TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Mathematik und Naturwissenschaften, Fachrichtung Physik

Recent Results from the ATLAS Experiment

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on behalf of the ATLAS Collaboration

PLANCK 2012, 28.5.2012

SPONSORED BY THE Federal Ministry of Education and Research

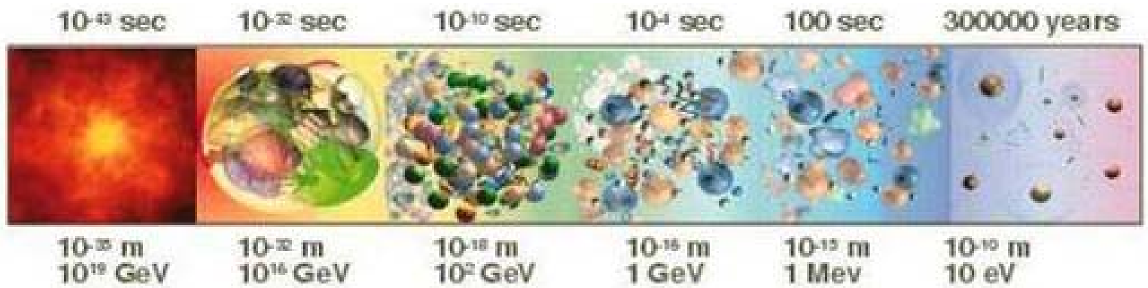
FSP 101 ATLAS

GRADUIERTEN KOLLEG Masse-Spektrum-Symmetrie

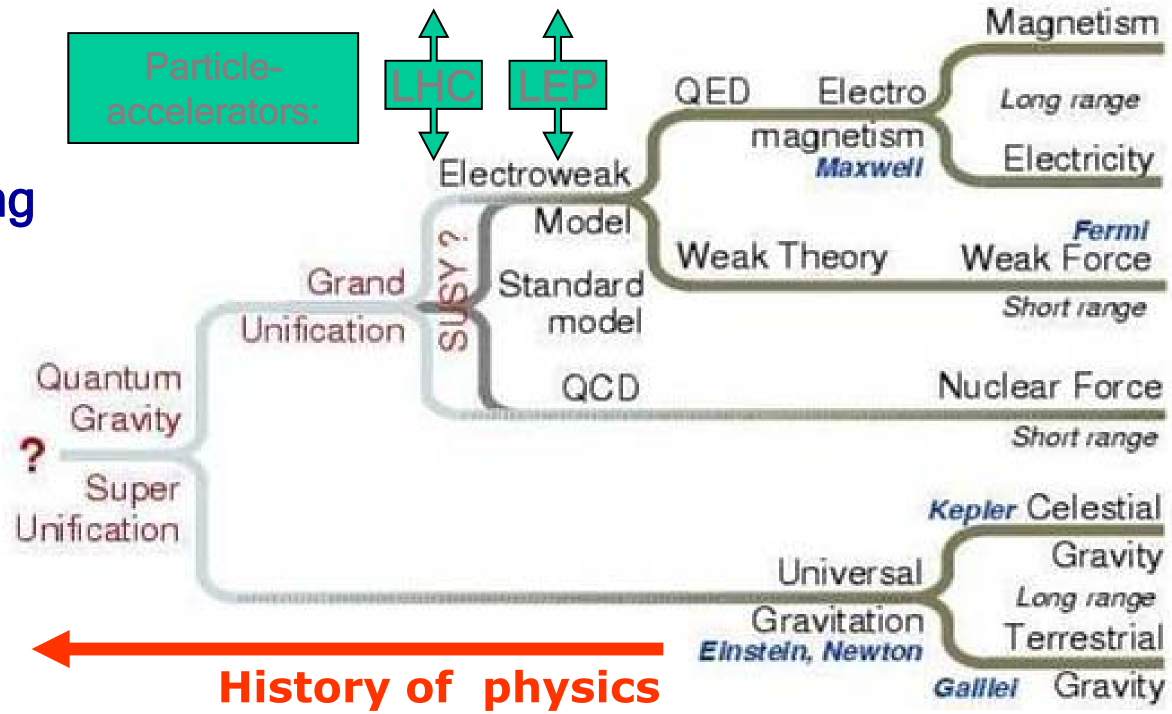
PHYSICS AT THE TERA SCALE Helmholtz Alliance

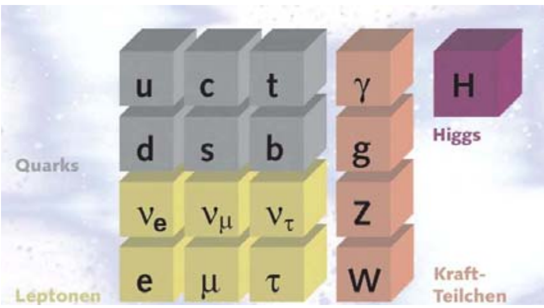
DRESDEN concept

The big picture



- Recreate processes between elementary particles having happened about 10^{-12} s after the Big Bang





History of physics back to the Big Bang

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ATLAS

Most prominent goals of the LHC

- Further scrutinize the Standard Model
  - Are there indeed only 3 families? (Why?)
  - Is the top quark just a normal quark?
- Find symmetry breaking mechanism at the Origin of Mass
  - LHC is exactly at the right energy ~ TeV (10^{-12} sec)!
  - Something MUST happen!
    - SM Higgs mechanism will either be detected or excluded
    - If excluded, another mechanism should be found
- Are there additional symmetries?
  - Supersymmetry between Fermions and Bosons?
  - Extra Gauge symmetries (Z´, W´, …)
- Any other expected or unexpected New Physics?
  - Extra dimensions, exotic …

LHC: Cross-sections and Luminosity

❖ Story of success:

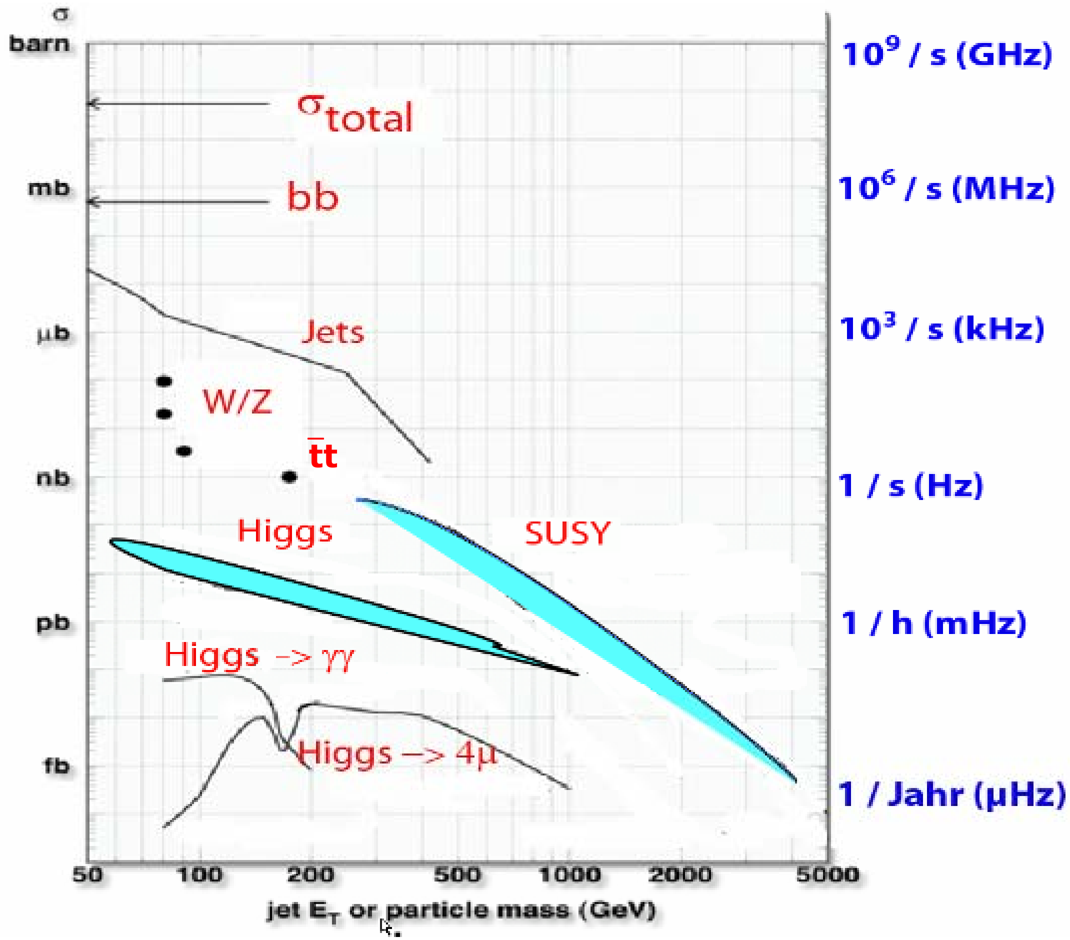
- 2010:
  $\mathcal{L} \sim 10^{31}\text{cm}^{-2}\text{s}^{-1}$
  $\int\mathcal{L}dt \sim 0.04\ \text{fb}^{-1}$

- 2011:
  $\mathcal{L} = 1\text{-}3.5 \times 10^{33}\text{cm}^{-2}\text{s}^{-1}$
  $\int\mathcal{L}dt = 5\ \text{fb}^{-1}$

- 2012:
  $\mathcal{L} = 3\text{-}7 \times 10^{33}\text{cm}^{-2}\text{s}^{-1}$
  $\int\mathcal{L}dt = 15\text{-}20\ \text{fb}^{-1}$?

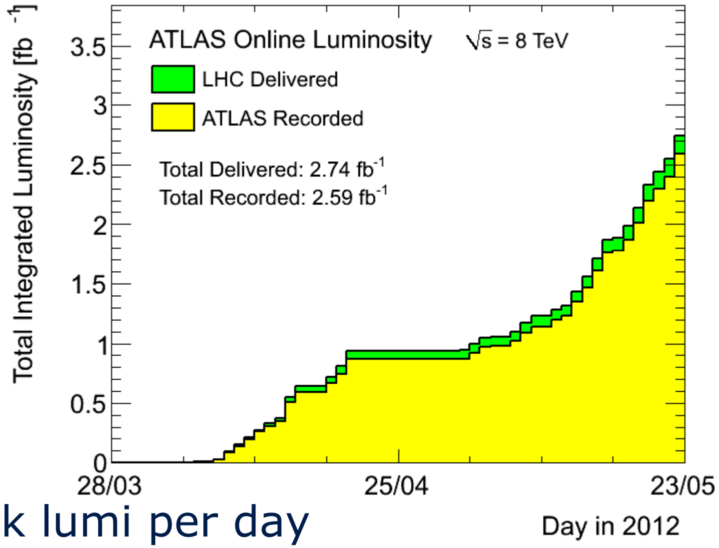
- $\geq$ 2015:
  $\mathcal{L} \geq 10^{34}\text{cm}^{-2}\text{s}^{-1}$?
  $\int\mathcal{L}dt \geq 100\ \text{fb}^{-1}$ per year ?

For $\mathcal{L} = 10^{33}\text{cm}^{-2}\text{s}^{-1}$

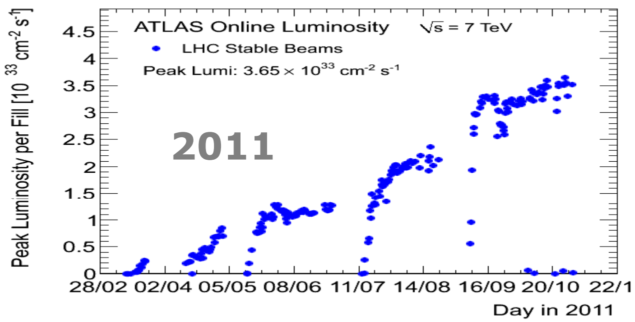


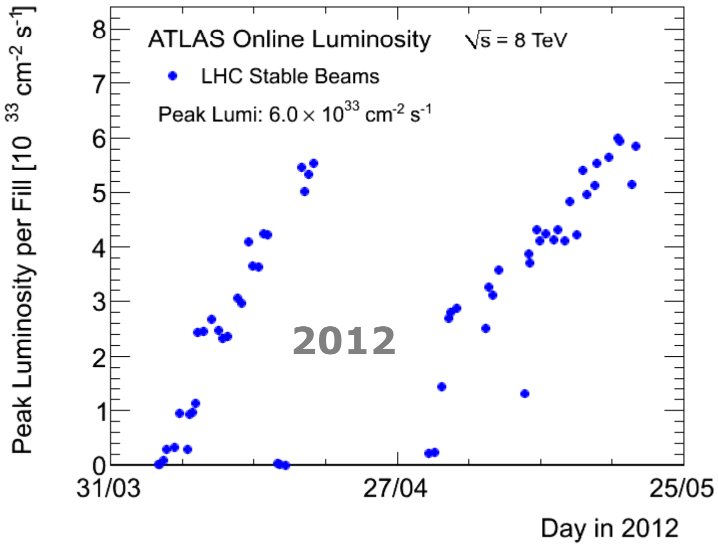
LHC: performance 2012

- Integrated Lumi 2012: so far 2.6 fb^{-1} (2011: 4.8 fb^{-1})



Peak lumi per day

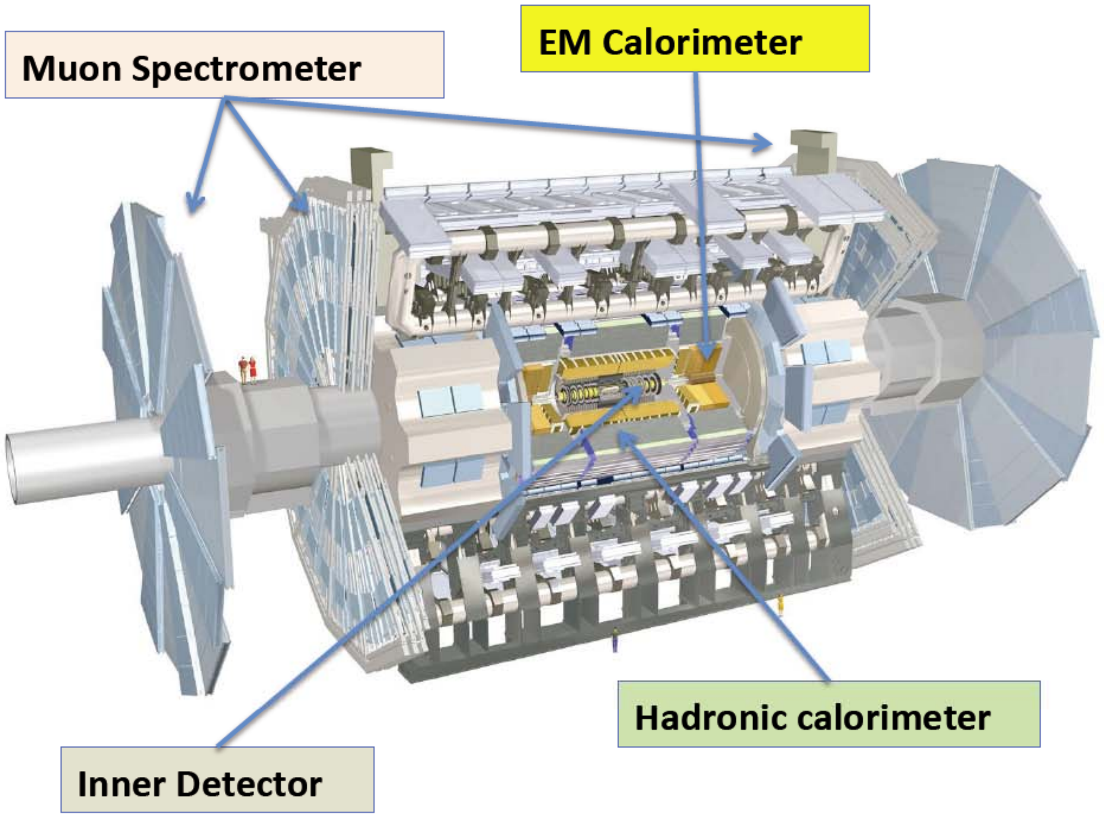




ATLAS:

Multi-purpose, high resolution and highly hermetic detector

- Magnets → 1 Central Solenoid + 3 air-core toroids
- Tracking → Silicon+Transition radiation tracker
- EM calo → Sampling LAr calo
- HAD calo → Plastic scintillator (barrel) + LAr technology (endcap)
- Muon → Trigger chambers (RPC and TGC) + Precision chambers (MDT and CSC)

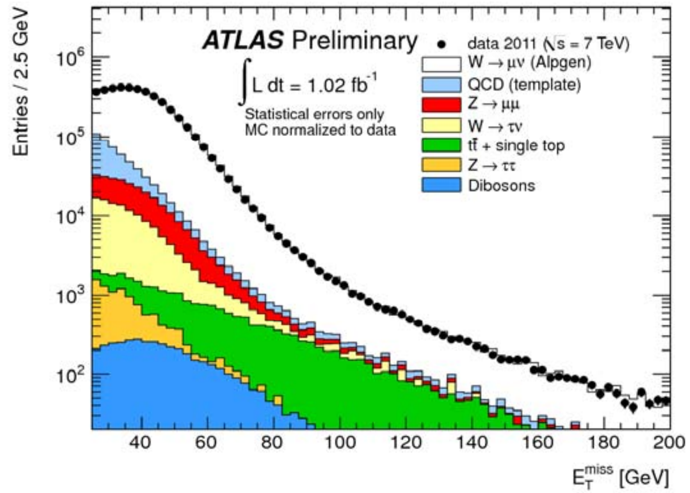


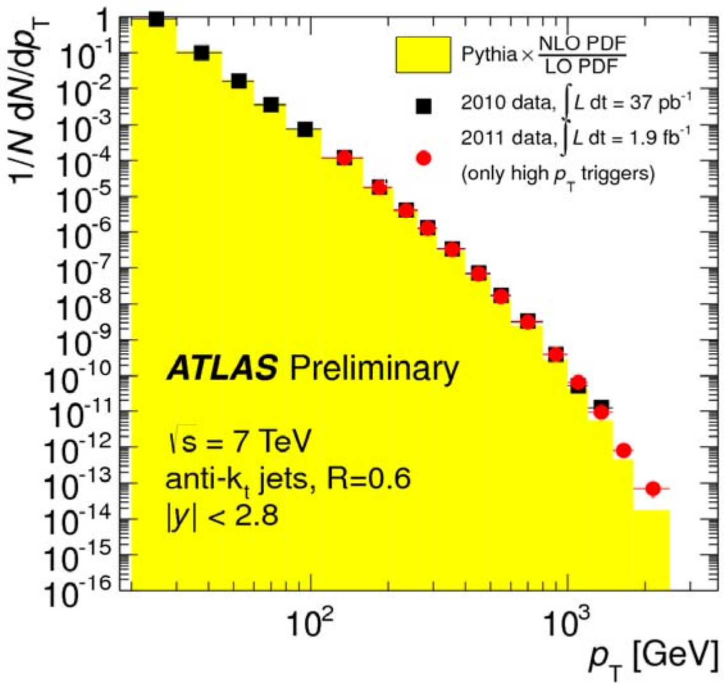
Reconstructed Objects:
- leptons
  - *electrons*
  - *muons*
  - *taus*
- photons
- jets
- missing energy
- b-jets

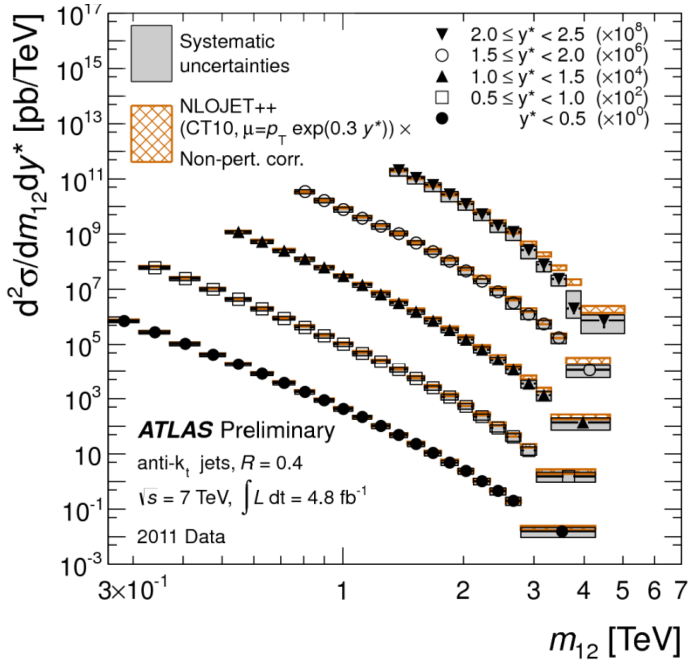
Kinematic variables:
- $p_T=|p|\sin\theta$
- $\eta = -\log\tan(\theta/2)$

ATLAS Performance:

- p_T , E_T^{miss}, di-jet masses…
- understood over many orders of magnitide



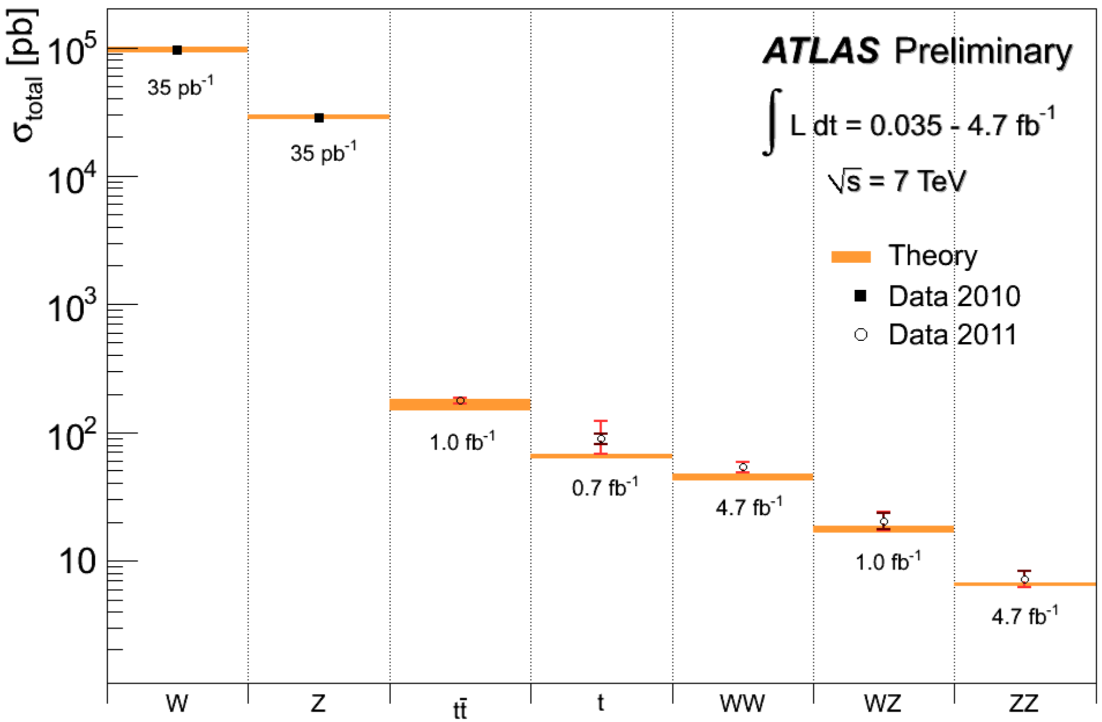




STANDARD MODEL MEASUREMENTS

Out of ~ 50 SM papers 2 topics selected :

