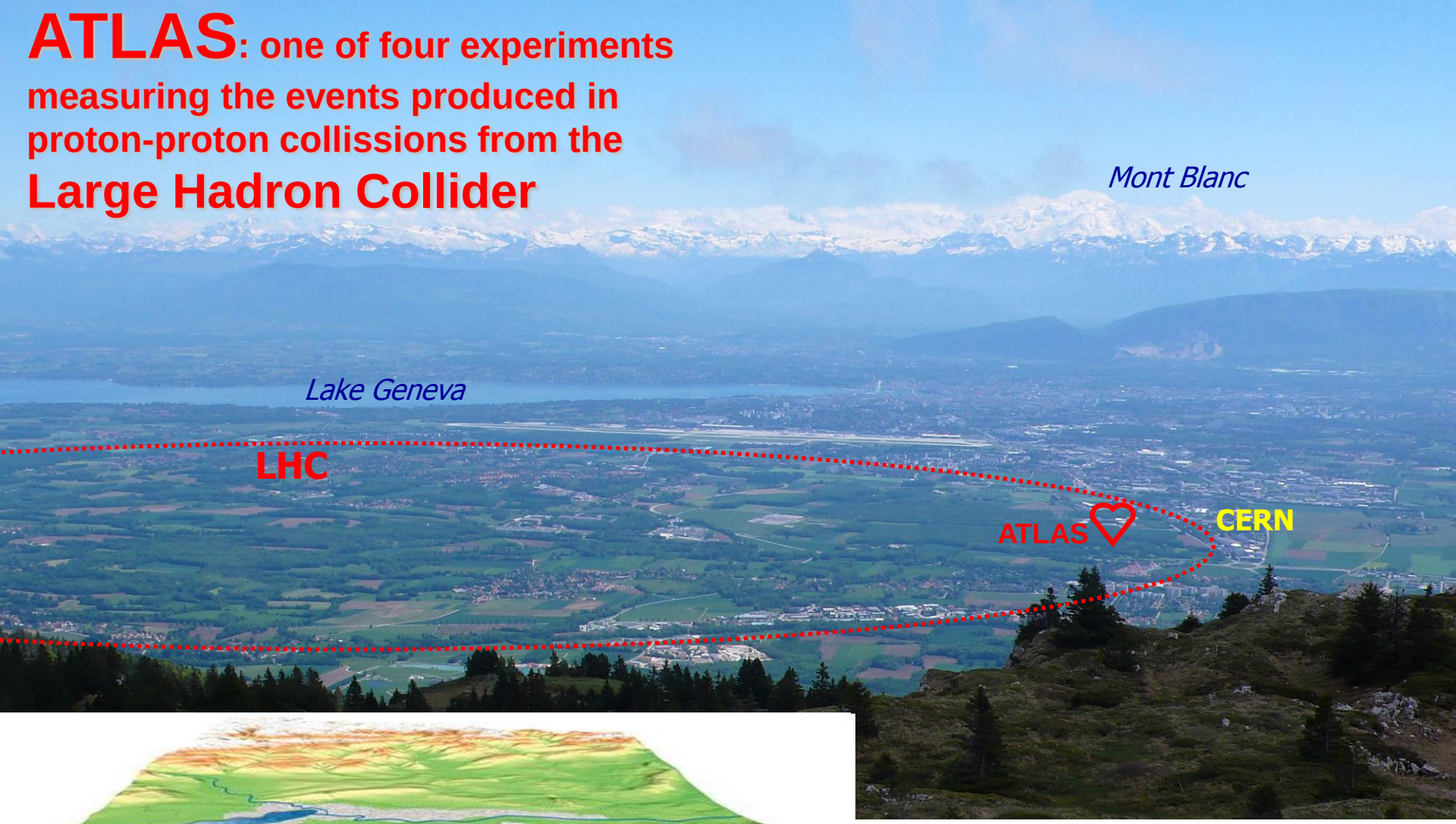
Latest results from ATLAS

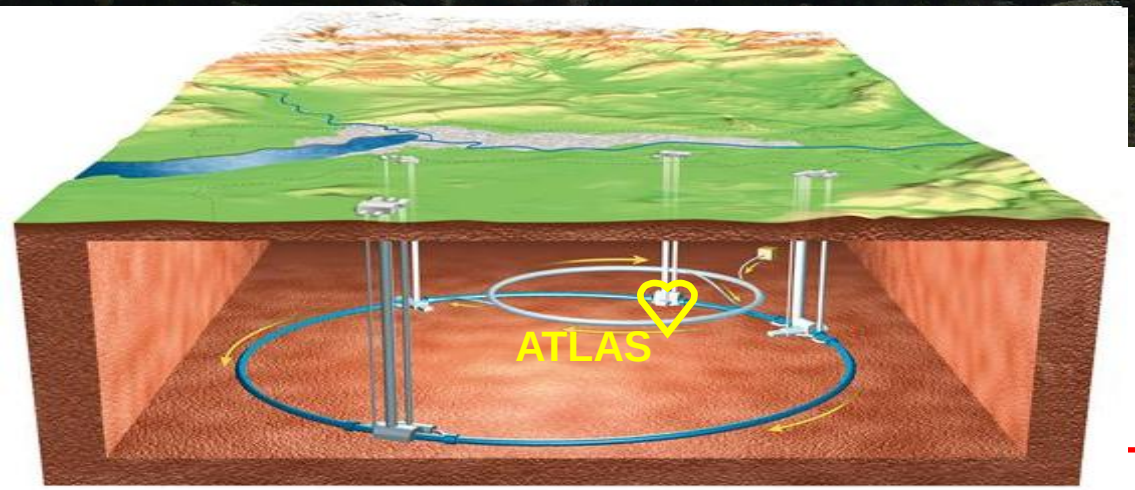
Outline:

ATLAS data taking in 2011
Top physics
Search for SM Higgs boson
SUSY searches

Maaike Limper - University of Iowa

ATLAS: one of four experiments measuring the events produced in proton-proton collissions from the Large Hadron Collider



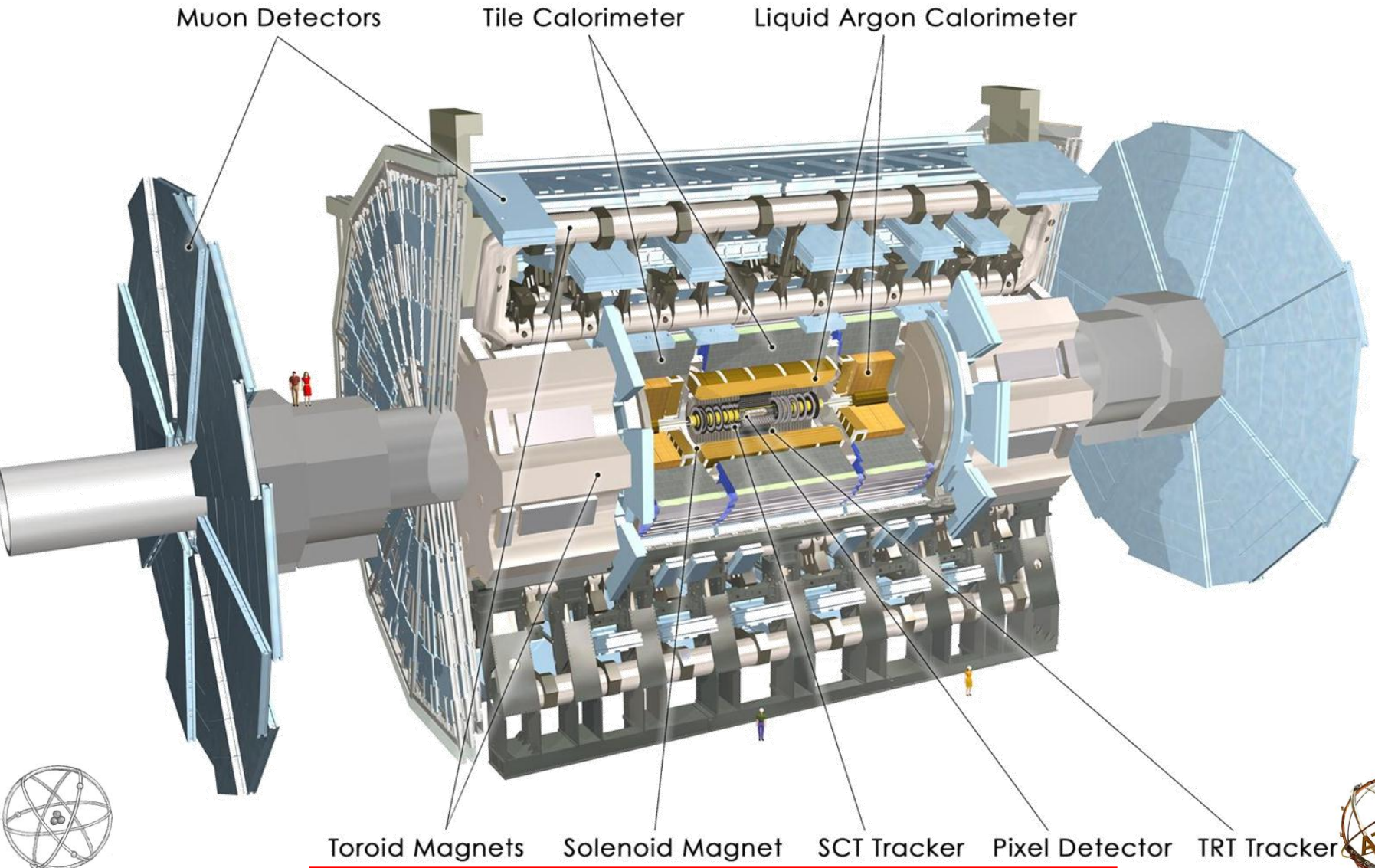


ATLAS

38 Countries
174 Institutions
~3000 Scientists
~1000 Students
ATLAS
Collaboration

ATLAS

... and 1 experiment!

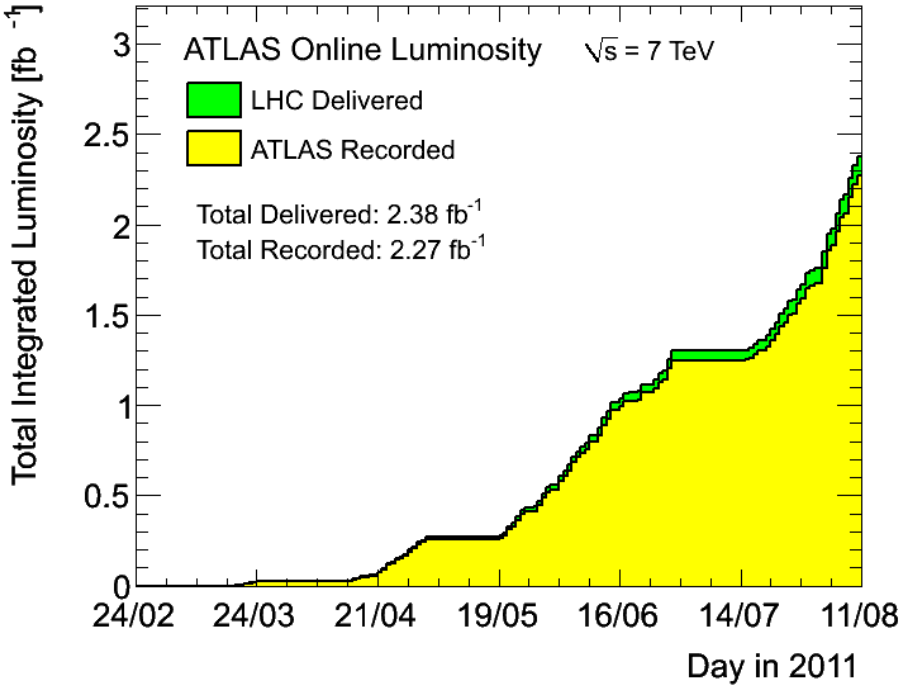


2T solenoid, toroid system (∫Bdl=1-7.5 Tm)
Tracking to |η|=2.5, calorimetry to |η|=4.9

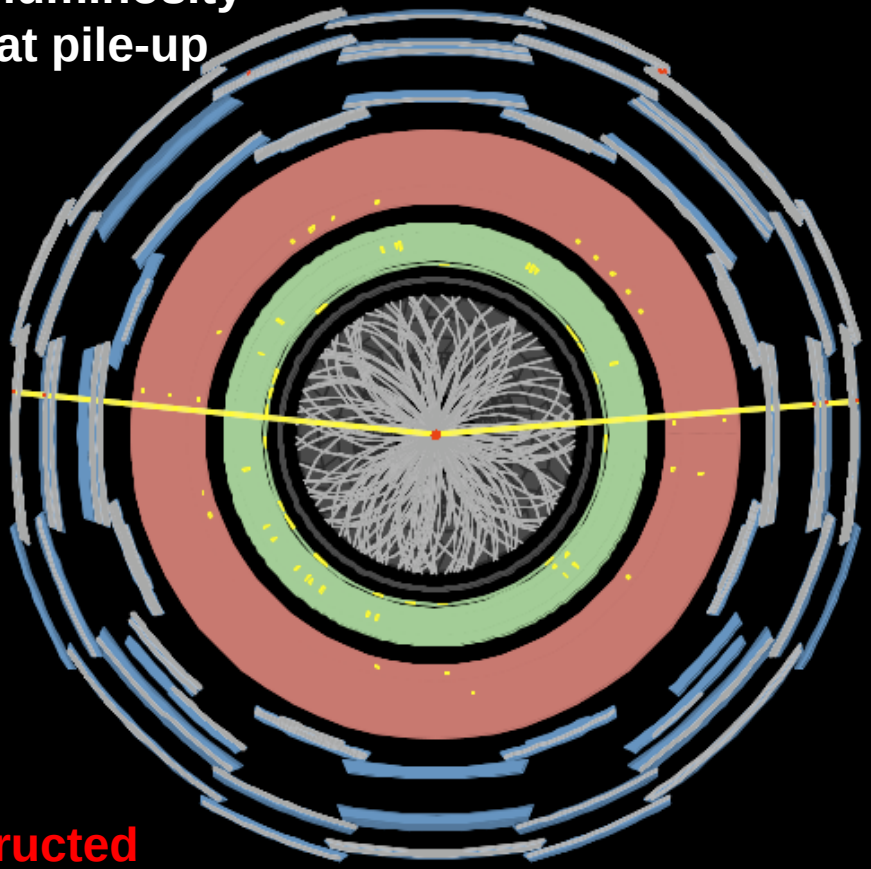
ATLAS data collection

Good LHC performance in 2011!
Many new ATLAS results made public with ~1 fb^{-1} for EPS conference
Records:
Peak luminosity: **2.11×10^{33} $cm^{-2}s^{-1}$** (nominal: 10^{34} $cm^{-2}s^{-1}$)
Max. luminosity delivered in one week: 499.45 pb^{-1} (last week!)

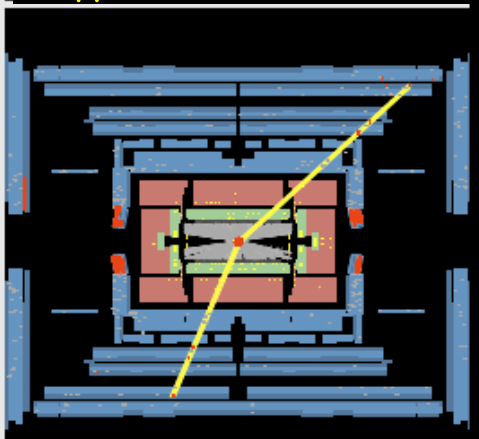
Expect to have approx. ~4 fb^{-1} by November 2011



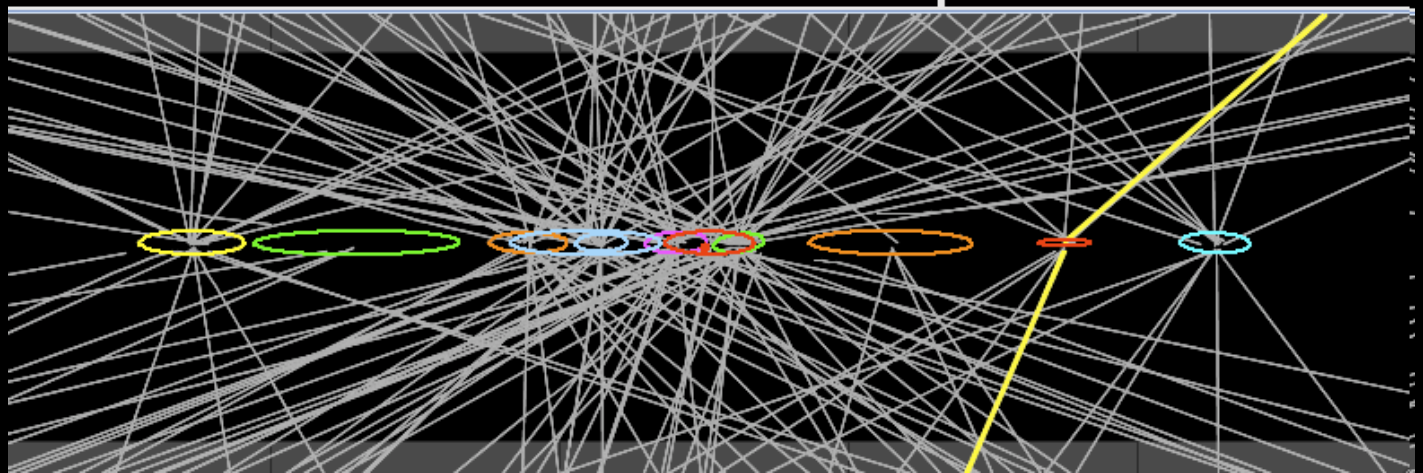
With great luminosity comes great pile-up



Z->μμ candidate, $m_{\mu\mu}$=93.4 GeV



11 reconstructed vertices



ATLAS data taking

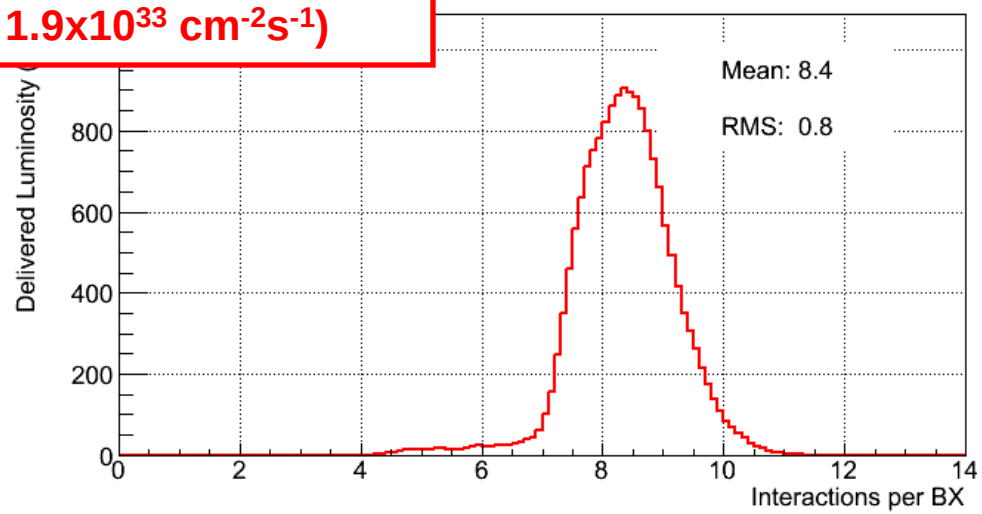
LHC currently provides 1317 colliding bunches in ATLAS

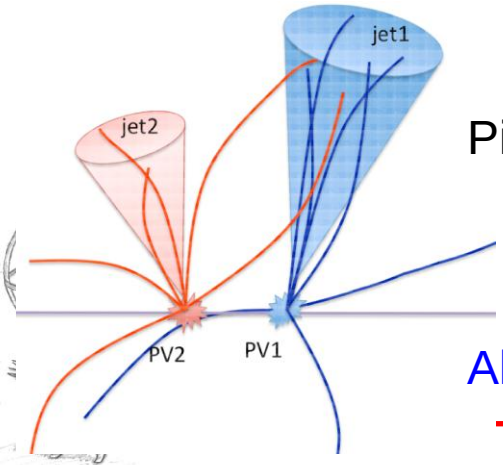
Number of colliding bunches is limited by 50 ns bunch-spacing

As LHC continues to break luminosity records, pile-up continues to increase!

Luminosity of 2.03×10^{33} cm^{-2}s^{-1} corresponds to an average of 9.8 interactions per bunch crossing

Interactions per BX, run 186669 (peak lumi 1.9×10^{33} cm^{-2}s^{-1})





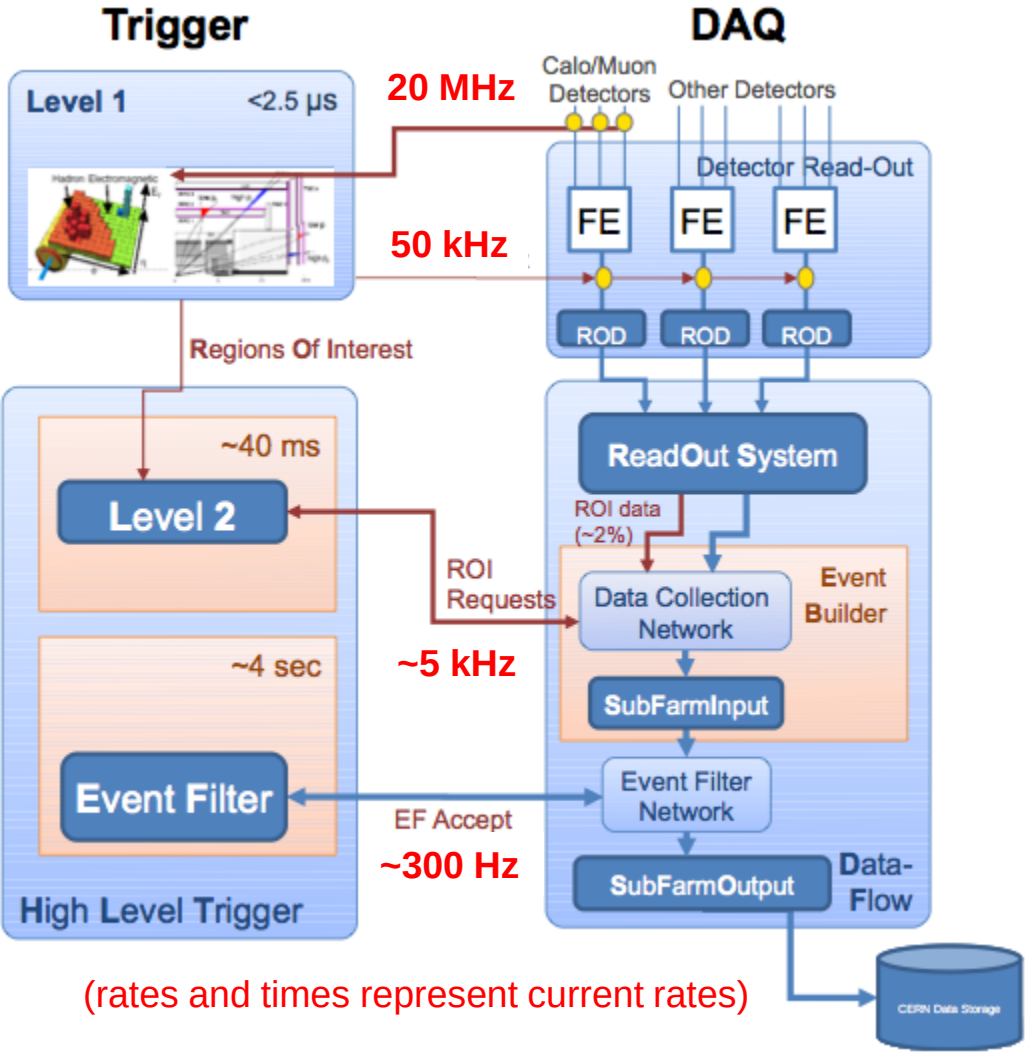
Pile-up needs to be taken into account in physics analysis:

- Assign reconstructed object to correct vertex
- Jet-filtering to reduce impact from pile-up
- Re-weight simulated to match pile-up measured in data

Also consider **out-of-time pileup** with 50 ns bunch-spacing

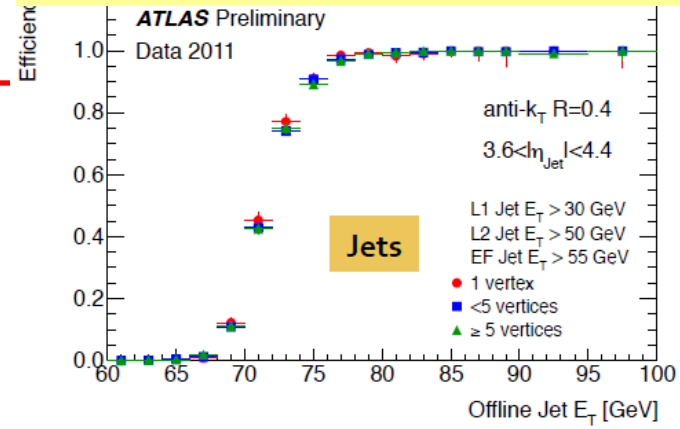
Trigger

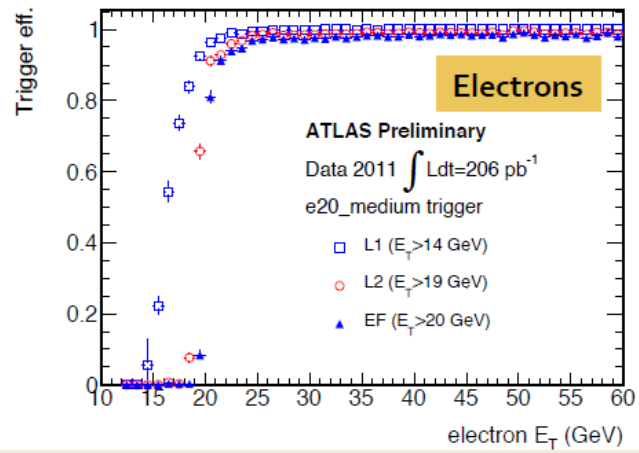
Flexible menus are used to keep the the rate after the Event Filter at ~300 Hz
Supplemented by supporting & monitoring triggers



(rates and times represent current rates)

Example of HLT performance plots





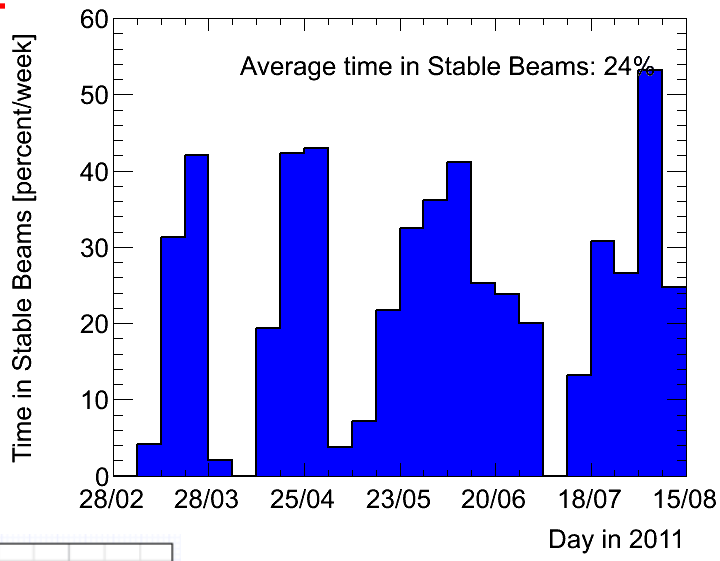
Primary triggers are kept stable, e.g.

- Inclusive e p_T>20 GeV
- Inclusive μ p_T>18 GeV
- Inclusive jet p_T>180 GeV
- E_T^{miss} > 60 GeV
- Di-photon p_T> 20 GeV etc.

Such triggers are not prescaled

Prompt Reconstruction

Time in stable beam (percent/week)

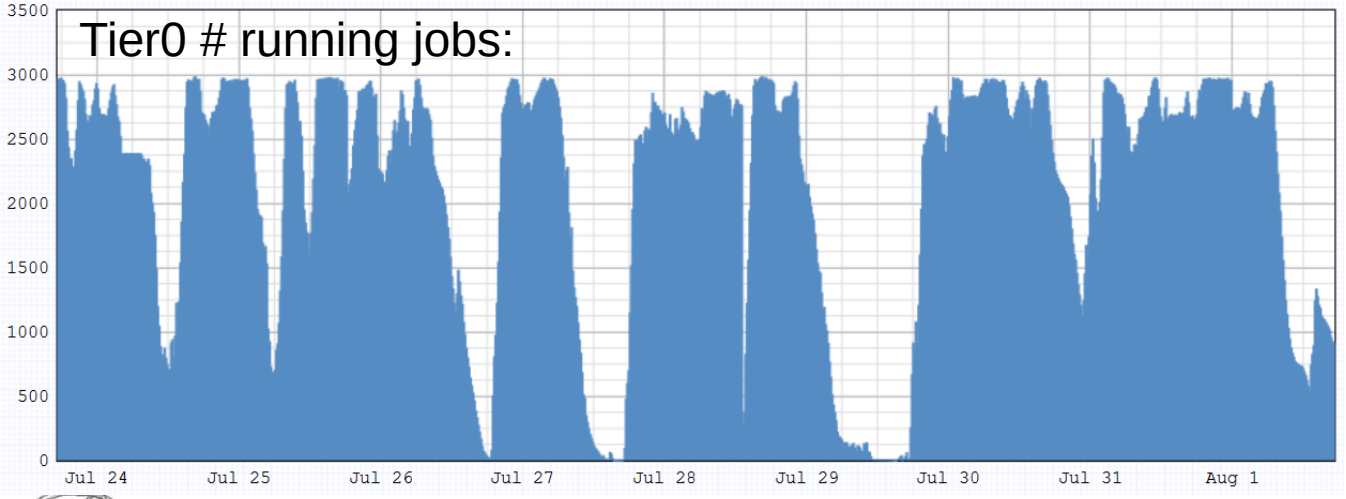


Tier0 resources designed to handle 300 Hz data-taking with 30% time in stable beam

Tier-0: 3000 CPUs available for ATLAS data reconstruction (raised to 4100 CPUs this week)

"Express" reconstruction of data during data-taking

Bulk reconstruction of data 36 hours after end of run, using beamspot and calibration constants derived from express reconstruction



Analysis-ntuples centrally produced at Tier-1 from reconstructed data

Data quality

Percentage of delivered data passing good data-quality requirement per sub-detector: (corresponding to 1.25 fb^{-1} of 2011 data)

Inner Tracking Detectors			Calorimeters				Muon Detectors				Magnets	
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.9	99.8	100	89.0	92.4	94.2	99.7	99.8	99.7	99.8	99.7	99.3	99.0

Luminosity weighted relative detector uptime and good quality data delivery during 2011 stable beams in pp collisions at $\sqrt{s}$=7 TeV between March 13th and June 29th (in %). The inefficiencies in the LAr calorimeter will partially be recovered in the future. The magnets were not operational for a 3-day period at the start of the data taking.

Inefficiencies in the LAr calorimeter are mostly due to isolated HV trips and noise bursts, will partially be recovered in the future

"All good" fraction will increase by ~7% after reprocessing campaign, using fine-grained flagging of calo noise bursts

Solenoid and Toroid magnets were not operational for 3-day period at start 2011 data-taking

Fast DQ-signoff allows analysis groups to look at new data as soon as possible!

Centrally provided "GoodRunLists" used for analyzing data: determines which LBs to use per run based on sub-detectors required to have good DQ

Luminosity calculation recently updated, systematic uncertainty is 3.7%

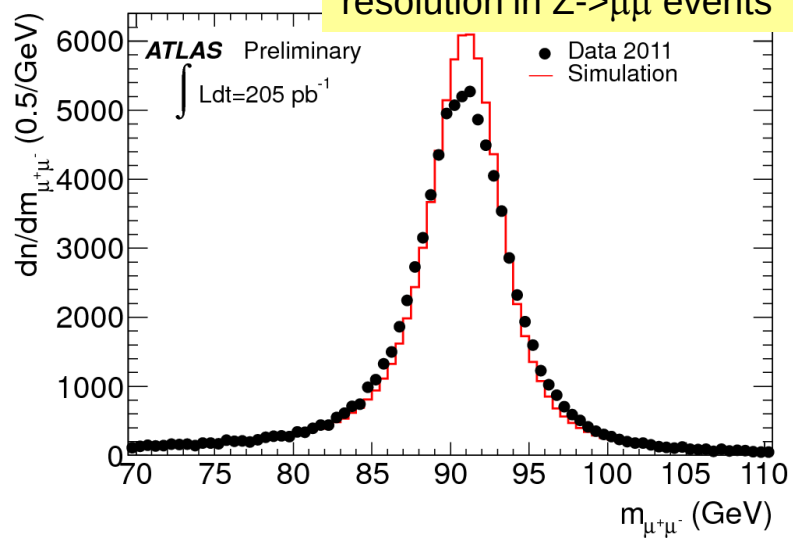
Detector performance

Increased statistics for 2011 data allowed to improve various data-driven performance studies

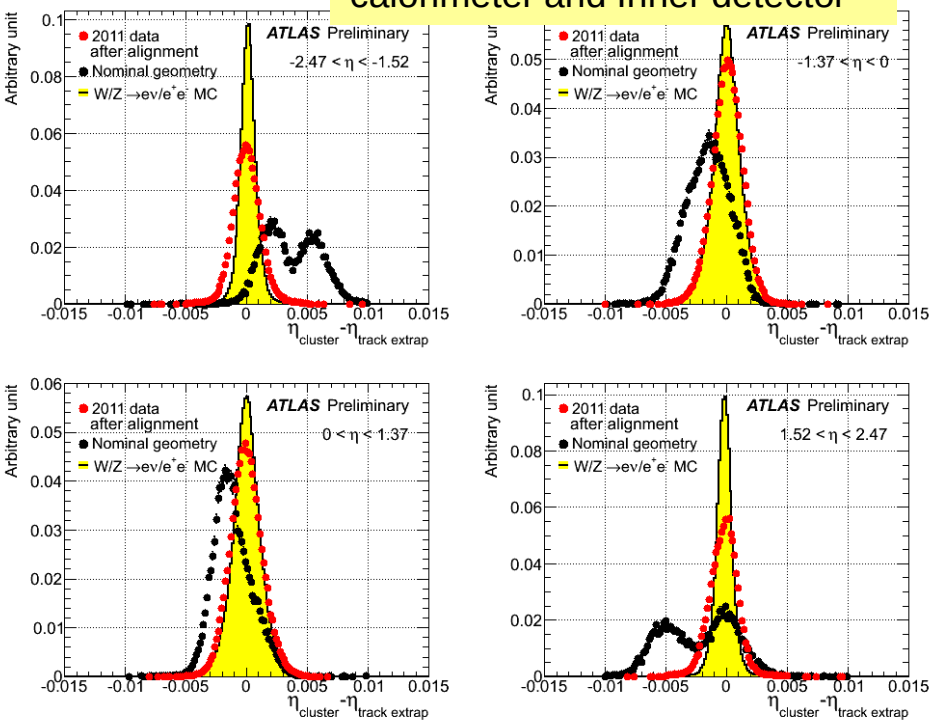
- Inner detector alignment
- Jet energy scale calibration
- Combined muon reconstruction
- b-tagging efficiency

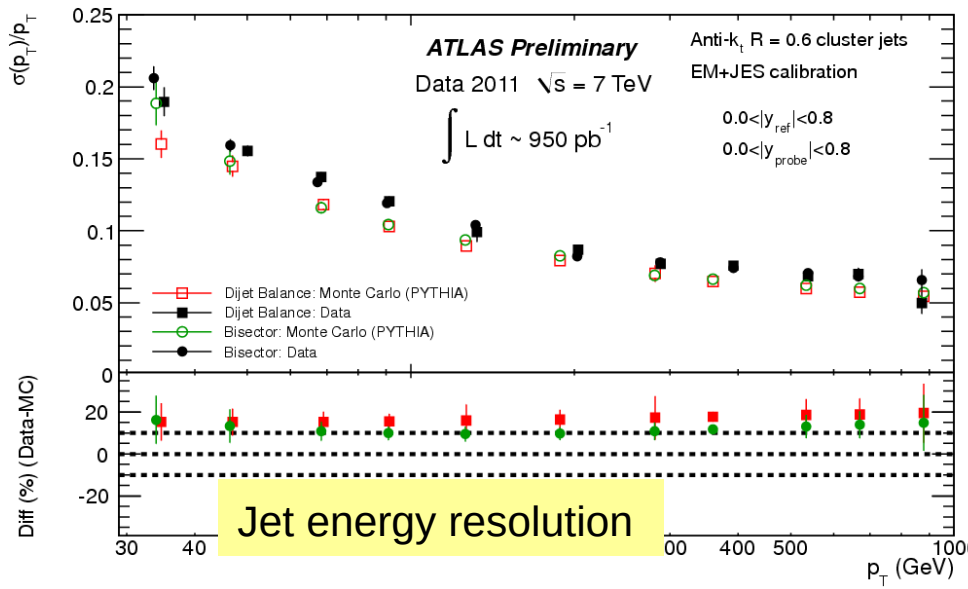
(no time to go into detail today)

Di-muon invariant mass resolution in Z->μμ events



Inter-alignment between EM calorimeter and Inner detector





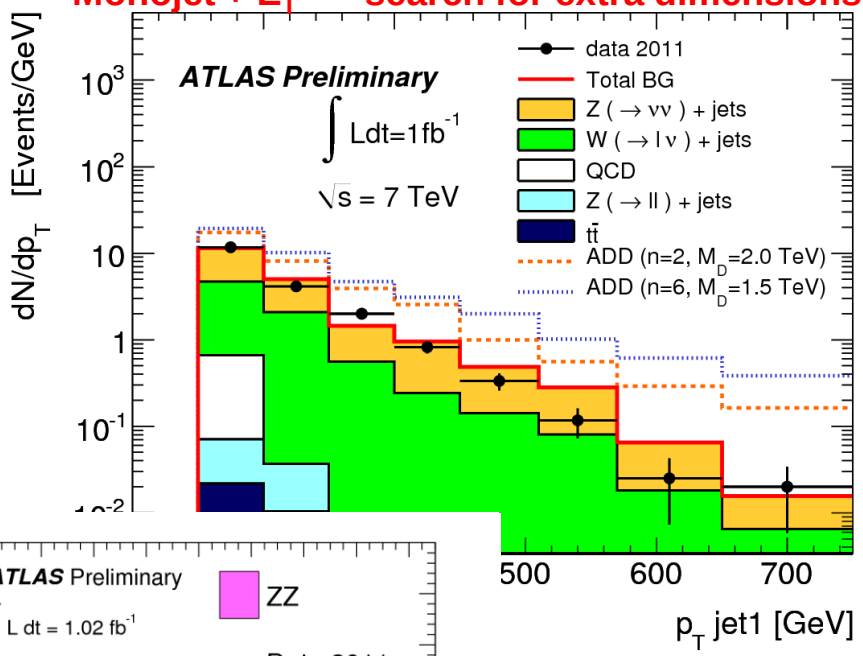
Jet energy resolution

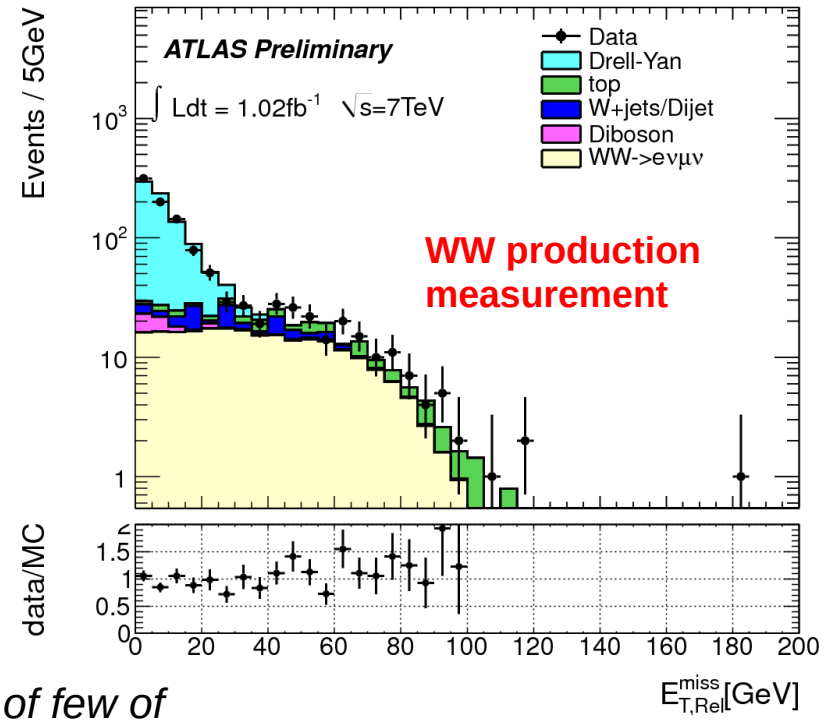
ATLAS physics results

Many new results for ATLAS available: https://twiki.cern.ch/twiki/bin/view/AtlasPublic

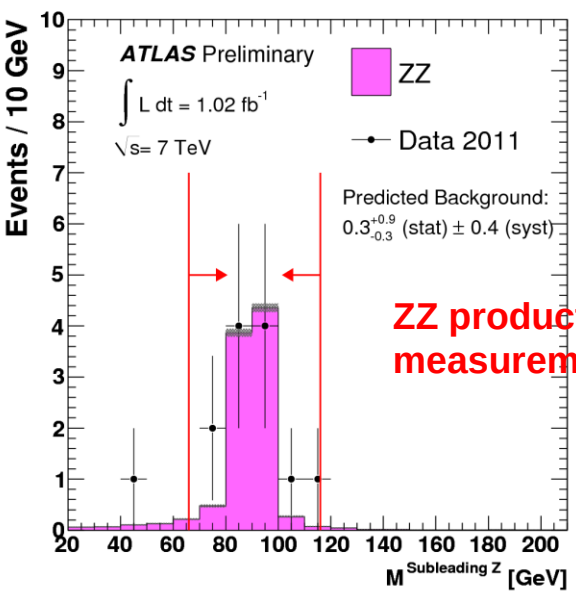
Too many to mention all today!

