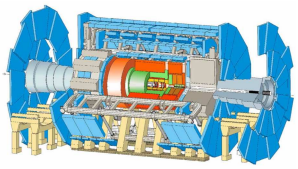


Searches for

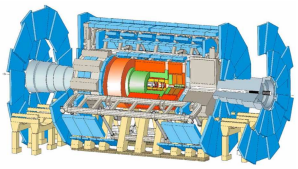
Exotica

with the ATLAS detector

Dr Tracey Berry

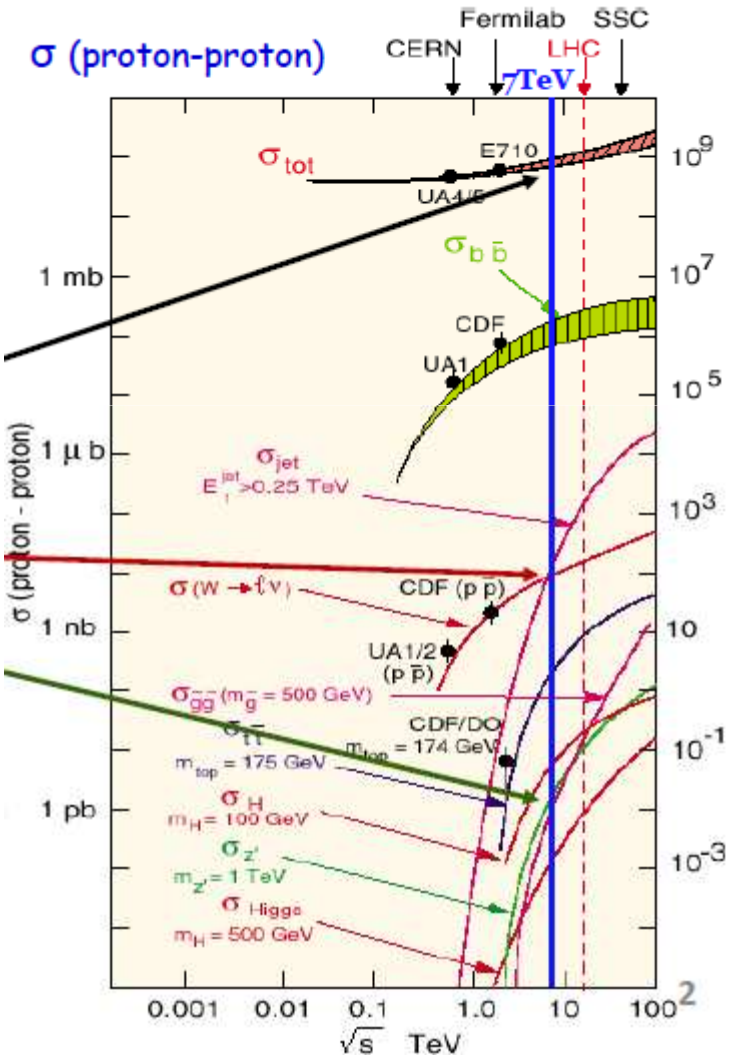
Royal Holloway

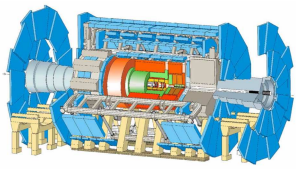
University of London



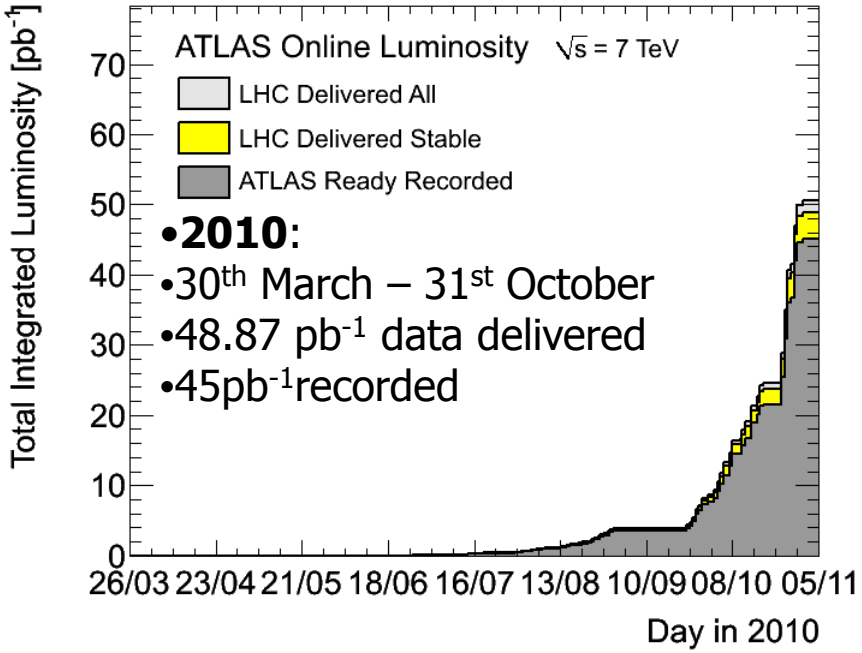
Introduction

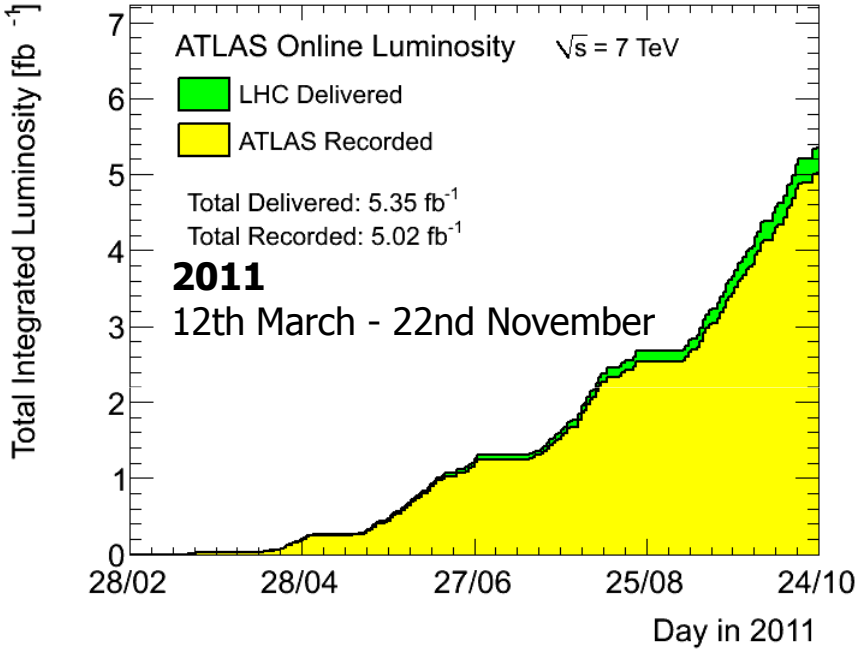
- Standard Model describes data very well, but is only a low energy effective theory
- New Physics is needed at the weak scale ~ 1 TeV
- Physics Processes at LHC:
  - Total cross-section
  - SM Processes: W→eν
  - New Physics: hard lepton/photon (Z'→ee, etc)
- Need large luminosity and efficient background rejection to see interesting signal events: & effective lepton/photon & jet identification





LHC data

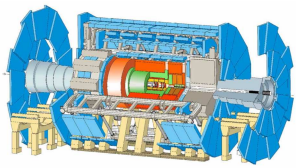




Of 48.87 pb^{-1} delivered:
40% in the last week
over 60% in the last month

equivalent of 2010 dataset:
collected in one day in 2011 running

A Toroidal LHC AppartuS (ATLAS) DETECTOR



EM Calorimeters, $\sigma/E \approx 10\%/\sqrt{E(GeV)} \oplus 0.7\%$

excellent electron/photon identification

Good *E* resolution (e.g., G→γγ)

Full coverage for |η|<2.5

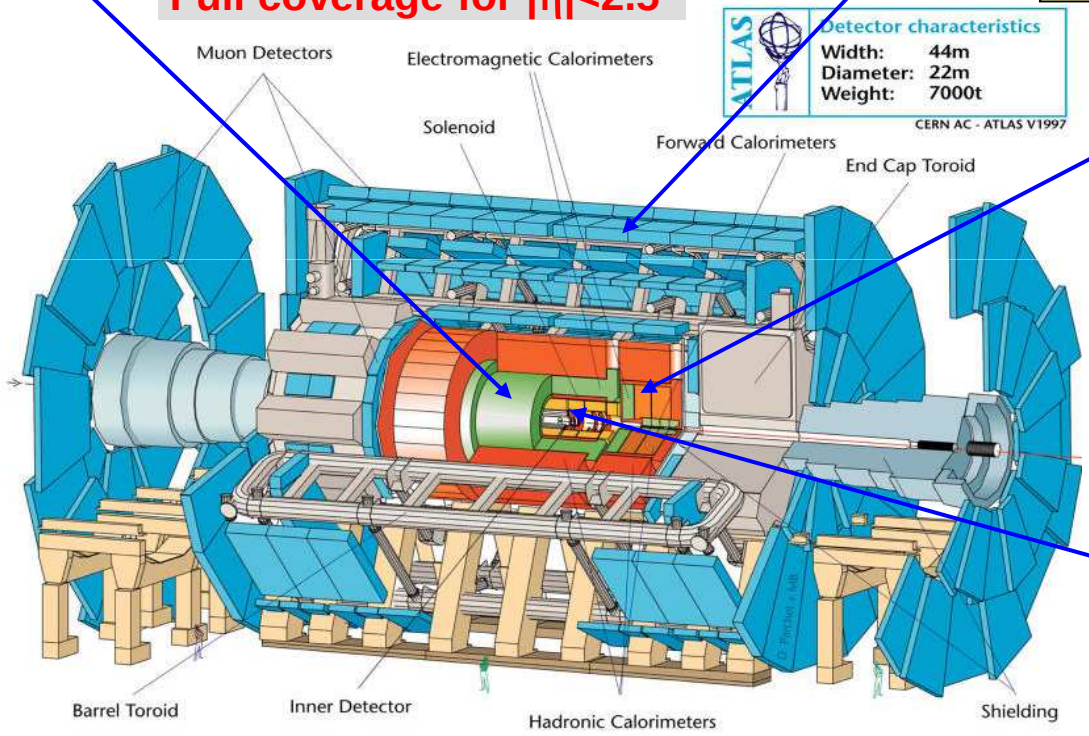
Precision Muon Spectrometer,

$\sigma/p_T \approx 10\%$ at 1 TeV/c

Fast response for trigger

Good *p* resolution

(e.g., Z' → μμ)



Hadron Calorimeters,

$\sigma/E \approx 50\% / \sqrt{E(GeV)} \oplus 3\%$

Good jet and E_T miss performance

Inner Detector:

Si Pixel and strips (SCT) &

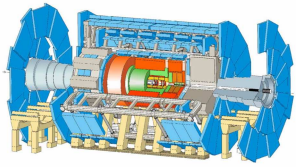
Transition radiation tracker (TRT)

$\sigma/p_T \approx 5 \times 10^{-4}\ p_T \oplus 0.001$

Good impact parameter res.

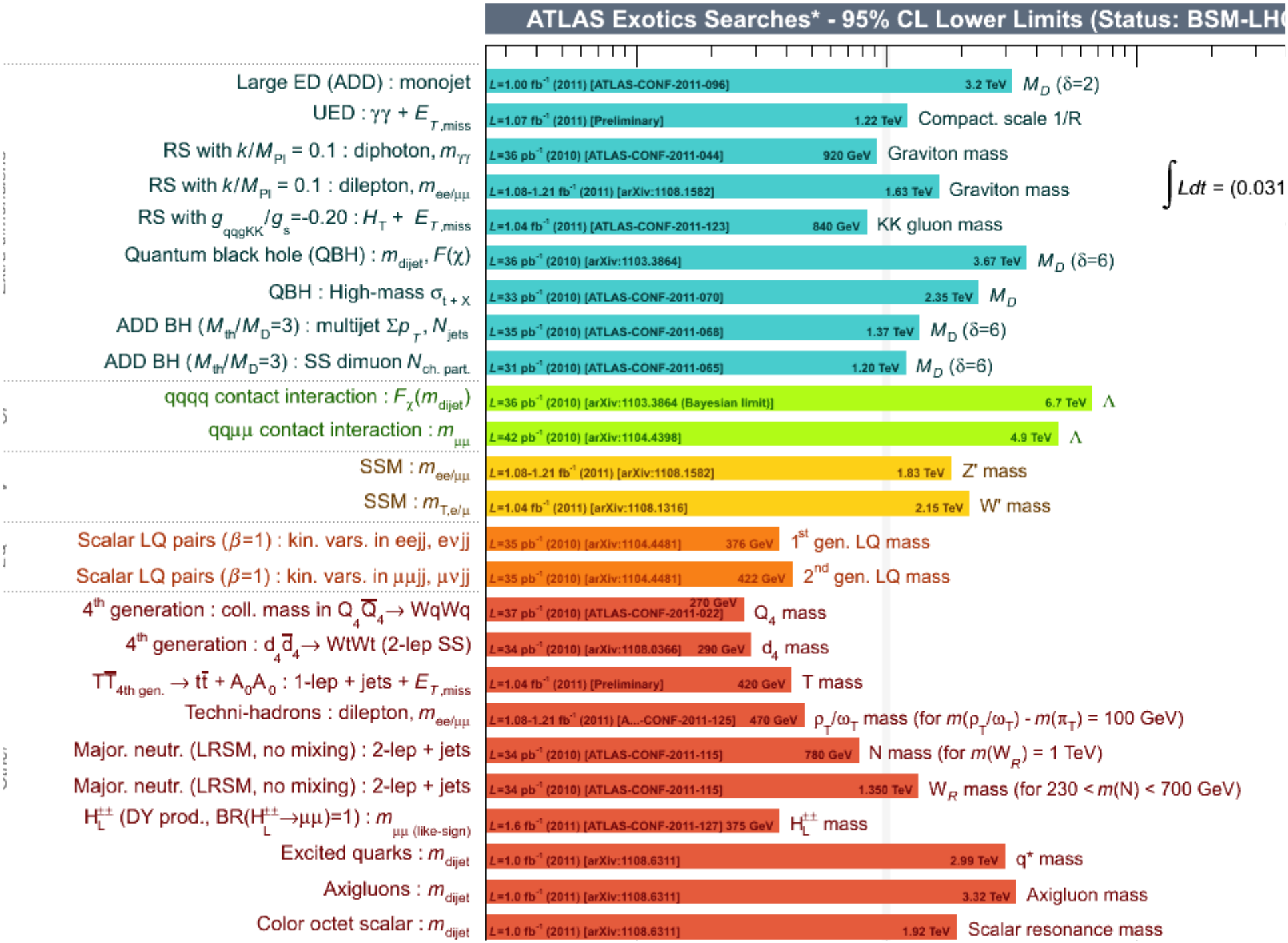
$\sigma(d_0)$=15μm@20GeV

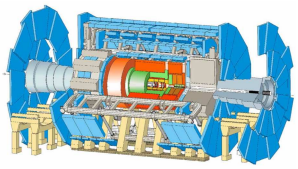
Magnets: solenoid (Inner Detector) 2T, air-core toroids (Muon Spectrometer) ~0.5T



ATLAS Publications

- 2011 : 13 conference notes + 4 submitted papers
- 2010: 12 conference notes + 12 papers

