No stone left unturned?

Searches for Physics Beyond the Standard Model at the ATLAS experiment

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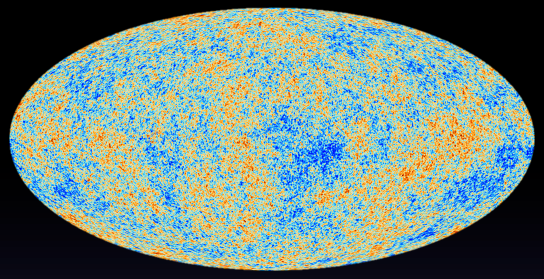
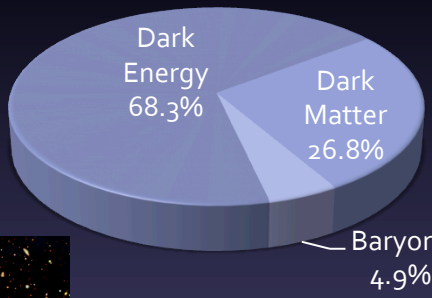
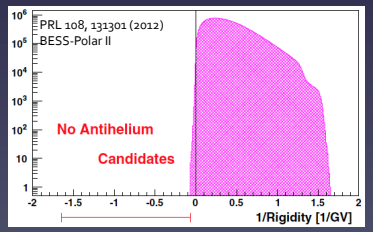
Big open questions



(ESA/Planck)



NASA CXC, STScI- Magellan/U.Arizona; ESO WFI.



What is Dark Matter?

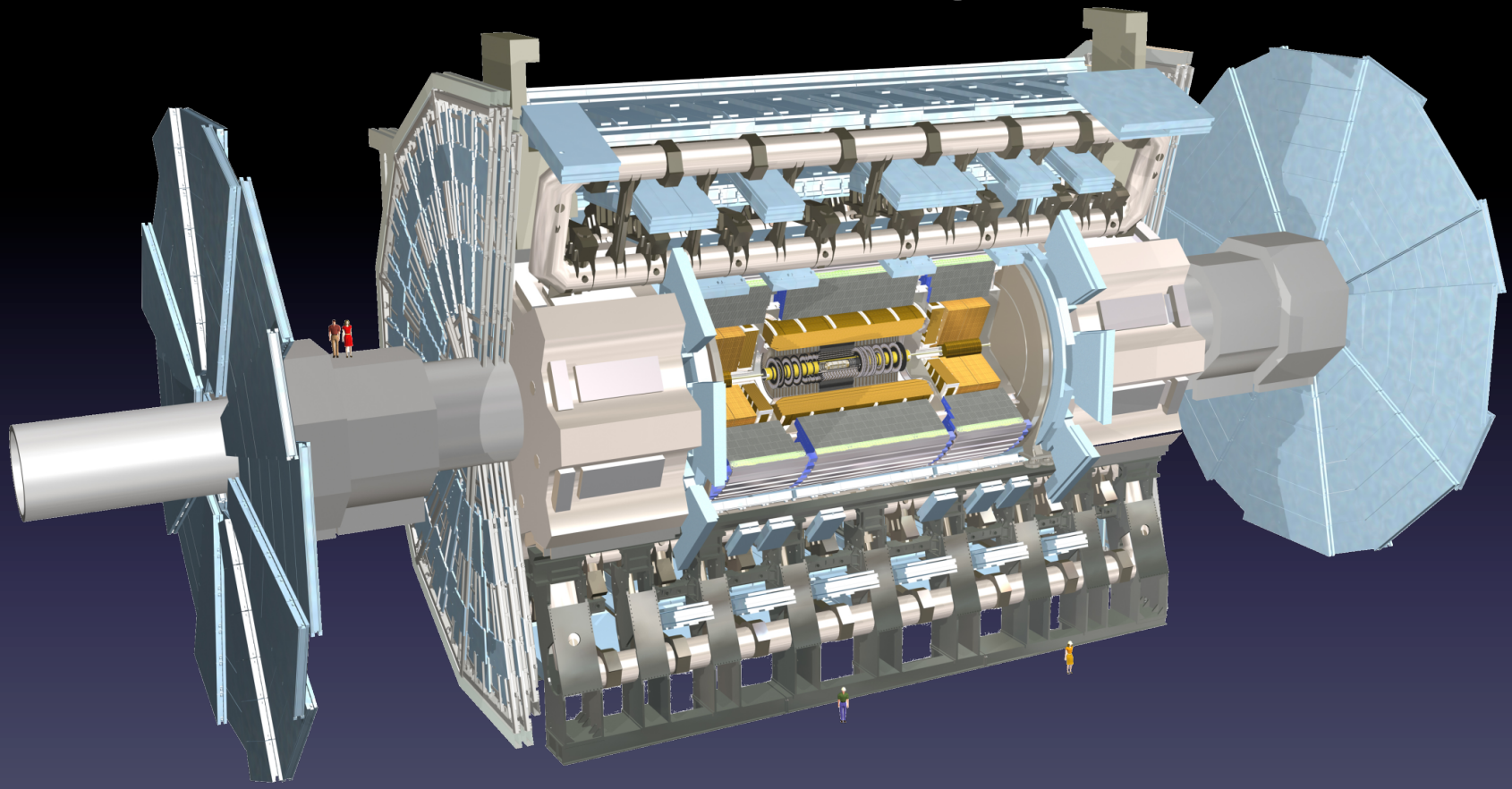
What is Dark Energy?

What happened to anti-matter?

Why is gravity so weak?

Why is Higgs so light?

LHC + ATLAS: searching for surprises

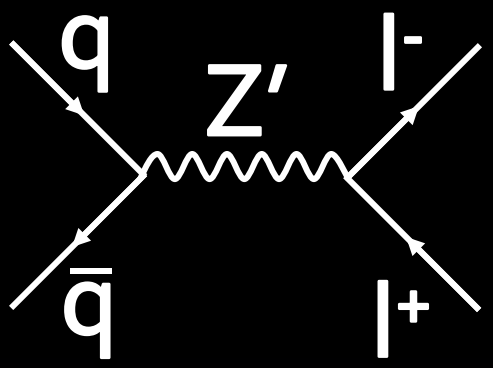


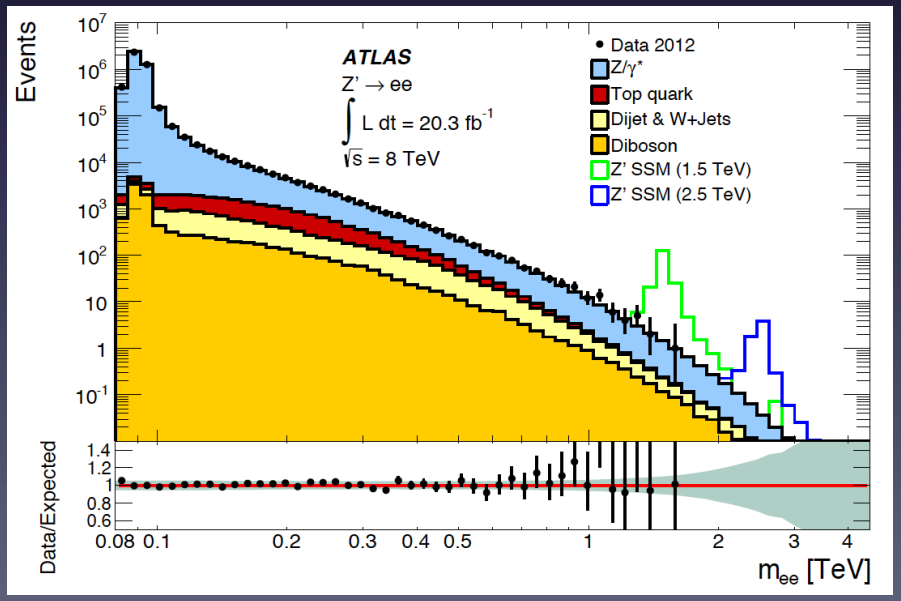
- In this talk: Searches for (non-SUSY) New Physics
- Simple final states to more complex

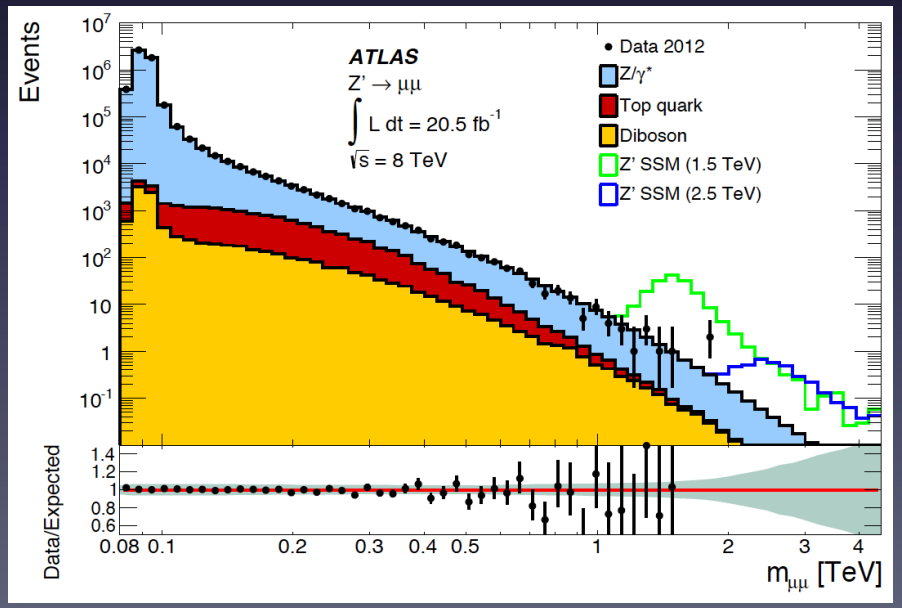
Dilepton Resonance Search

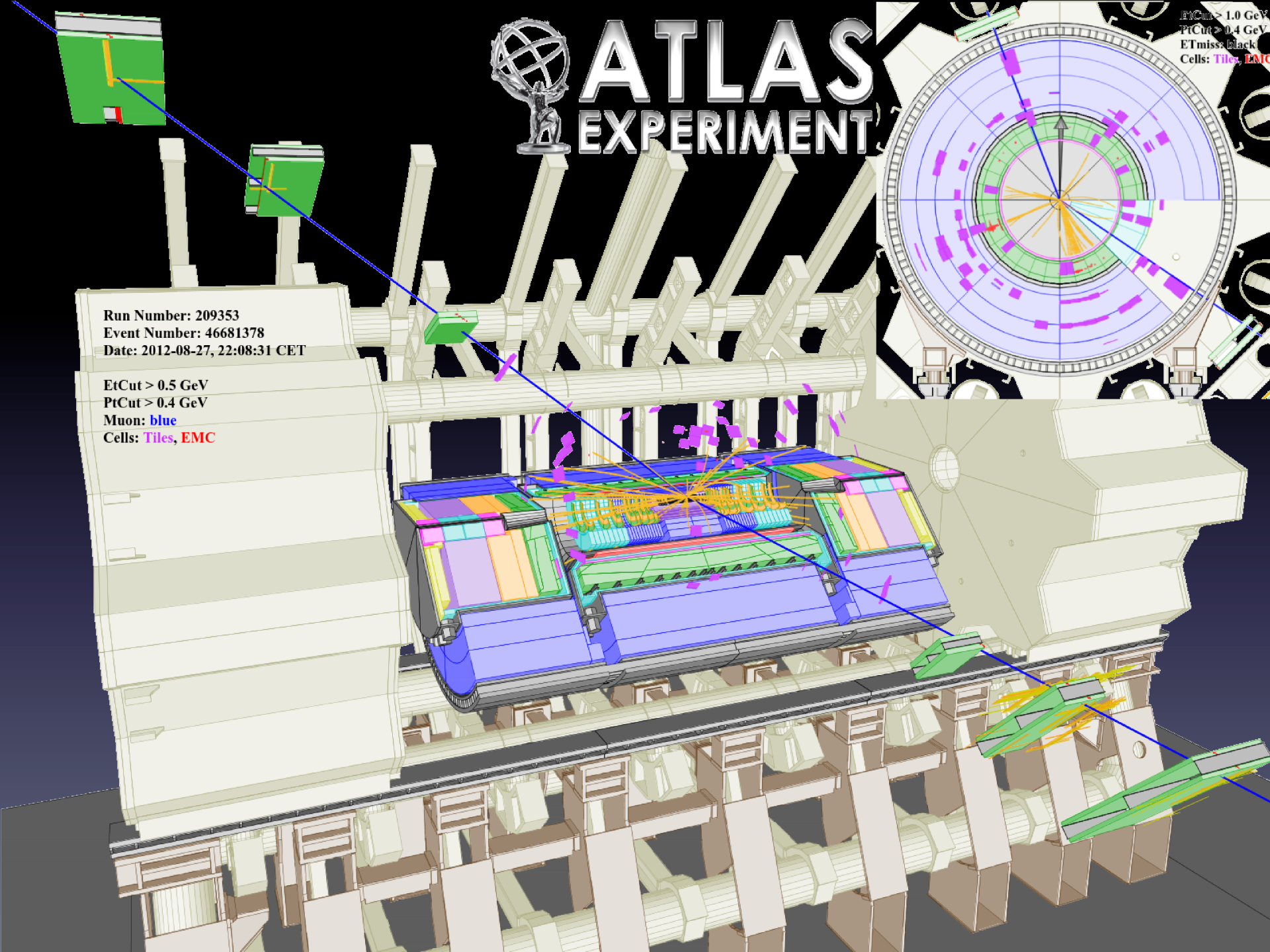
arXiv:1405.4123

- Di-electrons channel
  - Leading E_T > 40 GeV, Sub-leading E_T > 30 GeV, both isolated
- Di-muon channel
  - p_T > 25 GeV, isolated
  - High p_T quality cuts
  - Opposite sign

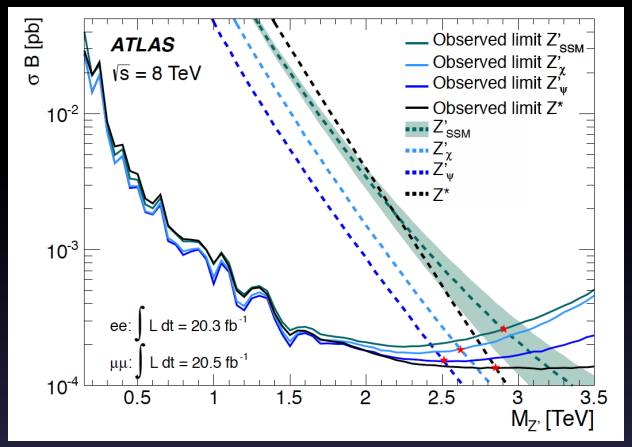


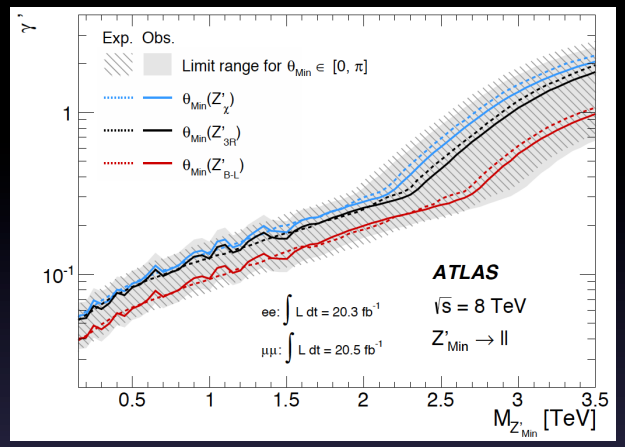


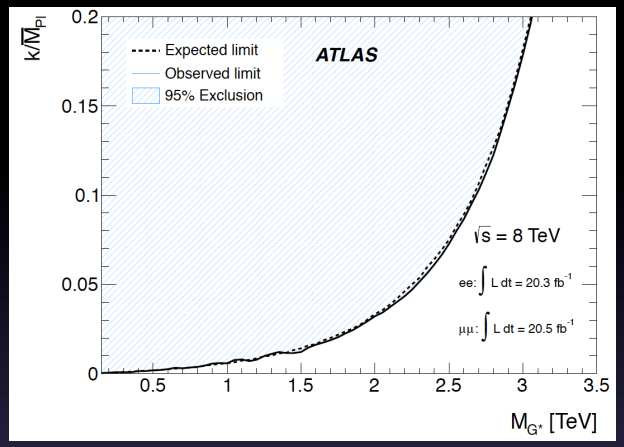



ATLAS
EXPERIMENT
Run Number: 209353
Event Number: 46681378
Date: 2012-08-27, 22:08:31 CET
EtCut > 0.5 GeV
PtCut > 0.4 GeV
Muon: blue
Cells: Tiles, EMC
PtCut > 1.0 GeV
PtCut > 0.4 GeV
Cells: Tiles, EMC

