Searches for W'/Z' and W*/Z* and new contact interactions in di-lepton final states with ATLAS

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ATLAS Collaboration

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Layout:

- **Introduction**
- **Object definition**

Search for:

- **Lepton + E_T^{miss}** arXiv:1103.1391
- **Dilepton Resonant** arXiv:1103.6218
- **Dimuon Non resonant** arXiv:1104.4398
  (Contact interactions)

Introduction: Motivation

Heavy gauge bosons are expected in several Beyond Standard Model (BSM) theories

Models studied here

- SSM W', Z'

SM-like couplings
Width linearly increasing with mass
Decays to WZ, or non-SM fermions suppressed
Pre-LHC Limits: W':1.12 TeV, Z' :1.071 TeV,
CDF: arXiv:1012.5145v1
D0:Phys.Lett.B695 88(2011)
CDF:Phys.Rev.Lett.106,121801 (2011)
Recent CMS Limits: W':1.58 TeV, Z' :1.14 TeV
arXiv:1103.0030, arXiv:1103.0981

- GUT E_6 inspired Z'

- W*, Z*

Different kinematics
Anomalous (magnetic moment type) couplings
Total W* (Z*) width equal to W'_{SSM} (Z'_{SSM})

- Contact Interactions

(Non-resonant di-muon production)
Effective Lagrangian:

$$\mathcal{L} = \frac{g^2}{2\Lambda^2}\,[\;\; \eta_{LL}\;\bar{\psi}_L\gamma_\mu\psi_L\,\bar{\psi}_L\gamma^\mu\psi_L + \eta_{RR}\;\bar{\psi}_R\gamma_\mu\psi_R\,\bar{\psi}_R\gamma^\mu\psi_R + 2\eta_{LR}\,\bar{\psi}_L\gamma_\mu\psi_L\,\bar{\psi}_R\gamma^\mu\psi_R\;]$$

Left-Left Isoscalar Model (**LLIM**):
$\eta_{LL}=\pm 1$, $\eta_{LR}=\eta_{RR}=0$

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

Pre-LHC Limits: $\Lambda^- > 4.2$ TeV, $\Lambda^+ > 2.9$ TeV
CDF: Phys.Rev.Lett.79, 2198 (1997)

Introduction: Signatures and backgrounds

Decay channel: ***W'→l ν*, with *l* = *e* or *μ***

Discriminant Variable: m_T

Backgrounds:
W → l ν *(irreducible)*
Drell-Yan, ttbar, diboson
QCD multi-jet, Cosmic rays (from data)

Decay channel: ***Z'→l⁺l⁻*, with *l* = *e* or *μ***

Discriminant Variable: m_{ll}

Backgrounds:
Drell-Yan *(irreducible)*
W+jets, diboson
ttbar (cross checked with data)
QCD multi-jet, Cosmic rays (from data)

Backgrounds from MC

Process	Order	σ B [pb]
W-> l ν	NNLO	10460
Z/γ -> l l* (m_{ll} > 60 GeV)	NNLO	989
t tbar -> l X	Near-NNLO	89.4

Mass dependent k-factors are applied in the following

Backgrounds estimated from data

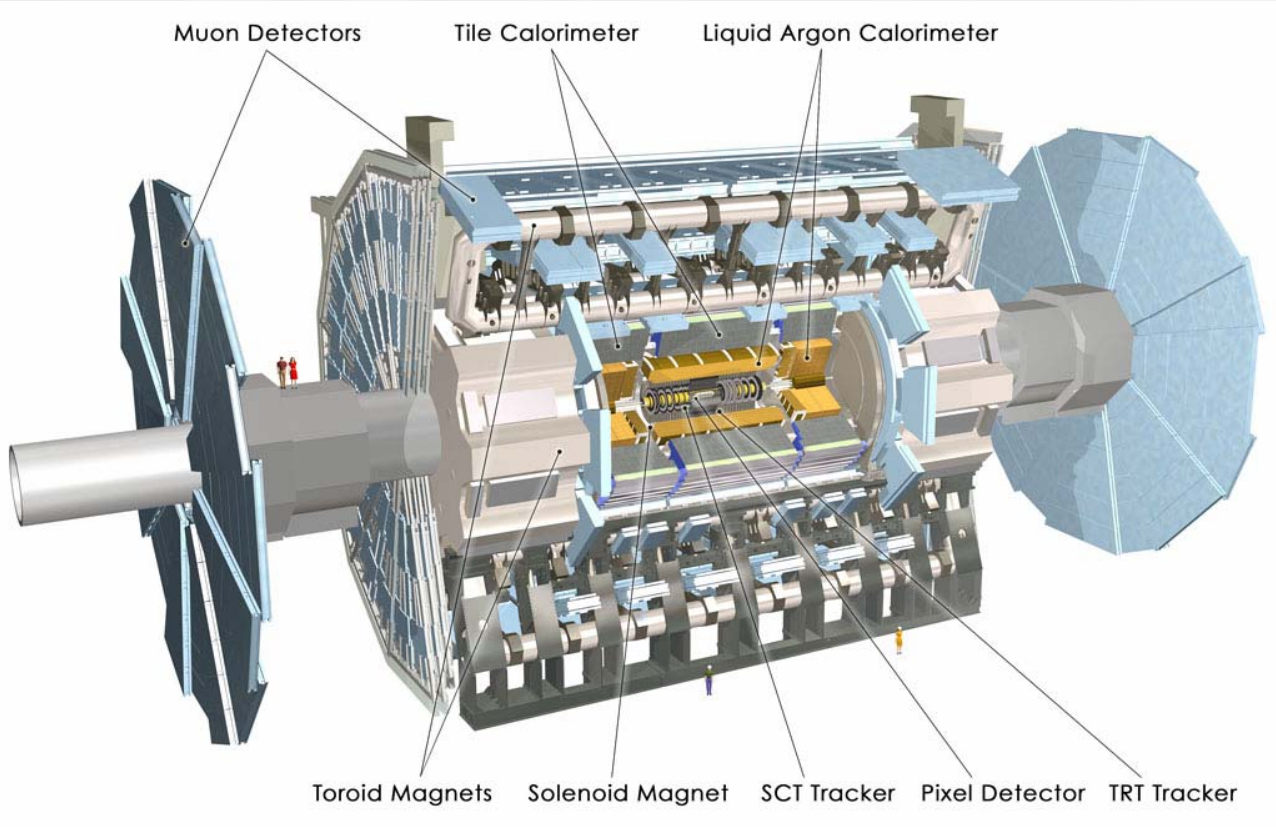
- ttbar:
  Use of e-μ pairs
- QCD:
  Use of several methods for electrons or isolation criteria for muons
- Cosmic ray events:
  Use of impact parameter criteria

Introduction: The ATLAS Detector

Inner Detector (ID)
Silicon pixel, strips $|\eta|<2.5$
TRT $|\eta|<2.0$
Solenoid magnetic field 2T

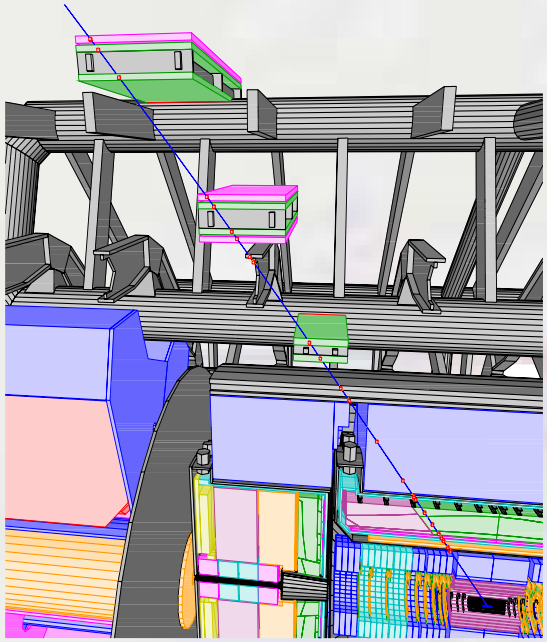
Calorimeters $|\eta|<4.9$
EL Liquid Argon
BHAD Tile $|\eta|<1.7$
EHAD Liquid Argon

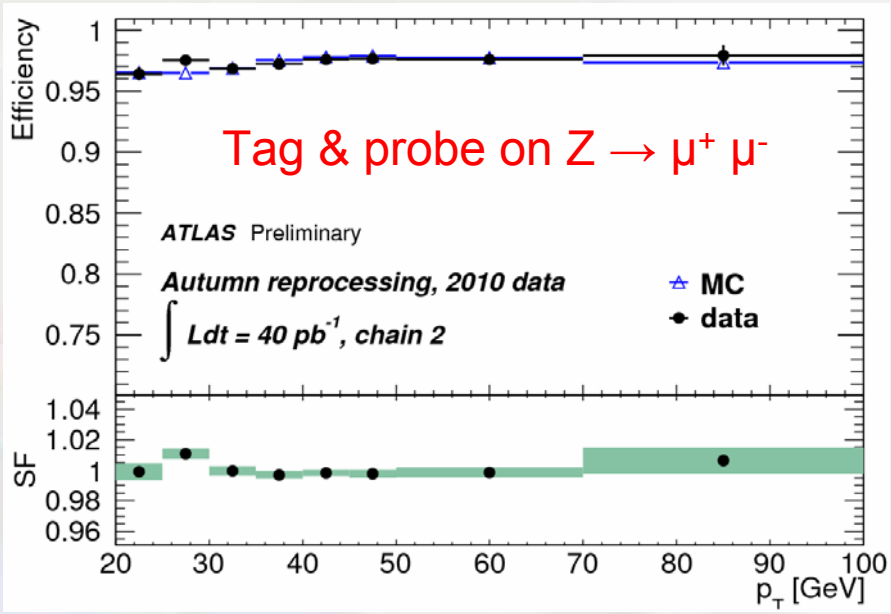
Muon Spectometer (MS)
Precision MDT, CSC $|\eta|<2.7$
Trigger RPC, TGC $|\eta|<2.4$
Air core Toroids
Field integral ~3Tm

