TOP2017

Search for SM production of four top quarks with the CMS detector

CMS-PAS-TOP-17-009

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on behalf of the CMS Collaboration

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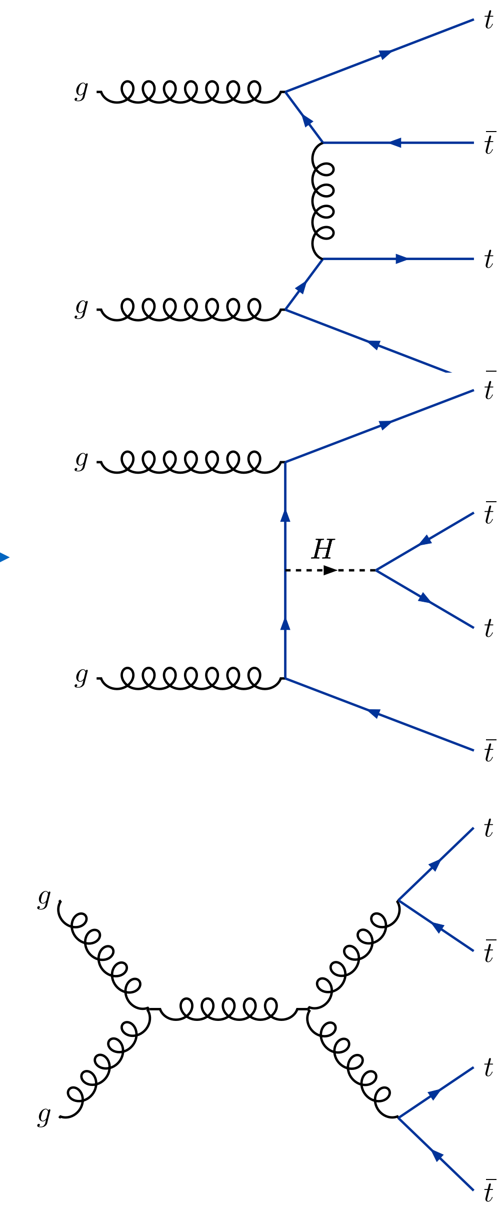
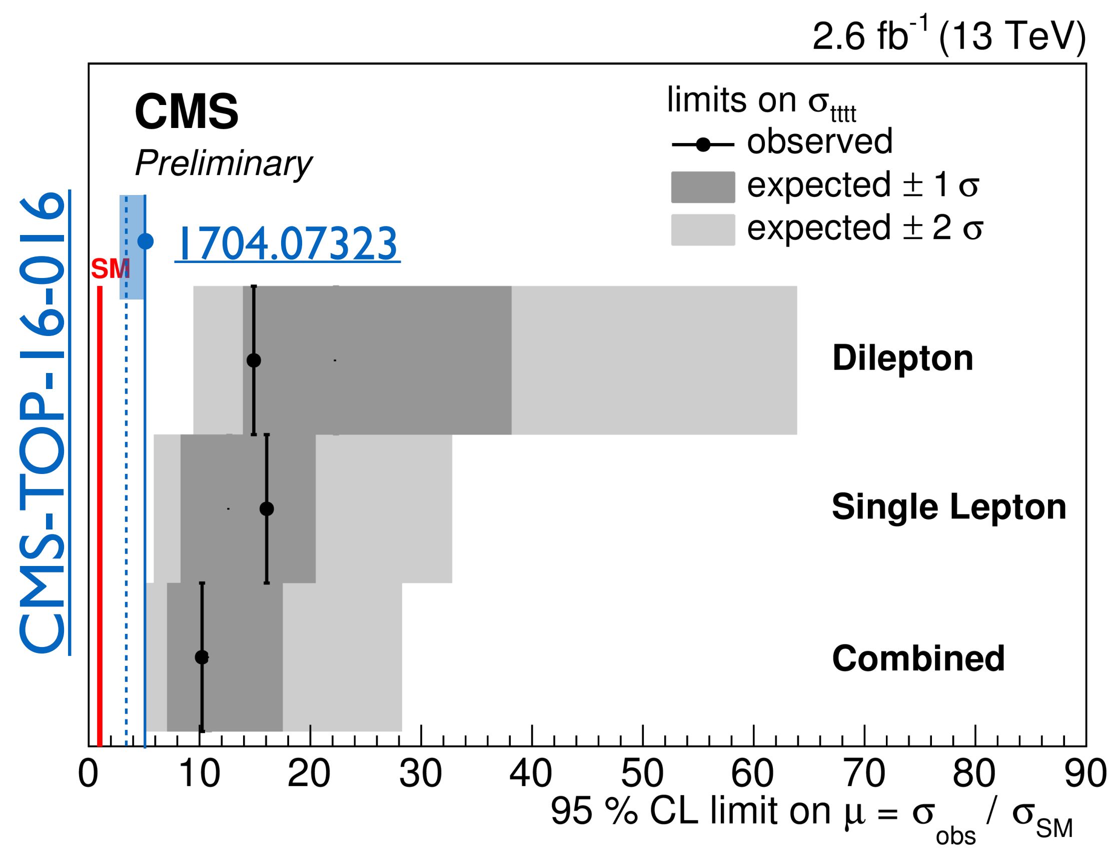
Introduction

