Search for new physics using jets at ATLAS

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On behalf of ATLAS Collaboration

DISCRETE 2012 - Third Symposium on Prospects in the Physics of Discrete Symmetries

Outline of the talk

New results with 8 TeV

- Monojet + missing Et
- Dijet final states
- Multijets

- **Large diversity of theoretical models:**
- Dark Matter, Extra-Dimensions, Lepto-Quark, etc,
- Alternative solutions to the hierarchy problem, weakness of gravity, dark matter, grand unification, etc.

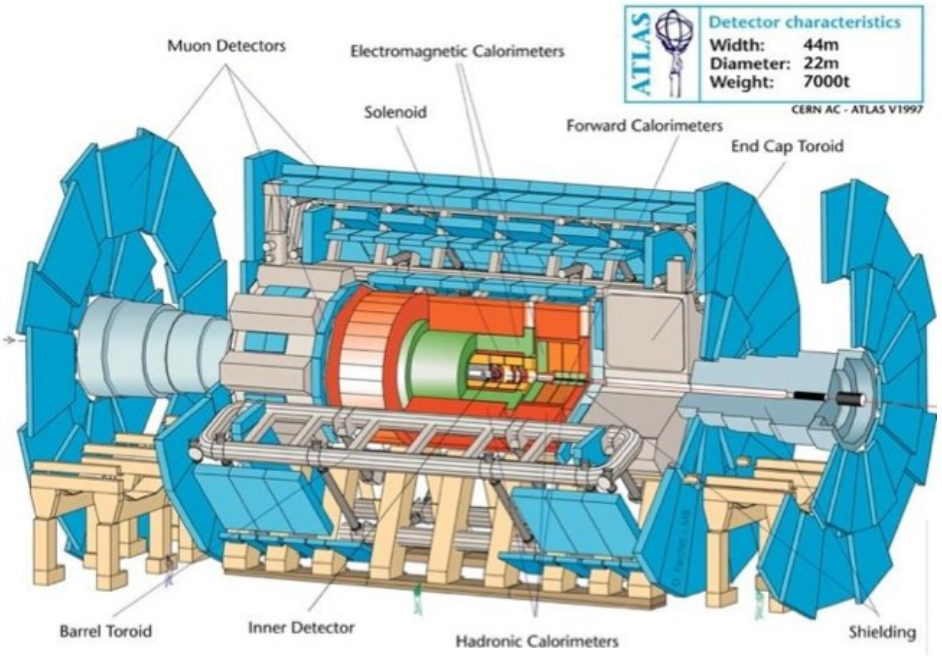
- **All public results from ATLAS:**
  https://twiki.cern.ch/twiki/bin/view/AtlasPublic

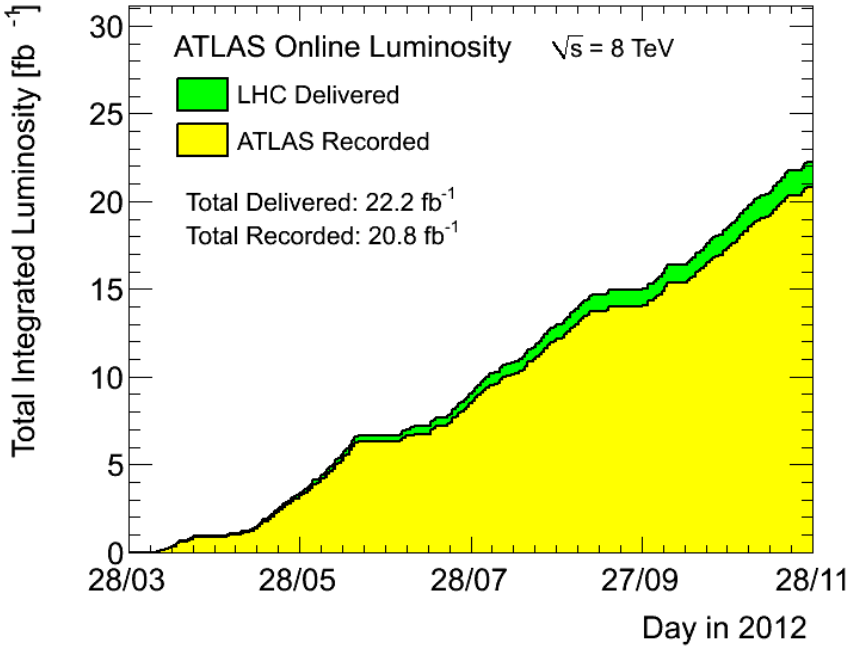
Related talks:

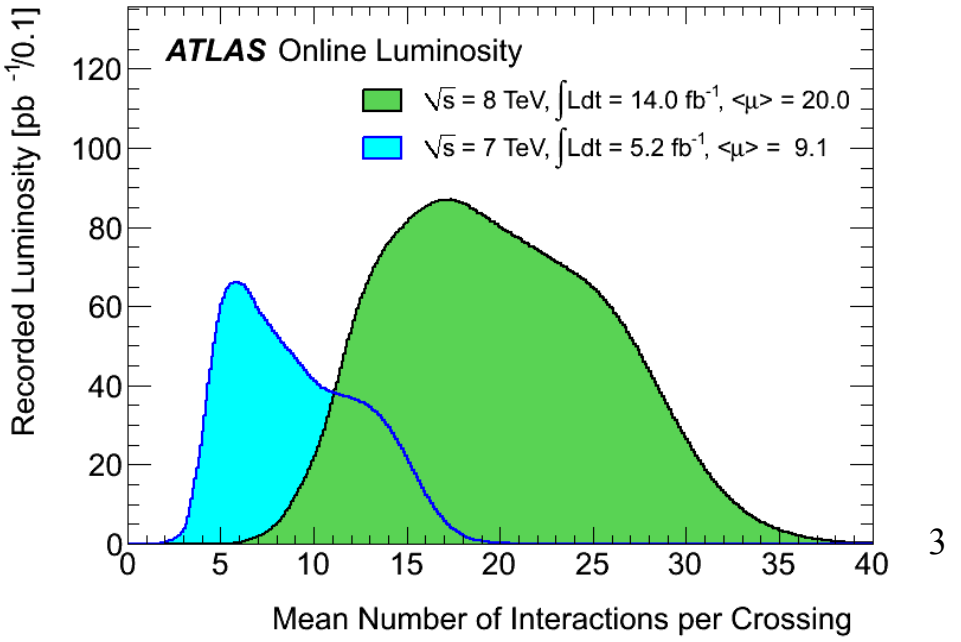
- Search in gamma + X final states in ATLAS - V. Giangiobbe
- Searches for heavy quarks at the ATLAS experiment – A. Succurro

ATLAS and LHC Operations

- To date the LHC has delivered a total luminosity more than 20 fb^{-1}!
- The data taking efficiency is about 94%.



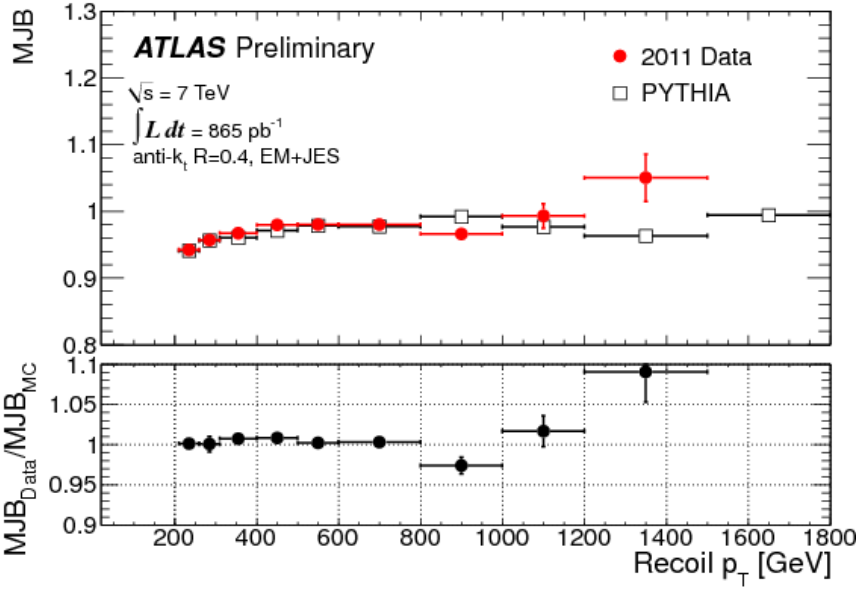


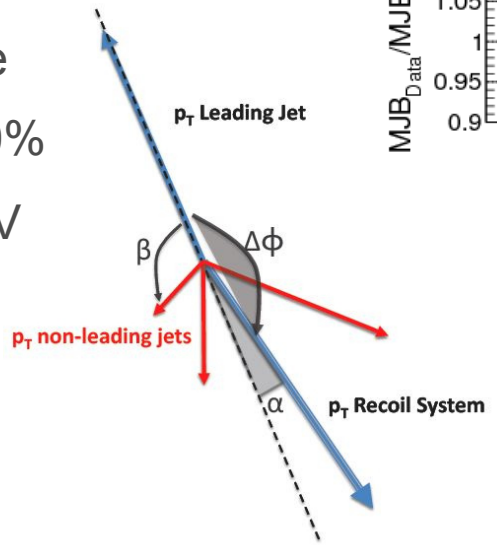


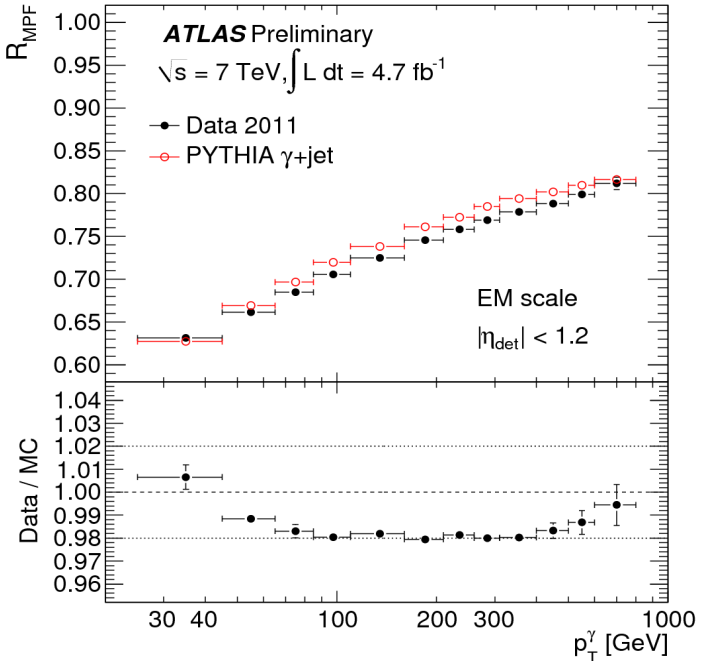
Performance of Jet Energy measurement

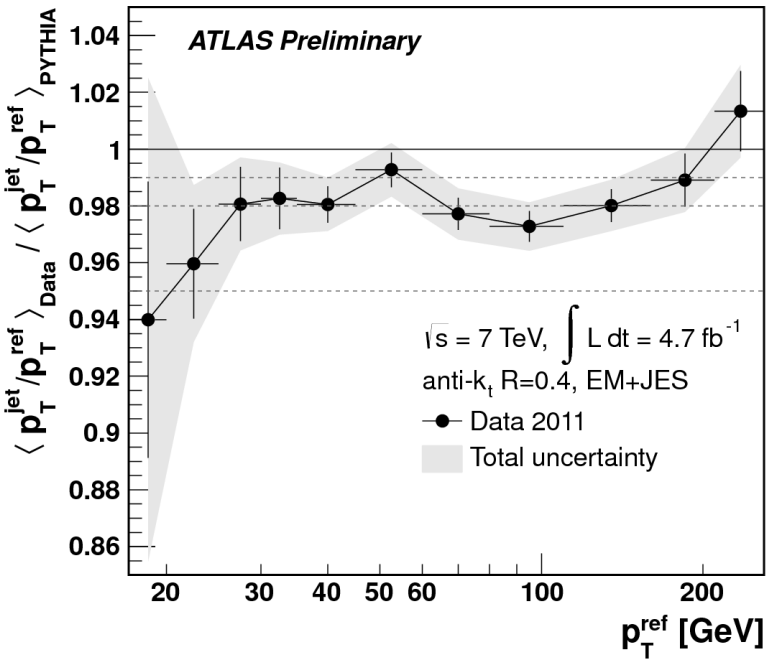
- Multiple methods for setting the Jet Energy Scale (JES)
  - Z-jet balance
  - Gamma-jet balance
  - Balance of high-pT jet against low-pT recoil system
- Hight pT central jets performance
  - JES < 2.5%, Resolution < 10%
  - JES uncertainty up to 1.4 TeV

ATLAS-CONF-2012-063
ATL-CONF-2012-053





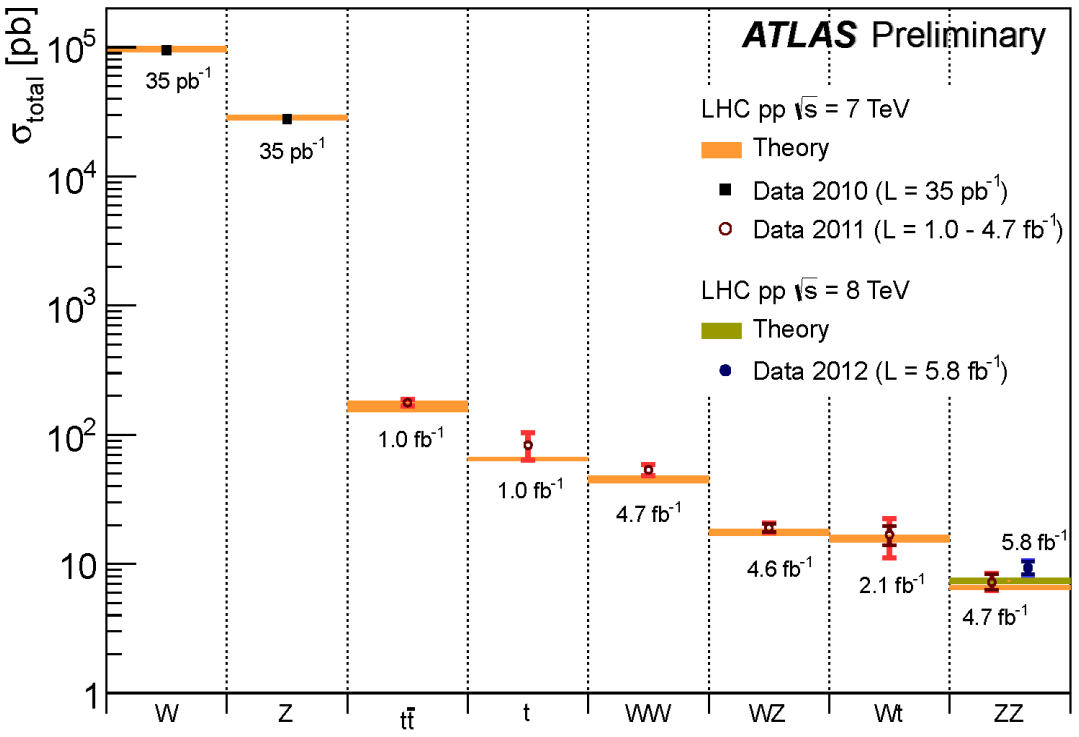




Standard Model measurements

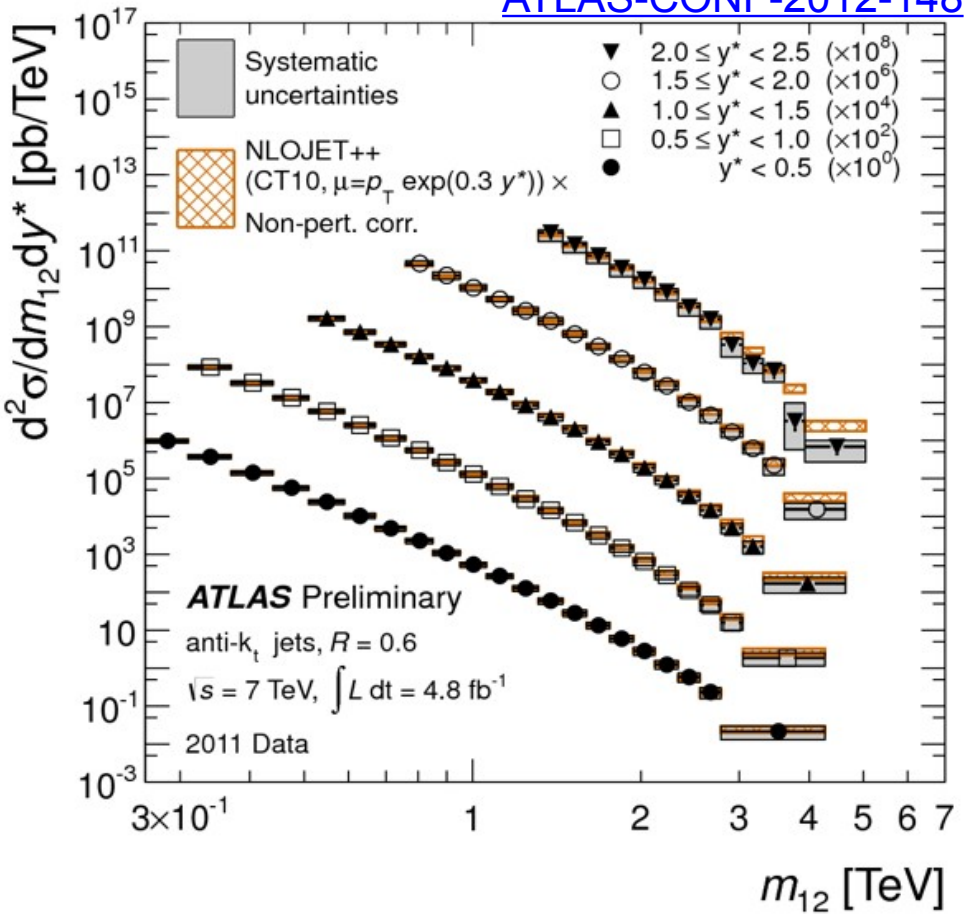
- Deep understanding of the Standard Model (SM) processes is the basic requirement for any BSM search
- Very good agreement between measured cross sections and theoretical predictions

