Leptons + MET final states in ATLAS

"Status of Higgs and BSM searches at the LHC"
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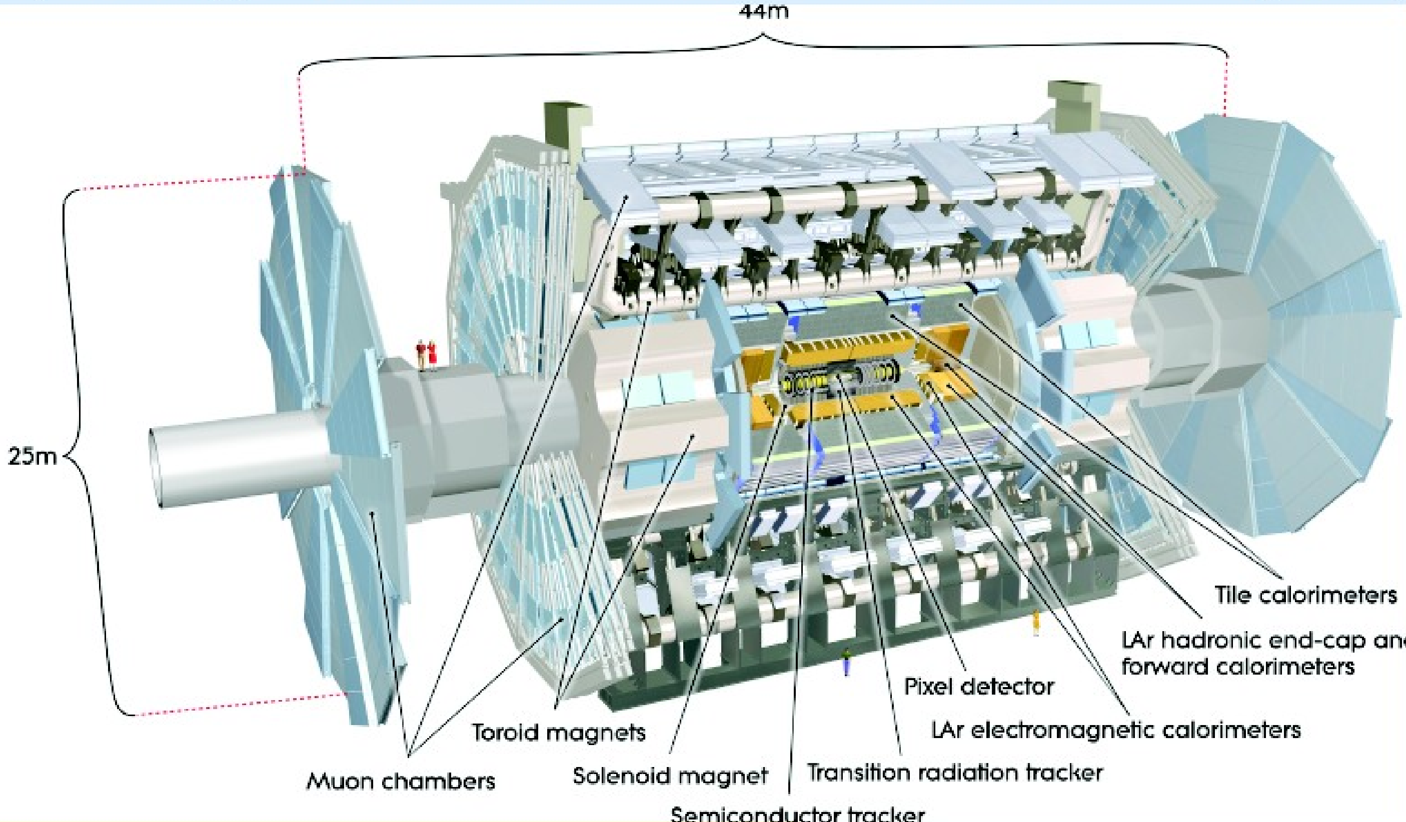
(on behalf of the ATLAS collaboration)

Outline

- ATLAS detector, datataking
- SUSY, models, signatures, leptons
- Standard Model background
- RPC: 2-lepton searches
  - Opposite-Sign (OS) and Same-Sign (SS) searches
  - OS, flavour-subtraction
  - Exclusion: model-independent, mSUGRA, PhenoGrids
- RPV: OS eμ-resonance (sneutrino)
- Summary

A Toroidal Lhc ApparatuS (ATLAS)

- **Muon Spectrometer(|n|<2.47):**
  - **air-core toroids with gas-based muon chambers**
  - **Muon trigger and measurement with momentum resolution < 10% up to PT(mu) ~ 1 TeV**



- **General :**
  - **~10^8 electronic channels**
  - **~$3x10^3$ km of cables**
  - **weighs 7000 tons (metal structure of Eiffel Tower)**
  - **~3200 authors, 174 institutions from 38 coutries**

Inner Detector (|n| < 2.5, B=2T):

- **(Si Pixel layers(Pix), Stereo pairs of Si microstrips (SCT), transition radiation tracker (TRT)**
- **precise tracking and vertexing**
- **Nice e and Pi separation**
- **Momentum resolution : sigma/pT < 4% for pT up to 100 GeV**

EM calorimeter (|n|<3.2):

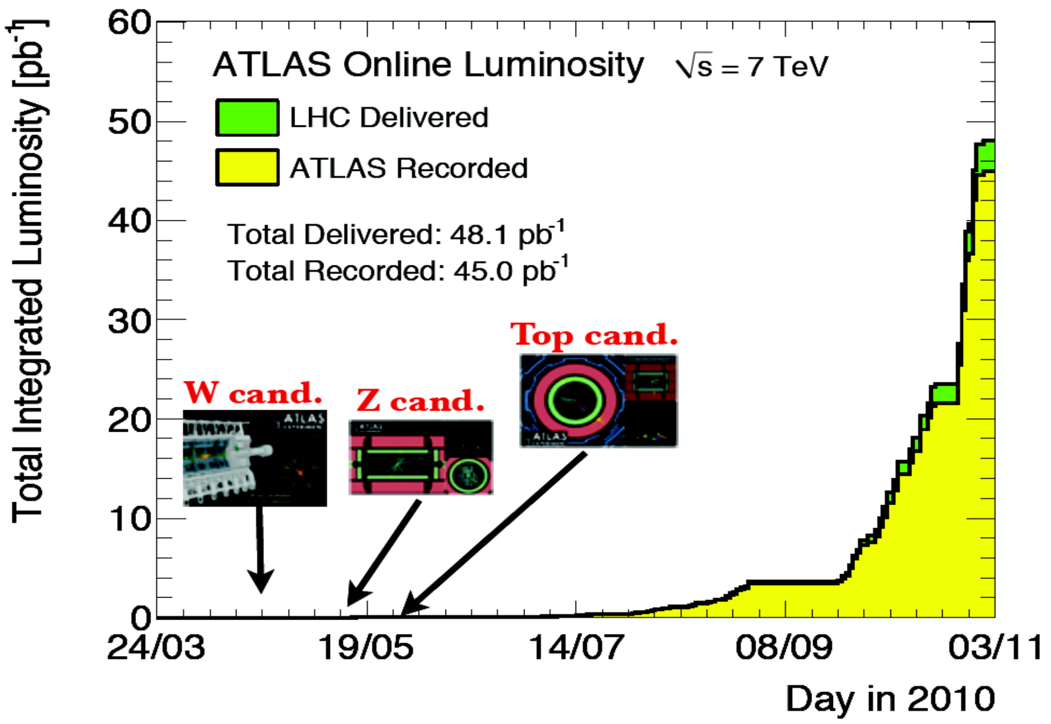
- **LAr calorimeter with accordion geometry for phi symmetry and faster signal readout**
- **electron, photon identification and measurement**
- **energy resolution : sigma/E ~ 10%/sqrt(E)**

Hadronic Calorimeter (|n|<5):

- **Tile (steel and scintillators) calorimeter (|n|<1.7)**
- **Cu/LAr sampling calorimeter (1.5<|n|<3.2)**
- **Forward calorimeter (3.1<|n|<5)**
- **Jets and Missing energy measurement**
- **energy resolution : sigma/E ~ 50%/sqrt(E)+0.03**

Slide: T.Sarangi

Datataking, integrated luminosity



2010 was a great year

- Calibrating ATLAS
- "Rediscovering" the SM
  First W, Z, top candidates a small year back
- Lots of data in uncharted territory

Analyses based on 35 pb-1

SUSY models, exp. signatures

SUSY comes in many shapes

- mSUGRA
  - Nice/concise model, few parameters
  - Unification at high values
  - RGE running down to EW scale
  - Collider signatures
    - MET (missing transverse energy)
    - hard jets
    - leptons: taus ; e, mu
  - 4½ pars cover lot of pheno-space
  - Allows for, well-motivated search strategies which can me more or less generic
  - Limitations:
    - Partially fixed mass structure, e.g. roughly m(gl) : m(N2) : m(N1) = 7 : 2 : 1
    - Lepton fraction constrained
    - ...
-

- Beyond mSUGRA: 24-par MSSM
  - Sparticle masses set at EW scale
  - Allows less model-dependent / more signature-based scan
  - Main signatures remain mostly the same (MET, many jets and maybe leptons)
  - Kinematics (pt) can vary a lot

And some are very different

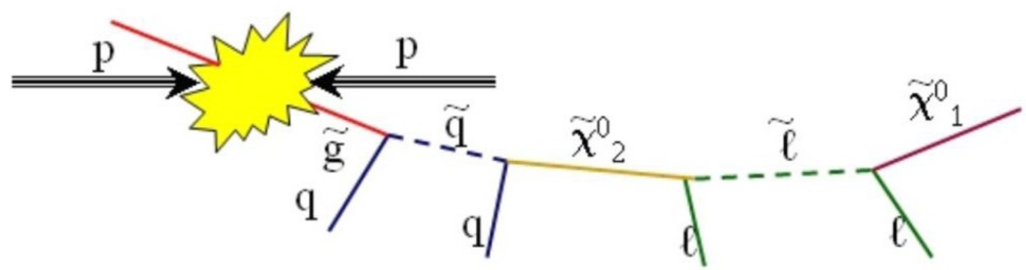
- R-Parity Violating (RPV) scenarios
  - Lightest Supersymmetri Particle (LSP) not stable : no MET signature
  - Sparticles can be singly produced
  - jets?