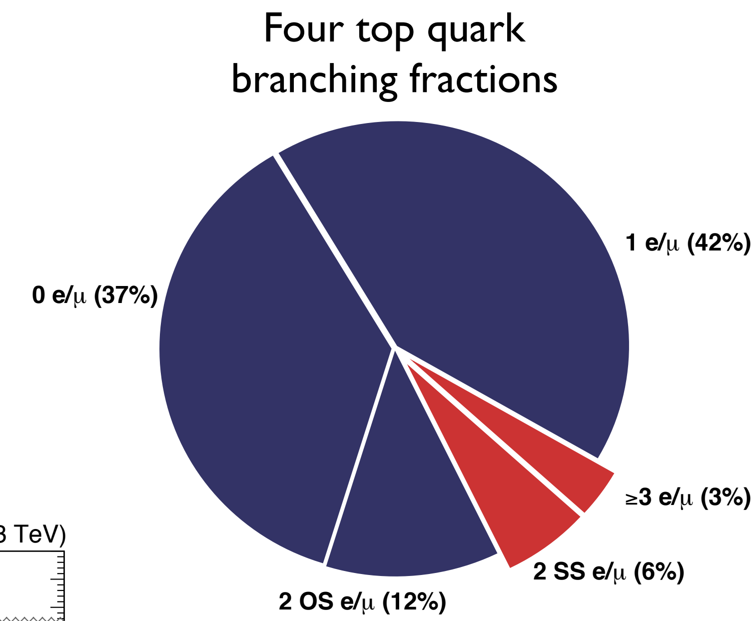
- Four top quarks are *rare* in the Standard Model
  → 9.2 fb NLO cross section at 13TeV
- $t\bar{t}t\bar{t}$ production could be impacted by BSM scenarios (e.g., gluino pair production in SUSY, two-Higgs-doublet models)
- Process is sensitive to top quark Yukawa coupling through off shell Higgs bosons
- *Latest constraints getting closer to SM cross-section…*

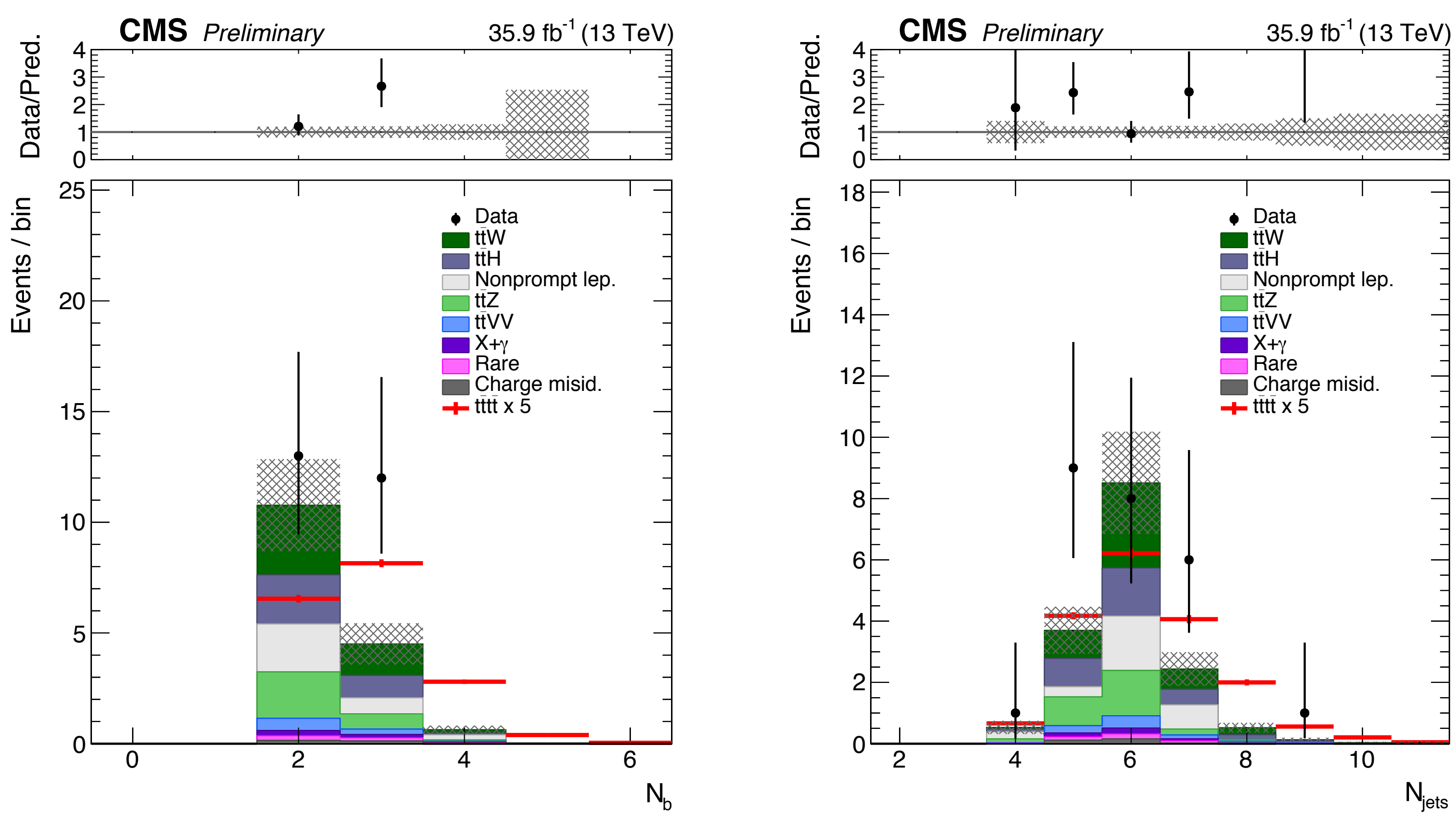




Measurement strategy

- Utilize events containing a dilepton pair with same charge → gives access to ~10% of branching fraction of $t\bar{t}t\bar{t}$ and suppresses the pervasive $t\bar{t}$ background
- Four top quarks results in 4 b-tagged jets, and up to 8 jets when requiring at least a same-sign lepton pair





