ATLAS Status Report

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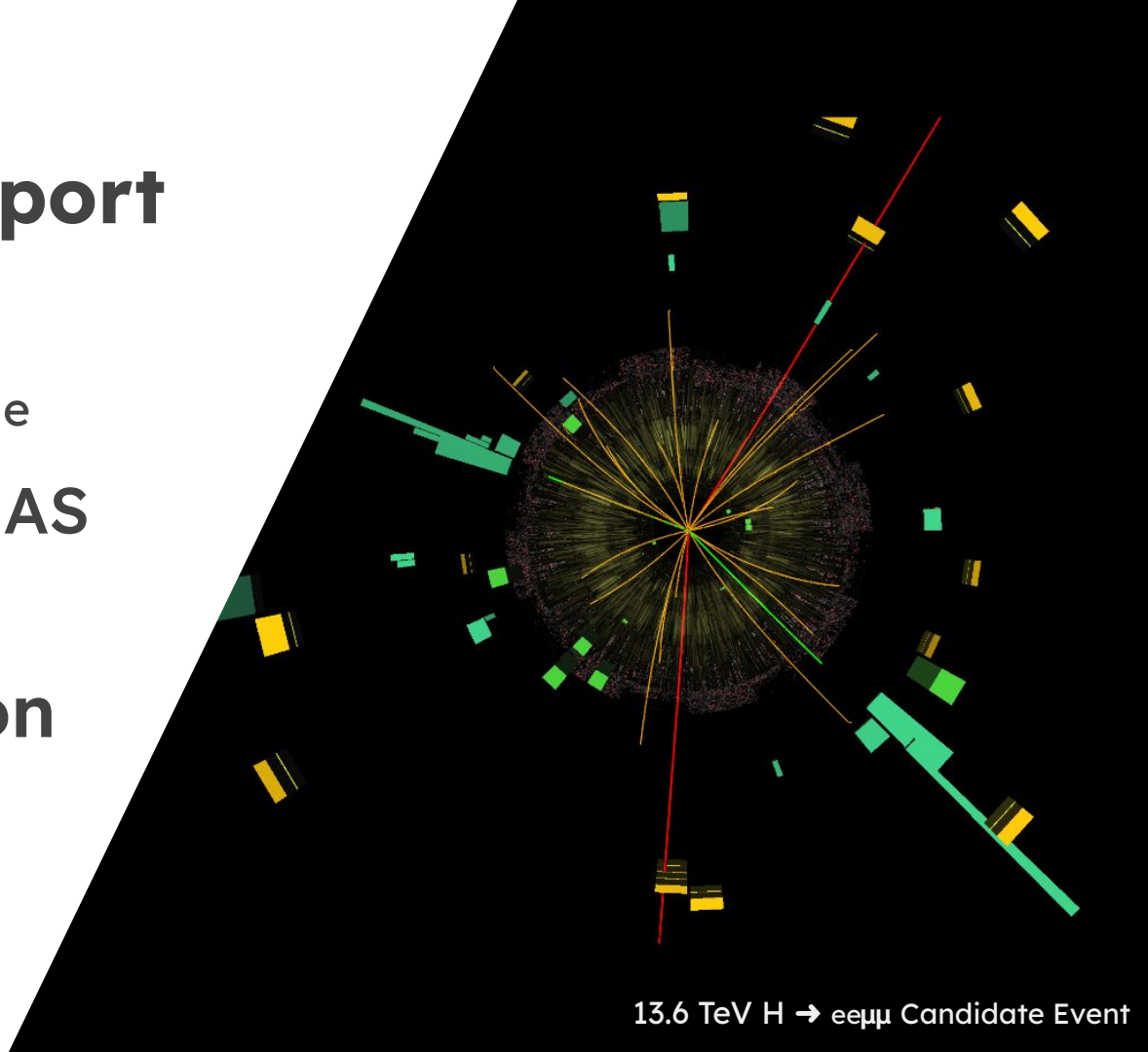
On behalf of the ATLAS collaboration

LHCC Open Session

13. Sep 2023

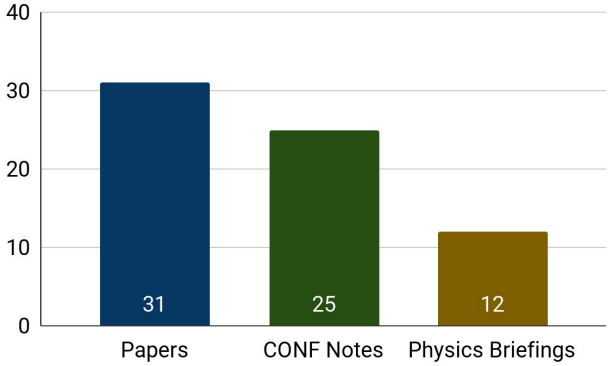


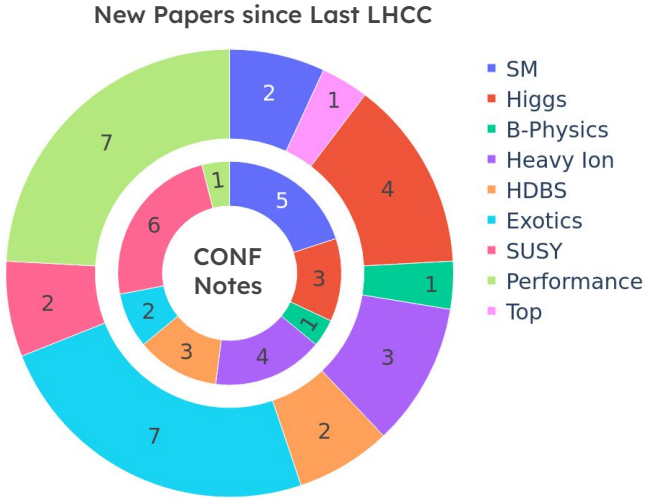
1 Analysis

2 Detector Status

3 Upgrade Status

Since Last LHCC





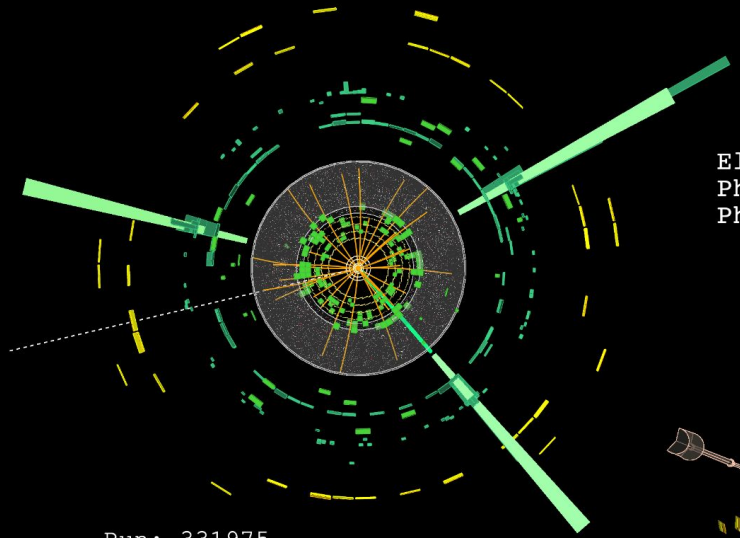
1 Standard Model

2 Higgs Physics

3 BSM Searches

4 Heavy Ion

$W\gamma\gamma$ Observation at 5.6σ



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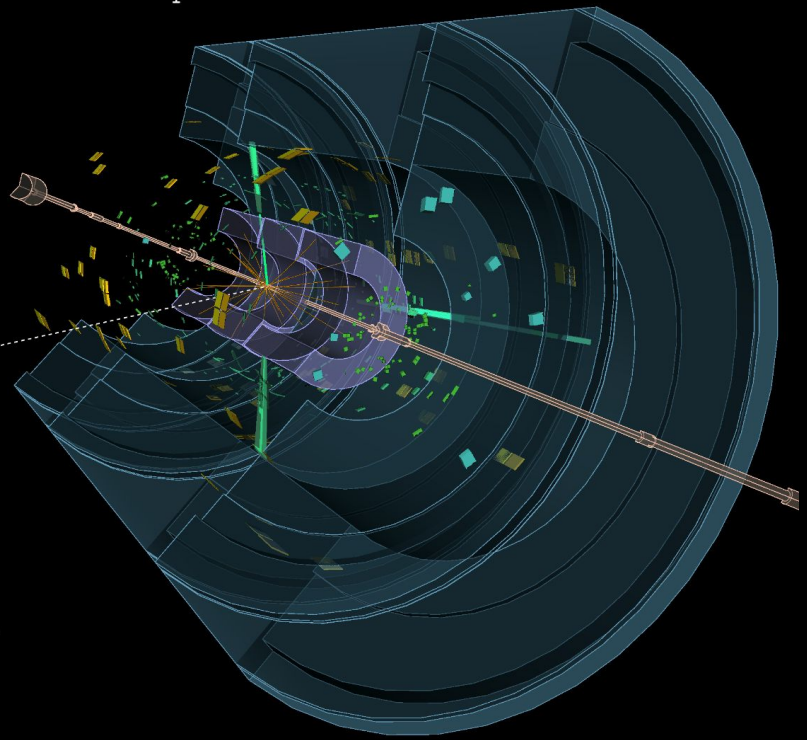
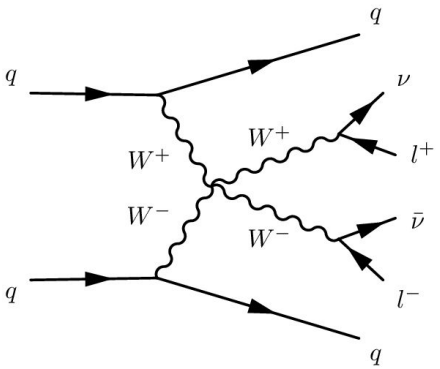


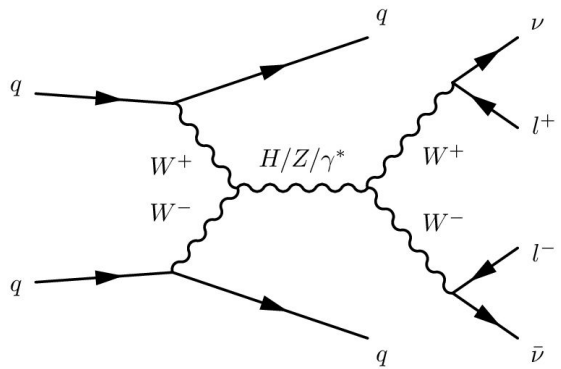
ATLAS EXPERIMENT

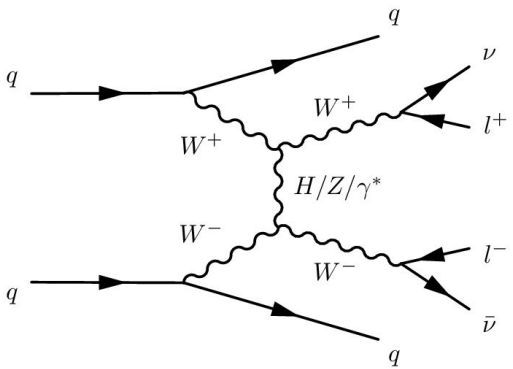
W^+W^-jj VBS Observation

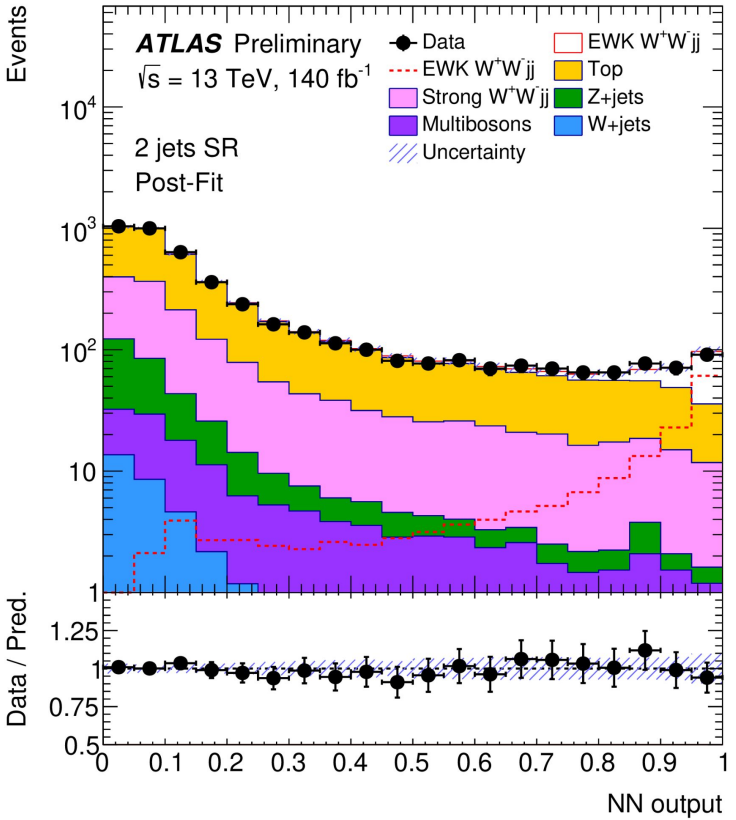
ATLAS-CONF-2023-039

- Sensitive to electroweak symmetry breaking
- Uses NN to differentiate background from signal
- **Observation with 7.1σ** (6.2σ expected)
- Measured $\sigma = 2.65^{+0.52}_{-0.48}$ fb





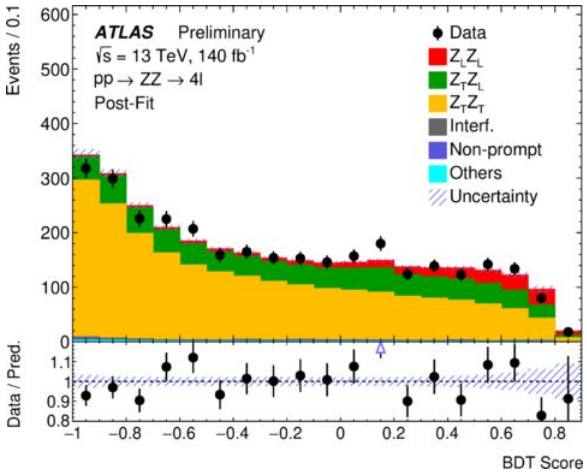


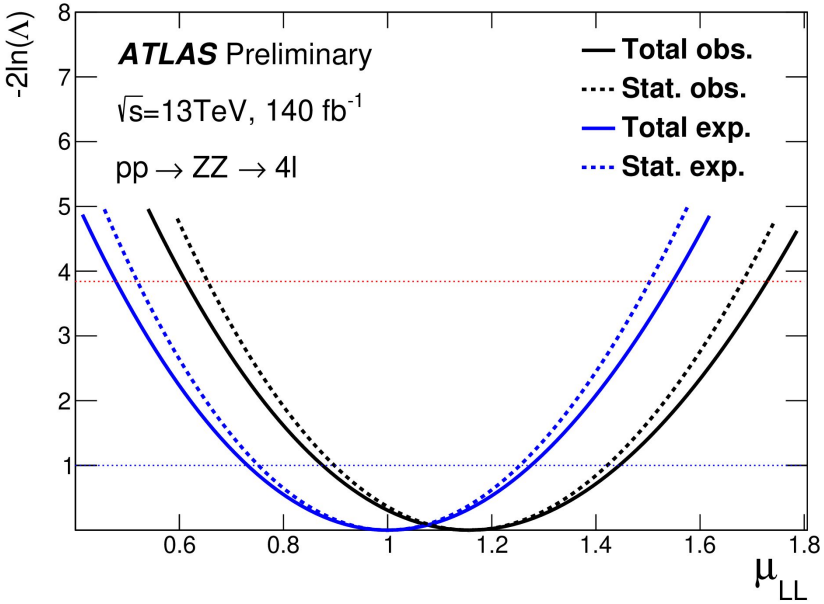


ZZ Longitudinal Polarization

ATLAS-CONF-2023-038

- **New analysis** probing of the electroweak symmetry breaking mechanism in ZZ → 4l
- Adds to ATLAS observation of joint W & Z longitudinal polarisation in WZ production
- **Evidence for longitudinally polarized Z bosons at 4.3σ** (3.8σ expected)
- Also measured several CP properties in agreement with SM

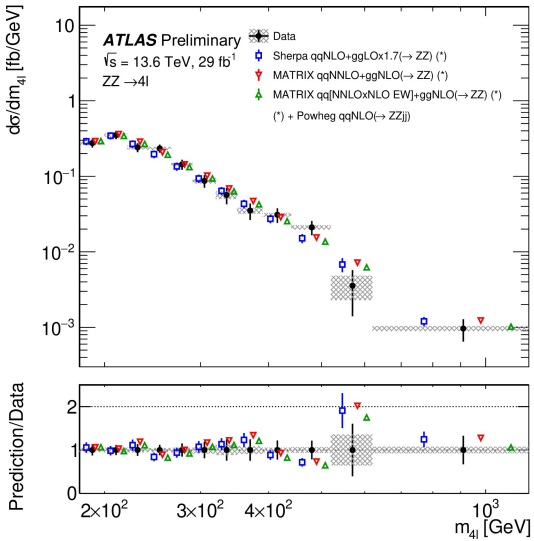


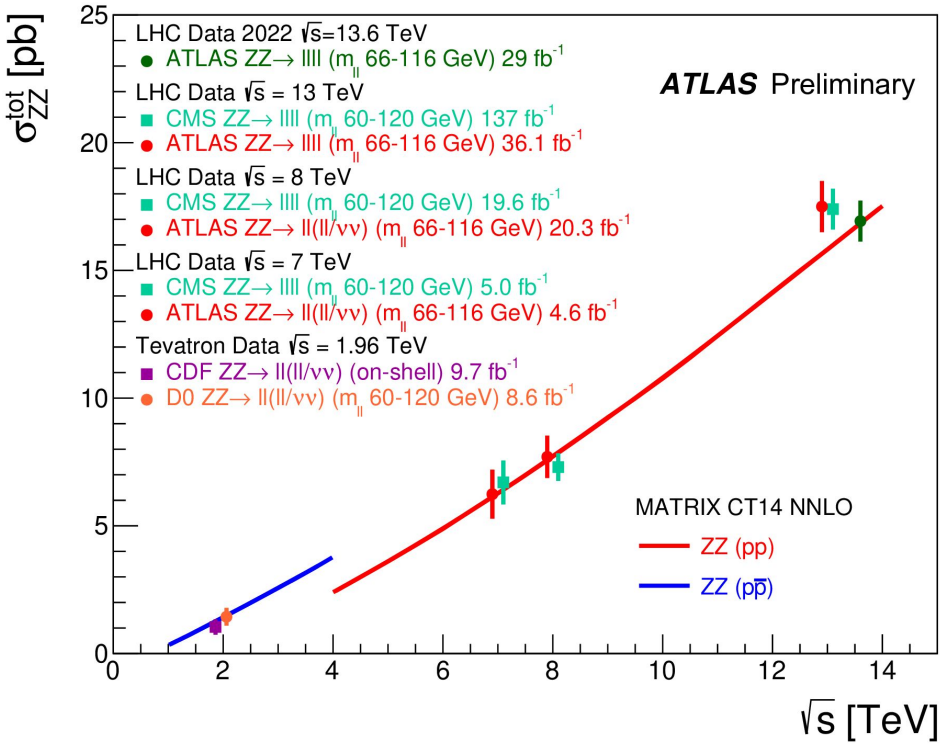


ZZ → 4ℓ Measurement with Run 3 Data

ATLAS-CONF-2023-062

- Measured cross section in agreement with SM (16.9 ± 1.1 pb)
- Already used slim data format developed for HL-LHC
- Also measured differential cross sections over m_{4l} and p_T^{4l}



