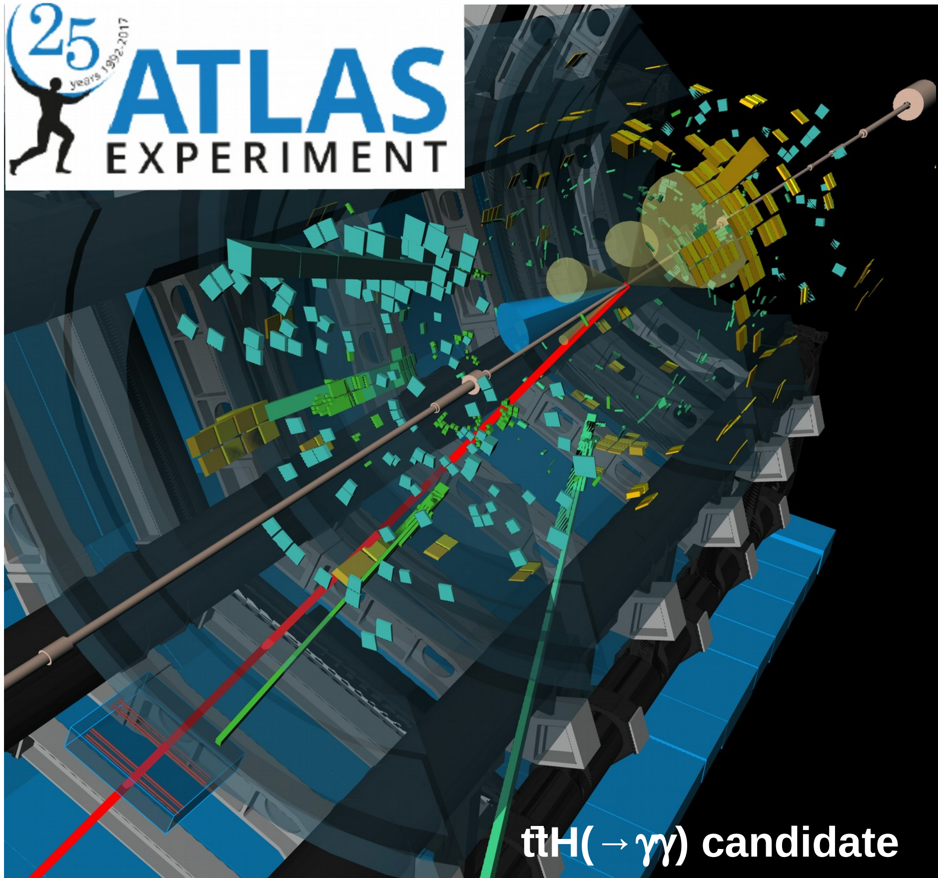
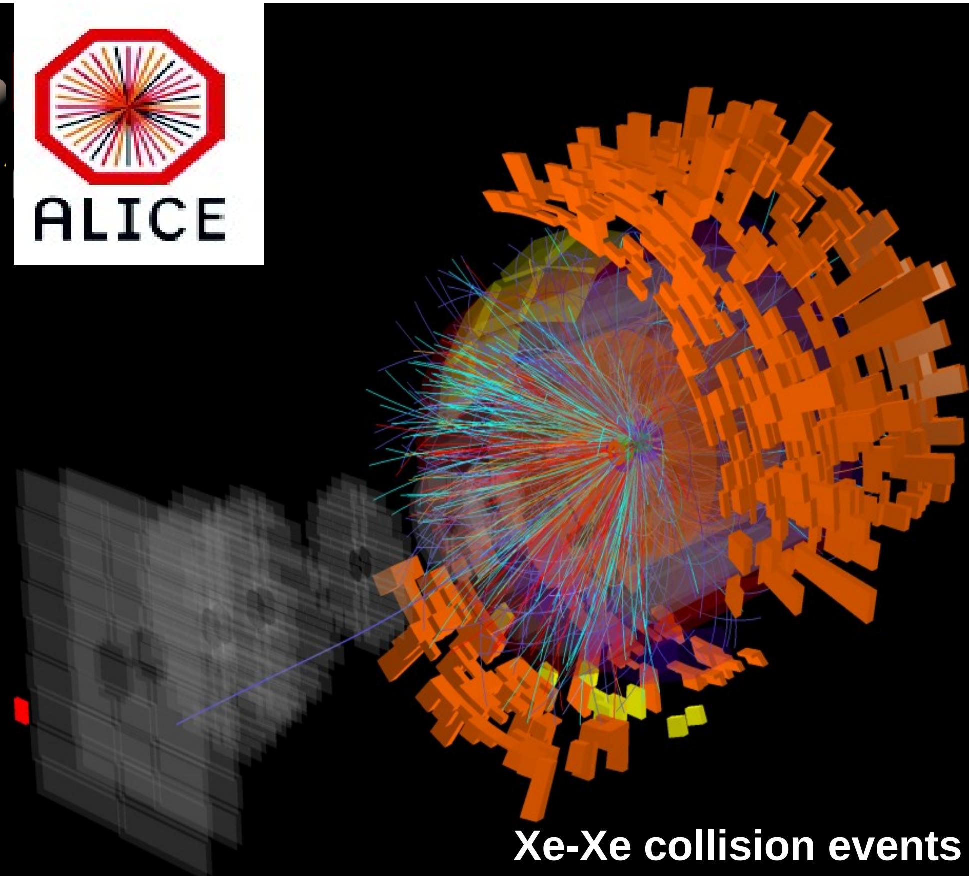
Physics Highlights of ATLAS and ALICE



$t\bar{t}H(\rightarrow\gamma\gamma)$ candidate



Xe-Xe collision events

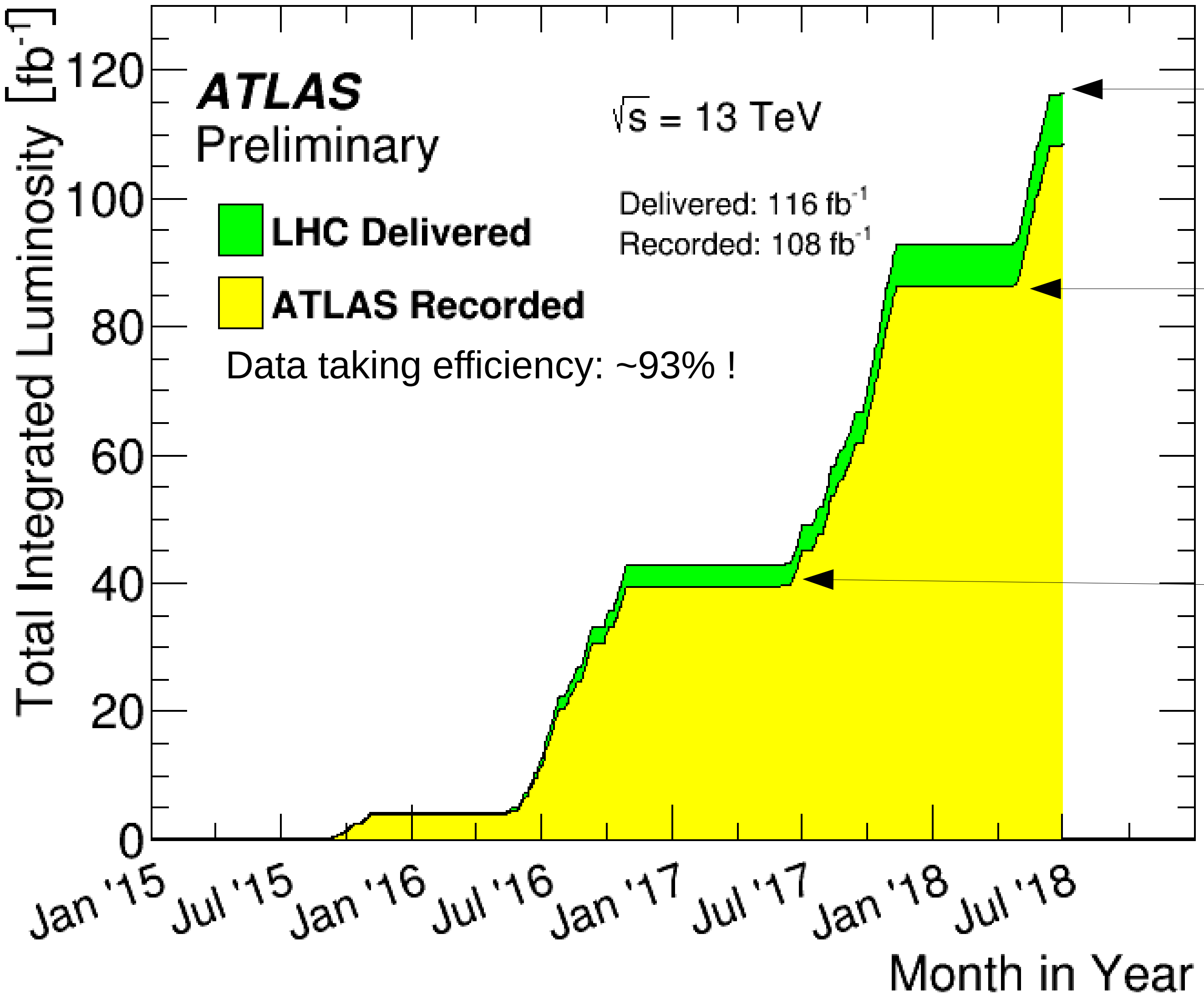
ICHEP2018 SEOUL

XXXIX INTERNATIONAL CONFERENCE ON *high Energy* PHYSICS

JULY 4 - 11, 2018 COEX, SEOUL

Tancredi Carli (CERN)

LHC performance and data-set



2015-2018 data-set:
L= 108 fb^{-1} recorded

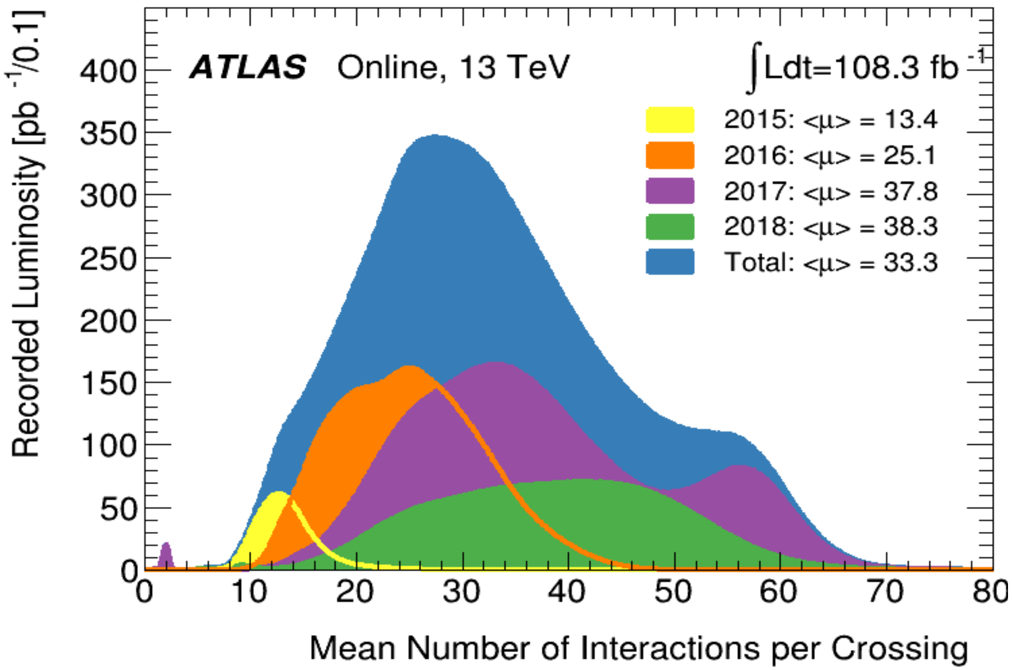
2015-2017 data-set:
L = 80 fb^{-1}
13 public results

2015-2016 data-set:
L = 36 fb^{-1}
88 publications on arXiv

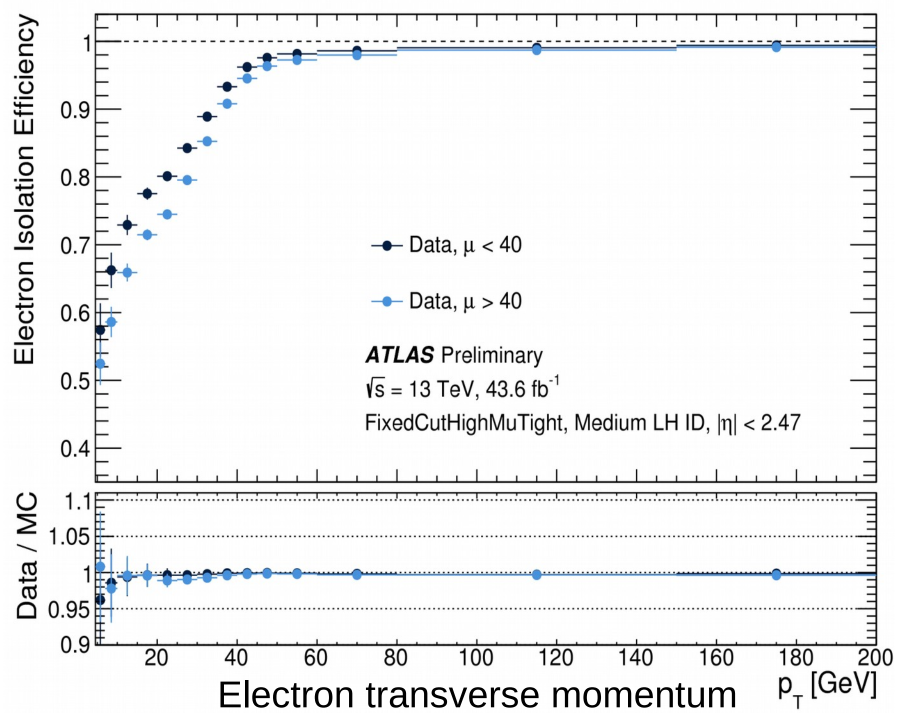
We are about a factor of 2 above LHC design luminosity.
Expect L = 140 - 150 fb^{-1} for full 2015-2018 data-set.

Challenge to cope with pile-up interactions

Interactions per bunch per crossing:



Electron isolation efficiency:



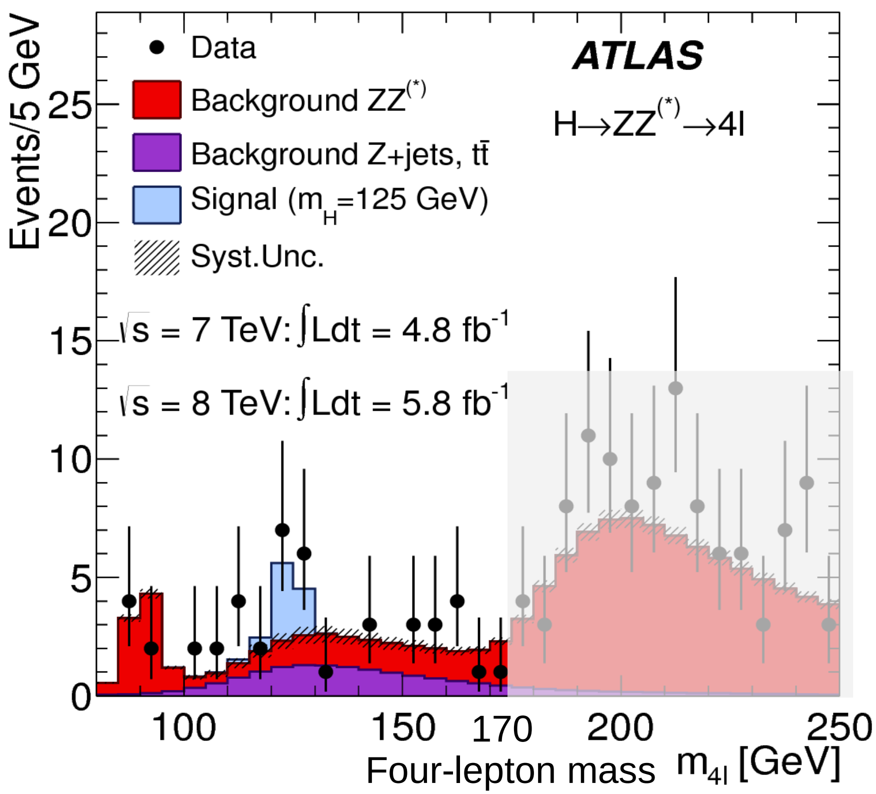
Large number of additional interactions (pile-up) cause performance degradation.
Powerful pile-up mitigation techniques developed.
The performance loss is well described by Monte Carlo simulation.

Example: H (→ZZ→4l) channel

Higgs boson discovered in July 2012 at LHC.
Is the new particle the SM Higgs boson ? → measure it properties !

Example for high purity but low branching fraction Higgs decay to four leptons H (→ZZ→4l):

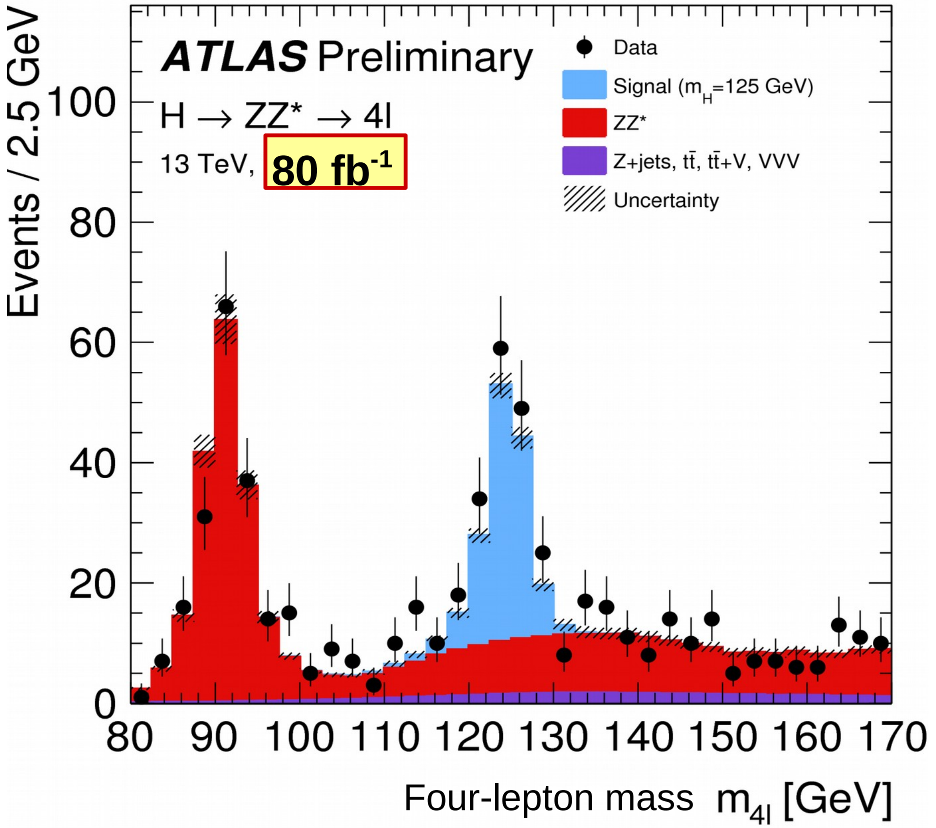
L=4.8 fb^{-1} and 5.8 fb^{-1} at 7 and 8 TeV



13 events 120< m_{4l} < 130 GeV

Phys. Lett. B 716 (2012) 1-29

L=80 fb^{-1} at 13 TeV

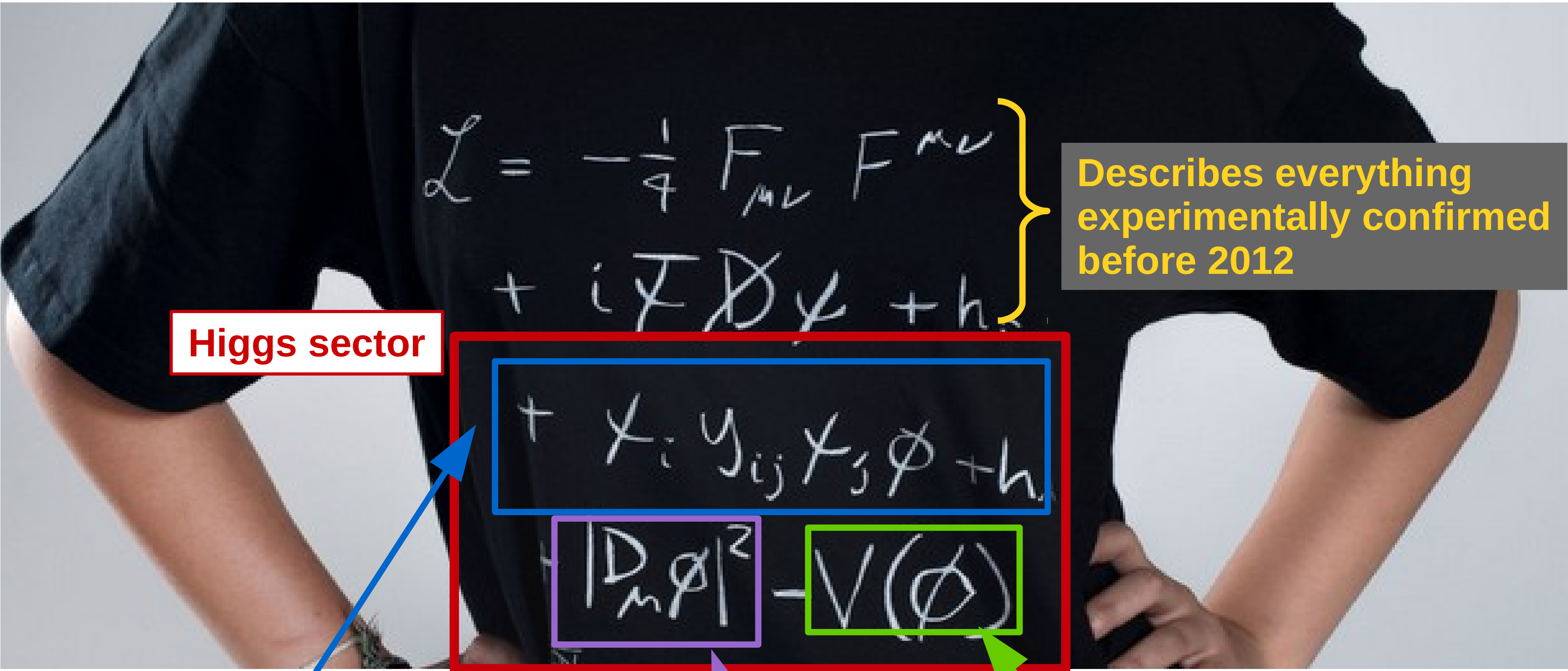


195 events for 115< m_{4l} < 130 GeV

ATLAS-CONF-2018-018

Nice peak of new fundamental scalar !

Standard Model Lagrangian



Yukawa coupling with new scalar (completely new interaction type)
ttH, H → bb and H → ττ are important !

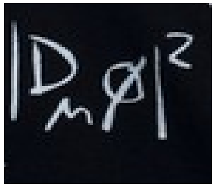
Higgs potential ($\mu^2 \phi^2 + \lambda \phi^4$)
(to be explored by High Lumi-LHC)

Gauge boson interaction with new scalar
(new for scalar, but known for fermions)

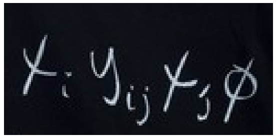
Higgs measurements at LHC test new part of SM

Inspired by G Salam LHCP2018

Gauge boson and Yukawa fermion coupling



Interaction with gauge bosons:



Yukawa coupling to fermions:

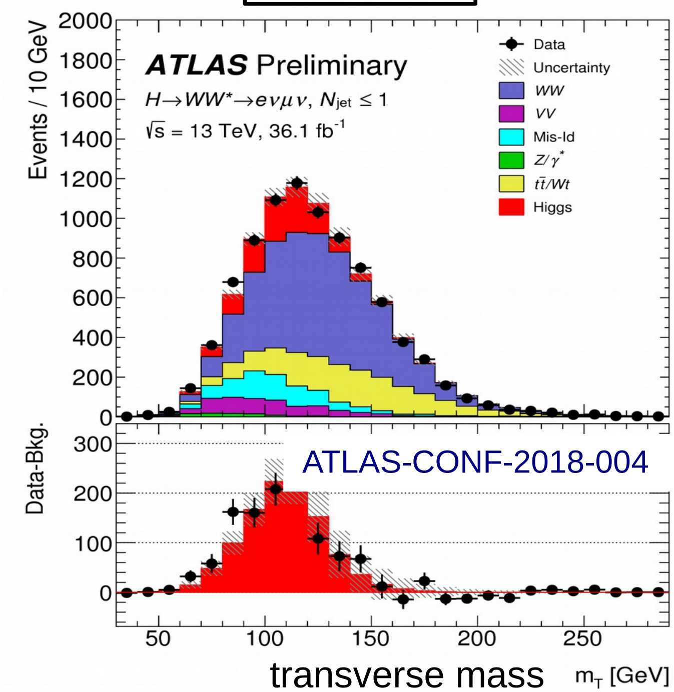
Earlier 7 and 8 TeV results:

At 7 and 8 TeV Higgs boson discovered.
Main channels: $H \to \gamma\gamma$, $H \to ZZ$, $H \to WW$

Only glimpse at 7 and 8 TeV (2012)
ATLAS/CMS combined $H \to \tau\tau$:
5.5σ (5.0σ) obs (exp) for 7/8/13 TeV
JHEP 08 (2016) 045

Recent 13 TeV results:

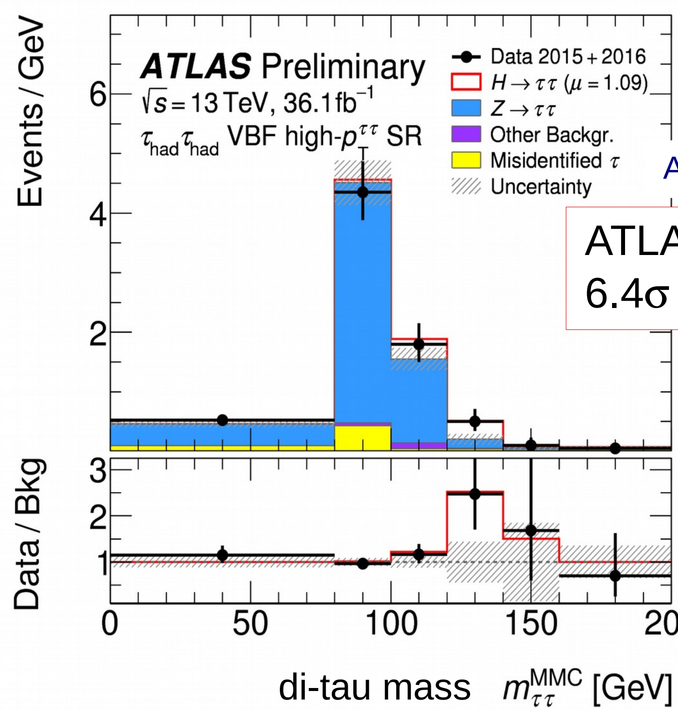
$H \to WW$



ATLAS-CONF-2018-004

transverse mass

$H \to \tau\tau$



ATLAS-CONF-2018-021

ATLAS 7/8/13 TeV:
6.4σ (5.4σ) obs (exp)

di-tau mass $m_{\tau\tau}^{MMC}$

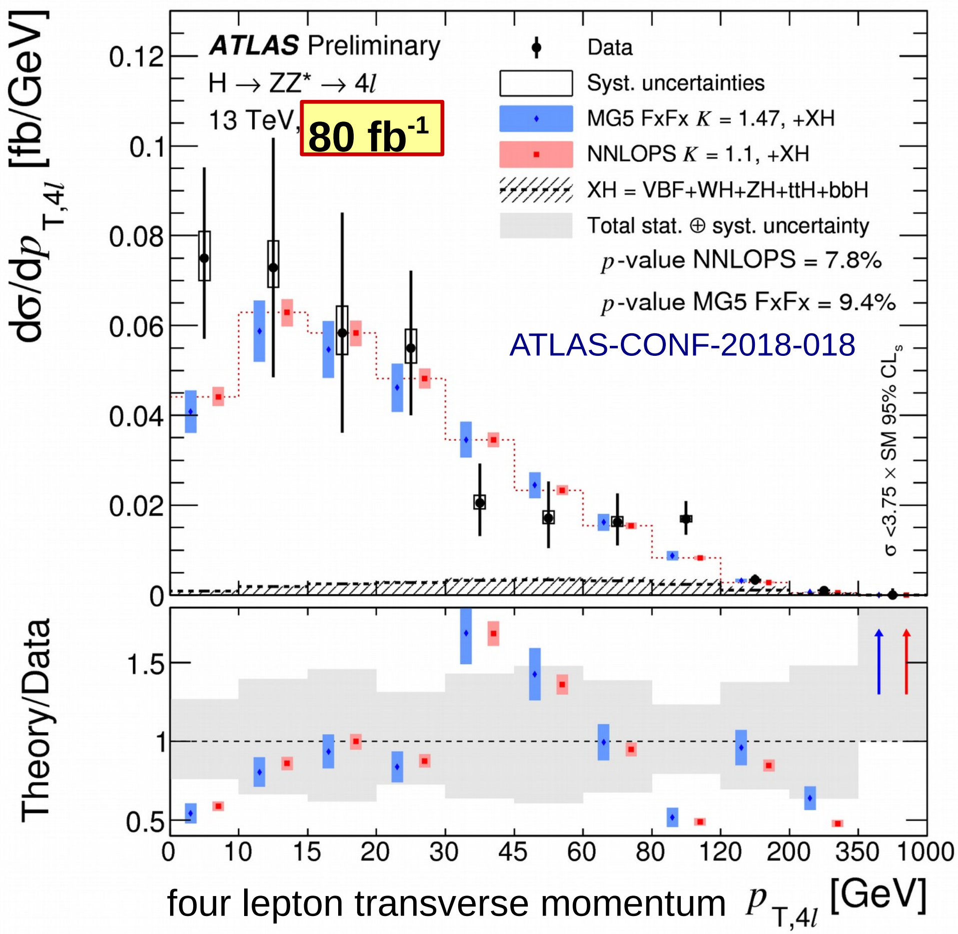
Example of mass in 1/13 signal categories

Differential cross-section using gauge boson decays

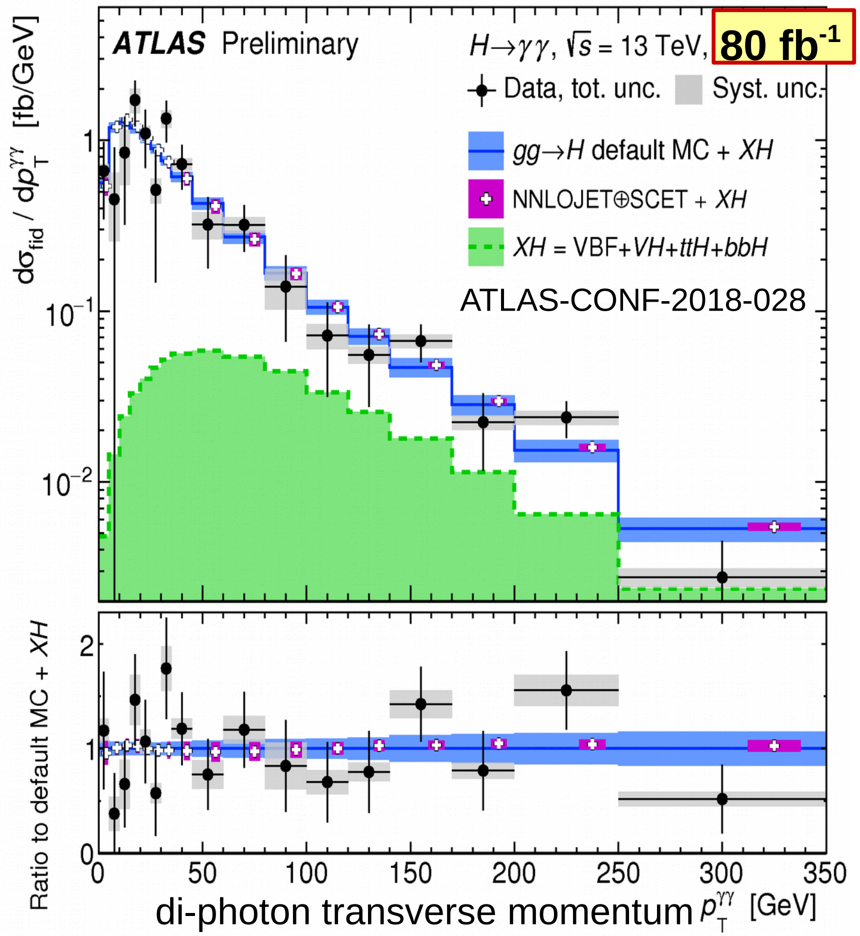
Higgs decays to gauge bosons used for differential cross-section measurements.

