

# ATLAS Status and Overview

Heather M. Gray on behalf of the ATLAS Collaboration

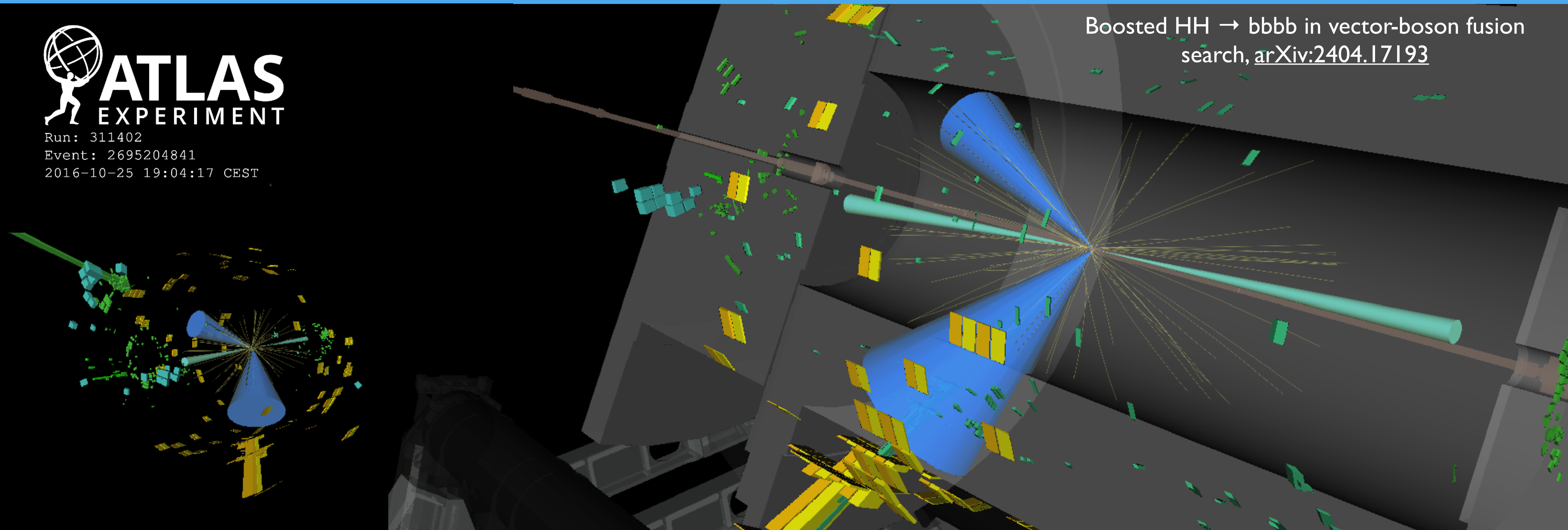


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2024-04-05 19:16:36 CEST

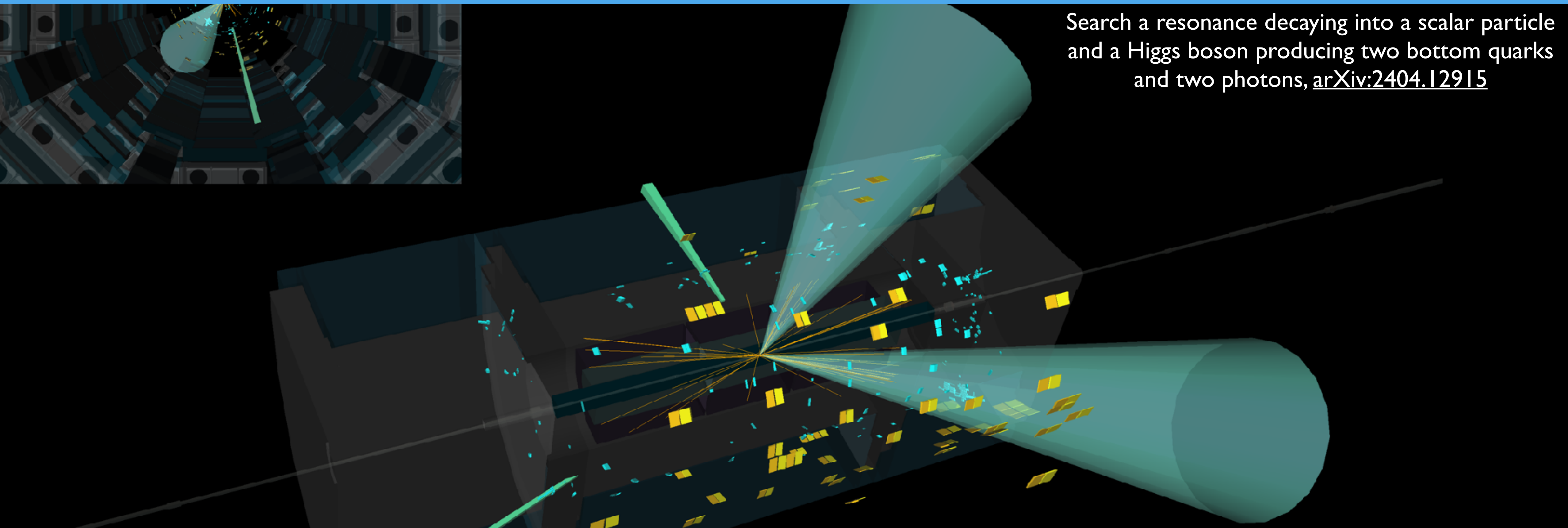


Run: 311402  
Event: 2695204841  
2016-10-25 19:04:17 CEST

Boosted HH  $\rightarrow$  bbbb in vector-boson fusion  
search, [arXiv:2404.17193](https://arxiv.org/abs/2404.17193)



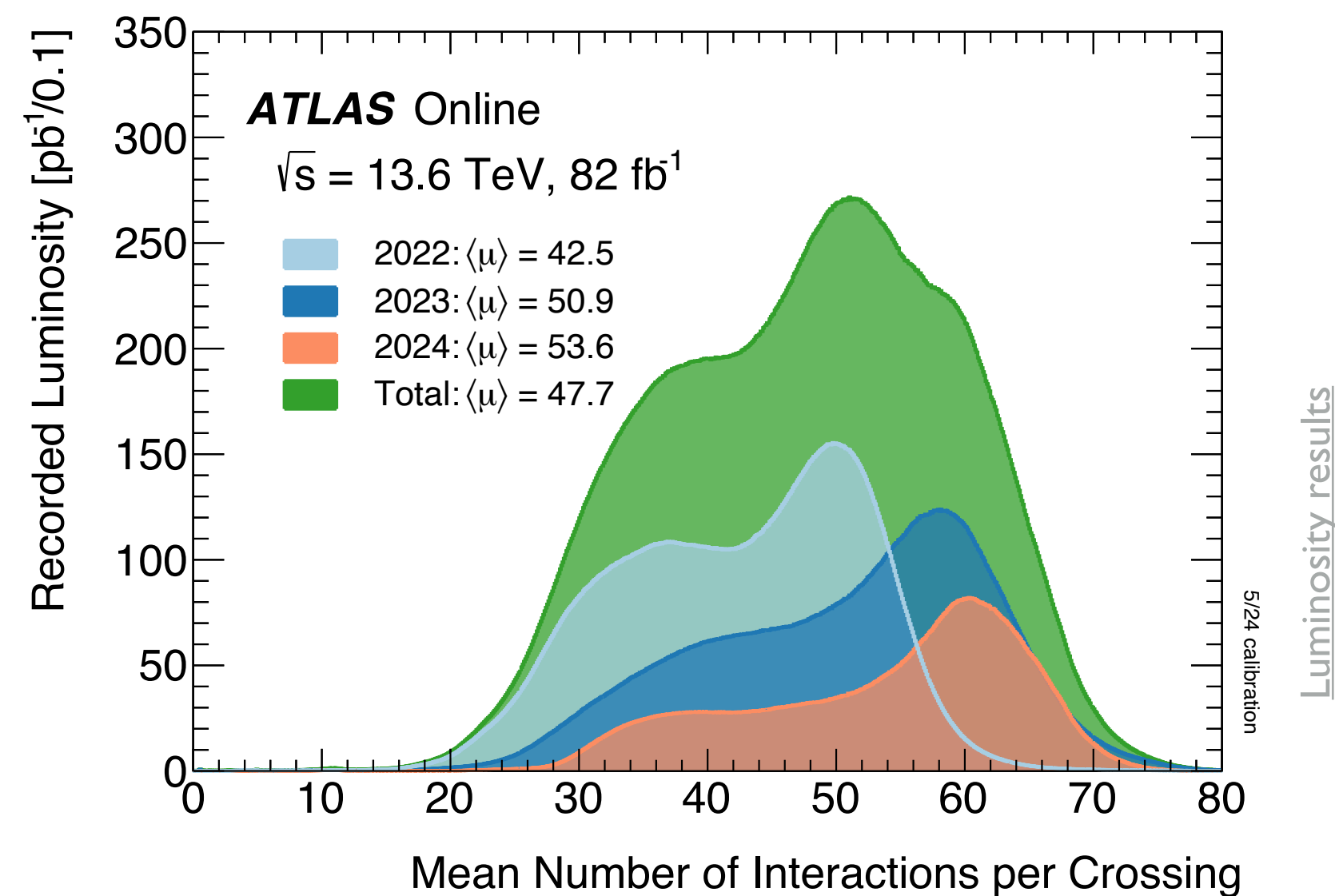
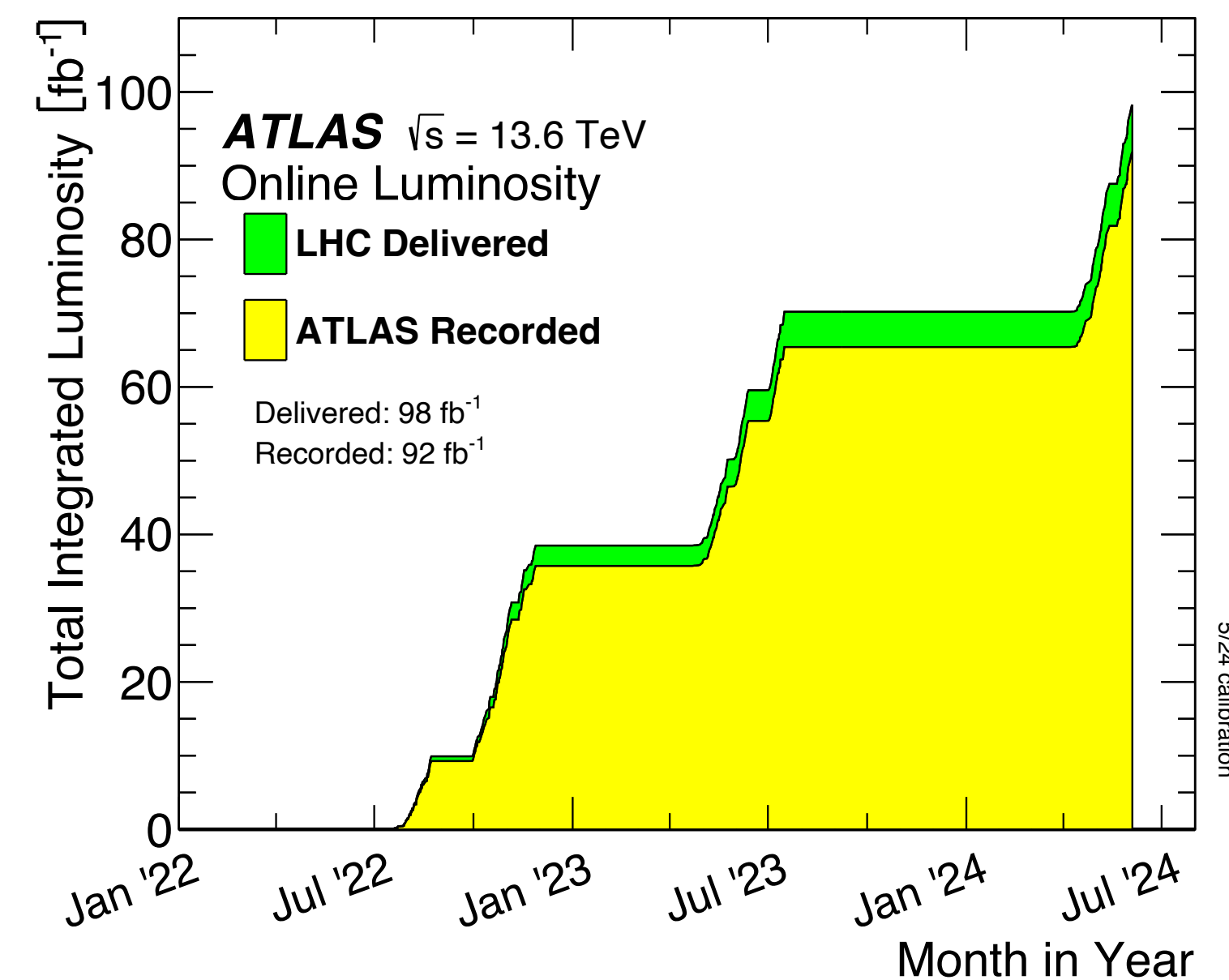
- Current status
- Searches for physics beyond the Standard Model (BSM)
- Precision measurements of the Standard Model



Search a resonance decaying into a scalar particle and a Higgs boson producing two bottom quarks and two photons, [arXiv:2404.12915](https://arxiv.org/abs/2404.12915)

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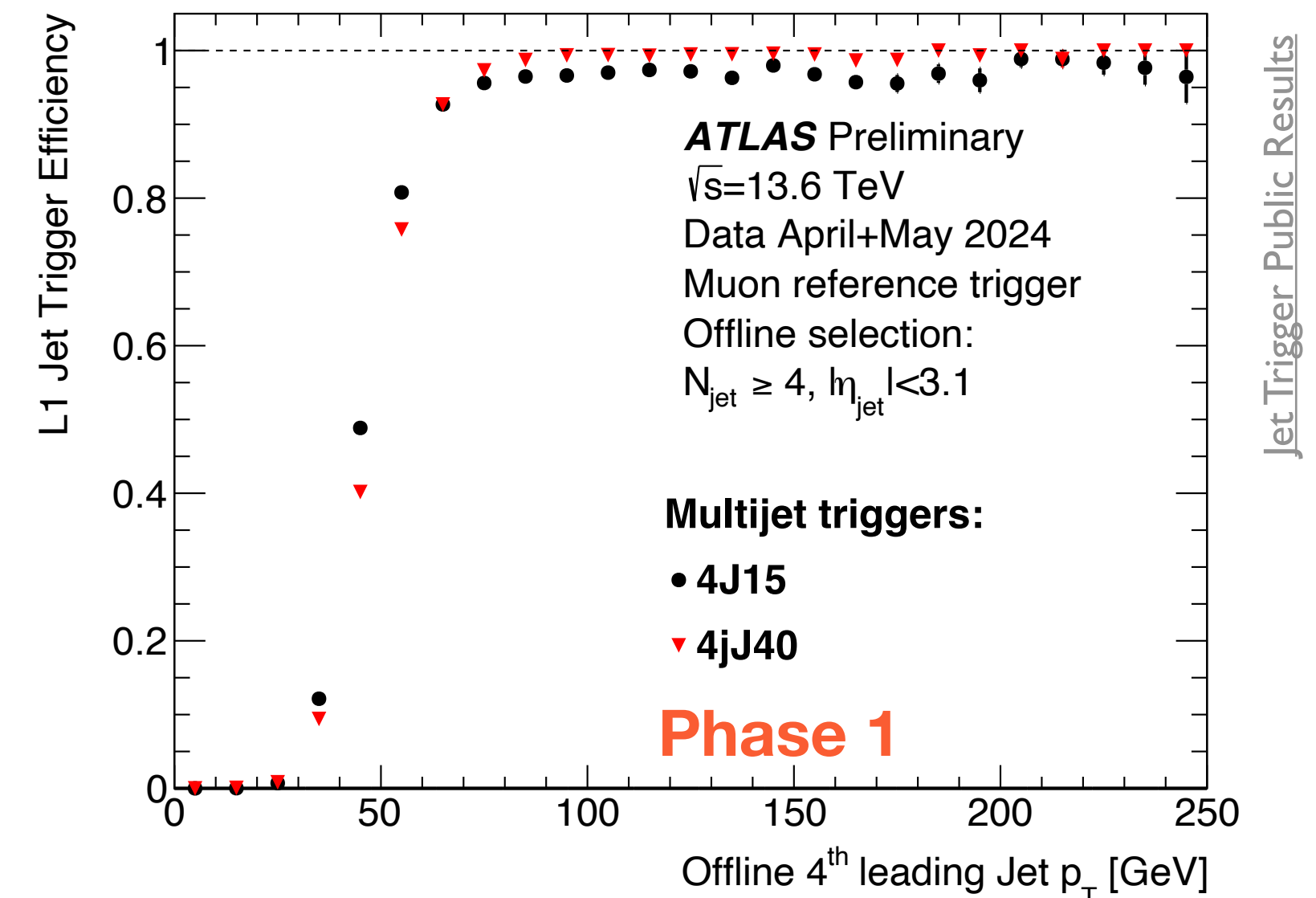
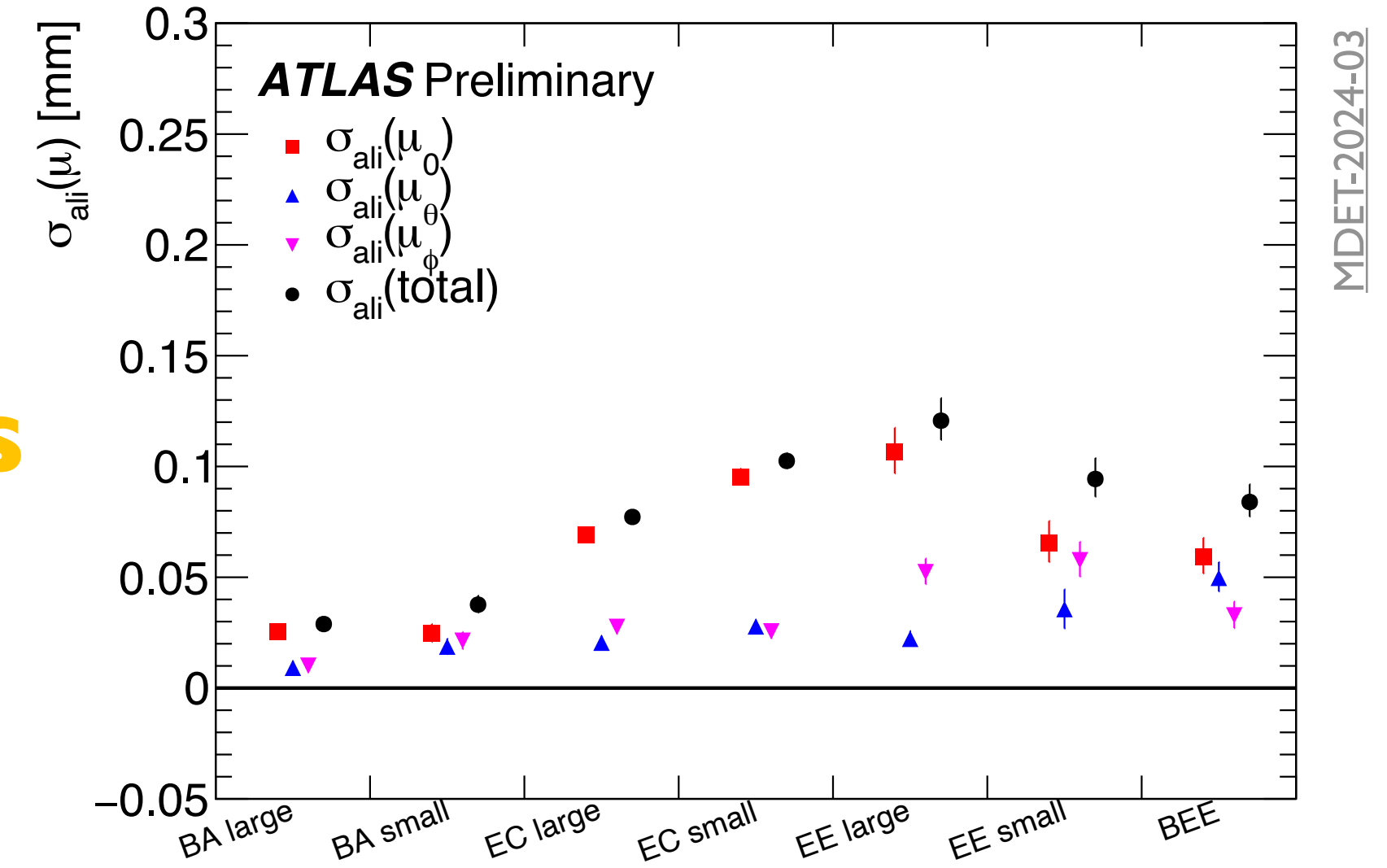
- Well into Run-3, with **98 fb<sup>-1</sup>** of delivered **proton-proton** luminosity at 13.6 TeV
  - 1.91 nb<sup>-1</sup> of **PbPb** data during 2023
- LHC is currently leveling at  $\mu = 63$ 
  - 94% ATLAS **recording** efficiency
- Already **9 Run-3** papers
- Many results shown use **Run-2 dataset**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



# Operations Highlights

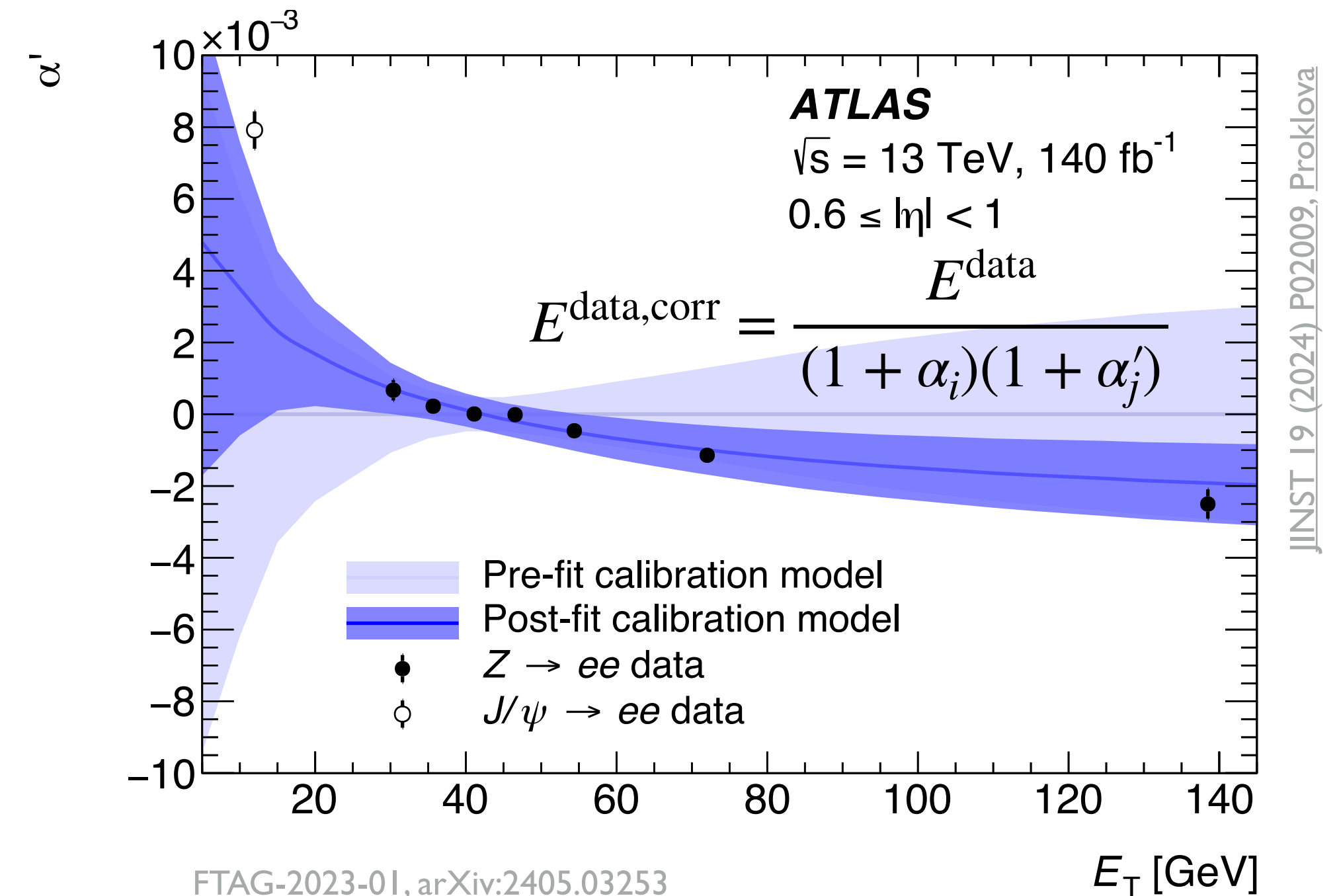
- Improved performance with **Phase-I trigger** system
- High granularity digital calorimeter trigger **reduces LI rate** while maintaining low  $p_T$  thresholds
- New Small Wheel (NSW) reduces **muon fake rate**
- Updated **muon alignment** using data taken with toroid off
  - **~2-4x** improvement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