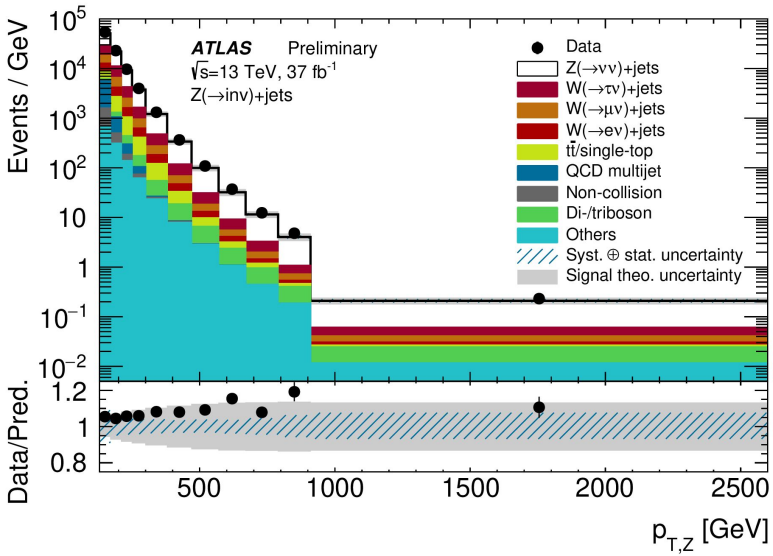


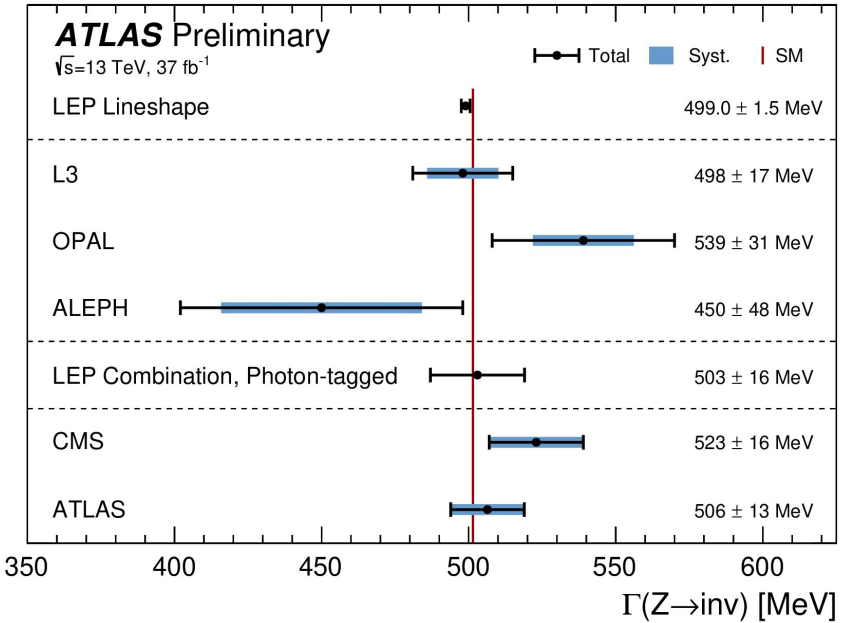
Adds to Higgs re-observation and tt̄ and Z measurement with Run 3 data

Z ➜ Invisible Width

ATLAS-CONF-2023-053

- Select events where Z recoils against jet
- Measure ratio of Z → invisible to Z → 2l to cancel many systematic uncertainties
- Important test of SM
- **Most precise recoil-based constraint on Γ(Z ➜ inv)** (LEP lineshape result more precise)





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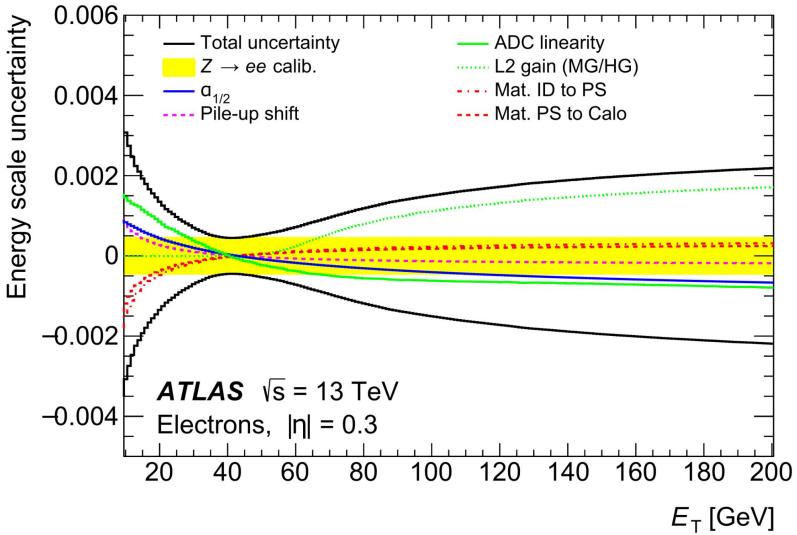
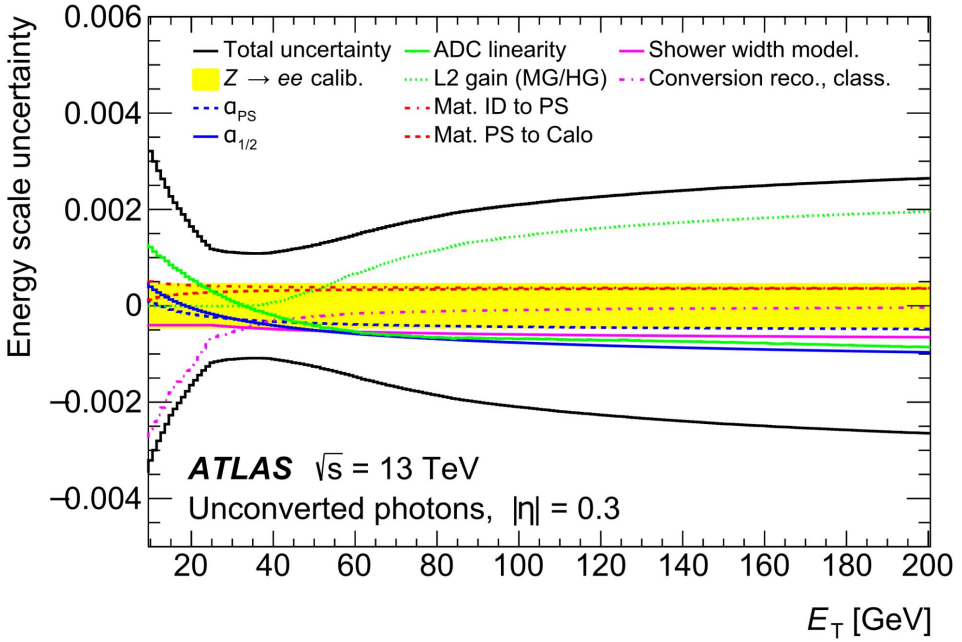
Electron and Photon Energy Scale

arXiv:2309.05471

- Improved electron and photon energy scale calibration
- **Improvement** compared to previous calibration **by factor 2-3**
- Electrons: 0.4% at 10 GeV, 0.3 % at 1 TeV
- Photons: 0.2 % at 60 GeV

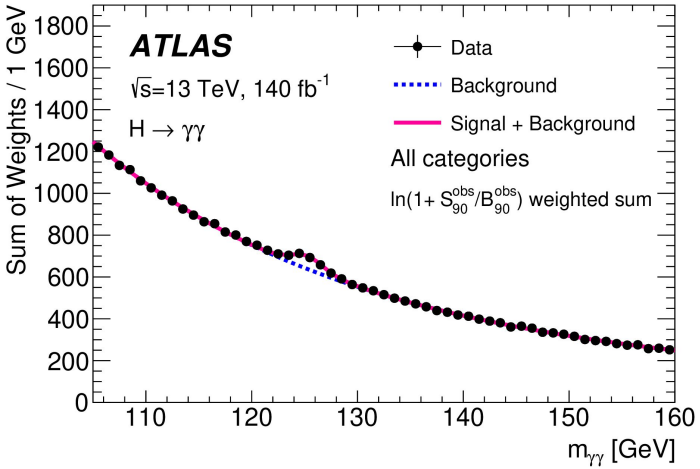


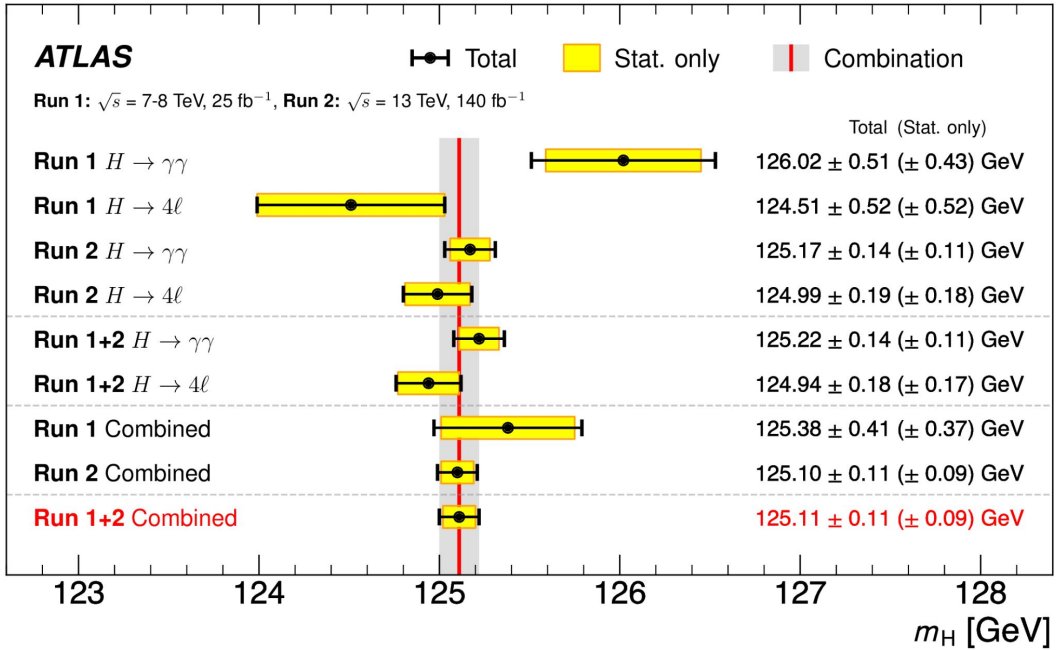


Higgs Mass Measurement (H→$\gamma\gamma$ & ZZ combination)

- Combination with full Run 2 dataset
- **Reduced uncertainties** to partial Run 2 analysis **by factor 3**
  - Improved energy scale calibration for photons
- **Best to-date precision of 0.09%**

arXiv:2308.07216, arXiv:2308.04775

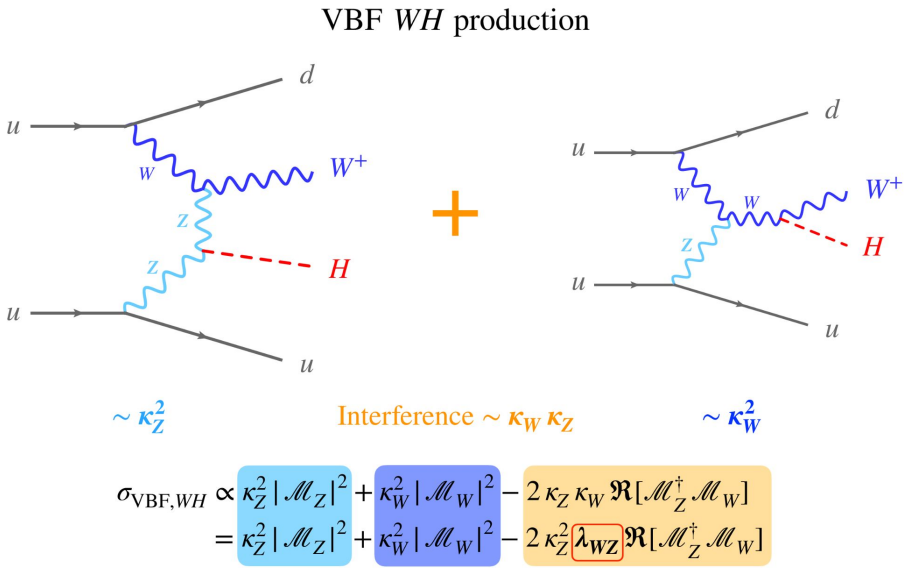


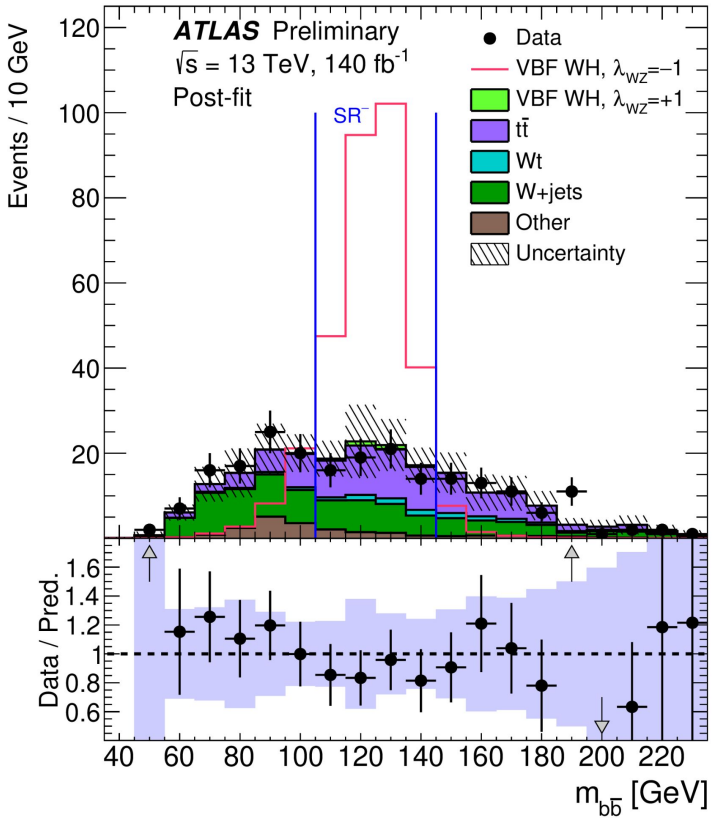


VBF WH → bb

ATLAS-CONF-2023-057

- Sensitive to relative sign of κ_W to κ_Z ($\lambda_{WZ} = \kappa_W / \kappa_Z$)
- **Excluded non-SM negative sign by 8σ**
- Measured signal strength wrt. SM coupling to $\mu = 2.6^{+4.6}_{-4.5}$

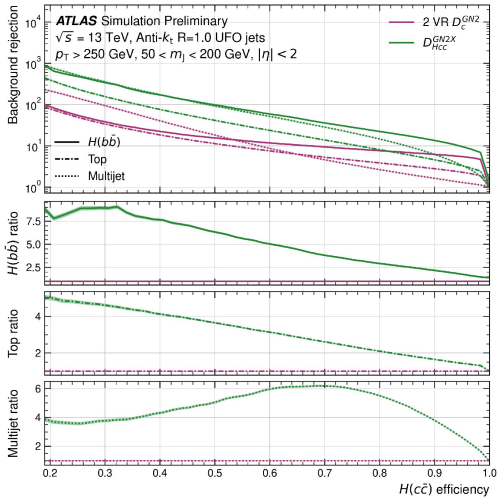


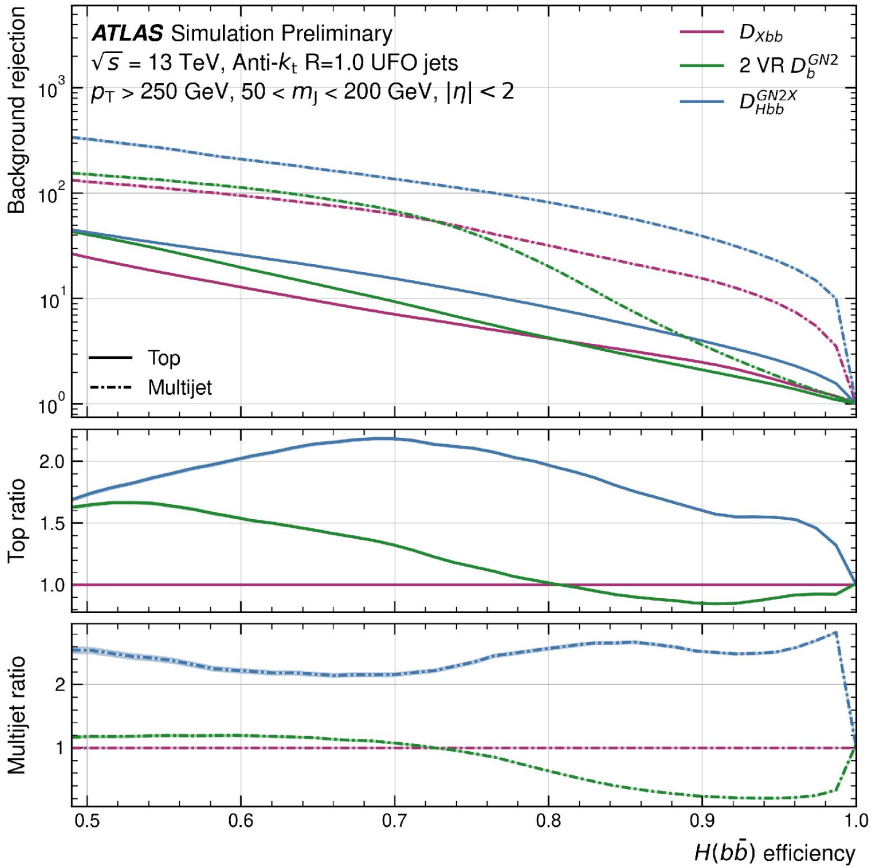


H ➜ bb/cc Tagging Improvements

ATL-PHYS-PUB-2023-021

- Developed new double b/c tagger using graph neural networks and transformer architecture
- At 50% H ➜ bb efficiency rejects
  - top by factor 40
  - multijet by factor 300
- **Improves** previous tagger **by factor 1.6 and 2.5** for top and multijet background





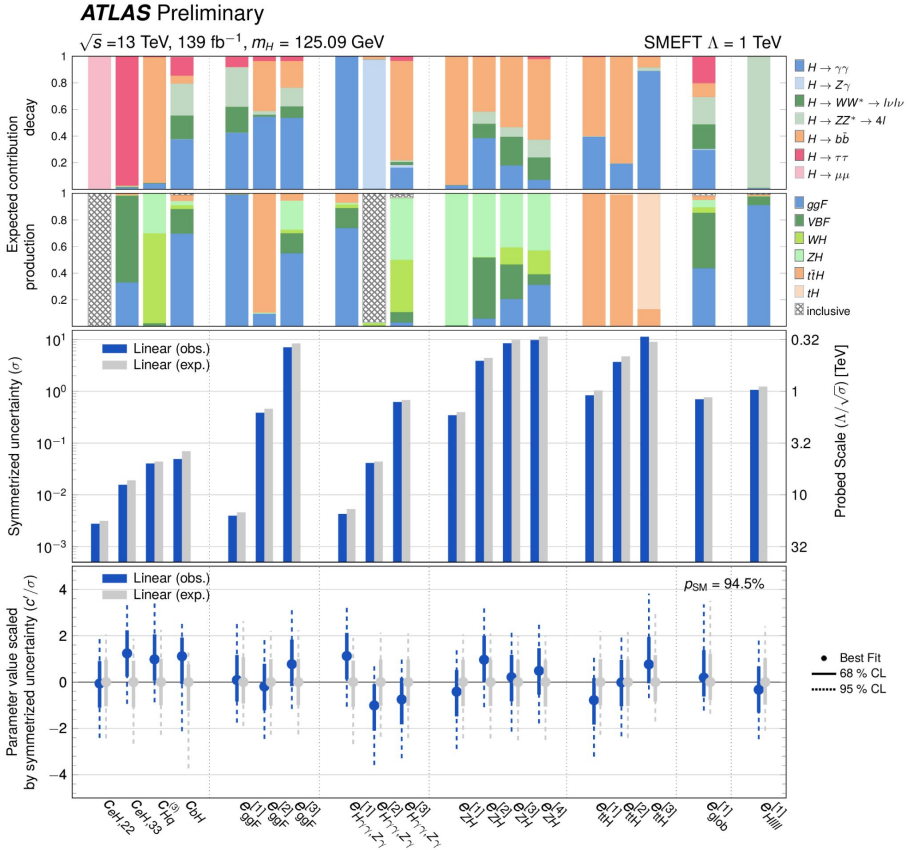
Higgs EFT/BSM interpretation

ATLAS-CONF-2023-052

- Comprehensive study using ATLAS Higgs-boson anniversary combination [Nature 607, pages 52 (2022)] and H → ZZ → 4l and H → $\gamma\gamma$ differential cross section measurements
- EFT parametrizes high-energy $\Lambda \gg v$ BSM effects at low energy $E \ll \Lambda$ as an effective operator product expansion