New

4 lepton channel



2 photon channel

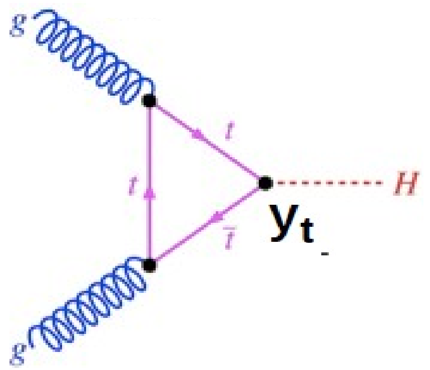


Differential cross-section becoming more and more precise with increasing statistics.
Data well described by recent SM predictions.

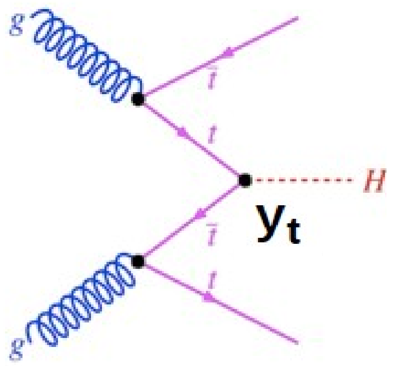
Associated Higgs top quark pair production

Higgs production:

Gluon-gluon fusion (ggF)



Associated ttH production (ttH)



σ(ttH)~ 1% σ(H)

Yukawa coupling:

$$y_t \approx v/(m_t\sqrt{2}) \approx 1$$

Large top mass → Higgs coupling is strong.
Top Yukawa y_t coupling is in loop for ggF (might contain BSM contribution).
but ttH production gives direct constraint on $\mathbf{y_t}$

Branching fraction:

H → bb	58%
H → WW*	21%
H → ττ	6%
H → ZZ*	2.6%
H → γγ	0.2%

For H→WW and H→ZZ only leptonic decays

Evidence in December 2017 (36 fb^{-1}):

Channel	Significance	
	Observed	Expected
Multilepton	4.1σ	2.8σ
$H \to b\bar{b}$	1.4σ	1.6σ
$H \to \gamma\gamma$	0.9σ	1.7σ
$H \to 4\ell$	—	0.6σ
Combined	4.2σ	3.8σ

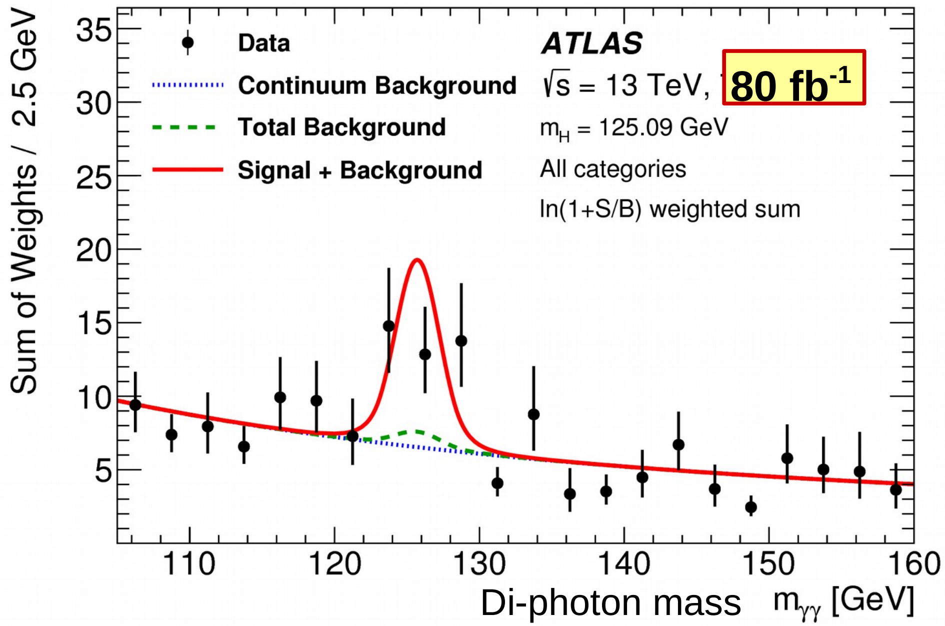
Phys.Rev. D 97 (2018) 072003
Phys. Rev. D 97 (2018) 072016
arXiv:1802.04146

Observation of ttH production

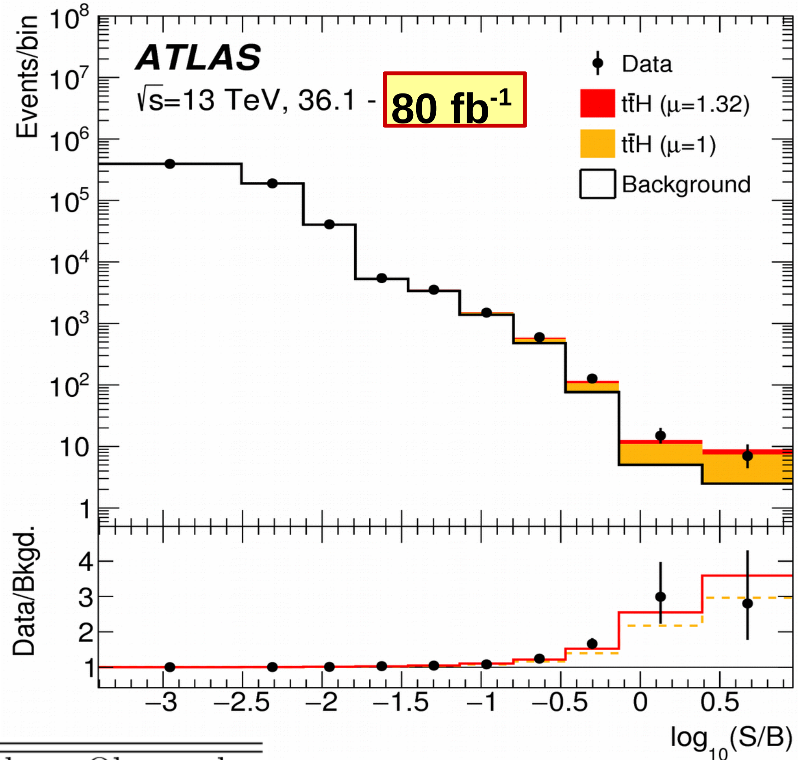
arXiv:1806.00425

June 2018 update: ttH(→γγ) and ttH(ZZ→4l) with 80 fb^{-1}

ttH(→γγ):



All channels combined:



Analysis	Integrated luminosity [fb^{-1}]	Expected significance	Observed significance
$H \to \gamma\gamma$	79.8	3.7 σ	4.1 σ
$H \to$ multilepton	36.1	2.8 σ	4.1 σ
$H \to b\bar{b}$	36.1	1.6 σ	1.4 σ
$H \to ZZ^* \to 4\ell$	79.8	1.2 σ	0 σ
Combined (13 TeV)	36.1–79.8	4.9 σ	5.8 σ
Combined (7, 8, 13 TeV)	4.5, 20.3, 36.1–79.8	5.1 σ	6.3 σ

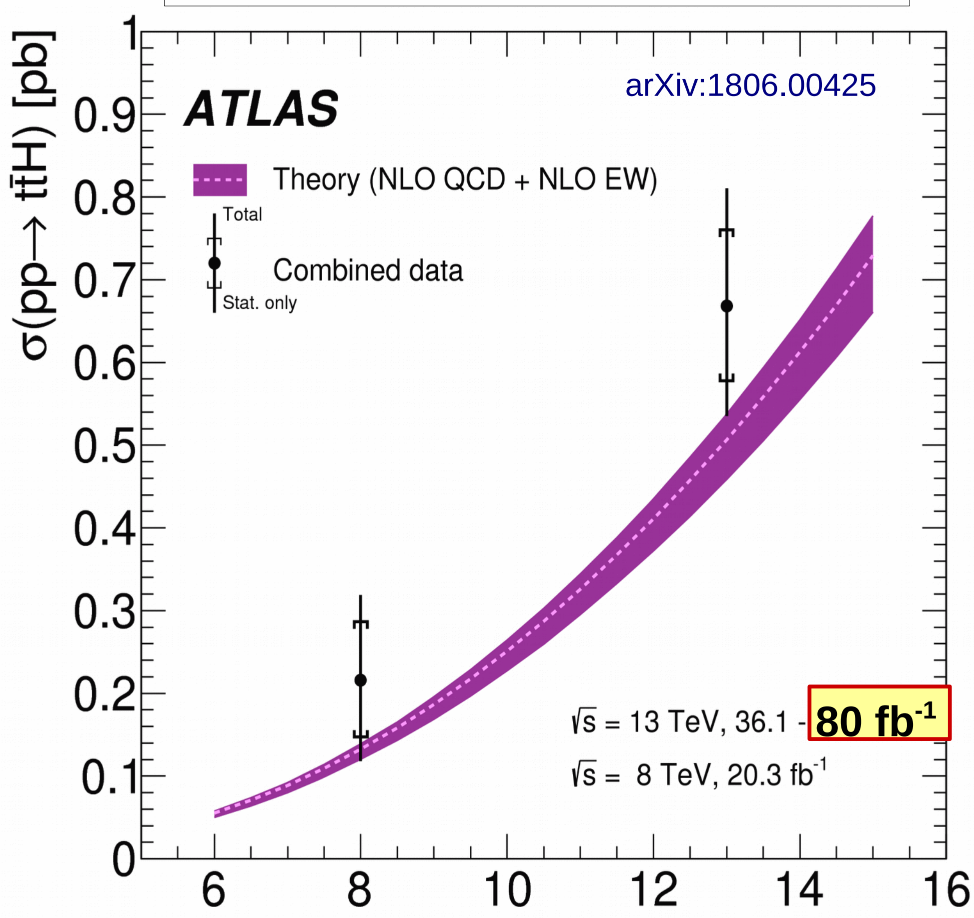
Direct observation of top Higgs coupling.
Confirmation of Yukawa coupling to fermions.

ttH production cross-section

June 2018 update: ttH(→γγ) and ttH(→ZZ→4l) with 80 fb^{-1}

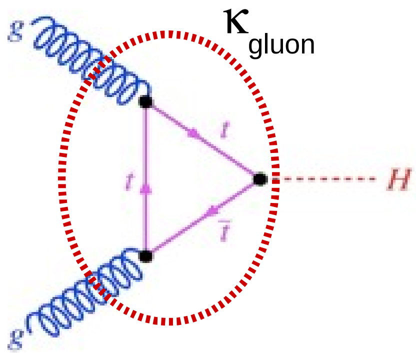
ATLAS-CONF-2018-031

Inclusive ttH production cross-section

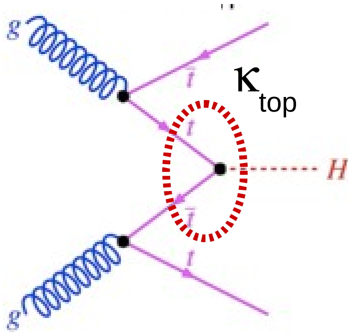


Already 20% precision !

Gluon-gluon fusion



Associated ttH production



Effective coupling $\kappa_{gluon} / \kappa_{top}$ =1.09+-0.14

Consistent with Higgs boson coupling as in SM.

Constrains BSM contributions.

New

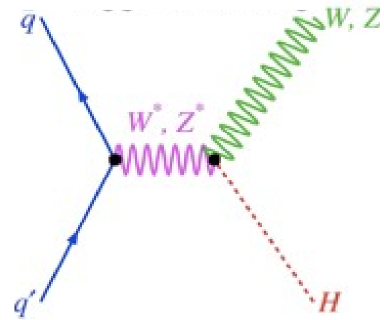
Associated VH production and H → bb

H → bb highest branching ratio: Br=58%

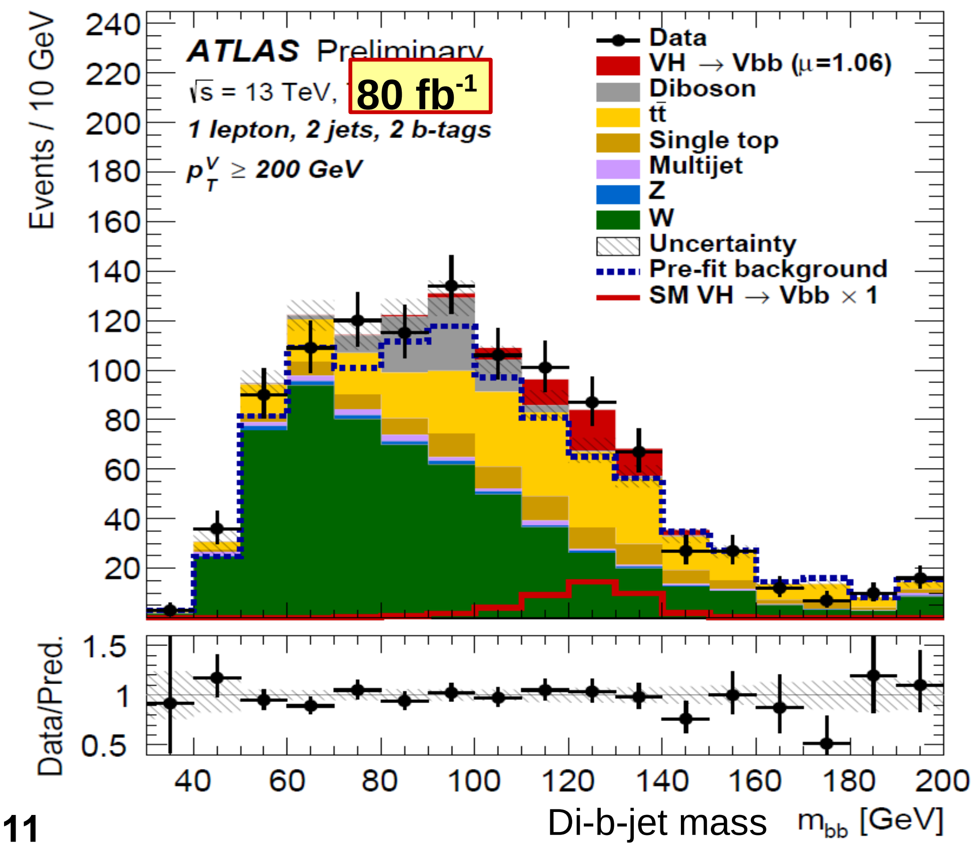
→ Br(H → bb) constrains invisible Higgs decays
→ Tests Higgs Yukawa coupling to fermions

Analysis with large background:
→ Use high-p_T boson region
→ Multi-variate analysis in 0, 1 and 2 lepton channels
→ Dijet mass analysis as cross-check

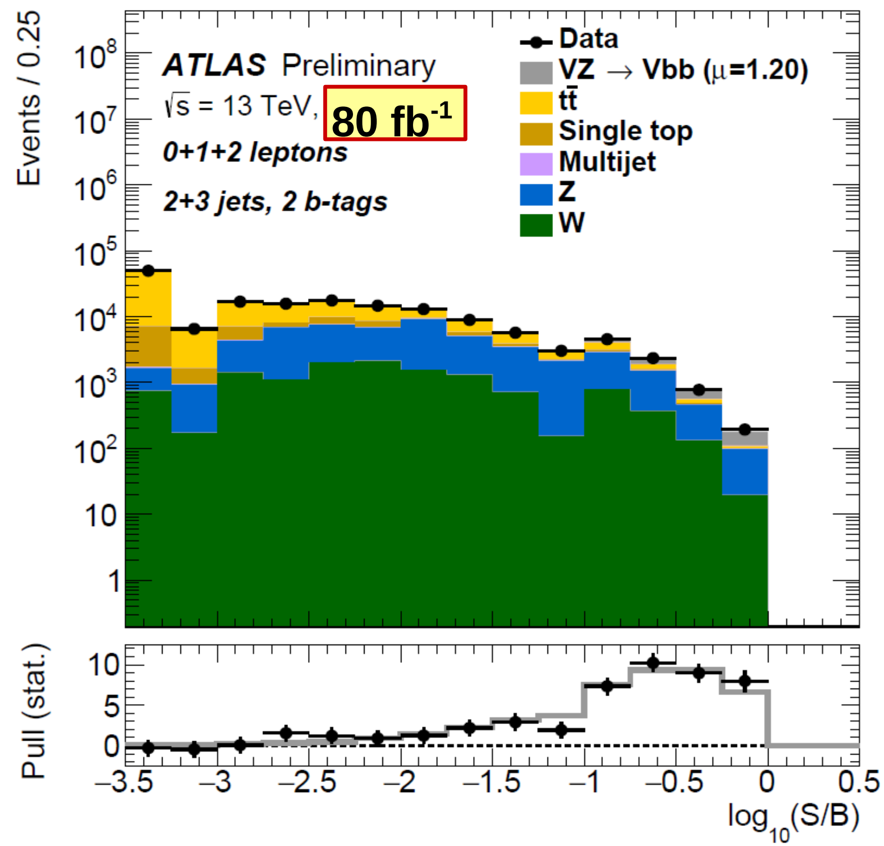
Associated WH or ZH production (VH)



Example: One input to di-jet mass analysis global fit



Di-boson validation analysis VZ(→ bb):

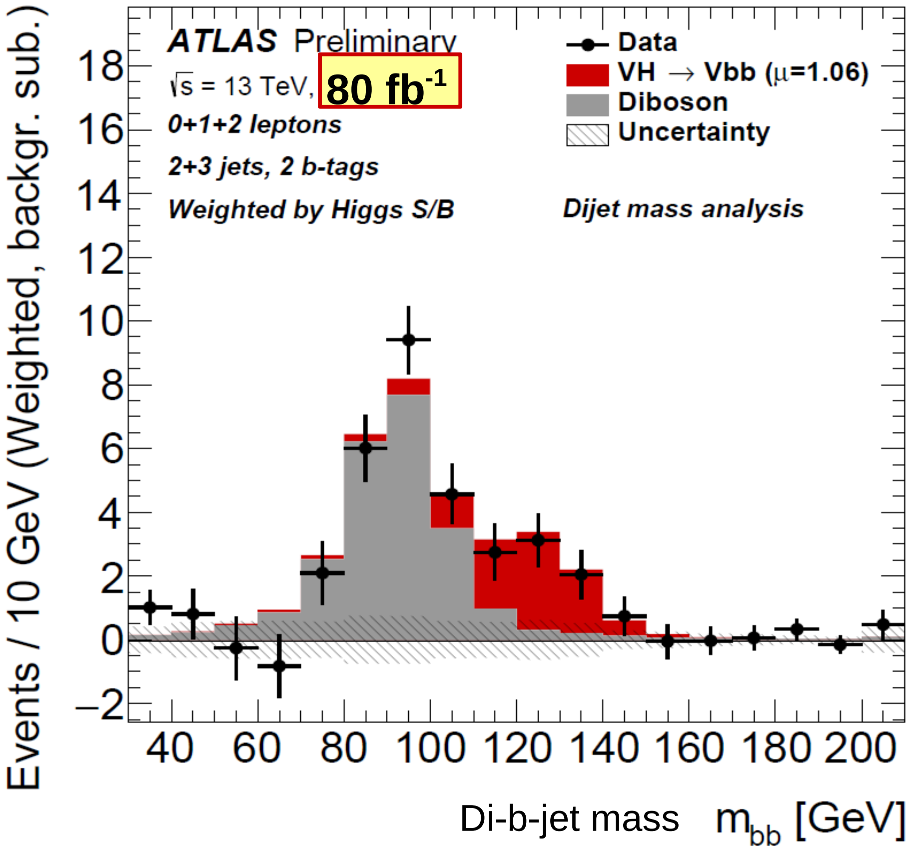


Observation of H → bb

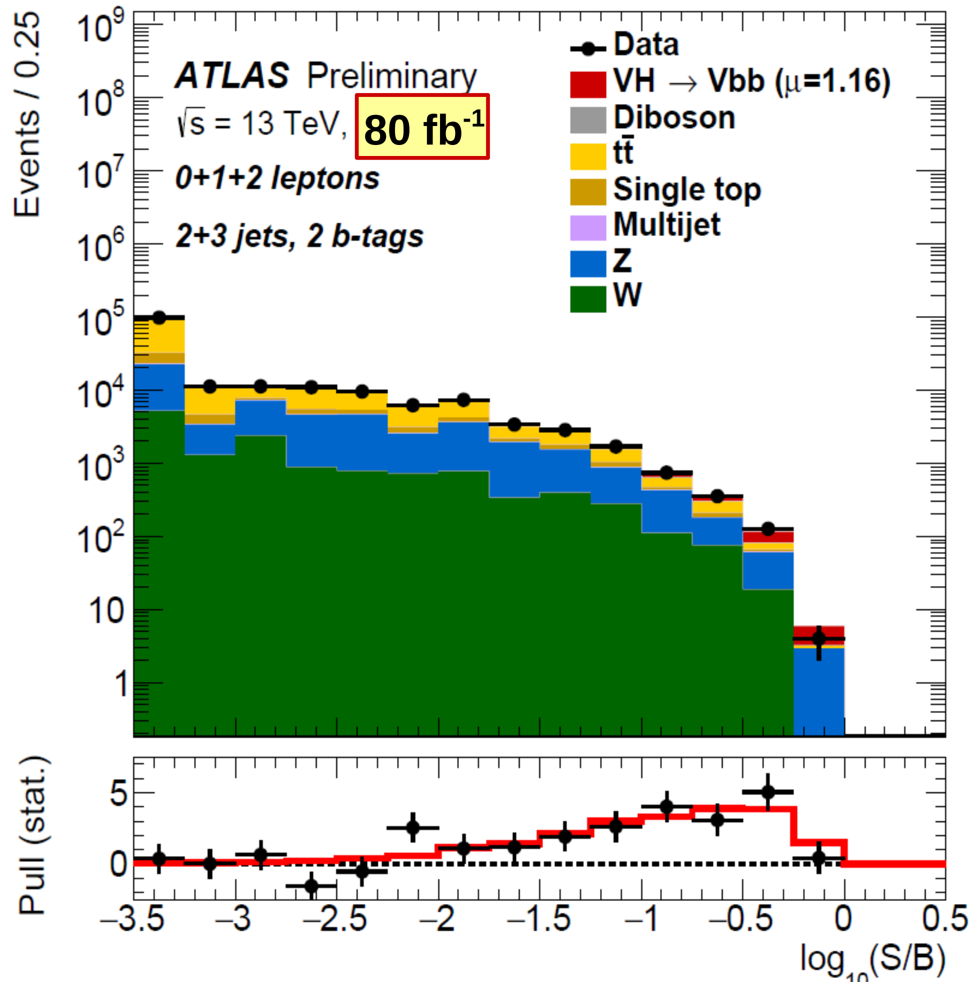
New

ATLAS-CONF-2018-036

Di-jet mass analysis:



Main multi-variate analysis:



Observation of Higgs decay to beauty quarks !

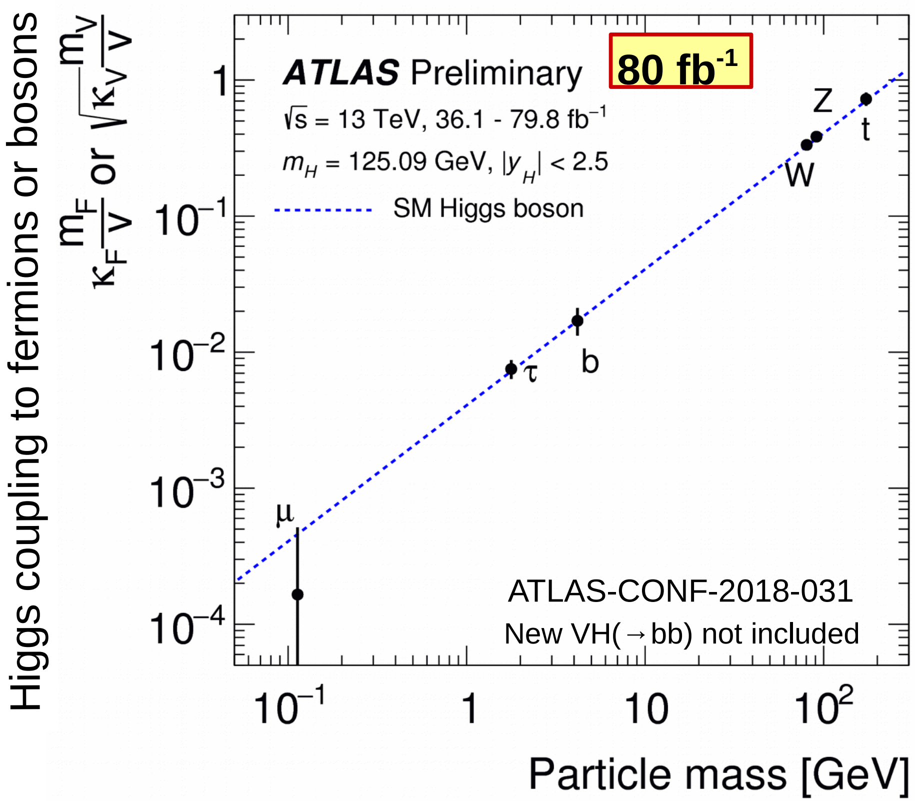
VH alone: 4.9σ (4.3σ) obs (exp) (13 TeV)

Combined (7,8,13 TeV) VBF, ttH, VH:
5.4σ (5.5σ) obs (exp)

Higgs coupling measurements

New

Key feature:
Higgs coupling depends on the particle mass



All couplings to high mass particles measured.
Next challenge: muon, charm-quark...

+ detailed cross-section measurements !

Interaction with gauge bosons:

$H \rightarrow ZZ^*$ ATLAS-CONF-2018-018

Well established in run-1

$H \rightarrow WW^*$ ATLAS-CONF-2018-004

6.3 (5.2) σ obs (exp) (run-2 only)

Yukawa coupling to fermions:

Top-quark: ttH **80 fb^{-1}**

6.3σ (5.1σ) obs (exp) arXiv:1806.00425

Beauty-quark $H \rightarrow bb$: **80 fb^{-1}** New

5.4σ (5.5σ) obs (exp) ATLAS-CONF-2018-036

Tau-lepton: $H \rightarrow \tau\tau$

6.4σ (5.4σ) obs (exp) ATLAS-CONF-2018-021

Muon $H \rightarrow \mu\mu$: **80 fb^{-1}** New

$\sigma_{limit}/\sigma_{SM}<2.1$ (obs) ATLAS-CONF-2018-026

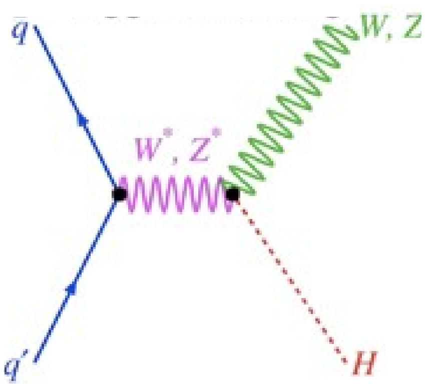
Charm-quark: $H \rightarrow cc$:

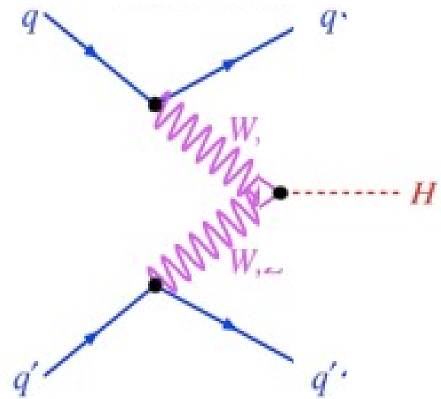
$\sigma_{limit}/\sigma_{SM}<104$ (obs) PRL 120 (2018) 211802

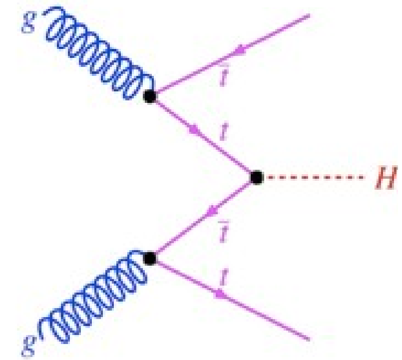
New

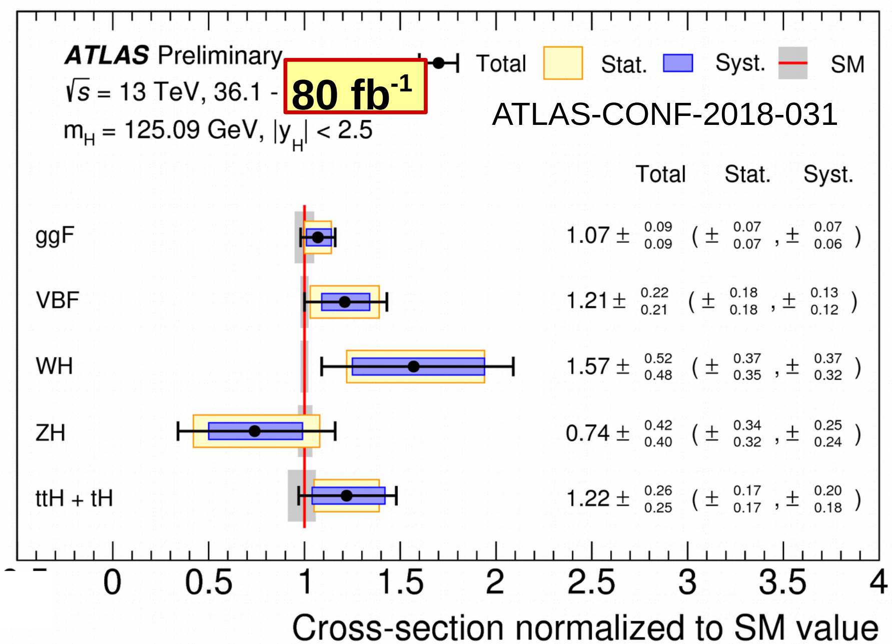
Higgs production modes

Associated WH or ZH production (VH)	Vector-boson fusion (VBF)	Associated ttH production (ttH)









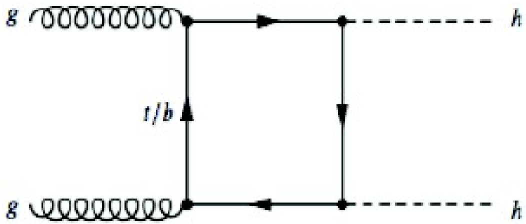
Gluon-gluon fusion (ggF) observed since 2012 and used for precision measurements (~10%).