SM total production cross section



Inclusive jet cross section

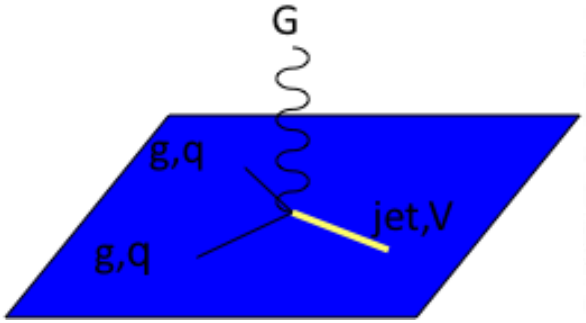
ATLAS-CONF-2012-148

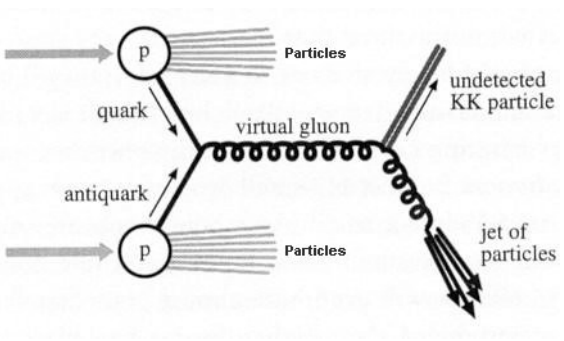


Monojet final states

Large extra dimensions

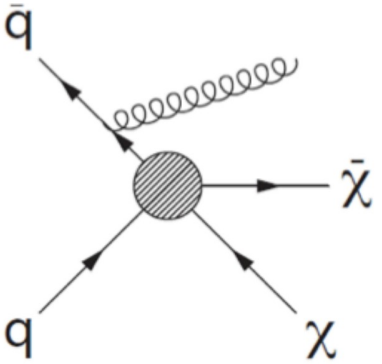
Graviton propagates into extra dimensions





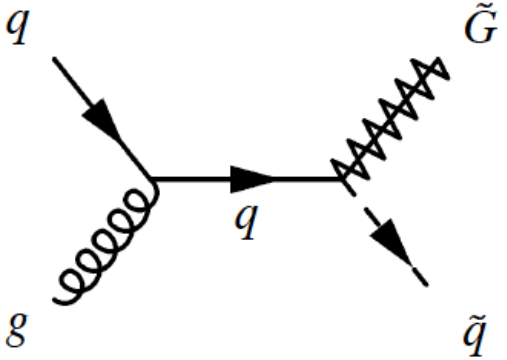
Arkani-Hamed, Dimopoulos, Dvali (ADD)

Dark Matter production

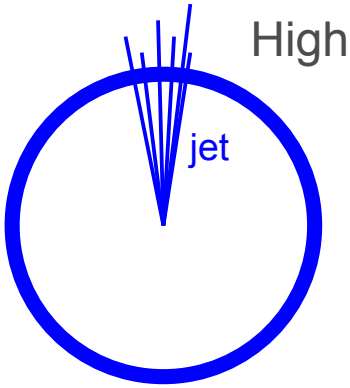


Production of undetected new particles and ISR

Light Gravitino production

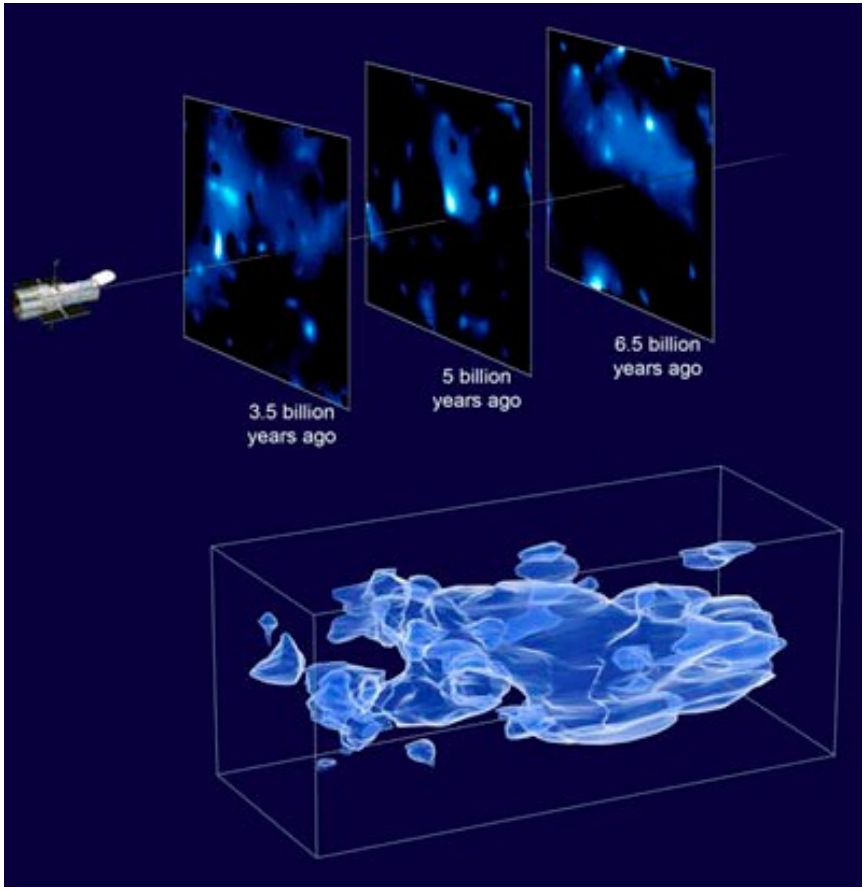


$$m_{3/2} = \langle F \rangle / \sqrt{3}\, \overline{M}_{\rm Pl}$$



High pT jet

Large MET *



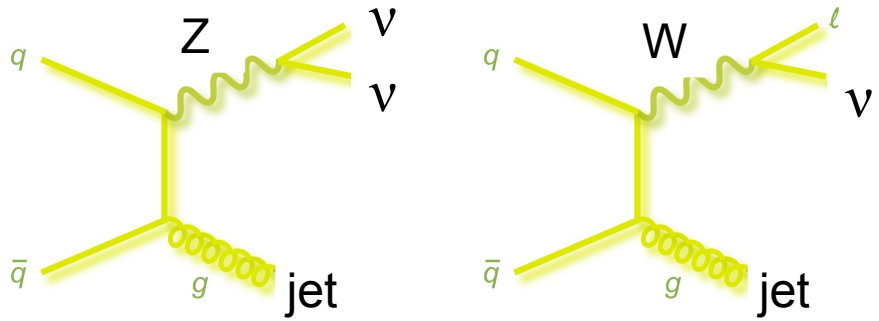
*MET = Missing Transverse Momentum

Monojet final states

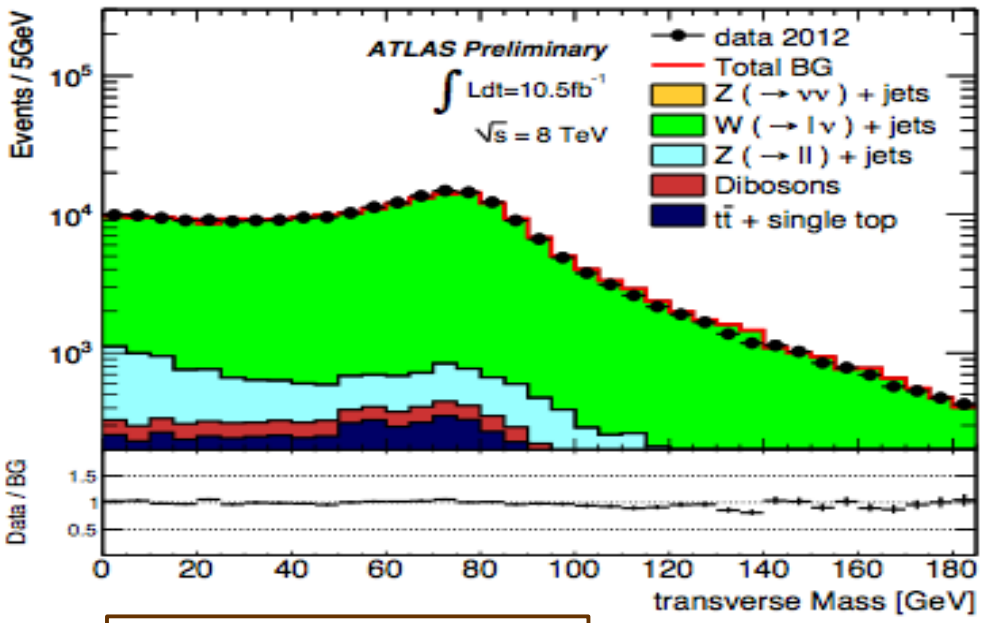
arXiv:1210.4491 (7 TeV)
ATL-CONF-2012-147 (8 TeV)

Selection criteria				
Primary vertex				
E_T^{miss} > 120 GeV				
Jet cleanup requirements				
Leading jet with p_T > 120 GeV and $\|\eta\|$ < 2.0				
At most two jets with p_T > 30 GeV and $\|\eta\|$ < 4.5				
$\Delta\phi$(jet, E_T^{miss}) > 0.5 (second-leading jet)				
Lepton vetoes				
signal region	SR1	SR2	SR3	SR4
minimum leading jet p_T (GeV)	120	220	350	500
minimum E_T^{miss} (GeV)	120	220	350	500
Events in data (10.5 fb^{-1})	350932	25515	2353	268

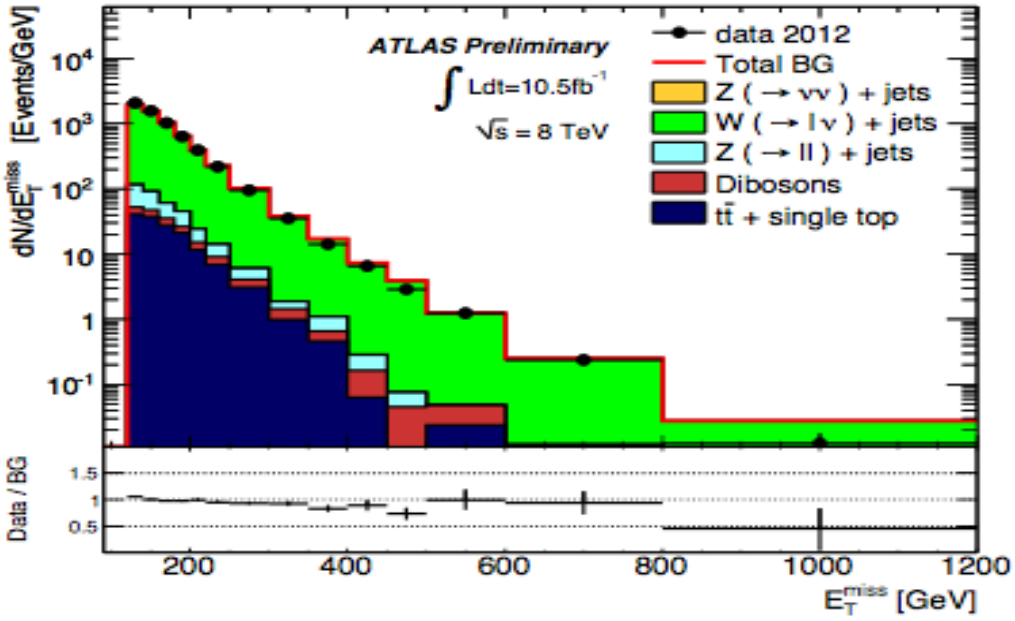
- Z/W+jets → Main background (BG) (~97% of the total)



- Estimated in a data driven way using well defined leptonic Control Regions
- QCD and non-collision BG from data, Top and Dibosons from MC.
- Good control over the background



Wμν Control Region

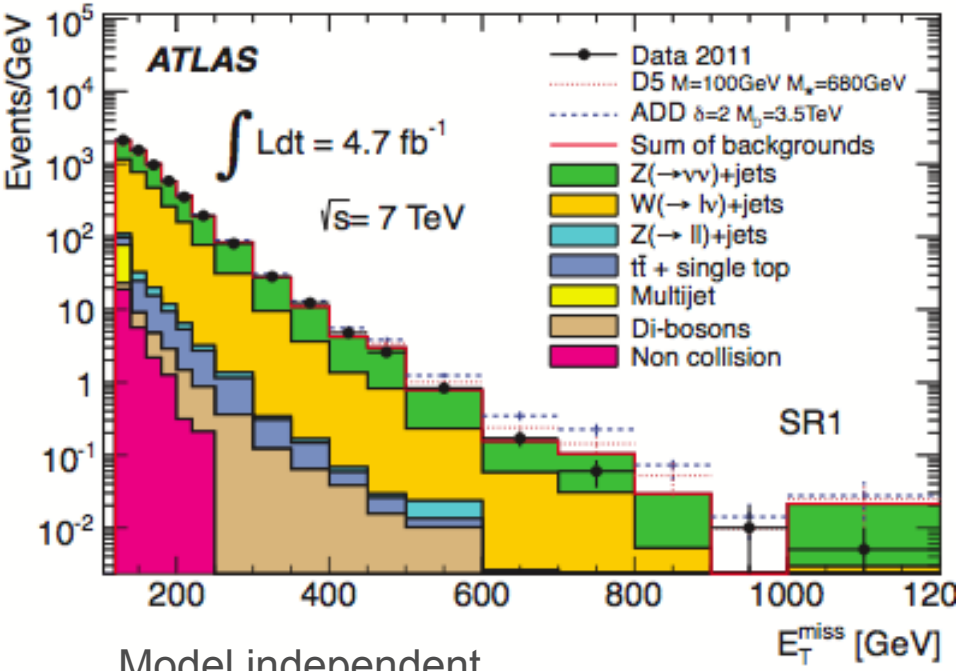


Monojet final states

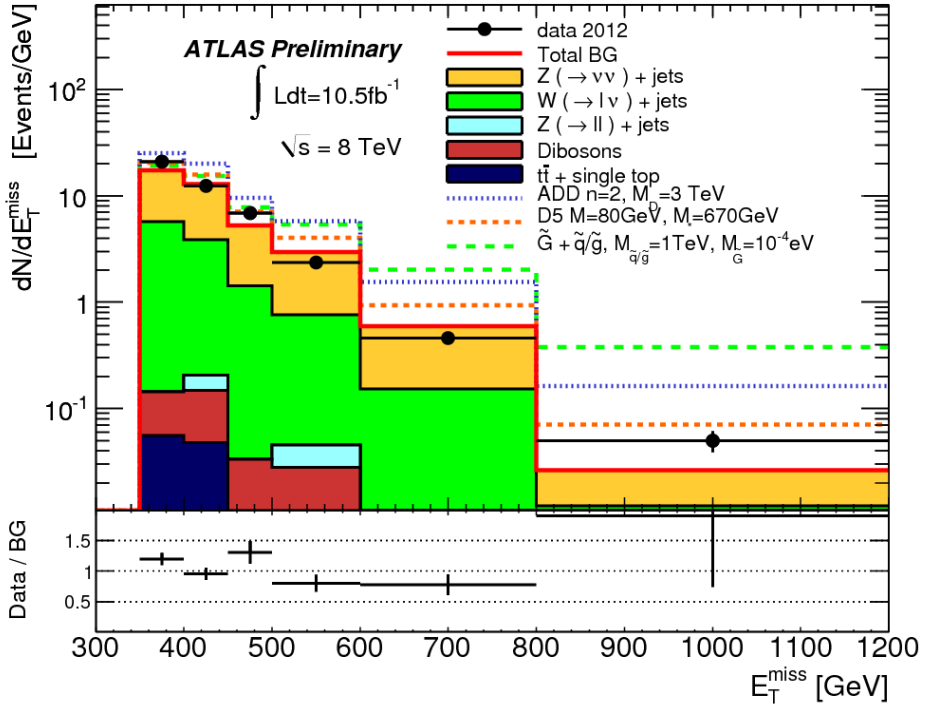
arXiv:1210.4491 (7 TeV)
ATL-CONF-2012-147 (8 TeV)

- Typical total uncertainties: from 3 to 15% for SR1 to SR4.
- Good agreement with the SM expectation
- The 8 TeV analysis suffered from limited MC statistics → limits are equivalent to the 7TeV analysis.