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_{i}^{N_{d=6}} \frac{c_i}{\Lambda^2} O_i^{(6)} + \sum_{j}^{N_{d=8}} \frac{b_j}{\Lambda^4} O_j^{(8)} + \dots$$

- Additional interpretations in terms of 2HDM and MSSM
- Complementary constraints to direct searches



1 Standard Model

2 Higgs Physics

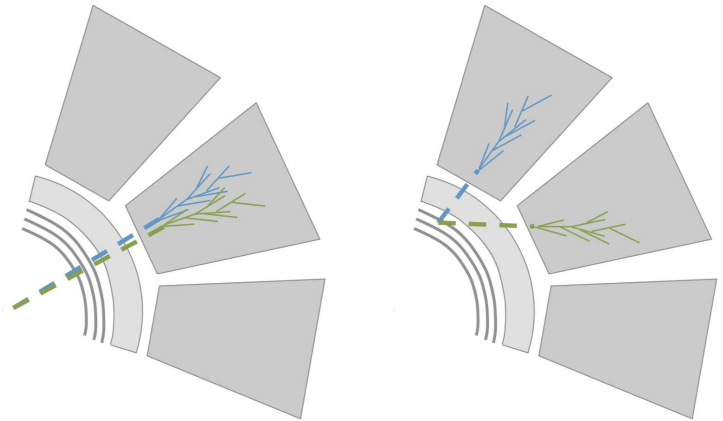
3 **BSM Searches**

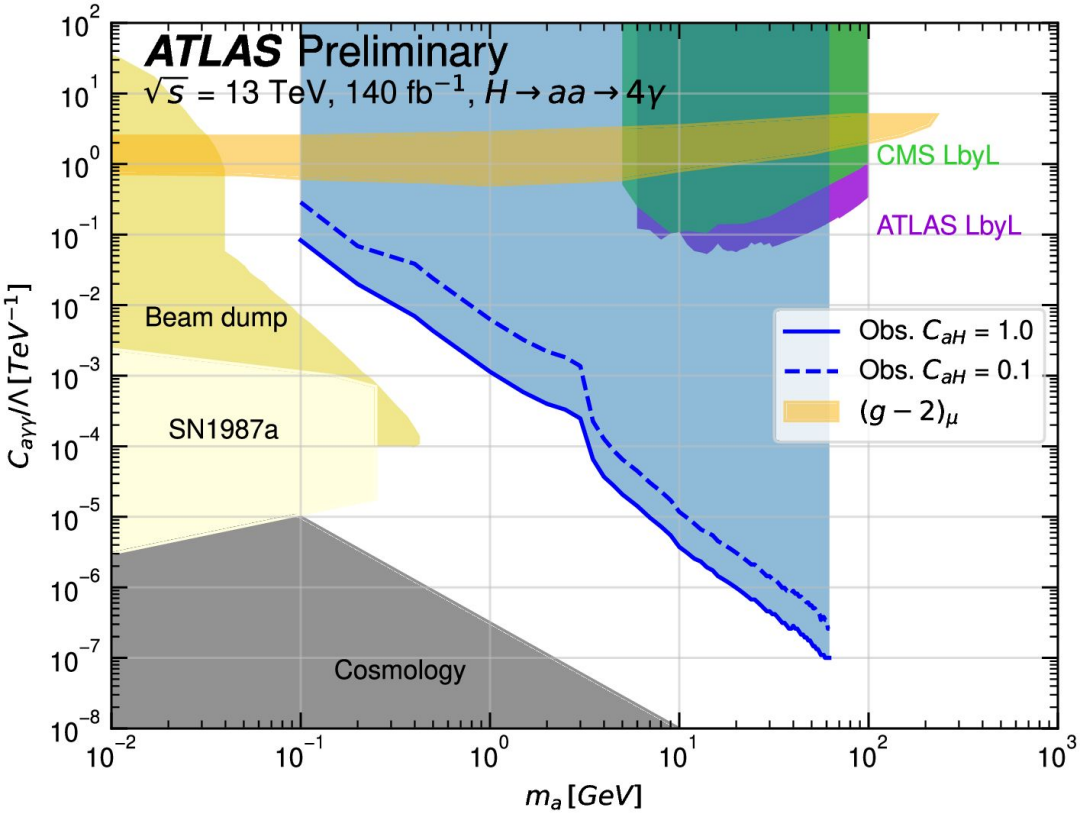
4 Heavy Ion

H → aa → 4γ

ATLAS-CONF-2023-040

- Search for Axion like particles (ALPs) in Higgs to 4γ decays
- **Excludes large parts of models explaining g-2 discrepancy with ALP models**
- Using NN to select signal like events
- Significantly increased sensitivity by extending analysis to displaced particles

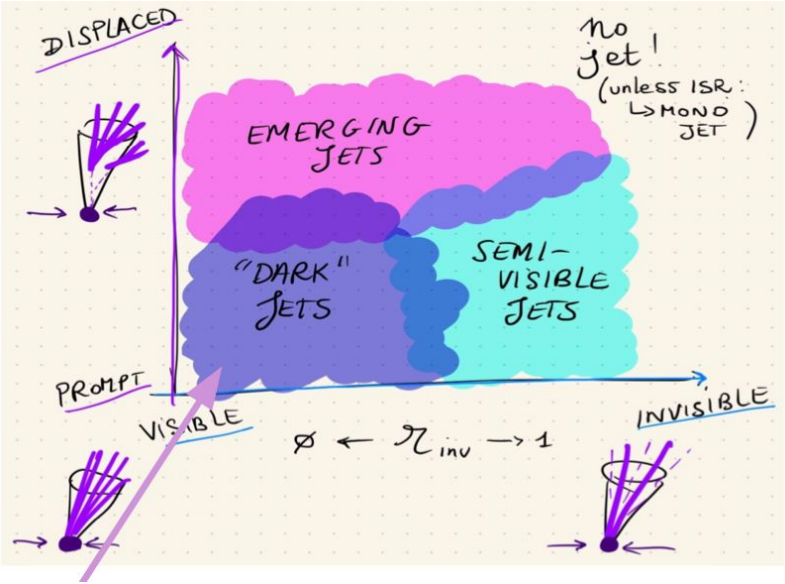


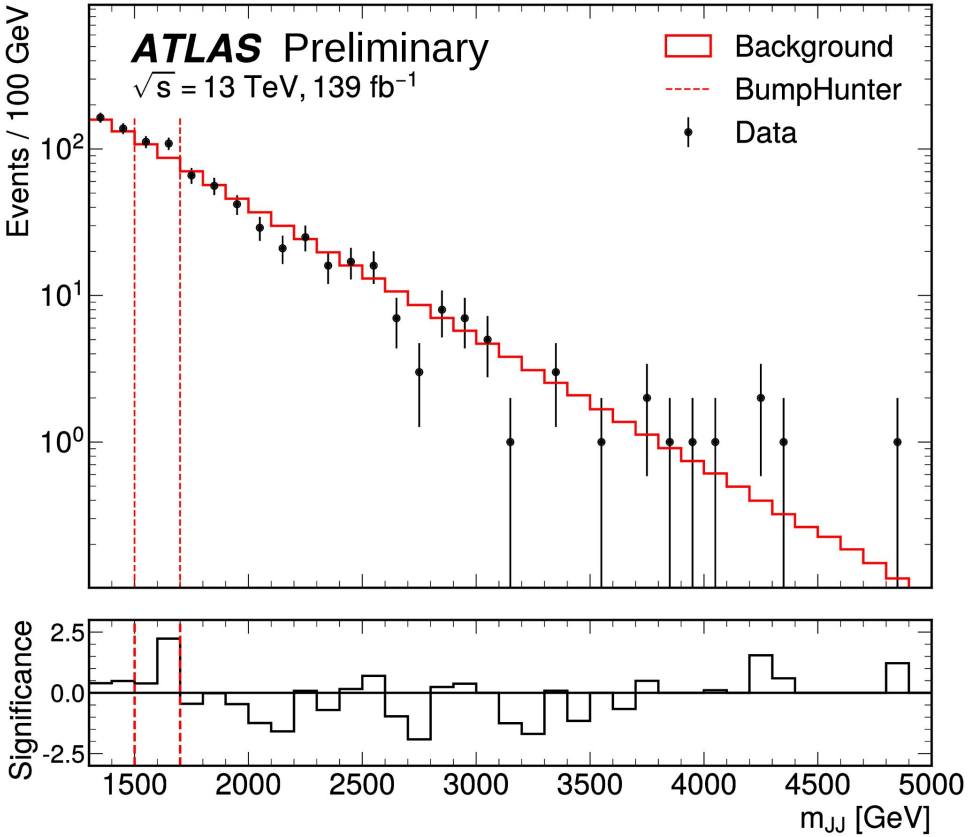


Dark Quarks

ATLAS-CONF-2023-047

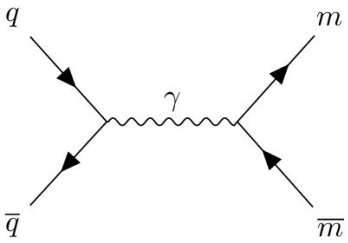
- Z' decaying into dark quarks
- **Special selection** on 2 large-R jets with high multiplicity
- Fully data driven background
- No deviation found

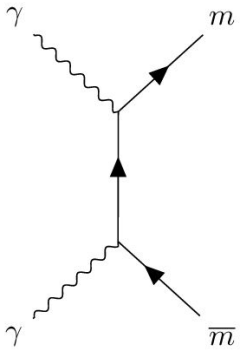




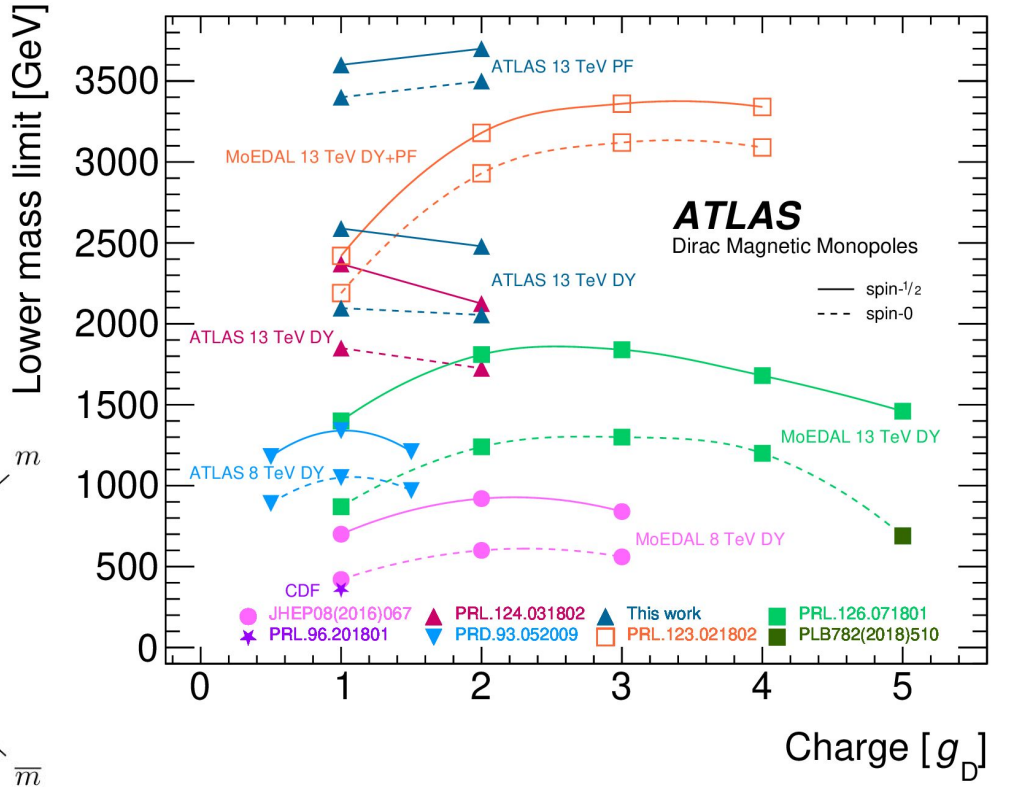
Highly Ionizing Particles: Magnetic Monopoles

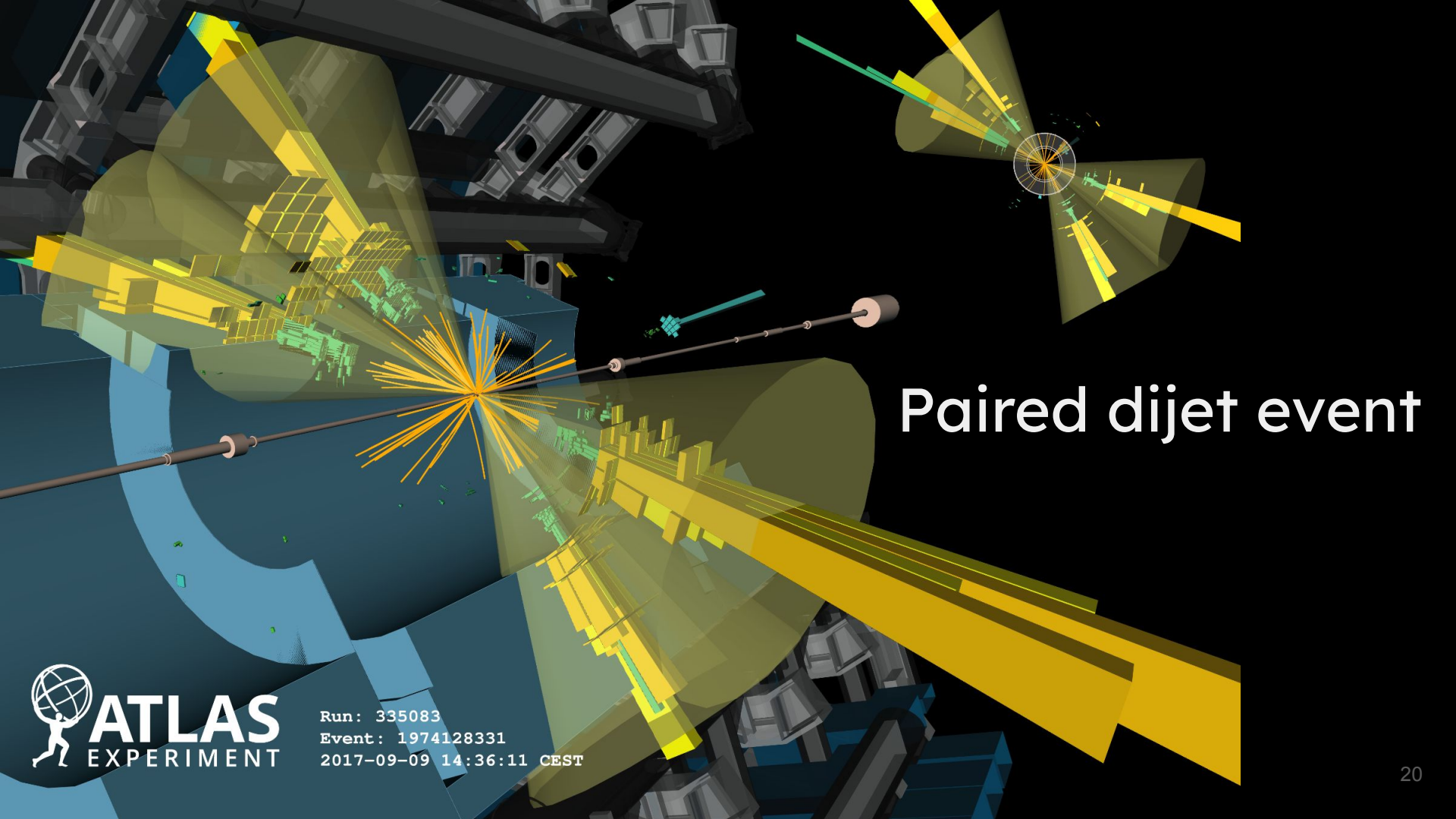
- Selection based on special interaction in detector
  - Lots of high threshold hits in TRT
  - Narrow shower along track in calorimeter
- **Limits on DY improved by factor 3** (compared to 2016)
- **New limits on photon fusion**





arXiv:2308.04835



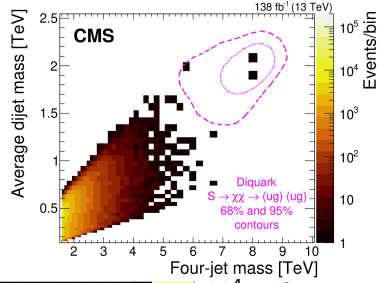


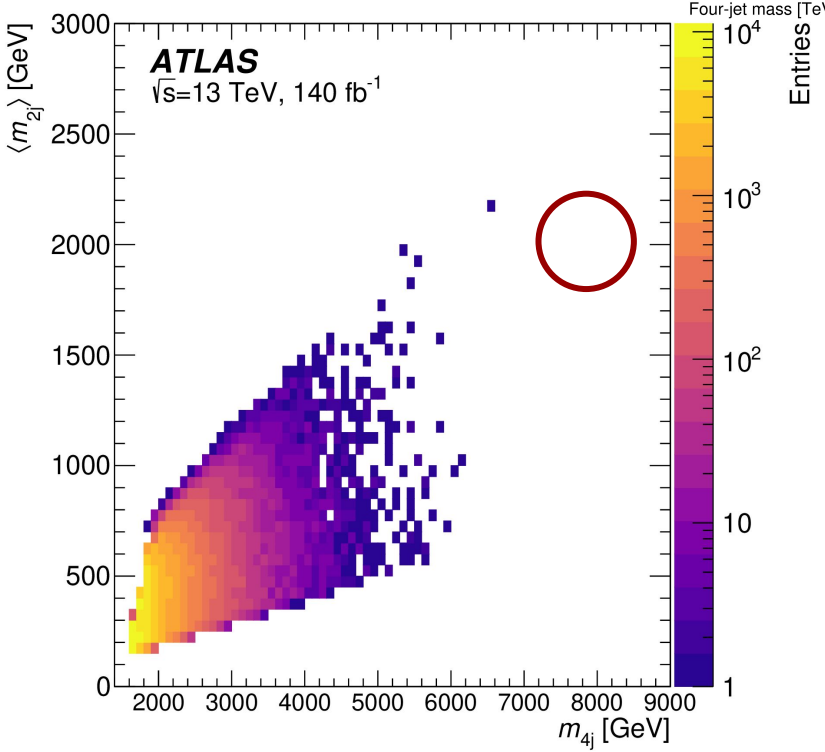
Paired dijet event

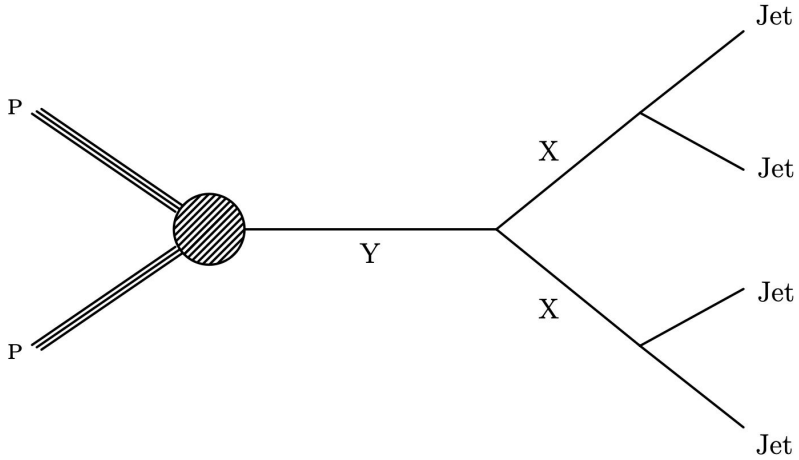
Y ➜ XX ➜ jjjj Generic Tetrajet Search

- Generic search for hadronic resonances with paired dijets
- Bump hunt in dijet vs. tetrajet mass spectrum
- No deviation found
  - CMS deviation **not confirmed**

