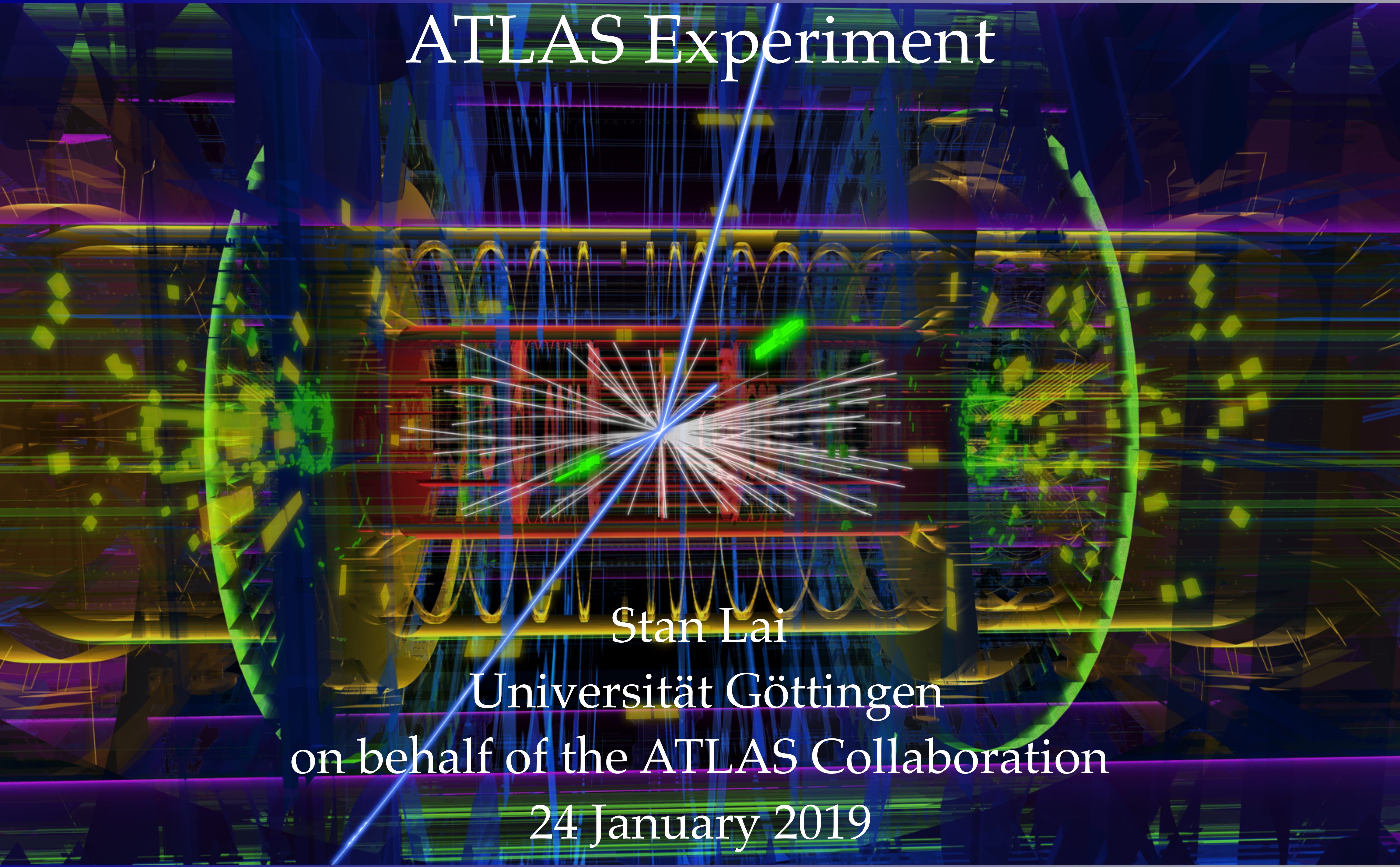
Latest Results from the ATLAS Experiment



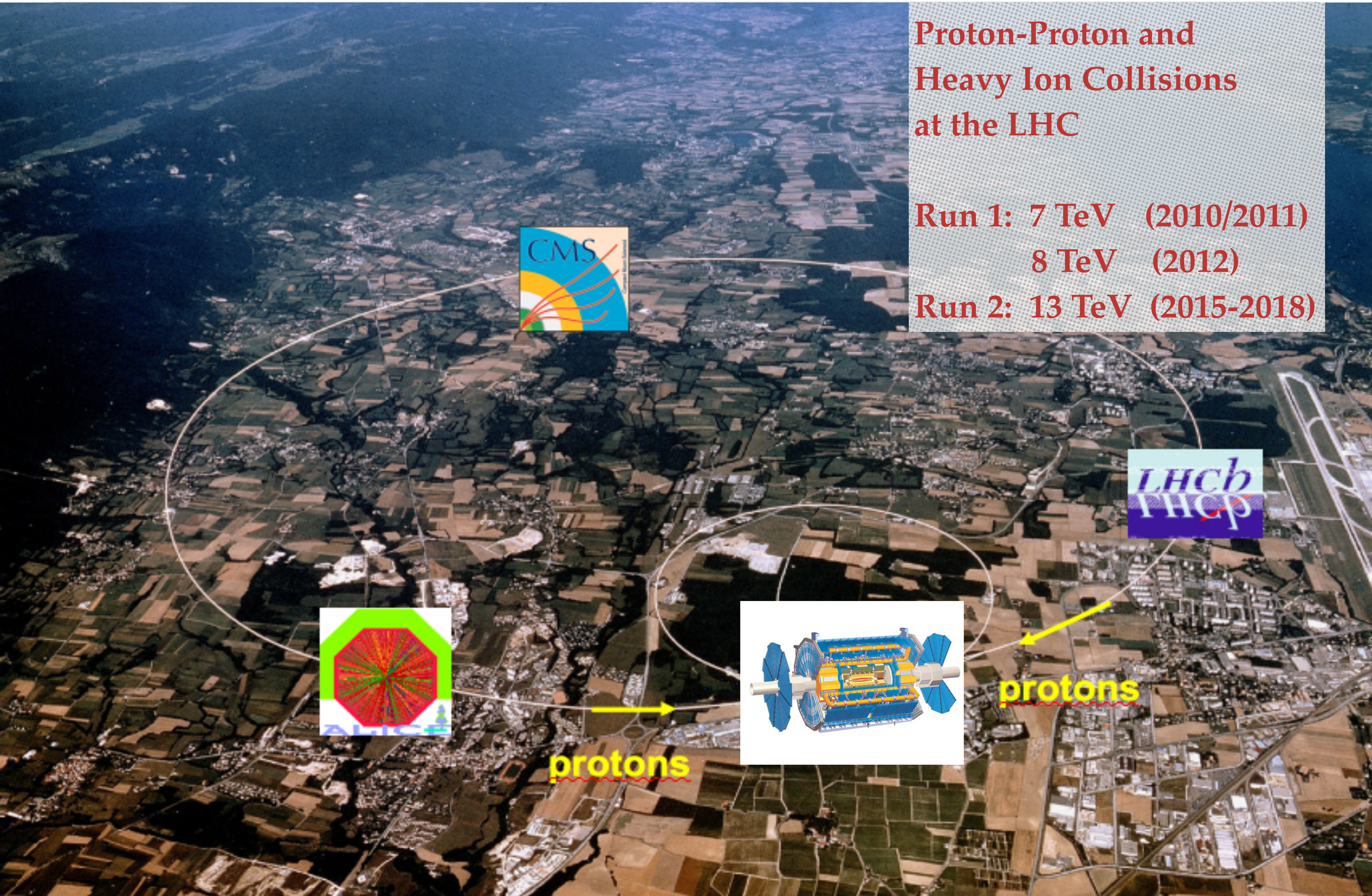
Stan Lai

Universität Göttingen

on behalf of the ATLAS Collaboration

24 January 2019

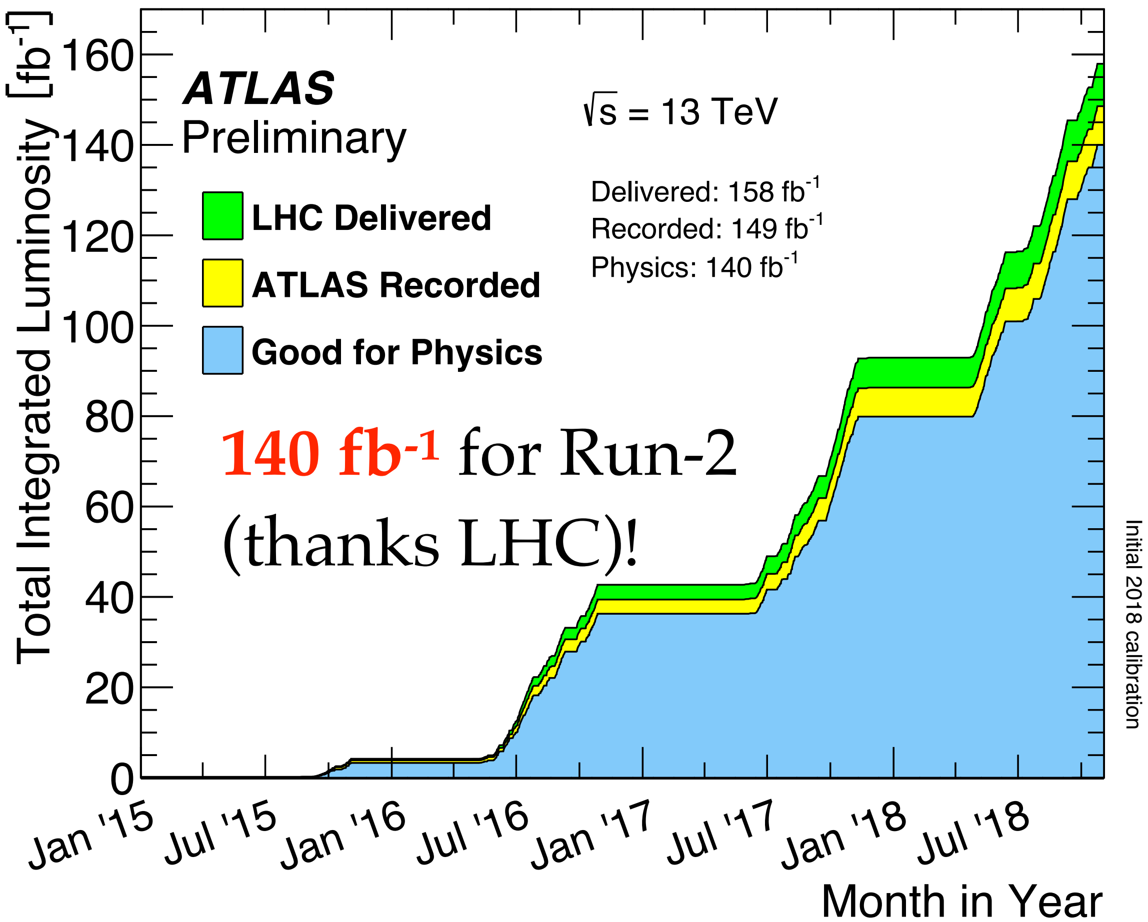
The ATLAS Detector

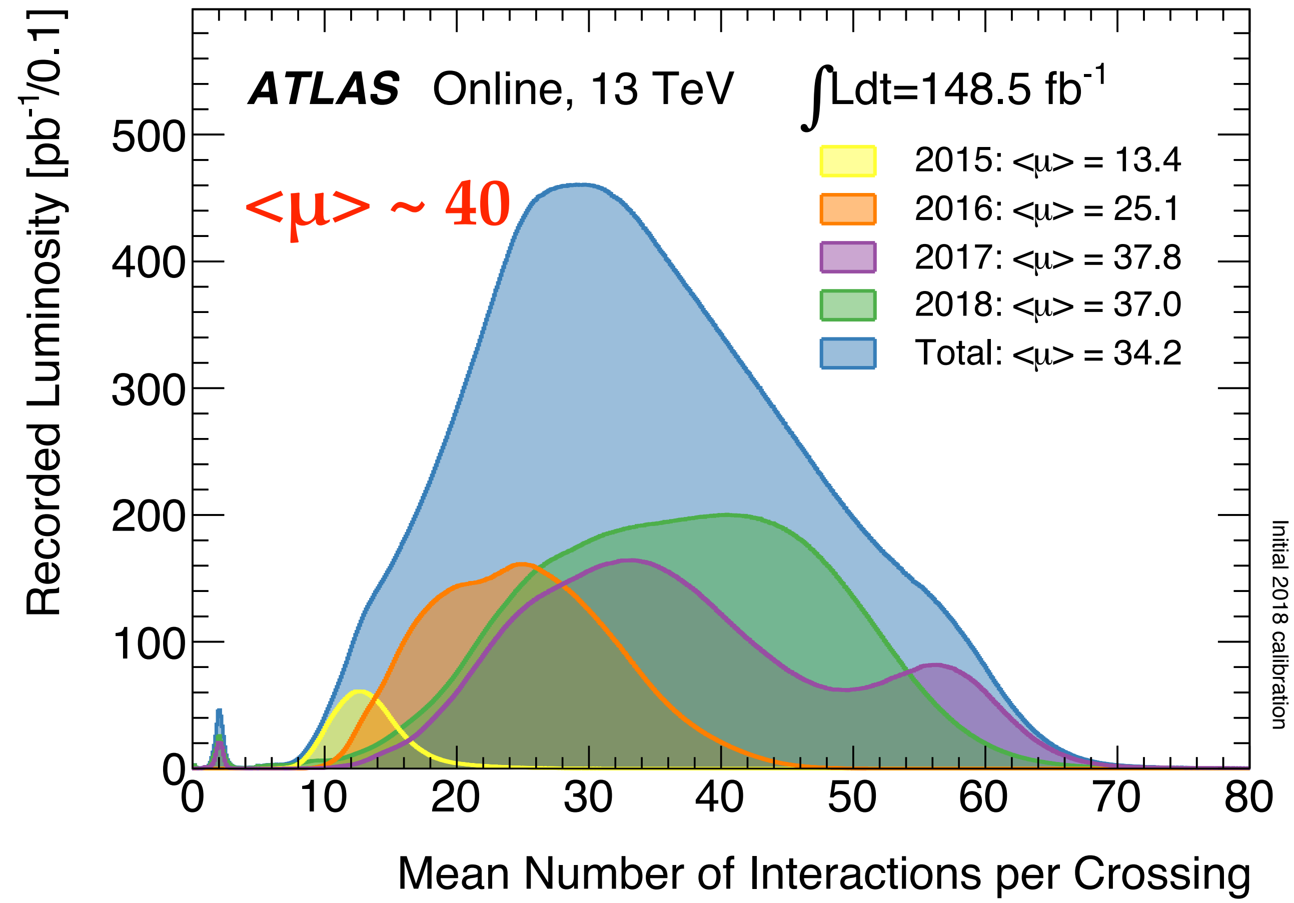


Proton-Proton and
Heavy Ion Collisions
at the LHC

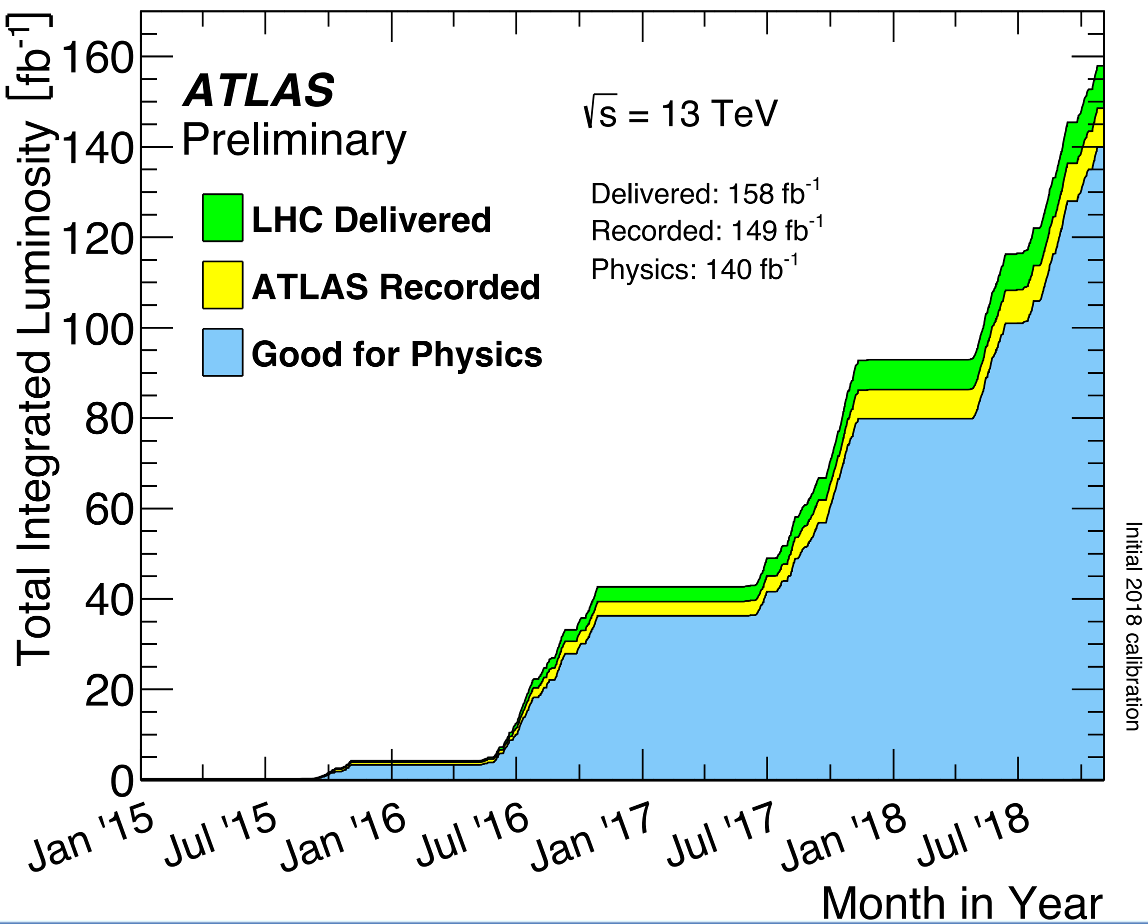
Run 1: 7 TeV (2010/2011)
8 TeV (2012)
Run 2: 13 TeV (2015-2018)

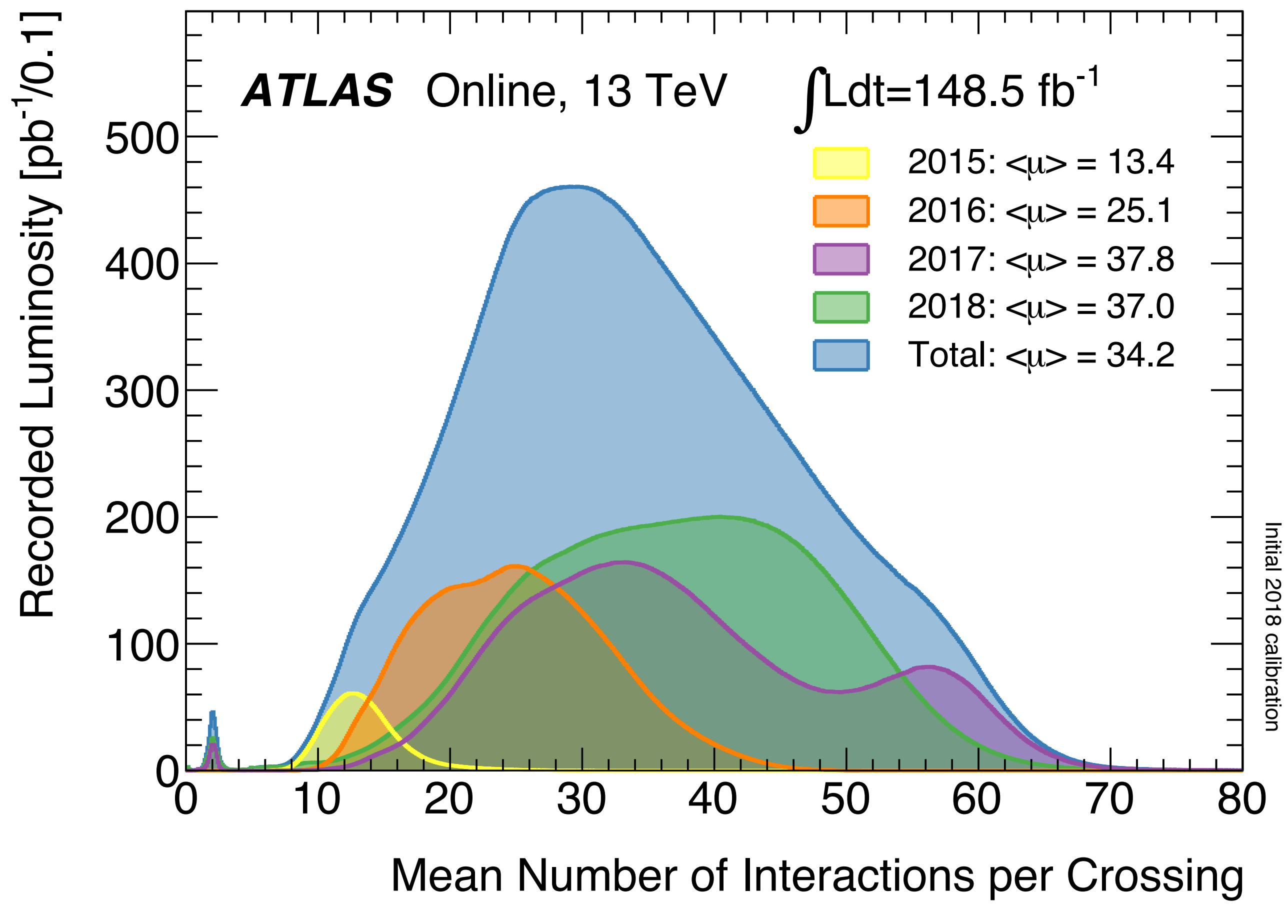
The Run-2 Legacy





The Run-2 Legacy

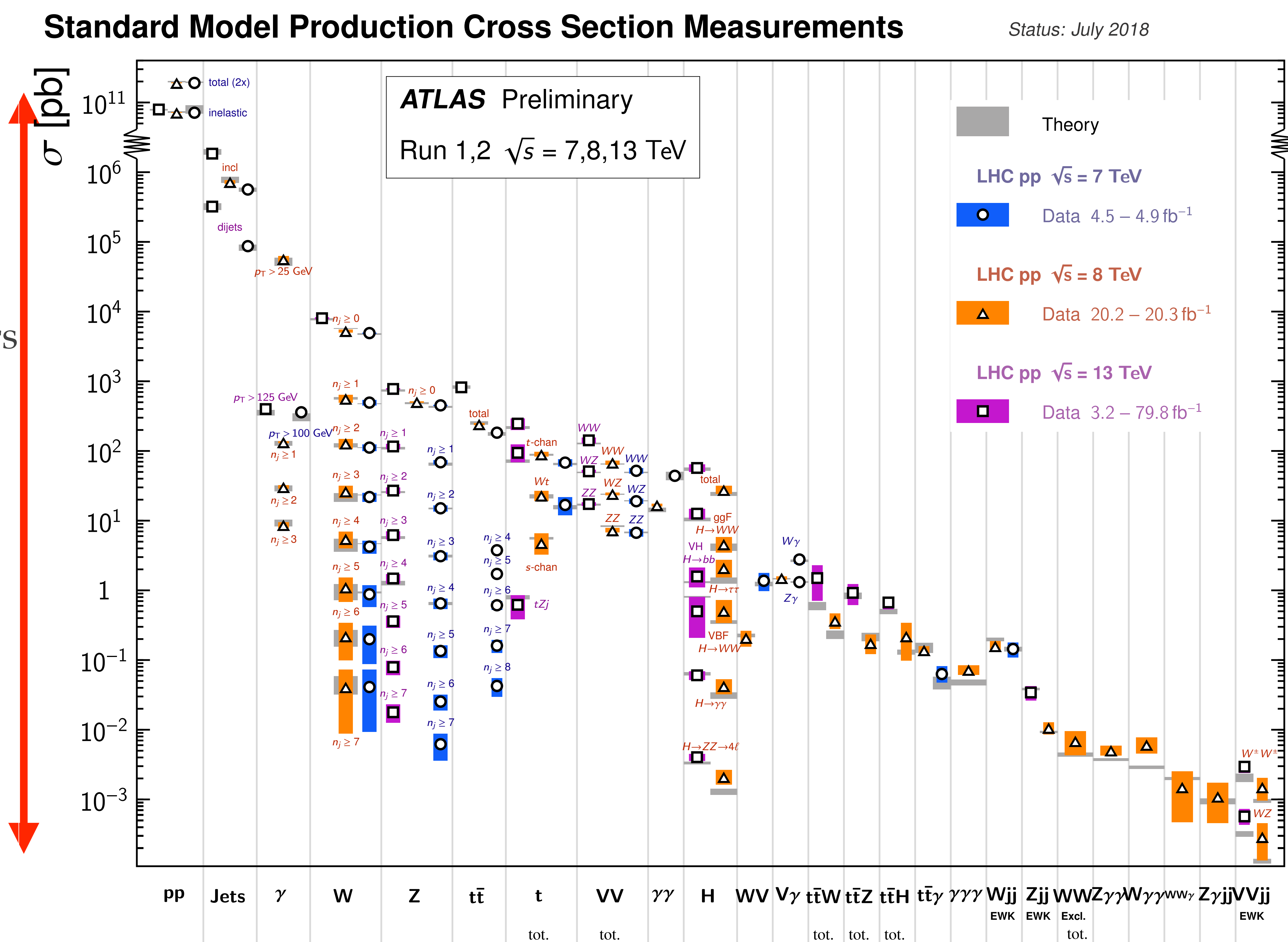




ATLAS pp data: April 25-October 24 2018										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.8	99.8	100	99.7	100	99.8	99.7	100	100	100	99.6
Good for physics: 97.5% (60.1 fb^{-1})										

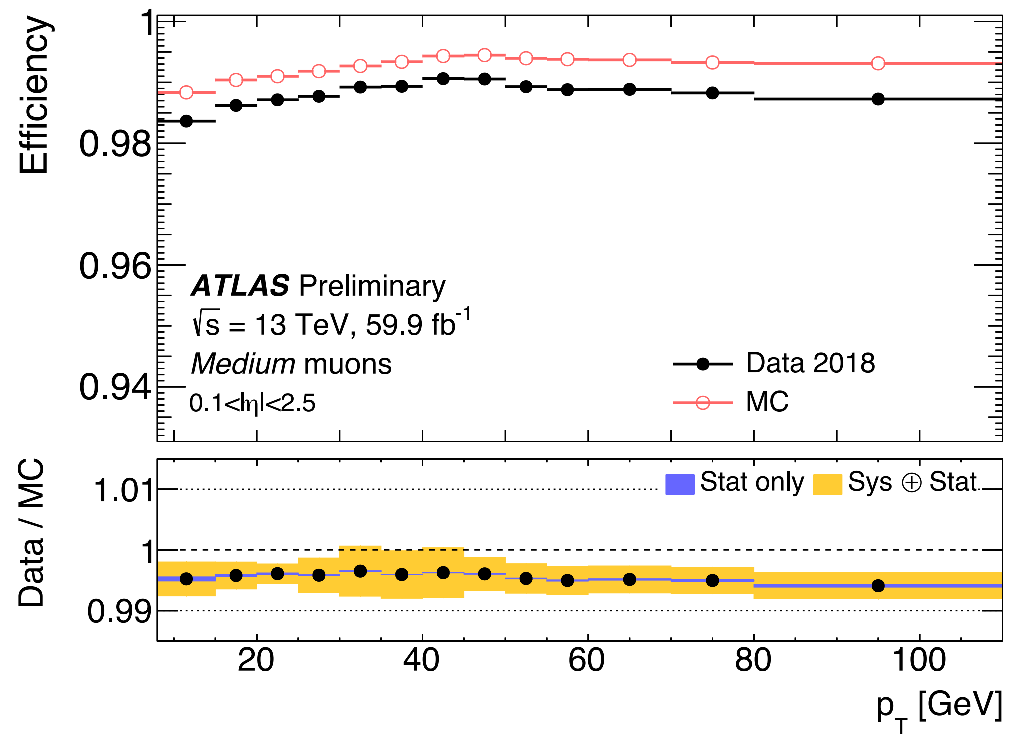
Cross-Section Summary

measurements span ~14 orders of magnitude

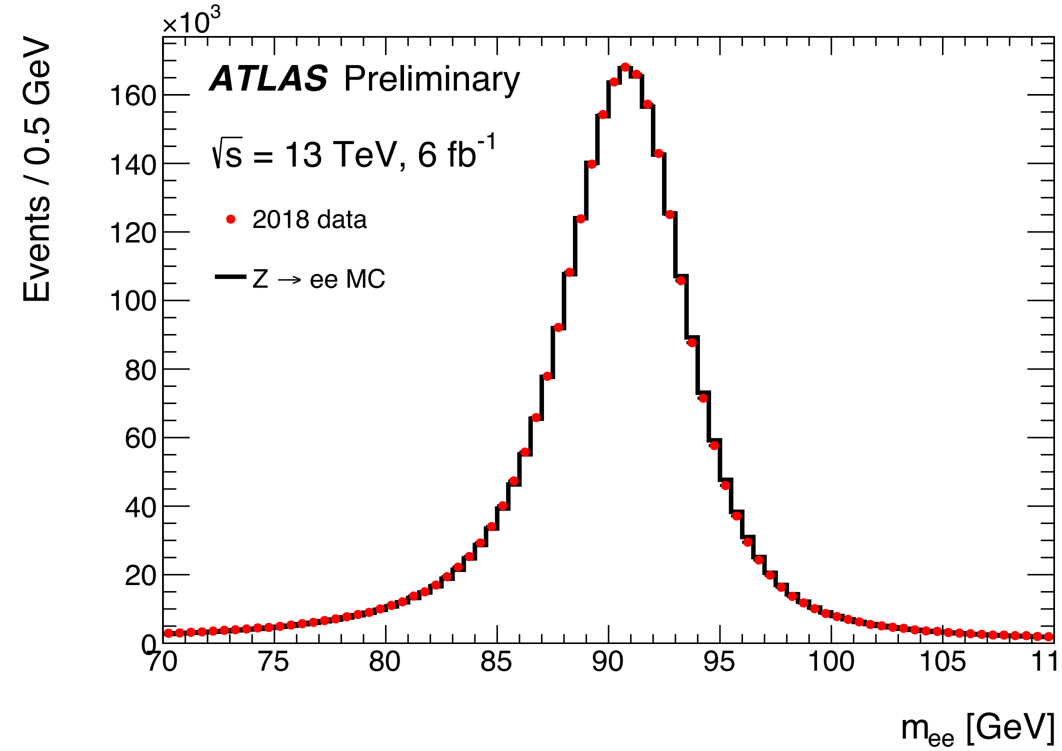


ATLAS Performance: Selection

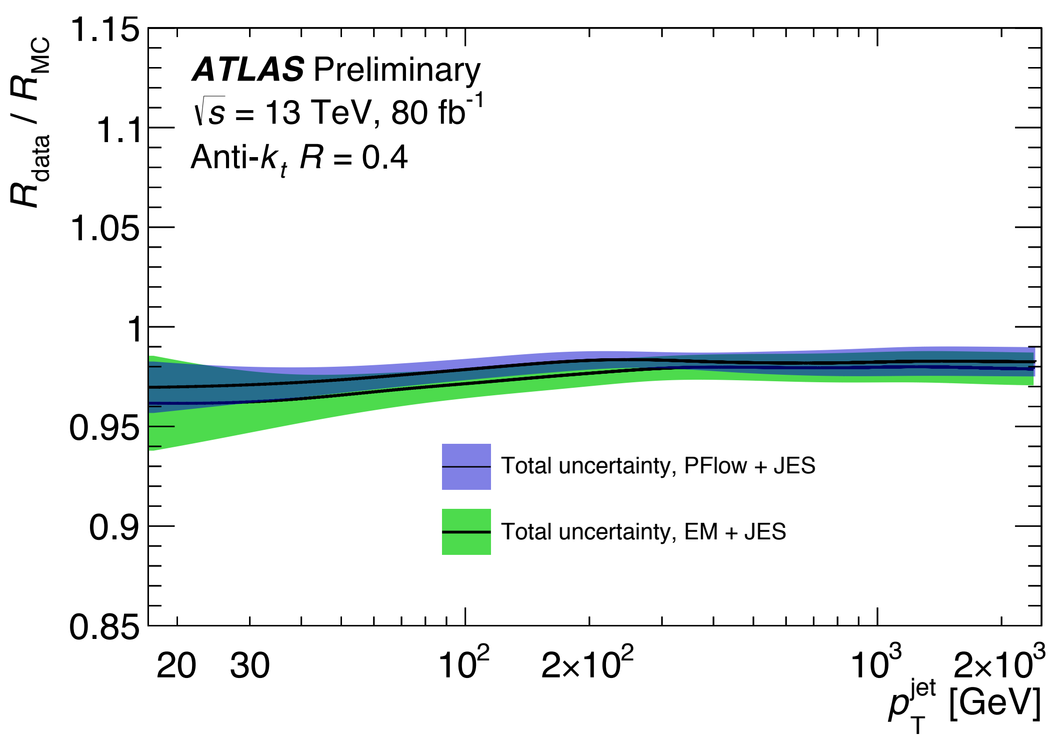
muon reco efficiency



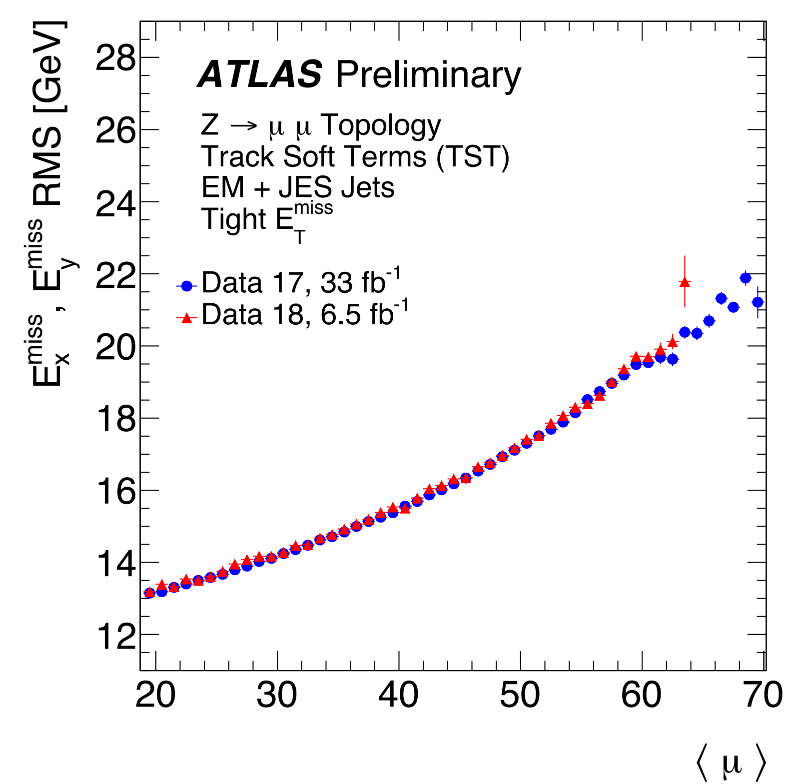
Z→ee reconstruction



jet energy response



E_T^{miss} resolution stability



Latest ATLAS Results: Highlights

Huge spectrum of physics results - selection bias necessary

SM Precision Measurements

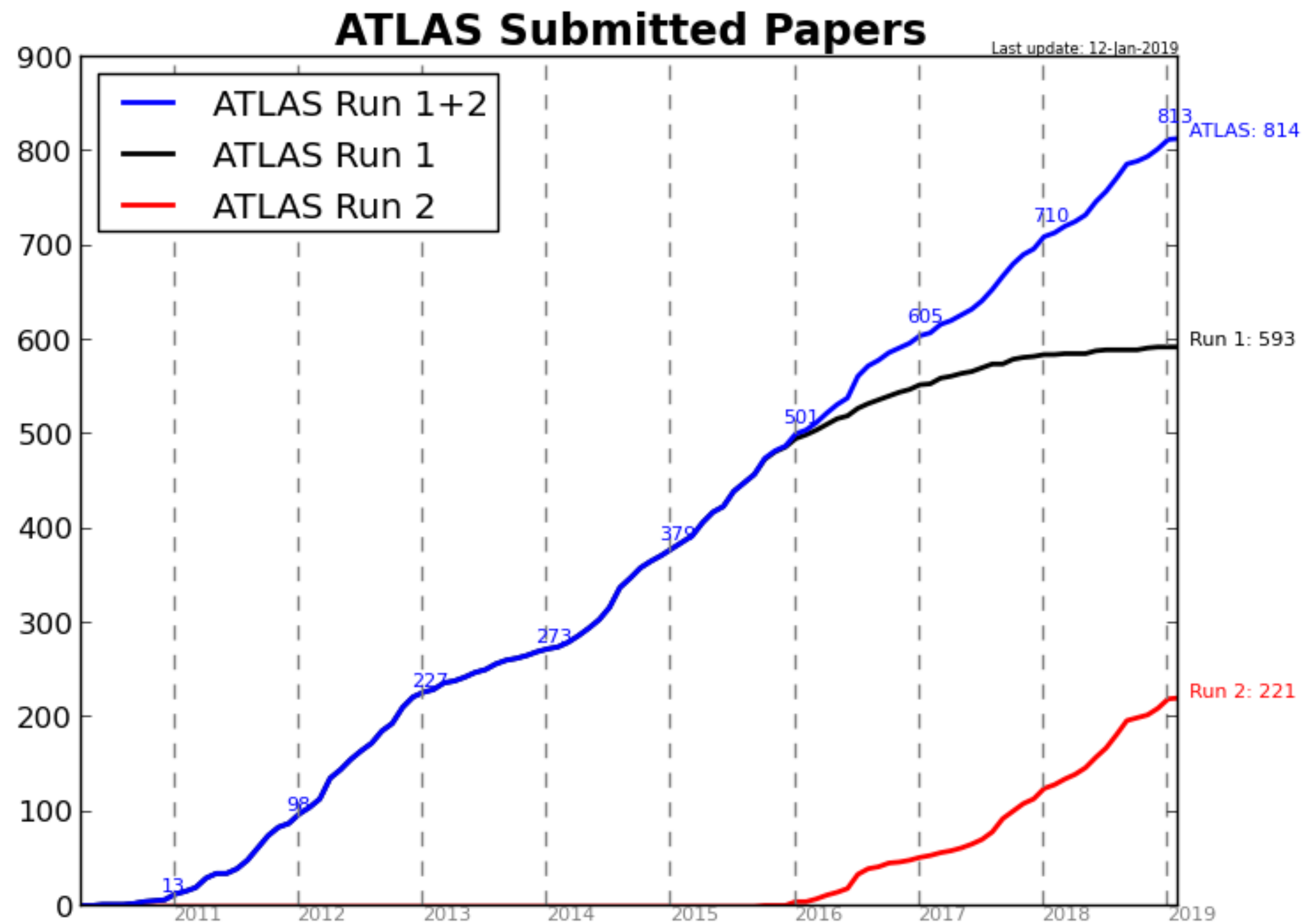
- Flavour and Jet physics
- Electroweak physics

Properties of Heavy Particles

- top quark physics
- Higgs physics

Searches for BSM Physics

Heavy-Ion Physics



Latest ATLAS Results: Highlights

SM Precision Measurements

- ***Flavour and Jet physics***
- Electroweak physics

Properties of Heavy Particles

- top quark physics
- Higgs physics

Searches for BSM Physics

Heavy-Ion Physics

Latest ATLAS Results: Highlights

SM Precision Measurements

- ***Flavour and Jet physics***
- Electroweak physics

Properties of Heavy Particles

- top quark physics
- Higgs physics

Searches for BSM Physics

Heavy-Ion Physics

Latest ATLAS Results: Highlights

SM Precision Measurements
- *Flavour and Jet physics*
- Electroweak physics

Properties of Heavy Particles
- top quark physics
- Higgs physics

Searches for BSM Physics

Heavy-Ion Physics

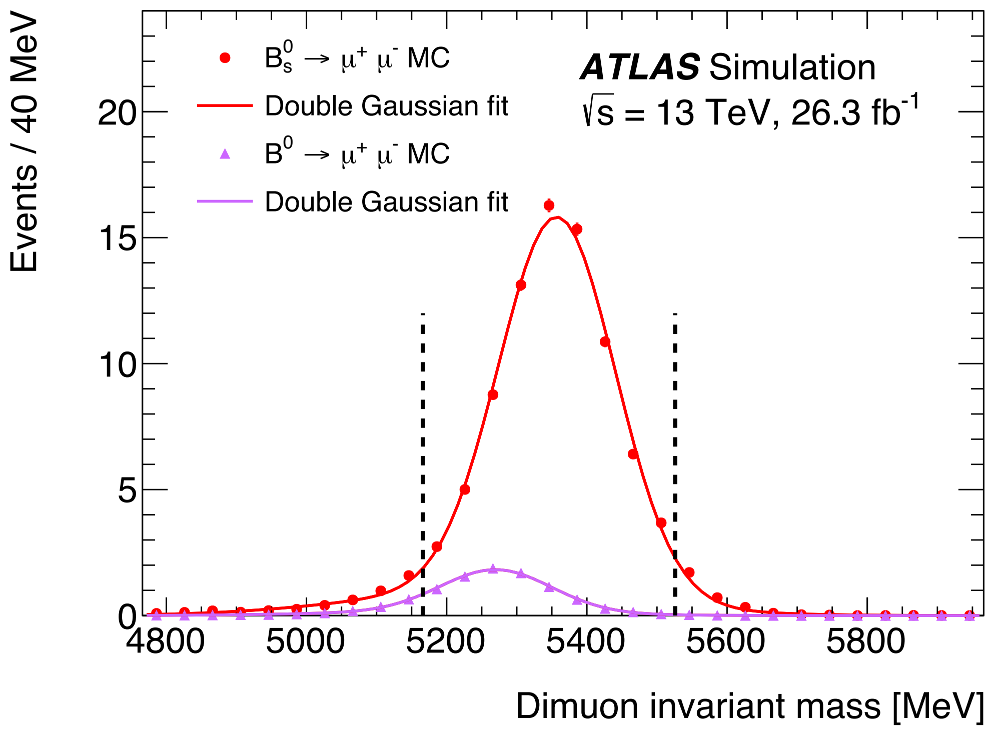
$B^0_{(s)} \rightarrow \mu^+\mu^-$

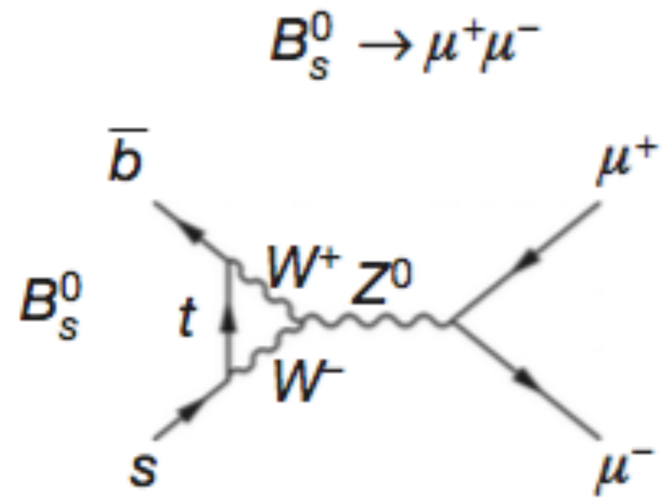
Tiny BR predicted: FCNC, suppressed due to CKM, helicity

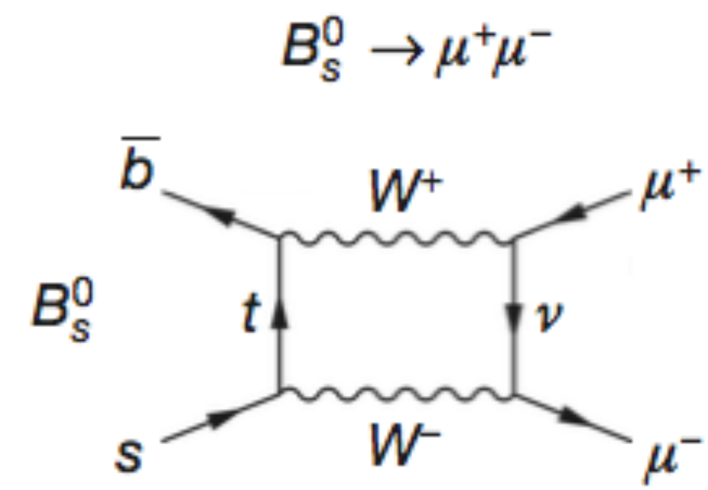
Sensitive to exotic particles in loops (provides strong BSM constraints)