Monojet + E_T^{miss} search for extra dimensions





WW production measurement



ZZ production measurement

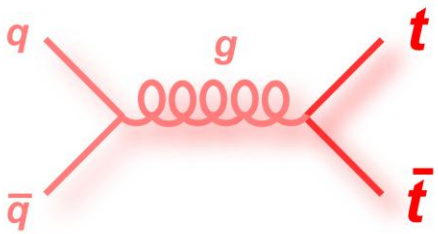
Just a snapshot of few of the many other new ATLAS physics results!

Today I will focus on results for top physics, SM Higgs search and SUSY searches

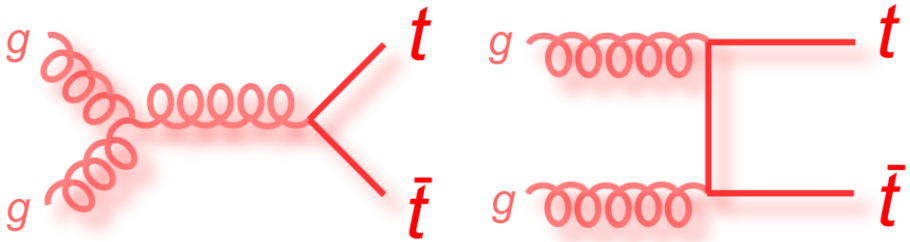
Top physics at ATLAS

ttbar production at LHC:

15% quark-antiquark annihiliation

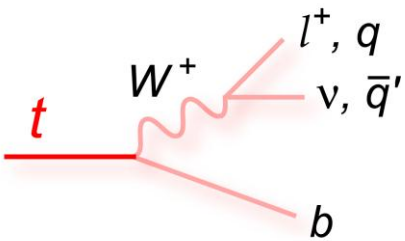


85% gluon-gluon fusion

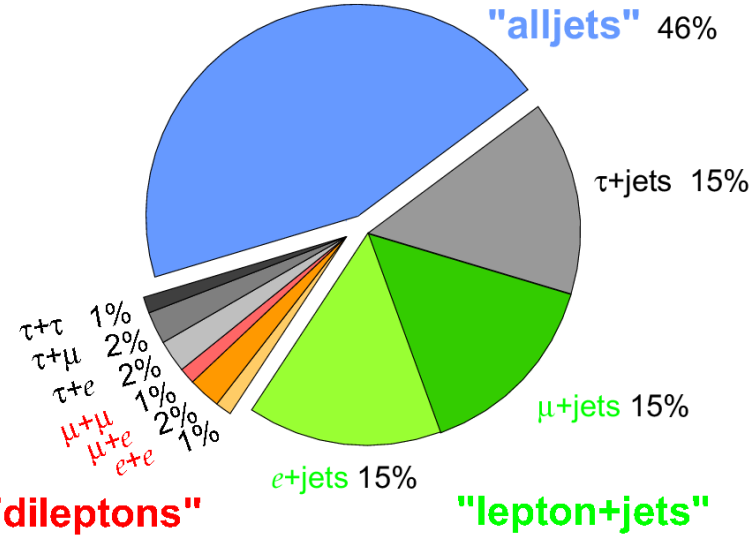


ttbar cross-section at LHC (at 7 TeV) is >20 times higher than tevatron

Each top decays to W+b
W-decay either to quarks or leptons



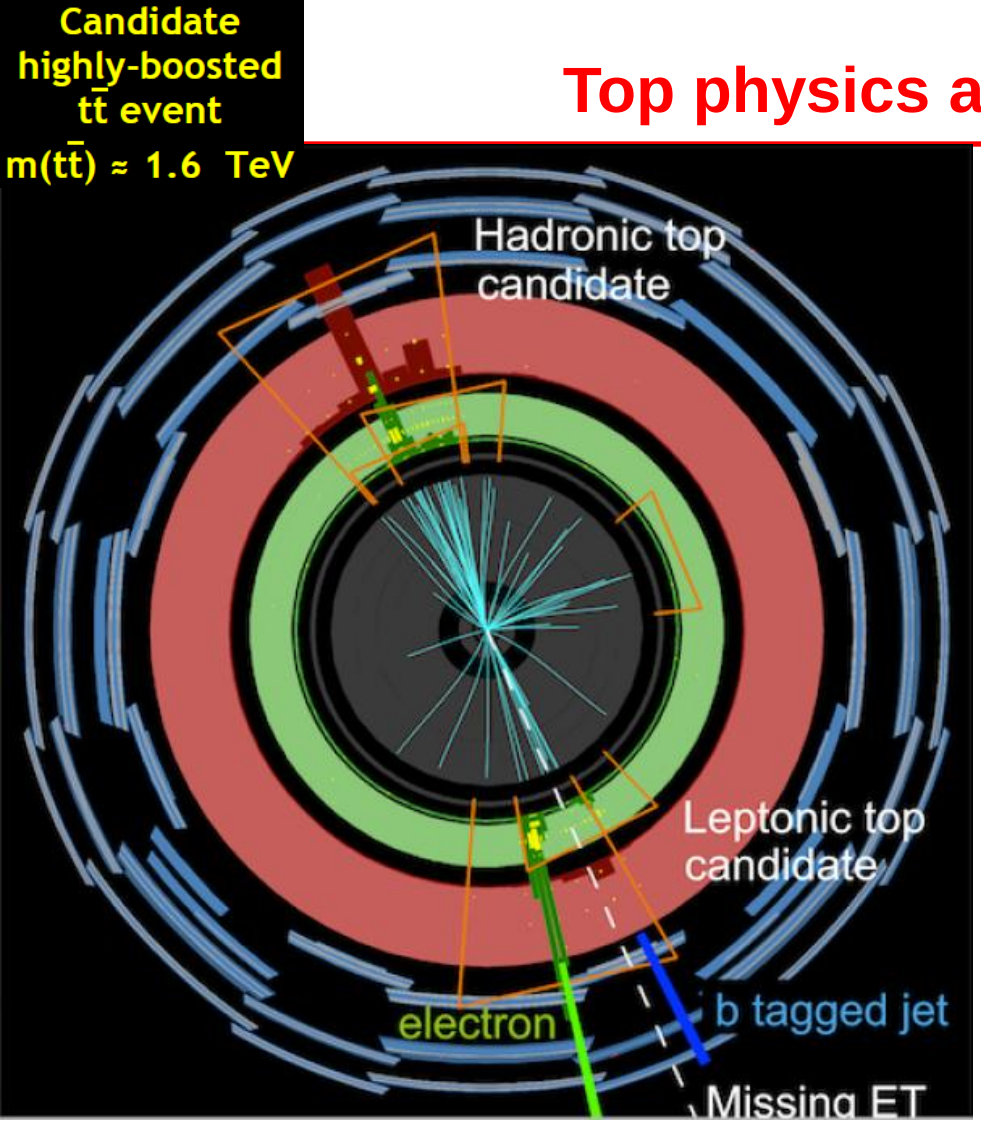
Top Pair Branching Fractions



Why study top pair production?

- Test of perturbative QCD and of the SM description of the top quark decay
- Important background in searches for Higgs and BSM physics.
- Might reveal new physics that modifies the production and/or decay of top quarks

Top physics at ATLAS



Example of semi-leptonic ttbar decay as seen in the ATLAS detector:

Leptonic W-decay:

high p_T lepton (e/μ) + **missing E_T from ν**

2-jets from hadronic W-decay

2 b-jets from top-decay

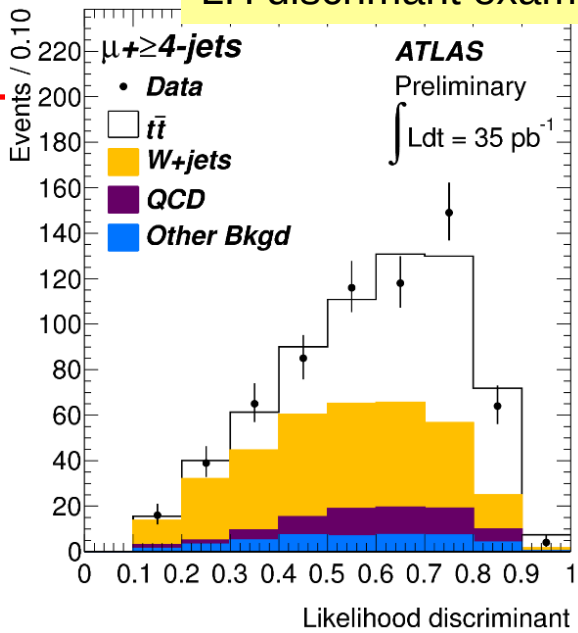
each b-jet has a chance to be tagged using secondary vertex and/or displaced vertex information

pre-EPS results ttbar cross-section from semi-lepton ttbar decay with 35 pb^{-1}

New results shown at EPS for ttbar cross-section from di-leptons with 0.7 pb^{-1}

ttbar cross-section measurement

LH discrimant example



Semi-leptonic analysis used template fit to a Likelihood discriminant

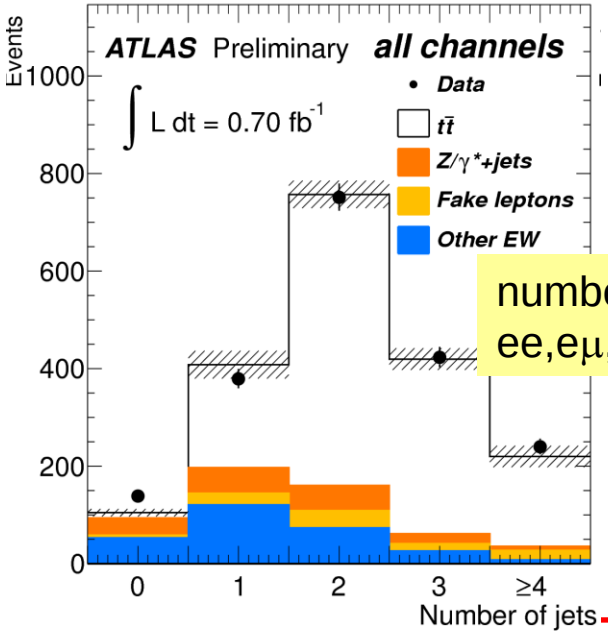
Exactly 1 lepton (e or μ) with p_T> 20 GeV

E_T^{miss} > 20 GeV, $E_T^{miss}+m_T(W)$ > 60 GeV (μ)

E_T^{miss} > 35 GeV, $m_T(W)$> 25 GeV (e)

At least 3 jets with p_T> 25 GeV and |η|<2.5

Systematics for both analysis dominated by jet energy scale & resolution, and b-tagging efficiency



number of jets in ee,eμ,μμ w/o b-tag

Di-leptonic used cut-and-count analysis

with and without b-tagging

Exactly 2 oppositely charged leptons

with p_T> 20 GeV (μ), E_T>25 GeV (e)

Dilepton mass m_{ll}>15 GeV

E_T^{miss}> 60 (40) GeV and $|m_{ll}-m_Z|$>10 GeV (ee, μμ channel)

H_T(sum of p_T of jets and leptons) > 130 (140) GeV (eμ channel)

At least 2 jets with p_T> 25 GeV and |η|<2.5

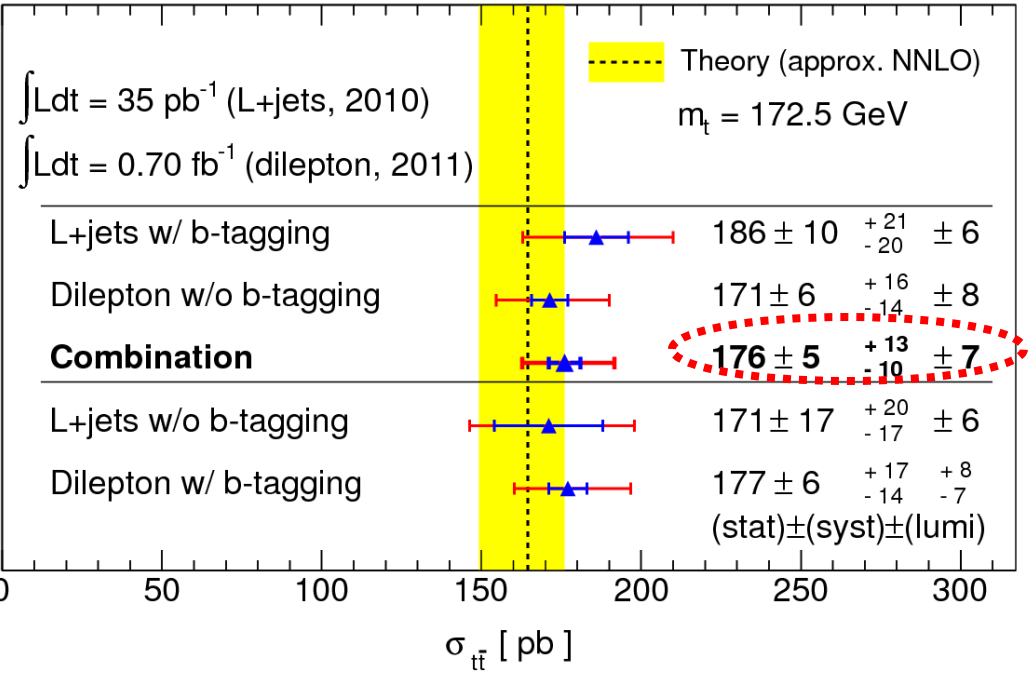
ttbar cross-section measurement

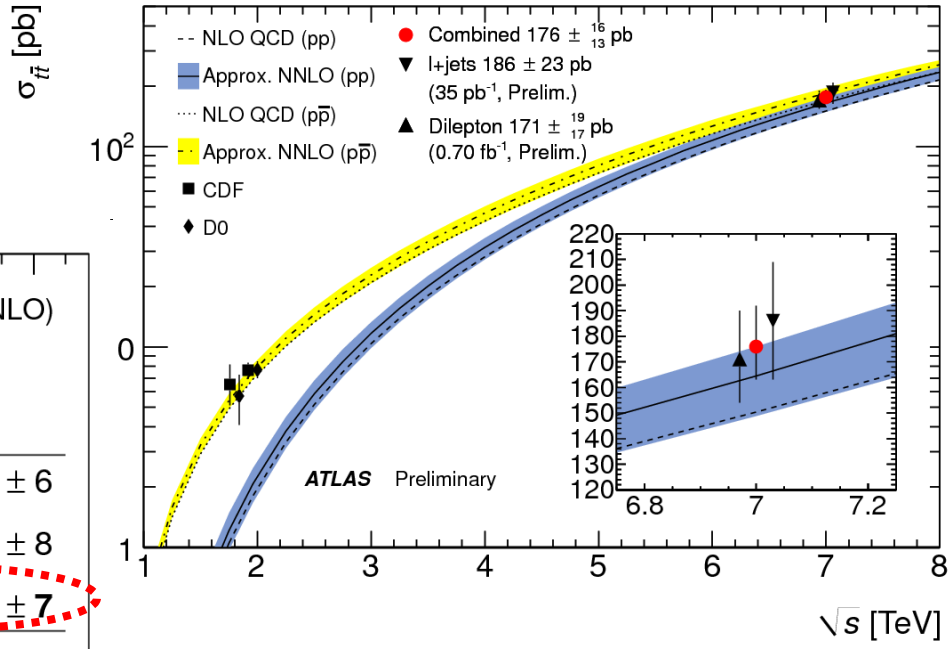
Cross section measured in ATLAS by combining:

results semi-leptonic channel with 35 pb^{-1}

resuts di-lepton channel with 0.70 fb^{-1}

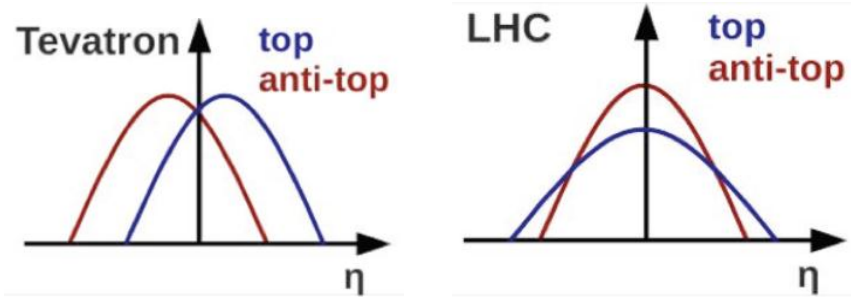
Results consistent with theoretical QCD predictions and with CMS results



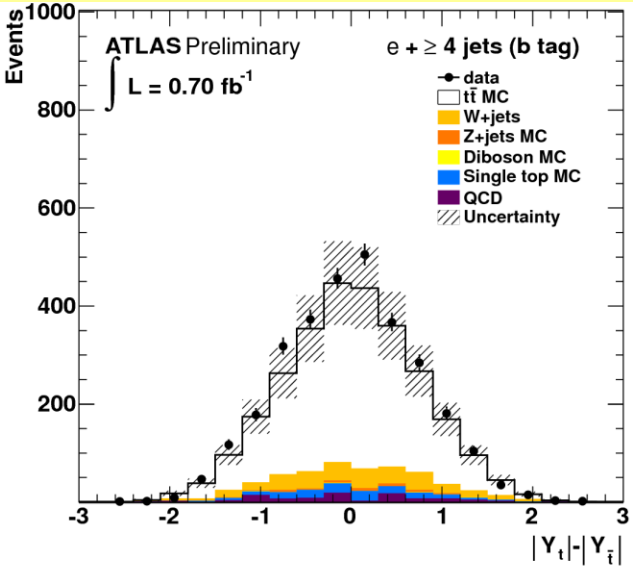


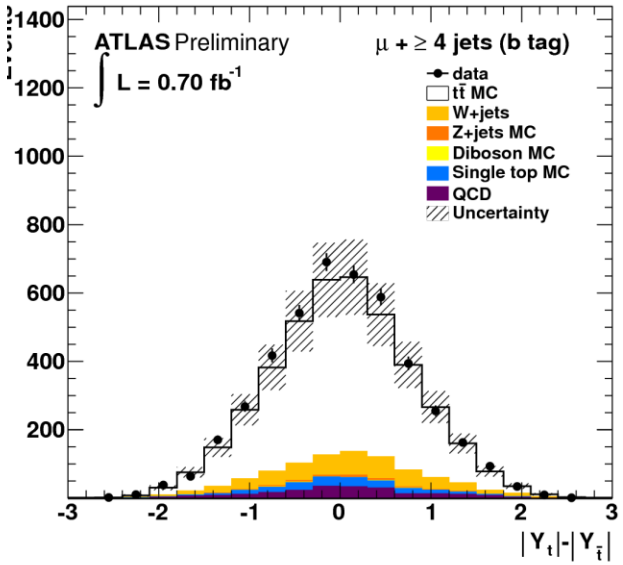
ttbar charge assymetry

At LHC, ttbar mainly produced via gg fusion which is symmetric still a small asymmetry is predicted from qqbar initial state



Results: difference in rapidity between reconstructed top and anti-top





$$A_C = \frac{N(\Delta|Y| > 0) - N(\Delta|Y| < 0)}{N(\Delta|Y| > 0) + N(\Delta|Y| < 0)},$$

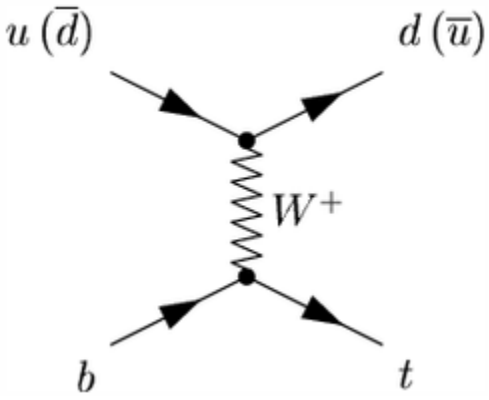
Main systematics from Jet Energy Scale, Jet Energy Resolution, ttbar modelling and top mass

	μ channel	e channel	combined	MC@NLO
A_C	-0.028±0.019(stat) ±0.022(syst)	-0.009±0.023(stat)±0.032(syst)	-0.023±0.015(stat)±0.021(syst)	0.005±0.001(stat)

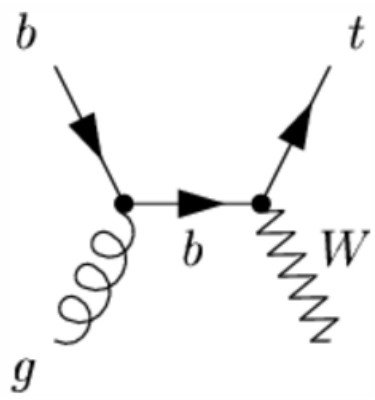
No significant hint of Beyond Standard Model assymetry...

Single top production

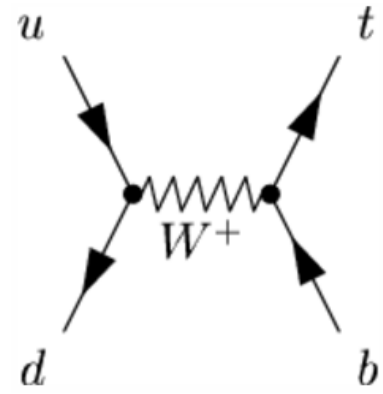
t-channel production



Wt associated production



s-channel production



Cross sections @ 7 TeV	
t-channel	$64.6\ ^{+3.2}_{-2.6}$ pb
Wt	15.7 ± 1.3 pb
s channel	4.6 ± 0.3 pb

Motivation of single top measurements:

Test of standard model predictions

- Cross section $\propto |V_{tb}|^2$
- Test of the unitarity of the CKM Matrix
- Test of the b-quark structure function

Probe and preparation for searches for new physics

- charged heavy Bosons W‘, H+ etc.

Wt process not accessible at the Tevatron

Single top: t-channel production

t-channel search with top decaying leptonically

Selection criteria:

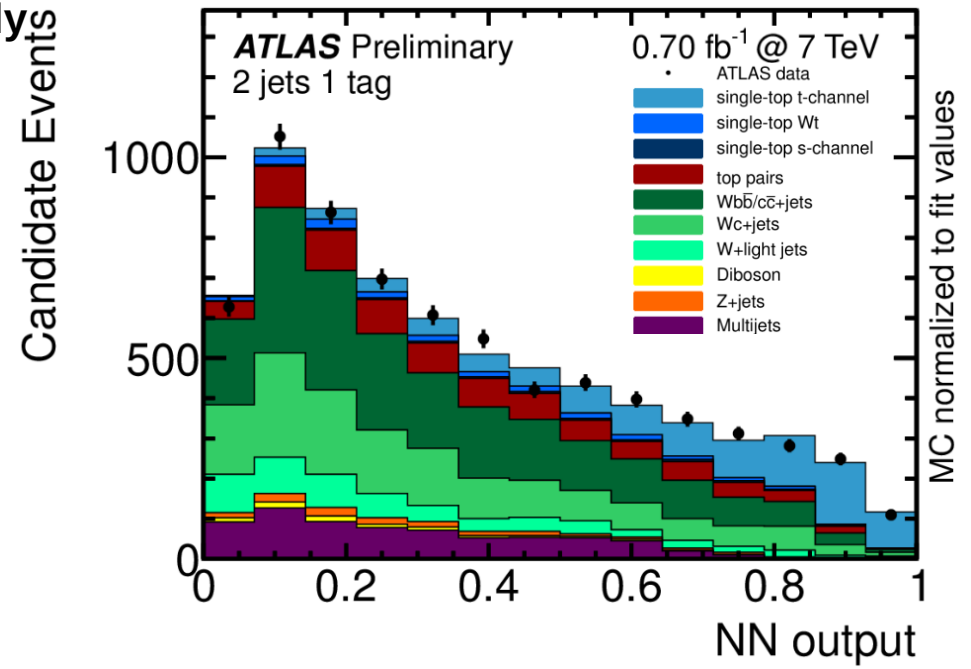
Lepton selection (e/μ):

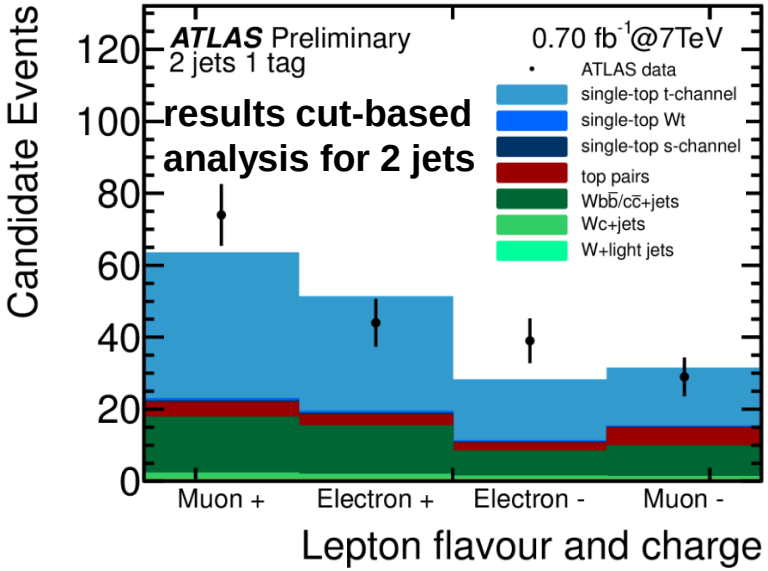
- p_T > 25 GeV and |η|< 2.5, relative Isolation

Jets

- jet p_T > 30 GeV and jet |η| < 4.5
- Exactly one jet
- One secondary vertex tag
- **Neural network analysis**: 2 jets
- **Cut based analysis**: 2 & 3 jets

Missing transverse energy E_T^{miss}> 25 GeV





t-channel results:

- **Using a neural network $\sigma_t = 107^{+37}_{-31}$ pb**
- **Cut based approach $\sigma_t = 90^{+32}_{-22}$ pb**

Wt production

W and top decaying leptonically

Selection criteria:

Lepton selection:

- p_T > 25 GeV and $|\eta|$< 2.5, relative Isolation
- **Exactly two leptons** (ee / $\mu\mu$ / em)

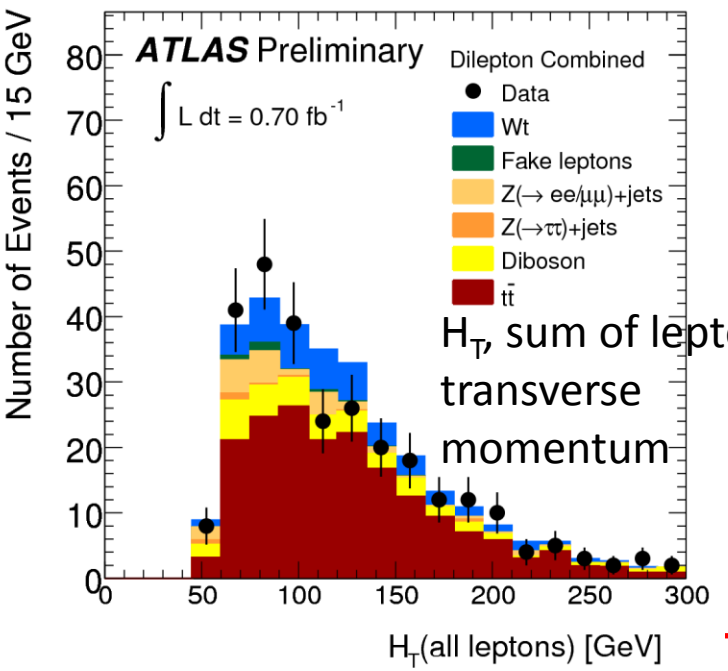
Jets

- jet p_T > 30 GeV and jet $|\eta|$ < 4.5
- Exactly one jet

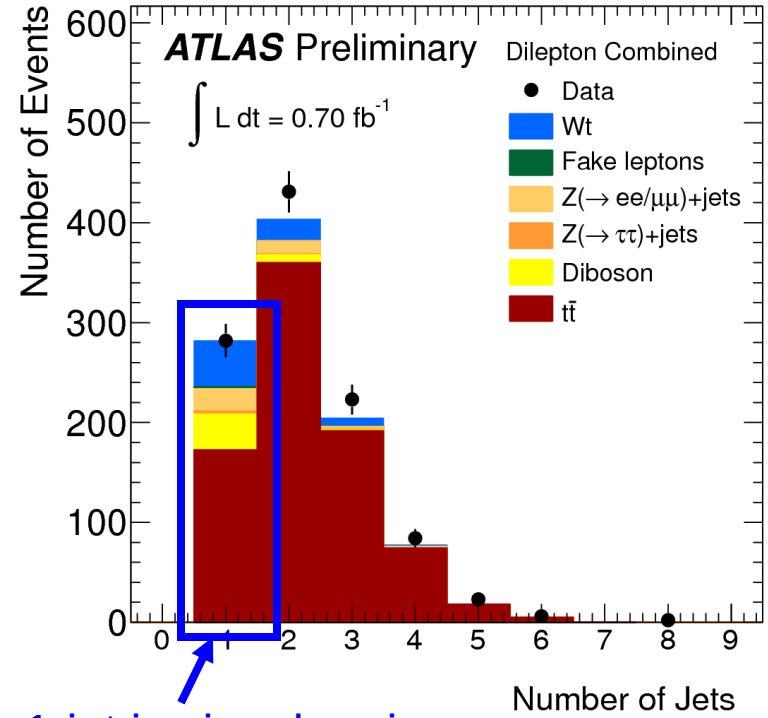
Missing transverse energy E_T^{miss}> 50 GeV

Z-mass veto for ee/$\mu\mu$ |m(ll)-m(Z)| > 10 GeV

$Z\rightarrow\tau\tau$ veto $\Delta\phi(l_1, E_T^{miss}) + \Delta\phi(l_1, E_T^{miss})$ > 2.5



H_T, sum of lepton transverse momentum



1-jet is signal region

>1 jet used as background control region

Wt-channel results, cut based approach

$\sigma_{Wt} = 14.4^{+5.3}_{-5.1}$ (stat.)$^{+9.7}_{-9.4}$ pb

Upper limit: 39pb @ 95% C.L.

Higgs in ATLAS

(Peter Higgs, while thinking how this picture will be used for ATLAS talks...)

The Higgs mechanism

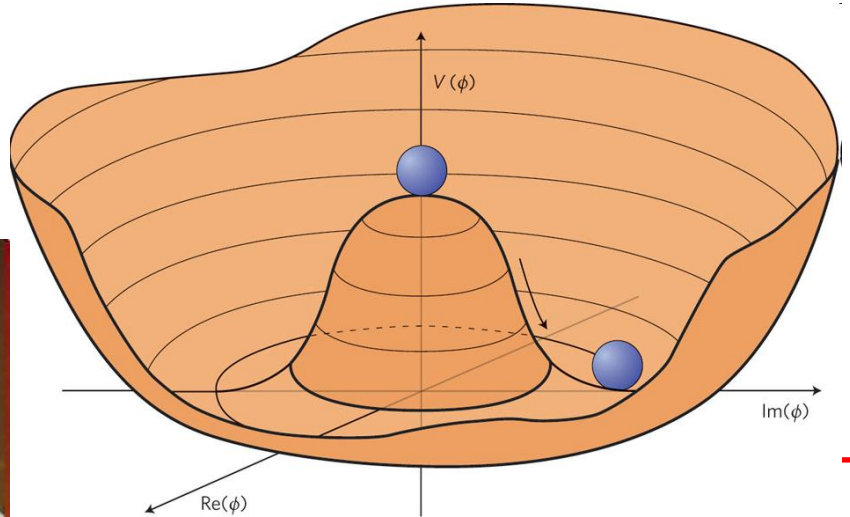
The Standard Model (SM) Higgs Mechanism:

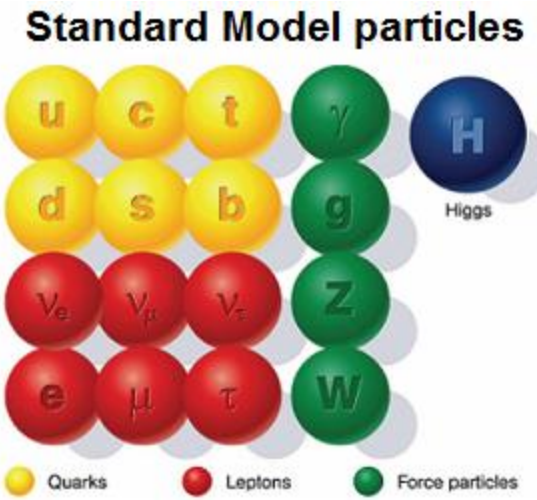
$$L = (D_\mu \phi)^\dagger D^\mu \phi + \mu^2 \phi^\dagger \phi - \lambda (\phi^\dagger \phi)^2$$

Higgs doublet: $\phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$

- Assumes one complex doublet of scalar fields
- Generates three Goldstone bosons leading to the fields describing massive W^+,W^-, Z bosons and massless γ
- Last component of the doublet generates the Higgs boson
- Higgs boson couples to fermions by Yukawa couplings, determining their masses
- Mass of the Higgs, m_H, is a free parameter

Understanding of electroweak symmetry breaking is a major goal of the LHC physics program: search for the Standard Model Higgs





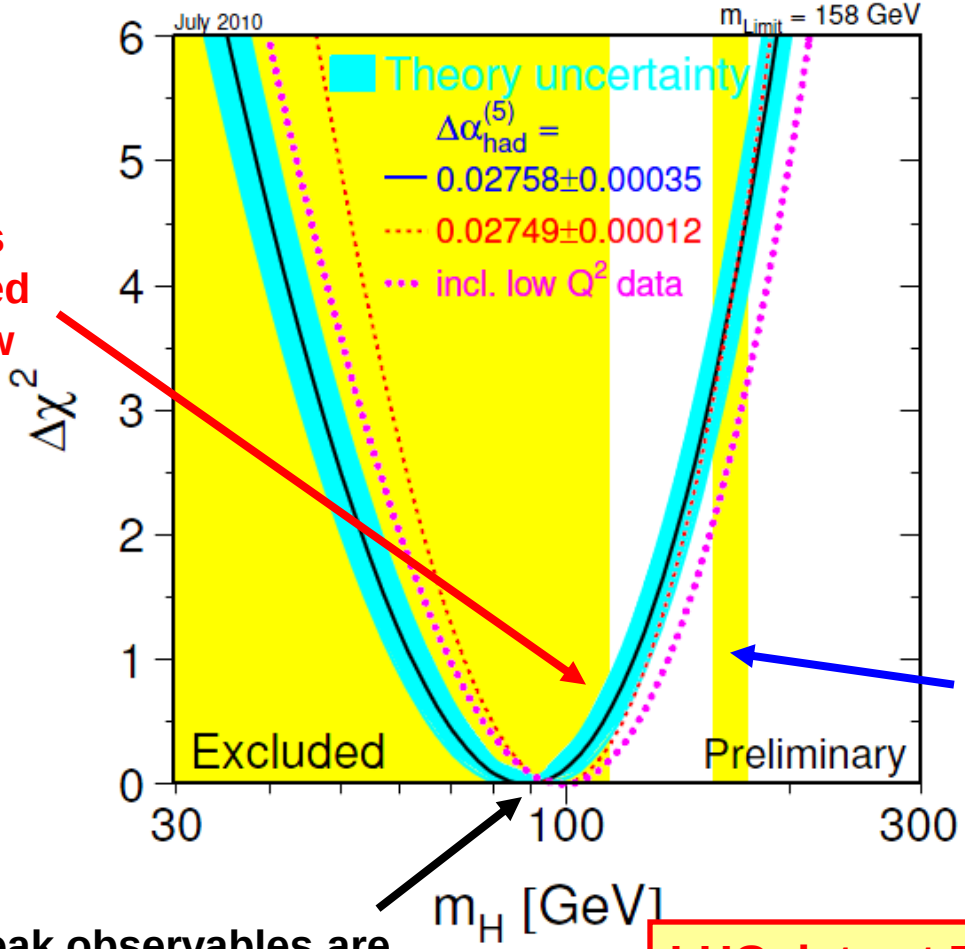
we've found all but one...

