RICERCA DI PRODUZIONE DIRETTA DI TOP SQUARK IN STATI FINALI A DUE LEPTONI IN COLLISIONI PP A 8 TEV CON L'ESPERIMENTO ATLAS A LHC

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Riunione di gruppo I

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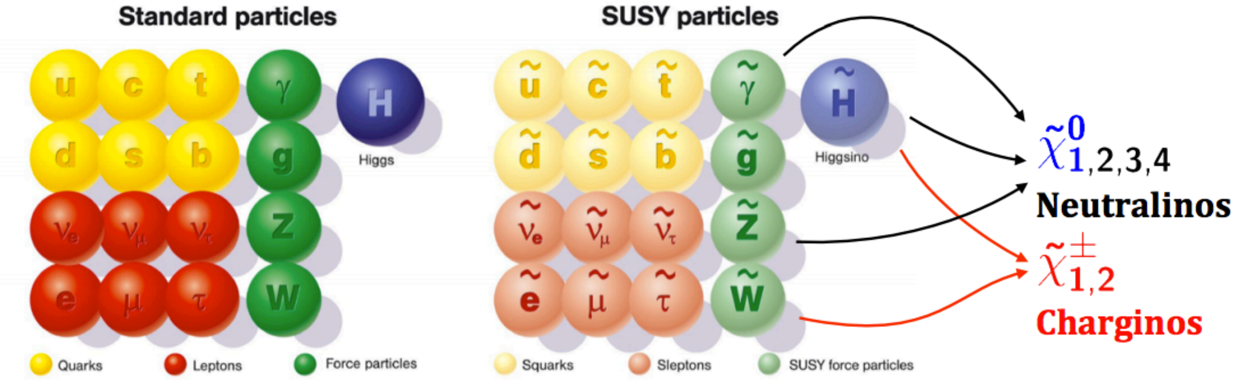
Outline

- Introduzione
  - Supersimmetria (SUSY)
  - Il rivelatore ATLAS
  - Ricerche di SUSY con ATLAS
  - Produzione diretta di top squark in ATLAS
- Progettazione dell'analisi
  - Motivazioni
  - Ottimizzazione e tagli
  - Stima dei fondi
  - Misura delle incertezze
- Risultati
  - Interpretazione dei risultati
  - Conclusioni e sviluppi futuri
- Sviluppi futuri

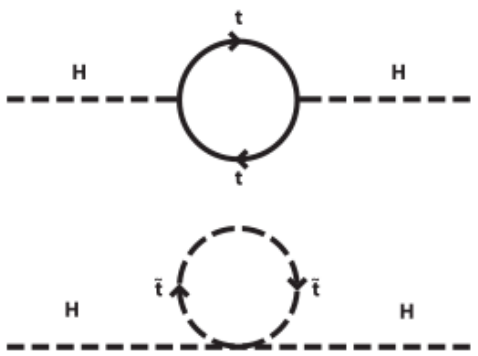
Supersimmetria (SUSY)

- SUSY è un'estensione del Modello Standard (MS)
- Lega fermioni e bosoni tramite una nuova simmetria
- Duplica lo spettro del MS, introducendo i *superpartner*, che differiscono per ½ unità di spin dai loro partner del MS

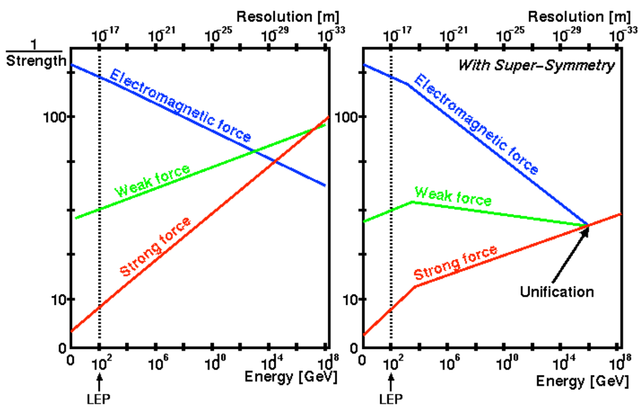
LSP = Lightest SUSY particle
2 doppietti di Higgs → 5 Higgses (h,H,A,H±)



Stabilizza la divergenza quadratica delle correzioni quantistiche alla **massa dell'Higgs**



Garantisce **unificazione** delle costanti di accoppiamento ED e forte



In caso di **R-parità conservata**, la LSP è stabile e si candida a spiegare la presenza di **Materia Oscura** nell'Universo

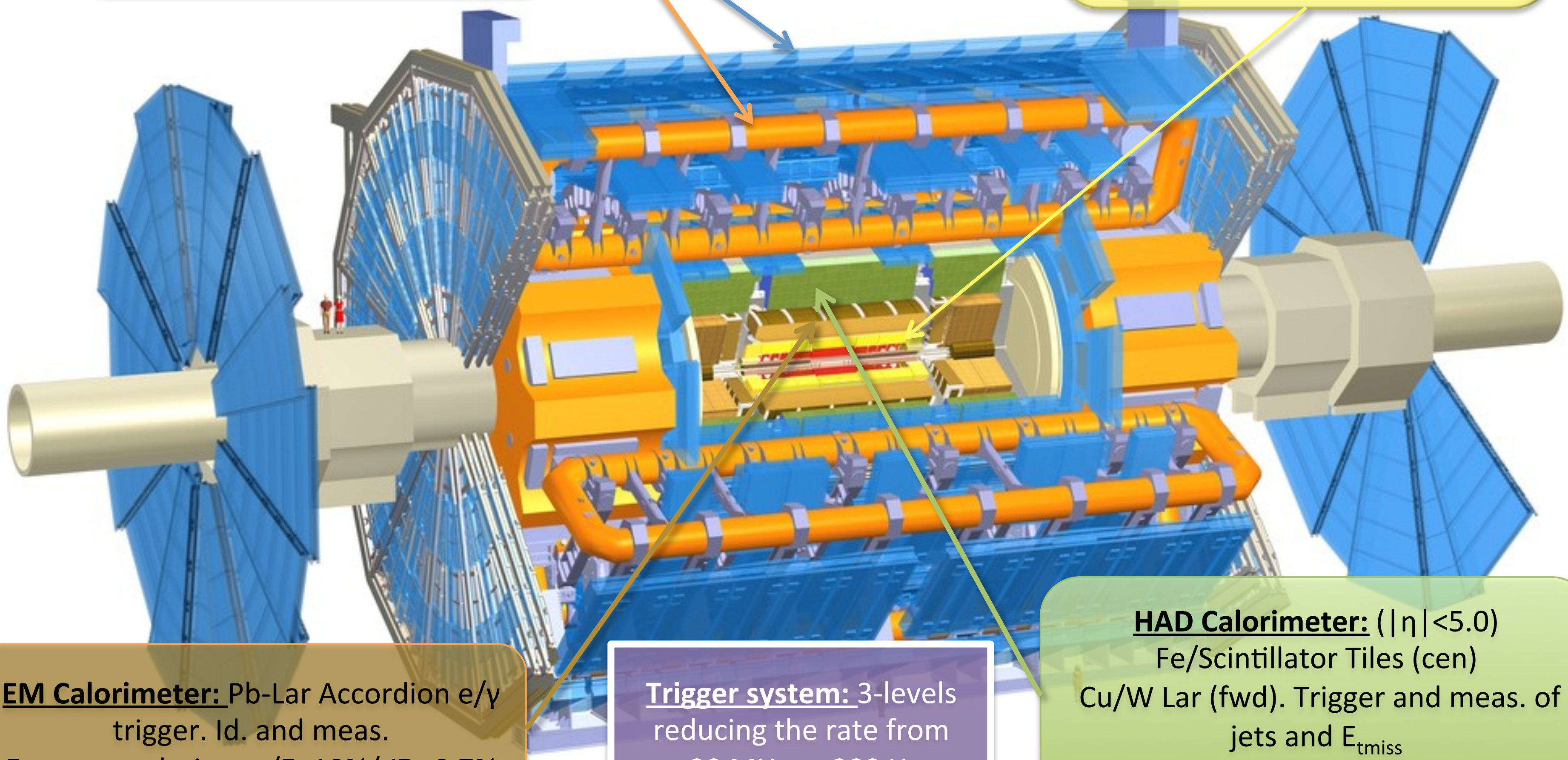
R-parità = $(-1)^{3(B-L)+2S}$
-1 per partic. SUSY
+1 per partic. MS

Il rivelatore ATLAS

Muon spectrometer: air-core toroids with gas-based muon chambers. Trigger and meas. with momentum resolution <10% for $p_T \approx 1$ TeV.

L 46 m ⃠ 22 m
7000 tons

Inner tracker: ($|\eta|<2.5$, B=2T)
Si pixel, Si strips, Trans. Rad. Det.
Precise tracking and vertexing, e/π separation, momentum resolution: $\sigma/p_T \approx 0.05\%\ p_T \oplus 1\%$

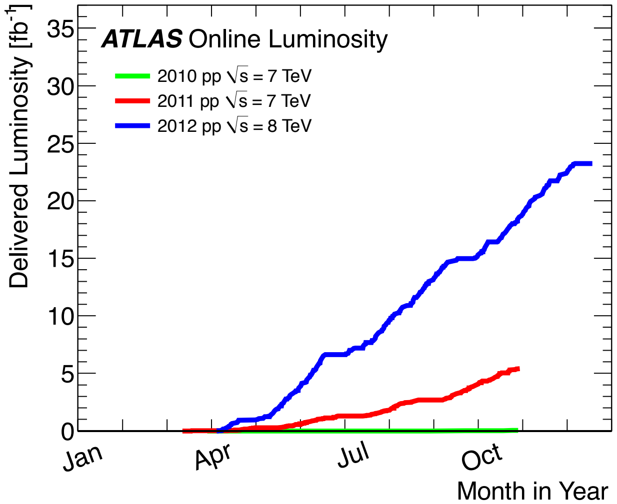


EM Calorimeter: Pb-Lar Accordion e/γ trigger. Id. and meas.
Energy resolution: $\sigma/E < 10\%/\sqrt{E} \oplus 0.7\%$

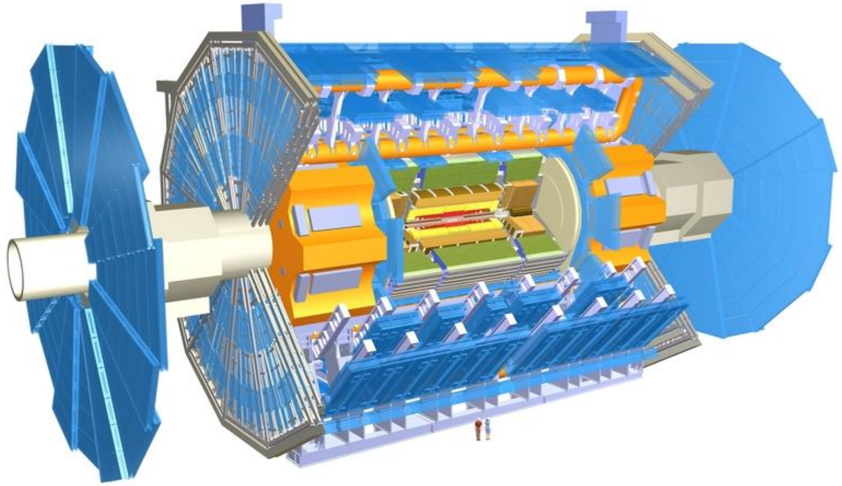
Trigger system: 3-levels reducing the rate from 20 MHz to 200 Hz

HAD Calorimeter: ($|\eta|<5.0$)
Fe/Scintillator Tiles (cen)
Cu/W Lar (fwd). Trigger and meas. of jets and E_{tmiss}
Energy resolution: $\sigma/E \approx 50\%/\sqrt{E} \oplus 10\%$

Ricerche di SUSY con ATLAS

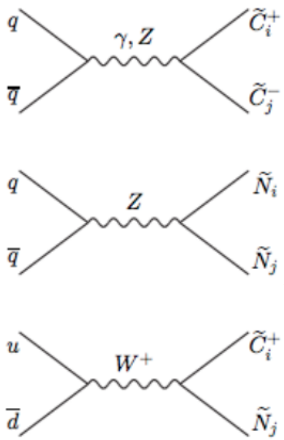


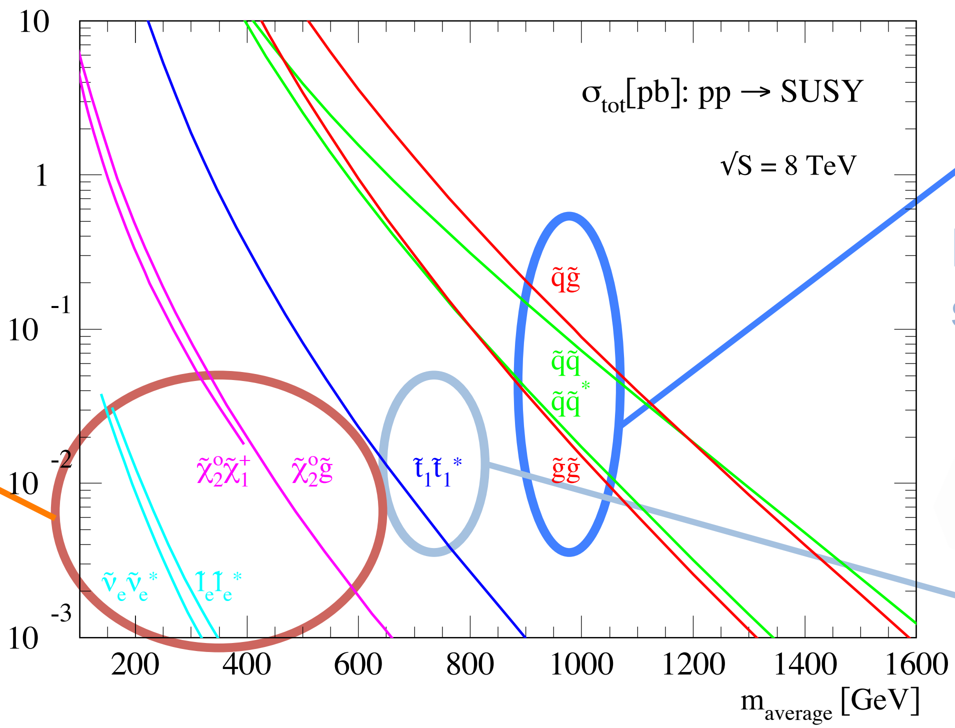
Luminosità raccolta da ATLAS in collisioni protone-protone con 7-8 TeV prodotte da LHC.



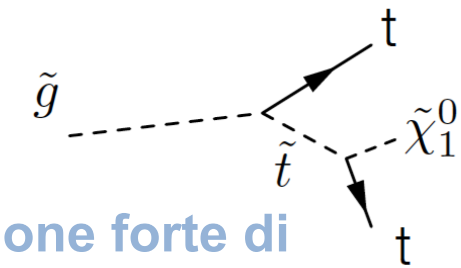
Strategia per ricerche di SUSY guidata da sezione d'urto e luminosità:

Produzione debole

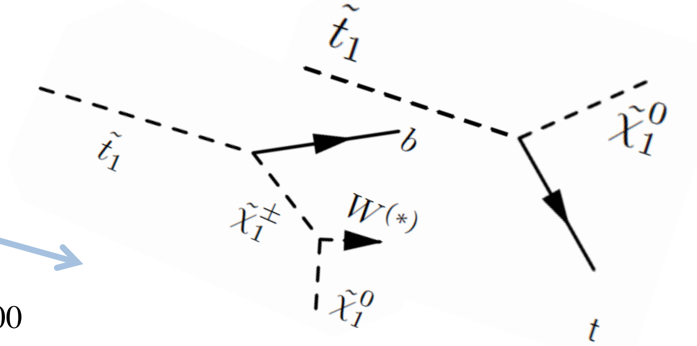




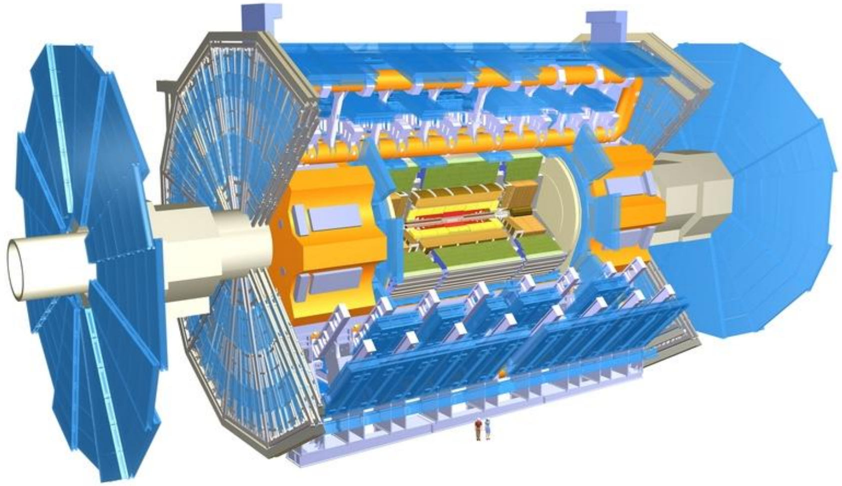
Produzione forte



Produzione forte di squarks di 3ª generazione



Ricerche di SUSY con ATLAS



SUSY Naturale
Risolve in maniera naturale la divergenza quadratica della massa dell'Higgs imponendo:

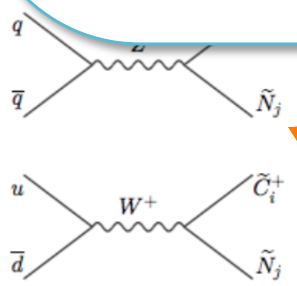
- **Stop e sbottom leggeri** (< 1 TeV)
- Gaugini leggeri (centinaia di GeV)
- Gluini più pesanti ($m_{\tilde{g}}$<1.5-2 TeV)

