Search for SUSY with Razor kinematic variables in 0-lepton channel

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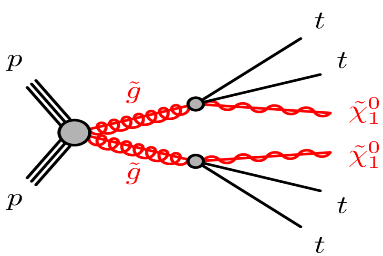
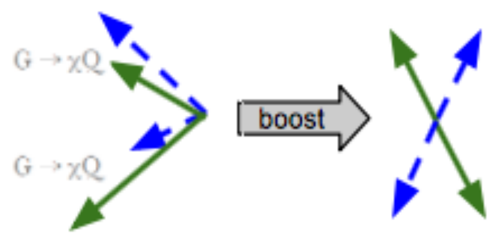
Physics process being studied

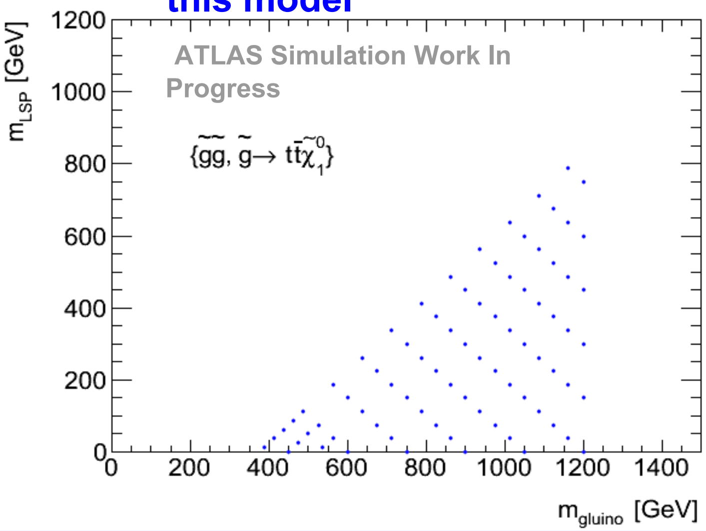
- **R parity conserved, strong direct** gluino pair production with the gluino decaying to the LSP via the emission of two (**top**) quarks (**0-lepton only**)
- Assume $BF(\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0) = 100\%$
- On-shell requirement: $m_{gluino} - m_{LSP} > 2 * m_{top}$
- Signature: **multijets + missing energy**
- 78 different mass scenarios are considered $q\bar{q}, gg \rightarrow \tilde{g}\tilde{g} \rightarrow t\bar{t}q\tilde{\chi}_1^0\, t\bar{t}\tilde{\chi}_1^0$



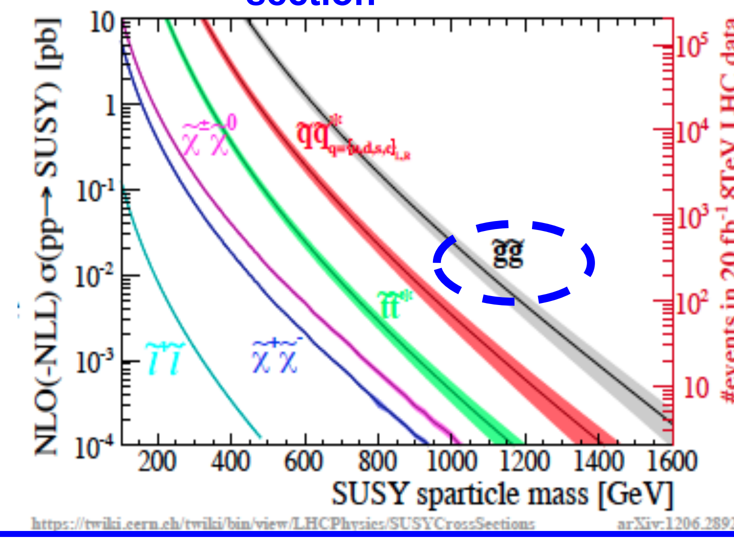


The analysis strategy: optimized for pair of (mega) jets.

Grid points covered by this model



Production cross-section



Razor variables. [Plots are signal MC.]

Razor variables:

mass variables: M'_R, M_T^R

discriminator: R

$$R = \frac{M_T^R}{M'_R} \sim \frac{E_T^{miss}}{H_T}$$

Tends to be flat for signal and peaks at low values for background

arXiv:1006.2727

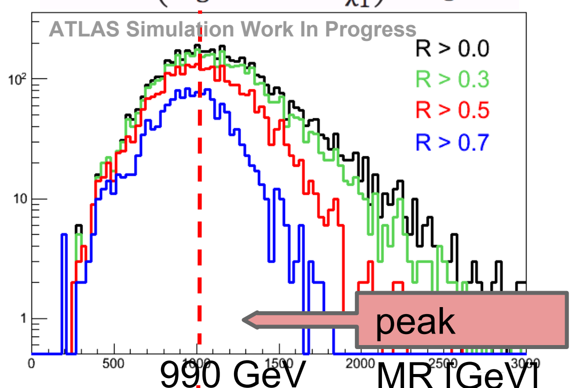
$$M_T^R = \left[\frac{1}{2} \times |E_T^{miss}| \times (|j_{1,T}| + |j_{2,T}|) - \frac{1}{2} \times E_T^{miss} \cdot (j_{1,T} + j_{2,T})\right]^{1/2},$$

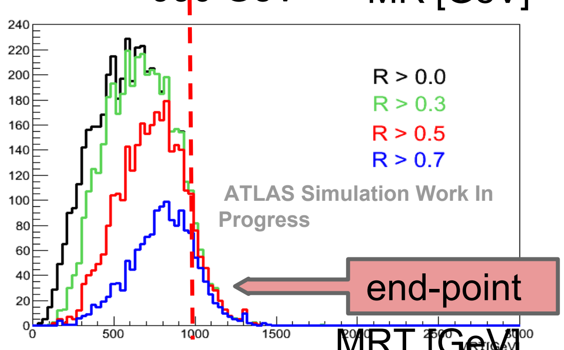
$$M'_R = \sqrt{(j_{1,E} + j_{2,E})^2 - (j_{1,z} + j_{2,z})^2}$$

For "fake" E_T^{miss}, M_T^R will take on small values

$$\langle M_R \rangle = \left(m_{gluino}^2 - m_{\tilde{\chi}_1^0}^2\right) / m_{gluino}$$

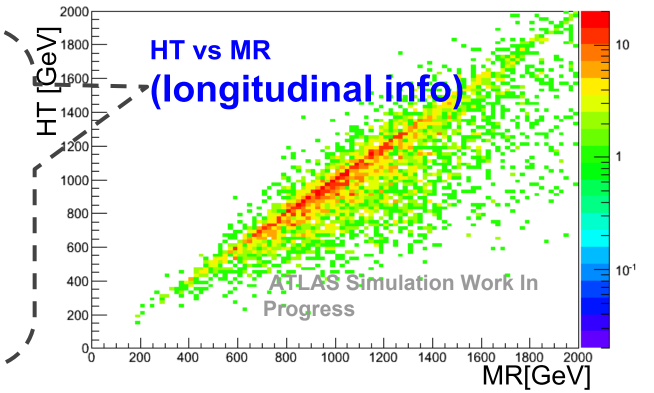
$m_{gluino} = 1000$ GeV, $m_{\tilde{\chi}_1^0} = 100$ GeV

