ATLAS
Status and Recent Physics Highlights

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LHCC Open Session, 5 Dec 2012

ATLAS Status and performance

Recorded luminosity in 2012

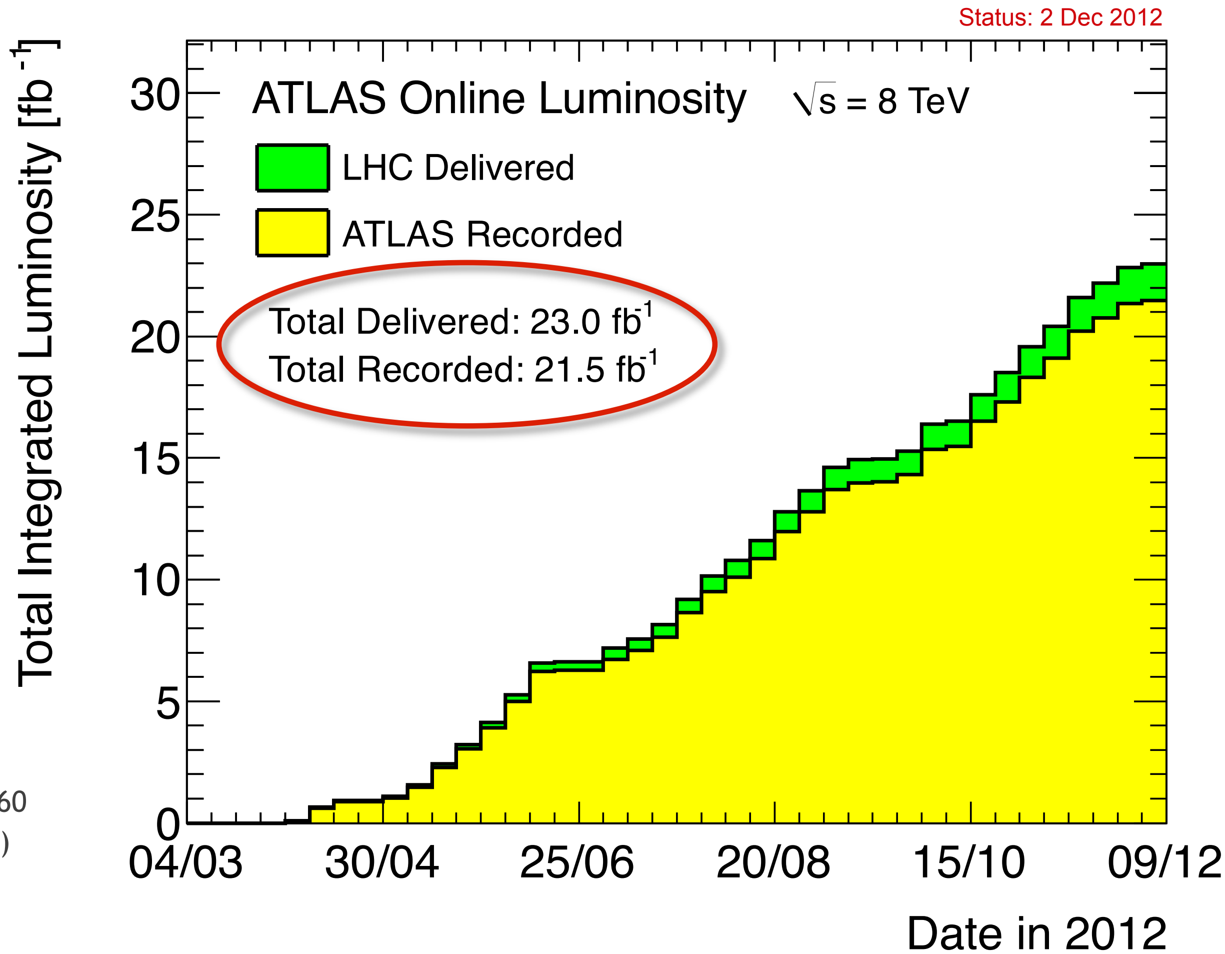
Measured with forward detectors, calibrated with beam separation scans

ATLAS integrated luminosity in 2012

- Peak $L = 7.7 \times 10^{33}\ s^{-1}cm^{-2}$ (Aug)
- Max L/fill: 237 pb^{-1} (June)
- Weekly record: 1350 pb^{-1} (June)
- Longest stable beams: 22.8 h (July)
- Fastest turn-around between stable beams: 2.1 h (April)
- Best weekly data-taking efficiency: 92 h (55%) (July)

At $L = 7 \times 10^{33}\ s^{-1}cm^{-2}$ and 8 TeV *pp* collisions, 560 Higgs bosons of mass 125 GeV ($\sigma_{pp \to H}$ = 22.3 pb) are produced in ATLAS and CMS per hour

Or: every 45 min. 1 $H \to \gamma\gamma$, need ~2 typical 160 pb^{-1} fills to produced one $H \to 4l$ ($l = e/\mu$)



Luminosity and pileup in 2012

Measured with forward detectors, calibrated with beam separation scans

Peak luminosity & pileup profiles

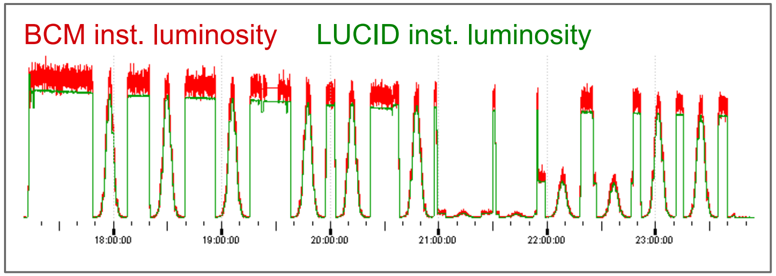
Current 2012 luminosity uncertainty 3.6%

- Dominated by non-linearities in beam profiles of April & July 2012 van-der-Meer scans

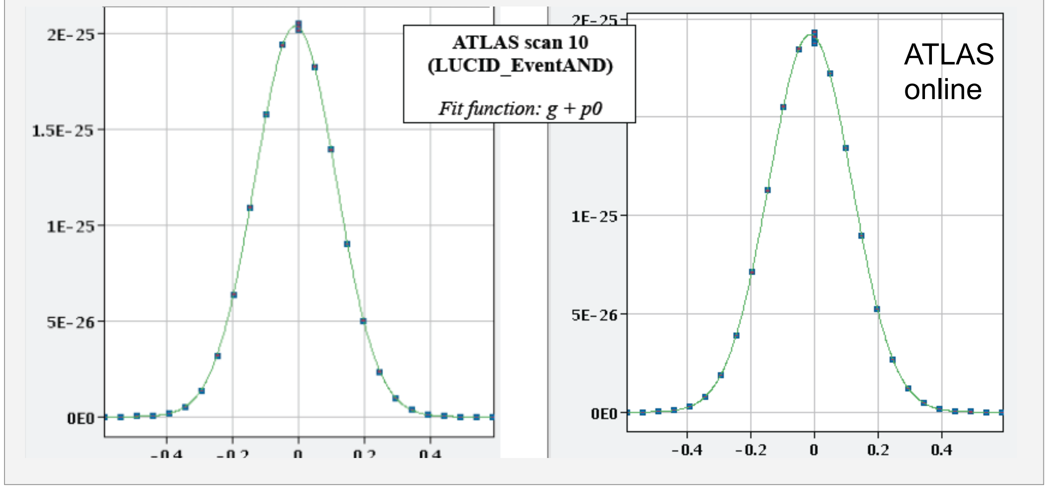
New van-der-Meer scan performed 22 Nov (β^* = 11m)

- First look promising: Gaussian shapes
- 3D beam shaping in injectors pays off

Luminosity profile during Nov 22 van-der-Meer scan



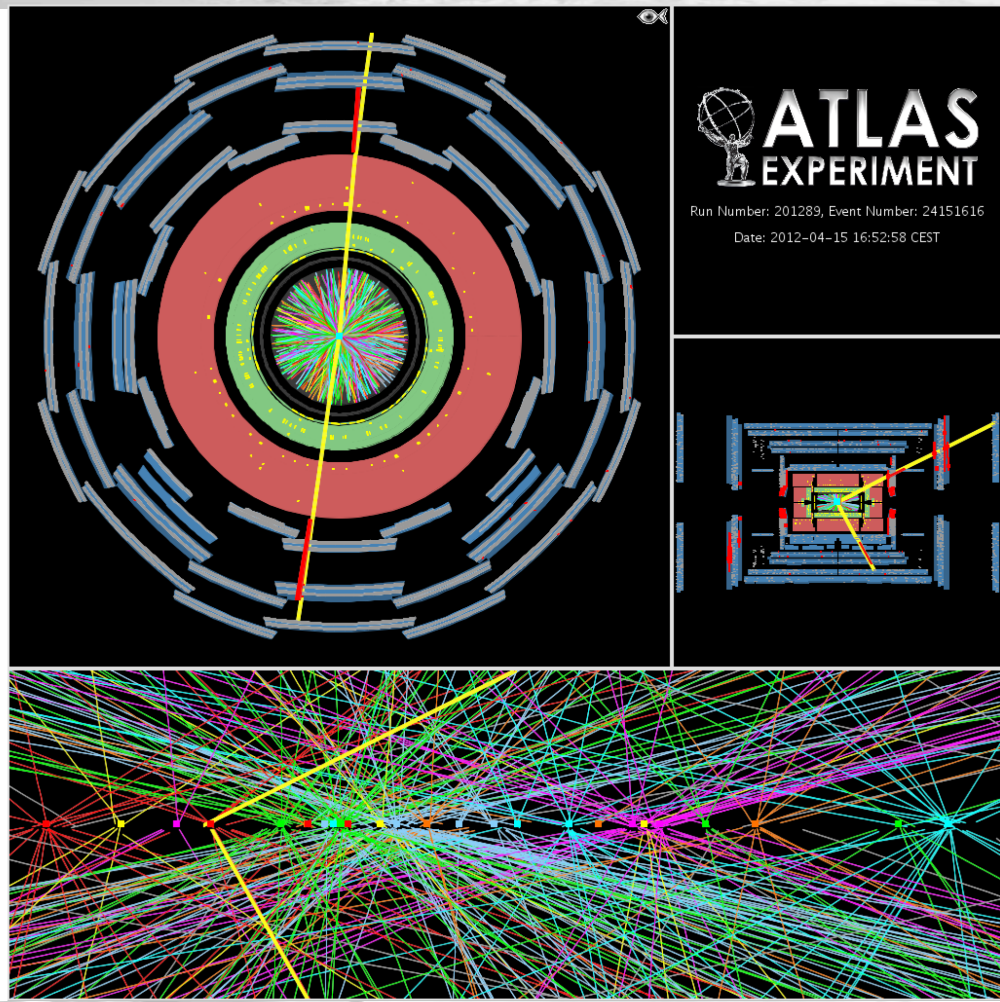
Test fits of horizontal (left) and vertical (right) scan profiles



Pileup in 2012

In general, do not expect a significant impact on tracking, nor muons, nor even electrons and photons

However, sizable impact on jets, E_T^{miss} and tau reconstruction as well as on trigger rates and computing



$Z \rightarrow \mu\mu$ event in ATLAS with 25 reconstructed vertices
Display with track p_T threshold of 0.4 GeV and all tracks are required to have at least 3 Pixel and 6 SCT hits

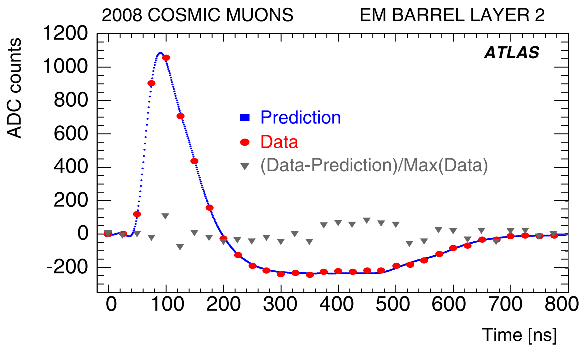
Stability of electron energy response versus pileup

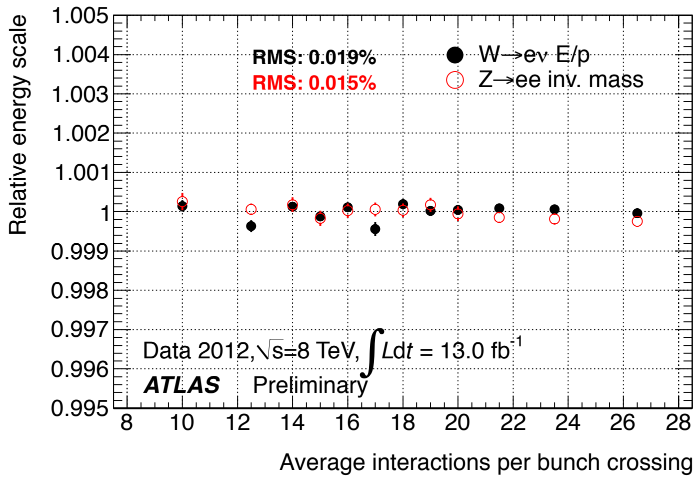
With bipolar LAr pulse shape bunch-integrated pileup contribution cancels*

**Designed for 25 ns bunches and uniform bunch luminosity*

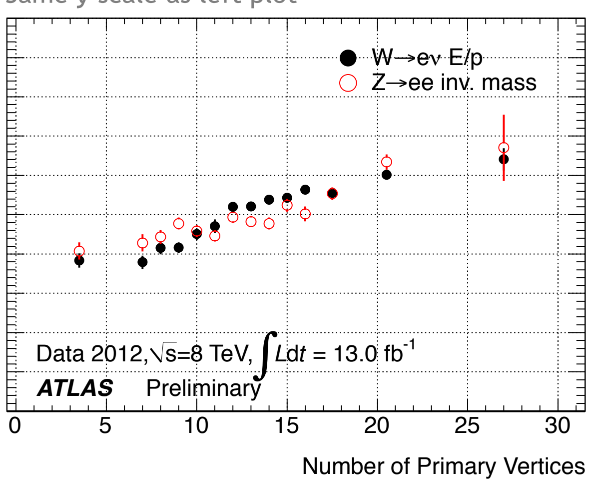
Reconstructed *e* energy in $Z \to ee$ and $W \to e\nu$ (E/p)

- Left plot: relative stability versus $<\mu>$ better than 0.1%
- Center: however, energy rise versus *number of vertices* seen: expected from in-time versus out-of time selection bias
- Right: data / MC ratio: effect well reproduced by simulation





Same *y* scale as left plot



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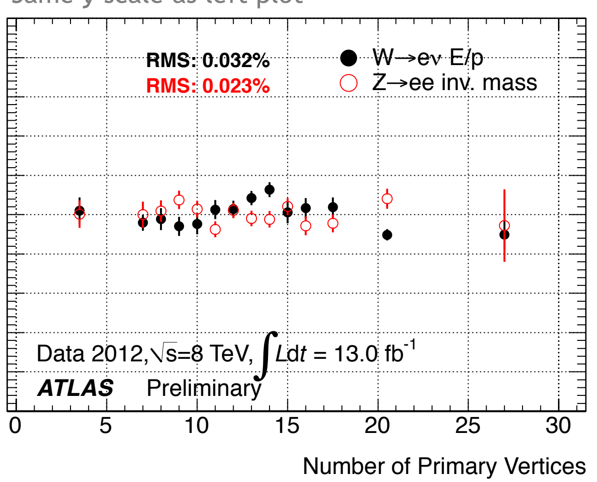
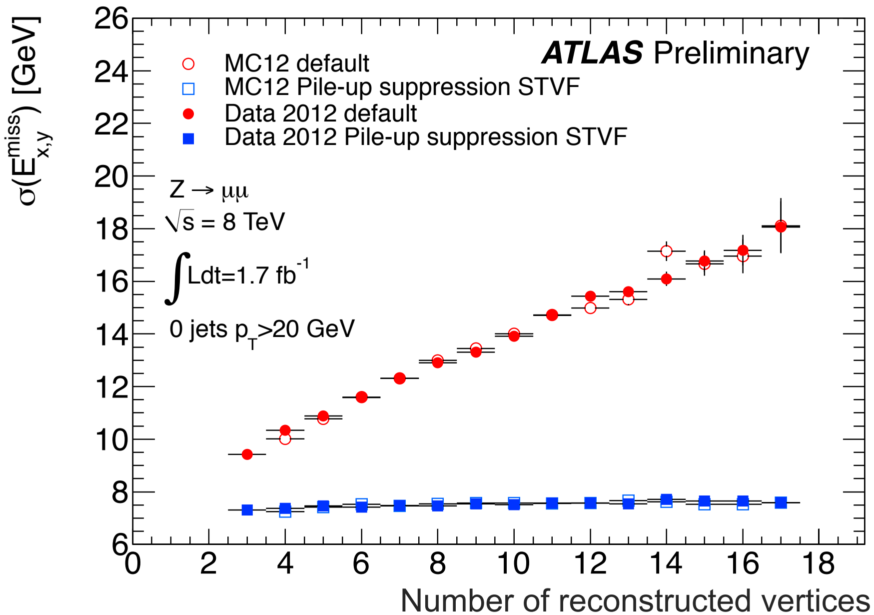


E_T^{miss} and tau reconstruction versus pileup

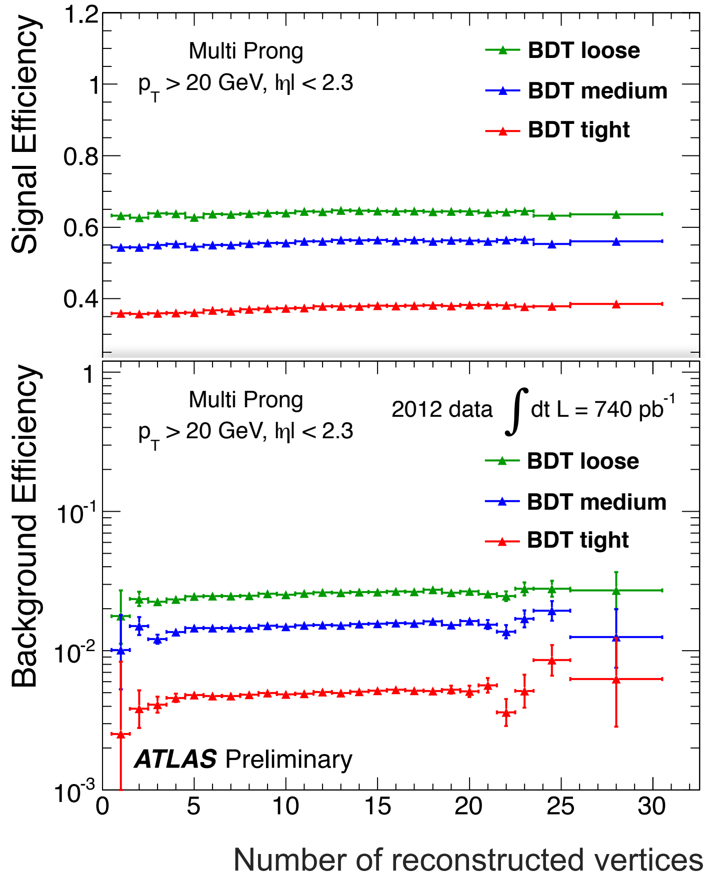
Pileup dependence from soft activity in calorimeter

Including tracking information helps to mitigate effects from pileup interactions

E_T^{miss} resolution in $Z \rightarrow \mu\mu$ events with and without soft-term vertex fraction correction



Tau BDT reconstruction efficiencies
versus number of vertices



Efficiencies predicted by PYTHIA8 MC

Tested in data with $Z \rightarrow \tau\tau$ tag-and-probe analysis

Background efficiencies measured from dijet data samples

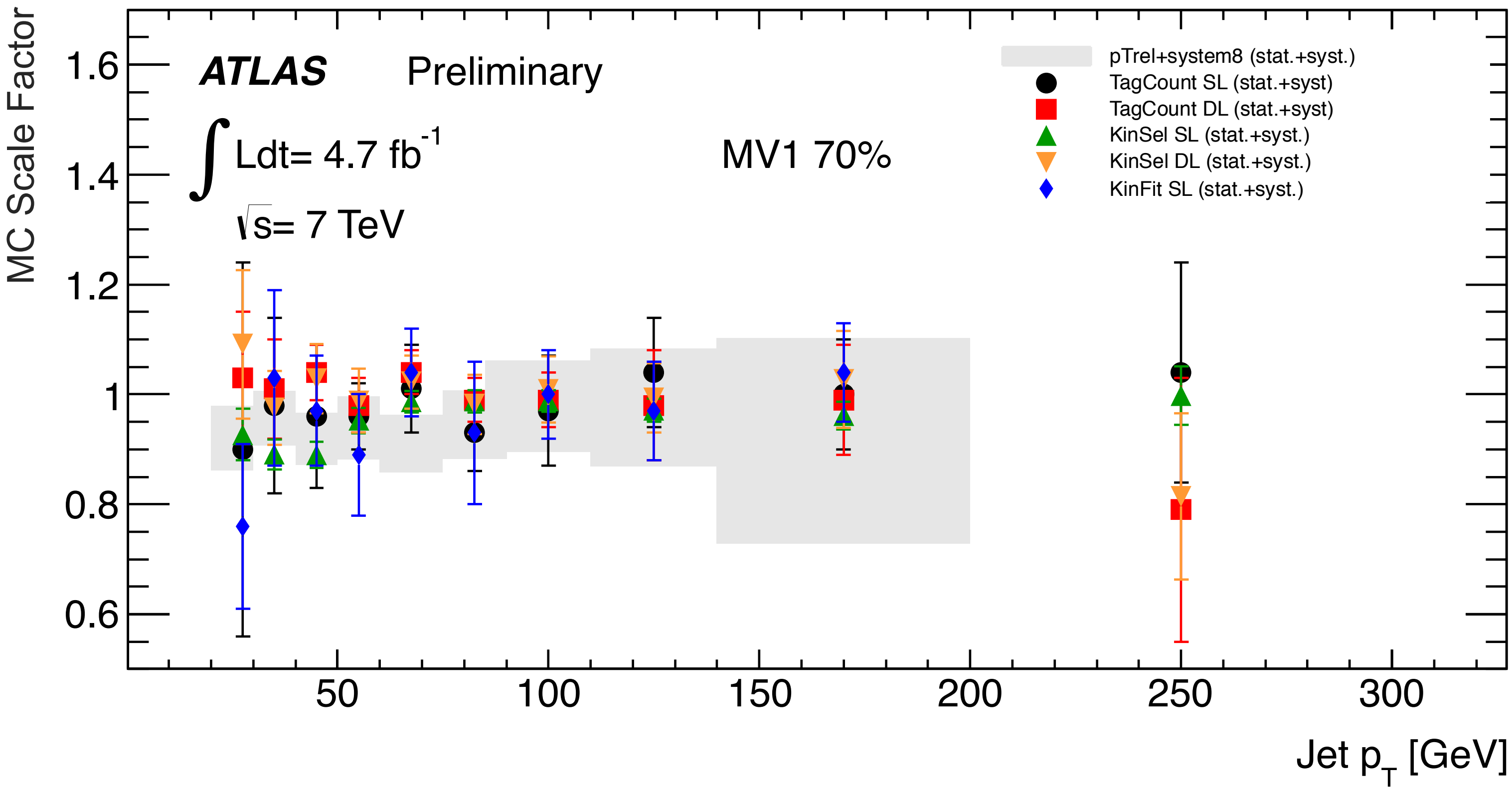
Flavour tagging

Understanding of *b*-tagging efficiencies crucial for many analyses (SM, $H \rightarrow bb$, *searches*)

Default tagger: 'MV1' neural network using other taggers as input

Several methods available to determine *b*-tagging efficiency versus *b*-jet p_T. Compatible results found among all of them, including those using *tt* and dijet events

ATLAS-CONF-2012-097



Comparison of all *tt*-based scale factors with the combined scale factors from the *System8* and *pTrel* calibration methods [see: ATLAS-CONF-2011-089]

Scale factors close to unity, systematic uncertainties between 5% and 15% versus p_T

Data taking efficiency

Continued excellent performance of detector, trigger and reconstruction

Average data taking efficiency: ~94%

- Deadtime is dominant inefficiency source (~4%)

Stable detector performance

ATLAS p-p run: April-Sept. 2012										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
100	99.3	99.5	97.0	99.6	99.9	99.8	99.9	99.9	99.7	99.2
All good for physics: 93.7%										

Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at $\sqrt{s}$=8 TeV between April 4th and September 17th (in %) – corresponding to 14.0 fb^{-1} of recorded data. The inefficiencies in the LAr calorimeter will partially be recovered in the future.

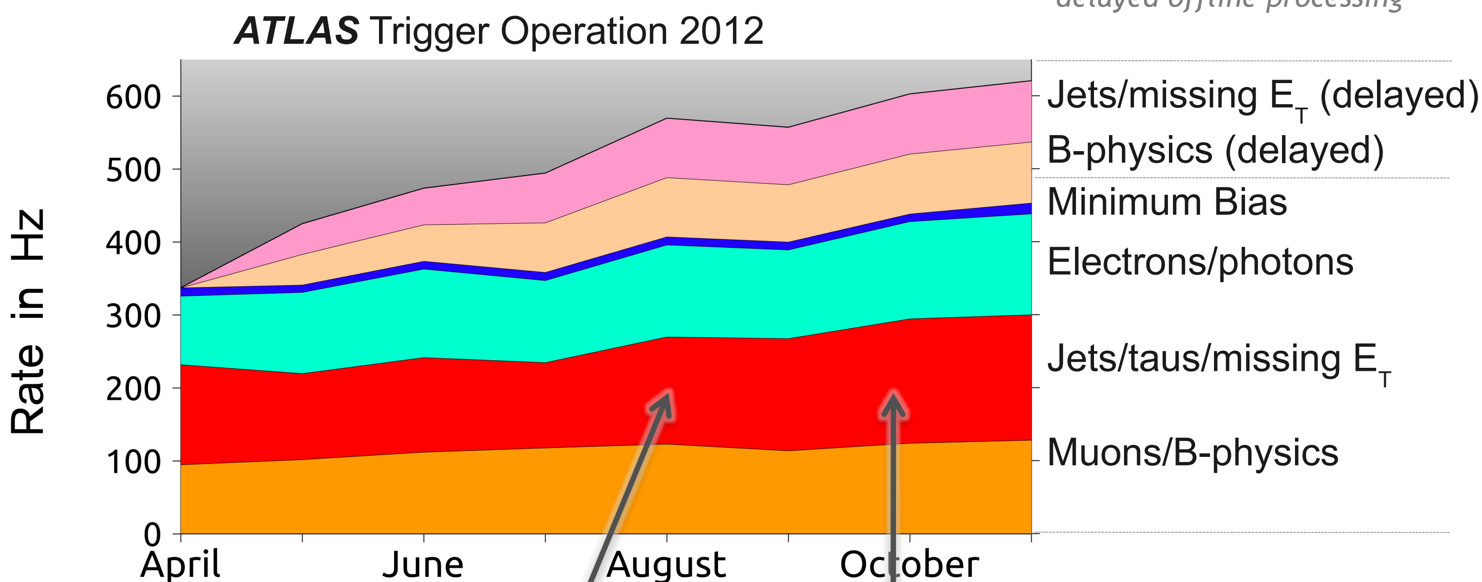
Total efficiency (delivered → physics): ~88%

2012 Trigger

Baseline menu designed for L = 8 ×10^{33} cm^{-2}s^{-1} and mostly unchanged during 2012 run

Average trigger rate during stable beam:

Spare DAQ capacity used for lower priority triggers with delayed offline processing



Delayed reconstruction
[0.8 B events so far]

Prompt Tier-0 reconstruction
[2.4 B events so far]

Additional / looser E_T^{miss} & tau as well as VBF triggers added to increase sensitivity for 125 GeV Higgs in *bb* and $\tau\tau$ modes

Average rate of 400 Hz over 2012 run for prompt trigger streams
(~1700 stable beam hours)

Primary triggers in 2012

★ *Looser selection available later in 2012 data in either prompt or delayed streams*

Signature	Offline selection	Trigger selection L1	Trigger selection EF	L1 Peak (kHz) $L_{peak} = 7\times10^{33}$	EF Ave (Hz) $L_{ave} = 5\times10^{33}$
Single leptons	Single muon p_T > 25 GeV	15 GeV	24 GeV	**8**	**45**
	Single electron p_T > 25 GeV	18 GeV	24 GeV	**17**	**70**
Two leptons	2 muons p_T > 6 GeV	2 × 6(4_{EOF}) GeV (also 2mu4 barrel only)	2 × 6 GeV	**3**	**2**
	2 muons p_T >15 GeV 2 muons p_T > 20,10 GeV	2 × 10 GeV 15 GeV	2 × 13 GeV 18,8 GeV	**1** **8**	**5** **8**
	2 electrons, each p_T > 15 GeV	2 × 10 GeV	2×12 GeV	**6**	**8**
	2 taus p_T > 45, 30 GeV	15,11 GeV	29,20 GeV ★	**12**	**12**
Two photons	2 photons, each p_T > 25 GeV 2 loose photons, p_T > 40,30 GeV	2 × 10 GeV 12,16 GeV	2 × 20 GeV 35, 25 GeV	**6** **6**	**10** **7**
Single jet	Jet p_T > 360 GeV	75 GeV	360 GeV ★	**2**	**5**
E_T^{miss}	E_T^{miss} > 120 GeV	40 GeV	80 GeV ★	**2**	**17**
Multi-jets	5 jets, each p_T > 60 GeV 6 jets, each p_T > 50 GeV	4×15 GeV	5 × 55 GeV 6 × 45 GeV ★	**1**	**8**
b-jets	*b* + 3 other jets p_T > 45 GeV	4 × 15 GeV	4 × 45 GeV + *b*-tag	**1**	**4**
TOTAL				**< 75**	**~ 400 (ave)**

Reconstruction, production, computing

Computing & grid cope with needs, providing the means for timely output of physics results
New Integrated Simulation Framework to flexibilise MC production for large needs → slide in the backup

2012 high pileup challenge

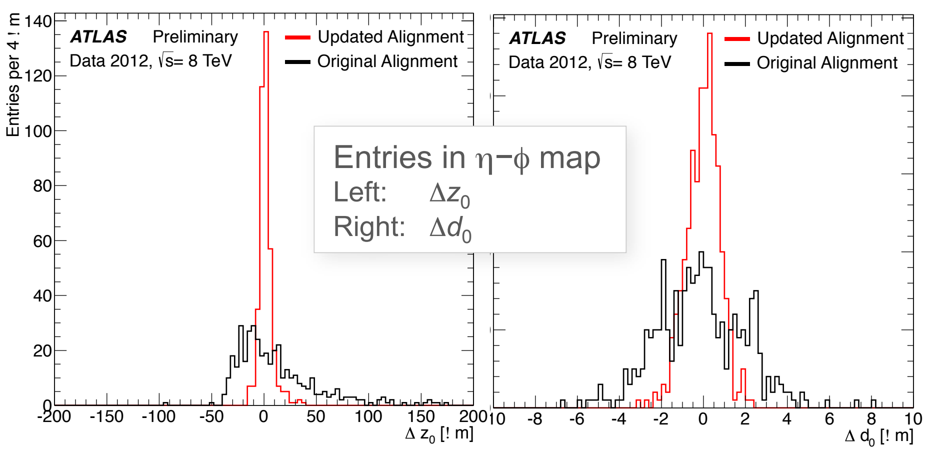
- 6k CPUs in Tier-0 (up to 7.5k when heavy load)
- Reco. time / event: 10–50 sec for $<\mu>$ = 5~50