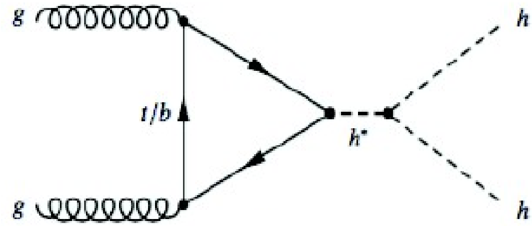
VH	5.3σ (4.8σ) obs (exp)	ATLAS-CONF-2018-036
VBF	6.5σ (5.3σ) obs (exp)	ATLAS-CONF-2018-031
ttH	6.3σ (5.1σ) obs (exp)	arXiv:1806.00425

Observed all major Higgs production modes ! Consistent with SM.

SM Di-Higgs production

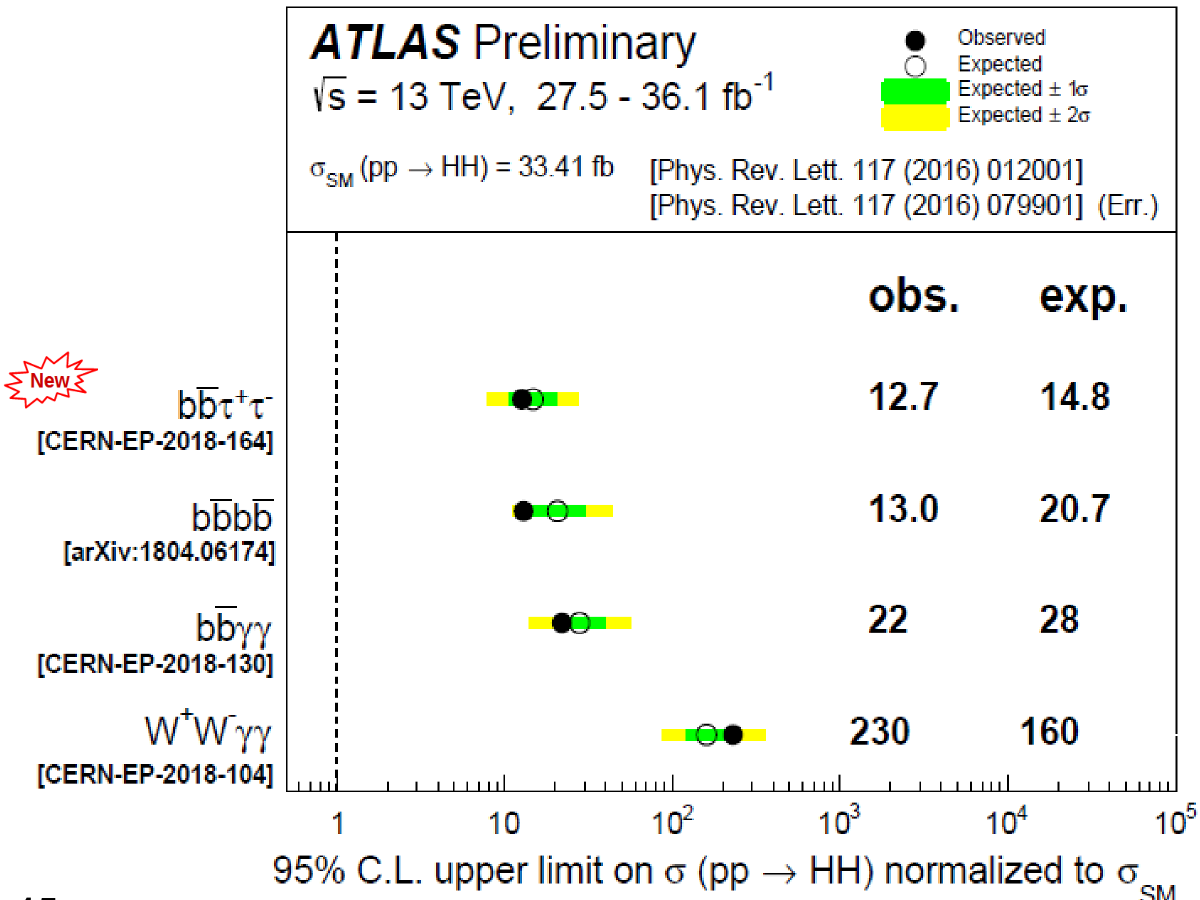
Production processes:





Di-Higgs production process is direct probe of SM trilinear coupling.

Strong destructive interference between processes.



Actively working on new techniques with increased sensitivity.

Considerably improved HH → bb ττ result.

Limit approaching:

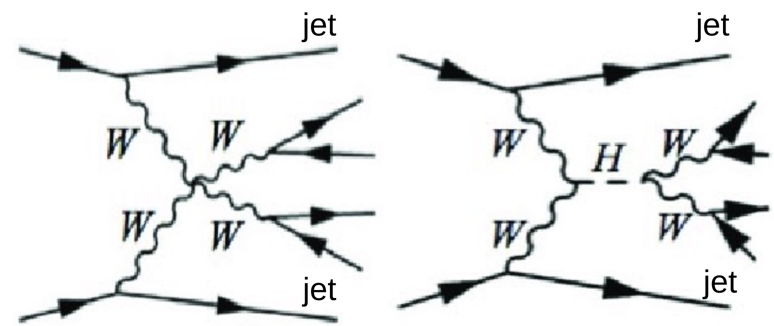
$\sigma_{limit}/\sigma_{SM}$ ~10

New

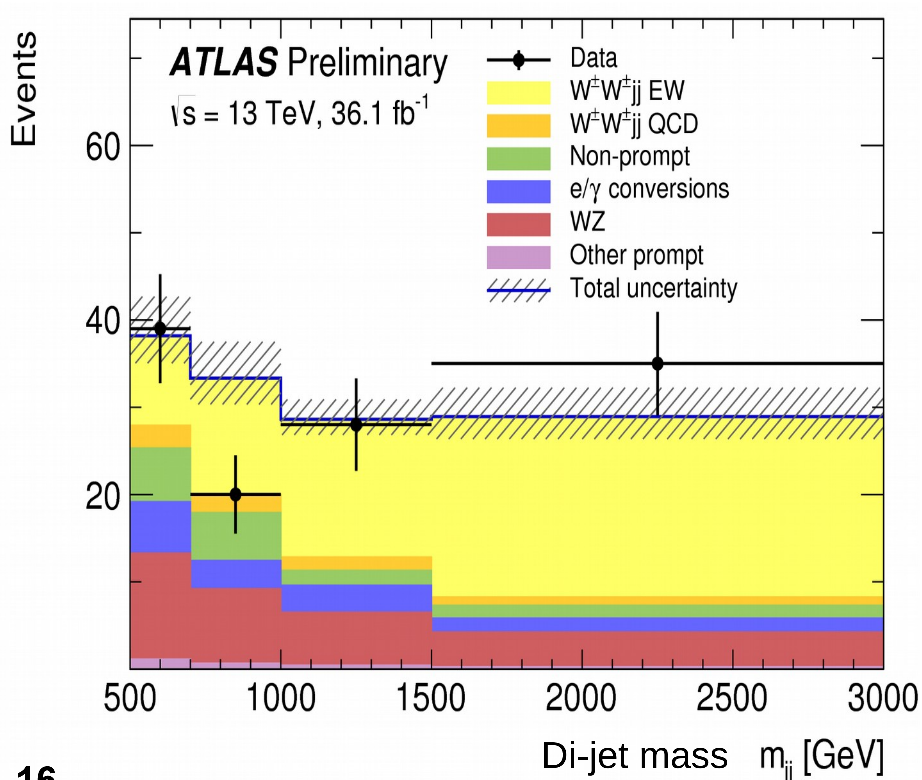
Observation of same-sign WWjj

ATLAS-CONF-2018-030

Higgs boson needed to restore unitarity of the WW scattering cross-section.
→ Higgs boson leads to strong suppression via gauge cancellation of individual EW diagrams.
→ Part of electroweak symmetry breaking studies.



pp → $W^{+/-}$ $W^{+/-}$ jet jet process:
-Large electroweak cross-section fraction (σ_{EW}/σ_{QCD}).
and a strong background suppression.



Significance:
6.9σ (4.6σ) obs (exp)

Fiducial cross-

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

$$\sigma^{\text{Sherpa}}_{\text{fid}} = 2.01^{+0.33}_{-0.23}\ \text{fb}$$

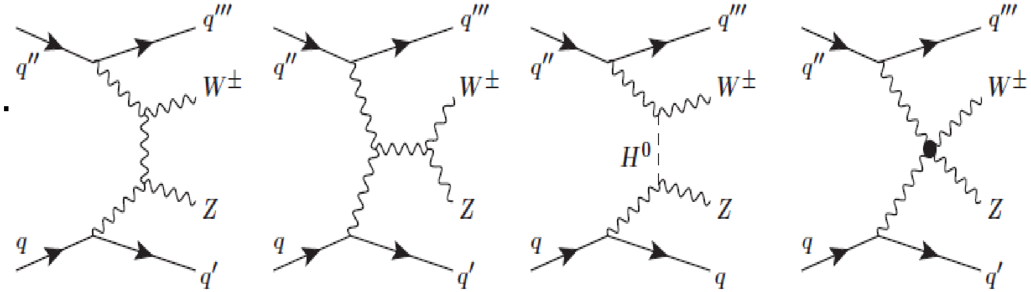
$$\sigma^{\text{Powheg}}_{\text{fid}} = 3.08^{+0.45}_{-0.46}\ \text{fb}$$

New

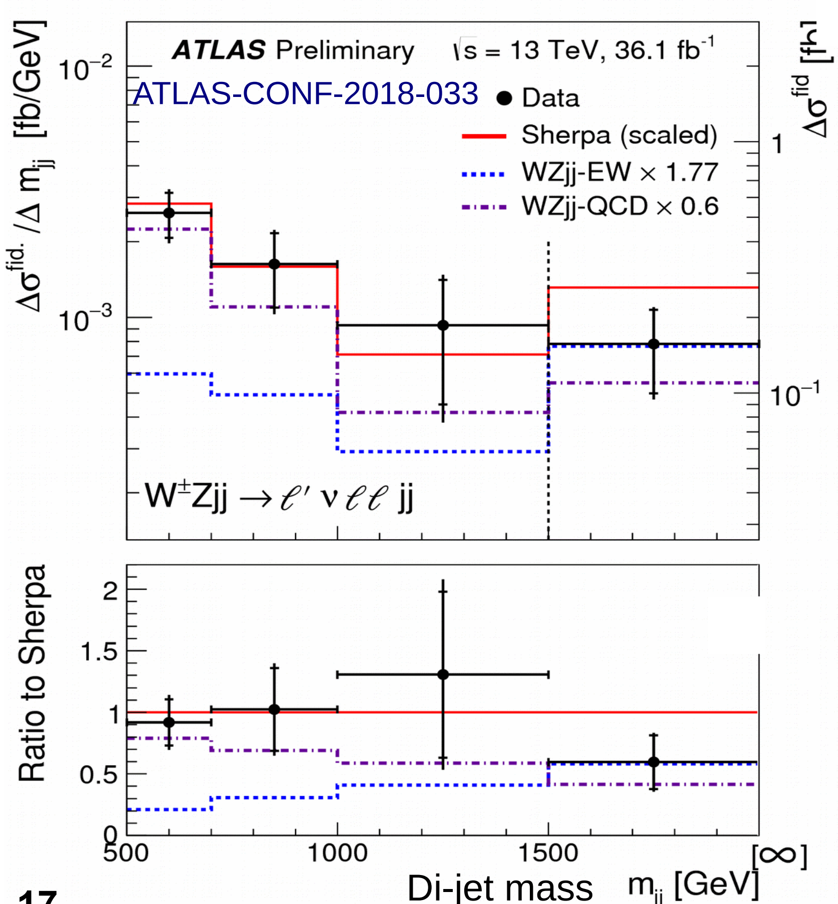
WZ and WZjj production

Electroweak production of WZ boson in association with two jets pp → W^{+-} Z jet jet

Process sensitive to triple and quartic gauge couplings and anomalous couplings.



Differential EW cross-section:



5.6σ (3.3σ) obs (exp)

ATLAS-CONF-2018-033

Observation of electroweak W/Z jet+jet process.

Total fiducial WZ jet jet cross section:
σ_{EW}(pp → W^{+-}Z jet jet)= 0.57 +-0.15 fb
LO (Sherpa): 0.32 +-0.03 fb

Also new result on inclusive WZ production:

1) Fiducial cross-section in agreement with NNLO QCD (inclusive and differential)
2) Evidence of longitudinally W polarization (4.2σ)
3) Measurement of Z polarization

ATLAS-CONF-2018-034

New Measurements of electroweak parameters

Measurement of electroweak mixing angle:

Drell-Yan cross-section qq→Z→ll expanded as sum of 9 harmonic polynomials (NNLO QCD).
In LO QCD (Z-boson rest frame):

A_4 (and A_3) sensitive to weak mixing angle

$$\frac{d\sigma}{dy^{\ell\ell}\, dm^{\ell\ell}\, d\cos\theta} = \frac{3}{16\pi}\frac{d\sigma^{U+L}}{dy^{\ell\ell}\, dm^{\ell\ell}}\left\{(1+\cos^2\theta) + A_4\cos\theta\right\}.$$

ATLAS-CONF-2018-037

A_4 measured using two leptons |η|<2.4 (cc)
and at least one forward electron 2.5<|η|<4.6 (cf).
Using 8 TeV data (2012).

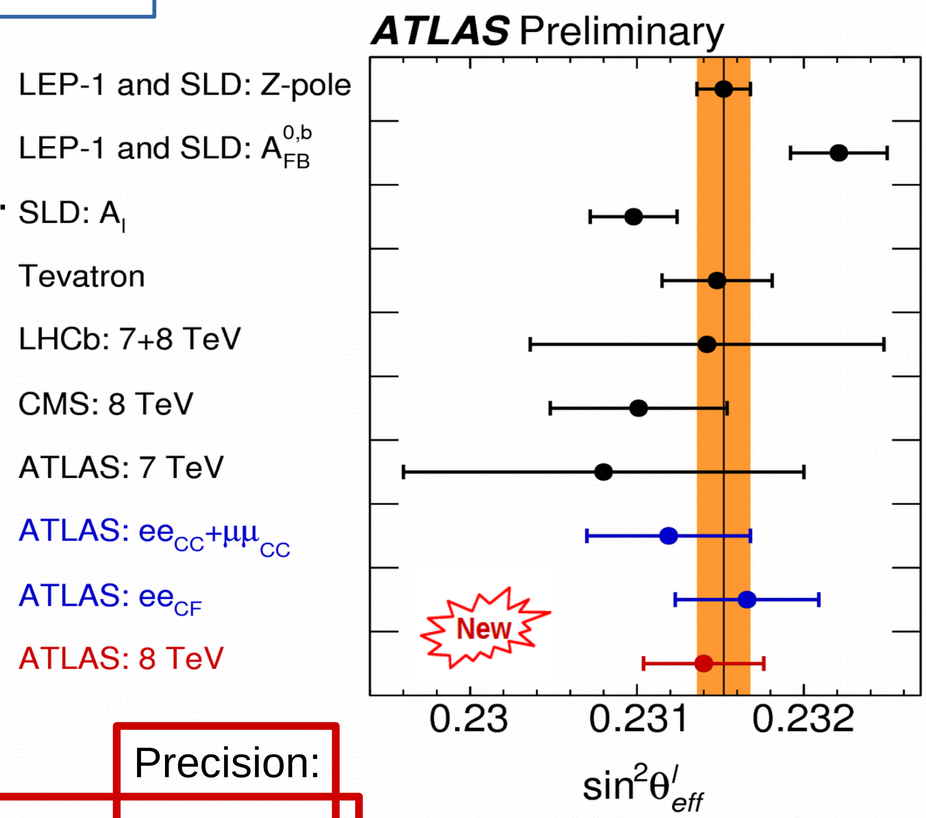
Result from likelihood fit:

$$\sin^2\theta^l_{eff} = 0.23140 \pm 0.00036$$

Uncertainty break-down:

$$0.00021(stat) \pm 0.00024(PDF) \pm 0.00016(syst)$$

Main limitation knowledge initial quark direction.



0.15% precision

Other recent electroweak measurements:

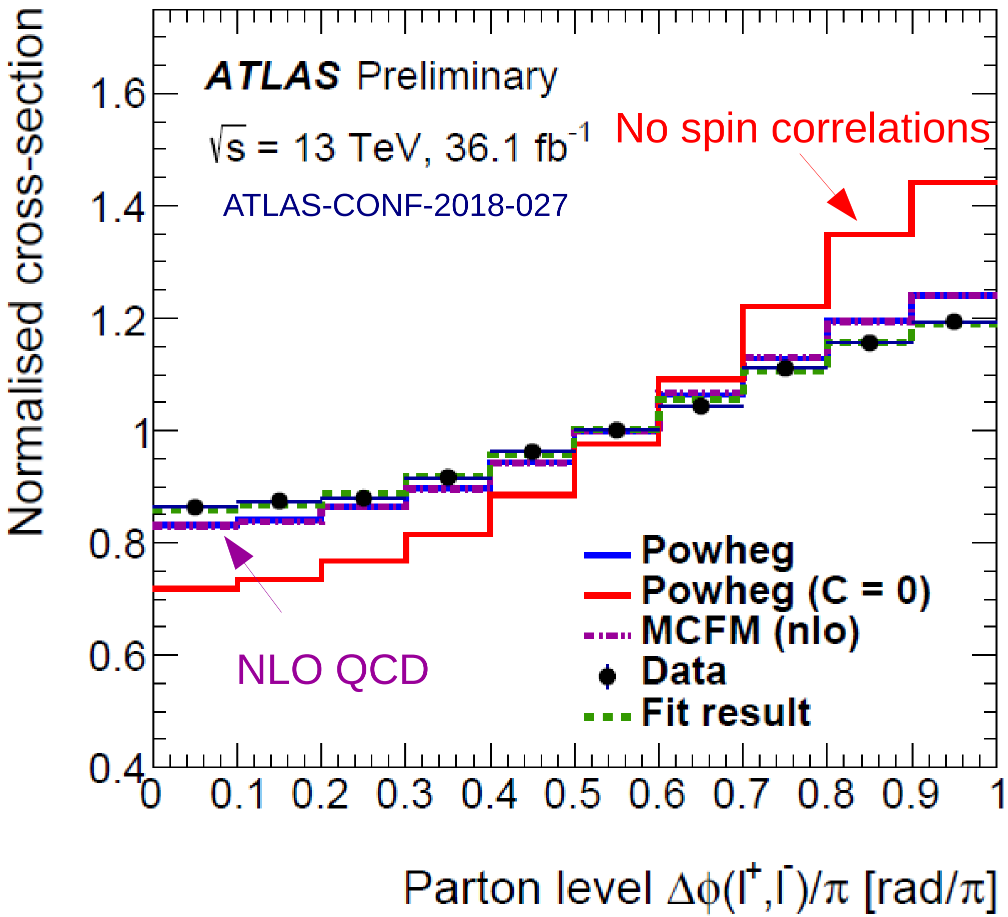
			Precision:
W-mass:	80370 +- 19 MeV	EPJ C78 (2018) 110	~0.02%
Higgs mass:	124970 +- 240 MeV	arXiv:1806.00242	~0.2%
Top-mass:	172510 +- 500 MeV	ATLAS-CONF-2017-071	~0.3%

Spin correlation in top pair events

New

Spin correlation for pp→tt→e μ b b measured between the top decay products and a spin axis.
ΔΦ(eμ) is a sensitive variable.

Example inclusive result:



Template fit on ΔΦ(eμ):
- f_{SM} fraction of expected cross-section under the SM spin hypothesis
- No spin correlation template: top decay with spin correlation disabled

Stronger spin correlations observed than expected by NLO QCD.

Fit result: f=1.250+-0.026+-0.063
3.2σ discrepancy with NLO QCD

ATLAS-CONF-2018-027

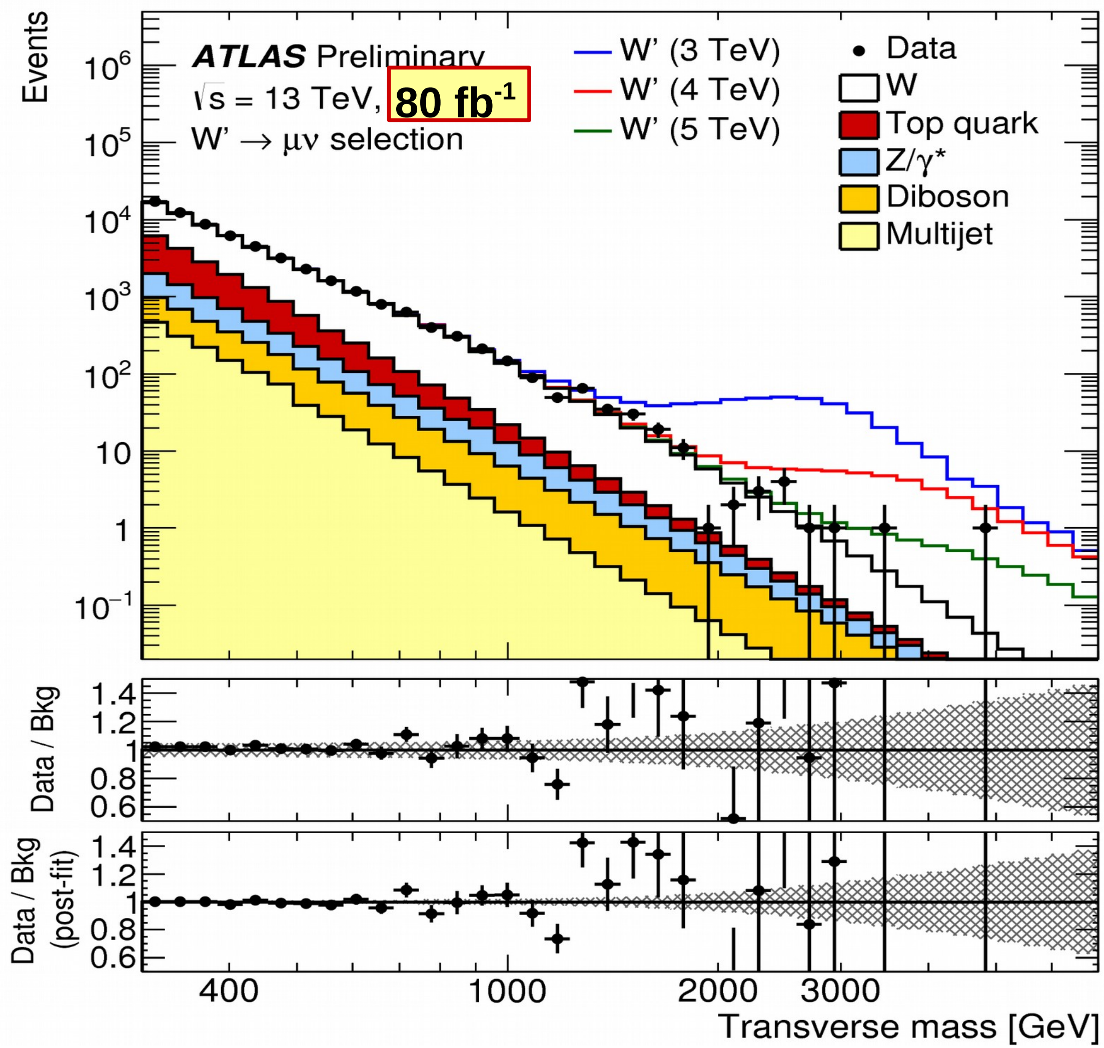
Previous analyses also measured stronger spin correlations (with large uncertainties).

Similar results for fiducial particle-level and comparisons of ME generators.

Search for new electro-weak boson

Very active search program (SUSY, dark matter, new Higgs models...)
In total, 62 search papers submitted (36 fb^{-1}). 8 new preliminary new physics searches with 80 fb^{-1}.

New electro-weak gauge boson (W') in context of sequential SM benchmark model.



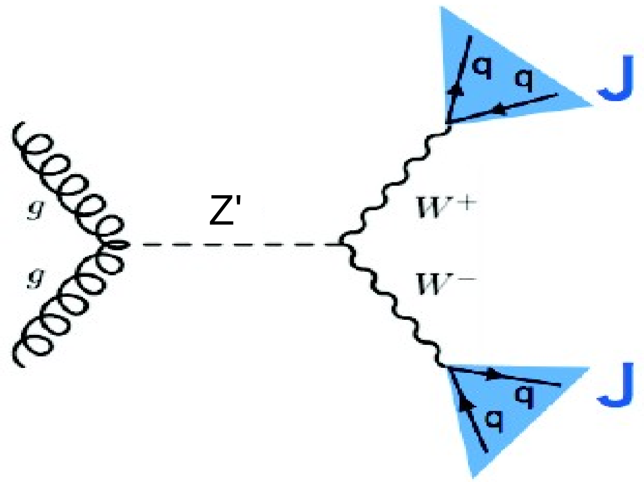
ATLAS-CONF-2018-017

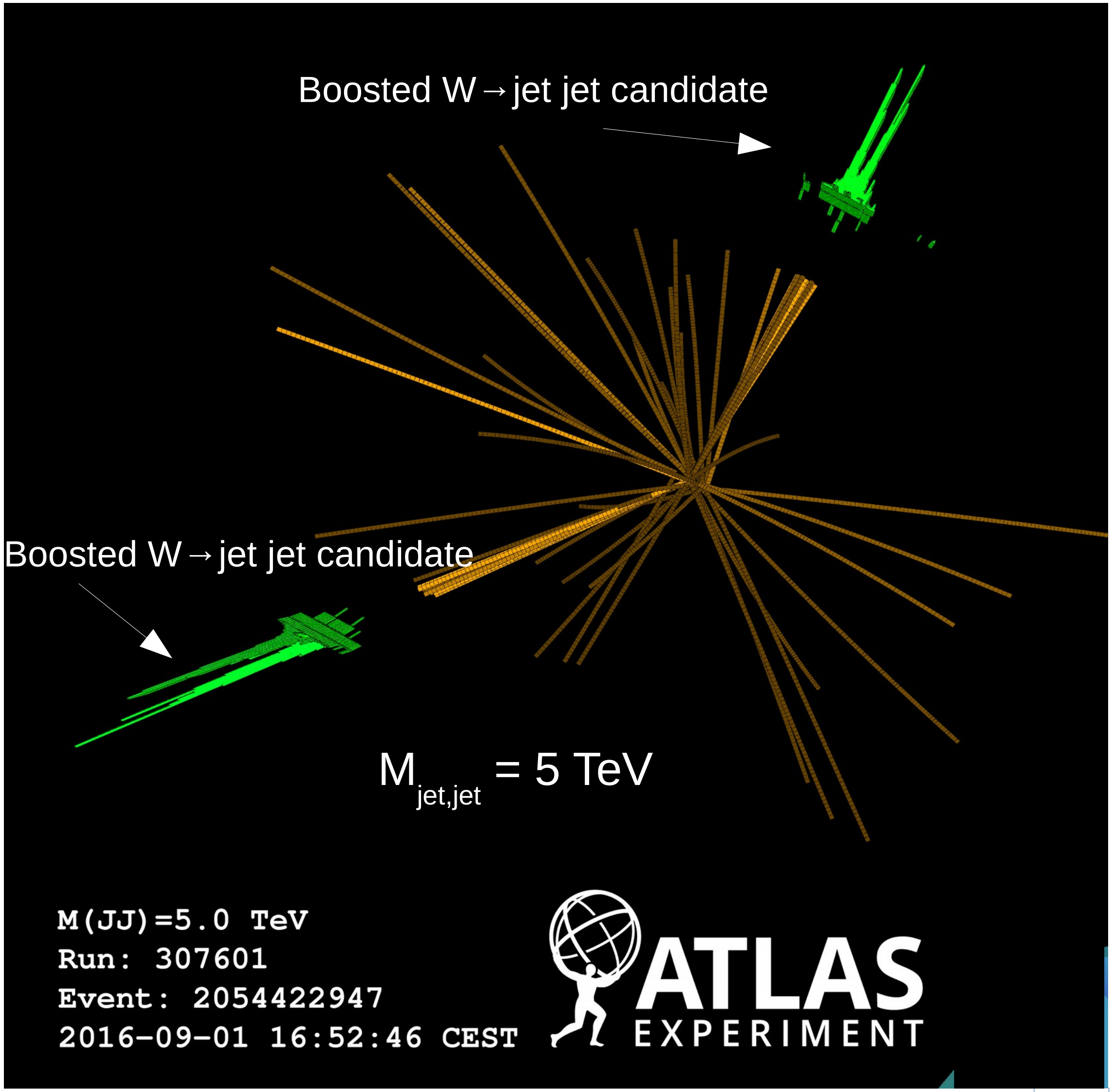
Assuming SM coupling:
Masses below excluded at 95%CL:
5.6 TeV (80 fb^{-1})
5.2 TeV (36 fb^{-1}) arXiv:1706.04786

→ Need new techniques
to increase further sensitivity.

High-mass Di-jet event from WW production

At high p_t jets from the $W \rightarrow qq$ decay are close-by and merge in a large-R jet.