arXiv:2307.14944



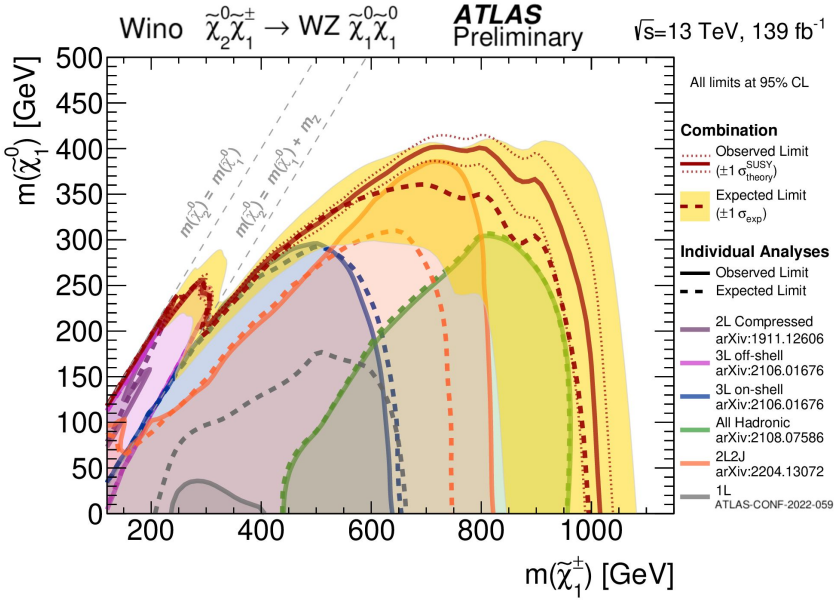


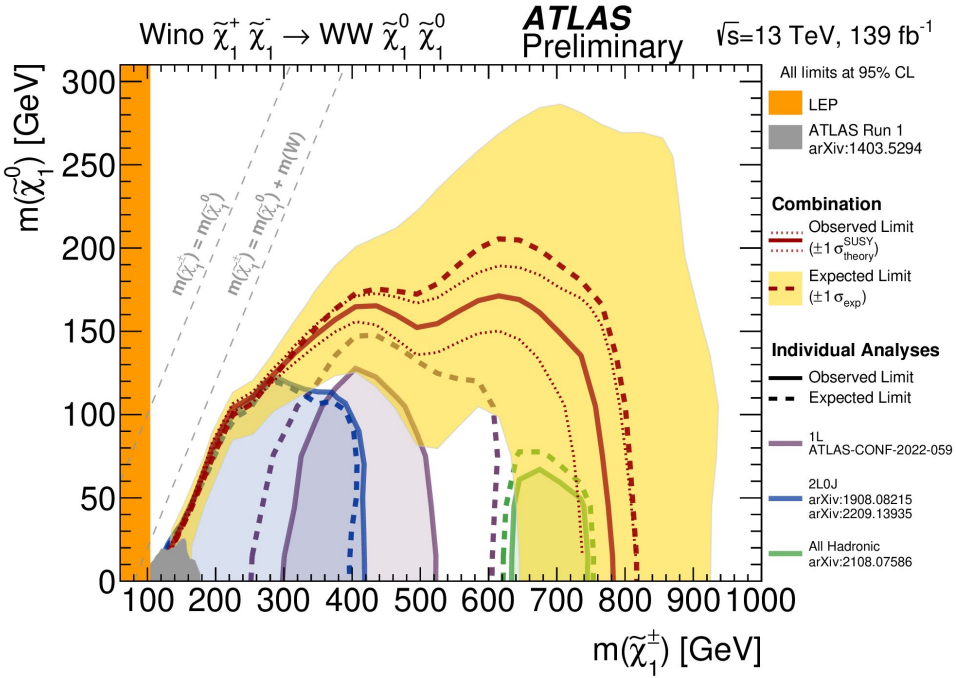


Combination of EWK SUSY Searches

ATLAS-CONF-2023-046

- Statistical combination of different chargino and neutralino searches
- **Improves sensitivity by 15 - 40 %** and covers gaps for challenging heavy-slepton scenarios

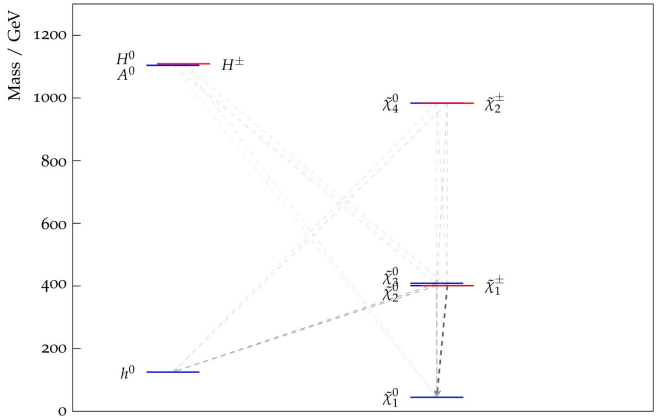


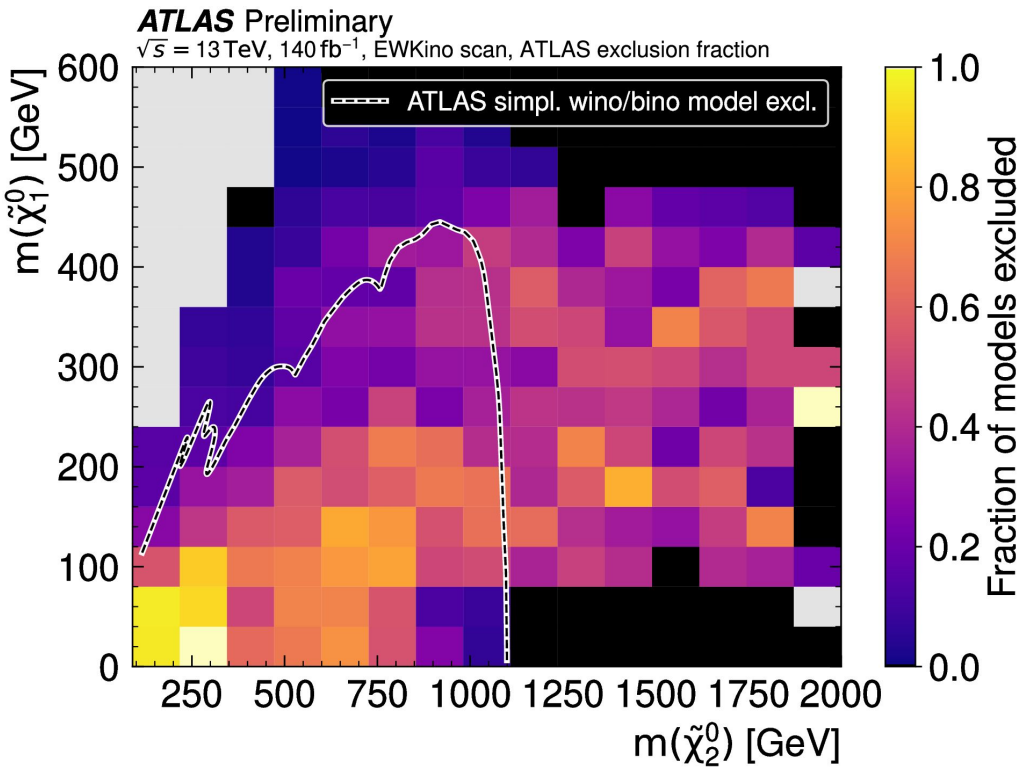


EWK pMSSM

ATLAS-CONF-2023-055

- Combination of 8 analyses in pMSSM framework
- Includes LHC and external constraints
- Tests overall 12280 models
- Almost full exclusion of low mass neutralino region that would not oversaturate the dark matter relic abundance
- Uncovers viable pMSSM models





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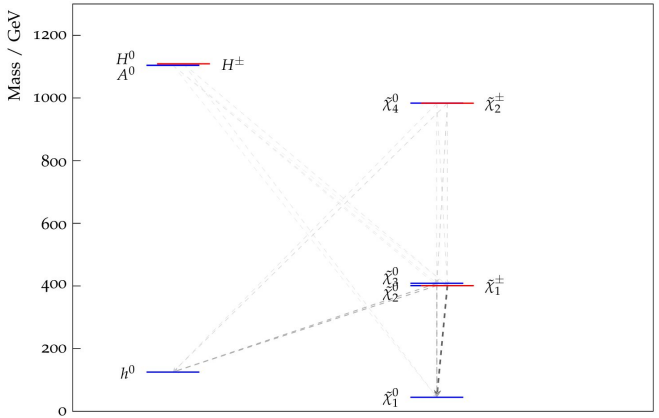

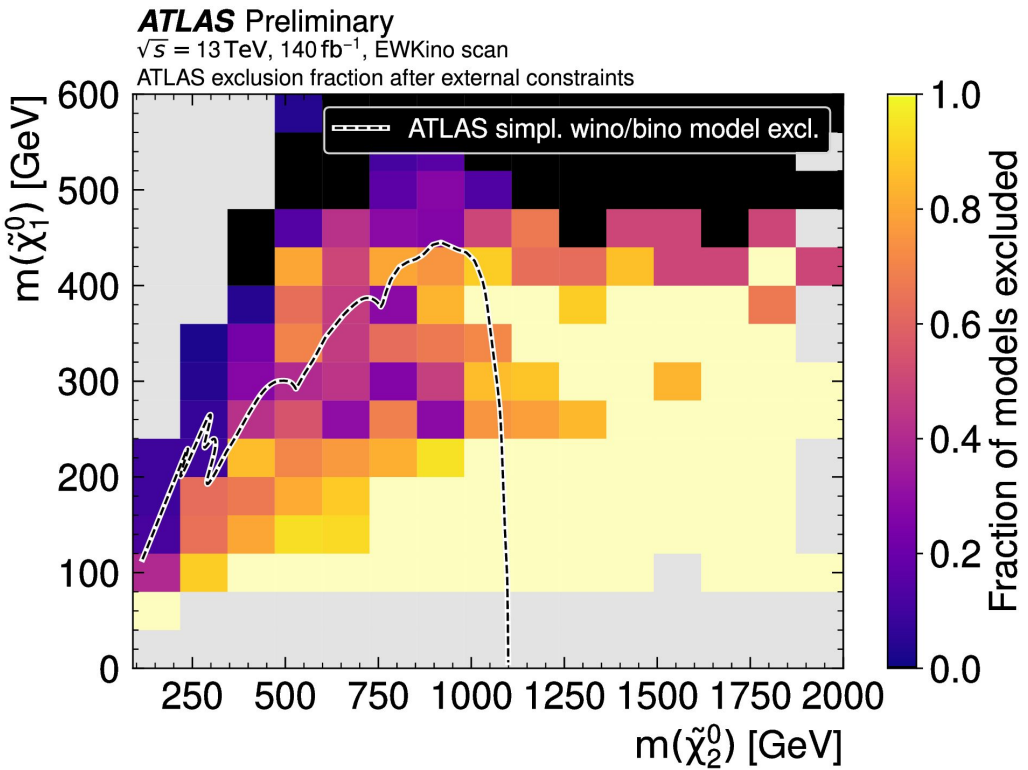

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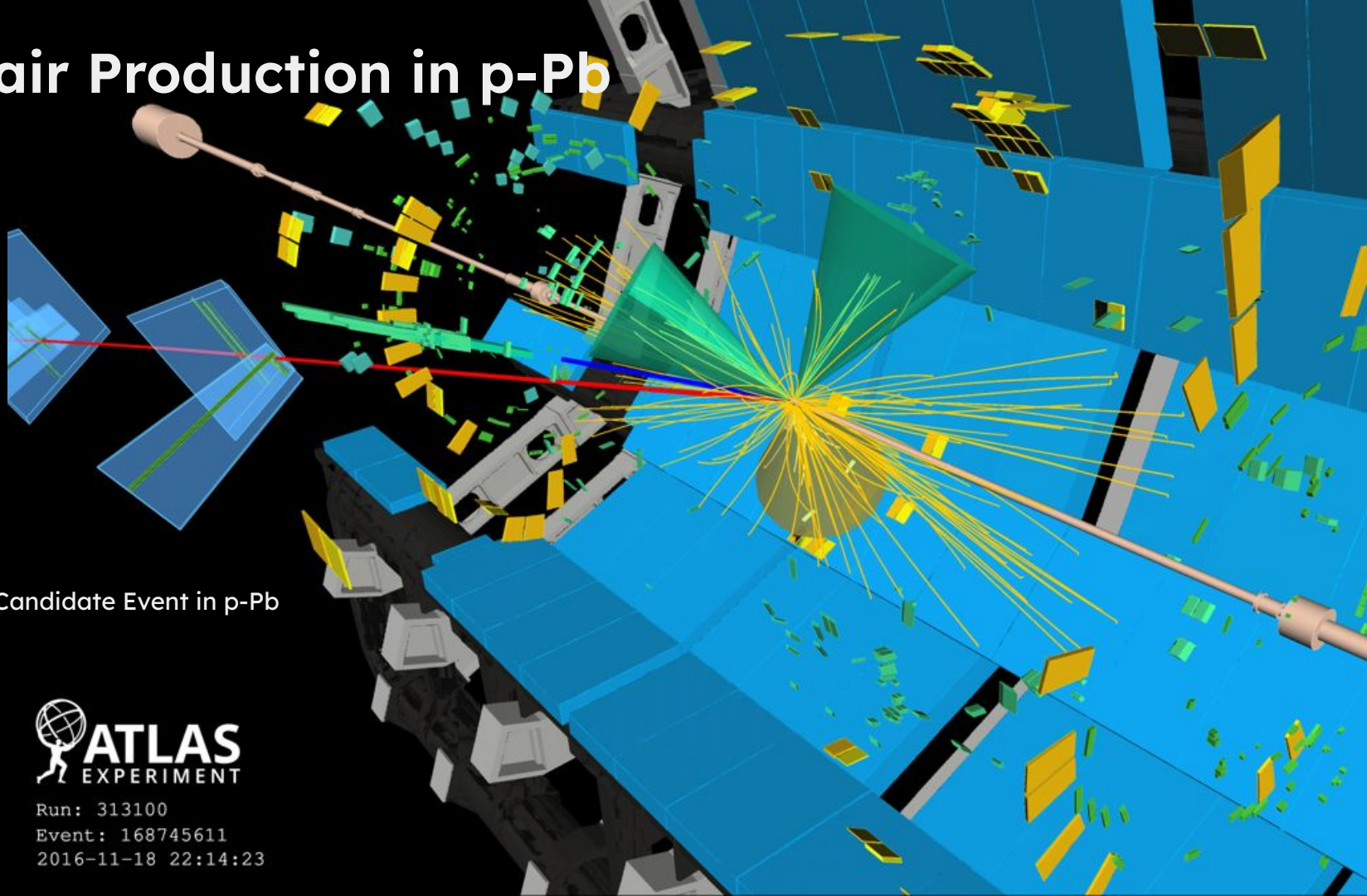
4 **Heavy Ion**

Top-pair Production in p-Pb

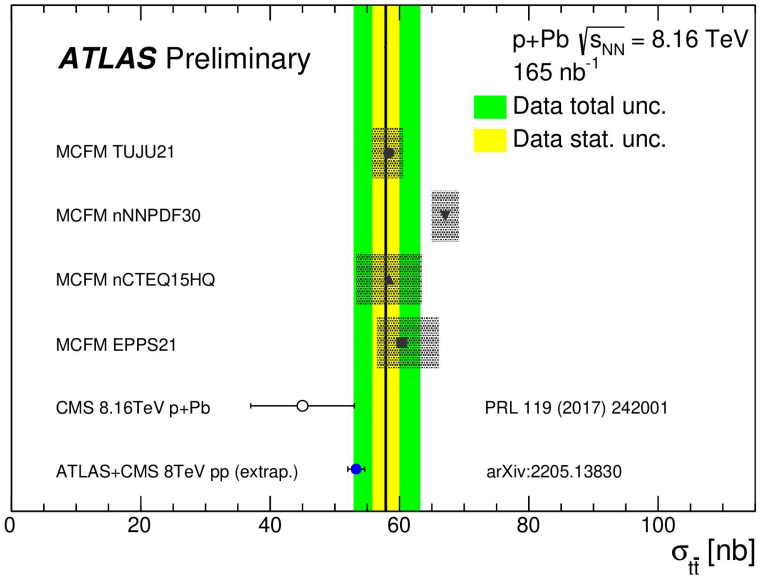


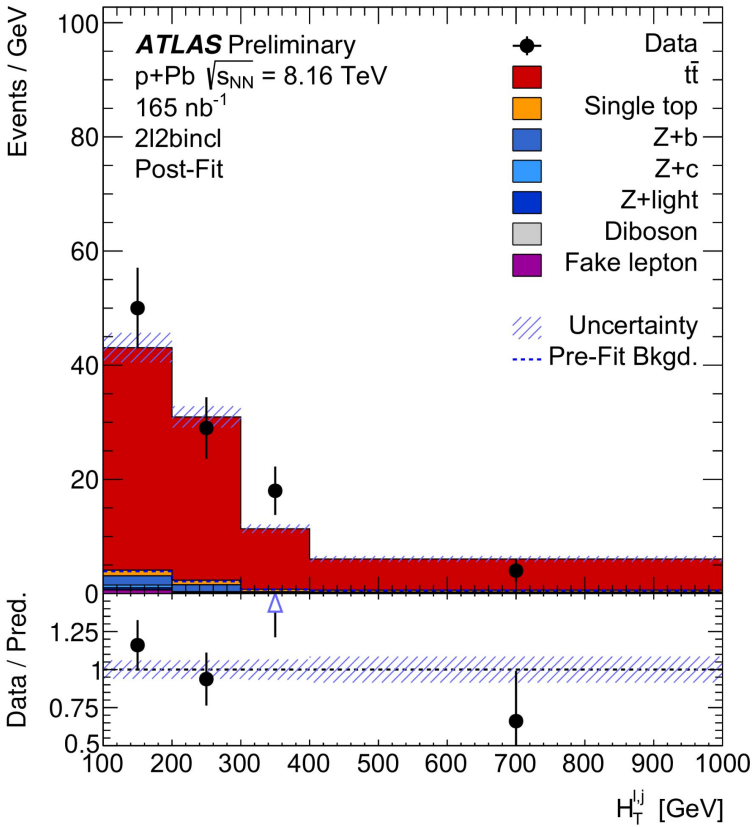
$t\bar{t} \rightarrow e\mu$ + jets Candidate Event in p-Pb Collisions

Observation of top-pair Production in p-Pb

ATLAS-CONF-2023-063

- Observed $t\bar{t}$ production in lepton + jets and dilepton channels with 1 and 2 b-tags
  - Following CMS observation in lepton+jets channel
  - **First observation in dilepton channel**
- Cross section measured to 57.9 $^{+5.1}_{-4.8}$ nb

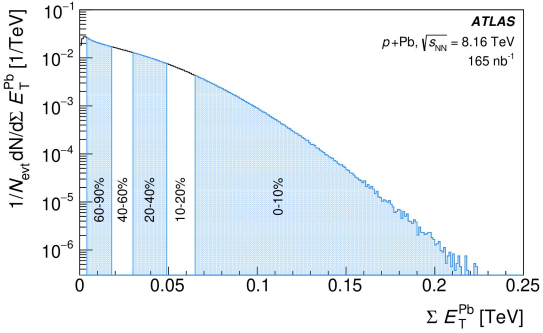


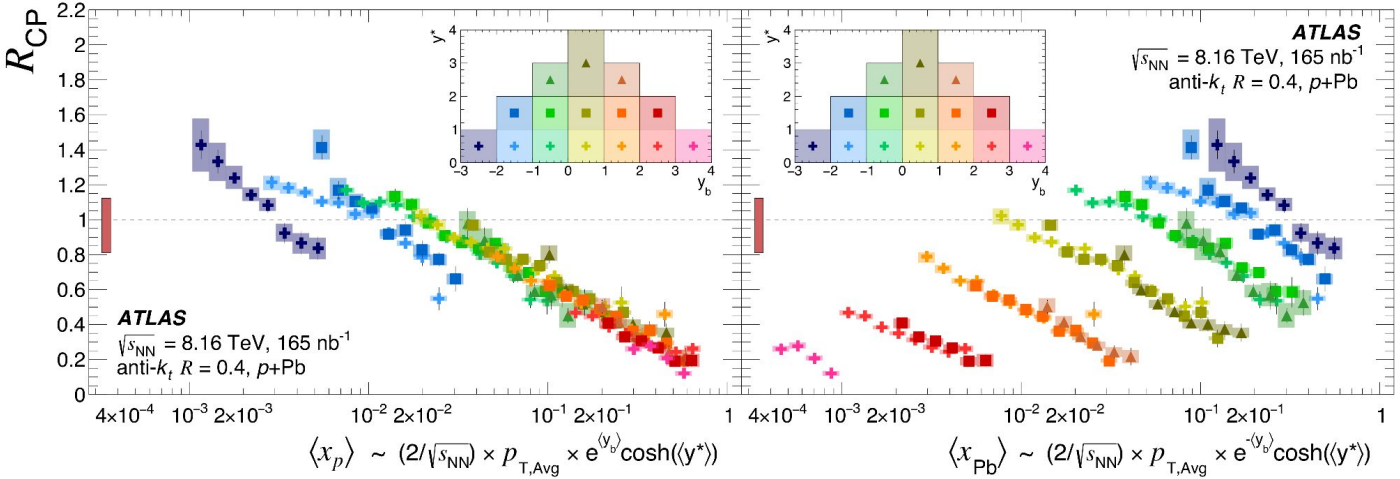


Di-jet Production in p-Pb Collisions

arXiv:2309.00033

- Measure hadronic activity dependence of dijet yield in p-Pb data
  - ΣE_T in forward calorimeter in Pb direction
  - Investigate central-to-peripheral ratio R_{CP} in different rapidity difference & boost bins
- Observed scaling with x_p strong suppression at high x_p indicating color transparency
- **Crucial to understand jet production in p-Pb collisions**