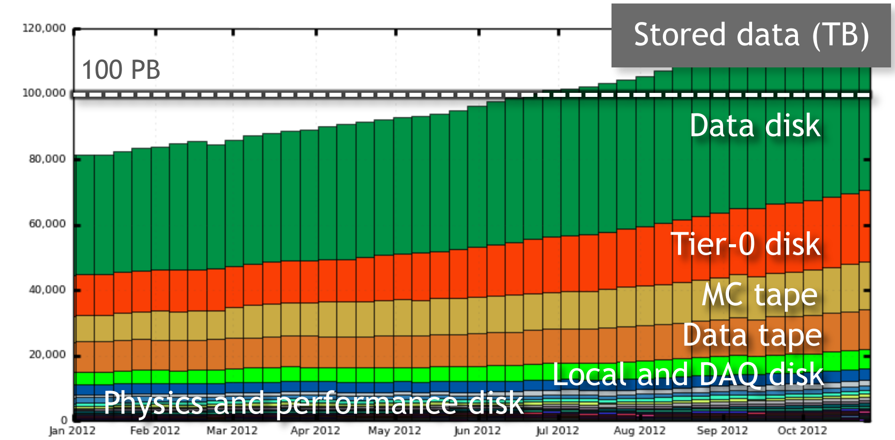
Reprocessing of 2012 data ongoing

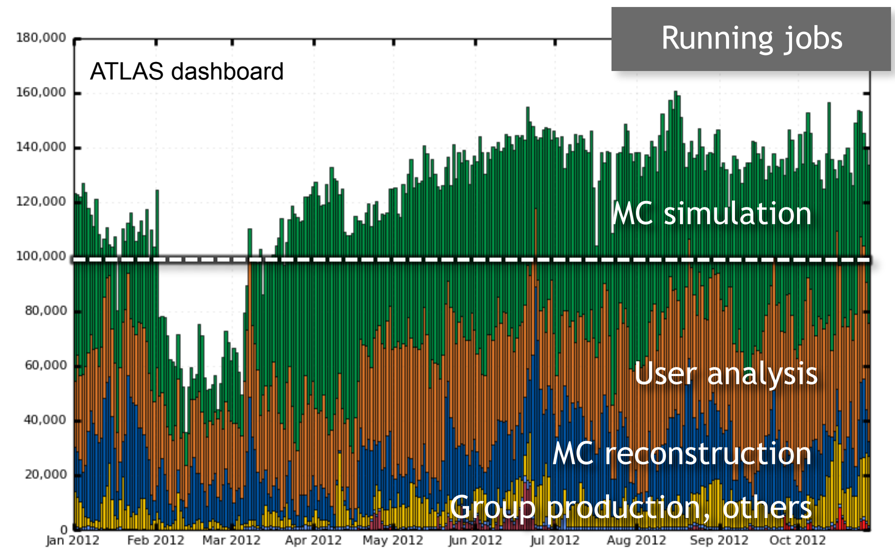
(~2B events)

- Conditions updates only (calibration & alignment, data quality, other fixes), no MC reprocessing

IP precision improvement after alignment (in reprocessing)

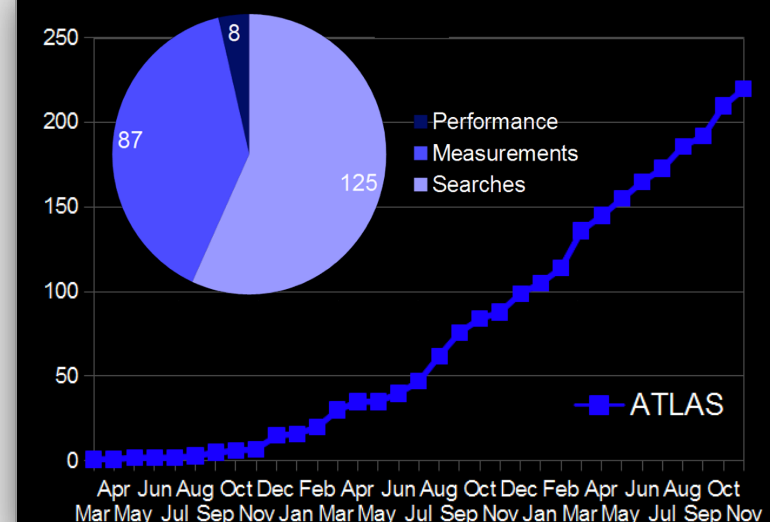






Small extract of huge amount of results available

ATLAS Physics



ATLAS publications

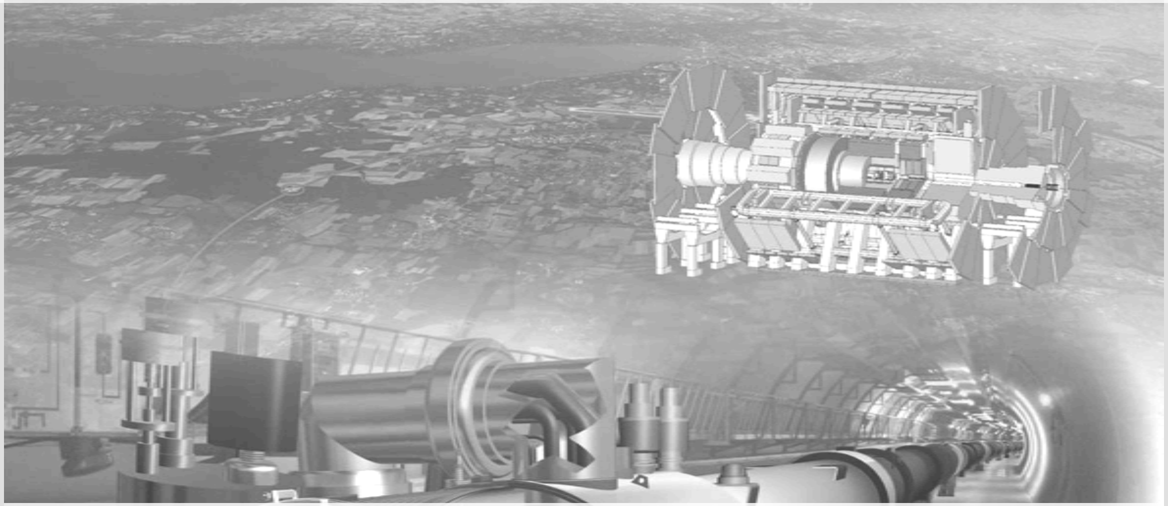
http://atlasresults.web.cern.ch/atlasresults

On Nov 30:

- ATLAS produced 220 papers using collision data
- 421 preliminary conference notes

ATLAS Physics — Recent Highlights

Standard Model Physics

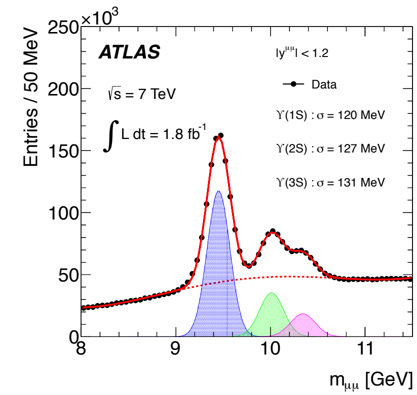


Available statistics allows to perform powerful fiducial and differential and cross-section measurements even in rare channels as dibosons

Differential Υ(1S/2S/3S) production cross-section

Sensitivity greatly improved compared to previous measurements (increased p_T range)

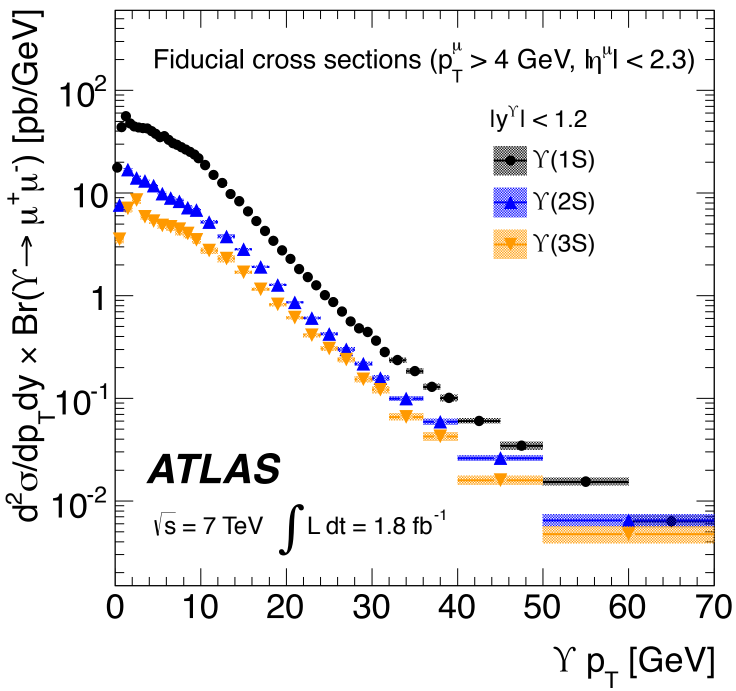
1211.7255



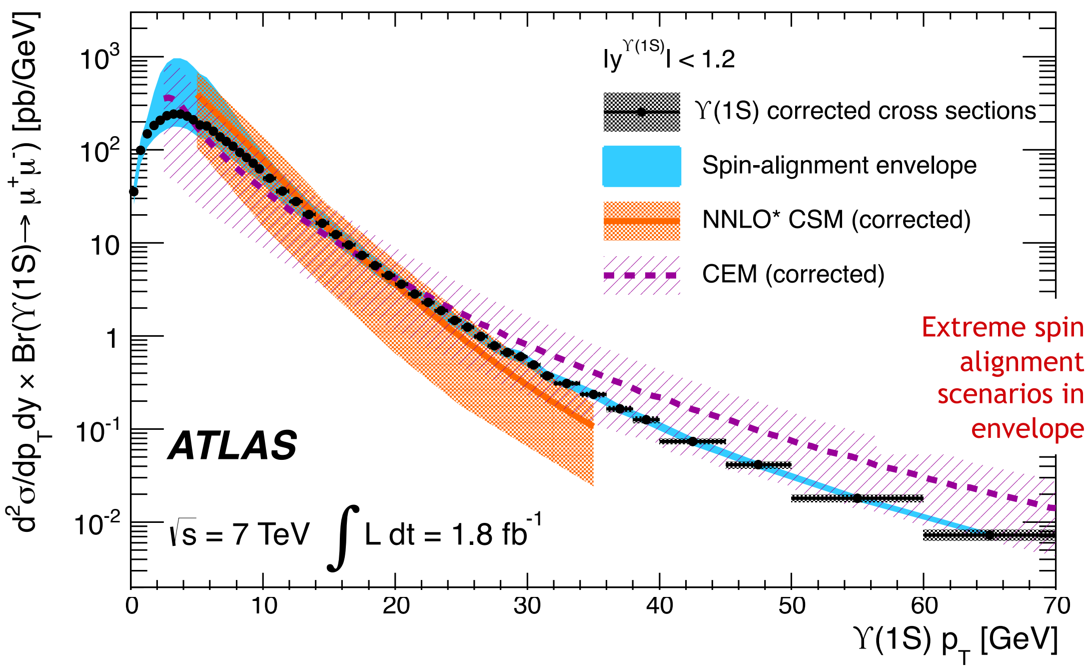
Dimuon final state for $p_T(\mu)$ > 4 GeV, $|\eta_\mu|$ < 2.3

- Comparison of the three states interesting because of contributions from direct production and feed-down from decays of higher mass states (Υ's, χ's)
- Comparison with theory models reveals problems at high p_T

Fiducial cross section



Corrected cross section



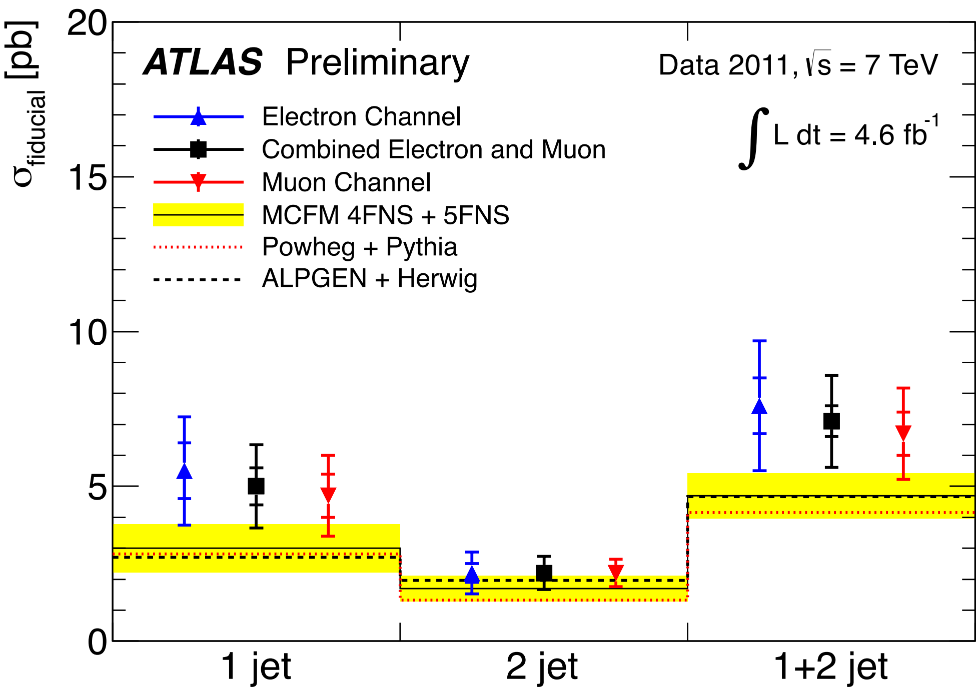
Extreme spin alignment scenarios in envelope

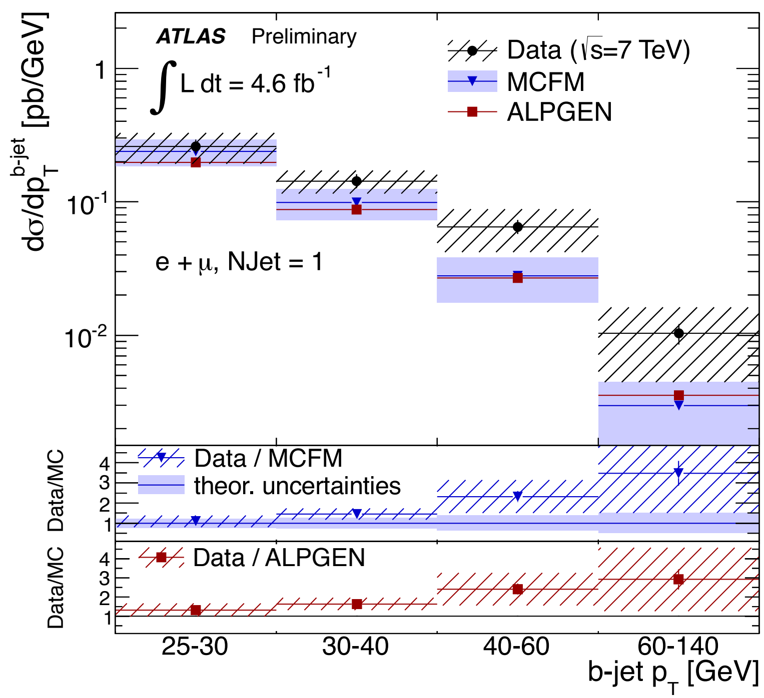
W and *Z* physics — differential measurements

Large statistics allows precise tests of generators/theory, PDFs and bkg to searches

ATLAS-CONF-2012-156

Measurement of *W* + *b*-jets fiducial (p_T > 25 GeV, $|\eta|$ < 2.1) & differential cross section





Fiducial cross section within 1.5σ of theory prediction
p_T spectrum harder in data, but compatible within uncertainties with generators

Diboson physics: WW, WZ, ZZ, $W\gamma$, $Z\gamma$, $\gamma\gamma$

ATLAS performed total, fiducial & differential diboson cross-sections measurements

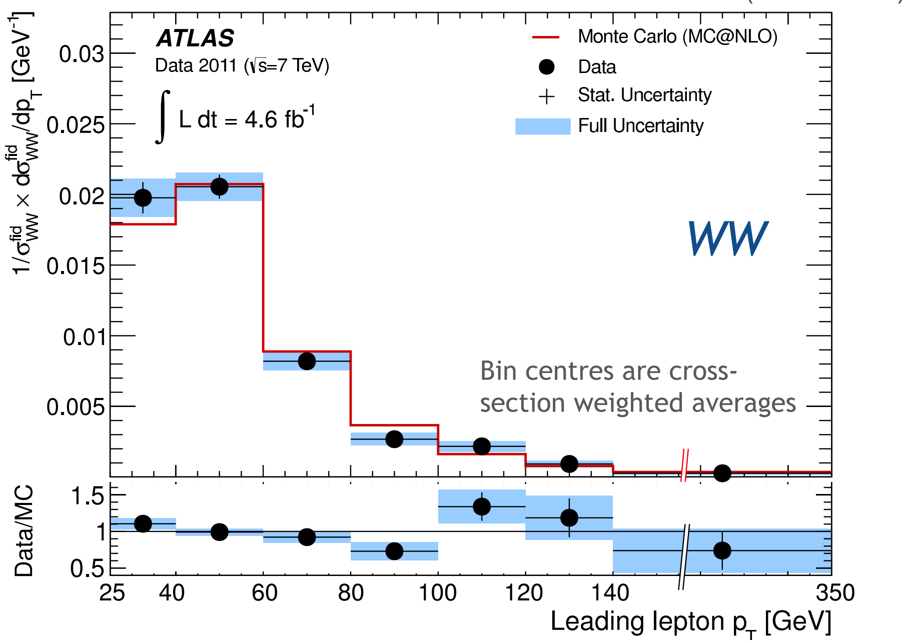
Measured 11 diboson fiducial cross-sections: most are slightly above theory expectation (but syst. and theo. errors correlated)

See last week's ATLAS diboson seminar by Shih-Chieh Hsu: http://indico.cern.ch/conferenceDisplay.py?confId=218398

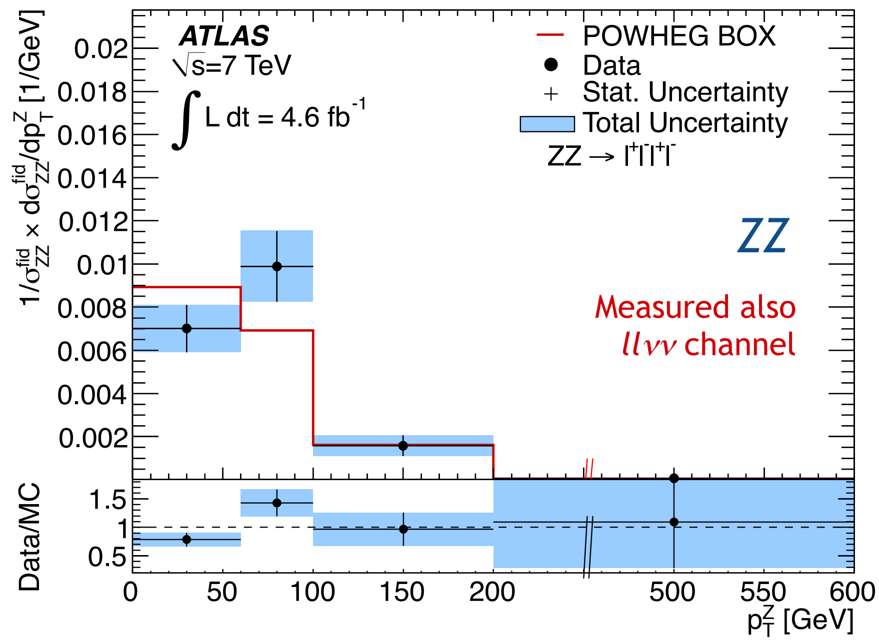
1210.2979, 1208.1390, 1211.6096

Examples for differential cross section measurements: WW, ZZ (7 TeV, 4.6 fb^{-1})

Normalised fiducial differential cross-section (→ unfolded)



Normalised fiducial differential cross-section



So far, satisfying agreement with NLO generators, also for mass spectra. Same for *WZ*

Also searched for diboson resonance production (*ZZ* [8 TeV, ATLAS-CONF-2012-150], $W\gamma$, $Z\gamma$)

Diboson physics: *WW*, *WZ*, *ZZ*, *W*γ, *Z*γ, $\gamma\gamma$

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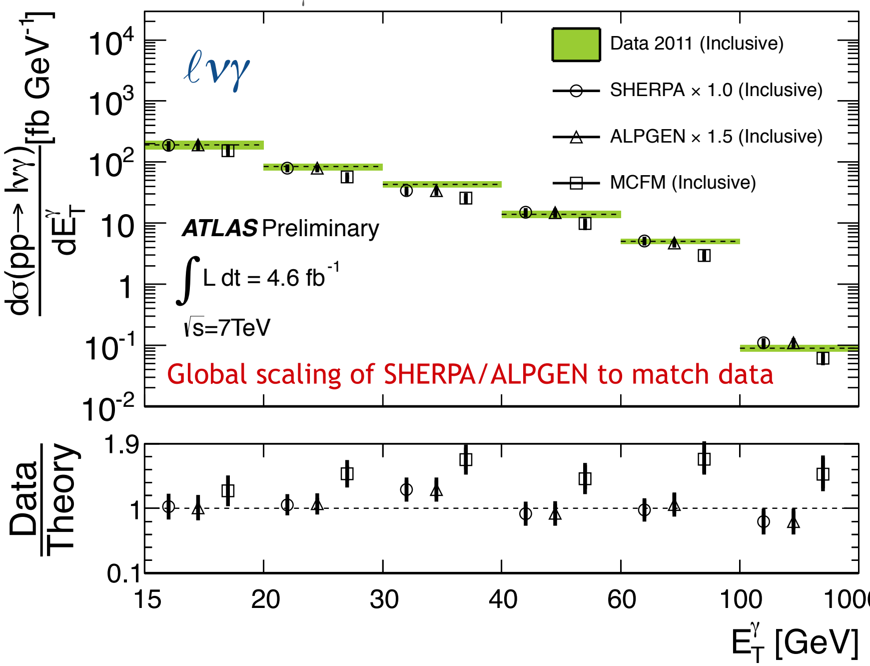
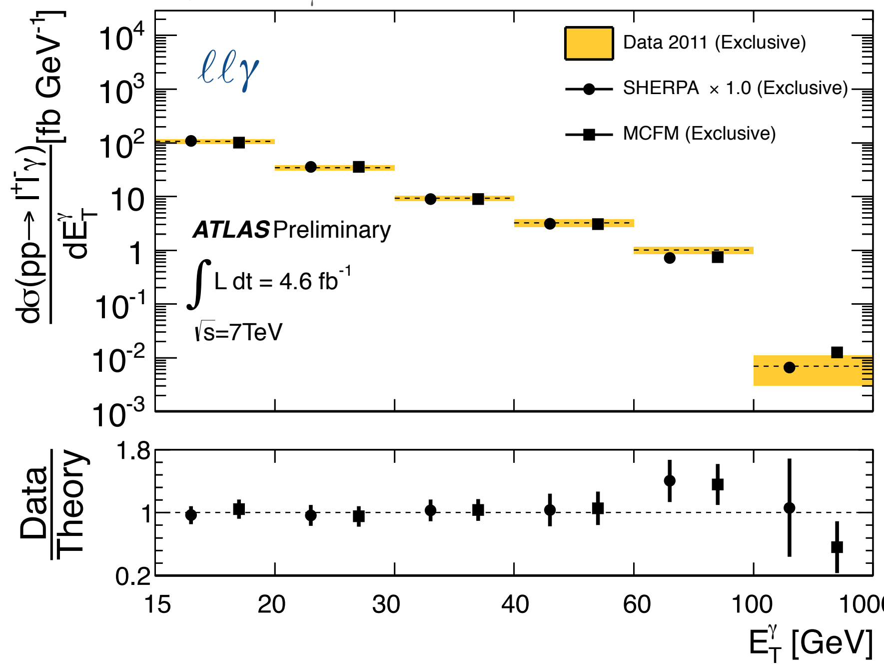
Examples for differential cross section measurements: *W*γ, *Z*γ (7 TeV, 4.6 fb^{-1})

Inclusive E_γ fiducial differential cross-section



N-jet = 0 E_γ fiducial differential cross-section



Too low incl. cross-section by MCFM (NLO, parton-level). Scaled ALPGEN/SHERPA (LO) with multiple quark/gluon emission in ME more accurate → Similar for $\gamma\gamma$ [1211.1913]

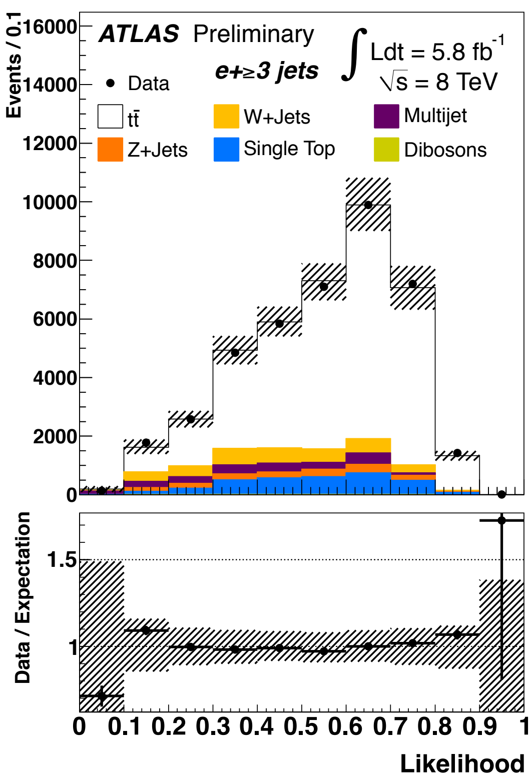
Top pair production cross-section measurement

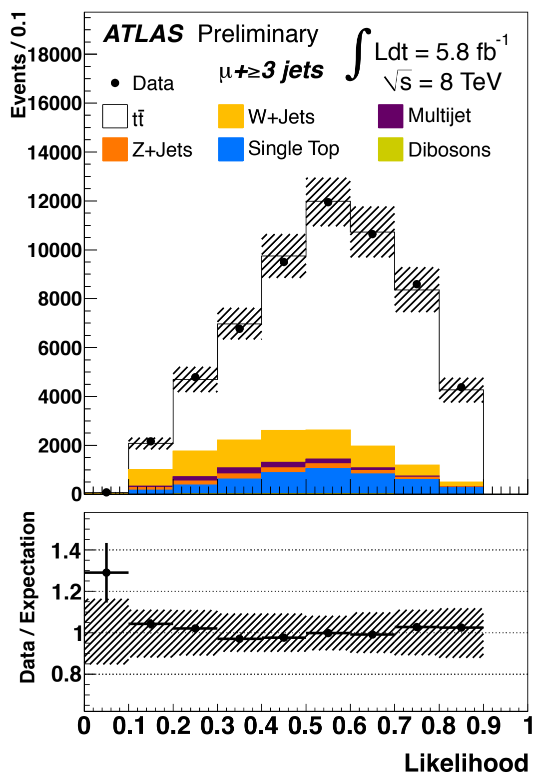
Precision measurement already — all the work is on understanding systematics

8 TeV: ATLAS-CONF-2012-149

Large variety of 7 TeV measurements public: 0/1/2-lepton (incl. taus) — agreement with theory

Measurement of 8 TeV cross-section in 1-lepton channel (5.8 fb^{-1}) using likelihood template fit





Inclusive *tt* cross section (using $m(t)$ = 172.5 GeV):

$$\sigma = 241 \pm 2\ \text{(stat)} \pm 31\ \text{(syst)} \pm 9\ \text{(lumi) pb}$$

Syst. dominated by MC signal modeling (ISR/FSR, generator, parton shower, PDF)

Agreement with theory:

238^{+22}_{-24} pb (HATHOR, approx. NNLO)

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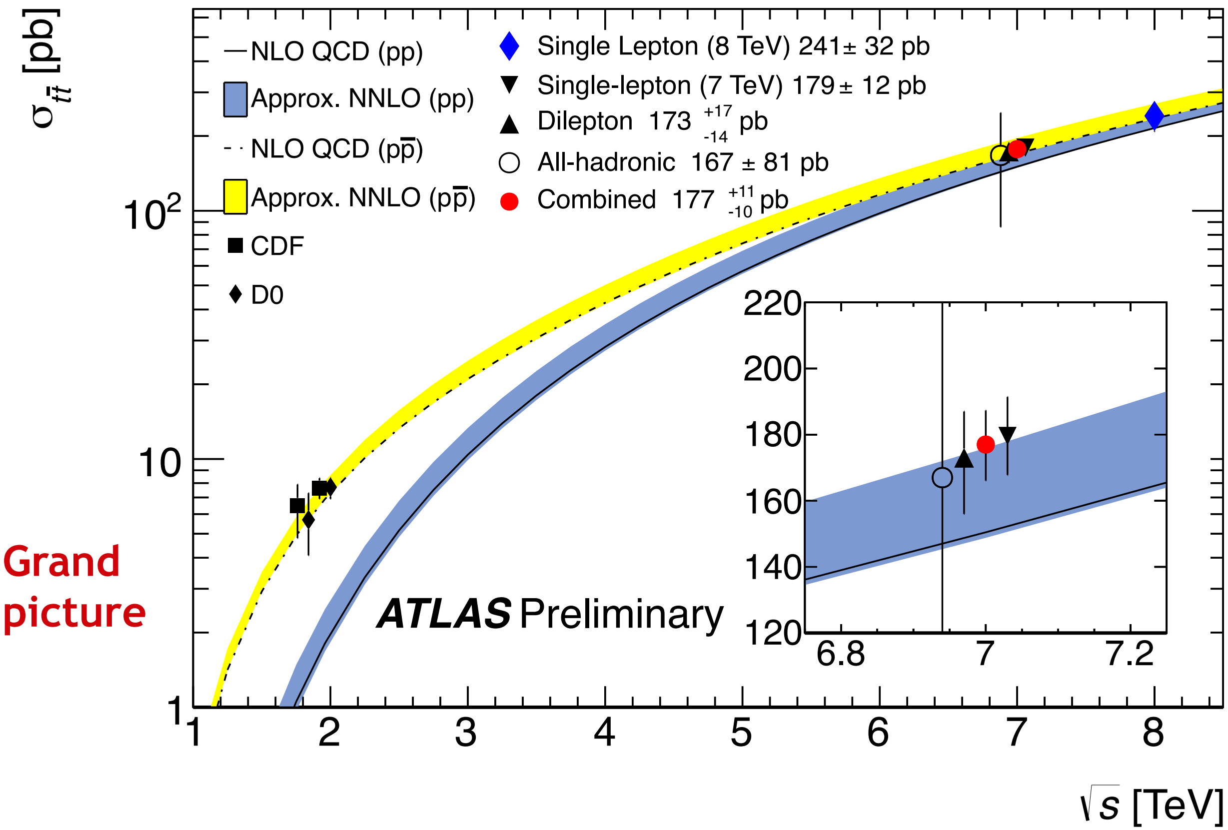