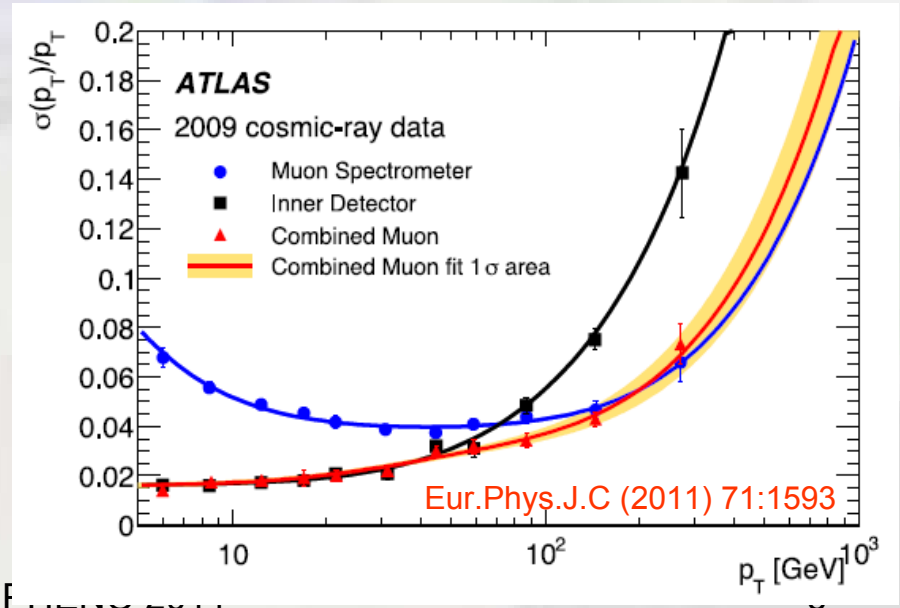


~40 pb^{-1} of data collected in 2010

Object definition: Muon reconstruction / identification







Muon Definition

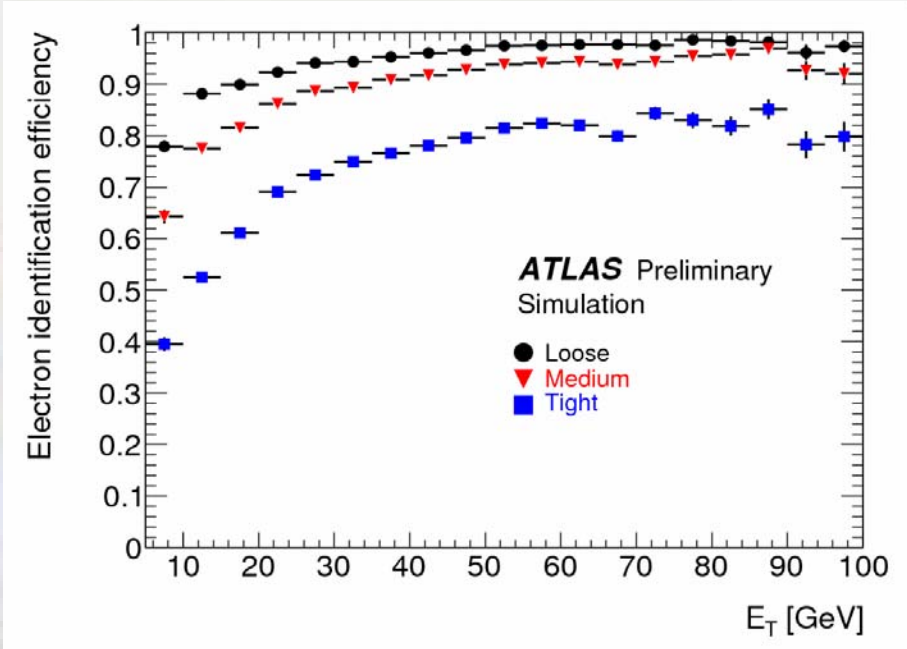
- Combined muon
- p_T > 20 GeV, |η|<2.4
- ID hits requirement
- **MS 3 precision hits in each layer**
- MS phi hit(s)

Object definition: Electron, E_T^{miss} reconstruction (identification)

Electron Definition

- EL cluster E_T> 20 GeV, |η|<2.47+ track
- EL Shower shapes + HAD leakage
- "Medium" selection
- Drop of readout problematic cells (8%)
- Hit in 1st Pixel Layer

Efficiency = 89%, Jet fakes < 1/5000



Missing E_T Definition

- Topological clusters, local calibration

e $E_T^{miss} = E_{Tcalo}^{miss} = -\sum_{topo} E_T^{cluster}$

μ $E_T^{miss} = E_{Tcalo}^{miss} - p_T^{\mu} + E_T^{\mu loss}$

Search lepton + E_T^{miss}: Event Selection

Common Selection Requirements:

- Single lepton trigger (thr. 10-20 GeV)
- Good Run Quality **(L ~ 36 pb^{-1})**
- Primary vertex 3 tracks, |z|<150 mm
- Exactly one lepton with p_T>25 GeV
- Corresp. ID track $|d_0|$<1 mm, $|z_0|$<5 mm
- E_T^{miss} > 25 GeV

Electron channel specific selection

- Calorimeter Isolation

$$\sum_{\Delta R=0.4} E_T < 10\ GeV$$

- E_T^{miss} > 0.6 E_T^e

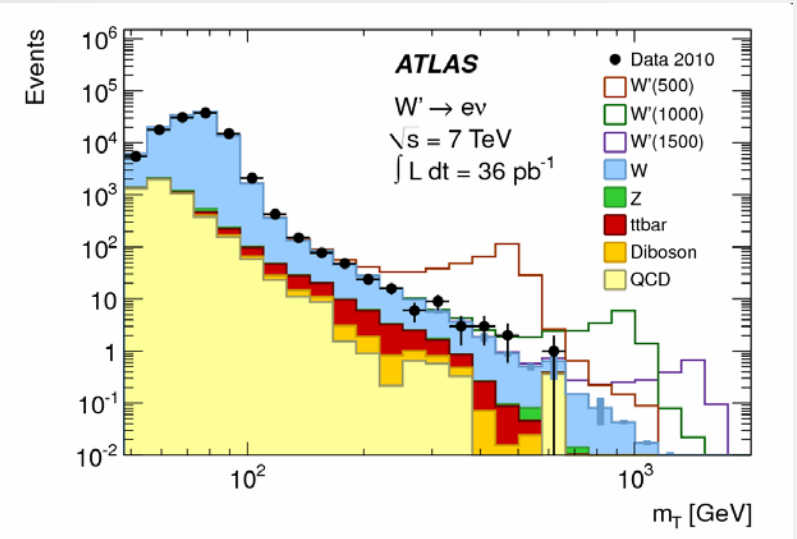
(Signal efficiency 48-56 %)

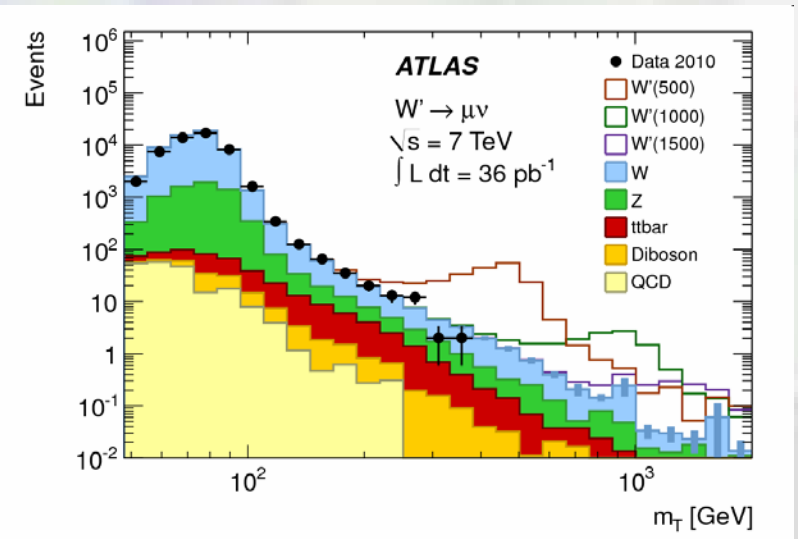
Muon channel specific selection

- Barrel muons |η| < 1.05
- Normalized Track Isolation

$$\sum_{\Delta R=0.3} p_T^{trk} < 0.05\ p_T^{\mu}$$

(Signal efficiency 25-39%)





Search lepton + E_T^{miss}: Results

Systematic Uncertainties

Luminosity 11% (for these results)

Signal Efficiency

Electron channel 5.3% (Rec/Id efficiency, isolation)

Muon channel 3.0% (Rec/Id efficiency)

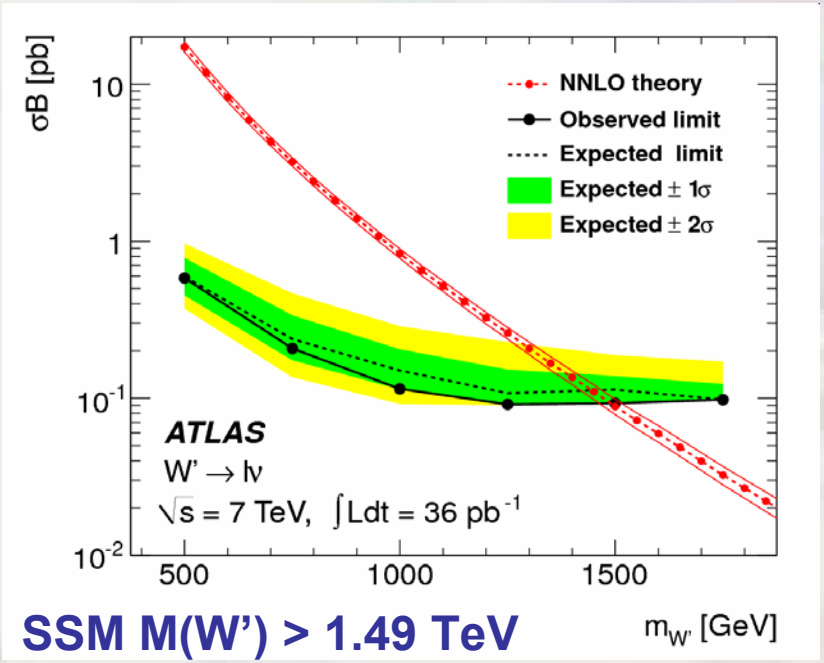
Background rate

Electron channel 12.6% (theory, energy scale)