Dilepton Resonance Search: interpretation





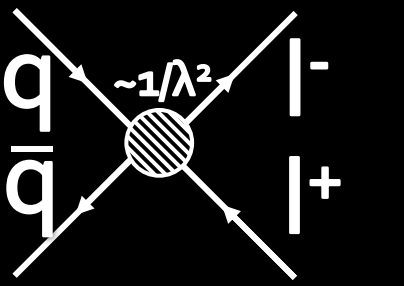


Model	Expected Limit [TeV]	Observed Limit [TeV]
Z'_{SSM}	2.87	2.90
Z'_{χ}	2.60	2.62
Z'_{ψ}	2.46	2.51
Z^*	2.82	2.85

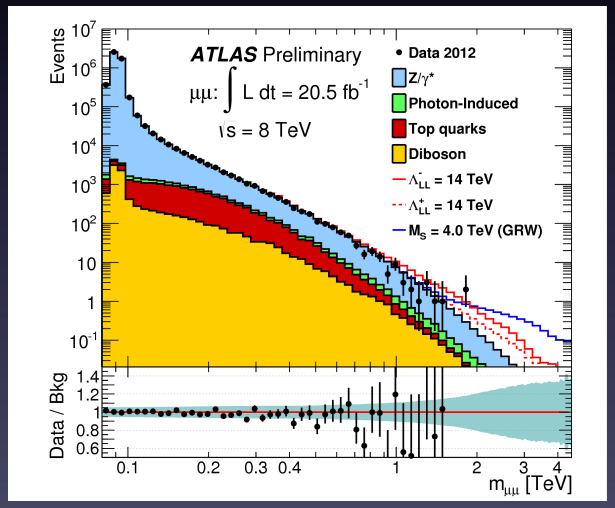
Also interpretations in QBH, MWT

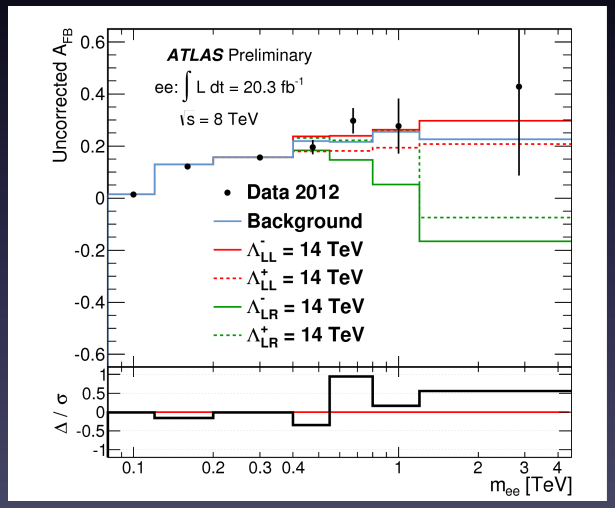
ATLAS-CONF-2014-030

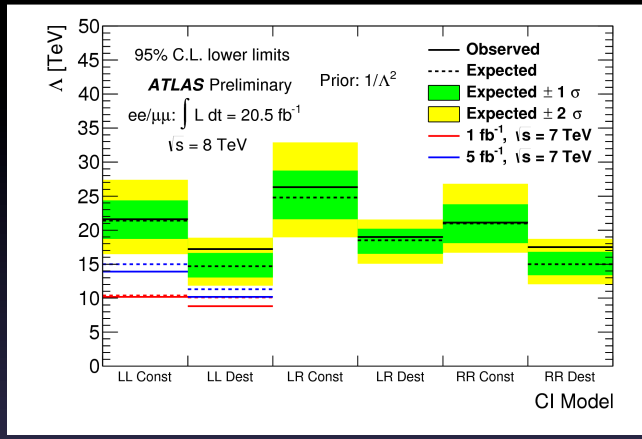
Di-lepton Contact interaction search

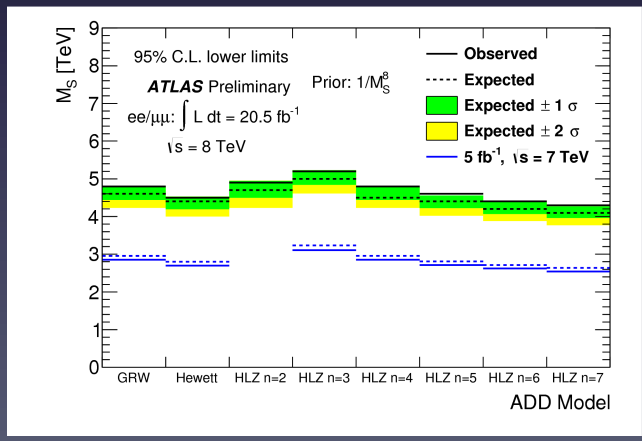


- Re-interpretation in terms of 'Fermi' interaction
- Opposite sign requirement for e^+e^-
- $\cos\theta^*$ utilized to improve sensitivity



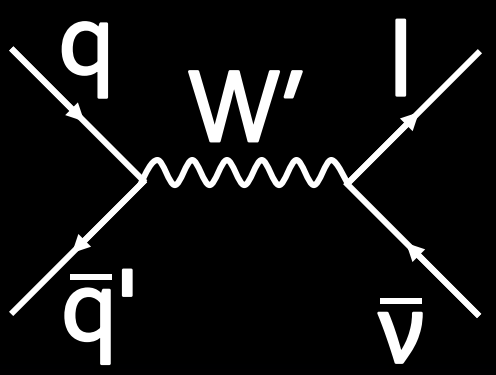




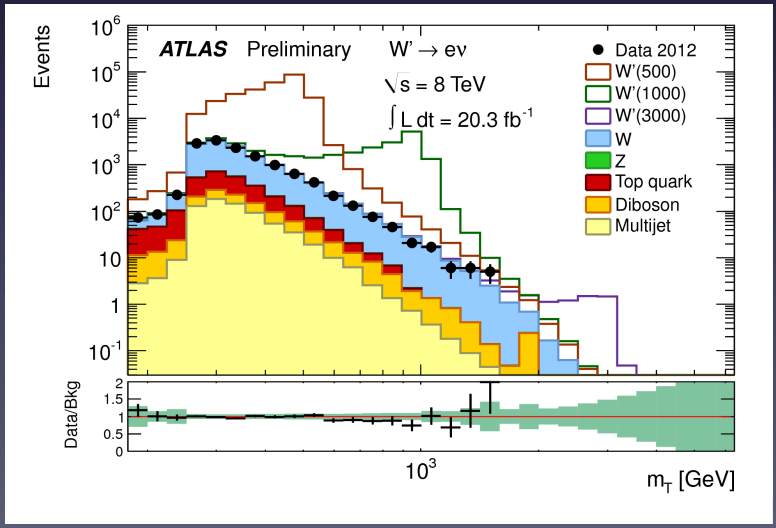


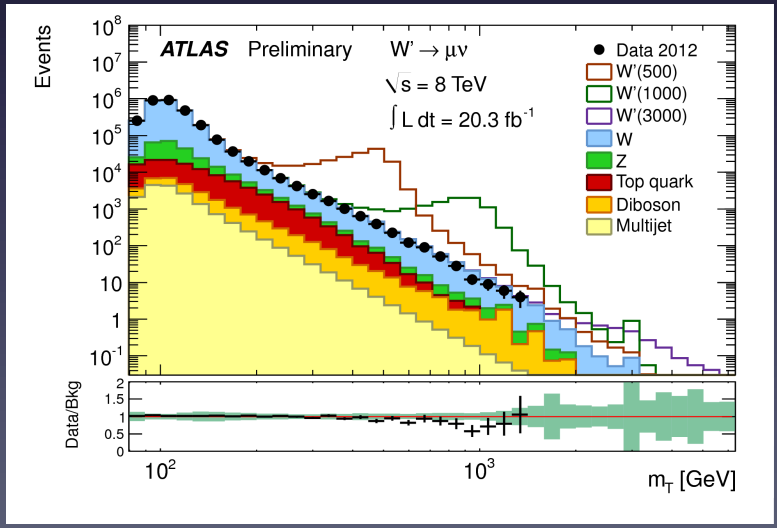
- CI limits set using priors flat in $1/\Lambda^2$ and $1/\Lambda^4$
- M_S limits set using priors flat in $1/M_S^4$ and $1/M_S^8$

Search in lepton and E_T^{miss} final state



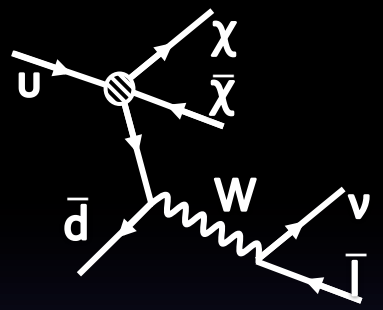
- Electrons:
  - E_T, E_T^{miss}> 125 GeV, isolated
- Muons:
  - E_T, E_T^{miss}> 45 GeV, isolated
- Optimized m_T cut (250-900 GeV)

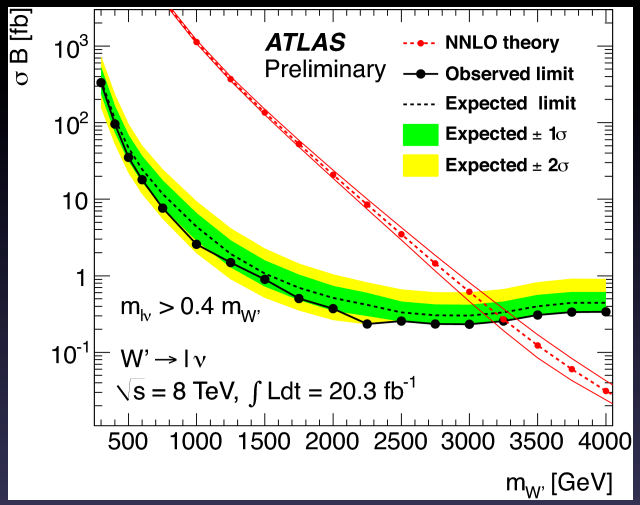


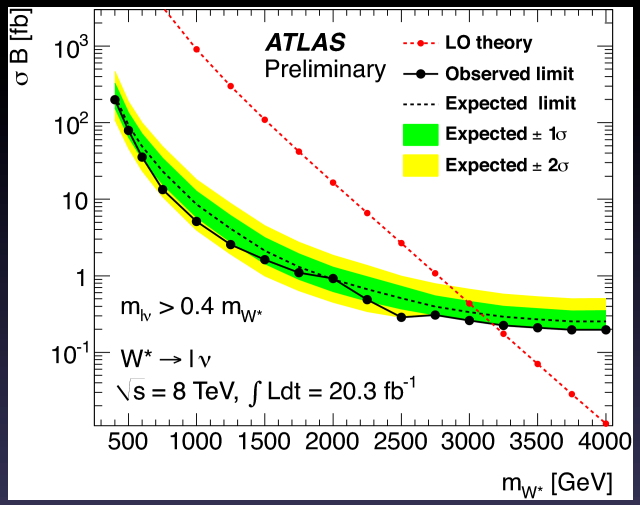


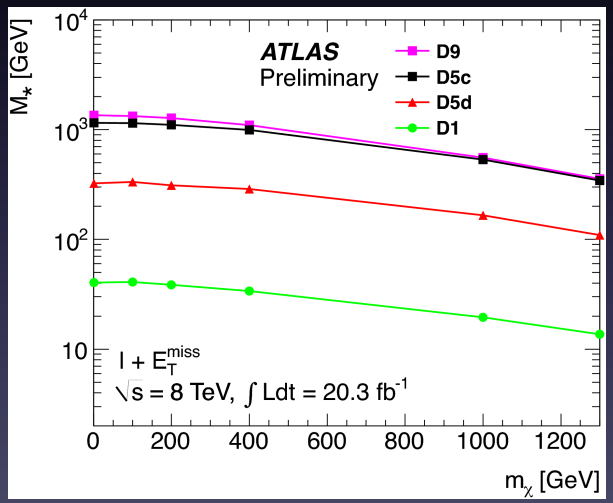
Search in to lepton and E_t^{miss} : interpretation

Mono-W interpretation:





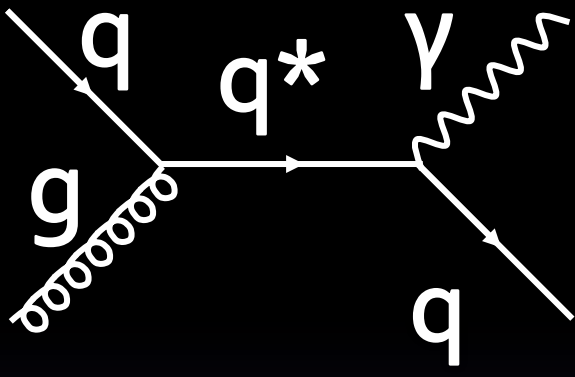




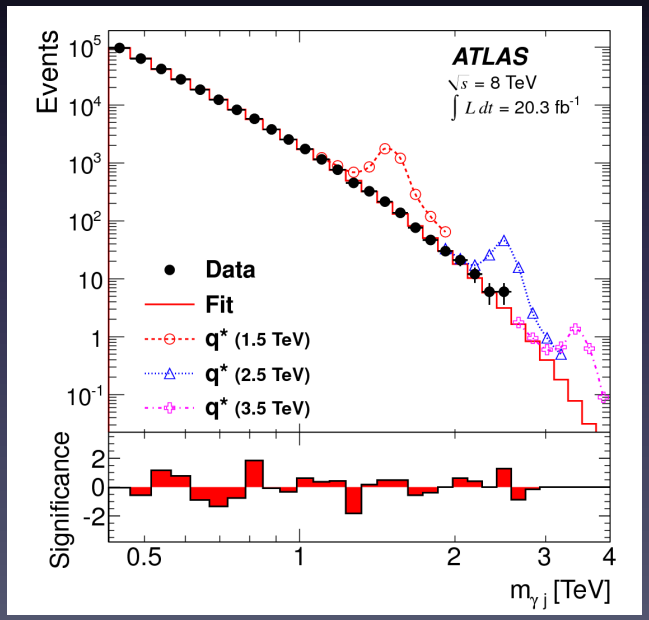
- Observed Mass Limits:
  - $m_{W'} > 3.19$ TeV
  - $m_{W^*} > 3.08$ TeV

PLB 728, 562 (2013)