Higgs mass

Limits on Higgs mass prior to LHC (95% Confidence Level)

Perturbativity and non-triviality require SM Higgs boson to be lighter than 700 GeV

Combined results from LEP excluded mass range below 114.4 GeV



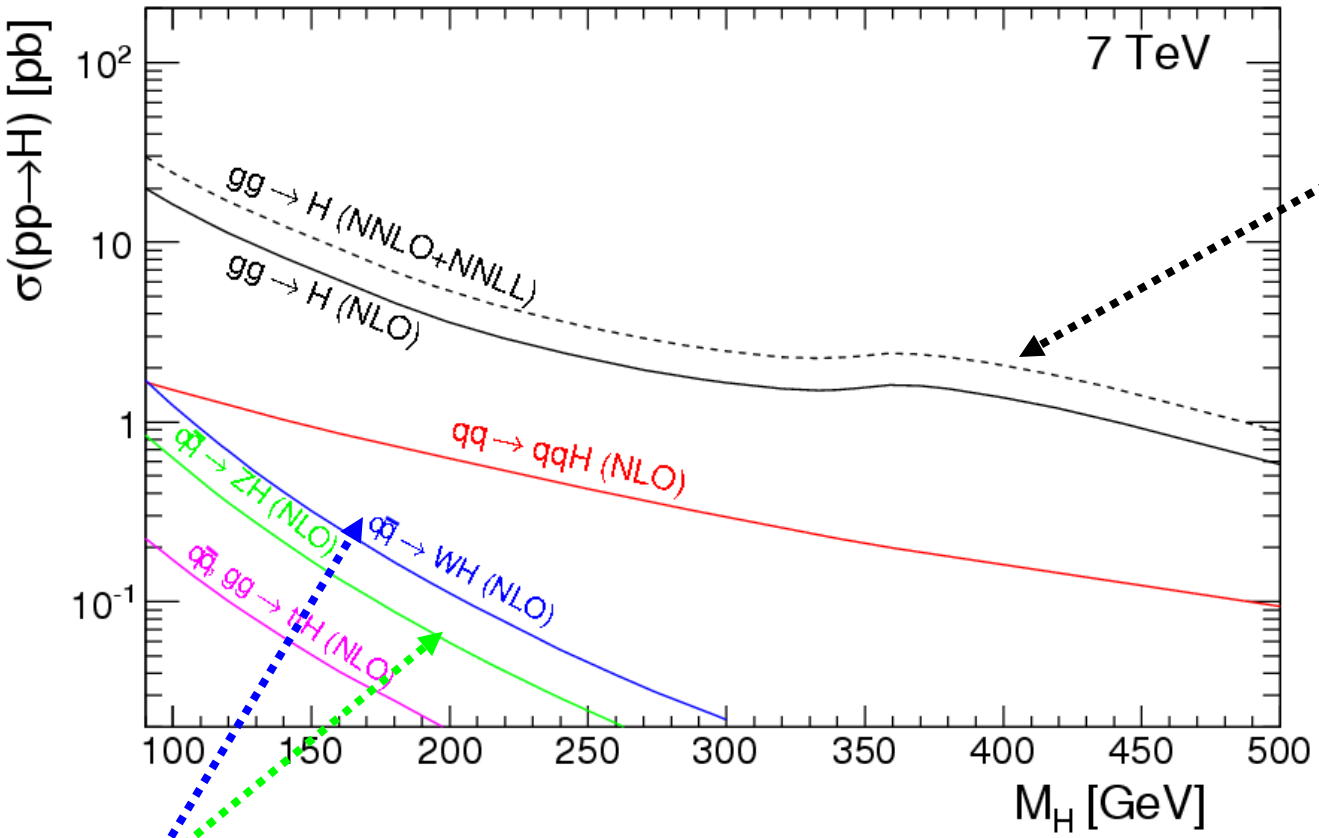
Combined results from Tevatron excluded m_H in range of 158–173 GeV

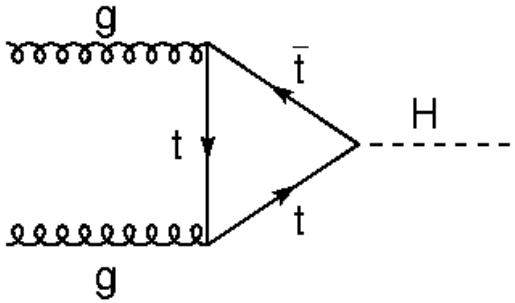
Electroweak observables are sensitive to m_H through loop diagrams, EW fit: $m_H=89^{+35}_{-26}$ GeV

LHC data at 7 TeV collision energy allows ATLAS to look for Higgs over a large range of masses...

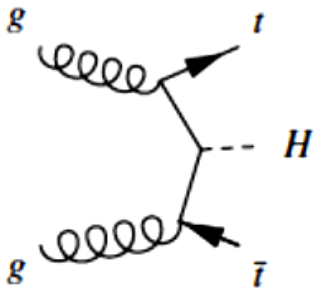
Higgs production at LHC

Higgs at LHC dominantly produced through gluon-gluon fusion (loop-diagrams)

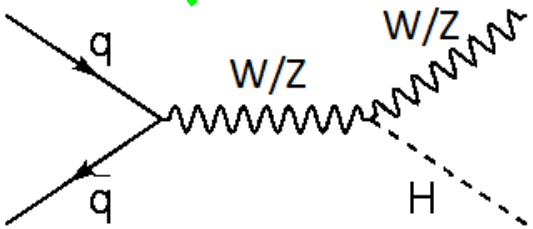




Theory uncertainty gg->H cross-section ±(15-20)%

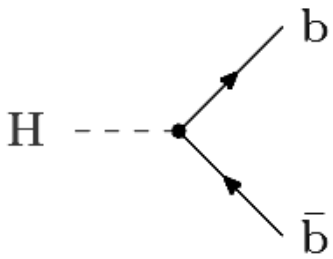


low σ for ttH not yet considered

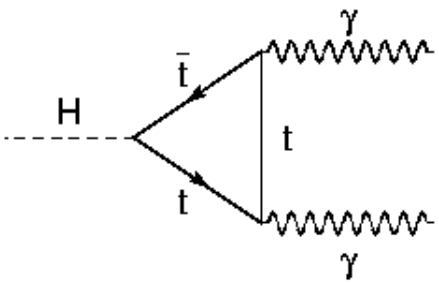


H+W/Z production: much lower cross-section, but considered for H->bb channel as leptonic decay of W/Z reduces QCD background

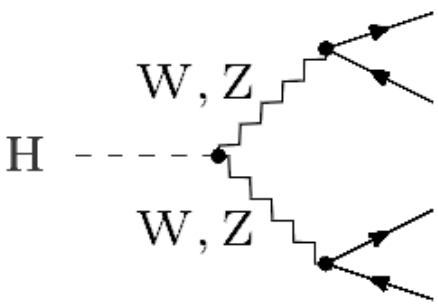
Higgs decay



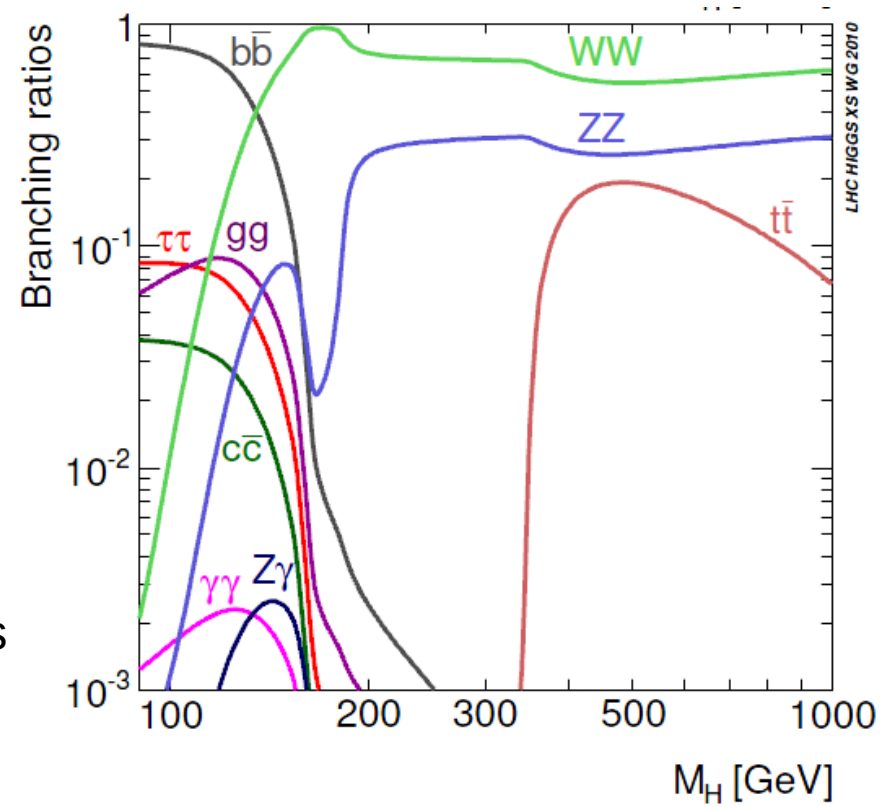
Higgs to b-quarks:
Low mass Higgs
large QCD background,
studied for H+Z/Wproduction
(not discussed today)



Higgs to photons:
Low mass Higgs
Irreducible di-photon
background



Higgs to WW or ZZ:
Medium/High mass Higgs
Leptonic modes provide
more clean signatures
Low cross-section



Higgs analysis in ATLAS

New ATLAS results presented at EPS conference for the following channels:

Channel		btag (veto)	Jets	MET (GeV)	Shape	Mass Range (GeV/c^2)	Main backgrounds
$\gamma\gamma$					M_{gg}	110-150	$\gamma\gamma$ (from sidebands)
WH		✓	2		M_{bb}	110-130	Top (3j - high M_{bb}) and W+jets (low M_{bb})
ZH		✓	2		M_{bb}	110-130	Z+jets (low M_{bb})
WW ($l\nu l\nu$)	0-jet		0	>30		110-240	WW (control region M_{ll})
	1-jet	veto	1	>30		110-240	Top (from reverse btag) and WW (M_{ll} CR)
WW ($l\nu qq$)	0-jet		0	>30	M_{WW}	200-600	W+jets (sidebands)
	1-jet	veto	1	>30	M_{WW}	200-600	W+jets (sidebands)
ZZ ($ll\nu\nu$)		✓		>30	M_T	200-600	VV(from MC) and top (MC and checks)
ZZ ($llqq$)		✓	2	<50	M_{llqq}	200-600	Z+jets (from MC) and top (from MC)
ZZ (4l)		IP			M_{4l}	110-600	ZZ (from MC), Z+jets (MC) and top (CR)

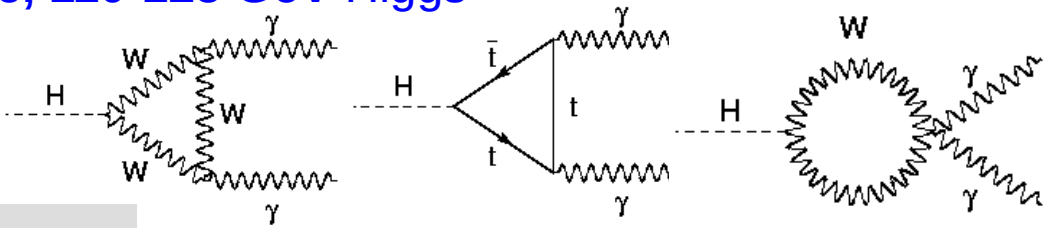
ATLAS Higgs searches with ~1 fb^{-1} of data cover a range of 110<m_H<600 GeV

Systematic uncertainty predominantly from Jet Energy Scale and b-tagging efficiency

Higgs search results expressed in terms of expected SM Higgs cross-section that can be excluded with 95% Confidence Level

Higgs to photons

Dominant channel in the low m_H range, 110-125 GeV Higgs decay to photons via loops:

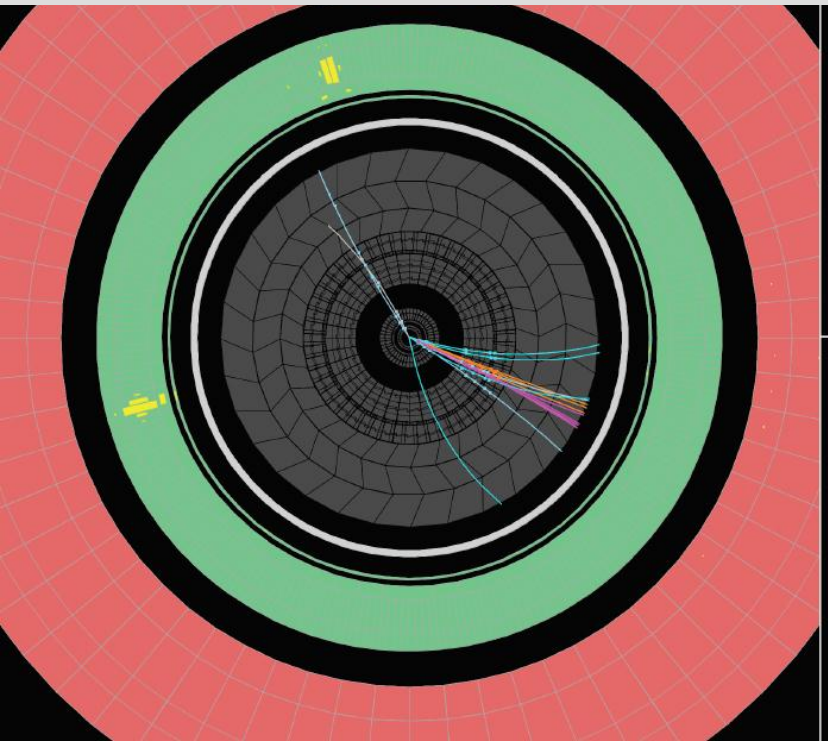


Selection criteria:

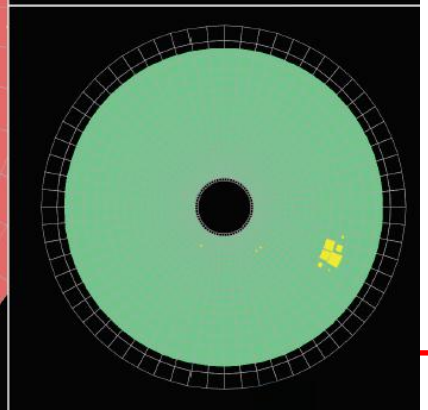
Two tightly identified and isolated photons with p_{T1}>40 GeV and p_{T2}>25 GeV

$|\eta_{1,2}|<1.37$ and $1.52<|\eta_{1,2}|<2.37$

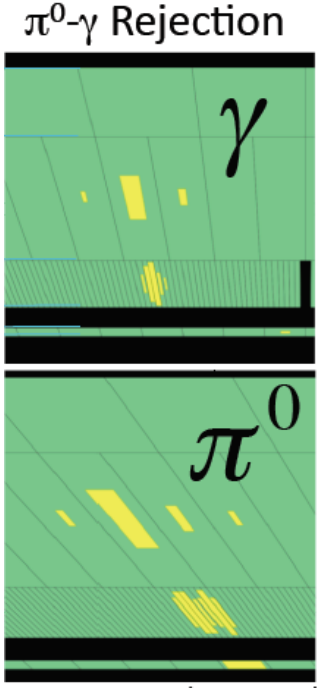
(avoid barrel/endcap transition)



Example of selected event



Photon ID based both on the lateral and longitudinal segmentation of the calorimeter



Higgs to photons

Electron scale calibration from data using Z→ee

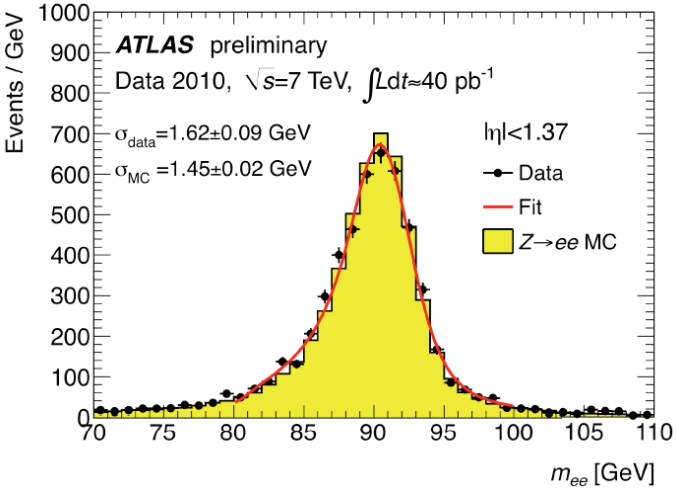
±14% uncertainty on $m_{\gamma\gamma}$ resolution, main contributions:

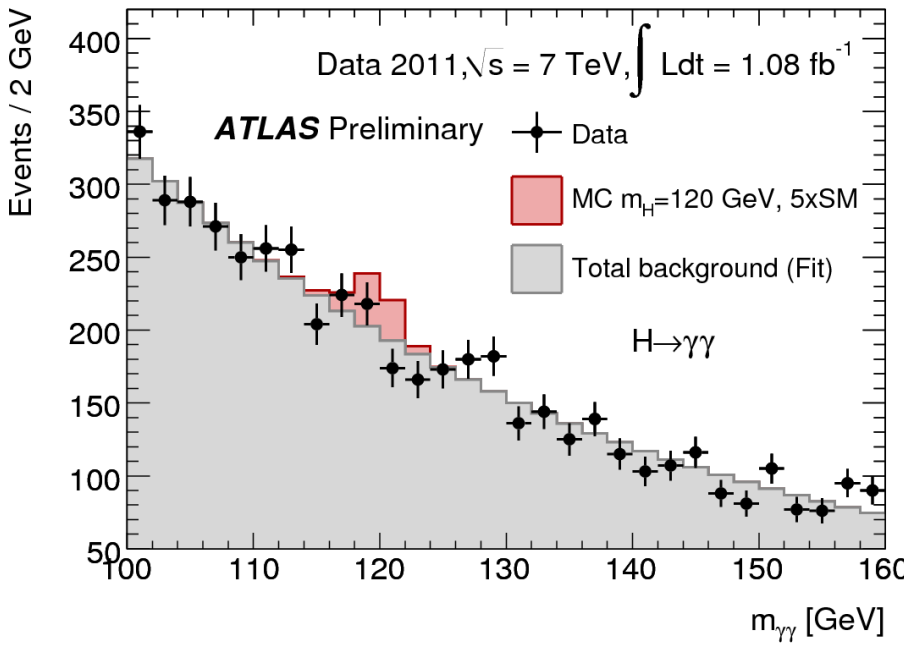
Constant term of the cluster energy resolution: ±12%

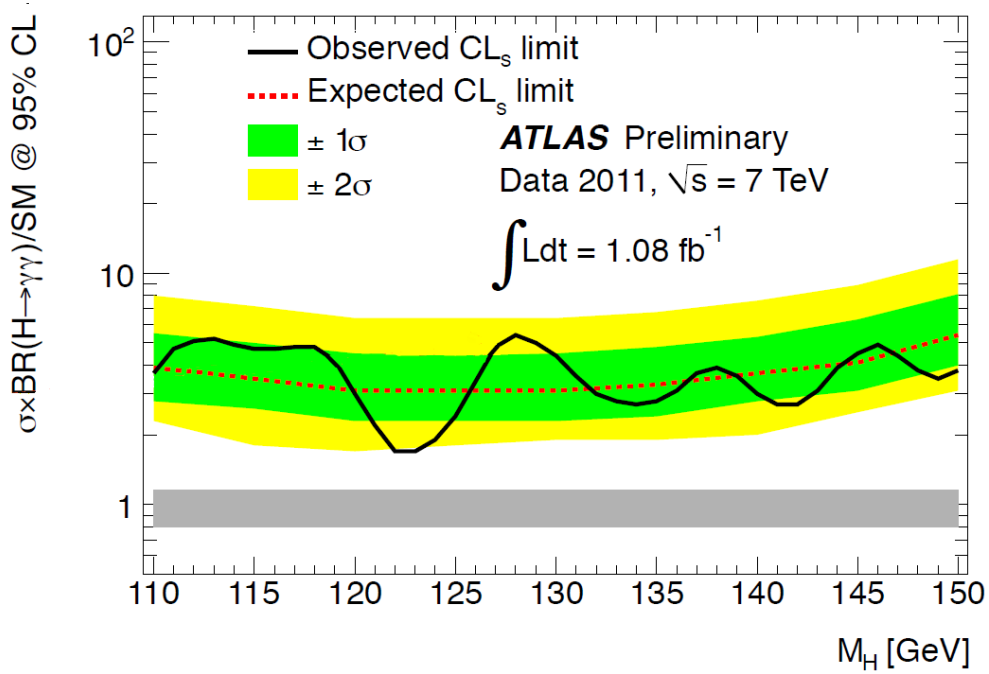
Electron to photon extrapolation of energy scale: ±6%

±12% uncertainty on the signal yield

mainly from reconstruction and ID efficiency







Dominant background from real diphoton events

Use a simple exponential model for the background

Results currently exclude ~3 x NNLO SM cross section (95% C.L)

H ➜ WW ➜ lνlν

Combines the large BR for H➜WW with a clean,leptonic final state

Selection criteria:

Exactly two opposite sign leptons (e/μ):

leading lepton p_T>25 GeV

sub-leading μ(e) p_T>15 (20) GeV

Same flavor leptons:

require m_{ll}>15 GeV and $|m_{ll} - m_Z|$>15 GeV

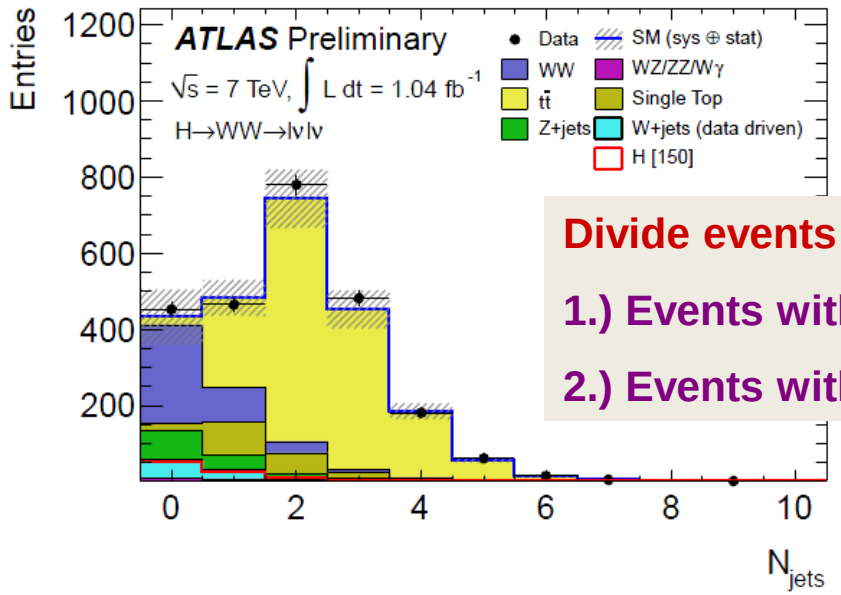
$E_T^{miss}{}_{,rel}$> 40 GeV

For eμ channel:

require m_{ll}>10 GeV

$E_T^{miss}{}_{,rel}$>25 GeV (eμ)

$$E_{\mathrm{T,rel}}^{\mathrm{miss}} = \begin{cases} E_{\mathrm{T}}^{\mathrm{miss}} & \text{if } \Delta\phi \geq \pi/2 \\ E_{\mathrm{T}}^{\mathrm{miss}} \cdot \sin\Delta\phi & \text{if } \Delta\phi < \pi/2 \\ \Delta\phi = \min(\Delta\phi(E_{\mathrm{T}}^{\mathrm{miss}}, \ell),\ \Delta\phi(E_{\mathrm{T}}^{\mathrm{miss}}, j)) \end{cases}$$



Divide events in 2 categories (reduces ttbar background**)**

1.) Events with no jets with p_T> 25 GeV and |η|<4.5

2.) Events with exactly one jet (Apply b-tag veto)

H ➜ WW ➜ lνlν

No mass peak reconstruction due to missing energy from neutrino's but transverse mass m_T sensitive to m_H

$$m_{\mathrm{T}} = \sqrt{(E_{\mathrm{T}}^{\ell\ell} + E_{\mathrm{T}}^{\mathrm{miss}})^2 - (\mathbf{P}_{\mathrm{T}}^{\ell\ell} + \mathbf{P}_{\mathrm{T}}^{\mathrm{miss}})^2}$$

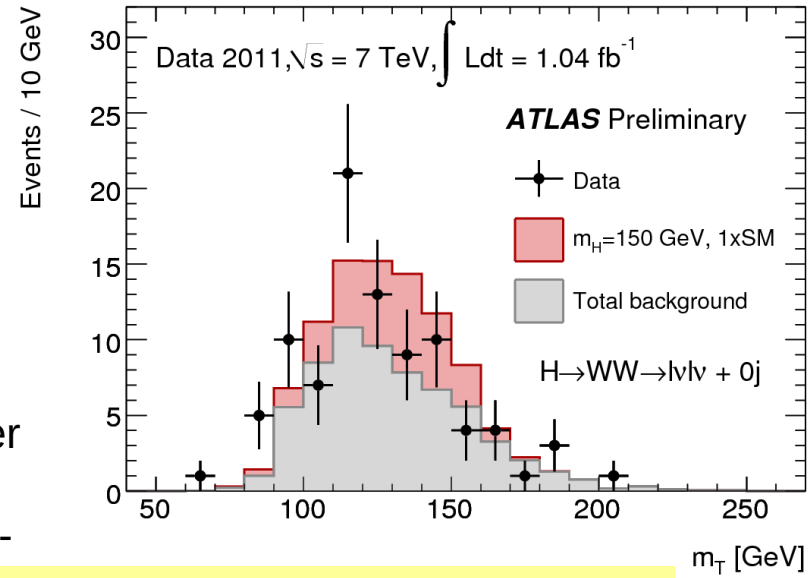
Two largest backgrounds, SM WW and top production, are normalized using dedicated control regions in data

W+jets background entirely determined from data, other (smaller) backgrounds are taken from Monte Carlo

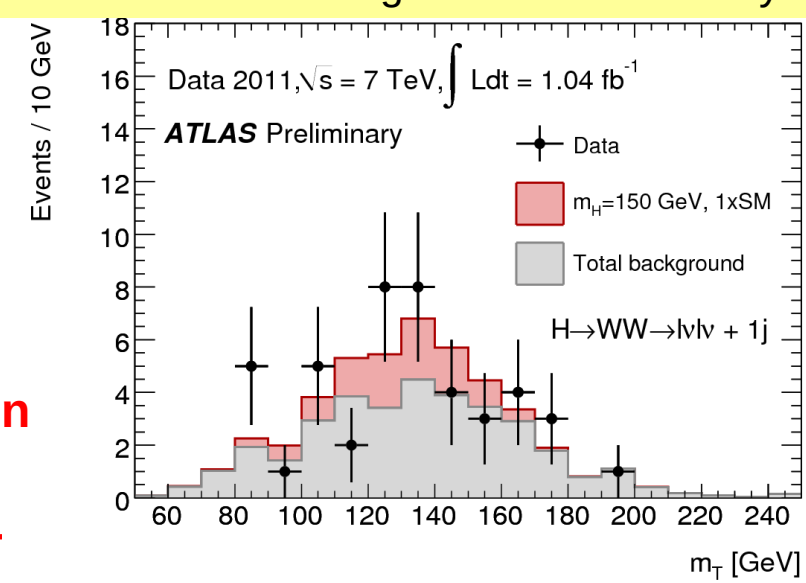
Scale factor applied to Z/γ+jets for potential E_T^{miss} miss-modeling

Control Region	Estimate	Obs
WW 0-jet	150 ± 30	153
WW 1-jet	109 ± 14	97
top 1-jet	130 ± 40	136

0-jet channel results: background dominated by WW

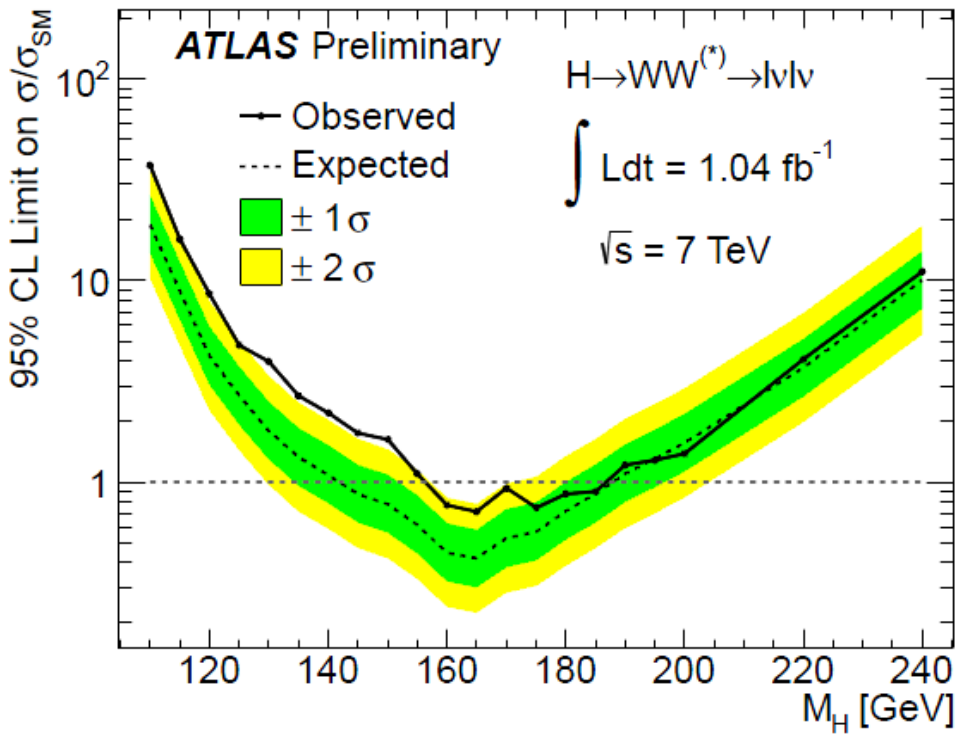


1-jet channel results: background dominated by ttbar



Some excess of events seen
more statistics needed...

H ➜ WW ➜ lνlν



Will come back to excess of events when discussing combination of Higgs analysis results

SM Higgs boson with 158 <m_H< 186 GeV is excluded at 95% CL
Excess of events (~2σ) in broad region 126 < m_H< 154 GeV

H ➜ WW ➜ lνqq

At large values of m_H, sensitive to the H→WW→lνqq

- ✓larger branching ratio then WW→lνlν
- ✓Higgs mass reconstructed from M(lνqq) by constraining m(lν) and m(qq) to the W-mass

Analysis performed for 240 < m_H < 600 GeV

Selection criteria:

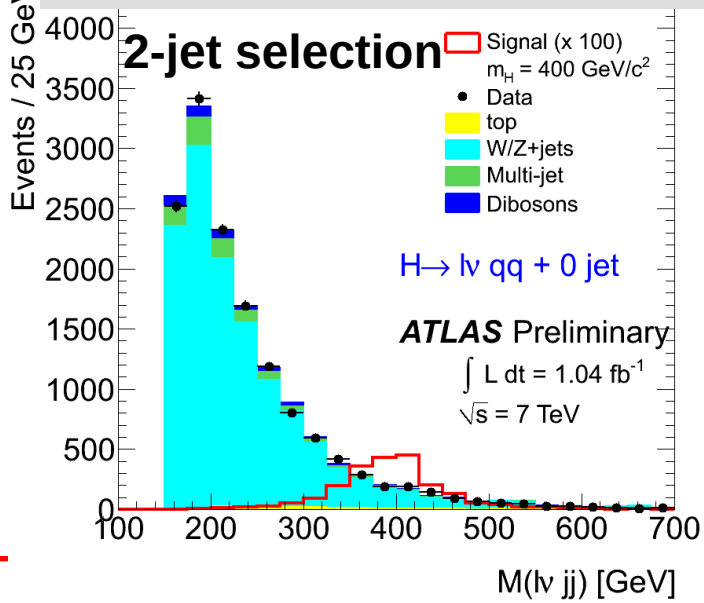
Exactly **one lepton (e/μ) with p_T>30 GeV**

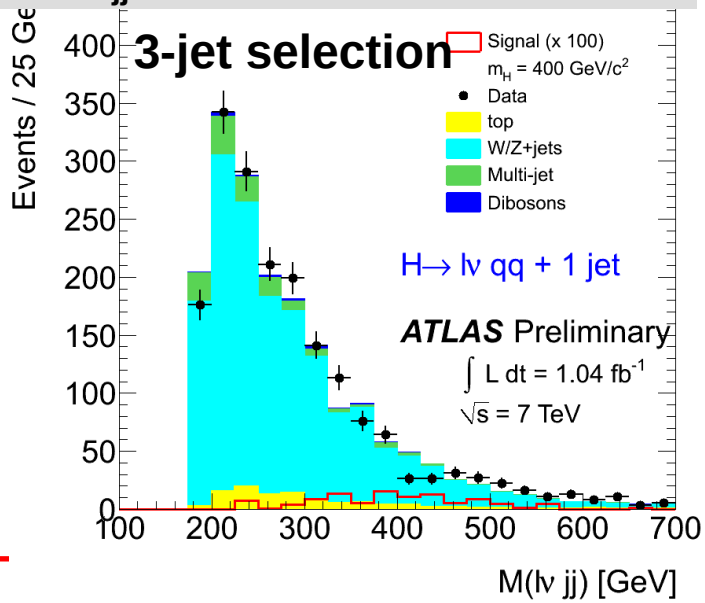
Require E_T^{miss}>30 GeV

Exactly two (H+0j) or exactly three jets (H+1j)

b-jet veto applied in the Higgs plus 1-jet channel

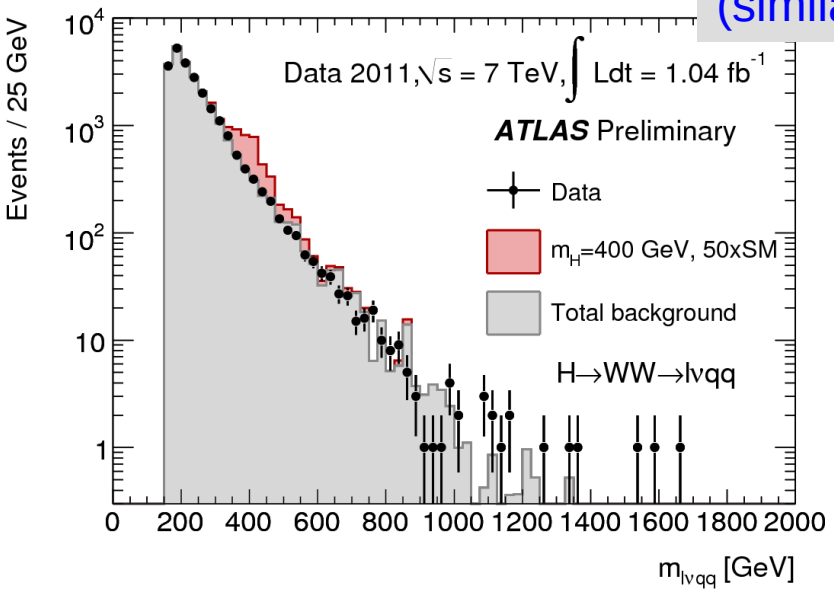
Require one pair of jets to have **71<m_{jj}< 91 GeV** (m_W constraint)

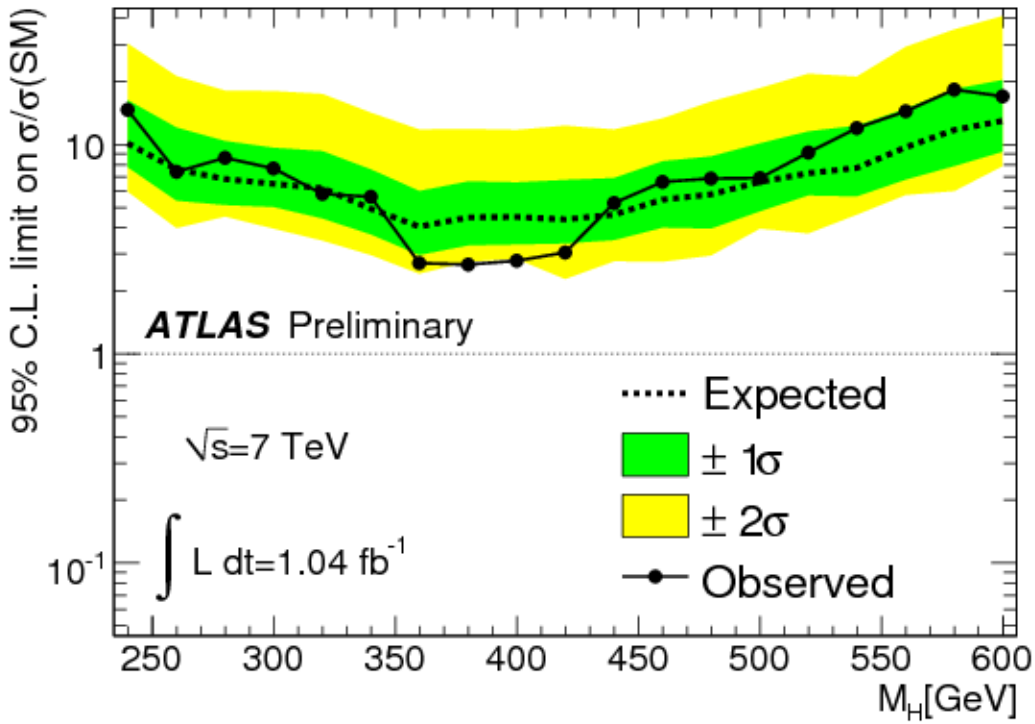




H ➜ WW ➜ lνqq

Smooth background mainly from *W*+jets process
Mass resolution is sufficient to directly fit the background normalization from data
(similar to the approach used in the *H*->γγ channel)





