ATLAS Sensitivity to Leptoquarks, W_R and Heavy Majorana Neutrinos in Final States with High-Pt Dileptons and Jets with Early LHC Data

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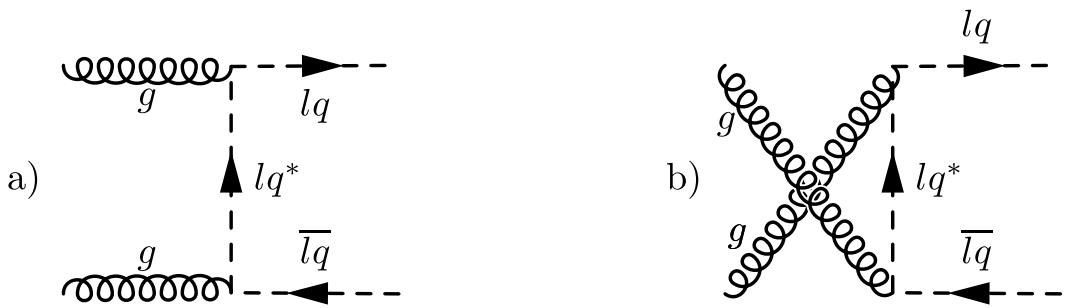
Neutrino Mass, Gauge Symmetries in Nature and Grand Unification

- Neutrino masses are still unexplained. Seesaw mechanism explains the observed tiny masses of neutrinos.
- Left-right symmetrical model is a higher symmetry gauge group that elegantly implements seesaw mechanism. Breaking of left-right symmetry introduces massive right-handed W bosons.
- Leptoquarks are hypothetical particles that are introduced in GUT-inspired models.
- Leptoquarks have implication for SUSY where squarks may or may not be leptoquarks depending on R-parity ($(-1)^{3(B-L)+2S}$) conservation.



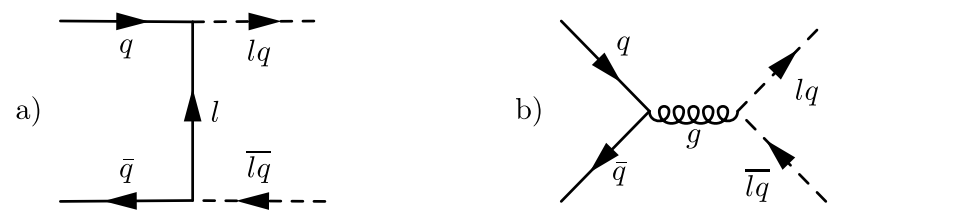


Figure 2: Diagrams for leptoquark-pair-production from $q\bar{q}$. a) $t-channel$ b) $s-channel$

Figure 1: Diagrams for leptoquark-pair-production from gg.

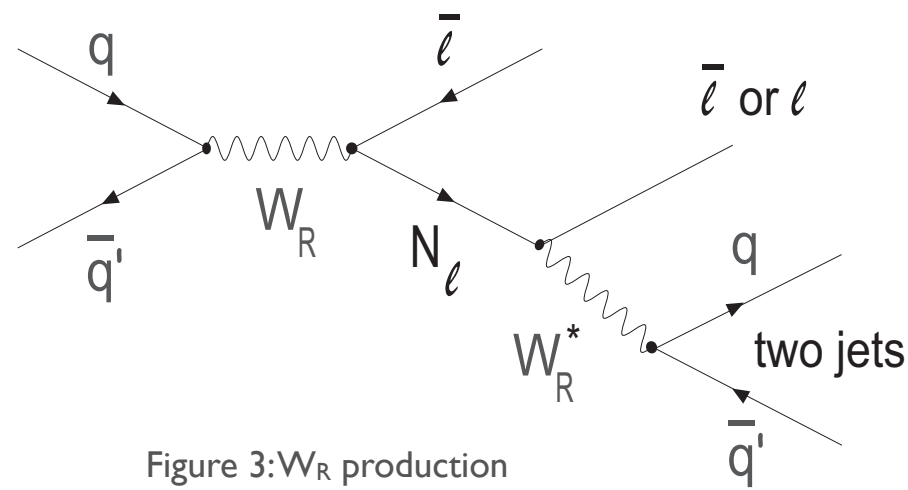


Figure 3: W_R production

A Large Toroidal LHC ApparatuS (ATLAS)

