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Top Quark Partners with Exotic Charge ($T_{5/3}$)

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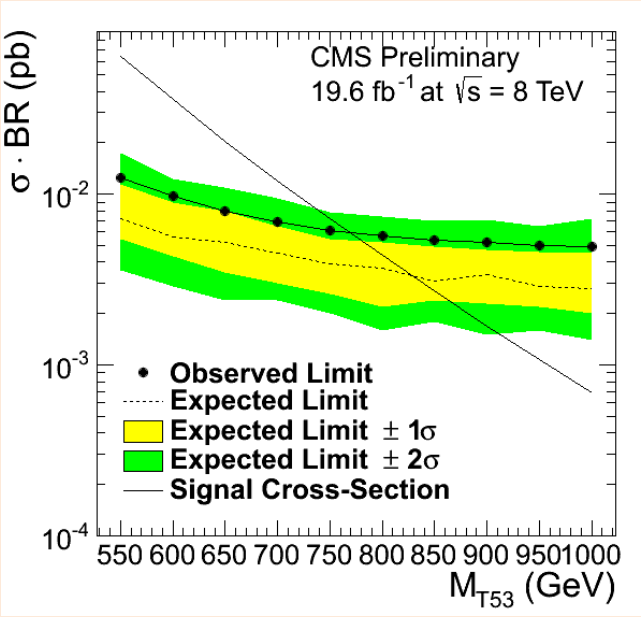
Top Partners

- Heavy top partners are a common prediction of different theories
  - Couple to 3rd generation quarks
  - Solve hierarchy problem
  - Compatible with 125 GeV Higgs
    - See arXiv:1212.1380 (Int. J. Mod. Phys. A Volume 28 (2013) 1330004)

- Can be found in
  - Composite Higgs
  - Extra dimensions (KK gluons)

The $T_{5/3}$

- Top partner models include several particles
  - Focus on quark with charge 5/3
  - Typically the lightest



- Theoretical descriptions
  - ***Contino & Servant***, JHEP 0806:026 (2008)
  - ***Mrazek & Wulzer***, Phys. Rev. D 81, 075006 (2010)
  - More recently: **CERN-PH-TH/2012-323** (arXiv:1211.5663)

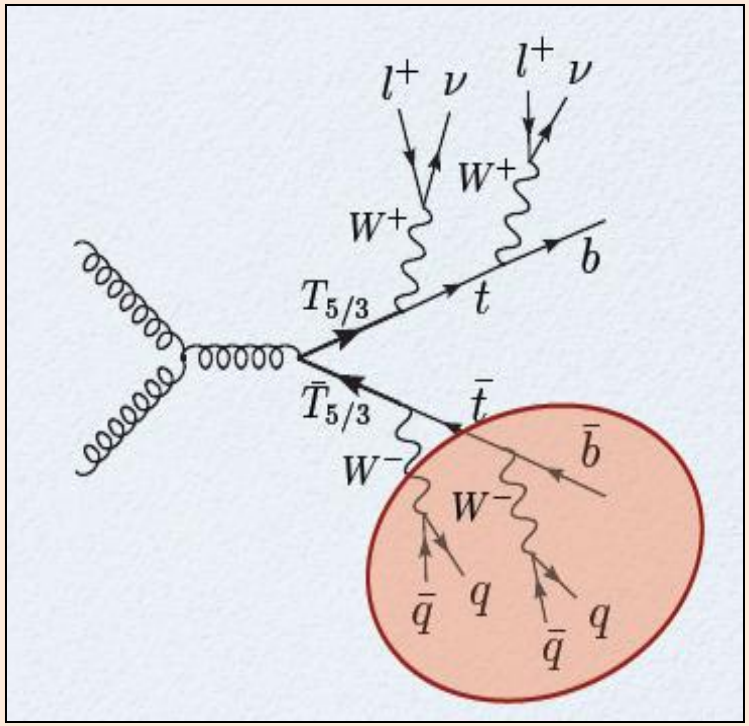
- Experimental results
  - **CMS-PAS-B2G-12-012** (8 TeV) excludes $M(T_{5/3}) < 770$ GeV at 95% C.L.
  - **ATLAS-CONF-2012-130** (7 TeV): 670-700 GeV depending on coupling
  - Published result: CDF (Phys.Rev.Lett.104:091801, 2010), 365 GeV