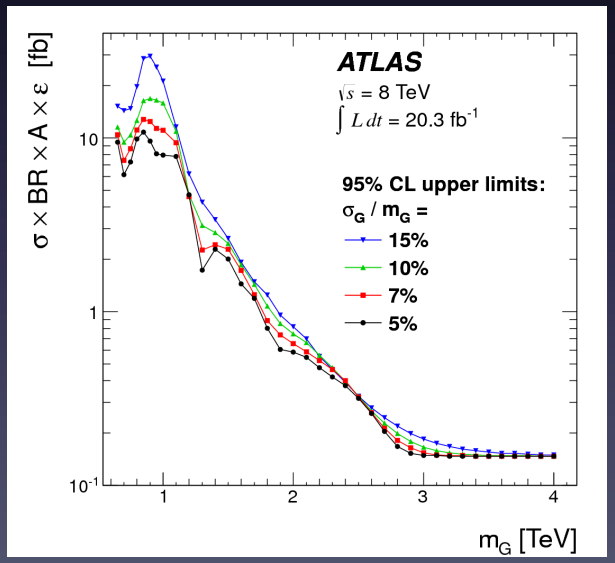
Search for new phenomena in lepton+jet final state



- Anti-k_T R=0.6 jet E_T > 125 GeV
- Isolated, central photon, separated from the jet E_T > 125 GeV
- Pseudorapidity separation < 1.6



Generic Gaussian resonance limit:

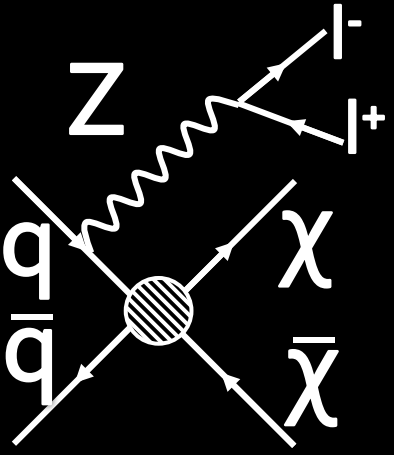


QBH Limit:
M_{TH} > 4.6 TeV

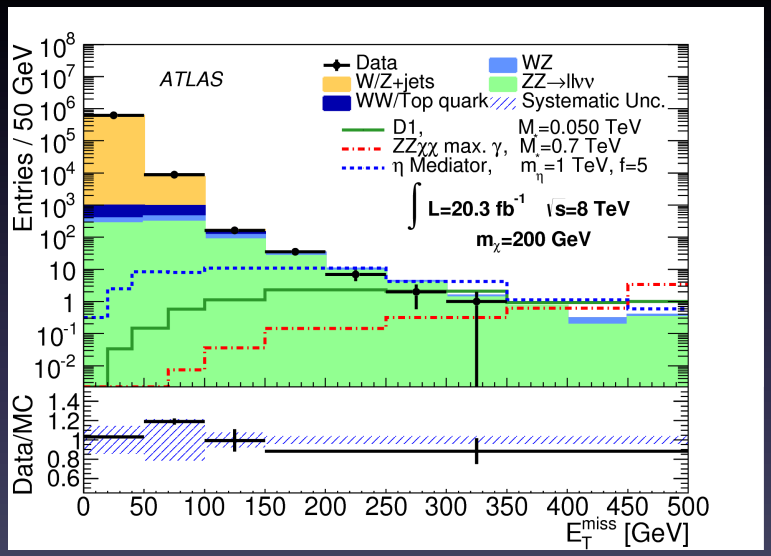
q* Limit
m_{q^*} > 3.5 TeV

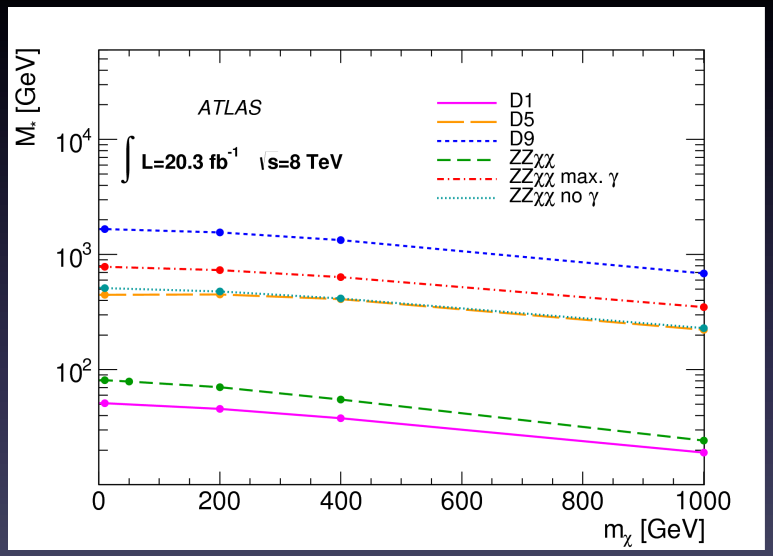
$Z(\rightarrow l^+l^-)+E_T^{miss}$ search

arXiv:1404.0051



- e^+e^- or $\mu^+\mu^-$ pair in Z window, leptons isolated
- Topological cuts on E_T^{miss} and p_T^{ll}
- E_T^{miss} cut selected depending on the model, fiducial region





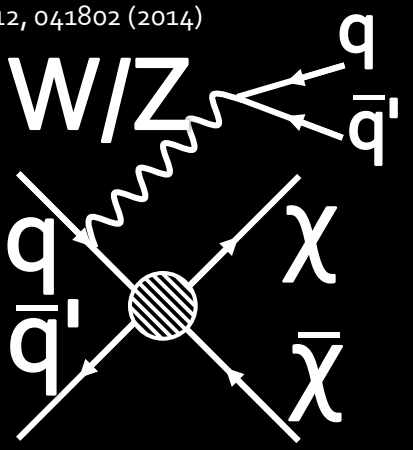
Interpretations for DM-nucleon scattering, scalar particle mediator model and ZZχχ

Fiducial cross-section limits [fb]:

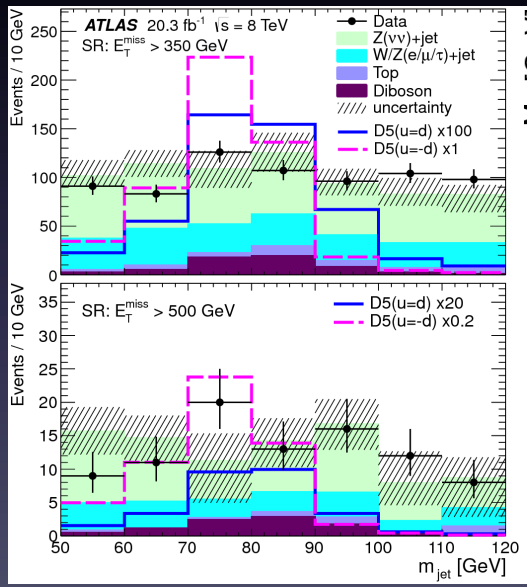
E_t^{miss} threshold [GeV]	150	250	350	450
Expected limit	3.0	0.73	0.36	0.27
Observed limit	2.7	0.57	0.27	0.26

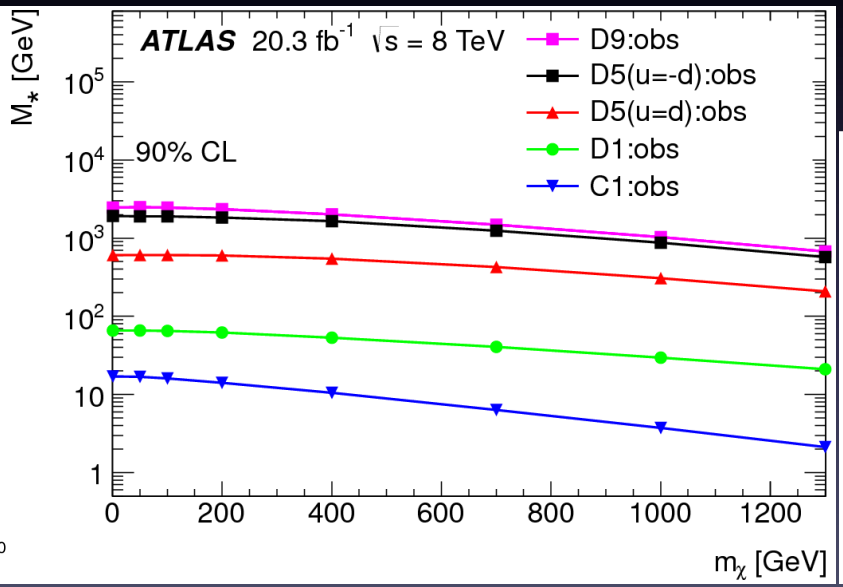
W/Z(→ qq′)+E_T^{miss} search

PRL 112, 041802 (2014)

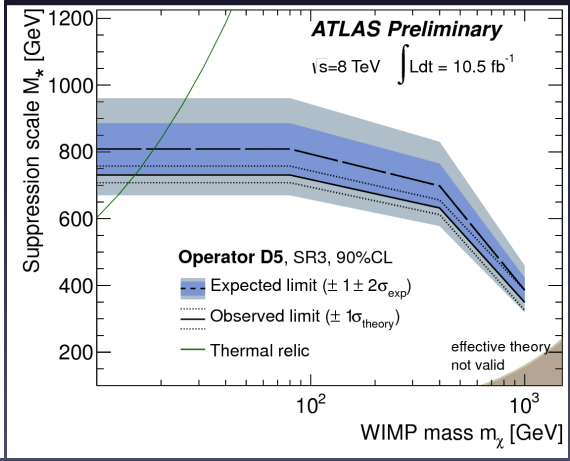


- One 'Cambridge-Aachen' large radius (1.2) jet
  - p_T > 120 GeV, m_j 50-120 GeV, |η|<1.2, sub-jets balanced
- Veto on additional narrow jets and leptons
- Signal regions E_T^{miss} > 350, 500 GeV





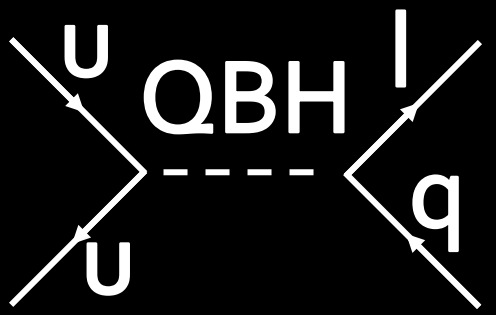
M* lower limits from monojet search: ATLAS-CONF-2012-147

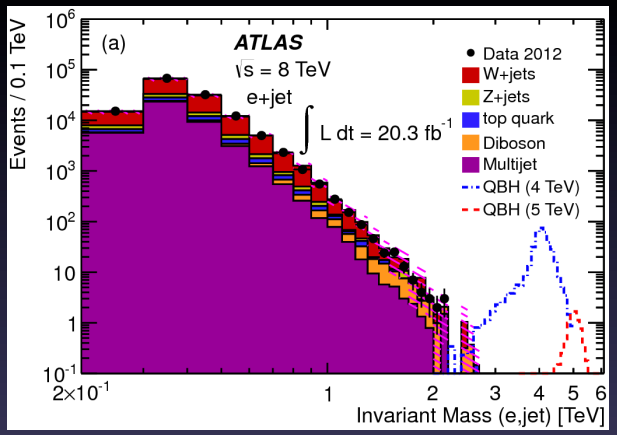


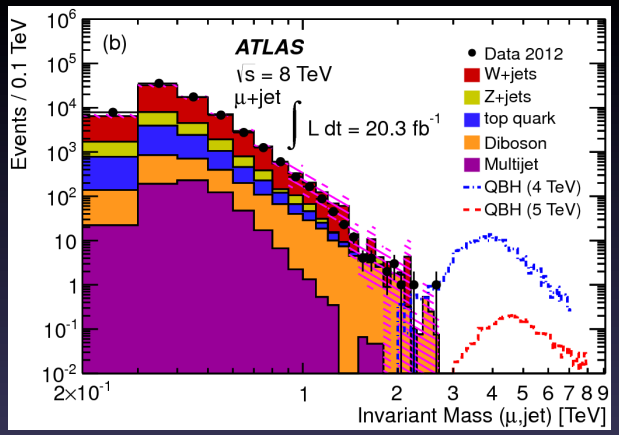
Interpretations for DM-nucleon scattering;
Higgs as a mediator limit at m_H = 125 GeV: σ < 1.3 pb
Fiducial limits published

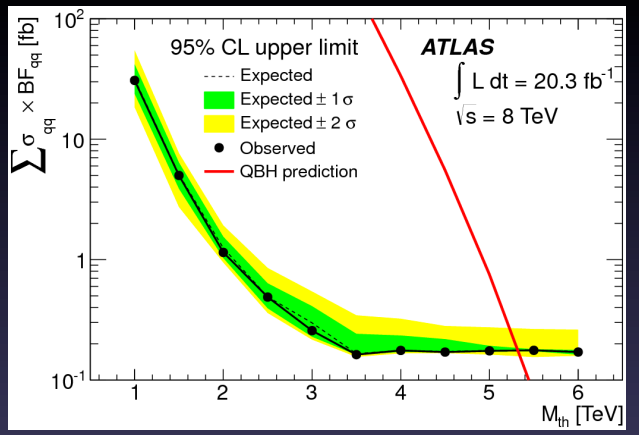
PRL 112, 091804 (2014)

Lepton + jet search for quantum black holes







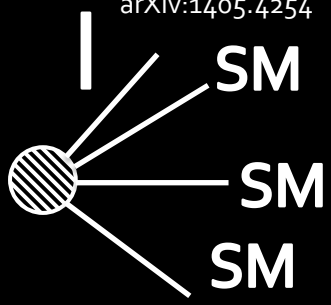


- $p_{T\ lepton}$, $p_{T\ jet}$> 130, leptons isolated
- Topological cuts: $|\Delta\phi_{l,j}|>\pi/2$, $|<\eta_{l,j}>|<1.25$, $|\Delta\eta|<1.5$
- m_{min} cut as a function of M_{TH}

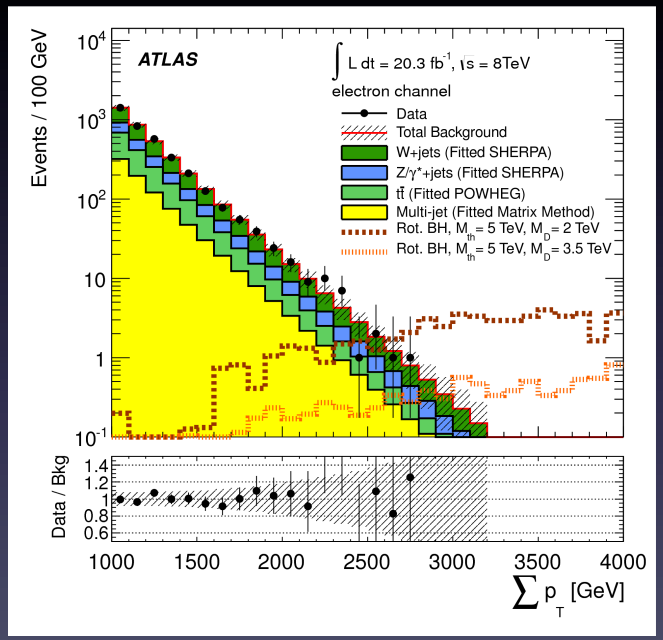
Observed limits:
n=6: M_{TH} > 5.3 TeV
n=2: M_{TH} > 4.7 TeV

