  - Direct Searches for signatures of physics beyond the standard model at the highest mass scales: SUSY, Extra dimensions
  - Indirect searches for modifications to the standard model in top quark sector
- Increase in luminosity
  - Probe higher mass scales
  - Search for rare processes
  - Precision measurements
- Need to maintain or improve ATLAS performance
  - Increased luminosity → increased pile-up

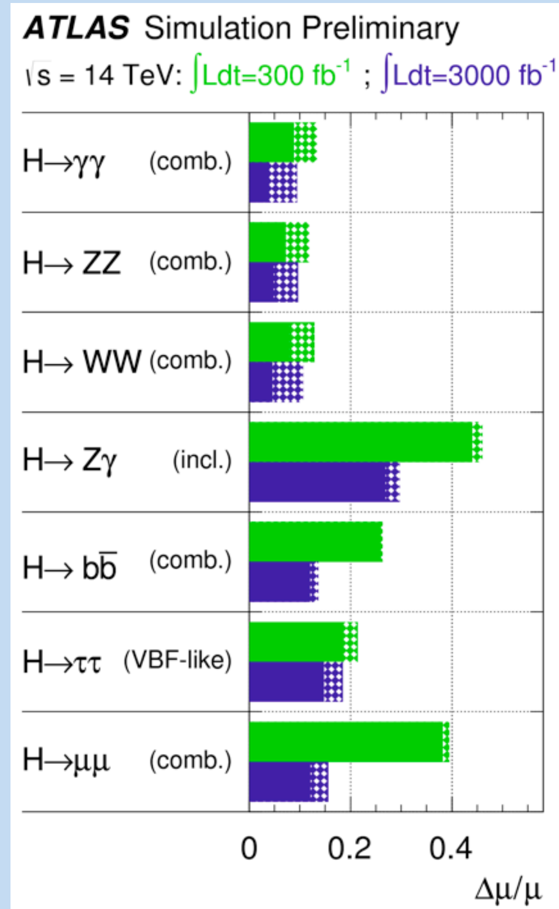
- *Note many of the physics studies were done with Letter of Intent layout and parameterisations for ECFA workshops in 2013 & 14*

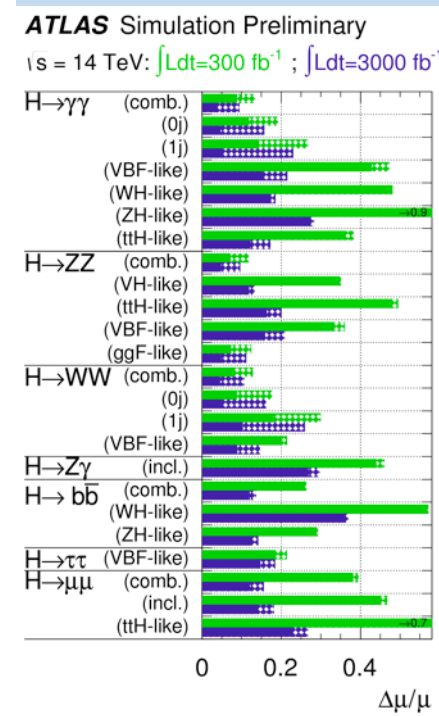
Higgs Couplings

	Higgs bosons at √s=14TeV
HL-LHC, 3000fb^{-1}	170M
VBF (all decays)	13M
ttH (all decays)	1.8M
H->Zγ	230k
H->μμ	37k
HH (all)	121k

- Higgs mass means a wide range of decays must be studied
- Precision on relative couplings
  - Phase-I: 10-80%
  - Phase-II: 5-30%
- gg→H, H→γγ are sensitive to new particles via loops
- H→Zγ new loops
- H→μμ 2nd/3rd generation
- ttH direct measurement of top coupling

Requires: maintain or improve trigger and reconstruction performance of all physics objects:
e, μ, τ, γ, jets, b-jets, Et-miss in the presence of increasing pileup

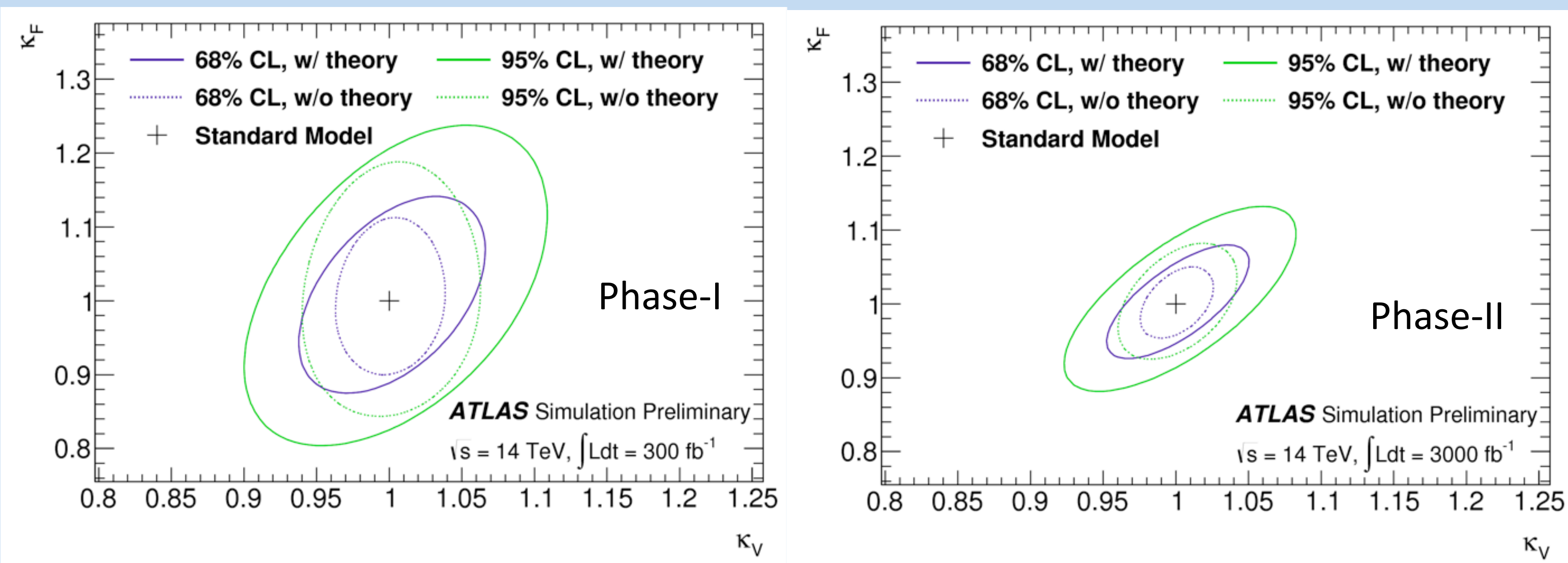




Access to different production and decay channels

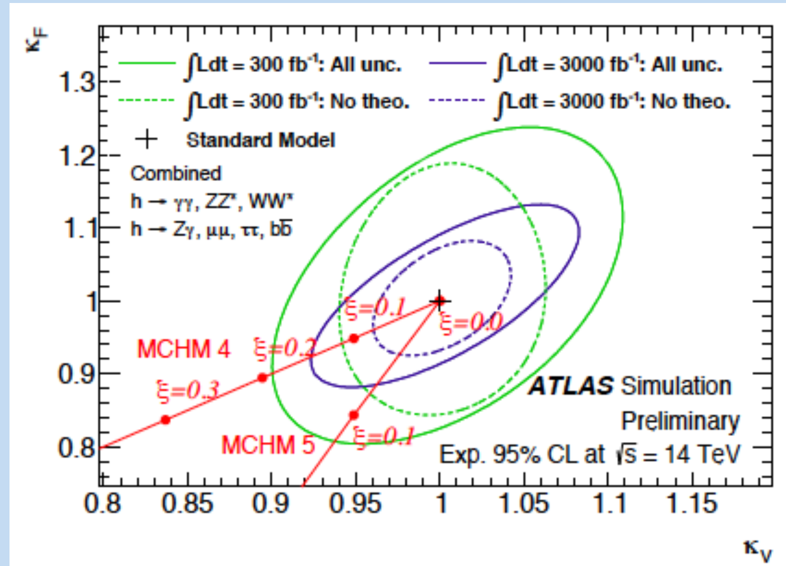
Higgs couplings: global fits

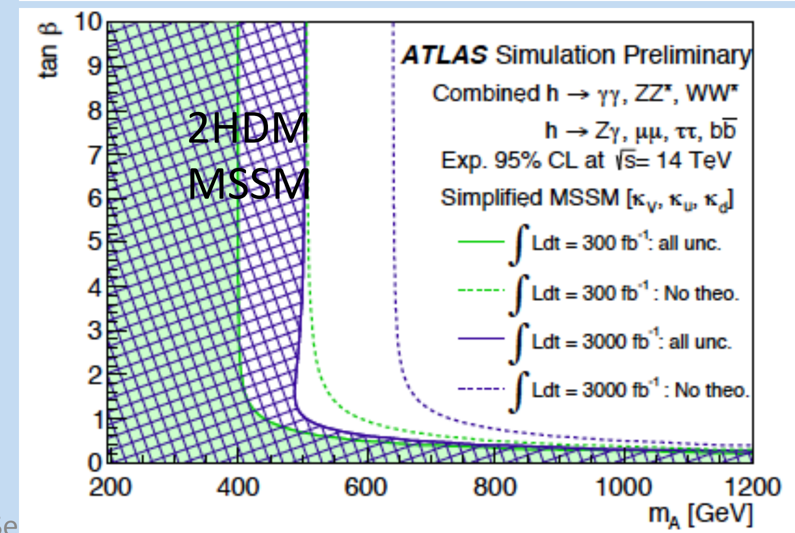
- Global coupling fits
- Bosonic coupling precision ~2.5% at 300 fb^{-1} → 1.7% at 3000fb^{-1}
- Fermionic coupling precision ~7.1% at 300 fb^{-1} → 3.3% at 3000fb^{-1}