Model

- $T_{5/3}$ with $Q_e = 5/3$ and B with $Q_e = -1/3$ decay into W and top
  - Per Mrazek & Wulzer, B is typically more massive than $T_{5/3}$
  - Focus on $T_{5/3}$

- Most striking signature: same-sign dileptons

$$l^{\pm}l^{\pm} + 2b + 2\mathrm{W}$$

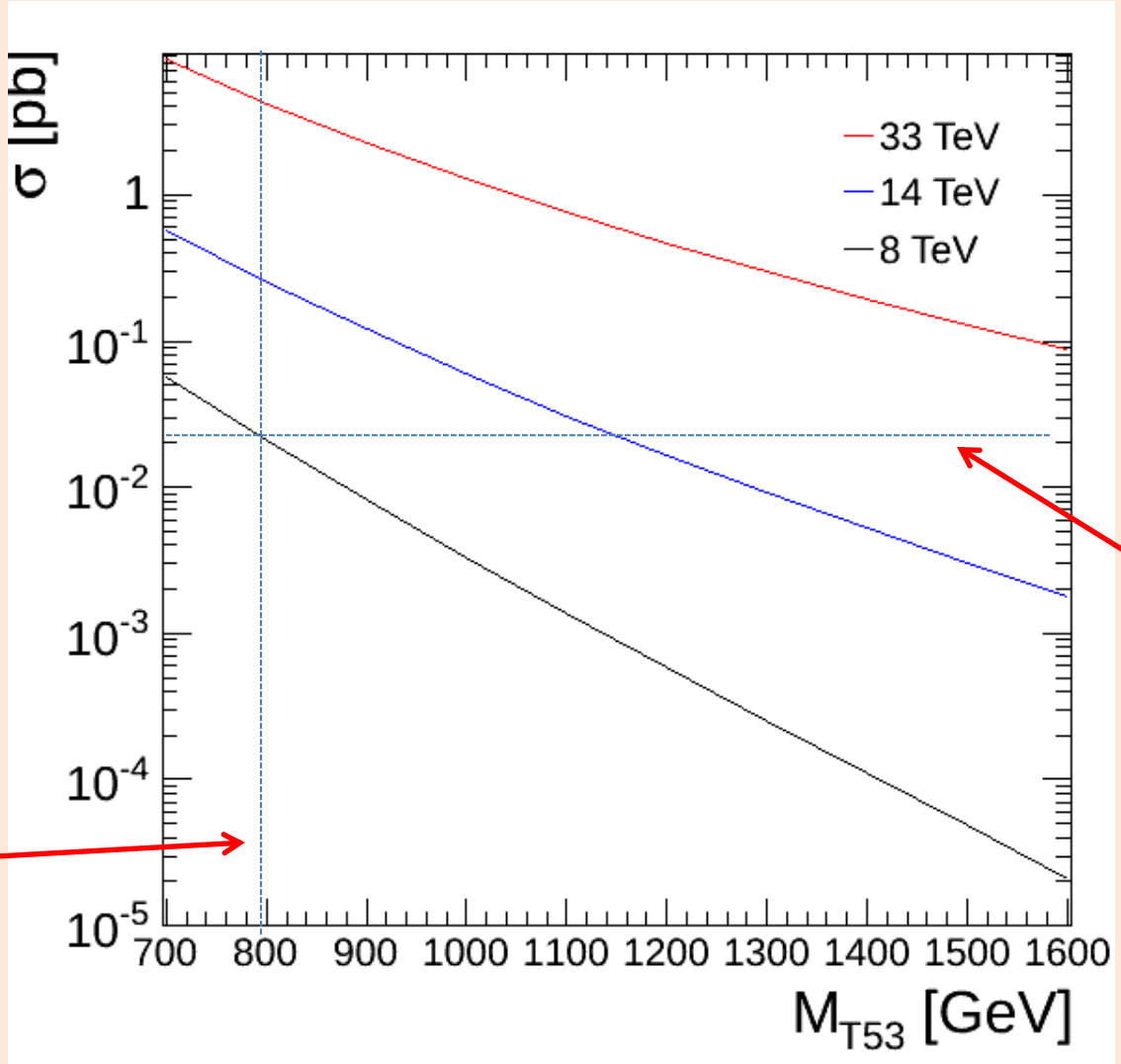


- The hadronically decaying $T_{5/3}$ can be reconstructed

Signal and Background Samples

- MadGraph 1.5.8/9 + Delphes 3.0.9.1
- Currently using inclusive background samples
  - Switch to HT-binned once ttbarW/ttbarZ are available
- Results shown here are with 14 TeV, 50 pileup
  - 33 TeV, 140 pileup in progress
