



Single top @ 13 TeV

Hamed BAKHSHIAN (IPM) on behalf of the CMS collaboration

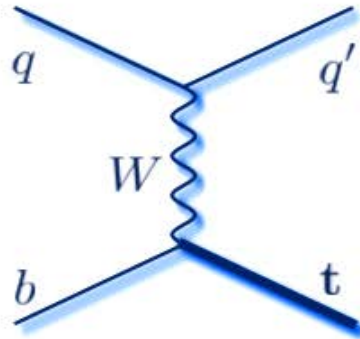
First METU-IPM joint conference on LHC physics
IZMIR, Turkey

Single Top Production at Hadron Colliders

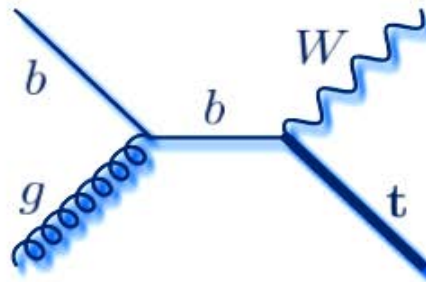
Introduction

Phys. Part. Nucl. 45, 2014 &
arXiv:1506.04072, 2015

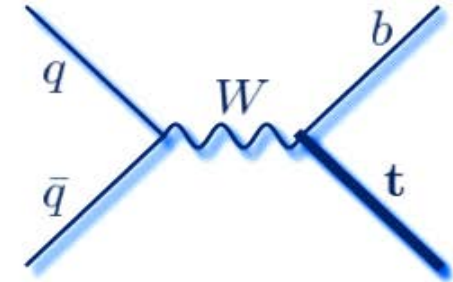
- single top quark production



t-channel

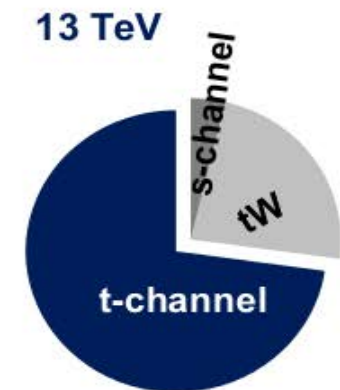
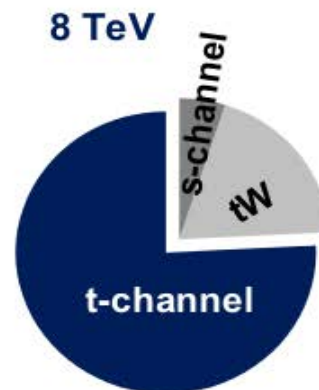
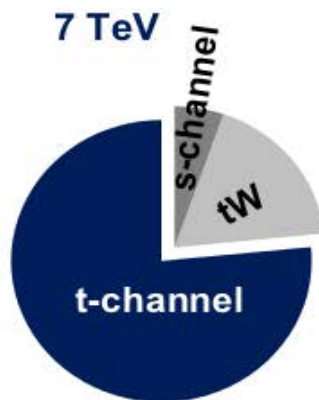


W associated production ("tW")



s-channel

- single top at different energies (approx. NNLO, $m_t = 173$ GeV, 4FS, MSTW2008)



$$\sigma_{t\text{-ch.}}^{7\text{TeV}} = 65.9_{-0.7}^{+2.1}(\text{scale})$$

$$+1.5_{-1.7}(\text{PDF}) \text{ pb}$$

$$\sigma_{t\text{-ch.}}^{8\text{TeV}} = 86.5_{-1.0}^{+2.8}(\text{scale})$$

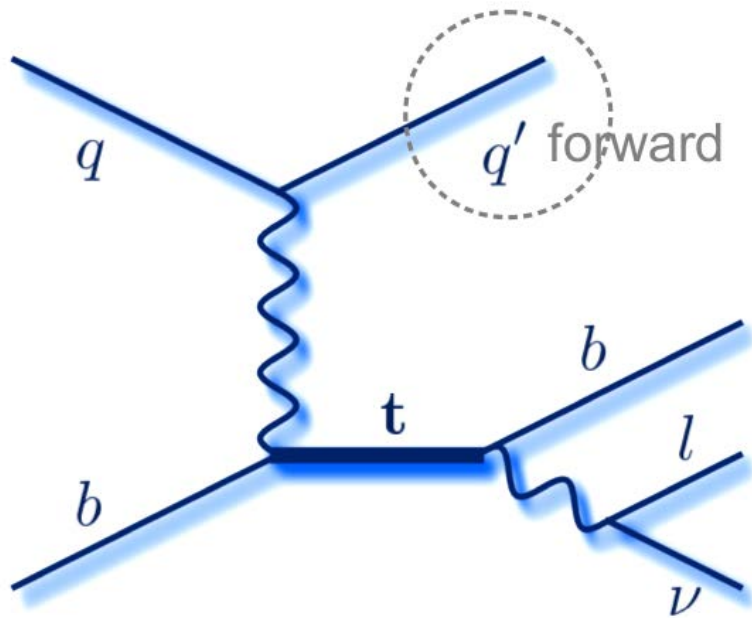
$$+2.0_{-2.2}(\text{PDF}) \text{ pb}$$

$$\sigma_{t\text{-ch.}}^{13\text{TeV}} = 218_{-5}^{+5}(\text{scale})$$

$$\pm 5(\text{PDF}) \text{ pb}$$

H

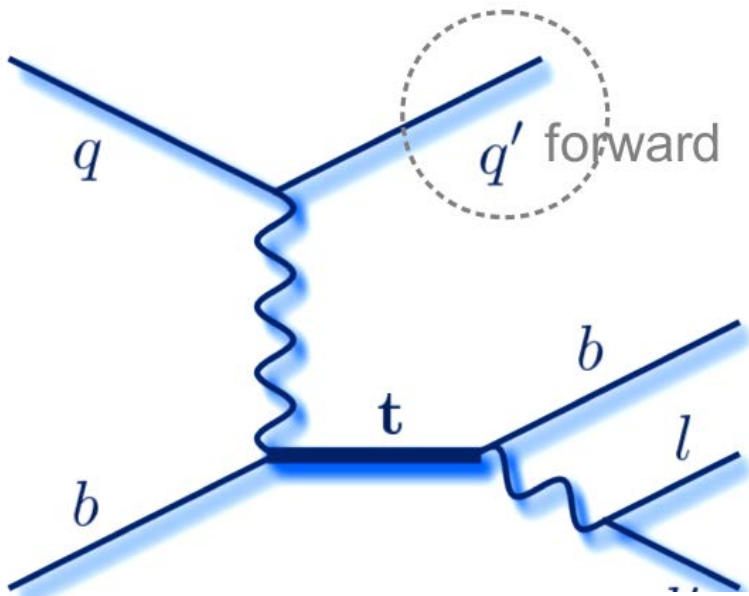
Single Top T-Channel Production



- Direct measurement of the $|V_{tb}|$
- Test of EWK coupling structure

$$\mathcal{L}_{Wtb}^{\text{SM}} \propto \bar{b} \begin{pmatrix} \gamma_\mu - \gamma_\mu \gamma_5 \\ V - A \end{pmatrix} t W^\mu + \text{h.c.}$$

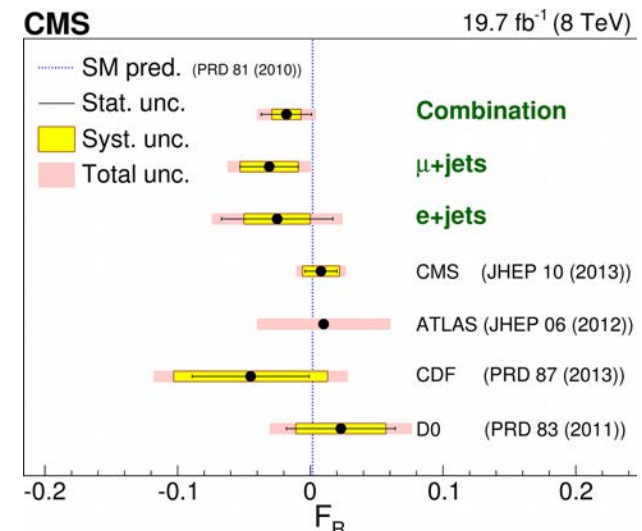
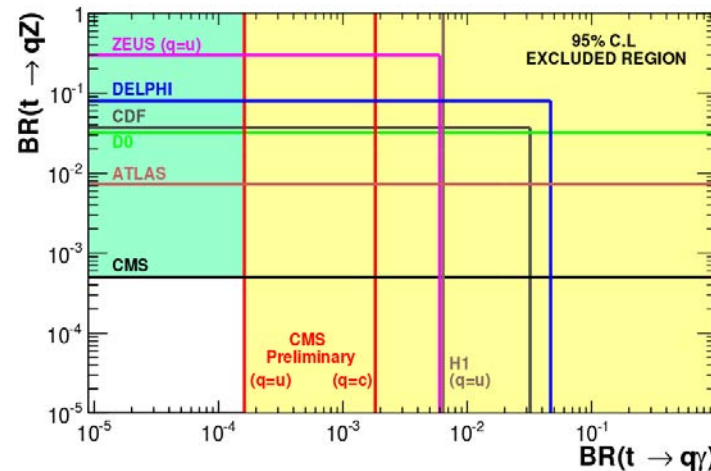
Single Top T-Channel Production