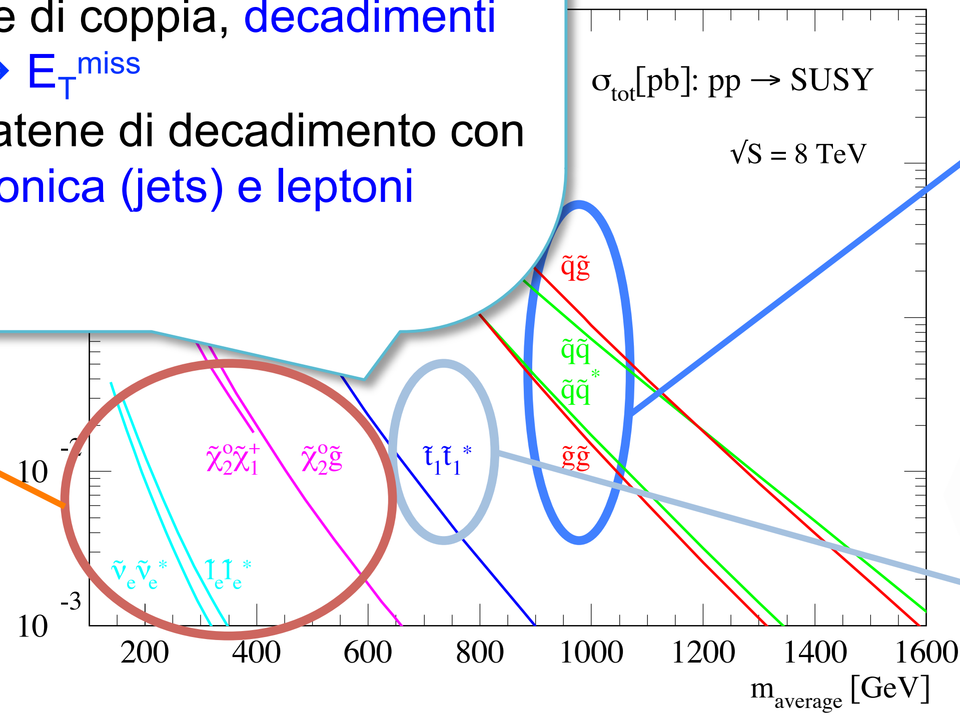
Segnatura tipica con **R-parità conservata**:

- ✓ Produzione di coppia, decadimenti con LSP → E_T^{miss}
- ✓ Possibili catene di decadimento con attività adronica (jets) e leptoni

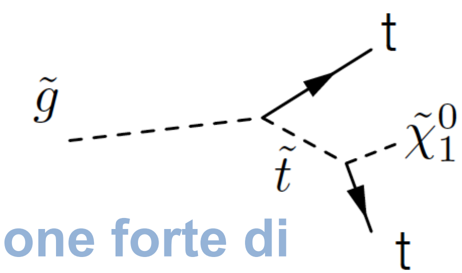
ta da
i
on 7-8
HC.

sezione d'urto e luminosità:

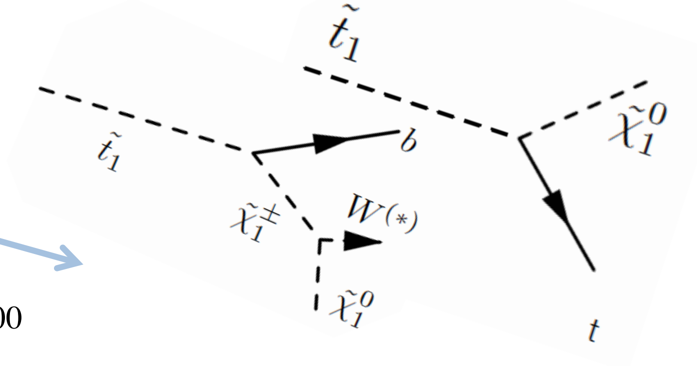




Produzione forte



Produzione forte di squarks di 3ª generazione



Ricerche di SUSY con ATLAS

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: SUSY 2013

ATLAS Preliminary

$\int \mathcal{L}\, dt = (4.6 - 22.9)\ \mathrm{fb}^{-1}$ $\sqrt{s} = 7, 8$ TeV

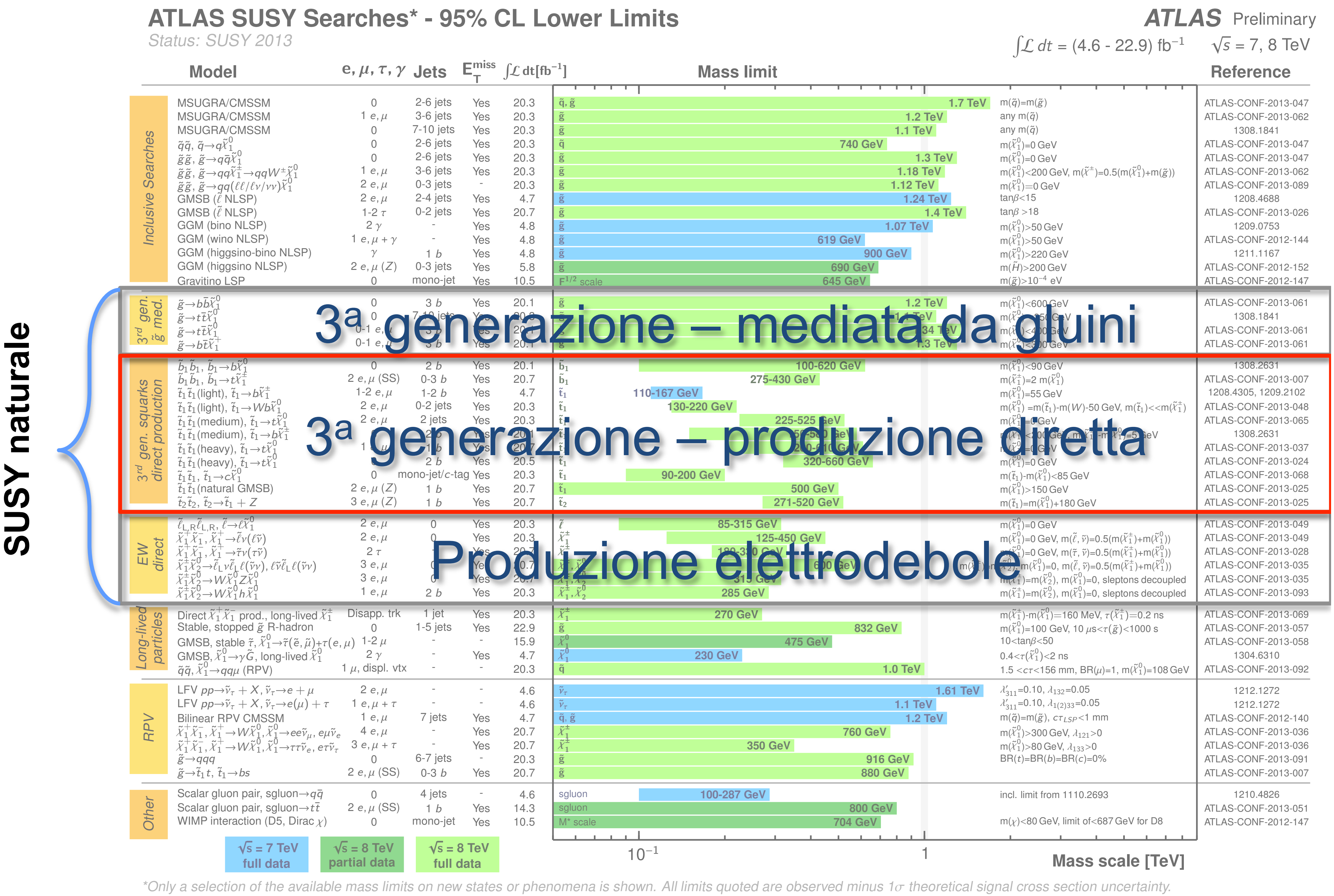
	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt[\mathrm{fb}^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	any $m(\tilde{q})$	1308.1841
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 740 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.18 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}^\pm)=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ	0-3 jets	-	20.3	$\tilde{g}$ 1.12 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e,μ	2-4 jets	Yes	4.7	$\tilde{g}$ 1.24 TeV	$\tan\beta$<15	1208.4688
	GMSB ($\tilde{\tau}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$ 1.4 TeV	$\tan\beta$ >18	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	-	Yes	4.8	$\tilde{g}$ 1.07 TeV	$m(\tilde{\chi}_1^0)$>50 GeV	1209.0753
	GGM (wino NLSP)	1 $e,\mu+\gamma$	-	Yes	4.8	$\tilde{g}$ 619 GeV	$m(\tilde{\chi}_1^0)$>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$ 900 GeV	$m(\tilde{\chi}_1^0)$>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e,μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$ 690 GeV	$m(\tilde{H})$>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale 645 GeV	$m(\tilde{g})>10^{-4}$ eV	ATLAS-CONF-2012-147
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$ 1.2 TeV	$m(\tilde{\chi}_1^0)$<600 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	$m(\tilde{\chi}_1^0)$ <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.34 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	ATLAS-CONF-2013-061
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$ 100-620 GeV	$m(\tilde{\chi}_1^0)$<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$ 275-430 GeV	$m(\tilde{\chi}_1^\pm)=2\, m(\tilde{\chi}_1^0)$	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e,μ	1-2 b	Yes	4.7	$\tilde{t}_1$ 110-167 GeV	$m(\tilde{\chi}_1^0)$=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e,μ	0-2 jets	Yes	20.3	$\tilde{t}_1$ 130-220 GeV	$m(\tilde{\chi}_1^0)=m(\tilde{t}_1)-m(W)$-50 GeV, $m(\tilde{t}_1)<<m(\tilde{\chi}_1^\pm)$	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e,μ	2 jets	Yes	20.3	$\tilde{t}_1$ 225-525 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-065
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	0	2 b	Yes	20.1	$\tilde{t}_1$ 150-580 GeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)$=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e,μ	1 b	Yes	20.7	$\tilde{t}_1$ 200-610 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$ 320-660 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$ 90-200 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}_1^0)$<85 GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_1$ 500 GeV	$m(\tilde{\chi}_1^0)$>150 GeV	ATLAS-CONF-2013-025
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1+Z$	3 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_2$ 271-520 GeV	$m(\tilde{t}_1)=m(\tilde{\chi}_1^0)$+180 GeV	ATLAS-CONF-2013-025
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$ 85-315 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$ 125-450 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.7	$\tilde{\chi}_1^\pm$ 180-330 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 600 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	3 e,μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 315 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0$	1 e,μ	2 b	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 285 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^\pm$ 270 GeV	$m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)$=160 MeV, $\tau(\tilde{\chi}_1^\pm)$=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$ 832 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$ 475 GeV	10<$\tan\beta$<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$ 230 GeV	0.4<$\tau(\tilde{\chi}_1^0)$<2 ns	1304.6310
	$\tilde{q}\tilde{q}, \tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$ 1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, $m(\tilde{\chi}_1^0)$=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\to e+\mu$	2 e,μ	-	-	4.6	$\tilde{\nu}_\tau$ 1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\to e(\mu)+\tau$	1 $e,\mu+\tau$	-	-	4.6	$\tilde{\nu}_\tau$ 1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	1 e,μ	7 jets	Yes	4.7	$\tilde{q}, \tilde{g}$ 1.2 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.7	$\tilde{\chi}_1^\pm$ 760 GeV	$m(\tilde{\chi}_1^0)$>300 GeV, λ_{121}>0	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e,\mu+\tau$	-	Yes	20.7	$\tilde{\chi}_1^\pm$ 350 GeV	$m(\tilde{\chi}_1^0)$>80 GeV, λ_{133}>0	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$ 880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon 100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e,μ (SS)	1 b	Yes	14.3	sgluon 800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale 704 GeV	$m(\chi)$<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

$\sqrt{s}$ = 7 TeV full data | $\sqrt{s}$ = 8 TeV partial data | $\sqrt{s}$ = 8 TeV full data

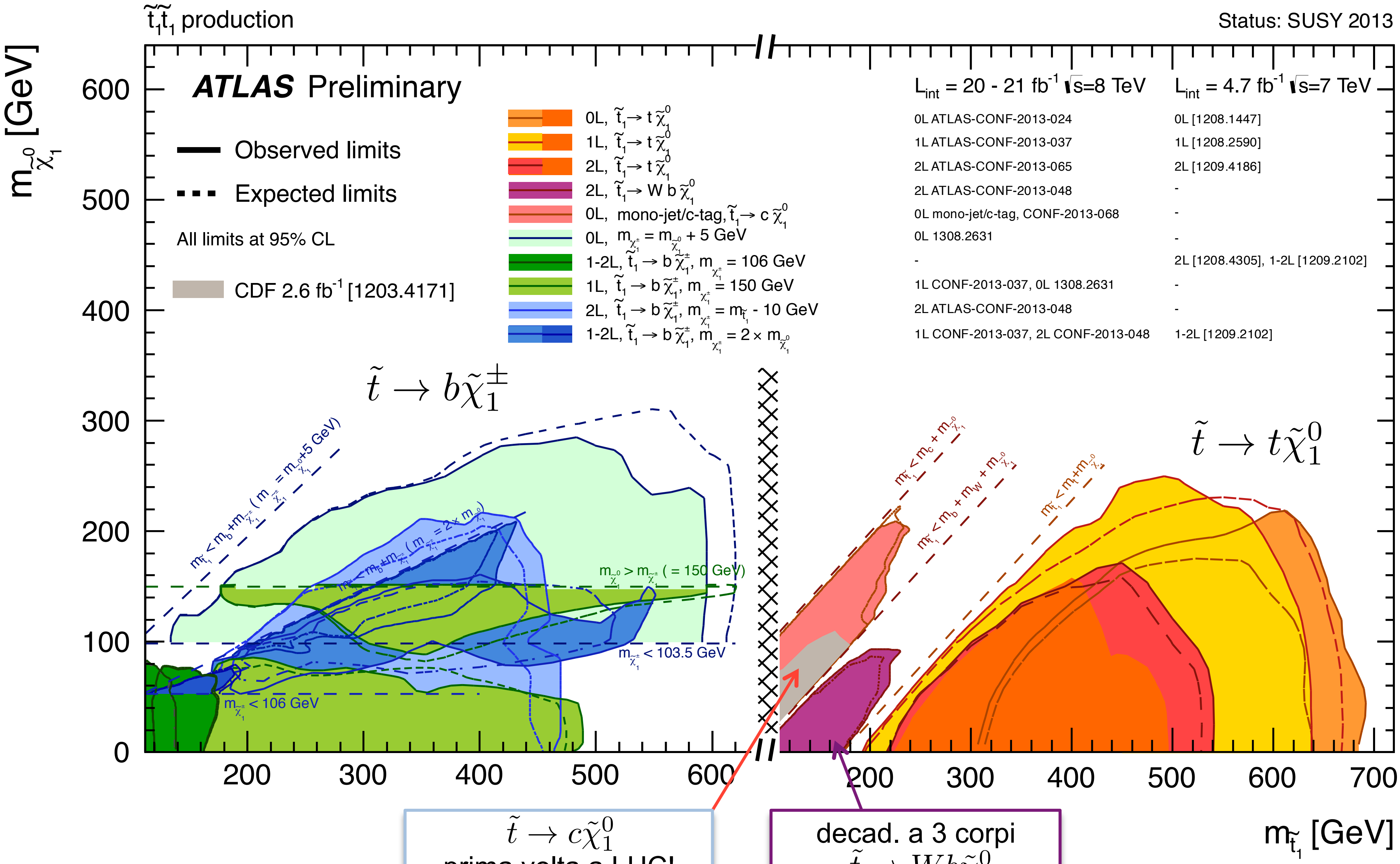
10^{-1} 1 **Mass scale [TeV]**

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Ricerche di SUSY con ATLAS



Produzione diretta di top squark (aka stop)



$\tilde{t} \to c\tilde{\chi}^0_1$
prima volta a LHC!

decad. a 3 corpi
$\tilde{t} \to Wb\tilde{\chi}^0_1$

Produzione diretta di stop in stati finali con due leptoni

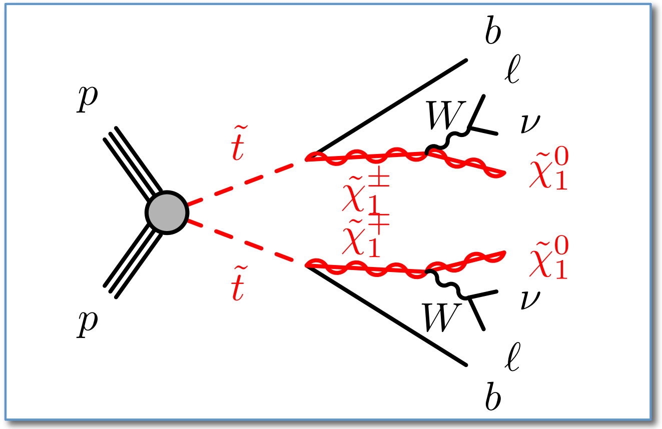
ATLAS-CONF-2013-048: Ricerca di produzione diretta di stop in stati finali con due leptoni (*e*,*μ*) in 20.3 fb^{-1} collisioni pp. Ottimizzata per:

a. decadimento bC con differenza di massa C-N elevata

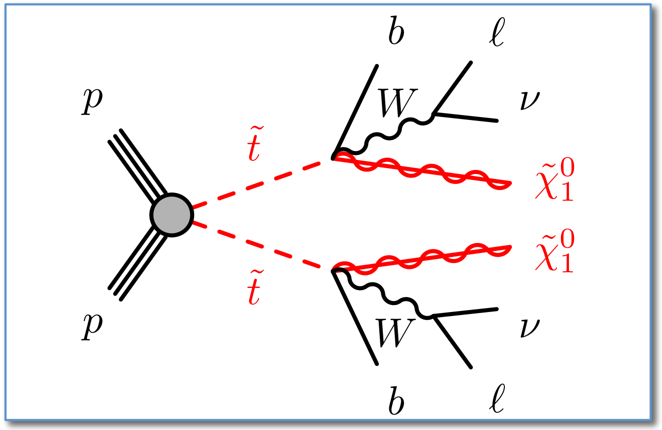
b. decadimento a 3 corpi in bWN, se m(C)>m(stop) e m(t)>m(stop)-m(N)>m(W)