New physics through the Higgs

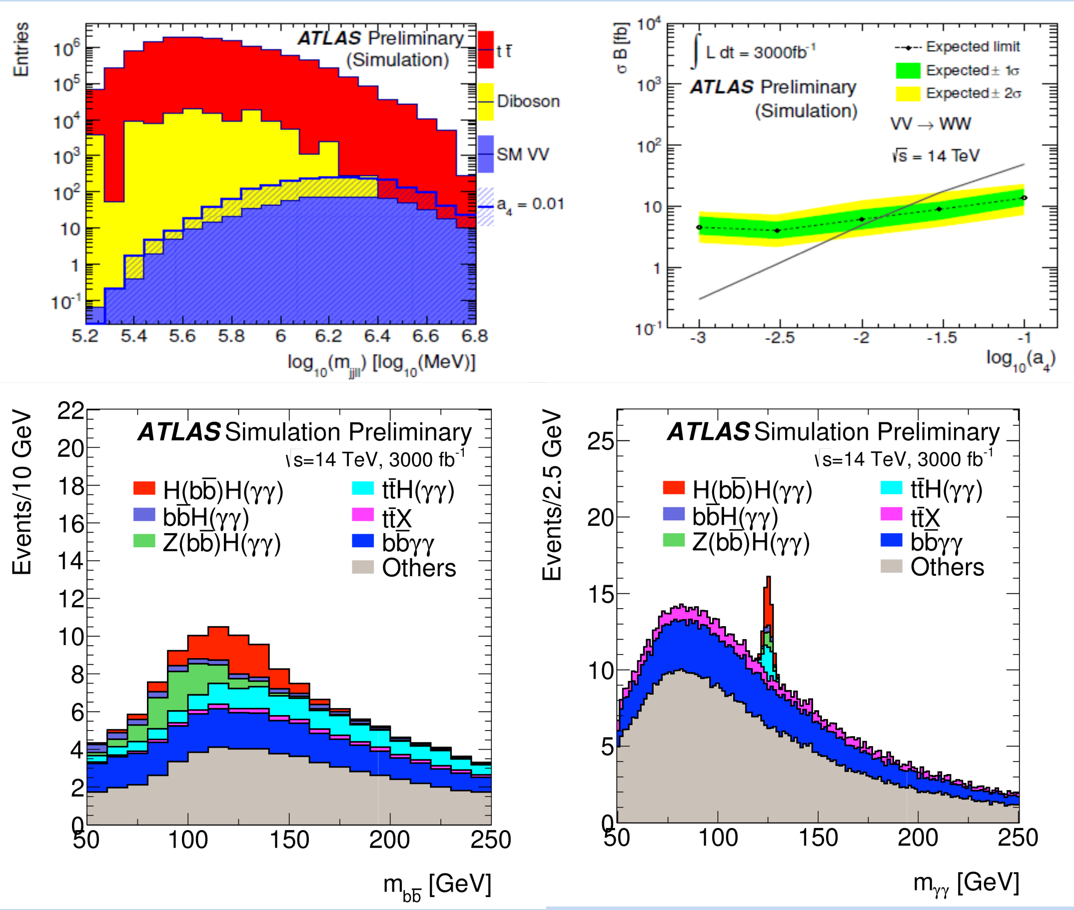
- Sensitive to composite Higgs models for scales of ~1TeV
- Searches for 2-Higgs doublet modiels (2HDM) can exclude large region of BSM parameter space
- Higgs portal to Dark Matter, similar sensitivity to WIMPS as direct searches





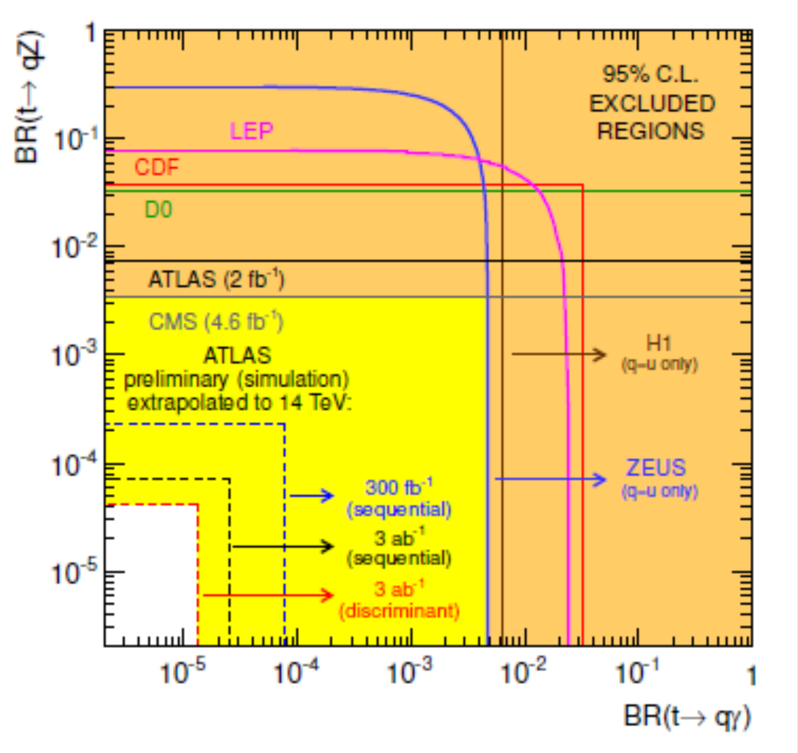
Electroweak symmetry breaking in high mass Weak boson (VV) scattering

- HL-LHC upgrade can have a major impact in discovering extended electroweak symmetry breaking sector beyond SM higgs mechanism
  - Good forward jet reconstruction with pile-up rejection
- Higgs-self coupling, SM rates are very challenging but also sensitive to new physics
  - Studies of HH→bbγγ, other channels under investigation



Searches for New physics in top sector

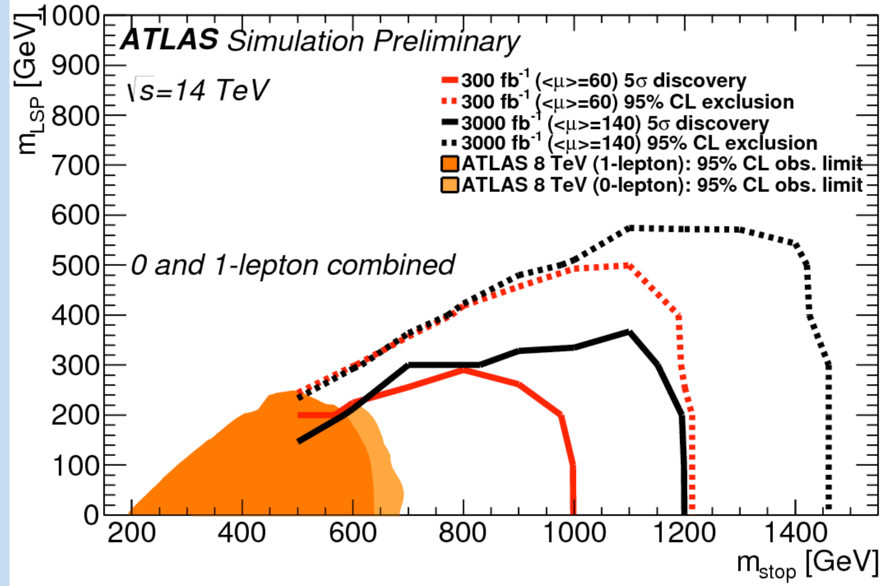
- Several BSM predicts FCNC couplings in the top sector
  - Sensitivity to new physics through measurements of rare processes
- $(t\rightarrow qZ)/(t\rightarrow q\gamma)$
  - Sensitivity is in the range $10^{-4}\rightarrow 10^{-5}$ at 95%CL
- FCNC in $t\rightarrow cH$; $H\rightarrow\gamma\gamma$
  - Br limit = 1.4×10^{-4} at 95%CL
  - Rule out a range of BSM models (or find a signal)

