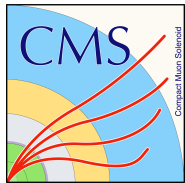


In Search of Top Quark Pairs With Zero Total Angular Momentum

CMS-PAS-HIG-22-013

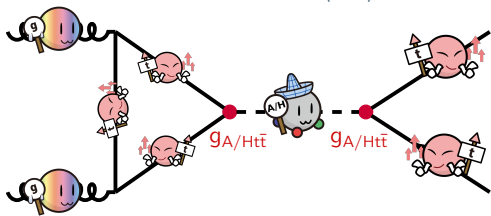
Afiq Anuar (DESY)

CERN Collider Cross Talk – 2025/01/23

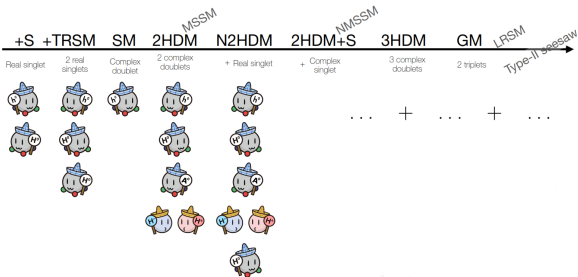


Signal models

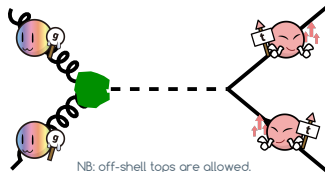
Gluon fusion $A/H \rightarrow t\bar{t}$
 Previous work: JHEP 04 (2020) 171



To probe the **extended Higgs** sector.



Effective η_t model
 Based on PRD 104, 034023 (2021)



To approximate the $^1S_0^{[1]}$ toponium formation.

ℓj analysis selection

- exactly one lepton (e/μ)

- split in 4 categories:
e vs μ and 3 jets vs ≥ 4 jets

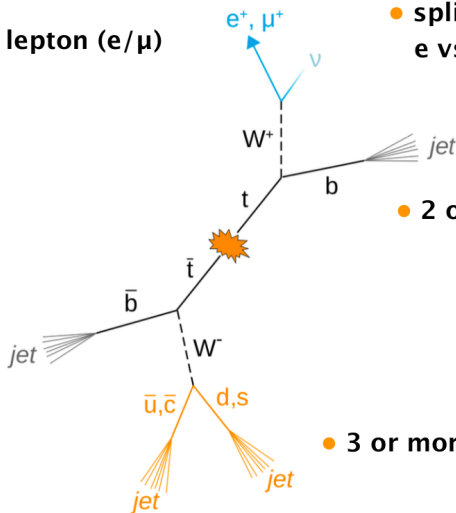
- Reconstruct $t\bar{t}$ system with NeutrinoSolver algorithm

NIM A 736 (2014) 169

– assign b-jets by maximum likelihood

– energy correction factor applied for 3 jet events (lost or merged jets)

NIM A 788 (2015) 128



- 2 or more b-jets

- 3 or more jets

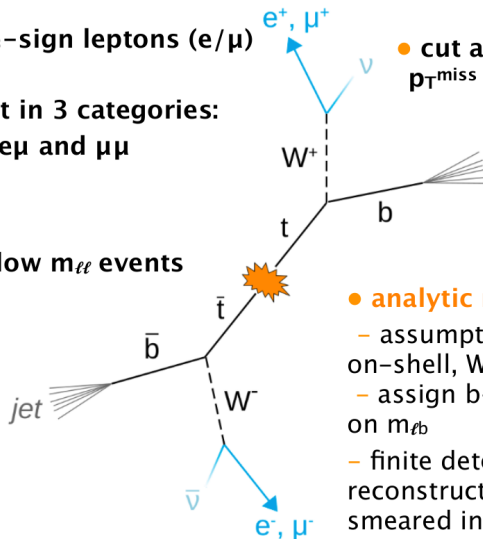
ll analysis selection

- exactly two opposite-sign leptons (e/μ)