Sagitta residuals after muon alignment

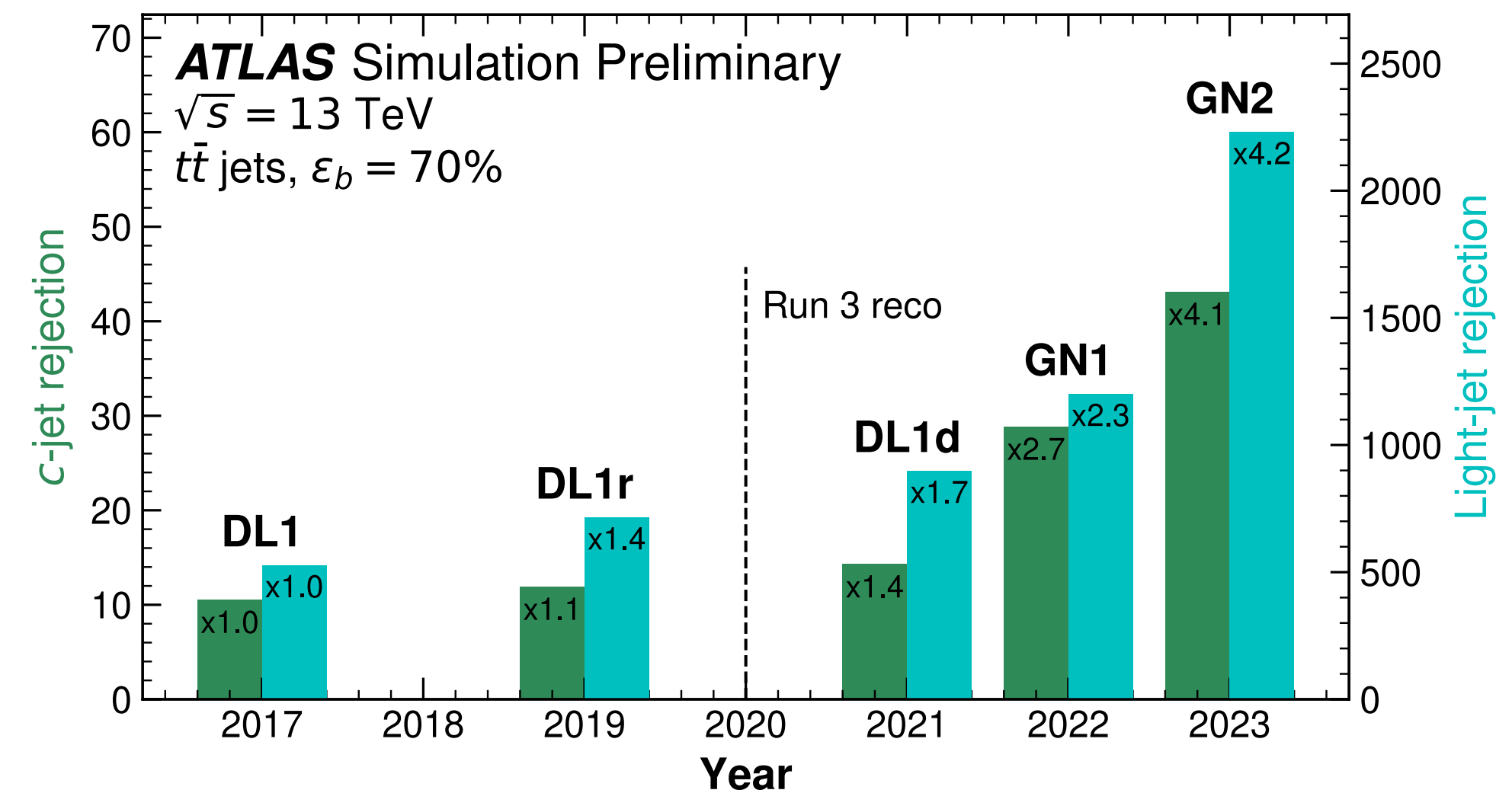


# Performance Highlights

- 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

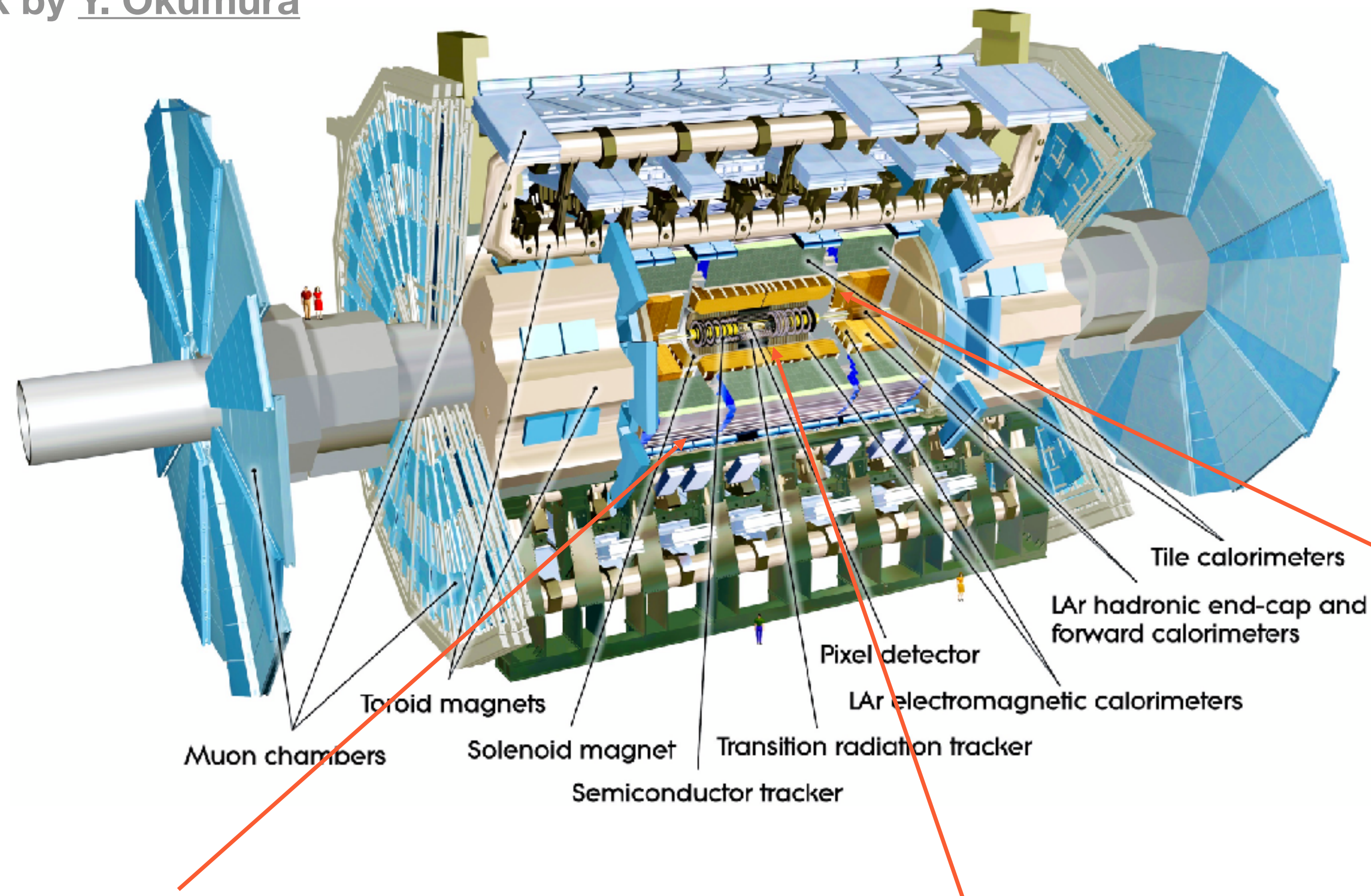


FTAG-2023-01, arXiv:2405.03253



# 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

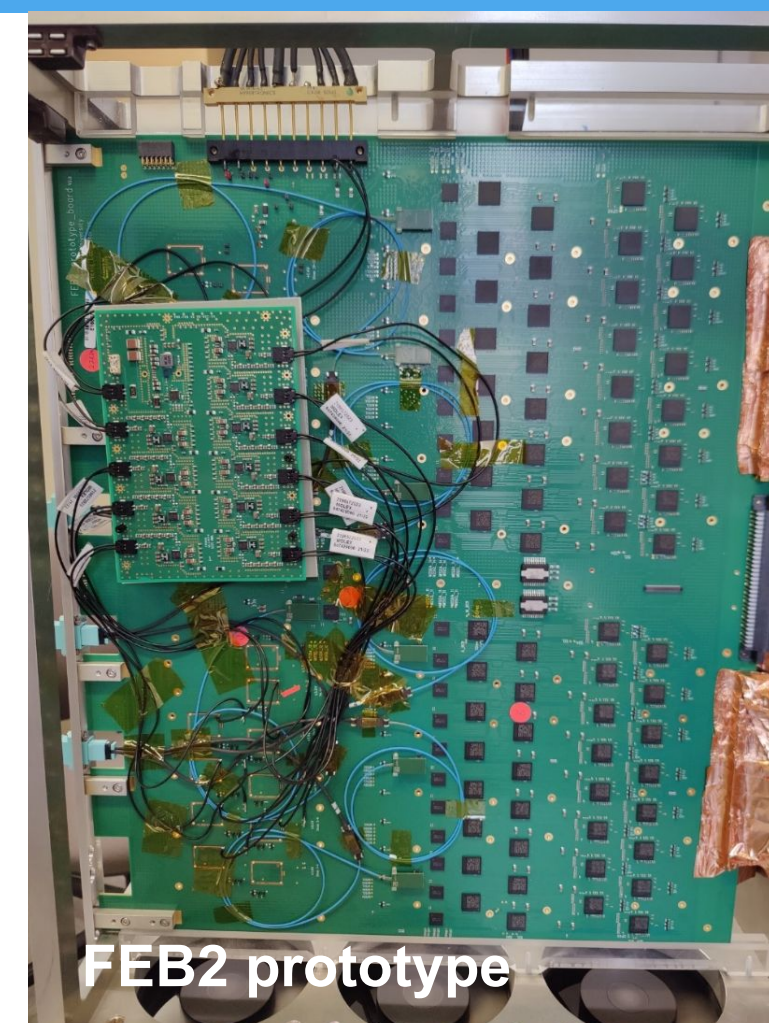
Offline software and computing

# Phase-II Highlights



SRI 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

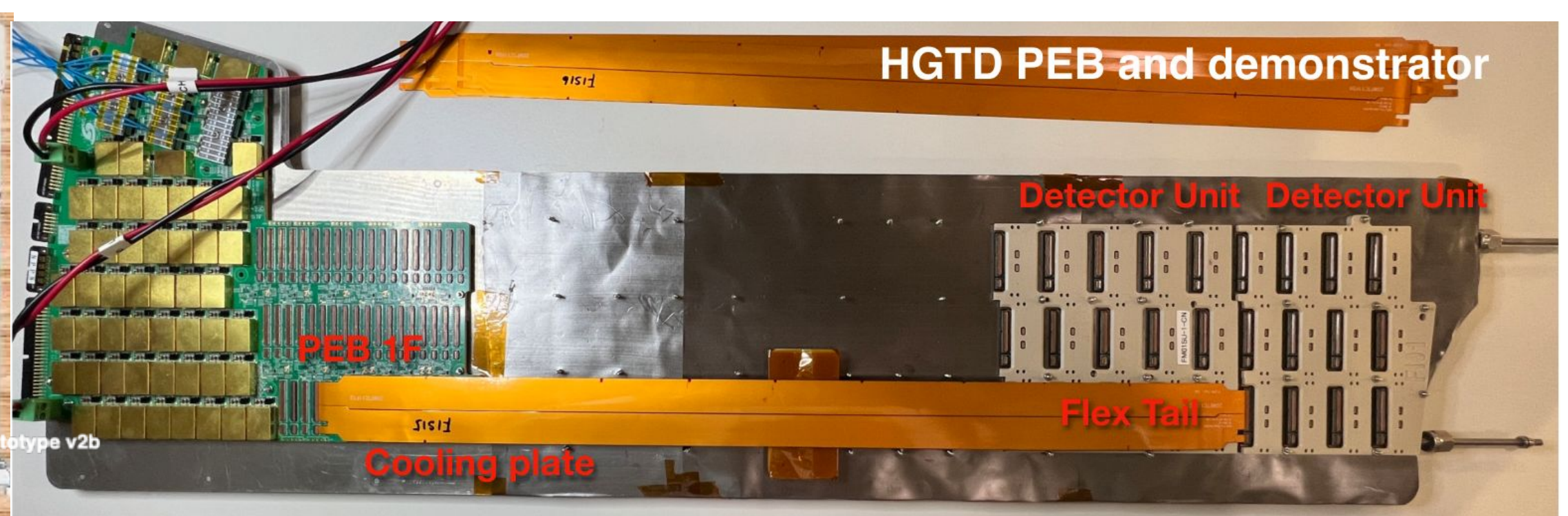


sMDT chambers at CERN (BB5)

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



GCM prototype v2b



HGTD PEB and demonstrator

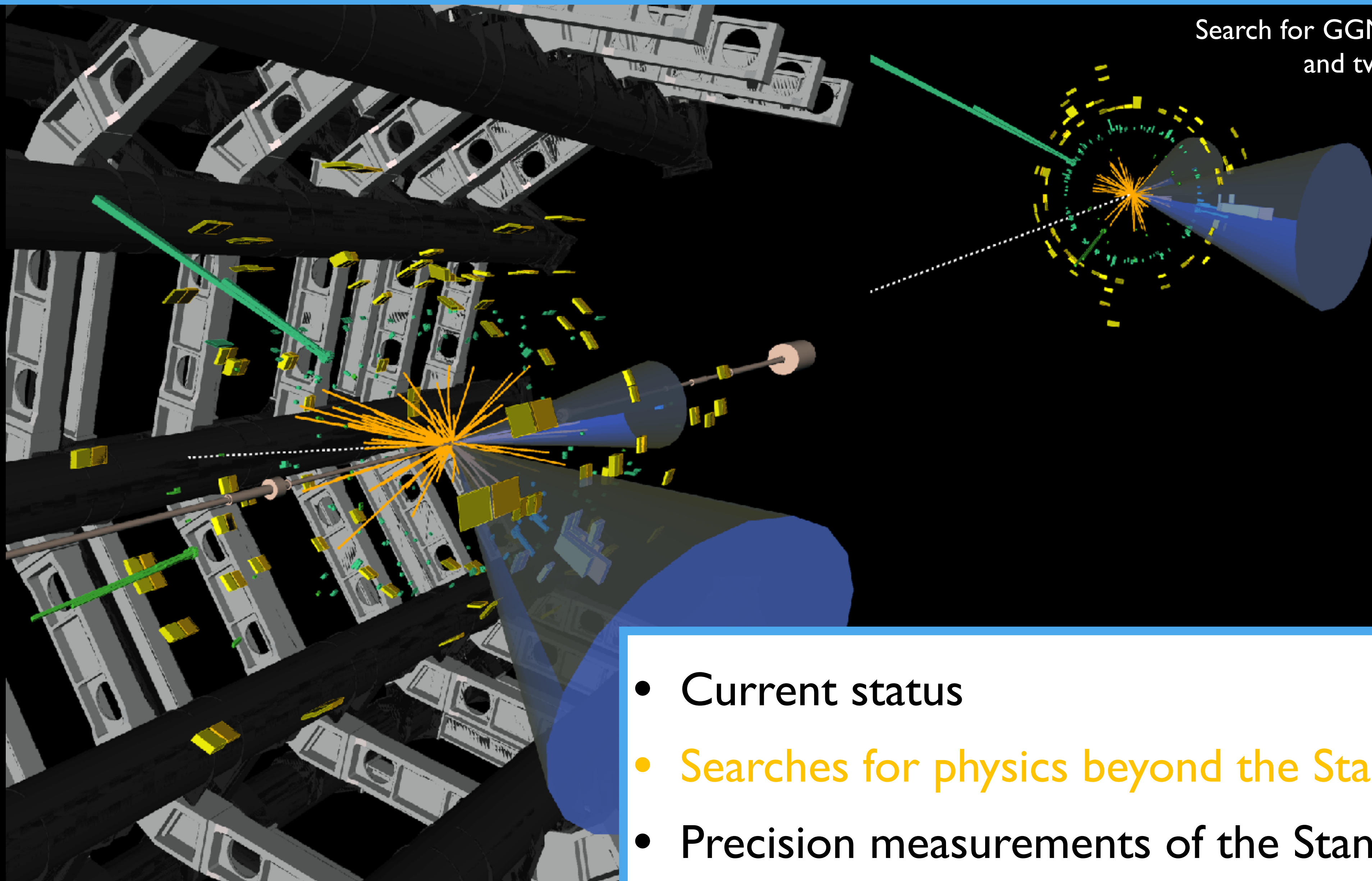
Detector Unit Detector Unit

Cooling plate

Flex Tail



Search for GGM higgsinos decaying to two photons and two b-jets, [arXiv:2404.01996](https://arxiv.org/abs/2404.01996)

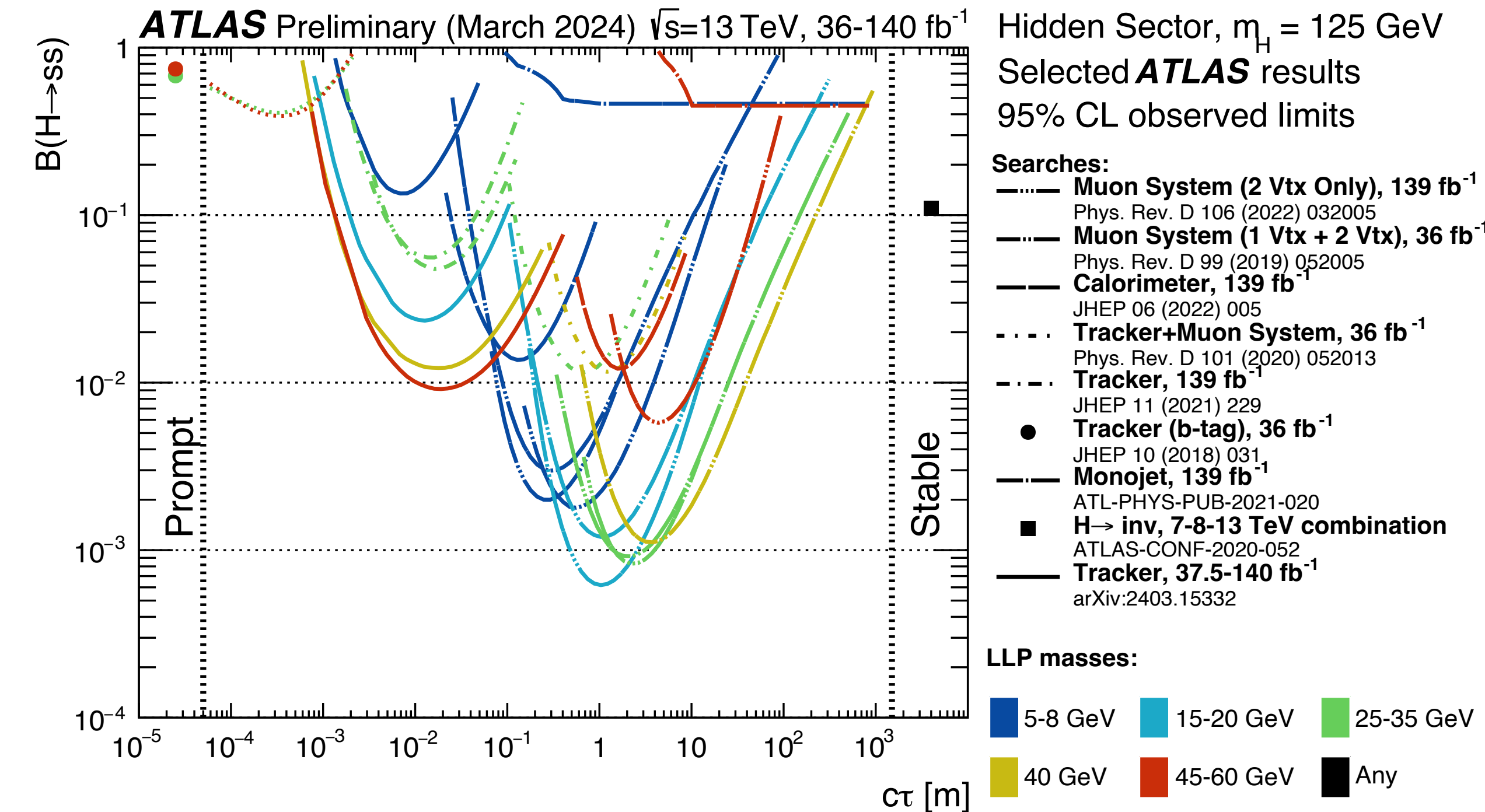


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# Broadly Searching for New Physics

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

ATL-PHYS-PUB-2022-007, Frattari



Model and final state	Section	Excluded Range	
		Run 1	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 $LQ_3^u$ ( $LQLQ \rightarrow tvtv$ )	7	$m < 640$ GeV [330]	$m < 1240$ GeV
LFV $Z \rightarrow e\mu$	8.1	$\mathcal{B} < 7.5 \times 10^{-7}$ [331]	$\mathcal{B} < 2.62 \times 10^{-7}$
FRVZ $\gamma_d$ in $H \rightarrow 2\gamma_d + X$ with $\mathcal{B}(H \rightarrow 2\gamma_d) = 10\%$ and $m_{\gamma_d} = 0.4$ GeV	9.1	$15 < c\tau < 260$ mm [332]	$0.42 < c\tau < 1001$ mm
$H \rightarrow$ invisible combination	10.3	$\mathcal{B} < 0.252$ [333]	$\mathcal{B} < 0.113$
Multi-charged particle with $ z  = 2$	11	$m < 660$ GeV [334]	$m < 1060$ GeV
ADD with $n = 6$ in jet+ $E_T^{\text{miss}}$	12.1	$M_D < 3.06$ TeV [335]	$M_D < 5.9$ TeV

