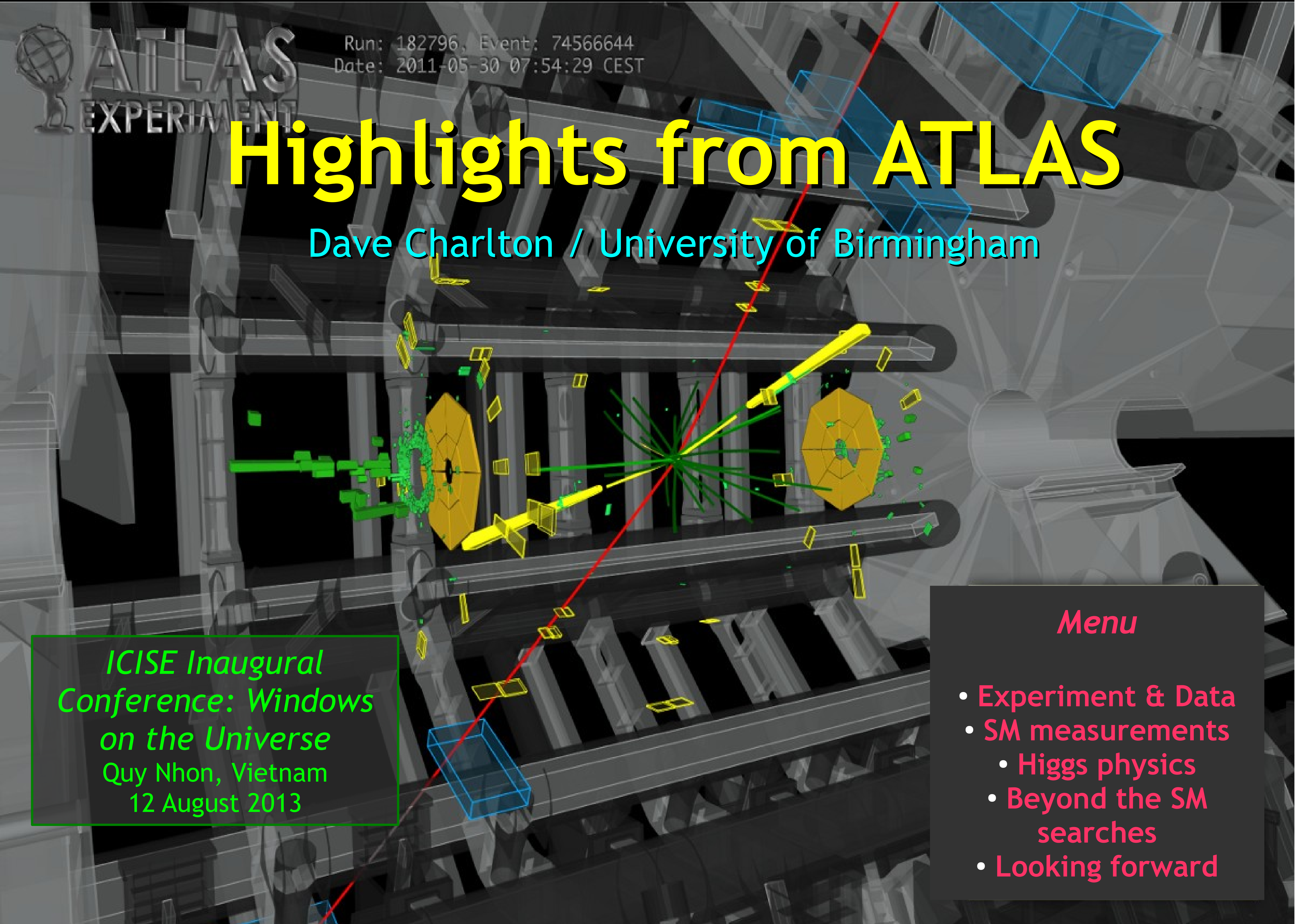


Highlights from ATLAS

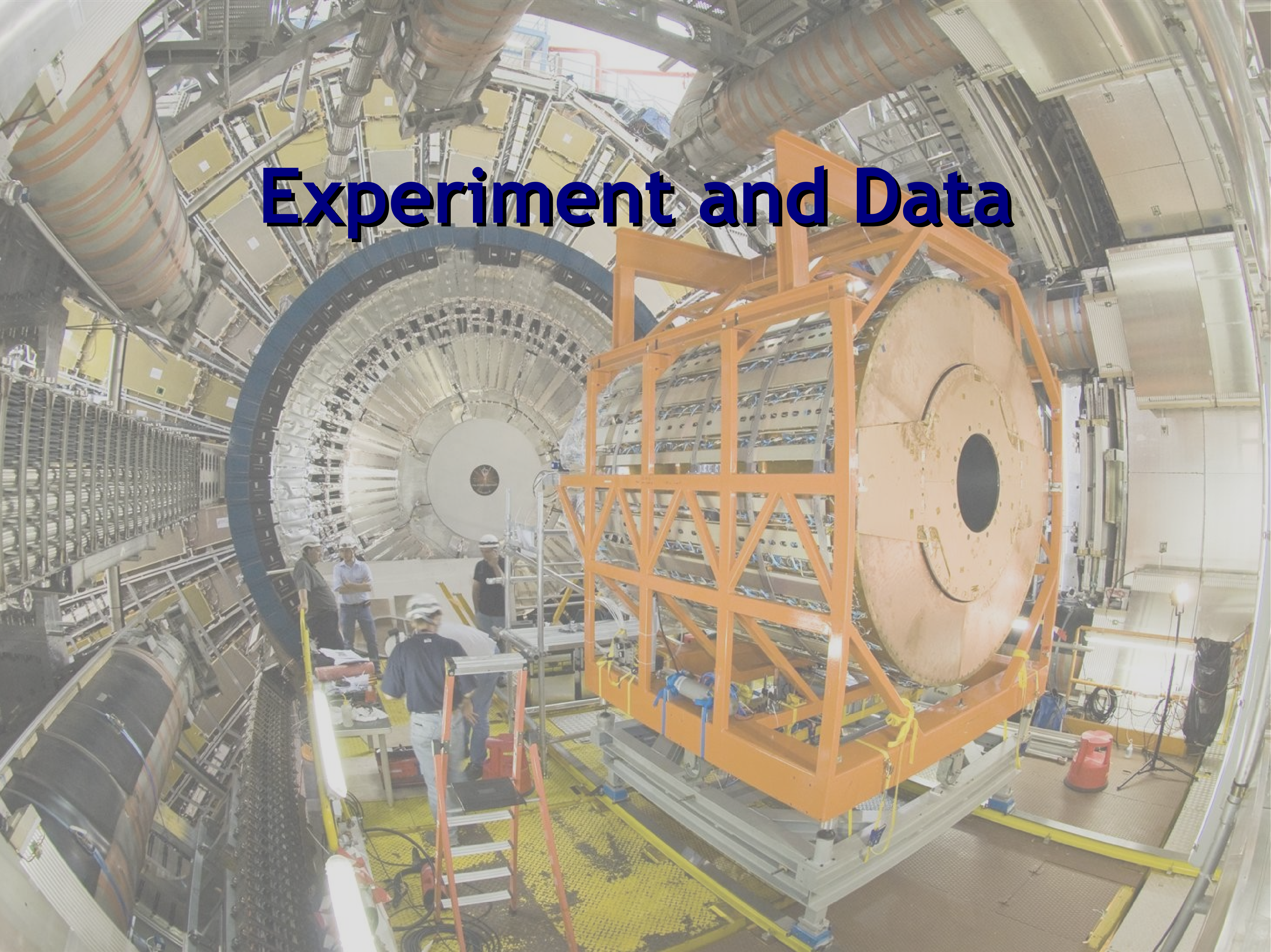
Dave Charlton / University of Birmingham

ICISE Inaugural Conference: Windows on the Universe
Quy Nhon, Vietnam
12 August 2013

Menu

- Experiment & Data
- SM measurements
- Higgs physics
- Beyond the SM searches
- Looking forward

Experiment and Data




Argentina
Armenia
Australia
Austria
Azerbaijan
Belarus
Brazil
Canada
Chile
China
Colombia
Czech Republic
Denmark
France
Georgia
Germany
Greece
Israel
Italy
Japan
Morocco
Netherlands
Norway
Poland
Portugal
Romania
Russia
Serbia
Slovakia
Slovenia
South Africa
Spain
Sweden
Switzerland
Taiwan
Turkey
UK
USA
CERN
JINR
ATLAS
Collaboration
July 2010

38 countries, 177 Institutions
~2900 scientific authors
~1800 with PhD, ~1100 students

Adelaide, Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, Birmingham, UAN Bogota, Bologna, Bonn, Boston, Brandeis, Bratislava/SAS Kosice, Brazil Cluster, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, CERN, Chinese Cluster, Chicago, Chile, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, AGH UST Cracow, IFJ PAN Cracow, SMU Dallas, UT Dallas, DESY, Dortmund, TU Dresden, JINR Dubna, Duke, Edinburgh, Frascati, Freiburg, Geneva, Genoa, Giessen, Glasgow, Göttingen, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Iowa, UC Irvine, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Kyushu, Lancaster, UN La Plata, Lecce, Lisbon LIP, Liverpool, Ljubljana, QM London, RH London, UC London, Louisiana Tech, Lund, UA Madrid, Mainz, Manchester, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, RUPHE Morocco, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, Munich LMU, MPI Munich, Nagasaki IAS, Nagoya, Naples, New Mexico, New York, Nijmegen, Northern Illinois University, BINP Novosibirsk, NPI Petersburg, Ohio SU, Okayama, Oklahoma, Oklahoma SU, Olomouc, Oregon, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Rome I, Rome II, Rome III, RAL-STFC, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC, South Africa Cluster, Stockholm, KTH Stockholm, Stony Brook, Sydney, Sussex, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Tokyo Tech, Toronto, TRIUMF, Tsukuba, Tufts, Udine/ICTP, Uppsala, UI Urbana, Valencia, UBC Vancouver, Victoria, Warwick, Waseda, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin, Wuppertal, Würzburg, Yale, Yerevan

France
Georgia
Germany
Greece
Israel
Italy
Japan

Switzerland
Taiwan
Turkey

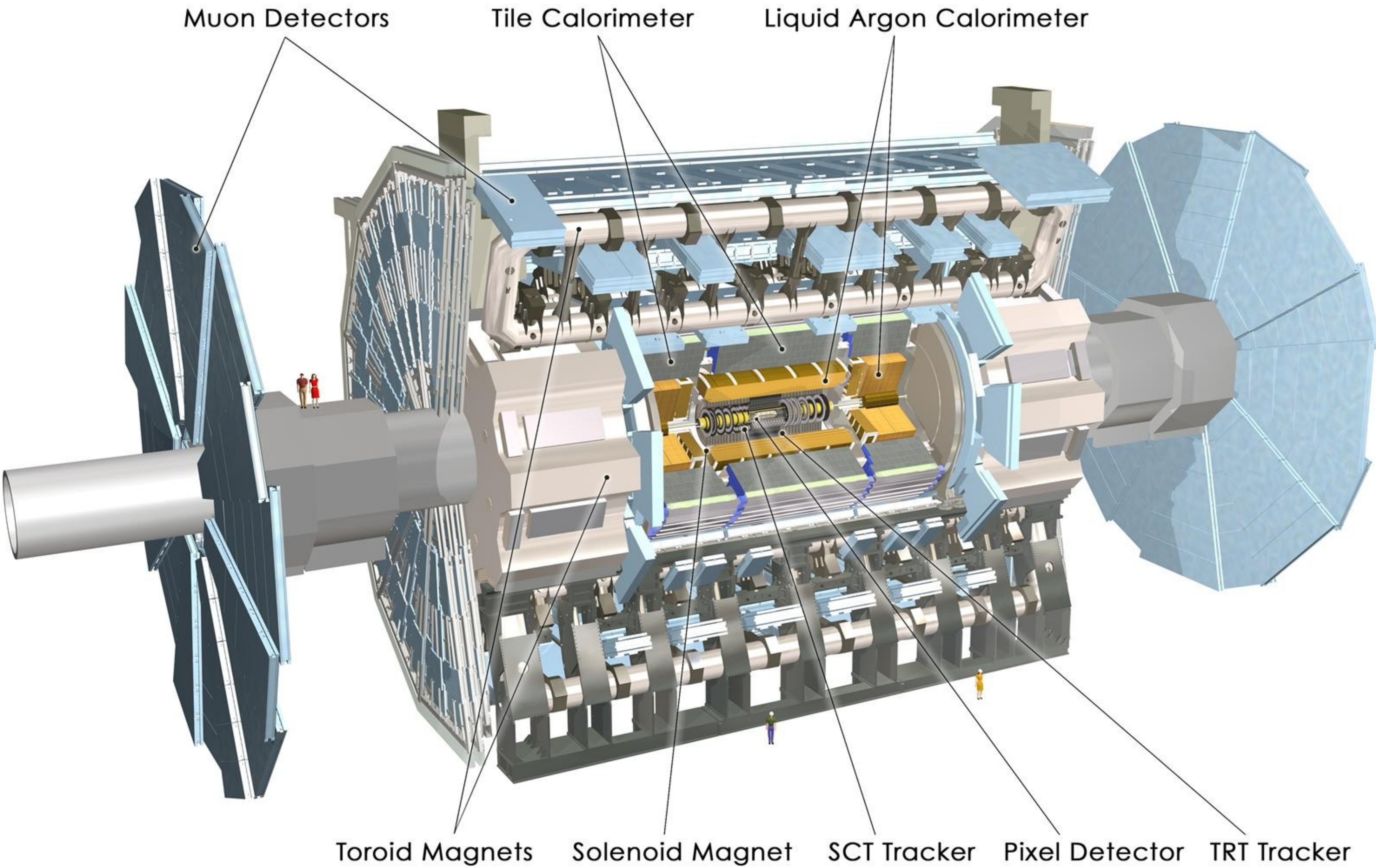
ATLAS

East Asian collaborating institutes from China (5 institutes), Japan (16 institutes), Taiwan (1 institute) and Hong Kong SAR (3 institutes) joining ; some Vietnam students via French institutes

July 2010

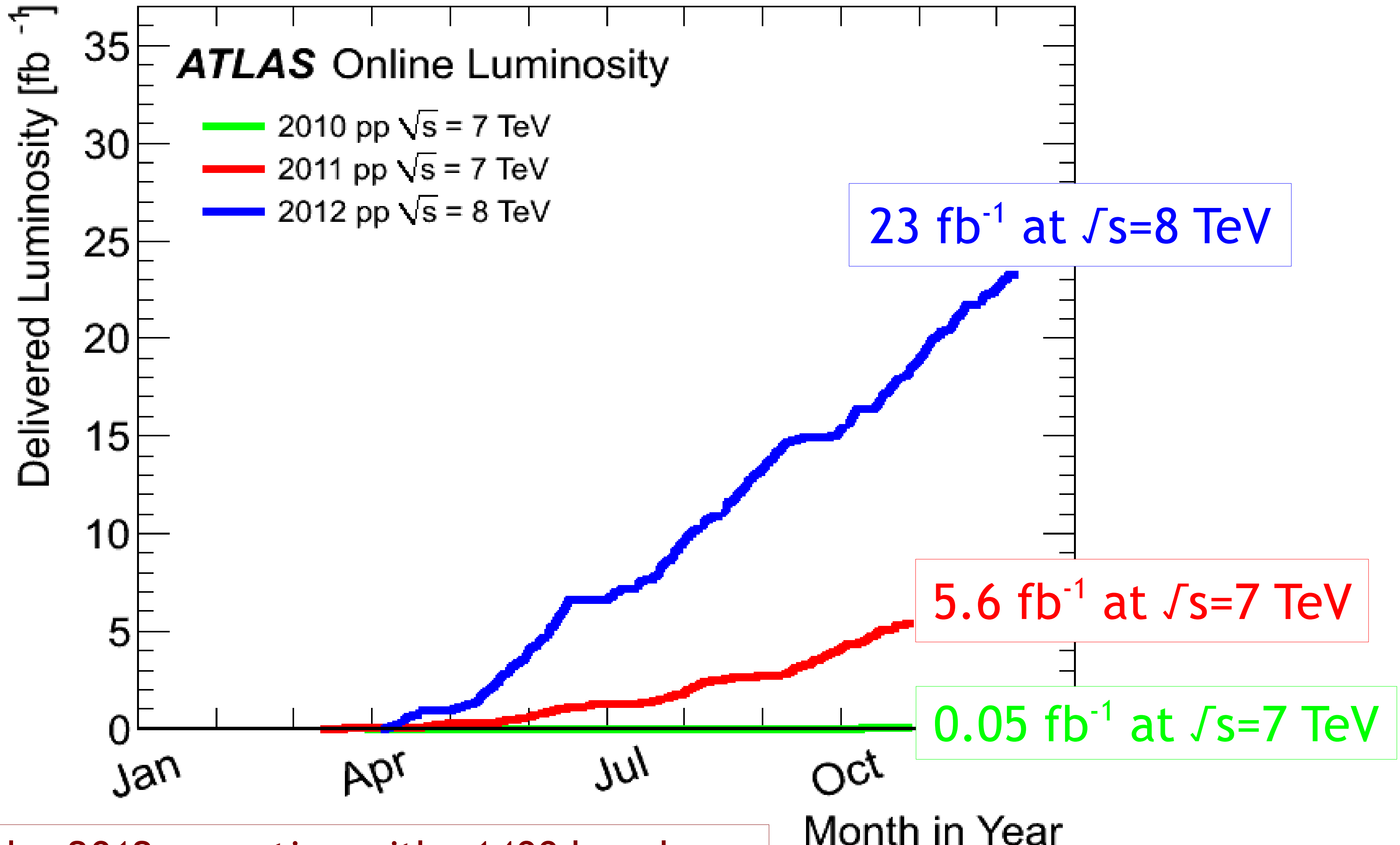
ATLAS Detector

Central tracking out to |η|=2.5, calorimetry to |η|=4.9
2T solenoid and toroids with ∫Bdl=1-7.5 Tm
25m high, 45m long, 100M channels, 7000t, 10y construction



February 2009: Visit to ATLAS of H.E. Professor Nguyen Thien Nhan, Deputy Prime Minister of Vietnam

Recorded pp data over the three years of “Run-1”

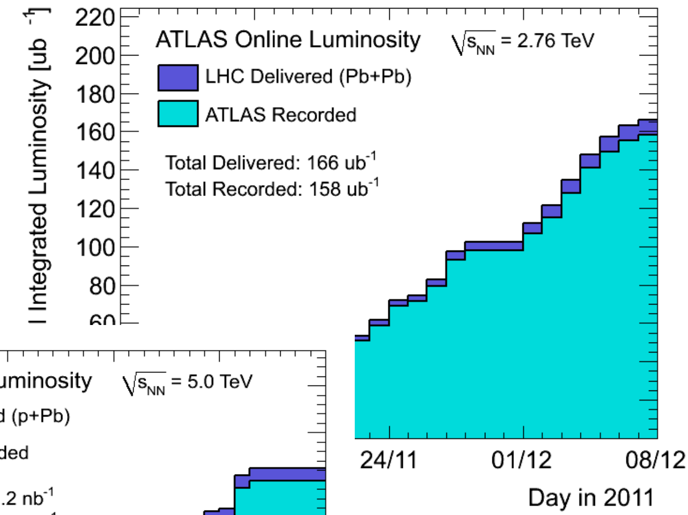


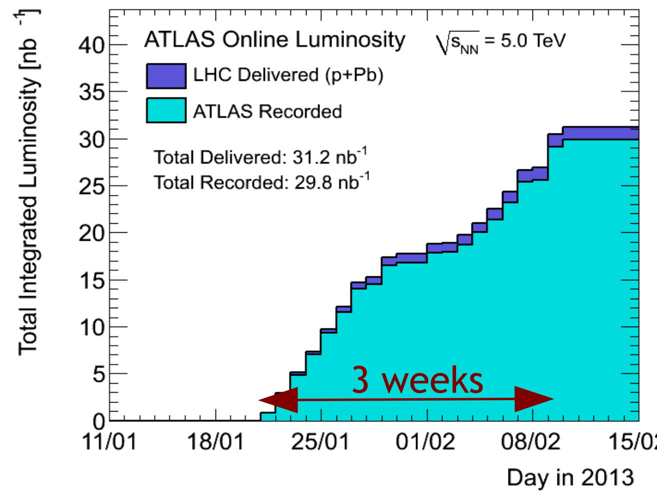
Regular 2012 operation with ~1400 bunches with 50 ns separation

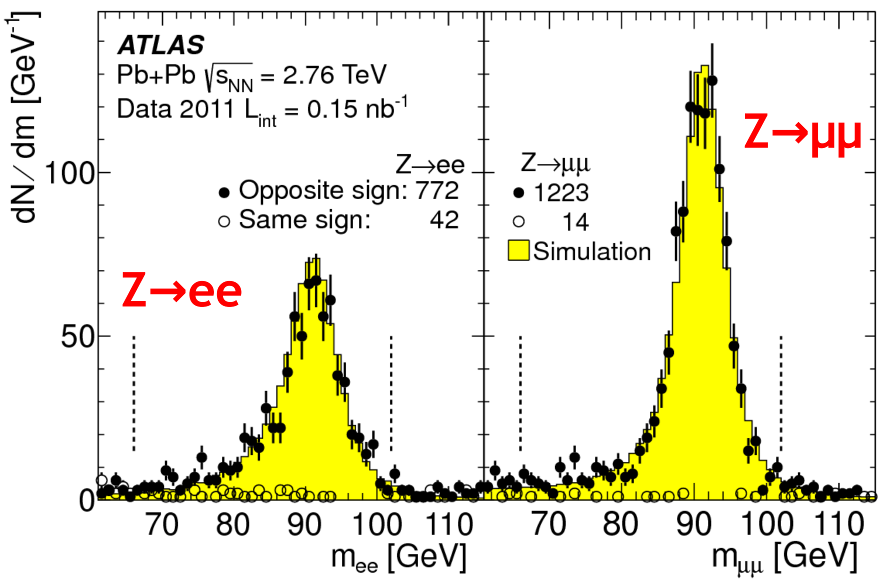
Heavy-ion data

In addition to the large 7/8 TeV pp sample

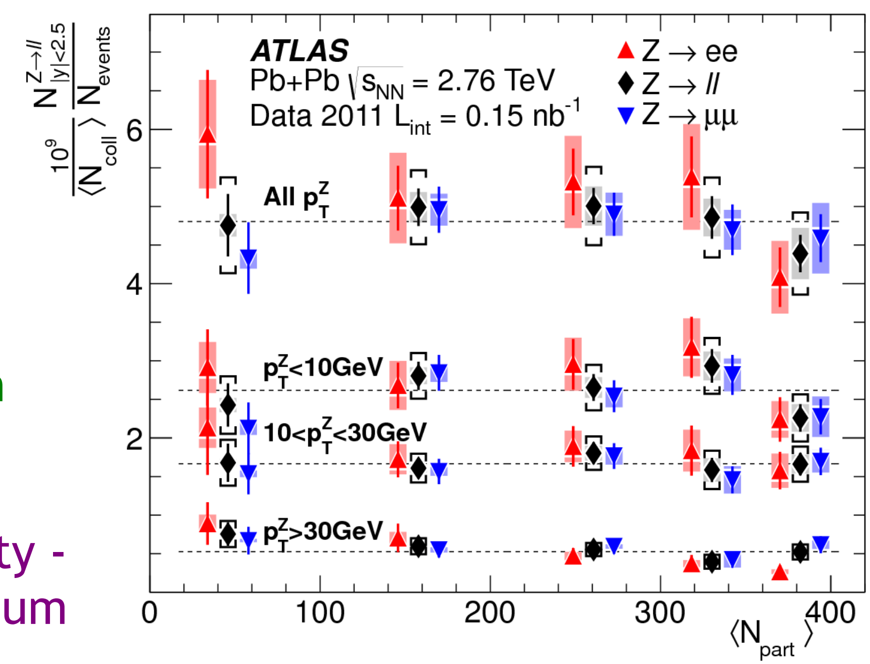
- 170 μb^{-1} Pb+Pb data @ $\sqrt{s_{NN}}$=2.76 TeV
- 30 nb^{-1} of p+Pb data @ $\sqrt{s_{NN}}$=5.02 TeV
- 5 pb^{-1} of 2.76 TeV pp data
  - Important for normalising Pb+Pb hard probes







Just one example analysis: Z → ℓℓ production in Pb+Pb collisions



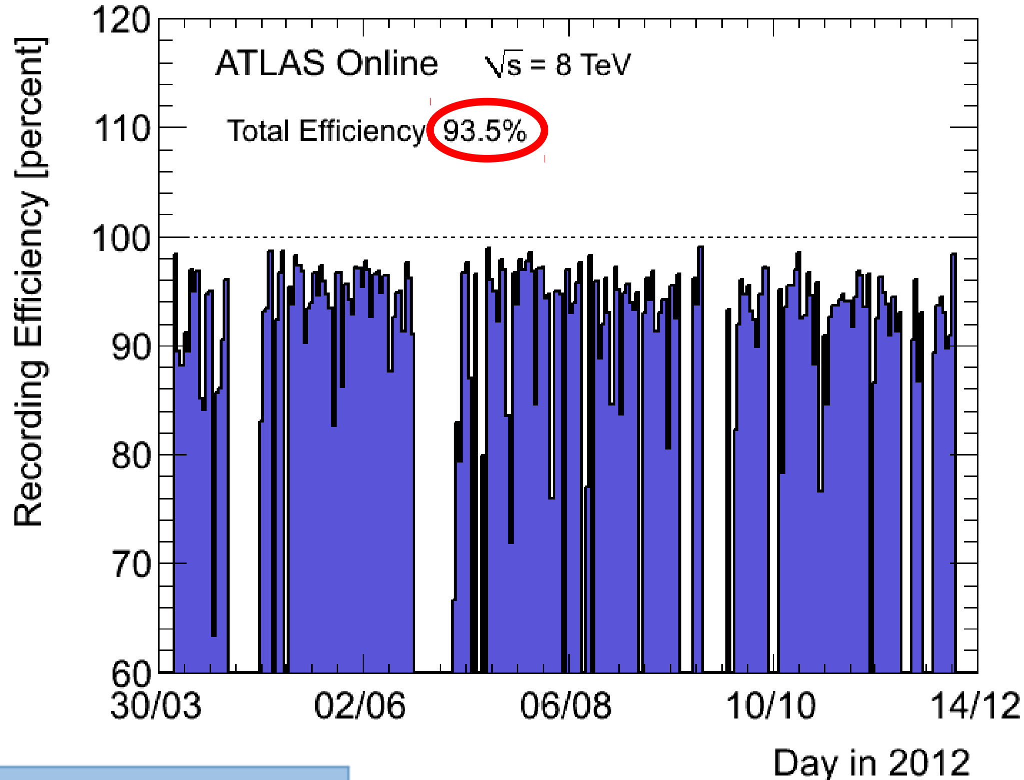
Z production/decays independent of centrality - unaffected by hot dense medium

Data-taking efficiency and data quality

2012 8 TeV pp data

Around 90% of data delivered is used for analysis

(all analyses use same status cuts)



ATLAS p-p run: April-December 2012										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.9	99.4	99.8	99.1	99.6	99.6	99.8	100.	99.6	99.8	99.5
All good for physics: 95.8%										
Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at √s=8 TeV between April 4th and December 6th (in %) – corresponding to 21.6 fb^{-1} of recorded data.										