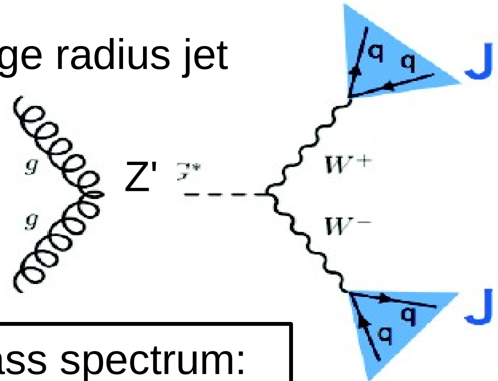
Many techniques developed
to reconstruct boosted particles.

W-boson tagging based on
large-R jet substructure.

New experimental technique:
Energies from calorimeter clusters,
but angles from tracks.

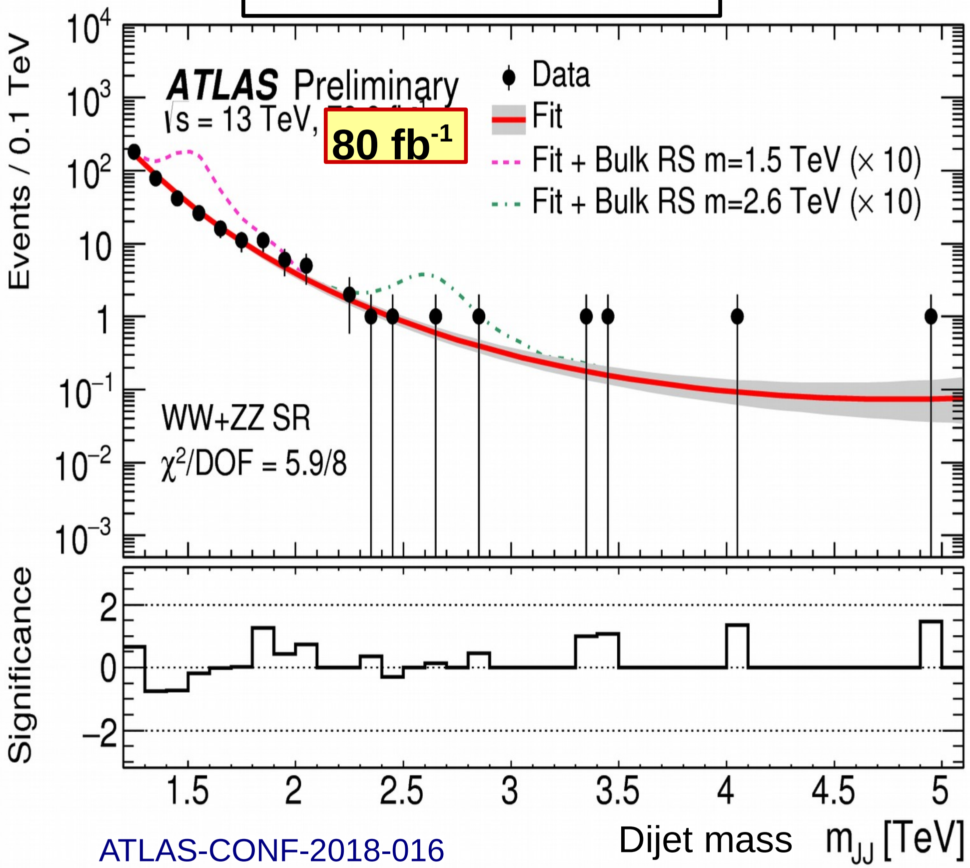
Di-boson resonance search

Select large p_t and large radius jet with boosted W-tag



Recent improvements:
- W-boson tagging using angles from tracker and energies from calorimeter
- Tagger working point optimization at high p_t

Di-jet mass spectrum:



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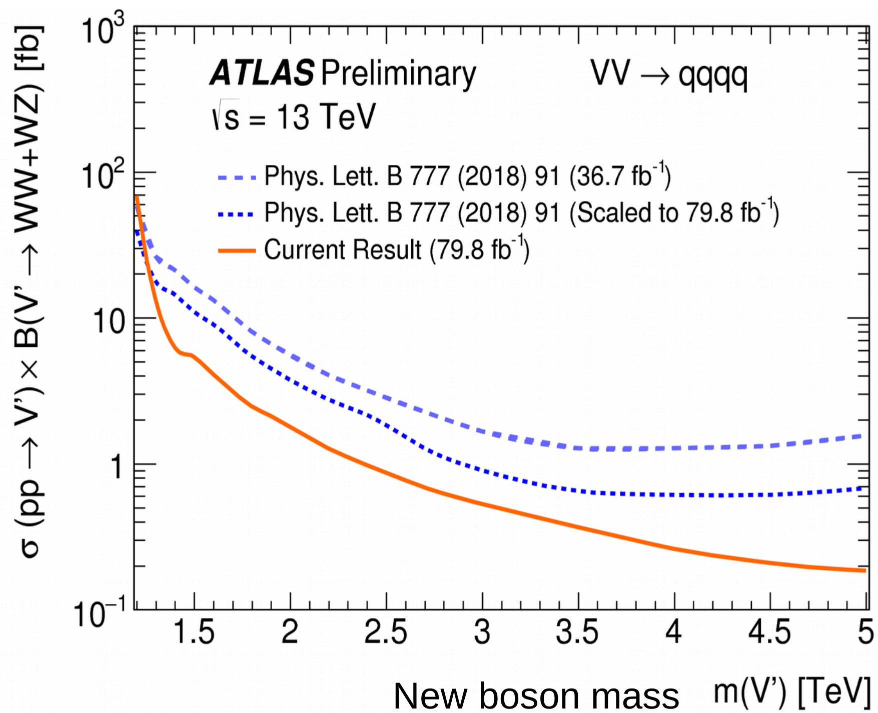
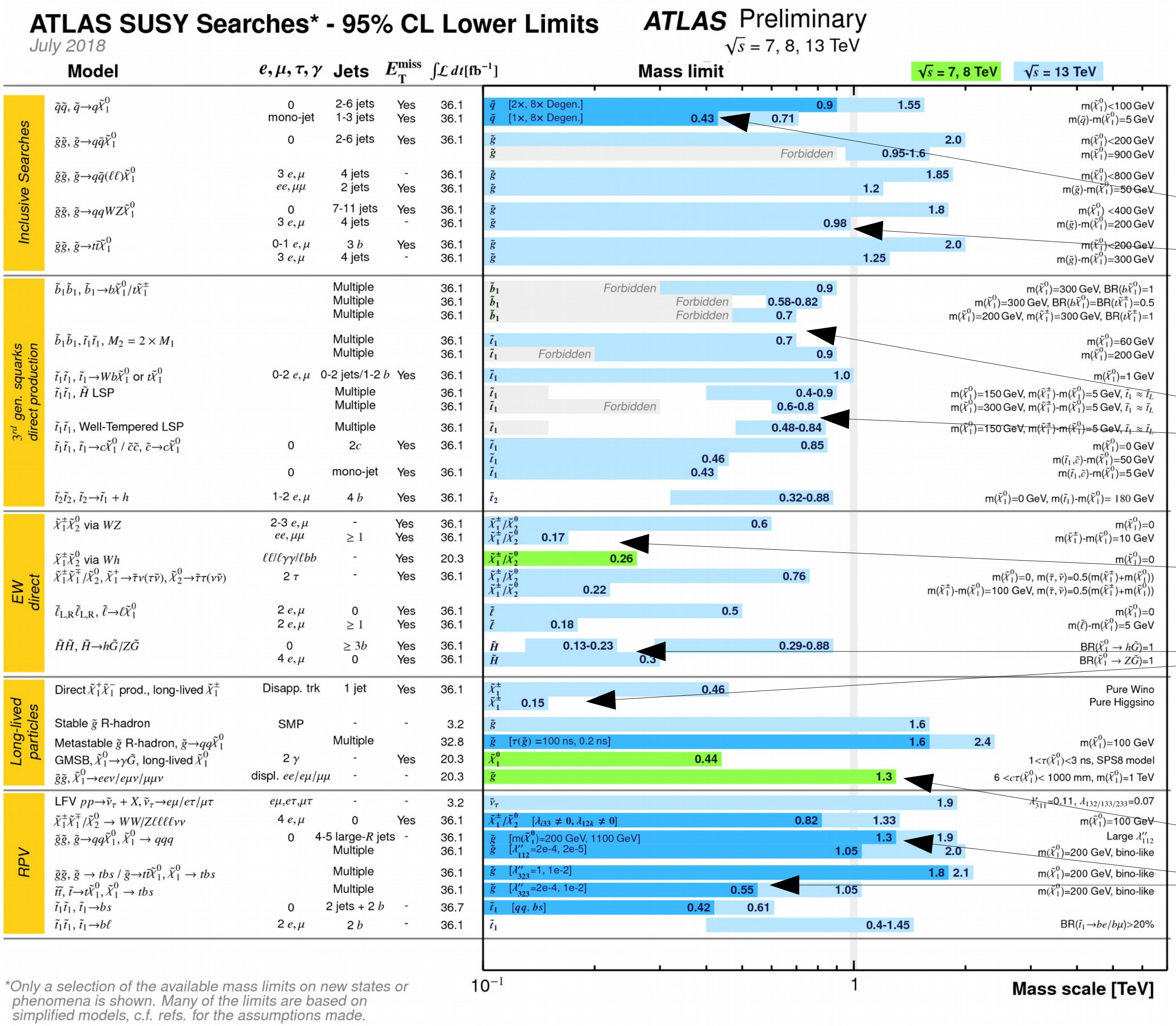
Cross-section limit:



Active SUSY search program

28 publications on SUSY searches with 2015-2016 data (36 fb^{-1}).



Compressed spectrum squark degeneracy:
squarks O(500 GeV)
gluinos O(1 TeV)

Longer decay chain more realistic models:
sbottom O(700 GeV)
stop O(700 GeV)

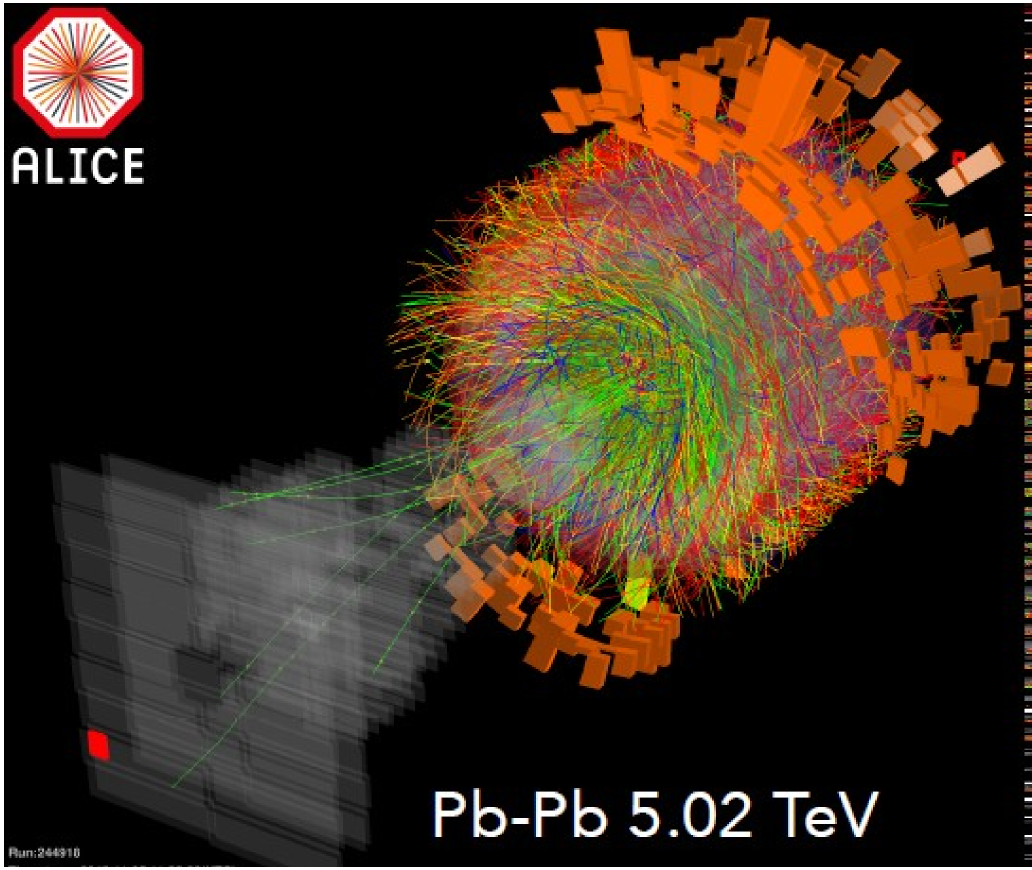
Low rate, compressed:
winos O(~100 GeV)
sleptons O(~100 GeV)
higgsino O(~100 GeV)

Complexity, long-lived:
gluinos O(1 TeV)
stop O(500 GeV)

Simplified signatures covered to high masses, but plenty of low mass unexplored model space.

Heavy Ion Data-set

System	Year(s)	$\sqrt{s_{NN}}$ (TeV)	L_{int}
Pb-Pb	2010-2011	2.76	~75 μb^{-1}
	2015	5.02	~250 μb^{-1}
	by end of 2018	*5.02*	*~1 nb^{-1}*
Xe-Xe	2017	5.44	~0.3 μb^{-1}
p-Pb	2013	5.02	~15 nb^{-1}
	2016	5.02, 8.16	~3 nb^{-1}, ~25 nb^{-1}
pp	2009-2013	0.9, 2.76, 7, 8	~200 μb^{-1}, ~100 nb^{-1}, ~1.5 pb^{-1}, ~2.5 pb^{-1}
	2015,2017	5.02	~1.3 pb^{-1}
	2015-2017	13	~25 pb^{-1}



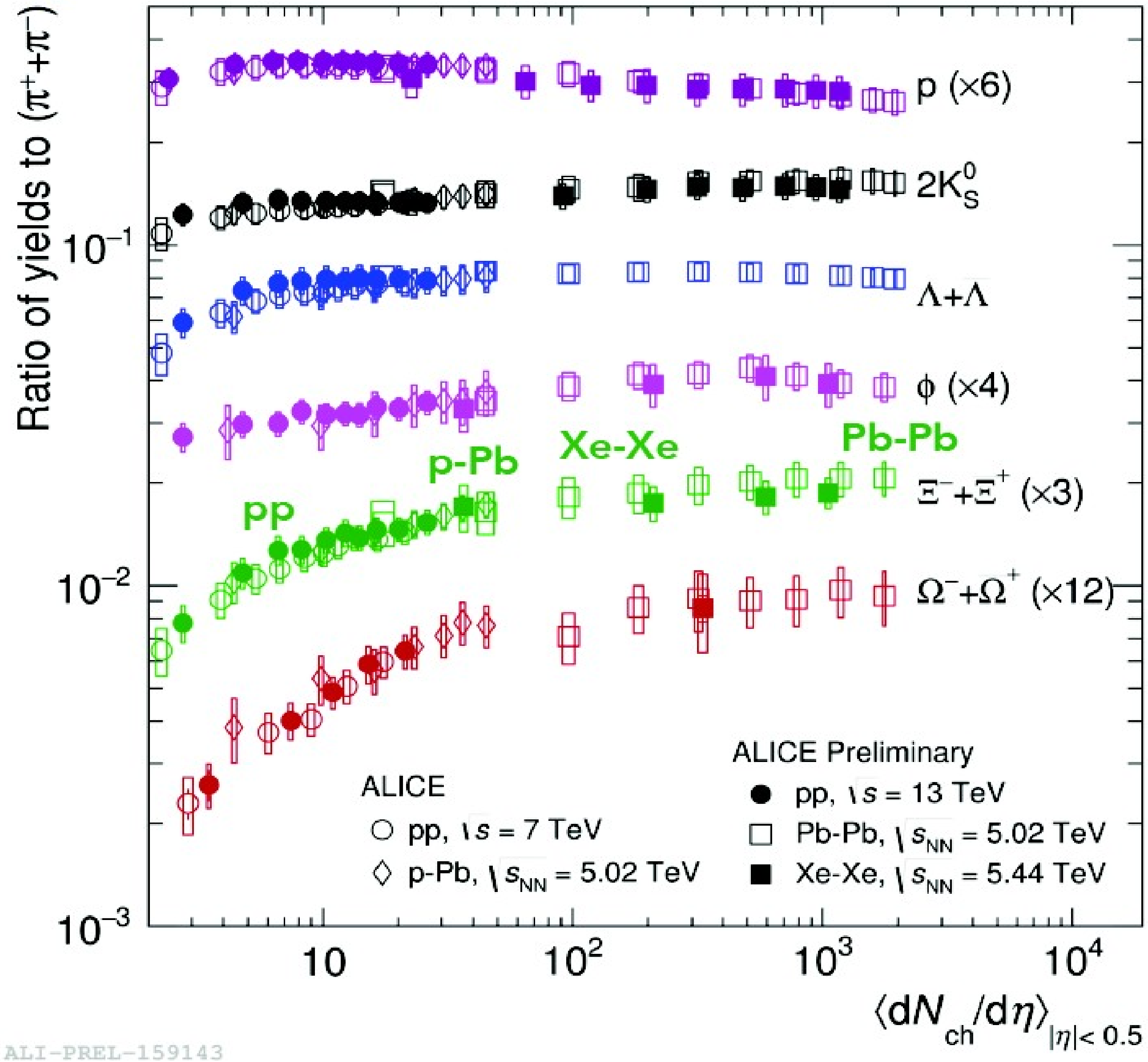
Special data-sets:
p-p, Xe-Xe, p-Pb, Pb-Pb collisions.

6h Xe-Xe run in 2017

Significant increase in luminosity to study rare processes more and more precisely.
LHC scheduled: 3.5 week of Pb-Pb collision in November 2018.

Strange particle yields in pp, Xe-Xe, Pb-Pb

Alice detector with impressive particle-ID capabilities

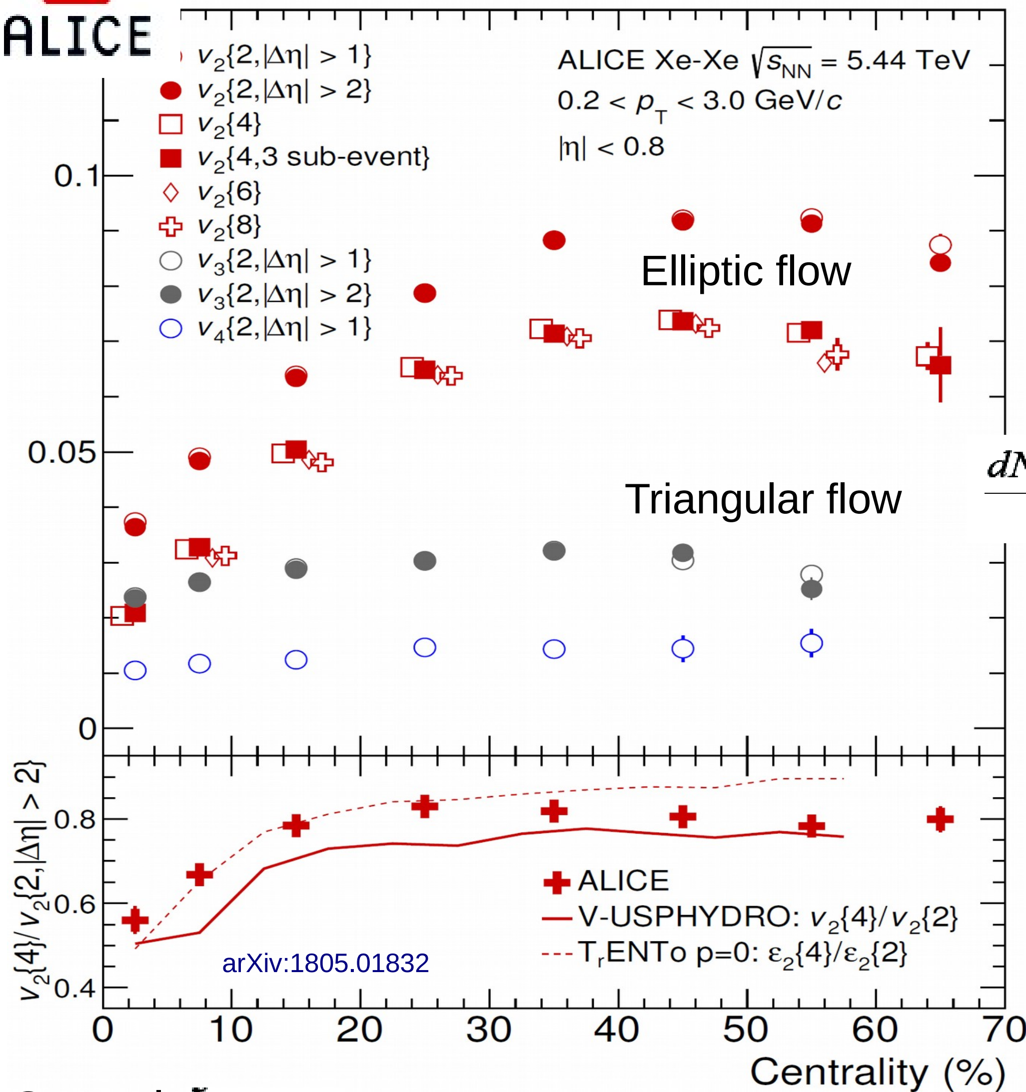


Smooth evolution of charged particle multiplicities from small (pp), medium (Xe-Xe) to large (Pb-Pb) systems.

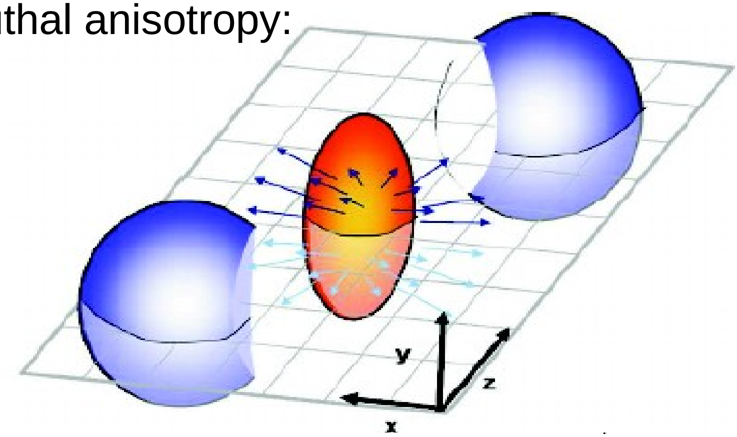
Increasing strange particle production with multiplicity until plateau is reached.

Confirmed by recent Xe-Xe data.

Anisotropic flow in Xe-Xe collisions



Azimuthal anisotropy:

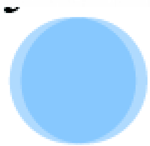


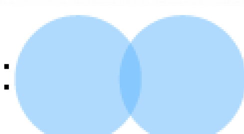
$$\frac{dN(p_T,\varphi)}{d\varphi} \propto 1 + 2v_1\cos(\varphi-\psi_1) + 2v_2\cos(2[\varphi-\psi_2]) + \ldots$$

Elliptic flow: v2 (initial density profile)
Triangular flow: v3 (viscosity)
(due to nucleons fluctuations in nuclei)

Models tuned in Pb-Pb data agree with Xe-Xe

Good understanding of initial density and viscosity in nucleus-nucleus collision.

Central:
Head-on: 

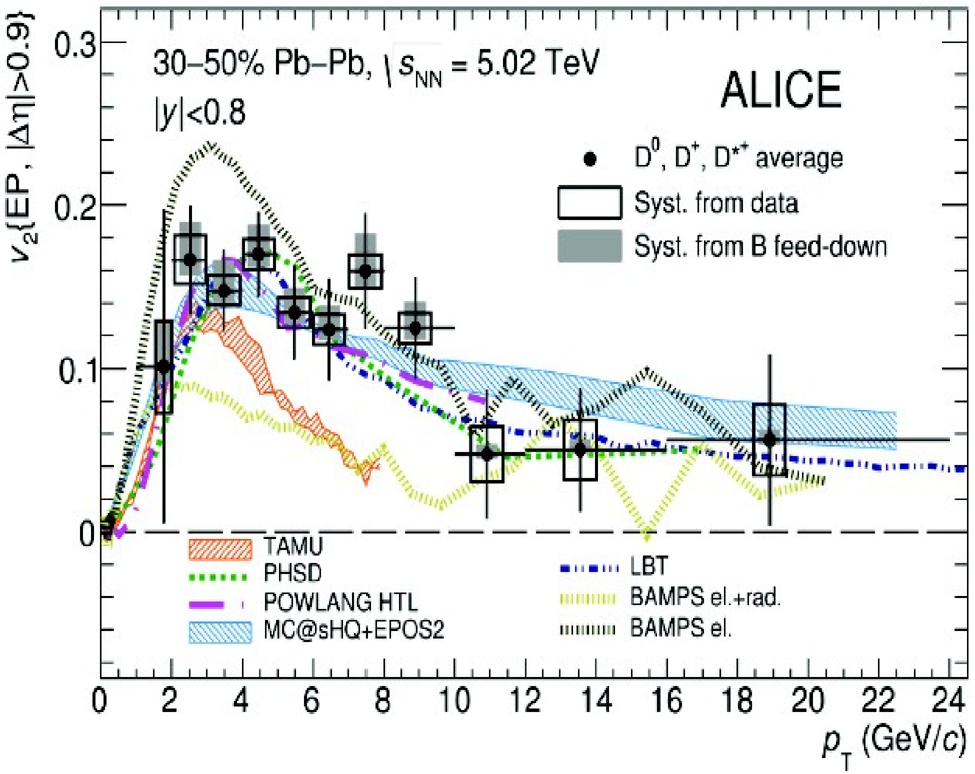
Peripheral: 

D-meson suppression in Pb-Pb collisions

Elliptic flow:

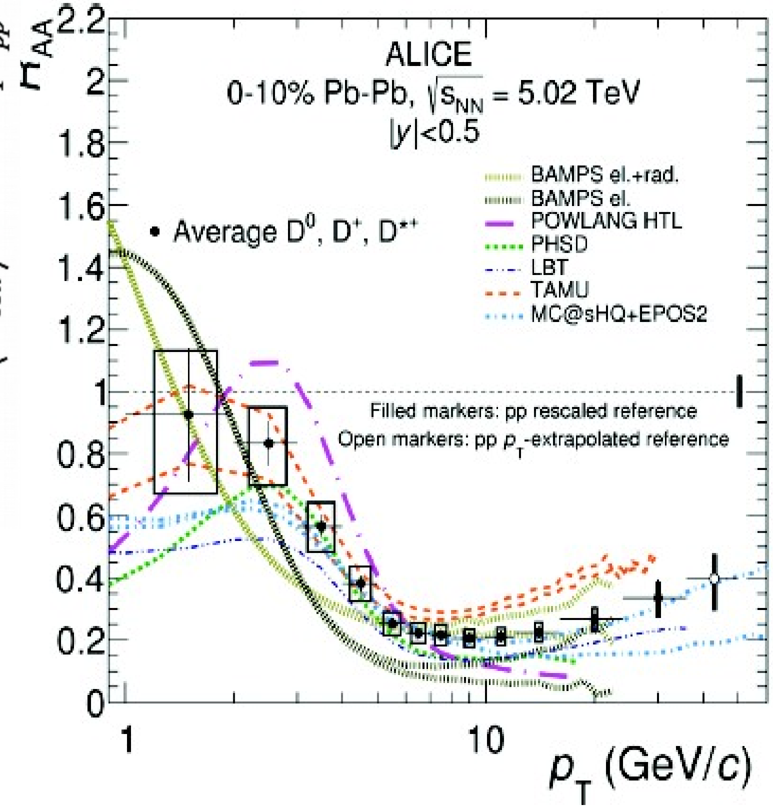
arXiv:1804.09083

Charged particle spectra:



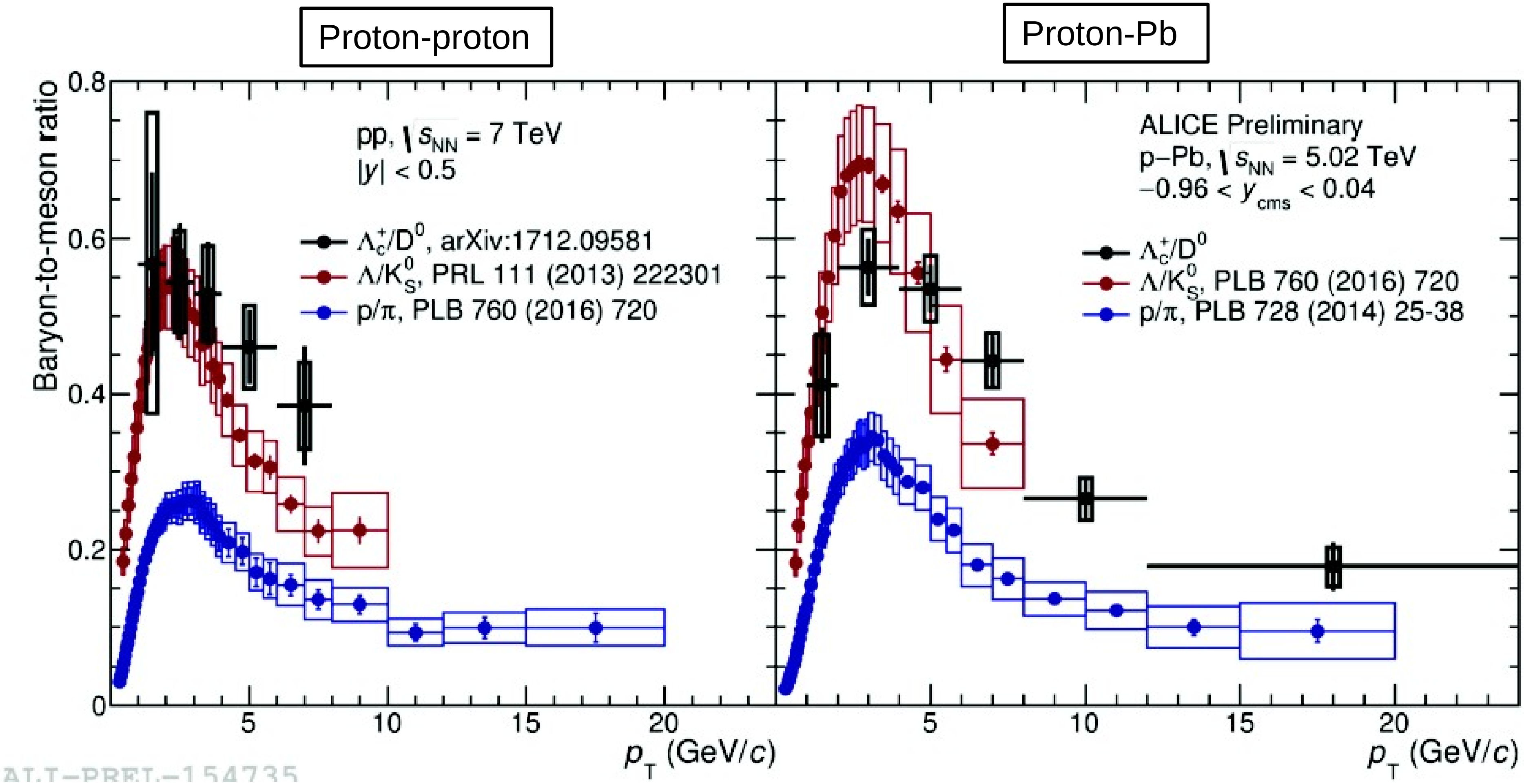
$$\frac{dN(p_T,\varphi)}{d\varphi} \propto 1 + 2v_1\cos(\varphi-\psi_1) + 2v_2\cos(2[\varphi-\psi_2]) + \ldots$$

$$R_{AA} = \frac{(dN/dp_T)_{AA}}{\langle N_{coll}\rangle (dN/dp_T)_{pp}}$$



Less elliptic flow at high-pt. Strong charged particle suppression at high pt.
→constrains charm transport in dense nucleonic environment.