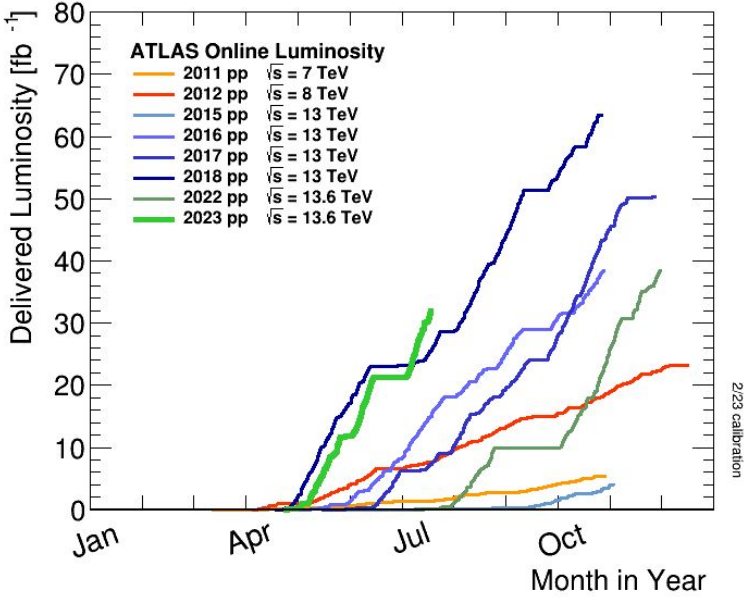


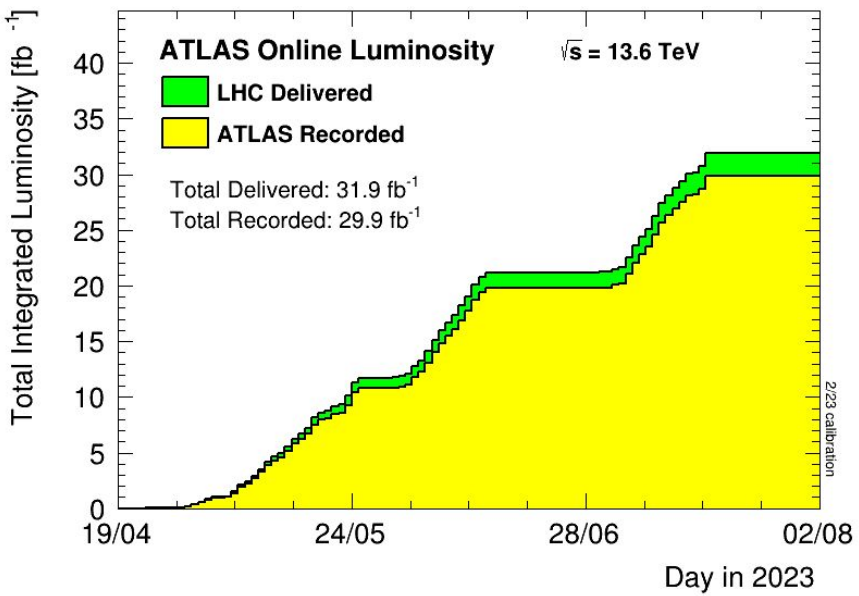
1 Analysis

2 **Detector Status**

3 Upgrade Status

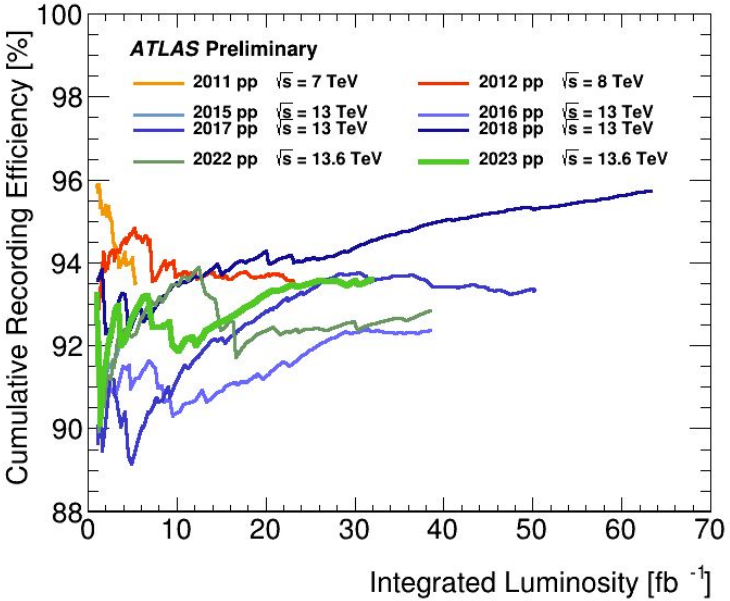
2023 High Intensity Proton Data Taking

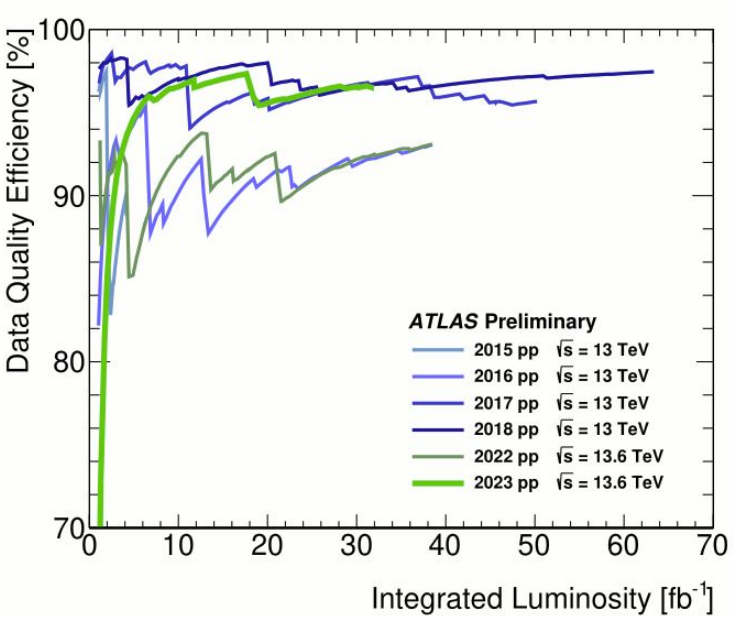




- Recorded nearly 30 fb^{-1}
- 94% data taking efficiency increasing towards the end of the run
- Collected cosmic data during LHC down-time

2023 High Intensity Proton Data Taking

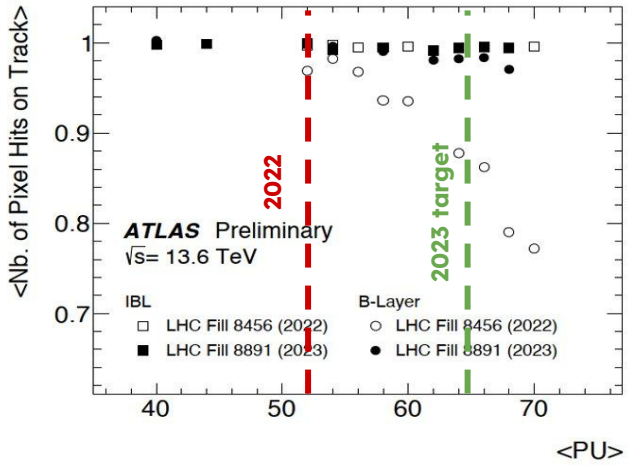


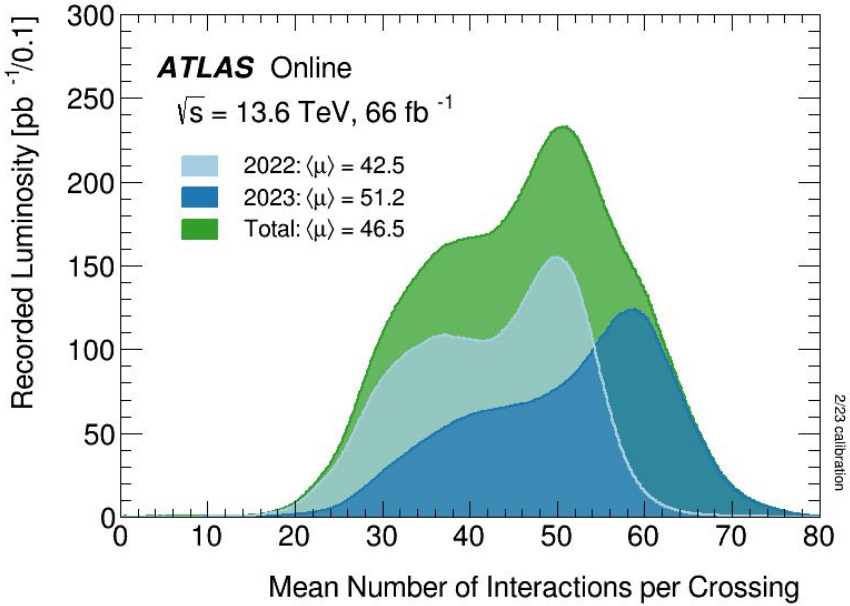


- 27.2 - 27.8 fb^{-1} good for physics (94.6 - 96.5% of data recorded for physics)

2023 Proton Data Taking Conditions

- Mean pileup during levelling increased to 60
- Integration of 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
- Thanks to LHC for accommodating constraints and adjusting leveling strategies

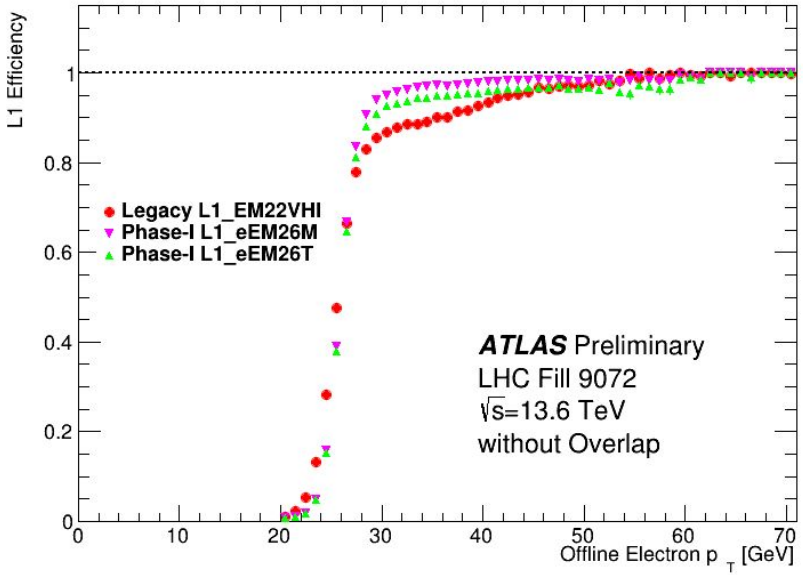


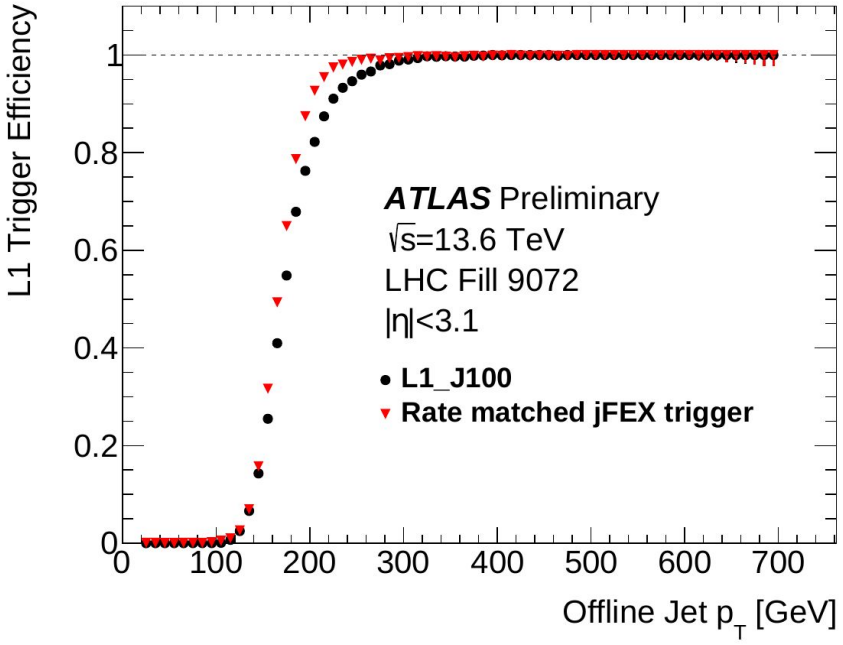


- Pixel coping with ATLAS target conditions despite outer layers being designed for μ of 23
  - Optimized operational settings and new DAQ FW + SW

L1Calo Phase-I Upgrades

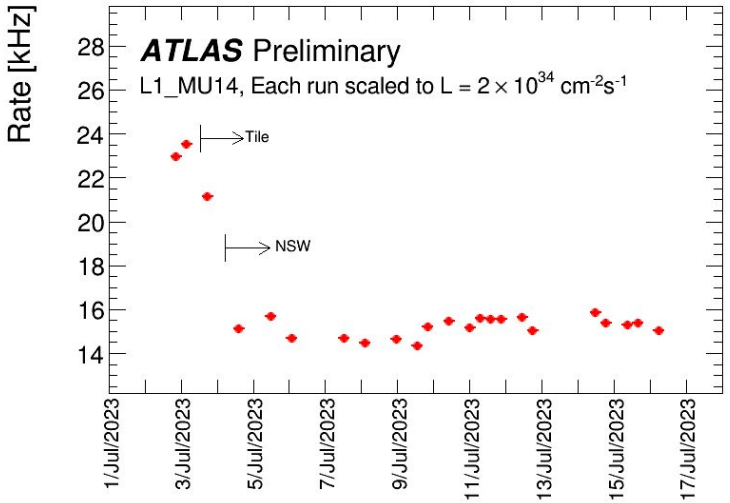
- eFEX brought online early this year (5 kHz rate saving)
- Focus switched to jFEX achieving higher efficiency than legacy trigger at same rate

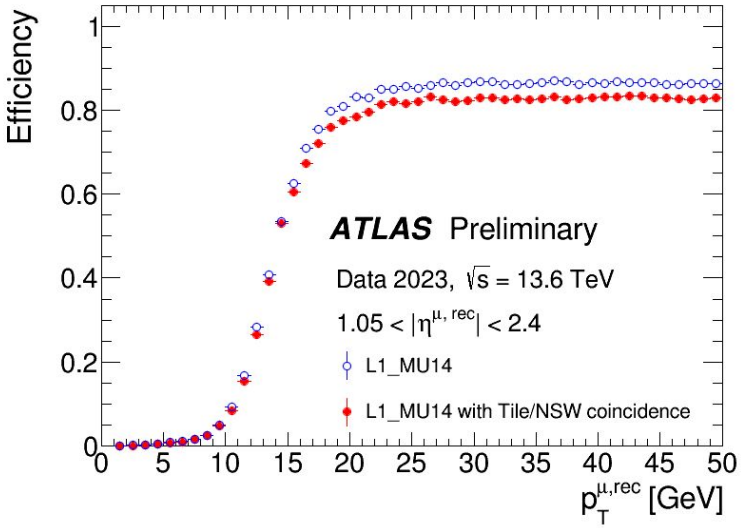




NSW Trigger

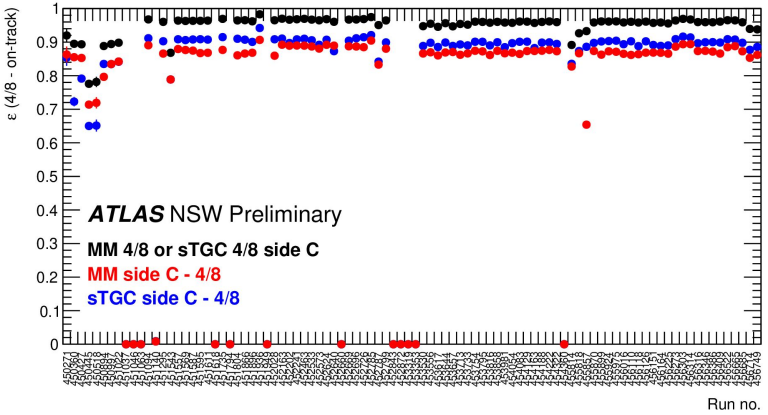
- Decided to concentrate on pad trigger first
  - Provides sufficient rate reduction for Run 3
  - Currently, coincidence logic with big wheel enabled for 75% of sectors
  - Activated sectors are >95% efficient
  - Reduced L1 rate by 6 kHz as expected
  - Recovered transition regions
  - Improved coincidence logic
  - Ongoing work to improve time alignment
- Work also ongoing for MM and strips
  - MM trigger readout already enabled to gain experience

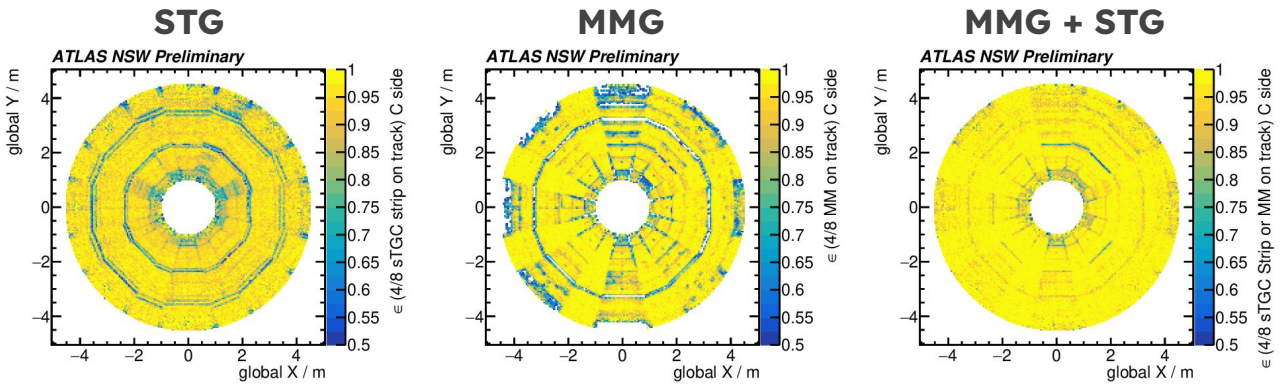




Muon Status

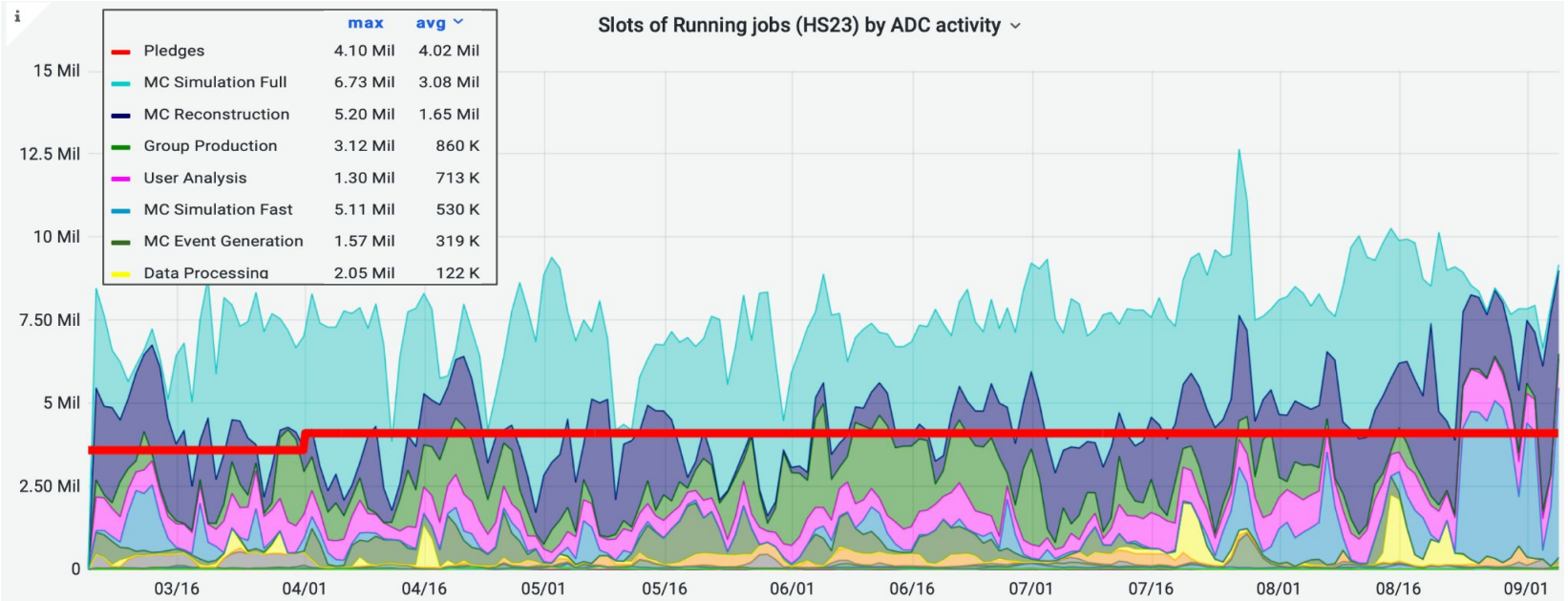
- NSW DAQ stability improvements
  - Focused on NSW DAQ performance and minimizing impact on ATLAS data taking efficiency
  - More detailed investigation of remaining link stability issues ongoing
- RPC gas mixture change (exchanged 30% of R134a with CO_2)
  - Reduced greenhouse impact (13.5% smaller CO2-e)
  - Similar performance validated in extensive tests
  - LHC down time allowed to make change during the year before YETS
- TGC and MDT running without major issues