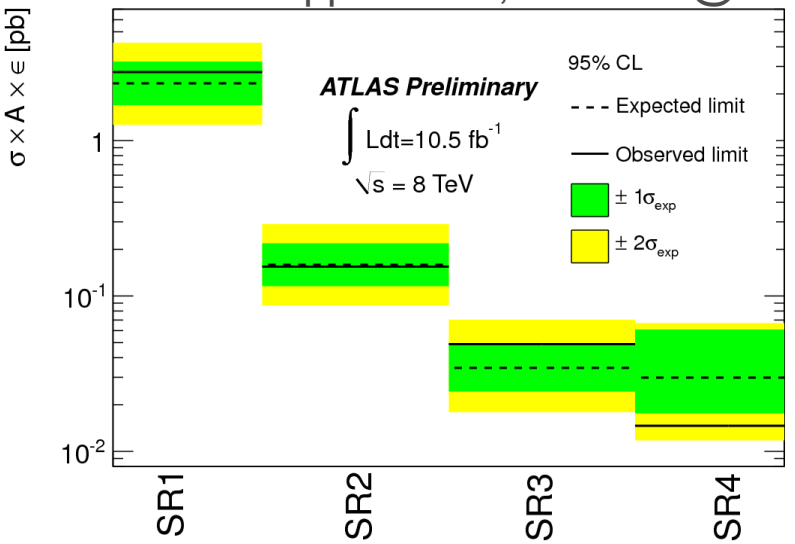
SR1, 4.7 fb^{-1} @ 7 TeV



SR3, 10.5 fb^{-1} @ 8 TeV



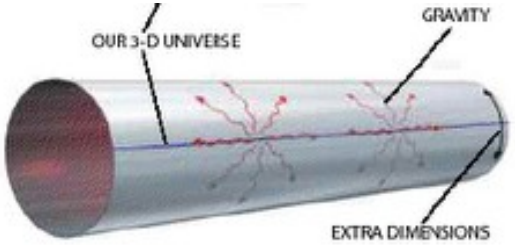
Model independent
95% CL upper limits, 10.5 fb^{-1} @ 8 TeV



ADD interpretation

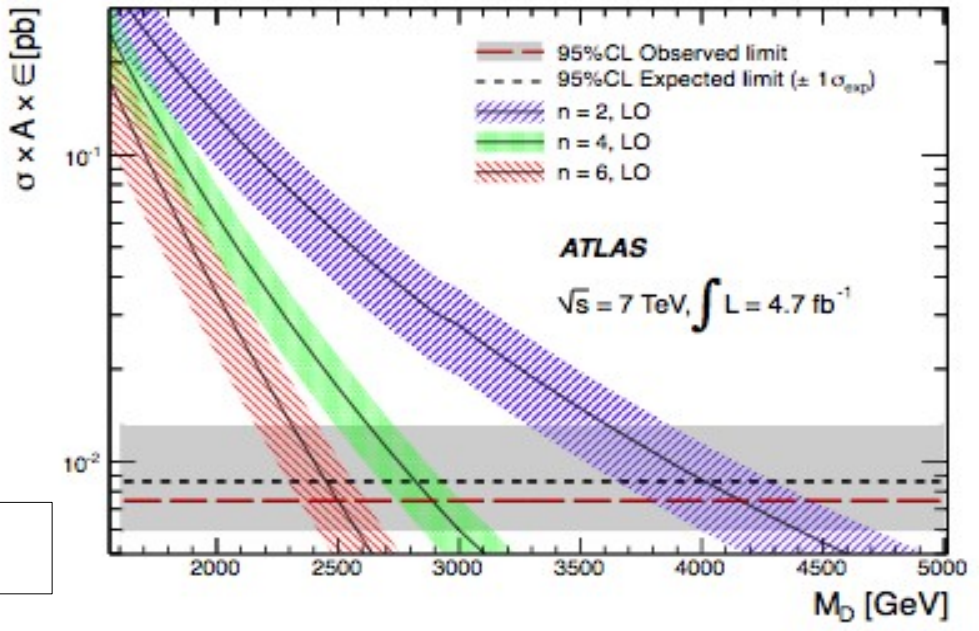
[arXiv:1210.4491 (7 TeV)](arXiv:1210.4491)
[ATL-CONF-2012-147 (8 TeV)](ATL-CONF-2012-147)

- Limits on ADD scenario with n compac extra dimensions
- Graviton field propagates in the extra dimensions.
- The fundamental gravity scale is much closer to the scales of the SM

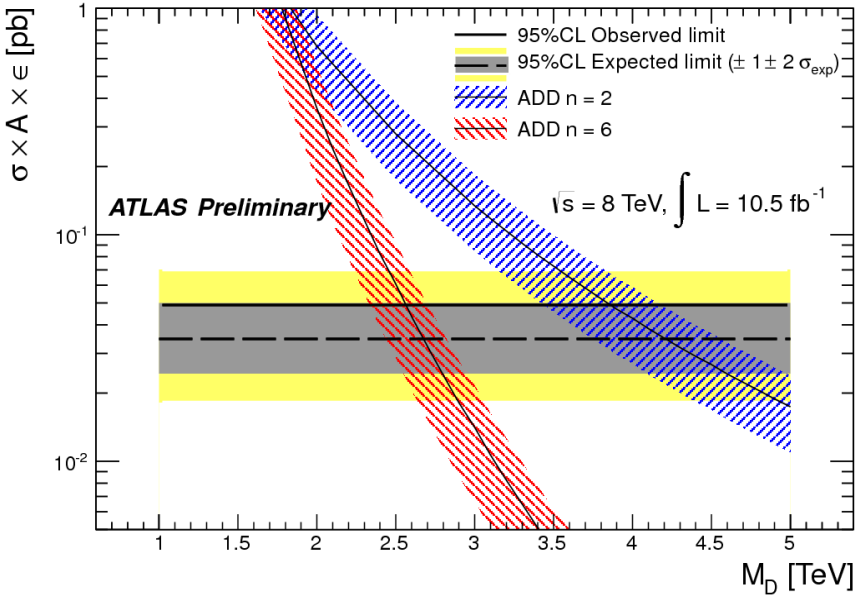


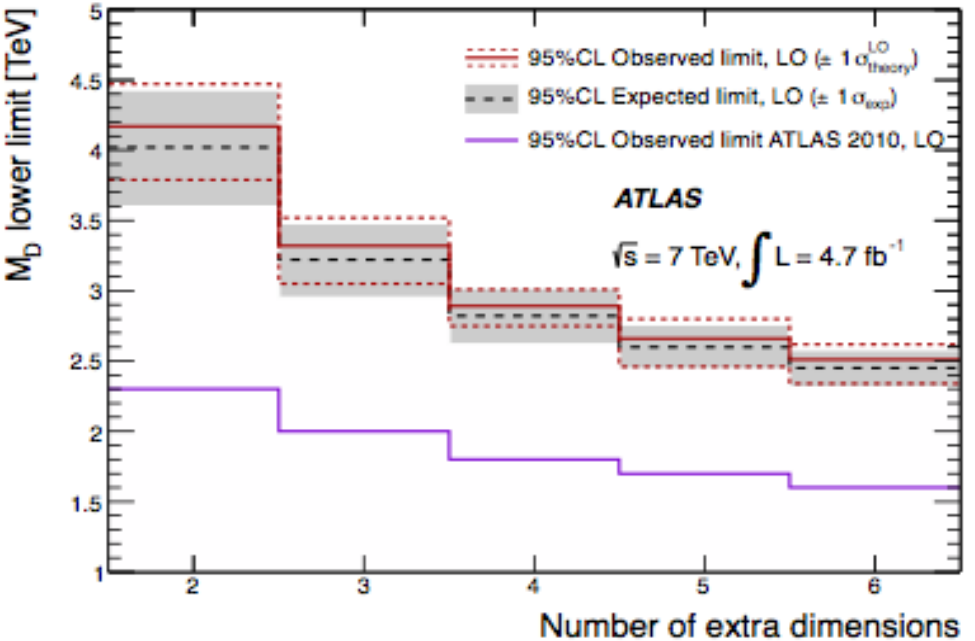
$$M_{pl}^{2} \sim M_{D}^{2+n} R^{n}$$

SR4, 4.7 fb^{-1} @ 7 TeV



SR3, 10.5 fb^{-1} @ 8 TeV





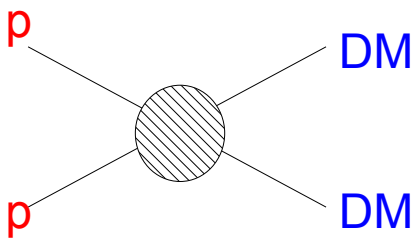
WIMP dark matter production

arXiv:1210.4491 (7 TeV)
ATL-CONF-2012-147 (8 TeV)

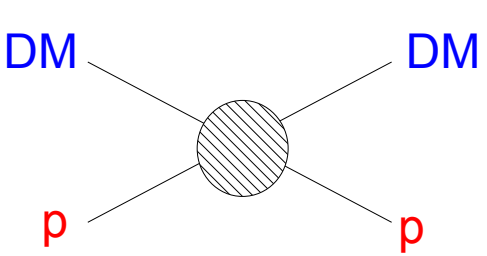
- Effective theory based on different interaction Lagrangians
- WIMP production limits are translated to WIMP-nucleon scattering cross section and compared with direct detection experiments

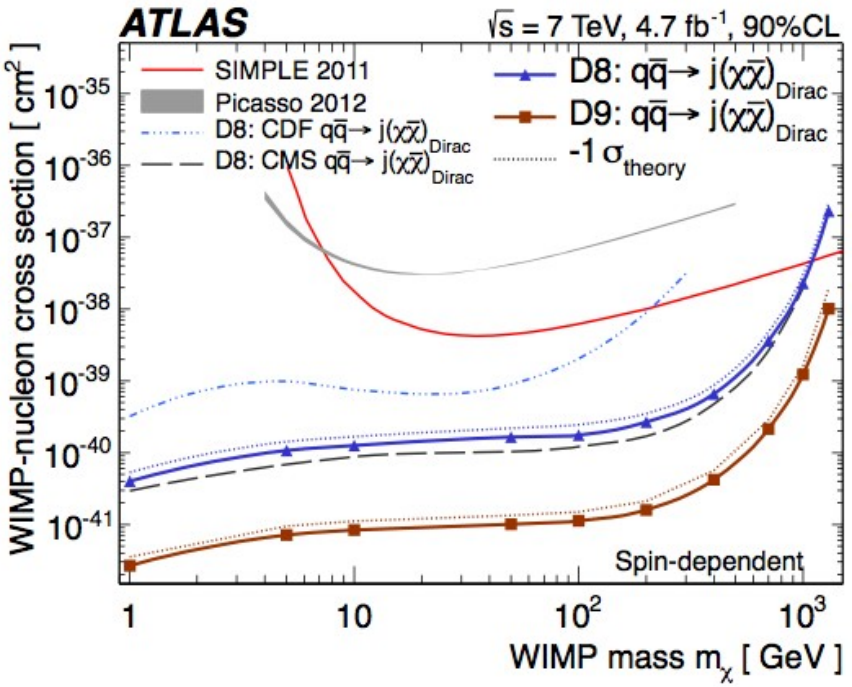
	Type	Operator
D1	scalar	$\frac{m_q}{M_\star^3}\bar{\chi}\chi\bar{q}q$
D5	vector	$\frac{1}{M_\star^2}\bar{\chi}\gamma^\mu\chi\bar{q}\gamma_\mu q$
D8	axial-vector	$\frac{1}{M_\star^2}\bar{\chi}\gamma^\mu\gamma^5\chi\bar{q}\gamma_\mu\gamma^5 q$
D9	tensor	$\frac{1}{M_\star^2}\bar{\chi}\sigma^{\mu\nu}\chi\bar{q}\sigma_{\mu\nu}q$
D11	scalar	$\frac{1}{4M_\star^3}\bar{\chi}\chi\alpha_s(G^a_{\mu\nu})^2$

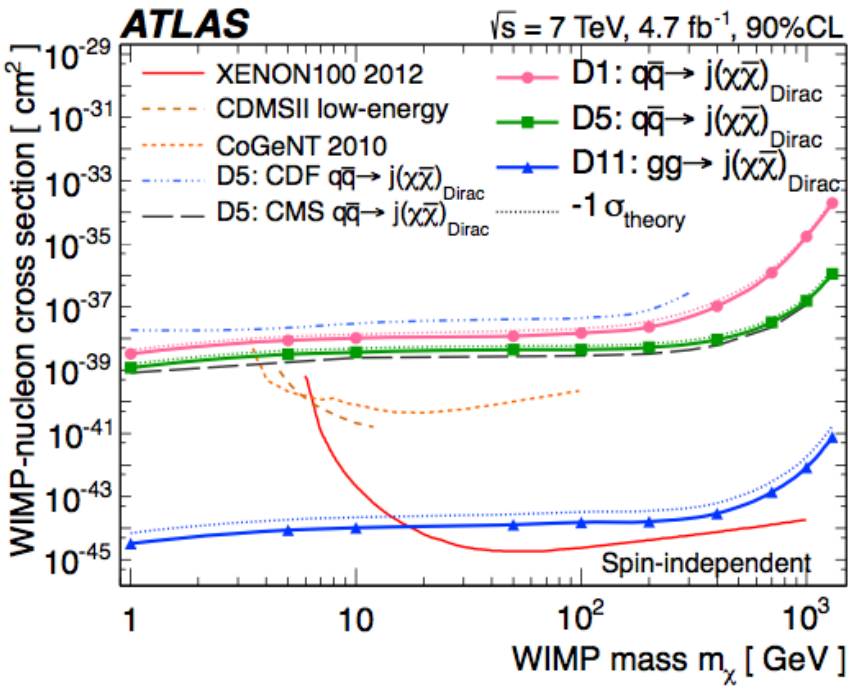
WIMP production (LHC)



Direct detection (e.g. XENON, CDMS)







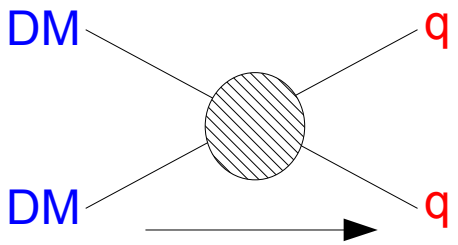
WIMP annihilation limits

arXiv:1210.4491 (7 TeV)
ATL-CONF-2012-147 (8 TeV)