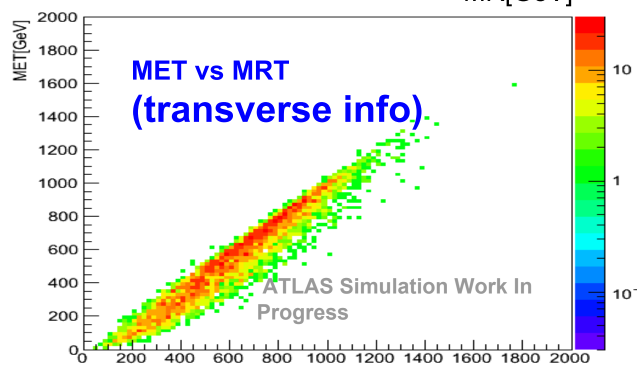




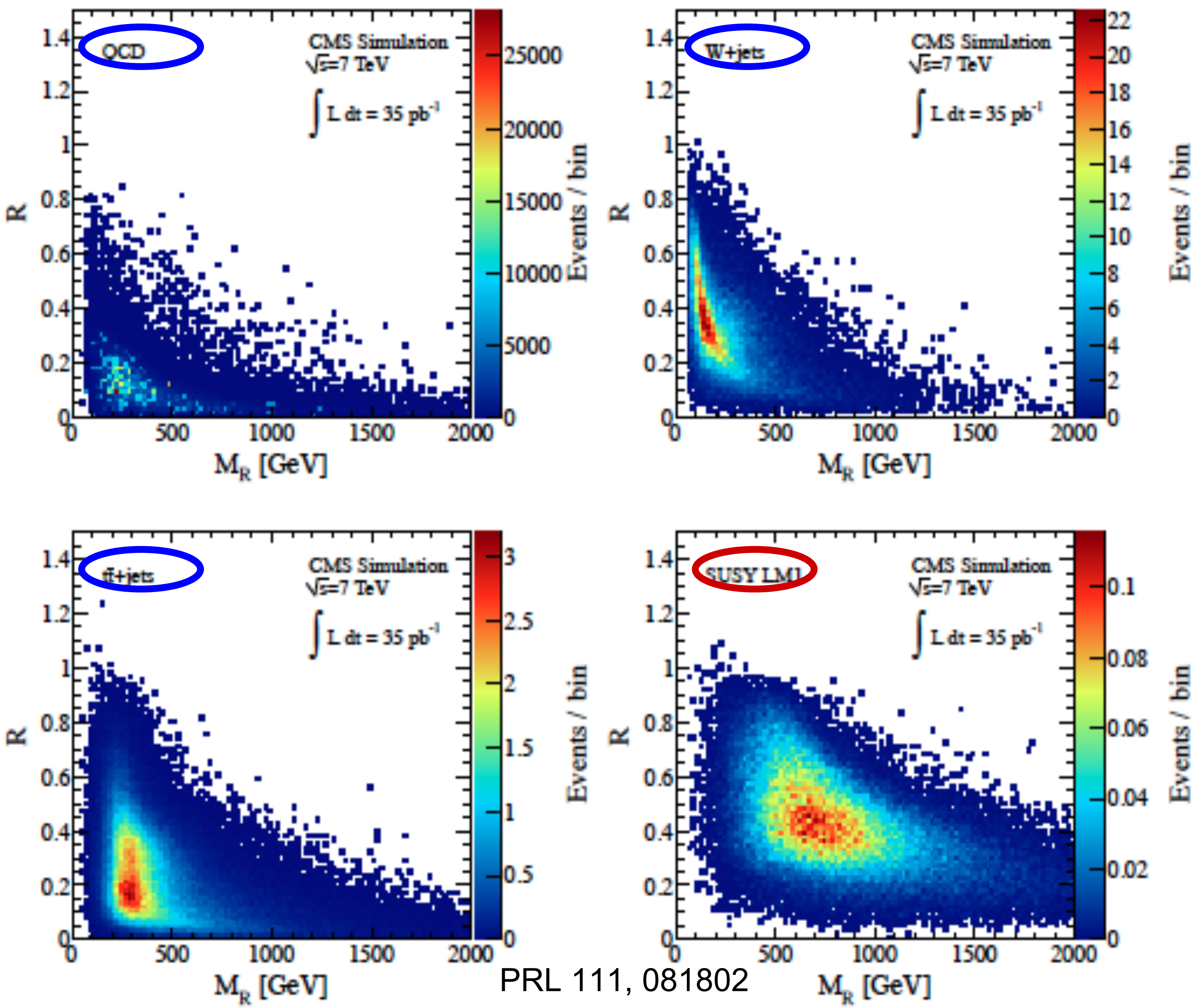
longitudinal info allows to probe different kinematic phase space

M_T^R and M_R measure the same mass scale, one as an end-point and the other as a peak





Signal, Backgrounds in R vs. MR plane



PRL 111, 081802

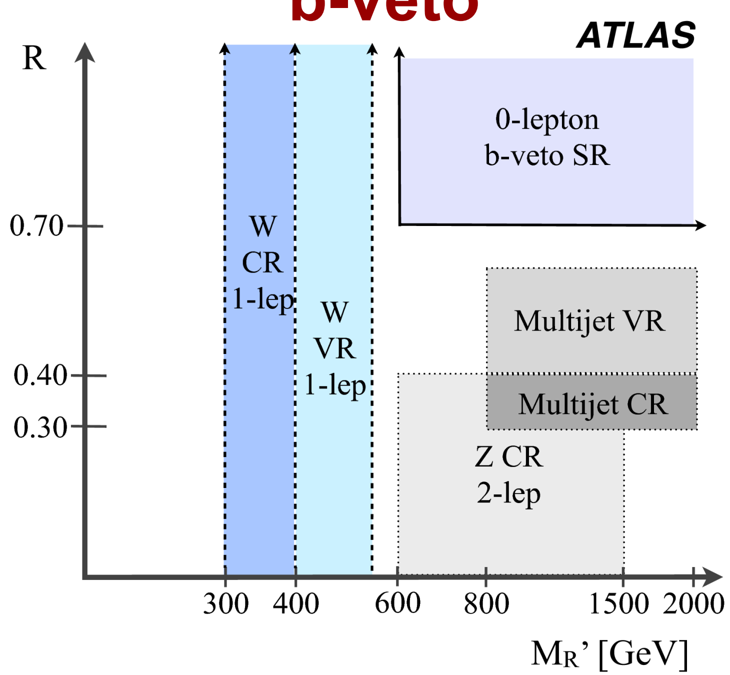
W+jets and ttbar+jets peak at M_R values partially determined by the W and top quark masses, respectively.

Initial estimates of the background distributions are obtained from the individual simulated background components, but their shape and normalization are then corrected using data.

