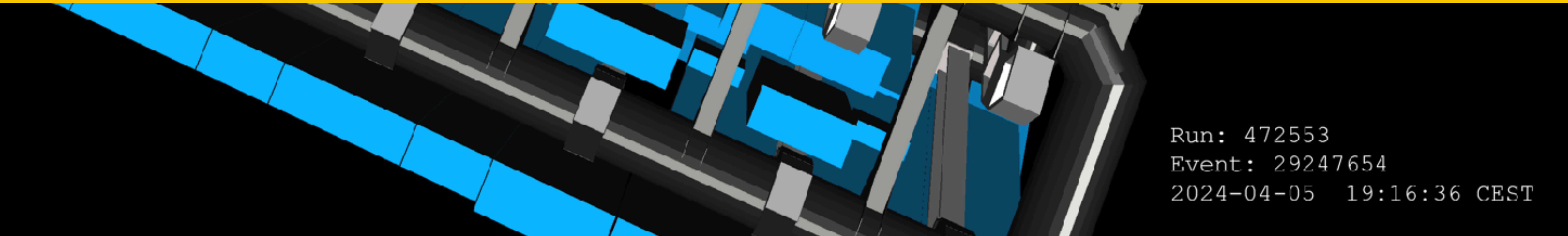
ATLAS Status and Overview

Heather M. Gray on behalf of the ATLAS Collaboration

Berkeley UNIVERSITY OF CALIFORNIA
BERKELEY LAB
CERN

ATLAS EXPERIMENT



Outline

Boosted HH → bbbb in vector-boson fusion search, arXiv:2404.17193

- Current status
- Searches for physics beyond the Standard Model (BSM)
- Precision measurements of the Standard Model

Outline

Search a resonance decaying into a scalar particle and a Higgs boson producing two bottom quarks and two photons, arXiv:2404.12915

- Current status
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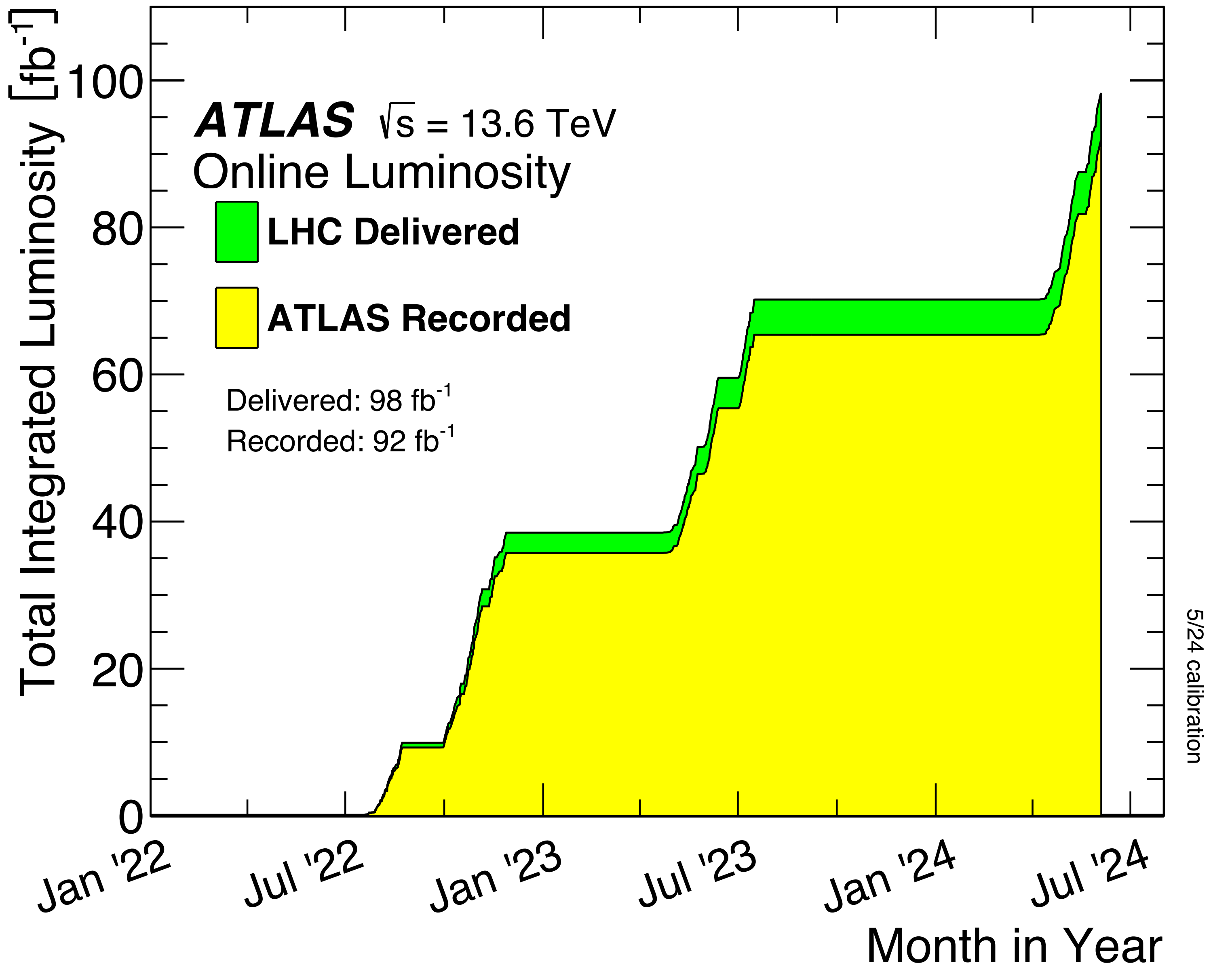
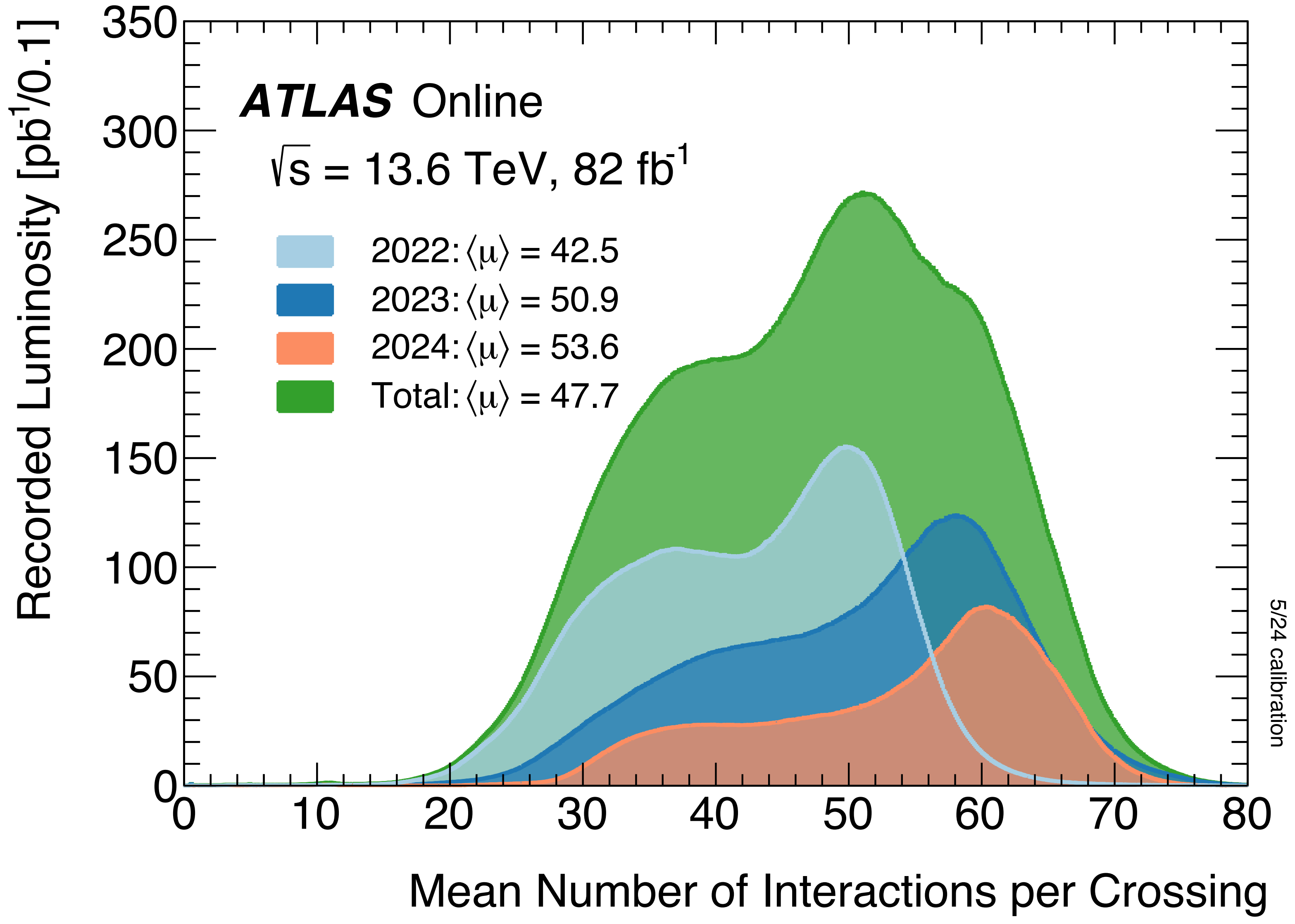
NEW

Run 3

- Well into Run-3, with **98 fb^{-1}** of delivered **proton-proton** luminosity at 13.6 TeV
  - 1.91 nb^{-1} of **PbPb** data during 2023
- LHC is currently leveling at μ = 63
  - 94% ATLAS **recording** efficiency
- Already **9 Run-3** papers
- Many results shown use **Run-2 dataset**
  - 140 fb^{-1} and **0.83% lumi** uncertainty
- Run-2 results summarized in six **physics reports**
- Run-3 performance: detector, trigger, software & computing





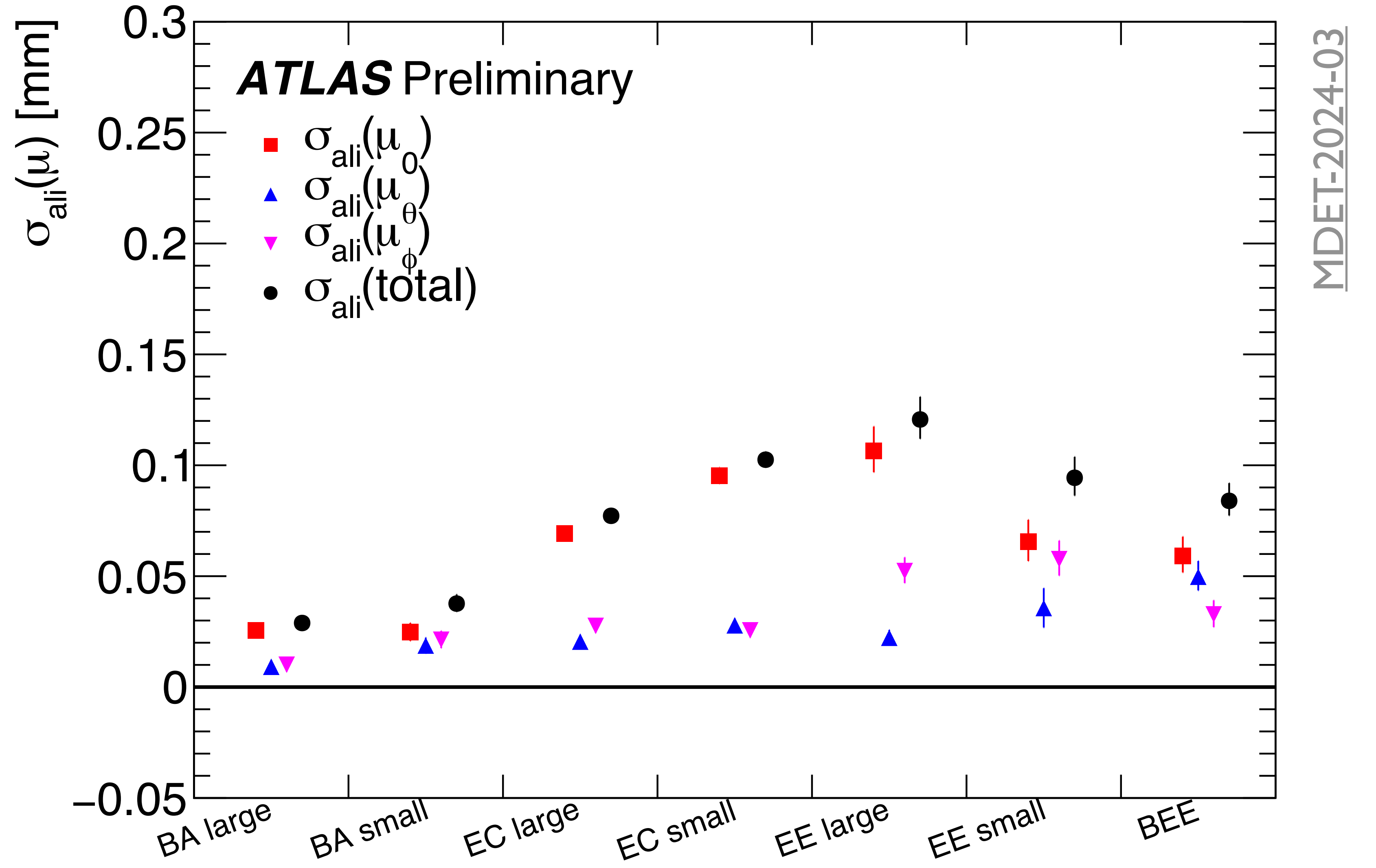
Luminosity results

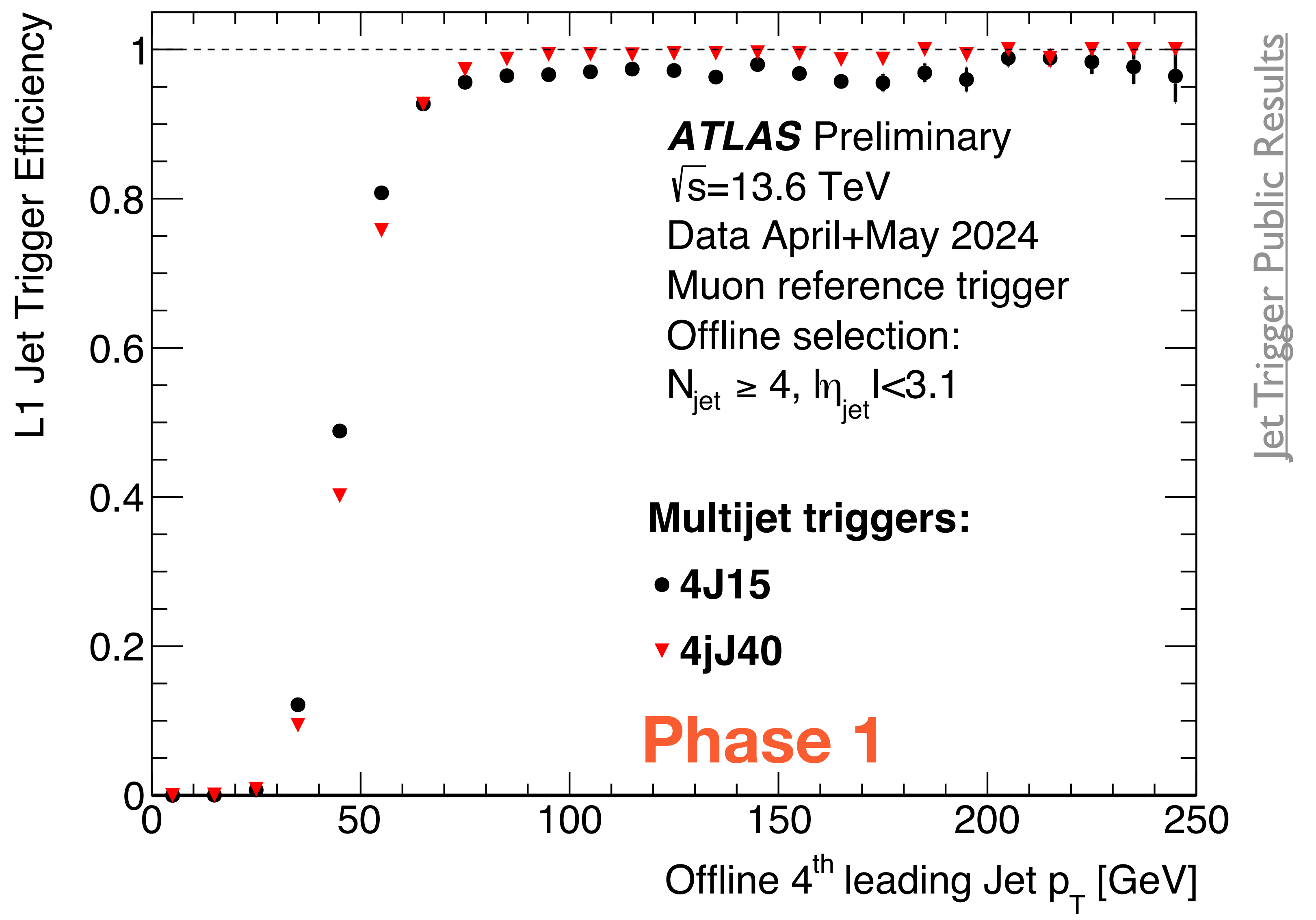
NEW

Operations Highlights

- Improved performance with **Phase-I trigger** system
  - High granularity digital calorimeter trigger **reduces L1 rate** while maintaining low p_T thresholds
  - New Small Wheel (NSW) reduces **muon fake rate**
- Updated **muon alignment** using data taken with toroid off
  - **~2-4x** improvement vs early **Run-3**
  - $\sigma_{\text{ali}} = 50\mu\text{m} \rightarrow \sigma(P)/P$ =10% @ 1 TeV

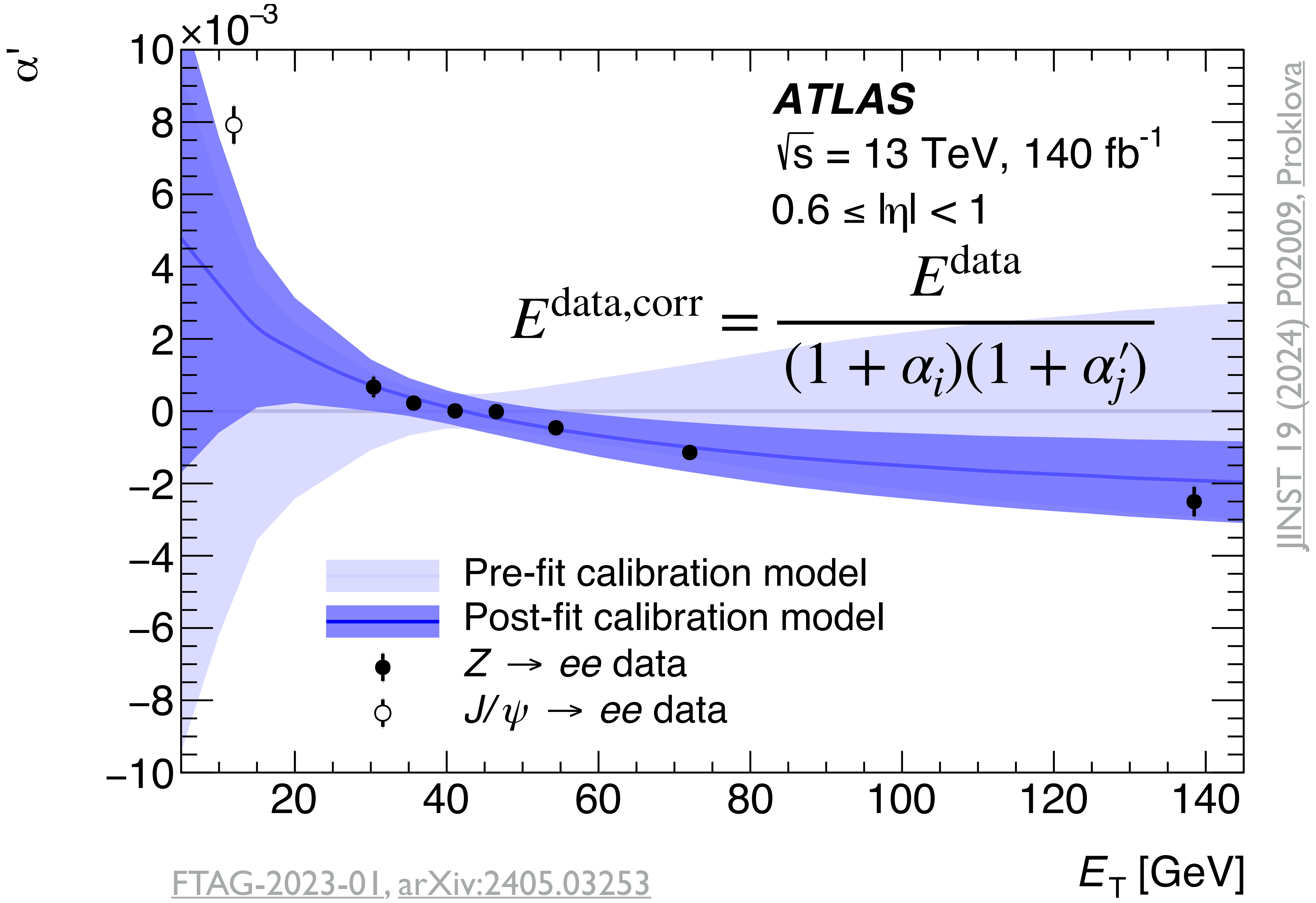
Sagitta residuals after muon alignment



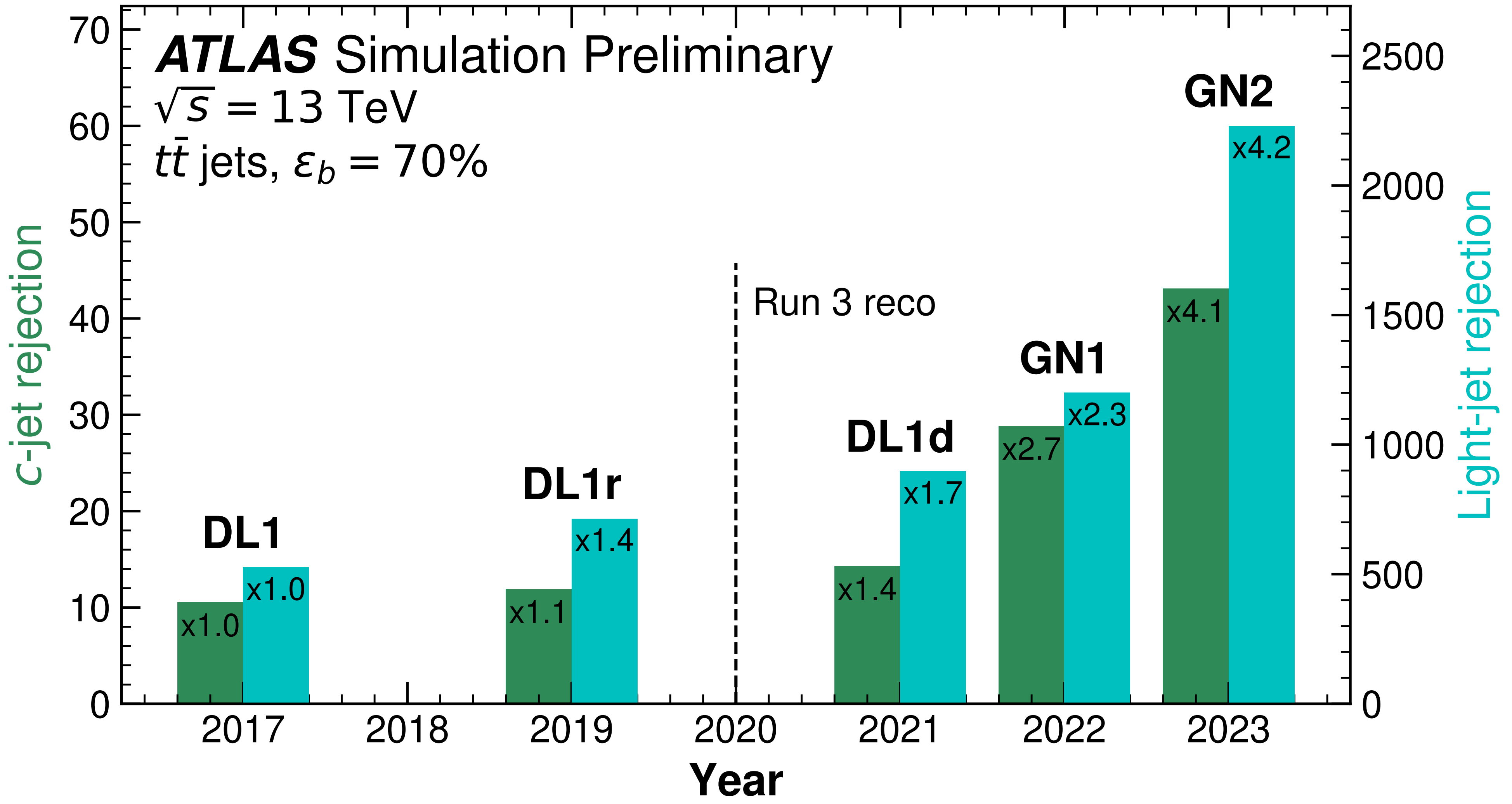


Performance Highlights

- More than **2x** improvement in **photon** and **electron calibration**
  - Dynamical EM clustering for reconstruction
  - New energy dependence scale corrections
  - **~0.05%** for $Z \rightarrow e^+e^-$, **~0.2%** for $E_T(\gamma) = 60$ GeV
- **Flavor tagging** performance transformed through the use of **advanced AI/ML** techniques
  - 4x background rejection improvement with **graph neural network** tagger (GN2) compared to Run-2