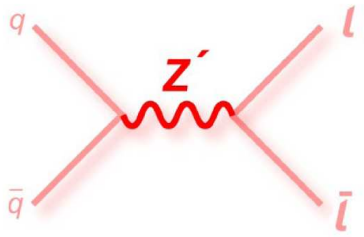

ATLAS Exotics Searches* - 95% CL Lower Limits (Status: BSM-LH
Large ED (ADD) : monojet
UED : γγ + E T,miss
RS with k/M Pl = 0.1 : diphoton, m γγ
RS with k/M Pl = 0.1 : dilepton, m ee/μμ
RS with g qqgKK /g s =-0.20 : H T + E T,miss
Quantum black hole (QBH) : m dijet , F(χ)
QBH : High-mass σ t + X
ADD BH (M th /M D =3) : multijet Σp T , N jets
ADD BH (M th /M D =3) : SS dimuon N ch. part.
qqqq contact interaction : F χ (m dijet)
qqμμ contact interaction : m μμ
SSM : m ee/μμ
SSM : m T,e/μ
Scalar LQ pairs (β=1) : kin. vars. in eejj, evjj
Scalar LQ pairs (β=1) : kin. vars. in μμjj, μvjj
4th generation : coll. mass in Q 4 Q̄ 4 → WqWq
4th generation : d 4 d̄ 4 → WtWt (2-lep SS)
TT̄ 4th gen. → tt̄ + A 0 A 0 : 1-lep + jets + E T,miss
Techni-hadrons : dilepton, m ee/μμ
Major. neutr. (LRSM, no mixing) : 2-lep + jets
Major. neutr. (LRSM, no mixing) : 2-lep + jets
H L±± (DY prod., BR(H L±± →μμ)=1) : m μμ (like-sign)
Excited quarks : m dijet
Axigluons : m dijet
Color octet scalar : m dijet
∫Ldt = (0.031
L=1.00 fb-1 (2011) [ATLAS-CONF-2011-096] 3.2 TeV M D (δ=2)
L=1.07 fb-1 (2011) [Preliminary] 1.22 TeV Compact. scale 1/R
L=36 pb-1 (2010) [ATLAS-CONF-2011-044] 920 GeV Graviton mass
L=1.08-1.21 fb-1 (2011) [arXiv:1108.1582] 1.63 TeV Graviton mass
L=1.04 fb-1 (2011) [ATLAS-CONF-2011-123] 840 GeV KK gluon mass
L=36 pb-1 (2010) [arXiv:1103.3864] 3.67 TeV M D (δ=6)
L=33 pb-1 (2010) [ATLAS-CONF-2011-070] 2.35 TeV M D
L=35 pb-1 (2010) [ATLAS-CONF-2011-068] 1.37 TeV M D (δ=6)
L=31 pb-1 (2010) [ATLAS-CONF-2011-065] 1.20 TeV M D (δ=6)
L=36 pb-1 (2010) [arXiv:1103.3864 (Bayesian limit)] 6.7 TeV Λ
L=42 pb-1 (2010) [arXiv:1104.4398] 4.9 TeV Λ
L=1.08-1.21 fb-1 (2011) [arXiv:1108.1582] 1.83 TeV Z' mass
L=1.04 fb-1 (2011) [arXiv:1108.1316] 2.15 TeV W' mass
L=35 pb-1 (2010) [arXiv:1104.4481] 376 GeV 1st gen. LQ mass
L=35 pb-1 (2010) [arXiv:1104.4481] 422 GeV 2nd gen. LQ mass
L=37 pb-1 (2010) [ATLAS-CONF-2011-022] 270 GeV Q 4 mass
L=34 pb-1 (2010) [arXiv:1108.0366] 290 GeV d 4 mass
L=1.04 fb-1 (2011) [Preliminary] 420 GeV T mass
L=1.08-1.21 fb-1 (2011) [A...-CONF-2011-125] 470 GeV ρ T /ω T mass (for m(ρ T /ω T) - m(π T) = 100 GeV)
L=34 pb-1 (2010) [ATLAS-CONF-2011-115] 780 GeV N mass (for m(W R) = 1 TeV)
L=34 pb-1 (2010) [ATLAS-CONF-2011-115] 1.350 TeV W R mass (for 230 < m(N) < 700 GeV)
L=1.6 fb-1 (2011) [ATLAS-CONF-2011-127] 375 GeV H L±± mass
L=1.0 fb-1 (2011) [arXiv:1108.6311] 2.99 TeV q* mass
L=1.0 fb-1 (2011) [arXiv:1108.6311] 3.32 TeV Axigluon mass
L=1.0 fb-1 (2011) [arXiv:1108.6311] 1.92 TeV Scalar resonance mass

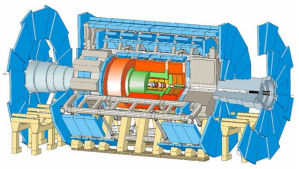


New Heavy Gauge Bosons

W': leptons+ E_T^{Miss}

Z' : μμ + ee



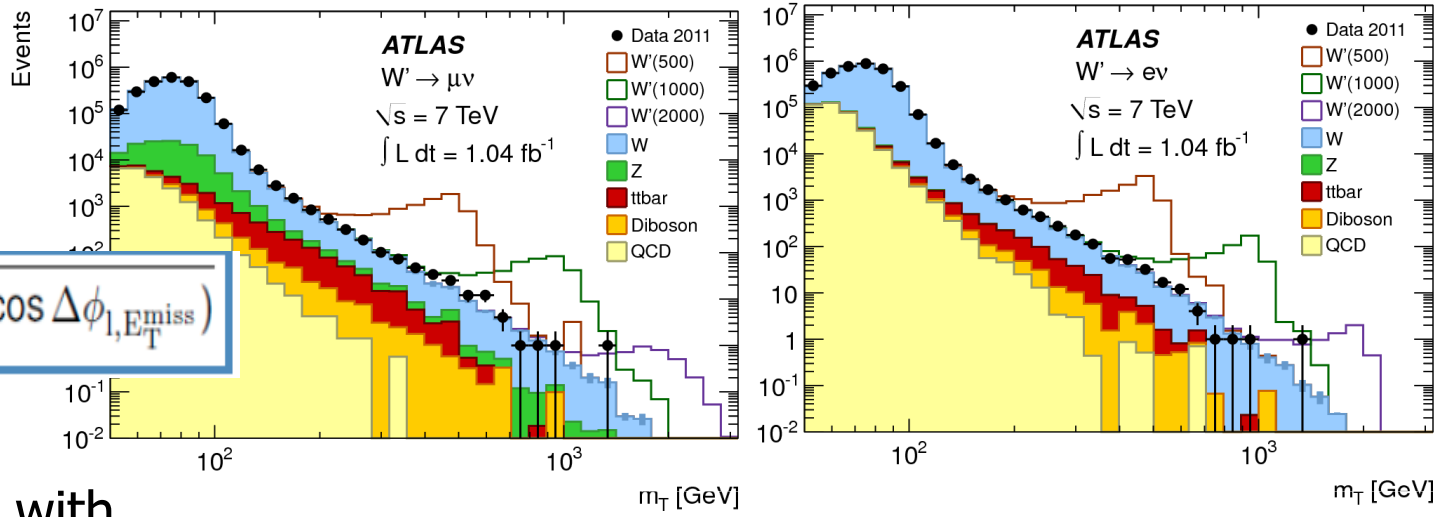


W': Lepton $+E_T^{Miss}$

Signal: W'→lν

Observable :

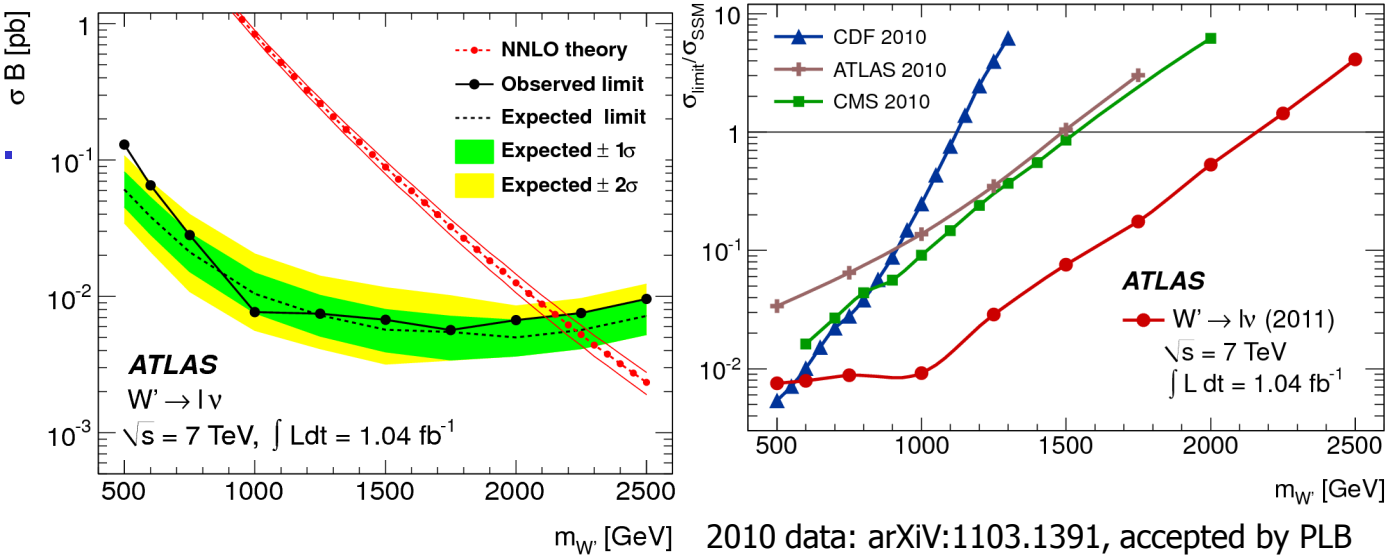
$$M_T = \sqrt{2p_T^l E_T^{miss}(1 - \cos\Delta\phi_{l,E_T^{miss}})}$$



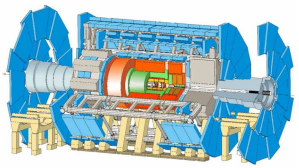
Data consistent with SM prediction

Limit @ 95 % C.L.
Mass of SSM:
W' > 2.15 TeV

(2.08 TeV e & 1.98 TeV μ)

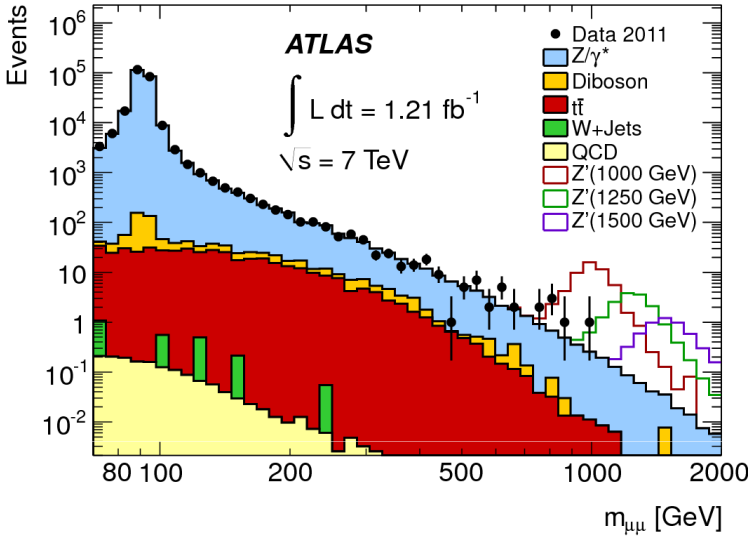


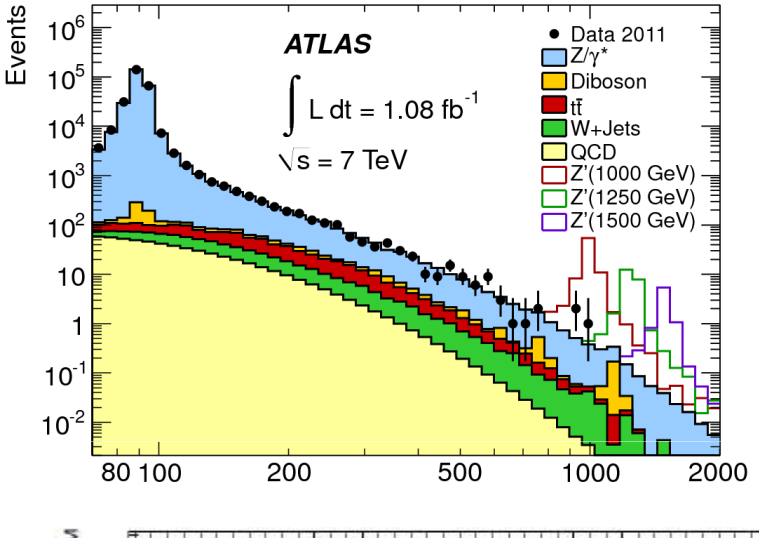
2010 data: arXiV:1103.1391, accepted by PLB
2011 data 200 pb-1 update: ATL-CONF-2011-082.
arXiv:1108.1316 , accepted by PLB



Z′: Dilepton Channel

Signal Z′→ll



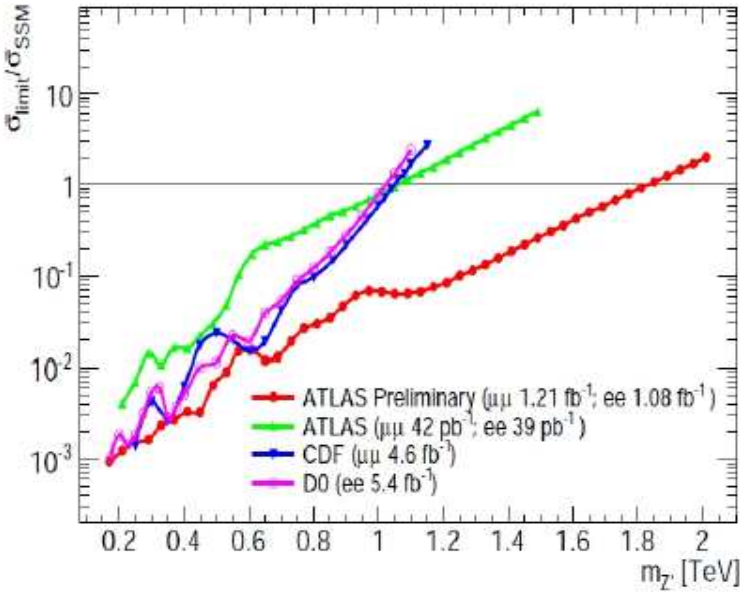


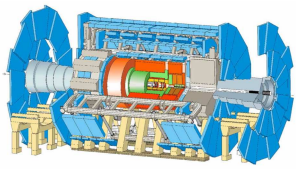
Data consistent with SM prediction

Observed (Expected) 95 % C.L. mass lower limit in TeV on Z'_{SSM} resonance

Model	e^+e^-	$\mu^+\mu^-$	$\ell^+\ell^-$
Z'_{SSM}	1.70 (1.70)	1.61 (1.61)	1.83 (1.83)

	E_6 Z' Models					
Model/Coupling	Z'_ψ	Z'_N	Z'_η	Z'_I	Z'_S	Z'_χ
Mass limit [TeV]	1.49	1.52	1.54	1.56	1.60	1.64

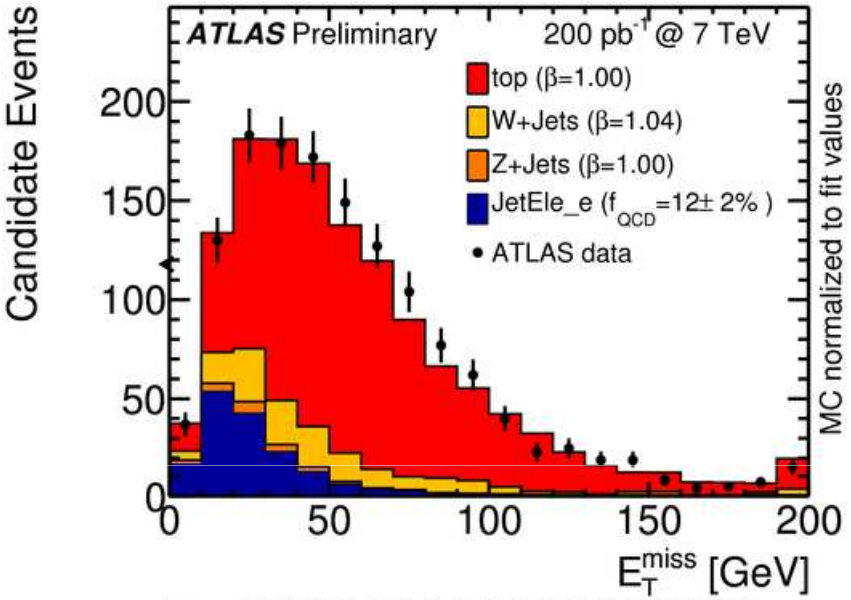


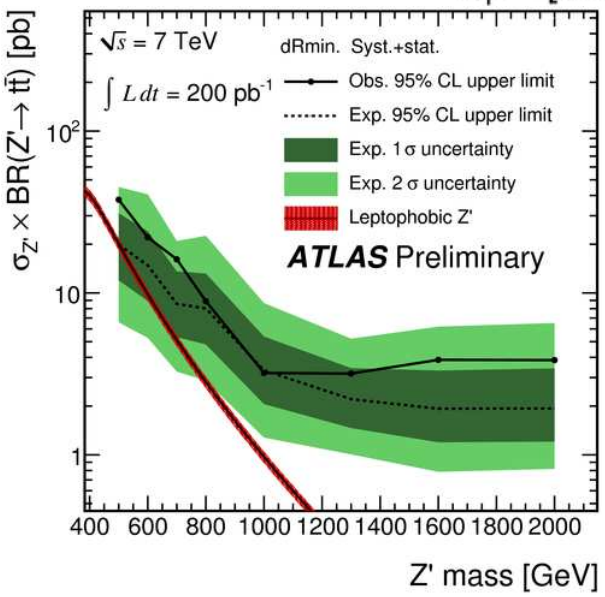


Z': tt-bar

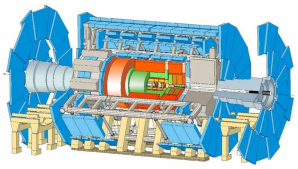
- Search for top quark pair ($t\bar{t}$) resonances : lepton (e /μ) + jets
- No evidence for a resonance is found.
- Limits set using the reconstructed $t\bar{t}$ mass spectrum: on production cross-section X BR(to $t\bar{t}$ for narrow and wide resonances)

- For narrow Z' models, the observed 95% C.L. limits range from approximately 38 pb to 3.2 pb for masses $M_{Z'}$ = 500 GeV to 1300 GeV





ATLAS-CONF-2011-087

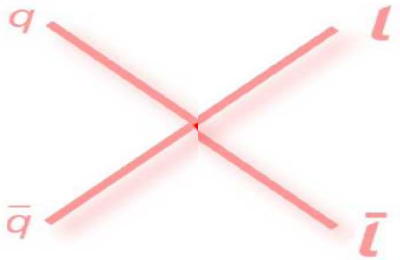


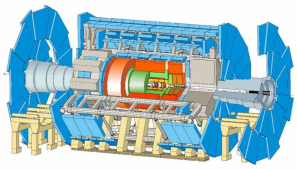
Contact Interactions

$\mu\mu$ NEW!