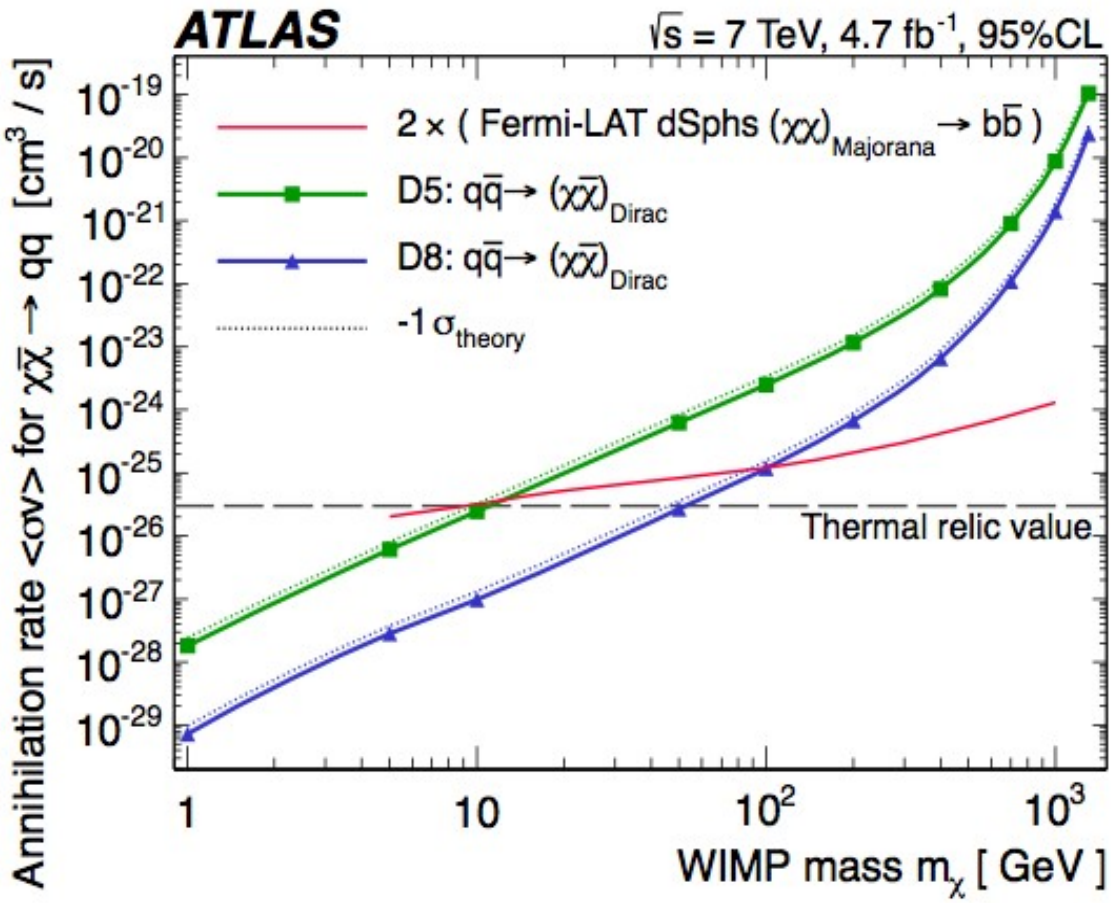
- The results are also interpreteted in terms of limits on WIMPs annihilation to light quarks

  arXiv:1109.4398 [hep-ph]

Indirect detection WIMPs annihilation



- Comparison with FERMI LAT



- Below 10 GeV for D5 and 70 GeV for D8, the ATLAS limits are below the values needed for WIMPs to make up the cold dark matter abundance in the early universe

Gravitino production

ATL-CONF-2012-147 (8 TeV)

- GMSB scenario with very light gravitino (spin 3/2) as LSP
- Associated production with squark/gluino

  arXiv:hep-ph/0610160

  arXiv:1010.4255

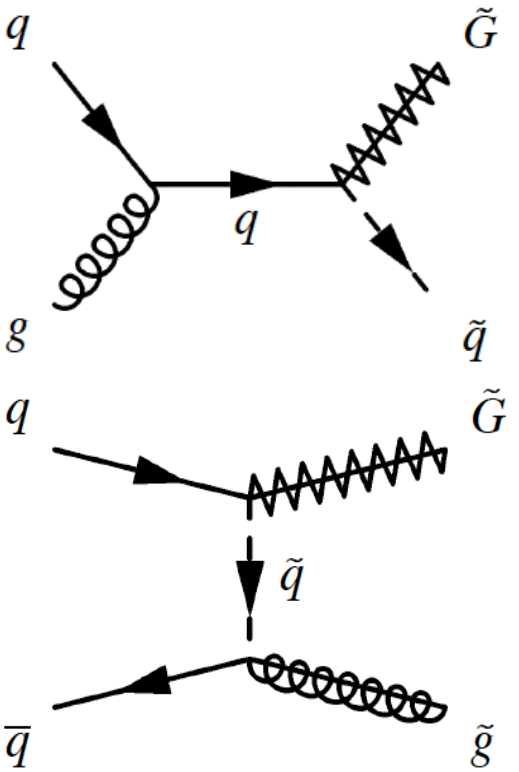
- Gravitino mass probes the SUSY-breaking scale

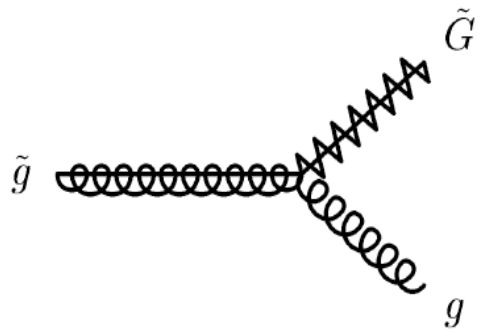
$$m_{3/2} = \langle F \rangle / \sqrt{3}\,\overline{M}_{\rm Pl}$$

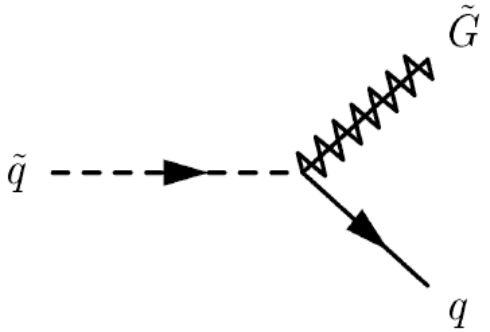
- Too light to be the unique DM but in some models it represent a significant fraction of DM composition

  arXiv:1004.4213

- Assuming 100% branching ratio of gluino/squark decay to gluino/quark + gravitino







Gravitino production

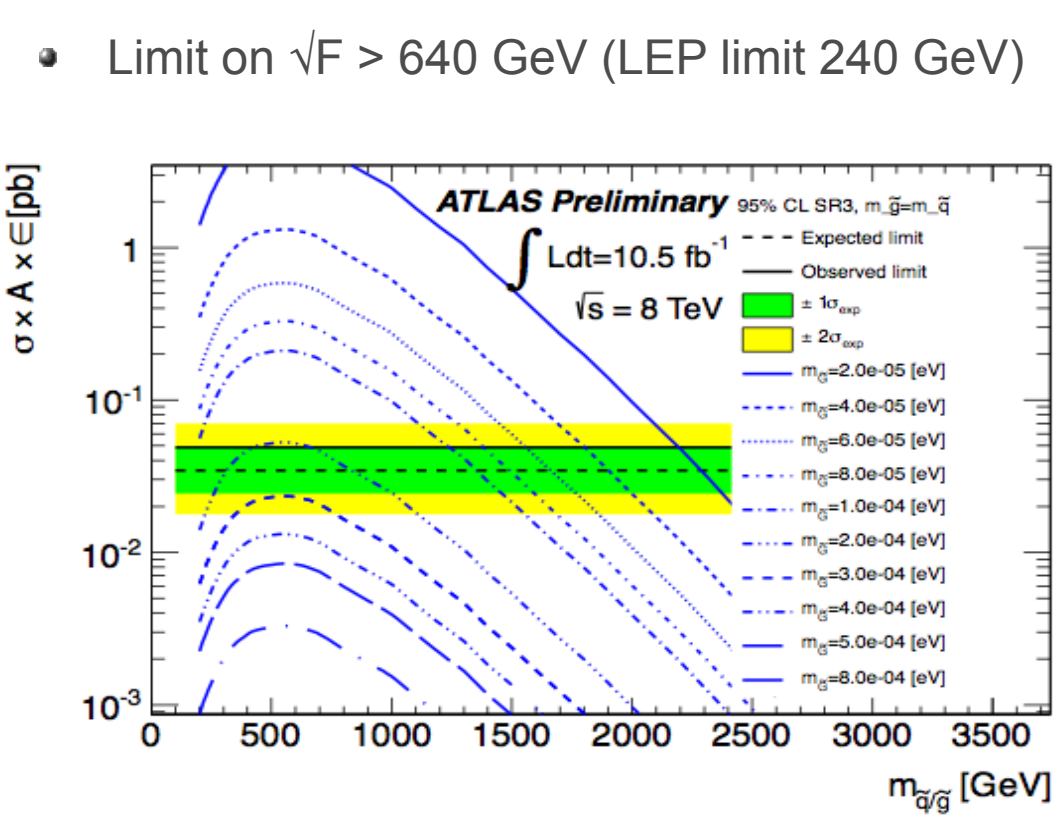
ATL-CONF-2012-147 (8 TeV)

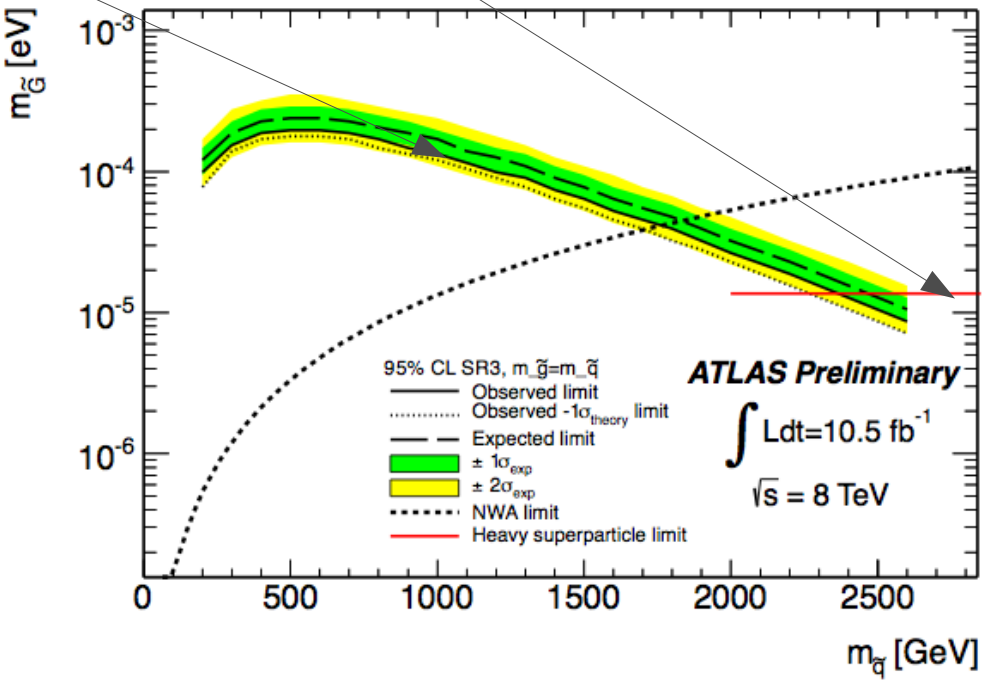
- ATLAS limits on gravitino mass are one order of magnitude higher than LEP/Tevatron limits:

ATLAS: $m_{\tilde{G}} > 1.0 \times 10^{-4}$ eV
For $m_{\tilde{q}} = m_{\tilde{g}} \approx 1$ TeV

LEP/Tevatron: $m_{\tilde{G}} > 1.37 \times 10^{-5}$ eV

- Limit on $\sqrt{F} > 640$ GeV (LEP limit 240 GeV)

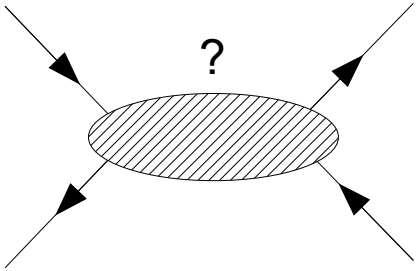


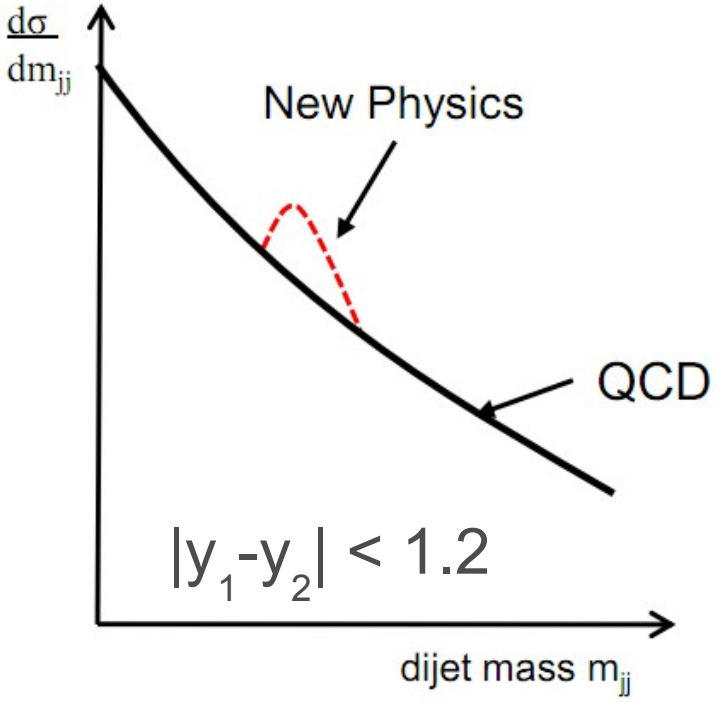


Dijet final states: Resonance

Excited quarks, Contact interaction, etc

Dijet event resulting from resonance/contact interaction





Analysis baseline

- Search for “bumps” in the invariant mass spectrum
- QCD background is parametrized using a fit functio trained on data:

$$f(x) = p_1(1-x)^{p_2} x^{p_3 + p_4 \ln x}$$

where $x \equiv m_{jj} / \sqrt{s}$

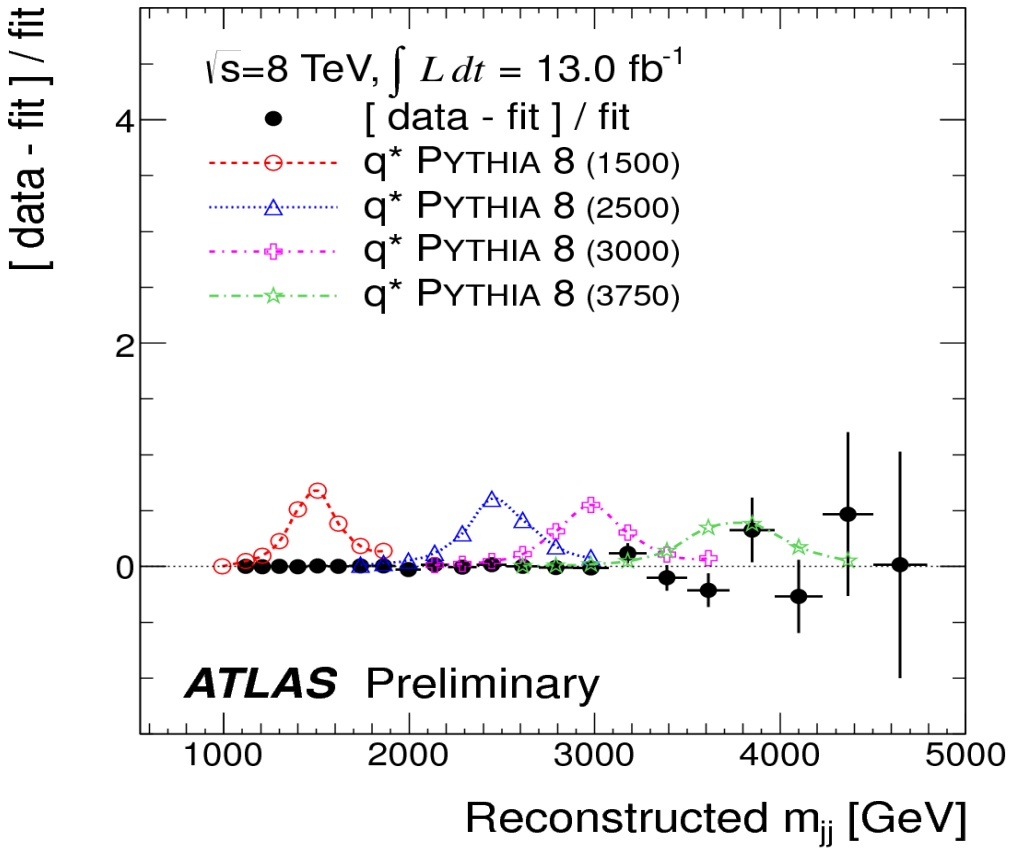
- The selection of dijet events is done by requiring:
  - High invariant mass: m_{jj} > 1 TeV
  - Central events: |y1-y2|<1.2