Following results from CMS-PAS-TOP-17-009

Take advantage of this high jet multiplicity and perform a <u>fit to data in bins of number of jets N_j and b-tagged jets N_b</u>, to extract the four top cross-section

Selection and backgrounds

- Require at least a tight same-sign lepton pair + baseline selection, splitting 2 or ≥3 lepton events
- Categorize in N_j, N_b to obtain 8 signal regions, with 2 control regions

Baseline selection

$p_T(\ell_1,\ell_2,\ell_3)$>25, 20, 20 GeV
$N_j \geq 2$ (40 GeV, $|\eta|<2.4$ jets)
$N_b \geq 2$ (25 GeV $|\eta|<2.4$ jets)
H_T>300 GeV
$\not{E}_T$>50 GeV

Primary backgrounds

O(100) fb → O(1) fb

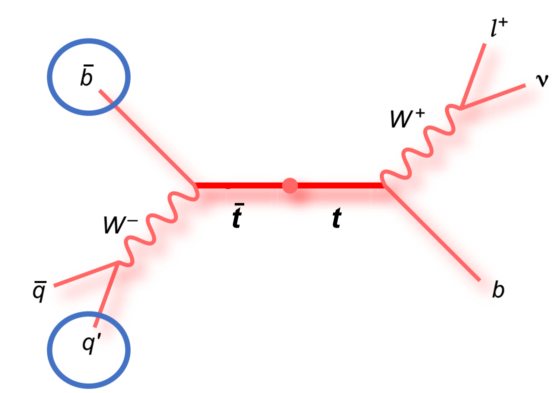
- ttW, ttZ → Normalize to data in dedicated control regions
- ttH
- non-prompt leptons → Data-driven fake rate method
- tttj, tttV, ttVV, VVV
- charge misidentification → Reweighted opposite-sign data control region

N_{lep}	N_b	N_{jets}	Region
2	2	≤ 5	CRW
		6	SR1
		7	SR2
		≥ 8	SR3
	3	5, 6	SR4
		≥ 7	SR5
	≥ 4	≥ 5	SR6
≥ 3	2	≥ 5	SR7
	≥ 3	≥ 4	SR8
Inverted Z veto			CRZ

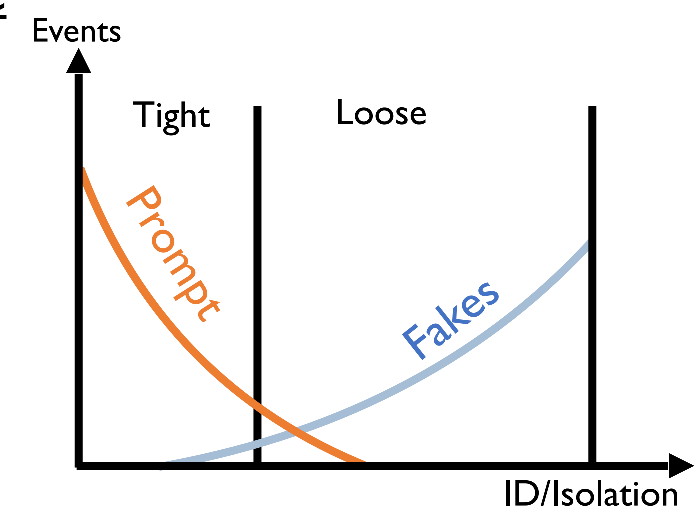
Non-prompt leptons + charge flips

Fakes

- Estimate *fake* or *non-prompt* lepton background by determining probability $\varepsilon(p_T,\eta)$ for loose lepton to pass nominal tight selection in QCD-enriched region in data

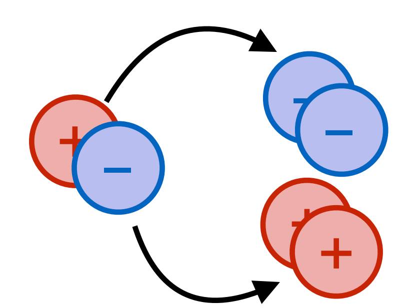


- Reweight sideband events with one tight and one loose-not-tight lepton by $\varepsilon/(1\text{-}\varepsilon)$ to obtain signal region prediction



