BILINEAR R-PARITY VIOLATION IN SUPERSYMMETRY

EMMA TORRÓ

in collaboration with VASILIKI MITSOU , CARMEN GARCÍA

(IFIC Valencia)

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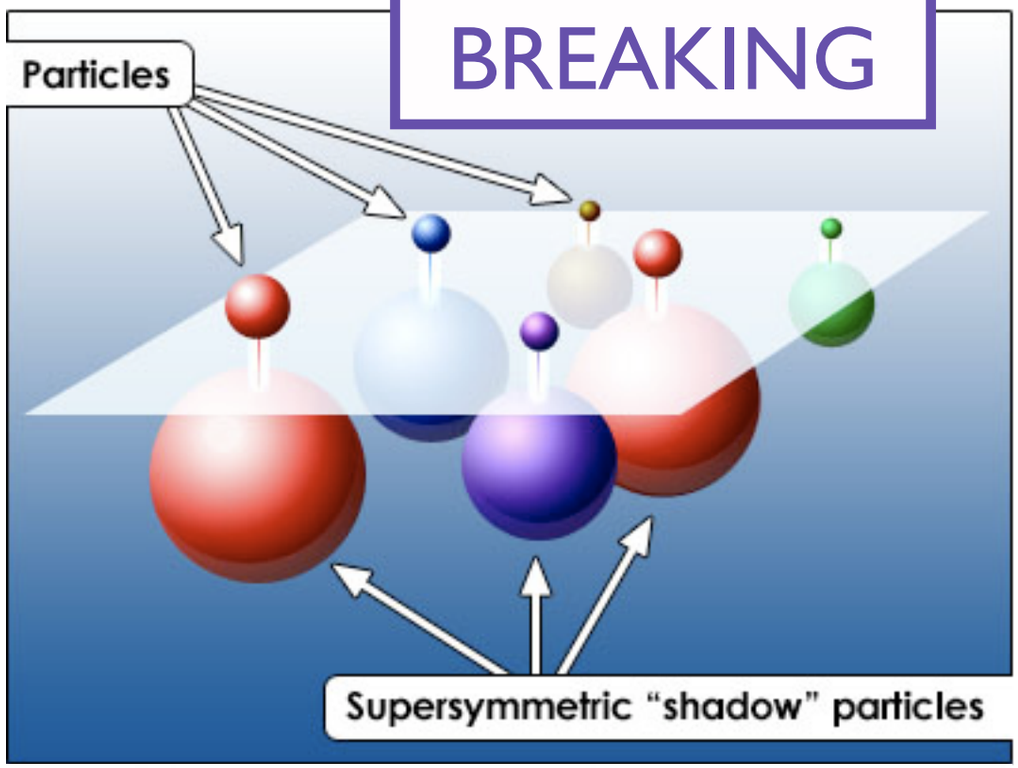
SUPERSYMMETRY

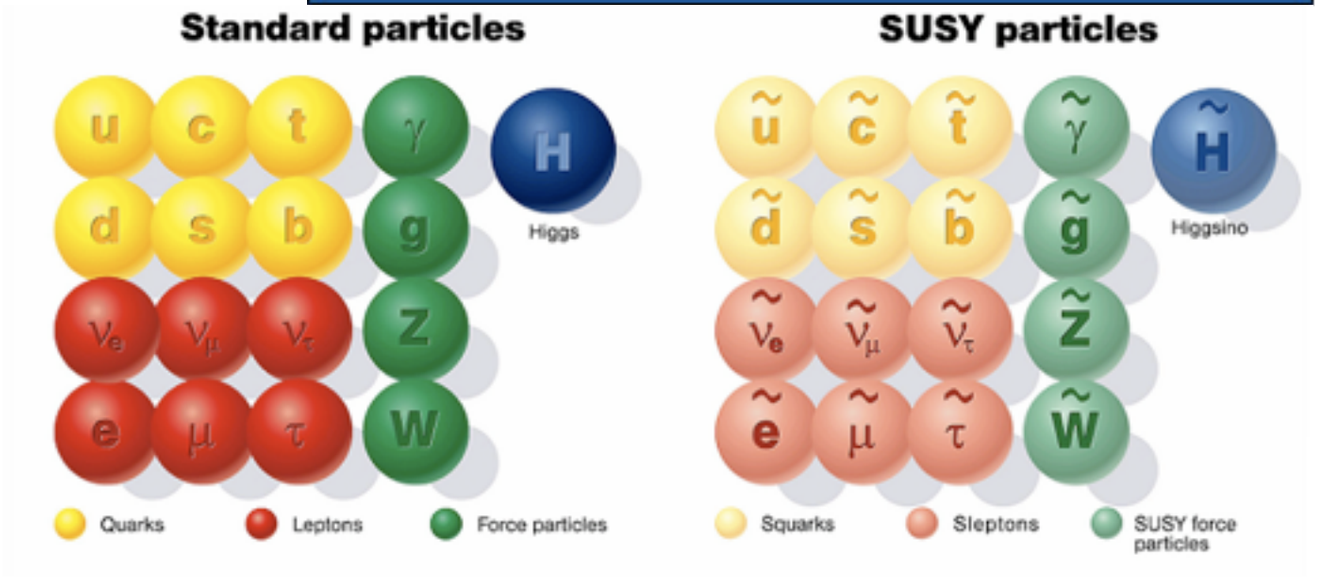
Fermion - boson symmetry

Every SM fermion have a boson susy-partner

Every SM boson have a fermion susy-partner

quarks	q	$\tilde{q}$	squarks
leptons	l	$\tilde{l}$	sleptons
photon	γ	$\tilde{\gamma}$	photino
	Z	$\tilde{Z}$	zino
Higgs	H	$\tilde{H}$	higgsino
	W	$\tilde{W}$	wino
gluon	g	$\tilde{g}$	gluino
graviton	G	$\tilde{G}$	gravitino

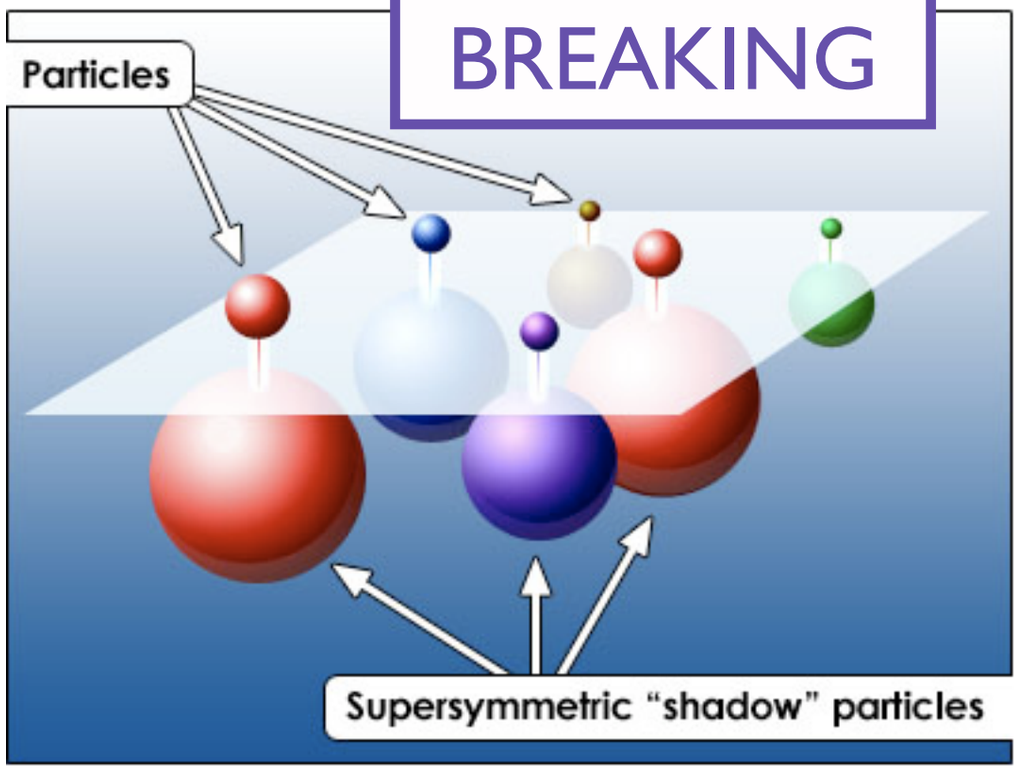




LHC: very good chance to observe supersymmetric particles

SUPERSYMMETRY

SUSY BREAKING



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$\tilde{\chi}_1^0, \tilde{\chi}_2^0, \tilde{\chi}_3^0, \tilde{\chi}_4^0$ neutralinos