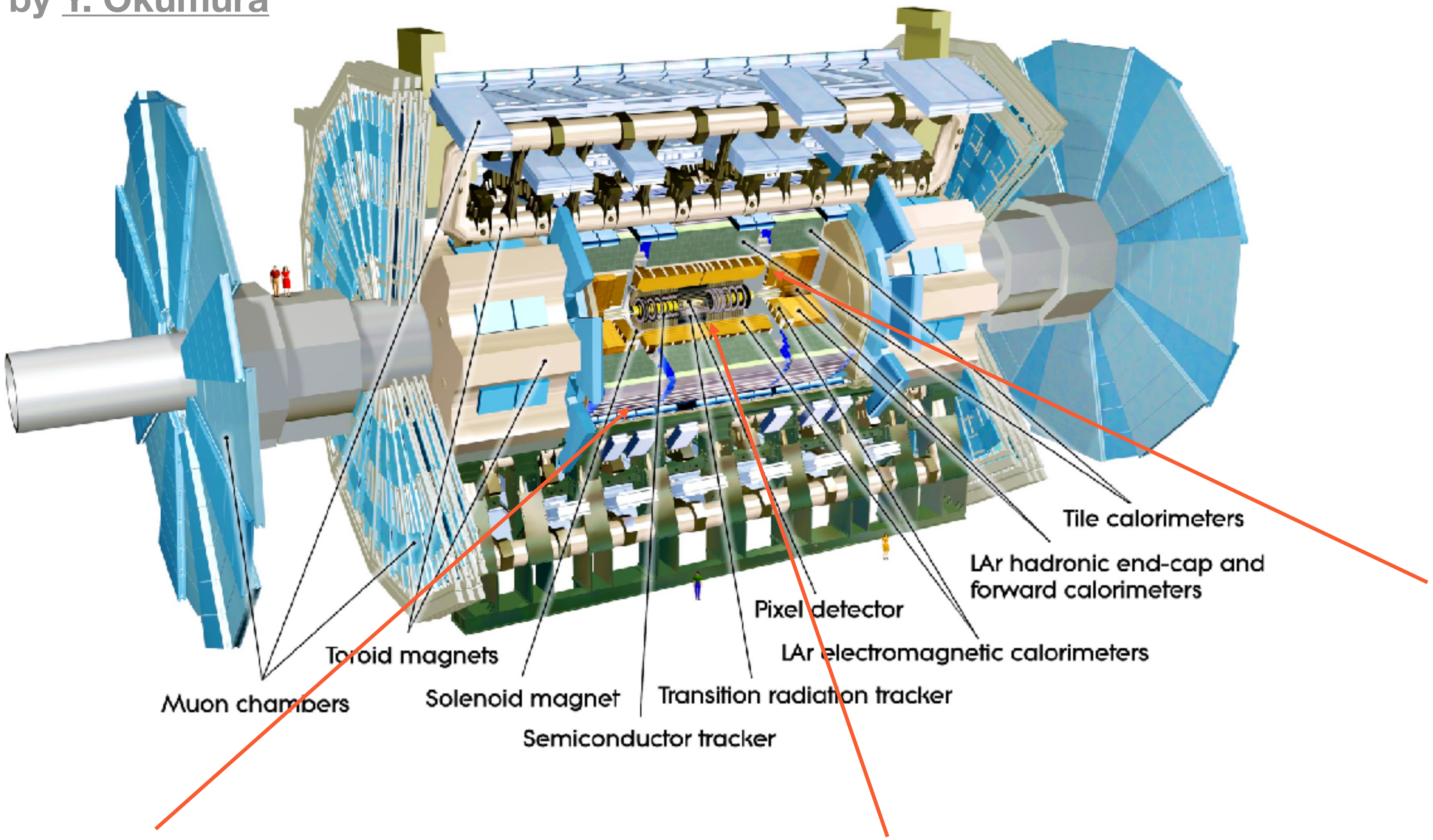


FTAG-2023-01, arXiv:2405.03253



ATLAS Phase-II upgrade

Dedicated talk by Y. Okumura



Upgraded Trigger and Data Acquisition system

Level-0 Trigger at 1 MHz

Improved High-Level Trigger

(150 kHz full-scan tracking)

Electronics Upgrades

LAr Calorimeter

Tile Calorimeter

Muon system

High Granularity Timing Detector (HGTD)

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

Low-Gain Avalanche Detectors (LGAD)

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 $|\eta| = 4$
High-granularity Pixel and Strip systems

Additional upgrades

Luminosity detectors (1% precision goal)

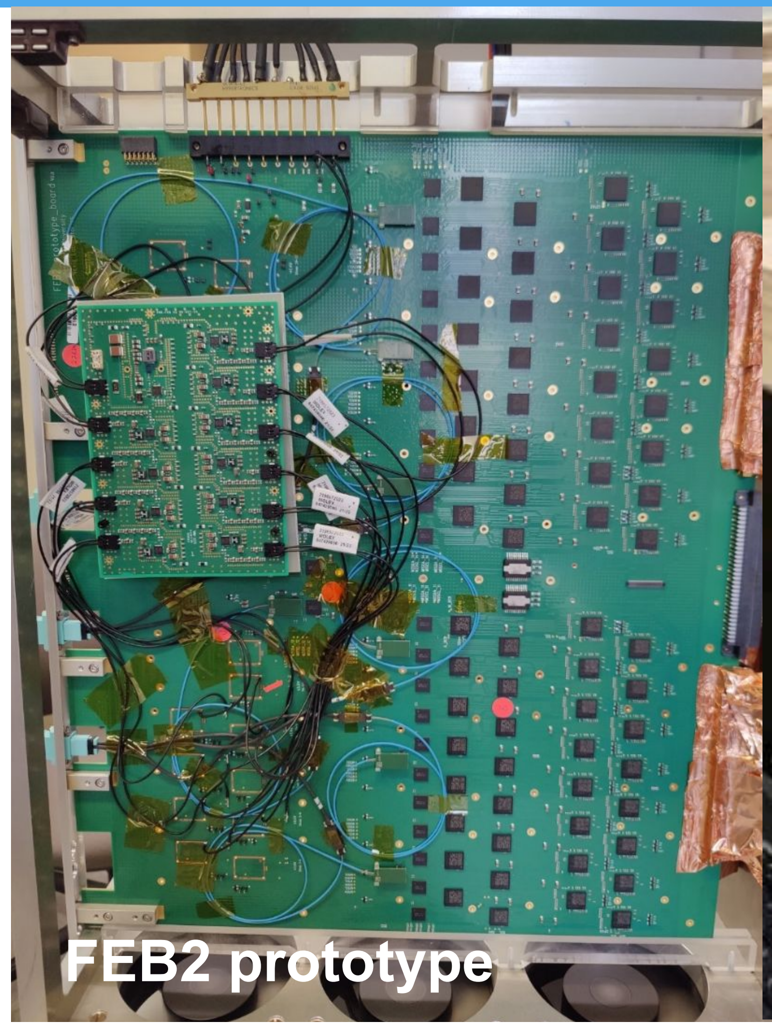
HL-ZDC

Offline software and computing

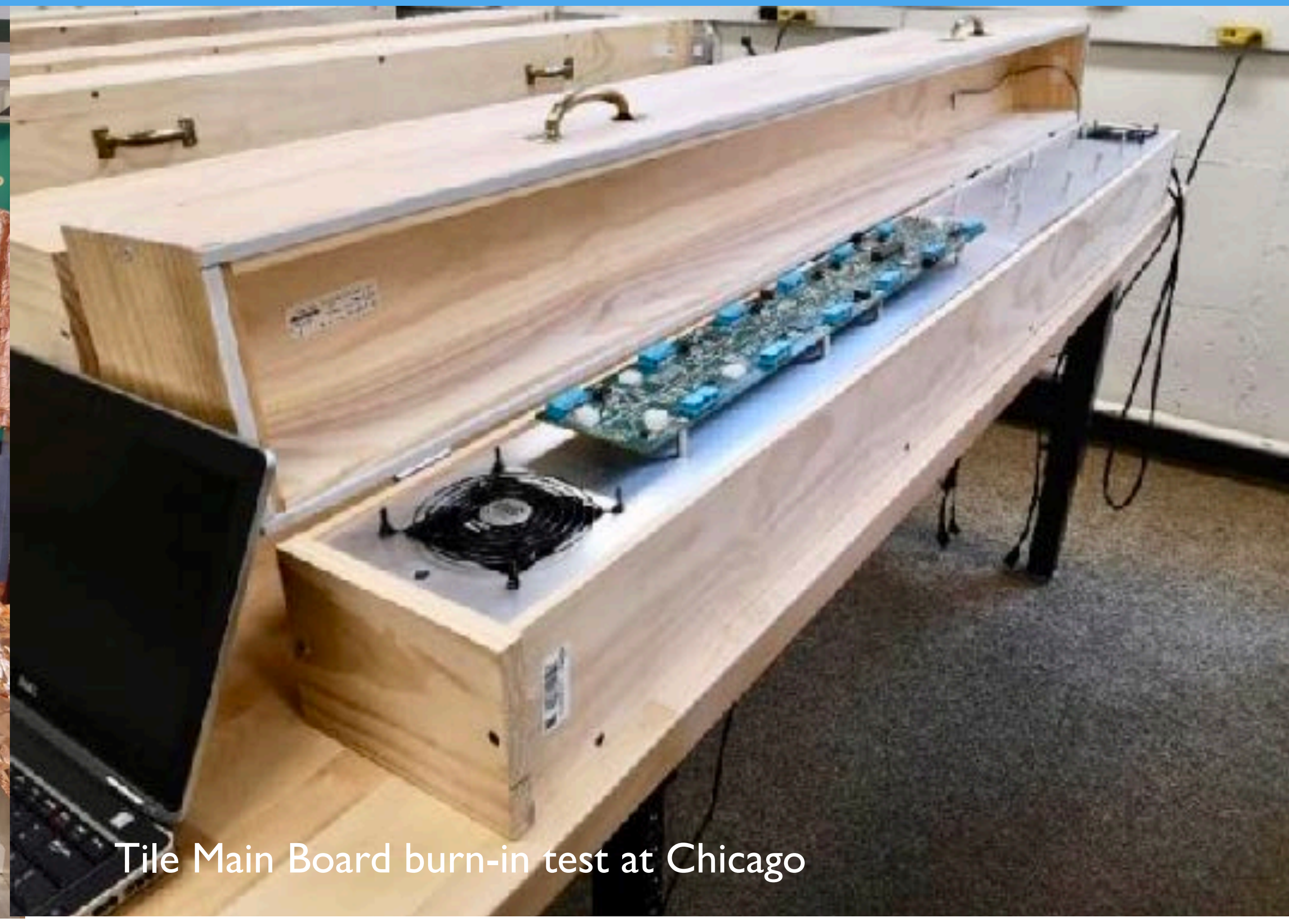
Phase-II Highlights

SR1 ITk surface assembly cleanroom at CERN

ITk ASICs in production
Pixel module production ongoing
Strip sites ready for production but ongoing studies to mitigate sensor fracturing under thermal stress
Cold noise mitigated



FEB2 prototype



Tile Main Board burn-in test at Chicago

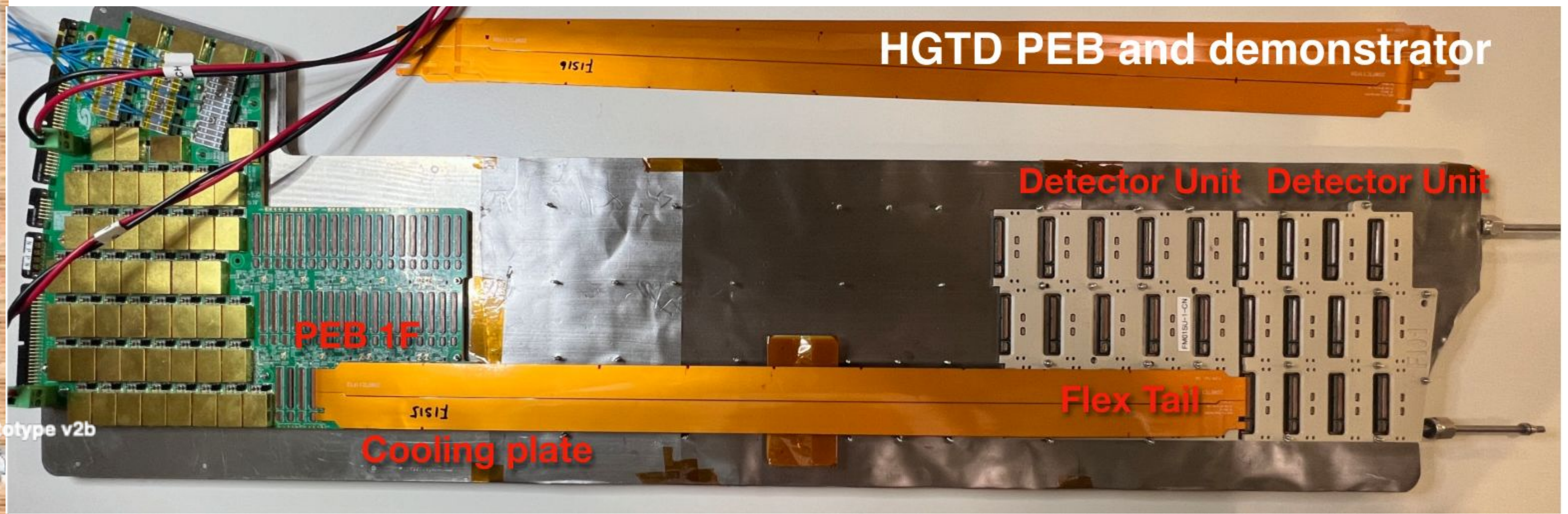
New **LAr** prototype FEB board tested
Tile Phase-II demonstrator taking data

All **sMDTs** at CERN
Testing **RPC** read out chain prototype

sMDT chambers at CERN (BB5)

Testing common module of **Global Trigger**
Complete prototype of most challenging **HGTD** board

GCM prototype v2b



Outline

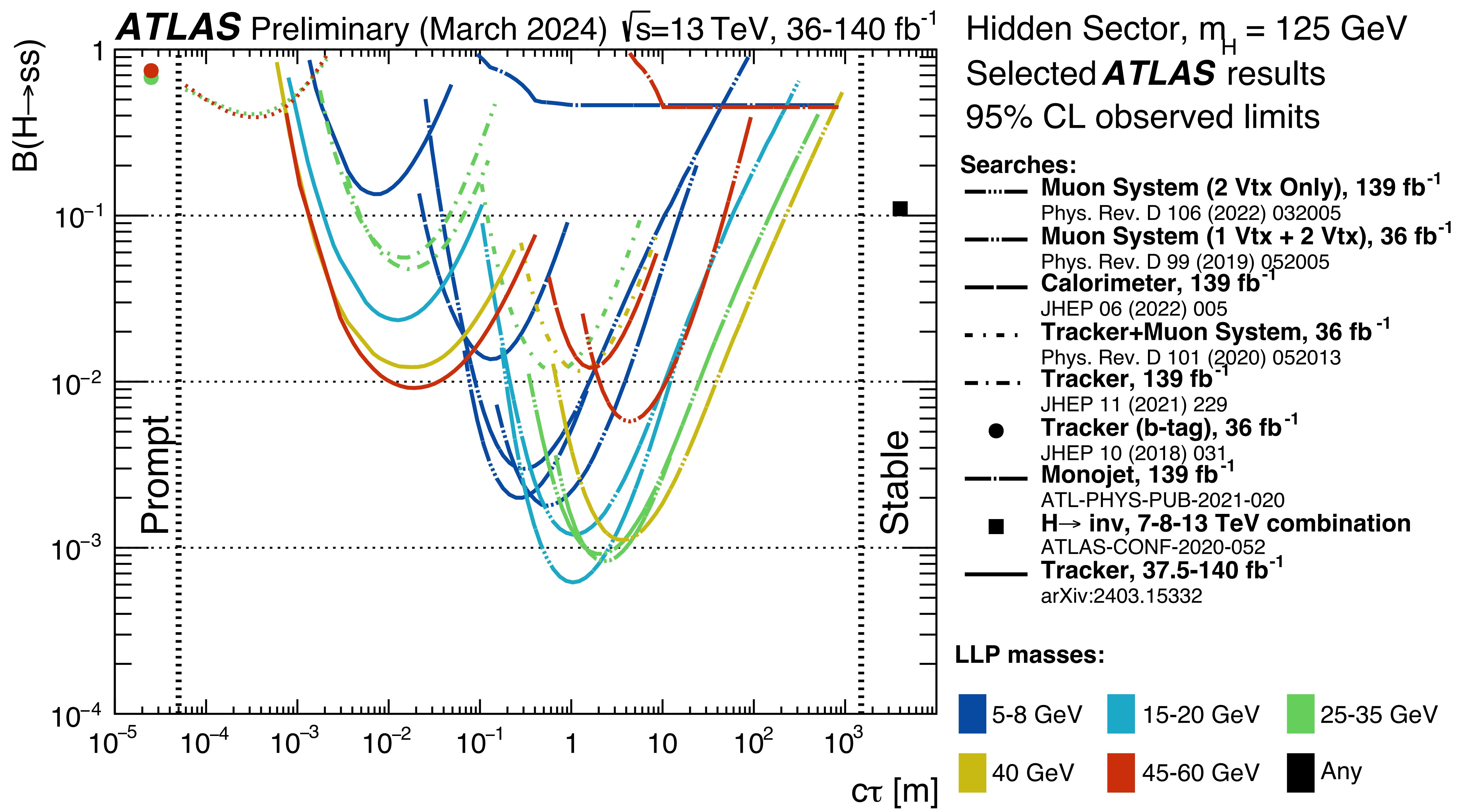
Search for GGM higgsinos decaying to two photons and two b-jets, arXiv:2404.01996

- Current status
- Searches for physics beyond the Standard Model (BSM)
- Precision measurements of the Standard Model

Broadly Searching for New Physics

Extending mass reach from
Run-1 to **Run-2**

ATL-PHYS-PUB-2022-007, Frattari

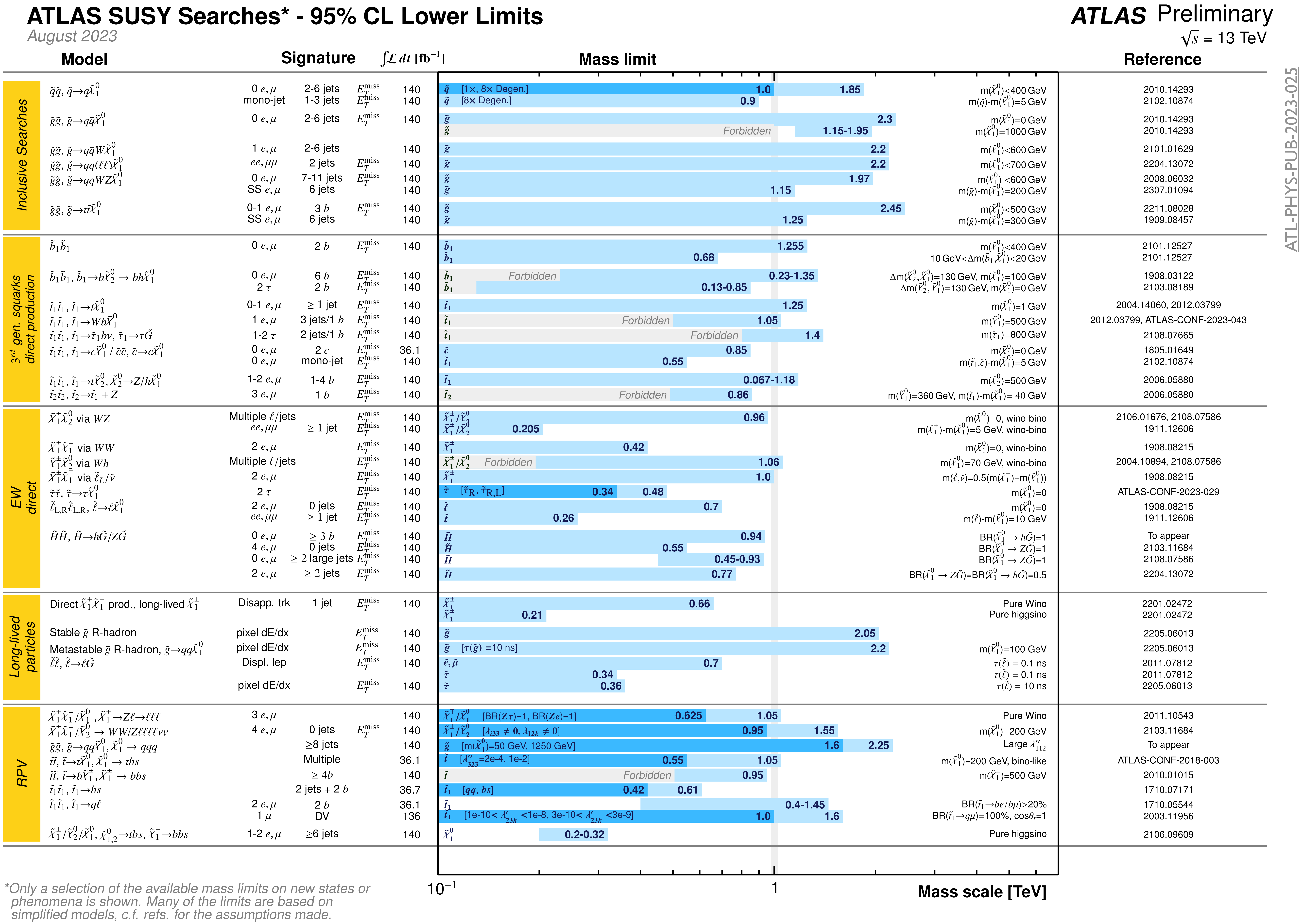


Model and final state	Section	Excluded Range Run 1	Excluded Range Run 2
q^* in a dijet resonance	3.1	m < 4.06 TeV [326]	m < 6.7 TeV
Z'_{SSM} in a dilepton resonance	4.1.1	m < 2.90 TeV [327]	m < 5.1 TeV
Type-III seesaw heavy leptons in $\ell\ell\nu\nu qq$	5.3	m < 335 GeV [328]	m < 790 GeV
VLQ T (Singlet, $2\ell + 3\ell$)	6.2	m < 0.66 TeV [329]	m < 1.27 TeV
Scalar LQ_3^u ($LQLQ \to t\nu t\nu$)	7	m < 640 GeV [330]	m < 1240 GeV
LFV $Z \to e\mu$	8.1	$\mathcal{B} < 7.5 \times 10^{-7}$ [331]	$\mathcal{B} < 2.62 \times 10^{-7}$
FRVZ γ_d in $H \to 2\gamma_d + X$ with $\mathcal{B}(H \to 2\gamma_d) = 10\%$ and $m_{\gamma_d} = 0.4$ GeV	9.1	$15 < c\tau < 260$ mm [332]	$0.42 < c\tau < 1001$ mm
$H \to$ invisible combination	10.3	$\mathcal{B} < 0.252$ [333]	$\mathcal{B} < 0.113$
Multi-charged particle with $\lvert z \rvert = 2$	11	m < 660 GeV [334]	m < 1060 GeV
ADD with $n = 6$ in jet+E_T^{miss}	12.1	M_D < 3.06 TeV [335]	M_D < 5.9 TeV

