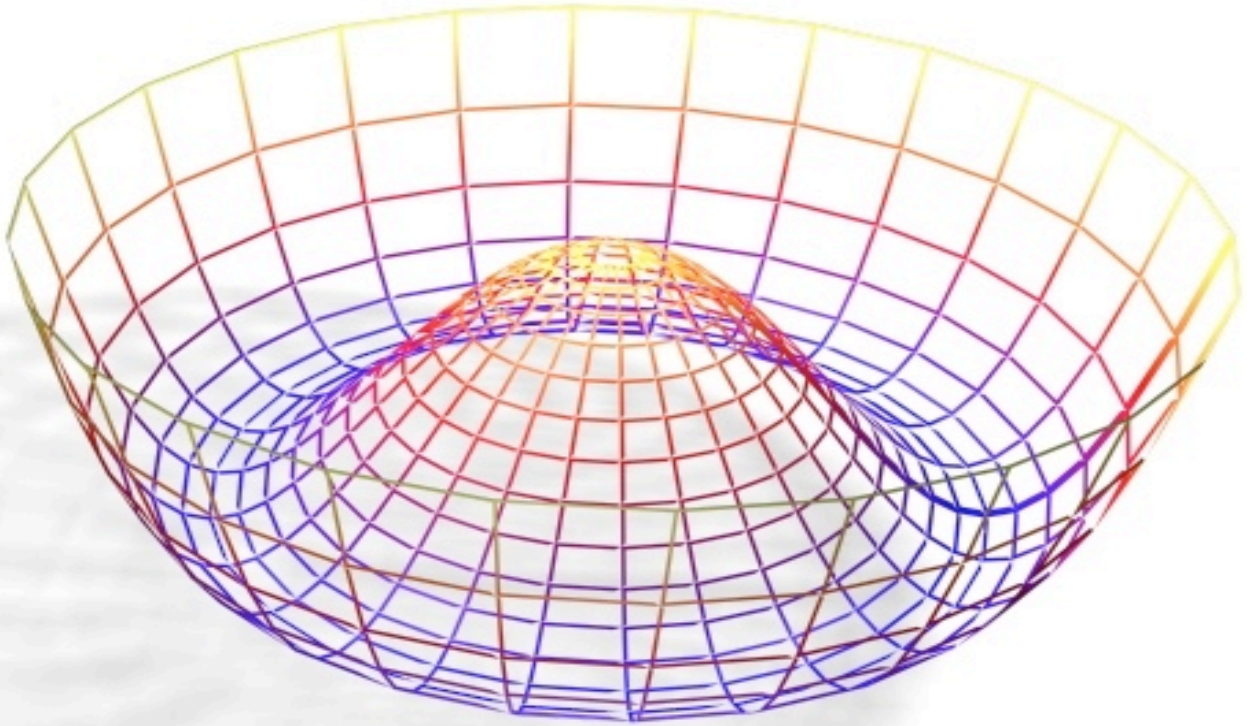
Center for
Cosmology and
Particle Physics

Recent results from ATLAS



Kyle Cranmer, *for the ATLAS Collaboration*
New York University

Outline

A tremendous amount of physics produced from 2011 data

- 59 papers submitted for publication in 2012 alone

LHC Higgs results covered earlier today by Jake Anderson

Overview of SUSY and Exotics results

Focus:

- Di-bosons
  - fiducial and inclusive cross sections, triple gauge couplings
- top-quark related measurements and searches
  - resonances, same-sign tops,
- Jet mass and substructure, new tools for the LHC
- long-lived heavy particles
  - slow, disappearing, and stopped

Overview of the ATLAS Detector

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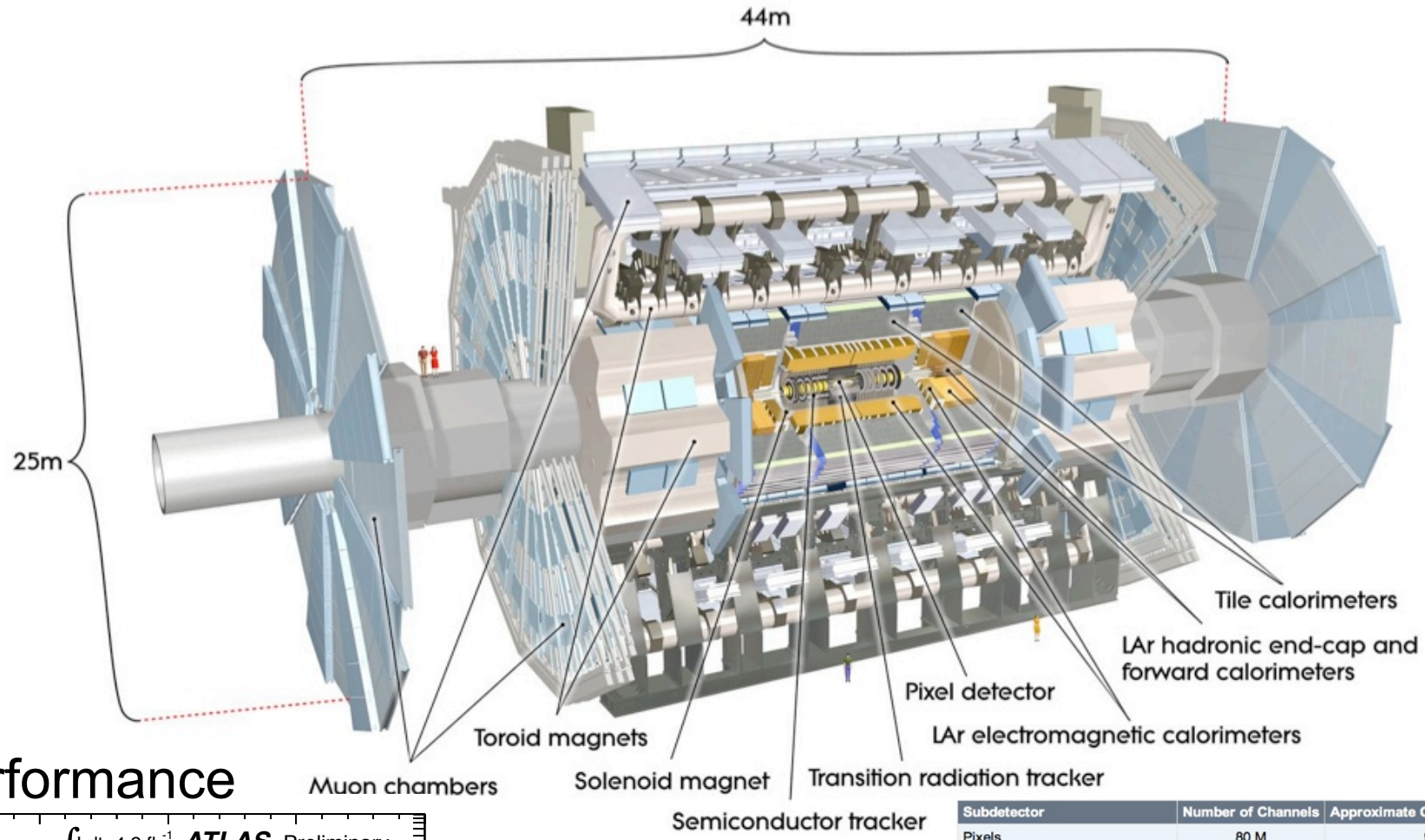
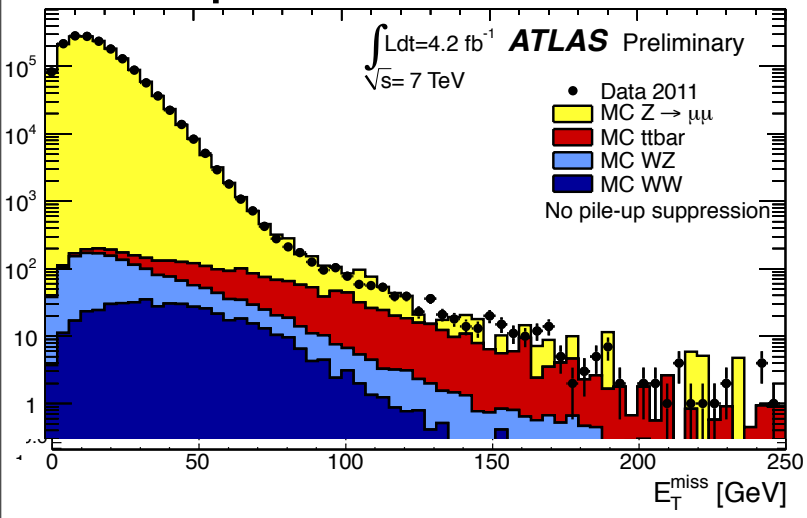


E_T^{miss} performance



Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	95.9%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	97.5%
LAr EM Calorimeter	170 k	99.9%
Tile calorimeter	9800	99.5%
Hadronic endcap LAr calorimeter	5600	99.6%
Forward LAr calorimeter	3500	99.8%
LVL1 Calo trigger	7160	100%
LVL1 Muon RPC trigger	370 k	99.5%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	97.7%
RPC Barrel Muon Chambers	370 k	97.1%
TGC Endcap Muon Chambers	320 k	99.7%

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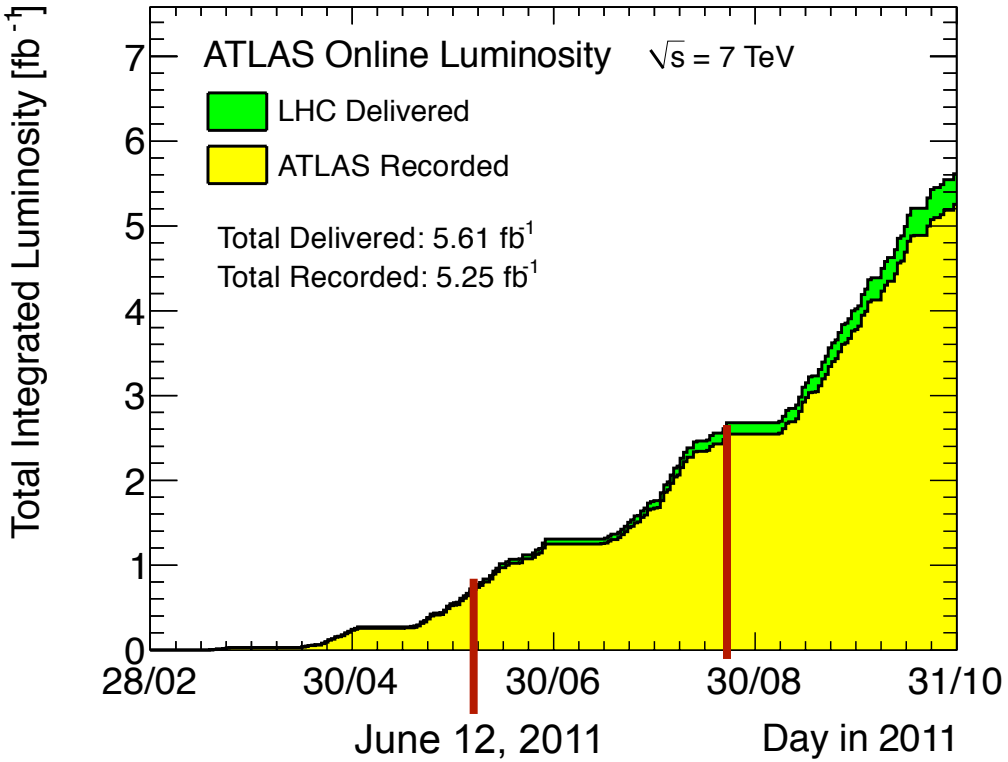
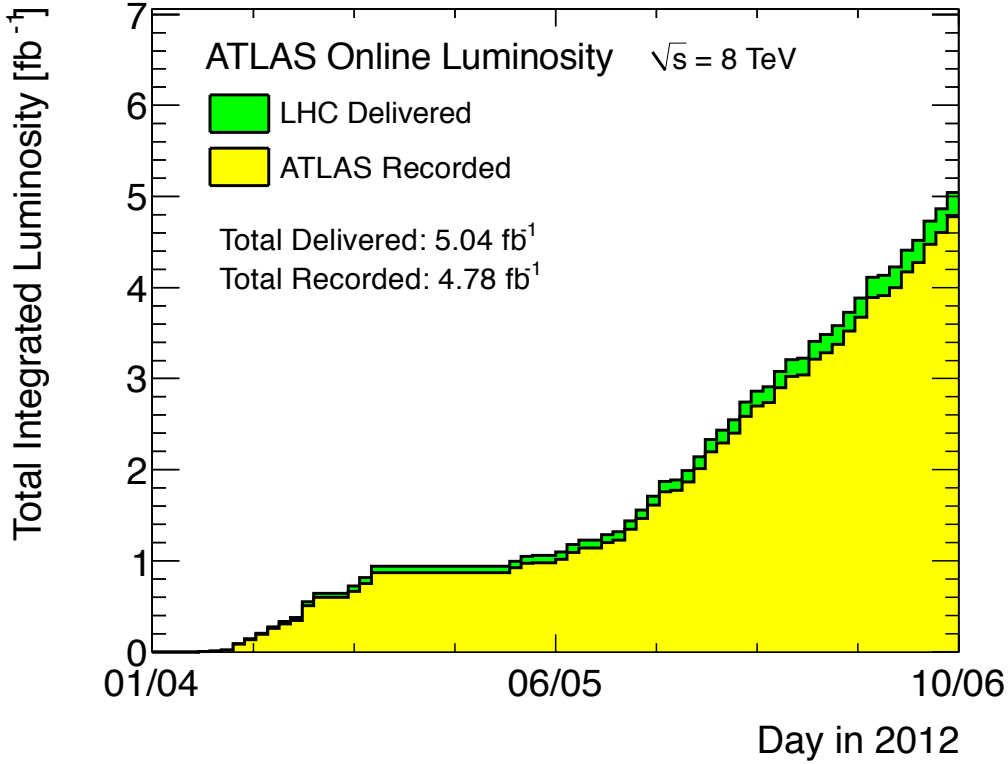
The LHC has been performing very well