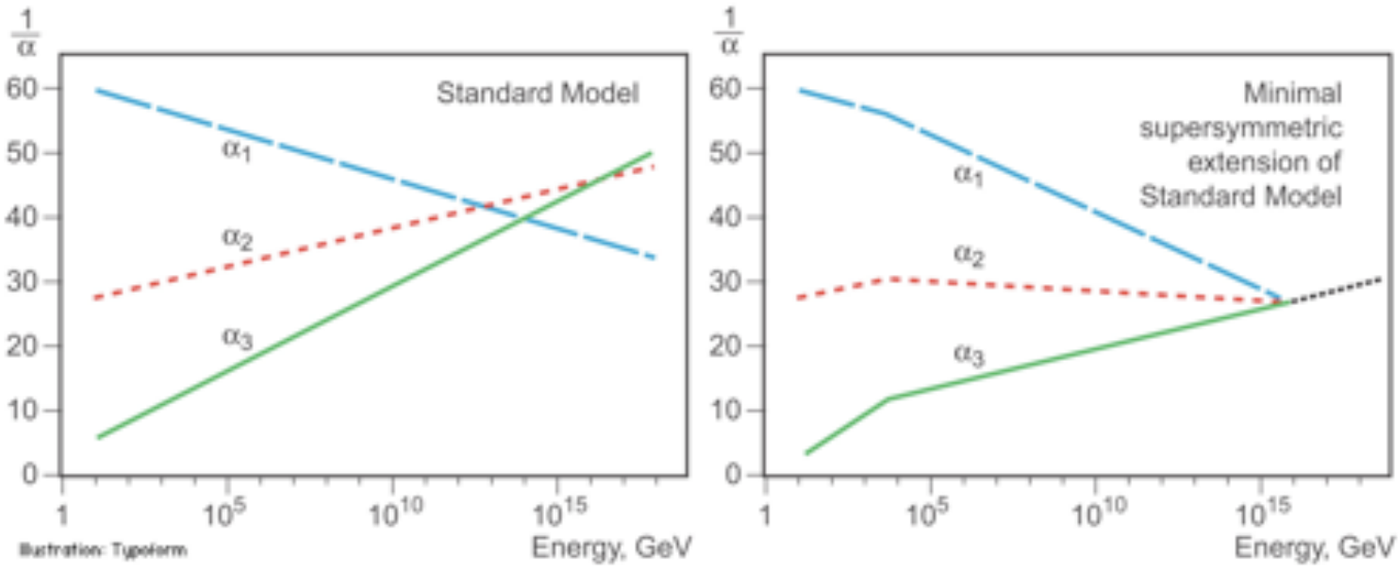
$\tilde{\chi}_1^\pm, \tilde{\chi}_2^\pm$ charginos

LHC: very good chance to observe supersymmetric particles

MOTIVATION FOR SUSY

- Avoids Fine-Tunning for the Higgs mass

- Grand Unification EW + strong interactions



- If R-Parity is conserved:

  the Lightest Supersymmetric Particle (LSP) has to be stable, neutral and not strong-interacting: candidate to DM

R-PARITY

$$R = (-1)^{3B + L + 2s} = \begin{cases} +1 \text{ for SM particles} \\ -1 \text{ for SUSY particles} \end{cases}$$

- Constructing a theory: { renormalizable; conserving symmetries of the system (Gauge, Lorentz...)

- There is not a fundamental reason to conserve L, B.

- A hard violation of B and L ⟶ p fast decay BUT soft violation of B OR L keeps p lifetime ok.

RPC	VS.	RPV
→ susy particles generation in pairs		→ susy single particles
→ Stable LSP		→ LSP decay → new signals; → new background
Interacting Massive Stable particle would form part of atoms. Their mass would be different!!		
no em charge, no strong interaction		no need to be em neutral, can have strong int
→ undetectable ⇒large E_T^{miss}		→ not so large E_T^{miss}

BILINEAR R-PARITY VIOLATION

- L_{MSSM}: no ~~L~~, no ~~B~~ ⟶ RPC

L-number violating terms

$$W^{MSSM}_{\not RP} = \lambda_{ijk}\,\hat{L}_i\,\hat{L}_j\,\hat{E}_k + \lambda'_{ijk}\,\hat{L}_i\,\hat{Q}_j\,\hat{D}_k + \varepsilon_i\,\hat{L}_i\,\hat{H}_u + \lambda''_{ijk}\,\hat{U}^c_i\,\hat{D}^c_j\,\hat{D}^c_k$$

bilinear terms

B-number violating terms

- 3 parameters ε_i in bilinear terms $\varepsilon_i L_i H_u$
- 3 "alignment" parameters: $\Lambda_i = \varepsilon_i v_d + \mu v_i$

  v_i : sneutrino vev's

  v_d : vev of H_d

but

fixing:
- ew symmetry breaking and
- neutrino oscilation data

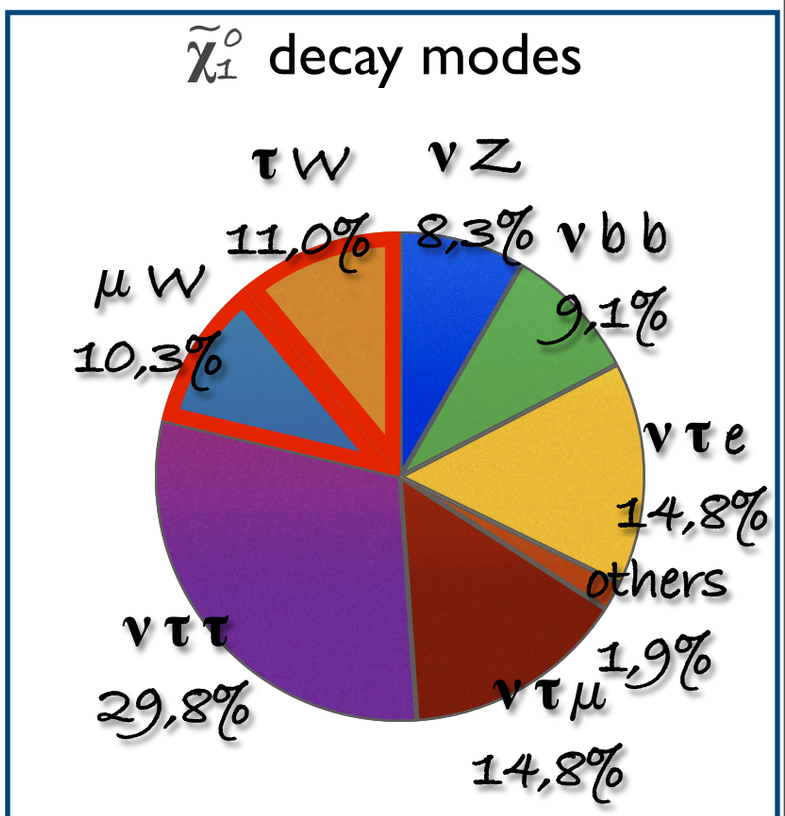
1 remaining free parameter

BILINEAR RPV & NEUTRINO MIXING

- RPV through bilinear terms ($\varepsilon_i \neq 0$) in the super-potential and the SUSY-breaking potential:
  [c.f. M. Hirsch et al., JHEP 0805:048,2008 and references therein]
- LSP = LIGHTEST NEUTRALINO: $\tilde{\chi}_1^0$
- Bilinear RPV connected to neutrino physics:

$$\tan^2\theta_{atm} \simeq \frac{BR(\tilde{\chi}_1^0 \to \mu^\pm W)}{BR(\tilde{\chi}_1^0 \to \tau^\pm W)}$$