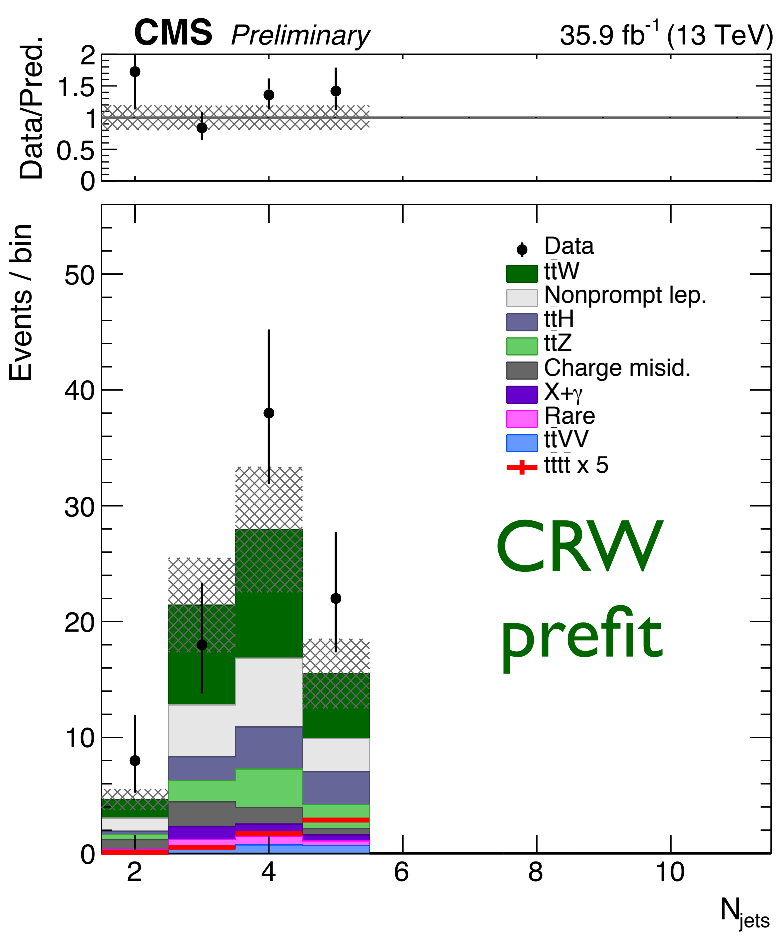
Flips

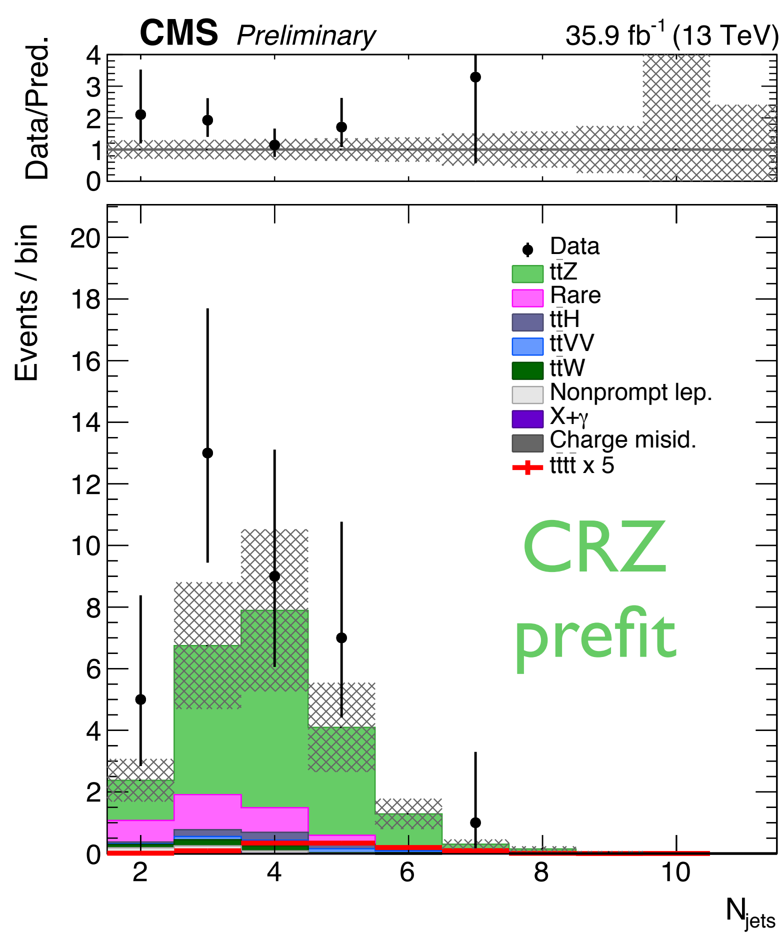
- Electron charge flip rate $\varepsilon_{flip}(p_T,\eta)$ measured in simulation and applied as a weight $\varepsilon_{flip}/(1\text{-}\varepsilon_{flip})$ to opposite-sign events in data