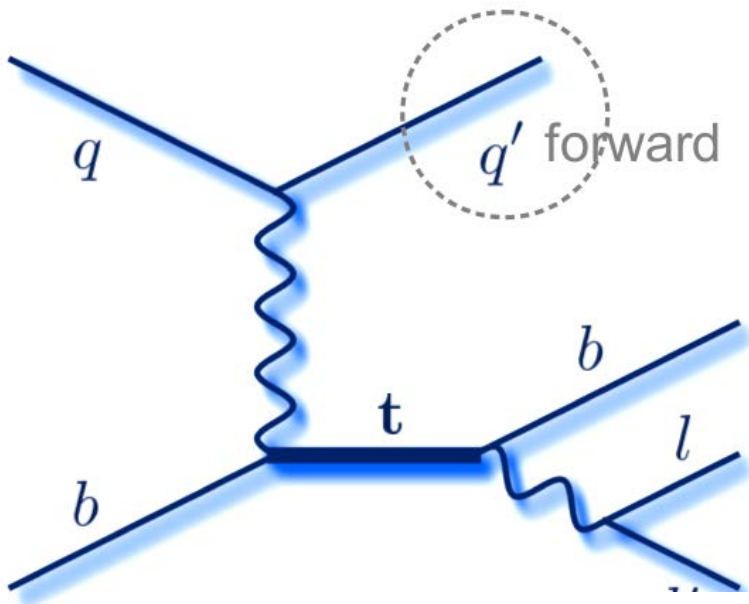
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- Study the properties of top



Single Top T-Channel Production



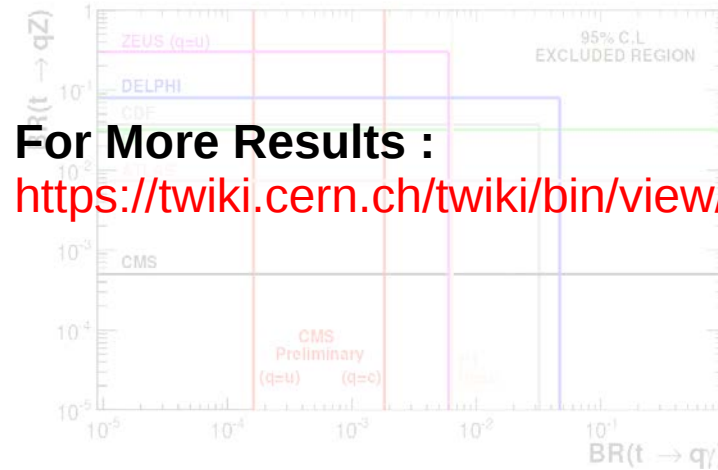
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- Study the properties of top

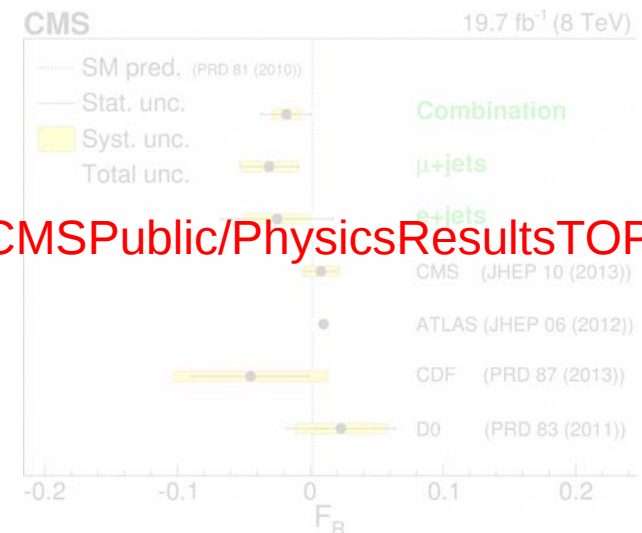
Signature :

**Lepton + MET +
b-tagged jet +
A forward jet**



For More Results :

<https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsTOP>



LHC Run II

- $\sim 42 \text{ pb}^{-1}$ of pp data with 50 ns bunching space was recorded at July 2015 by CMS
- Many developments (HW/SW) were implemented since 2012
- Some Early-Analysis were designed to validate the current status of the CMS
- Before we can show any sign of new physics, we have to prove that we are able to correctly re-discover SM

TOP Early Analysis

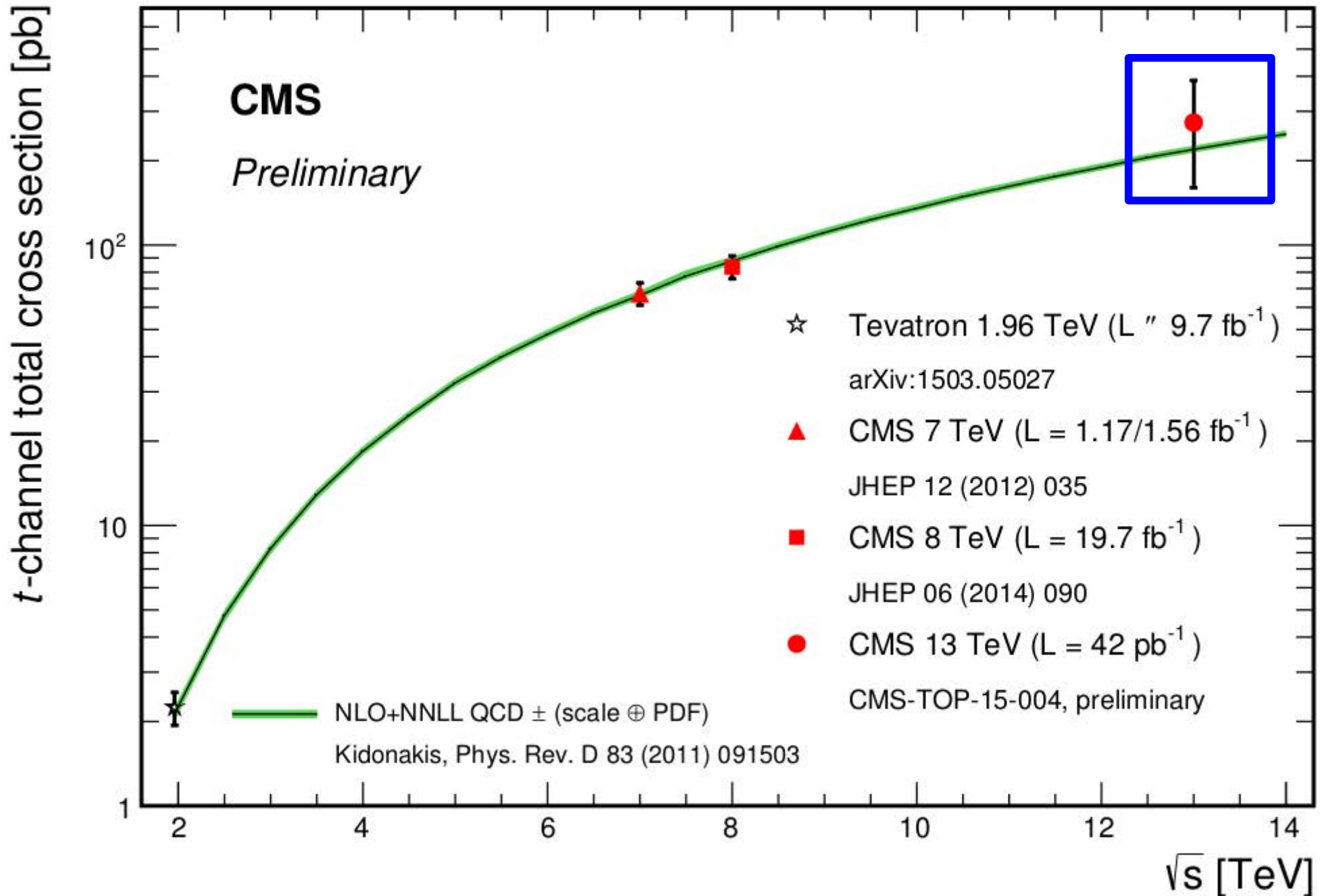
Date	ID	Analysis	Luminosity	Approved Figures and Tables	CDS Document
NEW September 2015	TOP-15-004	Measurement of the t-channel single top-quark cross section at 13 TeV	42/pb	PhysicsResultsTOP15004	CMS PAS TOP-15-004
NEW September 2015	TOP-15-005	Measurement of the inclusive and differential top quark pair production cross sections in lepton + jets final states at $\sqrt{s} = 13$ TeV	42/pb	PhysicsResultsTOP15005	CMS PAS TOP-15-005
NEW August 2015	TOP-15-010	First measurement of the differential cross section for ttbar production in the dilepton final state at $\sqrt{s} = 13$ TeV	42/pb	PhysicsResultsTOP15010	CMS PAS TOP-15-010
NEW August 2015	TOP-15-003	Measurement of the top quark pair production cross section in proton-proton collisions at $\sqrt{s} = 13$ TeV with the CMS detector	42/pb	PhysicsResultsTOP15003	CMS PAS TOP-15-003
NEW July 2015	CMS DP-2015/019	First look at top-quark selections with 13 TeV data	41/pb	PublicPlotsEPS2015	CMS DP-2015/019