1 fb-1 ee+ μμ

Updates to come soon!





Contact Interactions: μμ

- Four-fermion contact interactions (CI) at low energy limit describe phenomena as:
  - Large Extra Dimension ADD model
  - Quark-lepton compositeness
- Benchmark composite model is left-left isoscalar model

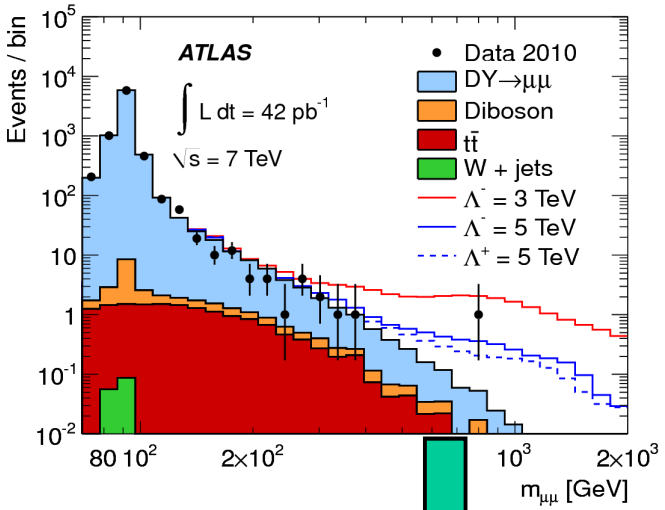
$$\frac{d\sigma}{dm_{\mu\mu}} = \frac{d\sigma_{DY}}{dm_{\mu\mu}} - \eta_{LL}\frac{F_I(m_{\mu\mu})}{\Lambda^2} + \frac{F_C(m_{\mu\mu})}{\Lambda^4}$$

  - $F_{I(C)}$ is interference (CI) term, $\eta_{LL}=\pm 1$
  - Λ is the energy scale (below which fermion constituences are bound)

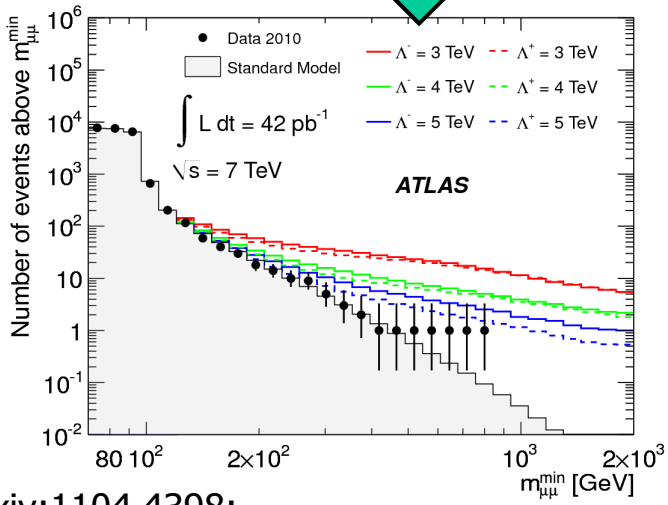
No excess, limits at 95 % CL:

$\Lambda^- > 4.9$ TeV for constructive interference

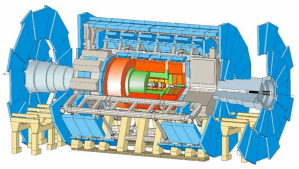
$\Lambda^+ > 4.5$ TeV for destructive interference



Taking the integral



arxiv:1104.4398;
Phys.Rev.D84, 011101(R) (2011)



Searches for Extra Dimensions

Diphotons+E_T^{Miss} (UED)

Dileptons (RS)

Diphotons (RS)

g_{qqgKK}/g_s: H_T+E_T^{miss} (RS)

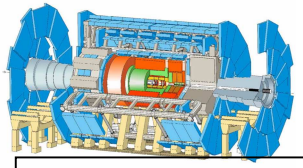
Same-sign dimuons (ADD) NEW!

Monojet: (ADD)

High mass σ_{t+X}(QBH: Quantum Black Holes)

Multijet Σp_T, N_{jets}(ADD BH)

SS dimuon $N_{ch\ part}$ (ADD BH)



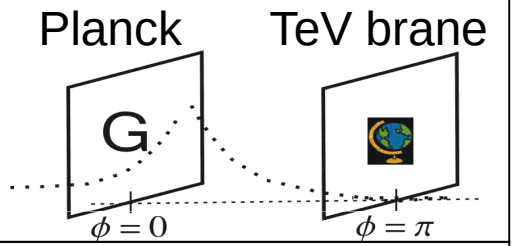
Extra Dimensional Models

ADD **A**rkani-Hamed, **D**imopoulos, **D**vali,
Phys Lett B429 (98)

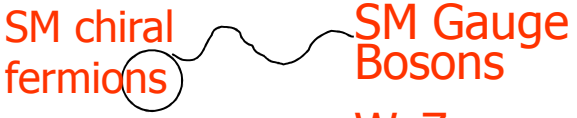
(Many) Large flat Extra-Dimensions (LED) could be as large as a few μm
In which G can propagate, SM particles restricted to 3D brane

RS **R**andall, **S**undrum,
Phys Rev Lett 83 (99)b

Small highly curved extra spatial dimension
(RS1 – two branes) Gravity localised in the ED



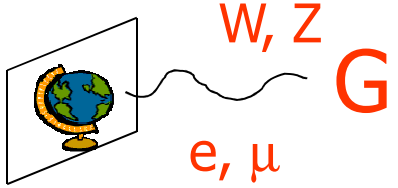
TeV^{-1} sized EDs Dienes, Dudas, Gherghetta,
Nucl Phys B537 (99)

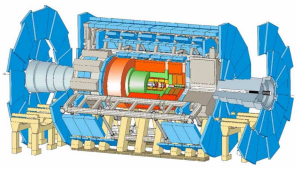


Bosons could also propagate in the bulk
Fermions are localized at the same (opposite) orbifold point: destructive (constructive) interference between SM gauge bosons and KK excitations

UED

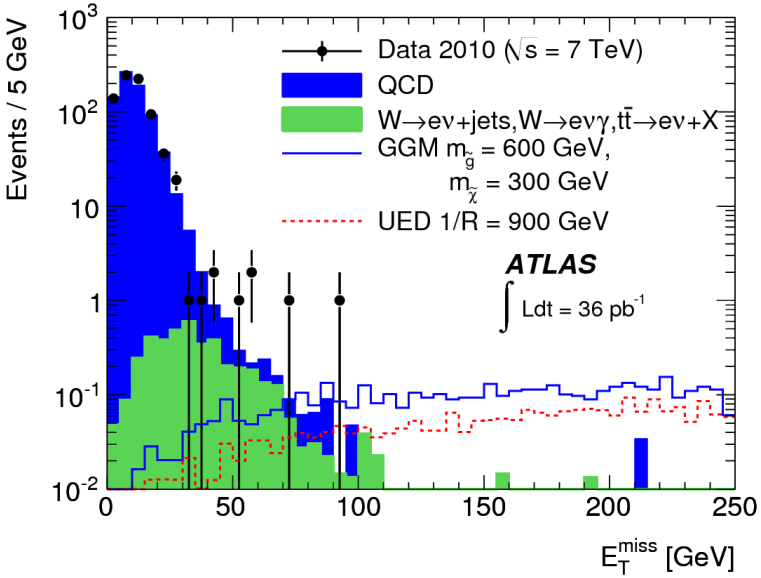
All SM particles propagate in "Universal" ED
often embedded in large ED





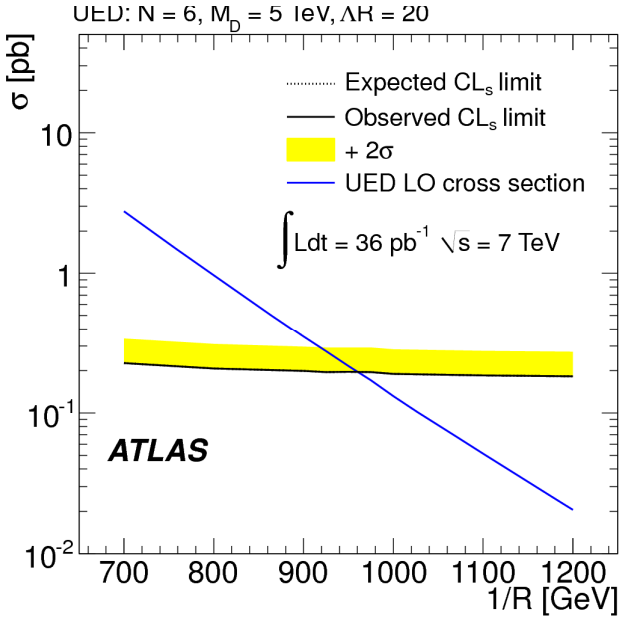
Universal Extra Dimensions
Diphoton + E_T^{Miss}

- Effective theory of one TeV^{-1} size UED valid at >1/R (R = ED size)
  - –SM particles in bulk→KK excitations
  - –Mass degeneracy of KK excitations broken by radiative corrections
  - -Lowest KK particle γ^* decays to γ +G

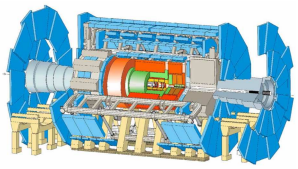


- Expect excess of UED events at high E_T^{Miss}:
  - –No events observed in E_T^{Miss}>125GeV
  - –Background events expected
    0.10±0.04(stat) ±0.05(syst)

- UL @ 95% CL on σ<0.18-0.23pb for 1/R=700-1200 GeV in UED model
- Exclude @95% C.L. 1/R<961 GeV



arXiv:1107.05661, submitted to EPJC



Large ED ADD Model: BH

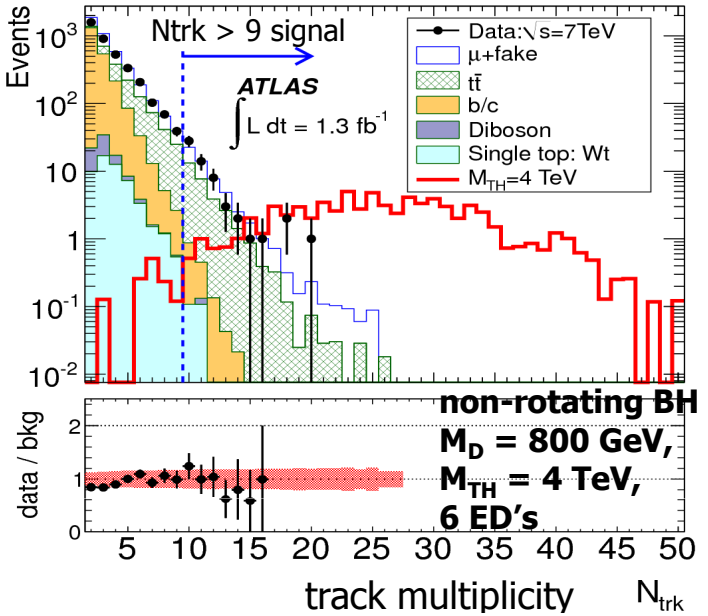
NEW!

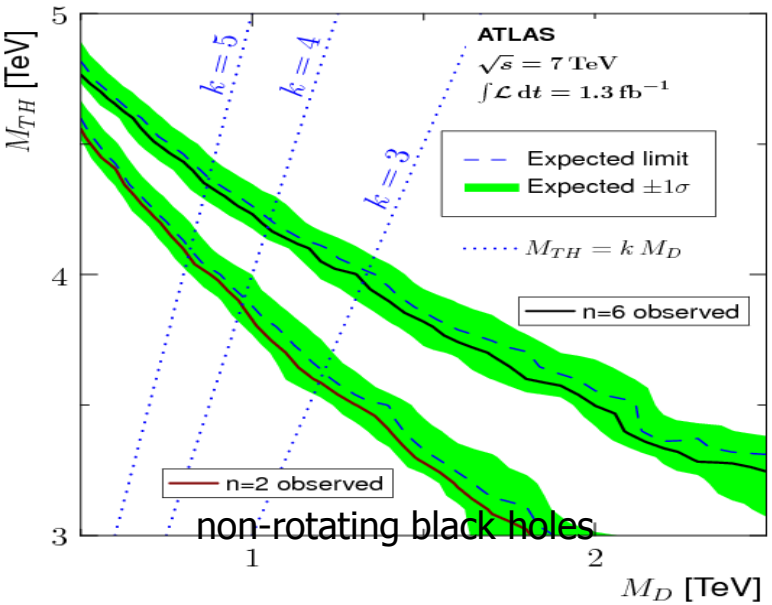
Benchmark Model: Large ED ADD Model

- M_D is the Planck scale in n+4 D ($M_D << M_{Pl}$)
- If there are ED and $M_D \sim 1$TeV, microscopic black holes (BH) can be produced at LHC

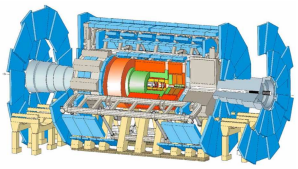
- Assume continuous BH production from M_D to LHC $\sqrt{s}$=7 TeV, but remove mass region (M_{TH}) close to M_D where classical BH production and semi-classical BH decay approximations are not valid

- Strategy:
  - –Select events with same sign di muons, with at least one being isolated, to minimize SM bkgs
  - –Look at track multiplicity distribution
- No excess over SM expectations seen





2010 data: ATLAS-CONF-2011-065: 31 pb-1
2011: submitted to PLB

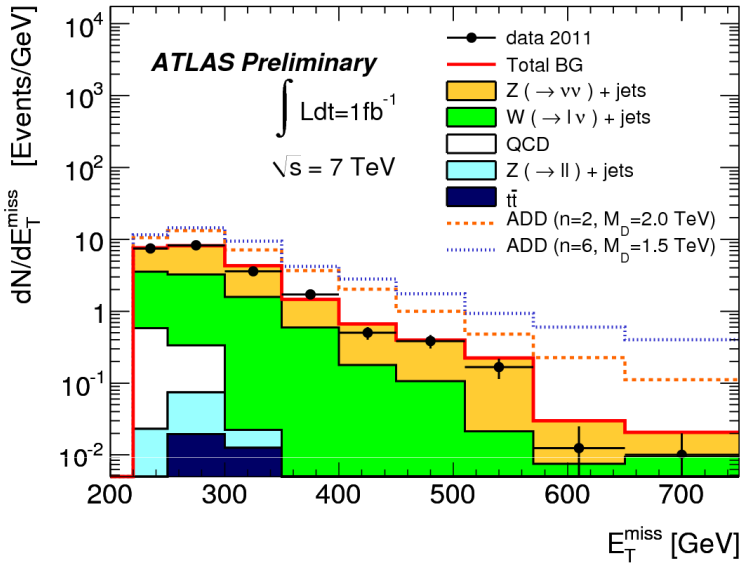


ADD: Monojet Search a single jet plus missing ET

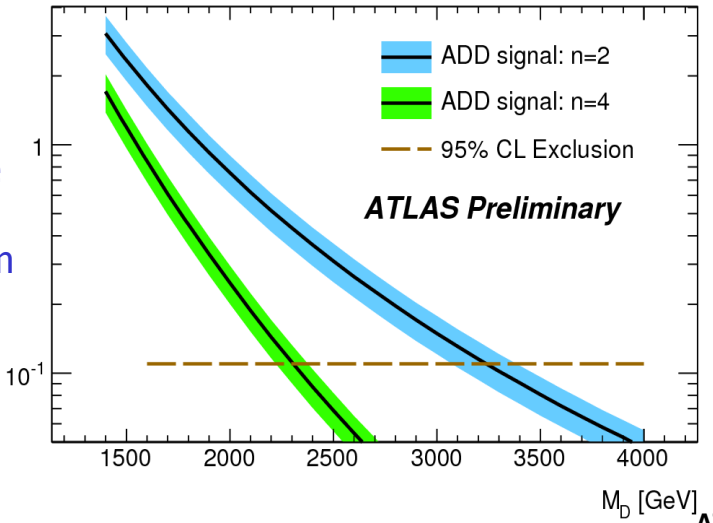
- ADD: Graviton Emission: Produce jet + G
- G disappears into the extra dimension
- Signature: single (high pT) jet and missing E_T