ttW, ttZ

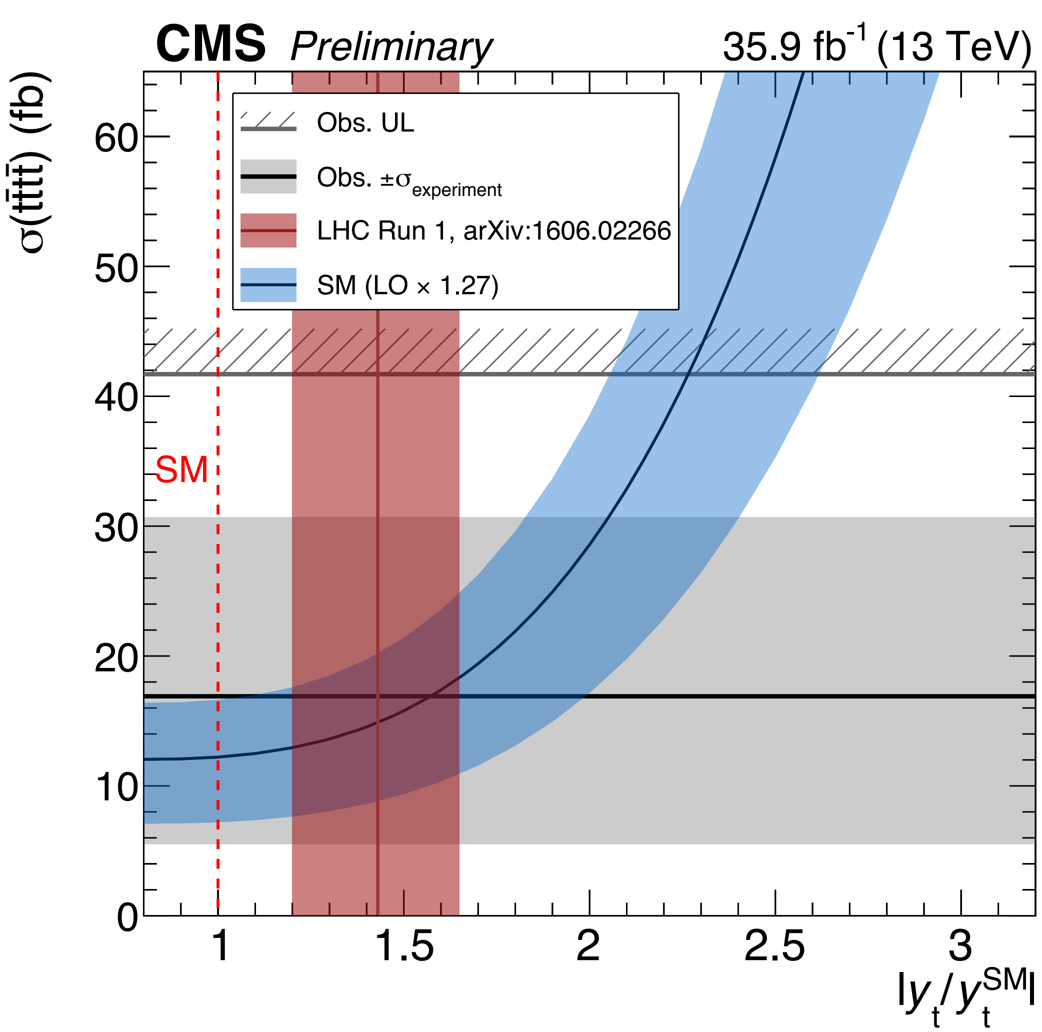
- ttW control region (CRW) formed from events with 2 btags, ≤5 jets
- ttZ control region (CRZ) contains baseline events with an opposite-sign same flavour Z candidate
- In the maximum likelihood fit to data, these processes are scaled up by about 30%

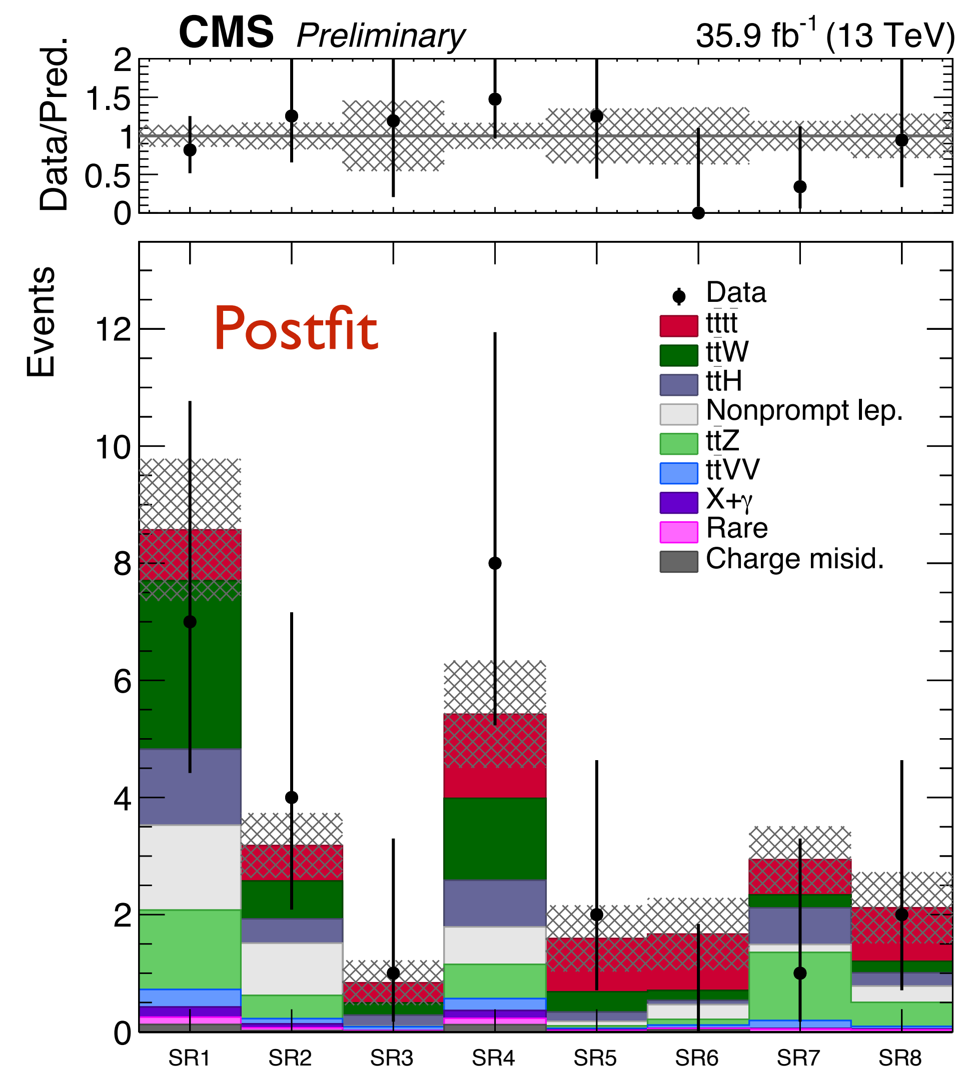




Results

- After the fit to data in the signal + control regions, the four top cross-section is measured to be $16.9^{+13.8}_{-11.4}$ fb, with an observed (expected) significance wrt the bg-only hypothesis of 1.6σ (1.0σ)
- Additionally, this measurement is used to constrain the top Yukawa coupling $|y_t/y_t^{SM}|<2.27$ at 95% confidence, as motivated by Cao, et al. in 1602.01934