Baryon to Meson ratio in pp and p-Pb collisions



Clear increase in Λ_c/D-meson towards pt ~ 3 GeV (similar to Λ/Kaon and p/pi).

This specific effect in baryon formation is difficult to describe with pQCD+fragmentation.

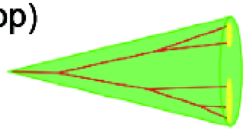
http://aliceinfo.cern.ch/Figure/node/13827

Parton energy loss in jets

Soft-drop jet substructure grooming:

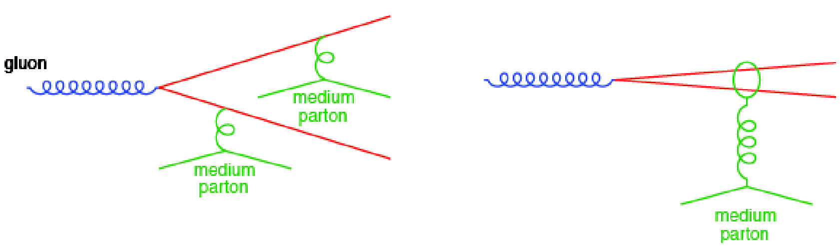
e.g.: declustering: “peel apart” the shower

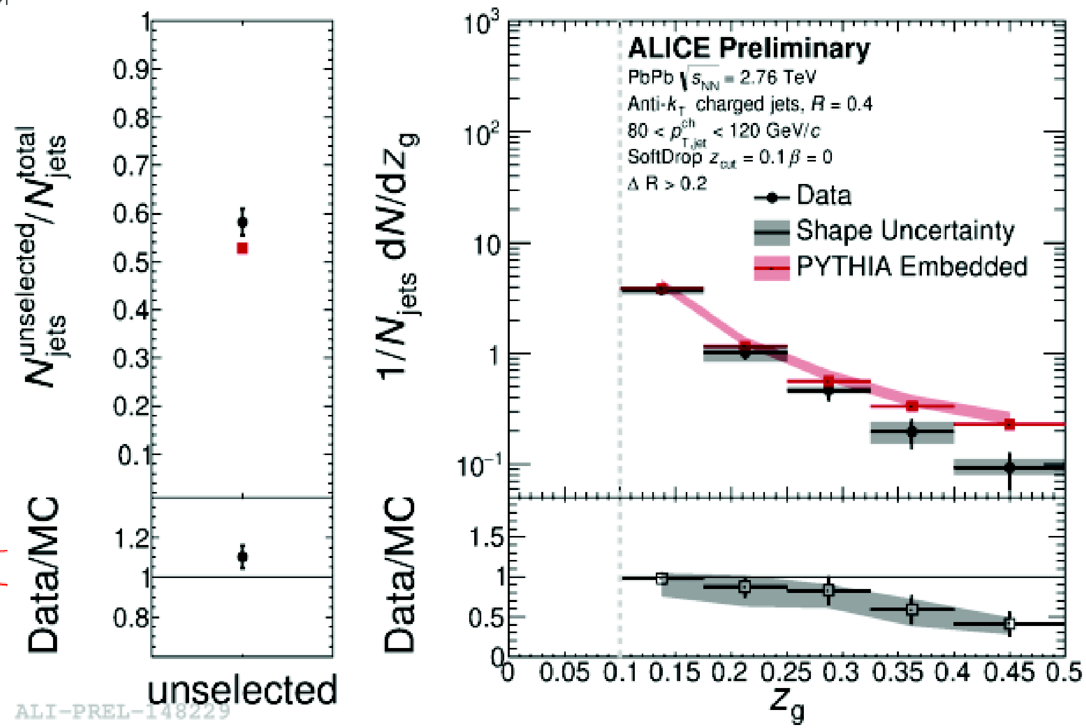
(Soft Drop)



$$z_g = \frac{\min(p_{\perp,1}, p_{\perp,2})}{p_{\perp,1} + p_{\perp,2}} \qquad z_g > 0.1$$

sensitive to coherence of energy loss





Result shown for dR>0.2: suppression of symmetric splittings.
Soft drop mass also used by ATLAS and CMS to characterize internal jet substructure.

Conclusions

ATLAS 13 TeV data analysis is in full swing. 13 results with 80 fb^{-1} (2015-2017 data).

Important new Higgs physics results:
- $H\rightarrow bb$ observation. Main Higgs decays are now observed.
- Direct observation of Higgs coupling to top quark (via ttH).

→ Yukawa coupling to fermions confirmed (ttH, $H\rightarrow bb$, $H\rightarrow\tau\tau$)

- VH production observed. All major Higgs production modes observed.

Observation of electro-weak processes with dominant vector boson scattering:
Same-sign WWjj and WZjj production.
→ Important test of SM electro-weak sector.

New electro-weak mixing angle measurement with precision of 0.15%.

Top pairs: Indication for stronger top spin correlation than expected by NLO QCD.

Extensive and active search program for full run-2 (>150 fb^{-1} achievable).
New directions looking at more refined signatures.

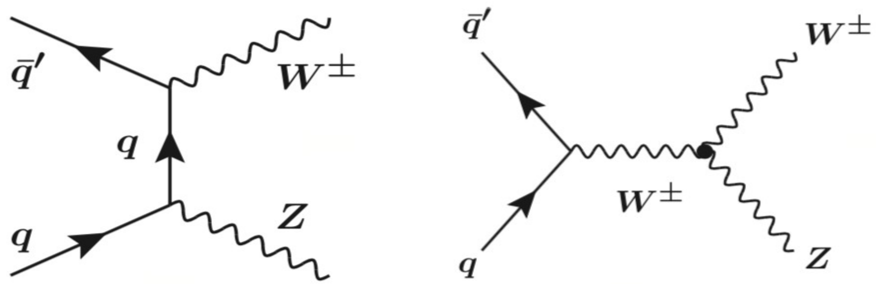
ALICE:
Heavy-ion collisions: understanding the properties of QCD matter:
- Azimuthal anisotropies: Xe-Xe results confirm understanding of expanding QGP, viscosity
- Charm, jets probe the QGP with partons:
  Quantitative understanding of charm transport and QCD bremsstrahlung progressing.

Back-up

WZ cross-section and polarization

New

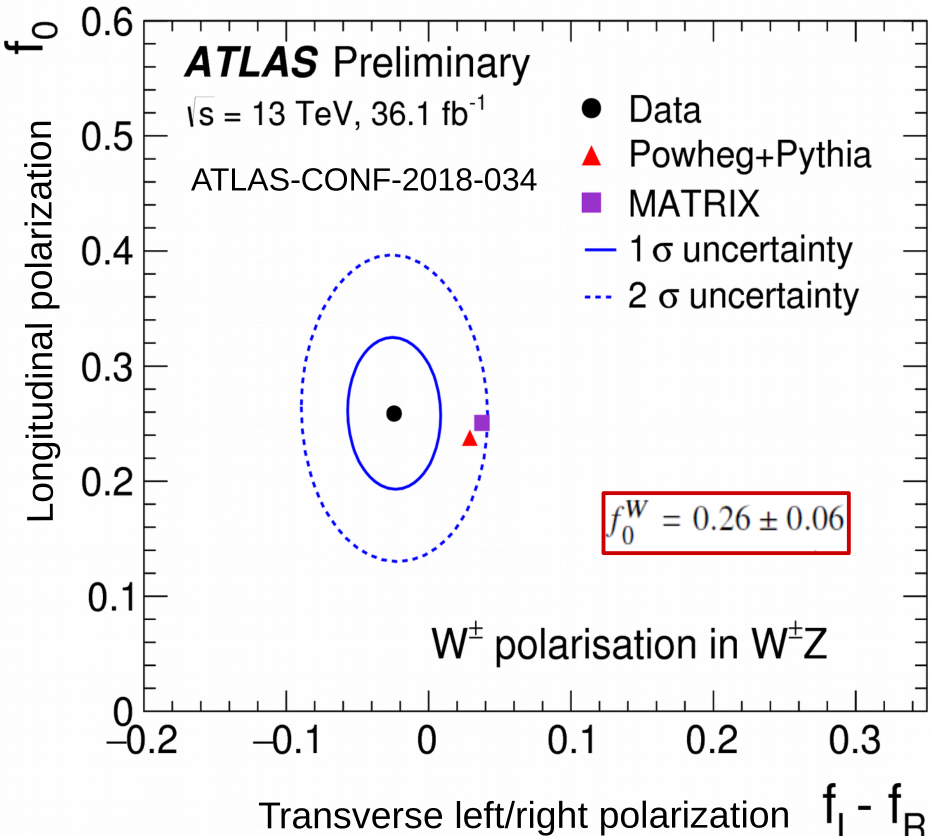
Electroweak production of WZ boson pp → $W^{+-}Z$:



Total fiducial cross section:
σ_{EW}(WZ) = 63.7 +- 2.9 fb
NNLO (Matrix): 61.5 +- 1.4 fb

→ good agreement inclusive and differential cross-sections

Polarization measurement:



In WZ production:

1) Evidence of longitudinally W polarization (f_0)
2) Measurement of Z polarization

Longitudinal W-polarisation:

4.2σ (3.8σ) obs (exp)

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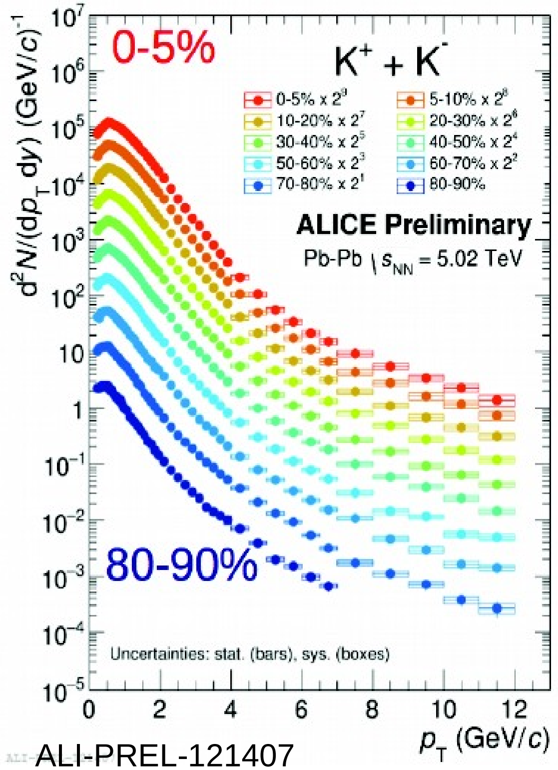
Compatible with NLO QCD and LO EW (Powheg)

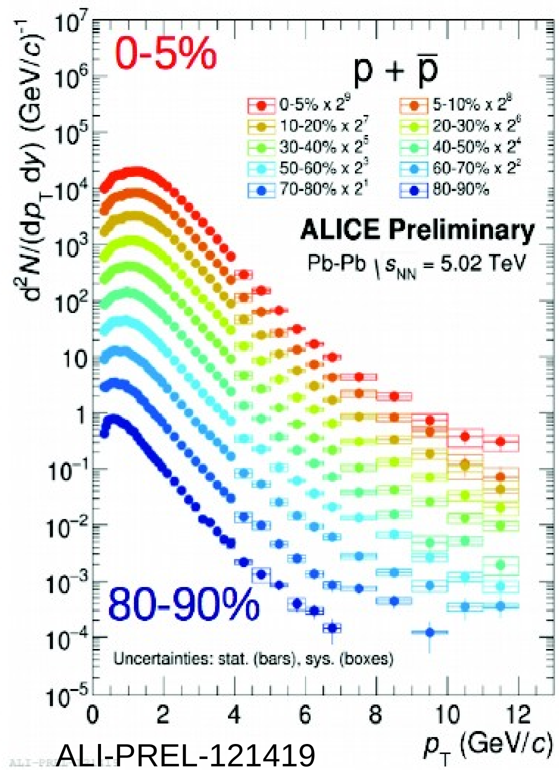
Identified particle spectra in Pb-Pb collisions

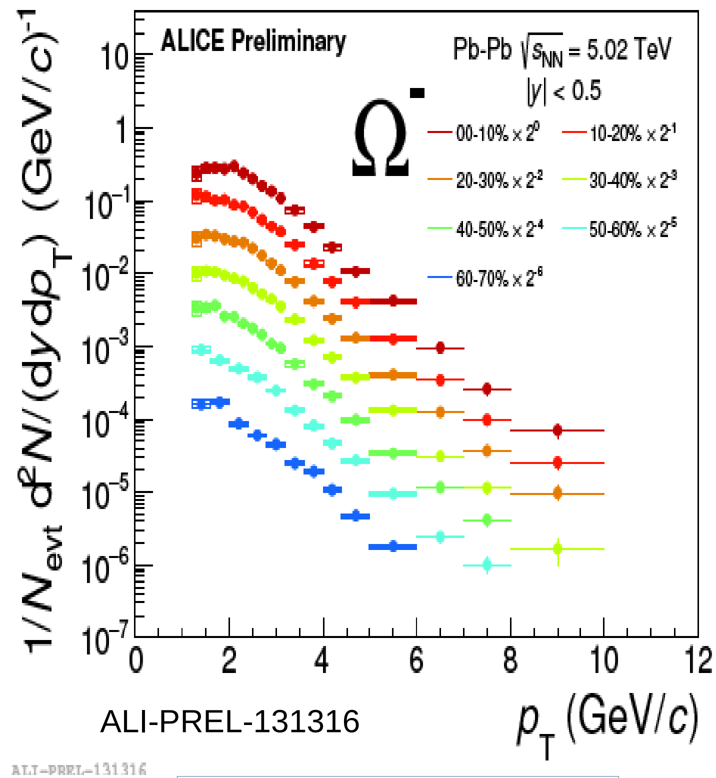
Alice detector with impressive particle-ID capabilities.

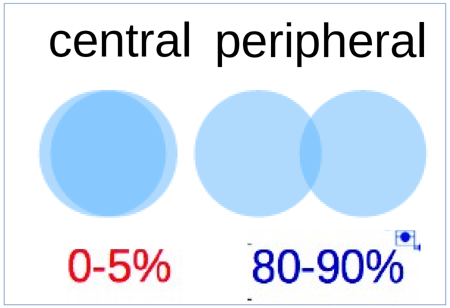
Particle spectra: pions, kaons, protons, Phis, Omegas, deuterons...

Examples:









Increase in mean pt with centrality.

Centrality: 0-5% head-on nucleus collision (many nucleons) (central)

80-90% nucleon-nucleon collision peripheral

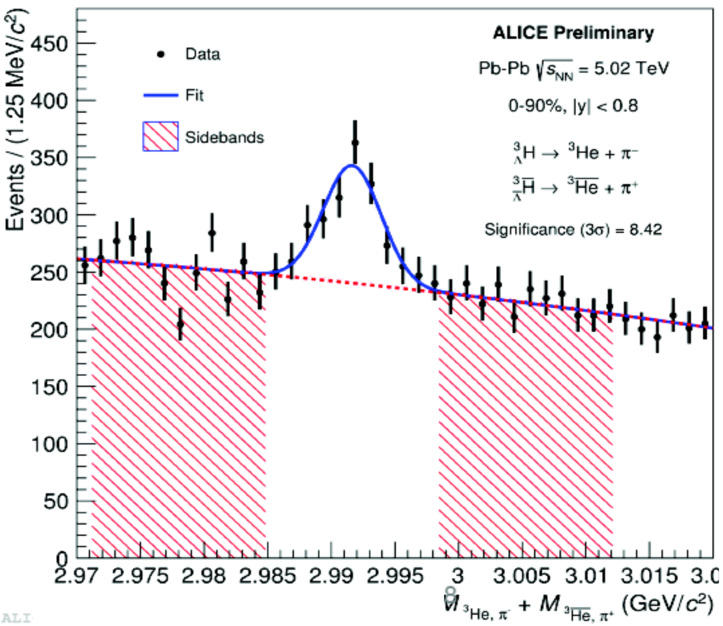
Hyper-triton lifetime

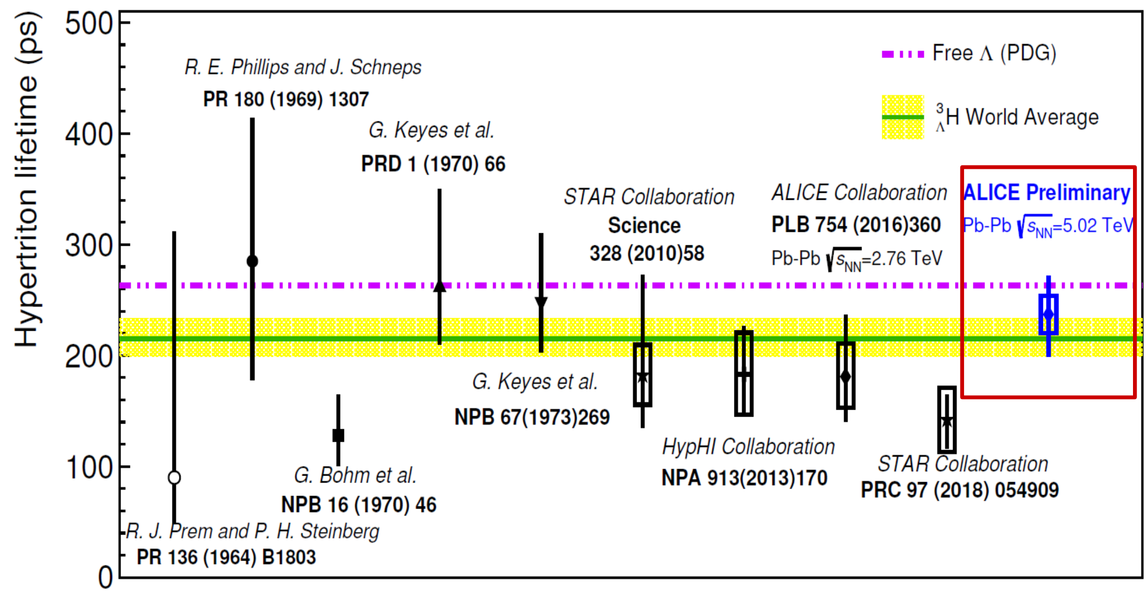
Hyper-triton: Hyper-nucleus formed by proton, neutron and Lambda

$^{3}_{\Lambda}H$: pnΛ bound state

$^{3}_{\Lambda}H \rightarrow {}^{3}He + \pi^{-}$

One of the most precise Hyper-triton lifetime measurements





Live time agrees with the free lambda live time (expected since hyper-triton is loosely bound).

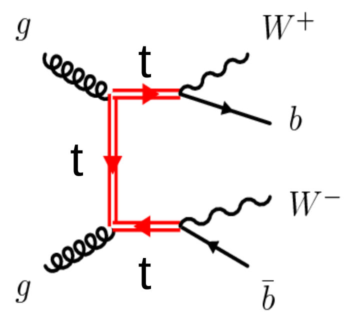
Resolution of hyper-triton live time puzzle.

Heavy ion collisions as a laboratory for strange/exotic nuclei.

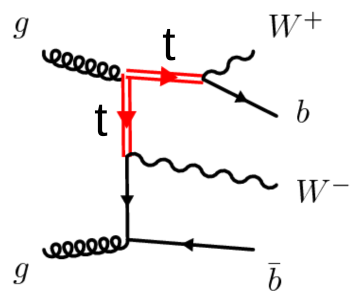
Tests of advanced tt → WW bb calculation

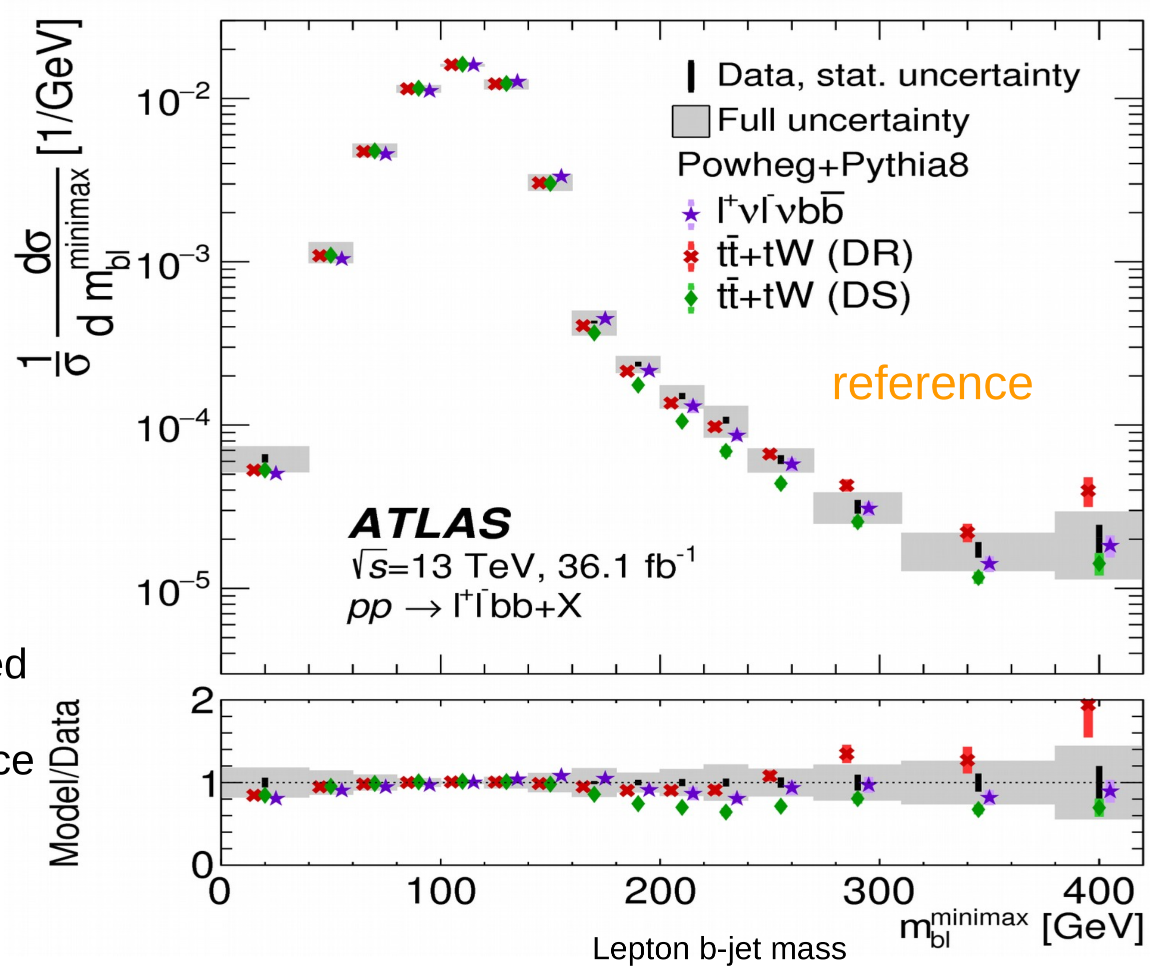
Wt and tt processes have same final state at NLO QCD $|\mathcal{A}_{WWbb}|^2 \sim |\mathcal{A}^{(Wtb)}|^2 + |\mathcal{A}^{(t\bar{t})}|^2 + 2\mathcal{R}\{\mathcal{A}^{(Wtb)}\mathcal{A}^{(t\bar{t})}\}$

tt



tWb





So far, tops produce stable and decayed (narrow width approximation)
Systematic handled ttbar/Wt interference
DR: tt removed at amplitude level
DS: tt removed at cross-section level

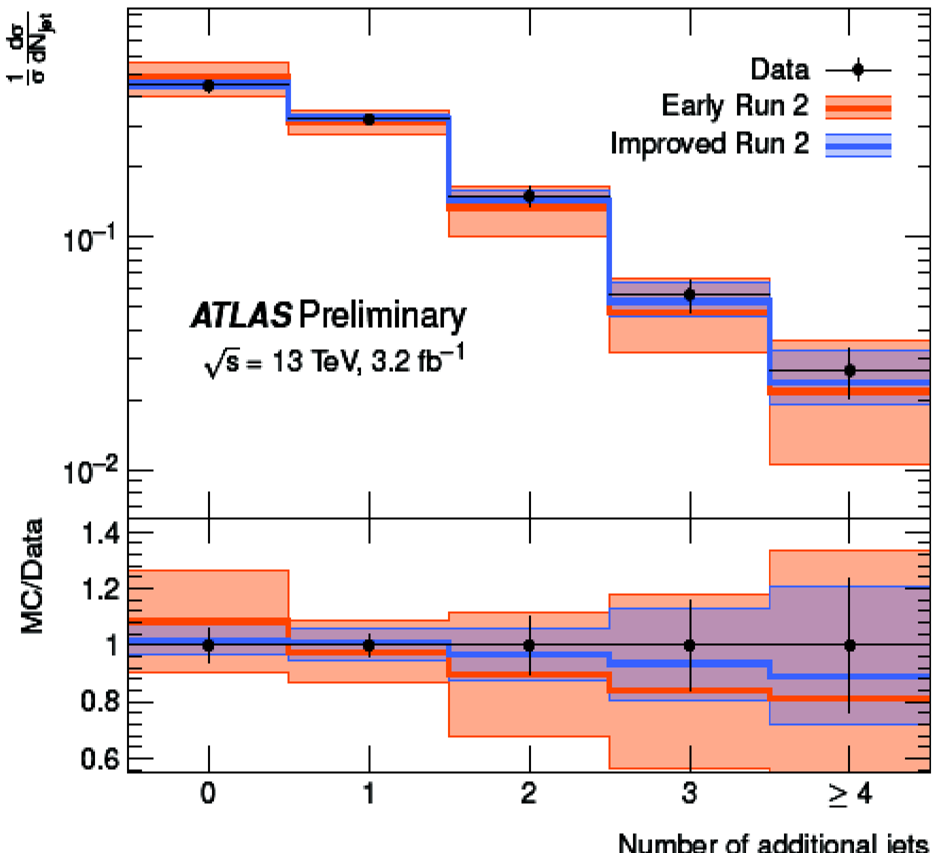
New calculation $p\,p \rightarrow W\,W\,b\,\bar{b}$
(full matrix element)

$$m_{b\ell}^{\mathrm{minimax}} \equiv \min\{\max(m_{b_1\ell_1}, m_{b_2\ell_2}), \max(m_{b_1\ell_2}, m_{b_2\ell_1})\}$$

Top final state modeling progress

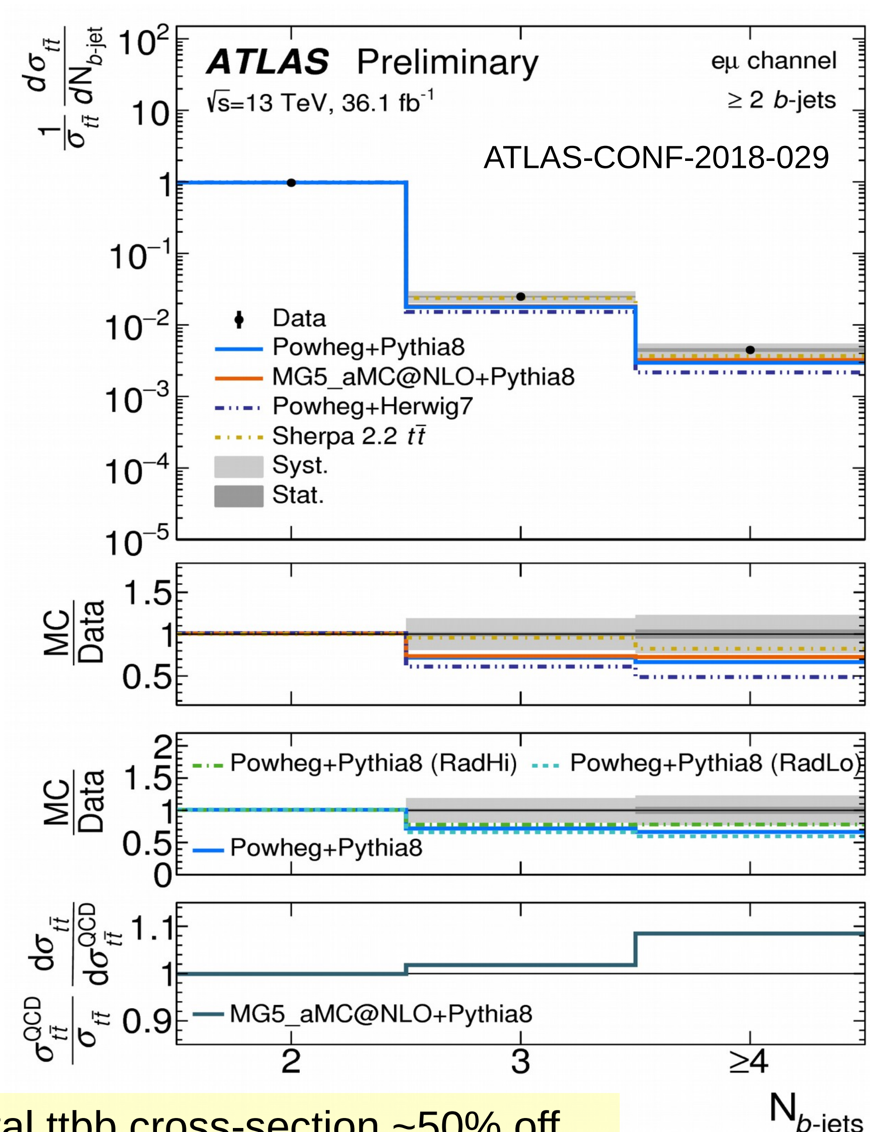
New

Since several years ATLAS has measured fiducial cross-sections defined using the particles entering the detector. Indispensable for the tuning of modern ME(2->n)+PS MC simulations.



ATLAS-PUB-2018-XXX

tt+bb cross-section



Total ttbb cross-section ~50% off, but shapes ~ok after tuning efforts.