- Signal points in intervals of 100 GeV starting at 700 GeV
- Backgrounds are actually 13 TeV
  - Scale cross-section by 1.2

Signal Cross Sections



Same cross-section as current limit

Current limit

Jet Substructure

- Decay products of $T_{5/3}$ are boosted
  - More noticeable with the W
  - Effect increases with $T_{5/3}$ mass

- Use W and top tagging techniques
  - Implementation by J. Dolen and J. Stupak
    - Present in all 3.0.9.1 Delphes files
  - Trimmed Cambridge-Aachen jets with R = 0.8

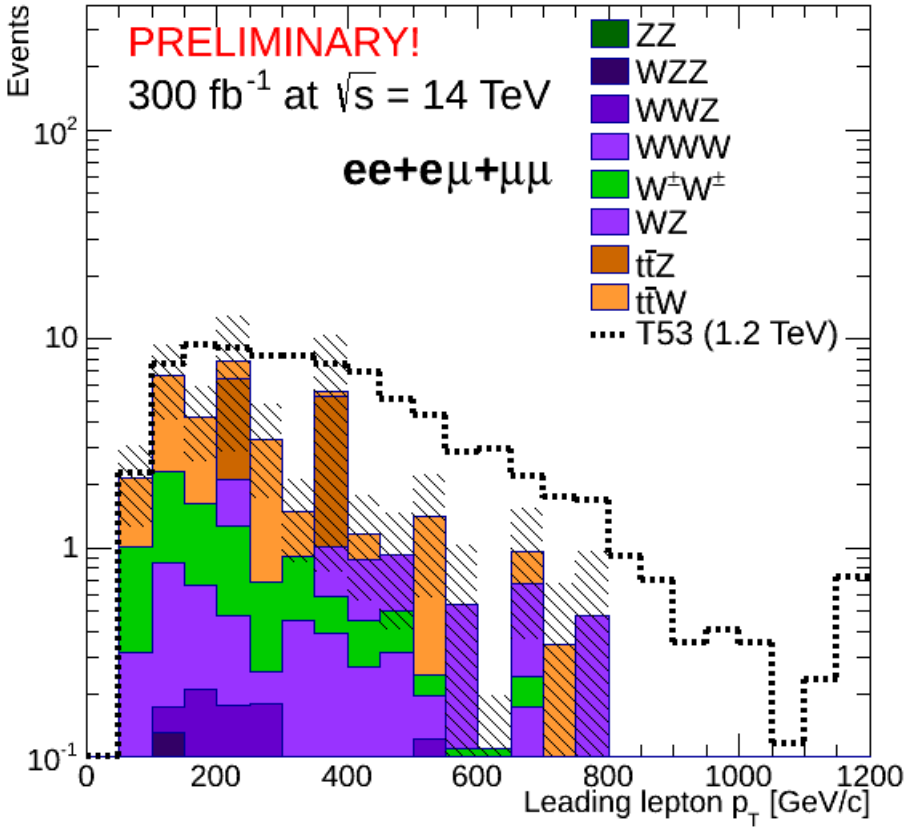
- W-tag: 60 GeV < M_{jet} < 120 GeV and mass drop < 0.4