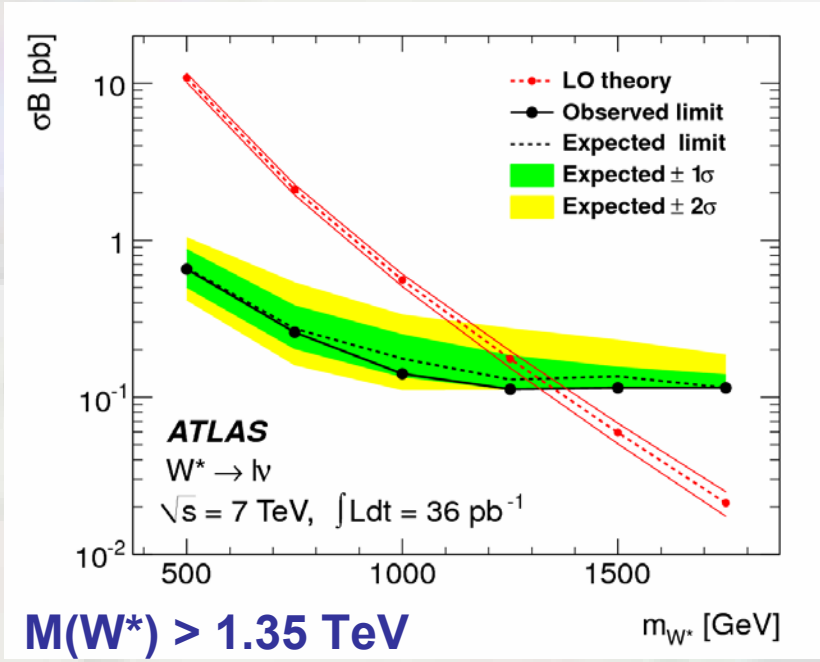
Muon channel 20.7% (MC stat, theory, resolution)

Limit estimation procedure:

- CLs method
- Counting Exp. with m_T>0.5 m(W'*)
- Uncertainty on luminosity correlated



SSM M(W') > 1.49 TeV



M(W*) > 1.35 TeV

Search dilepton: Event Selection

Common Selection Requirements:

- Single lepton trigger (thr. 10-20 GeV)
- Good Run Quality **(L ~ 39 - 42 pb^{-1})**
- Primary vertex
- Two leptons with p_T>25 GeV
- m_{ll} > 70 GeV

Electron channel

Signal efficiency: ~60% @ 1TeV

3 events with mass ~ 600 GeV
correspond to a p-value of 5%
(for background only hypothesis)

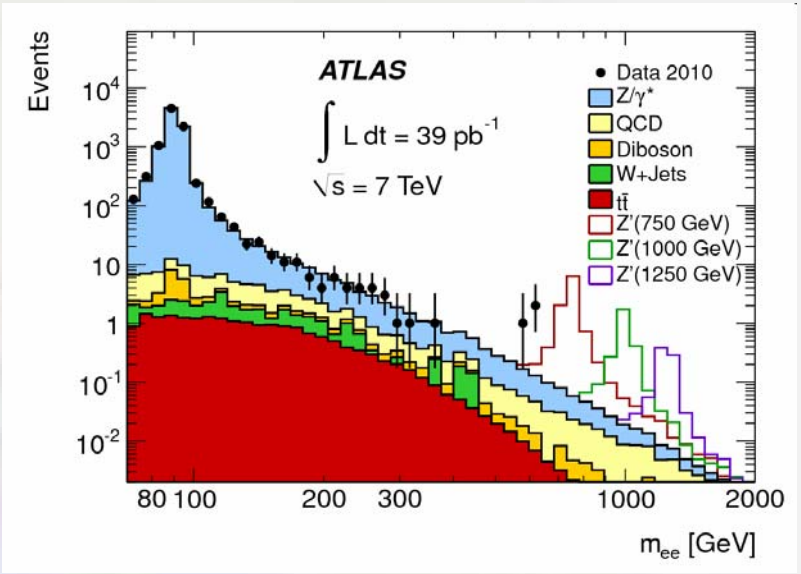
Muon channel specific selection

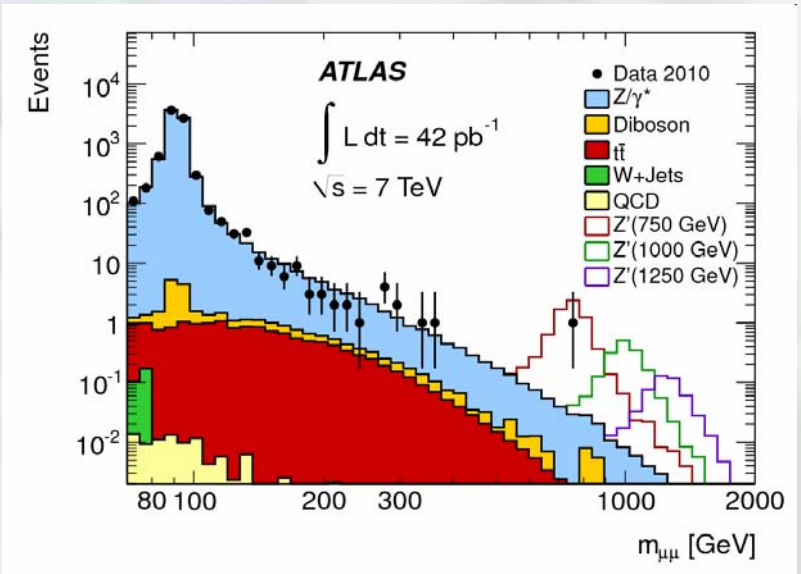
- Opposite charge
- Normalized Track Isolation
- $|d_0|$<0.2 mm, $|z_0|$<1 mm

Signal efficiency: ~40% @ 1TeV

1 event with mass 768 GeV
corresponds to a p-value of 22%
(for background only hypothesis)

No significant excess is observed





Search dilepton (resonant): Results

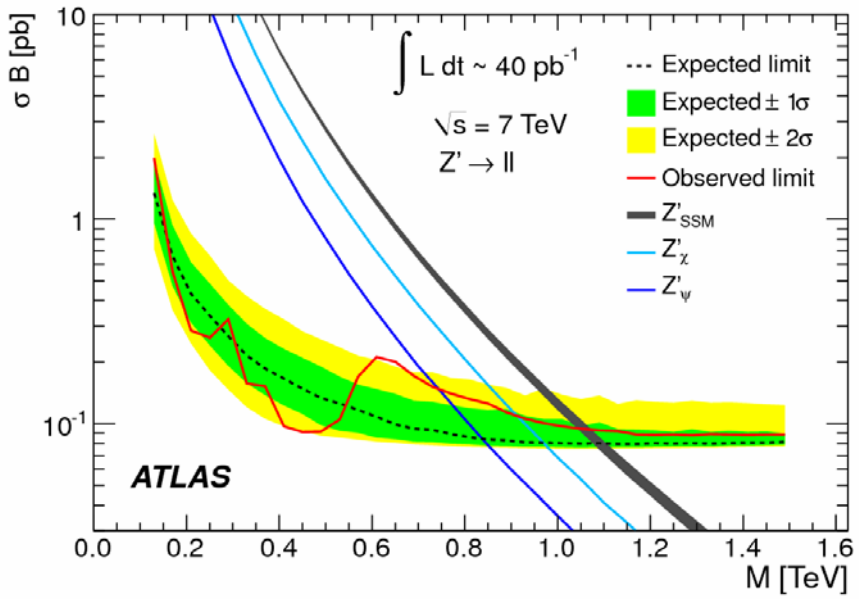
In both channels MC is normalized to the data in the mass interval 70<mll<110 GeV
(mass independent systematics cancel)

Limit estimation procedure:

- **Bayesian**
- **Template method**

Main Systematic Uncertainties

Source	dielectrons		dimuons	
	signal	background	signal	background
Normalization	5%	5%	5%	5%
PDFs	6%	6%	6%	6%
QCD K-factor	3%	3%	3%	3%
Weak K-factor	NA	4.5%	NA	4.5%
Efficiency	-	-	3%	3%
Resolution	-	-	3%	3%
Total	8.4%	9.5%	9.4%	10.4%

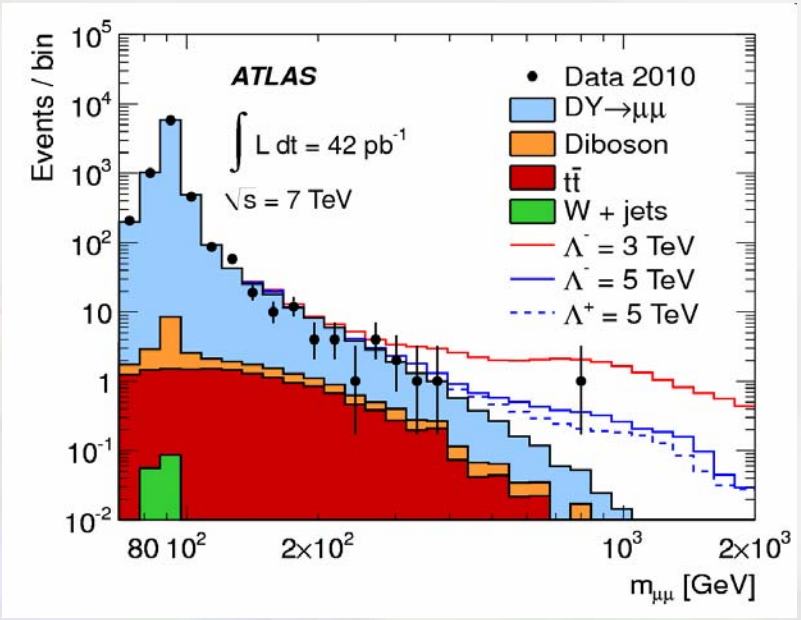


SSM M(Z') > 1.048 TeV
E6 model inspired
$M(Z'_{\psi}) > 0.738$ TeV, $M(Z'_{\chi}) > 0.900$ TeV