arXiv:2403.09292

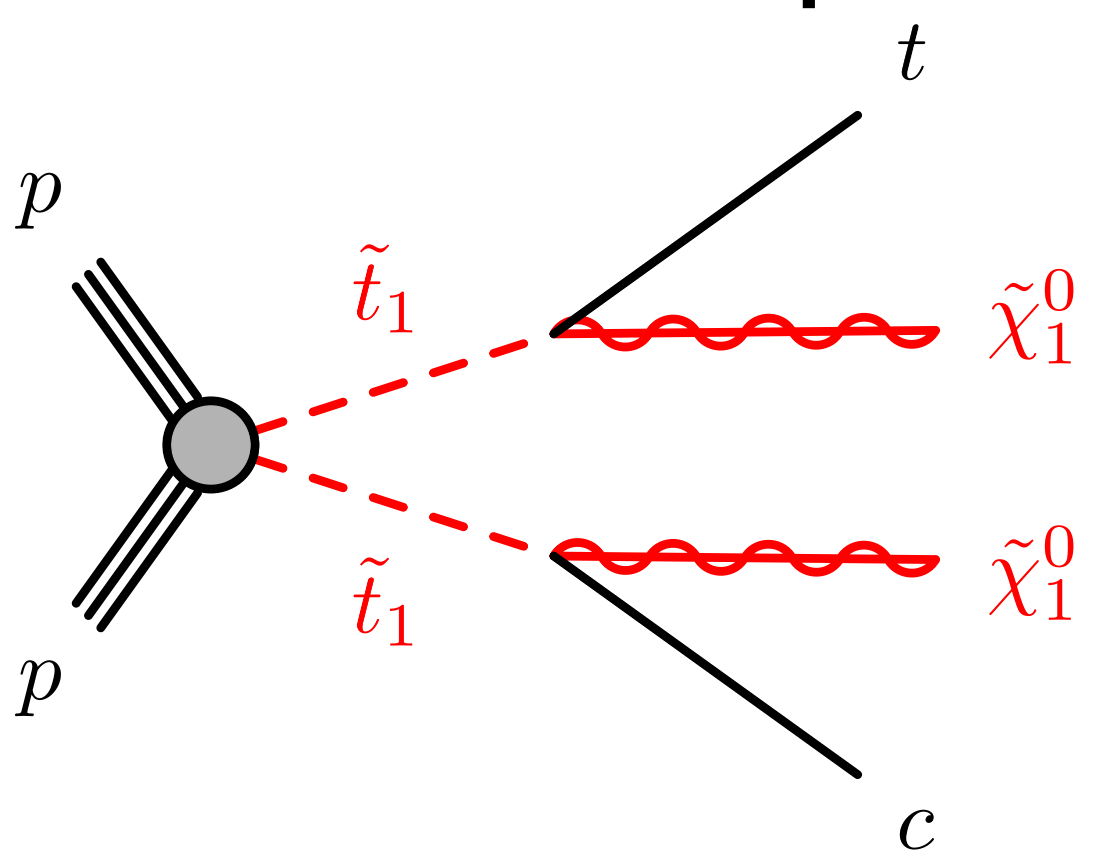
Wide range of **hidden** sector BR and lifetimes

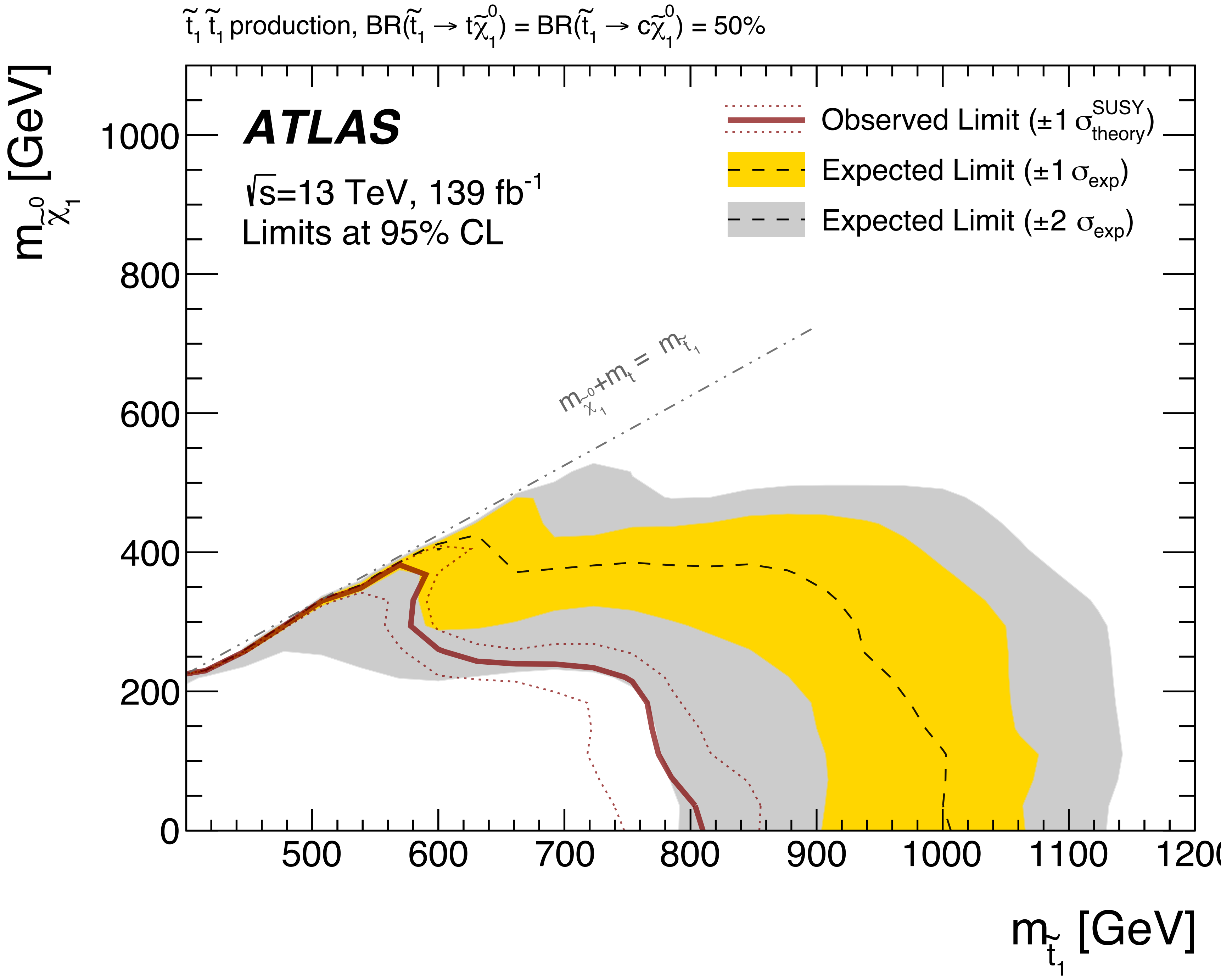
Probing supersymmetry around the TeV scale



Strong and EW Production Searches

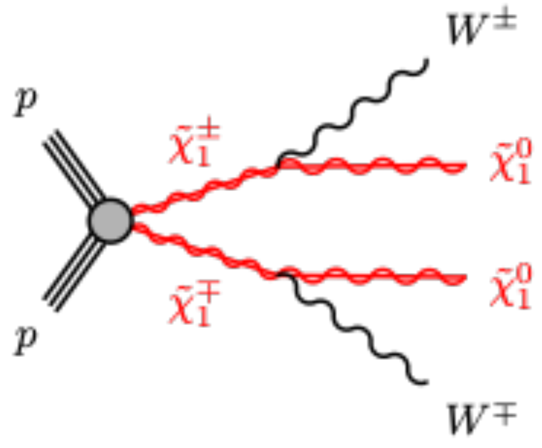
Exploit powerful **charm tagging** algorithms in **stop searches** in events with top, charm and MET

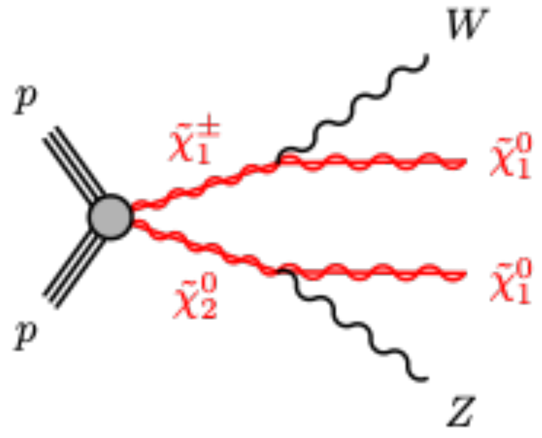


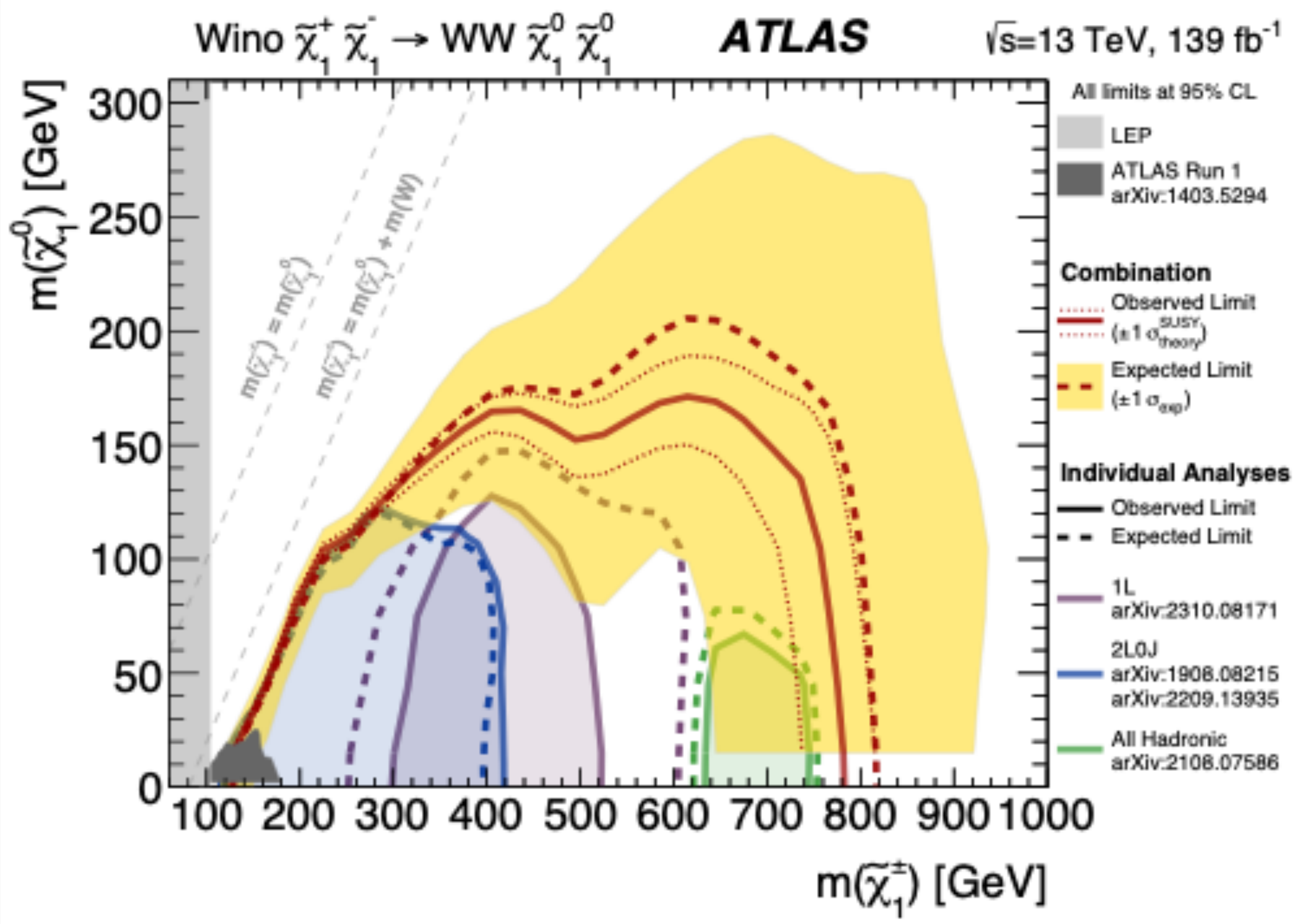


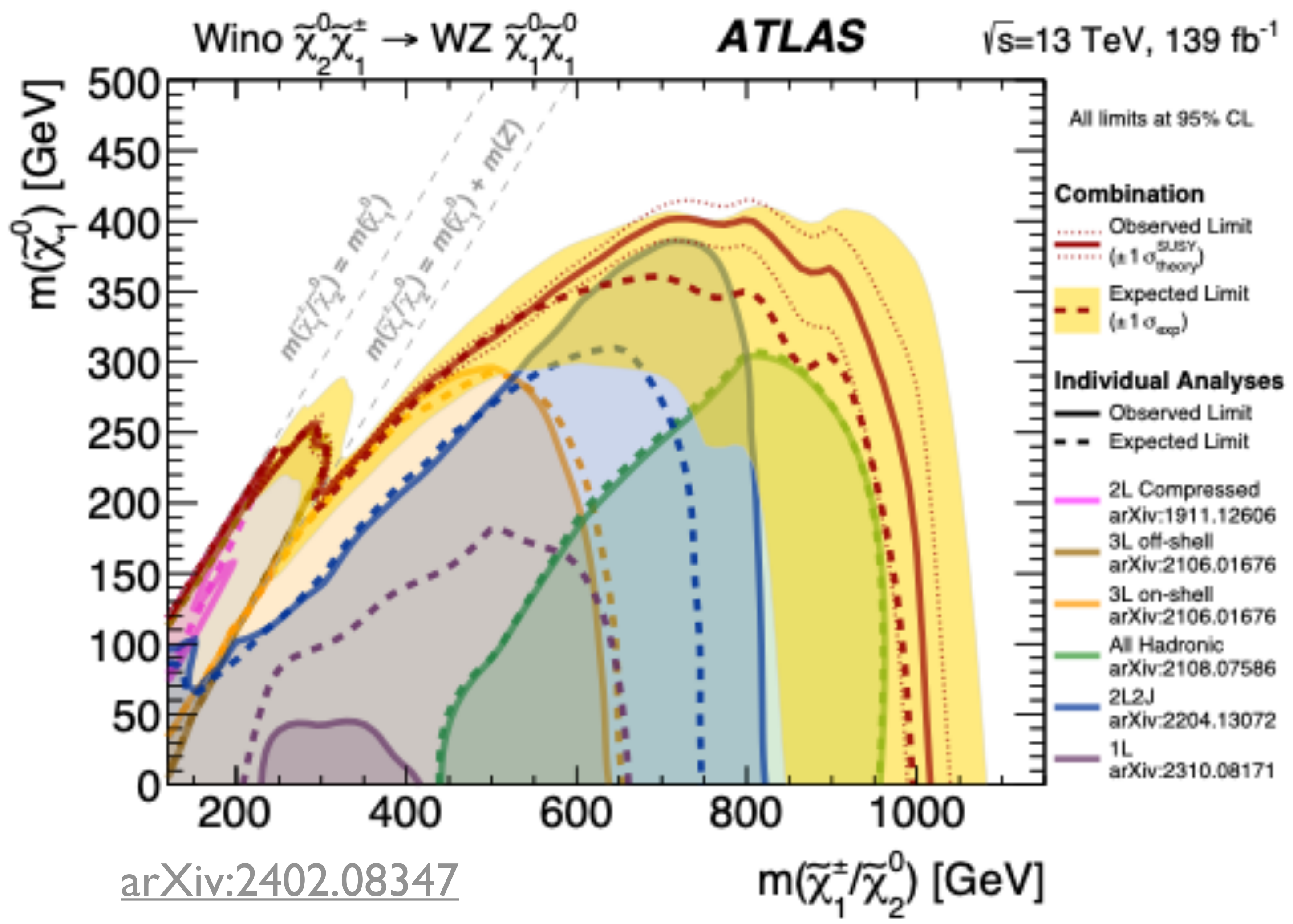
arXiv:2402.12137, Gurdasani

Comprehensive searches for **electroweak SUSY**, including detailed pMSSM study exploring 12k full models