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

# ATLAS SUSY Searches\* - 95% CL Lower Limits

August 2023

ATLAS Preliminary

$\sqrt{s} = 13$  TeV

Probing  
supersymmetry  
around the **TeV**  
scale

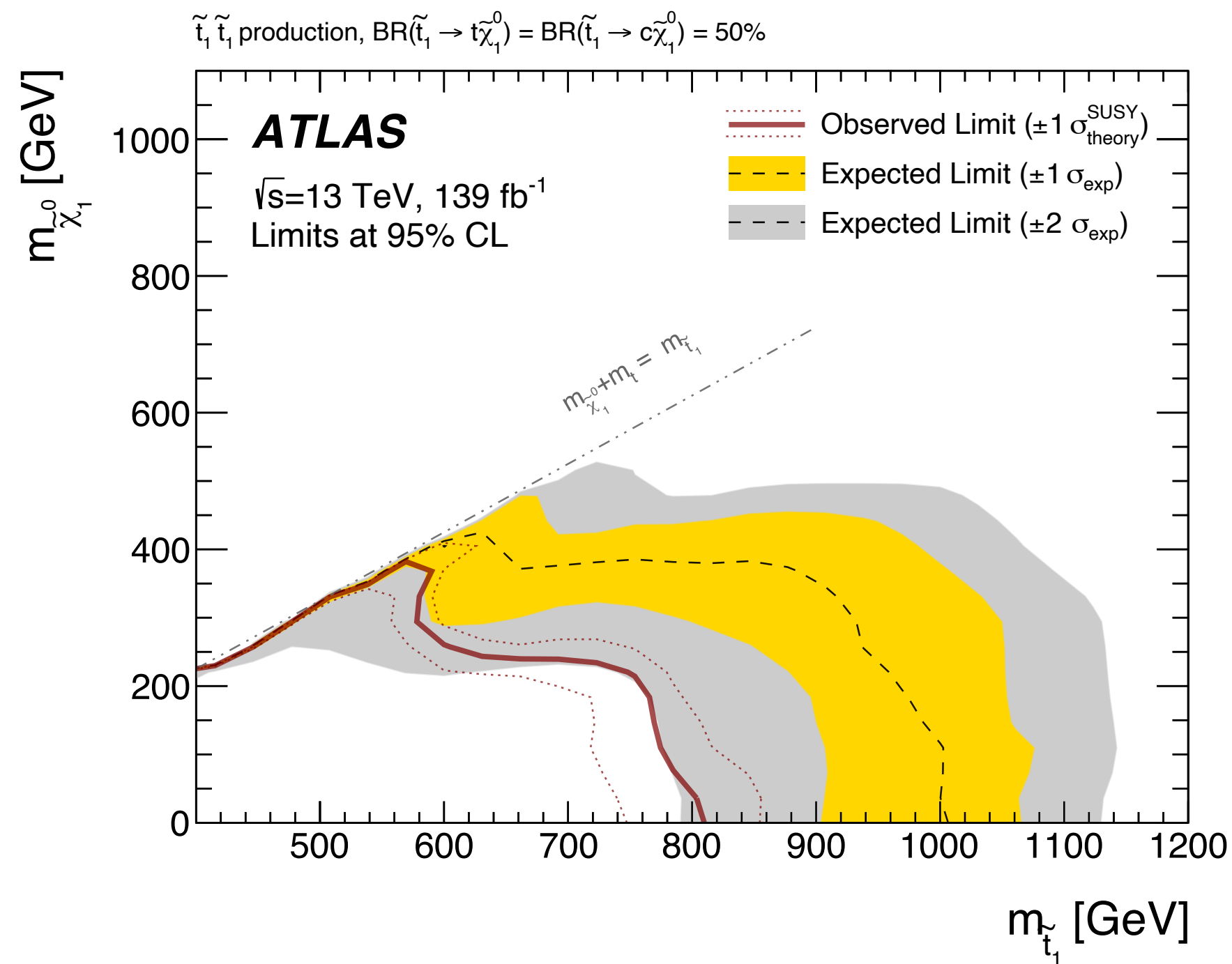
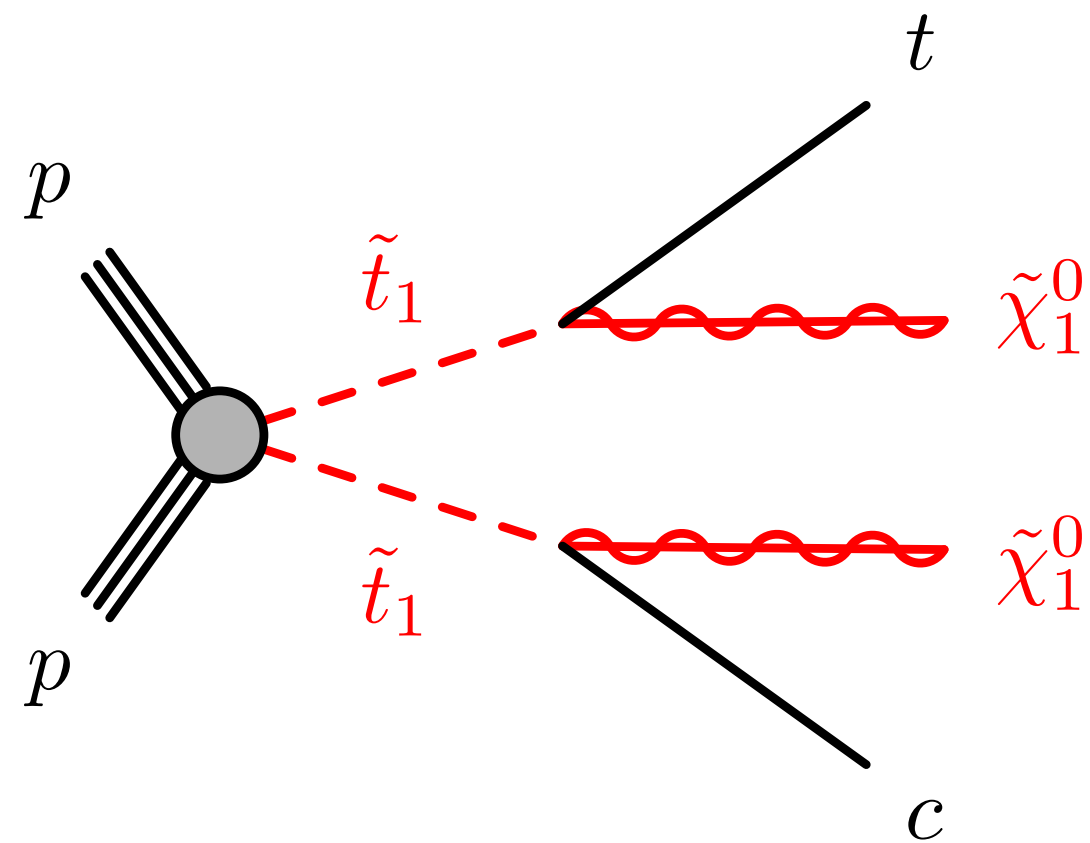
Model	Signature	$\int \mathcal{L} dt$ [fb <sup>-1</sup> ]	Mass limit	Reference			
Inclusive Searches	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_1^0$	0 $e, \mu$ mono-jet	2-6 jets 1-3 jets $E_T^{\text{miss}}$	140 140	$\tilde{q}$ [1x, 8x Degen.] 1.0 1.85 $\tilde{q}$ [8x Degen.] 0.9	$m(\tilde{\chi}_1^0) < 400$ GeV $m(\tilde{q}) - m(\tilde{\chi}_1^0) = 5$ GeV	210.14293 2102.10874
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0$	0 $e, \mu$	2-6 jets $E_T^{\text{miss}}$	140	$\tilde{g}$ 2.3 $\tilde{g}$ Forbidden 1.15-1.95	$m(\tilde{\chi}_1^0) = 0$ GeV $m(\tilde{g}) = 1000$ GeV	210.14293 210.14293
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}W\tilde{\chi}_1^0$	1 $e, \mu$	2-6 jets	140	$\tilde{g}$ 2.2	$m(\tilde{\chi}_1^0) < 600$ GeV	2101.01629
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}(\ell\ell)\tilde{\chi}_1^0$	$ee, \mu\mu$	2 jets $E_T^{\text{miss}}$	140	$\tilde{g}$ 2.2	$m(\tilde{\chi}_1^0) < 700$ GeV	2204.13072
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}WZ\tilde{\chi}_1^0$	0 $e, \mu$	7-11 jets $E_T^{\text{miss}}$	140	$\tilde{g}$ 1.97	$m(\tilde{\chi}_1^0) < 600$ GeV	2008.06032
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow t\tilde{\chi}_1^0$	SS $e, \mu$	6 jets $E_T^{\text{miss}}$	140	$\tilde{g}$ 1.15 2.45 $\tilde{g}$ 1.25	$m(\tilde{g}) - m(\tilde{\chi}_1^0) = 200$ GeV $m(\tilde{\chi}_1^0) < 500$ GeV $m(\tilde{g}) - m(\tilde{\chi}_1^0) = 300$ GeV	2307.01094 2211.08028 1909.08457
3 <sup>rd</sup> gen. squarks direct production	$\tilde{b}_1\tilde{b}_1$	0 $e, \mu$	2 $b$ $E_T^{\text{miss}}$	140	$\tilde{b}_1$ 1.255 $\tilde{b}_1$ 0.68	$m(\tilde{\chi}_1^0) < 400$ GeV 10 GeV $< \Delta m(\tilde{b}_1, \tilde{\chi}_1^0) < 20$ GeV	2101.12527 2101.12527
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1 \rightarrow b\tilde{\chi}_2^0 \rightarrow bh\tilde{\chi}_1^0$	0 $e, \mu$ 2 $\tau$	6 $b$ 2 $b$ $E_T^{\text{miss}}$	140 140	$\tilde{b}_1$ Forbidden 0.23-1.35 $\tilde{b}_1$ 0.13-0.85	$\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0) = 130$ GeV, $m(\tilde{\chi}_1^0) = 100$ GeV $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0) = 130$ GeV, $m(\tilde{\chi}_1^0) = 0$ GeV	1908.03122 2103.08189
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$	0-1 $e, \mu$	$\geq 1$ jet $E_T^{\text{miss}}$	140	$\tilde{t}_1$ 1.25	$m(\tilde{\chi}_1^0) = 1$ GeV	2004.14060, 2012.03799
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow Wb\tilde{\chi}_1^0$	1 $e, \mu$	3 jets/1 $b$ $E_T^{\text{miss}}$	140	$\tilde{t}_1$ Forbidden 1.05	$m(\tilde{\chi}_1^0) = 500$ GeV	2012.03799, ATLAS-CONF-2023-043
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow \tilde{\tau}_1 b\nu, \tilde{\tau}_1 \rightarrow \tau\tilde{G}$	1-2 $\tau$	2 jets/1 $b$ $E_T^{\text{miss}}$	140	$\tilde{t}_1$ Forbidden 1.4	$m(\tilde{\tau}_1) = 800$ GeV	2108.07665
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow c\tilde{\chi}_1^0 / \tilde{c}\tilde{c}, \tilde{c} \rightarrow c\tilde{\chi}_1^0$	0 $e, \mu$ 0 $e, \mu$	2 $c$ mono-jet $E_T^{\text{miss}}$	36.1 140	$\tilde{c}$ 0.85 $\tilde{t}_1$ 0.55	$m(\tilde{\chi}_1^0) = 0$ GeV $m(\tilde{t}_1, \tilde{c}) - m(\tilde{\chi}_1^0) = 5$ GeV	1805.01649 2102.10874
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{\chi}_2^0, \tilde{\chi}_2^0 \rightarrow Z/h\tilde{\chi}_1^0$	1-2 $e, \mu$	1-4 $b$ $E_T^{\text{miss}}$	140	$\tilde{t}_1$ 0.067-1.18	$m(\tilde{\chi}_2^0) = 500$ GeV	2006.05880
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + Z$	3 $e, \mu$	1 $b$ $E_T^{\text{miss}}$	140	$\tilde{t}_2$ Forbidden 0.86	$m(\tilde{\chi}_1^0) = 360$ GeV, $m(\tilde{t}_1) - m(\tilde{\chi}_1^0) = 40$ GeV	2006.05880
EW direct	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ via WZ	Multiple $\ell$ /jets $ee, \mu\mu$	$\geq 1$ jet $E_T^{\text{miss}}$	140 140	$\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$ 0.96 $\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$ 0.205	$m(\tilde{\chi}_1^0) = 0$ , wino-bino $m(\tilde{\chi}_1^{\pm}) - m(\tilde{\chi}_1^0) = 5$ GeV, wino-bino	2106.01676, 2108.07586 1911.12606
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ via WW	2 $e, \mu$	$E_T^{\text{miss}}$	140	$\tilde{\chi}_1^{\pm}$ 0.42	$m(\tilde{\chi}_1^0) = 0$ , wino-bino	1908.08215
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ via Wh	Multiple $\ell$ /jets	$E_T^{\text{miss}}$	140	$\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$ Forbidden 1.06	$m(\tilde{\chi}_1^0) = 70$ GeV, wino-bino	2004.10894, 2108.07586
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ via $\tilde{\ell}_L/\tilde{\nu}$	2 $e, \mu$	$E_T^{\text{miss}}$	140	$\tilde{\chi}_1^{\pm}$ 1.0	$m(\tilde{\ell}, \tilde{\nu}) = 0.5(m(\tilde{\chi}_1^{\pm}) + m(\tilde{\chi}_1^0))$	1908.08215
	$\tilde{\tau}\tilde{\tau}, \tilde{\tau} \rightarrow \tau\tilde{\chi}_1^0$	2 $\tau$	$E_T^{\text{miss}}$	140	$\tilde{\tau}$ [ $\tilde{\tau}_R, \tilde{\tau}_{R,L}$ ] 0.34 0.48	$m(\tilde{\chi}_1^0) = 0$	ATLAS-CONF-2023-029
	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell} \rightarrow \ell\tilde{\chi}_1^0$	2 $e, \mu$ $ee, \mu\mu$	0 jets $\geq 1$ jet $E_T^{\text{miss}}$	140 140	$\tilde{\ell}$ 0.7 $\tilde{\ell}$ 0.26	$m(\tilde{\chi}_1^0) = 0$ $m(\tilde{\ell}) - m(\tilde{\chi}_1^0) = 10$ GeV	1908.08215 1911.12606
	$\tilde{H}\tilde{H}, \tilde{H} \rightarrow h\tilde{G}/Z\tilde{G}$	0 $e, \mu$ 4 $e, \mu$ 0 $e, \mu$ 2 $e, \mu$	$\geq 3$ $b$ 0 jets $\geq 2$ large jets $E_T^{\text{miss}}$	140 140 140 140	$\tilde{H}$ 0.94 $\tilde{H}$ 0.55 $\tilde{H}$ 0.45-0.93 $\tilde{H}$ 0.77	$\text{BR}(\tilde{\chi}_1^0 \rightarrow h\tilde{G}) = 1$ $\text{BR}(\tilde{\chi}_1^0 \rightarrow Z\tilde{G}) = 1$ $\text{BR}(\tilde{\chi}_1^0 \rightarrow Z\tilde{G}) = 1$ $\text{BR}(\tilde{\chi}_1^0 \rightarrow Z\tilde{G}) = \text{BR}(\tilde{\chi}_1^0 \rightarrow h\tilde{G}) = 0.5$	To appear 2103.11684 2108.07586 2204.13072
Long-lived particles	Direct $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ prod., long-lived $\tilde{\chi}_1^{\pm}$	Disapp. trk	1 jet $E_T^{\text{miss}}$	140	$\tilde{\chi}_1^{\pm}$ 0.66 $\tilde{\chi}_1^{\pm}$ 0.21	Pure Wino Pure higgsino	2201.02472 2201.02472
	Stable $\tilde{g}$ R-hadron	pixel dE/dx	$E_T^{\text{miss}}$	140	$\tilde{g}$ 2.05		2205.06013
	Metastable $\tilde{g}$ R-hadron, $\tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0$	pixel dE/dx	$E_T^{\text{miss}}$	140	$\tilde{g}$ [ $\tau(\tilde{g}) = 10$ ns] 2.2	$m(\tilde{\chi}_1^0) = 100$ GeV	2205.06013
	$\tilde{\ell}\tilde{\ell}, \tilde{\ell} \rightarrow \ell\tilde{G}$	Displ. lep	$E_T^{\text{miss}}$	140	$\tilde{\ell}, \tilde{\mu}$ 0.7 $\tilde{\tau}$ 0.34 $\tilde{\tau}$ 0.36	$\tau(\tilde{\ell}) = 0.1$ ns $\tau(\tilde{\ell}) = 0.1$ ns $\tau(\tilde{\ell}) = 10$ ns	2011.07812 2011.07812 2205.06013
RPV	$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}/\tilde{\chi}_1^0, \tilde{\chi}_1^{\pm} \rightarrow Z\ell \rightarrow \ell\ell\ell$	3 $e, \mu$	$E_T^{\text{miss}}$	140	$\tilde{\chi}_1^{\pm}/\tilde{\chi}_1^0$ [BR(Z $\tau$ )=1, BR(Z $e$ )=1] 0.625 1.05	Pure Wino	2011.10543
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}/\tilde{\chi}_2^0 \rightarrow WW/Z\ell\ell\ell\nu\nu$	4 $e, \mu$	0 jets $E_T^{\text{miss}}$	140	$\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$ [ $\lambda_{133} \neq 0, \lambda_{12k} \neq 0$ ] 0.95 1.55	$m(\tilde{\chi}_1^0) = 200$ GeV	2103.11684
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow qq\tilde{q}$	$\geq 8$ jets	140	$\tilde{g}$ [ $m(\tilde{\chi}_1^0) = 50$ GeV, 1250 GeV] 1.6 2.25	Large $\lambda'_{112}$	To appear	
	$\tilde{t}, \tilde{t} \rightarrow t\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow tbs$	Multiple $\geq 4b$	36.1 140	$\tilde{t}$ [ $\lambda'_{323} = 2e-4, 1e-2$ ] 0.55 1.05	$m(\tilde{\chi}_1^0) = 200$ GeV, bino-like	ATLAS-CONF-2018-003	
	$\tilde{t}, \tilde{t} \rightarrow b\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^{\pm} \rightarrow bbs$	$\geq 4b$	140	$\tilde{t}$ Forbidden 0.95	$m(\tilde{\chi}_1^{\pm}) = 500$ GeV	2010.01015	
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow bs$	2 jets + 2 $b$	36.7	$\tilde{t}_1$ [ $qq, bs$ ] 0.42 0.61		1710.07171	
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow q\ell$	2 $e, \mu$ 1 $\mu$	2 $b$ DV	36.1 136	$\tilde{t}_1$ [ $1e-10 < \lambda'_{23k} < 1e-8, 3e-10 < \lambda'_{23k} < 3e-9$ ] 1.0 0.4-1.45 1.6	$\text{BR}(\tilde{t}_1 \rightarrow b\ell/b\mu) > 20\%$ $\text{BR}(\tilde{t}_1 \rightarrow q\mu) = 100\%, \cos\theta_t = 1$	1710.05544 2003.11956	
$\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0/\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow tbs, \tilde{\chi}_1^{\pm} \rightarrow bbs$	1-2 $e, \mu$	$\geq 6$ jets	140	$\tilde{\chi}_1^0$ 0.2-0.32	Pure higgsino	2106.09609	

\*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

10<sup>-1</sup> 1 Mass scale [TeV]

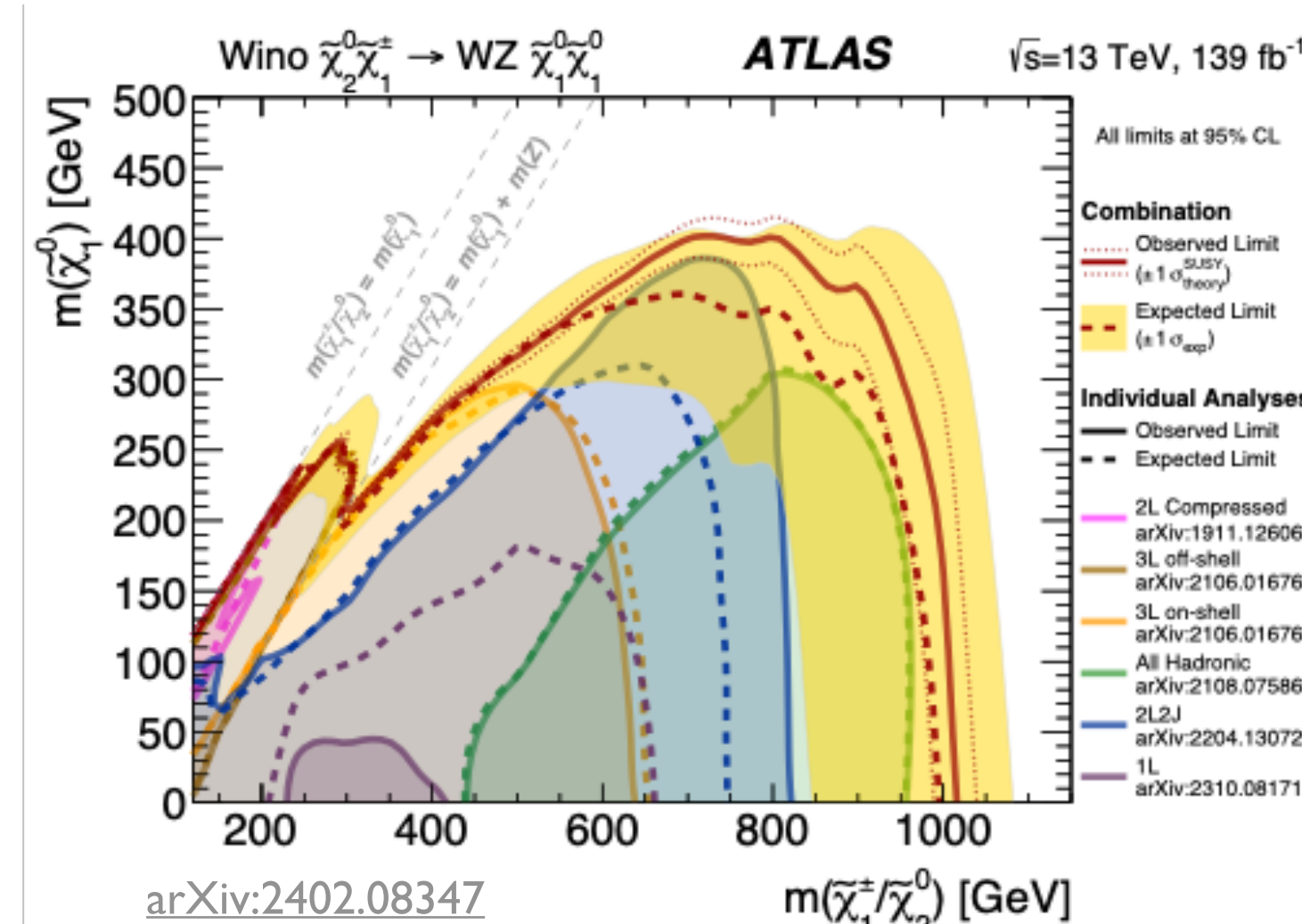
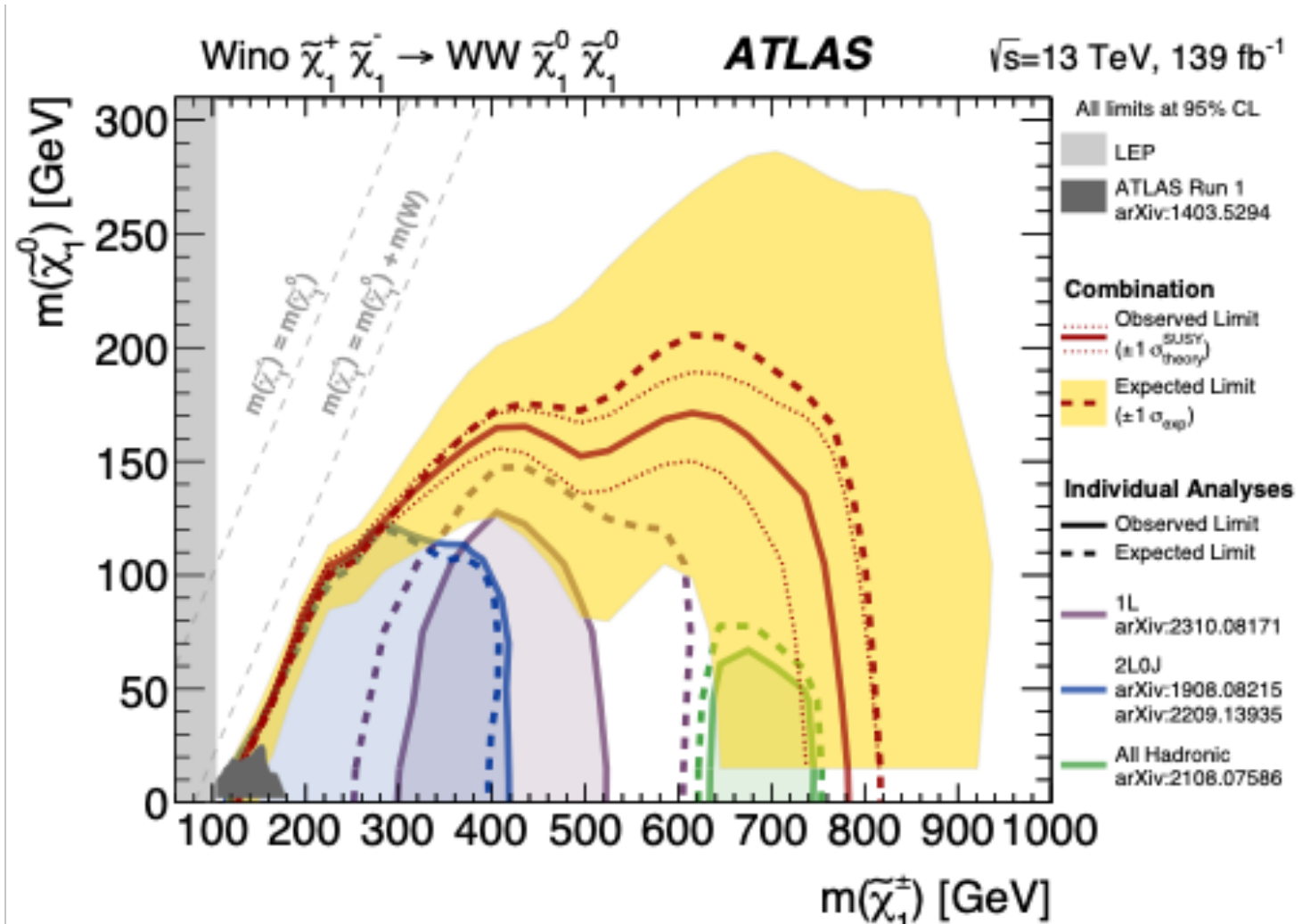
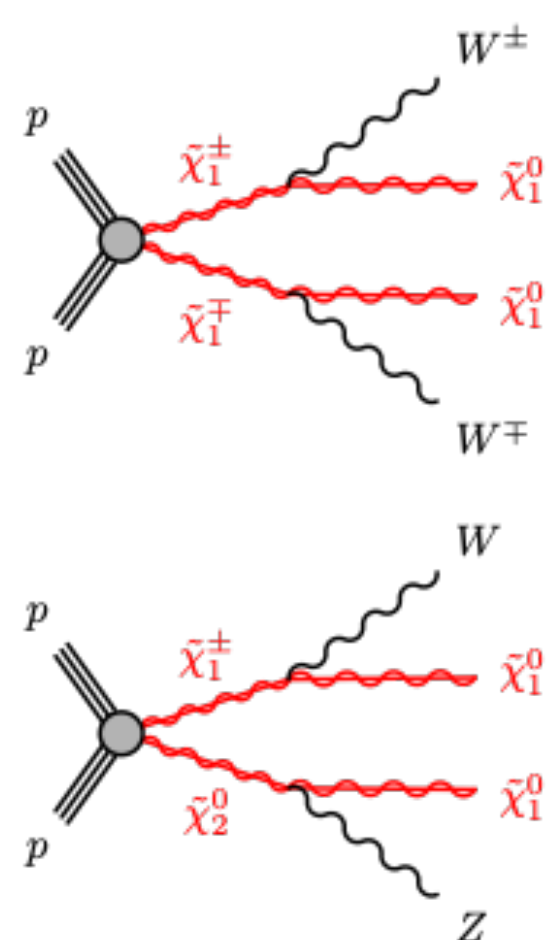
# Strong and EW Production Searches <sup>12</sup>