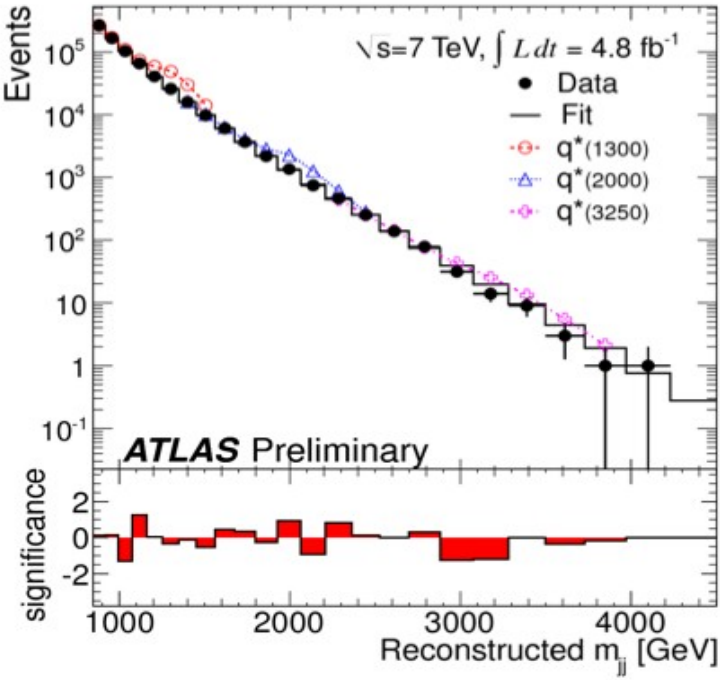
* y1 (y2) = rapidity of the leading (2nd leading) jet

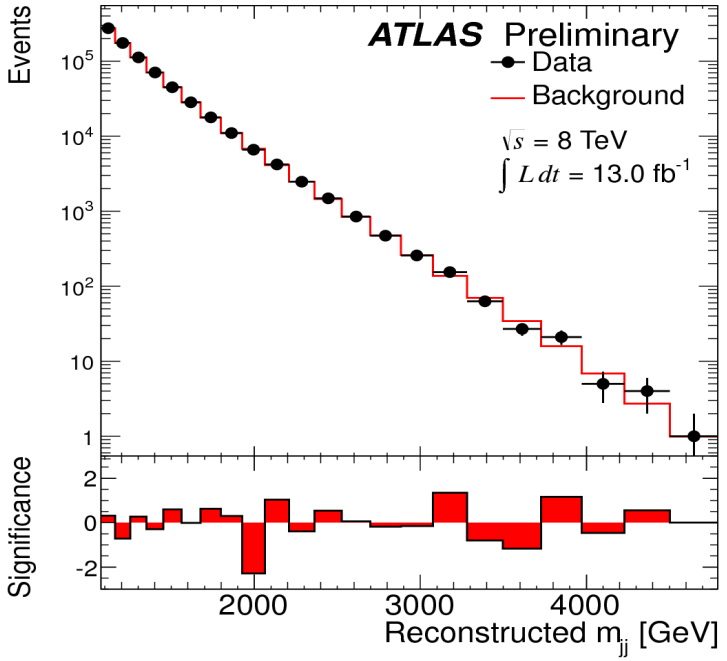
Dijet final states: Resonance

ATLAS-CONF-2012-038 (7 TeV)
ATLAS-CONF-2012-148 (8 TeV)

- Good agreement between the data and the fit.
- Local deviations are not very significant.







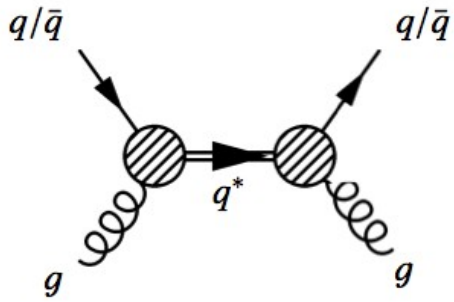
Dijet final states: Resonance

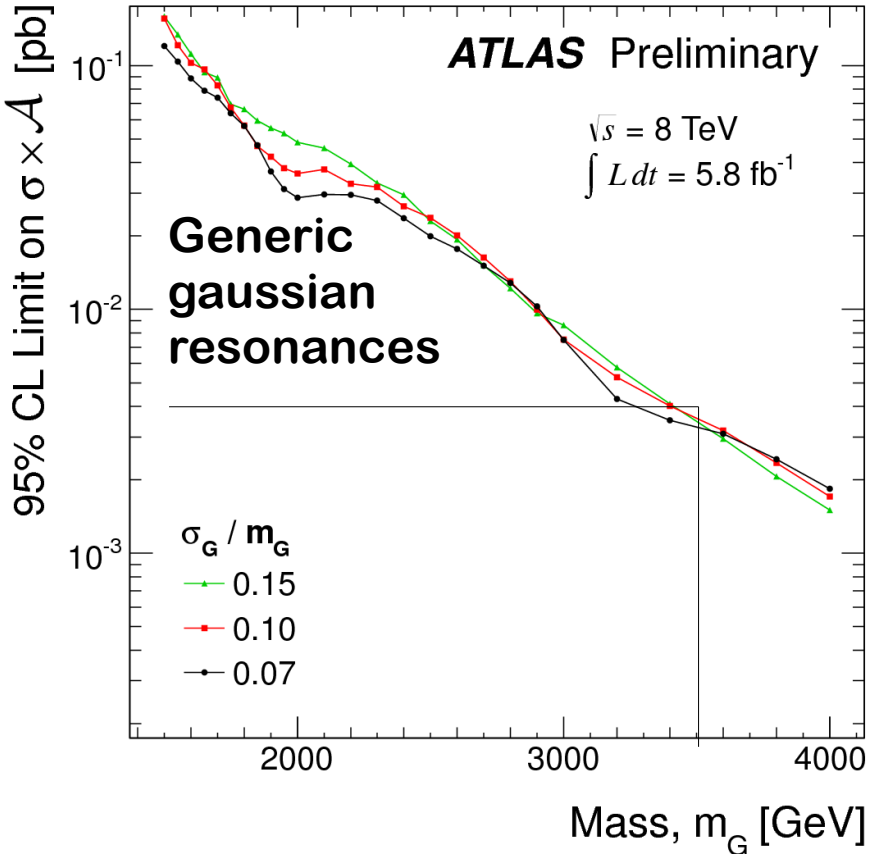
ATLAS-CONF-2012-148 (8 TeV)

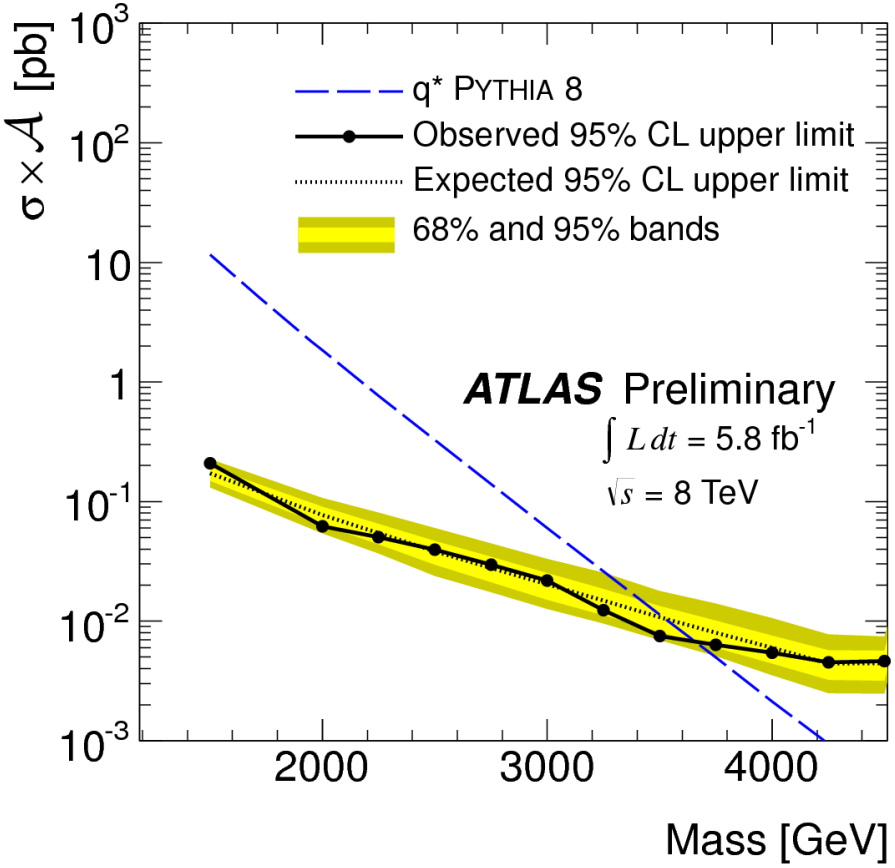
Results are translated into 95% CL limits on:

- Generic gaussian resonances → excluded 3.5TeV resonances with σ x A > 4fb
- Excited quarks → excluded up to M_{q^*} = 3.66TeV

Excited quark







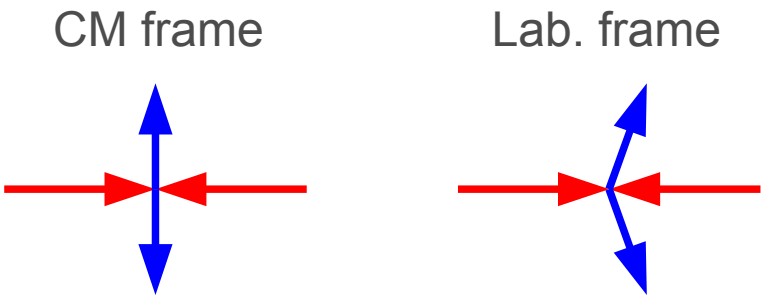
Dijet final states: Angular distribution

Main idea

- Heavy particle mediator produces events that have high centrality in the cm frame:

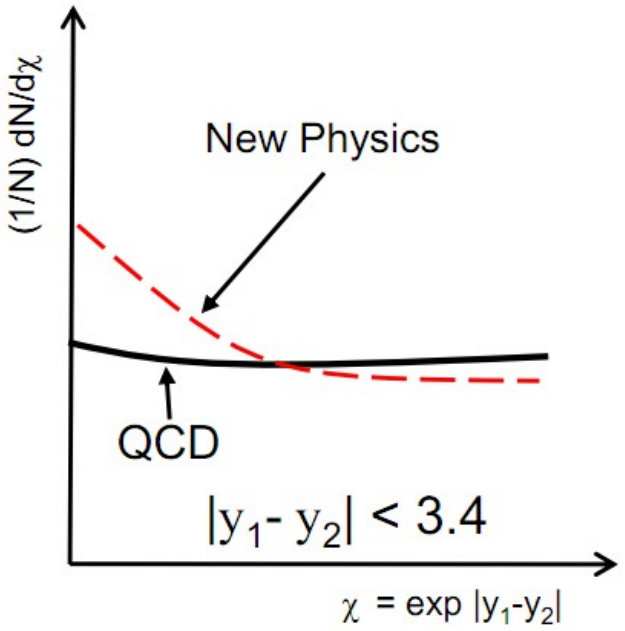
$$\chi = e^{|y_1 - y_2|}$$

- New physics at high scattering angles

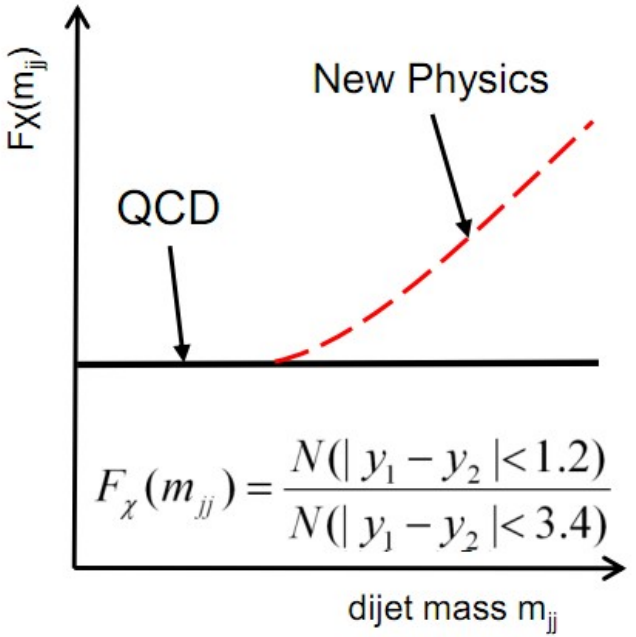


Event selection

- Requiring invariant mass m_{jj} > 850 GeV



Centrality ratio in cm frame



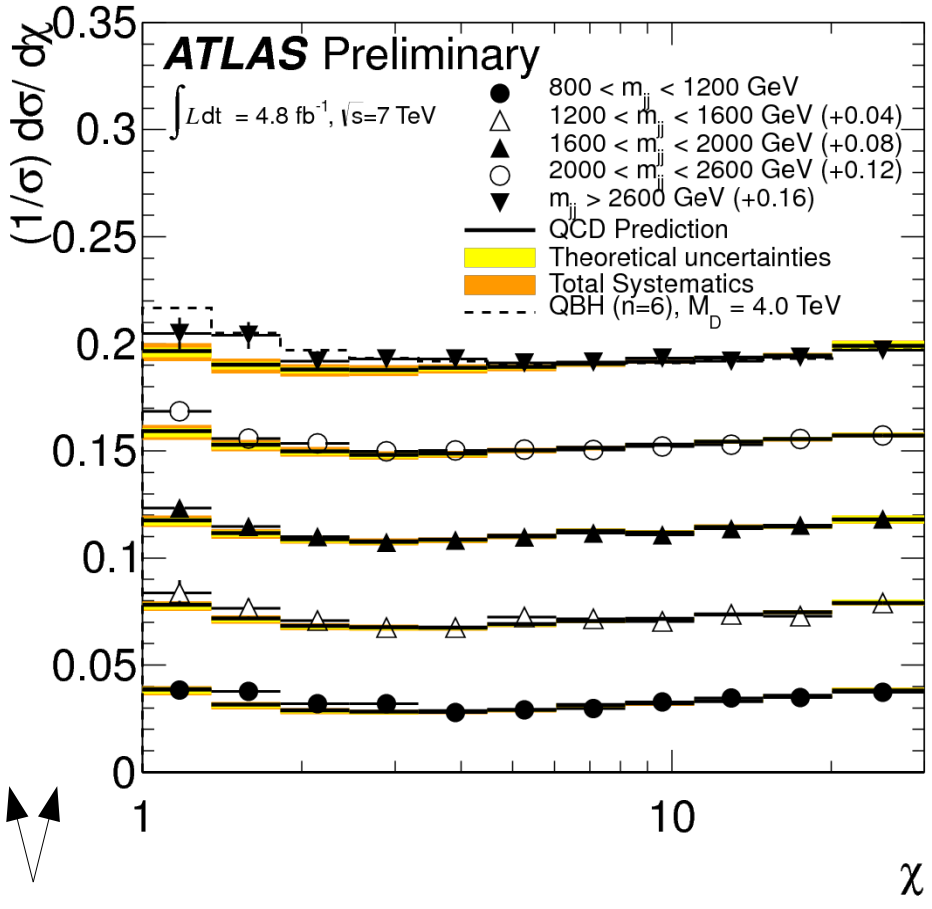
Dijet final states: Angular distribution