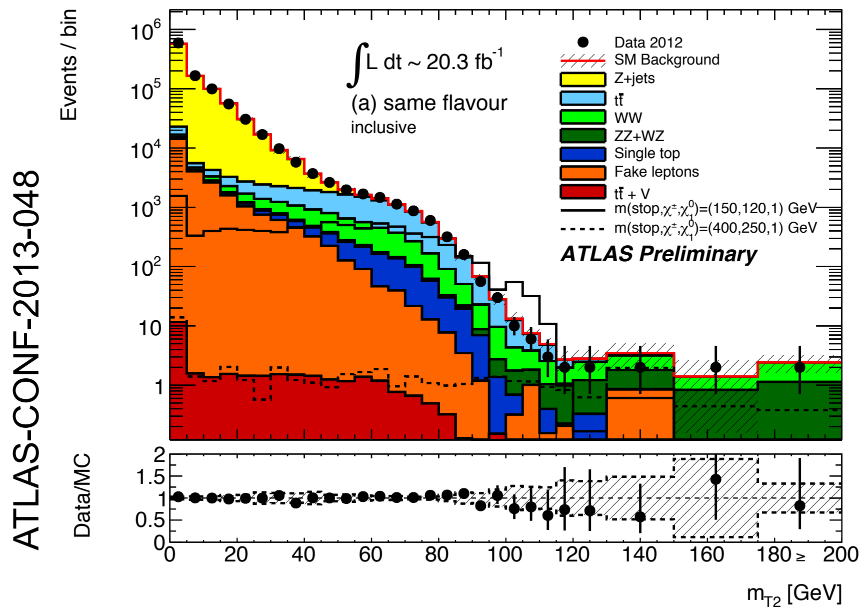
M_{T2}(ll) viene usata per discriminare il fondo dal segnale:

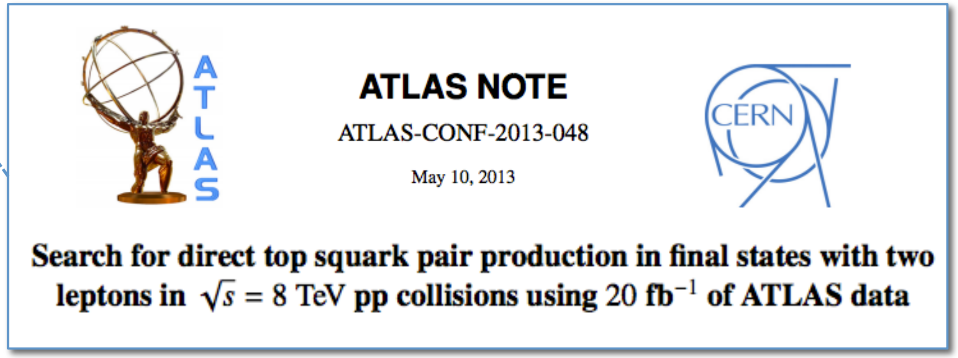
a.



b.







ATLAS NOTE

ATLAS-CONF-2013-048

May 10, 2013

Search for direct top squark pair production in final states with two leptons in $\sqrt{s}$ = 8 TeV pp collisions using 20 fb^{-1} of ATLAS data

La variabile m_{T2}

- E' una generalizzazione della massa trasversa per un sistema con **due particelle invisibili**
- Per eventi SM, la massa trasversa del leptone-neutrino è limitata superiormente dal bosone *W*

$$m_T(l,\nu) = \sqrt{(}2p_T(l)p_T(\nu)[cos(\phi_l - \phi_\nu)]) < m(W)$$

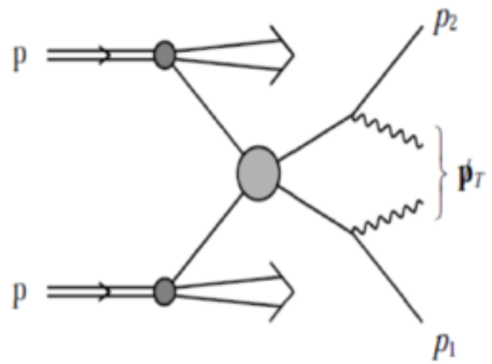
  in tutte e due le gambe:

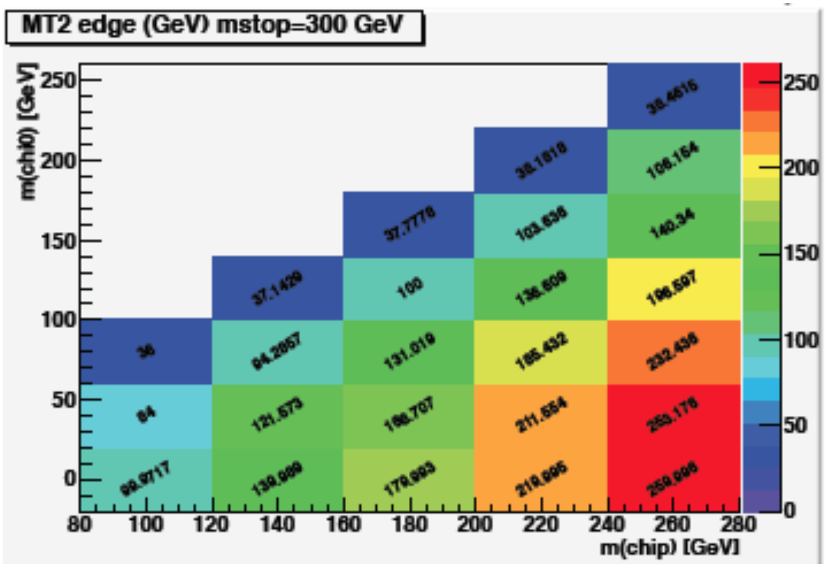
$$max[m_T(\vec{p}_T^1, \vec{q}_T^1), m_T(\vec{p}_T^2, \vec{q}_T^2)] < m(W)$$

- La direzione del neutrino è impossibile da ricostruire, ma è possibile prendere il minimo fra **tutte le combinazioni**:

$$m_{T2}(\vec{p}_T^1, \vec{p}_T^2, \vec{p}_T^{miss}) = \min_{\vec{q}_T^1+\vec{q}_T^2=\vec{p}_T^{miss}} \{max[m_T^2(\vec{p}_T^1, \vec{q}_T^1), m_T^2(\vec{p}_T^2, \vec{q}_T^2)]\}$$

- m_{T2}<m(W) per coppie di top, Wt and WW.
- Il segnale si estende a valori più alti, in base alla differenza di massa fra C e N.
- Maggiore la differenza, maggiore la sensitività.





Limite superiore di m_{T2}(ll) per differenti valori delle masse di C e N.

Monte Carlo (MC)

Physics process	$\sigma \cdot$BR [pb]	Perturbative order
$Z/\gamma^\star \to ll, m(ll) > 40$ GeV	1240 ± 60	DYNNLO
$t\bar{t} \to ll + X$	129^{+12}_{-13}	NLO+NNLL
Wt	22.4 ± 1.5	NLO+NNLL
$t\bar{t}W$	0.231 ± 0.046	NLO
$t\bar{t}$	0.206 ± 0.021	NLO
WW	54.7 ± 3.3	NLO
WZ	33.3 ± 1.7	NLO
ZZ	11.2 ± 0.8	NLO

Alcuni dettagli:

- Top: POWHEG+PYTHIA, massa del top quark fissata a 172.5 GeV, CTEQ10 PDF
- Segnale: MADGRAPH or HERWIG++, NLO+NLL
- Simulazione del rivelatore basata su GEANT4
- Effetto delle interazioni multiple protone-protone (pileup) considerato nella simulazione → eventi ripesati →distribuzione del numero medio di interazioni per bunch crossing uguale a quella nei dati.

Selezioni

Strategia del **trigger**:

- OR fra trigger chains con 1L e 2L

Single Electron	e24vhi_medium1 or e60_medium1
Single Muon	mu24i_tight or mu36_tight
Double Electron	e24vh_medium1_e7_medium1 or 2e12Tvh_loose1
Double Muon	mu24_tight_mu6_EFFS or EF_2mu13
Electron-Muon	EF_e12Tvh_medium1_mu8 or EF_mu18_tight_e7_medium1

Preselezioni comuni ad altre analisi SUSY, includono:

- 2 leptoni di segno opposto (OS)
- Quality cuts e veto sui muoni cosmici

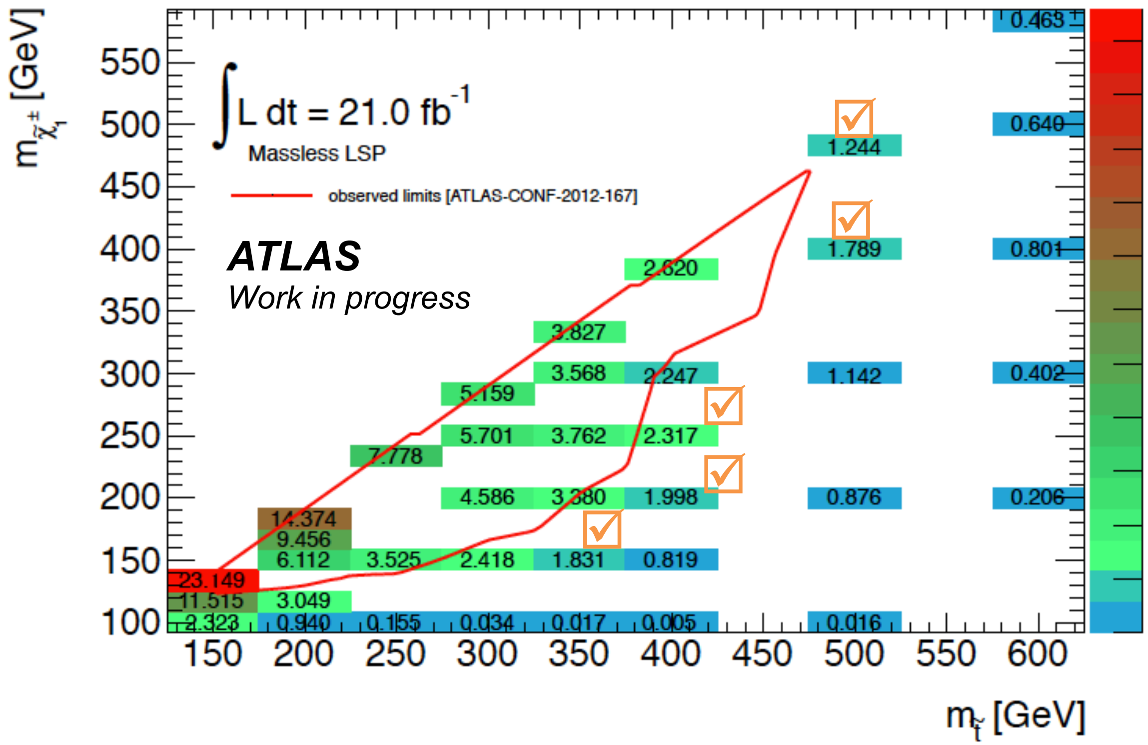
$$\vec{p}_{Tb}^{ll} = \vec{p}_T^{miss} + \vec{p}_T^{l_1} + \vec{p}_T^{l_2}$$

Definizione delle **Signal Regions**:

SR	M90	M100	M110	M120
p_T leading lepton	> 25 GeV			
$\Delta\phi(E_T^{miss}$, closest jet)	> 1.0			
$\Delta\phi(E_T^{miss}, p_b^{ll})$	< 1.5			
m_{T2}	> 90 GeV	> 100 GeV	> 110 GeV	> 120 GeV
p_T leading jet	no selection	> 100 GeV	> 20 GeV	> 20 GeV
p_T second jet	no selection	> 50 GeV	> 20 GeV	> 20 GeV

Riduce il fondo da WW/WZ

➢ Studio di sensitività dell'analisi



Sensitività nella griglia di segnale con m(N) = 1 GeV.

$S/\sqrt{(S+B+\delta B^2)}$, con **$\delta B=0.3B$**.

Un valore superiore a 1.6 equivale ad un p-value di 0.05 ed esclude quindi il punto.

— Analisi precedente senza tagli sui getti ($13 fb^{-1}$).

☑ Nuovi punti esclusi

dium1
ht
12Tvh_loose1
_2mu13
tight_e7_medium1

				M120
$\Delta\phi(E_T \quad, p_b)$		< 1.5		
m_{T2}	> 90 GeV	> 100 GeV	> 110 GeV	> 120 GeV
p_T leading jet p_T second jet	no selection no selection	> 100 GeV > 50 GeV	> 20 GeV > 20 GeV	> 20 GeV > 20 GeV

Stima dei processi di fondo

① Sorgenti dominanti: **ttbar, WW, WZ/ZZ**:
- Stimate tramite un likelihood fit combinato in 3 regioni di controllo (CR). Le incertezze sistematiche vengono incluse in questo fit come parametri nuisance.

② Sorgenti secondarie: **Z+jets,Wt,ttbar+V**
- Misurate direttamente dal MC.

③ Fondo da **leptoni fake o non isolati**:
- Misurato usando una tecnica data-driven che utilizza il metodo chiamato Matrix Method (MM)

Dopo aver applicato i tagli in $\Delta\phi$, le seguenti regioni di validazione (VR) sono usate per validare il fit dei processi di fondo:

VRSF: Stesso sapore (SF), $80<m_{T2}<90$ GeV
VRDF: Sapore differente (DF), $80<m_{T2}<90$ GeV

Stima dei processi di fondo

① Sorgenti dominanti: **ttbar, WW, WZ/ZZ**:

- Stimate tramite un likelihood fit combinato in 3 regioni di controllo (CR). Le incertezze sistematiche vengono incluse in questo fit come parametri nuisance.

CRT (ttbar)*:

- DF, $40<m_{T2}<80$ GeV, $p_b^{ll}>30$ GeV

CRW (WW):

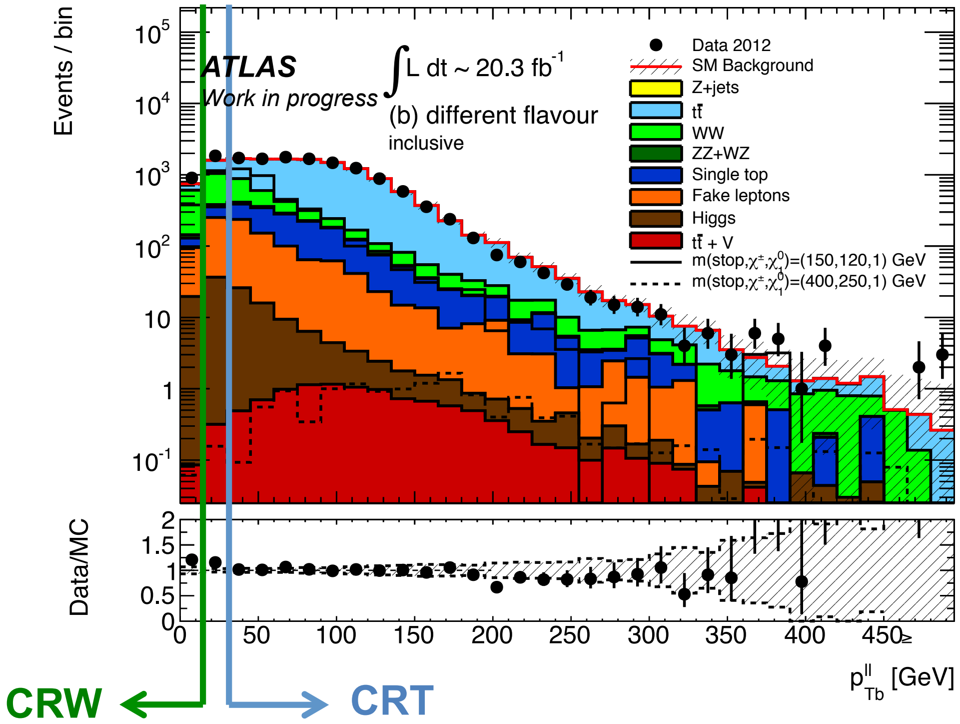
- DF, $40<m_{T2}<80$ GeV, $p_b^{ll}<15$ GeV

CRZ (WZ/ZZ):

- SF, $m_{T2}>90$ GeV, $71<m_{ll}<111$ GeV

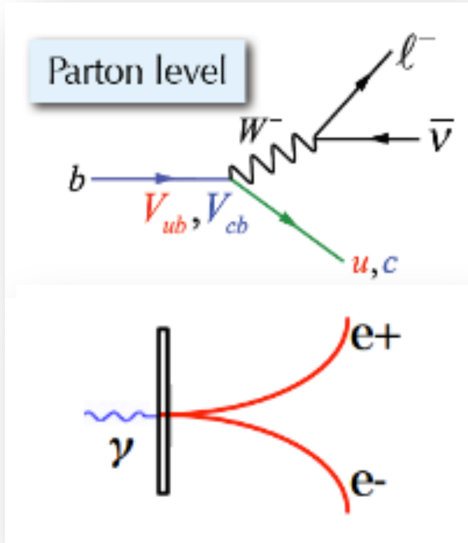
Tutti gli altri tagli in $\Delta\phi$ inclusi.

*Una CRT identificata per ogni SR, aggiungendo i corrispettivi tagli

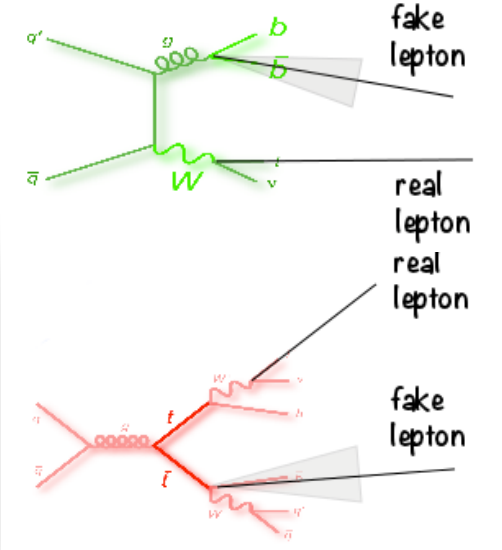


Fondo da leptoni fake

- In stati finali con due leptoni, una sorgente di fondo non trascurabile è dovuta a leptoni non prompt o erroneamente ricostruiti tali (fake) che si possono originare da:
  - decadimenti leptonici di b-jets in eventi con jets
  - sciami da π^0 ricostruiti come leptoni
  - decadimenti in-flight di B-adroni
  - elettroni da conversione di fotoni
  - jet punch-trough



- Questi contributi si possono dividere in:



- **processi double-fake** originati da fondo QCD multijet con due leptoni fake e non prompt.