Grand picture

Inclusive tt cross section (using $m(t)$ = 172.5 GeV):

$$\sigma = 241 \pm 2\,(\text{stat}) \pm 31\,(\text{syst}) \pm 9\,(\text{lumi})$$

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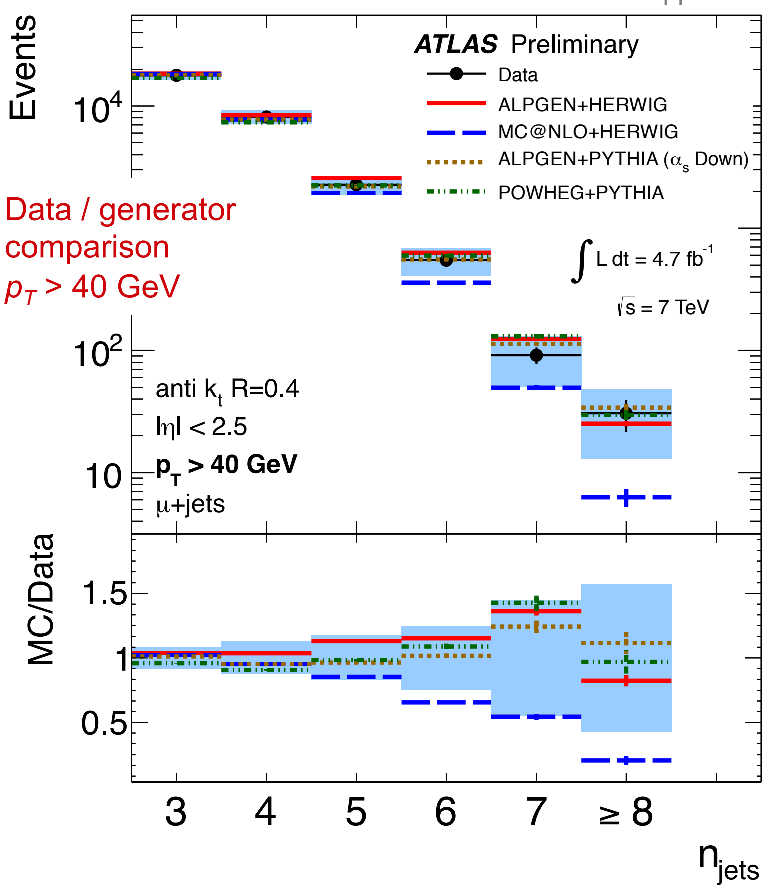
Understanding top pair production at the LHC

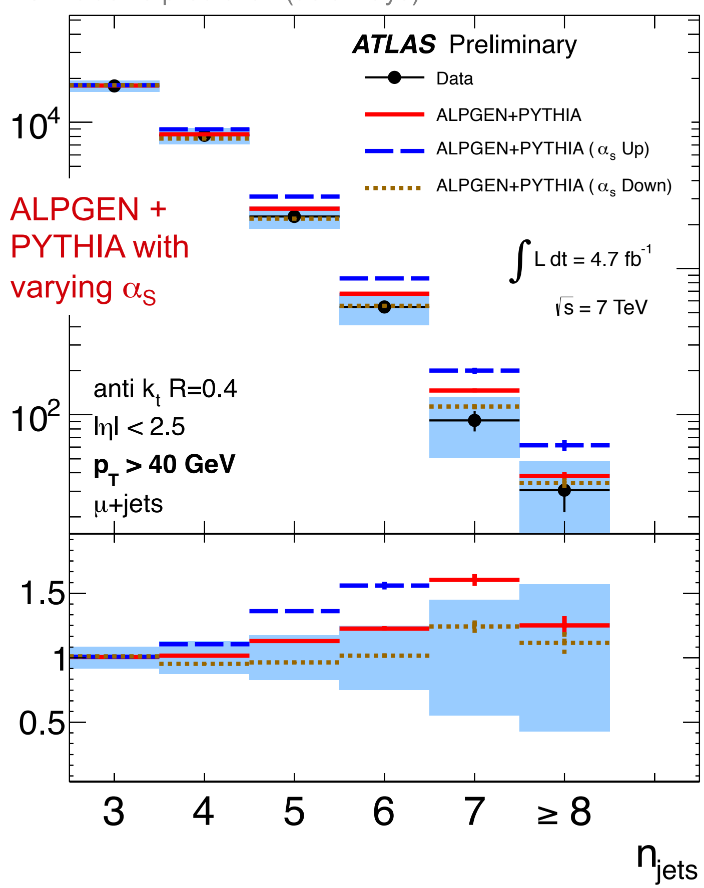
Top pairs in association with jets are dominant background for many BSM searches

ATLAS-CONF-2012-155, see also: 1203.5015

Prelim. measurement of fiducial jet multiplicity in tt production (lepton+jets) at 7 TeV (4.7 fb^{-1})

MC scaled to approx. NNLO inclusive prediction (as always)





Rapidity gap fraction(*) measurements vs. |y| help to assess uncertainties related to ISR/FSR

Variation of α_S and PS parameters describes ISR/FSR uncertainties

Q_0 is the fraction of events with no additional jet radiated within a considered rapidity interval

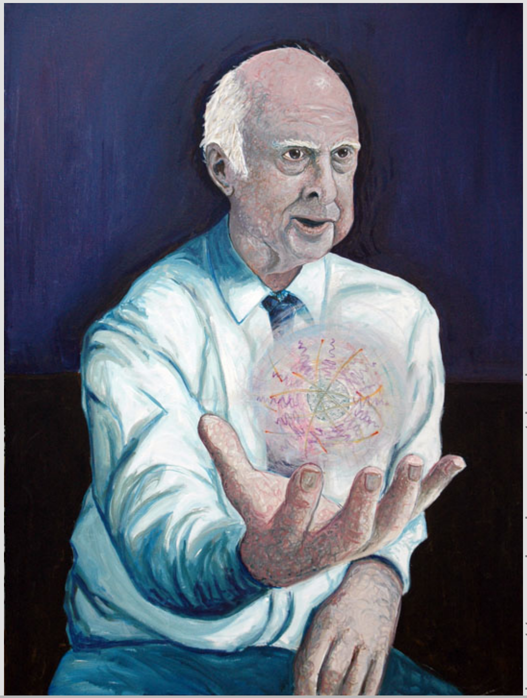
ATLAS Physics — Recent Highlights

Higgs (-*like*)

A new era, new challenges

Higgs physics moves from searches to measurements

Huge efforts spent on scrutinising systematic effects and designing robust analyses



http://www.shardcore.org/shardpress

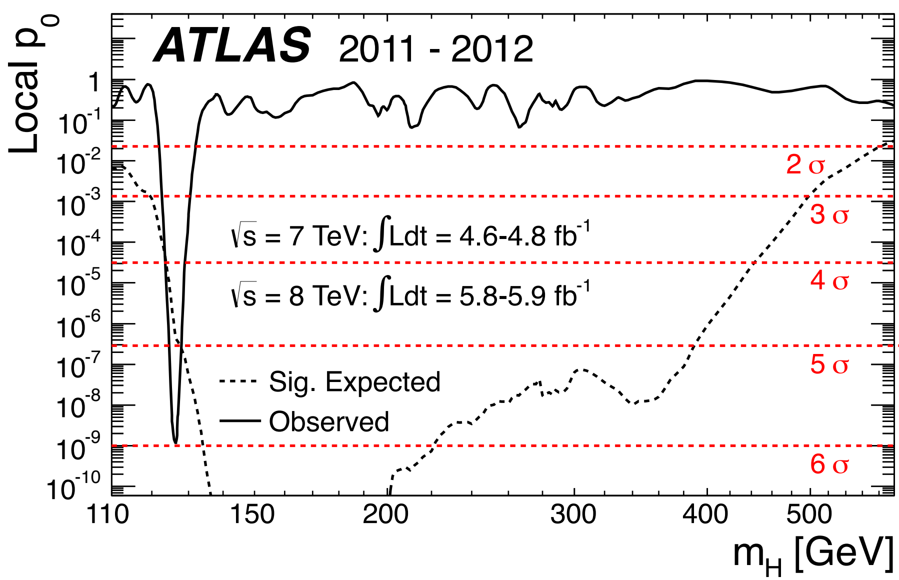
Higgs status after Summer 2012

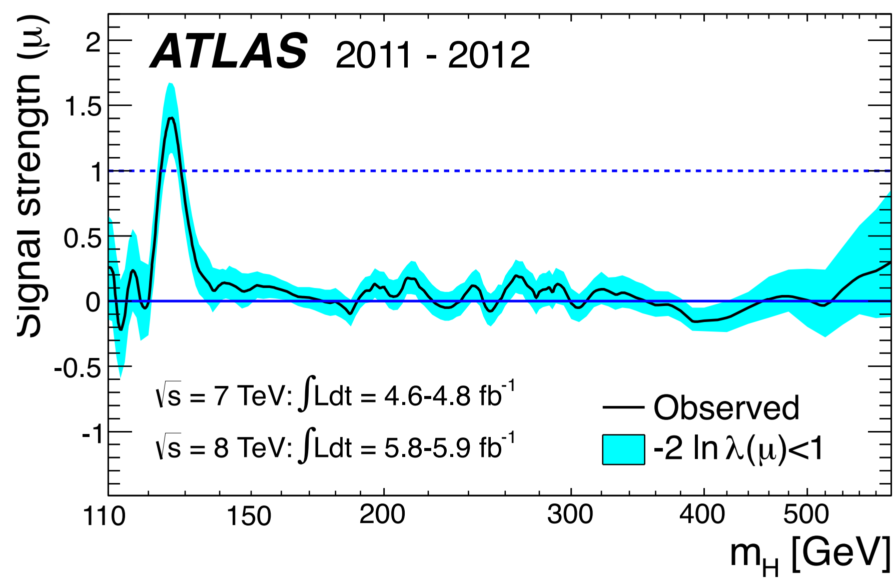
One new boson with Higgs-like properties … nothing else around

1207.7214

Combination of 7 TeV (~4.7 fb^{-1}) and 8 TeV (~5.8 fb^{-1}) data

Discovery *p*-value with contributions from $\gamma\gamma$, *ZZ** and *WW*, slighter stronger signal than SM





For HCP 2012: update of *H* → *WW*, $\tau\tau$, *bb* analyses with 13.0 fb^{-1} at 8 TeV

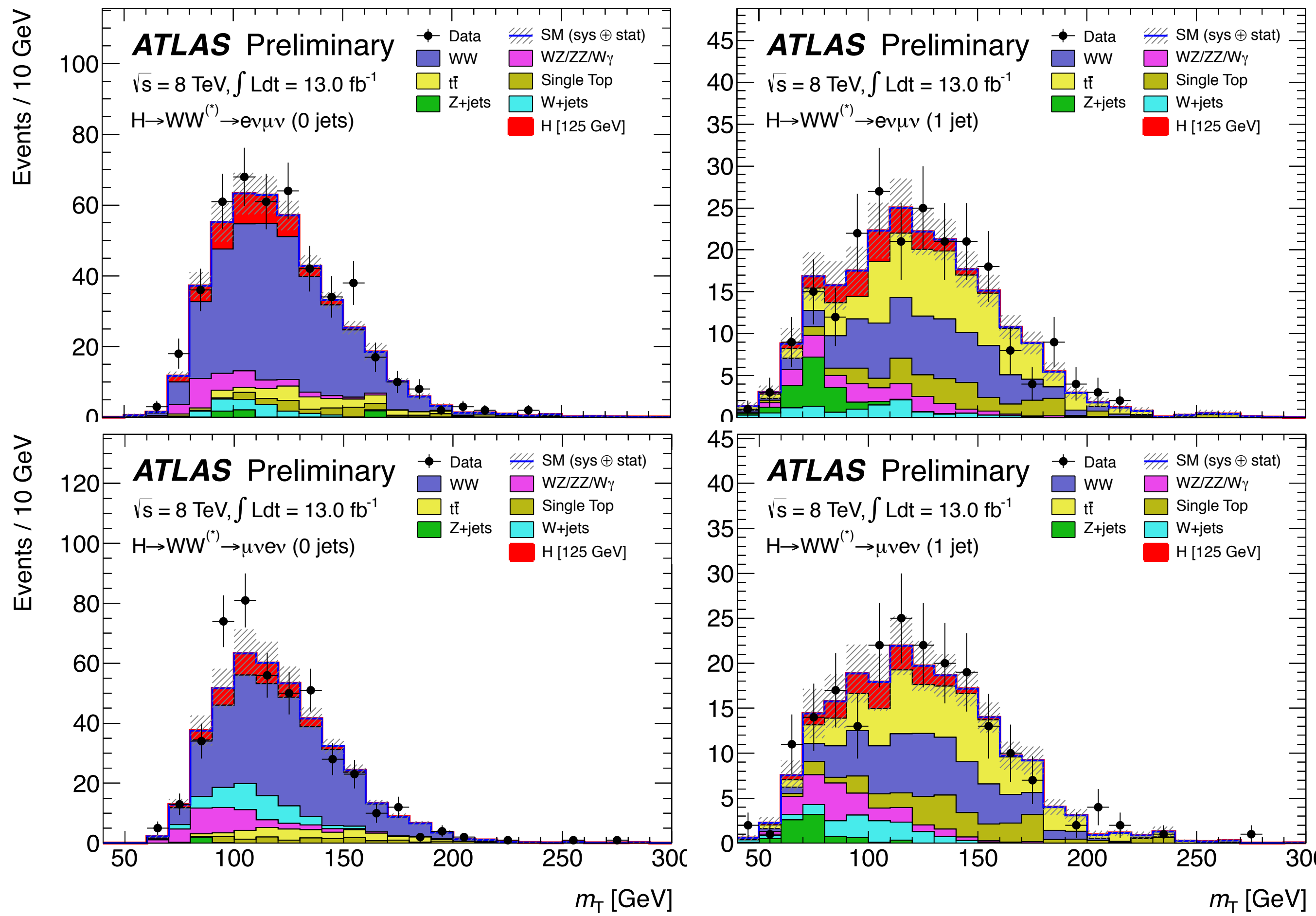
$H \rightarrow WW^{(*)} \rightarrow e\mu + 2\nu$

Different-flavour channel and 8 TeV (13 fb^{-1}) uncombined result only for this update

ATLAS-CONF-2012-158

Numerous relevant backgrounds: diboson, top, *W*/*Z*+jets, estimated from control regions

Distinguish 0/1 jet and leading lepton
→ 4 categories, main discrimination with: m_{ll}, $\Delta\phi_{ll}$, m_T

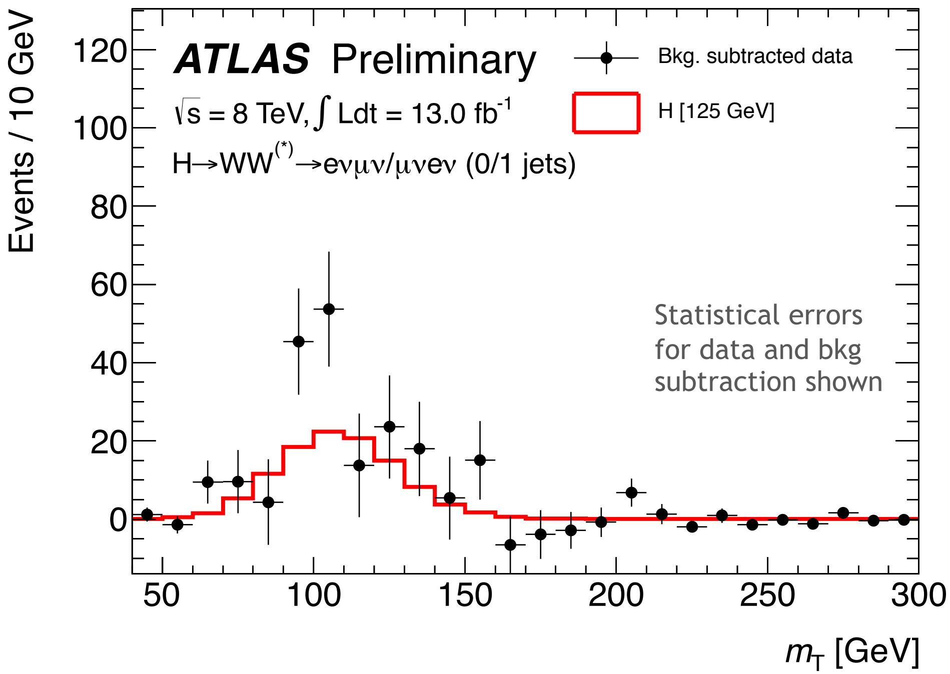


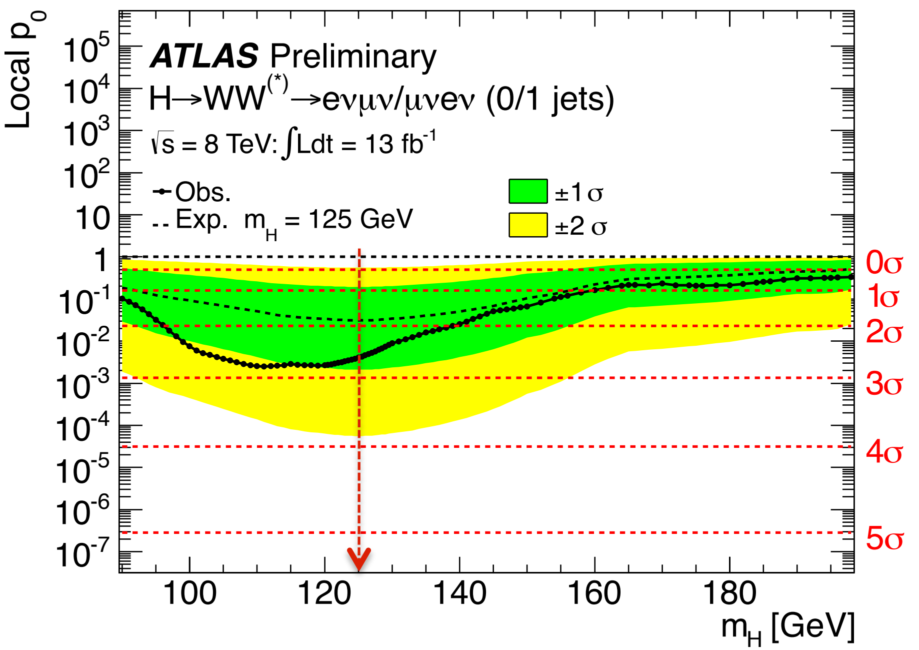
$H \rightarrow WW^{(*)} \rightarrow e\mu + 2\nu$

Different-flavour channel and 8 TeV (13 fb^{-1}) uncombined result only for this update

ATLAS-CONF-2012-158

Background subtracted transverse mass (stat errors only) with expected *H*(125) signal (left)
Background-only *p*-value (right)





$\mu(125) = 1.5 \pm 0.6$ / Significance (125): 2.6σ [exp: 1.9σ]

$\sigma(pp \rightarrow H(125)) \cdot \mathrm{BR}(H \rightarrow WW) = 7.0^{+1.7}_{-1.6}(\mathrm{stat})^{+1.7}_{-1.6}(\mathrm{syst\ theo}) \pm 1.3(\mathrm{syst\ exp}) \pm 0.3(\mathrm{lumi})$ pb

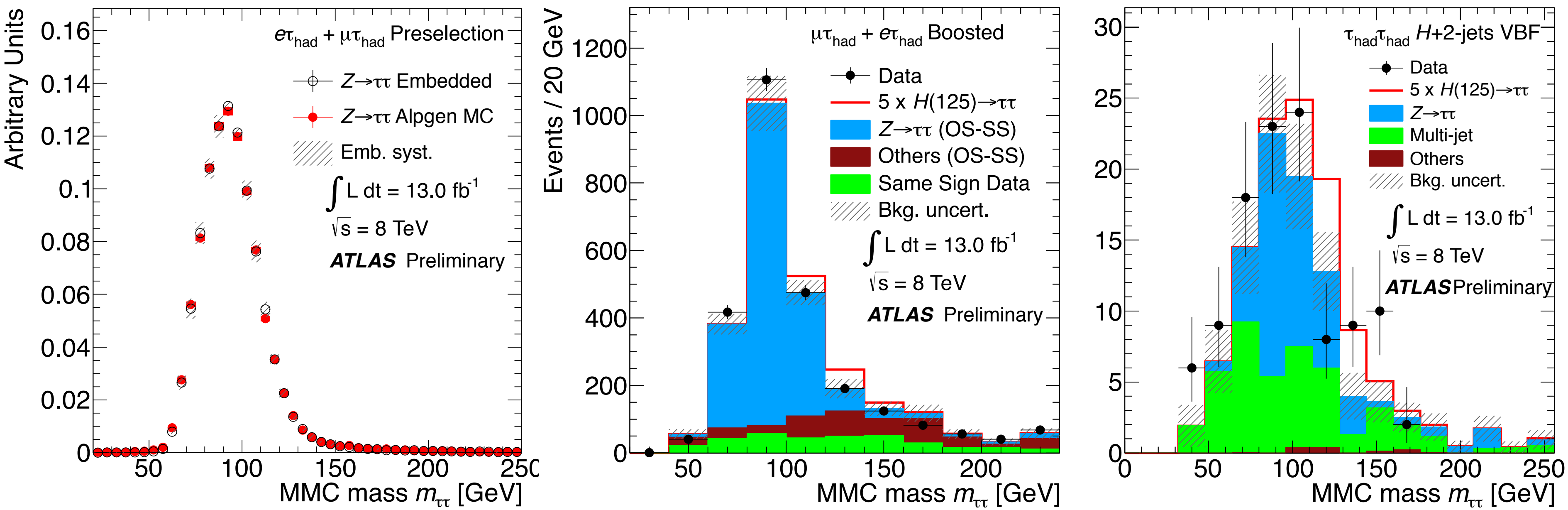
$H \rightarrow \tau\tau$

Combined and reoptimised 7+8 TeV analysis

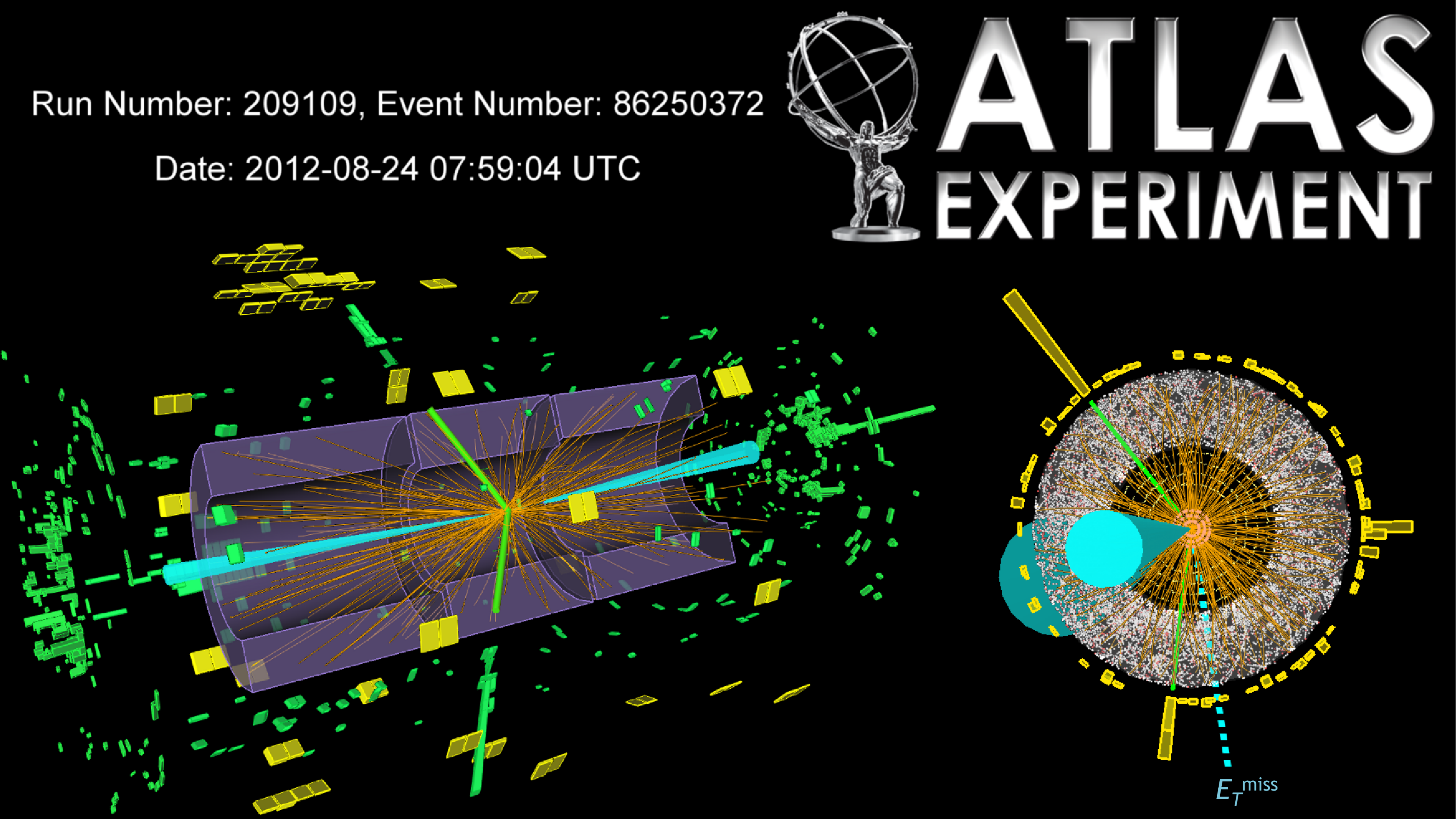
ATLAS-CONF-2012-160

- Build exclusive categories: lep-lep, lep-had, had-had and jets: 0, 1 (boosted or not), 2 (VBF, VH)
- BDT-based tau identification, Higgs discrimination based on $m_{\tau\tau}$
- Use MMC (missing mass calculator) to estimate $m_{\tau\tau}$, $\sigma(m_{\tau\tau})$ = 13% ~ 20%, best for boosted τ
- Backgrounds dominated by $Z \rightarrow \tau\tau$ (use "τ embedded" $Z \rightarrow \mu\mu$), also top and fakes important

Test embedding in MC in $\tau\tau$ (also $\mu\mu$)



$H \rightarrow \tau\tau$ (doubly hadronic) candidate in VBF channel (m_{MMC} = 131 GeV)

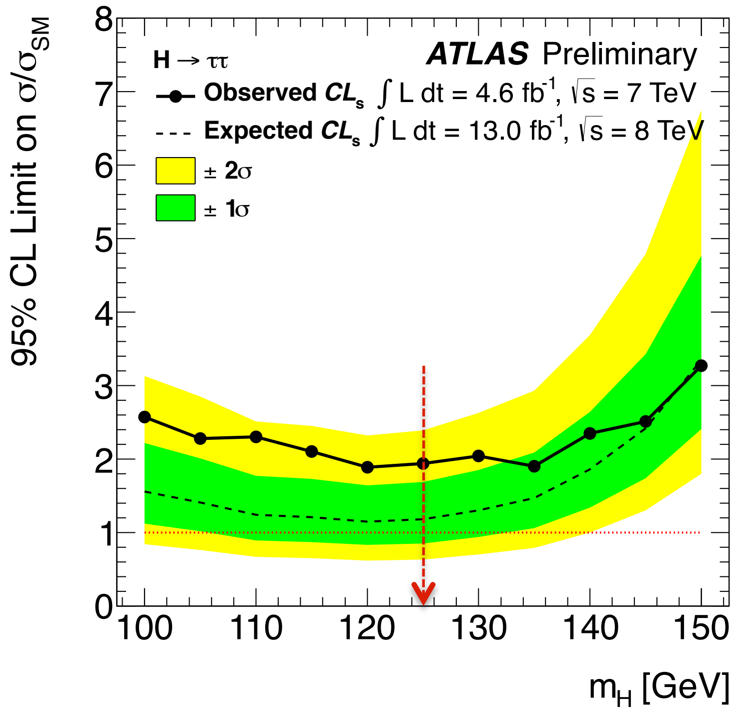


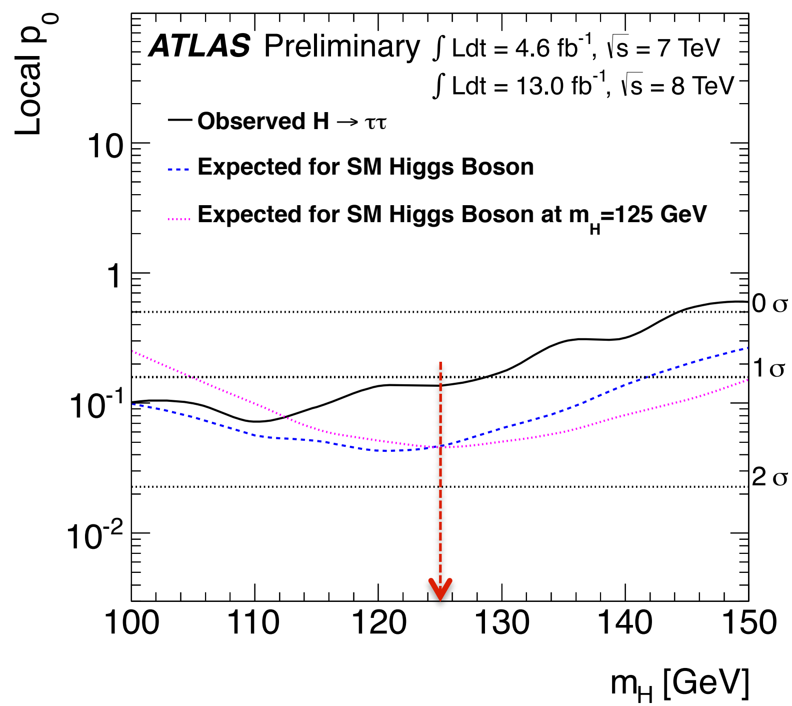
$H \rightarrow \tau\tau$

Combined and reoptimised 7+8 TeV analysis → total of 25 exclusive fit categories

ATLAS-CONF-2012-160

Available statistics allows meaningful VFB vs. non-VBF scan, similar sensitivity in both modes, but best VBF constraint from all Higgs decays