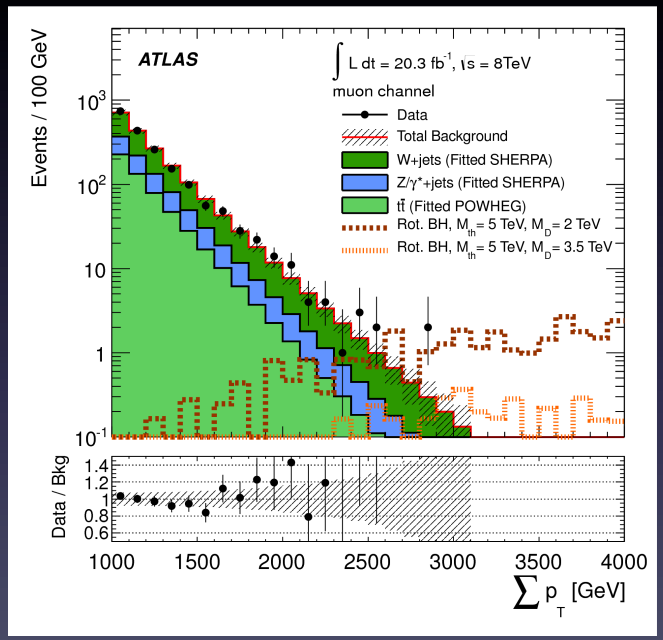
Lepton+jets search for microscopic black holes

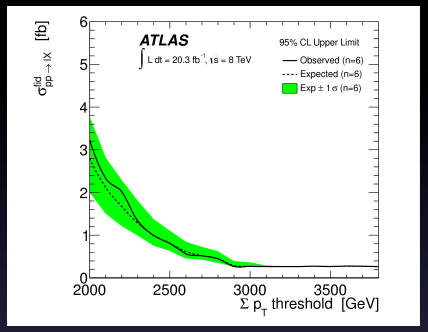
arXiv:1405.4254

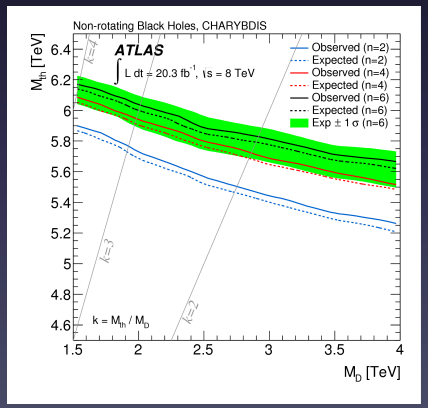


- $\Sigma p_T > 2$ TeV
- 3 objects with $p_T > 100$ GeV, one- an isolated lepton







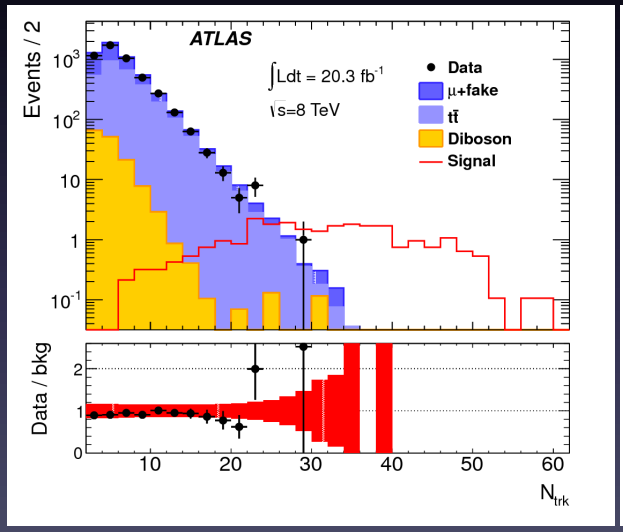


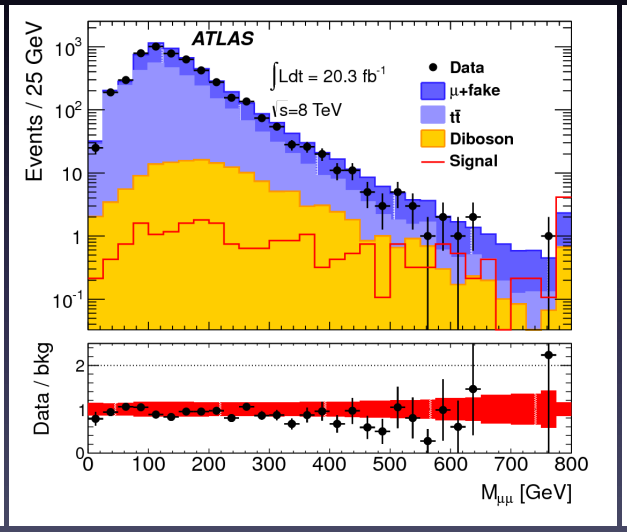
- Observed Limits (non-rotating, $M_D = 1.5$ TeV, n = 6) $M_{TH} > 6.2$ TeV
- Limits published on variety of microscopic black hole scenarios and string balls.

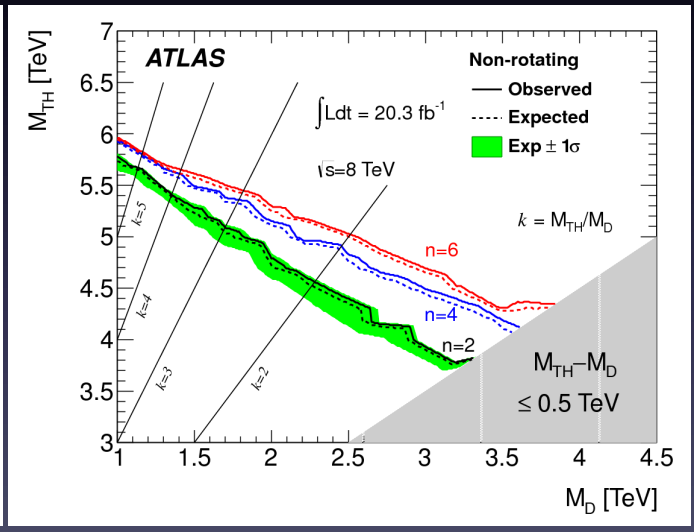
PRD 88, 072001 (2013)

Same-sign dimuon + tracks search for microscopic black holes

- Leading muon p_T > 100 GeV isolated
- Subleading p_T > 15 GeV
- Leading and sub-leading p_T muons same-sign, separated $\Delta R > 0.2$
- 40 tracks with p_T > 10 GeV



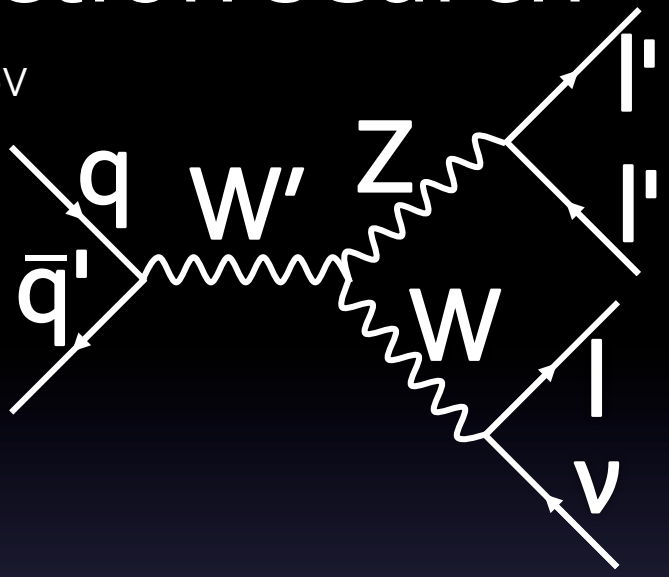


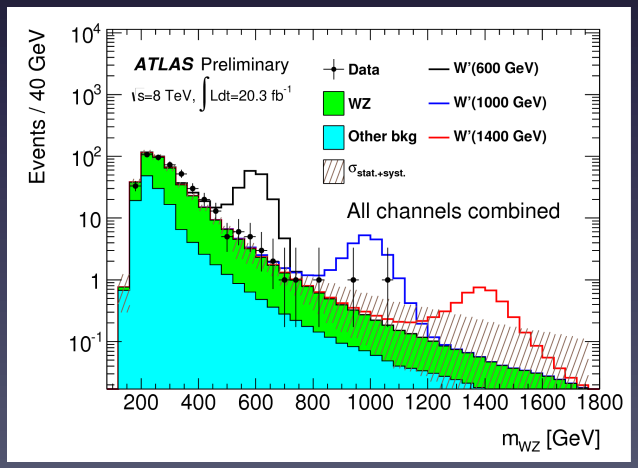


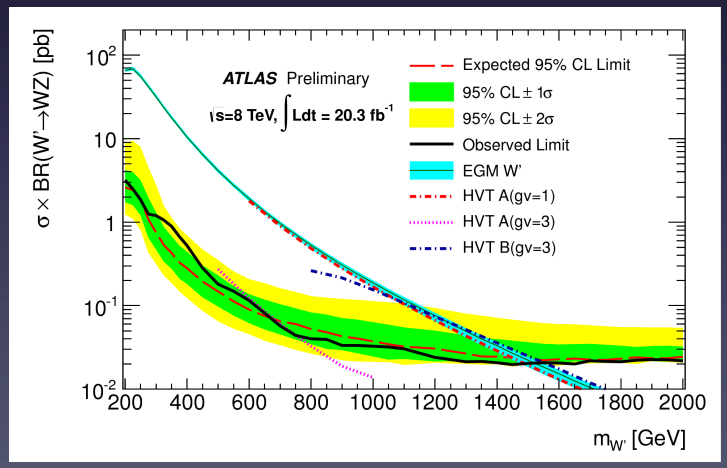
- Observed limit on σ_{vis} < 0.16 fb
- Observed limit on M_{TH} (non-rotating M_D = 1.5 TeV, n=6) M_{TH} > 5.7 TeV
- Variety of microscopic black hole scenarios and string balls constrained

lνl'l' WZ resonant production search

- Exactly 3 isolated (calo+track) electrons and muons $p_T > 25$ GeV
  - Isolation criteria exclude same flavor lepton
  - Two must be same flavor, opposite sign with m_{ll} within 20 GeV of the Z
  - e-μ separation $\Delta R > 0.1$
- $E_T^{miss} > 25$ GeV
- $p_{z\nu}$ from m_W constraint
- $\Delta y(W,Z) < 1.5$
- For searches for $m_{W'} > 250$ GeV SR1: $\Delta\Phi(l,E_T^{miss}) < 1.5$; $m_{W'} < 250$ GeV SR2: $\Delta\Phi(l,E_T^{miss}) > 1.5$;



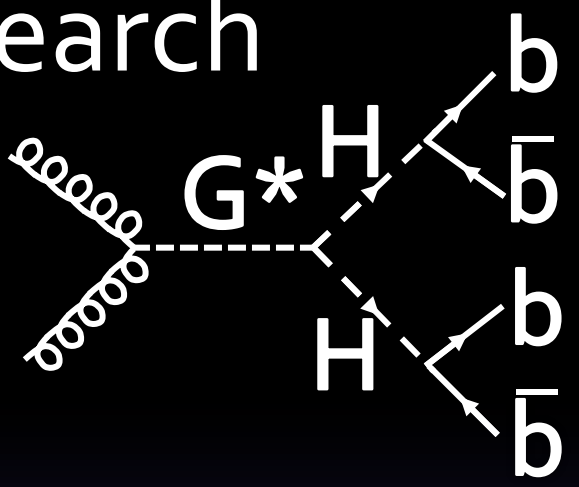


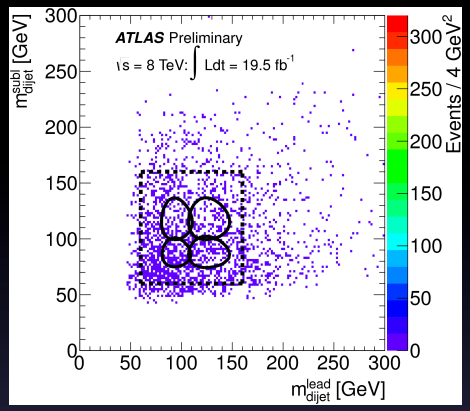


Observed limits:
EGM W': $m_{W'} > 1.52$ TeV
HVT W': $m_{W'} > 0.76 - 1.56$ TeV

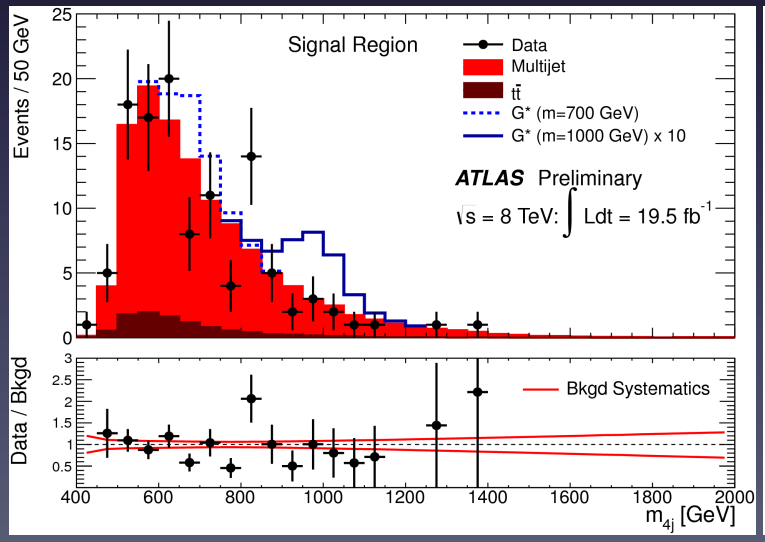
Fiducial cross section limits published

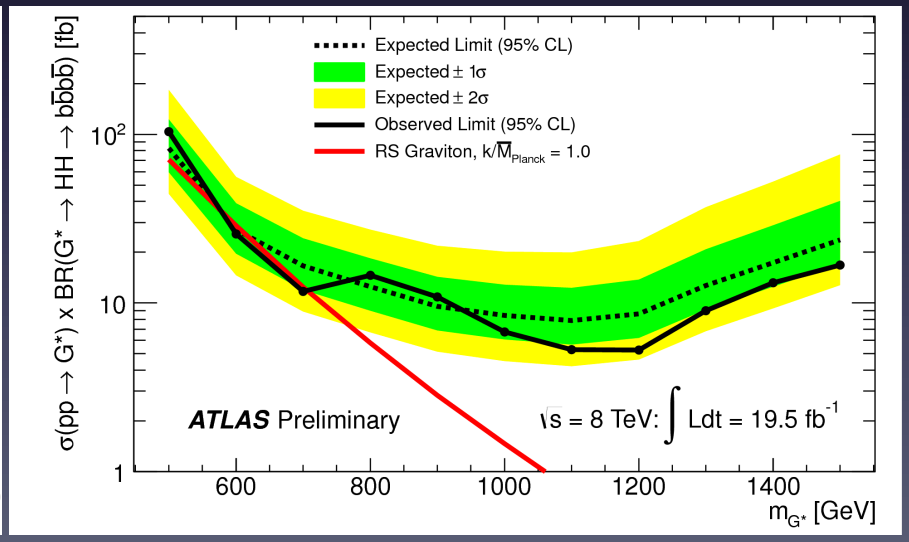
Resonant HH production search decay to 4 b quarks