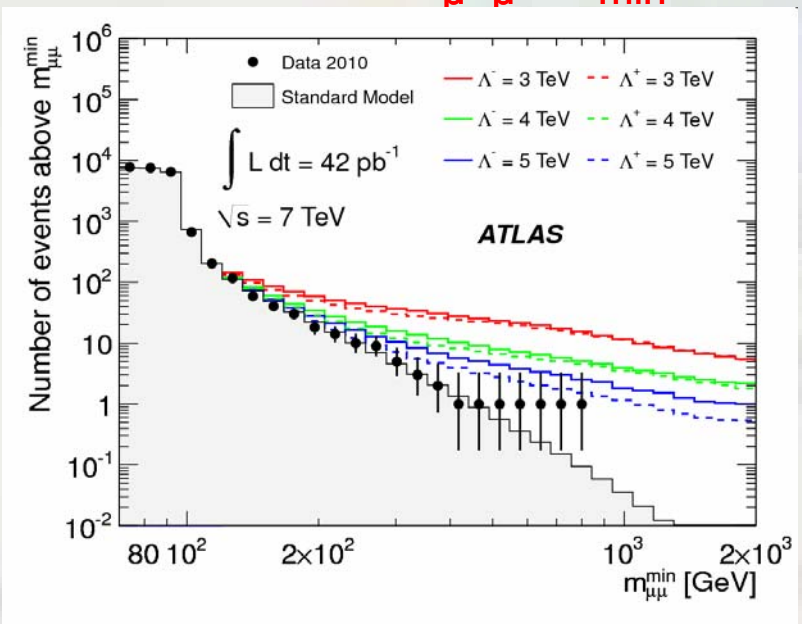
Search dilepton (non-resonant): Results

Event selection
As in dimuon resonant search

Data consistent with expectation
Binned likelihood fit on pseudo-experiments (SM only hypothesis)
56% have higher deviation than data



Events with $m_{\mu^+\mu^-} > m_{min}$



Limit estimation procedure:

- **Bayesian with flat prior in $1/\Lambda^2$**
- **Binned dimuon mass**

$\Lambda^- > 4.9$ TeV
$\Lambda^+ > 4.5$ TeV

Summary

A search for high mass dilepton final states has been performed with the ~ 40 pb^{-1} of data collected by the ATLAS detector in 2010

No significant deviations from the SM expectations are observed

95% CL limits are imposed on σxBR on the production of resonant states

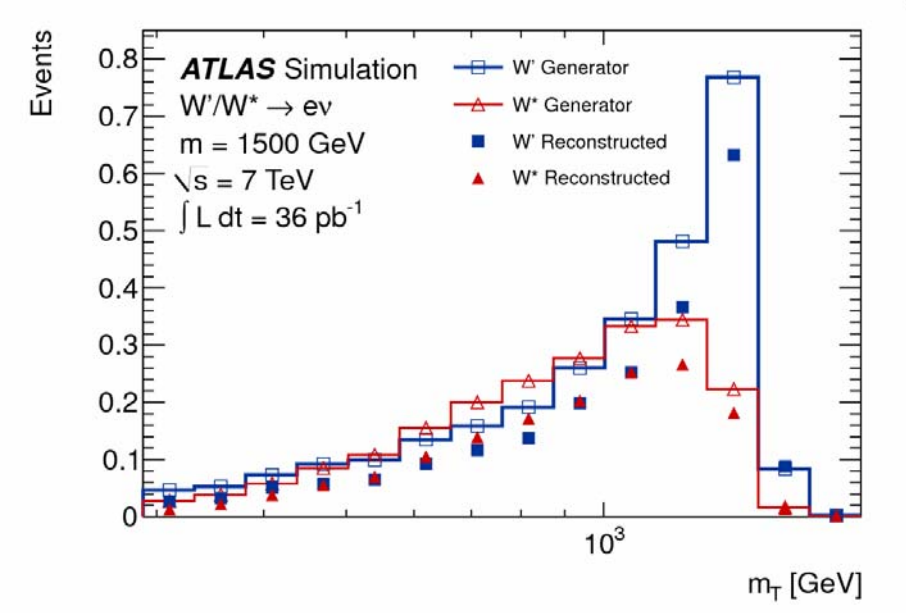
The high centre of mass energy provided by LHC has resulted in considerable improvement of the limits on SSM W' consistent with the CMS results

Limits on W*, Z* are the most stringent limits to date

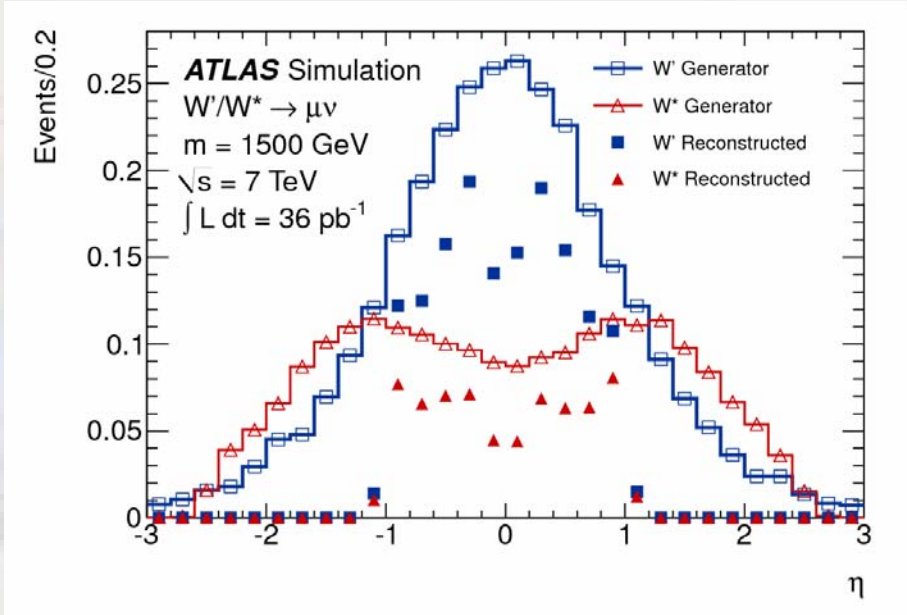
The dimuon mass spectrum is interpreted in the LLIM model providing the most stringent limits to date on Λ for μμqq contact interactions

Additional slides

Introduction: Examples of kinematic differences of W' and W*



Transverse mass



Pseudorapidity

Introduction: MC samples

W′, Z’	Pythia 6.421 with MRST LO*
DY+CI	Pythia 6.421 with MRST LO*
W*,Z*	CompHEP with CTEQ
W, Z ds	Pythia 6.421 with MRST LO*
W+jets	Alpgen with CTEQ
ttbar	MC@NLO 3.41 with CTEQ
Diboson	Herwig 6.510 with MRST LO*

For all samples, final-state photon radiation is handled by Photos

W,W’	Mass dependent NNLO K-factors FEWZ with MSTW2008 PDFs
Z, Z’	Mass dependent NNLO K-factors PHOZPR with MSTW2008 PDFs
W, Z	Higher-order electroweak corrections Horace (beyond the photon radiation included in the simulation)