TOP Early Analysis

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NEW September 2015				PhysicsResultsTOP15005	CMS PAS TOP-15-005
NEW August 2015				PhysicsResultsTOP15010	CMS PAS TOP-15-010
NEW August 2015				PhysicsResultsTOP15003	CMS PAS TOP-15-003
NEW July 2015	CMS DP-2015/019	First look at top-quark selections with 13 TeV data	41/pb	PublicPlotsEPS2015	CMS DP-2015/019

**Hunting the very first single-tops
lepton and jet performances
Forward region validation**

Early Summary



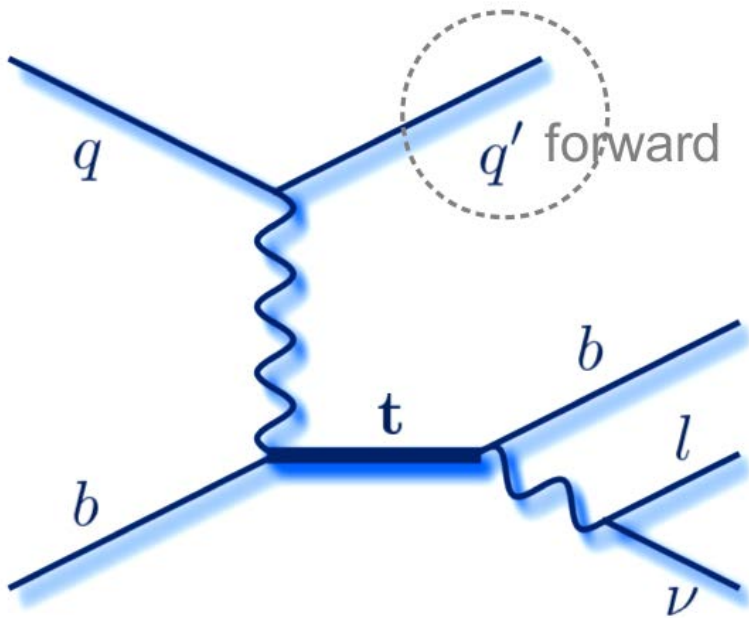
The first single-top measurement at 13 TeV

CMS-PAS-TOP-15-004

<http://cds.cern.ch/record/2052187>

Event Selection

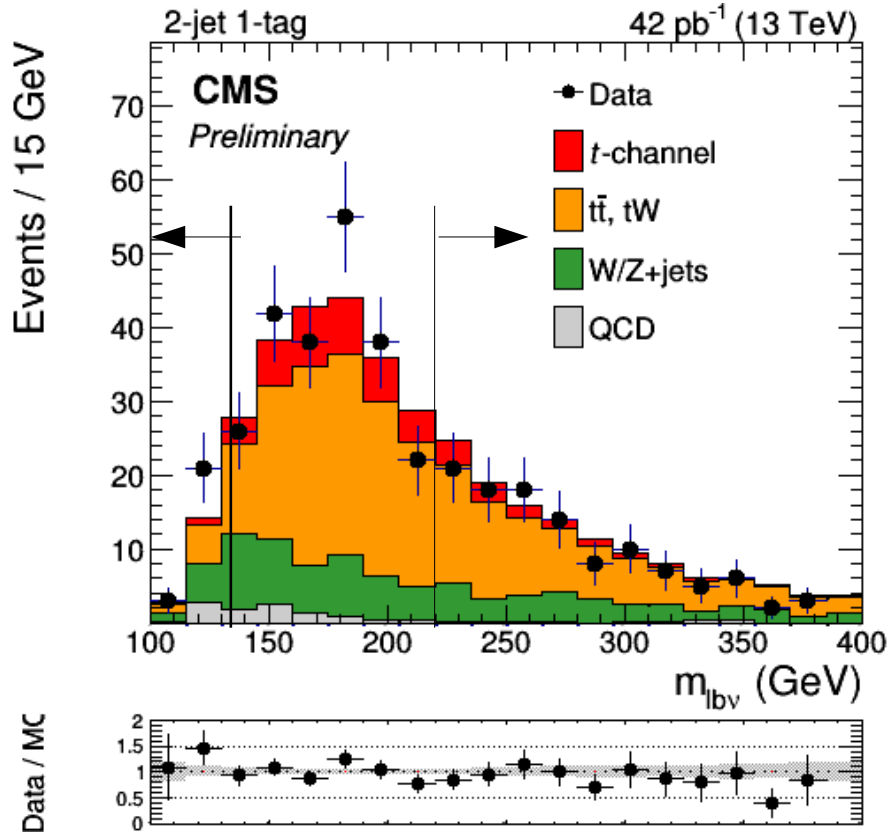
- Single Muon Trigger
- Exactly one Isolated Muon
 - $P_t > 22 \text{ GeV}$
 - $|\eta| < 2.1$
- 2 Jets
 - $P_t > 40 \text{ GeV}$
 - $|\eta| < 4.7$
 - One of them is b-tagged (MVA Based)
- $M_T^W > 50 \text{ GeV}$
- No extra cut on MET
- $130 < \text{Top Mass} < 225 \text{ (GeV)}$



Top Mass Reconstruction

- The W-Mass Constraint to find the p_z of neutrino
- For the cases with no solution, the MET is smeared within its uncertainty
- Top mass is the invariant mass of muon+b+neutrino

2J1T (SideBand) Selection



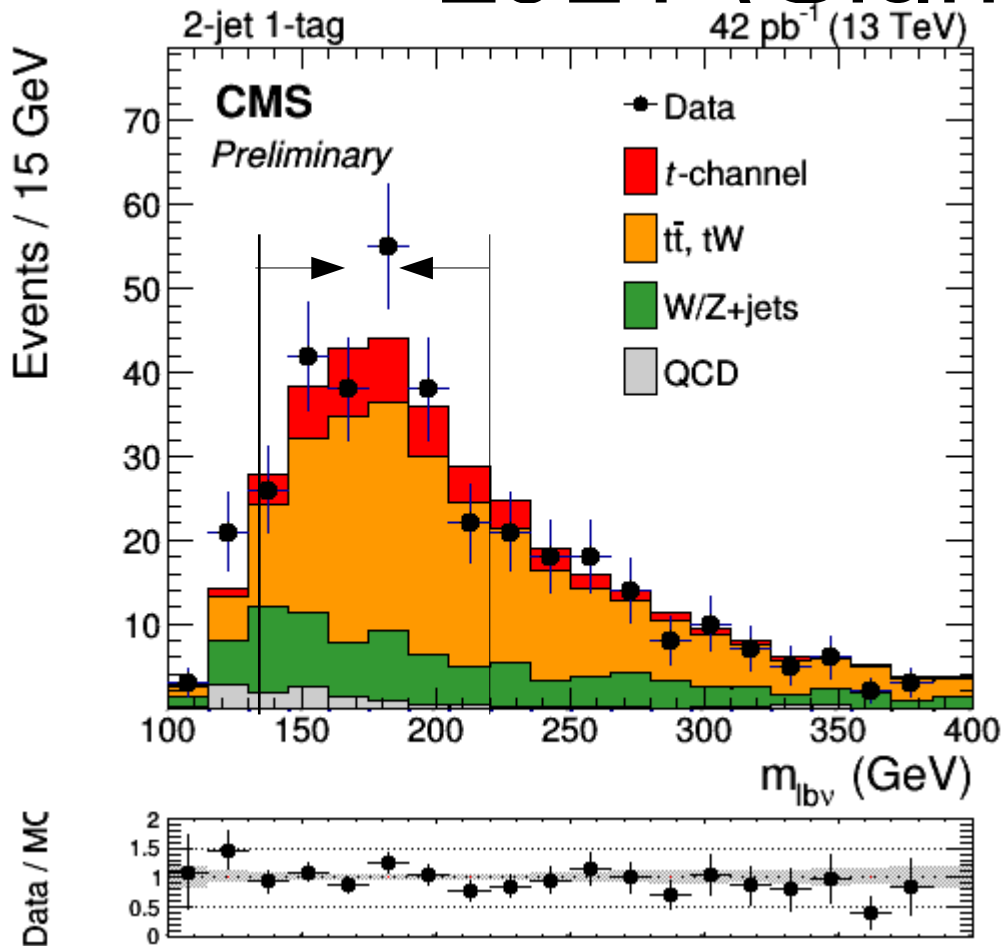
Process	SR	SB
$t\bar{t}$ & tW	157 ± 1	71.7 ± 0.4
W/Z +jets	40 ± 4	47 ± 4
QCD	10 ± 5	2 ± 1
t -channel	33 ± 1	7.2 ± 0.3
Total expected	240 ± 6	128 ± 4
Data	252	127