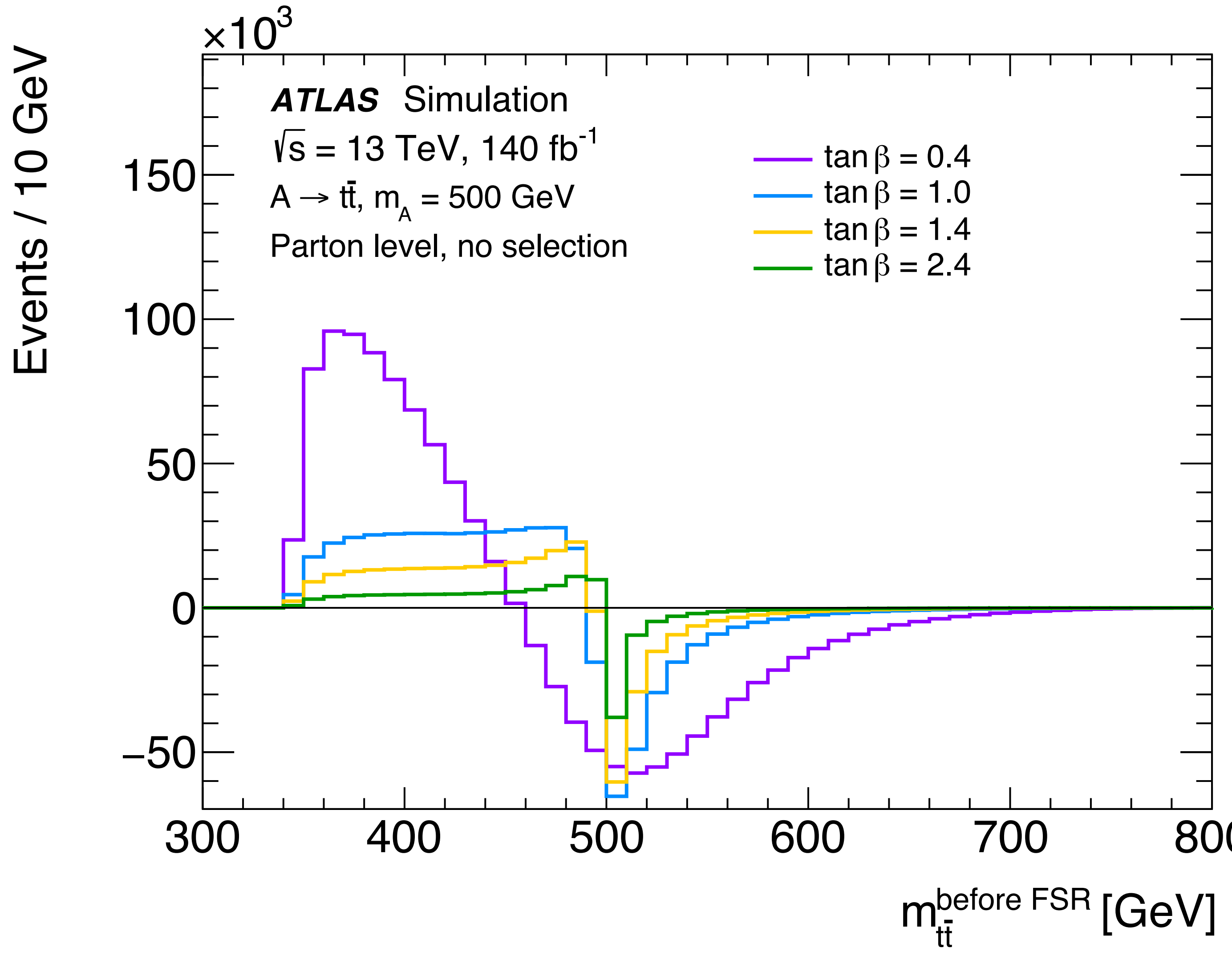


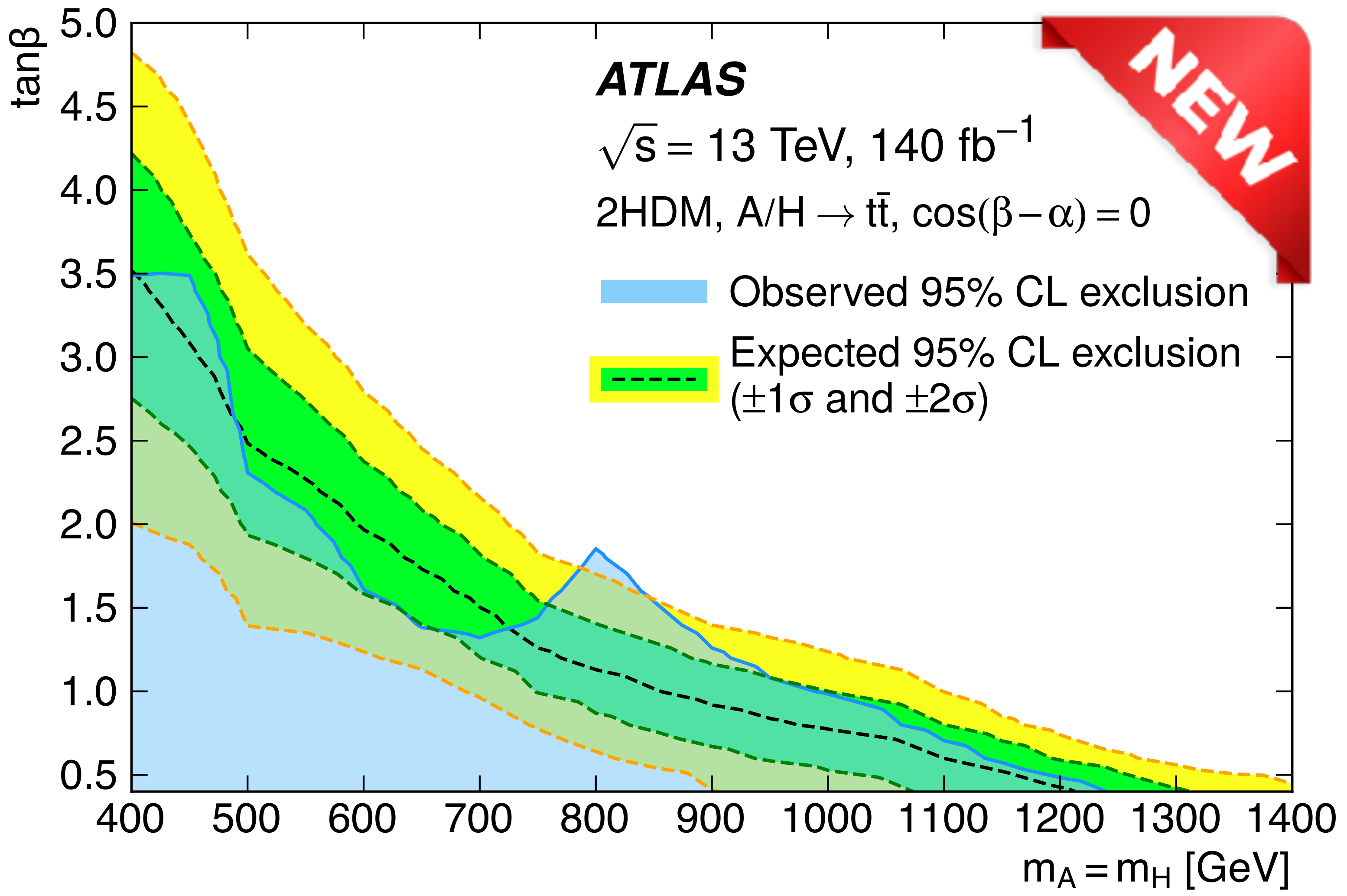


arXiv:2402.08347

Higgs-related Searches

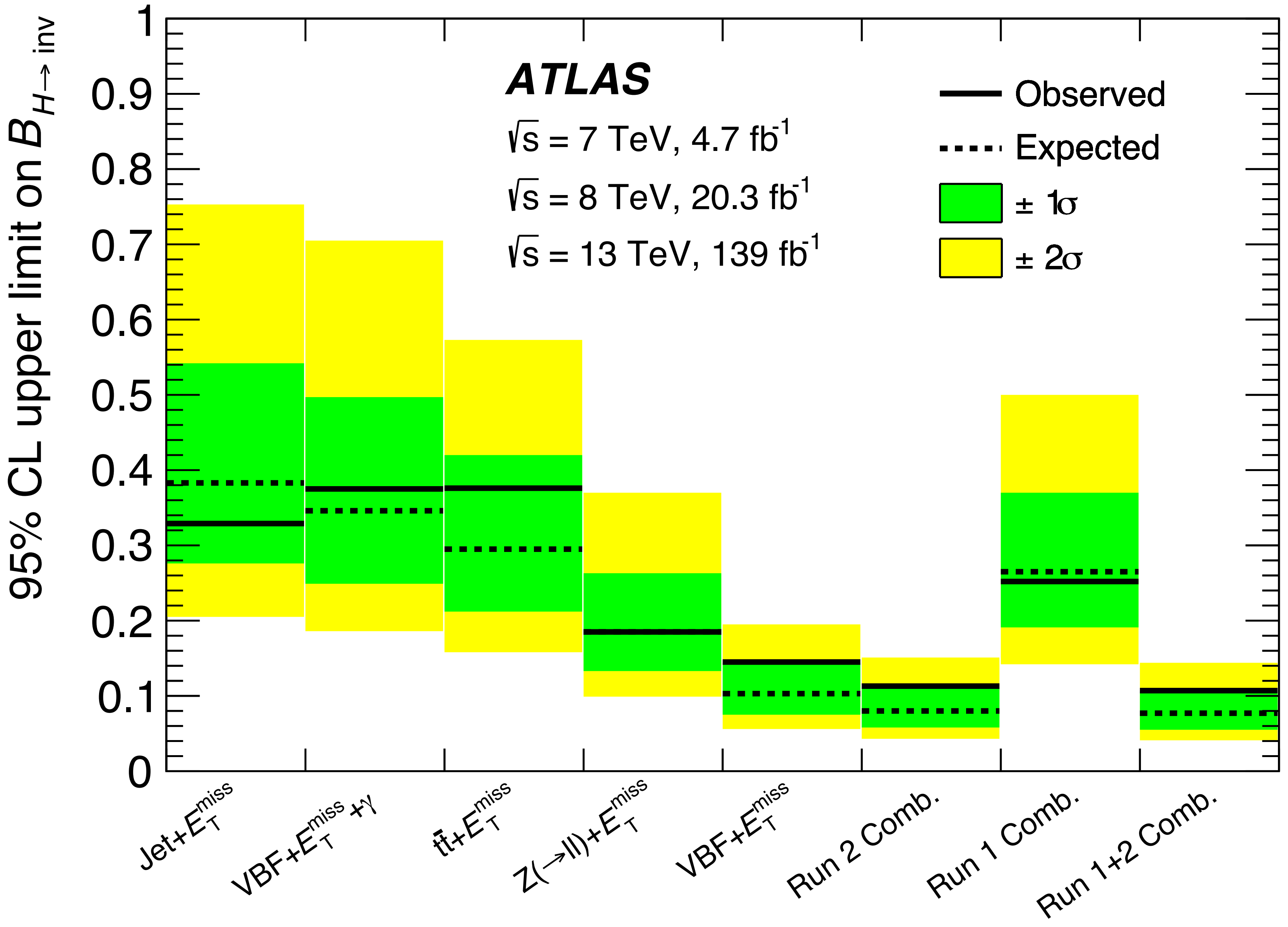
- Search for additional Higgs bosons with **interference pattern** in $t\bar{t}$ decays
  - Narrow excess (2.7σ) in 1-lepton channel @ ~850 GeV

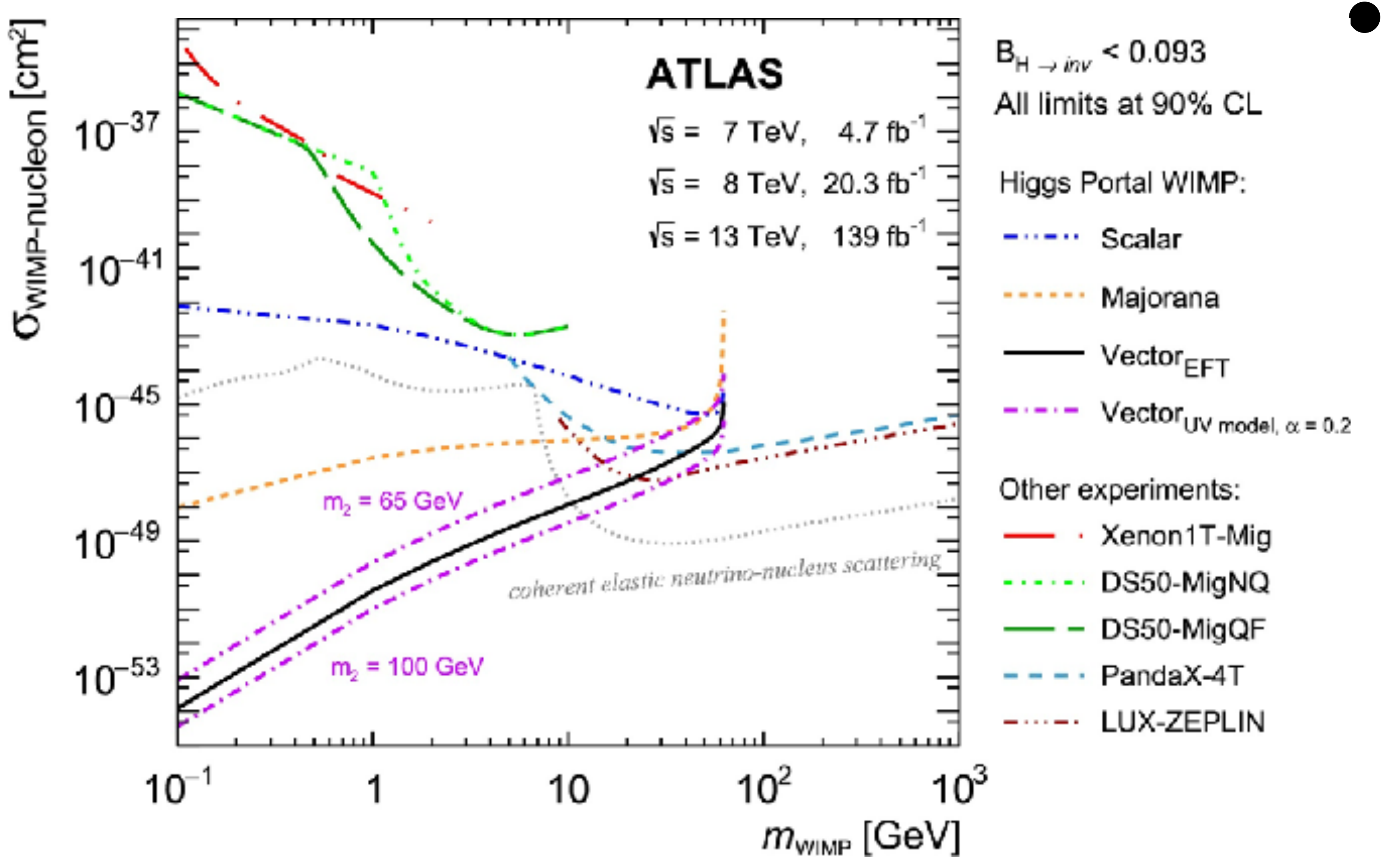




arXiv:2404.18986, De Biase

PLB 842 (2023) 137963

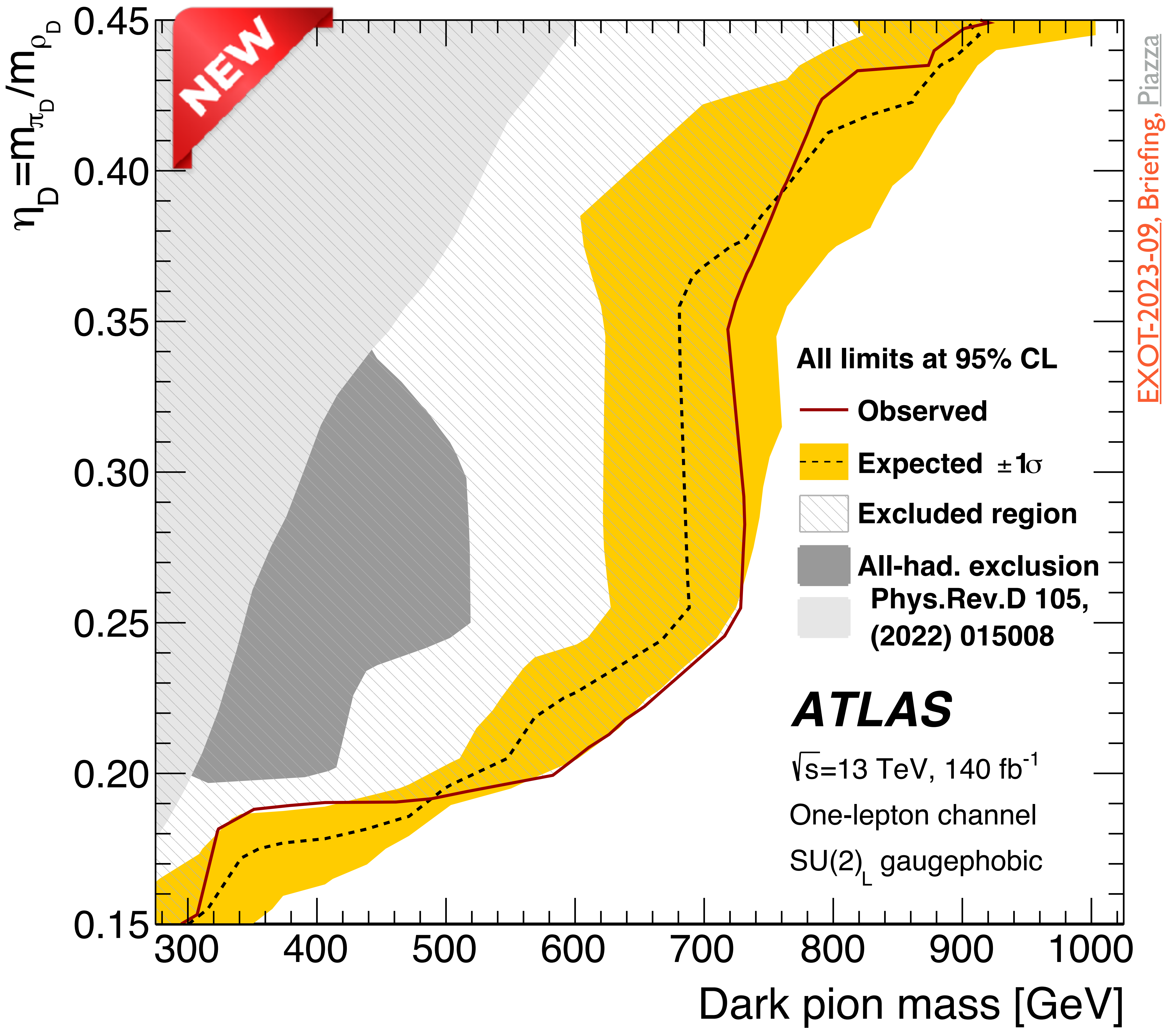




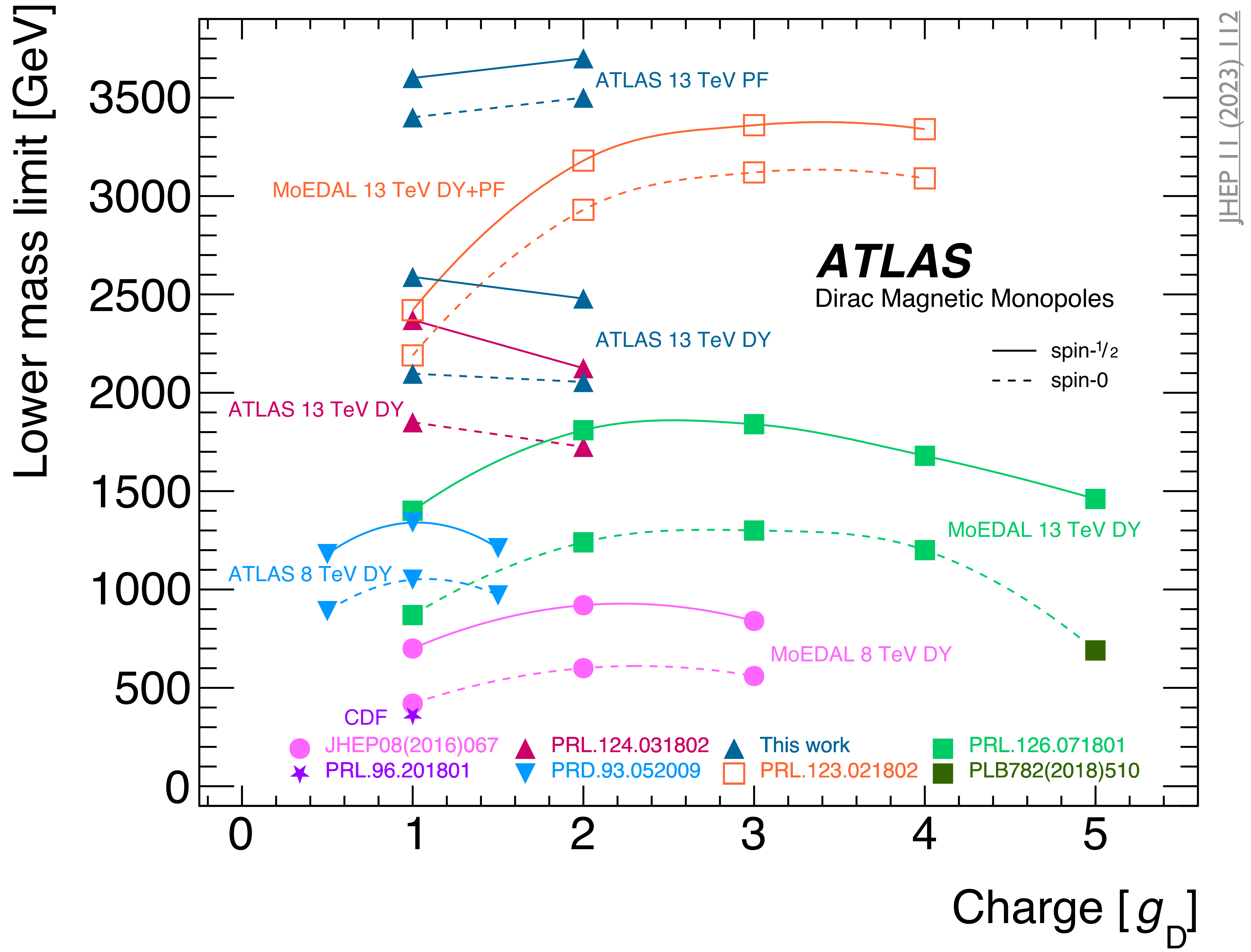
- Observed (expected) **H → inv** branching ratio limit of 0.107 (0.077)
  - World-leading constraints on **light dark matter**

Exotics Highlights

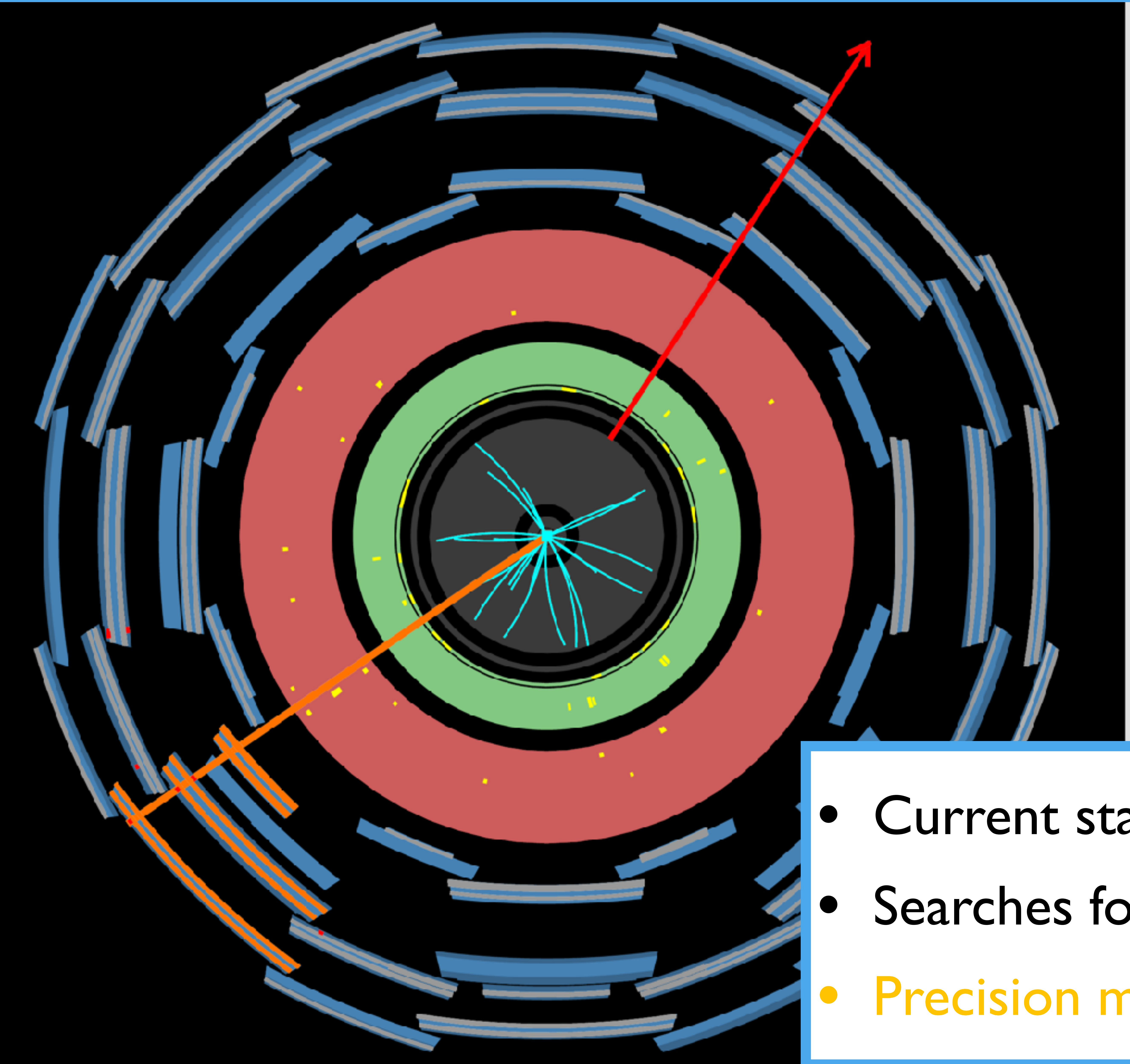
First LHC search for **dark mesons** decaying to top and bottom quarks

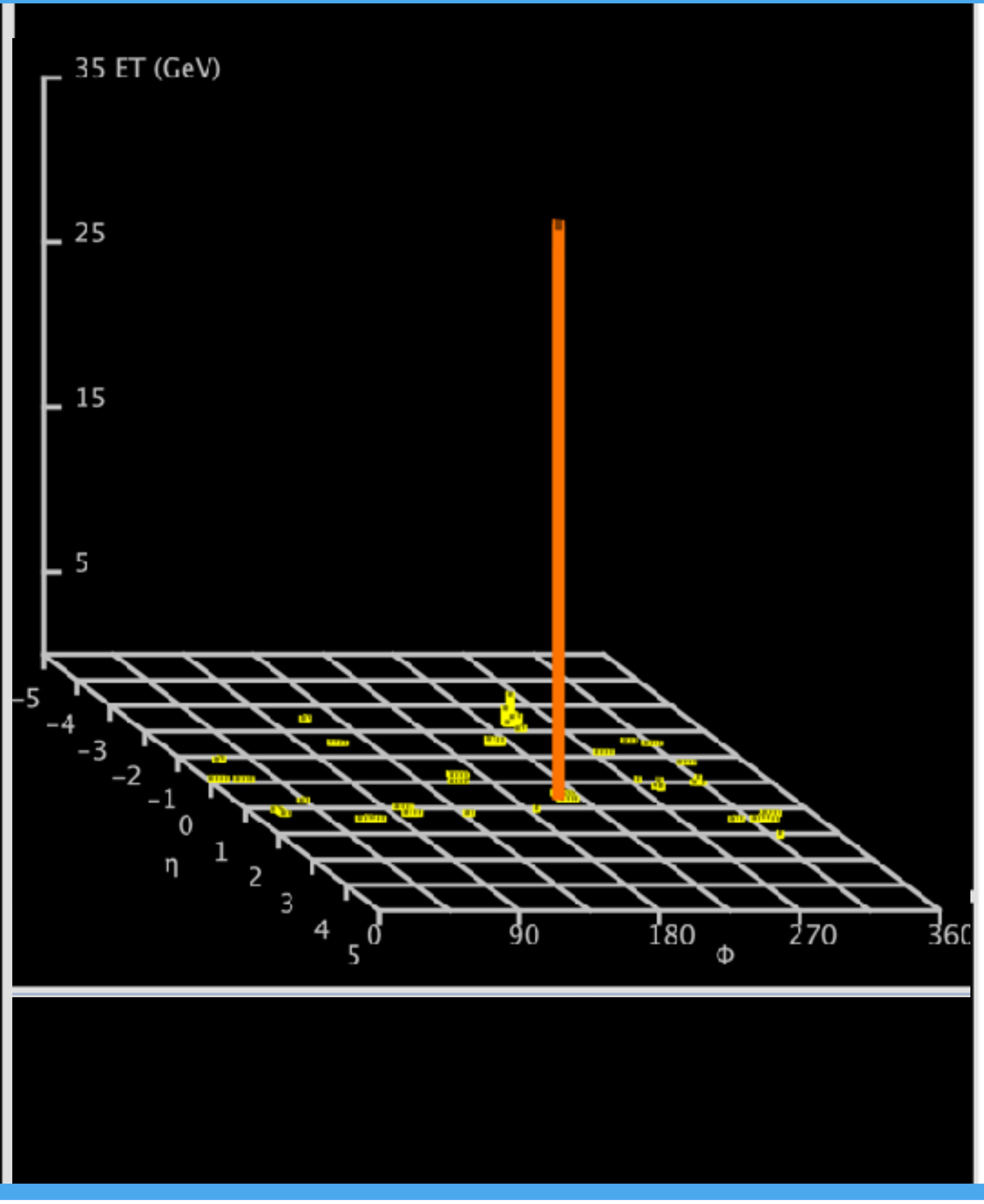


Search for **magnetic monopoles** as highly ionizing particles



Outline





$W^- \to \mu^- \nu$ candidate event from precise measurements of W and Z transverse momentum spectra, arXiv:2404.06204