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



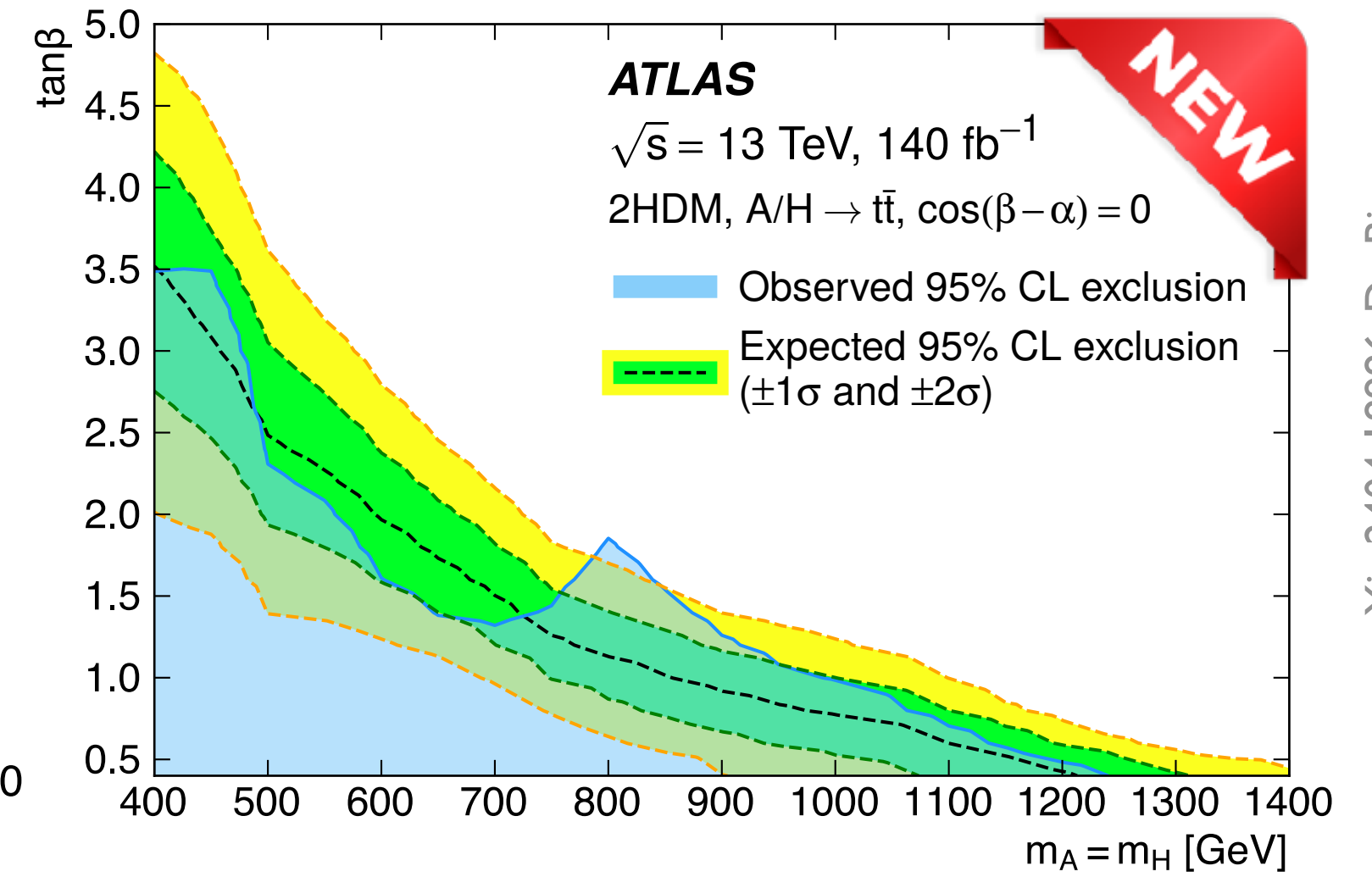
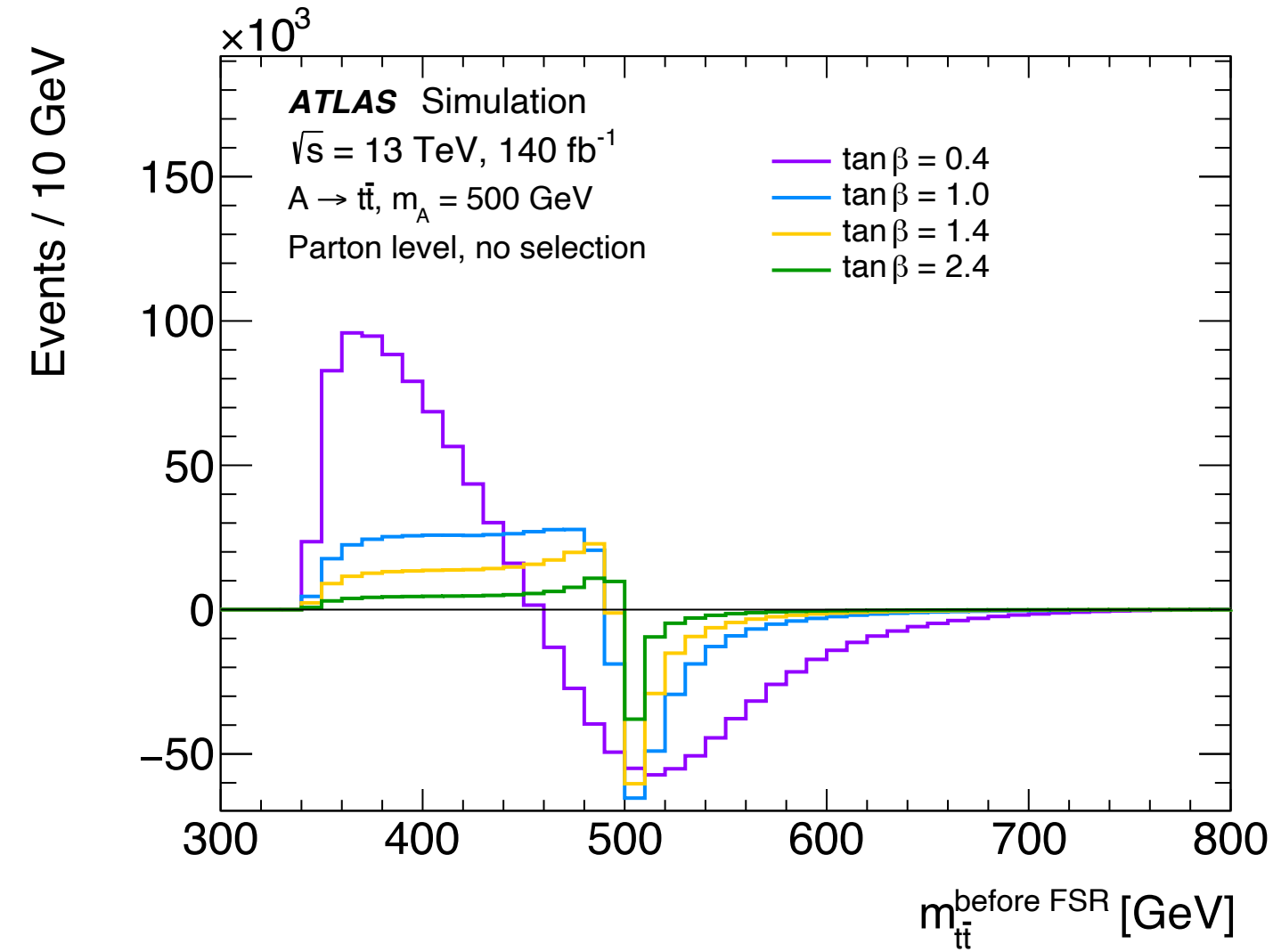
arXiv:2402.12137, Gurdasani

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

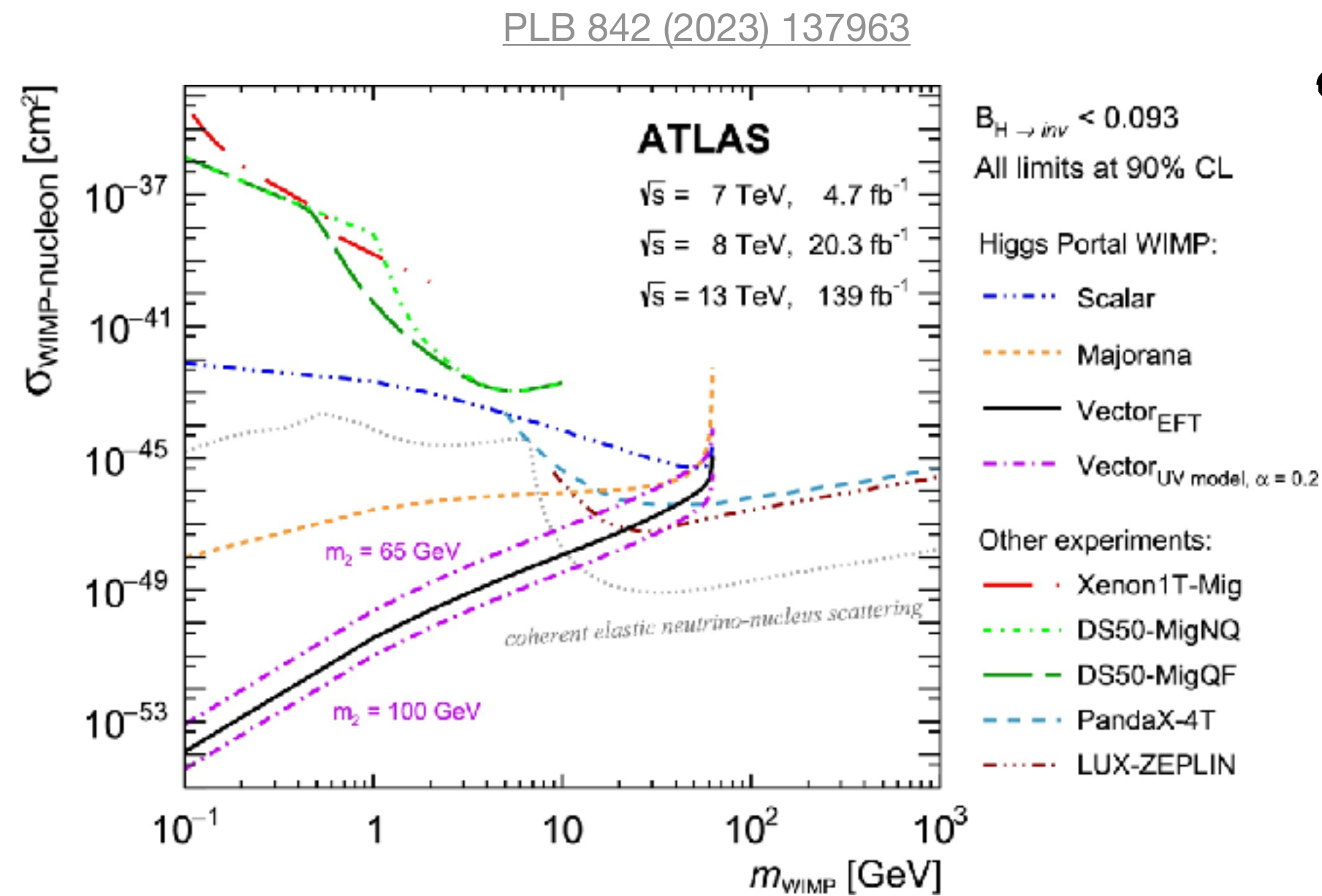
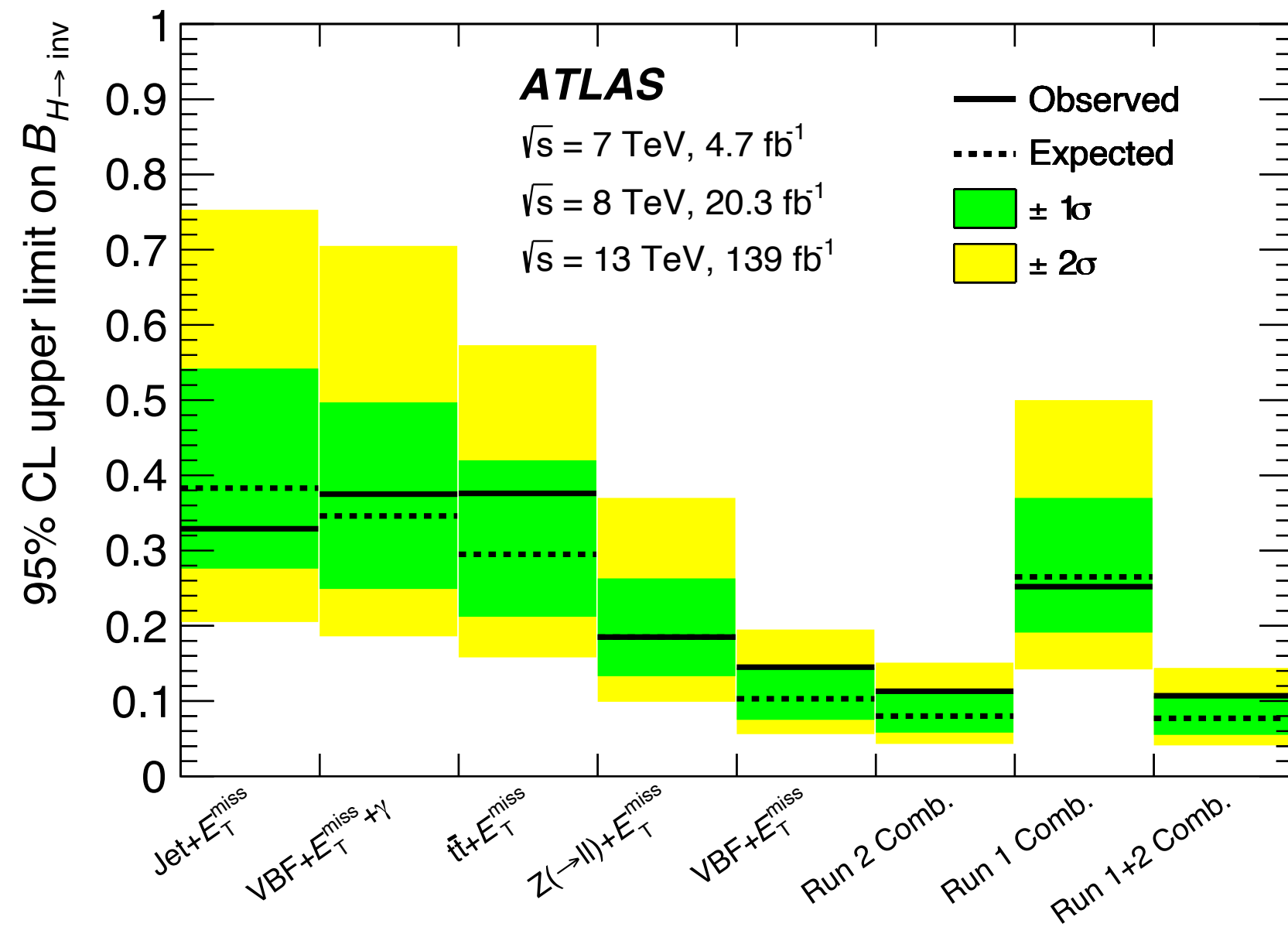