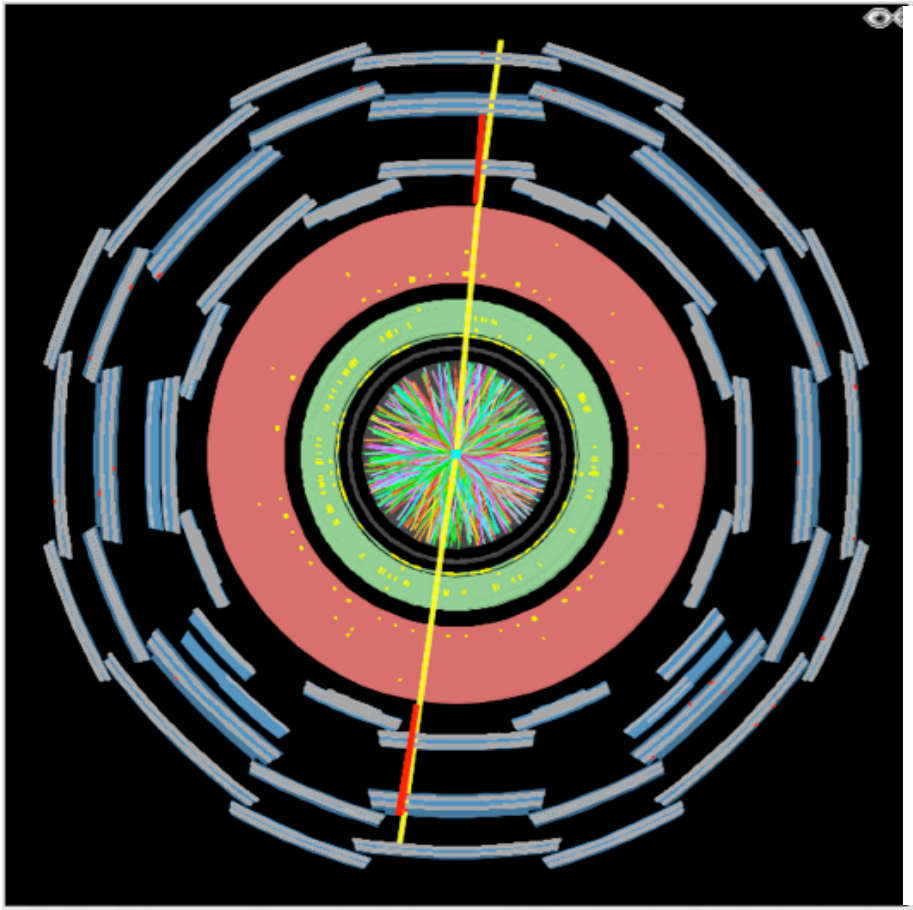
- >5 fb^{-1} delivered in 2011 at 7 TeV (2 β* running conditions)
- already >5 fb^{-1} delivered in 2012, running at 8 TeV
- peak luminosity $6.7 \cdot 10^{33}$ $cm^{-2}s^{-1}$ (high pile-up environment)

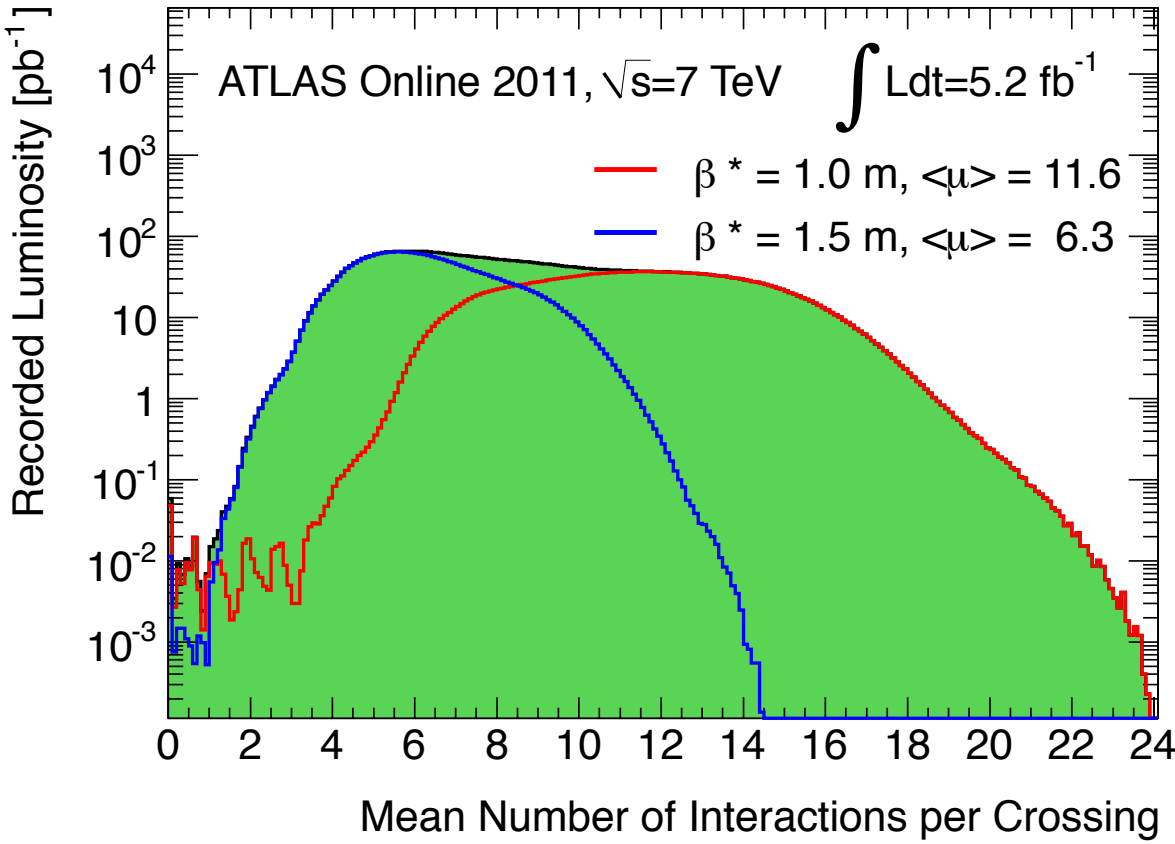
ATLAS data taking efficiency >93%

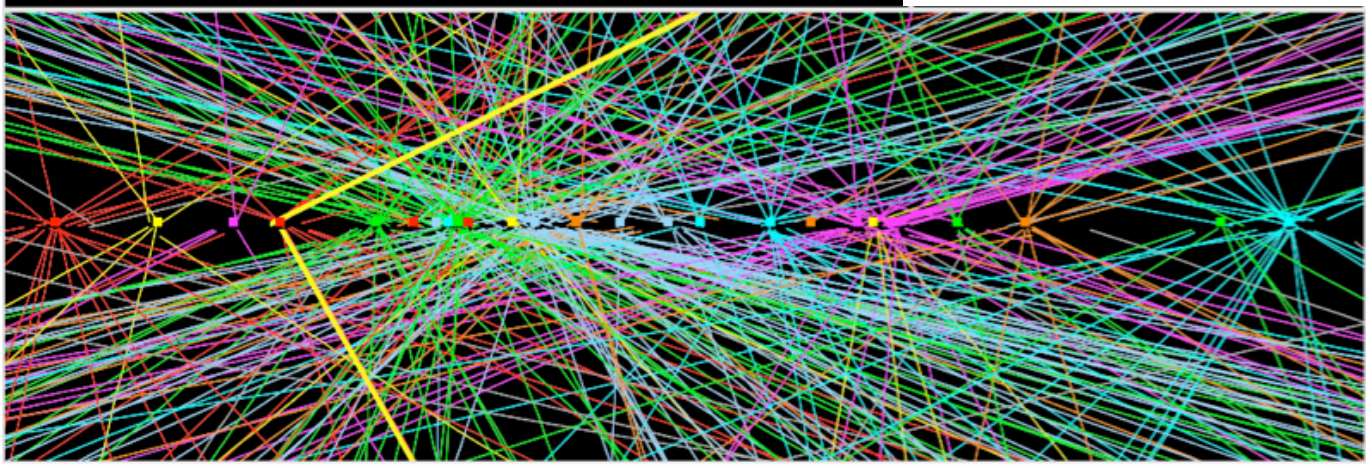




Pile-up

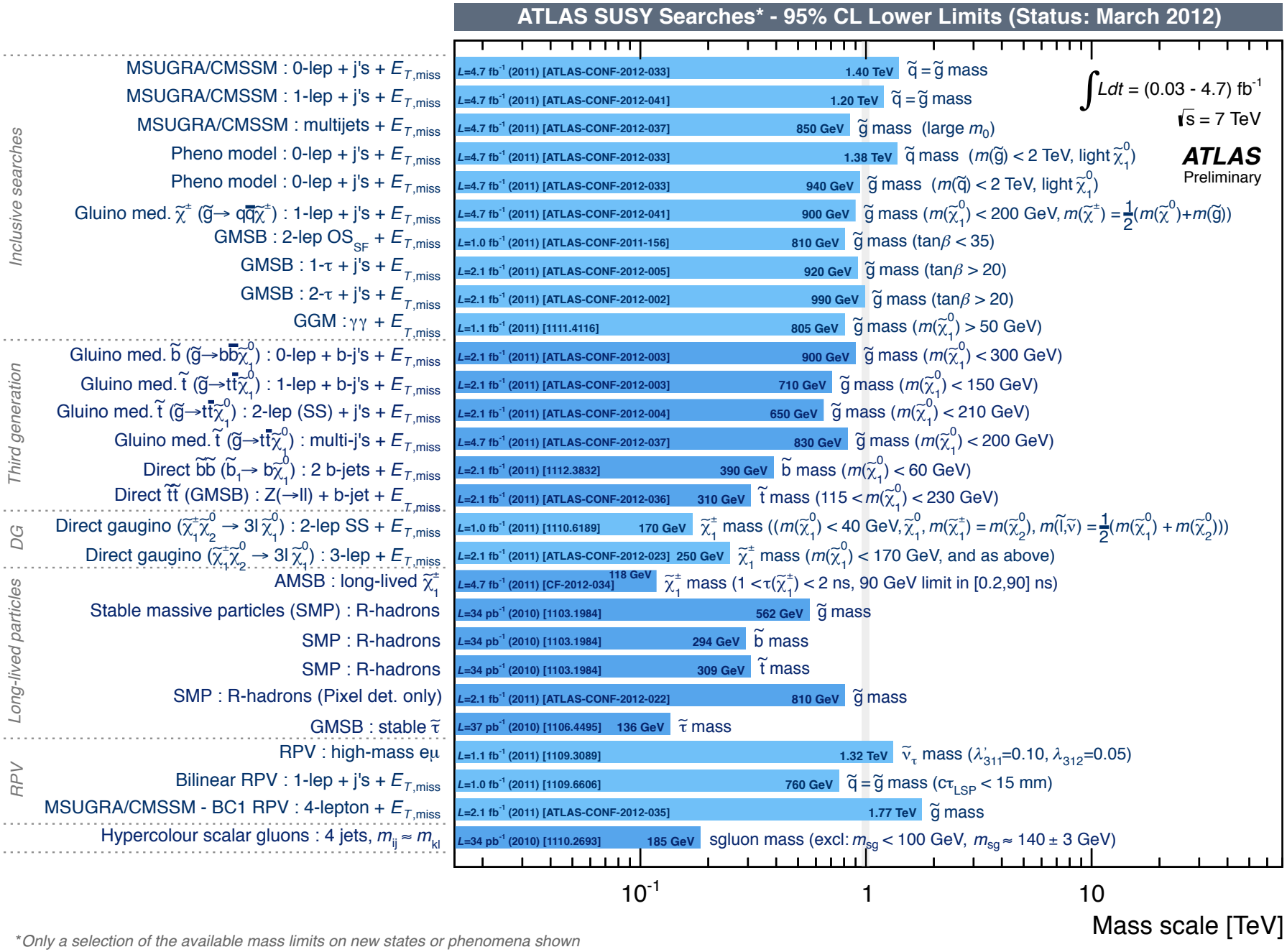






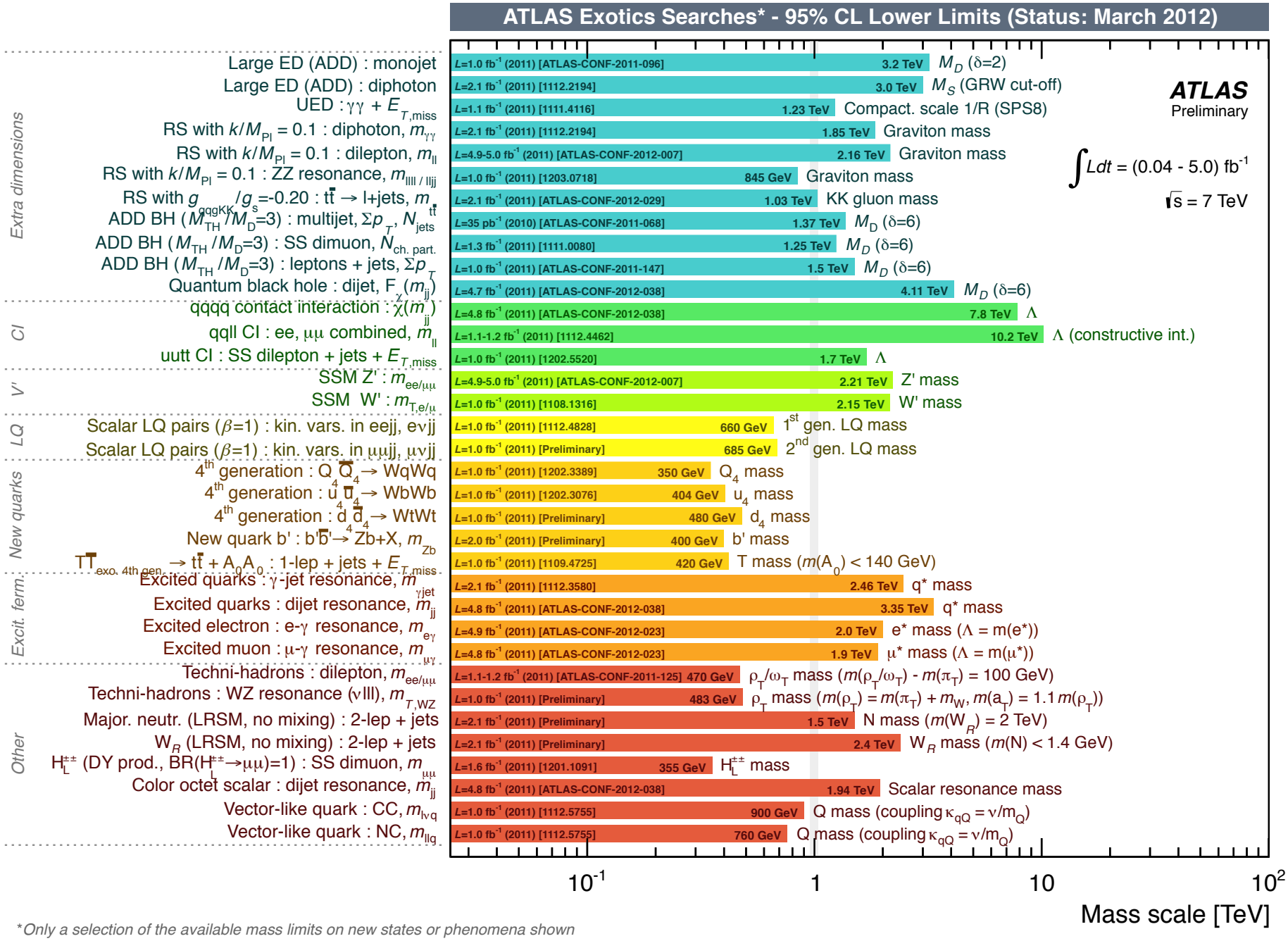
Z→μμ with 25 pile-up interactions in 2012