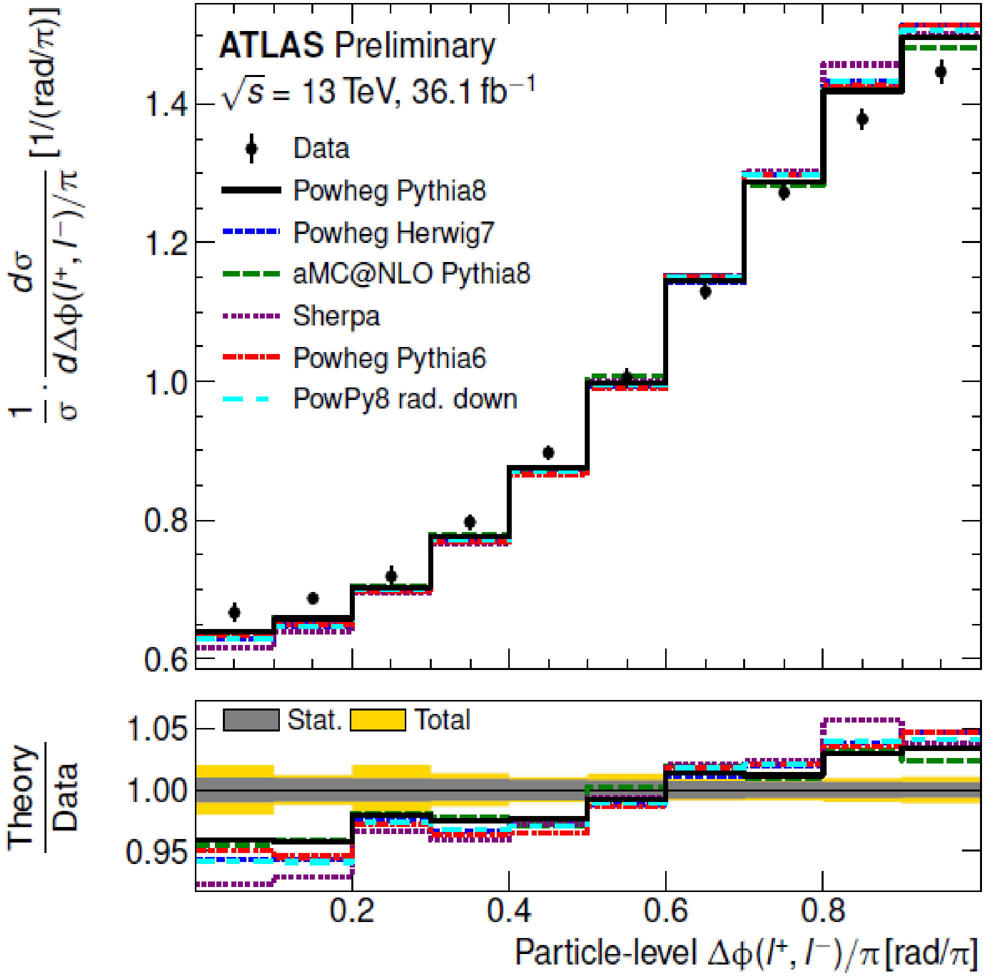
ttbb cross-section measurement

Generator	Process	Matching	Tune	Use
POWHEG-BOX v2 + PYTHIA 8.210	$t\bar{t}$ NLO	Powheg h_{damp}=1.5 m_t	A14	nom.
MADGRAPH5_aMC@NLO + PYTHIA 8.210	$t\bar{t} + V/H$ NLO	MC@NLO	A14	nom.
POWHEG-BOX v2 + PYTHIA 8.210 RadLo	$t\bar{t}$ NLO	Powheg h_{damp}=1.5 m_t	A14Var3cDown	syst.
POWHEG-BOX v2 + PYTHIA 8.210 RadHi	$t\bar{t}$ NLO	Powheg h_{damp}=3.0 m_t	A14Var3cUp	syst.
POWHEG-BOX v2 + HERWIG 7.01	$t\bar{t}$ NLO	Powheg h_{damp}=1.5 m_t	H7UE	syst.
SHERPA 2.2.1	$t\bar{t}$ +1jet NLO +3 jets LO	MC@NLO	SHERPA	syst.
SHERPA 2.2.1	$t\bar{t}b\bar{b}$ NLO	NLO $t\bar{t}b\bar{b}$	SHERPA	comp.
MADGRAPH5_aMC@NLO + PYTHIA 8.210	$t\bar{t}$ NLO	MC@NLO	A14	comp.
POWHEL + PYTHIA 8.210	$t\bar{t}b\bar{b}$ NLO	NLO $t\bar{t}b\bar{b}$	A14	comp.

Spin correlation in top pair events

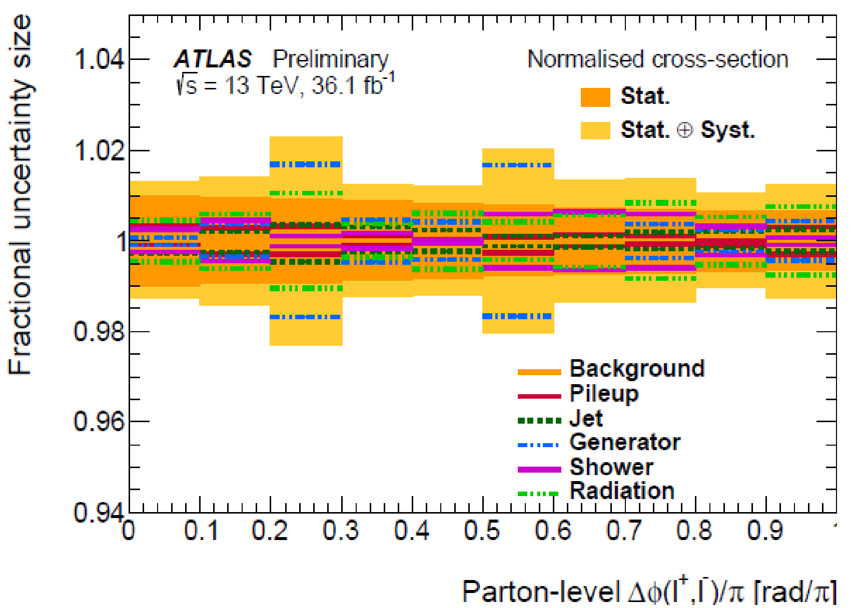
New

ATLAS-CONF-2018-027

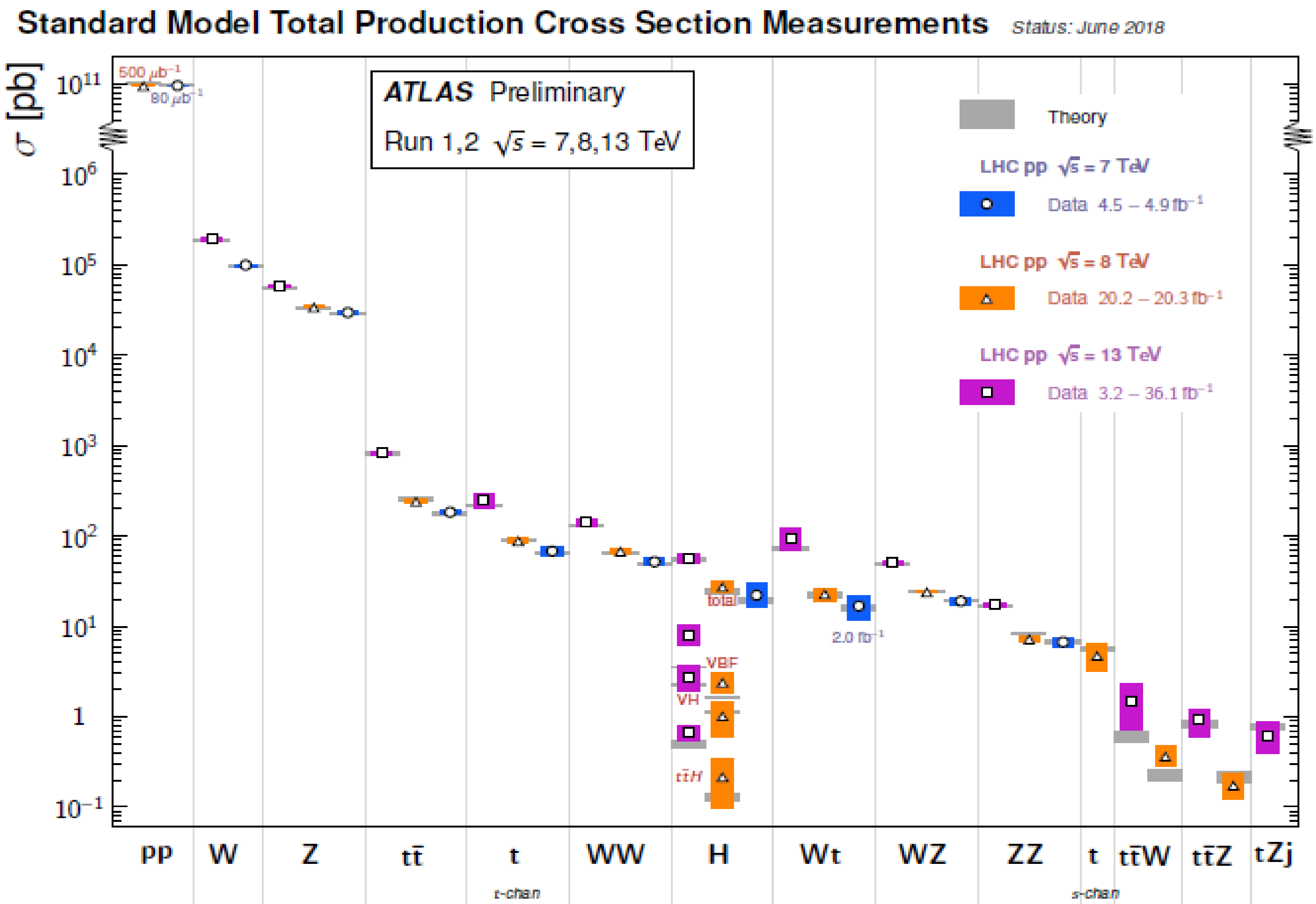


Generator	inclusive
f_{SM} values	
Powheg + Pythia 8	1.25
Powheg + Pythia 8 (2.0 μ_F, 2.0 μ_R)	1.29
Powheg + Pythia 8 (0.5 μ_F, 0.5 μ_R)	1.18
Powheg + Pythia 8 (PDF variations)	1.26
Powheg + Pythia 8 RadLo tune	1.29
Powheg + Herwig7	1.32
MadGraph5_aMC@NLO + Pythia 8	1.20

Table 3: Summary of the extracted spin correl



Measurements overview



Measurements of weak mixing angle

Polarized Drell-Yann cross-section pp → Z → ll can be expanded as sum of 9 harmonic polynomials

Z-boson CM frame

$$\frac{d\sigma}{dp_T^{\ell\ell}\, dy^{\ell\ell}\, dm^{\ell\ell}\, d\cos\theta\, d\phi} = \frac{3}{16\pi}\frac{d\sigma^{U+L}}{dp_T^{\ell\ell}\, dy^{\ell\ell}\, dm^{\ell\ell}}$$

unpolarized

$$\Big\{(1+\cos^2\theta) + \frac{1}{2}A_0(1-3\cos^2\theta) + A_1\ \sin 2\theta\ \cos\phi + \frac{1}{2}A_2\ \sin^2\theta\ \cos 2\phi + A_3\ \sin\theta\ \cos\phi + A_4\ \cos\theta + A_5\ \sin^2\theta\ \sin 2\phi + A_6\ \sin 2\theta\ \sin\phi + A_7\ \sin\theta\ \sin\phi\Big\}.$$

A_4 non-zero in LO

A_0-A_3 non-zero only in NLO

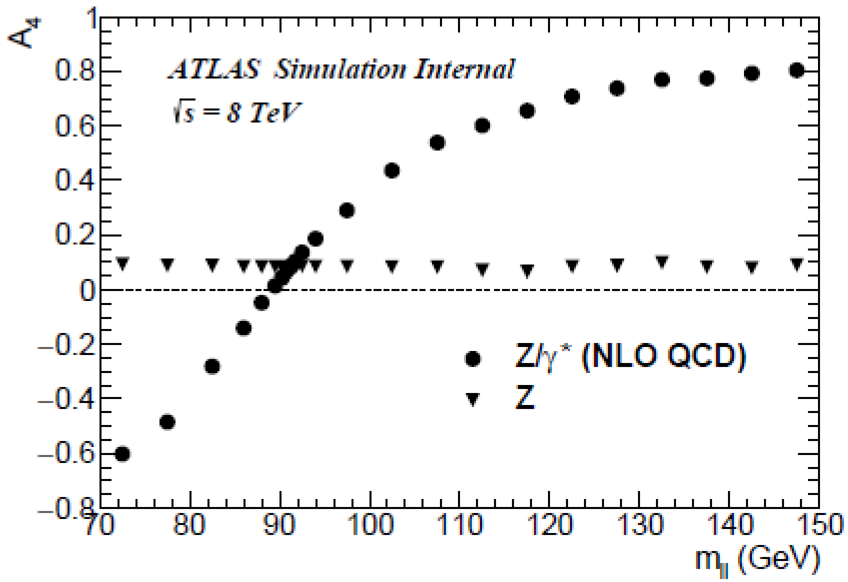
A_5-A7 non-zero only in NNLO

A_3 and A_4 depend on vector and axial couplings to Z-boson ~ sensitive to sin θ_W

A_4 sensitive to weak mixing angle 3/8 $A_4 \sim \sin^2\theta_W$

Measurement for |η|<2.4 (cc) and with one electron in forward region 2.5<|η|<4.6 (cf)

A_4 is parity violating, best sensitivity at Z-pole

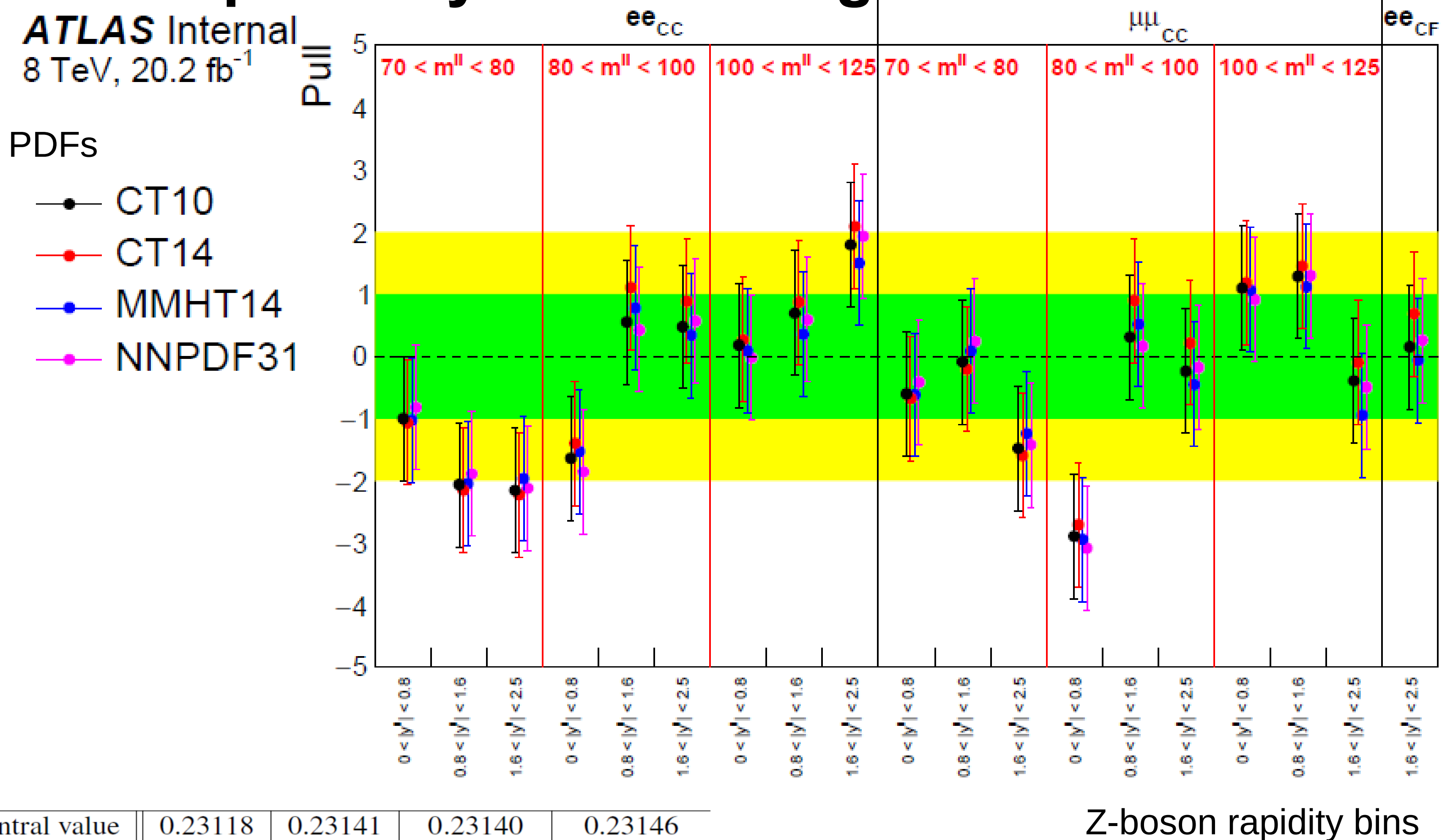


Limitation by radiation of initial state quarks
→ large systematics from PDFs

PDF set	CT10	CT14	MMHT14	NNPDF31
Central value	0.23118	0.23141	0.23140	0.23146
	Uncertainties in measurements			
Total	40	37	36	38
Stat.	21	21	21	21
Syst.	32	31	29	31

Final uncertainty from PDF spread

Compatibility weak mixing measurements



Central value	0.23118	0.23141	0.23140	0.23146
	Uncertainties in measurements			
Total	40	37	36	38
Stat.	21	21	21	21
Syst.	32	31	29	31

Result also compatible with reinterpretation of recent triple-differential Drell-Yan cross-section measurement.

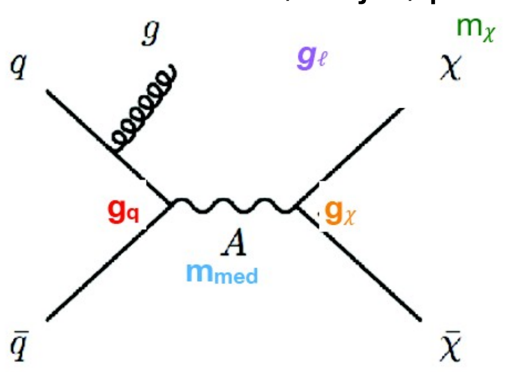
Final uncertainty from PDF spread.
CT10 considered since it fits best the 7 TeV Drell-Yan data.

Search for dark matter at LHC

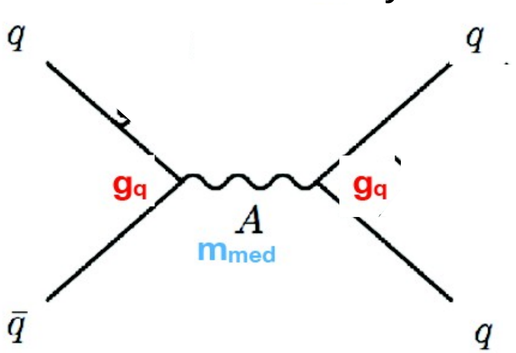
Particle physics relevant for understanding of early universe.
DM model require new stable particle beyond SM.
Coupling to SM particle via mediator (A).

Two strategies:

1) Events only visible if strong boost by radiation
   Signature: Mono-X, X=jet, photon, Z/W etc.



2) Look for mediator decay to SM particles.



LHC is sensitive to some models
(not too heavy, sizable couplings)

MET + jet search

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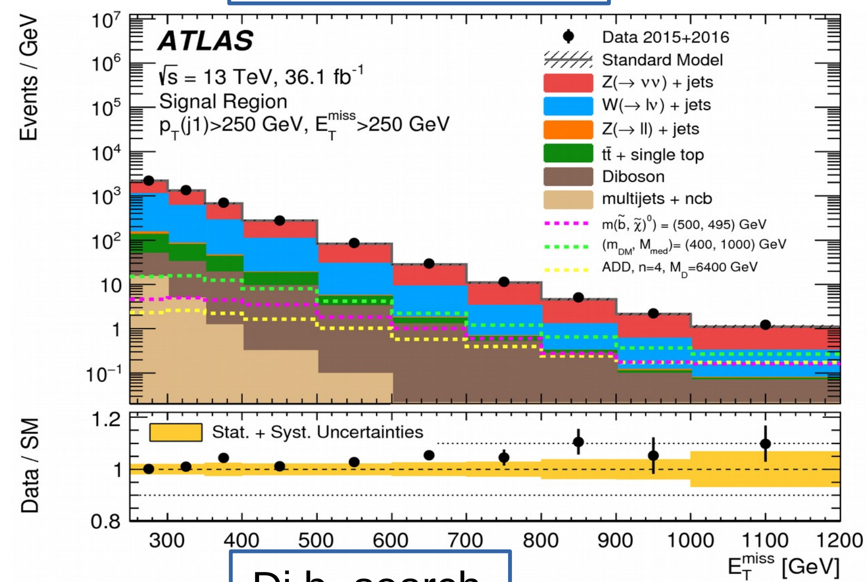
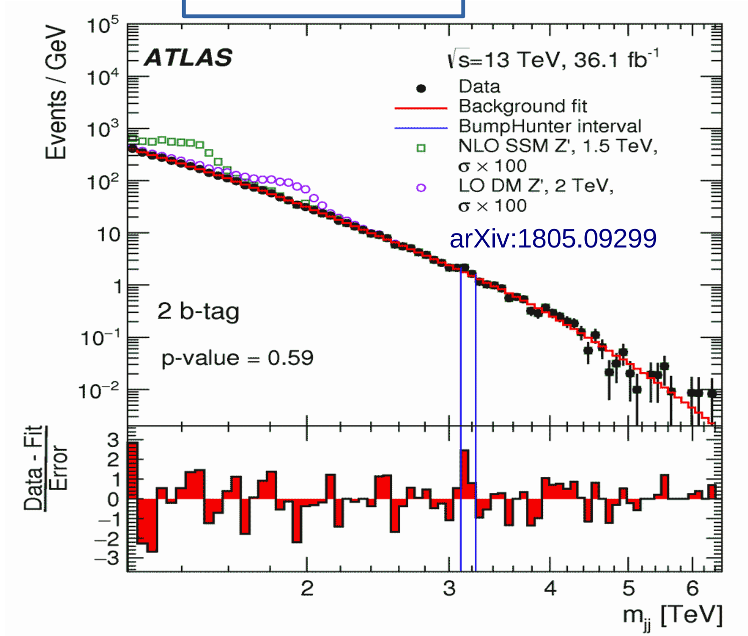
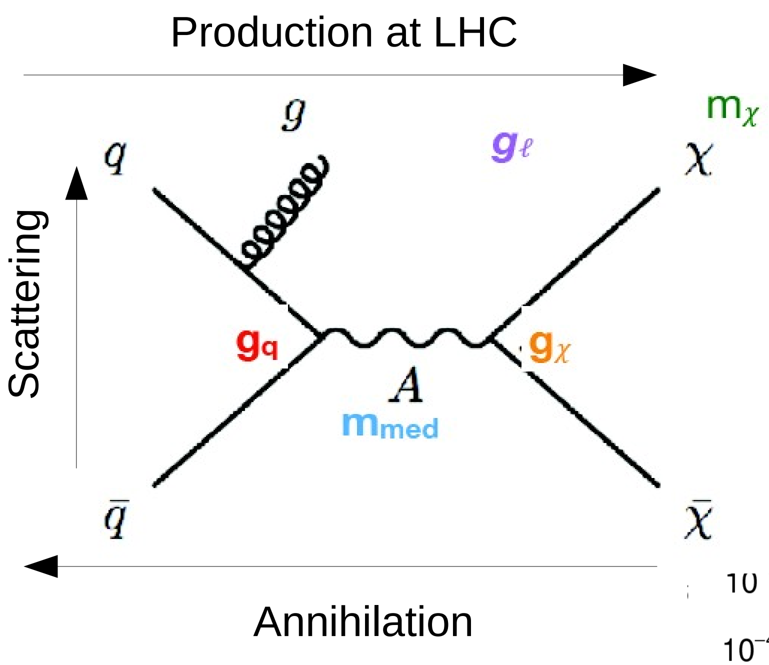


Di b- search

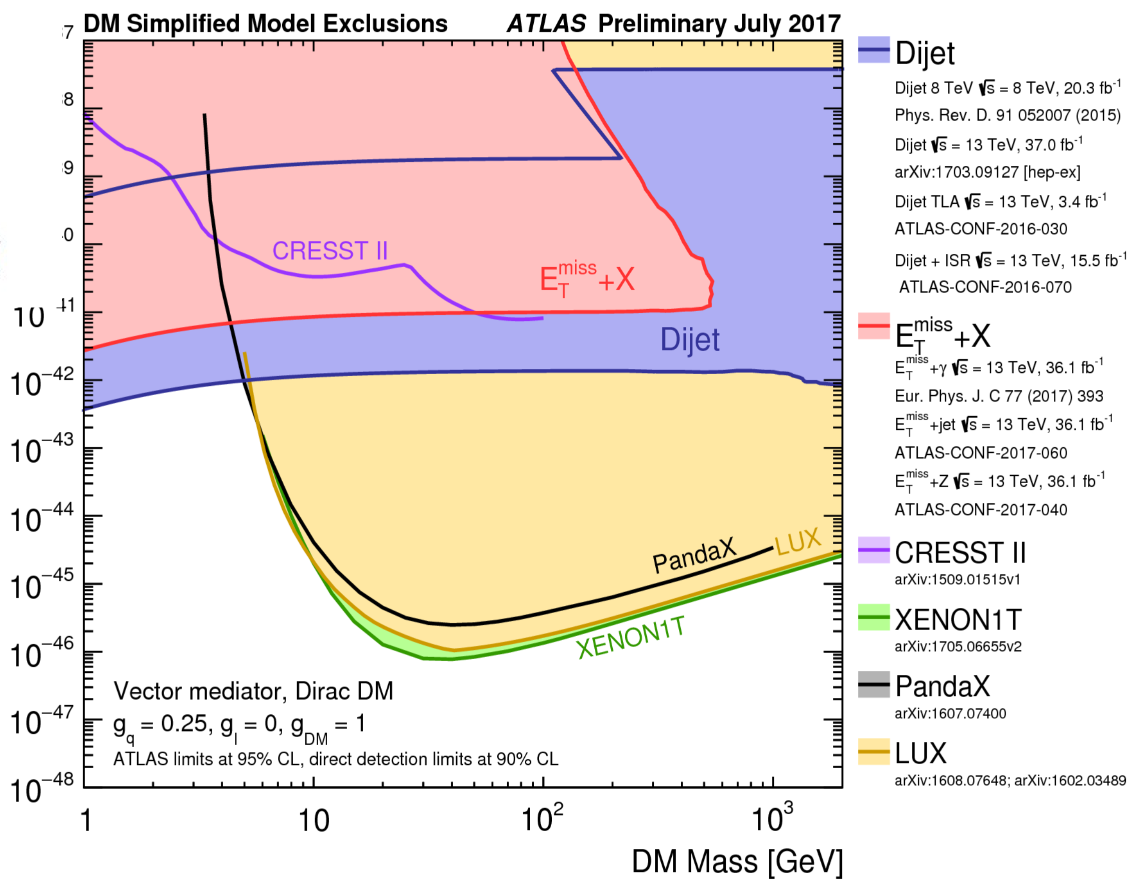


Search for dark matter at LHC

Complementarity to direct detection experiments

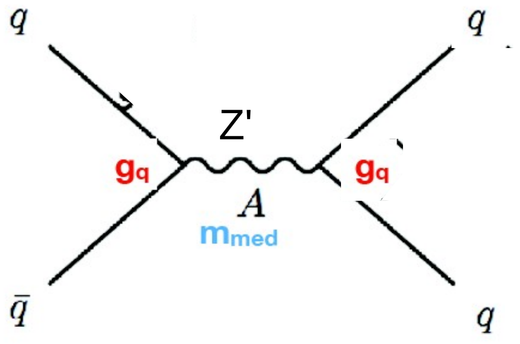


Example for g_q=0.25 g_χ=1 for vector mediator:



Dijet resonance search

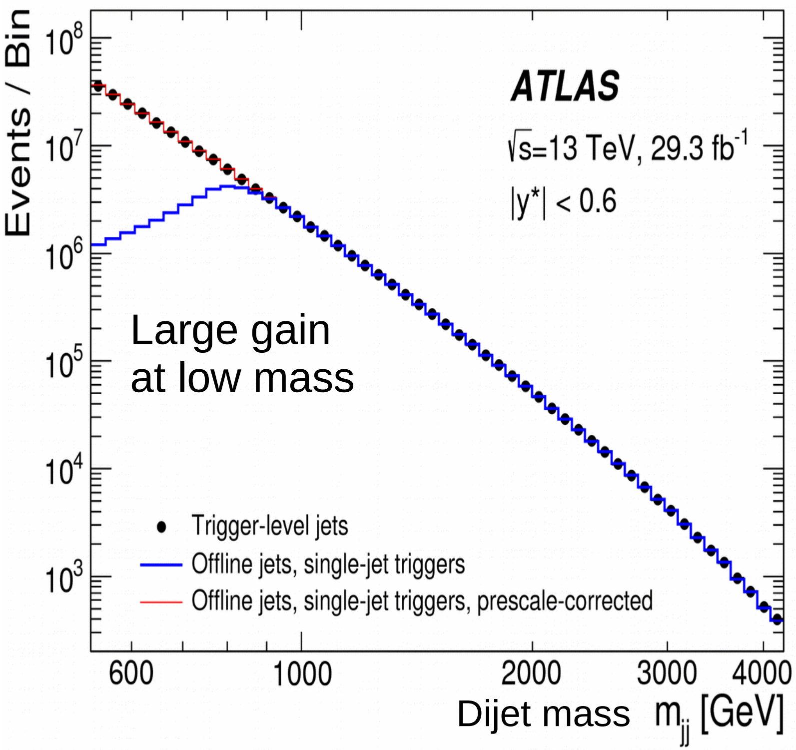
arXiv:1804.03496

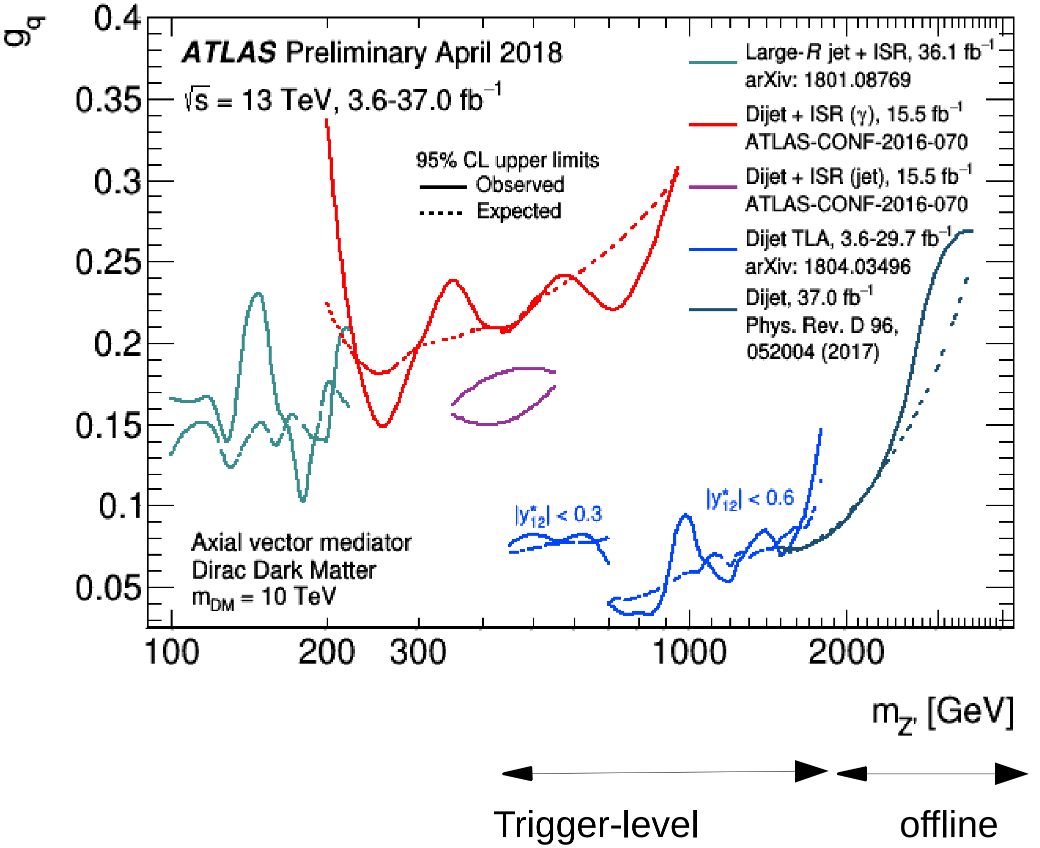


Dijet resonance search limited by trigger $p_{t,jet}$ threshold.