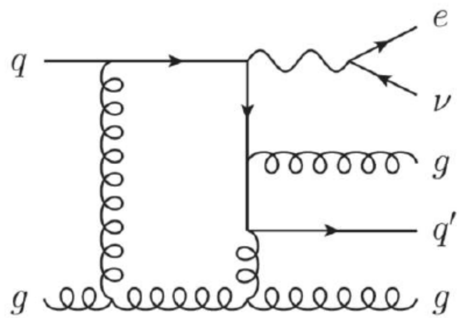
1. W/Z + Jets
2. Di-Boson Production (WW,ZW,ZZ)



Understanding Z/W+Jets

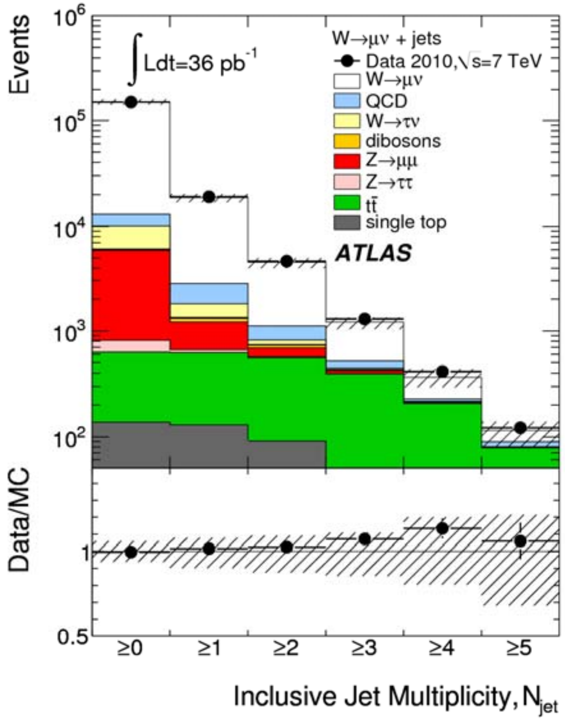
[Phys. Rev. D 85 (2012) 092002](https://doi.org/) (6.1.12)

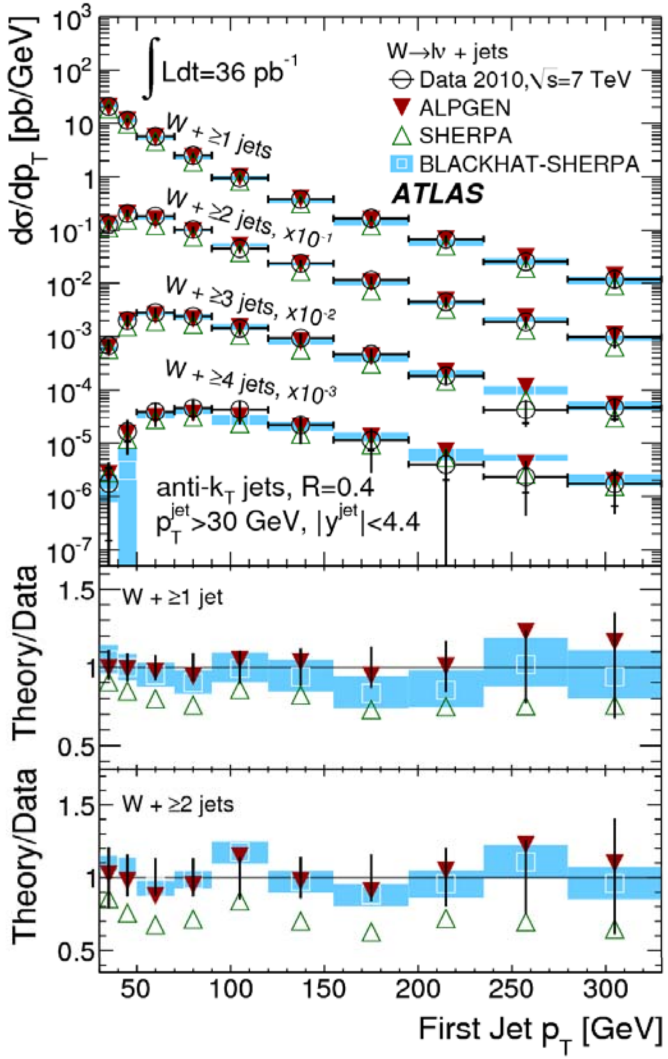
- W and Z total cross-sections:
  - Δ lumi = 3.4% dominant already w/ 2010 data
  - limits conclusions from comparison with theory
- W/Z, W^+/W^- ratios, or extra jets
  - Enable test of
    - MC generators
    - Proton pdfs



- Current reach
  - Up to 5 extra jets

W→ ℓν





W+b and Z+b cross-sections

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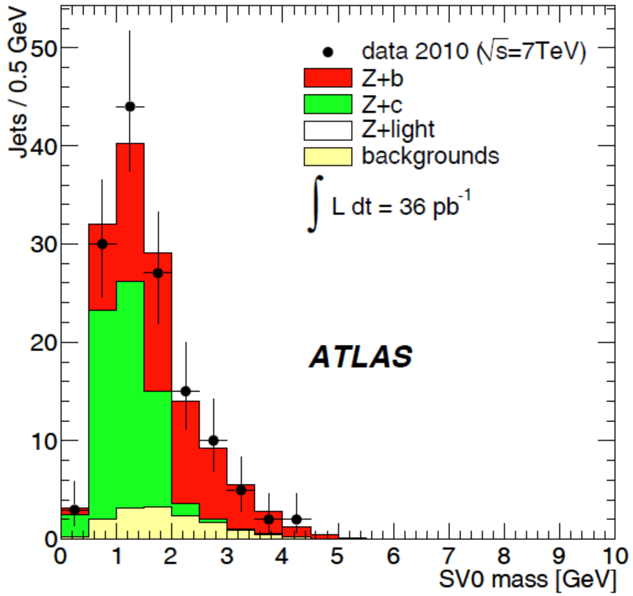
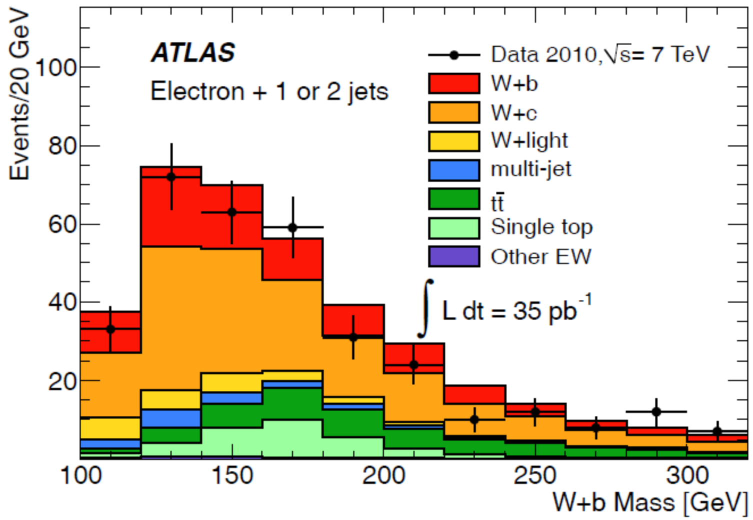
http://arxiv.org/abs/1109.1403, http://arxiv.org/abs/1109.1410

- ~ 1/100 of all jets expected to be b-jets
- Crucial for
  - b-pdfs
  - Background to searches
- Template fits to
  - M_{vertex}, M_{Wb}

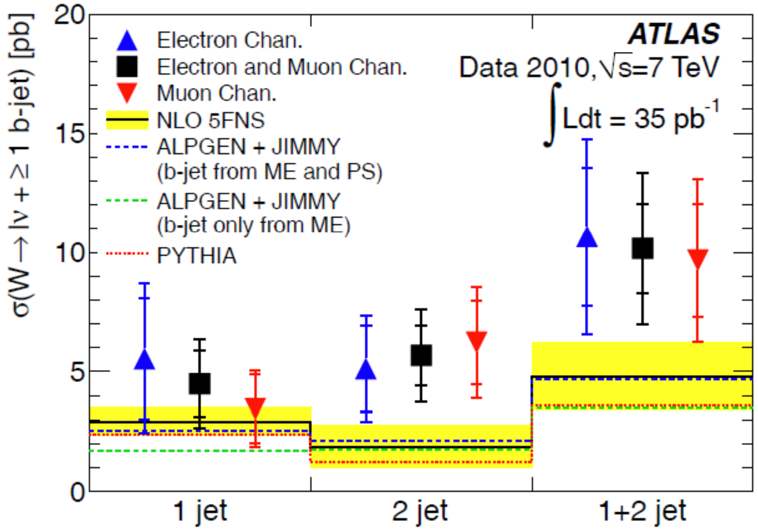




- Z+b: Fraction of b-jets / all jets:
  - agree well with simulations

Experiment	$(7.6^{+1.8}_{-1.6}(\text{stat})^{+1.5}_{-1.2}(\text{syst})) \times 10^{-3}$
MCFM	$(8.8 \pm 1.1) \times 10^{-3}$
ALPGEN	$(6.2 \pm 0.1\ (\text{stat only})) \times 10^{-3}$
SHERPA	$(9.3 \pm 0.1\ (\text{stat only})) \times 10^{-3}$

- W+b
  - Somewhat larger than expected



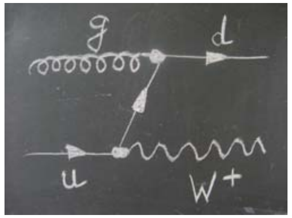
W charge asymmetry

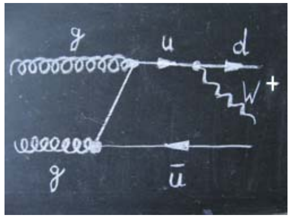
ATLAS-CONF-2011-129 (22.8.11)

- Only valence quarks and gluons:

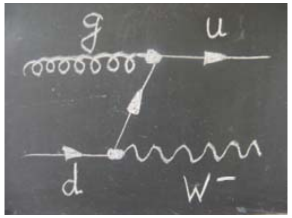
q+g → W+X   g+g→ W+X

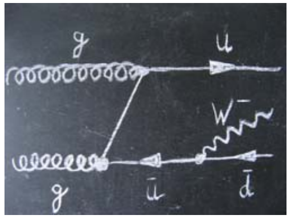
W^+

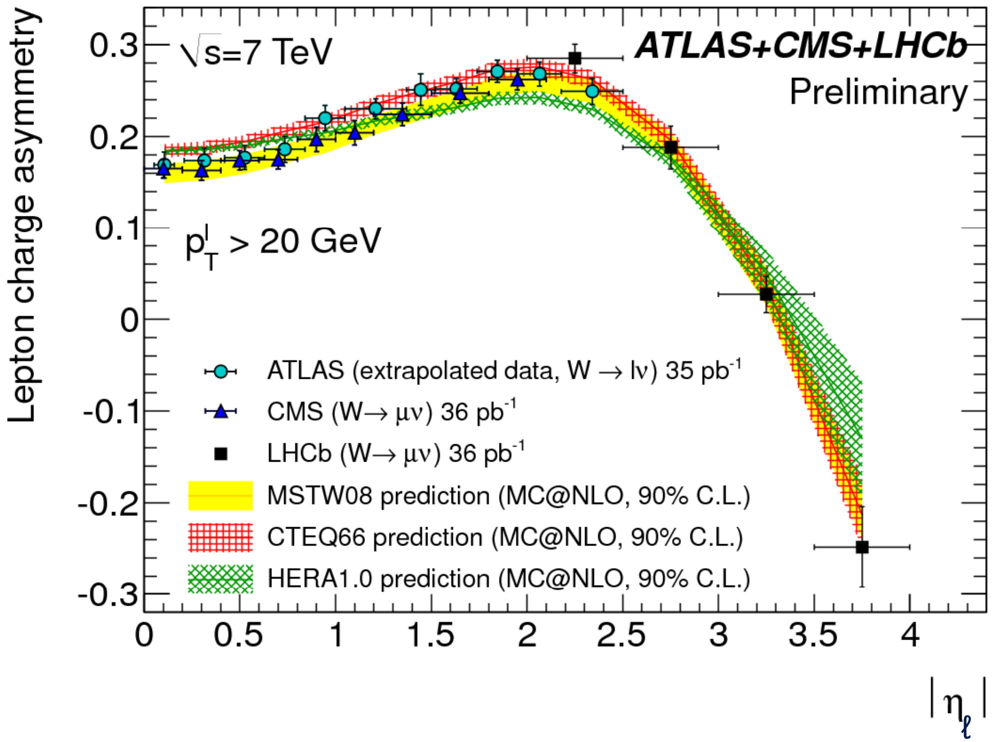




W^-







- Charge asymmetry

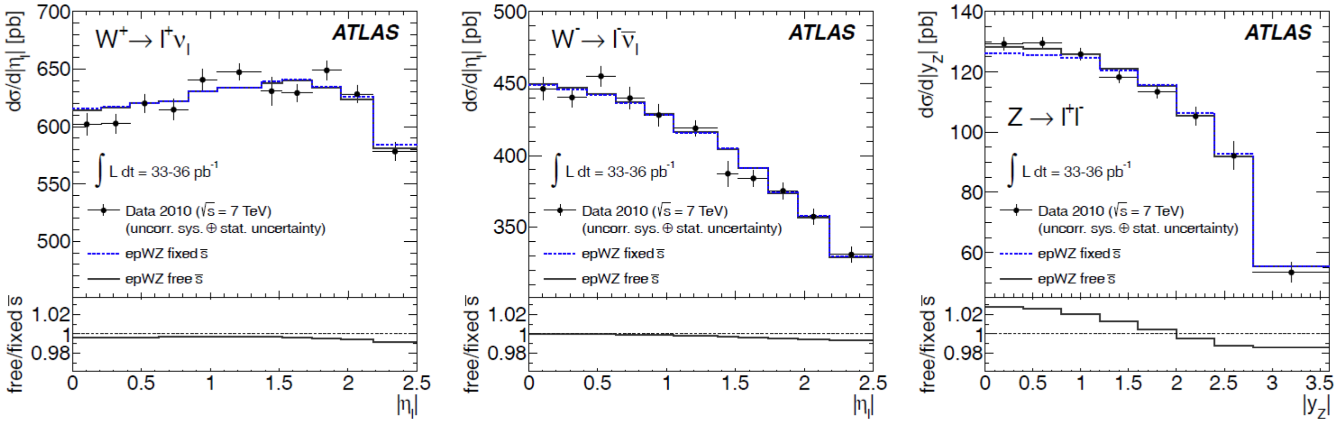
$$\frac{\#W^+ - \#W^-}{\#W^+ + \#W^-} \qquad \frac{2-1}{2+1} = \frac{1}{3} \qquad \frac{1-1}{1+1} = 0$$

- Sensitive test for parton density function (pdf) models
- η-dependent mix between contributing processes (plus sea quarks):
  - dependence on parton distributions visible as function on η_ℓ
  - Very forward η_ℓ : sign inversion due to weak parity violation (ℓ_L^- preferred)

Determination of the strange quark density

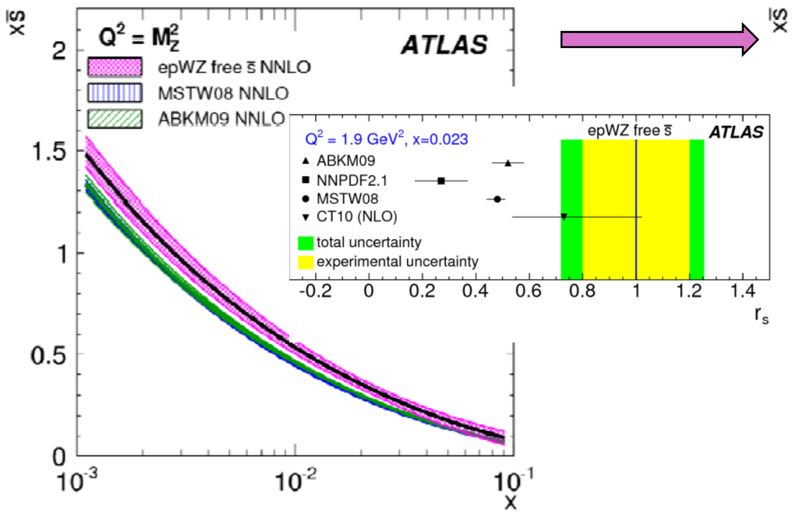
http://arxiv.org/abs/1203.4051, 19.3.2012, accepted by PRL

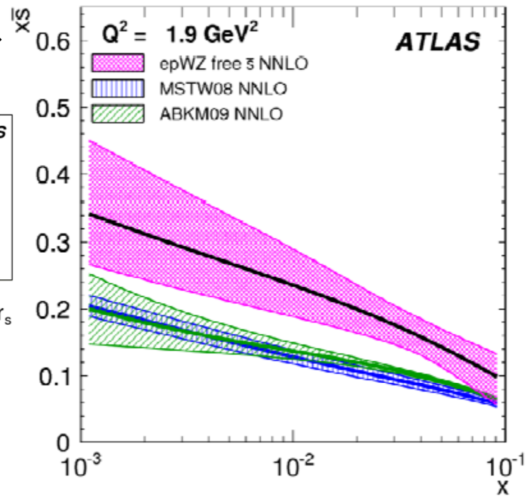
- Joint fit of ATLAS W/Z diff. x-sections and HERA DIS data using open access tool HERAfitter http://projects.hepforge.org/herafitter

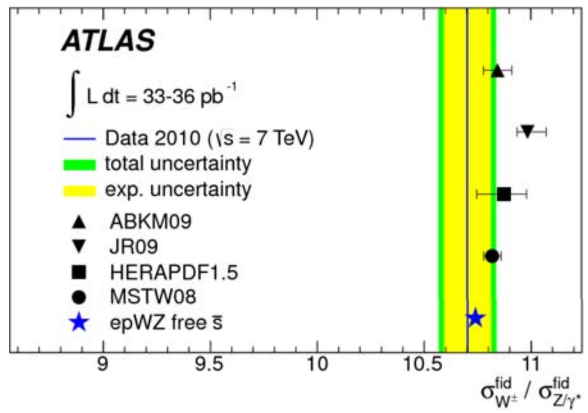


- Yields info about flavor composition of the light quark see: $x\Sigma := 2x(\bar{u} + \bar{d} + \bar{s})$
- Two NNLO fits
  - **fixed** $r_s := \bar{s} / \bar{d} = 0.5$ (taken from CC ν-Scatt. involving $W^- \bar{s} \to \bar{c}$)
  - **free** $\bar{s}$

Result: better fit w/o s-suppression, i.e. $r_s \sim 1$

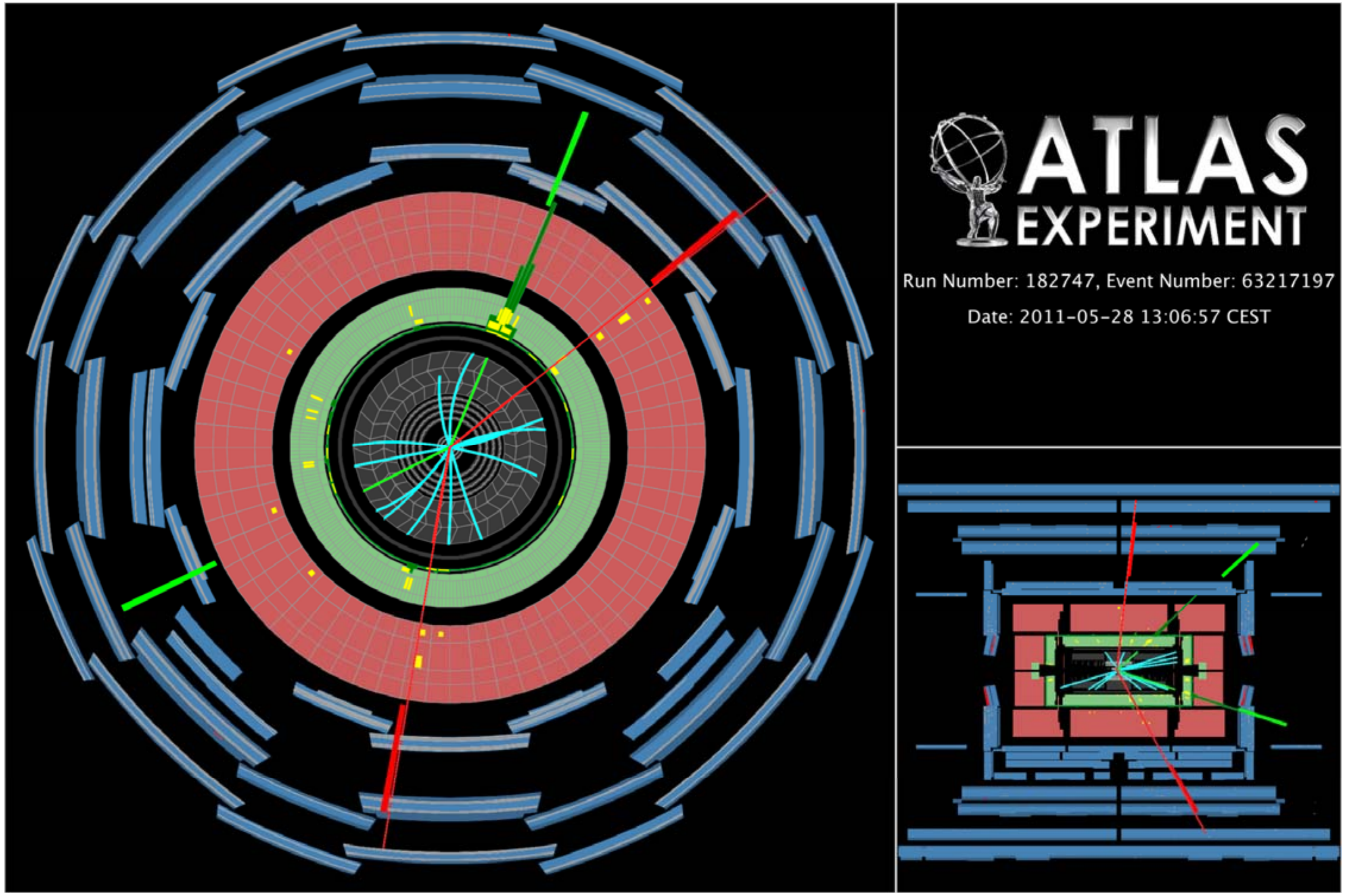






Di-Boson Productions (ZZ:WZ:WW ~ 1:2:4)