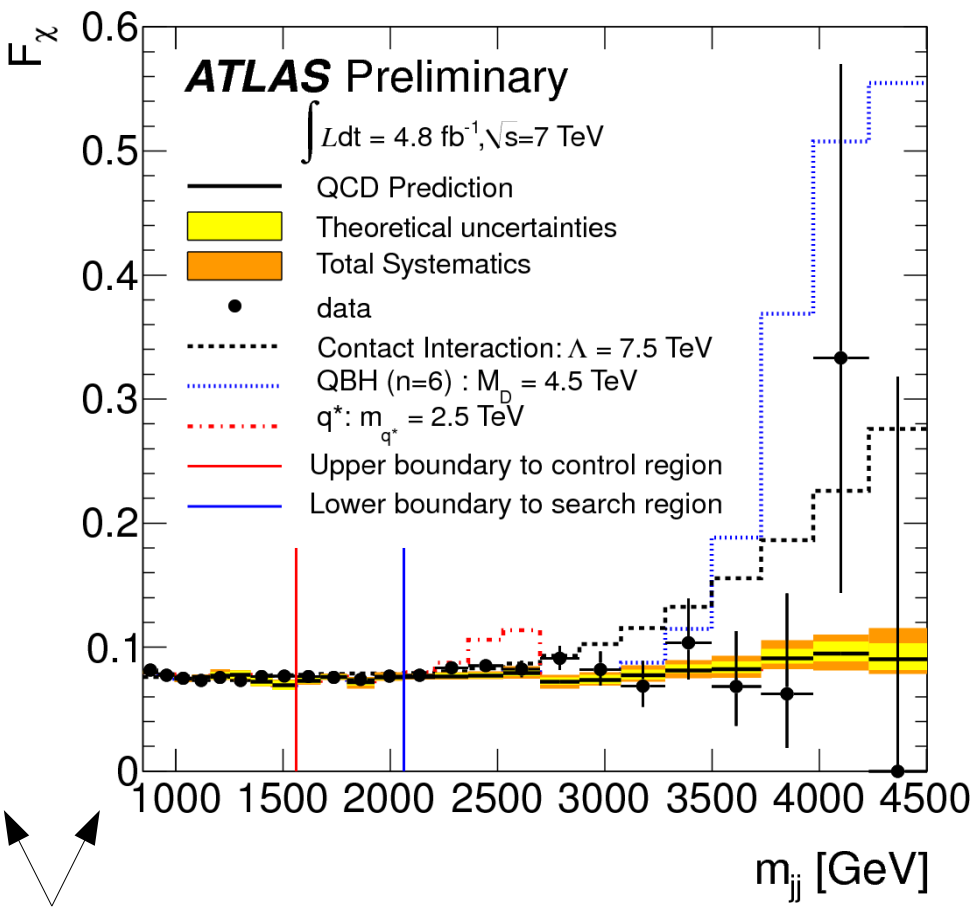
ATL-CONF-2012-038

- Prediction of the background done from NLOjet++ and Pythia6
- Binned Log-likelihood distribution of data and background show no significant excess

$$\chi = e^{|y_1 - y_2|}$$

$$F_\chi(m_{jj}) = \frac{N_{central}}{N_{total}}$$

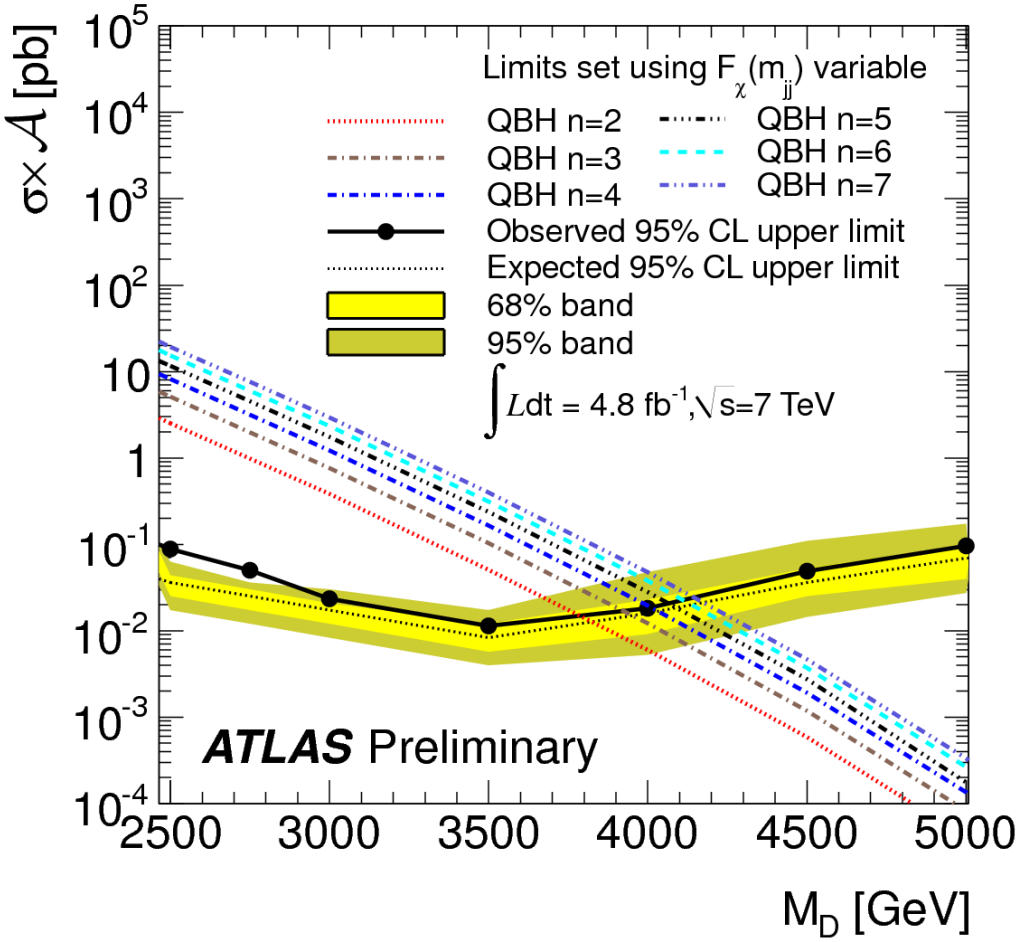




Dijet final states: Angular distribution

ATL-CONF-2012-038

- Angular distribution analysis shows that the data is consistent with QCD prediction



- Constrains are established on a variety o new physics models:
  - Quantum Black Holes (QBH in extra dimensions scenario (see next)
  - Contact interactions
  - Excited quarks

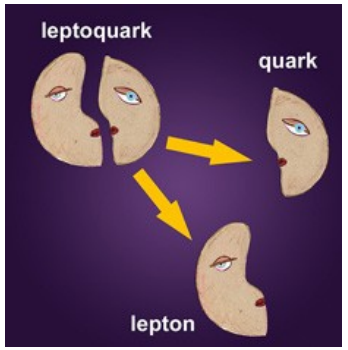
Summary of the dijet analyses

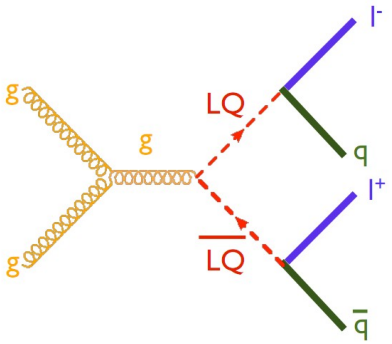
Model, and Analysis Strategy	95% C.L. Limits (TeV) Expected	Observed
Excited quark, mass of q^*		
Resonance in m_{jj}	3.53	3.66
Resonance in $F_\chi(m_{jj})$	2.97	2.58
Colour octet scalar, mass of s8		
Resonance in m_{jj}	1.94	1.94
Quantum Black Hole for $n = 6$, M_D		
$F_\chi(m_{jj})$	4.14	4.11
11-bin χ , $m_{jj} > 2.6$ TeV	4.23	3.96
Contact interaction, Λ, destructive interference		
$F_\chi(m_{jj})$	8.2	7.6
11-bin χ , $m_{jj} > 2.6$ TeV	8.7	7.8

Multijet final states

Leptoquarks (LQ)

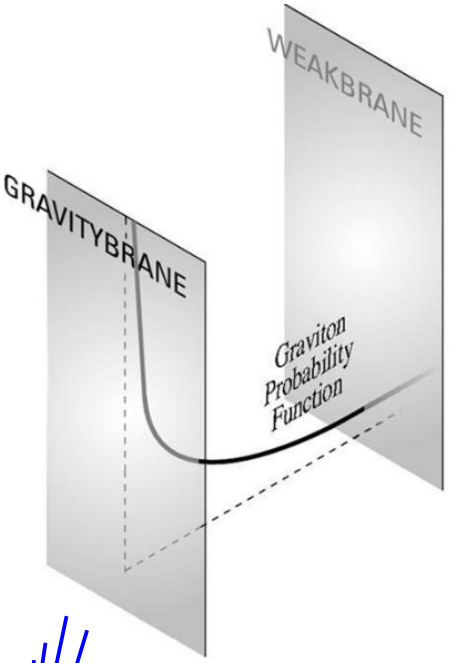
New gauge bosons symmetry between quarks and leptons





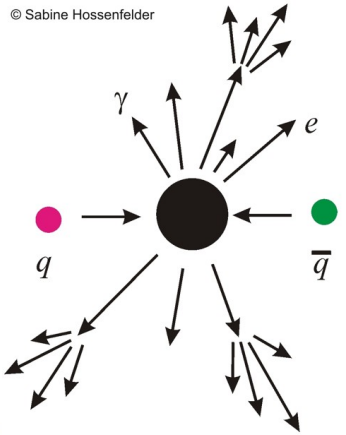
Randall-Sundrum Graviton

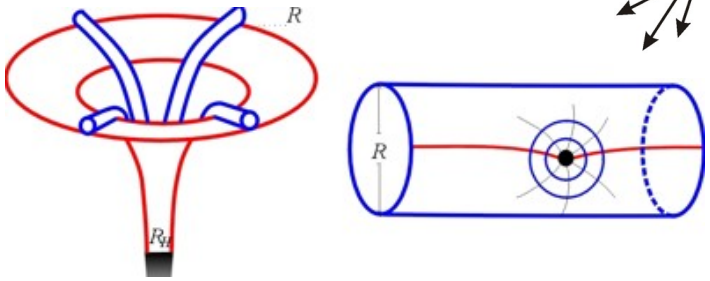
5-dimensional warped geometry, and the elementary particles except the graviton are localized on a (3+1)-dimensional brane.

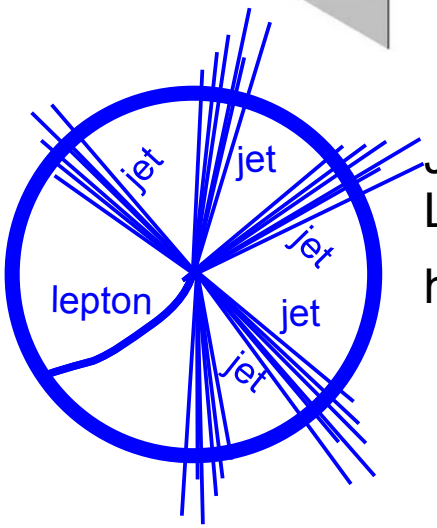


TeV-scale gravity

Extra-dimensions models with Black Holes states with masses above M_D decaying into multiple energetic leptons and quarks.







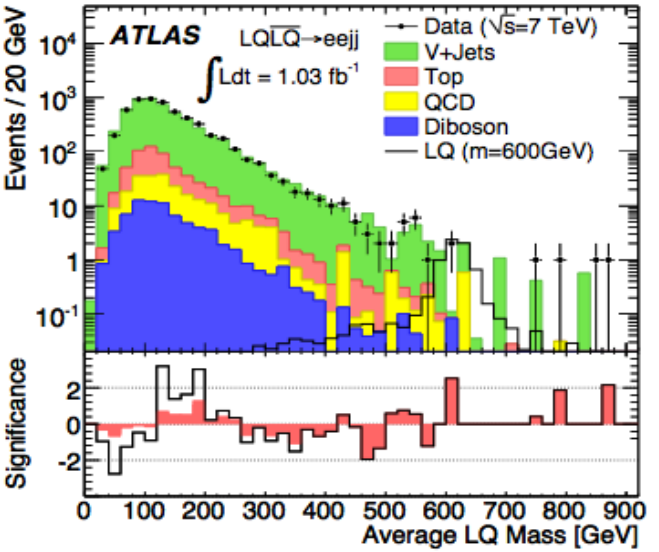
Jets and Leptons with high $\sum P_T$

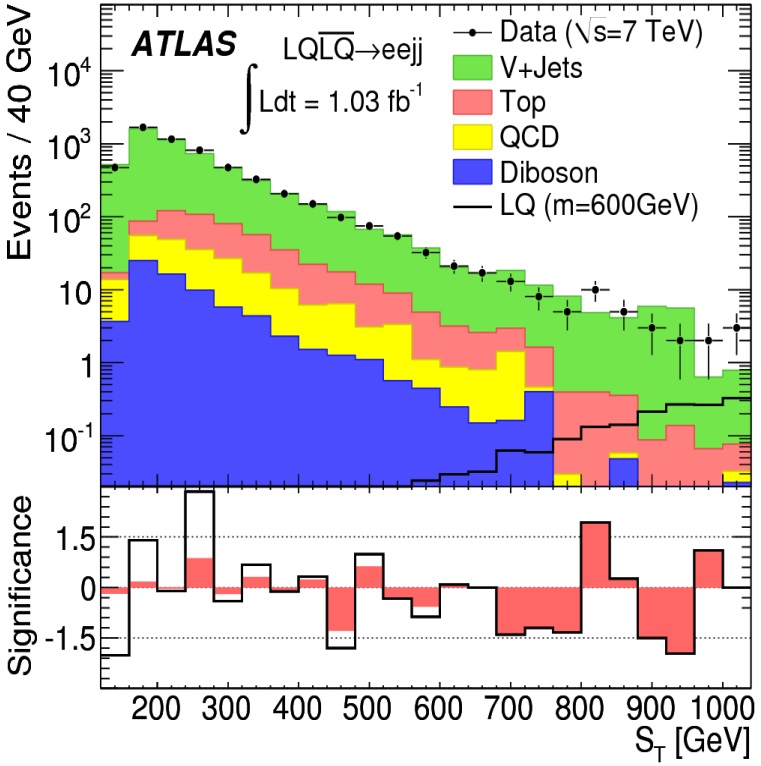
* $\sum P_T$ = $\sum$ of P_T of jets and leptons

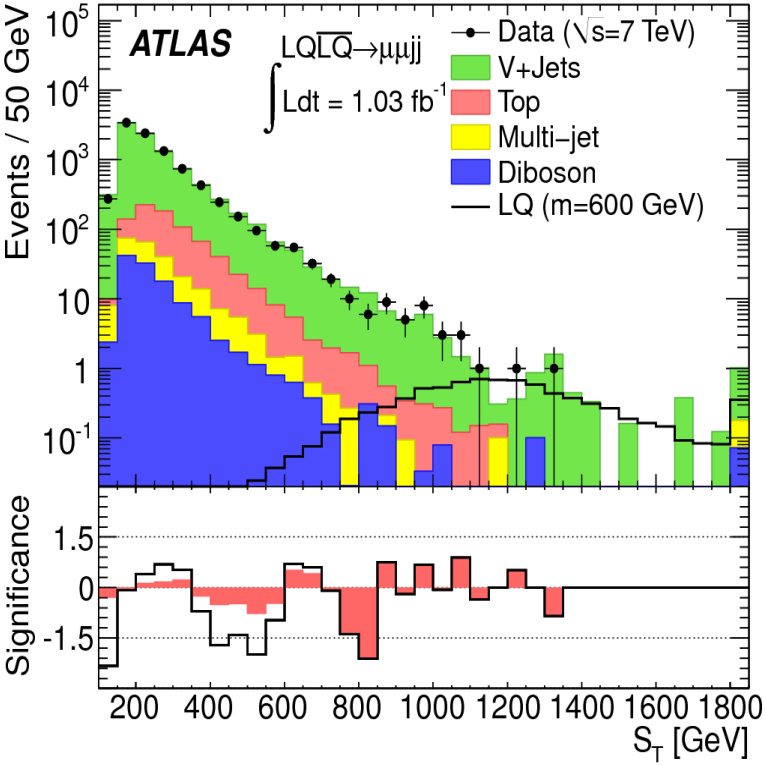
Search for leptoquarks

arXiv:1203.3172
arXiv:1112.4828v5 [hep-ex]