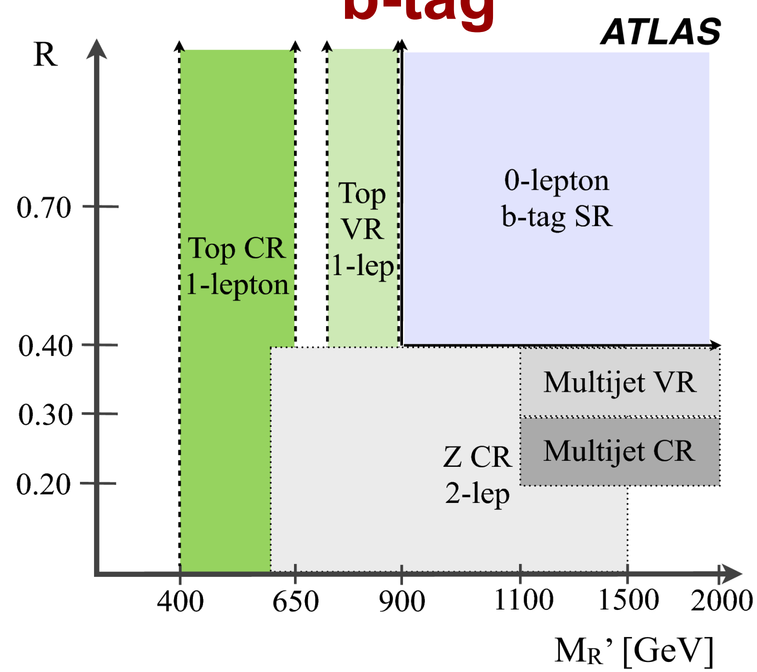
Search Regions in R vs MR plane

Baseline Selection (in back-up) sample is split into two statistically independent regions: b-veto and b-tag. Then, using **R vs MR as an optimization plane**, one can identify regions with high $N_{sig}/sqrt(N_{bkg})$ - call them **Signal Regions (SRs)**;
based on the MC event yields one can further select regions that are enriched in specific background and have minimal signal contamination - call them **Control Regions (CRs)**; additionally, **Validation Region (VRs)** are constructed to evaluate the agreement between data and MC simulation.

b-veto

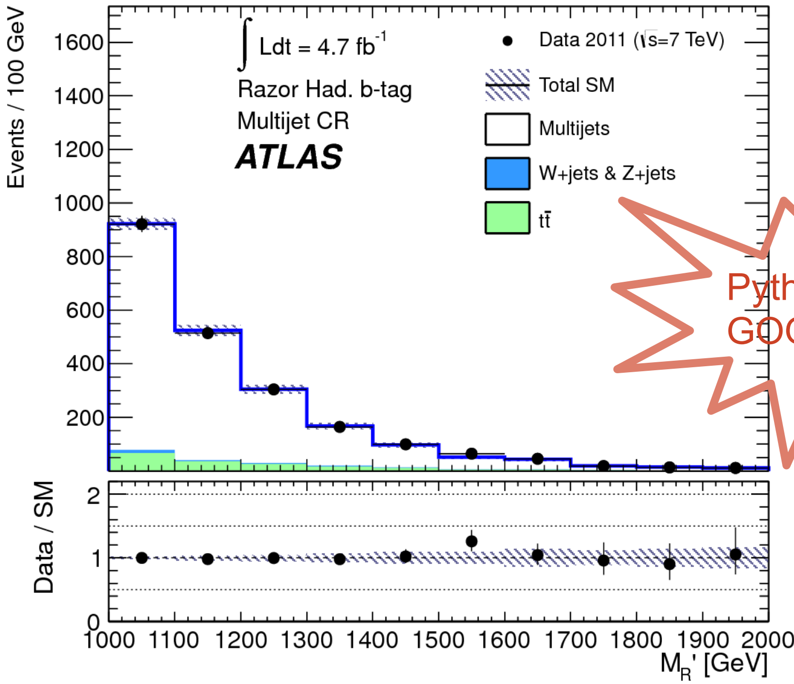


b-tag



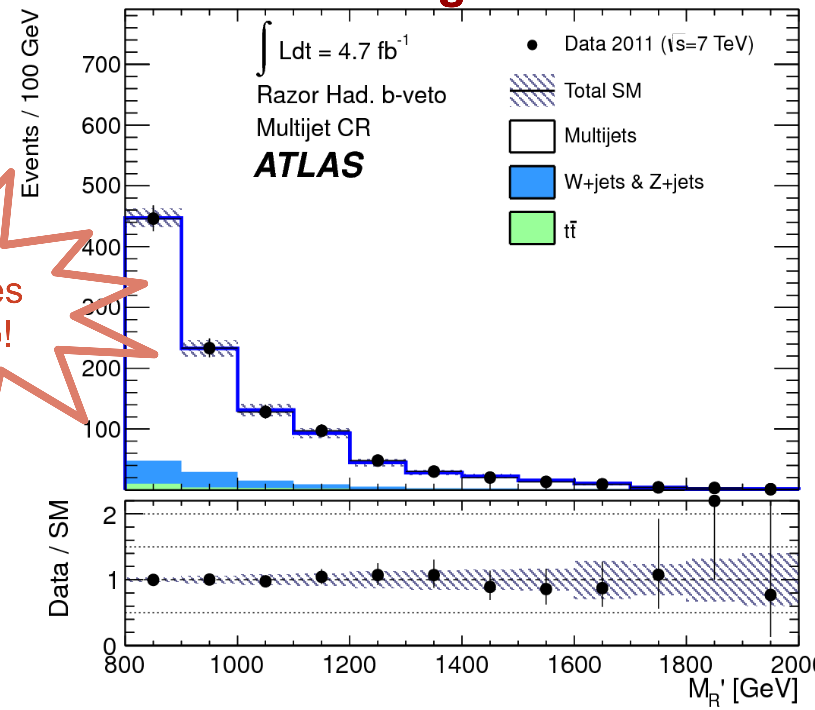
Multijet Control Region MR distributions

b-veto



Pythia does GOOD job!

b-tag



By design, the multijet background is dominant in these regions. The small contributions from ttbar and W+jets are constrained by other CRs in simultaneous fit.

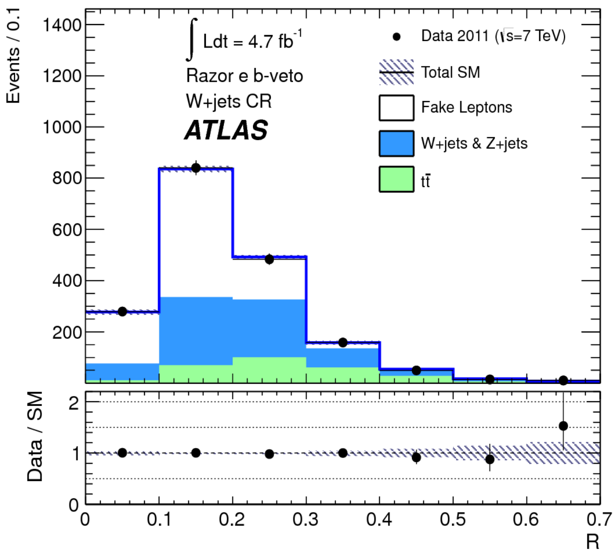
Under dominant Multijets background B-veto channel has more of W+jets, and B-tag - more of Top, as one would expected.

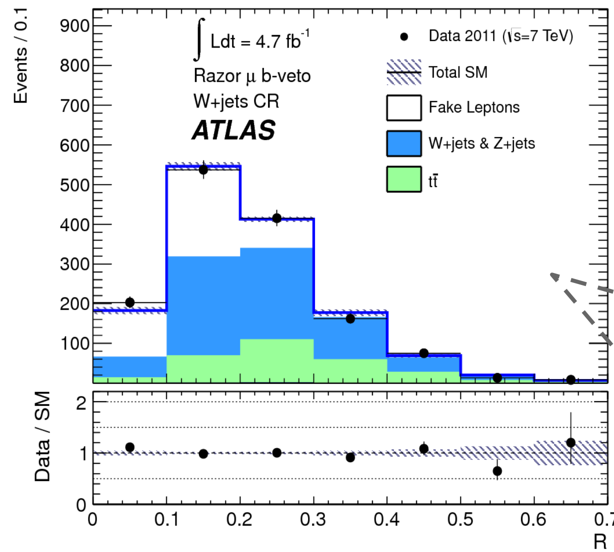
Important: Data and MC have good MR shape agreement. Other distributions (N_{jets} and E_T^{miss} in back up) don't have a bias.

