Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

PHYSICS AT THE TERA SCALE
Helmholtz Alliance

CMS Germany
BMBF FSP-CMS

Bundesministerium für Bildung und Forschung

Cross Section Measurement for the Production of Isolated Muons, Jets and Top Quarks with CMS

Holger Enderle, Martin Görner, Peter Schleper,
Jörn Lange, Georg Steinbrück, Roger Wolf

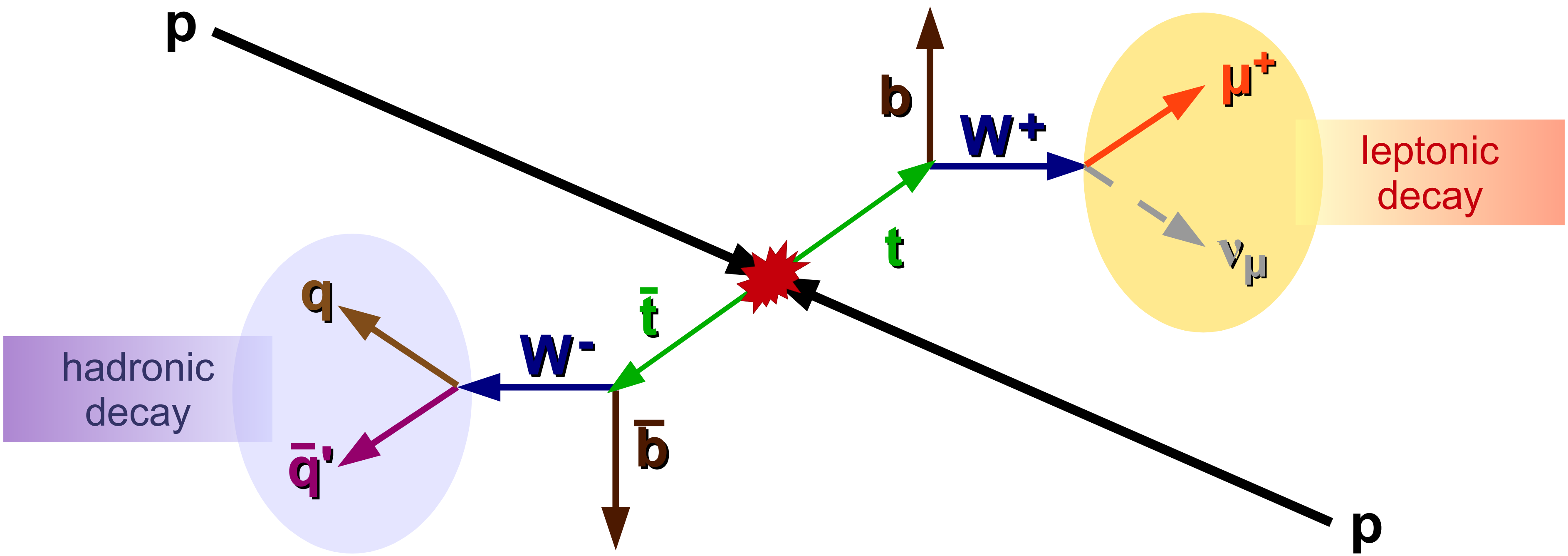
(no official CMS results)

4th Annual Workshop of the Helmholtz Alliance "Physics at the Terascale"
1-3 December 2010

Internationales Congress Center Dresden

Top and μ + Jets Physics

– main goal: σ(tt) in semileptonic tt decay with muon in final state
→ detector signature: 1 isolated muon and additional jets



– same signature for the production of a W-Boson in association with additional jets
→ idea: study the transition from W+jets dominated phase spaces to toplike phase spaces in an isolated μ+jets measurement

Motivation μ + Jets

- support σ(tt) measurement by σ(μ + jets) measurement:
  - high statistics
  - similar phase space
  - differential in p_t, η, φ (μ)

    → μ: directly observable
  - can be scaled to inclusive cross section

    → independent of luminosity, less dependent on JES

Analysis strategy:

- use selection equivalent to official top selection

  → measure μ+jets cross sections (≥ 1,2,3,4 jets)

  → study transition from μ+jets to tt dominated phase spaces

- inclusive 4-jet bin

  → unfolding to inclusive σ(tt) :

  a) only correct for remaining background

  b) use additional b-tag

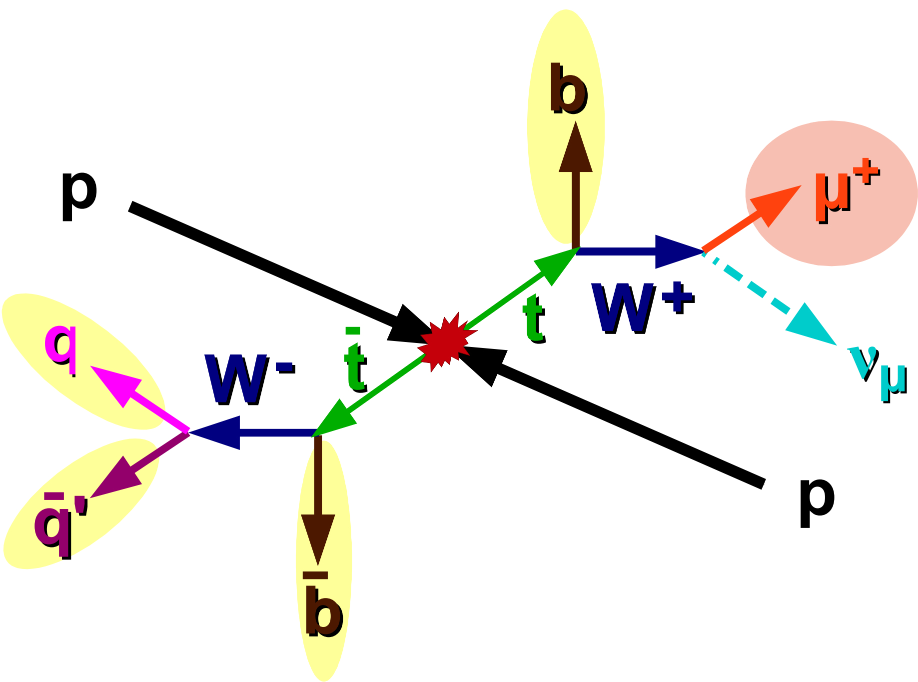
Event Selection

Data:

– 35 pb^{-1}, $\sqrt{s}$ = 7 TeV pp collisions

Simulation:

– tt, Z+jets, W+jets, QCD

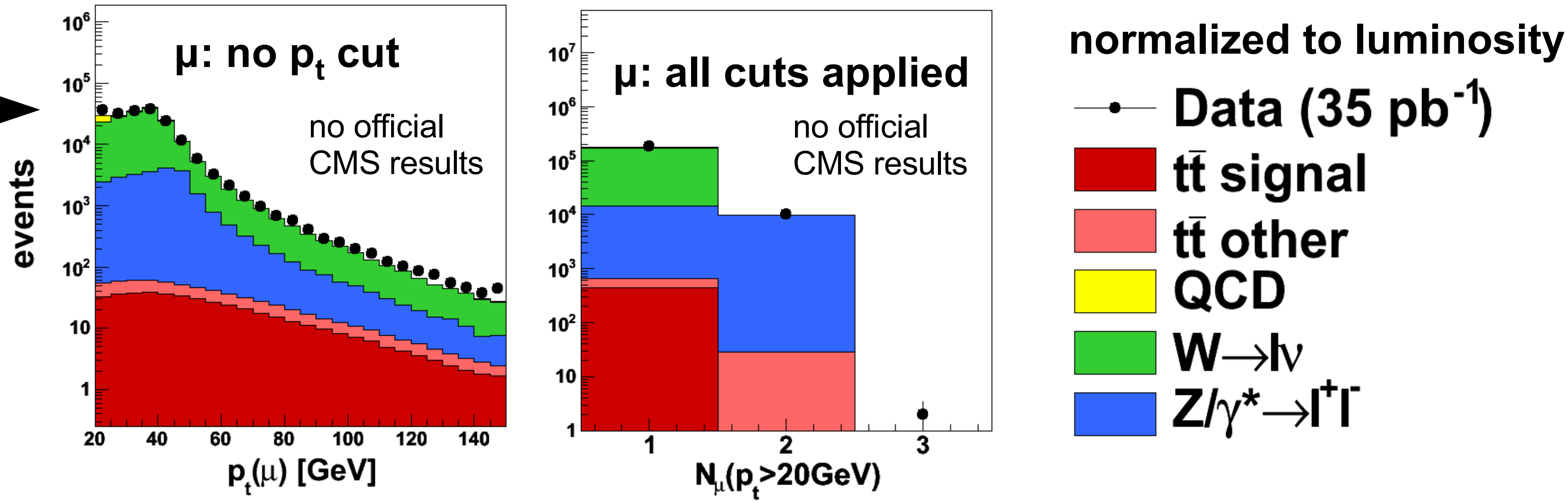


Selection:

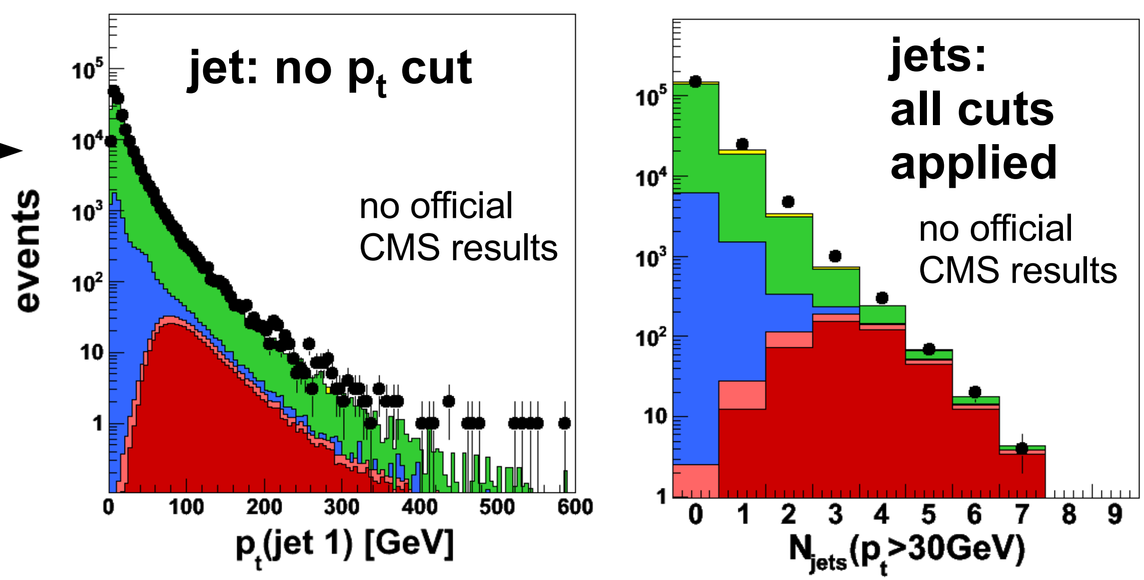
1. Trigger (muon with p_t > 9 / 15 GeV)
2. Good primary vertex
3. Muon selection:
   - p_t > 20 GeV, $|\eta|$ < 2.1
   - good track qualities
   - coming from PV
   - no nearby jet
   - isolated
4. Veto on additional lepton
5. Jet selection:
   - p_t > 30 GeV, $|\eta|$ < 2.4,
   - cut on noisy cells in calorimeter
6. B-tagging:
   - track counting algorithm