Overview of the SUSY Searches



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

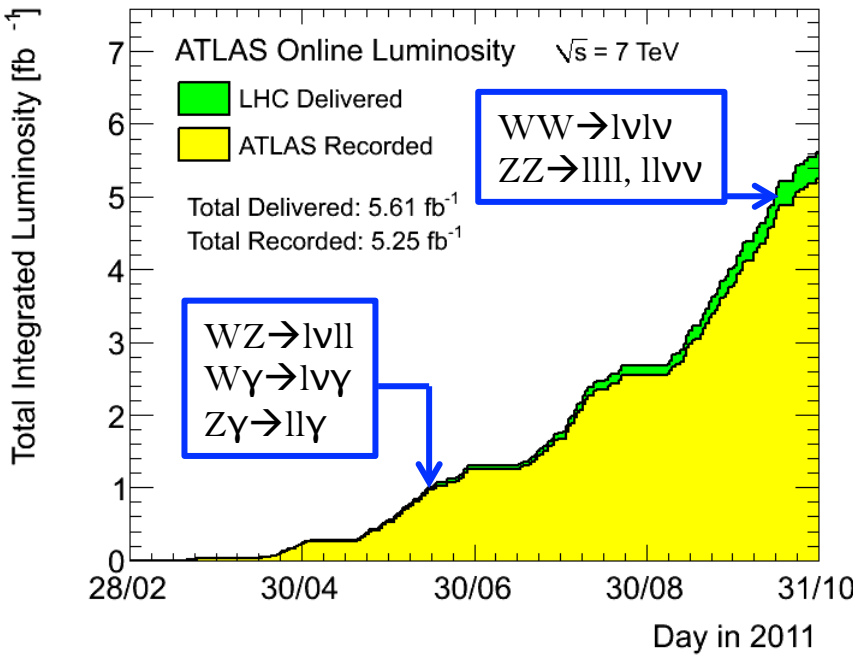
Overview of exotic searches

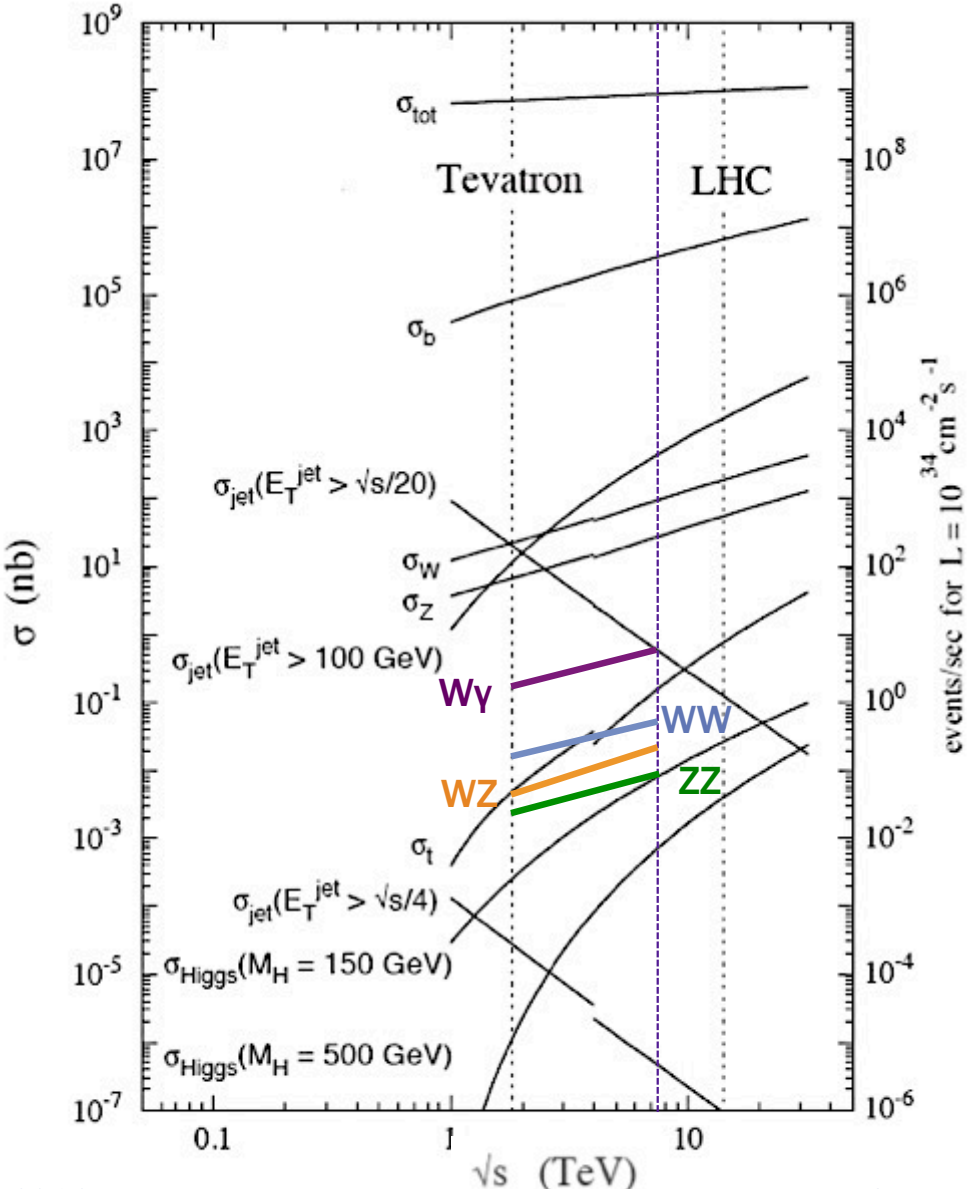


*Only a selection of the available mass limits on new states or phenomena shown

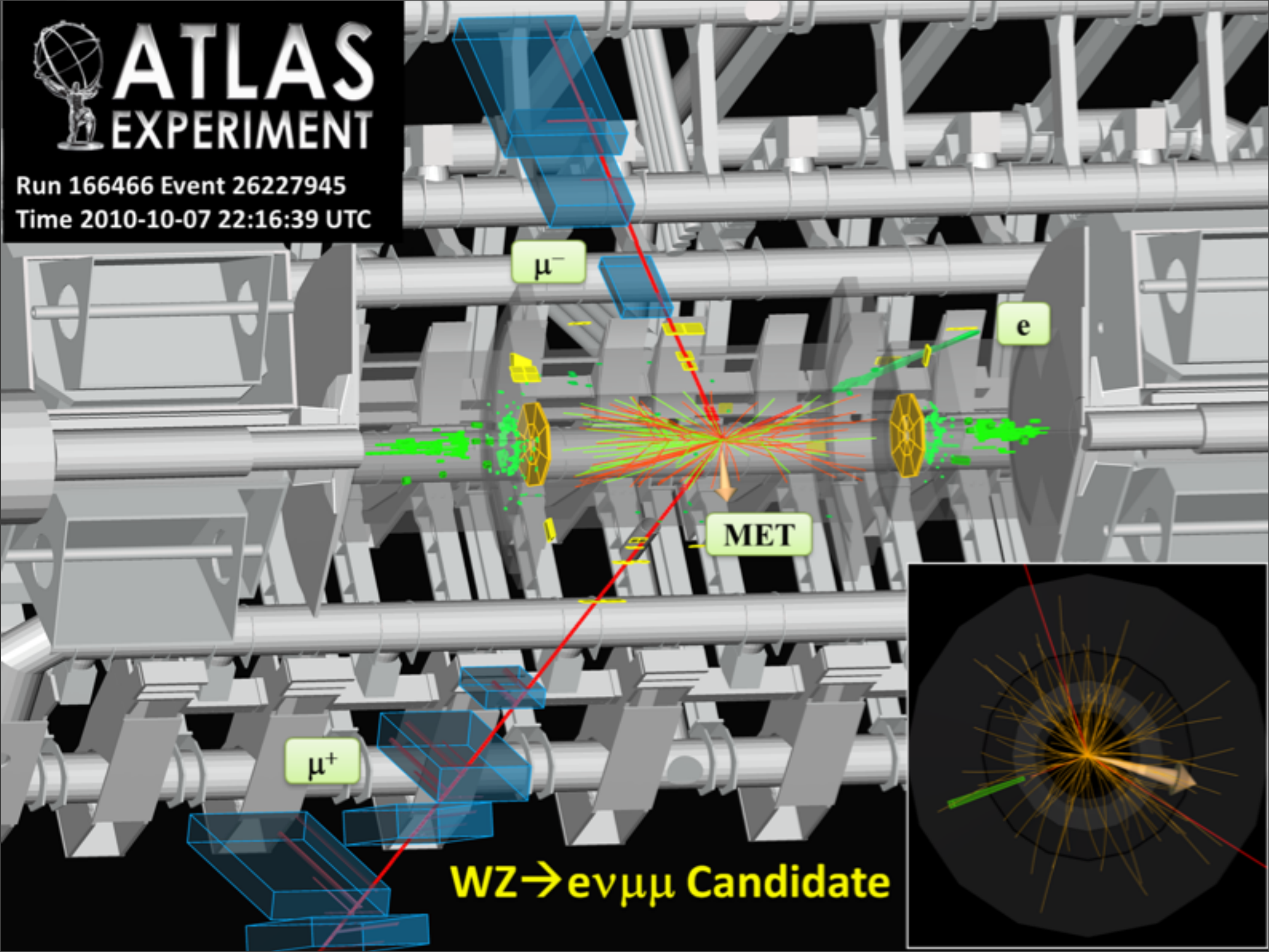
Physics with dibosons

Dibosons are relatively rare processes that provide powerful probes of the standard model in the electroweak sector





Wγ→lνγ arXiv :1205.2531
Zγ→llγ arXiv :1205.2531
WW→lνlν ATLAS-CONF-2012-025
WZ→lνll PLB 709 (2012) 341-357
ZZ→llll ATLAS-CONF-2012-026
ZZ→llνν ATLAS-CONF-2012-027


ATLAS
EXPERIMENT
Run 166466 Event 26227945
Time 2010-10-07 22:16:39 UTC
μ⁻
e
MET
μ⁺
WZ→eνμμ Candidate

$W\gamma$ & $Z\gamma$

arXiv :1205.2531

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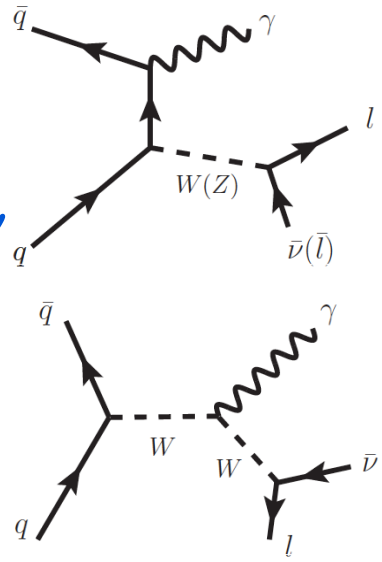
Selection:

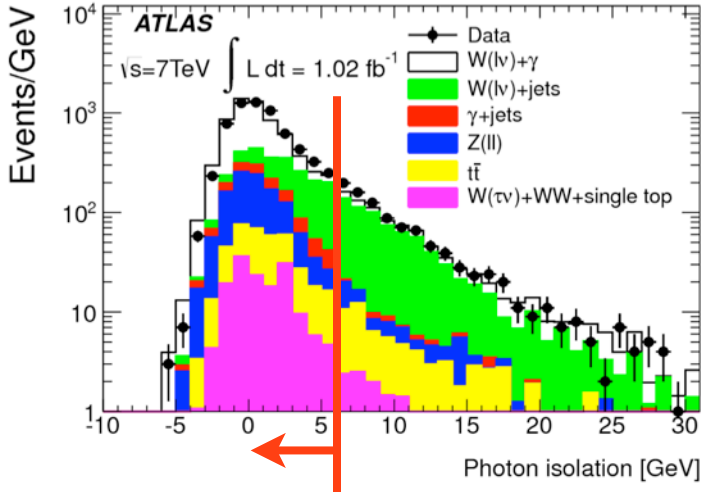
- W or Z candidate, $m_{\ell\ell}$ or m_T > 40 GeV
- Isolated photon with p_T>15 GeV
- $\Delta R(\ell,\gamma)$>0.7

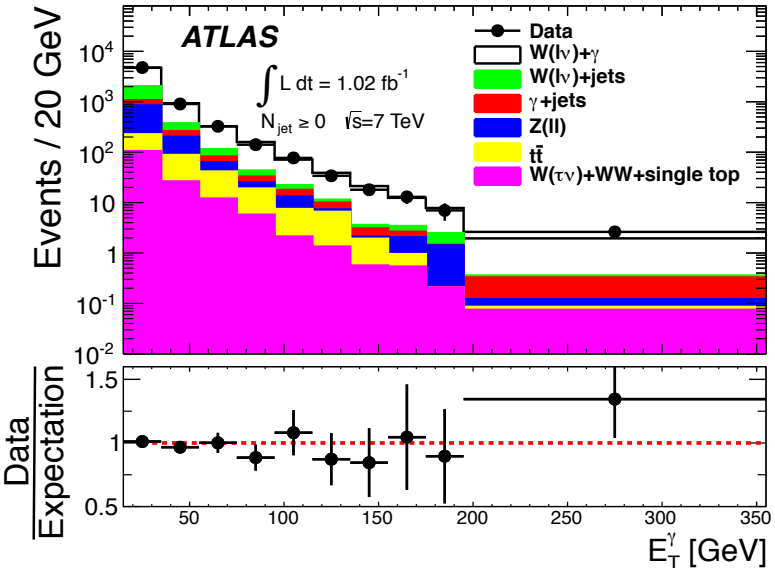
Main Backgrounds

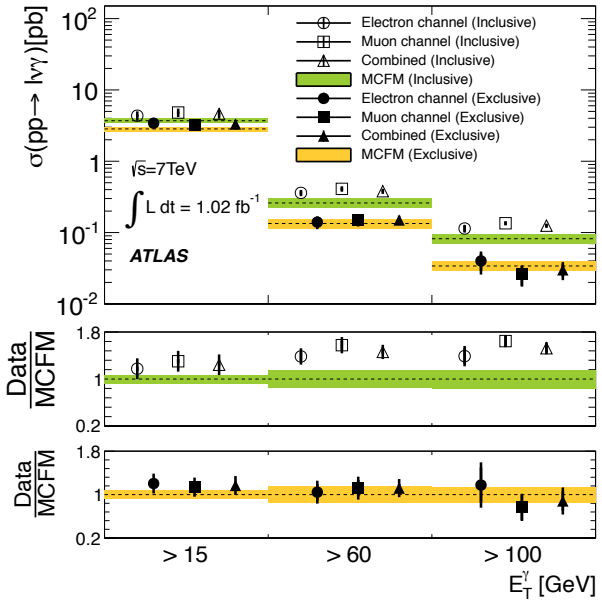
- W/Z+jets, where jet fakes a ℓ or γ

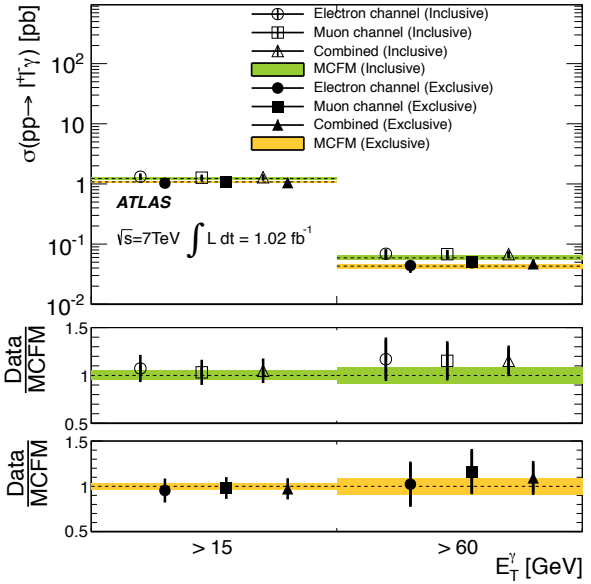
Measure exclusive (0-jet) and inclusive (no cut on number of jets) cross section