- **processi real-fake** come produzione di coppie di top o W/Z+jets, dove uno dei due leptoni è prompt e l’altro è fake .

Il Matrix Method

- Il numero di leptoni reali (R) e fake (F) si può ottenere a partire dal numero di eventi osservati con leptoni tight (T) o loose (L):

$$\begin{bmatrix} N_{TT} \\ N_{TL} \\ N_{LT} \\ N_{LL} \end{bmatrix} = \begin{bmatrix} r_1 r_2 & r_1 f_2 & f_1 r_2 & f_1 f_2 \\ r_1(1-r_2) & r_1(1-f_2) & f_1(1-r_2) & f_1(1-f_2) \\ (1-r_1)r_2 & (1-r_1)f_2 & (1-f_1)r_2 & (1-f_1)f_2 \\ (1-r_1)(1-r_2) & (1-r_1)(1-f_2) & (1-f_1)(1-r_2) & (1-f_1)(1-f_2) \end{bmatrix} \begin{bmatrix} N_{RR} \\ N_{RF} \\ N_{FR} \\ N_{FF} \end{bmatrix}$$

- $r_{1(2)}$: efficienza di ricostruzione per leptoni reali (sub-)leading.
- $f_{1(2)}$: "fake rate" ratio per leptoni (sub-)leading loose.
- Sia *r* che *f* dipendono dalle definizioni di leptoni T e L:
  - Loose: baseline, senza taglio di isolamento
  - Tight: signal, con taglio di isolamento

- CR per *r*:
  - 1 tight + 1 loose lepton
  - $86 < m_{ll} < 96$ GeV
- Fake rate preso come combinazione da 2 CR:
  - Sample con un leptone loose
    - almeno un jet
    - $\Delta\phi(l - E_T^{miss}) < 0.5$
    - $E_T^{miss} < 25$ GeV
  - 2-lepton $e\mu$ same-sign
    - $E_T^{miss} < 30$ GeV

Incertezze sistematiche

Statistica MC (sample size)

- Limitato numero di eventi simulati nelle CR o SR

Modelling teorico

- Ottenuta comparando i risultati di differenti generatori MC
- Parton Showering (PS) e radiazione iniziale/finale (ISR/FSR)

Jet

- Jet Energy Scale calibration (JES)
- Jet Energy Resolution (JER)

Leptoni

- Ricostruzione, identificazione, misura dell'energia e del momento dei leptoni.

Energia trasversa mancante (Cluster)

- Depositi di energia non assegnati a nessun oggetto ricostruito.

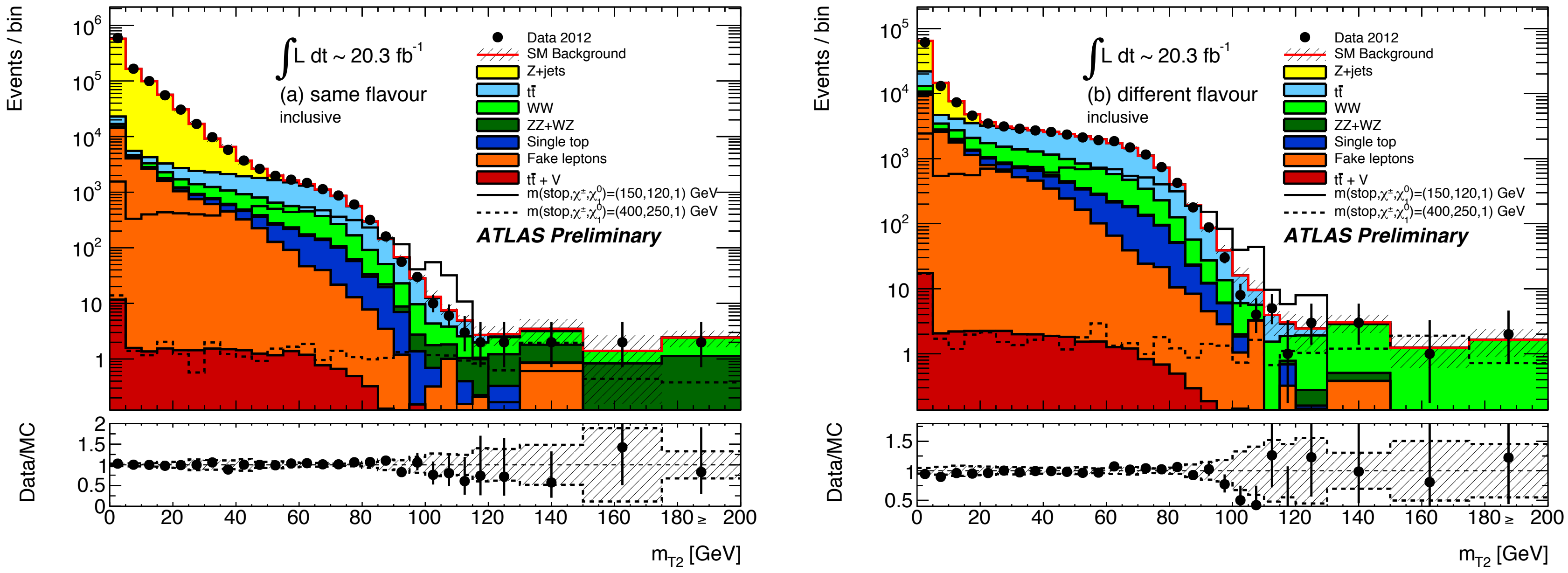
Fondo da leptoni fake

- Limitata statistica nelle CR
- Differenze di misura nelle due CR per il fake rate. **Luminosità**
- Calibrazioni preliminari della scala di luminosità

Segnale

- Differenti set di input per PDF, scala di fattorizzazione e normalizzazione.

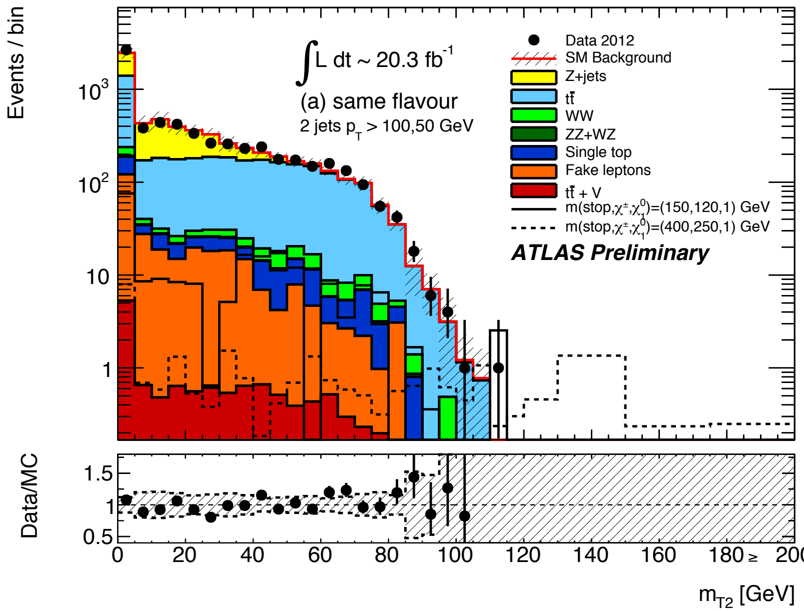
Distribuzioni cinematiche dopo il fit

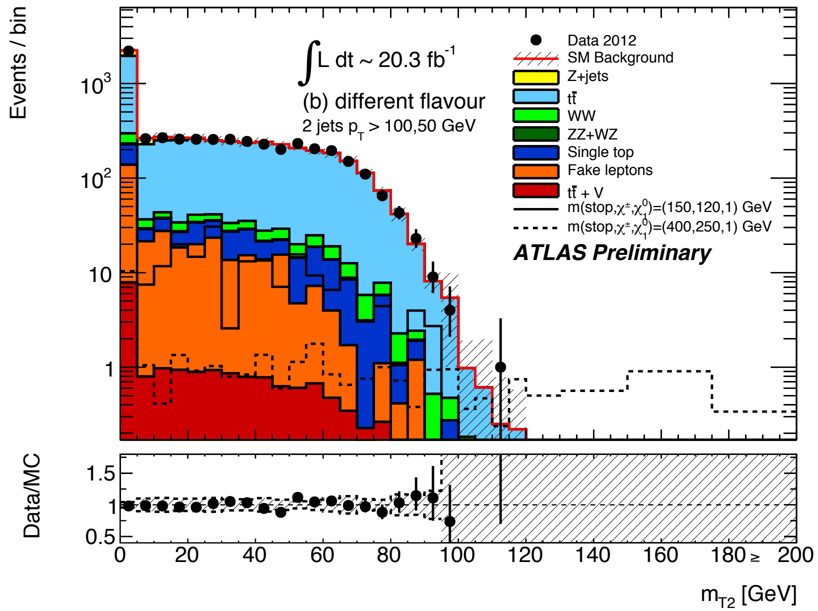


m_{T2} dell'evento nei canali SF e DF, dopo i tagli delle SR M90/M120, ma prima del taglio in m_{T2}.

M90/M120

Distribuzioni cinematiche dopo il fit

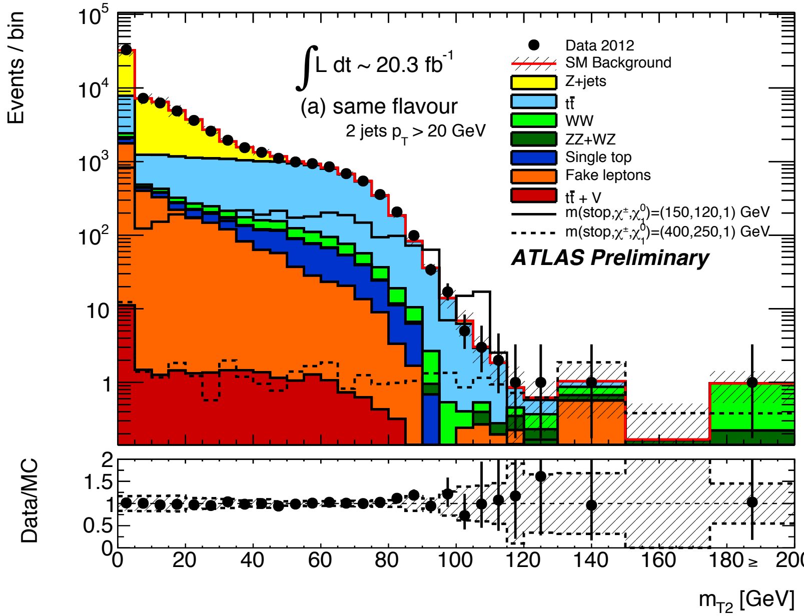


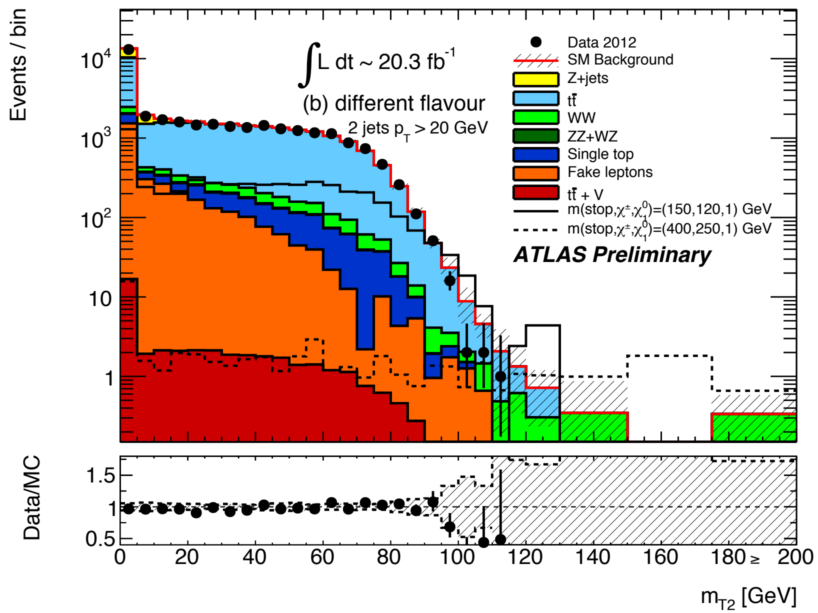


m_{T2} dell'evento nei canali SF e DF, dopo i tagli delle SR M100, ma prima del taglio in m_{T2}.

M100

Distribuzioni cinematiche dopo il fit





m_{T2} dell'evento nei canali SF e DF, dopo i tagli delle SR M110, ma prima del taglio in m_{T2}.

M110

Risultati

Process	M90	M100	M110	M120
Observed events	260	3	7	3
Total expected bkg events	300 ± 40	4.8 ± 2.2	11 ± 4	4.3 ± 1.3
Fitted $t\bar{t}$ events	181 ± 25	3.2 ± 2.0	5.1 ± 3.4	0.8 ± 0.7
Fitted WW events	71 ± 17	0.9 ± 0.4	3.1 ± 0.9	2.0 ± 0.7
Fitted $WZ - ZZ$ events	12 ± 2	0.18 ± 0.13	0.9 ± 0.4	0.7 ± 0.3
Expected Z+jets	2.9 ± 1.4	0.2 ± 0.2	0.08 ± 0.13	0.05 ± 0.06
Expected $t\bar{t}V$ events	1.7 ± 0.5	0.3 ± 0.1	0.5 ± 0.2	0.35 ± 0.11
Expected Wt events	20 ± 7	-	-	-
Events with fake leptons	14 ± 8	-	0.8 ± 0.5	0.5 ± 0.4
Signal, m($\tilde{t}_1$,$\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_1^0$) = (150,120,1) GeV	610 ± 110	2.6 ± 1.9	10 ± 6	5 ± 3
Signal, m($\tilde{t}_1$, $\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_1^0$) = (400,250,1) GeV	21 ± 4	8.1 ± 1.5	11.1 ± 2.2	7.6 ± 1.5
Fit inputs, expected $t\bar{t}$ events	180 ± 30	3.0 ± 2.0	4.5 ± 3.5	0.7 ± 0.8
Fit inputs, expected WW events	55 ± 9	0.7 ± 0.3	2.5 ± 0.8	1.6 ± 0.7
Fit inputs, expected $WZ - ZZ$ events	13 ± 4	0.2 ± 0.4	1.0 ± 0.7	0.8 ± 0.4
95% CL limit on $\sigma_{\rm vis}^{\rm obs}$[fb]	2.5	0.27	0.40	0.23
95% CL limit on $\sigma_{\rm vis}^{\rm exp}$[fb]	3.5	0.30	0.42	0.27

Risultati

$\mu_T = 1.02 \pm 0.04$
$\mu_{WW} = 1.29 \pm 0.18$
$\mu_{WZ+ZZ} = 0.90 \pm 0.15$

Process	M90	M100	[illegible]	[illegible]
Observed events	260	3	7	3
Total expected bkg events	300 ± 40	4.8 ± 2.2	11 ± 4	4.3 ± 1.3
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Risultati

No excess found ☹

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95% CL limit on $\sigma_{\mathrm{vis}}^{\mathrm{exp}}$[fb]	3.5	0.30	0.42	0.27

Sistematiche

	M90	M100	M110	M120
jet energy scale and resolution	6%	22%	7%	5%
cluster energy scale and resolution	5%	24%	5%	5%
pile-up	6%	6%	3%	7%
diboson generator	3%	4%	8%	14%
top generator	3%	6%	11%	5%
top ISR/FSR	2%	6%	1%	5%
top parton shower	4%	19%	27%	7%
samples size	3%	17%	11%	19%
$t\bar{t}$ normalization	3%	4%	1%	0%
WW normalization	4%	2%	2%	2%
WZ/ZZ normalization	1%	0%	1%	2%
Fake-lepton uncertainties	2%	0%	1%	2%
Total uncertainty	12%	46%	35%	28%

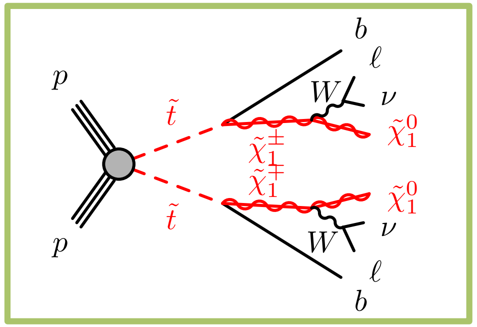
JES/JER

Generators

Top unc.

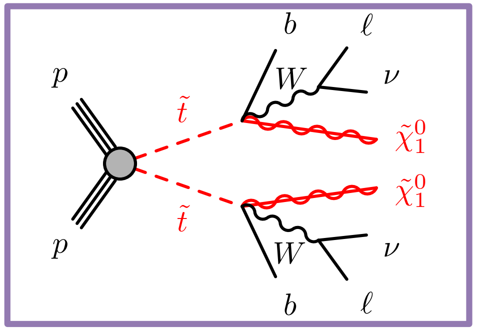
FIT unc.