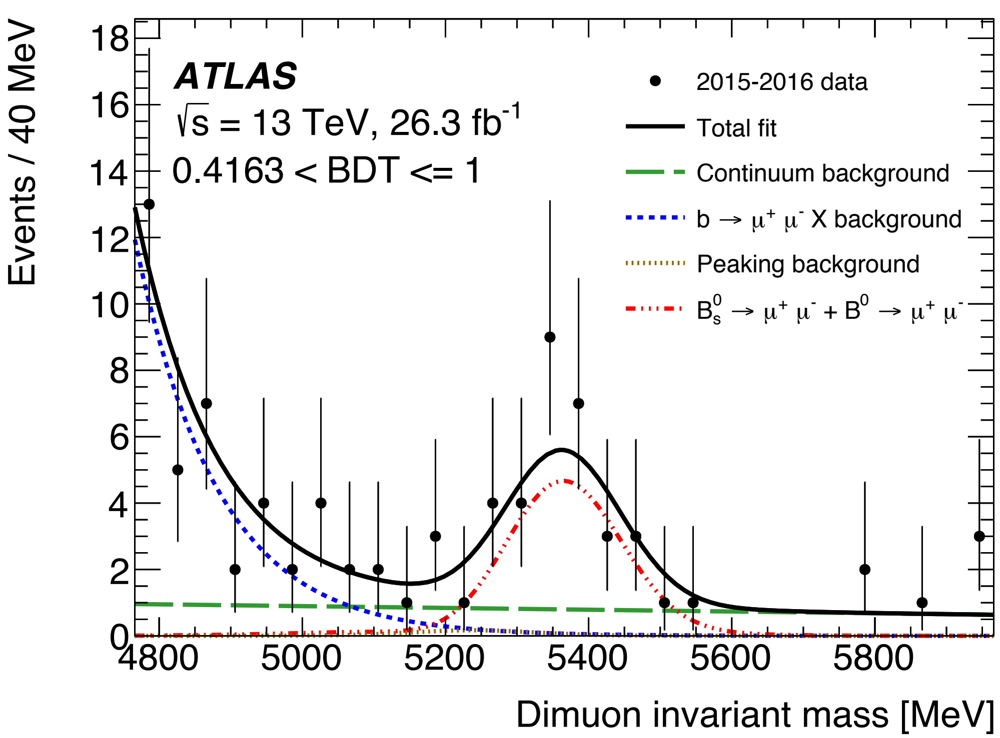
$BR(B_s) \sim 3.7 \times 10^{-9}$

$BR(B_d) \sim 1.1 \times 10^{-10}$



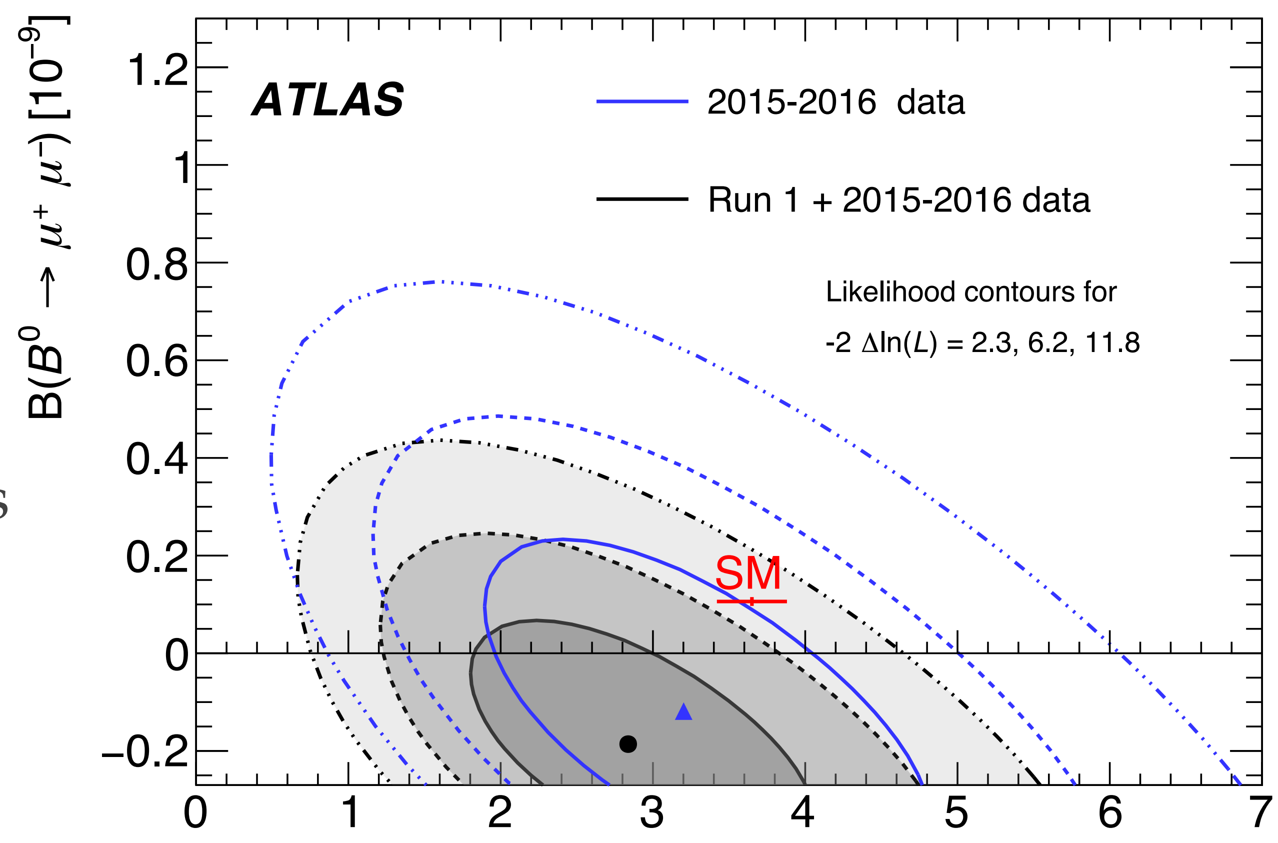






BDT used to suppress bkgds

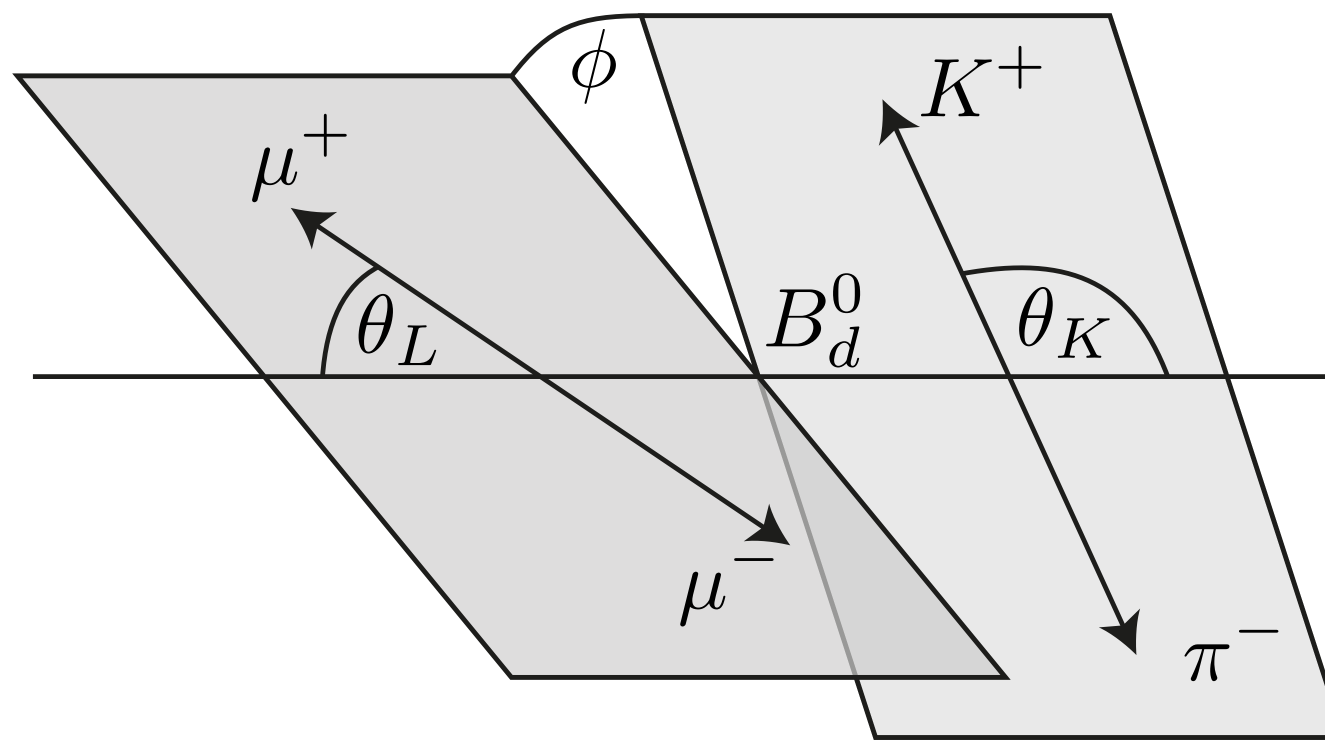
evt yields from $m_{\mu\mu}$ spectrum



arXiv:1812.03017

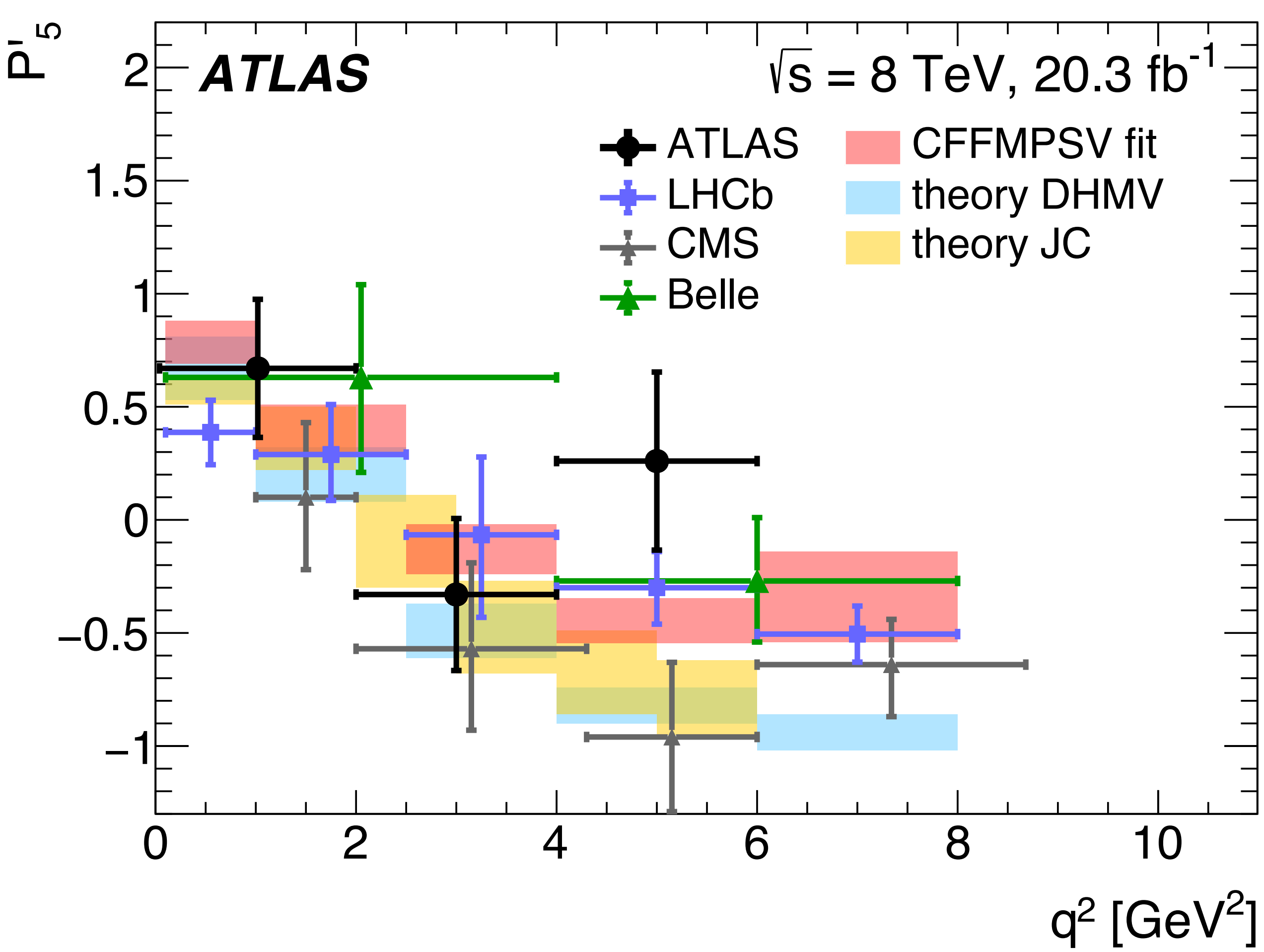
Angular Analysis of $B^0 \to K^* \mu^+\mu^-$

$$\frac{1}{d\Gamma/dq^2}\frac{d^4\Gamma}{d\cos\theta_L d\cos\theta_K d\phi dq^2} = \mathbf{f(P_5')}$$



JHEP 10 (2018) 047

P_5': Wilson coeff. dependent on
fraction of longitud. polarized K*



LHCb discrepancy with SM: **3.4σ**

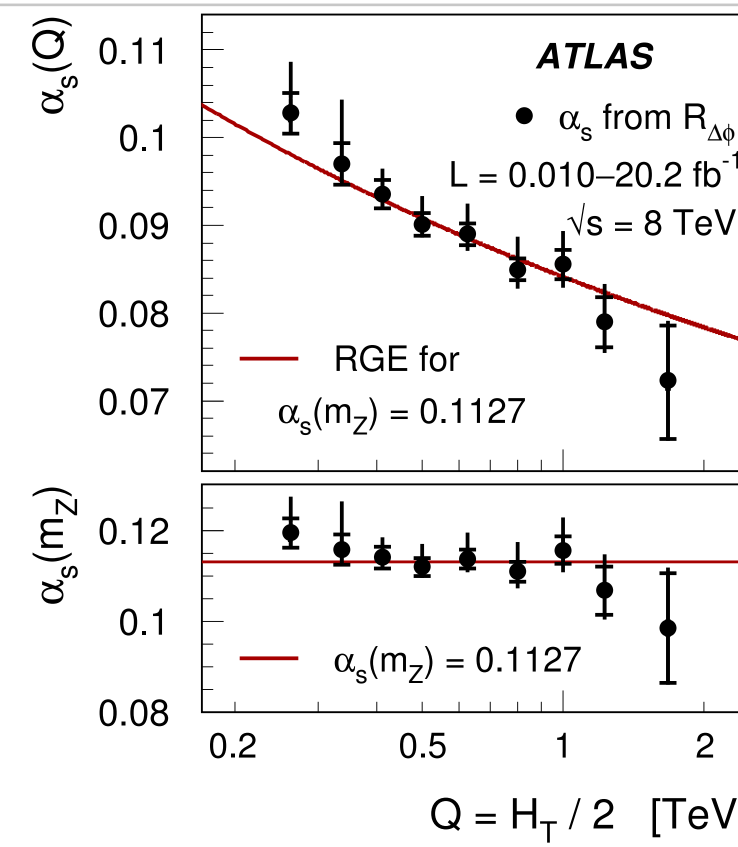
ATLAS: consistent with SM prediction within 3σ

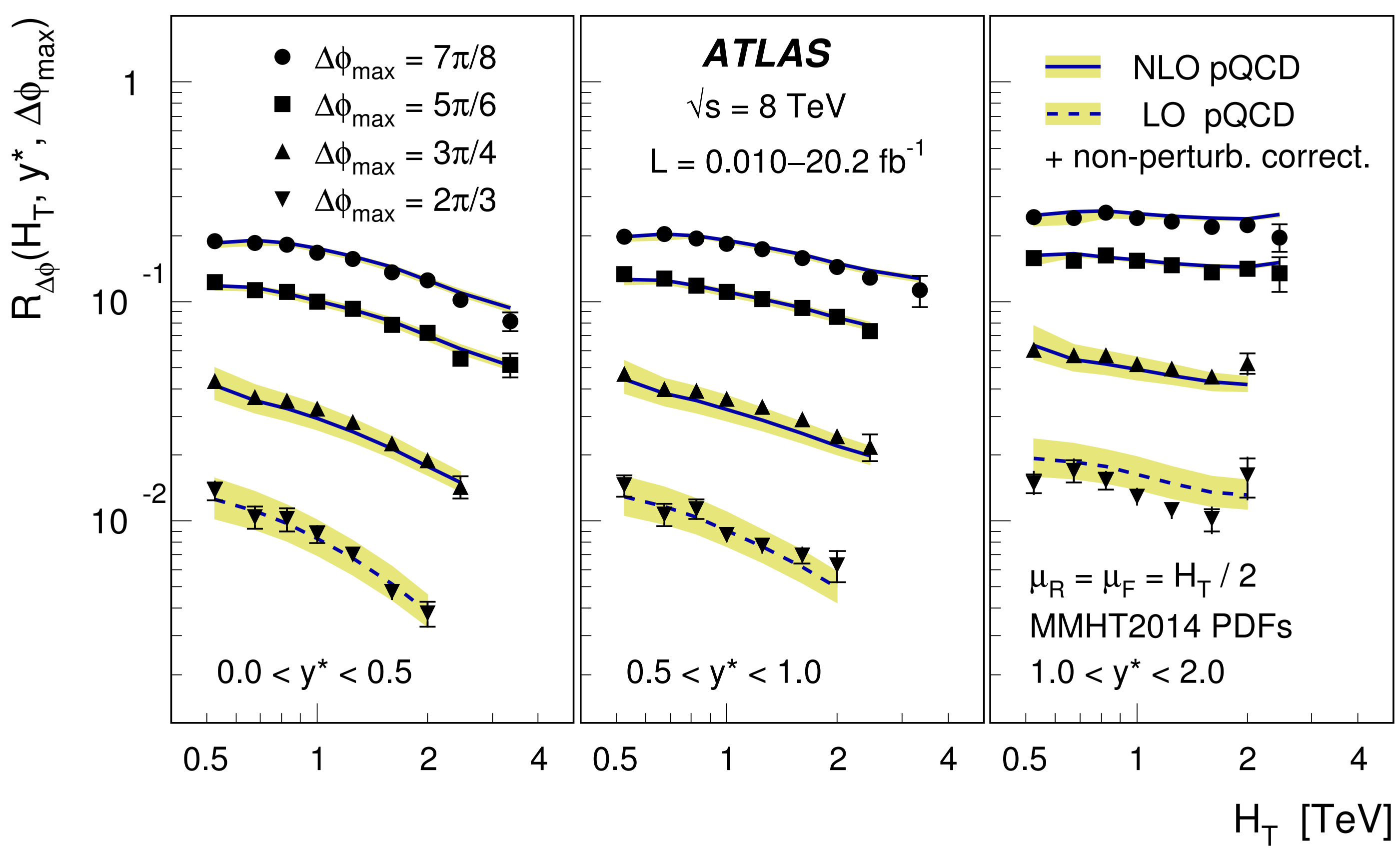
Largest local deviation found: **2.7σ**
P_5' for $4 < q^2 < 6$ GeV²

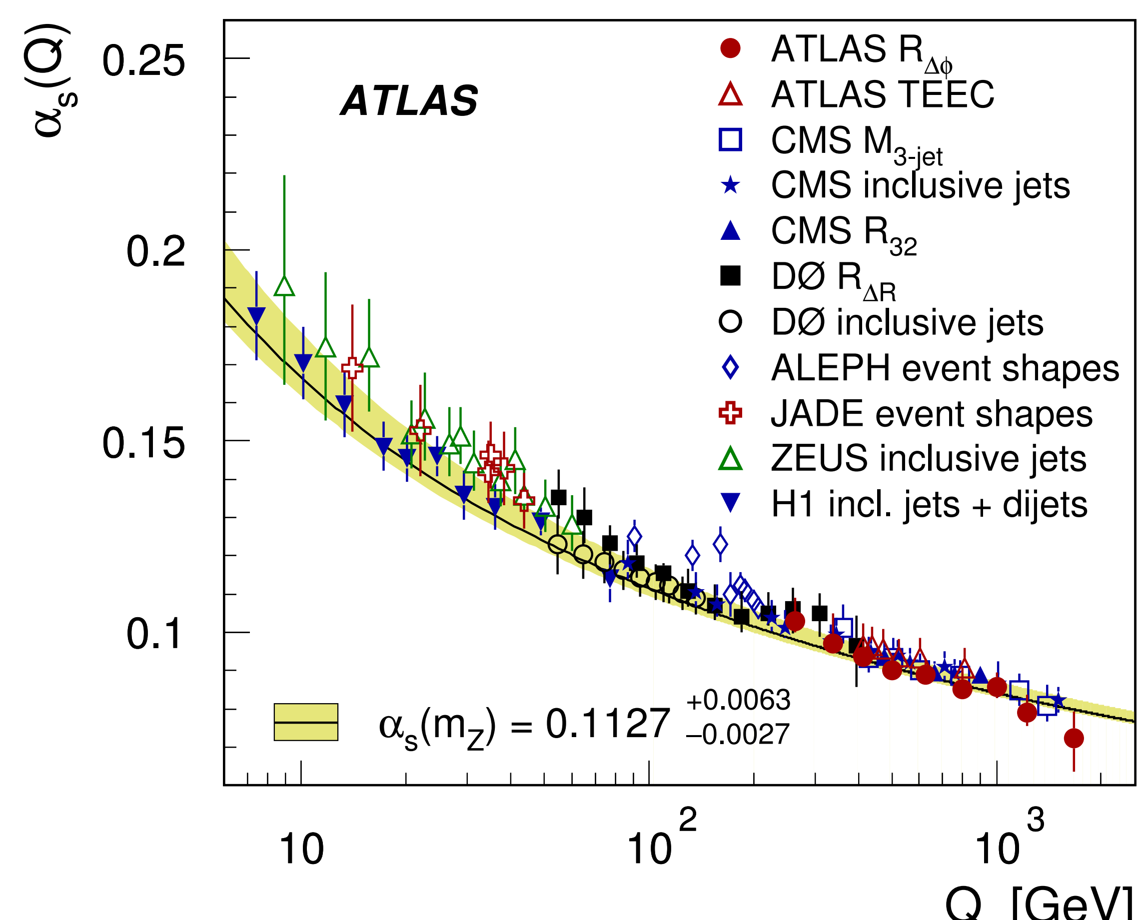
Jet Production (Azimuthal Correlations)

Use $R_{\Delta\Phi}$ to extract α_S at high Q

$$R_{\Delta\phi}(H_\mathrm{T}, y^*, \Delta\phi_\mathrm{max}) = \frac{\dfrac{d^2\sigma_\mathrm{dijet}(\Delta\phi_\mathrm{dijet} < \Delta\phi_\mathrm{max})}{dH_\mathrm{T}dy^*}}{\dfrac{d^2\sigma_\mathrm{dijet}(\mathrm{inclusive})}{dH_\mathrm{T}dy^*}}$$







PRD 98 (2018) 092004

Latest ATLAS Results: Highlights

SM Precision Measurements

- Flavour physics
- ***Electroweak physics***

Properties of Heavy Particles

- top quark physics
- Higgs physics

Searches for BSM Physics

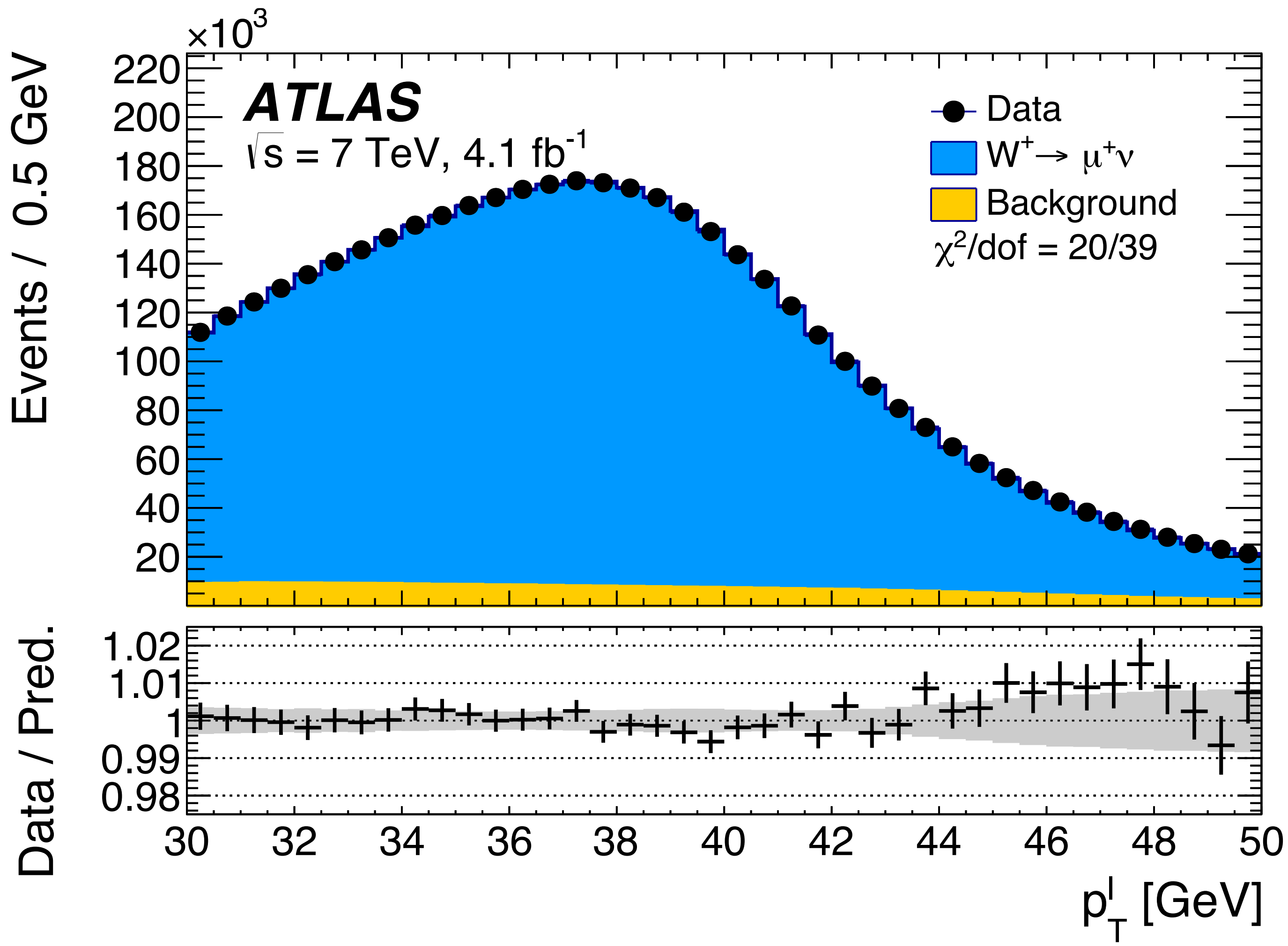
Heavy-Ion Physics

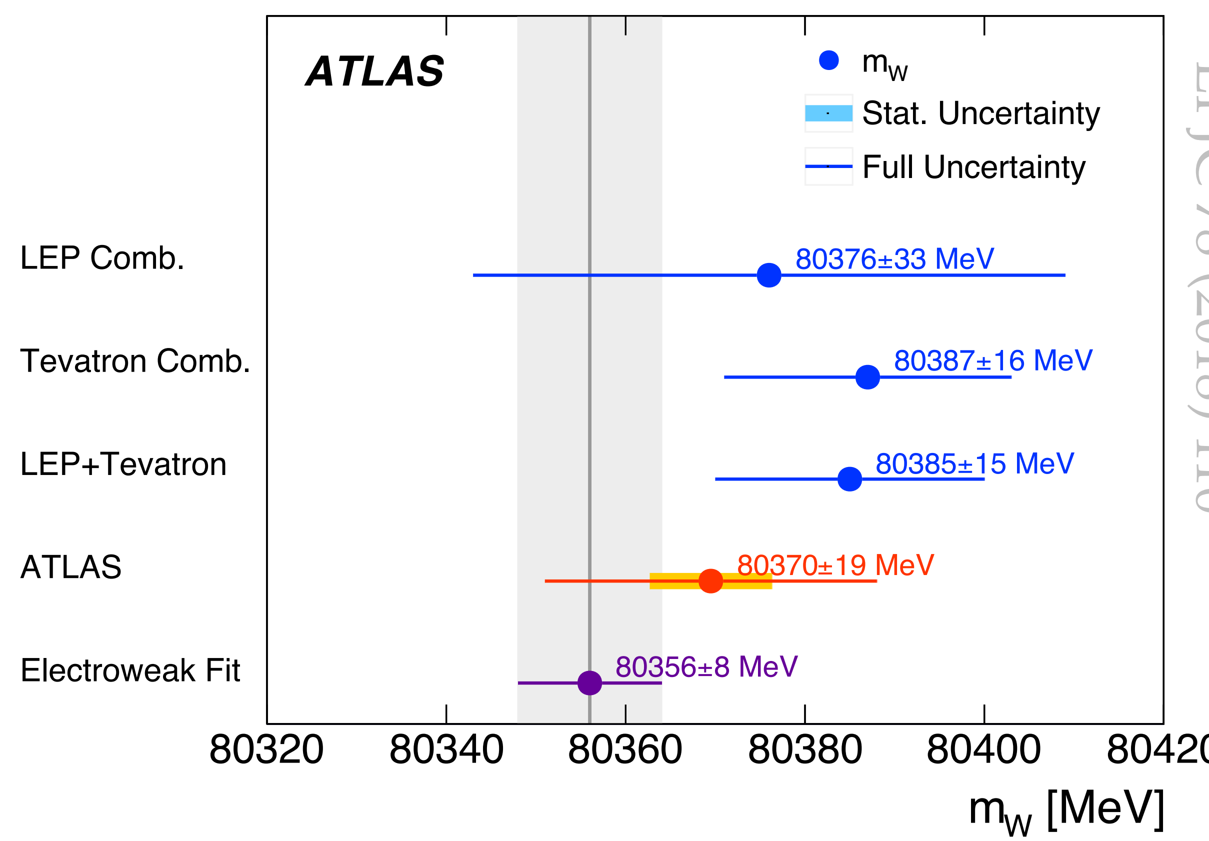
$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + i\bar{\psi}\not{D}\psi + h.c$$

W Mass Measurement

Flagship measurement: W boson mass measurement with 7 TeV data

Analysis: template fits to p_T^ℓ and m_T distributions
requires detailed calibration studies, understanding of detector





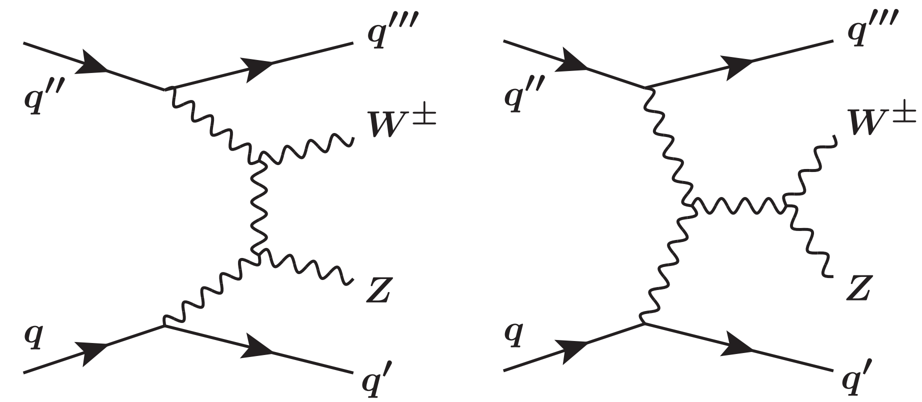
EPJC 78 (2018) 110

Astounding precision: 0.02%

Electroweak WW/WZ Production (VBS)

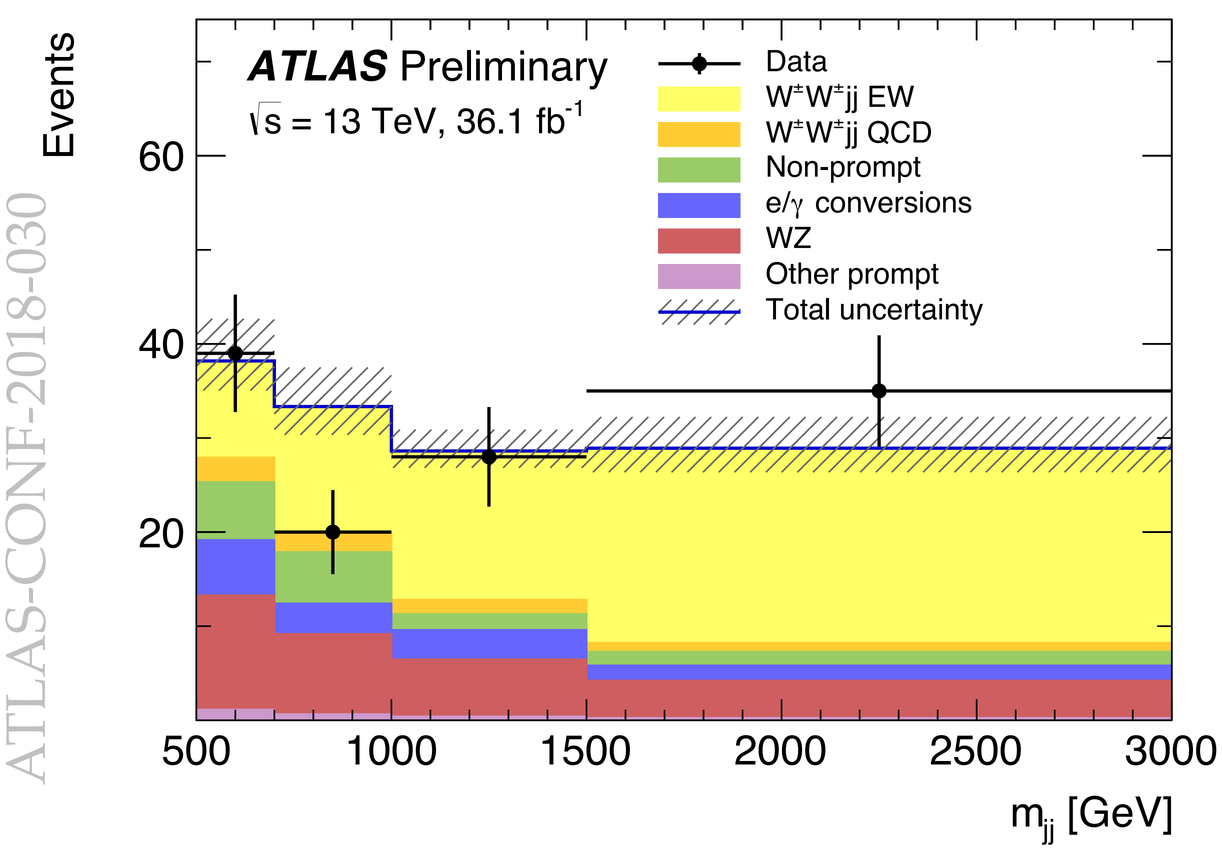
Vector Boson Scattering linked to EWSB

- cross-section unitarity restored by Higgs boson
- key background to Higgs signals
- probes triple gauge boson couplings



W±W±jj final state (same sign leptons)

ATLAS-CONF-2018-030

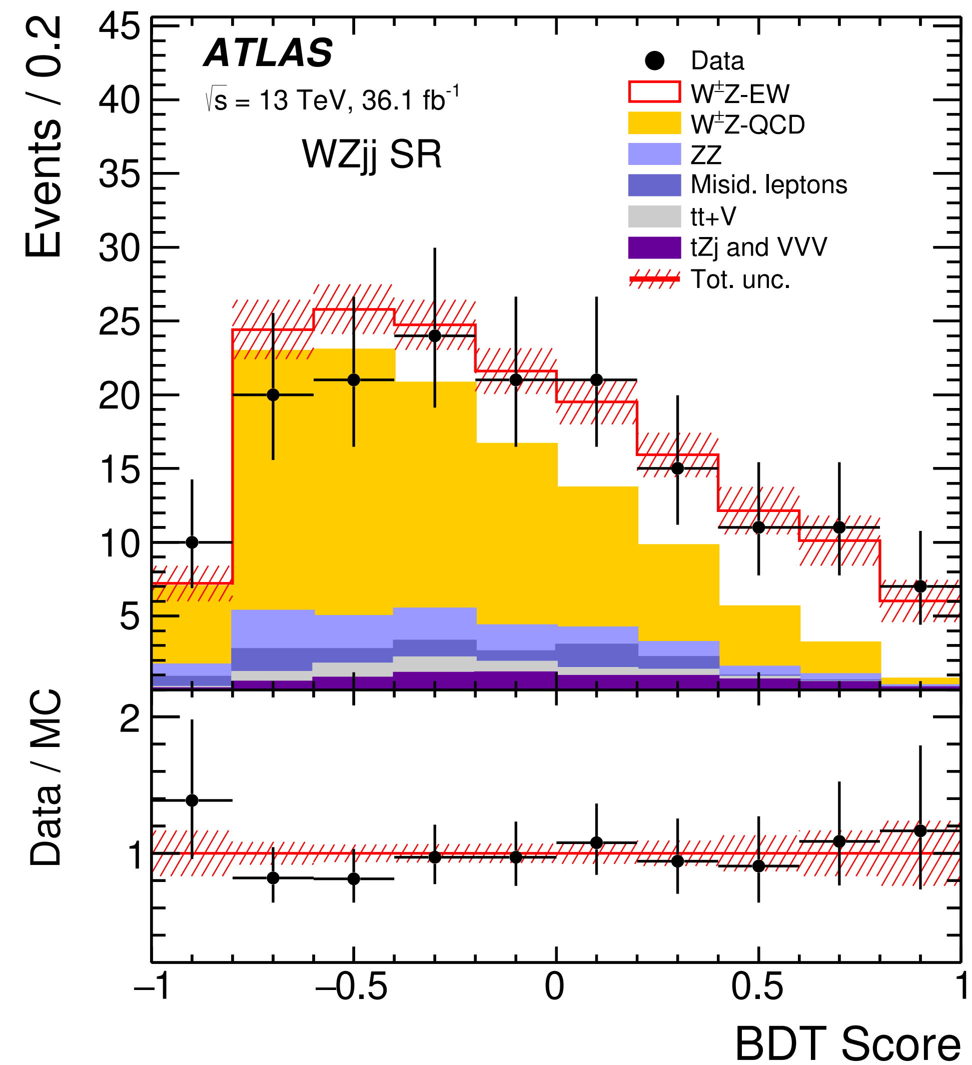


Signal significance: **6.9σ** (4.6σ)

$$\sigma_{\mathrm{fid}} = 2.91^{+0.51}_{-0.47}\ (\mathrm{stat.}) \pm 0.27\ (\mathrm{sys.})\ \mathrm{fb}$$

WZjj final state ($\ell'\nu\ell\ell jj$)

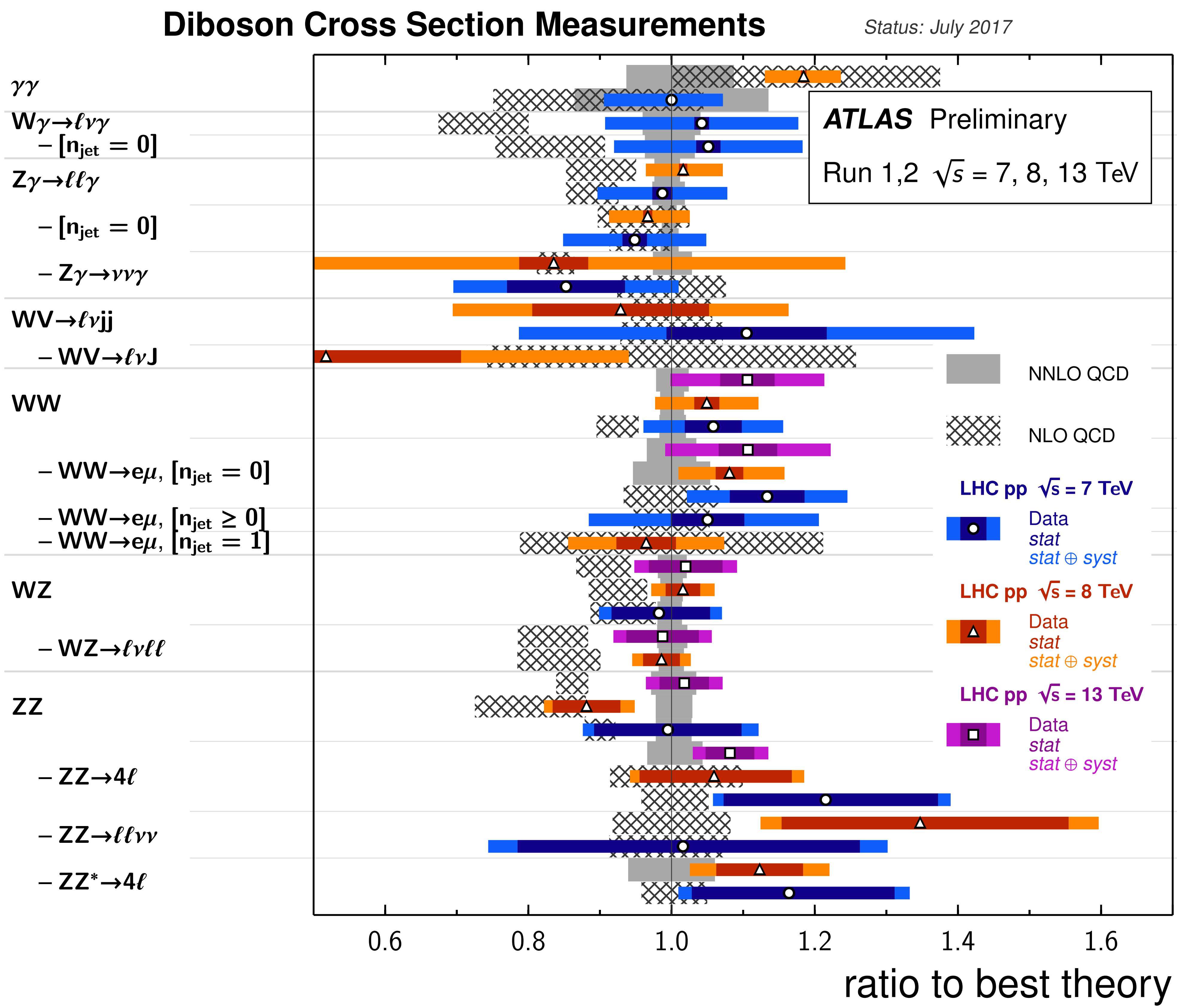
arXiv:1812.09740



Signal significance: **5.3σ** (3.2σ)

$$\sigma_{WZjj\text{-EW}} = 0.57\ {}^{+0.14}_{-0.13}\ (\mathrm{stat.})\ {}^{+0.07}_{-0.06}\ (\mathrm{syst.})\ \mathrm{fb}$$

Other Measurements of Gauge Boson Production



Also:

- fiducial x-sections
- differential x-sections
- constraints on anomalous couplings
- interpretations in effective field theory

