Highlight of recent ATLAS results

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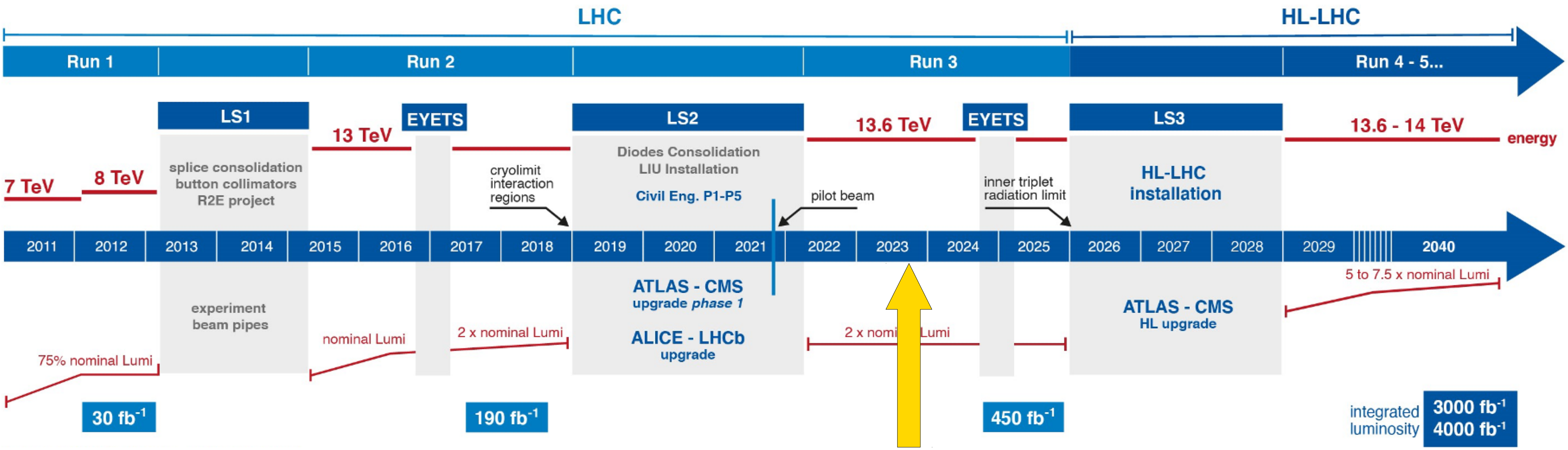
14th Workshop of France China Particle Physics Laboratory

7th of November 2023

Run: 451896
Event: 349429897
2023-05-11 11:46:34 CEST

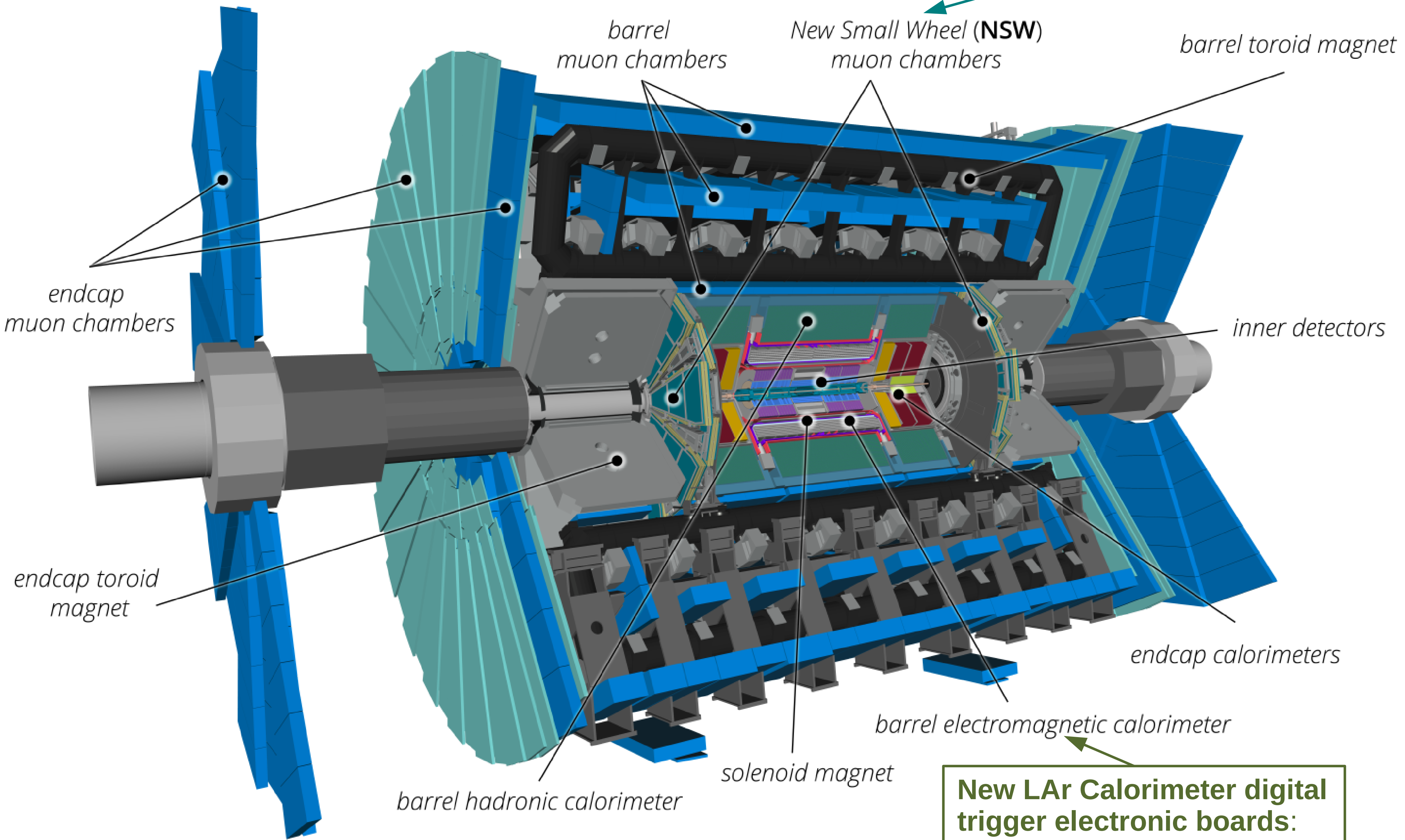
LHC program


LHC
HL-LHC
Run 1
Run 2
Run 3
Run 4 - 5...
LS1
EYETS
LS2
EYETS
LS3
7 TeV
8 TeV
13 TeV
13.6 TeV
13.6 - 14 TeV
energy
splice consolidation
button collimators
R2E project
cryolimit
interaction
regions
Diodes Consolidation
LIU Installation
Civil Eng. P1-P5
pilot beam
inner triplet
radiation limit
HL-LHC
installation
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2040
experiment
beam pipes
ATLAS - CMS
upgrade phase 1
ALICE - LHCb
upgrade
ATLAS - CMS
HL upgrade
5 to 7.5 x nominal Lumi
75% nominal Lumi
nominal Lumi
2 x nominal Lumi
2 x nomi Lumi
30 fb-1
190 fb-1
450 fb-1
integrated
luminosity
3000 fb-1
4000 fb-1