Interpretazione dei risultati dipendente da modello

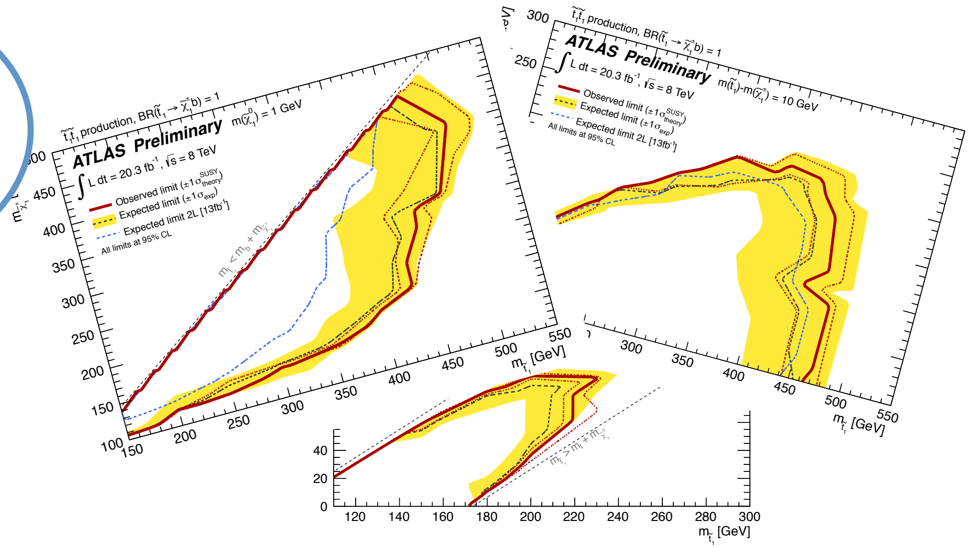


Simplified models focalizzati su $\boxed{t \to bC}$ e $\boxed{t \to WbN}$ (100% BR).

Limiti sulle masse dei superpartner in proiezioni 2D

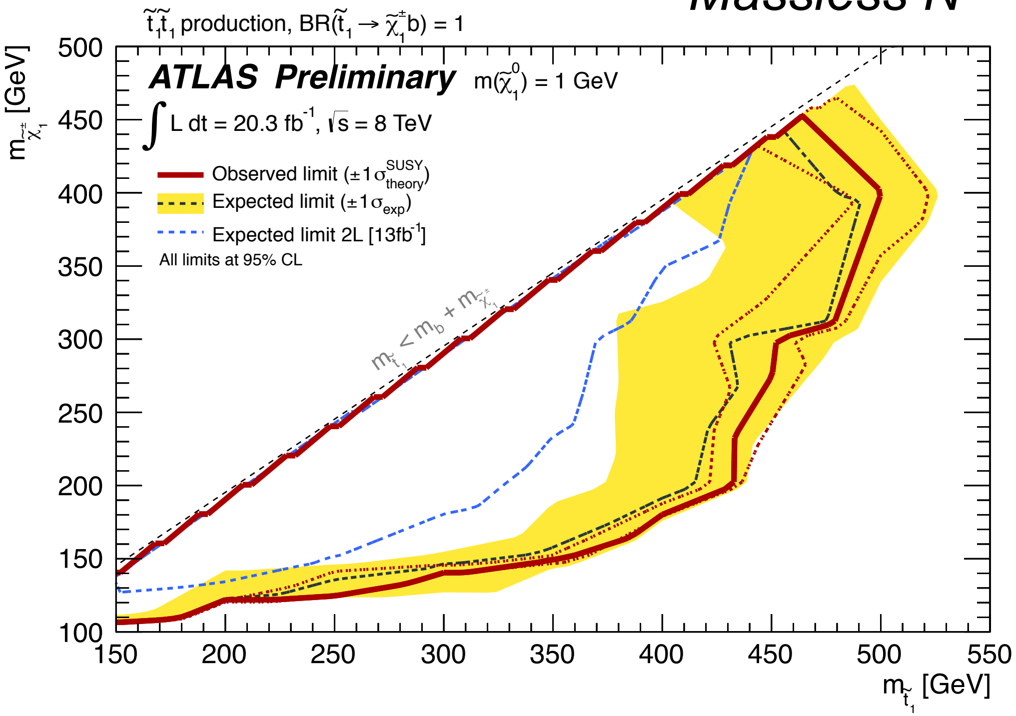


- 95% CL
- **Profile likelihood ratio** come statistica test
- Incertezze sperimentali sul segnale considerate nel fit
- Limiti ri-calcolati per variazioni ±1σ sulle **incertezze teoriche del segnale**
- Contaminazione di segnale nelle CR

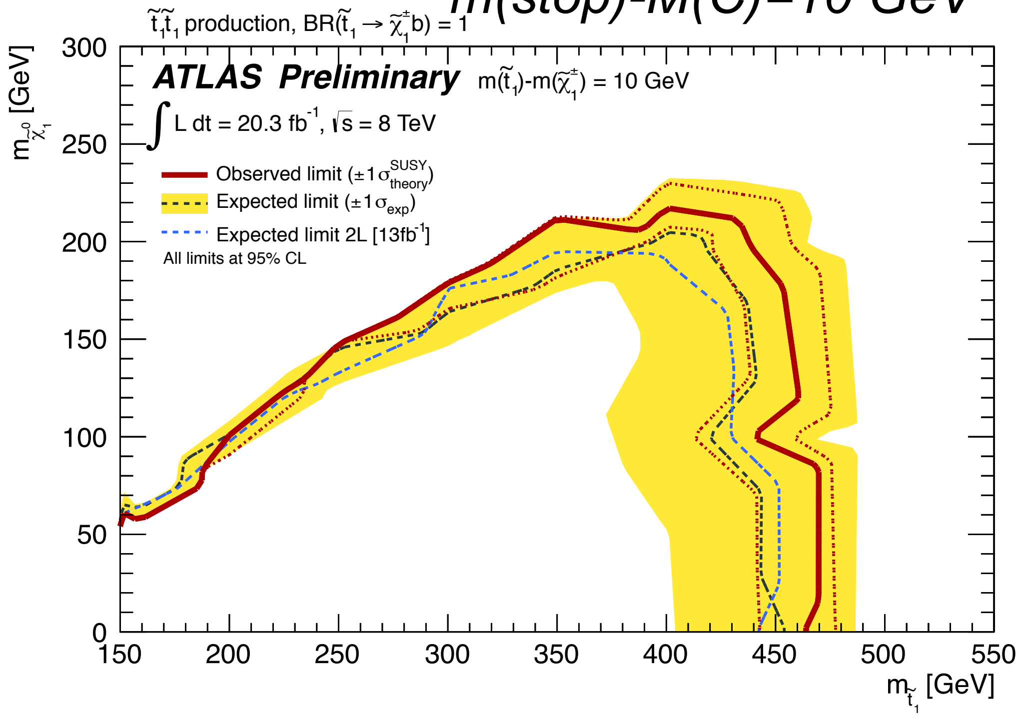


Limiti

Massless N



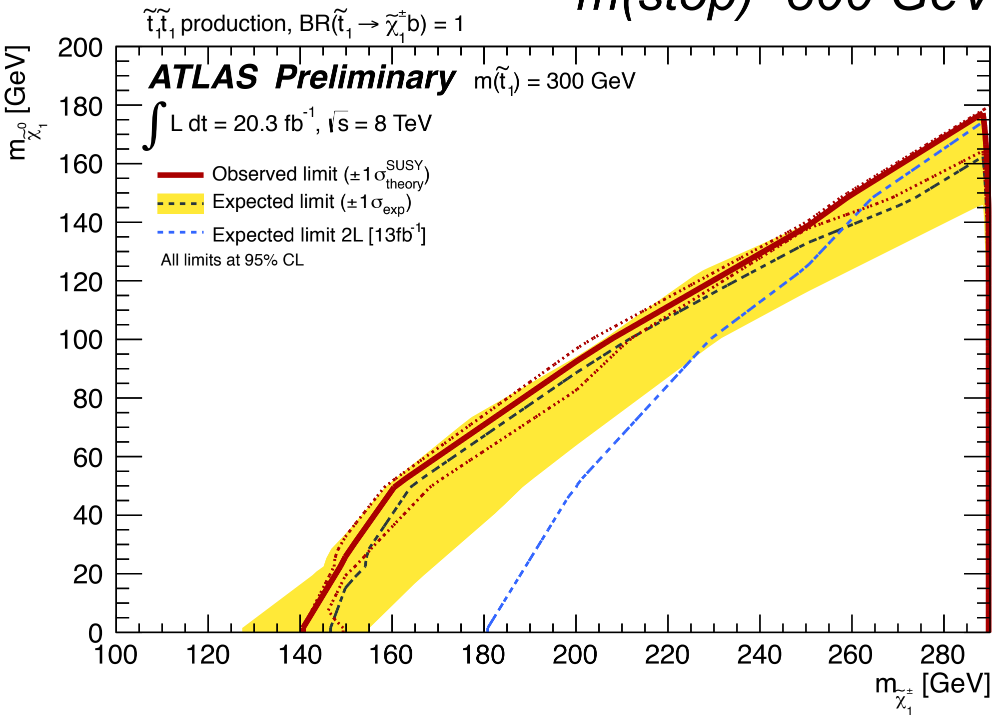
m(stop)-M(C)=10 GeV



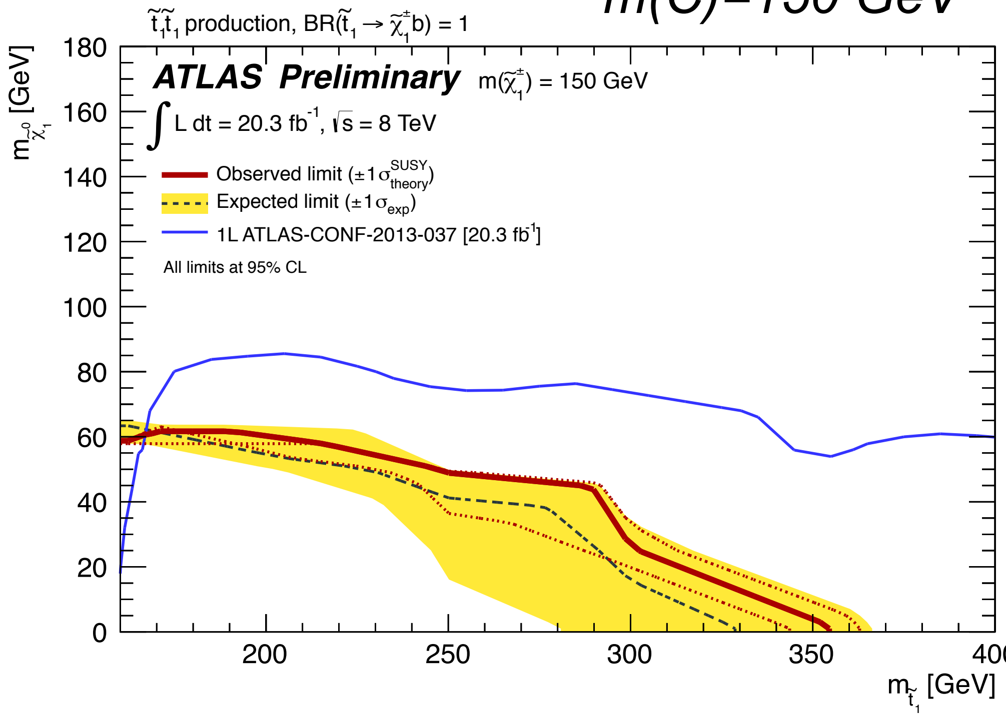
- Limite osservato
- Limite aspettato
- Limite osservato ± 1σ teorica
- Limite precedente analisi con 13 fb^{-1}

Limiti

m(stop)=300 GeV



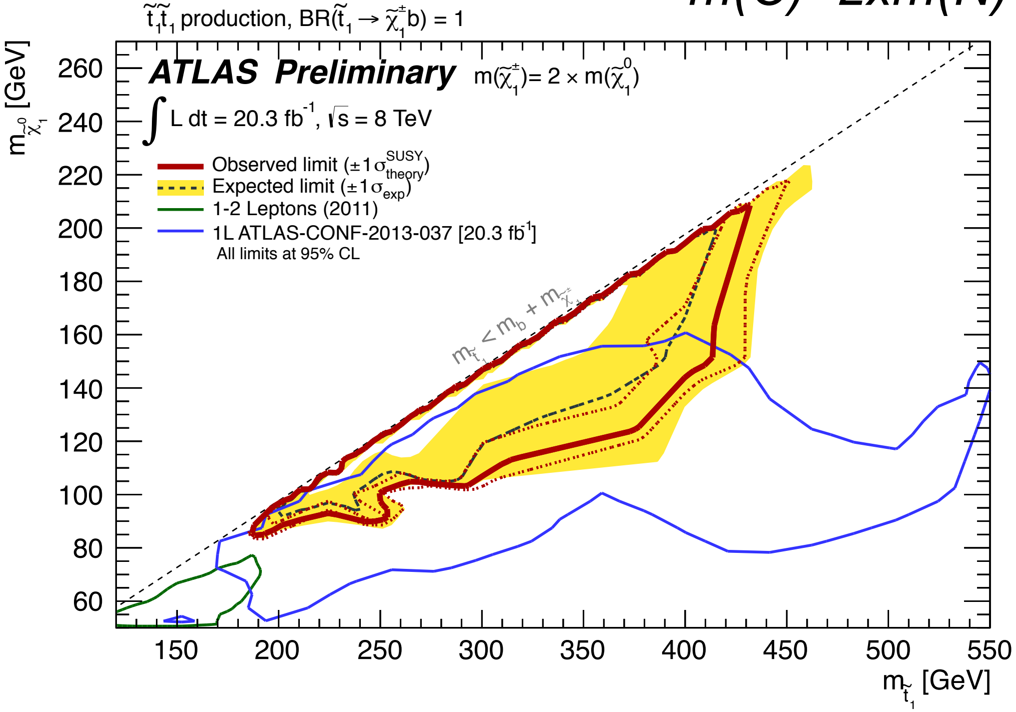
m(C)=150 GeV



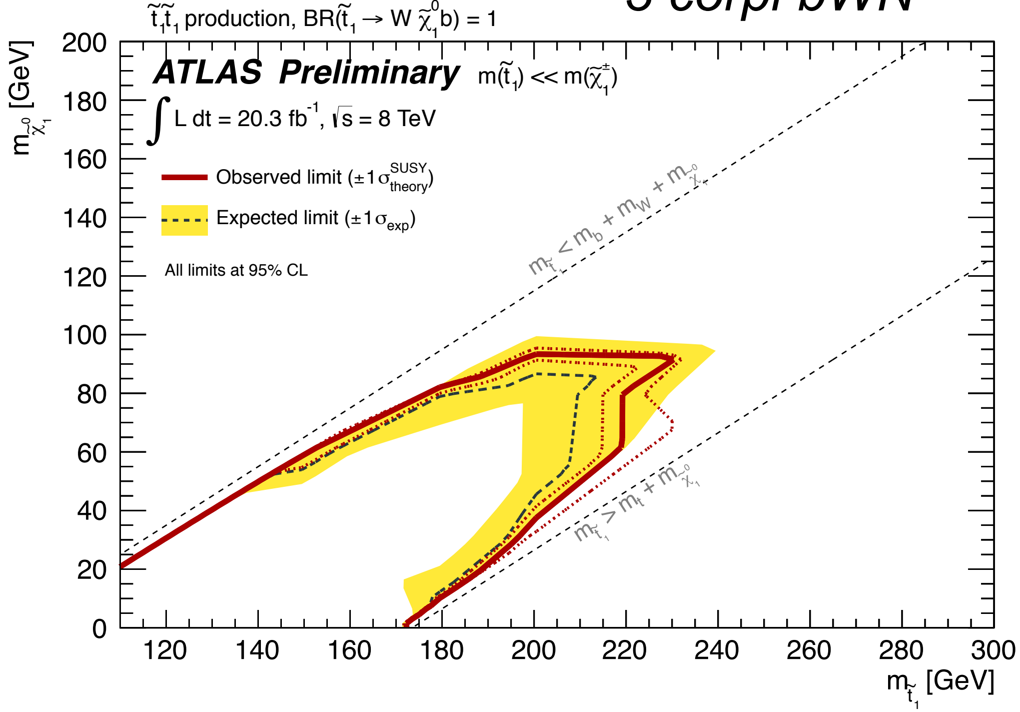
Limite osservato
Limite aspettato
Limite osservato ± 1σ teorica
Limite precedente analisi con 13 fb^{-1}
Limite analisi ATLAS con 1 leptone

Limiti

m(C)=2xm(N)



3 corpi bWN



- Limite osservato
- Limite aspettato
- Limite osservato ± 1σ teorica
- Limite analisi ATLAS con 1-2 leptoni
- Limite analisi ATLAS con 1 leptone

Conclusioni e sviluppi futuri dell'analisi

✧ L'analisi **esclude stop fino a 450 GeV** per decadimenti t→bC (100%BR) e bassi valori di m(N). Per la prima volta in ATLAS è stata esclusa una regione dello spazio dei parametri nel **decadimento a 3 corpi bWN** ☺

❖ L'analisi è stata già revisionata ed un articolo è in fase di approvazione in ATLAS.

Rispetto a quanto descritto in questo talk, le più importanti differenze sono:

- Combinazione statistica delle SR
- Ri-ottimizzazione di alcune SR
- Inclusione del fondo da Higgs
- Re-ottimizzazione della misura del fondo da fakes

❖ Miglioramento della regione esclusa di un 5-10%.