Candidate event for ZZ → ee μμ



❖ Aims:

- SM test, limits on anomalous triple gauge couplings (TGC)
- Understand ZZ and WW background for Higgs searches

Di-Boson Production: ZZ → ℓℓℓℓ + ℓℓνν

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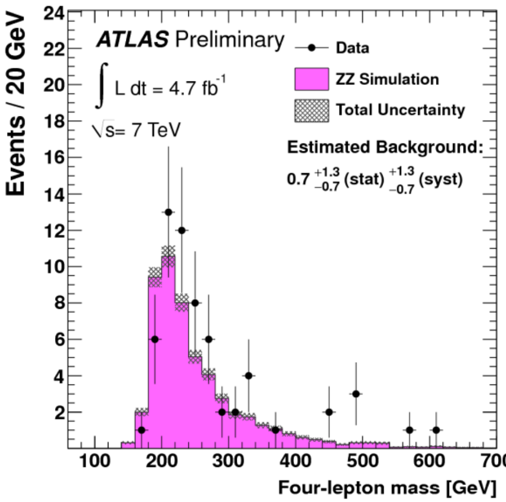
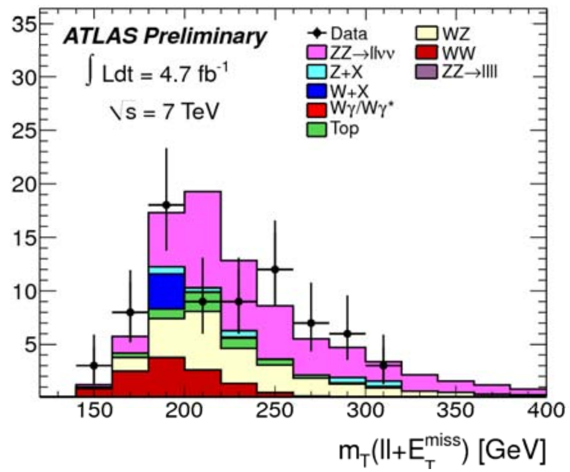
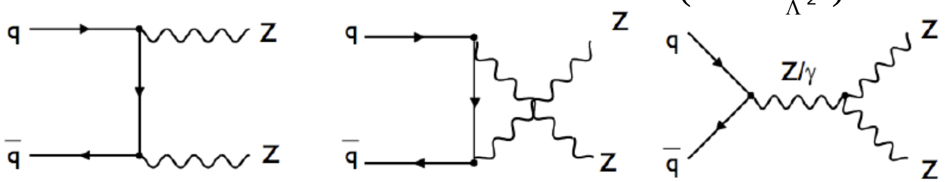
ATLAS-CONF-2012-021, ATLAS-CONF-2012-026 (4.+7.3.12)
arXiv:1110.5016v1(TGC limits) (23.10.11)

$$\sigma_{ZZ}^{tot} = 7.2^{+1.1}_{-0.9}\,(\text{stat})\,^{+0.4}_{-0.3}\,(\text{syst}) \pm 0.3\,(\text{lumi})\,\text{pb} \quad \text{SM:} \quad 6.5^{+0.3}_{-0.2}\,\text{pb}$$

- 4.7 fb^{-1} of 2011 data:
  - ℓℓℓℓ: nearly background-free
  - ℓℓνν: mainly Di-Boson bckgr.
- Non- SM contributions:
  - Neutral TGC
    - $f_4^{\gamma,Z}$: CP-violating
    - $f_5^{\gamma,Z}$: CP-conserving
  - Would introduce excess at high M_{ZZ} and p_t^Z
  - Unitarity reinstalled by $f_i^V = \dfrac{f_{i,0}^V}{\left(1 + \frac{\hat{s}}{\Lambda^2}\right)^3}$

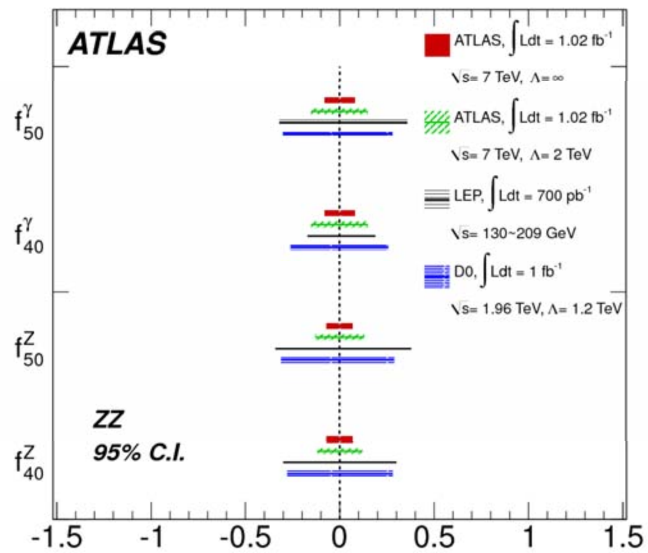






Standard Model Production   SM Forbidden

- 1 fb^{-1} limits improve over LEP & TeVatron
  - BSM physics predict typ. $O(10^{-2} – 10^{-3})$
  - SM loop contribution $O(10^{-4})$



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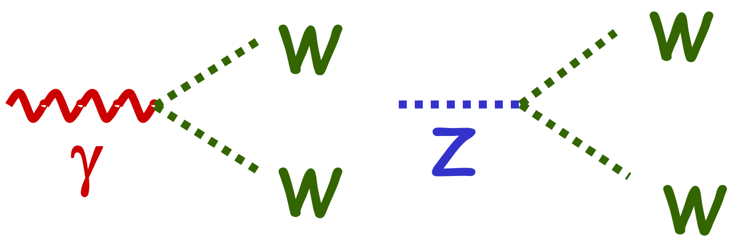
Charged triple gauge couplings WWγ WWZ



general WWγ and WWZ interaction: 14 parameters

applying C and P invariance & low-energy constraints: 3 parameters left

→ SM values

$$\kappa_\gamma = 1, \qquad g_1^Z = 1, \qquad \lambda_\gamma = 0$$

related by custodial SU(2) with:

$$\kappa_Z = g_1^Z - \tan^2\theta_W(\kappa_\gamma - 1), \qquad \lambda_Z = \lambda_\gamma$$

relation with static W properties:

magnetic dipole moment

$$\mu_W = \frac{e}{2m_W}\left(1 + \kappa_\gamma + \lambda_\gamma\right)$$

electric quadrupole moment

$$Q_W = \frac{e}{m_W^2}\left(\kappa_\gamma - \lambda_\gamma\right)$$

relation with W substructure:

Average W radius

$$R_W = \frac{\kappa_\gamma + \lambda_\gamma - 1}{m_W} = \tfrac{2}{e}\Delta\mu_W$$

Deformation

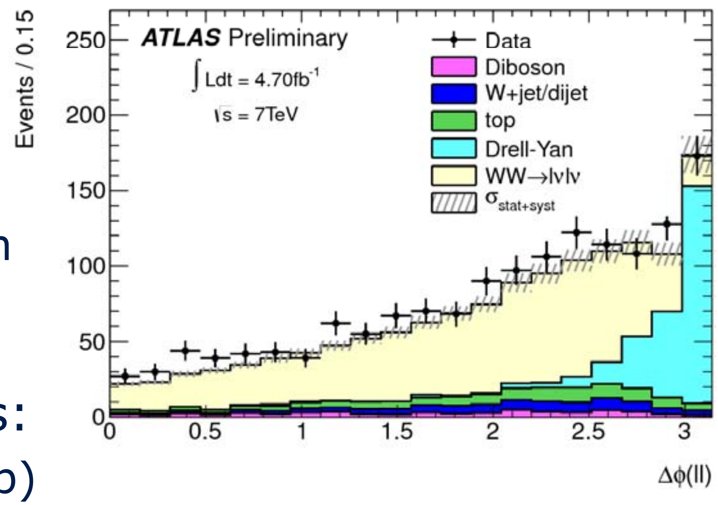
$$D_W = \frac{5}{4}\frac{\kappa_\gamma - \lambda_\gamma - 1}{m_W^2} = \frac{5}{4e}\Delta Q_W$$

Di-Boson Production: WW and WZ

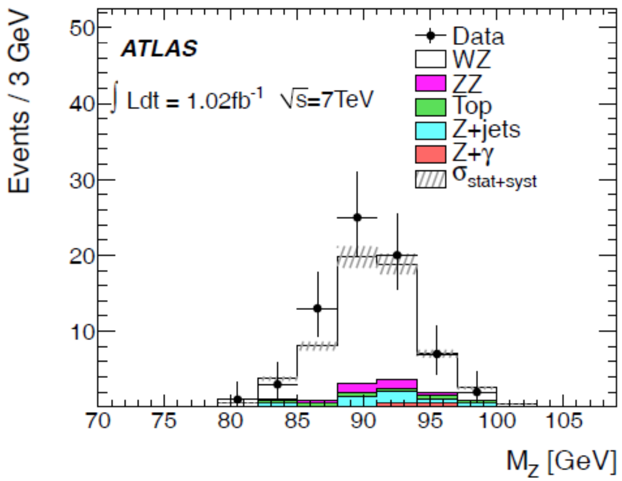
ATLAS-CONF-2012-025 (5.3.12) , CERN-PH-EP-2011-184

- ❖ 4.7 fb^{-1} (WW) and 1.0 fb^{-1} (WZ)
  - All lept.channels
  - Good agreement with SM prediction

WW



WZ



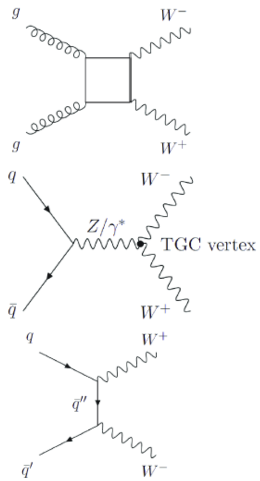
- ❖ Total cross-sections:
  - WW (SM: 45±3 pb)

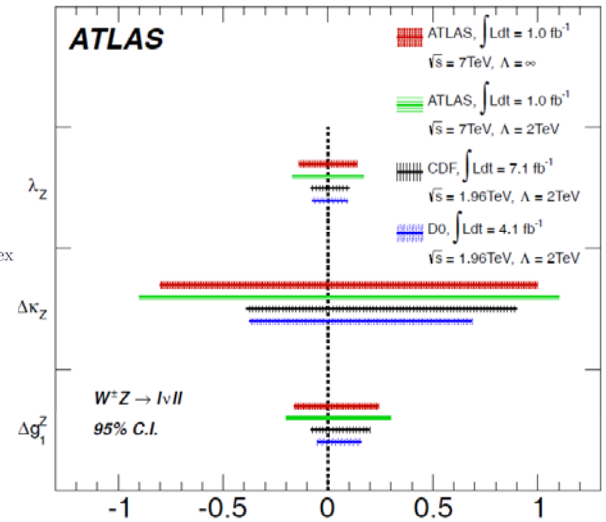
$$53.4 \pm 2.1(\text{stat}) \pm 4.5(\text{syst}) \pm 2.1(\text{lumi})\ \text{pb}$$

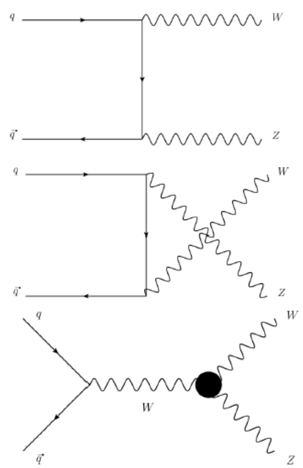
  - WZ (SM: 17±1 pb)

$$20.5^{+3.1}_{-2.8}(\text{stat.})^{+1.4}_{-1.3}(\text{syst.})^{+0.9}_{-0.8}(\text{lumi.})\ \text{pb.}$$

- ❖ Anomal.TGC limits
  - esp. good for λ_Z
  - Approaching TeVatron sensitivity







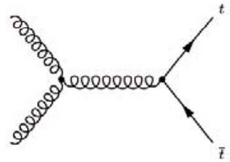
TOP PHYSICS

1. Cross-sections
2. Mass
3. FCNC

Production @ LHC 7 TeV

ttbar pairs

QCD resonances?

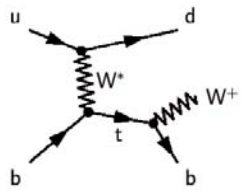


$$\sigma_{t\bar{t}}^{NLO} = 165^{+11}_{-16}\ pb$$

single top

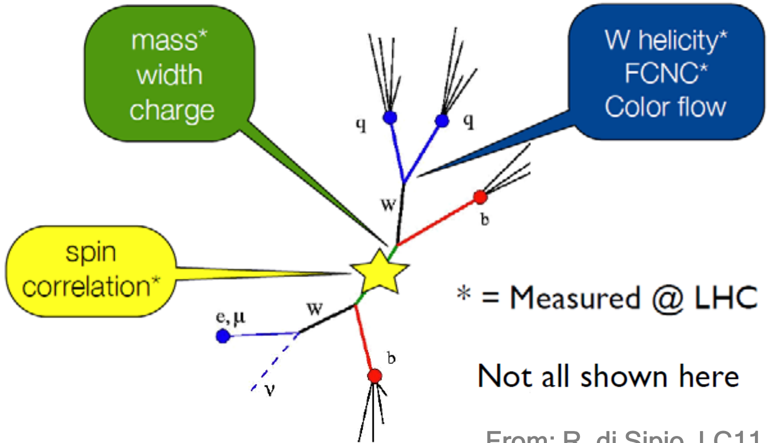
EW

FCNC, V_{tb}



$$\sigma_{t-ch}^{NLO} = 64.57^{+3.32}_{-2.62}\ pb$$
$$\sigma_{Wt-ch}^{NLO} = 15.74^{+1.34}_{-1.36}\ pb$$
$$\sigma_{s-ch}^{NLO} = 4.63^{+0.29}_{-0.27}\ pb$$

Properties



From: R. di Sipio, LC11, Sept. 11

$t\bar{t}$ cross-sections

http://arxiv.org/abs/1202.4892 (22.2.12)
ATLAS-CONF-2011-121 (22.8.11) , ATLAS-CONF-2012-024 (5.3.12)

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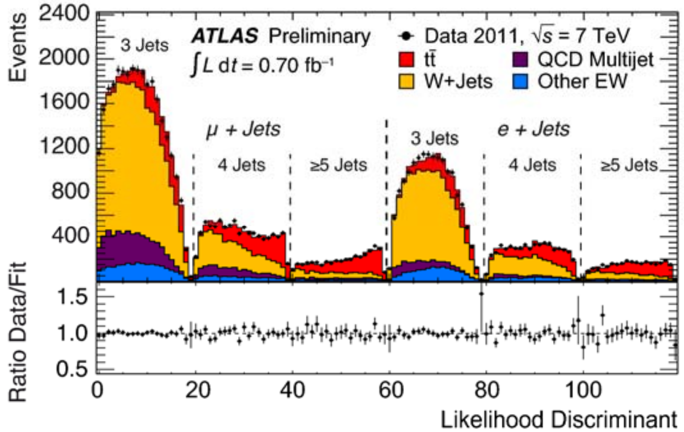
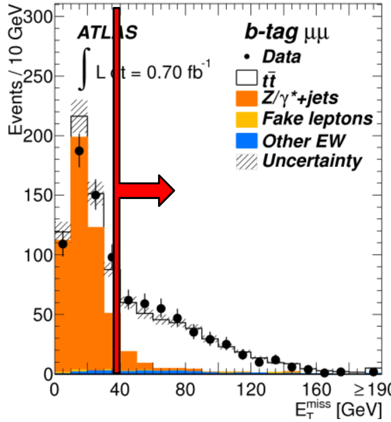
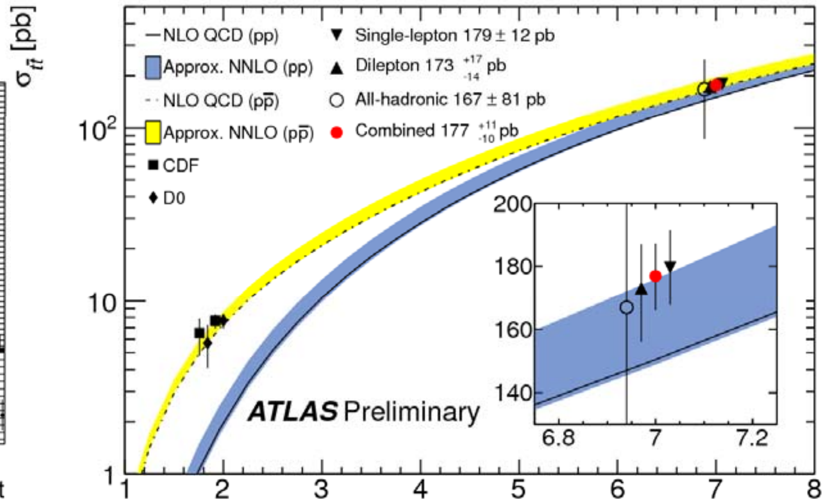
- $t\bar{t}$ cross-section measurement dominated by
  - Single lepton, ℓ+jets ($0.7\ fb^{-1}$, likelihood)

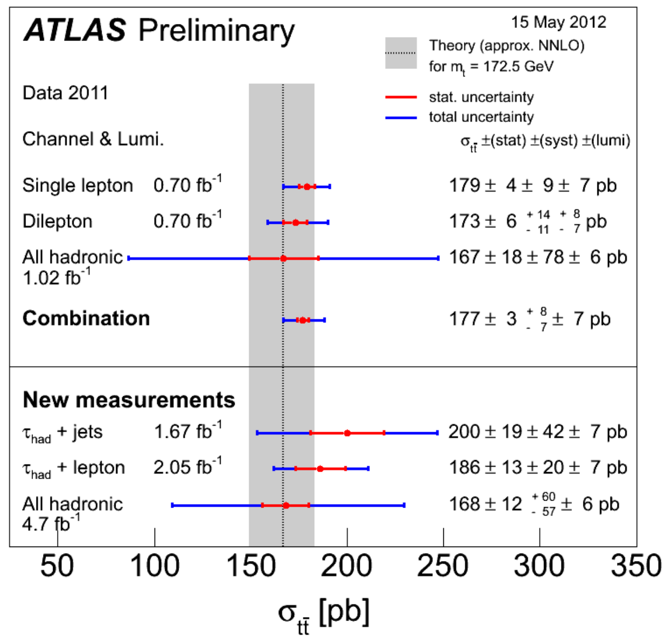


  - Di-lepton ($0.7\ fb^{-1}$, cut-based)



  - Other:
    - All hadronic
    - τ_{had} + jets
    - τ_{had} + lepton





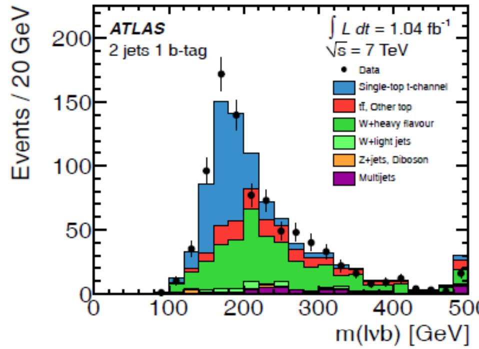
- Measurement more precise than theory:
  - ATLAS: σ_{tt} (7 TeV) = 177^{+11}_{-10} pb
  - Theory: σ_{tt} (7 TeV) = 165^{+11}_{-16} pb

Some single t analyses

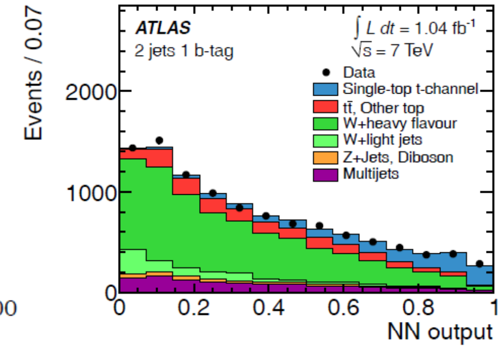
http://arxiv.org/abs/1205.3130v1 , 14.5.2012
http://arxiv.org/abs/1203.0529 , 2.3.2012

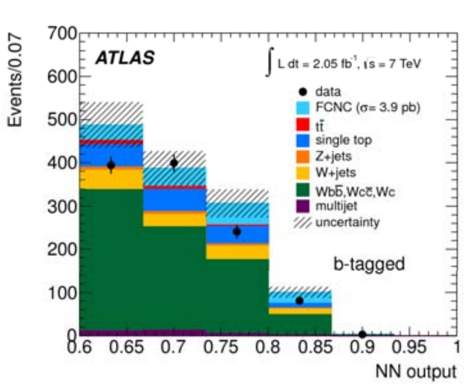
- Single-top t-channel (2 or 3 jets + 1 b-tag)
  - Sensitive to FCNC (u,c→t) and V_{tb}
    - Cut-based: $\sigma_{tq} = 92^{+29}_{-26}$ pb
    - NN-selection: $\sigma_{tq} = 83 \pm 4^{+20}_{-19}$ pb
    - SM-Theory: $\sigma_{tq} = 65 \pm 3$ pb
  - Extraction of $V_{tb} = \sqrt{[\sigma_{tq}(NN)/\sigma_{tq}(SM)]}$
    - $V_{tb} = 1.13^{+0.14}_{-0.13} \pm 0.02$
  - Sensitive to FCNC (q→t)
    - $\sigma_{qg \to t} \times \mathcal{B}(t \to Wb) < 3.9$ pb