SUSY lepton sources (RPC)

ℓ = electron/muon

PRODUCTION

- Strong-force induced dominates if gluino / squark accessible:
  - ➔ pairs of gluinos/squarks produced
  - ➔ cascade decays
- (Otherwise XX and/or di-sleptons)



MAIN SOURCE:
• decay of neutralinos&charginos

$$\tilde{\chi}_i^\pm(\to \ell^\pm\tilde{\nu}_\ell/\nu\tilde{\ell}^\pm/W^\pm\tilde{\chi}_j^0) \to \nu\ell^\pm\tilde{\chi}_j^0$$
$$\tilde{\chi}_i^0(\to \nu\tilde{\nu}_\ell/W^\mp\tilde{\chi}_j^\pm) \to \nu\ell^\mp\tilde{\chi}_j^\pm$$

single-lepton

$$\tilde{\chi}_i^\pm(\to \ell^\pm\tilde{\nu}_\ell/Z\tilde{\chi}_j^\pm) \to \ell^+\ell^-\tilde{\chi}_j^\pm$$
$$\tilde{\chi}_i^0(\to \ell^\pm\tilde{\ell}^\mp/Z\tilde{\chi}_j^0) \to \ell^+\ell^-\tilde{\chi}_j^0$$

di-lepton

Depends on:
• gaugino/higgsino composition of neutralinos&charginos
• slepton whereabouts (and type)
• squark whereabouts (and type)

SECONDARY SOURCE:
• *W* through third-generation squark

$$\tilde{g} \to t\tilde{t} \to Wb\tilde{t}$$
$$\tilde{g} \to tb\tilde{\chi}_i^\pm \to Wbb\tilde{\chi}_i^\pm$$
$$\tilde{b} \to W\tilde{t}$$
$$\tilde{b} \to t\tilde{\chi}_i^\pm \to Wb\tilde{\chi}_i^\pm$$
$$\tilde{t} \to t\tilde{\chi}_i^0 \to Wb\tilde{\chi}_i^0$$

Depends on:
• stop/sbottom mass / production

Di-lepton combinations (RPC)

- Di-lepton transitions give leptons correlated in flavour and sign:

  (A) Opposite-Sign Same-Flavour (OSSF)

  $$e^+e^-,\ \mu^+\mu^-$$

- Di-leptons from two single-lepton transitions are uncorrelated in flavour, and often in sign.

  (B) OSSF and OSDF (same rate)

  $$e^+e^-,\ \mu^+\mu^-,\ e^\pm\mu^\mp$$

  (C) SSSF and SSDF (same rate)

  $$e^\pm e^\pm,\ \mu^\pm\mu^\pm,\ e^\pm\mu^\pm$$

Standard Model background can also be classified in A-C:

- Type A: Z, Drell-Yan
- Type B: Top, (fully/partially) QCD-induced
- Type C: diboson, charge-mismeas., [few]

arXiv:1103.6208

(1) Flavour-subtraction OSSF channel

- uses the identity of OSSF and OSDF from uncorrelated sources to subtract
  - SM background (top)
  - but also SUSY signal (Type B)
- uses well-identifiable SM Type A bck (Z)

arXiv:1103.6214

(2) SS channel

- very small SM bck (no type C)

(3) OS channel

- Signal from (A) and (B)
- SM background larger than for SS

SS vs OS

- Simple structure for neutralino/chargino single-lepton transition, e.g.:

$$\text{SS}: \quad \tilde{u}\tilde{u} \to dd\tilde{\chi}^+\tilde{\chi}^+ \to dd\nu\nu\ell^+\ell^+\tilde{\chi}^0\tilde{\chi}^0$$

$$\text{SS}: \quad \tilde{d}\tilde{d} \to uu\tilde{\chi}^-\tilde{\chi}^- \to uu\bar{\nu}\bar{\nu}\ell^-\ell^-\tilde{\chi}^0\tilde{\chi}^0$$

$$\text{OS}: \quad \tilde{u}\tilde{d} \to du\tilde{\chi}^+\tilde{\chi}^- \to du\nu\bar{\nu}\ell^+\ell^-\tilde{\chi}^0\tilde{\chi}^0$$

SM bck

SM di-lepton sources:

- Z/γ → ll + jets *[partially data-driven estimate]*
- ttbar (fully dileptonic) *[partially data-driven est.]*
- Di-bosons WW, WZ, ZZ *[MC only]*
- Fakes (one or both leptons not from heavy objects; W, QCD, semi-leptonic ttbar) *[fully data-driven est.]*
- Cosmics *[fully data-driven estimate]*

Signal region:

- Exactly two leptons of pt > 20 GeV
  m(ll) > 5 GeV
- Considerable MET, above 100/150 GeV
- (No jet requirement)

SS channel

- Fakes dominate ee and co-dominates eμ, μμ
  - in particular semi-leptonic ttbar where the second lepton comes from a *b*.
- Dibosons
  - WZ/ZZ can produce SS when 1/2 leps are lost
- Charge-flip (of e) mainly in di-leptonic ttbar

OS channel

- ttbar dominates, has real MET
- (Z important in ee)

Flavour-subtracted OSSF channel

- ttbar subtracts to 0 (but large stat uncertainty)
- Z/γ*, WZ, fakes and ttbar similar size at this lumi

SAMPLE	GENERATOR
W+jets	Alpgen+Herwig+Jimmy
Wbb+jets	Alpgen+Herwig+Jimmy
Z+jets	Alpgen+Herwig+Jimmy
Drell-Yan	Pythia
ttbar	McAtNlo+Herwig+Jimmy
single-top	McAtNlo+Herwig+Jimmy
QCD	Pythia
bbbar	Pythia
Di-bosons	Herwig

BCK estimation: ttbar (OS)

Estimation procedure:

- Define a ttbar-dominated CR region
  - Based on the co-transverse mass tagger
  - 60 GeV < MET < 80 GeV
- Estimate non-top bck in the CR region
- Apply MC to find the ratio of ttbar events in the SR and the CR region
- Get estimated number of ttbar events in SR from simple scaling, e.g.

$$(N_{tt})_{SRee} = \left((N^{tag}_{data})_{CR} - (N^{tag}_{non-tt,MC})_{CR}\right)\frac{(N_{top,MC})_{SRee}}{(N^{tag}_{top,MC})_{CR}}$$

Evaluation

- results backed by other “top tagger”
- Contamination of 10-15 % if low-mass SUSY (Reduces discovery significance)
- SR: total uncertainty: 44%

Co-transverse mass tagger

- For two identical decays of heavy particles into two visible particles (or -aggregates), v1 and v2, and invisible particles, as in

  $$t\bar{t} \rightarrow (W^+b)(W^-\bar{b}) \rightarrow (\ell^+\ \nu_\ell\ b)\ (\ell^-\ \bar{\nu}_\ell\ \bar{b})$$

  the co-transverse mass mCT is defined by

  $$m^2_{\mathrm{CT}}(v_1, v_2) = [E_{\mathrm{T}}(v_1) + E_{\mathrm{T}}(v_2)]^2 - [\mathbf{p}_{\mathrm{T}}(v_1) - \mathbf{p}_{\mathrm{T}}(v_2)]^2$$

  $$E_{\mathrm{T}} = \sqrt{p^2_{\mathrm{T}} + m^2}$$

  where v1 can then be a lepton, a jet or a lepton-jet combination, giving three mCT variables (per leg assignment)

- The values are then compared to appropriate distributions and the various leg assignments are rejected or accepted as compatible with dileptonic ttbar
- If at least one leg assignment is ok, the event is top-tagged
- (With MET between 60-80 GeV MC dileptonic ttbar has a top-tagging efficiency of 83%)

BCK estimation: Fakes

- Matrix method
  - Define two lepton definitions/qualities, one "loose", the other "tight".
  - Define a "real" region where leptons are expected to be real (from Z, W)
  - Define a "fake" region where leptons are expected to be from jets
  - Find the probability that a real/fake lepton also passes the tight definition. This gives the real and fake efficiency ("rate"), r and f.
  - Then count the number of TT, TL, LT and LL in the Signal Region (SR) of the analysis
  - Invert the matrix and get the number of RR, RF, FR and FF events in the SR.

- Estimation done for 6 combinations: (SS, OS) x (*ee, μμ, eμ*)
- SS: fake contribution dominant. Well described.
- OS: fake contribution less important

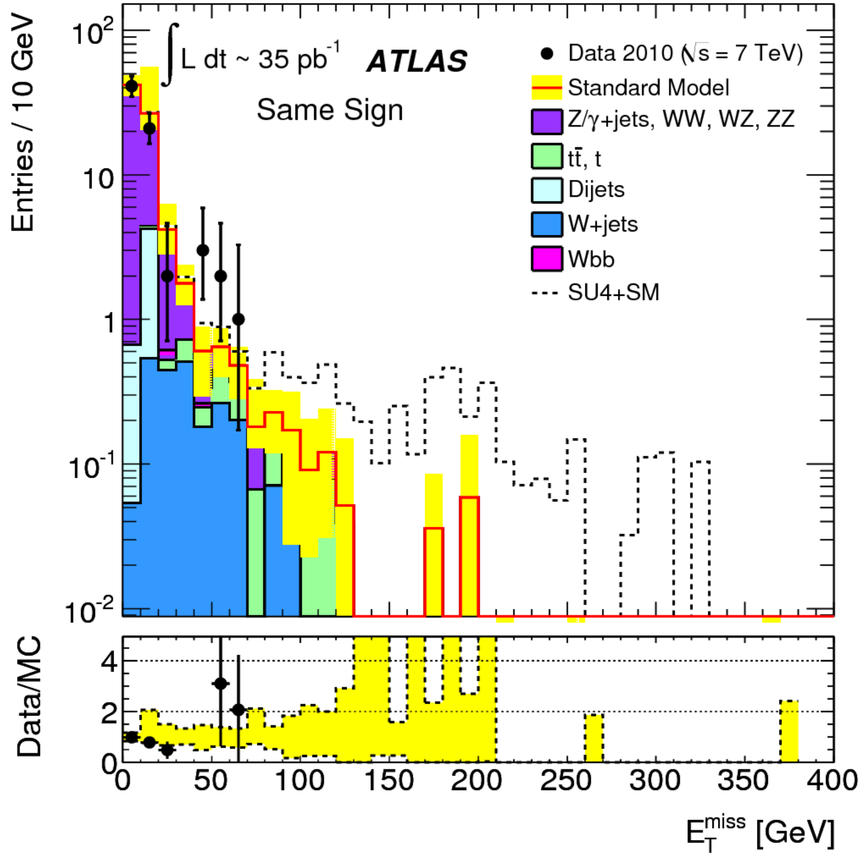
$$\begin{bmatrix} N_{TT} \\ N_{TL} \\ N_{LT} \\ N_{LL} \end{bmatrix} = \begin{bmatrix} rr & rf & fr & ff \\ r(1-r) & r(1-f) & f(1-r) & f(1-f) \\ (1-r)r & (1-r)f & (1-f)r & (1-f)f \\ (1-r)(1-r) & (1-r)(1-f) & (1-f)(1-r) & (1-f)(1-f) \end{bmatrix} \begin{bmatrix} N_{RR} \\ N_{RF} \\ N_{FR} \\ N_{FF} \end{bmatrix}$$

Limit setting

- If no significant excess of data above bck expectations:
- Use likelihood function to fit event count in SR
  - $L(n|s,b,\theta) = P_S \times C_{\mathrm{syst}}$
    - n: number of observed data events
    - s: new-physics population to be tested
    - b: background
    - θ: systematic uncertainties, treated as nuisance parameters with Gaussian pdf
    - P_S Poisson prob. distr. for the event count in the SR
    - C_{syst}: correlations of systematic errors
- Limits are derived from the profile likelihood ratio
  - $\Lambda(s) = -2(\ln L(n|s,\hat{\hat{b}},\hat{\hat{\theta}}) - \ln L(n|\hat{s},\hat{b},\hat{\theta}))$
    - $\hat{s},\hat{b},\hat{\theta}$: maximise the likelihood function
    - $\hat{\hat{s}},\hat{\hat{\theta}}$: maximise the likelihood for a given s
- Exclusion p-values are obtained from pseudo-experiments with test statistic $\Lambda(s)$ and one-sided upper limits set.
- Next: from data and SM expectations in the signal regions, 95% confidence limits on cross-section $\times$ BR $\times$ acceptance are found

SS results

- None expected, none observed
- Model-independent limit in combined SS channels (2-leptons above 20 GeV and MET > 100 GeV) :
  - Cross-section x BR x acceptance < 0.07 pb