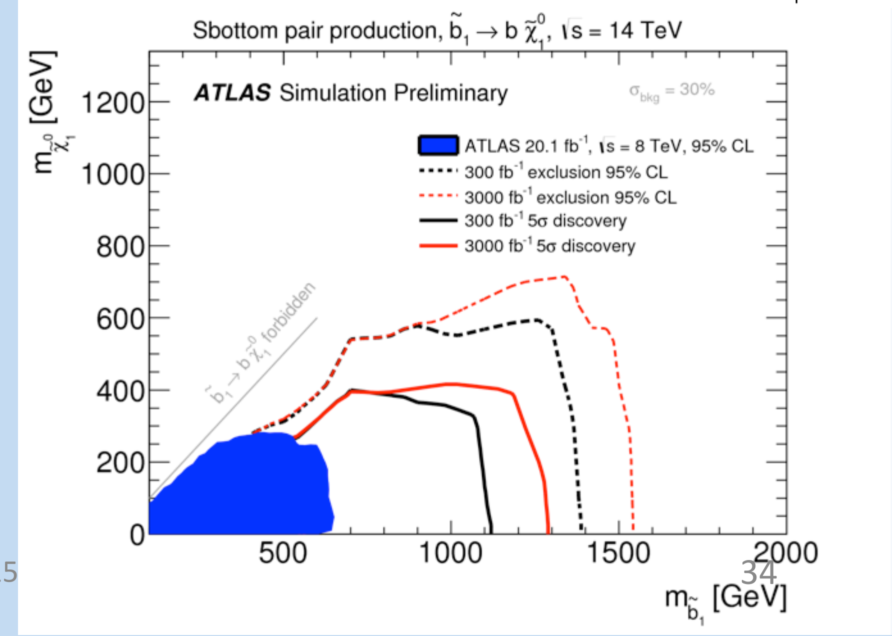


Naturalness test

- Is SUSY natural?
- General arguments require a light third generation for SUSY to be natural
- Requires stop mass ≤ O(1TeV)
- Exclusion can be extended to 1.4TeV

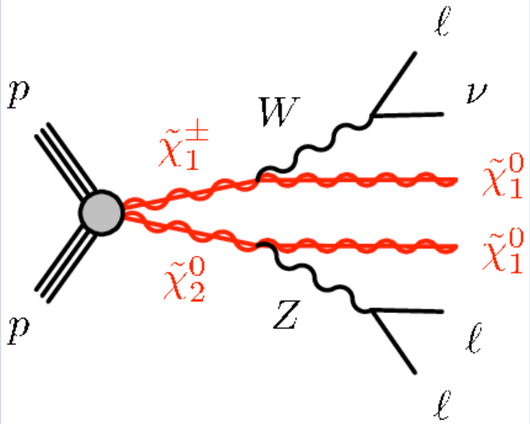
- Sbottom production also tests naturalness
- Extend sensitivity to 1.3TeV

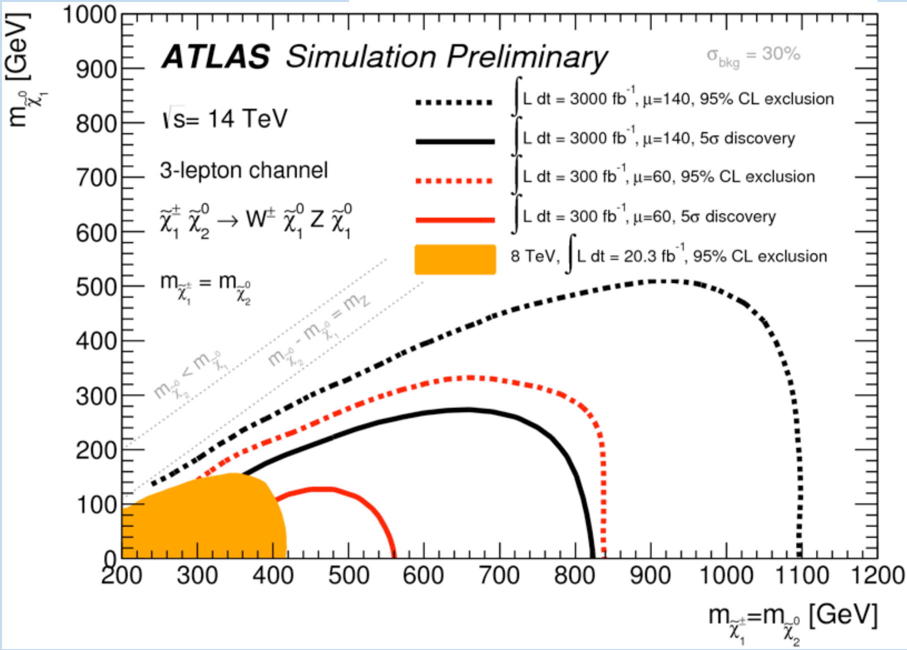




Electroweak SUSY Production

- High luminosity allows electroweak production of neutralinos to be probed
- Sensitive to models with high mass gluinos and squarks





ATLAS Phase-II upgrades: International Upgrade approval and funding

- Discussions between funding agencies, CERN and ATLAS (& CMS) management have established the path to funding Phase-II Upgrades
- Stage-1 is Scoping exercise
  - Updated total cost of Phase-II Upgrades required
  - Physics and technical case for Phase-II Upgrades
    - Discussion of different detector configurations
    - Reference: ~275MCHF, Middle: ~235MCHF, Low: ~200MCHF CORE costs
    - Major updating of Letter of Intent
  - Scoping document submitted and reviewed by LHCC and UCG this week
  - Discussion between CERN management, Experiments' management & Funding Agencies at October RRB. Approval to proceed to TDRs anticipated
- ATLAS Scoping document
  - Cost review to update costing relative to Letter of Intent
  - Look at physics capability and cost of detector configurations
  - Submitted to LHCC and UCG this week
  - Public release on Friday

Scoping scenarios

The Reference Detector

- The TDAQ (Trigger and Data Acquisition):
  - uses a 2-level hardware trigger (L0/L1) with specifications of 1 MHz/400 kHz rates and 10μs/60μs latencies, and a 10 kHz EF output rate.
- The ITk(Inner Tracker):
  - (outer) Strip system uses LoI layout defined in 2012,
  - (inner) Pixel layout starts from LoI layout and extends tracking from η=2.7 → 4.0
- The LAr:
  - includes a full readout upgrade to 40 MHz streaming off-detector, a replacement of the current Fcal with a finely segmented sFCal, and the addition of a high-precision timing detector in the η-range of 2.4 → 4.3
- The Tile:
  - includes a full readout upgrade to 40 MHz streaming off-detector, and the inclusion of the outer layer information in the L0 Muon trigger.
- The Muons:
  - include replacement of all on-chamber electronics, including the BI inner-barrel region, with replacement of MDTs with sMDT+RPCin this region, addition of an RPC-seeded L0 MDT trigger, and a muon-tagger for η of 2.6→4.0

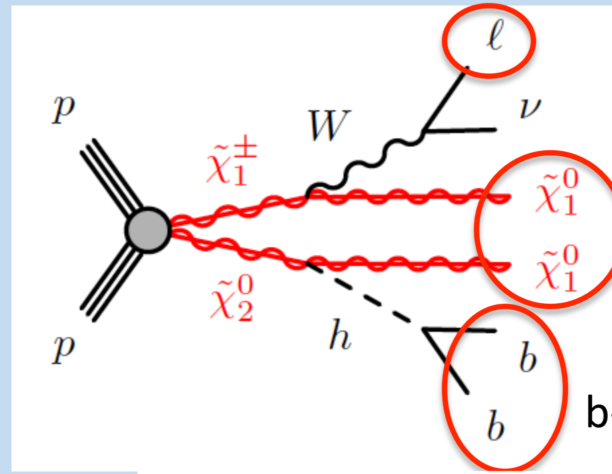
- For middle and low scenarios
  - Main cost drivers are ITk and TDAQ
  - ITk: reduce large-radius silicon strip tracker; reduce pixel η coverage ; compromise efficiency/fake rates and robustness against module failure
  - TDAQ: reduce L0/L1 and EF output rates, reduce L1 Track & FTK++ associative memory track engines – compromises P_t threshold and η coverage → impact on single lepton/di-lepton thresholds