Event Selection in Data

trigger and PV selection →

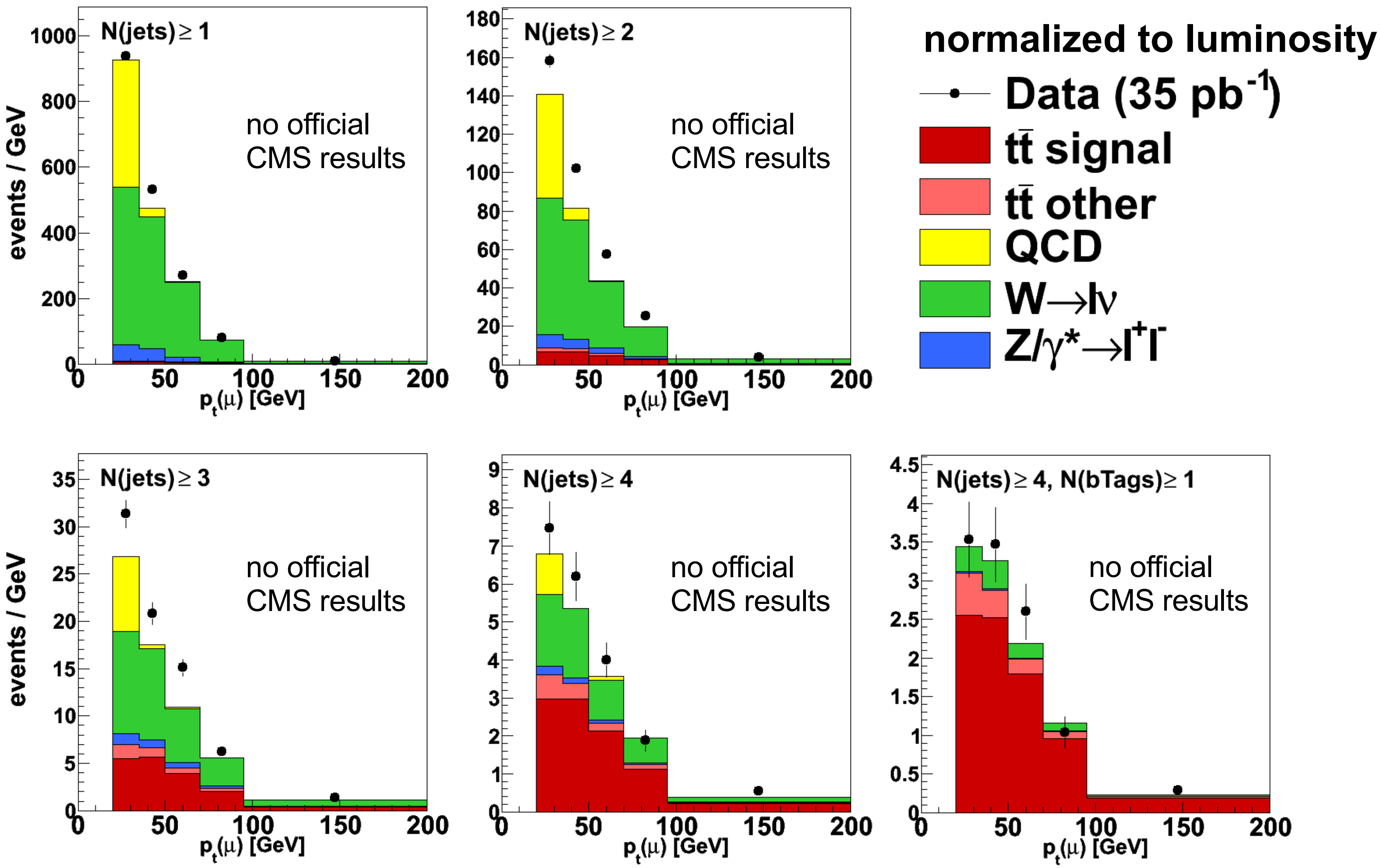


muon selection & lepton veto →



– only statistical errors
– good agreement between MC and data in μ-selection
– jet selection agrees within 20%

After Final Data Selection



– only statistical errors
– QCD normalized to data driven estimate
– N(jets): transition from W+jets dominated to top dominated phase space

Cross Section Determination

$$\sigma = \frac{N(data) - N(bkg)}{\varepsilon \cdot L}$$

– **subtract background**
– **correct for detector and reco effects**
– **divide by luminosity**

μ+jets:

– **N(bkg)**: estimate QCD from a template fit, Z+jets from simulation
– **ε(μ+jets)**: MC based efficiency (for each bin)
→ first results from data driven methods: good agreement for μ efficiencies
– definition of **phase space**:
- 1 μ: $|\eta| < 2.1$, $p_t > 20$ GeV,
from tt or W+jets (including μ from τ)
- ≥ 1/2/3/4 jets: $|\eta| < 2.4$, $p_t > 30$ GeV

top:

– **N(bkg):** in addition W+jets background (from simulation)
– **ε(tt)**: same method as for μ+jets

QCD Estimation

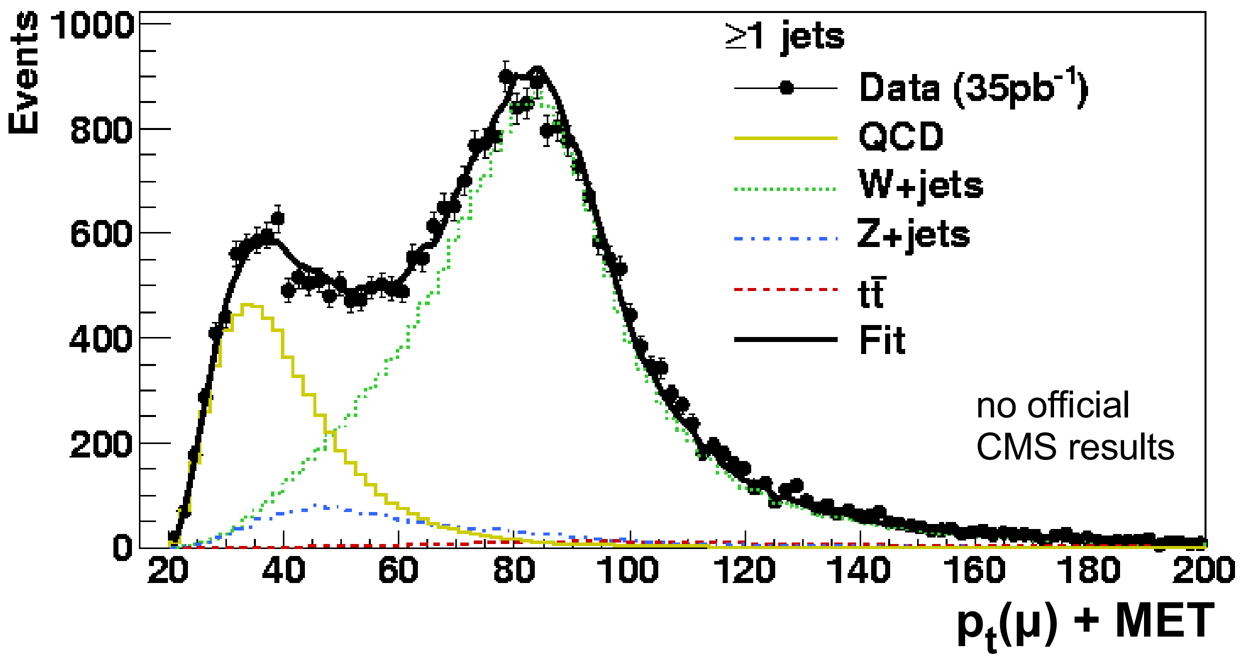
Template fit:

– $p_t(\mu)$ + MET

– different shapes for tt, Z+jets, W+jets, QCD

– determine template for each contribution
(take shape from simulation, shape of QCD from control region with non isolated muons)