Same Sign, $E_T^{miss} > 100$ GeV			
	$e^\pm e^\pm$	$e^\pm \mu^\pm$	$\mu^\pm \mu^\pm$
Data	0	0	0
Fakes	0.12 ± 0.13	0.030 ± 0.026	0.014 ± 0.010
Di-bosons	0.015 ± 0.005	0.035 ± 0.012	0.021 ± 0.009
Charge-flip	0.019 ± 0.008	0.026 ± 0.011	-
Cosmics	-	$0^{+1.17}_{-0}$	-
Total	0.15 ± 0.13	$0.09\ ^{+1.17}_{-0.03}$	0.04 ± 0.01

SU4: mSUGRA benchmark scenario

$M_0 = 200$ GeV, $M_{1/2} = 160$ GeV, $A = -400$ GeV, $\tan\beta = 10$, $\mu > 0$

$BR(\tilde{\chi}_2^0 \to \ell^+\ell^-\tilde{\chi}_1^0) = 7.2\%$

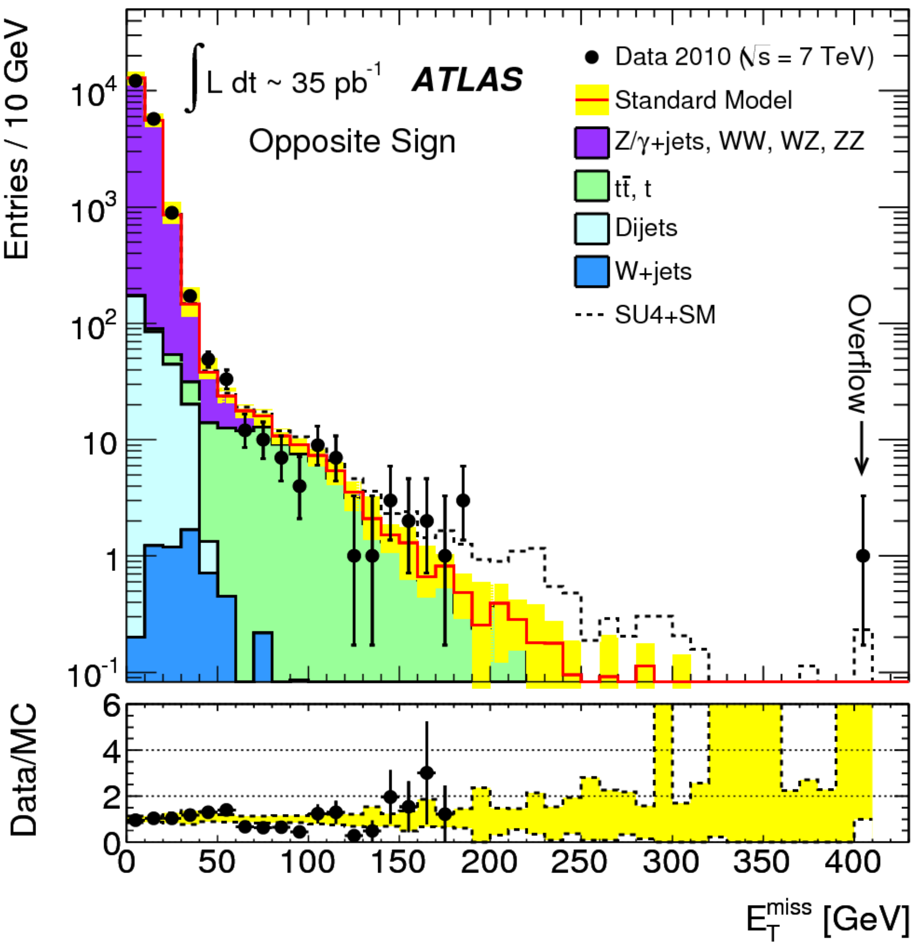
$BR(\tilde{\chi}_1^\pm \to \nu\ell^\pm\tilde{\chi}_1^0) = 23\%$

OS results

- Observed 9, estimated 3.7 (+2.2-0.9)
- post-investigations strongly suggest that the high-MET event (μμ) is a cosmic ray
- Excess is in eμ and μμ
- The probability for the bck to exceed the number of observed events is 14% and 13% for eμ and μμ

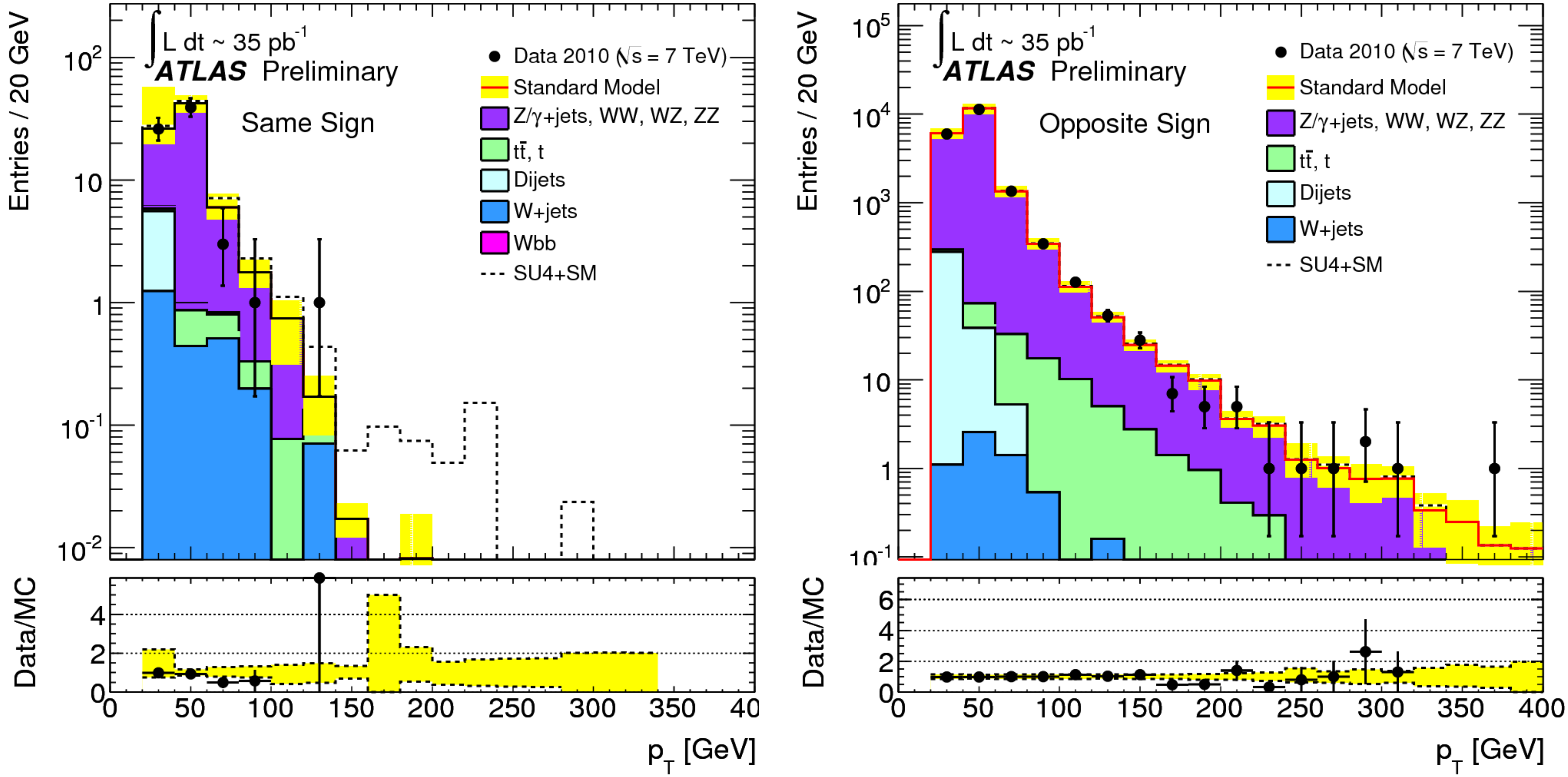
- Limits can still be set on the existence of new physics which produces OS di-leptons (leptons above 20 GeV and MET > 150 GeV) :

  - ee: cross-section x BR x acceptance < 0.09 pb
  - eμ: cross-section x BR x acceptance < 0.21 pb
  - μμ: cross-section x BR x acceptance < 0.22 pb



Opposite Sign, $E_{\mathrm{T}}^{\mathrm{miss}} > 150$ GeV			
	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$
Data	1	4	4
$t\bar{t}$	$0.62^{+0.31}_{-0.28}$	$1.24^{+0.62}_{-0.56}$	$1.00^{+0.50}_{-0.45}$
Z+jets	0.19 ± 0.15	0.08 ± 0.08	0.14 ± 0.17
Fakes	-0.02 ± 0.02	-0.05 ± 0.04	-
Single top	0.03 ± 0.05	0.06 ± 0.08	0.10 ± 0.07
Di-bosons	0.09 ± 0.03	0.06 ± 0.03	0.15 ± 0.03
Cosmics	-	-0.2 ± 1.18	-0.43 ± 1.27
Total	$0.92^{+0.42}_{-0.40}$	$1.43^{+1.45}_{-0.59}$	$1.39^{+1.41}_{-0.53}$

Pt of leading lepton, SS and OS



Flavour-subtracted OSSF analysis

- Uses the observation that some of the most SM di-lepton mechanisms, in particular ttbar, give uncorrelated (OS) di-leptons, AND that the combinations come in equal rates, SF = DF.

- This gives opportunity to subtract one with the other.

- Useful if a signal is expected in SF

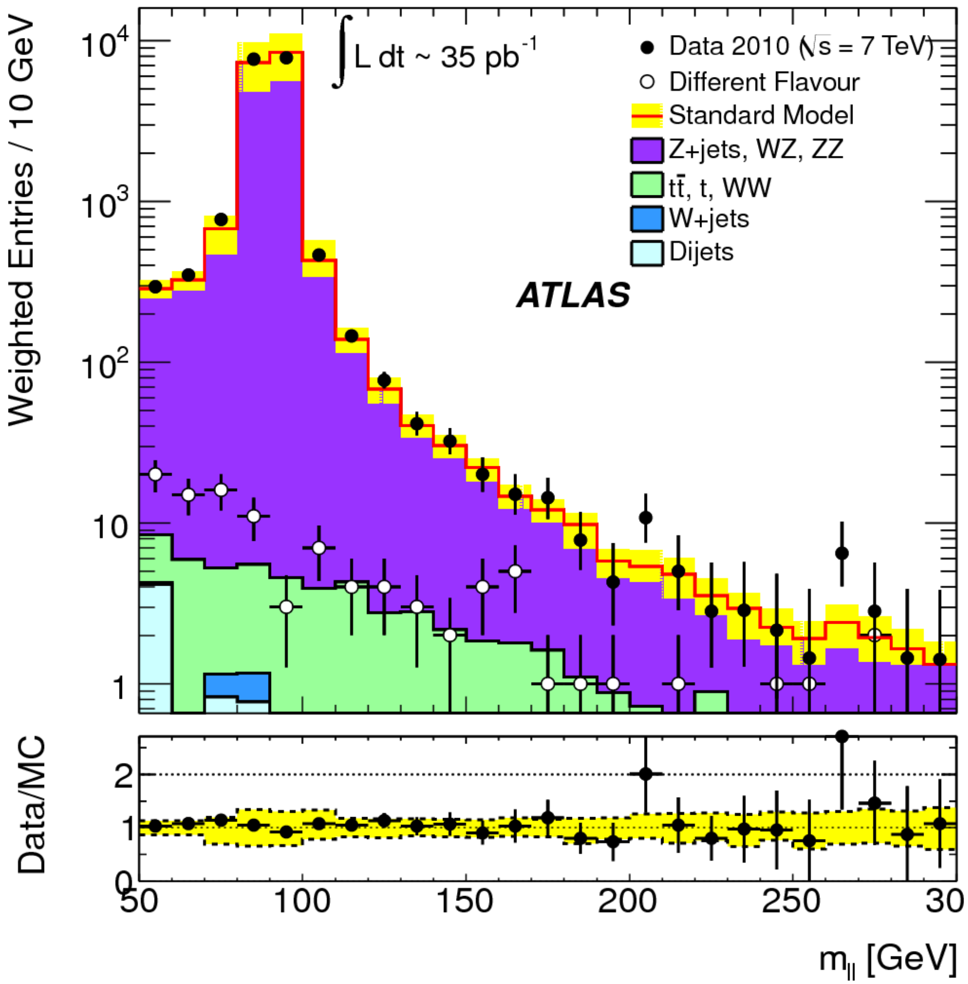
Unfortunately, experiments break flavour.
Corrections are needed to get the subtraction right:

$$\mathcal{S} = \frac{N(e^{\pm}e^{\mp})}{\beta(1-(1-\tau_e)^2)} - \frac{N(e^{\pm}\mu^{\mp})}{1-(1-\tau_e)(1-\tau_\mu)} + \frac{\beta N(\mu^{\pm}\mu^{\mp})}{(1-(1-\tau_\mu)^2)}$$