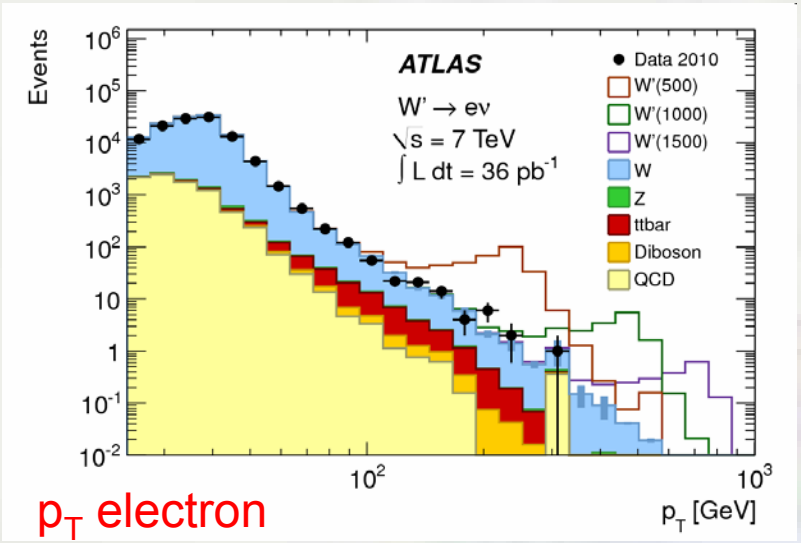
Search lepton + E_T^{miss}: Selection

Expected and observed events

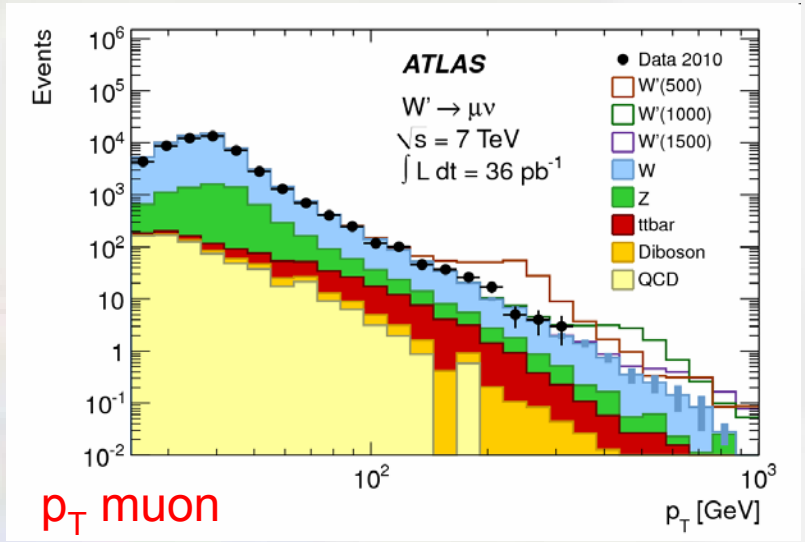
m [GeV]	decay	ε_{sig} W'	ε_{sig} W^*	N_{sig} W'	N_{sig} W^*	N_{bg}	N_{obs}
500	$e\nu$	0.556 ± 0.024	0.530 ± 0.022	349 ± 30	208 ± 18	21.5 ± 2.0	24
	$\mu\nu$	0.339 ± 0.008	0.265 ± 0.005	212 ± 17	104 ± 8	20.3 ± 1.1	16
750	$e\nu$	0.565 ± 0.025	0.520 ± 0.022	65.8 ± 4.8	39.6 ± 3.5	4.05 ± 0.35	6
	$\mu\nu$	0.362 ± 0.009	0.257 ± 0.005	42.1 ± 2.7	19.6 ± 1.5	5.48 ± 0.44	0
1000	$e\nu$	0.562 ± 0.025	0.516 ± 0.022	17.1 ± 1.4	10.5 ± 1.0	1.11 ± 0.11	1
	$\mu\nu$	0.381 ± 0.010	0.264 ± 0.006	11.6 ± 0.9	5.4 ± 0.5	2.05 ± 0.25	0
1250	$e\nu$	0.552 ± 0.026	0.505 ± 0.023	5.23 ± 0.51	3.22 ± 0.42	0.400 ± 0.054	0
	$\mu\nu$	0.386 ± 0.011	0.255 ± 0.006	3.66 ± 0.33	1.63 ± 0.20	1.01 ± 0.17	0
1500	$e\nu$	0.530 ± 0.028	0.488 ± 0.025	1.71 ± 0.21	1.06 ± 0.17	0.159 ± 0.020	0
	$\mu\nu$	0.383 ± 0.012	0.252 ± 0.006	1.24 ± 0.14	0.54 ± 0.08	0.62 ± 0.13	0
1750	$e\nu$	0.503 ± 0.027	0.482 ± 0.028	0.59 ± 0.09	0.37 ± 0.07	0.069 ± 0.009	0
	$\mu\nu$	0.360 ± 0.012	0.254 ± 0.007	0.43 ± 0.06	0.20 ± 0.04	0.47 ± 0.09	0

Table 4: Inputs for the $W'/W^* \to \ell\nu$ σB limit calculations for an integrated luminosity of 36 pb^{-1}. The first two columns are the W'/W^* mass and decay mode. The next four are the corrected signal selection efficiency, ε_{sig}, and the prediction for the number of signal events, N_{sig}, obtained with this efficiency. The last two columns are the expected number of background events, N_{bg}, and the number of events observed in data, N_{obs}. The uncertainties for N_{sig} and N_{bg} include contributions from the uncertainties in the cross sections but not from the integrated luminosity.