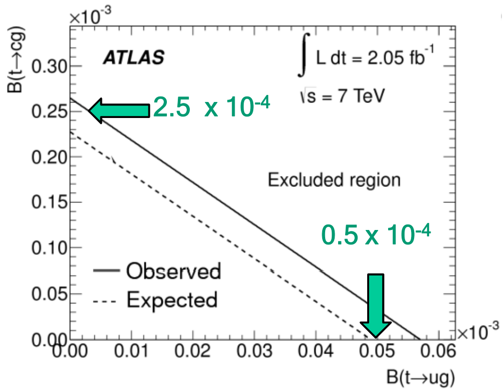
cut-based

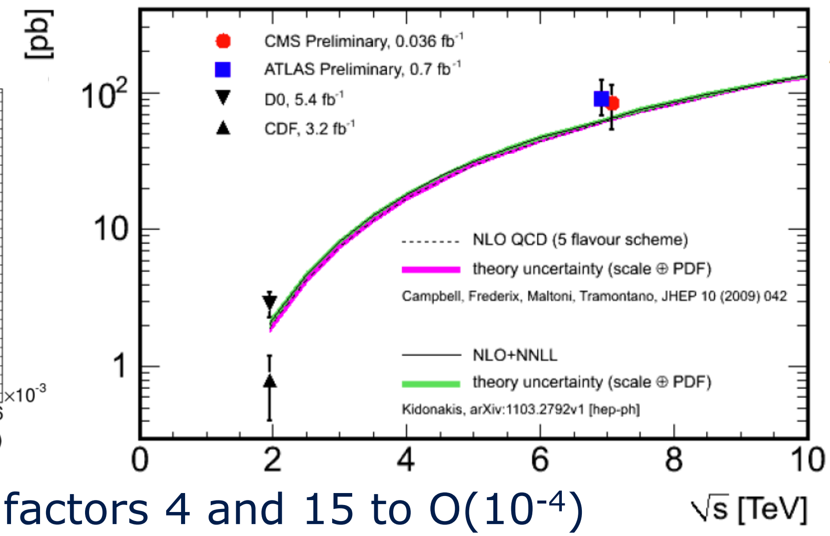


NN-based









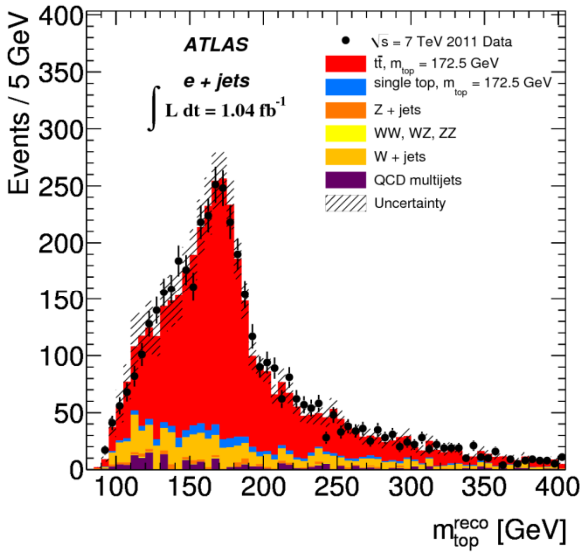
- Improves previous limits on t→c/u+g by factors 4 and 15 to O(10^{-4})
  - BSM physics: FCNC up to O(10^{-4}) possible

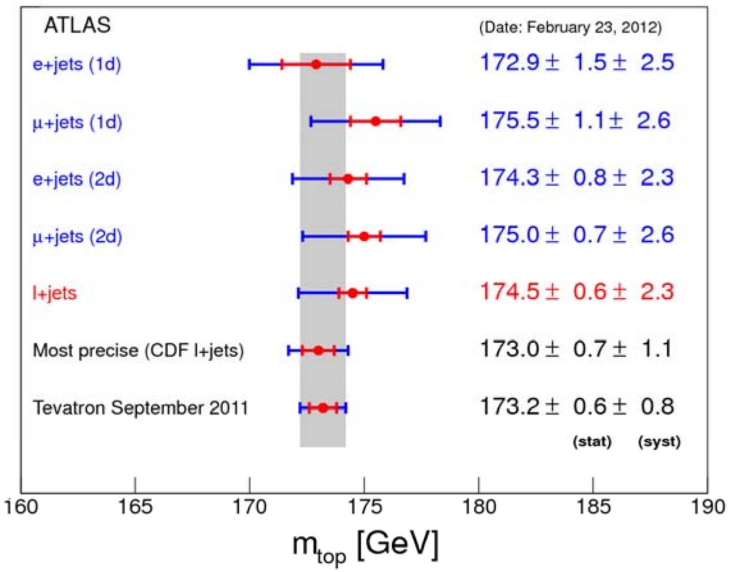
top quark mass

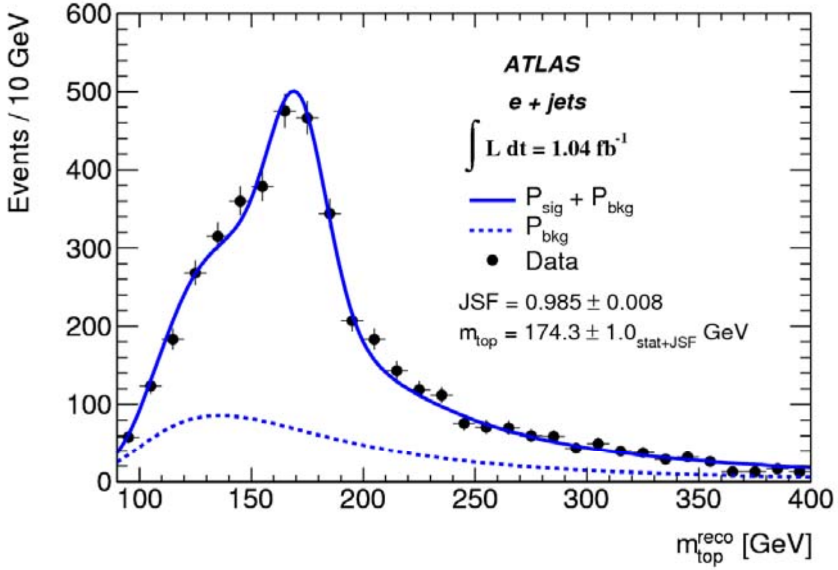
http://arxiv.org/abs/1203.5755 (26.3.12)

ATLAS-CONF-2012-030, (14.3.12)

- Measured w/ 1.04 fb^{-1} in ℓ+jets channel
  - ≥ 4 jets with ≥ 1 b-tag
  - jjb combination w/ highest p_T defines m_t^{reco}
  - In-situ Jet Scaling Factor JSF from m_W^{reco}
- 2d (m_t^{reco},JSF) template analysis resulting in
  - JSF(e)=0.985±0.008, JSF(μ)=0.986±0.006
  - m_t^{reco} =174.5 ± 0.6 ± 2.3 GeV
- Also first measurement in all-had channel
  - m_t^{reco} = 174.9 ± 2.1 ± 3.8 GeV







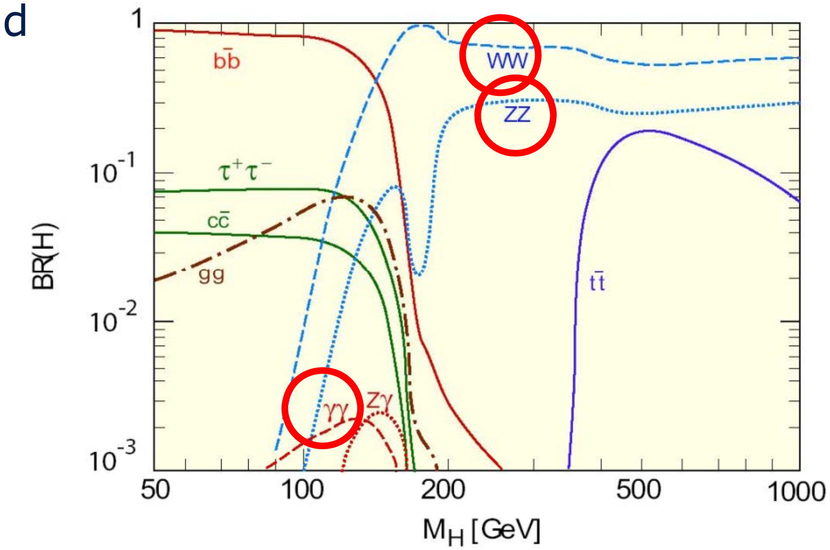
SM HIGGS SEARCHES

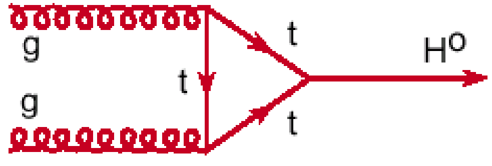
1. ZZ
2. WW
3. $\gamma\gamma$

SM Higgs Boson production and decay

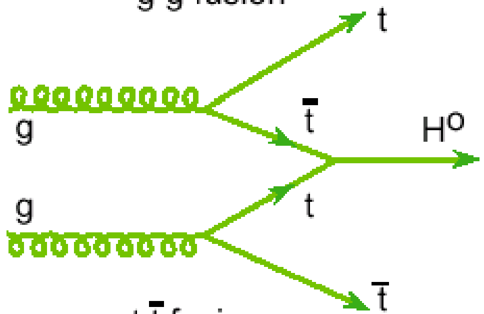
- Discover Higgs field by Higgs Boson production
  - Higgs Boson ~ excitation of Higgs field (Rather like a vortex ~ excitation of air)
  - Need to move massive particles with high E through Higgs field to create excitations

- Higgs decays predicted
  - In SM just depend on unknown M_H

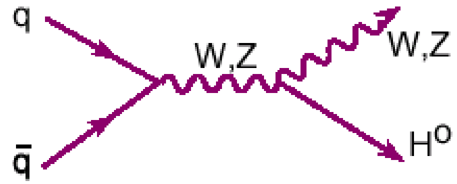




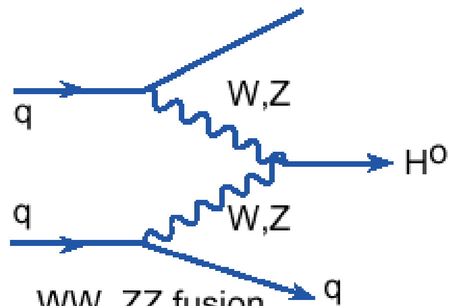
g g fusion



$t\bar{t}$ fusion



W, Z bremsstrahlung



WW, ZZ fusion

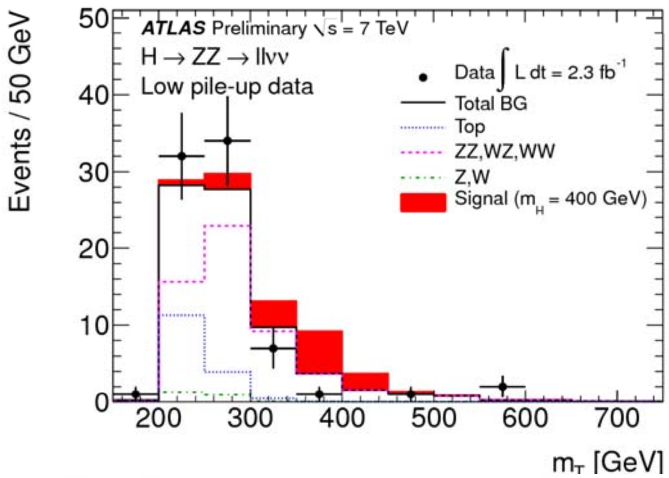
H → ZZ

ATLAS-CONF-2012-016 (2.3.12), ATLAS-CONF-2012-017 (2.3.12)

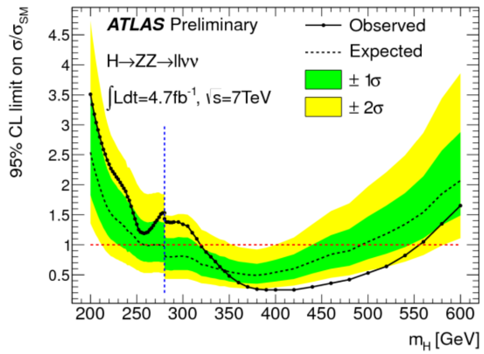
❖ ZZ: most sensitive channel above m_H > 200 GeV

- **llνν subchannel** (most sensitive above 300 GeV)
  - Discriminant: transverse mass

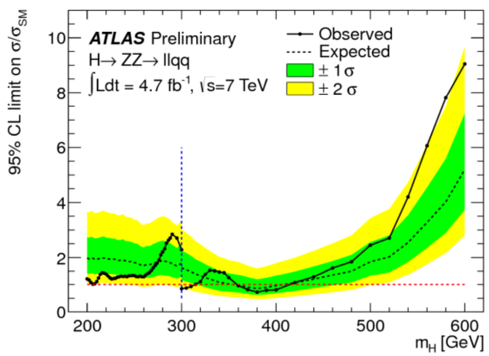
$$m_T^2 \equiv \left[\sqrt{m_Z^2 + |\vec{p}_T^{\,\ell\ell}|^2} + \sqrt{m_Z^2 + |\vec{p}_T^{\,\text{miss}}|^2}\right]^2 - \left[\vec{p}_T^{\,\ell\ell} + \vec{p}_T^{\,\text{miss}}\right]^2$$

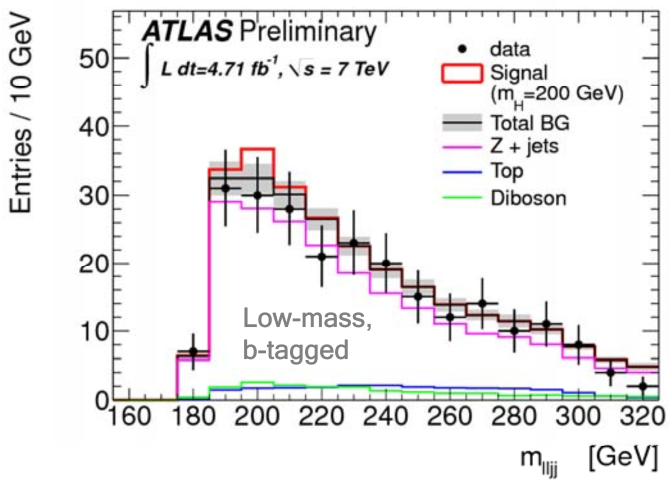


  - exclusion range 320 GeV<m_H<560GeV



- llqq subchannel
  - Discriminant: lljj mass, low/high mass cuts, optional Z→bb tagging (to suppress Z+Jets)
  - Contributes significantly to limit below ~ 400 GeV

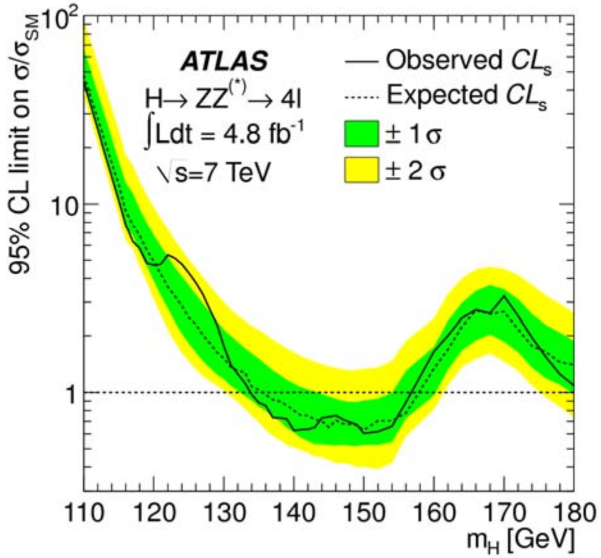


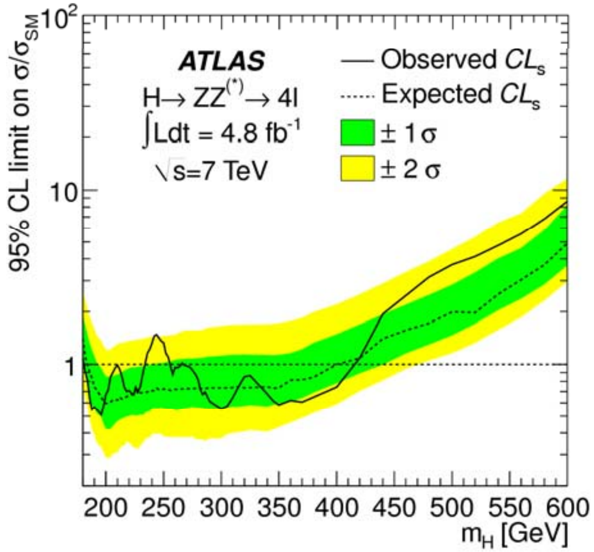


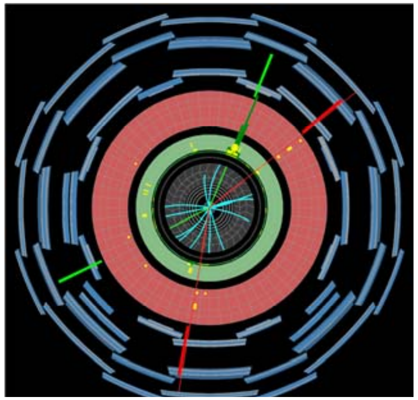
H→ZZ→ 4 leptons

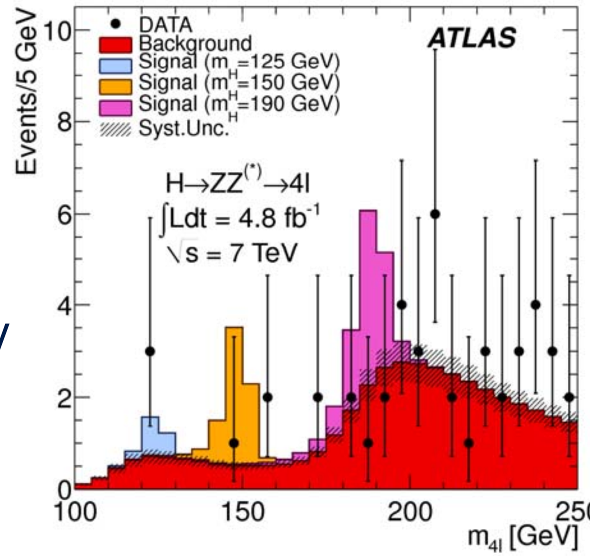
Phys.Lett. B710 (2012) 383-402, *7.2.12*

- „Golden channel" (virtually no background, other than true SM ZZ)
- Most sensitive of all channels for 200 GeV<m_H<300 GeV
- 2nd most sensitive (after WW) for 130 GeV<m_H<200 GeV but much better mass resolution than WW







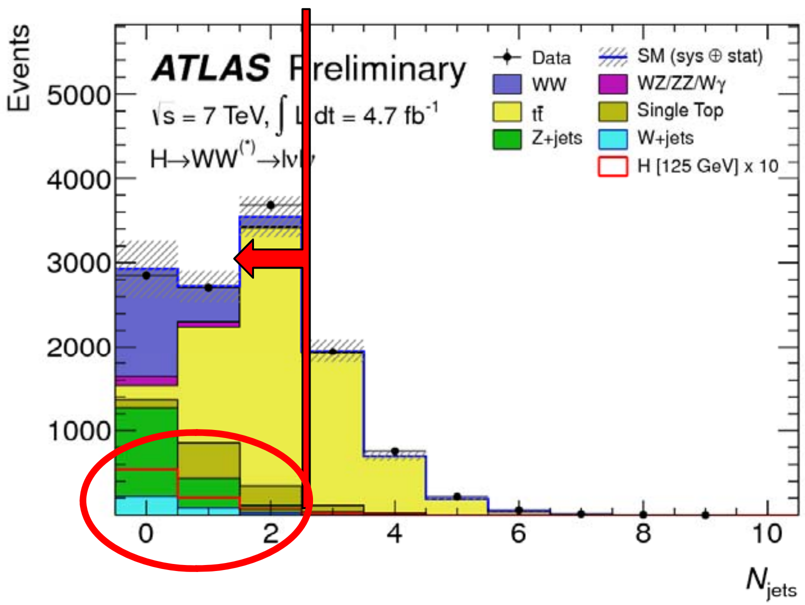


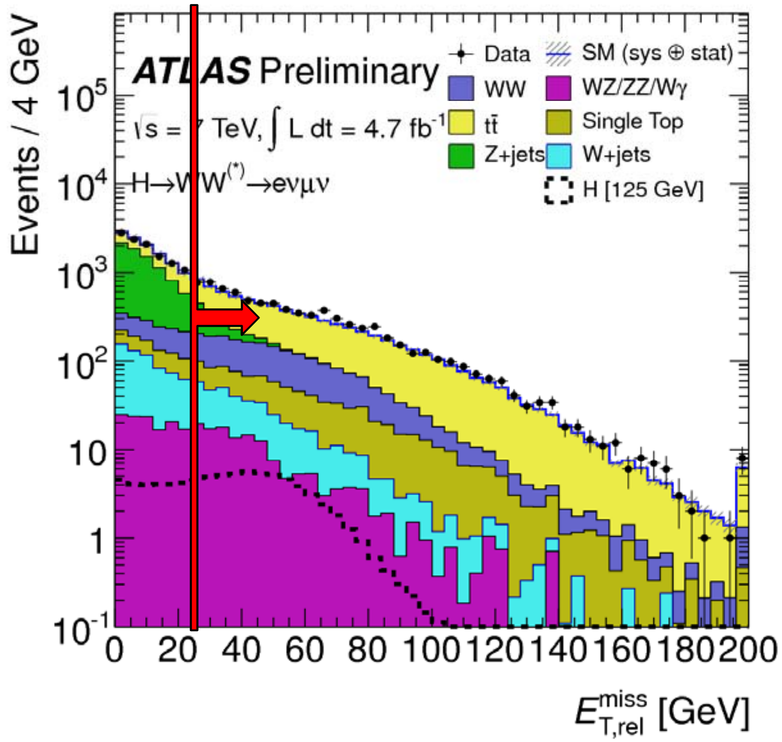
- Exclusion at 95% CL
  - 134–156 GeV, 182–233 GeV, most of 256-415 GeV
- „Excesses"
  - ~ 125 GeV, ~ 240 GeV w/in 2σ