$\mu(125) = 0.7 \pm 0.7$

95% CL limit (125): 1.9 [exp: 1.2] × SM / Significance (125): 1.1σ [exp: 1.7σ]

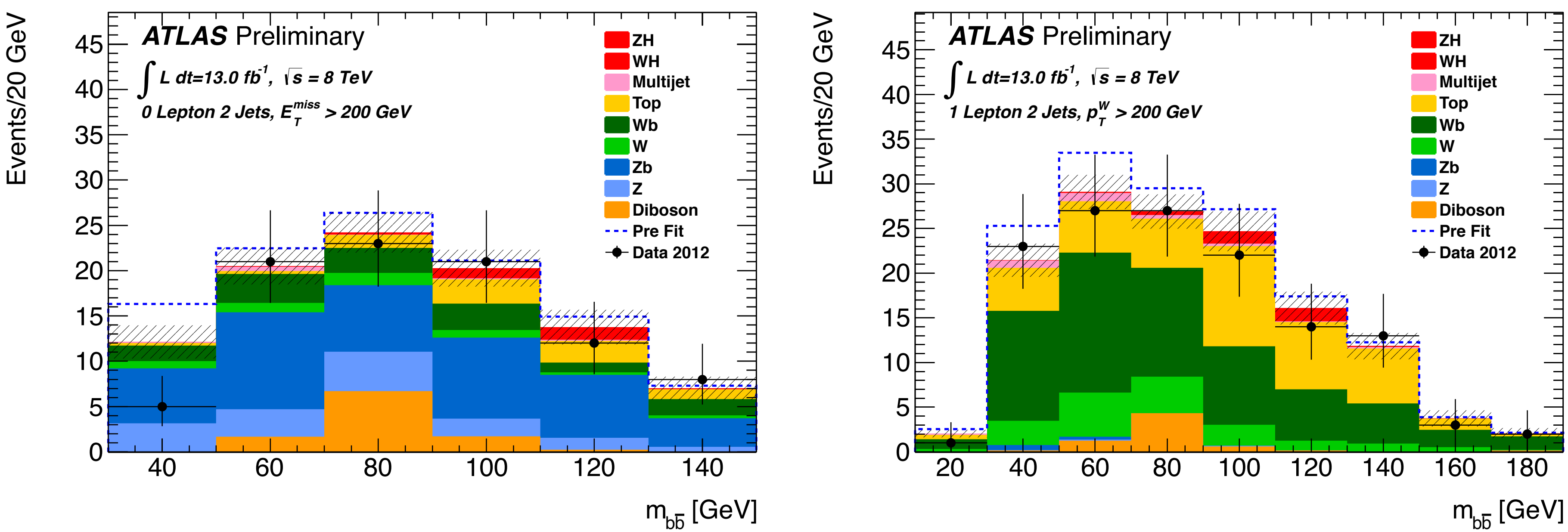
VH production with $H \rightarrow bb$

Combined and reoptimised 7+8 TeV analysis

Also new 7 TeV analysis of tt+H, with $H \rightarrow bb$ [ATLAS-CONF-2012-135]

ATLAS-CONF-2012-161

- Require 2 *b*-tags and distinguish 0, 1, 2 lepton channels, where 0-lepton uses E_T^{miss} trigger
- Higgs discrimination based on m_{bb}, resolution of ~16%, improved by including muons
- Categories in E_T^{miss}, jets, $p_T(V)$ [depending on channel] → reduced background for boosted Higgs
- Obtain *W*/*Z* + light/*c*/*b* & top scale factors from flavour pre-fit, *W*/*Z*+*b* and top vary in final fit
- Dominant systematics from the *b* and *c* tagging and jet/E_T^{miss} scales



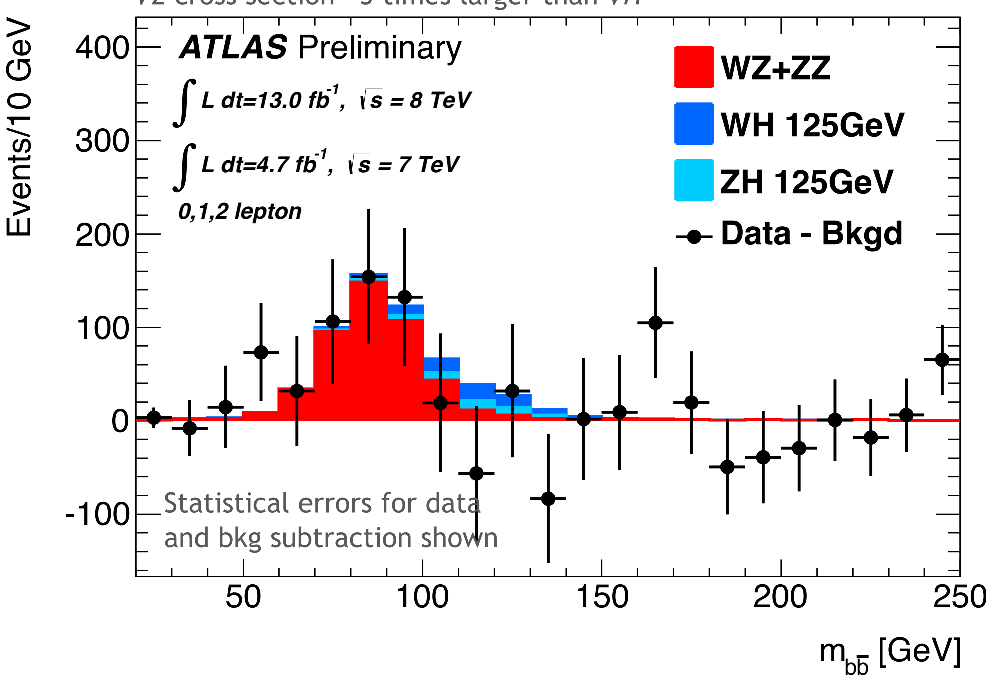
VH production with $H \rightarrow bb$

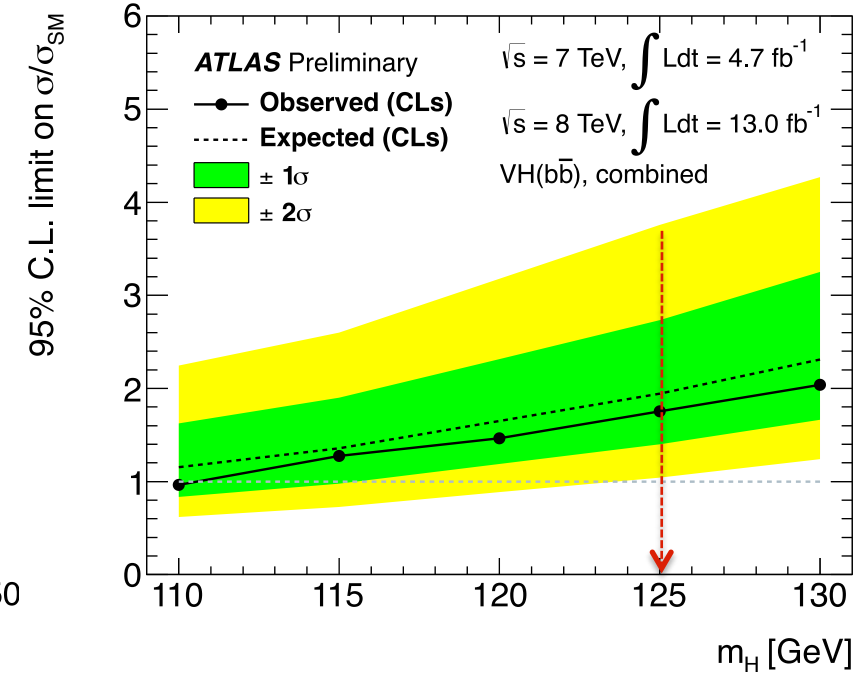
Combined and reoptimised 7+8 TeV analysis → 16 exclusive fit categories

ATLAS-CONF-2012-161

Fitting cross check (left): detect expected *WZ* and *ZZ* peak with $Z \rightarrow bb$.
Plot sums over categories, all non-diboson bkgs subtracted. Significance of peak: 4σ

VZ cross section ~5 times larger than *VH*





$\mu(125) = -0.4 \pm 0.7(\text{stat}) \pm 0.8(\text{syst})$ / 95% CL limit (125): 1.8 [exp: 1.9] × SM

Updated Higgs combination

Simplest analysis only: combination of three new results to derive combined μ

ATLAS-CONF-2012-162

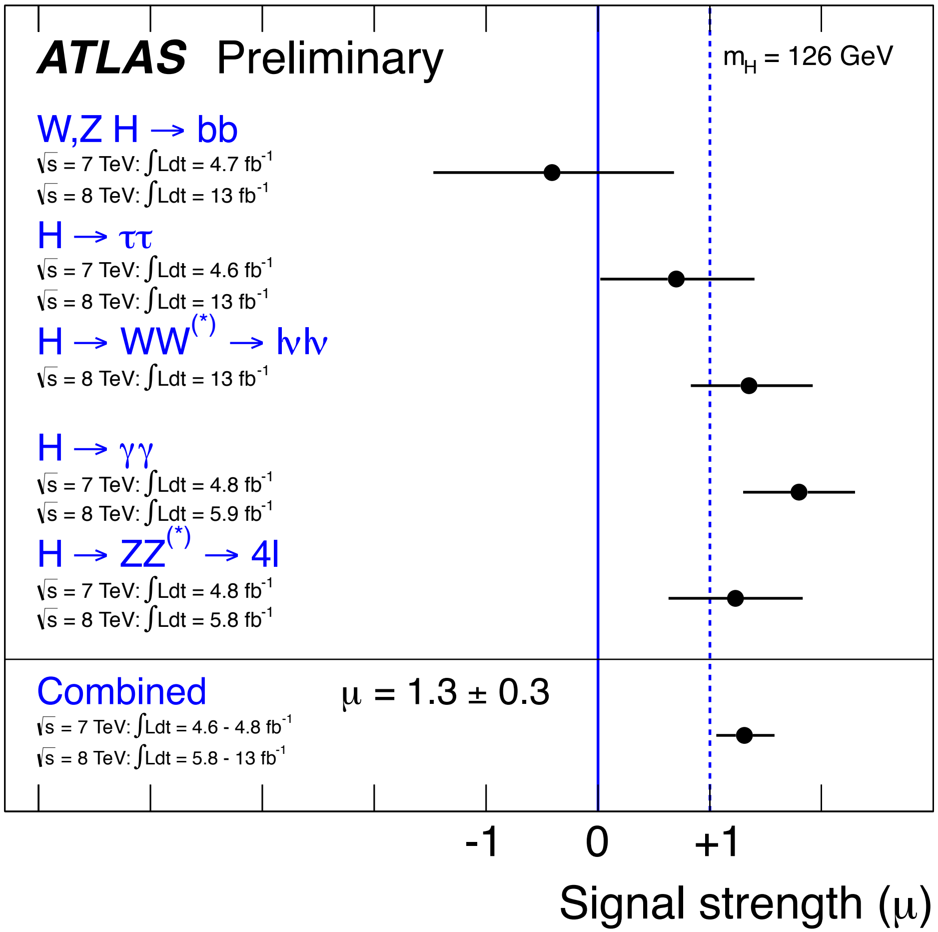
Previous result [July paper, using 7 TeV analyses of $\tau\tau$, bb, 5.8 fb^{-1} analyses for $\gamma\gamma$, ZZ, WW] gave: $\mu = 1.4 \pm 0.3$

New result: $\mu = 1.3 \pm 0.3$

Compatibility with common μ is 36%

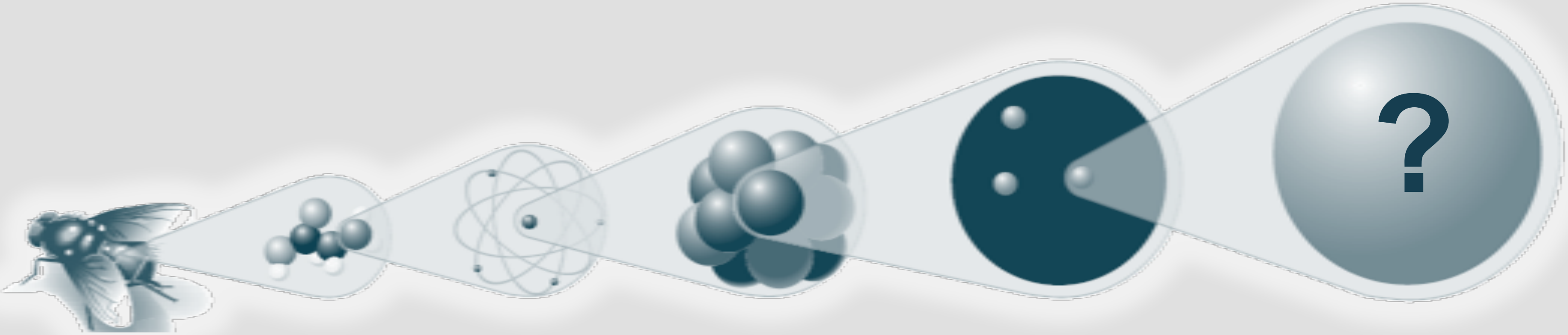
Compatibility with SM $\mu = 1$ is 23%

Higgs or Higgs-like, that is the …



ATLAS Physics — Recent Highlights

Searches



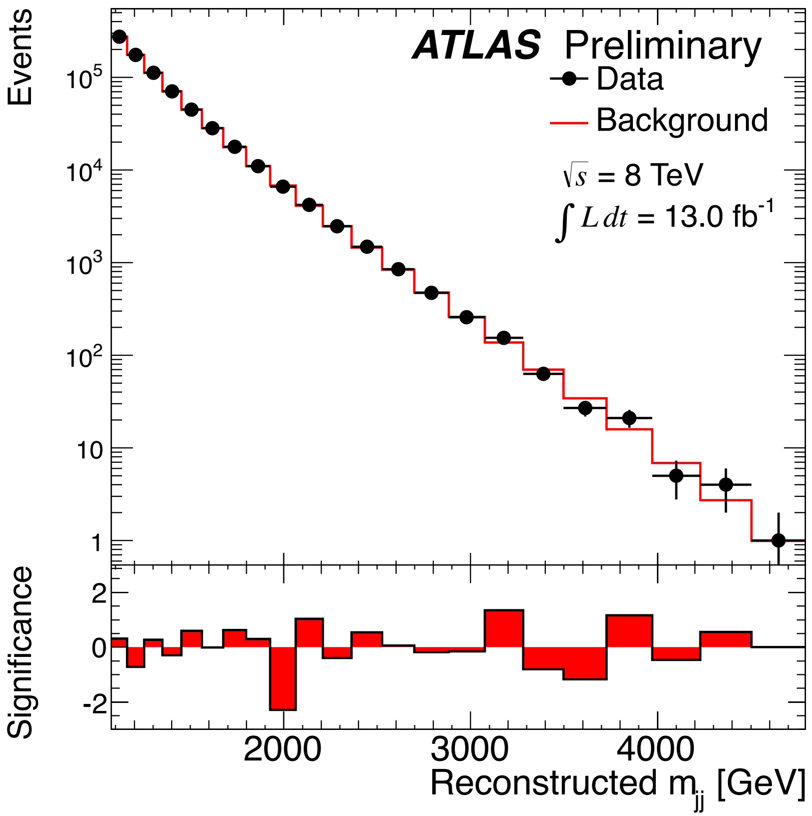
LHC reaches deeply into matter

ATLAS responds with a broad and intense BSM research programme

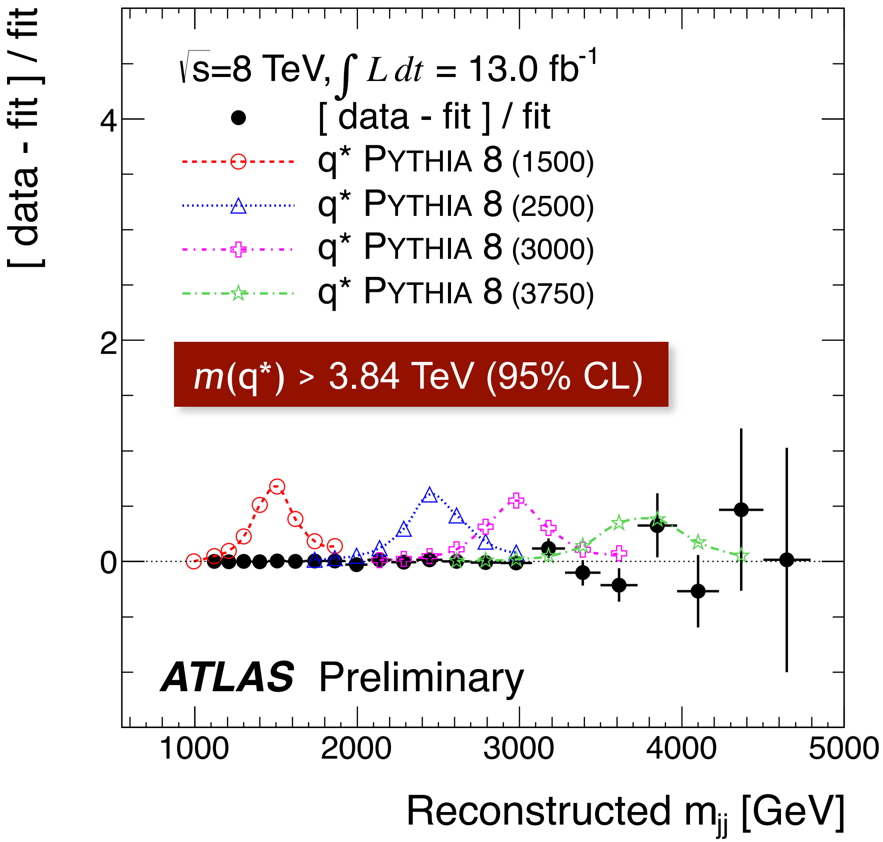
ATLAS mines its data for new physics in events with jets … gradually approaching the limits of phase space

ATLAS-CONF-2012-148

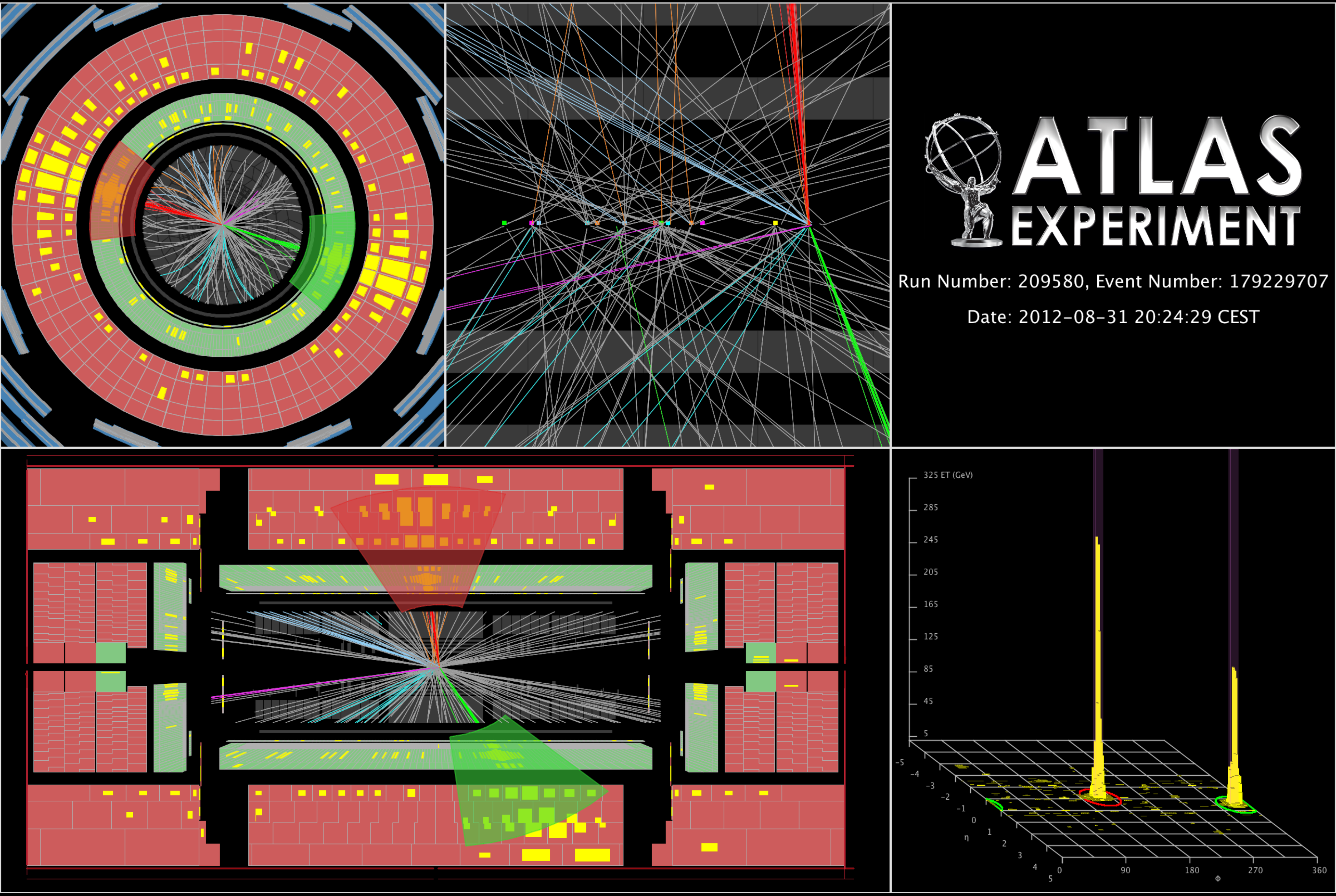
Observed and fitted **dijet mass**



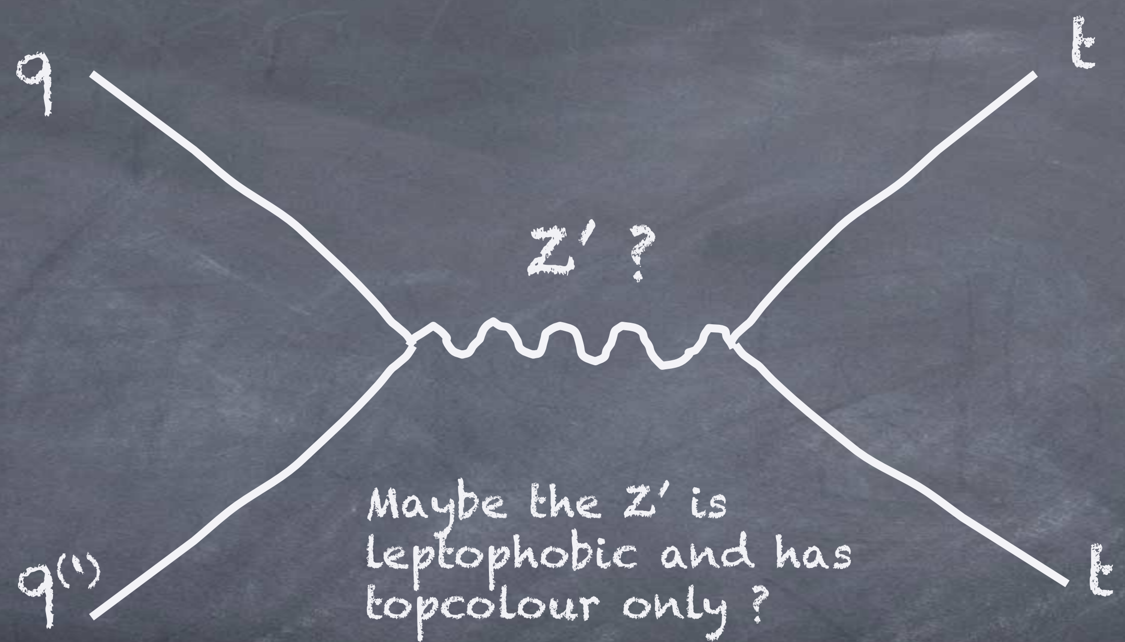
Data / fit ratio, compared to four q* models



The highest-mass central dijet event collected. The two central high-p_T jets have an invariant mass of 4.69 TeV



ATLAS mines its data for new resonances decaying to top pairs …



If the *Z'* is very heavy, the outgoing tops will be strongly boosted; hadronic tops will be merged
A powerful semileptonic *tt* resonance search w/ boosted techniques already presented last time

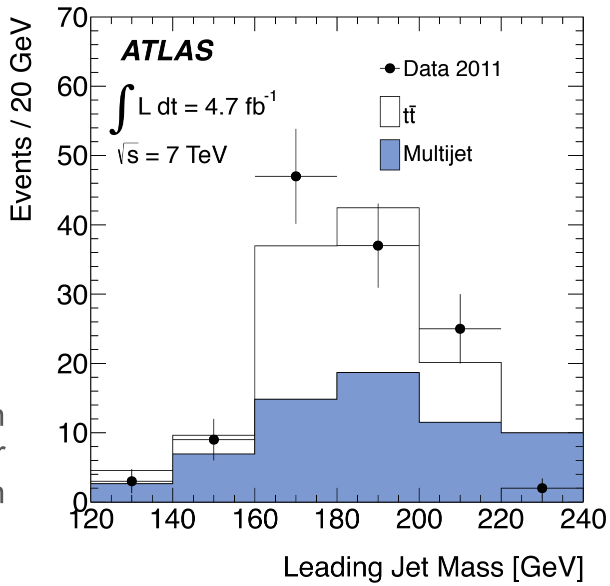
ATLAS-CONF-2012-136, limit: 1.7 TeV (95% CL)

ATLAS mines its data for new resonances decaying to top pairs … searching for *tt* fully-hadronic resonances in boosted regime

1211.2202, see also: ATLAS-CONF-2012-136

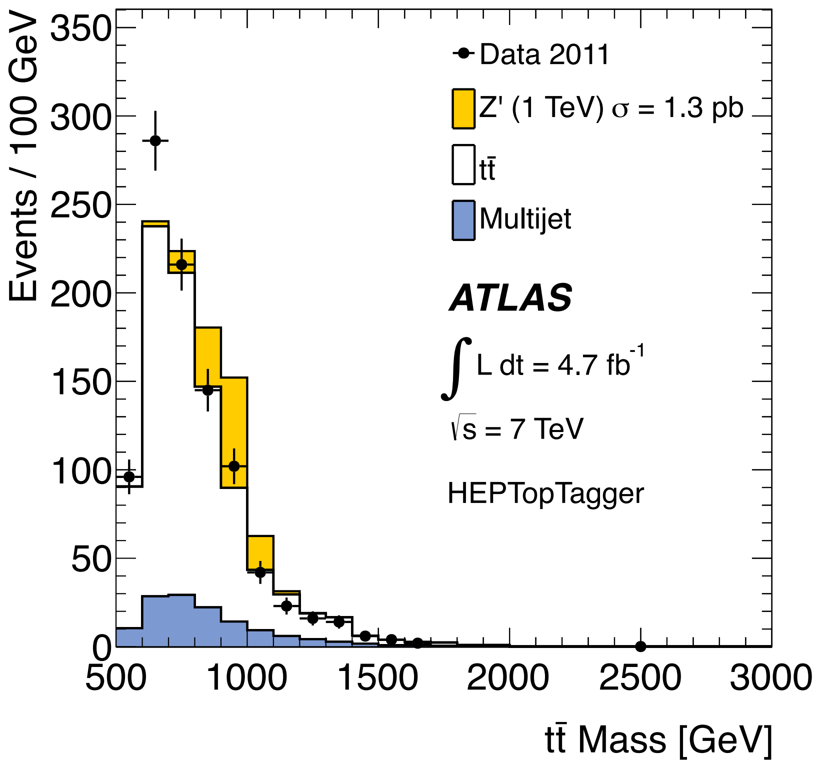
Two methods identify merged hadronic top decays

- ***HEP-Top-Tagger*** uses substructure of "fat jets"
- ***Top-Template-Tagger*** uses calorimeter templates



Jet mass of leading jets in Top-Template-Tagger signal region

m(*tt*) after HEP-Top-Tagger identification



Leptophobic topcolour *Z'* excluded up to 1 TeV at 95% CL

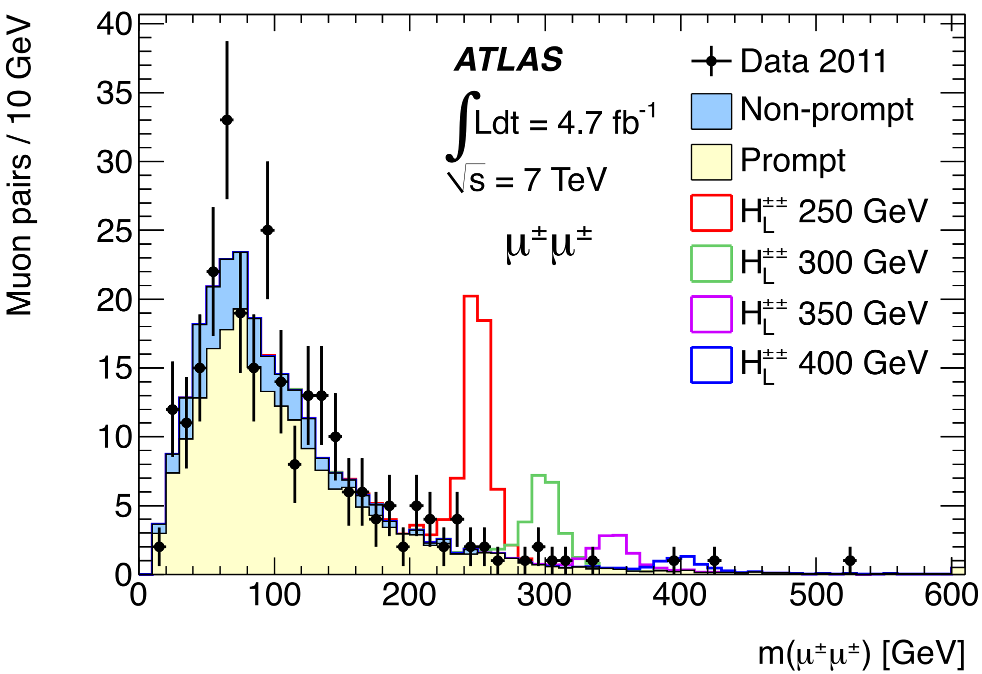
Boosted technique also exploited for other searches

ATLAS mines its data for new resonances in events with leptons … for example: dilepton, like-sign dilepton, lepton-γ resonances