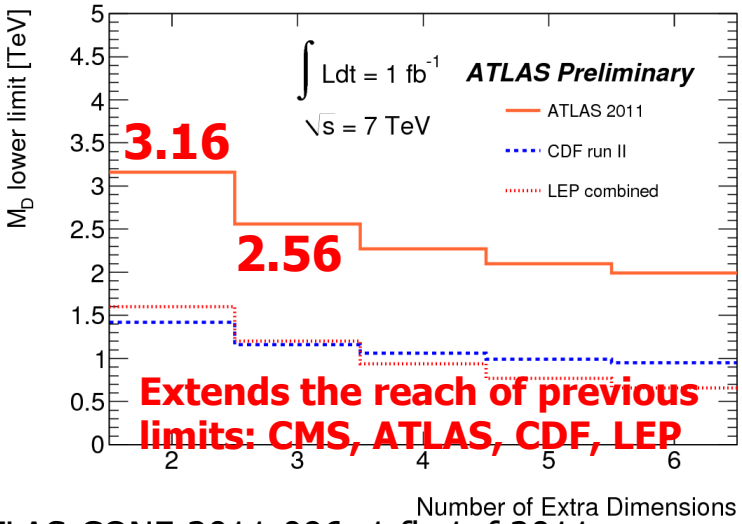
Missing ETtrigger
•Signal region ("HighPt")
–p_T^{j1}> 250 GeV, missing E_T> 220 GeV
–p_T^{j2}< 60 GeV, Δφ(j2, missing E_T) > 0.5
–No reasonable e's, μ's

Good Agreement between data and background prediction: 965 events: 1010 ± 37 (stat) ± 65 (syst)

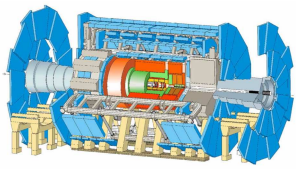


•Model-independent limit on σ*Acceptance @ 95% CL = 0.11 pb
Using Acceptance from ADD signal samples (Pythia): 95% CL on fiducial σ = 0.13 pb





ATLAS-CONF-2011-096; 1 fb-1of 2011
2010: arxiv:1106.5327, submitted to PLB (33 pb-1



Randall Sundrum ED

RS Gravitons (G)

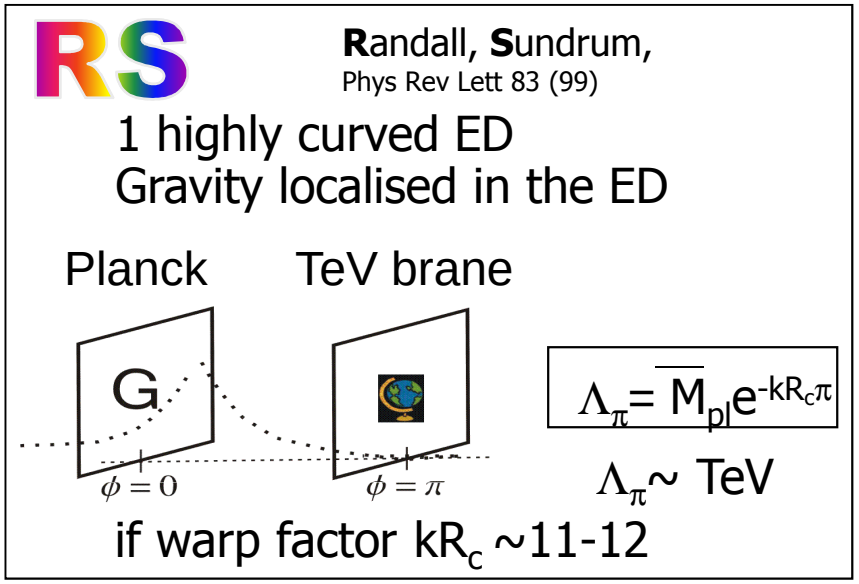
•5-D space-time bound by two 3+1D branes with SM particles localized on one and gravity on the other

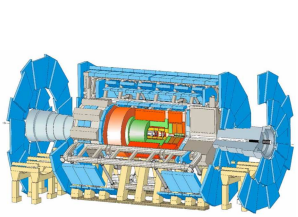
•Only G propagate in bulk resulting in massive spin-2 Kaluza-Klein (KK) excitations

Signature:
Narrow, high-mass resonance states in dilepton/dijet/diboson channels

•Narrow intrinsic width if $k/M_{Pl}<0.1$ (k is space-time curvature in ED)

•Graviton decays to SM fermions or bosons: Diphoton branching fraction is twice higher than dilepton one



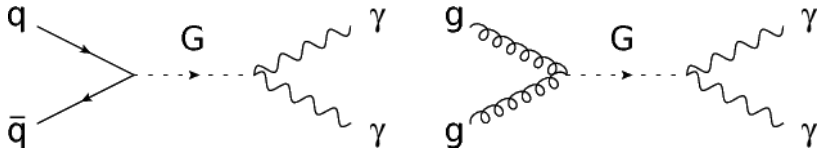


NEW!

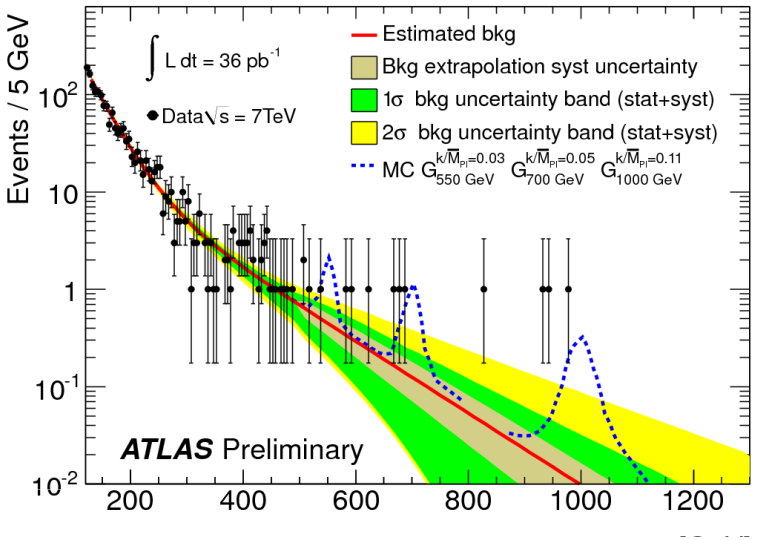
1+ fb-1 gg Updates to come!

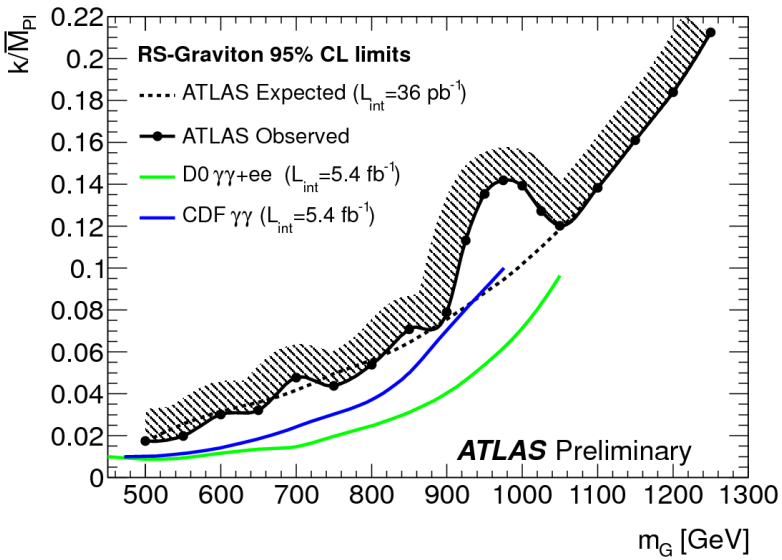
RS ED: Diphotons

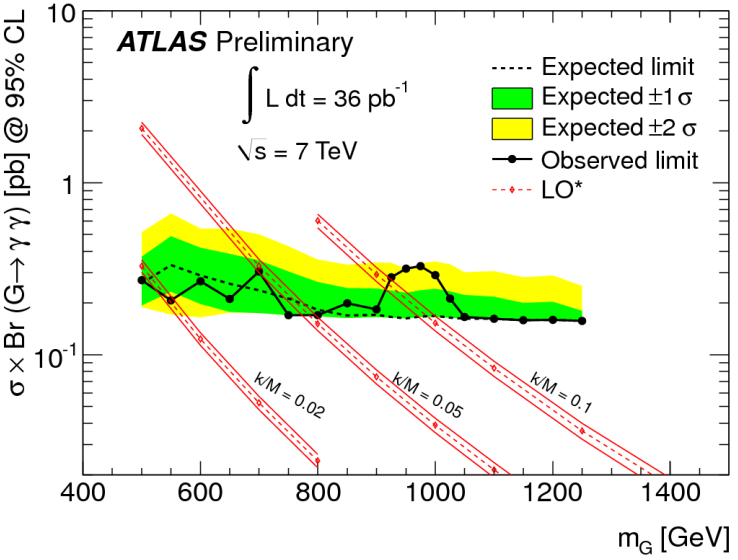
RS Gravitons (G)



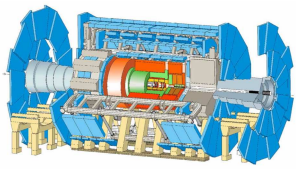
- Data consistent with SM predictions
- Limit @ 95% CL >920(545) GeV for k/MPl=0.1(0.02)







ATL-CONF-2011-044

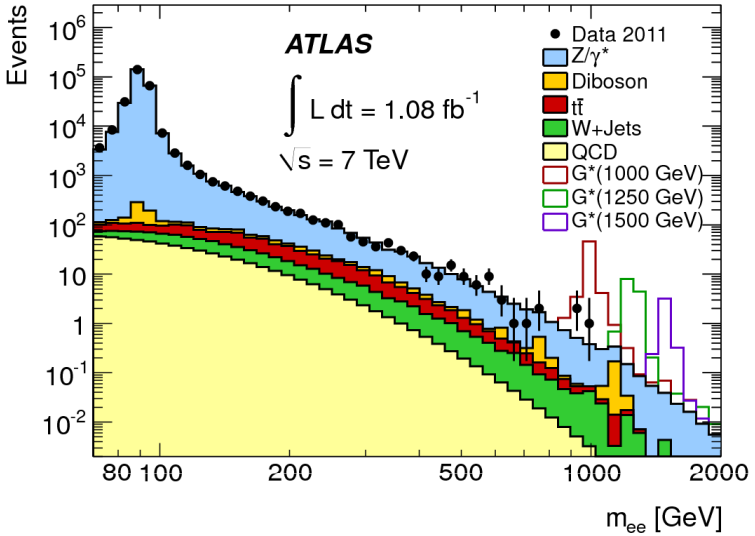


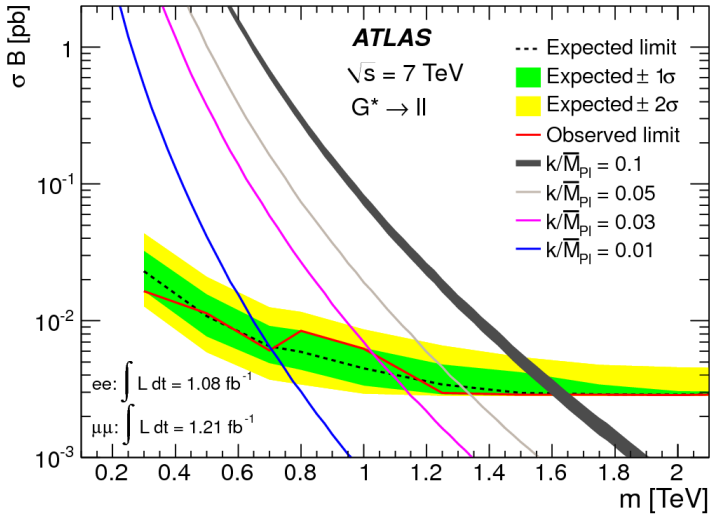
RS ED G*: Dileptons

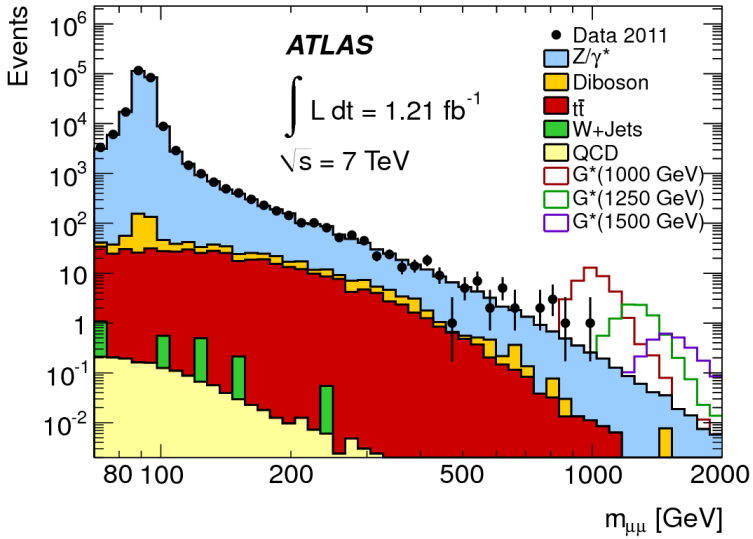
- Signal RS G*→ll
- Same Spectra as for Z', no excess

Upper Limits @ 95 % CL on RS M_{G^*}

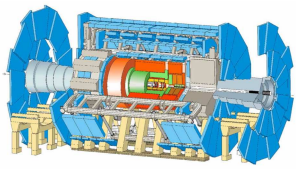
Coupling(k/M_{Pl})	0.01	0.03	0.05	0.1
UL@95%CL(TeV)	0.70	1.03	1.33	1.63







arXiv:1108.1582, accepted by PRL



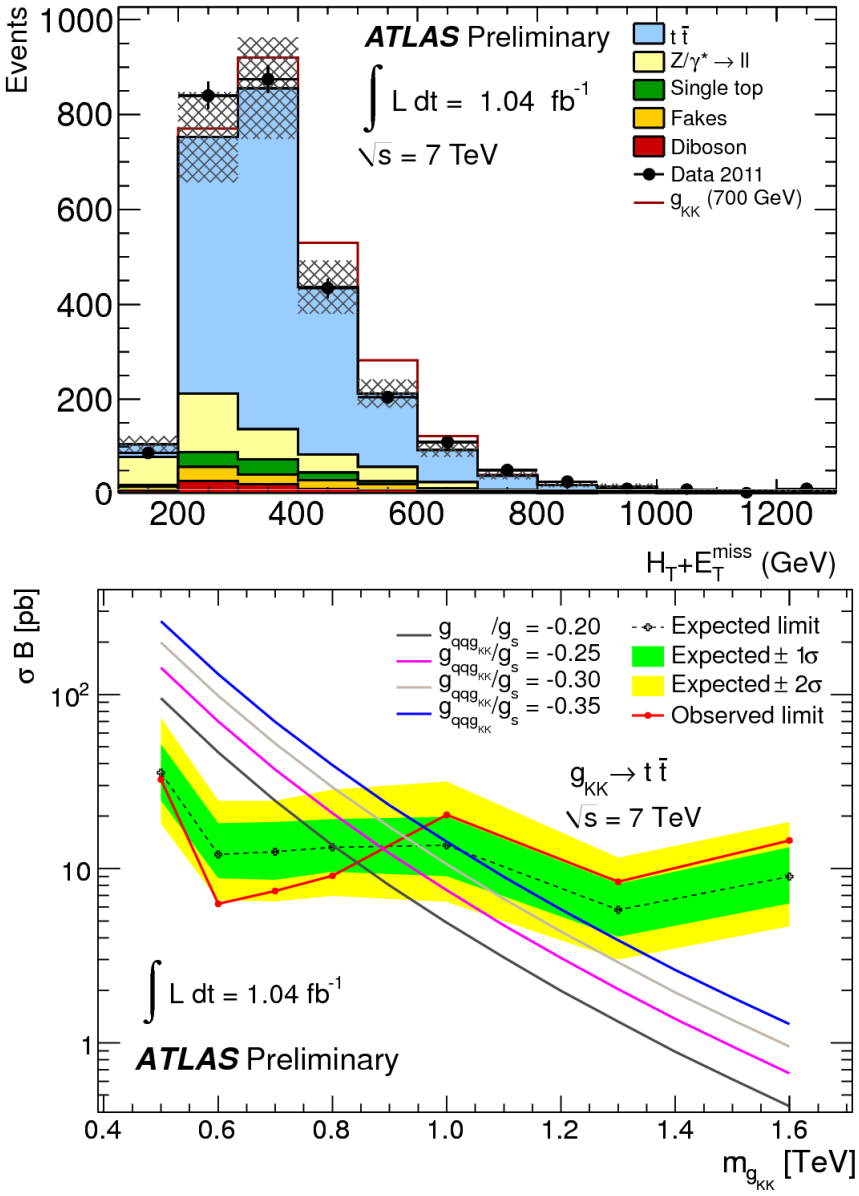
tt Resonances in the Dilepton Channel

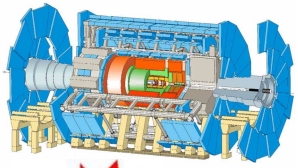
- Signal RS $g_{KK} \rightarrow$ tt-bar :
- tt-bar$\rightarrow$bW+$\bar{b}$W-$\rightarrow$bb-bar lνlν