- split in 3 categories:
 ee , $e\mu$ and $\mu\mu$

- reject low $m_{\ell\ell}$ events

- 2 or more jets



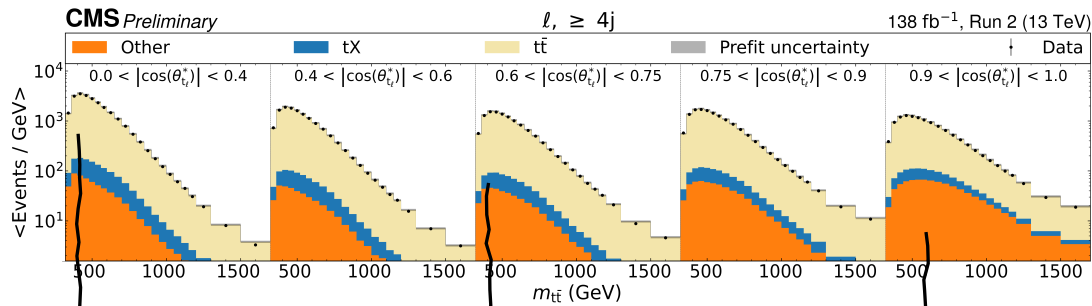
- cut away Z peak & require $p_{T^{\text{miss}}} > 40$ GeV in $ee/\mu\mu$

- 1 or more b-jets

- analytic reconstruction of $t\bar{t}$ system

- assumptions: all $p_{T^{\text{miss}}}$ from $\nu\nu$, tops on-shell, Ws on-shell
- assign b-jets using likelihood, based on $m_{\ell b}$
- finite detector resolution: repeat reconstruction 100 times with randomly smeared inputs, take weighted average

Background modelling



FO pQCD top pair $t\bar{t}$: most important

- NLO QCD reweighted to NNLO QCD + NLO EW
- Unc. on top Yukawa coupling through EW correction
- + standard th/ex NPs: m_t , ME/PS scales, JECs...

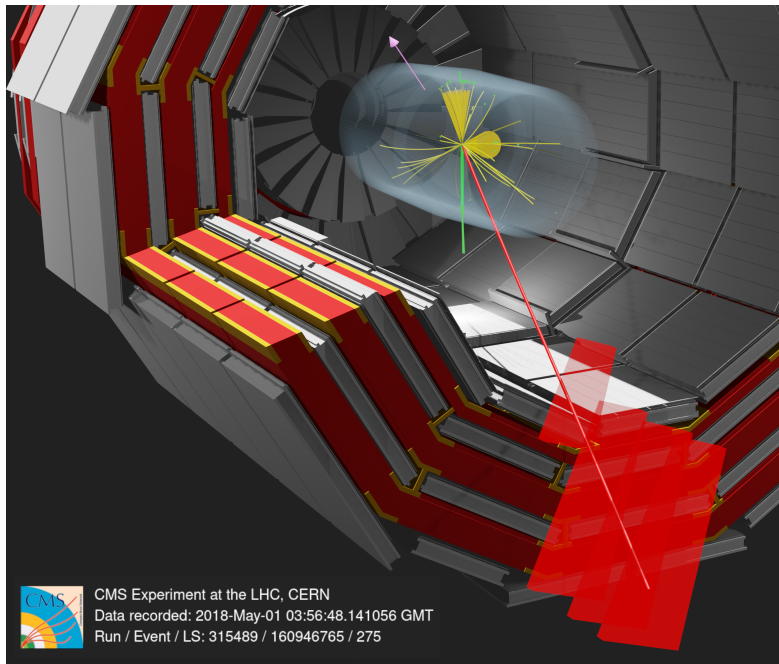
Other minor backgrounds

- ℓj : multijet QCD + EW in b-tag sideband CRs
- $\ell\ell$: NNLO $Z/\gamma^* \rightarrow \ell\ell$, NLO $t\bar{t}V$, LO VV MCs

Single top tX

- NLO QCD MC for all three modes
- t-channel important in ℓj , tW in $\ell\ell$

Signal event, maybe?