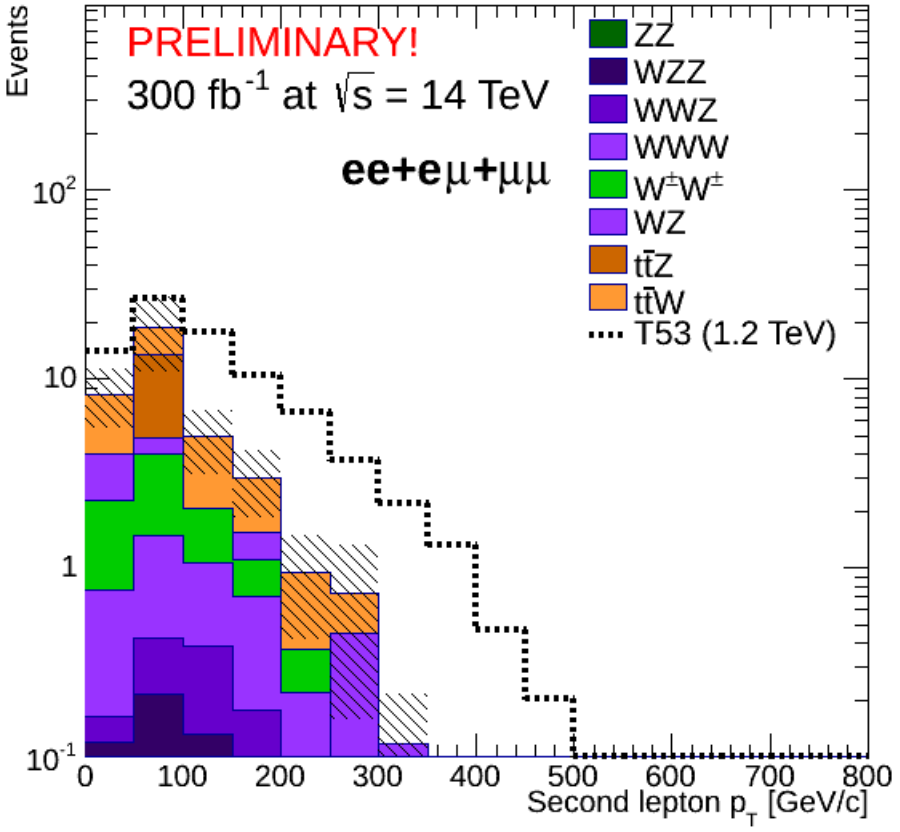
- Top-tag: at least 3 sub-jets and 140 GeV < M_{jet} < 230 GeV

$T_{5/3}$ Selection

- Two same-sign leptons:
  - Leading p_T > 80 GeV, the other p_T > 30 GeV
  - Trilepton Z-veto
- Jets:
  - Leading jet p_T > 150 GeV, second p_T > 50 GeV
  - Minimum of 5 constituents
    - Top-tagged jet = 3 constituents
    - W-tagged jet = 2 constituents
    - Jets and leptons (other than the 2 same-sign ones) with p_T > 30 GeV = 1 constituent each
- H_T = Sum of all selected lepton and jet p_T > 1400 GeV
- Missing E_T > 100 GeV
- **PRELIMINARY!**