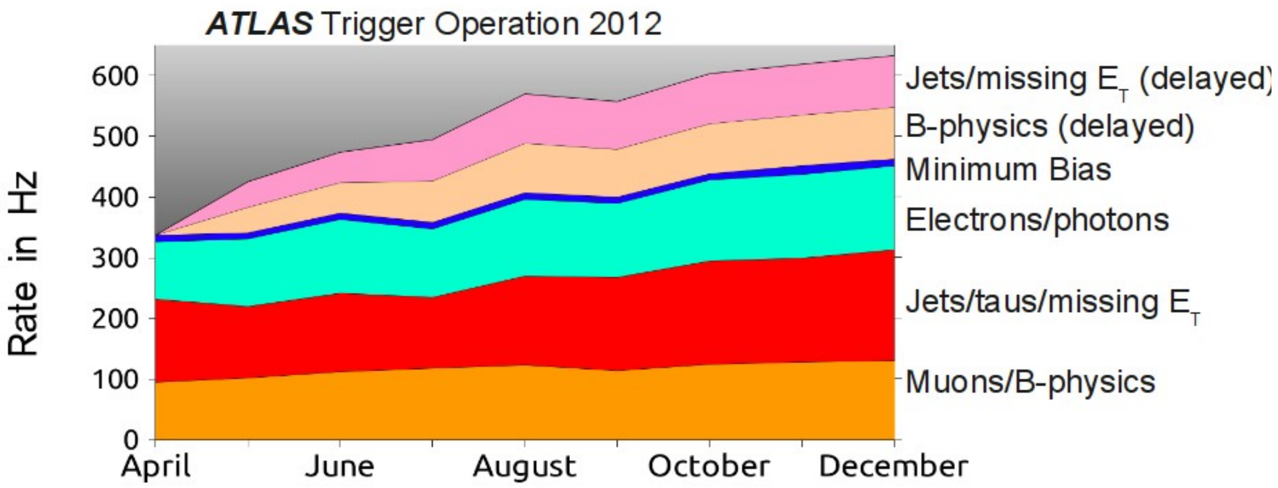
Constant attention to detail, by many people, at CERN and in home institutes, was essential to obtain such high efficiencies for data-taking and data quality

Triggering

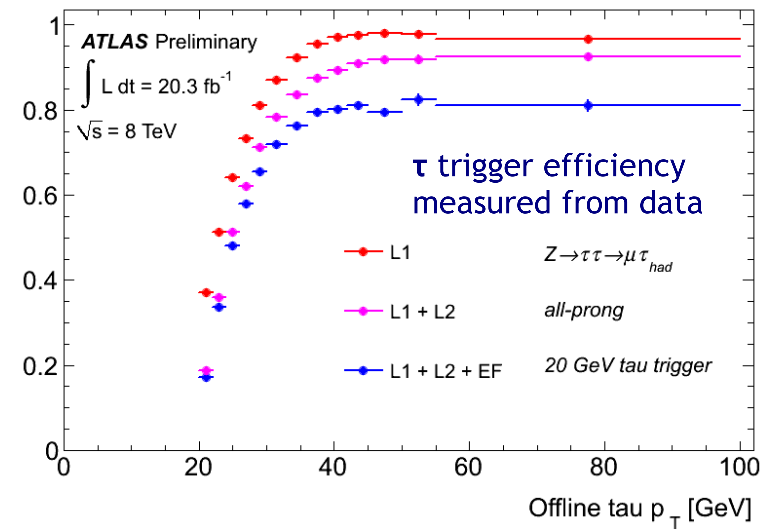
In 2012 the rather constant peak luminosity allowed a stable trigger menu

- Low **inclusive- & di-lepton thresholds** – with tight selections at low-p_T
- Very complex trigger menu

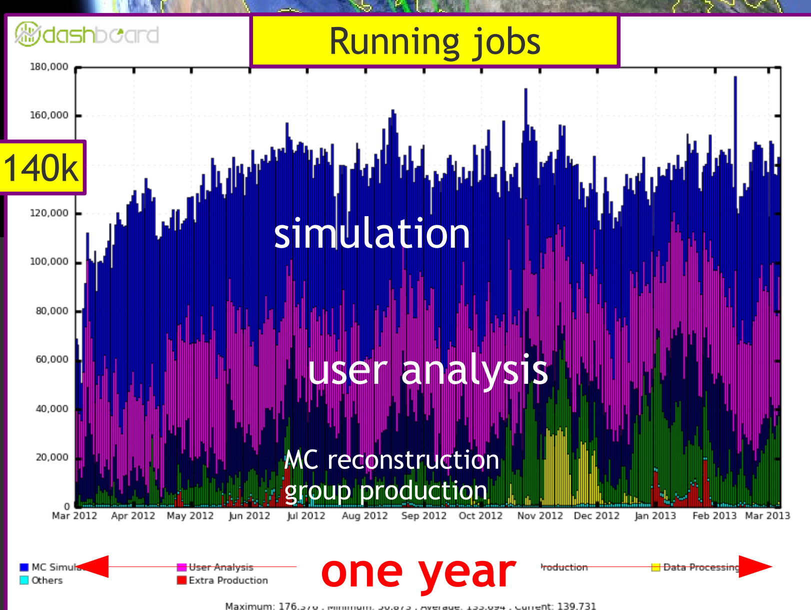
Trigger	Threshold / GeV
inclusive μ	24
inclusive e	24
dimuon	13,13 or 18,8
dielectron	12,12
ditau	29,20
diphoton	20,20
plus a couple of hundred others	

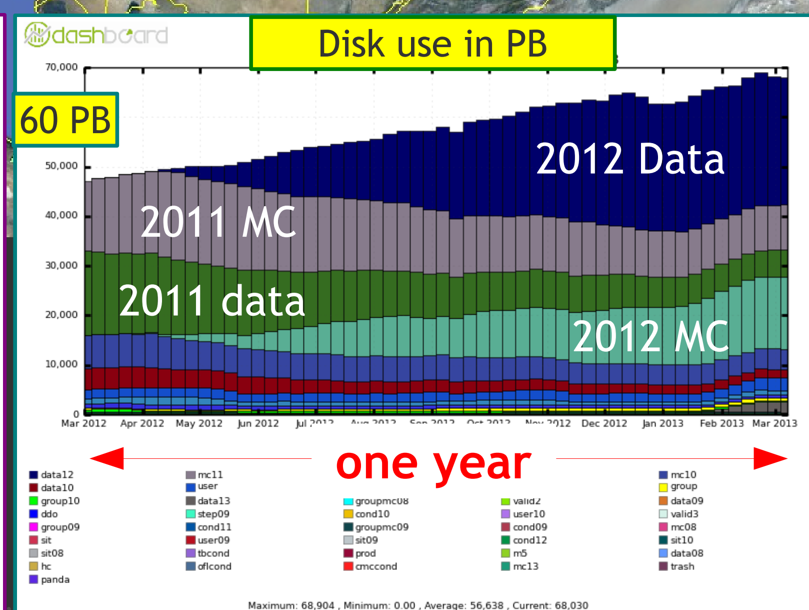


Average output rate of ~550 Hz over 2012 run (design ~200 Hz)



Worldwide LHC Computing Grid WLCG



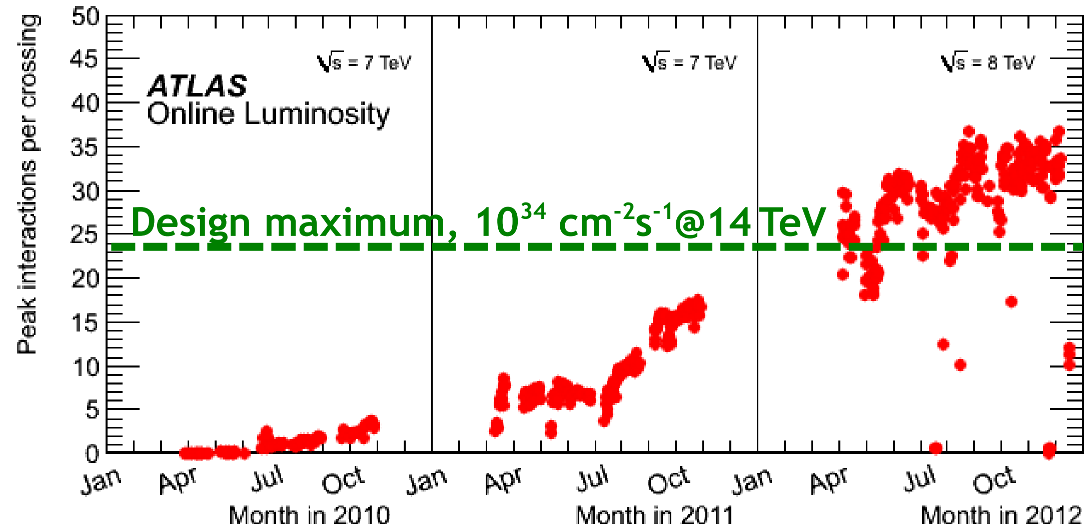


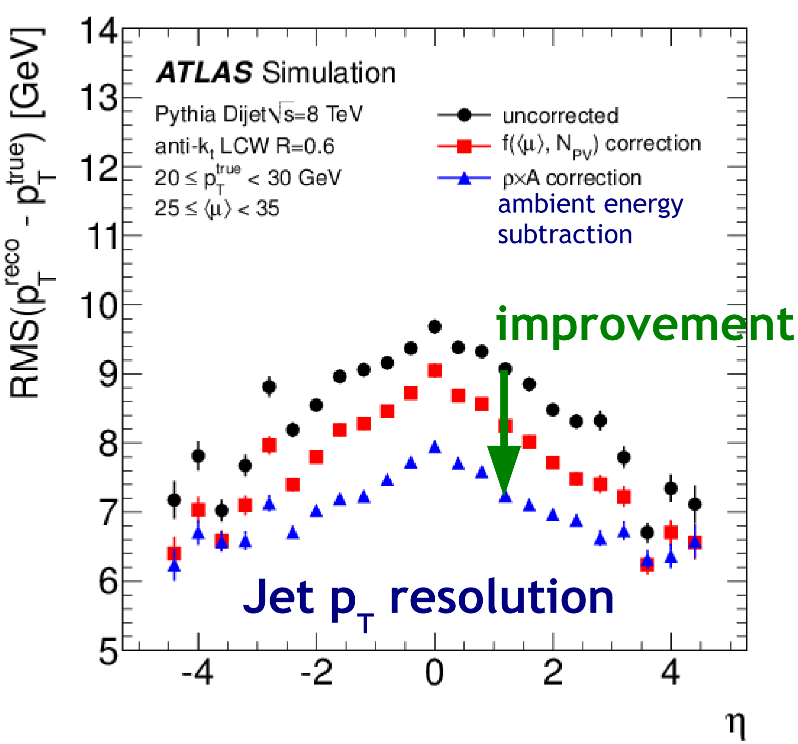
ATLAS uses ~80 WLCG sites world-wide
Performance is superb

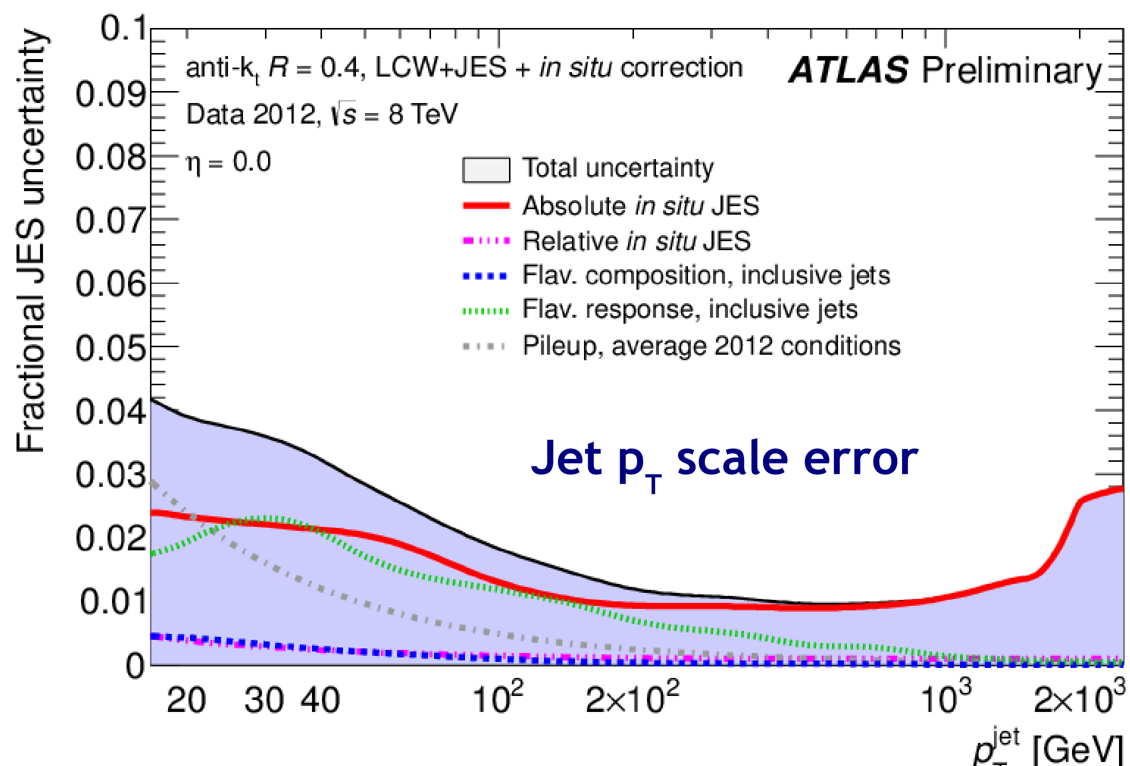
The pervasive problem of pileup

Huge challenge in 2012:
pileup levels of ~35 were routine

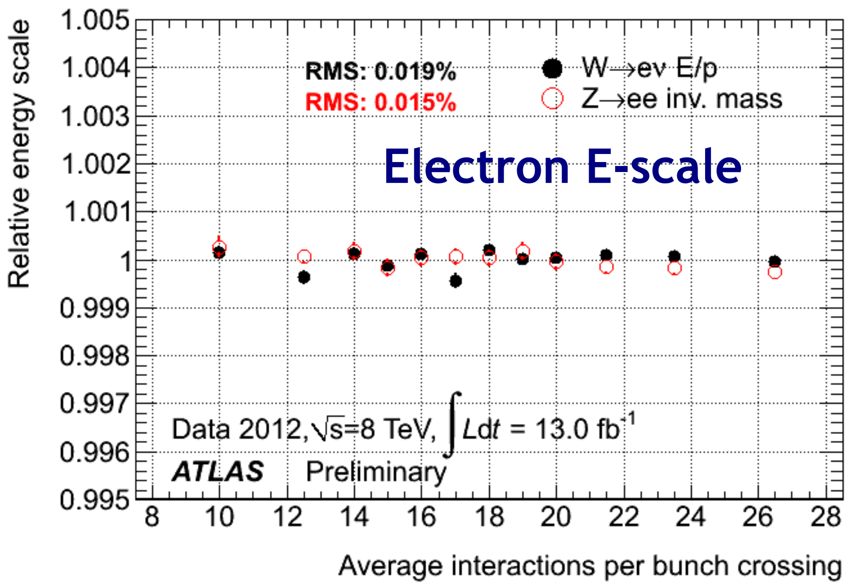
Impact of pileup substantially reduced by an inventive programme of performance improvements

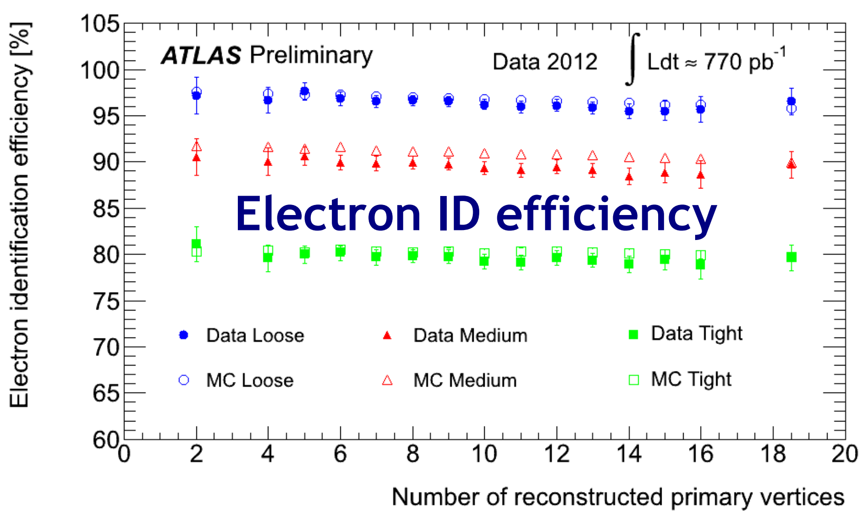


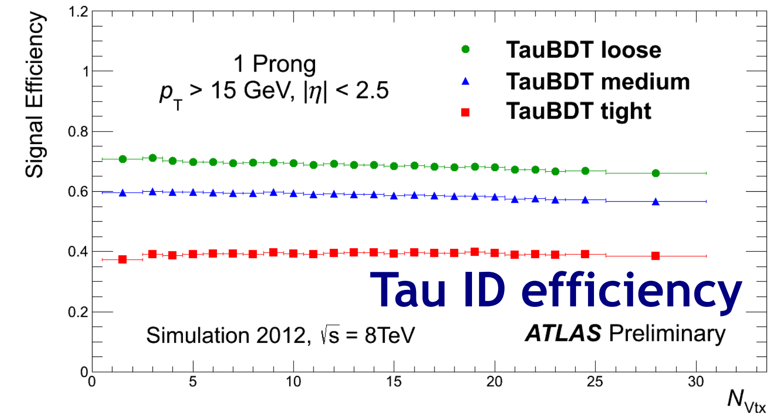


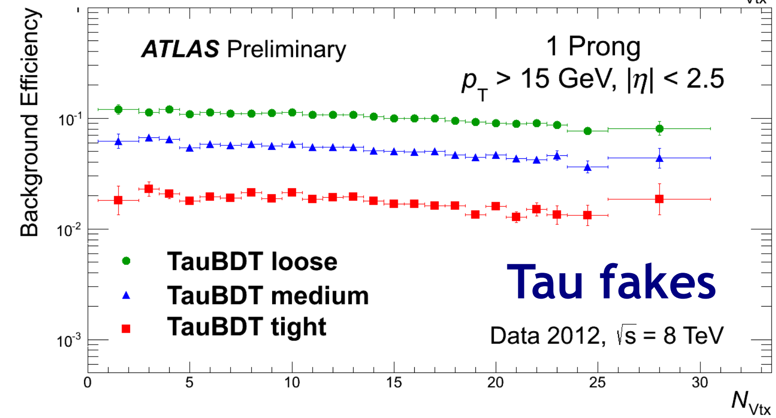


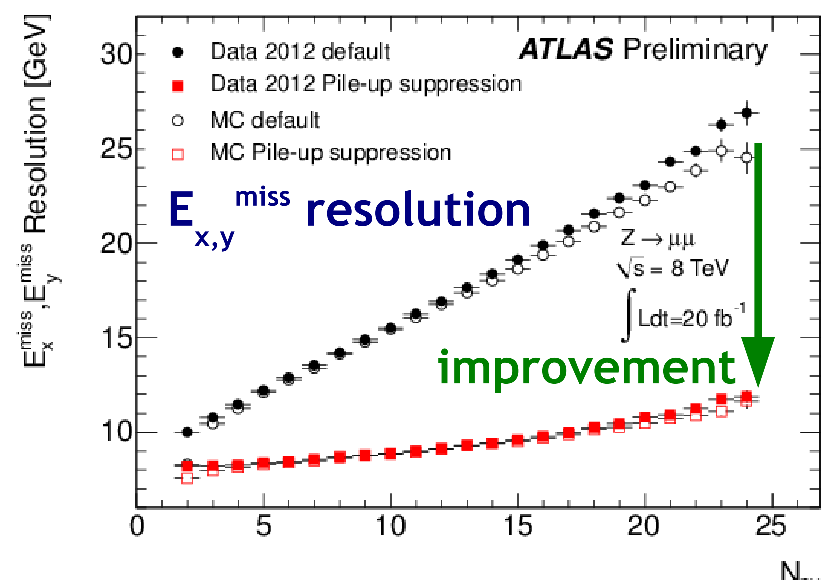
Handling pileup





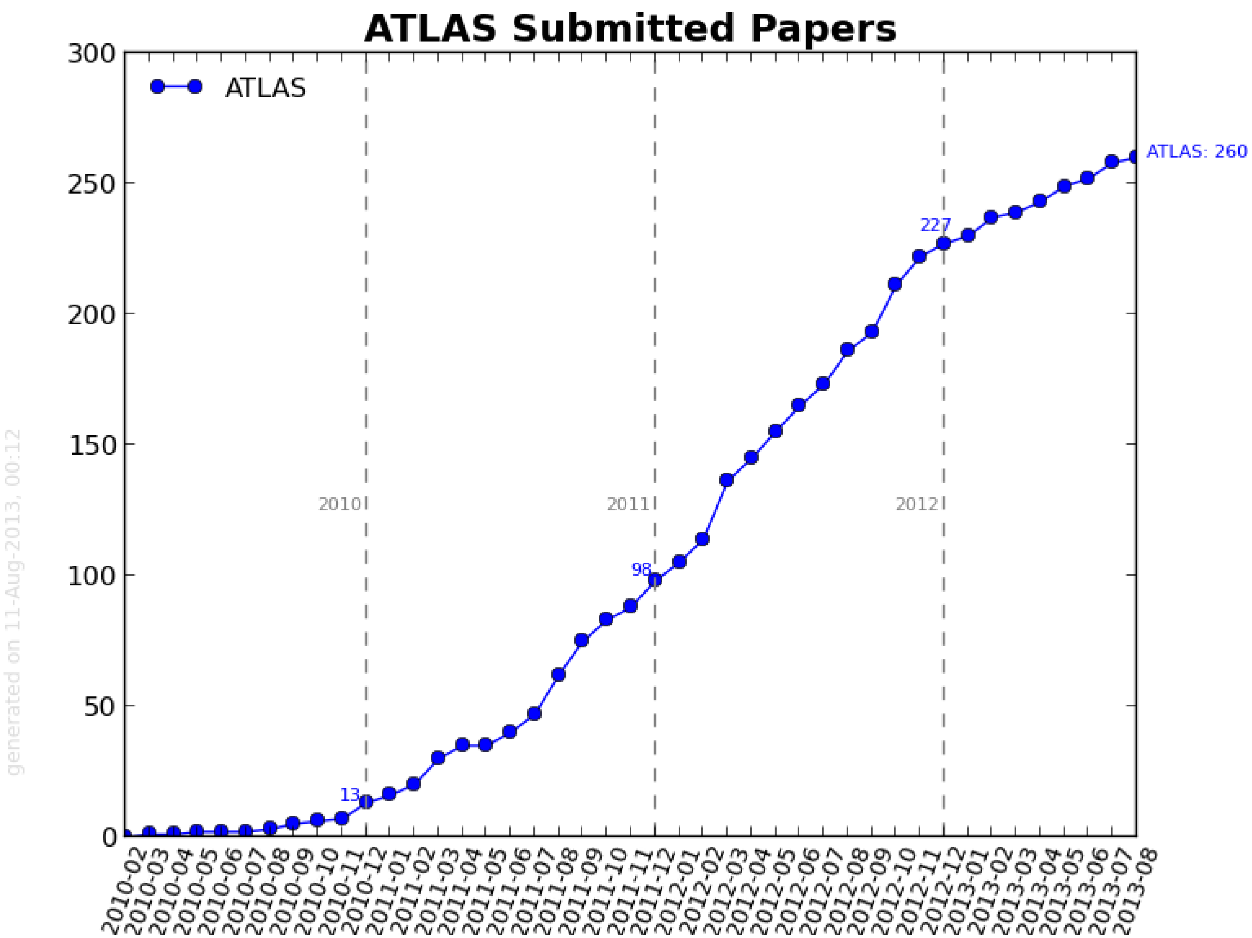






After intense work, impact of pileup can be much reduced, even beyond the design maximum of μ~25

Publications



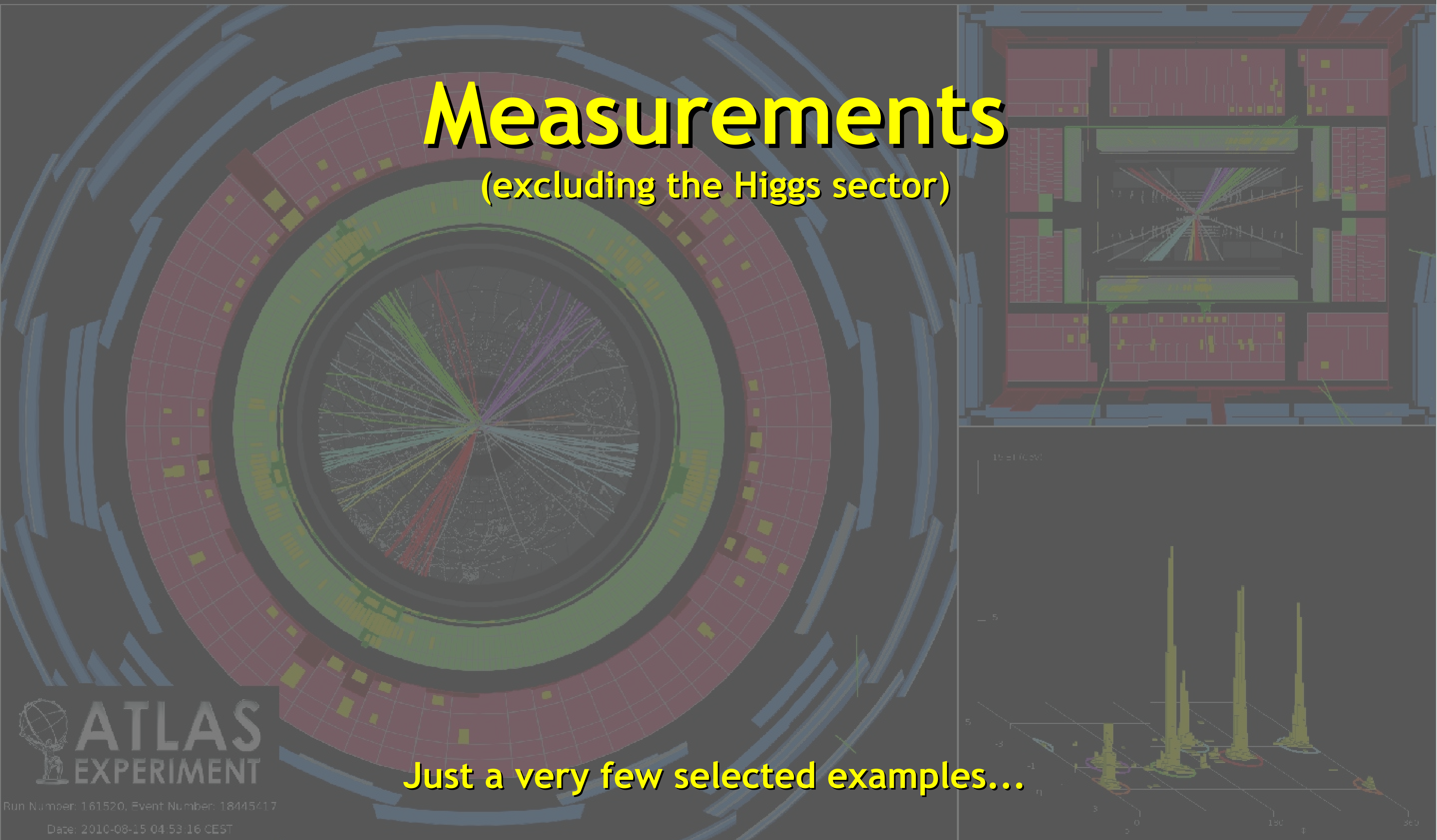
To date, 260 papers have been submitted with collision data

Sustained rate of 2.5 papers/week during 2012

In addition, 520 ATLAS CONF notes since the start of 2010

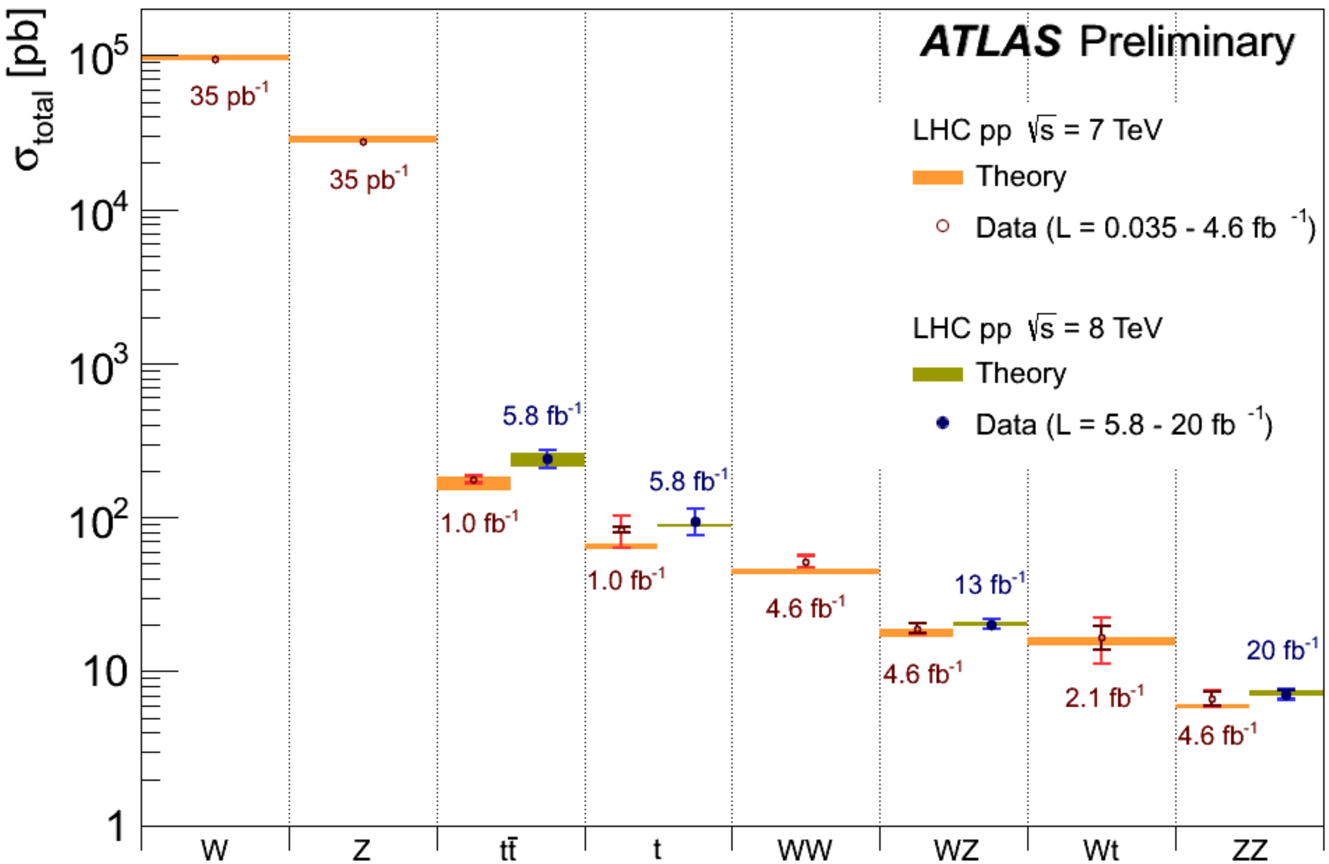
Measurements

(excluding the Higgs sector)



Just a very few selected examples...