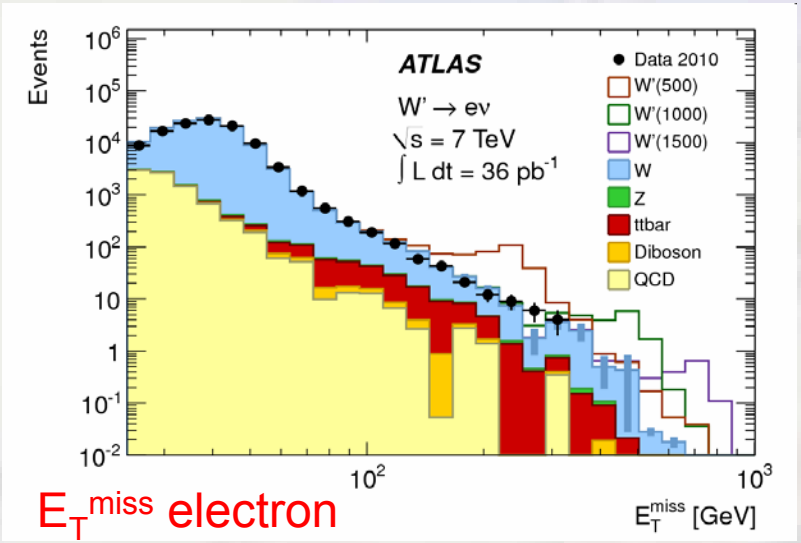
Search lepton + E_T^{miss}: Selection



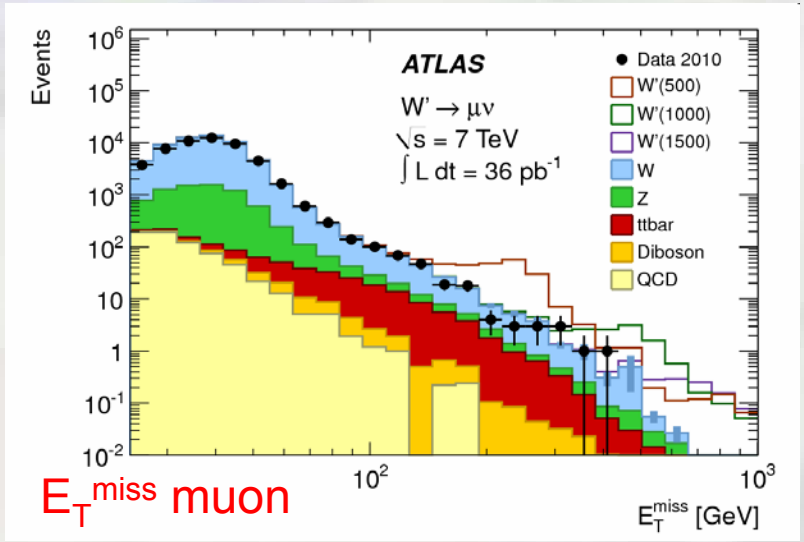
p_T electron



p_T muon



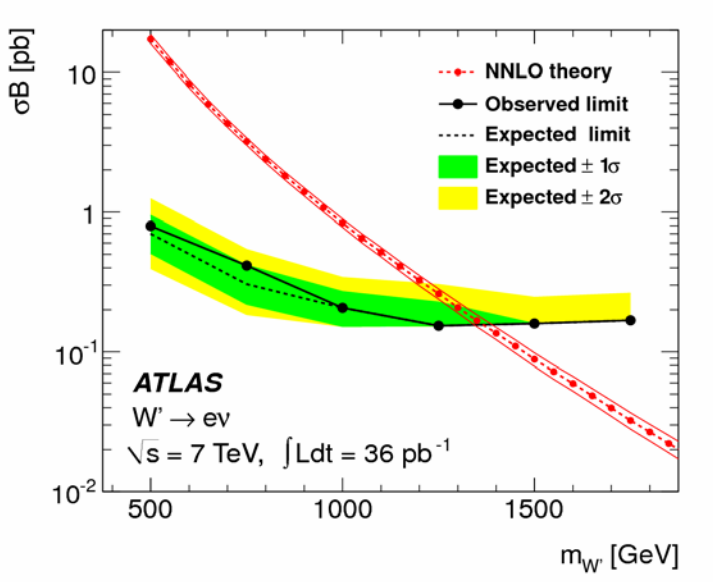
E_T^{miss} electron

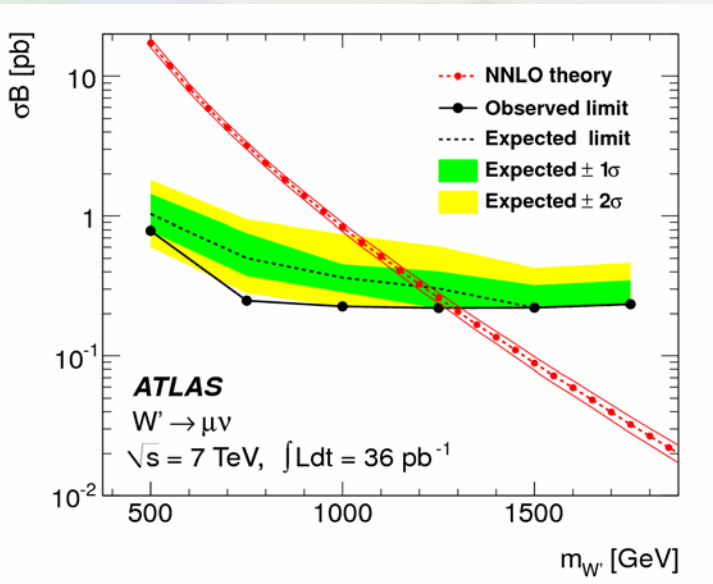


E_T^{miss} muon

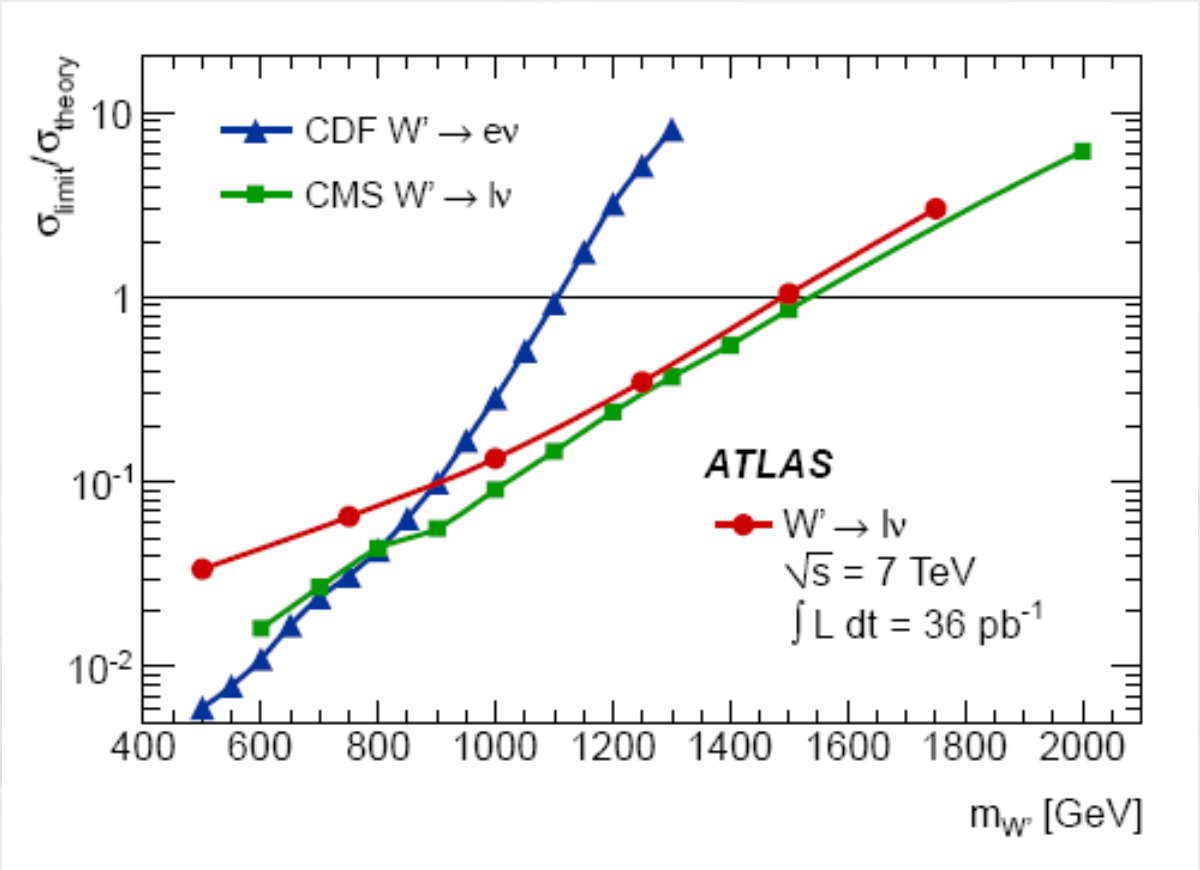
Search lepton + E_T^{miss}: Results

mass [GeV]		95% CL limit on σB [fb] W' none	S	SB	SBL	W^* none	SBL
500	$e\nu$	647	649	682	795	679	834
	$\mu\nu$	625	625	640	786	799	1005
	both	413	416	444	583	473	655
750	$e\nu$	390	391	393	416	423	452
	$\mu\nu$	227	228	228	248	320	350
	both	186	184	188	208	232	259
1000	$e\nu$	199	200	200	207	217	225
	$\mu\nu$	216	216	216	226	320	326
	both	108	109	109	115	133	141
1250	$e\nu$	149	150	150	153	163	167
	$\mu\nu$	213	214	213	220	323	333
	both	88	88	88	91	108	112
1500	$e\nu$	155	156	156	159	169	173
	$\mu\nu$	215	215	215	221	327	336
	both	90	90	90	93	111	115
1750	$e\nu$	164	163	164	168	171	175
	$\mu\nu$	229	229	229	235	324	332
	both	95	96	96	98	112	115





Search lepton + E_T^{miss}: Comparison with CDF and CMS results



Search dilepton (resonant): Selection

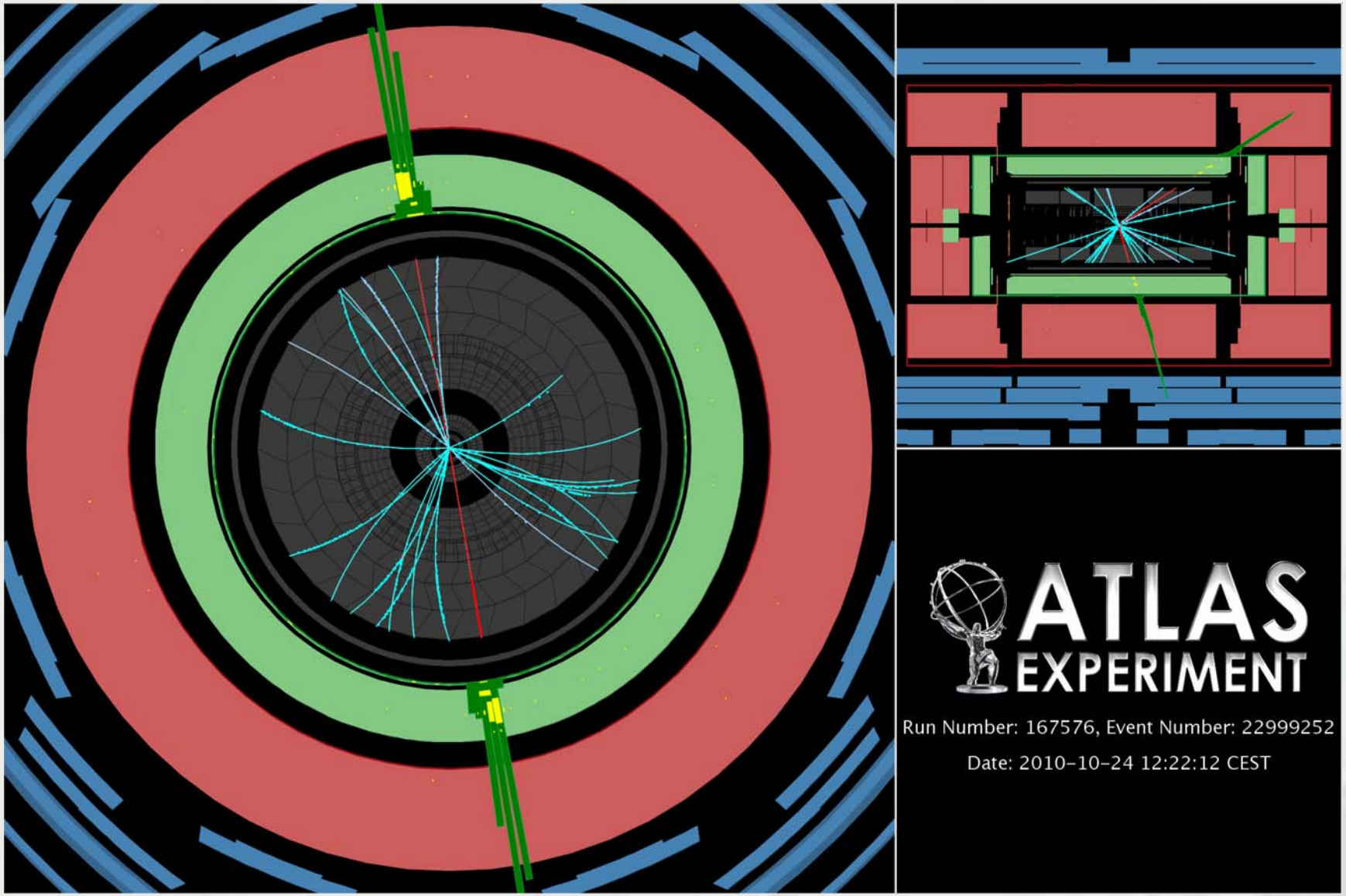
TABLE I: Expected and observed number of events in the dielectron channel. The uncertainties quoted include both statistical and systematic uncertainties. The systematic uncertainties are correlated across bins and are discussed in the text. Entries of 0.0 indicate a value < 0.05.

$m_{e^+e^-}$ [GeV]	70-110	110-130	130-150	150-170	170-200
Z/γ^*	8498.5 ± 7.9	104.9 ± 3.3	36.8 ± 1.3	19.4 ± 0.7	14.7 ± 0.6
$t\bar{t}$	8.2 ± 0.8	2.8 ± 0.3	2.1 ± 0.2	1.7 ± 0.2	1.7 ± 0.2
Diboson	12.1 ± 0.9	1.0 ± 0.2	0.7 ± 0.2	0.5 ± 0.2	0.5 ± 0.1
W + jets	6.0 ± 1.8	3.7 ± 1.2	1.2 ± 0.5	1.3 ± 0.5	1.2 ± 0.4
QCD	32.1 ± 7.1	8.4 ± 1.8	5.5 ± 0.8	3.2 ± 0.6	2.8 ± 0.8
Total	8557.0 ± 10.8	120.9 ± 4.0	46.4 ± 1.6	26.2 ± 1.1	20.8 ± 1.1
Data	8557	131	49	20	18
$m_{e^+e^-}$ [GeV]	200-240	240-300	300-400	400-800	800-2000
Z/γ^*	9.5 ± 0.4	6.0 ± 0.3	3.2 ± 0.1	1.6 ± 0.1	0.1 ± 0.0
$t\bar{t}$	1.2 ± 0.1	0.9 ± 0.1	0.5 ± 0.0	0.2 ± 0.0	0.0 ± 0.0
Diboson	0.4 ± 0.1	0.3 ± 0.1	0.2 ± 0.1	0.1 ± 0.1	0.0 ± 0.0
W + jets	1.1 ± 0.4	0.3 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.0 ± 0.0
QCD	1.9 ± 0.8	1.3 ± 0.7	0.8 ± 0.4	0.5 ± 0.2	0.1 ± 0.1
Total	14.1 ± 1.0	8.8 ± 0.7	4.8 ± 0.5	2.7 ± 0.3	0.2 ± 0.1
Data	13	9	3	3	0