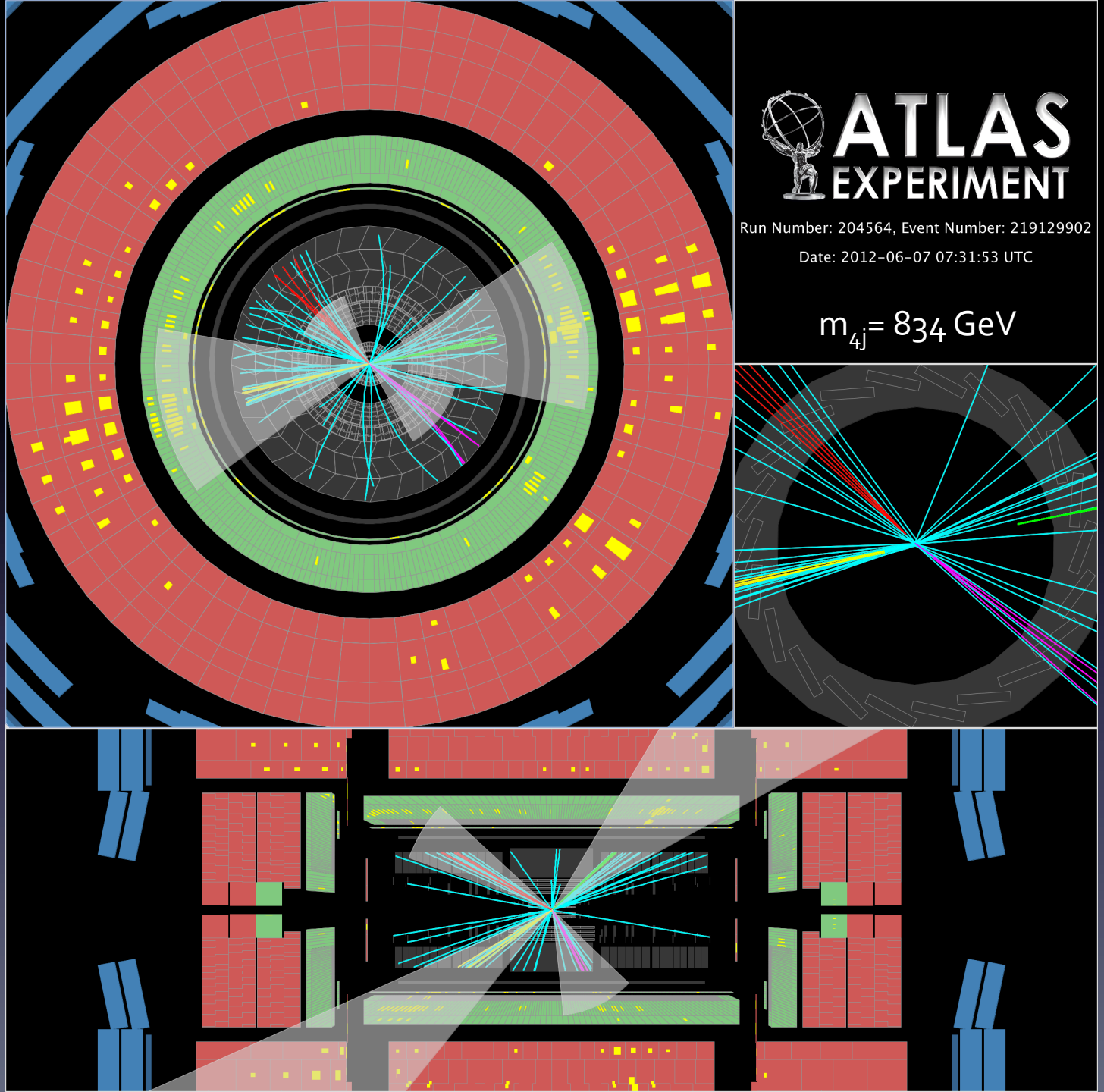




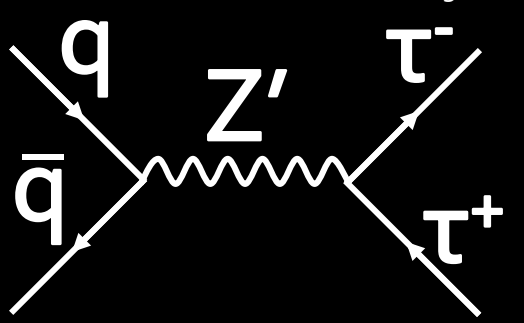
- 4 b-tagged jets $p_T > 20$ GeV
- 2 'dijets' $\Delta R_{jj} < 1.5$, $p_{T,jj} > 200$ GeV
- $t\bar{t}$ veto, t hypothesis formed using extra jets
- Elliptical cut in m_{jj}^{lead}-$m_{jj}^{sublead}$ plane



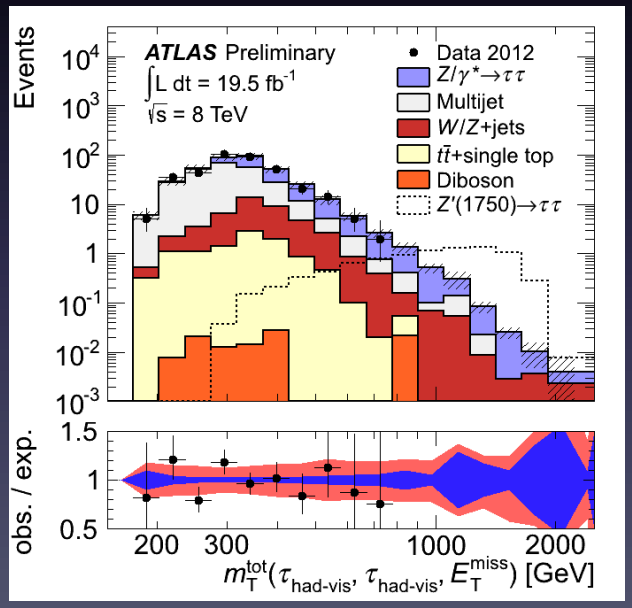


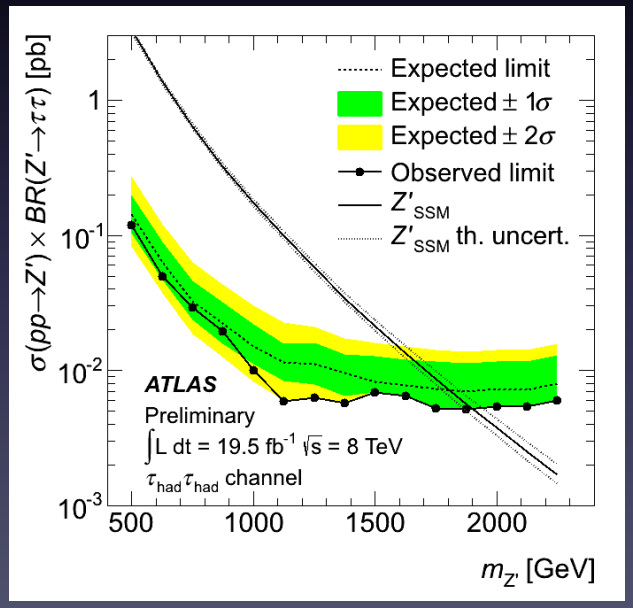

ATLAS
EXPERIMENT
Run Number: 204564, Event Number: 219129902
Date: 2012-06-07 07:31:53 UTC
m_{4j}= 834 GeV

Di-tau resonance search (all hadronic channel)



- τ candidates: jets with 1 or 3 tracks, p_T > 50 GeV
- 2 τ opposite sign, back-to-back candidates, leading p_T > 150 GeV
  - BDT ID
- $m_{T,}^{tot}$ threshold dependent on signal hypothesis (400-850 GeV)

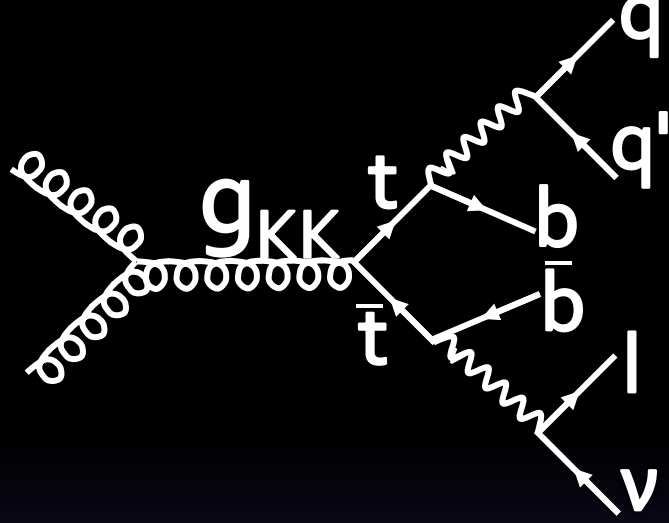




SSM Z′ limit $m_{Z'}$ > 1. 90 TeV

Di-top resonance search (l+jets channel)

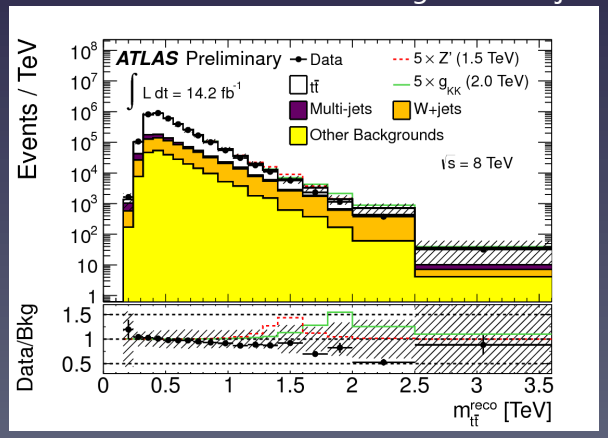
ATLAS-CONF-2013-052

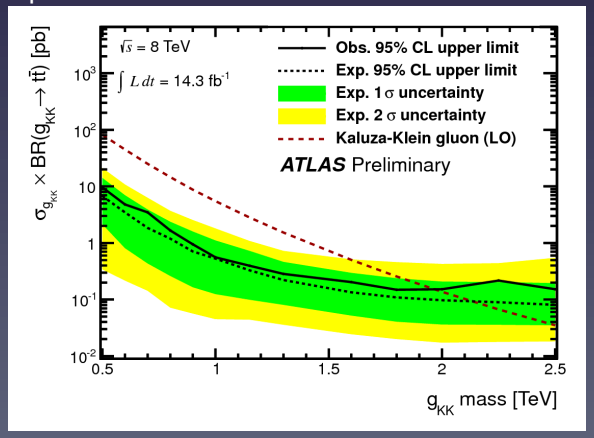


- Exactly one mini-isolated e or μ, p_T > 25 GeV
- E_T^{miss} > 30 GeV (e-channel); E_T^{miss} > 20

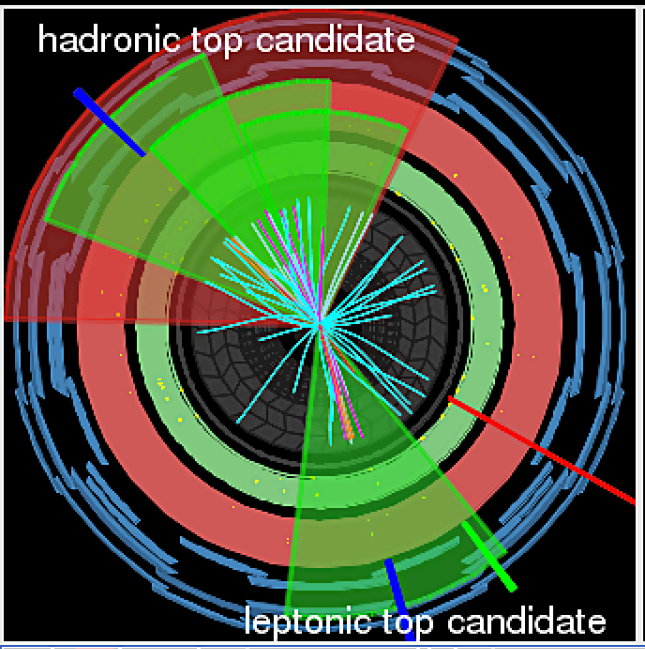
  E_T^{miss} + $m_{T,l\,met}$ > 60 GeV, $p_{z\,\nu}$ from W constraint
- Boosted sample:
  - One narrow (R=0.4) p_T > 25 GeV, b-tagged
  - One large radius (R=1.0) 'trimmed' jet p_T > 300 GeV, m_j > 100 GeV, splitting scale 40 GeV
- Resolved sample (fails boosted sample first)
  - 4 narrow jets or 3 narrow jets with one m_j > 60 GeV, one b-taged
  - X^2 selects best assignment of jets to partons

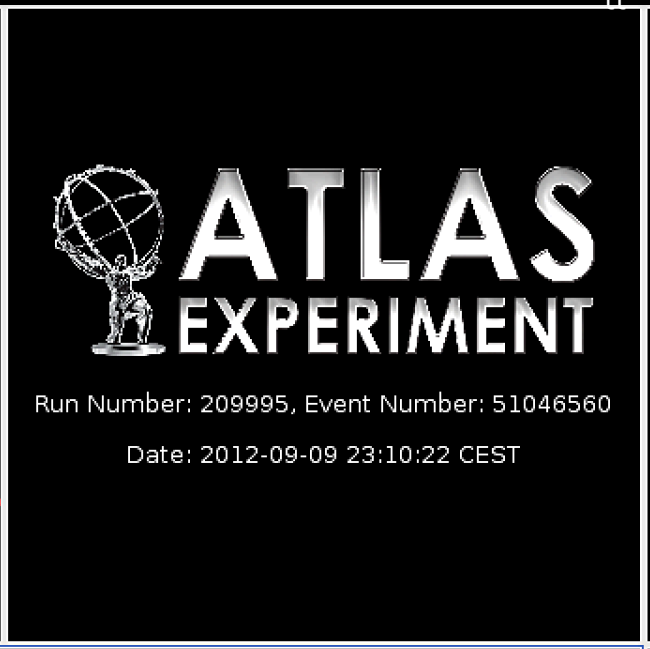
Limits:
m_{gKK} > 2.0 TeV
$m_{Z'}$ > 1.8 TeV