ATLAS detector in Run 3

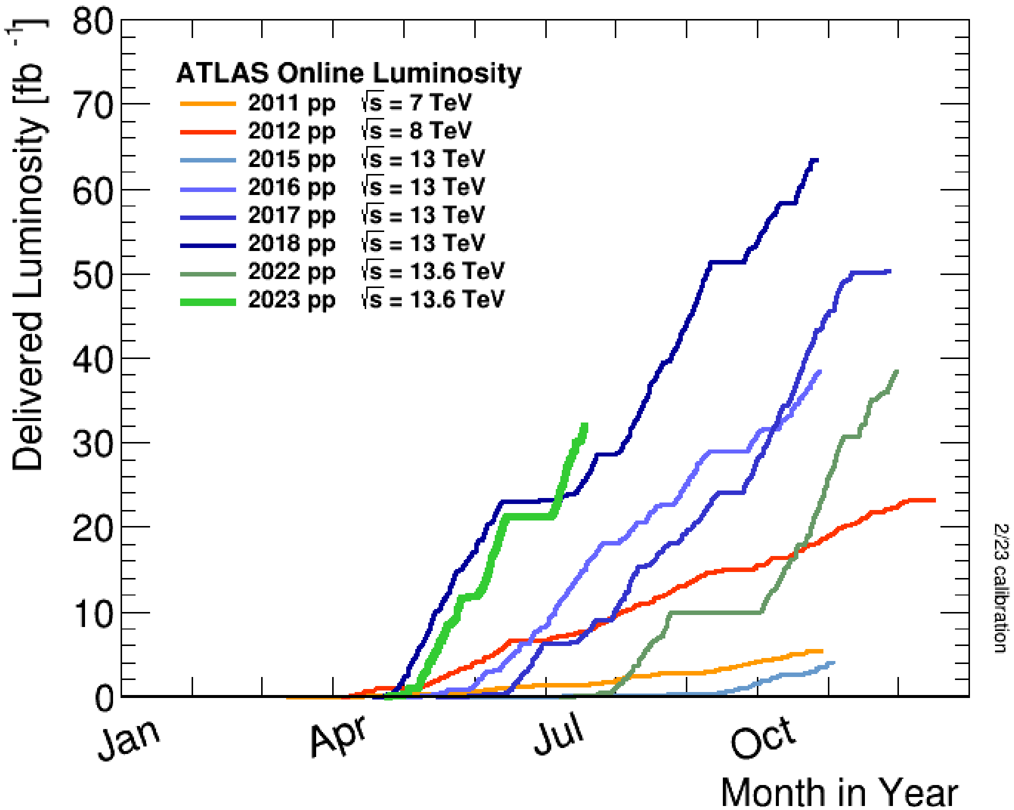
arxiv:2305.16623

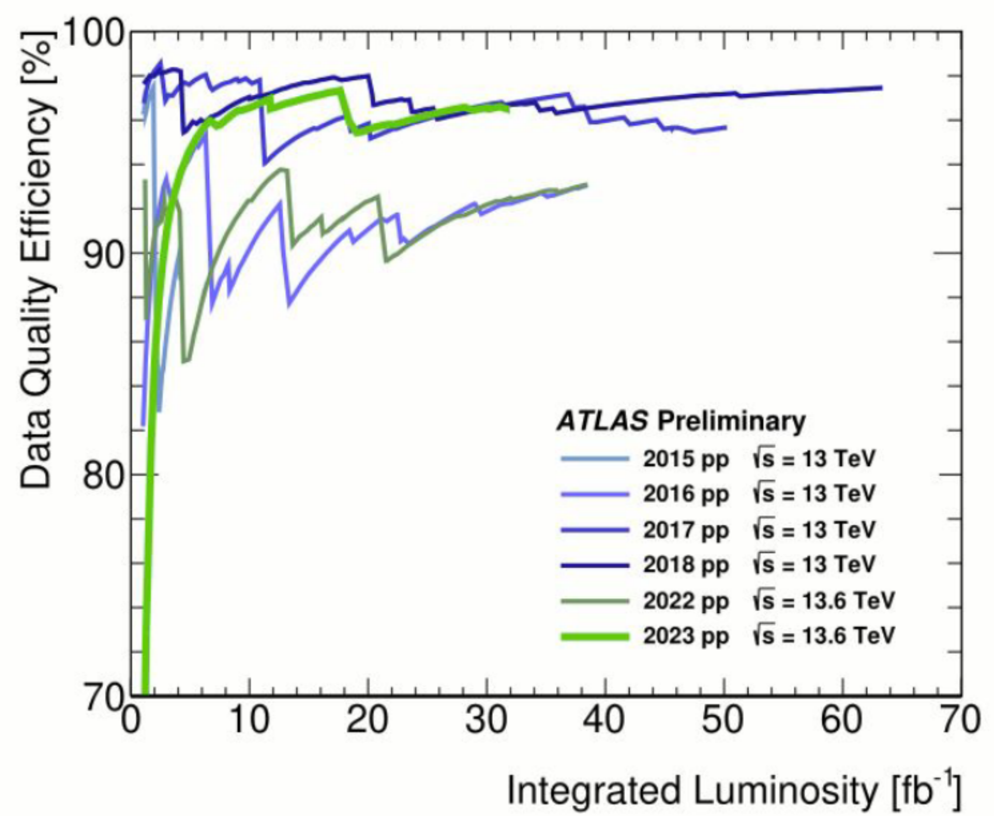
Muon New Small Wheels to replace innermost forward Muon station to
- improve Level 1 trigger
- maintain good tracking in end-cap region



New LAr Calorimeter digital trigger electronic boards: improved trigger granularity

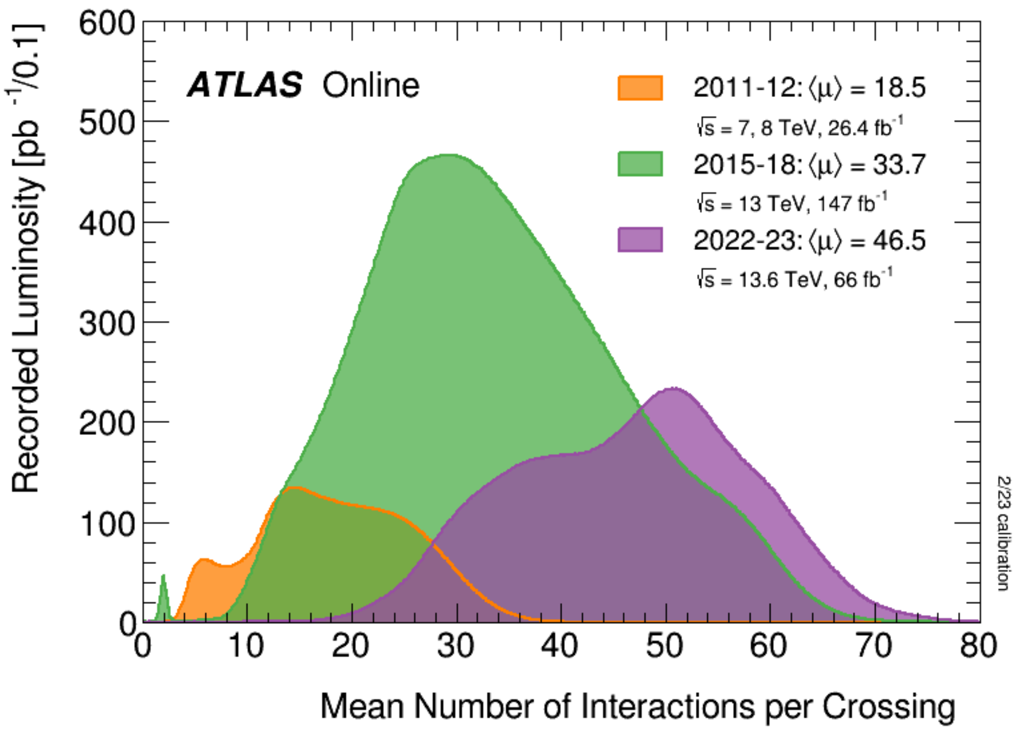
Run 3 so far (1)





- ~66 fb^{-1} of data recorded in Run 3
- 93(94)% data taking efficiency in 2022(2023)
- High data-quality efficiency
- Target Run2+3: 450 fb^{-1} by the end of 2025

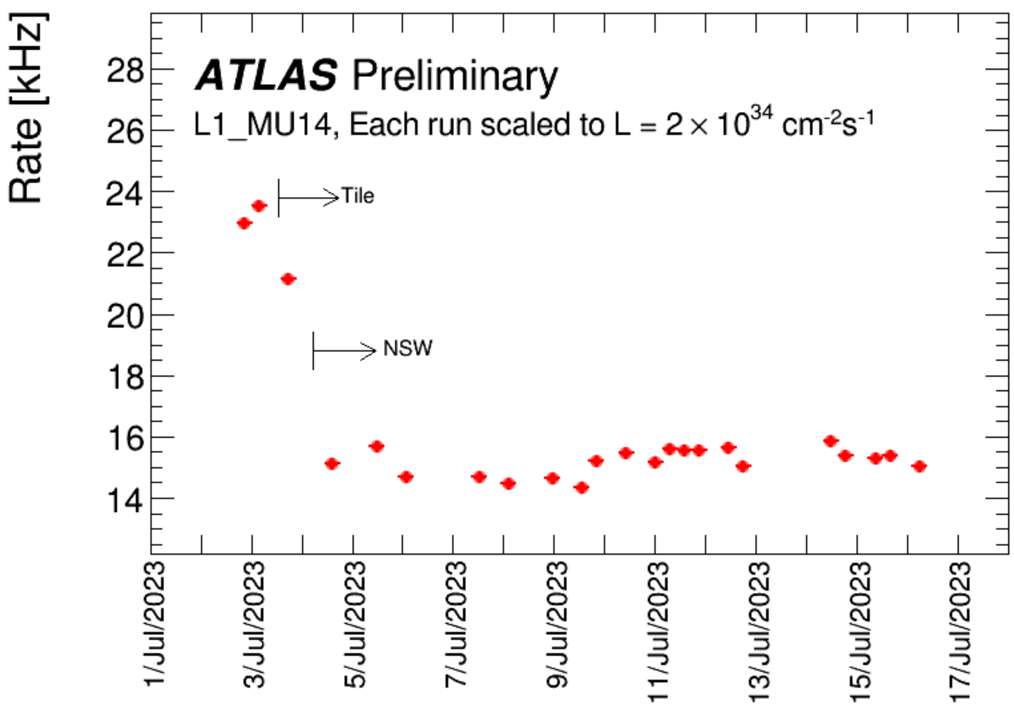
Run 3 so far (2)

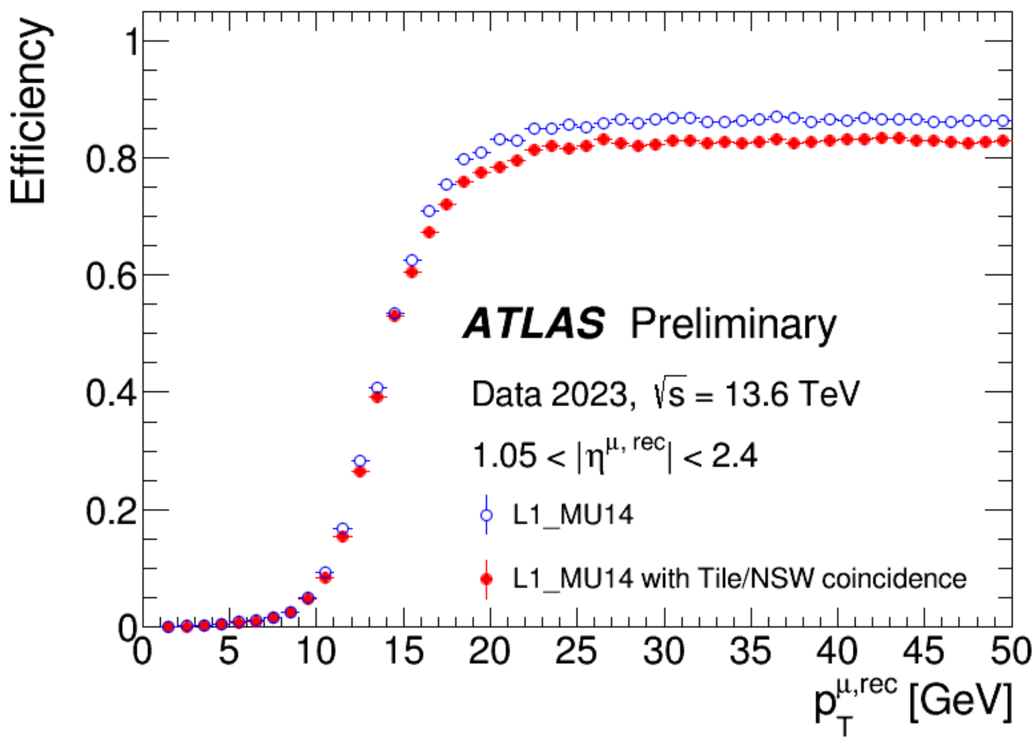


- Mean pileup increased to 60
- Phase-1 upgrades vital to keep trigger rate under control by reducing rate by:
  - 5 kHz by eFEX (L1Calo)
  - 6 kHz by NSW
  - 2 kHz by muon-tile coincidence
- Pixel coping with those conditions despite outer layers being designed for $\mu = 23$
  - optimised operational settings and new DAQ

New triggers for Run 3 (1)