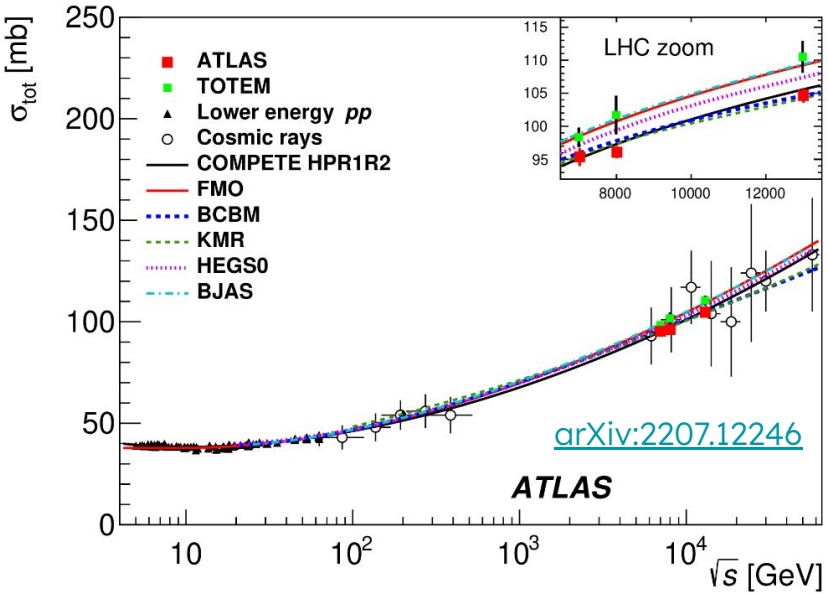


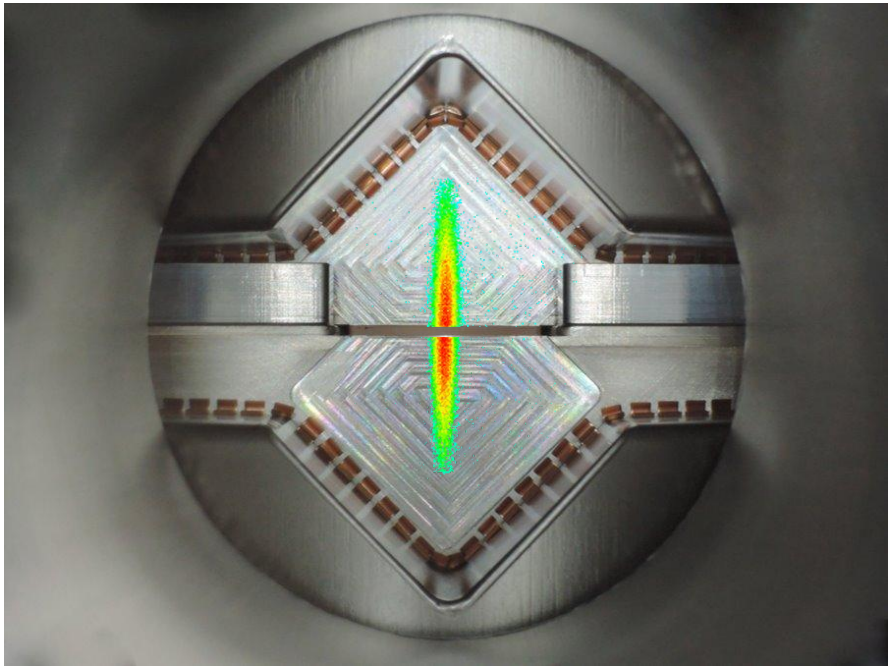
Software and Computing Activities

- Excellent performance of our computing centers world-wide, including T1s and T2s; significant opportunistic resources (HPCs and HLT farm)
- Major detector simulation campaigns modeling 2022 and 2023 data conditions well advanced; new fast simulation now validated and in production
- First official ARM-based production queue running jobs now



High β* Run





- Study energy evolution of σ_{tot} and ϱ
- Timing in of ALFA done
- Challenging setup of the LHC accelerator
  - After few tests of collimator settings background situation in ALFA significantly improved
- Data-taking campaign started during the weekend.

Heavy Ion Preparation

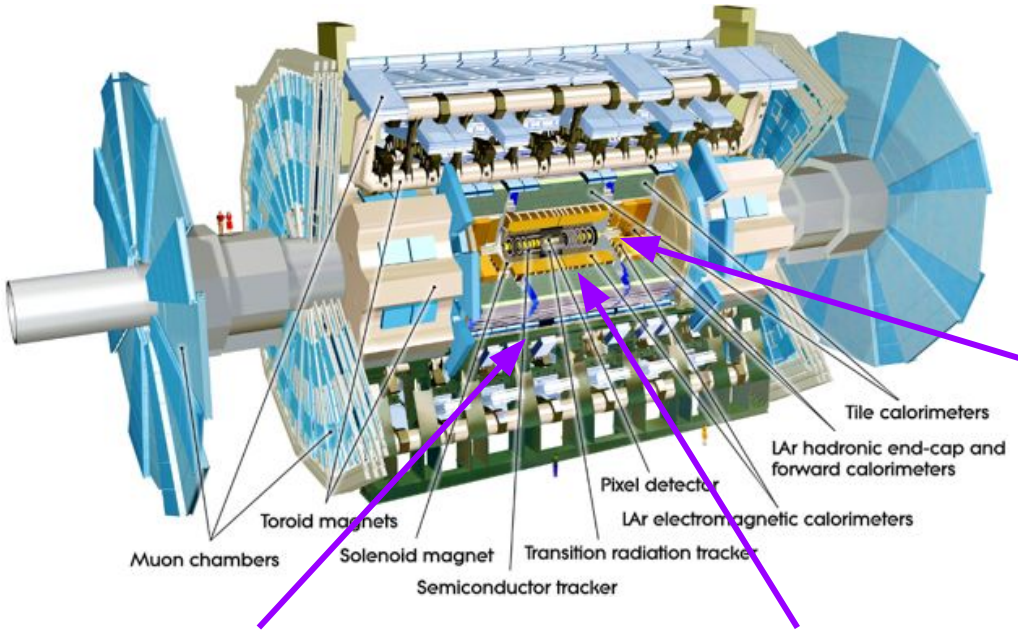
- Installed ZDC detector
  - Commissioned during LHC down-time and startup
- LAr + L1Calo commissioning of very low calorimeter trigger thresholds

1 Analysis

2 Detector Status

3 **Upgrade Status**

Phase-II Upgrade Program



Upgraded Trigger and Data Acquisition system

Level-0 Trigger at 1 MHz

Improved High-Level Trigger (150 kHz full-scan tracking)

High Granularity Timing Detector (HGTD)

Forward region ($2.4 < |\eta| < 4.0$)

Low-Gain Avalanche Detectors (LGAD) with 30 ps track resolution

New Muon Chambers

Inner barrel region with new RPC and sMDT detectors

New Inner Tracking Detector (ITk)

All silicon, up to $|\eta| = 4$

Electronics Upgrades

LAr Calorimeter

Tile Calorimeter

Muon system

Additional small upgrades

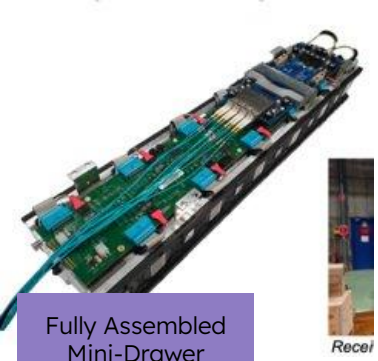
Luminosity detectors (1% precision goal)

HL-ZDC

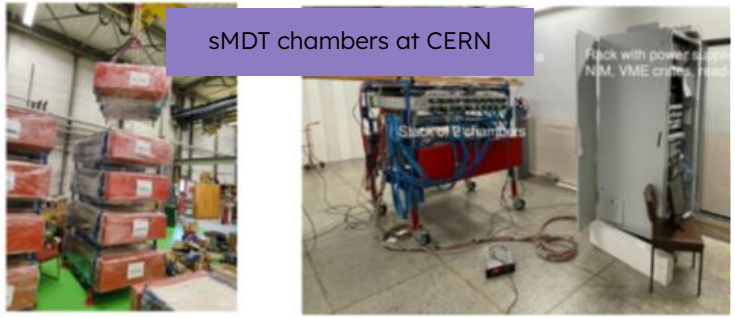
Detailed scope described in 7 TDRs approved by the CERN Research Board in 2017, 2018, 2020

Upgrade Status Overview

- ATLAS Upgrade projects are steadily moving into production
- We completed essential steps in critical technical areas
  - Tests of the final ITk Pixel ASIC (v2) give very promising results
    - The chip is fully working for ATLAS needs so far
      - The critical data merging bug of v1.1 has been fixed in v2
  - The muon RPC final FE ASIC is ready to be submitted
- Various vendor delays are being successfully addressed
  - Carbon foam, ITk Strip data cables, ITk Pixel connectors
- Few outstanding technical issues are still being investigated
  - E.g. issues with hybridization (ITk Pixel and HGTD), ITk Strip cold noise
- Continued contingency loss in all projects during the last months
  - Several measures have been launched since and still looking for further optimizations
    - We are in particular addressing the ITk services production that drives the critical path
    - The ITk production plan will be reviewed by an external consultant in October

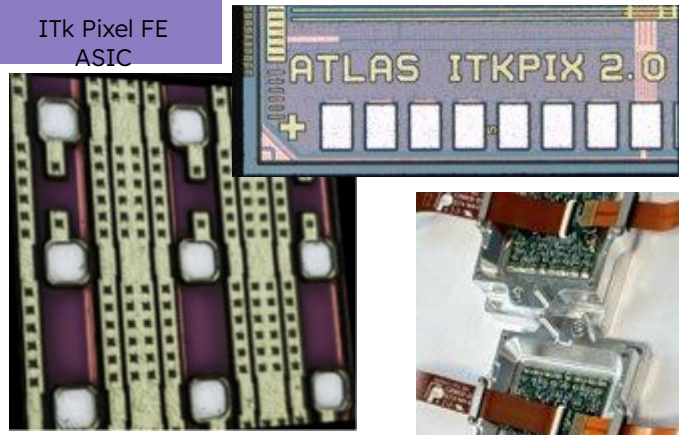


Fully Assembled Mini-Drawer

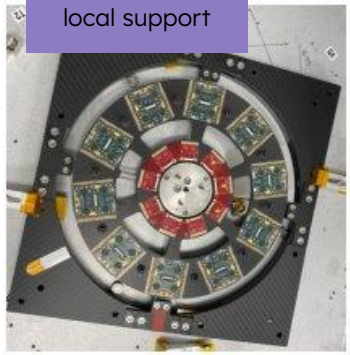


sMDT chambers at CERN

ITk Pixel FE ASIC

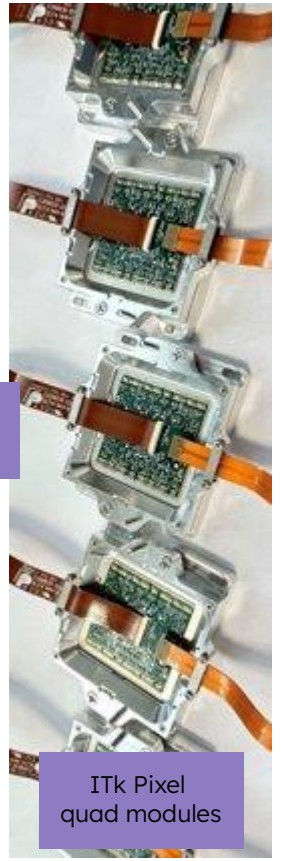


ALTIROC3 diced wafer



ITk Pixel loaded local support

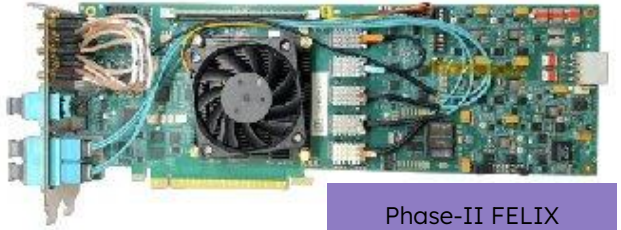
Fully Assembled Mini-Drawer



ITk Pixel quad modules

Global Common Module v2b prototype

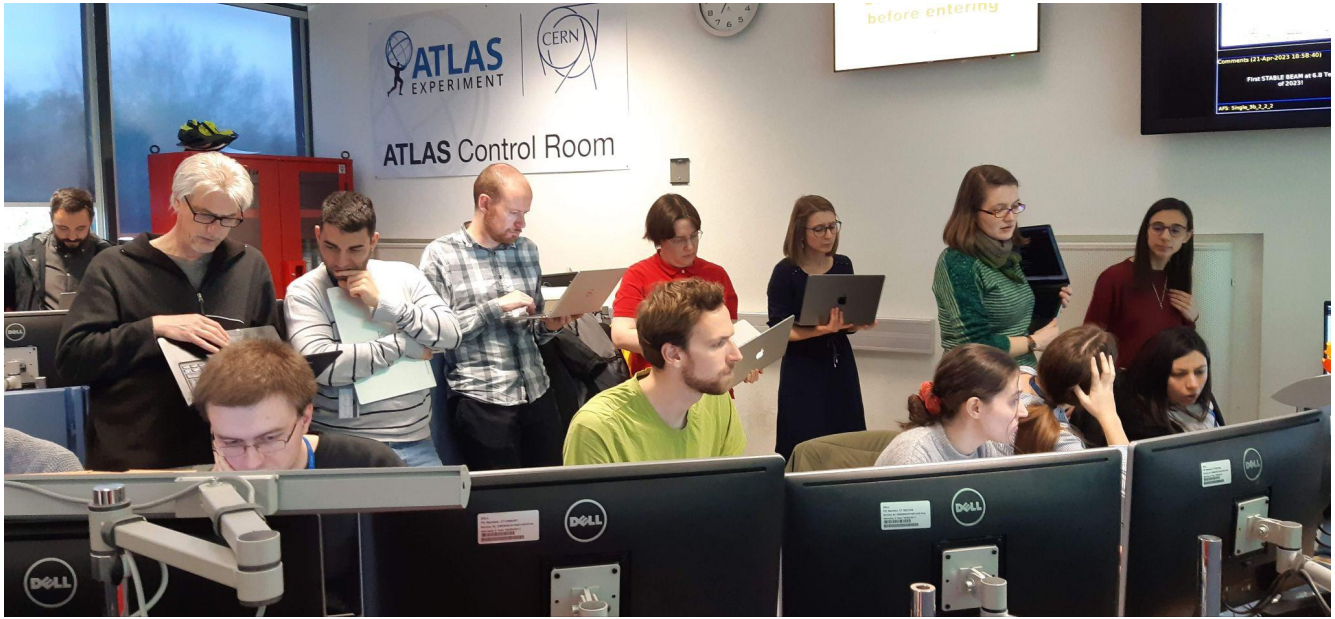
LAr FEB2 v1 prototype



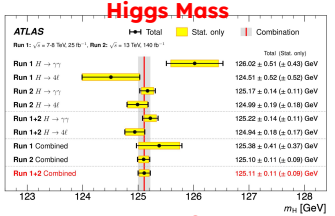
Phase-II FELIX prototype (FLX-182)

Summary

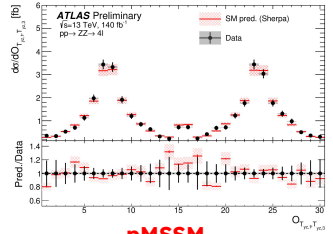
- Released a plethora of new physics analyses (31 papers, 25 CONF notes)
  - Mix of Run 3, Run 2 and even Run 1 datasets
- Phase-II upgrades progressing well
  - Reducing contingency is being addressed
- 28 fb^{-1} good for physics with 94% recording efficiency and 96.5% DQ efficiency
- Detector prepared for heavy ion data daking