W+jets and Top Control Region R distributions

electron channel / muon channel

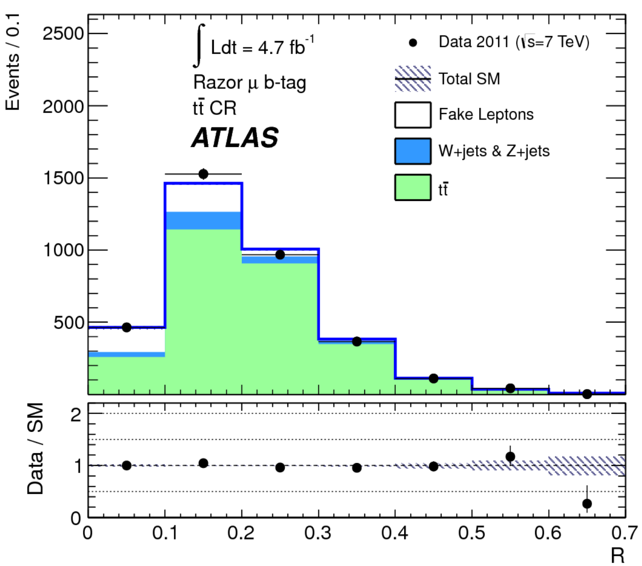
W+jets

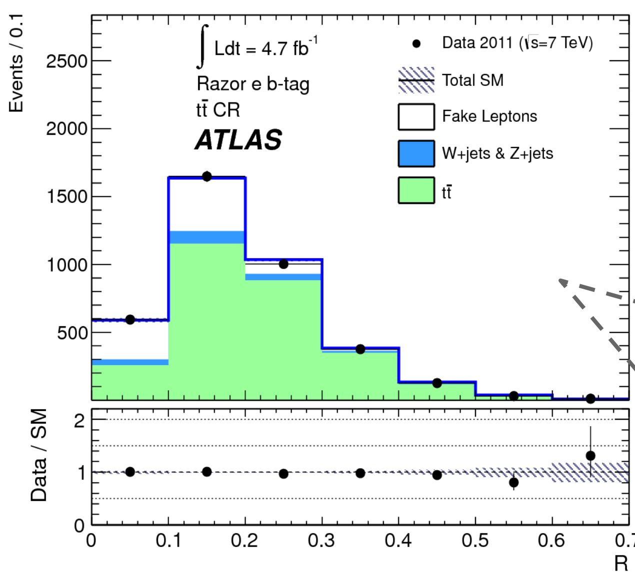




Low R regions are dominated by fake backgrounds, and at moderate -to-high R they are dominated by W+jets.

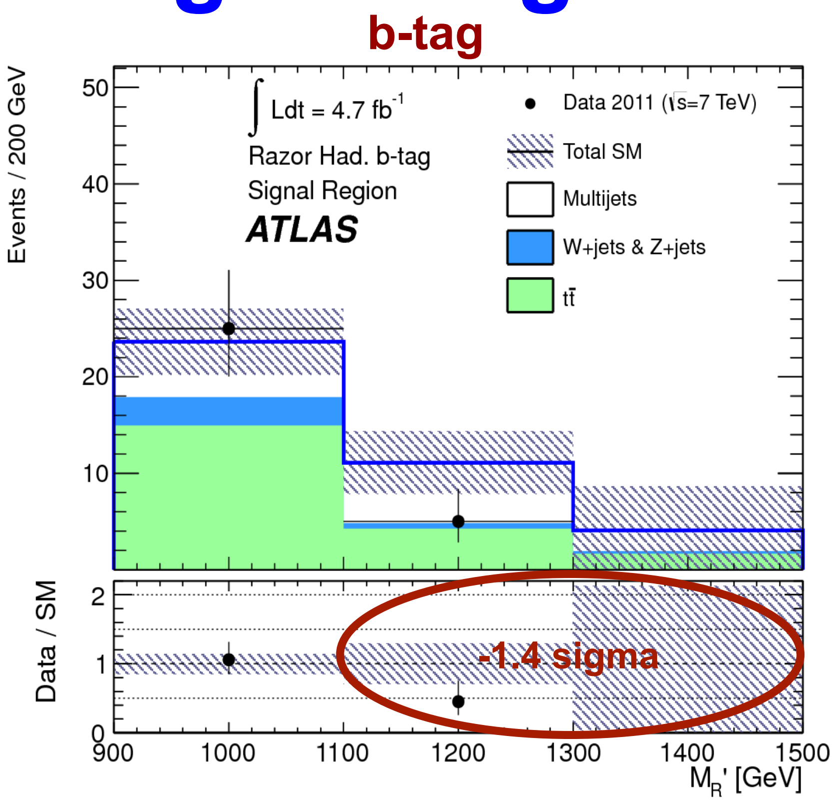
Top

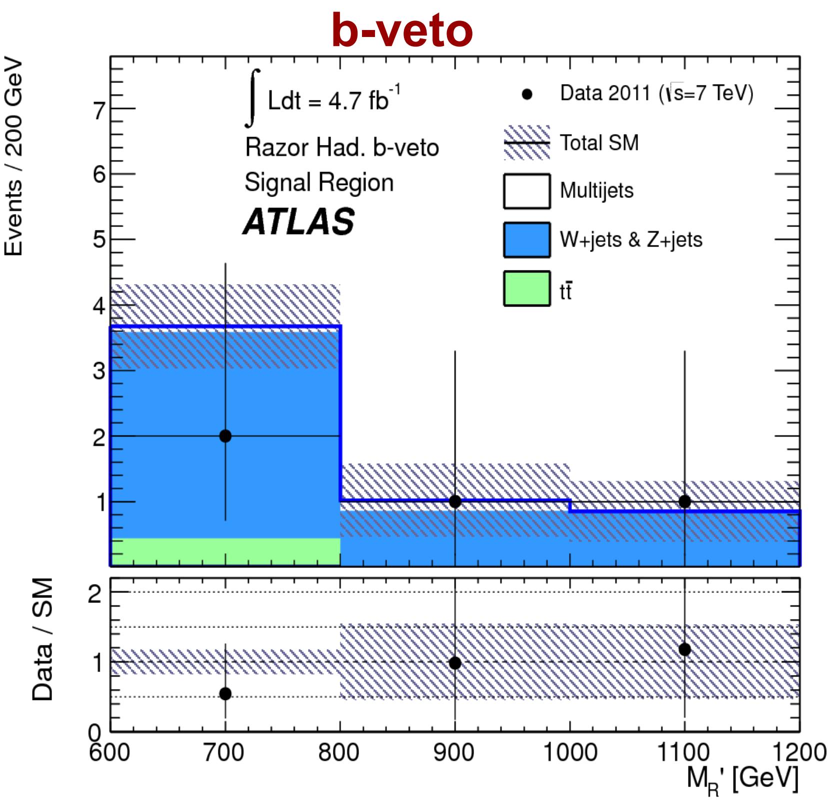




Low R regions are dominated by fake backgrounds, and at moderate -to-high R they are dominated by ttbar.