– perform combined fit to data
→ get scaling w.r.t. MC prediction for QCD

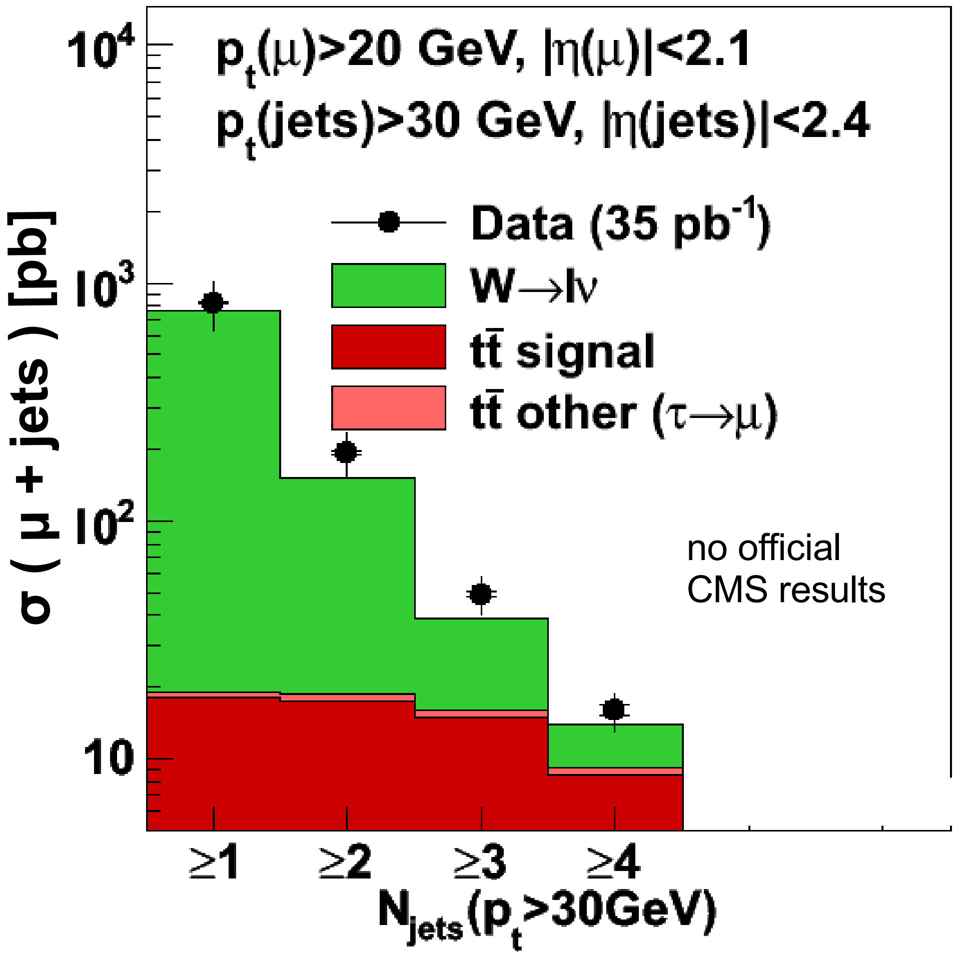


- results in recent data:

N(jets)	QCD scale factor
≥ 1	2.11 ± 0.04
≥ 2	2.77 ± 0.13
≥ 3	3.10 ± 0.46
≥ 4	3.57 ± 1.60

(only statistical errors from fit)

μ+jets Cross Sections



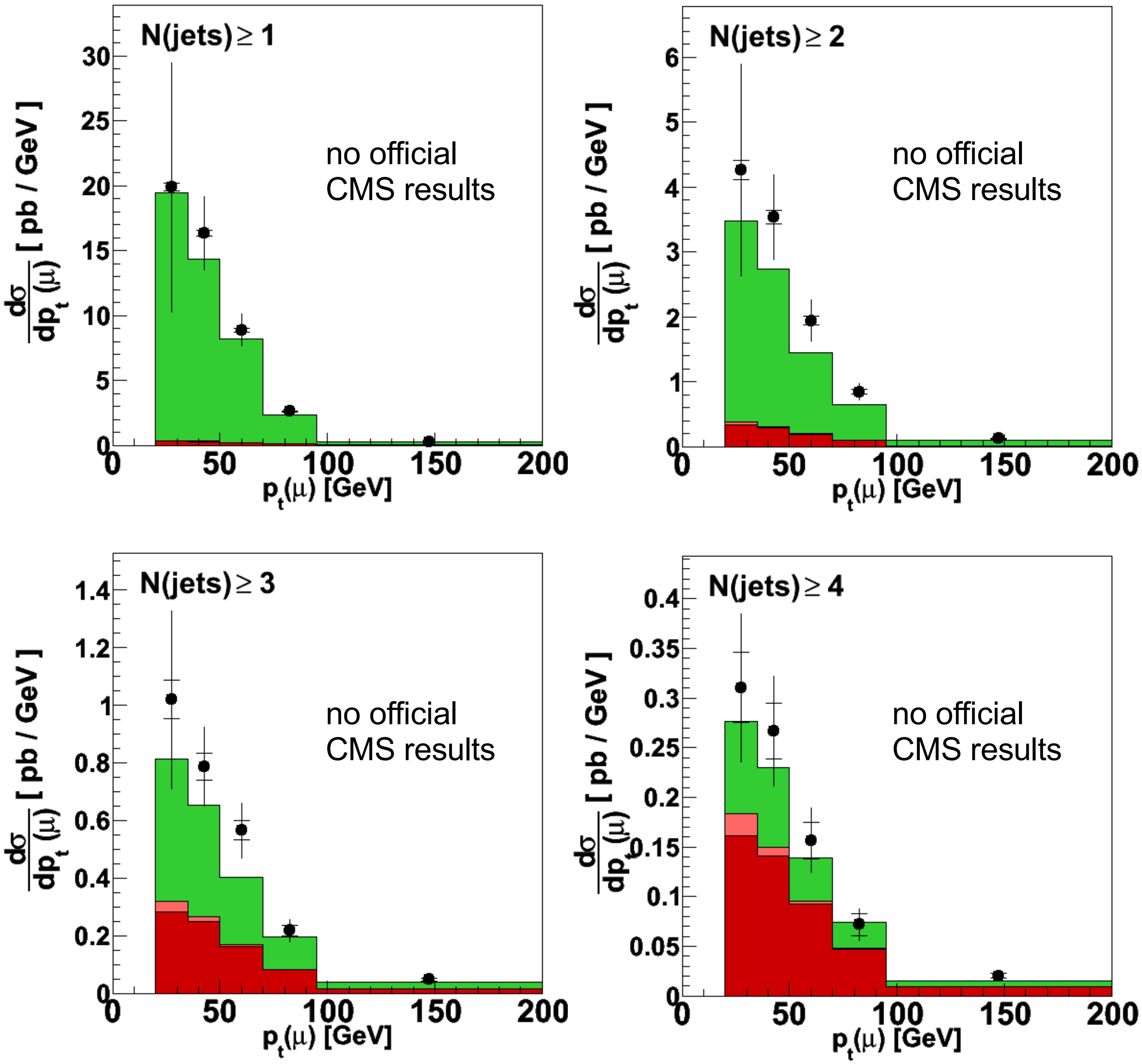
– agreement within errors

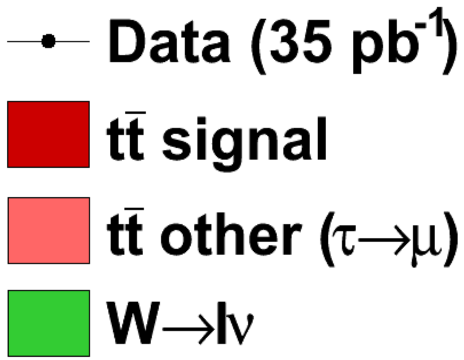
– N(QCD) from template fit, N(Z+jets) from simulation
– inner error bars: statistical error only
– outer error bars: combined statistical and systematic error