The upper limit at m_H=400 GeV is 2.5 times the SM cross section

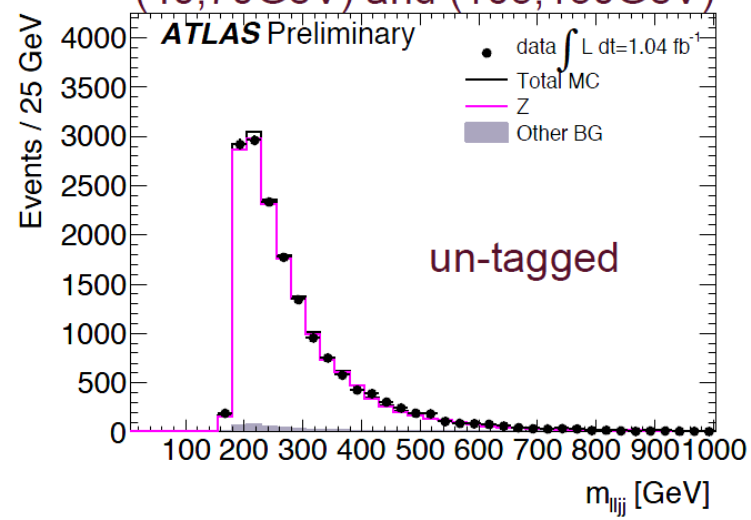
H ➜ ZZ➜ llqq

Signature: lepton pair + 2 jets
Main Background: Z+jets production
Search in 200 GeV≤m_H≤600 GeV region
Final discriminant: lljj invariant mass (m_{jj} constrained to m_Z)

Event Selection
Same-flavor opposite-sign pair of isolated leptons with p_T>20 GeV
Di-lepton mass: 76 GeV < m_{ll} < 106 GeV
3rd lepton veto
E_T^{miss}<50 GeV
At least 2 jets with p_T>25GeV and $|\eta|$<2.5
Di-jet mass: 70< m_{jj}<105 GeV
For "high-mass region" (m_H≥300GeV):
p_T(jets)>50 GeV
angle between leptons $\Delta\phi_{ll}<\pi/2$
angle between jets $\Delta\phi_{jj}<\pi/2$

Background estimation:
Normalize Z+jets using m_{jj} sidebands
uncertainty <10% for un-tagged
uncertainty ~20% for tagged

Side-bands of M_{jj}
(40,70GeV) and (105,150GeV)

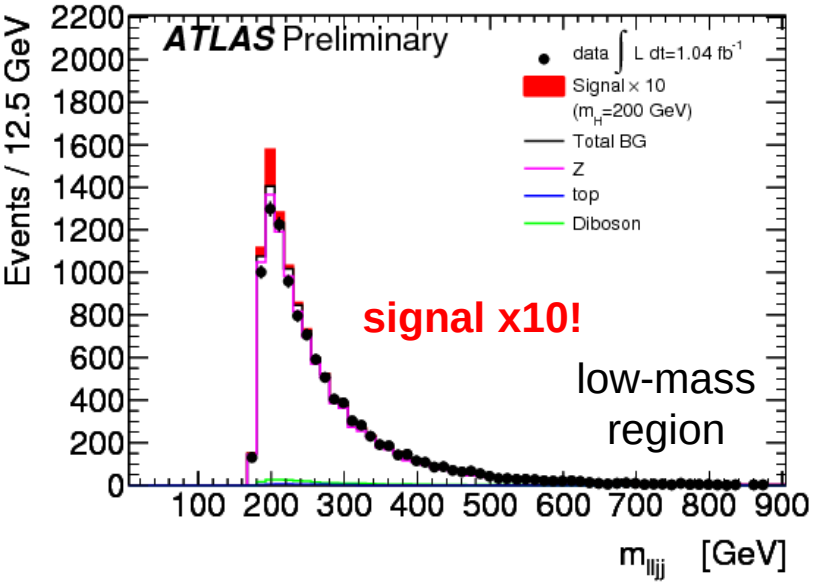


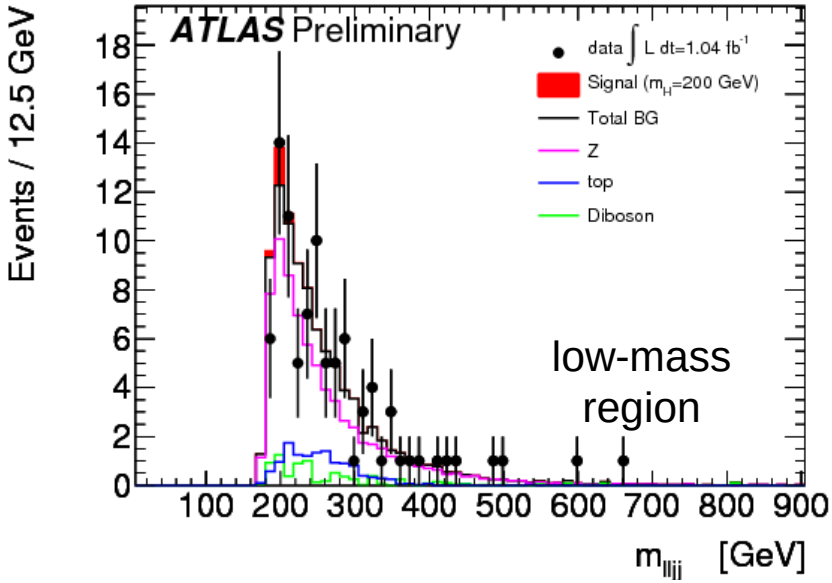
Verify top expectation from m_{ll} sidebands
uncertainty 10% from theory
Diboson backgrounds from MC:uncertainty ~10%
Data-Driven QCD background: small contributions

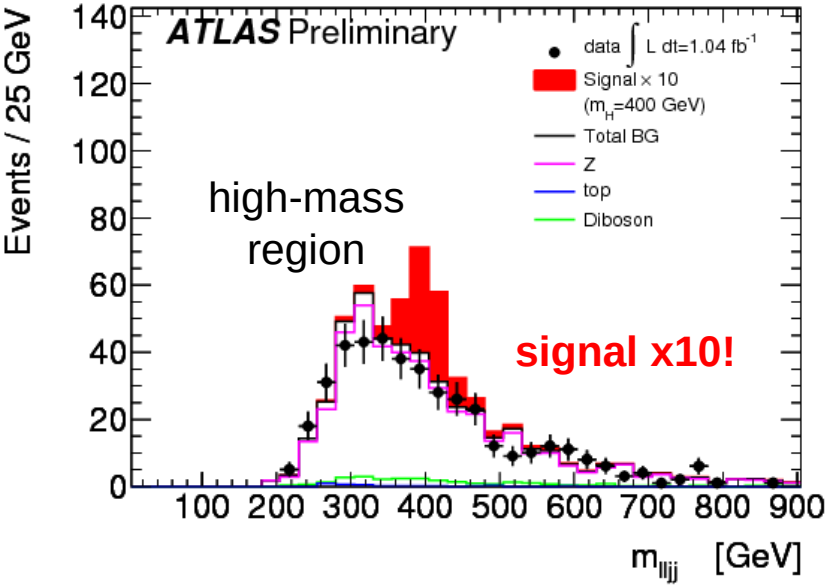
H ➜ ZZ➜ llqq

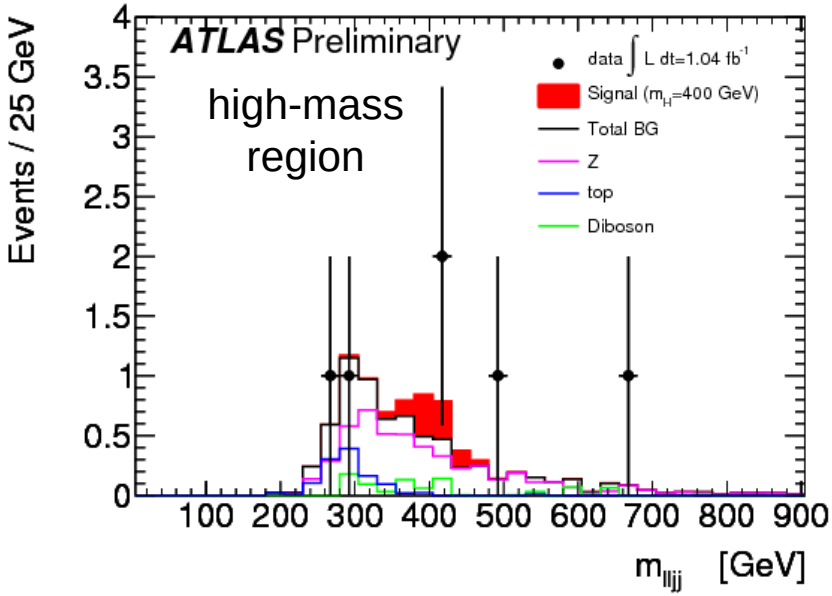
“un-tagged” (0/1 b-tags)

“tagged” (2 b-tags)

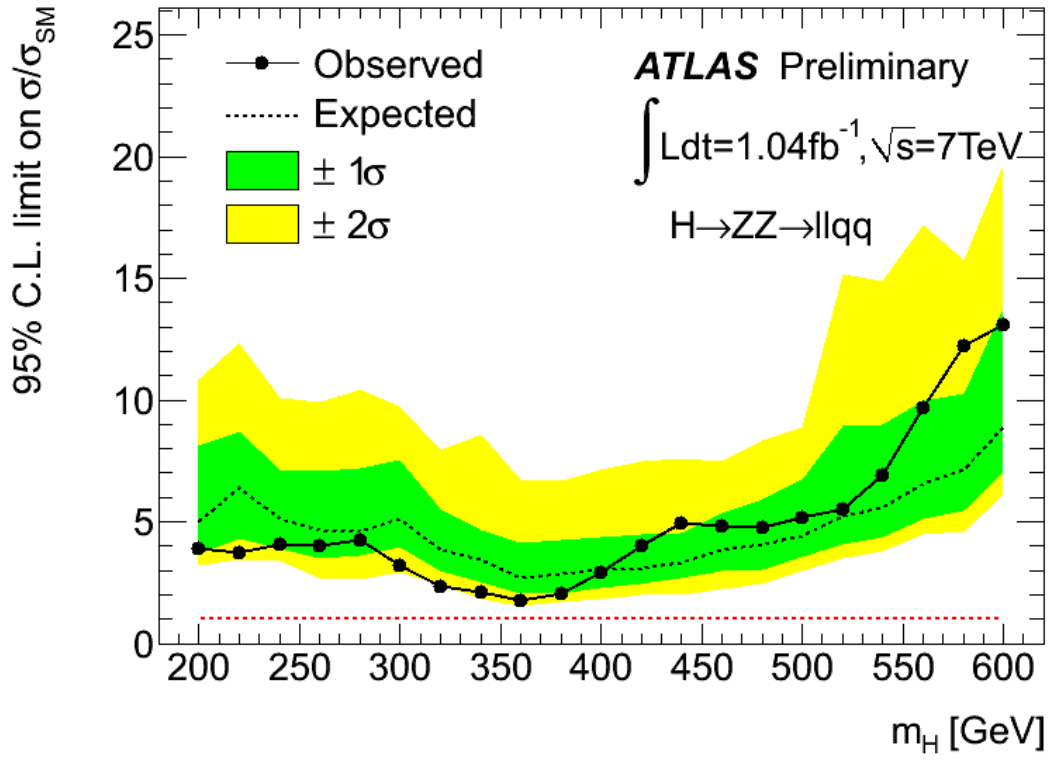








H ➜ ZZ➜ llqq



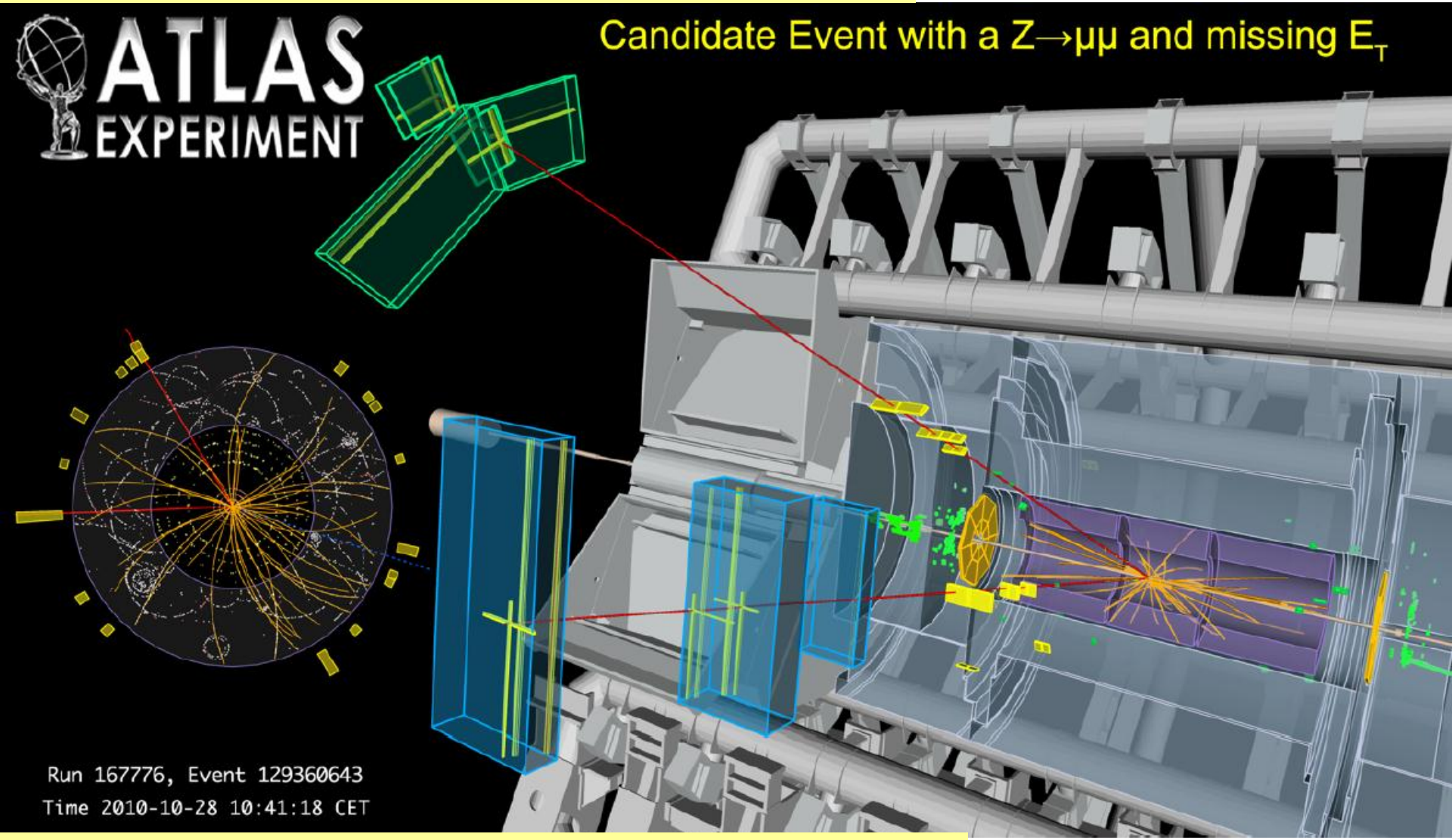
Exclusion limits for SM Higgs withs 95% Confidence level

Expected limit between 2.7 - 9 x SM cross section

Highest sensitivity at m_H=360 GeV where 1.7 x σ_{SM} is excluded

H ➜ ZZ➜ llvv

Signature : lepton pair + missing transverse energy



Main backgrounds: top and diboson production

H →ZZ→ llvv searches in 200 GeV≤m_H≤600 GeV region

H ➜ ZZ➜ llνν

Event Selection (separated in high/low mass regions, $m_H \geq 280$GeV):

Same-flavor opposite-sign pair of isolated leptons with p_T>20 GeV

3rd lepton veto, b-jet veto

E_T^{miss} > 66 GeV (m_H<280 GeV) or **E_T^{miss}> 82 GeV** (m_H>280 GeV)

Angle between E_T^{miss} and leading jet $\Delta\phi_{jet,MET}$>0.3

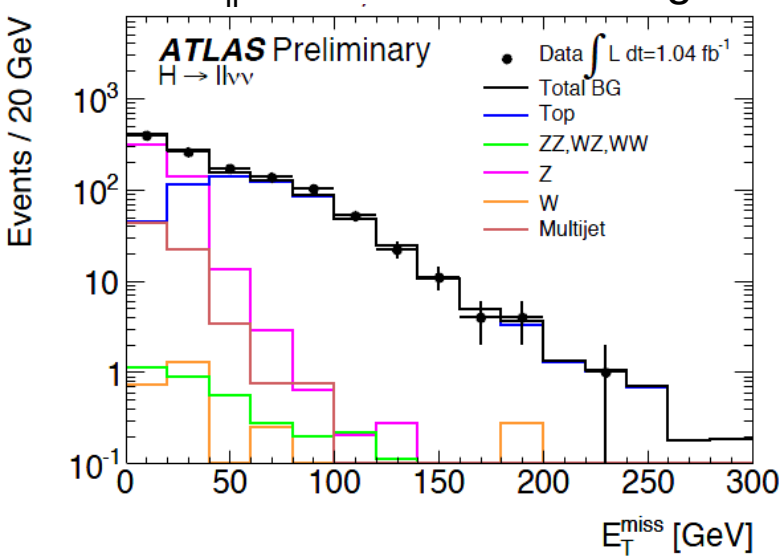
Opening angle between lepton $\Delta\phi_{ll}$ (correlated to Z-boost):

1.<$\Delta\phi_{ll}$<2.64 (m_H<280GeV) or **1.<$\Delta\phi_{ll}$<2.25** (m_H>280GeV)

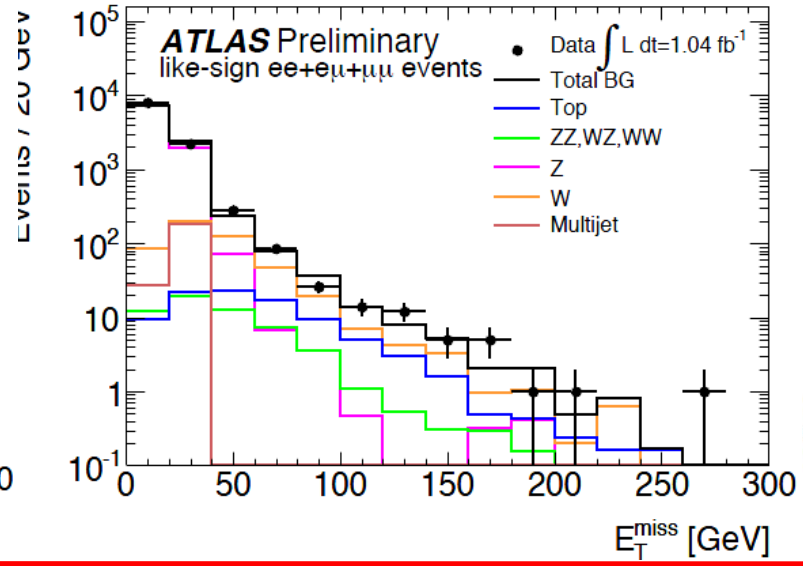
For "high-mass" also angle between reconstructed Z and **E_T^{miss}** $\Delta\phi_{jet,MET}$>1.

Verification of MC prediction of backgrounds:

m_{ll} sidebands with b-tags



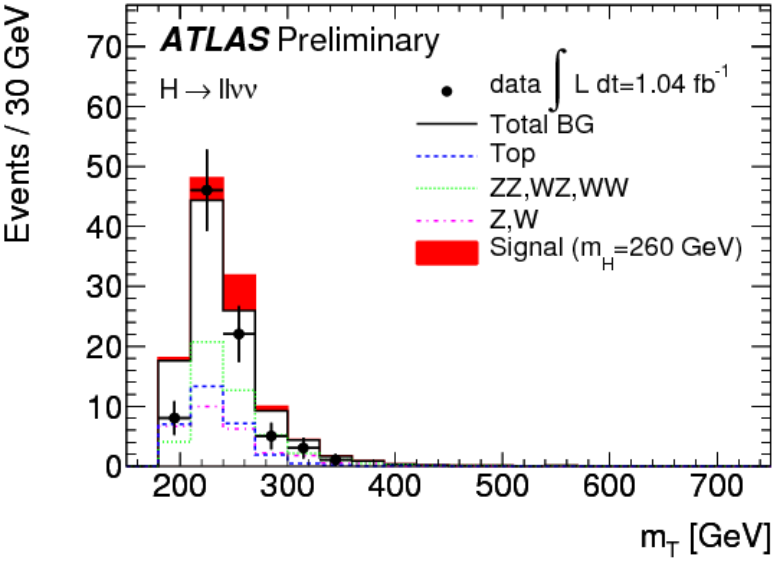
same-sign lepton pairs

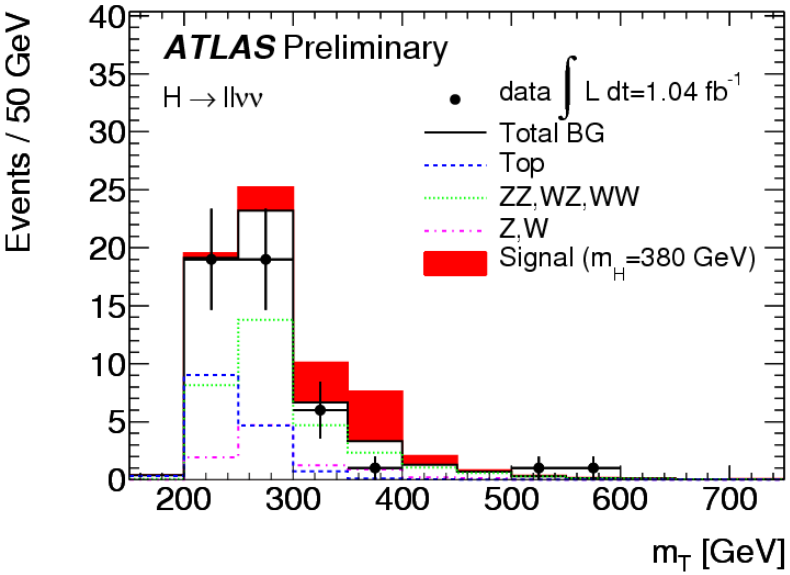


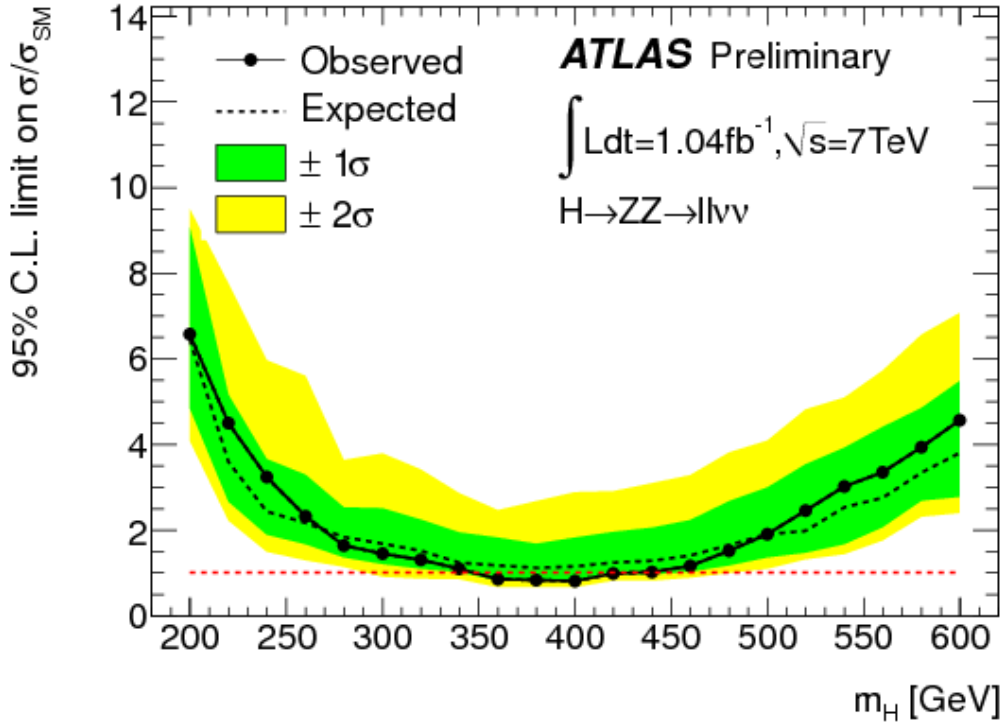
H ➜ ZZ➜ llνν

Final discriminant is transverse mass, m_T

$$m_T^2 \equiv \left[\sqrt{m_Z^2+|\vec{P}_T^{ll}|^2}+\sqrt{m_Z^2+|\vec{P}_T^{miss}|^2}\right]^2-\left[\vec{P}_T^{ll}+\vec{P}_T^{miss}\right]^2$$



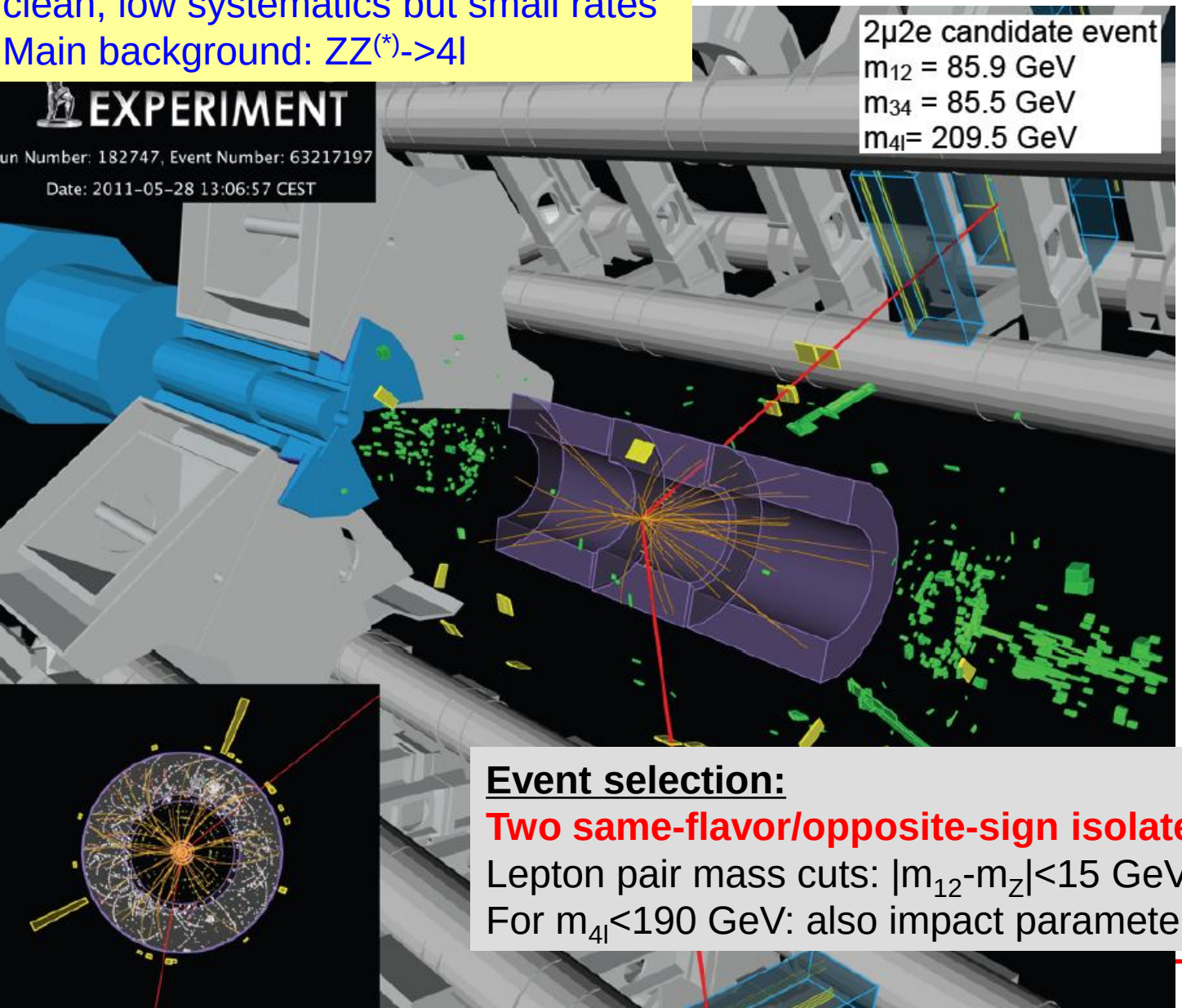




ATLAS results in this channel exclude SM Higgs boson with 360<m_H<420 GeV (95% C.L)

H ➜ ZZ➜ llll

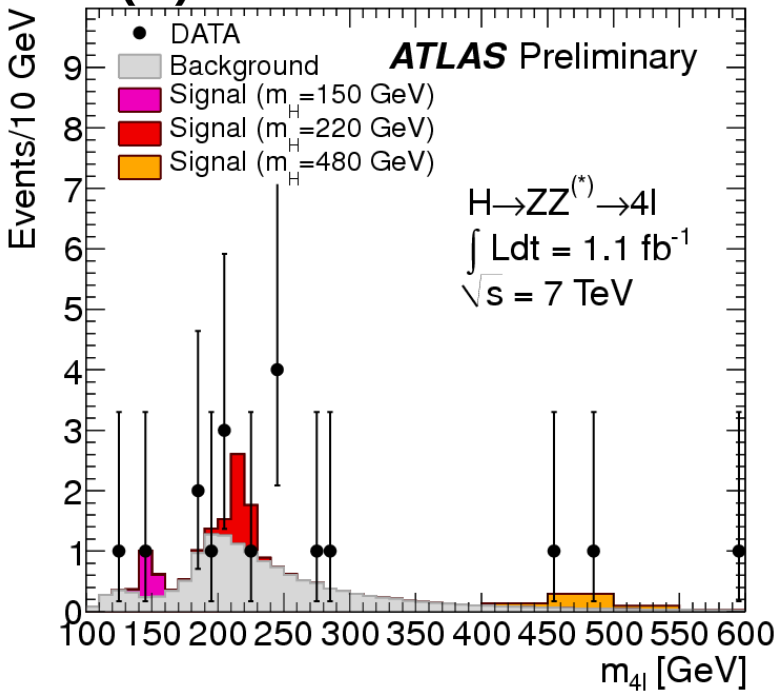
The "golden channel":
clean, low systematics but small rates
Main background: $ZZ^{(*)}$->4l

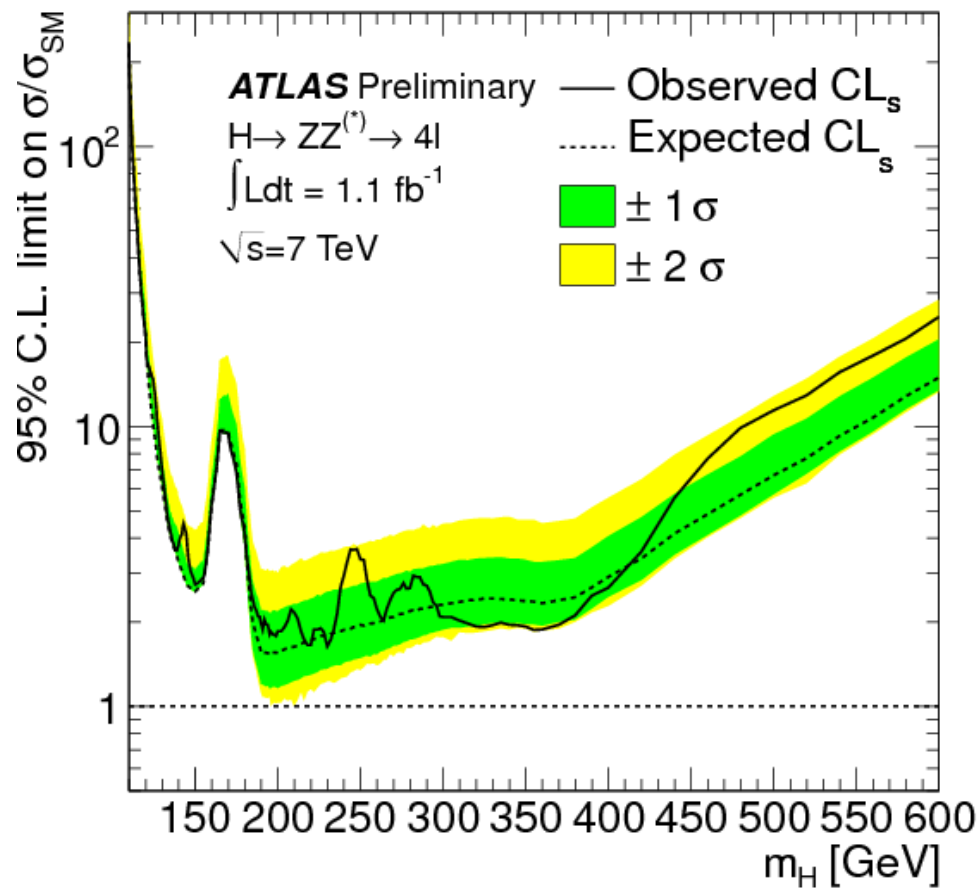


<u>Event selection:</u>
Two same-flavor/opposite-sign isolated lepton (e/μ) pairs
Lepton pair mass cuts: $|m_{12}-m_Z|<15$ GeV, m34<115 GeV
For $m_{4l}<190$ GeV: also impact parameter requirements

H ➜ ZZ➜ llll

m(4l) after selection:





Limits approaching SM Higgs cross-section, 1.8 x σ_{SM} at Higgs mass of 200 GeV
Slight excess of events at m_H~250 GeV

Higgs combined results: overview of systematics

Signal-related systematic uncertainties result from detector effects and are mostly correlated

Background-related systematic uncertainties are typically uncorrelated since most backgrounds are estimated from data in control regions

Relative uncertainties corresponding to overall effect on the per-event signal efficiency:

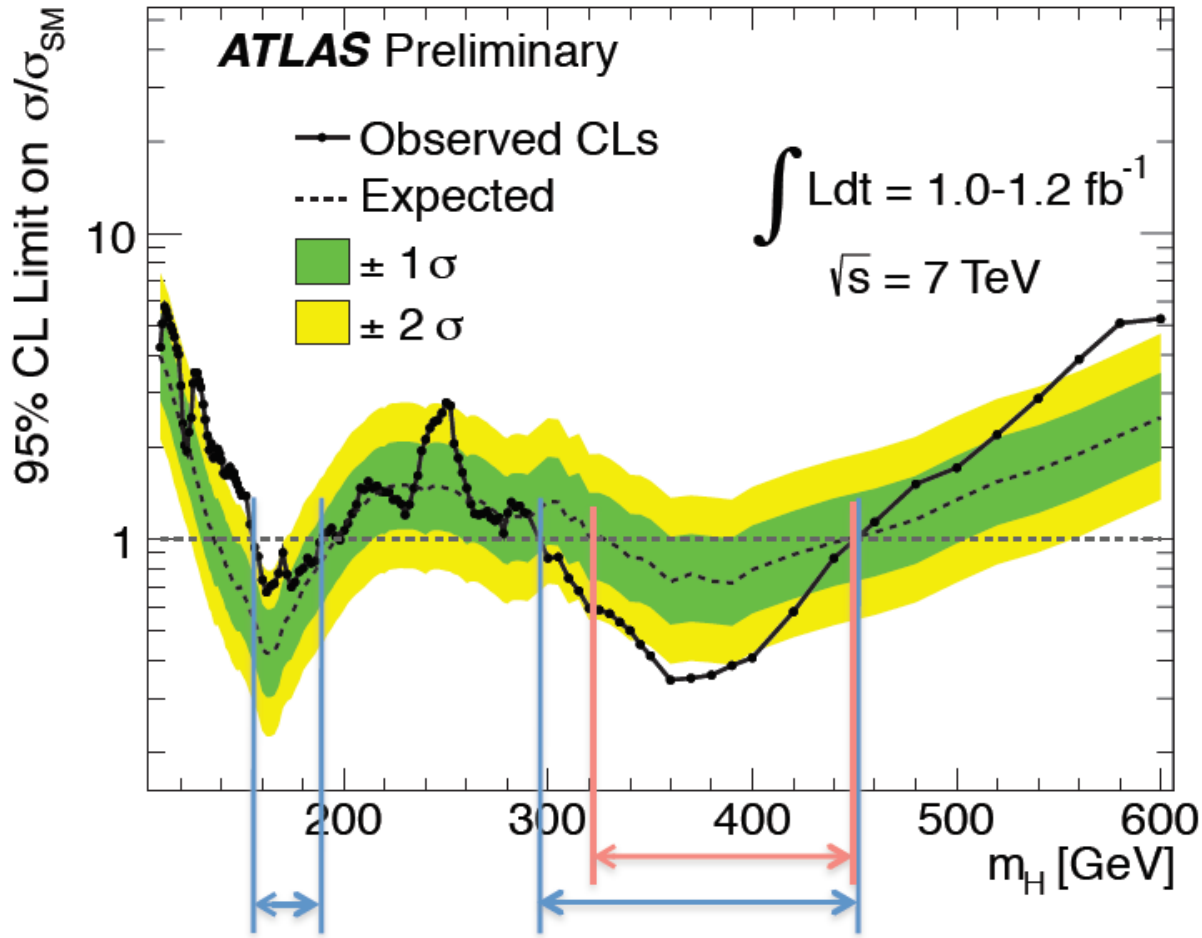
	$H \to \gamma\gamma$	$H \to b\bar{b}$	$H \to WW^{(*)}$		$H \to ZZ^{(*)}$		
			$\ell\nu\ell\nu$	$\ell\nu qq$	$\ell\ell\ell\ell$	$\ell\ell\nu\nu$	$\ell\ell qq$
Luminosity	± 3.7	± 3.7	± 3.7	± 3.7	± 3.7	± 3.7	± 3.7
e/γ efficiency	$^{+11.6}_{-10.4}$	± 2.3	± 1.4	$^{+0.9}_{-0.8}$	± 1.9	± 1.2	± 1.1
e/γ energy scale	-	$^{+1.5}_{-1.6}$	$^{+0.1}_{-0.4}$	-	-	$^{+0.8}_{-1.1}$	
e/γ resolution	-	$^{+2.1}_{-1.5}$	$^{+0.0}_{-0.5}$	-	-	-	
μ efficiency	-	$^{+1.1}_{-2.0}$	$^{+0.6}_{-0.6}$	± 0.3	± 1.2	$^{+0.8}_{-0.7}$	± 0.6
μ resolution	-	± 5.8	$^{+4.2}_{-4.5}$	-	-	-	
Jet/MET energy scale	-	$^{+21}_{-17}$	$^{+4.6}_{-7.9}$	$^{+15}_{-18}$	-	$^{+5.9}_{-4.0}$	$^{+3.7}_{-10.4}$
Jet resolution	-	± 2.5	-	$^{+8.2}_{-9.0}$	-	-	$^{+2.1}_{-0.0}$
MET	-	$^{+5.5}_{-6.1}$	-	-	-	$^{+6.6}_{-4.2}$	-
b-tag efficiency	-	$^{+37}_{-33}$	-	-	-	$^{+4.3}_{-4.4}$	-
Theory	$^{+15.0}_{-20.0}$	± 5	$^{+15.0}_{-20.0}$	$^{+15.0}_{-20.0}$	$^{+15.0}_{-20.0}$	$^{+15.0}_{-20.0}$	$^{+15.0}_{-20.0}$