No statistically significant excess above the SM expectation observed

UL @ 95\% C.L on σ.BR(resonance$\rightarrow$tt-bar) pairs as a function of the resonance pole mass

Lower mass limit of 0.84TeV for a Kaluza Klein gluon resonance in the RS Model

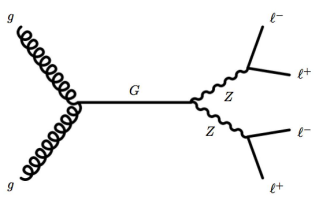


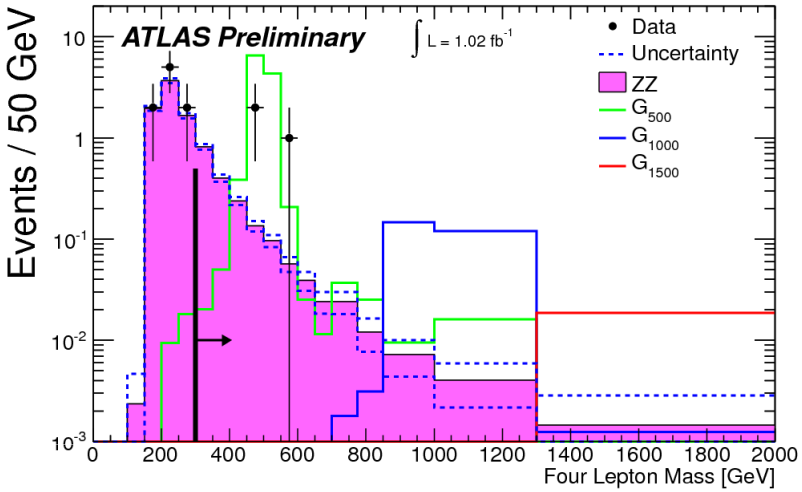


NEW!

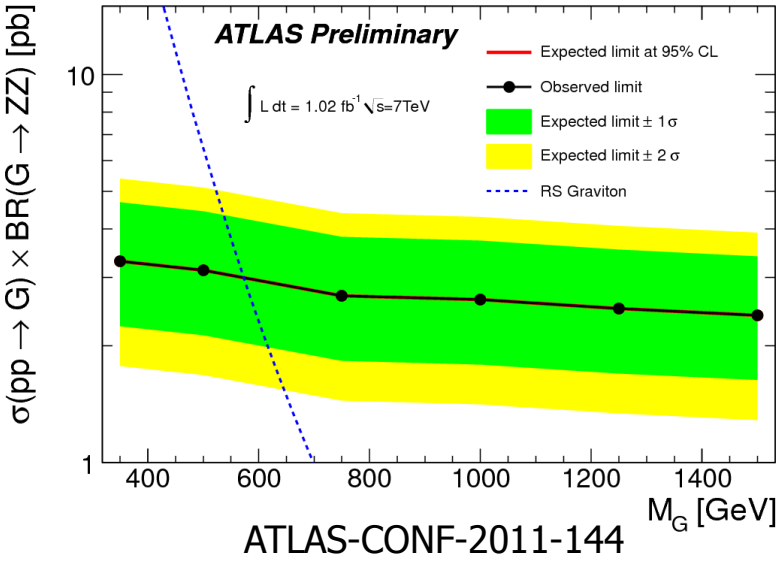
RS G*→ZZ → llll with Four Charged Leptons

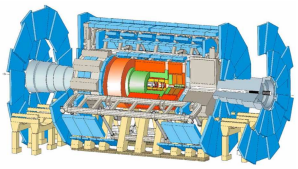
- Signal: Four Charged Leptons
- 2 searches performed in this decay channel ZZ & H++H--
- Events with two identified Z→ℓ+ℓ− decays
- For $M_{\ell\ell\ell\ell}$>300 GeV: from SM expect $1.9^{+1.0}_{-0.1}$ (stat) $^{+0.8}_{-0.1}$ (syst) events
- Observe: 3 events



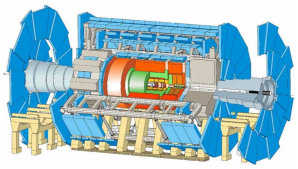


- 95% C.L. Limit σ(production of ZZ from high-mass sources) <0.9 pb in the fiducial region
- For RS model: limits on σ(pp→G)×BF(G→ZZ) of 2.6-3.3 pb depending on the resonance mass
- For a coupling of k/M_{pl}=0.1 , the median expected 95% C.L. lower limit M_G>575 GeV, equal to the observed limit



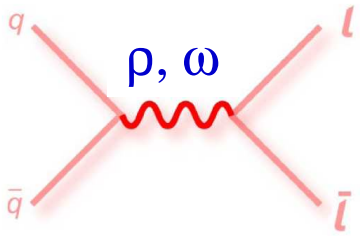


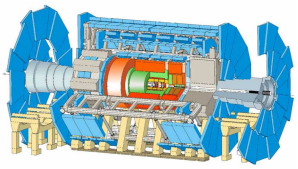
"Other Searches"



Technihadrons

ρ, ω→ μμ + ee





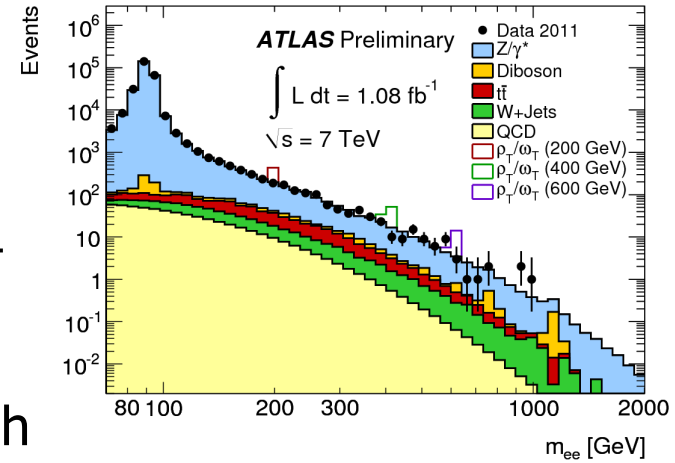
Technihadrons

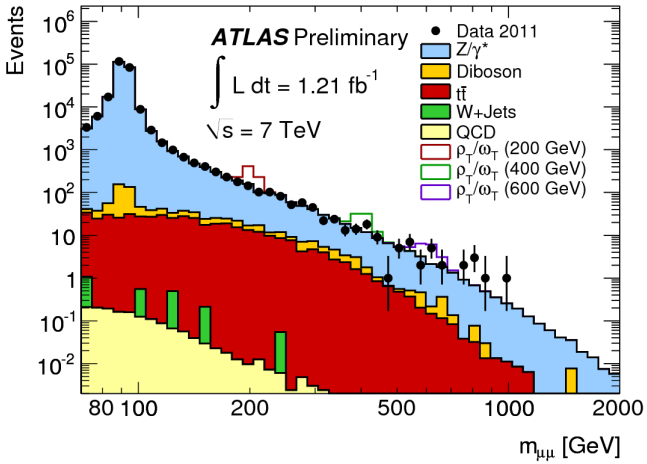
Signal: Low Scale TechniColour Model (LSCT) ρ_T, ω_T

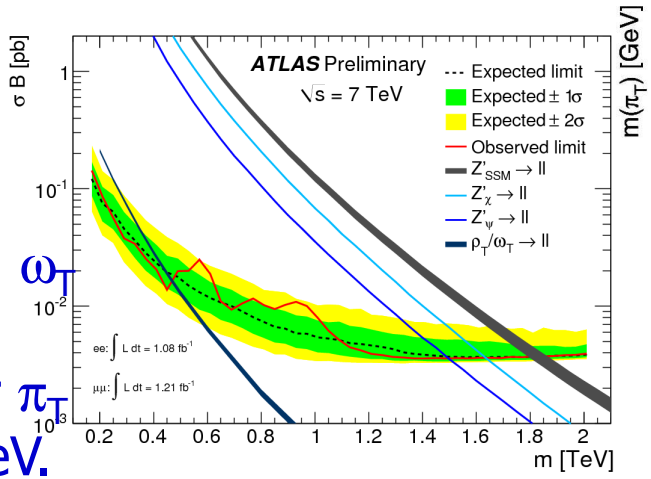
ρ_T, ω_T : narrow, spin 1 resonances, like Z' search uses the limit results of the Z' search

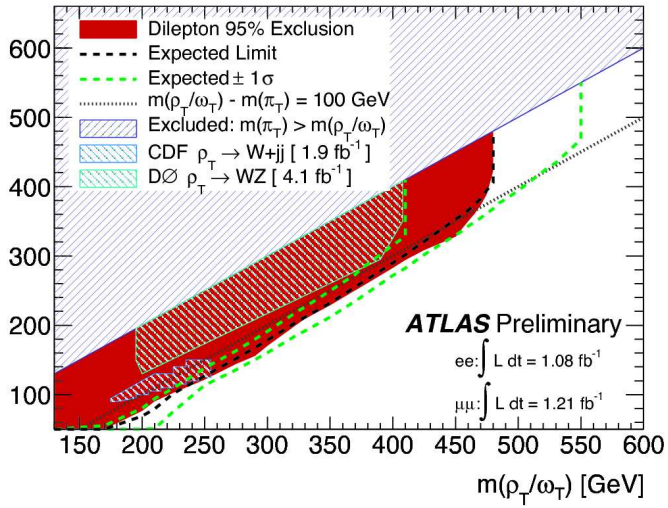
No evidence for a technihadron signal is observed

LSCT: masses of ρ_T and ω_T from 130–480GeV excluded at 95% CL for π_T masses from 50–480GeV.

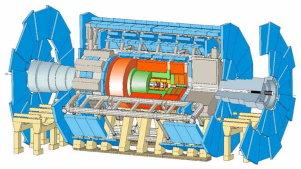








ATLAS-CONF-2011-125



Leptoquarks

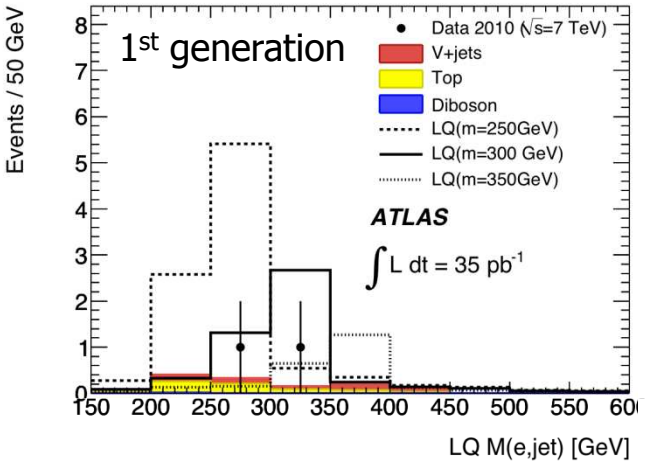
SM extension: lepton-quark symmetry
⇒LQ: colour triplets with couplings to quarks and leptons

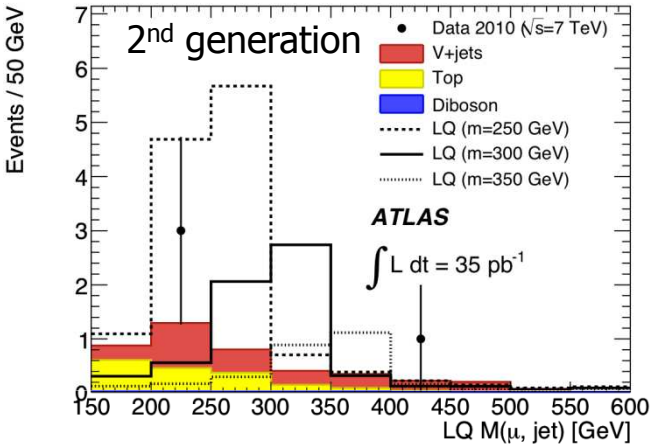
•Look for pair production of particles with both lepton and baryon quantum numbers