Fine

Backup slides

Definizione degli oggetti

Elettroni

baseline:
- p_T>10 GeV, $|\eta|$<2.47

signal:
- all baseline cuts
- track isolation $\Sigma p_T < 0.1 x p_T$

Muoni

baseline:
- Combined ID+MS
- p_T>10 GeV, $|\eta|$<2.47

signal:
- all baseline cuts
- track isolation Σp_T<1.8 GeV

Jets

- AntiKt4
- p_T>20 GeV $|\eta|$<2.5

- Remove jets within ΔR<0.2 of a baseline electron
- Remove electrons and muons within ΔR<0.4 of a jet

Overlap Removal

Missing Transverse Energy

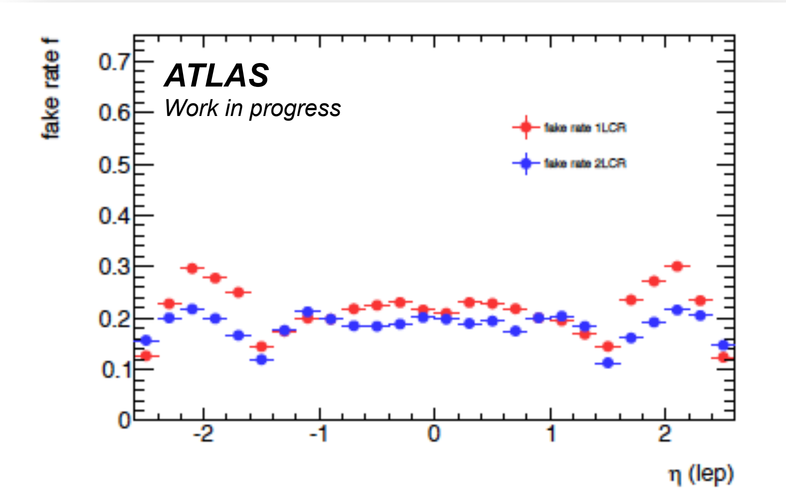
- *MET_Egamma10NoTau*
- Sum of jets and lepton momenta and unassociated cluster energies

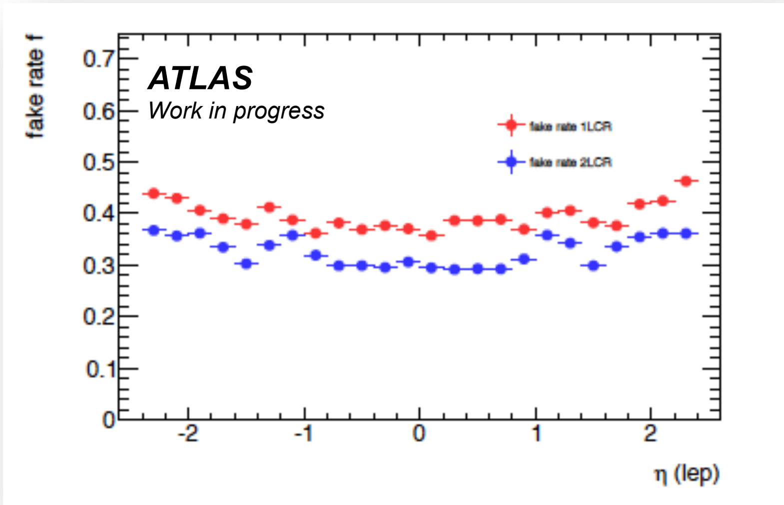
Il fake rate

- Fake rate combinato dalla misura in due CR arricchite in fakes:
  - regioni con un leptone, dominate da QCD (1LCR)
  - regioni con due leptoni same-sign si sapore differente (2LCR)
- Per considerare l'effetto di Heavy Flavour jets (HF), la misura viene ri-effettuata in regioni con b-jets aggiuntivi (btag).
- Il contributo da leptoni prompt viene sottratto attraverso MC.

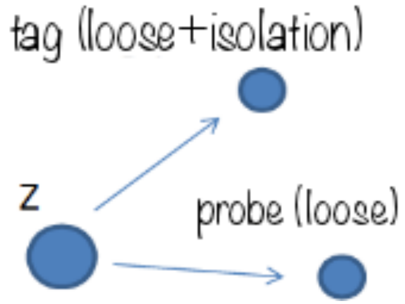
$$f = \frac{\#\ \text{fake lepton passing tight}}{\#\ \text{fake loose lepton}}$$

- Parametrizzato per p_T e η, ΔR_{lj}^{min} (elettroni) e $\sum E_T$ (muoni).



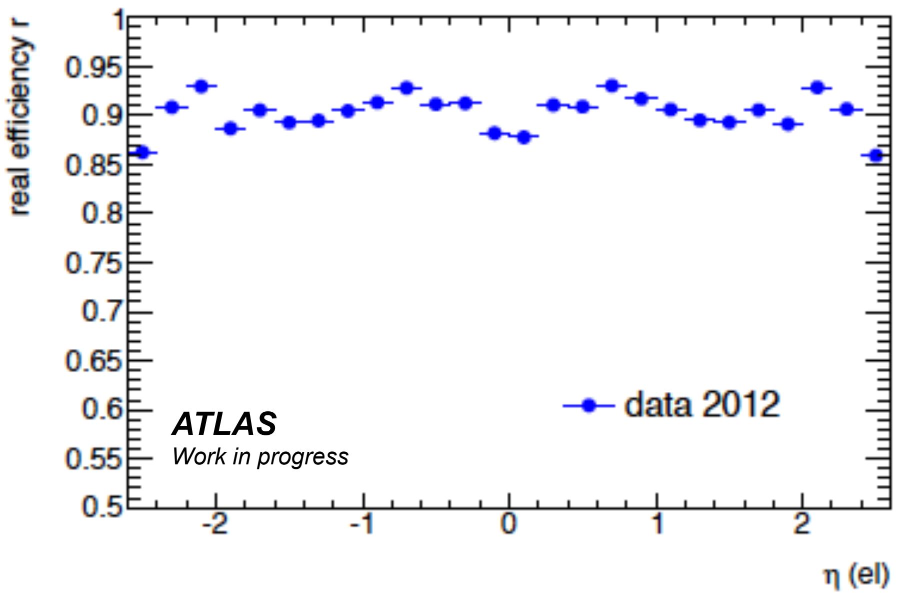


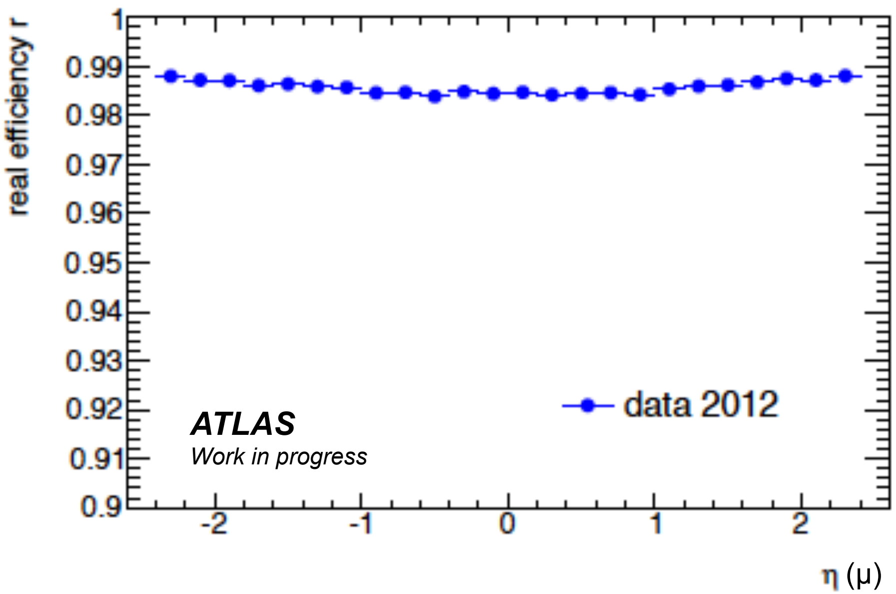
L’efficienza real



- Efficienza real misurata in regioni arricchite in Z per mezzo di un tag&probe:
  - 2 leptoni opposite-sign, same-flavour
  - $86 < m_{ll} < 96$ GeV
- Parametrizzata per p_T, η del leptone.

$$r = \frac{\#\ \text{real lepton passing tight}}{\#\ \text{real probe lepton}}$$





Incertezze sulla stima dei fakes

- Differenti sorgenti di sistematica sono state considerate per la stima:
  - dovute alla misura del fake rate:
    - Limitata statistica nelle CRs e discrepanza fra le misure di *f* nelle due CRs.
    - Risoluzione della misura di E_T^{miss} (5 GeV).
    - Correzione MC riscalata del 25%.

Parametrizzata in η e p_T. Dell'ordine di10-40% della stima totale.

  - dovute alla misura di *r*:
    - *r* misurata in sample MC con Z.

Trascurabile

Risultati del fit per M90

Good agreement ☺

Process	CRTM90	CRW	CRZ	VRSF	VRDF
Observed events	11615	854	169	478	603
Expected bkg events	11615 ± 110	854 ± 27	169 ± 13	450 ± 50	600 ± 40
Fitted $t\bar{t}$ events	8300 ± 400	142 ± 26	27 ± 6	300 ± 40	410 ± 30
Fitted WW events	1500 ± 290	580 ± 40	9.7 ± 2.0	87 ± 17	108 ± 21
Fitted WZ, ZZ events	60 ± 9	13 ± 4	112 ± 15	5.7 ± 1.4	2.3 ± 1.7
Expected Z+jets events	26 ± 27	0.7 ± 0.8	17 ± 7	4 ± 6	-
Expected $t\bar{t}V$ events	10 ± 3	-	0.6 ± 0.2	0.5 ± 0.2	0.8 ± 0.3
Expected Wt events	1050 ± 80	34 ± 7	1.6 ± 1.1	39 ± 7	54 ± 9
Events with fake leptons	710 ± 220	82 ± 17	-	11 ± 7	18 ± 8
Fit input, expectation $t\bar{t}$	8100 ± 1000	138 ± 25	27 ± 9	290 ± 50	400 ± 60
Fit input, expectation WW	1160 ± 120	450 ± 60	7.5 ± 1.1	67 ± 7	83 ± 8
Fit input, expectation WZ, ZZ	67 ± 9	15 ± 7	125 ± 26	6.3 ± 2.5	2.6 ± 1.4

Risultati del fit per M100

Good agreement ☺

Process	CRTM100	CRW	CRZ	VRSF	VRDF
Observed events	1322	854	169	60	66
Total expected bkg events	1322 ± 38	854 ± 27	169 ± 12	48 ± 10	62 ± 9
Fitted $t\bar{t}$ events	1180 ± 40	150 ± 40	29 ± 8	41 ± 10	57 ± 8
Fitted WW events	37 ± 11	580 ± 50	10 ± 2	1.3 ± 0.6	1.6 ± 0.9
Fitted WZ, ZZ events	1.3 ± 0.7	13 ± 4	112 ± 19	0.1 ± 0.1	0.1 ± 0.2
Expected Z+jets events	0.9 ± 1.1	0.7 ± 0.8	17 ± 7	0.3 ± 0.5	-
Expected $t\bar{t}V$ events	3.9 ± 1.2	-	0.6 ± 0.2	0.16 ± 0.08	0.3 ± 0.1
Expected Wt events	60 ± 10	34 ± 7	1.6 ± 1.1	2.1 ± 1.5	1.4 ± 2.4
Expected events with fake leptons	42 ± 19	82 ± 18	-	3.0 ± 2.1	1.3 ± 0.8
Fit input, expectation $t\bar{t}$	1090 ± 190	138 ± 25	27 ± 9	38 ± 12	53 ± 14
Fit input, expectation WW	29 ± 9	450 ± 60	7.7 ± 1.1	1.0 ± 0.8	1.3 ± 1.1
Fit input, expectation WZ, ZZ	1.5 ± 1.6	15 ± 7	125 ± 26	0.1 ± 0.1	0.1 ± 0.2

Risultati del fit per M110

Good agreement ☺

Process	CRTM110	CRW	CRZ	VRSF	VRDF
Observed events	7872	854	169	306	370
Expected total bkg events	7872 ± 90	854 ± 29	169 ± 12	270 ± 30	370 ± 30
Fitted $t\bar{t}$ events	6910 ± 120	153 ± 15	30 ± 7	240 ± 30	330 ± 30
Fitted WW events	270 ± 30	570 ± 30	10.2 ± 2.1	11 ± 2	13 ± 3
Fitted WZ, ZZ events	12 ± 2	13 ± 3	110 ± 15	1.1 ± 0.4	0.2 ± 0.2
Expected Z+jets events	3.5 ± 1.1	0.7 ± 0.8	17 ± 7	1.2 ± 1.1	-
Expected $t\bar{t}V$ events	9.7 ± 2.3	-	0.6 ± 0.2	0.42 ± 0.16	0.7 ± 0.2
Expected Wt events	420 ± 30	34 ± 7	1.6 ± 1.1	12 ± 4	18 ± 4
Events with fake leptons	250 ± 100	82 ± 18	-	5 ± 4	9 ± 4
Fit input, expectation $t\bar{t}$	6200 ± 700	138 ± 25	27 ± 9	210 ± 40	290 ± 50
Fit input, expectation WW	220 ± 30	450 ± 60	7.5 ± 1.1	8.8 ± 1.2	10 ± 3
Fit input, expectation WZ, ZZ	14 ± 4	15 ± 7	125 ± 26	1.2 ± 0.4	0.3 ± 0.3

Fake rate measurement

NEW

A. pT<25 GeV

2D binned parametrization over the plane X-M_{eff}, where X is one of the following variables:

- p_T
- η
- n.jets
- M_{T2}

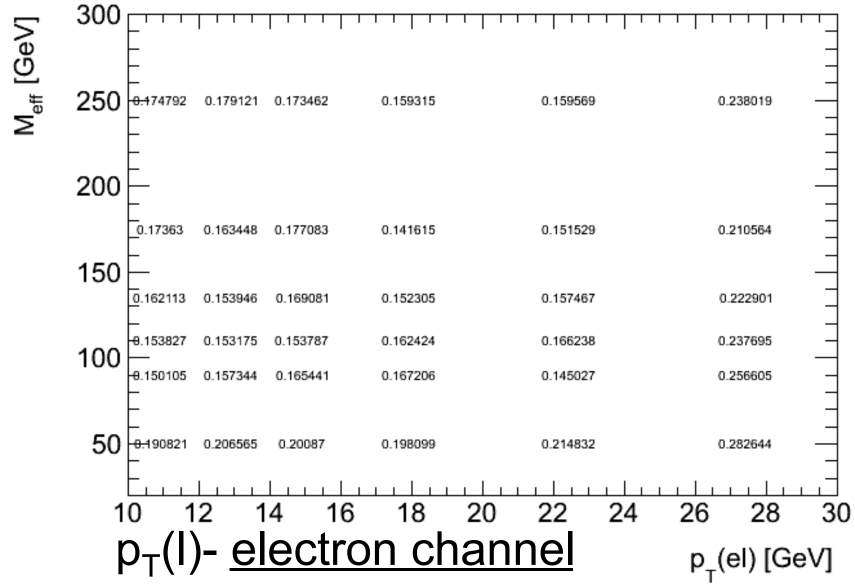
B. pT>25

Measured as a function of p_T from a 1LCR:

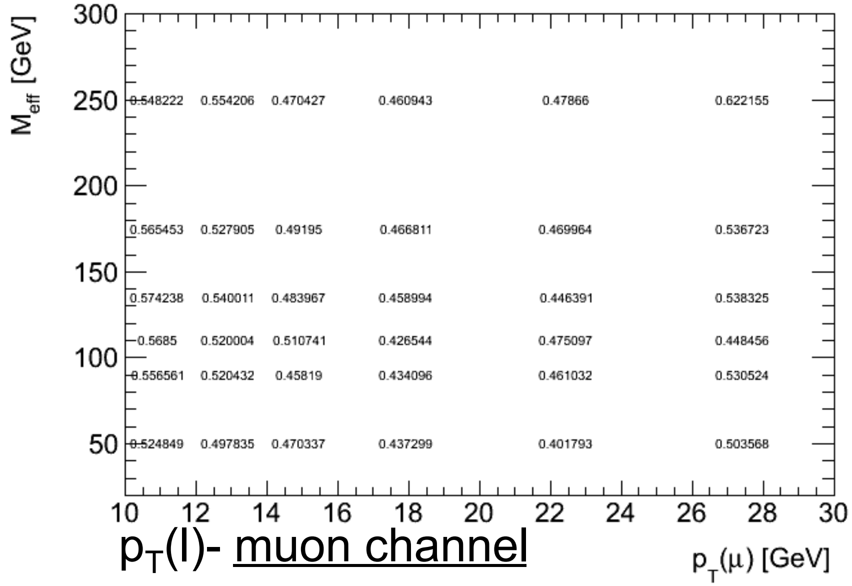
- 1 lepton
- >1 jet
- MET<25 GeV, $\Delta\phi$(l,MET)<0.5

1D parametrizitation on X={η, n.jets, M_{T2}.} as in the previous case.