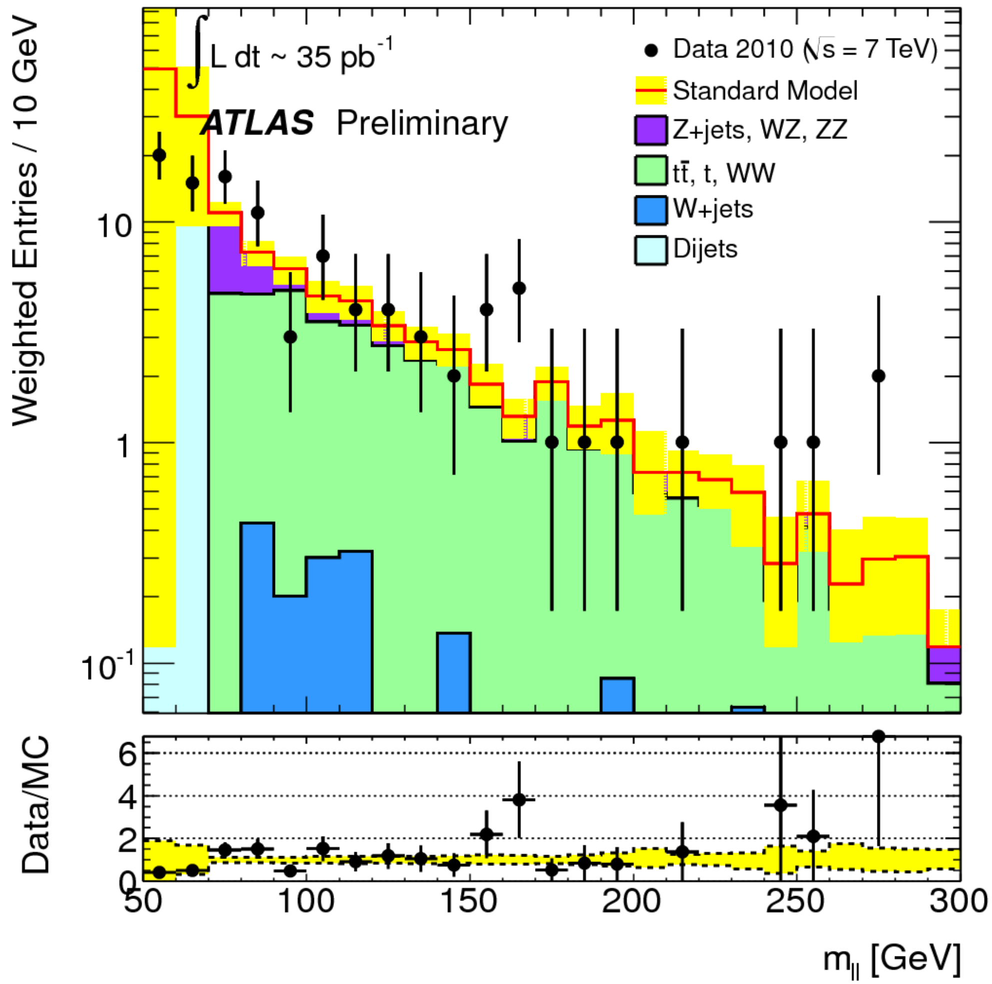
β: ratio of electron to muon efficiency times acceptance
τ_e(τ_μ): plateau electron (muon) trigger efficiency
β = 0.69(±0.3), τ_e = 98.5(±1.1)%, τ_μ = 83.7(±1.9)%

Flavour-subtracted OSSF analysis

OSSF – no MET cut



OSDF – no MET cut



OSSF: *Z* totally dominates before MET cut
(Note: Removing the Z-peak would not remove the OSSF excess)

OSDF: ttbar main bck above certain m(ll)

Note the approximate equality between OSSF and OSDF ttbar

Events are appropriately weighted with β, τ_e and τ_μ

Flavour-subtracted OSSF results

MET > 100 GeV:

- ttbar: still some, but subracts to zero
- Diboson: significant in all channels, also after flavour subtraction
- Others (including Z): nearly consistent with zero

- Some excess in data relative to SM estimation, eμ and μμ
- Not present after flavour-subtraction

	$e^{\pm}e^{\mp}$	$e^{\pm}\mu^{\mp}$	$\mu^{\pm}\mu^{\mp}$
Data	4	13	13
Z/γ^*+jets	0.40±0.46	0.36±0.20	0.91±0.67
Dibosons	0.30±0.11	0.36±0.10	0.61±0.10
$t\bar{t}$	2.50±1.02	6.61±2.68	4.71±1.91
Single top	0.13±0.09	0.76±0.25	0.67±0.33
Fakes	0.31±0.21	-0.15±0.08	0.01±0.01
Total SM	3.64±1.24	8.08±2.78	6.91±2.20

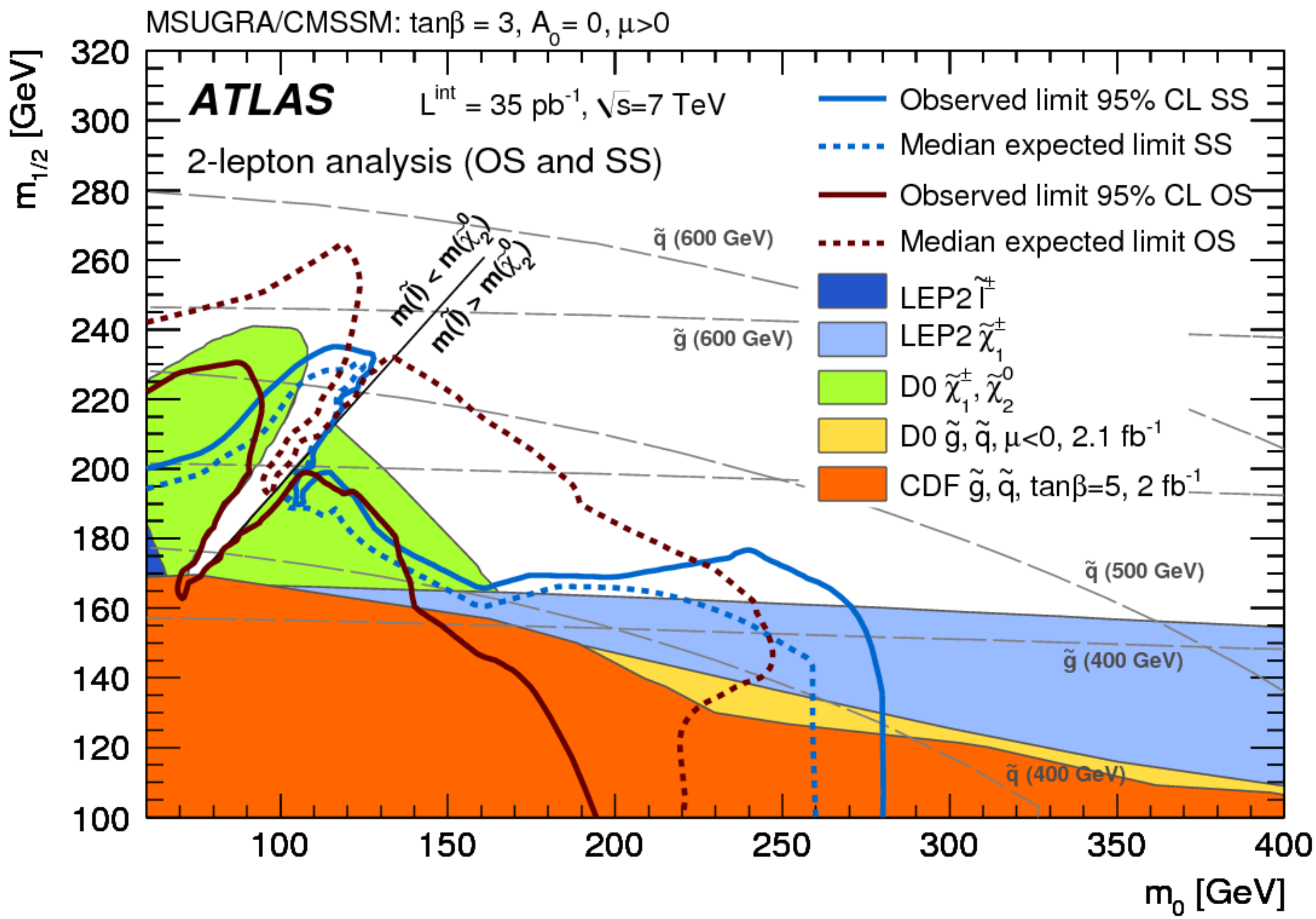
Flavour-subtracted

Process	$\mathcal{S}_b$
Z/γ^*+jets	0.86 ± 0.33 (stat.) ± 0.74 (sys.)
Dibosons	0.51 ± 0.04 (stat.) ± 0.12 (sys.)
$t\bar{t}$	0.34 ± 0.61 (stat.) ± 0.13 (sys.)
Single top	-0.10 ± 0.23 (stat.) ± 0.08 (sys.)
Fakes	0.46 ± 0.31 (stat.) ± 0.10 (sys.)
SM total	2.06 ± 0.79 (stat.) ± 0.78 (sys.)