Tracking

$$\sigma(\frac{1}{p_T}) = 0.6 \oplus \frac{18.0}{p_T}(TeV^{-1})$$

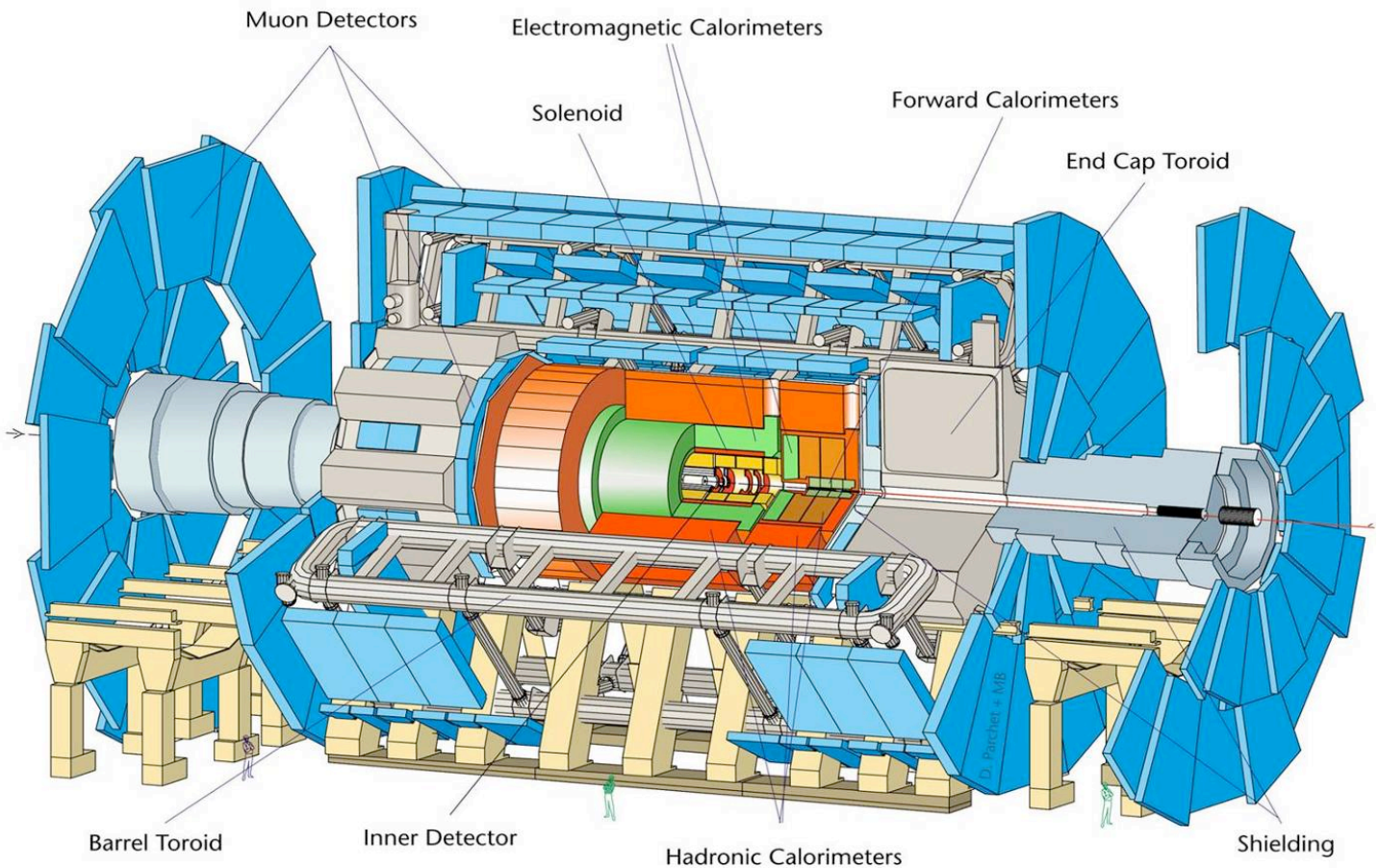
Calorimetry

$$\frac{\sigma(E)}{E}(\%) = \frac{10\%}{\sqrt{E}} \oplus 0.7\%(GeV)$$

Muon Spectrometer

Muon Pt resolution better

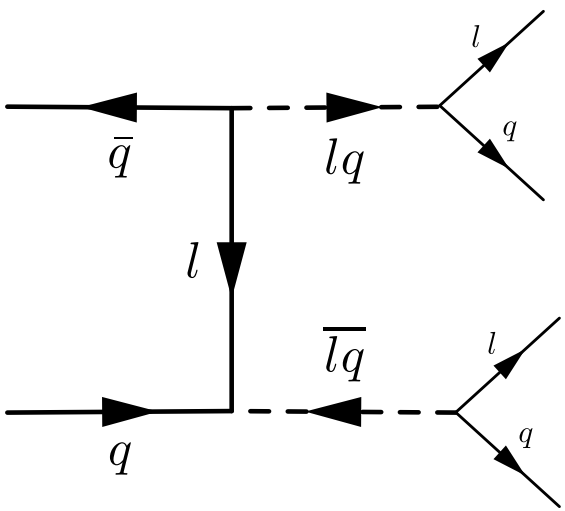
than 10% at 1 TeV

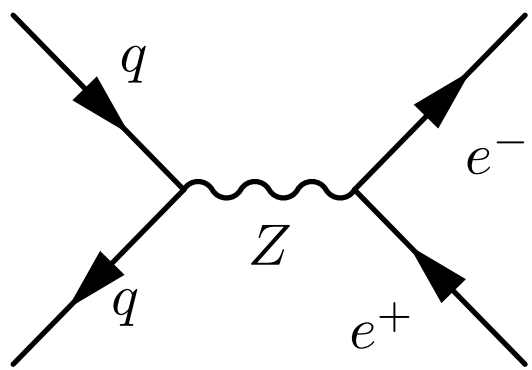


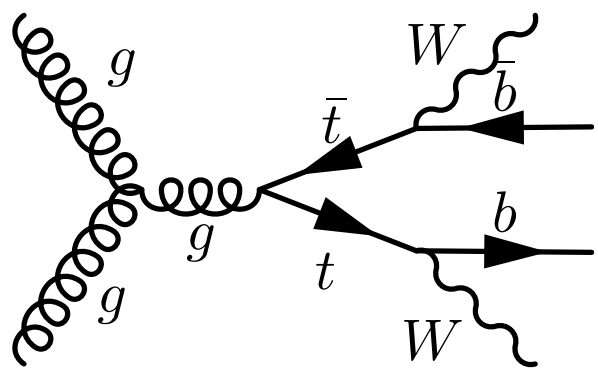
Diameter (X-Y plane)
25 m
Barrel toroid magnet length 26 m
End-cap end-wall chamber span 46 m
Overall weight 7000 Tons

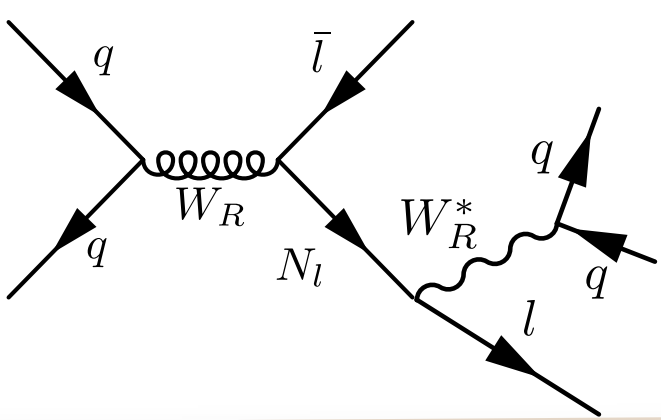
Backgrounds to Dilepton-Jets Channel

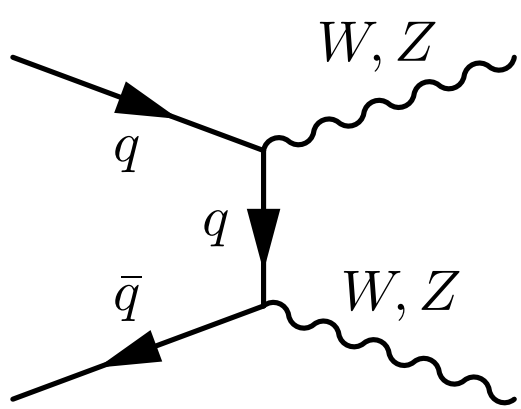
- pp →lq lq → ljlj
- pp →W_R → lN_l → lljj
- There are many other known Standard Model processes giving rise to the same final state.
- Drell-Yan, top anti-top pair, vector boson pairs are the main background processes.