Muon

Electron

b jets

\cancel{E}_T

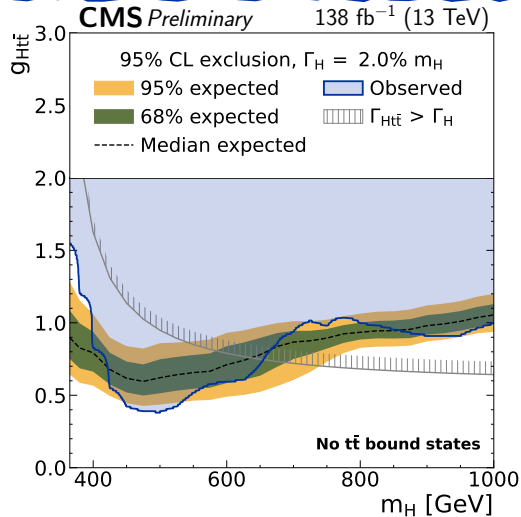
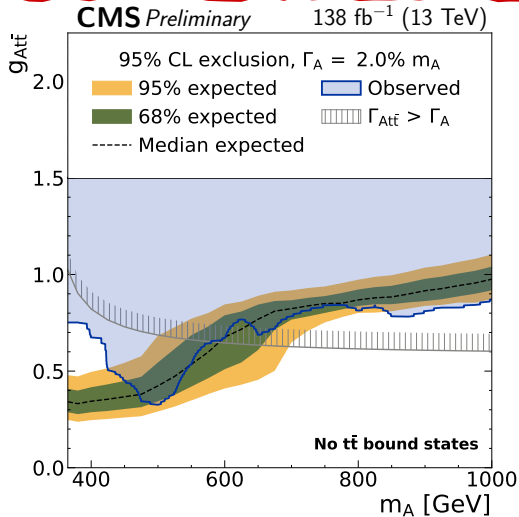


CMS Experiment at the LHC, CERN

Data recorded: 2018-May-01 03:56:48.141056 GMT

Run / Event / LS: 315489 / 160946765 / 275

One signal interpretation



Interpretation	Best-fit point	Difference in $-2 \ln L$
η_t	$\mu(\eta_t) = 1.11$	-86.2
Single A boson	$m_A = 365 \text{ GeV}, \Gamma_A/m_A = 2\%, g_{A t\bar{t}} = 0.78$	-72.6
Single H boson	$m_H = 365 \text{ GeV}, \Gamma_H/m_H = 2\%, g_{H t\bar{t}} = 1.45$	-10.4

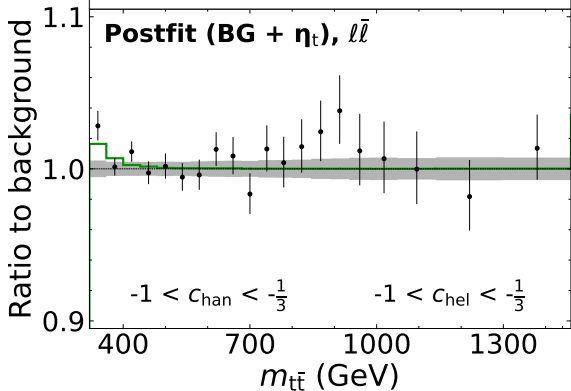
Small and big peaks

CMS Preliminary 138 fb⁻¹, Run 2 (13 TeV)

—+— η_t , $\mu(\eta_t) = 1.11 \pm 0.12$

■ Uncertainty

Postfit (BG + η_t), $l\bar{l}$

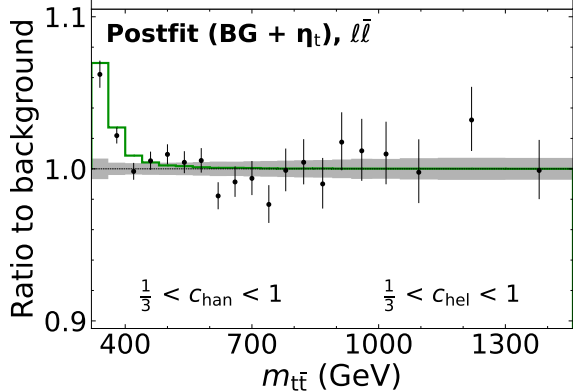


CMS Preliminary 138 fb⁻¹, Run 2 (13 TeV)