# Higgs-related Searches

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

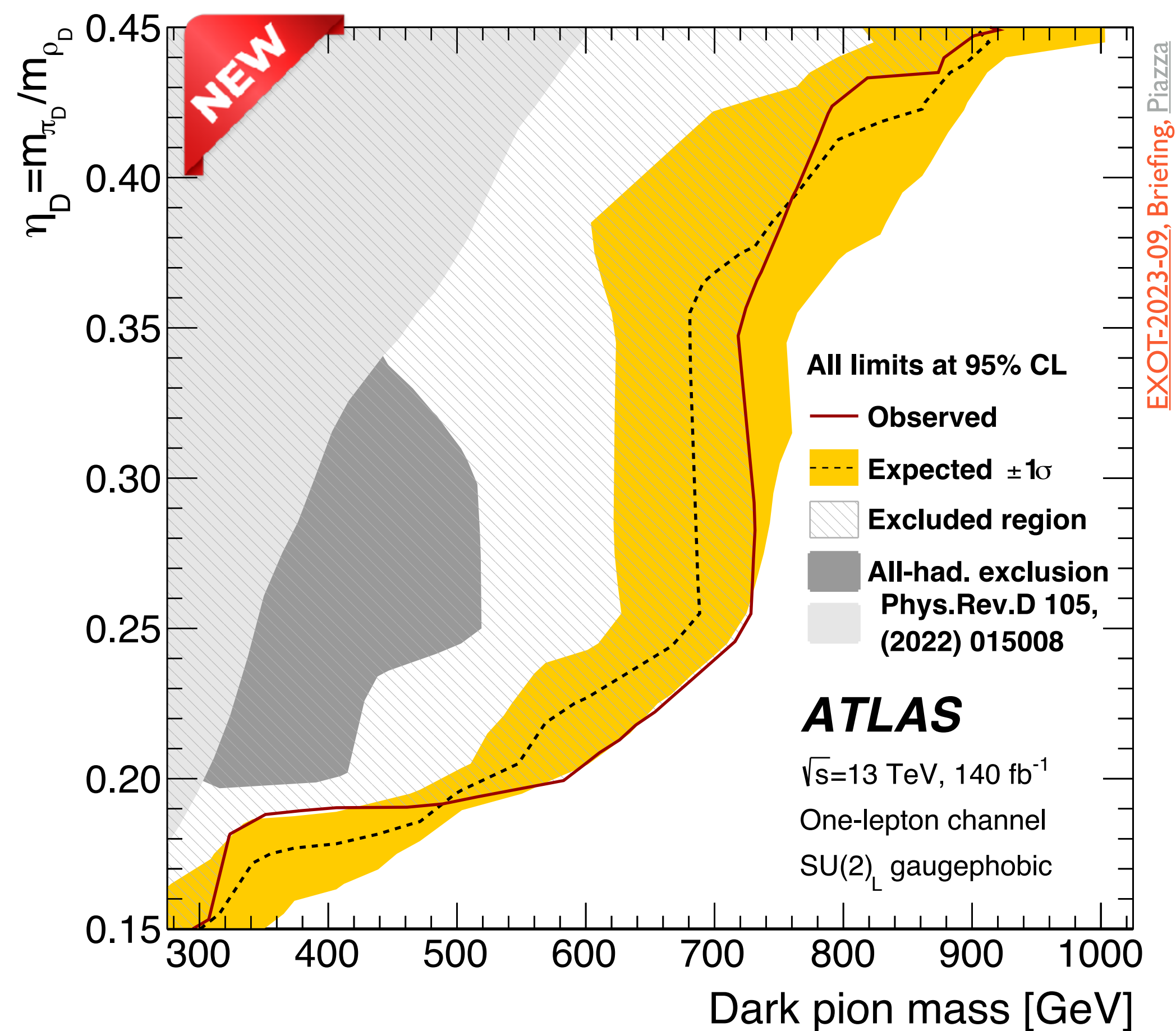


arXiv:2404.18986, De Biase

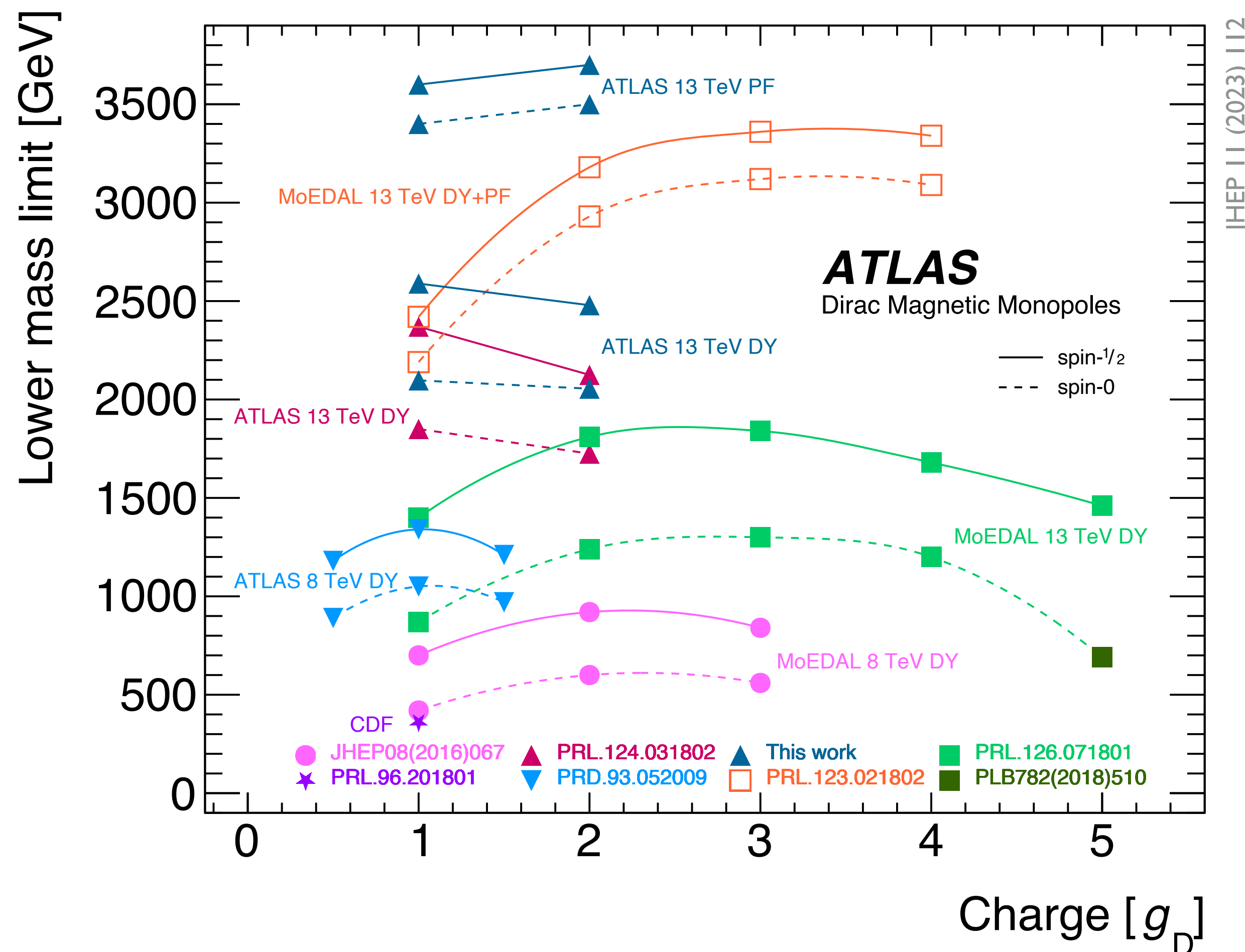


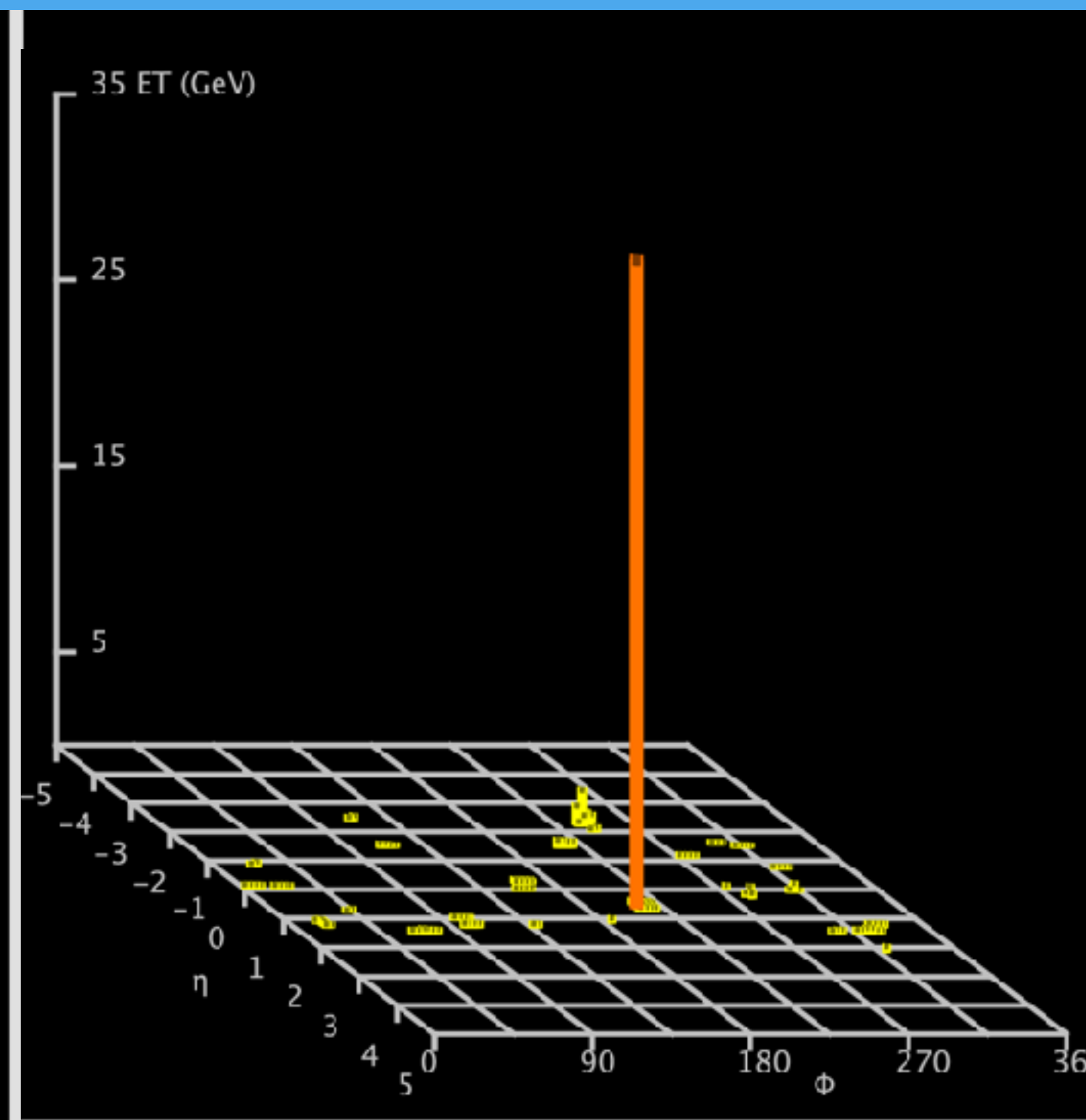
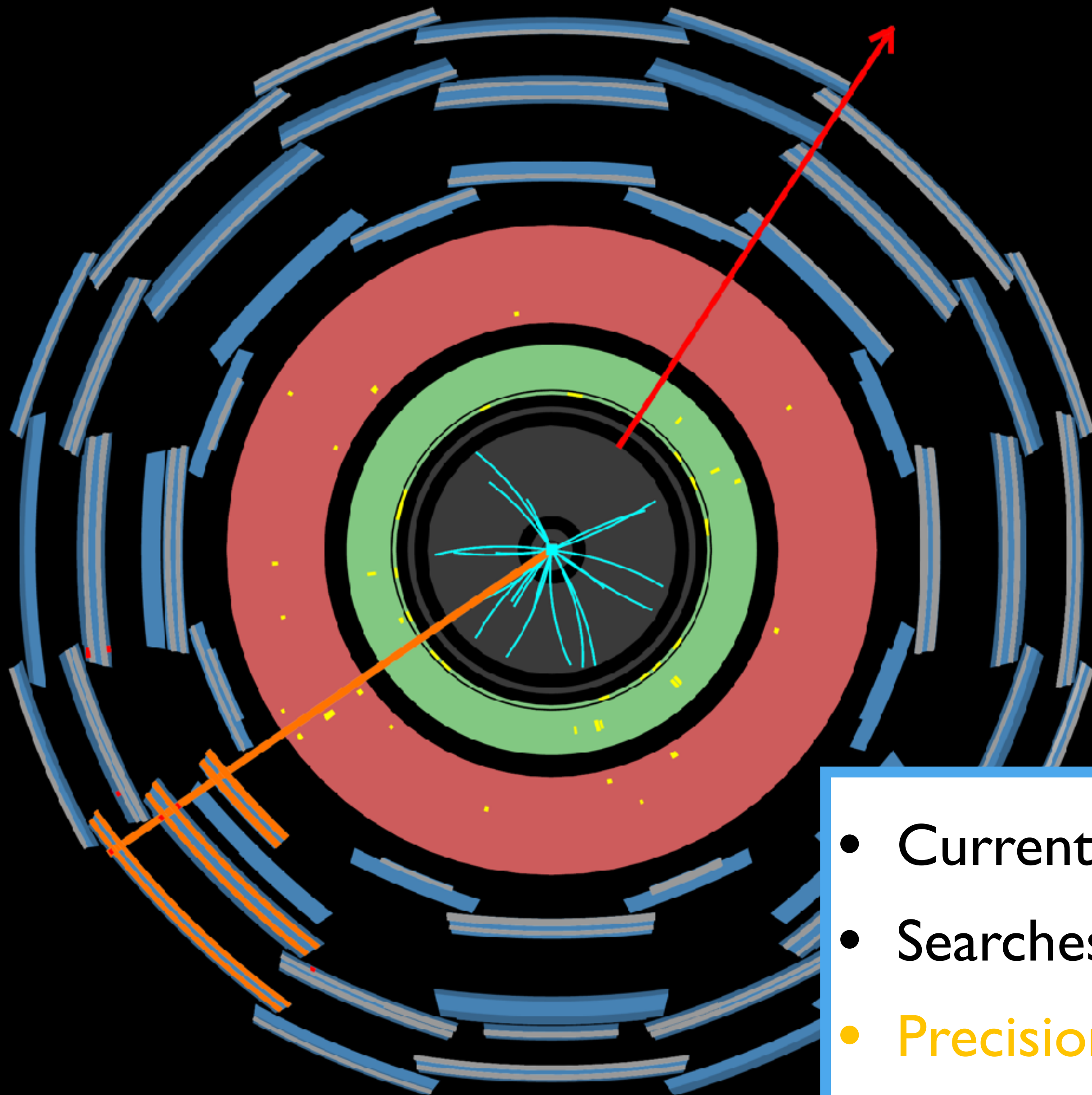
- Observed (expected) **H**  $\rightarrow$  **inv** branching ratio limit of 0.107 (0.077)
- World-leading constraints on **light dark matter**

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



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





$W^- \rightarrow \mu^- \nu$  candidate event from precise measurements of W and Z transverse momentum spectra, [arXiv:2404.06204](https://arxiv.org/abs/2404.06204)

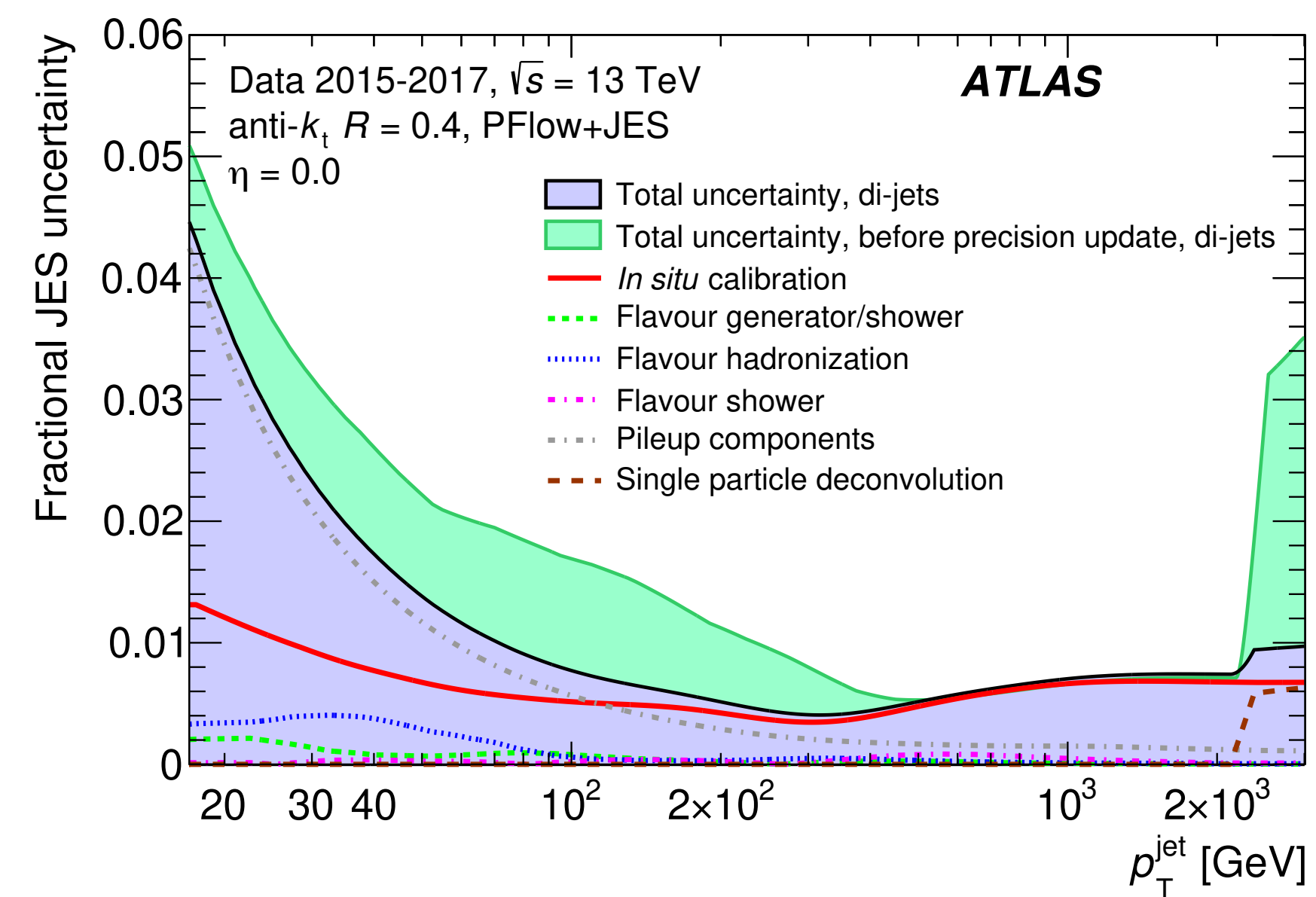
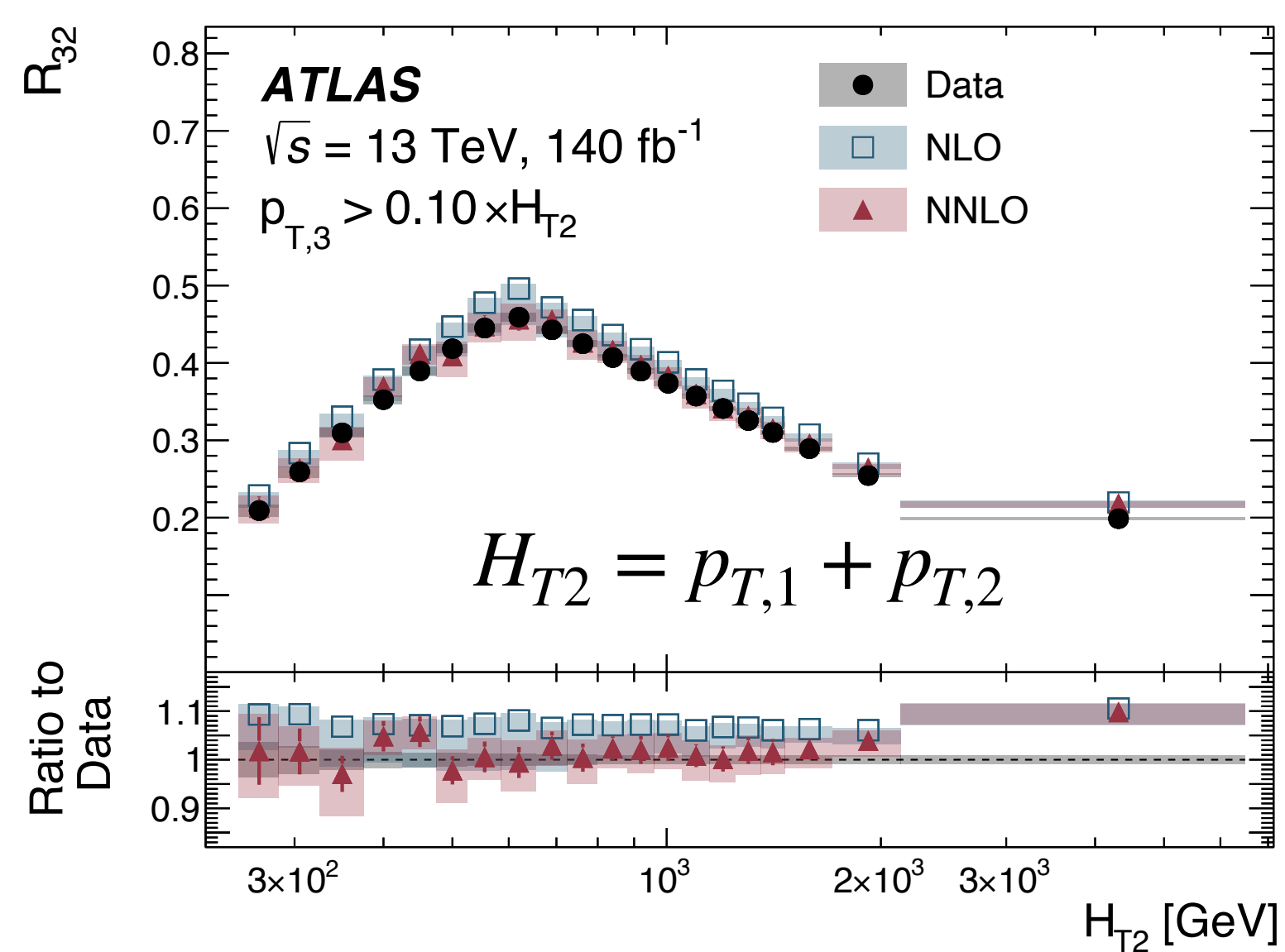
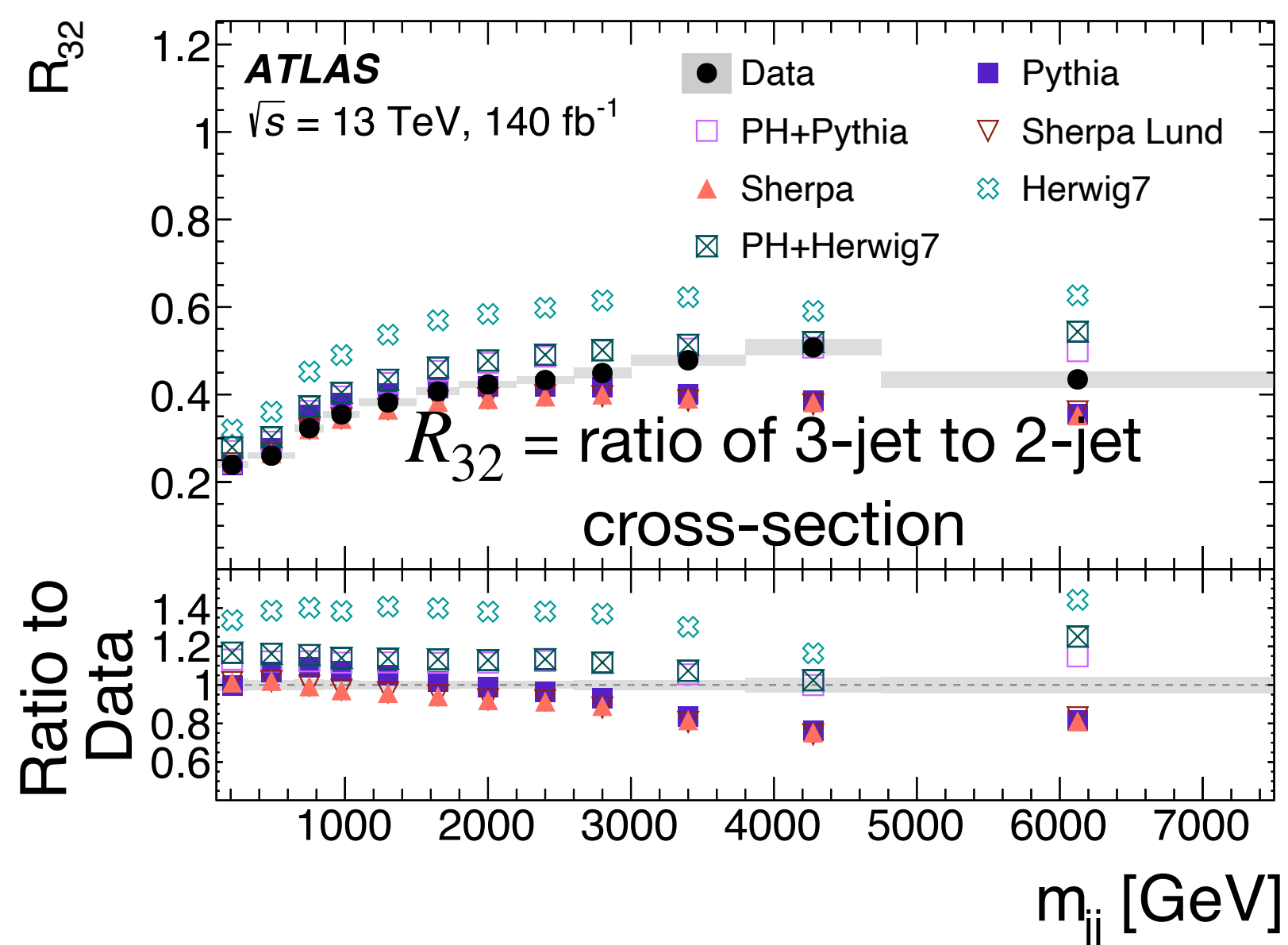
- Current status
- Searches for physics beyond the Standard Model (BSM)
- Precision measurements of the Standard Model





# Jet Cross-section Ratios

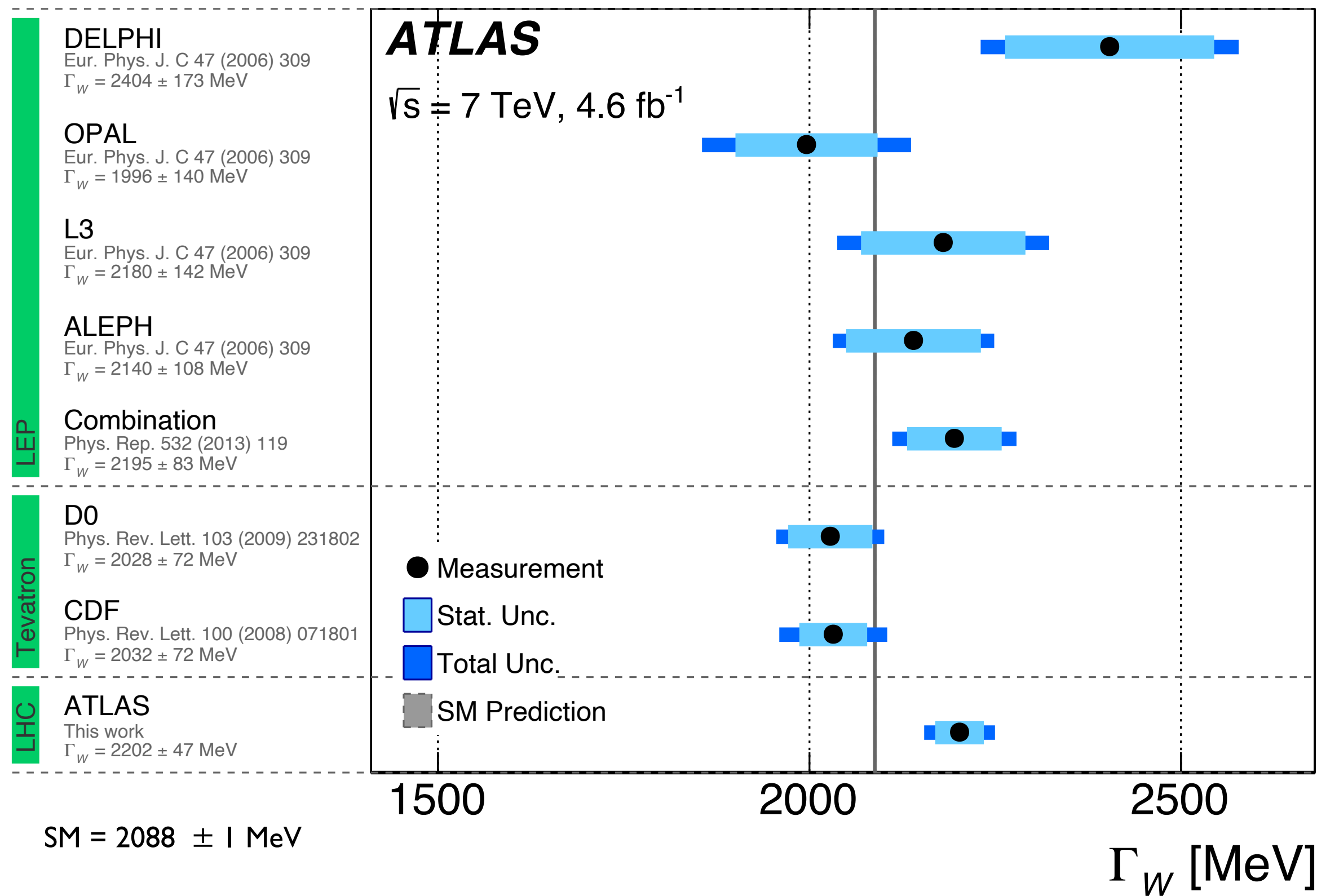
- Measure **jet cross-section ratios** between bins of jet multiplicity
  - Double differential: Energy-scale or angular radiation (**< 10% precision**)
  - Triple differential:  $H_{T2}$  (**< few %**)
- Relies on improved JES uncertainty (**< 1%**)
- Can be used to extract  $\alpha_S$