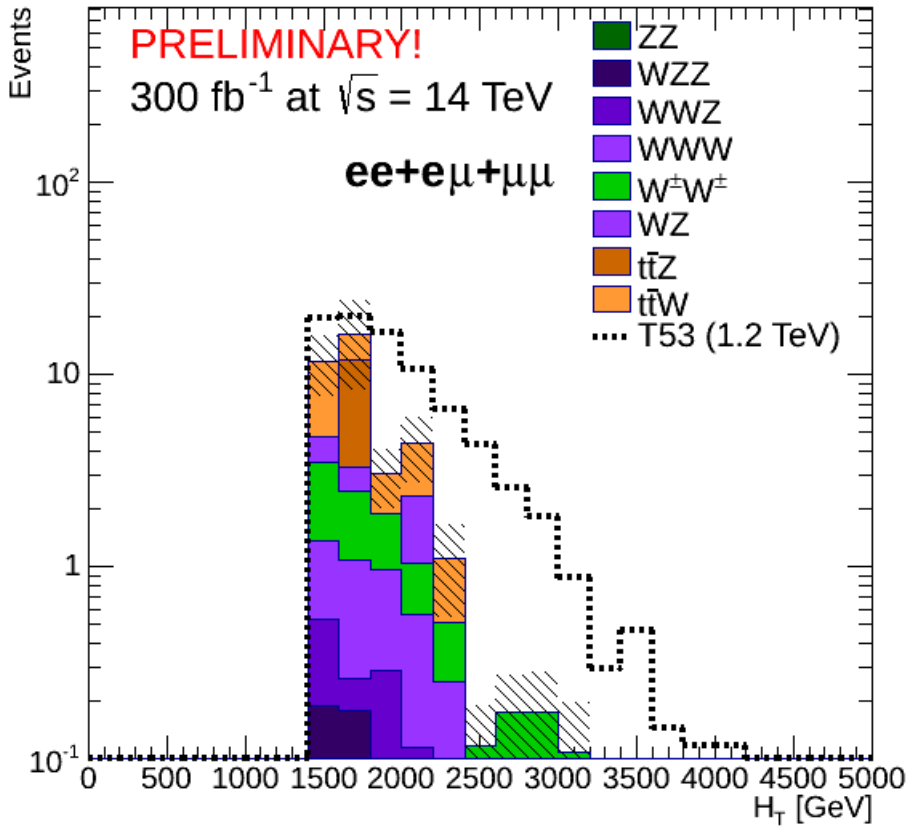
Lepton p_T

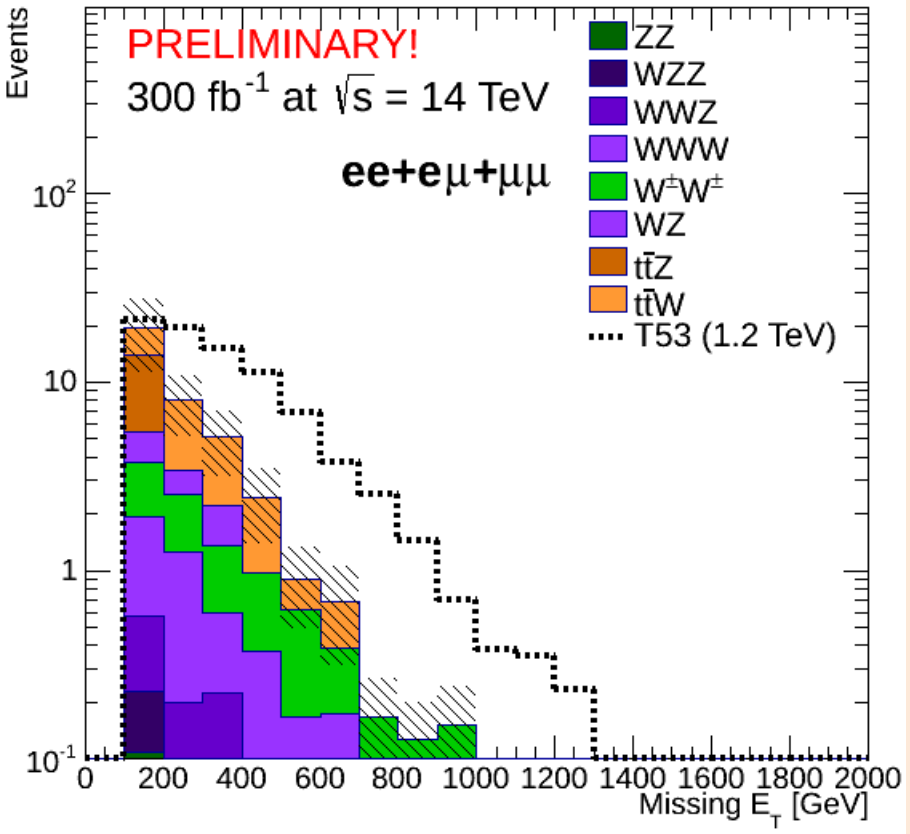