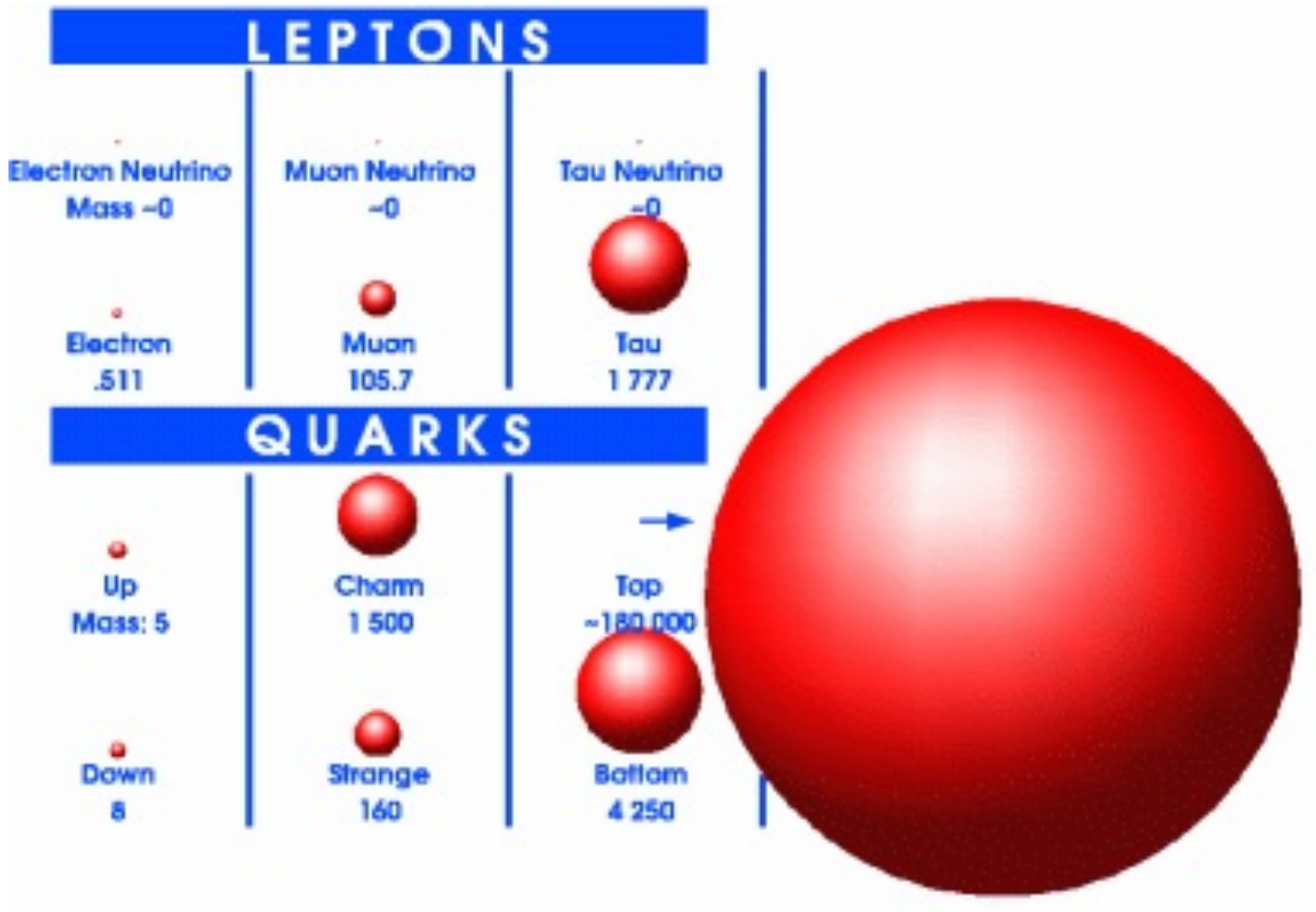
Latest ATLAS Results: Highlights

SM Precision Measurements
- Flavour and Jet physics
- Electroweak physics

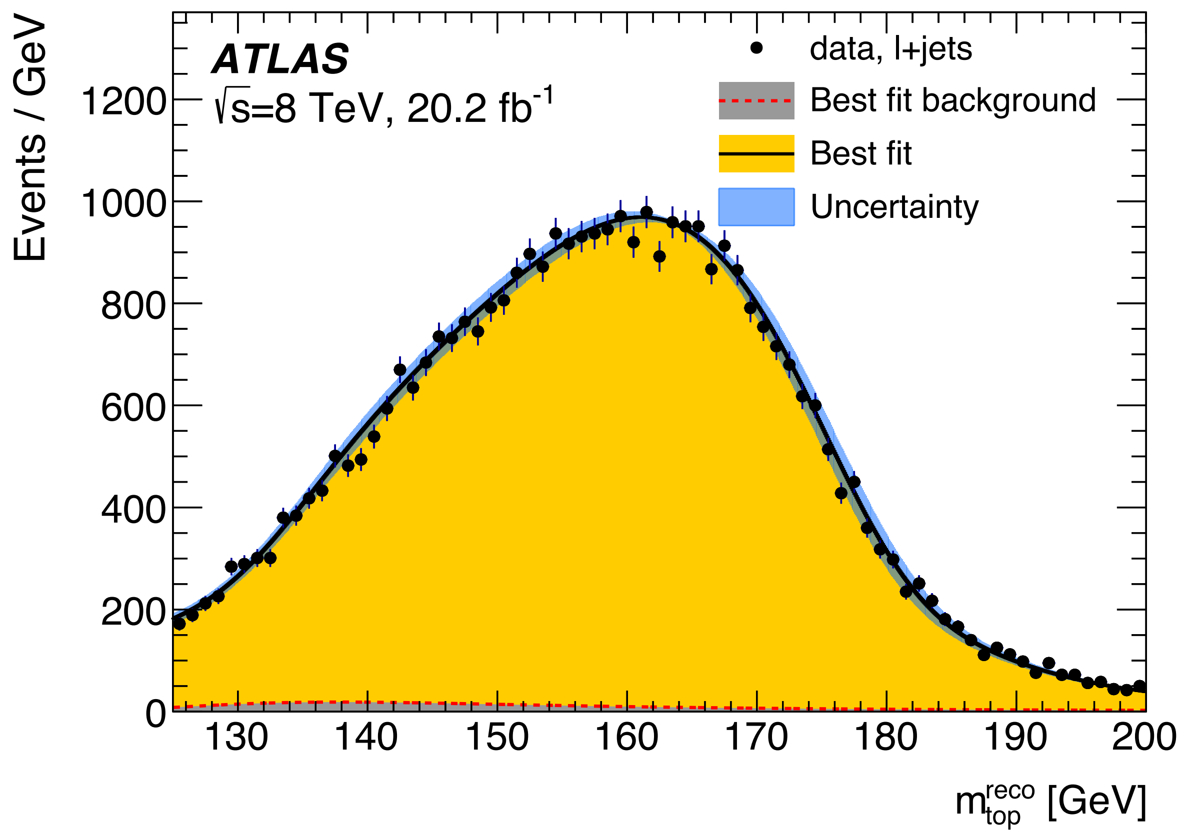
Properties of Heavy Particles
- *top quark physics*
- Higgs physics

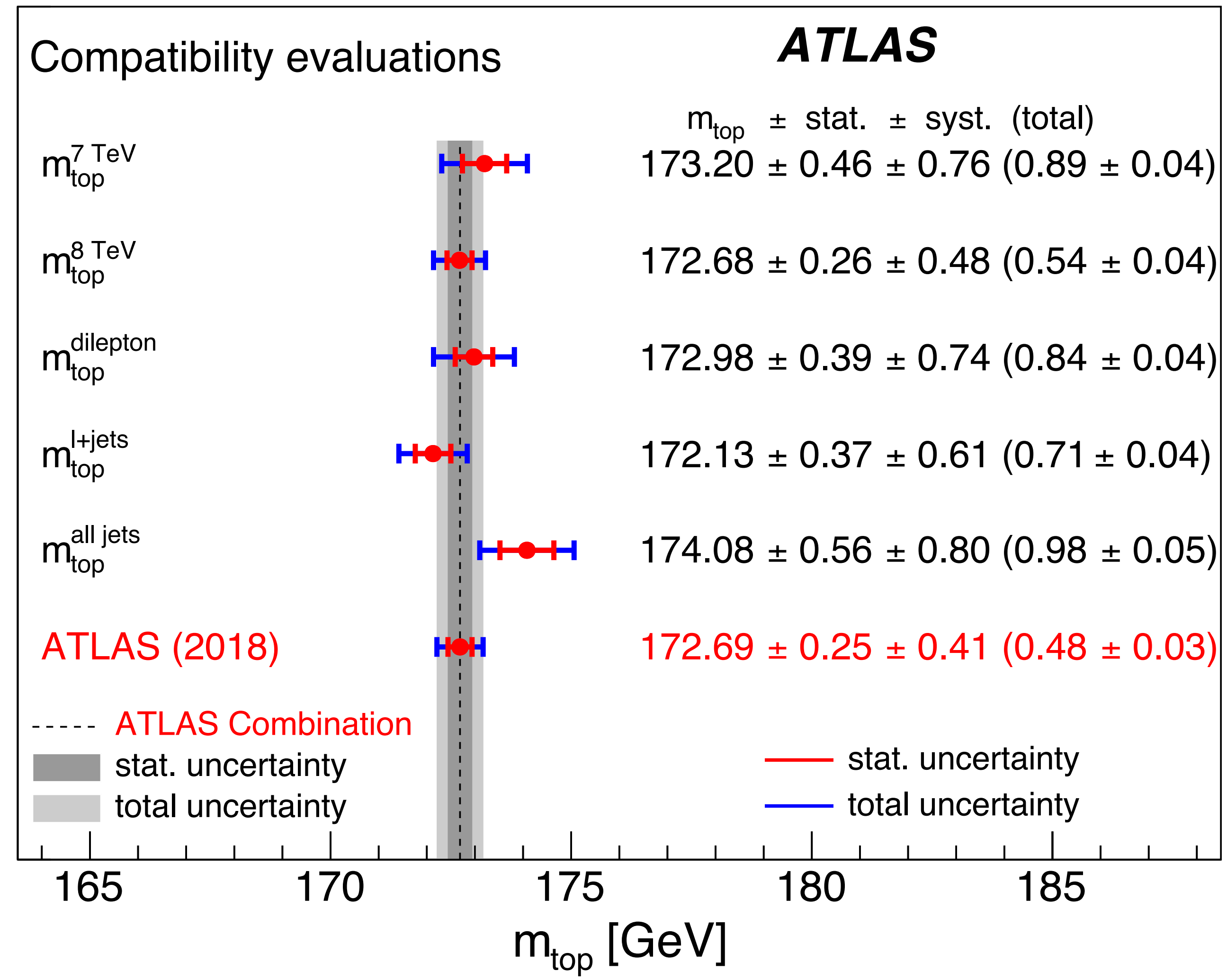
Searches for BSM Physics

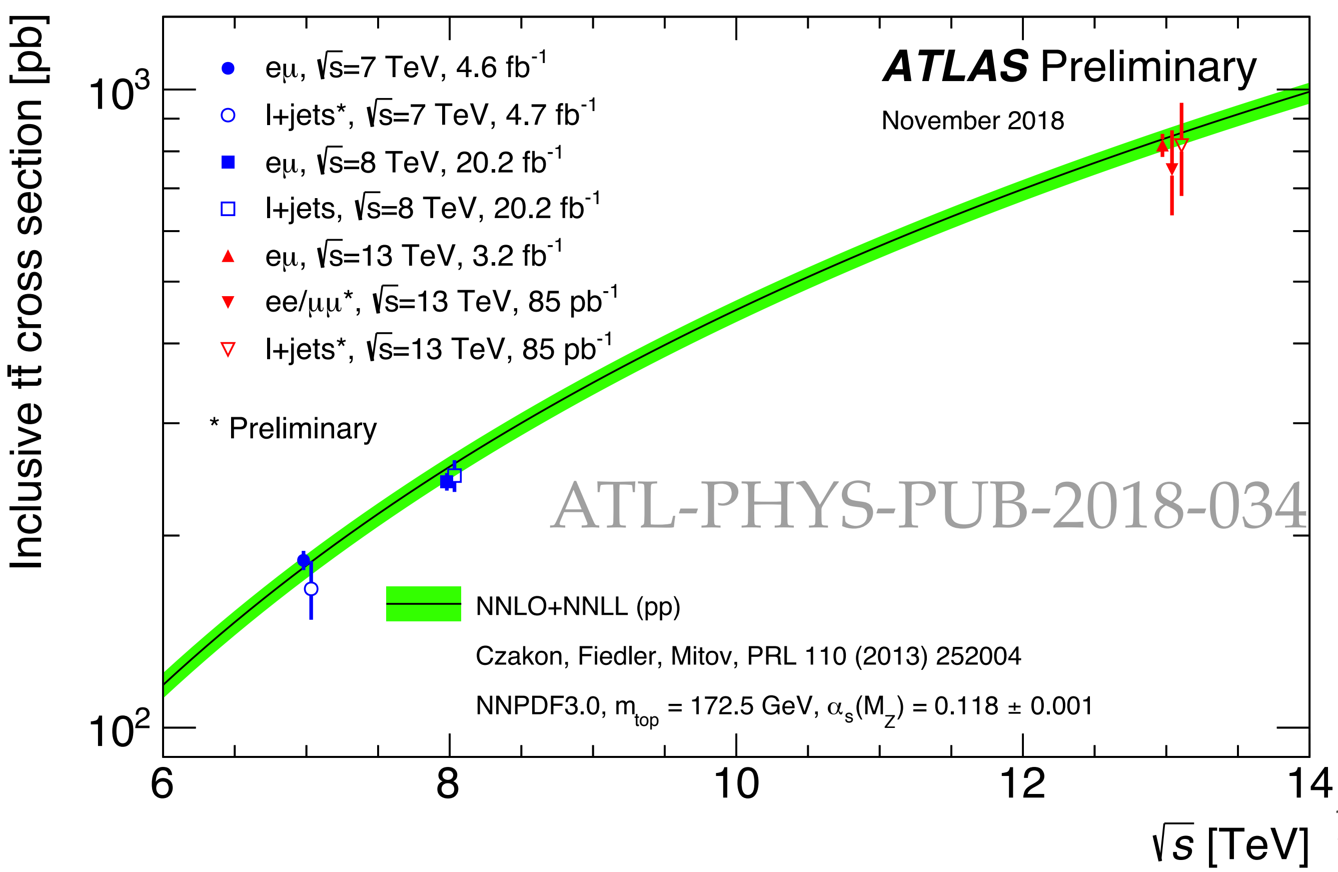
Heavy-Ion Physics



Top Quark Precision Measurements







	Precision
m_{top}	0.3%
σ(tt)	4% @ 13 TeV
σ(t) t-chan	18% @ 13 TeV
Γ_{top}	45%

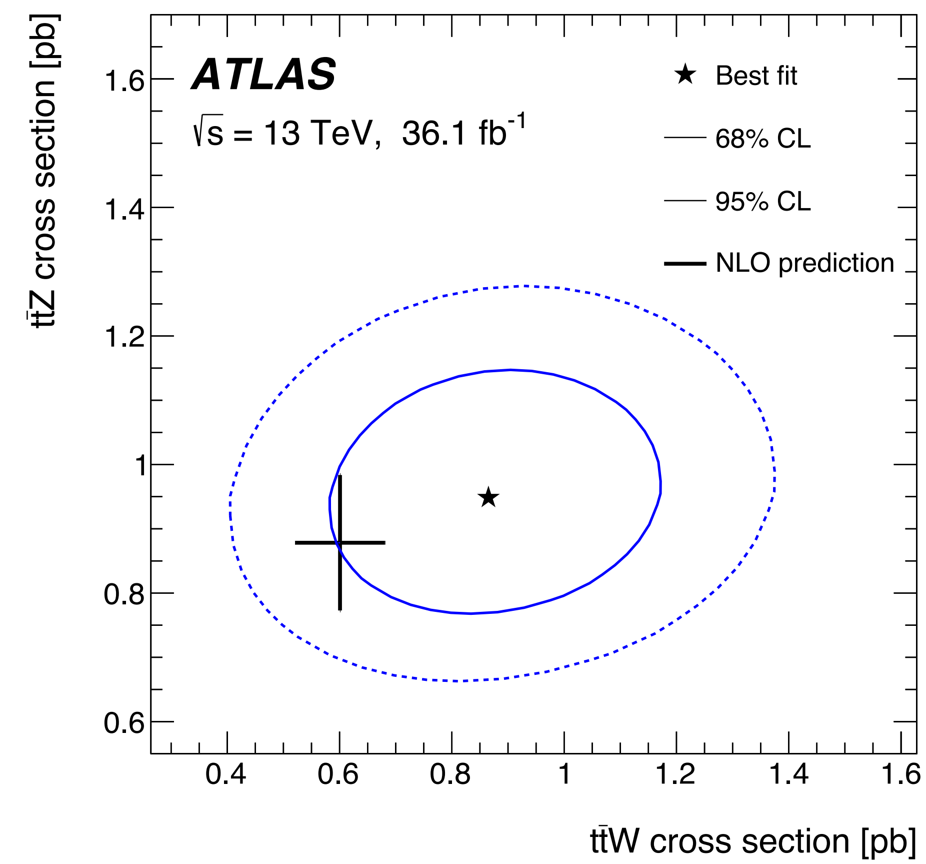
arXiv:1810.01772

Associated Top Production Modes

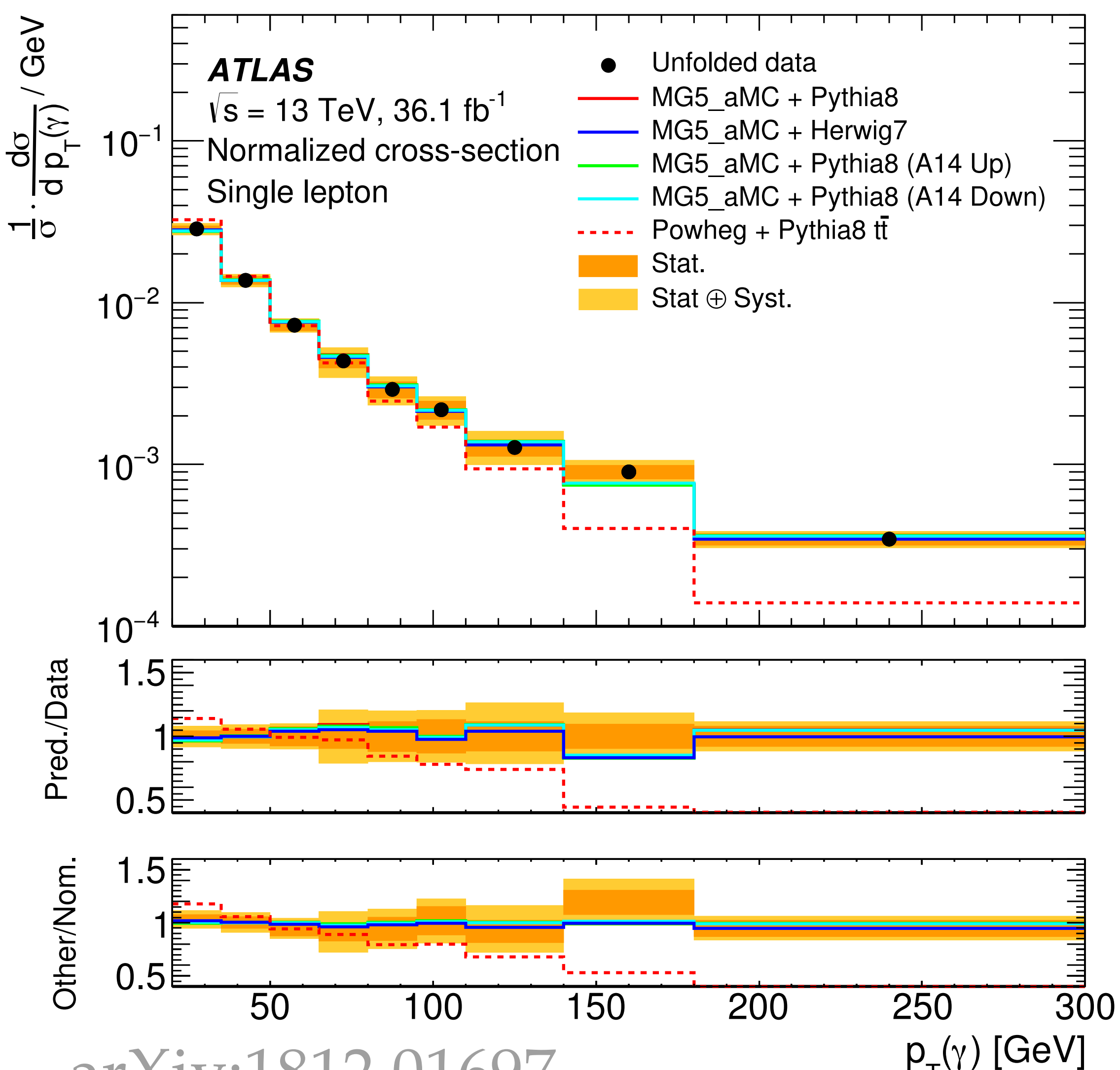
ttγ, tt+heavy flavour:
differential / fiducial cross-sections extracted

ttZ: well established signal (≫5σ)

ttW: signal significance 4.3σ (3.4σ expected)



arXiv:1901.03584



arXiv:1812.01697

- Constraints on top quark couplings to gauge sector (extracting weak isospin T_3^{top})
- Constraints on BSM physics coupling to top quark (Intepretation in effective field theory)

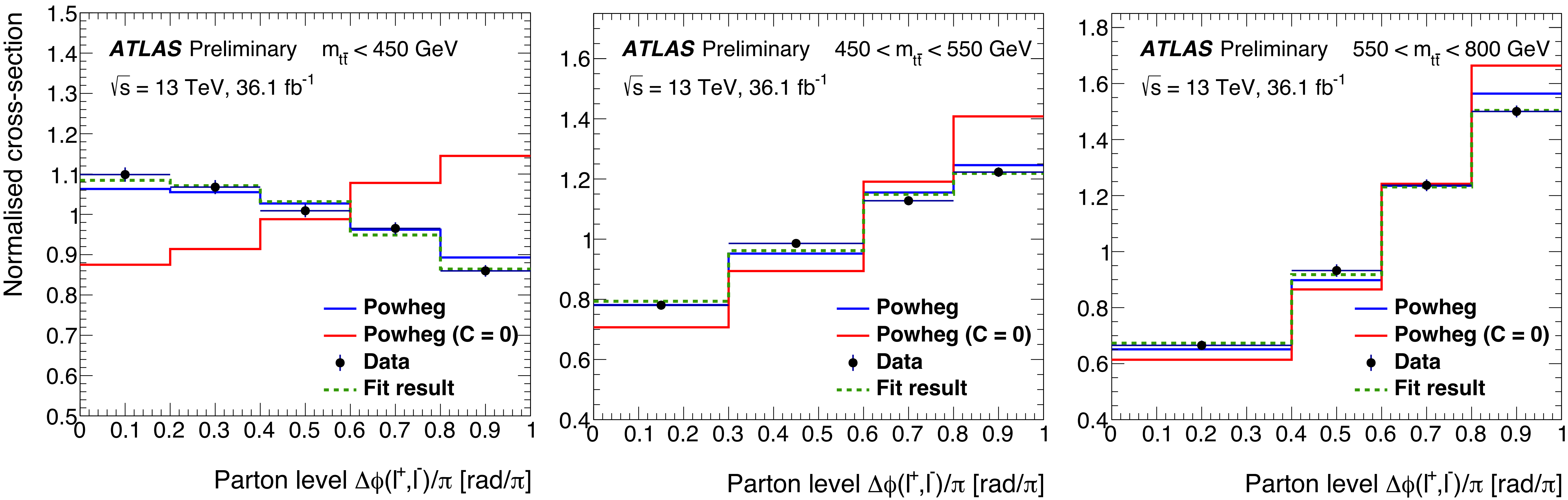
Spin Correlations in Top Pair Decays

Top quark spin transmitted directly to decay products

- test angular distribution of charged leptons in di-lepton events
- observable: **$\Delta\phi(\ell^+,\ell^-)$** in various m_{tt} ranges
- Distributions unfolded to parton level to compare with prediction

Larger spin correlations seen than predicted by SM (corresponds to **3.2σ**)
(hint at BSM effects?)

ATLAS-CONF-2018-027



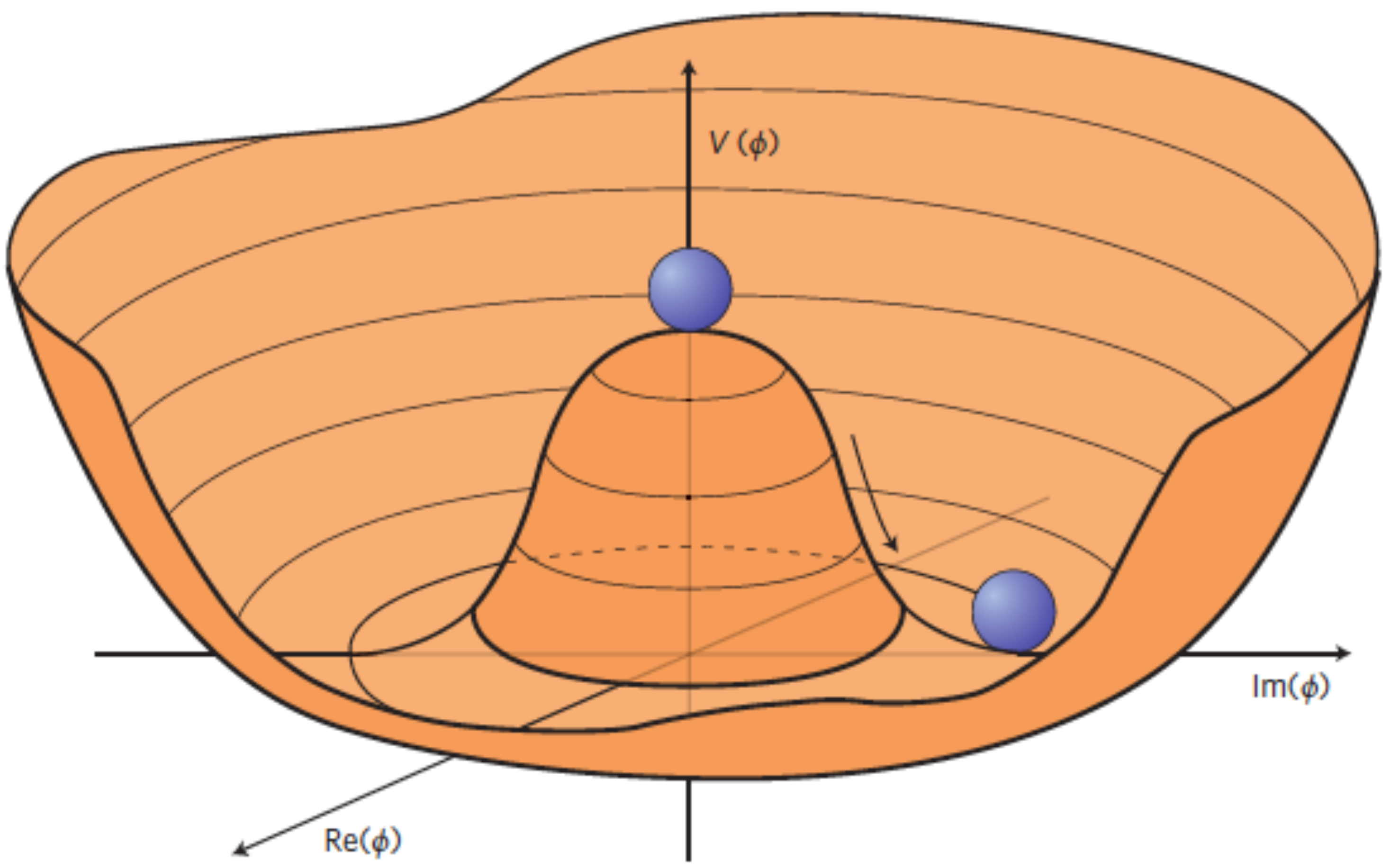
Latest ATLAS Results: Highlights

SM Precision Measurements
- Flavour and Jet physics
- Electroweak physics

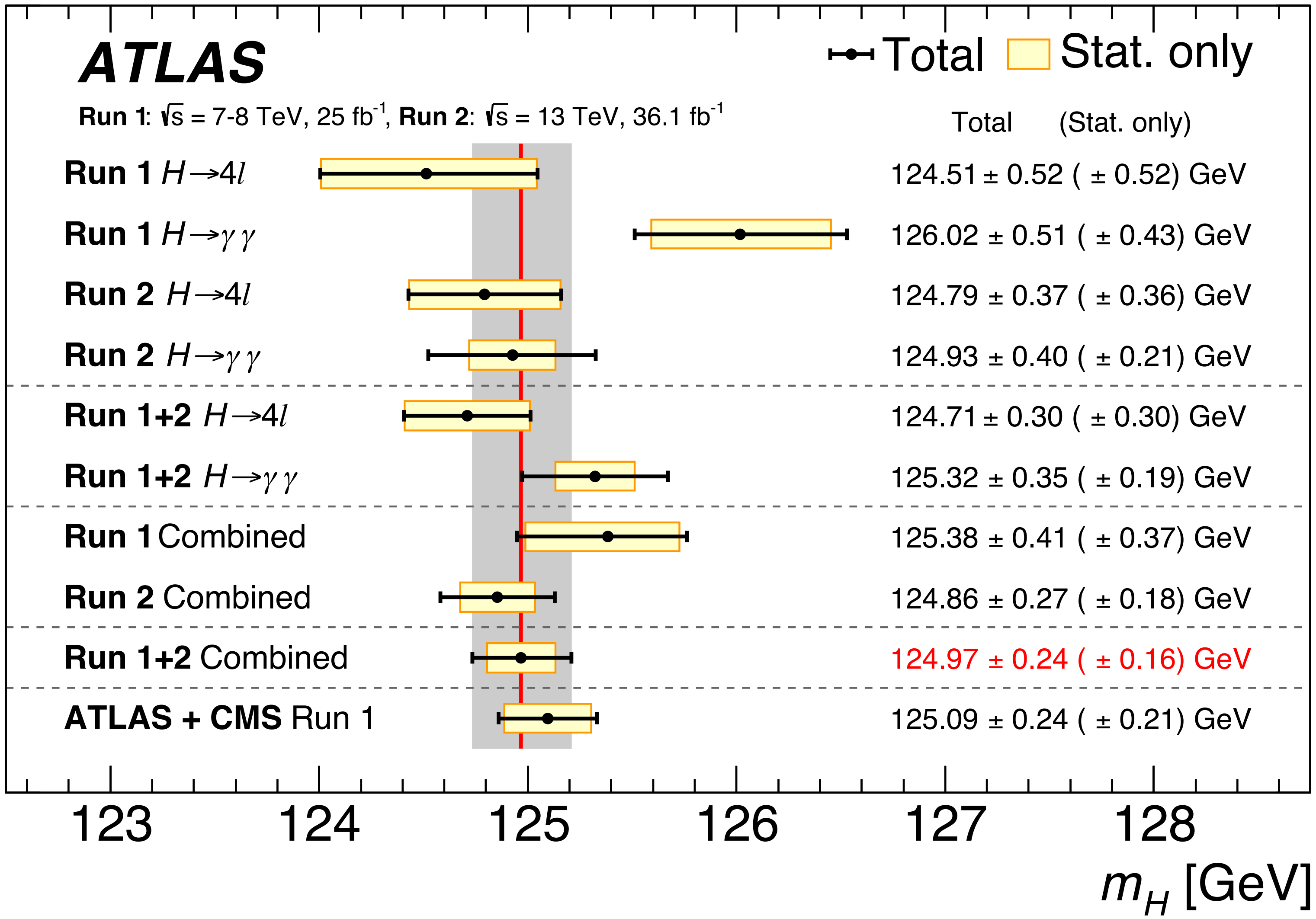
Properties of Heavy Particles
- top quark physics
- *Higgs physics*

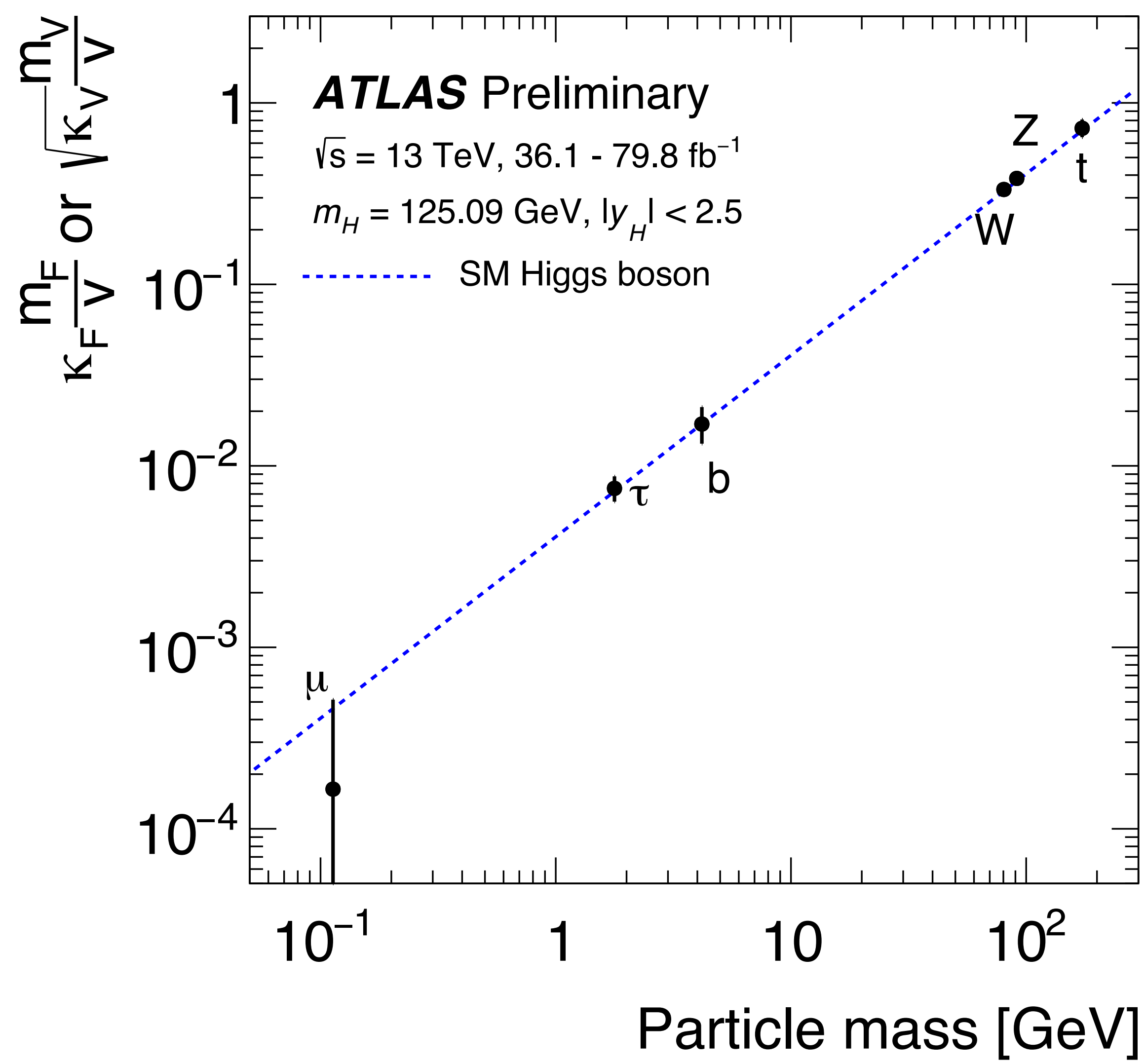
Searches for BSM Physics

Heavy-Ion Physics



Precision Higgs Physics

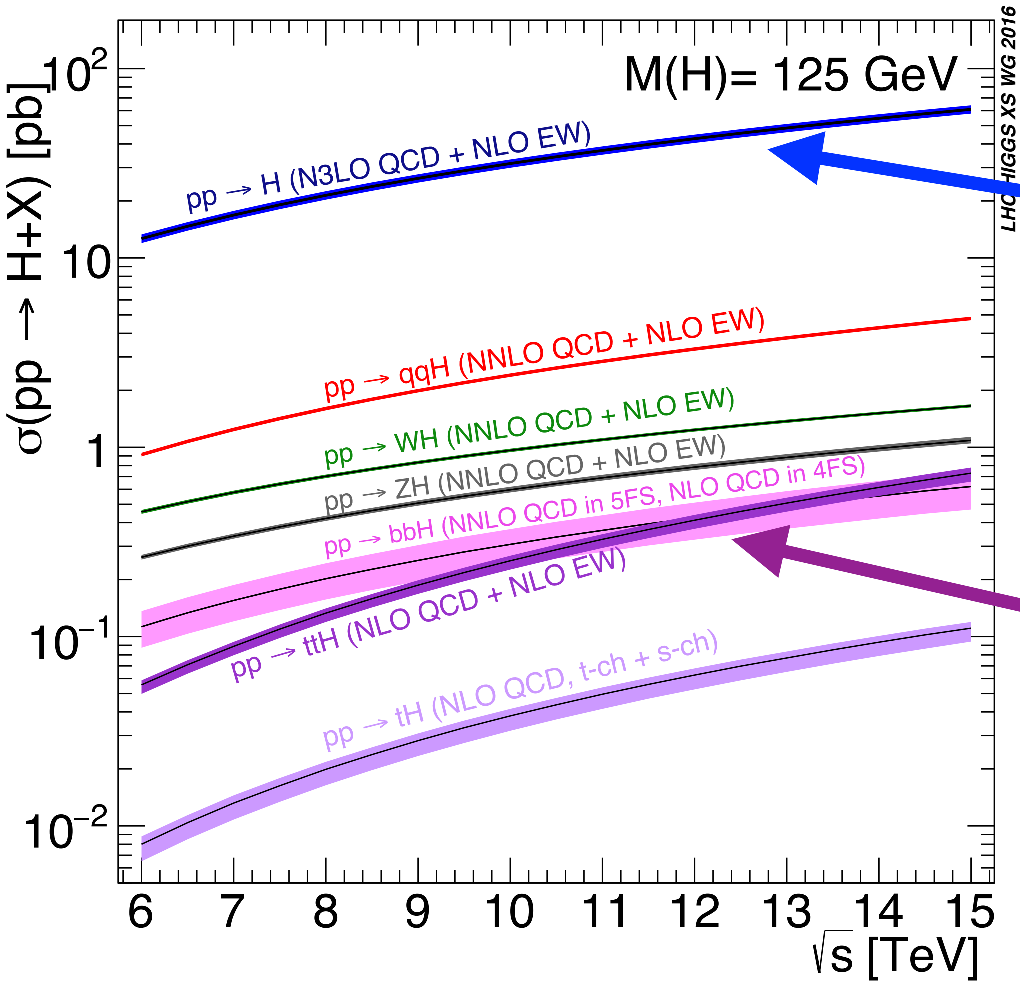


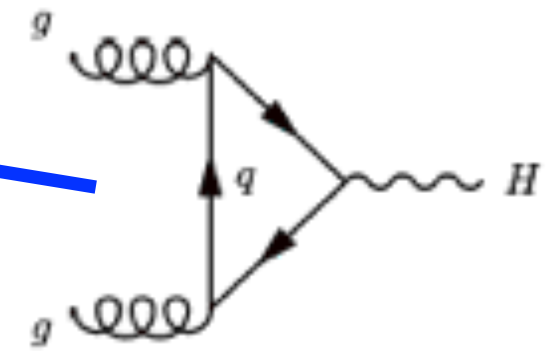


Astonishing quick arrival to the precision era in Higgs physics

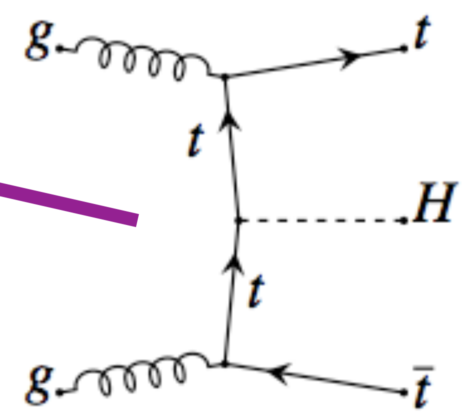
- 0.2% precision on Higgs mass
- numerous couplings measured/confirmed (especially to ***fermion sector***)
- differential cross-sections, measurements of quantum numbers

Higgs-Top Coupling (ttH)





Higgs-quark couplings inferred *indirectly* through gluon-fusion (dominated by top quark)

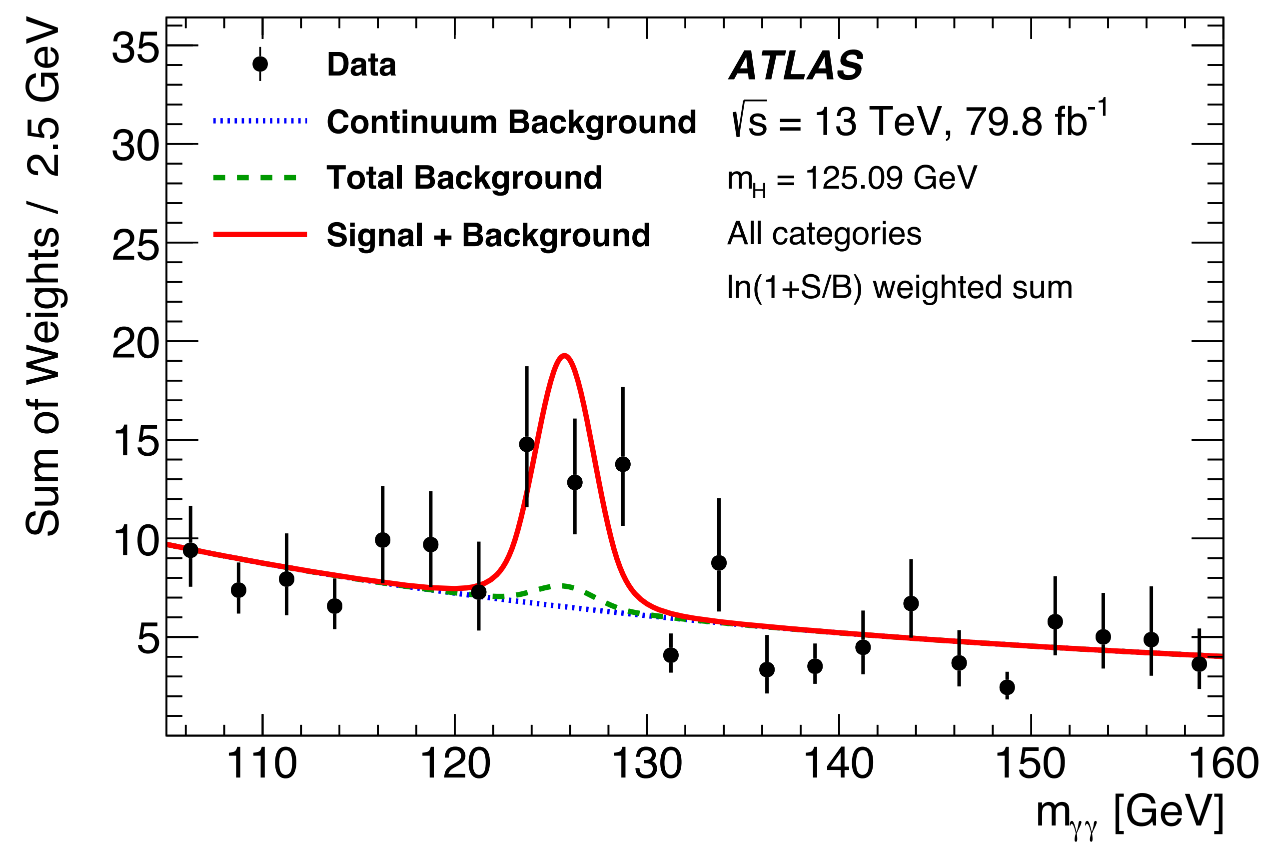


Direct confirmation requires observation of ttH (or tH) process

Higgs-Top Yukawa Coupling: $y_{top} \sim 1$

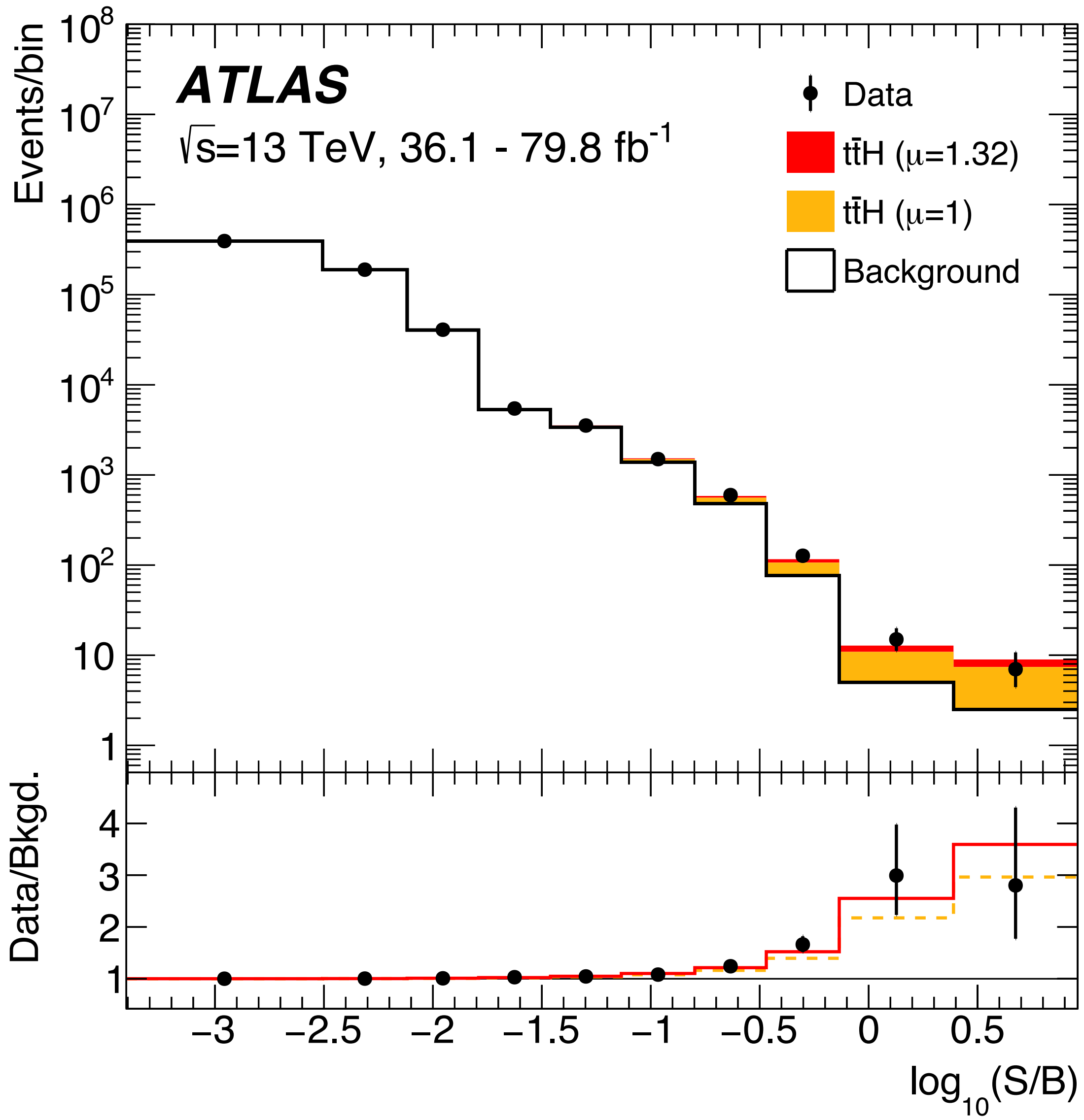
All sensitive decay modes investigated:

- γγ, ZZ→4l, bb, multi-leptons (WW, ττ)

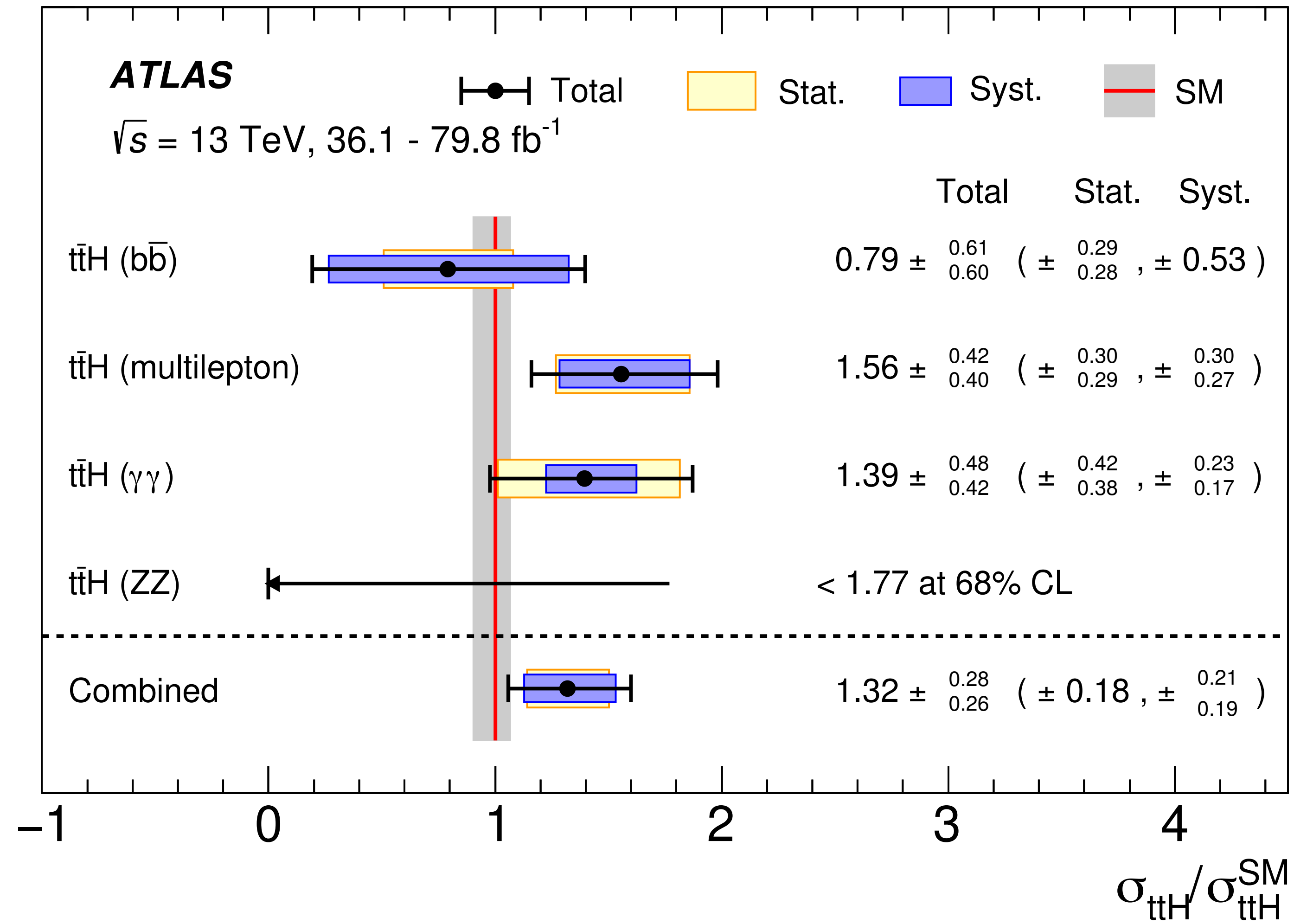


PLB 784 (2018) 173

Higgs-Top Coupling (ttH)



Extensive use of event categorization, multi-variate discriminants



Signal significances (σ):

ATLAS	7,8 TeV	13 TeV	Comb.
Observed	2.7	5.8	6.3
Expected	1.6	4.9	5.1

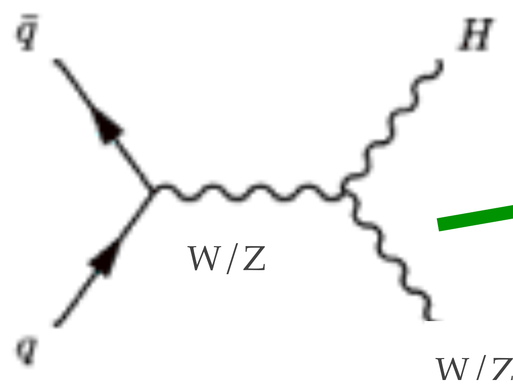
PLB 784 (2018) 173

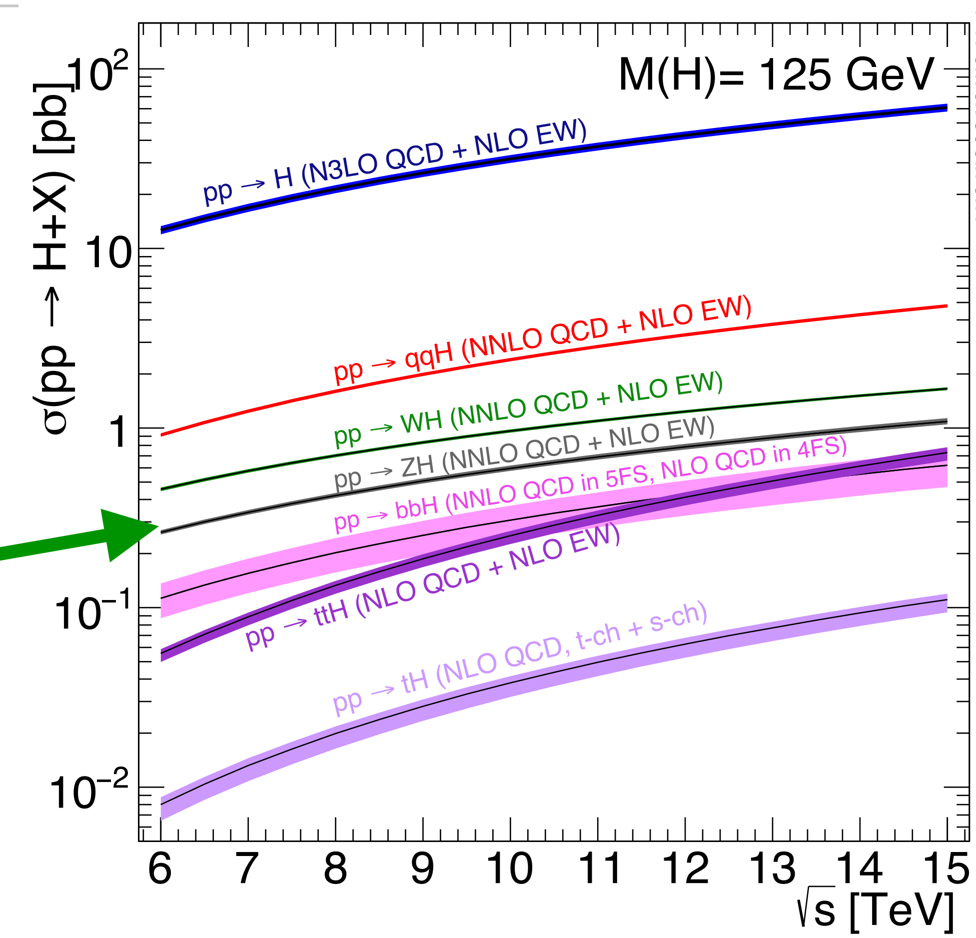
Production mode firmly established despite low cross-section

Higgs-Bottom Coupling (H→bb, VH)

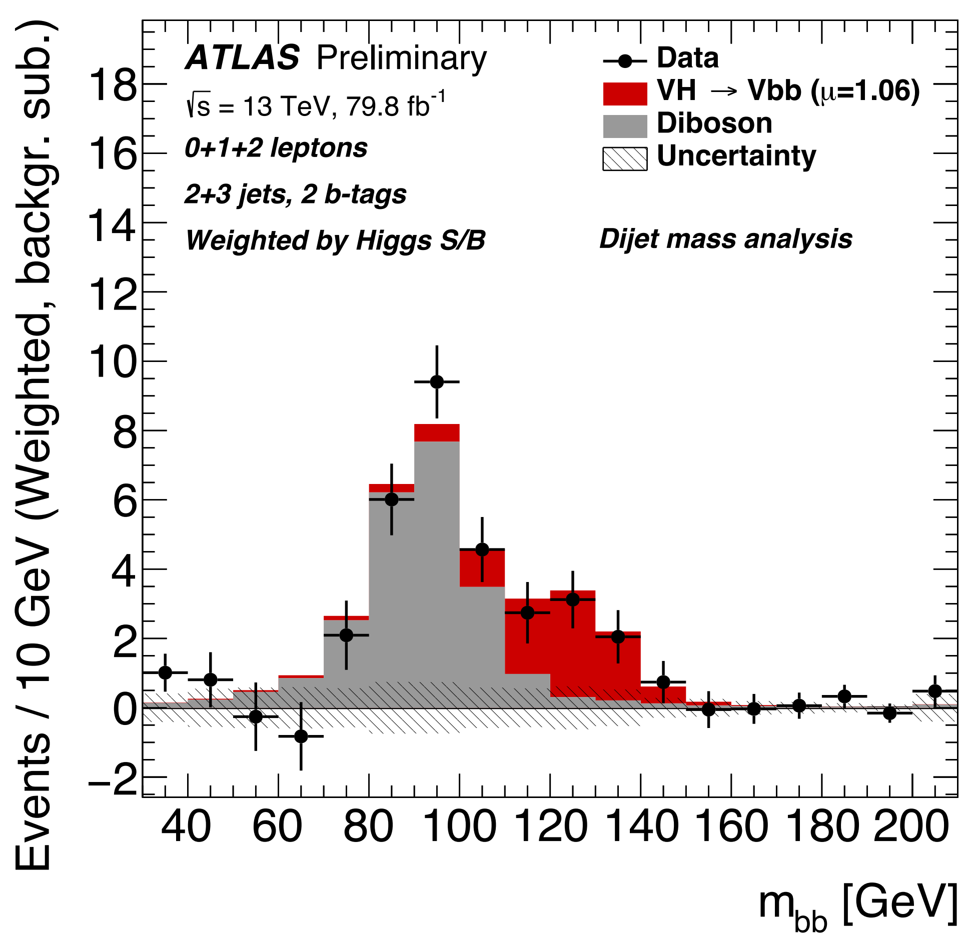
Most copious Higgs decay: H→bb (~58%)

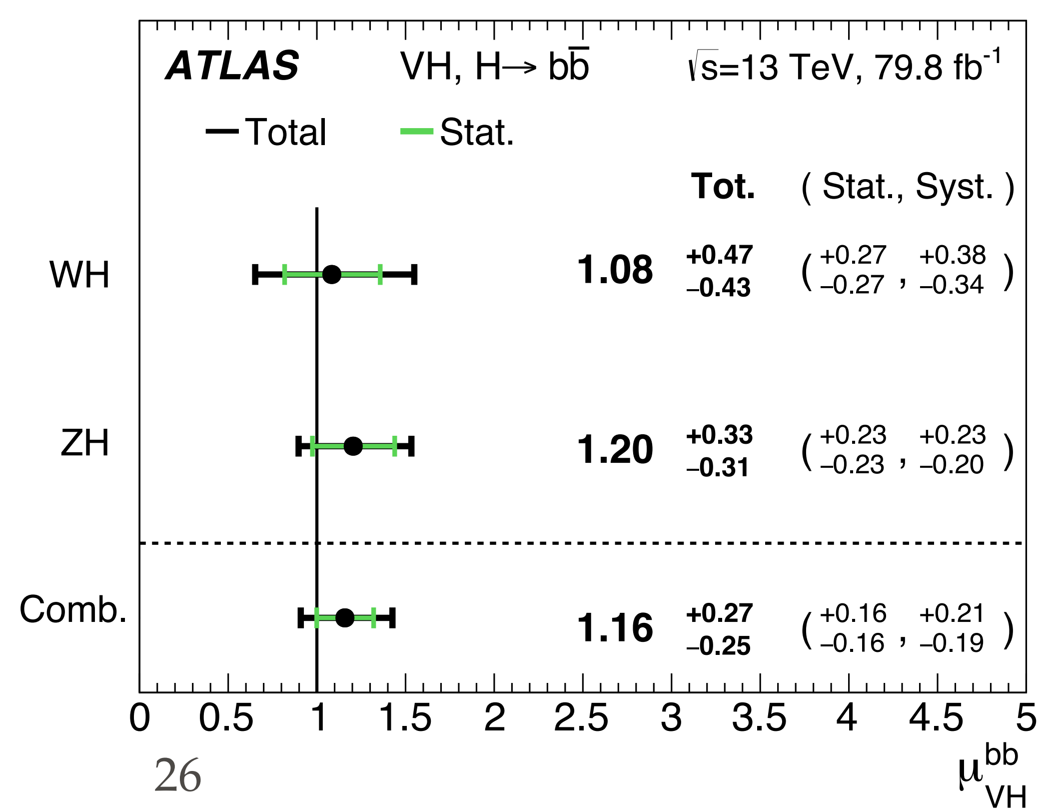
- important to constrain (inv.) Higgs width
- challenging QCD backgrounds
- most sensitive through VH production





PLB 786 (2018) 59





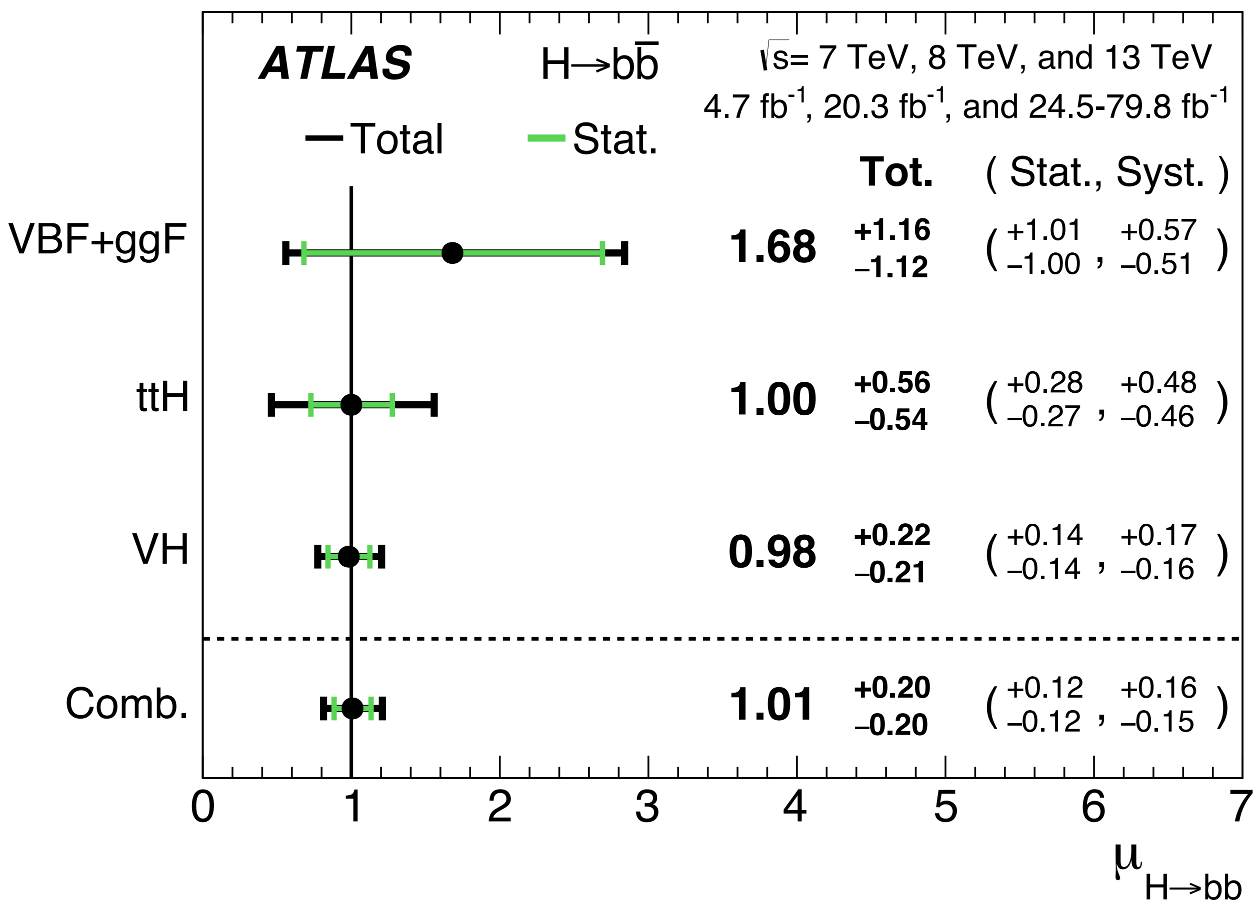
Significance for VH(→bb):

4.9σ (4.3σ)

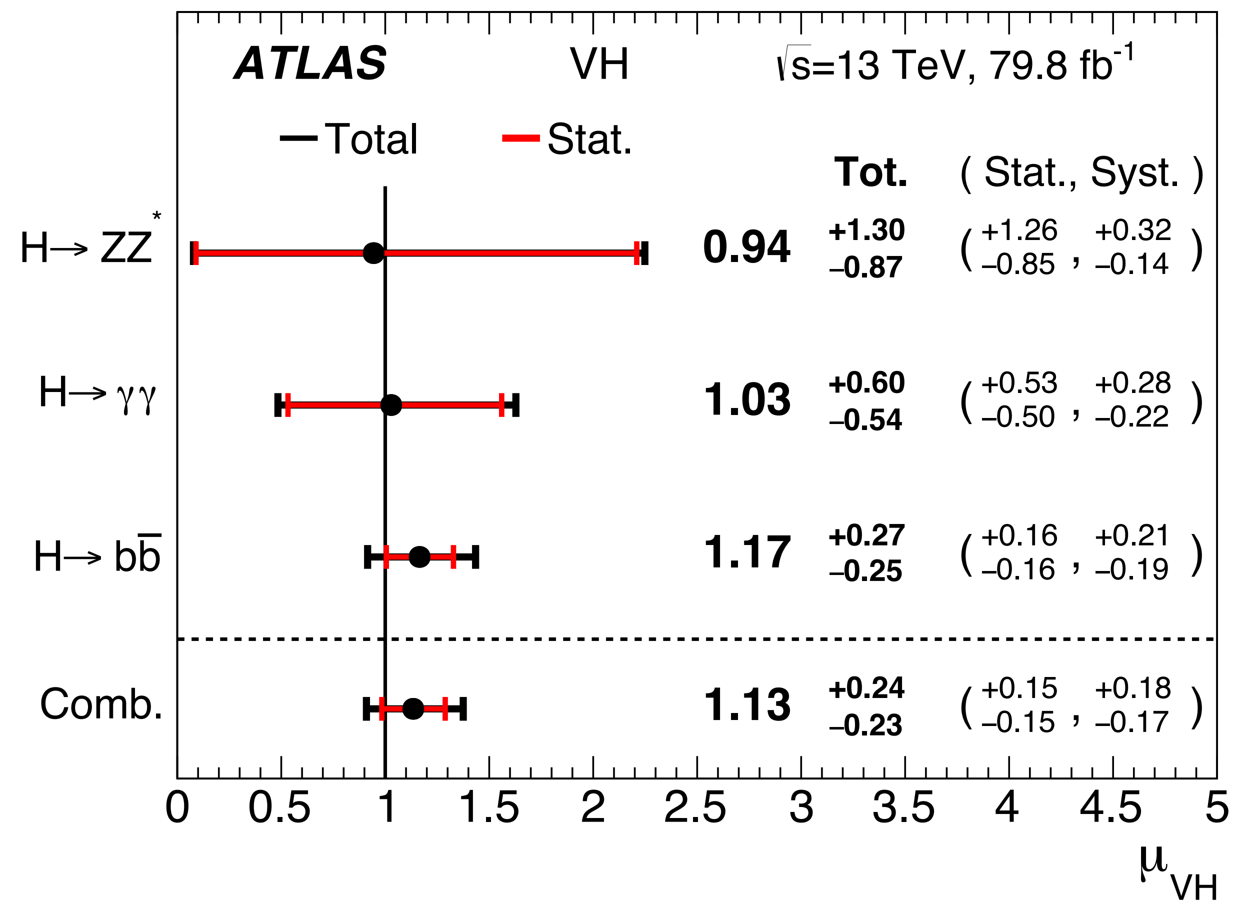
Combined H→bb and VH Results

Combined results for H→bb: include analyses targeting VBF, ttH

Combined results for VH: include analyses targeting H→γγ, H→ZZ



PLB 786 (2018) 59



corresponds to **5.4σ** (5.5σ)

corresponds to **5.3σ** (4.8σ)

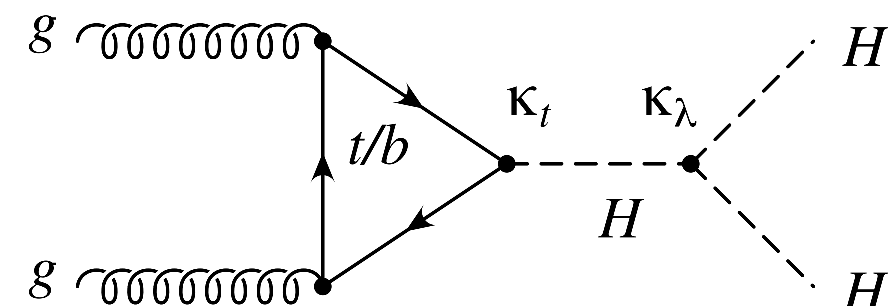
The H→bb decay and VH production mode are now firmly established

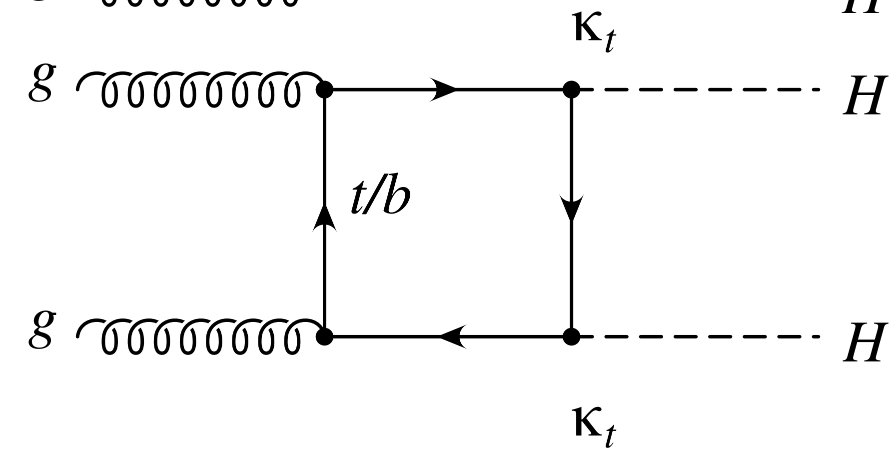
Yukawa couplings of Higgs boson to fermion sector verified

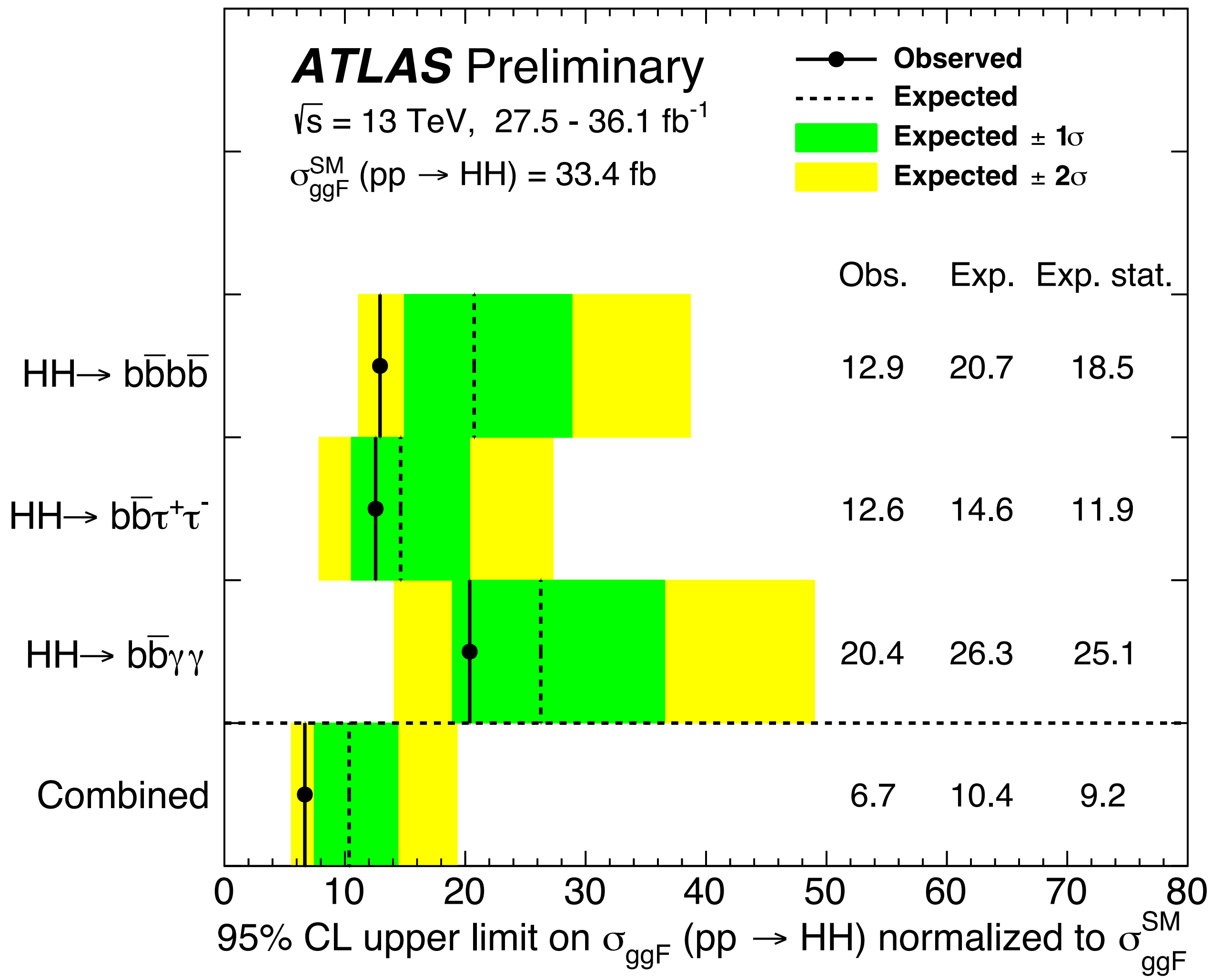
Search for Higgs Pair Production

Key SM prediction: Higgs self-coupling

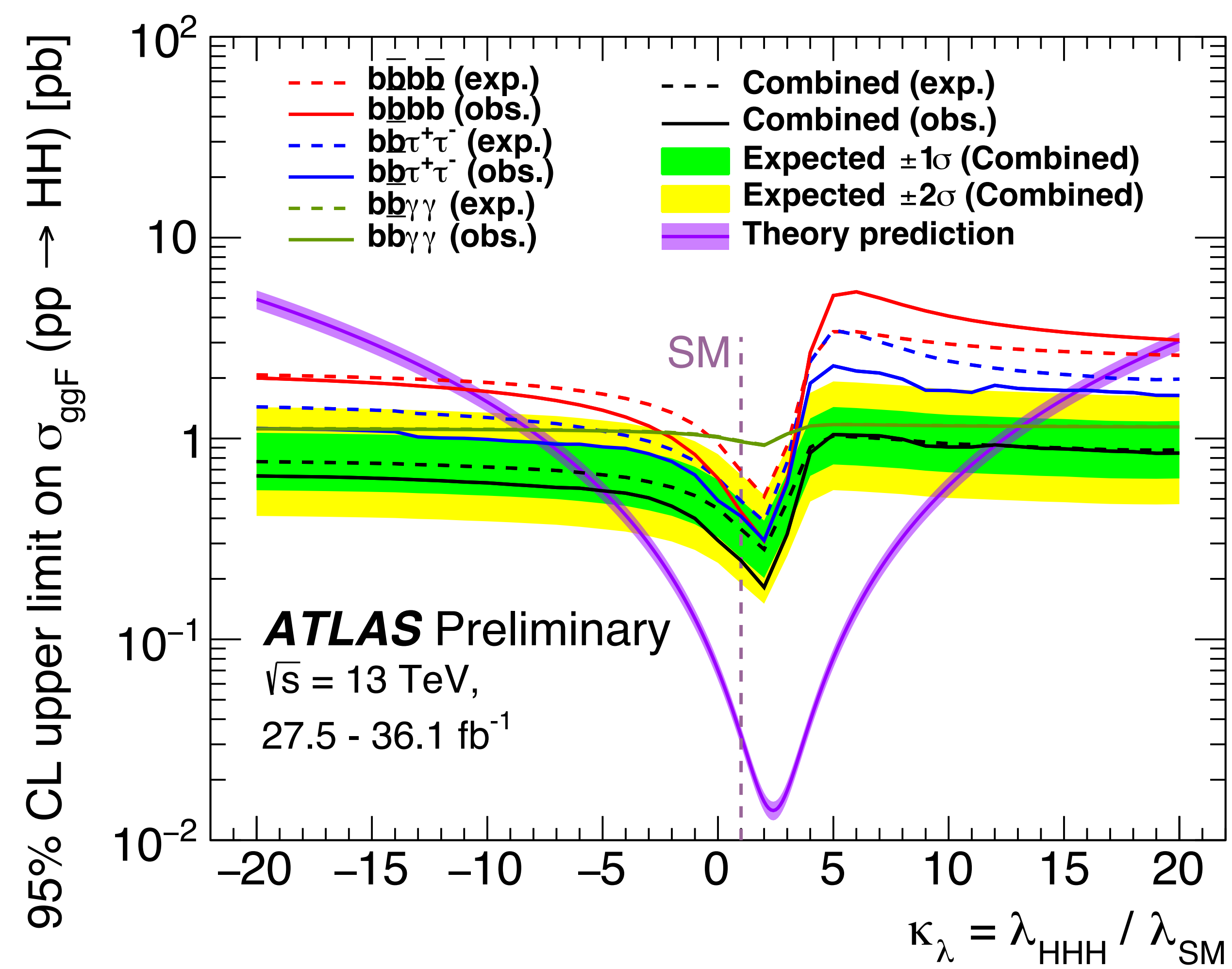
- coupling strength directly related to Higgs potential
- experimental access through Higgs pair production
- interference with other SM HH diagrams







ATLAS-CONF-2018-043



$-5.1 < \kappa_\lambda < 12.1$ (95% CL)

Latest ATLAS Results: Highlights

SM Precision Measurements

- Flavour physics
- Electroweak physics

Properties of Heavy Particles

- top quark physics
- Higgs physics

Searches for BSM Physics

Heavy-Ion Physics

Latest ATLAS Results: Highlights

SM Precision Measurements

- Flavour physics
- Electroweak physics

Properties of Heavy Particles

- top quark physics
- Higgs physics

Searches for BSM Physics

Heavy-Ion Physics

Not predicted by the SM:
Italians drinking cappuccino after dinner

So far: 3 events observed in Bormio, Background ~ 0
Significance passes **5σ**

ATLAS Search Summary

many types of different BSM scenarios considered

will present two of the most recent results

ATLAS Exotics Searches* - 95% CL Upper Exclusion Limits

Status: July 2018

ATLAS Preliminary

$\int \mathcal{L}\, dt = (3.2 - 79.8)\ \text{fb}^{-1}$ $\sqrt{s} = 8, 13$ TeV

	Model	ℓ, γ	Jets†	E_T^{miss}	$\int \mathcal{L}\, dt [\text{fb}^{-1}]$	Limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	$0\ e, \mu$	$1-4$ j	Yes	36.1	M_D 7.7 TeV	$n=2$	1711.03301
	ADD non-resonant $\gamma\gamma$	$2\ \gamma$	–	–	36.7	M_S 8.6 TeV	$n=3$ HLZ NLO	1707.04147
	ADD QBH	–	2 j	–	37.0	M_{th} 8.9 TeV	$n=6$	1703.09217
	ADD BH high $\sum p_T$	$\geq 1\ e, \mu$	≥ 2 j	–	3.2	M_{th} 8.2 TeV	$n=6$, $M_D = 3$ TeV, rot BH	1606.02265
	ADD BH multijet	–	≥ 3 j	–	3.6	M_{th} 9.55 TeV	$n=6$, $M_D = 3$ TeV, rot BH	1512.02586
	RS1 $G_{KK} \to \gamma\gamma$	$2\ \gamma$	–	–	36.7	G_{KK} mass 4.1 TeV	$k/\overline{M}_{Pl} = 0.1$	1707.04147
	Bulk RS $G_{KK} \to WW/ZZ$	multi-channel			36.1	G_{KK} mass 2.3 TeV	$k/\overline{M}_{Pl} = 1.0$	CERN-EP-2018-179
	Bulk RS $g_{KK} \to tt$	$1\ e, \mu$	≥ 1 b, ≥ 1J/2j	Yes	36.1	g_{KK} mass 3.8 TeV	$\Gamma/m = 15\%$	1804.10823
	2UED / RPP	$1\ e, \mu$	≥ 2 b, ≥ 3 j	Yes	36.1	KK mass 1.8 TeV	Tier (1,1), $\mathcal{B}(A^{(1,1)} \to tt) = 1$	1803.09678
Gauge bosons	SSM $Z' \to \ell\ell$	$2\ e, \mu$	–	–	36.1	Z' mass 4.5 TeV		1707.02424
	SSM $Z' \to \tau\tau$	$2\ \tau$	–	–	36.1	Z' mass 2.42 TeV		1709.07242
	Leptophobic $Z' \to bb$	–	2 b	–	36.1	Z' mass 2.1 TeV		1805.09299
	Leptophobic $Z' \to tt$	$1\ e, \mu$	≥ 1 b, ≥ 1J/2j	Yes	36.1	Z' mass 3.0 TeV	$\Gamma/m = 1\%$	1804.10823
	SSM $W' \to \ell\nu$	$1\ e, \mu$	–	Yes	79.8	W' mass 5.6 TeV		ATLAS-CONF-2018-017
	SSM $W' \to \tau\nu$	$1\ \tau$	–	Yes	36.1	W' mass 3.7 TeV		1801.06992
	HVT $V' \to WV \to qqqq$ model B	$0\ e, \mu$	2 J	–	79.8	V' mass 4.15 TeV	$g_V = 3$	ATLAS-CONF-2018-016
	HVT $V' \to WH/ZH$ model B	multi-channel			36.1	V' mass 2.93 TeV	$g_V = 3$	1712.06518
	LRSM $W'_R \to tb$	multi-channel			36.1	W' mass 3.25 TeV		CERN-EP-2018-142
CI	CI $qqqq$	–	2 j	–	37.0	Λ 21.8 TeV η^-_{LL}		1703.09217
	CI $\ell\ell qq$	$2\ e, \mu$	–	–	36.1	Λ 40.0 TeV η^-_{LL}		1707.02424
	CI $tttt$	$\geq 1\ e, \mu$	≥ 1 b, ≥ 1 j	Yes	36.1	Λ 2.57 TeV	$\lvert C_{4t}\rvert = 4\pi$	CERN-EP-2018-174
DM	Axial-vector mediator (Dirac DM)	$0\ e, \mu$	$1-4$ j	Yes	36.1	m_{med} 1.55 TeV	g_q=0.25, g_χ=1.0, $m(\chi) = 1$ GeV	1711.03301
	Colored scalar mediator (Dirac DM)	$0\ e, \mu$	$1-4$ j	Yes	36.1	m_{med} 1.67 TeV	g=1.0, $m(\chi) = 1$ GeV	1711.03301
	$VV\chi\chi$ EFT (Dirac DM)	$0\ e, \mu$	1 J, ≤ 1 j	Yes	3.2	M_* 700 GeV	$m(\chi) < 150$ GeV	1608.02372
LQ	Scalar LQ 1st gen	$2\ e$	≥ 2 j	–	3.2	LQ mass 1.1 TeV	$\beta = 1$	1605.06035
	Scalar LQ 2nd gen	$2\ \mu$	≥ 2 j	–	3.2	LQ mass 1.05 TeV	$\beta = 1$	1605.06035
	Scalar LQ 3rd gen	$1\ e, \mu$	≥ 1 b, ≥ 3 j	Yes	20.3	LQ mass 640 GeV	$\beta = 0$	1508.04735
Heavy quarks	VLQ $TT \to Ht/Zt/Wb + X$	multi-channel			36.1	T mass 1.37 TeV	SU(2) doublet	ATLAS-CONF-2018-032
	VLQ $BB \to Wt/Zb + X$	multi-channel			36.1	B mass 1.34 TeV	SU(2) doublet	ATLAS-CONF-2018-032
	VLQ $T_{5/3} T_{5/3} \lvert T_{5/3} \to Wt + X$	2(SS)/$\geq 3\ e, \mu$	≥ 1 b, ≥ 1 j	Yes	36.1	$T_{5/3}$ mass 1.64 TeV	$\mathcal{B}(T_{5/3} \to Wt) = 1$, $c(T_{5/3} Wt) = 1$	CERN-EP-2018-171
	VLQ $Y \to Wb + X$	$1\ e, \mu$	≥ 1 b, ≥ 1j	Yes	3.2	Y mass 1.44 TeV	$\mathcal{B}(Y \to Wb) = 1$, $c(YWb) = 1/\sqrt{2}$	ATLAS-CONF-2016-072
	VLQ $B \to Hb + X$	$0\ e, \mu$, $2\ \gamma$	≥ 1 b, ≥ 1j	Yes	79.8	B mass 1.21 TeV	$\kappa_B = 0.5$	ATLAS-CONF-2018-024
	VLQ $QQ \to WqWq$	$1\ e, \mu$	≥ 4 j	Yes	20.3	Q mass 690 GeV		1509.04261
Excited fermions	Excited quark $q^* \to qg$	–	2 j	–	37.0	q^* mass 6.0 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1703.09127
	Excited quark $q^* \to q\gamma$	$1\ \gamma$	1 j	–	36.7	q^* mass 5.3 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1709.10440
	Excited quark $b^* \to bg$	–	1 b, 1 j	–	36.1	b^* mass 2.6 TeV		1805.09299
	Excited lepton ℓ^*	$3\ e, \mu$	–	–	20.3	ℓ^* mass 3.0 TeV	$\Lambda = 3.0$ TeV	1411.2921
	Excited lepton ν^*	$3\ e, \mu, \tau$	–	–	20.3	ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	Type III Seesaw	$1\ e, \mu$	≥ 2 j	Yes	79.8	N^0 mass 560 GeV		ATLAS-CONF-2018-020
	LRSM Majorana ν	$2\ e, \mu$	2 j	–	20.3	N^0 mass 2.0 TeV	$m(W_R) = 2.4$ TeV, no mixing	1506.06020
	Higgs triplet $H^{\pm\pm} \to \ell\ell$	2,3,4 e, μ (SS)	–	–	36.1	$H^{\pm\pm}$ mass 870 GeV	DY production	1710.09748
	Higgs triplet $H^{\pm\pm} \to \ell\tau$	$3\ e, \mu, \tau$	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, $\mathcal{B}(H^{\pm\pm}_L \to \ell\tau) = 1$	1411.2921
	Monotop (non-res prod)	$1\ e, \mu$	1 b	Yes	20.3	spin-1 invisible particle mass 657 GeV	$a_{\text{non-res}} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	multi-charged particle mass 785 GeV	DY production, $\lvert q\rvert = 5e$	1504.04188
	Magnetic monopoles	–	–	–	7.0	monopole mass 1.34 TeV	DY production, $\lvert g\rvert = 1 g_D$, spin 1/2	1509.08059

$\sqrt{s} = 8$ TeV $\sqrt{s} = 13$ TeV

Mass scale [TeV] (10^{-1}, 1, 10)

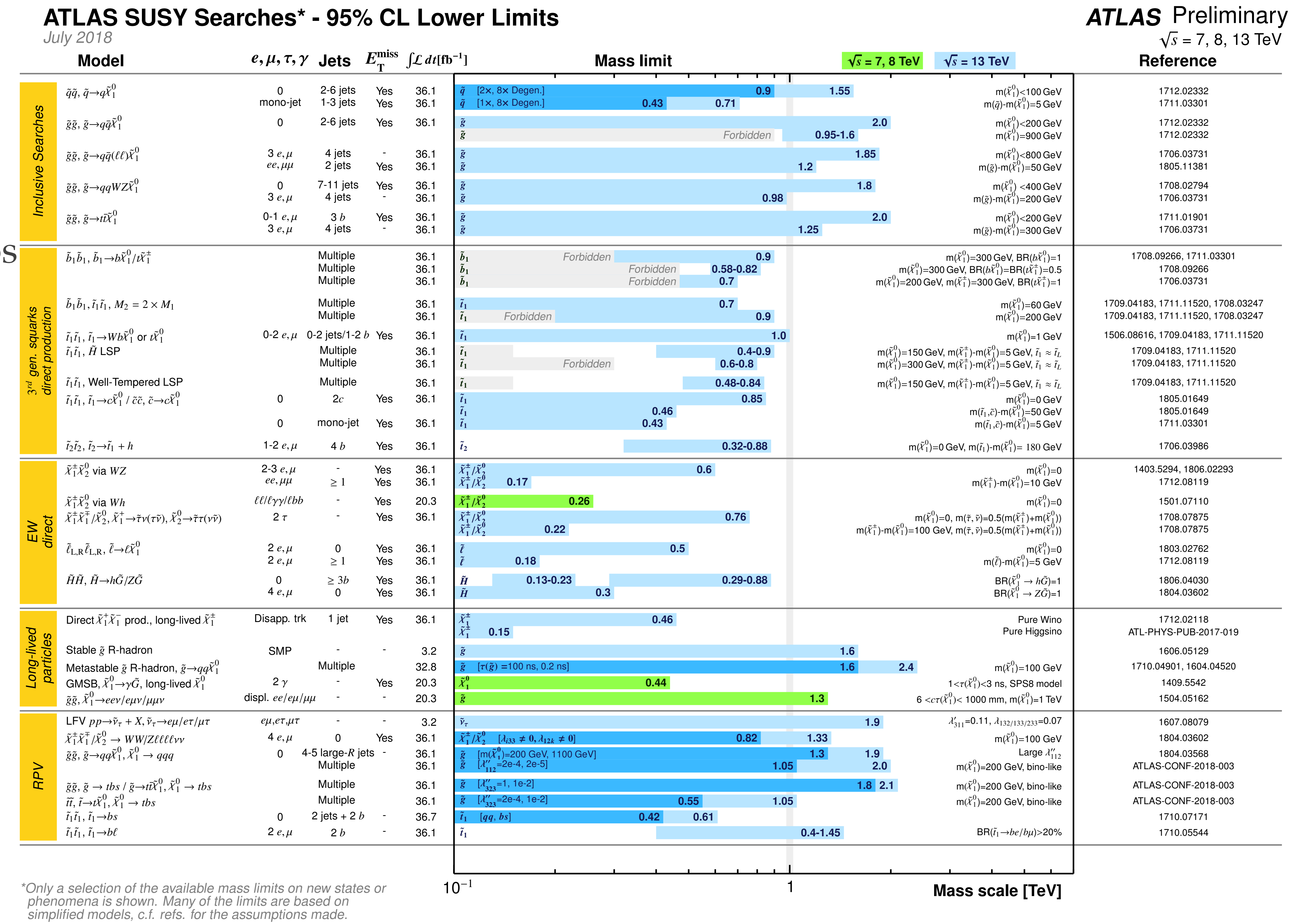
*Only a selection of the available mass limits on new states or phenomena is shown.