– considered systematic variations:

source	variation
tt MC model	MC@NLO/ MADGRAPH
Jet Energy Scale	± 5 %
Luminosity	± 11 %
W+jets MC prediction	± 30 %
QCD estimation	± 50 %
MC efficiencies	± 4.5 %

Differential Cross Sections μ+jets

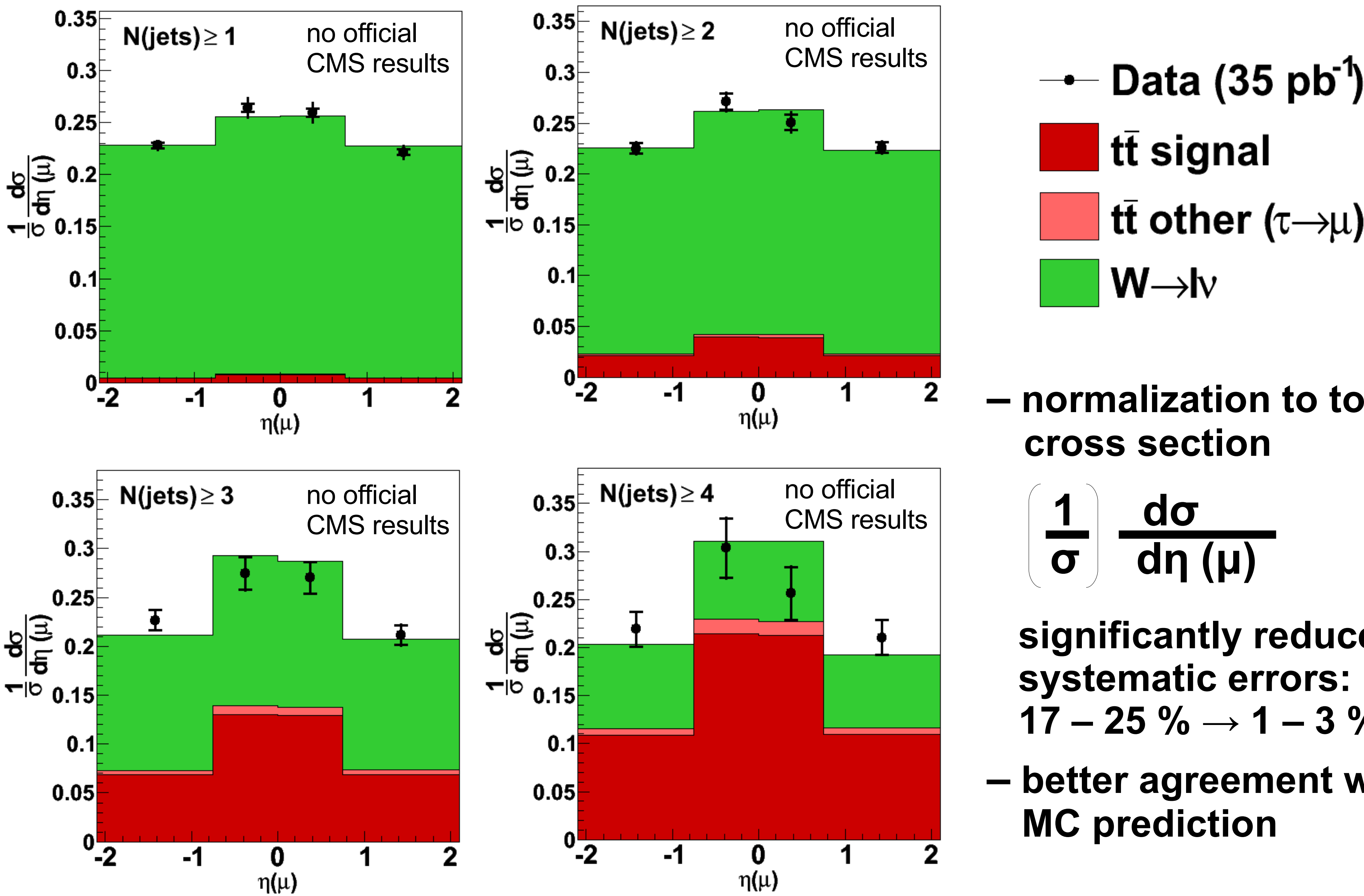




– description within 2σ in all four jet multiplicity bins

– large systematic uncertainties

Norm. Diff. Cross Sections μ+jets



– normalization to total cross section

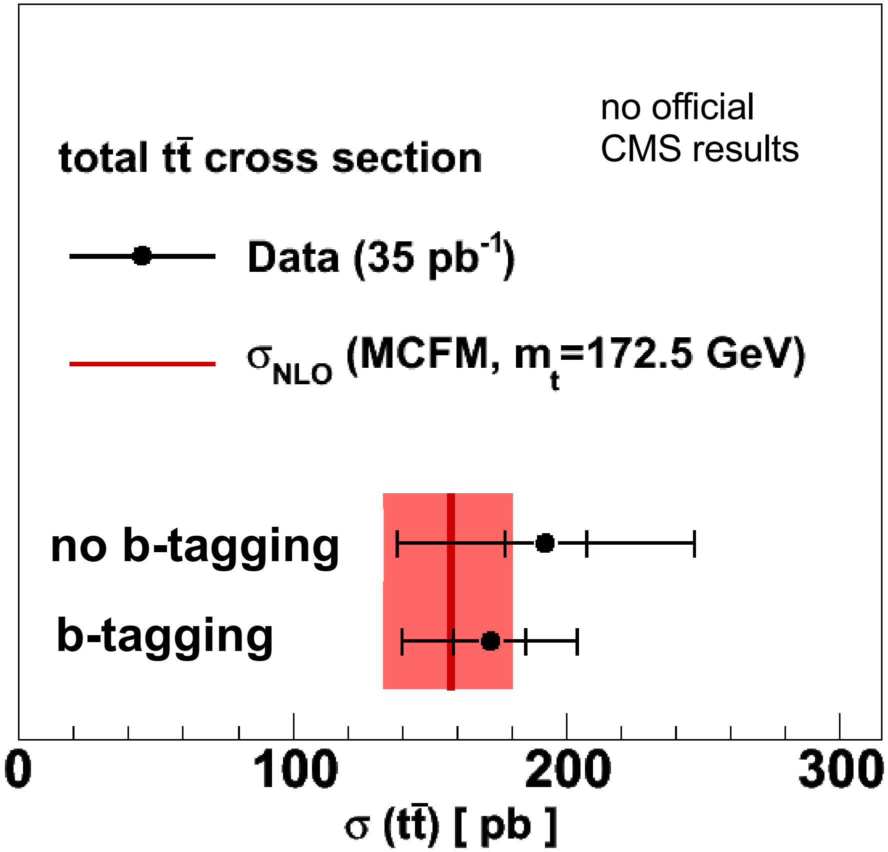
$$\left(\frac{1}{\sigma}\right)\frac{d\sigma}{d\eta\,(\mu)}$$