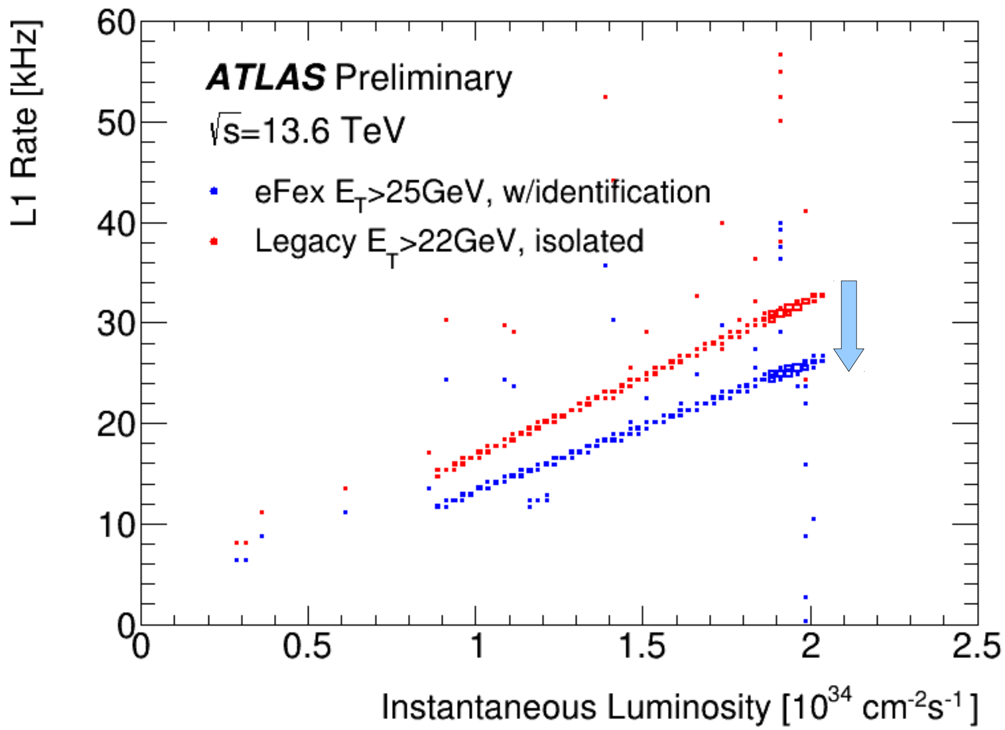
- L1-Muon:
  - decrease of rate with coincidences with Tile and NSW
  - good efficiency

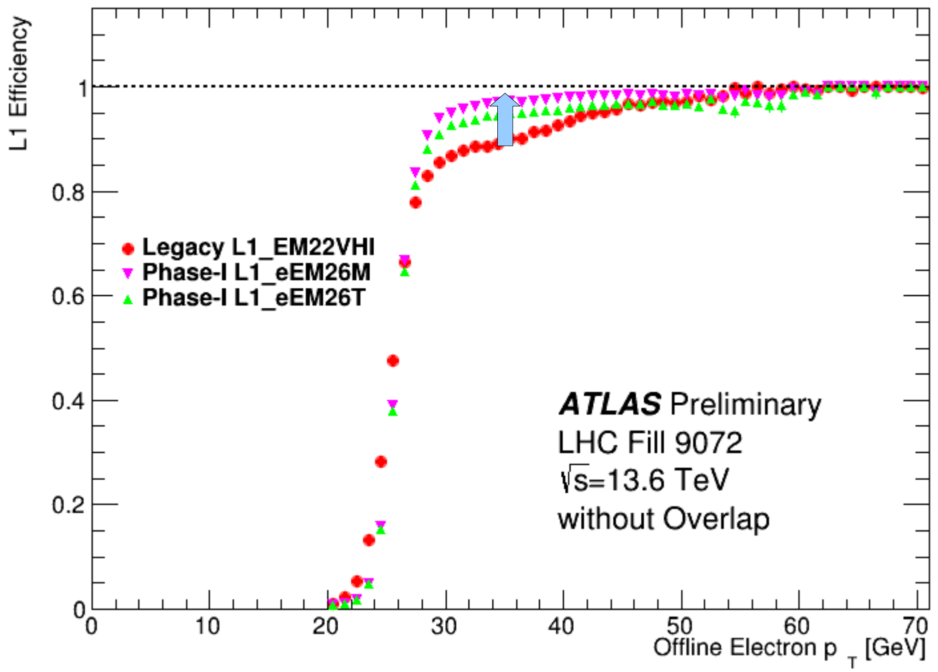




New triggers for Run 3 (2)

- L1-Calo:
  - decrease of trigger rate
  - increase of trigger efficiency

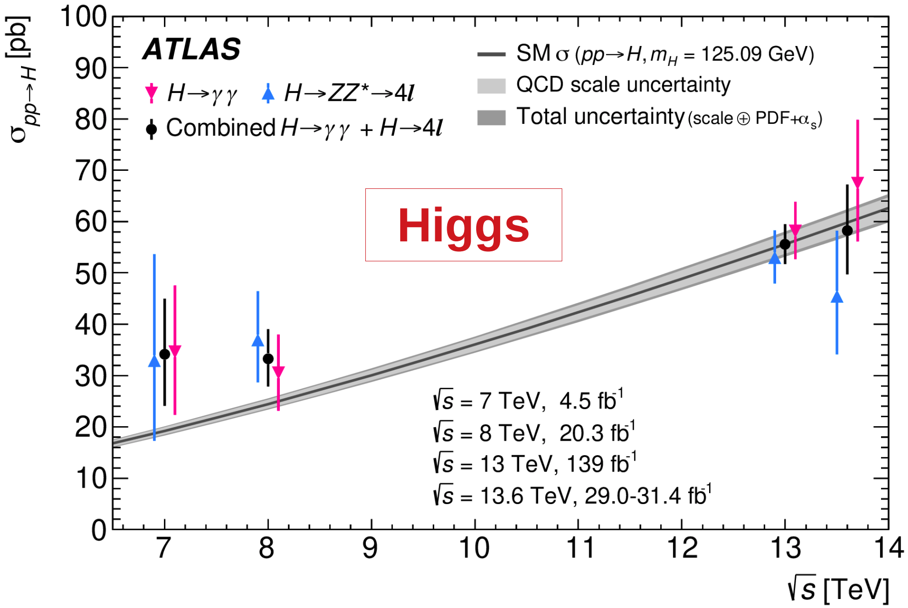


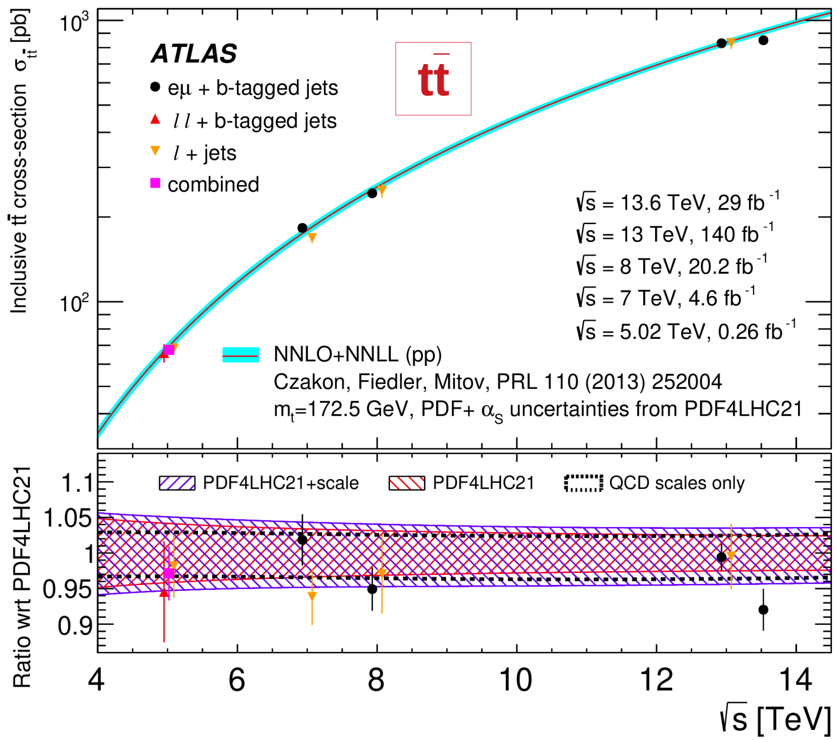


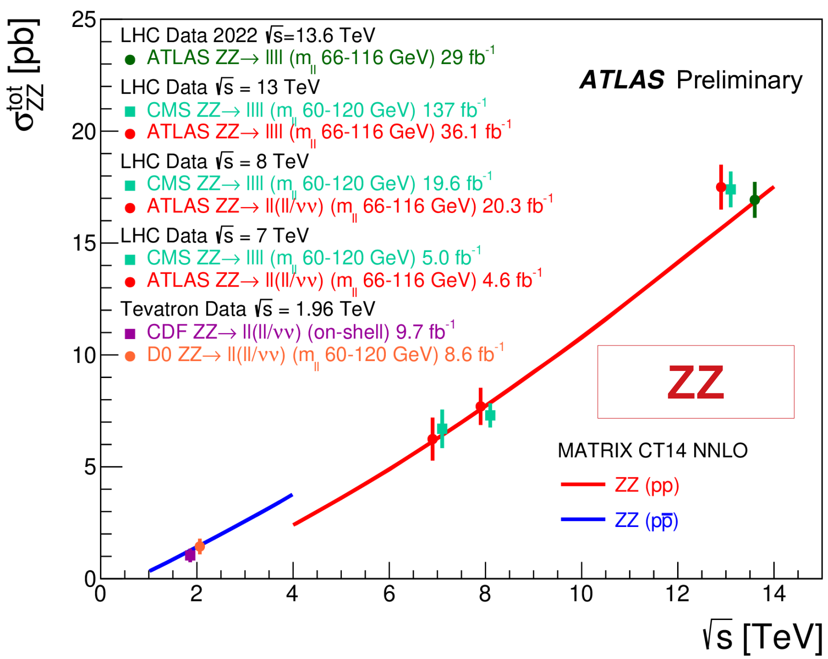
arxiv:2306.11379
arxiv:2308.09529
ATLAS-CONF-2023-062

First Run 3 measurements!