$\bar{q}q'$



10 TeV, 2 fb^{-1}, SU3 mSUGRA point

mSUGRA point SU3:

m_0 = 100 GeV, $m_{1/2}$= 300 GeV

tanβ = 6, A_0 = -300 GeV, sgn μ = +1

RPV parameters:

ε_1 = 102 MeV, ε_2 = -102 MeV, ε_3 = 102 MeV

V_1 = - 8.8 MeV, V_2 = 9.0 MeV, V_3 = - 8.6 MeV

Neutrino mixing parameters:

$\Delta m^2_{atm} = 2.2 \cdot 10^{-3}$ eV^2, $\Delta m^2_{sol} = 2.8 \cdot 10^{-5}$ eV^2

$\tan^2\theta_{atm} = 0.96$, $\tan^2\theta_{sol} = 0.64$

$M_{inv}(\tilde{\chi}_1^0) = 118$ GeV

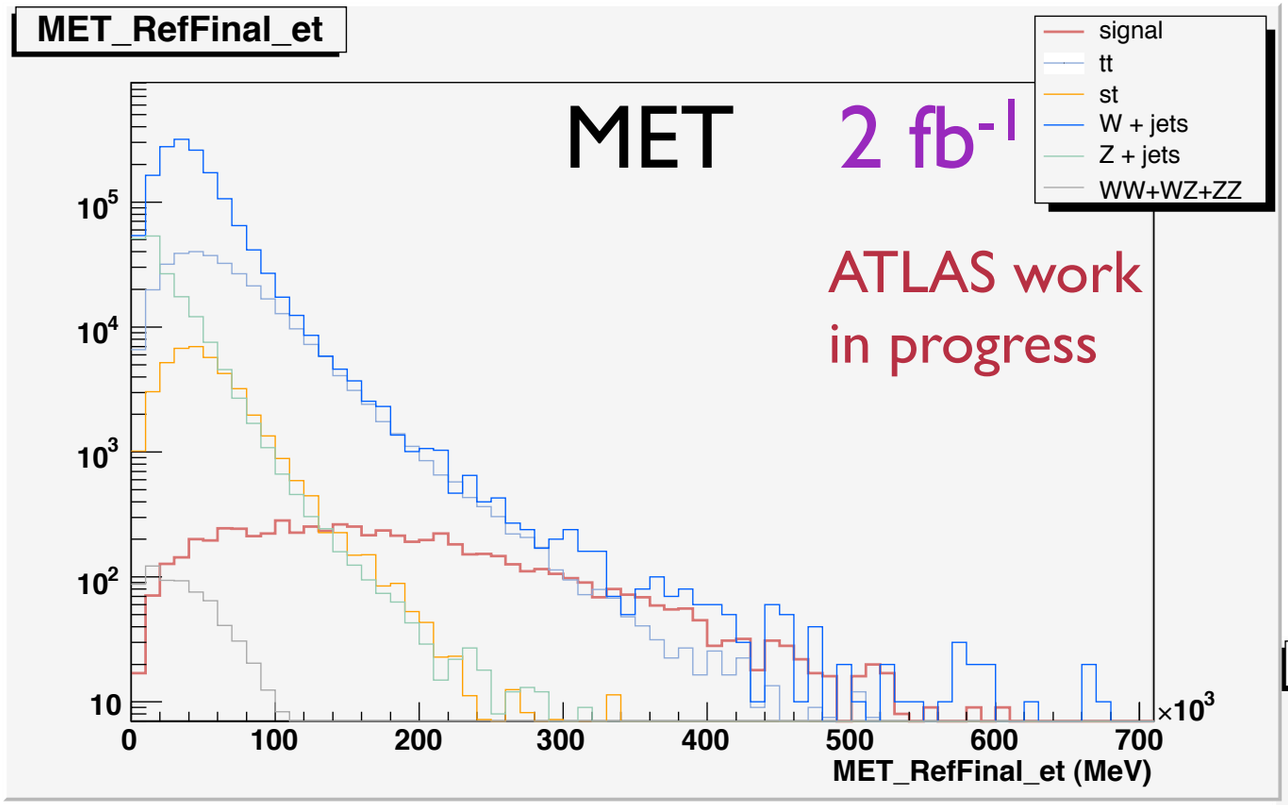
decay length $(\tilde{\chi}_1^0) = 290\ \mu m$

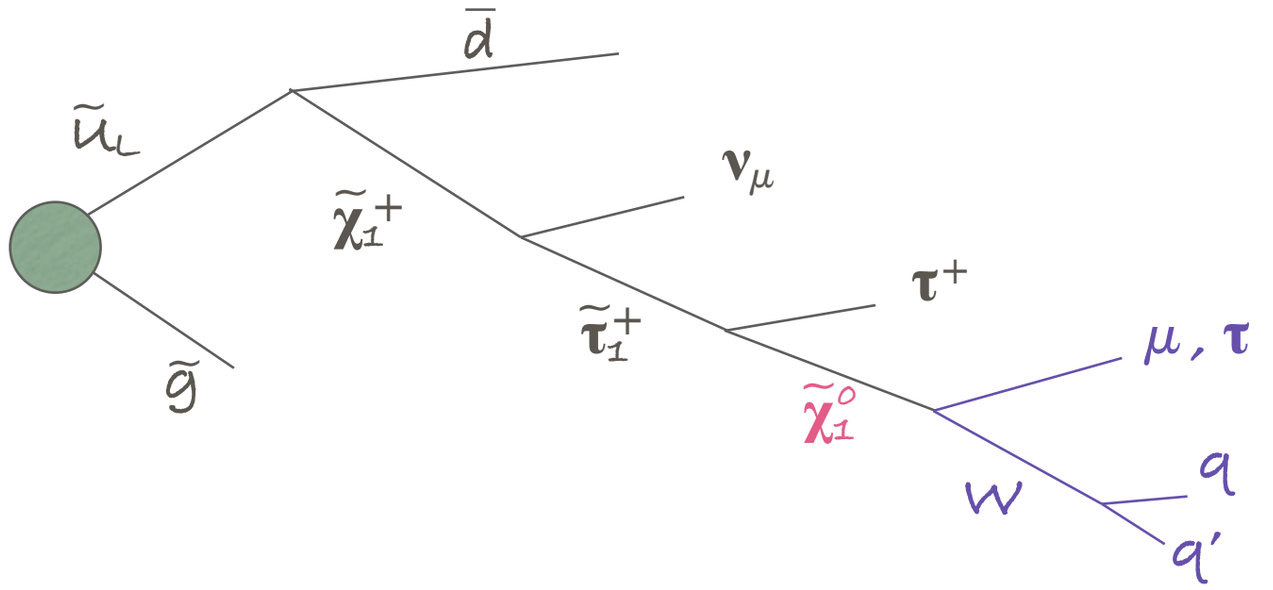
other mSUGRA points $\lambda \in (0.1, 100)$ mm

← same decay modes as in RPC case except for the LSP decay!!

SM BACKGROUND

- After trigger mu10 jet 18 selection (no cuts):