- **Data/MC = 99%**
- **Signal Ratio = 5%**
- **Backgrounds :**
 - **$t\bar{t}$ + tW (56%)**
 - **W/Z +Jets (37%)**
 - **QCD (1%)**

This region is used to validate the simulation of W/Z Background

- We validate and trust the $t\bar{t}$ simulation (see next slides)
- The normalization of W +Jets is extracted from data
- New [amc@nlo](#) generator seems to be able to produce W +HF Jets perfectly

2J1T (Signal) Selection

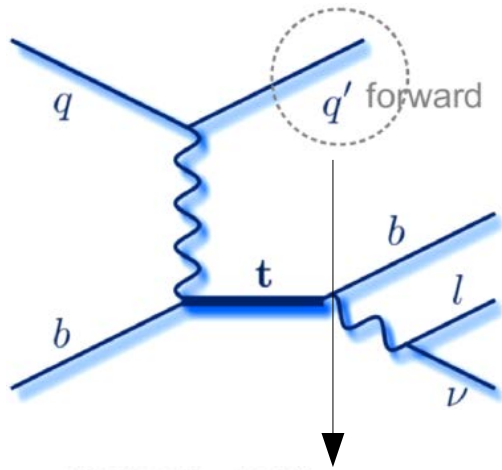


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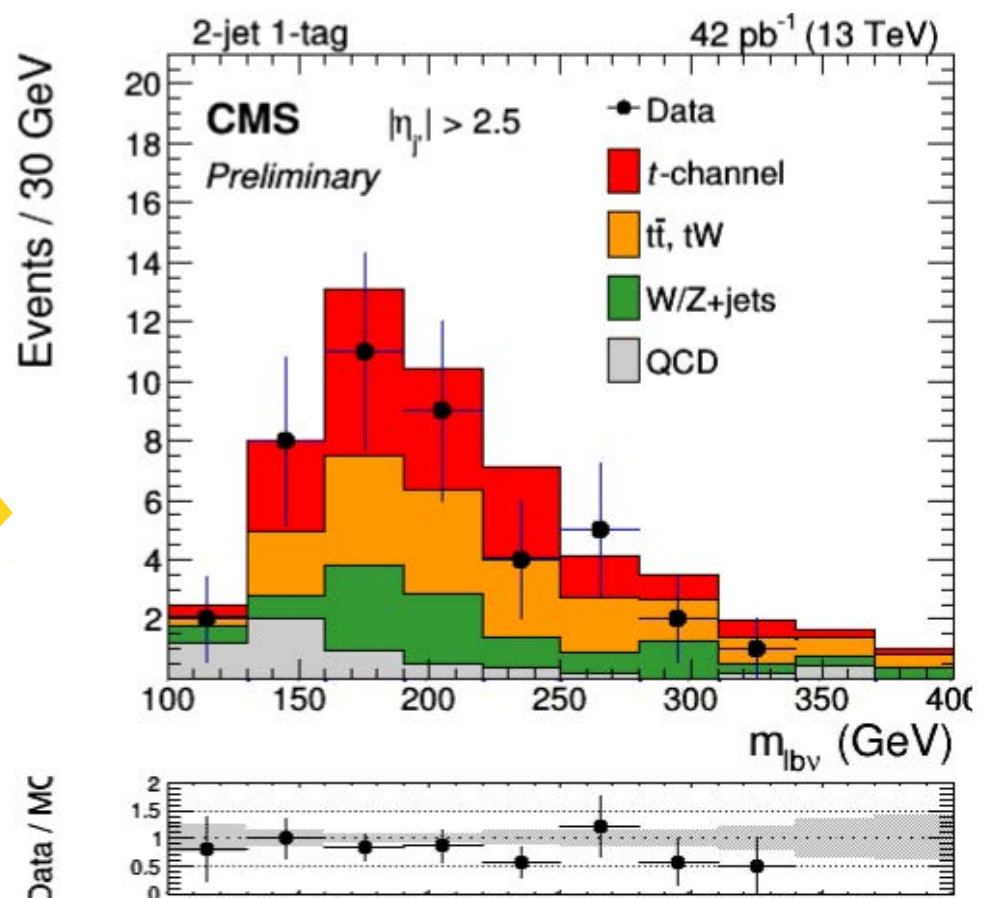
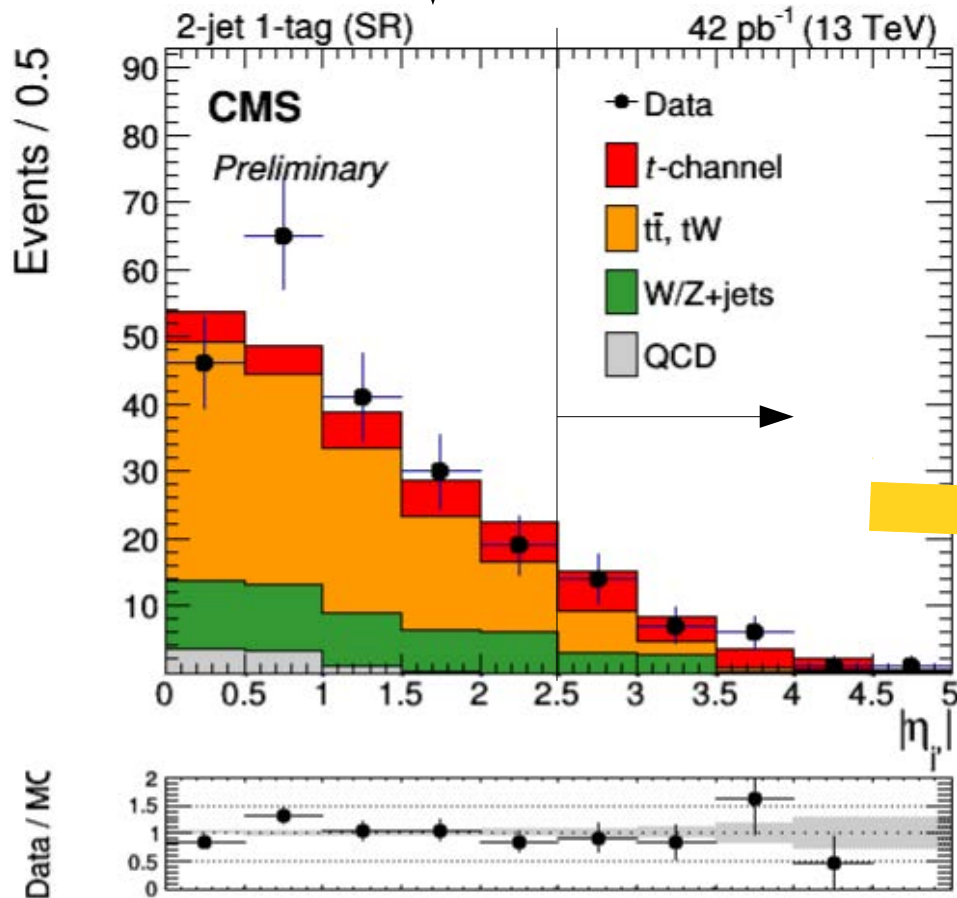
- **Data/MC = 105%**
- **Signal Ratio = 14%**
- **Backgrounds :**
 - **$t\bar{t}$ + tW (62%)**
 - **W/Z +Jets (16%)**
 - **QCD (4%)**

The goal is to find/use the most sensitive variable(s) to separate signal and backgrounds