Inclusive cross-sections



Event statistics with ~22 fb^{-1} at 8 TeV

- 1.5 quadrillion (10^{15}) pp collisions
- 3 billion recorded (+PU)

After selections:

- 100 M W→ℓν
- 10 M Z→ℓℓ
- 400k $t\bar{t}$→ℓX
- hundreds of H(125)

Beyond inclusive cross-sections: ATLAS has made a wealth of high precision measurements – can only flash a few examples here – intricate studies needing time and care

ATLAS strategy: make measurements fully corrected to fiducial acceptances, which can be reproduced easily in Monte Carlo generators, as well as extrapolating to total cross-sections

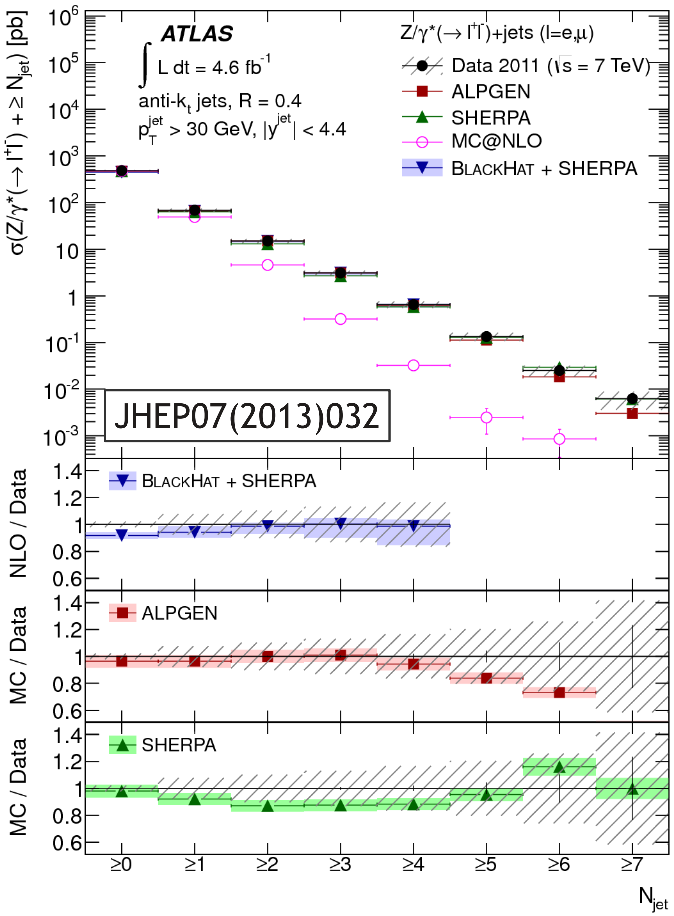
More complex topologies are important backgrounds for searches – validate MC models in more inclusive regions

W, Z in association with jets

Z+jets – measure 32 fully corrected distributions, fiducial region:

$p_T(\ell)$>20 GeV, $|\eta(\ell)|$<2.5, $\Delta R(\ell\ell)$>0.2, 66< $m(\ell\ell)$<116 GeV

$p_T(j)$>30 GeV, $|y(j)|$<4.4, $\Delta R(\ell j)$>0.5

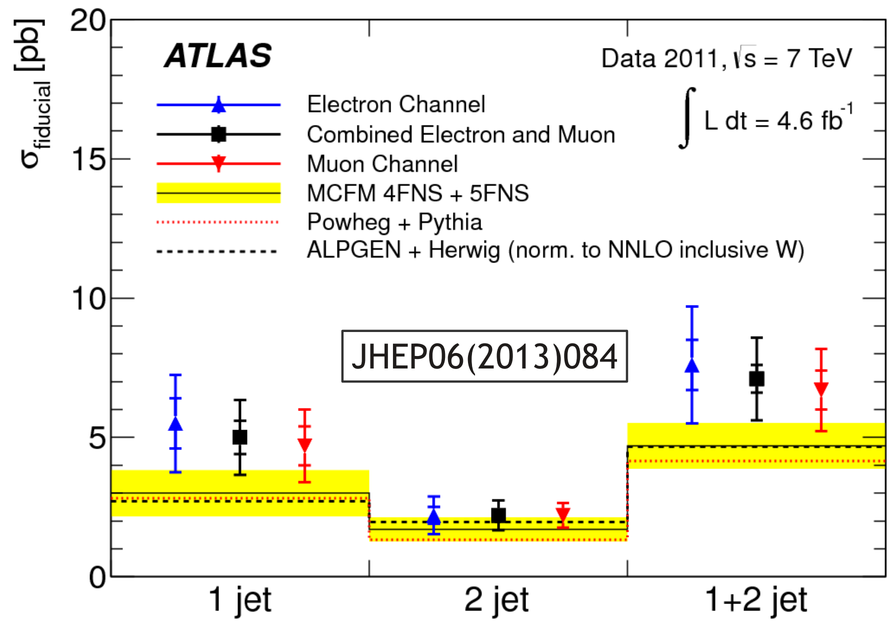


BlackHat+SHERPA performs very well, differences in detail for ALPGEN & SHERPA; MC@NLO fails for N(jet)>1

W+b-jets – measure inclusive cross-sections, and differential with respect to p_T(b-jet)

$p_T(\ell)$>25 GeV, $|\eta(\ell)|$<2.5, $p_T(\nu)$>25 GeV, $m_T(W)$>60 GeV

$p_T(j)$>25 GeV, $|y(j)|$<2.1, 1 or 2 jets, ≥1 b-tag, $\Delta R(\ell j)$>0.5



Data lie above all predictions but errors large, aim to resolve with more data

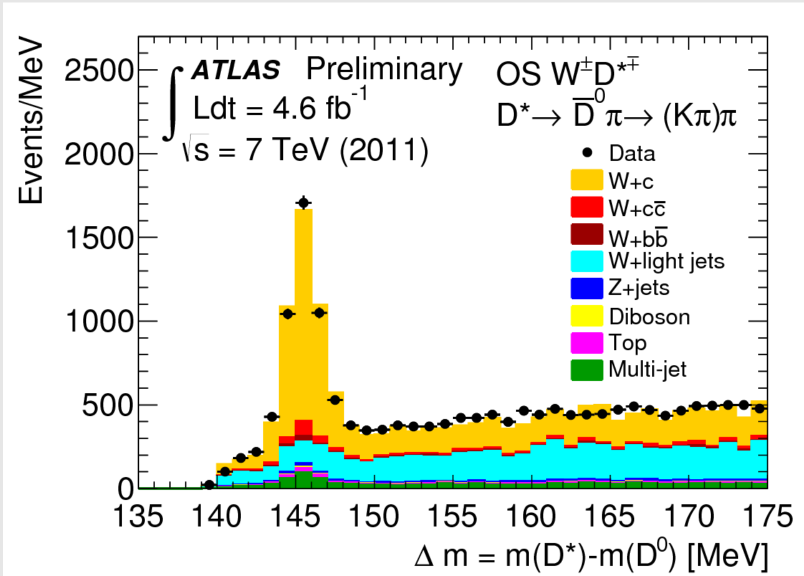
W, Z in association with jets

Z ... ions,

et)

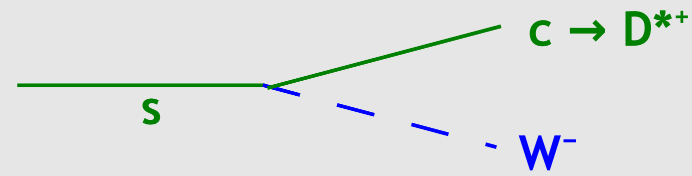
$p_T(\ell)>$ ... eV

>0.5



ATLAS-CONF-2013-045

W+c using D*-tag

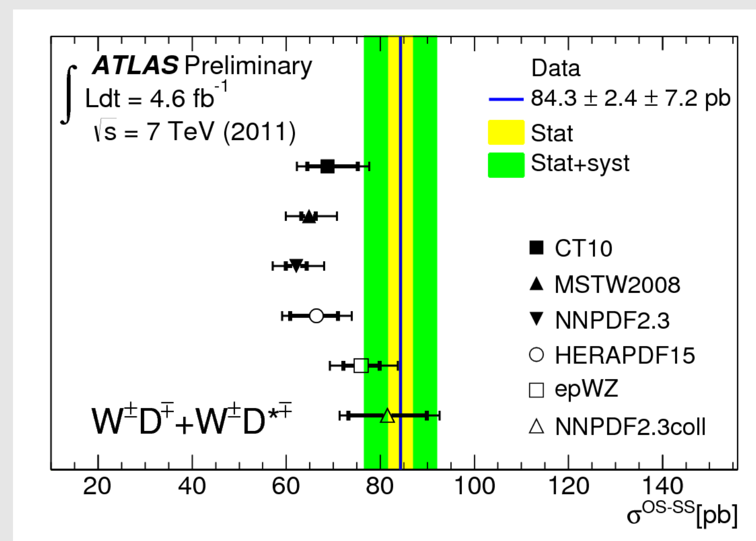


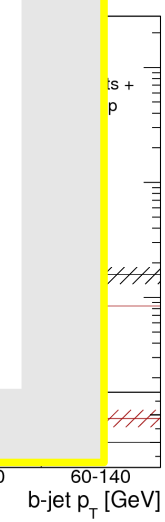
Measure $\sigma(W^{\pm}D^{(*)\mp})/\sigma(W)$ inclusively and differentially in $p_T(D^*)$, $\eta(\ell)$

$p_T(\ell)>20$ GeV, $|\eta(\ell)|<2.5$, $p_T(\nu)>25$ GeV, $m_T(W)>40$ GeV
$p_T(D)>8$ GeV, $|\eta(D)|<2.2$

Sensitive to strangeness content of the proton at $Q^2 \approx m_W^{\ 2}$

epWZ and NNPDF2.3coll have s-quark sea PDFs at x≈0.01 not suppressed relative to d-quark sea PDF





dif

MC@NLO fails for N(j)>1

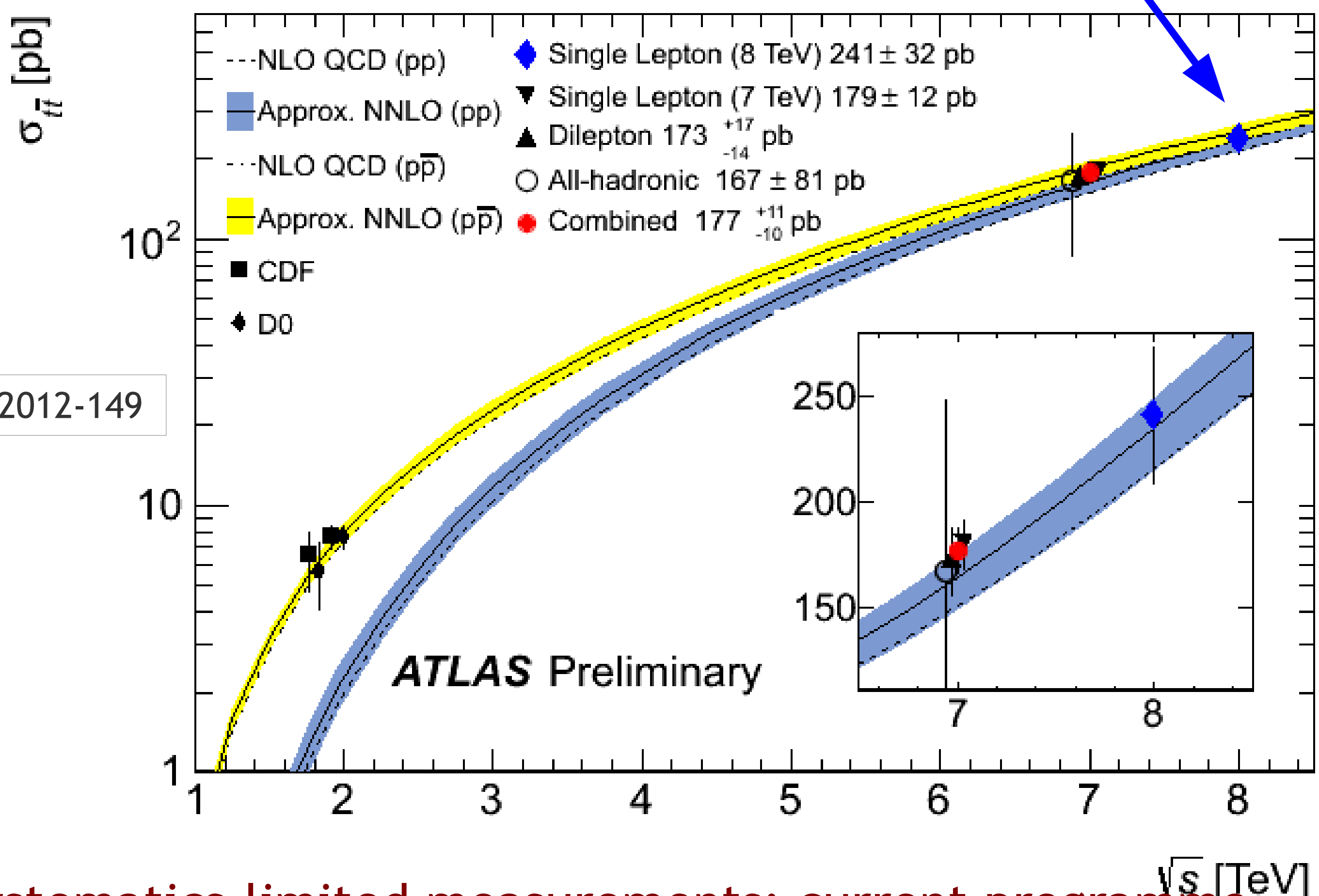
Top pair cross-section

7 TeV measurements: 0/1/2-lepton (e, μ, τ)

– well-described by approximate-NNLO predictions

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

ATLAS-CONF-2012-149



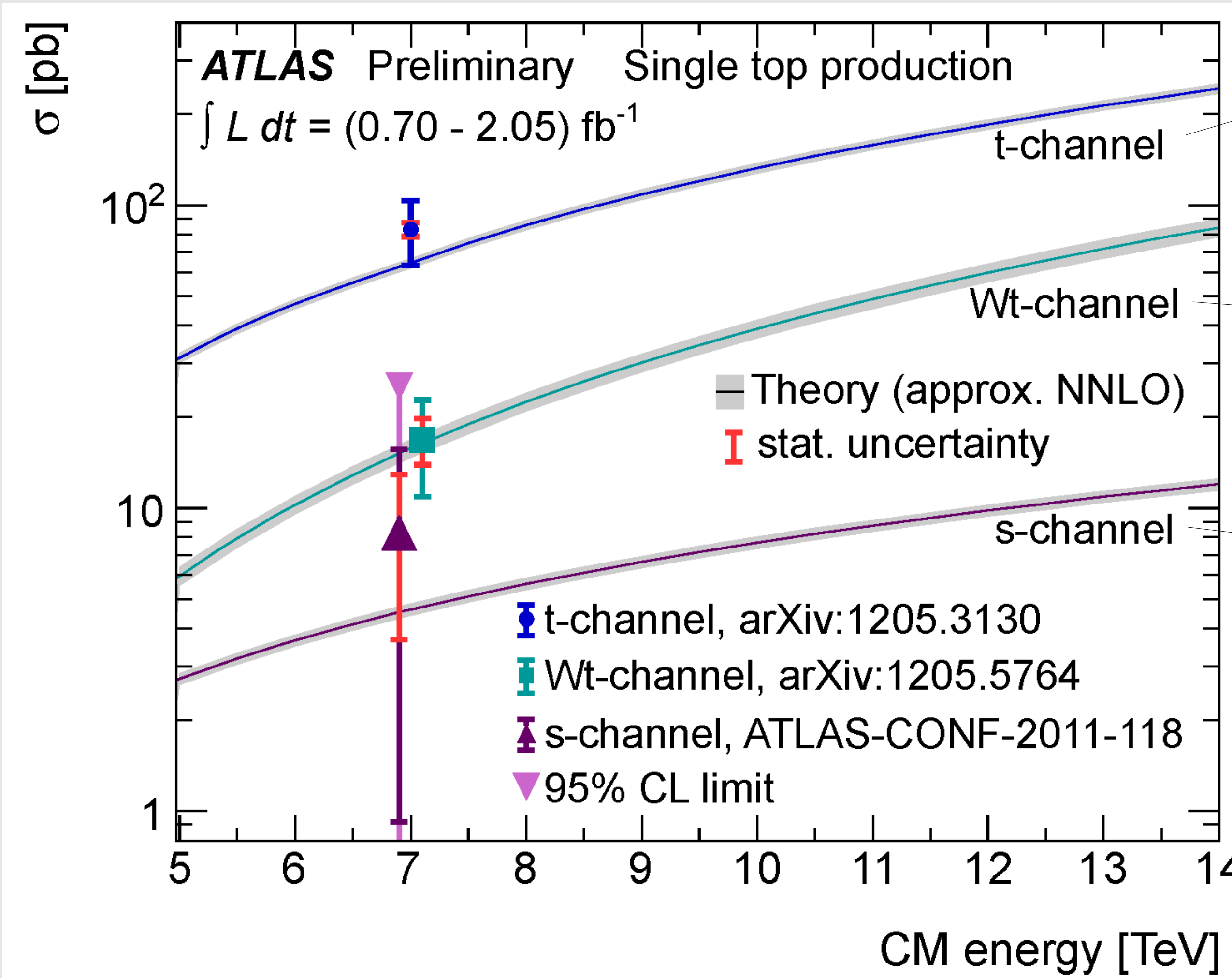
Precise systematics-limited measurements: current programme is to obtain and reduce robust systematic errors

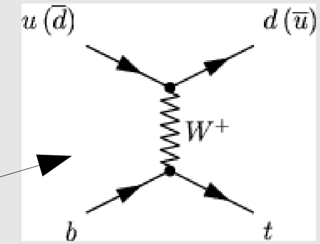
Top pair cross-section

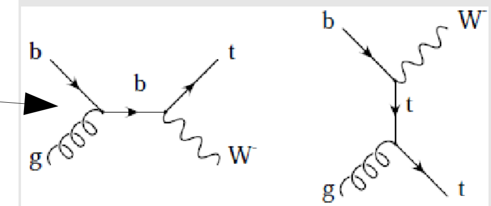
Lar

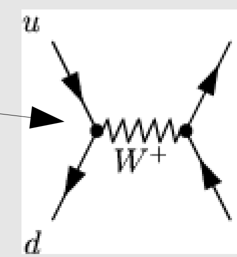
Me
like

Single-top cross-sections









3.3σ evidence for Wt production (May 2012)

Pre
obtain and reduce robust systematic errors

A Higgs Boson
Latest ATLAS Results

ATLAS EXPERIMENT
http://atlas.ch
Run: 204769
Event: 71902630
Date: 2012-06-10
Time: 13:24:31 CEST

Joe has covered the history up until “Higgsdependence Day” 4th July 2012

Here I will briefly discuss the progress from ATLAS of our new boson in its first year since birth

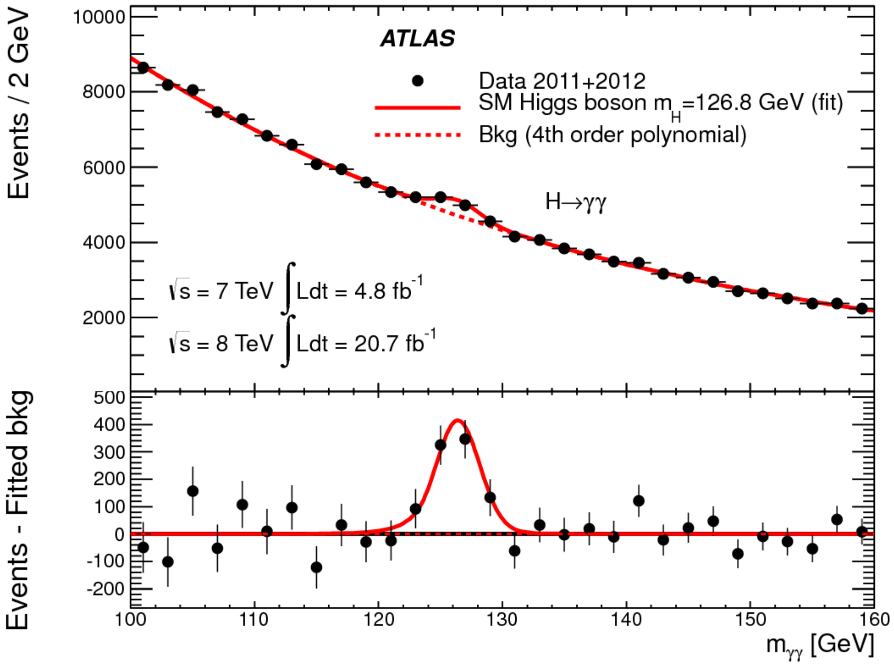
Theme – explore all we can with Run-1 data:
- Evolution of the signal
- Spin-parity of the boson
- Probe HVV & Hff couplings in as many ways as possible
- Look for unexpected decays (but not here)
- Start the programme of fully-corrected measurements

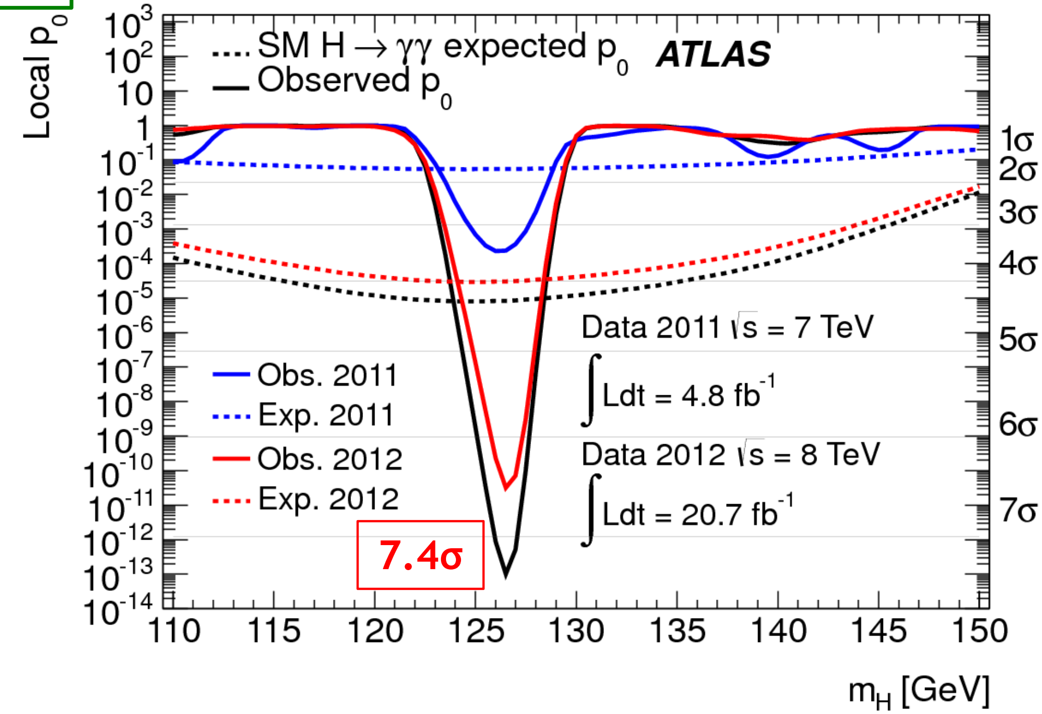
Much more tomorrow morning in the session after coffee, and in a parallel session on Wednesday afternoon

H → γγ

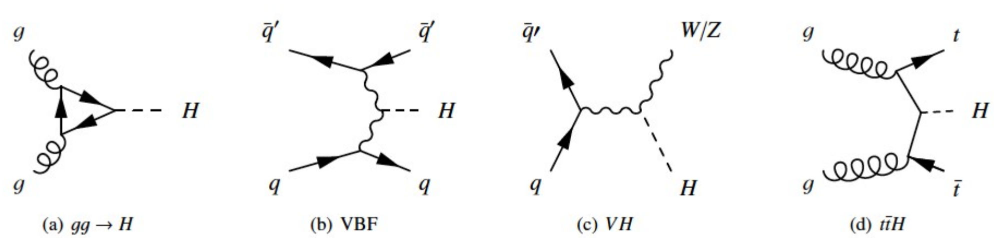
Excellent mass resolution (γ pointing in calorimeter), poor S/B

Signal significance 7.4σ, expected 4.3σ (SM)

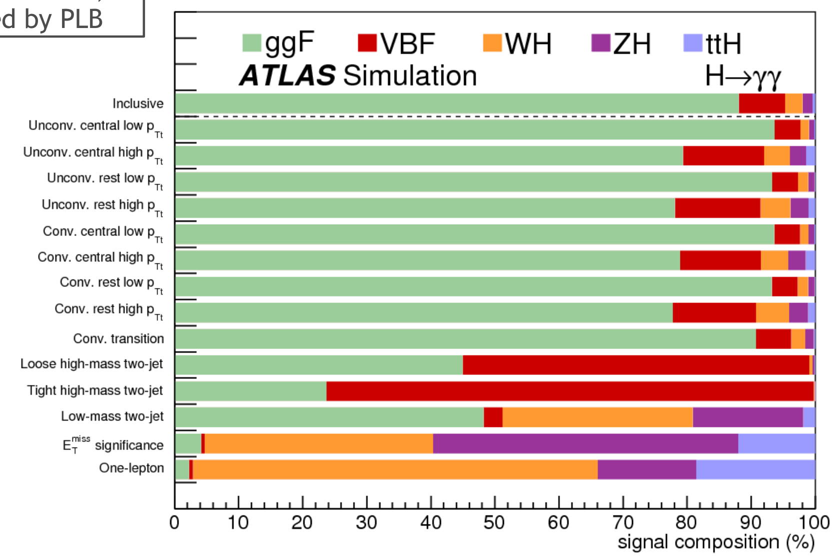


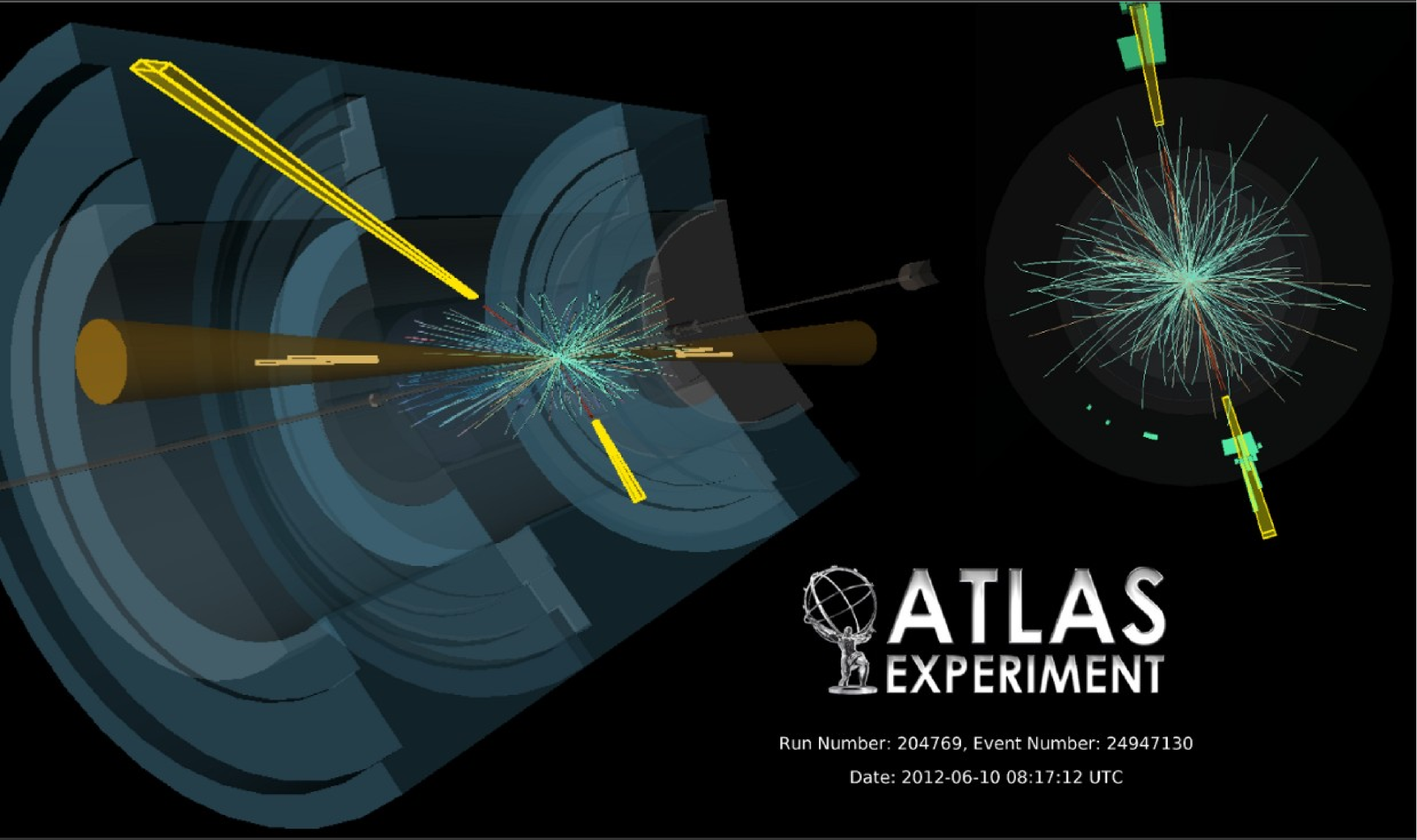


arXiv:1307.1427, accepted by PLB



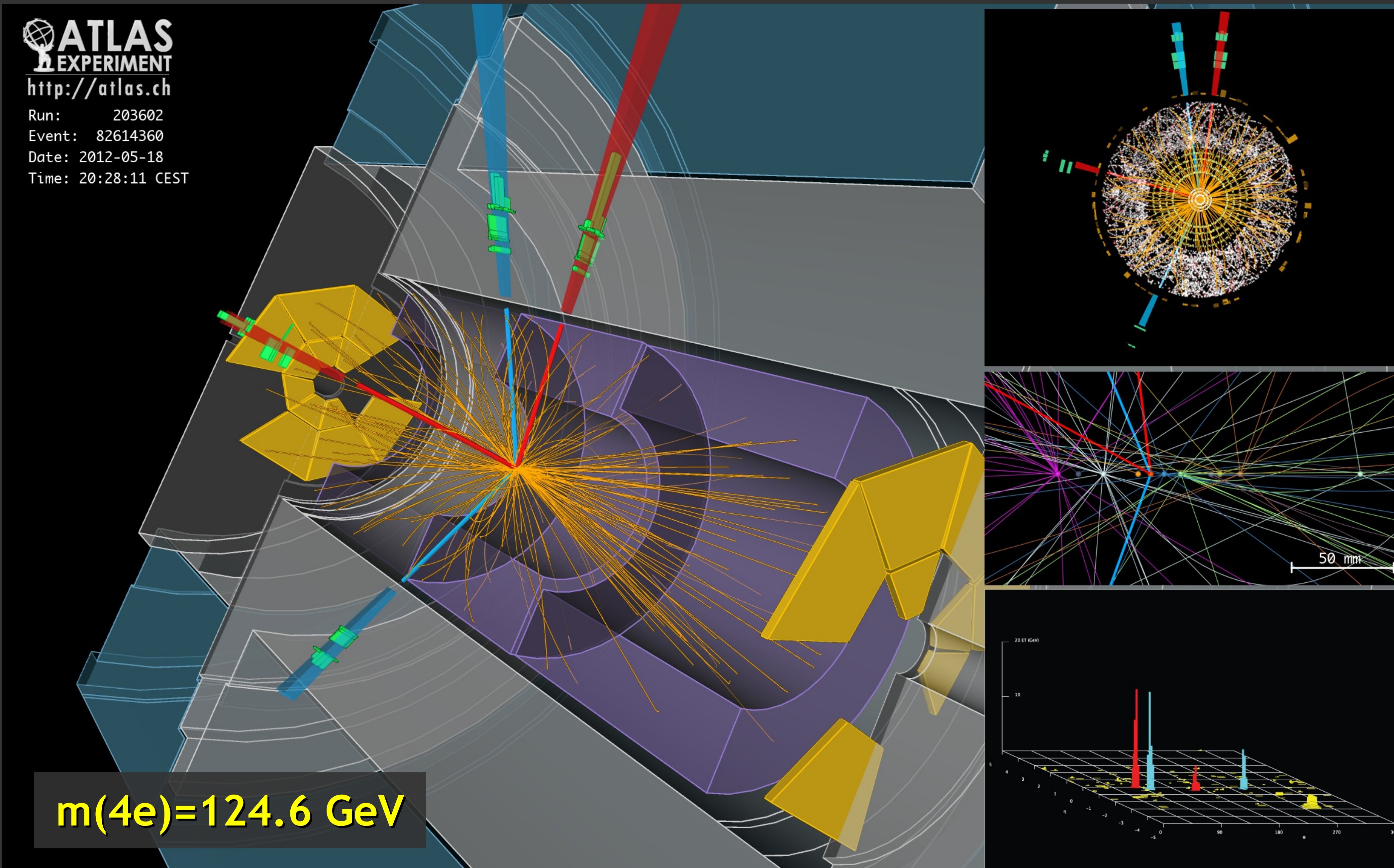
Subdivide into categories, including vector-boson fusion (VBF) and (W/Z)H (=VH) targeted selections