H->bb not discussed today, exclusion limit (95% CL) is approx. 15 x SM prediction

Higgs analysis results combined: exclusion limits

Additional high mass channels extend the H→ZZ→llνν exclusion

Notable excess around 250 GeV from H→ZZ→4l candidates



155<m_H<190 and 295<m_H<450 GeV excluded at 95% Confidence Level

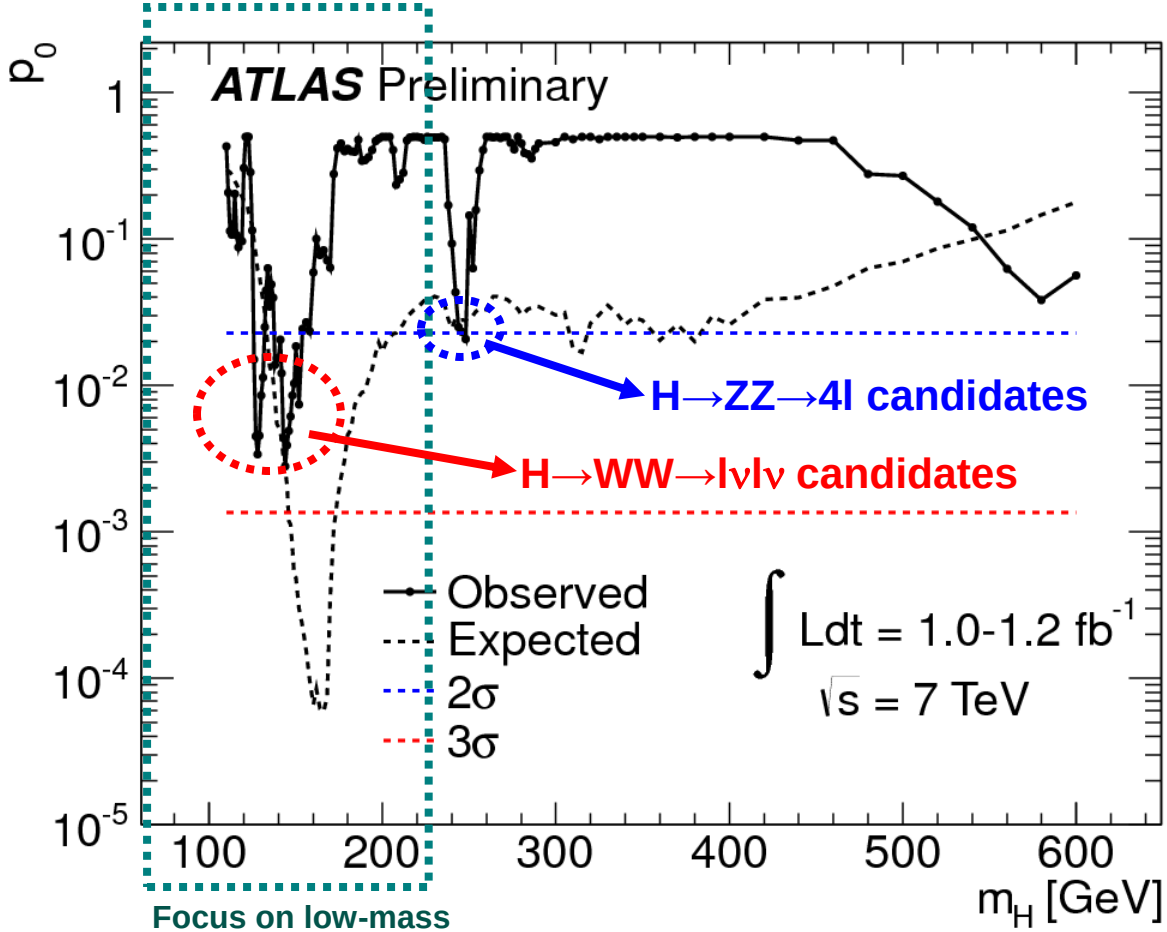
Higgs candidate signals

Intepretation of significance of Higgs candidate signals

Background fluctuation probability, p_0

The probability that a background-only experiment fluctuates more than a given observation

(p_0 is set to 0.5 for downward fluctuations of the background)



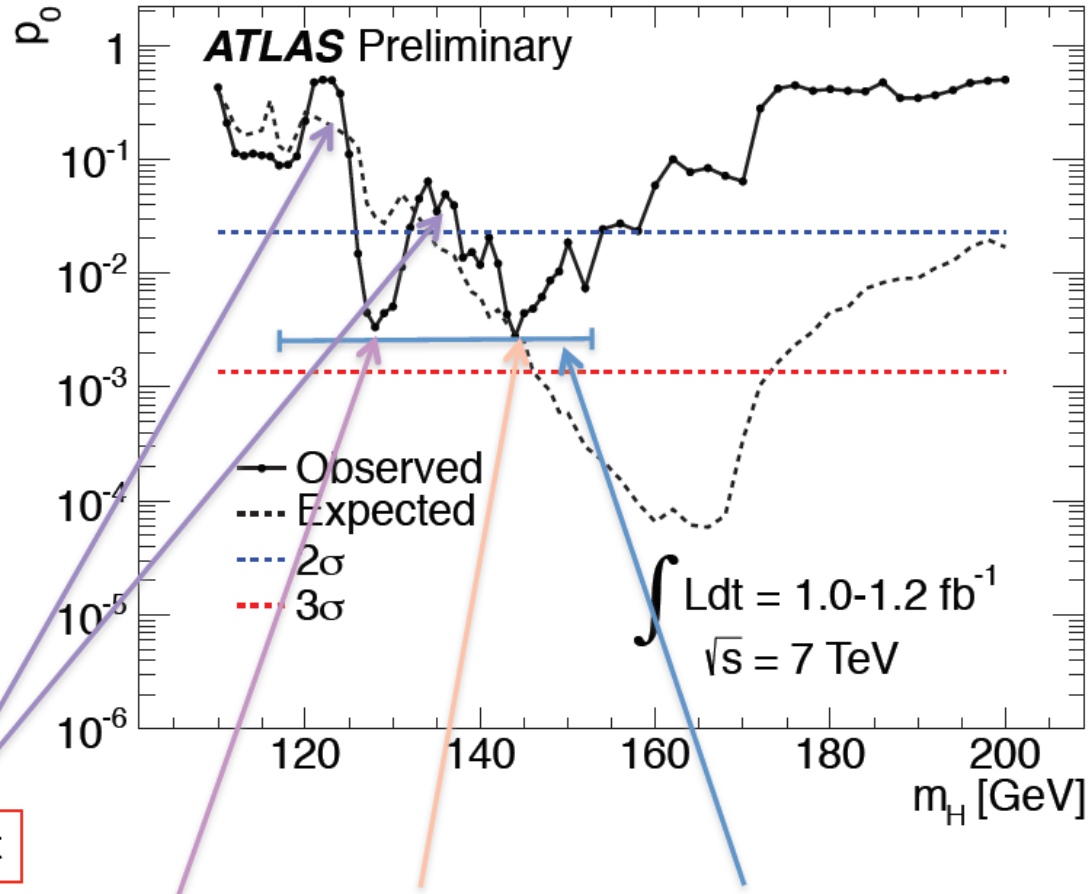
Focus on low-mass region (next slide)

Lines indicating p_0 values corresponding to 2σ and 3σ represent local significance =>not corrected for look-elsewhere effect*!

***look -elsewhere effect:** looking in many places (m_H values), makes finding a 3 sigma effect more likely!

Higgs candidate signals in low mass region

Broad WW→lνlν excess is modulated by local fluctations in γγ and 4l



γγ deficit

γγ excess

4l candidate

Broad WW→ lνlν excess

Most extreme value has 2.8σ significance and is observed at m_H=144 GeV, due to excess observed in H→WW→lνlν channel and one event observed in H→ZZ$^{(*)}$→4l channel

Probability of observing such a fluctuation anywhere in the range studied (taking into account *look-elsewhere effect*) is estimated to be ~8%

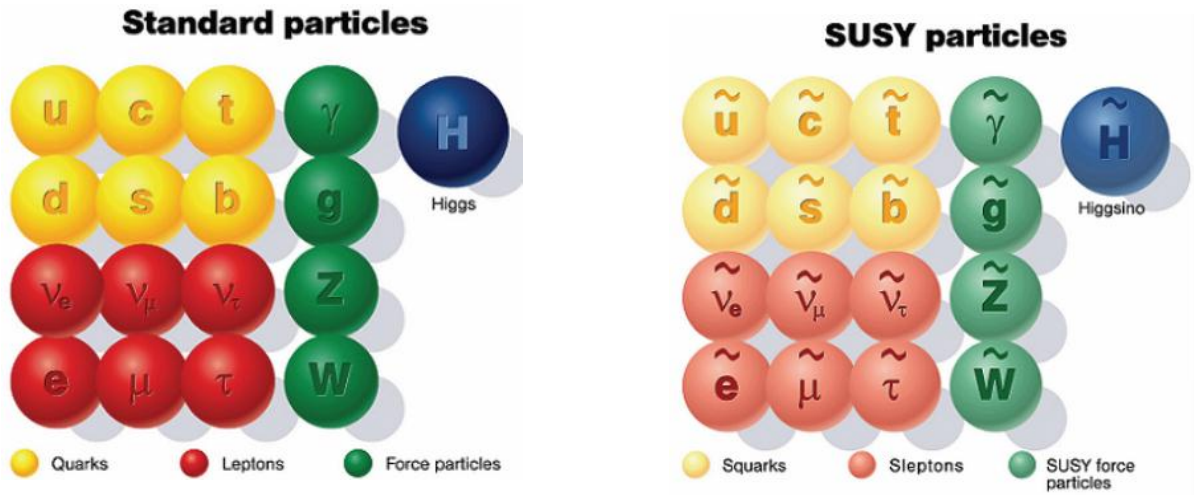
Another small excess is observed around 128 GeV, from H→WW→lνlν and γγ candidates

Supersymmetry

Supersymmetry (SUSY) is the most popular extension of the Standard Model:

- ✓Allows unification of gauge couplings
- ✓Provides a solution to the hierarchy problem
- ✓The fermion/boson contribution to the Higgs mass exactly cancel
- ✓Offers a dark matter candidate

SUSY postulates "superpartners" (that differ by spin 1/2) **to all SM particles:** squarks, gluinos...



SUSY is very predictive in terms of spins and couplings, but tells us nothing about the masses after symmetry breaking

Result: 124 free parameters !

All possible mass hierarchies between SUSY particles: 9 models!

Experimental challenge: where to start looking in SUSY phase-space?

Supersymmetry

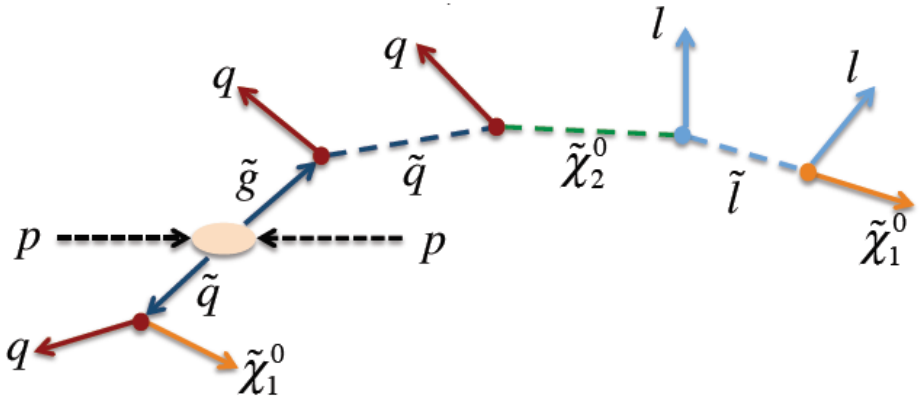
SUSY searches

Look for the production of squarks (˜*q*) and gluinos (˜*g*), superpartners of quarks and gluons and therefore strongly interacting particles
Use broad search window for masses of supersymmetric particles

R-parity conserving scenario:

Pair produced SUSY particles and Lightest Supersymmetric Particle (LSP) is stable
LSP is typically neutralino (good dark matter candidate)
LSP escapes the detection, resulting in missing transverse energy in the event

R_p = (-1)^(3B+L+2S)
B, L and S are baryon number, lepton number and spin of each particle
For all SM particles, R_p= +1,
while R_p=-1 for SUSY particles



Incomplete event reconstruction:

No mass peaks, SUSY evidence in tails of distributions
Analysis concentrates on understanding backgrounds (top, W/Z+jets, QCD)
Each background component is taken from/verified in control regions

SUSY searches in ATLAS

Generic SUSY searches for a given final state guided by a SUSY model (eg. R-parity conserving SUSY)

Channel	Signature	Main backgrounds
0 lepton + jets + E_T^{miss}	≥2-4 jets, large E_T^{miss}, $m_{eff}^{(*)}$	W/Z+jets, top, QCD
1 lepton + jets + E_T^{miss}	e/μ, ≥3 jets, large E_T^{miss}, m_{eff}, m_T	Top, W/Z+jets, QCD
2 leptons (SS/OS) + E_T^{miss}	2 e/μ, large E_T^{miss}	SS: Fakes, diboson, top OS: top, Z+jets
≥3 leptons + E_T^{miss}	≥2 jets, E_T^{miss}, $m_{l^+l^-} \neq m_Z$	Z+jets, top
0 lepton + b-jets + $E_t^{miss(**)}$	1-2 b-jets, m_{eff}	Top, W/Z+jets, QCD
γγ + E_T^{miss}	2 γ, E_T^{miss}	QCD, top, Wγ+jets

* $m_{eff} \equiv \sum_{i=1}^{n} \left|\mathbf{p}_T^i\right| + E_T^{miss}$

** Large mixing scenario can give light sbottom, stop with $\tilde{g} \to \tilde{b}_1 b,\ \tilde{g} \to \tilde{t}_1 t$

Signal includes various production mechanisms:

$$\tilde{q}\tilde{q} \to (q\tilde{\chi}_0^1)(q\tilde{\chi}_0^1)$$

$$\tilde{g}\tilde{g} \to (qq\tilde{\chi}_0^1)(qq\tilde{\chi}_0^1)$$

$$\tilde{g}\tilde{q} \to (qq\tilde{\chi}_0^1)(q\tilde{\chi}_0^1)$$

Jets+E_T^{miss} Search

Uses various signal regions

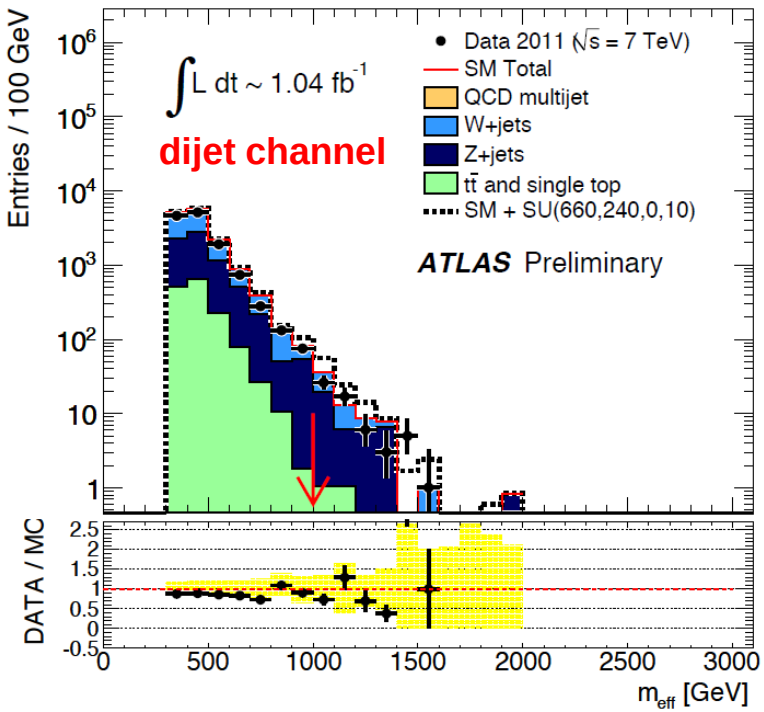
+lepton-veto: Discard events with e(μ) pT>20 (10) GeV

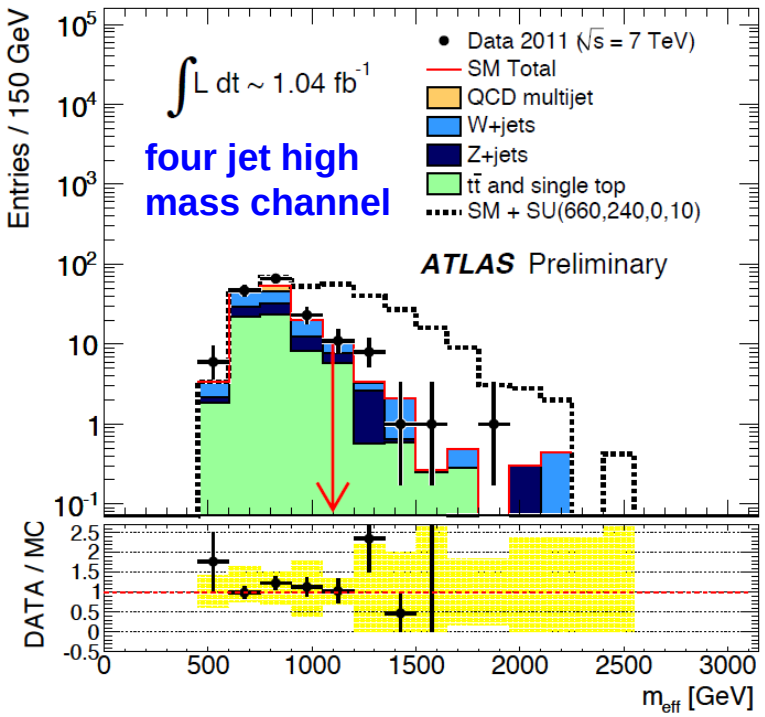
Backgrounds estimated using dedicated control regions

Look for signal in tail of effective mass:

$$m_{eff} \equiv \sum_{i=1}^{n} \left| \mathbf{p}_T^i \right| + E_T^{miss}$$

Signal Region	≥ 2 jets	≥ 3 jets	≥ 4 jets	High mass
E_T^{miss}	> 130	> 130	> 130	> 130
Leading jet p_T	> 130	> 130	> 130	> 130
Second jet p_T	> 40	> 40	> 40	> 80
Third jet p_T	–	> 40	> 40	> 80
Fourth jet p_T	–	–	> 40	> 80
$\Delta\phi(\text{jet}, E_T^{miss})_{min}$	> 0.4	> 0.4	> 0.4	> 0.4
E_T^{miss}/m_{eff}	> 0.3	> 0.25	> 0.25	> 0.2
m_{eff} [GeV]	> 1000	> 1000	> 500/1000	> 1100





Minimal Supersymmetric Standard Model (MSSM) interpretation:

Exclude at 95% C.L

$m_{\tilde{g}} \leq 800$ GeV $m_{\tilde{q}} \leq 850$ GeV

If $m_{\tilde{g}} = m_{\tilde{q}}$, masses < 1075 GeV

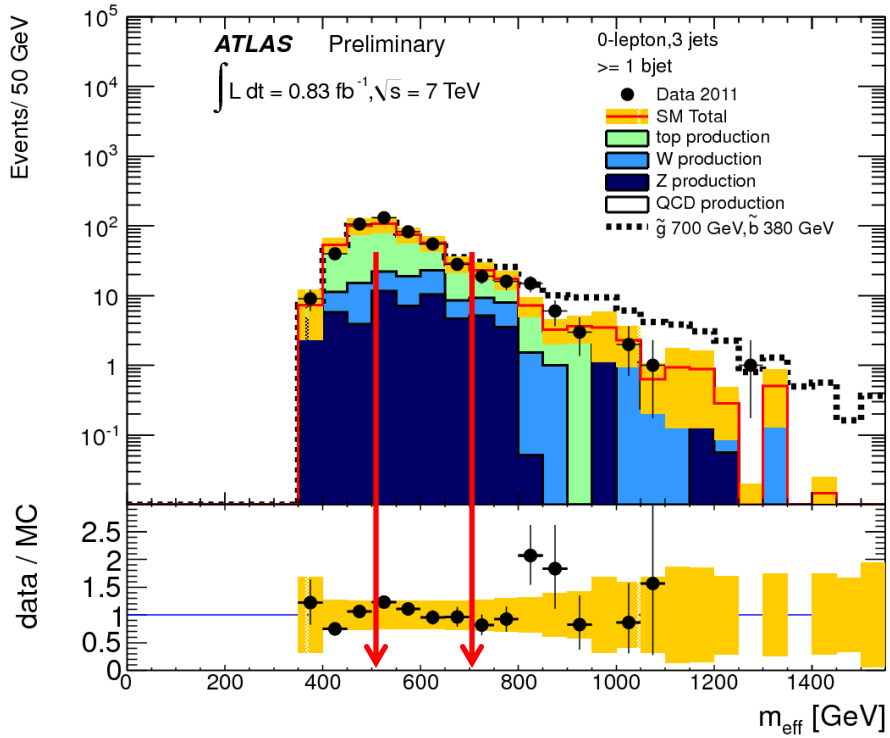
b-jets+E_T^{miss} Search

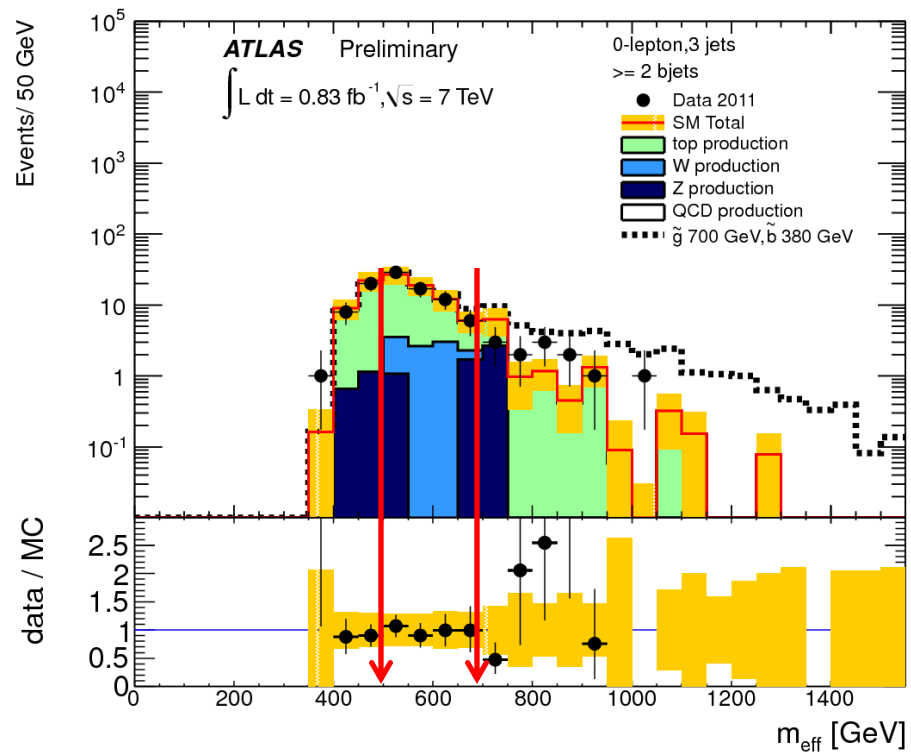
In MSSM large mixing between the chiral states of the super-partners of the Standard Model fermions could yield low masses for the lightest scalar bottom and scalar top states

Selection similar to the Jets+ETmiss analysis, add the requirement of at least one b-jet

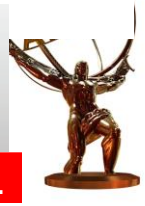
Define 4 signal regions:

≥1 b-tag m_{eff}>500 GeV	≥1 b-tag M_{eff}>700 GeV	≥2 b-tag m_{eff}>500 GeV	≥2 b-tag M_{eff}>700 GeV





MSSM interpretation: Gluino masses below 720 GeV excluded for sbottom masses below 600 GeV



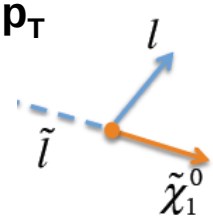
Jets+E_T^{miss}+1-lepton search

Different minimum p_T for electron or muon

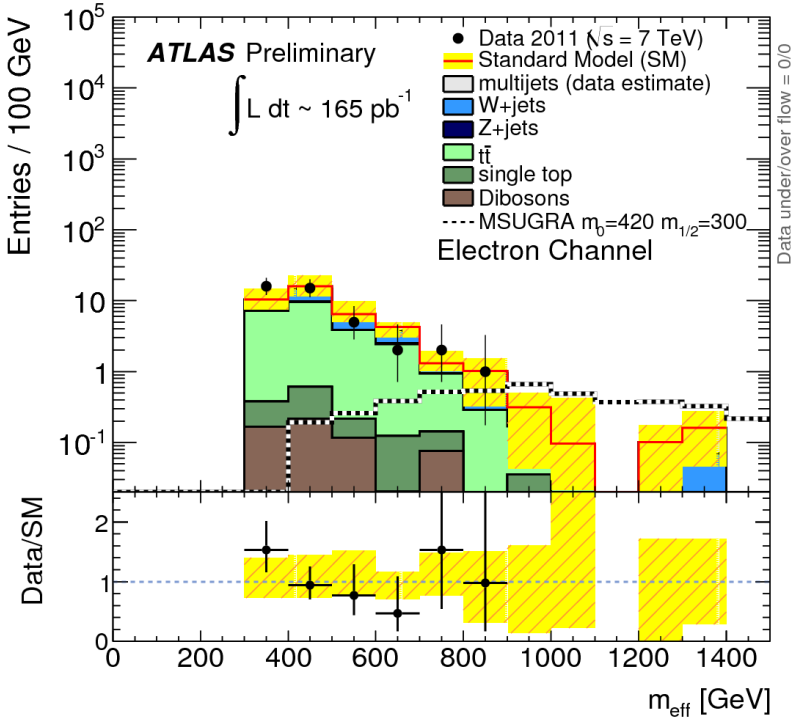
+2nd lepton-veto: discard events with additional e(μ) p_T>20 (10) GeV

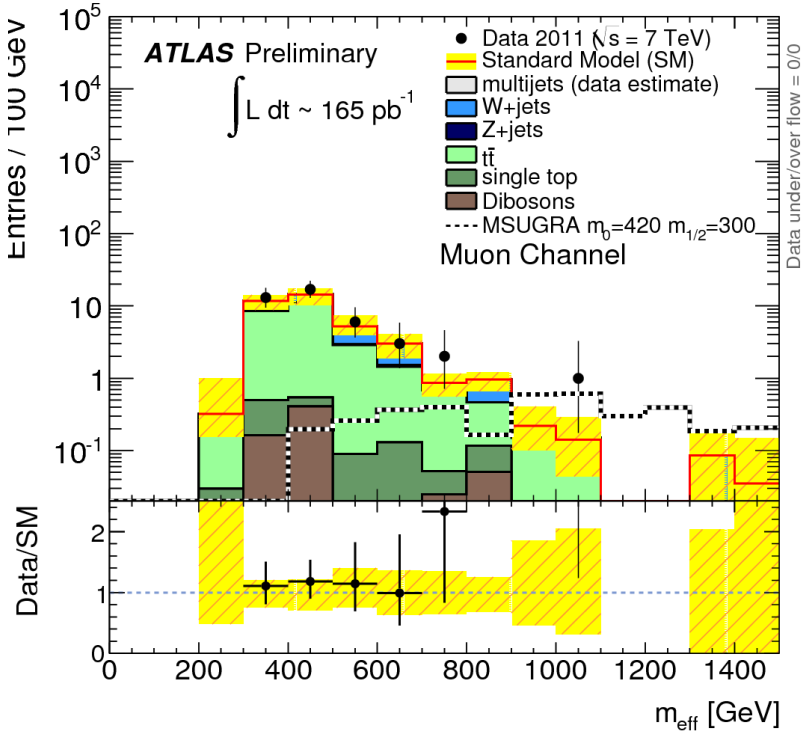
Transverse mass formed by E_T^{miss} and p_T of the lepton (l)

$$m_T = \sqrt{2 \cdot p_T^l \cdot E_T^{miss} \cdot (1 - \cos(\Delta\phi(\vec{l}, \vec{E}_T^{miss})))}$$



Signal region	e-channel	μ-channel
Lepton p_T (GeV)	>25	>20
3 leading jets p_T (GeV)	>60, >25, >25	
$\Delta\Phi(Jet_i, E_T^{miss})_{i=1,2,3}$	>0.2	
m_T (GeV)	>100	
E_T^{miss} (GeV)	125	
E_t^{miss}/m_{eff}	>0.25	
m_{eff} (GeV)	500	

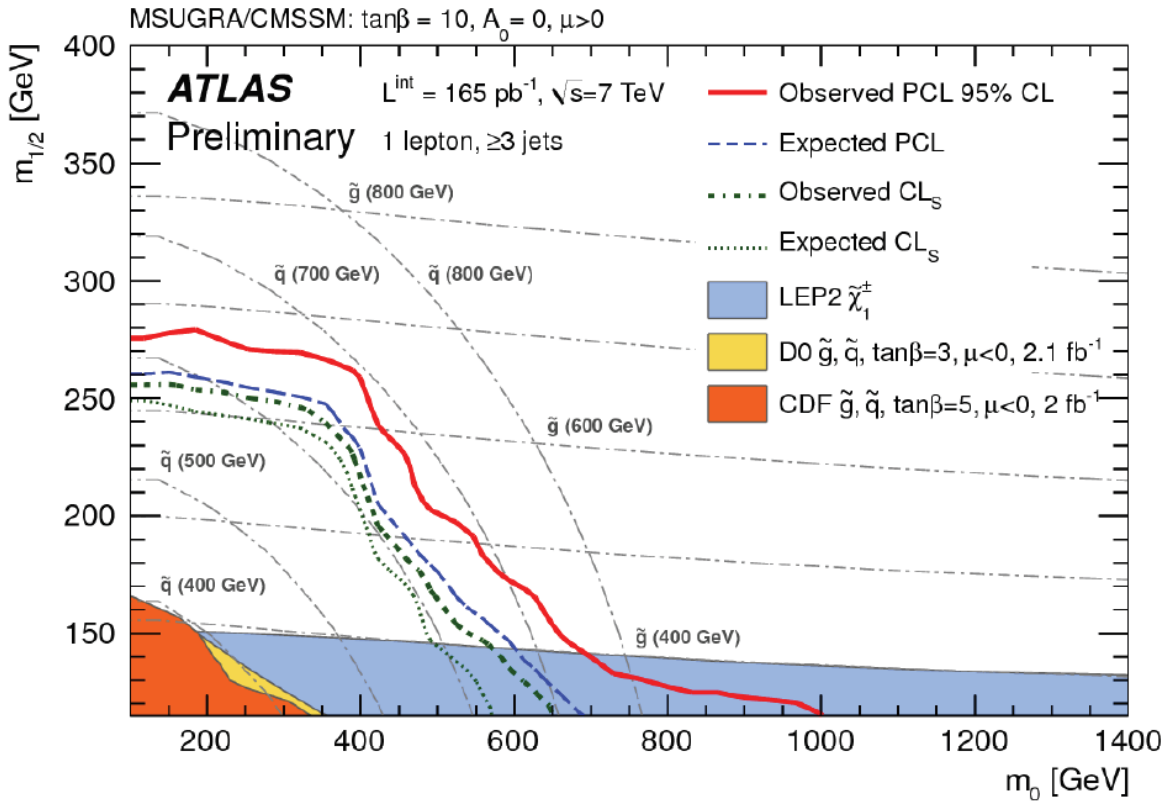




Jets+E_T^{miss}+1-lepton search

Results interpreted as constraints of phase-space for a specific SUSY-model: mSUGRA

mSUGRA: number of free parameters of the MSSM are contrained to 5: Scalar mass parameters: $\mathbf{m_0}$
Gaugino mass parameter: $\mathbf{m_{1/2}}$
Ratio of Higgs vacuum expectation values: **tanβ**
Trilinear Higgs-sfermion coupling: $\mathbf{A_0}$
Sign SUSY Higgs parameter: **sign(μ)**



Model independent fiducial cross-section limit, 95 % C.L

e-channel	μ-channel
41 fb	53 fb

SUSY results overview

Not shown: SUSY searches with multilepton and photon signatures

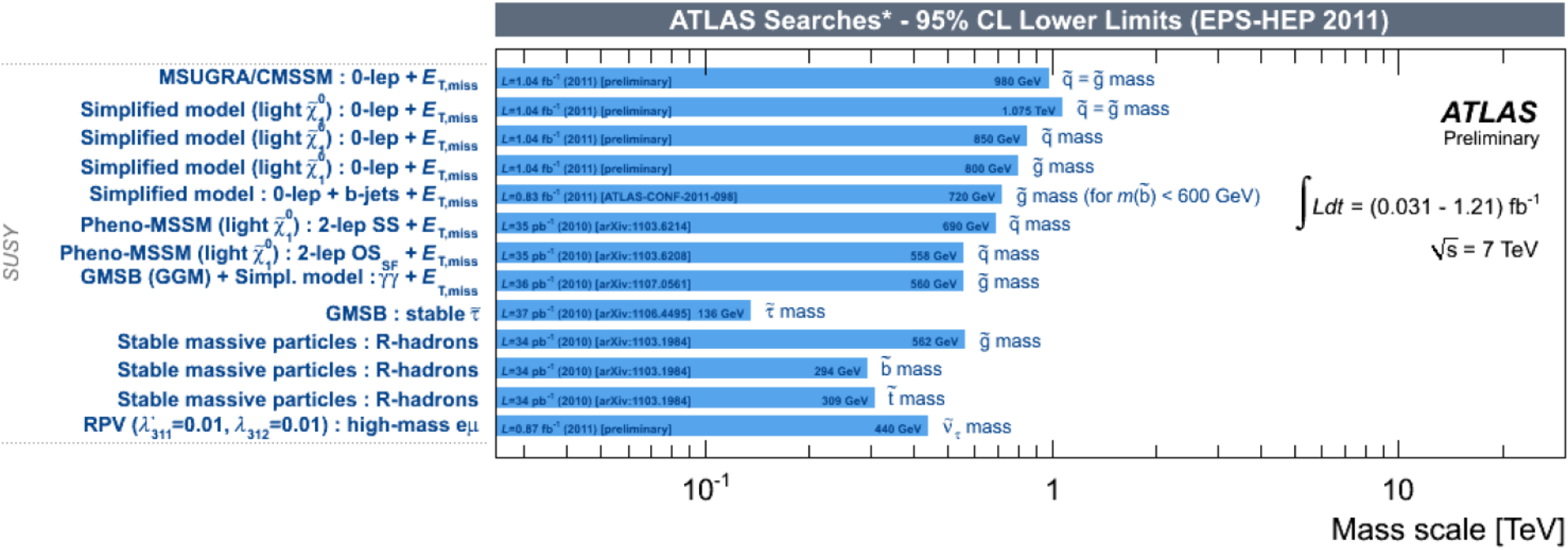
Results of these analyses so far only with 36 pb^{-1}

To be updated with more data soon

ATLAS SUSY analysis results interpreted for various models

ATLAS results exclude new regions of SUSY phasespace

Analyses with increased data in progress



Conclusion

Good LHC performance in 2011

- **2.27 fb^{-1} integrated recorded luminosity in ATLAS so far**
- **4 fb^{-1} expected by 2011!**

ATLAS copes well with large stream of data:

- **flexible trigger menus**
- **prompt reconstruction of data**
- **data-quality efficiency of ~90% (good LB for all sub-detectors)**

ATLAS results prepared for the recent EPS conference:

- **Many more results than presented today**
  (W/Z physics, top quark studies, exotics..)
- **New limits on the Higgs mass:**
  - **$155<m_H<190$ and $295<m_H<450$ GeV excluded at 95% Confidence Level**
- **New regions of SUSY phasespace excluded**