- *More details in backup*

Electroweak SUSY production: impact of scoping

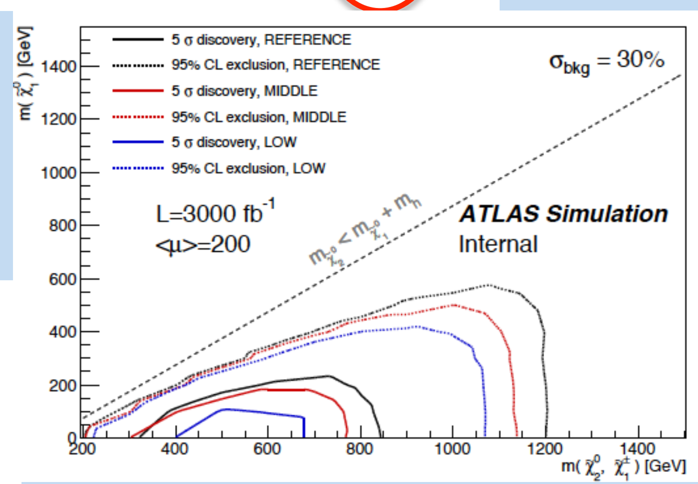
- Study made with updated detector parameterisations
- Trigger thresholds
  - Maintain single lepton thresholds at low P_t to maintain acceptance of W, Z, Hs
- b-tagging
  - Maximise eta range of b-tagging
  - Optimise tracker to maintain b-tagging in a high pile-up environment
- Et-miss resolution
  - Maximise eta range of tracking for Et-miss and pile-up rejection

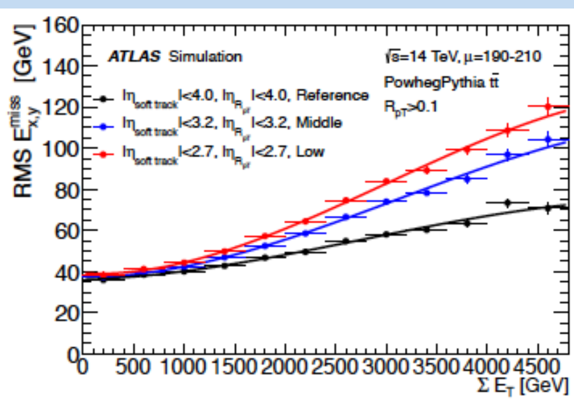
Trigger thresholds

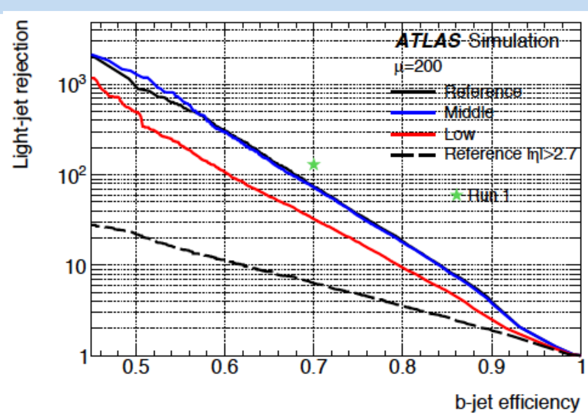


Et-miss

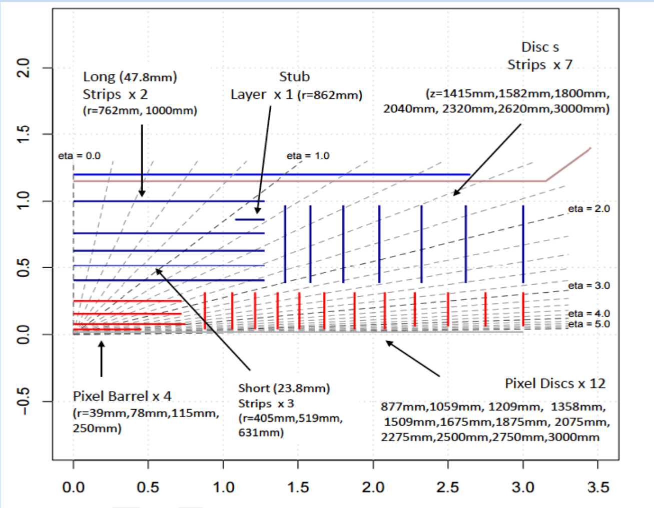
b-tagging

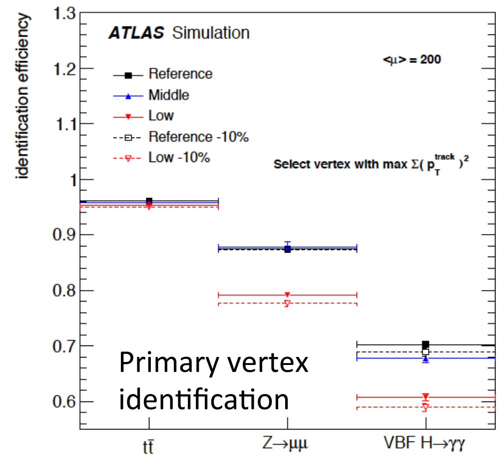


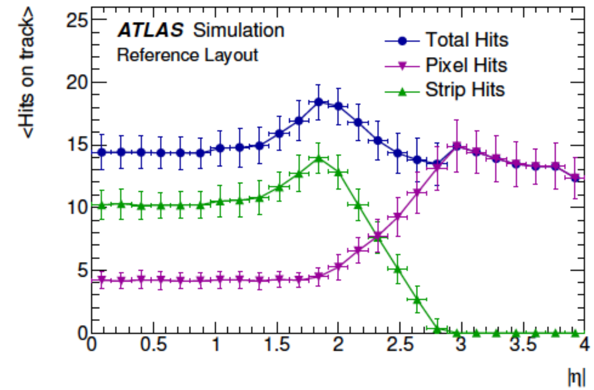




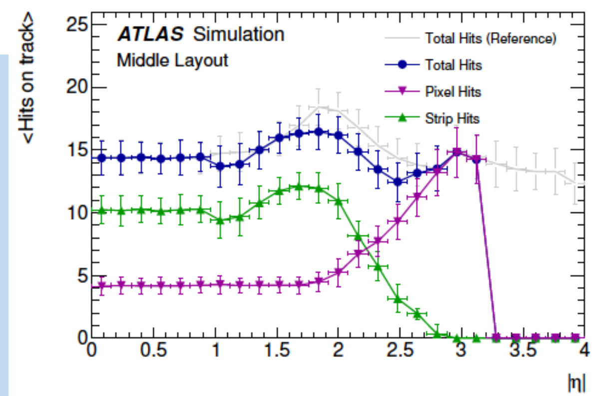
Tracker Upgrade

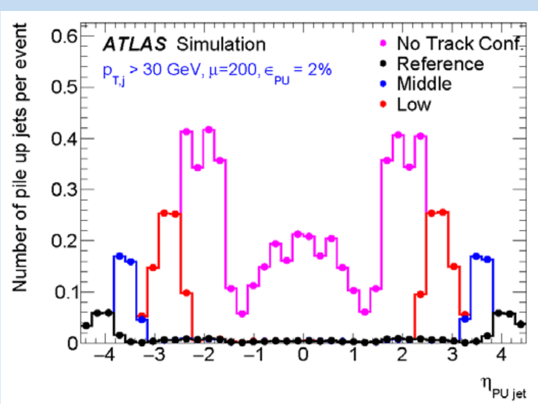




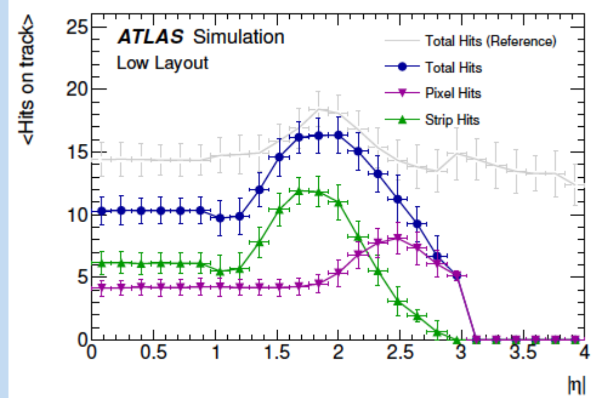


- Reference scenario designed to give fake rate <1% at high efficiency, and be robust against loss of modules
- Middle and low scenarios require compromise in efficiency or fake rate
- Tracker is not robust against module failure in low scenario
- Extended tracker plays a critical role in pile-up rejection