In sub-TeV regime need to do analysis on trigger level overcoming bandwidth limitations by writing only small amount of trigger jet information.
Need full jet calibration for trigger-level jets.

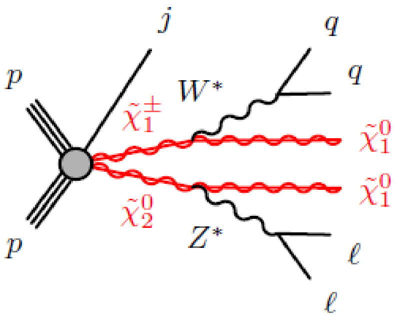
Example coupling limits for DM axial vector mediator:





plots

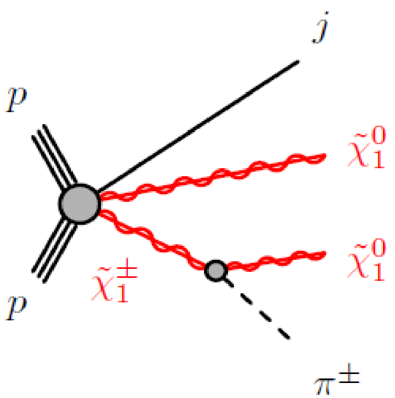
Search for electroweak SUSY particles



2ℓ compressed

Soft $p_T^{e,\mu} > 4.5, 4$ GeV

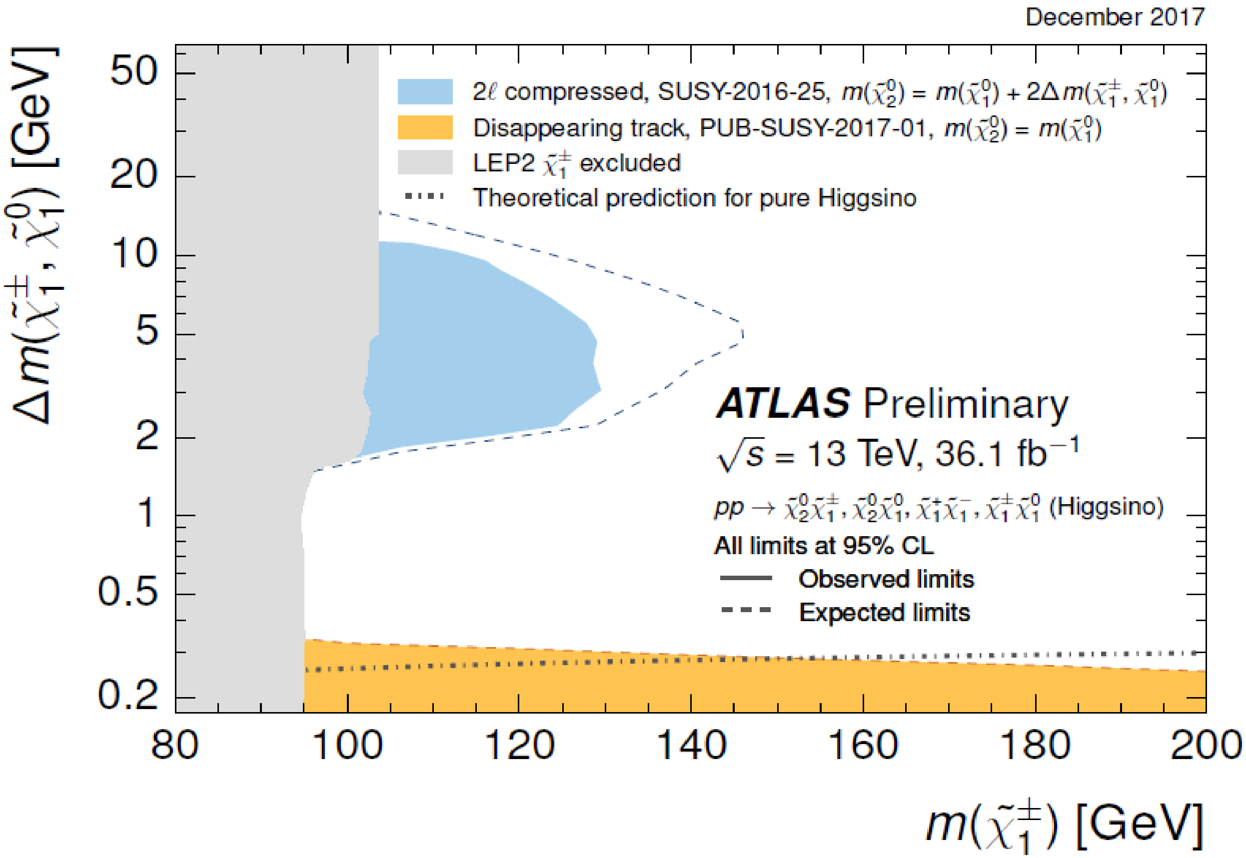
[1712.08119]

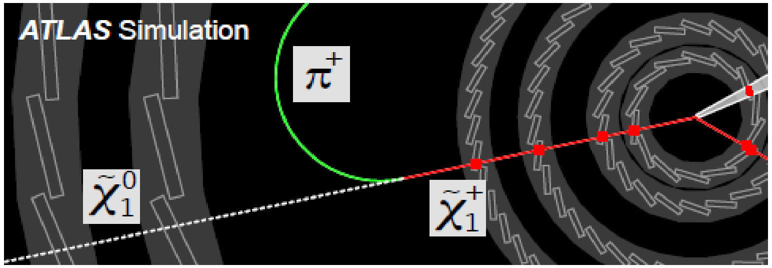


Disappearing track

IBL+Pixel tracklets

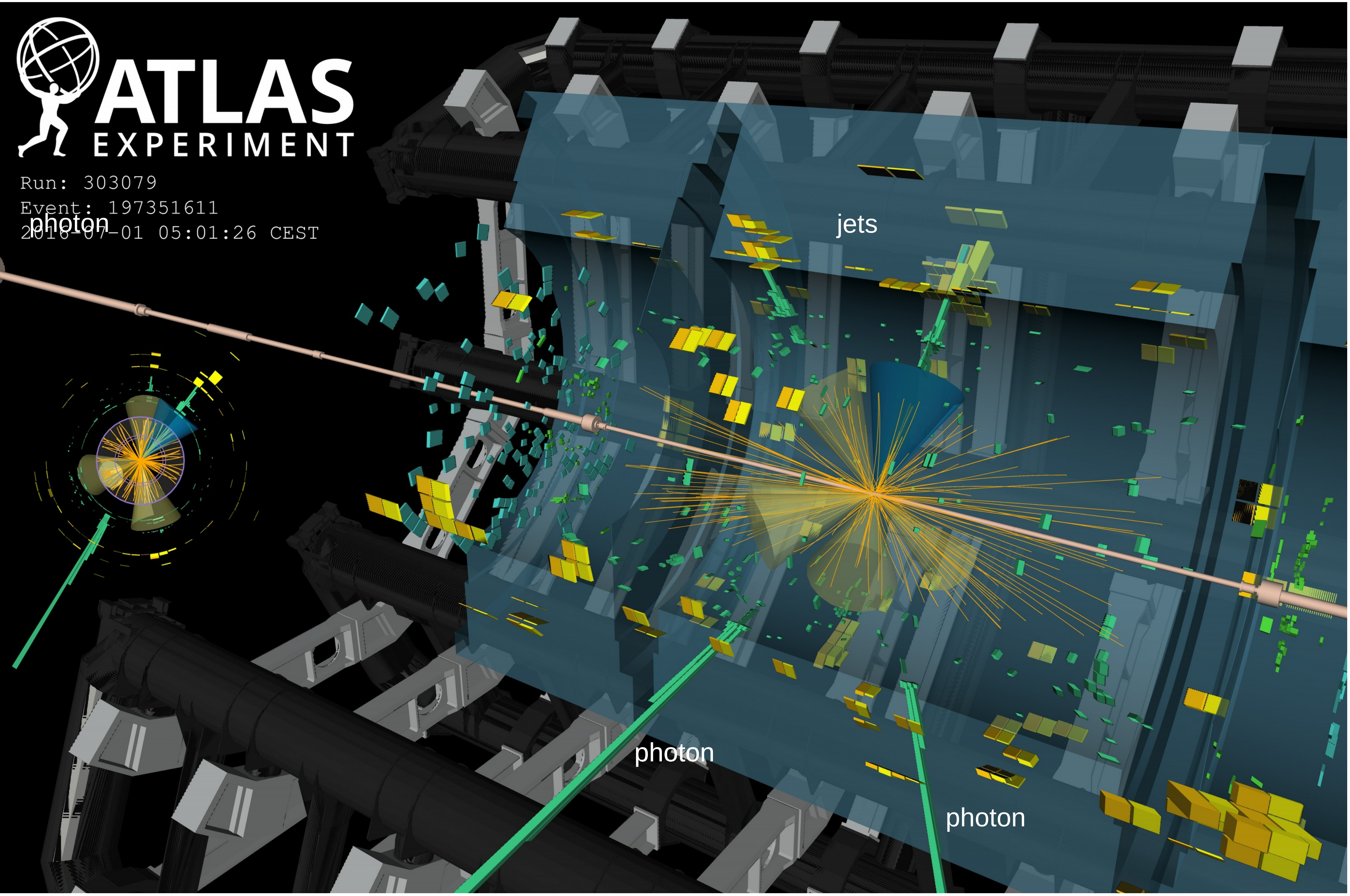
[PHYS-PUB-2017-019]



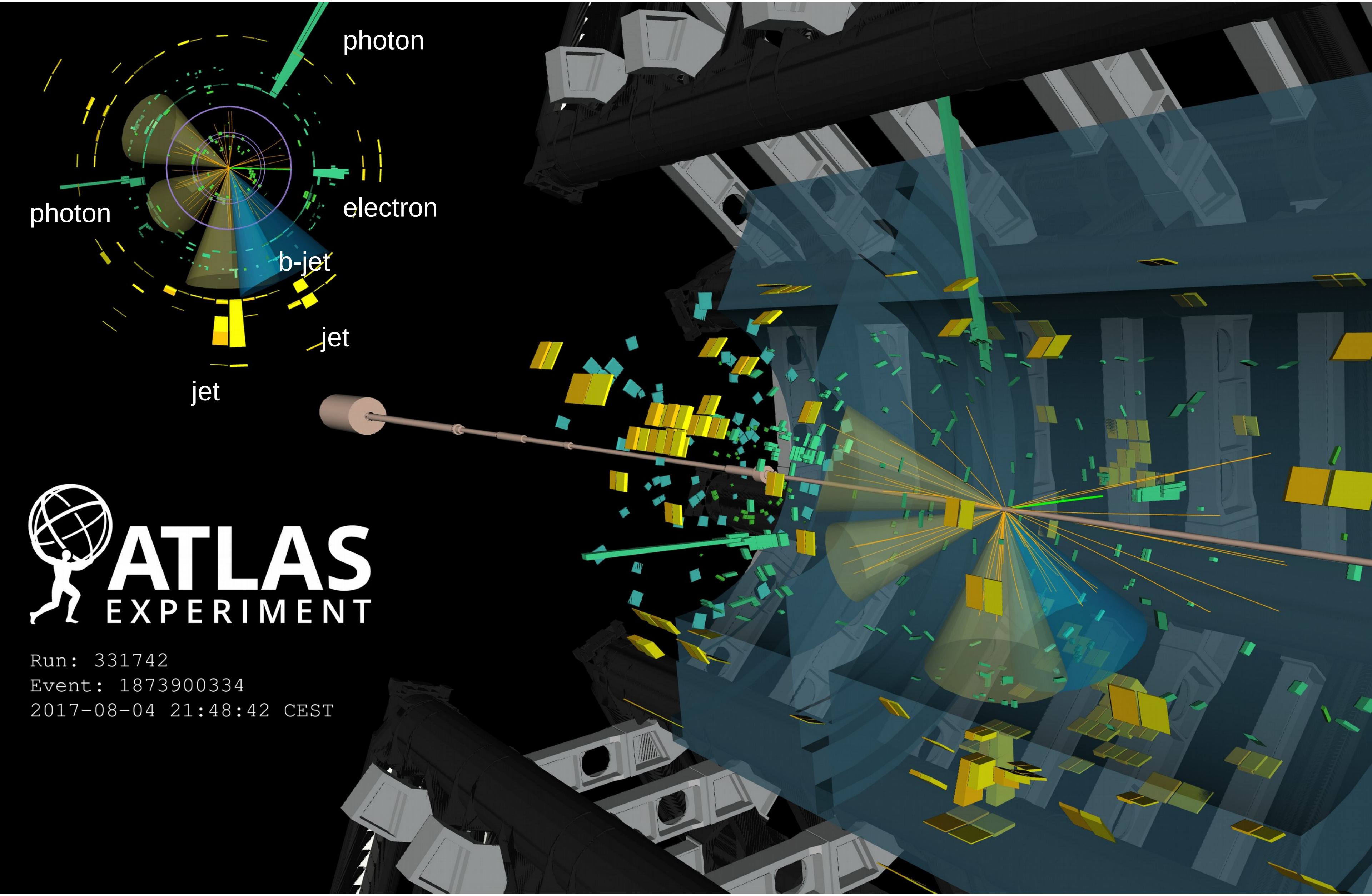


[CONF-2017-081]

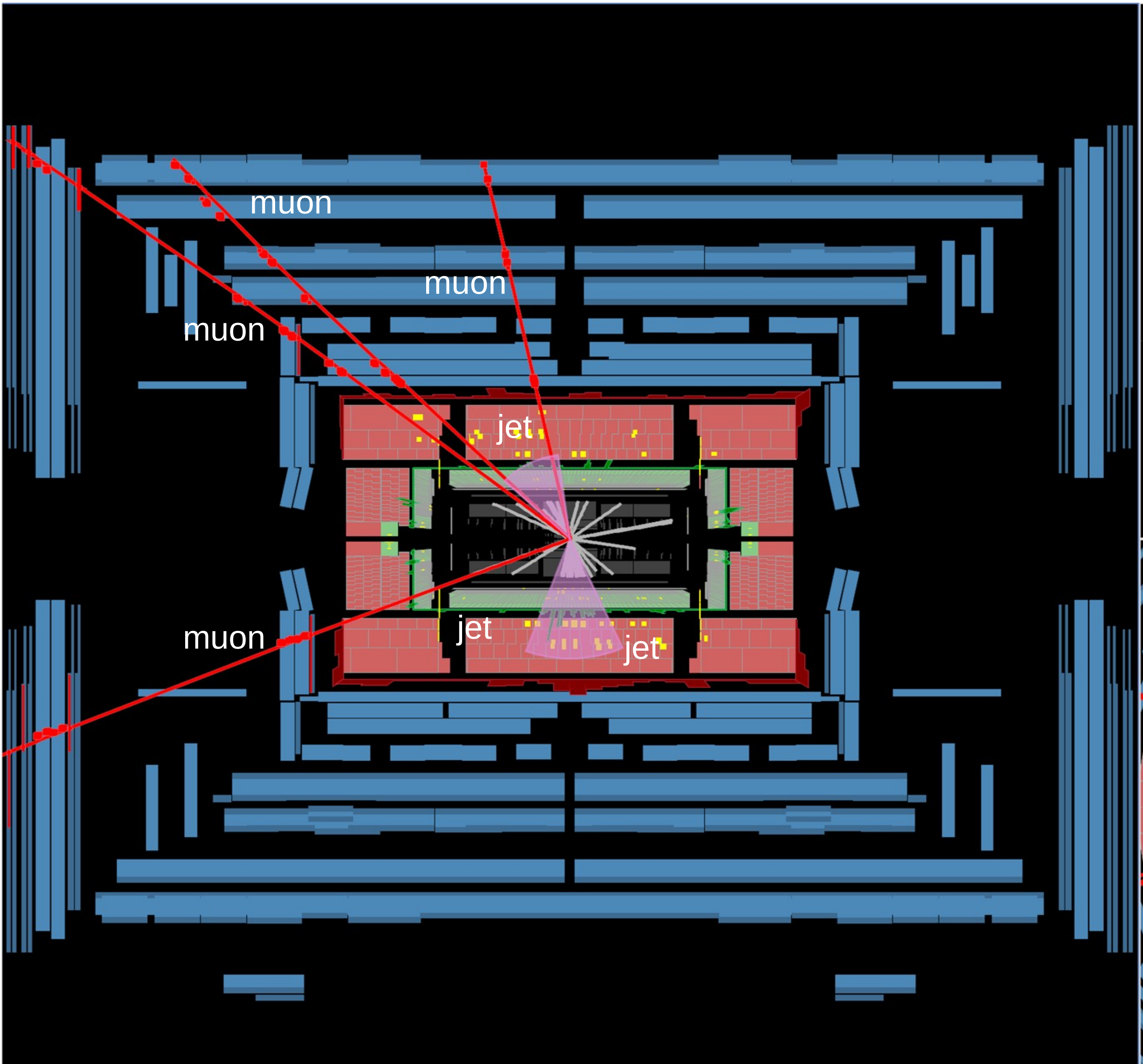
ttH event candidate



ttH event candidate

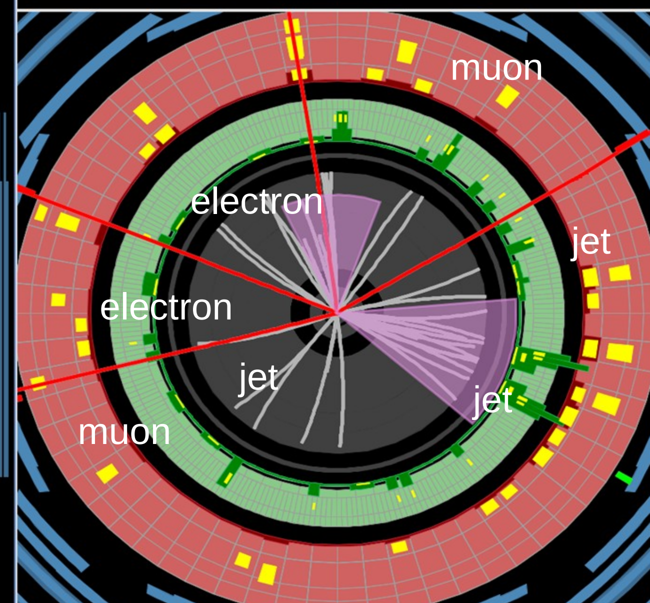


ttH four lepton event candidate



Run Number: 331875, Event Number: 2155358561

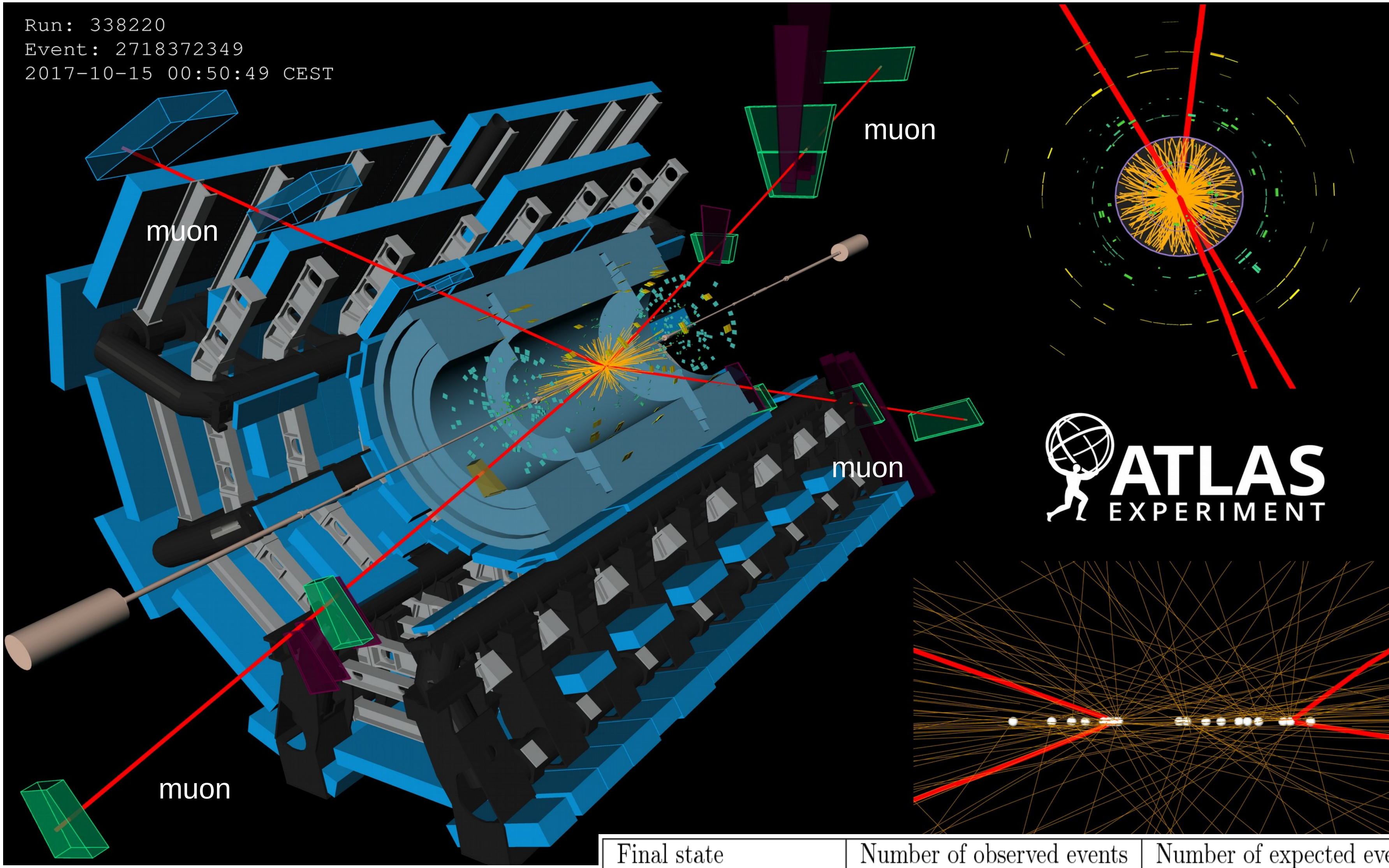
Date: 2017-08-08 02:55:43 CEST



Event display of the 4μ VH-Had candidate with the with BDTVH-Had = 0.47. The invariant mass of the 4-lepton system is 128.2 GeV, the muons are indicated b red tracks (pT = 103.7, 16.9, 16.4 and 15.4 GeV). The two jets, with an invariant mass of 96.2 GeV, are marked with purple cones (pT,j1 = 64.9 GeV and pT,j2 =

ATL-PHYS-PUB-2018-007

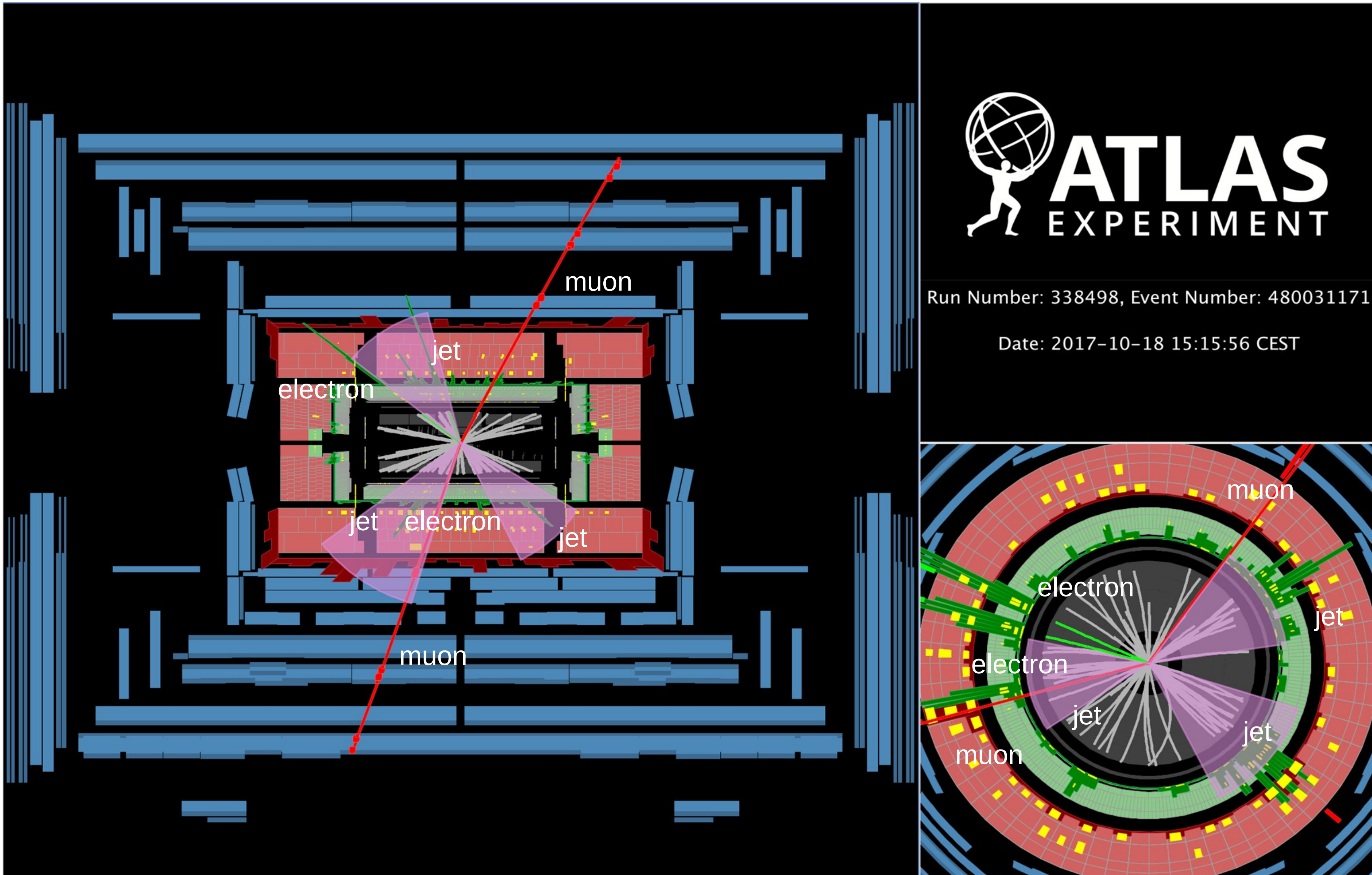
Four muon event



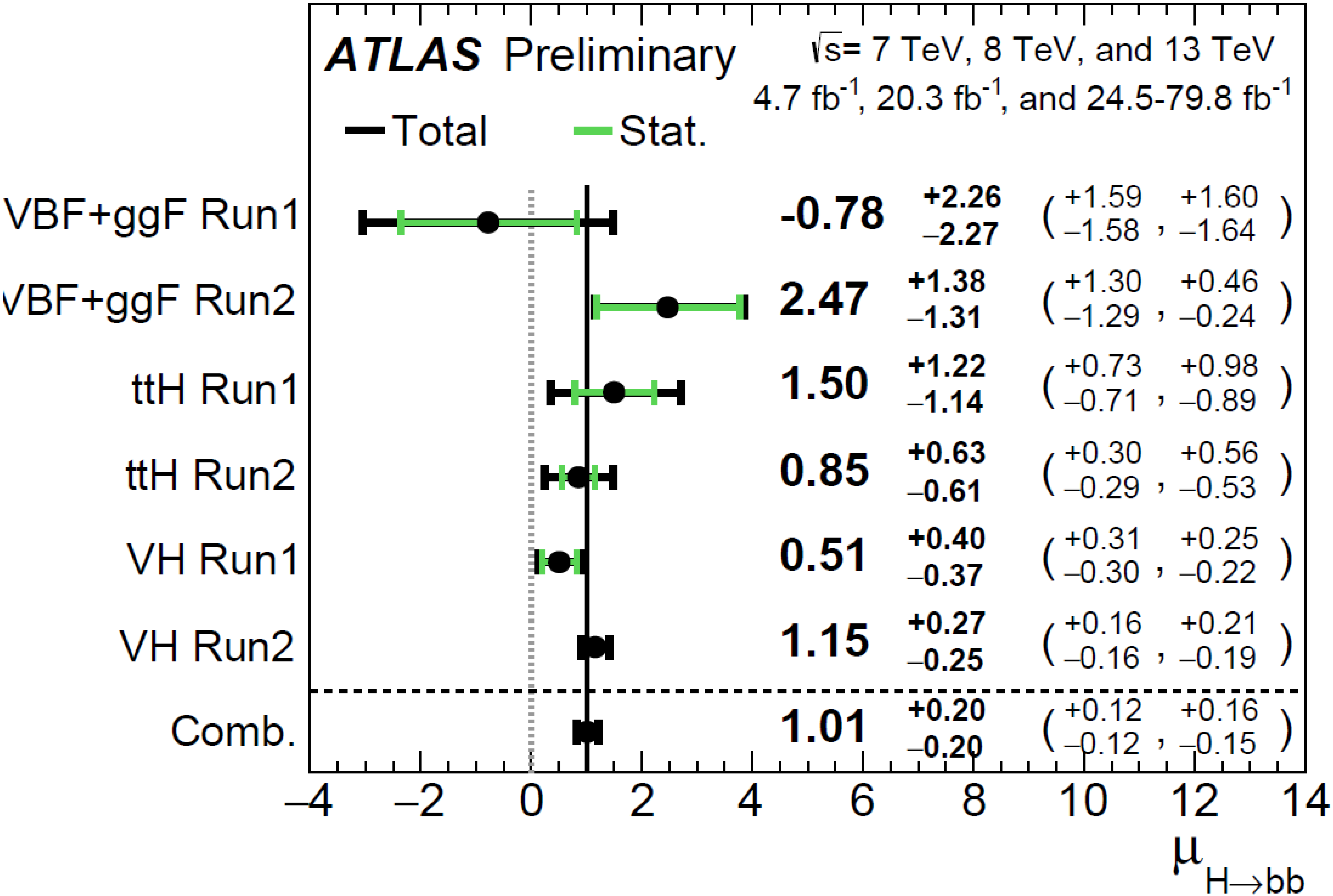
Final state	Number of observed events	Number of expected events
$e^+e^-e^+e^-$	2	2.1
$\mu^+\mu^-e^+e^-$	6	6.6
$\mu^+\mu^-\mu^+\mu^-$	5	5.4
Sum over all channels	13	14.1

Two Z->mm events superimposed.
With high LHC luminosity starts to matter even for rare processes.