$H \rightarrow \gamma\gamma$ candidate in the VBF category

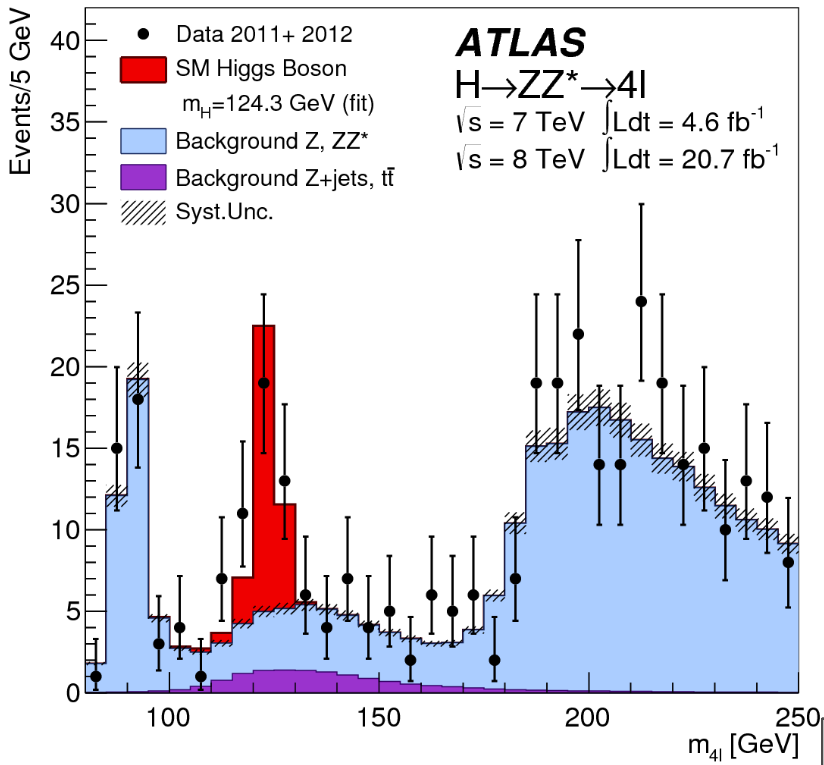
H → eeee candidate

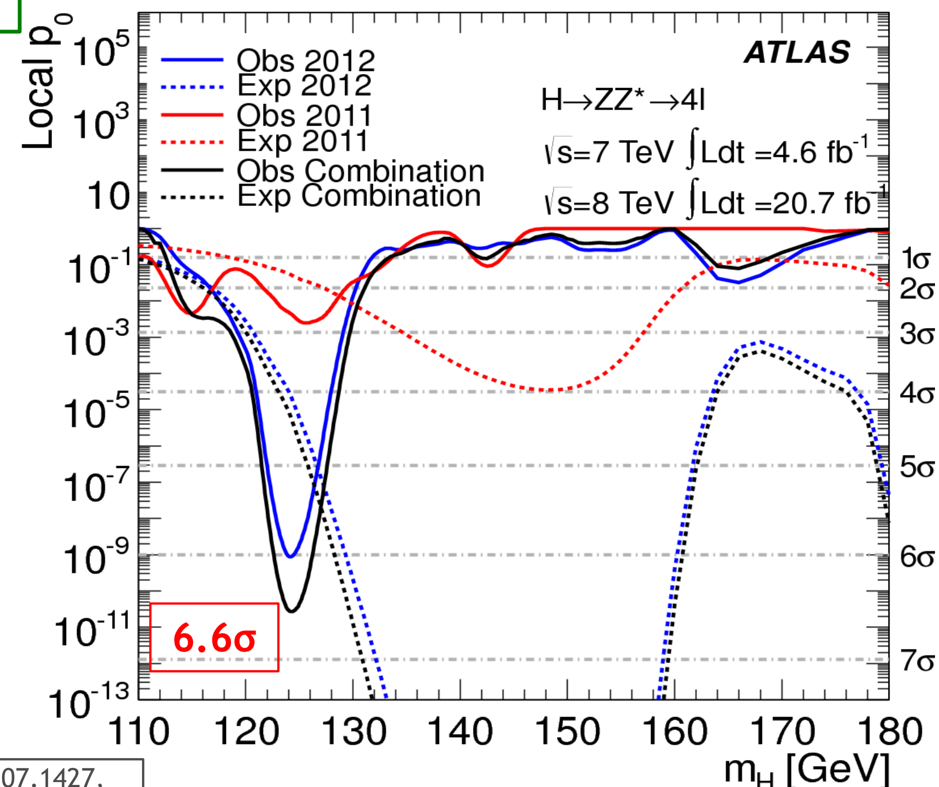


H → 4ℓ±

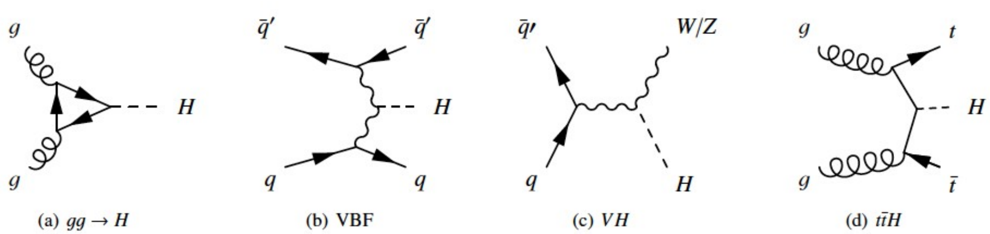
“Golden” channel, high S/B, excellent mass resolution, but low statistics

Signal significance 6.6σ, expected 4.4σ (SM)





arXiv:1307.1427, accepted by PLB



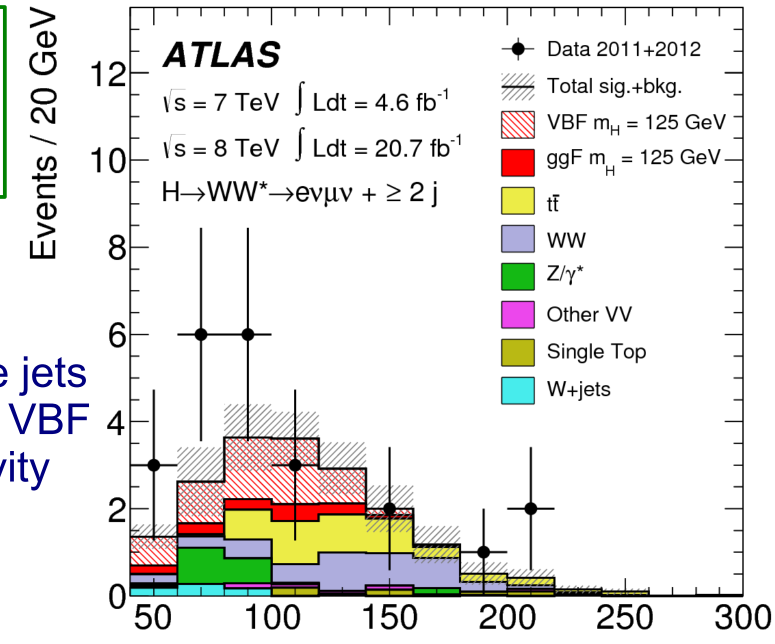
Again, categorisation of events to enhance VBF and VH sensitivity

Combining H→γγ and H → 4ℓ, obtain

$$m_H = 125.5 \pm 0.2 \pm {}^{0.5}_{0.6} \text{ GeV}$$

$H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$

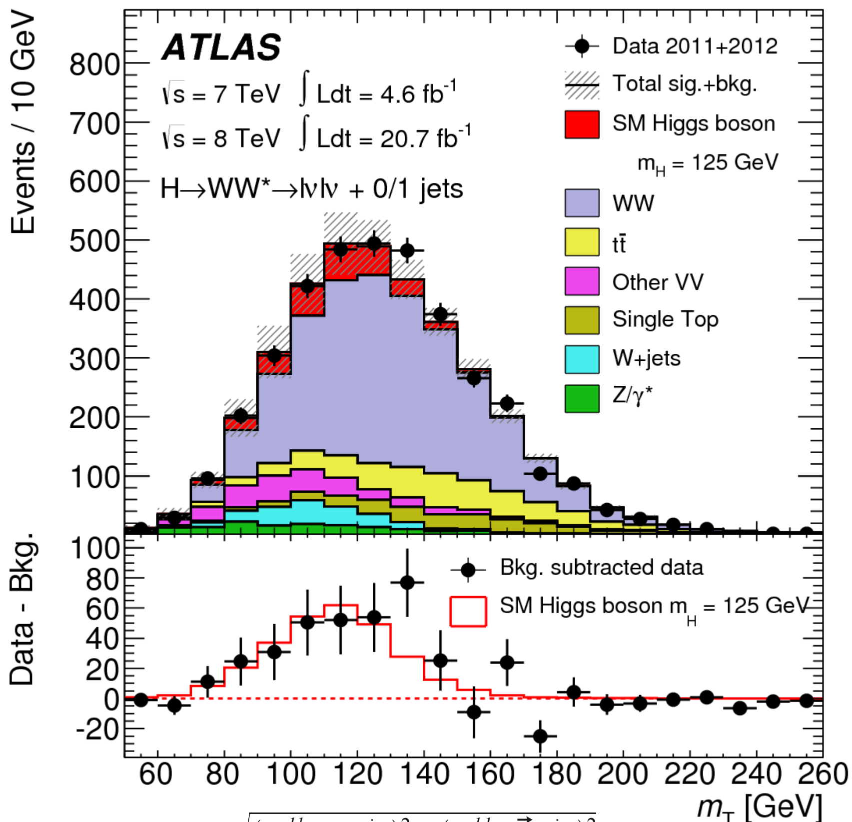
Moderate statistics but poor mass resolution → poor S/B



$$m_T = \sqrt{(E_T^{ll} + E_T^{miss})^2 - (\vec{p}_T^{\,ll} + \vec{E}_T^{miss})^2}$$

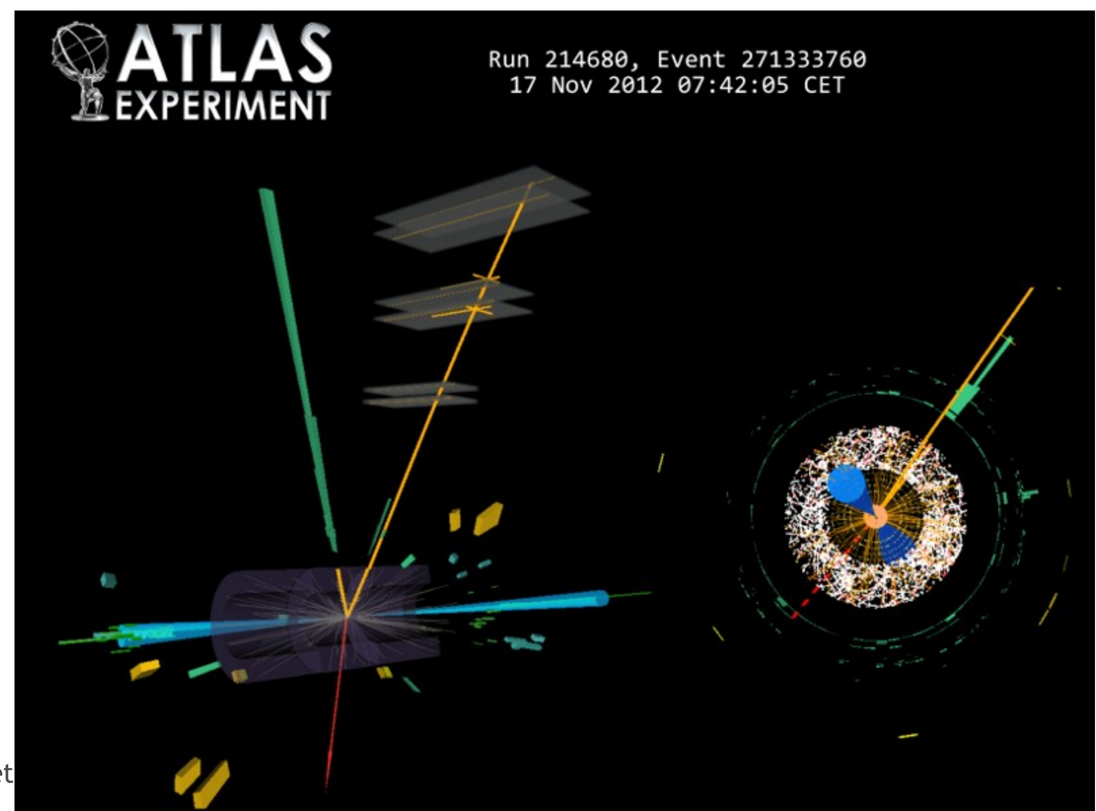
2 or more jets → strong VBF sensitivity

arXiv:1307.1427, accepted by PLB



$$m_T = \sqrt{(E_T^{ll} + E_T^{miss})^2 - (\vec{p}_T^{\,ll} + \vec{E}_T^{miss})^2}$$

Transverse mass distribution for e and μ, 0 or 1 jet



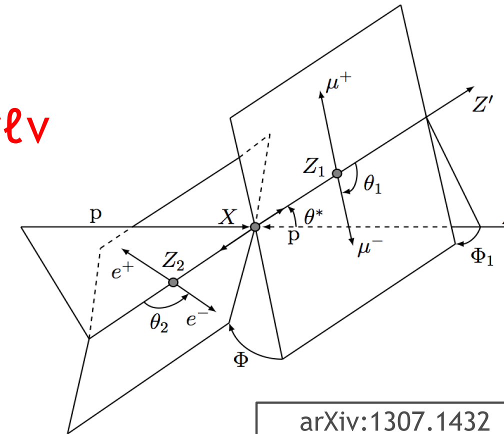
Signal significance of 3.8σ at m_H=125.5 GeV, expect 3.8σ (SM)

Spin-parity

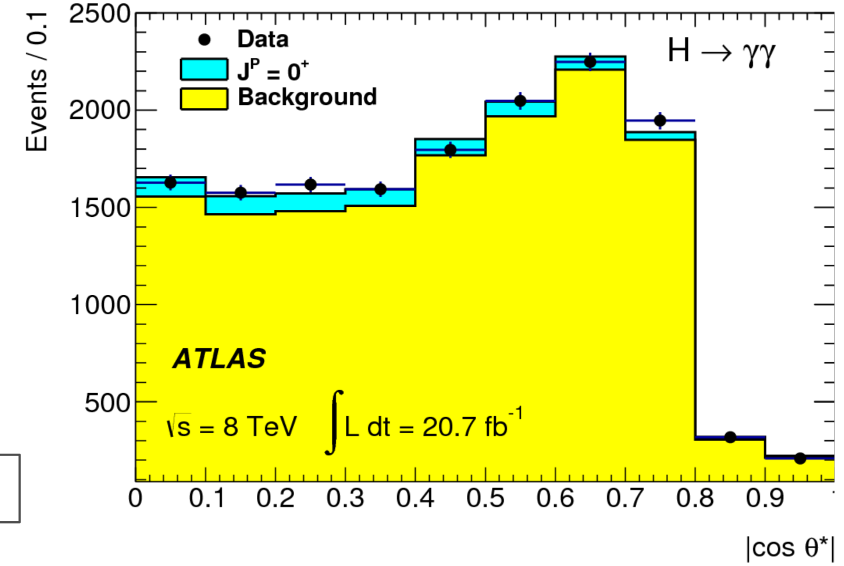
Use H→γγ, H→4ℓ, H→WW→ℓνℓν

Variables sensitive to decay angles

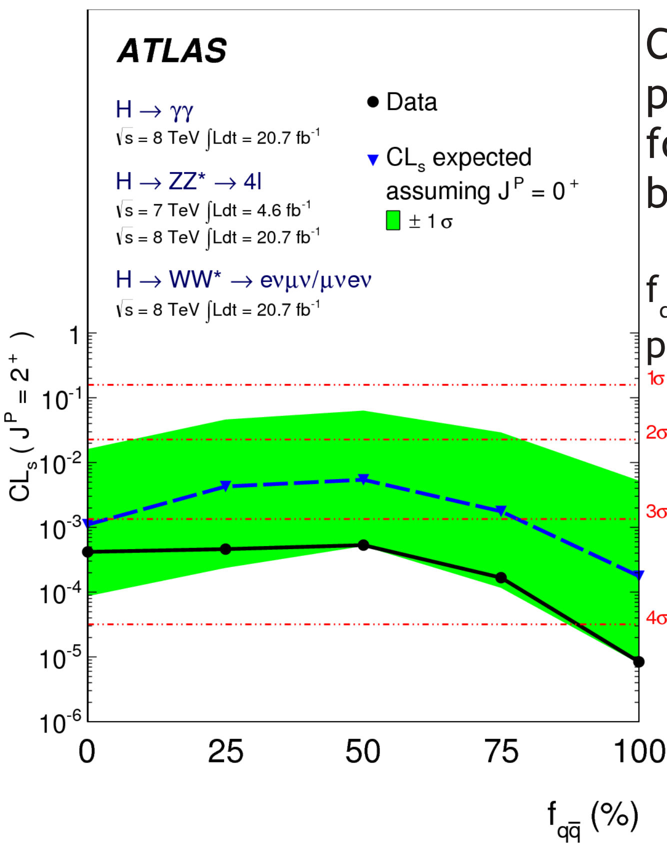
Make pairwise hypothesis tests J^P vs 0^+



arXiv:1307.1432
accepted by PLB



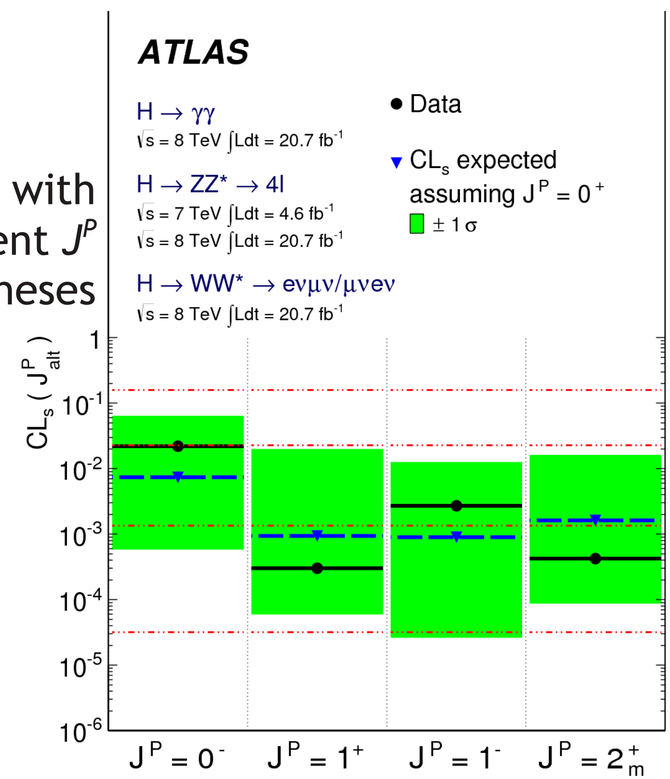
Data are consistent with 0^+ on every test



Compare with a range of production hypotheses for a spin-2 graviton-like boson

f_{qq} = fraction of qq production (rather than gg)

Compare with different J^P hypotheses



All alternative hypotheses disfavoured at >97.8% CL

Production processes

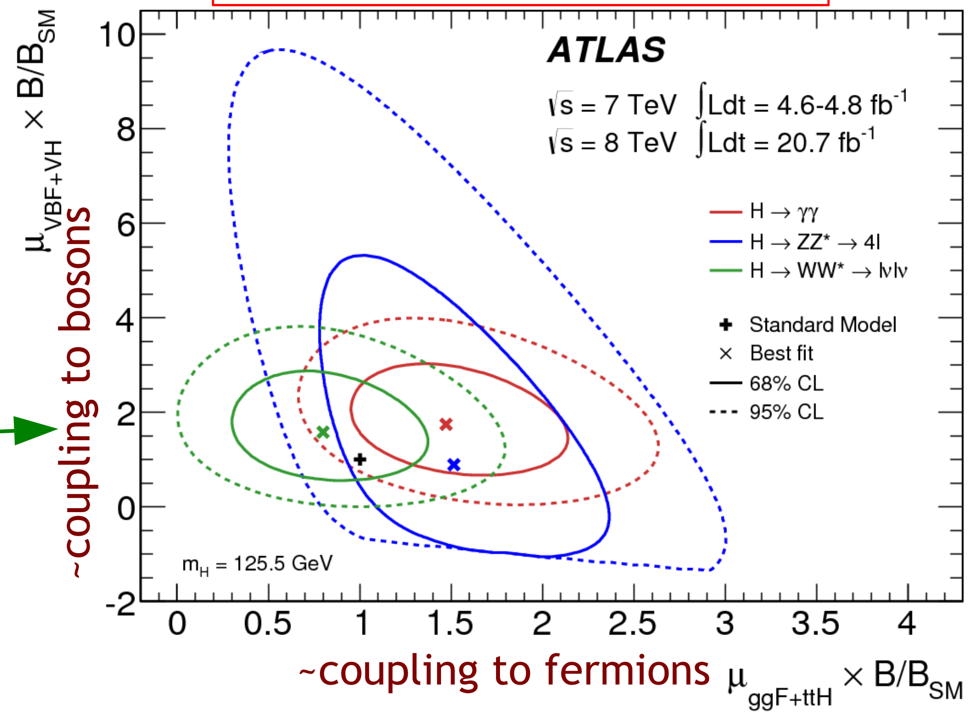
Detailed combined studies of couplings
(following LHC HXSWG approach; many more results than shown here)

Coupling strength to vector-bosons in initial state vs that to fermions, SM=(1,1)

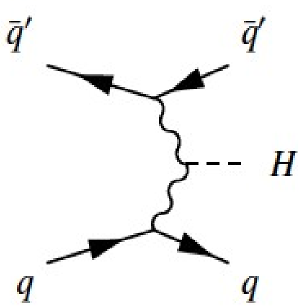
Ratio of vector-boson mediated production compared to gluon(top)-initiated production:

$$\mu_{VBF+VH}/\mu_{ggF+ttH} = 1.4^{+0.7}_{-0.5}$$

B/B$_{SM}$ may differ → don't combine here

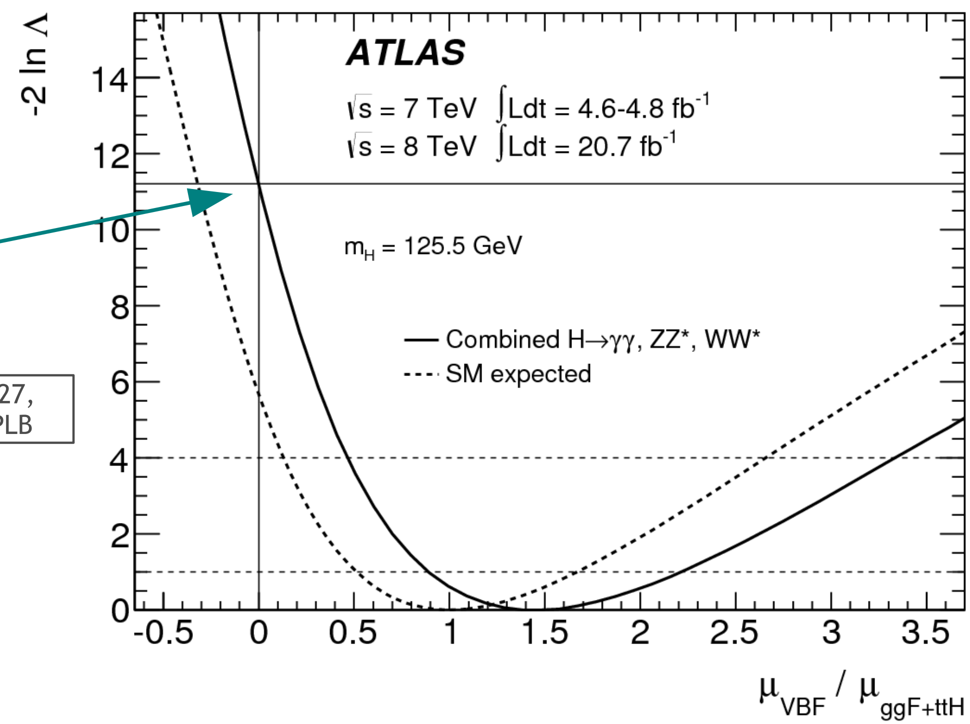


Looking purely for vector-boson fusion production



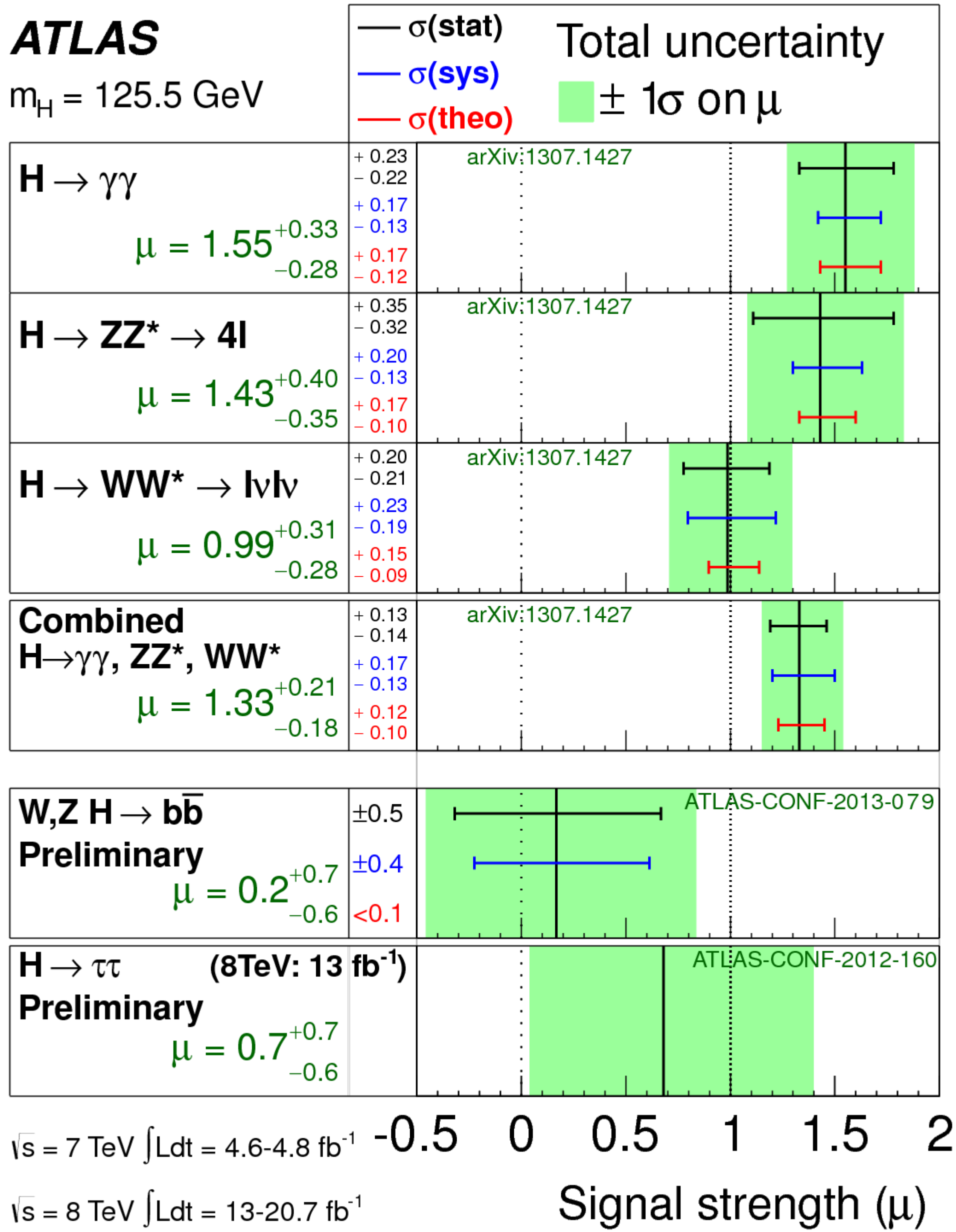
(b) VBF

arXiv:1307.1427, accepted by PLB



More than **3σ evidence** for vector-boson fusion production

Signal strengths μ

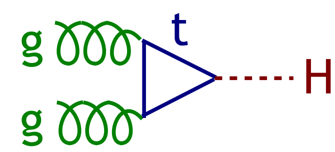


Individual channels are consistent

SM describes the rates well, so far

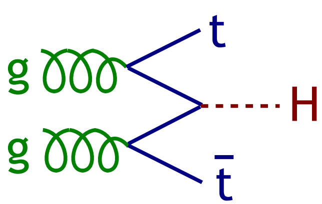
More detailed studies have been done of coupling constraints which can be derived, including on new processes in the loops

