SUSY searches with Taus: The tau+muon channel

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Oxford Tau Workshop

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March 22, 2012

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Outlook

- very brief outline of analysis
- concentrate on the tau-related aspects of the analysis
- main part: Rel 17 results with 4.64 fb^{-1}:
  - investigate the tauID performance in the object selection
  - tauID in the background control regions used for data driven BG estimate
- small part still on Rel 16 results with 2.05 fb^{-1}:
  - tau related systematic uncertainties
  - electron fakes in signal region

Analysis outline

Analysis goal

- looking for SUSY events with high missing energy, hadronic activity
- di-tau: hadronic decay and one leptonic decay
- use lepton for trigger
- have lepton as more reliable object (QCD suppression)
- so far only muon, electron channel just started
- most important background is $t\bar{t}$

Event selection

- μ-Trigger
- event cleaning
- trigger plateau cuts
- $N_\mu == 1$
- and $N_\tau \geq 1$ (hardest Pt)
- SUSY-cuts

TauID

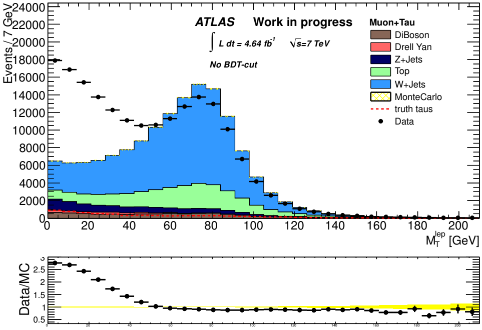
- `tau_author`=1||3
- $p_T^\tau > 20$ GeV and $|\eta^\tau| < 2.5$
- `tau_numTrack`=1||3
- `!tau_muonVeto` and `!tau_EleBDTMedium`
- charge $= \pm 1$
- BDT cut

Cutflow of object selection

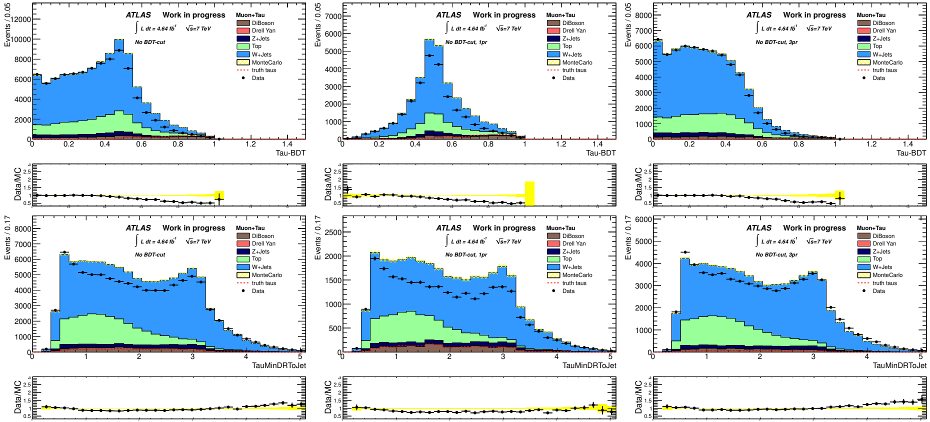
	2011 Data	DiBoson	Drell Yan	Z+Jets	Top	W+Jets	SM
Pass GRL	2.288801e+08	773027.8	5.519403e+07	1.93506e+07	950153.5	1.454805e+08	2.216514e+08±4.81e+04
Pass Trigger	1.369212e+08	243248.4	275198.4	3559624	160926.1	2.38617e+07	2.807953e+07±1.5e+04
Pass cleaning cuts	1.32618e+08	234040.2	269193.1	3372636	150169.9	2.220467e+07	2.621028e+07±1.44e+04
Pass $N_{\text{jet}}^{60\text{ GeV}} \geq 1$	3.163059e+07	58104.91	21555.11	149538.5	115378.5	811682.4	1145035±1.27e+03
Pass $N_{\mu}^{20\text{ GeV}} = 1$	1290501	25303.17	10605.48	60519.91	71658.61	724894.8	883775±1.17e+03
Pass $N_{\tau} \geq 1$ (no BDT cut)	188705	7863.285	1944.515	10089.88	28891.3	99302.56	146196.4±314
Pass $M_{\text{T}}^{\ell} > 50$ GeV	89190	4253.286	391.1873	4011.407	19610.93	69136.5	96058.27±257

cutflow

- TauID has still no BDT cut, only preselection
- still much QCD
- apply cut on $M_{\text{T}}^{\ell} > 50$ GeV
- following Rel17 results will be with this preselection
- slight excess in MC