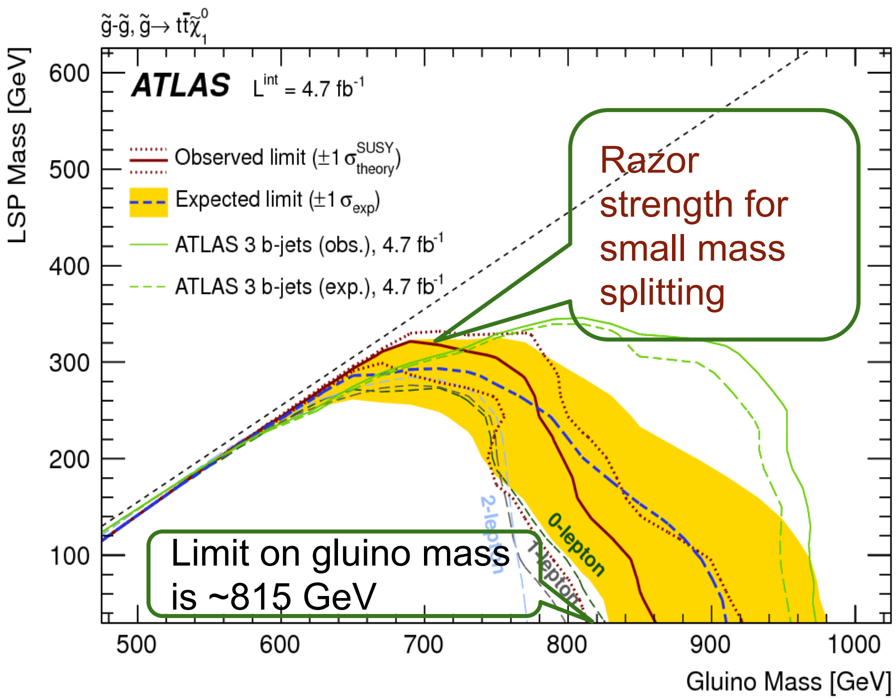
Signal Regions: MR distributions

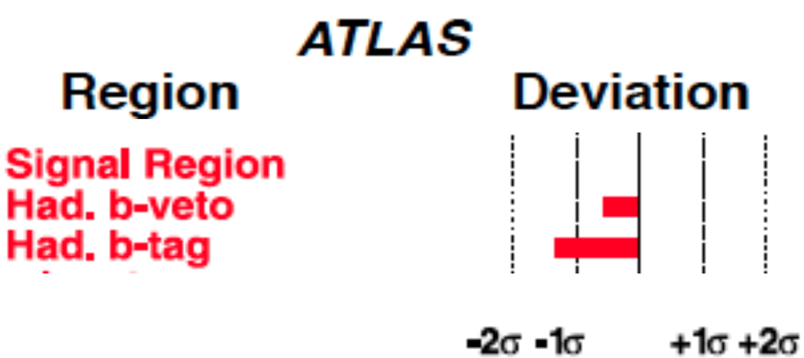




Fit is done using shape of MR’. MET and HT distribution are shown in back-up. NO bump is present on top of falling Standard Model backgrounds in MR’, MET and HT distributions. The biggest deviation is -1.4 sigma is created in the last two bins of MR’ in b-tag channel.

Results





Signal region	Had. *b*-veto	Had. *b*-tag
Observed events	4	30
Fitted background events	5.5 ± 1.5	39 ± 7
	Fitted background decomposition	
Fitted top events	0.40 ± 0.14	21 ± 3
Fitted *W*/*Z* events	4.9 ± 1.3	3.8 ± 0.7
Fitted *WW* diboson events	0.03 ± 0.02	0.029 ± 0.010
Fitted multijet events	0.25 ± 0.10	14 ± 5
Fitted charge flip events	0 ± 0	0 ± 0
Fitted fake lepton events	0 ± 0	0 ± 0
Expected background events	6.7	55
	Expected background decompositi	
MC exp. top events	0.88	30
MC exp. *W*/*Z* events	5.6	4.0
MC exp. *WW* diboson events	0.04	0.046
MC exp. multijet events	0.20	21
Charge flip events (estimated from data)	0	0
Fake lepton events (estimated from data)	0	0
Tight M'_R cut (GeV)	600	1100
Observed events	4	5
Background events	6.2 ± 1.8	13 ± 3
p_0-value (Gauss. σ)	0.72 (−0.57)	0.91 (−1.35)
Upper limit on N_{BSM}	5.2 ($6.3^{\uparrow 9.4}_{\downarrow 4.3}$)	6.5 ($9.3^{\uparrow 12.9}_{\downarrow 6.9}$)
Upper limit on σ (fb)	1.1 ($1.3^{\uparrow 2.0}_{\downarrow 0.9}$)	1.4 ($2.0^{\uparrow 2.7}_{\downarrow 1.5}$)

Data

MC

Before Fit

Discovery Cut

Data

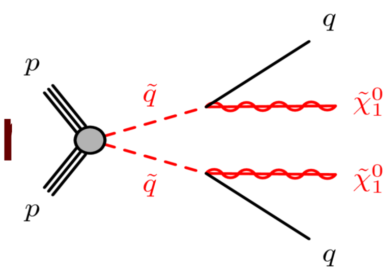
MC

Model-independent limits!

Conclusions and Future plans

- With 20.3 fb^{-1} ATLAS data, and using a new Razor analysis, limits should improve!

- Will add simplified direct production squark model:

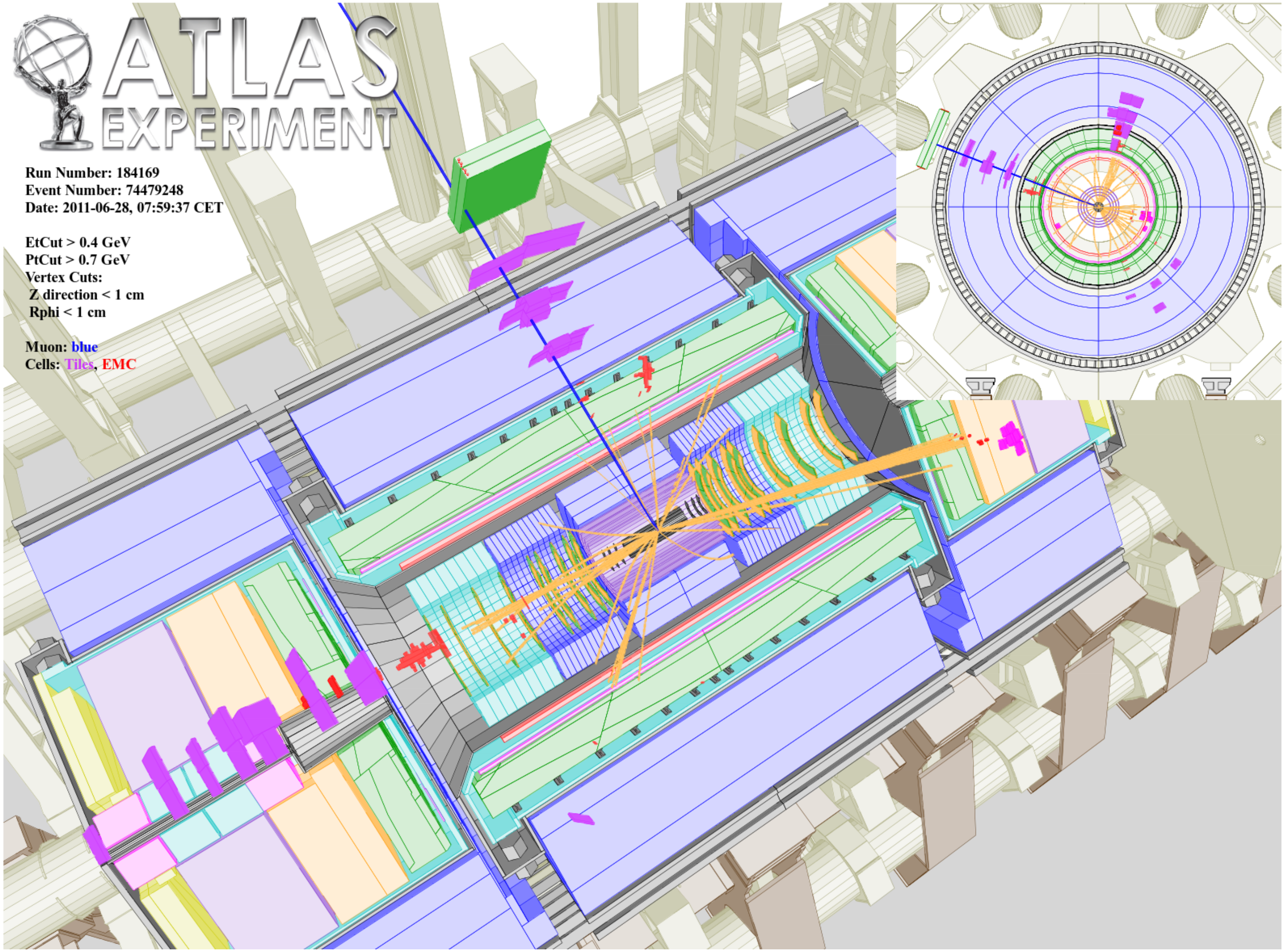


- Monojet: add Dark Matter model (CMS theory paper Phys. Rev. D 86, 015010 (2012) claiming the Razor is the best for DM search)

Extras

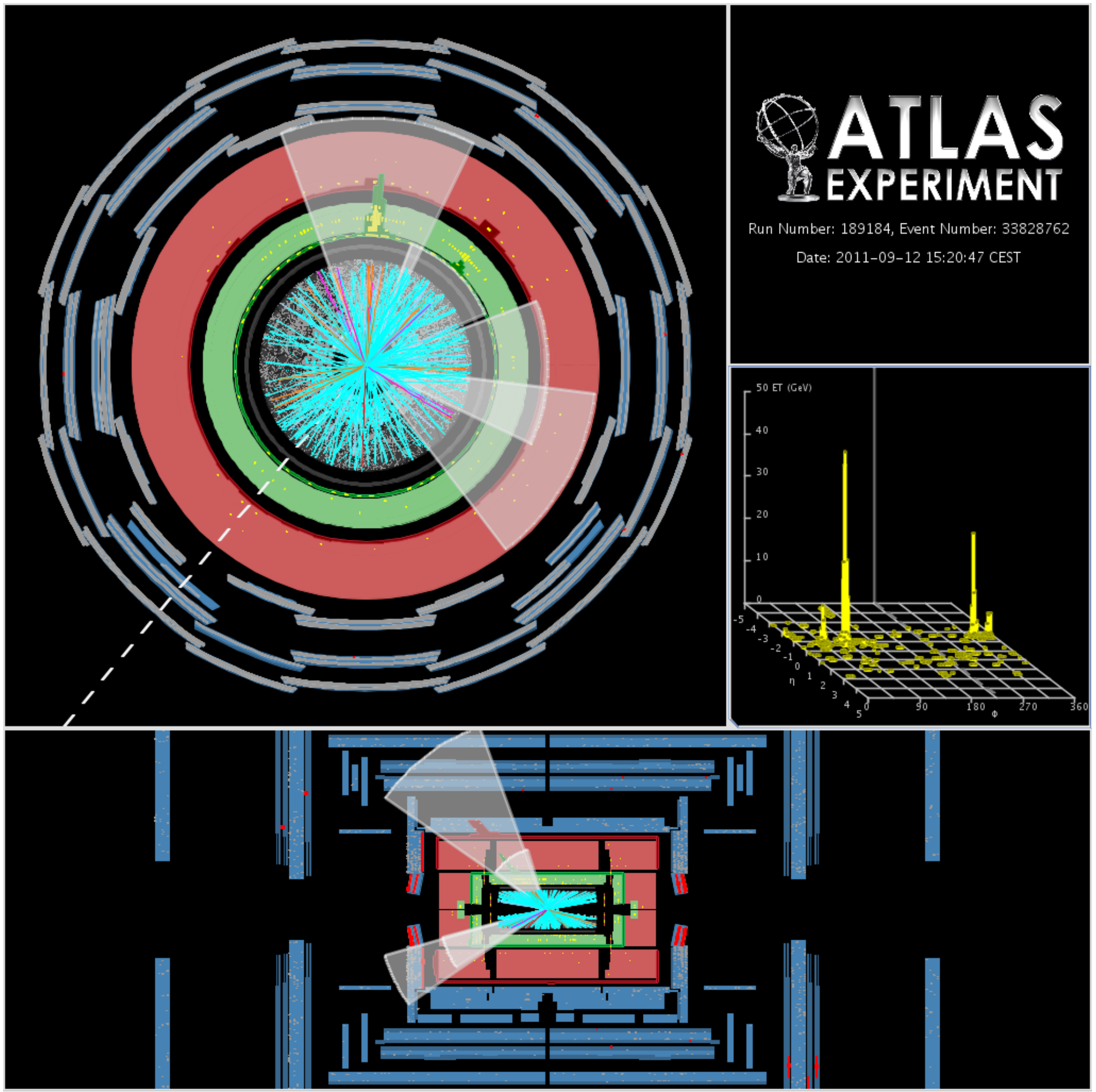
SUSY-like event from Razor point of view

A high-M_R' event in the all-hadronic b-tagged jet veto signal region, run 184169, event 74479248. M_R'=1125 GeV, R=0.45. Six jets with p_T>20 GeV are present in the event. The leading jet has (p_T,η,φ)=(270 GeV,1.36,1.27). The sub-leading jet has (p_T,η,φ)=(270 GeV,-0.54, 2.92). The missing transverse momentum in the event is 445 GeV at φ=-0.86. A muon that fails the baseline selection cuts is visible near η=0.



SUSY-like event from Razor point of view

A high-M_R' event in the all-hadronic b-tagged jet signal region, run 189194, event 33828762. M_R'=735 GeV, R=0.70. Six jets with p_T>20 GeV are present in the event. The leading jet has (p_T,η,φ)=(338 GeV,-0.76,1.52). The sub-leading jet has (p_T,η,φ)=(150 GeV,-1.57,-0.52). The missing transverse momentum in the event is 467 GeV at φ=-2.24. The event has two baseline electrons that fail the signal isolation and shower shape requirements.



Baseline, CRs, SRs, VRs selection

Baseline Selection:

GRL, Cleaning Cuts (against cosmic muons and beam backgrounds),

EF j100 ht400 is fired and efficient, N_{jets}>5, N_{elec}=0 (or $p^{elec}{}_{T}$ <25 GeV), N_{muon}=0 (or $p^{muon}{}_{T}$ <20 GeV)

For W+jets and Top+jets CRs, VRs: EF e20 medium requires a single electron with ET > 20 GeV, EF mu18, requires a single muon with pT > 18 GeV

Name	Leptons	b-jets	N_{Jets}	R range	M'_R range	Number of bins
Control regions						
Had. b-veto Multijet	0 leptons	$=0$	>5	$0.3 < R < 0.4$	$800 < M'_R < 2000$ GeV	12 in M'_R
Had. b-tag Multijet	0 leptons	>0	>5	$0.2 < R < 0.3$	$1000 < M'_R < 2000$ GeV	10 in M'_R
$e\ W+$jets	1 electron	$=0$	>5	$0 < R < 0.7$	$300 < M'_R < 400$ GeV	7 in R
$\mu\ W+$jets	1 muon	$=0$	>5	$0 < R < 0.7$	$300 < M'_R < 400$ GeV	7 in R
$e\ t\bar{t}$	1 electron	>0	>5	$0 < R < 0.7$	$400 < M'_R < 650$ GeV	7 in R
$\mu\ t\bar{t}$	1 muon	>0	>5	$0 < R < 0.7$	$400 < M'_R < 650$ GeV	7 in R
Signal regions						
Had. b-veto	0 leptons	$=0$	>5	$R > 0.70$	$600 < M'_R < 1200$ GeV	3 in M'_R
Had. b-tag	0 leptons	>0	>5	$R > 0.40$	$900 < M'_R < 1500$ GeV	3 in M'_R
Validation regions						
Had. b-veto Multijet	0 leptons	$=0$	>5	$0.4 < R < 0.6$	$800 < M'_R < 2000$ GeV	N/A
Had. b-tag Multijet	0 leptons	>0	>5	$0.3 < R < 0.4$	$1100 < M'_R < 2000$ GeV	N/A
1-lep b-veto $W+$jets	1 lepton	$=0$	>5	N/A	$400 < M'_R < 550$ GeV	N/A
1-lep b-tag $t\bar{t}$	1 lepton	>0	>5	N/A	$700 < M'_R < 850$ GeV	N/A