Four lepton event



Coupling fits in H→bb analysis

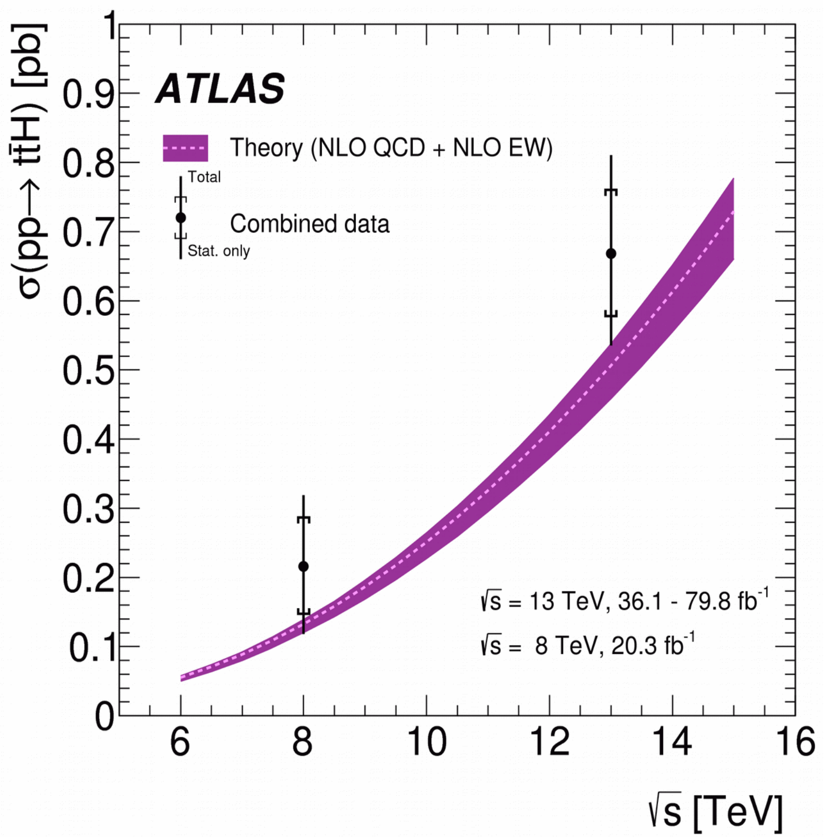


ttH production cross-section

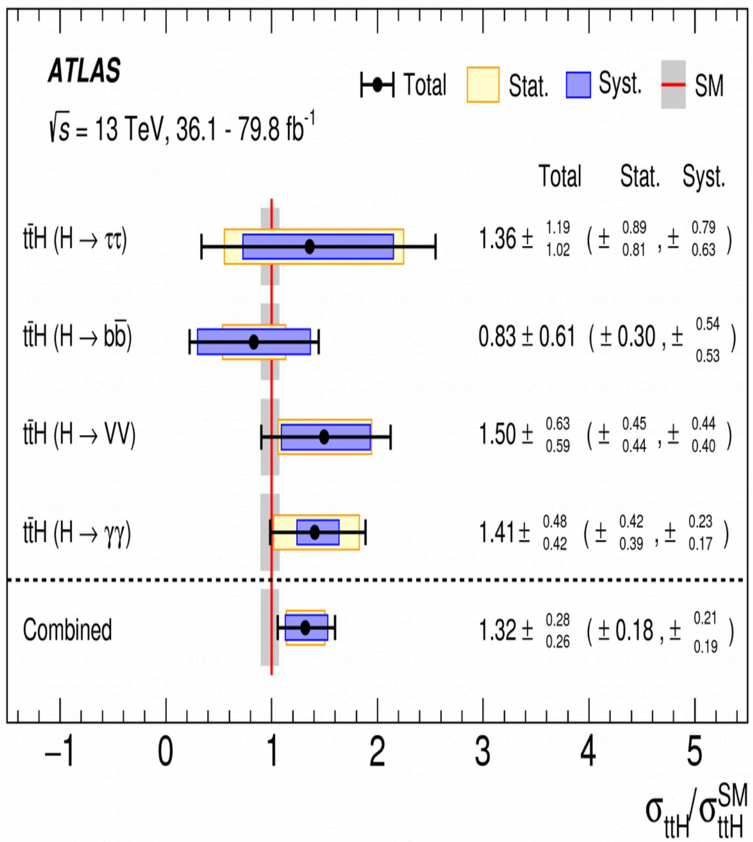
June 2018 update: ttH → γγ and tt(ZZ→4l) with **80 fb^{-1}**

arXiv:1806.00425

Inclusive ttH production cross-section



ttH cross-section per production modes



ttH cross-section

at 8 TeV: $sigma_{ttH} = 220 \pm 100(stat) \pm 70(syst)$

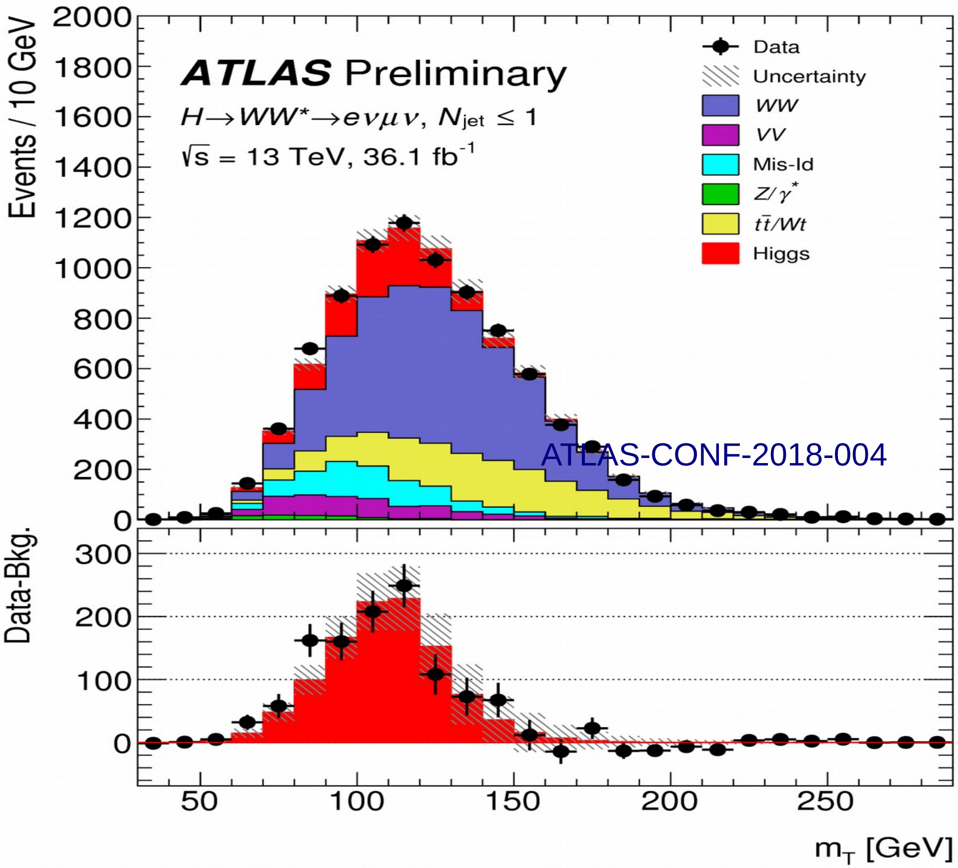
at 13 TeV: $sigma_{ttH} = 670 \pm 90(stat) \pm 105(syst)$

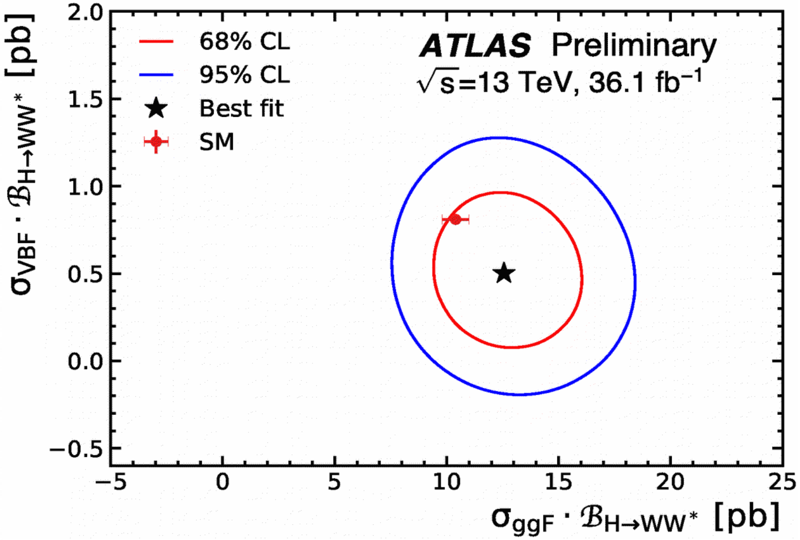
Already 20% precision !

Coupling ratios in Kappa-framework

Parameter	Definition in terms of κ modifiers	Result
κ_{gZ}	$\kappa_g \kappa_Z / \kappa_H$	1.06 ± 0.07
λ_{tg}	κ_t / κ_g	$1.09^{+0.14}_{-0.14}$
λ_{Zg}	κ_Z / κ_g	$1.06^{+0.14}_{-0.13}$
λ_{WZ}	κ_W / κ_Z	$0.99^{+0.09}_{-0.08}$
$\lambda_{\gamma Z}$	κ_γ / κ_Z	$0.95^{+0.08}_{-0.07}$
$\lambda_{\tau Z}$	κ_τ / κ_Z	0.95 ± 0.13
λ_{bZ}	κ_b / κ_Z	$0.91^{+0.17}_{-0.16}$

$H \to WW$

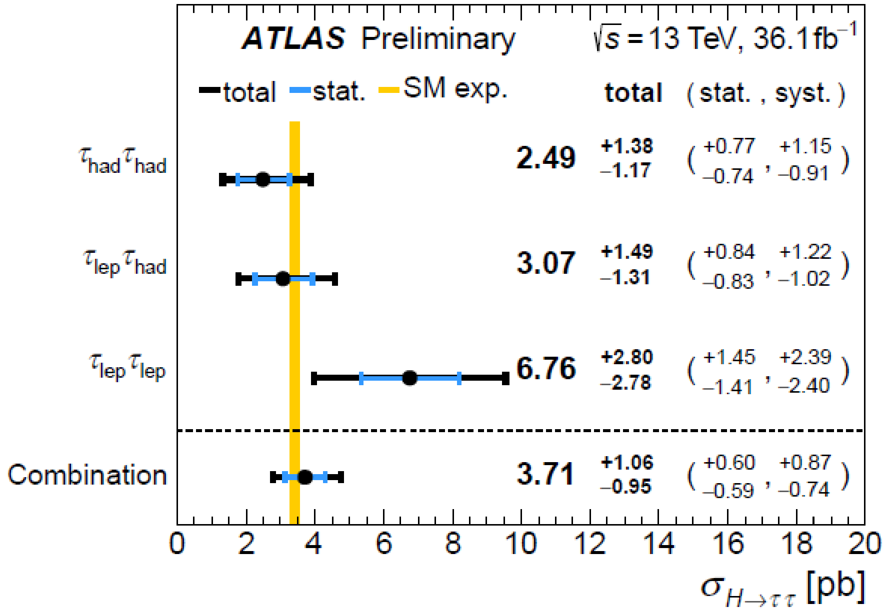


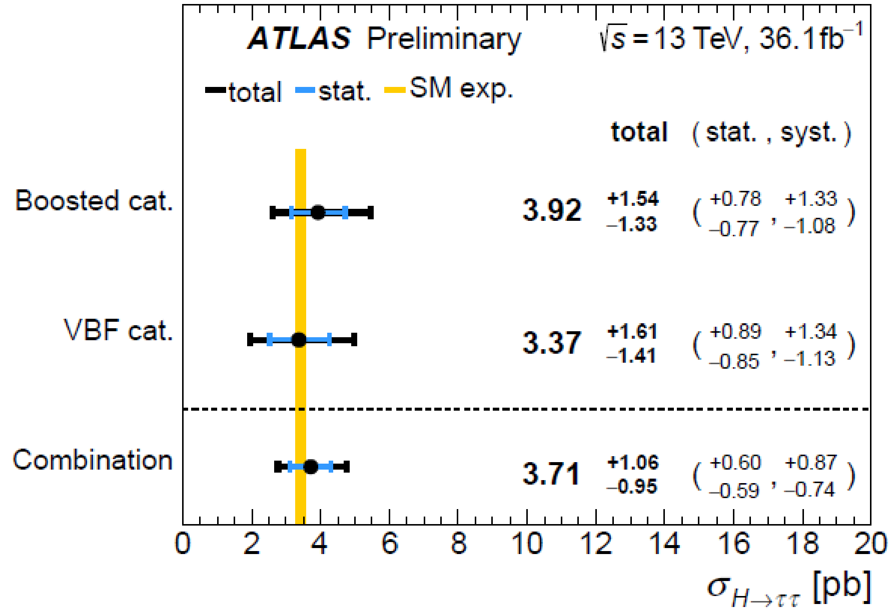


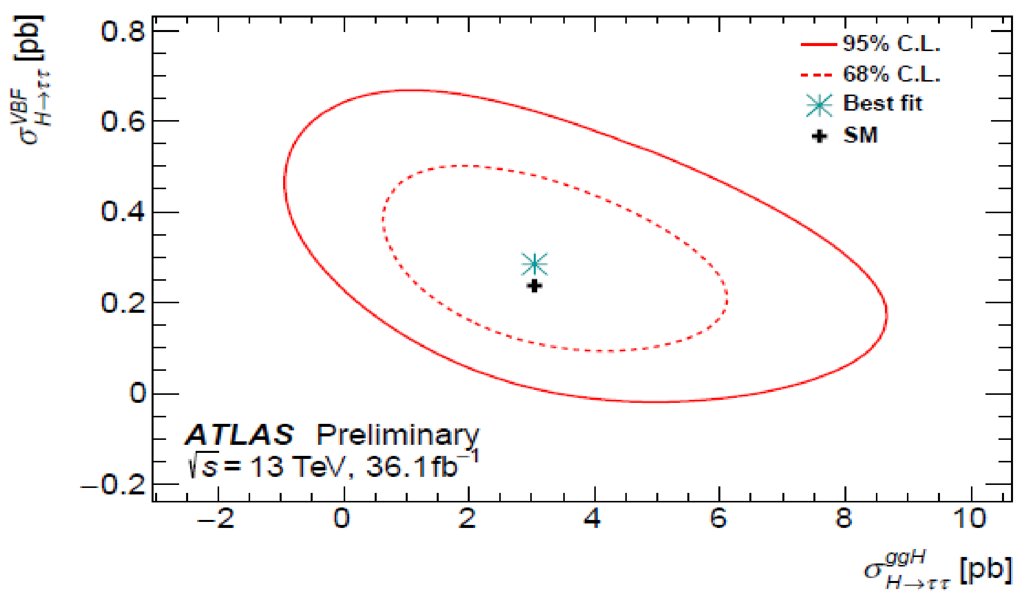
$$\mu_{\text{ggF}} = 1.21^{+0.12}_{-0.11}(\text{stat.})^{+0.18}_{-0.17}(\text{sys.}) = 1.21^{+0.22}_{-0.21}$$

$$\mu_{\text{VBF}} = 0.62^{+0.30}_{-0.28}(\text{stat.}) \pm 0.22(\text{sys.}) = 0.62^{+0.37}_{-0.36}.$$

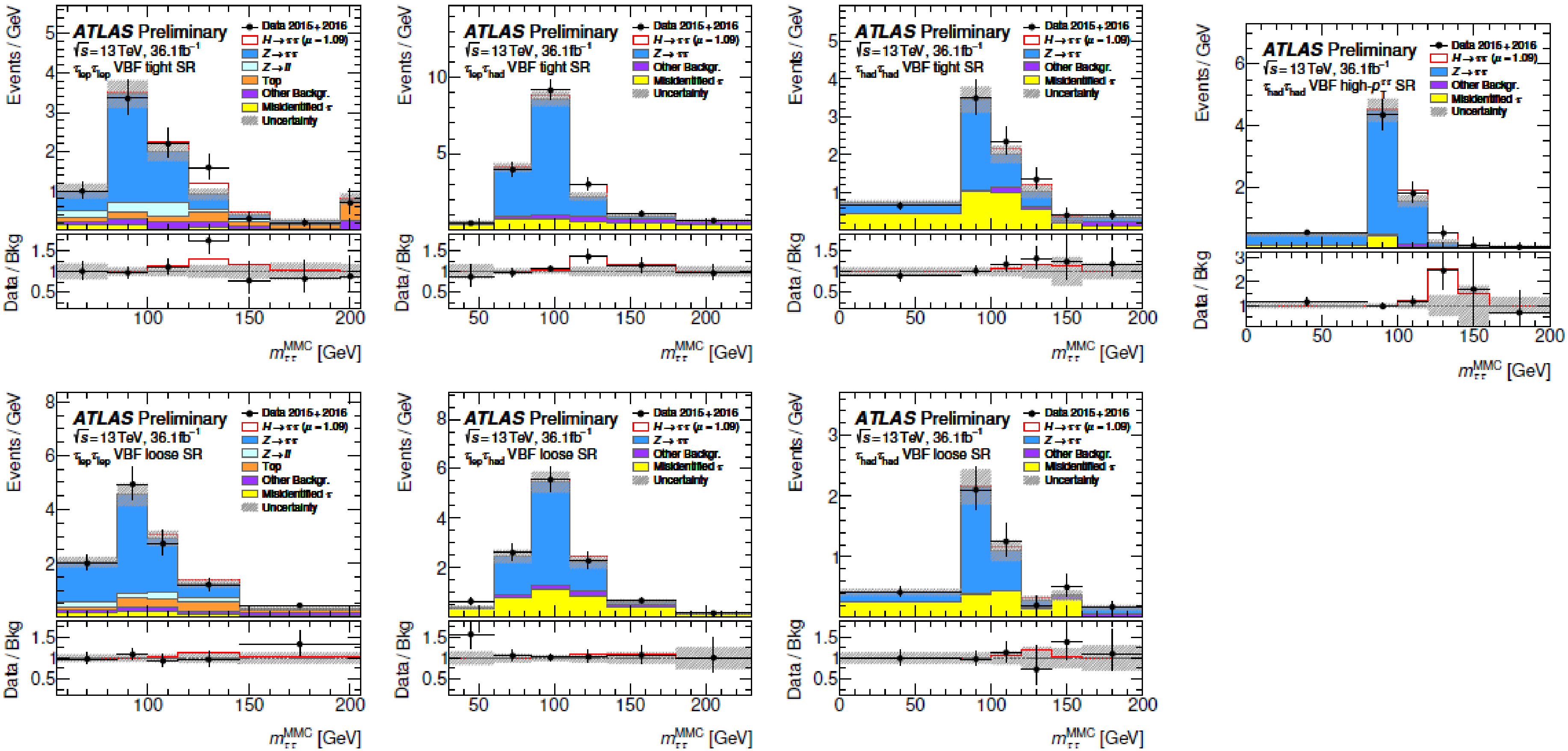
Cross-section measurement for H->ττ



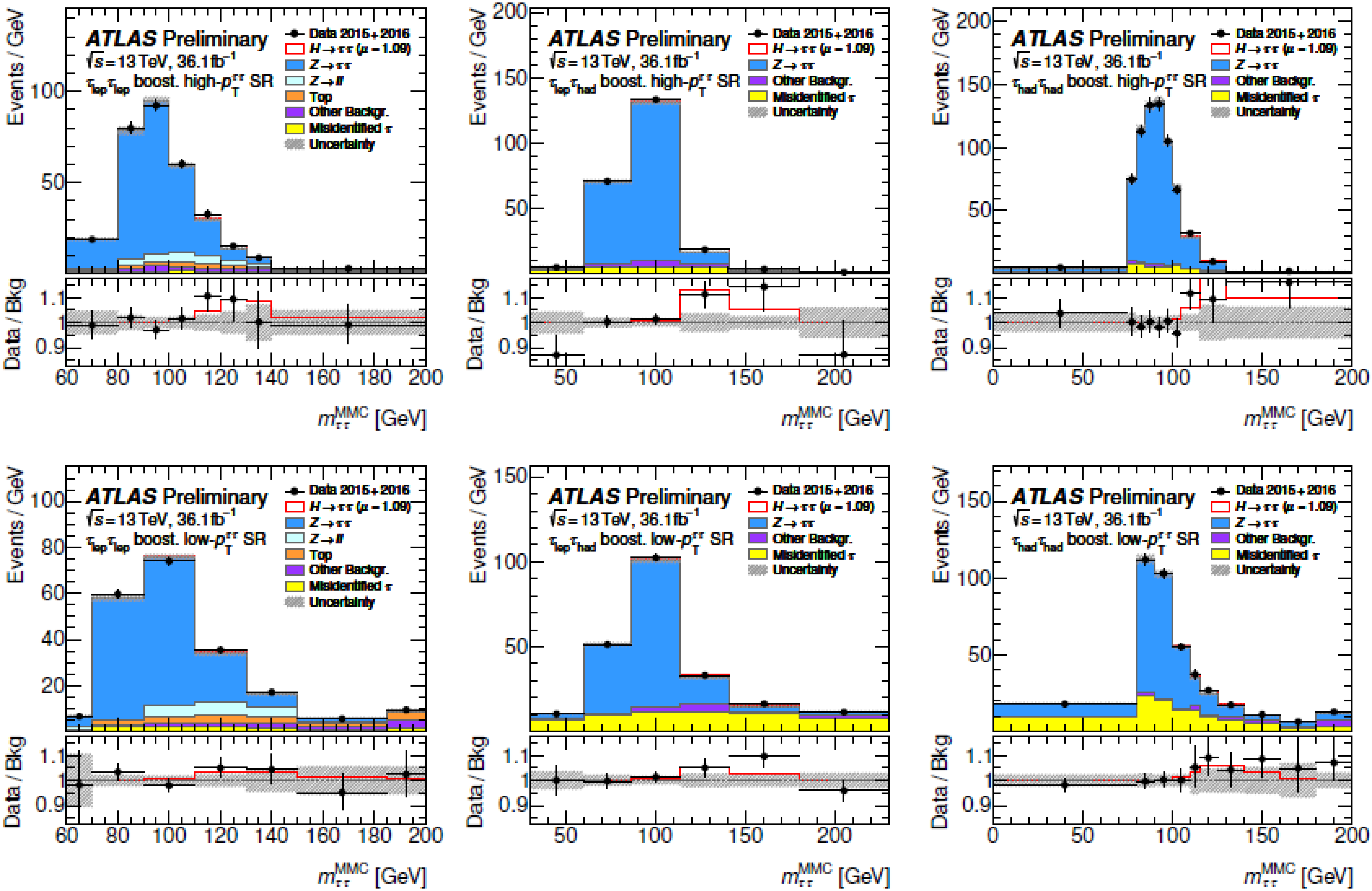




Mass distributions in H->ττ VBF categories



Mass distributions in H->ττ boosted categories



Search summary

ATLAS Exotics Searches* - 95% CL Upper Exclusion Limits

Status: July 2017

ATLAS Preliminary

$\int \mathcal{L}\, dt = (3.2 - 37.0)\ \text{fb}^{-1}$ $\sqrt{s}$ = 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, μ	1 – 4 j	Yes	36.1	M_D 7.75 TeV	$n = 2$	ATLAS-CONF-2017-060
	ADD non-resonant $\gamma\gamma$	2 γ	–	–	36.7	M_S 8.6 TeV	$n = 3$ HLZ NLO	CERN-EP-2017-132
	ADD QBH	–	2 j	–	37.0	M_{th} 8.9 TeV	$n = 6$	1703.09217
	ADD BH high $\sum p_T$	≥ 1 e, μ	≥ 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 γ	–	–	36.7	G_{KK} mass 4.1 TeV	$k/\overline{M}_{Pl} = 0.1$	CERN-EP-2017-132
	Bulk RS $G_{KK} \to WW \to qq\ell\nu$	1 e, μ	1 J	Yes	36.1	G_{KK} mass 1.75 TeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2017-051
	2UED / RPP	1 e, μ	≥ 2 b, ≥ 3 j	Yes	13.2	KK mass 1.6 TeV	Tier (1,1), $\mathcal{B}(A^{(1,1)} \to tt) = 1$	ATLAS-CONF-2016-104
Gauge bosons	SSM $Z' \to \ell\ell$	2 e, μ	–	–	36.1	Z' mass 4.5 TeV		ATLAS-CONF-2017-027
	SSM $Z' \to \tau\tau$	2 τ	–	–	36.1	Z' mass 2.4 TeV		ATLAS-CONF-2017-050
	Leptophobic $Z' \to bb$	–	2 b	–	3.2	Z' mass 1.5 TeV		1603.08791
	Leptophobic $Z' \to tt$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	3.2	Z' mass 2.0 TeV	$\Gamma/m = 3\%$	ATLAS-CONF-2016-014
	SSM $W' \to \ell\nu$	1 e, μ	–	Yes	36.1	W' mass 5.1 TeV		1706.04786
	HVT $V' \to WV \to qqqq$ model B	0 e, μ	2 J	–	36.7	V' mass 3.5 TeV	$g_V = 3$	CERN-EP-2017-147
	HVT $V' \to WH/ZH$ model B	multi-channel			36.1	V' mass 2.93 TeV	$g_V = 3$	ATLAS-CONF-2017-055
	LRSM $W'_R \to tb$	1 e, μ	2 b, 0-1 j	Yes	20.3	W' mass 1.92 TeV		1410.4103
	LRSM $W'_R \to tb$	0 e, μ	≥ 1 b, 1 J	–	20.3	W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	37.0	Λ 21.8 TeV	η_{LL}^-	1703.09217
	CI $\ell\ell qq$	2 e, μ	–	–	36.1	Λ 40.1 TeV	η_{LL}^-	ATLAS-CONF-2017-027
	CI $uutt$	2(SS)/≥3 e,μ	≥1 b, ≥1 j	Yes	20.3	Λ 4.9 TeV	$\lvert C_{RR}\rvert = 1$	1504.04605
DM	Axial-vector mediator (Dirac DM)	0 e, μ	1 – 4 j	Yes	36.1	m_{med} 1.5 TeV	g_q=0.25, g_χ=1.0, $m(\chi)$ < 400 GeV	ATLAS-CONF-2017-060
	Vector mediator (Dirac DM)	0 e, μ, 1 γ	≤ 1 j	Yes	36.1	m_{med} 1.2 TeV	g_q=0.25, g_χ=1.0, $m(\chi)$ < 480 GeV	1704.03848
	$VV\chi\chi$ EFT (Dirac DM)	0 e, μ	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 μ	≥ 2 j	–	3.2	LQ mass 1.05 TeV	$\beta = 1$	1605.06035
	Scalar LQ 3rd gen	1 e, μ	≥1 b, ≥3 j	Yes	20.3	LQ mass 640 GeV	$\beta = 0$	1508.04735
Heavy quarks	VLQ $TT \to Ht + X$	0 or 1 e, μ	≥ 2 b, ≥ 3 j	Yes	13.2	T mass 1.2 TeV	$\mathcal{B}(T \to Ht) = 1$	ATLAS-CONF-2016-104
	VLQ $TT \to Zt + X$	1 e, μ	≥ 1 b, ≥ 3 j	Yes	36.1	T mass 1.16 TeV	$\mathcal{B}(T \to Zt) = 1$	1705.10751
	VLQ $TT \to Wb + X$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	36.1	T mass 1.35 TeV	$\mathcal{B}(T \to Wb) = 1$	CERN-EP-2017-094
	VLQ $BB \to Hb + X$	1 e, μ	≥ 2 b, ≥ 3 j	Yes	20.3	B mass 700 GeV	$\mathcal{B}(B \to Hb) = 1$	1505.04306
	VLQ $BB \to Zb + X$	2/≥3 e, μ	≥2/≥1 b	–	20.3	B mass 790 GeV	$\mathcal{B}(B \to Zb) = 1$	1409.5500
	VLQ $BB \to Wt + X$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	36.1	B mass 1.25 TeV	$\mathcal{B}(B \to Wt) = 1$	CERN-EP-2017-094
	VLQ $QQ \to WqWq$	1 e, μ	≥ 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 γ	1 j	–	36.7	q^* mass 5.3 TeV	only u^* and d^*, $\Lambda = m(q^*)$	CERN-EP-2017-148
	Excited quark $b^* \to bg$	–	1 b, 1 j	–	13.3	b^* mass 2.3 TeV		ATLAS-CONF-2016-060
	Excited quark $b^* \to Wt$	1 or 2 e, μ	1 b, 2-0 j	Yes	20.3	b^* mass 1.5 TeV	$f_g = f_L = f_R = 1$	1510.02664
	Excited lepton ℓ^*	3 e, μ	–	–	20.3	ℓ^* mass 3.0 TeV	$\Lambda = 3.0$ TeV	1411.2921
	Excited lepton ν^*	3 e, μ, τ	–	–	20.3	ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	LRSM Majorana ν	2 e, μ	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	ATLAS-CONF-2017-053
	Higgs triplet $H^{\pm\pm} \to \ell\tau$	3 e, μ, τ	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, $\mathcal{B}(H_L^{\pm\pm} \to \ell\tau) = 1$	1411.2921
	Monotop (non-res prod)	1 e, μ	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, $\lvert g\rvert = 1g_D$, spin 1/2	1509.08059

$\sqrt{s}$ = 8 TeV (green) $\sqrt{s}$ = 13 TeV (yellow)

Mass scale [TeV] (axis: 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).

Vector-like Quark summary