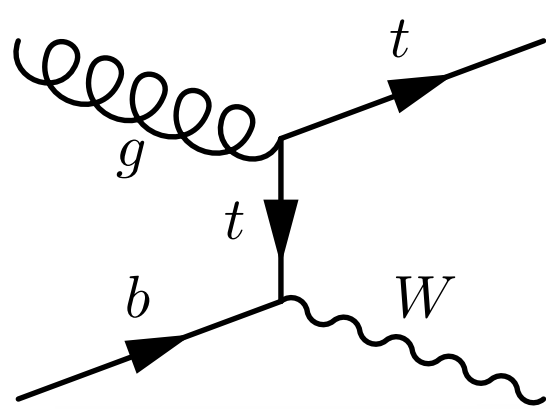












Leptoquarks: Background Suppression

Scalar leptoquark pairs

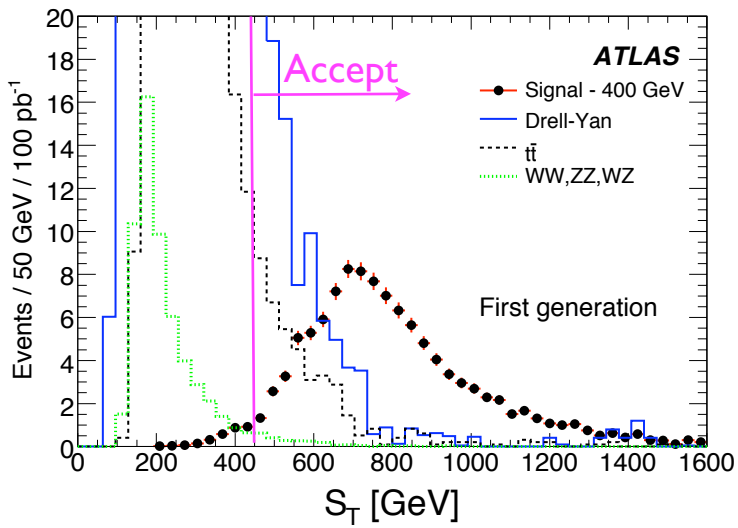
Based on full simulation of ATLAS detector

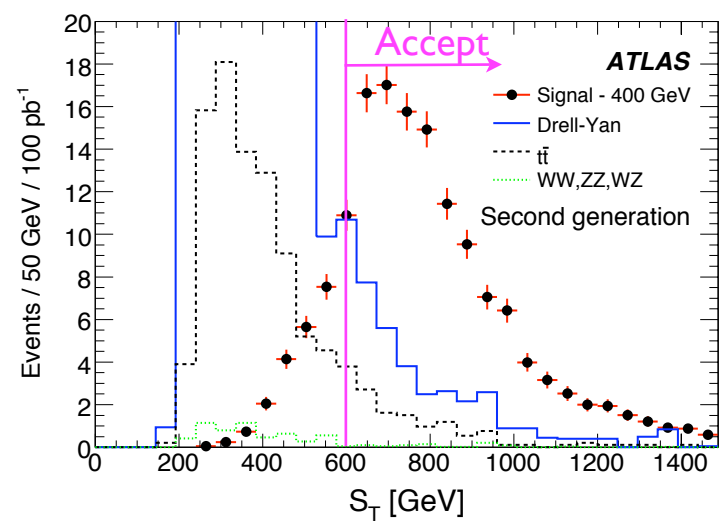
Final states studied:

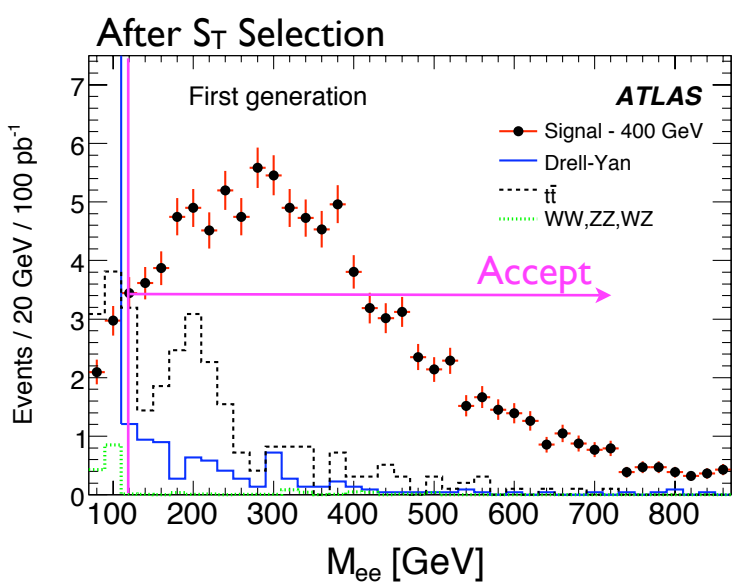
eejj → 1st generation

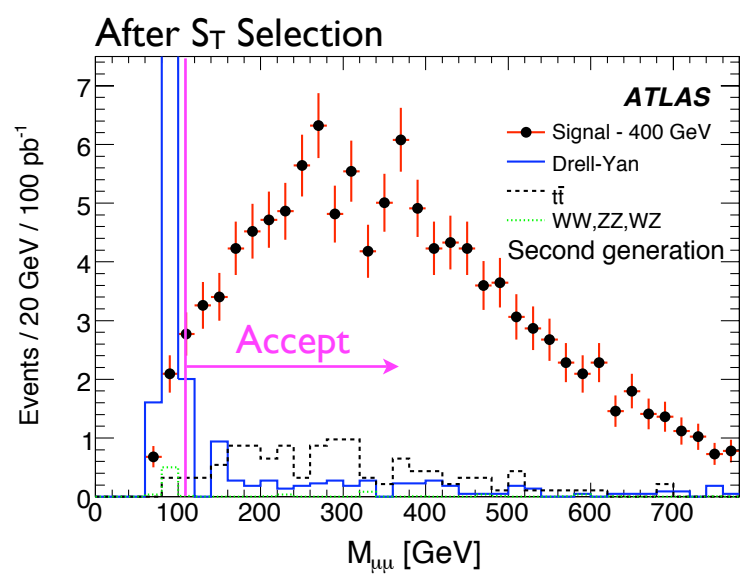
μμjj → 2nd generation

- High P_T final states → S_T
- Z^0 resonance → M_{ee}
- Variables optimized for discovery with minimal integrated luminosity