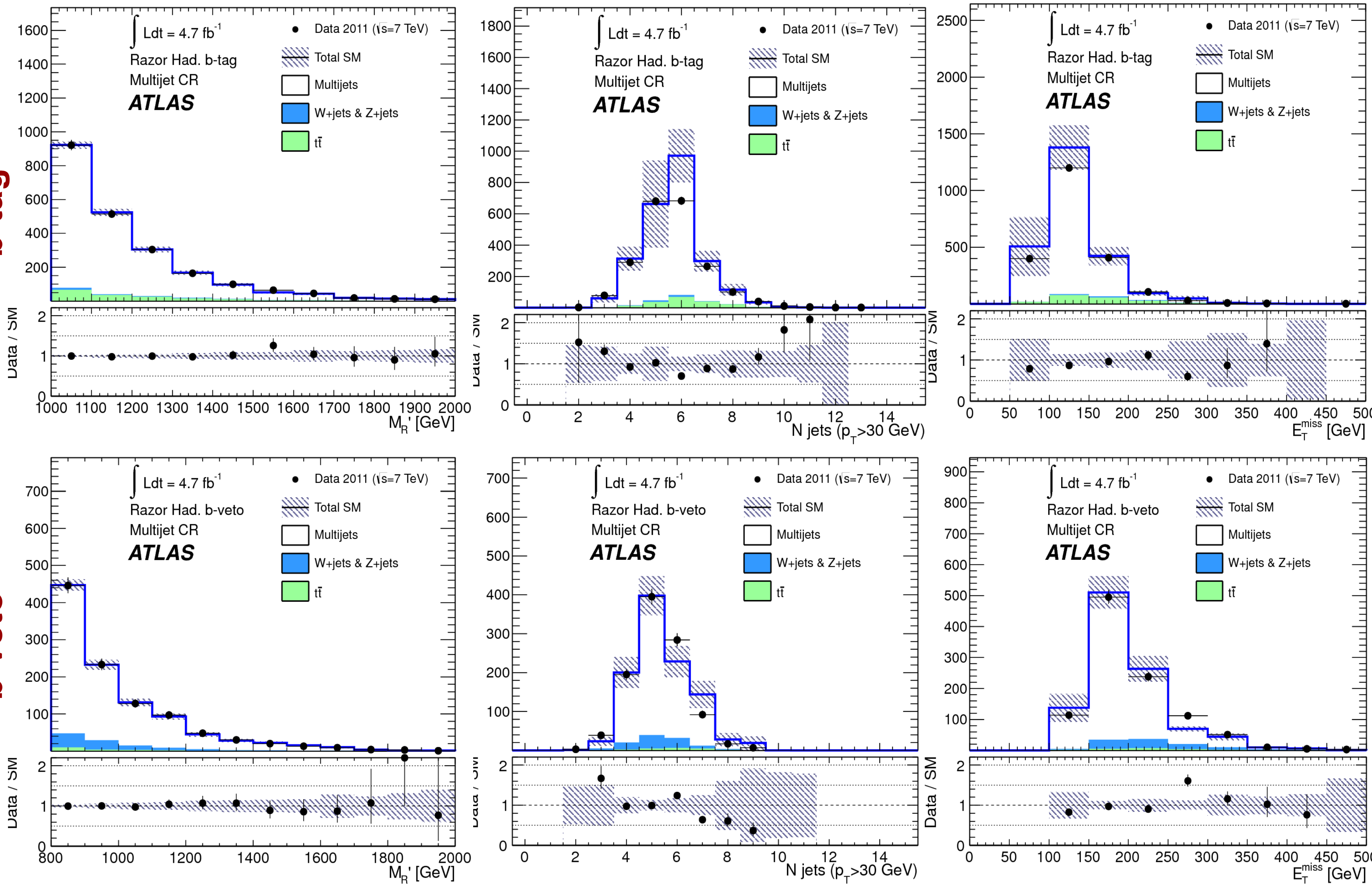
Razor 7 TeV paper: Eur.Phys.J. C73 (2013) 2362

Multijet CRs

MR | Njets | MET

b-tag

b-veto



W+jets CRs

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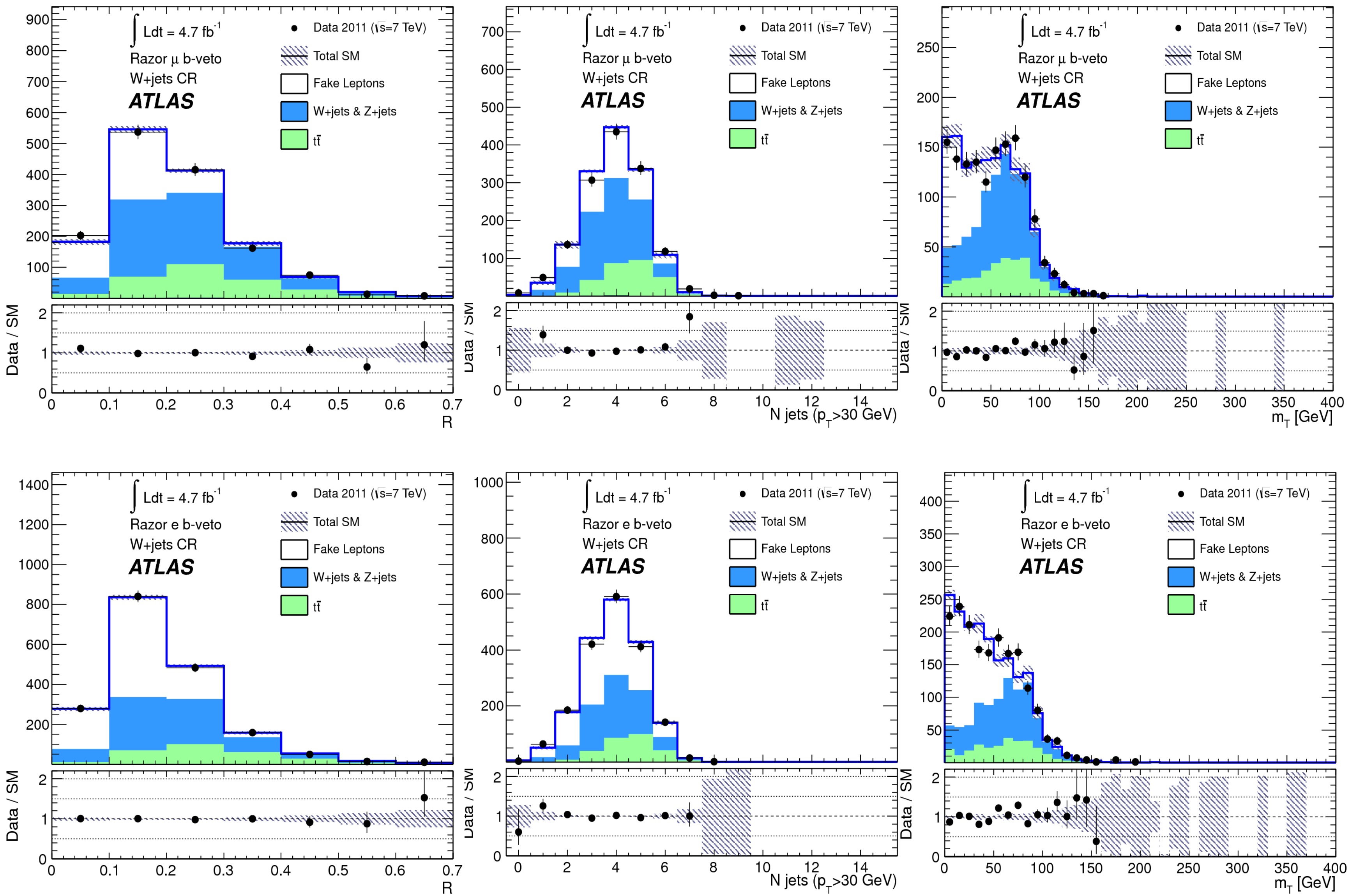
R | Njets | MT