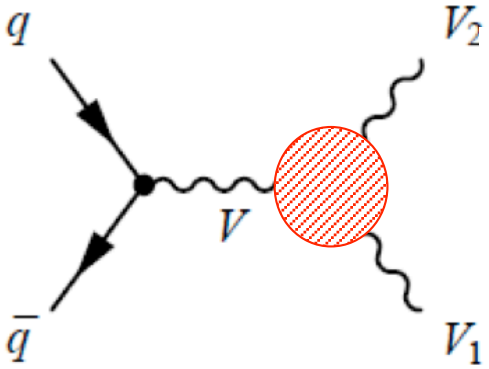


Anomalous TGCs

arXiv :1205.2531

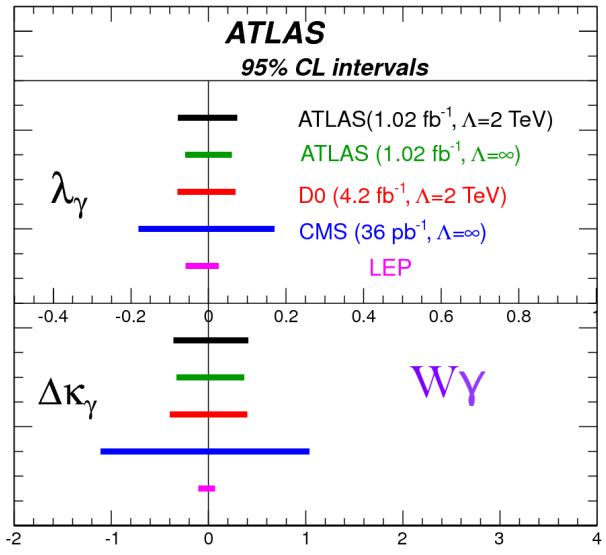
Effective Lagrangian to model generic new contributions to TGCs

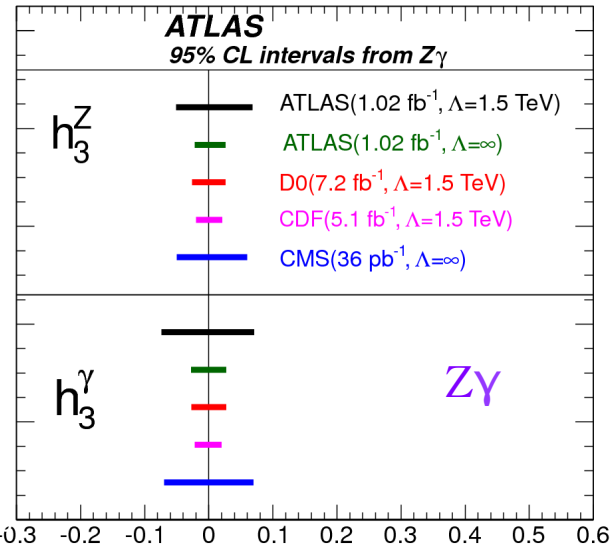
- In SM, all new couplings are zero, except $g_1^V=\kappa^V=1$
- For WWγ vertex analysis, fix $g_1^\gamma=1$ to ensure EM gauge invariance
- Form factor, with scale Λ, can be used to suppress divergent cross section at large √s and preserve unitarity

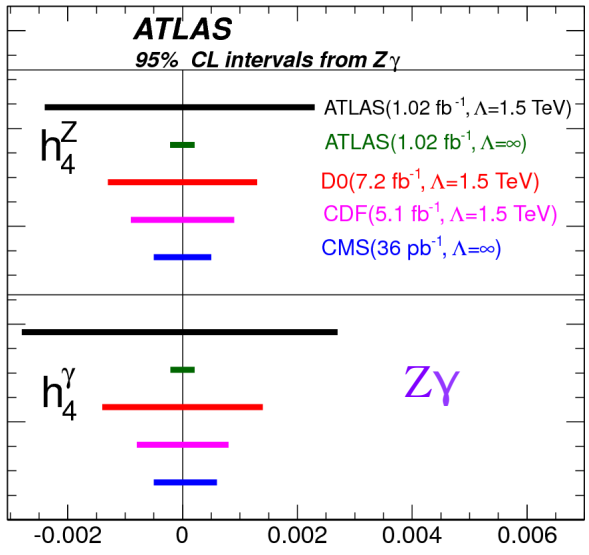


$$\frac{\mathcal{L}_{WWV}}{g_{WWV}} = i\left[g_1^V(W^\dagger_{\mu\nu}W^\mu V^\nu - W_{\mu\nu}W^{\dagger\mu}V^\nu) + \kappa^V W^\dagger_\mu W_\nu V^{\mu\nu} + \frac{\lambda^V}{m_W^2}W^\dagger_{\rho\mu}W^\mu_\nu V^{\nu\rho}\right]$$

$$\mathcal{L}_{VZZ} = -\frac{e}{M_Z^2}\left[f_4^V(\partial_\mu V^{\mu\beta})Z_\alpha(\partial^\alpha Z_\beta) + f_5^V(\partial^\sigma V_{\sigma\mu})\tilde{Z}^{\mu\beta}Z_\beta\right]$$







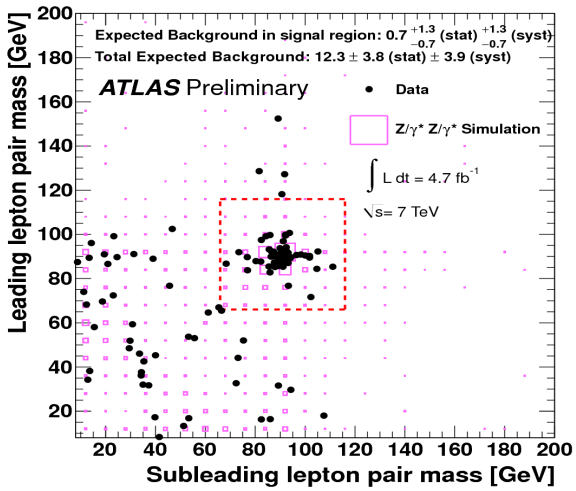
WZ→lvll, ZZ→4l & WW→lvlv

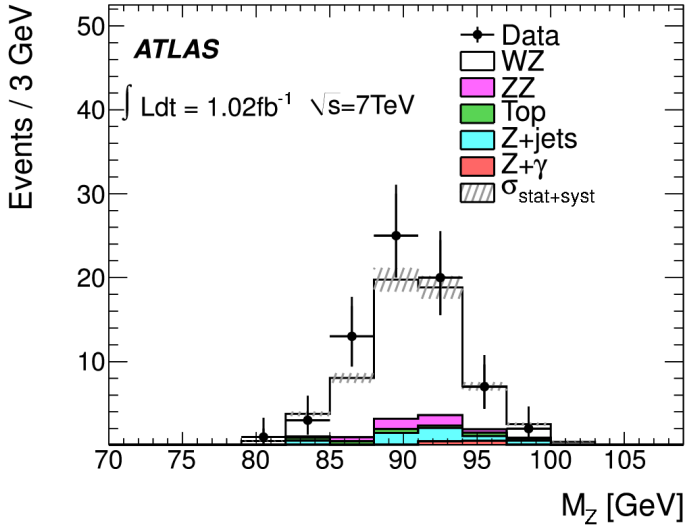
Fiducial and inclusive cross sections measured for all diboson processes

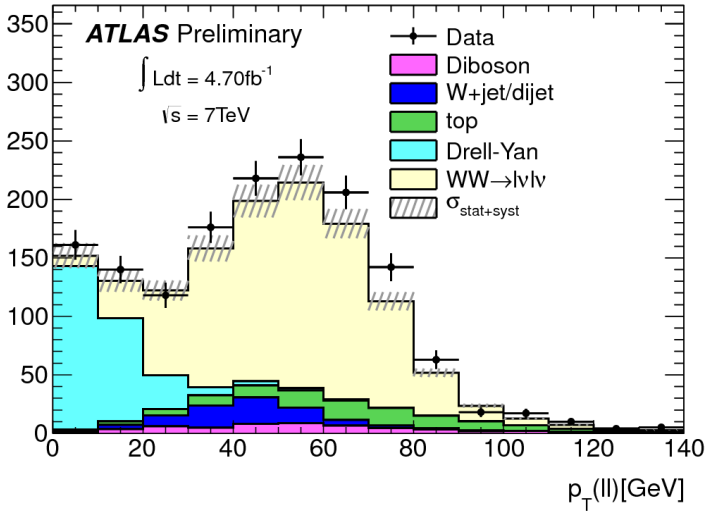
ZZ→4l Selection:
- Four isolated leptons with p_T>7 GeV
- Leading lepton pT>20, 25 GeV (μ,e)
- Two Z candidates with $|m_{ll}-M_Z^{pole}|$<25 GeV

WZ→lvll Selection:
- At least 3 isolated leptons, p_T>15 GeV
- E_T^{miss} > 25 GeV
- A Z candidate with $|m_{ll}-M_Z^{pole}|$<10 GeV
- A W candidate with m_T > 20 GeV

WW→ lvlvSelection:
- Exactly 2 opposite-charge, isolated leptons with p_T>20 GeV
- Z Veto
- No jet/b-jet with p_T>25, 20 GeV
- m_{ll}>15,15,10 GeV (μμ,ee,eμ)
- $E_{T\ rel}^{miss}$>55,50,25 GeV (μμ,ee,eμ)







Total Cross Section

Measured: $7.2^{+1.1}_{-0.9}\,(stat)\,^{+0.4}_{-0.3}\,(sys)\pm 0.3(lumi)\ pb$

SM NLO prediction: $6.5^{+0.3}_{-0.2}\ pb$

Fiducial Cross Section

Measured: $21.2^{+3.2}_{-2.7}\,(stat)\,^{+1.0}_{-0.9}\,(sys)\pm 0.8(lumi)\ fb$

Total Cross Section

Measured: $20.5^{+3.1}_{-2.8}\,(stat)\pm 1.4(sys)\,^{+0.9}_{-0.8}\,(lumi)\ pb$

SM NLO prediction: $17.3^{+1.3}_{-0.8}\ pb$

Fiducial Cross Section

Measured: $102^{+15}_{-14}\,(stat)\pm 7(sys)\pm 4(lumi)\ fb$

Channels	expected σ^{fid} (fb)	measured σ^{fid} (fb)
$ee\nu\nu$	44.9±3.7	41.4 ± 8.8
$\mu\nu\mu\nu$	38.0±3.1	48.2 ± 6.3
$e\nu\mu\nu$	237.4±19.4	284.9 ± 22