Acknowledgements, page 1

ATLAS Collaboration[-], G. Aad[48], B. Abbott[111], J. Abdallah[11], A.A. Abdelalim[49], A. Abdesselam[118], O. Abdinov[10], B. Abi[112], M. Abolins[88], H. Abramowicz[153], H. Abreu[115], E. Acerbi[89a, 89b], B.S. Acharya[164a, 164b], D.L. Adams[24], T.N. Addy[56], J. Adelman[175], M. Aderholz[99], S. Adomeit[98], P. Adragna[75], T. Adye[129], S. Aefsky[22], J.A. Aguilar-Saavedra[124b, a], M. Aharrouche[81], S.P. Ahlen[21], F. Ahles[48], A. Ahmad[148], M. Ahsan[40], G. Aielli[133a, 133b], T. Akdogan[18a], T.P.A. Åkesson[79], G. Akimoto[155], A.V. Akimov[94], A. Akiyama[67], M.S. Alam[1], M.A. Alam[76], S. Albrand[55], M. Aleksa[29], I.N. Aleksandrov[65], M. Aleppo[89a, 89b], F. Alessandria[89a], C. Alexa[25a], G. Alexander[153], G. Alexandre[49], T. Alexopoulos[9], M. Alhroob[20], S. Ali[142], M. Aliev[15], G. Alimonti[89a], J. Alison[120], M. Aliyev[10], P.P. Allport[73], S.E. Allwood-Spiers[53], J. Almond[82], A. Aloisio[102a, 102b], R. Alon[171], A. Alonso[79], M.G. Alviggi[102a, 102b], K. Amako[66], P. Amaral[29], C. Amelung[22], V.V. Ammosov[128], A. Amorim[124a, b], G. Amorós[167], N. Amram[153], C. Anastopoulos[139], T. Andeen[34], C.F. Anders[20], K.J. Anderson[30], A. Andreazza[89a, 89b], V. Andrei[58a], M.-L. Andrieux[55], X.S. Anduaga[70], A. Angerami[34], F. Anghinolfi[29], N. Anjos[124a], A. Annovi[47], A. Antonaki[8], M. Antonelli[47], S. Antonelli[19a, 19b], A. Antonov[96], J. Antos[144b], F. Anulli[132a], S. Aoun[83], L. Aperio Bella[4], R. Apolle[118], G. Arabidze[88], I. Aracena[143], Y. Arai[66], A.T.H. Arce[44], J.P. Archambault[28], S. Arfaoui[29, c], J.-F. Arguin[14], E. Arik[18a]-, M. Arik[18a], A.J. Armbruster[87], O. Arnaez[81], C. Arnault[115], A. Artamonov[95], G. Artoni[132a, 132b], D. Arutinov[20], S. Asai[155], R. Asfandiyarov[172], S. Ask[27], B. Åsman[146a, 146b], L. Asquith[5], K. Assamagan[24], A. Astbury[169], A. Astvatsatourov[52], G. Atoian[175], B. Aubert[4], B. Auerbach[175], E. Auge[115], K. Augsten[127], M. Aurousseau[145a], N. Austin[73], R. Avramidou[9], D. Axen[168], C. Ay[54], G. Azuelos[93, d], Y. Azuma[155], M.A. Baak[29], G. Baccaglioni[89a], C. Bacci[134a, 134b], A.M. Bach[14], H. Bachacou[136], K. Bachas[29], G. Bachy[29], M. Backes[49], M. Backhaus[20], E. Badescu[25a], P. Bagnaia[132a, 132b], S. Bahinipati[2], Y. Bai[32a], D.C. Bailey[158], T. Bain[158], J.T. Baines[129], O.K. Baker[175], M.D. Baker[24], S. Baker[77], F. Baltasar Dos Santos Pedrosa[29], E. Banas[38], P. Banerjee[93], Sw. Banerjee[169], D. Banfi[29], A. Bangert[137], V. Bansal[169], H.S. Bansil[17], L. Barak[171], S.P. Baranov[94], A. Barashkou[65], A. Barbaro Galtieri[14], T. Barber[27], E.L. Barberio[86], D. Barberis[50a, 50b], M. Barbero[20], D.Y. Bardin[65], T. Barillari[99], M. Barisonzi[174], T. Barklow[143], N. Barlow[27], B.M. Barnett[129], R.M. Barnett[14], A. Baroncelli[134a], A.J. Barr[118], F. Barreiro[80], J. Barreiro Guimarães da Costa[57], P. Barrillon[115], R. Bartoldus[143], A.E. Barton[71], D. Bartsch[20], R.L. Bates[53], L. Batkova[144a], J.R. Batley[27], A. Battaglia[16], M. Battistin[29], G. Battistoni[89a], F. Bauer[136], H.S. Bawa[143, e], B. Beare[158], T. Beau[78], P.H. Beauchemin[118], R. Beccherle[50a], P. Bechtle[41], H.P. Beck[16], M. Beckingham[48], K.H. Becks[174], A.J. Beddall[18c], A. Beddall[18c], V.A. Bednyakov[65], C. Bee[83], M. Begel[24], S. Behar Harpaz[152], P.K. Behera[63], M. Beimforde[99], C. Belanger-Champagne[166], P.J. Bell[49], W.H. Bell[49], G. Bella[153], L. Bellagamba[19a], F. Bellina[29], G. Bellomo[89a, 89b], M. Bellomo[119a], A. Belloni[57], O. Beloborodova[107], K. Belotskiy[96], O. Beltramello[29], S. Ben Ami[152], O. Benary[153], D. Benchekroun[135a], C. Benchouk[83], M. Bendel[81], B.H. Benedict[163], N. Benekos[165], Y. Benhammou[153], D.P. Benjamin[44], M. Benoit[115], J.R. Bensinger[22], K. Benslama[130], S. Bentvelsen[105], D. Berge[29], E. Bergeaas Kuutmann[41], N. Berger[4], F. Berghaus[169], E. Berglund[49], J. Beringer[14], K. Bernardet[83], P. Bernat[77], R. Bernhard[48], C. Bernius[24], T. Berry[76], A. Bertin[19a, 19b], F. Bertinelli[29], F. Bertolucci[122a, 122b], M.I. Besana[89a, 89b], N. Besson[136], S. Bethke[99], W. Bhimji[45], R.M. Bianchi[29], M. Bianco[72a, 72b], O. Biebel[98], S.P. Bieniek[77], J. Biesiada[14], M. Biglietti[134a, 134b], H. Bilokon[47], M. Bindi[19a, 19b], S. Binet[115], A. Bingul[18c], C. Bini[132a, 132b], C. Biscarat[177], U. Bitenc[48], K.M. Black[21], R.E. Blair[5], J.-B. Blanchard[115], G. Blanchot[29], C. Blocker[22], J. Blocki[38], A. Blondel[49], W. Blum[81], U. Blumenschein[54], G.J. Bobbink[105], V.B. Bobrovnikov[107], A. Bocci[44], C.R. Boddy[118], M. Boehler[41], J. Boek[174], N. Boelaert[35], S. Böser[77], J.A. Bogaerts[29], A. Bogdanchikov[107], A. Bogouch[90]-, C. Bohm[146a], V. Boisvert[76], T. Bold[163, f], V. Boldea[25a], M. Bona[75], V.G. Bondarenko[96], M. Boonekamp[136], G. Boorman[76], C.N. Booth[139], P. Booth[139], S. Bordoni[78], C. Borer[16], A. Borisov[128], G. Borissov[71], I. Borjanovic[12a], S. Borroni[132a, 132b], K. Bos[105], D. Boscherini[19a], M. Bosman[11], H. Boterenbrood[105], D. Botterill[129], J. Bouchami[93], J. Boudreau[123], E.V. Bouhova-Thacker[71], C. Boulahouache[123], C. Bourdarios[115], N. Bousson[83], A. Boveia[30], J. Boyd[29], I.R. Boyko[65], N.I. Bozhko[128], I. Bozovic-Jelisavcic[12b], J. Bracinik[17], A. Braem[29], E. Brambilla[72a, 72b], P. Branchini[134a], G.W. Brandenburg[57], A. Brandt[7], G. Brandt[15], O. Brandt[54], U. Bratzler[156], B. Brau[84], J.E. Brau[114], H.M. Braun[174], B. Brelier[158], J. Bremer[29], R. Brenner[166], S. Bressler[152], D. Breton[115], N.D. Brett[118], P.G. Bright-Thomas[17], D. Britton[53], F.M. Brochu[27], I. Brock[20], R. Brock[88], T.J. Brodbeck[71], E. Brodet[153], F. Broggi[89a], C. Bromberg[88], G. Brooijmans[34], W.K. Brooks[31b], G. Brown[82], E. Brubaker[30], P.A. Bruckman de Renstrom[38], D. Bruncko[144b], R. Bruneliere[48], S. Brunet[61], A. Bruni[19a], G. Bruni[19a], M. Bruschi[19a], T. Buanes[13], F. Bucci[49], J. Buchanan[118], N.J. Buchanan[2], P. Buchholz[141], R.M. Buckingham[118], A.G. Buckley[45], S.I. Buda[25a], I.A. Budagov[65], B. Budick[108], V. Büscher[81], L. Bugge[117], D. Buira-Clark[118], E.J. Buis[105], O. Bulekov[96], M. Bunse[42], T. Buran[117], H. Burckhart[29], S. Burdin[73], T. Burgess[13], S. Burke[129], E. Busato[33], P. Bussey[53], C.P. Buszello[166], F. Butin[29], B. Butler[143], J.M. Butler[21], C.M. Buttar[53], J.M. Butterworth[77], W. Buttinger[27], T. Byatt[77], S. Cabrera Urbán[167], M. Caccia[89a, 89b], D. Caforio[19a, 19b], O. Cakir[3a], P. Calafiura[14], G. Calderini[78], P. Calfayan[98], R. Calkins[106], L.P. Caloba[23a], R. Caloi[132a, 132b], D. Calvet[33], S. Calvet[33], R. Camacho Toro[33], A. Camard[78], P. Camarri[133a, 133b], M. Cambiaghi[119a, 119b], D. Cameron[117], J. Cammin[20], S. Campana[29], M. Campanelli[77], V. Canale[102a, 102b], F. Canelli[30], A. Canepa[159a], J. Cantero[80], L. Capasso[102a, 102b], M.D.M. Capeans Garrido[29], I. Caprini[25a], M. Caprini[25a], D. Capriotti[99], M. Capua[36a, 36b], R. Caputo[148], C. Caramarcu[25a], R. Cardarelli[133a], T. Carli[29], G. Carlino[102a], L. Carminati[89a, 89b], B. Caron[159a], S. Caron[48], C. Carpentieri[48], G.D. Carrillo Montoya[172], A.A. Carter[75], J.R. Carter[27], J. Carvalho[124a, g], D. Casadei[108], M.P. Casado[11], M. Cascella[122a, 122b], C. Caso[50a, 50b]-, A.M. Castaneda Hernandez[172], E. Castaneda-Miranda[172], V. Castillo Gimenez[167], N.F. Castro[124a], G. Cataldi[72a], F. Cataneo[29], A. Catinaccio[29], J.R. Catmore[71], A. Cattai[29], G. Cattani[133a, 133b], S. Caughron[88], D. Cauz[164a, 164c], A. Cavallari[132a, 132b], P. Cavalleri[78], D. Cavalli[89a], M. Cavalli-Sforza[11], V. Cavasinni[122a, 122b], A. Cazzato[72a, 72b], F. Ceradini[134a, 134b], A.S. Cerqueira[23a], A. Cerri[29], L. Cerrito[75], F. Cerutti[47], S.A. Cetin[18b], F. Cevenini[102a, 102b], A. Chafaq[135a], D. Chakraborty[106], K. Chan[2], B. Chapleau[85], J.D. Chapman[27], J.W. Chapman[87], E. Chareyre[78], D.G. Charlton[17], V. Chavda[82], S. Cheatham[71], S. Chekanov[5], S.V. Chekulaev[159a], G.A. Chelkov[65], M.A. Chelstowska[104], C. Chen[64], H. Chen[24], L.Chen[2], S. Chen[32c], T. Chen[32c], X. Chen[172], S. Cheng[32a], A. Cheplakov[65], V.F. Chepurnov[65], R. Cherkaoui El Moursli[135e], V. Chernyatin[24], E. Cheu[6], S.L. Cheung[158], L. Chevalier[136], F. Chevallier[136], G. Chiefari[102a, 102b], L. Chikovani[51], J.T. Childers[58a], A. Chilingarov[71], G. Chiodini[72a], M.V. Chizhov[65], G. Choudalakis[30], S. Chouridou[137], I.A. Christidi[77], A. Christov[48], D. Chromek-Burckhart[29], M.L. Chu[151], J. Chudoba[125], G. Ciapetti[132a, 132b], K. Ciba[37], A.K. Ciftci[3a], R. Ciftci[3a], D. Cinca[33], V. Cindro[74], M.D. Ciobotaru[163], C. Ciocca[19a, 19b], A. Ciocio[14], M. Cirilli[87], M. Ciubancan[25a], A. Clark[49], P.J. Clark[45], W. Cleland[123], J.C. Clemens[83], B. Clement[55], C. Clement[146a, 146b], R.W. Clifft[129], Y. Coadou[83], M. Cobal[164a, 164c], A. Coccaro[50a, 50b], J. Cochran[64], P. Coe[118], J.G. Cogan[143], J. Coggeshall[165], E. Cogneras[177], C.D. Cojocaru[28], J. Colas[4], A.P. Colijn[105], C. Collard[115], N.J. Collins[17], C. Collins-Tooth[53], J. Collot[55], G. Colon[84], R. Coluccia[72a, 72b], G. Comune[88], P. Conde Muiño[124a], E. Coniavitis[118], M.C. Conidi[11], M. Consonni[104], S. Constantinescu[25a], C. Conta[119a, 119b], F. Conventi[102a, h], J. Cook[29], M. Cooke[14], B.D. Cooper[77], A.M. Cooper-Sarkar[118], N.J. Cooper-Smith[76], K. Copic[34], T. Cornelissen[50a, 50b], M. Corradi[19a], F. Corriveau[85, i], A. Cortes-Gonzalez[165], G. Cortiana[99], G. Costa[89a], M.J. Costa[167], D. Costanzo[139], T. Costin[30], D. Côté[29], R. Coura Torres[23a], L. Courneyea[169], G. Cowan[76], C. Cowden[27], B.E. Cox[82], K. Cranmer[108], F. Crescioli[122a, 122b], M. Cristinziani[20], G. Crosetti[36a, 36b], R. Crupi[72a, 72b], S. Crépé-Renaudin[55], C. Cuenca Almenar[175], T. Cuhadar Donszelmann[139], S. Cuneo[50a, 50b], M. Curatolo[47], C.J. Curtis[17], P. Cwetanski[61], H. Czirr[141], Z. Czyczula[117], S. D Auria[53], M. D Onofrio[73], A. D Orazio[132a, 132b], A. Da Rocha Gesualdi Mello[23a], P.V.M. Da Silva[23a], C. Da Via[82], W. Dabrowski[37], A. Dahlhoff[48], T. Dai[87], C. Dallapiccola[84], S.J. Dallison[129]-, M. Dam[35], M. Dameri[50a, 50b], D.S. Damiani[137], H.O. Danielsson[29], R. Dankers[105], D. Dannheim[99], V. Dao[49], G. Darbo[50a], G.L. Darlea[25b], C. Daum[105], J.P. Dauvergne[29], W. Davey[86], T. Davidek[126], N. Davidson[86], R. Davidson[71], M. Davies[93], A.R. Davison[77], E. Dawe[142], I. Dawson[139], J.W. Dawson[5]-, R.K. Daya[39], K. De[7], R. de Asmundis[102a], S. De Castro[19a, 19b], P.E. De Castro Faria Salgado[24], S. De Cecco[78], J. de Graat[98], N. De Groot[104], P. de Jong[105], C. De La Taille[115], H. De la Torre[80], B. De Lotto[164a, 164c], L. De Mora[71], L. De Nooij[105], M. De Oliveira Branco[29], D. De Pedis[132a], P. de Saintignon[55], A. De Salvo[132a], U. De Sanctis[164a, 164c], A. De Santo[149], J.B. De Vivie De Regie[115], S. Dean[77], D.V. Dedovich[65], J. Degenhardt[120], M. Dehchar[118], M. Deile[98], C. Del Papa[164a, 164c], J. Del Peso[80], T. Del Prete[122a, 122b], A. Dell Acqua[29], L. Dell Asta[89a, 89b], M. Della Pietra[102a, h], D. della Volpe[102a, 102b], M. Delmastro[29], P. Delpierre[83], N. Delruelle[29], P.A. Delsart[55], C. Deluca[148], S. Demers[175], M. Demichev[65], B. Demirkoz[11], J. Deng[163], S.P. Denisov[128], D. Derendarz[38], J.E. Derkaoui[135d], F. Deruc[78], P. Dervan[73], K. Desch[20], E. Devetak[148], P.O. Deviveiros[158], A. Dewhurst[129], B. DeWilde[148], S. Dhaliwal[158], R. Dhullipudi[24, i], A. Di Ciaccio[133a, 133b], L. Di Ciaccio[4], A. Di Girolamo[29], B. Di Girolamo[29], S. Di Luise[134a, 134b], A. Di Mattia[88], B. Di Micco[29], R. Di Nardo[133a, 133b], A. Di Simone[133a, 133b], R. Di Sipio[19a, 19b], M.A. Diaz[31a], F. Diblen[18c], E.B. Diehl[87], H. Dietl[99], J. Dietrich[48], T.A. Dietzsch[58a], S. Diglio[115], K. Dindar Yagci[39], J. Dingfelder[20], C. Dionisi[132a, 132b], P. Dita[25a], S. Dita[25a], F. Dittus[29], F. Djama[83], R. Djilkibaev[108], T. Djobava[51], M.A.B. do Vale[23a], A. Do Valle Wemans[124a], T.K.O. Doan[4], M. Dobbs[85], R. Dobinson[29]-, D. Dobos[42], E. Dobson[29], M. Dobson[163], J. Dodd[34], O.B. Dogan[18a]-, C. Doglioni[118], T. Doherty[53], Y. Doi[66]-, J. Dolejsi[126], I. Dolenc[74], Z. Dolezal[126], B.A. Dolgoshein[96]-, T. Dohmae[155], M. Donadelli[23b], M. Donega[120], J. Donini[55], J. Dopke[29], A. Doria[102a], A. Dos Anjos[172], M. Dosil[11], A. Dotti[122a, 122b], M.T. Dova[70], J.D. Dowell[17], A.D. Doxiadis[105], A.T. Doyle[53], Z. Drasal[126], J. Drees[174], N. Dressnandt[120], H. Drevermann[29], C. Driouichi[35], M. Dris[9], J.G. Drohan[77], J. Dubbert[99], T. Dubbs[137], S. Dube[14], E. Duchovni[171], G. Duckeck[98], A. Dudarev[29], F. Dudziak[64], M. Dührssen[29], I.P. Duerdoth[82], L. Duflot[115], M.-A. Dufour[85], M. Dunford[29], H. Duran Yildiz[3b], R. Duxfield[139], M. Dwuznik[37], F. Dydak[29], D. Dzahini[55], M. Düren[52], W.L. Ebenstein[44], J. Ebke[98], S. Eckert[48], S. Eckweiler[81], K. Edmonds[81], C.A. Edwards[76], I. Efthymiopoulos[49], W. Ehrenfeld[41], T. Ehrich[99], T. Eifert[29], G. Eigen[13], K. Einsweiler[14], E. Eisenhandler[75], T. Ekelof[166], M. El Kacimi[4], M. Ellert[166], S. Elles[4], F. Ellinghaus[81], K. Ellis[75], N. Ellis[29], J. Elmsheuser[98], M. Elsing[29], R. Ely[14], D. Emeliyanov[129], R. Engelmann[148], A. Engl[98], B. Epp[62], A. Eppig[87], J. Erdmann[54], A. Ereditato[16], D. Eriksson[146a], J. Ernst[1], M. Ernst[24], J. Ernwein[136], D. Errede[165], S. Errede[165], E. Ertel[81], M. Escalier[115], C. Escobar[167], X. Espinal Curull[11], B. Esposito[47], F. Etienne[83], A.I. Etienvre[136], E. Etzion[153], D. Evangelakou[54], H. Evans[61], L. Fabbri[19a, 19b], C. Fabre[29], K. Facius[35], R.M. Fakhrutdinov[128], S. Falciano[132a], A.C. Falou[115], Y. Fang[172], M. Fanti[89a, 89b], A. Farbin[7], A. Farilla[134a], J. Farley[148], T. Farooque[158], S.M. Farrington[118], P. Farthouat[29], D. Fasching[172], P. Fassnacht[29], D. Fassouliotis[8], B. Fatholahzadeh[158], A. Favareto[89a, 89b], L. Fayard[115], S. Fazio[36a, 36b], R. Febbraro[33], P. Federic[144a], O.L. Fedin[121], I. Fedorko[29], W. Fedorko[88], M. Fehling-Kaschek[48], L. Feligioni[83], D. Fellmann[5], C.U. Felzmann[86], C. Feng[32d], E.J. Feng[30], A.B. Fenyuk[128], J. Ferencei[144b], J. Ferland[93], B. Fernandes[124a, b], W. Fernando[109], S. Ferrag[53], J. Ferrando[118], V. Ferrara[41], A. Ferrari[166], P. Ferrari[105], R. Ferrari[119a], A. Ferrer[167], M.L. Ferrer[47], D. Ferrere[49], C. Ferretti[87], A. Ferretto Parodi[50a, 50b], M. Fiascaris[30], F. Fiedler[81], A. FilipČIČ[74], A. Filippas[9], F. Filthaut[104], M. Fincke-Keeler[169], M.C.N. Fiolhais[124a, g], L. Fiorini[11], A. Firan[39], G. Fischer[41], P. Fischer[20], M.J. Fisher[109], S.M. Fisher[129], J. Flammer[29], M. Flechl[48], I. Fleck[141], J. Fleckner[81], P. Fleischmann[173], S. Fleischmann[174], T. Flick[174], L.R. Flores Castillo[172], M.J. Flowerdew[99], F. Föhlisch[58a], M. Fokitis[9], T. Fonseca Martin[16], D.A. Forbush[138], A. Formica[136], A. Forti[82], D. Fortin[159a], J.M. Foster[82], D. Fournier[115], A. Foussat[29], A.J. Fowler[44], K. Fowler[137], H. Fox[71], P. Francavilla[122a, 122b], S. Franchino[119a, 119b], D. Francis[29], T. Frank[171], M. Franklin[57], S. Franz[29], M. Fraternali[119a, 119b], S. Fratina[120], S.T. French[27], R. Froeschl[29], D. Froidevaux[29], J.A. Frost[27], C. Fukunaga[156], E. Fullana Torregrosa[29], J. Fuster[167], C. Gabaldon[29], O. Gabizon[171], T. Gadfort[24], S. Gadomski[49], G. Gagliardi[50a, 50b], P. Gagnon[61], C. Galea[98], E.J. Gallas[118], M.V. Gallas[29], V. Gallo[16], B.J. Gallop[129], P. Gallus[125], E. Galyaev[40], K.K. Gan[109], Y.S. Gao[143, e], V.A. Gapienko[128], A. Gaponenko[14], F. Garberson[175], M. Garcia-Sciveres[14], C. García[167], J.E. García Navarro[49], R.W. Gardner[30], N. Garelli[29], H. Garitaonandia[105], V. Garonne[29], J. Garvey[17], C. Gatti[47], G. Gaudio[119a], O. Gaumer[49], B. Gaur[141], L. Gauthier[136], I.L. Gavrilenko[94], C. Gay[168], G. Gaycken[20], J.-C. Gayde[29], E.N. Gazis[9], P. Ge[32d], C.N.P. Gee[129], D.A.A. Geerts[105], Ch. Geich-Gimbel[20], K. Gellerstedt[146a, 146b], C. Gemme[50a], A. Gemmell[53], M.H. Genest[98], S. Gentile[132a, 132b], M. George[54], S. George[76], P. Gerlach[174], A. Gershon[153], C. Geweniger[58a], H. Ghazlane[135b], P. Ghez[4], N. Ghodbane[33], B. Giacobbe[19a], S. Giagu[132a, 132b], V. Giakoumopoulou[8], V. Giangiobbe[122a, 122b], F. Gianotti[29], B. Gibbard[24], A. Gibson[158], S.M. Gibson[29], G.F. Gieraltowski[5], L.M. Gilbert[118], M. Gilchriese[14], V. Gilewsky[91], D. Gillberg[28], A.R. Gillman[129], D.M. Gingrich[2, d], J. Ginzburg[153], N. Giokaris[8], R. Giordano[102a, 102b], F.M. Giorgi[15]

Acknowledgements, page 2

P. Giovannini[99], P.F. Giraud[136], D. Giugni[89a], P. Giusti[19a], B.K. Gjelsten[117], L.K. Gladilin[97], C. Glasman[80], J. Glatzer[48], A. Glazov[41], K.W. Glitza[174], G.L. Glonti[65], J. Godfrey[142], J. Godlewski[29], M. Goebel[41], T. Göpfert[43], C. Goeringer[81], C. Gössling[42], T. Göttfert[99], S. Goldfarb[87], D. Goldin[39], T. Golling[175], S.N. Golovnia[128], A. Gomes[124a,b], L.S. Gomez Fajardo[41], R. Gonçalo[76], J. Goncalves Pinto Firmino Da Costa[41], L. Gonella[20], A. Gonidec[29], S. Gonzalez[172], S. González de la Hoz[167], M.L. Gonzalez Silva[26], S. Gonzalez-Sevilla[49], J.J. Goodson[148], L. Goossens[29], P.A. Gorbounov[95], H.A. Gordon[24], I. Gorelov[103], G. Gorfine[174], B. Gorini[29], E. Gorini[22a,22b], A. Gorišek[74], E. Gornicki[38], S.A. Gorokhov[128], V.N. Goryachev[128], B. Gosdzik[41], M. Gosselink[105], M.I. Gostkin[65], M. Gouanère[4], I. Gough Eschrich[163], M. Gouighri[135a], D. Goujdami[135a], M.P. Goulette[49], A.G. Goussiou[138], C. Goy[4], I. Grabowska-Bold[163,f], V. Grabski[176], P. Grafström[29], C. Grah[174], K.-J. Grahn[147], F. Grancagnolo[72a], S. Grancagnolo[15], V. Grassi[148], V. Gratchev[121], N. Grau[34], H.M. Gray[29], J.A. Gray[148], E. Graziani[134a], O.G. Grebenyuk[121], D. Greenfield[129], T. Greenshaw[73], Z.D. Greenwood[24,j], I.M. Gregor[41], P. Grenier[143], E. Griesmayer[46], J. Griffiths[138], N. Grigalashvili[65], A.A. Grillo[137], S. Grinstein[11], P.L.Y. Gris[33], Y.V. Grishkevich[97], J.-F. Grivaz[115], J. Grognuz[29], M. Groh[99], E. Gross[171], J. Grosse-Knetter[54], J. Groth-Jensen[29], M. Gruwe[29], K. Grybel[141], V.J. Guarino[5], D. Guest[175], C. Guicheney[33], A. Guida[72a,72b], T. Guillemin[4], S. Guindon[54], H. Guler[85,k], J. Gunther[125], B. Guo[158], J. Guo[34], A. Gupta[30], Y. Gusakov[65], V.N. Gushchin[128], A. Gutierrez[93], P. Gutierrez[111], N. Guttman[153], O. Gutzwiller[172], C. Guyot[136], C. Gwenlan[118], C.B. Gwilliam[73], A. Haas[143], S. Haas[29], C. Haber[14], R. Hackenburg[24], H.K. Hadavand[39], D.R. Hadley[17], P. Haefner[99], F. Hahn[29], S. Haider[29], Z. Hajduk[38], H. Hakobyan[176], J. Haller[54], K. Hamacher[174], P. Hamal[113], A. Hamilton[49], S. Hamilton[161], H. Han[32a], L. Han[32b], K. Hanagaki[116], M. Hance[120], C. Handel[81], P. Hanke[58a], C.J. Hansen[166], J.R. Hansen[35], J.B. Hansen[35], J.D. Hansen[35], P.H. Hansen[35], P. Hansson[143], K. Hara[160], G.A. Hare[137], T. Harenberg[174], D. Harper[87], R.D. Harrington[21], O.M. Harris[138], K. Harrison[17], J. Hartert[48], F. Hartjes[105], T. Haruyama[66], A. Harvey[56], S. Hasegawa[101], Y. Hasegawa[140], S. Hassani[136], M. Hatch[29], D. Hauff[99], S. Haug[16], M. Hauschild[29], R. Hauser[88], M. Havranek[20], B.M. Hawes[118], C.M. Hawkes[17], R.J. Hawkings[29], D. Hawkins[163], T. Hayakawa[67], D. Hayden[76], H.S. Hayward[73], S.J. Haywood[129], E. Hazen[21], M. He[32d], S.J. Head[17], V. Hedberg[79], L. Heelan[7], S. Heim[88], B. Heinemann[14], S. Heisterkamp[35], L. Helary[4], M. Heldmann[38], M. Heller[115], S. Hellman[146a,146b], C. Helsens[11], R.C.W. Henderson[71], M. Henke[58a], A. Henrichs[54], A.M. Henriques Correia[29], S. Henrot-Versille[115], F. Henry-Couannier[83], C. Hensel[54], T. Henß[174], Y. Hernández Jiménez[167], R. Herrberg[15], A.D. Hershenhorn[152], G. Herten[48], R. Hertenberger[98], L. Hervas[29], N.P. Hessey[105], A. Hidvegi[146a], E. Higón-Rodriguez[167], D. Hill[5,*], J.C. Hill[27], N. Hill[5], K.H. Hiller[41], S. Hillert[20], S.J. Hillier[17], I. Hinchliffe[14], E. Hines[120], M. Hirose[116], F. Hirsch[42], D. Hirschbuehl[174], J. Hobbs[148], N. Hod[153], M.C. Hodgkinson[139], P. Hodgson[139], A. Hoecker[29], M.R. Hoeferkamp[103], J. Hoffman[39], D. Hoffmann[83], M. Hohlfeld[81], M. Holder[141], A. Holmes[118], S.O. Holmgren[146a], T. Holy[127], J.L. Holzbauer[88], Y. Homma[67], L. Hooft van Huysduynen[108], T. Horazdovsky[127], C. Horn[143], S. Horner[48], K. Horton[118], J.-Y. Hostachy[55], T. Hott[99], S. Hou[151], M.A. Houlden[73], A. Hoummada[135a], J. Howarth[82], D.F. Howell[118], I. Hristova[41], J. Hrivnac[115], I. Hruska[125], T. Hryn ova[4], P.J. Hsu[175], S.-C. Hsu[14], G.S. Huang[111], Z. Hubacek[127], F. Hubaut[83], F. Huegging[20], T.B. Huffman[118], E.W. Hughes[34], G. Hughes[71], R.E. Hughes-Jones[82], M. Huhtinen[29], P. Hurst[57], M. Hurwitz[14], U. Husemann[41], N. Huseynov[65,l], J. Huston[88], J. Huth[57], G. Iacobucci[102a], G. Iakovidis[9], M. Ibbotson[82], I. Ibragimov[141], R. Ichimiya[67], L. Iconomidou-Fayard[115], J. Idarraga[115], M. Idzik[37], P. Iengo[102a,102b], O. Igonkina[105], Y. Ikegami[66], M. Ikeno[66], Y. Ilchenko[39], D. Iliadis[154], D. Imbault[78], M. Imhaeuser[174], M. Imori[155], T. Ince[20], J. Inigo-Golfin[29], P. Ioannou[8], M. Iodice[134a], G. Ionescu[4], A. Irles Quiles[167], K. Ishii[66], A. Ishikawa[67], M. Ishino[66], R. Ishmukhametov[39], C. Issever[118], S. Istin[18a], Y. Itoh[101], A.V. Ivashin[128], W. Iwanski[38], H. Iwasaki[66], J.M. Izen[40], V. Izzo[102a], B. Jackson[120], J.N. Jackson[73], P. Jackson[143], M.R. Jaekel[29], V. Jain[61], K. Jakobs[48], S. Jakobsen[35], J. Jakubek[127], D.K. Jana[111], E. Jankowski[158], E. Jansen[77], A. Jantsch[99], M. Janus[20], G. Jarlskog[79], L. Jeanty[57], K. Jelen[37], I. Jen-La Plante[30], P. Jenni[29], A. Jeremie[4], P. Jež[35], S. Jézéquel[4], M.K. Jha[19a], H. Ji[172], W. Ji[81], J. Jia[148], Y. Jiang[32b], M. Jimenez Belenguer[41], G. Jin[32b], S. Jin[32a], O. Jinnouchi[157], M.D. Joergensen[35], D. Joffe[39], L.G. Johansen[13], M. Johansen[146a,146b], K.E. Johansson[146a], P. Johansson[139], S. Johnert[41], K.A. Johns[6], K. Jon-And[146a,146b], G. Jones[82], R.W.L. Jones[71], T.W. Jones[77], T.J. Jones[73], O. Jonsson[29], C. Joram[29], P.M. Jorge[124a,b], J. Joseph[14], X. Ju[130], V. Juranek[125], P. Jussel[62], V.V. Kabachenko[128], S. Kabana[16], M. Kaci[167], A. Kaczmarska[38], P. Kadlecik[35], M. Kado[115], H. Kagan[109], M. Kagan[57], S. Kaiser[99], E. Kajomovitz[152], S. Kalinin[174], L.V. Kalinovskaya[65], S. Kama[39], N. Kanaya[155], M. Kaneda[155], T. Kanno[157], V.A. Kantserov[96], J. Kanzaki[66], B. Kaplan[175], A. Kapliy[30], J. Kaplon[29], D. Kar[43], M. Karagoz[118], M. Karnevskiy[41], K. Karr[5], V. Kartvelishvili[71], A.N. Karyukhin[128], L. Kashif[172], A. Kasmi[39], R.D. Kass[109], A. Kastanas[13], M. Kataoka[4], Y. Kataoka[155], E. Katsoufis[9], J. Katzy[41], V. Kaushik[6], K. Kawagoe[67], T. Kawamoto[155], G. Kawamura[81], M.S. Kayl[105], V.A. Kazanin[107], M.Y. Kazarinov[65], S.I. Kazi[86], J.R. Keates[82], R. Keeler[169], R. Kehoe[39], M. Keil[54], G.D. Kekelidze[65], M. Kelly[82], J. Kennedy[98], C.J. Kenney[143], M. Kenyon[53], O. Kepka[125], N. Kerschen[29], B.P. Kerševan[74], S. Kersten[174], K. Kessoku[155], C. Ketterer[48], M. Khakzad[28], F. Khalil-zada[10], H. Khandanyan[165], A. Khanov[112], D. Kharchenko[65], A. Khodinov[148], A.G. Kholodenko[128], A. Khomich[58a], T.J. Khoo[27], G. Khoriauli[20], N. Khovanskiy[65], V. Khovanskiy[95], E. Khramov[65], J. Khubua[51], G. Kilvington[76], H. Kim[7], M.S. Kim[2], P.C. Kim[143], S.H. Kim[160], N. Kimura[170], O. Kind[15], B.T. King[73], M. King[67], R.S.B. King[118], J. Kirk[129], G.P. Kirsch[118], L.E. Kirsch[22], A.E. Kiryunin[99], D. Kisielewska[37], T. Kittelmann[123], A.M. Kiver[128], H. Kiyamura[67], E. Kladiva[144b], J. Klaiber-Lodewigs[42], M. Klein[73], U. Klein[73], K. Kleinknecht[81], M. Klemetti[85], A. Klier[171], A. Klimentov[24], R. Klingenberg[42], E.B. Klinkby[35], T. Klioutchnikova[29], P.F. Klok[104], S. Klous[105], E.-E. Kluge[58a], T. Kluge[73], P. Kluit[105], S. Kluth[99], E. Kneringer[62], J. Knobloch[29], E.B.F.G. Knoops[83], A. Knue[54], B.R. Ko[44], T. Kobayashi[155], M. Kobel[43], B. Koblitz[29], M. Kocian[143], A. Kocnar[113], P. Kodys[126], K. Köneke[29], A.C. König[104], S. Koenig[81], S. König[48], L. Köpke[81], F. Koetsveld[104], P. Koevesarki[20], T. Koffas[29], E. Koffeman[105], F. Kohn[54], Z. Kohout[127], T. Kohriki[66], T. Koi[143], T. Kokott[20], G.M. Kolachev[107], H. Kolanoski[15], V. Kolesnikov[65], I. Koletsou[89a], J. Koll[88], D. Kollar[29], M. Kollefrath[48], S.D. Kolya[82], A.A. Komar[94], J.R. Komaragiri[142], T. Kondo[66], T. Kono[41,m], A.I. Kononov[48], R. Konoplich[108,n], N. Konstantinidis[77], A. Kootz[174], S. Koperny[37], S.V. Kopikov[128], K. Korcyl[38], K. Kordas[154], V. Koreshev[128], A. Korn[14], A. Korol[107], I. Korolkov[11], E.V. Korolkova[139], V.A. Korotkov[128], O. Kortner[99], S. Kortner[99], V.V. Kostyukhin[20], M.J. Kotamäki[29], S. Kotov[99], V.M. Kotov[65], C. Kourkoumelis[8], V. Kouskoura[154], A. Koutsman[105], R. Kowalewski[169], T.Z. Kowalski[37], W. Kozanecki[136], A.S. Kozhin[128], V. Kral[127], V.A. Kramarenko[97], G. Kramberger[74], O. Krasel[42], M.W. Krasny[78], A. Krasznahorkay[108], J. Kraus[88], A. Kreisel[153], F. Krejci[127], J. Kretzschmar[73], N. Krieger[54], P. Krieger[158], K. Kroeninger[54], H. Kroha[99], J. Kroll[120], J. Kroseberg[20], J. Krstic[12a], U. Kruchonak[65], H. Krüger[20], Z.V. Krumshteyn[65], A. Kruth[20], T. Kubota[155], S. Kuehn[48], A. Kugel[58c], T. Kuhl[174], D. Kuhn[62], V. Kukhtin[65], Y. Kulchitsky[90], S. Kuleshov[31b], C. Kummer[98], M. Kuna[78], N. Kundu[118], J. Kunkle[120], A. Kupco[125], H. Kurashige[67], M. Kurata[160], Y.A. Kurochkin[90], V. Kus[125], W. Kuykendall[138], M. Kuze[157], P. Kuzhir[91], O. Kvasnicka[125], J. Kvita[29], R. Kwee[15], A. La Rosa[29], L. La Rotonda[36a,36b], L. Labarga[80], J. Labbe[4], S. Lablak[135a], C. Lacasta[167], F. Lacava[132a,132b], H. Lacker[15], D. Lacour[78], V.R. Lacuesta[167], E. Ladygin[65], R. Lafaye[4], B. Laforge[78], T. Lagouri[80], S. Lai[48], E. Laisne[55], M. Lamanna[29], C.L. Lampen[6], W. Lampl[6], E. Lancon[136], U. Landgraf[48], M.P.J. Landon[75], H. Landsman[152], J.L. Lane[82], C. Lange[41], A.J. Lankford[163], F. Lanni[24], K. Lantzsch[29], V.V. Lapin[128,*], S. Laplace[78], C. Lapoire[20], J.F. Laporte[136], T. Lari[89a], A.V. Larionov[128], A. Larner[118], C. Lasseur[29], M. Lassnig[29], W. Lau[118], P. Laurelli[47], A. Lavorato[118], W. Lavrijsen[14], P. Laycock[73], A.B. Lazarev[65], A. Lazzaro[89a,89b], O. Le Dortz[78], E. Le Guirriec[83], C. Le Maner[158], E. Le Menedeu[136], M. Leahu[29], A. Lebedev[64], C. Lebel[93], T. LeCompte[5], F. Ledroit-Guillon[55], H. Lee[105], J.S.H. Lee[150], S.C. Lee[151], L. Lee[175], M. Lefebvre[169], M. Legendre[136], A. Leger[49], B.C. LeGeyt[120], F. Legger[98], C. Leggett[14], M. Lehmacher[20], G. Lehmann Miotto[29], X. Lei[6], M.A.L. Leite[23b], R. Leitner[126], D. Lellouch[171], J. Lellouch[78], M. Leltchouk[34], V. Lendermann[58a], K.J.C. Leney[145b], T. Lenz[174], G. Lenzen[174], B. Lenzi[136], K. Leonhardt[43], S. Leontsinis[9], C. Leroy[93], J.-R. Lessard[169], J. Lesser[146a], C.G. Lester[27], A. Leung Fook Cheong[172], J. Levêque[4], D. Levin[87], L.J. Levinson[171], M.S. Levitski[128], M. Lewandowska[21], G.H. Lewis[108], M. Leyton[15], B. Li[83], H. Li[172], S. Li[32b], X. Li[87], Z. Liang[39], Z. Liang[118], B. Liberti[133a], P. Lichard[29], M. Lichtnecker[98], K. Lie[165], W. Liebig[13], R. Lifshitz[152], J.N. Lilley[17], C. Limbach[20], A. Limosani[86], S.C. Lin[151,n], F. Linde[105], J.T. Linnemann[88], E. Lipeles[120], L. Lipinsky[125], A. Lipniacka[13], T.M. Liss[165], D. Lissauer[24], A. Lister[49], A.M. Litke[137], C. Liu[28], D. Liu[28,u], H. Liu[87], J.B. Liu[87], M. Liu[32b], S. Liu[2], Y. Liu[32b], M. Livan[119a,119b], S.S.A. Livermore[118], A. Lleres[55], S.L. Lloyd[25], E. Lobodzinska[41], P. Loch[6], W.S. Lockman[137], S. Lockwitz[175], T. Loddenkoetter[20], F.K. Loebinger[82], A. Loginov[175], C.W. Loh[168], T. Lohse[15], K. Lohwasser[48], M. Lokajicek[125], J. Loken[118], V.P. Lombardo[89a], R.E. Long[71], L. Lopes[124a,b], D. Lopez Mateos[34,r], M. Losada[162], P. Loscutoff[14], F. Lo Sterzo[132a,132b], M.J. Losty[159a], X. Lou[40], A. Lounis[115], K.F. Loureiro[162], J. Love[21], P.A. Love[71], A.J. Lowe[143,t], F. Lu[32a], J. Lu[2], L. Lu[39], H.J. Lubatti[138], C. Luci[132a,132b], A. Lucotte[55], A. Ludwig[43], D. Ludwig[41], I. Ludwig[48], J. Ludwig[48], F. Luehring[61], G. Luijckx[105], D. Lumb[48], L. Luminari[132a], E. Lund[117], B. Lund-Jensen[147], B. Lundberg[79], J. Lundberg[146a,146b], J. Lundquist[35], M. Lungwitz[81], A. Lupi[122a,122b], G. Lutz[99], D. Lynn[24], J. Lys[14], E. Lytken[79], H. Ma[24], L.L. Ma[172], J.A. Macana Goia[93], G. Maccarrone[47], A. Macchiolo[99], B. Maček[74], J. Machado Miguens[124a], D. Macina[49], R. Mackeprang[35], R.J. Madaras[14], W.F. Mader[43], R. Maenner[58c], T. Maeno[24], P. Mättig[174], S. Mättig[41], P.J. Magalhaes Martins[124a,g], L. Magnoni[29], E. Magradze[51], C.A. Magrath[104], Y. Mahalalel[153], K. Mahboubi[48], G. Mahout[17], C. Maiani[132a,132b], C. Maidantchik[23a], A. Maio[124a,b], S. Majewski[24], Y. Makida[66], N. Makovec[115], P. Mal[6], Pa. Malecki[38], P. Malecki[38], V.P. Maleev[121], F. Malek[55], U. Mallik[63], D. Malon[5], S. Maltezos[9], V. Malyshev[107], S. Malyukov[65], R. Mameghani[98], J. Mamuzic[12b], A. Manabe[66], L. Mandelli[89a], I. Mandić[74], R. Mandrysch[15], J. Maneira[124a], P.S. Mangeard[88], I.D. Manjavidze[65], A. Mann[54], P.M. Manning[137], A. Manousakis-Katsikakis[8], B. Mansoulie[136], A. Manz[99], A. Mapelli[29], L. Mapelli[29], L. March[80], J.F. Marchand[29], F. Marchese[133a,133b], M. Marchesotti[29], G. Marchiori[78], M. Marcisovsky[125], A. Marin[21,*], C.P. Marino[61], F. Marroquim[23a], R. Marshall[82], Z. Marshall[34,r], F.K. Martens[158], S. Marti-Garcia[167], A.J. Martin[175], B. Martin[29], B. Martin[88], F.F. Martin[120], J.P. Martin[93], Ph. Martin[55], T.A. Martin[17], B. Martin dit Latour[49], M. Martinez[11], V. Martinez Outschoorn[57], A.C. Martyniuk[82], M. Marx[82], F. Marzano[132a], A. Marzin[111], L. Masetti[81], T. Mashimo[155], R. Mashinistov[94], J. Masik[82], A.L. Maslennikov[107], M. Maß[42], I. Massa[19a,19b], G. Massaro[105], N. Massol[4], A. Mastroberardino[36a,36b], T. Masubuchi[155], M. Mathes[20], P. Matricon[115], H. Matsumoto[155], H. Matsunaga[155], T. Matsushita[67], C. Mattravers[118,s], J.M. Maugain[29], S.J. Maxfield[73], D.A. Maximov[107], E.N. May[5], A. Mayne[139], R. Mazini[151], M. Mazur[20], M. Mazzanti[89a], E. Mazzoni[122a,122b], S.P. Mc Kee[87], A. McCarn[165], R.L. McCarthy[148], T.G. McCarthy[28], N.A. McCubbin[129], K.W. McFarlane[56], J.A. Mcfayden[139], H. McGlone[53], G. Mchedlidze[51], R.A. McLaren[29], T. Mclaughlan[17], S.J. McMahon[129], R.A. McPherson[169,i], A. Meade[84], J. Mechnich[105], M. Mechtel[174], M. Medinnis[41], R. Meera-Lebbai[111], T. Meguro[116], R. Mehdiyev[93], S. Mehlhase[35], A. Mehta[73], K. Meier[58a], J. Meinhardt[48], B. Meirose[79], C. Melachrinos[30], B.R. Mellado Garcia[172], L. Mendoza Navas[162], Z. Meng[151,u], A. Mengarelli[19a,19b], S. Menke[99], C. Menot[29], E. Meoni[11], P. Mermod[118], L. Merola[102a,102b], C. Meroni[89a], F.S. Merritt[30], A. Messina[29], J. Metcalfe[103], A.S. Mete[64], S. Meuser[20], C. Meyer[81], J.-P. Meyer[136], J. Meyer[173], J. Meyer[54], T.C. Meyer[29], W.T. Meyer[64], J. Miao[32d], S. Michal[29], L. Micu[25a], R.P. Middleton[129], P. Miele[29], S. Migas[73], L. Mijović[41], G. Mikenberg[171], M. Mikestikova[125], B. Mikulec[49], M. Mikuž[74], D.W. Miller[143], R.J. Miller[88], W.J. Mills[168], C. Mills[57], A. Milov[171], D.A. Milstead[146a,146b], D. Milstein[171], A.A. Minaenko[128], M. Miñano[167], I.A. Minashvili[65], A.I. Mincer[108], B. Mindur[37], M. Mineev[65], Y. Ming[130], L.M. Mir[11], G. Mirabelli[132a], L. Miralles Verge[11], A. Misiejuk[76], J. Mitrevski[137], G.Y. Mitrofanov[128], V.A. Mitsou[167], S. Mitsui[66], P.S. Miyagawa[82], K. Miyazaki[67], J.U. Mjörnmark[79], T. Moa[146a,146b], P. Mockett[138], S. Moed[57], V. Moeller[27], K. Mönig[41], N. Möser[20], S. Mohapatra[148], B. Mohn[13], W. Mohr[48], S. Mohrdieck-Möck[99], A.M. Moisseev[128,*], R. Moles-Valls[167], J. Molina-Perez[29], L. Moneta[49], J. Monk[77], E. Monnier[83], S. Montesano[89a,89b], F. Monticelli[70], S. Monzani[19a,19b], R.W. Moore[2], G.F. Moorhead[86], C. Mora Herrera[49], A. Moraes[53], A. Morais[124a,b], N. Morange[136], J. Morel[54], G. Morello[36a,36b], D. Moreno[81], M. Moreno Llácer[167], P. Morettini[50a], M. Morii[57], J. Morin[75], Y. Morita[66], A.K. Morley[29], G. Mornacchi[29], M.-C. Morone[49], S.V. Morozov[96], J.D. Morris[75], H.G. Moser[99], M. Mosidze[51], J. Moss[109], R. Mount[143], E. Mountricha[9], S.V. Mouraviev[94], E.J.W. Moyse[84], M. Mudrinic[12b], F. Mueller[58a], J. Mueller[123], K. Mueller[20], T.A. Müller[98], D. Muenstermann[29], A. Muijs[105], A. Muir[168], Y. Munwes[153], K.