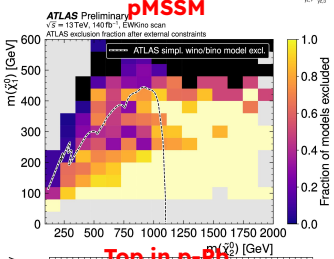
Higgs Mass



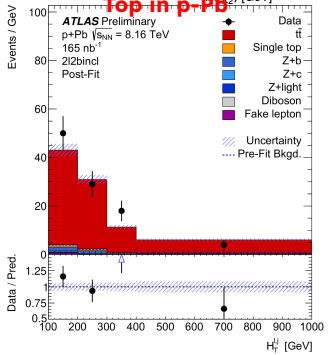
ZZ EWSB

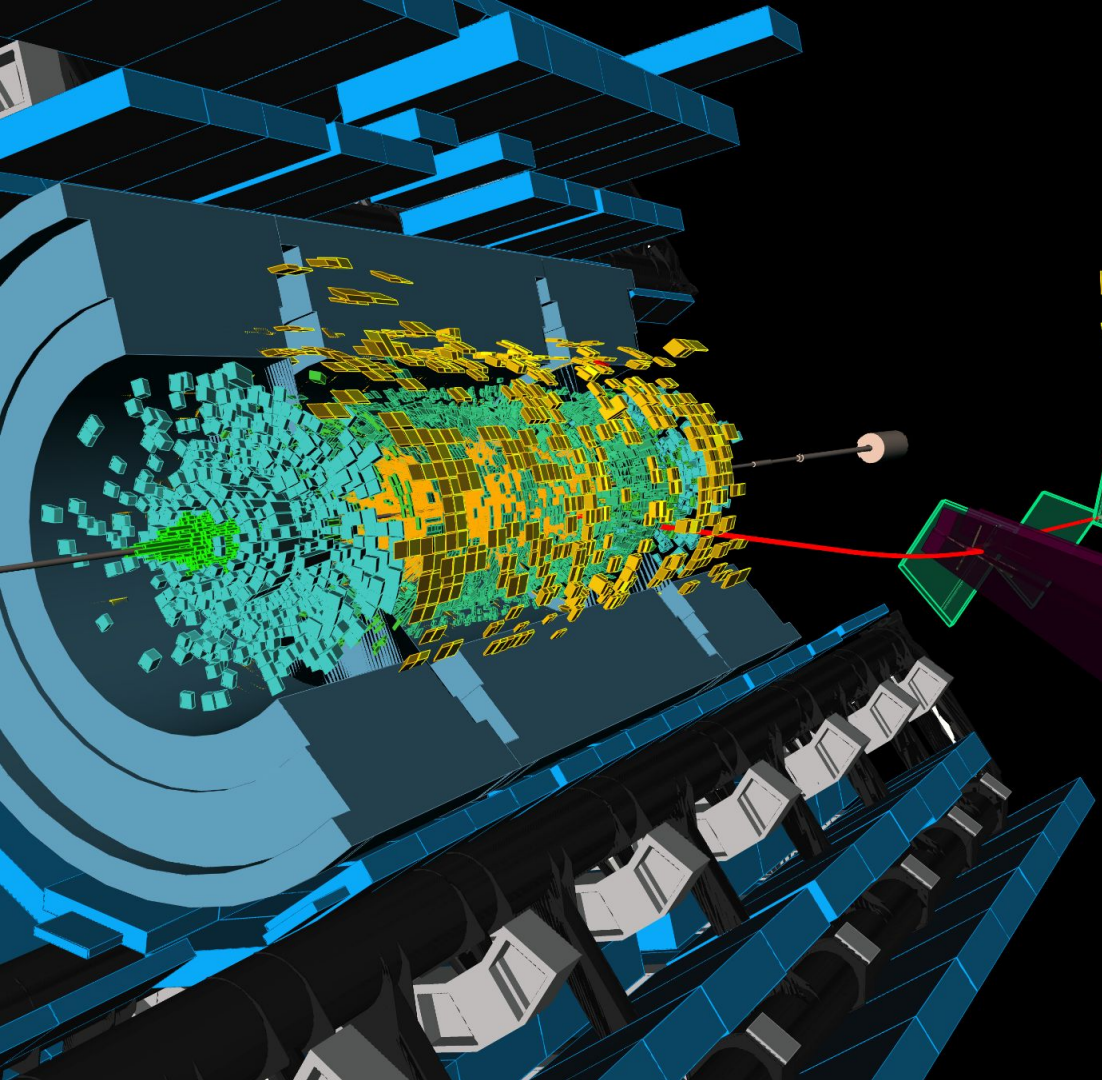


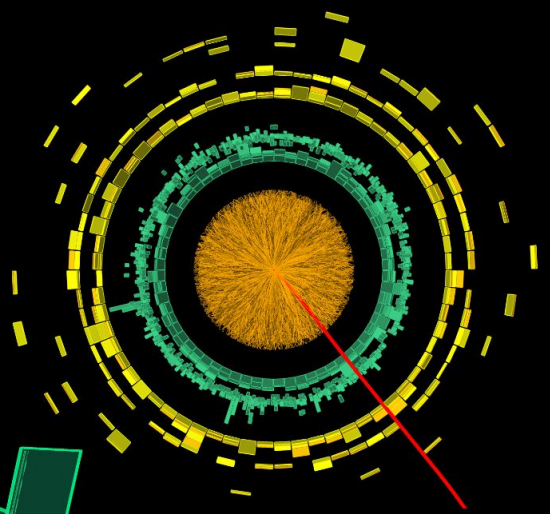
pMSSM



Top in p-Pb







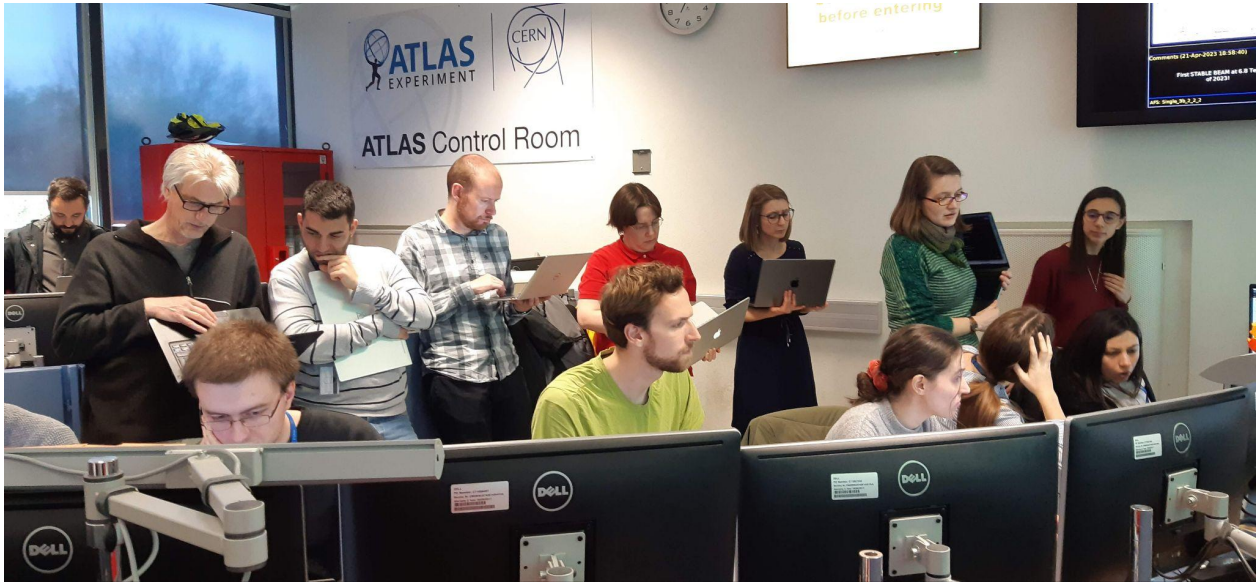
Looking Forward to Heavy Ion Data Taking

ATLAS EXPERIMENT

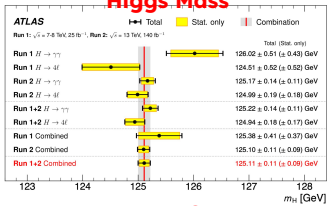
Run: 440101
Event: 823635
2022-11-18 16:45:12 CEST

Summary

- Released a plethora of new physics analyses (29 papers, 25 CONF notes)
  - Mix of Run 3, Run 2 and even Run 1 datasets
- Phase-II upgrades progressing well
  - Reducing contingency is being addressed
- 28 fb^{-1} good for physics with 94% recording efficiency and 96.5% certification efficiency
- Detector prepared for heavy ion data daking



Higgs Mass



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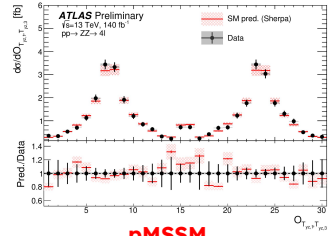
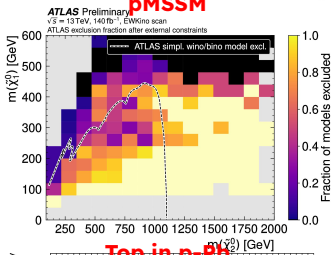


pMSSM



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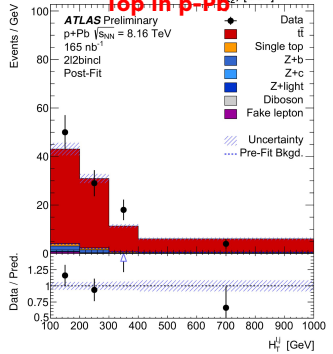
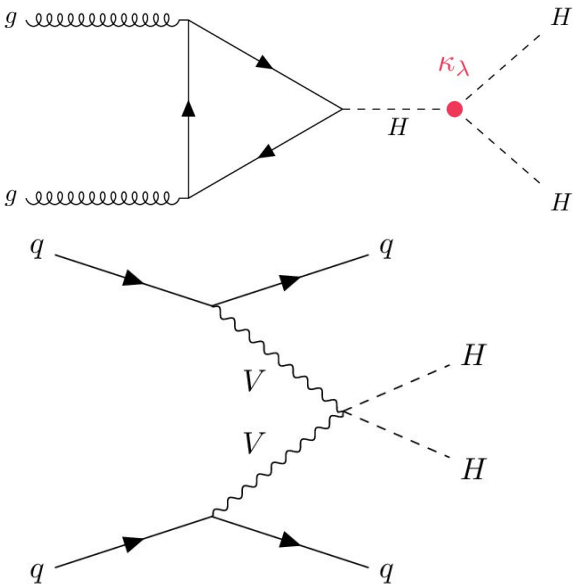


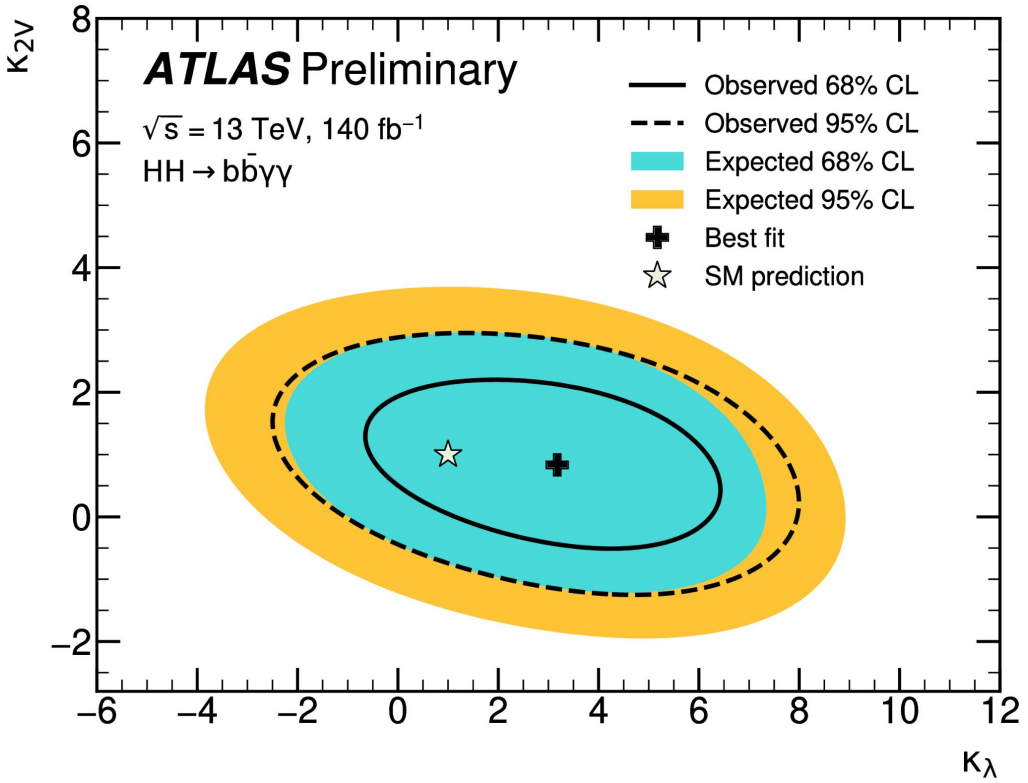
Backup

Improvement of HH → bb$\gamma\gamma$ Search

ATLAS-CONF-2023-050

- Probing Higgs self coupling κ_λ and quartic HHVV coupling κ_{2V}
- No excess above SM found (limit $\mu_{HH} < 4$)
- **6 - 17 % improvement** due to optimized event categorization

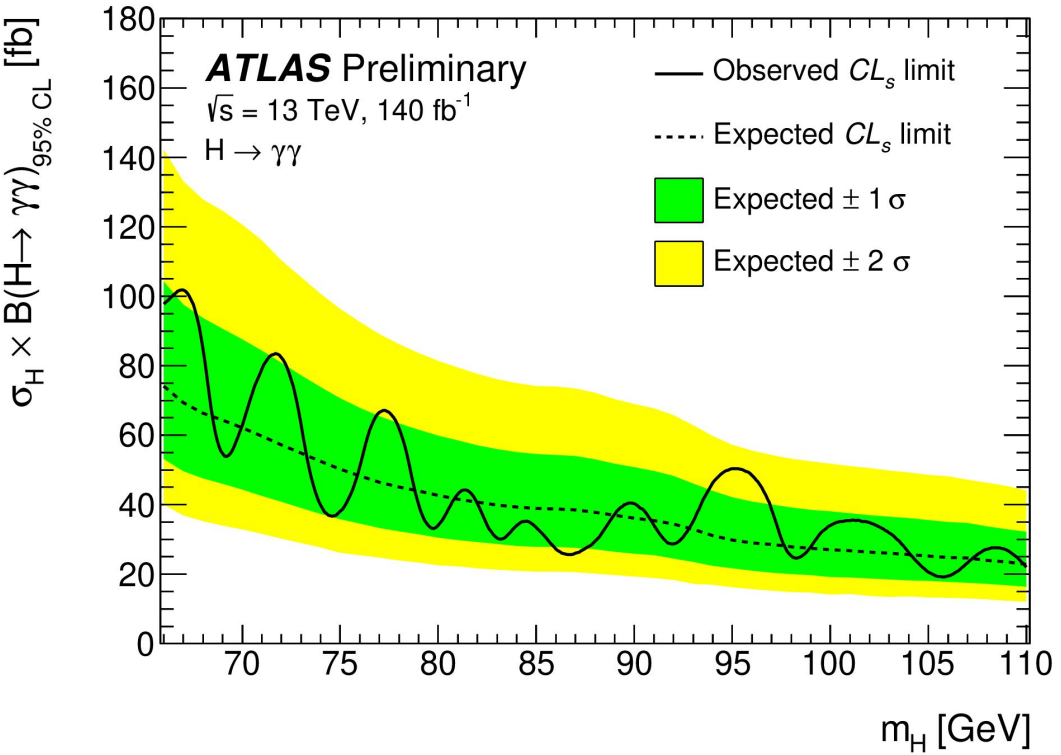




Search for Light Higgs or Generic Spin-0 Boson

- Uses BDT to classify events
- Sets model independent limit on generic spin-0 particle and on light Higgs bosons
- No deviation found
- 1.7σ local excess at 95 GeV for light Higgs interpretation
  - CMS local excess of 2.9σ
  - No deviation seen in model independent limit
- **Factor ~2 improvement** over partial Run 2 analysis

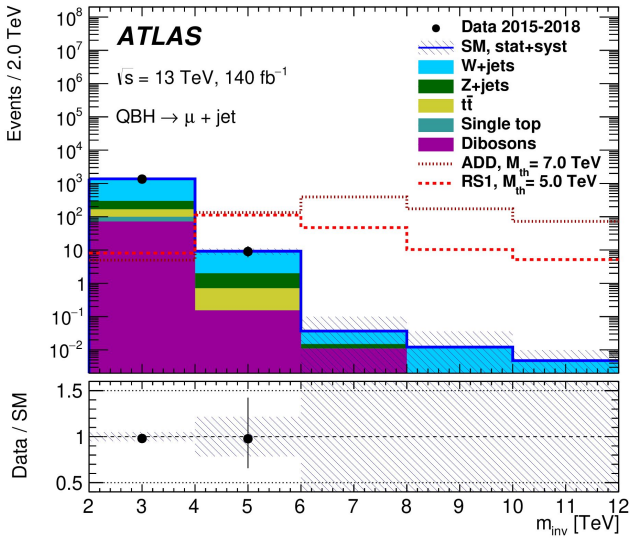
ATLAS-CONF-2023-035

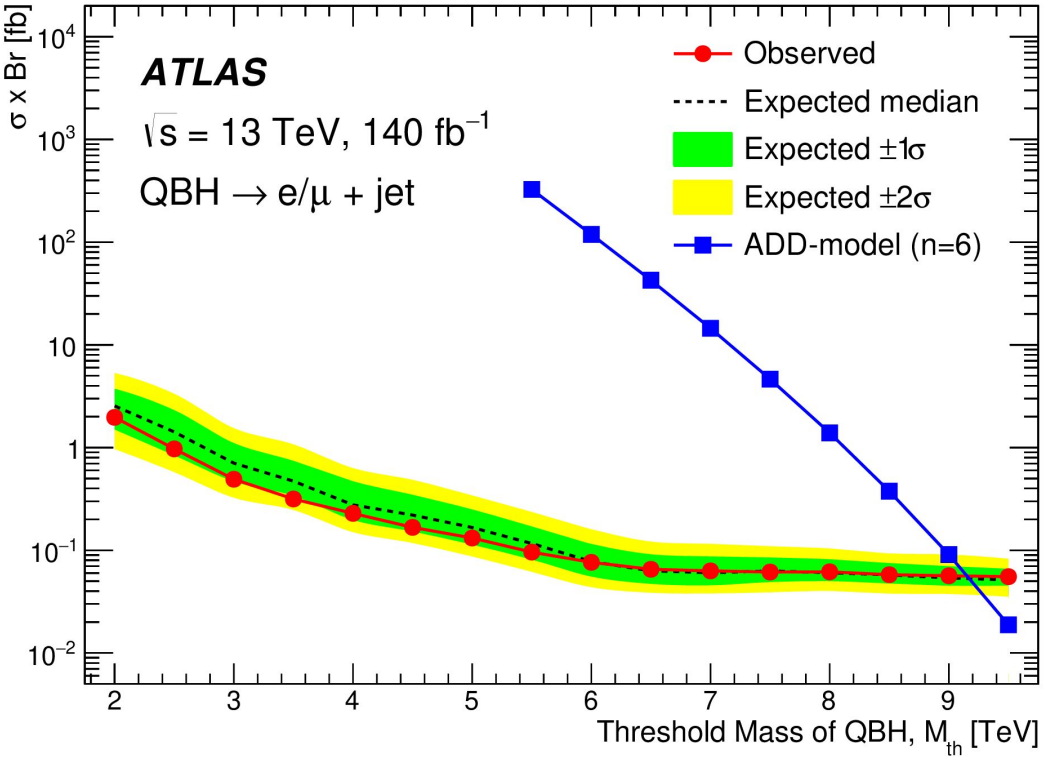


QBH in e/μ + jet

arXiv:2307.14967

- Limits on ADD and RS1 model and model independent limits
- No deviation found
- **Factor ~3.5 improvement** over Run 1 analysis

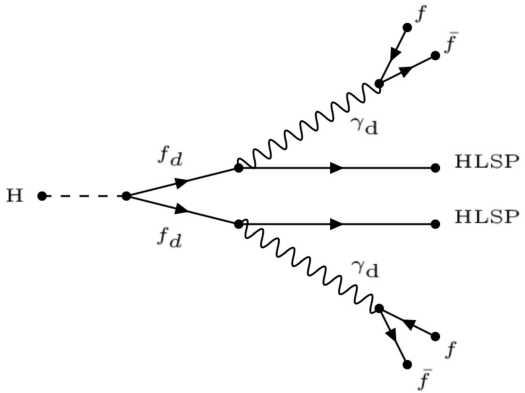


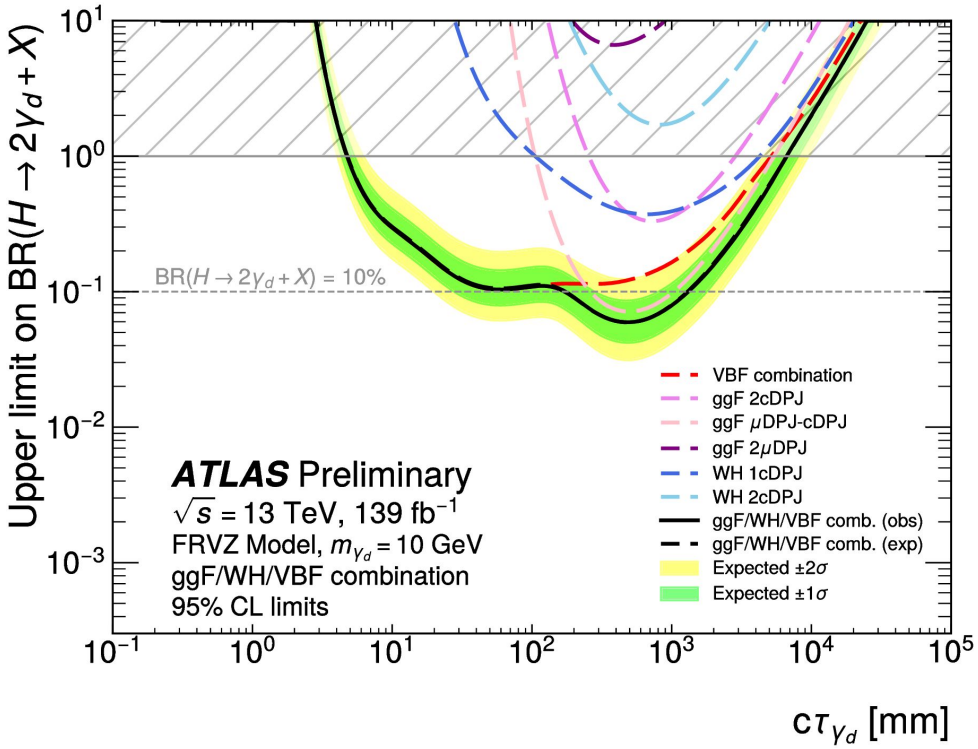


Dark Photons In Displaced ℓ + jets Final States

- Exotic Higgs decay to dark photons in VBF production channel
- Events with displaced, collimated jets of fermions or light hadrons
- Result is combined with ggF and WH production channels
- **Significant improvement** due to VBF contribution