N_{lep}	N_b	N_{jets}	Region
2	2	6	SR1
		7	SR2
		≥ 8	SR3
	3	5, 6	SR4
		≥ 7	SR5
	≥ 4	≥ 5	SR6
≥ 3	2	≥ 5	SR7
	≥ 3	≥ 4	SR8

Summary

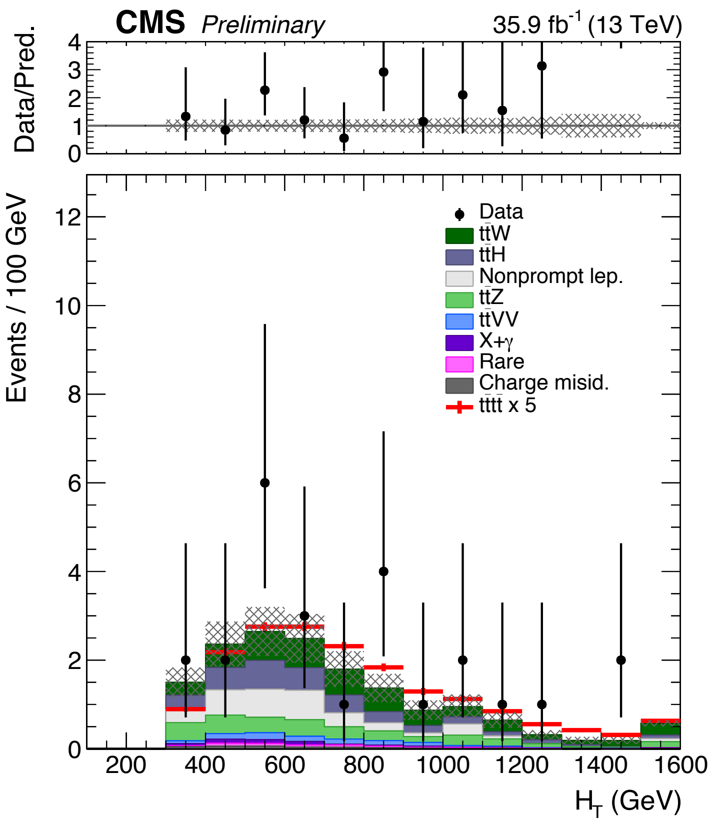
- While $t\bar{t}t\bar{t}$ production is rare, the similarly rare same-sign signature is effective at isolating this process

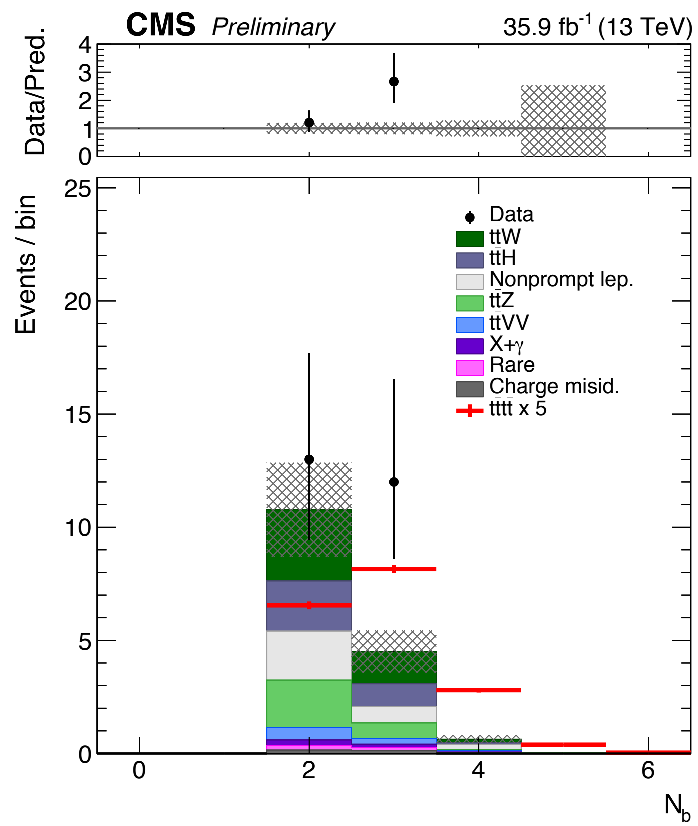
- First measurement of four top quark production with the CMS detector at 13 TeV with a same-sign dilepton and multilepton final state shown here
  - CMS also working to release results in opposite-sign and single lepton channels

- Measurement uncertainty currently dominated by statistics
  → to improve in the coming future as data accumulates