•Signal final states:
2 lepton + 2 jets &
lepton+2 jets+E_T^{Miss}

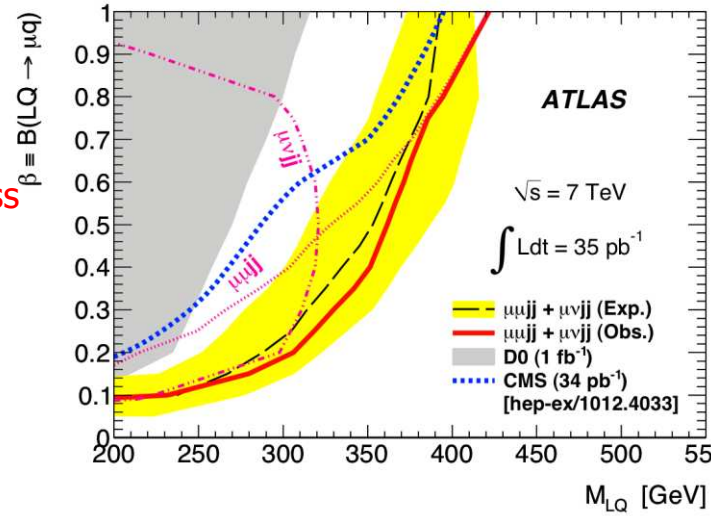
$LQLQ \rightarrow l^+ q l^- q$

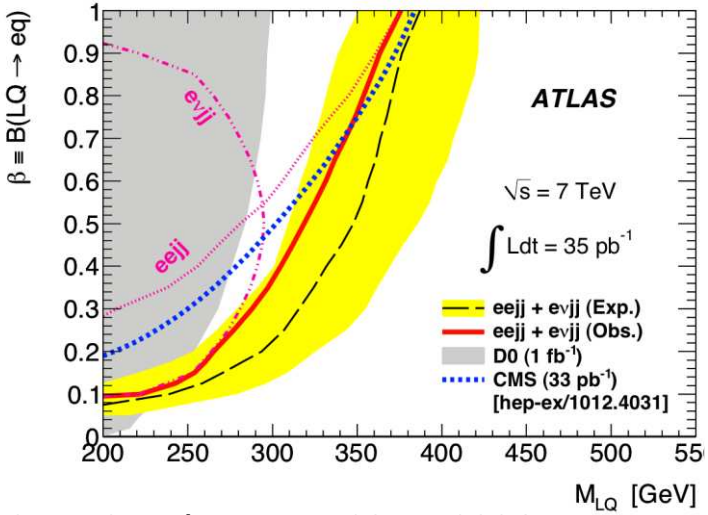
Average lj invariant mass

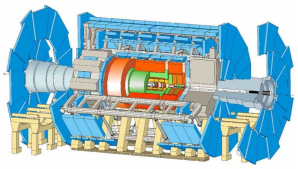




95 % C.L. exclusion region



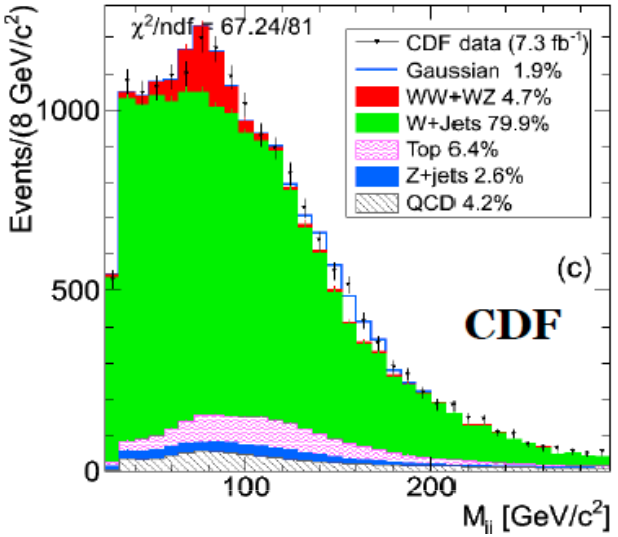




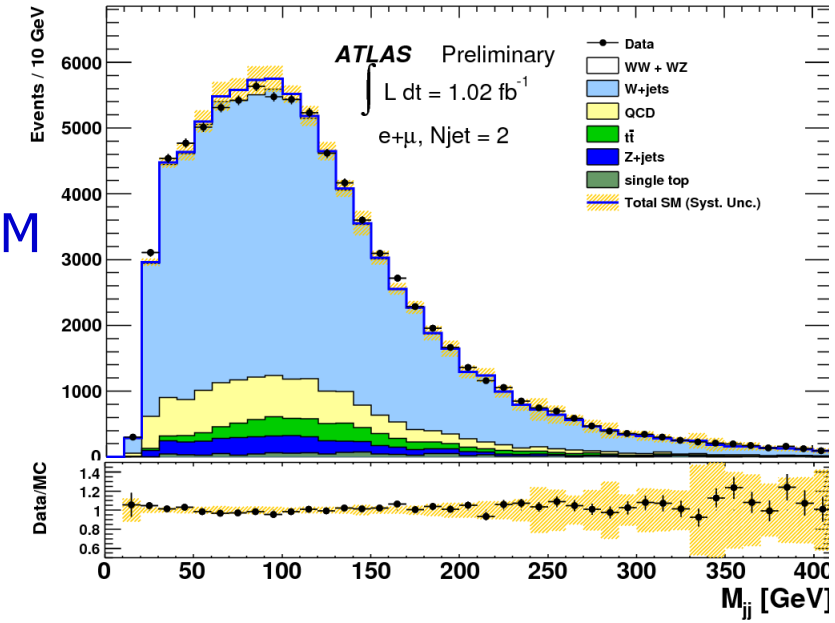
Wjj / lνjj Search

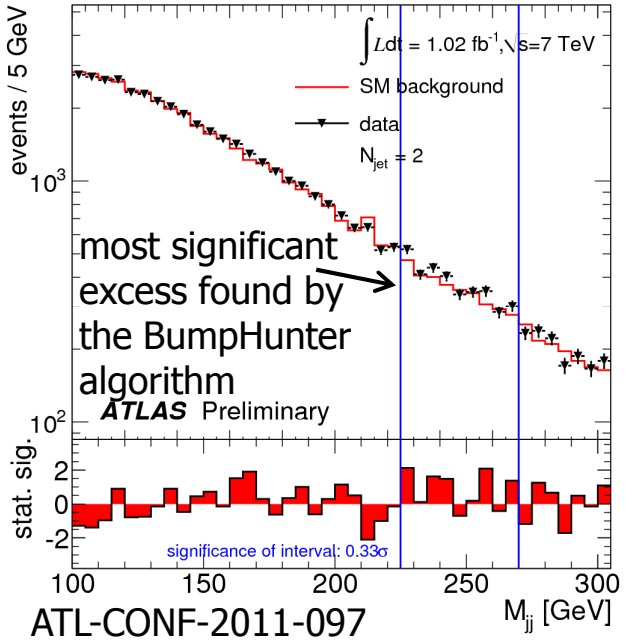
CDF has reported an excess of 4.1 at ~145GeV in jj mass distribution in ljj channel with 7.3fb^{-1}of data

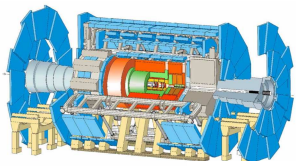
- This channel is not optimal at LHC with W+jet bkg 20 times higher, but this can be model dependent
- Selection: p_T^j>30GeV, p_T^e>25GeV p_T^μ>20GeV, p_T^{jj}>40GeV, E_T^{Miss}>25GeV, M_T^W>40GeV, $|\eta|$<2.5, $|\Delta\phi^{j1,ETMiss}|$>0.4GeV
- Looked at N_j=2 (shown) and N_j>2



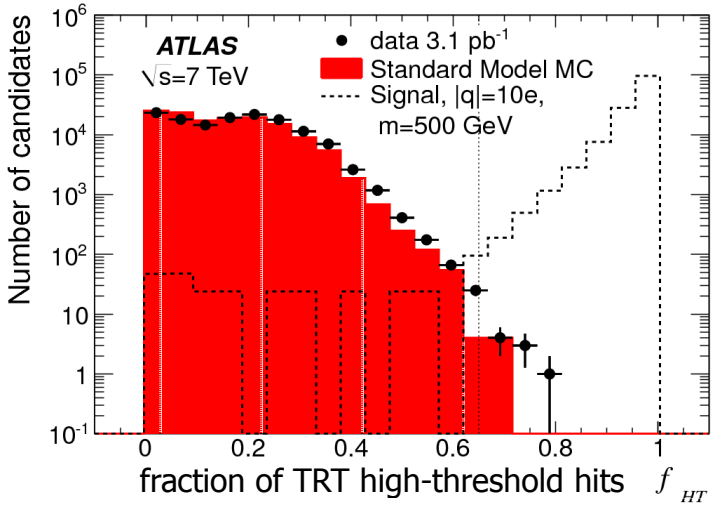
No significant excess over SM processes

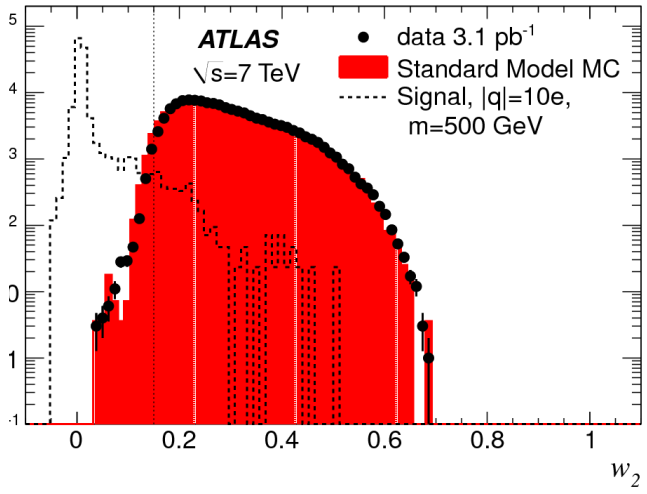






Massive Long-Lived HIP:





- Search concentrates on large mass (>100GeV), non-relativistic speed, charges 6-17e (Q-balls, stable micro black holes)
- Signal has high ionization in tracker, narrow calorimeter deposits
- No events pass selection (96% efficient for signal)

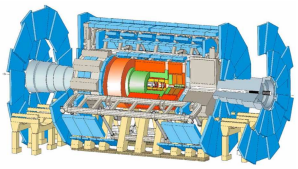
Cross-section limits @ 95% CL in pb for any model

m [GeV]	$\|q\| = 6e$	$\|q\| = 10e$	$\|q\| = 17e$
200	1.4	1.2	2.1
500	1.2	1.2	1.6
1000	2.2	1.2	1.5

Cross-section limits at 95% CL in pb assuming Drell-Yan-like production mechanism

m [GeV]	$\|q\| = 6e$	$\|q\| = 10e$	$\|q\| = 17e$
200	11.5	5.9	9.1
500	7.2	4.3	5.3
1000	9.3	3.4	4.3

arXiv: 1102.0459, PLB698:353-370,2011 **16**



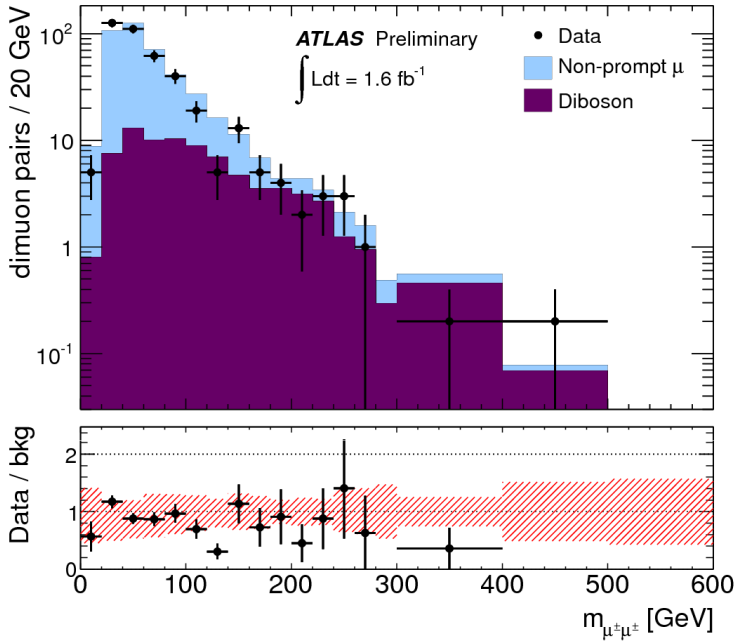
Anomalous Production of Prompt Like-sign Muon Pairs

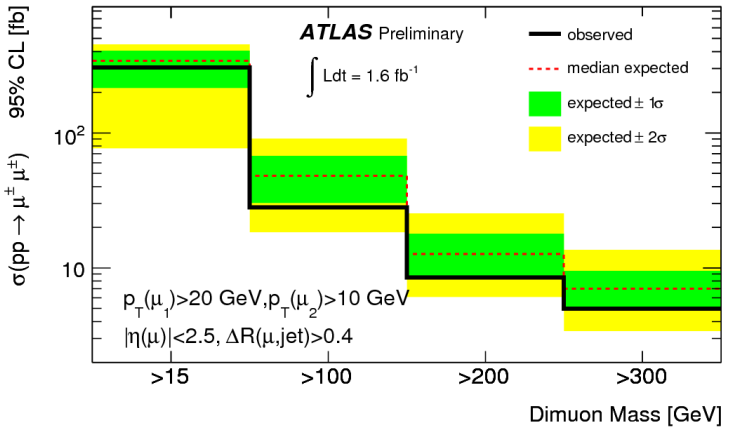
Inclusive search for non-SM production of two prompt, isolated SS muons

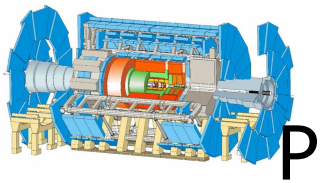
Selection: SS μμ: 2 isolated μ with $p_T^{leading}$>20 GeV & $p_T^{subleading}$>10 GeV
Minimal requirements are placed on the non-muon related activity in the event.

The data are found to agree well with the background estimate.

95 % confidence level upper limit on σ(non SM prompt SS mm production) ranges from 303 fb for $M_{\mu\mu}$>15 GeV to 8 fb for $M_{\mu\mu}$>300 GeV
for fiducial region





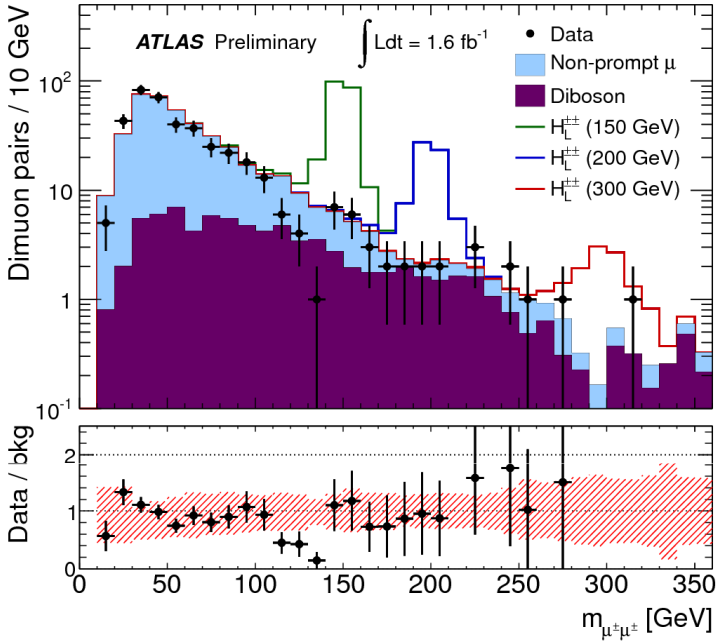


Doubly Charged Higgs Boson Production in Like-sign Muon Pairs

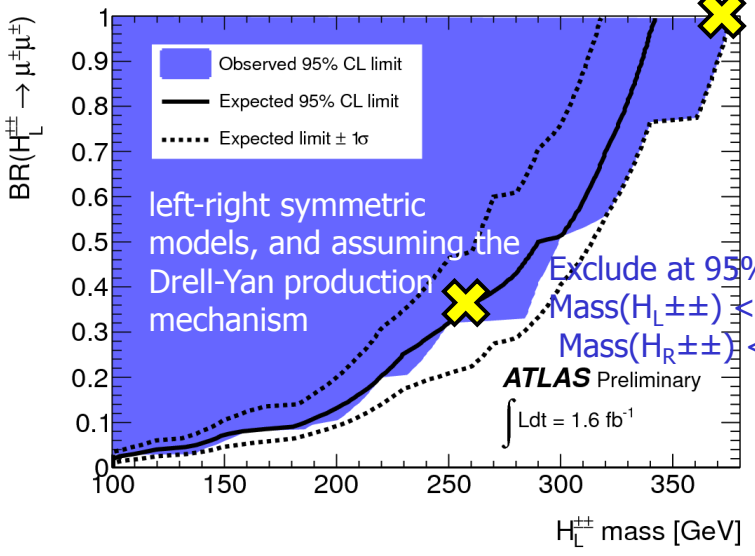
Select: two high p_T SS μ
Examine: dimuon invariant mass distribution

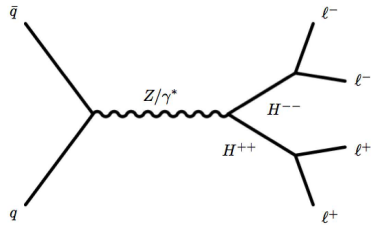
No evidence for resonant production of such dimuon pairs is found respectively.