M. Limper

Acknowledgements, page 3

Murakami[66], W.J. Murray[129], I. Mussche[105], E. Musto[102a,102b], A.G. Myagkov[128], M. Myska[125], J. Nadal[11], K. Nagai[160], K. Nagano[66], Y. Nagasaka[60], A.M. Nairz[29], Y. Nakahama[115], K. Nakamura[155], I. Nakano[110], G. Nanava[20], A. Napier[161], M. Nash[77,x], N.R. Nation[21], T. Nattermann[20], T. Naumann[41], G. Navarro[162], H.A. Neal[87], E. Nebot[80], P.Yu. Nechaeva[94], A. Negri[119a,119b], G. Negri[29], S. Nektarijevic[49], A. Nelson[64], S. Nelson[143], T.K. Nelson[143], S. Nemecek[125], P. Nemethy[108], A.A. Nepomuceno[23a], M. Nessi[29,i], S.Y. Nesterov[121], M.S. Neubauer[165], A. Neusiedl[81], R.M. Neves[108], P. Nevski[24], P.R. Newman[17], R.B. Nickerson[118], R. Nicolaidou[136], L. Nicolas[139], B. Nicquevert[29], F. Niedercorn[115], J. Nielsen[137], T. Niinikoski[29], A. Nikiforov[15], V. Nikolaenko[128], K. Nikolaev[65], I. Nikolic-Audit[78], K. Nikolopoulos[24], H. Nilsen[48], P. Nilsson[7], Y. Ninomiya[155], A. Nisati[132a], T. Nishiyama[67], R. Nisius[99], L. Nodulman[5], M. Nomachi[116], I. Nomidis[154], H. Nomoto[155], M. Nordberg[29], B. Nordkvist[146a,146b], P.R. Norton[129], J. Novakova[126], M. Nozaki[66], M. NožiČka[41], L. Nozka[113], I.M. Nugent[159a], A.-E. Nuncio-Quiroz[20], G. Nunes Hanninger[20], T. Nunnemann[98], E. Nurse[77], T. Nyman[29], B.J. O Brien[45], S.W. O Neale[17,*], D.C. O Neil[142], V. O Shea[53], F.G. Oakham[28,d], H. Oberlack[99], J. Ocariz[78], A. Ochi[67], S. Oda[155], S. Odaka[66], J. Odier[83], H. Ogren[61], A. Oh[82], S.H. Oh[44], C.C. Ohm[146a,146b], T. Ohshima[101], H. Ohshita[140], T.K. Ohska[66], T. Ohsugi[59], S. Okada[67], H. Okawa[163], Y. Okumura[101], T. Okuyama[155], M. Olcese[50a], A.G. Olchevski[65], M. Oliveira[124a,g], D. Oliveira Damazio[24], E. Oliver Garcia[167], D. Olivito[120], A. Olszewski[38], J. Olszowska[38], C. Omachi[67], A. Onofre[124a,u], P.U.E. Onyisi[30], C.J. Oram[159a], G. Ordonez[104], M.J. Oreglia[30], F. Orellana[49], Y. Oren[153], D. Orestano[134a,134b], I. Orlov[107], C. Oropeza Barrera[53], R.S. Orr[158], E.O. Ortega[130], B. Osculati[50a,50b], R. Ospanov[120], C. Osuna[11], G. Otero y Garzon[26], J.P. Ottersbach[105], M. Ouchrit[135d], F. Ould-Saada[117], A. Ouraou[136], Q. Ouyang[32a], M. Owen[82], S. Owen[139], A. Oyarzun[31b], O.K. Øye[13], V.E. Ozcan[18a], N. Ozturk[7], A. Pacheco Pages[11], C. Padilla Aranda[11], E. Paganis[139], F. Paige[24], K. Pajchel[117], S. Palestini[29], D. Pallin[33], A. Palma[124a,b], J.D. Palmer[17], Y.B. Pan[172], E. Panagiotopoulou[9], B. Panes[31a], N. Panikashvili[87], S. Panitkin[24], D. Pantea[25a], M. Panuskova[125], V. Paolone[123], A. Paoloni[133a,133b], A. Papadelis[146a], Th.D. Papadopoulou[9], A. Paramonov[5], W. Park[24,y], M.A. Parker[27], F. Parodi[50a,50b], J.A. Parsons[34], U. Parzefall[48], E. Pasqualucci[132a], A. Passeri[134a], F. Pastore[134a,134b], Fr. Pastore[29], G. Pásztor[49,w], S. Pataraia[172], N. Patel[150], J.R. Pater[82], S. Patricelli[102a,102b], T. Pauly[29], M. Pecsy[144a], M.I. Pedraza Morales[172], S.V. Peleganchuk[107], H. Peng[172], R. Pengo[29], A. Penson[34], J. Penwell[61], M. Perantoni[23a], K. Perez[34,r], T. Perez Cavalcanti[41], E. Perez Codina[11], M.T. Pérez García-Estañ[167], V. Perez Reale[34], I. Peric[20], L. Perini[89a,89b], H. Pernegger[29], R. Perrino[72a], P. Perrodo[4], S. Persembe[3a], V.D. Peshekhonov[65], O. Peters[105], B.A. Petersen[29], J. Petersen[29], T.C. Petersen[35], E. Petit[83], A. Petridis[154], C. Petridou[154], E. Petrolo[132a], F. Petrucci[134a,134b], D. Petschull[41], M. Petteni[142], R. Pezoa[31b], A. Phan[86], A.W. Phillips[27], P.W. Phillips[129], G. Piacquadio[29], E. Piccaro[75], M. Piccinini[19a,19b], A. Pickford[53], S.M. Piec[41], R. Piegaia[26], J.E. Pilcher[30], A.D. Pilkington[82], J. Pina[124a,b], M. Pinamonti[164a,164c], A. Pinder[118], J.L. Pinfold[2], J. Ping[32c], B. Pinto[124a,b], O. Pirotte[29], C. Pizio[89a,89b], R. Placakyte[41], M. Plamondon[169], W.G. Plano[82], M.-A. Pleier[24], A.V. Pleskach[128], A. Poblaguev[24], S. Poddar[58a], F. Podlyski[33], L. Poggioli[115], T. Poghosyan[20], M. Pohl[49], F. Polci[55], G. Polesello[119a], A. Policicchio[138], A. Polini[19a], J. Poll[75], V. Polychronakos[24], D.M. Pomarede[136], D. Pomeroy[22], K. Pommès[29], L. Pontecorvo[132a], B.G. Pope[88], G.A. Popeneciu[25a], D.S. Popovic[12a], A. Poppleton[29], X. Portell Bueso[48], R. Porter[163], C. Posch[21], G.E. Pospelov[99], S. Pospisil[127], I.N. Potrap[99], C.J. Potter[149], C.T. Potter[85], G. Poulard[29], J. Poveda[172], R. Prabhu[77], P. Pralavorio[83], S. Prasad[57], R. Pravahan[7], S. Prell[64], K. Pretzl[16], L. Pribyl[29], D. Price[61], L.E. Price[5], M.J. Price[29], P.M. Prichard[73], D. Prieur[123], M. Primavera[72a], K. Prokofiev[108], F. Prokoshin[31b], S. Protopopescu[24], J. Proudfoot[5], X. Prudent[43], H. Przysiezniak[4], S. Psoroulas[20], E. Ptacek[114], J. Purdham[87], M. Purohit[24,y], P. Puzo[115], Y. Pylypchenko[117], J. Qian[87], Z. Qian[83], Z. Qin[41], A. Quadt[54], D.R. Quarrie[14], W.B. Quayle[172], F. Quinonez[31a], M. Raas[104], V. Radescu[58b], B. Radics[20], T. Rador[18a], F. Ragusa[89a,89b], G. Rahal[177], A.M. Rahimi[109], D. Rahm[24], S. Rajagopalan[24], S. Rajek[42], M. Rammensee[48], M. Rammes[141], M.Ramstedt[146a,146b], K. Randrianarivony[28], P.N. Ratoff[71], F. Rauscher[98], E. Rauter[99], M. Raymond[29], A.L. Read[117], D.M. Rebuzzi[119a,119b], A. Redelbach[173], G. Redlinger[24], R. Reece[120], K. Reeves[40], A. Reichold[105], E. Reinherz-Aronis[153], A. Reinsch[114], I. Reisinger[42], D. Reljic[12a], C. Rembser[29], Z.L. Ren[151], A. Renaud[115], P. Renkel[39], B. Rensch[35], M. Rescigno[132a], S. Resconi[89a], B. Resende[136], P. Reznicek[98], R. Rezvani[158], A. Richards[77], R. Richter[99], E. Richter-Was[38,z], M. Ridel[78], S. Rieke[81], M. Rijpstra[105], M. Rijssenbeek[148], A. Rimoldi[119a,119b], L. Rinaldi[19a], R.R. Rios[39], I. Riu[11], G. Rivoltella[89a,89b], F. Rizatdinova[112], E. Rizvi[75], S.H. Robertson[85,j], A. Robichaud-Veronneau[49], D. Robinson[27], J.E.M. Robinson[77], M. Robinson[114], A. Robson[53], J.G. Rocha de Lima[106], C. Roda[122a,122b], D. Roda Dos Santos[29], S. Rodier[80], D. Rodriguez[162], Y. Rodriguez Garcia[15], A. Roe[54], S. Roe[29], O. Røhne[117], V. Rojo[1], S. Rolli[161], A. Romaniouk[96], V.M. Romanov[65], G. Romeo[26], D. Romero Maltrana[31a], L. Roos[78], E. Ros[167], S. Rosati[138], M. Rose[76], G.A. Rosenbaum[158], E.I. Rosenberg[64], P.L. Rosendahl[13], L. Rosselet[49], V. Rossetti[11], E. Rossi[102a,102b], L.P. Rossi[50a], L. Rossi[89a,89b], M. Rotaru[25a], I. Roth[171], J. Rothberg[138], I. Rottländer[20], D. Rousseau[115], C.R. Royon[136], A. Rozanov[83], Y. Rozen[152], X. Ruan[115], I. Rubinskiy[41], B. Ruckert[98], N. Ruckstuhl[105], V.I. Rud[97], G. Rudolph[62], F. Rühr[6], F. Ruggieri[134a,134b], A. Ruiz-Martinez[64], E. Rulikowska-Zarebska[37], V. Rumiantsev[91,*], L. Rumyantsev[65], K. Runge[48], O. Runolfsson[20], Z. Rurikova[48], N.A. Rusakovich[65], D.R. Rust[61], J.P. Rutherfoord[6], C. Ruwiedel[14], P. Ruzicka[125], Y.F. Ryabov[121], V. Ryadovikov[128], P. Ryan[88], M. Rybar[126], G. Rybkin[115], N.C. Ryder[118], S. Rzaeva[10], A.F. Saavedra[150], I. Sadeh[153], H.F.-W. Sadrozinski[137], R. Sadykov[65], F. Safai Tehrani[132a,132b], H. Sakamoto[155], G. Salamanna[105], A. Salamon[133a], M. Saleem[111], D. Salihagic[99], A. Salnikov[143], J. Salt[167], B.M. Salvachua Ferrando[5], D. Salvatore[36a,36b], F. Salvatore[149], A. Salzburger[29], D. Sampsonidis[154], B.H. Samset[117], H. Sandaker[13], H.G. Sander[81], M.P. Sanders[98], M. Sandhoff[174], P. Sandhu[158], T. Sandoval[27], R. Sandstroem[105], S. Sandvoss[174], D.P.C. Sankey[129], A. Sansoni[47], C. Santamarina Rios[85], C. Santoni[33], R. Santonico[133a,133b], H. Santos[124a], J.G. Saraiva[124a,b], T. Sarangi[172], E. Sarkisyan-Grinbaum[7], F. Sarri[122a,122b], G. Sartisohn[174], O. Sasaki[66], T. Sasaki[66], N. Sasao[68], I. Satsounkevitch[90], G. Sauvage[4], J.B. Sauvan[115], P. Savard[158,d], V. Savinov[123], D.O. Savu[29], P. Savva[9], L. Sawyer[24,j], D.H. Saxon[53], L.P. Says[33], C. Sbarra[19a,19b], A. Sbrizzi[19a,19b], O. Scallon[93], D.A. Scannicchio[163], J. Schaarschmidt[115], P. Schacht[99], U. Schäfer[81], S. Schaepe[20], S. Schaetzel[58b], A.C. Schaffer[115], D. Schaile[98], R.D. Schamberger[148], A.G. Schamov[107], V. Scharf[58a], V.A. Schegelsky[121], D. Scheirich[87], M.I. Scherzer[14], C. Schiavi[50a,50b], J. Schieck[98], M. Schioppa[36a,36b], S. Schlenker[29], J.L. Schlereth[5], E. Schmidt[48], M.P. Schmidt[175,*], K. Schmieden[20], C. Schmitt[81], M. Schmitz[20], A. Schöning[58b], M. Schott[29], D. Schouten[142], J. Schovancova[125], M. Schram[85], C. Schroeder[81], N. Schroer[58c], S. Schuh[29], G. Schuler[29], J. Schultes[174], H.-C. Schultz-Coulon[58a], H. Schulz[15], J.W. Schumacher[20], M. Schumacher[48], B.A. Schumm[137], Ph. Schune[136], C. Schwanenberger[82], A. Schwartzman[143], Ph. Schwemling[78], R. Schwienhorst[88], R. Schwierz[43], J. Schwindling[136], W.G. Scott[129], J. Searcy[114], E. Sedykh[121], E. Segura[11], S.C. Seidel[103], A. Seiden[137], F. Seifert[43], J.M. Seixas[23a], G. Sekhniaidze[102a], D.M. Seliverstov[121], B. Sellden[146a], G. Sellers[73], M. Seman[144b], N. Semprini-Cesari[19a,19b], C. Serfon[98], L. Serin[115], R. Seuster[99], H. Severini[111], M.E. Sevior[86], A. Sfyrla[29], E. Shabalina[54], M. Shamim[114], L.Y. Shan[32a], J.T. Shank[21], Q.T. Shao[86], M. Shapiro[14], P.B. Shatalov[95], L. Shaver[6], C. Shaw[53], K. Shaw[164a,164c], D. Sherman[175], P. Sherwood[77], A. Shibata[108], S. Shimizu[29], M. Shimojima[100], T. Shin[56], A. Shmeleva[94], M.J. Shochet[30], D. Short[118], M.A. Shupe[6], P. Sicho[125], A. Sidoti[15], A. Siebel[174], F. Siegert[48], J. Siegrist[14], Dj. Sijacki[12a], O. Silbert[171], J. Silva[124a,b], Y. Silver[153], D. Silverstein[143], S.B. Silverstein[146a], V. Simak[127], O. Simard[136], Lj. Simic[12a], S. Simion[115], B. Simmons[77], M. Simonyan[35], P. Sinervo[158], N.B. Sinev[114], V. Sipica[141], G. Siragusa[81], A.N. Sisakyan[65], S.Yu. Sivoklokov[97], J. Sjölin[146a,146b], T.B. Sjursen[13], L.A. Skinnari[14], K. Skovpen[107], P. Skubic[111], N. Skvorodnev[22], M. Slater[17], T. Slavicek[127], K. Sliwa[161], T.J. Sloan[71], J. Sloper[29], V. Smakhtin[171], S.Yu. Smirnov[96], L.N. Smirnova[97], O. Smirnova[79], B.C. Smith[57], D. Smith[143], K.M. Smith[53], M. Smizanska[71], K. Smolek[127], A.A. Snesarev[94], S.W. Snow[82], J. Snow[111], J. Snuverink[105], S. Snyder[24], M. Soares[124a], R. Sobie[169,j], J. Sodomka[127], A. Soffer[153], C.A. Solans[167], M. Solar[127], J. Solc[127], E. Soldatov[96], U. Soldevila[167], E. Solfaroli Camillocci[132a,132b], A.A. Solodkov[128], O.V. Solovyanov[128], J. Sondericker[24], N. Soni[2], V. Sopko[127], B. Sopko[127], M. Sorbi[89a,89b], M. Sosebee[7], A. Soukharev[107], S. Spagnolo[72a,72b], F. Spanò[34], R. Spighi[19a], G. Spigo[29], F. Spila[132a,132b], E. Spiriti[134a], R. Spiwoks[29], M. Spousta[126], T. Spreitzer[158], B. Spurlock[7], R.D. St. Denis[53], T. Stahl[141], J. Stahlman[120], R. Stamen[58a], E. Stanecka[29], R.W. Stanek[5], C. Stanescu[134a], S. Stapnes[117], E.A. Starchenko[128], J. Stark[55], P. Staroba[125], P. Starovoitov[91], A. Staude[98], P. Stavina[144a], G. Stavropoulos[14], G. Steele[53], P. Steinbach[43], P. Steinberg[24], I. Stekl[127], B. Stelzer[142], H.J. Stelzer[41], O. Stelzer-Chilton[159a], H. Stenzel[52], K. Stevenson[75], G.A. Stewart[53], J.A. Stillings[20], T. Stockmanns[20], M.C. Stockton[29], K. Stoerig[48], G. Stoicea[25a], S. Stonjek[99], P. Strachota[126], A.R. Stradling[7], A. Straessner[43], J. Strandberg[87], S. Strandberg[146a,146b], A. Strandlie[117], M. Strang[109], E. Strauss[143], M. Strauss[111], P. Strizenec[144b], R. Ströhmer[173], D.M. Strom[114], J.A. Strong[76,*], R. Stroynowski[39], J. Strube[129], B. Stugu[13], I. Stumer[24,*], J. Stupak[148], P. Sturm[174], D.A. Soh[151,v], D. Su[143], HS. Subramania[2], Y. Sugaya[116], T. Sugimoto[101], C. Suhr[106], K. Suita[67], M. Suk[126], V.V. Sulin[94], S. Sultansoy[3d], T. Sumida[29], X. Sun[55], J.E. Sundermann[48], K. Suruliz[164a,164b], S. Sushkov[11], G. Susinno[36a,36b], M.R. Sutton[139], Y. Suzuki[66], Yu.M. Sviridov[128], S. Swedish[168], I. Sykora[144a], T. Sykora[126], B. Szeless[29], J. Sánchez[167], D. Ta[105], K. Tackmann[29], A. Taffard[163], R. Tafirout[159a], A. Taga[117], N. Taiblum[153], Y. Takahashi[101], H. Takai[24], R. Takashima[69], H. Takeda[67], T. Takeshita[140], M. Talby[83], A. Talyshev[107], M.C. Tamsett[24], J. Tanaka[155], R. Tanaka[115], S. Tanaka[131], S. Tanaka[66], Y. Tanaka[100], K. Tani[67], N. Tannoury[83], G.P. Tappern[29], S. Tapprogge[81], D. Tardif[158], S. Tarem[152], F. Tarrade[24], G.F. Tartarelli[89a], P. Tas[126], M. Tasevsky[125], E. Tassi[36a,36b], M. Tatarkhanov[14], C. Taylor[77], F.E. Taylor[92], G.N. Taylor[86], W. Taylor[159b], M. Teixeira Dias Castanheira[75], P. Teixeira-Dias[76], K.K. Temming[48], H. Ten Kate[29], P.K. Teng[151], S. Terada[66], K. Terashi[155], J. Terron[80], M. Terwort[41,m], M. Testa[47], R.J. Teuscher[158,j], C.M. Tevlin[82], J. Thadome[174], J. Therhaag[20], T. Theveneaux-Pelzer[78], M. Thioye[175], S. Thoma[48], J.P. Thomas[17], E.N. Thompson[84], P.D. Thompson[17], P.D. Thompson[158], A.S. Thompson[53], E. Thomson[120], M. Thomson[27], R.P. Thun[87], T. Tic[125], V.O. Tikhomirov[94], Y.A. Tikhonov[107], C.J.W.P. Timmermans[104], P. Tipton[175], F.J. Tique Aires Viegas[29], S. Tisserant[83], J. Tobias[48], B. Toczek[37], T. Todorov[4], S. Todorova-Nova[161], B. Toggerson[163], J. Tojo[66], S. Tokár[144a], K. Tokunaga[67], K. Tokushuku[66], K. Tollefson[88], M. Tomoto[101], L. Tompkins[14], K. Toms[103], A. Tonazzo[134a,134b], G. Tong[32a], A. Tonoyan[13], C. Topfel[16], N.D. Topilin[65], I. Torchiani[29], E. Torrence[114], E. Torró Pastor[167], J. Toth[83,w], F. Touchard[83], D.R. Tovey[139], D. Traynor[75], T. Trefzger[173], J. Treis[20], L. Tremblet[29], A. Tricoli[29], I.M. Trigger[159a], S. Trincaz-Duvoid[78], T.N. Trinh[78], M.F. Tripiana[70], N. Triplett[64], W. Trischuk[158], A. Trivedi[24,y], B. Trocmé[55], C. Troncon[89a], M. Trottier-McDonald[142], A. Trzupek[38], C. Tsarouchas[29], J.C.-L. Tseng[118], M. Tsiakiris[105], P.V. Tsiareshka[90], D. Tsionou[4], G. Tsipolitis[9], V. Tsiskaridze[48], E.G. Tskhadadze[51], I.I. Tsukerman[95], V. Tsulaia[123], J.-W. Tsung[20], S. Tsuno[66], D. Tsybychev[148], A. Tua[139], J.M. Tuggle[30], M. Turala[38], D. Turecek[127], I. Turk Cakir[3e], E. Turlay[105], R. Turra[89a,89b], P.M. Tuts[34], A. Tykhonov[74], M. Tylmad[146a,146b], M. Tyndel[129], D. Typaldos[17], H. Tyrvainen[29], G. Tzanakos[8], K. Uchida[20], I. Ueda[155], R. Ueno[28], M. Ugland[13], M. Uhlenbrock[20], M. Uhrmacher[54], F. Ukegawa[160], G. Unal[29], D.G. Underwood[5], A. Undrus[24], G. Unel[163], Y. Unno[66], D. Urbaniec[34], E. Urkovsky[153], P. Urquijo[49], P. Urrejola[31a], G. Usai[7], M. Uslenghi[119a,119b], L. Vacavant[83], V. Vacek[127], B. Vachon[85], S. Vahsen[14], C. Valderanis[99], J. Valenta[125], P. Valente[132a], S. Valentinetti[19a,19b], S. Valkar[126], E. Valladolid Gallego[167], S. Vallecorsa[152], J.A. Valls Ferrer[167], H. van der Graaf[105], E. van der Kraaij[105], R. Van Der Leeuw[105], E. van der Poel[105], D. van der Ster[29], B. Van Eijk[105], N. van Eldik[84], P. van Gemmeren[5], Z. van Kesteren[105], I. van Vulpen[105], W. Vandelli[29], G. Vandoni[29], A. Vaniachine[5], P. Vankov[41], F. Vannucci[78], F. Varela Rodriguez[29], R. Vari[132a], E.W. Varnes[6], D. Varouchas[14], A. Vartapetian[7], K.E. Varvell[150], V.I. Vassilakopoulos[56], F. Vazeille[33], G. Vegni[89a,89b], J.J. Veillet[115], C. Vellidis[8], F. Veloso[124a], R. Veness[29], S. Veneziano[132a], A. Ventura[72a,72b], D. Ventura[138], M. Venturi[48], N. Venturi[16], V. Vercesi[119a], M. Verducci[138], W. Verkerke[105], J.C. Vermeulen[105], A. Vest[43], M.C. Vetterli[142,d], I. Vichou[165], T. Vickey[145b,v], G.H.A. Viehhauser[118], S. Viel[168], M. Villa[19a,19b], M. Villaplana Perez[167], E. Vilucchi[47], M.G. Vincter[28], E. Vinek[29], V.B. Vinogradov[65], M. Virchaux[136,*], S. Viret[33], J. Virzi[14], A. Vitale[19a,19b], O. Vitells[171], M. Viti[41], I. Vivarelli[48], F. Vives Vaque[11], S. Vlachos[9], M. Vlasak[127], N. Vlasov[20], A. Vogel[20], P. Vokac[127], G. Volpi[47], M. Volpi[11], G. Volpini[89a], H. von der Schmitt[99], J. von Loeben[99], H. von Radziewski[48], E. von Toerne[20], V. Vorobel[126], A.P. Vorobiev[128], V. Vorwerk[11], M. Vos[167], R. Voss[29], T.T. Voss[174], J.H. Vossebeld[73], A.S. Vovenko[128], N. Vranjes[12a], M. Vranjes Milosavljevic[12a], V. Vrba[125], M. Vreeswijk[105], T. Vu Anh[81], R. Vuillermet[29], I. Vukotic[115], W. Wagner[174], P. Wagner[120], H. Wahlen[174], J.

Acknowledgements, page 4

Wakabayashi[101], J. Walbersloh[42], S. Walch[87], J. Walder[71], R. Walker[98], W. Walkowiak[141], R. Wall[175], P. Waller[73], C. Wang[44], H. Wang[172], J. Wang[151], J. Wang[32d], J.C. Wang[138], R. Wang[103], S.M. Wang[151], A. Warburton[85], C.P. Ward[27], M. Warsinsky[48], P.M. Watkins[17], A.T. Watson[17], M.F. Watson[17], G. Watts[138], S. Watts[82], A.T. Waugh[150], B.M. Waugh[77], J. Weber[42], M. Weber[129], M.S. Weber[16], P. Weber[54], A.R. Weidberg[118], P. Weigell[99], J. Weingarten[54], C. Weiser[48], H. Wellenstein[22], P.S. Wells[29], M. Wen[47], T. Wenaus[24], S. Wendler[123], Z. Weng[151,u], T. Wengler[29], S. Wenig[29], N. Wermes[20], M. Werner[48], P. Werner[29], M. Werth[163], M. Wessels[58a], K. Whalen[28], S.J. Wheeler-Ellis[163], S.P. Whitaker[21], A. White[7], M.J. White[86], S. White[24], S.R. Whitehead[118], D. Whiteson[163], D. Whittington[61], F. Wicek[115], D. Wicke[174], F.J. Wickens[129], W. Wiedenmann[172], M. Wielers[129], P. Wienemann[20], C. Wiglesworth[73], L.A.M. Wiik[48], P.A. Wijeratne[77], A. Wildauer[167], M.A. Wildt[41,m], I. Wilhelm[126], H.G. Wilkens[29], J.Z. Will[98], E. Williams[34], H.H. Williams[120], W. Willis[34], S. Willocq[84], J.A. Wilson[17], M.G. Wilson[143], A. Wilson[87], I. Wingerter-Seez[4], S. Winkelmann[48], F. Winklmeier[29], M. Wittgen[143], M.W. Wolter[38], H. Wolters[124a,q], G. Wooden[118], B.K. Wosiek[38], J. Wotschack[29], M.J. Woudstra[84], K. Wraight[53], C. Wright[53], B. Wrona[73], S.L. Wu[172], X. Wu[49], Y. Wu[32b], E. Wulf[34], R. Wunstorf[42], B.M. Wynne[45], L. Xaplanteris[9], S. Xella[35], S. Xie[48], Y. Xie[32a], C. Xu[32b], D. Xu[139], G. Xu[32a], B. Yabsley[150], M. Yamada[66], A. Yamamoto[66], K. Yamamoto[64], S. Yamamoto[155], T. Yamamura[155], J. Yamaoka[44], T. Yamazaki[155], Y. Yamazaki[67], Z. Yan[21], H. Yang[87], U.K. Yang[82], Y. Yang[61], Y. Yang[32a], Z. Yang[146a,146b], S. Yanush[91], W.-M. Yao[14], Y. Yao[14], Y. Yasu[66], G.V. Ybeles Smit[130], J. Ye[39], S. Ye[24], M. Yilmaz[3c], R. Yoosoofmiya[123], K. Yorita[170], R. Yoshida[5], C. Young[143], S. Youssef[31], D. Yu[24], J. Yu[7], J. Yu[32c,z], L. Yuan[32a,aa], A. Yurkewicz[148], V.G. Zaets[128], R. Zaidan[63], A.M. Zaitsev[128], Z. Zajacova[29], Yo.K. Zalite[121], L. Zanello[132a,132b], P. Zarzhitsky[39], A. Zaytsev[107], C. Zeitnitz[174], M. Zeller[175], P.F. Zema[29], A. Zemla[38], C. Zendler[20], A.V. Zenin[128], O. Zenin[128], T. Ženiš[144a], Z. Zenonos[122a,122b], S. Zenz[14], D. Zerwas[115], G. Zevi della Porta[57], Z. Zhan[32d], D. Zhang[32b], H. Zhang[88], J. Zhang[5], X. Zhang[32d], Z. Zhang[115], L. Zhao[108], T. Zhao[138], Z. Zhao[32b], A. Zhemchugov[65], S. Zheng[32a], J. Zhong[151,ab], B. Zhou[87], N. Zhou[163], Y. Zhou[151], C.G. Zhu[32d], H. Zhu[41], Y. Zhu[172], X. Zhuang[98], V. Zhuravlov[99], D. Zieminska[61], B. Zilka[144a], R. Zimmermann[20], S. Zimmermann[20], S. Zimmermann[48], M. Ziolkowski[141], R. Zitoun[4], L. ŽivkoviĆ[34], V.V. Zmouchko[128,*], G. Zobernig[172], A. Zoccoli[19a,19b], Y. Zolnierowski[4], A. Zsenei[29], M. zur Nedden[15], V. Zutshi[106] and L. Zwalinski[29]

I am but one ATLAS author humbly presenting the results of our collaboration
Large number people involved to make high-quality ATLAS data-taking possible
Each slide filled with results represents the hard work of the different analysis groups!

And still more analysis results went unmentioned today...