†Small-radius (large-radius) jets are denoted by the letter j (J).

ATLAS Search Summary

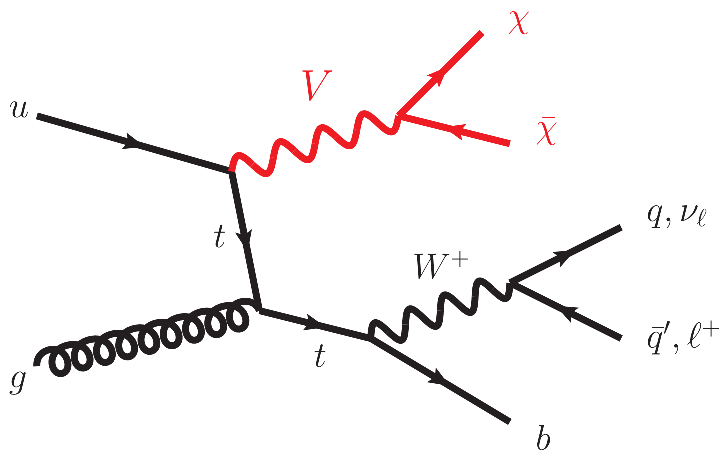
many types of different BSM scenarios considered

will present two of the most recent results

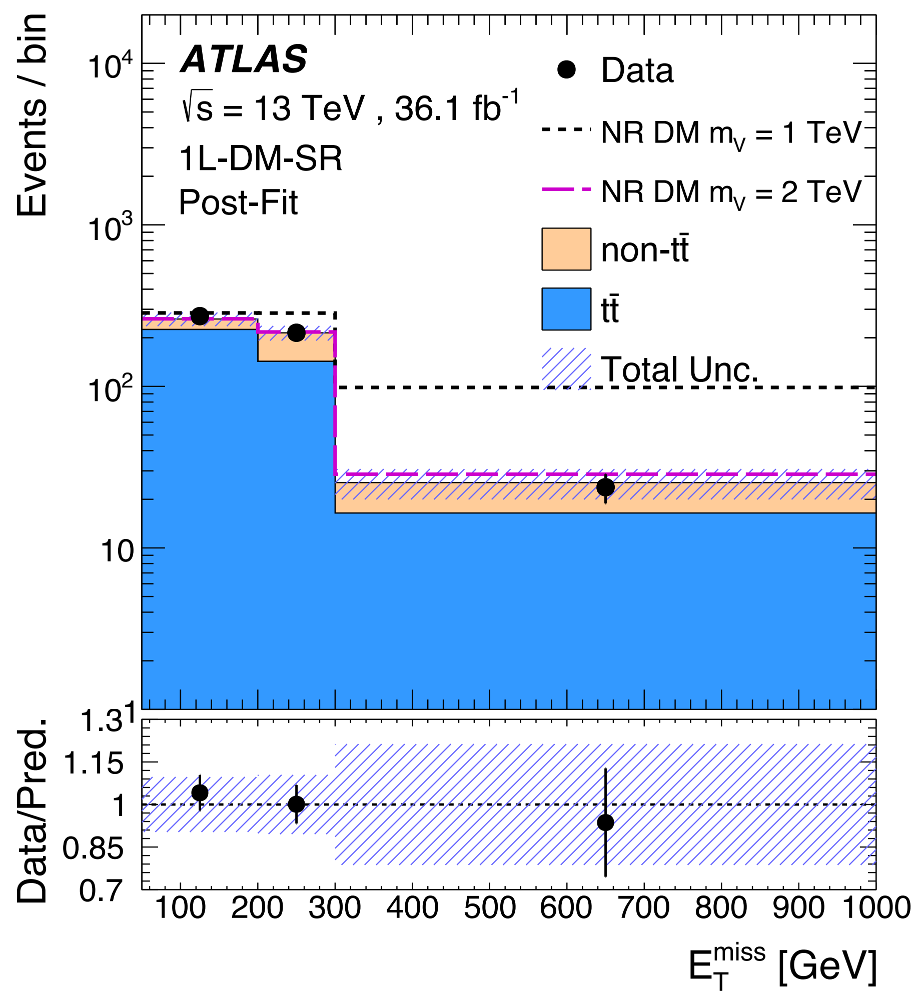


Search for single top + E_T^{miss}

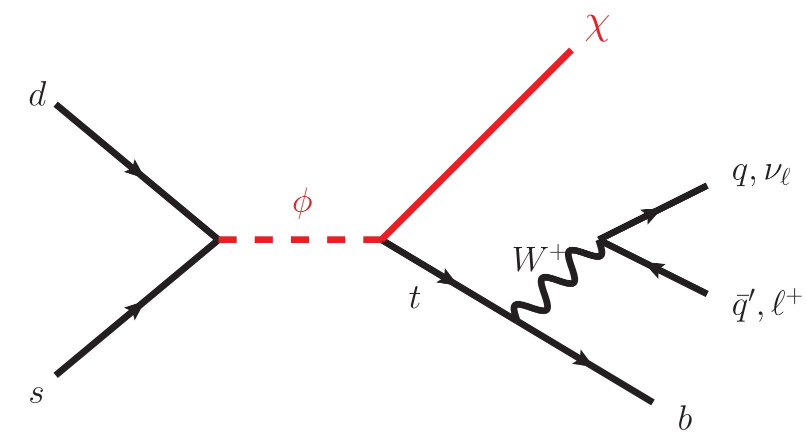
Probes new vector particle V decaying invisibly



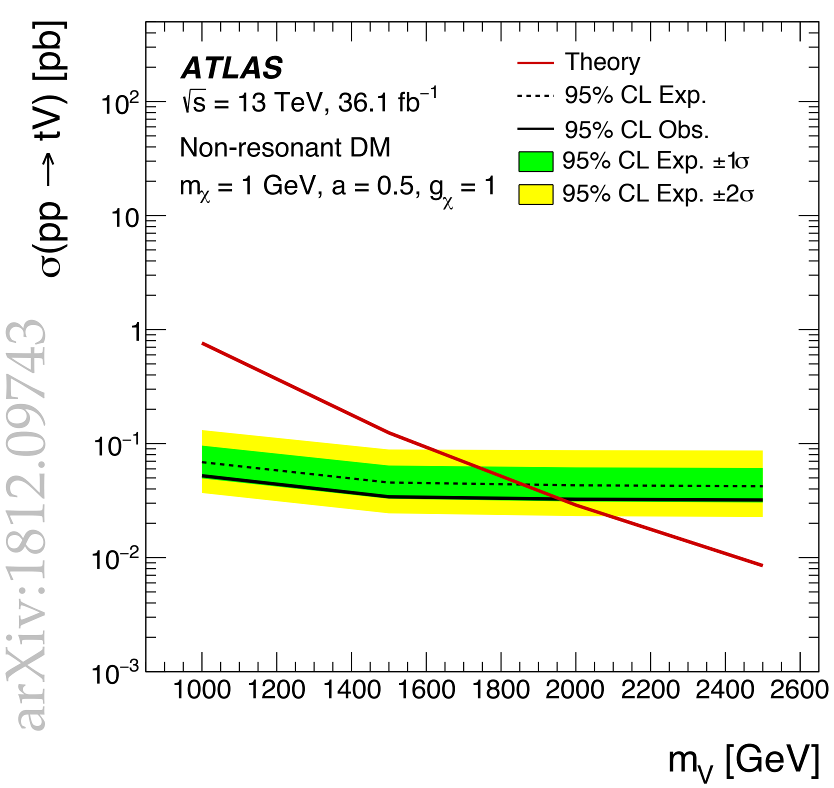
$$\mathcal{L}_{\text{int}} = aV_\mu \bar{u}\gamma^\mu P_{\text{R}} t + g_\chi V_\mu \bar{\chi}\gamma^\mu \chi + \text{h.c.}$$



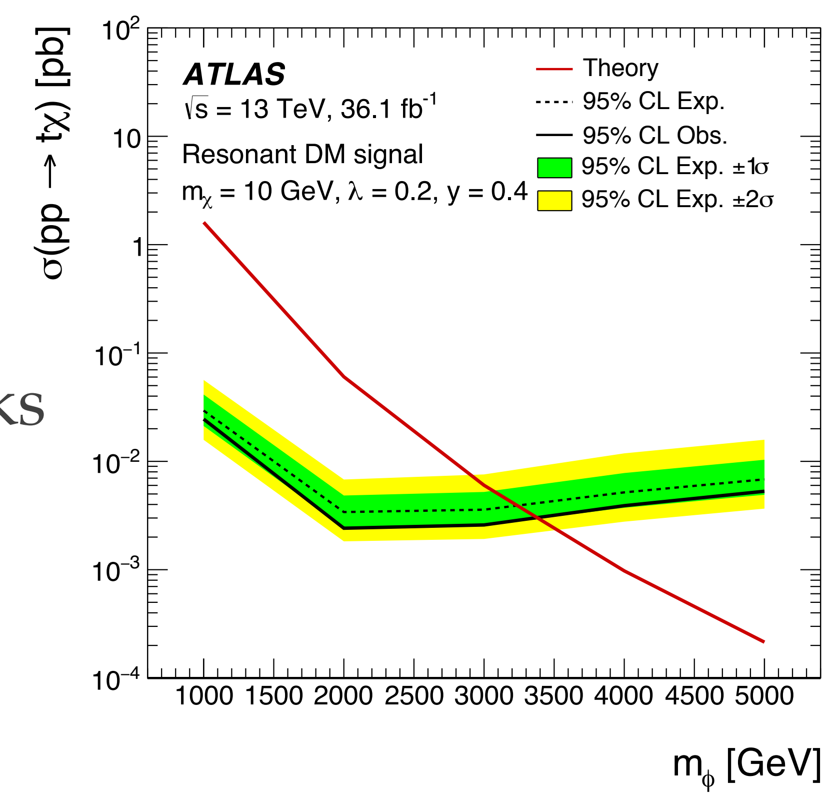
Probes charge +2/3 scalar resonance



$$\mathcal{L}_{\text{int}} = \lambda \phi \bar{d}^c P_{\text{R}} s + y \phi \bar{\chi} P_{\text{R}} t + \text{h.c.}$$



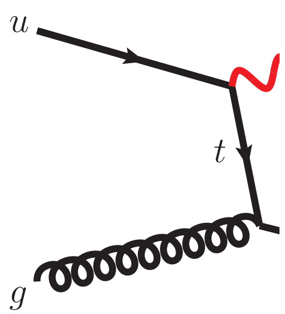
Also probes vector-like T-quarks



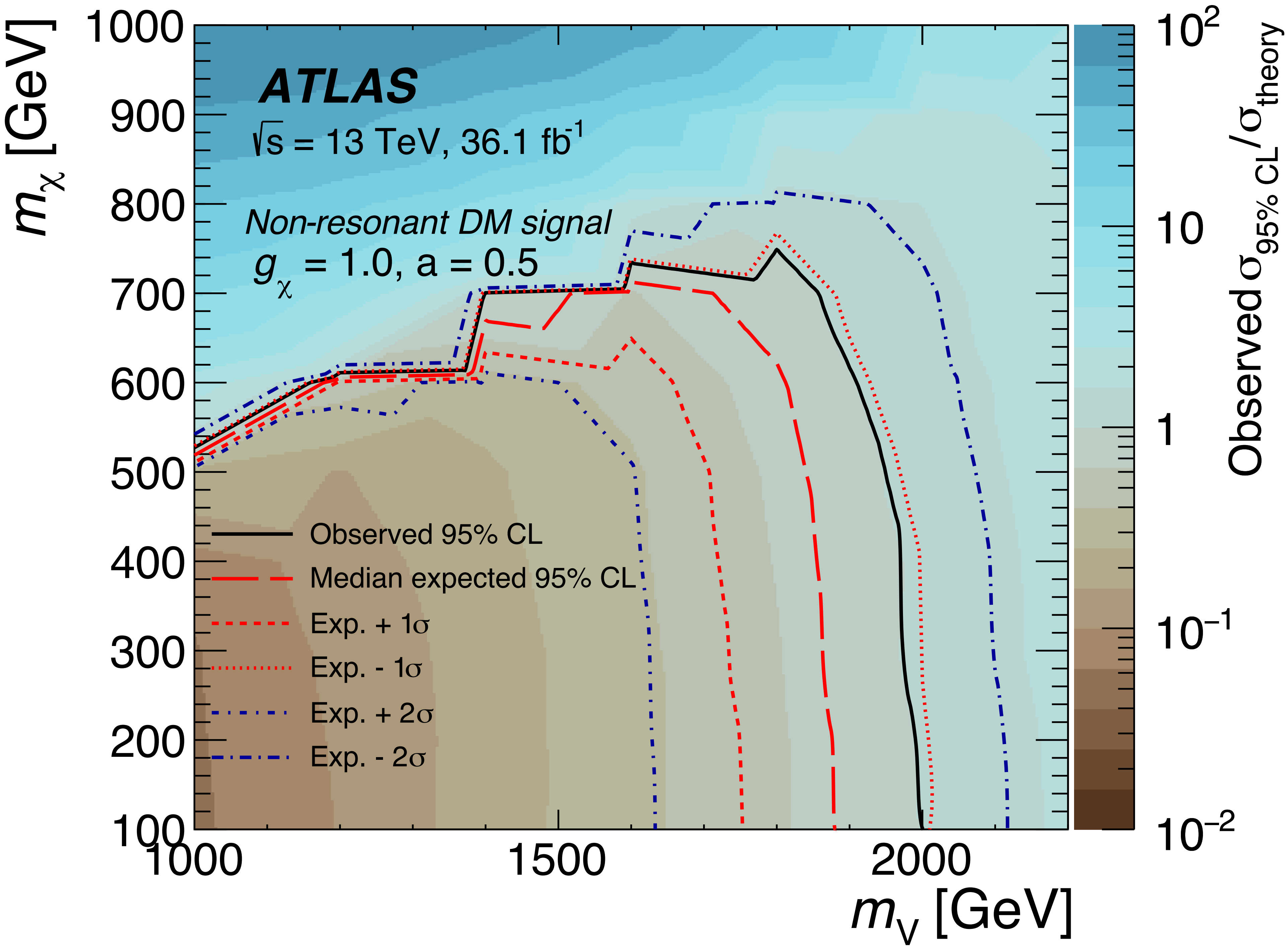
Search for single top + E_T^{miss}

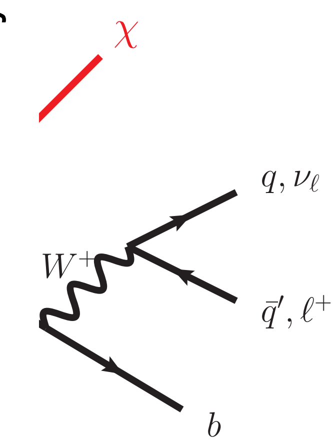
Probes new vector particle V decaying in

Probes charge +2/3 scalar

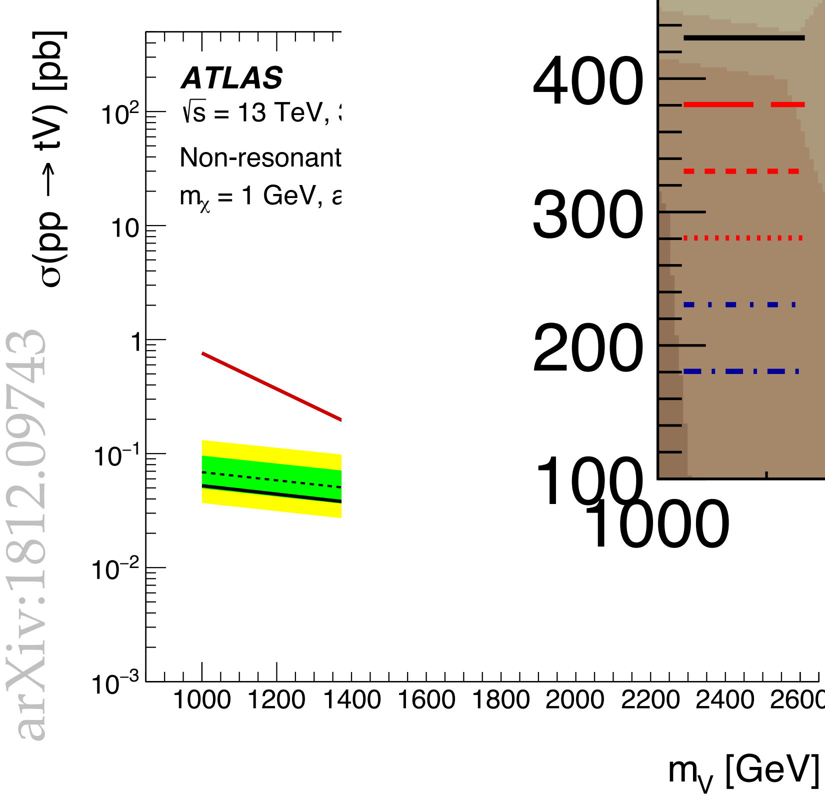


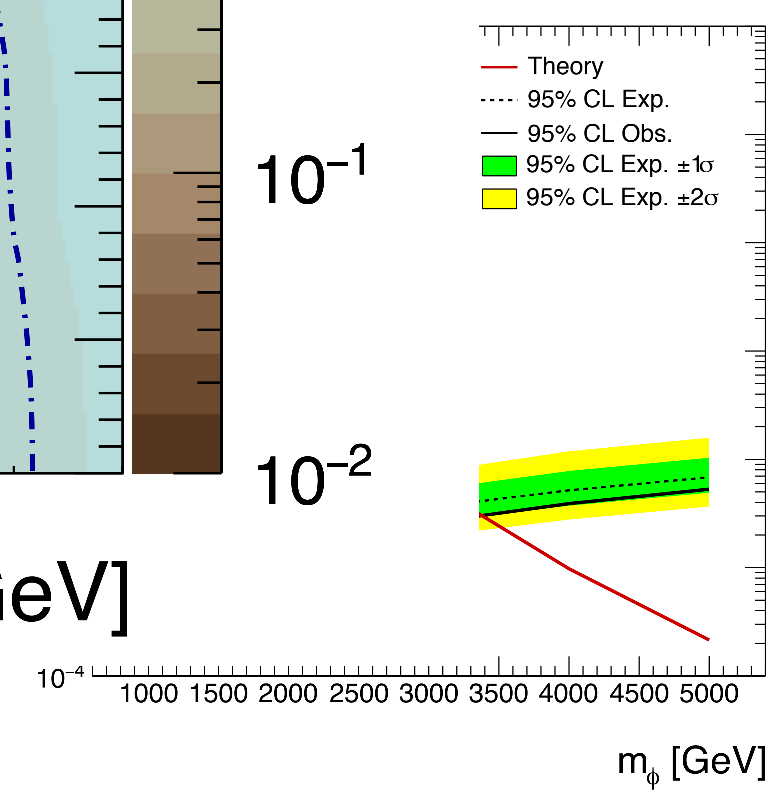
$\mathcal{L}_{\text{int}} = aV_\mu \bar{u}\gamma^\mu$





$\bar{\chi} P_R t + \text{h.c.}$

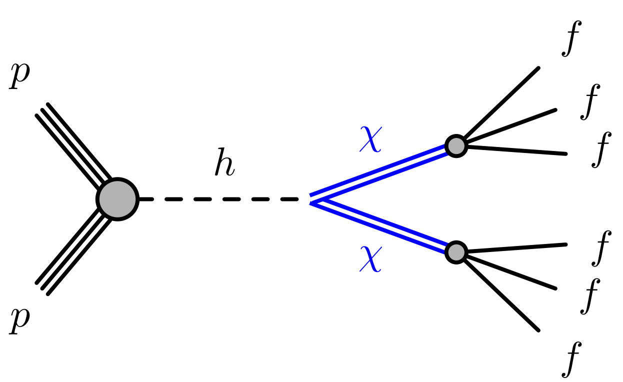


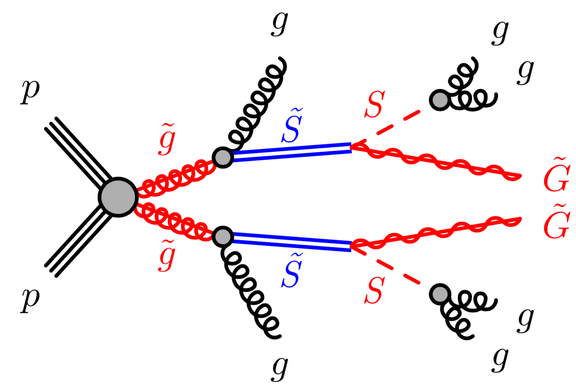


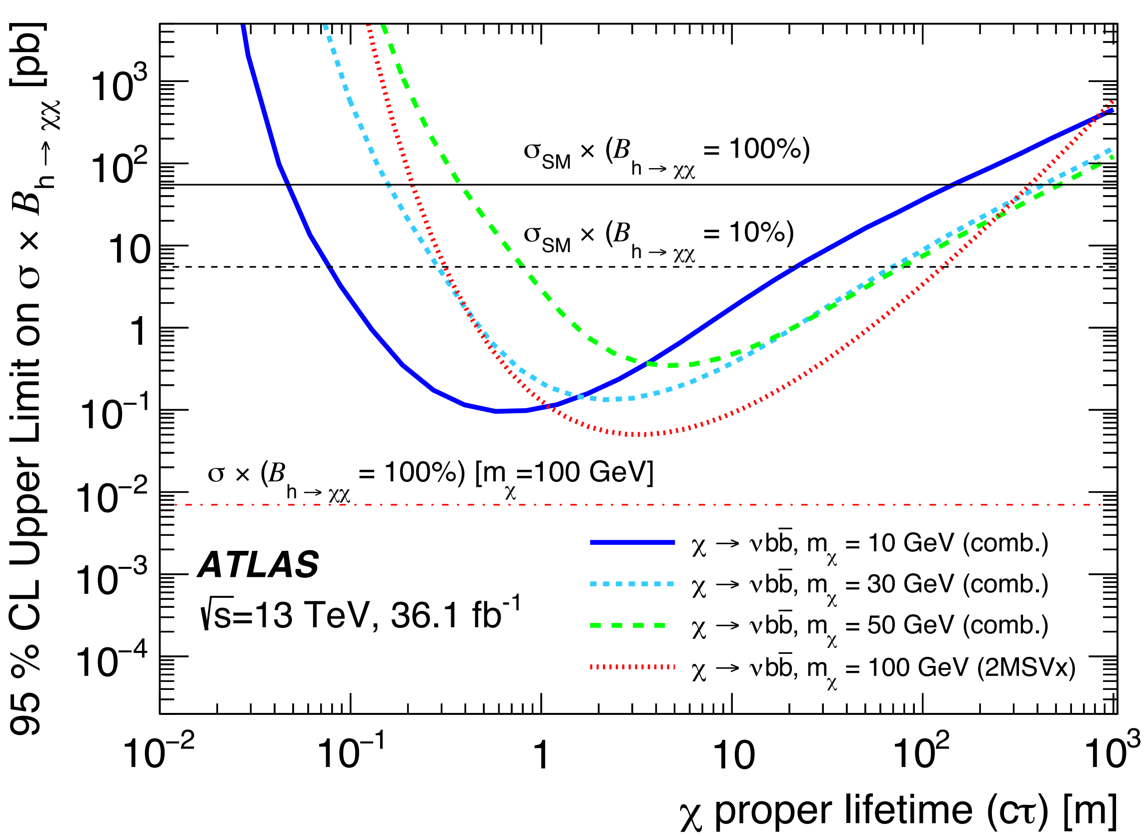
arXiv:1812.09743

Displaced Jets in Muon System

Plethora of models predicted long-lived particles:
SUSY, Neutral Naturalness, DM



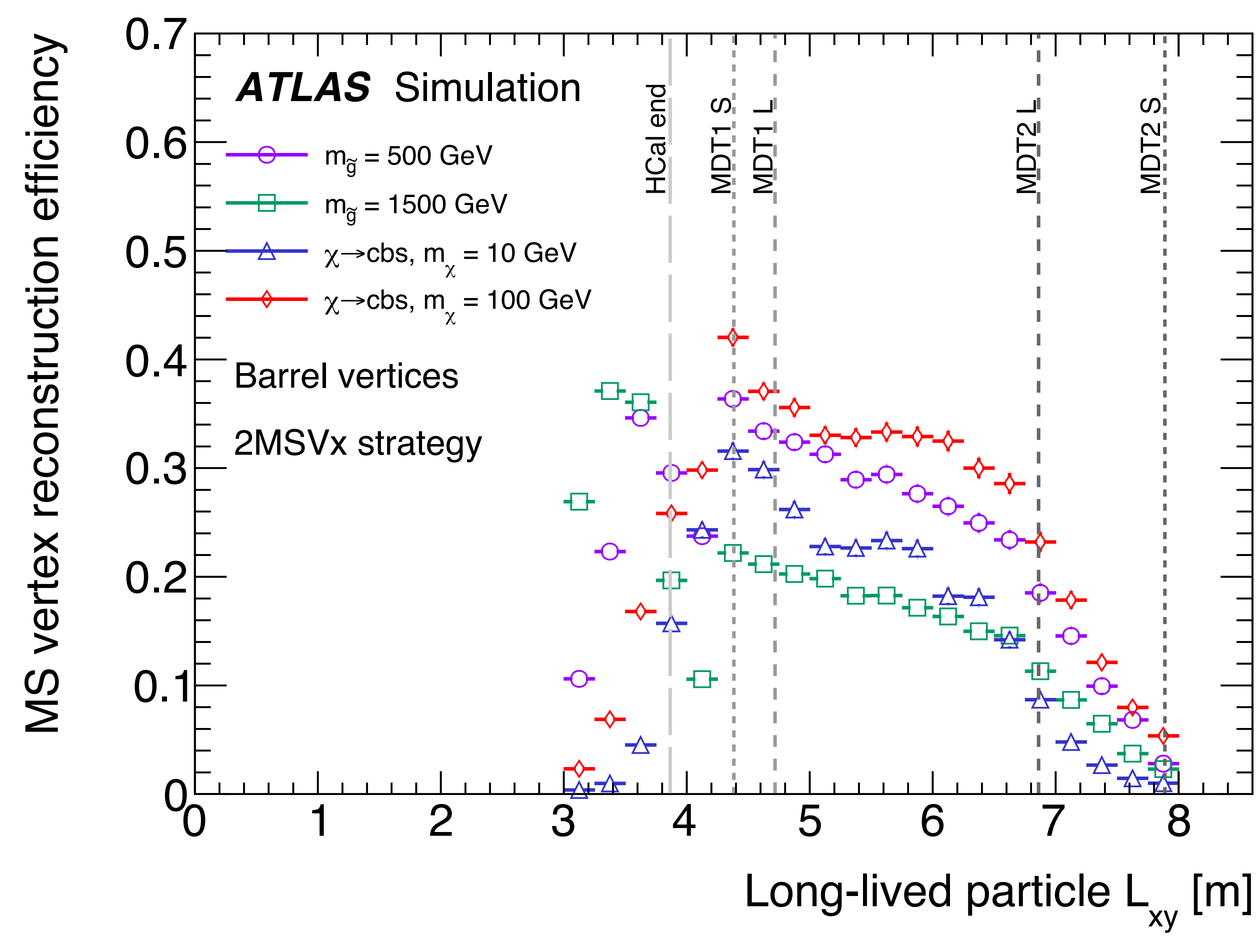




limits extracted based on event yields

Event selection relies on reconstruction of displaced vertices in the Muon Spectrometer

- isolation criteria from ID vertices and calo-jets imposed



SRs include 1 MS-vtx and 2 MS-vtx events

arXiv:1811.07370

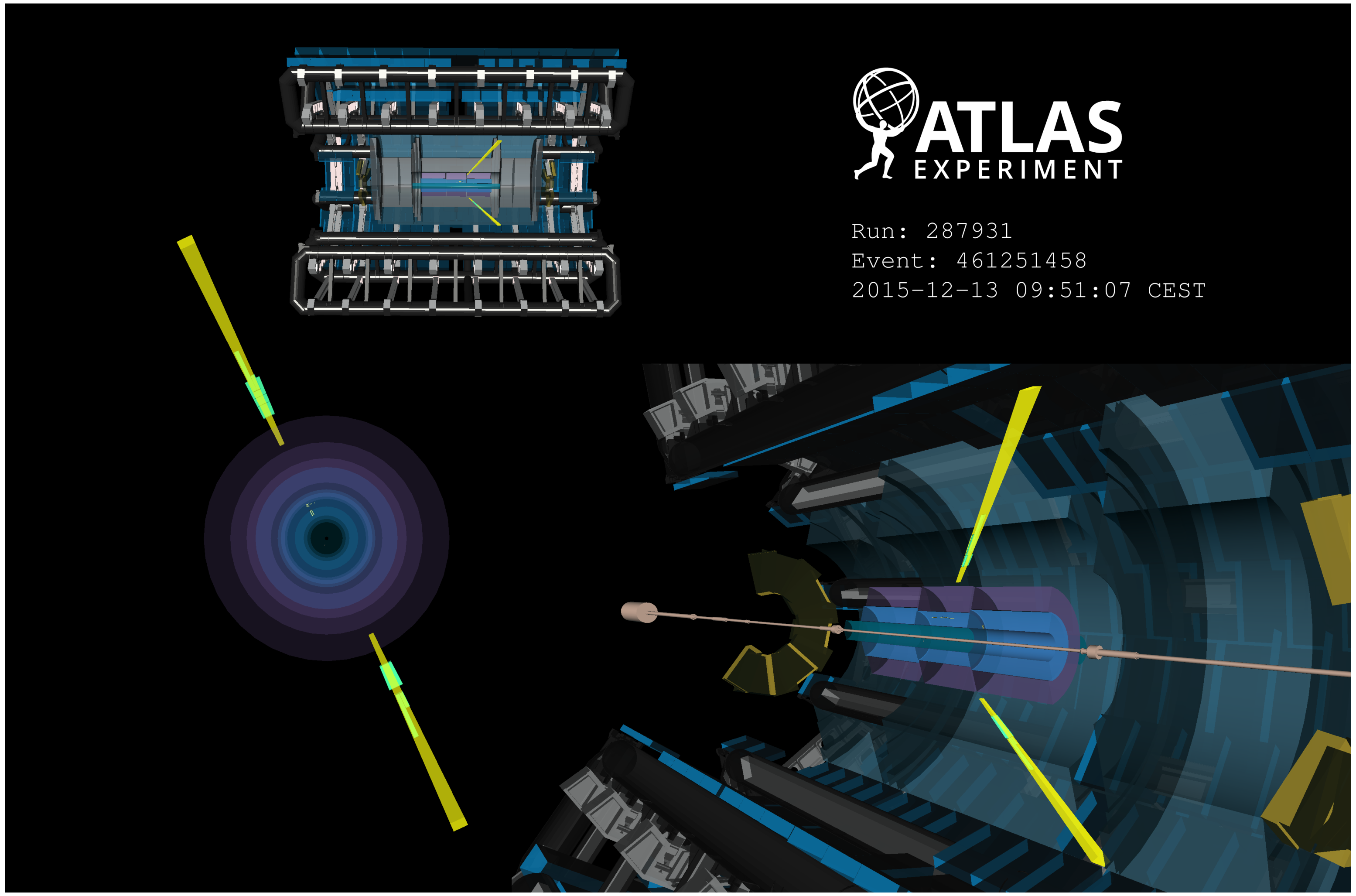
Latest ATLAS Results: Highlights

SM Precision Measurements
- Flavour physics
- Electroweak physics

Properties of Heavy Particles
- top quark physics
- Higgs physics

Searches for BSM Physics

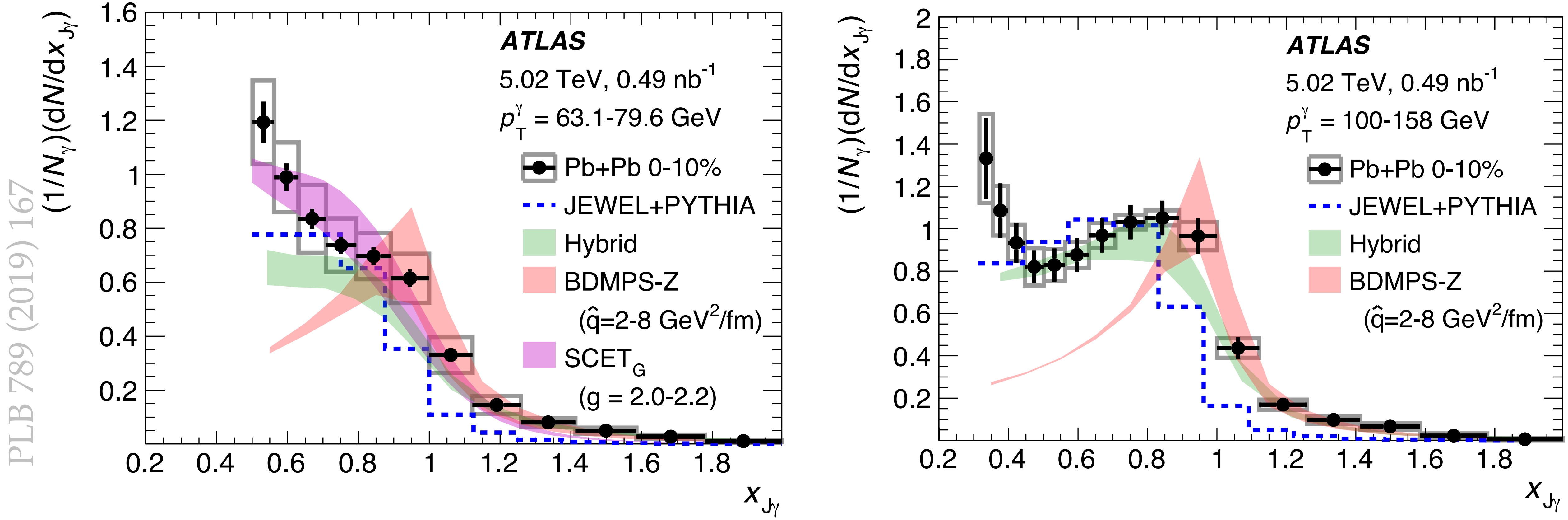
Heavy-Ion Physics



Candidate event: light-by-light scattering in Pb-Pb collisions

Photon-Jet Momentum Correlations in Pb+Pb

Allows to probe energy loss behaviour of jets in hot, deconfined medium
Investigate **$x_{J\gamma} = p_T^{jet} / p_T^{\gamma}$** in back-to-back photon+jet events
in **$\sqrt{s}$ = 5.02 TeV Pb+Pb** collisions (and compare also with pp data)

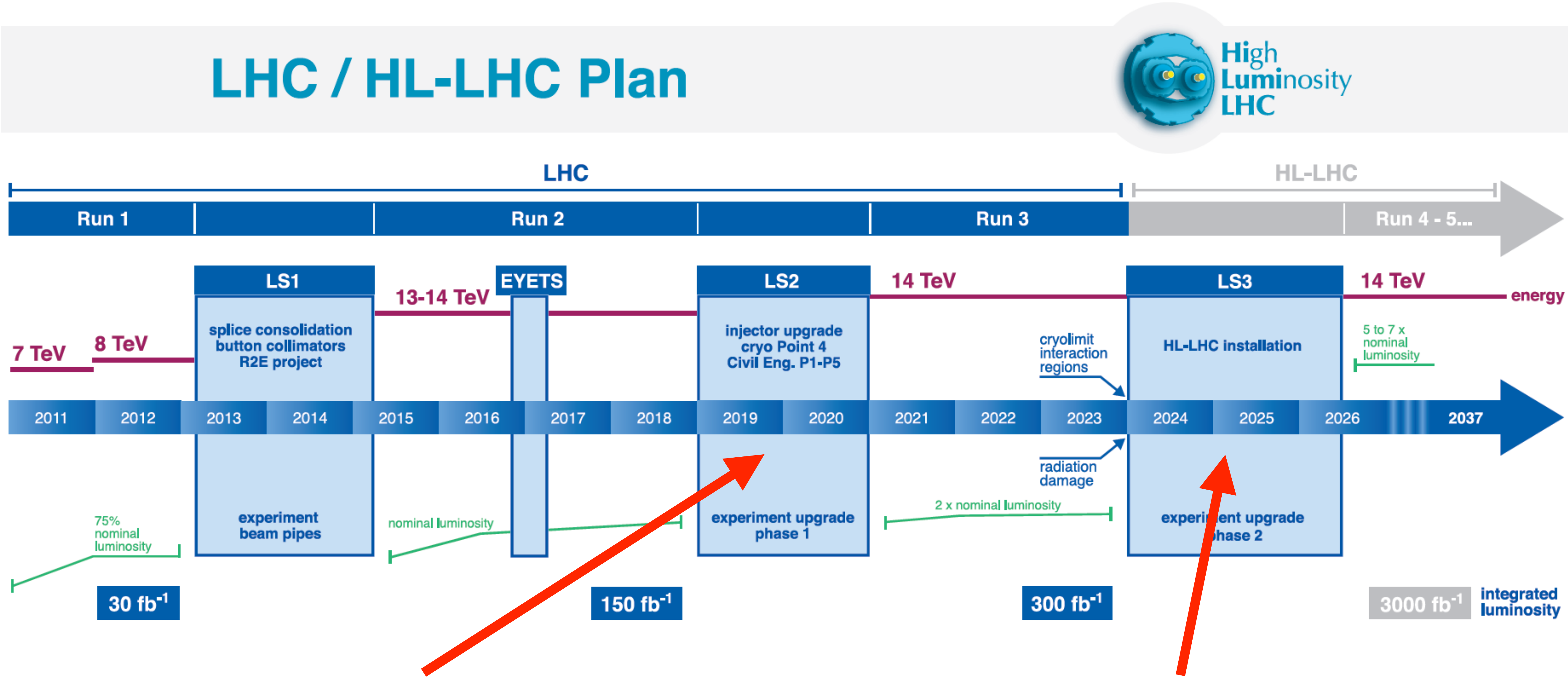


shown: bins with highest ΣE_T

Distributions corrected back to particle level for comparison with predictions

Allow tuning of models predicting energy loss of energetic partons in hot nuclear medium

Upgrade Schedule



ATLAS Phase 1 Upgrades:

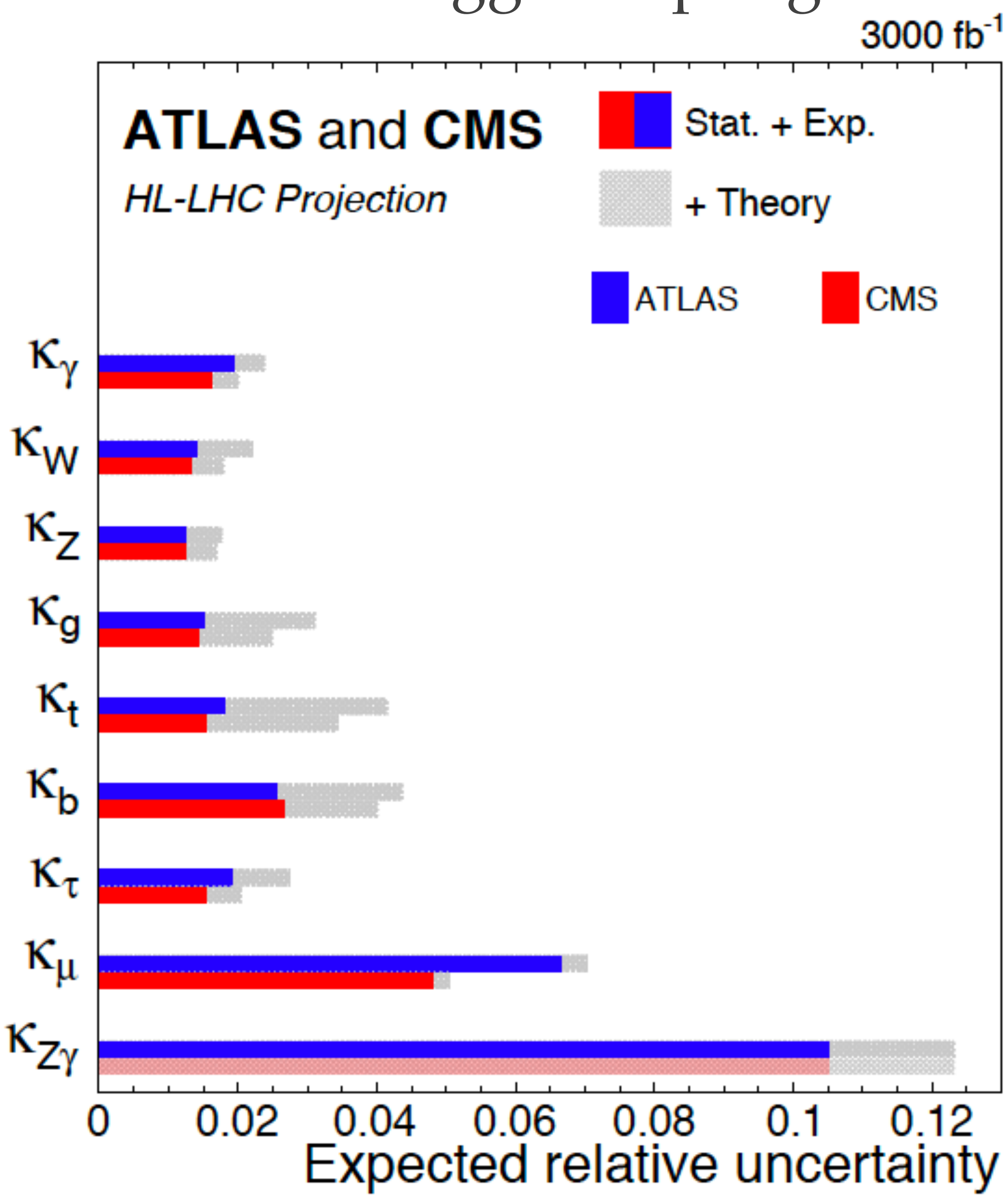
- Install New Small Wheel (Muon System)
- Improved Triggering (L1Calo, Fast Track Trigger)
- Revamp read-out electronics

ATLAS Phase 2 Upgrades:

- complete new Inner Tracker (ITk) (all-silicon tracking)
- High-Granularity Timing Detector
- Muon Spectrometer Upgrade