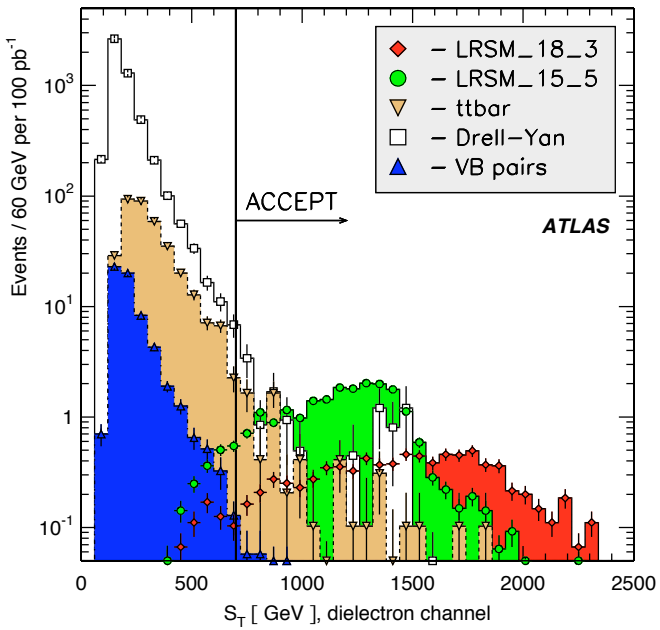


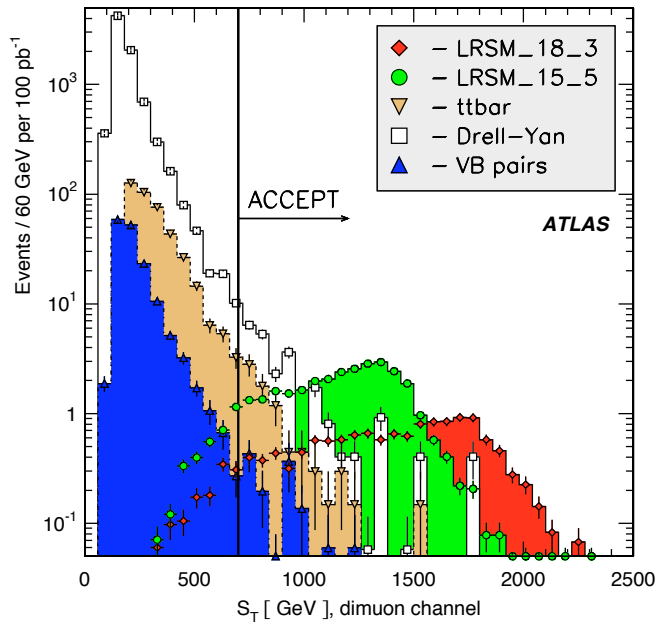




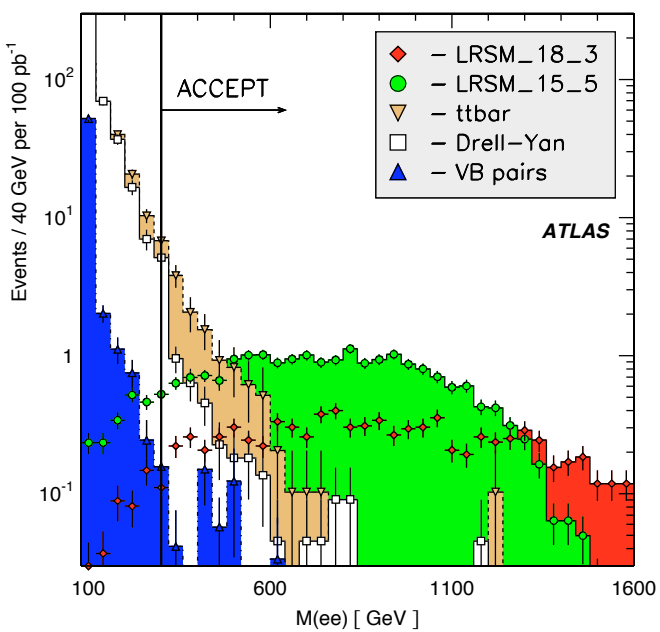
LRSM: Background Suppression

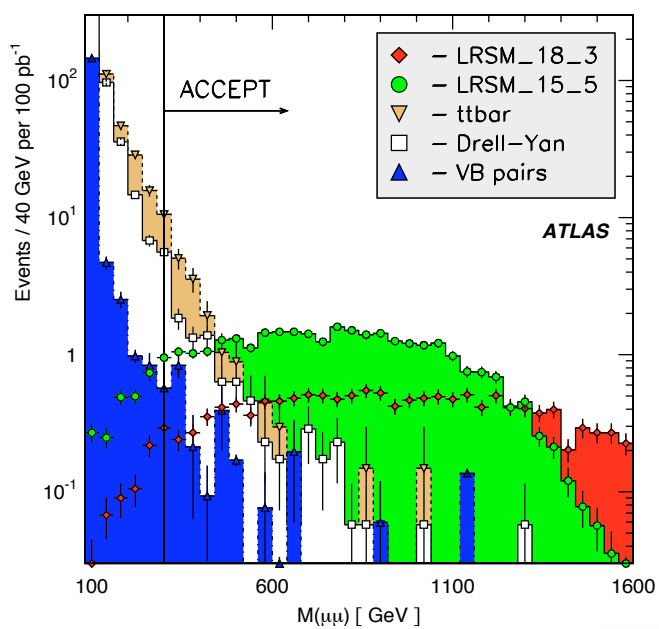
- High P_T final states
  → S_T > 700 GeV





- Drell-Yan →
  M_{ee} > 300 GeV





Scalar Leptoquarks Pair Production: Analysis

Partial cross-sections in (picobarns) that survive analysis selection criteria

1st generation

Physics sample	Before selection	Baseline selection	S_T $\geq$ 490 GeV	M_{ee} $\geq$ 120 GeV	M^1_{lj} - M^2_{lj} mass window [320-480] - [320-480] [GeV]
LQ (400 GeV)	2.24	1.12	1.07	1.00	0.534
Z/DY $\geq$ 60 GeV	1808.	49.77	0.722	0.0664	0.0036
$t\bar{t}$	450.	3.23	0.298	0.215	0.0144
VB pairs	60.94	0.583	0.0154	0.0036	0.00048
Multijet	10^8	20.51	0.229	0.184	0.0

2nd generation

Physics sample	Before selection	Baseline selection	$p_T^{\mu}\geq$60 GeV $p_T^{jet}\geq$25 GeV	S_T $\geq$ 600 GeV	$M(\mu\mu)$ $\geq$ 110 GeV	M_{lj} mass window [300 - 500] [GeV]
LQ (400 GeV)	2.24	1.70	1.53	1.27	1.23	0.974
Z/DY$\geq$60 GeV	1808.	79.99	2.975	0.338	0.0611	0.021
$t\bar{t}$	450.	4.17	0.698	0.0791	0.0758	0.0271
VB pairs	60.94	0.824	0.0628	0.00846	0.00308	0.00205
Multijet	10^8	0.0	0.0	0.0	0.0	0.0