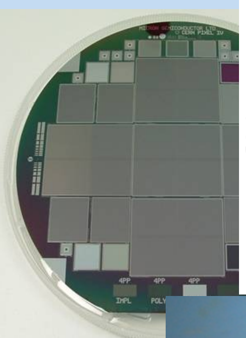


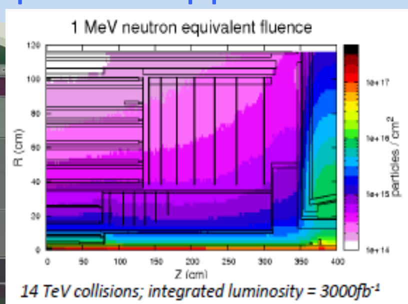
Inclusive pile up jet multiplicity
Critical for VBF & VBS measurements

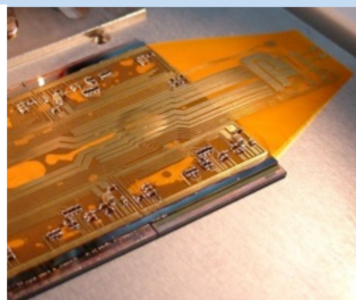


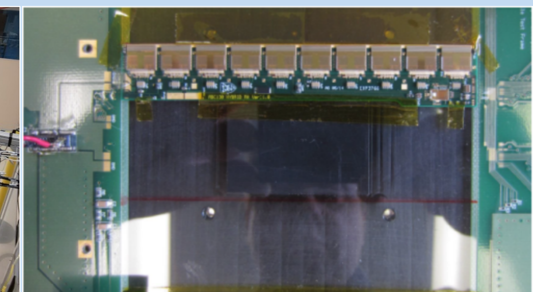
UK Phase-II: Tracker upgrade

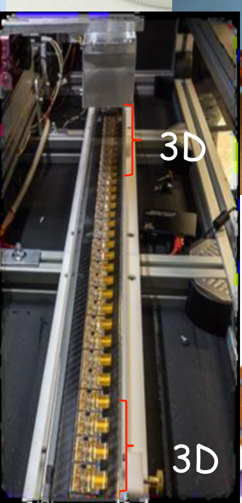
- UK programme
  - Continue to exploit expertise on strip tracker, building on ATLAS SCT
  - Decision to move into pixels to take build on expertise in silicon tracking
- UK plans for upgrade
  - Half of strip barrel modules & staves including DAQ, power supplies, type 1 service modules and support cylinders
  - 1 assembled pixel end-cap, supplying modules, common services to PP1, DAQ and power supplies

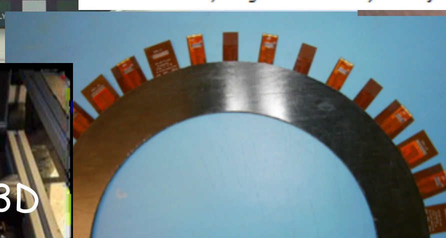


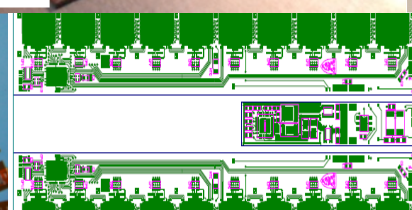


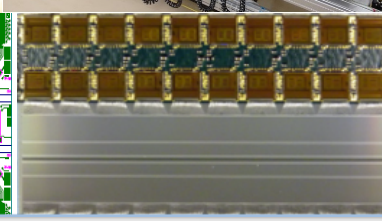


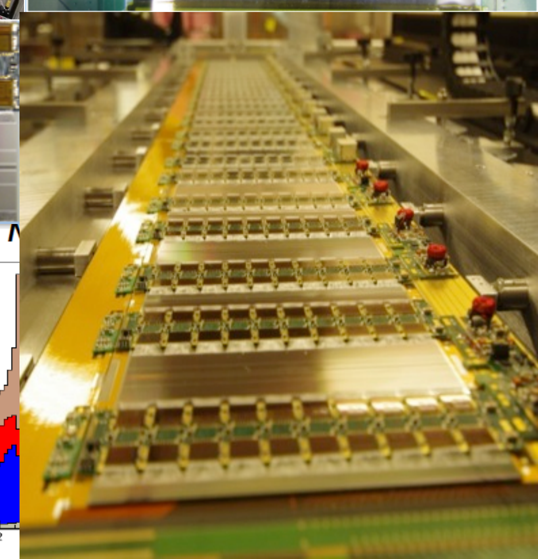


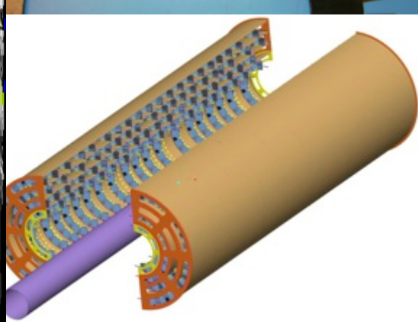


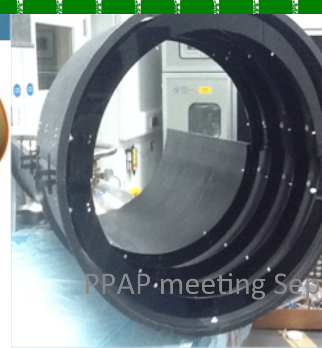


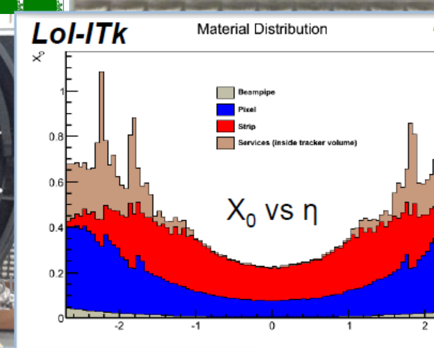




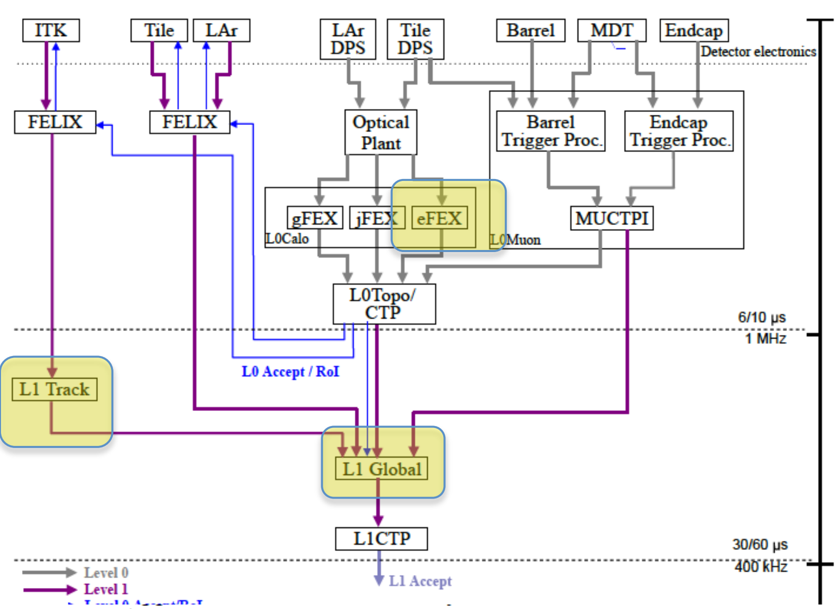








Phase-II Trigger Upgrade



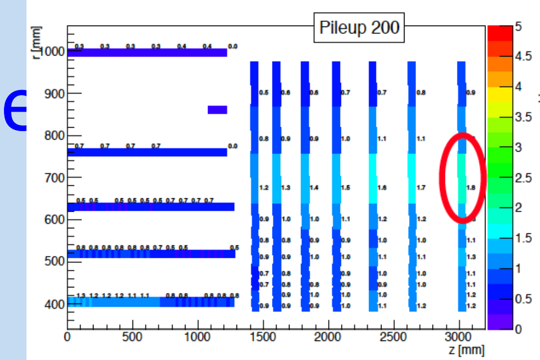
item	Reference			Middle			Low		
	p_T Threshold [GeV]	$\|\eta\|$	Eff.	p_T Thr. Threshold [GeV]	$\|\eta\|$	Eff.	p_T Thr. Threshold [GeV]	$\|\eta\|$	Eff.
iso. Single e	22	< 2.5	95%	28	< 2.5	95%	28	< 2.5	91%
forward e	35	$2.5 - 4.0$	90%	40	$2.5 - 3.2$	90%	-	-	-
single γ	120	< 2.4	100%	120	< 2.4	100%	120	< 2.4	100%
single μ	20	< 2.4	95%	25	< 2.4	80%	25	< 2.4	65%
di-γ	25	< 2.4	100%	25	< 2.4	100%	25	< 2.4	100%
di-e	15	< 2.5	90%	15	< 2.5	90%	15	< 2.5	82%
di-μ	11	< 2.4	90%	15	< 2.4	80%	15	< 2.4	65%
$e - \mu$	15	< 2.4	90%	15	< 2.4	84%	15	< 2.4	70%
single τ	150	< 2.5	80%	150	< 2.5	80%	150	< 2.5	80%
di-τ	40,30	< 2.5	65%	50,40	< 2.5	65%	50,40	< 2.5	55%
single jet	180	< 3.2	90%	225	< 3.2	90%	275	< 3.2	90%
fat jet	375	< 3.2	90%	400	< 3.2	90%	450	< 3.2	90%
four-jet	75	< 3.2	90%	85	< 3.2	90%	90	< 3.2	90%
HT	500	< 3.2	90%	600	< 3.2	90%	750	< 3.2	90%
E_T^{miss}	200	< 4.9	90%	225	< 4.9	90%	250	< 4.9	90%
jet + E_T^{miss}	140,125	< 4.9	90%	150,175	< 4.9	90%	160,200	< 4.9	90%
forward jet**	180	3.2 - 4.9	90%	225	3.2 - 4.9	90%	275	3.2 - 4.9	90%

