

Razor variables in the search for Top Partners

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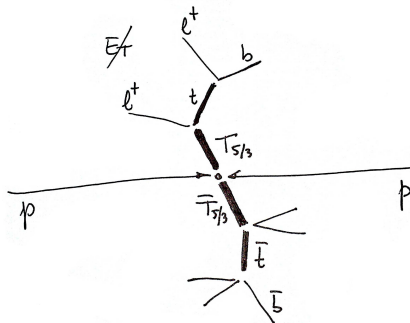
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Top Partners

- couple to third generation
- solve hierarchy problem
 - ▶ *Contino, Servant*, JHEP 0806:026 (2008)
 - ▶ *Mrazek, Wulzer*, Phys. Rev. D81, 075006 (2010)
- focus on pair production of $T_{5/3}$
- experimental signature: same-sign leptons + jets



Signal MC

Fall11 production

mass (GeV)	$\sigma \times \text{BR (pb)}$	events
400	0.295	86205
450	0.139	86211
500	0.069	86684
550	0.036	86724
600	0.019	86965
650	0.011	87592
700	0.006	88145
750	0.004	88410

Table: Signal Monte Carlo samples. The branching ratio is 0.21.

Background MC

Summer11 production

process	MC generator	σ (pb)	events
WZJets	MADGRAPH	0.879	1221134
ZZ+Jets	MADGRAPH	0.076	1185188
W^+W^+ +Jets	MADGRAPH	0.165	130000
W^-W^- +Jets	MADGRAPH	0.055	160000
WWW+Jets	MADGRAPH	0.038	1201777
$t\bar{t}W$	MADGRAPH	0.169	1029608
$t\bar{t}Z$	MADGRAPH	0.139	793155

Table: Details of the background Monte Carlo samples used for the analysis.

Data

2011 golden JSON, 5.0 fb^{-1}

Dataset	Run range
/DoubleMuon/Run2011A-May10ReReco-v1/AOD	160329-163869
/DoubleMuon/Run2011A-PromptReco-v4/AOD	165071-168437
/DoubleMuon/Run2011A-05AugReReco-v1/AOD	170053-172619
/DoubleMuon/Run2011A-PromptReco-v6/AOD	172620-175770
/DoubleMuon/Run2011B-PromptReco-v1/AOD	175832-180296
/DoubleElectron/Run2011A-May10ReReco-v1/AOD	160329-163869
/DoubleElectron/Run2011A-PromptReco-v4/AOD	165071-168437
/DoubleElectron/Run2011A-05AugReReco-v1/AOD	170053-172619
/DoubleElectron/Run2011A-PromptReco-v6/AOD	172620-175770
/DoubleElectron/Run2011B-PromptReco-v1/AOD	175832-180296
/MuEG/Run2011A-May10ReReco-v1/AOD	160329-163869
/MuEG/Run2011A-PromptReco-v4/AOD	165071-168437
/MuEG/Run2011A-05AugReReco-v1/AOD	170053-172619
/MuEG/Run2011A-PromptReco-v6/AOD	172620-175770
/MuEG/Run2011B-PromptReco-v1/AOD	175832-180296

Triggers

HLT_DoubleMu7_v1,2 or
HLT_Mu13_Mu8_v2,3,4,6,7 or
HLT_Mu17_Mu8_v10,11

HLT_Ele17_CaloldL_CalIsoVL_Ele8_CaloldL_CalIsoVL_v1,2,3,4,5,6 or
HLT_Ele17_CCTT_Ele8_CCTT_v6,7,8,9,10

HLT_Mu10_Ele10_CaloldVL_v2,3,4,or
HLT_Mu17_Ele8_CaloldVL_v1,2,3,4,5,6,8 or
HLT_Mu17_Ele8_CaloldT_CalIsoVL_v4,7,8 or
HLT_Mu8_Ele17_CaloldL_v1,2,3,4,5,6 or
HLT_Mu8_Ele17_CaloldT_CalIsoVL_v3,4,7,8

Table: List of triggers used in the analysis.

