Measurement of the single top quark and antiquark production cross sections in the *t* channel and their ratio at 13 TeV

Karlsruhe Institute of Technology

Denise Müller – Institute of Experimental Particle Physics, KIT

On behalf of the CMS Collaboration

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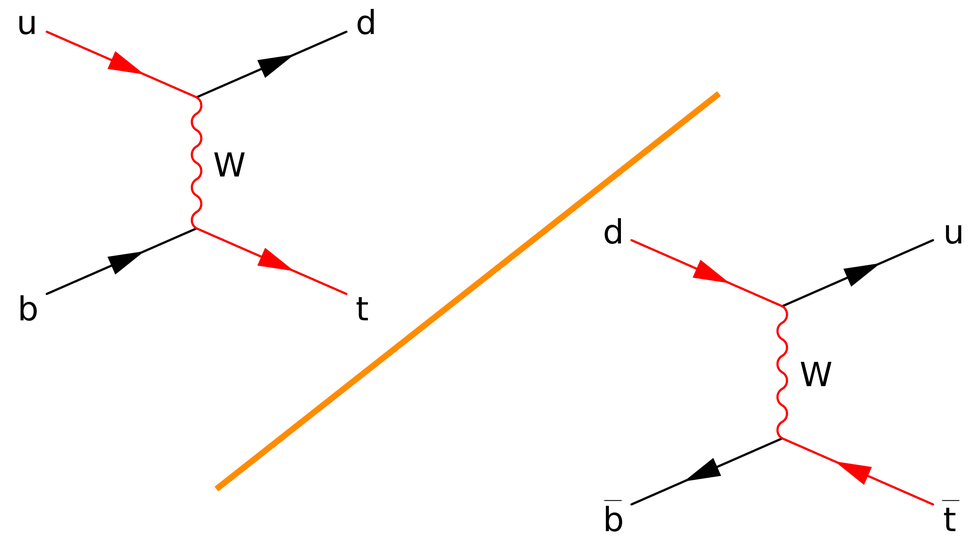
Motivation

- Electroweak production of **single top quarks**
- Most dominant production mode at LHC: ***t* channel**
  - At 13 TeV: ≈70%
- **Insight into inner proton structure** via ratio of top quark and antiquark cross sections $R_{t\text{-ch}}$
  - Sensitive to flavor of initial quarks
  - Sensitive to different PDF predictions
- Direct measurement of **CKM matrix element $|V_{tb}|$**

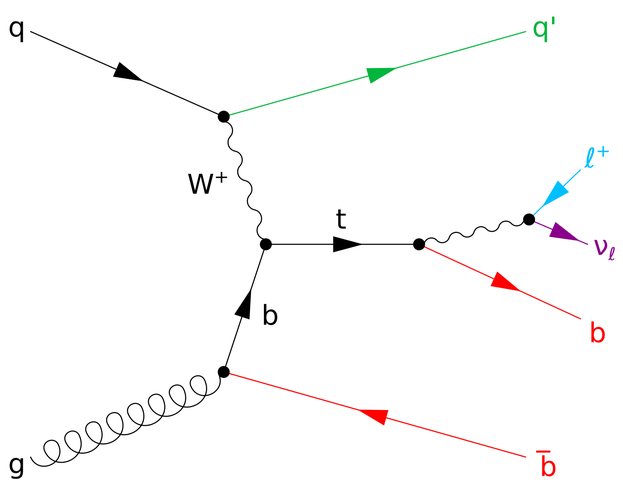
$$\sigma_{t\text{-ch,t}} = 136.0^{+4.1}_{-2.9}(\text{scale}) \pm 3.5(\text{PDF}+\alpha_s)\ \text{pb}$$
$$\sigma_{t\text{-ch,}\bar{t}} = 81.0^{+2.5}_{-1.7}(\text{scale}) \pm 3.2(\text{PDF}+\alpha_s)\ \text{pb}$$
$$\sigma_{t\text{-ch,t}+\bar{t}} = 217.0^{+6.6}_{-4.6}(\text{scale}) \pm 6.2(\text{PDF}+\alpha_s)\ \text{pb}$$

[Hathor v2.1]