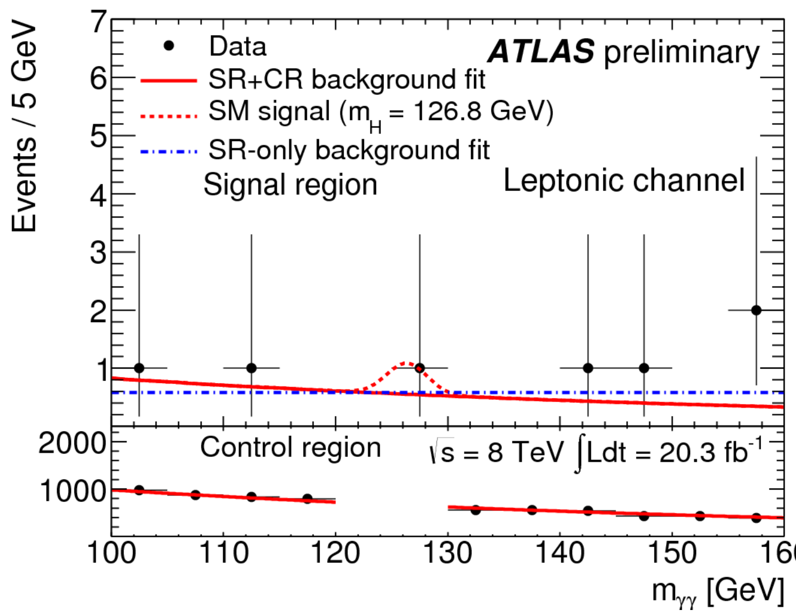
Couplings to fermions - production

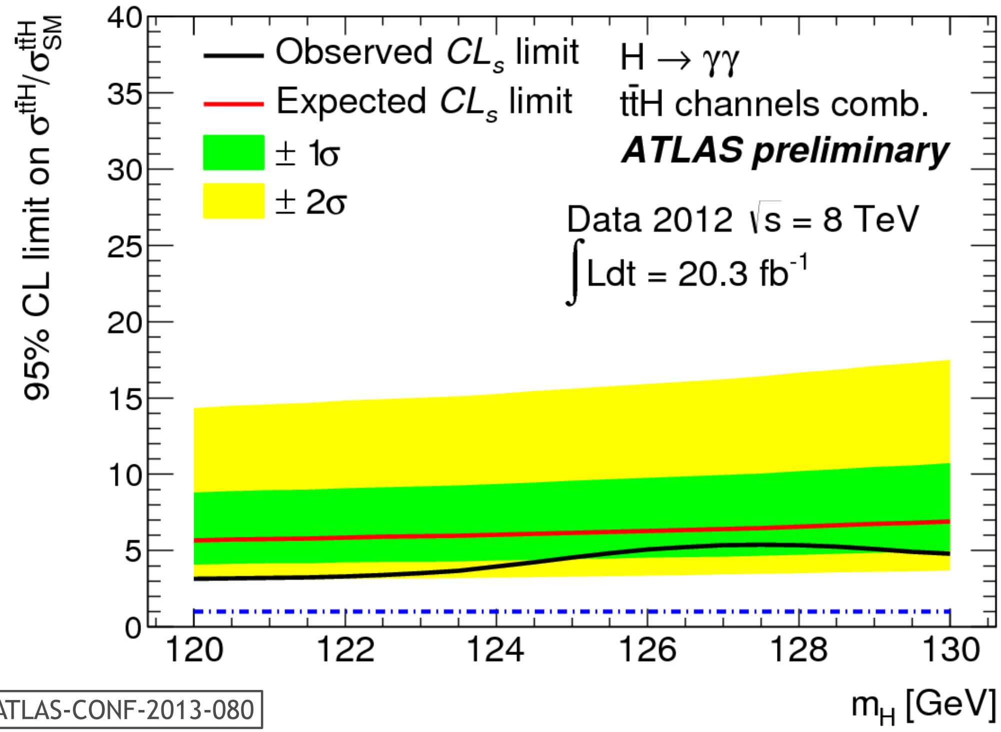


With only the SM particles, indirect observation (>5σ) for Hff coupling from measured production cross-section

Can also probe in ttH associated production, e.g. with H→γγ
With current statistics, sensitivity is low – more channels are being analysed







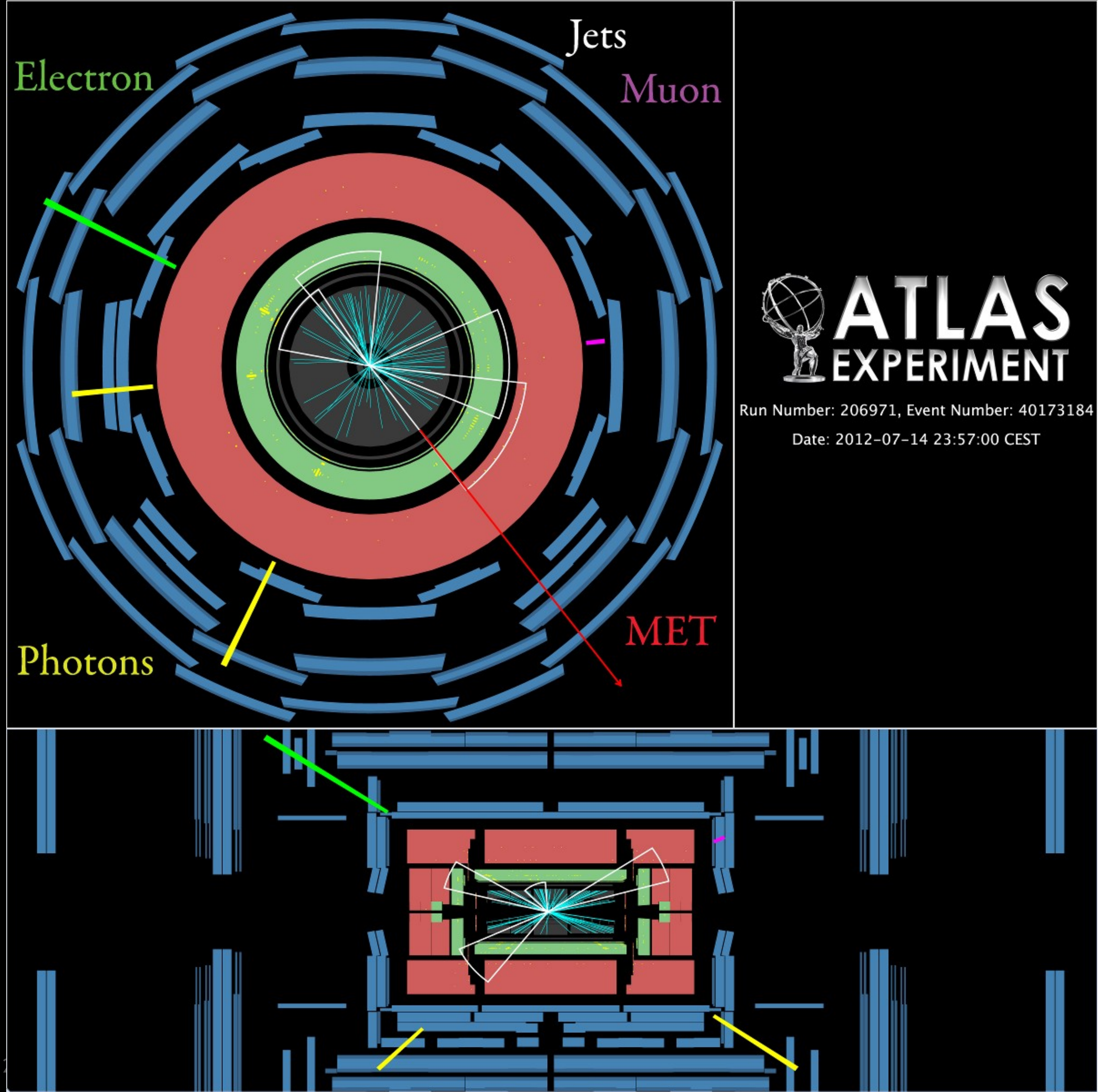
ATLAS-CONF-2013-080

Limit at 5.3xSM rate, expected limit if no signal would be 6.4xSM (m_H=126.8 GeV)

Search for $t\bar{t}H$, $H\to\gamma\gamma$

One nice candidate
$m_{\gamma\gamma}$ =126.6 GeV
S/B ~ 0.45 in 120-130 GeV

Statistics very low (just one candidate!) → set limits



Also search for Hff couplings directly in decays of H → bb and H → ττ
New bb result, ττ still in work (blinded), for the full data sample

→ tomorrow

Higgs measurements – differential cross-sections

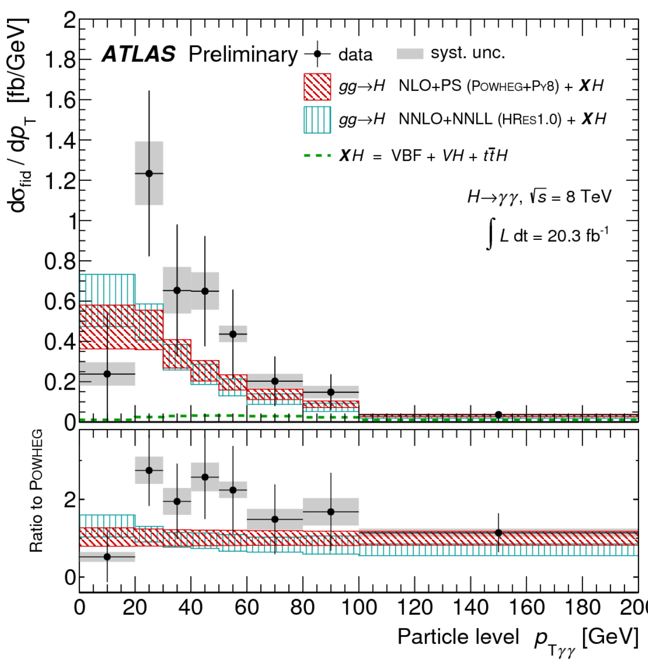
Fully corrected differential cross-section measurements of H → γγ production

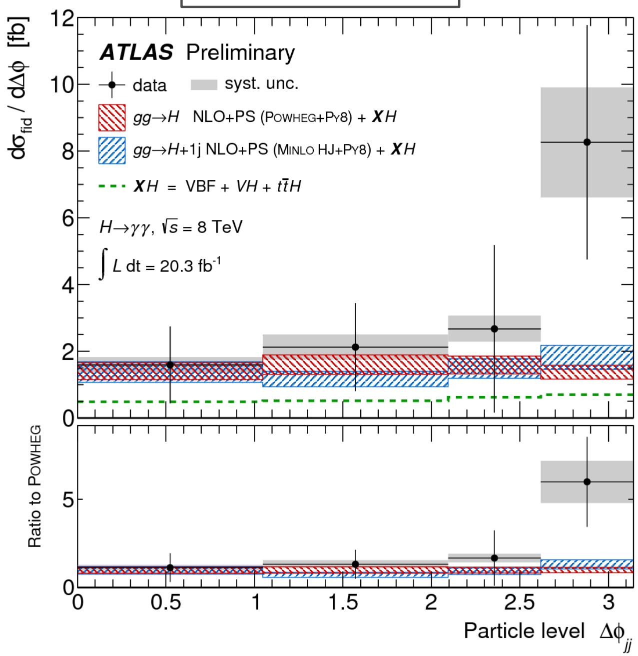
Measure 7 differential distributions $p_T(\gamma\gamma)$, $|y_{\gamma\gamma}|$, $|\cos\theta^*|$, $p_T(j1)$, N(jets), $\Delta\varphi(jj)$, $p_T(\gamma\gamma jj)$ in fiducial region

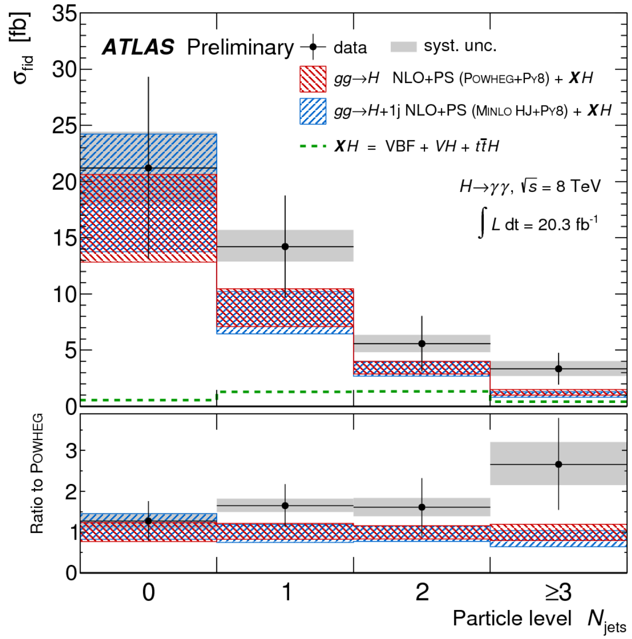
Distributions consistent with predictions (Powheg, MINLO, HRes1.0) within current errors: χ^2 compatibilities

	N_{jets}	$p_T^{\gamma\gamma}$	$\lvert y^{\gamma\gamma}\rvert$	$\lvert\cos\theta^*\rvert$	$p_T^{j_1}$	$\Delta\phi_{jj}$	$p_T^{\gamma\gamma jj}$
POWHEG	0.54	0.55	0.38	0.69	0.79	0.42	0.50
MINLO	0.44	–	–	0.67	0.73	0.45	0.49
HRes 1.0	–	0.39	0.44	–	–	–	–

ATLAS-CONF-2013-072





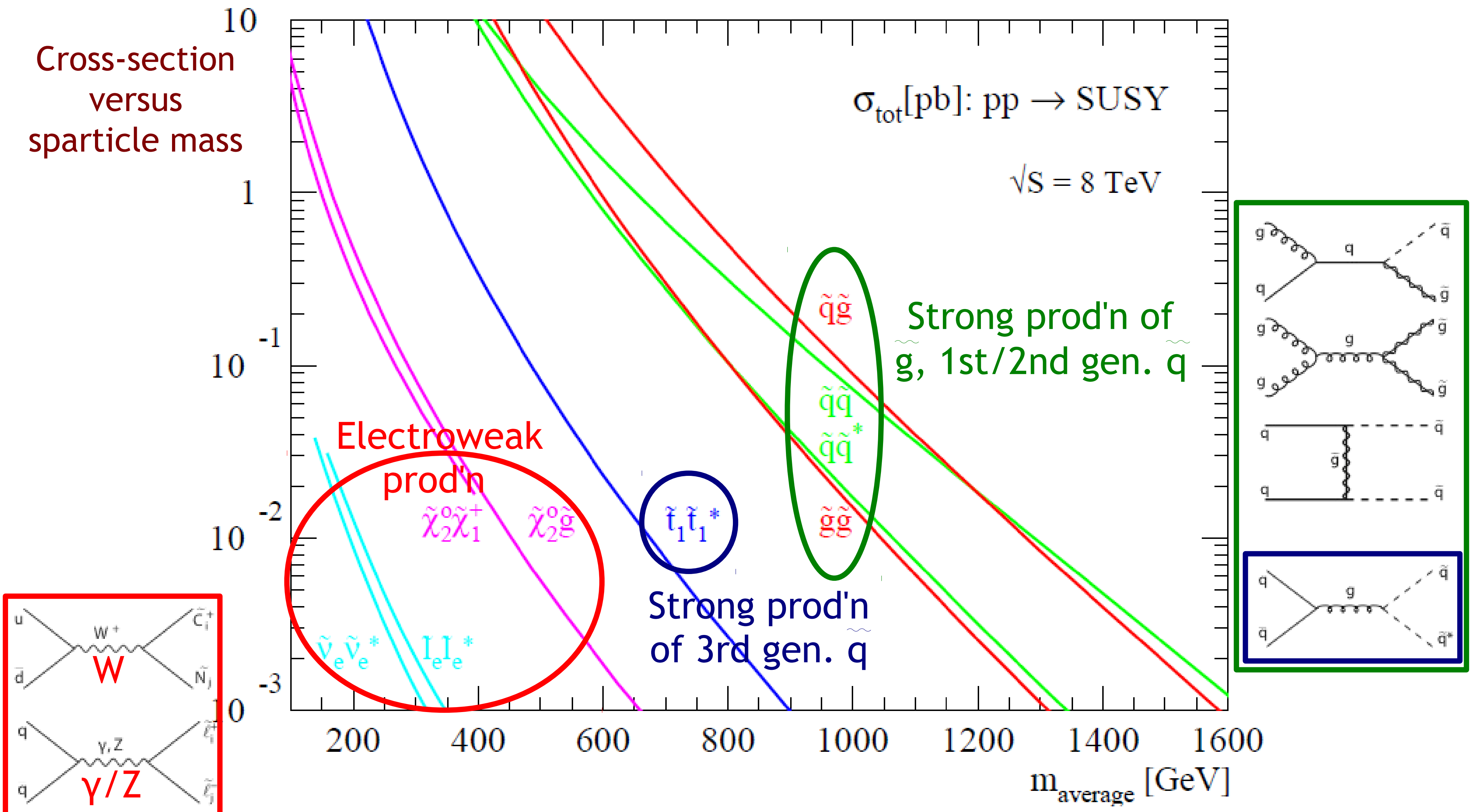


Searches for physics beyond the Standard Model

A huge array of searches have been carried out, including:

- Extra dimensions
- Excited vector bosons
- Contact interactions
- Leptoquarks
- New heavy quarks (eg vector-like)
- Excited fermions
- Technicolor
- Strongly produced $\tilde{q}$, $\tilde{g}$
- Gluino-mediated $\tilde{t}$, $\tilde{b}$ production
- Direct $\tilde{t}$, $\tilde{b}$ production
- Electroweak SUSY production
- Long-lived particles
- R-parity violating SUSY signatures
- … … …

Still Seeking SUSY...



ATLAS pursues an extensive and deep programme of SUSY searches with the full 2012 data set - to date 20 CONF notes covering wide spectrum of production mechanisms & topologies - I give just a flavour here

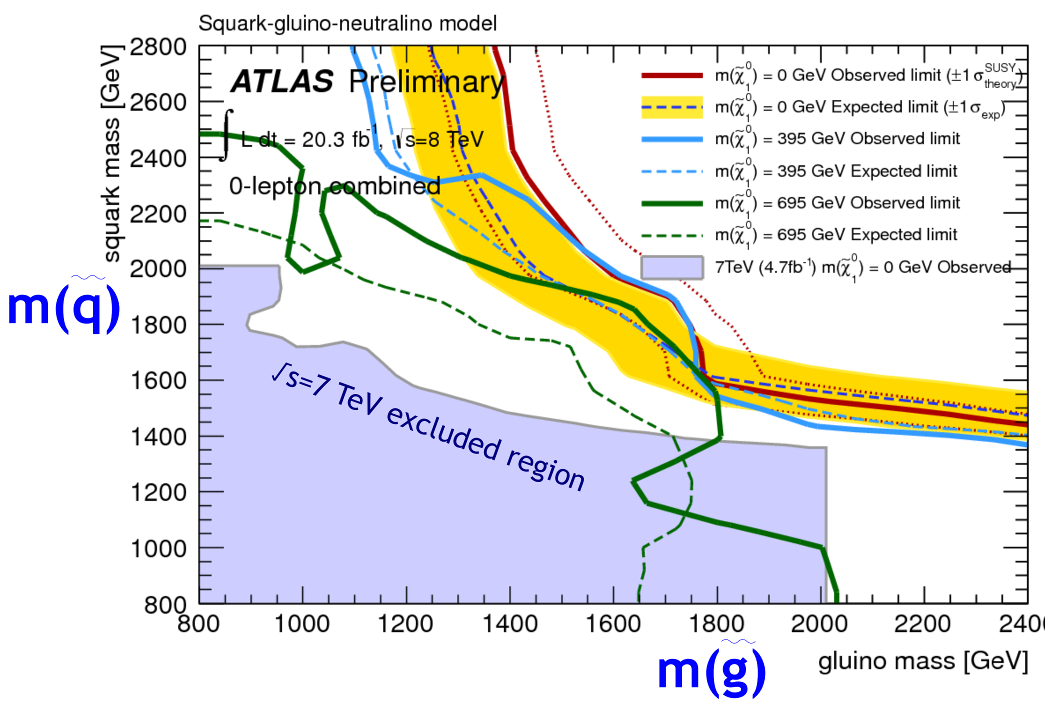
Strong production of squarks and gluinos

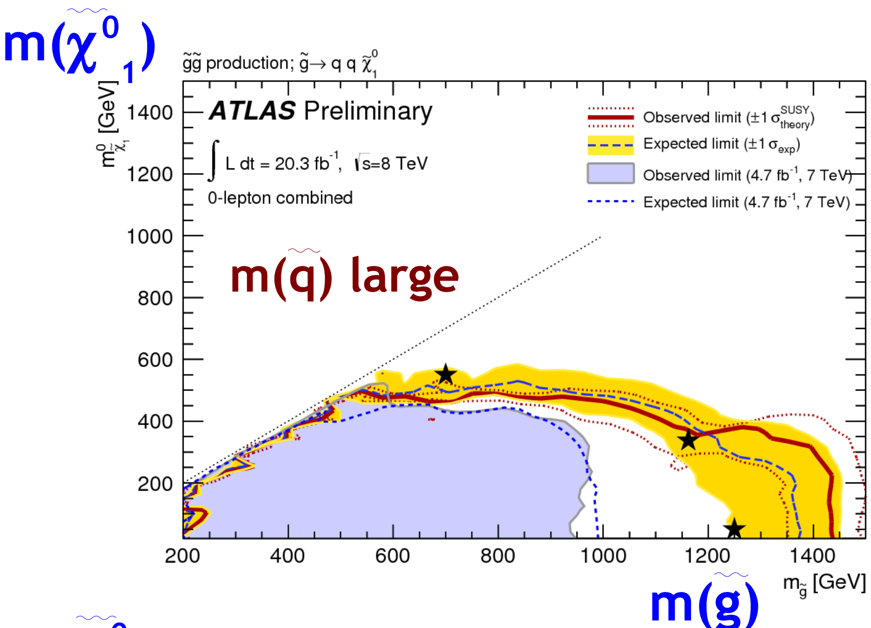
Extensive "jets + X + E_T^{miss}" programme

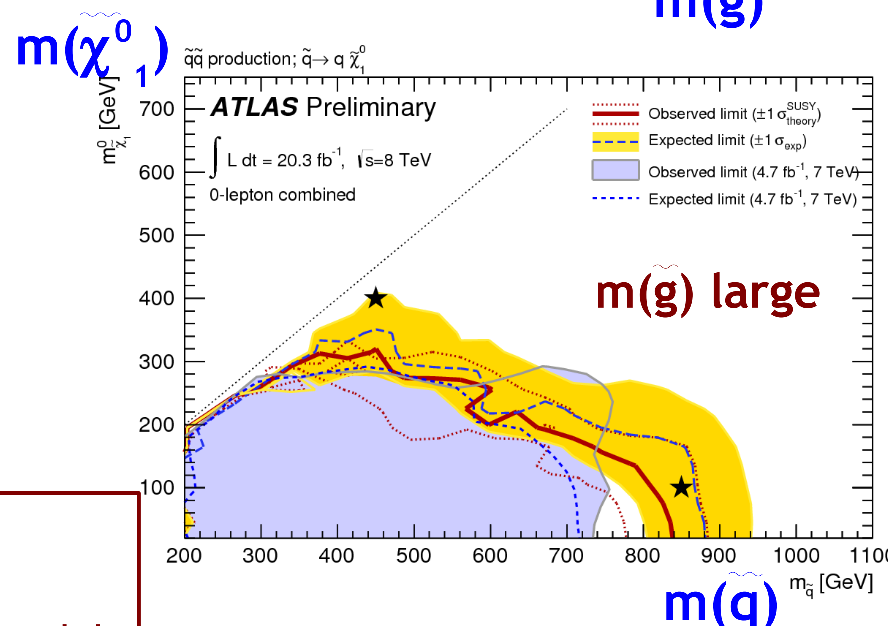
Example: 0-lepton+(2-6 jets)+E_T^{miss}

Ten signal regions – select by best *expected* limit

Results presented in MSUGRA/CMSSM and in a range of simplified models, to aid re-use with other assumptions → show some examples here...