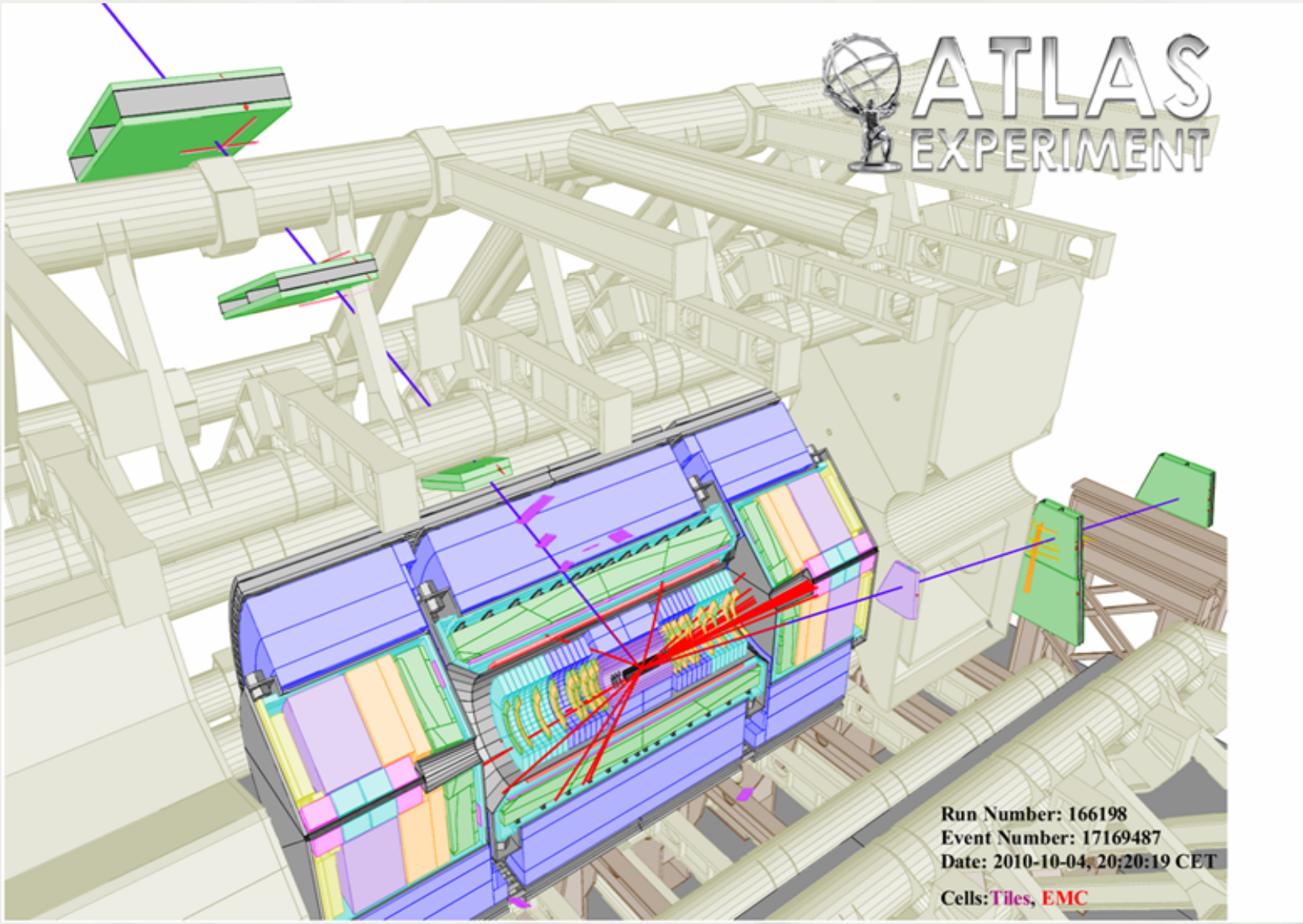
TABLE II: Expected and observed number of events in the dimuon channel. The uncertainties quoted include both statistical and systematic uncertainties. The systematic uncertainties are correlated across bins and are discussed in the text. Entries of 0.0 indicate a value < 0.05.

$m_{\mu^+\mu^-}$ [GeV]	70-110	110-130	130-150	150-170	170-200
Z/γ^*	7546.7 ± 7.1	98.4 ± 3.1	33.4 ± 1.1	17.2 ± 0.6	12.8 ± 0.5
$t\bar{t}$	6.0 ± 0.6	2.4 ± 0.3	1.7 ± 0.2	1.2 ± 0.1	1.2 ± 0.1
Diboson	10.0 ± 0.5	0.8 ± 0.1	0.6 ± 0.0	0.5 ± 0.0	0.4 ± 0.0
W + jets	0.3 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
QCD	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Total	7563.0 ± 7.2	101.6 ± 3.1	35.7 ± 1.2	18.9 ± 0.7	14.4 ± 0.5
Data	7563	101	41	11	11
$m_{\mu^+\mu^-}$ [GeV]	200-240	240-300	300-400	400-800	800-2000
Z/γ^*	7.8 ± 0.3	5.1 ± 0.2	2.5 ± 0.1	1.3 ± 0.1	0.1 ± 0.0
$t\bar{t}$	1.0 ± 0.1	0.7 ± 0.1	0.4 ± 0.0	0.1 ± 0.0	0.0 ± 0.0
Diboson	0.3 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.1 ± 0.0	0.0 ± 0.0
W + jets	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
QCD	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Total	9.1 ± 0.4	6.0 ± 0.2	3.0 ± 0.1	1.5 ± 0.1	0.1 ± 0.0
Data	7	6	2	1	0

Search dilepton: Event display of highest mass dielectron event



Search dilepton: Event display of highest mass dimuon event



Search dilepton (resonant): Results

TABLE IV: e^+e^-, $\mu^+\mu^-$ and combined 95% C.L. mass and σB limits on $Z'_{\rm SSM}$.

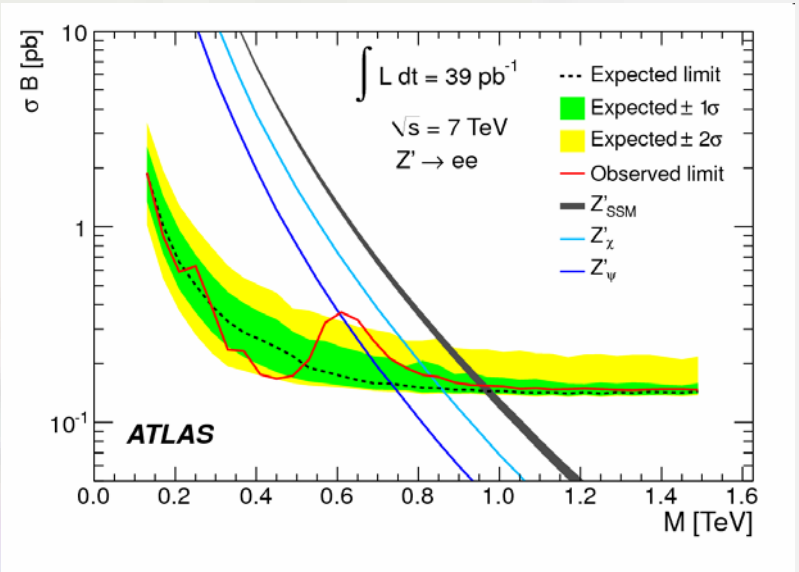
	Observed limit		Expected limit	
	mass [TeV]	σB [pb]	mass [TeV]	σB [pb]
$Z'_{\rm SSM} \to e^+e^-$	0.957	0.155	0.967	0.145
$Z'_{\rm SSM} \to \mu^+\mu^-$	0.834	0.297	0.900	0.201
$Z'_{\rm SSM} \to \ell^+\ell^-$	1.048	0.094	1.088	0.081

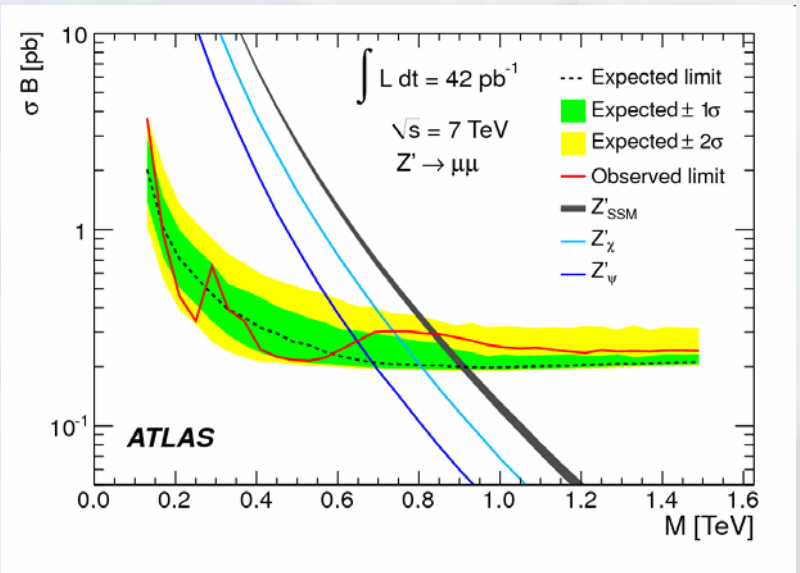
TABLE V: Combined mass limits at 95% C.L. on the E_6-motivated Z' models.

Model	Z'_ψ	$Z'_{\rm N}$	Z'_η	Z'_I	$Z'_{\rm S}$	Z'_χ
Mass limit [TeV]	0.738	0.763	0.771	0.842	0.871	0.900

TABLE VI: e^+e^-, $\mu^+\mu^-$ and combined 95% C.L. mass and σB limits on Z^* production.