TauID Variables before BDT cut (only preselection)

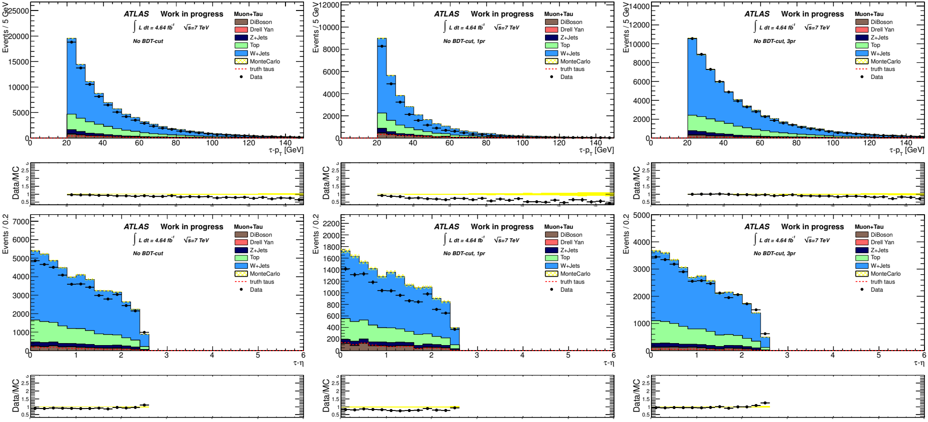


all taus 1-prong 3-prong

TauBDT and ΔR to closest jet

- left: all taus, middle: 1-prong, right: 3-prong
- slightly lesser high BDT-taus in data, MC overestimates high BDT tail
- three prongs seem to be better described (fakes)

Tau kinematic Variables



all taus | 1-prong | 3-prong

Tau-Pt and η to closest jet

- left: all taus, middle: 1-prong, right: 3-prong
- tau-pt slightly softer in data
- three prongs seem to be better described (fakes)

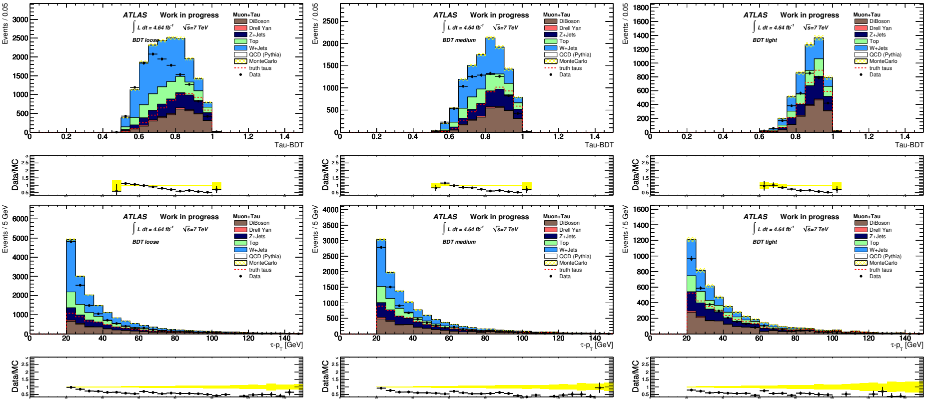
Applying the BDT cuts

	2011 Data	DiBoson	Drell Yan	Z+Jets	Top	W+Jets	SM
Pass $N_\tau \geq 1$	13350	3408.3	214	2636.7	3164.3	7892	17217±125
Purity	–	0.85	0.16	0.71	0.34	0	0.34
BDT medium	8225	2735.6	138.7	2028.9	2094.4	4510.6	11454±104
Purity	–	0.89	0.22	0.77	0.42	0	0.42
BDT tight	3279	1552.9	60.9	1105.7	914.2	1447.7	5063.4±73.4
Purity	–	0.94	0.3	0.84	0.58	0	0.58

cutflow

- selection includes: trigger, cleaning, muon, tau BDT loose
- Tau-preselection and $M_T^\ell > 50$ GeV: data: 89190; MC: 96058.27
- MC/data ratio gets worse: loose: 1.29, medium: 1.39, tight: 1.45
- tau-like fakes worse described in MC (high BDT tail)
- purity: fraction of events where tau is truth matched