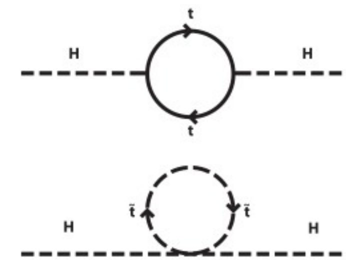
Benchmark MSUGRA/CMSSM tanβ=30, A_0=-2m_0, μ>0

[m(q̃)=m(g̃)] > 1.7 TeV at 95% CL

Same limit found for equal-mass case in simplified MSSM models with massless light neutralino

ATLAS-CONF-2013-047

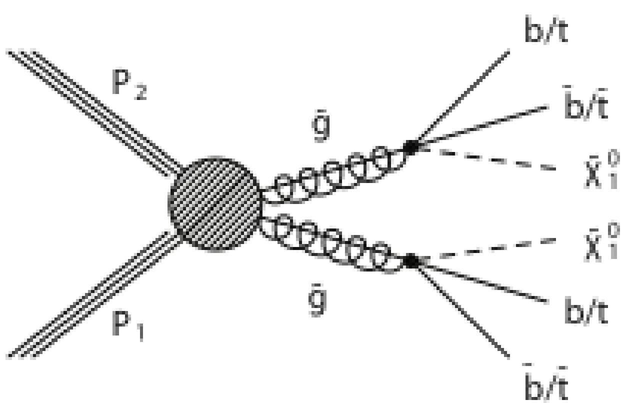
"Natural" Models – evading the absence of $\tilde{q}$ and $\tilde{g}$



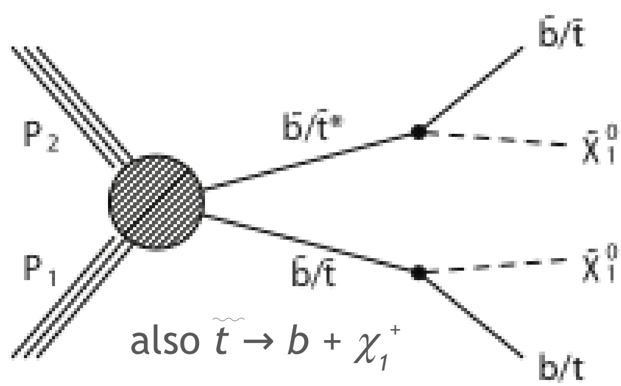
In these models, the lightest squarks are $\tilde{t}/\tilde{b}$, gluinos possibly too heavy, gauginos may be accessible – but the Higgs mass can be stabilised

Lower cross-sections and larger SM backgrounds require dedicated searches

Systematic and comprehensive set of searches

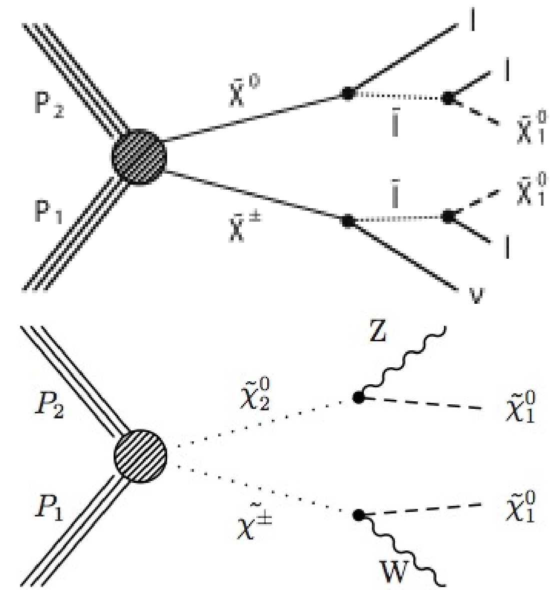


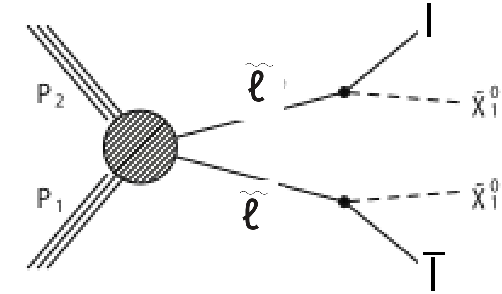
Gluino-mediated $\tilde{b}/\tilde{t}$ production



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

Associated gaugino production



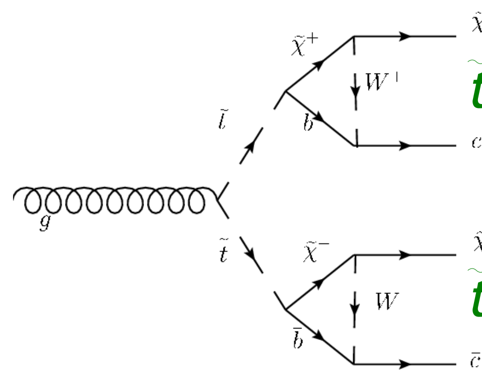


Direct slepton-pair production

Direct stop production and decay to charm

New analysis: charm tagging to search for direct stop pair production in cases where

$m(\tilde{t}_1) < m(\tilde{\chi}_1^0)+m_b+m_W$ but $m(\tilde{t}_1) > m(\tilde{\chi}_1^0)+m_c$

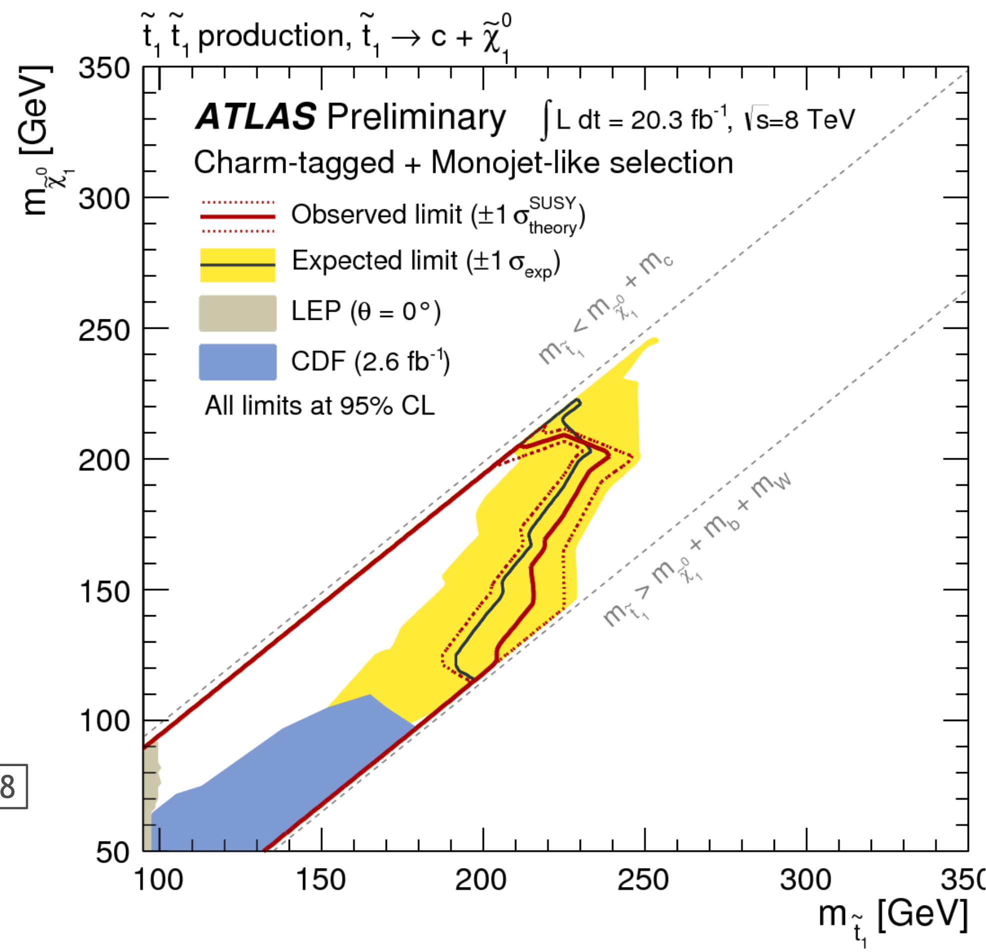


$\tilde{t}_1 \rightarrow \tilde{\chi}_1^0 c$

$\tilde{t}_1 \rightarrow \tilde{\chi}_1^0 c$

Multivariate discriminators (track impact parameters, secondary and tertiary vertexing)

e.g. "medium" operating point: ϵ(c)≈20%, rejection ≈5 and ≈140 for b- and light-jets, ≈10 for tau-jets



Also monojet analysis, no c-tagging (small Δm)

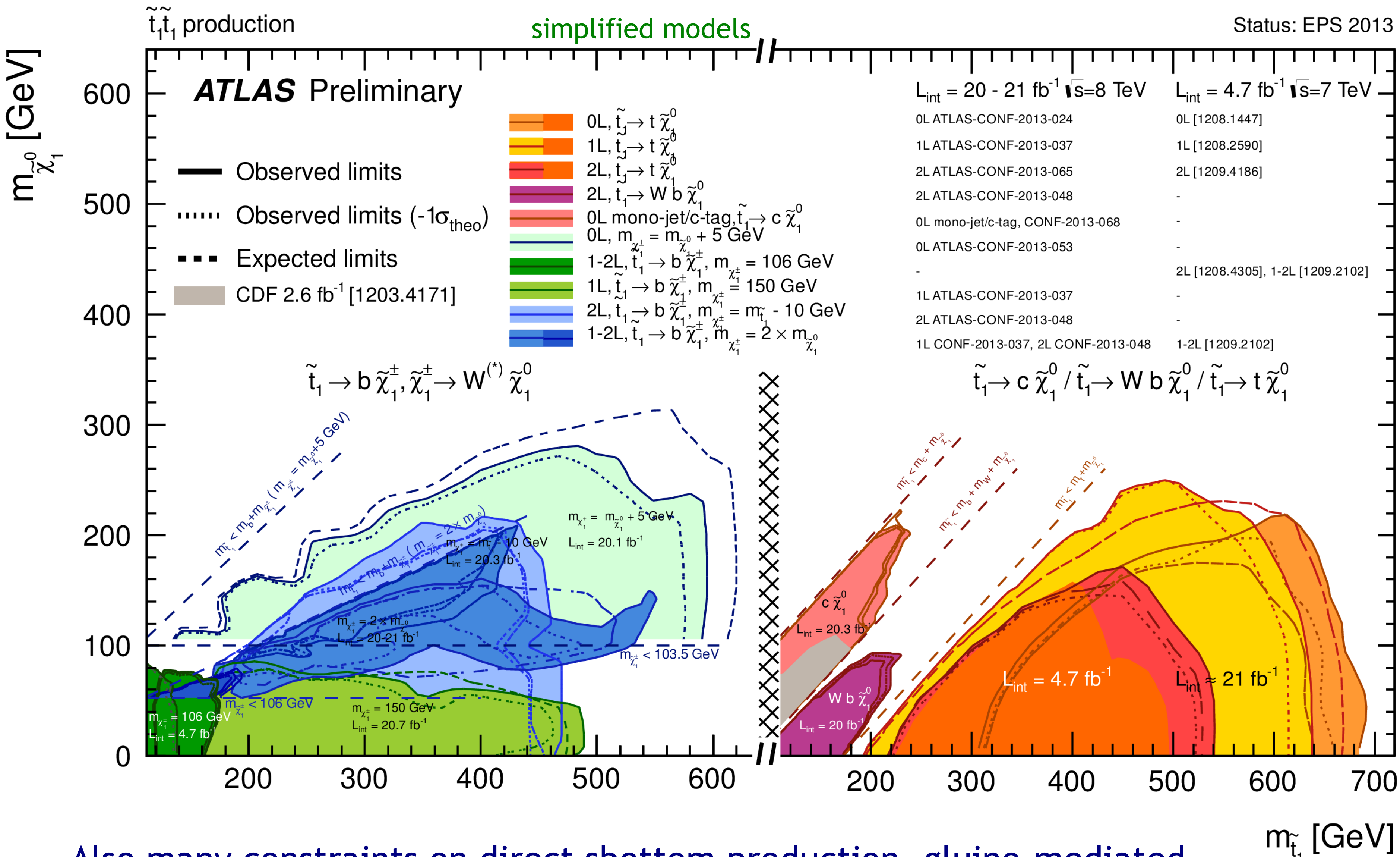
Both cases require hard initial-state radiation to give a high-p_T jet

ATLAS-CONF-2013-068

Direct stop searches

Global picture of multitude of complementary direct stop searches by ATLAS

Caution: simplified decay models!!!



Also many constraints on direct sbottom production, gluino-mediated stop and sbottom production

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: EPS 2013

ATLAS Preliminary

$\int \mathcal{L}\,dt = (4.4 - 22.9)\ \mathrm{fb}^{-1}$ $\sqrt{s} = 7,\ 8$ TeV

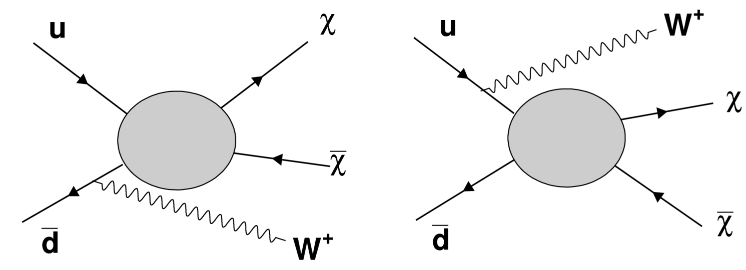
	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\,dt[\mathrm{fb}^{-1}]$		Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$	1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-054
	$\tilde{q}\tilde{q},\ \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$	740 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g},\ \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g},\ \tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.18 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}^\pm)$=0.5($m(\tilde{\chi}_1^0)$+$m(\tilde{g})$)	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}\to qqqq\ell\ell(\ell\ell)\tilde{\chi}_1^0\tilde{\chi}_1^0$	2 e,μ (SS)	3 jets	Yes	20.7	$\tilde{g}$	1.1 TeV	$m(\tilde{\chi}_1^0)$<650 GeV	ATLAS-CONF-2013-007
	GMSB ($\tilde{\ell}$ NLSP)	2 e,μ	2-4 jets	Yes	4.7	$\tilde{g}$	1.24 TeV	$\tan\beta$<15	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$	1.4 TeV	$\tan\beta$ >18	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	0	Yes	4.8	$\tilde{g}$	1.07 TeV	$m(\tilde{\chi}_1^0)$>50 GeV	1209.0753
	GGM (wino NLSP)	1 $e,\mu+\gamma$	0	Yes	4.8	$\tilde{g}$	619 GeV	$m(\tilde{\chi}_1^0)$>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$	900 GeV	$m(\tilde{\chi}_1^0)$>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e,μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$	690 GeV	$m(\tilde{H})$>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale	645 GeV	$m(\tilde{g})$>10^{-4} eV	ATLAS-CONF-2012-147
3rd gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$	1.2 TeV	$m(\tilde{\chi}_1^0)$<600 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.14 TeV	$m(\tilde{\chi}_1^0)$ <200 GeV	ATLAS-CONF-2013-054
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$	1.34 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	ATLAS-CONF-2013-061
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1,\ \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$	100-630 GeV	$m(\tilde{\chi}_1^0)$<100 GeV	ATLAS-CONF-2013-053
	$\tilde{b}_1\tilde{b}_1,\ \tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$	430 GeV	$m(\tilde{\chi}_1^\pm)$=2 $m(\tilde{\chi}_1^0)$	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e,μ	1-2 b	Yes	4.7	$\tilde{t}_1$	167 GeV	$m(\tilde{\chi}_1^0)$=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e,μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	220 GeV	$m(\tilde{\chi}_1^0)$ =$m(\tilde{t}_1)$-$m(W)$-50 GeV, $m(\tilde{t}_1)$<<$m(\tilde{\chi}_1^\pm)$	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e,μ	2 jets	Yes	20.3	$\tilde{t}_1$	225-525 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-065
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	0	2 b	Yes	20.1	$\tilde{t}_1$	150-580 GeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}_1^\pm)$-$m(\tilde{\chi}_1^0)$=5 GeV	ATLAS-CONF-2013-053
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e,μ	1 b	Yes	20.7	$\tilde{t}_1$	200-610 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$	320-660 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$	200 GeV	$m(\tilde{t}_1)$-$m(\tilde{\chi}_1^0)$<85 GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_1$	500 GeV	$m(\tilde{\chi}_1^0)$>150 GeV	ATLAS-CONF-2013-025
	$\tilde{t}_2\tilde{t}_2,\ \tilde{t}_2\to\tilde{t}_1+Z$	3 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_2$	520 GeV	$m(\tilde{t}_1)$=$m(\tilde{\chi}_1^0)$+180 GeV	ATLAS-CONF-2013-025
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R},\ \tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$	85-315 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-,\ \tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$	125-450 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})$=0.5($m(\tilde{\chi}_1^\pm)$+$m(\tilde{\chi}_1^0)$)	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-,\ \tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	0	Yes	20.7	$\tilde{\chi}_1^\pm$	180-330 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})$=0.5($m(\tilde{\chi}_1^\pm)$+$m(\tilde{\chi}_1^0)$)	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu),\ \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	600 GeV	$m(\tilde{\chi}_1^\pm)$=$m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})$=0.5($m(\tilde{\chi}_1^\pm)$+$m(\tilde{\chi}_1^0)$)	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W^*\tilde{\chi}_1^0Z^*\tilde{\chi}_1^0$	3 e,μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	315 GeV	$m(\tilde{\chi}_1^\pm)$=$m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-035
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^\pm$	270 GeV	$m(\tilde{\chi}_1^\pm)$-$m(\tilde{\chi}_1^0)$=160 MeV, $\tau(\tilde{\chi}_1^\pm)$=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$	857 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	0	-	15.9	$\tilde{\chi}_1^0$	475 GeV	10<$\tan\beta$<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	0	Yes	4.7	$\tilde{\chi}_1^0$	230 GeV	0.4<$\tau(\tilde{\chi}_1^0)$<2 ns	1304.6310
	$\tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ	0	Yes	4.4	$\tilde{q}$	700 GeV	1 mm<$c\tau$<1 m, $\tilde{g}$ decoupled	1210.7451
RPV	LFV $pp\to\tilde{\nu}_\tau+X,\ \tilde{\nu}_\tau\to e+\mu$	2 e,μ	0	-	4.6	$\tilde{\nu}_\tau$	1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X,\ \tilde{\nu}_\tau\to e(\mu)+\tau$	1 $e,\mu+\tau$	0	-	4.6	$\tilde{\nu}_\tau$	1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	1 e,μ	7 jets	Yes	4.7	$\tilde{q}, \tilde{g}$	1.2 TeV	$m(\tilde{q})$=$m(\tilde{g})$, $c\tau_{LSP}$<1 mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-,\ \tilde{\chi}_1^+\to W\tilde{\chi}_1^0,\ \tilde{\chi}_1^0\to ee\tilde{\nu}_\mu,\ e\mu\tilde{\nu}_e$	4 e,μ	0	Yes	20.7	$\tilde{\chi}_1^\pm$	760 GeV	$m(\tilde{\chi}_1^0)$>300 GeV, λ_{121}>0	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-,\ \tilde{\chi}_1^+\to W\tilde{\chi}_1^0,\ \tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e,\ e\tau\tilde{\nu}_\tau$	3 $e,\mu+\tau$	0	Yes	20.7	$\tilde{\chi}_1^\pm$	350 GeV	$m(\tilde{\chi}_1^0)$>80 GeV, λ_{133}>0	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6 jets	-	4.6	$\tilde{g}$	666 GeV		1210.4813
	$\tilde{g}\to\tilde{t}_1t,\ \tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$	880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon	0	4 jets	-	4.6	sgluon	100-287 GeV	incl. limit from 1110.2693	1210.4826
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale	704 GeV	$m(\chi)$<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

10^{-1} 1 **Mass scale [TeV]**

$\sqrt{s}$ = 7 TeV full data | $\sqrt{s}$ = 8 TeV partial data | $\sqrt{s}$ = 8 TeV full data

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

Direct dark matter searches



New result from monojet signature with a "fat jet" which could be from a W or Z decay

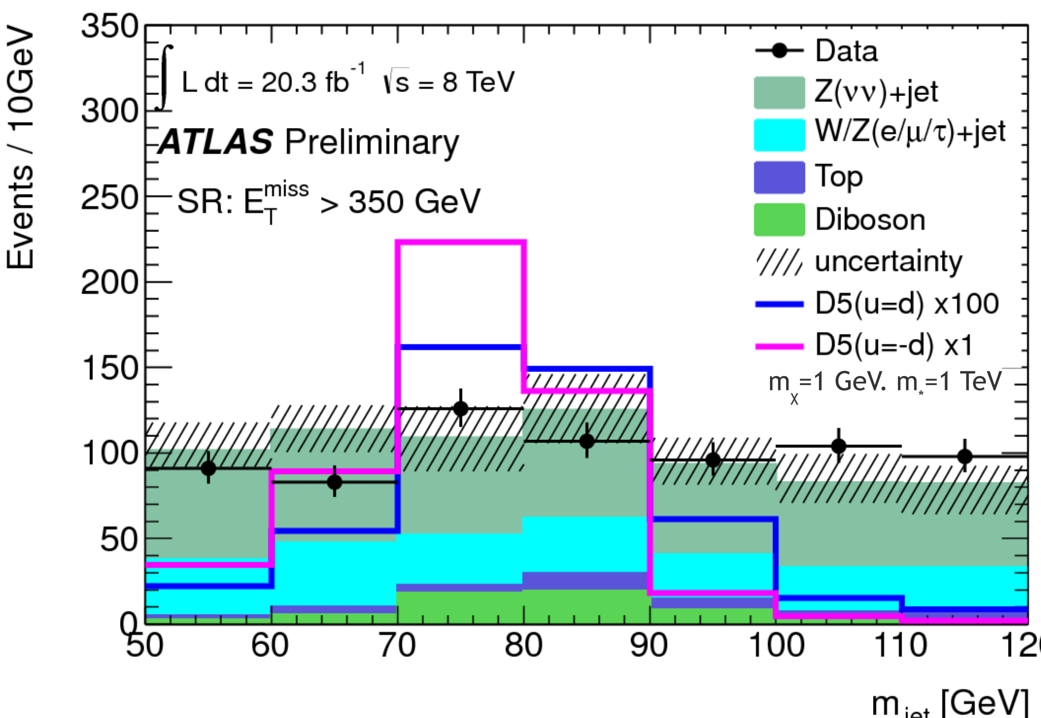
Complements earlier "inclusive monojet" searches

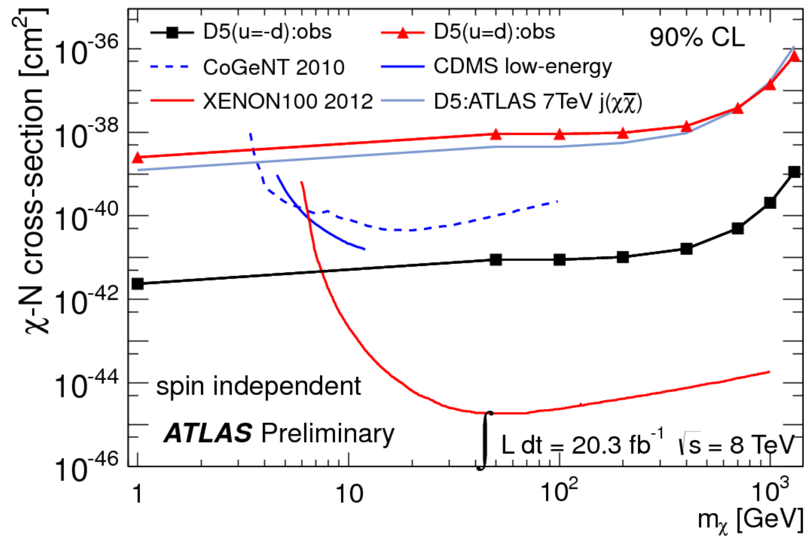
JHEP04(2013)075

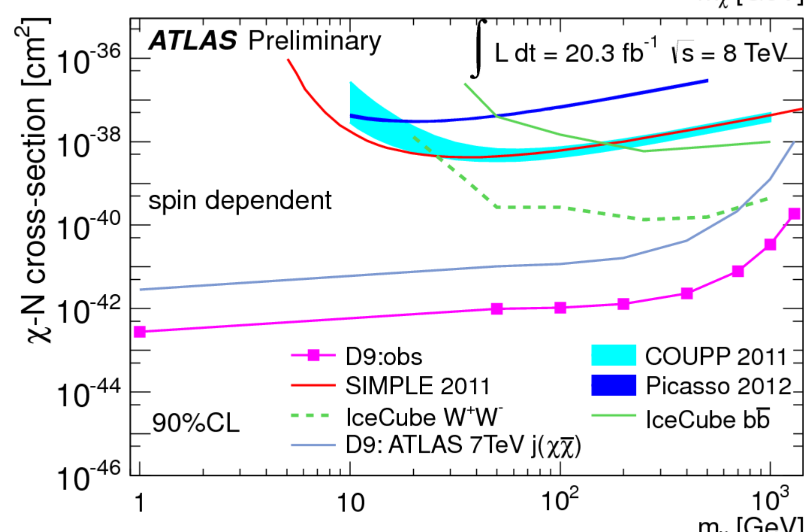
Search is for WIMP (χ) pair-production

→ missing-E_T signature

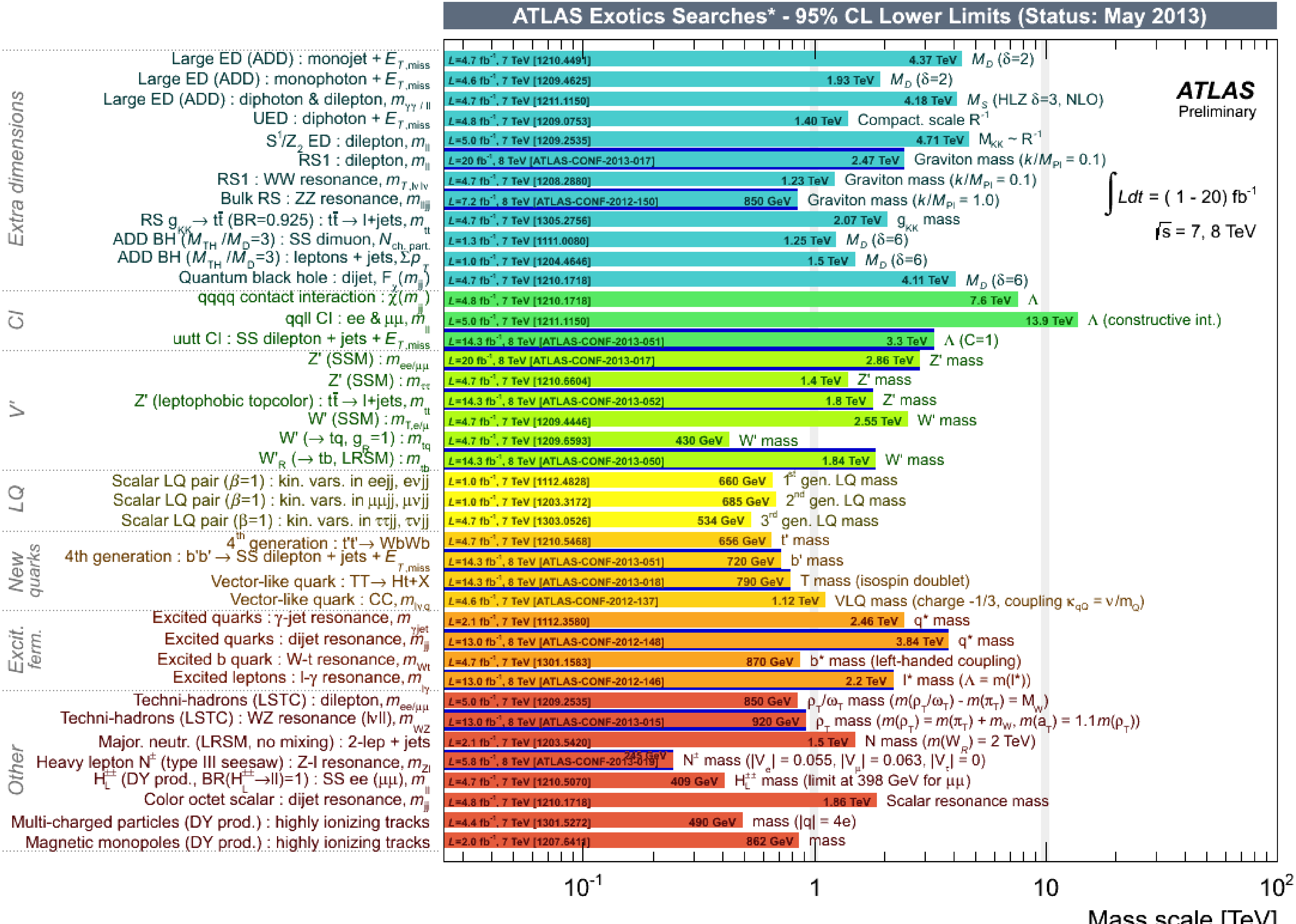
Limits placed in context of effective theories of DM interactions with SM particles: spin-independent (D5) and spin-dependent(D9) with C(u)=±C(d) (– sign enhances $W\chi\chi$)