$R_{t\text{-ch}} = 1.68 \pm 0.02(\text{scale}\oplus\text{PDF}+\alpha_s)$

Event selection



- One isolated muon (electron) with $p_T > 26$ (35) GeV and $|\eta| < 2.4$ (2.1)
- Jets with $p_T > 40$ GeV and $|\eta| < 4.7$
  - b-tagged jets: $|\eta| < 2.4$
- $m_T^W > 50$ GeV (muon)
- $p_T^{miss} > 30$ GeV (electron)
- Second b jet often not detected
  - Signal category: **2-jets–1-tag**
  - $t\bar{t}$ control categories: **3-jets–1-tag** and **3-jets–2-tags**

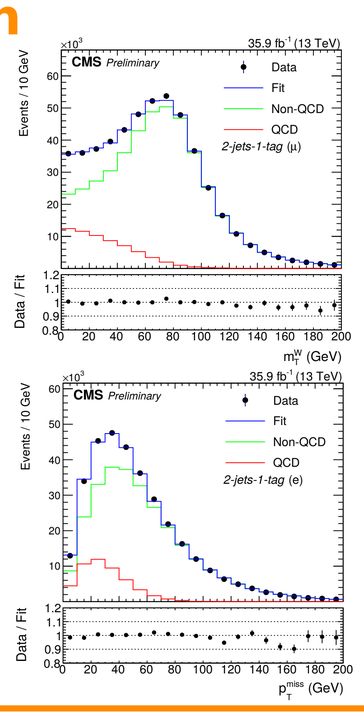
35.9 fb^{-1}, 2-jets–1-tag

Process	μ^+	e^+
$t\bar{t}$	81 000 ± 13 000	65 000 ± 10 000
tW	8800 ± 1800	6800 ± 1400
W/Z+jets	38 000 ± 12 000	23 900 ± 8100
QCD	6700 ± 3200	11 300 ± 5400
t channel	23 600 ± 2900	15 100 ± 1800
Total expected	158 000 ± 18 000	122 000 ± 14 000
Observed	166 446	124 857

Process	μ^-	e^-
$t\bar{t}$	82 000 ± 14 000	65 000 ± 10 000
tW	8800 ± 1800	6900 ± 1400
W/Z+jets	33 000 ± 11 000	21 500 ± 6800
QCD	6700 ± 3200	10 600 ± 5100
t channel	14 600 ± 1900	9400 ± 1200
Total expected	145 000 ± 18 000	113 000 ± 13 000
Observed	151 440	116 206

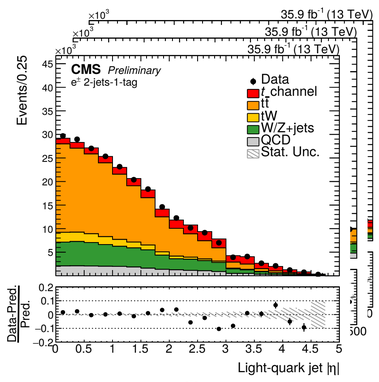
QCD estimation

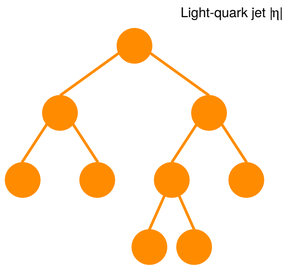
- Small selection efficiency of QCD MC
- **Data-driven** QCD estimation via two-template fit
  - QCD template with anti-isolated selection
  - Non-QCD template containing all MC processes including signal
- Estimate yield via fit to discriminating variable in each event category
  - Muon: m_T^W
  - Electron: p_T^{miss}