significantly reduces systematic errors:
17 – 25 % → 1 – 3 %

– better agreement with MC prediction

Top Cross Section

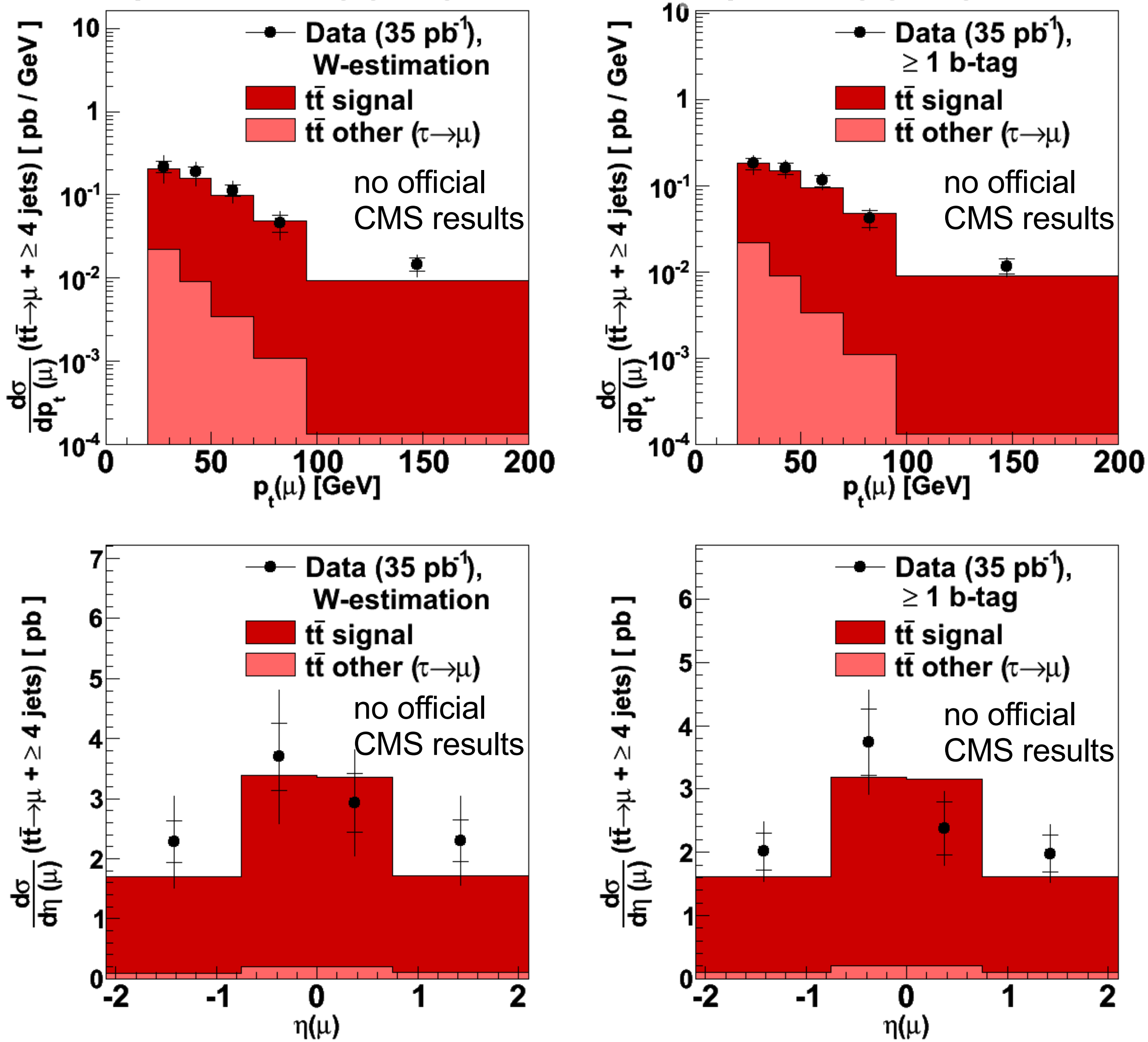
- N(Z+Jets), N(W+Jets) from MC prediction
- N(QCD):
  - from template fit for method without b-tagging
  - from simulation for b-tagging method
- MC based extrapolation factor (total phase space) ≈ 17



Diff. Top Cross Sections in Data

a) no b-tagging

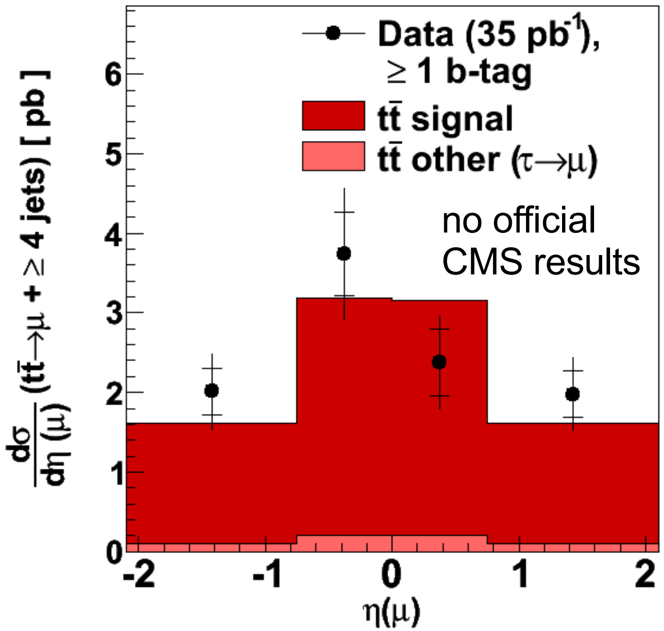
b) b-tagging



- **good agreement within errors for both methods**

Summary and Outlook

- Measurement for isolated muons and jets describes transition from W+jets dominated region to top dominated region
- Stay with directly observable variables like $p_t(\mu)$ in the beginning
- First results for the cross section for muon + jets (≥ 1,2,3,4): MC prediction ≈ 20% lower, agreement within errors
- First results for σ(tt) with / without b-tagging: in agreement with NLO prediction
- Also first differential cross sections for tt production have been measured