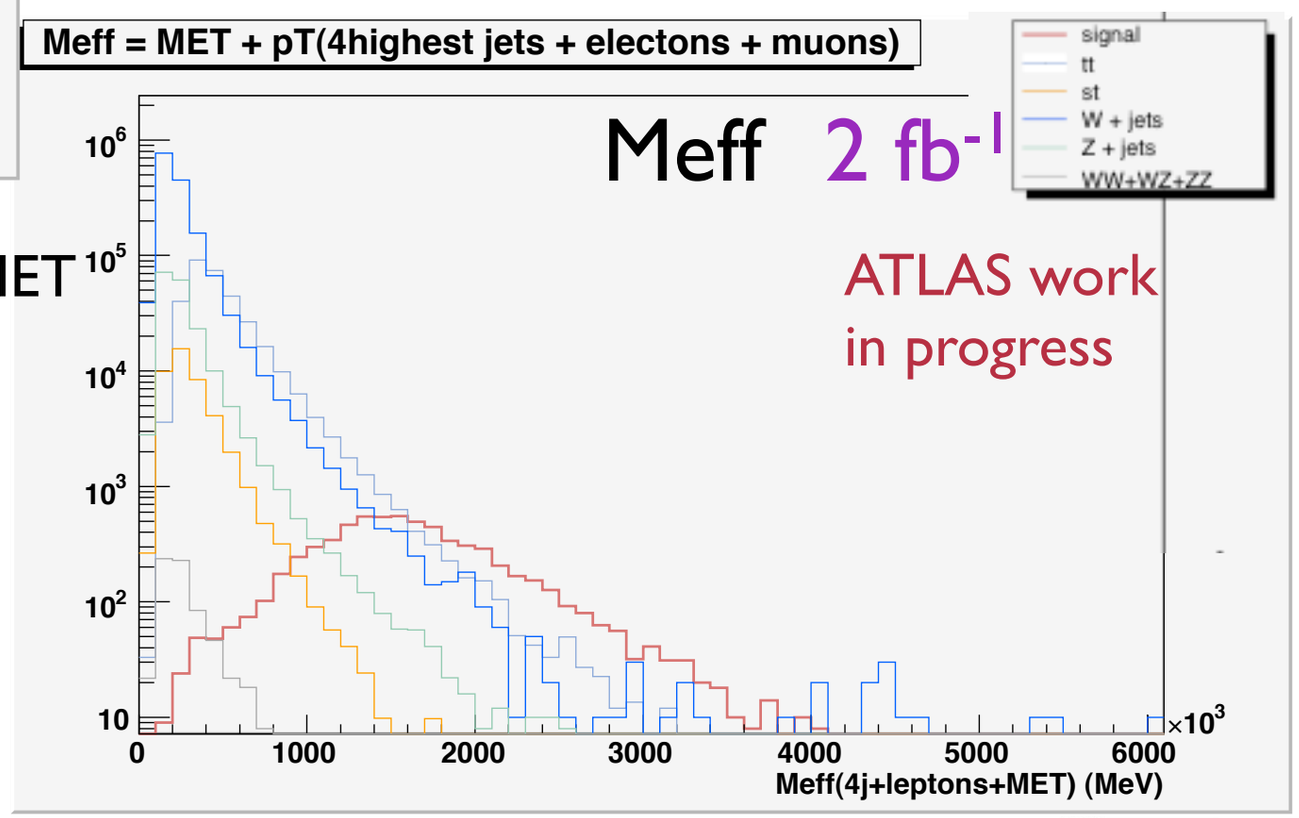




- Meff = Σ p_T(electrons, muons, 4highest jets) + MET
- 'tveto' ∀ W candidate, reject event

  ⟶ if $|M_{inv}(W,\text{highest jet}) - M_{top}| < 20\text{-}40$ GeV

- W candidate: every pair of jets with inv. mass = $M_W \pm 5$ GeV.



SM BACKGROUND

	loose		medium		tight		80%	
	# events	eff (%)	# events	eff (%)	# events	eff (%)	# events	eff (%)
SUSY signal	4445	66.9	3900	58.7	3481	52.4	3875	58.4
ttbar	8346	2.5	3773	1.1	2566	0.8	3858	1.1
single top	104	0.2	45	0.1	26	0.1	45	0.1
W + jets	2426	0.2	1113	0.1	761	0.1	1132	0.1
Z + jets	422	0.2	194	0.1	132	0.1	215	0.1
WW + WZ + ZZ	2	0.2	0	0.0	0	0.0	0	0.0
total bkg	**11300**	**0.6**	**5126**	**0.3**	**3485**	**0.2**	**5250**	**0.3**
S/B	0.3934		0.7609		0.9987		0.7381	
$S/\sqrt{B}$	41.815		54.475		58.962		53.480	

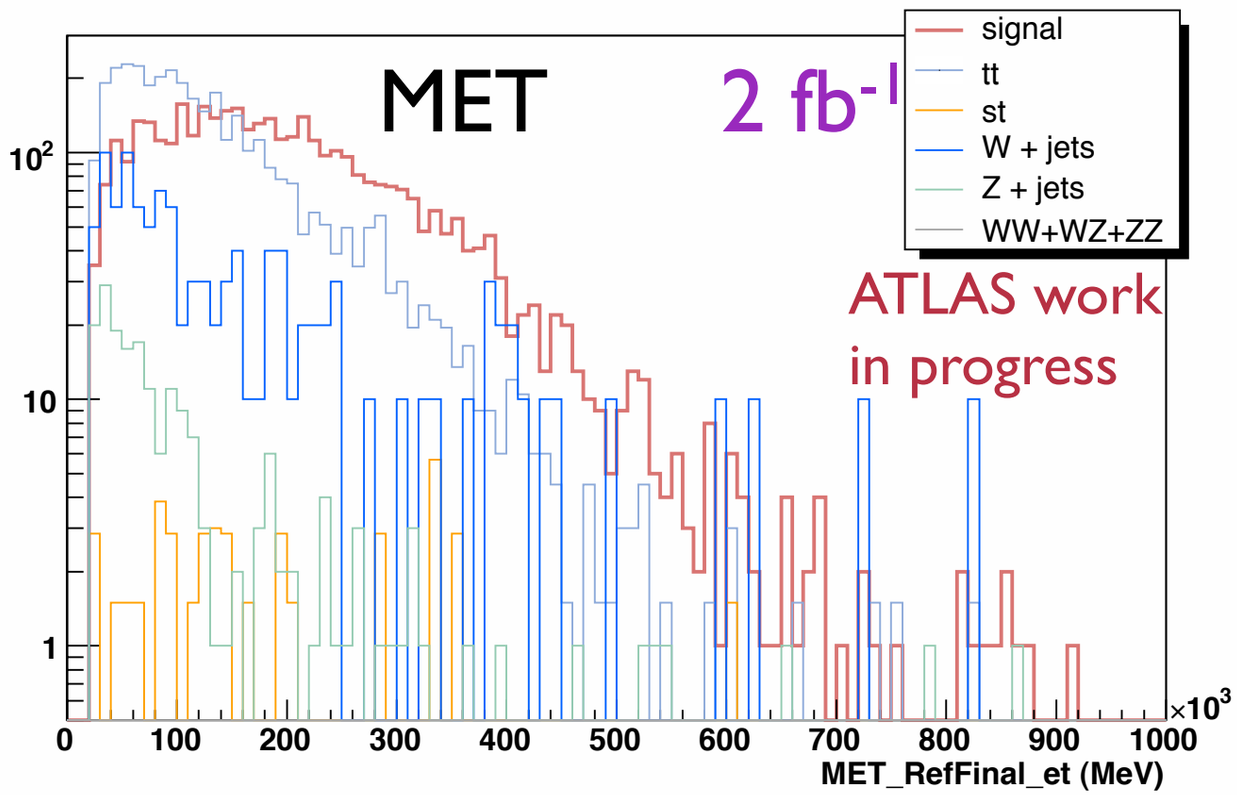
loose = M_{eff} > 1 TeV; MET > 20 GeV;
tveto: M_{top} ± 20 GeV; mu10jet18