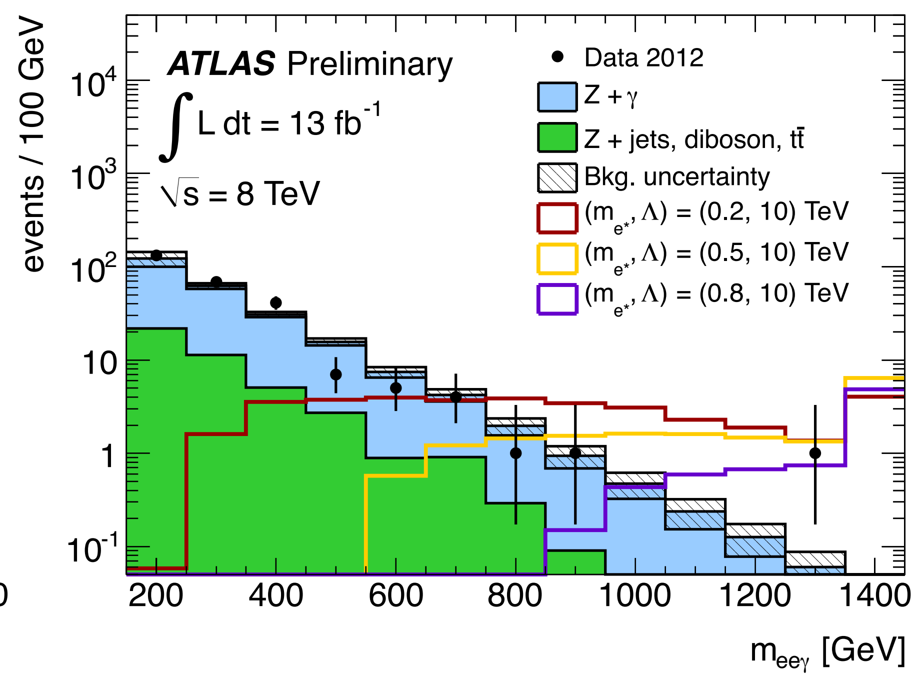
Dilepton resonance search: $m(Z'_{SSM}) > 2.49$ TeV (95% CL, 6.1 fb^{-1}) ATLAS-CONF-2012-129

1210.4538, 1210.5070, 1210.8389, ATLAS-CONF-2012-146

Doubly charged Higgs produce narrow like-sign resonance



Observed and predicted $ee\gamma$ mass and signal models



Prompt like-sign leptons powerful probe for many forms of new physics

For compositeness scale $\Lambda = m(l^*)$: exclude excited leptons < 2.2 TeV (95% CL)

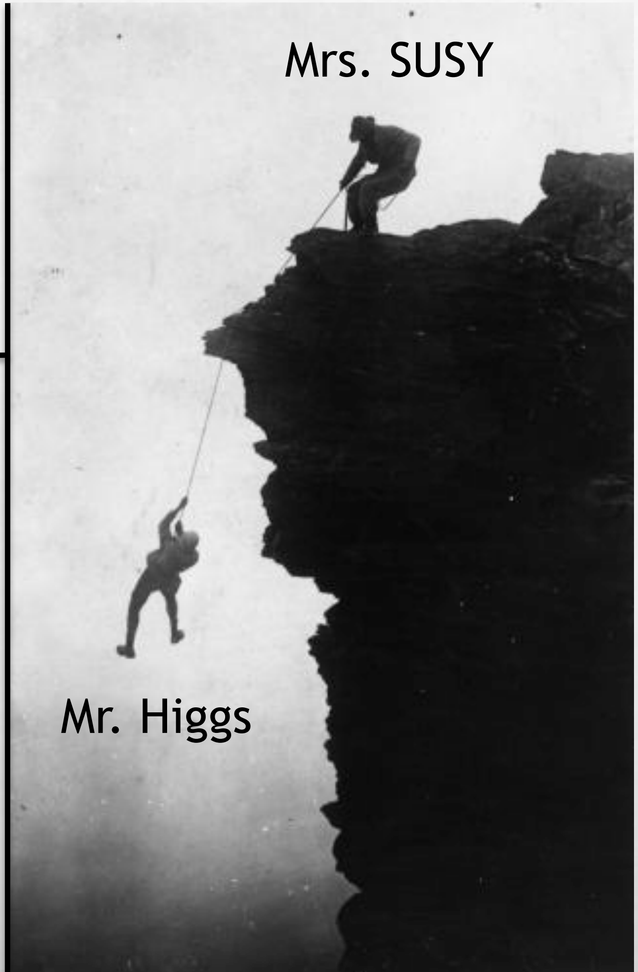
Supersymmetry

Not only that ! Very rich phenomenology

Broad and deep SUSY research programme in ATLAS

See recent (Oct 23) ATLAS seminar by Nick Barlow reviewing results on long-lived particle searches with ATLAS

The scalar precipice



EW scale^{-1}

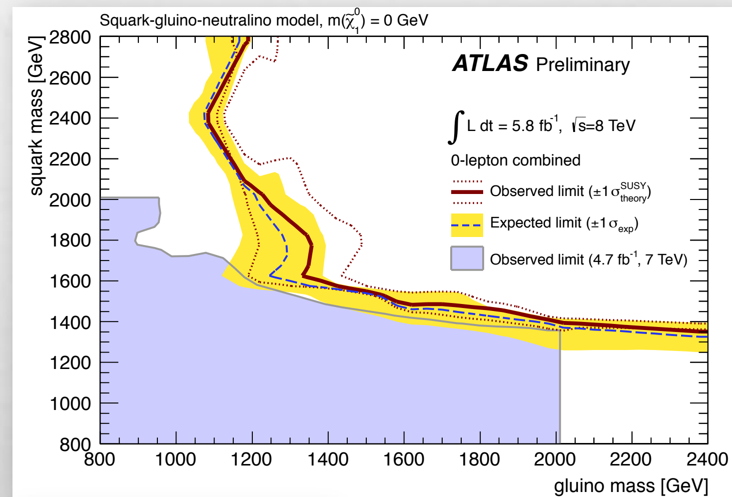
GUT scale^{-1}

Fundamental scalar length scale

After …

- 25 papers at 7 TeV with full 2011 statistics
- 13 preliminary 8 TeV results

No discovery yet …



ATLAS-CONF-2012-109

Limits from this model:

$m(\tilde{q}) \approx m(\tilde{g}) < 1.5$ TeV

$m(\tilde{q}) < 1.4$ TeV ($\forall\ m(\tilde{g}) < 2$ TeV)

$m(\tilde{g}) < 1$ TeV ($\forall\ m(\tilde{q}) < 2$ TeV)

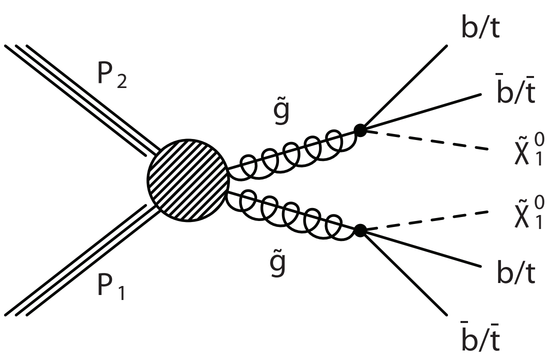
"Natural" SUSY

Lightest squarks are stop/sbottom, gluinos possibly too heavy, gauginos accessible ?

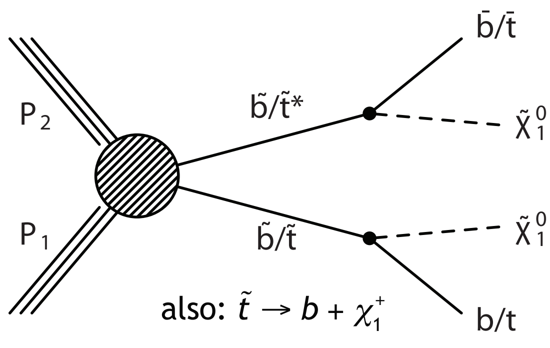
1208.2884, 1208.3144, ATLAS-CONF-2012-154

Lower cross-sections and larger SM backgrounds require dedicated searches

Strong & strategic approach by ATLAS



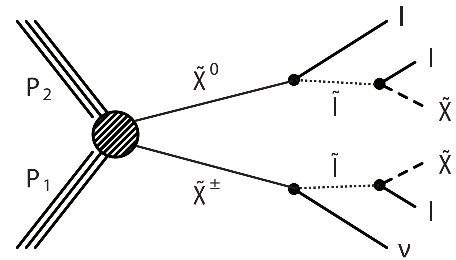
Gluino-mediated $\tilde{b}/\tilde{t}$ production

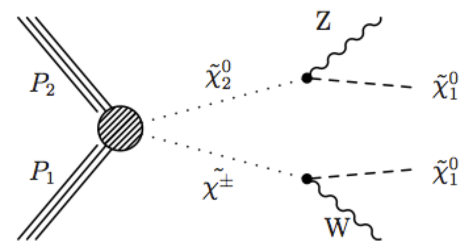


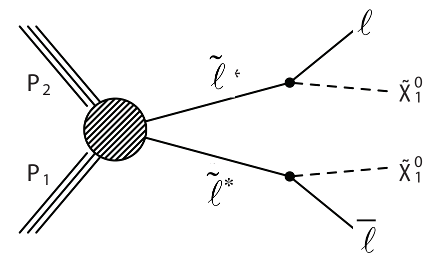
also: $\tilde{t} \rightarrow b + \chi^+_1$

Direct $\tilde{b}/\tilde{t}$ pair production

Associated gaugino production







Direct slepton-pair production

→ see backup

"Natural" SUSY

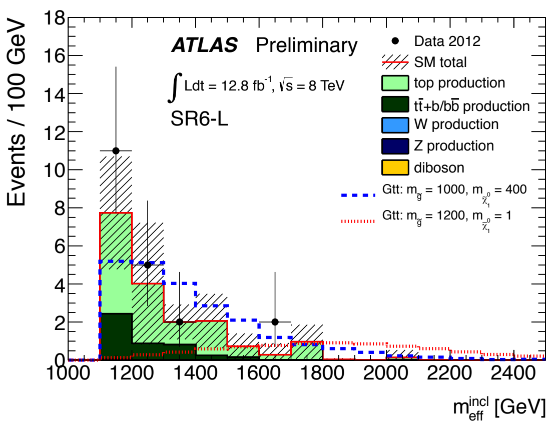
Gluino-mediated stop production

ATLAS-CONF-2012-145, ATLAS-CONF-2012-151

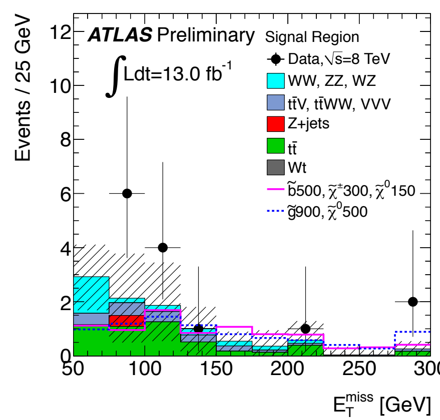
Characteristic signatures:

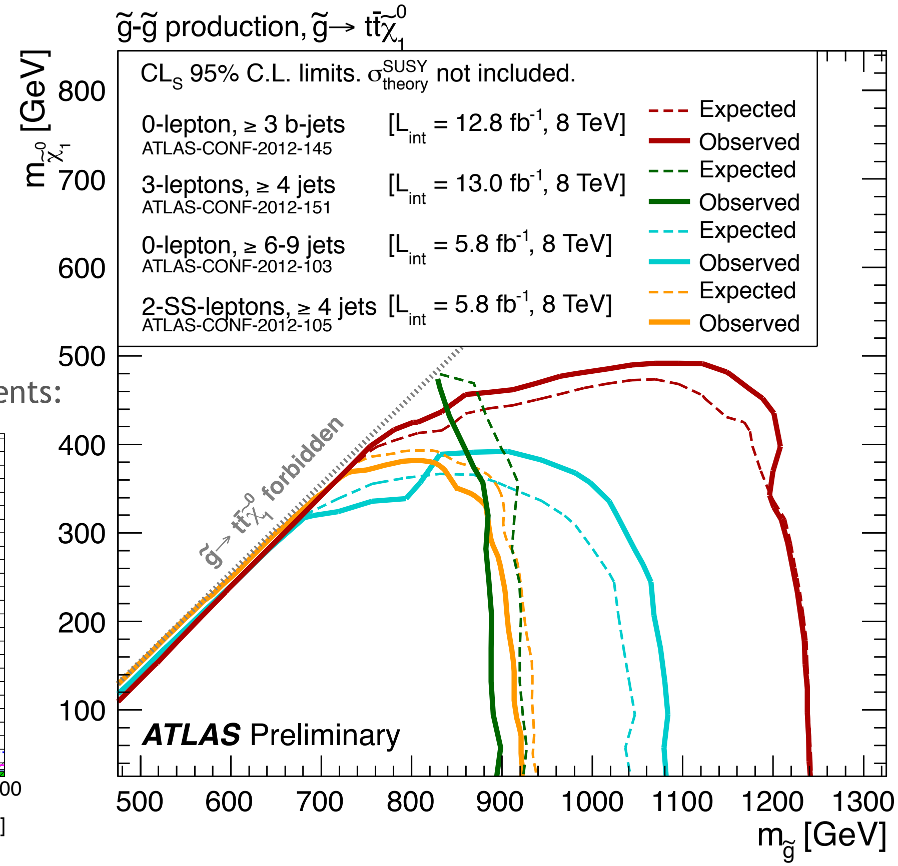
Gluino-mediated stop/sbottom produces
4 *b*-quarks and/or multileptons
additional jets and E_T^{miss} in finals state

m_{eff} in 3*b* + jets + E_T^{miss} events:



E_T^{miss} in 3*L* + jets + E_T^{miss} events:





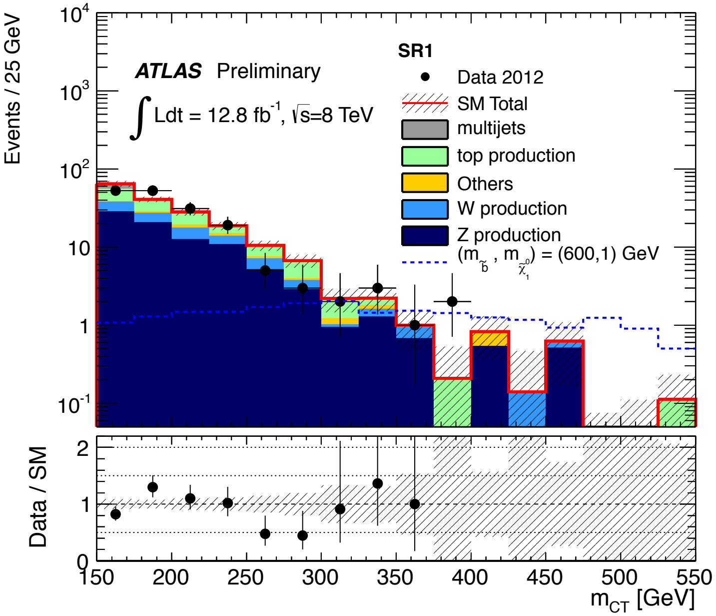
"Natural" SUSY

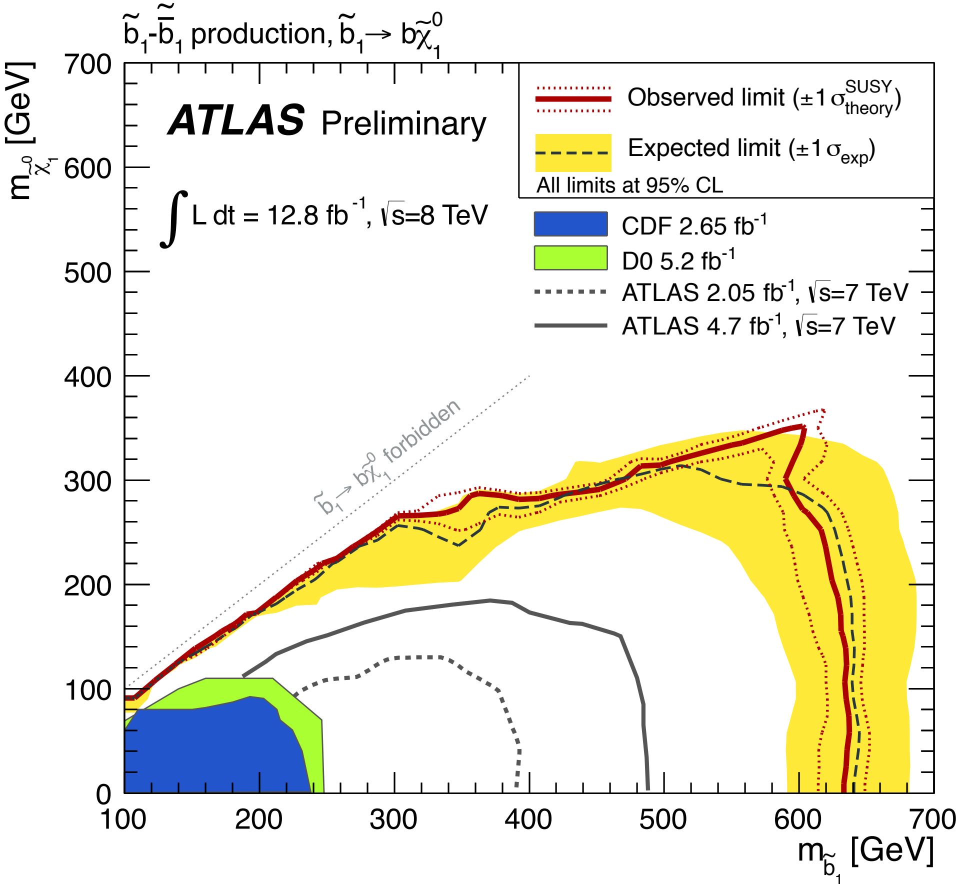
Direct sbottom production (here $2b$ + E_T^{miss} final state)

ATLAS-CONF-2012-151, ATLAS-CONF-2012-165

Direct sbottom production can lead to $2b$ + E_T^{miss} (shown here) or also to multilepton + jets + E_T^{miss} final states

m_{CT} : boost-corrected contransverse mass





“Natural” SUSY

Direct stop production, including decays to top + neutralino and *b* + chargino

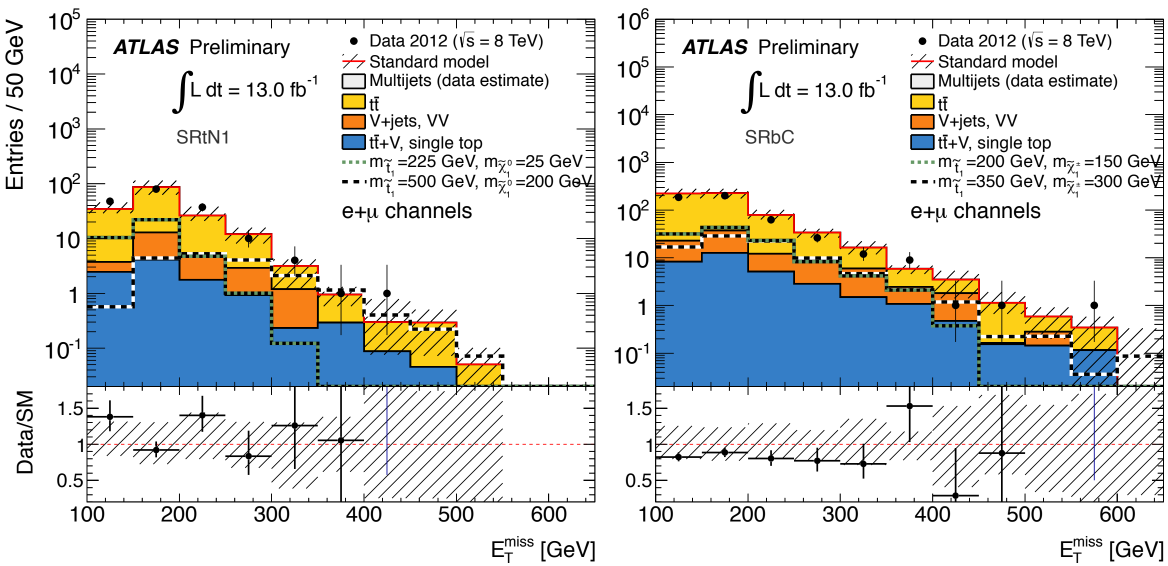
ATLAS-CONF-2012-166, ATLAS-CONF-2012-167

5 papers on 7 TeV: 1208.4305, 1209.2102, 1209.4186, 1208.2590, 1208.1447

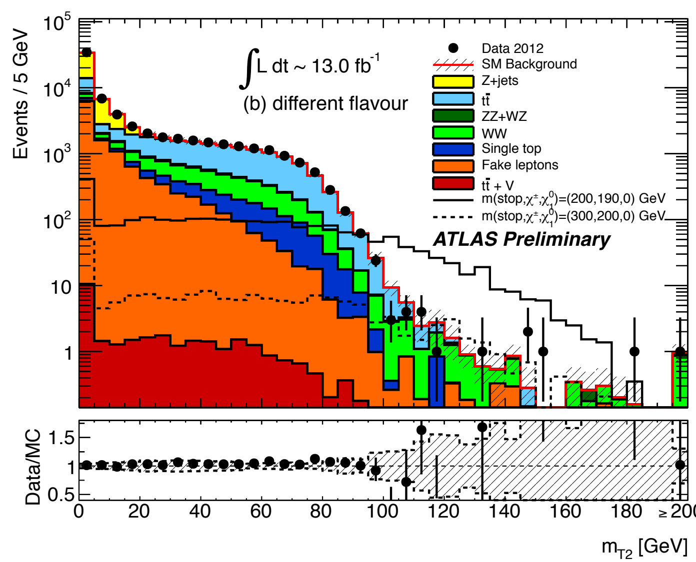
Direct stop production features similar final states as top pairs, searches use 0/1/2-lepton final states and depend on sparticle masses and stop decays

New results on 8 TeV 13 fb^{-1} in 1-*L* and 2-*L* final states, optimising for stop → top + *N* and stop → *b* + *C* decays

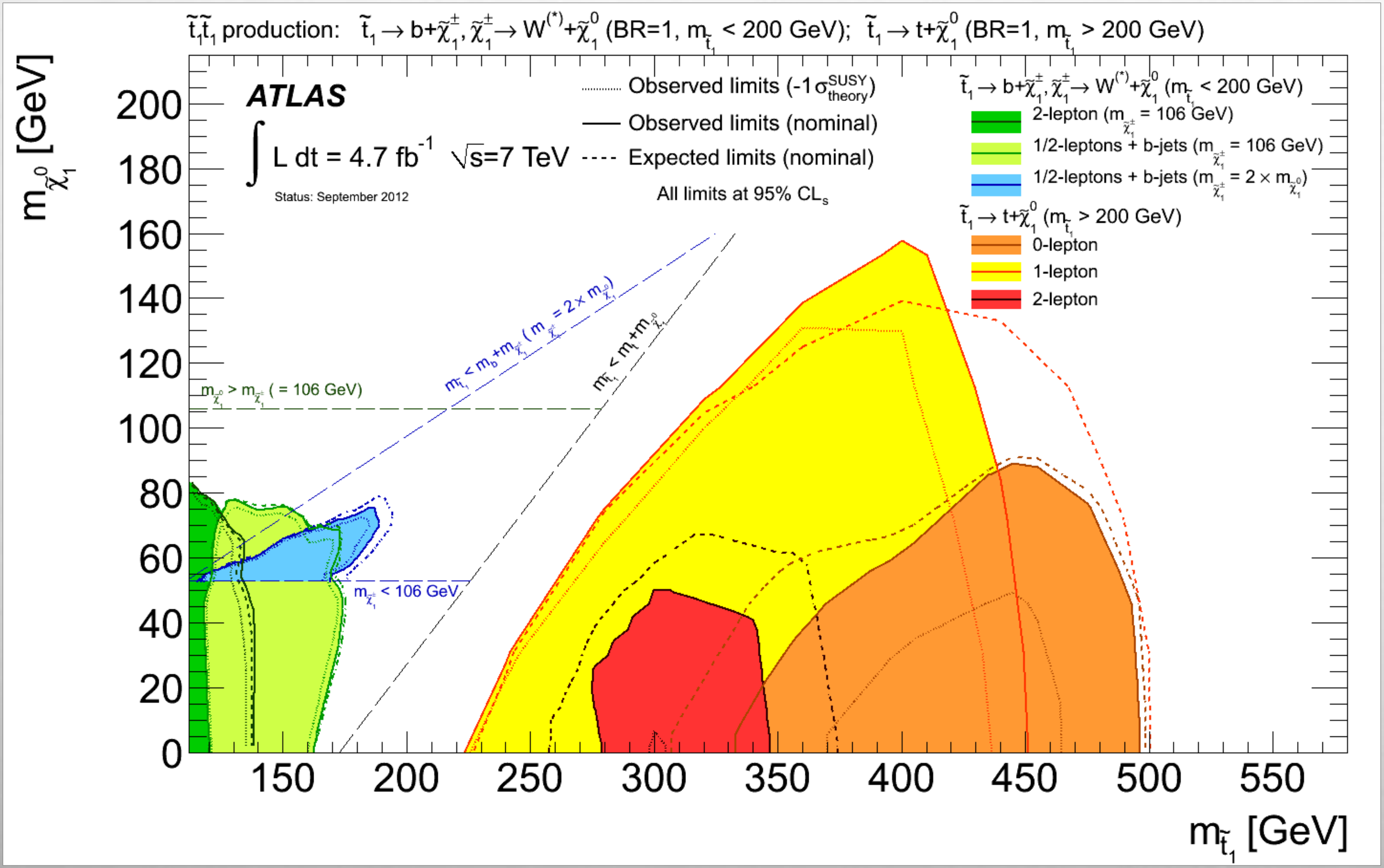
E_T^{miss} distributions in top + *N* (left) and *b* + *C* (right) signal regions [1-*L* analysis]



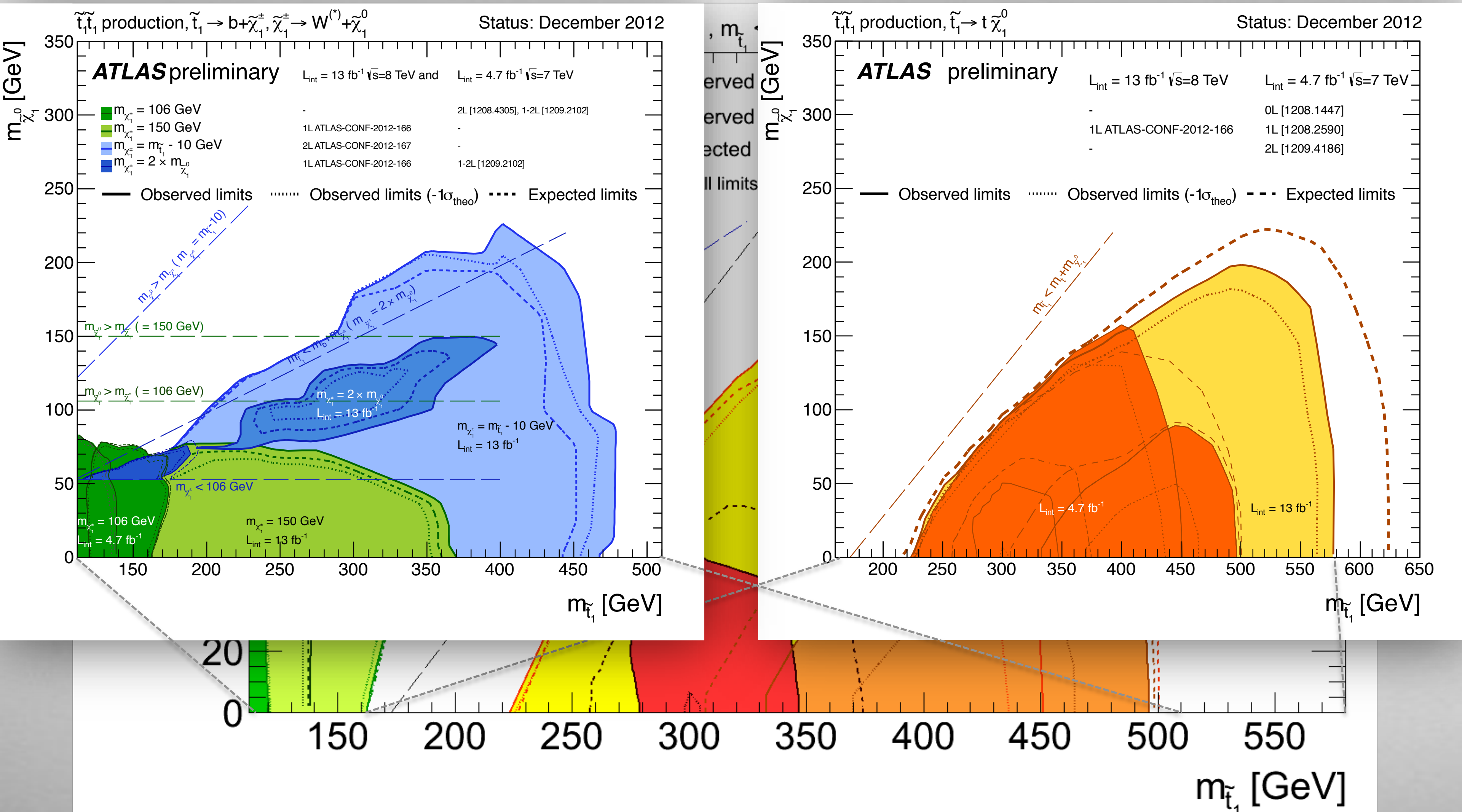
M_{T2} distributions in *b* + *C* (right) signal region [2-*L* analysis]