H → WW

ATLAS-CONF-2012-012, 5.3.12

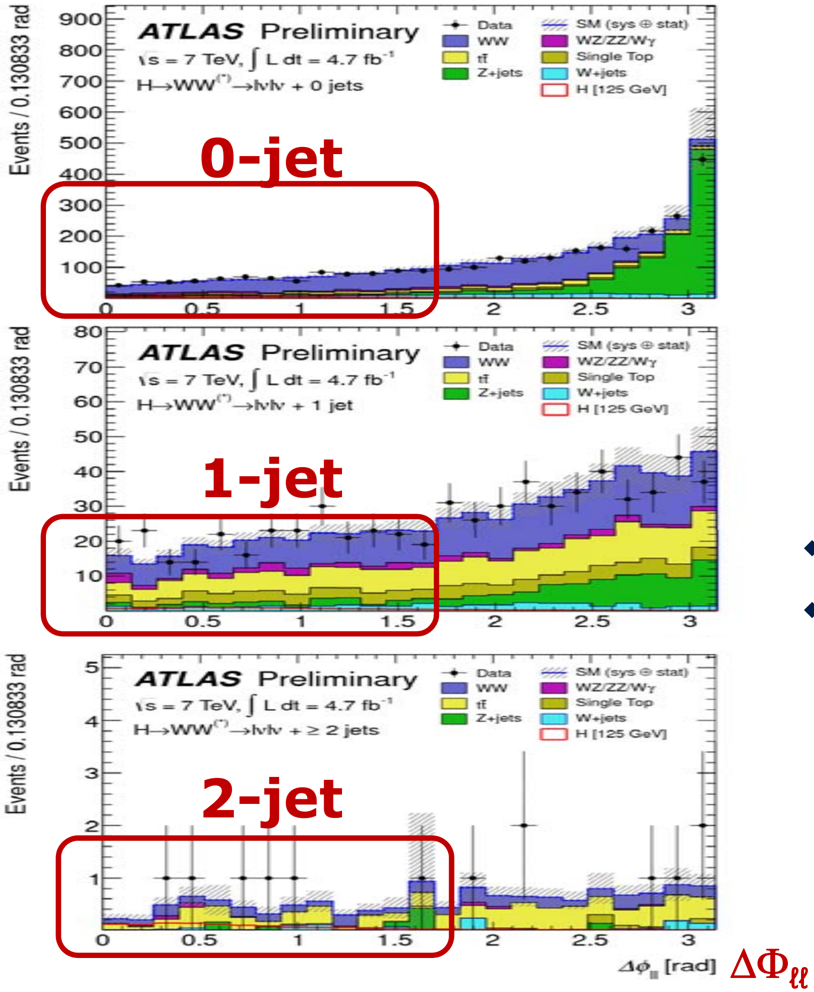
- Most sensitive SM Higgs decay channel in range [120;200] GeV but much worse mass resolution than ZZ
- Most promising final state: $\ell^+\nu\ell^-\nu$, ℓ =(e,μ)
- Essential preselection cuts:
  - $E_{T,rel}^{miss} = \begin{cases} E_T^{miss} & \text{if } \Delta\phi \geq \pi/2 \\ E_T^{miss} \cdot \sin\Delta\phi & \text{if } \Delta\phi < \pi/2 \end{cases}$ > 40(ℓℓ) / 25(eμ) GeV with $\Delta\phi = \angle(E_T^{miss}, \ell \text{ or jet})$
  - N_{jets} = 0, 1 or 2

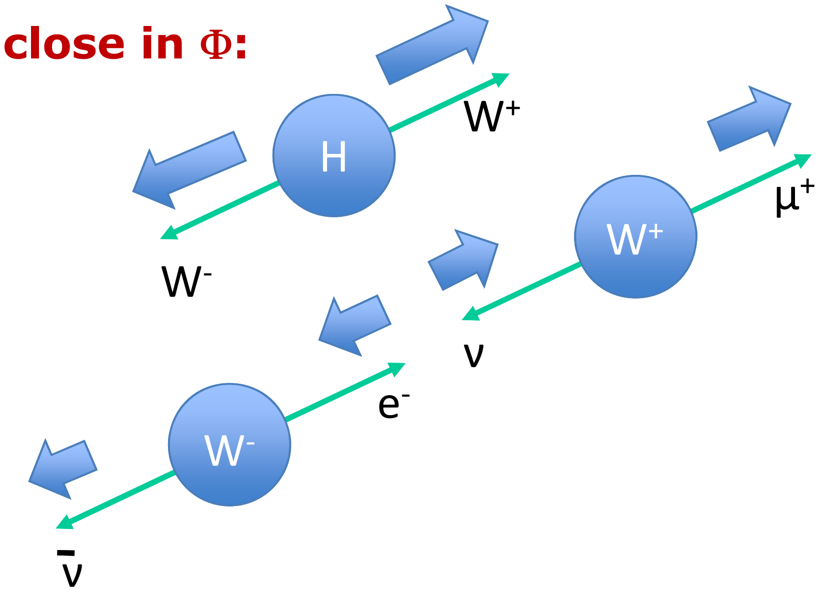




Kinematic separation

- Spin correlation:
  - **Leptons from Higgs tend to be close in Φ:**



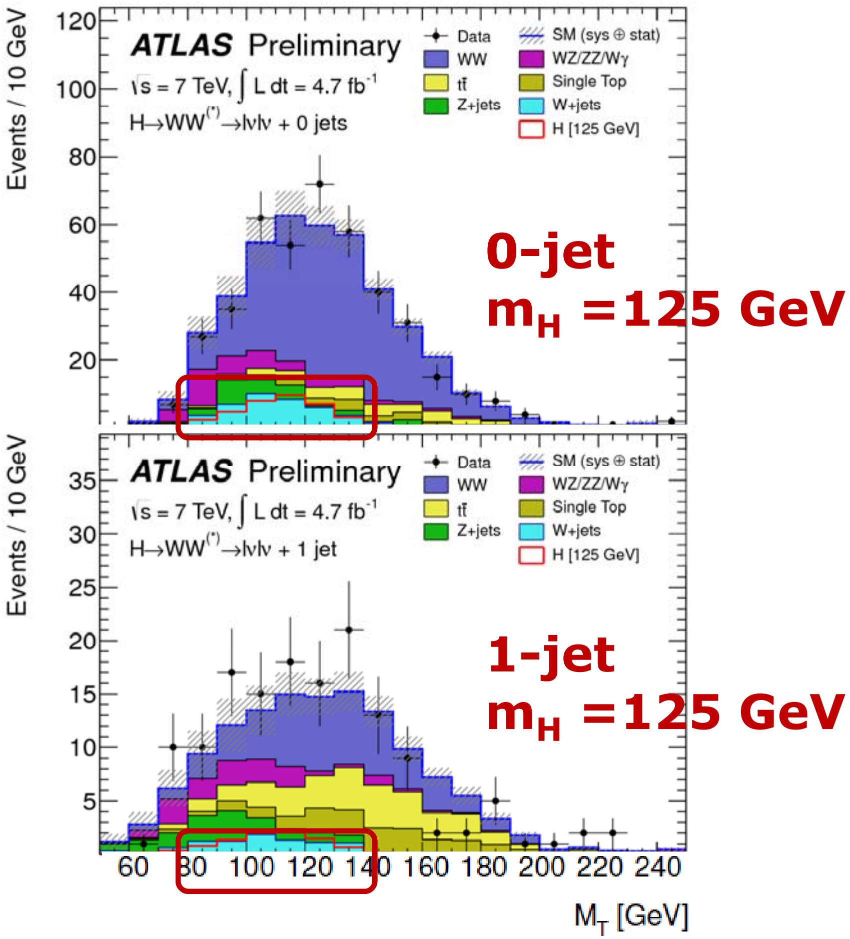


- Require $\Delta\Phi_{\ell\ell}$ < 1.8 (for m_H < 200 GeV)
- Further cuts:
  - b-Jet veto, Z→ ττ veto (1-jet)
  - $p_T^{\ell\ell}$(0-jet) > 30-45 GeV (dep. on ℓℓ)
  - p_T^{tot}(1-jet) > 30-45 GeV (dep. on ℓℓ,m_H)
  - $m_{\ell\ell}$ < 50-80 GeV (dep. on n-jet, ℓℓ)
  - 2-jet: Cuts for Vector Boson Fusion
    - $|\Delta\eta_{jj}|$ > 3.8, m_{jj} > 500 GeV, CJV

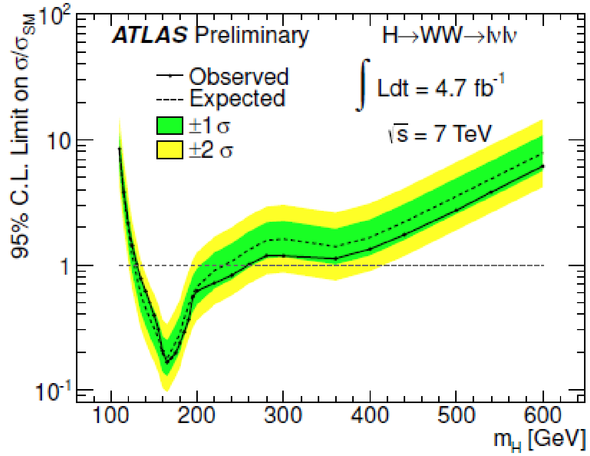
WW-Results

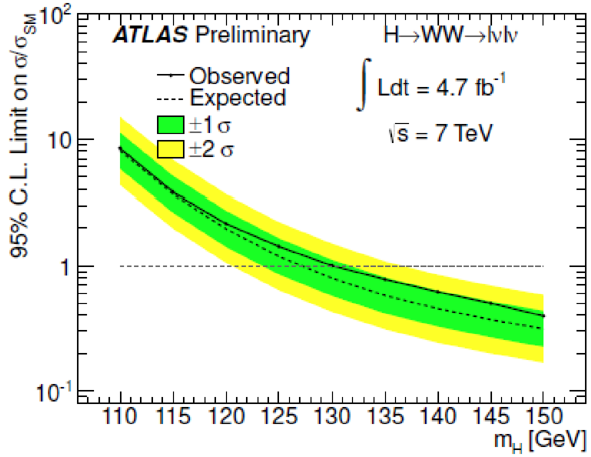
ATLAS-CONF-2012-12

- Final discriminant: m_T
  - $$m_T = \sqrt{(E_T^{\ell\ell} + E_T^{miss})^2 - (\mathbf{p}_T^{\ell\ell} + \mathbf{p}_T^{miss})^2}$$



- Exclusion @ 95% CL
  - 130 GeV < m_H < 260 GeV
- No excess above 1σ

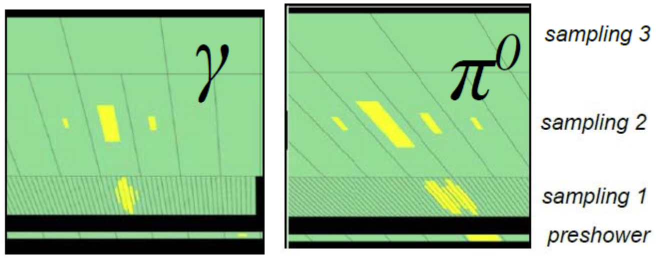


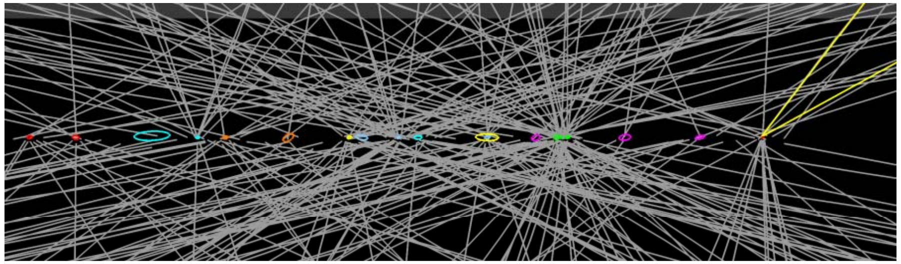


H → $\gamma\gamma$

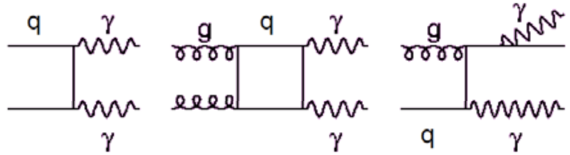
http://arxiv.org/abs/1202.1414 (7.2.12)

- Most sensitive channel for m_H < 120 GeV
- 2nd most sensitive for 120 < m_H < 130 GeV
- Calorimeter segmentation helps reducing π^0 and „pile-up“ from additional vertices