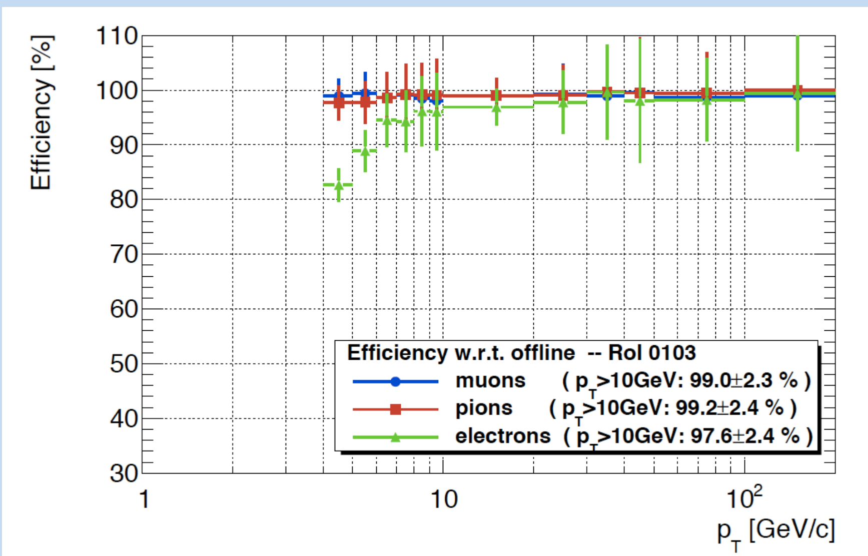
UK Phase-II: Trigger and DAQ upgrade

- Physics simulation
  - Understanding requirements
- Calorimeter Trigger
  - L1 eFeX → L0 eFex; upgrade firmware
  - Use experience to design and build L1Global
- L1 Track
  - Implementation in Itk readout
  - Simulation of track patterns and implementation in AM chips
  - Hardware construction
- Event Filter & DAQ
  - Readout
  - Develop EF tracking for Itk
  - Extrapolate trigger rates and develop selection strategies and menus
  - Develop EF steering and monitoring
  - Develop, with offline computing, software framework to make efficient use of 2020s technology

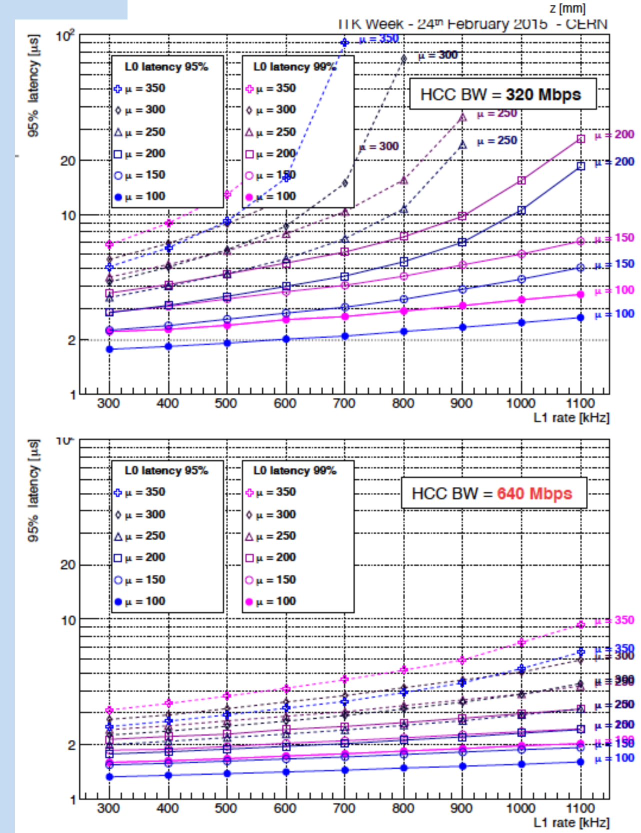
UK Phase-II: L1 Track Trigger

- Latency studies for Strips readout
  - Detailed discrete event simulation that takes into account strip readout
- Pattern recognition
  - Optimise use of patterns and associative memory banks





η range	(0.1, 0.3)	(0.7, 0.9)	(1.2, 1.4)	(2.0, 2.2)
Bank size ($\times 10^6$)	1.1	1.1	1.0	1.1
Muon efficiency	99.2	99.3	96.7	98.9
$\langle$patterns$\rangle$ for $\langle\mu\rangle$=140	2.2	1.6	2.9	2.7
$\langle$patterns$\rangle$ for $\langle\mu\rangle$=200	10.8	6.9	9.9	9.4
$\langle$fits$\rangle$ for $\langle\mu\rangle$=200	28	18	21	15
$\langle$fits$\rangle$ for $\langle\mu\rangle$=200 in $B\to\mu X$	117			
$\langle$fits$\rangle$ for $\langle\mu\rangle$=200 in jet	163			
95% range of fits for $\langle\mu\rangle$=200 in jet	507			



640Mbps Bandwidth ensures that system is robust against pileup and L0 trigger rate

Preparations for ATLAS-UK Phase-II construction project

- Phase-II construction proposal
  - SoI to Science Board: February 2015
  - SoI approved for submission to PPRP and indicative funding level given
  - Plan to submit to PPRP mid-2016 (under discussion with STFC)
    - STFC budget known from CSR
    - CERN scoping exercise completed and detector configuration known
  - CG process finished
    - Understand funding of CG posts and be able to allocate project posts effectively
- ATLAS process
  - ITk has completed IDR and is a formal project
  - ITk TDRs: Strip Tracker Q4 2016, Pixel Tracker Q4 2017
  - TDAQ IDR: Q1 2016, TDR Q4 2017