W_R and Majorana Neutrinos: Analysis

Partial cross-sections in (picobarns) that survive analysis selection criteria

Dielectron channel

Physics sample	Before selection	Baseline selection	$M(ejj)$ $\geq$100 GeV	$M(eejj)$ $\geq$ 1000 GeV	$M(ee)$ $\geq$ 300 GeV	S_T $\geq$ 700 GeV
LRSM_18_3	0.248	0.0882	0.0882	0.0861	0.0828	0.0786
LRSM_15_5	0.470	0.220	0.220	0.215	0.196	0.184
Z/DY$\geq$60 GeV	1808.	49.77	43.36	0.801	0.0132	0.0064
$t\bar{t}$	450.	3.23	3.13	0.215	0.0422	0.0165
VB pairs	60.94	0.610	0.548	0.0163	0.0017	0.0002
Multijet	10^8	20.51	19.67	0.0490	0.0444	0.0444

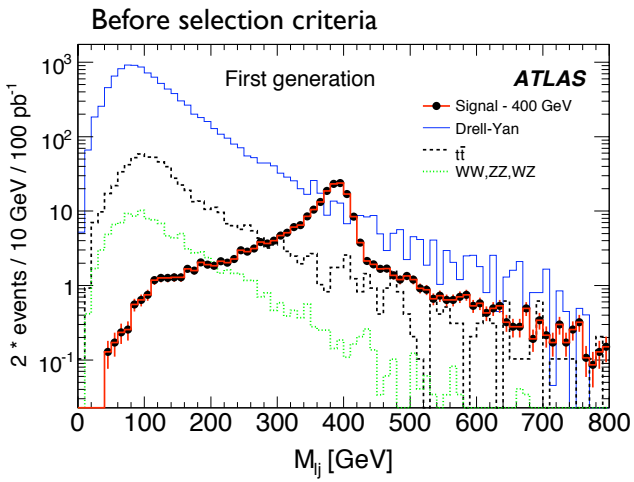
Dimuon channel

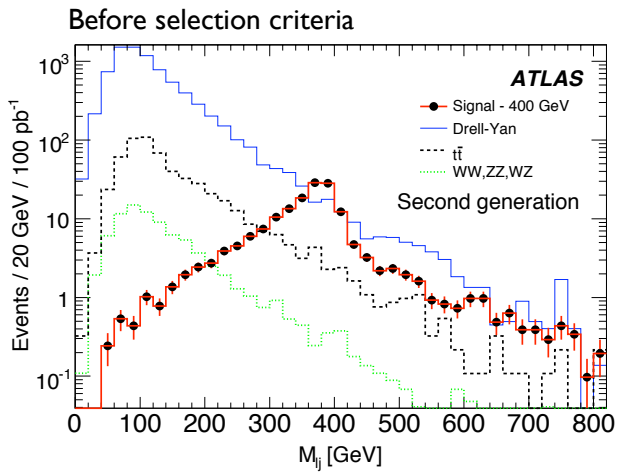
Physics sample	Before selection	Baseline selection	$M(\mu jj)$ $\geq$100 GeV	$M(\mu\mu jj)$ $\geq$ 1000 GeV	$M(\mu\mu)$ $\geq$ 300 GeV	S_T $\geq$ 700 GeV
LRSM_18_3	0.248	0.145	0.145	0.141	0.136	0.128
LRSM_15_5	0.470	0.328	0.328	0.319	0.295	0.274
Z/DY$\geq$60 GeV	1808.	80.02	69.13	1.46	0.0231	0.0127
$t\bar{t}$	450.	4.44	4.27	0.275	0.0527	0.0161
VB pairs	60.94	0.883	0.824	0.0257	0.0047	0.0015
Multijet	10^8	0.0	0.0	0.0	0.0	0.0

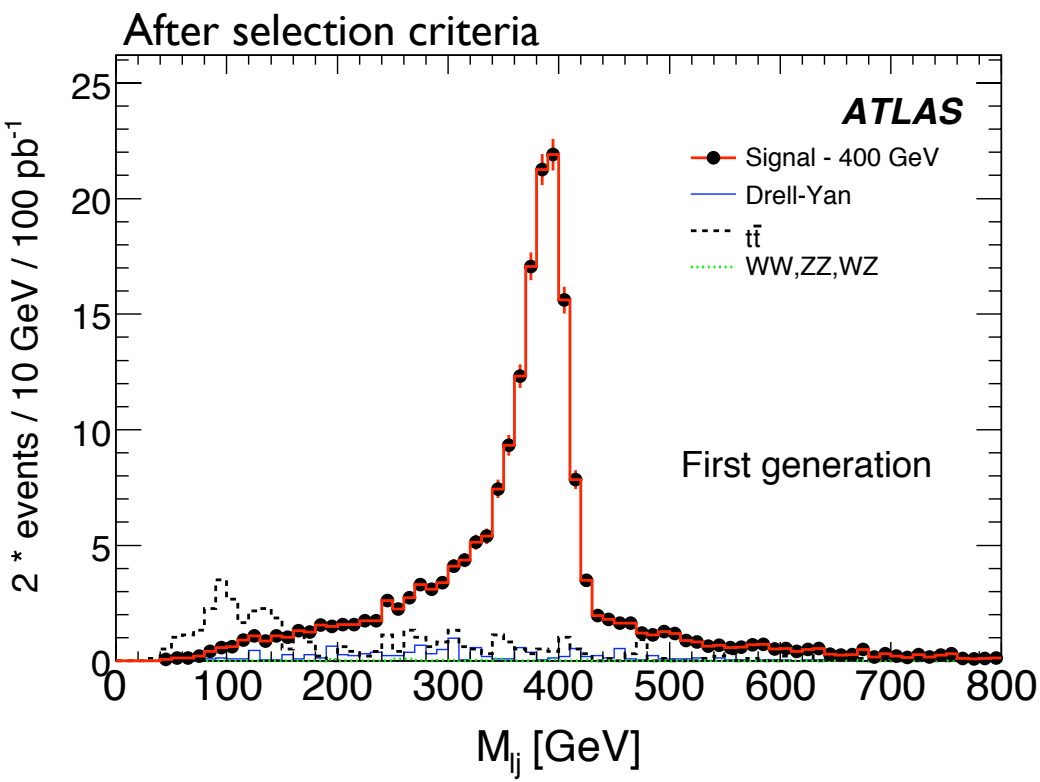
Leptoquarks: Reconstructed Invariant Mass Distribution