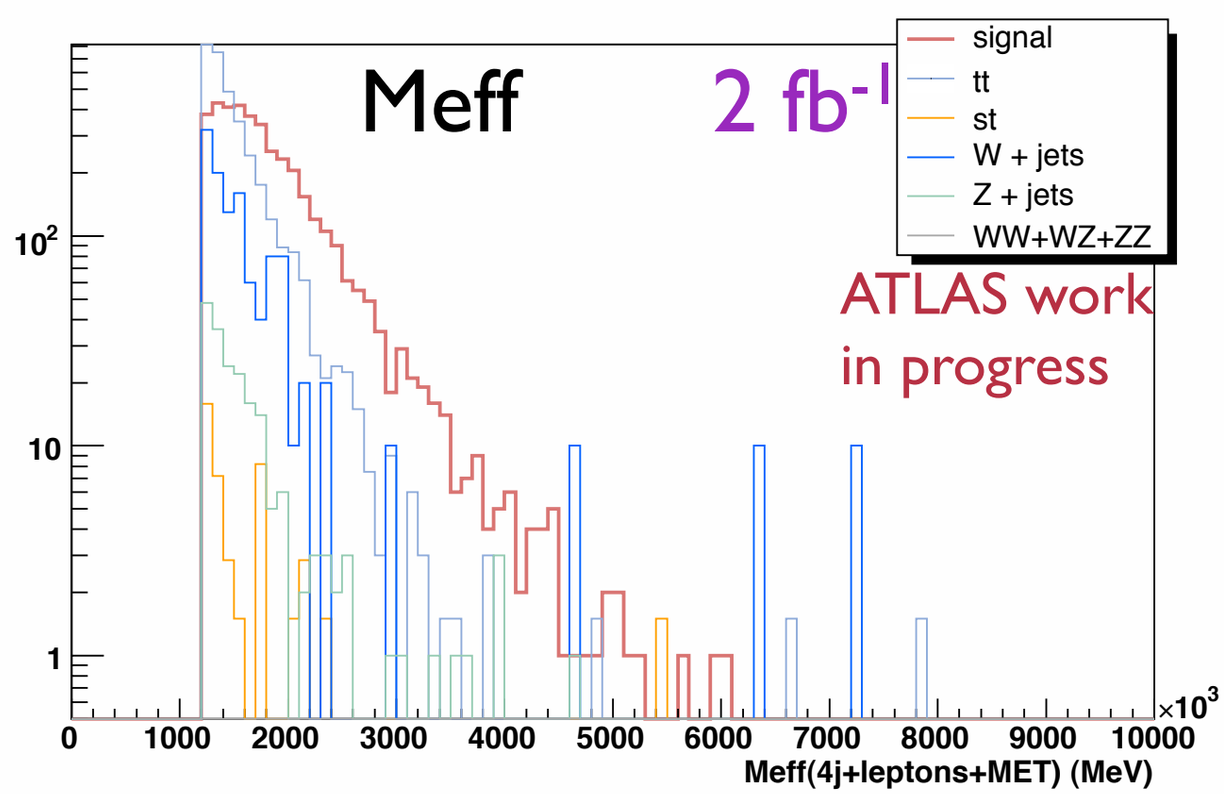
medium = M_{eff} > 1.2 TeV; MET > 25 GeV;
tveto: M_{top} ± 30 GeV; mu10jet18

tight = M_{eff} > 1.3 TeV; MET > 30 GeV;
tveto: M_{top} ± 40 GeV; mu10jet18

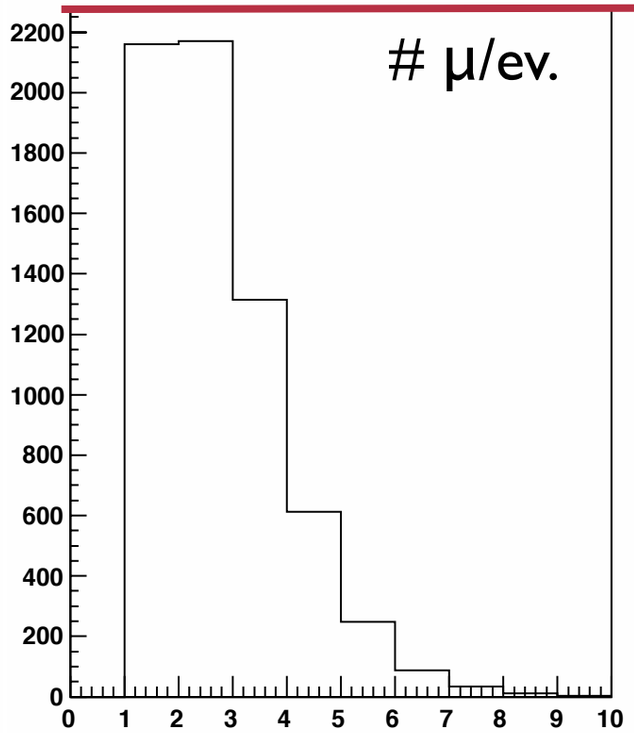
80% = M_{eff} > 1.2 TeV; MET > 30 GeV;
tveto: M_{top} ± 20 GeV; mu10jet18

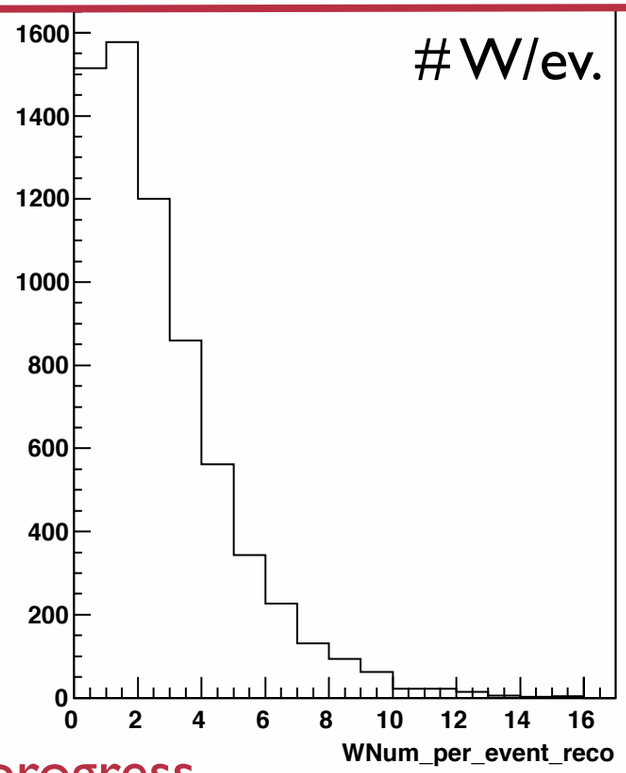
- After medium cuts:



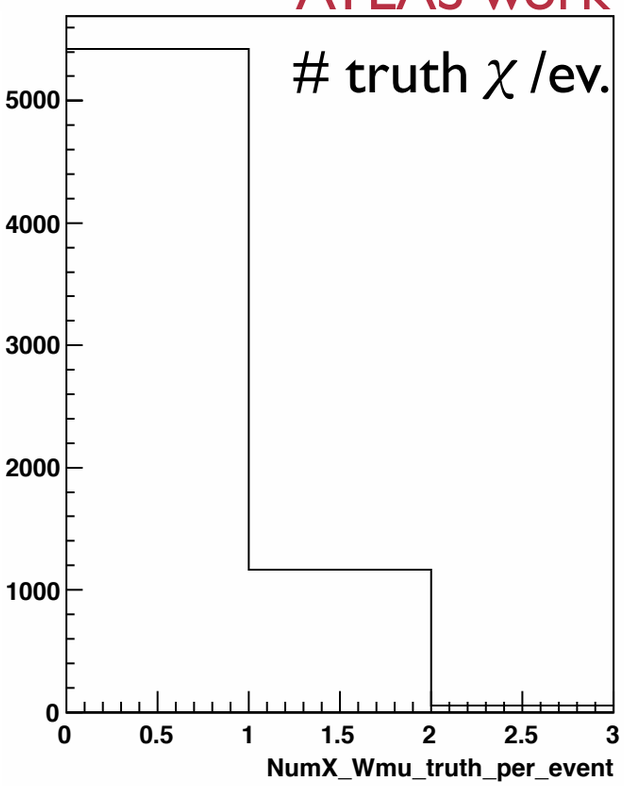


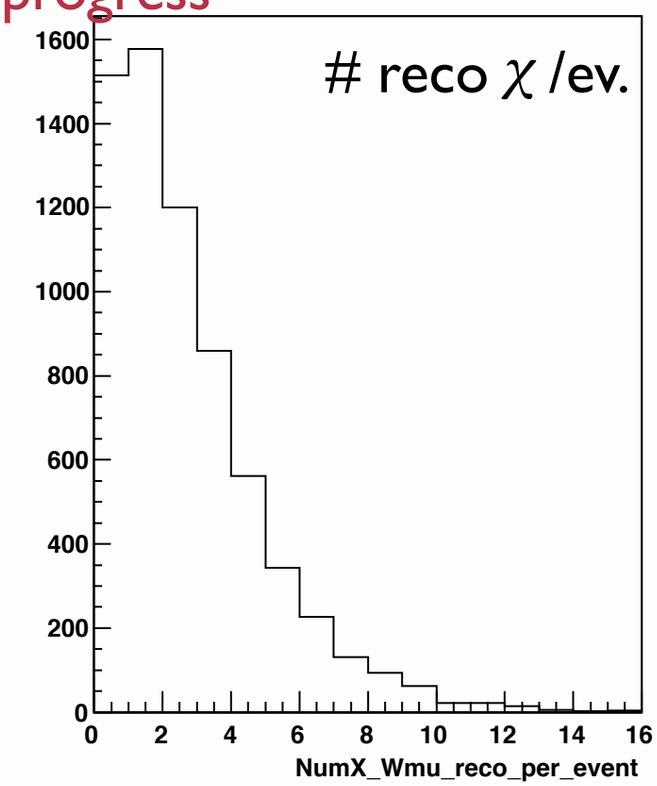
COMBINATORIAL BACKGROUND

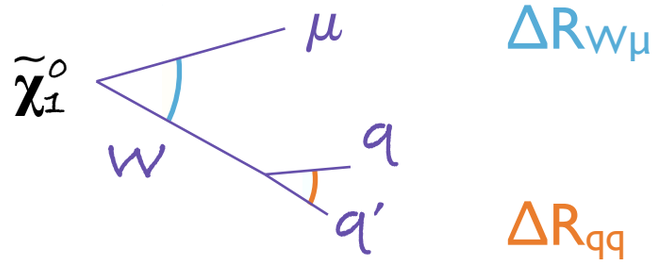




ATLAS work in progress





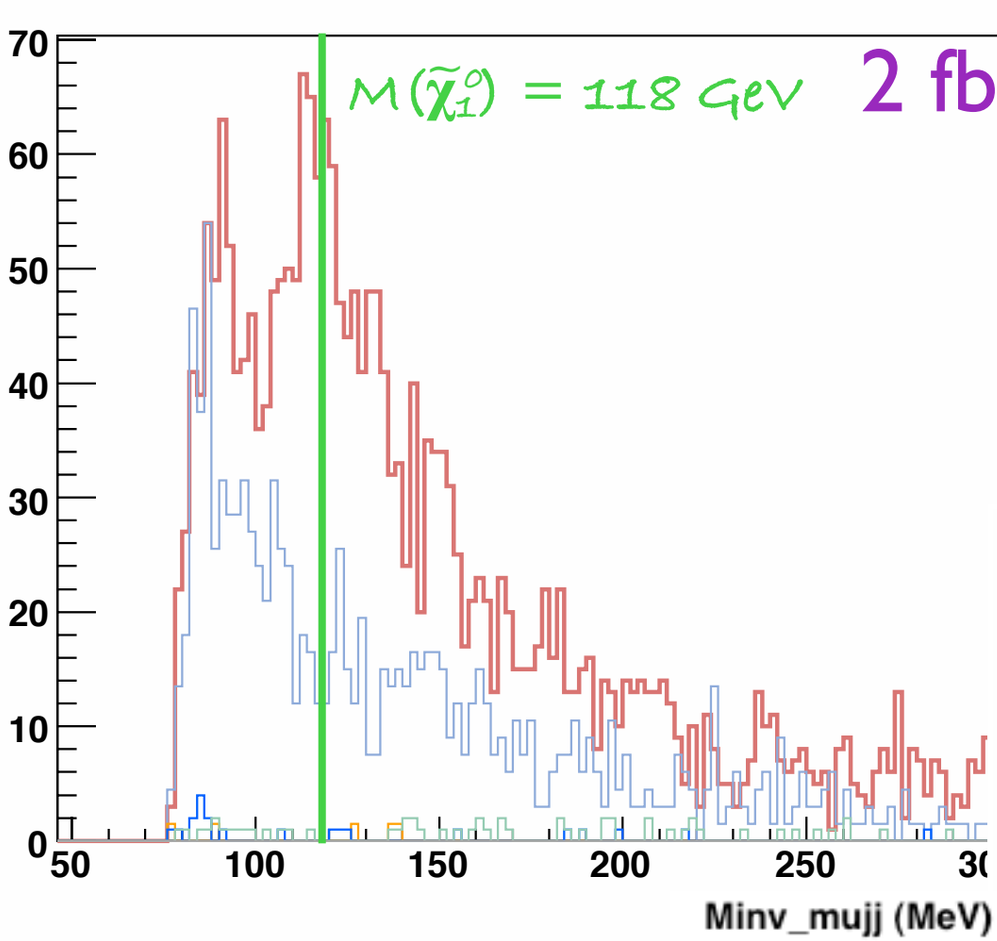


- W candidate: every pair of jets with inv mass = M_W ± 5 GeV.
- $\tilde{\chi}_1^0$ candidate: combination of every W candidate with all μ in the event.

BR($\tilde{\chi}_1^0 \rightarrow$ W μ) = 10%

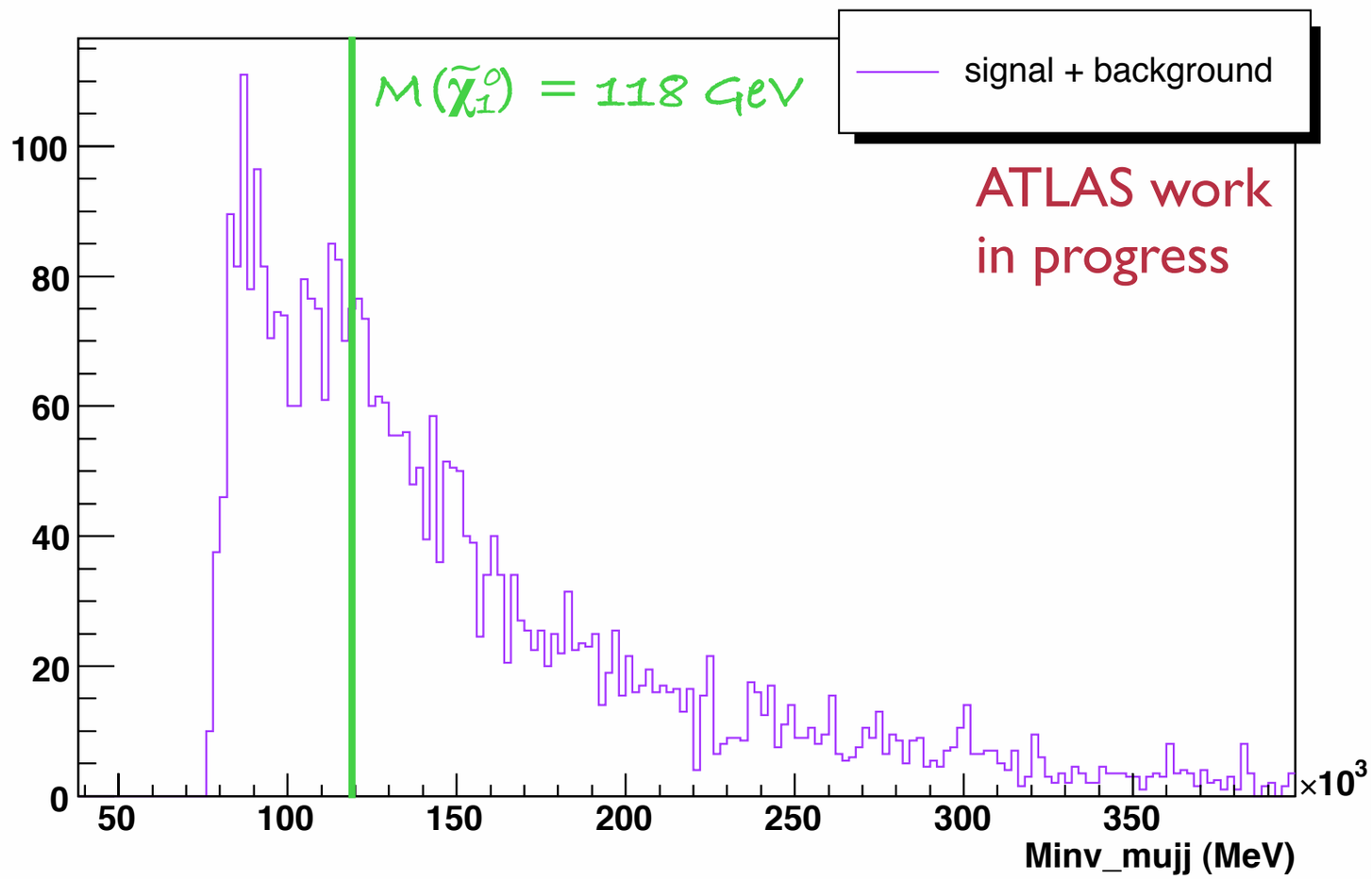
BR(W→ qq) = 68%

μ jj INVARIANT MASS



Meff > 1.2 GeV
MET > 25 GeV
tveto: M_{top} ± 30 GeV

$p_T(\mu)$ > 10 GeV
$\Delta R_{W\mu} < 2.5$
$\Delta R_{jj} < 1.5$



With 2 fb^{-1} it is possible to see a peak in the neutralino mass.