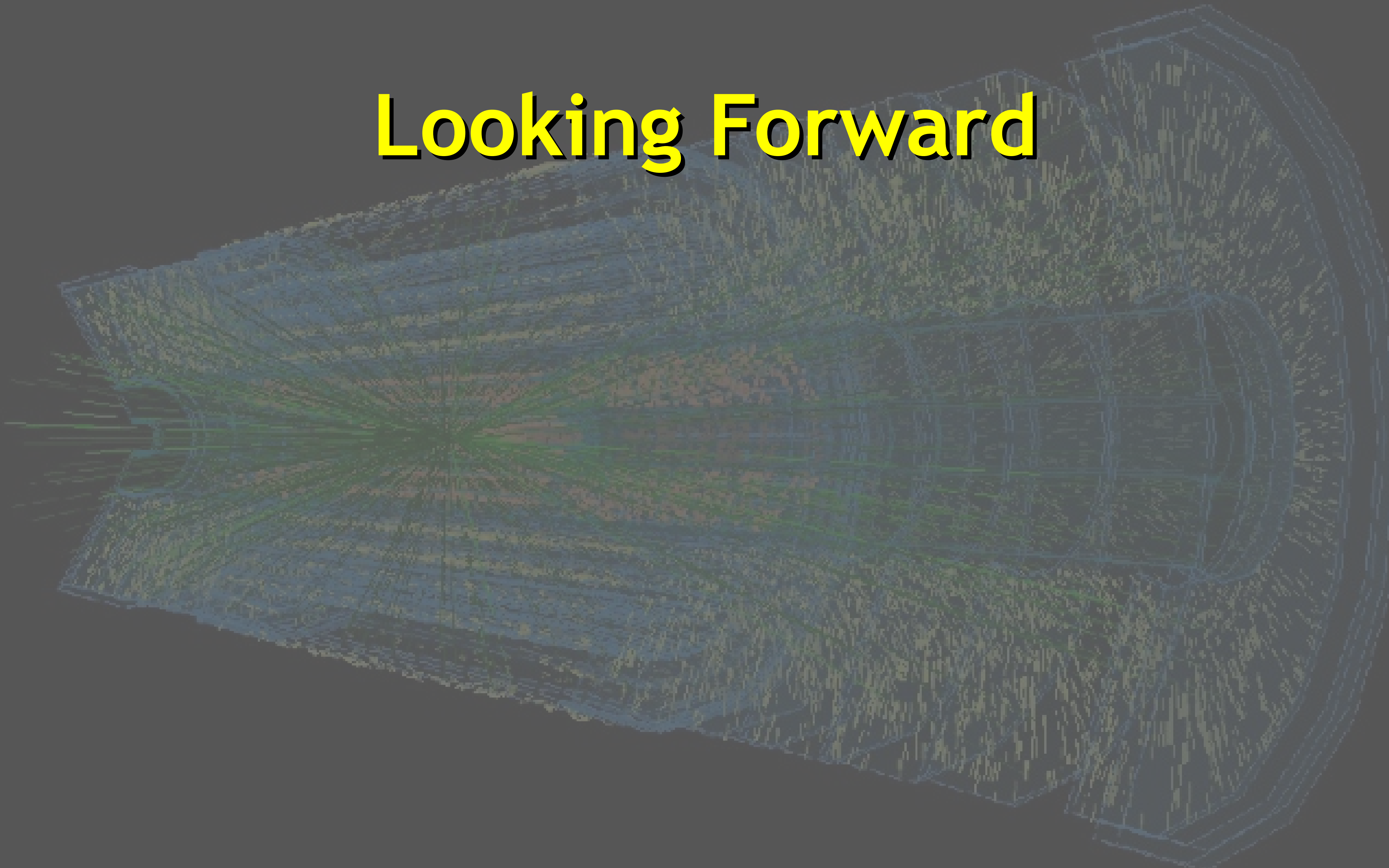


ATLAS-CONF-2013-073

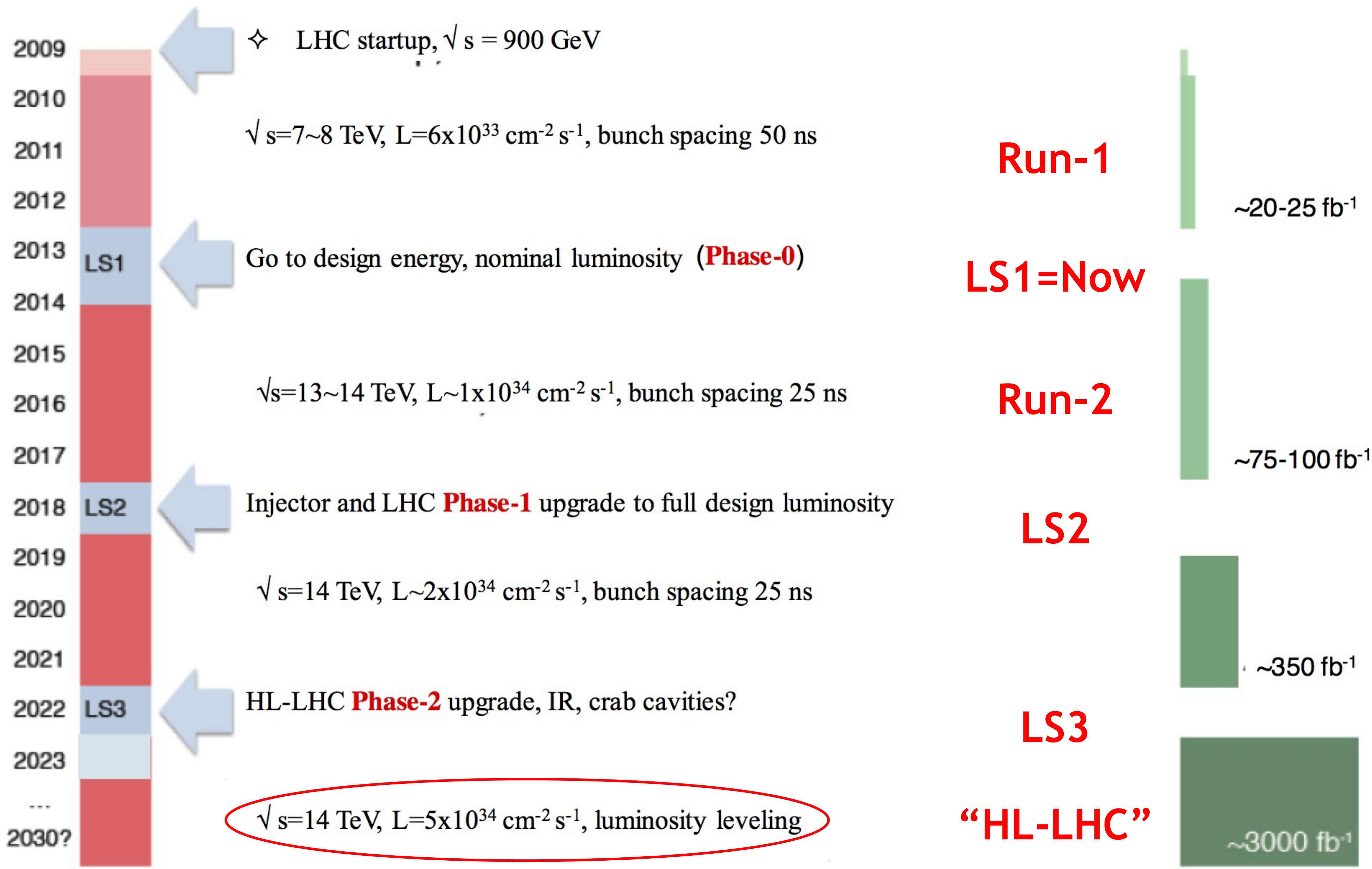


*Only a selection of the available mass limits on new states or phenomena shown

Looking Forward



The landscape in the next decade(s)



European Strategy for Particle Physics

c) The discovery of the Higgs boson is the start of a major programme of work to measure this particle's properties with the highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier. The LHC is in a unique position to pursue this programme.
Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.

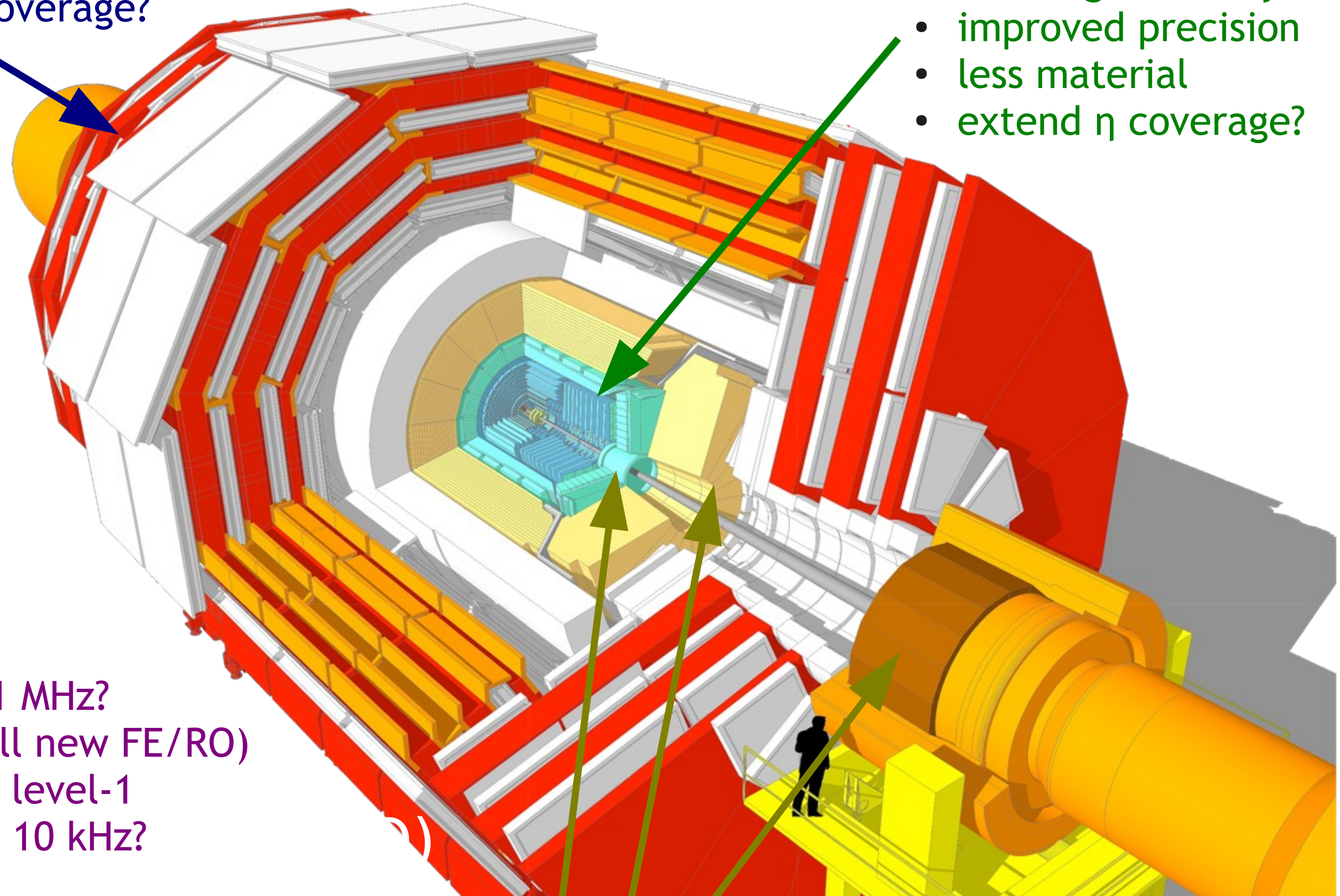
ATLAS and CMS are committed to deliver this programme, including substantial detector upgrades – small ones in LS2 (2018) and large ones in LS3 (2022-3)

Full participation of collaborators world-wide is necessary and expected

CMS upgrades for HL-LHC

Muons
- complete RPCs in forward region with new technology, GEM or GRPCs
- extend η coverage?

New Inner Tracker
- radiation hardness
- better granularity and faster links
- improved precision
- less material
- extend η coverage?



Technical Proposal in 2014

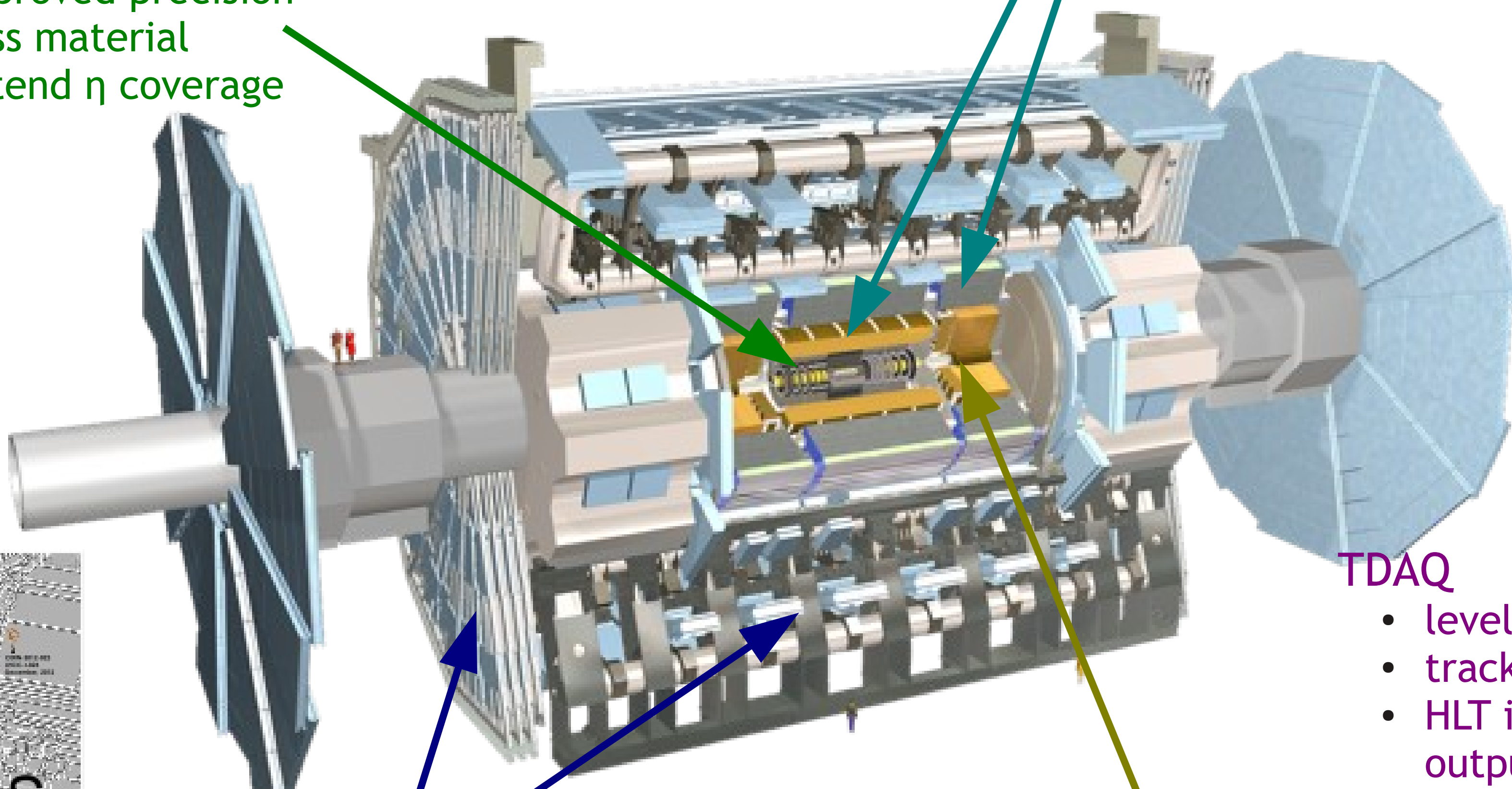
TDAQ
- level-1 at 1 MHz? (requires all new FE/RO)
- tracking at level-1
- HLT output 10 kHz?

Upgrade/replace Forward Calorimeters
- extend η coverage?
- mitigate pileup effects with tracking & precise timing

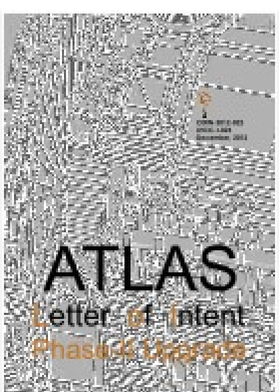
ATLAS upgrades for HL-LHC

New Inner Tracker
- Radiation hardness
- Better granularity and faster links
- Improved precision
- Less material
- Extend η coverage

LAr and Tile Calorimeters
- new FE and BE electronics



TDAQ
- level-0 at 0.5 MHz
- tracking at level-1
- HLT input 200 kHz, output 5 kHz?



Letter of Intent Dec 2012

Muons
- new FE electronics
- improve resolution

Forward Calorimeters
- Replace FCal?
- Replace endcap hadronic calorimeter cold electronics?

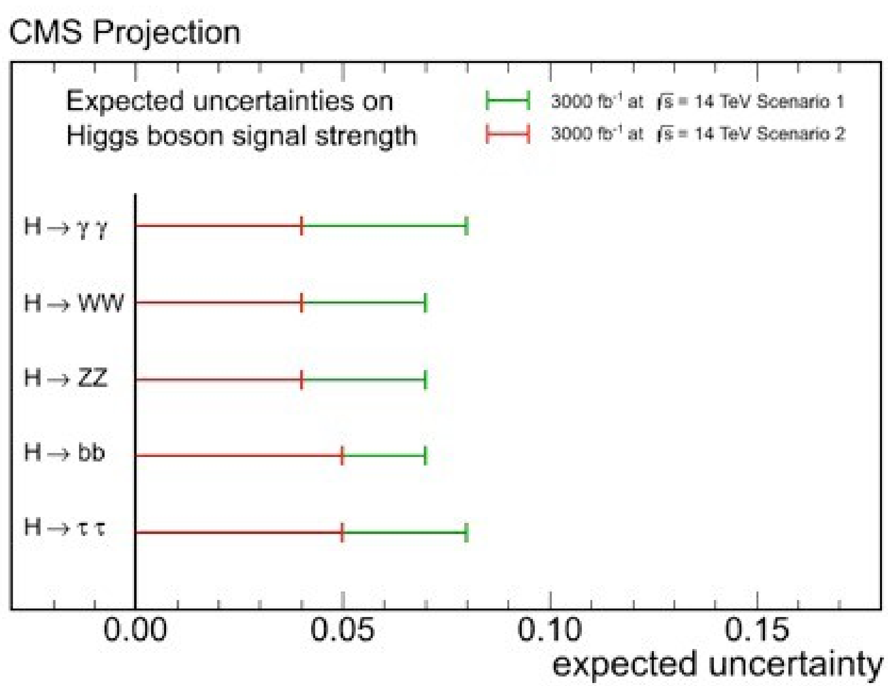
Prospects for Higgs measurement precisions

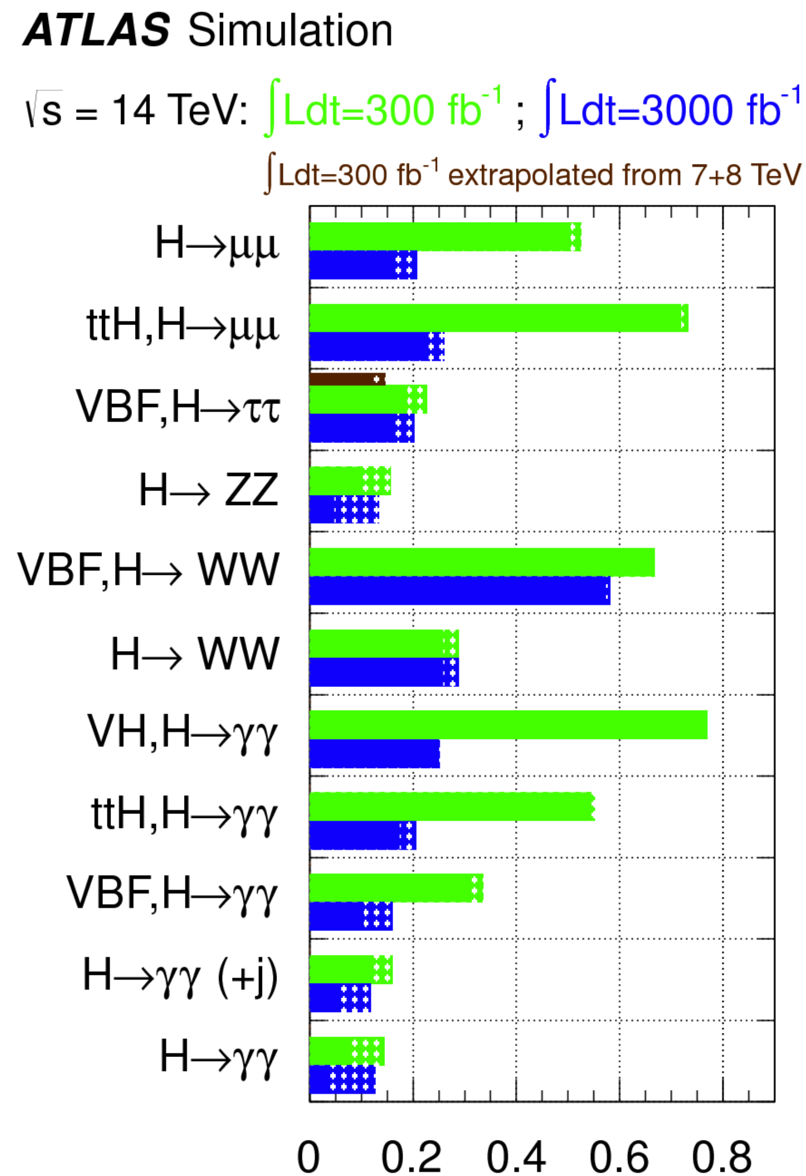
Extrapolating from 25 fb^{-1} to 300 fb^{-1} or 3000fb^{-1} is tough

Experimental systematic errors: will improve
- tighter/better selections
- constrain uncertainties increasingly using data

Theoretical uncertainties:
- Now 3-15% for production, 3-10% on decays
- Dominant errors: QCD scale (HOs) and PDFs

ATLAS and CMS made independent estimates with different assumptions – *should* bracket actual precision





Plots show estimated signal strength uncertainty extrapolations

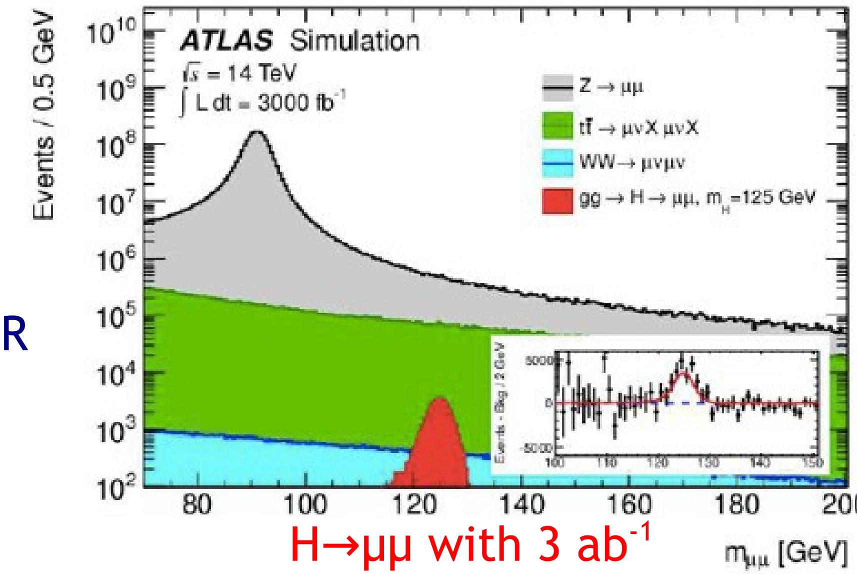
$\frac{\Delta\mu}{\mu}$

Prospects for Higgs measurement precisions

With 3000 fb^{-1}:

- signal strengths and partial width ratios to ~4-20% depending on channel
  - for WW, ZZ, γγ, bb, ττ, μμ, ttH
- → couplings (~√μ) to ~2-10%
- sensitivity to invisible decays directly at ~10% BR

Assuming substantial continuing progress on theory uncertainties



H→μμ with 3 ab^{-1}

What is the benchmark for precision?

It depends on the new physics expected!

e.g. Gupta and Wells

	ΔhVV	$\Delta h\bar{t}t$	Δhbb
Mixed-in Singlet	6%	6%	6%
Composite Higgs	8%	tens of %	tens of %
Minimal Supersymmetry	$< 1\%$	3%	$10\%^a$, $100\%^b$

i.e. 1-10% deviations expected for vector bosons, few to tens of % for fermions

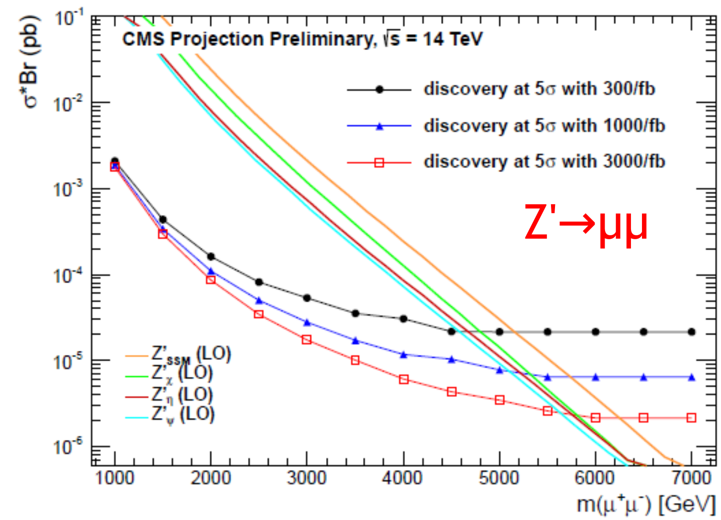
Higgs self-coupling HHH?

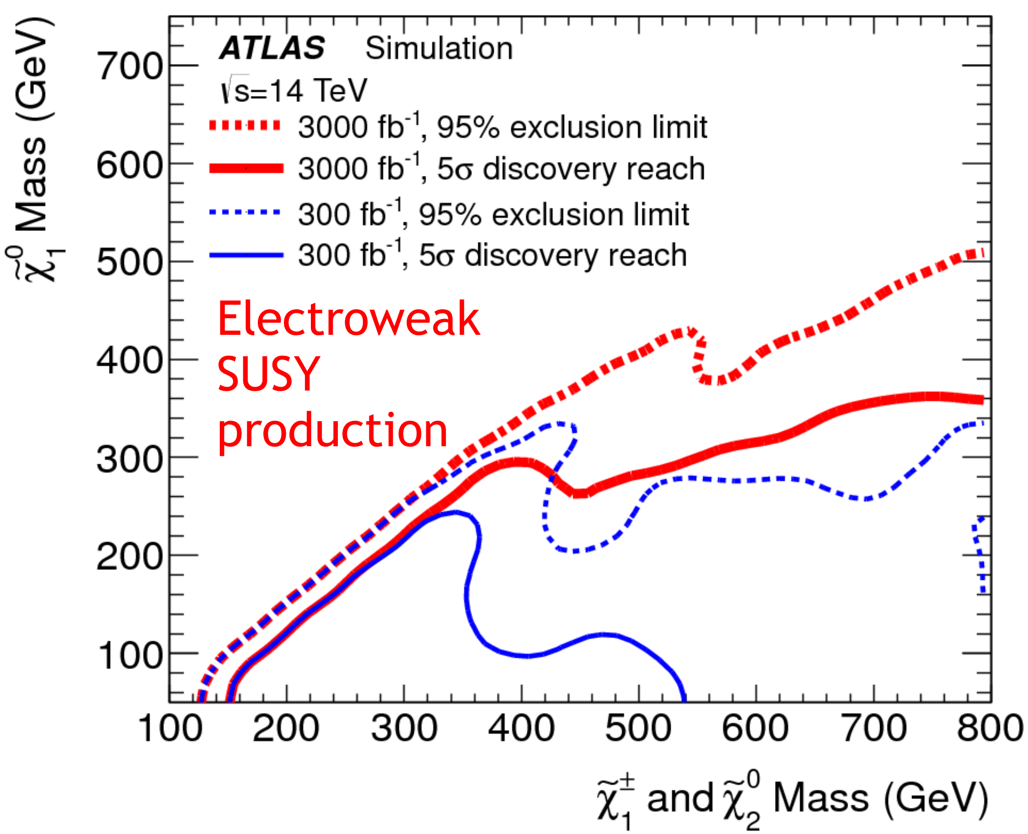
- Studies are ongoing – these will be very challenging analyses
- Estimate is that we may be able to achieve ~30% precision (per expt)

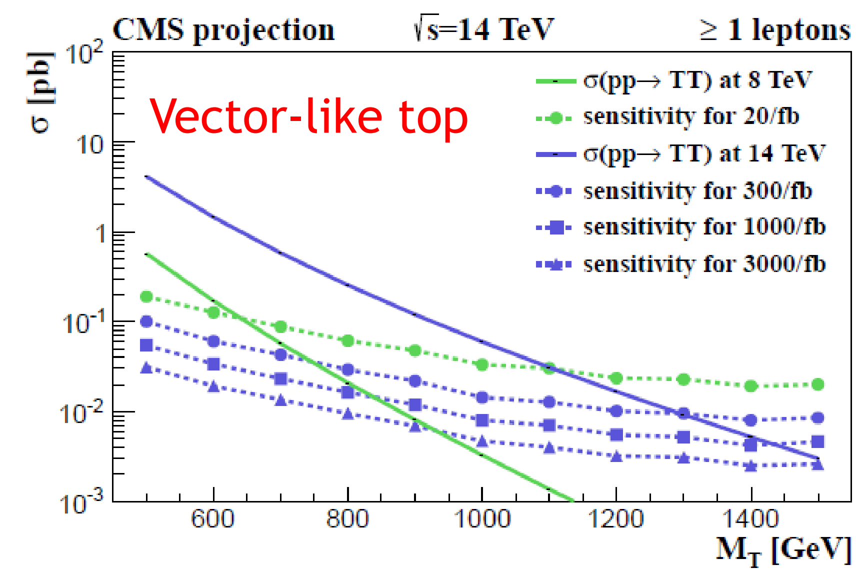
HL-LHC Beyond the Standard Model

European strategy update, Snowmass and ECFA HL-LHC experiments workshop provide context to deepen the HL-LHC case

Range of studies available and in progress







Summary

Fantastic delivery from the LHC accelerator and its teams in "Run-1"

Maintained excellent performance of ATLAS despite beyond-design pileup – ingenious performance work, and a highly capable detector

Fully corrected SM measurements challenge MC models in many areas

Moved beyond the discovery phase for our new Higgs boson

- $J^P = 0^+$ strongly favoured

Higgs analyses now are part of the measurement programme

- Precise coupling measurements
- 3σ evidence of VBF production
- Starting fully corrected differential measurements

Wide range of searches explore more challenging parts of SUSY space, and increasingly complex BSM signatures → but no sign yet of a second discovery

The ATLAS and LHC programmes have only just begun:

- 13 TeV approaching fast
- full LHC and HL-LHC programmes will fill the next 20 years with physics