- Rediscovery of SM at 13.6 TeV



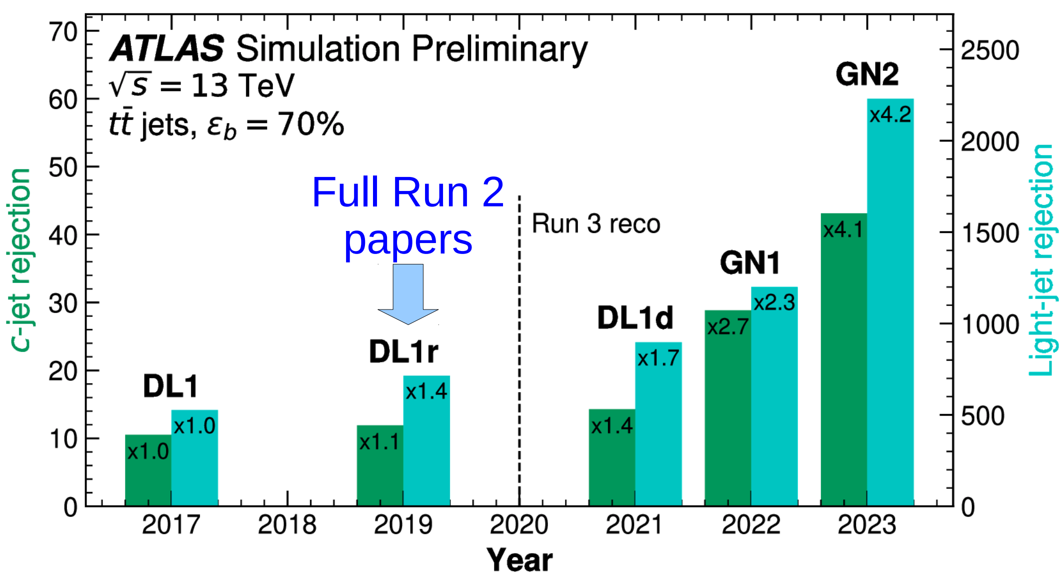




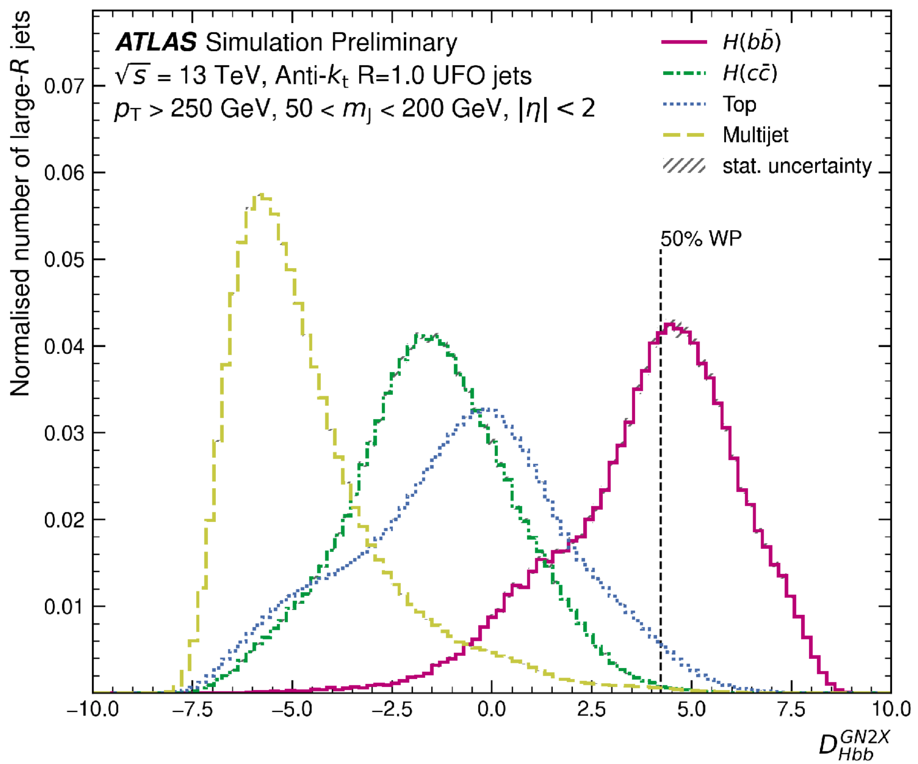
Performance: flavour-tagging

ATL-PHYS-PUB-2022-027
FTAG-2023-01
ATL-PHYS-PUB-2023-021

- New Graph Neural Network algorithms (GN) for Run 3
- Rejections over time for a 70% efficiency:



- Boosted H→ $b\bar{b}/c\bar{c}$ tagging:
  - new algorithm using a transformer neural network architecture: GN2X

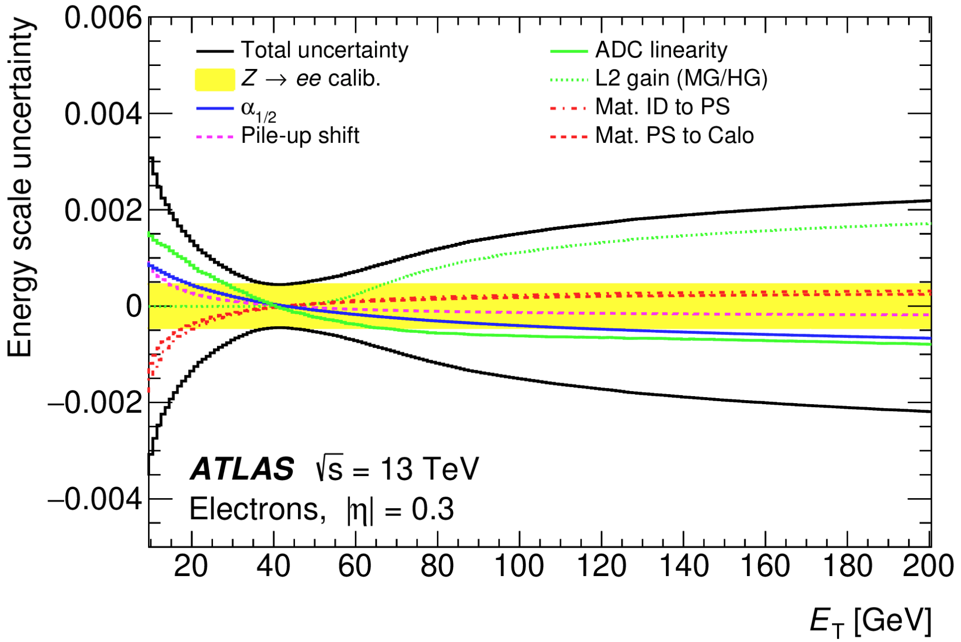


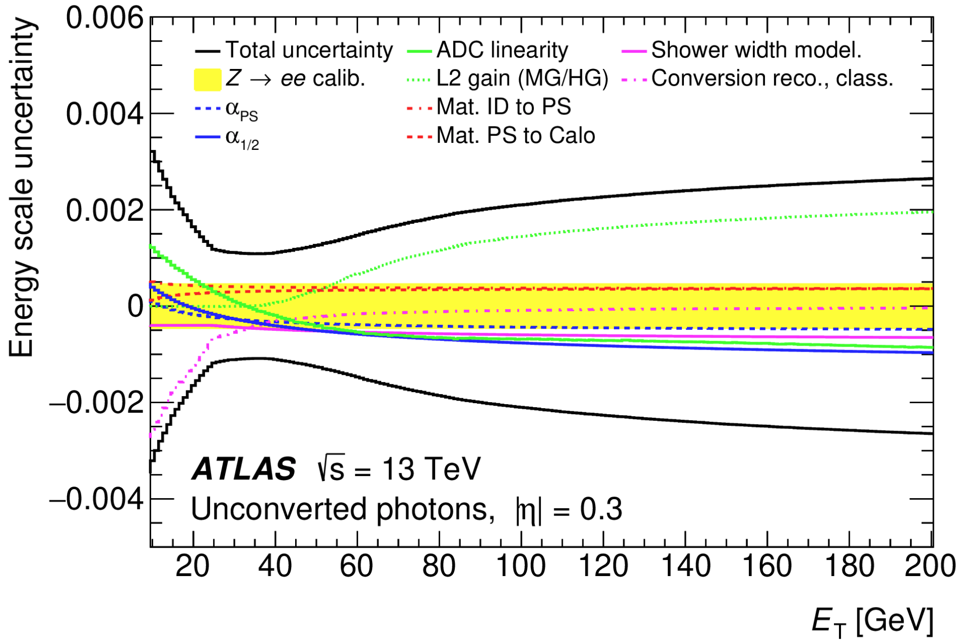
- For 50% signal efficiency:
  - top rejection increased by factor 1.6
  - multijet rejection by a factor 2.5

Performance: e/γ calibration

arxiv:2309.05471

- Improved electron and photon energy calibration
- Energy scale: factor 2-3 with respect to previous calibration



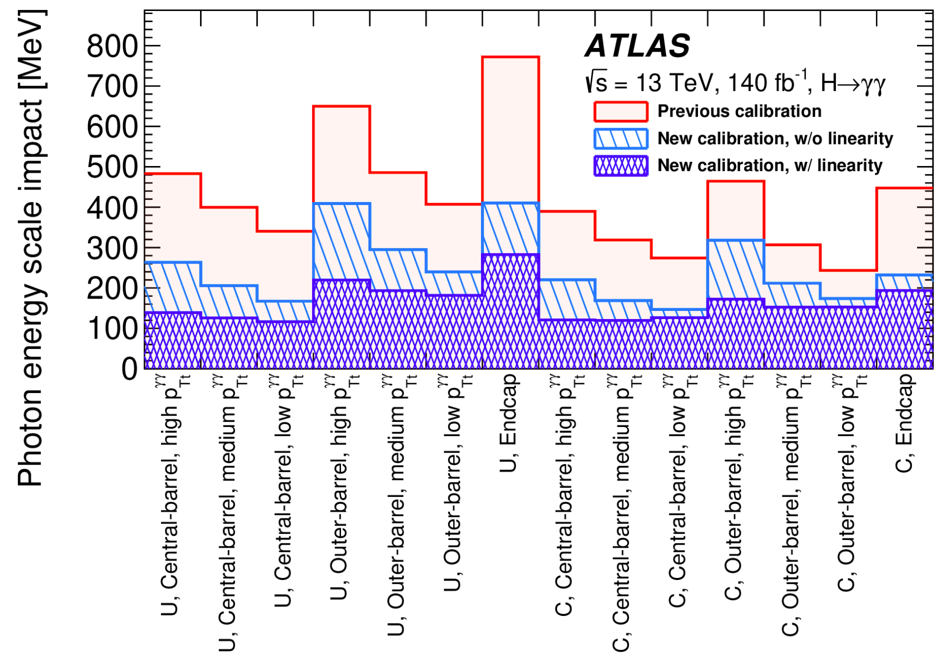


- Calibration uncertainties:
  - electrons: 0.4% at 10 GeV, 0.02% at Z mass, 0.3 % at 1 TeV
  - photons: 0.2 % at 60 GeV