Backup

SR+CR


CMS Preliminary
35.9 fb^{-1} (13 TeV)
Data/Pred.
Events / 100 GeV
Data
ttW
ttH
Nonprompt lep.
ttZ
ttVV
X+γ
Rare
Charge misid.
tttt x 5
H_T (GeV)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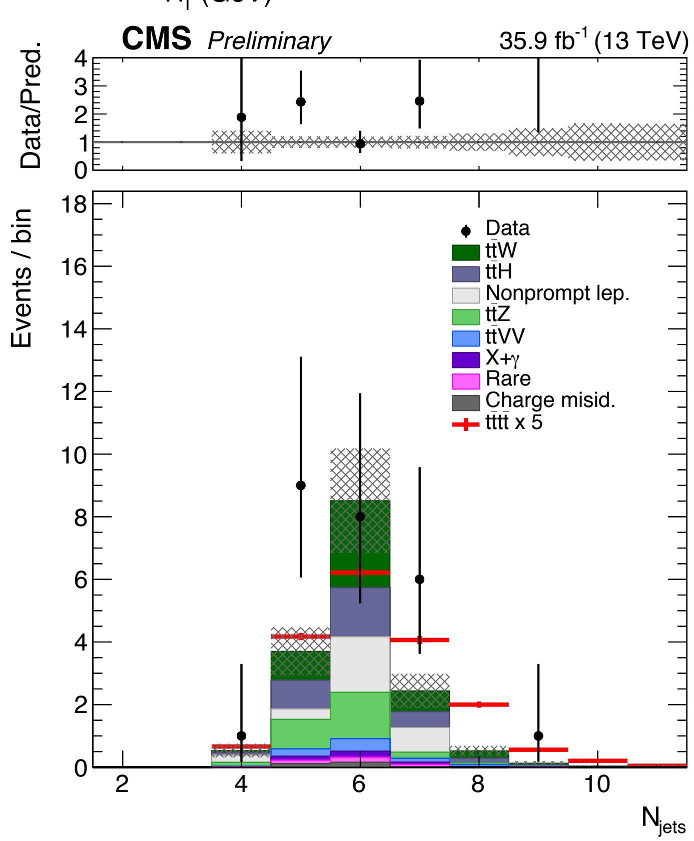
N_b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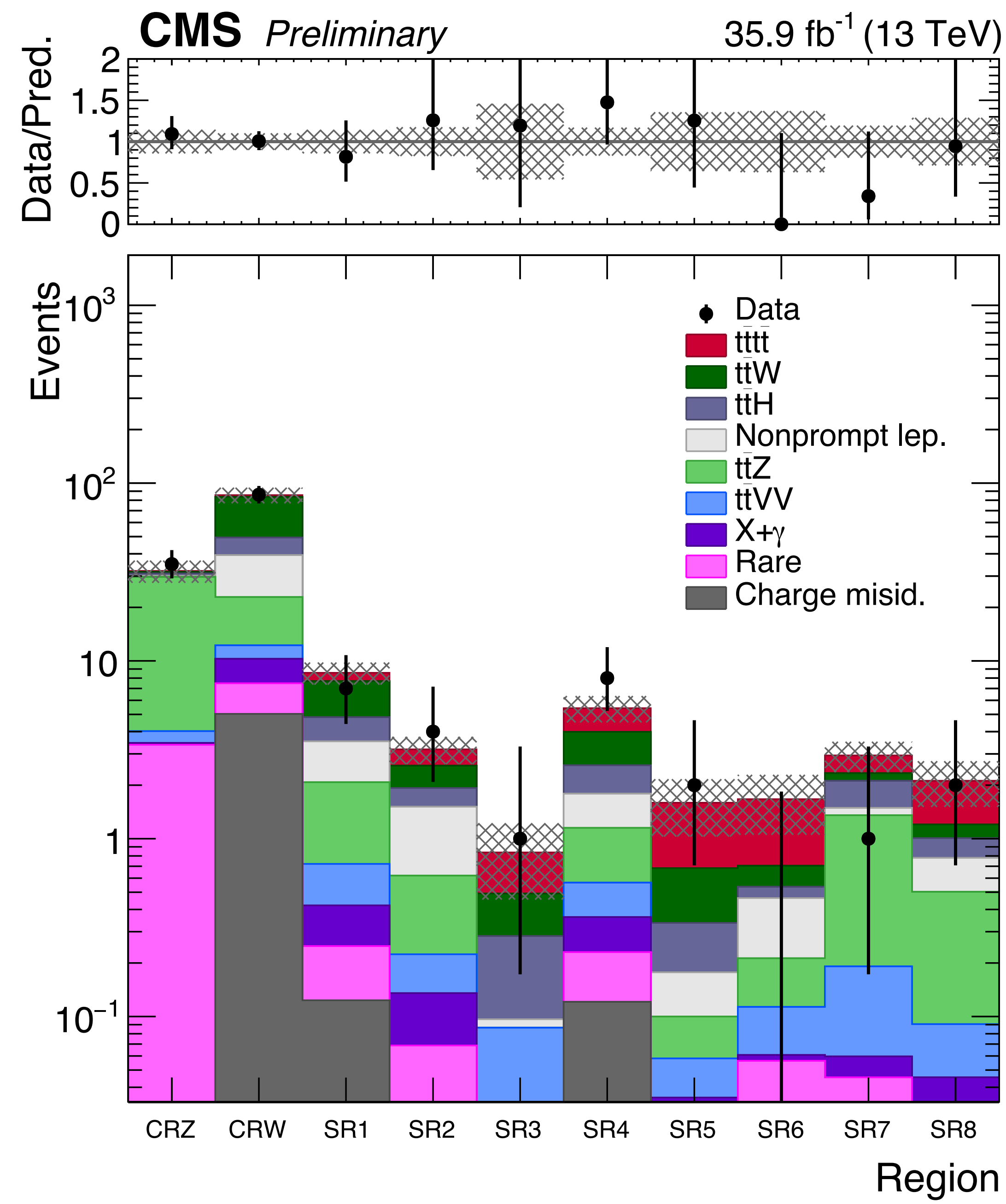
N_{jets}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SR2
SR3
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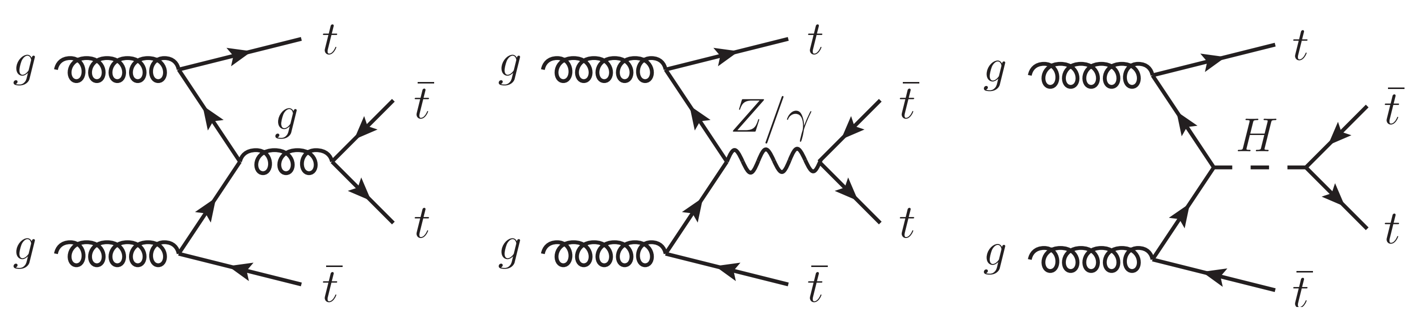
SR5
SR6
SR7
SR8
Region