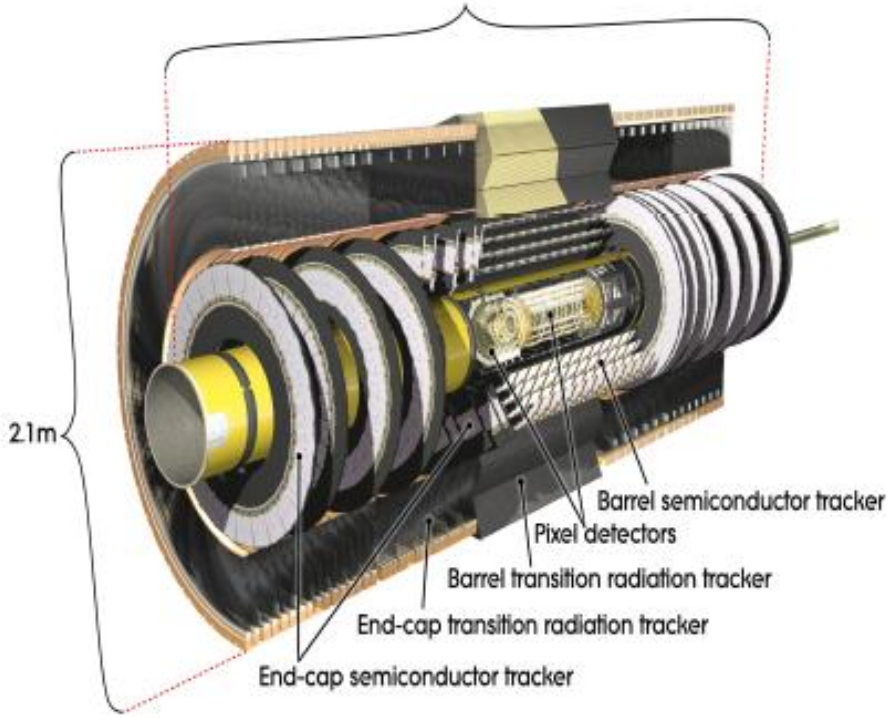
In short: thanks to the whole ATLAS collaboration!

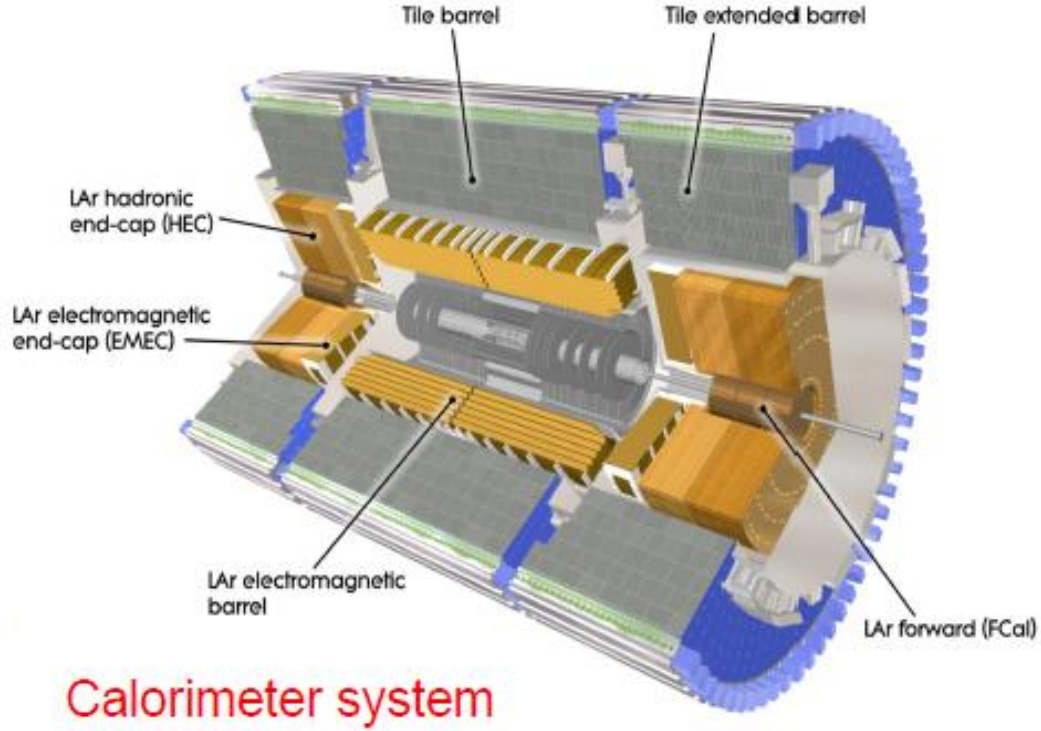
backup

ATLAS tracking and calorimeter

Tracking system

Pixel and SCT up to $|\eta| < 2.5$
TRT up to $|\eta| < 2.0$
(immersed in 2.0 T field)





Calorimeter system

Electromagnetic calorimeter up to $|\eta| < 3.2$
- with presampler up to $|\eta| < 1.8$

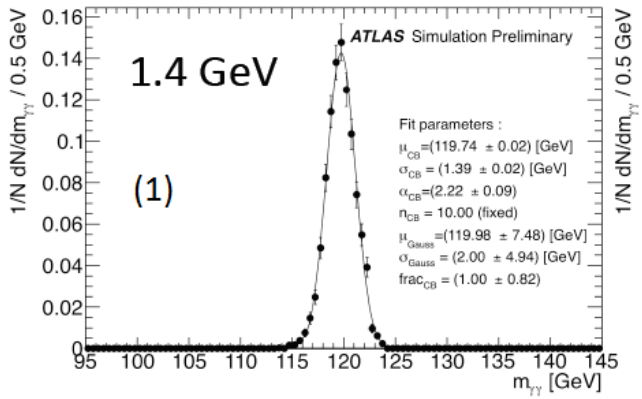
Hadronic calorimeter consists of
- Tile calorimeter up to $|\eta| < 1.7$
- Hadronic endcap for $1.5 < |\eta| < 3.2$

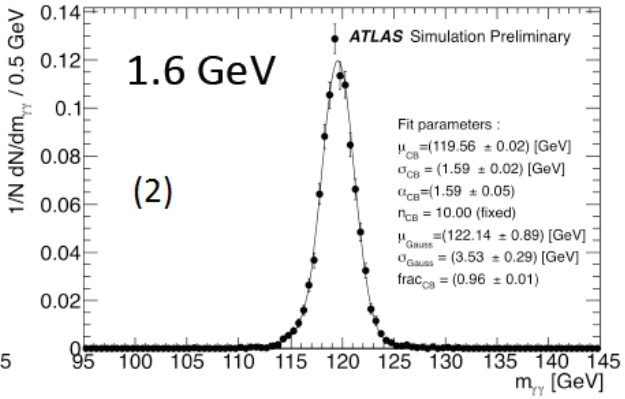
Higgs to photons

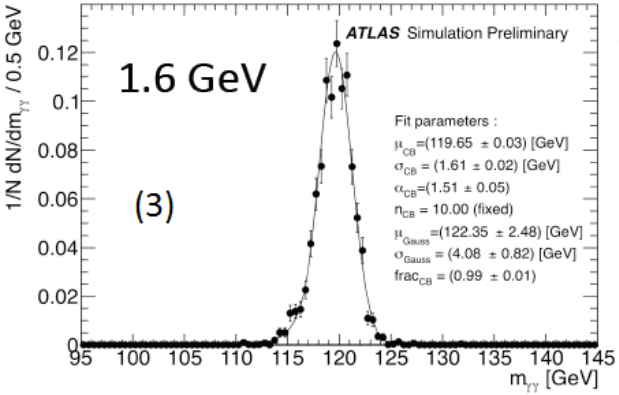
Selected events seperated into five independent categories, based on photon-direction and conversion-status:

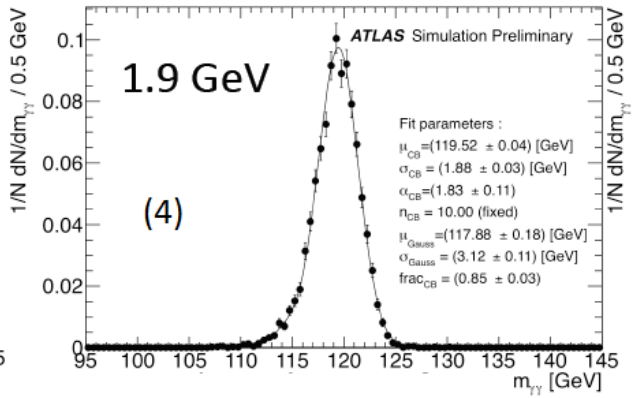
1. Unconverted-central: 2 un-coverted In the central barrel calorimeter (|η|<0.75)
2. Unconverted-rest: 2 un-converted , at least one not central
3. Converted-central: at least 1 converted, 2 central
4. Converted-transition: at least 1 converted, 1 near transition barrel/endcap(1.3< |η|<1.75)
5. Converted-rest: all other events with at least 1 converted

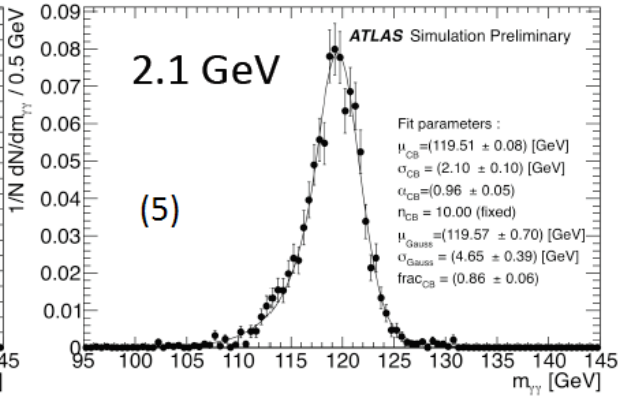
Each category treated as independent channel with fully correlated systematic uncertainties









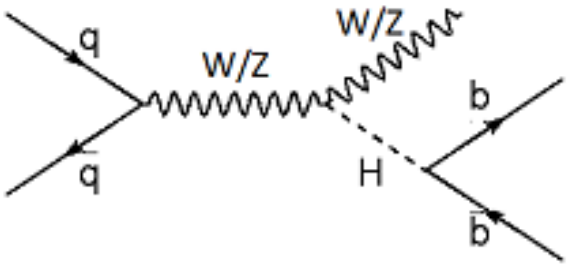


Higgs to b-jets

H → bb is dominant decay mode for light Higgs

Huge backgrounds make this signal difficult to spot for gg → H production channel

Look for H → bb in qq→H+W/Z production channel



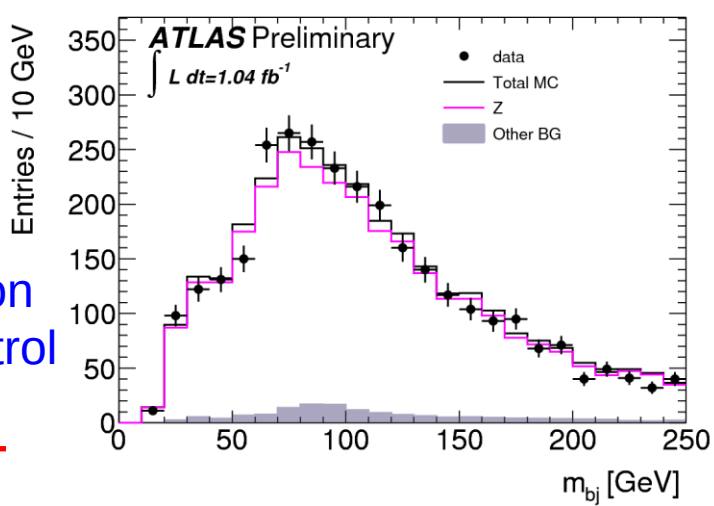
m_H (GeV)	$\sigma(WH)$ (pb)	$\sigma(ZH)$ (pb)	Branching Ratio $H \to b\bar{b}$
110	0.875	0.472	0.745
115	0.755	0.360	0.705
120	0.656	0.316	0.649
125	0.573	0.278	0.578
130	0.501	0.245	0.494

Select Z or W and search for two additional b-jets

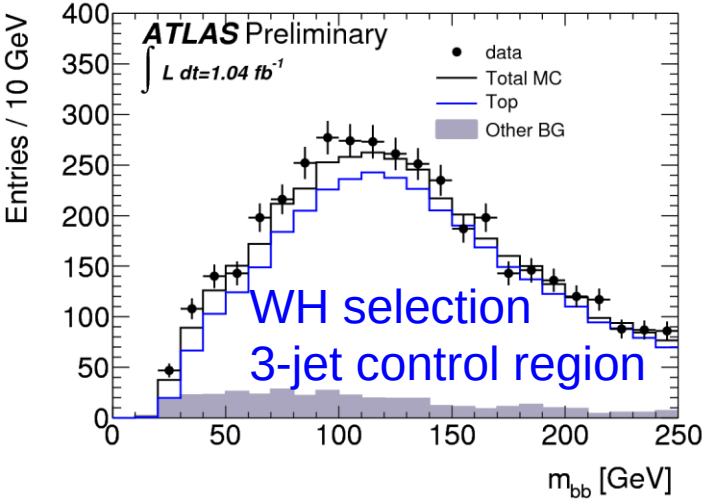
Search Higgs in m_{bb} spectrum

WH cross section factor≈2x higher than ZH, but ZH less affected by top background!

Backgrounds fitted to data using control regions:



ZH selection
1 b-jet control region



WH selection
3-jet control region

Higgs to b-jets

ZH→llbb selection:

Trigger:
- e (p_T^e>20GeV) or μ (p_T^μ>18GeV)
- 2e/2μ trigger (p_T>12GeV)

Exactly 2 leptons p_T > 20GeV
- Opposite charge for μ

Z mass cut: 76 < m_{ll} < 106 GeV

E_T^{miss} < 50GeV

Two leading jets b tagged

WH→lνbb selection:

Trigger: e (p_T^e>20GeV) or μ (p_T^μ>18GeV)

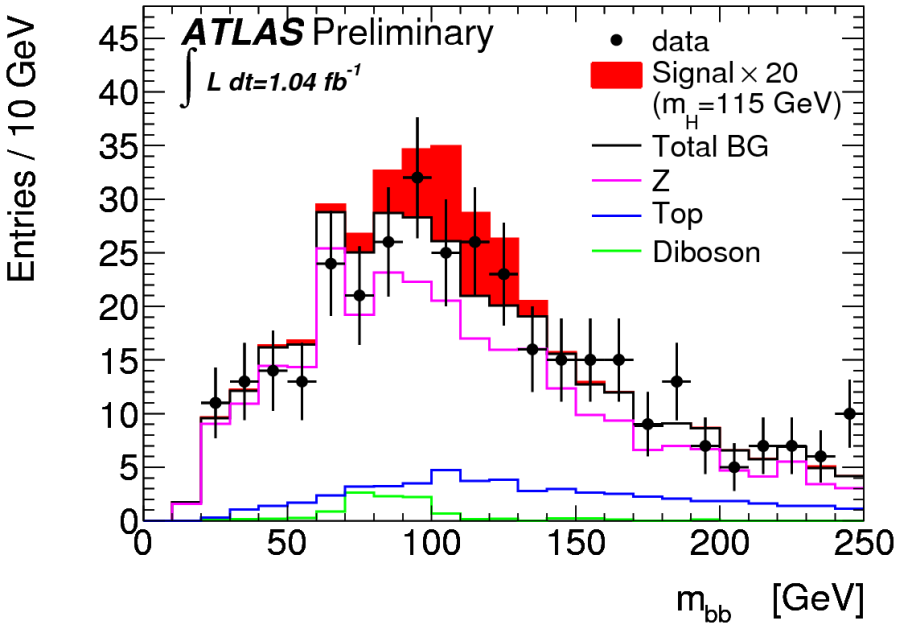
Exactly 1 lepton – p_T > 25GeV

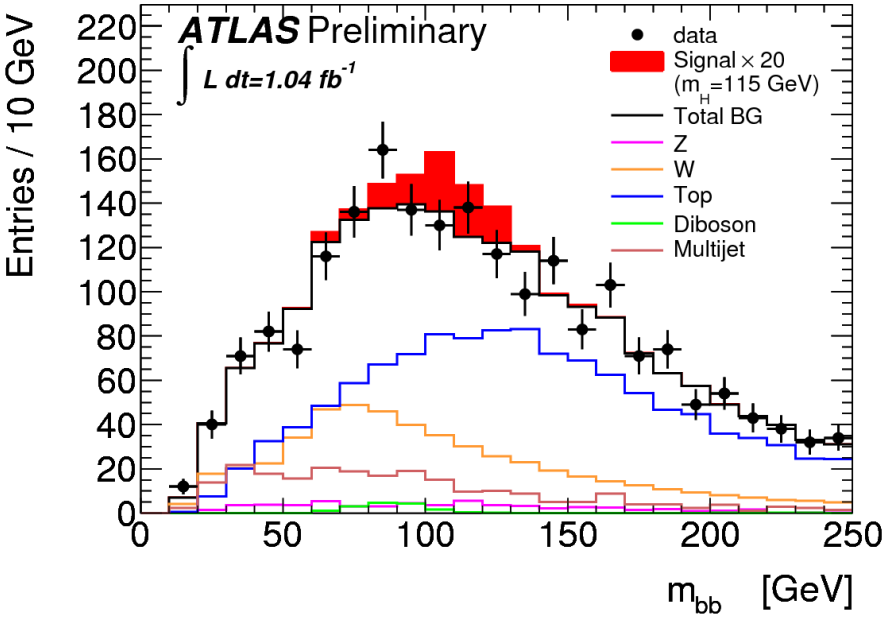
$M_T = \sqrt{2 p_T^l p_T^\nu (1 - \cos \Delta\phi_{l\nu})}$ > 40 GeV

E_T^{miss} > 25GeV

Exactly 2 jets (anti-k_T 0.4; E_T > 25GeV) to reduce top background

Both jets b tagged

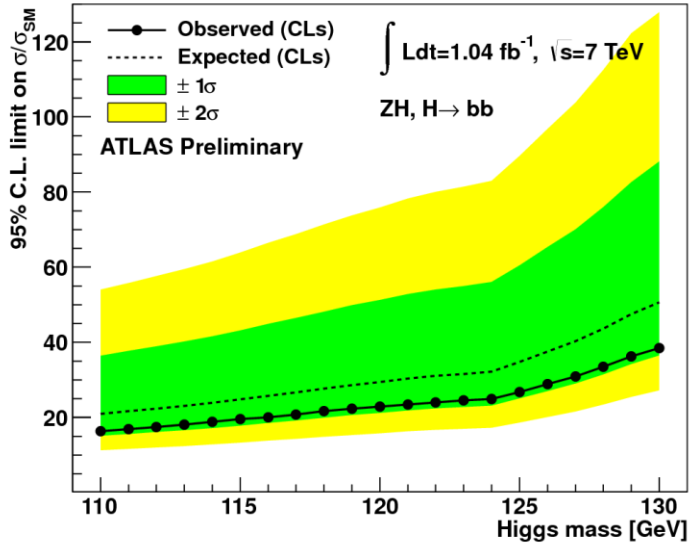




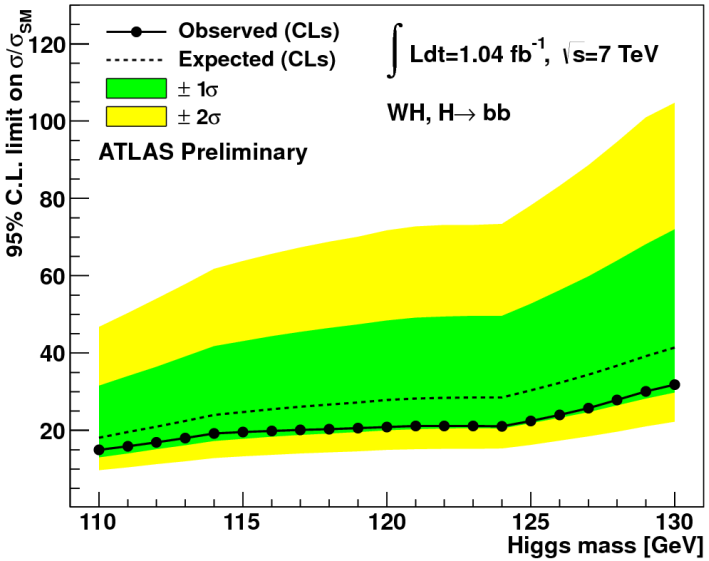
For both WH and ZH, main syst. uncertainty from b-tag efficiency: ~17%
Followed by systematic uncertainty from jet energy scale: ~9%

Higgs to b-jets

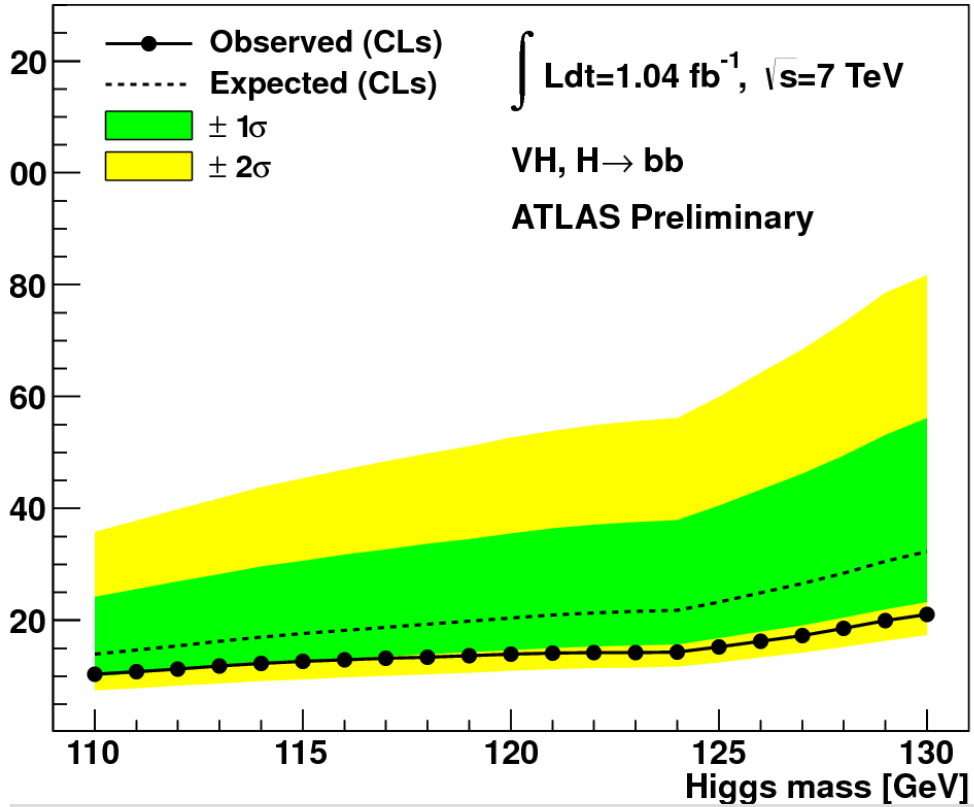
ZH result excludes ~20-30 x σ_{SM}



WH result excludes ~20-30 x σ_{SM}



WH and ZH results combined:



Combined limit (95% CL) for ZH and WH, with H→bb is approx. 15 x SM prediction

H→ZZ→llqq : Backgrounds

Normalize Z+jets using sidebands of M_{jj}

⇒ uncertainty <10% for un-tagged

⇒ uncertainty ~20% for tagged

Verify top expectation using sidebands of M_{ll}

⇒ uncertainty 10% from theory

Diboson backgrounds from MC

⇒ uncertainty ~10%

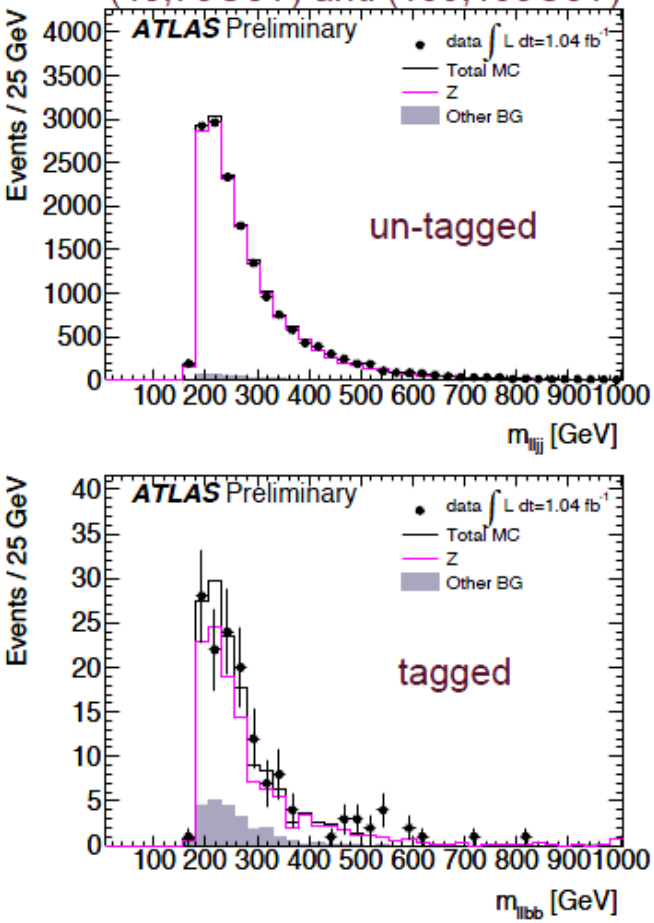
Data-Driven QCD background

⇒ generally small contributions

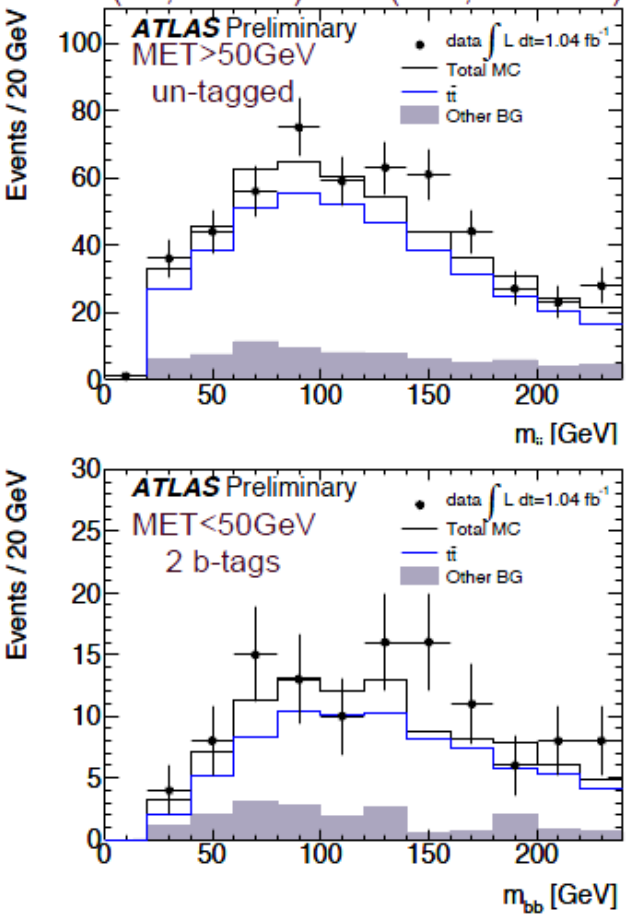
⇒ ee : QCD background templates

⇒ μμ : 2D sideband using isolation and invariant mass of the pair

Side-bands of M_{jj} (40,70GeV) and (105,150GeV)



Side-bands of M_{ll} (60,76GeV) and (106,150GeV)



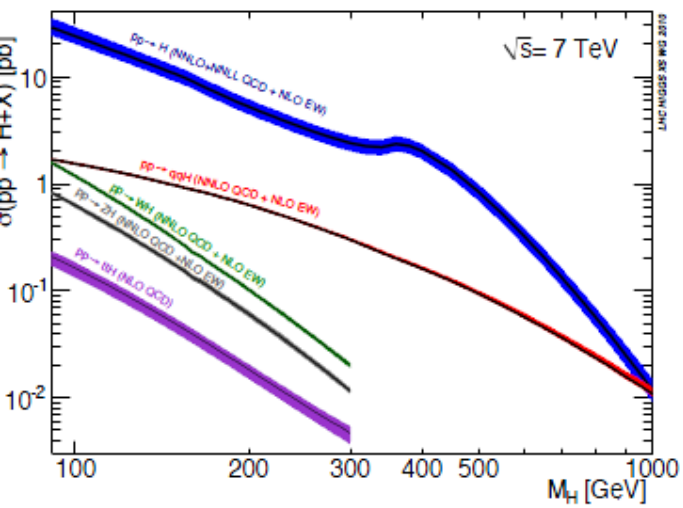
ATLAS Higgs combined results: systematics

The channels utilize three main strategies for addressing systematic uncertainties:

- **data-driven techniques:** eliminates dominant impact of uncertainty leaving uncertainties associated with extrapolation from control to signal region
- **implicit parametrization:** parametrized functions flexible enough to describe effect of uncertainty on distribution (eg. exponential + Crystal ball in $H\rightarrow\gamma\gamma$)
- **explicit parametrization:** variational histograms obtained from modifying simulated samples according to variations the source of uncertainty (eg. $H\rightarrow ZZ$)

Uncertainties in normalization described by log-normal distributions

The combination requires relations between rates of different channels, thus it is subject to theoretical uncertainties. Prescription agreed upon by LHC-HCG & Higgs cross-section working group.



	$H\rightarrow\gamma\gamma$	$H\rightarrow b\bar{b}$	$H\rightarrow WW^{(*)}$ $\ell\nu\ell\nu$	$H\rightarrow WW^{(*)}$ $\ell\nu qq$	$H\rightarrow ZZ^{(*)}$ $\ell\ell\ell\ell$	$H\rightarrow ZZ^{(*)}$ $\ell\ell\nu\nu$	$H\rightarrow ZZ^{(*)}$ $\ell\ell qq$
Luminosity	±3.7	±3.7	±3.7	±3.7	±3.7	±3.7	±3.7
e/γ efficiency	$^{+11.6}_{-10.4}$	±2.3	±1.4	$^{+0.9}_{-0.8}$	±1.9	±1.2	±1.1
e/γ energy scale	-	$^{+1.5}_{-1.6}$	$^{+0.1}_{-0.4}$	-	-	$^{+0.8}_{-1.1}$	
e/γ resolution	-	$^{+2.1}_{-1.5}$	$^{+0.0}_{-0.5}$	-	-	-	
μ efficiency	-	$^{+1.1}_{-2.0}$	$^{+0.6}_{-0.6}$	±0.3	±1.2	$^{+0.8}_{-0.7}$	±0.6
μ resolution	-	±5.8	$^{+4.2}_{-4.5}$	-	-	-	
Jet/MET energy scale	-	$^{+21}_{-17}$	$^{+4.6}_{-7.9}$	$^{+15}_{-18}$	-	$^{+5.9}_{-4.0}$	$^{+3.7}_{-10.4}$
Jet resolution	-	±2.5	-	$^{+8.2}_{-9.0}$	-	-	$^{+2.1}_{-0.0}$
MET	-	$^{+5.5}_{-6.1}$	-	-	-	$^{+6.6}_{-4.2}$	-
b-tag efficiency	-	$^{+37}_{-33}$	-	-	-	$^{+4.3}_{-4.4}$	-
Theory	$^{+15.0}_{-20.0}$	±5	$^{+15.0}_{-20.0}$	$^{+15.0}_{-20.0}$	$^{+15.0}_{-20.0}$	$^{+15.0}_{-20.0}$	$^{+15.0}_{-20.0}$

ATLAS Higgs combined: stastistical procedure

The full complexity of individual channels' likelihood functions are packaged using RooFit/RooStats workspaces, and a combined probability model is formed by identifying nuisance parameters ν associated to common systematic effects

- the common parameter of interest is a cross-section scale factor: $\mu = \sigma / \sigma_{SM}$

The profile likelihood ratio is used as a test statistic: $\lambda(\mu) = L_{s+b}(\mu, \hat{\hat{\nu}}) / L_{s+b}(\hat{\mu}, \hat{\nu})$

- nuisance parameters are "profiled" based on the data
- one-sided variants of the test statistic are used for upper-limits and discovery

The distribution of the test statistic is obtained in two ways:

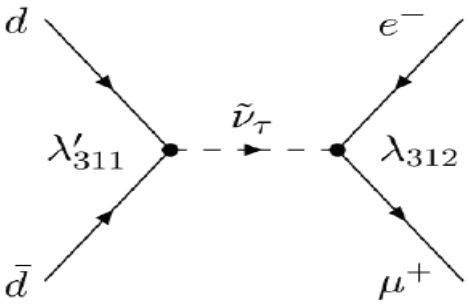
- Ensemble tests with toy Monte Carlo using a fully frequentist procedure
  - randomize auxiliary measurements instead of randomizing nuisance parameters
- Using asymptotic distribution of likelihood ratio Cowan, Cranmer, Gross, Vitells Eur.Phys.J. C71 (2011)
  - used for primary result

Primary result based CLs, conservatism introduced to protect against downward fluctuations

- results based on power-constrained CLs+b ("PCL") in backup
- Additional comparisons with Bayesian procedure with a uniform prior on μ

R-parity violating SUSY searches

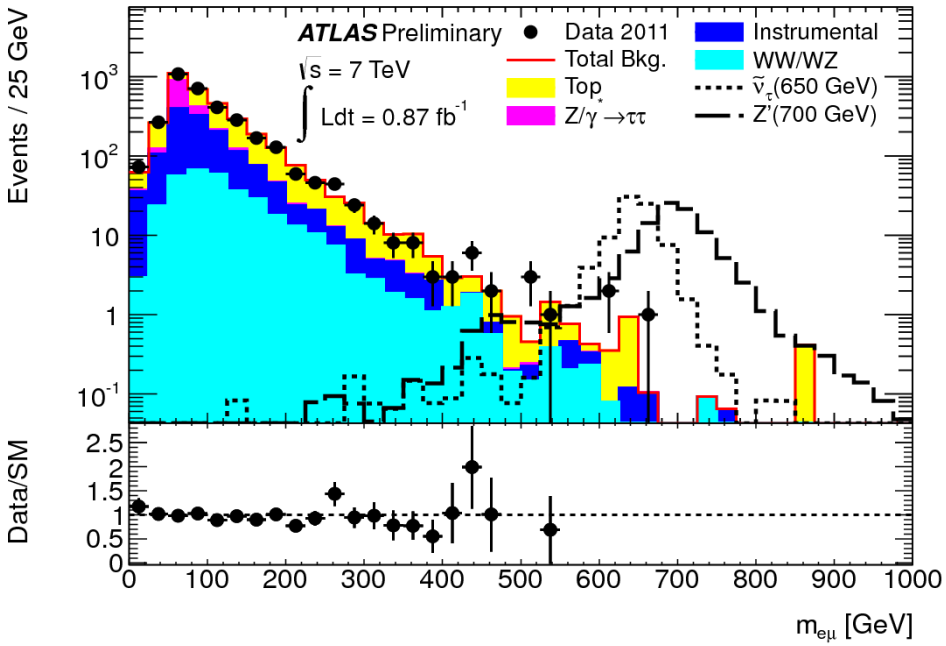
One possible R-parity violating scenario could lead to eμ resonance:



Exactly one electron and one muon selected (used to trigger)

Main event selection critera is electron p_T >25 GeV -and- muon p_T> 25GeV

(with usual quality and isolation criteria for leptons)



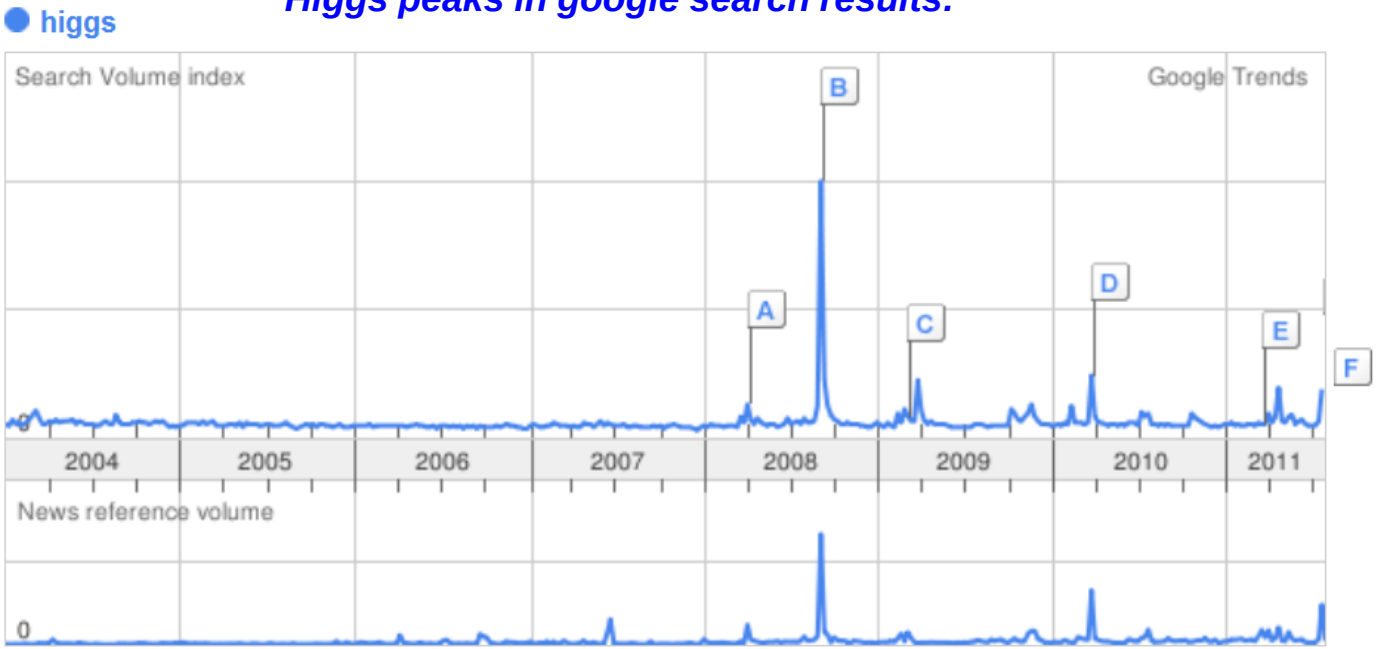
Tau sneutrinos mass < 440 GeV excluded, assuming coupling values λ'_{311} =0.01, λ'_{312}=0.01.

eμ resonance could also result from SM-like Z' with non-diagonal couplings

σ(Z') < 11 fb at 95% CL for m(Z') >700 GeV

Higgs peak in google search results

Higgs peaks in google search results:



A Scientist: Theoretical Higgs boson particle likely to be found in atoms soon
Detroit Free Press - Apr 8 2008

B Never mind the Higgs boson
ABC Science Online - Sep 10 2008

C New Experiments Constrain Higgs Mass
Science Daily (press release) - Mar 13 2009

D Large Hadron Collider a little closer to Higgs Boson answer after record collisions
NEWS.com.au - Mar 30 2010

E Time travel, God's particle and Higgs singlet: how messages might be sent to the past or future
Sydney Morning Herald - Mar 22 2011

F Hint of Higgs, but little more
Nature.com - Jul 25 2011