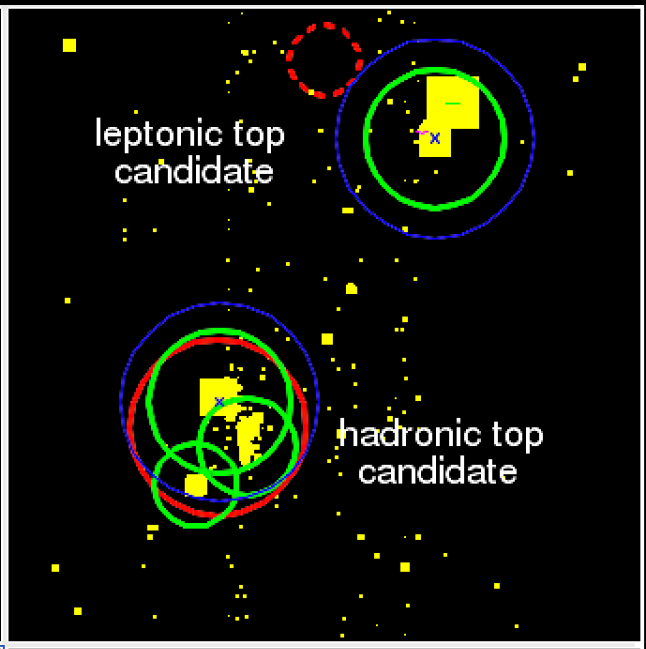


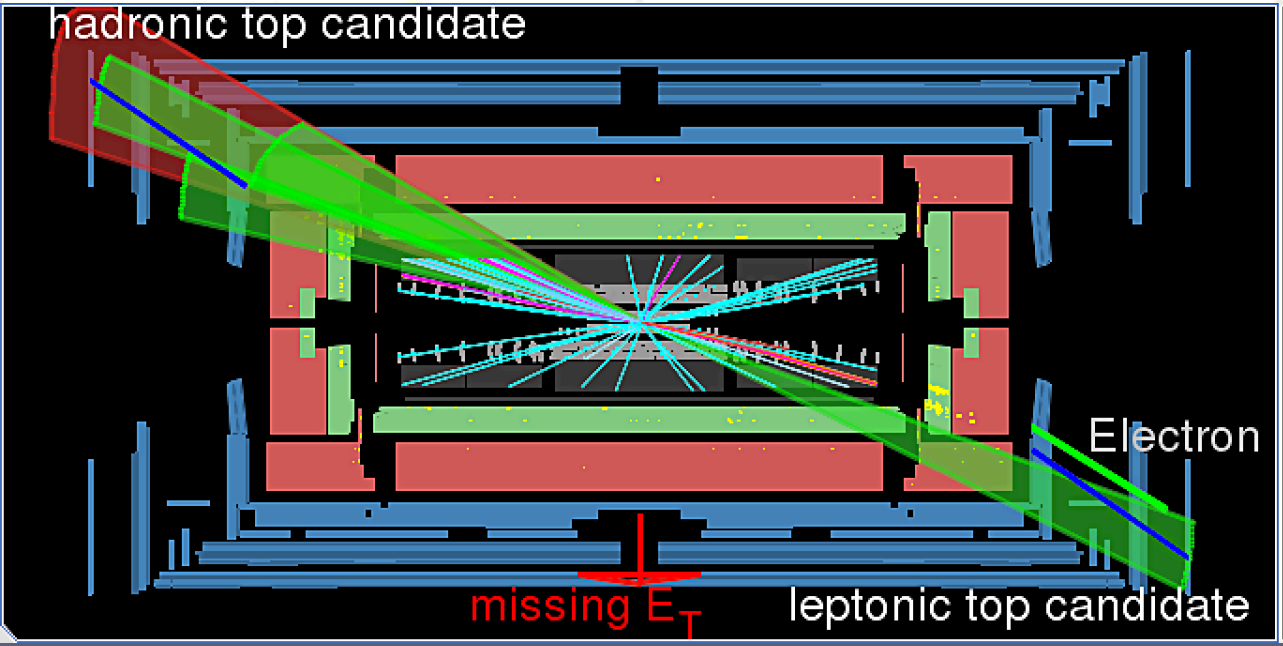


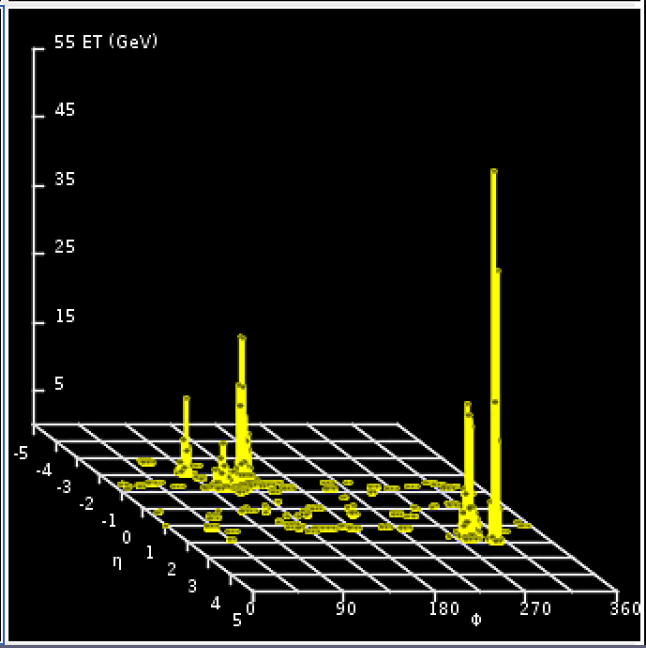
m_{tt}^{reco} = 2.6 TeV







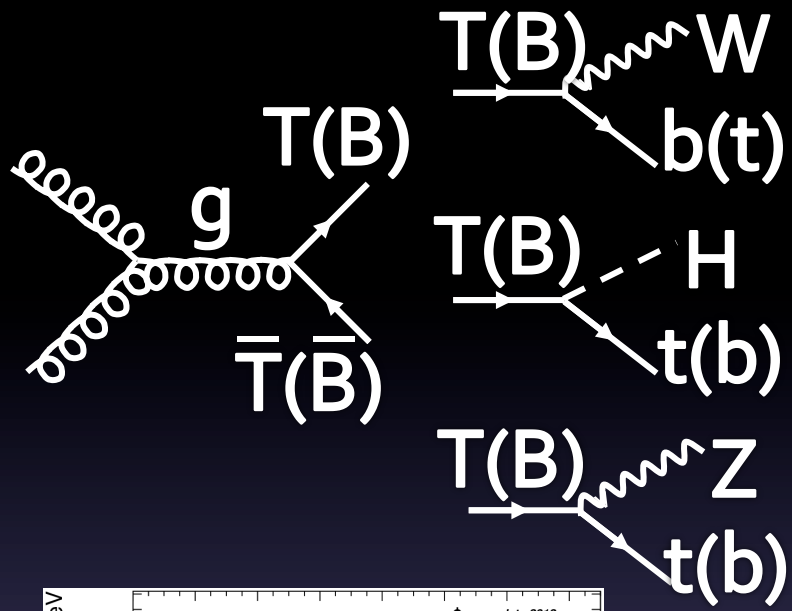


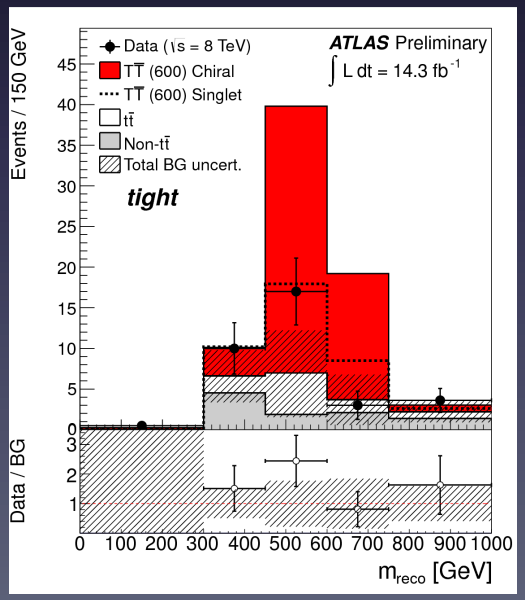


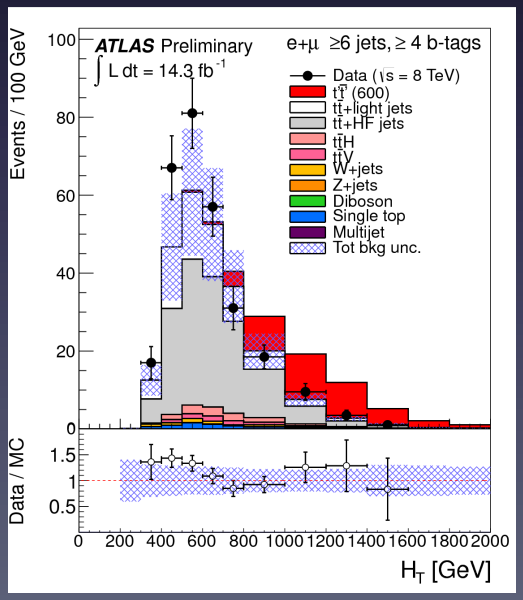
Heavy vector-like quark searches

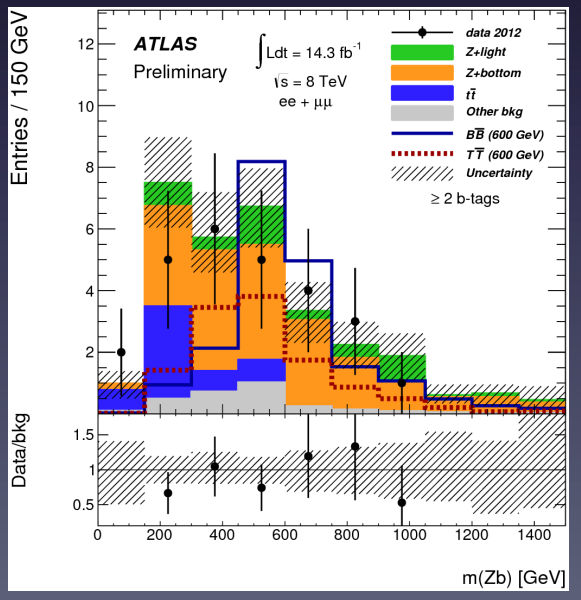
ATLAS-CONF-2013-060
ATLAS-CONF-2013-056
ATLAS-CONF-2013-018

- T->Wb search:
  - l+jets channel selection, 1 b-tag
  - Discrimination against tt:
    - H_T, l-ν collimated, W_{had}-b and l-b separation
- T->Ht search
  - l+jets + H->bb selection
  - High jet multiplicity 2,3,4 b-tag SRs
- T(B)->Zt(b) search
  - Selection of high p_T Z->e^+e^-, $\mu^+\mu^-$
  - 2 b-tagged jets
  - High H_T of central jets

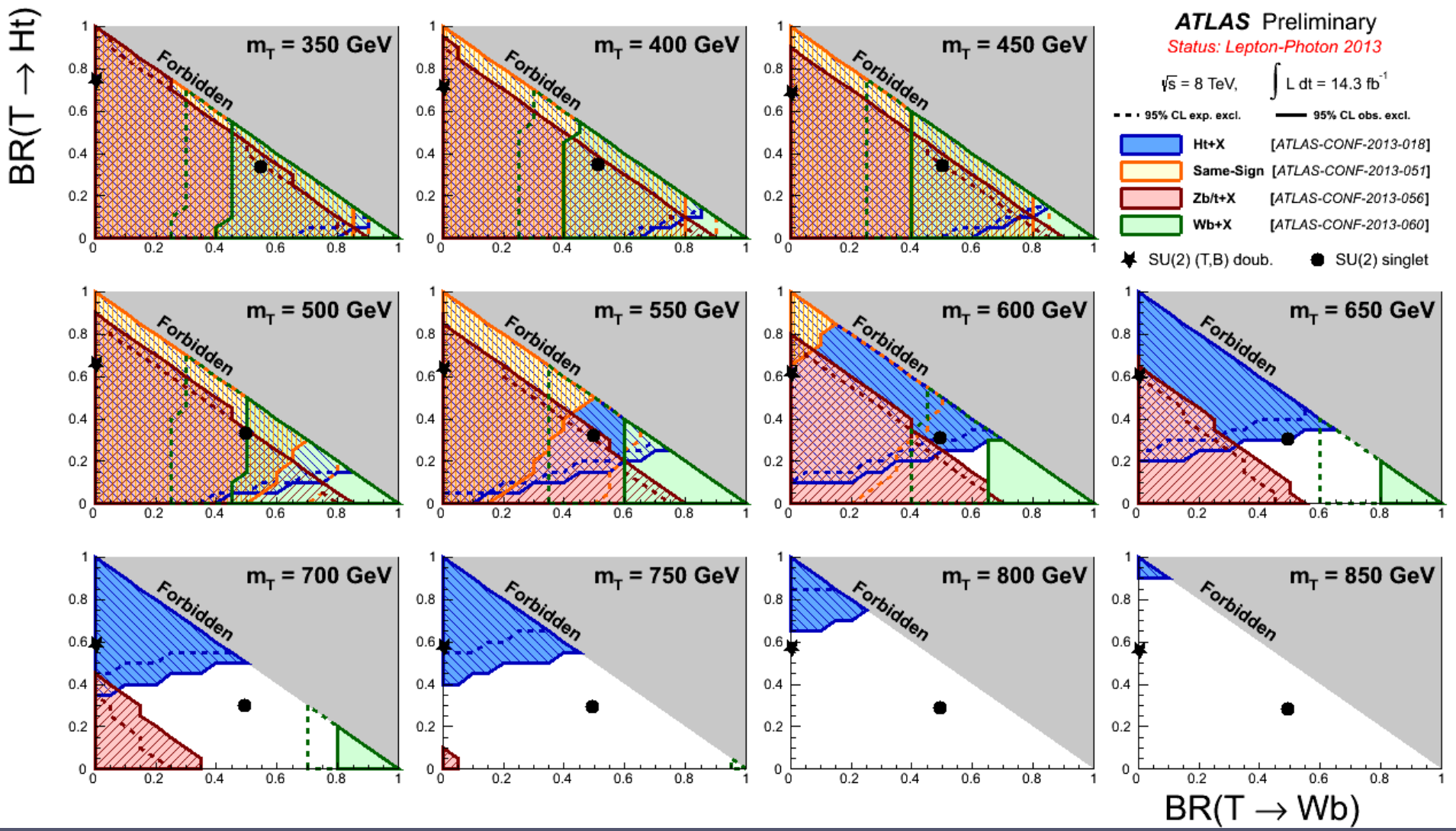






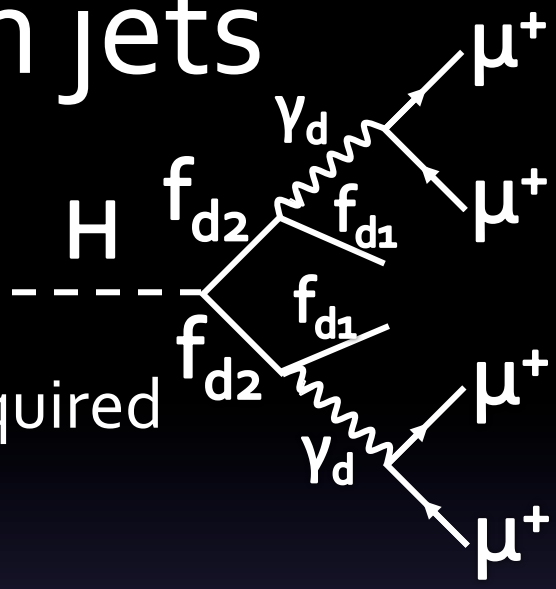


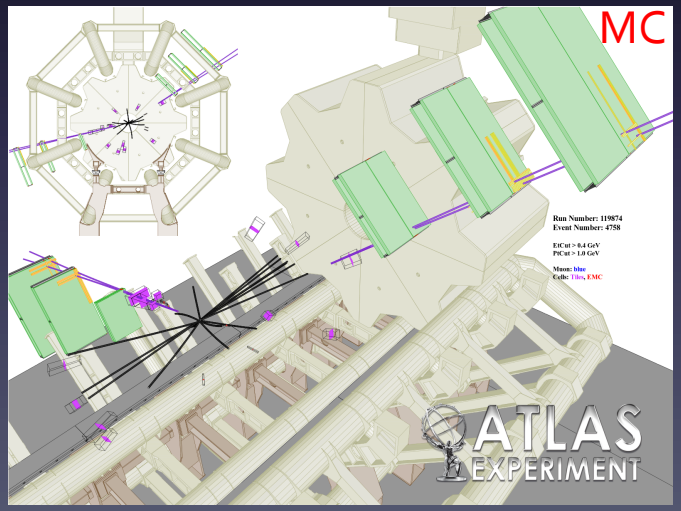
Heavy vector-like quark searches

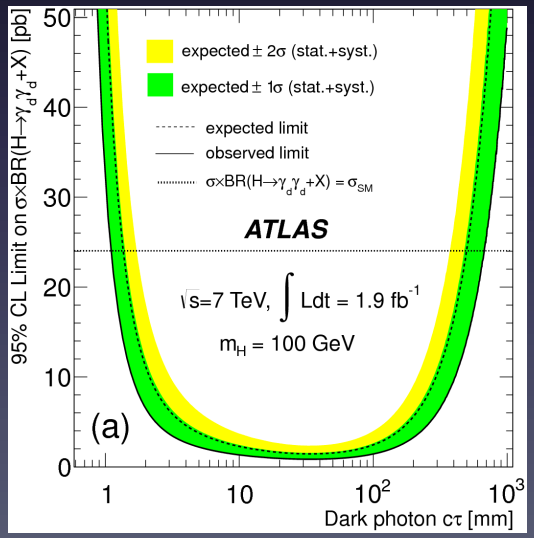


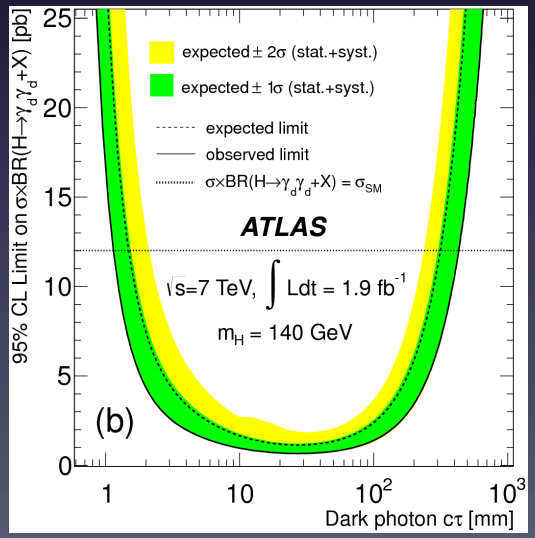
Search for muonic lepton jets

- 3 μ 'MS only' trigger
- Muon Jets : clustering of MS tracks
- Exclusively two 2 opposite sign μ-MJs required
  - Isolated, separated, with no ID activity