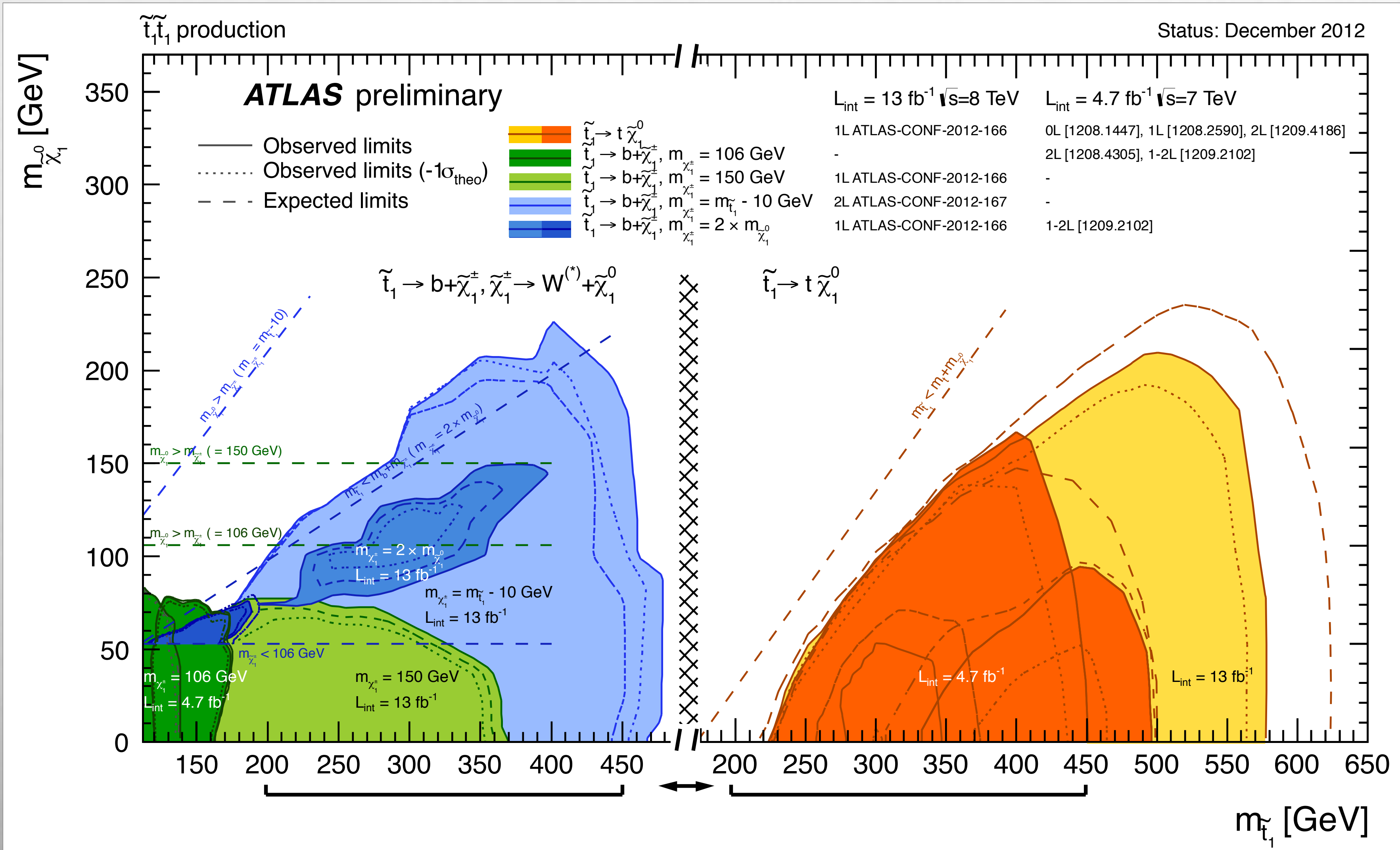
Direct stop search – status SUSY-12 workshop



Direct stop search – status LHCC 2012



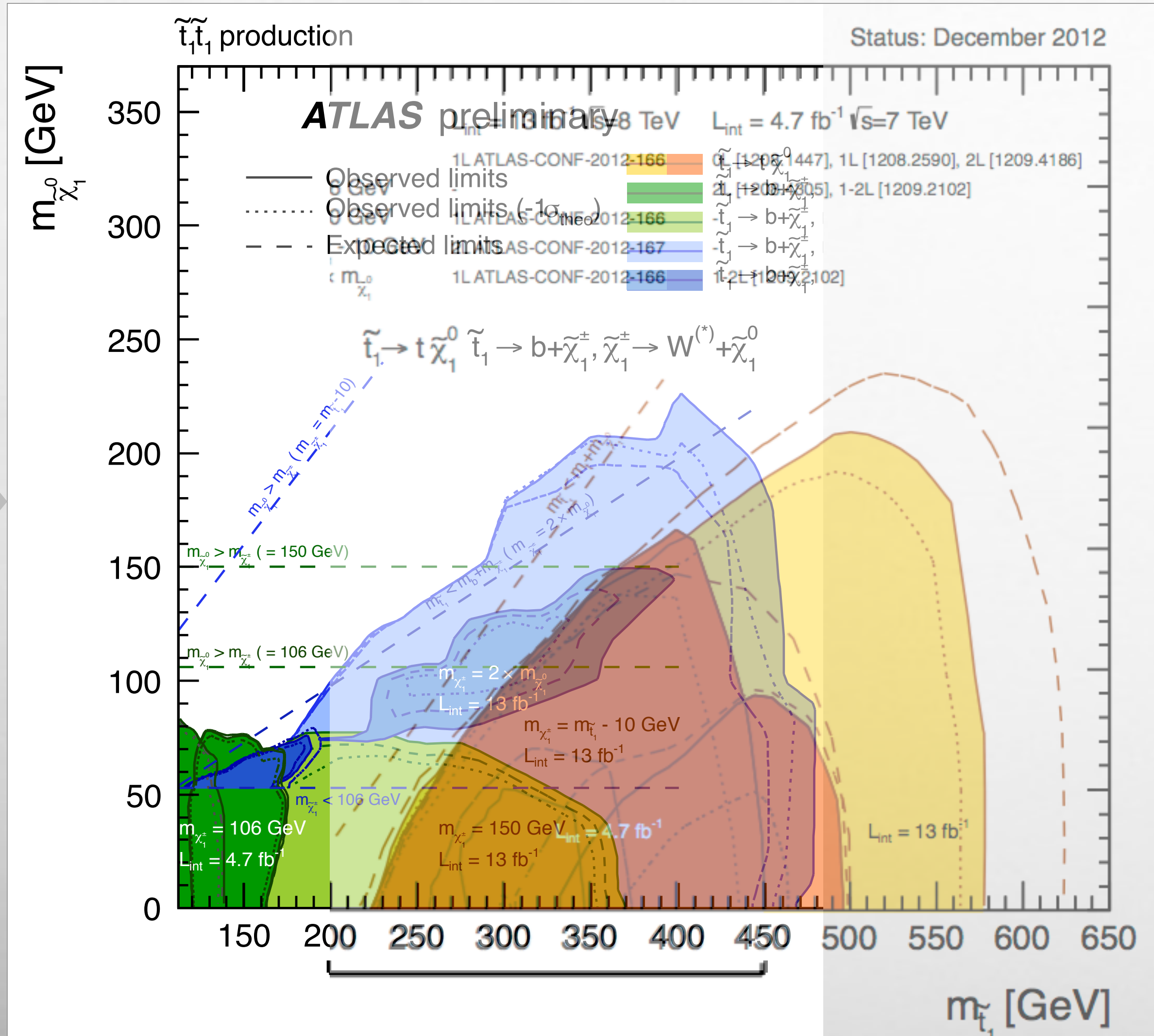
Direct stop search – status LHCC 2012



Significantly improved sensitivity at high stop mass with exp. limits up to 620 GeV (before 500 GeV)

Also, strongly enhanced sensitivity for lower mass stop decaying into *b* + chargino

Direct stop search – status LHCC 2012



Significantly improved sensitivity at high stop mass with exp. limits up to 620 GeV (before 500 GeV)
Also, strongly enhanced sensitivity for lower mass stop decaying into *b* + chargino
There is still room at low mass — remember: **our models are simplified**

What about Dark Matter ?

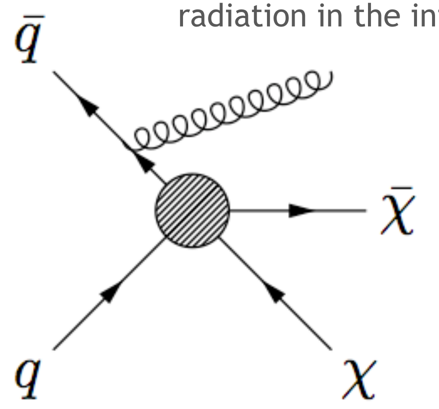
Detection of invisible particle production

1210.4491, ATLAS-CONF-2012-147

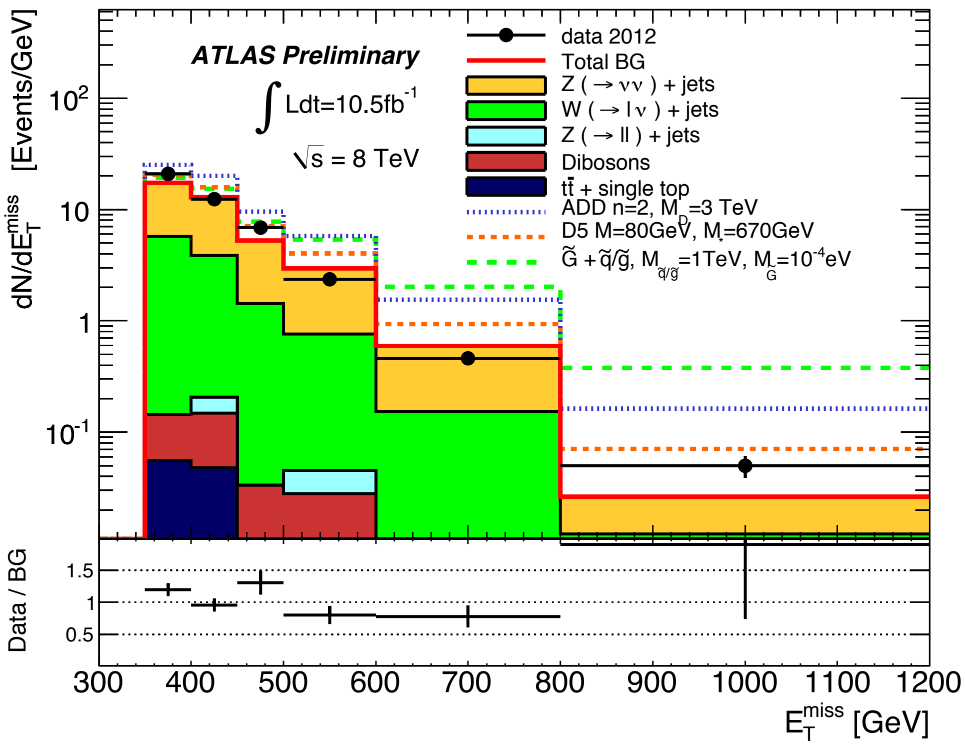
Should we give up on natural SUSY and directly search for WIMP (dark matter) production in proton−proton collisions ?

Exploit “ISR technique” (huge potential!)

Energetic gluon/photon radiation in the initial sate



→ Search for mono-jets events



Interpretation in variety of models: extra dimensions, WIMP, gravitinos

What about Dark Matter ?

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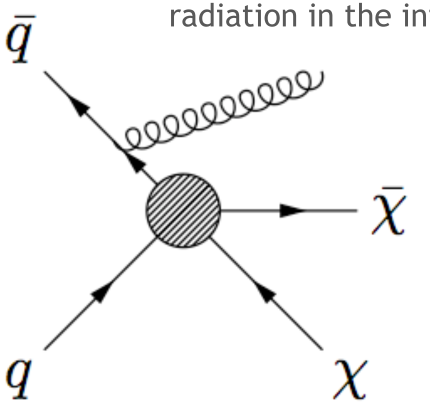
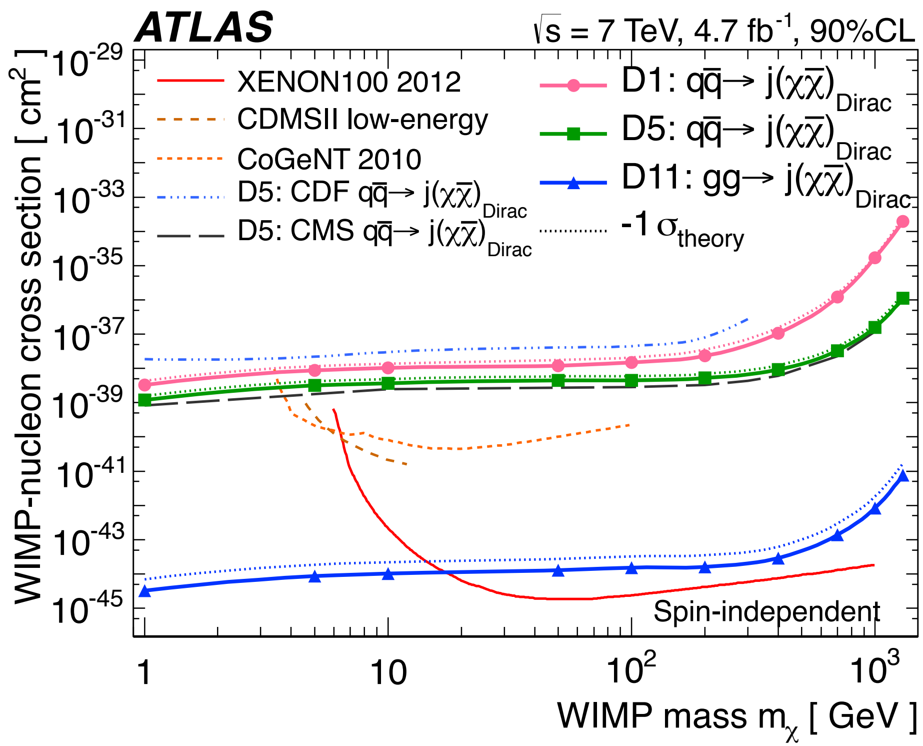


→ Search for mono-jets events



Complementarity between accelerator-based and space-based particle physics

ATLAS thoroughly studies signatures for new physics…

Huge variety of models probed, but also model-independent results

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

Exotics Models:

Extra dimensions:
- RS KK Graviton (dibosons, dileptons, diphotons)
- RS KK gluons (top antitop)
- ADD (monojets, monophotons, dileptons, diphotons)
- KK Z/gamma boosns (dileptons)

Grand Unification symmetries
- (dielectons, dimuons, ditaus)
- Leptophobic topcolor Z' boson (dilepton ttbar, l+j, all had)

S8- color octet scalars (dijets)
String resonance (dijets,)
Benchmark Sequential SM Z', W'
W' (lepton+MET, dijets, tb)
W* (lepton+MET, dijets)
Quantum Black Holes (dijet)
Black Holes (l+jets, same sign leptons)
Technihadrons (dileptons, dibosons)
Dark Matter
- WIMPs (Monojet, monophotons)

Excited fermions
- q*, Excited quarks (dijets, photon+jet)
- l*, excited leptons (dileptons+photon)

Leptoquarks (1st, 2nd, 3rd generations)
Higgs -> hidden sector
- (displaced vertices, lepton jets)

Contact Interaction
- llqq CI
- 4q CI (dijets)

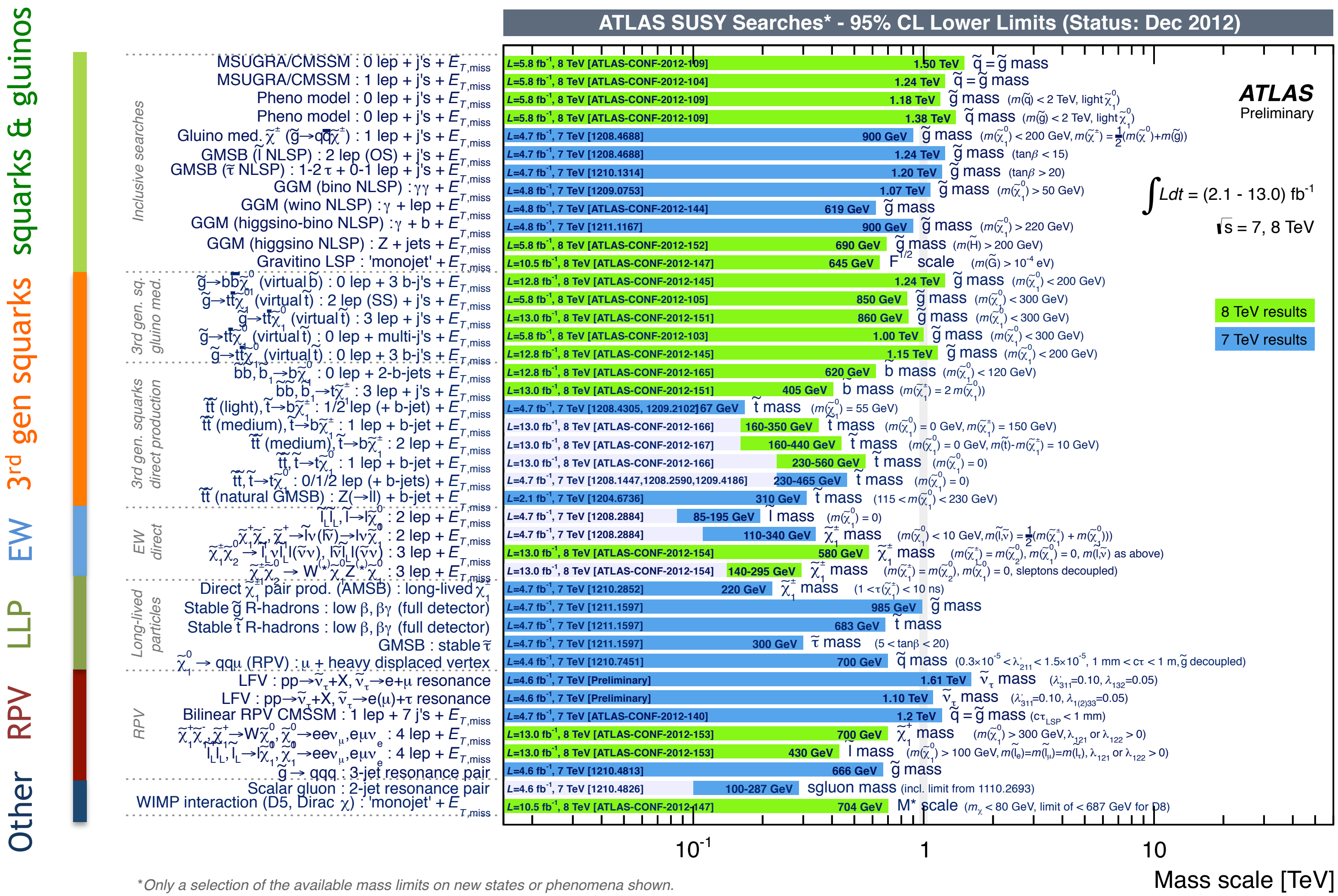
Doubly charged Higgs (
- multi leptons, same sign leptons)

4th generation
- t'->Wb, t'->ht, b'-Zb, b'->Wt (dileptons, same sign leptons, l+J)

VLQ-Vector Like quarks
Magnetic Monopoles (and HIP)
Heavy Majorana neutrino and RH W

…and deeply mines SUSY signature and model space

Strong push on naturalness dedicated searches, but also long-lived particles and RPV



*Only a selection of the available mass limits on new states or phenomena shown.
All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

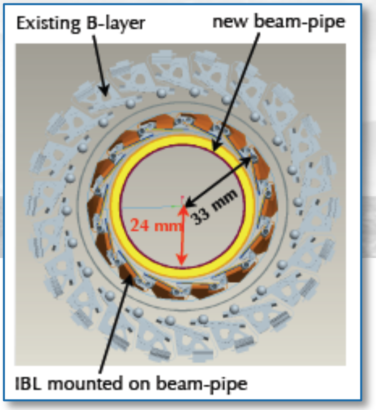
Summary

I attempted a (necessarily incomplete) overview of the ATLAS status and recent physics highlights after 3 years of running

- The accelerator (thanks to the LHC team!) and ATLAS detector are continuously delivering data of excellent quality and efficiency; 88% of the delivered luminosity is included in our physics results
- We strive to further improve the detector understanding and to cope with the pileup exceeding expectations
- The 2011 and 2012 data samples provide huge opportunities in all areas of the LHC physics programme
- ATLAS, as well as the other LHC experiments, has proven to deliver high-quality analyses. Fully exploiting the available data will engage the collaborations for years, and engages the theorists to continue improving MC tools allowing us to exploit our data for precision measurements and searches
- Measuring the properties of the new particle is a central pillar of the ATLAS physics programme. It needs all the prerequisites mentioned above. The Higgs-like boson also re-emphasises the importance of our searches
- Physics beyond the SM did not show up yet. There is no need for preliminary conclusions. Let’s continue our work and look were we haven’t looked so far

Extra slides…

LS1 and more



LS1 consolidation and upgrade work

- New Insertable Pixel *B*-layer (IBL)
  [installation either on surface (preferred) or in situ / decision end of Jan 2013]
- New Pixel service quarter panels (nSQP) [***if IBL installed on surface***]
- New ID evaporative cooling plant
- New Al forward beam pipe
- New calorimeter LVPS
- Consolidation of other detectors and infrastructure
- Complete muon spectrometer (EE, RPC, feet)
- Add specific muon shielding
- Upgrade magnet cryogenics
- Detector readout for Level-1 100 kHz rate

Towards the Phase-1 upgrade

- LoI submitted Marc 2012 / received strong support from LHCC
- Work for TDRs in full swift: four (new μ SW, FTK, LAr+Tiles, TDAQ) expected to be completed in 2013, AFP in 2014

LHC timeline

2009	Start of LHC
	Run 1, 7+8 TeV, ~25 fb^{-1} int. lumi
2013/14	LS1: prepare LHC for design *E* & lumi
	Collect ~30 fb^{-1} per year at 13/14 TeV
2018	Phase-1 upgrade for ultimate lumi
	Twice nominal lumi at 14 TeV, ~100 fb^{-1} per year
~2022	Phase-2 upgrade to HL-LHC
	~300 fb^{-1} per year, run up to > 3 ab^{-1} collected
~2030	

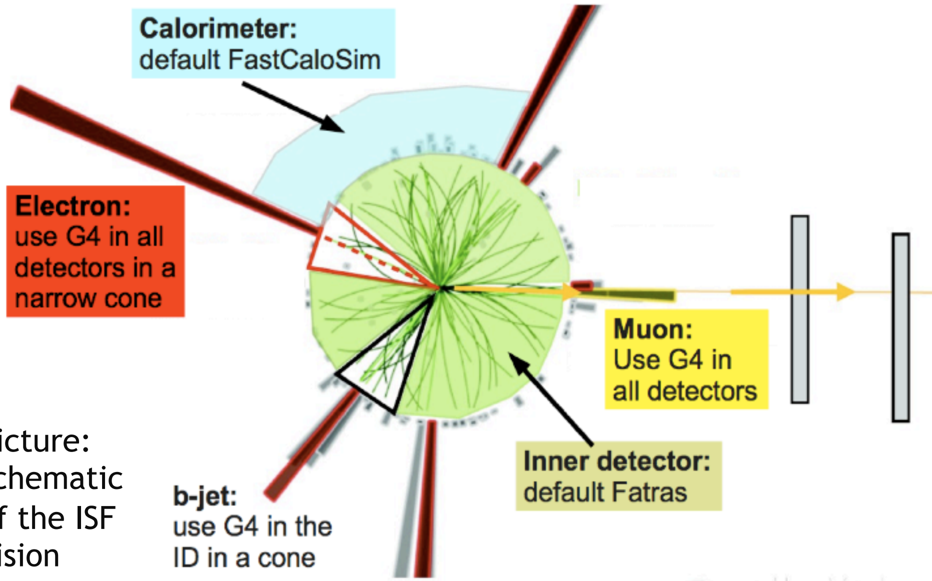
Integrated Simulation Framework (ISF) developments

Need to increase simulation flexibility to cope with vast MC needs: ~4B events / year
[some fits, eg, *W* mass templates, require 10^8 events per parameter setting]

Several analyses MC stat. limited (eg, $H \rightarrow bb$, searches), all would benefit from more MC

ISF allows to mix into detector regions by particle type and dynamically per event:

- Full simulation (Geant4)
- Calorimeter shower parametrisation (FastCaloSim)
- Fast track simulation (Fatras)
- and possible future technologies



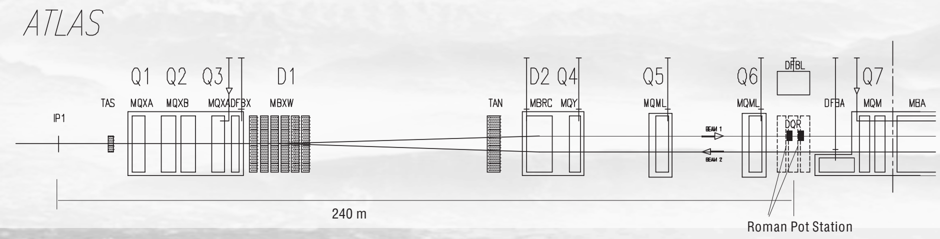
Picture: schematic of the ISF vision

MC sample for $gg \rightarrow H \rightarrow \gamma\gamma$ (no pileup)

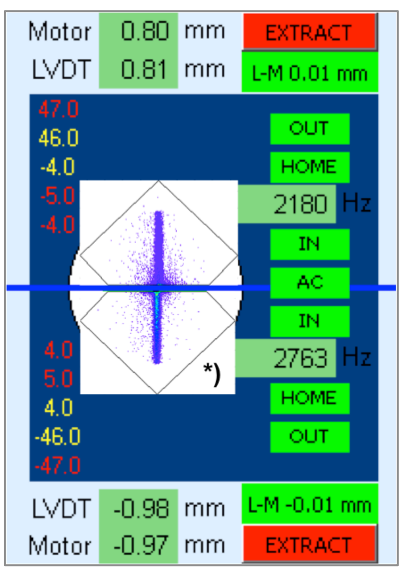
	ISF exec time/event	Speed-up factor
Full Geant4 (G4)	560 s	1
ATLFAST-2 (G4 + FastCaloSim)	25 s	~25
ATLAST-2-F (ATLFAST-2 + Fatras)	0.75 s	~750
FastGamma (ATLFAST-2-F with partial sim. only)	0.18 s	~3000

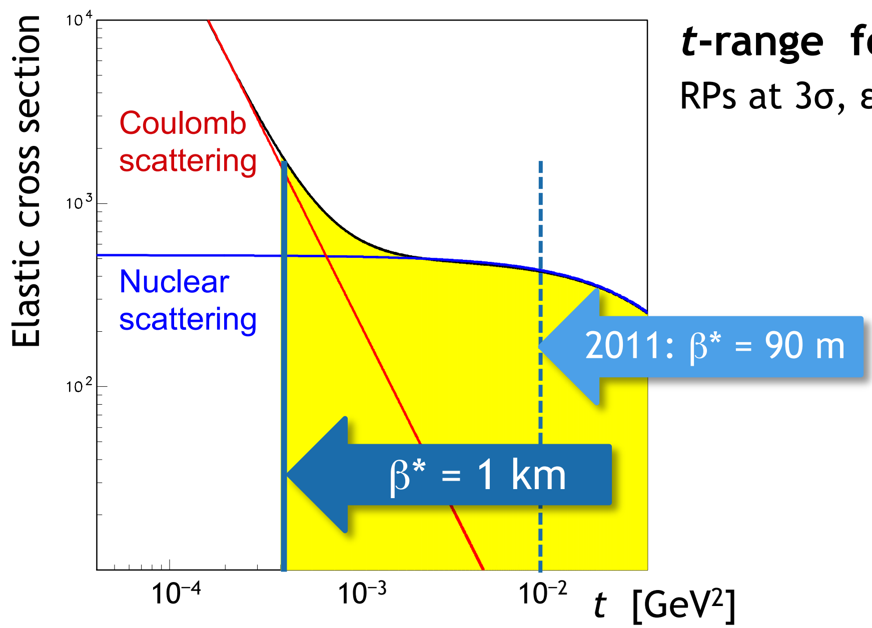
Forward detectors: ALFA

2 LHC fills at β* = 1 km run on Oct 24/25



- De-squeeze to β* = 1 km in ~45 min
- Repeated scraping with primary collimators to 2σ, followed by retraction to 2.5σ to reduce backgrounds
- About 10 h data taking with Roman Pots at 3σ, about 0.85 mm distance to beam centers
- About 300k elastic events and many diffractive triggers recorded





***t*-range for β*= 1km**

RPs at 3σ, ε = 2.4 μm

t_{min} ~ 0.0005 GeV^2: first measurement in the Coulomb-Nuclear interference region

Beam induced backgrounds (BIB)

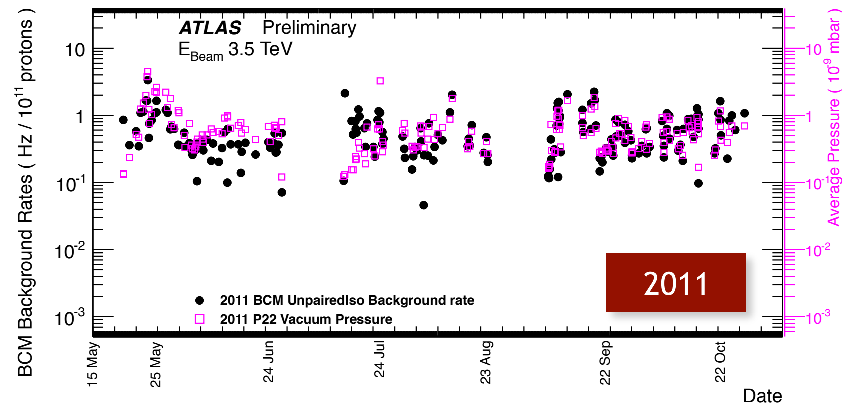
Measured with various subdetectors, monitored throughout the year

BIB rates low in 2012 as in 2011

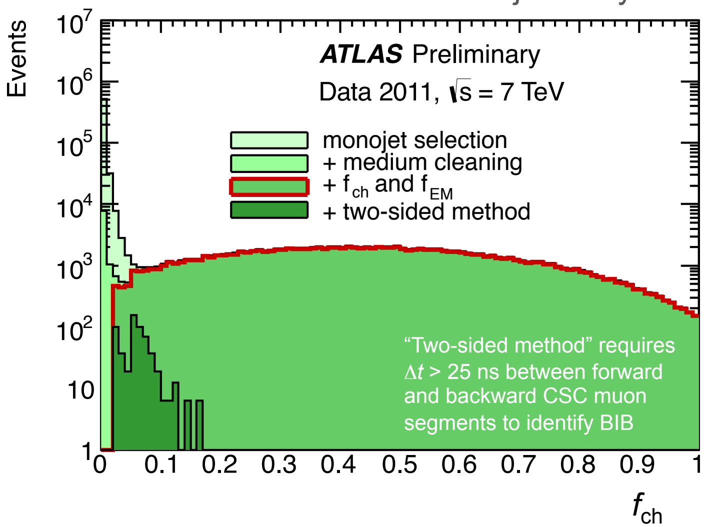
- No significant change between years

BIB can nevertheless be harmful in searches

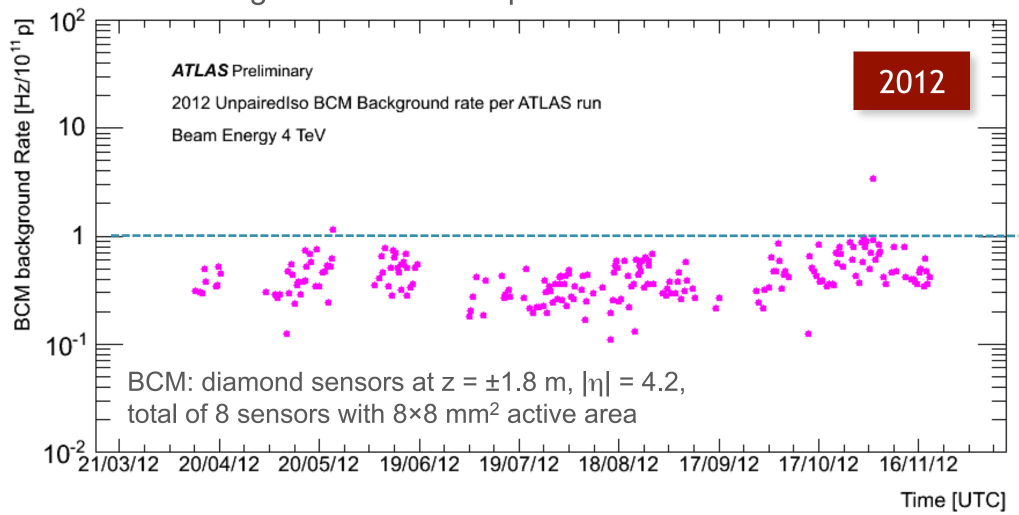
- Relatively loose cleaning applied everywhere
- Tighter cleaning in, eg, monojet analysis: require minimum charge and EM fractions for jets