95% C.L. :
$\sigma(pp \rightarrow H^{\pm\pm})x\ BR(H^{\pm\pm} \rightarrow \mu^{\pm}\mu^{\pm}) < 13 - 1.6$ fb
for $100 < M_{H^{\pm\pm}} < 400$ GeV

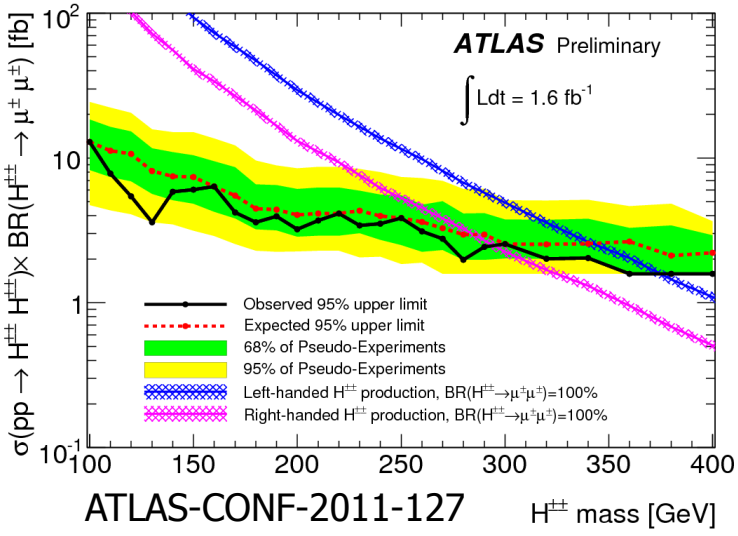


Mass($H_R^{\pm\pm}$) <295 GeV
Mass($H_L^{\pm\pm}$) <375 GeV



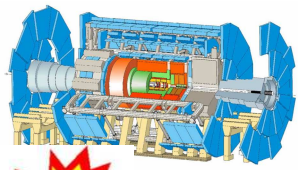


Exclude at 95% C.L.
Mass($H_L^{\pm\pm}$) <268 GeV,
Mass($H_R^{\pm\pm}$) <210 GeV



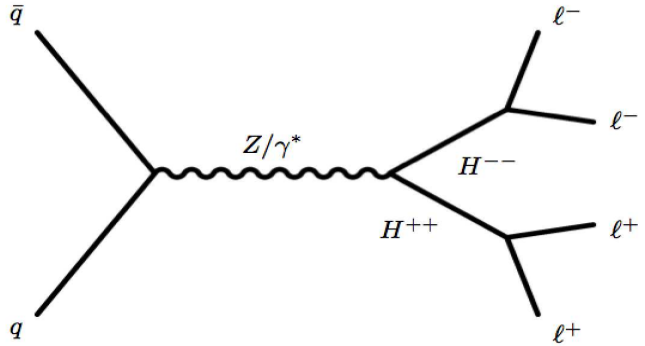
ATLAS-CONF-2011-127

racey Berry (RHUL)

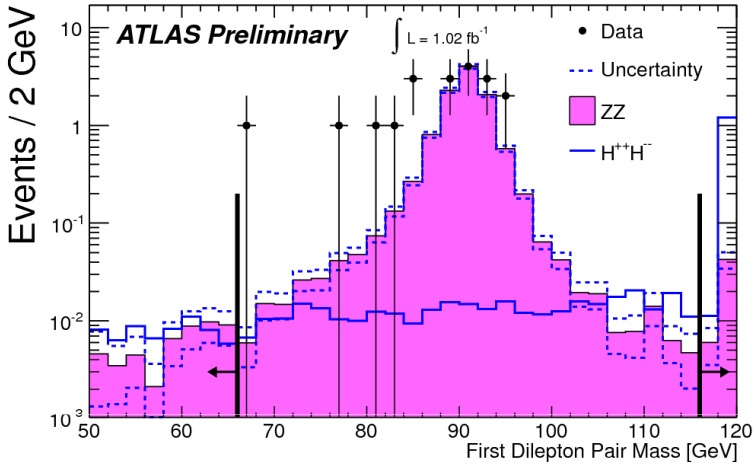


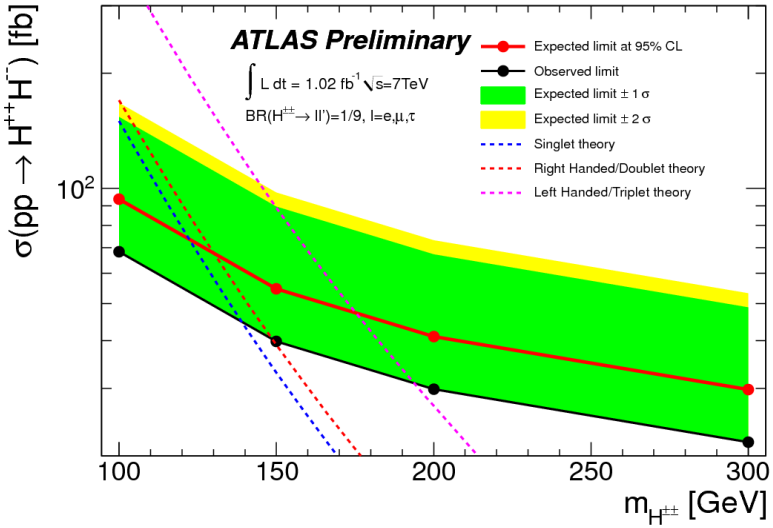
NEW!

Doubly Charge Higgs Production: with Four Charged Leptons

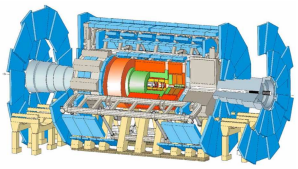


- Search for events that contain no identified $Z \rightarrow \ell^+\ell^-$ decays.
- Very low expected background,
- So even a small number of such events would be of interest.
- After selection: SM Expectation: $0.7^{+1.3}_{0.6}(\text{stat})\ ^{+0.9}_{-0.5}(\text{syst})$ events
- Observed: no events
- Using doubly-charged Higgs production as a benchmark model, upper limits are set on a fiducial cross-section for four-lepton production of 4.7 fb.



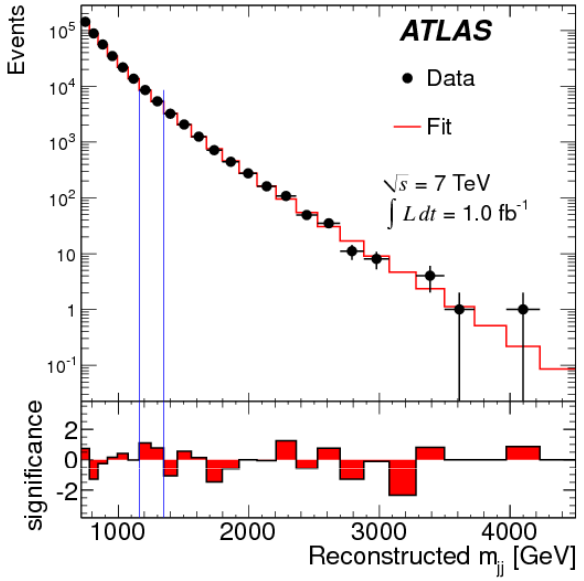


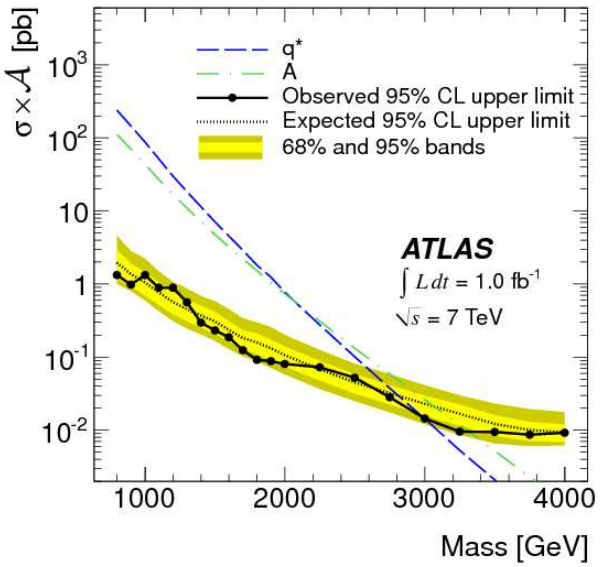
Same paper as RS $G^* \rightarrow ZZ \rightarrow$ llll search
ATLAS-CONF-2011-144

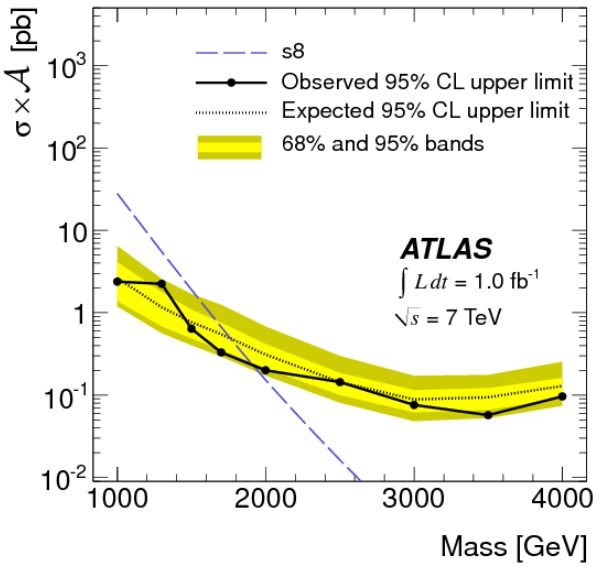


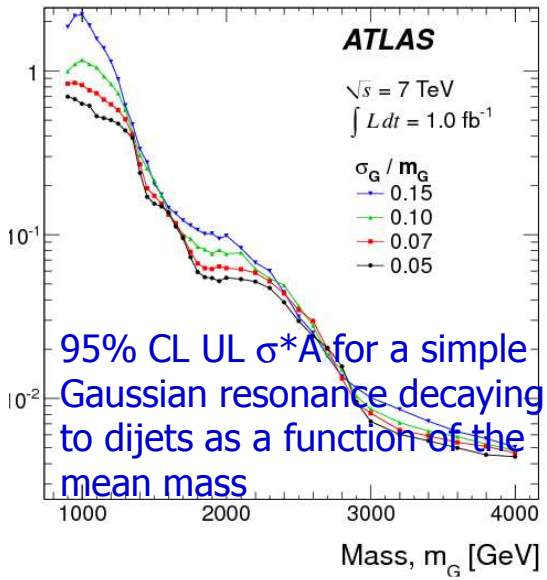
Axigluon/Excited Quarks

Dijet masses up to ~4 TeV are observed in the data
No evidence of resonance production over background is found
95% CL for
M(excited quarks) excluded<2.99 TeV
M(Axigluons) excluded <3.32 TeV,
M(colour octet scalar resonances) <1.92 TeV

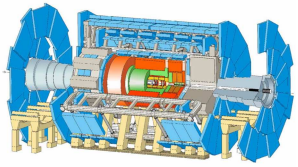








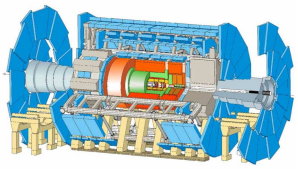
95% CL UL σ*A for a simple Gaussian resonance decaying to dijets as a function of the mean mass



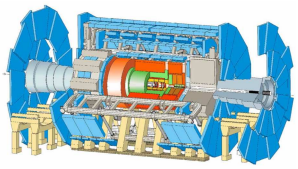
Conclusion

- LHC is working very well
- ATLAS detector is efficiently collecting data
- We are searching for New Physics – probing the highest energies directly accessible at the LHC
  - distributions so far consistent with SM expectations
  - set limits of particular models and model-independent limits
  - previous limits substantially improved
- We now have more than 5fb^{-1} of 2011 data, so more exciting results from ATLAS to come…

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



Thank you
for inviting me!



Extra Dimensions: Motivations

In the late 90's Large Extra Dimensions (LED) were proposed as a solution to the hierarchy problem M_{EW} (1 TeV) << M_{Planck} (10^{19} GeV)?

ADD **A**rkani-Hamed, **D**imopoulos, **D**vali, Phys Lett B429 (98)

Many (δ) large compactified EDs
In which G can propagate

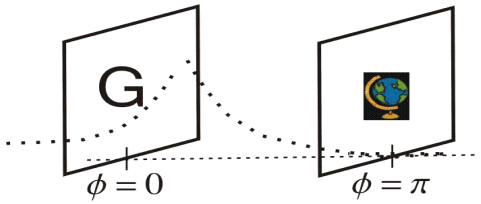
$$M_{Pl}^2 \sim R^{\delta} M_{Pl(4+\delta)}^{(2+\delta)}$$

Effective $M_{Pl} \sim 1$TeV $\rightarrow$ if compact space (R^{δ}) is large

RS **R**andall, **S**undrum, Phys Rev Lett 83 (99)

1 highly curved ED
Gravity localised in the ED

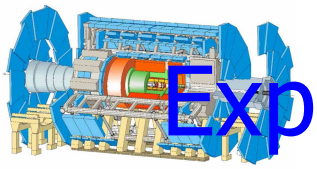
Planck TeV brane



$$\Lambda_{\pi} = \overline{M}_{pl} e^{-kR_c\pi}$$

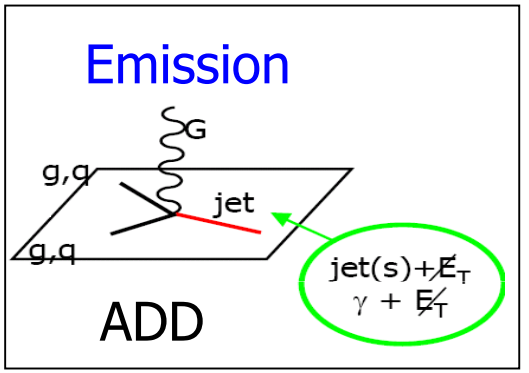
$\Lambda_{\pi} \sim$ TeV

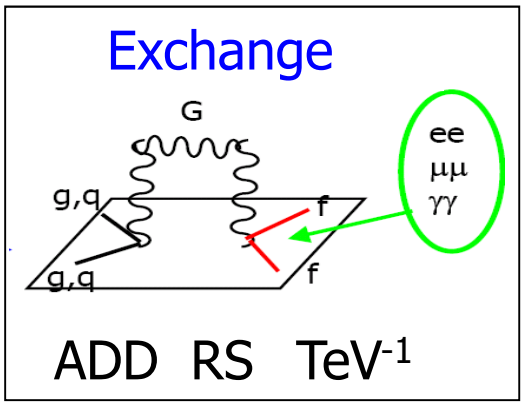
if warp factor $kR_c \sim 11$-12

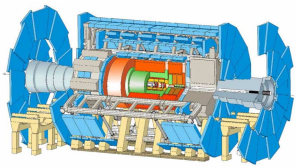


Experimental Signatures of ED

- Large Extra Dimensions (ADD)
  - KK Graviton Direct Production → Missing E_T signature
    Single jets/Single photons + missing ET
  - KK Graviton Exchange → Drell-Yan
    Di-lepton, di-jet continuum modifications
- Randall-Sundrum Model
  - KK Graviton →TeV resonances
    Di-lepton, di-jet and di-photon resonances
    Diboson resonances
- TeV^{-1} Model
  - KK Gauge Bosons (Z_{KK}) (also W_{KK})
    Di-lepton resonances



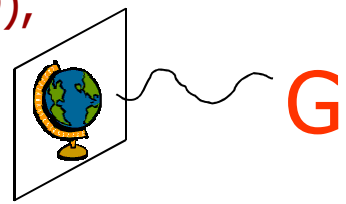


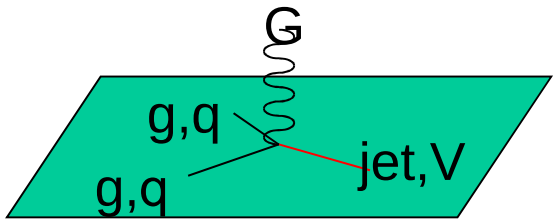


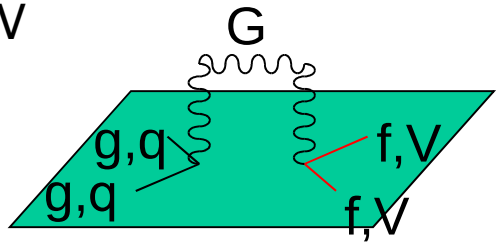
Extra Dimensions: ADD Model

Arkani-Hamed, **D**imopoulos, **D**vali, Phys Lett B429 (98), Nuc.Phys.B544(1999)

(Many) Large flat Extra-Dimensions (LED),
could be as large as a few μm
G can propagate in ED
SM particles restricted to 3D brane
The fundamental scale is not planckian: $M_D = M_{Pl(4+\delta)} \sim$ TeV





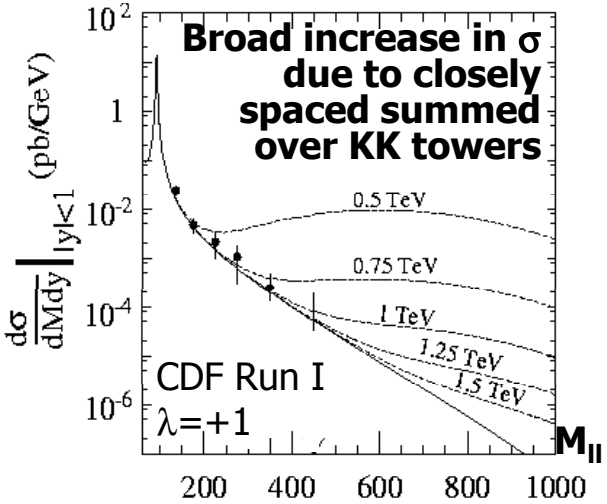


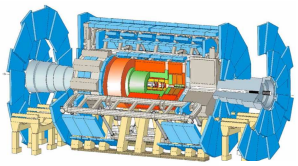
Model parameters are:
- δ = number of ED
- $M_{Pl}(4+\delta)$ = Planck mass in the 4+δ dimensions

$$M_{Pl}^2 \sim R^{\delta} M_{Pl(4+\delta)}^{(2+\delta)}$$

Signature:

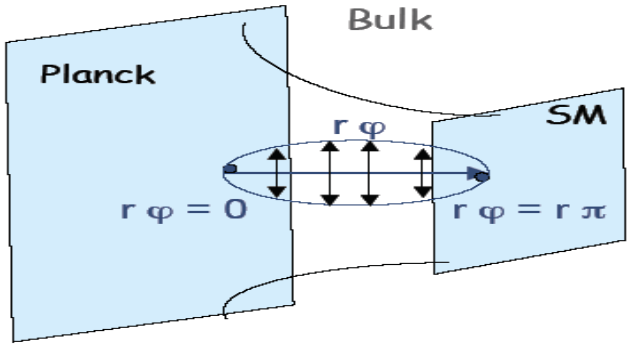
- ❖ Real graviton emission: in association with a vector-boson
  jets + missing ET, V+missing ET
- ❖ Or deviations in virtual graviton exchange
  e.g. Excess above di-lepton continuum