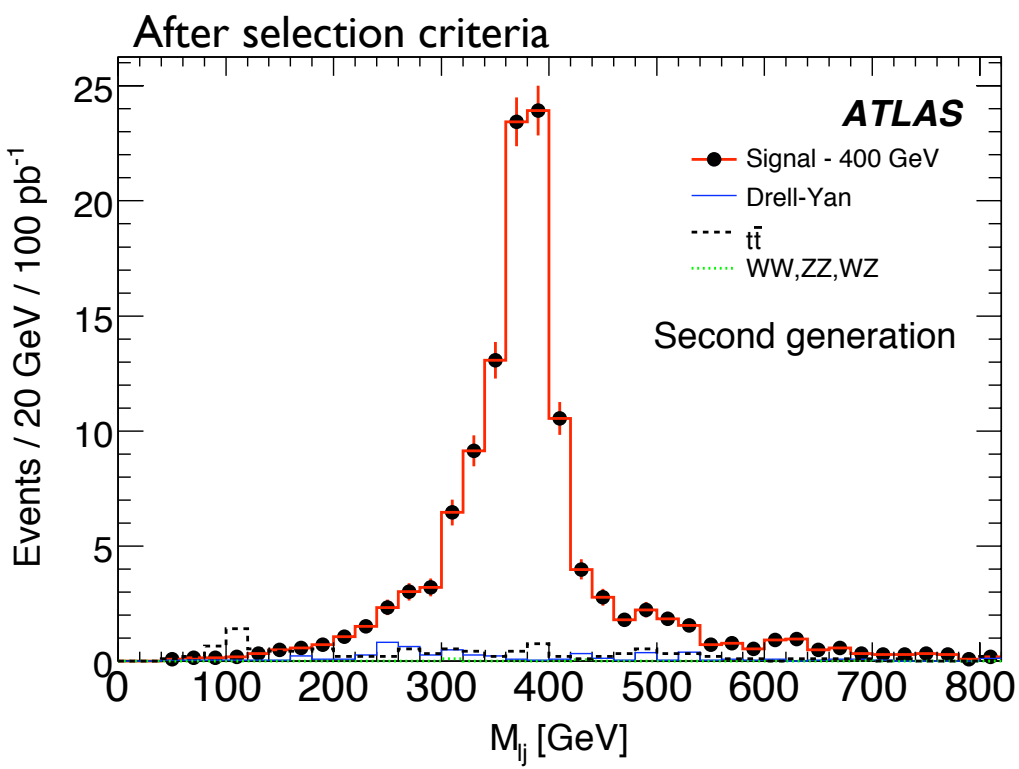
1st generation: Mass of each of two leptoquark candidates considered