Pseudorapidity of the non-tagged jet, $|\eta_j|$

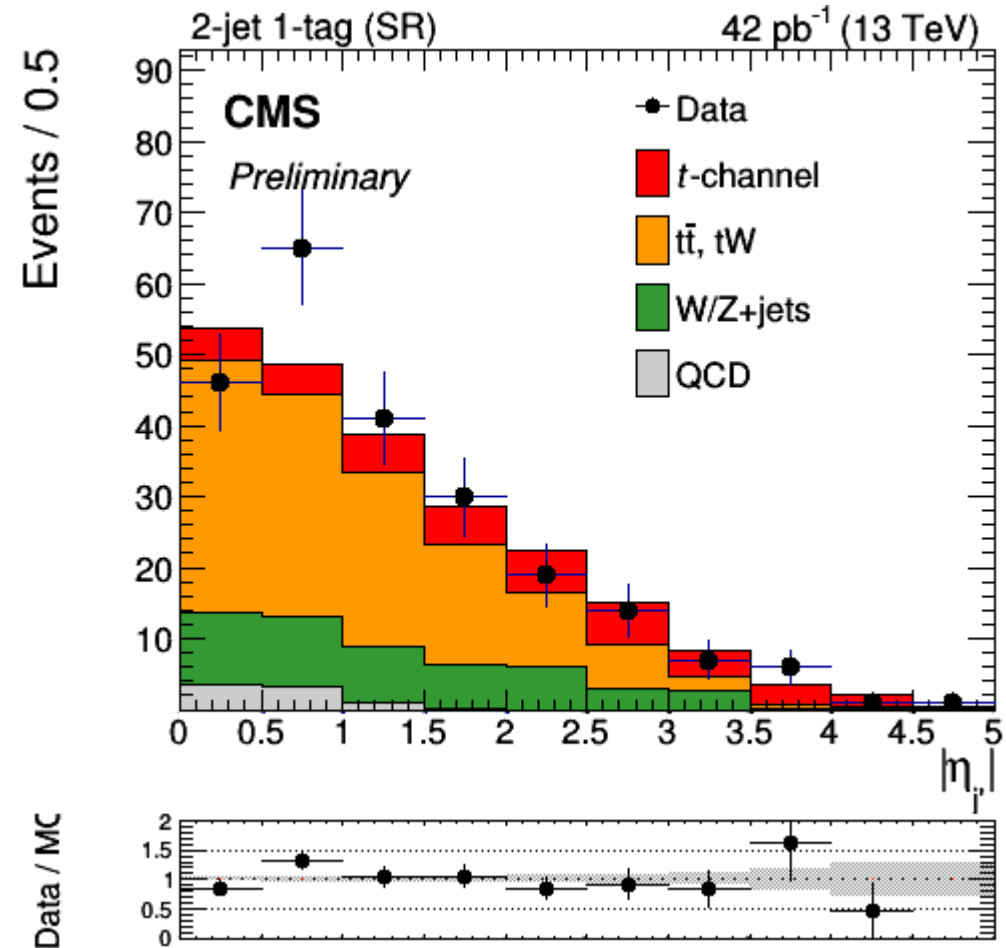


Signature of the signal:
The non-tagged jet tends to be forward



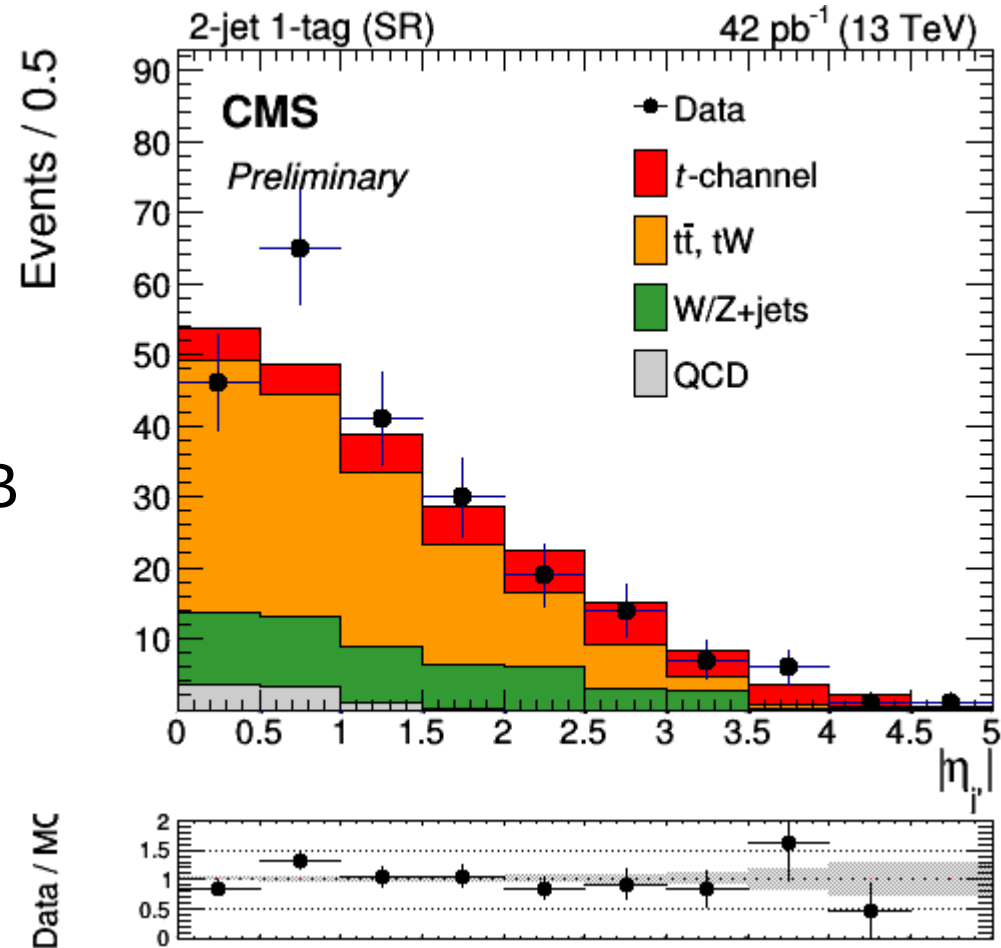
Analysis Strategy

- Binned Likelihood Fit on the shape of $|\eta|$ of j'



Analysis Strategy

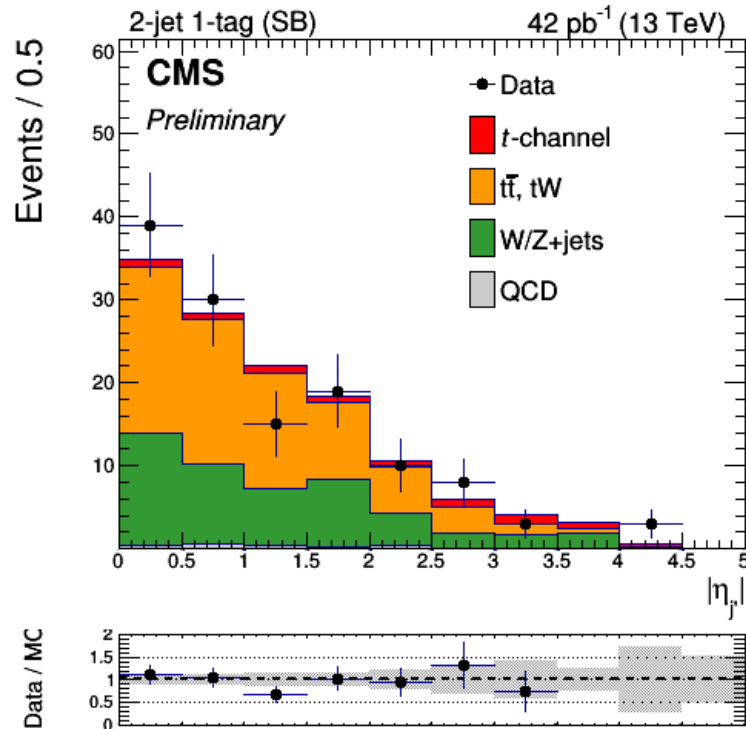
- Binned Likelihood Fit on the shape of $|\eta|$ of j'
- Backgrounds
 - W/Z+Jets
 - MC is already validated in SB



Analysis Strategy

- Binned Likelihood Fit on the shape of $|\eta|$ of j'