- Current status
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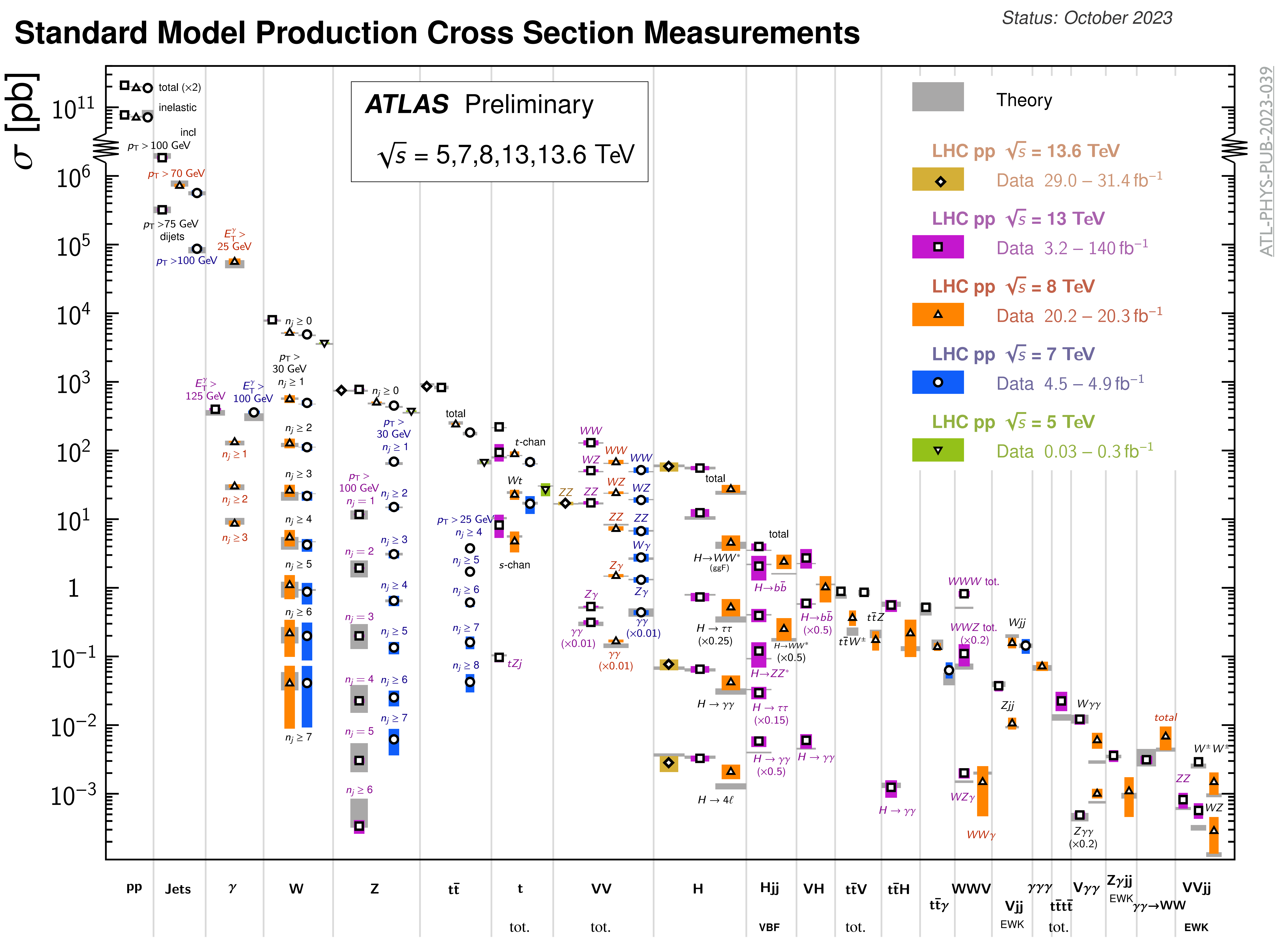
Precision Measurements of the **Standard Model**

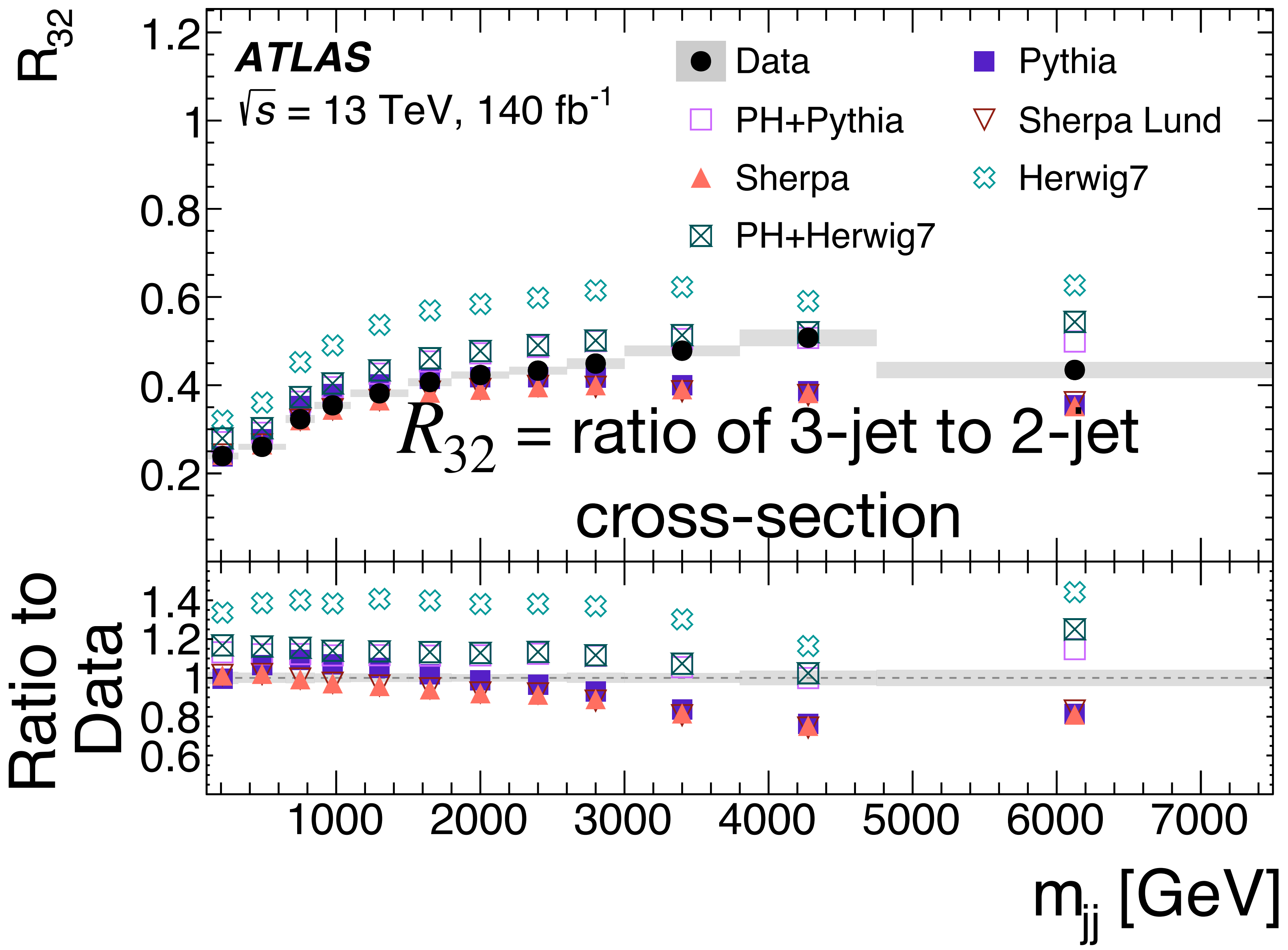


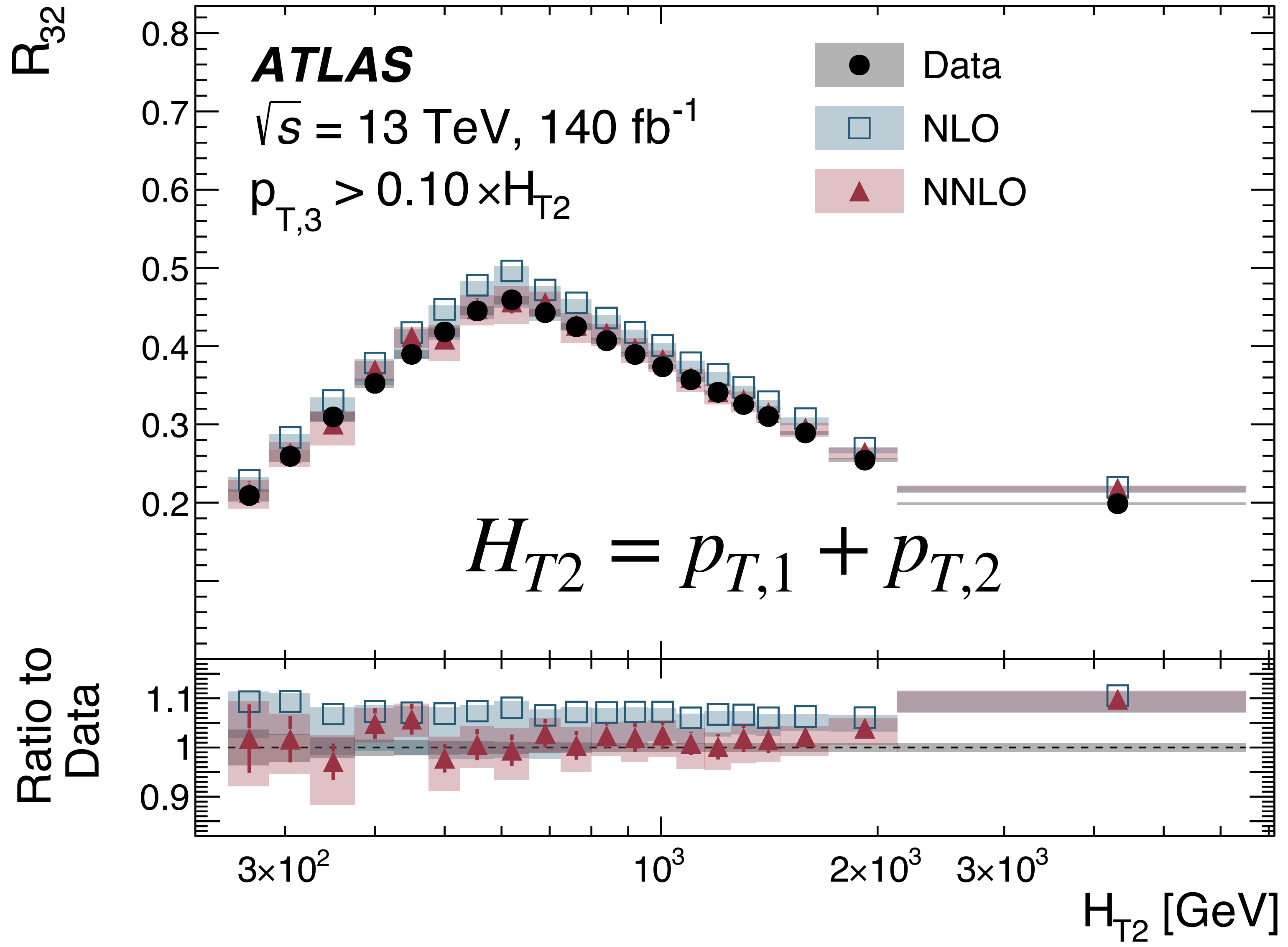
NEW

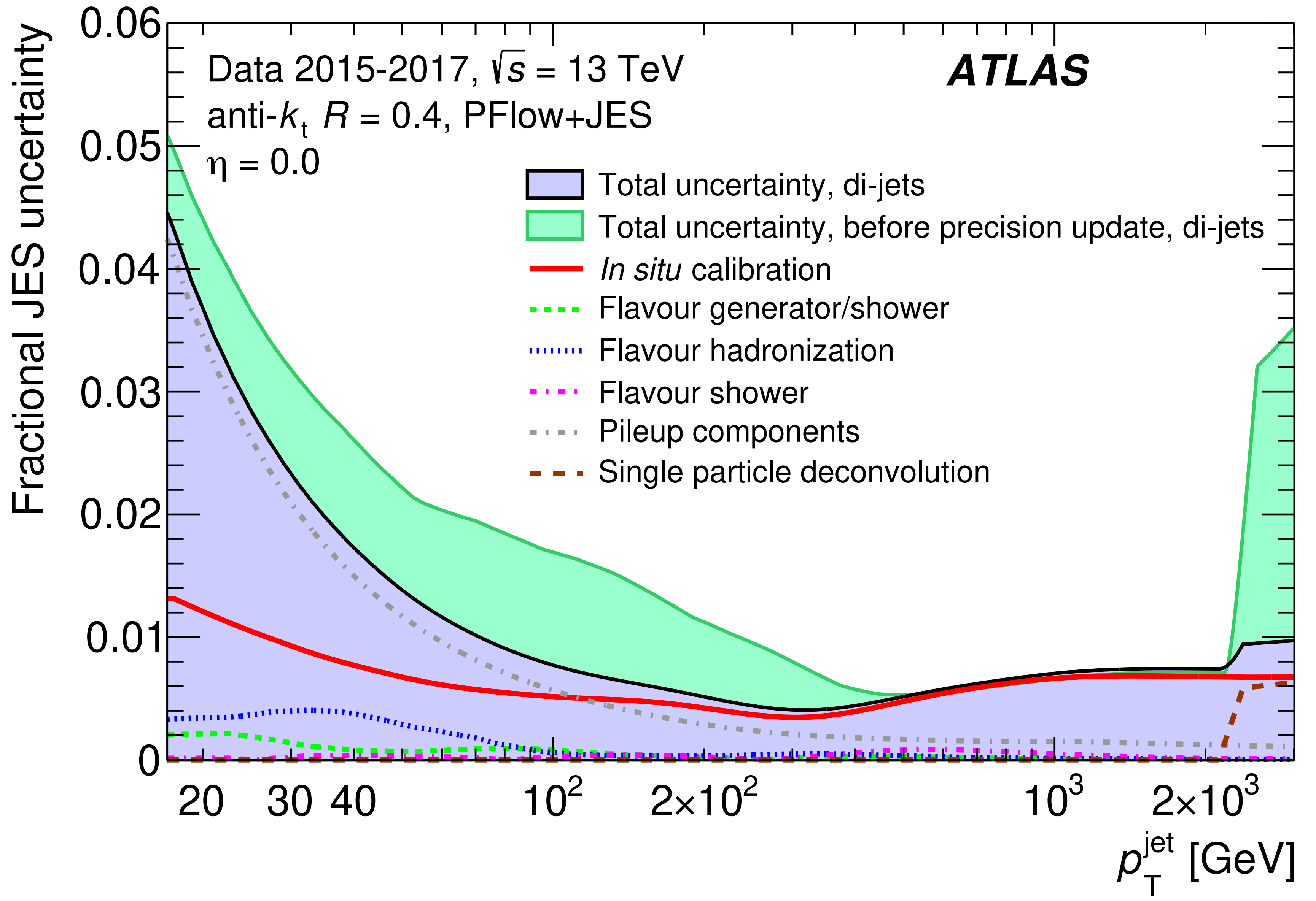
Jet Cross-section Ratios

- Measure **jet cross-section ratios** between bins of jet multiplicity
  - Double differential: Energy-scale or angular radiation (**<10% precision**)
  - Triple differential: H_{T2} (**<few %**)
- Relies on improved JES uncertainty (**<1%**)
- Can be used to extract α_S