- Search for scalar leptoquarks ($LQ\bar{L}\bar{Q} \rightarrow lqlq$)
  - 1st generation (coupling with e and ν_e)
  - 2nd generation (coupling with μ and ν_μ)
- Backgrounds W/Z+jets and Top estimated through control regions



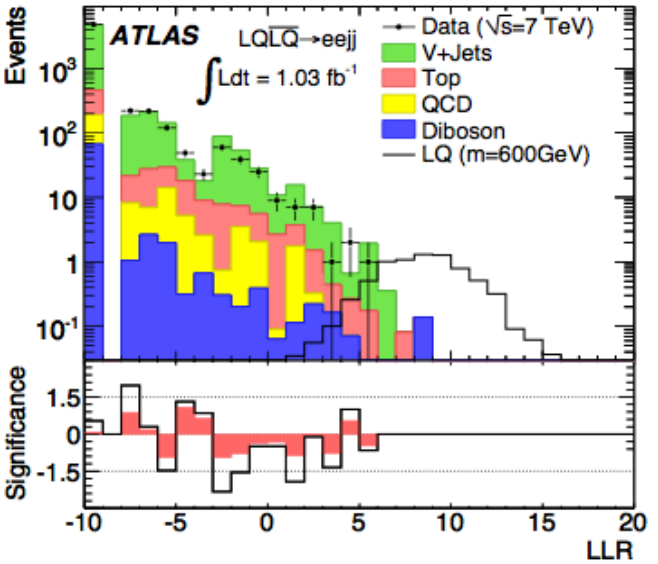


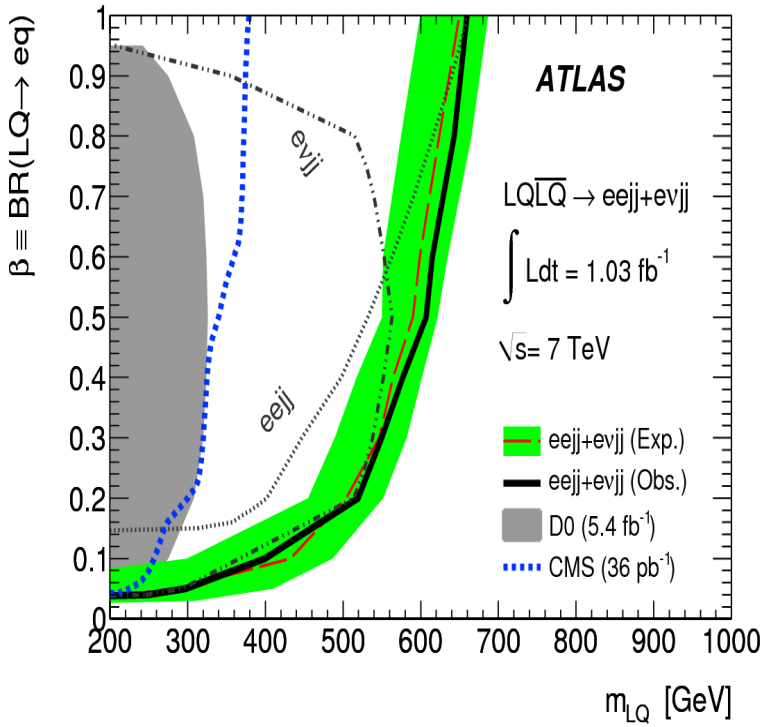


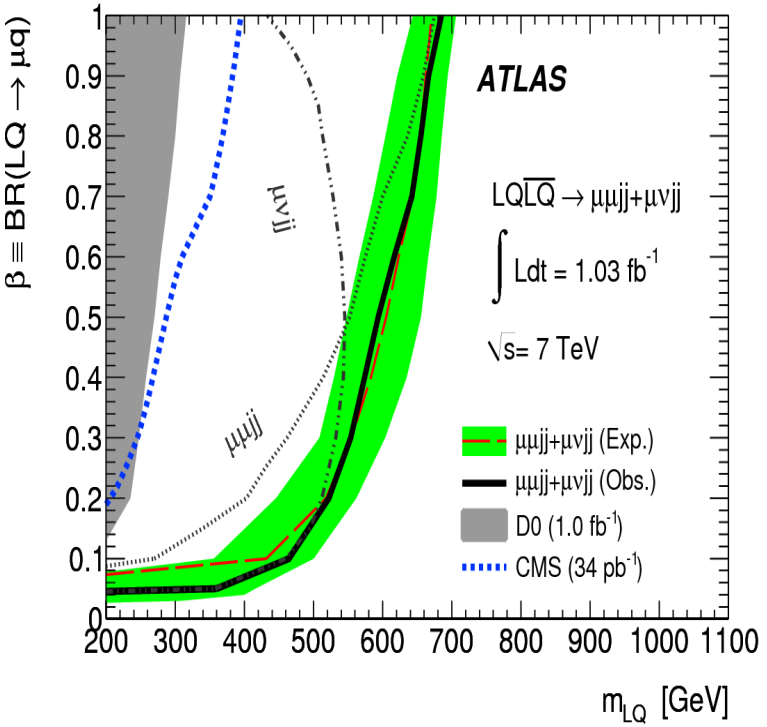
Search for leptoquarks

arXiv:1203.3172
arXiv:1112.4828v5 [hep-ex]

- Likelihood ratio is build out of $\sum p_T$, lepton invariant mass, and average LQ invariant mass.
- Limits are set n the plane M_{LQ} and BR(LQ→lq)
- Exclusion for BR(LQ→lq)=1
  - 1st generation LQ with M_{LQ} < 660GeV
  - 2nd generation LQ with M_{LQ} < 685GeV

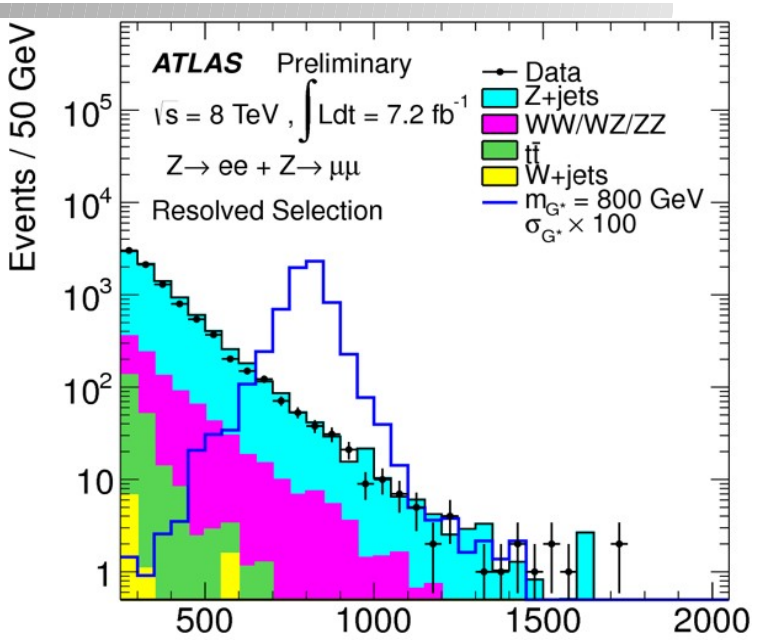


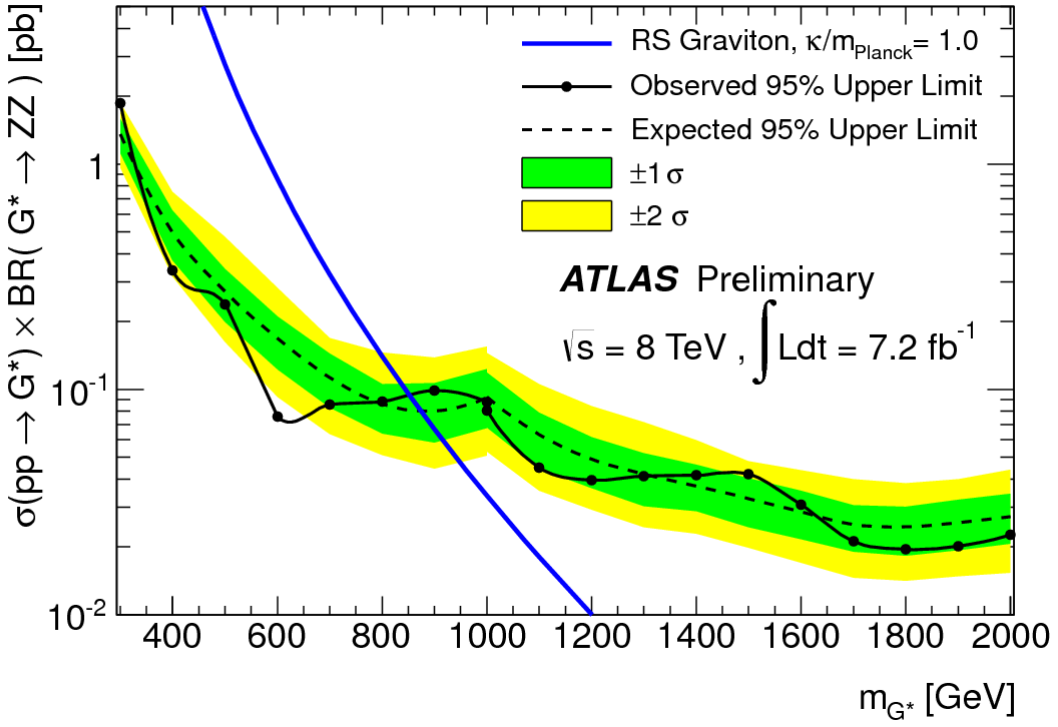


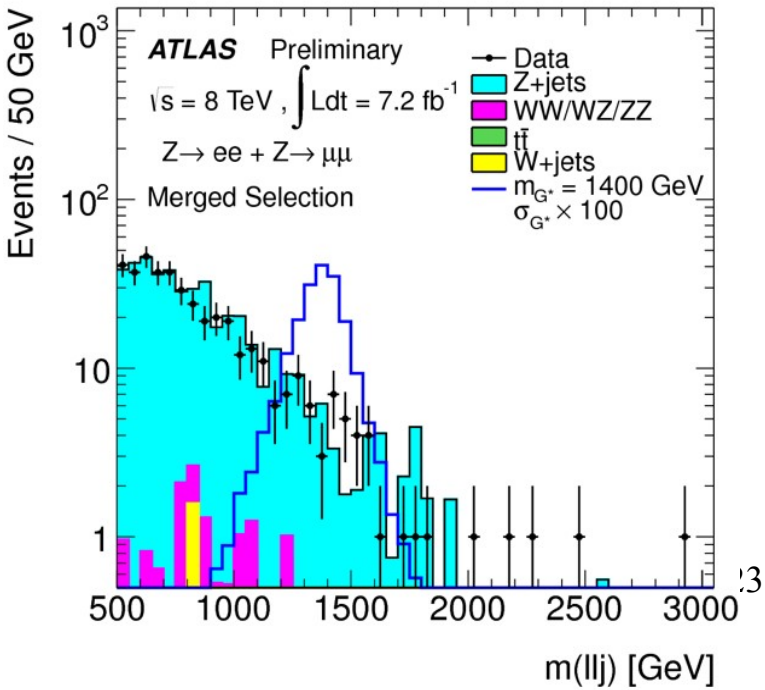


Search for ZZ--> *ll*qq resonance [ATLAS-CONF-2012-150]

- Production of di-bosons from RS graviton decay $G^* \rightarrow ZZ \rightarrow llqq$
- Select events with 2 leptons and 1 or 2 jets:
  - Reconstruct m_{lljj} in the resolved case and m_{llj} in the merged case.
  - Main backgrounds: Z+jets, ZZ/WZ/WW
- Results are translated into limits on the graviton mass for a coupling parameter $k/m_{Plank}=1$



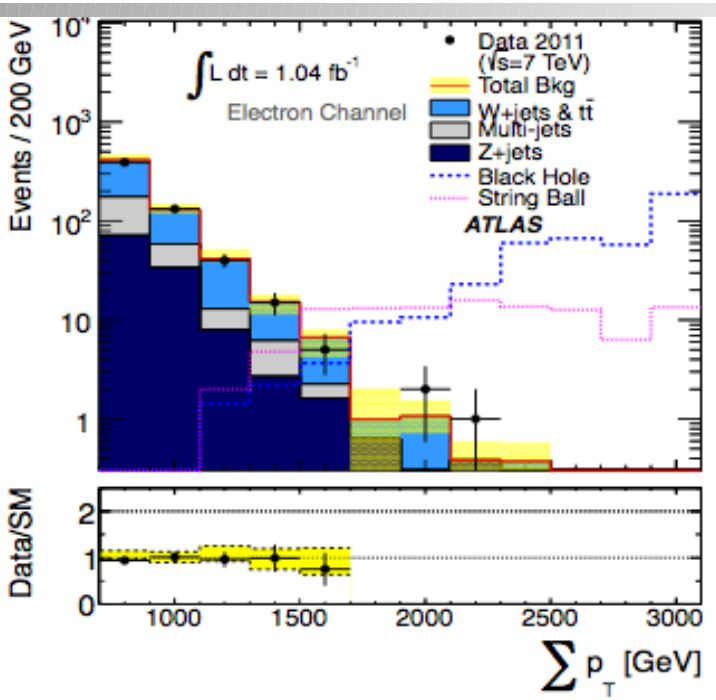


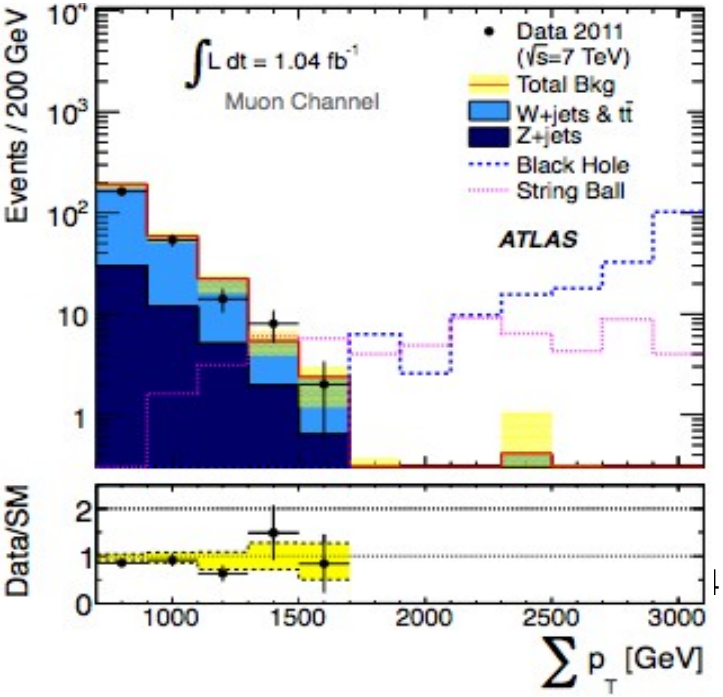


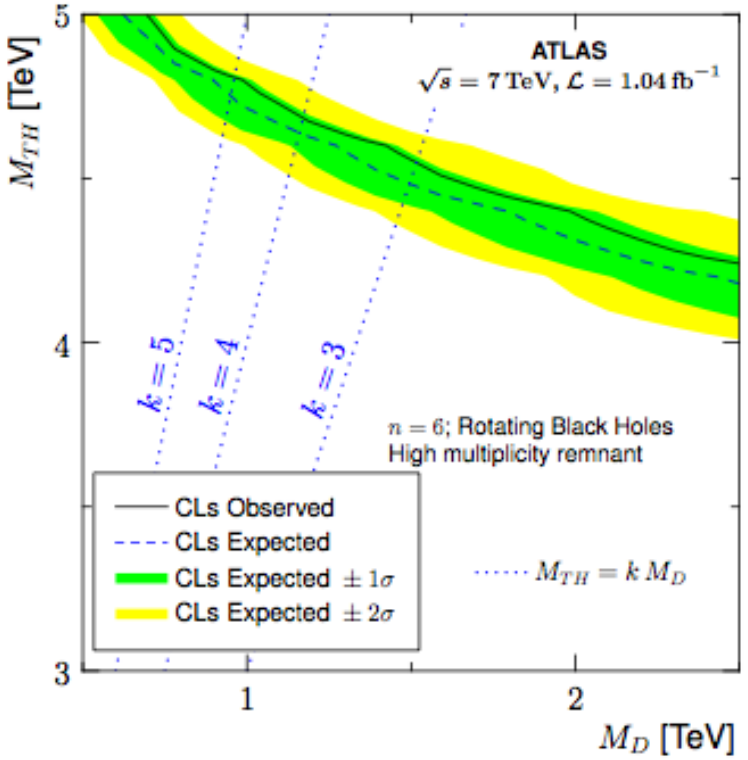
Search for microscopic Black Holes

arXiv:1204.4646v1 [hep-ex]