2nd generation: Average mass of two leptoquark candidates considered





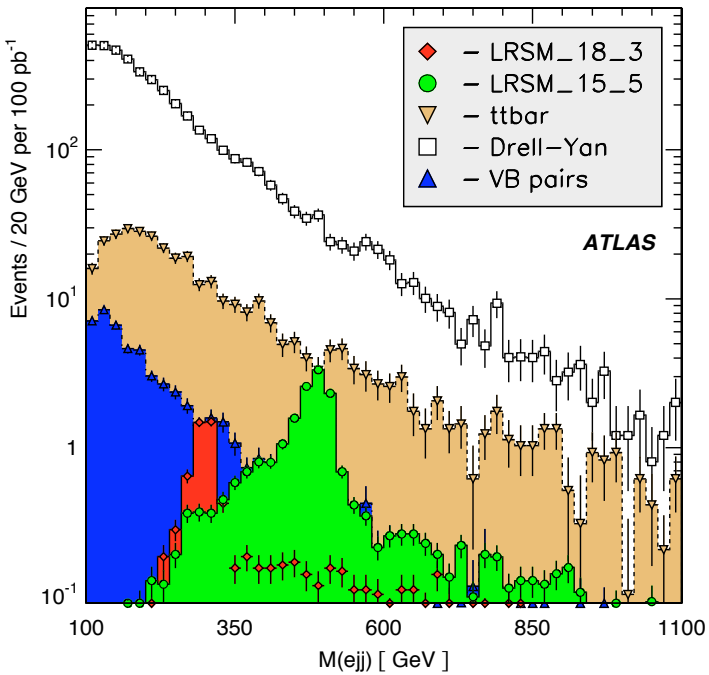


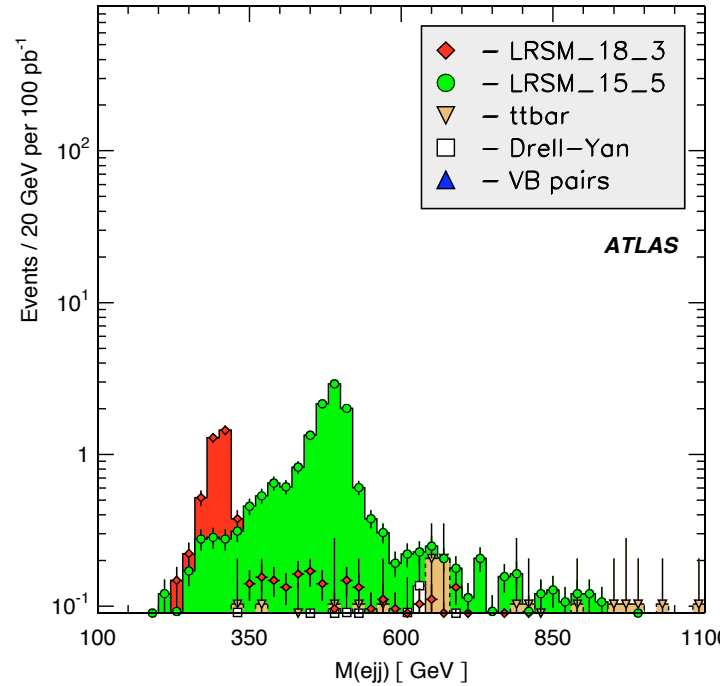


W_R Boson and Majorana Neutrino: Invariant Masses

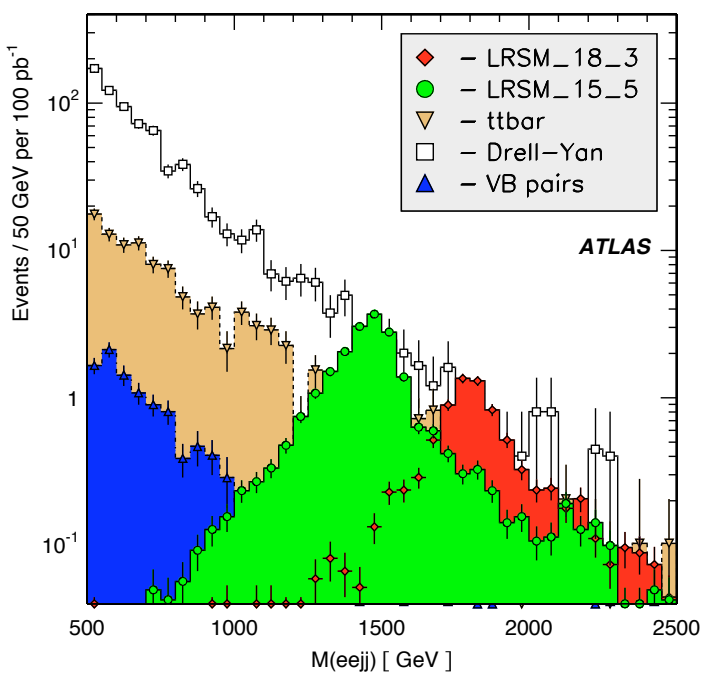
Dielectron Channel

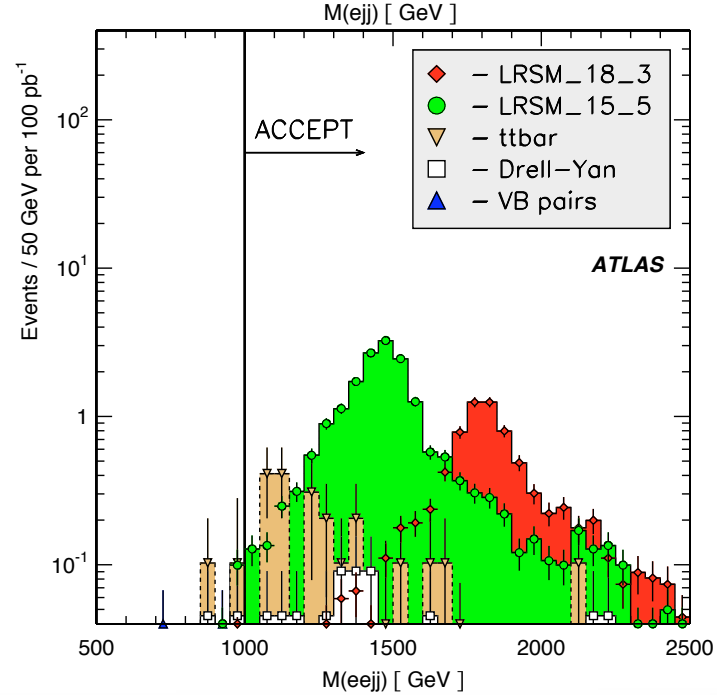
N_l (ejj)





W_R (eN_l)