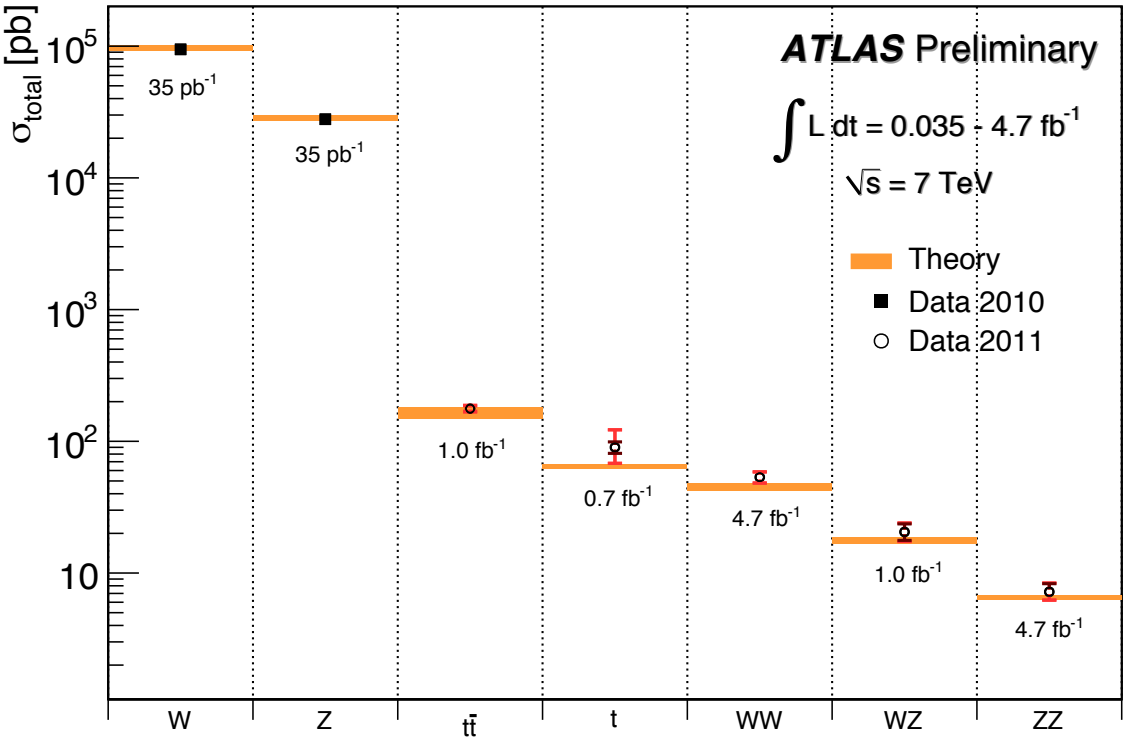
Summary of Diboson measurements

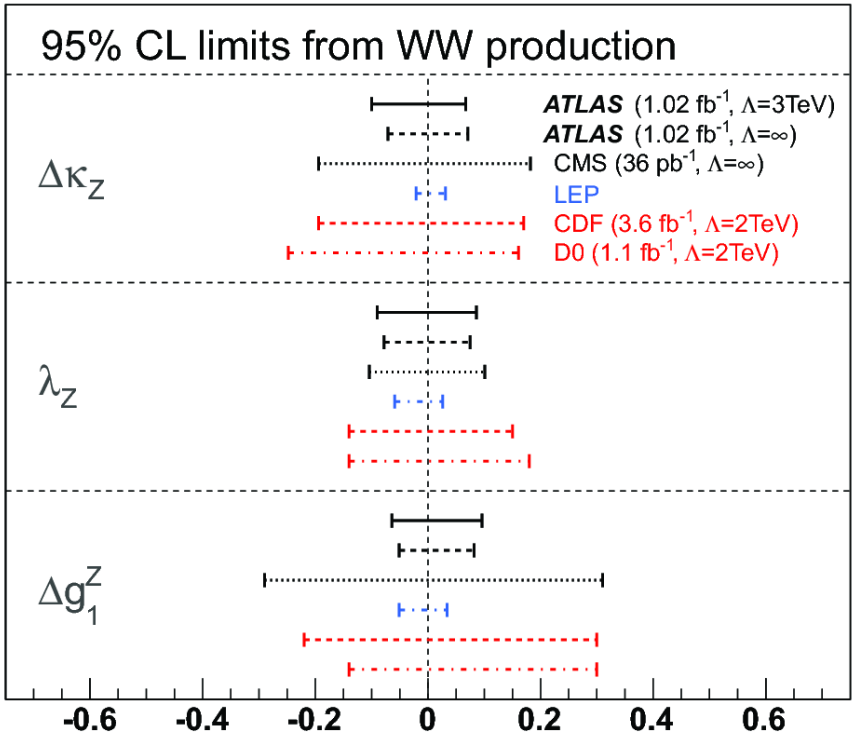
All diboson cross sections measured

- agree with SM within uncertainty

Limits on anomalous TGC derived

- Competitive with LEP and Tevatron

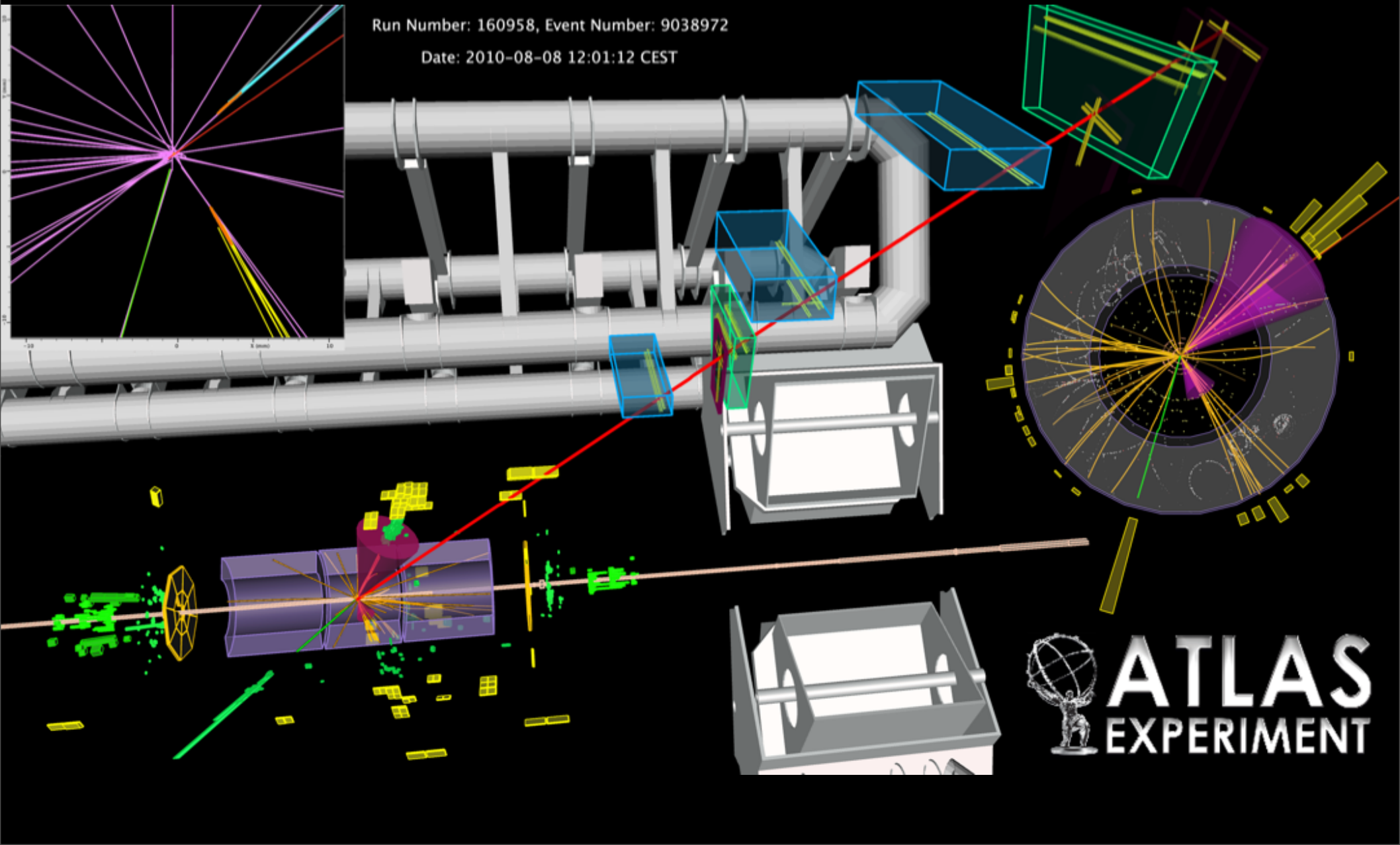




Outlook

- Update cross section and anomalous TGC analyses to 5 fb^{-1}
- WZ and ZZ will move to differential distributions for anomalous TGC analysis

Top Physics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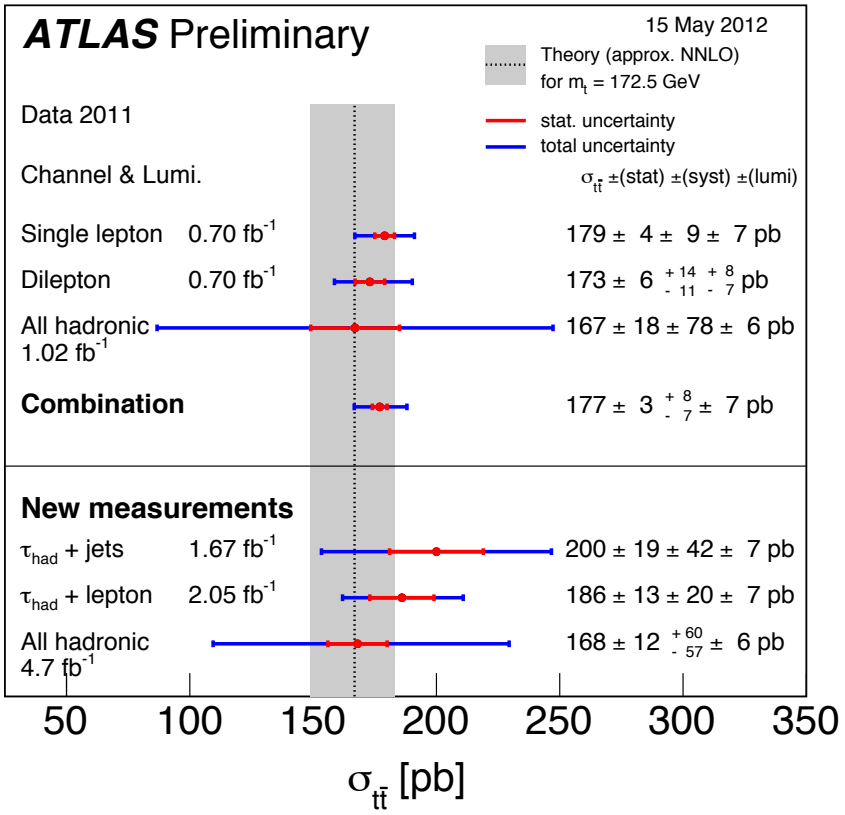
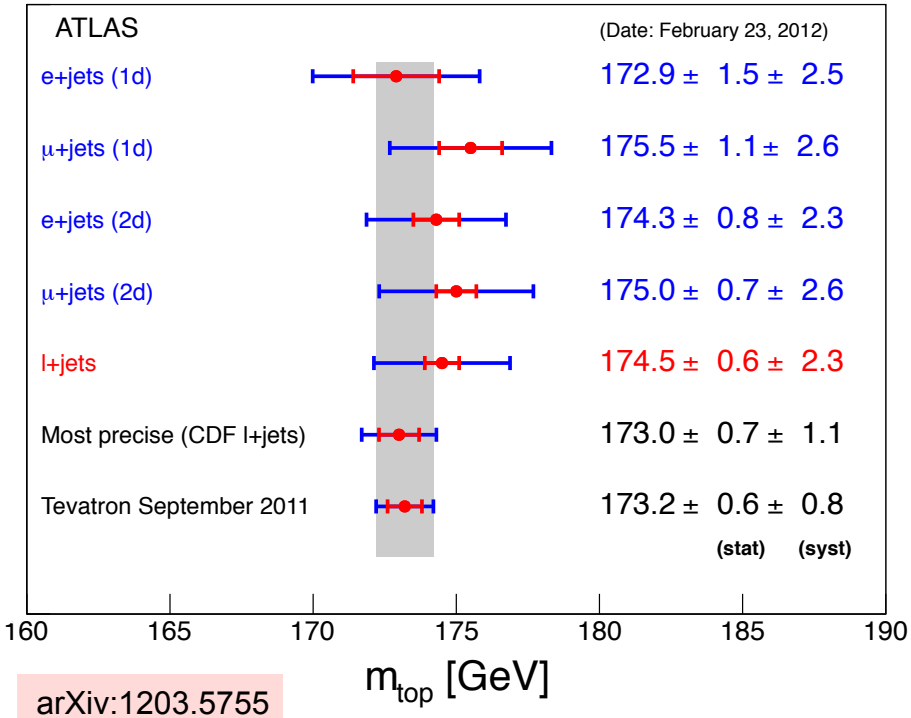
Date: 2010-08-08 12:01:12 CEST
ATLAS
EXPERIMENT

Top physics

The large mass of the top quark hints that it may play a special role in electroweak symmetry breaking and BSM physics

- $A_{FB}^{t\bar{t}}$ anomaly at the Tevatron -- many models predict same-sign top pairs
- $t\bar{t}$ resonances common in non-SUSY solutions to hierarchy problem
- $t\bar{t}$ production is a background to almost all searches





arXiv:1203.5755

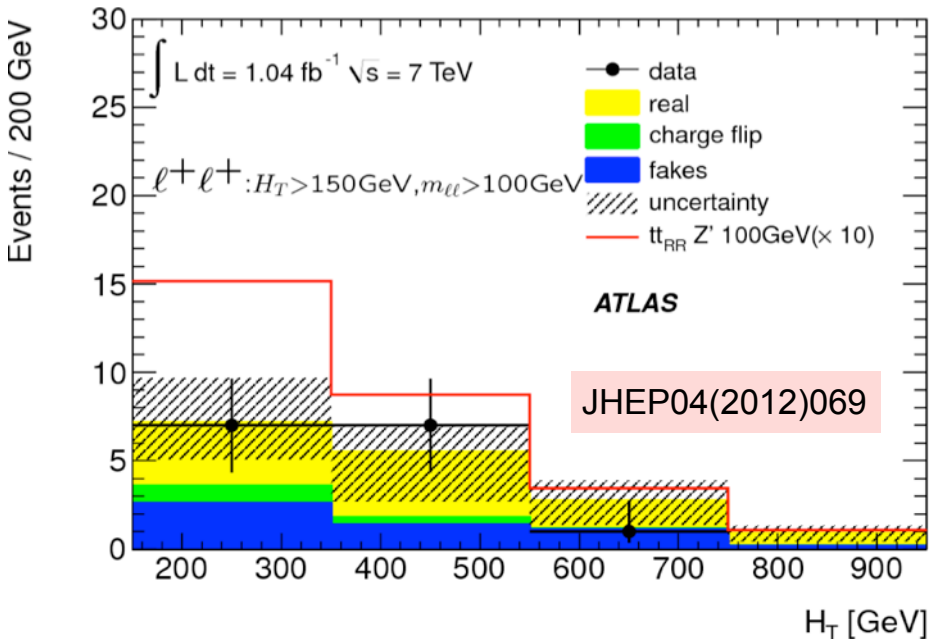
Same-sign top & 4th gen down-type quarks

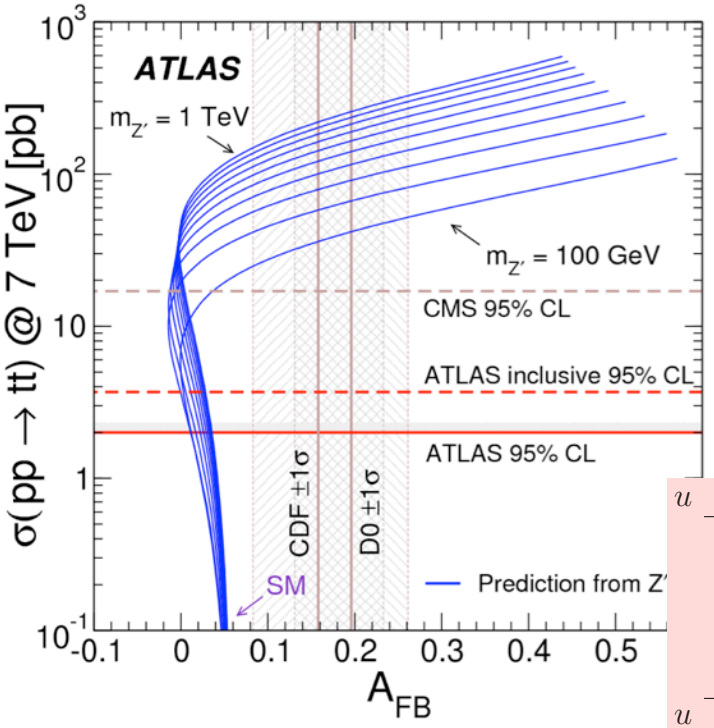
Experimental signature:

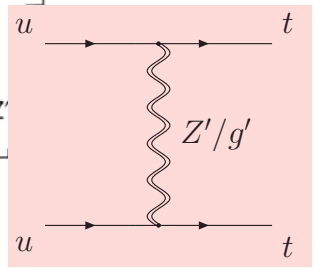
- ✓ Same sign lepton pair (ee, eμ, μμ)
- ✓ Large missing transverse energy