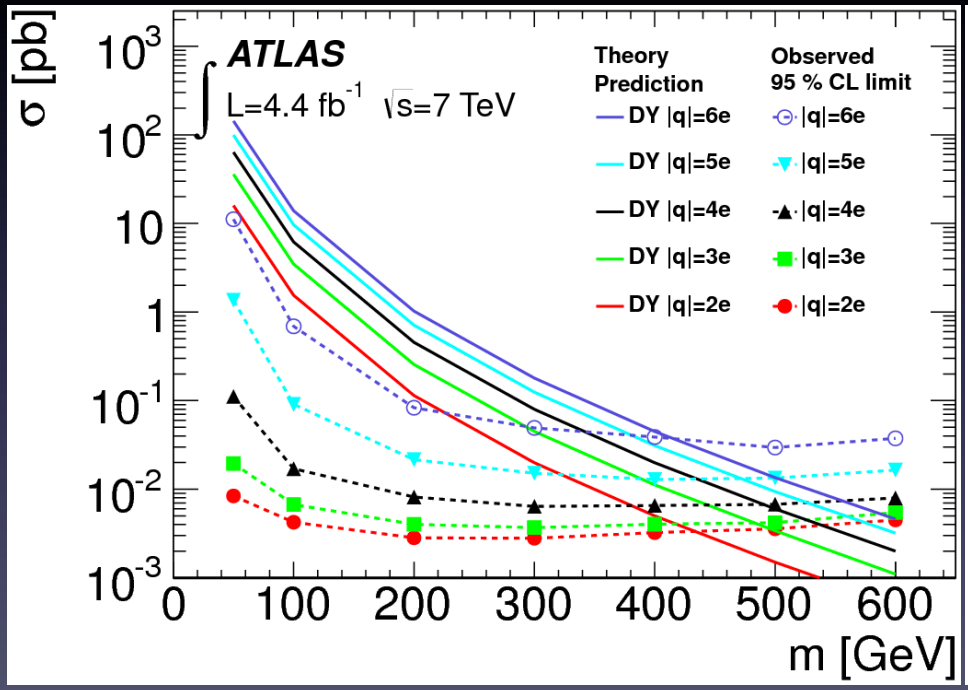


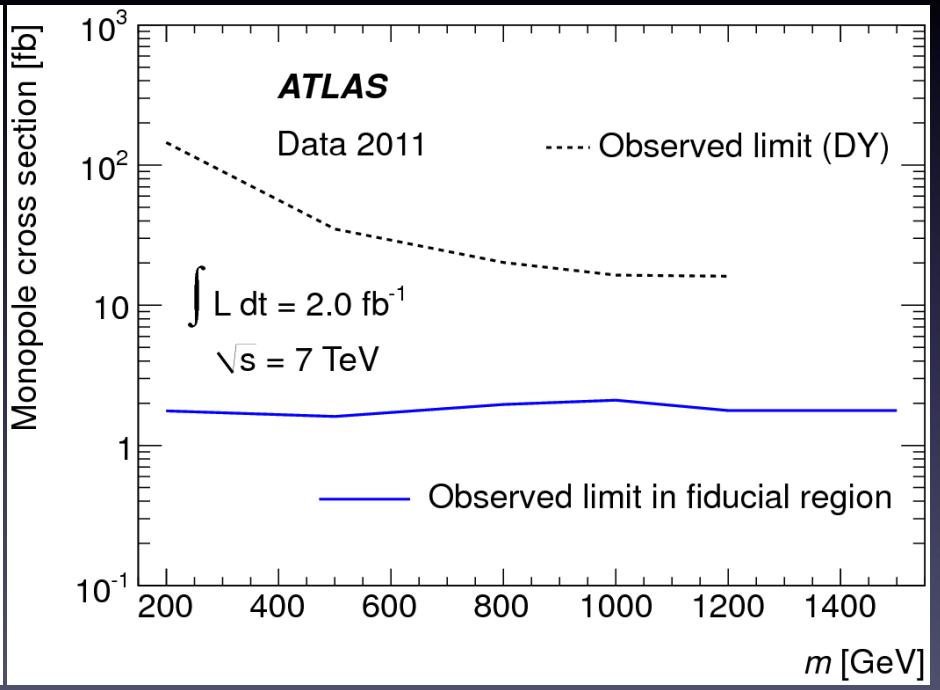


Monopoles, multi-charged particles

PLB 722, 305 (2013)
PRL 109 (2012) 261803

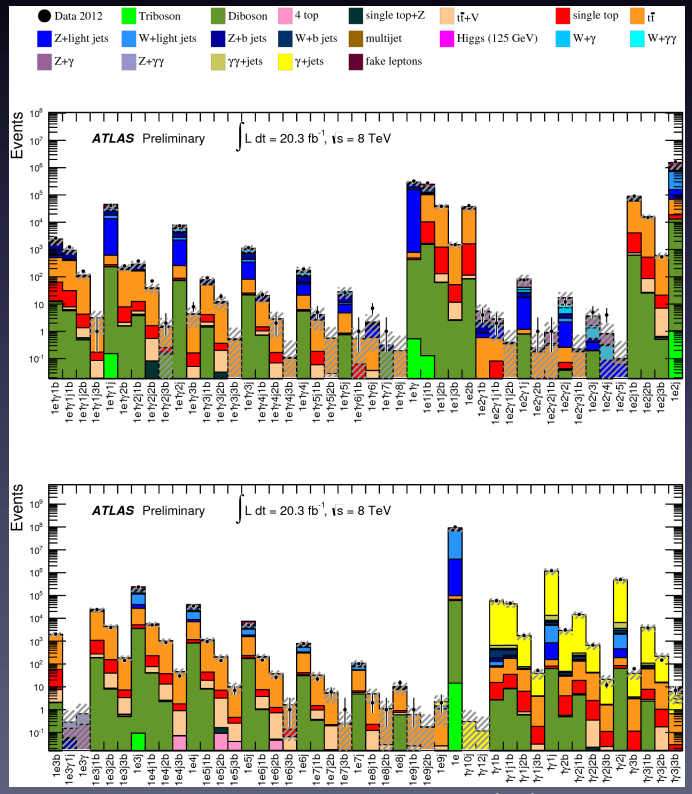
- Discriminate using the TRT dE/dX, high threshold hits

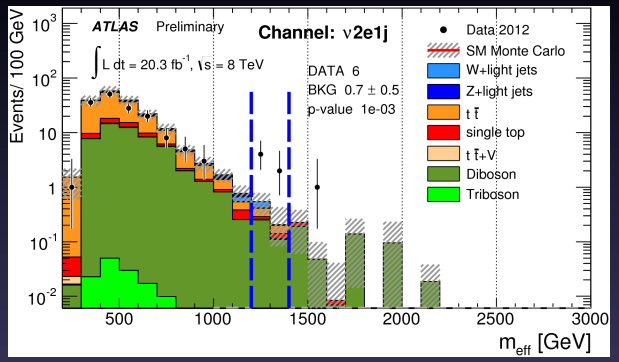


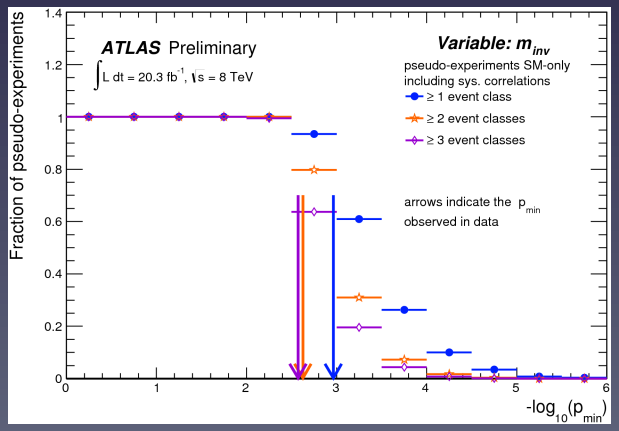


General search

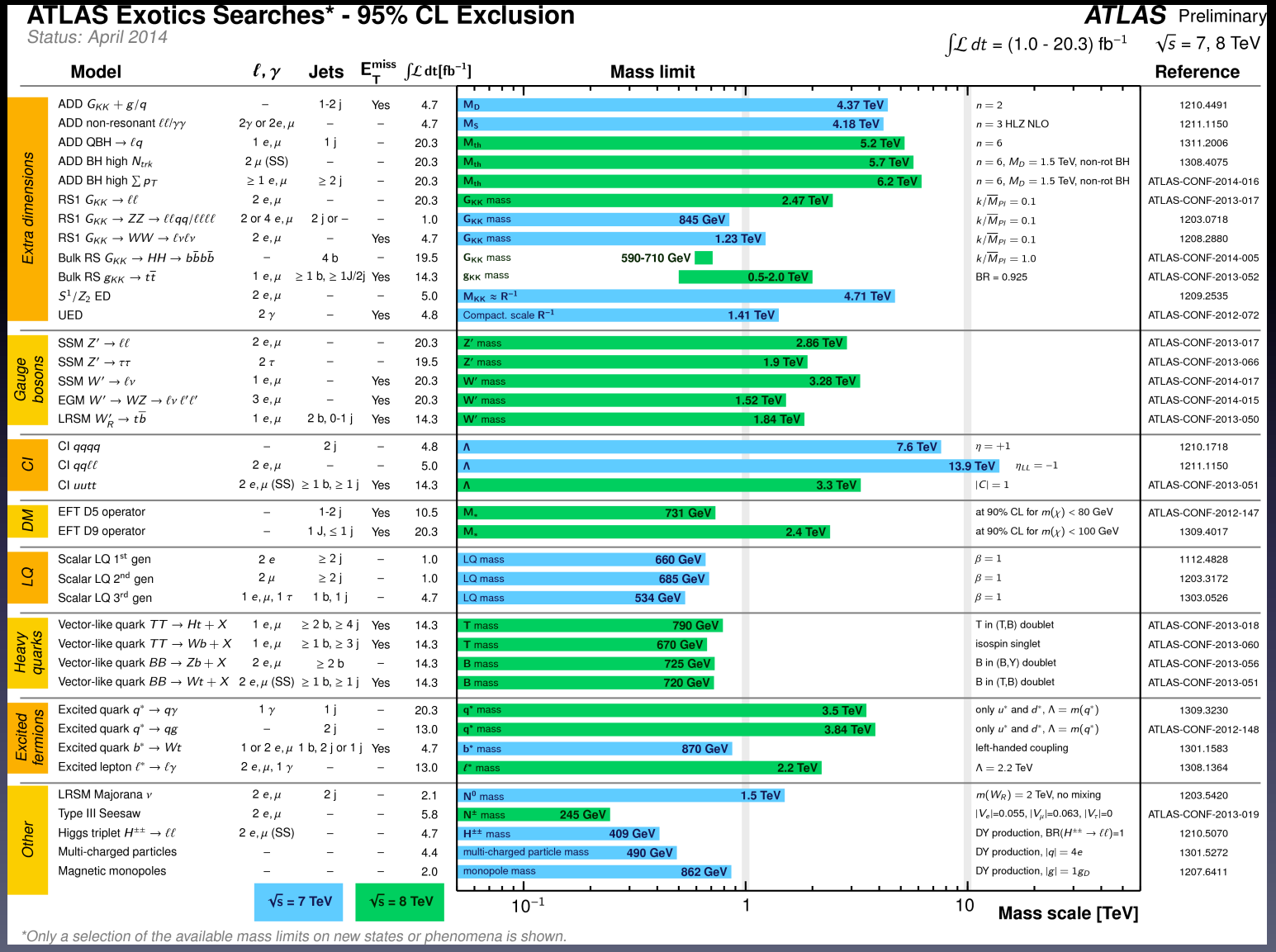
- Broad search
- Trigger and exclusive final state classification
- Regions of highest deviation from prediction identified in m_{inv} and m_{eff} spectra
- Trials factor accounted for using pseudo-experiments







No stone left unturned?