Tau Pt and BDT after object selection



BDT loose BDT medium BDT tight

Tau-BDT and Tau-Pt to closest jet

- left: loose, middle: medium, right: tight
- ratio plot: all cases: high BDT tail over predicted in MC
- ratio plot: all cases: high Pt tail over predicted in MC

Scale Monte Carlo to data in control regions

- μ-requirement has impact on expected purity of τ: $W \to \mu\nu_\mu + \tau_{\text{fake}}$
- Define three control regions enriched with:
  1. $W + \text{jets} \to \mu\nu_\mu + \tau_{\text{fake}}$
  2. Top with fake taus: $W \to \mu\nu_\mu$ and $W_{\text{had}} \to \tau_{\text{fake}}$
  3. Top with true taus: $W \to \mu\nu_\mu$ and $W \to \tau\nu_\tau$
- Get scaling factors for ω_{W_f}, ω_{T_f} and ω_{T_t}

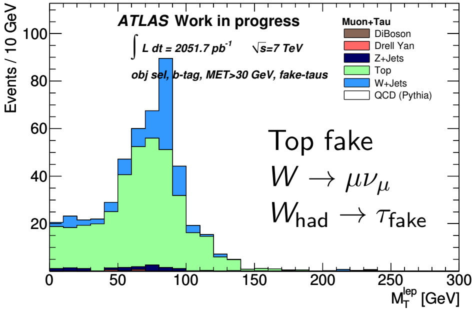
Method

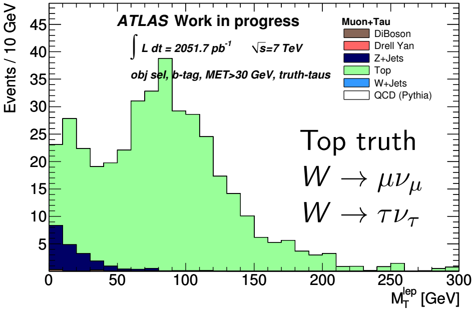
$$\underbrace{\begin{pmatrix} N_1^{\text{data}} - N_1^{\text{QCD,data}} - N_1^{\text{rest-MC}} \\ N_2^{\text{data}} - N_2^{\text{QCD,data}} - N_2^{\text{rest-MC}} \\ N_3^{\text{data}} - N_3^{\text{QCD,data}} - N_3^{\text{rest-MC}} \end{pmatrix}}_{\vec{N}} = \underbrace{\begin{pmatrix} N_1^{W\text{-MC}} & N_1^{\text{fake top-MC}} & N_1^{\text{truth top-MC}} \\ N_2^{W\text{-MC}} & N_2^{\text{fake top-MC}} & N_2^{\text{truth top-MC}} \\ N_3^{W\text{-MC}} & N_3^{\text{fake top-MC}} & N_3^{\text{truth top-MC}} \end{pmatrix}}_{A} \underbrace{\begin{pmatrix} \omega_{W_f} \\ \omega_{T_f} \\ \omega_{T_t} \end{pmatrix}}_{\vec{\omega}}$$

Invert A, multiply to $\vec{N}$, uncertainties: vary all parameters

<table>
<tr><td colspan="3">Top and W control region
30 GeV $< \not{E}_T <$ 100 GeV
50 GeV $< M_T^\mu <$ 150 GeV</td></tr>
<tr><td colspan="2">Top control region
$N_{b\text{-tag}} \geq 1$</td><td rowspan="2">W control region

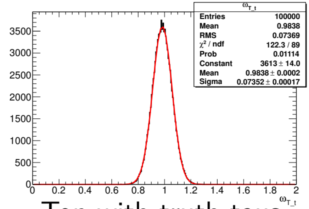
$N_{b\text{-tag}} = 0$</td></tr>
<tr><td>Top control region
fake taus
50 GeV $< M_T^\mu <$ 100 GeV</td><td>Top control region
true taus
100 GeV $< M_T^\mu <$ 150 GeV</td></tr>
</table>



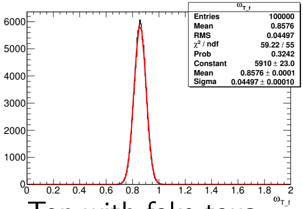


Plots still Rel16, just for illustration

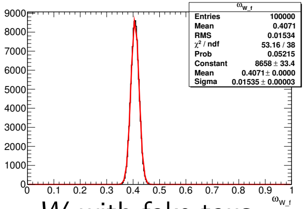
Obtained scalings (BDT loose)