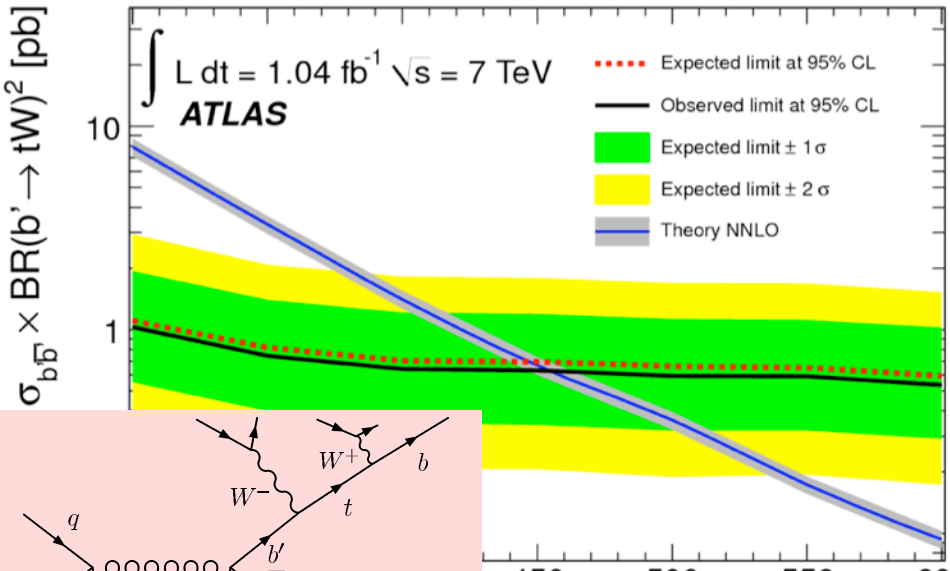
Background:

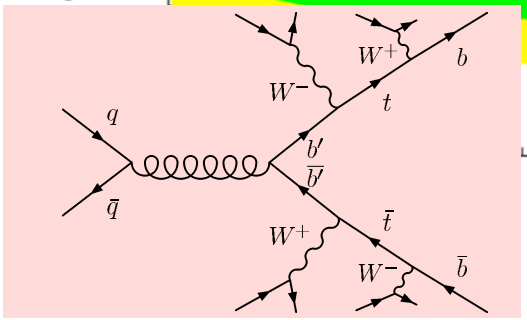
- ✓ Fake lep (hadron, photon conversion)
- ✓ Charge mid identification
- ✓ Di-boson (using MC)











$t\bar{t}$ resonance (dilepton channel)

arXiv:1205.5371

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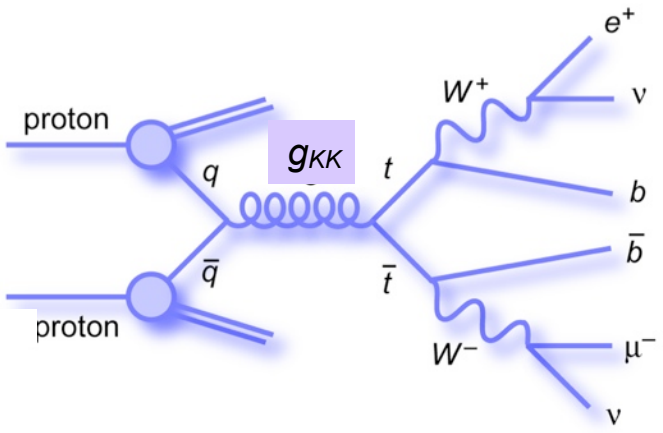
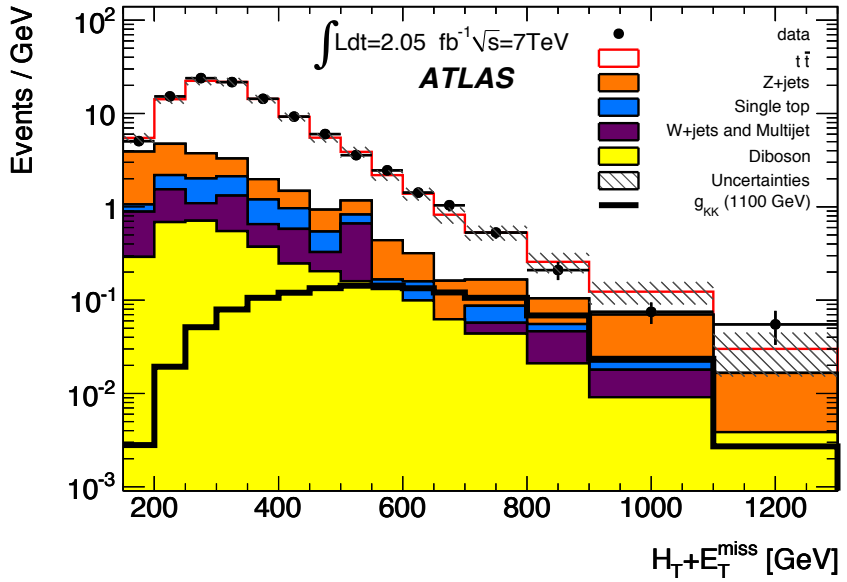
Benchmark models:

- Narrow Z' (topcolor model)
- Kaluza-Klein gluon (RS model)

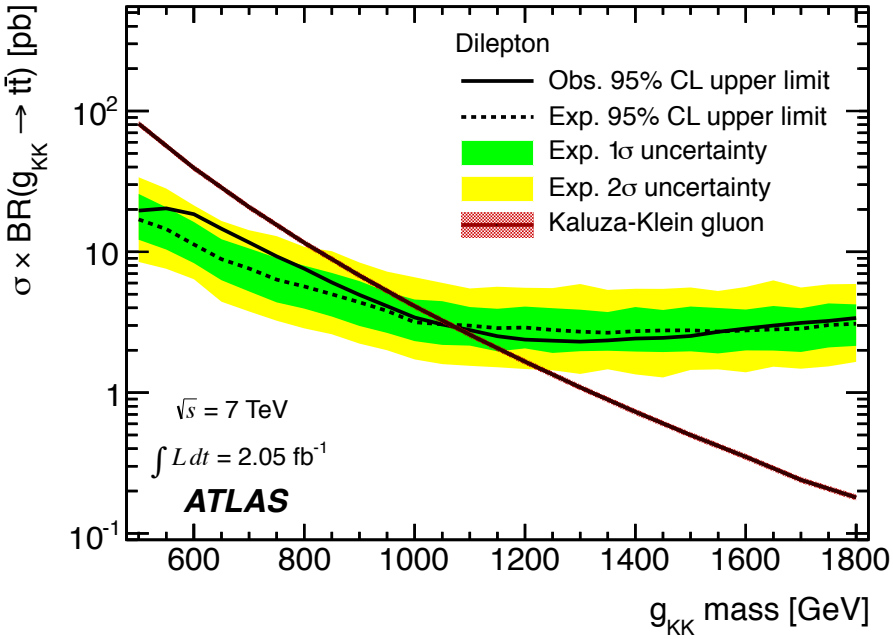


$$H_T \text{ and } \not{E}_T \text{ where } H_T = \sum_{\ell} p_T^{\ell} + \sum_{jets} p_T^{jet}$$



Event selection: No B tagging

- ≥ 2 jets and $= 2$ OS leptons
- $|m_Z - m_{\ell\ell}| > 10\,\text{GeV}$
- $\not{E}_T > 40\,\text{GeV}$
- $H_T > 130\,\text{GeV}$ in $e\mu$ channel



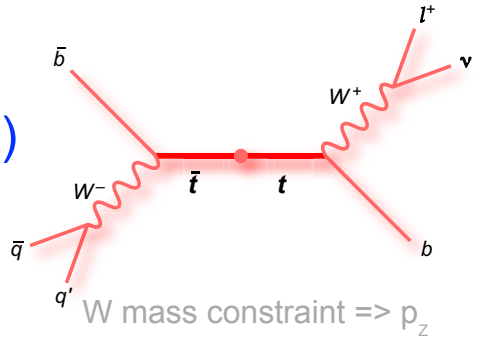
$t\bar{t}$ resonance (lepton+jets channel)

arXiv:1205.5371

Center for Cosmology and Particle Physics

Benchmark models:

- Narrow Z' (topcolor model)
- Kaluza-Klein gluon (RS model)



W mass constraint => p_z (choose small solution)

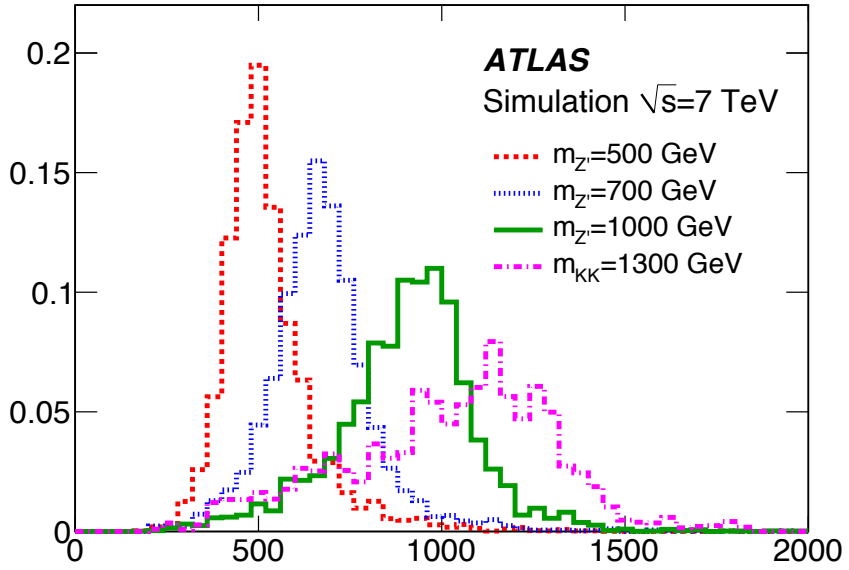
Jet selection:

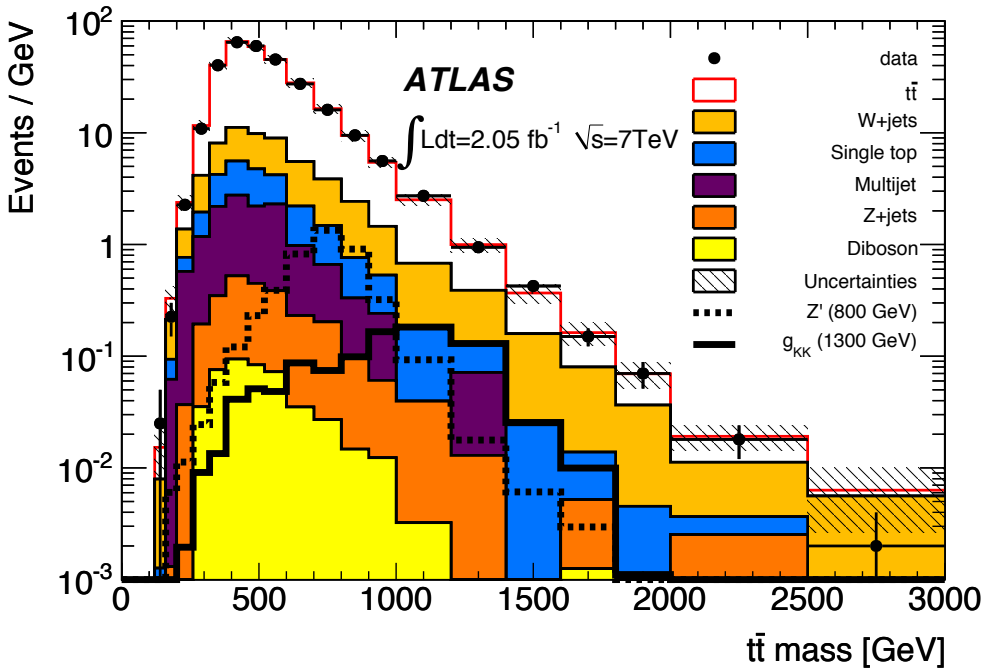
>=1 b tagged jet

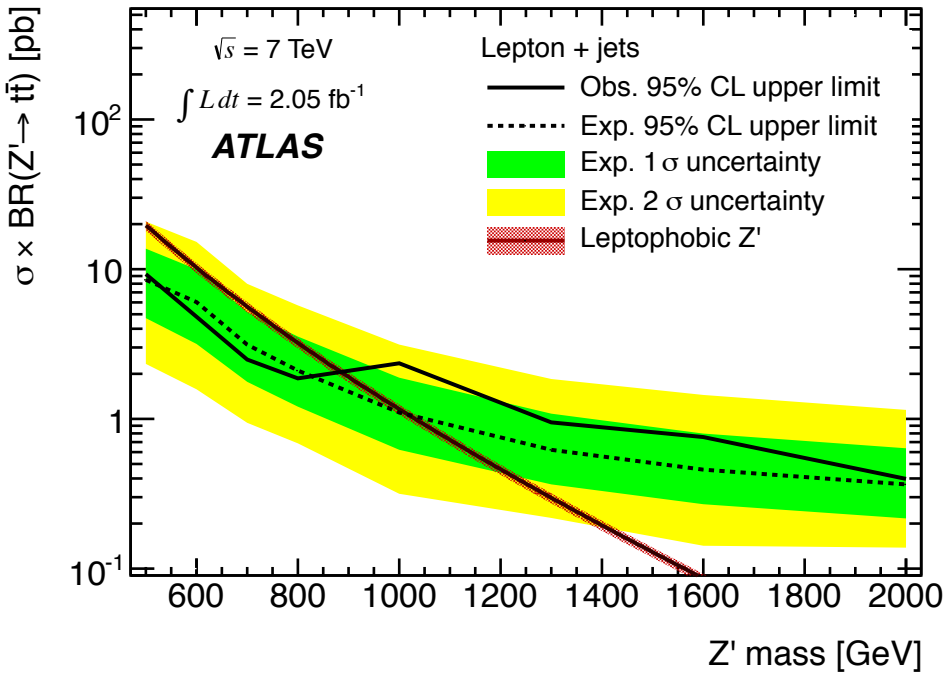
>=4 jets or >=3 jets if one m_{jet}>60 GeV

(Boosted W reconstructed by single jet, <1% data)

Not yet using jet substructure techniques





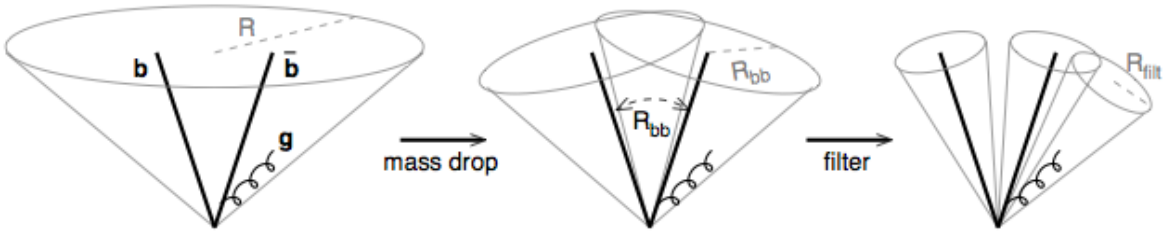


Jet mass & substructure

JHEP 1205 (2012) 128

Boosted topologies & jet substructure offer promising tool for new physics searches at LHC