Thank you for your attention

Backup

Event Selection

- corresponds to official CMS l+jets selection for PF objects

Trigger:

- hltMu9 (< run 147196)
- hltMu15 (≥ run 147196)

Primary Vertex

- not (isFake)
- ndof > 3
- |z| < 24 cm
- ρ < 2.0

μ -cuts:

exactly 1 "tight" μ

- global & tracker muon
- pt > 20, |η| < 2.1
- trkHits ≥ 11, χ2 < 10
- #valid μHits > 0
- > 1 matched segments
- $|d_z(\mu) - z_{PV}| < 1$
- $|d_B(bsp)| < 0.02$
- ΔR(μ,tight jet)>0.3
- relIso < 0.05

Veto cuts:

- **no "loose" e**
  - E_t >15 GeV, |η| < 2.5
  - relIso < 0.2
- **no additional "loose" μ**
  - global muon
  - p_t > 10 GeV, |η| < 2.5
  - relIso < 0.2

Jet cuts:

≥ 4 "tight" jets

- |η| < 2.4
- p_t > 30 GeV
- ΔR(mu,jet) < 0.1

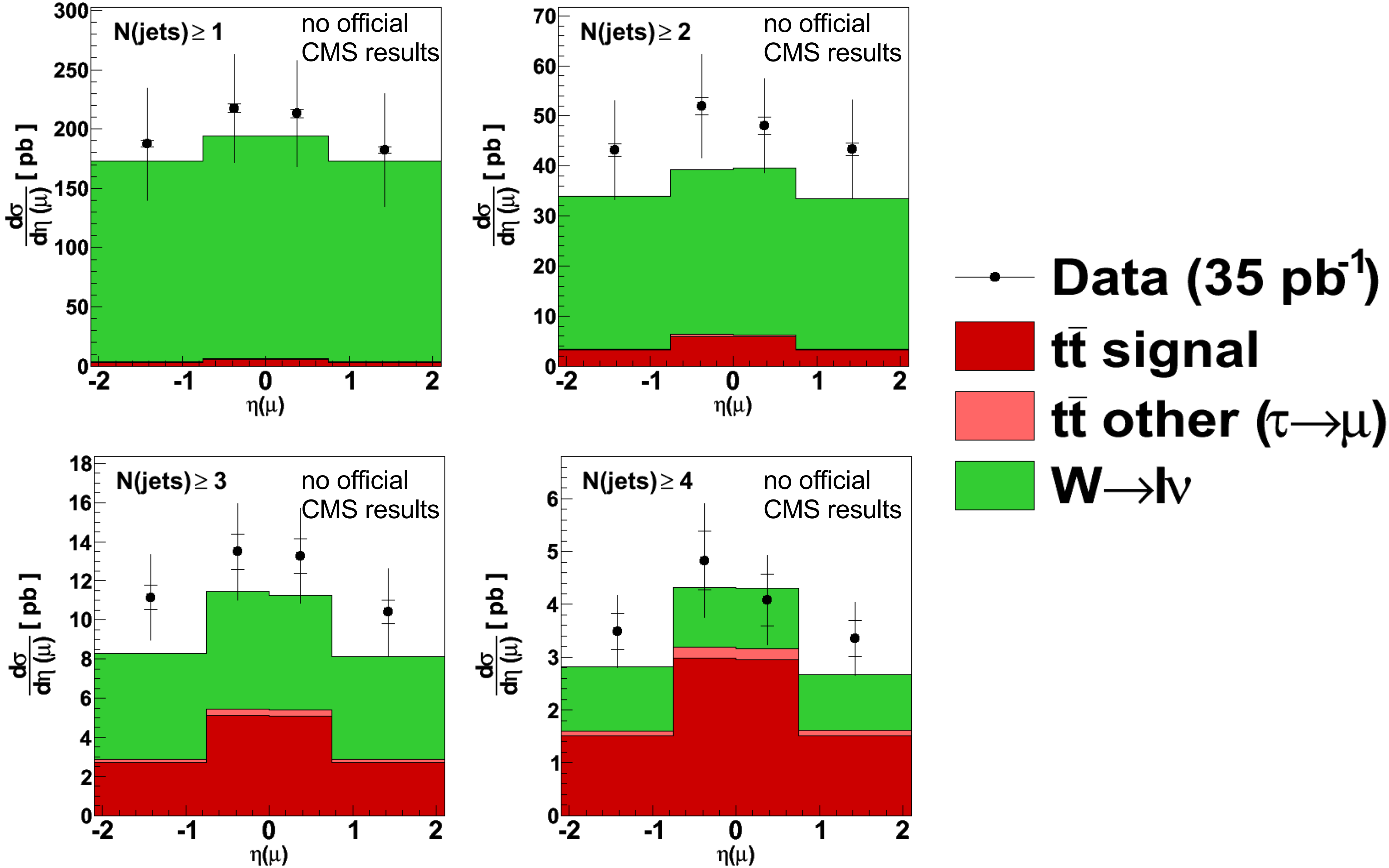
loose jet ID:

- > 1 constituents
- CEF < 0.99
- NEF < 0.99
- NHF < 0.99
- CHF > 0
- NCH > 0

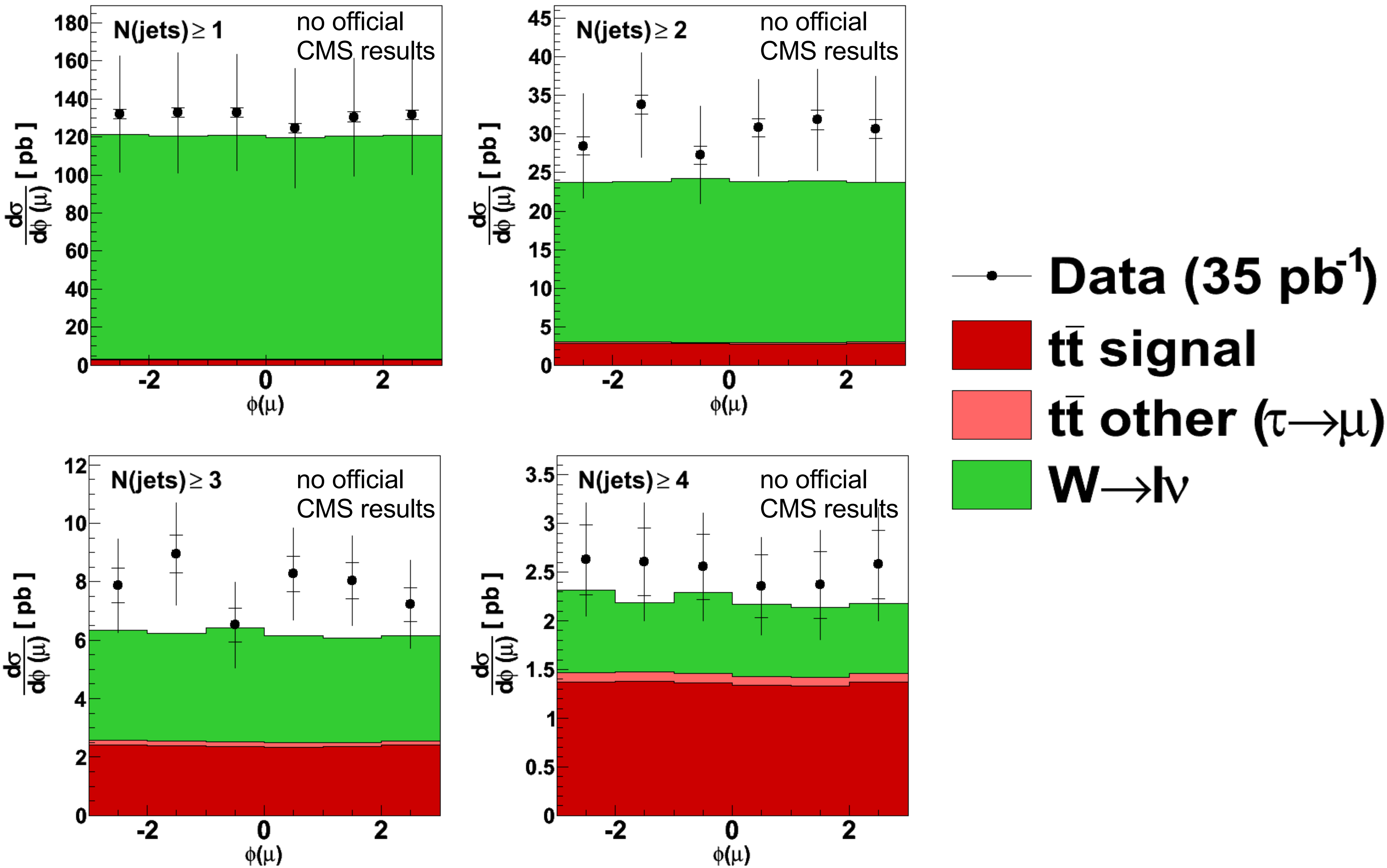
Simulation

MC sample	events	σ [pb]	filter-eff.	$\mathcal{L}$ [pb^{-1}]	weight(1/pb)
tt MADGRAPH	991,694	157.5	1.0	9,418	0.00011
QCD PYTHIA	4,377,187	296,900,000	0.0002684	55	0.01821
Z+jets MADGRAPH	1,084,921	3,048	1.0	356	0.00281
W+jets MADGRAPH	10,068,895	31,314	1.0	322	0.00311

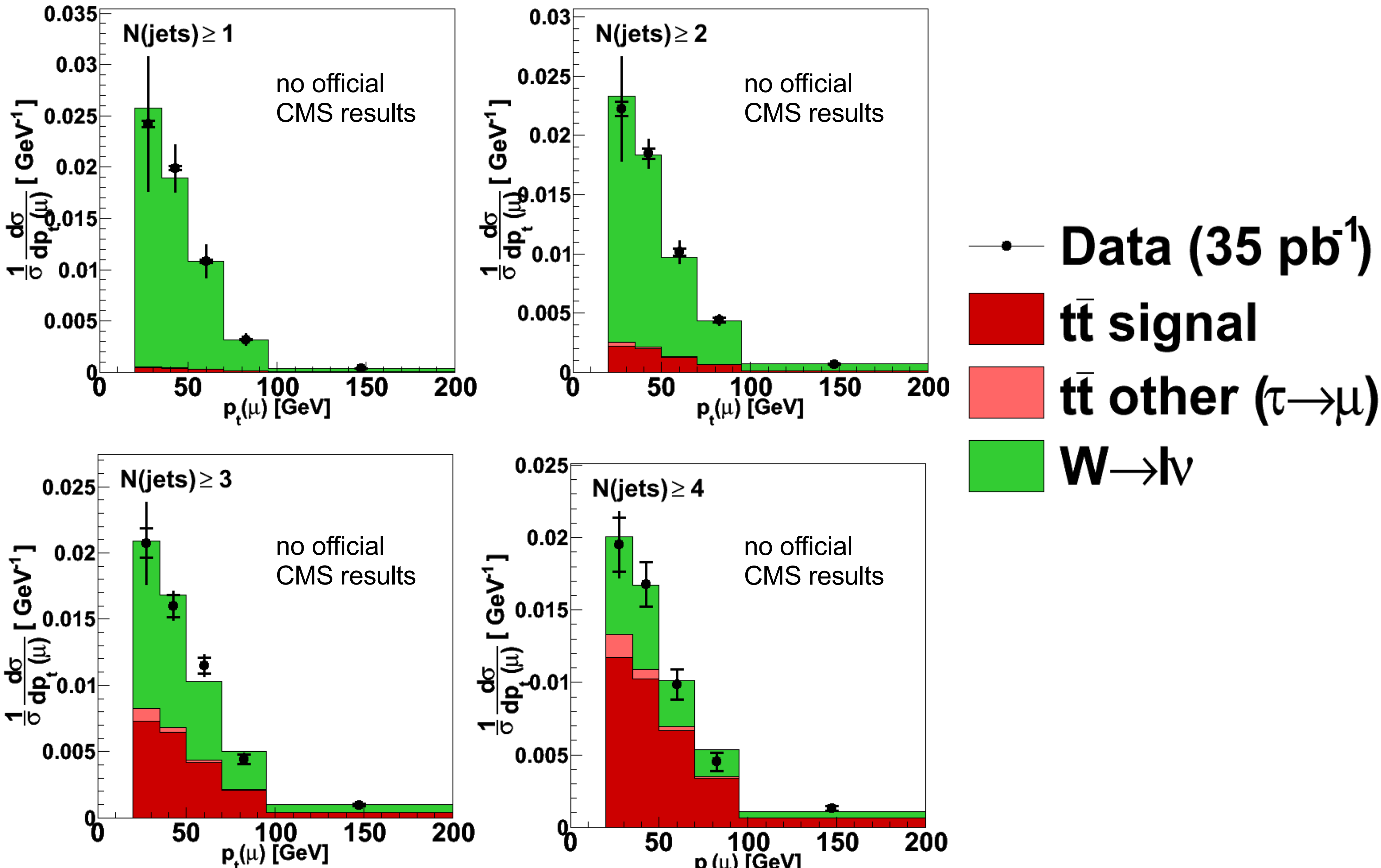
Diff. Cross Section in Data II



Diff. Cross Section in Data III



Norm. Diff. Cross Section in Data II



Norm. Diff. Cross Section in Data III