$$\mathcal{S}_{obs} = 1.98 \pm 0.15(\beta) \pm 0.02(\tau_e) \pm 0.06(\tau_\mu)$$

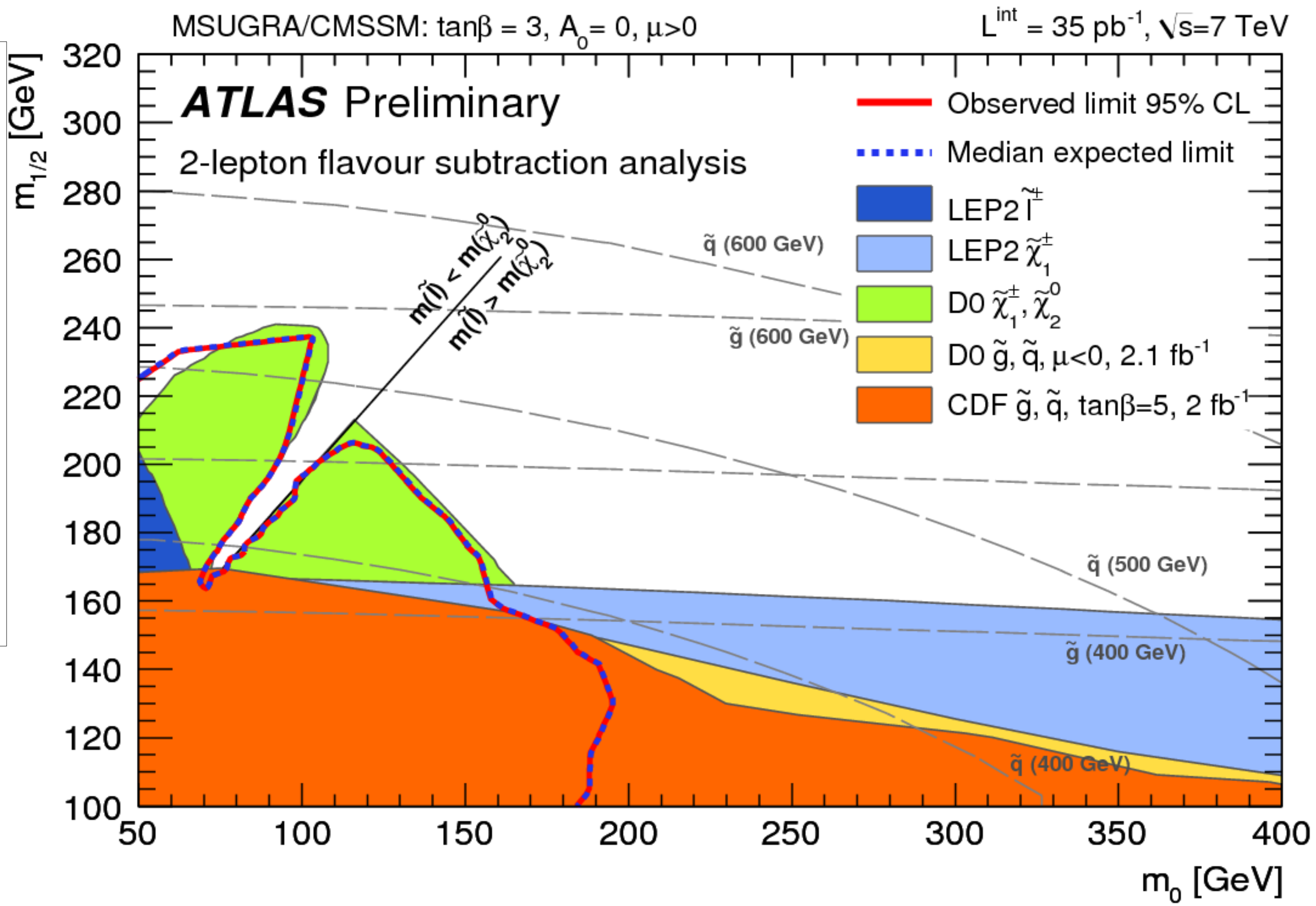
mSUGRA interpretation - OS, SS

- OS seen to have more potentiality ("expected") in mSUGRA plane than SS, though some complementarity
- SS better than expected
- OS worse than expected
- Limits partly extend previous 2L limits in mSUGRA
- (0 and 1-lepton searches exclude much larger parts of the mSUGRA plane)



mSUGRA interpretation - OSSF

- OSSF observed and expected limit are identical
- OSSF expected is less powerful than OS throughout the mSUGRA plane (for the given setup and lumi)
- Observed limit is better than SS and OS in part of the plane
- Follows very closely the D0 direct gaugino trilepton results



PhenoGrids

mSUGRA has some inner workings which limit the phenomenology

- M3:M2:M1 = 7:2:1
- squark and slepton masses
- 3d generation

It is e.g. not possible to scan a 3-dim mass space

→

The so-called "PhenoGrids" address this.

The main purpose is to

A) freely set the masses most relevant for phenomenology:

- gluino, squark, N2/C1, slepton, N1

B) mSUGRA-like neutralino/chargino sector:

- M1 < M2 << mu

C) Sleptons between N2 and N1

$\tan\beta = 4$

High mass: m(A), mu, third-gen. scalars

←

PhenoGrid2: scan in gluino and squark

Two modes:

- "light LSP"
  - m(N1) = 100 GeV, m(N2) = K-100 where K = min(squark, gluino)
- "Compressed"
  - m(N2) = K-50, m(N1) = m(N2)-100

In both modes the slepton is placed midway between N1 and N2

(PhenoGrid3: same as PhenoGrid2 except right-handed scalars are set to high mass)

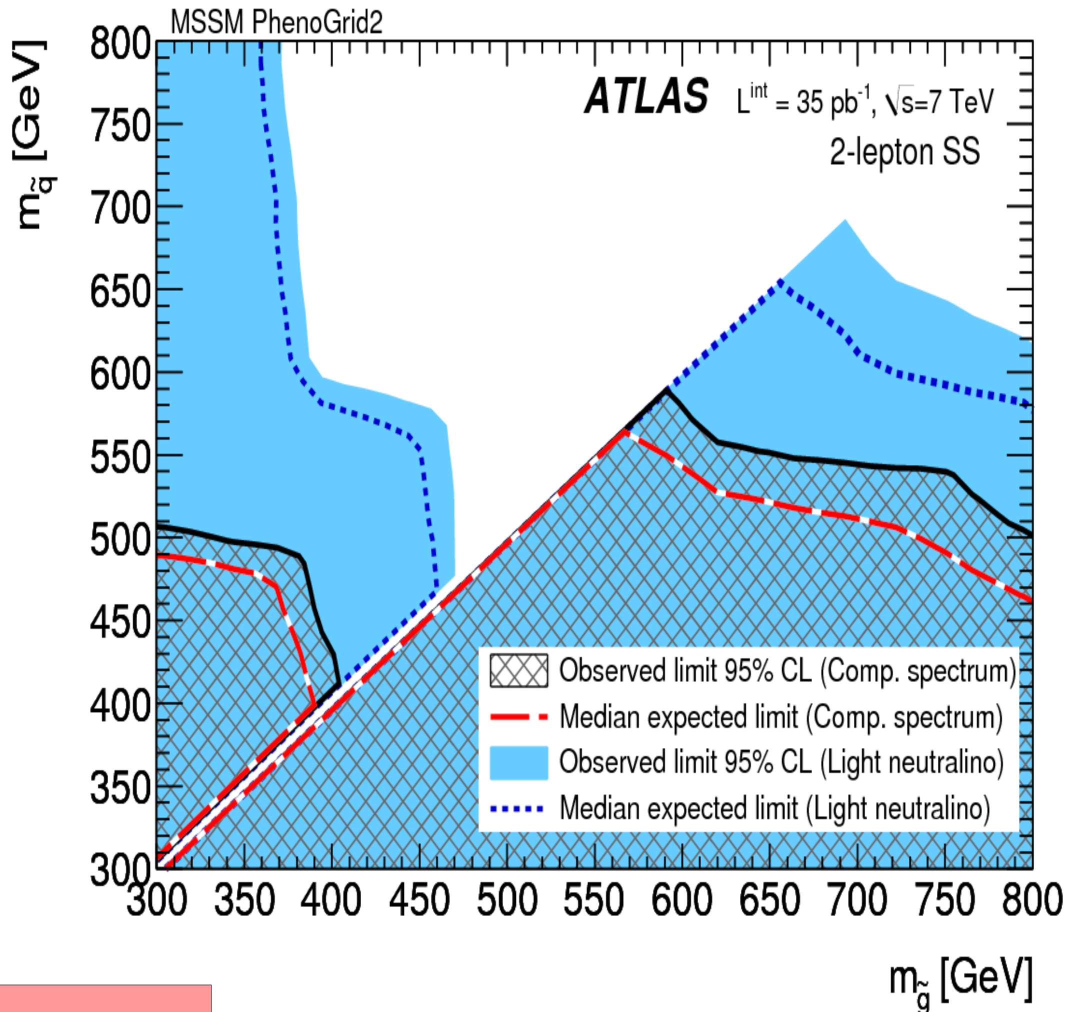
→

High lepton production built in, can be viewed as a lepton grid

PhenoGrid2 - SS

Plot shows exclusion limits for SS in the two modes, light neutralino and compressed