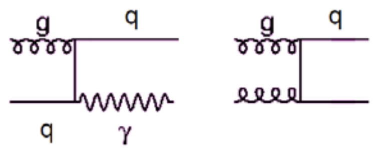




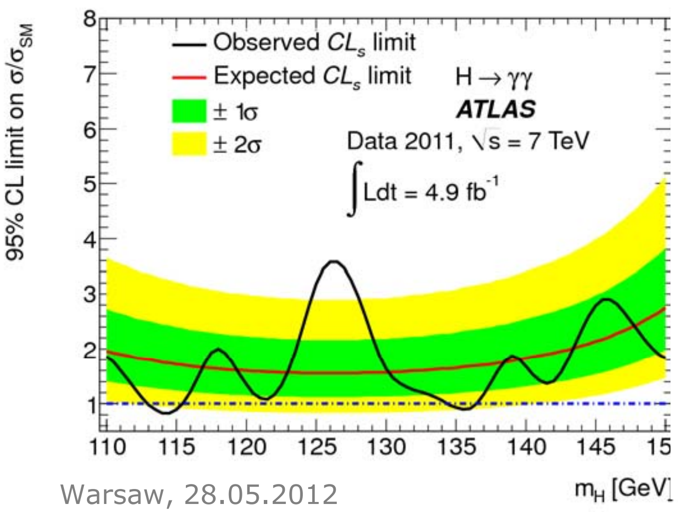
- Irreducible

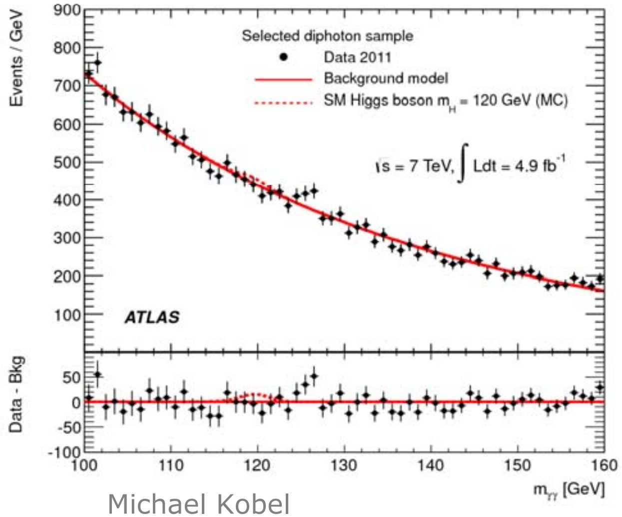


- Reducible : *one or more jets misidentified as photons*



- Small signal on huge background expected
- >2σ excess observed at 126 GeV



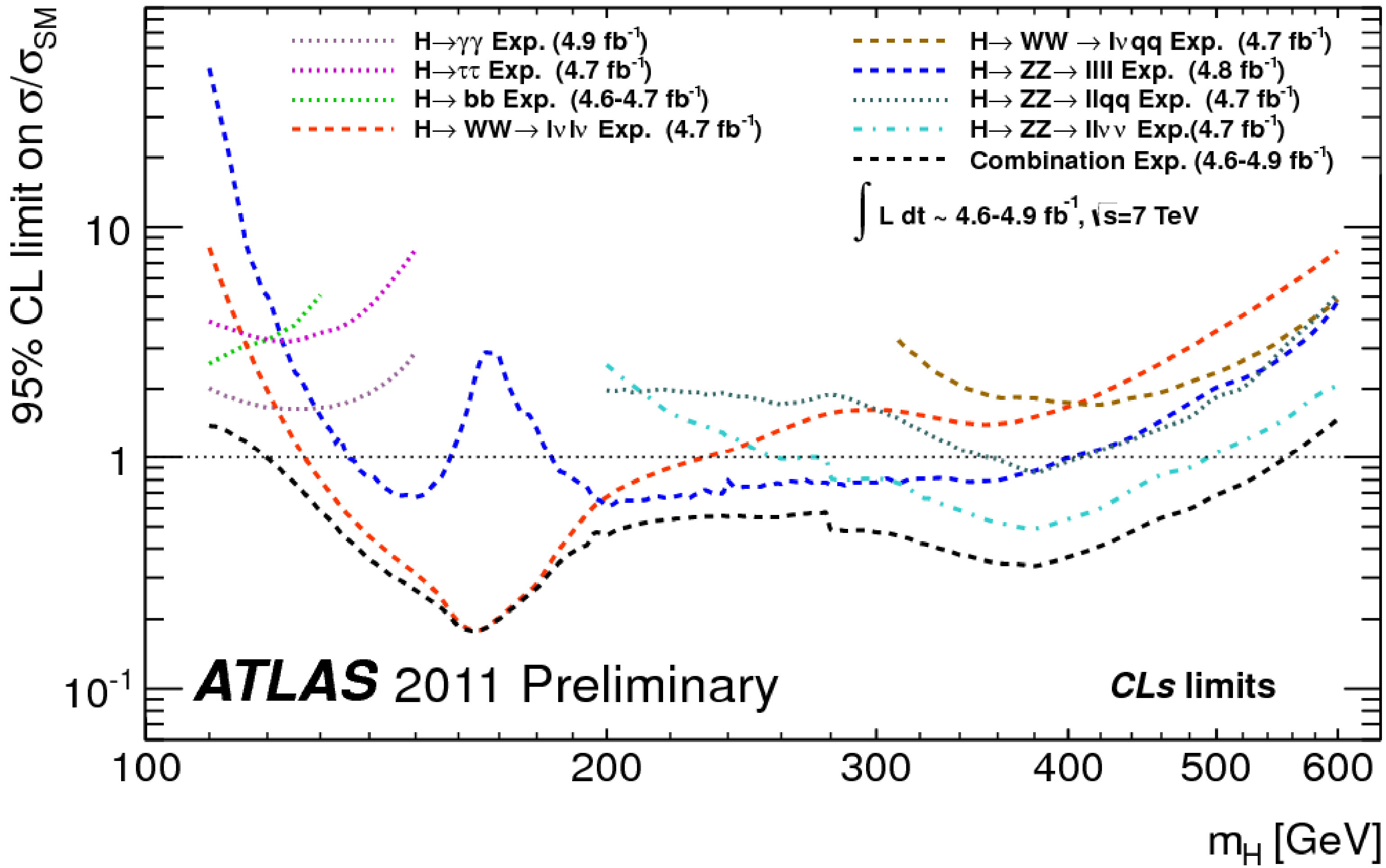


$$m_{\gamma\gamma}^2 = 2E_1E_2(1-\cos\theta)$$

ATLAS all channels

ATLAS-CONF-2012-019, 5.3.12

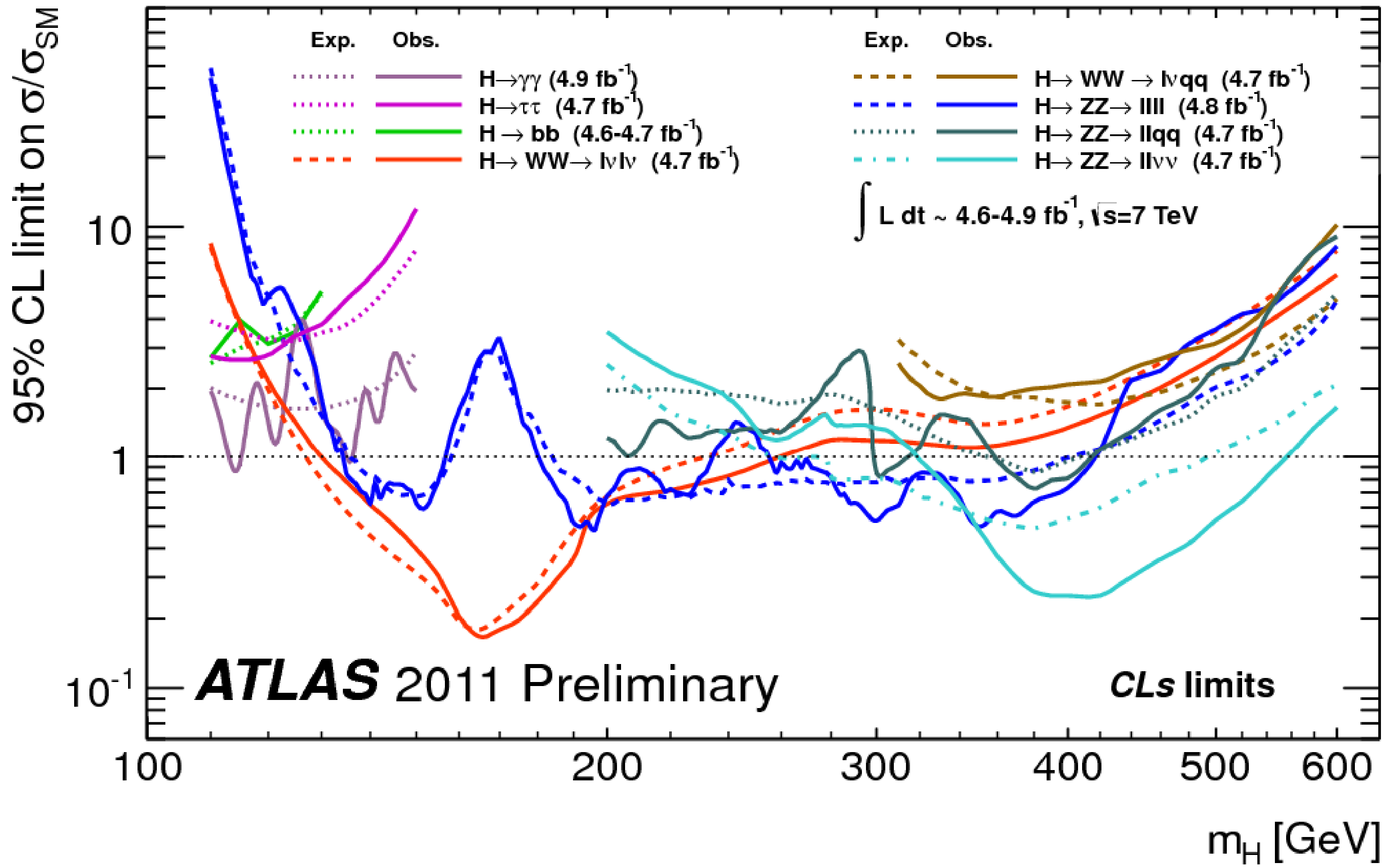
❖ Expected sensitivity per channel



ATLAS all channels

ATLAS-CONF-2012-019, 5.3.12

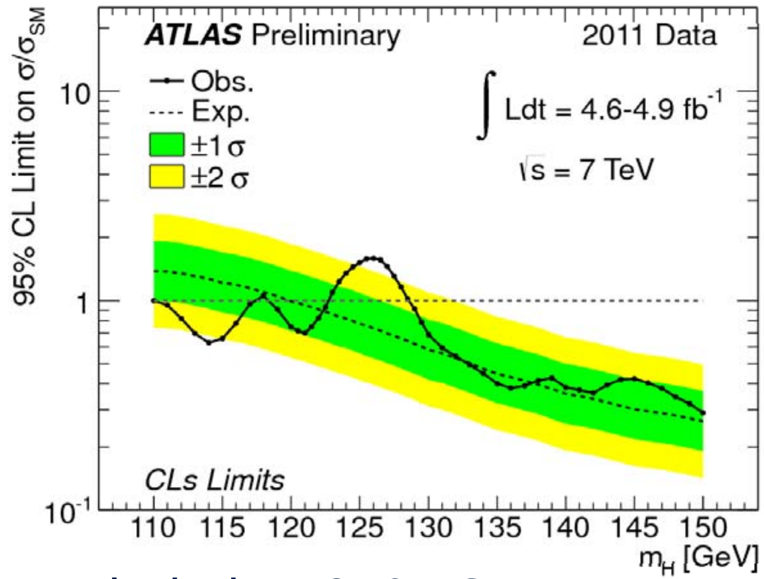
- Observed limits per channel



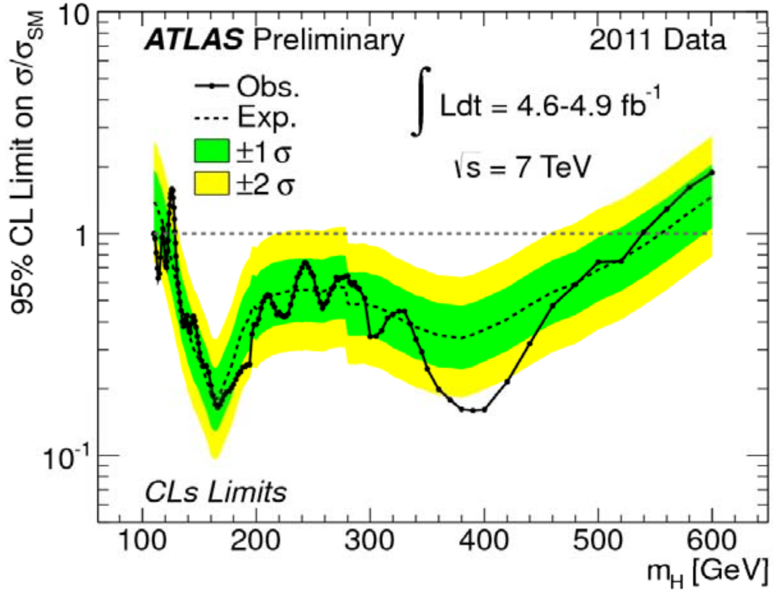
ATLAS combination

ATLAS-CONF-2012-019, 5.3.12

- Low-mass region



- Complete region

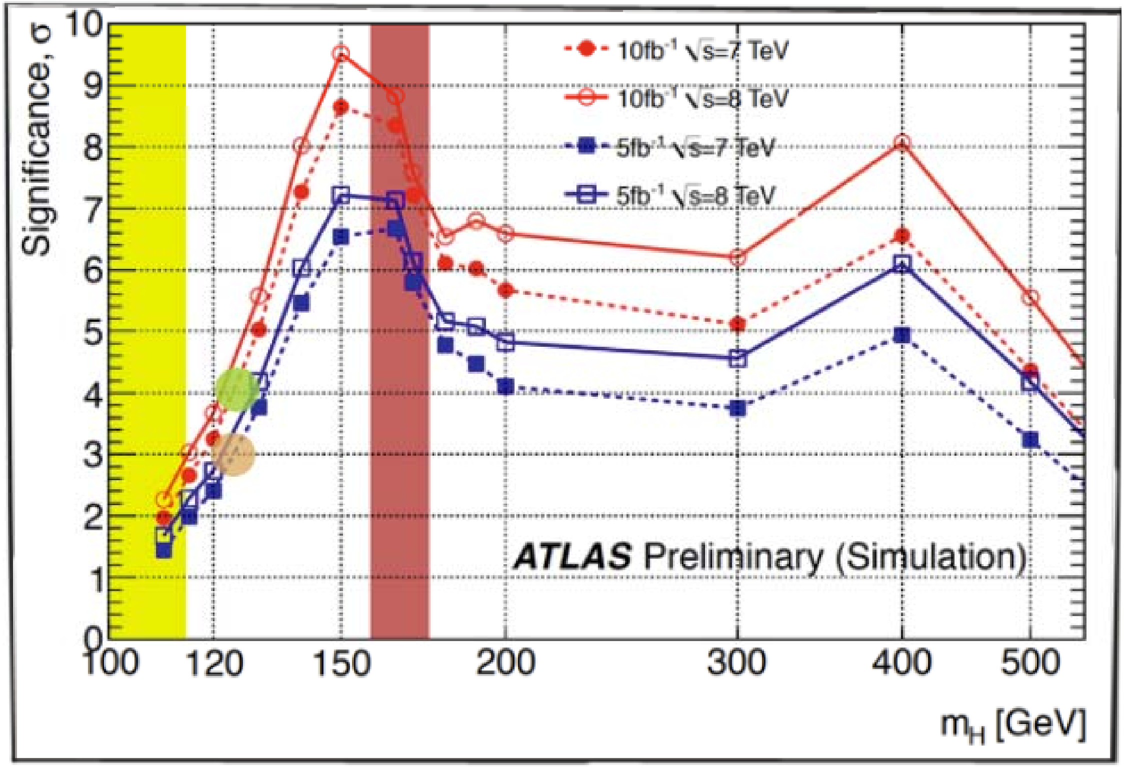


- Excluded at 95% CL
  - 110.0 - 117.5 GeV, 118.5 - 122.5 GeV, and 129 - 539 GeV
- Excess at ~ 126 GeV
  - Local significance: 2.5 σ (expect 2.9 σ for SM Higgs Boson at that mass)
  - *Prob. of such a background fluctuation including „look-elsewhere" effect*
    - 30% anywhere in the mass range 110–600 GeV
    - 10% anywhere in range* 110–146 GeV (*not excluded by LHC at 99%CL)

Prospects for 2012 at 125 GeV

From: Eilam Gross, LHC2TSP, March 2012

- With 5 fb^{-1} @ 7TeV
  - Expected ATLAS sensitivity: 3σ
  - Would need 15 fb^{-1} to get 5σ
- Gain from 7→ 8 TeV
  - Corresp. to 20% Lumi
  - Corresp. to 10% significance
- Need 12 fb^{-1} @ 8 TeV
  - For 5σ significance in each experiment
- Combining w/ 7 TeV
  - ~ 8 fb^{-1} @ 8 TeV needed for discovery

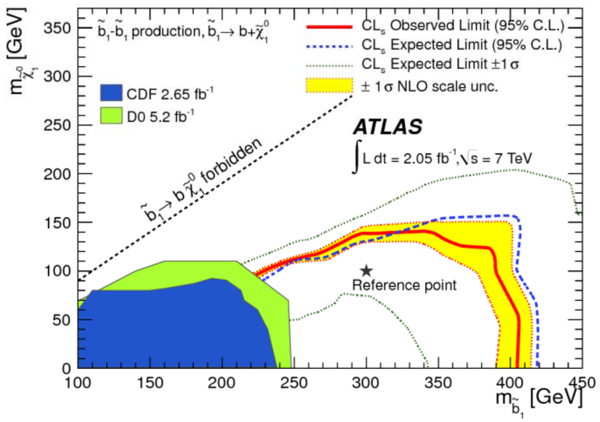


- Prospects for 8 TeV running in 2012
  - At least 15 fb^{-1} planned
  - So far 2.5 fb^{-1} delivered w/ ~ 0.5fb^{-1} /week

BSM SEARCHES (SELECTED EXAMPLES)

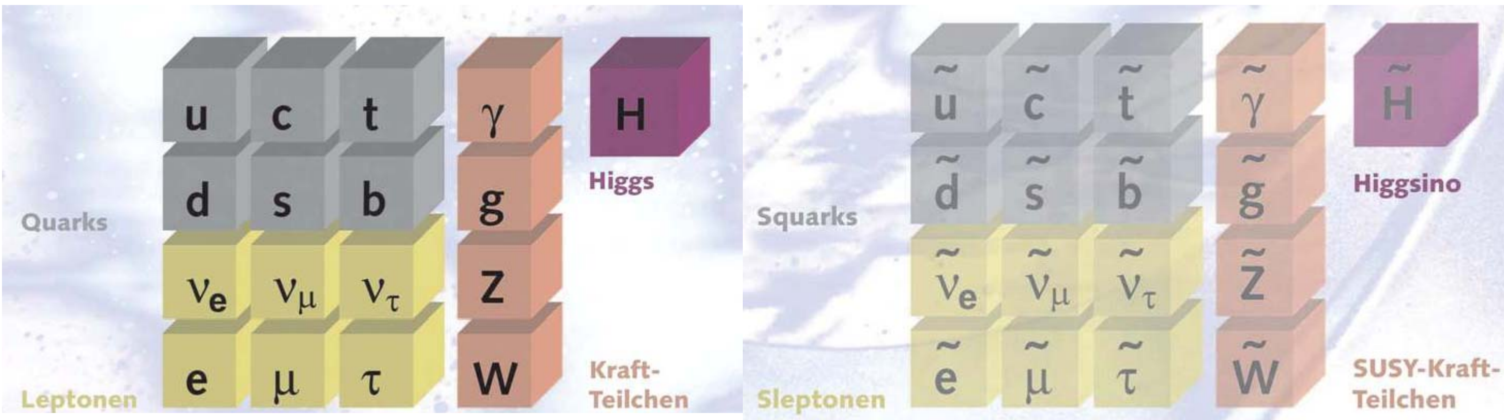
1. SUSY
   i. Dedicated sparticle searches (not covered, example here)
   ii. General topological searches

2. Extra dimensions



Phenomenology of Supersymmetry

- Super-Symmetrie between Fermions and Bosons
  O|Boson> = |Fermion> und O|Fermion> = |Boson>
  - For each Fermion there is a bosonic partner
  - For each Boson there is a fermionic partner



Masses “run” with known Q^2-dependence

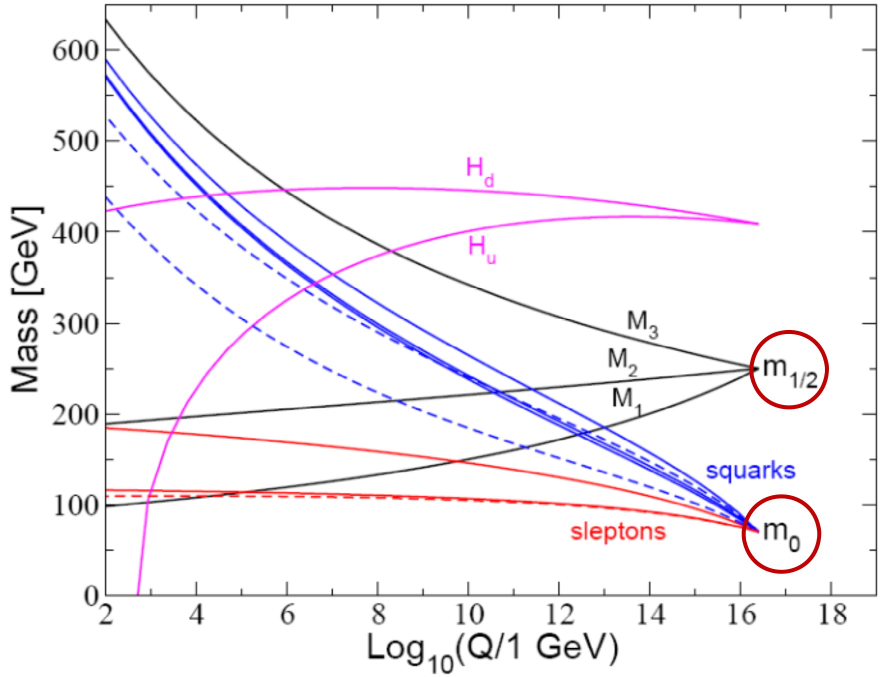
- Simplifying assumption of ConstraintMSSM: Unification at Λ_{GUT}

Gaugino masses M_1, M_2, M_3

Slepton masses (dashed=stau)

Squark masses (dashed=stop)

Higgs: $(m^2_{H_u} + \mu^2)^{1/2}$, $(m^2_{H_d} + \mu^2)^{1/2}$

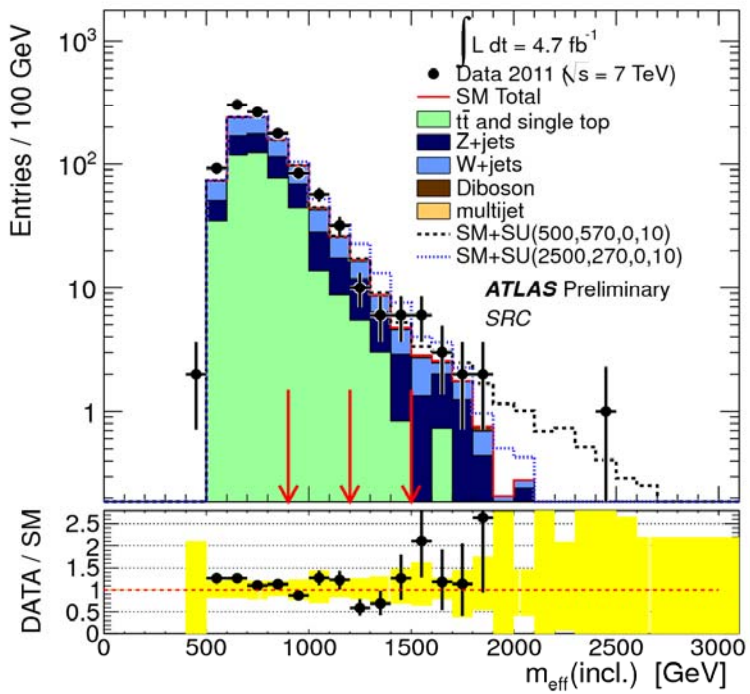


Electroweak symmetry breaking occurs because $m^2_{H_u} + \mu^2$ runs negative near the electroweak scale. This is due directly to the large top quark Yukawa coupling.

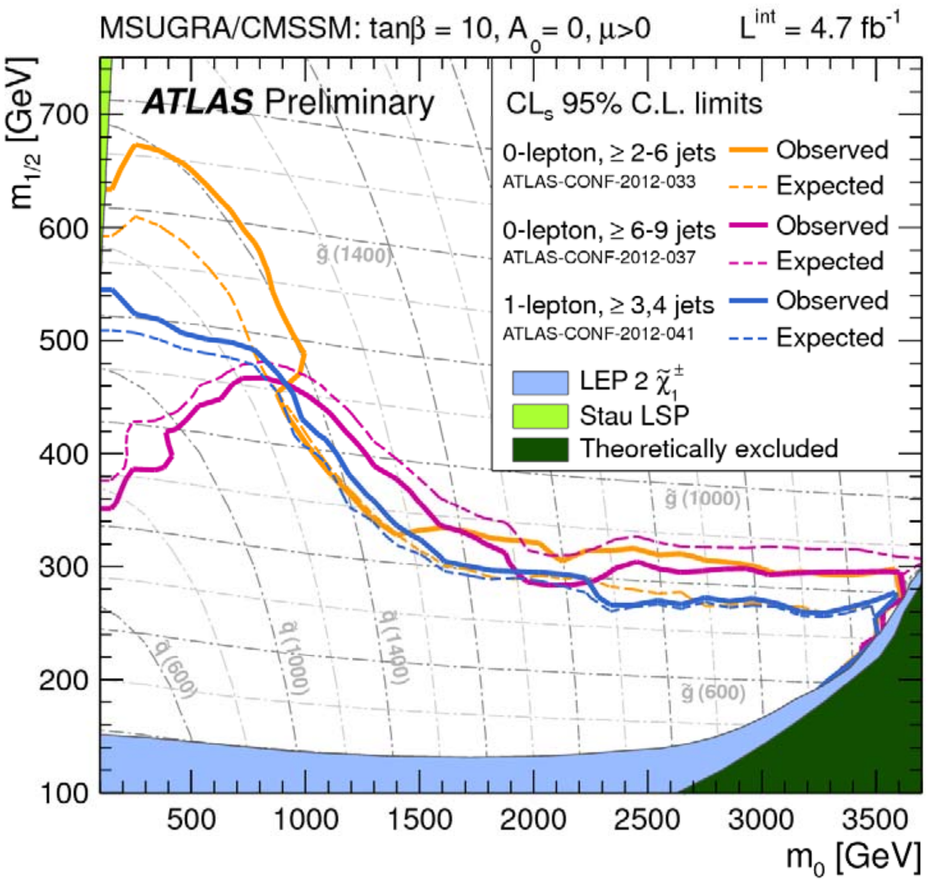
Topological search: 2-9 Jets + E_t^{miss} + 0-1 lepton

ATLAS-CONF-2012-33+37 (12.3.12) ,ATLAS-CONF-2012-41 (16.3.12)

- Basis: Squark/Gluino pair production
- Various decays, e.g. 0 Lepton, 2-6 Jets:
  - 6 signal channels depending on
    - Jet multiplicity
    - $m_{eff} = E_T^{miss} + \Sigma|p_{T,jet}^{(i)}|$
- huge exclusion gain since 2010



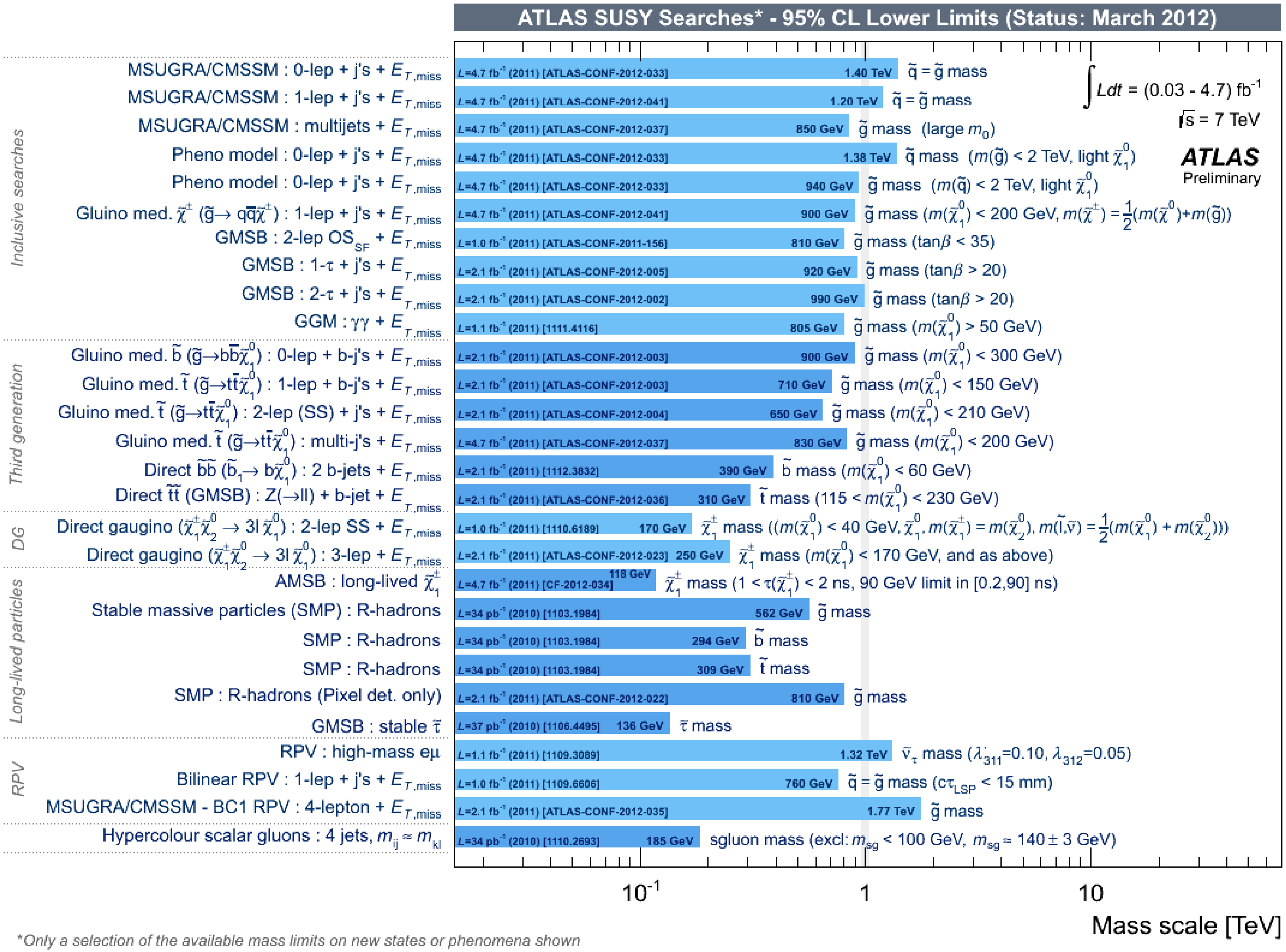
ATLAS exclusion in CMSSM



SUSY exclusion overview

Status: March 2012,

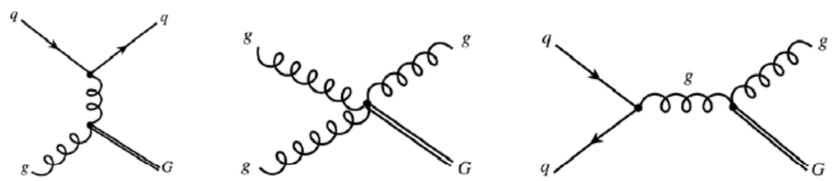
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/CombinedSummaryPlots