2D parametrization of f(p_T,M_{eff}) in the case A.



p_T(l)- electron channel



p_T(l)- muon channel

A. Fakes estimation p_T<25GeV()

NEW

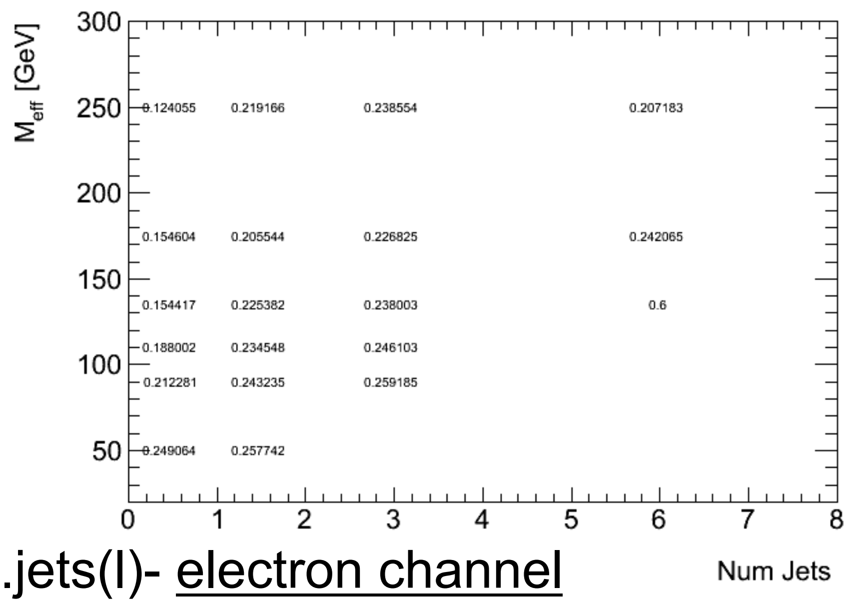
Overall strategy:

1. Take the fake rate $f(p_T,M_{eff})$ from the plane p_T vs. M_{eff}
2. Parametrize f by the variable $X=\{\eta, \text{n.jets}, M_{T2}\}$, by scaling

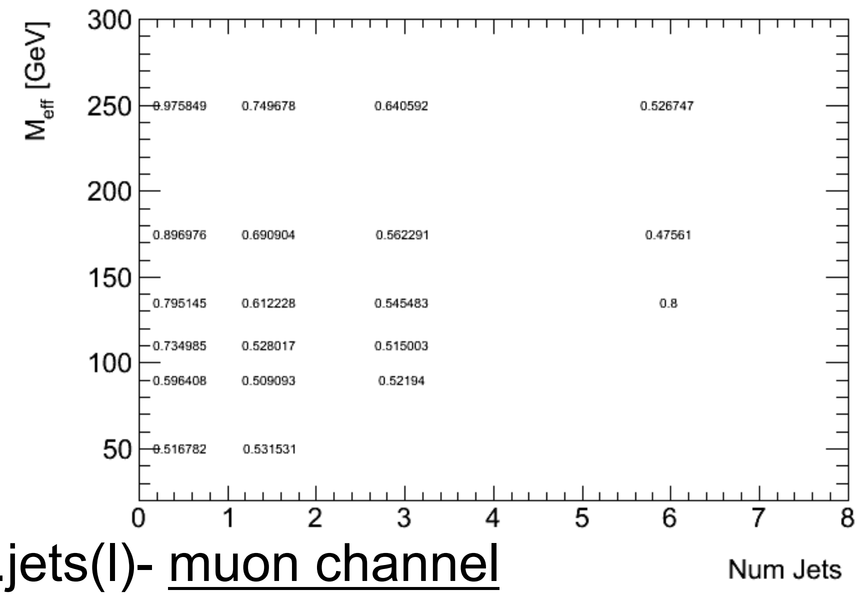
$$f' = f(p_T,M_{eff}) * f(X,M_{eff})/\langle f(M_{eff})\rangle$$

where $\langle f(M_{eff})\rangle$ is the nominal M_{eff} for that bin of M_{eff}.*

* In order to avoid contamination from prompt leptons, which is strong in the muon channel, refuse the parametrizazion if the scale factor is >1. This results in a better agreement in the validation plots.



n.jets(l)- electron channel



n.jets(l)- muon channel

B. Fakes estimation p_T>25GeV() NEW

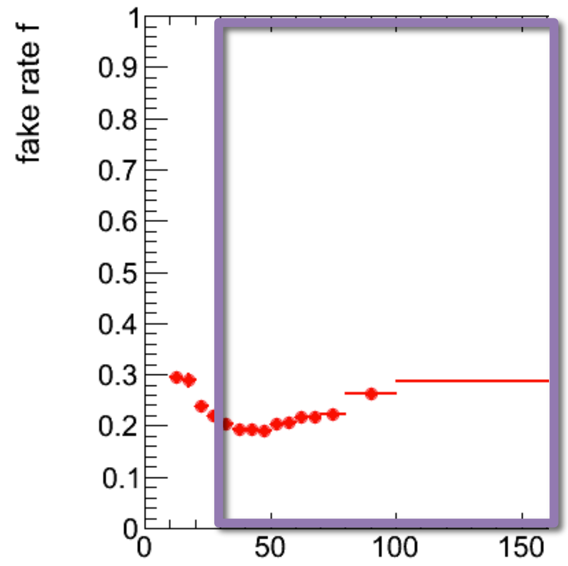
1. For leptons with p_T >25 GeV use a default $f(p_T)$ measured from a 1LCR yielded by single lepton prescaled triggers similar to those used in the analysis.

2. Parametrize $f(p_T)$ on X={η, n.jets, M_{T2}} as in the previous case.

1LCR:
- 1 lepton
- >1 jet
- MET<25 GeV, Δϕ(l,MET)<0.5

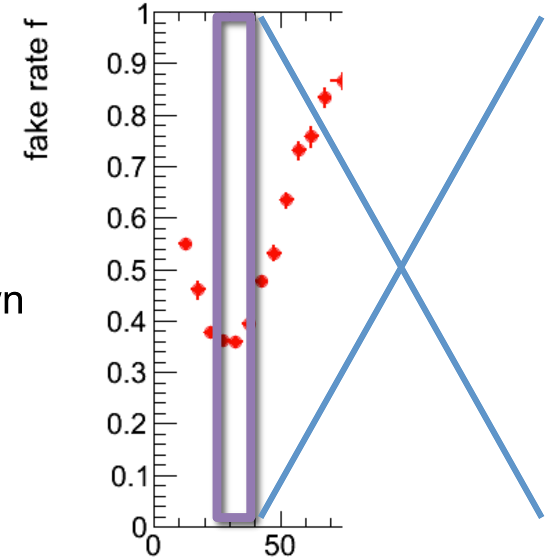
Trigger used
- e24vh_medium1 (electron)
- mu24_tight (muon)

p_T(l)- electron



p_T(l)- muon*

* A cut on 40 GeV is applied due to contamination from prompt leptons (known problem)



Fake bkg systematics

NEW

A complete revised treatment of the systematics:

p_T<25 GeV

The following source of systematics are considered:

1. Statistical error coming from the binned 2D planes.
2. A 10% uncertainty on p_T and M_{eff} values (very conservative): measurement is redone and the largest difference is taken as systematic.
3. A 25% uncertainty on the MC subtraction while measuring f (negligible).

All the sources are considered independent and summed in quadrature.

p_T>25 GeV

The following source of systematics are considered:

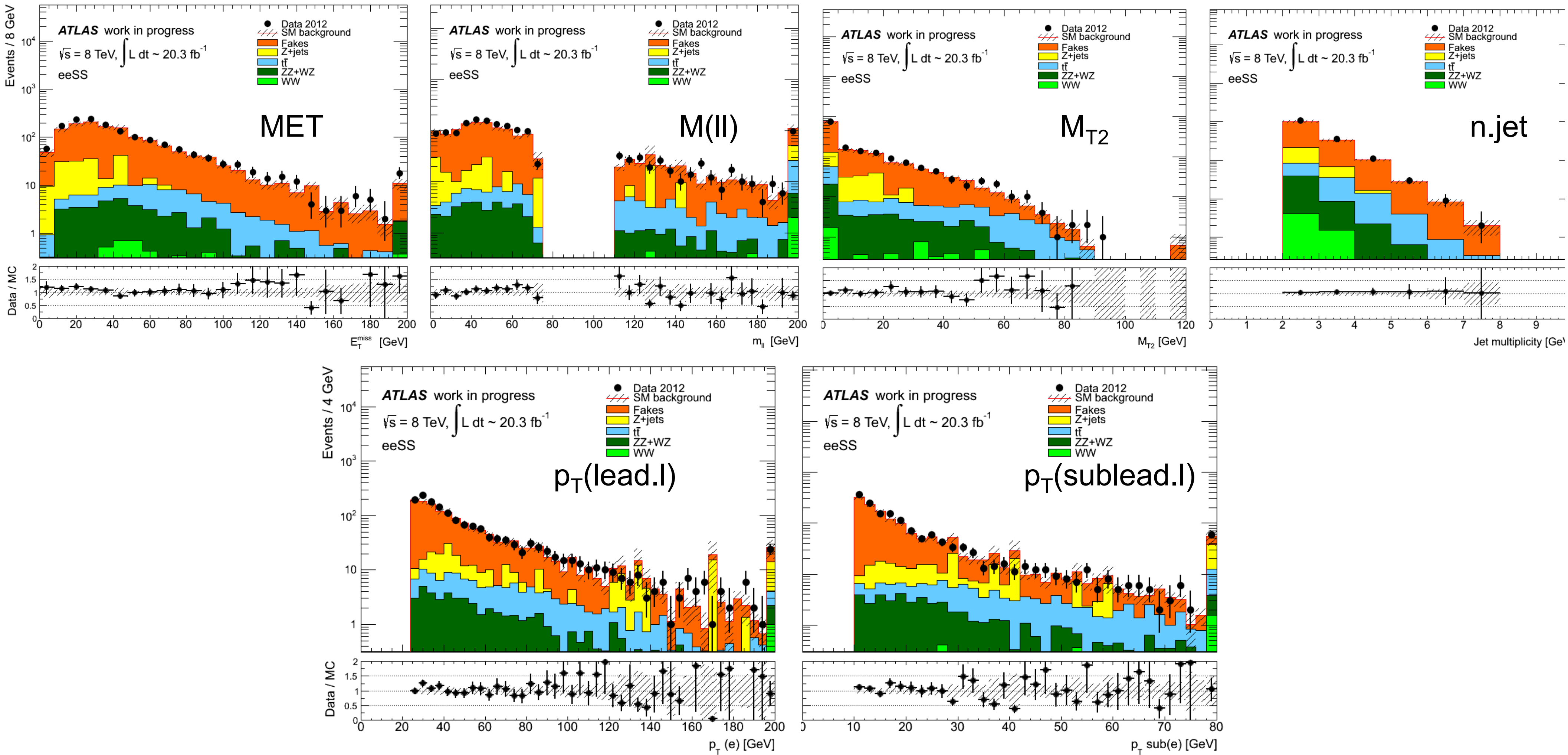
1. Statistical error in the $f(p_T)$ estimation.
2. The difference with the value obtained by using the <25GeV approach is considered as a systematic.
3. A 25% uncertainty on the MC subtraction while measuring f (negligible).

All the sources are considered independent and summed in quadrature.

Validazione della stima dei fakes

La stima dei fakes viene validata in regioni same-sign

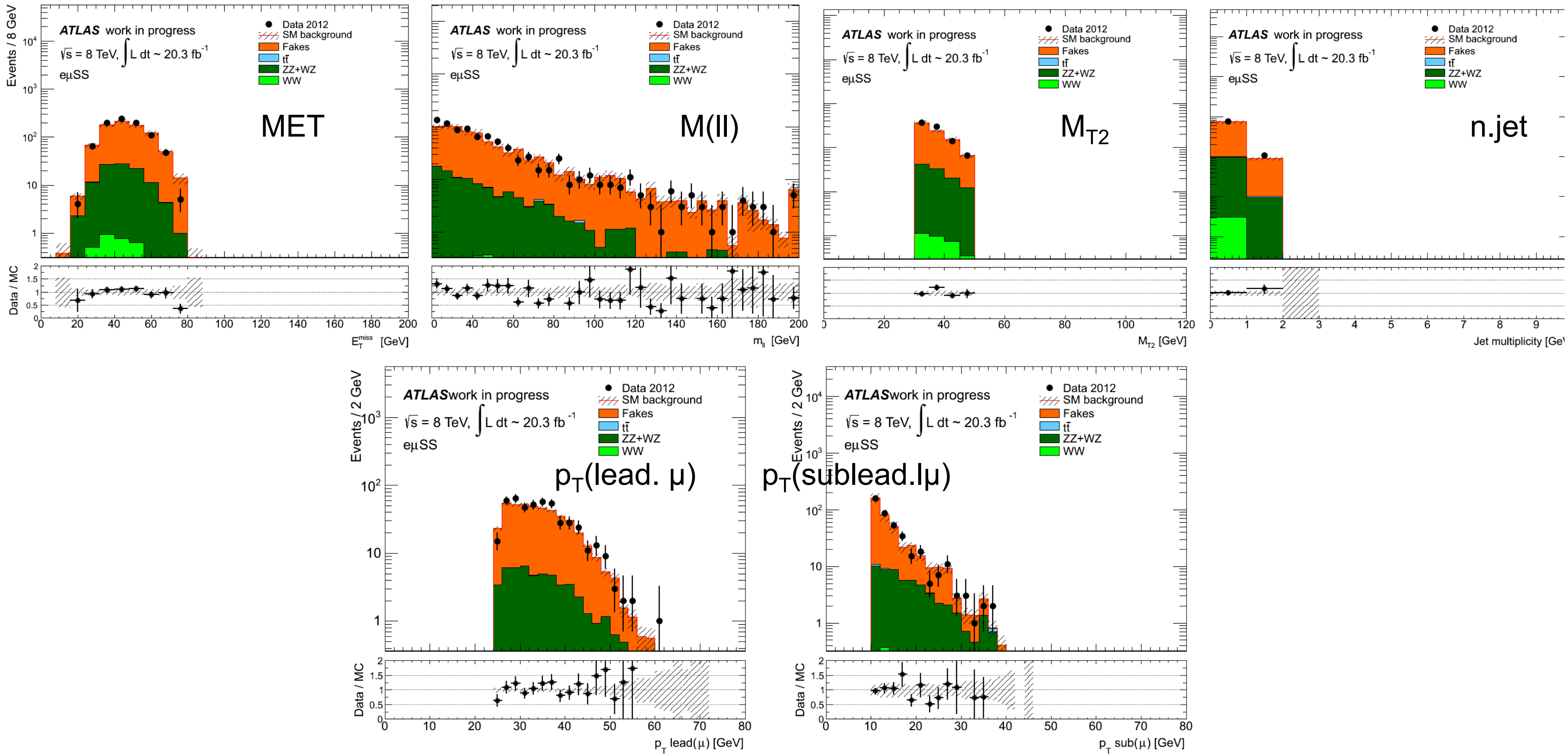
2L ee SS + dΦ(MET,j)>1.0 +dΦ(MET,pbll)<1.5 + Z veto + $p_T(j^0)$>100 + $p_T(j^1)$>50



Validazione della stima dei fakes

La stima dei fakes viene validata in regioni same-sign

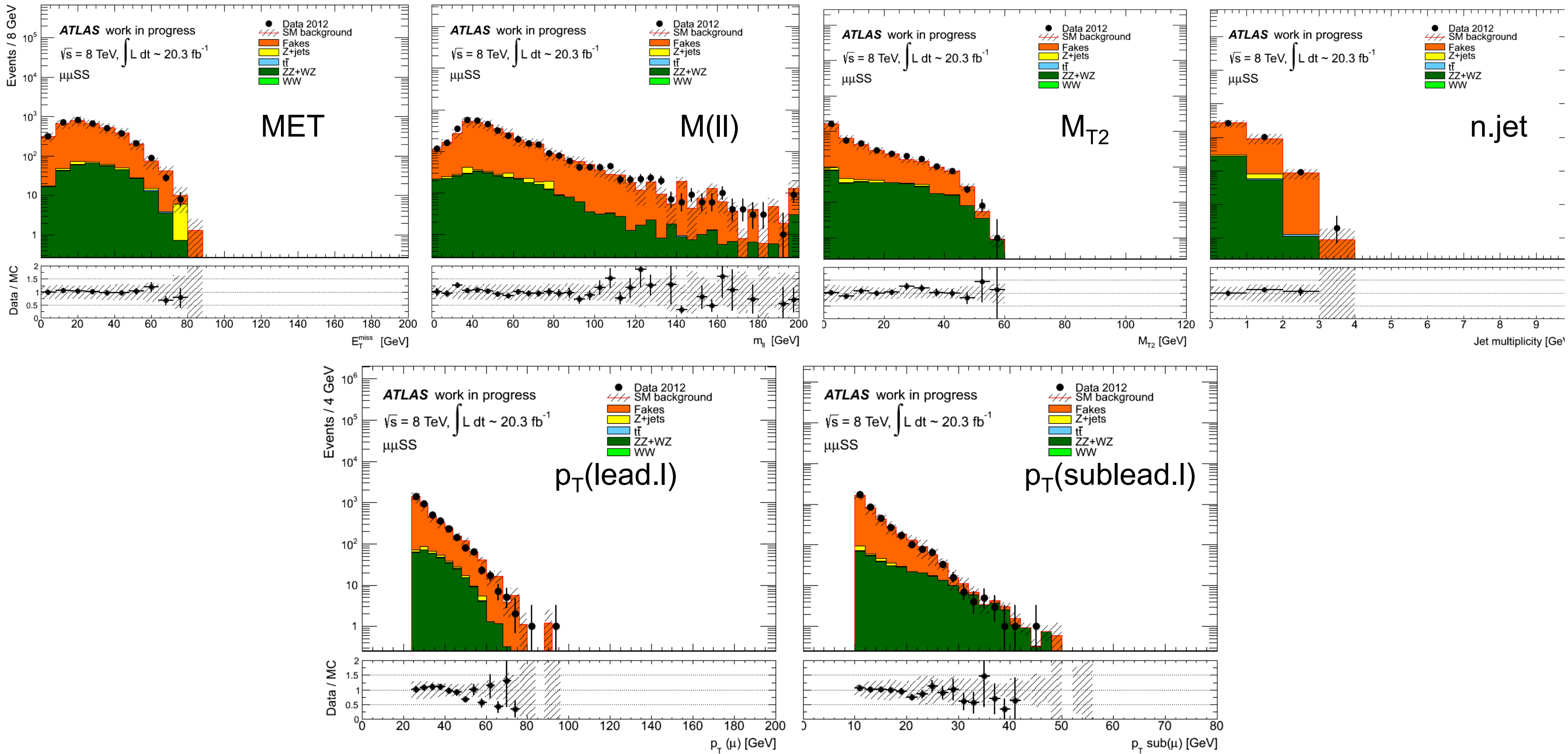
2L eμ SS + M_{eff}<120 + 30<M_{T2}<50



Validazione della stima dei fakes

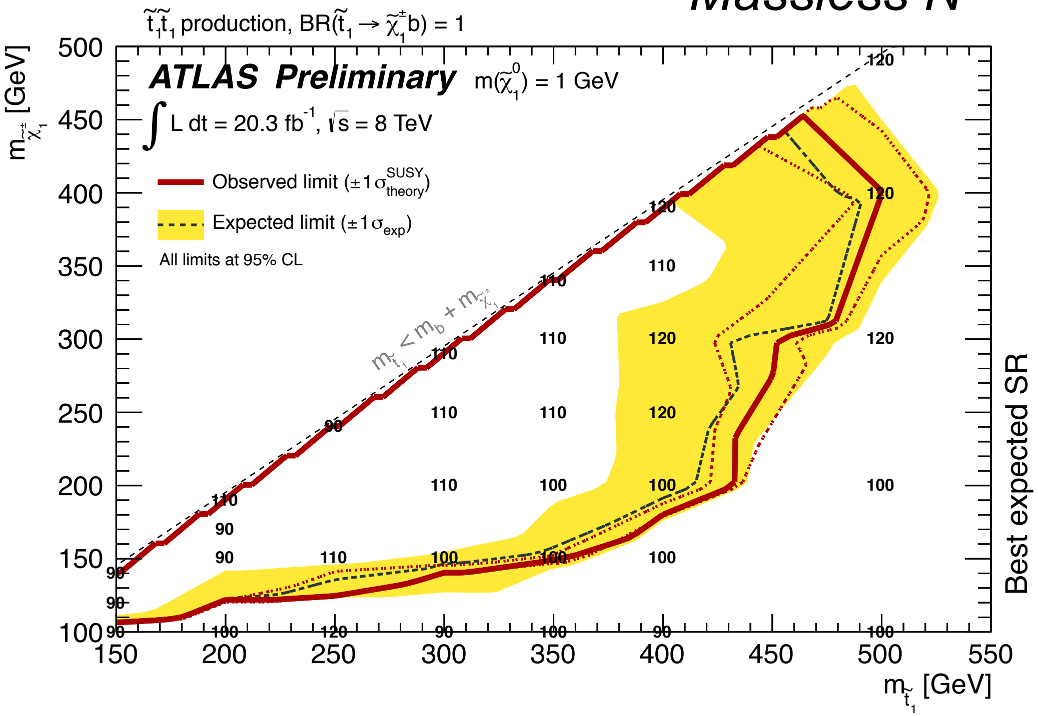
La stima dei fakes viene validata in regioni same-sign