Summary

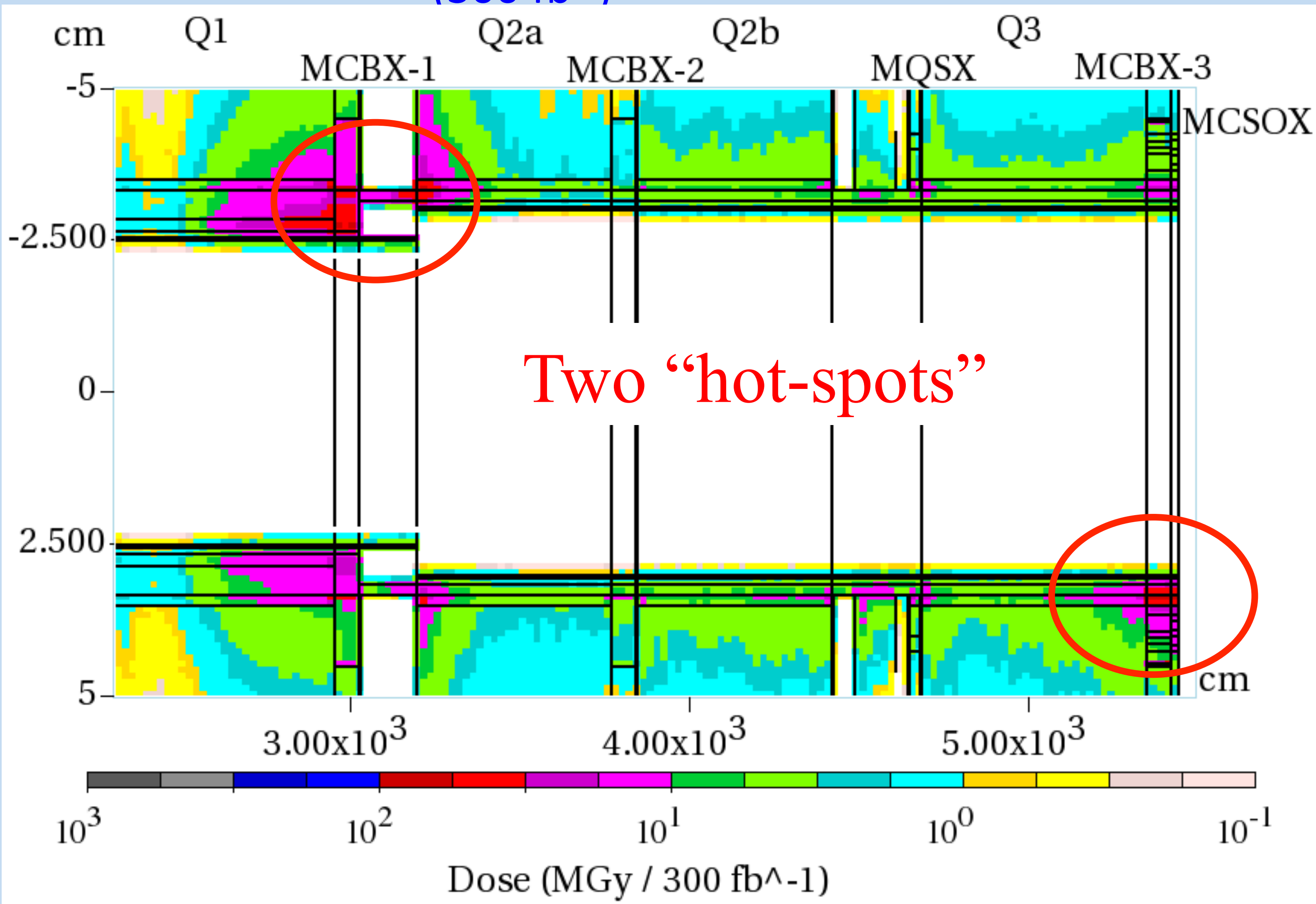
- The LHC will be energy frontier for the next two decades
- Run-1 was a great success with the prize of the discovery of the Higgs boson
  - Start of the exploration of the scalar sector
- Run-2 at 13TeV
  - ATLAS has successfully undergone consolidation and upgrade
  - Data taking has started smoothly and first physics results have been presented
  - Started to explore the landscape of physics at the TeV scale
  - Major discovery potential with increased energy and luminosity in the coming years
- ATLAS Phase-I Upgrades
  - Upgrades in construction to optimise performance at 2 nominal LHC luminosity
  - ROS and software upgrades delivered for start of Run-2
  - UK: L1 calorimeter trigger, High Level Trigger and Computing & Software Building on involvement in the original construction
- HL-LHC: an exciting and broad physics programme
  - Characterising the Higgs sector and further probes of electroweak symmetry breaking
  - extending searches for new phenomena well into the TeV region
  - ……
  - ATLAS has a well defined programme for upgrades to maintain and optimise the performance of ATLAS at HL-LHC luminosities
  - UK is moving towards Phase-II construction project, nearing completion of a highly successful R&D programme

BACKUP

Radiation dose in the present triplet

L. Bottura

(300 fb^{-1})



F. Cerutti, et al., WP10: Energy Deposition and Radiation Damage in Triplet Magnets, April 2013

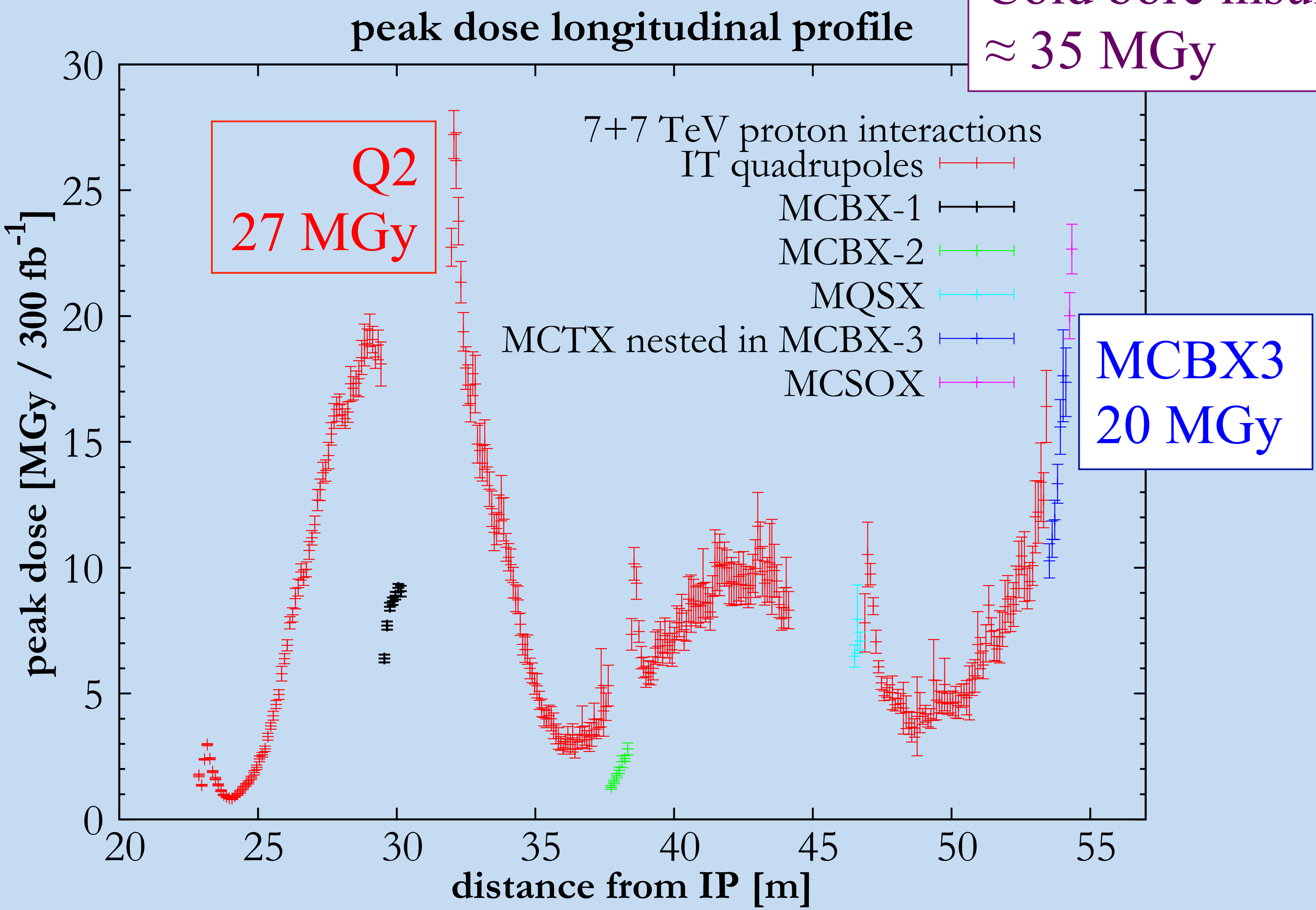
https://indico.fnal.gov/conferenceDisplay.py?confId=6164

Radiation dose in the present triplet

L. Bottura

(300 fb^{-1})

Cold bore insulation
≈ 35 MGy



F. Cerutti, et al., WP10: Energy Deposition and Radiation Damage in Triplet Magnets, April 2013

https://indico.fnal.gov/conferenceDisplay.py?confId=6164

RLIUP Summary on LHC Inner Triplets

L. Bottura https://indico.cern.ch/conferenceDisplay.py?ovw=True&confId=260492

- Expected dose by LS3 (300 fb^{-1}) with 50 % uncertainty(3)
  - Range of 27 [18…40] MGy in the Q2
  - Range of 20 [13…30] MGy in the MCBX
- Bonding strength (shear) of epoxies is strongly degraded (80 %) above 20 MGy
- Fracture strength of insulating materials degrades by about 50 % in the range of 20 MGy (G11) to 50 MGy (epoxies, kapton)
- Insulations (polyimide) become brittle above 50 MGy
- Triplet magnets may experience mechanically-induced insulation failure in the range of 300 fb^{-1} (LS3 ± 1 year)
  - Premature quenches (cracks in end spacers)
  - Insulation degradation (monitor on line(4))
  - Mechanical failure (nested coils in MCBX)