Event cleanup

Standard from TLBSM recipes

scrapping

- at least 25% of the tracks must be high-purity for events with at least ten tracks

good primary vertex

- at least 4 degrees of freedom
- less than 25 cm from interaction point in z
- less than 2 cm radially

HBHE noise filter

Electrons

Standard top selection, plus charge consistency

- $p_T > 30 \text{ GeV}$
- $|\eta| < 2.4$, except EBEE gap
- HyperTight1MC electron identification
- relative isolation < 0.15
- conversion rejection
- transverse impact parameter $< 0.02 \text{ cm}$
- GSF, CFT, ScPix charge consistency

Muons

Standard top selection

- $p_T > 30 \text{ GeV}$
- $|\eta| < 2.4$
- Global and Tracker muon
- relative isolation < 0.20
- $\chi^2/\text{NDF} < 10$
- at least one muon hit
- at least one pixel hit
- at least eleven silicon hits
- at least two chambers with matching segments

Jets

Standard top selection

- anti- k_T particle flow jets
- $p_T > 30 \text{ GeV}$
- $|\eta| < 2.4$
- Charged hadron subtractions, L1FastJets corrections, L2L3 jet energy scale corrections
- loose particle flow identification
- $\Delta R(\text{lepton}, \text{jet}) > 0.3$

Same-sign non-prompt background

Data-driven estimate, with the “tight-loose” method

- details in AN-2010/261, AN-2010/257, AN-2011/258
- define looser lepton selection
- measure the probability that a lepton passing the loose selection also passes the tight one
- estimate the number of non-prompt leptons passing the tight selection

The old selection

AN-11-419

- at least four jets
- $H_T > 300 \text{ GeV}$

The razor subsystem

Rogan, *Kinematical variables towards new dynamics at the LHC*, arXiv 1006.2727

The standard razor

Two pair-produced massive particles, both decaying to a final state with visible particles *and* $E_{\text{T}}^{\text{miss}}$.

Our events do not follow the razor topology.

The razor subsystem

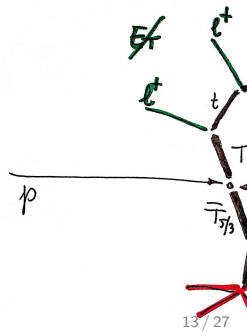
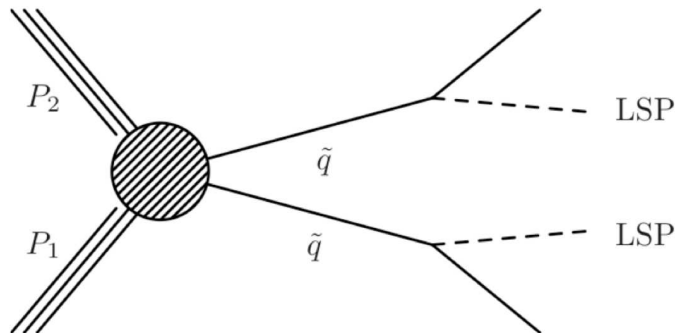
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The standard razor

Two pair-produced massive particles, both decaying to a final state with visible particles *and* E_T^{miss} .

Our events do not follow the razor topology.

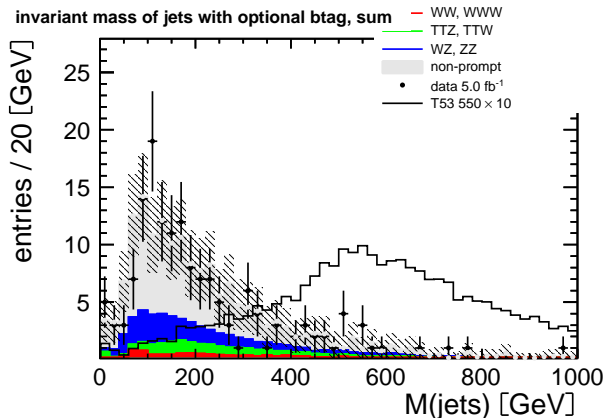
The leptonic subsystem does!



Hadronic invariant mass

The easy part

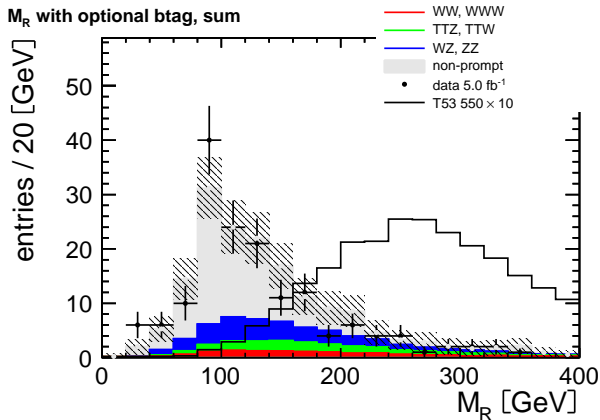
Mass of the sum of the jets in the event.