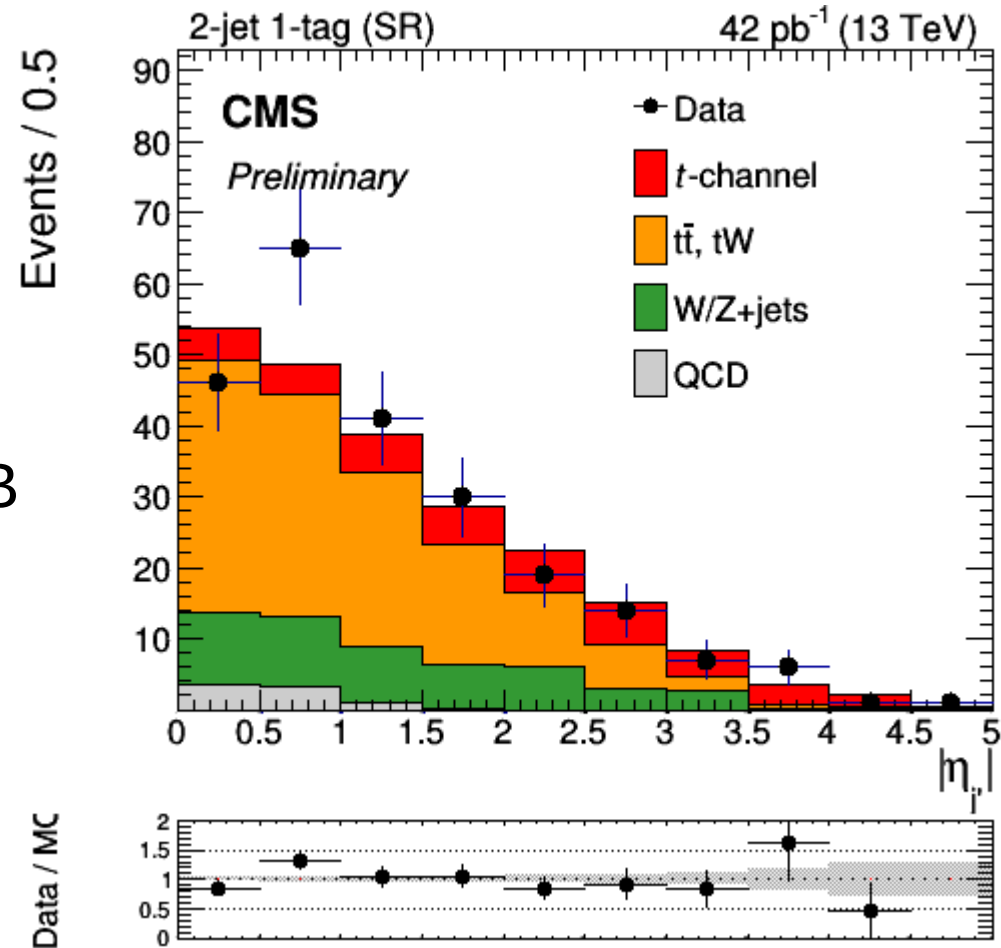
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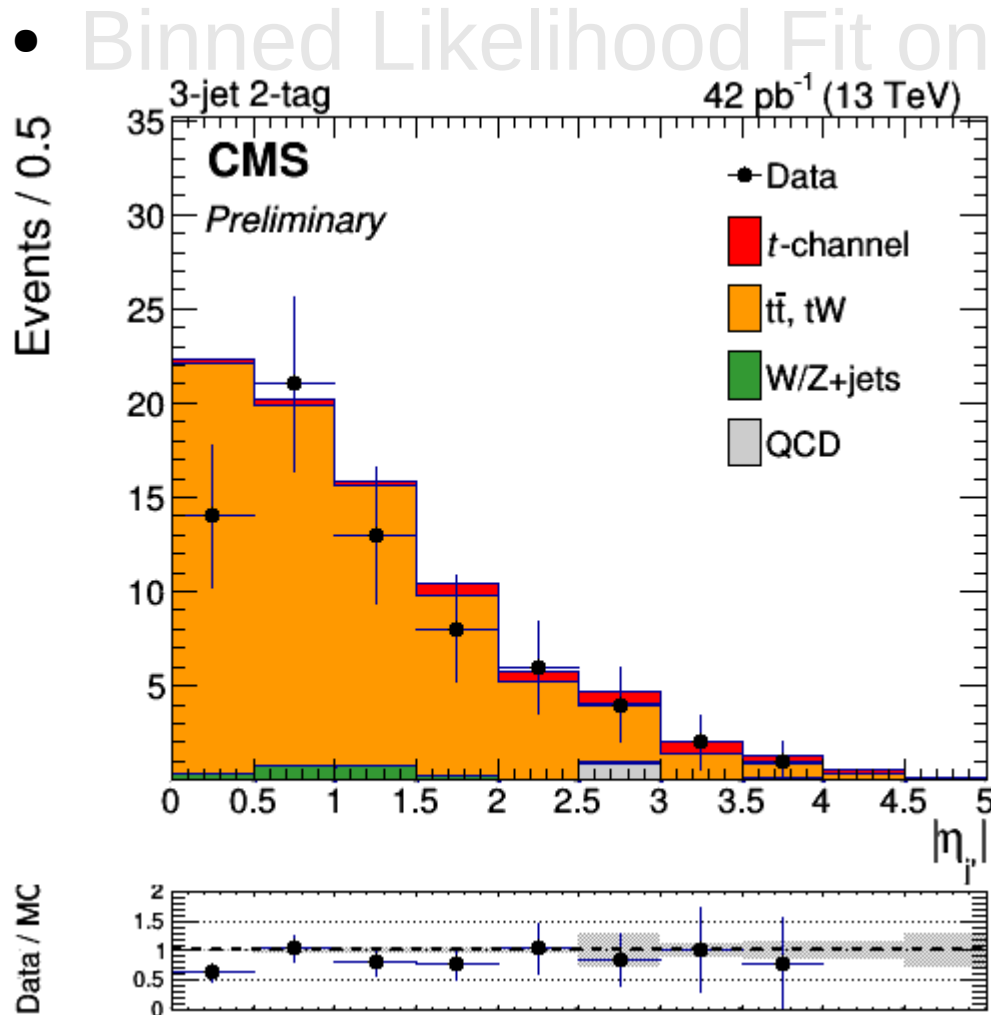
- Data/MC = 99%
- Signal Ratio = 5%
- Backgrounds :
 - $t\bar{t}$ + tW (56%)
 - W/Z +Jets (37%)
 - QCD (1%)

Analysis Strategy

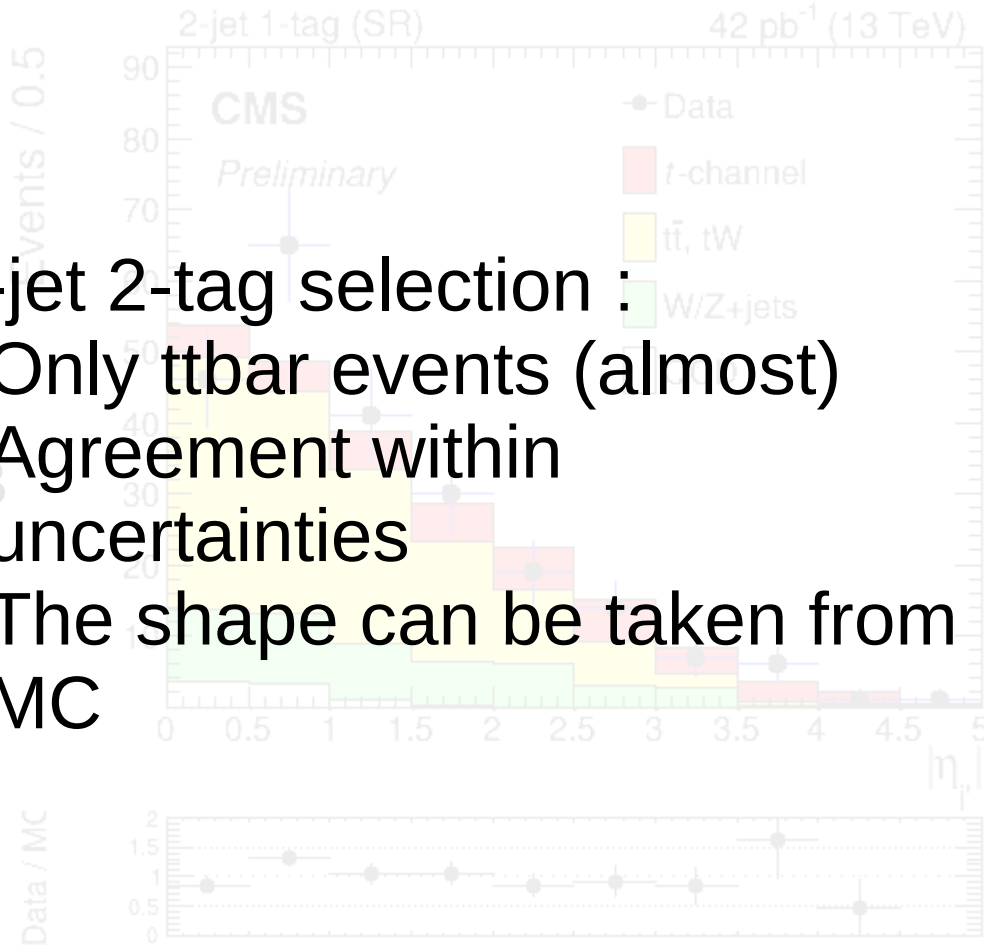
- Binned Likelihood Fit on the shape of $|\eta|$ of j'
- Backgrounds
 - W/Z+Jets
 - MC is already validated in SB
 - $t\bar{t}$
 - Shape is validated in data
 - Normalization from fit