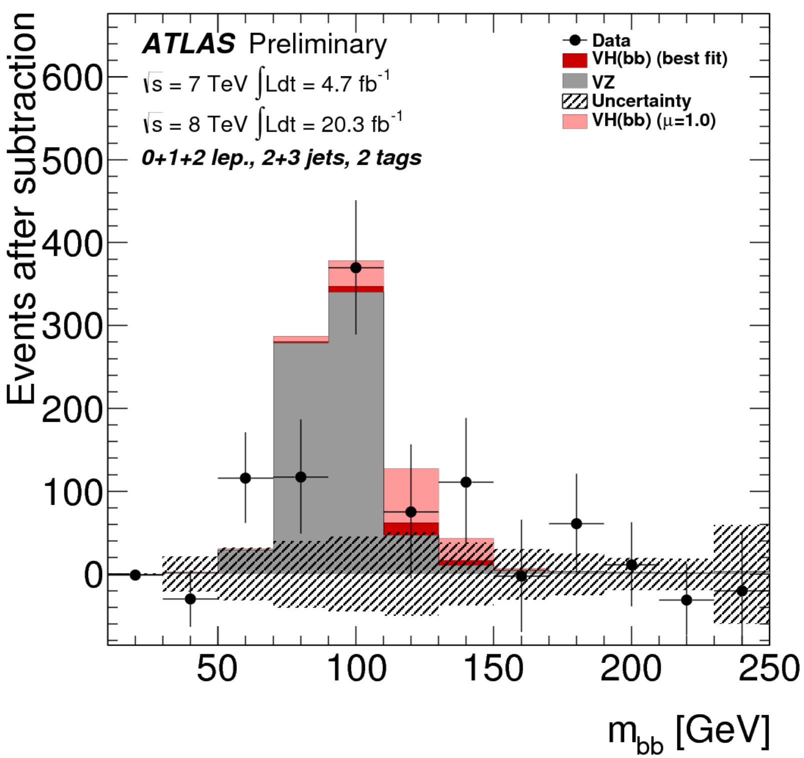
Couplings to fermions - decays

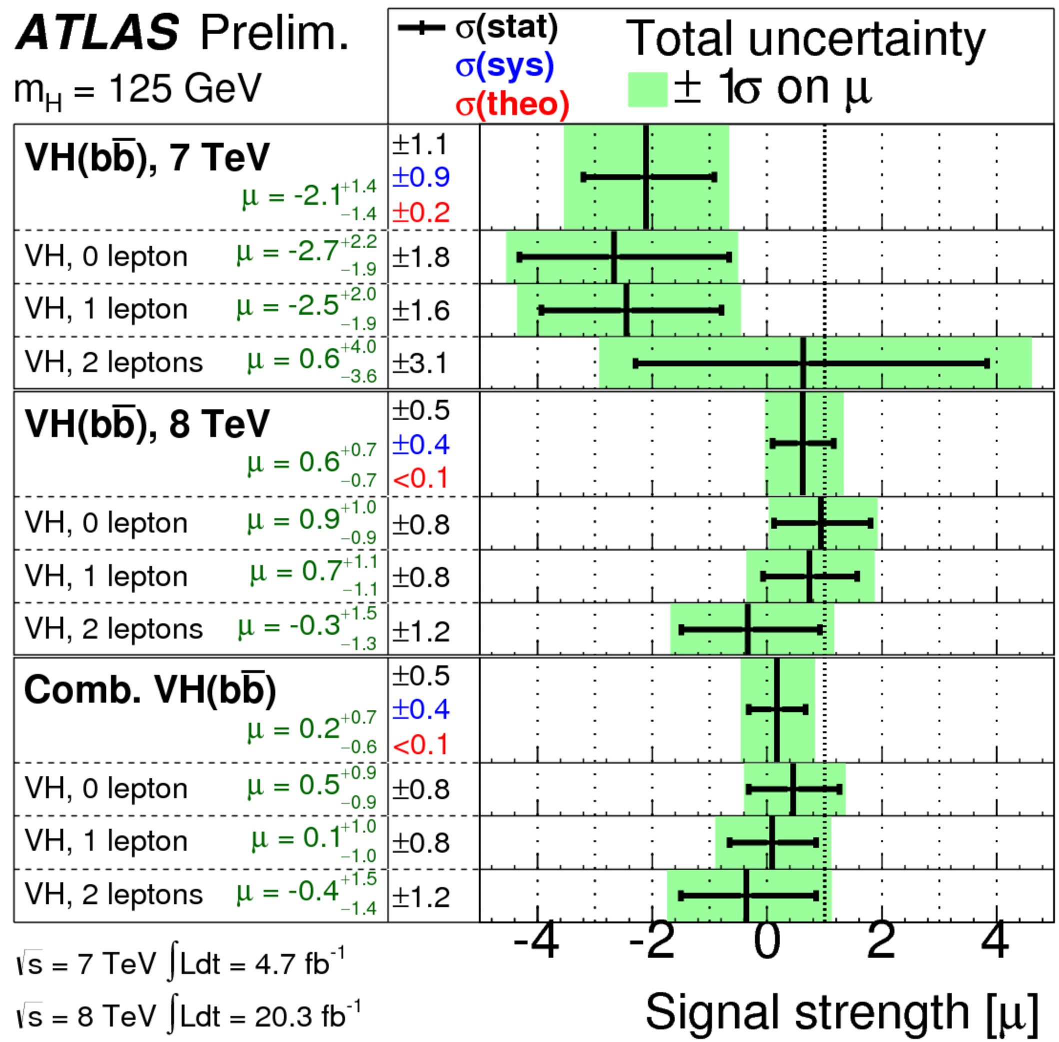
Tricky and delicate analyses

With current sample insufficient statistics for unambiguous (5σ) observation of these decays

$H \to b\bar{b}$ case: (W/Z)Z, (W/Z) → leptons, $Z \to b\bar{b}$ serves as proof of principle

ATLAS-CONF-2013-079





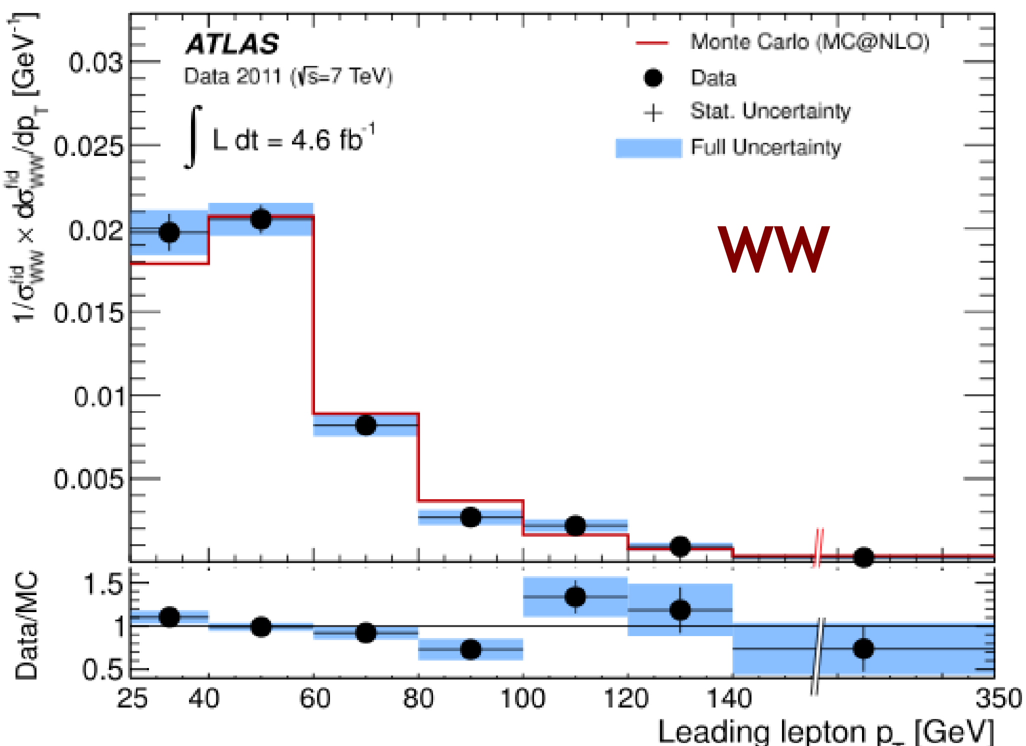
$H \to \tau\tau$ analysis update to full sample in progress, with $5{+}13\ fb^{-1}$, $\mu = 0.7^{+0.7}_{-0.6}$

ATLAS-CONF-2012-160

Dibosons – WW, WZ and ZZ

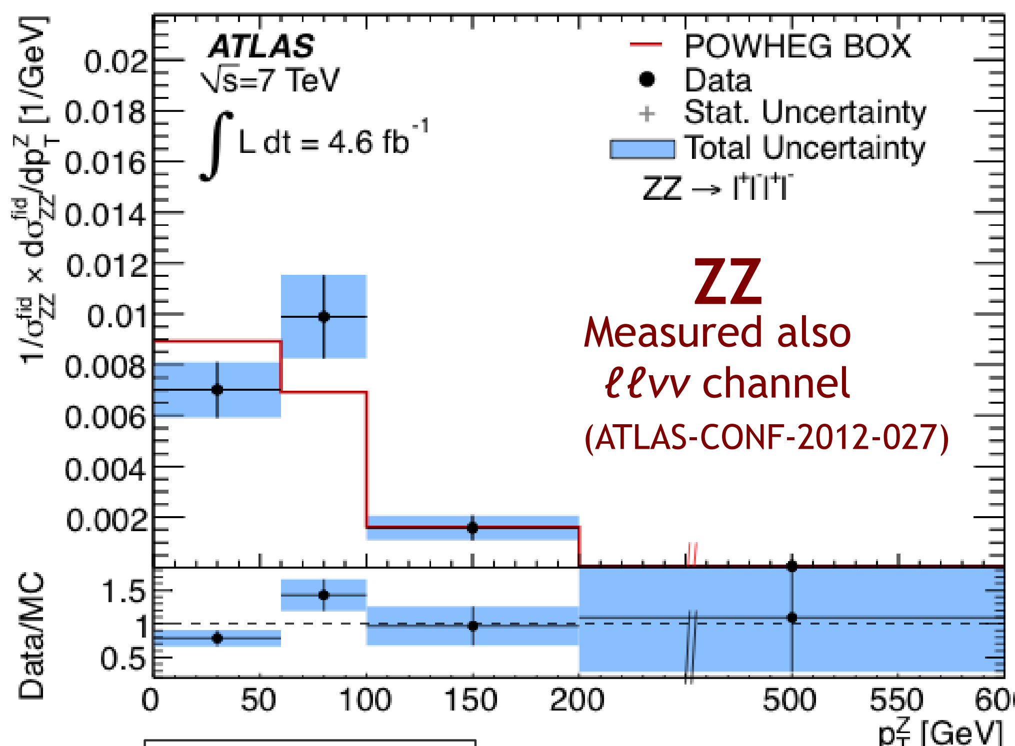
Example: differential cross section measurements: *WW*, *ZZ* (7 TeV, 4.6 fb^{-1})

Normalised fiducial differential cross-section



PRD87(2013)112001

Normalised fiducial differential cross-section



JHEP03(2013)128

NLO generators provide a good description of the data with these statistics, also for the mass spectra. Same conclusion for *WZ*

EPJC72 (2012) 2173

Dibosons – WW, WZ and ZZ

Exa

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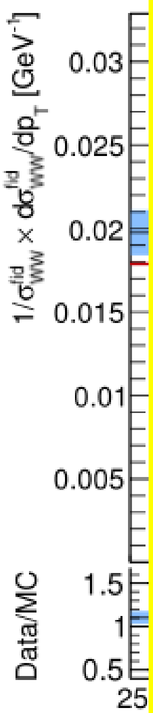
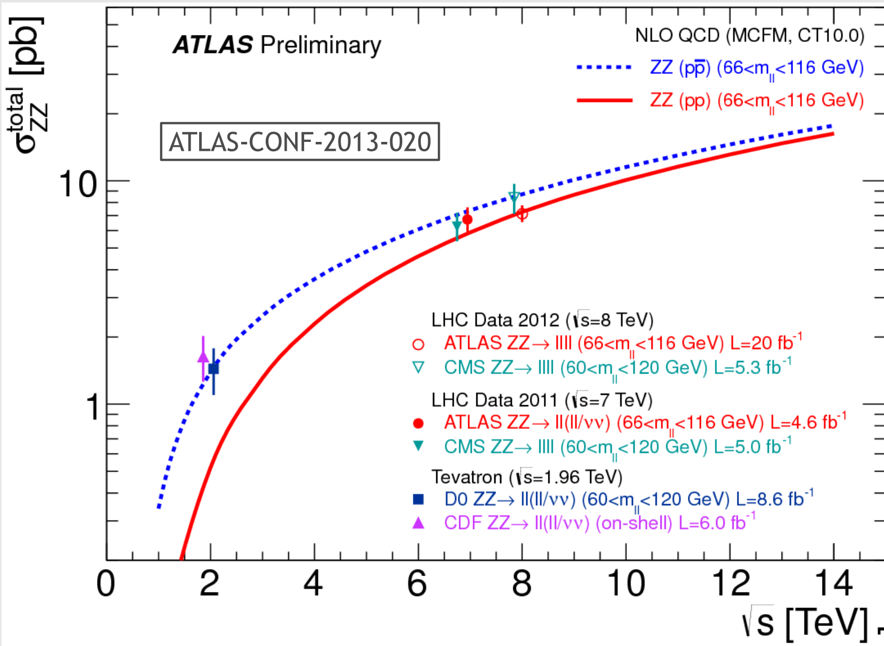
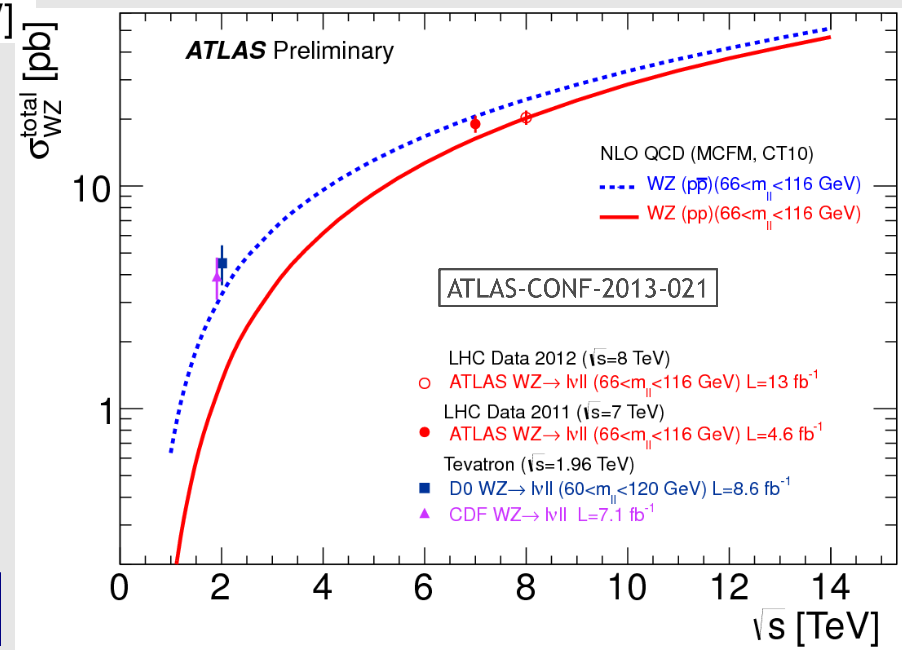
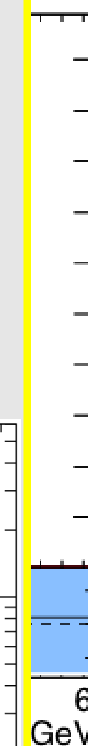




Inclusive cross-sections for WZ, ZZ with 2012 data

ZZ → 4ℓ (20 fb^{-1} @ 8 TeV)





WZ → 3ℓν (13 fb^{-1} @ 8 TeV)

Status of the detector

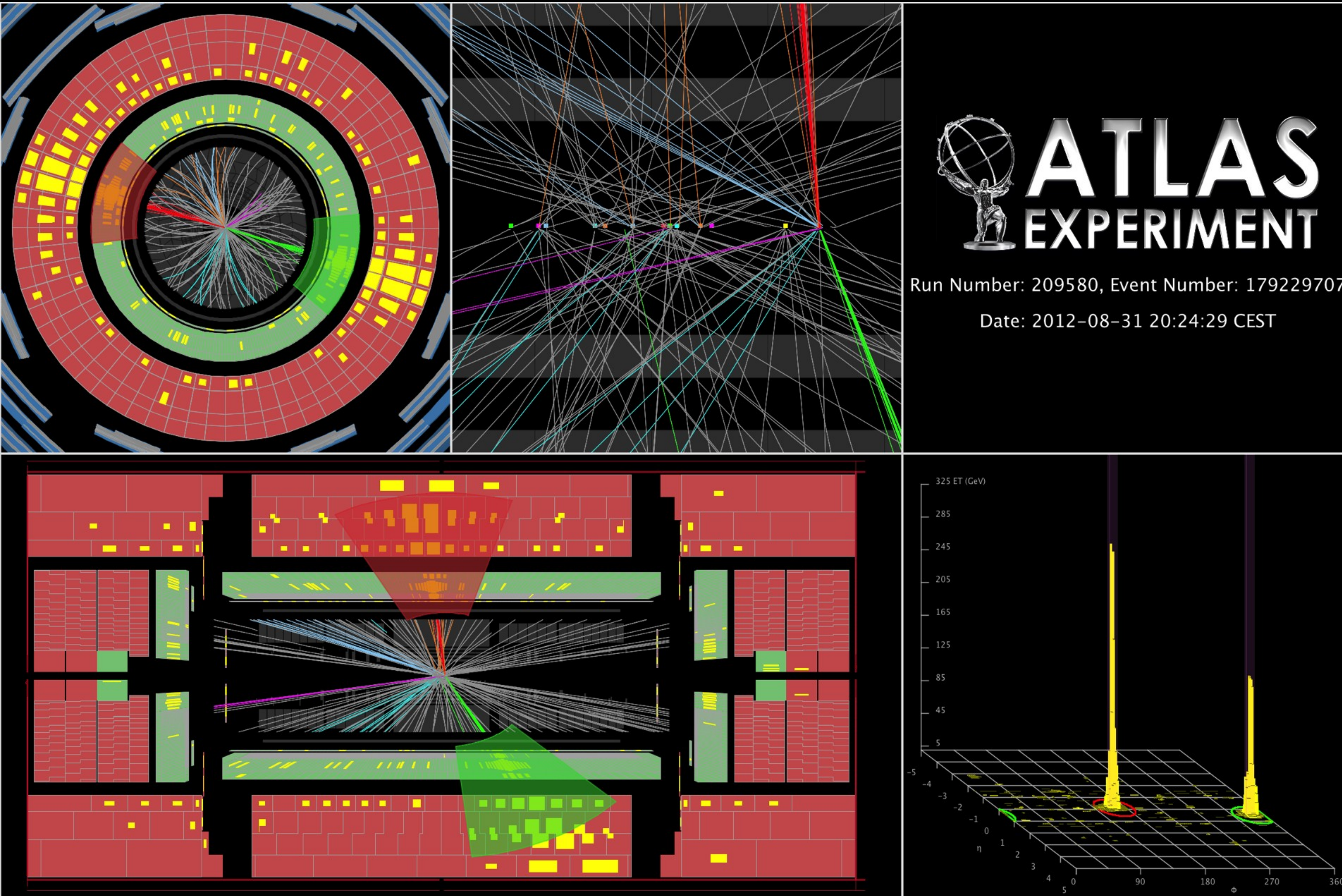
Typically >>95% of channels operational

At end of run-1, some systems closer to 95% than 100%

Drives part of the work programme for the current shutdown
(power supply replacements, electronics refurbishments, pipe and feedthrough repairs...)

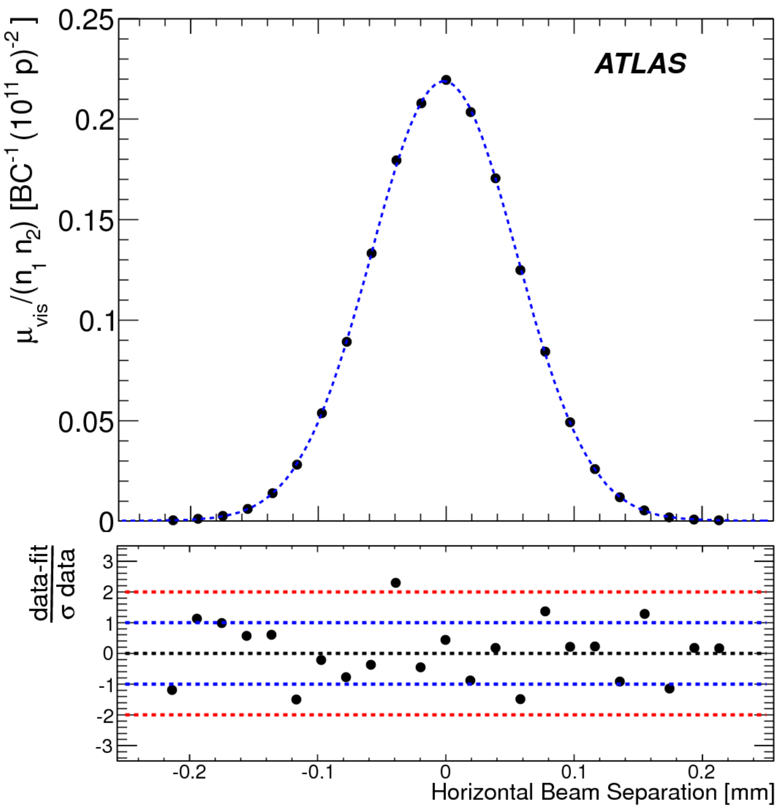
Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	95.0%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	97.5%
LAr EM Calorimeter	170 k	99.9%
Tile calorimeter	9800	98.3%
Hadronic endcap LAr calorimeter	5600	99.6%
Forward LAr calorimeter	3500	99.8%
LVL1 Calo trigger	7160	100%
LVL1 Muon RPC trigger	370 k	100%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	96.0%
RPC Barrel Muon Chambers	370 k	97.1%
TGC Endcap Muon Chambers	320 k	98.2%

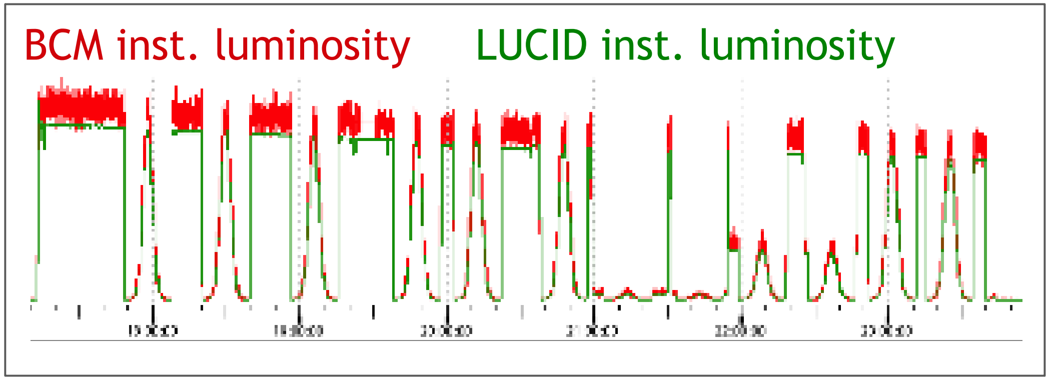
The highest-mass central dijet event. The two central high-p_T jets have an invariant mass of 4.69 TeV



Luminosity Precision – van der Meer Scans

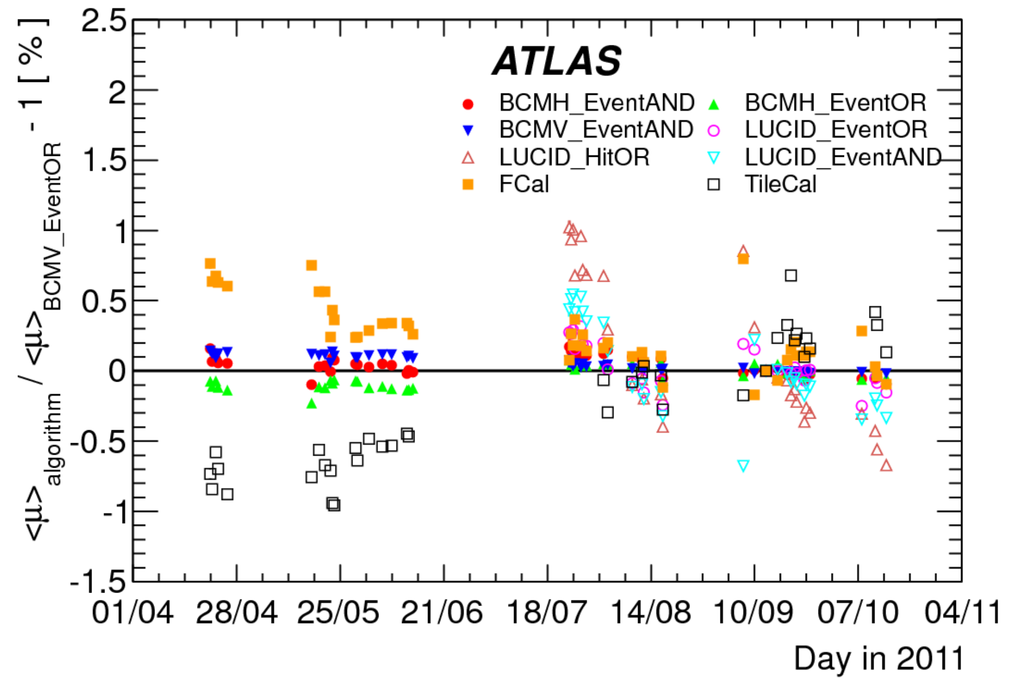
Absolute calibration comes from special fills with beam-separation scans in x & y





arXiv:1302.4393

Calibration transported to all fills using a range of luminosity-measuring detectors and algorithms

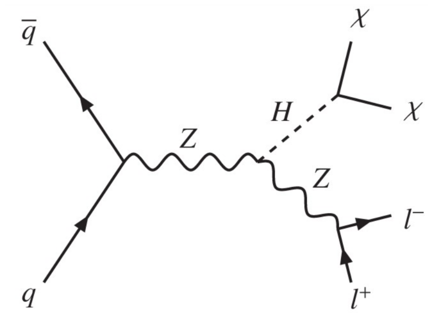


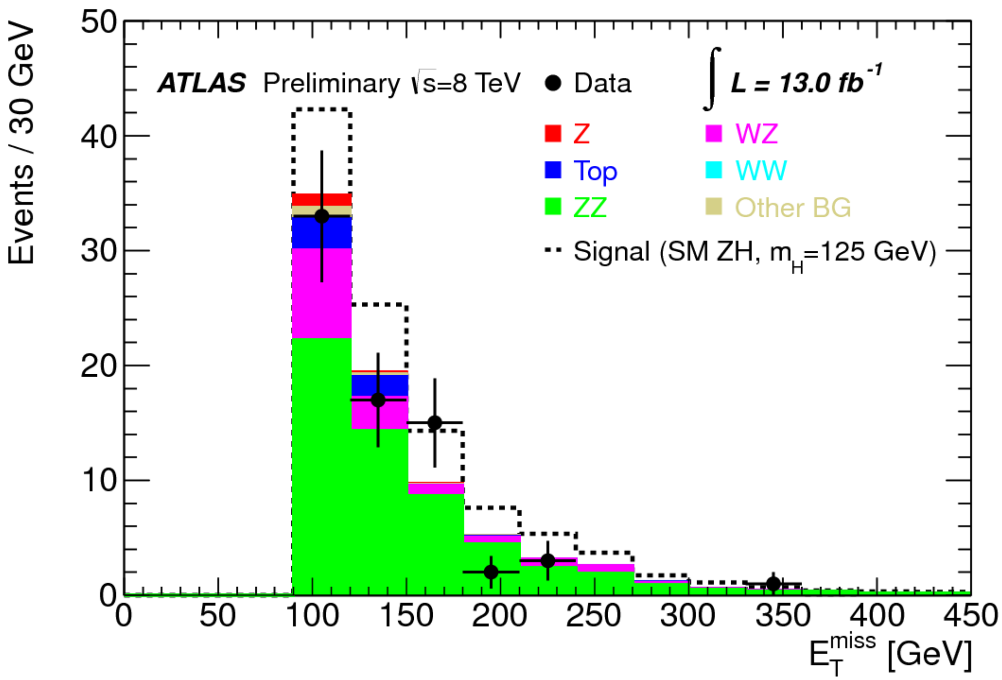
Luminosity error for 2011 ±1.8%

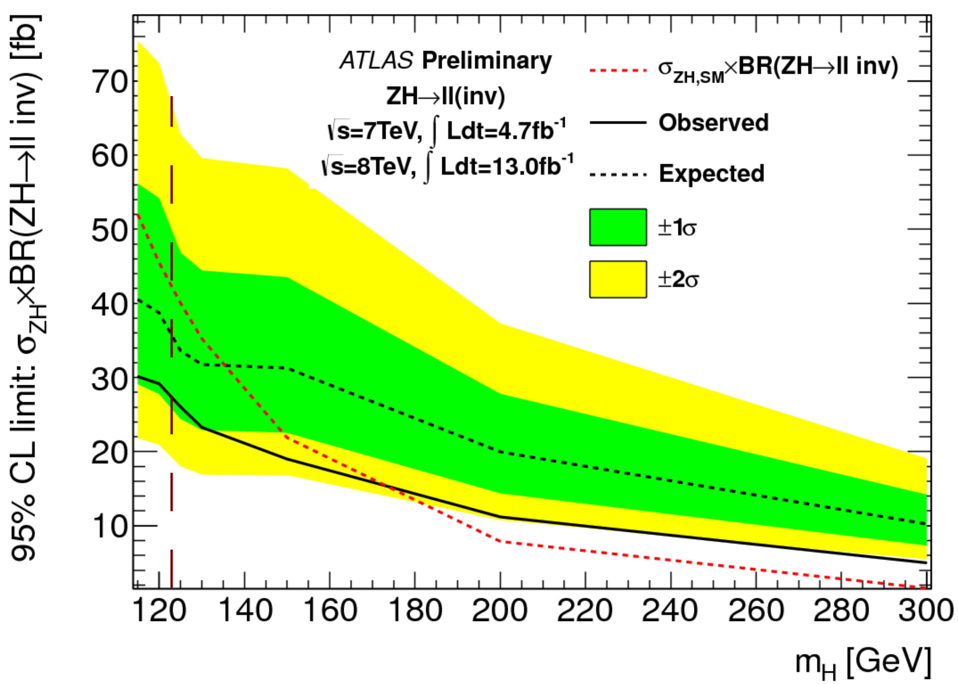
Invisible Higgs decays?

Technique: look for ZH production

- $Z \rightarrow \ell\ell$ recoiling against E_T^{miss}
- Require E_T^{miss} > 90 GeV, back-to-back with Z







At m_H=125 GeV, for SM σ(ZH)

- BR(H→invisible) < 0.65 at 95% CL
  (expected limit 0.84)

Background dominated by ZZ

ATLAS-CONF-2013-011