M_R

An indicator of the heavy particle mass scale

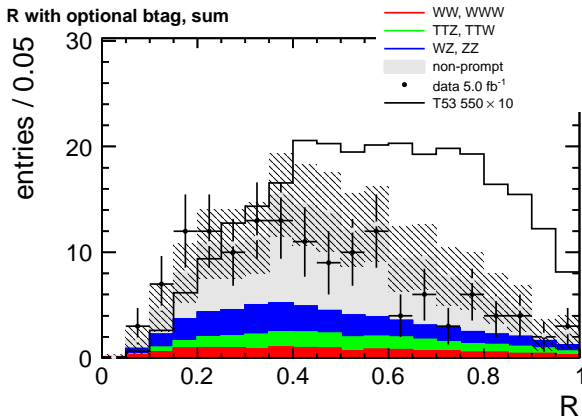
Peak expected around $M(T_{5/3})/2$.



R

A dimensionless variable related energy to the E_T^{miss}

- peaks near 0.5 for signal
- falls off exponentially for backgrounds after an endpoint



Event reconstruction enhancement and b-tagging

If two b-tagged CSVL jets are found, the closest in ΔR to a lepton is associated with the lepton subsystem

MC truth: improves reconstruction for 2/3 of the signal events

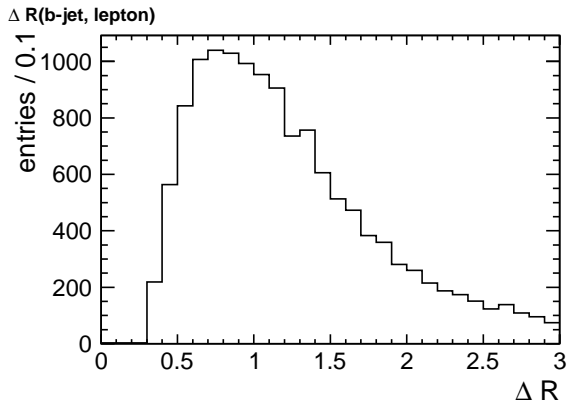
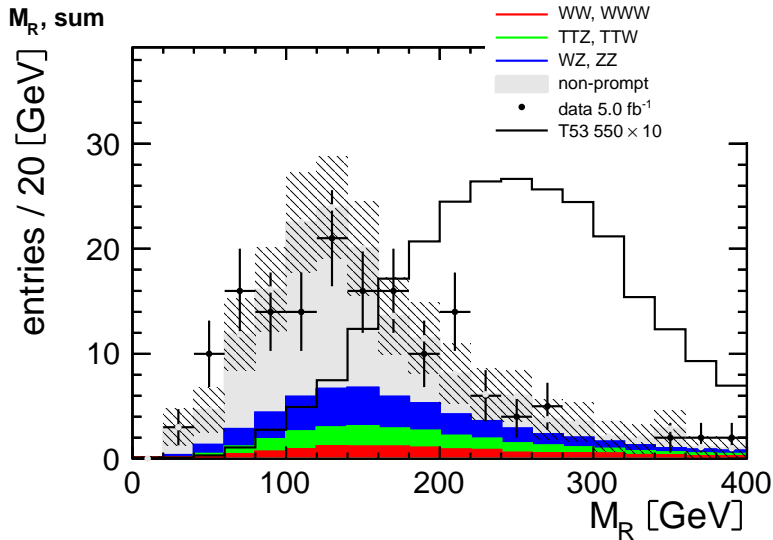


Figure: ΔR between the b-jet and the lepton from the top decay. MC truth from the 550 GeV mass point.