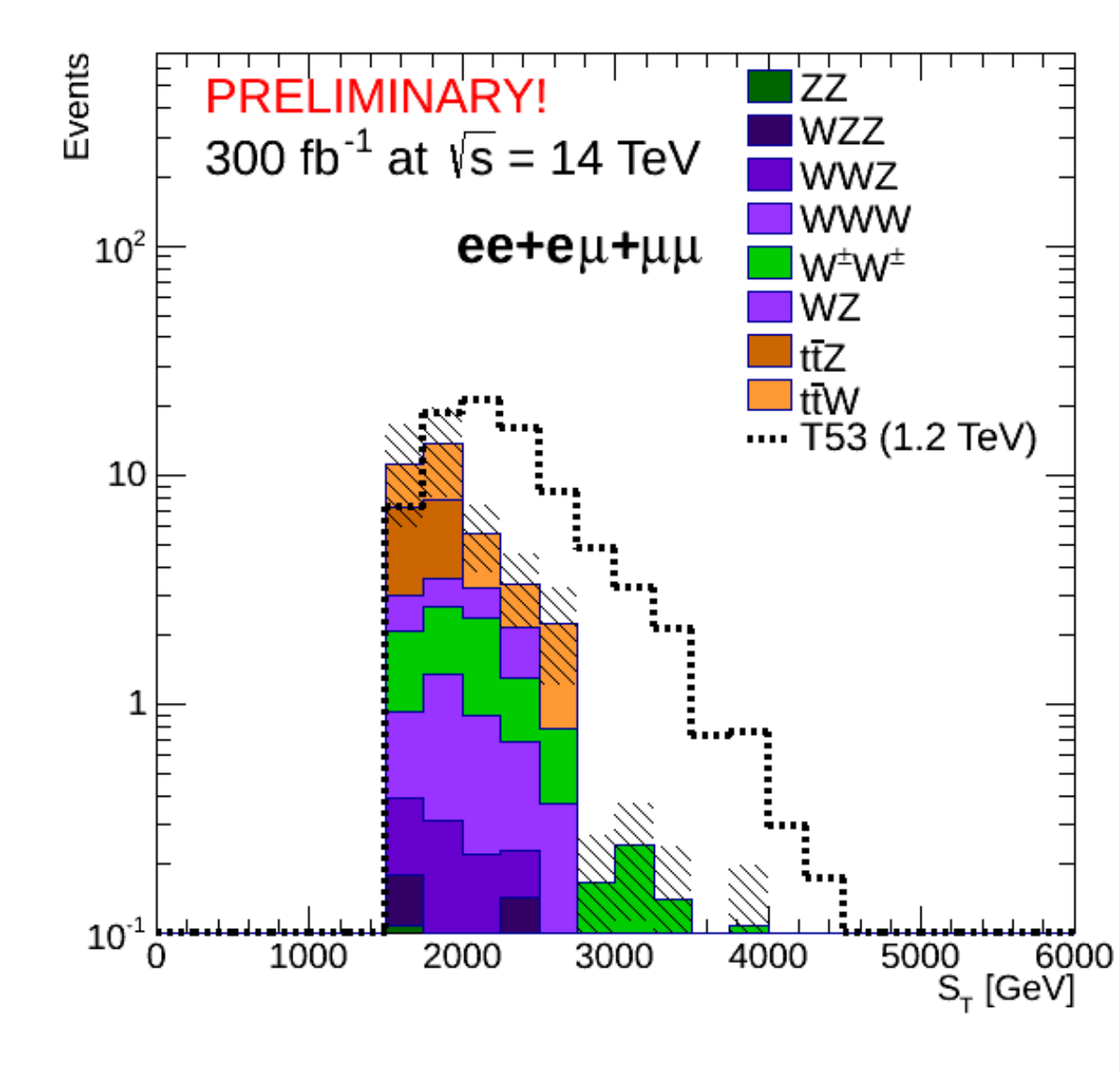
- All plots are after the full selection