The reach is highest in the light-neutralino mode

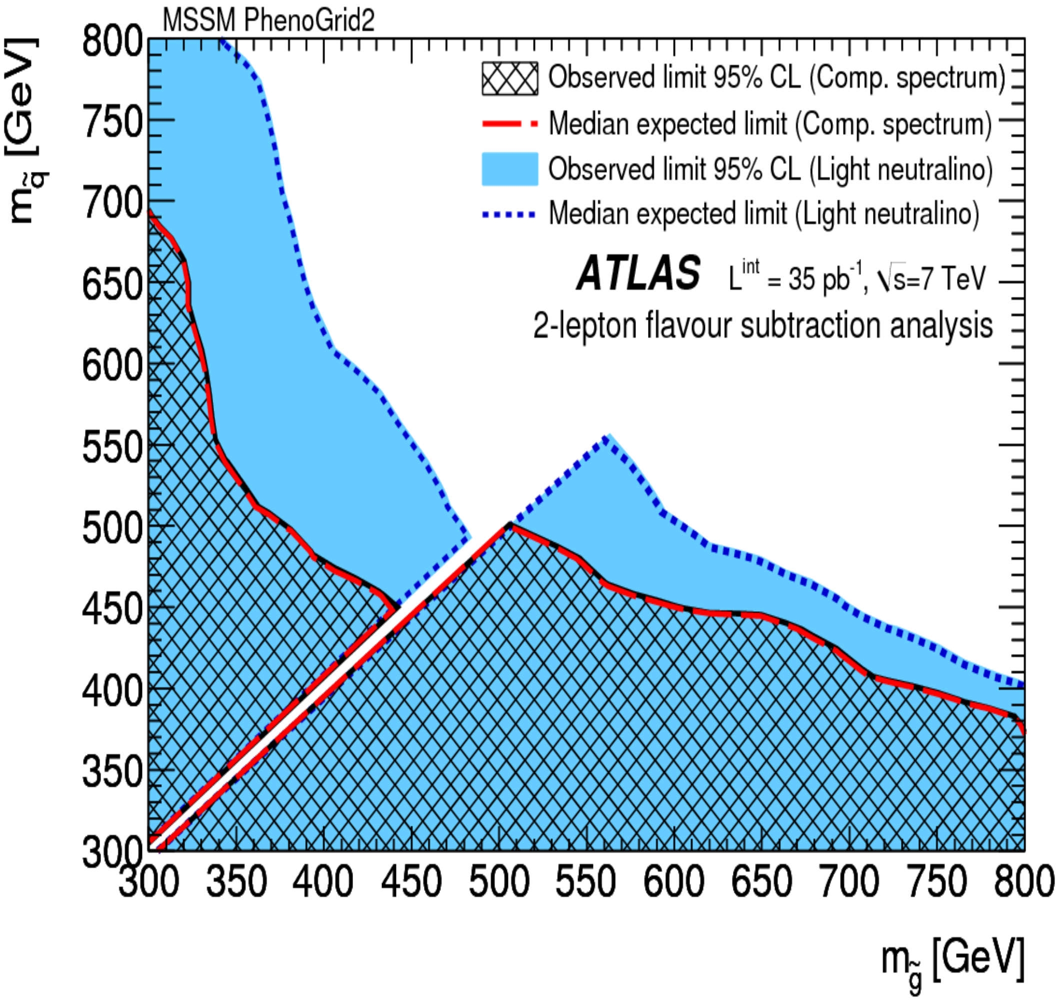


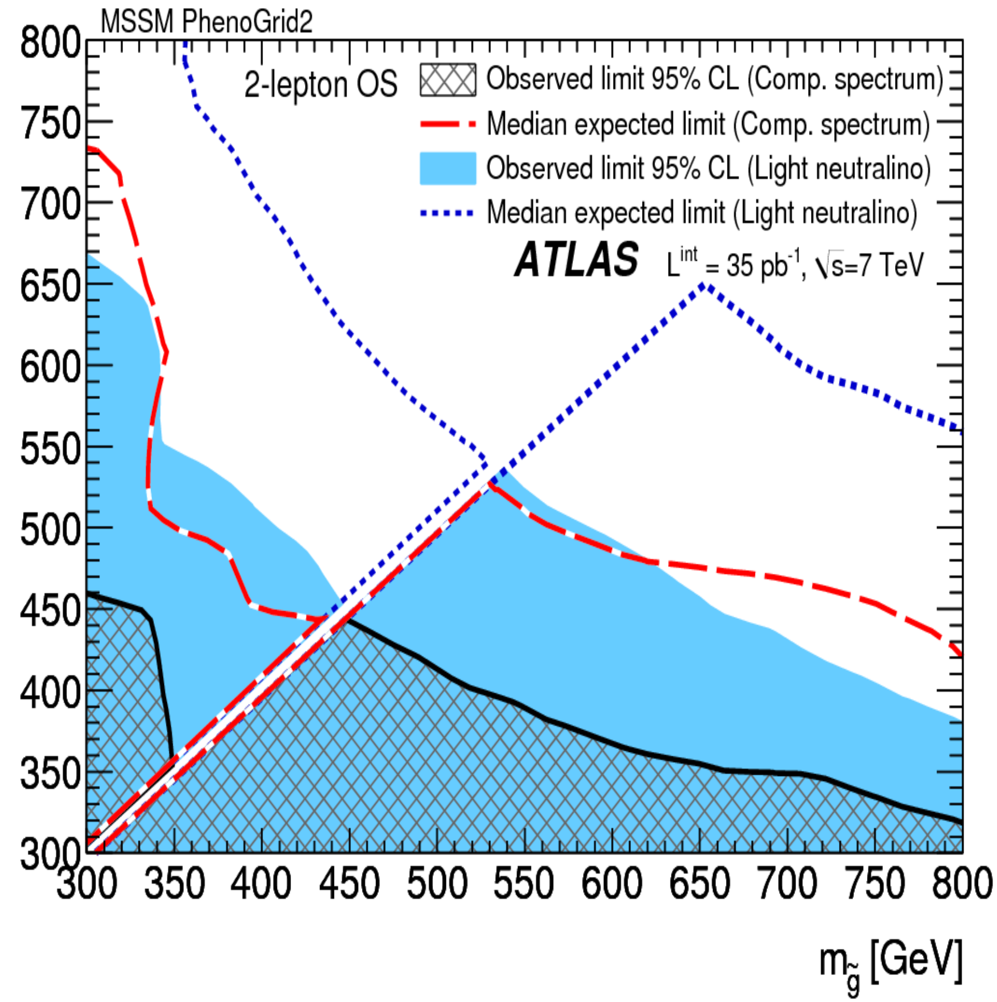
Discontinuity at gluino=squark

For squark > gluino the lepton fraction is lower. The gluino has a strong preference for direct decay into the LSP.

At the diagonal m(gl) = m(sq) + 10 GeV
- m(gl) < 690 GeV excluded for light-neutralino mode
- m(gl) < 550 GeV excluded for compressed mode

PhenoGrid2 – OS, OSSF flav.subtr.





R-parity violation: eμ resonance

eμ resonance

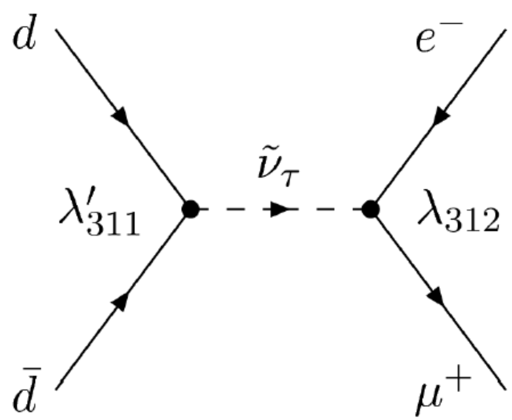
If R-parity conservation is mere fiction... ~~$R = (-1)^{3B+L+2S}$~~

then additional terms will be allowed in the superpotential,

$$\mathcal{W}_{\not R_p} = \frac{1}{2}\varepsilon_{ab}\lambda_{ijk}\hat{L}_i^a\hat{L}_j^b\hat{E}_k + \varepsilon_{ab}\lambda'_{ijk}\hat{L}_i^a\hat{Q}_j^b\hat{D}_k + \frac{1}{2}\varepsilon_{\alpha\beta\gamma}\lambda''_{ijk}\hat{U}_i^\alpha\hat{D}_j^\beta\hat{D}_k^\gamma + \varepsilon_{ab}\mu_i\hat{L}_i^a\hat{H}_2^b$$

many of which are literally dangerous,
while some are not -

$$\hat{\sigma}_{e\mu} \propto (\lambda'_{311})^2 \times (\lambda_{312})^2 \cdot \frac{1}{|\hat{s} - M^2 + i\Gamma M|^2}$$



We might be producing single sneutrinos,
which decay into an electron and a muon.

The would be visible as a resonance in eμ.

No MET, no jet.

For *e* and *μ* sneutrino, strong limits exist.
Look for tau sneutrino.
Benchmark point $\lambda'_{311} = 0.10$ and $\lambda_{312} = 0.05$
Sneutrino mass varied between 0.1-1 TeV

eμ resonance

Event selection:

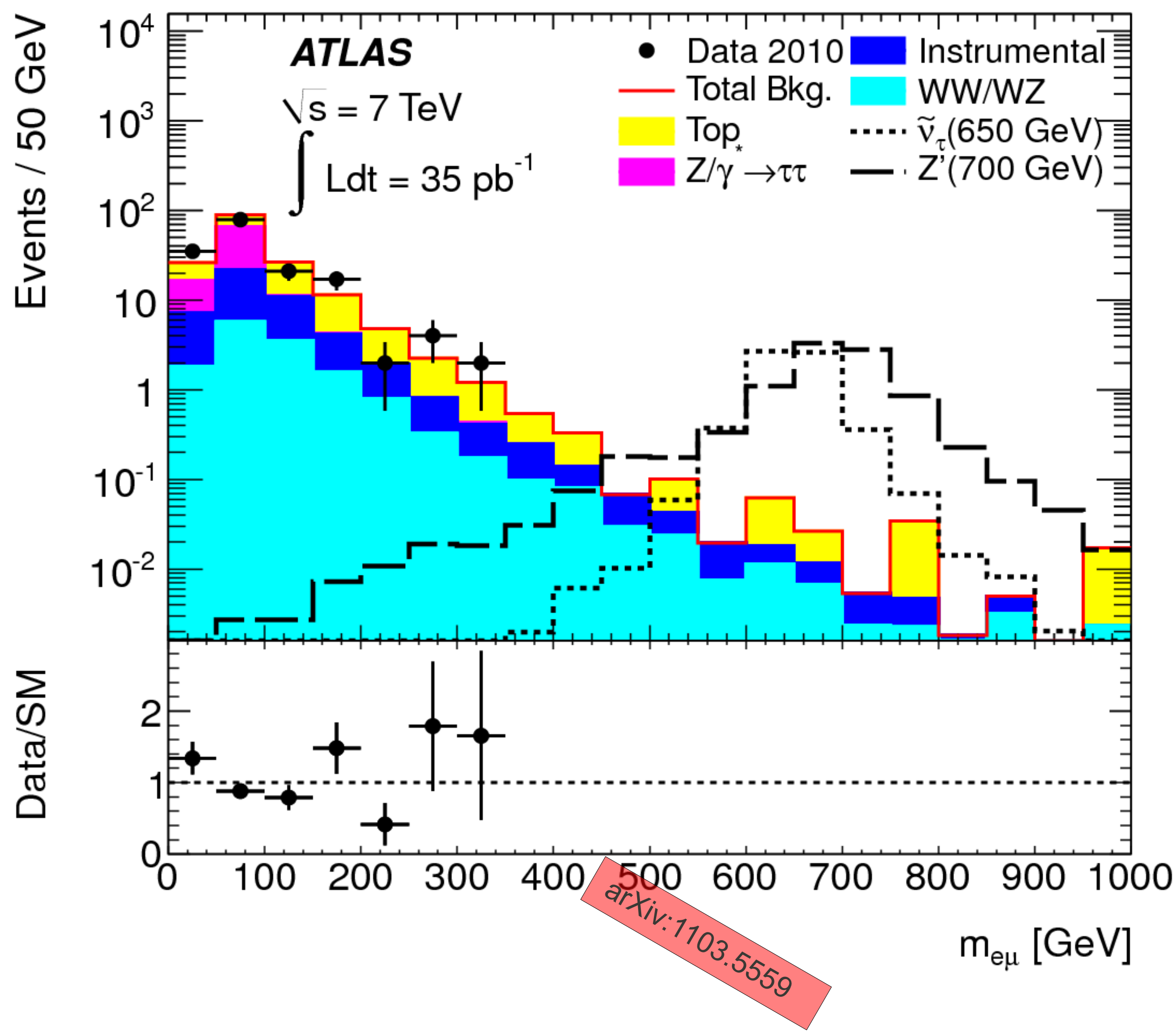
- exactly one e, one μ, OS
- pt > 20 GeV

Most bck estimated from MC

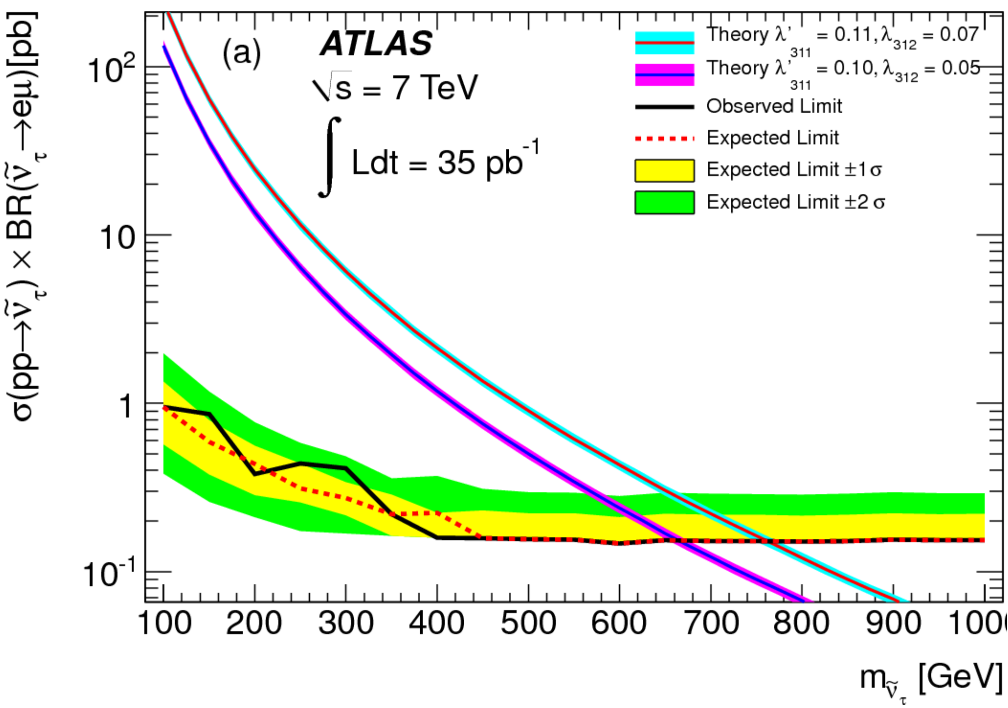
Instrumental bck estimated from data with Matrix Method