arXiv:2405.20206, Roloff





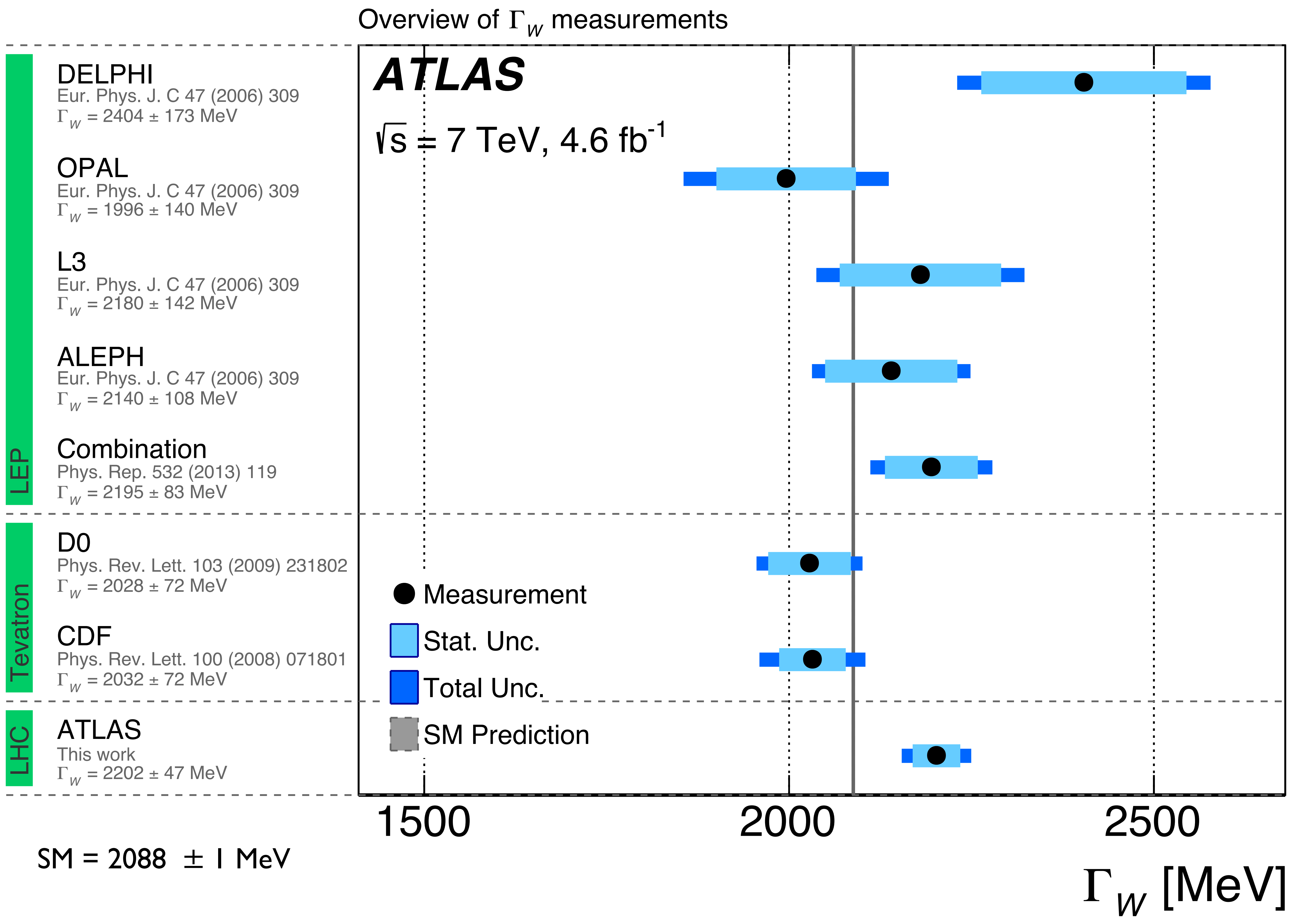


NEW

W Boson Mass and Width

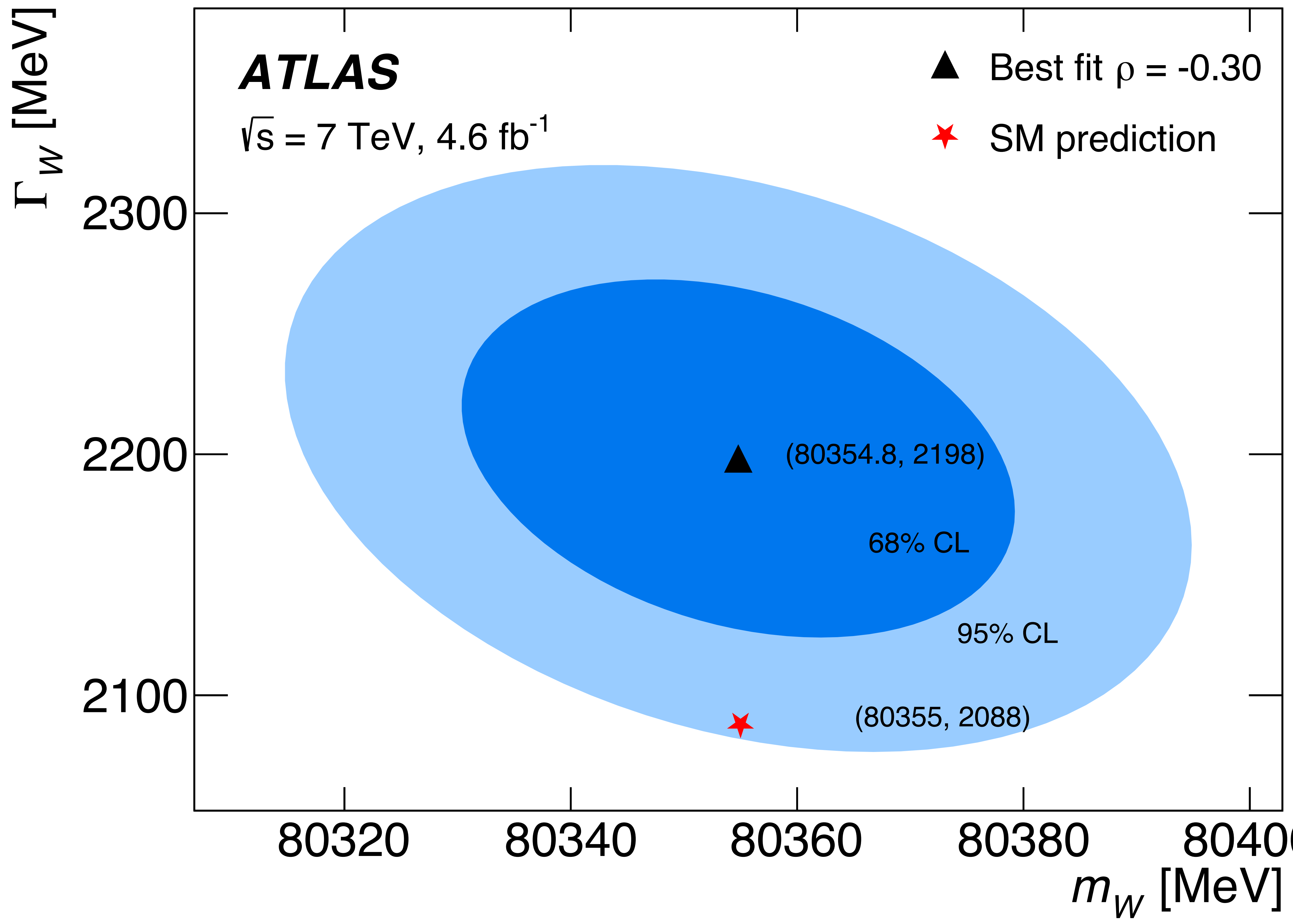
arXiv:2403.15085, Bachiu

First W boson width measurement at the LHC



SM = 2088 ± 1 MeV

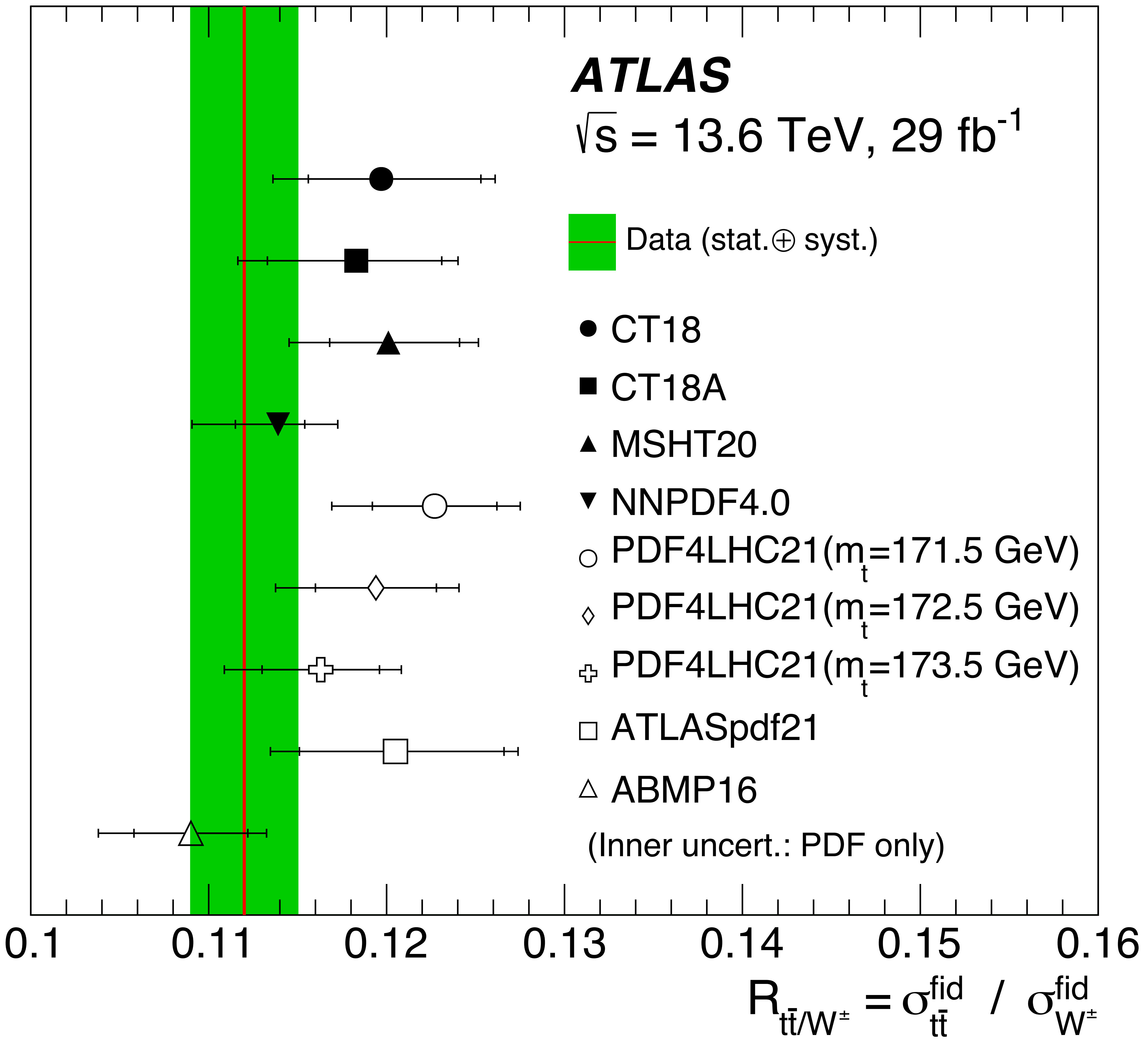
W boson width vs mass

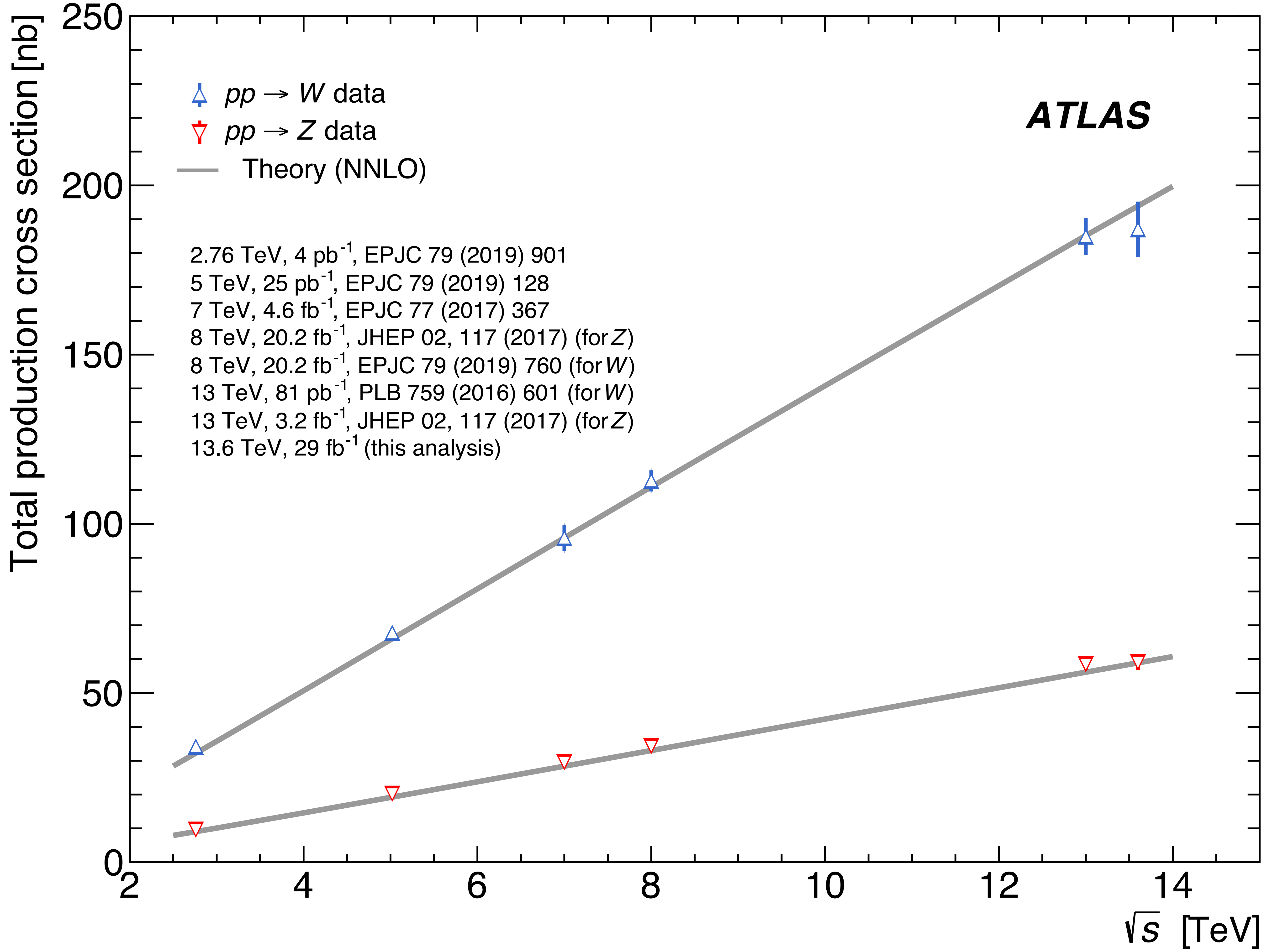


Run-3 Data Analysis

PLB 854 (2024) 138725, Bachiu

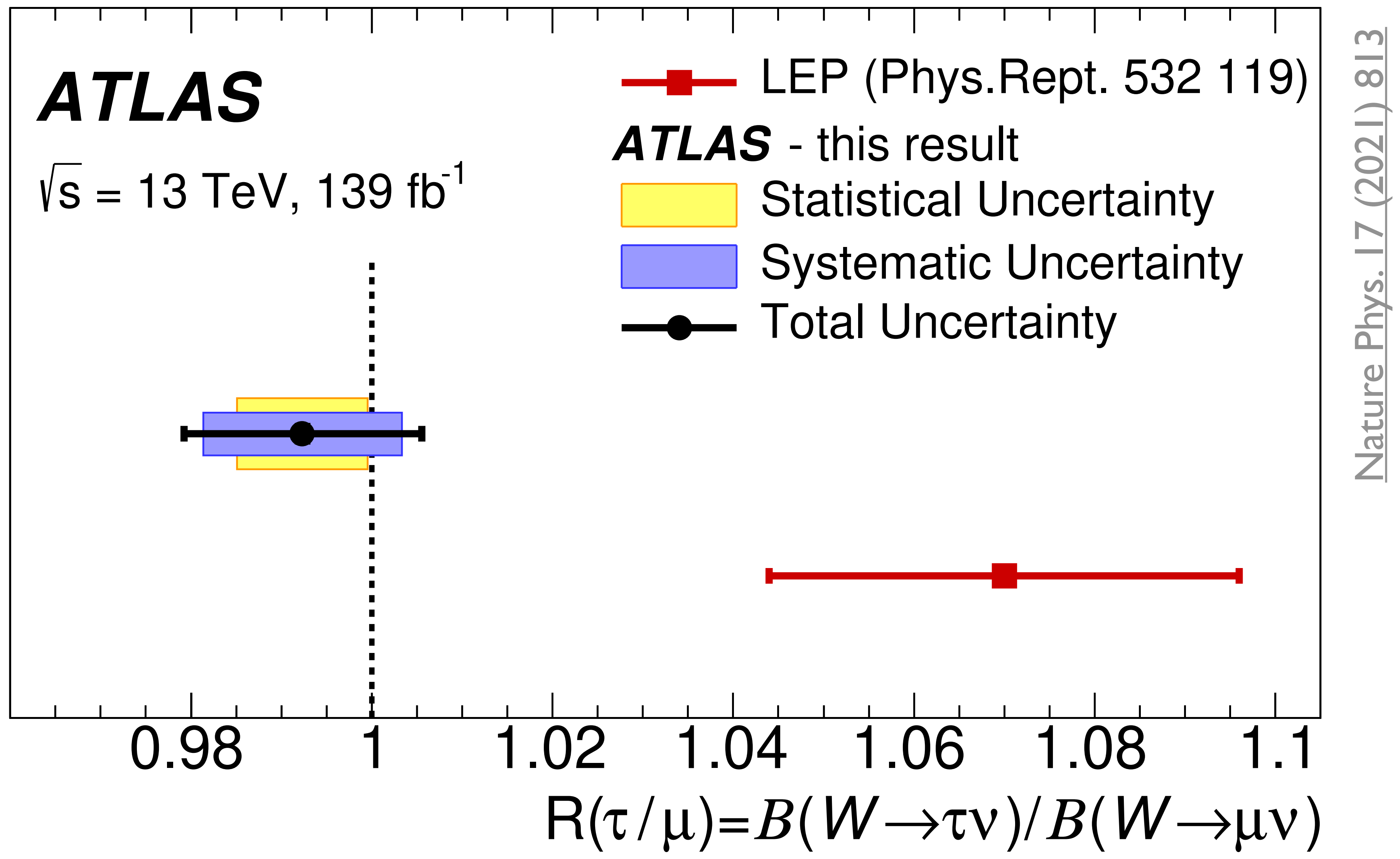
Weak boson production at 13.6 TeV: total, fiducial cross sections and ratios

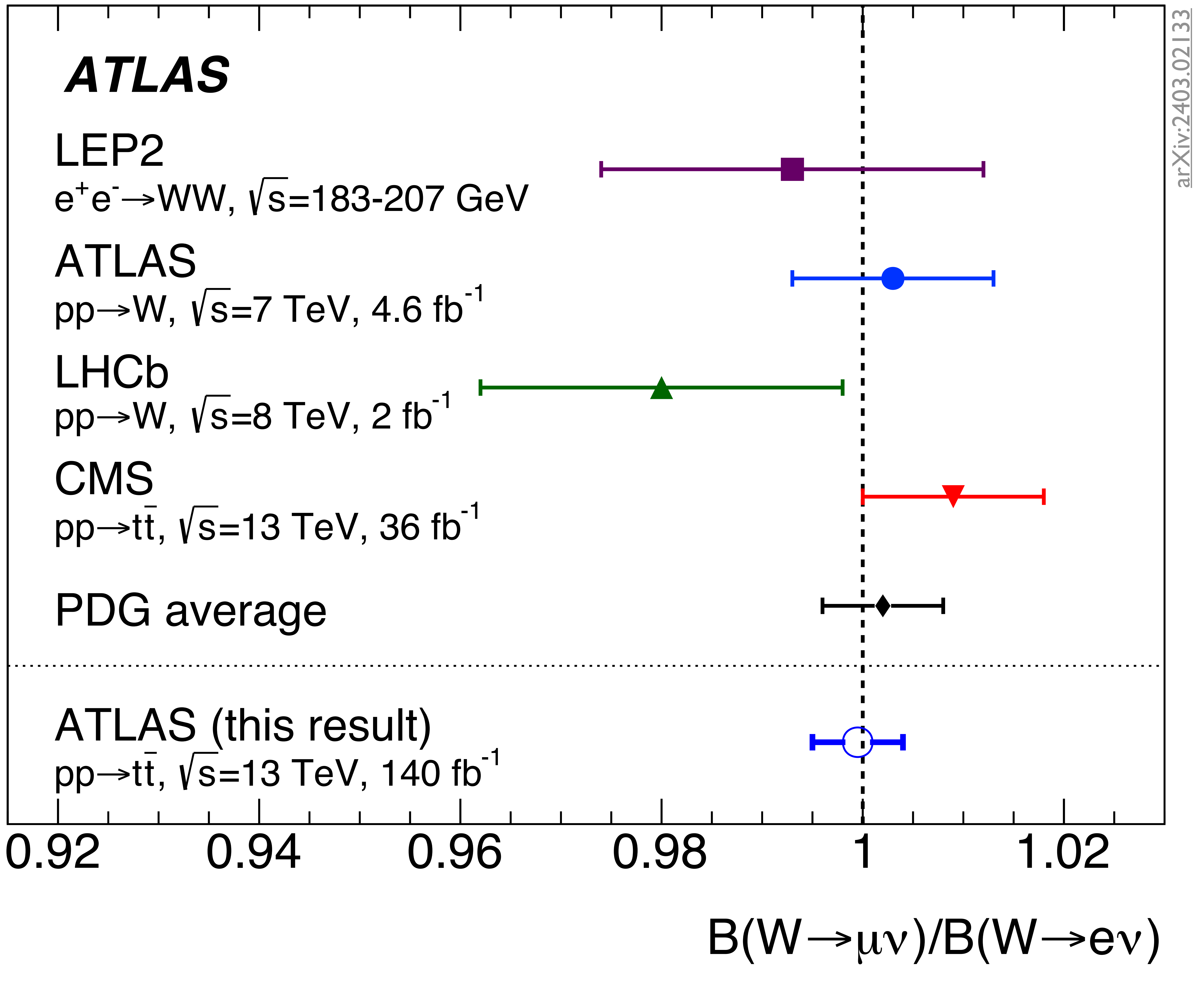




Lepton Universality

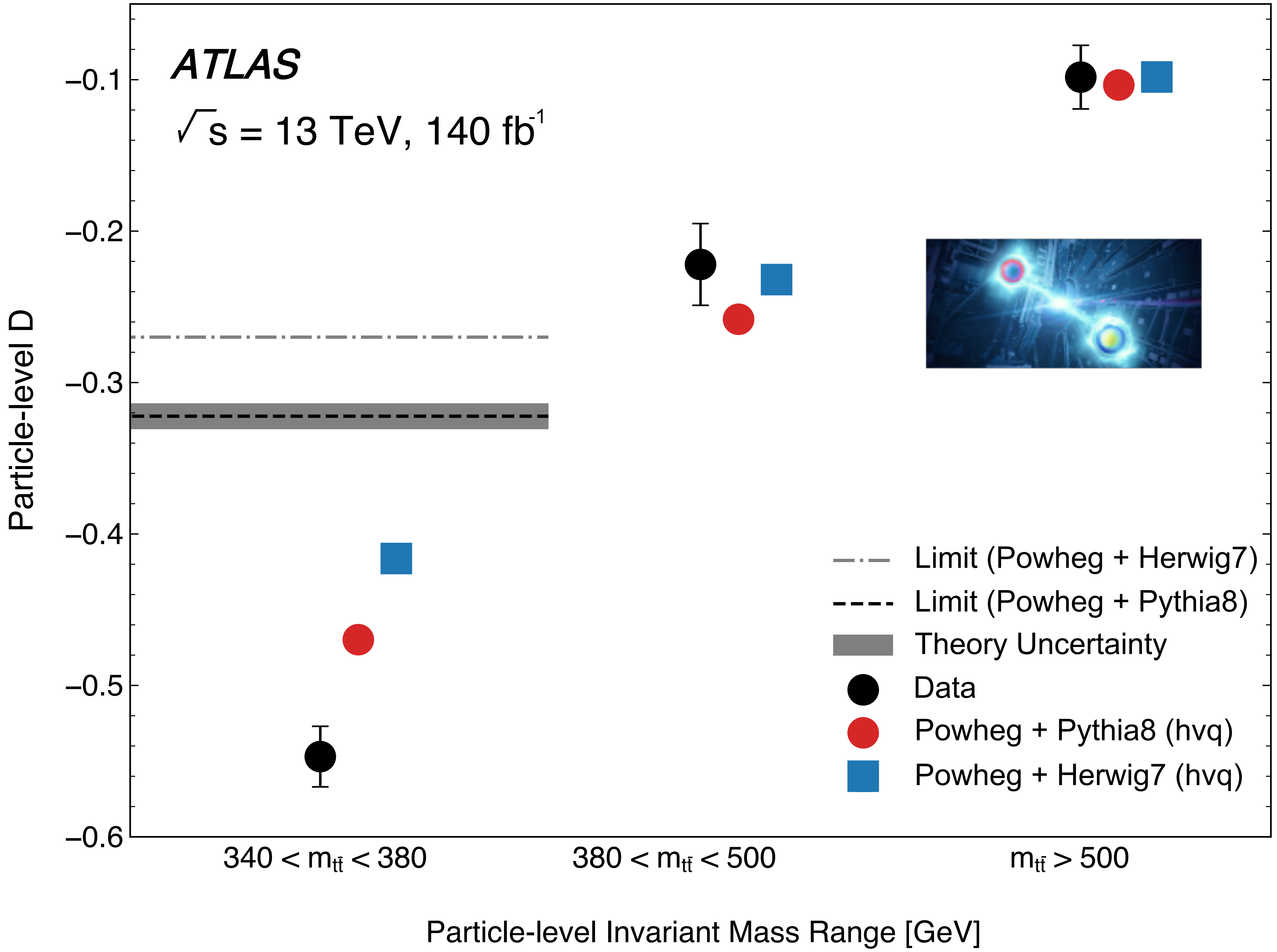
- Lepton universality in **W decays** to electrons and muons from top-pair events
  - **2x improvement** on single-experiment precision
  - 0.45% precision: more precise than **current world average**





Recent Top Highlights

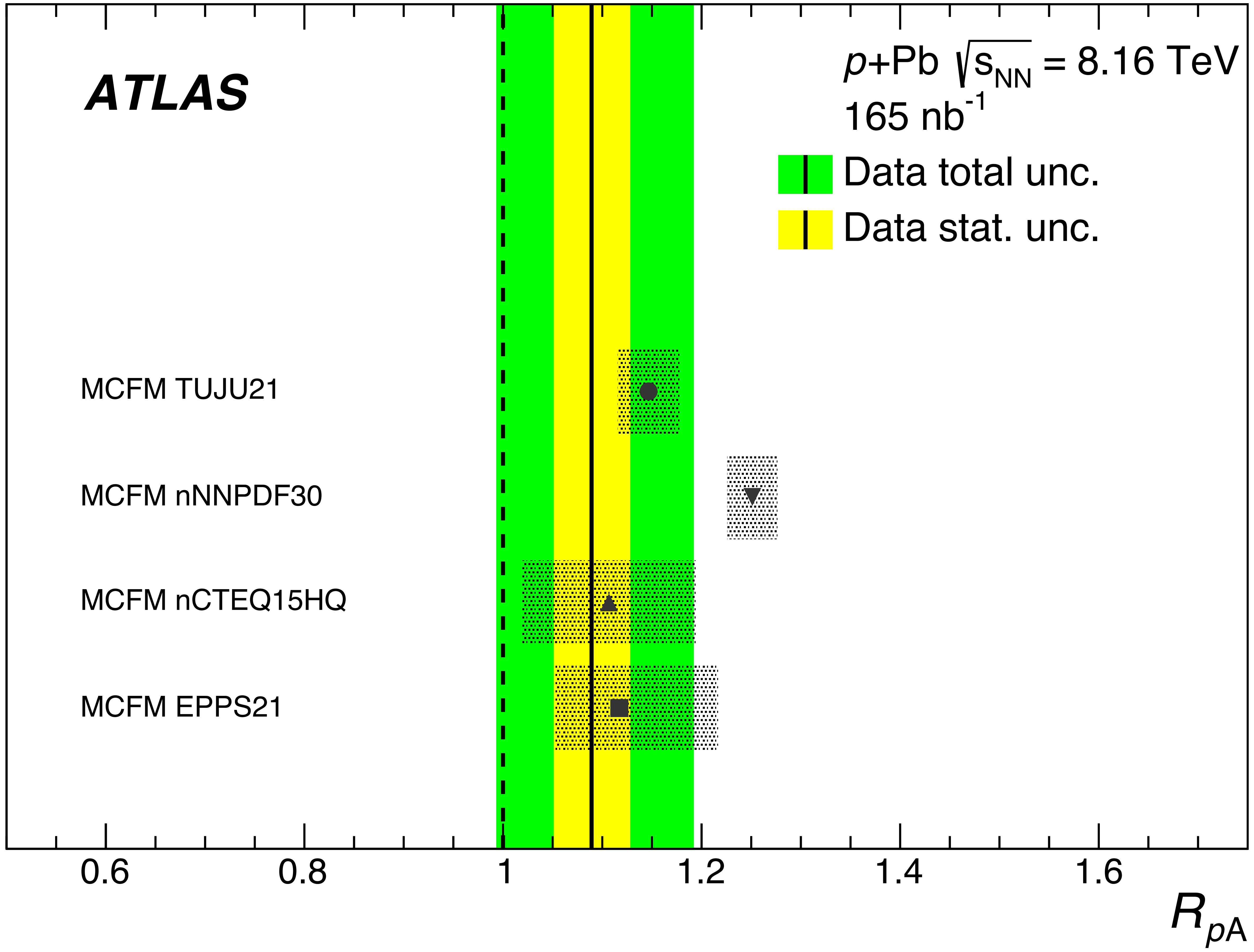
Observation of entanglement in quarks by measuring spin correlations in $t\bar{t}$ events



arXiv:2311.07288, Ravina

Observation of $t\bar{t}$ production in pPb events

$$\sigma_{t\bar{t}} = 58.1 \pm 2.0(\text{stat.})^{+4.8}_{-4.4}(\text{syst.})\ \text{nb}$$