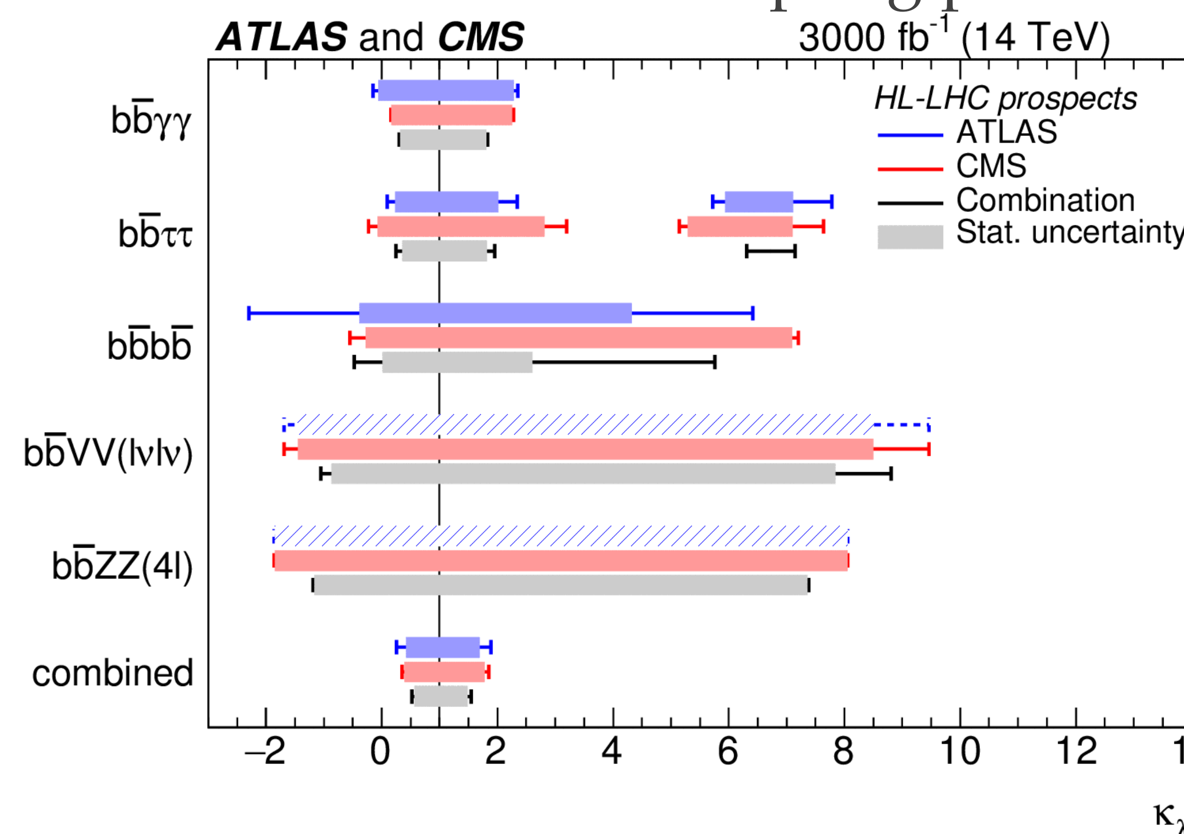
Some HL-LHC Prospects (assuming 3 ab^{-1})

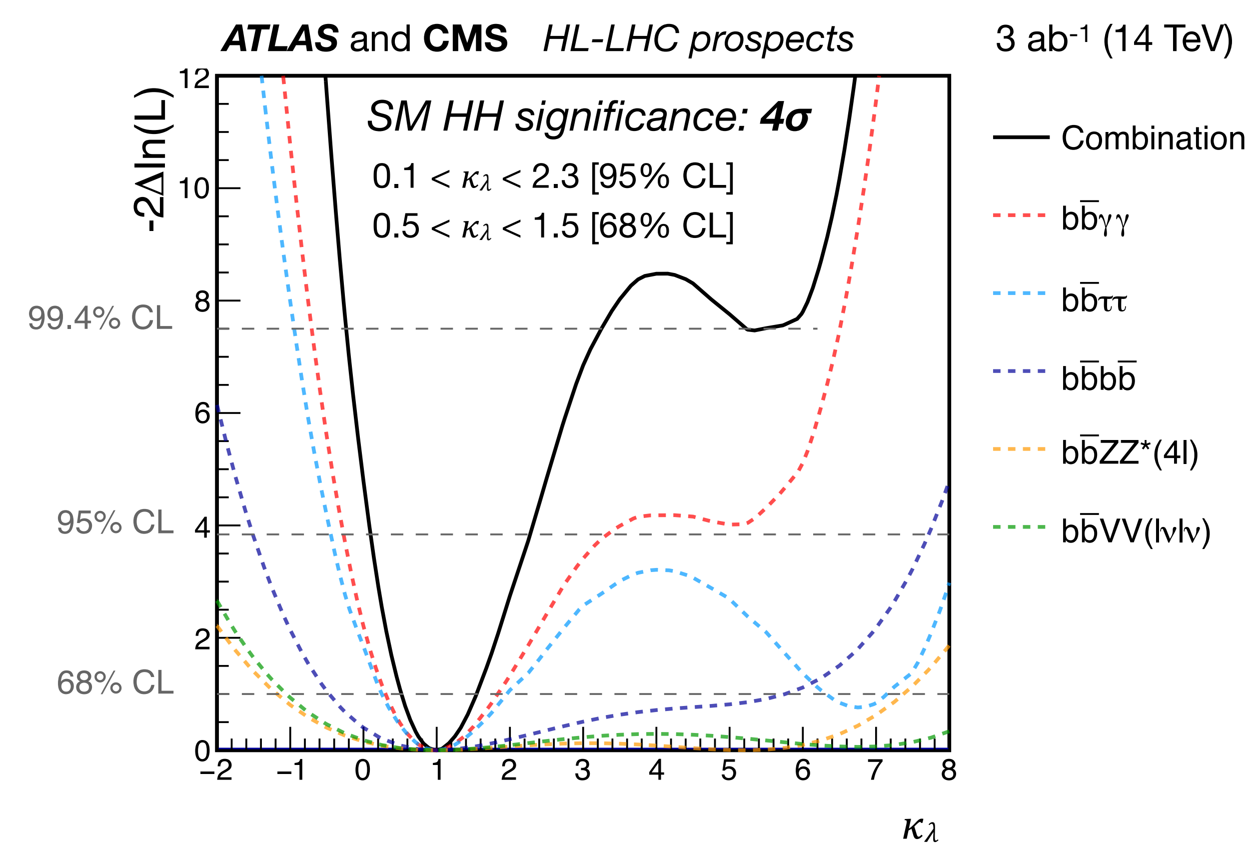
Precision on Higgs couplings



CERN-LPCC-2018-04

Precision on self-coupling param

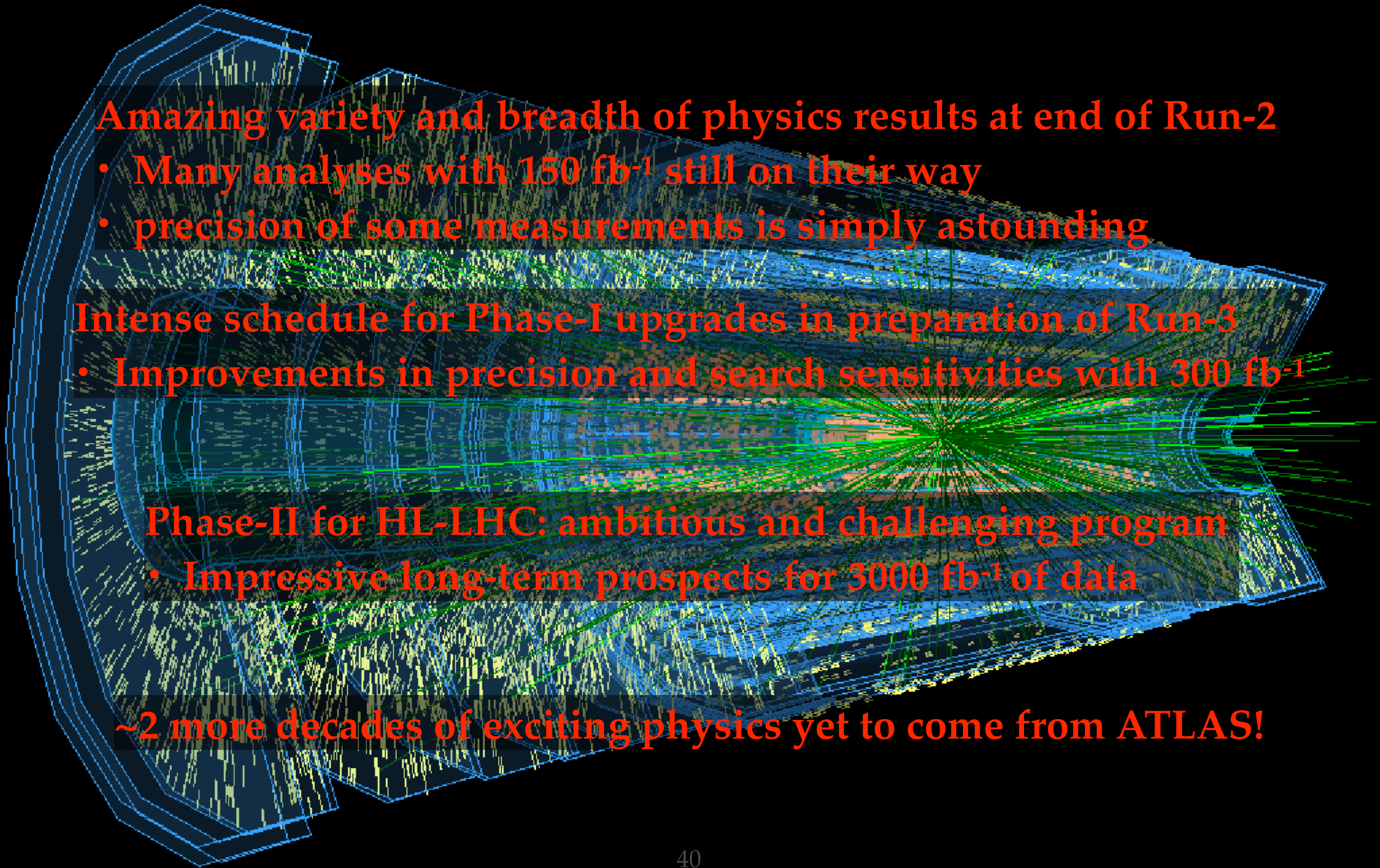




Full characterization of Higgs sector possible

Precision constraints on Higgs self-coupling

Summary



Amazing variety and breadth of physics results at end of Run-2

- Many analyses with 150 fb^{-1} still on their way
- precision of some measurements is simply astounding

Intense schedule for Phase-I upgrades in preparation of Run-3

- Improvements in precision and search sensitivities with 300 fb^{-1}

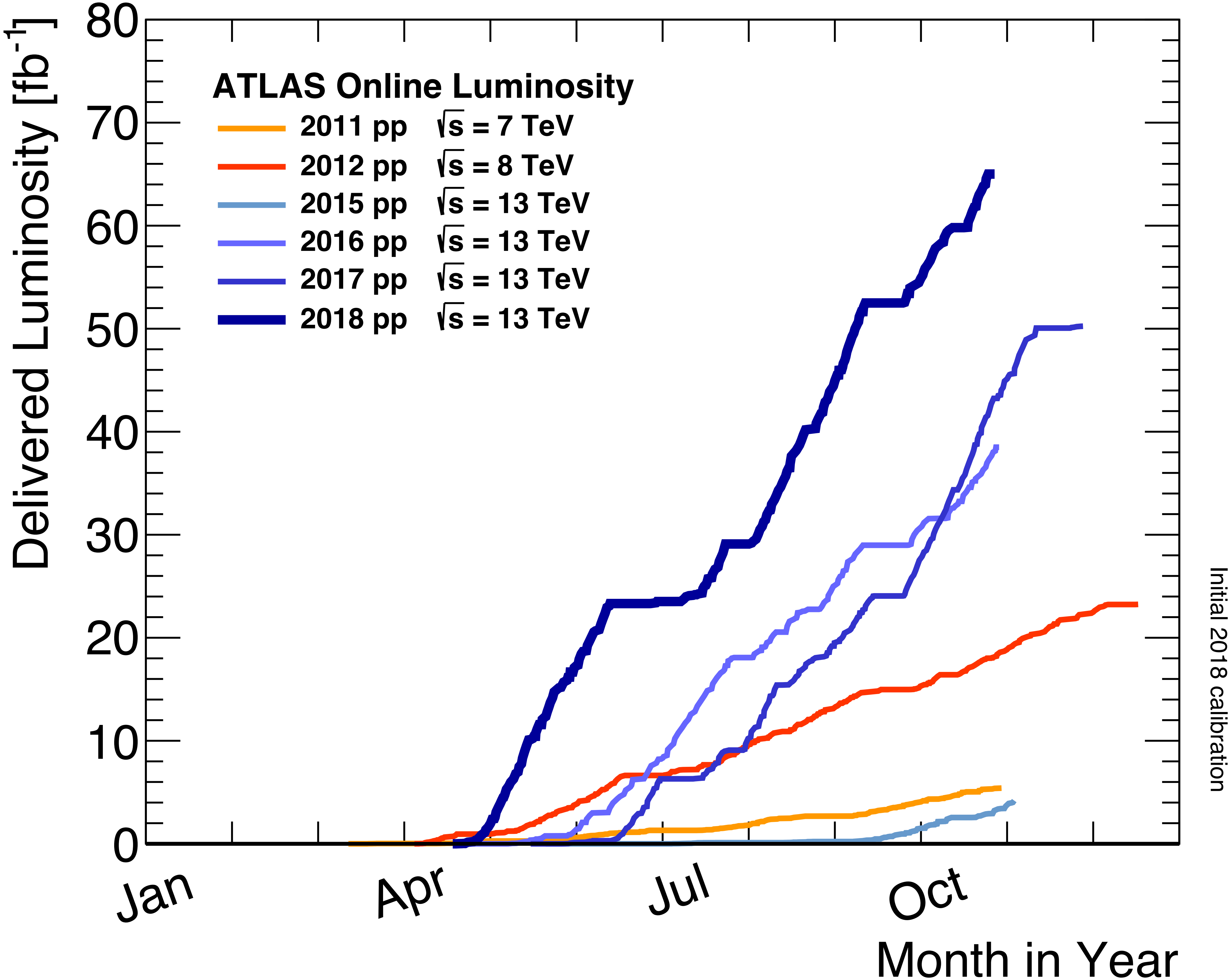
Phase-II for HL-LHC: ambitious and challenging program

- Impressive long-term prospects for 3000 fb^{-1} of data

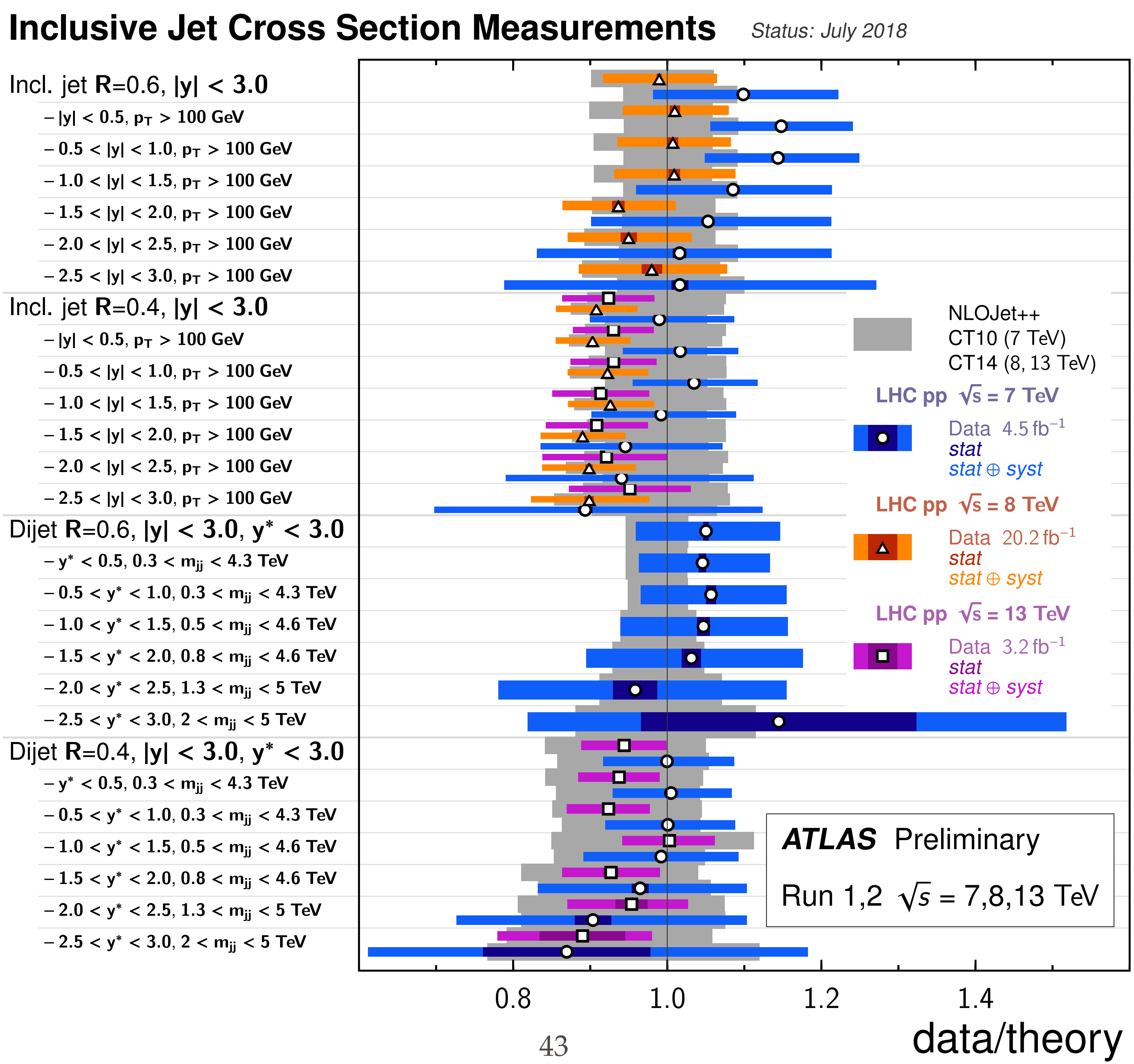
~2 more decades of exciting physics yet to come from ATLAS!

Grazie mille!

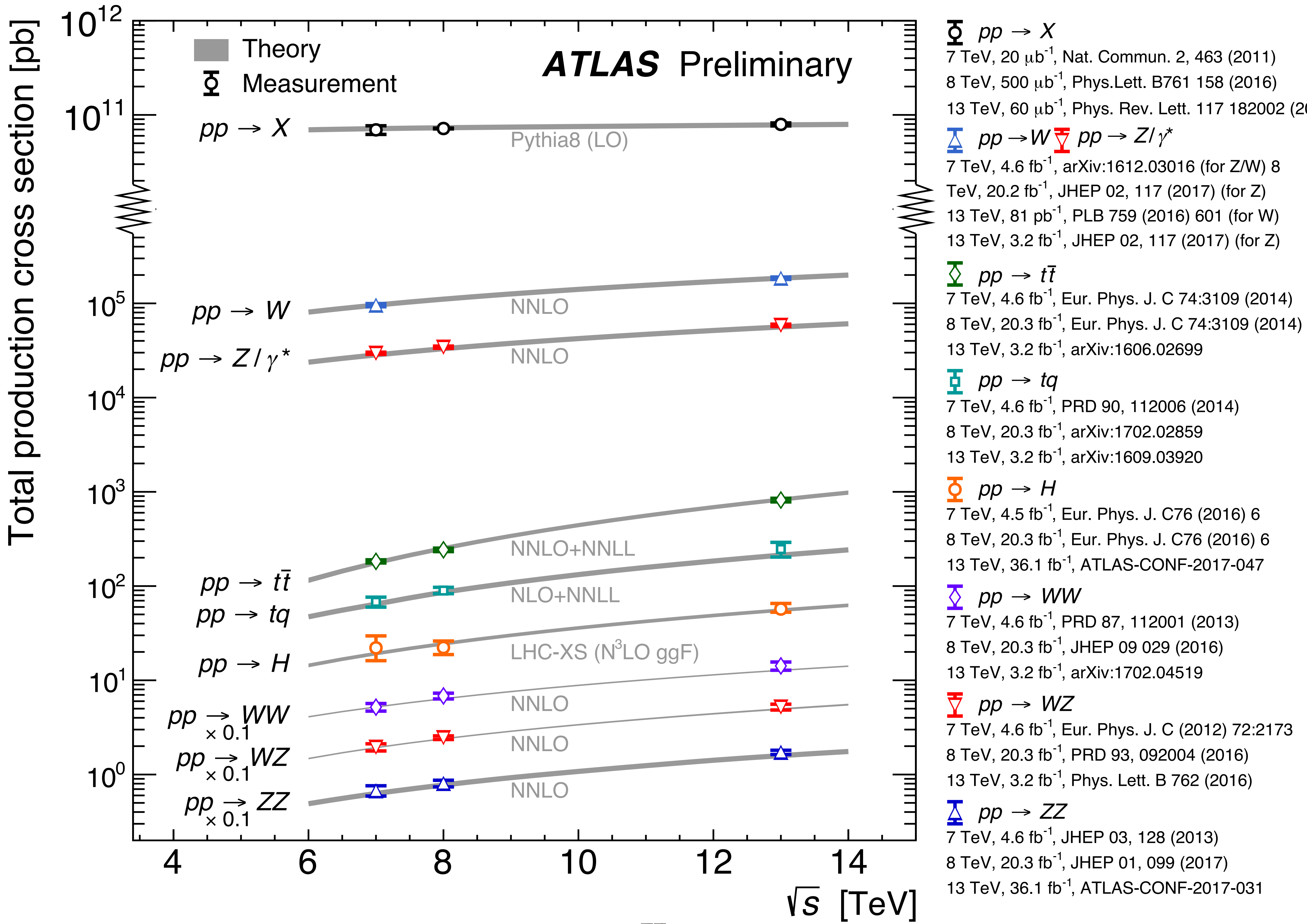
Accumulated Luminosity



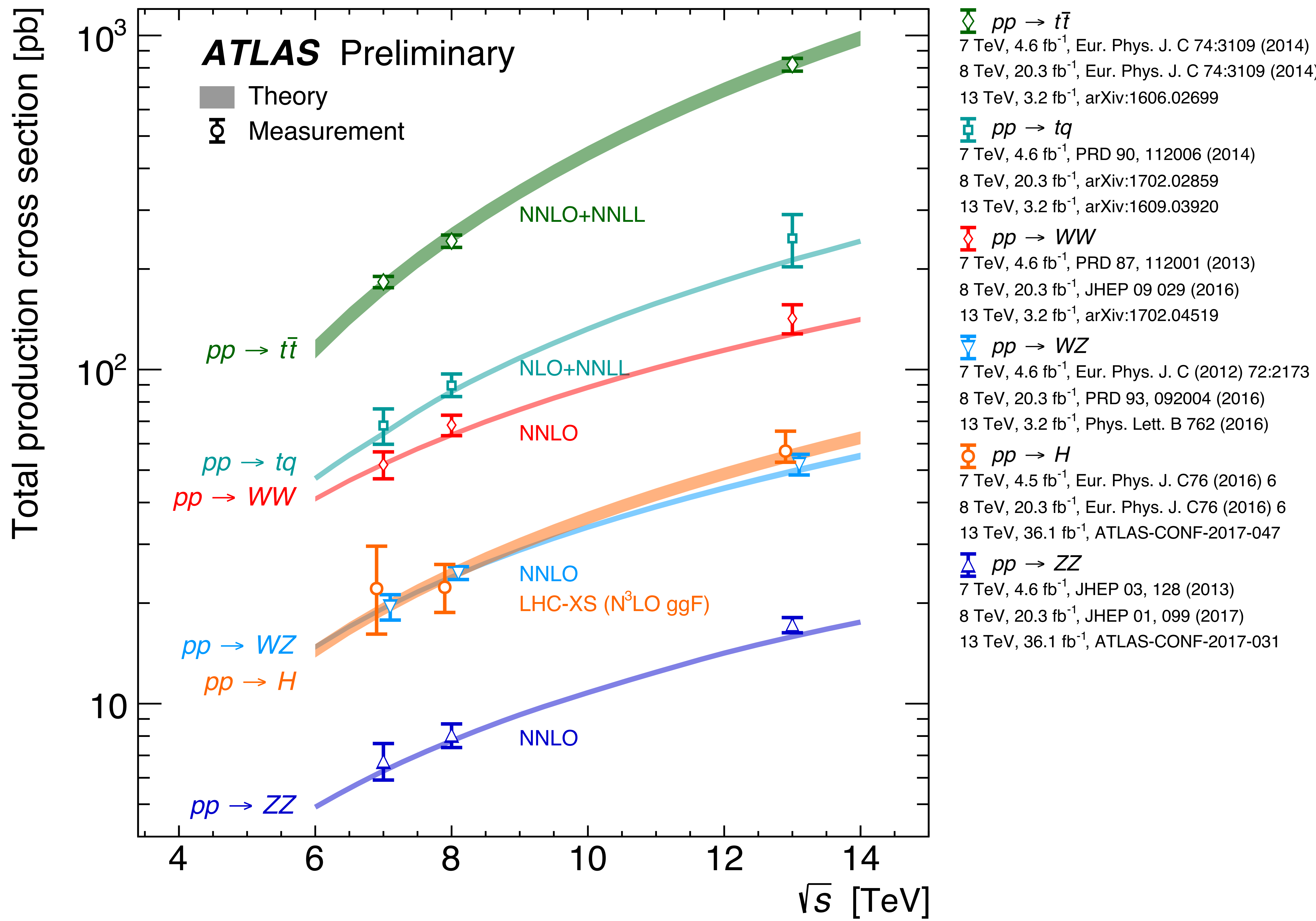
Jet Cross-Sections



Cross-Section Measurements

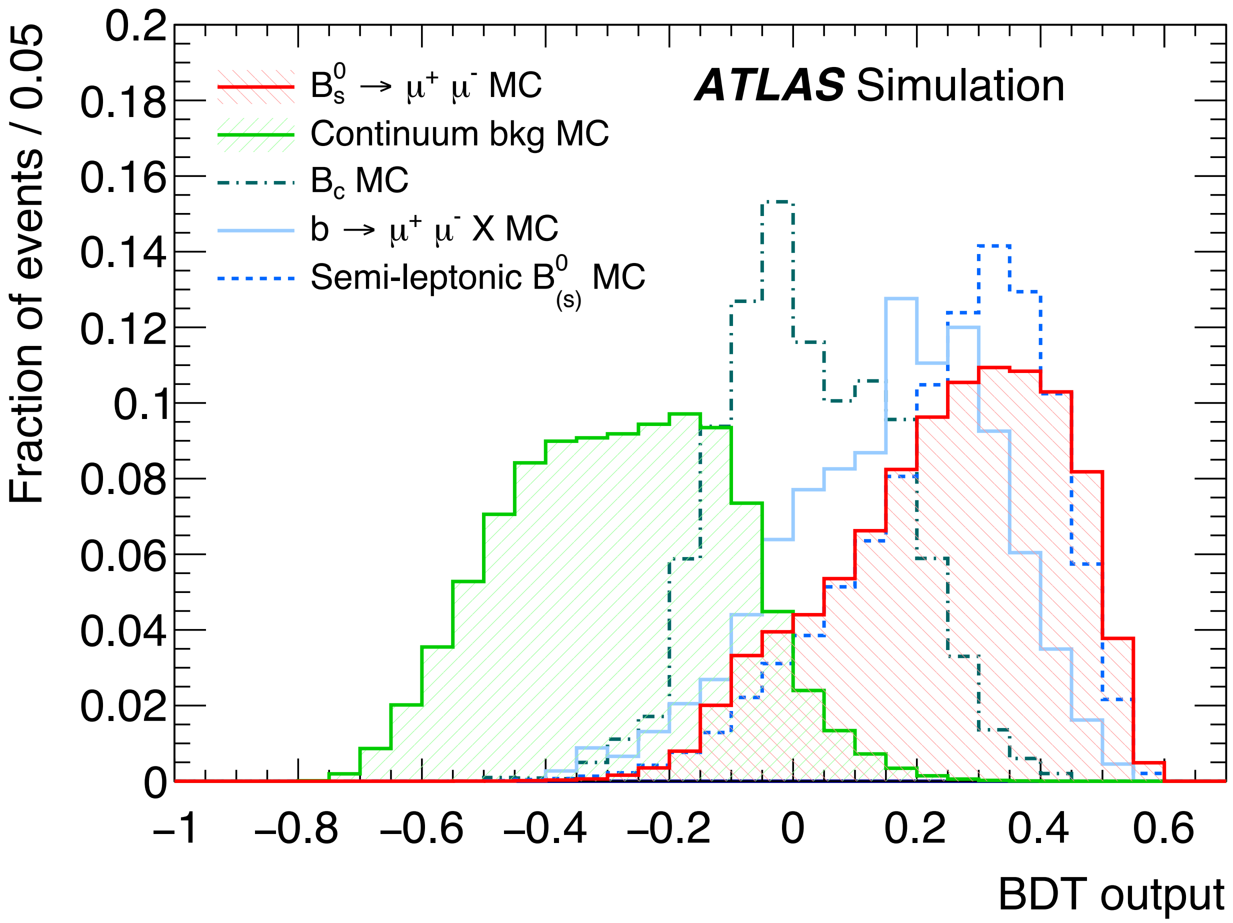


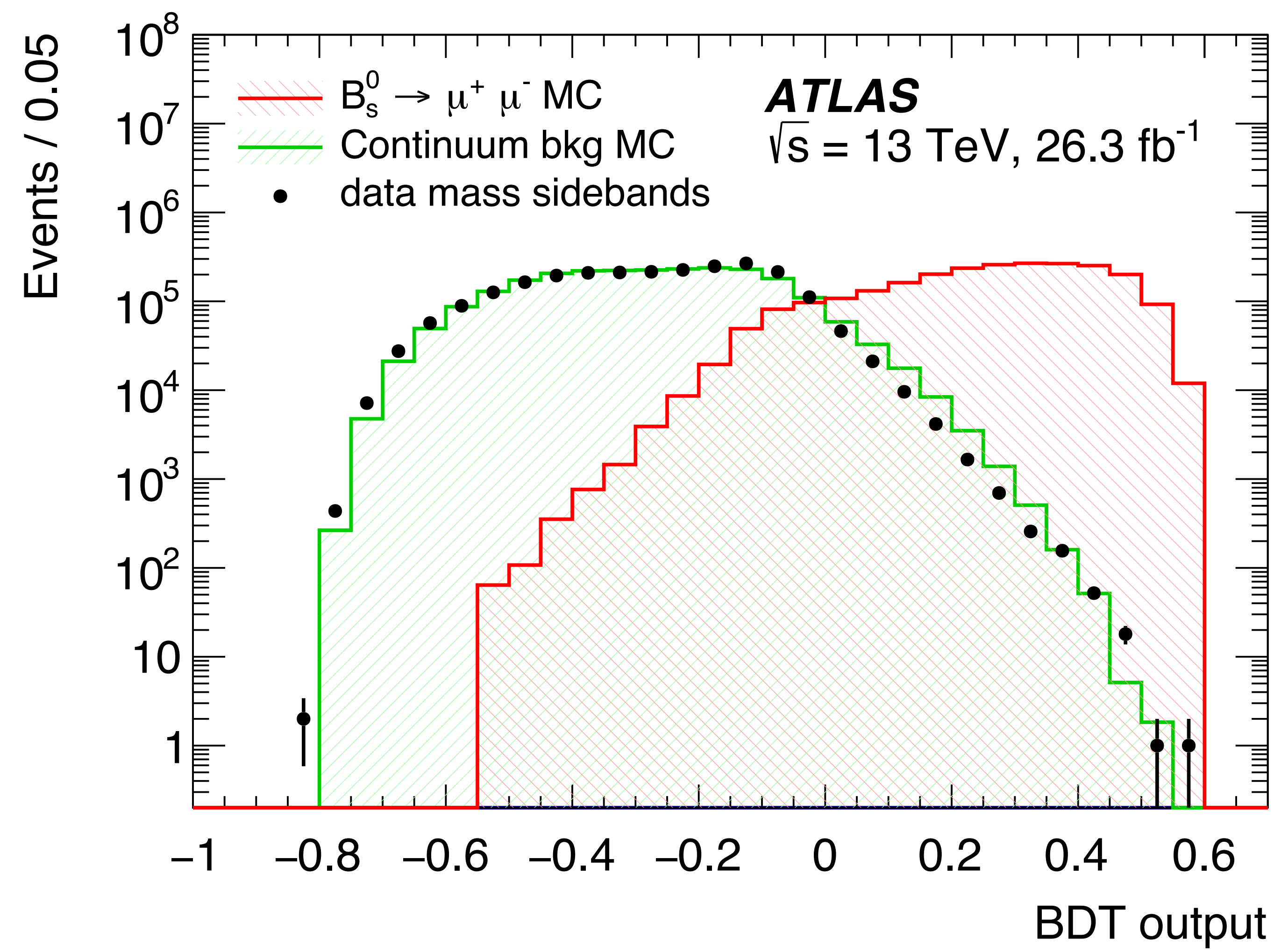
Cross-Section Measurements



BDTs for $B^0_{(s)} \to \mu^+\mu^-$

arXiv:1812.03017





BDTs for $B^0_{(s)} \to \mu^+\mu^-$

arXiv:1812.03017

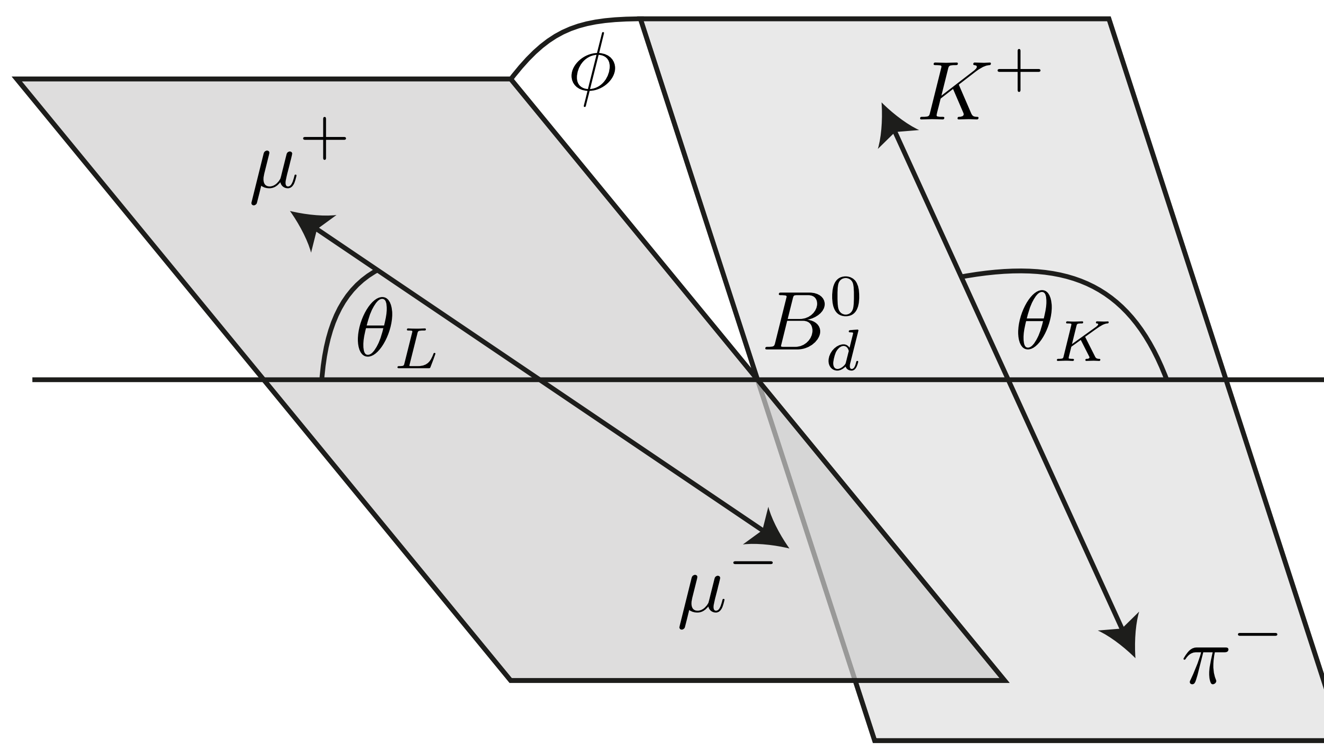
Variable	Description
p_{T}^{B}	Magnitude of the B candidate transverse momentum $\overrightarrow{p_{\mathrm{T}}}^{B}$.
$\chi^2_{\mathrm{PV,DV}\ xy}$	Compatibility of the separation $\overrightarrow{\Delta x}$ between production (i.e. associated PV) and decay (DV) vertices in the transverse projection: $\overrightarrow{\Delta x}_{\mathrm{T}} \cdot \Sigma^{-1}_{\overrightarrow{\Delta x}_{\mathrm{T}}} \cdot \overrightarrow{\Delta x}_{\mathrm{T}}$, where $\Sigma_{\overrightarrow{\Delta x}_{\mathrm{T}}}$ is the covariance matrix.
$\Delta R_{\mathrm{flight}}$	Three-dimensional angular distance between $\overrightarrow{p}^{B}$ and $\overrightarrow{\Delta x}$: $\sqrt{\alpha_{\mathrm{2D}}{}^2 + (\Delta\eta)^2}$
$\lvert\alpha_{\mathrm{2D}}\rvert$	Absolute value of the angle in the transverse plane between $\overrightarrow{p_{\mathrm{T}}}^{B}$ and $\overrightarrow{\Delta x}_{\mathrm{T}}$.
L_{xy}	Projection of $\overrightarrow{\Delta x}_{\mathrm{T}}$ along the direction of $\overrightarrow{p}^{B}_{\mathrm{T}}$: $(\overrightarrow{\Delta x}_{\mathrm{T}} \cdot \overrightarrow{p_{\mathrm{T}}}^{B})/\lvert\overrightarrow{p_{\mathrm{T}}}^{B}\rvert$.
$\mathrm{IP}_{B}^{\mathrm{3D}}$	Three-dimensional impact parameter of the B candidate to the associated PV.
$\mathrm{DOCA}_{\mu\mu}$	Distance of closest approach (DOCA) of the two tracks forming the B candidate (three-dimensional).
$\Delta\phi_{\mu\mu}$	Azimuthal angle between the momenta of the two tracks forming the B candidate.
$\lvert d_0\rvert^{\mathrm{max}}$-sig.	Significance of the larger absolute value of the impact parameters to the PV of the tracks forming the B candidate, in the transverse plane.
$\lvert d_0\rvert^{\mathrm{min}}$-sig.	Significance of the smaller absolute value of the impact parameters to the PV of the tracks forming the B candidate, in the transverse plane.
$P_{\mathrm{L}}^{\mathrm{min}}$	The smaller of the projected values of the muon momenta along $\overrightarrow{p_{\mathrm{T}}}^{B}$.
$I_{0.7}$	Isolation variable defined as ratio of $\lvert\overrightarrow{p_{\mathrm{T}}}^{B}\rvert$ to the sum of $\lvert\overrightarrow{p_{\mathrm{T}}}^{B}\rvert$ and the transverse momenta of all additional tracks contained within a cone of size $\Delta R = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2} = 0.7$ around the B direction. Only tracks matched to the same PV as the B candidate are included in the sum.
$\mathrm{DOCA}_{\mathrm{xtrk}}$	DOCA of the closest additional track to the decay vertex of the B candidate. Only tracks matched to the same PV as the B candidate are considered.
$N^{\mathrm{close}}_{\mathrm{xtrk}}$	Number of additional tracks compatible with the decay vertex (DV) of the B candidate with $\ln(\chi^2_{\mathrm{xtrk,DV}}) < 1$. Only tracks matched to the same PV as the B candidate are considered.
$\chi^2_{\mu,\mathrm{xPV}}$	Minimum χ^2 for the compatibility of a muon in the B candidate with any PV reconstructed in the event.