Events selected for the monojet analysis



BCM background rates in unpaired bunched



W and Z physics — differential measurements

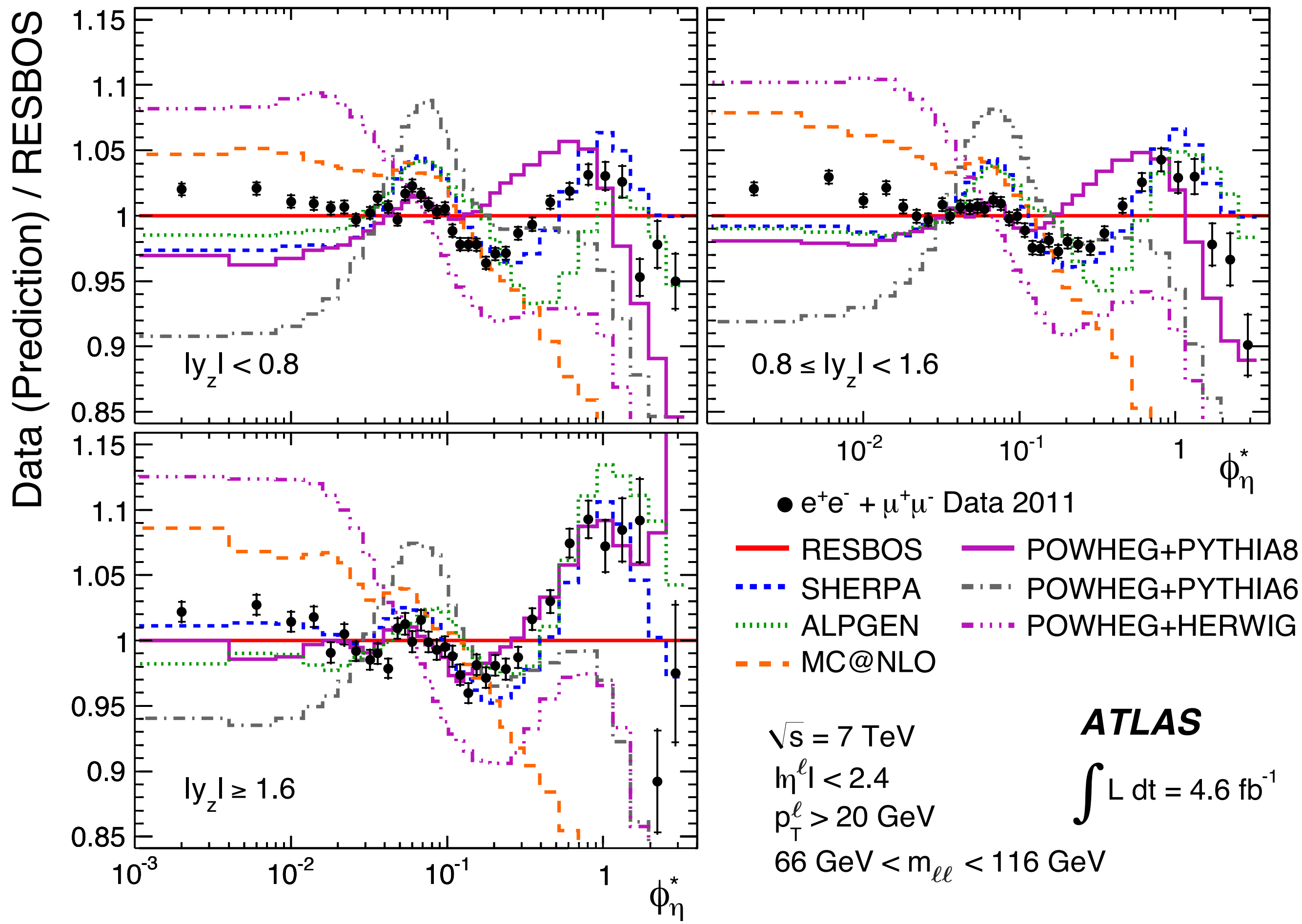
Large statistics allows precise tests of generators/theory, PDFs and bkg to searches

1211.6899

Measurement of Z/γ ϕ_η^* distribution

- ϕ_η^* is measure of scattering angle of leptons wrt. z in Z/γ rest frame
- Depends on lepton angles only, more precisely measured than momenta
- ϕ_η^* correlated to $p_{T,Z}/m_{ll}$ → probes same physics

ResBos provides best description (within 4%), large deviations for POWHEG / MC@NLO

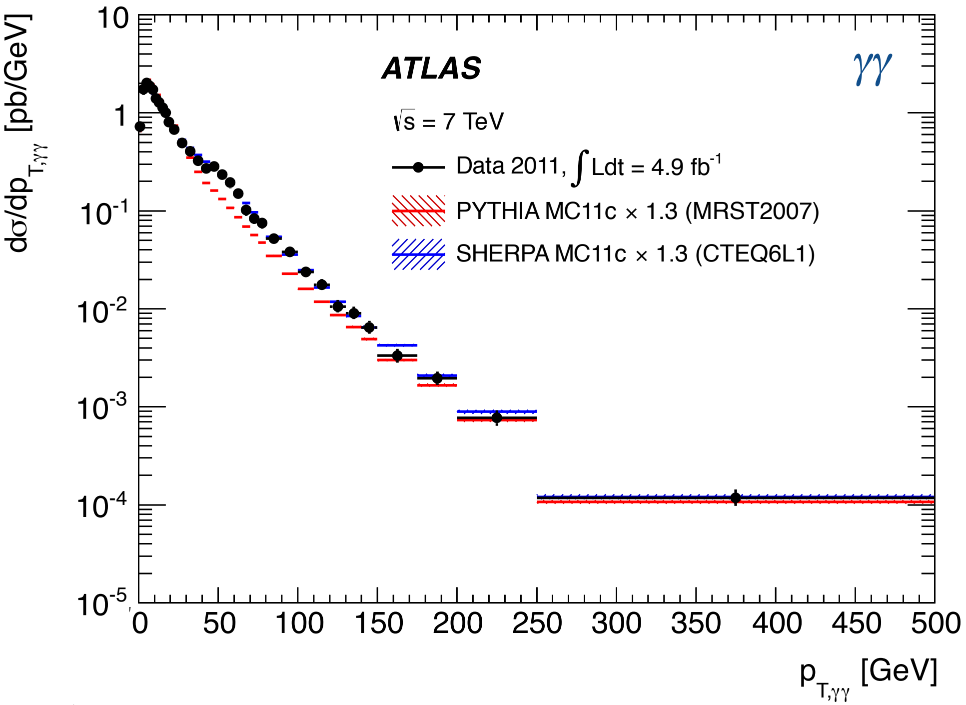


Diboson physics: *WW*, *WZ*, *ZZ*, *Wγ*, *Zγ*, *γγ*

ATLAS performed total, fiducial & differential diboson cross-sections measurements

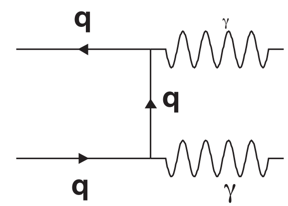
See last week's ATLAS diboson seminar by Shih-Chieh Hsu: http://indico.cern.ch/conferenceDisplay.py?confId=218398 | 1211.1913

Examples for differential cross section measurements: $\gamma\gamma$ (7 TeV, 4.9 fb^{-1})

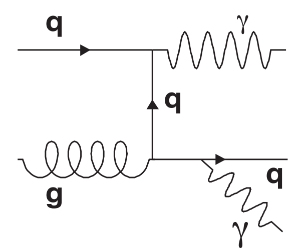


Rescaled LO PS generators describe spectra better than HO FO generators (DIPHOX, 2γNNLO) w/o soft gluon resummation

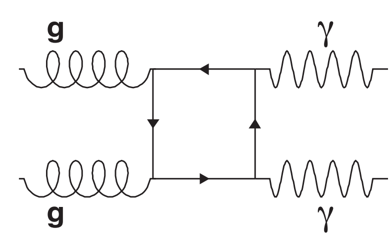
Powerful test of perturbative QCD and quark fragmentation



"Direct" quark annihilation (dominant: $O(\alpha^2)$)



Collinear fragmentation, $O(\alpha^2\alpha_S)$, but non-isolated γ



Box diagram, $O(\alpha^2\alpha_S^2)$, but due to *gg* luminosity comparable to LO terms

Diboson physics: *WW*, *WZ*, *ZZ*, *Wγ*, *Zγ*, *γγ*

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1211.1913

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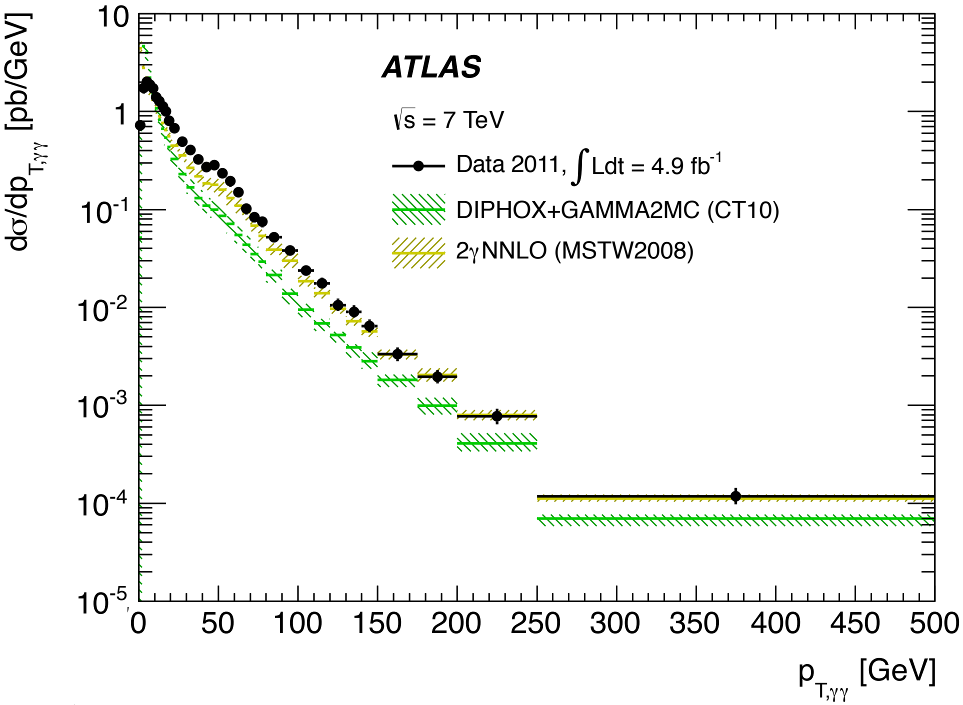
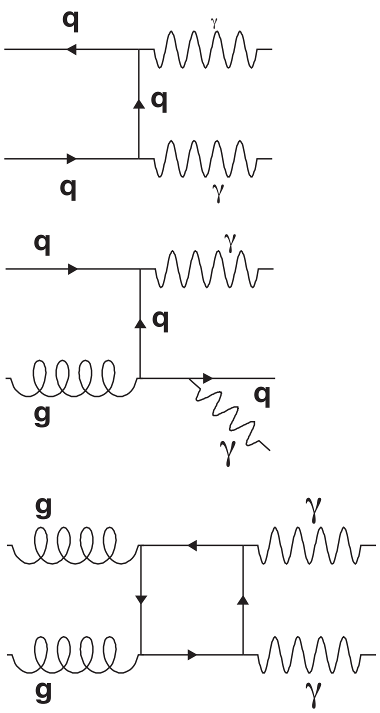


Fixed-order generators lack soft gluon resummation (IR divergence)

Powerful test of perturbative QCD and quark fragmentation



"Direct" quark annihilation (dominant: $O(\alpha^2)$)

Collinear fragmentation, $O(\alpha^2\alpha_S)$, but non-isolated γ

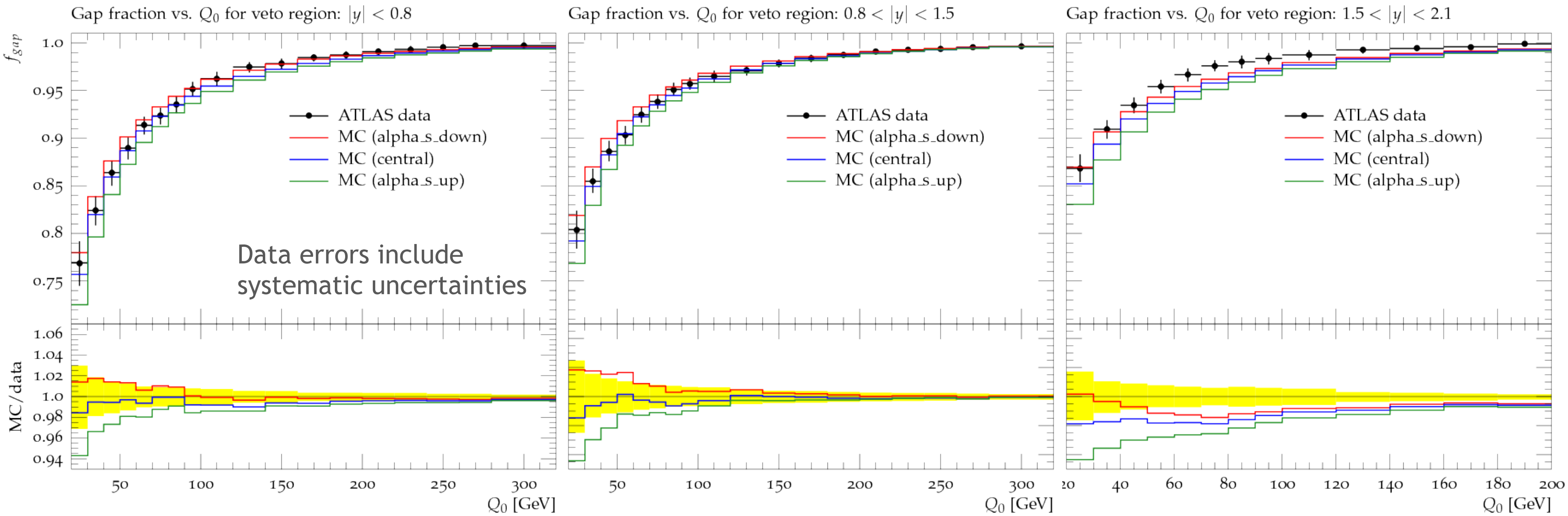
Box diagram, $O(\alpha^2\alpha_S^2)$, but due to *gg* luminosity comparable to LO terms

Understanding top pair production at the LHC

Top pairs in association with jets probe ISR/FSR activity

ATLAS-CONF-2012-155, see also: 1203.5015

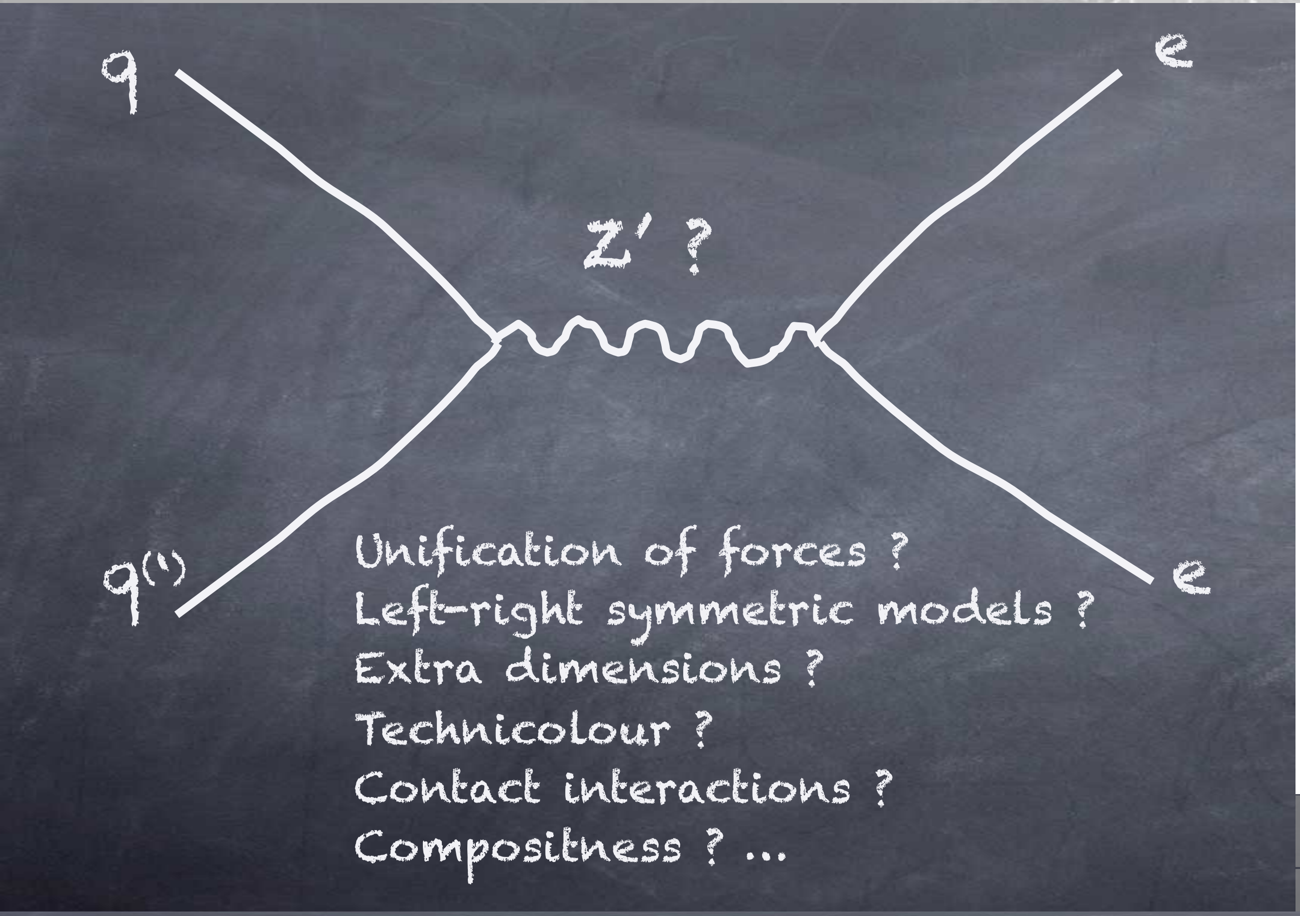
Rapidity gap fraction(*) measurements vs. |y| help to assess uncertainties related to ISR/FSR
ALPGEN+PYTHIA α_S up/down variations used in *tt* differential cross section measurement

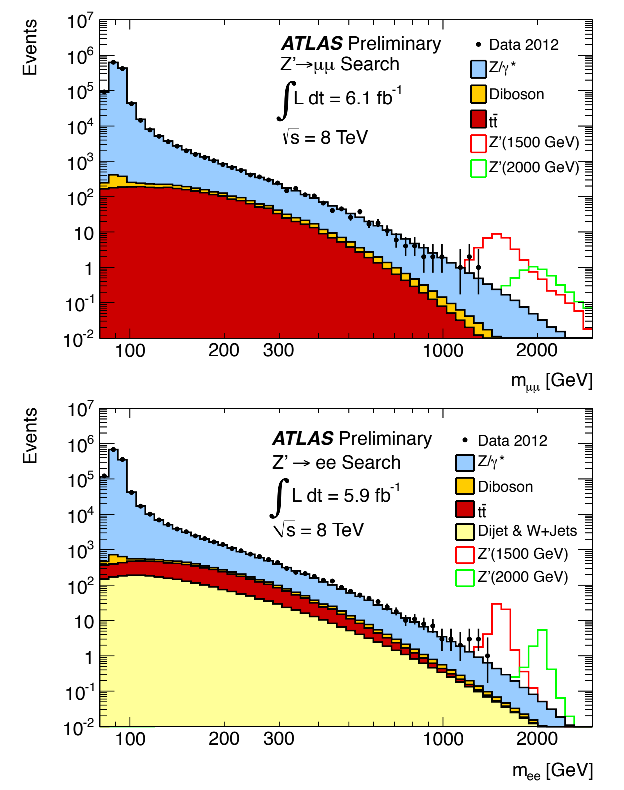


Satisfying description for |y| < 1.5, but for large |y| too much jet activity predicted

Q_0 is the fraction of events with no additional jet radiated within a considered rapidity interval

ATLAS mines its data for new physics in events with leptons …





$m(Z'_{SSM}) < 2.49$ TeV (95% CL)

ATLAS-CONF-2012-129, 6.1 fb^{-1}

Also: new 7 TeV dilepton limits on *llqq* contact interaction between 9.5 and 12.9 TeV [1211.1150]

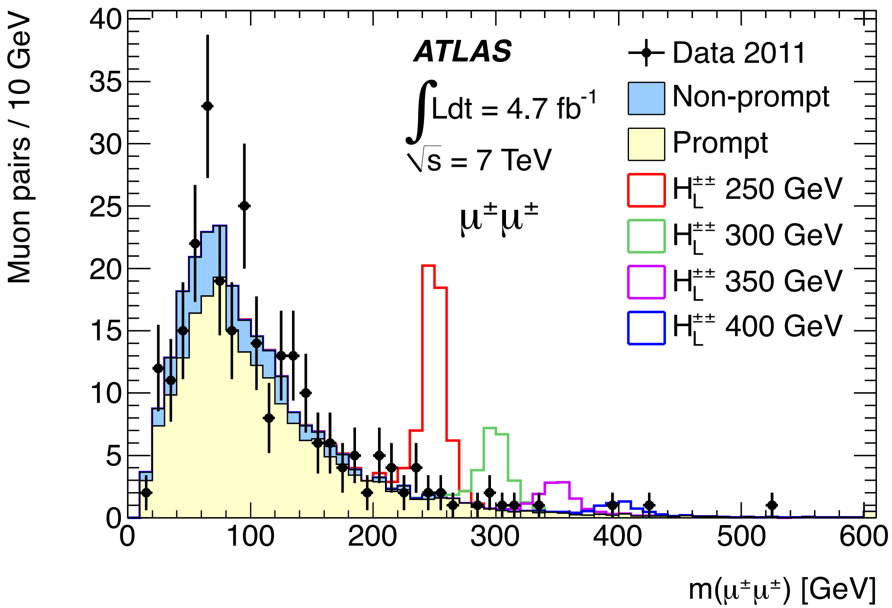
ATLAS mines its data for new resonances with leptons

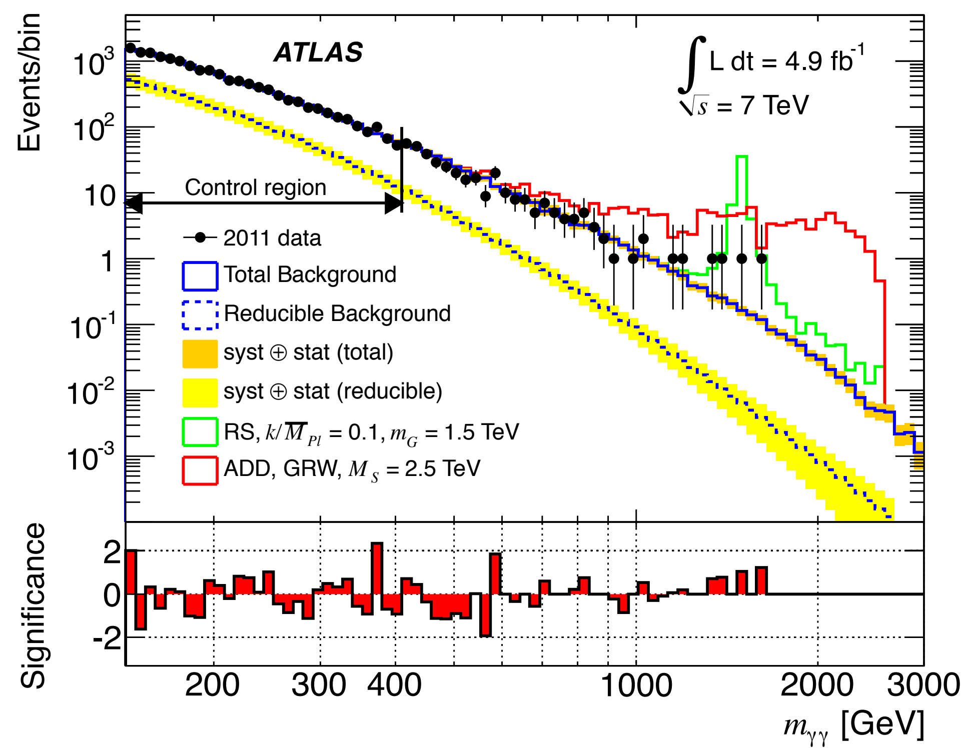
Many other searches, for example: dilepton, like-sign dilepton, lepton-γ resonances

Dilepton resonance search: $m(Z'_{SSM}) < 2.49$ TeV (95% CL, 6.1 fb^{-1}) ATLAS-CONF-2012-129

1210.4538, 1210.5070, 1210.8389

Doubly charged Higgs gives rise to a narrow like-sign resonance (left)
RS bulk graviton with strong coupling to SM can decay to a photon pair (right)





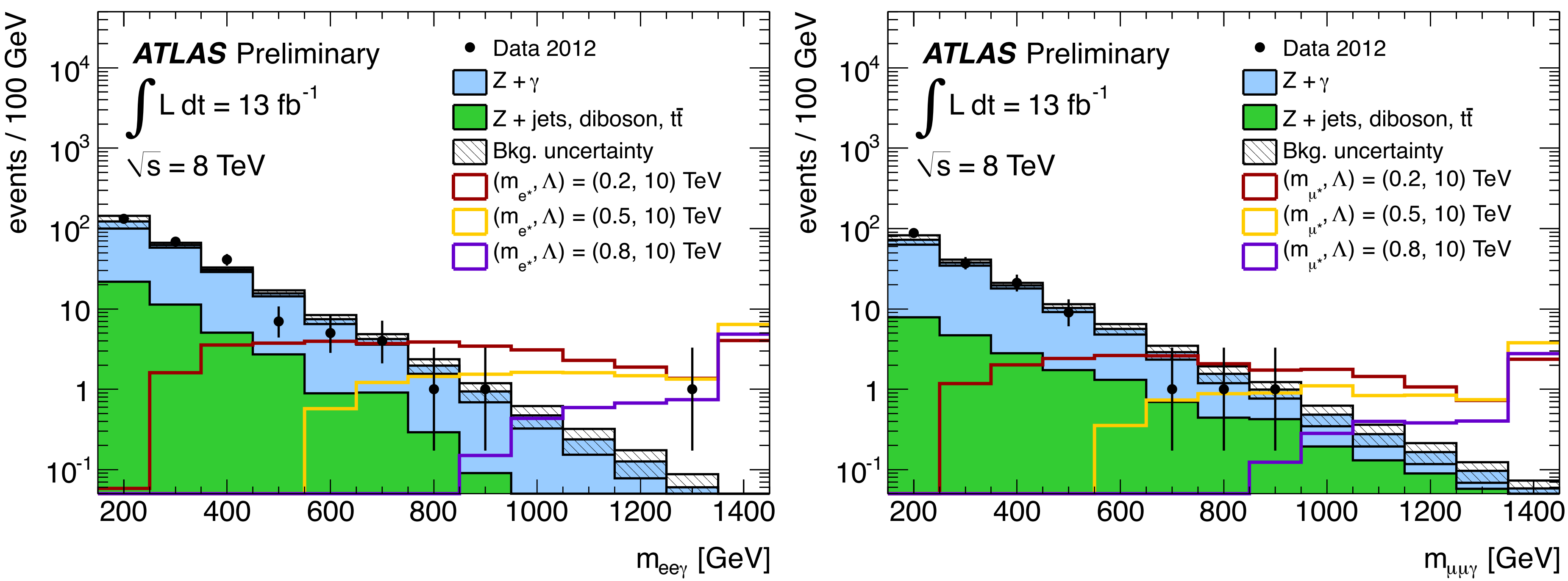
Prompt like-sign leptons powerful probe for many forms of new physics

ATLAS mines its data for new physics in events with leptons … searching for compositeness w/ excited leptons in $ll^* \rightarrow ll + \gamma$

ATLAS-CONF-2012-146

Observed and predicted $ee\gamma$ mass and signal models

Observed and predicted $\mu\mu\gamma$ mass and signal models



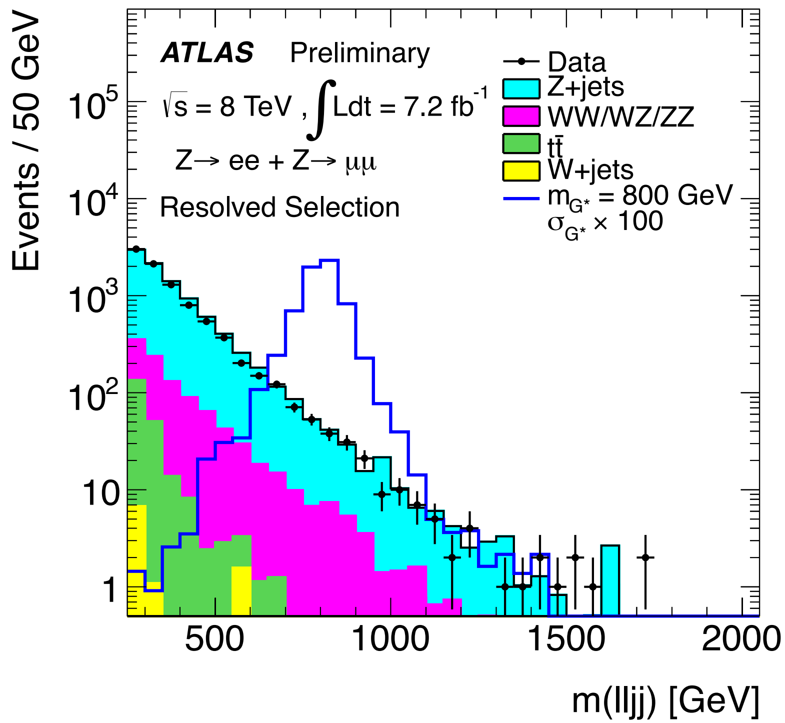
For compositeness scale $\Lambda = m(l^*)$: exclude excited leptons below 2.2 TeV at 95% CL

ATLAS mines its data for diboson resonances

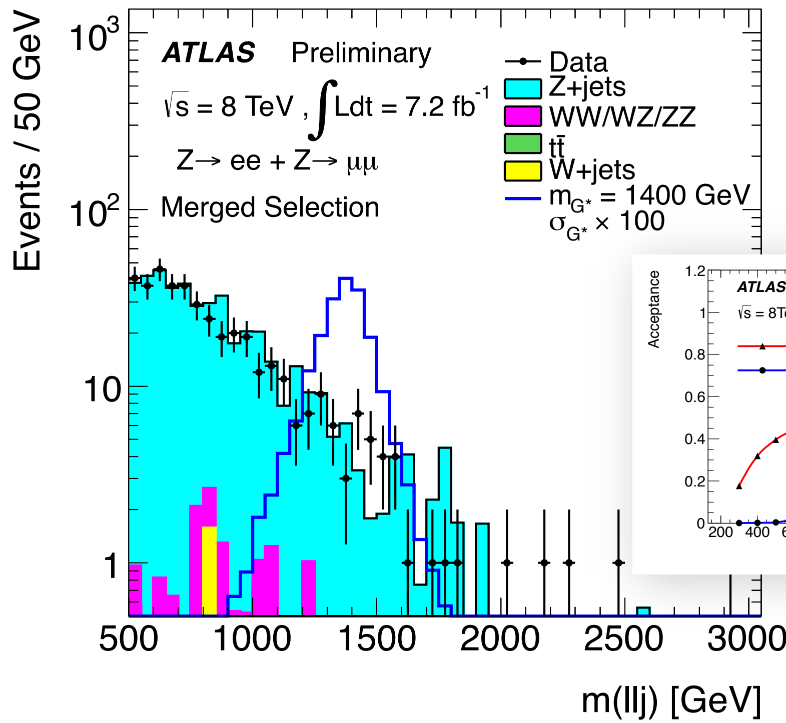
Search for narrow resonance decaying to *ZZ* (→ *llqq*)

ATLAS-CONF-2012-150

Observed and expected *lljj* mass (**resolved**)

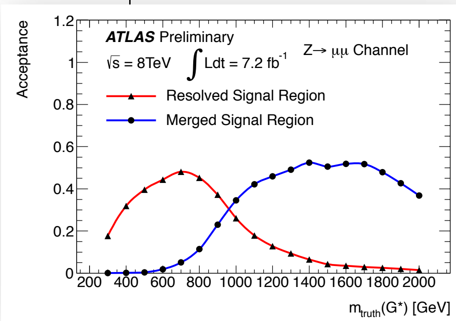


Observed and expected *lljj* mass (**merged**)



For illustration only.