Improvements for the M_R

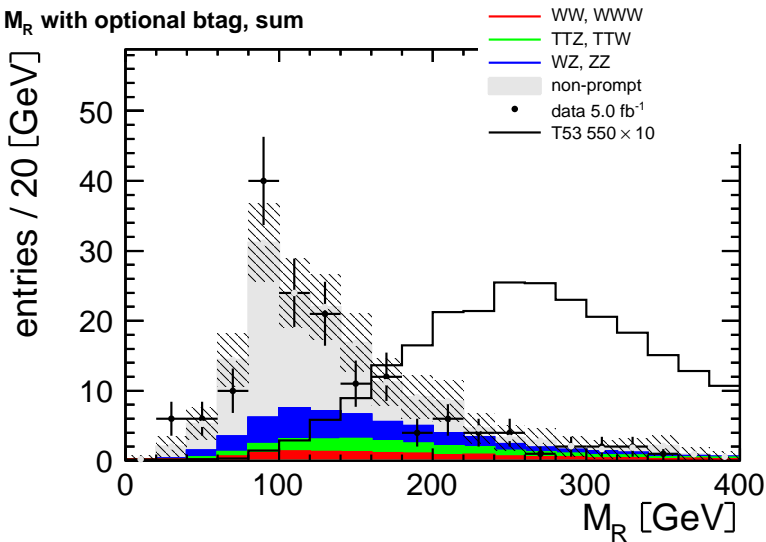
Without b-tagging



Improvements for the M_R

With b-tagging

M_R with optional btag, sum



More problems for the event reconstruction

- the double b-tag is inefficient ($\approx 2/3$ on signal)
- wrong lepton close to a jet by chance
- jet energy threshold
- lepton isolation
- $\Delta R > 0.3$ cut

Selection efficiencies for backgrounds

A better signal to noise ratio

Final razor selection optimized for S/\sqrt{B} :

- at least four jets
- hadronic mass > 350 GeV
- $M_R > 200$ GeV
- $R > 0.2$

dataset	SS + 2jets	$H_T > 300$	razor
WW (SS)	11.62 ± 5.84	0.64 ± 0.33	0.23 ± 0.12
TTW	14.60 ± 7.32	3.18 ± 1.59	1.10 ± 0.55
TTZ	3.97 ± 1.99	0.97 ± 0.49	0.29 ± 0.14
WWW	1.66 ± 0.83	0.09 ± 0.05	0.04 ± 0.02
WZ, ZZ	34.62 ± 6.17	1.18 ± 0.22	0.38 ± 0.07
total MC	66.47 ± 11.42	6.06 ± 1.71	2.04 ± 0.59
non-prompt	105.24 ± 52.80	4.67 ± 2.55	0.76 ± 0.56
T53 700	5.00 ± 0.25	3.85 ± 0.20	3.30 ± 0.17

Table: Event yields including statistical and systematic uncertainties.

Selection efficiencies for signal

A better signal to noise ratio

dataset	SS + 2jets	$H_T > 300$	razor
T53 400	211.10 ± 10.73	136.03 ± 6.97	53.40 ± 2.84
T53 450	104.52 ± 5.31	72.04 ± 3.68	40.57 ± 2.11
T53 500	52.76 ± 2.68	37.75 ± 1.93	25.10 ± 1.29
T53 550	28.53 ± 1.45	21.39 ± 1.09	15.94 ± 0.82
T53 600	15.34 ± 0.78	11.54 ± 0.59	9.20 ± 0.47
T53 650	8.65 ± 0.44	6.60 ± 0.34	5.46 ± 0.28
T53 700	5.00 ± 0.25	3.85 ± 0.20	3.30 ± 0.17
T53 750	2.97 ± 0.15	2.27 ± 0.12	1.96 ± 0.10

Table: Event yields including statistical and systematic uncertainties.

Limit

Expected: 658 GeV (was 645 GeV)

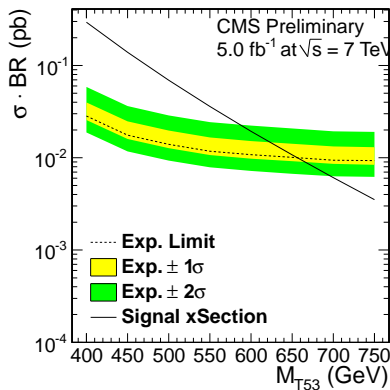


Figure: 95% CL limit with the RooStats CL95 tool for an event counting experiment.

Conclusions

- improved rejection of background, particularly $t\bar{t}$
- can still be improved in many ways: event reconstruction
- ???

Backup slides

Effect	Uncertainty (%)
Electron trigger	5.0
Muon trigger	5.0
Lepton efficiency	3.0
Luminosity	2.2

Table: Systematic uncertainties.

Systematics for MC

Sample	JES	Pileup	Normalization
WZ	5.0%	1.8%	17%
ZZ	1.1%	0.6%	7.5%
$W^{\pm}W^{\pm}$	4.5%	2.4%	50%
WWW	3.7%	0.5%	50%
$t\bar{t}W$	3.4%	0.94%	50%
$t\bar{t}Z$	3.7%	0.25%	50%

Table: Systematic uncertainties for Monte Carlo backgrounds.