OUTLOOK - SUMMARY

- We have studied the possibility to detect R-parity violating SUSY with ATLAS at 10 TeV in the muon + jets signature
  - simple cuts applied on relatively well-understood objects: muons, jets
  - (loose) MET cut not crucial: may be omitted
  - S/B ratio ~ 1
  - main background: ttbar
- With 2 fb^{-1}, the neutralino decay can be seen as a peak in the muon+2jets invariant mass. Analysis may be improved by:
  - applying b-tagging for suppressing ttbar bkg
  - use effective mass including taus
- Analysis optimised for bilinear RPV; similar cuts applicable for a general $\chi_1 \rightarrow \mu qq$ decay in RPV through trilinear terms
- The possibility to detect displaced vertices O(1cm) would be relevant for this scenario and RPV in general
- Determination of exclusion / discovery regions in mSUGRA space is in progress
- Analysis on taus + jets in progress

BACK UP SLIDES

CONTACTO

Presentación: Emma Torró emma.torro@ific.uv.es

Directora: Vasiliki Mitsou vasiliki.mitsou@ific.uv.es

Colabora: Carmen García carmen.garcia@ific.uv.es

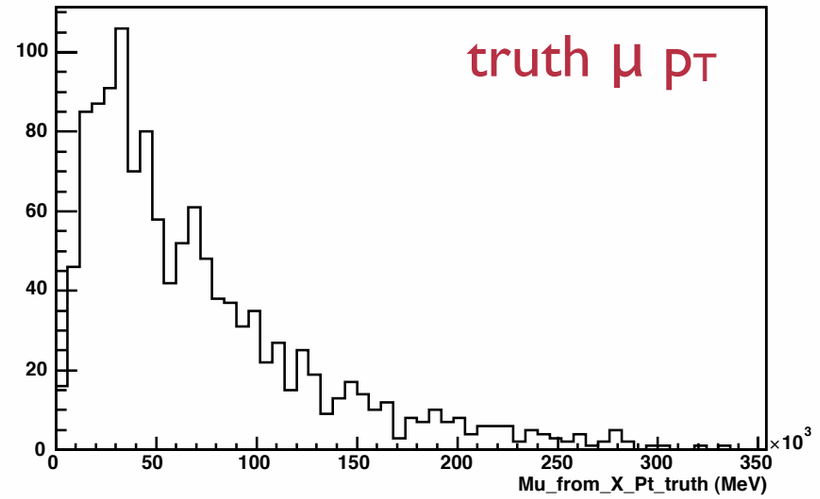
Convenors: Giacomo Polesello Giacomo.Polesello@cern.ch

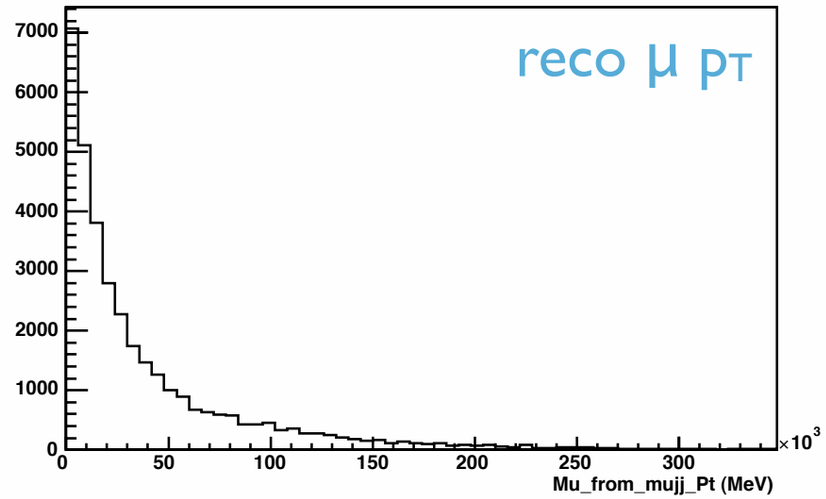
Paul de Jong h26@nikhef.nl

Removing comb. background

only truth μ and qq coming from

$\chi \longrightarrow \mu W$ (W → qq)





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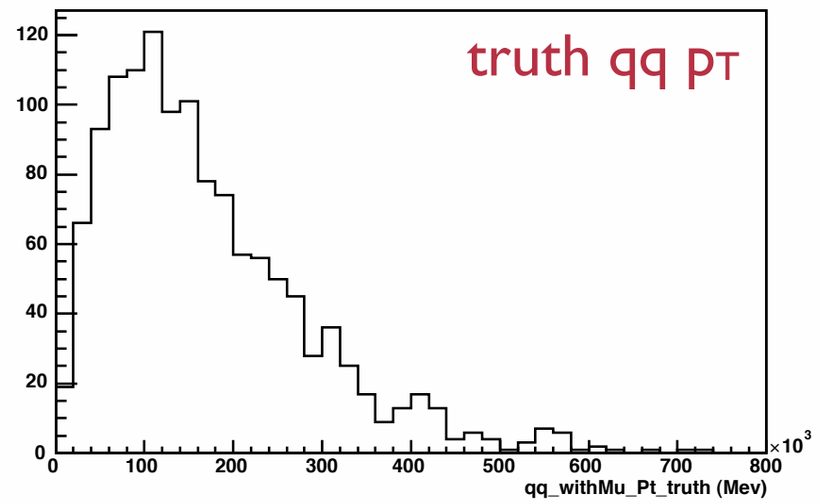
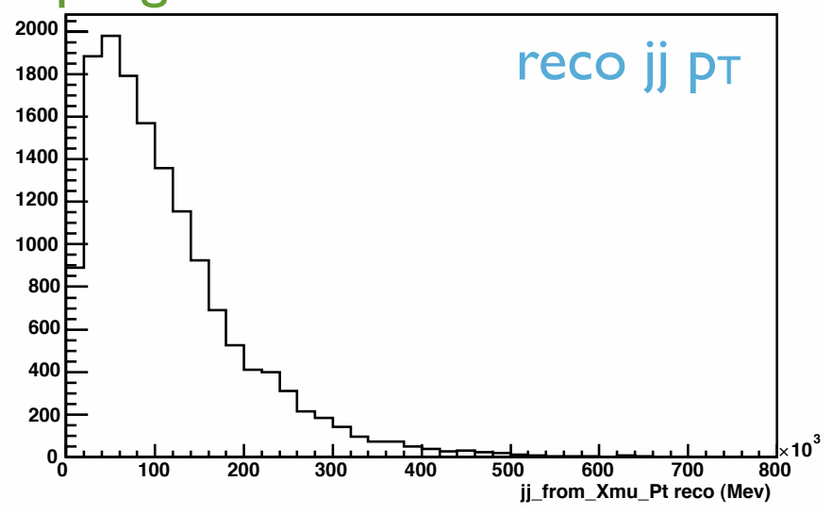