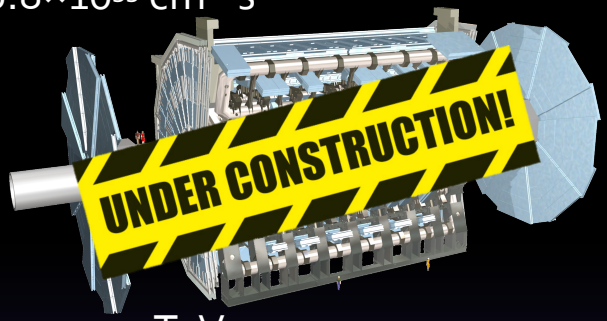


outlook

2011 ~25 fb^{-1}
2012
2013 LS1
2014
2015 ~75-100 fb^{-1}
2016
2017
2018 LS2
2019 ~350 fb^{-1}
2020
2021
2022 LS3
2023
…

$\sqrt{s}$ = 7,8 TeV

L=6.8×10^{33} cm^{-2} s^{-1}



- Muon
- Si (IBL)
- Trigger/DAQ

$\sqrt{s}$ = 13,14 TeV

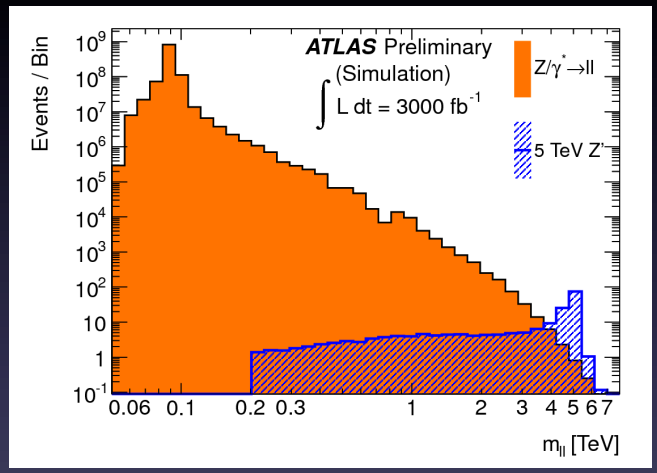
L=1×10^{34} cm^{-2} s^{-1}

$\sqrt{s}$ = 14 TeV

L=2×10^{34} cm^{-2} s^{-1}

$\sqrt{s}$ = 14 TeV

L=5×10^{34} cm^{-2} s^{-1}



Expected Limit prospects (TeV):

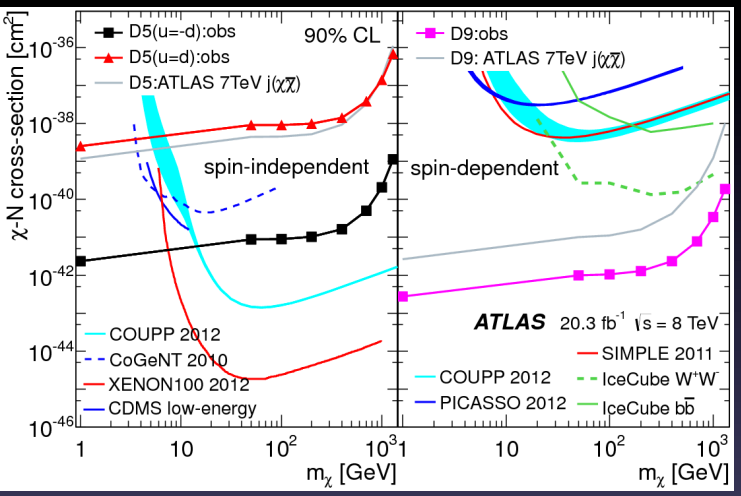
Model \ int Lumi	300 fb^{-1}	1000 fb^{-1}	3000 fb^{-1}
g_{KK} -> tt (l+jets)	4.3	5.6	6.7
Z'_{SSM}-> e^+e^-	6.5	7.2	7.8

ATL-PHYS-PUB-2013-007

Backup

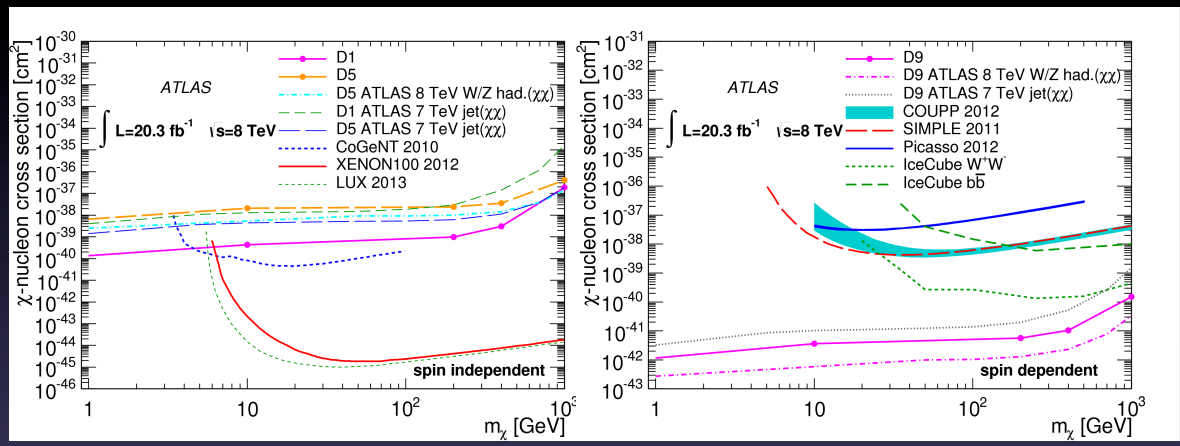
DM limits nucleon scattering interpretation

W/Z-> large jet + E_T^{miss}:



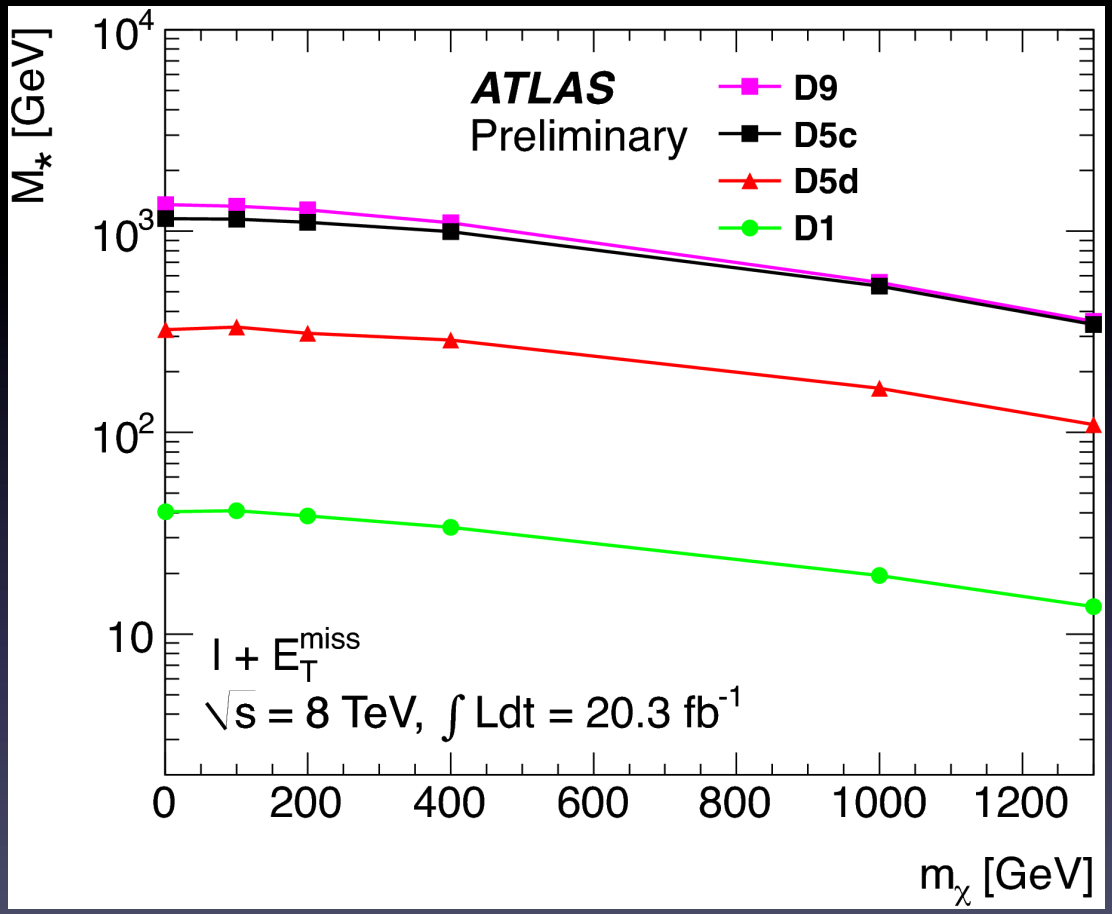
PRL 112, 041802 (2014)

Z-> ll + E_T^{miss}:



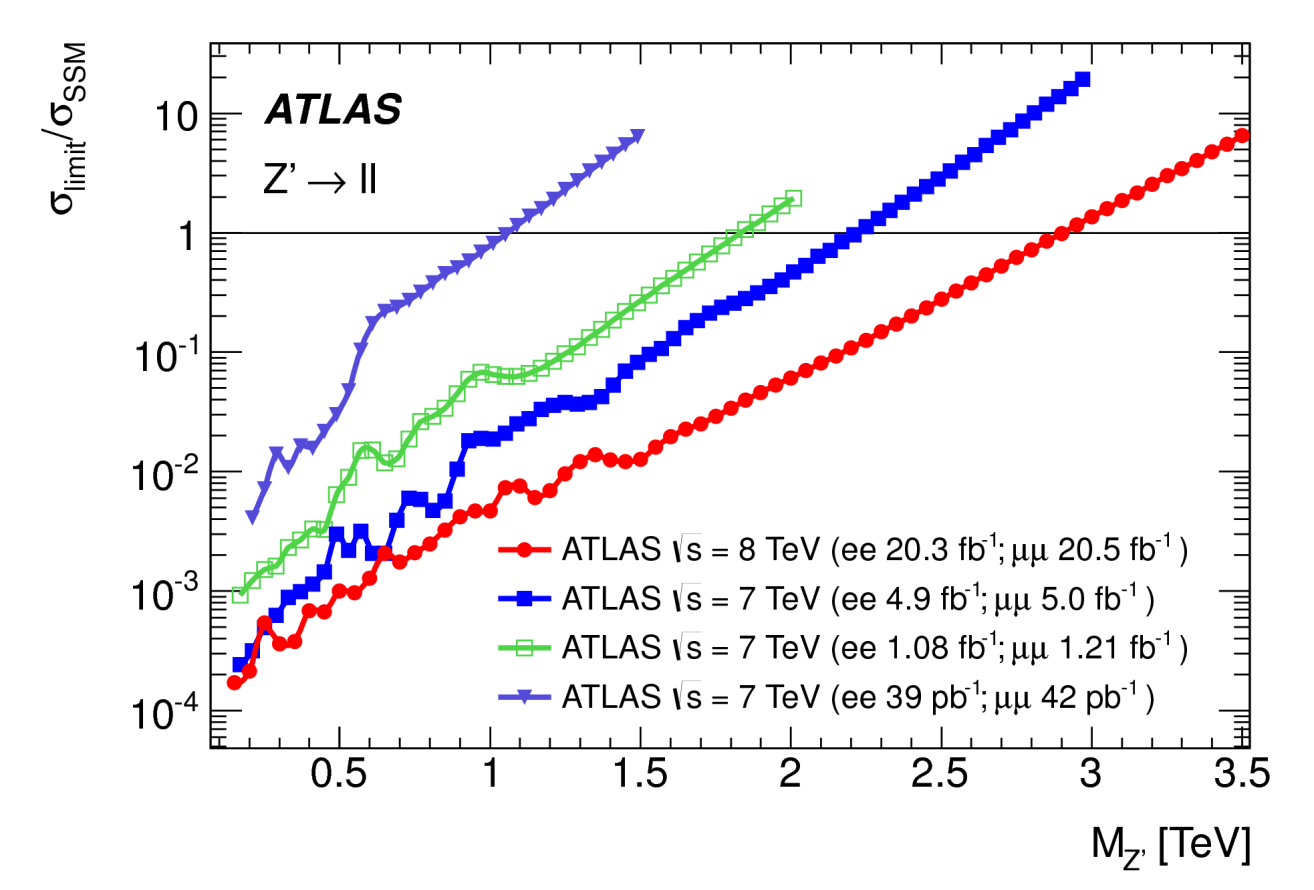
arXiv:1404.0051

DM limits from $l+E_T^{miss}$ search



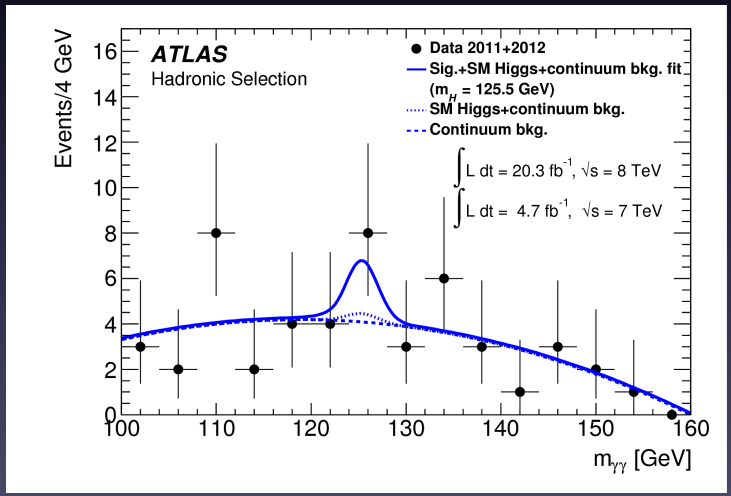
arXiv:1405.4123

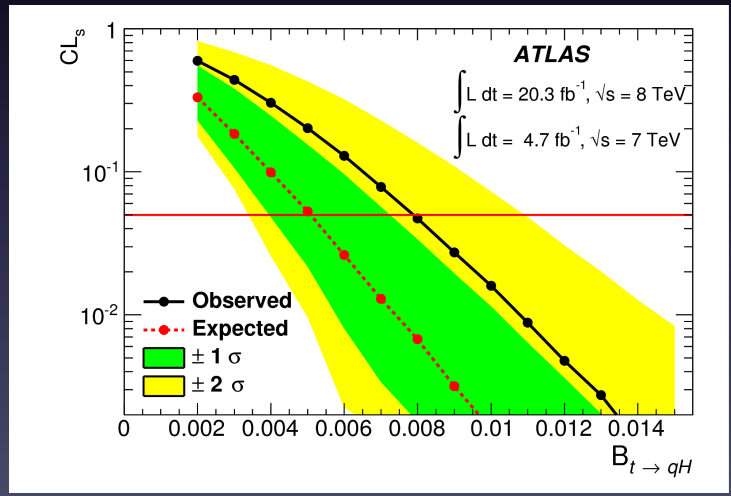
Z′ sensitivity



Searches in the Higgs Sector: FCNC: t->q H

- tt search with one t decaying to qH and H -> γγ
- Two isolated photons
- tt selection (hadronic in 7 TeV data, leptonic and hadronic in 8 TeV data)

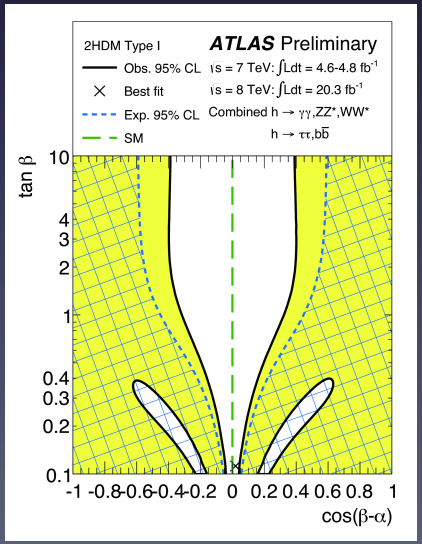




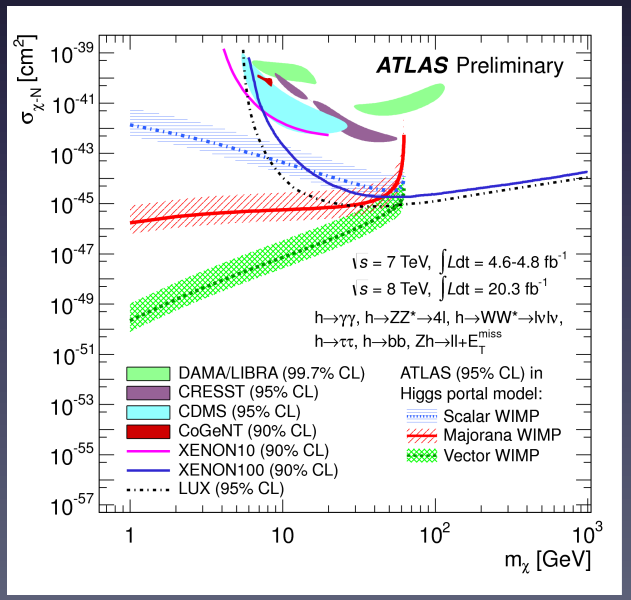
- Limits: B(t->qH)<0.79%, Yukawa coupling to c u < 0.17

New physics interpretations of Higgs properties

- Use measured properties:
  - Production and decay rates: h->γγ, h->ZZ->4, h->WW->lνlν, h->bb, h->ττ
  - Mass: h->ZZ->4l, h->γγ
- Constraints on:
  - Additional EW sinler
  - 2HDM
  - Simplified MSSM
  - Higgs portal



combines Zh->ll+E_T^{miss} data:



QBH and MWT limits in dilepton search

arXiv:1405.4123