ATLAS Phase-II Scoping Scenarios

Trigger and Data Acquisition	Scoping Scenarios Reference (275 MCHF)	Middle (235 MCHF)	Low (200 MCHF)
Level-0 Trigger System			
Central Trigger	✓	✓	✓
Calorimeter Trigger (e/γ)	$\lvert\eta\rvert < 4.0$	$\lvert\eta\rvert < 3.2$	$\lvert\eta\rvert < 2.5$
Muon Barrel Trigger	MDT everywhere RPC-BI Tile-μ	MDT (BM & BO only) Partial η coverage RPC-BI Tile-μ	MDT (BM & BO only) No RPC-BI Tile-μ
Muon End-cap Trigger	MDT everywhere	MDT (EE&EM only)	MDT (EE&EM only)
Level-1 Trigger System			
Output Rate [kHz]	400	200	200
Central Trigger	✓	✓	✓
Global Trigger	✓	✓	✓
Level-1 Track Trigger (*RoI based tracking*)	$p_T > 4$ GeV $\lvert\eta\rvert \leq 4.0$	$p_T > 4$ GeV $\lvert\eta\rvert \leq 3.2$	$p_T > 8$ GeV $\lvert\eta\rvert \leq 2.7$
High-Level Trigger			
FTK++ (*Full tracking*)	$p_T > 1$ GeV 100 kHz	$p_T > 1$ GeV 50 kHz	$p_T > 2$ GeV 50 kHz
Event Filter	10 kHz output	5 kHz	5 kHz
DAQ			
Detector Readout	✓ [400 kHz L1 rate]	✓ [200 kHz L1 rate]	✓ [200 kHz L1 rate]
DataFlow	✓ [400 kHz L1 rate]	✓ [200 kHz L1 rate]	✓ [200 kHz L1 rate]

Detector System	Scoping Scenarios Reference (275 MCHF)	Middle (235 MCHF)	Low (200 MCHF)
Inner Tracker			
Pixel Detector	$\lvert\eta\rvert \leq 4.0$	$\lvert\eta\rvert \leq 3.2$	$\lvert\eta\rvert \leq 2.7$
Barrel Strip Detector	✓	✓ [No stub layer]	✓ [No stereo in layers #2,#4] [Remove layer #3] [No stub layer]
Endcap Strip Detector	✓	✓ [Remove 1 disk/side]	✓ [Remove 1 disk/side]
Calorimeters			
LAr Calorimeter Electronics	✓	✓	✓
Tile Calorimeter Electronics	✓	✓	✓
Forward Calorimeter	✓	✗	✗
High Granularity Precision Timing Detector	✓	✗	✗

Muon Spectrometer	Scoping Scenarios Reference (275 MCHF)	Middle (235 MCHF)	Low (200 MCHF)
Barrel Detectors and Electronics			
RPC Trigger Electronics	✓	✓	✓
MDT Front-End and readout electronics (BI+BM+BO)	✓	✓ [BM+BO only]	✓ [BM+BO only]
RPC Inner layer in the whole layer	✓	✓ [in half layer only]	✗
Barrel Inner sMDT Detectors in the whole layer	✓	✓ [in half layer only]	✗
MDT L0 Trigger Electronics (BI +BM+BO)	✓	✓ [BI +BM only]	✓ [BI +BM only]
End-cap and Forward Muon Detectors and Electronics			
TGC Trigger Electronics	✓	✓	✓
MDT L0 Trigger and Front-End read-out electronics (EE+EM+EO)	✓	✓ [EE +EM only]	✓ [EE +EM only]
sTGC Detectors in Big Wheel Inner Ring	✓	✓	✓
Very-forward Muon tagger	✓	✗	✗

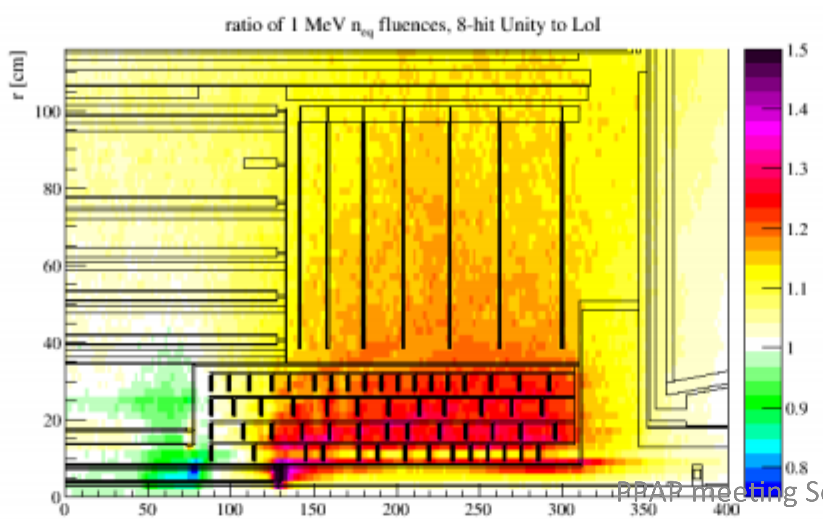
UK projects

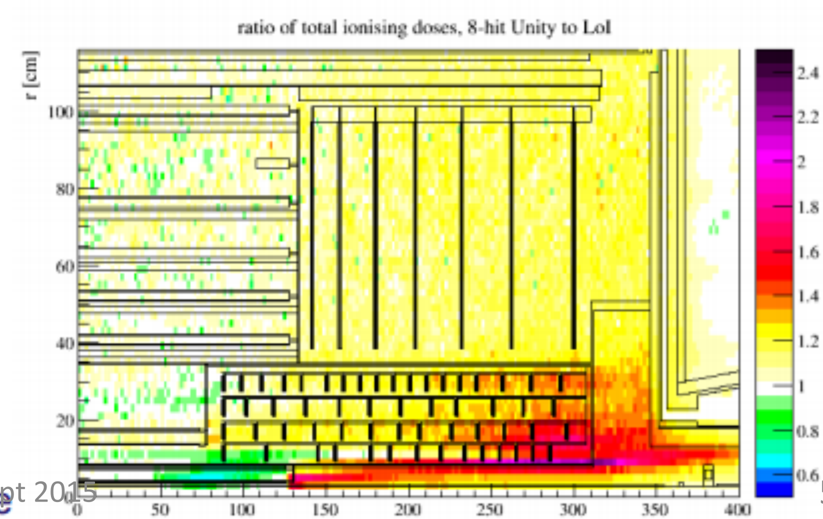
The University Of Sheffield.

ATLAS EXPERIMENT

8-hit Unity 1 MeV fluence + ionising dose

- Services for inner pixel barrel routed at lower radius compared to LoI layout due to smaller radius of Inner Support Tube
- Large number of pixel rings adds large mass in forward region
- These increase 1 MeV fluences + doses throughout the ITk, and particularly in the endcap region
- Effect extends into the FCal region
- Decreases in fluence and dose are artefacts of moving layers + services to different locations





Higgs couplings

- HL-LHC will be a Higgs factory
  - Experiment performance must be maintained or improved over all channels
- Improvements in theory can reduce uncertainties by up to 4%
  - Missing higher orders (scale uncertainties)
  - Improved PDFs
  - Better understanding of pT distributions
- First opportunity to probe the Higgs self-coupling
- HL-LHC brings significant reduction in uncertainties on Higgs coupling measurements
  - Reduce uncertainties on boson and fermionic couplings by ~x2

	Higgs bosons at $\sqrt{s}$=14TeV
HL-LHC, 3000fb^{-1}	170M
VBF (all decays)	13M
ttH (all decays)	1.8M
H->Zγ	230k
H->μμ	37k
HH (all)	121k

		κ_γ	κ_W	κ_Z	κ_g	κ_b	κ_t	κ_τ	$\kappa_{Z\gamma}$	κ_μ
300fb^{-1}	ATLAS	[9,9]	[9,9]	[8,8]	[11,14]	[22,23]	[20,22]	[13,14]	[24,24]	[21,21]
300fb^{-1}	CMS	[5,7]	[4,6]	[4,6]	[6,8]	[10,13]	[14,15]	[6,8]	[41,41]	[23,23]
3000fb^{-1}	ATLAS	[4,5]	[4,5]	[4,4]	[5,9]	[10,12]	[8,11]	[9,10]	[14,14]	[7,8]
3000fb^{-1}	CMS	[2,5]	[2,5]	[2,4]	[3,5]	[4,7]	[7,10]	[2,5]	[10,12]	[8,8]

ATLAS [no theory uncertainty, with theory uncertainty];
CMS [reduced theory and systematic uncertainties, current systematics]

2014 ECFA workshop

LHC Upgrades

- Run-II
  - Aim to achieve nominal LHC luminosity of $10^{34}cm^{-2}s^{-1}$ and deliver $100fb^{-1}$ per GPD by 2019
- Run-III
  - LHC Upgrades
    - PS booster
    - Collimator upgrades
  - Increase luminosity by x2 to $2x10^{34}cm^{-2}s^{-1}$ and deliver 300fb-1
- HL-LHC
  - LHC upgrades
    - New inner triplets, low β*
    - Crab cavities
  - Increase luminosity to $7.5x10^{34}cm^{-2}s^{-1}$ and deliver $3000fb^{-1}$ by 2035