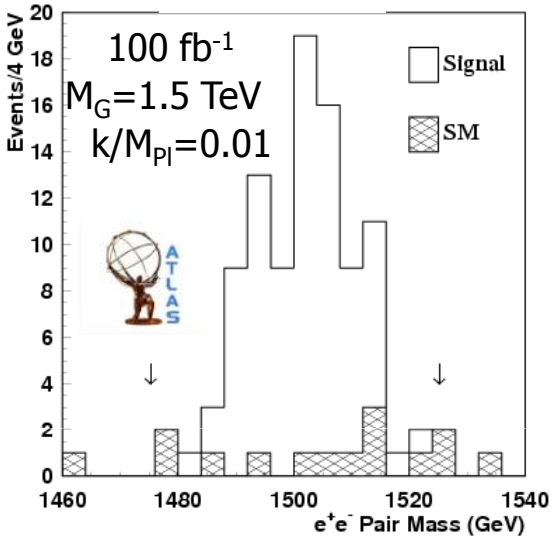


RS Model

1 extra warped dimension



$G_1 \rightarrow e^+e^-$



Signature:
Narrow, high-mass resonance states in dilepton/dijet/diboson channels

Model parameters:

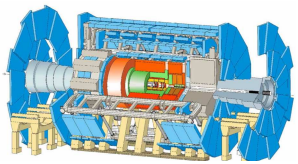
- Gravity Scale: $\Lambda_\pi = \overline{M}_{pl} e^{-kR_c\pi}$ **Resonance**
  1st graviton excitation mass: $m_1 \rightarrow$ position
  $\Lambda_\pi = m_1 \overline{M}_{pl}/kx_1$, & $m_n = kx_n e^{krc\pi}(J_1(x_n)=0)$
- Coupling constant: $c = k/M_{Pl}$
  $\Gamma_1 = \rho m_1 x_1^2 (k/\overline{M}_{pl})^2$ $\rightarrow$ width

k = curvature, R = compactification radius

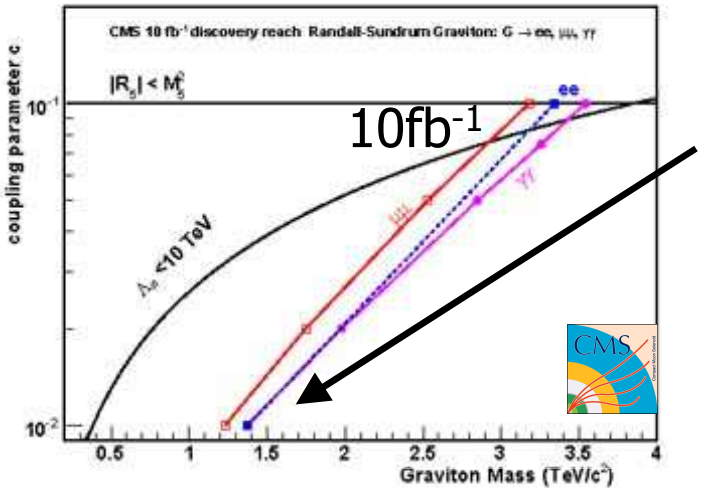
Best channels to search in are $G(1) \rightarrow e^+e^-$ and $G(1) \rightarrow \gamma\gamma$ due to the energy and angular resolutions of the LHC detectors

$G(1) \rightarrow e+e-$ best chance of discovery due to relatively small bkdg, from Drell-Yan

Allenach et al, hep-ph0211205 Allenach et al, hep-ph0006114



RS1 Discovery Limit

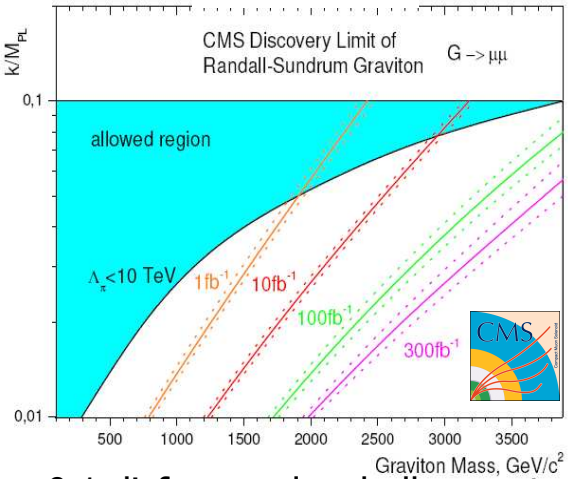


BR(G->γγ) = 2* BR(G->ee/μμ)

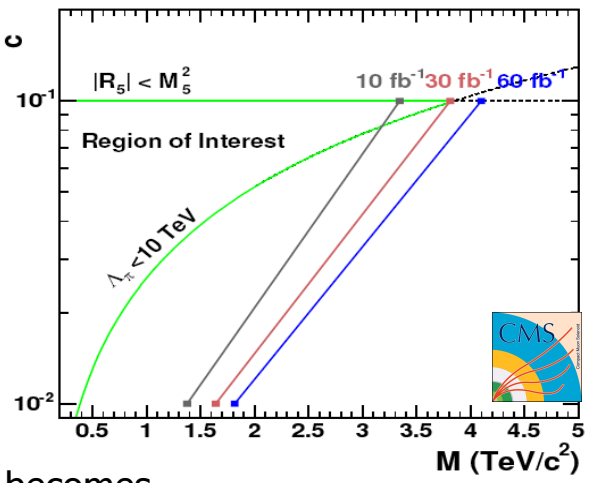
Reach for e and γ is comparable for low coupling and G mass due to the QCD and prompt photon bkgds in the γγ channel which are harder to efficiently suppress μμ channel trails ee chanel due to resolution

< 60 fb^{-1} LHC completely covers the region of interest

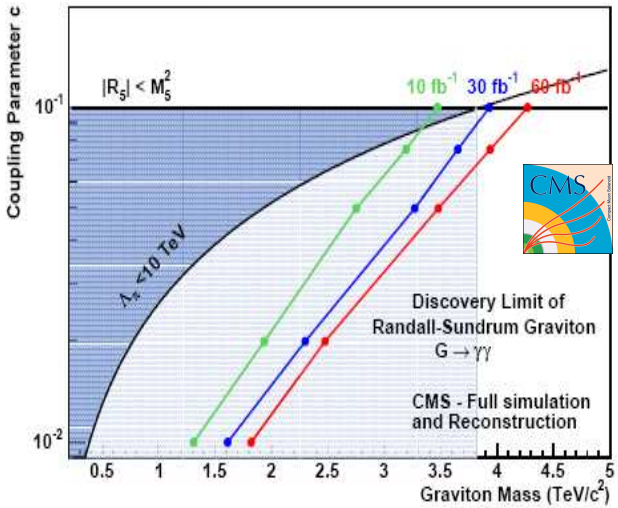
$G_1 \rightarrow \mu^+\mu^-$



$G_1 \rightarrow e^+e^-$

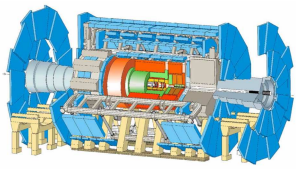


$G_1 \rightarrow \gamma\gamma$



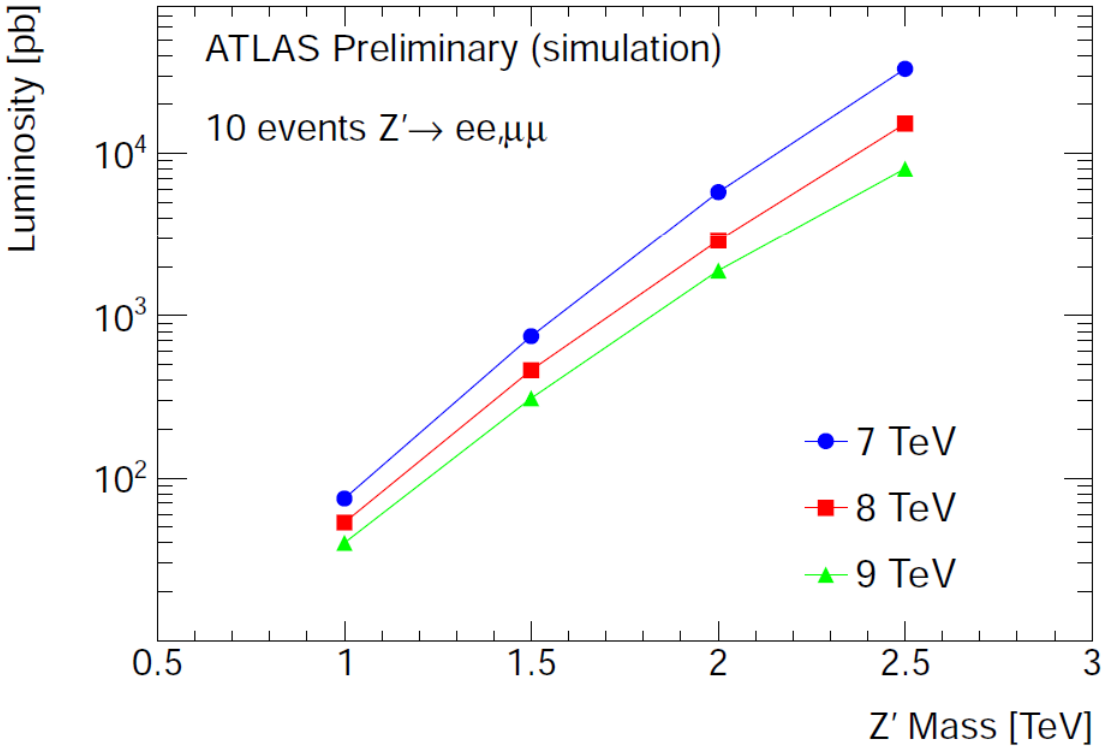
c>0.1 disfavoured as bulk curvature becomes to large (larger than the 5-dim Planck scale)

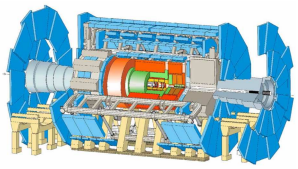
CMS PTDR 2006



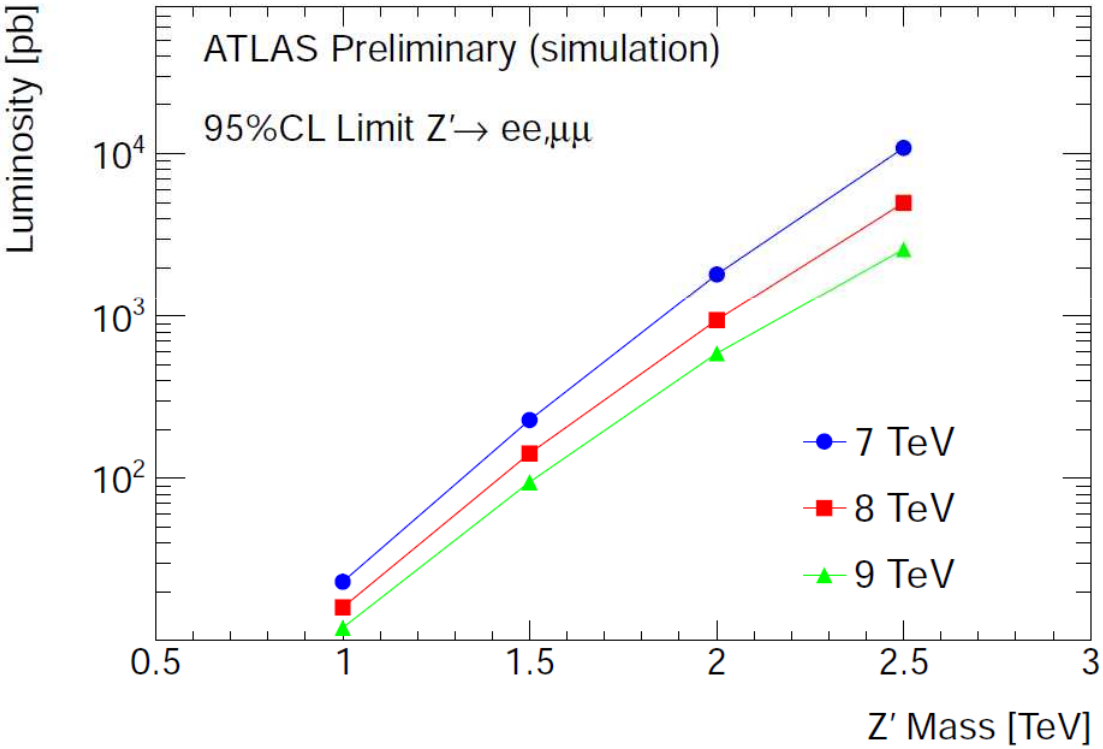
Sensitivity: 10 Signal Events

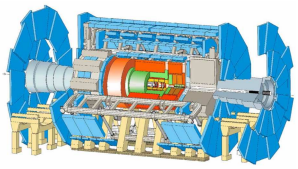
- D. Olivito's PLHC 2011 talk, June 10 2011





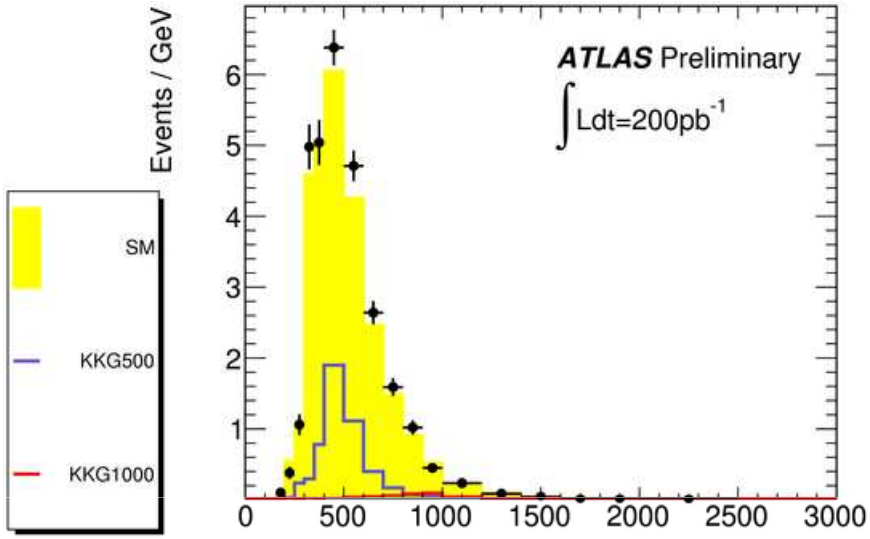
Sensitivity: Limit Setting

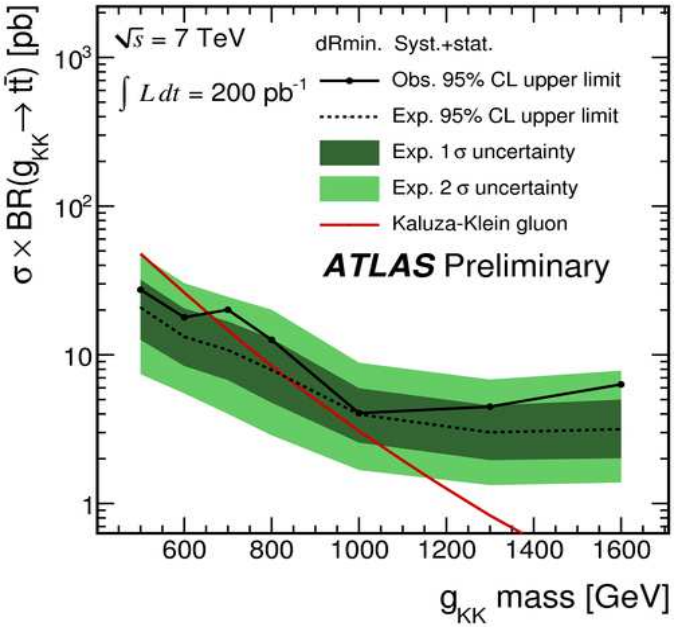




RS G*→tt-bar

- Search for top quark pair ($t\bar{t}$) resonances : lepton (e /μ) + jets
- Same search used as for Z' tt-bar search
- No evidence for a resonance is found.
- Limits set using the reconstructed $t\bar{t}$ mass spectrum
- 95% C.L. limits on RS model Kaluza-Klein gluons with masses excluded < 650 GeV





ATLAS-CONF-2011-087