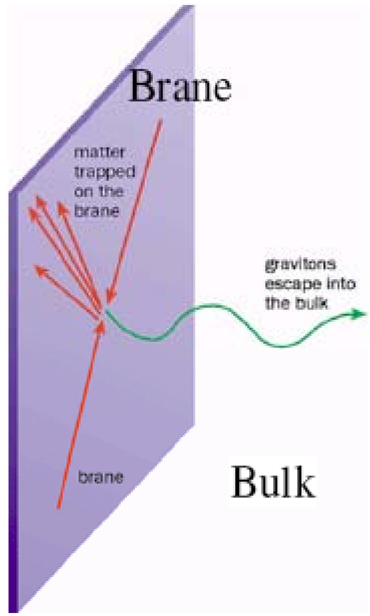


Exotic example 1: ADD extra dimension

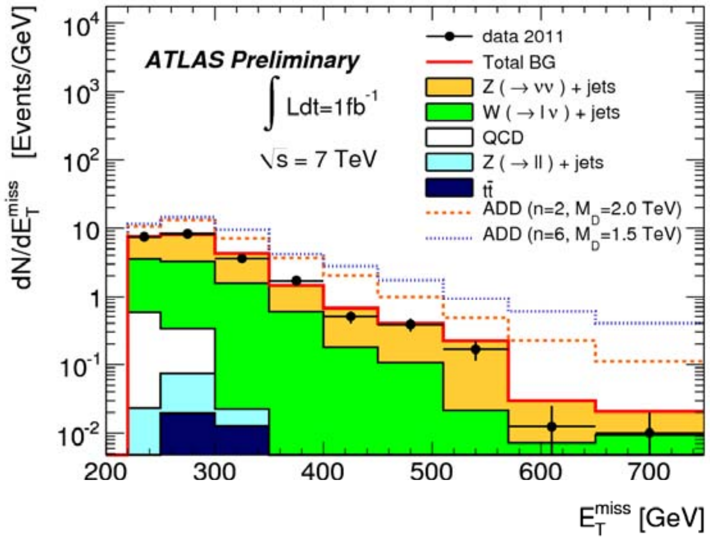
ATLAS-CONF-2011-096, 18.7.11

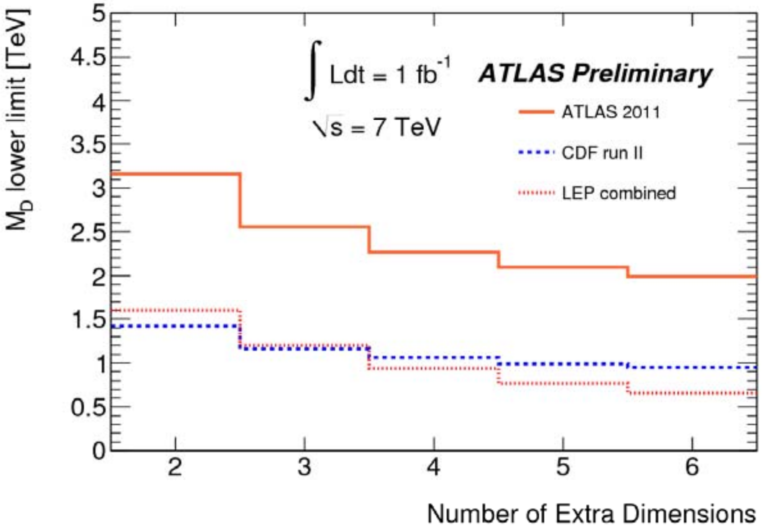
- N.Arkani-Hamed, S.Dimopoulos and G.Dvali (ADD):
  - Macroscopic n extra dimensions would explain EW-Planck hierarchy problem:
    - $M^2_{Planck} = M_D^{2+n} R^n$
    - with M_D~TeV fundamental Planck scale, R ~ nm(n=3) ~10fm(n=6)





- Signature:
  - Monojets $+E_T^{miss}$

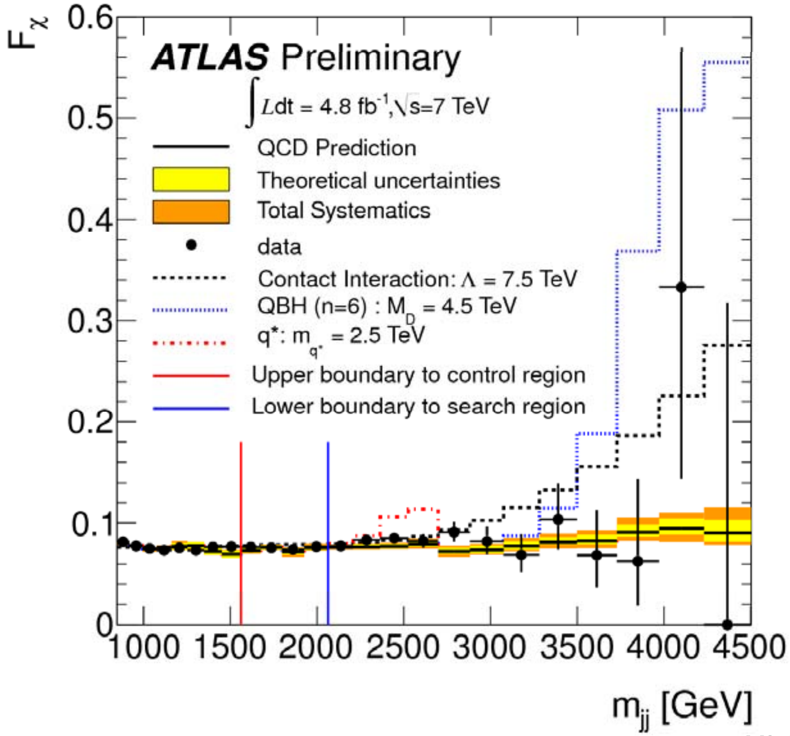


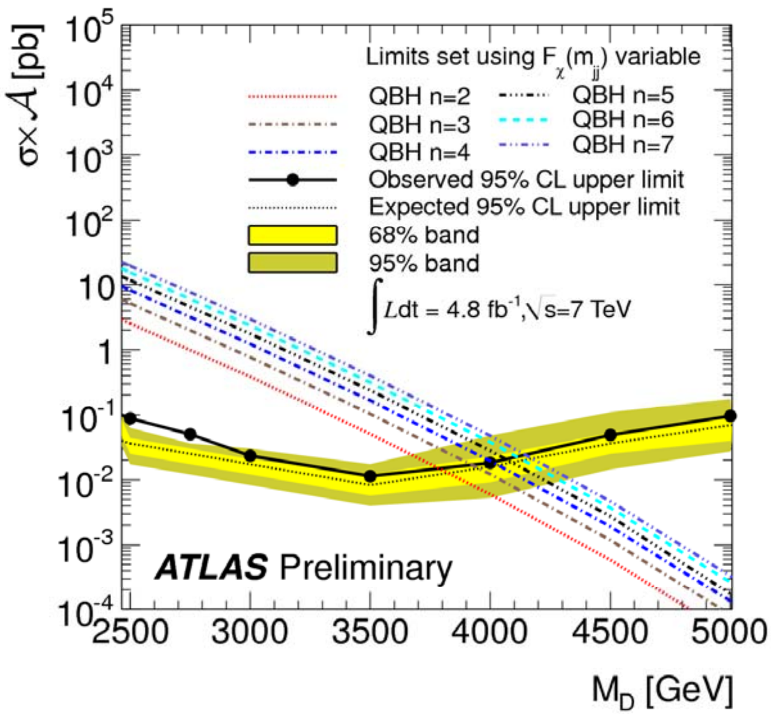


Exotic example 2: Quantum Black Hole

ATLAS-CONF-2012-038, 11.3.12

- Micro black holes near threshold might decay to few particles, i.e. 2 Jets
  - P. Meade and L. Randall, *Black Holes and Quantum Gravity at the LHC, JHEP 0805 (2008) 003,* arXiv:0708.3017
  - L. A. Anchordoqui, J. L. Feng, H. Goldberg, and A. D. Shapere, *Inelastic black hole production and large extra dimensions, Phys. Lett. B594 (2004) 363, arXiv:0311365*
- Centrality $F_\chi = \frac{N_{\text{central}}}{N_{\text{total}}}$ of Dijet spectrum as function of m_{jj}
  - → limits on production cross-section σ x acceptance $\mathcal{A}$
  - → limits of M_D of O(4 TeV)





exotic exclusion overview

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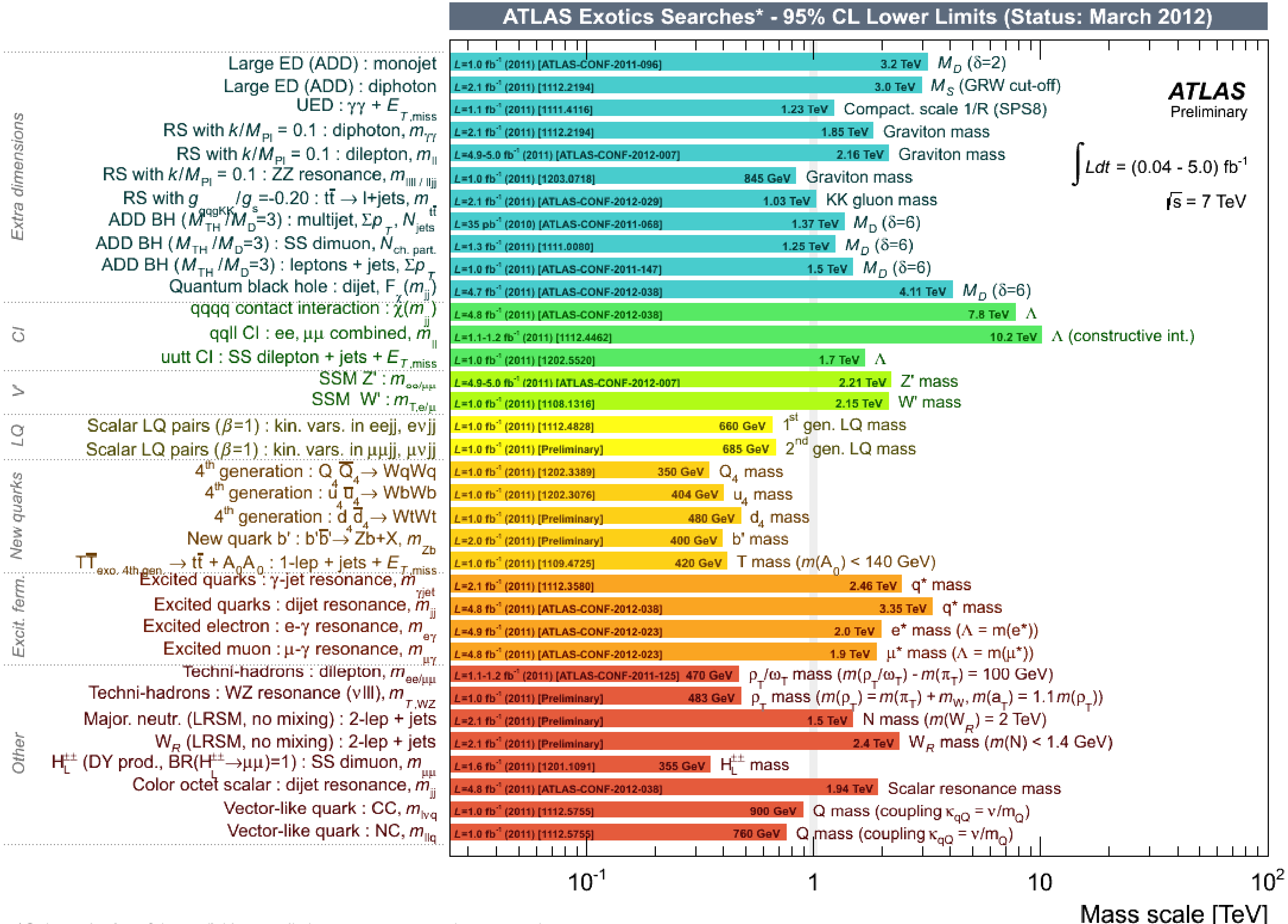
Status: March 2012, https://twiki.cern.ch/twiki/bin/view/AtlasPublic/CombinedSummaryPlots



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

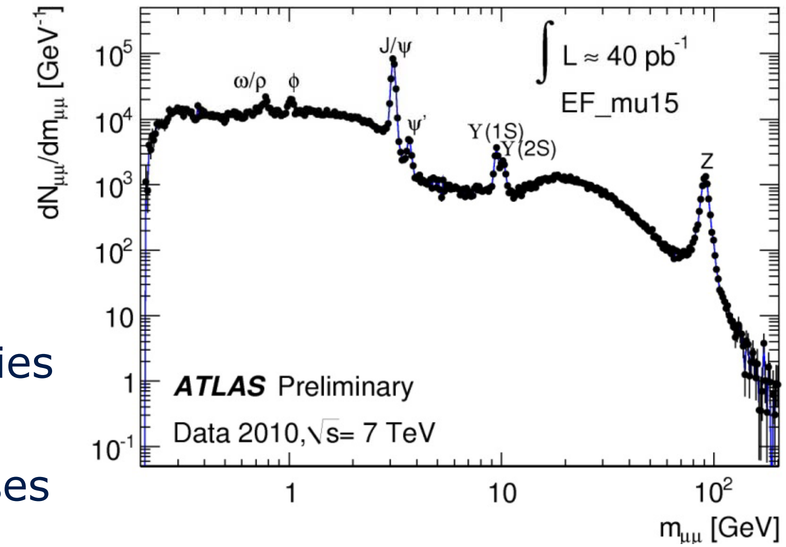
Summary

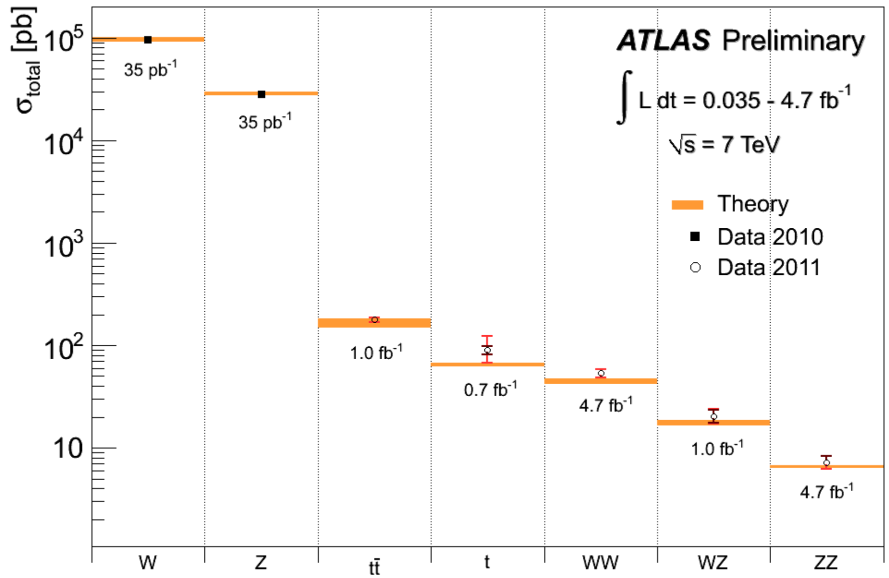
- Brilliant performance of LHC in 2011
- ATLAS detector very well understood
- Standard Model
  - W/Z + ≥ 5 jets: precision measurements
  - Di-Boson: observation and improvements of TGC limits
- Top-Quark
  - Precision cross-section and mass
  - Improving BSM limits, e.g. FCNC
- SM Higgs
  - Low-mass window narrowed to 118 GeV + 122.5 < m_H < 129 GeV
  - Local 2.5 s.d. excess at 126 GeV:
    - backgr. p_0 =10% including „look-elsewhere" in search range
    - most sensitive for 120 < m_H < 130 GeV: WW, $\gamma\gamma$, and ZZ→4l
- SUSY and Exotics
  - Considerably improved exclusions in parameter spaces

BACKUP

Strategy to reach physics goals

- 2010
  - Understand an calibrate detector
  - „Rediscover" Standard Model (SM)
- 2011
  - Precise understanding of SM at high energies
    - Influence of parton density functions
    - Distribution of extra jets in SM processes
    - Background to searches
  - New Physics
    - Severely restrict allowed regions
- 2012
  - Closing in on the mass mechanism (Higgs or no Higgs?)
  - … and maybe more

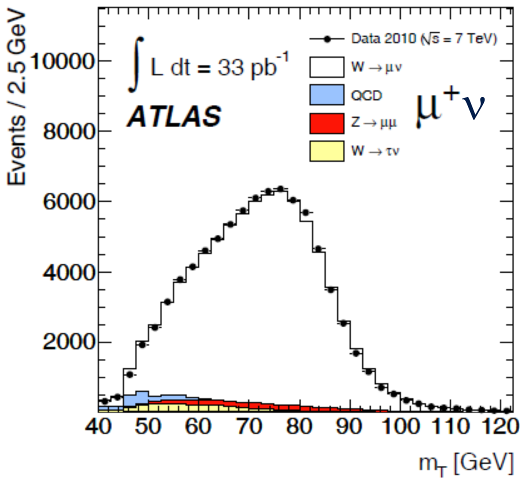


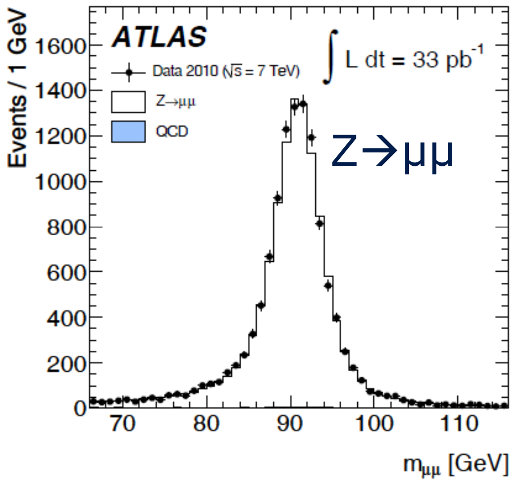


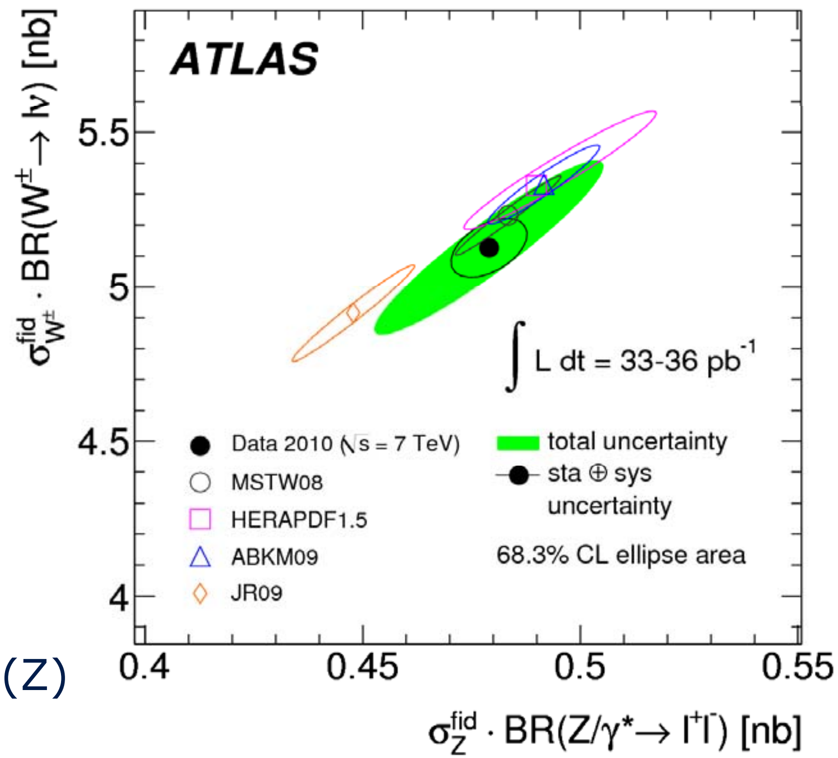
W and Z cross-sections

http://arxiv.org/abs/1109.5141 (27.9.11)

- W and Z Bosons
  - Large x-sections*BR of 1-10 nb (~ 1-10 /s)
  - can be reconstructed with extremely high purity in both e and μ final state







- Agree impressively well w/ predictions
- No distinction between pdfs possible
  - Lumi uncertainty: 3.4%
  - Other Syst uncertainties: ~ 1%
  - Stat uncertainties 2010: 0.2%(W)-0.6%(Z)

Understanding extra jets, e.g. W+Jets

Phys. Rev. D 85 (2012) 092002 (6.1.12)

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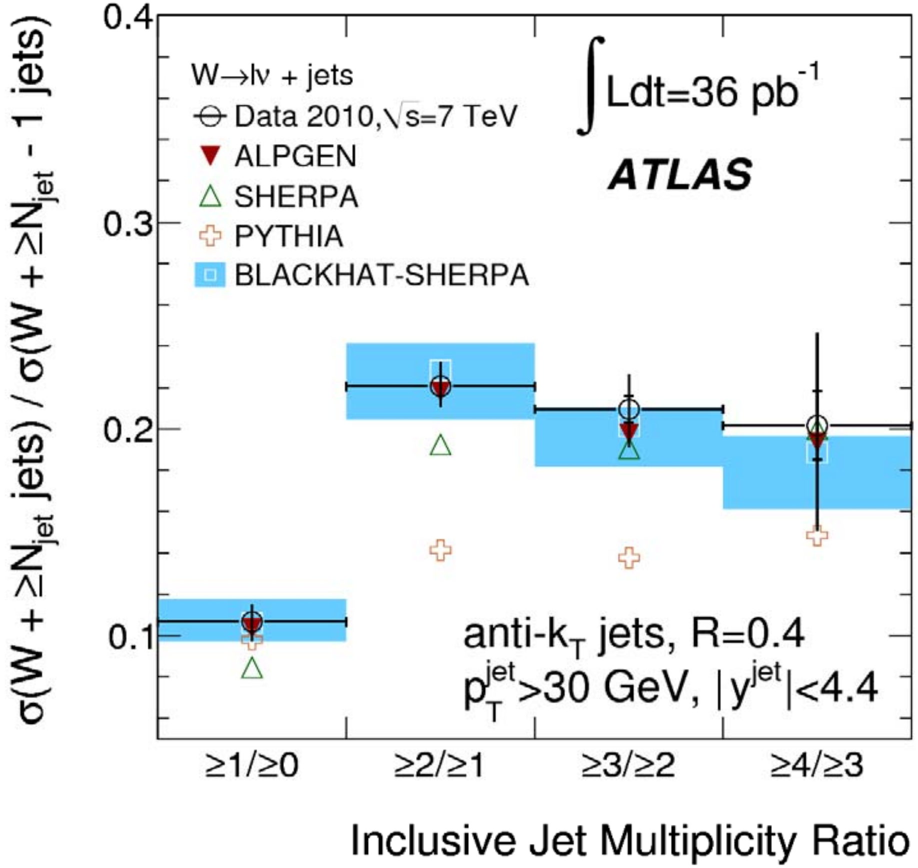
- Berends-Giele scaling:
  - Berends, Giele, Kuijf, Kleiss, Stirling, PLB 224, 237 (1989)
  - Adding one more jet reduces x-section by constant factor, i.e. $\sigma(\geq N \text{ jets}) / \sigma(\geq N\text{-}1 \text{ jets}) = \text{const}$
  - Has NLO corrections and depends on jet definition

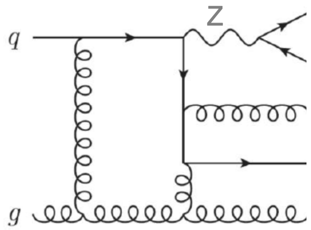


- MC models:
  - ALPGEN and SHERPA: LO ME for multipartonic states
  - MCFM: NLO pQCD up to $N_{jets} = 2$, LO for $N_{jets} = 3$
  - Blackhat-SHERPA: NLO pQCD up to $N_{jets} = 3$, LO for $N_{jets} = 4$