- Selecting events with three or more high pT objects with an electron or muon
- Requiring a high pT lepton reduce sensibly the QCD multi-jet background and makes its expectation more precise. Main discriminant: $\sum p_T$
- For $\sum p_T$>1.5 TeV, limit on fiducial σ is 16.7 fb.
- Results are translated in limits on the fundamental gravity scale in microscopic black hole models





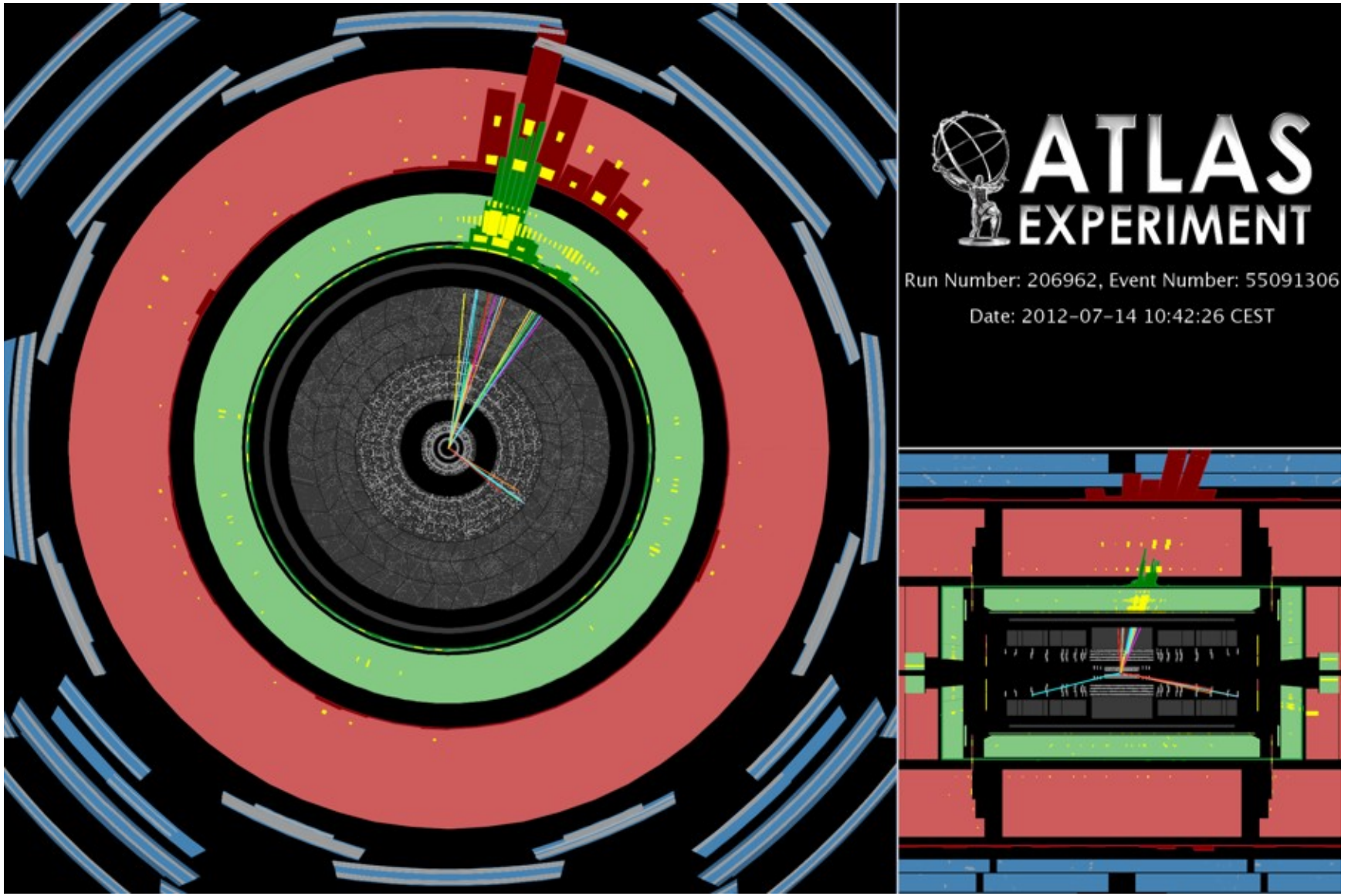


Summary

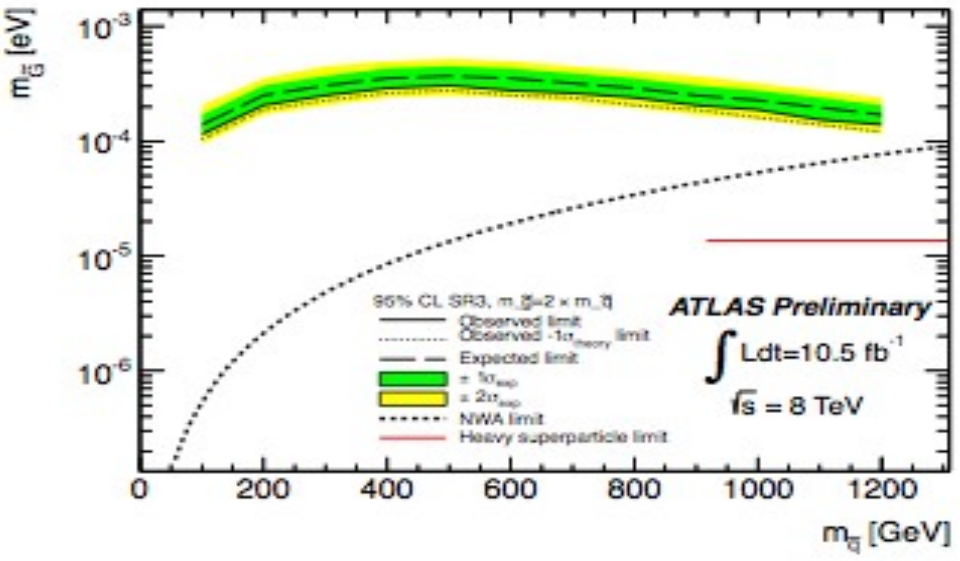
- Robust understanding of the SM with jets
- Jet + X searches in ATLAS showed no significant excess beyond the Standard Model predictions
- New results based on full 2012 luminosity will come soon.
- Stay tuned!

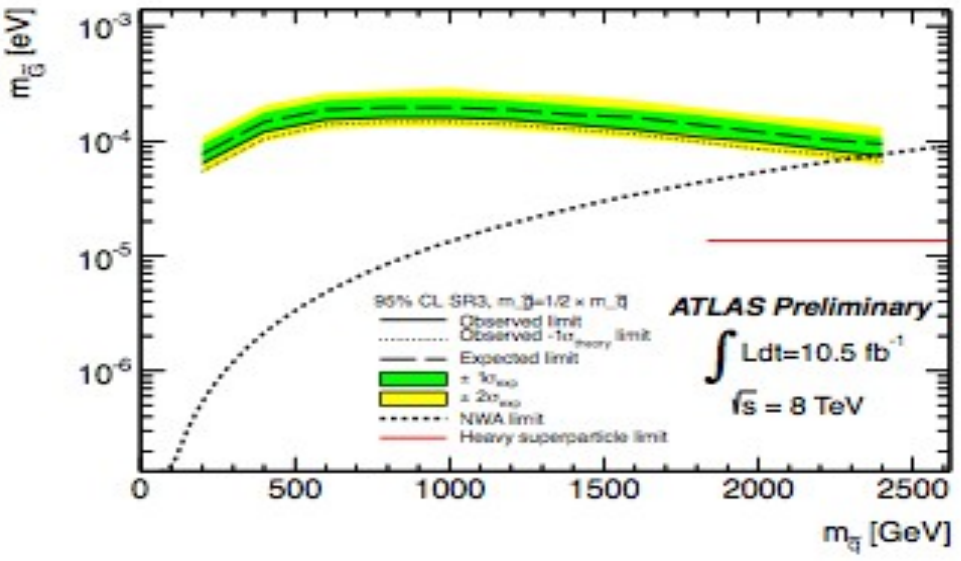
Backup slides

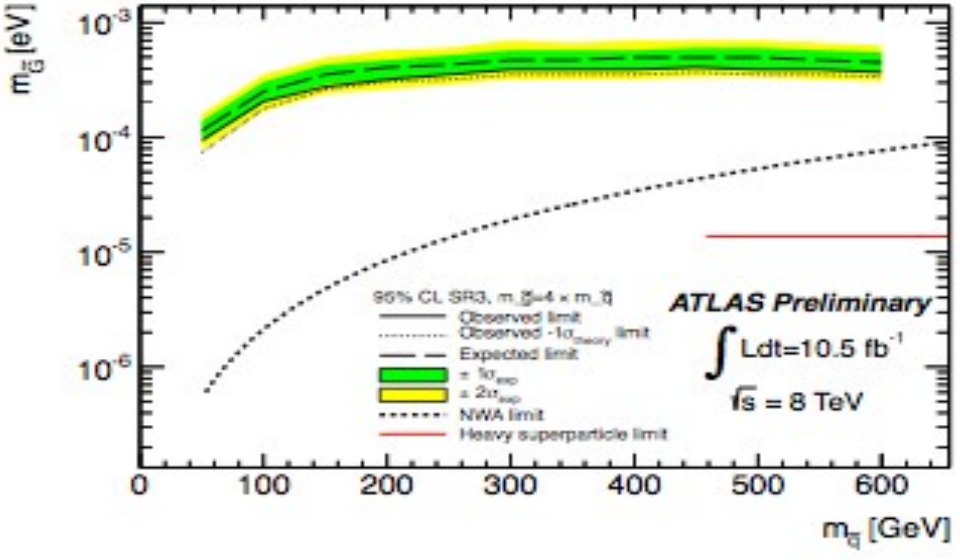
Monojet event from 8 TeV collisions

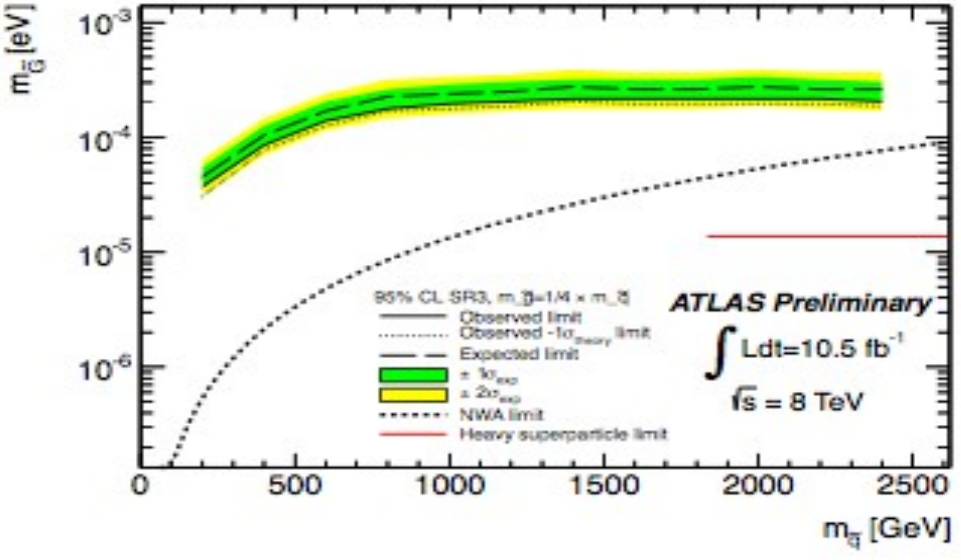


Gravitino limits for $m_{\tilde{q}} \neq m_{\tilde{g}}$

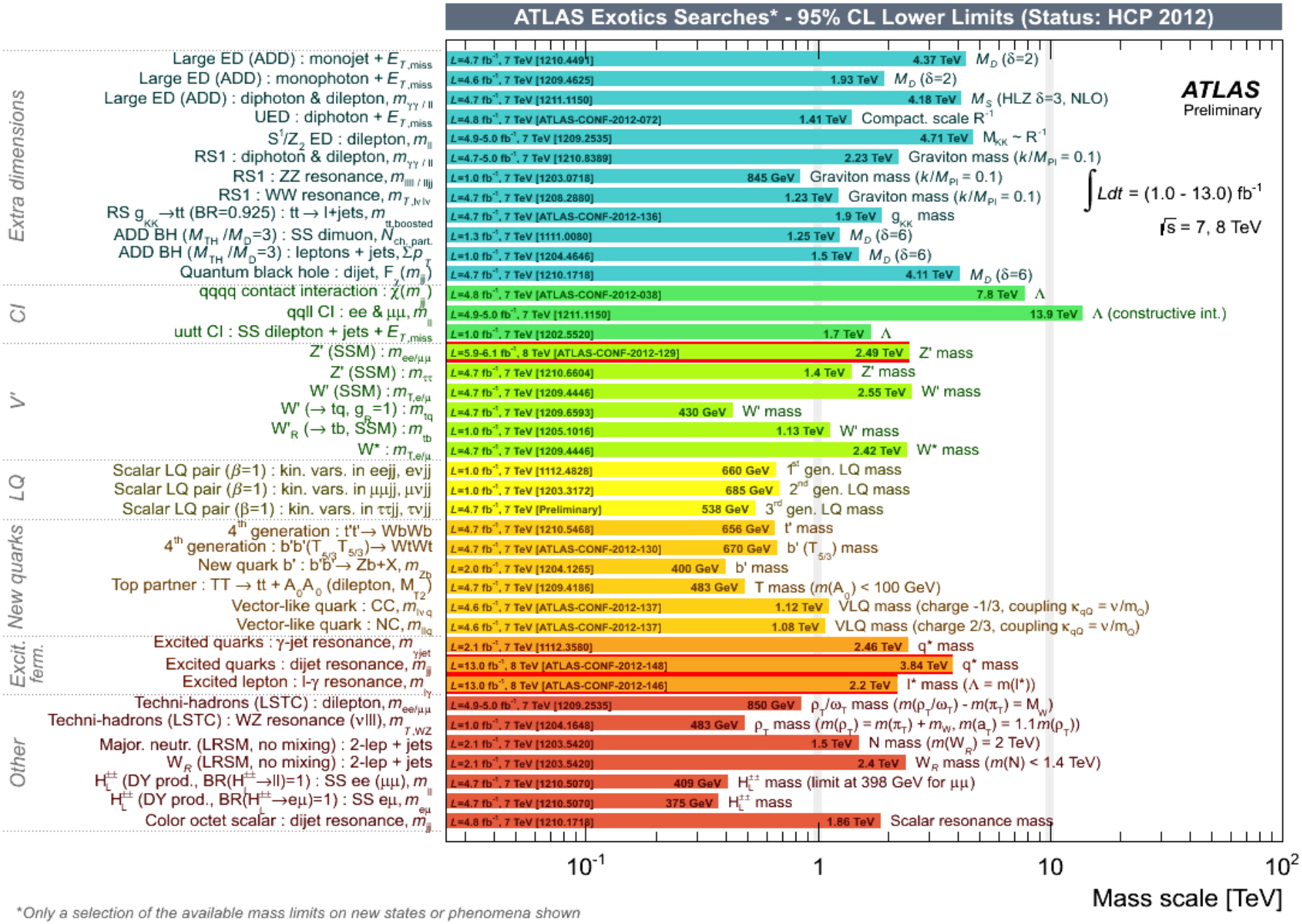








Summary plot of Exotics searches



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