—+— η_t , $\mu(\eta_t) = 1.11 \pm 0.12$

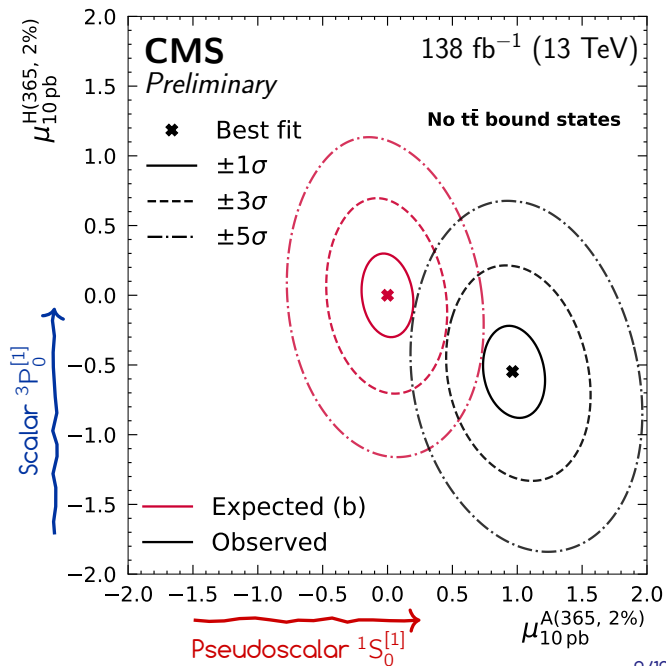
■ Uncertainty

Postfit (BG + η_t), $l\bar{l}$



Parity scan

- Use resonant A/H as $^1S_0^{[1]}$ and $^3P_0^{[1]}$ structural proxies

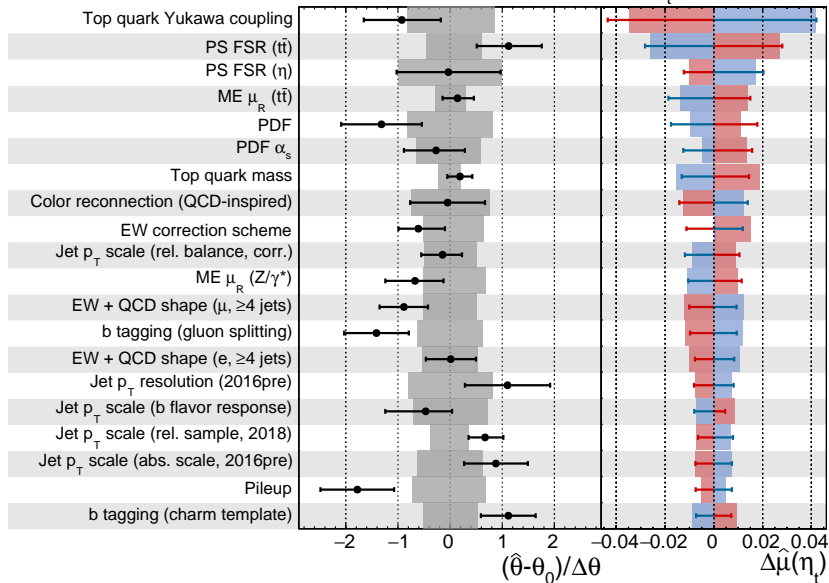


Uncertainties

CMS
Preliminary

—●— Fit constraint (obs.) — +1 σ impact (obs.) — -1 σ impact (obs.)
■ Fit constraint (exp.) ■ +1 σ impact (exp.) ■ -1 σ impact (exp.)

$$\hat{\mu}(\eta_t) = 1.11 \pm 0.12$$



Putting it together

Extract the size of the excess **under the effective η_t assumption**

→ the most compatible one signal interpretation of the data

“Cross section” = difference between the data and the pQCD predictions:

$$\sigma(\eta_t) = 7.1 \pm 0.8 \text{ pb}$$

Cf. the NRQCD prediction [[PRD 104, 034023 \(2021\)](#)]: $\sigma(\eta_t)_{\text{pred}} = 6.43 \text{ pb}$

Interpret with caution: missing uncertainties, color octet initial states, radiation...

Please view the number as an experimental input to guide further theorybuilding

The Exotics – HIG-22-013 *ll* and combination team

Left to right: Christian Schwanenberger, AA, Laurids Jeppe, Jonas Rübenach, Alexander Grohsjean

Dominic Stafford



Samuel Baxter



Jörn Bach



Thanks for your attention!