	Observed limit		Expected limit	
	mass [TeV]	σB [pb]	mass [TeV]	σB [pb]
$Z^* \to e^+e^-$	1.058	0.149	1.062	0.143
$Z^* \to \mu^+\mu^-$	0.946	0.265	0.995	0.199
$Z^* \to \ell^+\ell^-$	1.152	0.089	1.185	0.080





Search dilepton (non-resonant): Selection

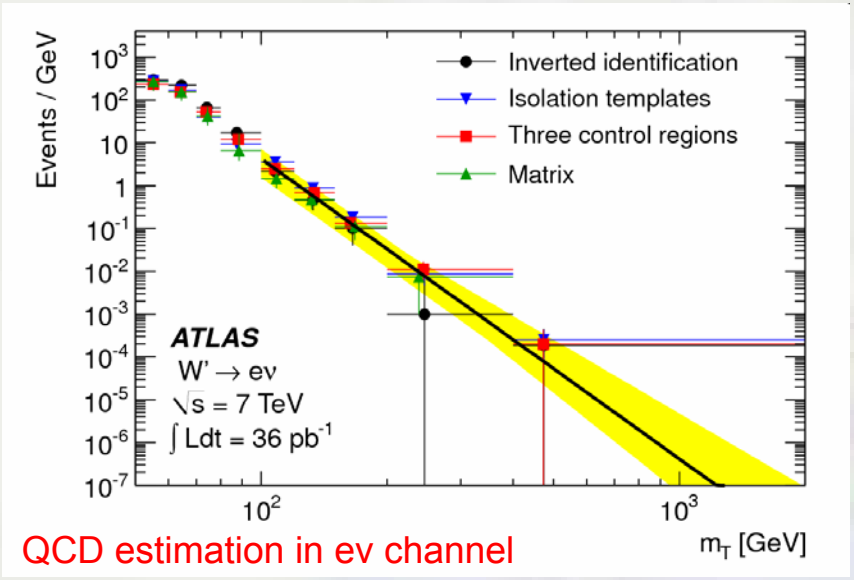
TABLE I. Expected and observed number of events in the dimuon channel. The errors quoted originate from the limited MC statistics. Entries of 0.0 indicate a value < 0.05.

$m_{\mu\mu}$ [GeV]	70-110	110-130	130-150	150-170	170-200	200-240	240-300	300-400	400-550	550-800	800-1200	1200-2000
DY	7547 ± 7	98.4 ± 0.8	33.4 ± 0.5	17.2 ± 0.3	12.8 ± 0.3	7.8 ± 0.2	5.1 ± 0.1	2.5 ± 0.0	1.0 ± 0.0	0.3 ± 0.0	0.1 ± 0.0	0.0 ± 0.0
$t\bar{t}$	6.0 ± 0.2	2.4 ± 0.1	1.7 ± 0.1	1.2 ± 0.0	1.2 ± 0.0	1.0 ± 0.0	0.73 ± 0.0	0.4 ± 0.0	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Diboson	10.1 ± 0.1	0.8 ± 0.2	0.6 ± 0.0	0.5 ± 0.0	0.4 ± 0.0	0.3 ± 0.0	0.24 ± 0.0	0.2 ± 0.0	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
W+jets	0.14 ± 0.08	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Total	7563 ± 7	101.6 ± 0.8	35.7 ± 0.5	18.9 ± 0.3	14.4 ± 0.3	9.1 ± 0.2	6.0 ± 0.1	3.0 ± 0.1	1.2 ± 0.0	0.3 ± 0.0	0.1 ± 0.0	0.0 ± 0.0
Data	7563	101	41	11	11	7	6	2	0	1	0	0

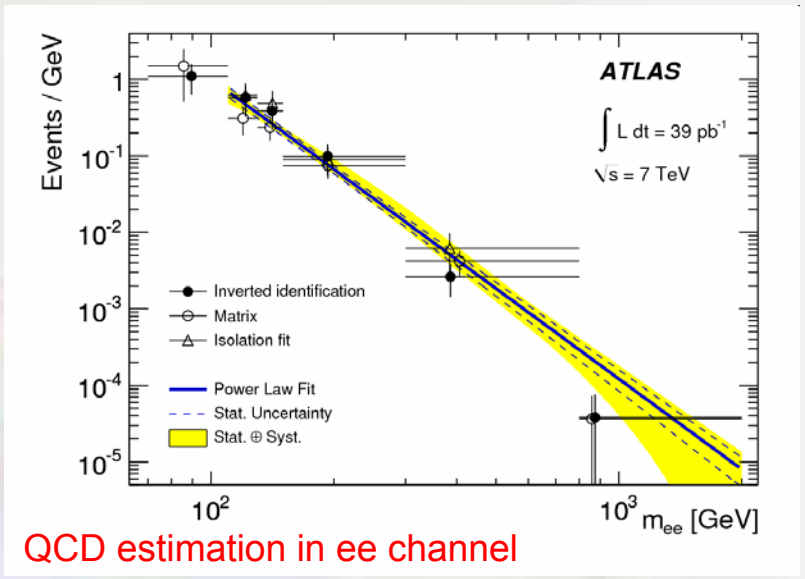
TABLE II. Expected number of events in the signal region of the analysis for various contact interaction scales with constructive (Λ^-) and destructive (Λ^+) interference. The errors quoted originate from the limited MC statistics.

$m_{\mu\mu}$ [GeV]	150-170	170-200	200-240	240-300	300-400	400-550	550-800	800-1200	1200-2000
Λ^- = 3 TeV	19.1 ± 0.5	15.7 ± 0.4	11.2 ± 0.4	8.5 ± 0.3	7.9 ± 0.3	6.0 ± 0.3	6.5 ± 0.3	5.1 ± 0.2	3.0 ± 0.2
Λ^- = 4 TeV	18.8 ± 0.4	14.3 ± 0.4	10.0 ± 0.3	6.5 ± 0.2	5.0 ± 0.2	3.0 ± 0.2	2.3 ± 0.2	1.5 ± 0.1	1.1 ± 0.1
Λ^- = 5 TeV	17.4 ± 0.4	14.3 ± 0.4	9.4 ± 0.3	6.2 ± 0.2	4.3 ± 0.2	2.0 ± 0.1	1.3 ± 0.1	0.7 ± 0.1	0.4 ± 0.1
Λ^- = 7 TeV	17.3 ± 0.4	13.8 ± 0.4	9.3 ± 0.3	6.3 ± 0.2	3.3 ± 0.2	1.3 ± 0.1	0.6 ± 0.1	0.2 ± 0.0	0.1 ± 0.0
Λ^+ = 2 TeV	21.6 ± 0.6	19.3 ± 0.6	15.8 ± 0.5	15.2 ± 0.5	21.2 ± 0.6	21.6 ± 0.6	25.5 ± 0.6	21.4 ± 0.6	15.1 ± 0.5
Λ^+ = 3 TeV	18.6 ± 0.4	15.2 ± 0.4	10.1 ± 0.3	7.2 ± 0.3	5.5 ± 0.2	4.6 ± 0.2	5.3 ± 0.2	4.3 ± 0.2	3.1 ± 0.2
Λ^+ = 4 TeV	18.2 ± 0.4	14.3 ± 0.4	8.8 ± 0.3	6.1 ± 0.2	3.6 ± 0.2	2.1 ± 0.1	1.6 ± 0.1	1.5 ± 0.1	0.8 ± 0.1
Λ^+ = 5 TeV	18.5 ± 0.4	13.6 ± 0.3	8.8 ± 0.3	5.4 ± 0.2	2.9 ± 0.2	1.6 ± 0.1	0.9 ± 0.1	0.5 ± 0.1	0.3 ± 0.1

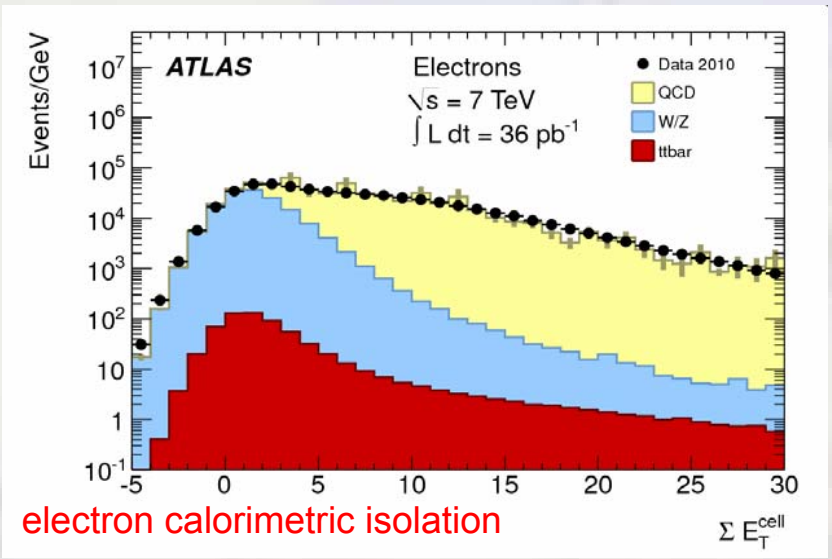
QCD background estimation from data



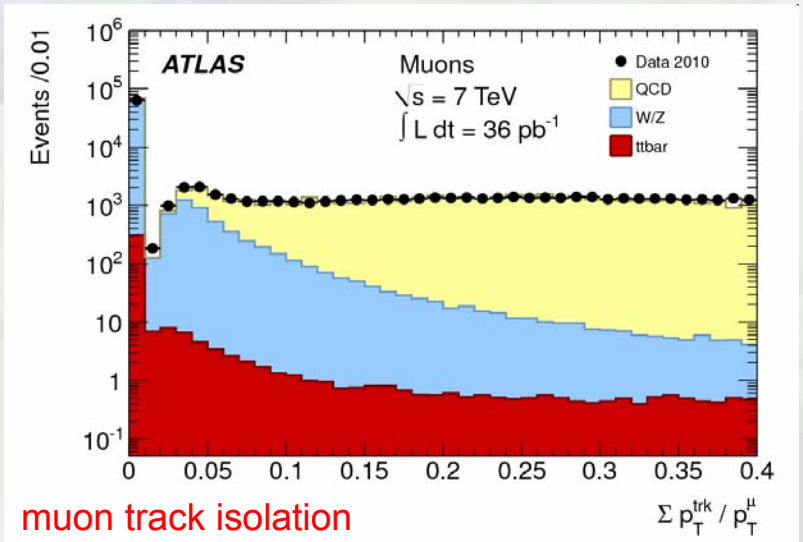
QCD estimation in eν channel



QCD estimation in ee channel



electron calorimetric isolation



muon track isolation