Angular Analysis of $B^0 \to K^* \mu^+ \mu^-$: Formalism

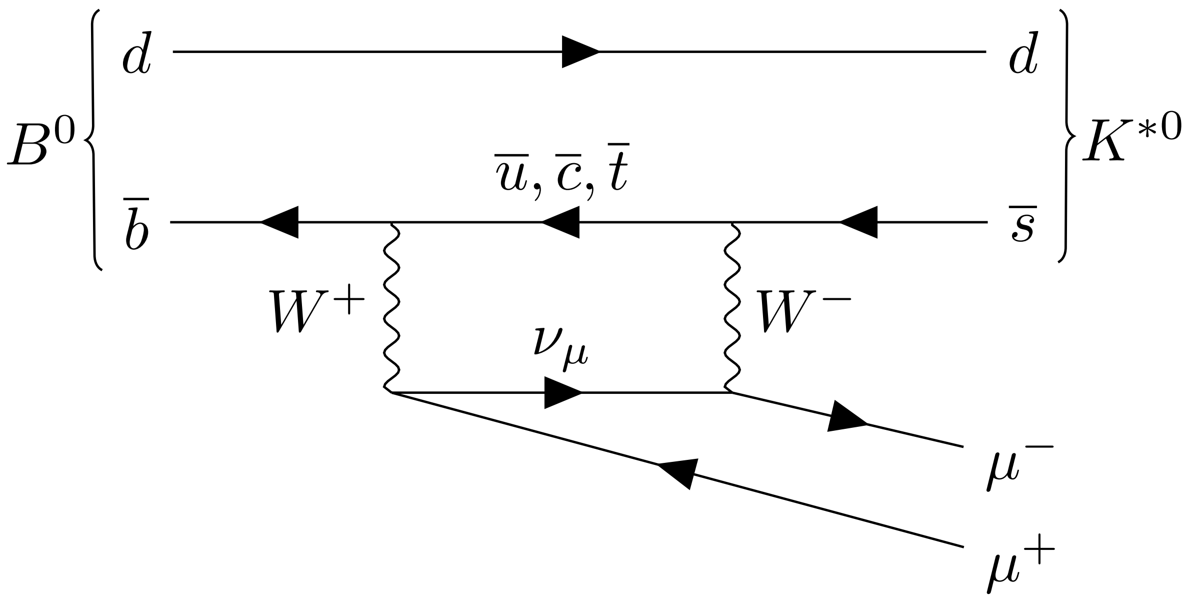
$$\frac{1}{\mathrm{d}\Gamma/\mathrm{d}q^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}\cos\theta_L \mathrm{d}\cos\theta_K \mathrm{d}\phi \mathrm{d}q^2} = \frac{9}{32\pi}\Bigg[\frac{3(1-F_L)}{4}\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1-F_L}{4}\sin^2\theta_K\cos 2\theta_L$$
$$- F_L\cos^2\theta_K\cos 2\theta_L + S_3\sin^2\theta_K\sin^2\theta_L\cos 2\phi$$
$$+ S_4\sin 2\theta_K\sin 2\theta_L\cos\phi + S_5\sin 2\theta_K\sin\theta_L\cos\phi$$
$$+ S_6\sin^2\theta_K\cos\theta_L + S_7\sin 2\theta_K\sin\theta_L\sin\phi$$
$$+ S_8\sin 2\theta_K\sin 2\theta_L\sin\phi + S_9\sin^2\theta_K\sin^2\theta_L\sin 2\phi\Bigg]. \qquad (2.1)$$

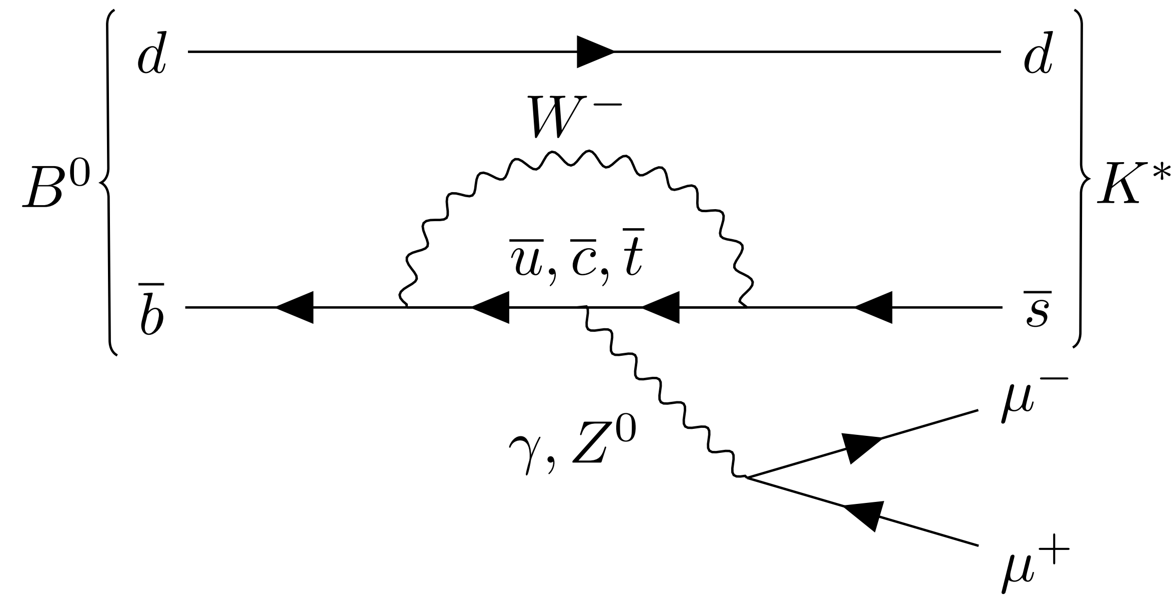
JHEP 10 (2018) 047

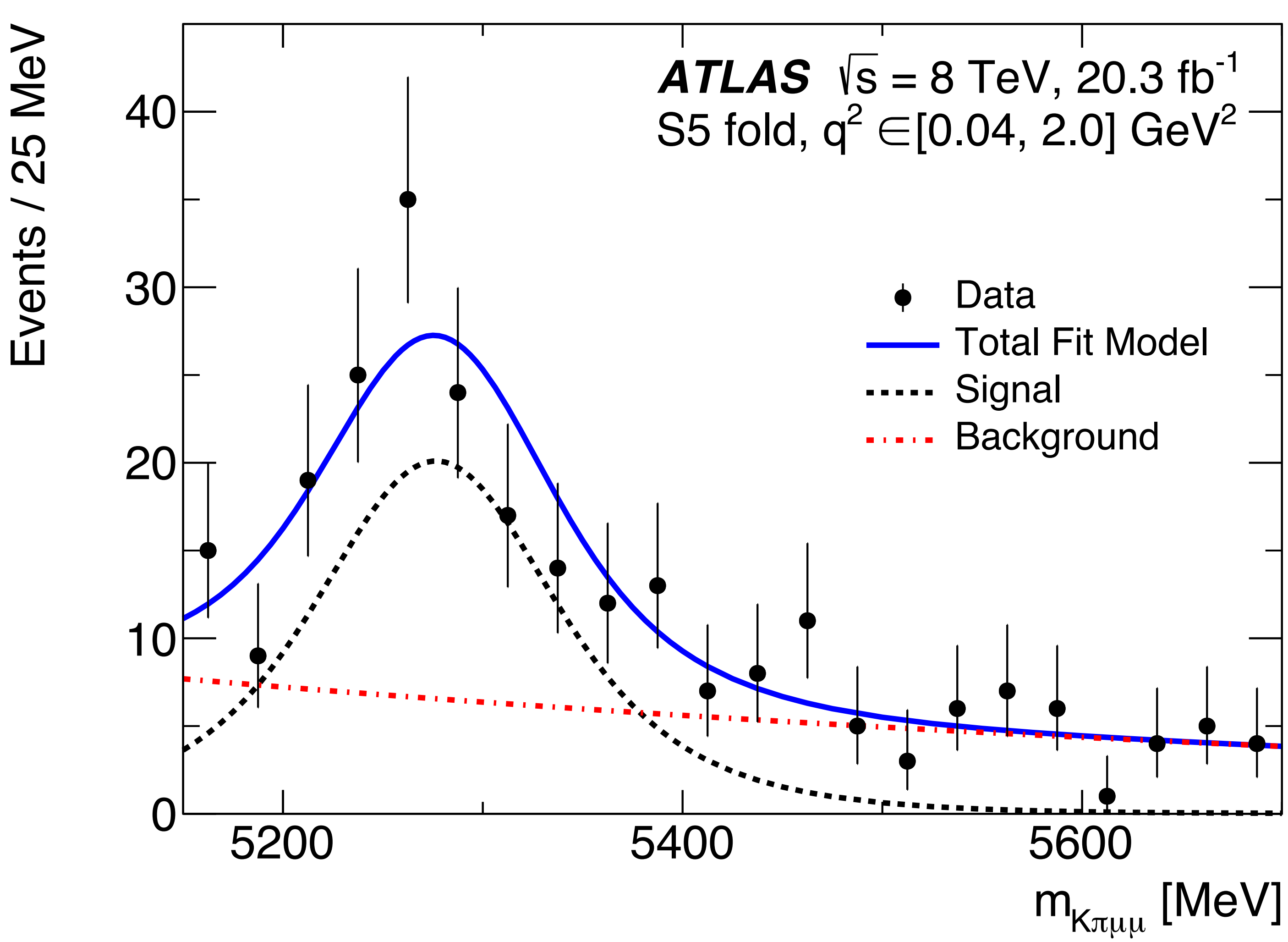
$$P_1 = \frac{2S_3}{1-F_L}$$
$$P_2 = \frac{2}{3}\frac{A_{\mathrm{FB}}}{1-F_L}$$
$$P_3 = -\frac{S_9}{1-F_L}$$
$$P'_{j=4,5,6,8} = \frac{S_{i=4,5,7,8}}{\sqrt{F_L(1-F_L)}}.$$

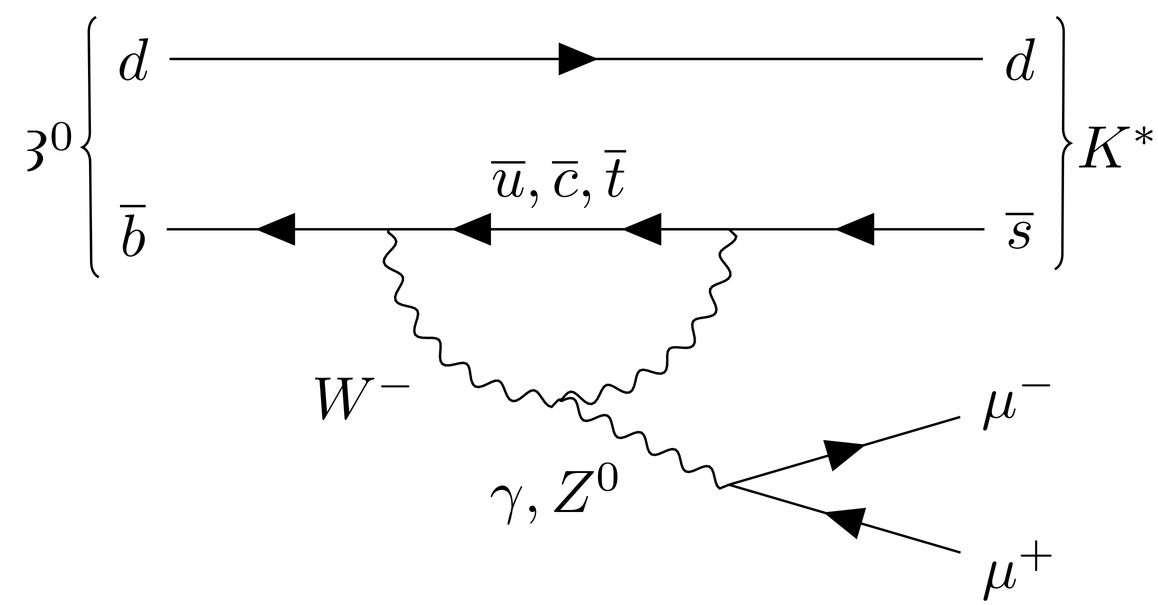


Angular Analysis of $B^0 \to K^* \mu^+\mu^-$: Diagrams



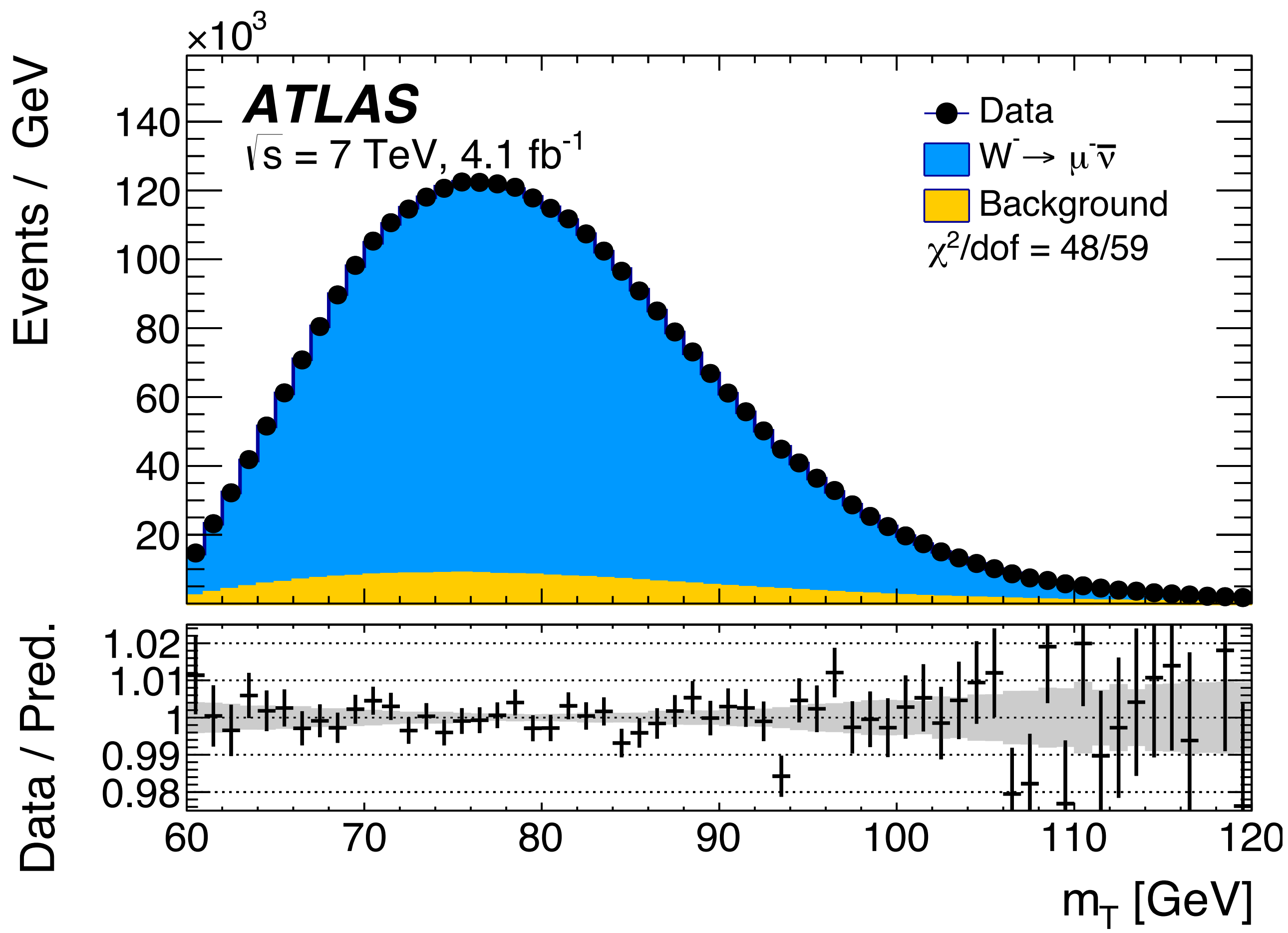


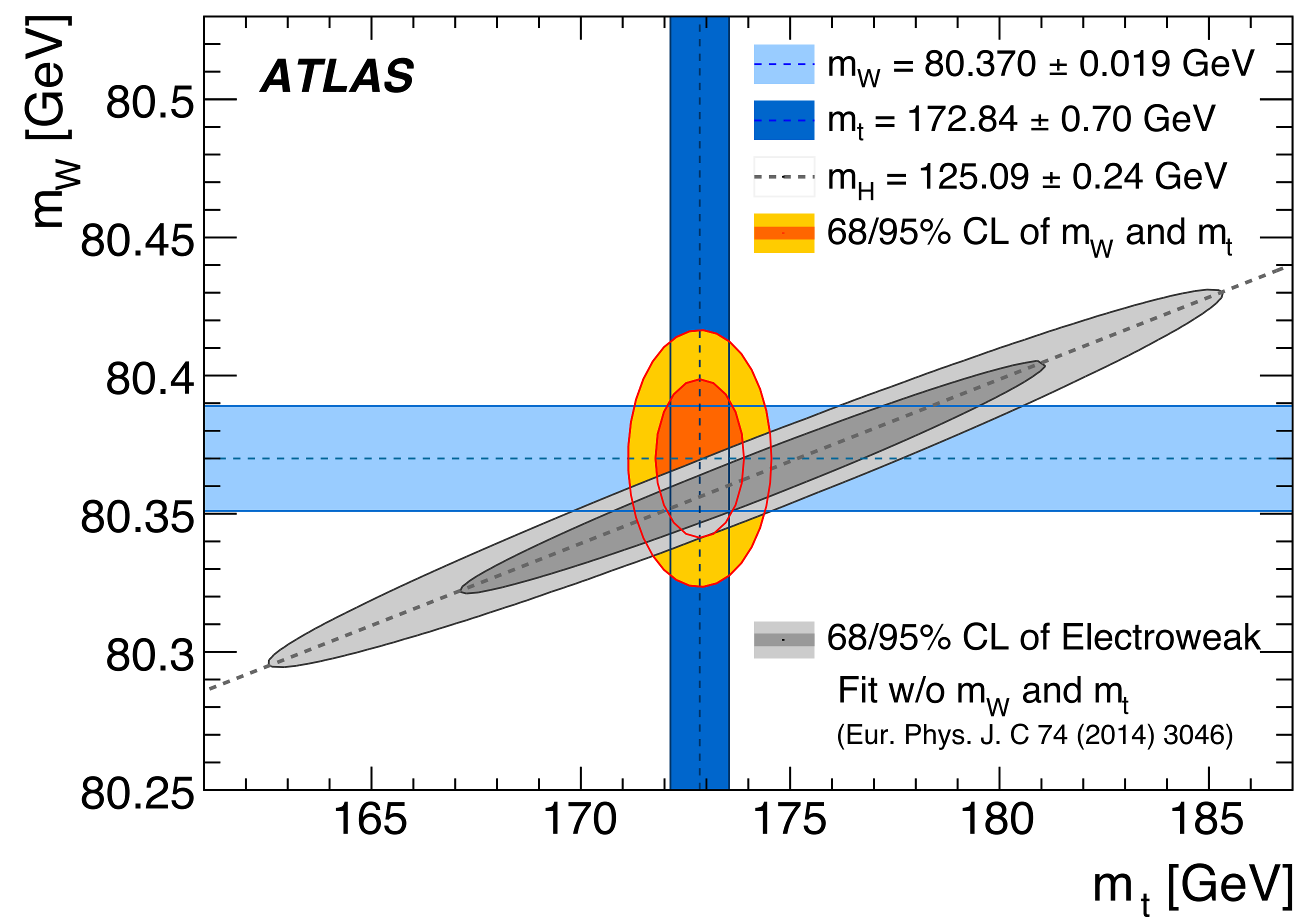


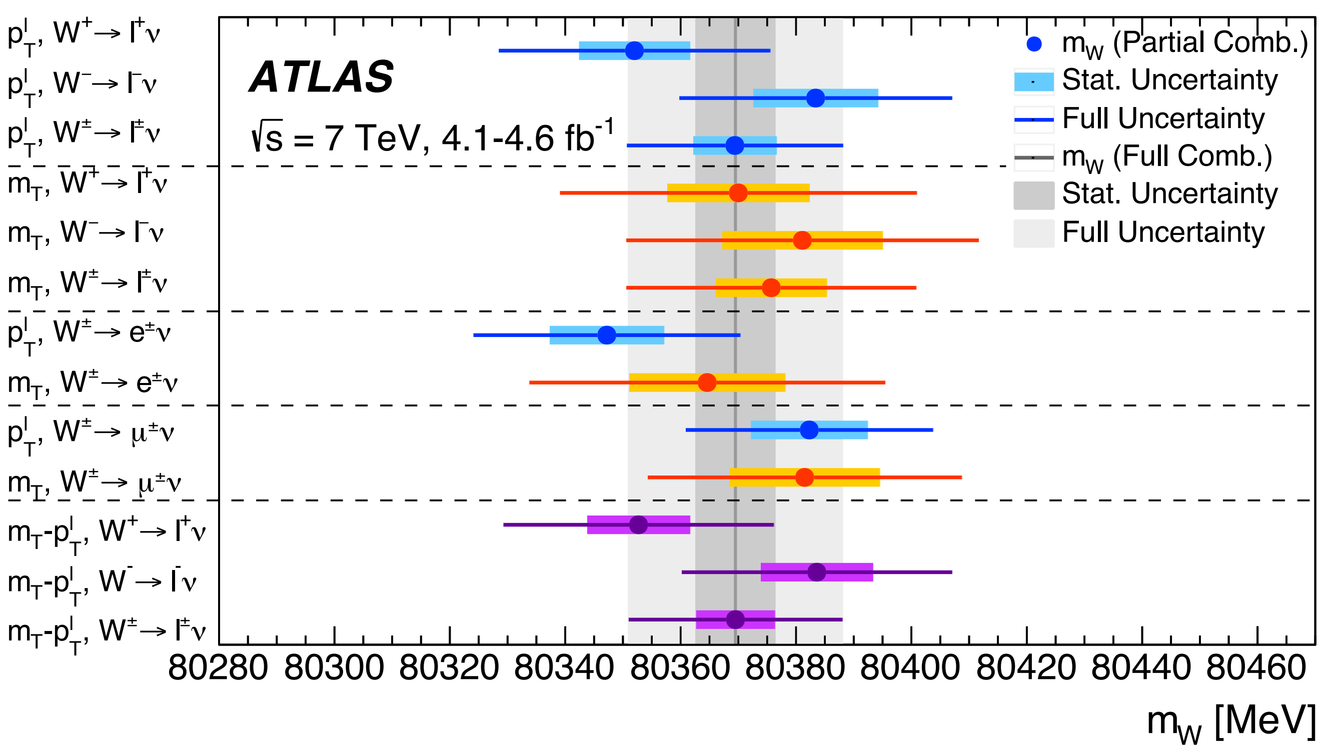


JHEP 10 (2018) 047

W Mass Measurement

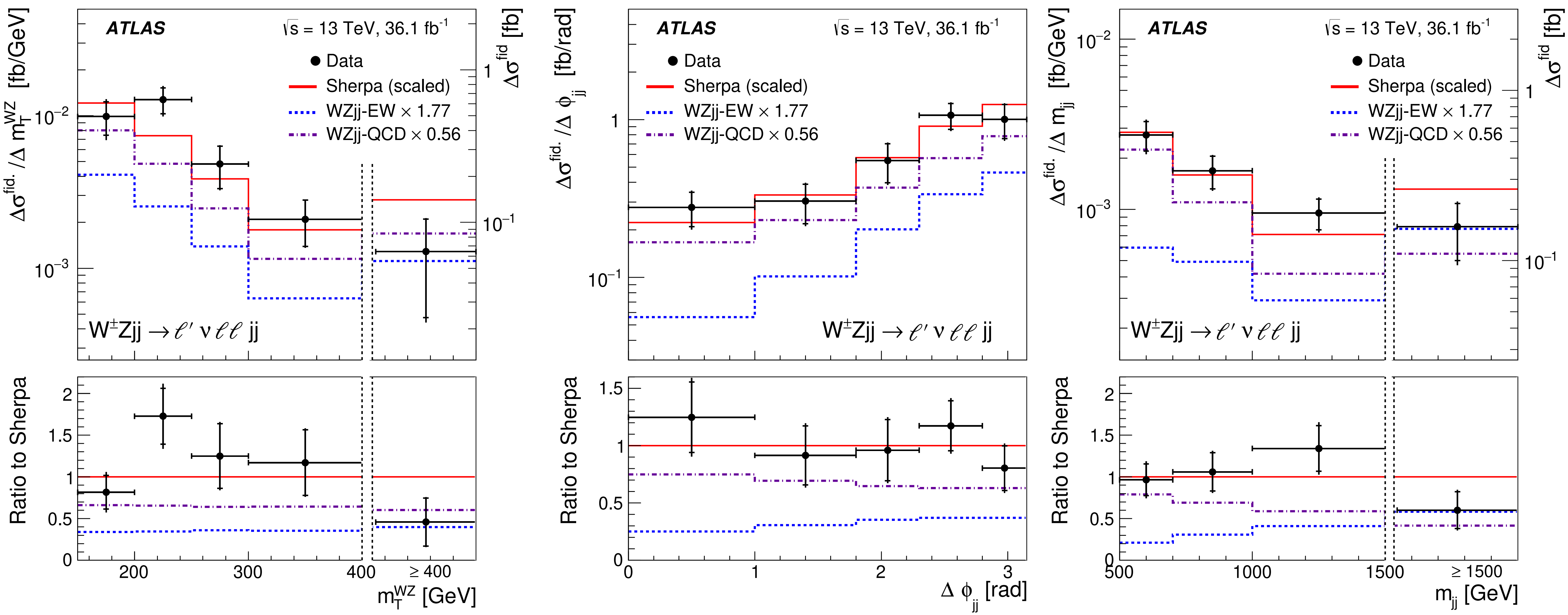






EPJC 78 (2018) 110

VBS WZ Differential Cross-Sections



arXiv:1812.09740

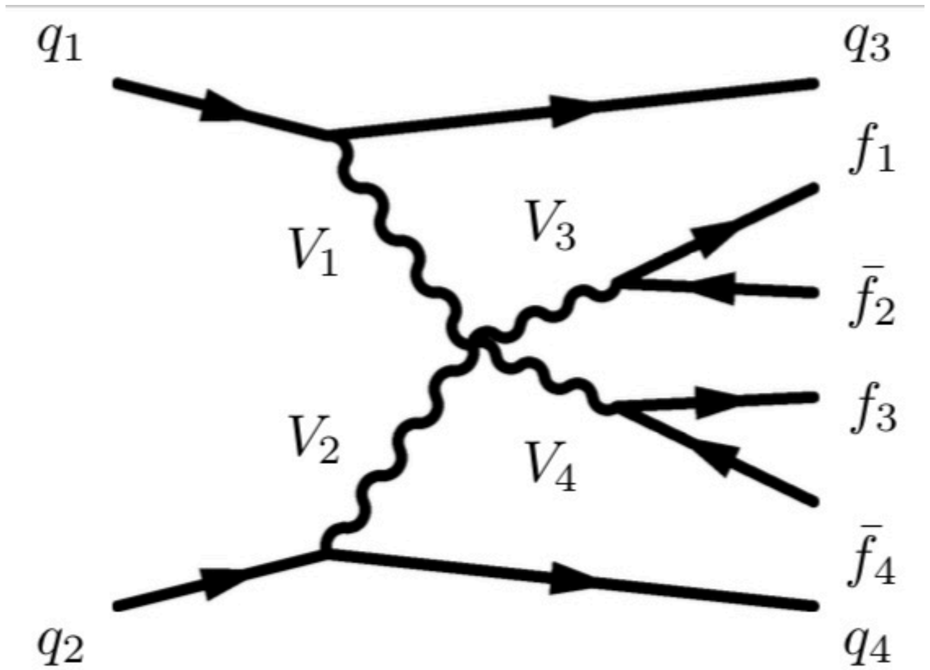
Interpretation: Anomalous Couplings

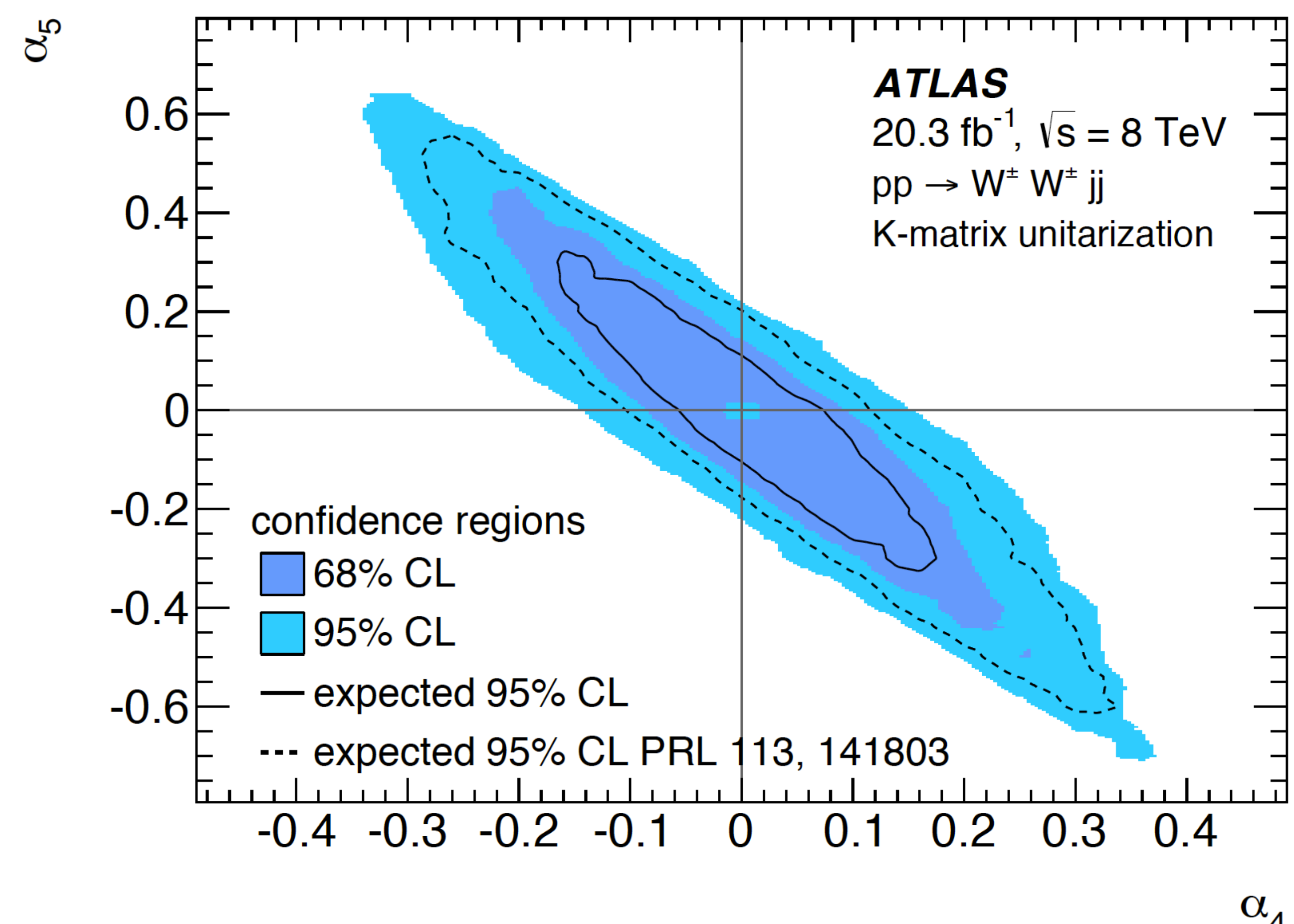
Interpret electroweak WW results in terms of anomalous quartic couplings

Use effective field theory:
lowest order BSM coefficients
parametrized by α_4 ,α_5

$$\alpha_4 \mathcal{L}_4 = \alpha_4 [\mathrm{tr}(V_\mu V_\nu)]^2$$

$$\alpha_5 \mathcal{L}_5 = \alpha_5 [\mathrm{tr}(V_\mu V^\mu)]^2$$





PRD 96 (2017) 012007

Interpretation not yet updated with latest Run-2 results

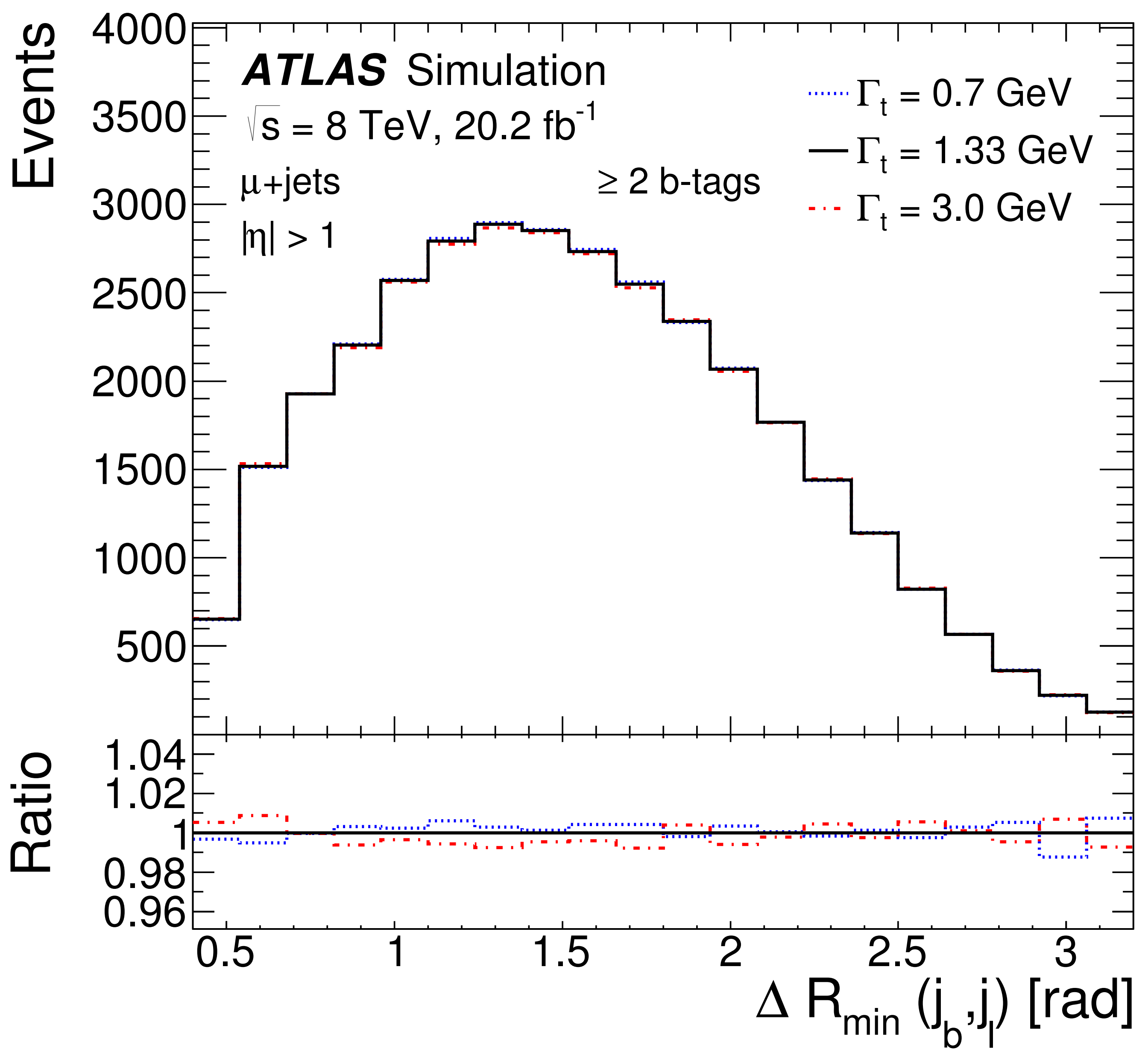
ATLAS accessing processes with sub-fb x-sections

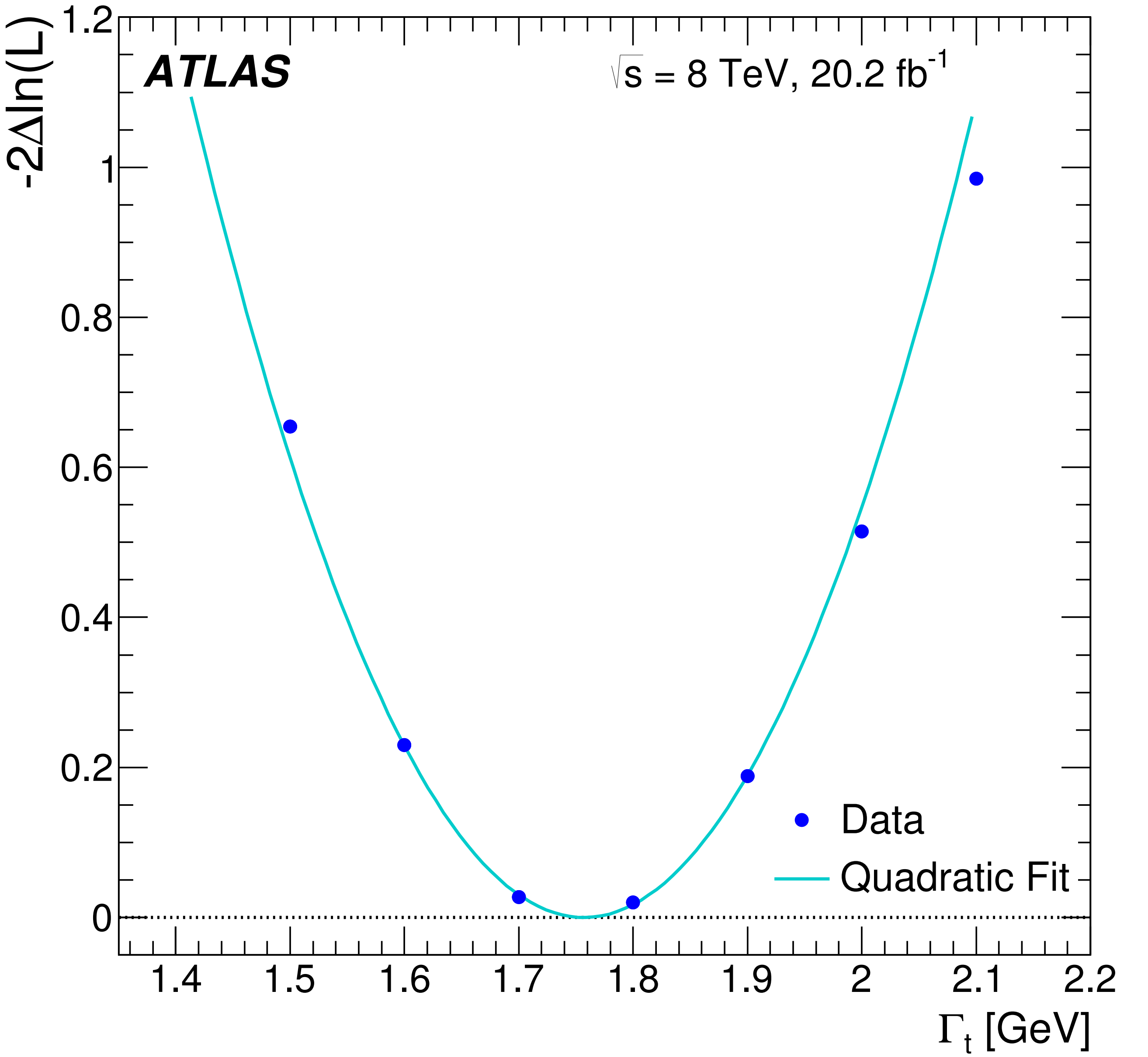
Top Mass: Uncertainties

	$\sqrt{s} = 7$ TeV	$\sqrt{s} = 8$ TeV	
Event selection	Standard	Standard	BDT
m_{top} result [GeV]	172.33	171.90	172.08
Statistics	0.75	0.38	0.39
– *Stat. comp.* (m_{top})	0.23	0.12	0.11
– *Stat. comp.* (JSF)	0.25	0.11	0.11
– *Stat. comp.* (bJSF)	0.67	0.34	0.35
Method	0.11 ± 0.10	0.04 ± 0.11	0.13 ± 0.11
Signal Monte Carlo generator	0.22 ± 0.21	0.50 ± 0.17	0.16 ± 0.17
Hadronization	0.18 ± 0.12	0.05 ± 0.10	0.15 ± 0.10
Initial- and final-state QCD radiation	0.32 ± 0.06	0.28 ± 0.11	0.08 ± 0.11
Underlying event	0.15 ± 0.07	0.08 ± 0.15	0.08 ± 0.15
Colour reconnection	0.11 ± 0.07	0.37 ± 0.15	0.19 ± 0.15
Parton distribution function	0.25 ± 0.00	0.08 ± 0.00	0.09 ± 0.00
Background normalization	0.10 ± 0.00	0.04 ± 0.00	0.08 ± 0.00
W+jets shape	0.29 ± 0.00	0.05 ± 0.00	0.11 ± 0.00
Fake leptons shape	0.05 ± 0.00	0	0
Jet energy scale	0.58 ± 0.11	0.63 ± 0.02	0.54 ± 0.02
Relative b-to-light-jet energy scale	0.06 ± 0.03	0.05 ± 0.01	0.03 ± 0.01
Jet energy resolution	0.22 ± 0.11	0.23 ± 0.03	0.20 ± 0.04
Jet reconstruction efficiency	0.12 ± 0.00	0.04 ± 0.01	0.02 ± 0.01
Jet vertex fraction	0.01 ± 0.00	0.13 ± 0.01	0.09 ± 0.01
b-tagging	0.50 ± 0.00	0.37 ± 0.00	0.38 ± 0.00
Leptons	0.04 ± 0.00	0.16 ± 0.01	0.16 ± 0.01
Missing transverse momentum	0.15 ± 0.04	0.08 ± 0.01	0.05 ± 0.01
Pile-up	0.02 ± 0.01	0.14 ± 0.01	0.15 ± 0.01
Total systematic uncertainty	1.04 ± 0.08	1.07 ± 0.10	0.82 ± 0.06
Total	1.28 ± 0.08	1.13 ± 0.10	0.91 ± 0.06

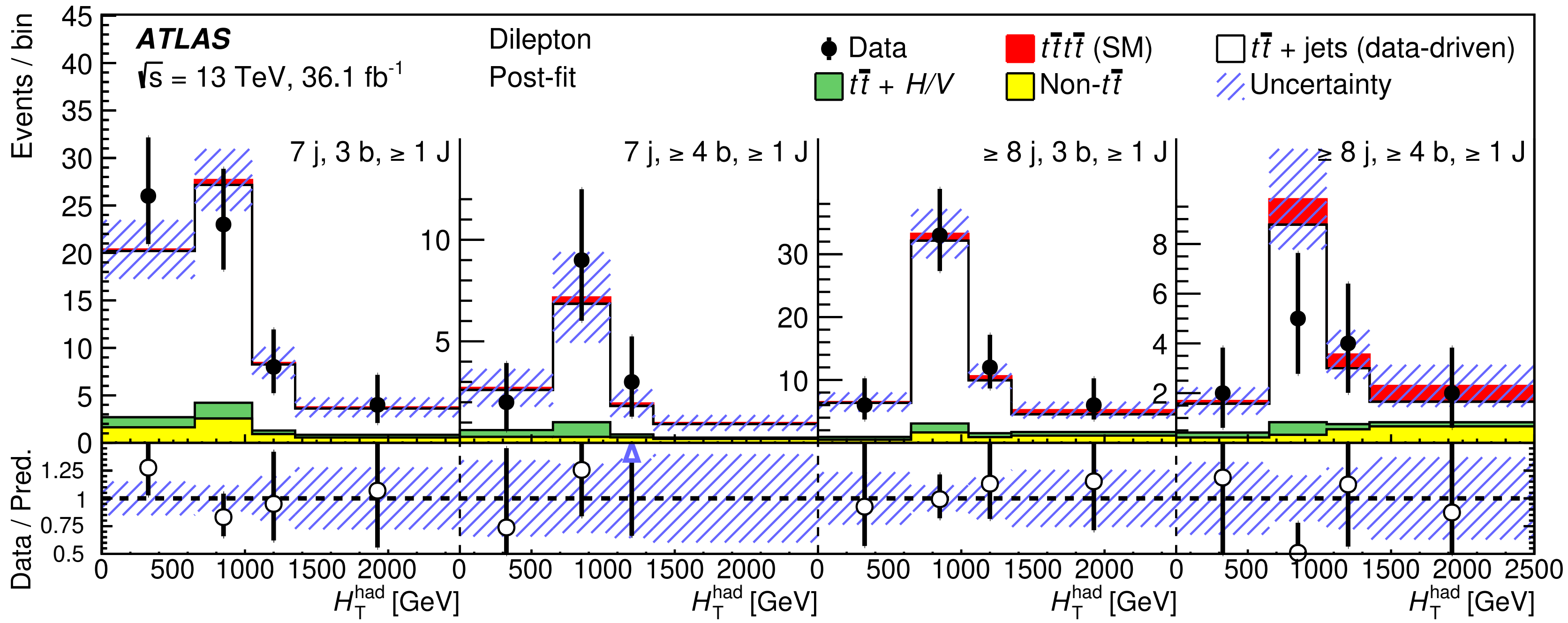
arXiv:1810.01772

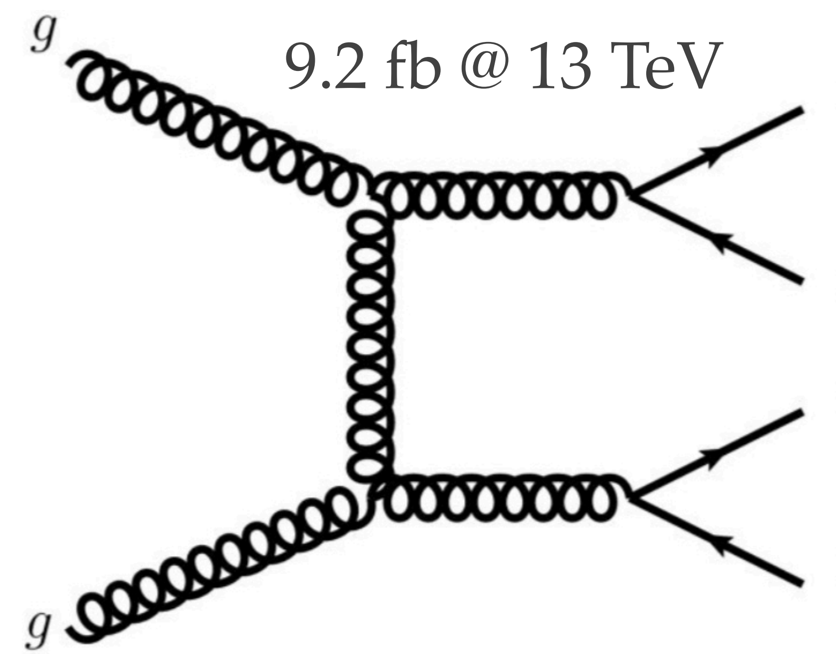
Top Width Measurement





Search for 4-Top Production



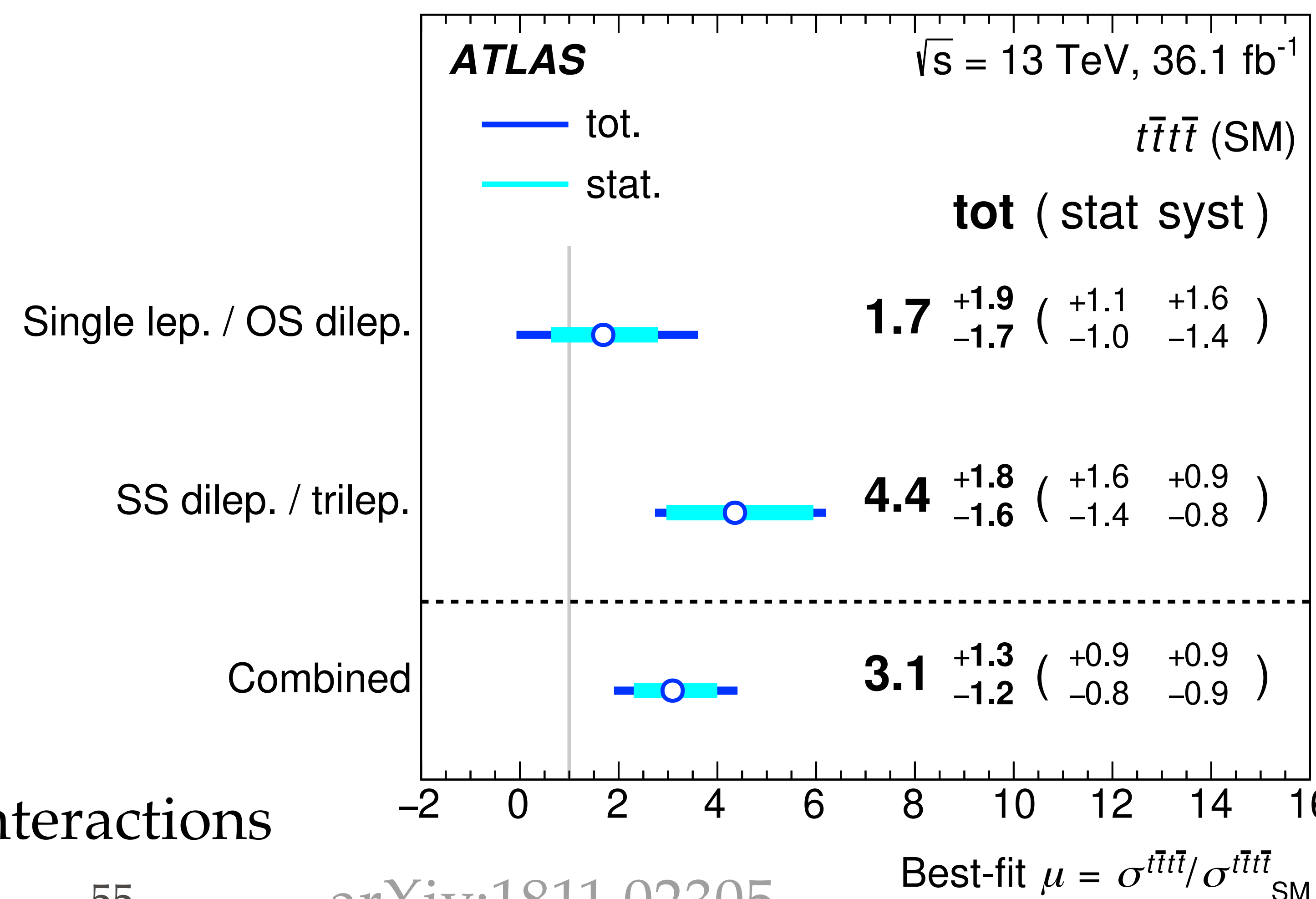


- 1/2/3-lepton final states investigated
- categories: N_{jet}, $N_{b\text{-}jet}$
- simultaneous fit to H_T^{had}