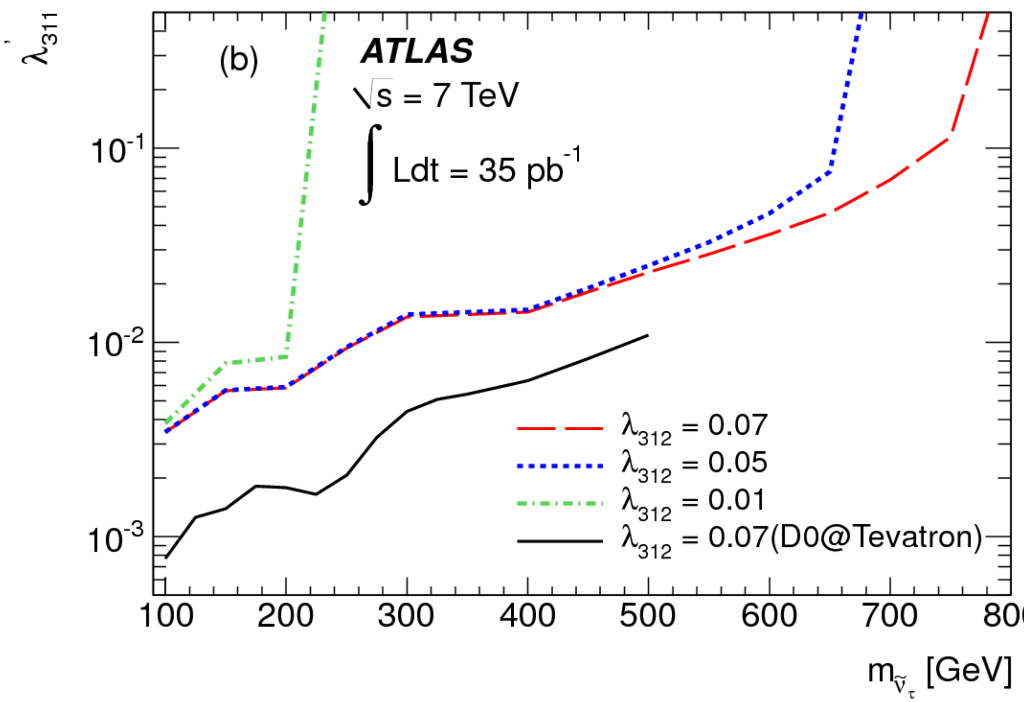
Good total agreement

Process	Number of events
$Z/\gamma^* \to \tau\tau$	54±7
$t\bar{t}$	57±9
WW	13.4±1.7
Single top	4.6±0.9
WZ	0.79±0.11
Instrumental background	33^{+30}_{-10}
Total background	163^{+34}_{-18}
Data	160



eμ resonance





Scan in m(eμ).
Look for excess in window $(m(\nu_\tau)-3\sigma, m(\nu_\tau)+3\sigma)$, where σ is the expected resolution

95% C.L. upper limit on λ'_{311} as a function of $m(\nu_\tau)$ for three different λ_{312} values

The region above the curve is excluded

Benchmark $\lambda'_{311} = 0.10$ and $\lambda_{312} = 0.05$:

- CDF: $m(\nu_\tau) > 0.56$ TeV
- ATLAS: m(vt) > 0.65 TeV

Summary, next

- 2010 was a great year for ATLAS; getting to know the detector; lots of good data
- ATLAS performed three SUSY searches in di-lepton channels with 2010 data
  - OS/SS + MET (arXiv: 1103.6214)
  - OSSF + MET (arXiv: 1103.6208)
  - eμ-resonance search (arXiv: 1103.5559)
- No sign of SUSY yet
- Have started to extend the Tevatron limits

- 2011 data is over us
- The Grid is already running hot with reconstructing data and simulating MC of SM and lots of different signal hypotheses
- Can hope for integrated luminosity in fb-1
- We hope for more

BACKUP

BACKUP

BACKUP

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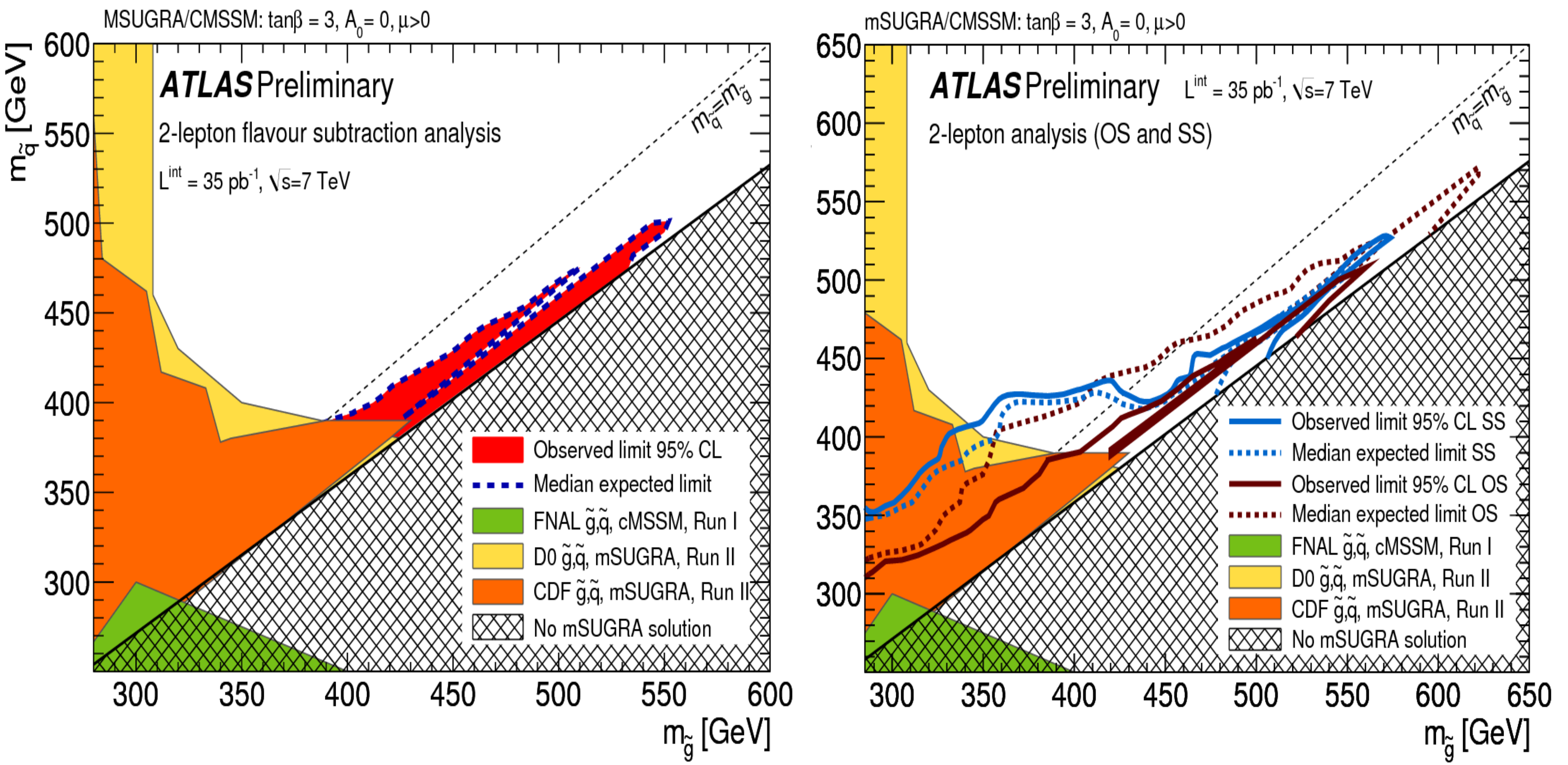
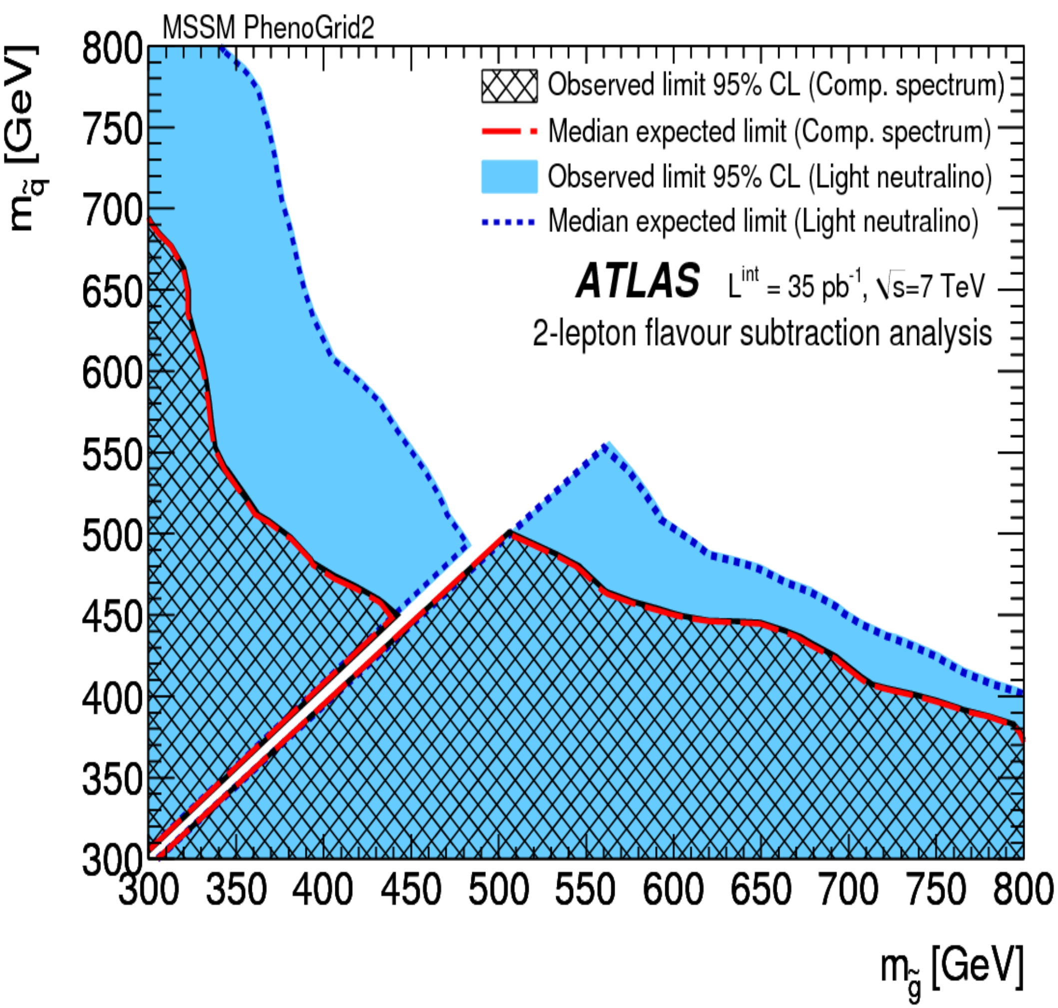
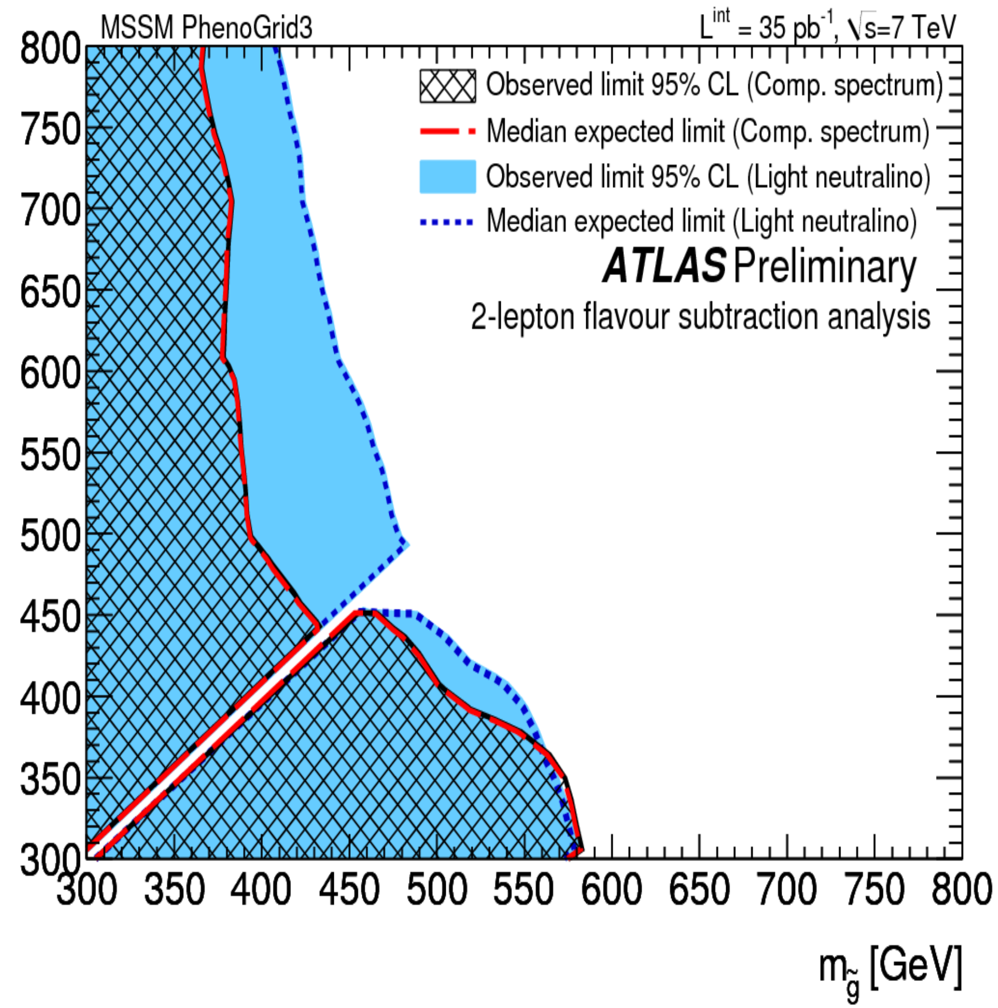
mSUGRA: m(gl) vs m(sq)