Actual limit setting from comparison of data with phenomeno-logical fit

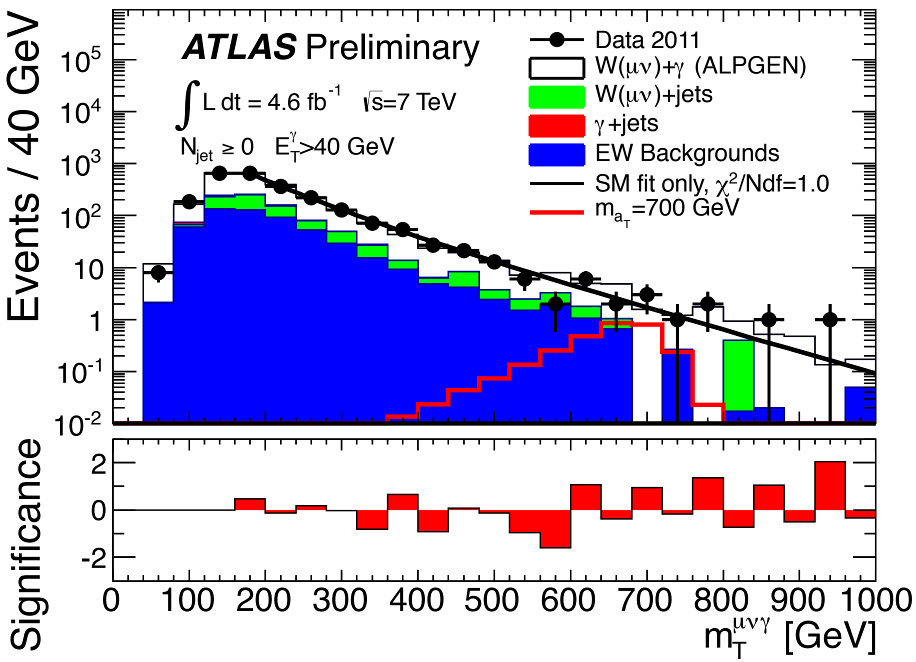


RS graviton with κ/m_{Pl} = 1.0 excluded below 850 GeV with 95% CL

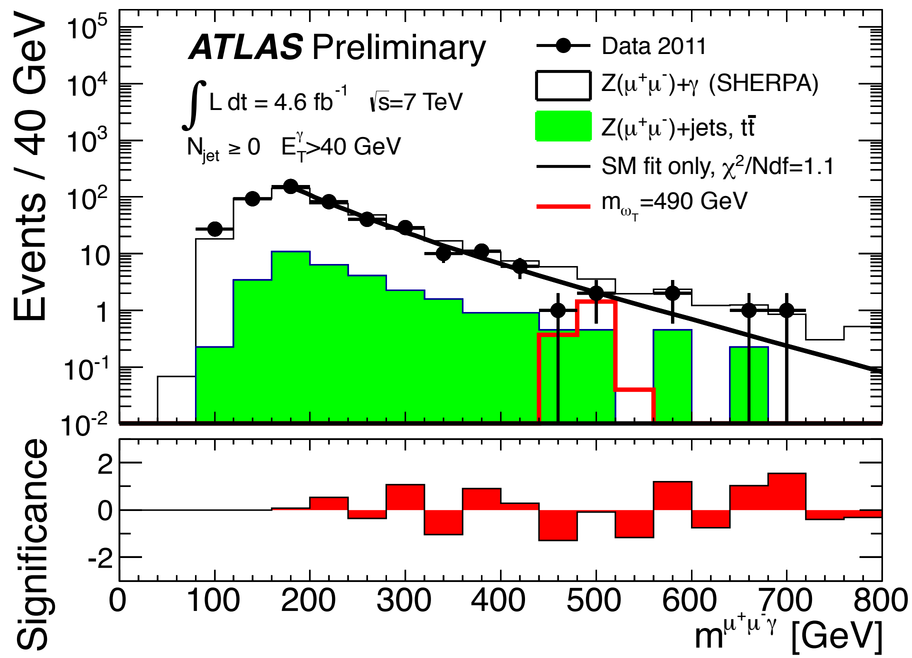
ATLAS mines its data for diboson resonances

Search for narrow resonance decaying to $W\gamma$ or $Z\gamma$

Observed and expected transverse $\mu\nu\gamma$ mass



Observed and expected $\mu\mu\gamma$ mass

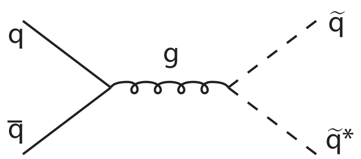


Limits obtained on fiducial cross-sections of narrow resonances. Low scale TC

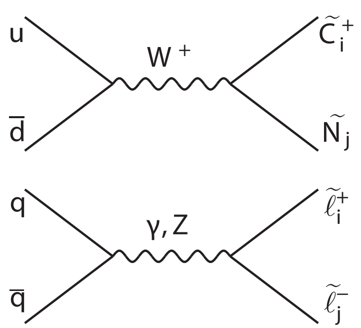
Once mass spectrum fixed, all cross-sections predicted

Spin structure of SUSY spectrum: lower σ than other BSM models, harder to find !

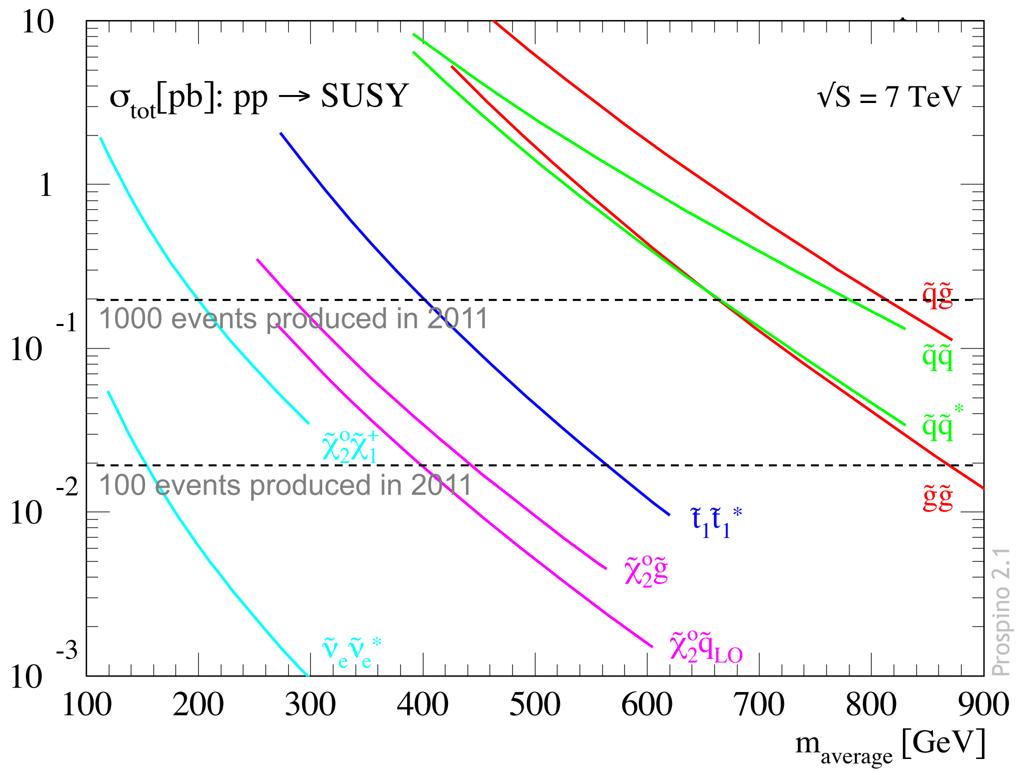
Direct squark pair production (example)



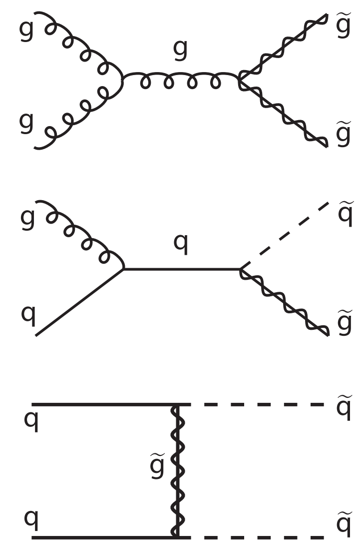
Direct gaugino/ slepton pair production (example)



SUSY cross-section versus sparticle mass



Gluino & squark production (examples)

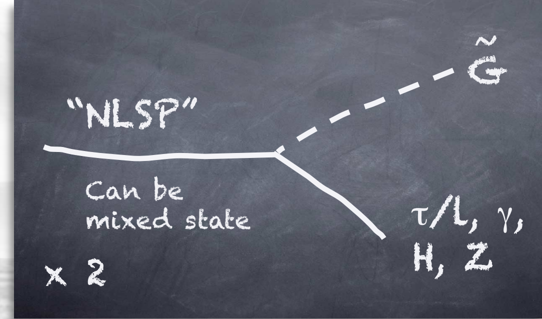


Also: dedicated searches for SUSY with long-lived particles and *R*-parity violation

Recent (Oct 23) ATLAS seminar by Nick Barlow reviewing results on long-lived particle searches with ATLAS

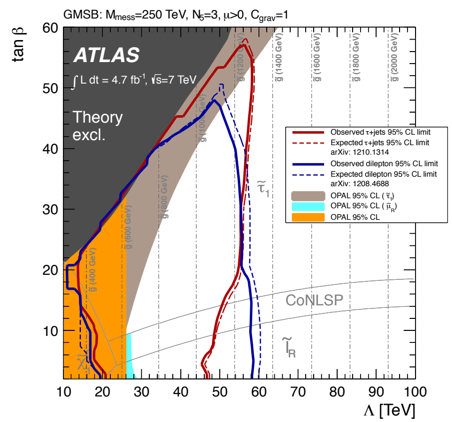
Inclusive squark and gluino searches

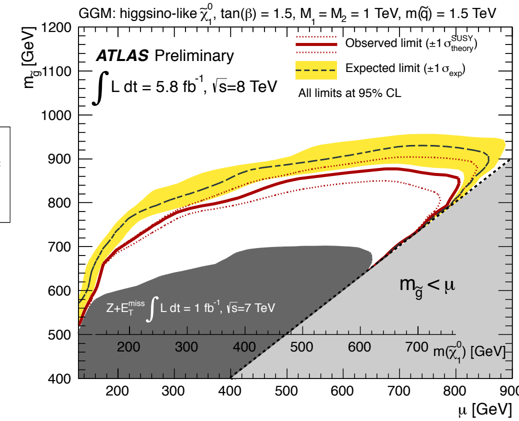
Complete "jets + X + E_T^{miss} " programme, for example: GM

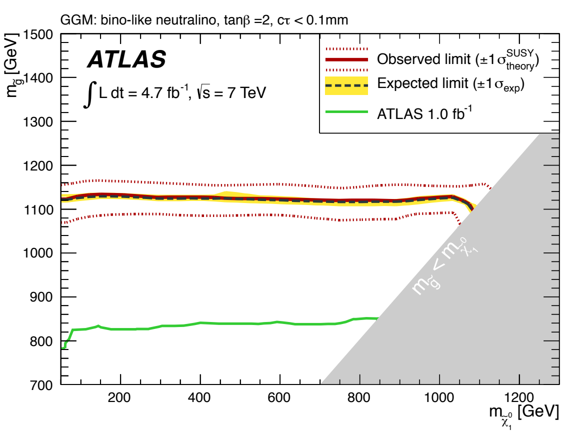


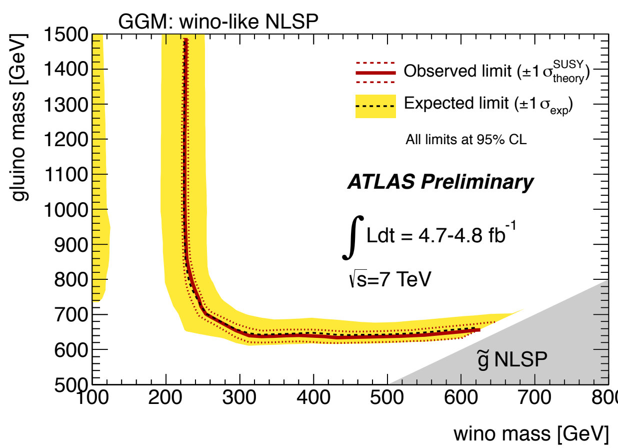
Gauge-mediated SUSY breaking scenarios feature very light gravitino. Phenomenology determined by nature of next-to-LSP

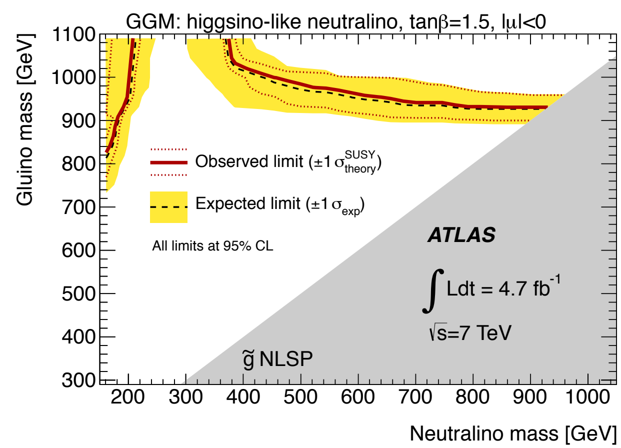
Dedicated search programme including final states with E_T^{miss} + taus, dilepton (Z & non-Z), diphotons, photon + lepton, photon + b











Top-left to bottom-right: 1210.1314, ATLAS-CONF-2012-152, 1209.0753, ATLAS-CONF-2012-144, 1211.1167

“Natural” SUSY

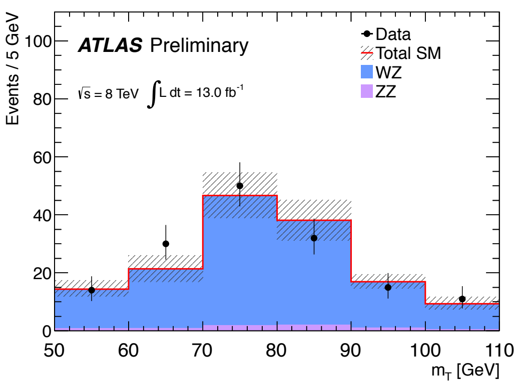
Are squarks & gluinos too heavy to be produced at 8 TeV ? Look at EW production !

1208.2884, 1208.3144, ATLAS-CONF-2012-154

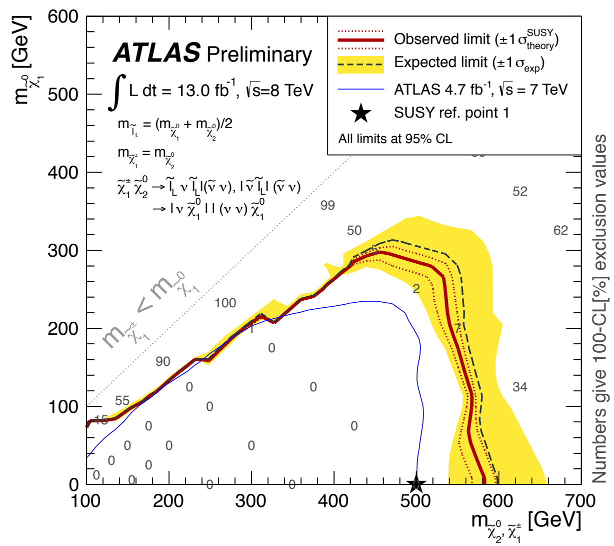
Dedicated searches for EW slepton/gaugino production in multilepton final states published this summer; 8 TeV 13 fb^{-1} update of 3-*L* search

Interpretation in simplified models but also in a phenomenological MSSM model (less “naïve”)

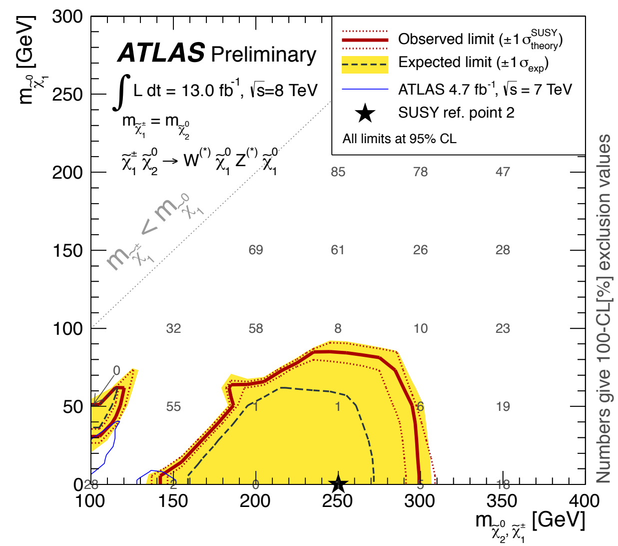
Significant background from *WZ* production; measured in dedicated control region



Limit on C+N2 production with intermediate sleptons



Limit on C+N2 production without intermediate sleptons



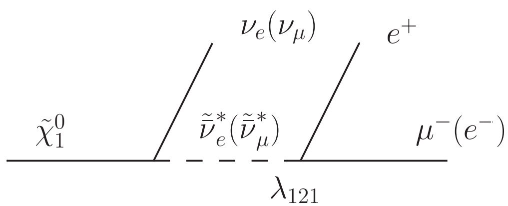
R-parity violating SUSY scenarios

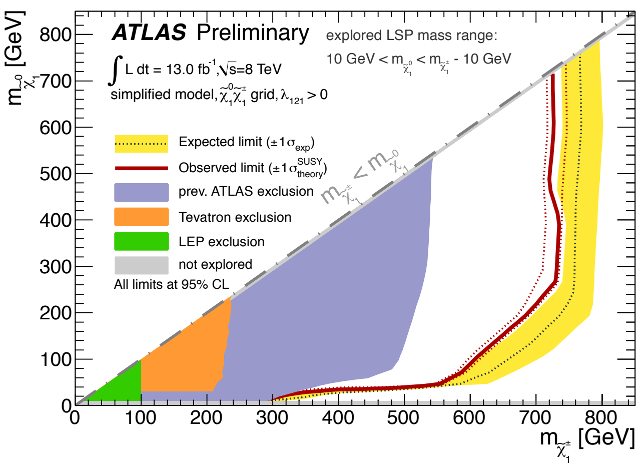
Decays of LSP in RPV models can lead to many leptons, many jets, resonances

ATLAS-CONF-2012-153, Preliminary, 1210.4813

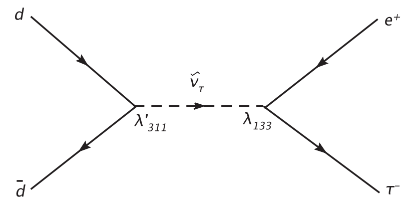
Dedicated research programme designed to assess extremely broad RPV phenomenology

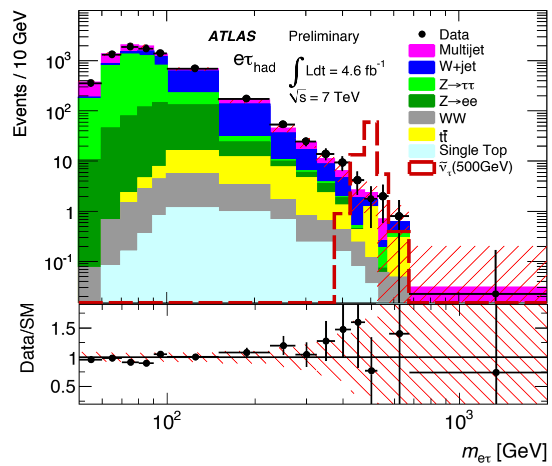
Search for strong and EW SUSY-RPV production in events with >=4-*L*





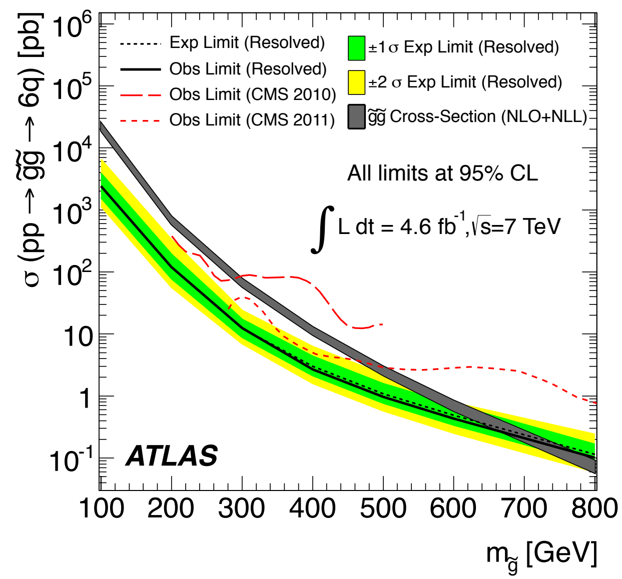
Search for RPV sneutrino production and decay through LFV into *LL'*





Search pairs of gluino decays to 3 *q*

- Powerful limit from jet multiplicity and p_T (no mass reconstruction)
- Boosted and resolved jets analysis



What about Dark Matter ?

Limits on WIMP production assuming high-scale contact interaction

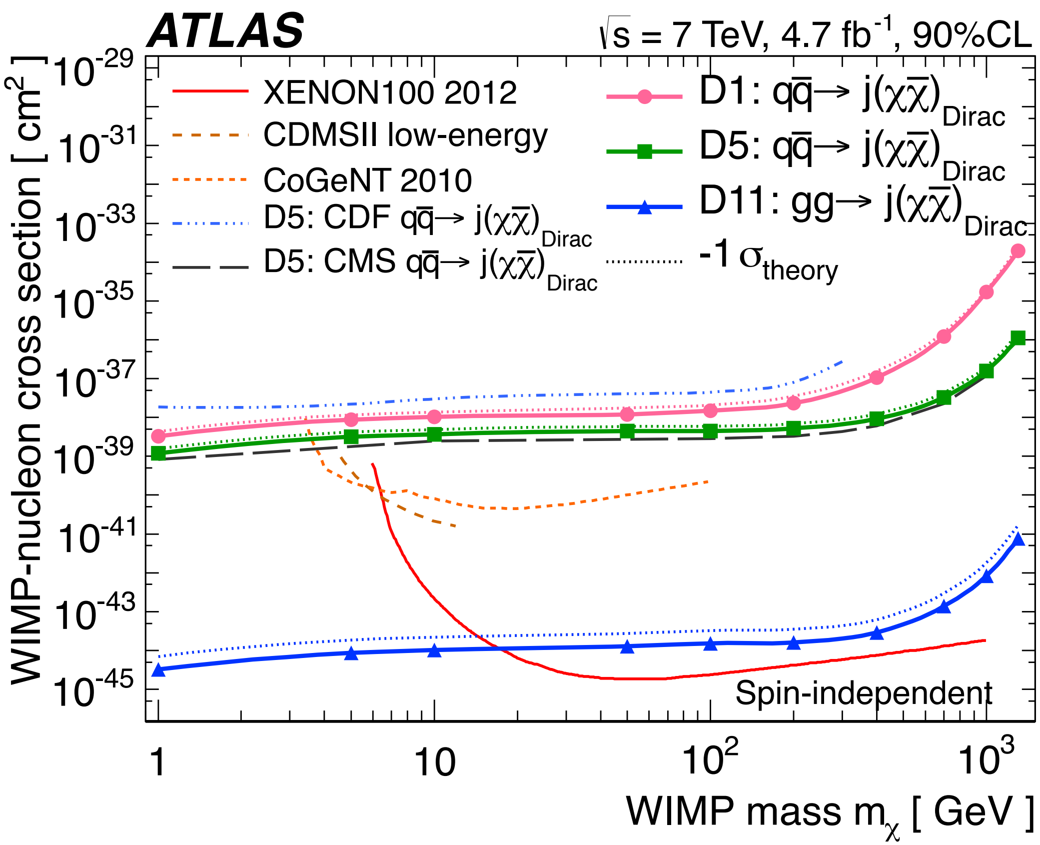
1210.4491, ATLAS-CONF-2012-147

Limit on WIMP pair production cross-section can be transformed into limit on effective WIMP-hadronic contact interaction:

Vector (SI): $(\bar{\chi}\gamma_{\mu}\chi)(\bar{q}\gamma^{\mu}q)\cdot\Lambda^{-2}$

Axial-v. (SD): $(\bar{\chi}\gamma_{\mu}\gamma^{5}\chi)(\bar{q}\gamma^{\mu}\gamma^{5}q)\cdot\Lambda^{-2}$

WIMP-nucleon scattering cross-section: $\sigma \propto \frac{1}{\Lambda^4}$

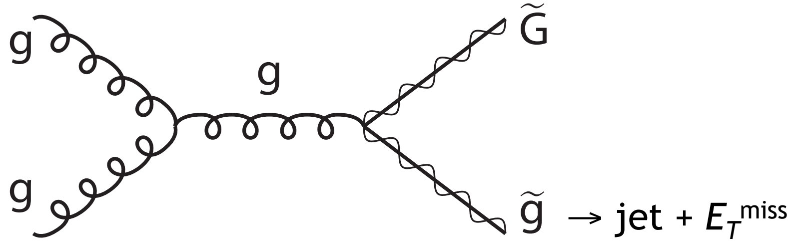


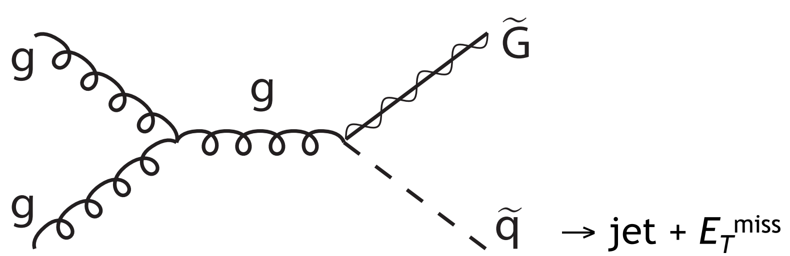
Monojet analysis as search for gravitino production

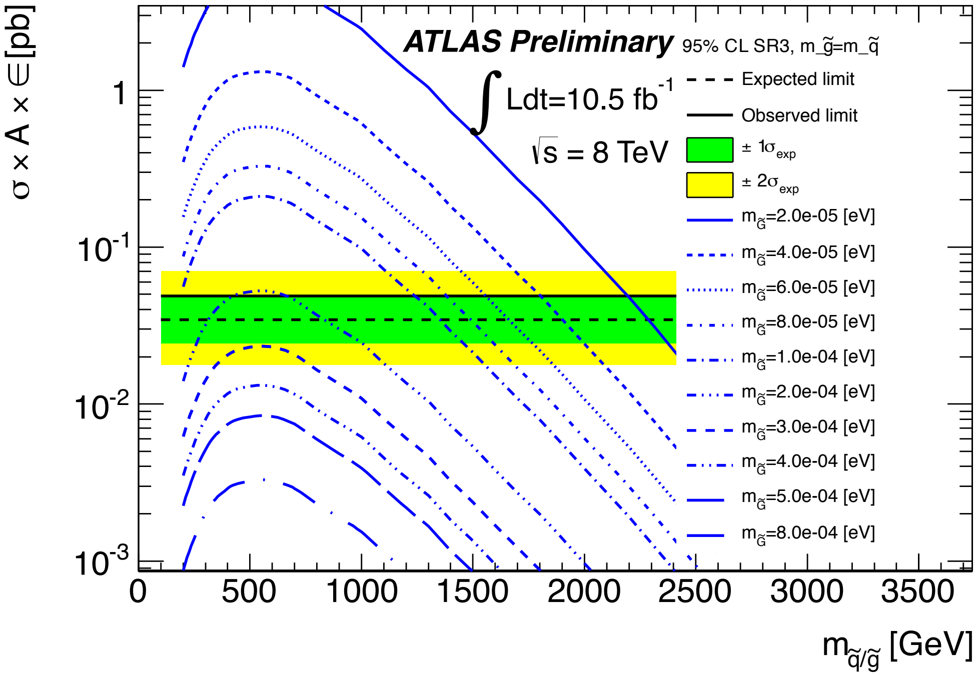
Same signature as WIMP production, but not ISR search (similar to ADD)

ATLAS-CONF-2012-147

In GM SUSY, gravitino LSP with mass related to SUSY breaking scale
At LHC with low-scale SUSY breaking, direct $\tilde{G}+\tilde{q}$ or $\tilde{G}+\tilde{g}$ production can dominate. Cross-section ~ $1/m^2(\tilde{G})$







Lower limits on gravitino mass as function of squark/gluino masses

Improves existing limits by *O*(magnitude)