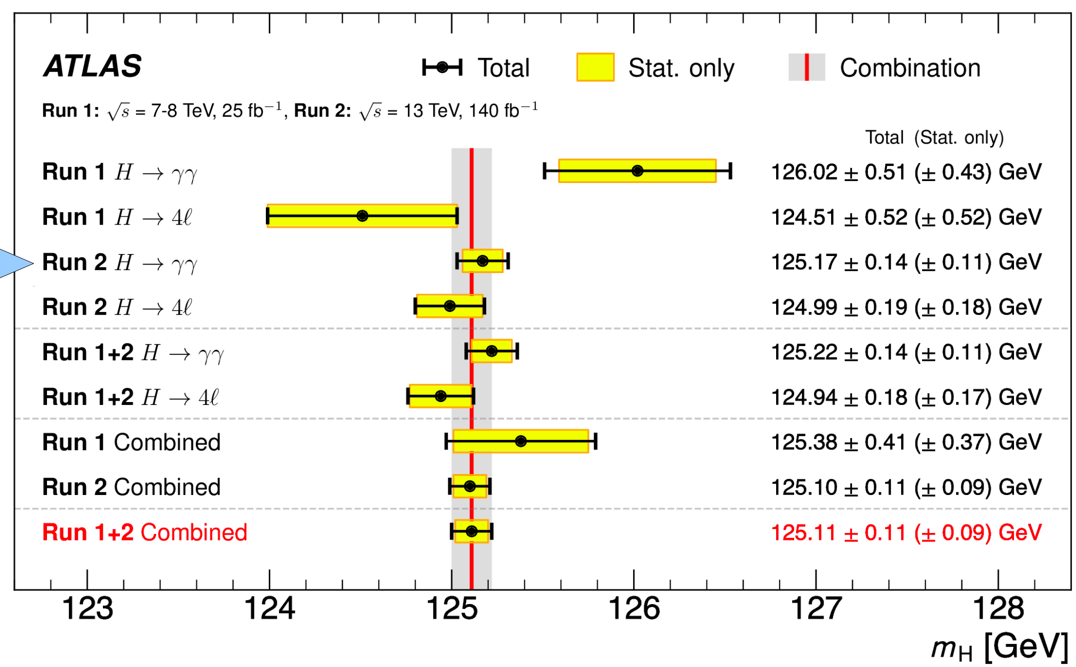
Higgs boson mass

arxiv:2308.07216
arxiv:2308.04775

- H→γγ
  - 30% improvement in systematics: EM calorimeter layer calibration, measure of E lost around e/γ clusters
  - residual electron E scale non-linearities used for first time to constrain systematic uncertainties: further x2 improvement
  - systematics reduced by factor 3: 330 MeV → 90 MeV



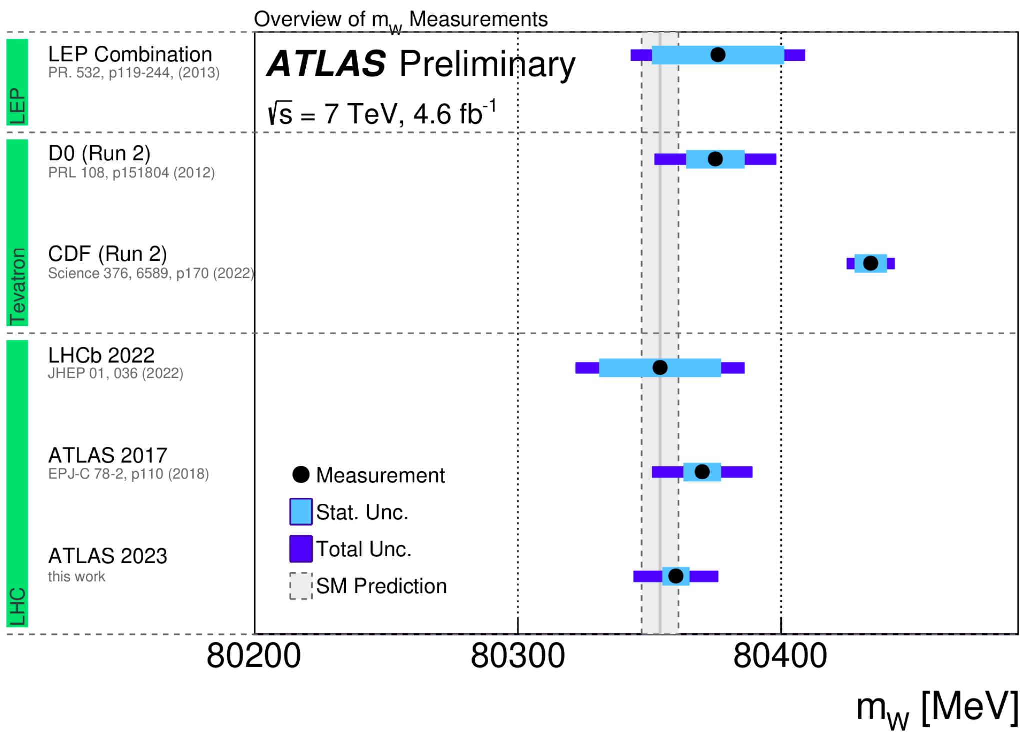
- H→γγ+H→4l:
  - 0.09 % precision achieved!



W boson mass

ATLAS-CONF-2023-004

- Re-analysis of the 7 TeV dataset with improved statistical methods and refinements in the treatment of the data
- W mass determined by fitting the kinematic distributions of the decay leptons in simulation to the data
  - new measurement simultaneously adjusts the systematic uncertainties together with the W mass: reduces several systematic uncertainties, particularly those related to the theoretical modelling of W-boson production and decay
- Special low-μ run at 5 TeV in 2017 to validate the modelling of p_T^W
- Modern PDF sets