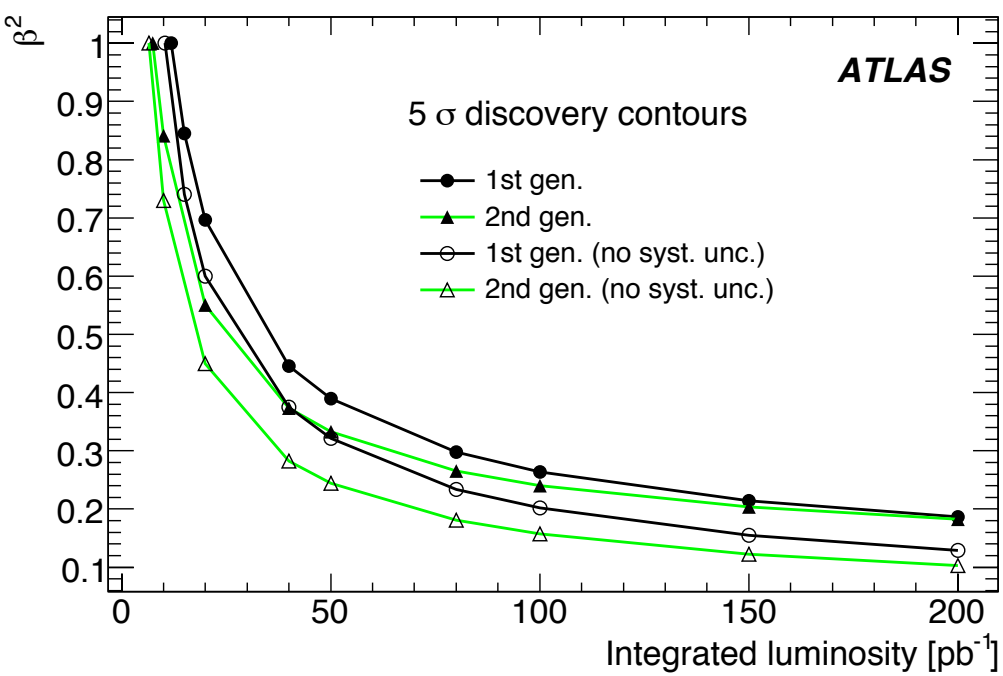




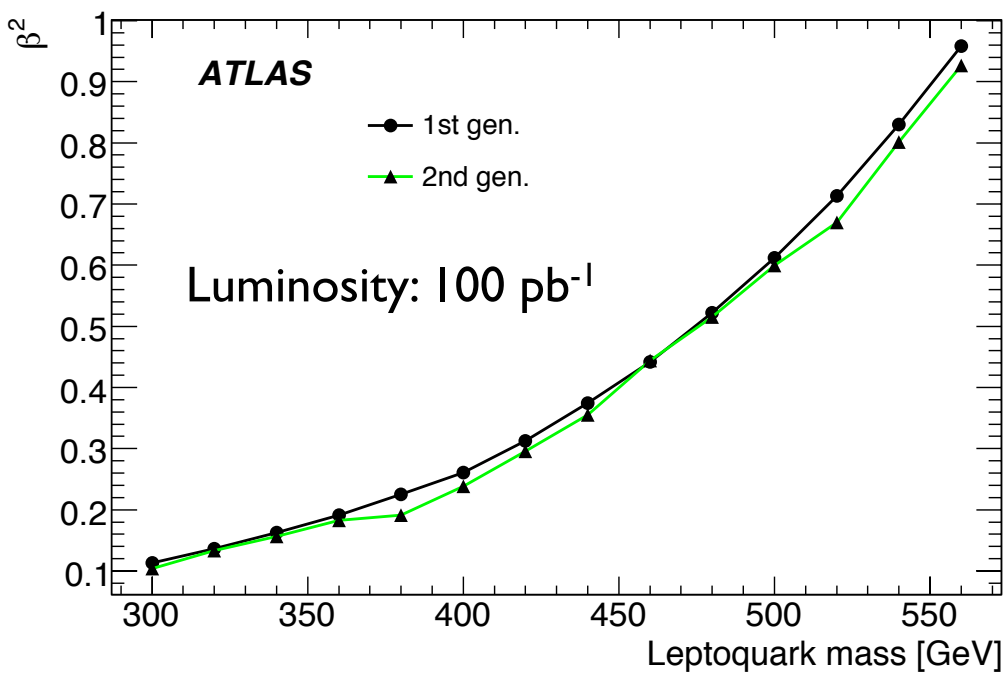
ATLAS Sensitivity to Leptoquarks

Trigger: High P_T lepton based, ~97% efficient

400 GeV leptoquark hypothesis discovery potential



Leptoquark mass reach

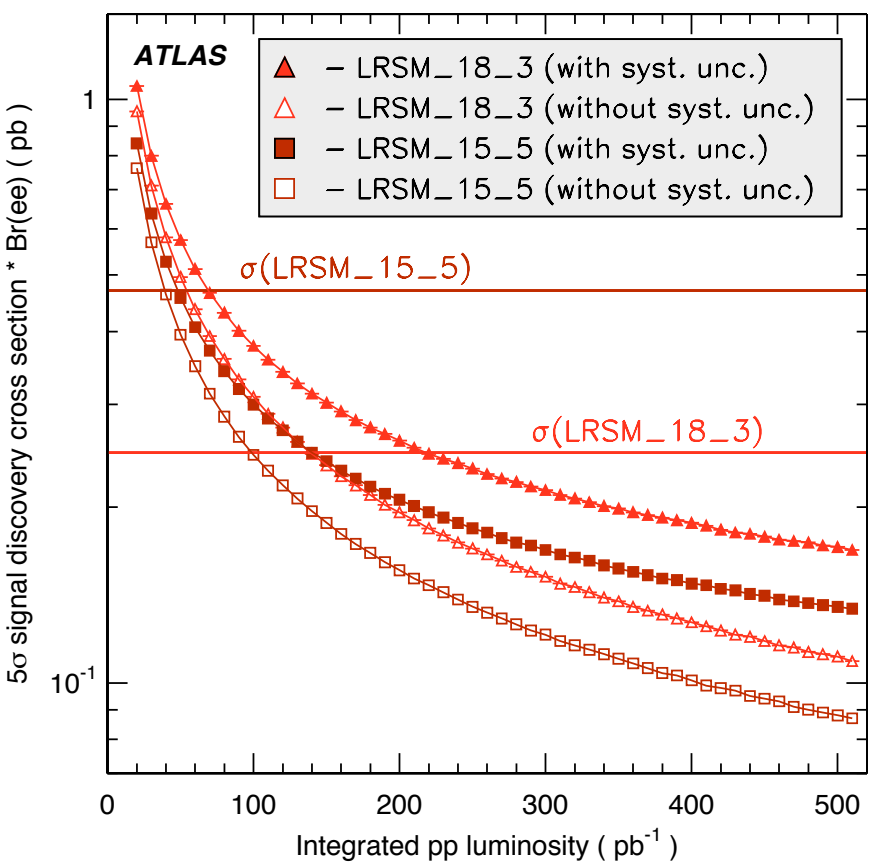


β is branching ratio of leptoquarks decaying into charged leptons

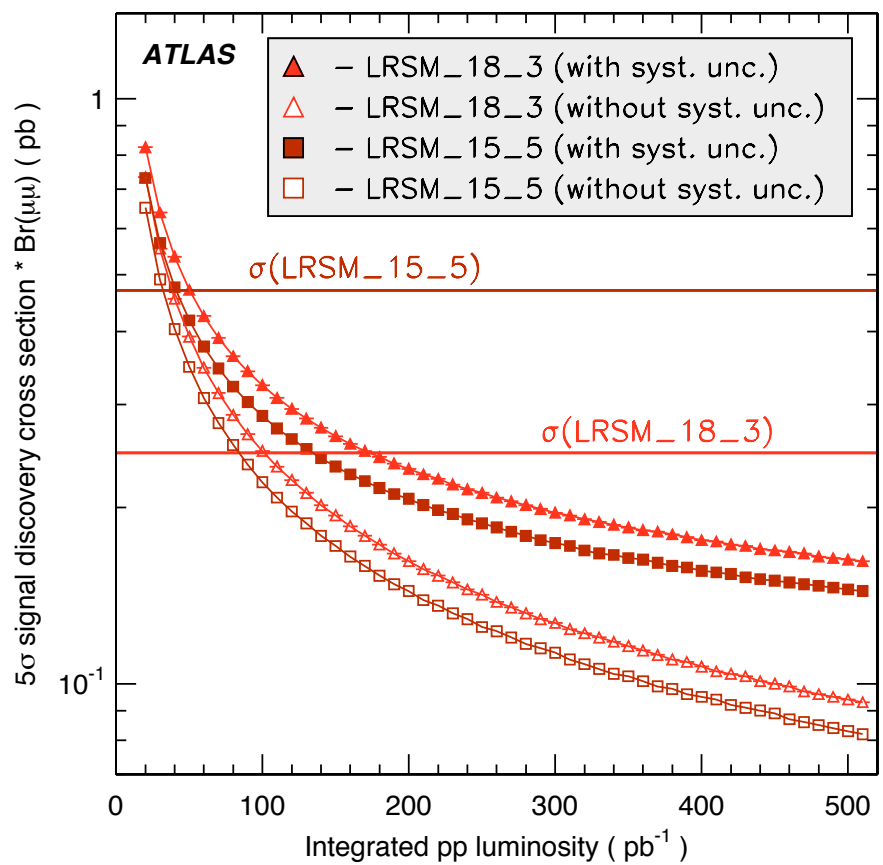
ATLAS Sensitivity to W_R and Majorana Neutrinos

Trigger: High P_T lepton based, ~96% efficient

Dielectron Channel



Dimuon Channel



Summary and Outlook

- Final states with dileptons and jets that can be used to search for important predictions of BSM models.
- ATLAS has an excellent sensitivity to leptoquarks, heavy Majorana neutrinos and right-handed W boson in the studied range of invariant masses with early LHC data.
- Look forward to early pp collisions at the LHC.

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