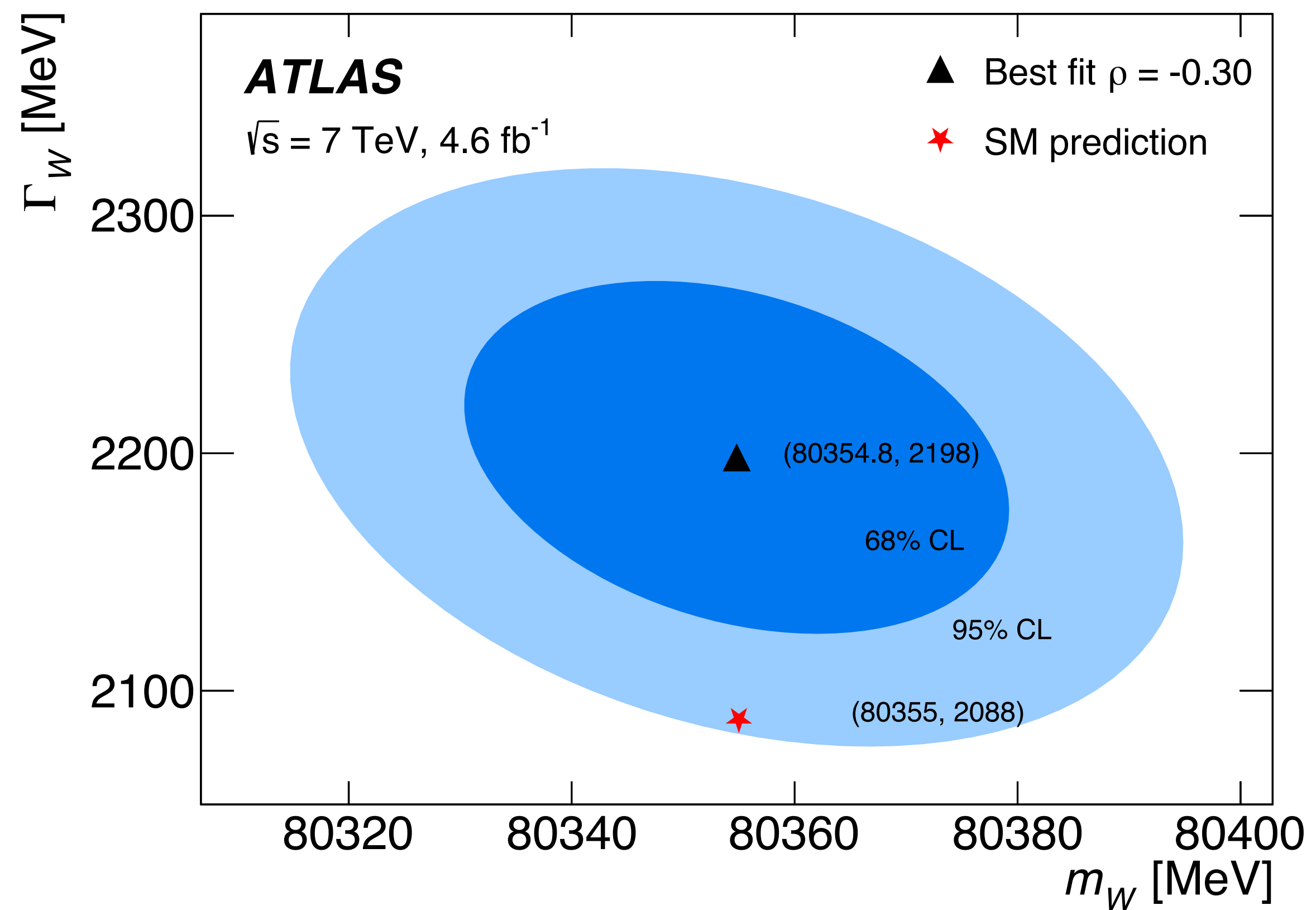
# W Boson Mass and Width

## First W boson width measurement at the LHC

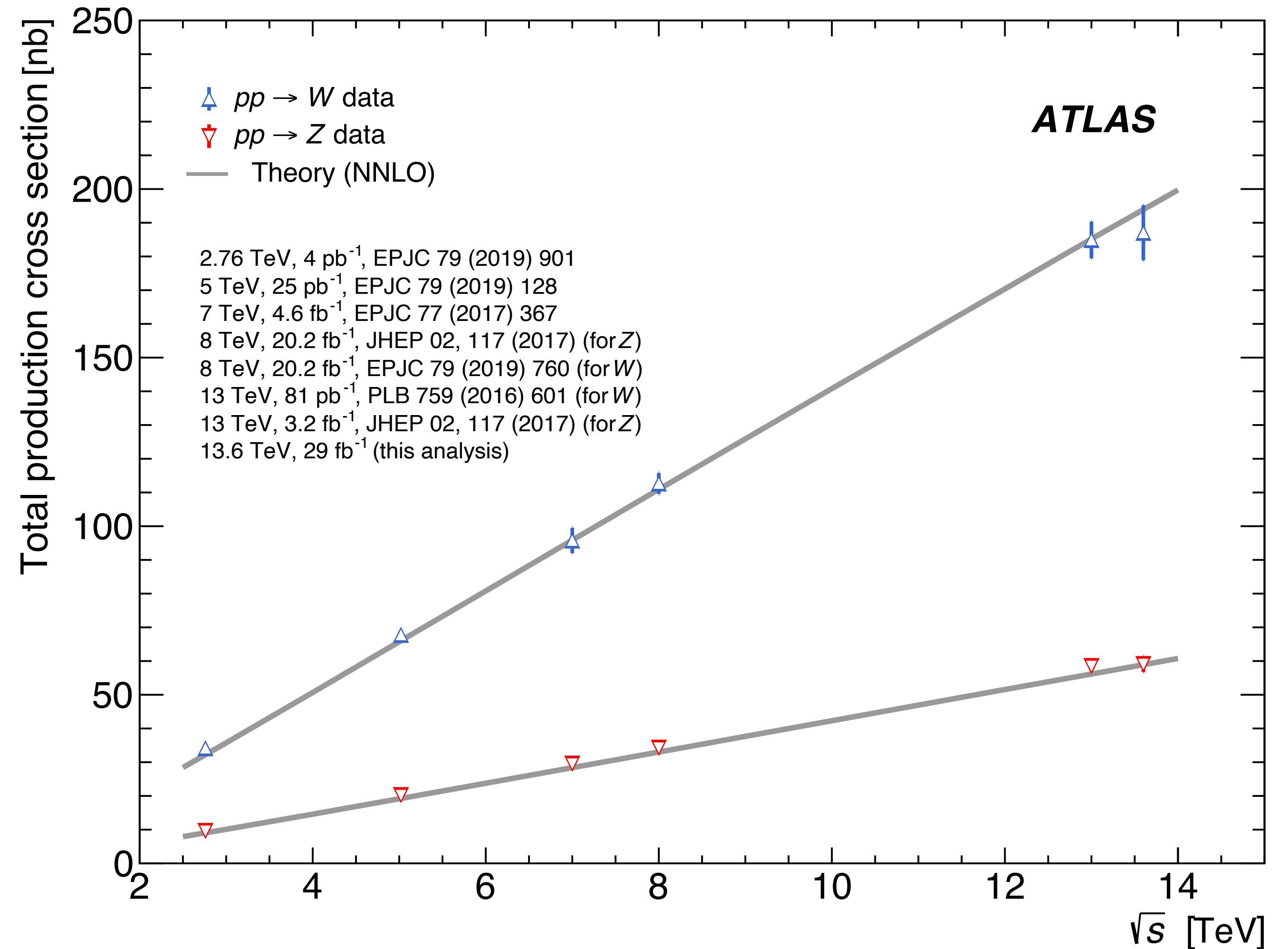
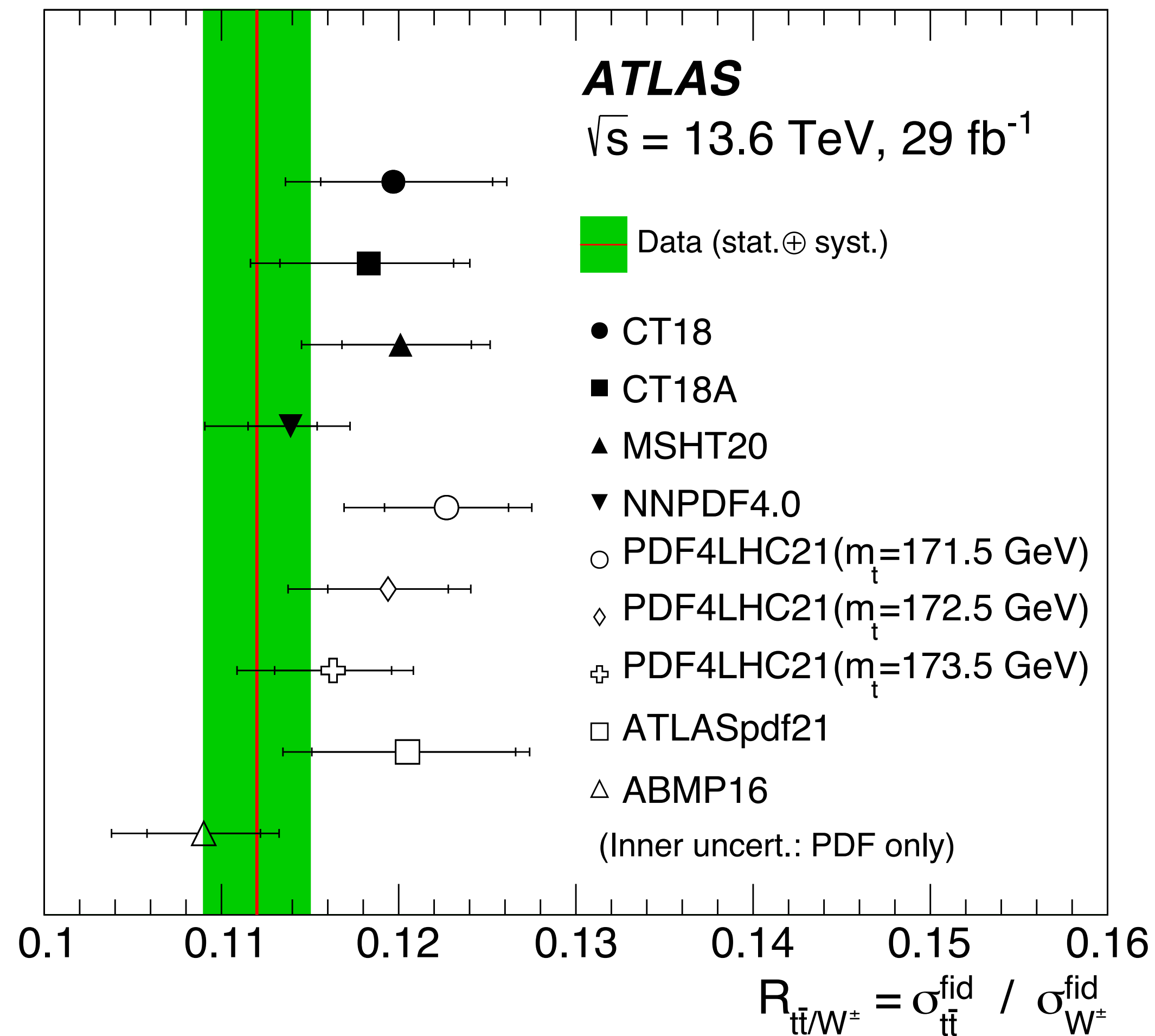
Overview of  $\Gamma_W$  measurements



## W boson width vs mass

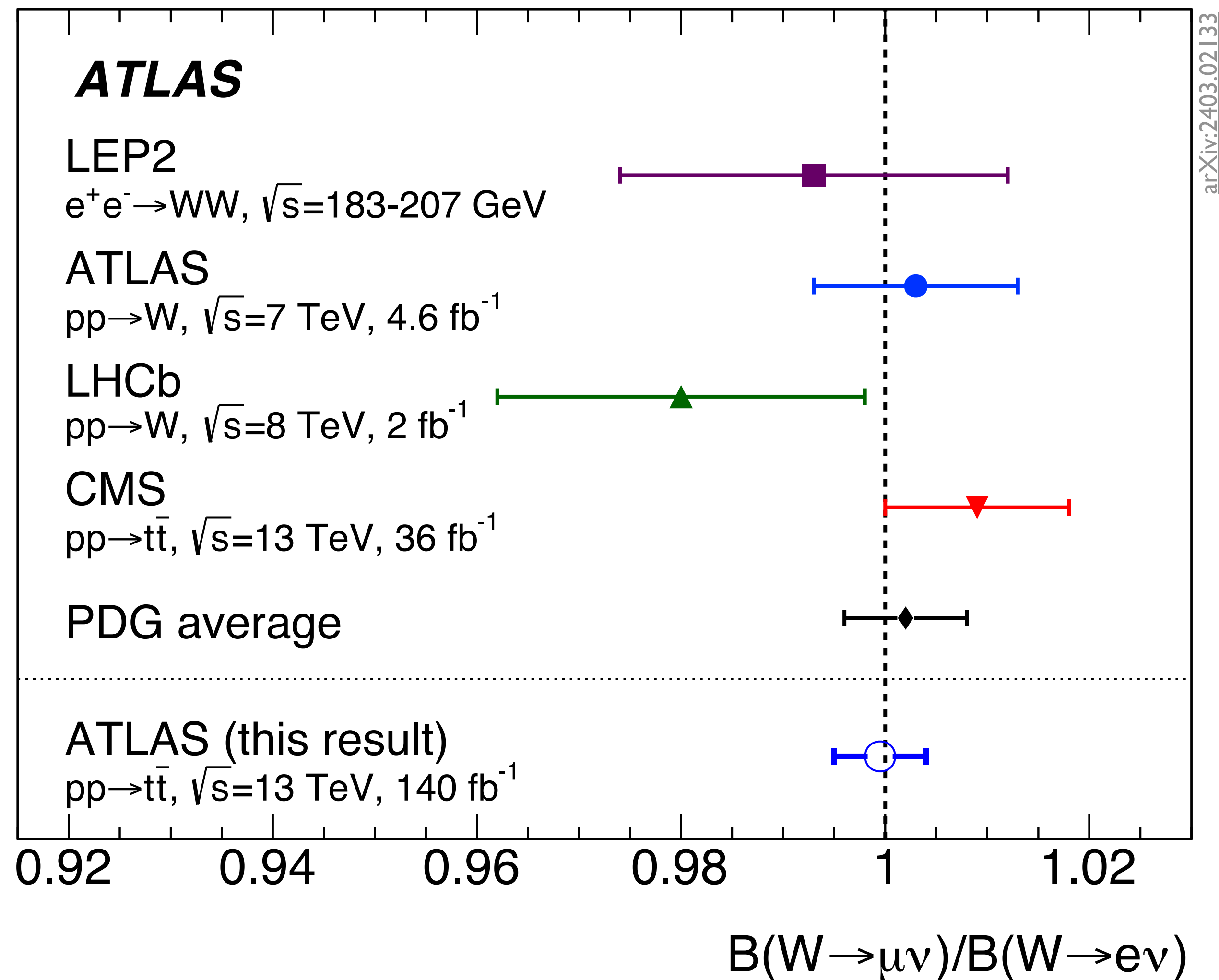
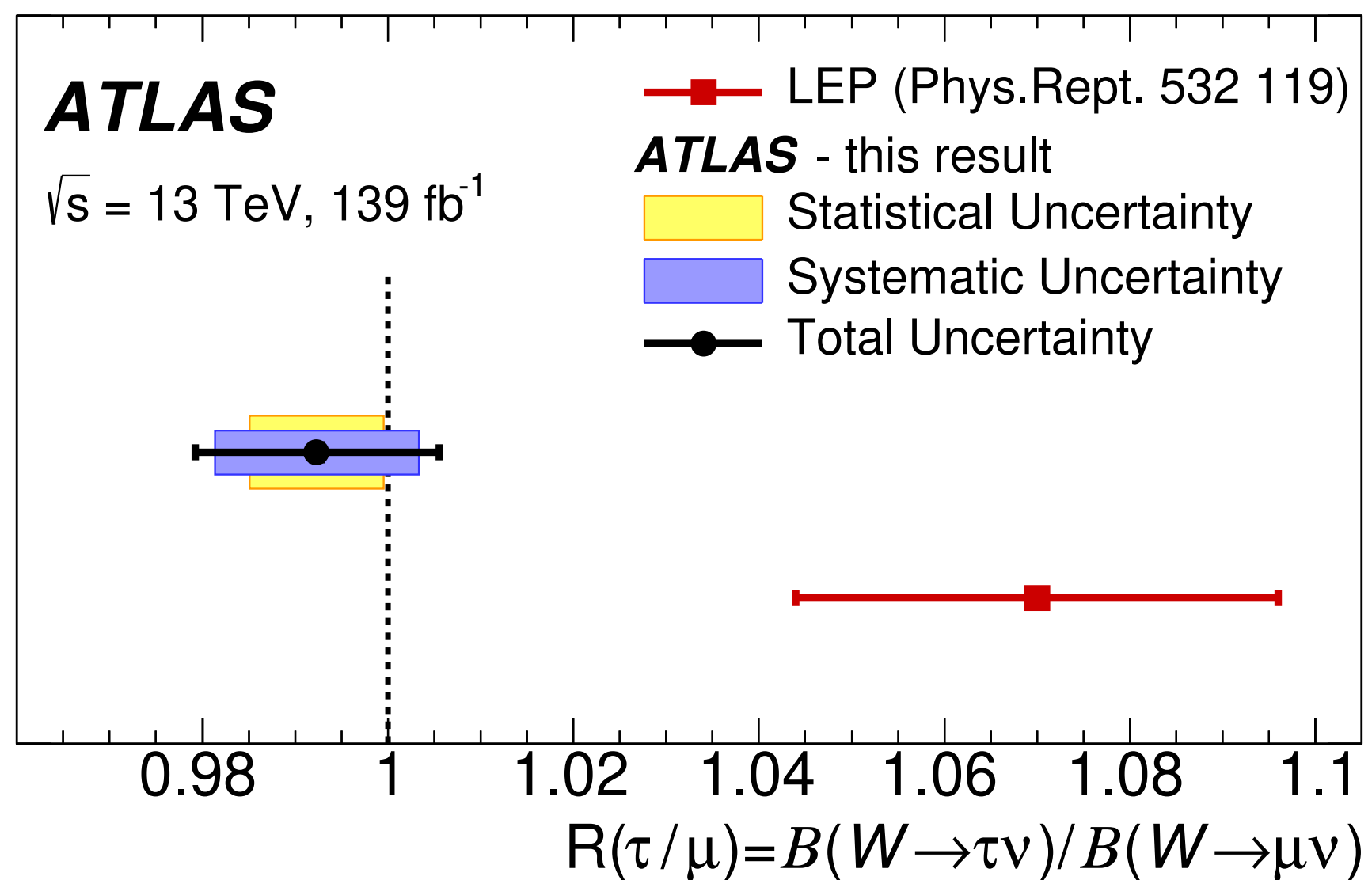


## Weak boson production at 13.6 TeV: total, fiducial cross sections and ratios



# Lepton Universality

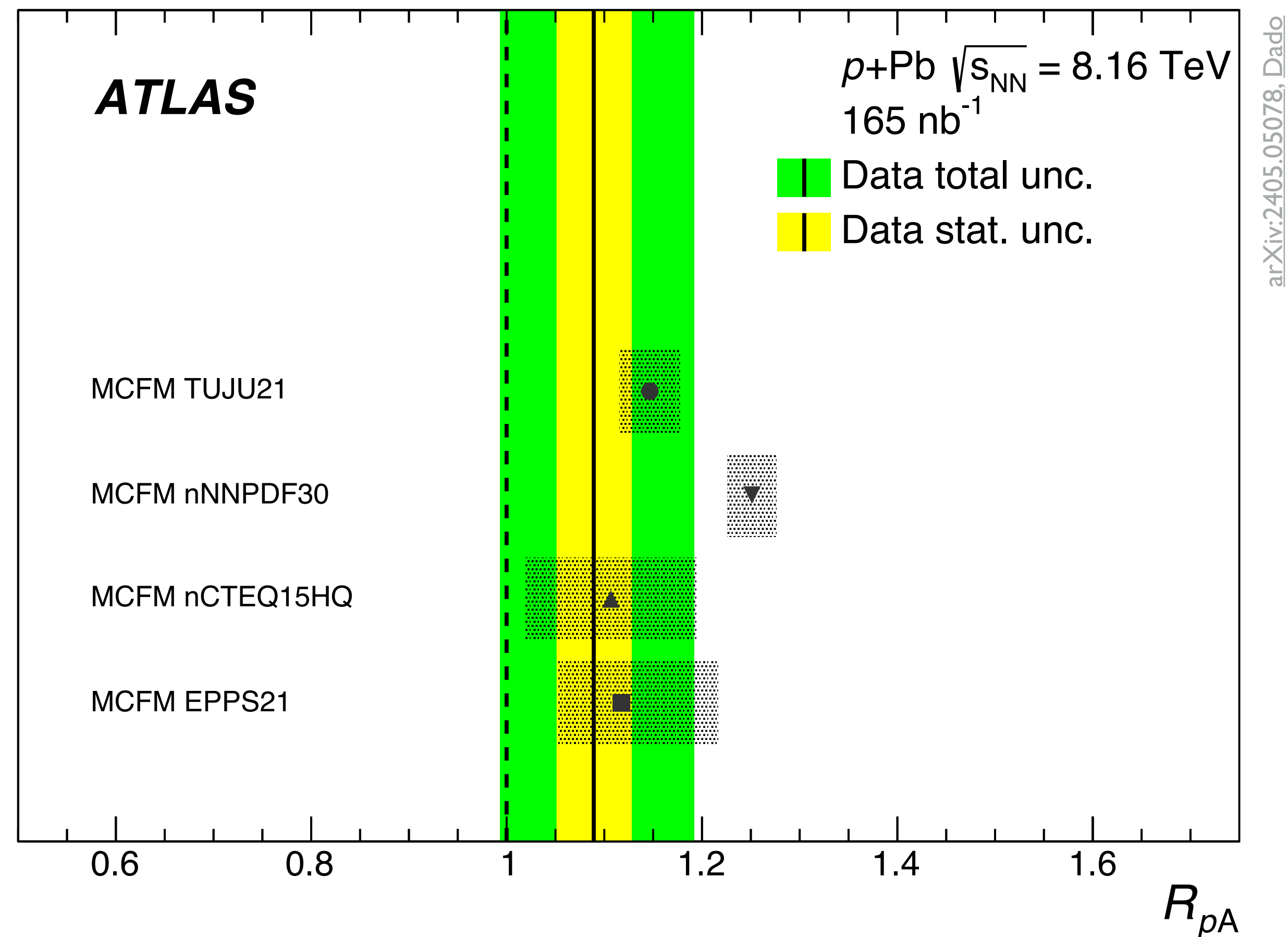
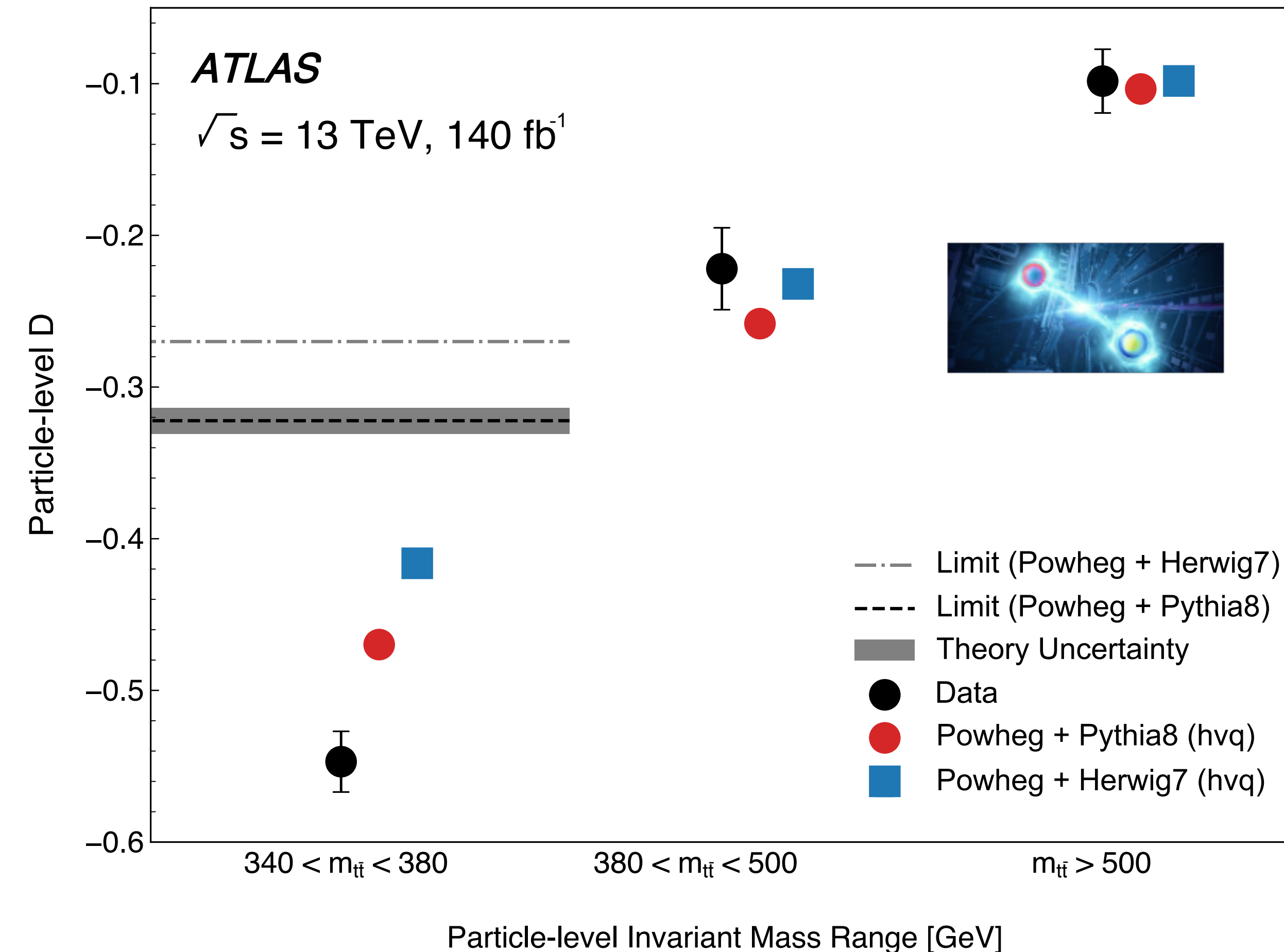
- Lepton universality in **W decays** to electrons and muons from top-pair events
- **2x improvement** on single-experiment precision
- **0.45% precision**: more precise than **current world average**