H_T and Missing E_T





S_T


PRELIMINARY!
300 fb^{-1} at $\sqrt{s}$ = 14 TeV
ee+eμ+μμ
ZZ
WZZ
WWZ
WWW
W$^{\pm}$W$^{\pm}$
WZ
tt̄Z
tt̄W
T53 (1.2 TeV)
Events
10^2
10
1
10^{-1}
0
1000
2000
3000
4000
5000
6000
S_T [GeV]

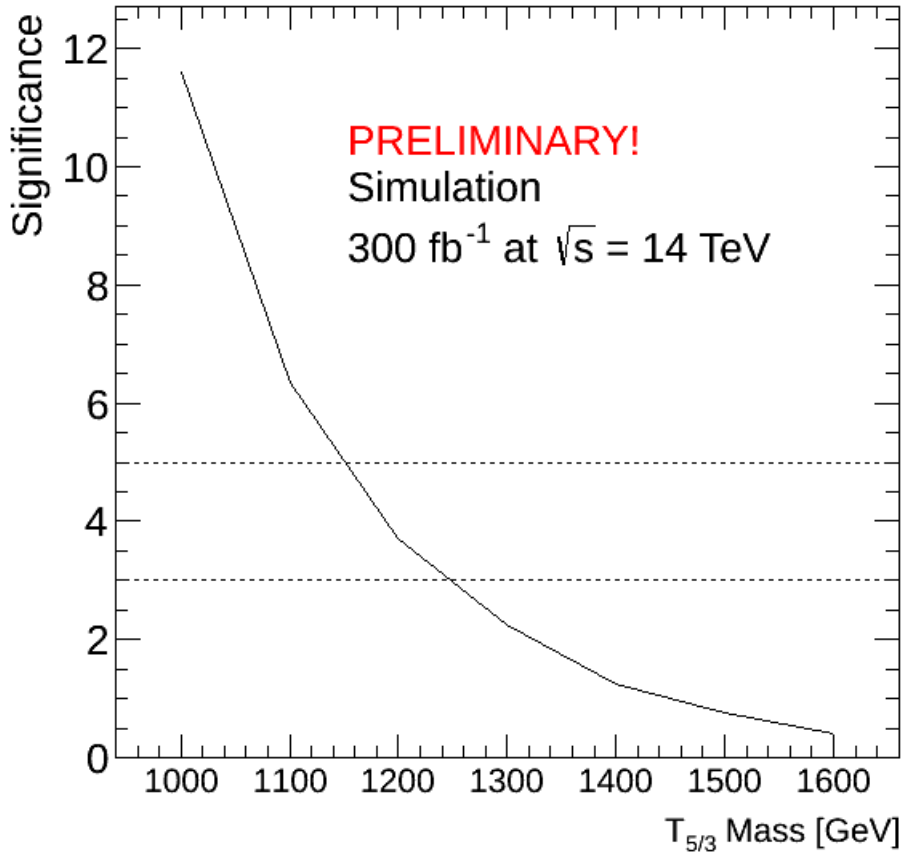
Signal Yields

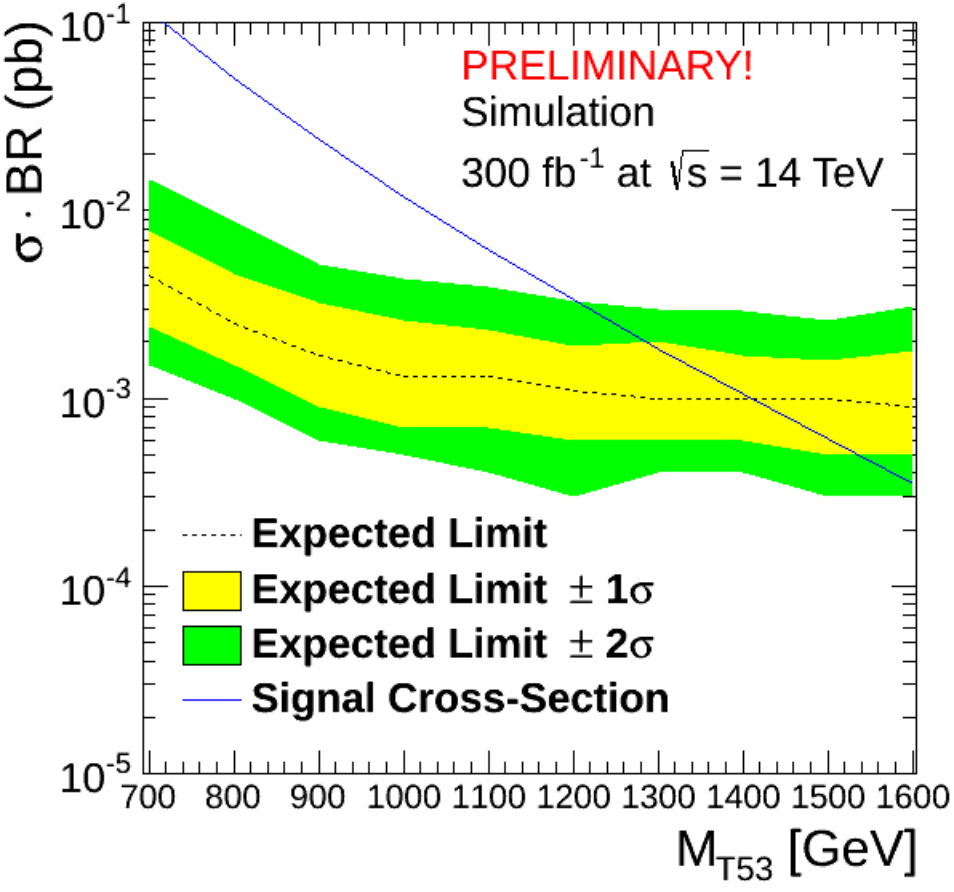
$T_{5/3}$ Mass (GeV)	2SS leptons	$M(ll)$ Veto	N(jet) cut	H_T cut	Missing E_T cut
700	6.61e+03	6.57e+03	4.11e+03	895	719 ± 21.3
800	3.02e+03	3.01e+03	1.91e+03	659	529 ± 12.7
900	1.45e+03	1.45e+03	935	433	358 ± 7.49
1000	712	711	462	272	233 ± 4.49
1100	373	372	241	164	143 ± 2.65
1200	199	199	127	94.3	83.8 ± 1.56
1300	111	111	69.3	55.6	49.3 ± 0.928
1400	59.9	59.8	36.3	29.7	26.9 ± 0.537
1500	35	35	21	18	16.3 ± 0.332
1600	19.8	19.8	12.1	10.3	9.55 ± 0.202

Background Yields

Sample	2SS leptons	$M(ll)$ Veto	N(jet) cut	H_T cut	Missing E_T cut