Top with truth taus



Top with fake taus

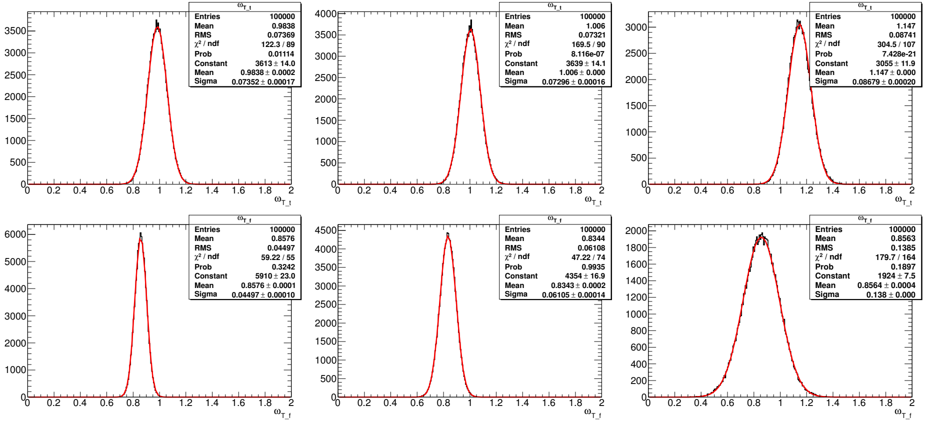


W with fake taus

Scalings (data driven estimate for most important backgrounds)

- Top with truth taus: 0.98±0.07 (Rel16: 0.55±0.12)
- Top with fake taus: 0.86± 0.04 (Rel16: 0.85±0.13)
- W with fake taus: 0.41±0.02 (Rel16: 0.47±0.02), talk from Alex Wed.
- Rel16-analysis: most discussed topic was Top truth scale
- Rel16 analysis: scalings are due to tau
- different ω_{W_f} and ω_{T_f} transverse momentum / event topology