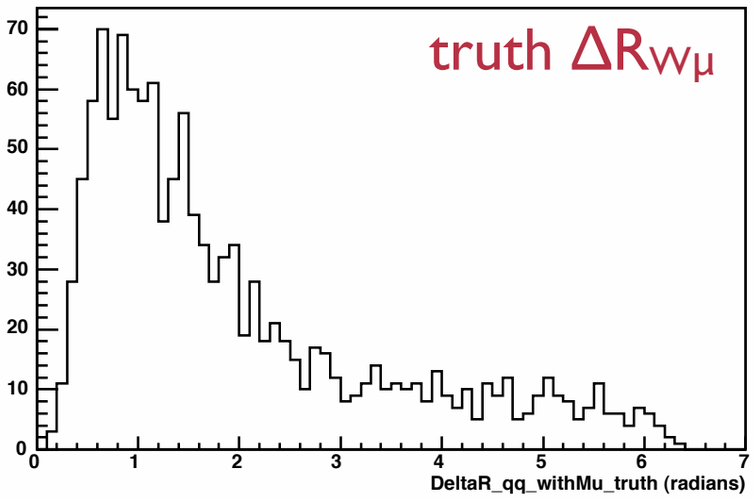


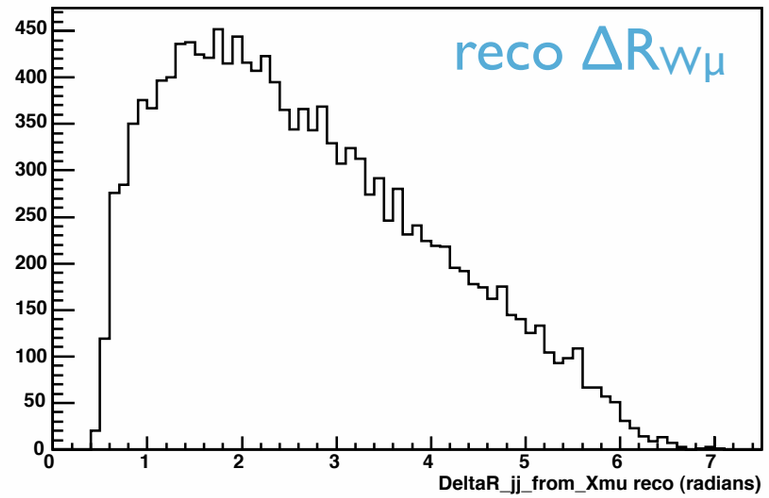
all reco μ and W candidates

Removing comb. background

only truth μ and qq coming from

$\chi \longrightarrow \mu W$
$\downarrow$
qq





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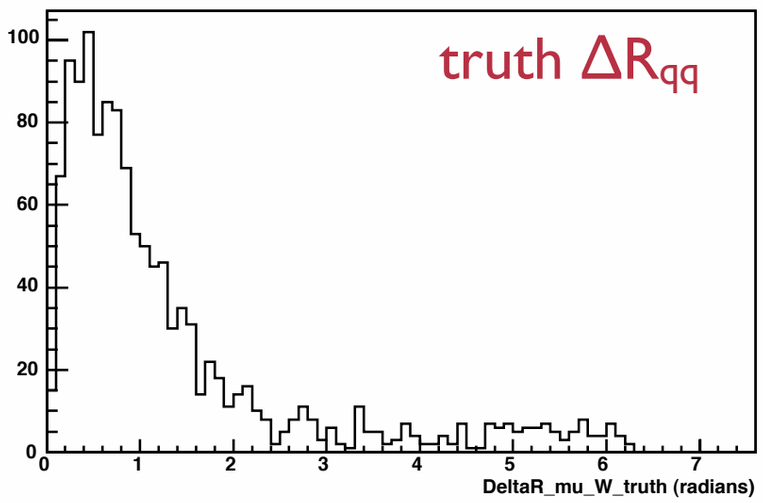
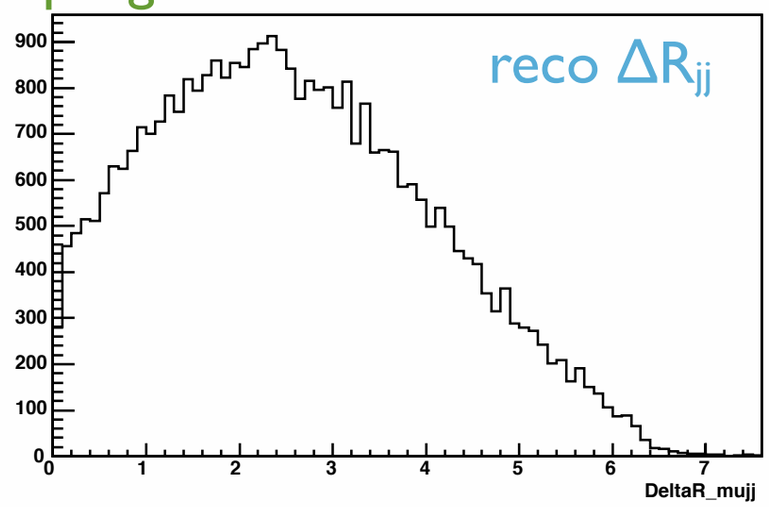
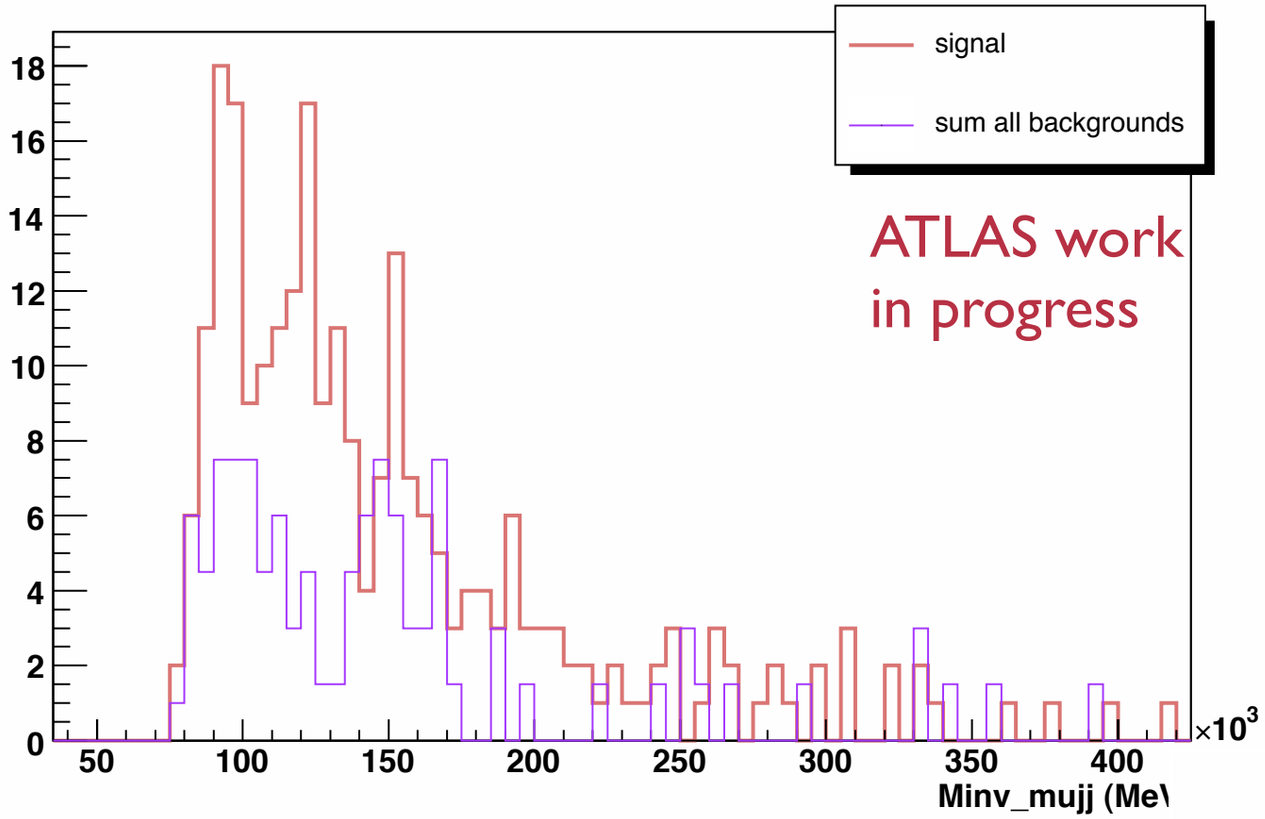




all reco μ and W candidates

200 pb^{-1}

μ jj INVARIANT MASS



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tveto: M_{top} ± 30 GeV

$p_T(\mu)$ > 10 GeV
$\Delta R_{W\mu} < 2.5$
$\Delta R_{jj} < 1.5$

- possible to detect an excess of events in Meff distribution.
- peak in the invariant mass distribution visible only if ttbar background is well determined.