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

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

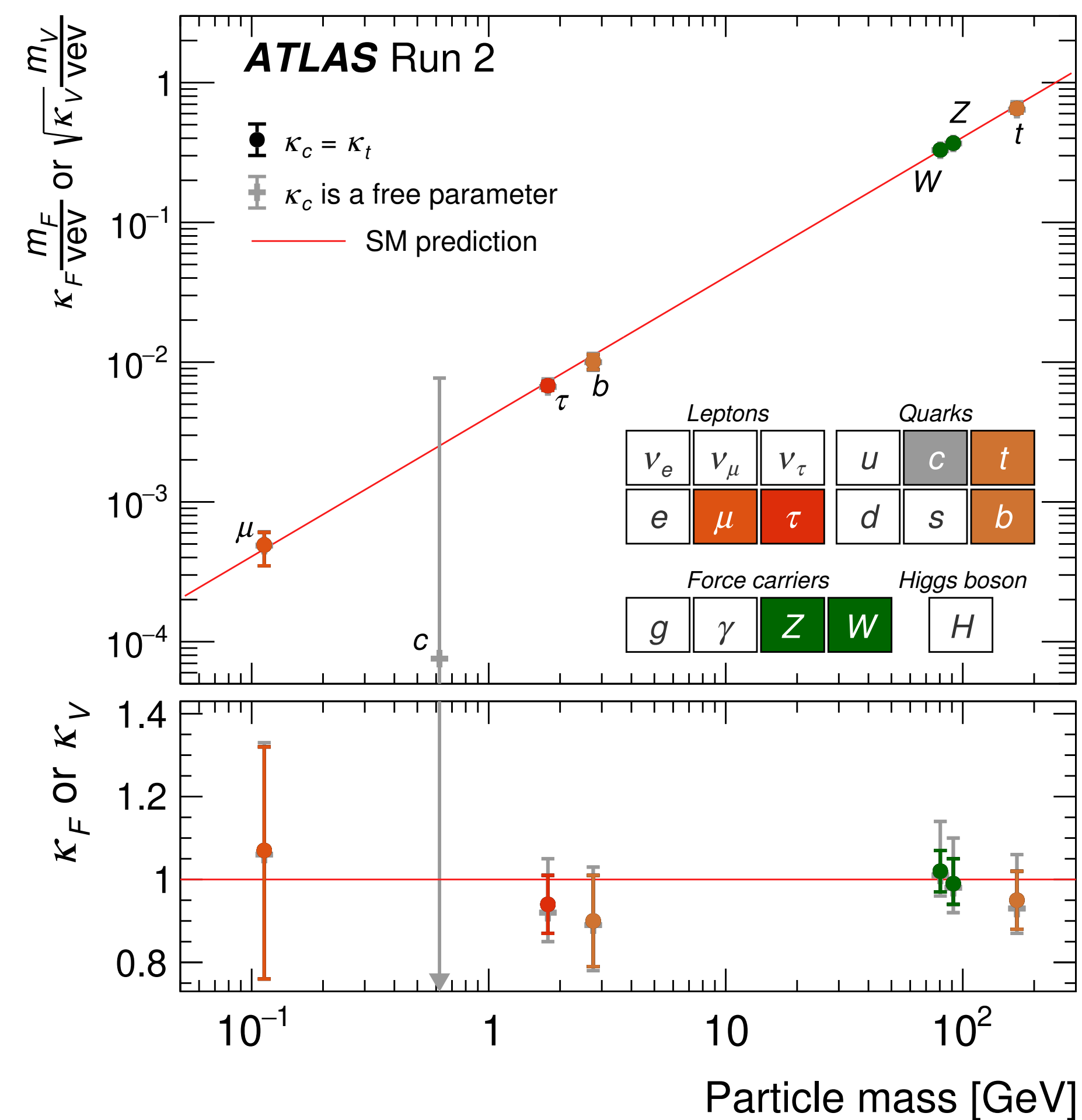
$$\sigma_{t\bar{t}} = 58.1 \pm 2.0(\text{stat.})_{-4.4}^{+4.8}(\text{syst.}) \text{ nb}$$



# The SM Higgs Boson

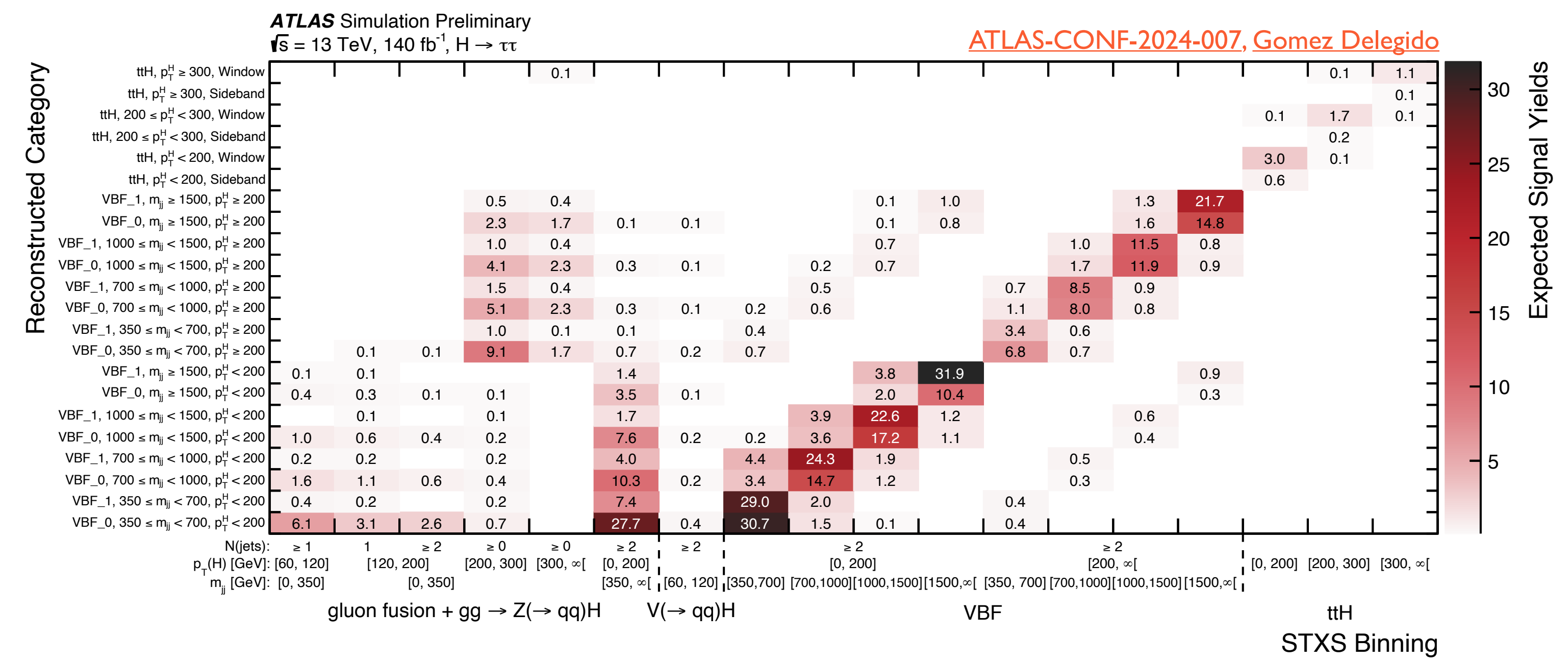
- **Mass** from Run 1+2 combination:  
 $m_H = 125.11 \pm 0.11 \text{ GeV}$
- Indirect Higgs **width** from offshell:  $\Gamma_H = 4.6^{+2.6}_{-2.5} \text{ MeV}$
- Probe **couplings** by measuring accessible production and decay modes
  - Evidence for  $Z\gamma$  decay ( $3.4\sigma$ ) (w/ CMS)
- Ongoing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

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



# Differential Higgs Production w/ $\tau$

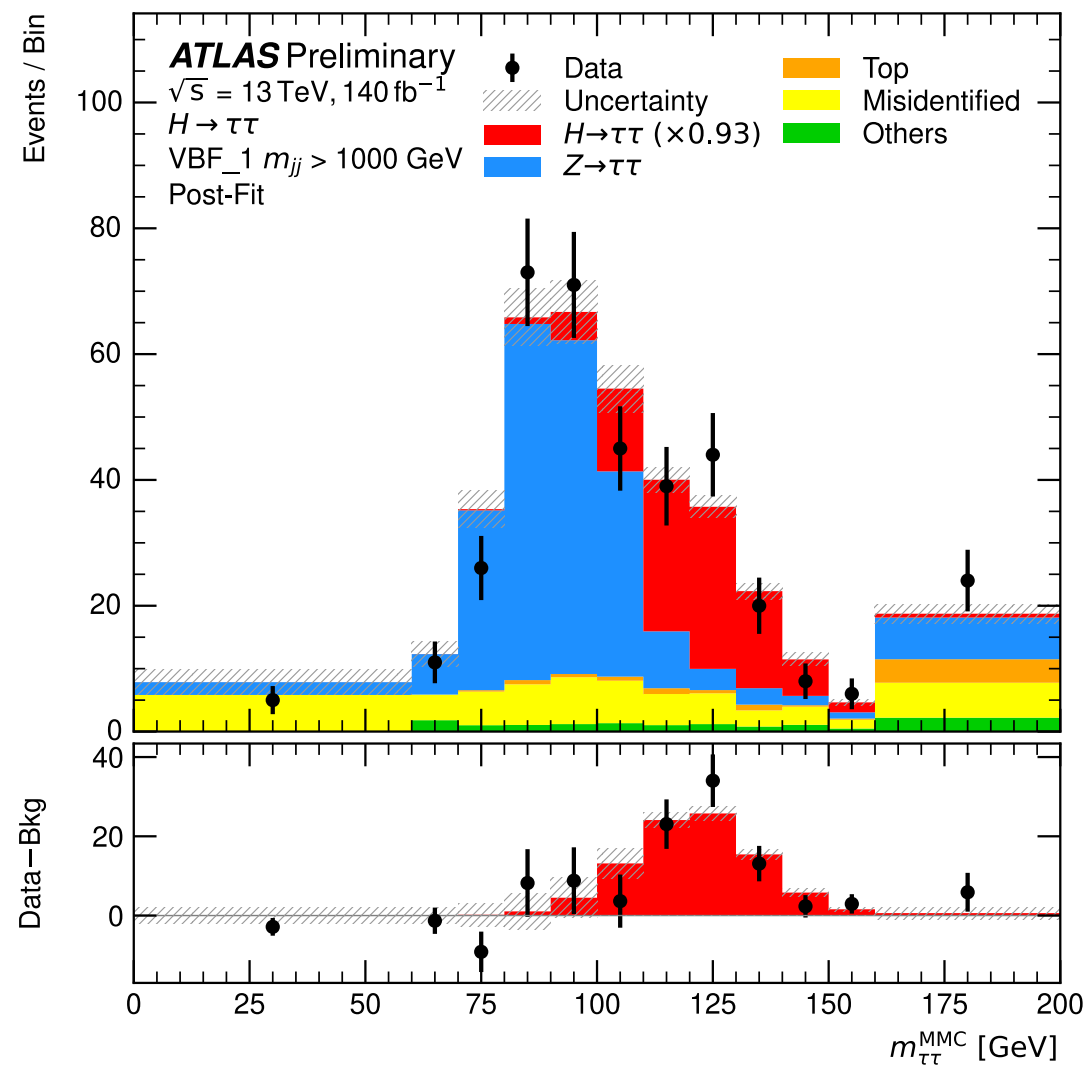
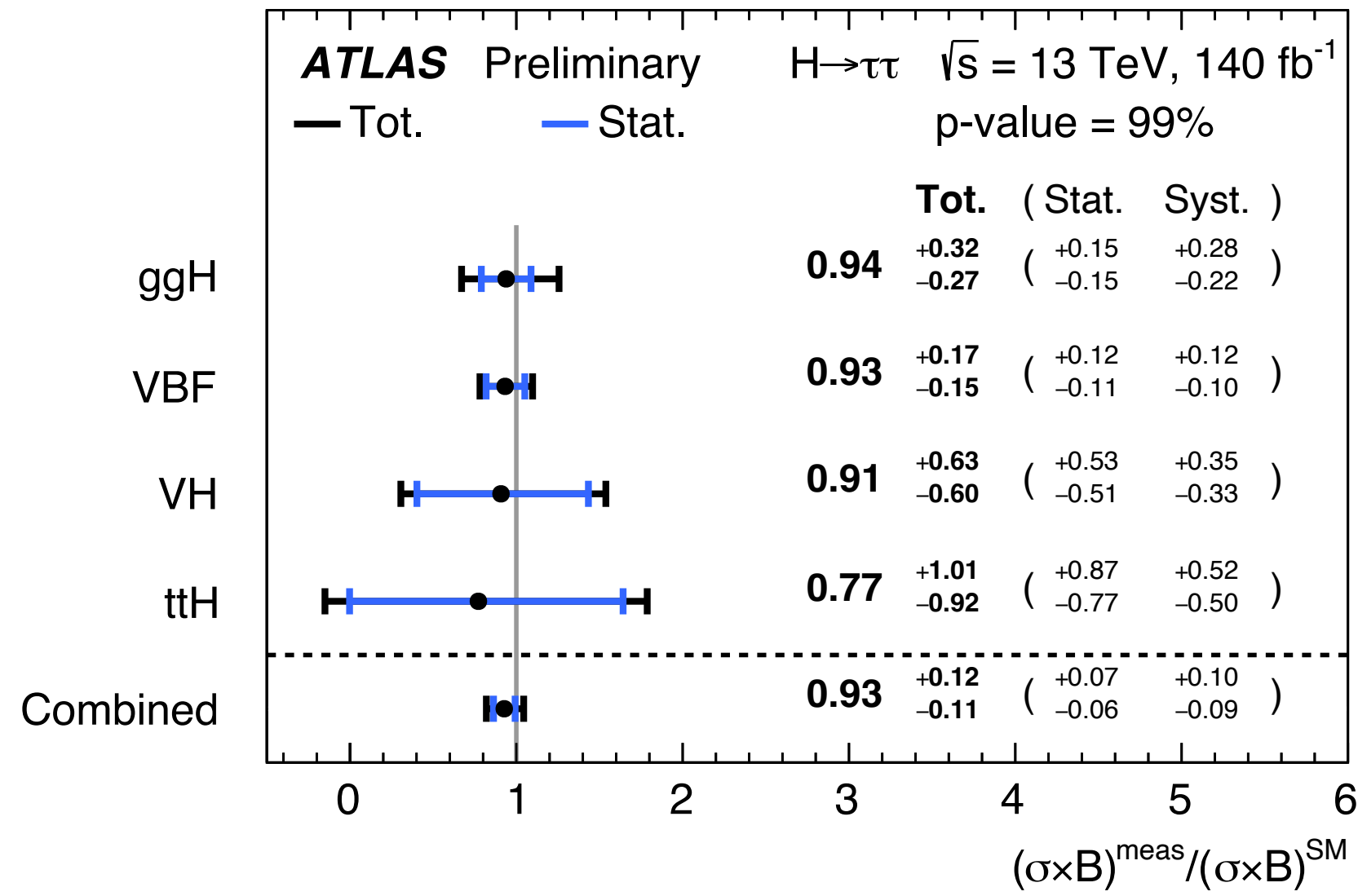
- Differential measurements of Higgs production with  $\tau$  **decays** in 18 STXS bins
- Most precise **VBF production** measurement; also probes **high  $p_T^H$**
- Part of a suite of **Run-2 analyses** to provide our final word on the Higgs in that dataset
- Range of **ML** methods: e.g. BDT for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



\*STXS = Simplified Template Cross-Section

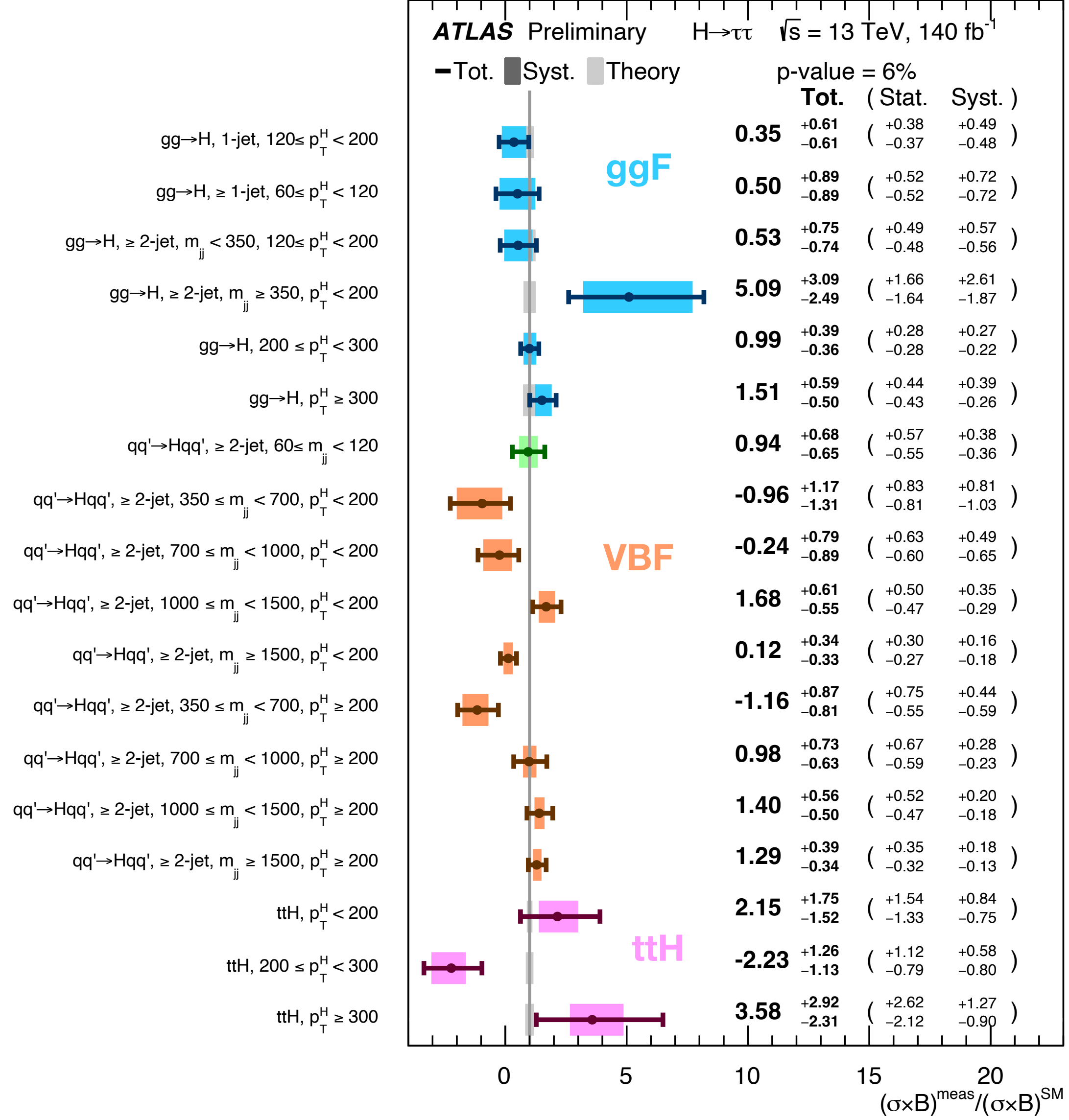
**NEW**

# $H \rightarrow \tau^+ \tau^-$ STXS Results



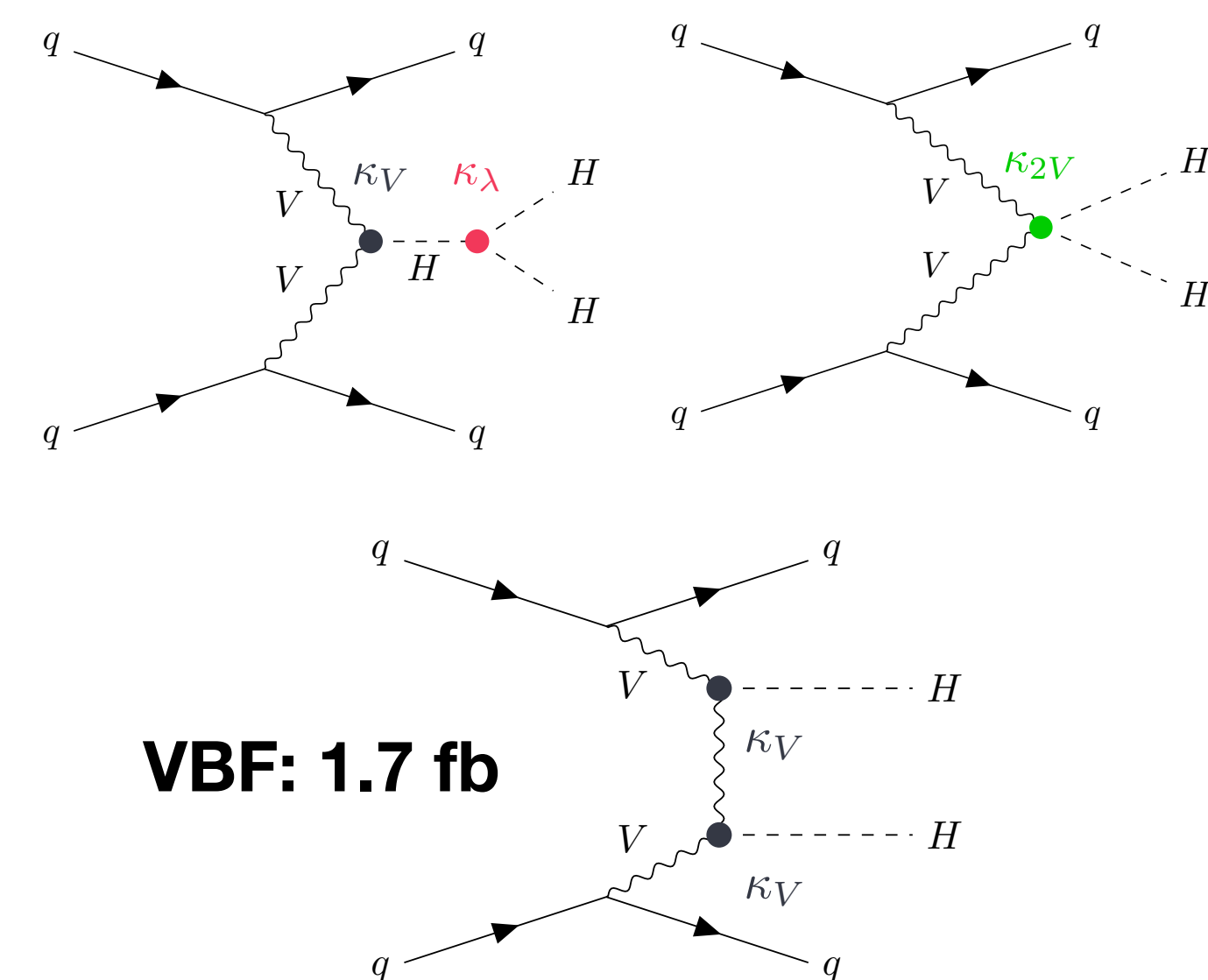
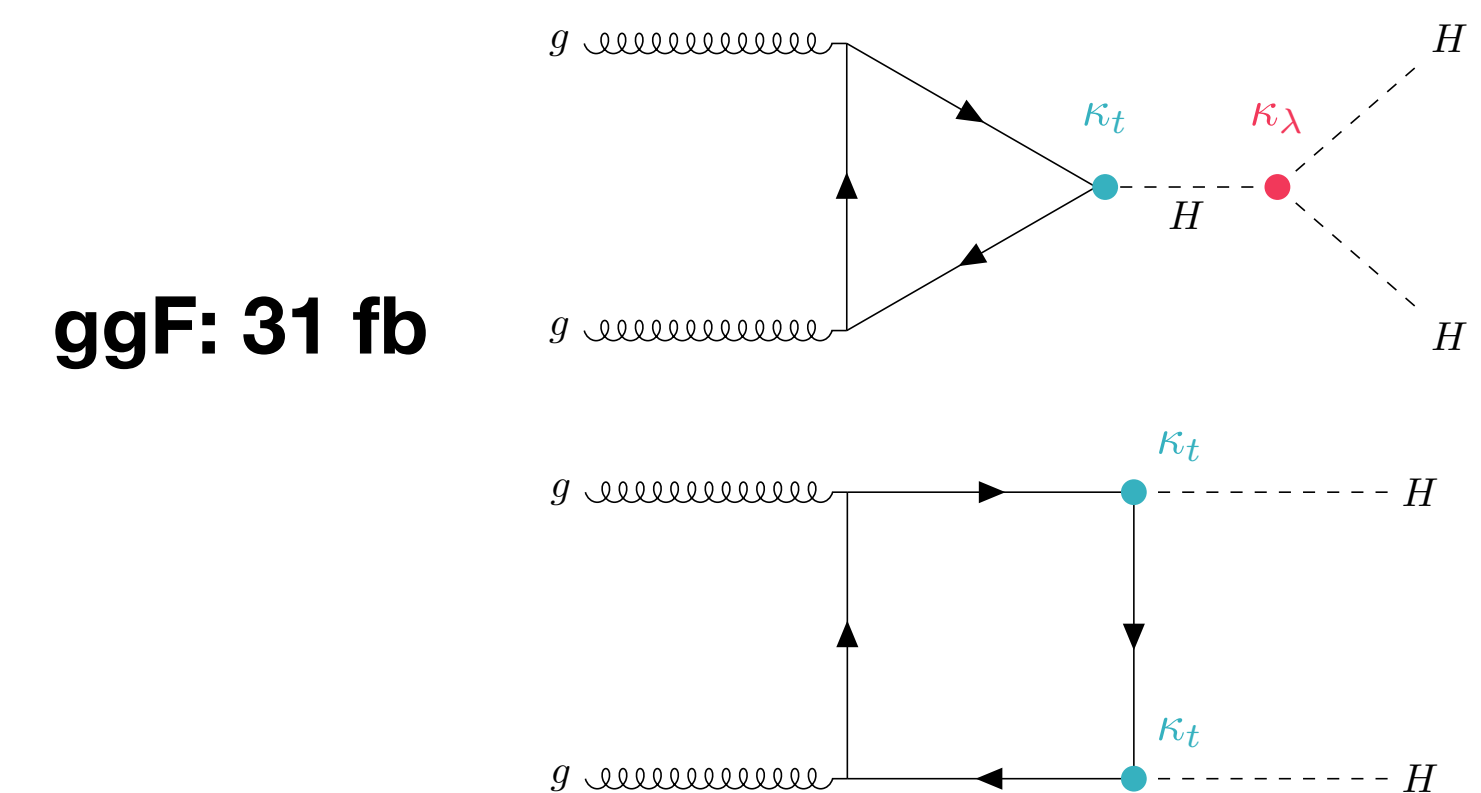
First measurement  
 in high  $m_{jj}$  and high