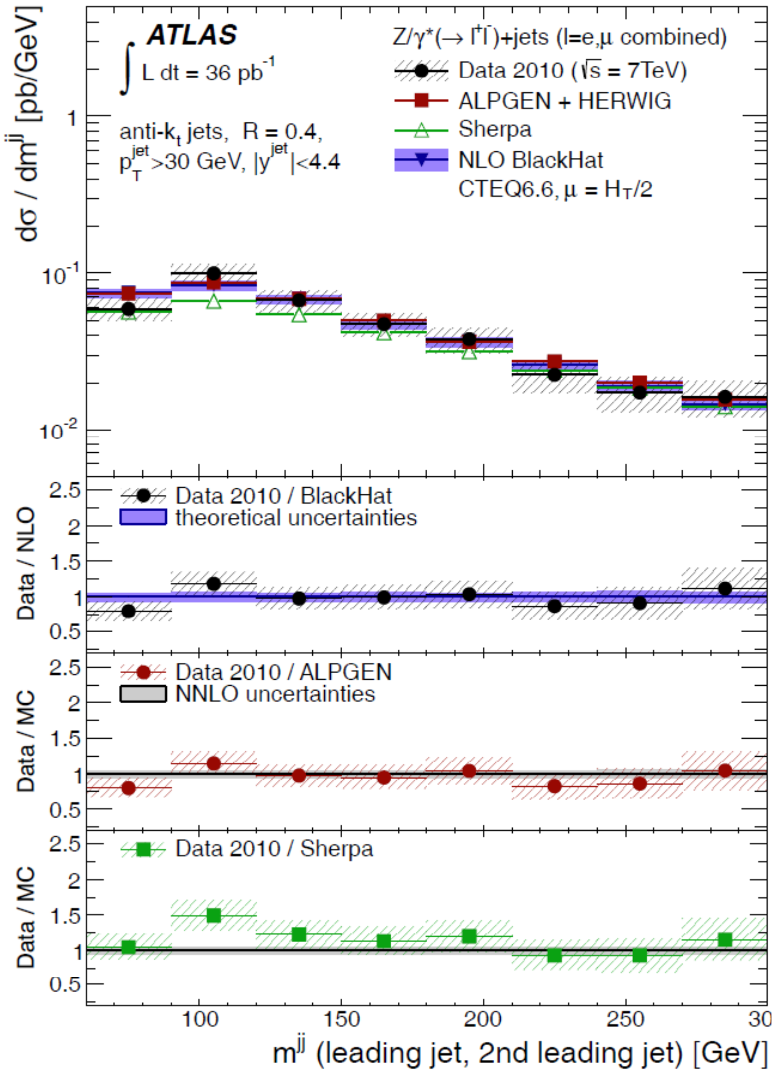
Z+Jets: No structures in Jet-Jet Masses

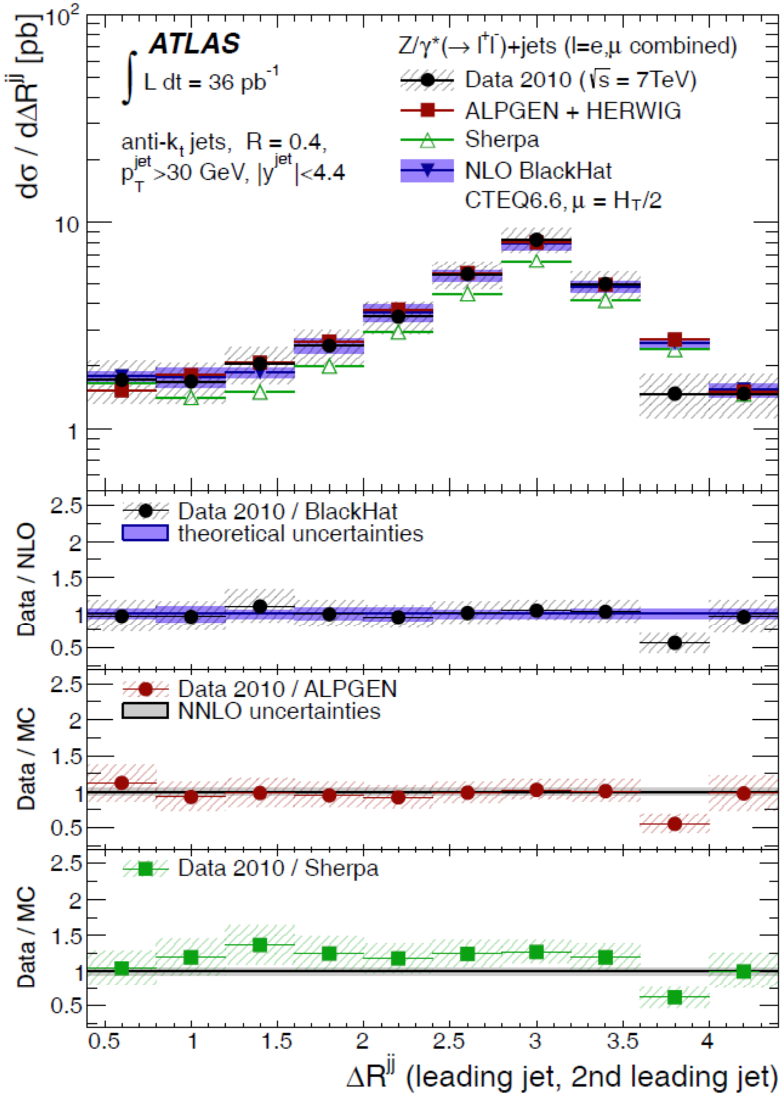
arxiv.org/abs/1111.2690 (11.11.11)

- Low $p_t(Z)$ → most $|p_t|$ in Jets → $\Delta\phi^{jj} \sim \pi$ needed for balance



- Well reproduced by simulations

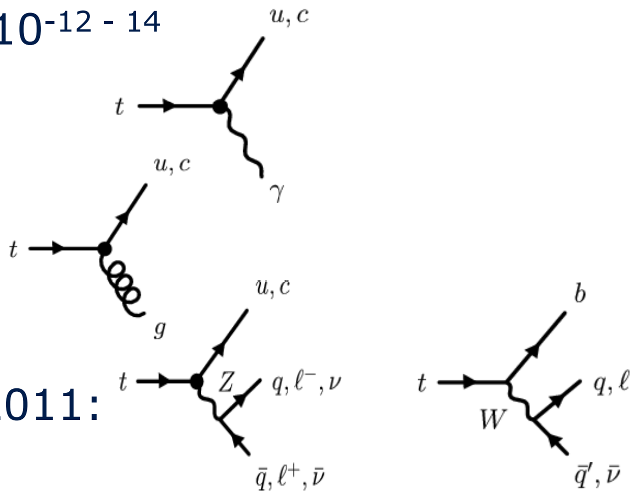




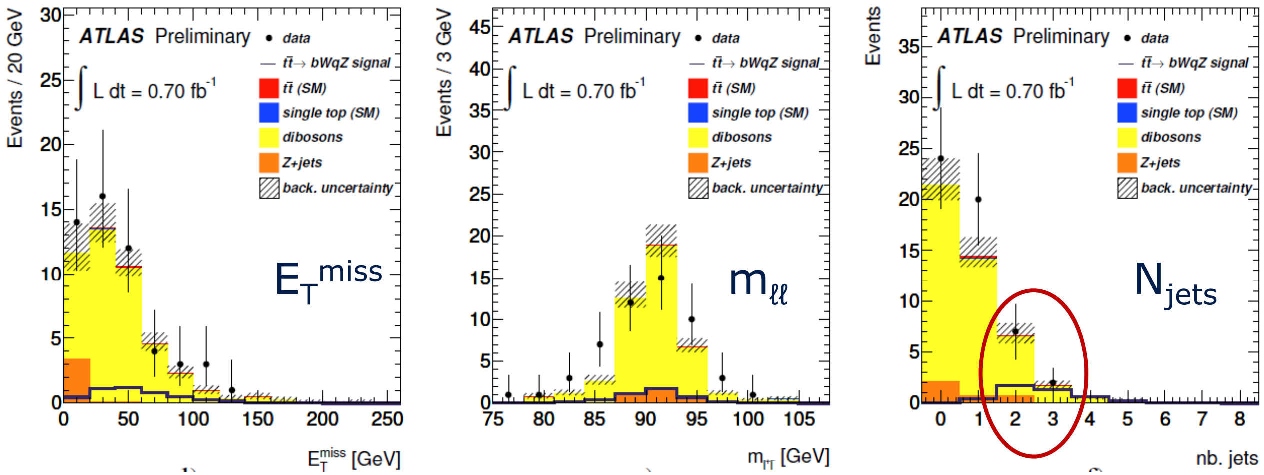
t→ Zq flavor changing neutral current

ATLAS-CONF-2011-154 (11.11.11)

- SM: only top decays: t→ qW, FCNC loops in SM ~ $10^{-12\ -\ 14}$
  - BSM physics: FCNC up to O(10^{-4}) possible
  - Best 95% CL limits so far:
    - t → qγ HERA: < 6 x 10^{-3}
    - t → qg TeVatron: < 0.2 x 10^{-3} (u), < 4 x 10^{-3} (c)
    - t → qZ TeVatron: < 32 x 10^{-3}



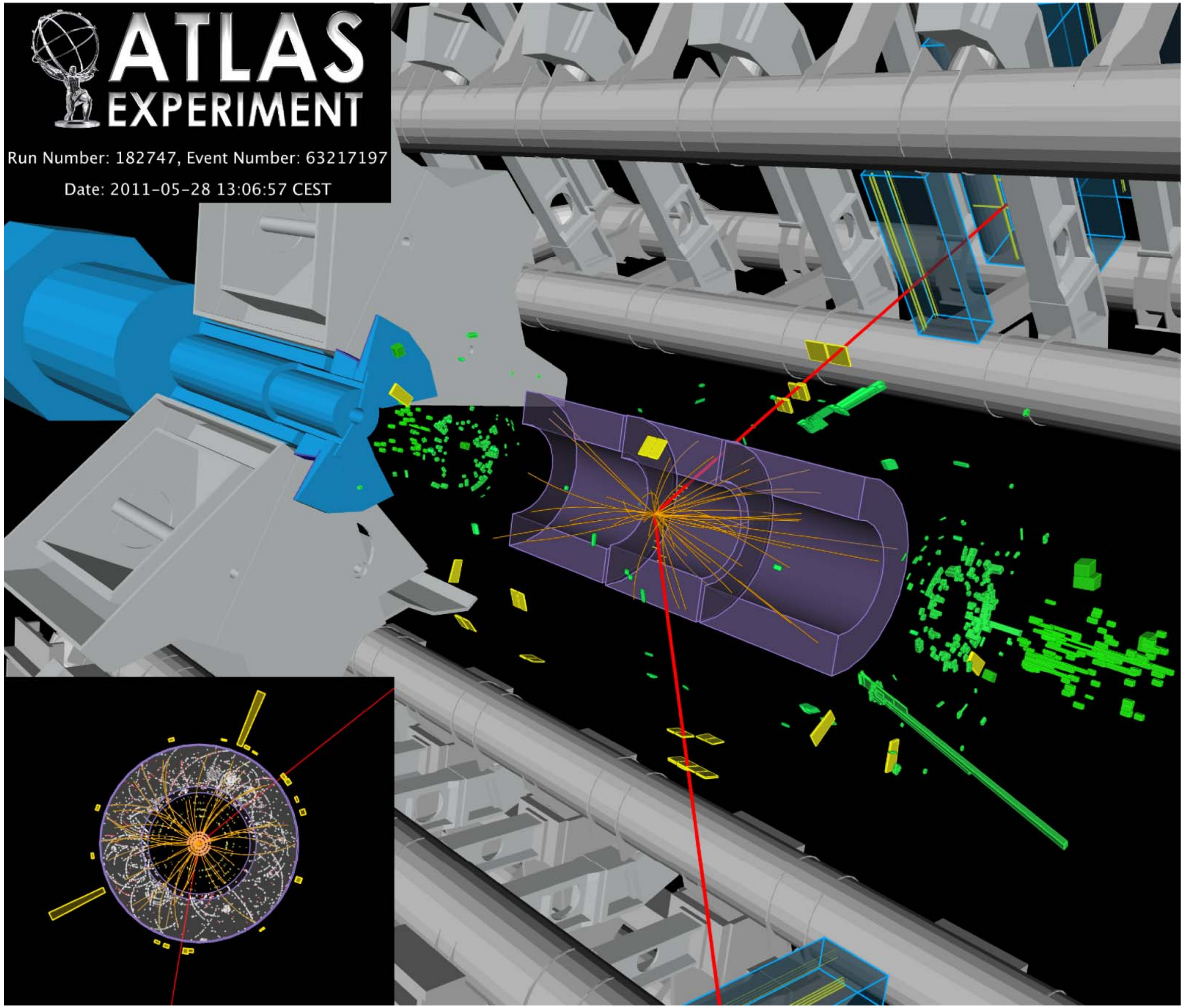
- ATLAS search for t → qZ (q=c+u) with 0.7 fb^{-1} in 2011:
  - Final state Zq Wb -> ℓℓq ℓνb
  - main background: Dibosons ZW, ZZ



- **ATLAS prelim. : t→ qZ < 11×10^{-3} at 95% CL (best to date)**

ZZ → μμee candidate (m_{4l} = 209.7 GeV)

ATLAS-CONF-2011-131, 21.8.2011

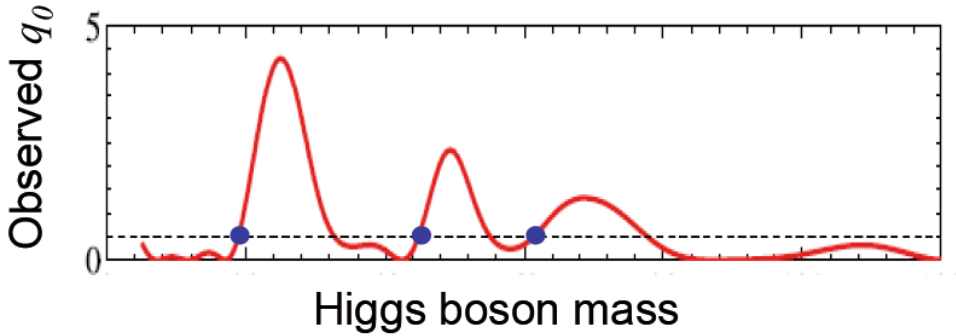


The „look-elsewhere“ effect

ATL-PHYS-PUB-2011-11, CMS NOTE-2011/005

Estimate of the Look-Elsewhere Effect

The local p_0, p_0^{min} and the corresponding maximum significance Z_{max} may be misleading. Estimate the global probability, $p_0^{gloabal}$ to observe p_0^{min} by counting the number of up-crossings



$$p_0^{global} \sim p_0^{min} + N_0 \, e^{-\frac{1}{2} Z_{max}^2}$$

Figure 4: An illustration of a hypothetical scan of the test statistic q_0 vs m_H for some data. Up-crossings for a given threshold value u are shown with blue points.

To quantify an excess of events, we use the test statistic q_0, defined as follows:

$$q_0 = -2 \ln \frac{\mathcal{L}(\text{data}|0, \hat{\hat{\theta}}_0)}{\mathcal{L}(\text{data}|\hat{\mu}, \hat{\theta})} \quad \text{and } \hat{\mu} \geq 0. \tag{4}$$

This test statistic is known to have the proper χ^2 distribution, which allows us to evaluate significances (Z) and p-values (p_0) from the following asymptotic formula:

$$Z = \sqrt{q_0^{obs}}, \tag{5}$$

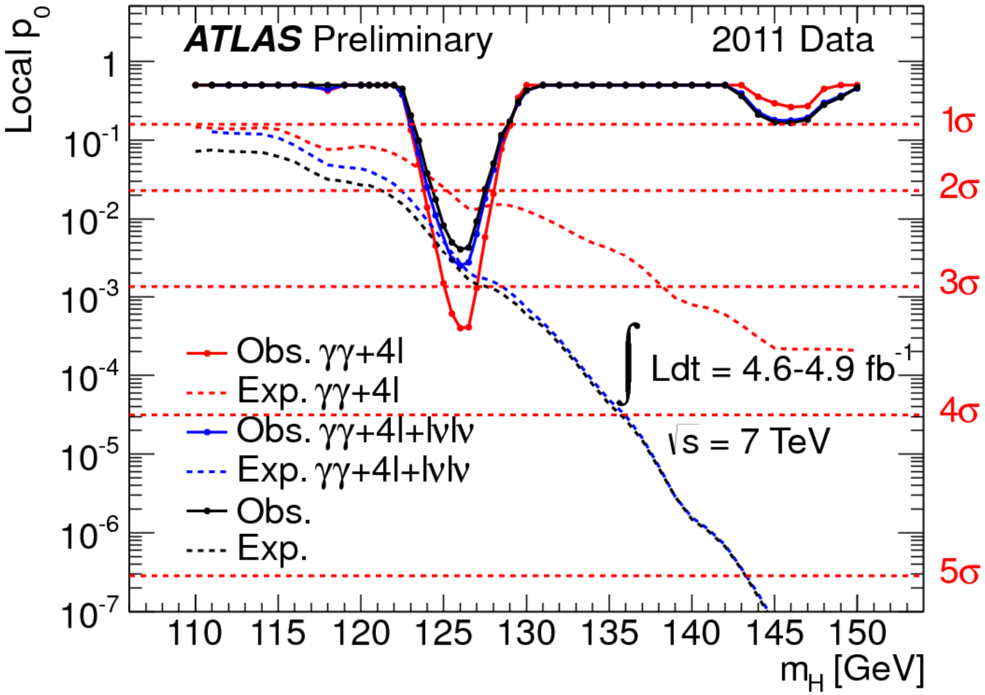
$$p_0 = P(q_0 \geq q_0^{obs}) = \int_Z^{\infty} \frac{e^{-x^2/2}}{\sqrt{2\pi}} \, dx = \frac{1}{2} \left[1 - \text{erf} \left(Z/\sqrt{2} \right) \right]. \tag{6}$$

ATLAS combination

ATLAS-CONF-2012-019, 5.3.12

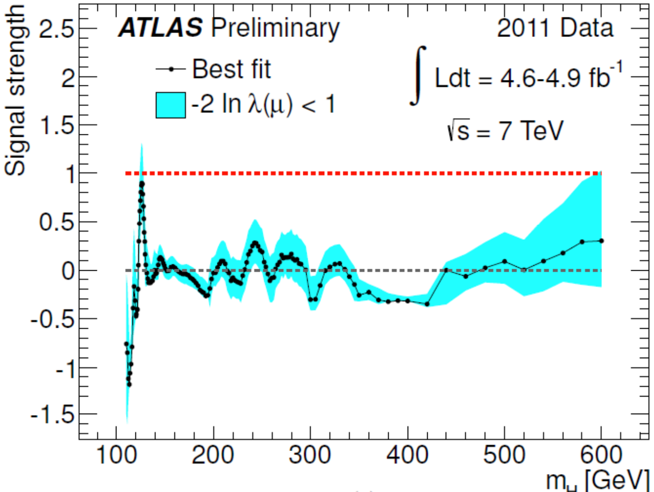
- Expected and observed significances for a 126 GeV Higgs

channel	WW→ℓ⁺νℓ⁻ν	γγ	ZZ→ℓ⁺ℓ⁻ℓ⁺ℓ⁻
expected	1.6 σ	1.4 σ	1.4 σ
observed	0.2 σ	2.8 σ	2.1 σ

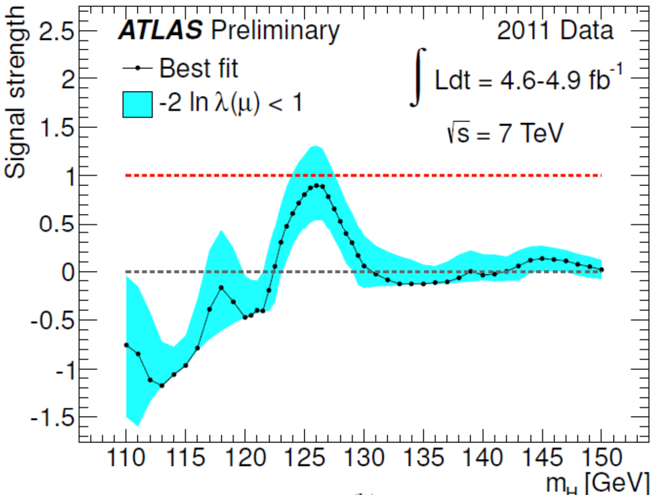


Best fit signal strengths

- All channels

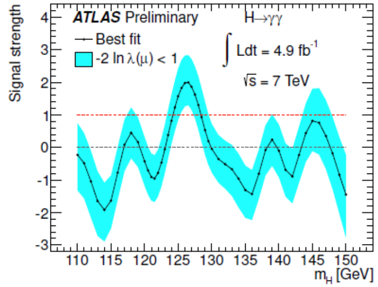


(a)

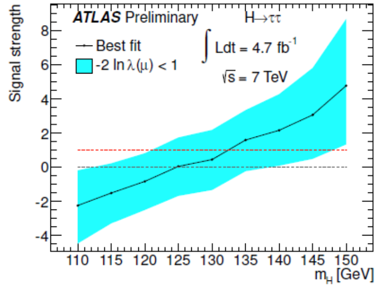


(b)

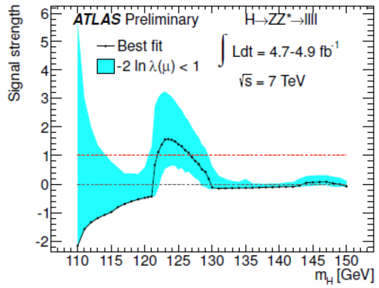
- single channels



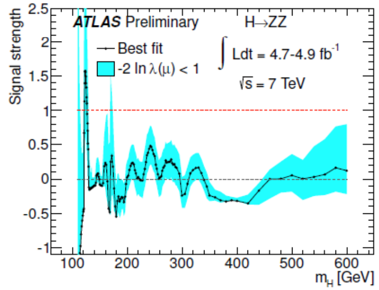
(a)



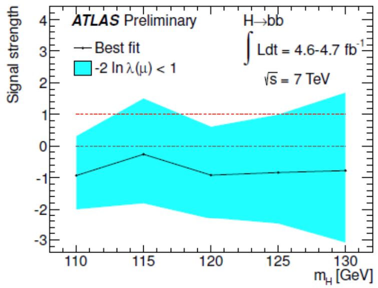
(b)



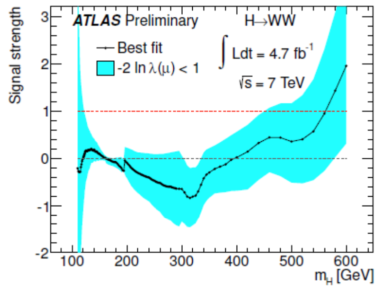
(c)



(d)



(e)



(f)