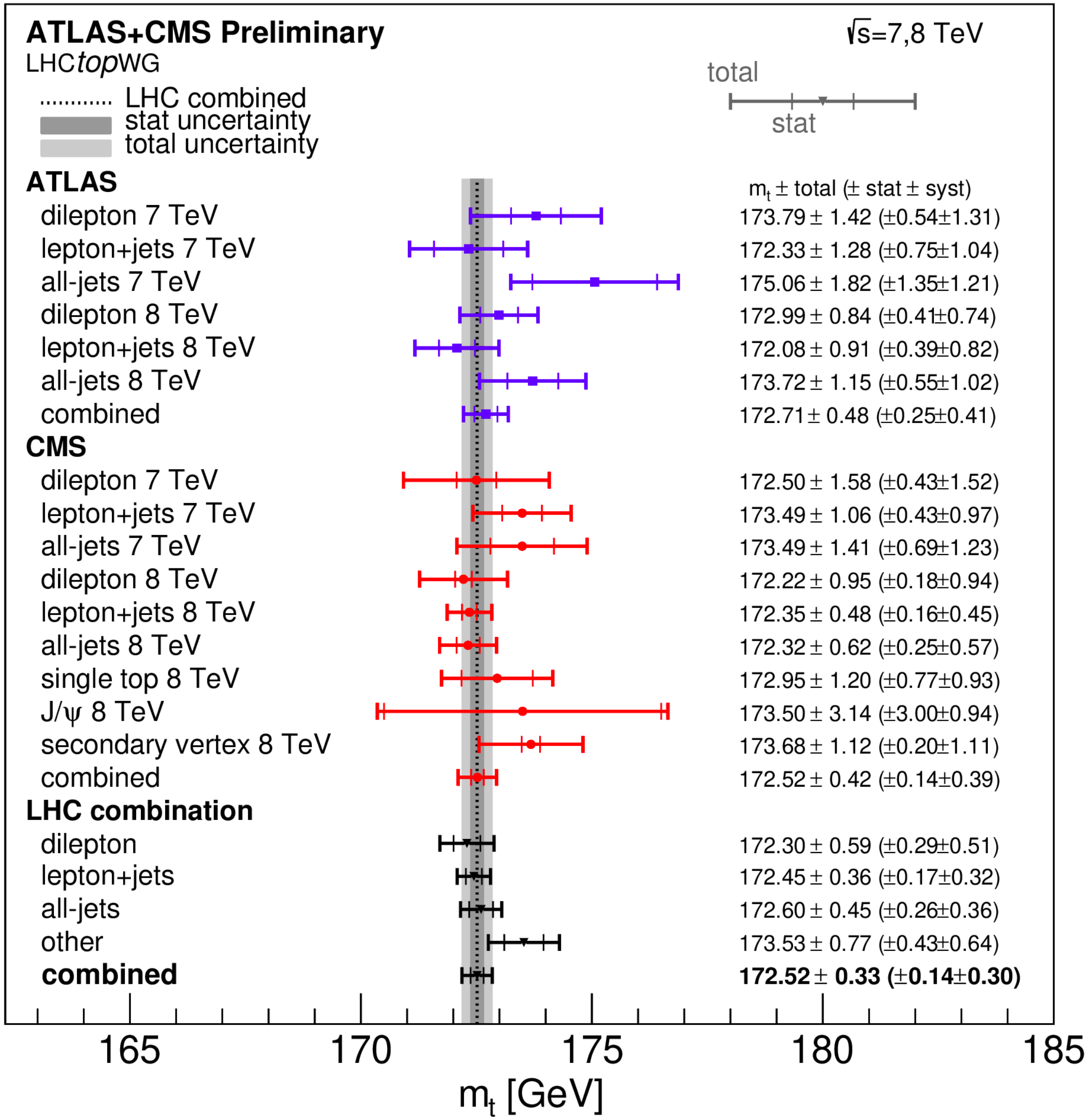
- 2017: m_W = 80370±19 MeV

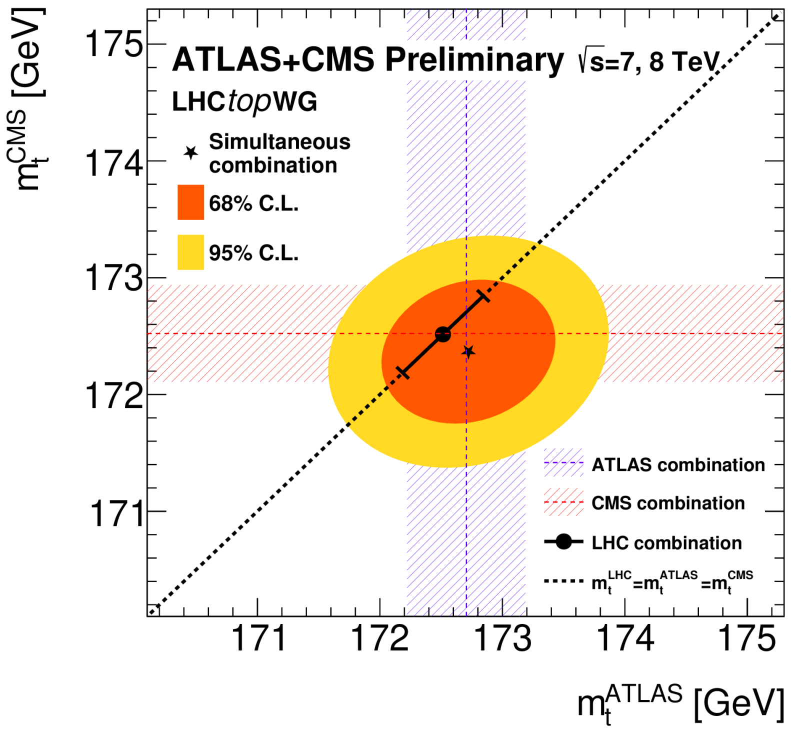
  ⇒ 2023: m_W = 80360±16 MeV

Top quark mass

ATLAS-CONF-2023-066

- Combination of 15 top quark mass measurements by ATLAS and CMS



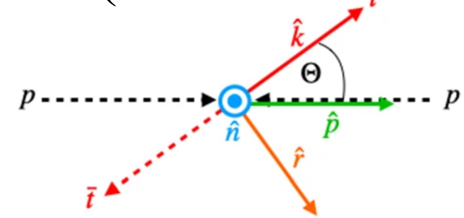


- $m_{top} = 172.52 \pm 0.33$ GeV

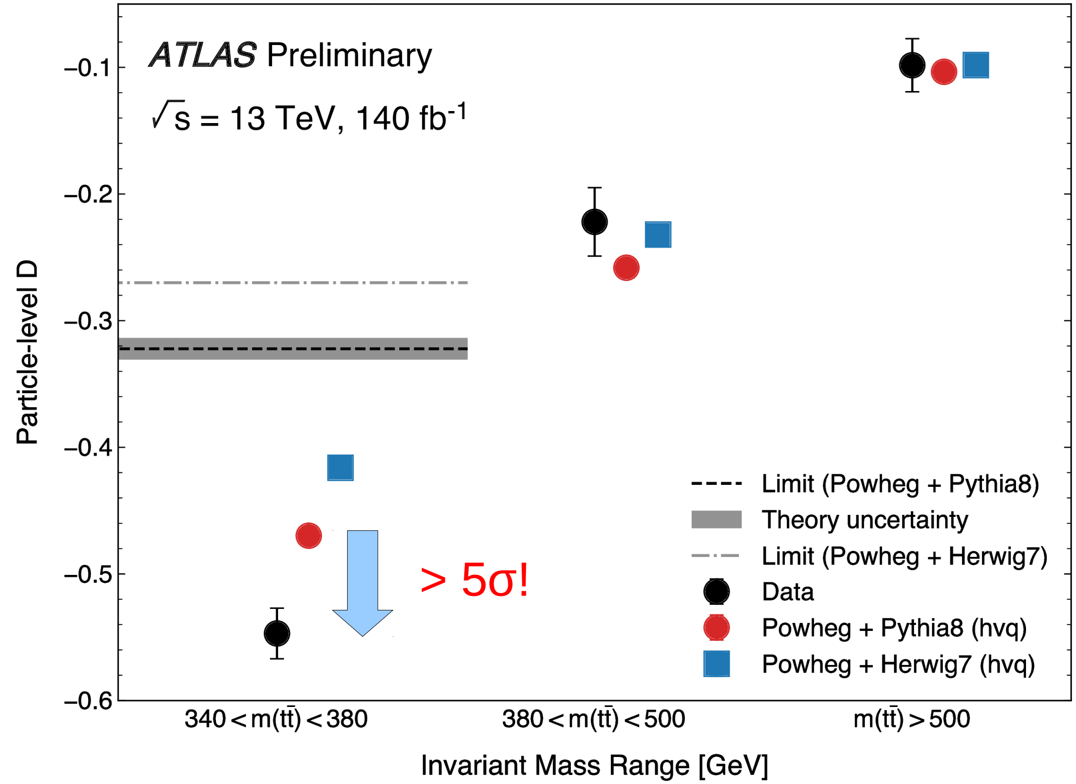
Quantum entanglement with top quark

ATLAS-CONF-2023-069

- Quantum entanglement: predicted in the 1930s, entangled pairs of non-relativistic photons measured in the 1980s (Nobel Prize 2022)



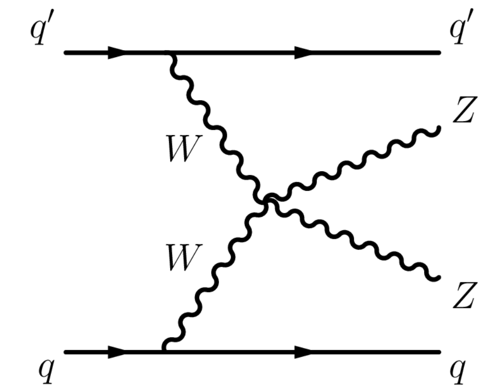
- Top quark decays before it has time to hadronise, transferring all of its quantum numbers to its decay particles ⇒ possible to reconstruct the quantum state of a top quark
  - degree of entanglement (D) from the angular separation of the decay products
    - D < -1/3 ⇒ entanglement
- top-quark pairs at production threshold: max entanglement expected



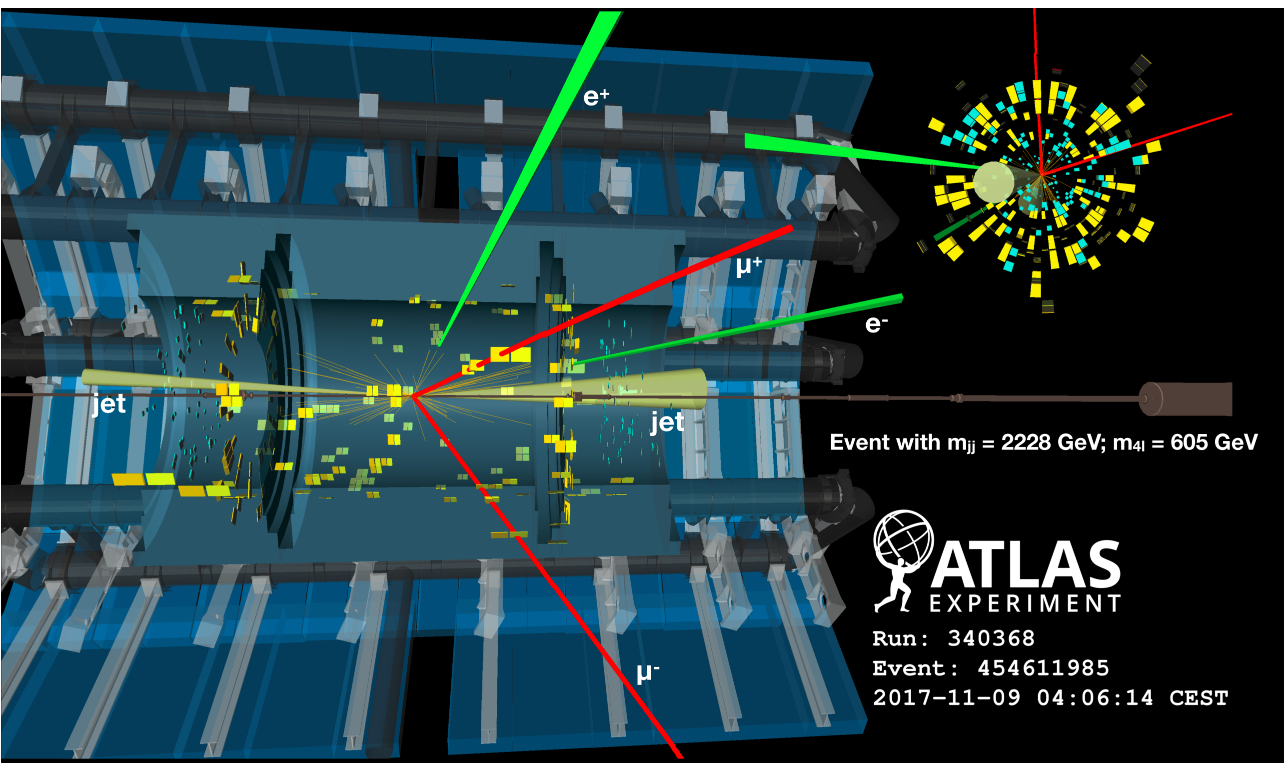
- Entanglement observed with a significance of more than 5σ
- Highest-energy measurement ever!
  - 12 orders of magnitude above usual measurements

Standard Model: VBS

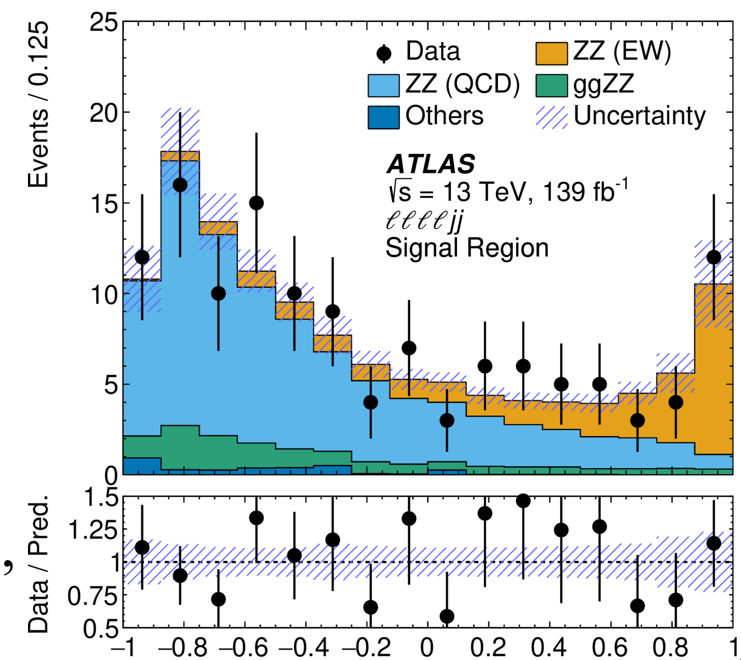
arxiv:2004.10612



- Vector Boson Scattering: probing EW symmetry
  - SM only allows WWWW, WWγγ, WWZγ and WWZZ, forbidding interactions among four neutral bosons
  - broad research programme
- Electroweak VVjj production via Vector Boson Scattering:



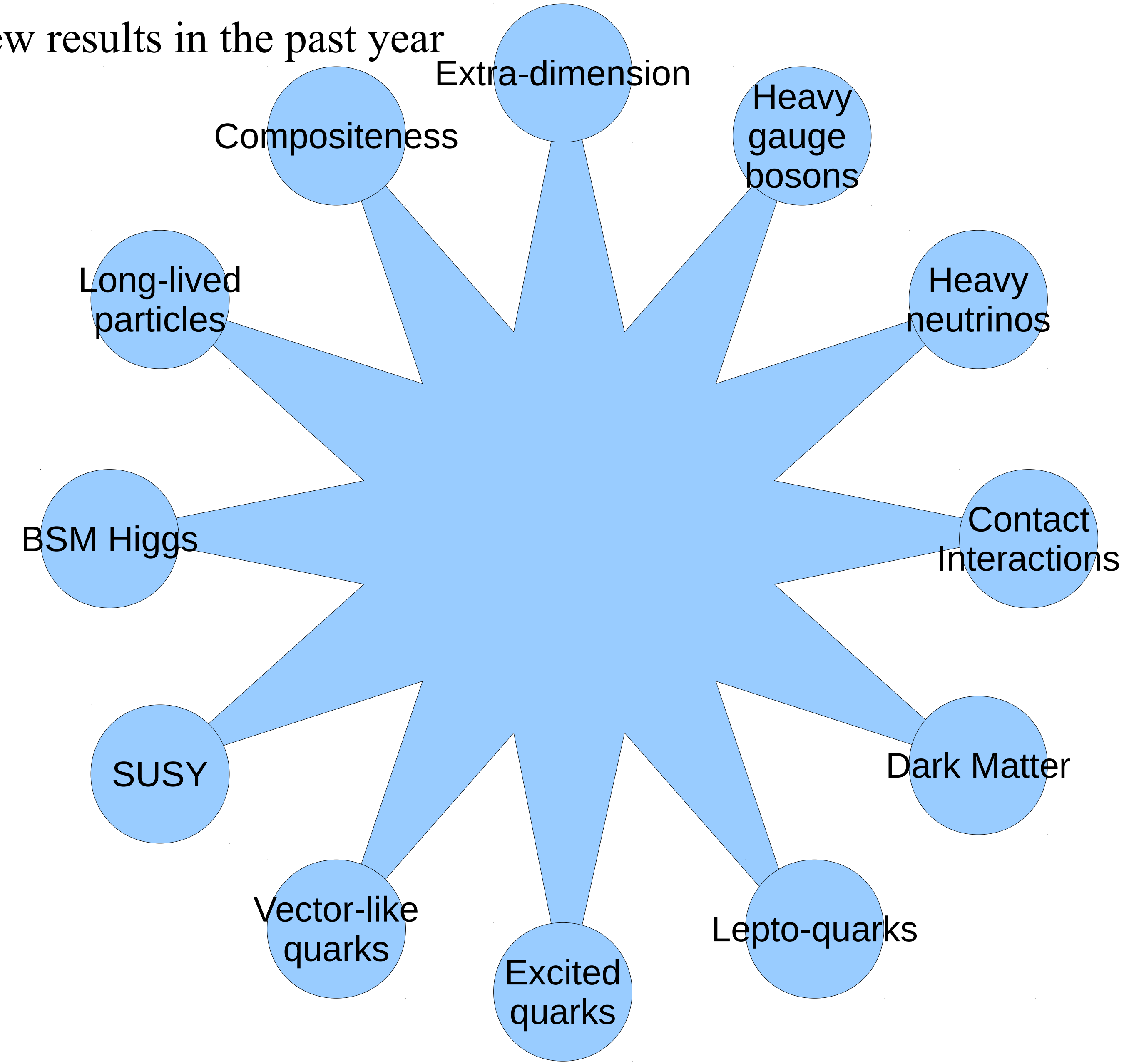
WWjj: observed in 2019
WZjj: observed in 2019
Zγjj: observed in 2022
ZZjj: observed in 2023



- ATLAS has observed all relevant VBS channels, setting constraints on anomalous couplings

BSM searches

- Huge search program
  - ~70 new results in the past year



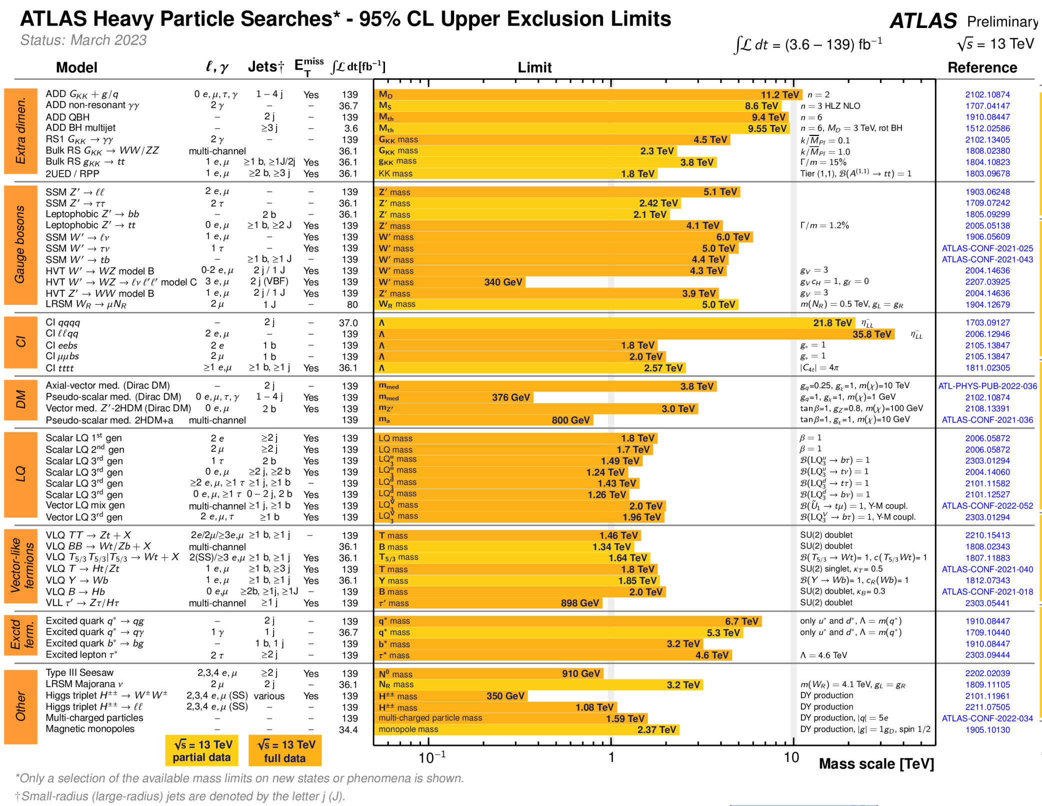
BSM searches

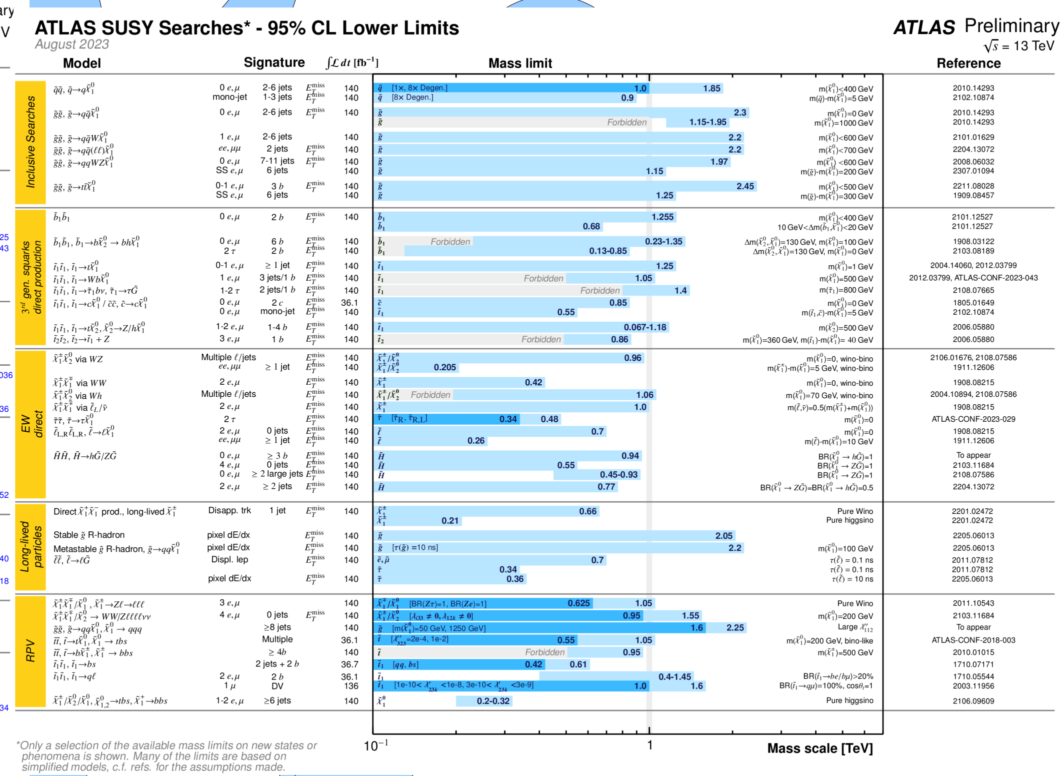
- Huge search program
  - ~70 new results in the past year