2L μμ SS + M_{eff}<120

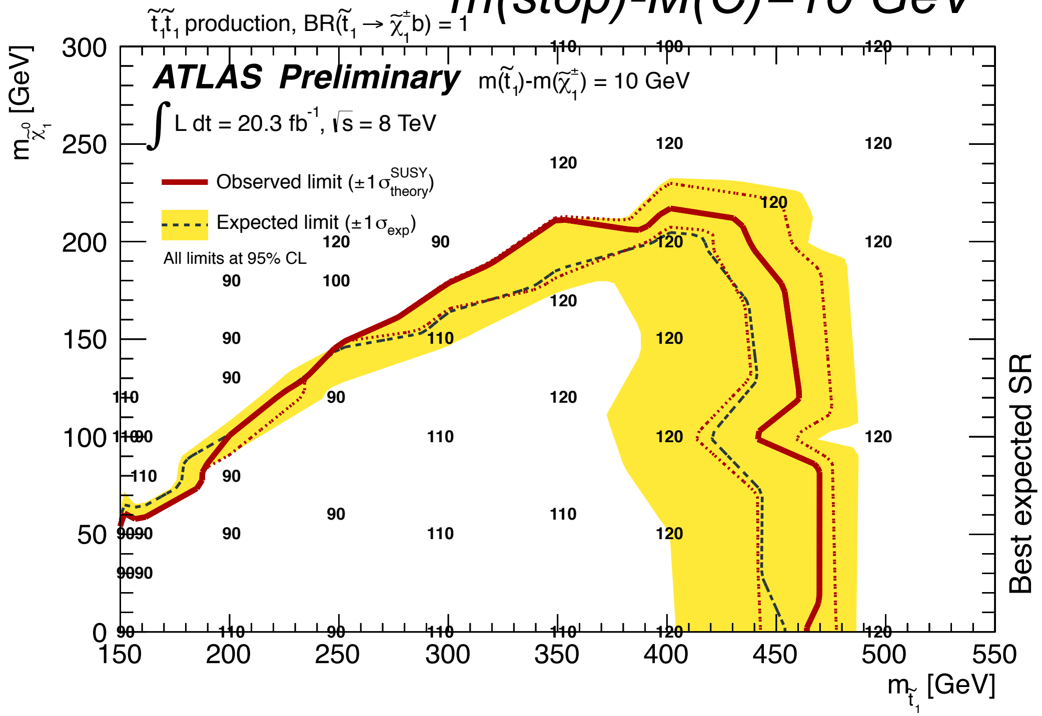


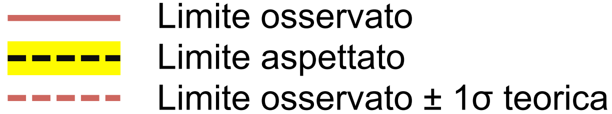
Limiti – best SR

Massless N



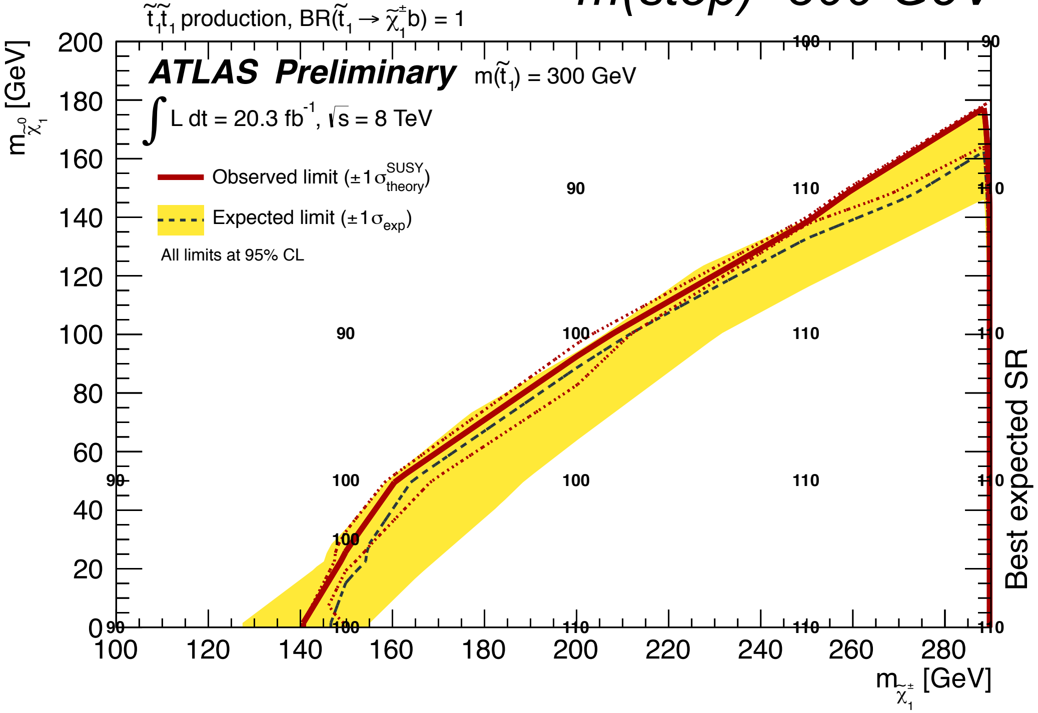
m(stop)-M(C)=10 GeV



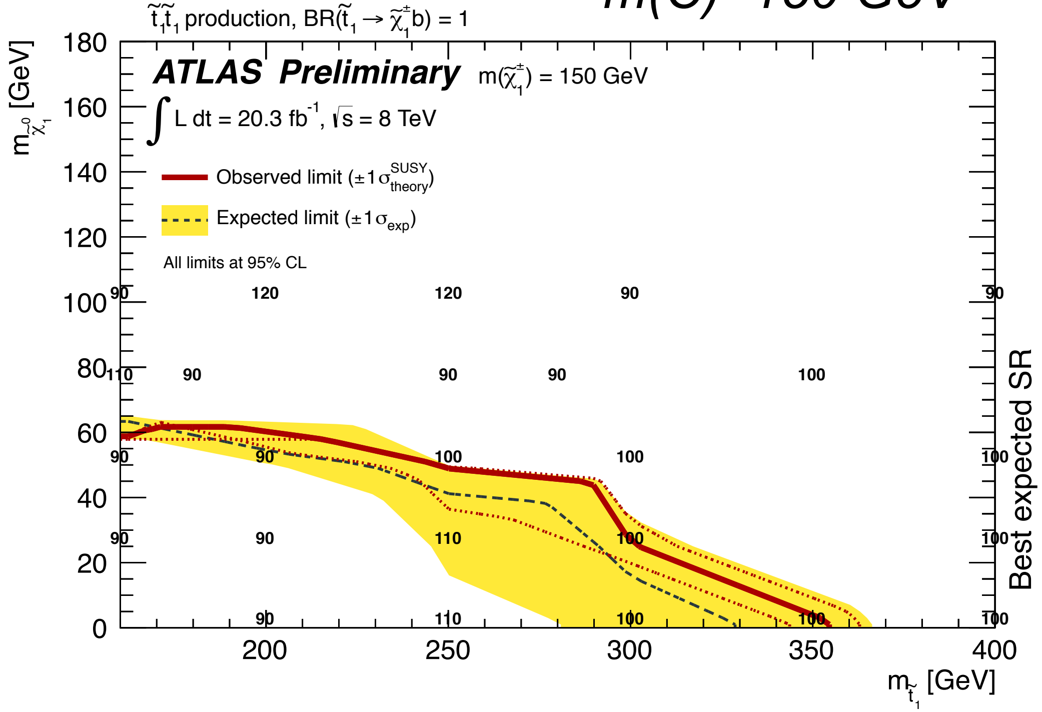


Limiti – best SR

m(stop)=300 GeV



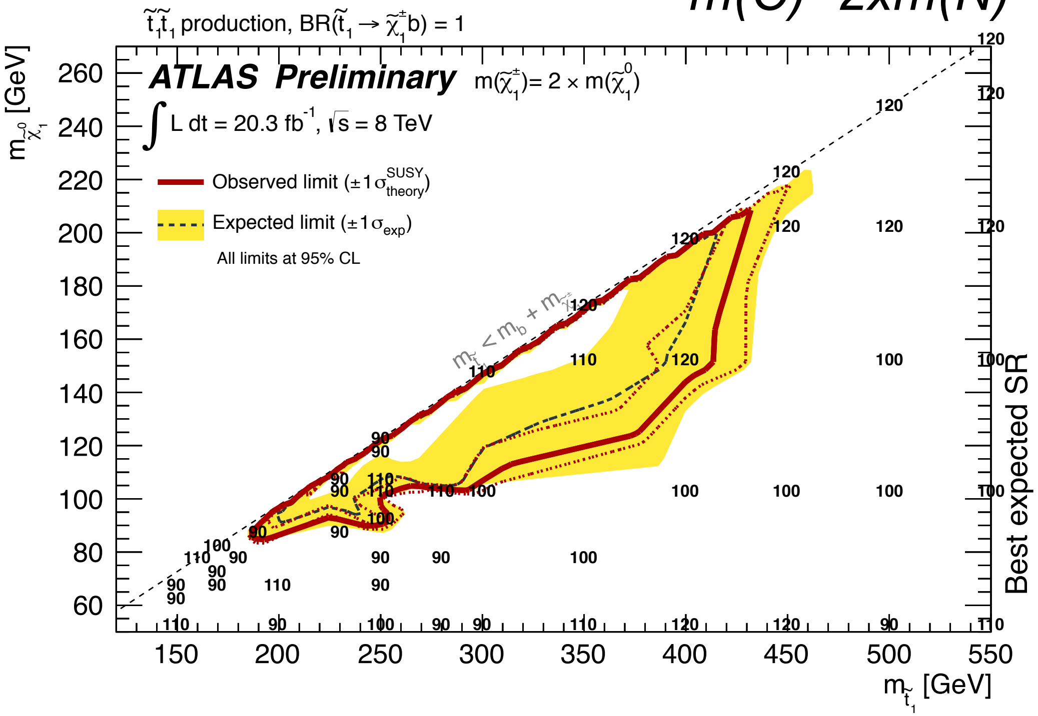
m(C)=150 GeV



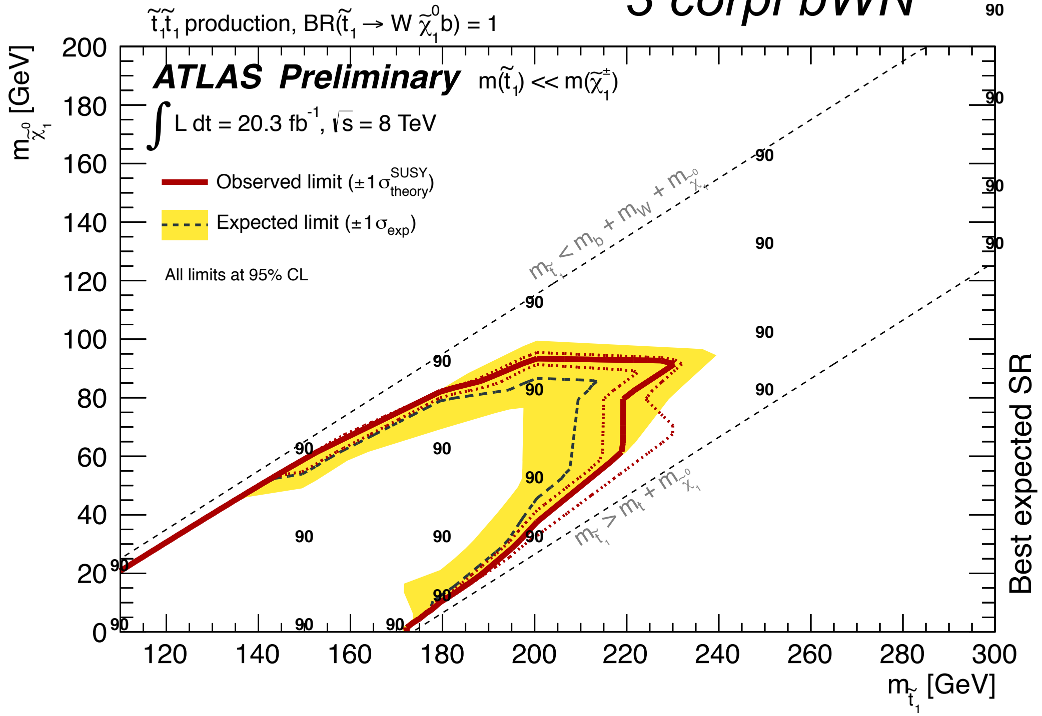
Limite osservato
Limite aspettato
Limite osservato ± 1σ teorica

Limiti – best SR

m(C)=2xm(N)

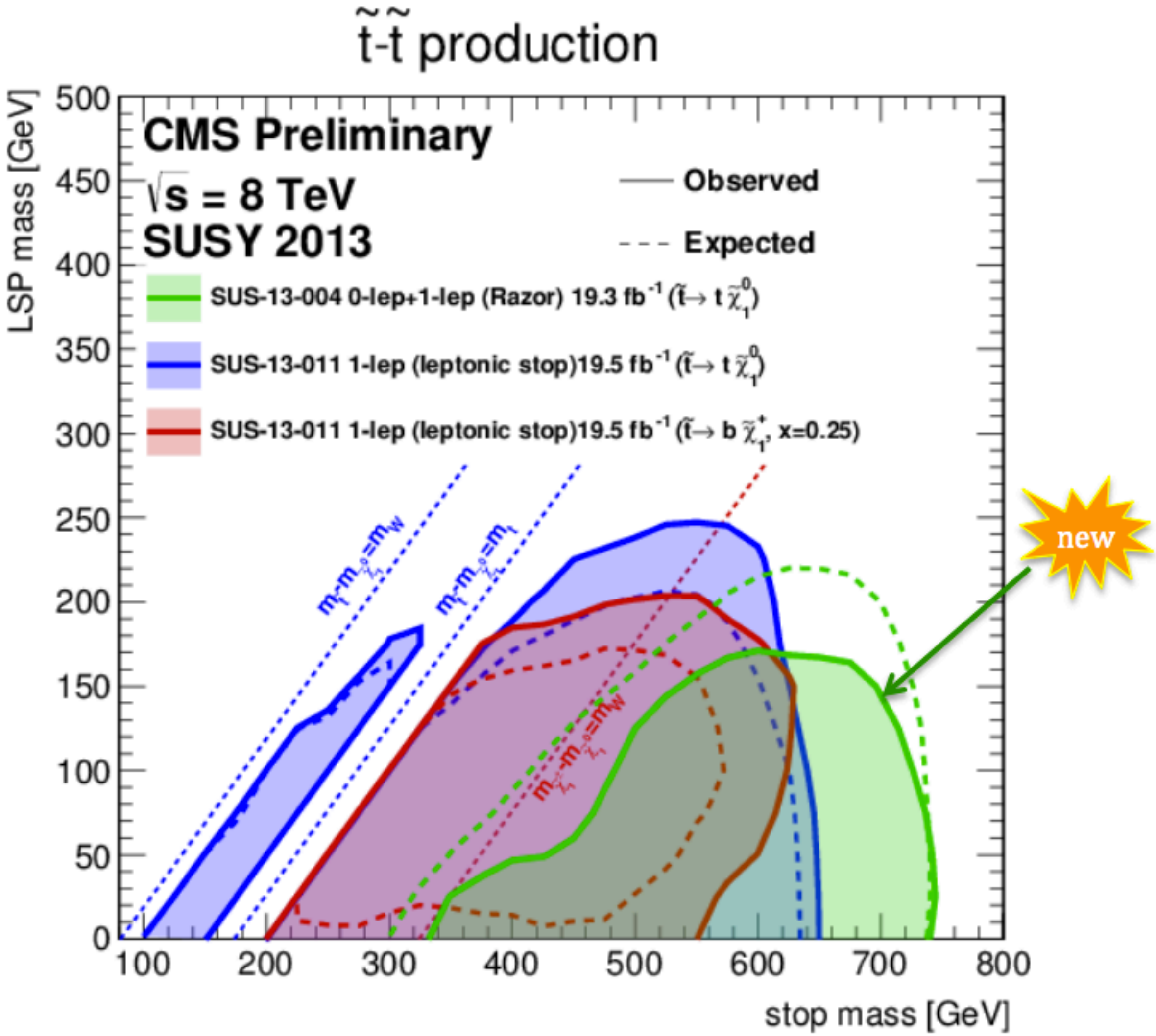


3 corpi bWN



Limite osservato
Limite aspettato
Limite osservato ± 1σ teorica

Summary on CMS results on direct Stop searches:



from CERN public presentation by C.Sander