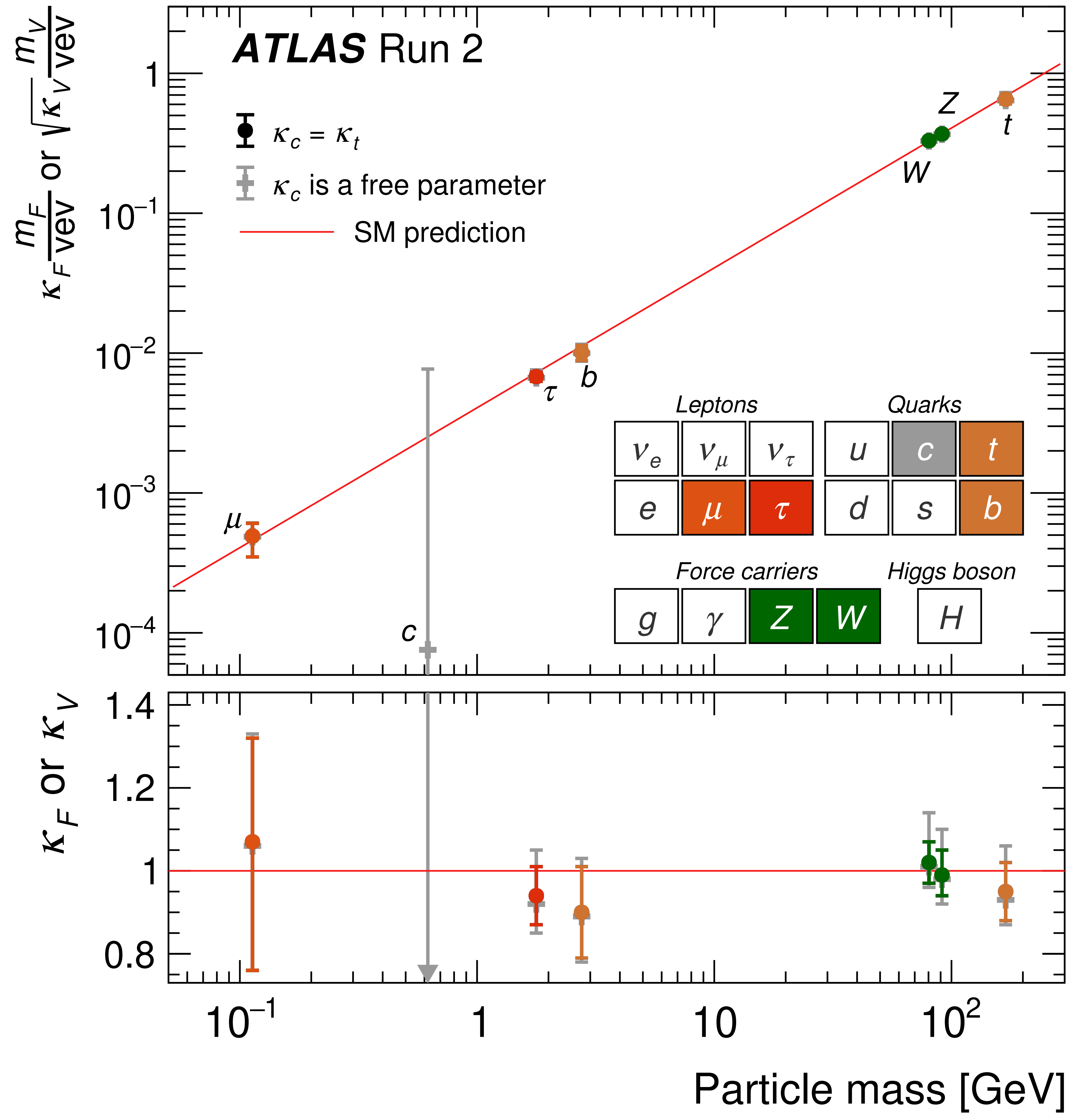


arXiv:2405.05078, Dado

The SM Higgs Boson

Nature 607, 52 (2022), arXiv:2404.05498, Phys. Rev. Lett. 132 (2024) 021803, Rettie, Gomez Delegido

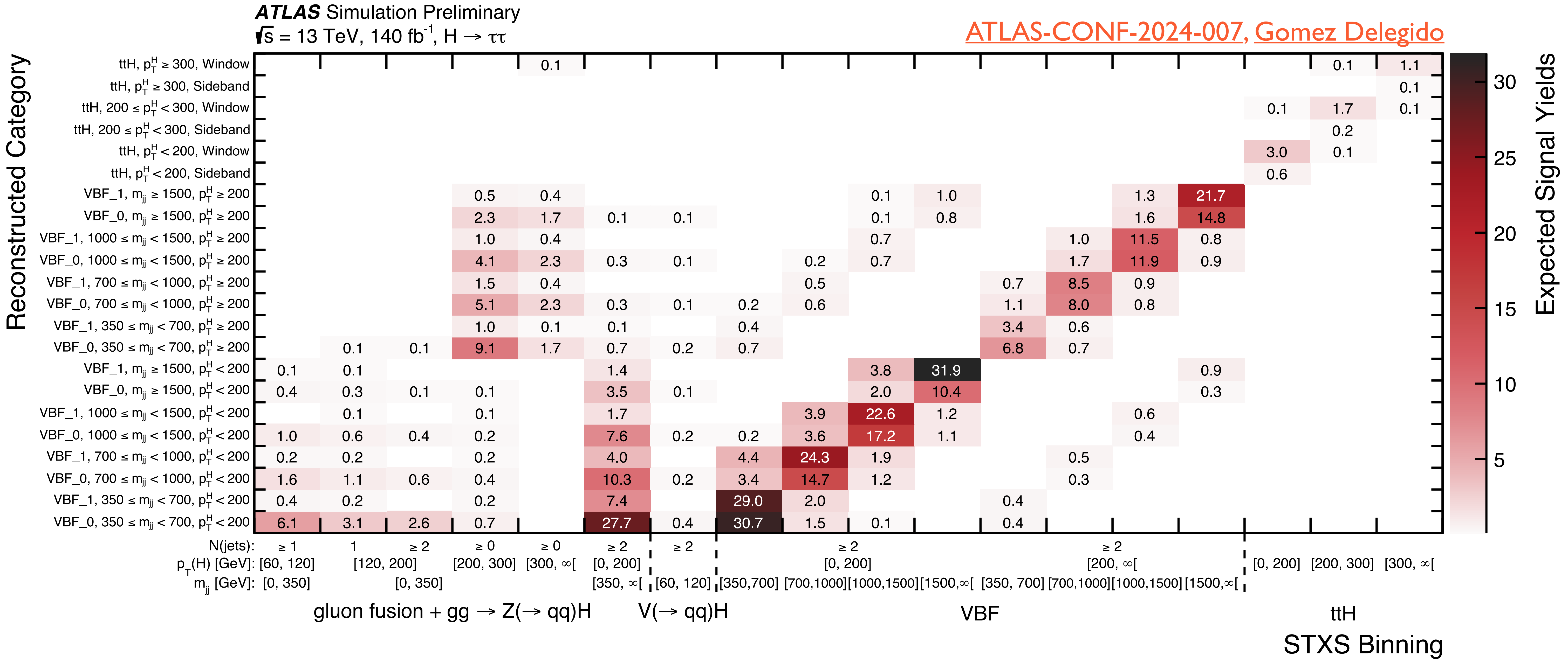
- **Mass** from Run 1+2 combination:
  $m_H = 125.11 \pm 0.11$ GeV
- Indirect Higgs **width** from offshell: $\Gamma_H = 4.6^{+2.6}_{-2.5}$ MeV
- Probe **couplings** by measuring accessible production and decay modes
  - Evidence for $Z\gamma$ decay (3.4σ) (w/ CMS)
- Ongoing studies include
  - Detailed **kinematic studies** of observed modes
  - Searches for **rarer** production/decay modes: bbH, tH, cc and $\mu\mu$
  - Higgs **self-coupling**



NEW

Differential Higgs Production w/ τ

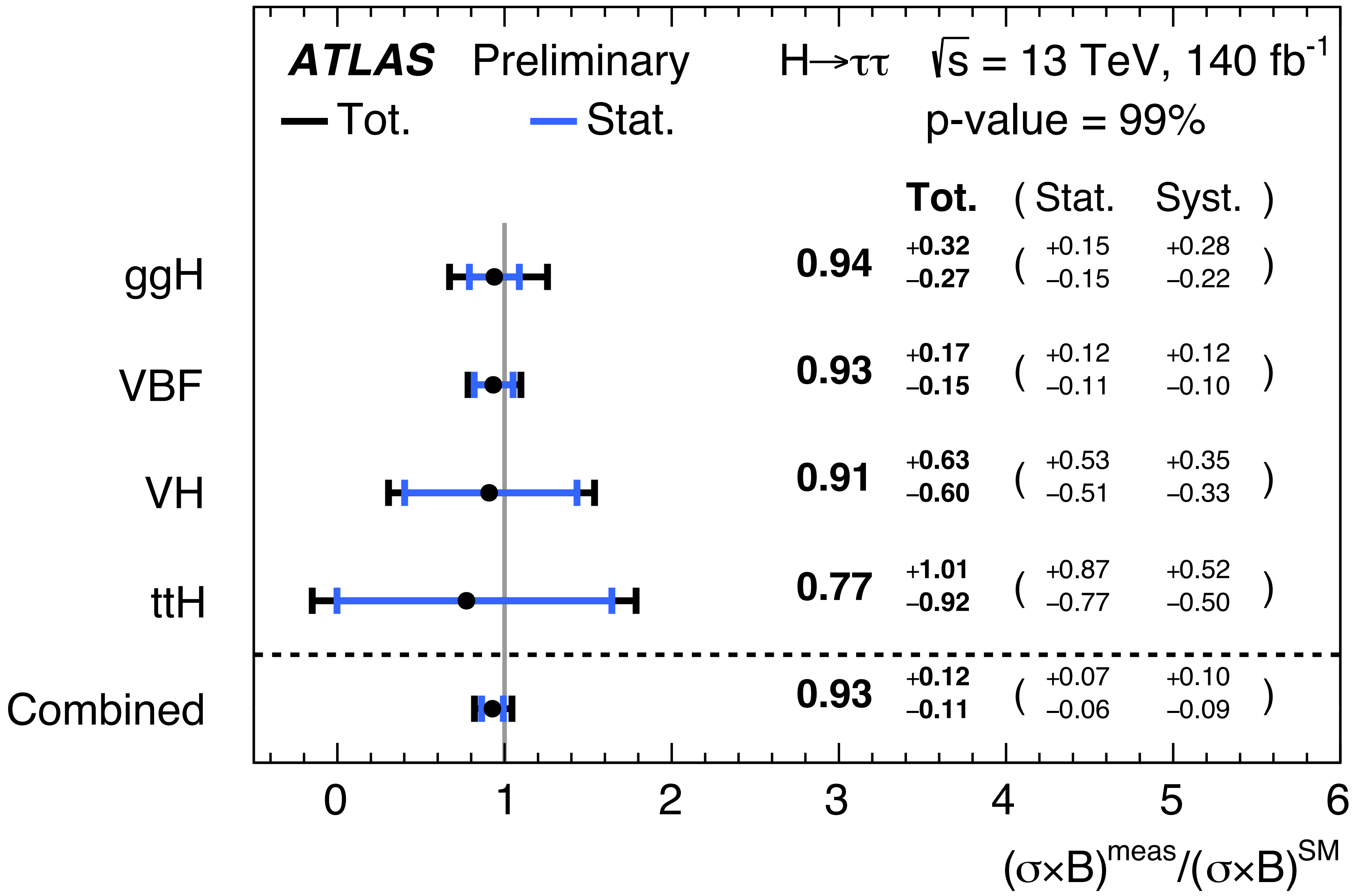
- Differential measurements of Higgs production with τ **decays** in 18 STXS bins
- Most precise **VBF production** measurement; also probes **high** p_T^H
- Part of a suite of **Run-2 analyses** to provide our final word on the Higgs in that dataset
- Range of **ML** methods: e.g. BDT for VBF categories; multiclass BDT for ttH categories

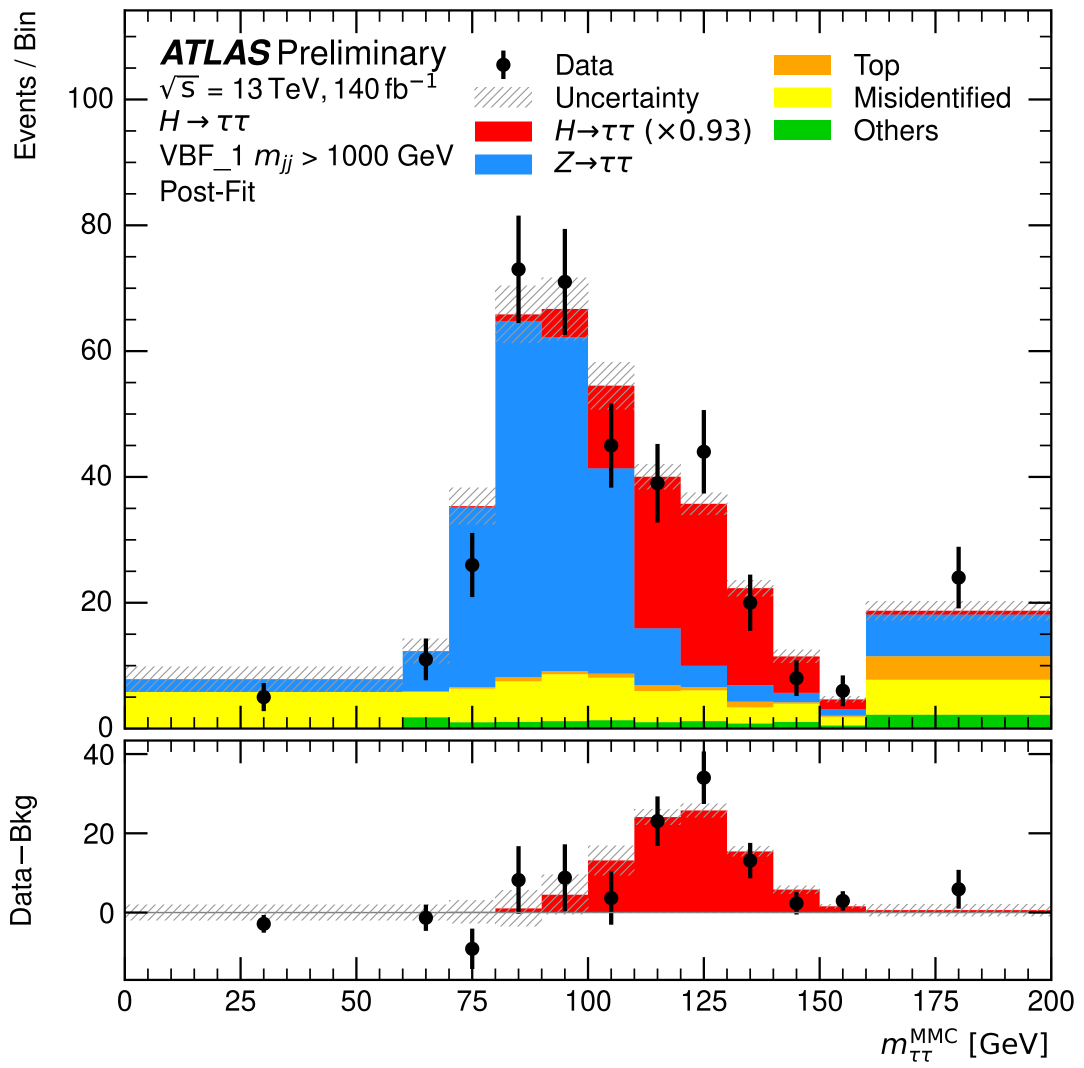


*STXS = Simplified Template Cross-Section

NEW

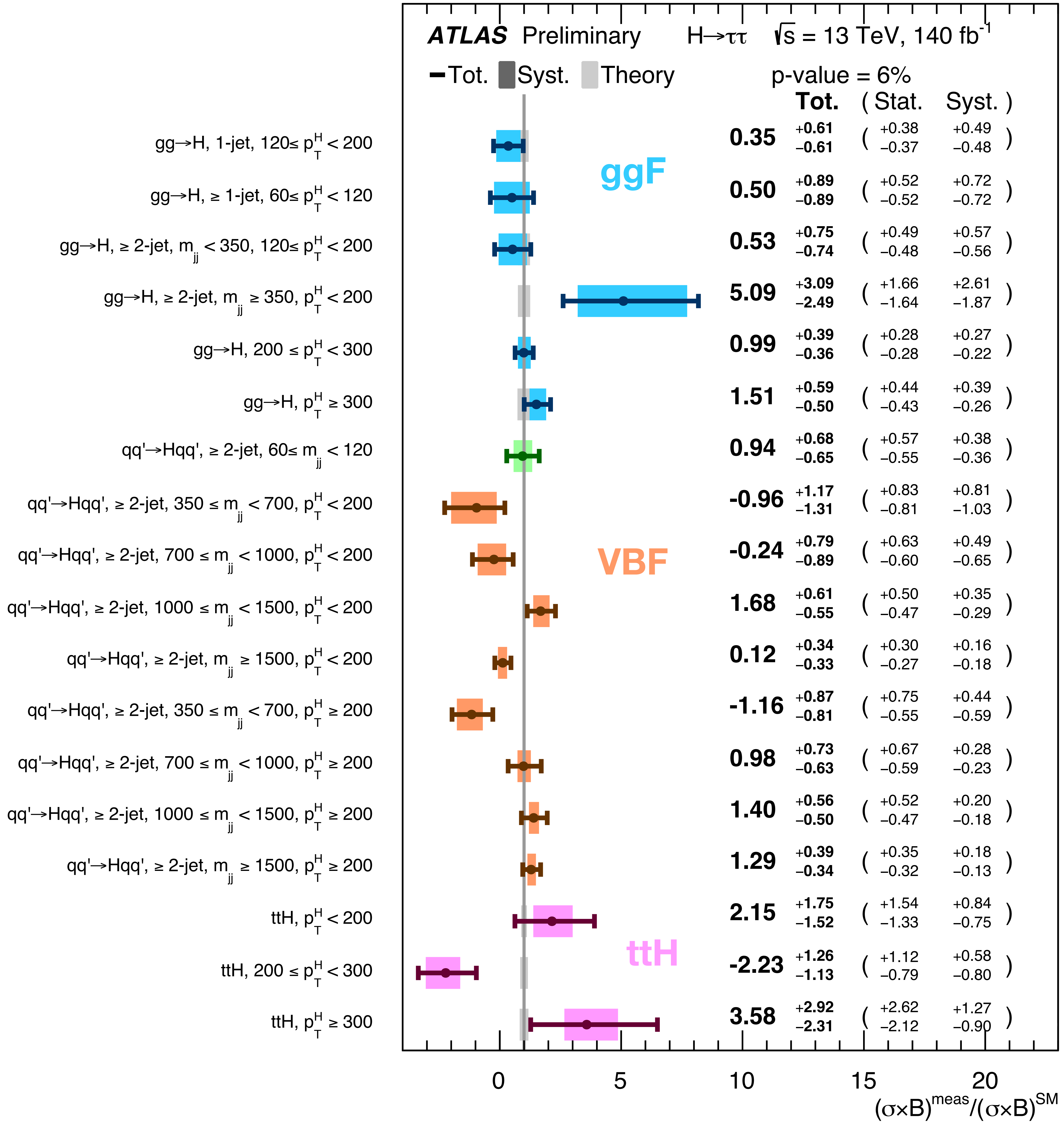
$H \to \tau^+\tau^-$ STXS Results





First measurement in high m_{jj} and high p_T regime

$\mu = 1.29^{+0.39}_{-0.34}$



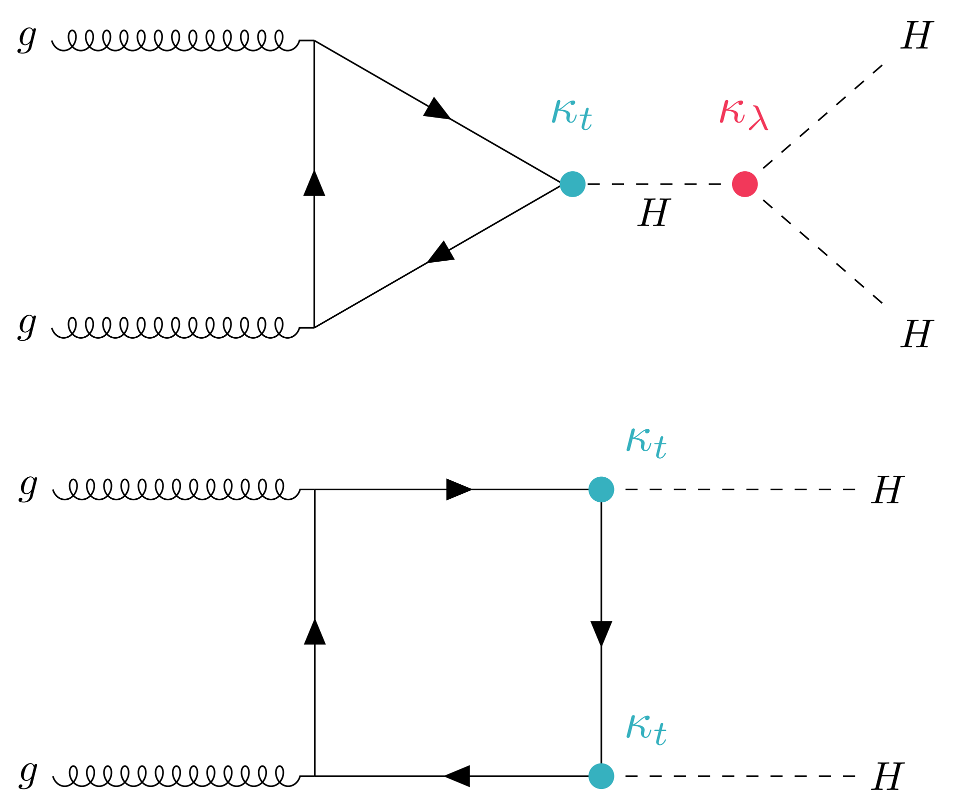
ATLAS-CONF-2024-007, Gomez Delegido

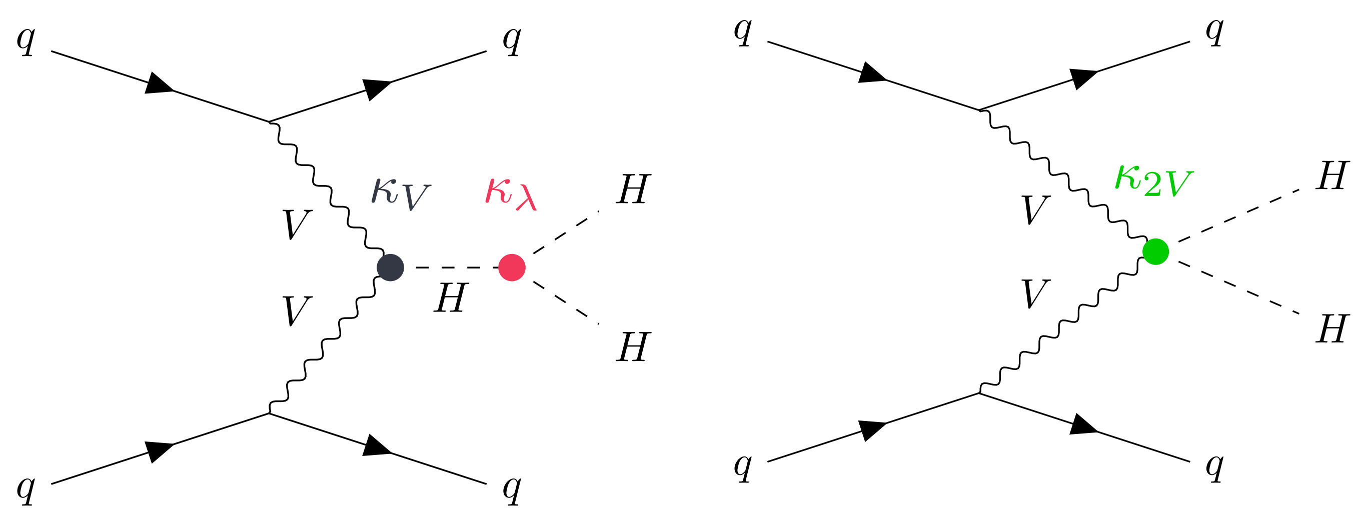
NEW

Probing the Higgs Self-Coupling

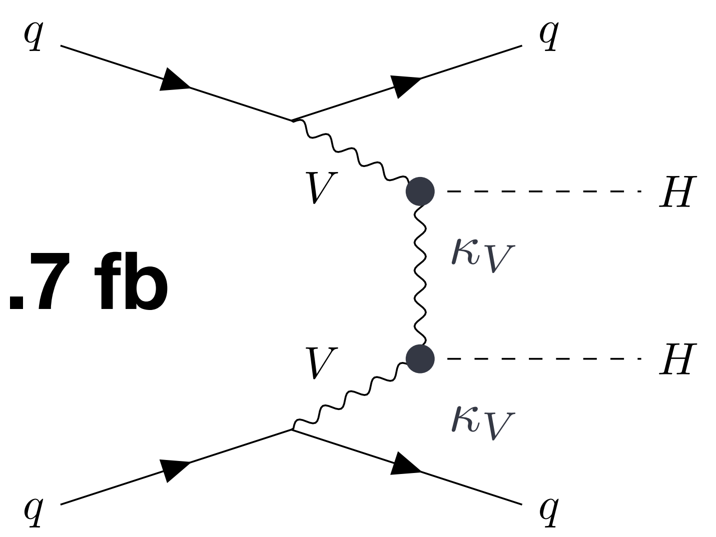
- **HH production** to directly probe Higgs self-coupling and hence electroweak symmetry breaking (EWSB) mechanism
- **New combined result** using the two major production modes: **gluon-gluon fusion (ggF)** and **vector boson fusion (VBF)**
  - VBF also provides sensitivity to κ_{2V}
- Combines **5 input channels** using the **full Run-2 dataset** with cut-based and multivariate techniques
- **Effective field theory** interpretation to probe low-energy dynamics of EWSB with 3 Wilson coefficients
  - c_{hhh}, c_{gghh} and c_{tthh}