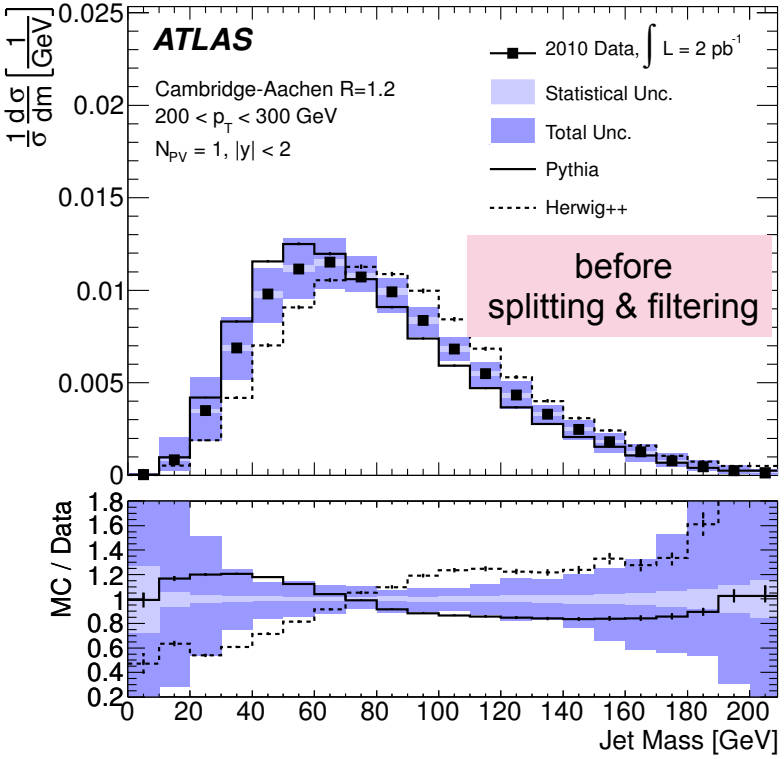
Study based on large anti-kT (R=1) and Cambridge-Aachen (R=1.2) jets in 4 pT bins



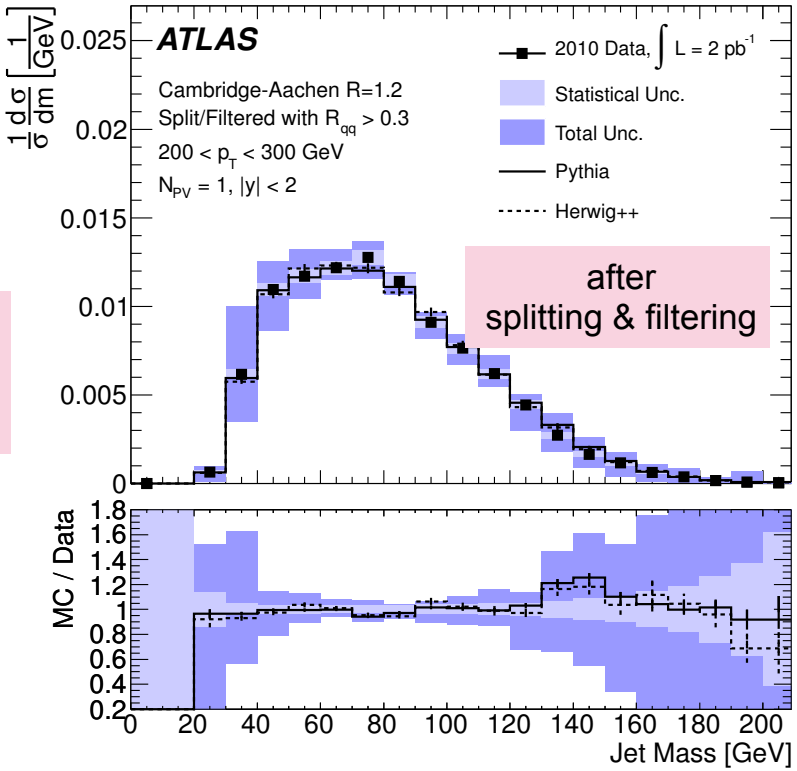
Butterworth, Davison, Rubin, Salam
PRL 100, 242001 (2008)

Iterative Dynamically Stabilized Unfolding technique (matrices published to HEPData)

Jet mass shows largest disagreement with LO MC, improved after splitting & filtering



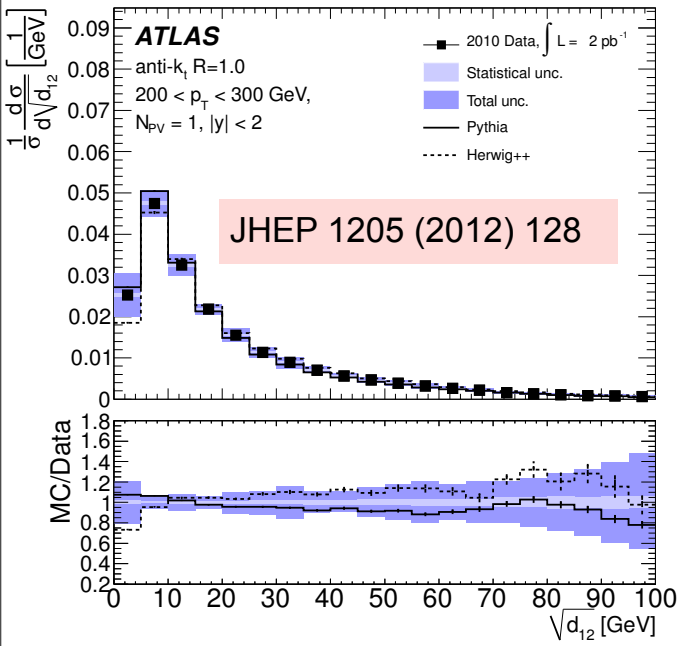
Low pileup:
<N_{vtx}> ~2

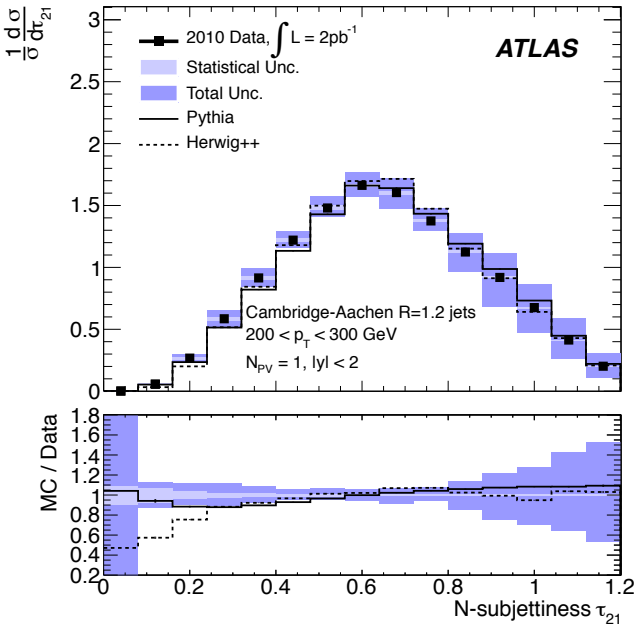


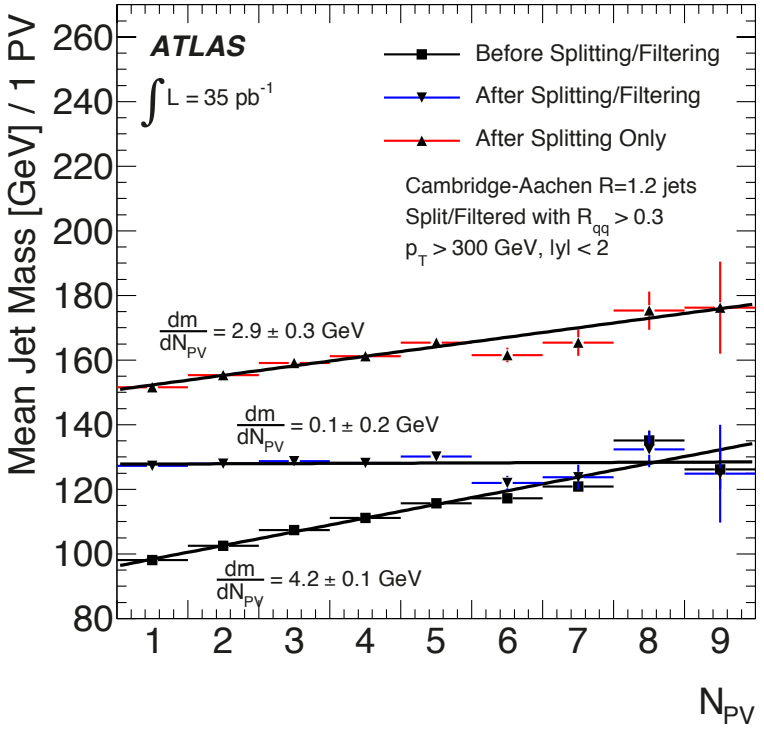
Jet mass & substructure

Jet mass, kT splitting scales, and N-subjettiness measured before and after unfolding

- Described reasonably well, large systematic uncertainties
  - sub-jet properties generally agree better
  - jet-mass after splitting and filtering shows less dependence on pile-up







$$\sqrt{d_{12}} = \min(p_{Tj1}, p_{Tj2}) \times \delta R_{j1,j2},$$

Outlook: A powerful new tool is being commissioned in the search for new physics at LHC

Charged long-lived heavy particles

ATLAS-CONF-2012-022

E.g., long lived $\tilde{q}$ or $\tilde{g}$ forms an R-hadron

Average dE/dX in pixel detector clusters

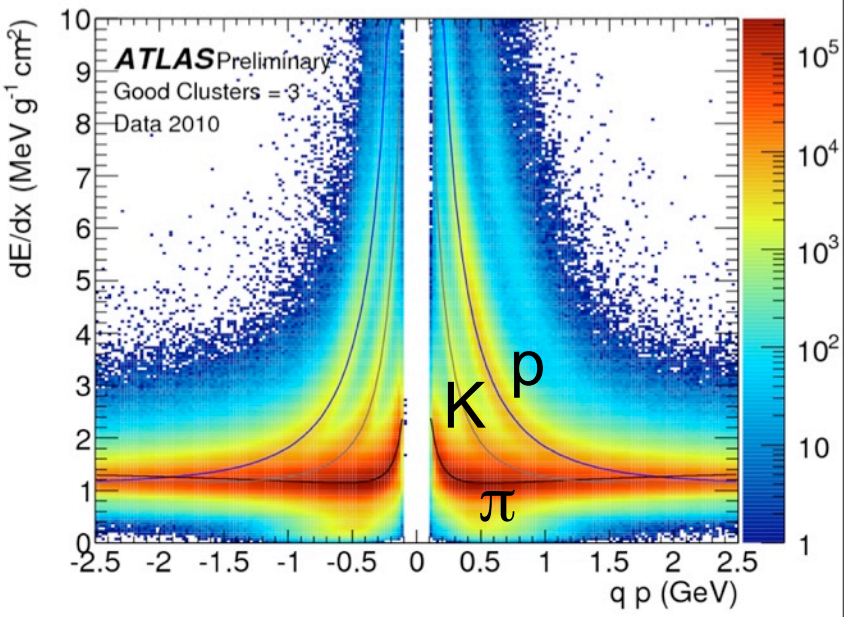
- mass determined from inverting Most Prob. Value

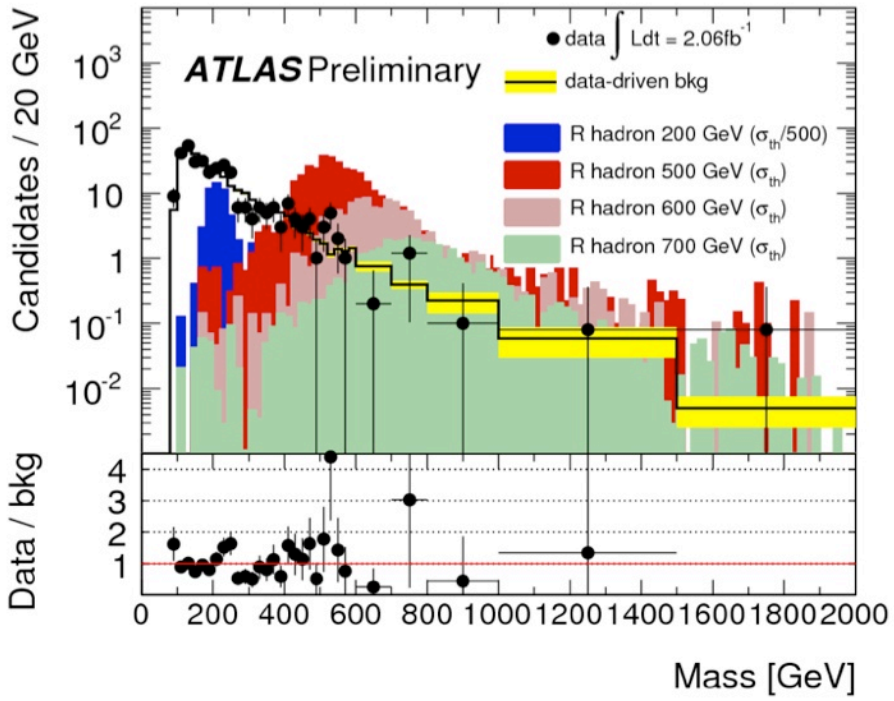
Using pixel only less sensitive to modeling of R-hadron in calorimeter

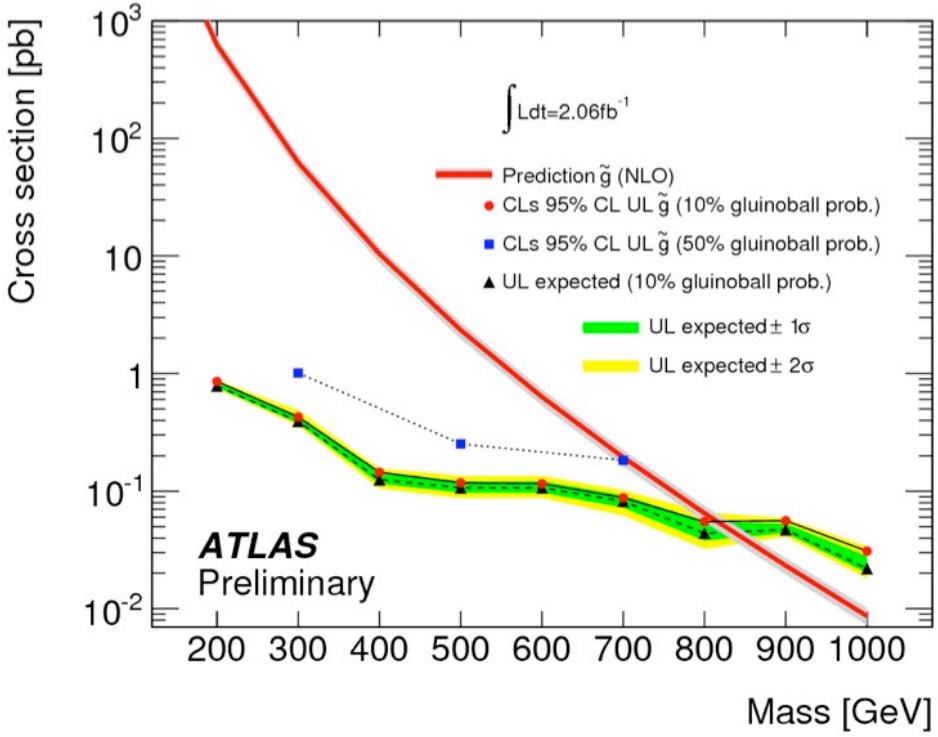
- several hadronization & material interaction models