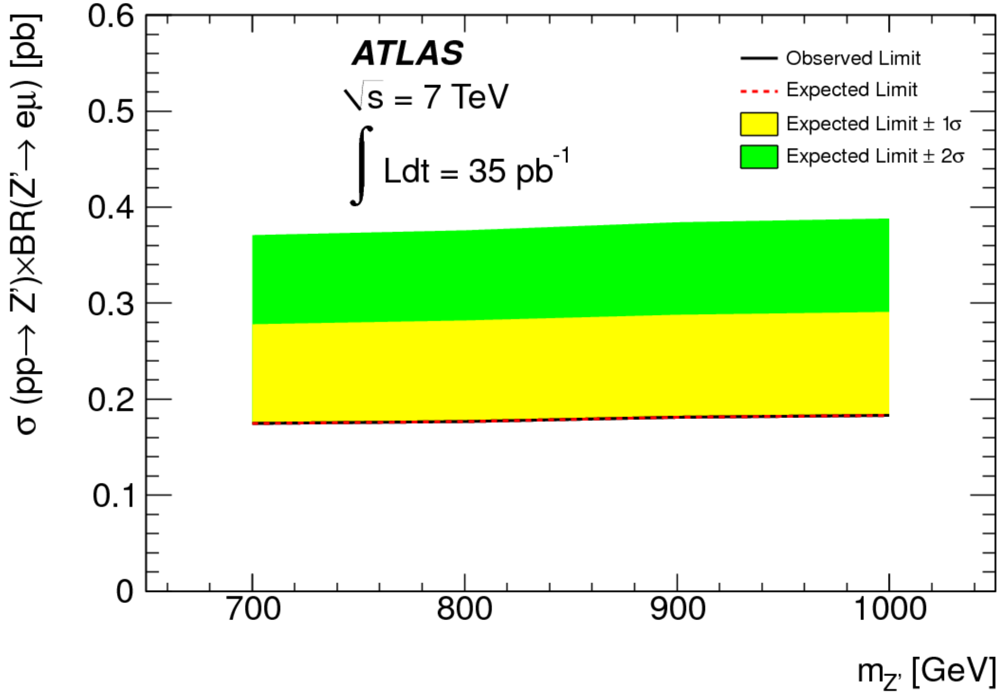


PhenoGrid2 and 3, OSSF subtr.





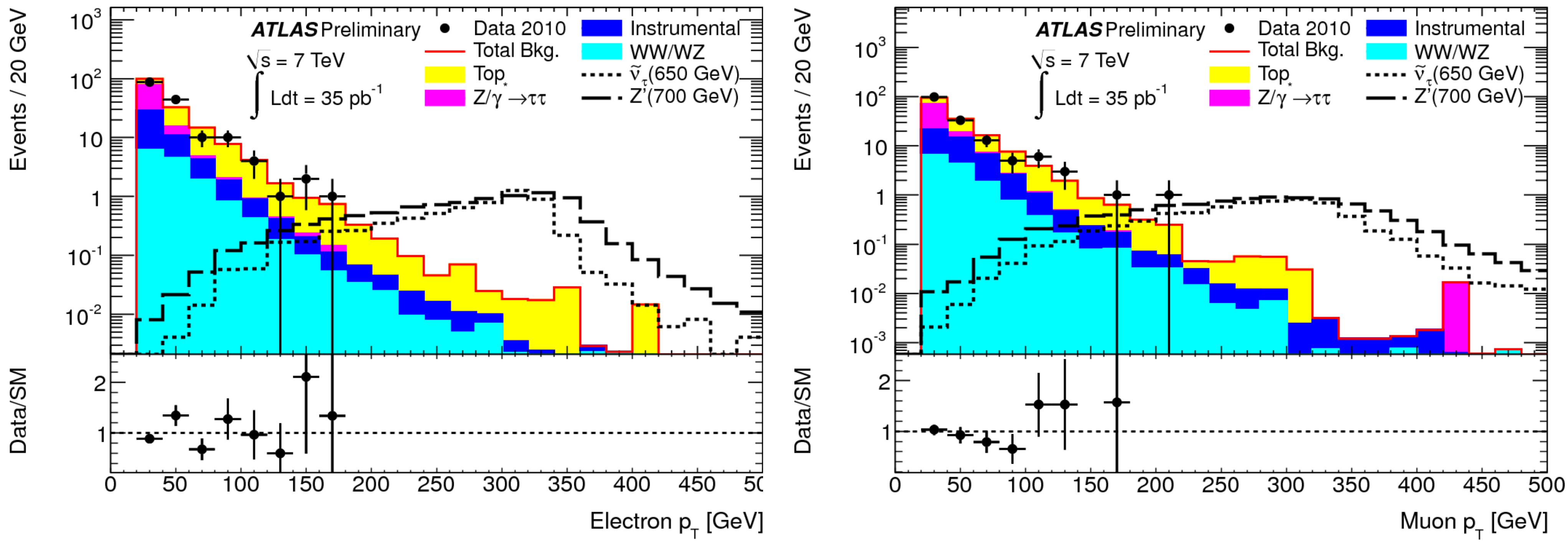
eμ resonance: Z' interpretation



An eμ resonance can also come from a lepton-flavour violating (LFV) decay of an extra gauge boson Z'.

Limits on cross-section x BR can be set as a function of mass extending the Tevatron limits.

eμ-resonance: lepton pt



BCK estimation: Z (OS)

Estimation procedure

- Define a CR by MET < 20 GeV, 81 < m(*ll*) < 101
- The SR is the usual, MET > 100 (150) GeV
- From MC find $\beta = \frac{N^{\text{MC,SR}}_{Z/\gamma^*}}{N^{\text{MC,CR}}_{Z/\gamma^*}}$
- Then find the number of *Z/γ** events in the CR

  $$N^{\text{data,CR}}_{Z/\gamma^*} = \left(N^{\text{data}} - N^{\text{MC}}_{W} - N^{\text{MC}}_{t\bar{t}} - N^{\text{est}}_{\text{QCD}}\right)^{\text{CR}}$$

  (the non *Z/γ**-contribution in CR is negligible)
- Finally extrapolate this number to the SR

  $$N^{\text{est,SR}}_{Z/\gamma^*} = \beta \cdot N^{\text{data,CR}}_{Z/\gamma^*}$$

- For *eμ* MC only since no events in CR
-

BCK estimation: Charge-flip (SS)

Charge-flip relevant for SS channel:

- When an electron, typically in di-leptonic ttbar:
  - emits a hard photon
  - and the hard photon undergoes conversion
  - and the electron with sign opposite to the original electron gets the largest energy share ("trident events")
    $e^{\mp}_{\text{hard}} \rightarrow \gamma_{\text{hard}}\, e^{\mp}_{\text{soft}} \rightarrow e^{\mp}_{\text{soft}}\, e^{\mp}_{\text{soft}}\, e^{\pm}_{\text{hard}}$
  - Then the reconstructed charge could easily be the "wrong" one and we have an SS event

Method:

- Obtain charge-flip probability in η from large-statistics Zee MC sample
- Apply probability on ttbar MC in SR

Results:

- Non-negligible for *ee* and more so for *eμ*

BCK estimation: Cosmics

- Cosmic muons enter the analysis in:
  - eμ, if a cosmic muons is incident with a collision event
  - μ+μ- if both incoming and outgoing is reconstructed within the same event

Estimation method:

- Use the transverse impact parameter in an additional “quality” cut to select cosmic muons; “cosmic-loose” and “cosmic-tight”
- obtain cosmic and collider efficiencies for “cosmic-loose” to also be “cosmic-tight” from calo-stream and MC
- Matrix method then applied to estimate cosmic contribution in SR

Results:

- Consistent with zero, but considerable uncertainty