ggF: 31 fb



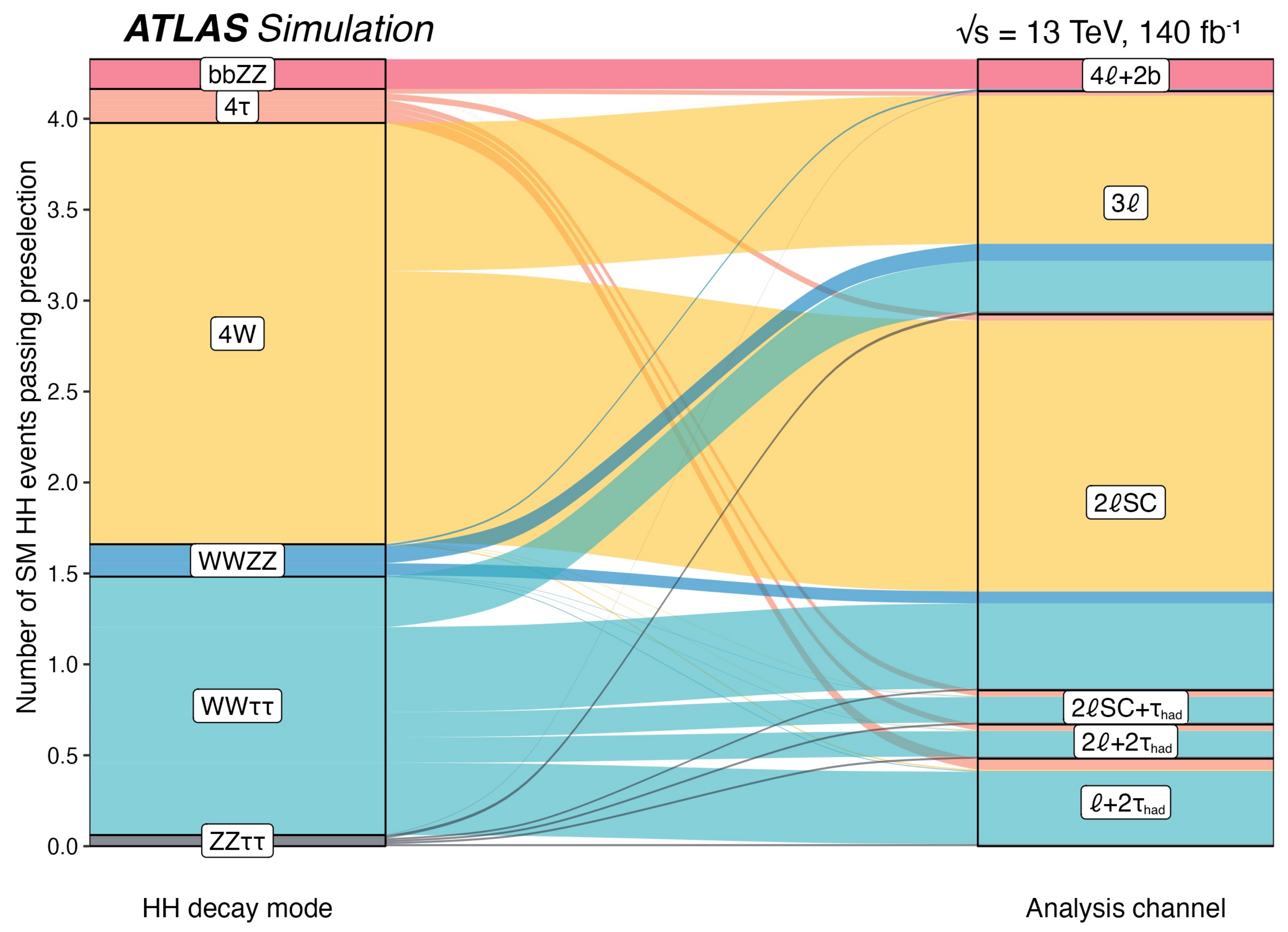


VBF: 1.7 fb

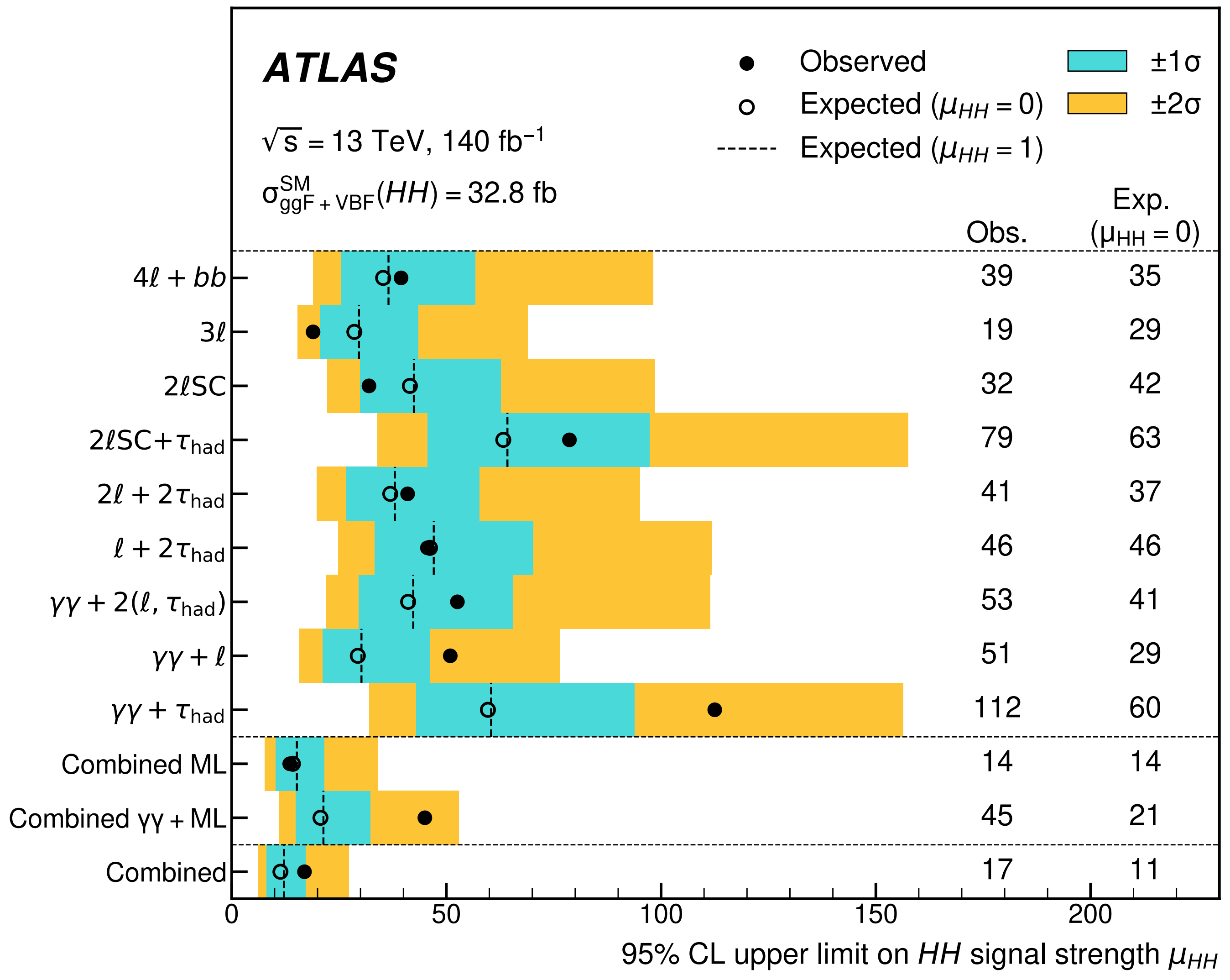


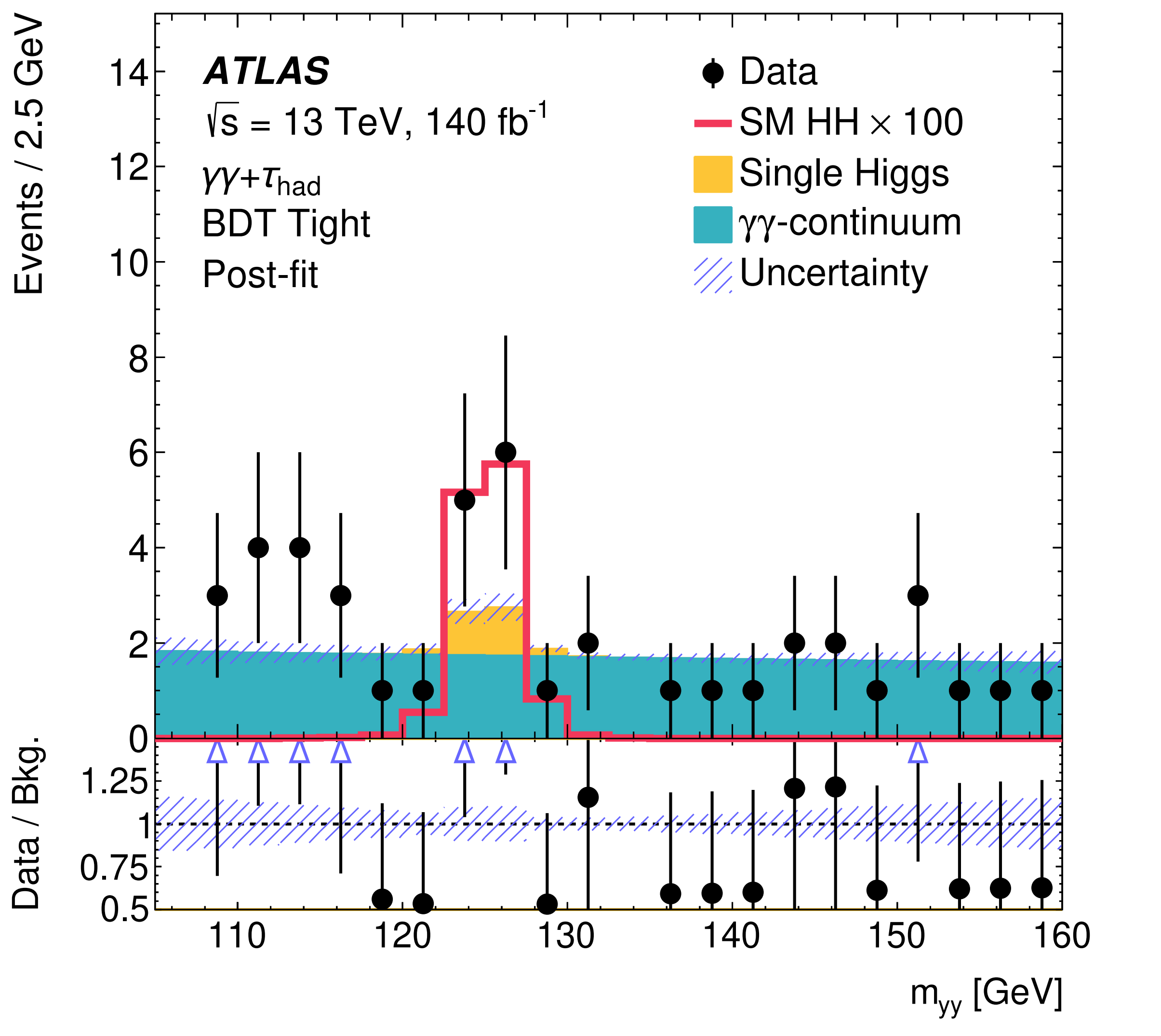
HH with multiple leptons

- **New strategy** targeting ggF production in final states with **multiple light leptons**, τ_{had} and $\gamma\gamma$ + additional light leptons and/or τ_{had}
- 9 signal and 19 control regions
  - ML: cut-based categorization, BDT fit
  - $\gamma\gamma$: BDT categorization, $m_{\gamma\gamma}$ fit
- $\mu_{HH} < 17$ **(obs)** and 11 (exp) at 95% CL
  - <2σ excess in the $\gamma\gamma + \tau_{\text{had}}$ channel, driven by the low statistics BDT tight category



arXiv:2405.20040, Cortes Gonzalez



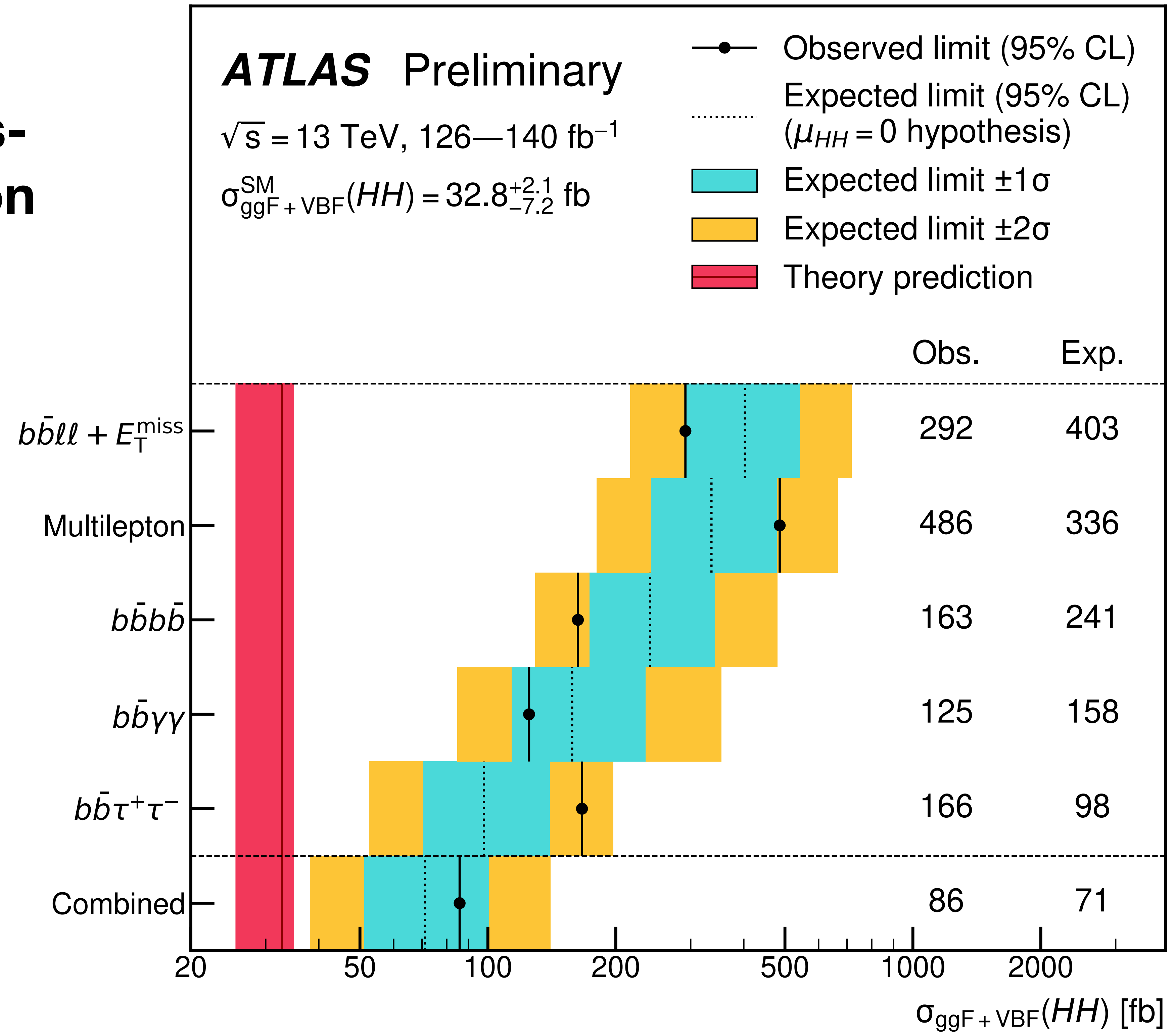


NEW

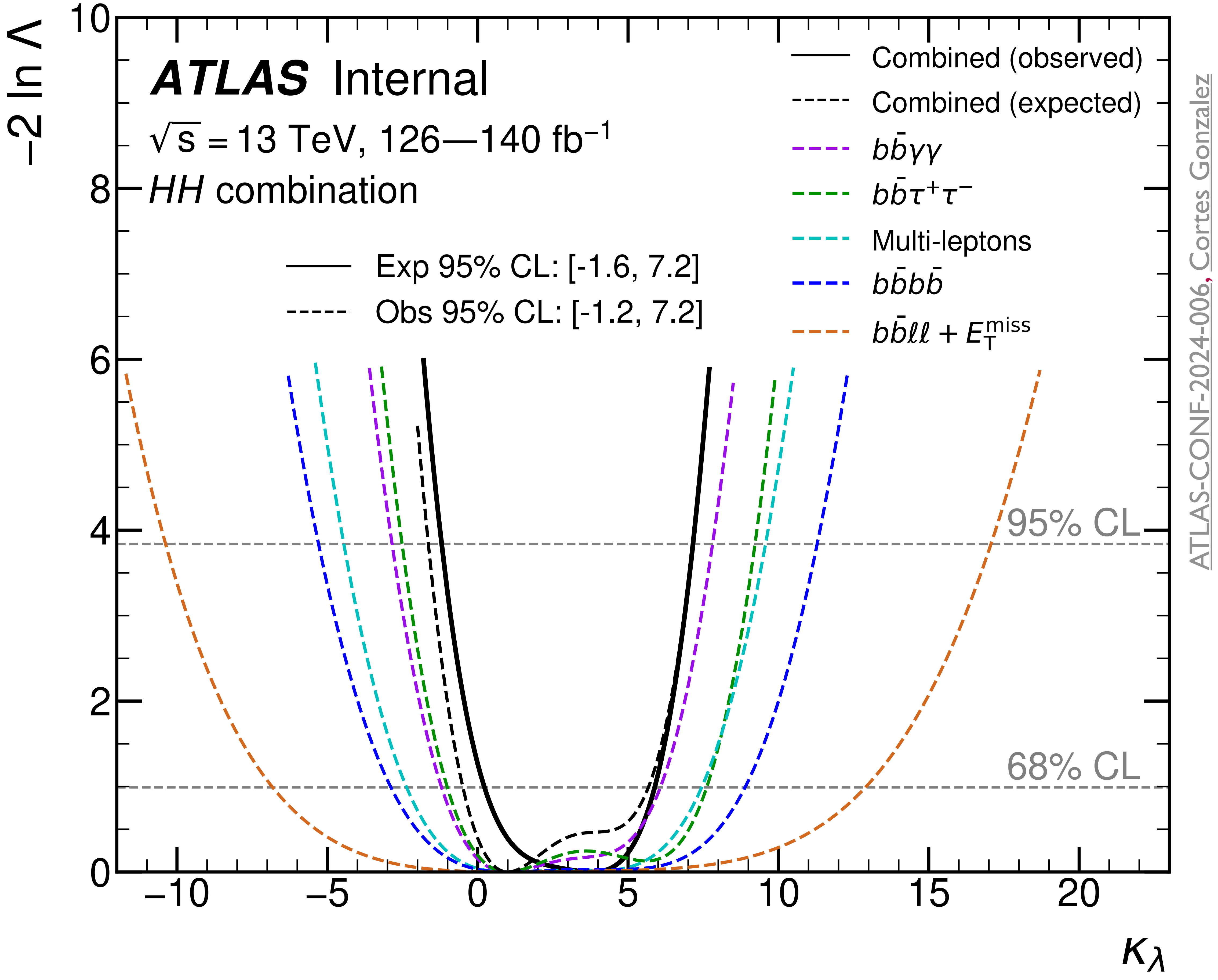
HH Combined Results

- Close to within 1σ of the SM
  - $\mu_{HH} < 2.9$ **(obs)** and 2.4 (exp) at 95% C
  - Sensitivity dominated by ggF mode
  - ~20% improvement over previous result

Cross-section



Self coupling



- $\kappa_\lambda \in [-1.2, 7.2] \left(\kappa_\lambda \in [-1.6, 7.2]\right)$
- $\kappa_{2V} \in [0.57, 1.48] \left(\kappa_{2V} \in [0.4, 1.6]\right)$

Conclusion

- Well into **Run-3** with a promising start to 2024 data-taking, excellent performance and good progress with the Phase-II upgrades
- Continue to search for **physics beyond the SM**
  - Exploring new areas of phase space
  - Exploiting novel performance and analysis techniques
- ATLAS is delivering a suite of **high-precision SM measurements**
  - W mass and width
  - HH production close to within 1σ of SM
- Stayed tuned for **many other exciting results** this week

Thank you!

The author thanks the DOE, NSF and the Sloan Foundation for Financial Support
“NEW” Image by Freepik

Event candidate for $t\bar{t}$ production in pPb collision decaying to dileptons

TOPQ-2023-32

Physics Output

- Since LHCP last year
  - 127 papers, 51 CONF notes, 40 PUB notes
- 1286 papers with collision data
  - 111 papers in 2023
  - 59 papers in 2024

  - 340 Run 2 papers
  - 9 Run 3 papers, 2 CONF notes, 7 PUB notes