Scalings for different tauID

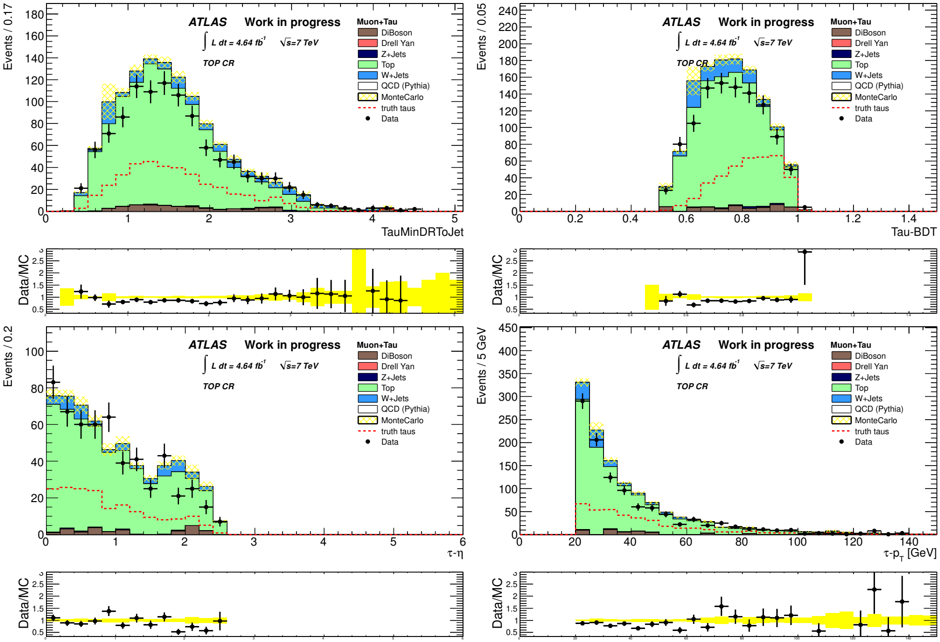


BDT loose   BDT medium   BDT tight

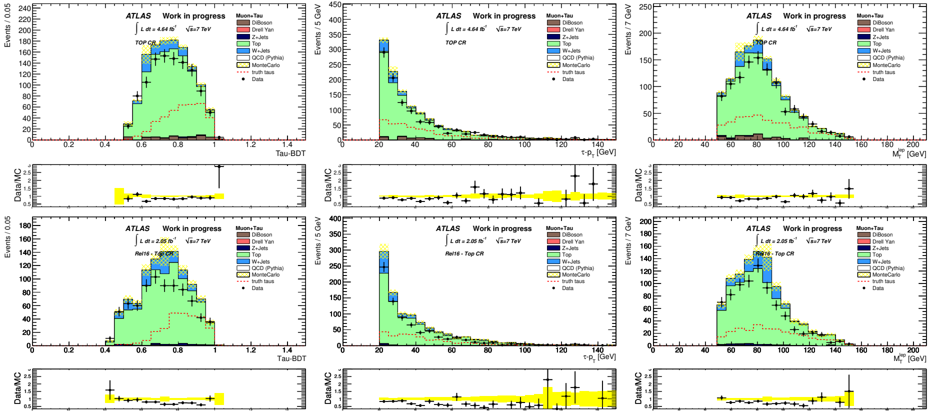
Top truth and Top fake scalings for different TauID

- top: Top with truth taus, bottom: Top with fake taus
- stable for different tau tightness
- tighter taus $\Delta\omega_{T_f}$ increases due to decreasing fake tau statistics

Tau ID Variables in combined Top control region



Comparing Rel16 and Rel17 in Top control region



tau-BDT tau-Pt M_T^{ℓ}

Comparison of Rel16 and Rel17 in Top CR

- top: Rel17; bottom: Rel16
- agreement is better in Rel17

Systematic uncertainties (Rel16, 2.05fb^{-1})

	Λ=30 TeV $\tan\beta$=20	Standard Model
JES (%)	8.9	20.8
TES (%)	2.6	24.9
JER (%)	2.8	15.4
TauID (%)	3.9	13.3
μ-ID (%)	1.6	1.8
scale (%)	–	11.7
PDF and NLO scale (%)	9.3	–
Lumi (%)	3	–

Systematic uncertainties in signal region

- TauID: tau fake rate and identification efficiency uncertainty
- μ-ID: Muon p_T smearing in ID and MS
- Scale: Uncertainties on data driven scalings
- PDF and NLO scale uncertainties from `Prospino`
- Lumi background: only 7.6% of background is unscaled: 2.3‰

Electron fakes in event selection

	Λ=30 TeV tan β=20	DiBoson	Drell Yan	Z+Jets	Top	W+Jets	SM
Pass $M_{\text{eff}} > 800$ GeV	31.7	0	0	0.0914	1.28	0.916	2.28±0.72
e-fake rate (%) $M_{\text{eff}} > 100$ GeV	0	0.046	0	0	6.042	0.517	3.598

signal region with Medium e-veto

- few e fakes, about 3.5%, can I gain by changing to tight or loose

% Deviation Tight e-Veto / Loose e-Veto	Λ=30 TeV tan β=20	DiBoson	Drell Yan	Z+Jets	Top	W+Jets	SM
Pass $M_{\text{eff}} > 100$ GeV	−7.29 1.53	−11.21 8.73	0 0	−6.95 1.11	−9.43 5.15	−6.4 1.63	−8.03 3.45
Pass $M_{\text{eff}} > 300$ GeV	−7.32 1.59	−10.77 10.61	0 0	−18.89 0	−9.17 5.04	−8.35 0.56	−9.44 3.86
Pass $M_{\text{eff}} > 500$ GeV	−7.72 1.73	−35.55 2.72	0 0	−1.16 0	−7.85 1.65	−8.11 0	−7.62 1.25

relative deviation to medium e veto when using tight or loose

- tight: reduce signal by 7%, background by $\approx$ 10%, worse significance
- loose: gain in signal only $< 2\%$

Conclusions

- Many things have improved in Rel17: Thanks to the TauWG for that!
- ... praise is still a little bit preliminary
- most Tau studies done with W and Z, Top more important for many SUSY analysis (good progress: talk from Pier-Olivier on Thu.)
- Top truth contributions seem to be much better (correctly) described
- Tau energy scale uncertainty has big influence on the event selection
- choice el-fake veto not so crucial for this analysis
- tau-fakes in $W \rightarrow \mu\nu_\mu$-events still over predicted in MC?

most important task

- Understand tau-fake rates in data in control regions
- high BDT tail over estimated in MC
- how to transfer this knowledge to our signal area (p_T dependent scalings)
- Alex talk on Wed: nice to see that there is progress

Variables defining the control regions