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



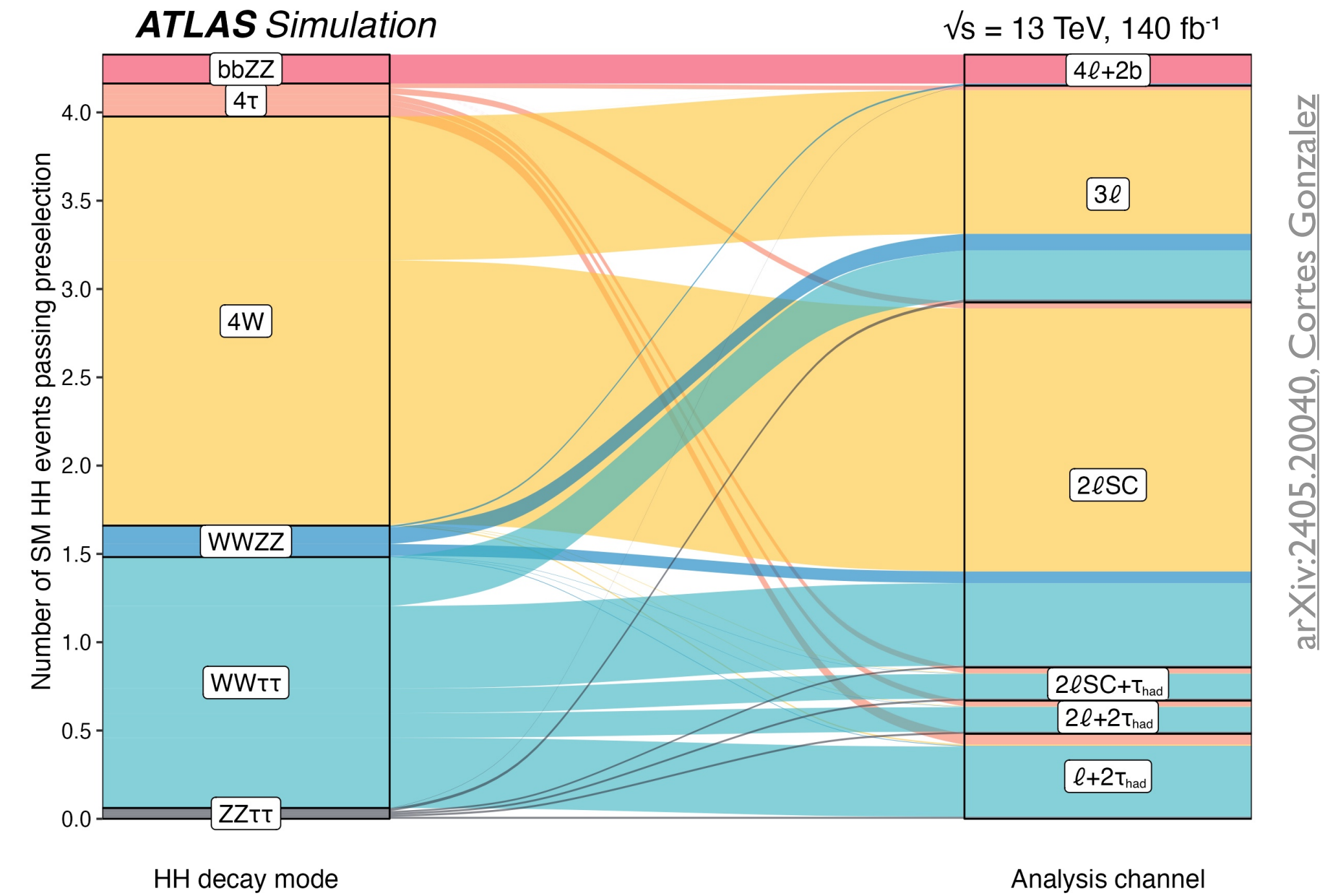


- **HH production** to directly probe Higgs self-coupling and hence electroweak symmetry breaking (EWSB) mechanism
- **New combined result** using the two major production modes: **gluon-gluon fusion (ggF)** and **vector boson fusion (VBF)**
  - VBF also provides sensitivity to  **$\kappa_{2V}$**
- Combines **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  $c_{tthh}$

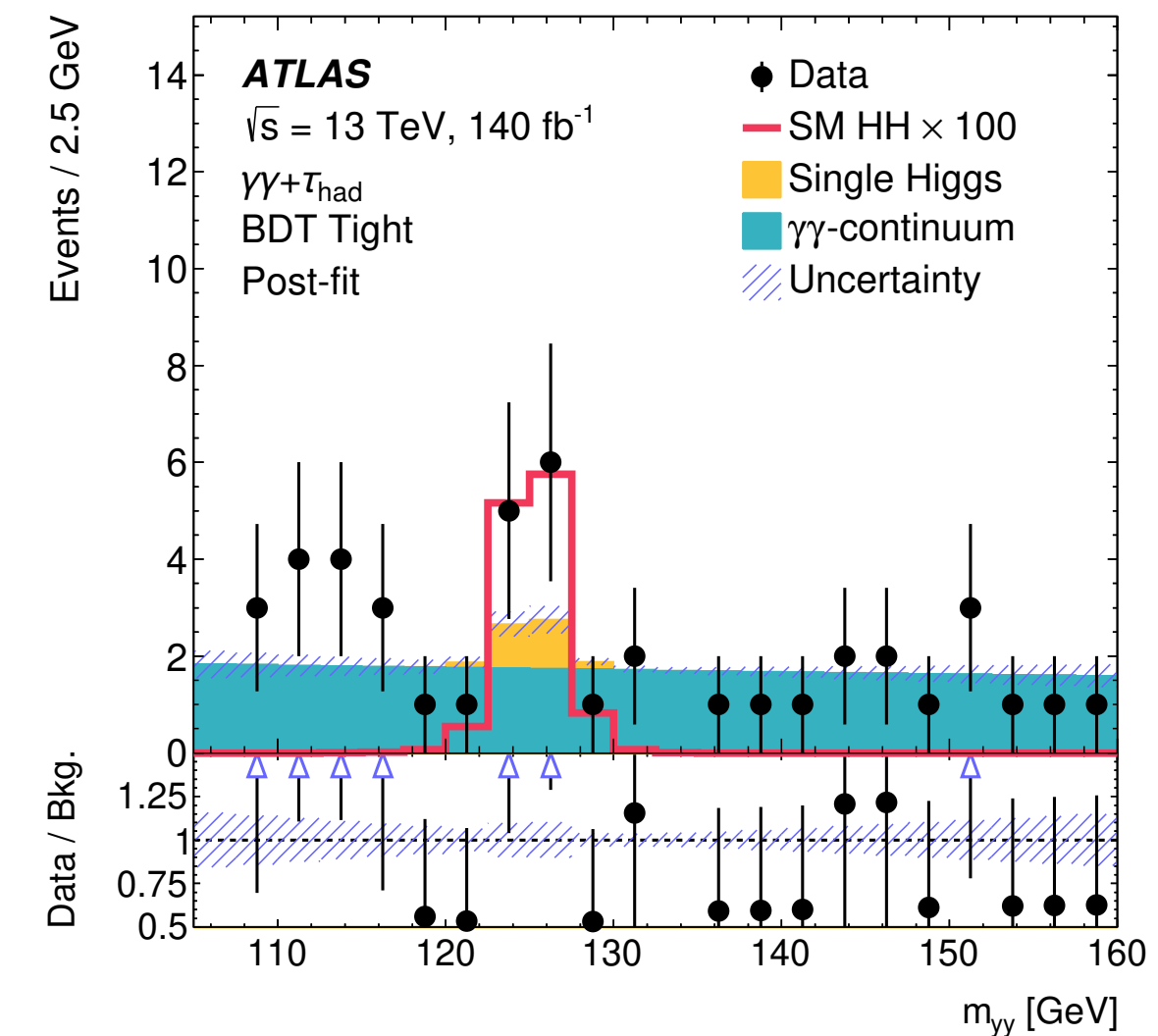
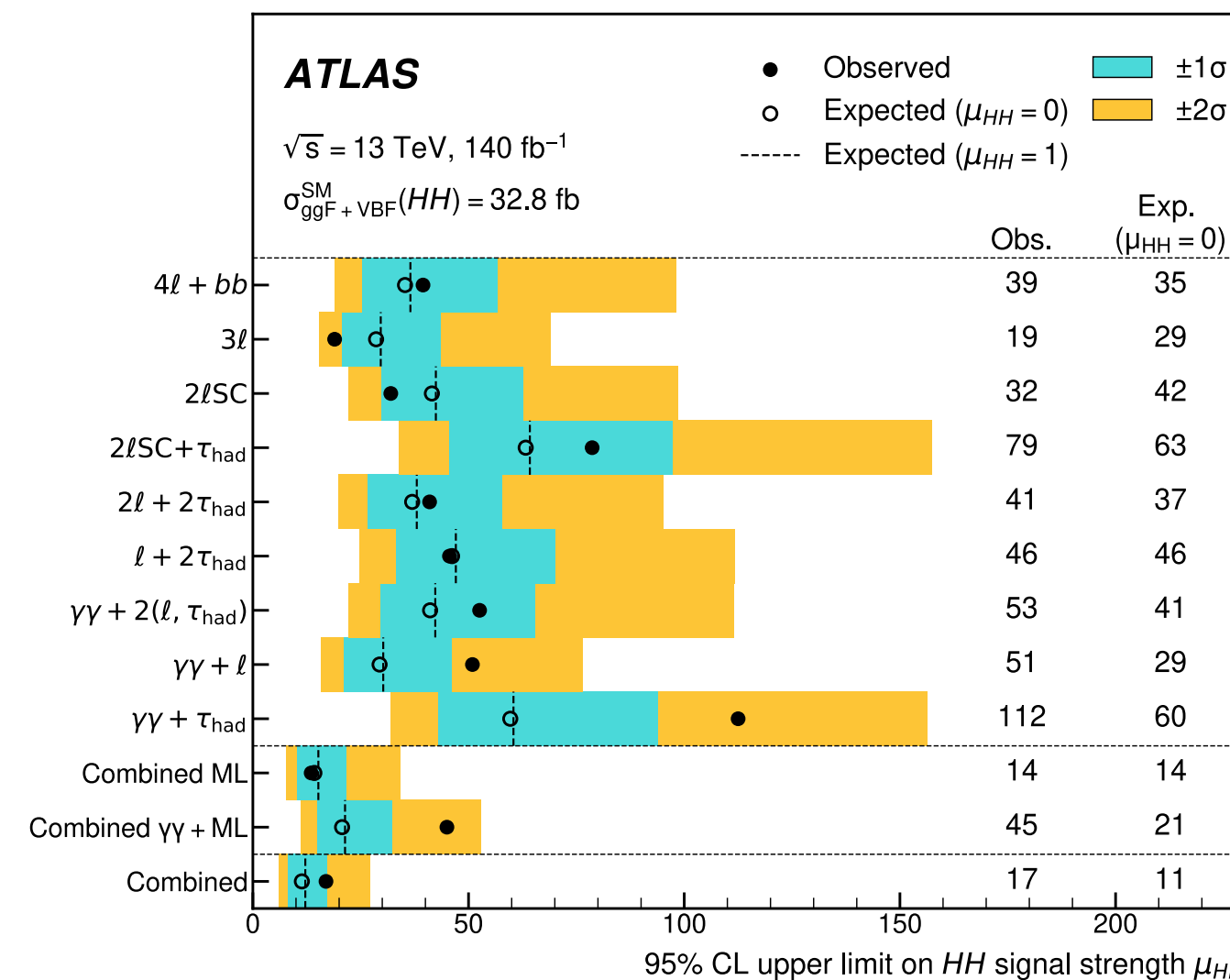


# HH with multiple leptons

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



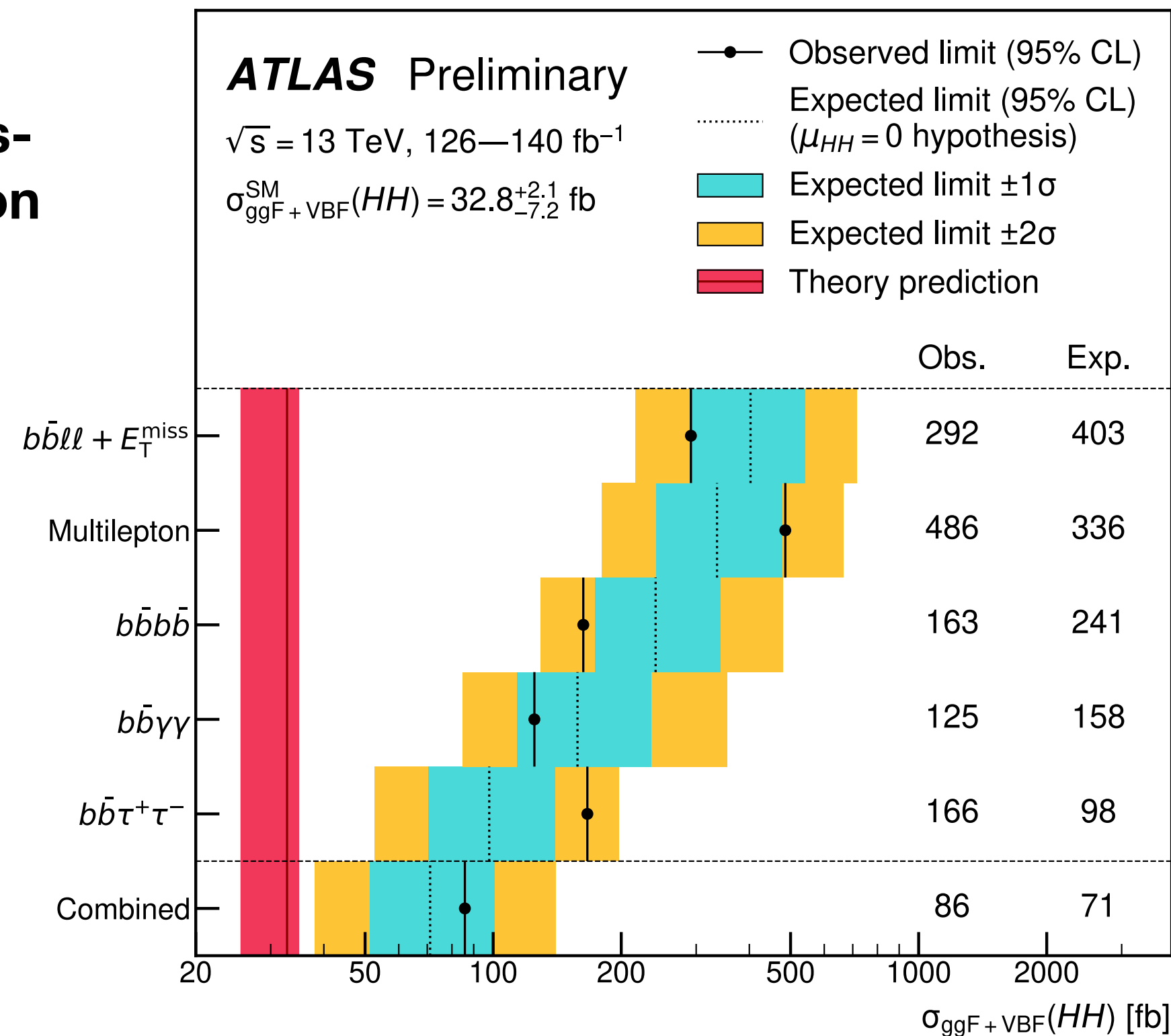
arXiv:2405.20040, Cortes Gonzalez



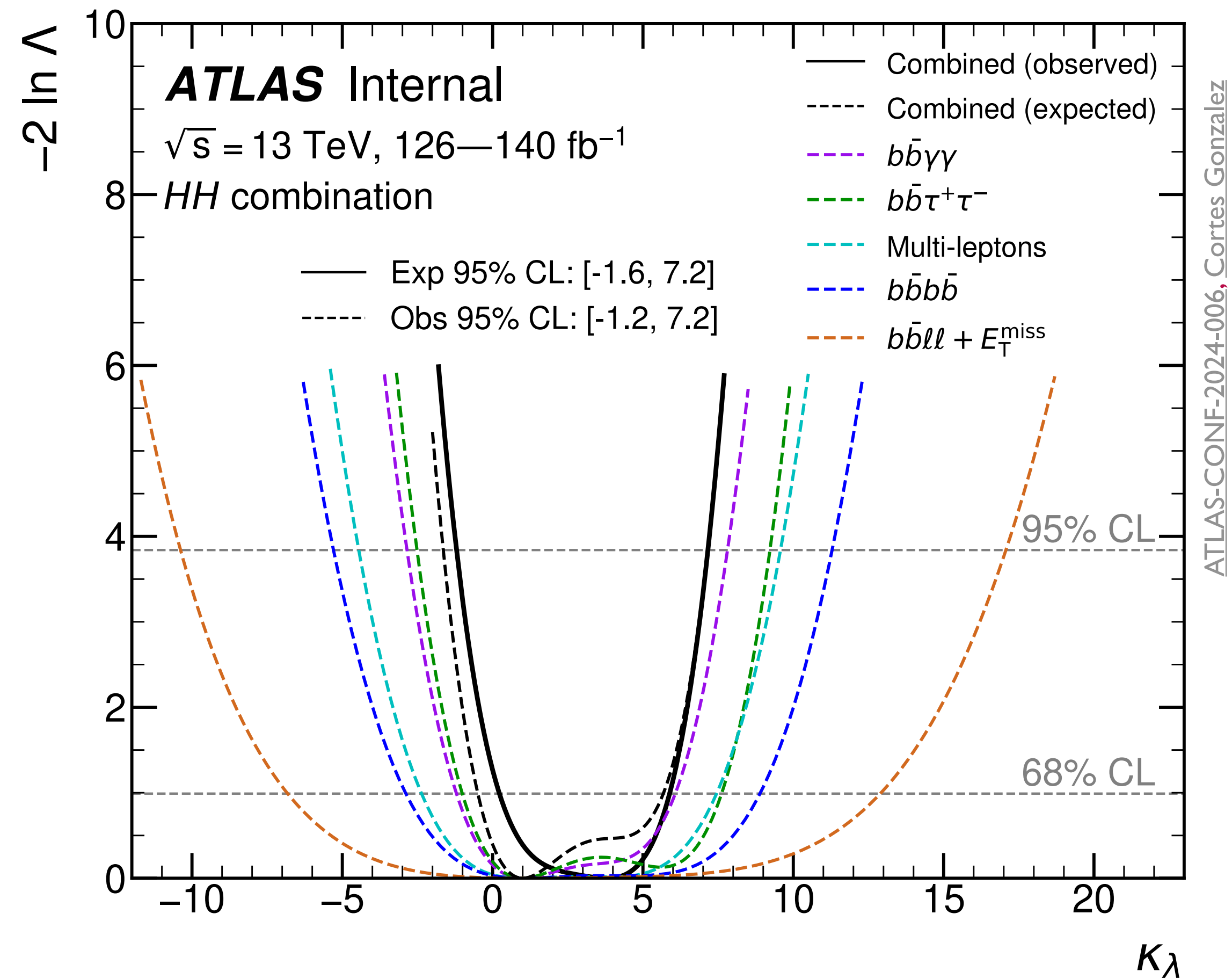
# HH Combined Results

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

## Cross-section



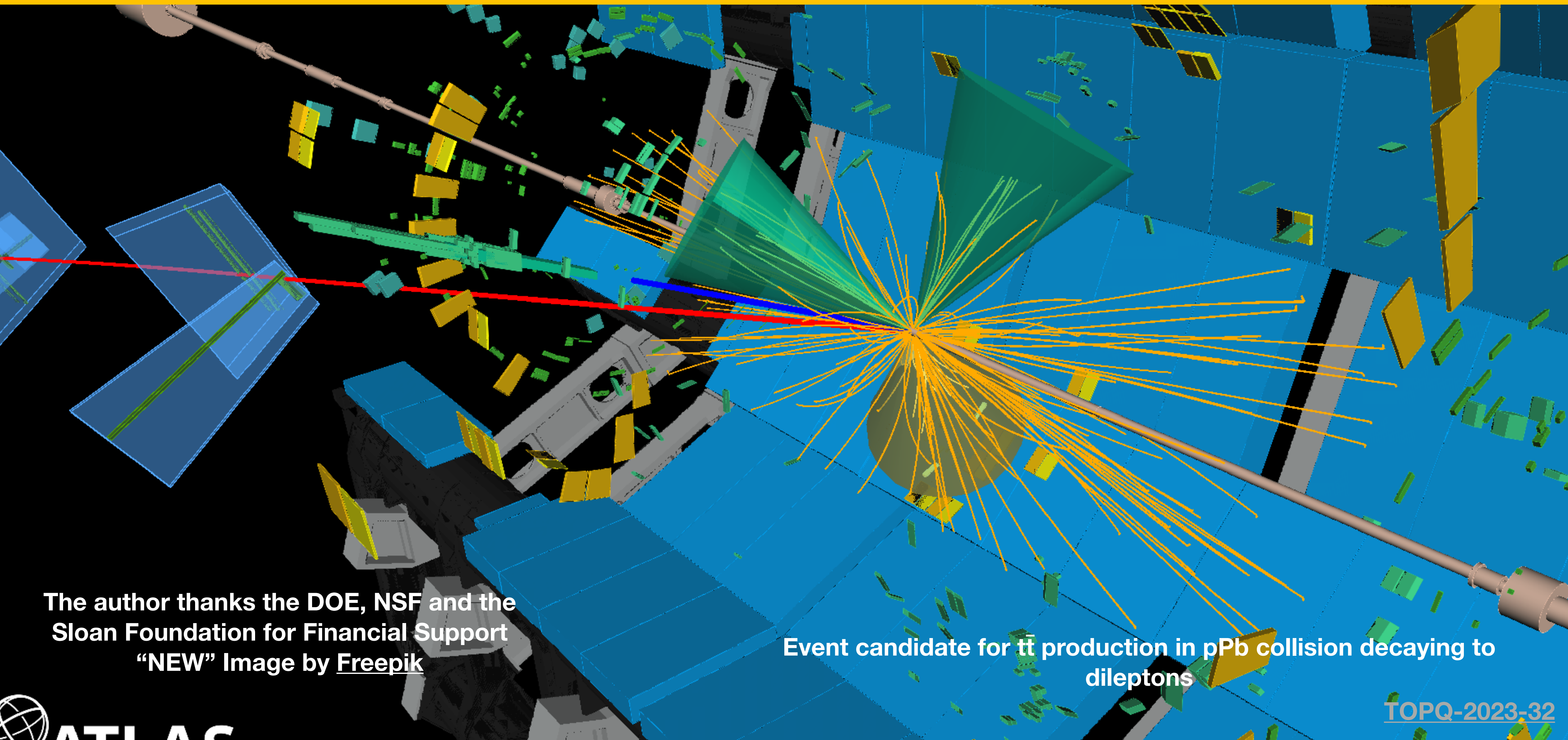
## Self coupling



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

- 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  $1\sigma$  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

- 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