μ < 5.3 @ 95% CL (expected μ < 2.1)

excess corresponds to **2.8σ**

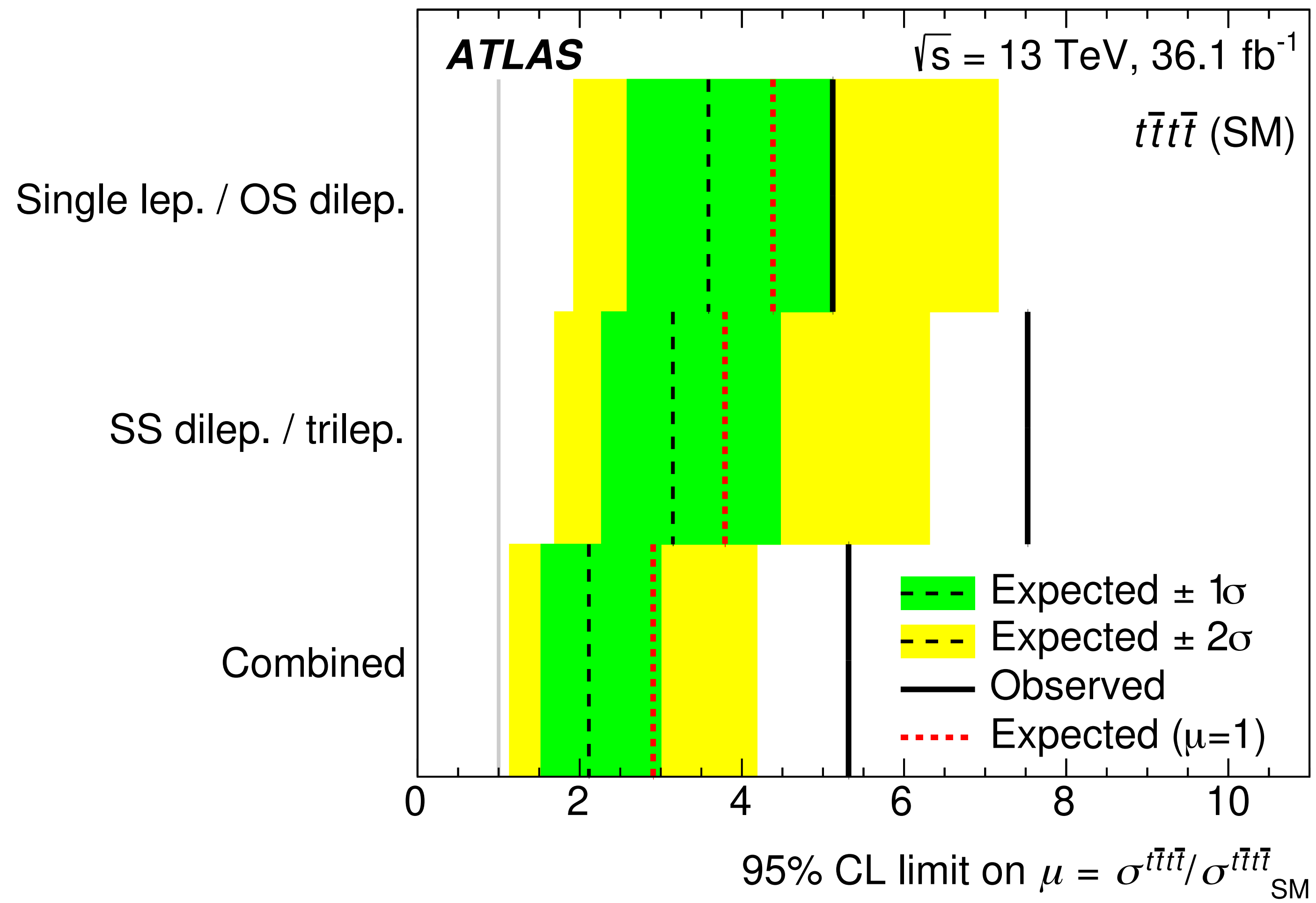
also sensitive to BSM 4-fermion contact interactions



arXiv:1811.02305

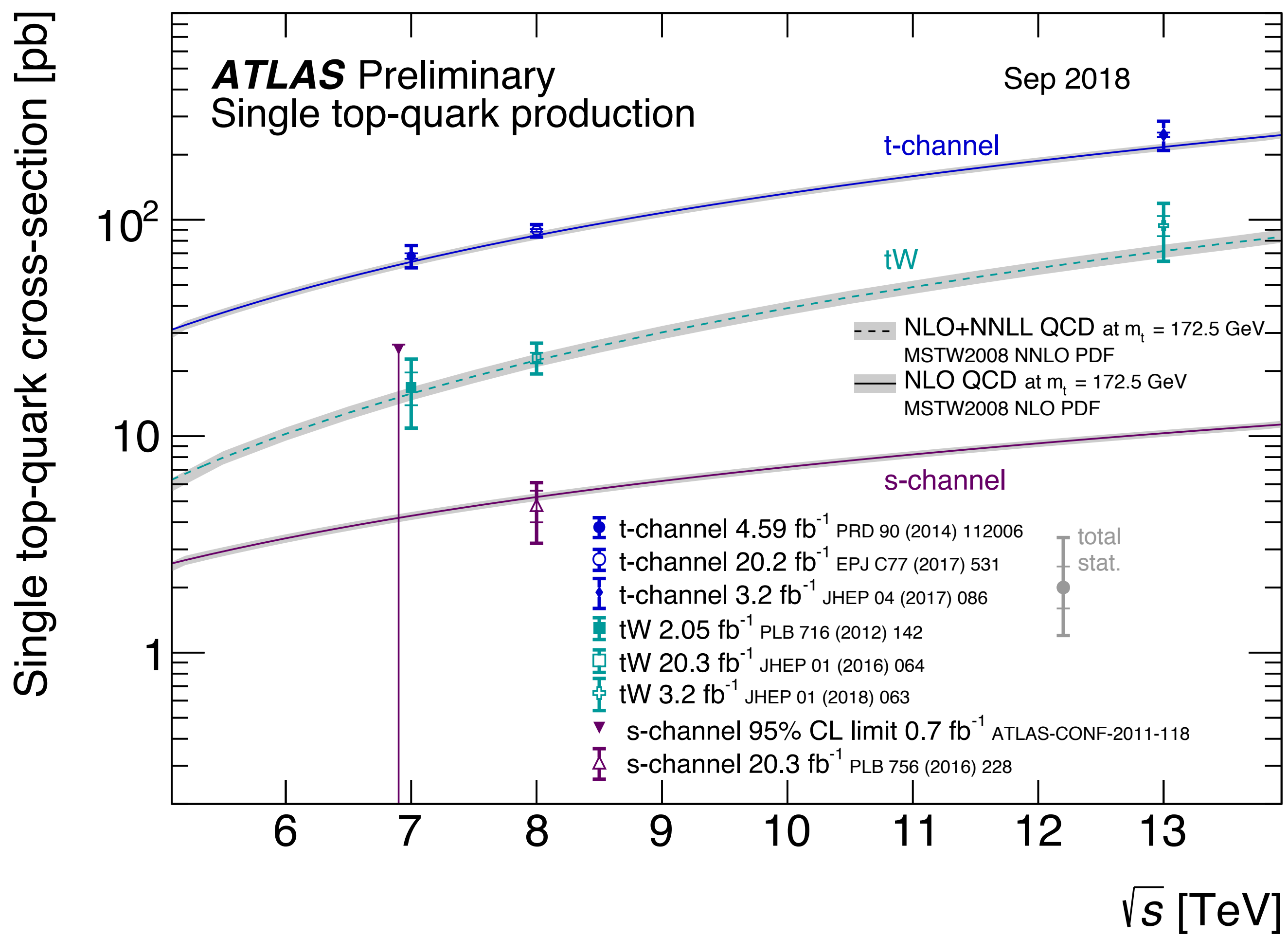
4 Top Search

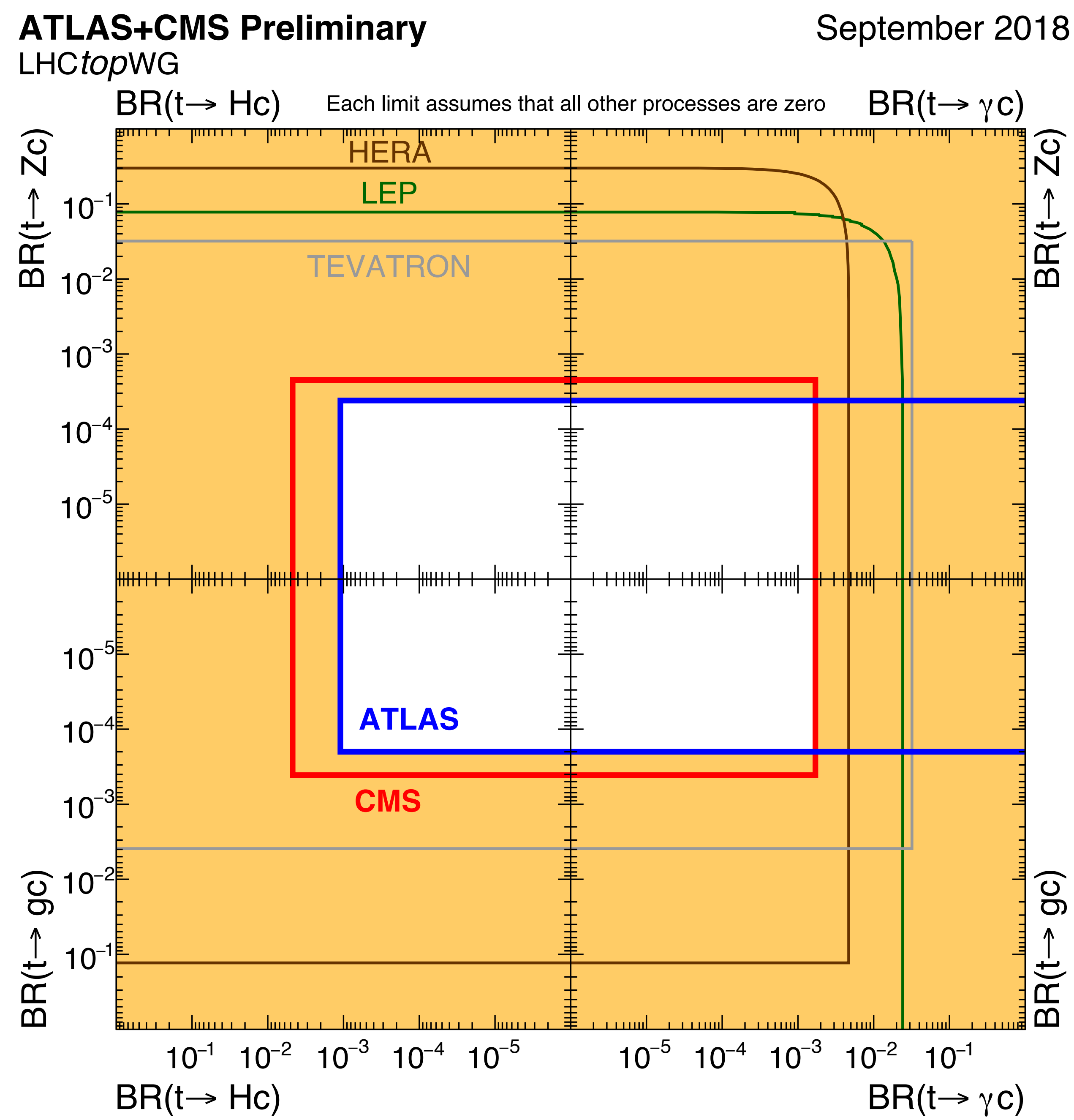
Preselection requirements		
Requirement	Single-lepton	Dilepton
Trigger	Single-lepton triggers	
Leptons	1 isolated	2 isolated, opposite-sign
Jets	$\geq$5 jets	$\geq$4 jets
b-tagged jets	$\geq$2 b-tagged jets	
Other	$E_{\mathrm{T}}^{\mathrm{miss}} > 20$ GeV	$m_{\ell\ell} > 50$ GeV
	$E_{\mathrm{T}}^{\mathrm{miss}} + m_{\mathrm{T}}^{W} > 60$ GeV	$\lvert m_{\ell\ell} - 91 \text{ GeV}\rvert > 8$ GeV



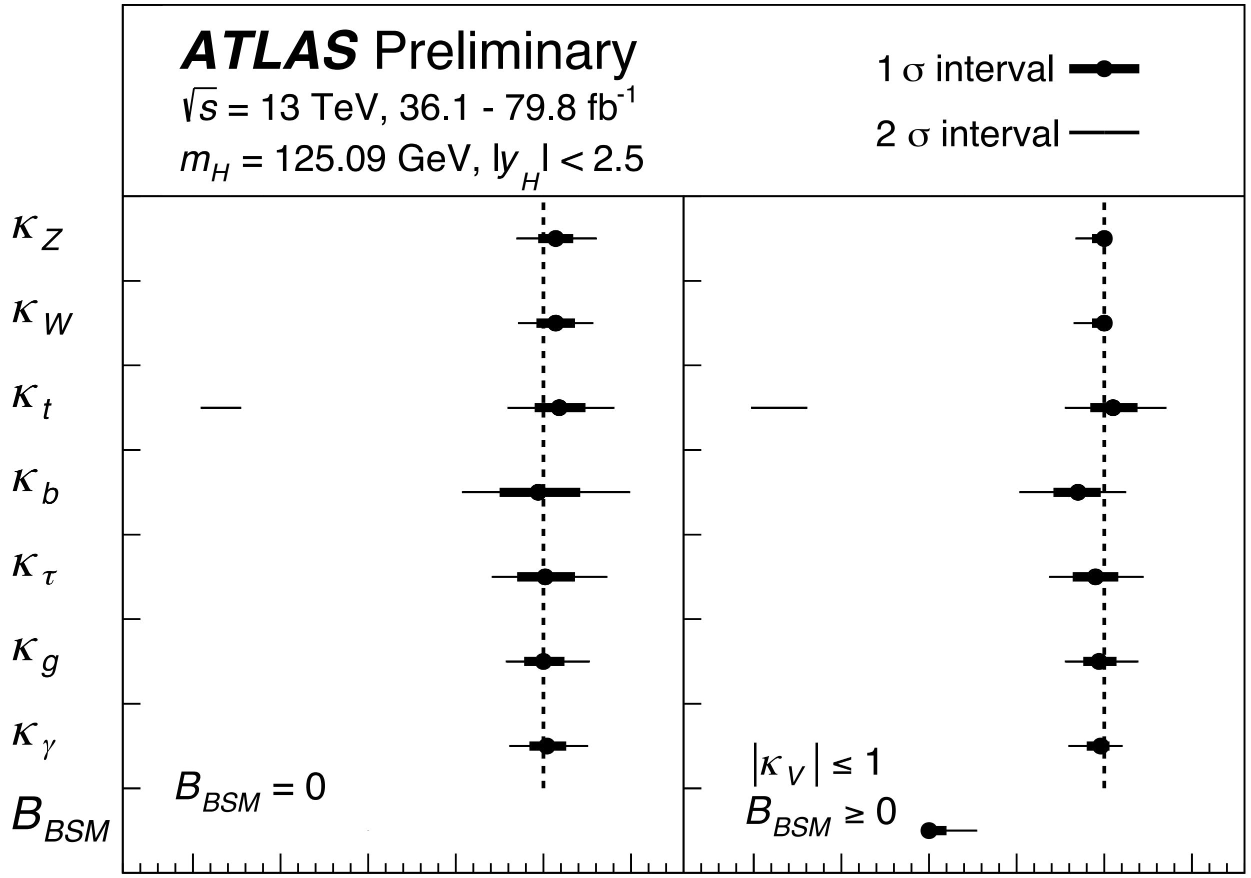
arXiv:1811.02305

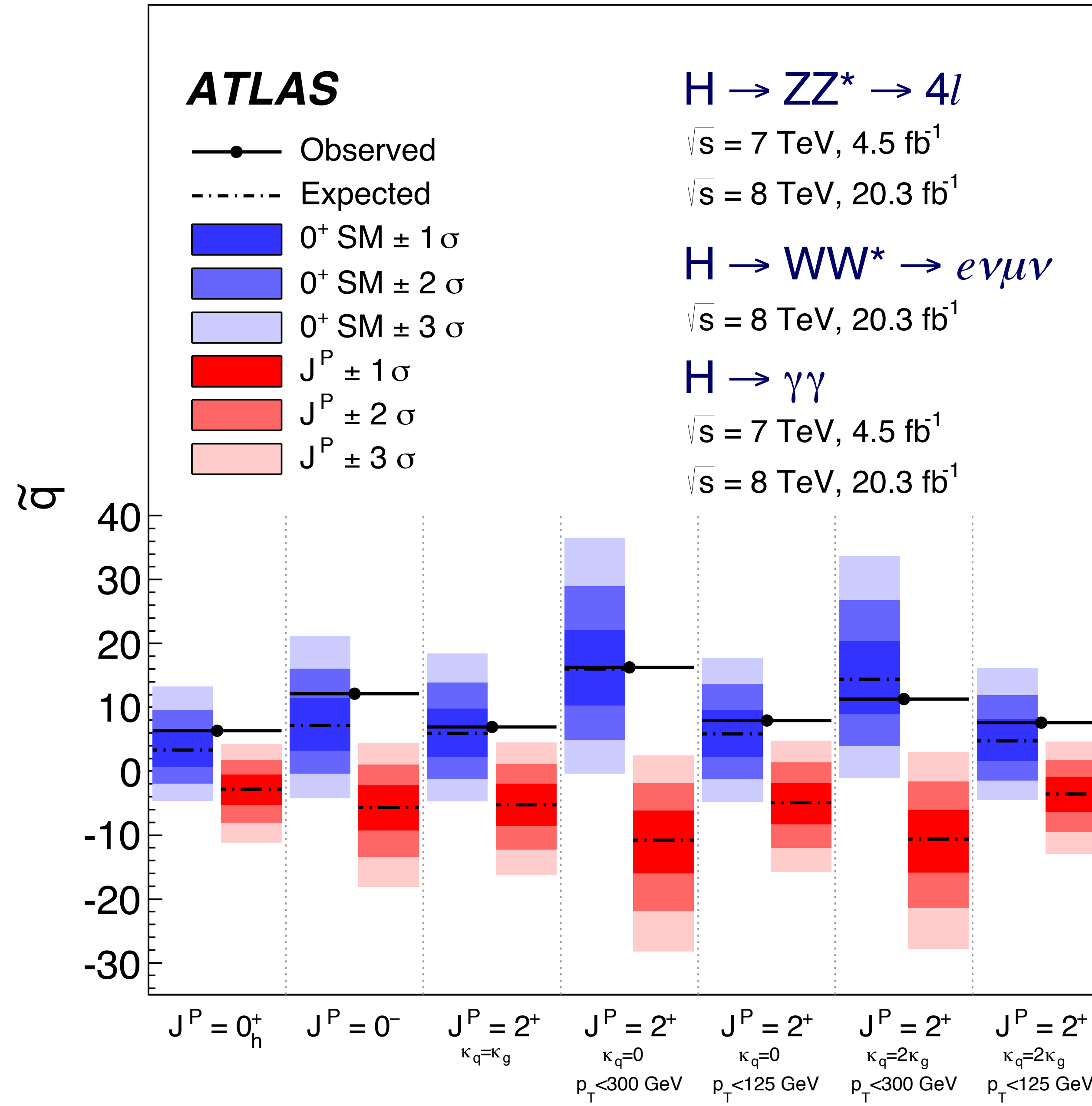
Other Top Measurements



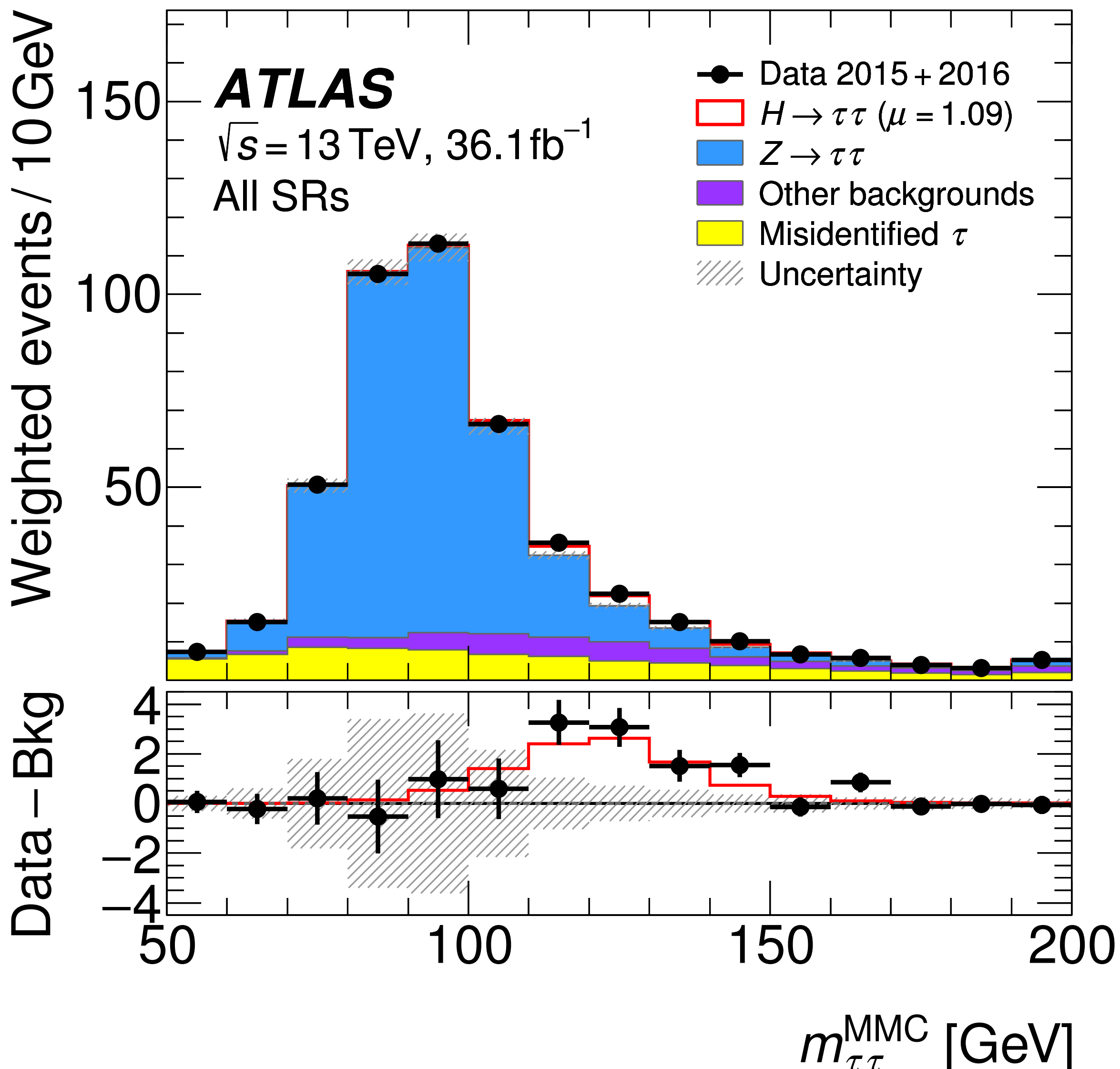


Higgs Summary Results





Higgs-Lepton Coupling: H→ττ

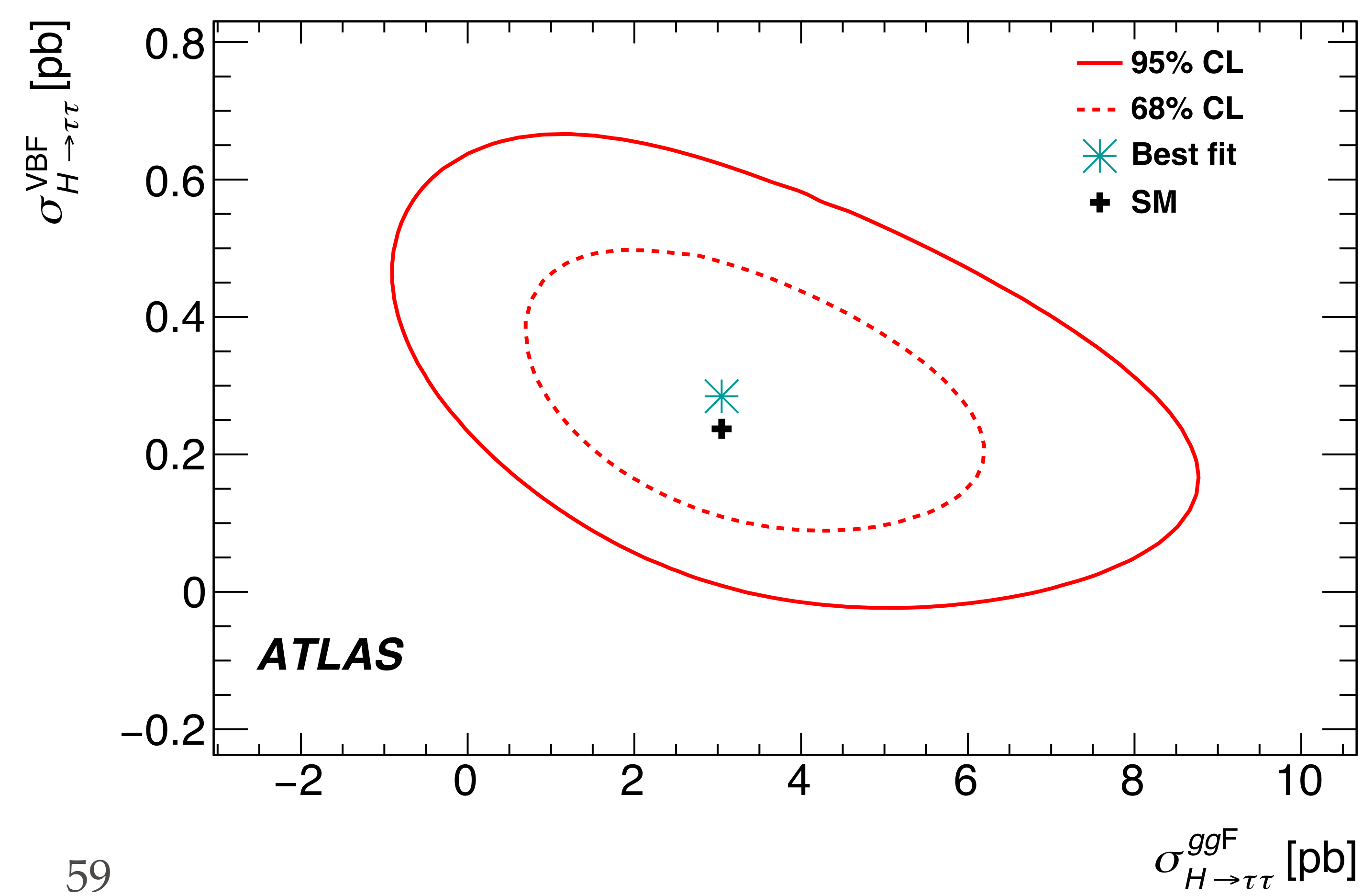


H→ττ allows to probe Higgs-lepton couplings

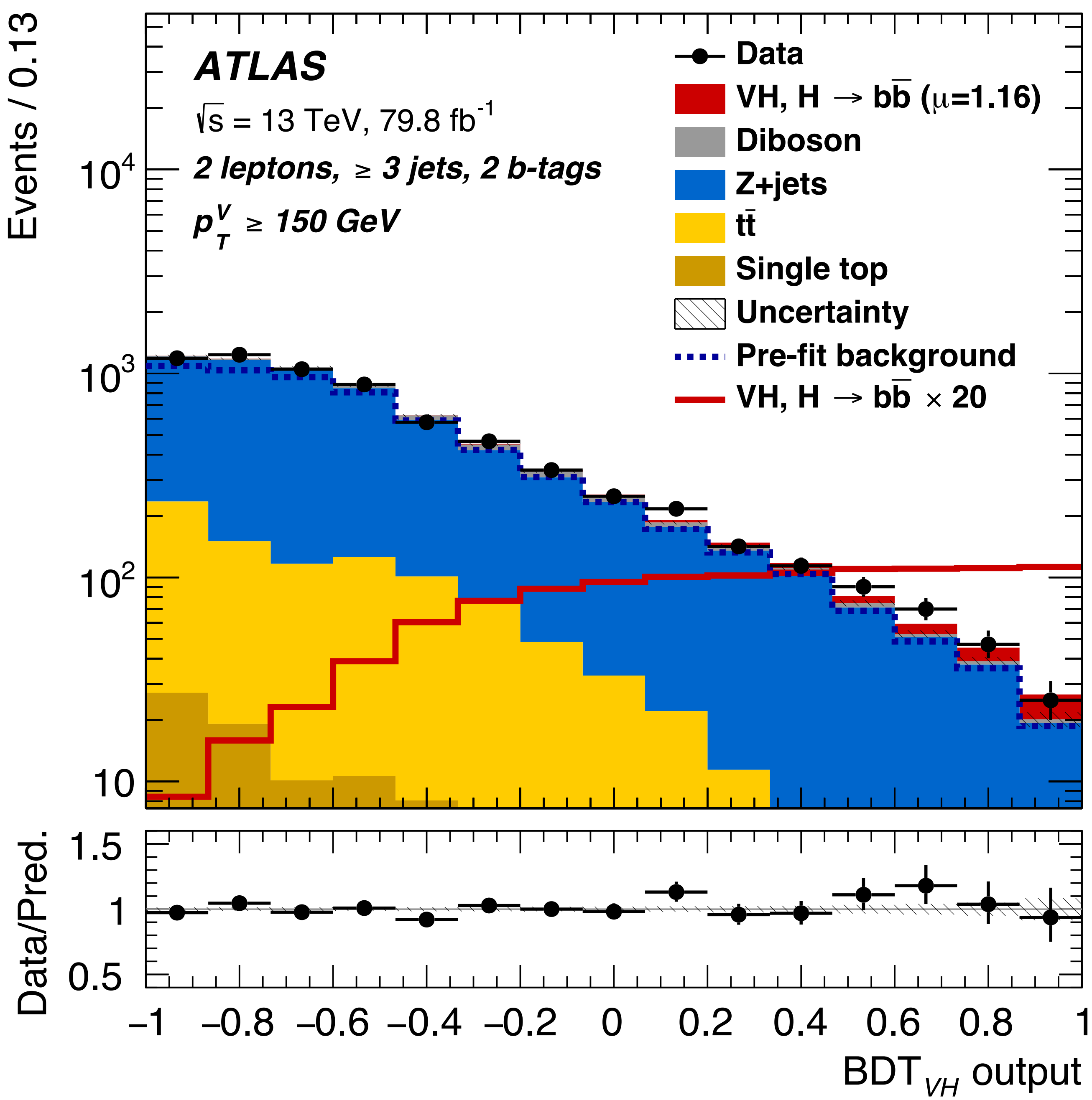
Run-2 data allows ATLAS to establish unequivocal observation of decay mode (Run-1 observation through ATLAS+CMS comb.)

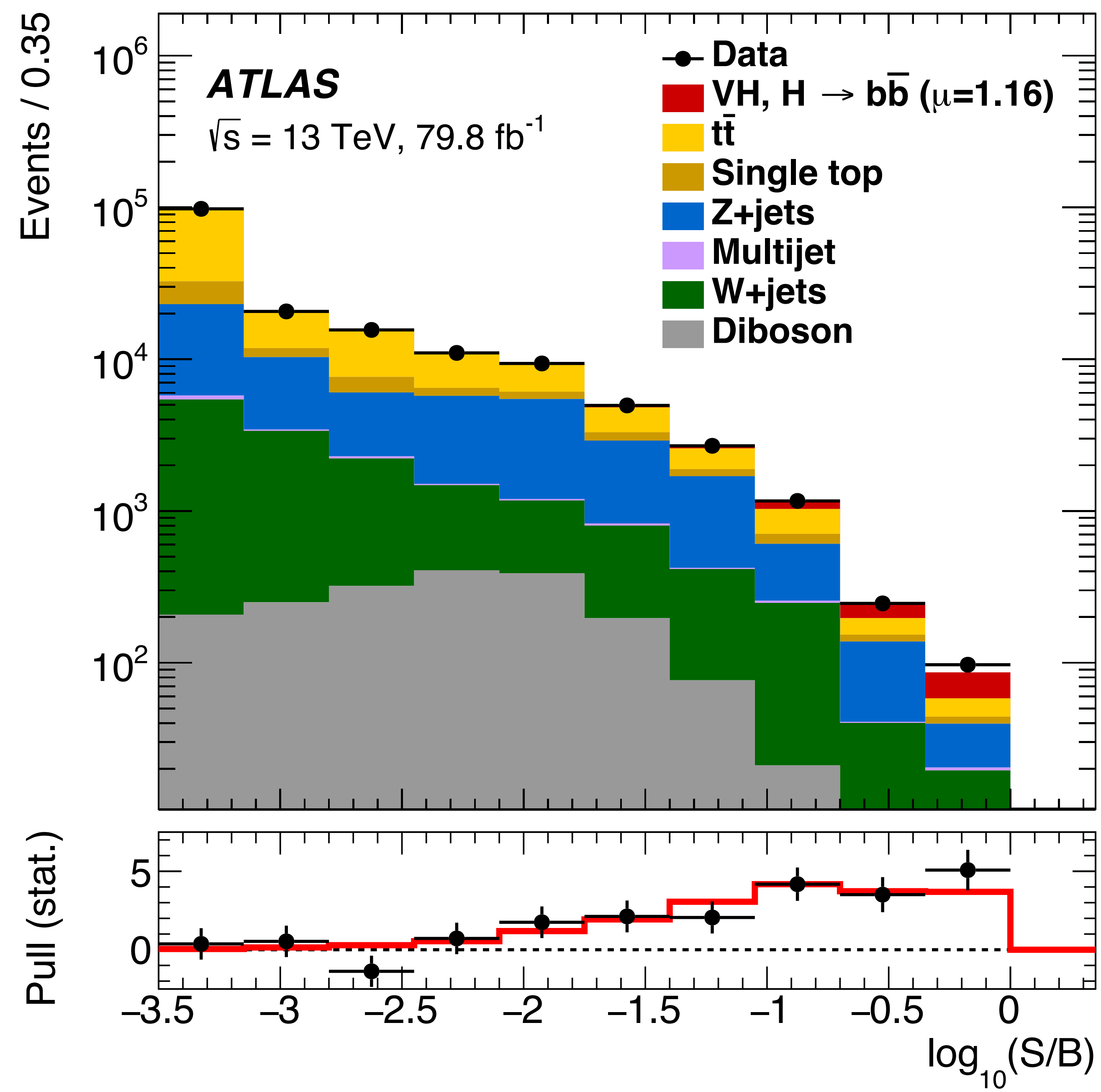
Signal significances (σ):

ATLAS	7,8 TeV	13 TeV	Comb.
Observed	4.5	4.4	6.4
Expected	3.4	4.1	5.4

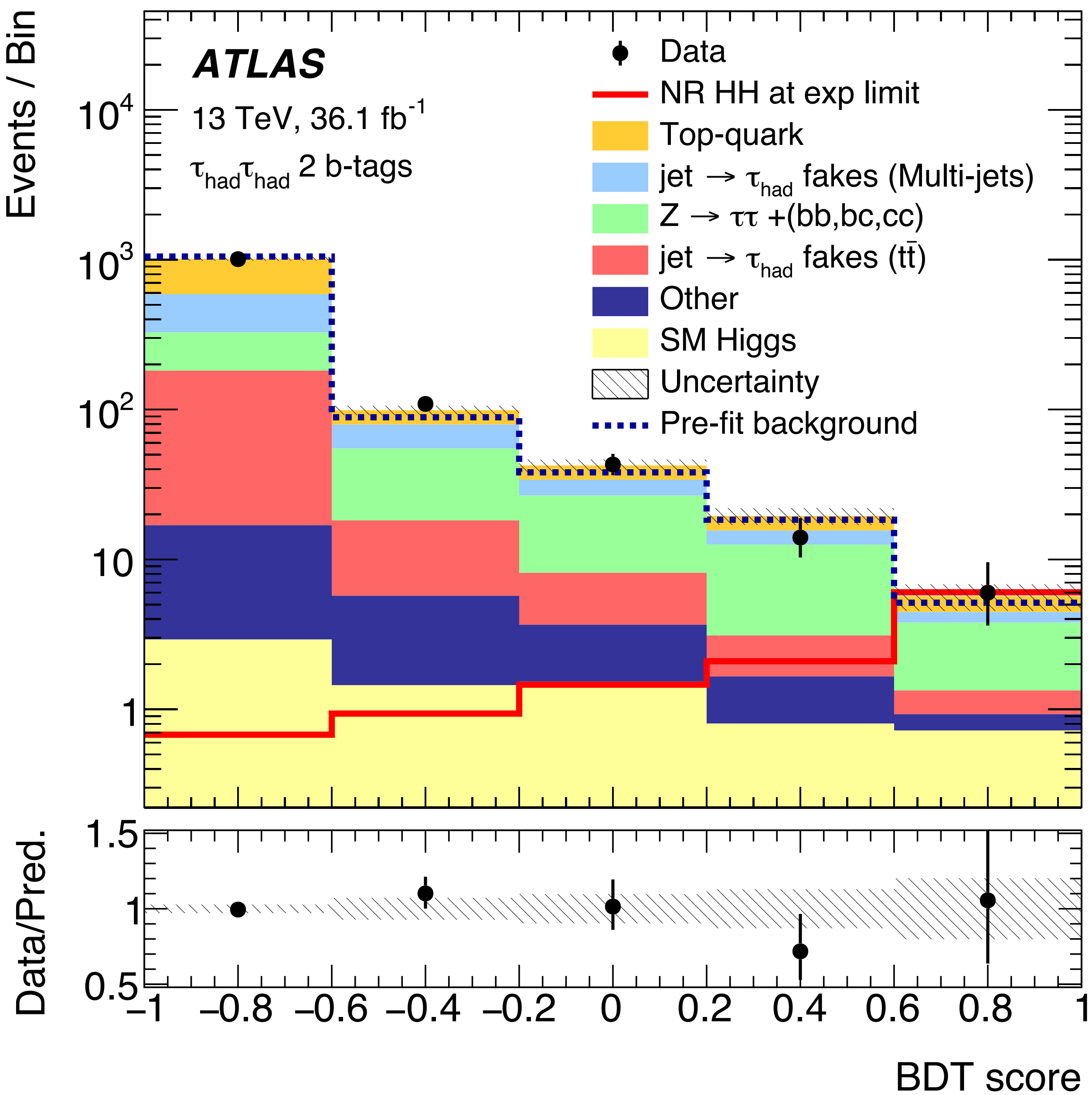


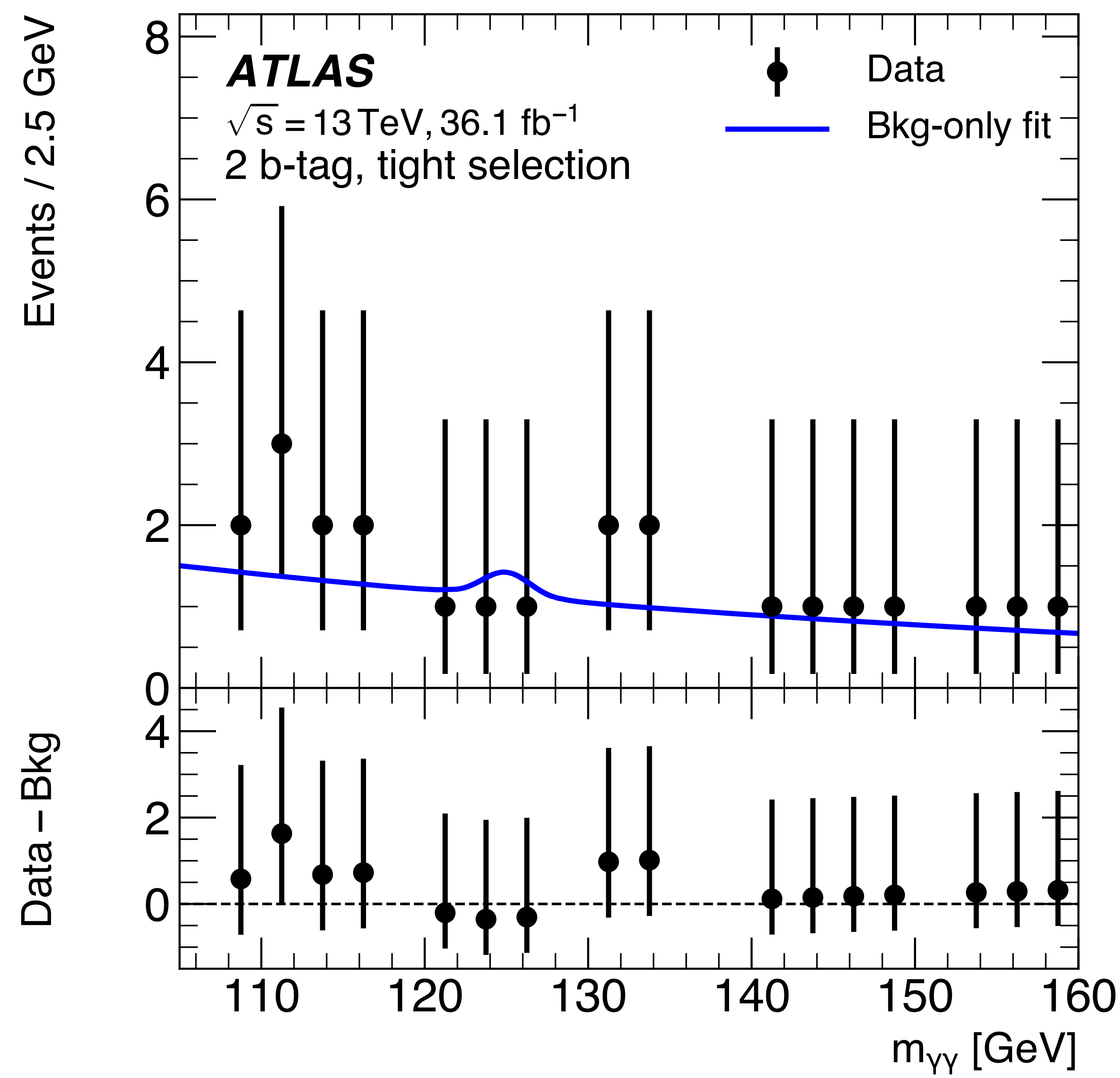
H→bb: Additional Plots





Higgs Pair Production: Additional Plots





Higgs Pair Production: Additional Plots