Top Yukawa Interpretation

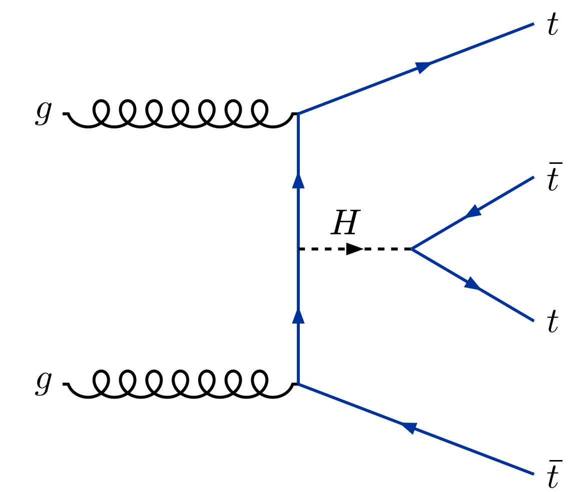
Measurement of tttt production can be used to constrain $k_t = y_t/y_t^{SM}$ following the discussion in arXiv:1602.01934.

arXiv:1602.01934, Cao et al.



$$\sigma(t\bar{t}t\bar{t}) = \sigma^{\rm SM}(t\bar{t}t\bar{t})_{g+Z/\gamma} + \kappa_t^2 \sigma_{\rm int}^{\rm SM} + \kappa_t^4 \sigma^{\rm SM}(t\bar{t}t\bar{t})_H$$

	8 TeV	13 TeV	14 TeV
$\sigma^{\rm SM}(t\bar{t}t\bar{t})_{g+Z/\gamma}$:	1.344 fb,	9.997 fb,	13.140 fb,
$\sigma^{\rm SM}(t\bar{t}t\bar{t})_H$:	0.171 fb,	1.168 fb,	1.515 fb,
$\sigma^{\rm SM}(t\bar{t}t\bar{t})_{\rm int}$:	−0.224 fb,	−1.547 fb,	−2.007 fb.



13 TeV uncertainties obtained from Cao et al.

	$[\mu/2, \mu, 2\mu]$
$\sigma^{SM}(t\bar{t}t\bar{t})_{g+Z/\gamma}$	[14.104, 9.997, 6.378] fb
$\sigma^{SM}(t\bar{t}t\bar{t})_H$	[1.625, 1.167, 0.7655] fb
$\sigma^{SM}_{\rm int}$	[-2.152, -1.547, -0.999] fb

Uncertainties, Yields

Source	Uncertainty (%)
Integrated luminosity	2.5
Lepton selection	4–10
Trigger efficiency	2–7
Pileup	0–6
Jet energy scale	1–15
Jet energy resolution	1–5
b tagging	1–15
Simulated sample size	1–10
Scale and PDF variations	10–20
ISR/FSR (signal only)	5–15
$t\bar{t}H$ (normalization)	50
$t\bar{t}Z$, $t\bar{t}W$ (normalization)	40
Nonprompt leptons	30–60
Charge misidentification	20

	SM background	$t\bar{t}t\bar{t}$	Total	Observed
CRZ	31.7± 4.6	0.4± 0.3	32.1± 4.6	35
CRW	83.7± 8.8	1.9± 1.2	85.6± 8.6	86
SR1	7.7± 1.2	0.9± 0.6	8.6± 1.2	7
SR2	2.6± 0.5	0.6± 0.4	3.2± 0.6	4
SR3	0.5± 0.3	0.4± 0.2	0.8± 0.4	1
SR4	4.0± 0.7	1.4± 0.9	5.4± 0.9	8
SR5	0.7± 0.2	0.9± 0.6	1.6± 0.6	2
SR6	0.7± 0.2	1.0± 0.6	1.7± 0.6	0
SR7	2.3± 0.5	0.6± 0.4	2.9± 0.6	1
SR8	1.2± 0.3	0.9± 0.6	2.1± 0.6	2