muon

electron

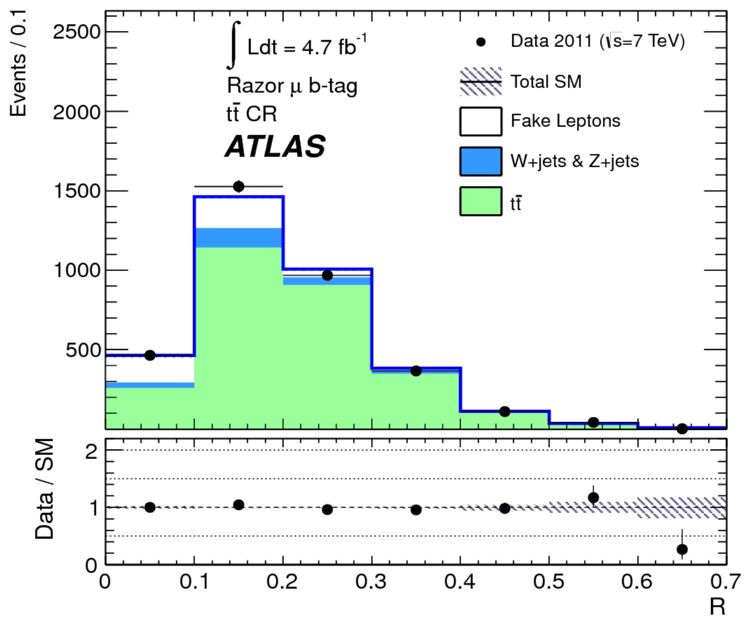


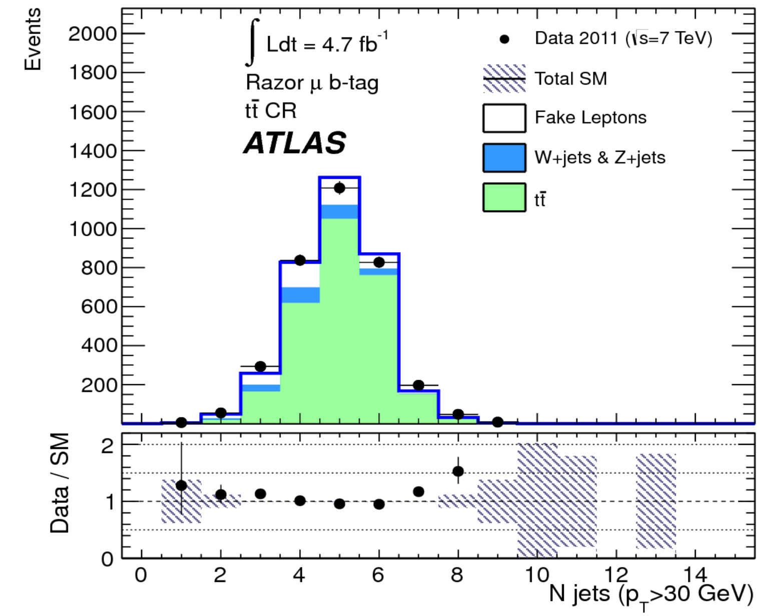
Top CRs

Razor 7 TeV paper: Eur.Phys.J. C73 (2013) 2362

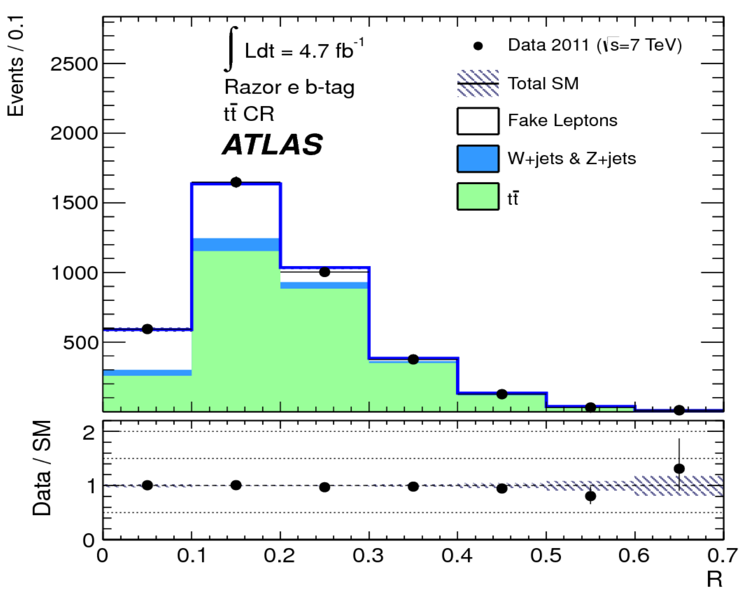
R | **Njets**

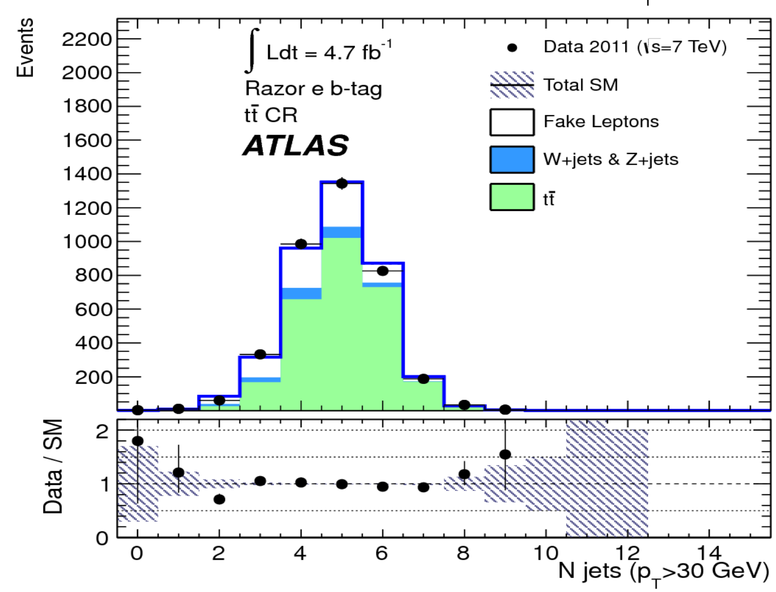
muon





electron





SRs

MR’ | MET | HT

b-tag

b-veto