Compositeness

Extra-dimension

Heavy gauge bosons





Vector-like quarks

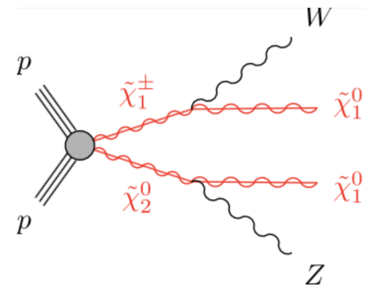
Excited quarks

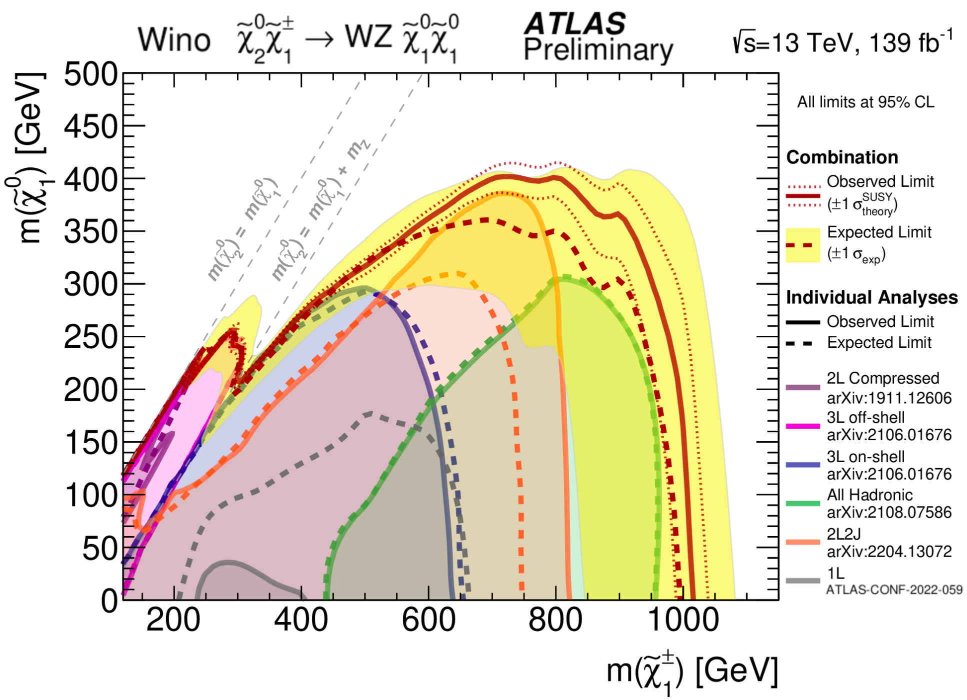
Lepto-quarks

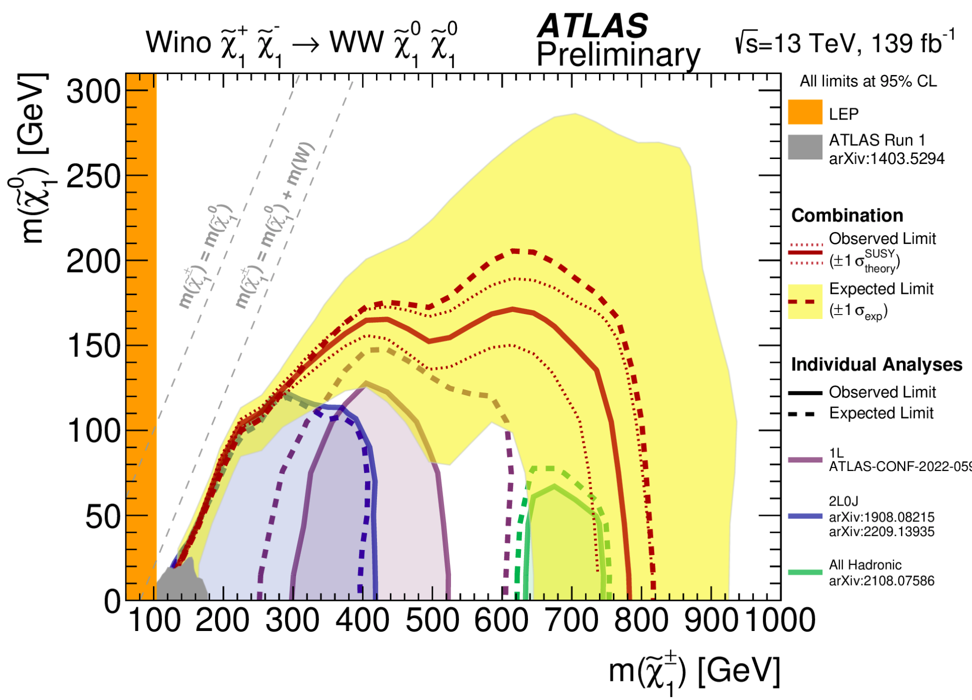
Combination of EWK SUSY Searches

ATLAS-CONF-2023-046

- Statistical combination of different chargino and neutralino production, decaying via W, Z and h



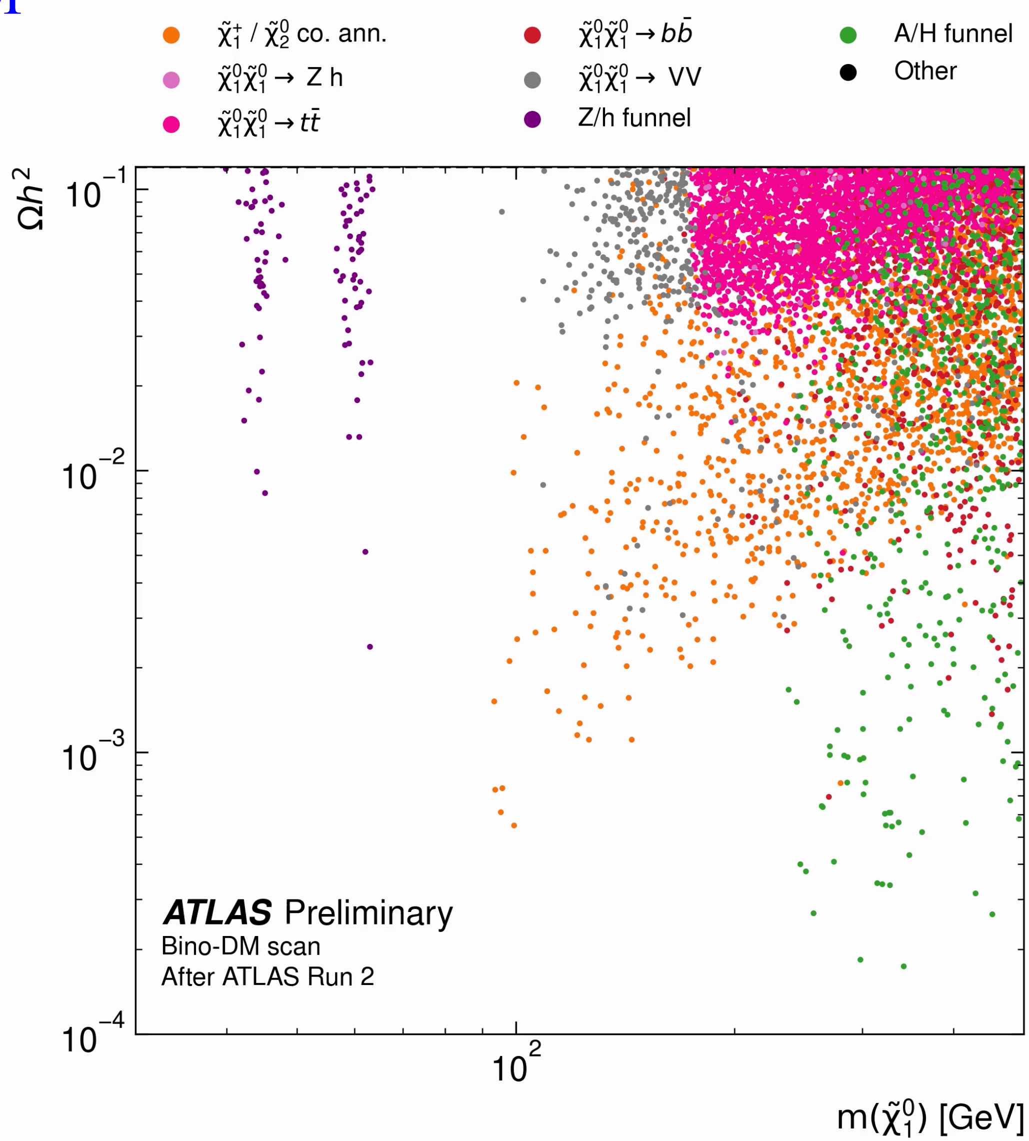




- Improves sensitivity by 15 - 40 %
- Covers gaps for challenging heavy-lepton scenarios

Electroweak pMSSM

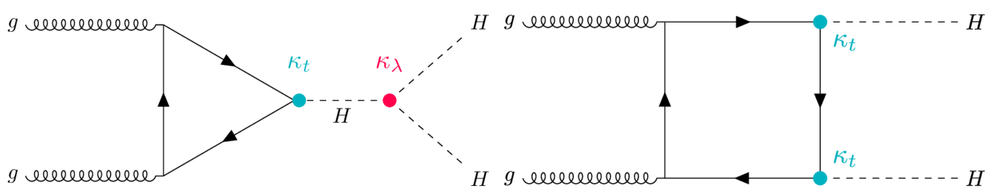
- Combination of 8 analyses in pMSSM framework
- Includes LHC (eg SUSY searches, Higgs → invisible) and external constraints (eg dark matter direct-detection)
- Overall 12280 models tested
- Almost full exclusion of low mass neutralino region that would not oversaturate the dark matter relic abundance

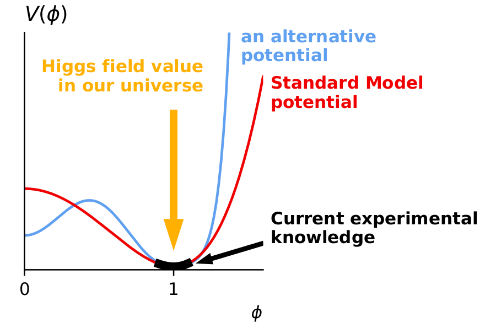


Higgs self-coupling: new prospects

ATL-PHYS-PUB-2022-053

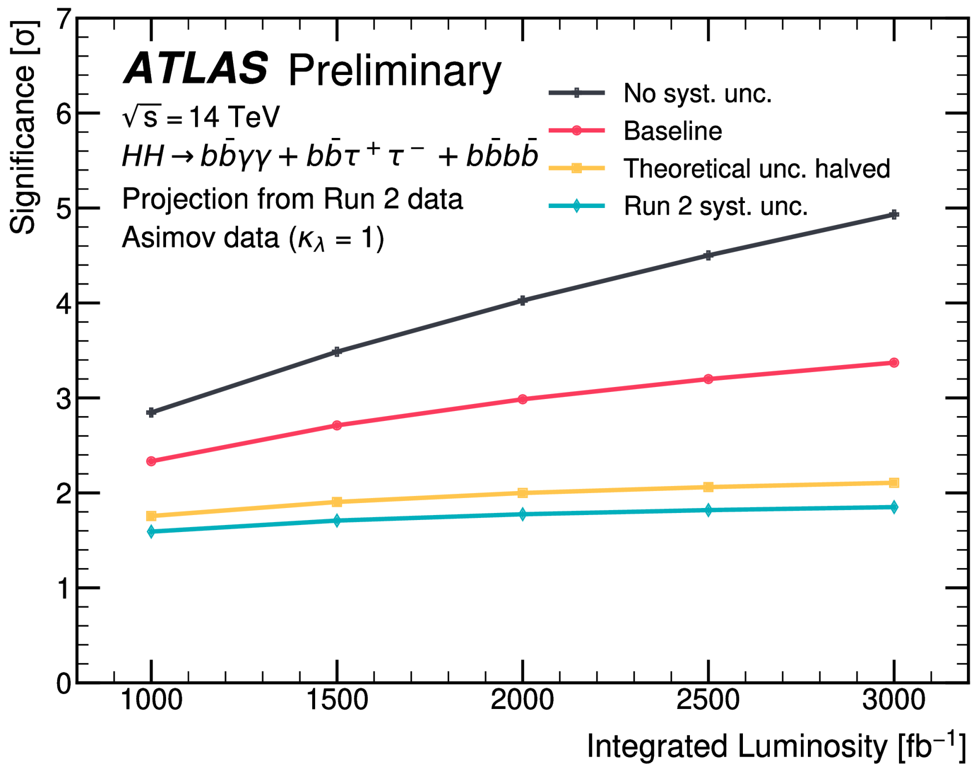
- Higgs self-coupling can be measured from the di-Higgs production
  - main goal of the HL-LHC program





- New projection from Full Run 2 HH→ 4b, $b\bar{b}\tau\tau$ and $b\bar{b}\gamma\gamma$
- Expected significance:

	Stat-only	Stat+Syst
YR2019	3.5σ	3.0σ
ATL-PHYS-PUB-2022-05	4.9σ	3.4σ



- 68% Confidence Intervals on κ_λ:

	Stat-only	Stat+Syst
YR2019	[0.4 ; 1.7]	[0.25 ; 1.9]
ATL-PHYS-PUB-2022-05	[0.7 ; 1.4]	[0.5 ; 1.6]

- ATLAS-only in new prospect ≈ ATLAS+CMS in 2019

Conclusion

- 118 new ATLAS results released since last year
- A lot of Full Run 2 results
  - precision measurements
  - searches
  - continuous improvement of the object reconstruction/calibration and analysis techniques
- Already some Run 3 results available
  - Latest detector upgrades working well

Back-up