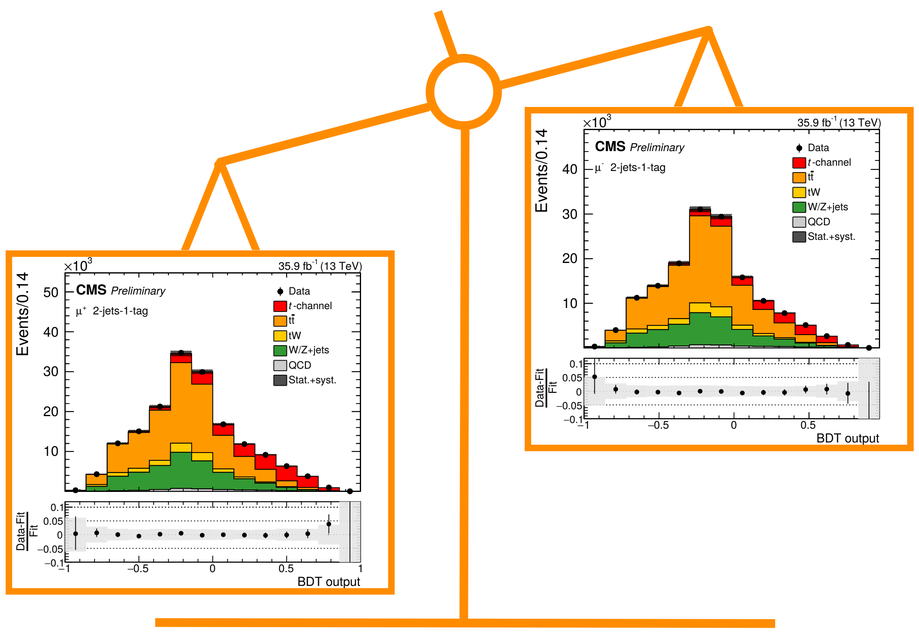
Signal extraction

- Train one **BDT** per lepton flavor in 2-jets–1-tag signal category
  - Backgrounds: $t\bar{t}$, W+jets, QCD
  - Most important input variable: light-quark jet $|\eta|$
- Apply BDT output to signal and $t\bar{t}$ control categories
- Simultaneous **maximum likelihood fit** on twelve different BDT outputs (three categories, two lepton charges and flavors)
  - Free parameters: $\sigma_{t\text{-ch,t}}$, $\sigma_{t\text{-ch,}\bar{t}}$, $R_{t\text{-ch}}$



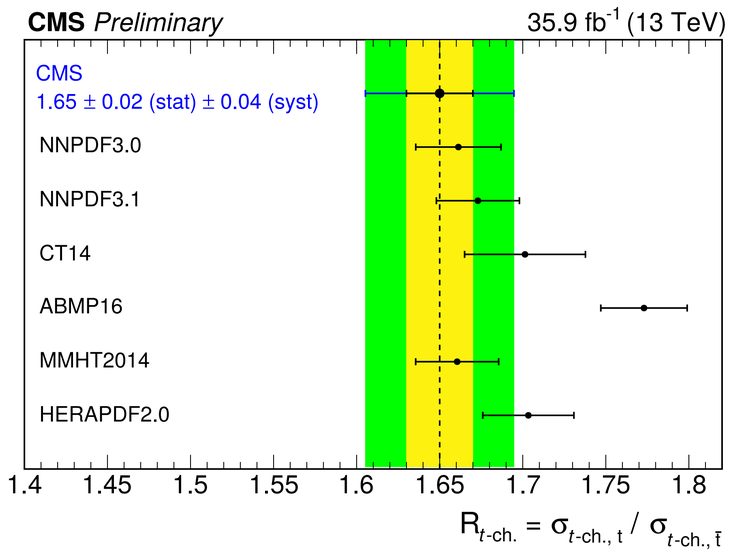


Results



$$\sigma_{t\text{-ch,t}} = 136.3 \pm 1.1(\text{stat}) \pm 20.0(\text{syst})\ \text{pb}$$
$$\sigma_{t\text{-ch,}\bar{t}} = 82.7 \pm 1.1(\text{stat}) \pm 13.0(\text{syst})\ \text{pb}$$
$$\sigma_{t\text{-ch,t}+\bar{t}} = 219.0 \pm 1.5(\text{stat}) \pm 33.0(\text{syst})\ \text{pb}$$
$$|f_{LV}V_{tb}| = 1.00 \pm 0.05(\text{exp}) \pm 0.02(\text{theo})$$

- Dominant uncertainties for $\sigma_{t\text{-ch}}$: Signal parton shower scale, jet energy scale
- Dominant uncertainties for $R_{t\text{-ch}}$: Signal PDF
- All results in agreement with SM



$R_{t\text{-ch}} = 1.65 \pm 0.02(\text{stat}) \pm 0.04(\text{syst})$

Agreement with most PDF sets

denise.muller@cern.ch