Analysis Strategy

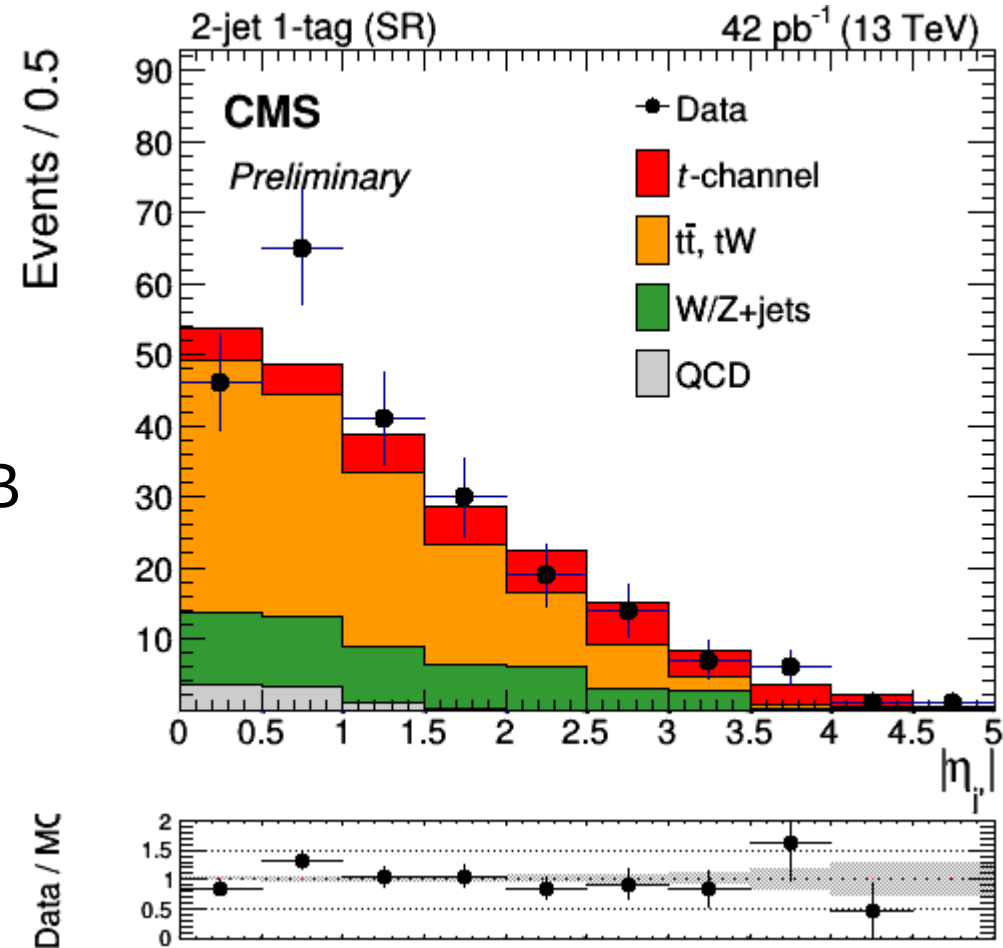


- 3-jet 2-tag selection :
- Only ttbar events (almost)
 - Agreement within uncertainties
 - The shape can be taken from MC



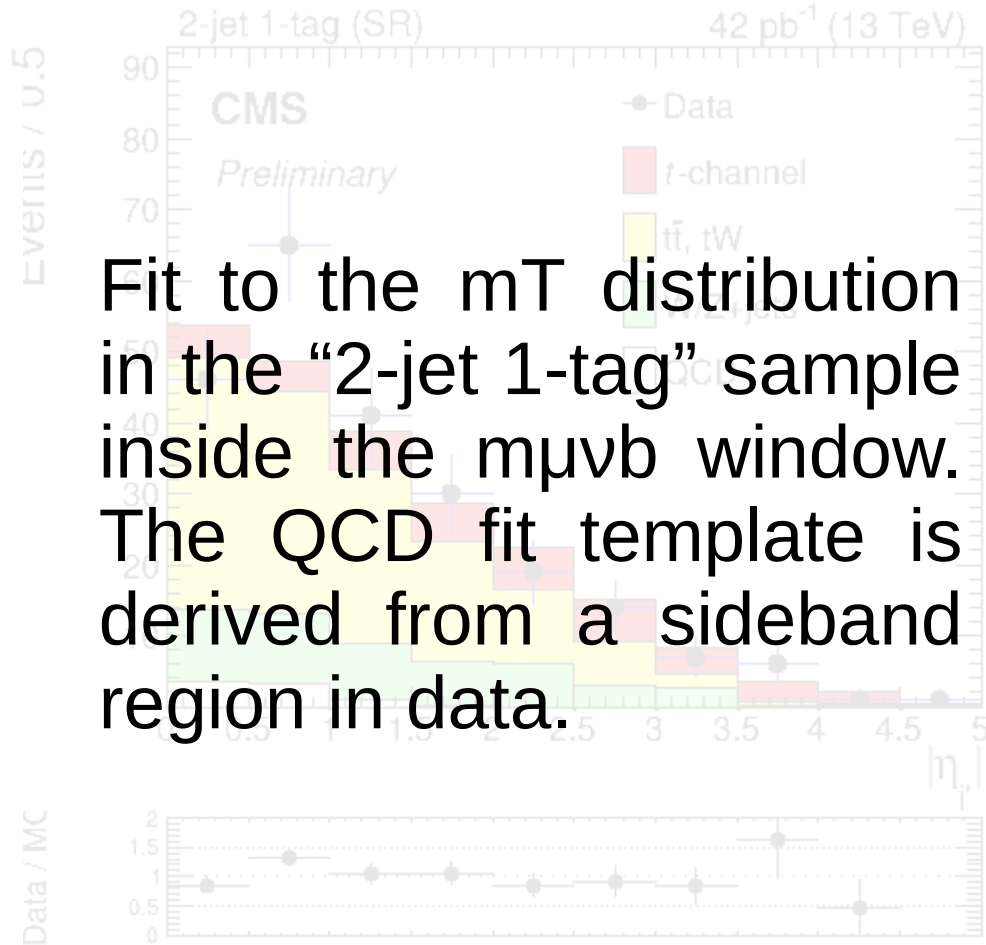
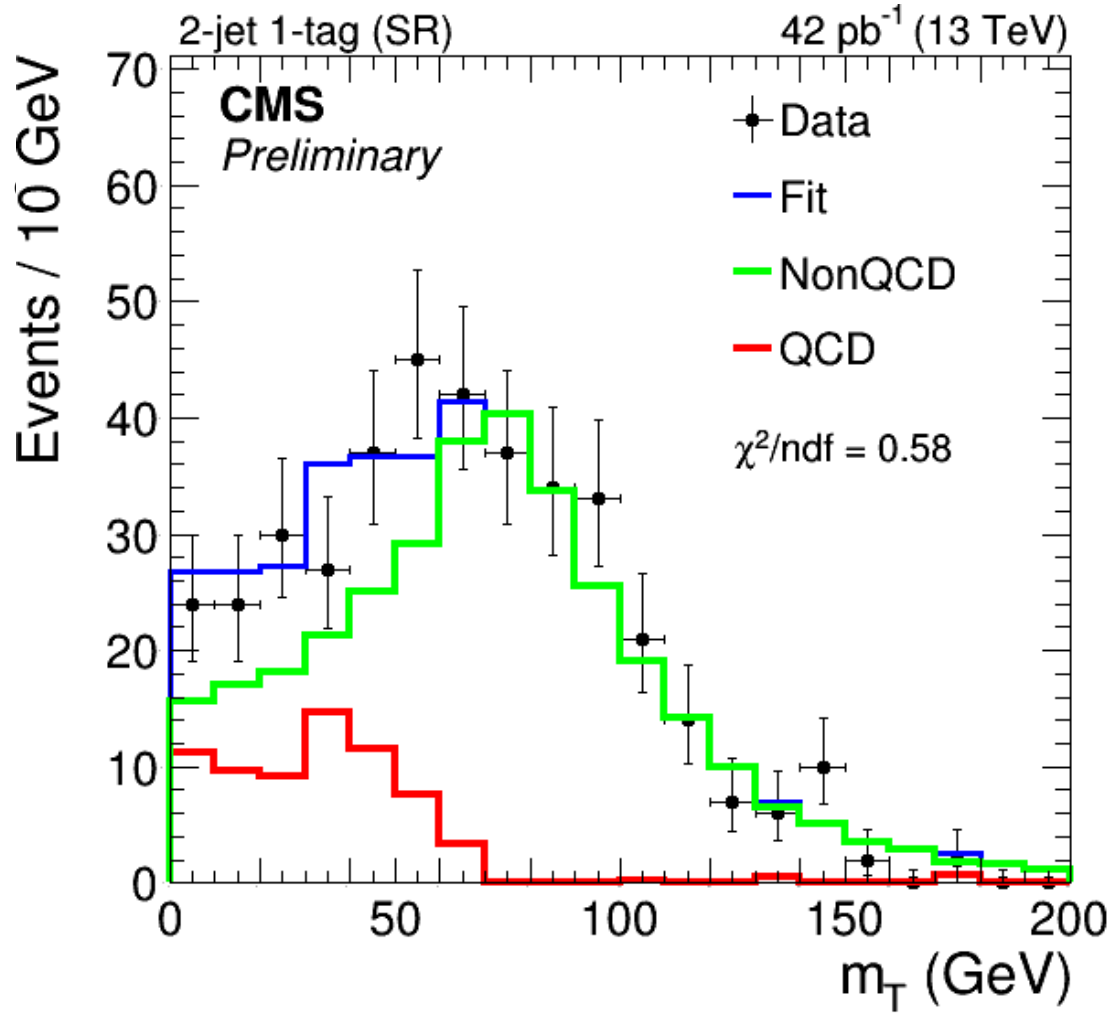
Analysis Strategy

- Binned Likelihood Fit on the shape of $|\eta|$ of j'
- Backgrounds
 - W/Z+Jets
 - MC is already validated in SB
 - ttbar
 - Shape is validated in data
 - Normalization from fit
 - QCD
 - Shape from data (Non-Isolated Leptons)
 - Yield from fit on the shape of $m_T(W)$ (before cut)