Data-driven background estimates

Trigger: E_T^{miss}>70







Disappearing-track search

arXiv:1202.4847

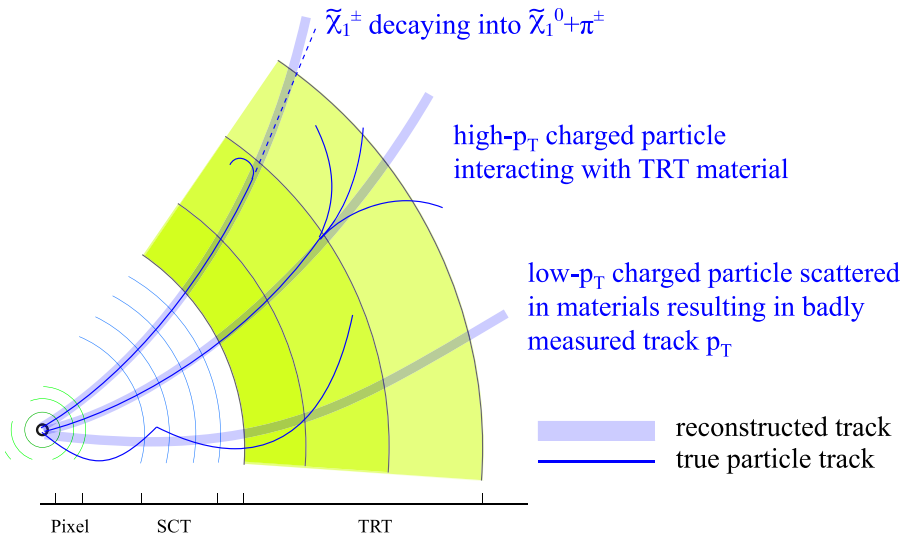
Center for Cosmology and Particle Physics

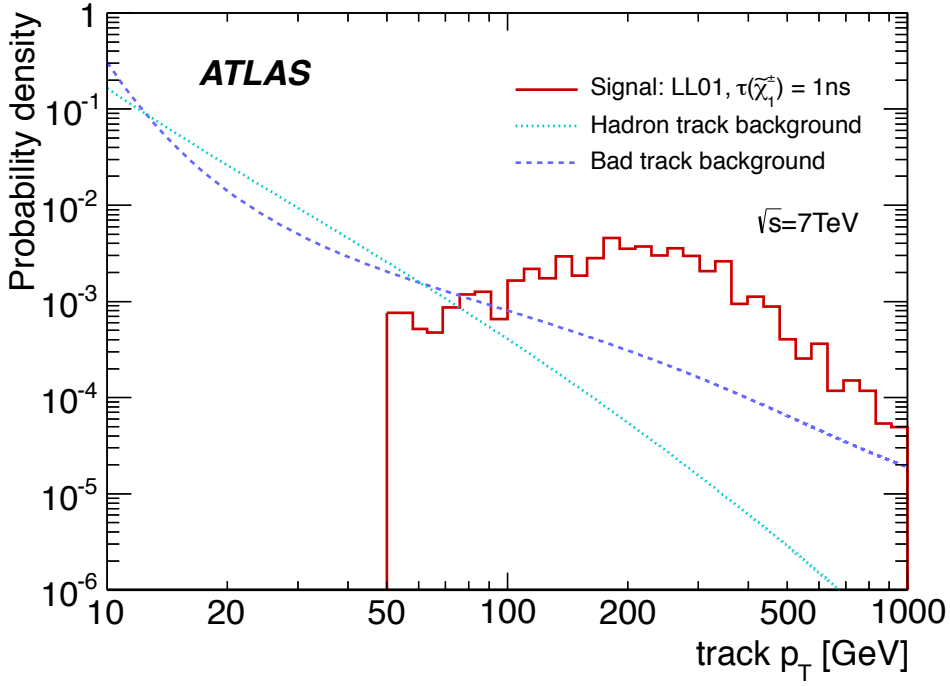
Long lived charged particle might decay in the tracking volume, giving rise to a `disappearing' track

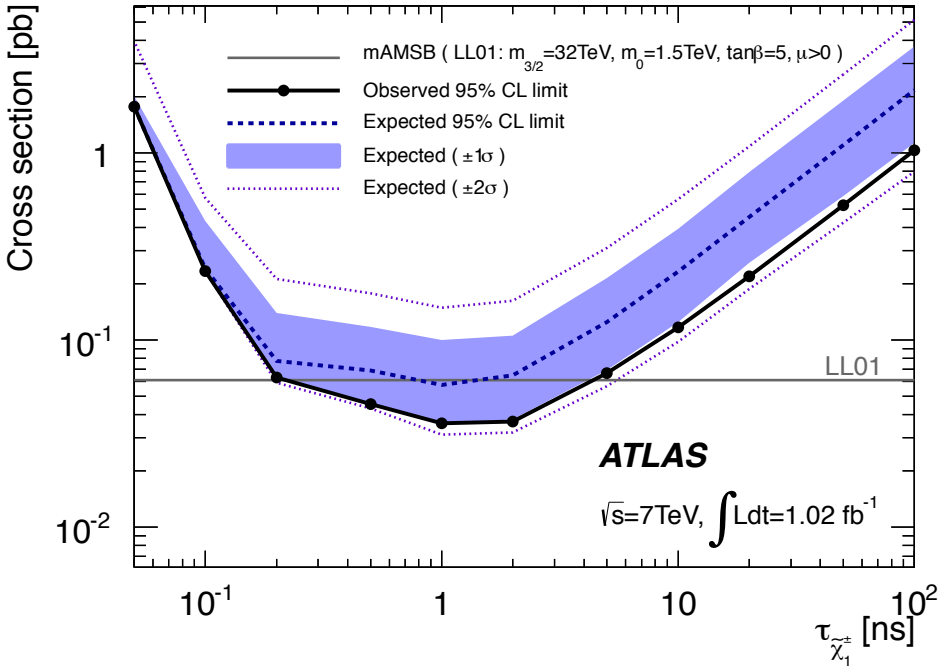
- for example, Anomaly mediated SUSY breaking with small mass splitting between $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_1^{0}$

Disappearing track has <5 hits in TRT

Backgrounds from material interaction and 'bad tracks' estimated from data





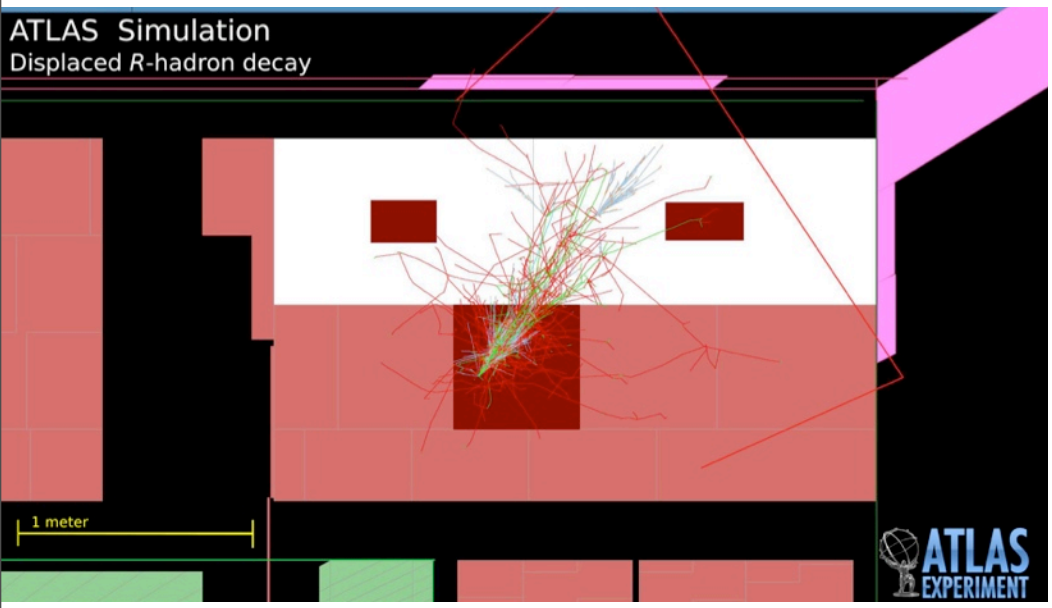


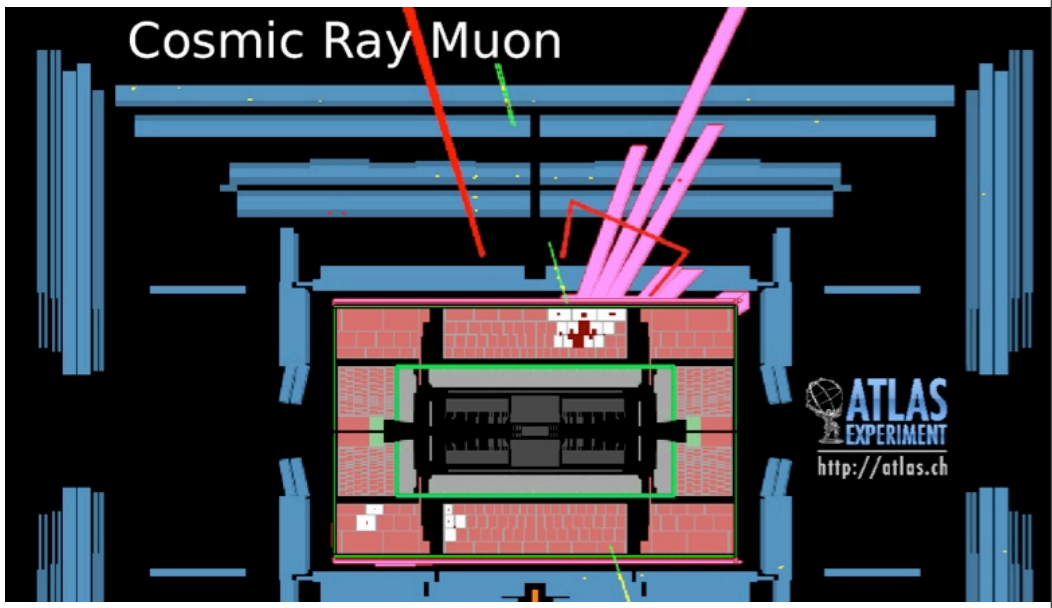
Stopped, Long-Lived Particles

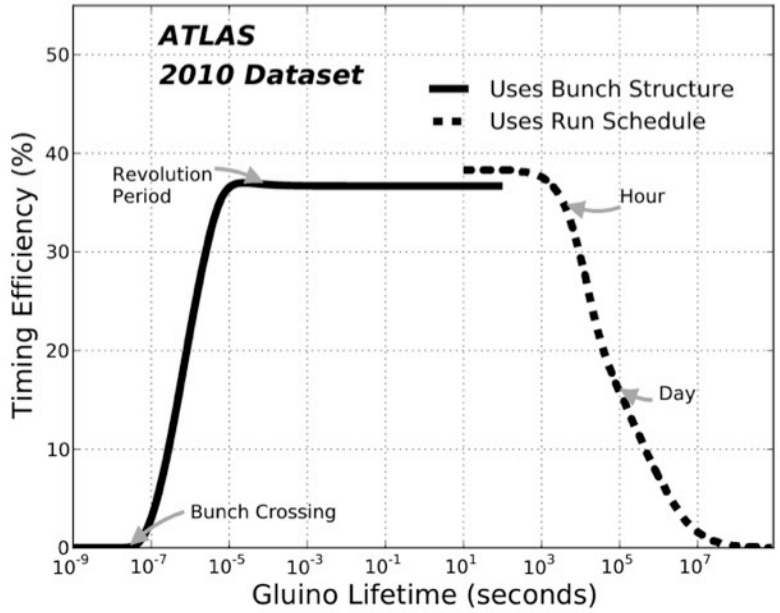
arXiv:1201.5595

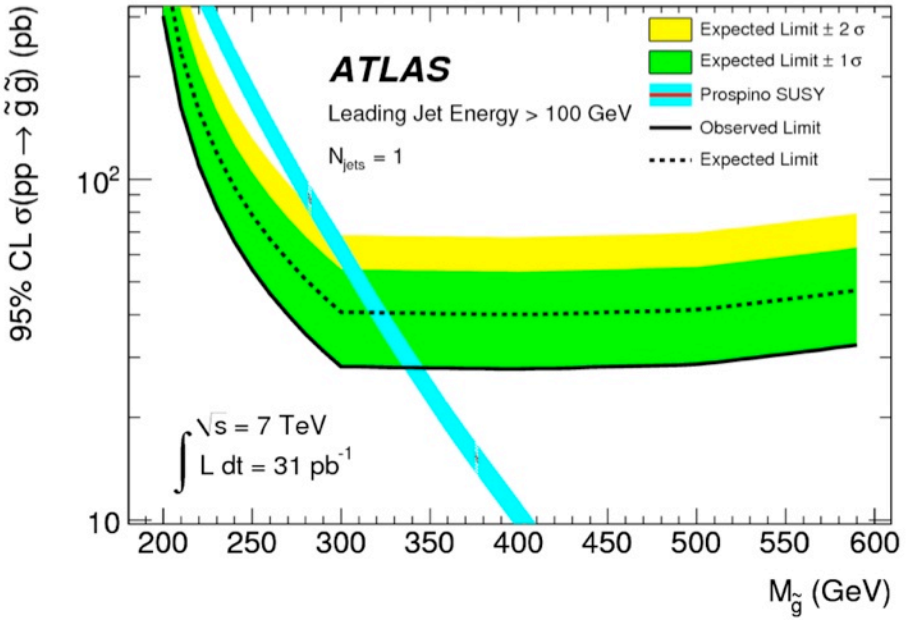
Center for Cosmology and Particle Physics

Even longer lived particles can stop in calorimeter, decay later









Summary

2011 was a fantastic year for the LHC and for ATLAS

- accelerator and detector both performing beyond expectations
- hundreds of papers submitted for publication
- high-precision measurements for electroweak and top physics
- stringent constraints for supersymmetry and exotica
- an intriguing excess in the search for the Higgs

2012 promises to be a year to remember

- already >5 fb^{-1} of pp collisions at 8 TeV
- the Higgs story will unfold
- will deploy several new tools commissioned in 2011

More results from ATLAS can be found here:

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