ATLAS-CONF-2023-051

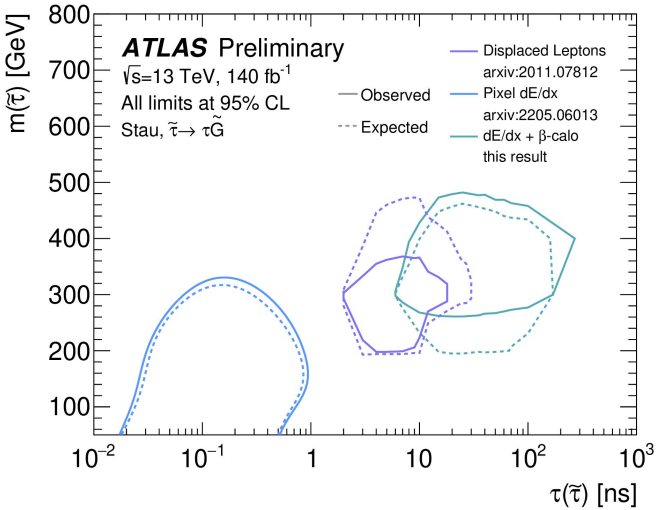


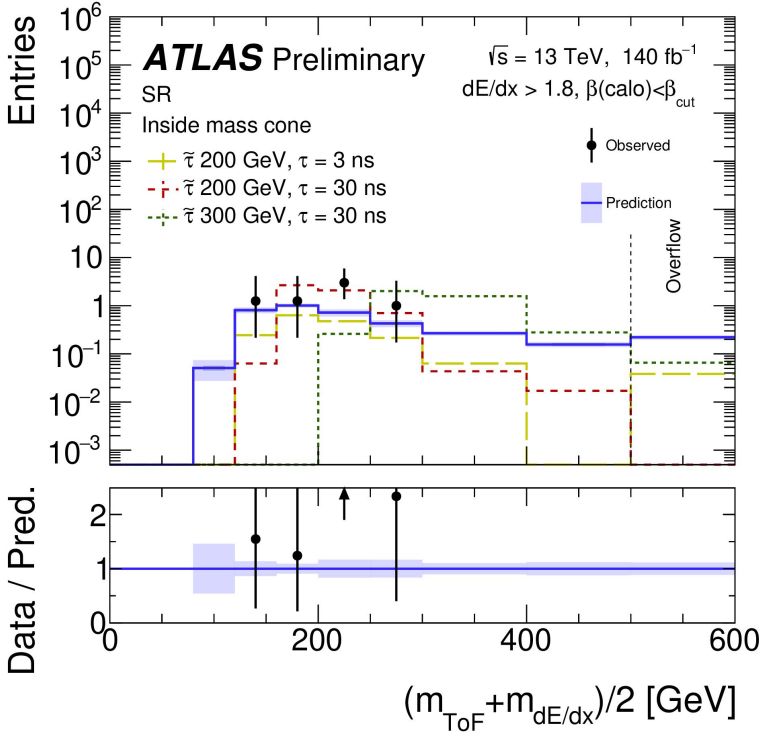


Highly Ionizing Particles with low β

ATLAS-CONF-2023-044

- Search for massive, charged, long-lived particles moving at low speeds (β)
- Special selection based on dE/dx (measured in pixel) and time of flight (measured with calorimeters)
- Various interpretations for production of R-hadrons, charginos and staus
- Significantly increases excluded parameter space

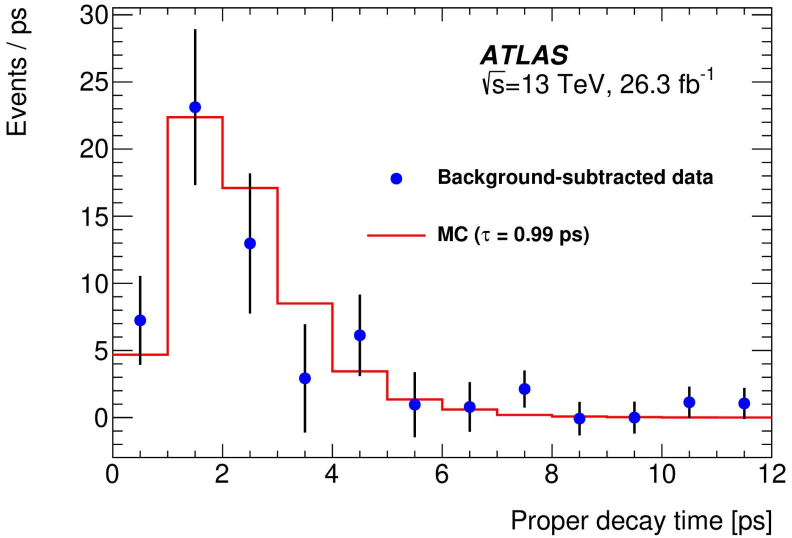


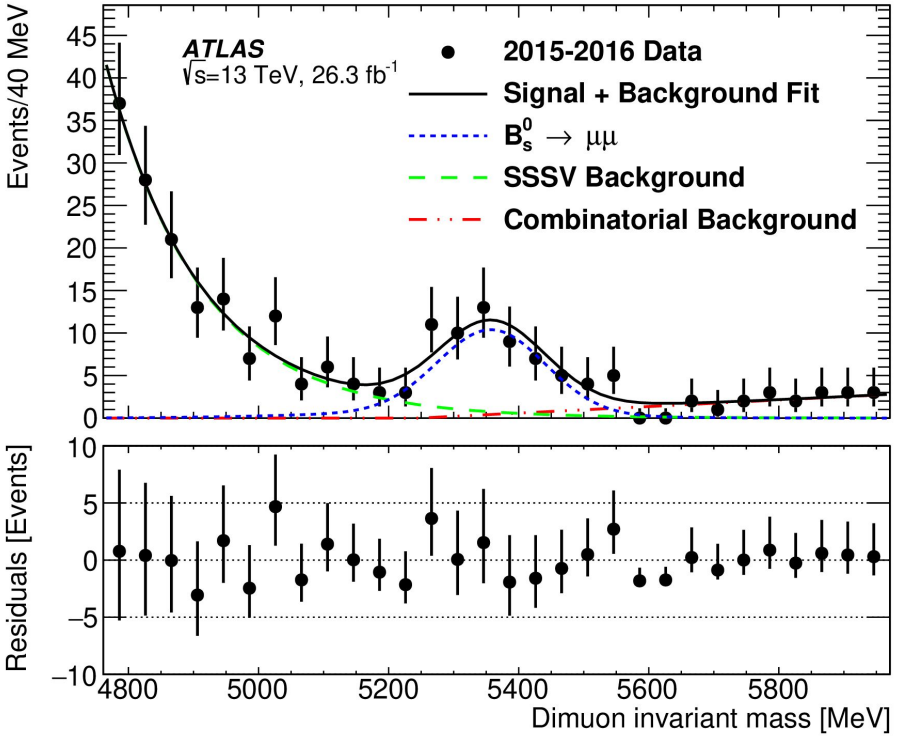


$B^0_s \rightarrow \mu\mu$ Lifetime Measurement

arXiv:2308.01171

- Using 2015 + 2016 data for new measurement
- Sensitive to BSM physics contributions
- **No deviation from SM observed**

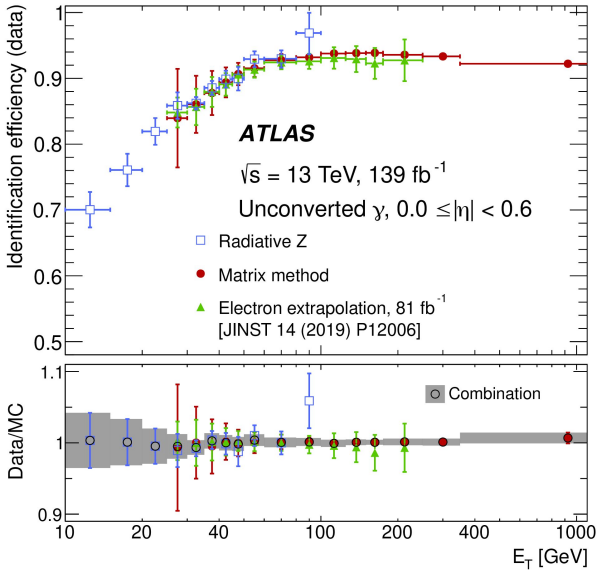


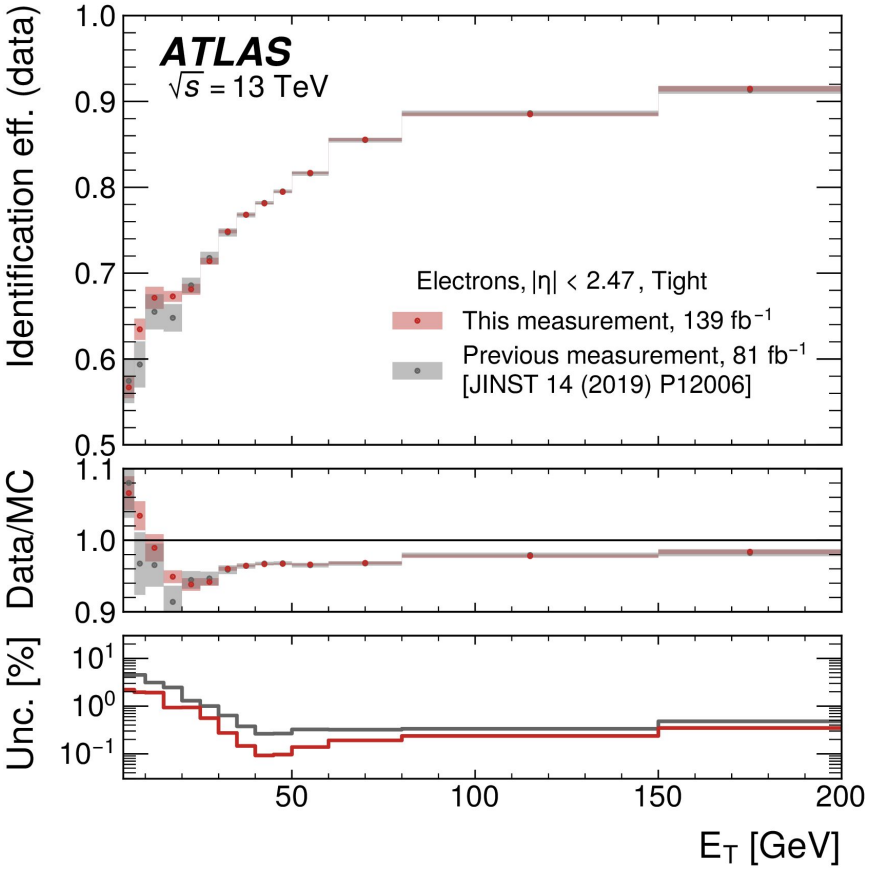


Electron and Photon Efficiencies

arXiv:2308.13362

- **ID uncertainty decreased by 30-50%**
  - Larger amount of data
  - Better methodology
- Improved stability of isolation variables over η and at high ET



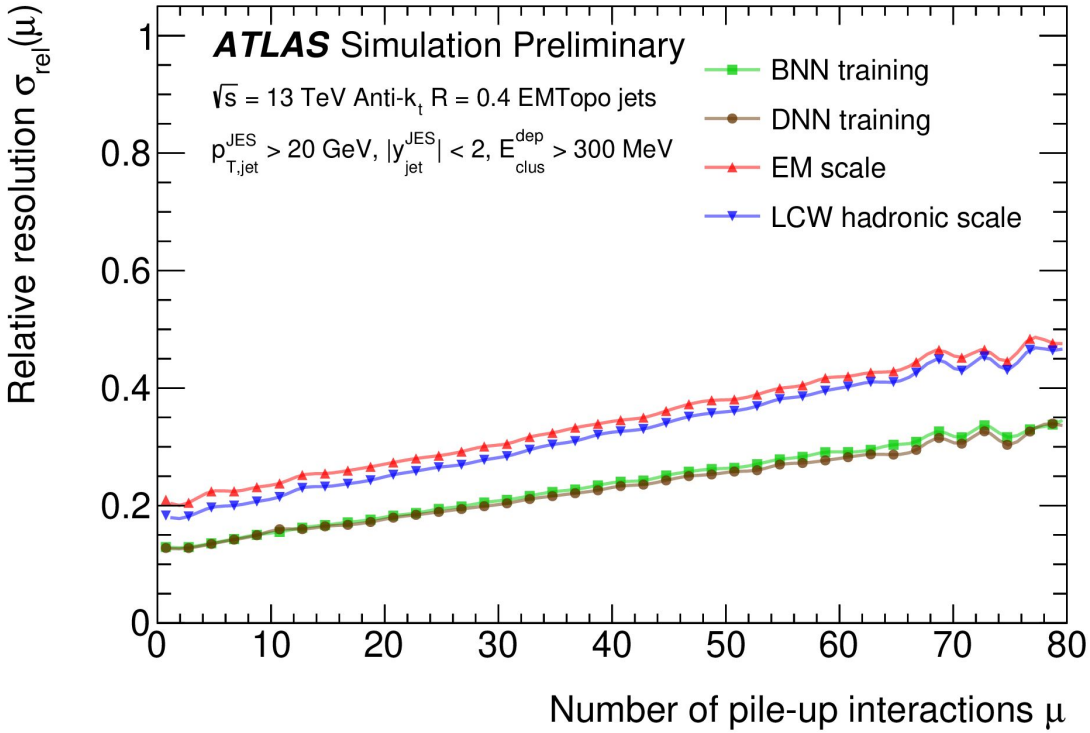


Calorimeter Clustering Improvements

ATLAS-CONF-2023-042

ATL-PHYS-PUB-2023-019

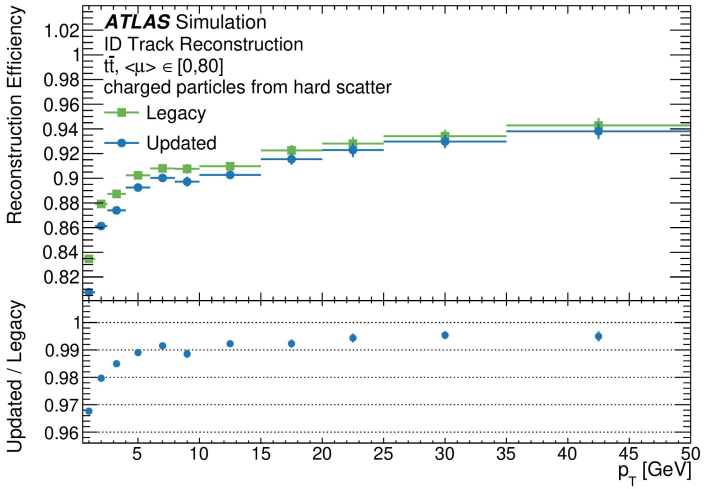
- Added timing cut to calo clusters to suppress out-of-time pileup
- **Reduces out-of-time pileup multiplicities by 50 - 80%**
- **Improves jet energy resolution by 5%** for 20 - 30 GeV jets
- Reduces event size by 6%
- Used for Run 3 reconstruction
- Studied local hadronic cluster energy calibration improvements using DNN and BNNs

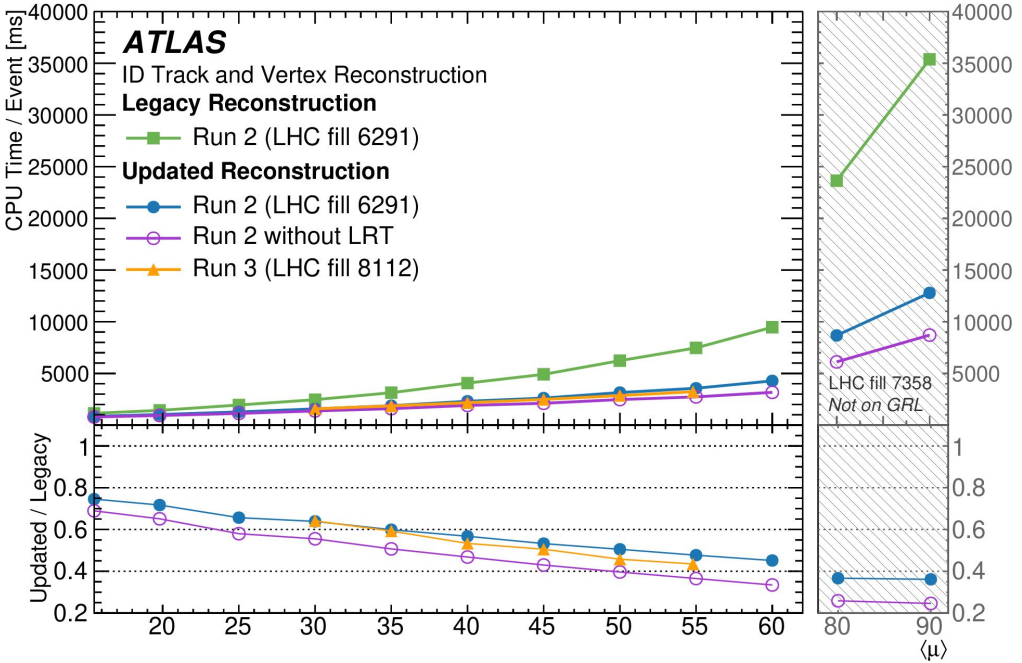


Run 3 Tracking Improvements

arXiv:2308.09471

- **Improved tracking processing time by factor 2 - 3**
- Reduced number of fake tracks by factor 2 (40% less storage)
- Efficiency not significantly degraded
- Allows extra reconstruction pass for displaced vertices

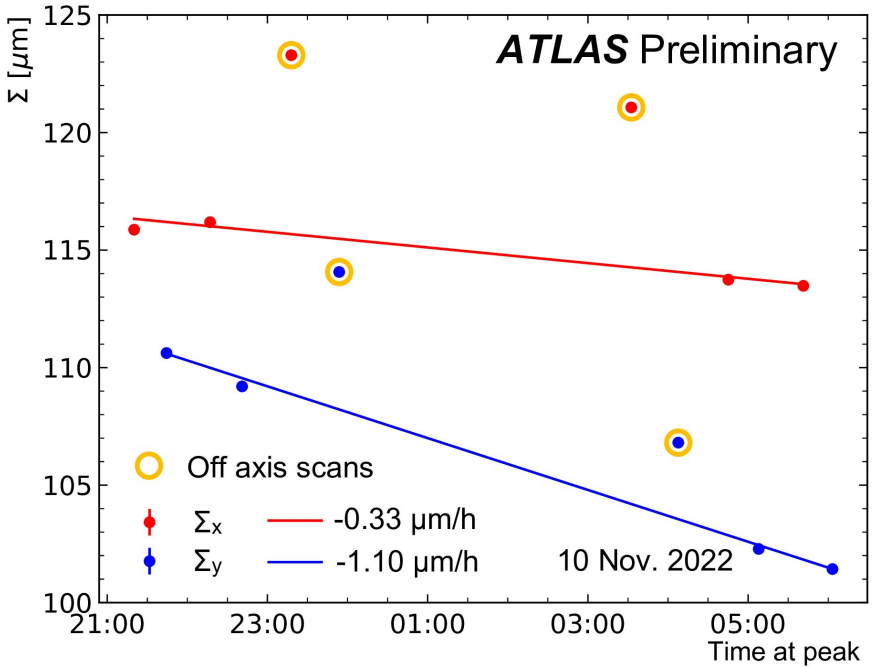




Luminosity Calibration

- Successful luminosity calibration session held during June 2023
- Included 2D Van Der Meer scan to explore the sizable non-factorization effects seen in the 2022 data

ATL-DAPR-PUB-2023-001



LUMI-2023-05