Analysis Strategy

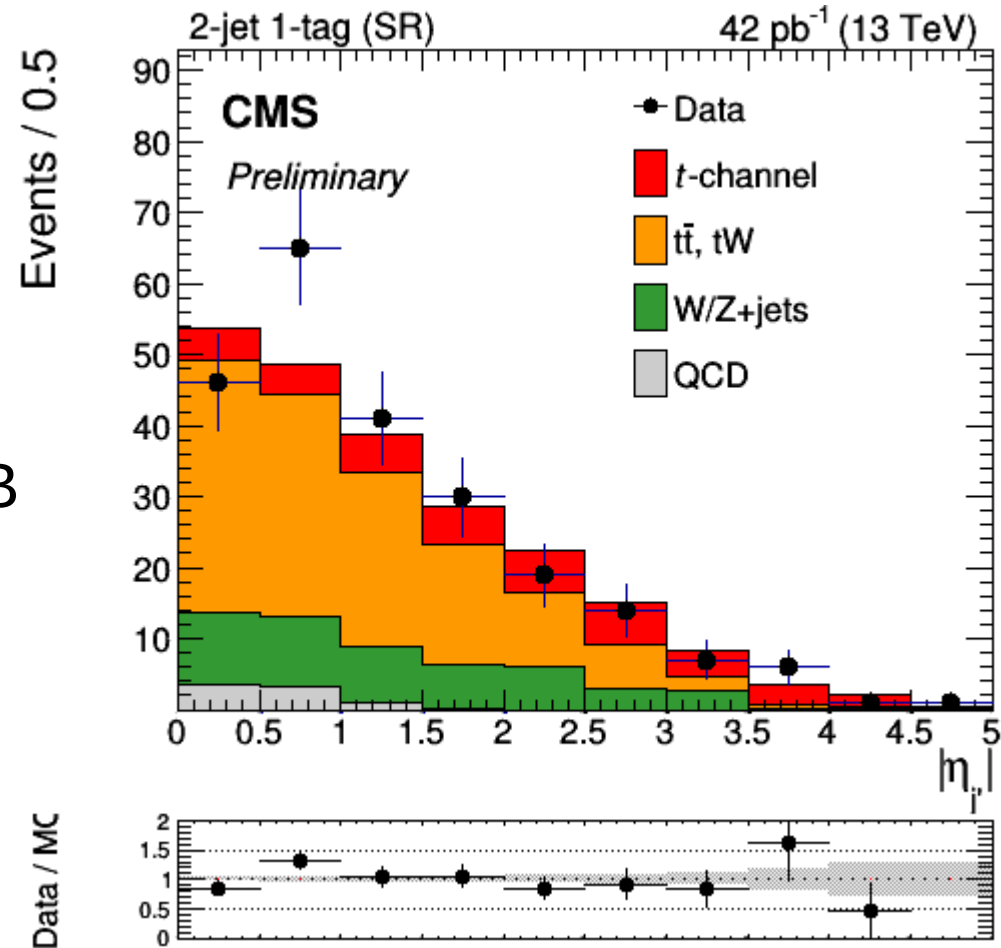
- Binned Likelihood Fit on



Fit to the m_T distribution in the “2-jet 1-tag” sample inside the $m_{\mu\nu b}$ window. The QCD fit template is derived from a sideband region in data.

Analysis Strategy

- Binned Likelihood Fit on the shape of $|\eta|$ of j'
- Backgrounds
 - W/Z+Jets
 - MC is already validated in SB
 - ttbar
 - Shape is validated in data
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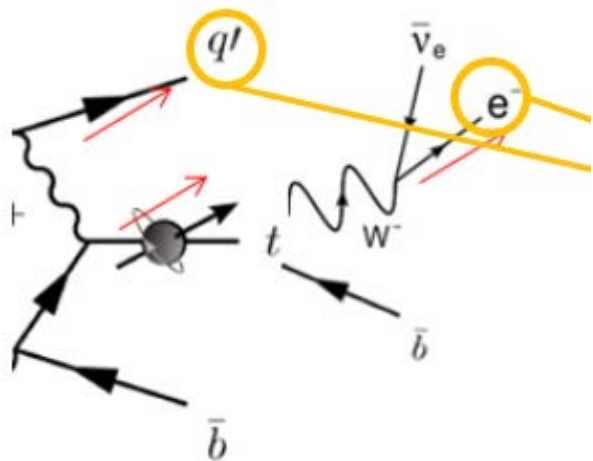


Fit Results

$$\sigma_{t\text{-ch.}} = 274 \pm 98 \text{ (stat.) pb}$$

- observed significance: 3.5σ
- Expected significance: 2.7σ

$\cos(\theta^*)$: the angle between the charged lepton and the light jet in the rest frame of the top quark

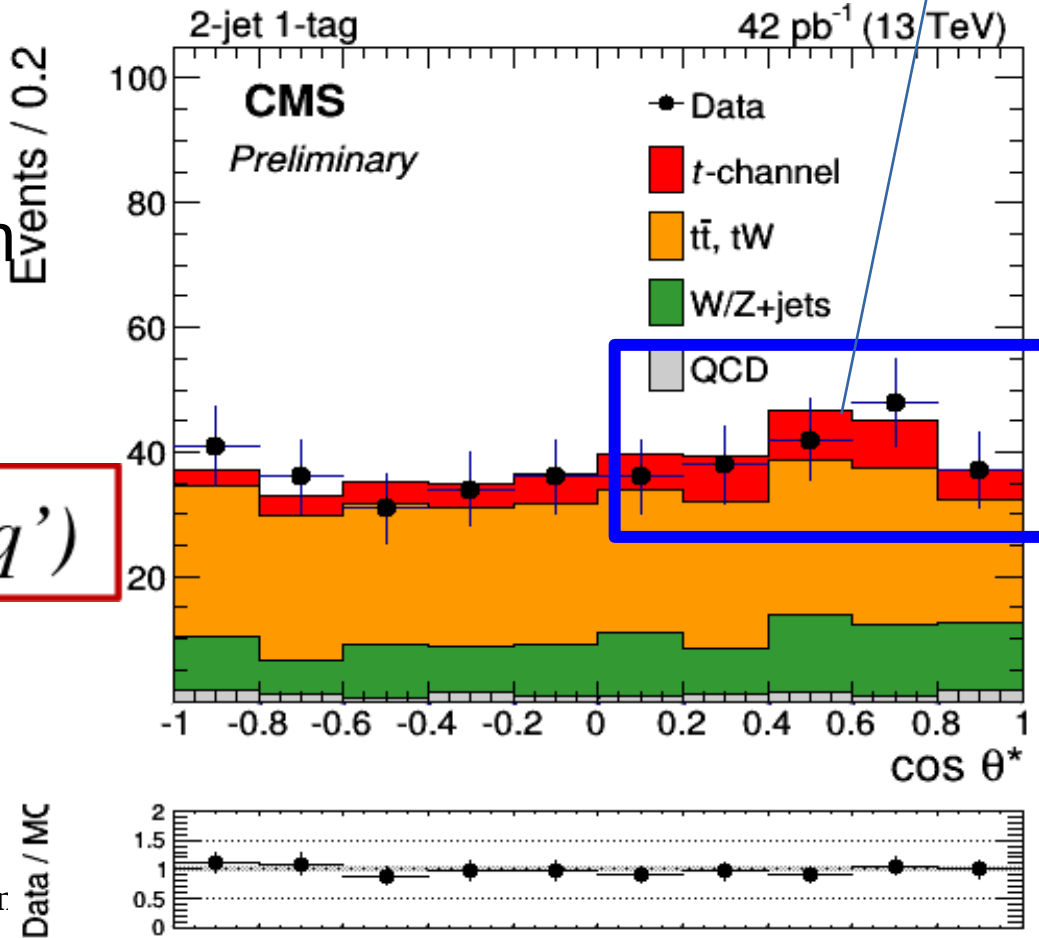


$$\theta^* \equiv \angle(l, q')$$

Hamed BAKHSHIAN (IPM)

First METU-IPM joir

Distinct feature of single-top
Observed even with low statistics



Systematic uncertainties

Uncertainty source	$\Delta\sigma_{t\text{-ch}} / \sigma_{t\text{-ch}}^{\text{obs}}$
Statistical uncertainty	36%
JES	17%
JER	1.1%
b-tagging	5.6%
Muon trigger/reconstruction	3.4%
QCD extraction	1.1%
Signal generator	1.9%
Factorization and renormalization scales (Q^2)	3.3%
PDF	4.5%
MET	1.2%
Pileup	1.4%
Total systematic uncertainty	19%
Luminosity	12%
Total uncertainty	42%

Conclusion

- CMS has performed the first single-top cross section measurement at the LHC using the first proton collisions

- Single top is produced in t-channel at 13 TeV (!!)

$$\sigma_{t\text{-ch}} = 273.4 \pm 97.6(\text{stat}) \pm 52.0(\text{syst}) \pm 26.0(\text{lumi}) \text{ pb}$$

$$= 273.4 \text{ pb} \pm 42\% \quad \Rightarrow V_{tb} = 1.12 \pm 0.21$$

$$\left[\sigma_{t\text{-ch.}}^{\text{theo.}} = 218 \pm 7 \text{ pb} \right]$$

- CMS is ready to analyze 13 TeV data
- More precise cross section is expected from the larger data sample in 13 TeV
 - Different top quark properties together with the tWb vertex structure will be investigated
- Stay tuned!

A photograph taken from a high-angle window looking out over a coastal town and mountains. The window frame is dark and visible in the foreground. The view outside shows a blue sea, a town with colorful buildings, and distant mountains under a clear blue sky. The text "Thank you" is overlaid in the center of the image.

Thank you