$W^{\pm}W^{\pm}$	776.4	766.4	35.17	7.313	5.597 ± 0.3054
WZ	7467	7329	107	9.027	3.439 ± 1.216
ZZ	517.7	510.1	6.265	0.537	0.1074 ± 0.062
WWW	550.6	542.1	21.7	3.842	3.315 ± 0.4998
WWZ	142.9	140.2	10.41	1.199	0.7282 ± 0.1766
WZZ	43.69	42.53	4.248	0.7357	0.4272 ± 0.1007
$t\bar{t}W$	1767	1739	282.6	24.59	15.04 ± 2.086
$t\bar{t}Z$	722.2	709.4	123.9	12.82	8.547 ± 6.043

Significance and Limit





- With 300 fb^{-1} at 14 TeV:
  - 5 sigma if $T_{5/3}$ mass is less than ~1.15 TeV
  - 3 sigma if $T_{5/3}$ mass is less than ~1.25 TeV
- OR…
  - 95% CL at ~1.4 TeV

Summary and Plans

- Analysis chain up to limits and discovery potential complete
- Will switch to H_T-binned background samples shortly
  - Also makes backgrounds 14 TeV
  - Enables meaningful charge misID measurement
- Optimize and finalize event selection
- Work on other energies and pileup scenarios in progress
- Reconstruct $T_{5/3}$ mass