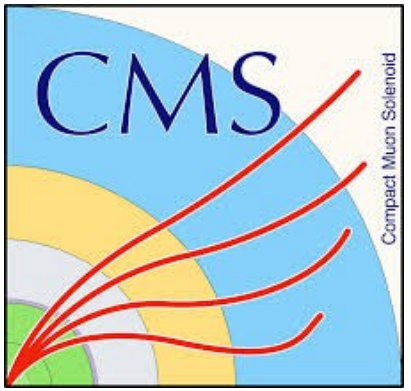


UCL Université catholique de Louvain

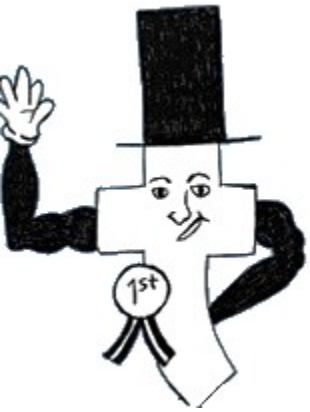
fnrs LA LIBERTÉ DE CHERCHER

Top Quark Production at the LHC

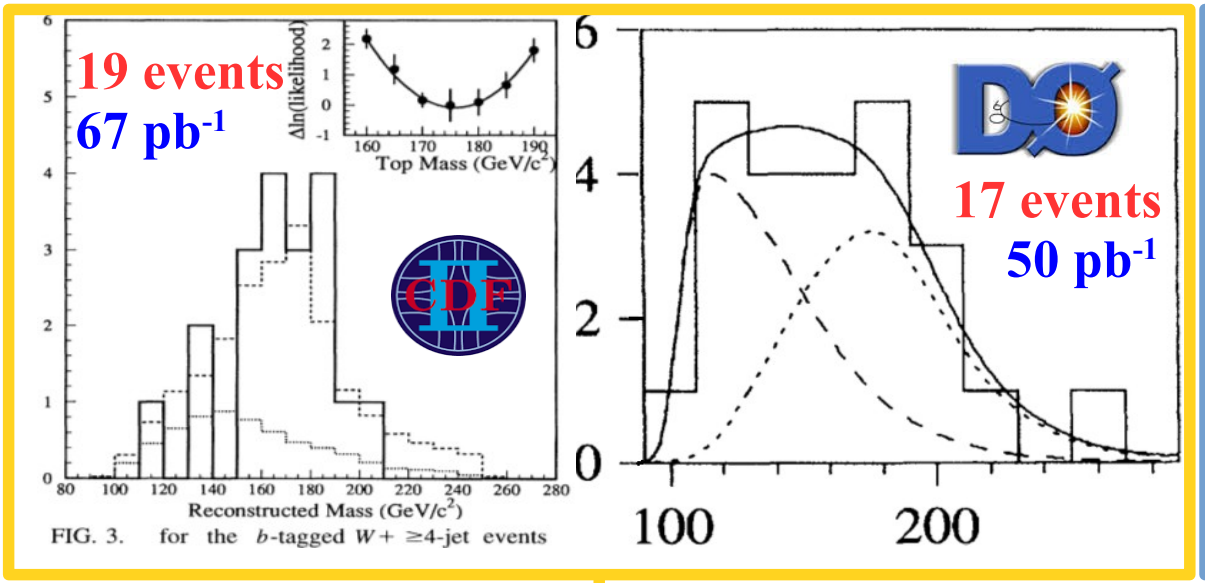
Abideh Jafari
UCLouvain and FNRS
for the CMS & ATLAS collaborations

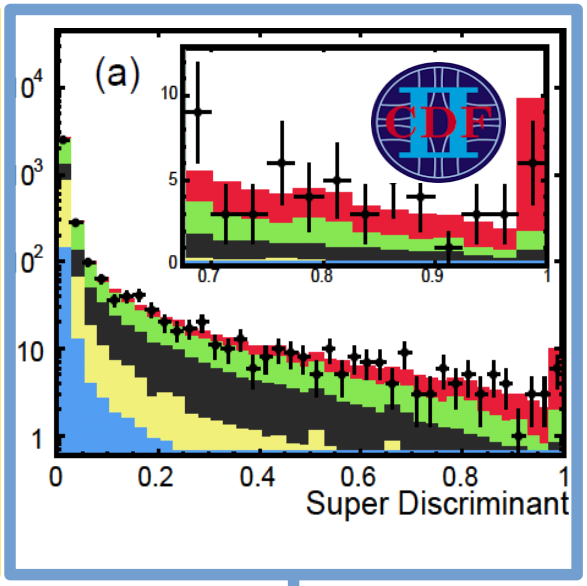
3rd Annual LHC Physics Conference
31st Aug. – 5th Sept. St. Petersburg, Russia

The Top Quark



Observed for the first time in Tevatron





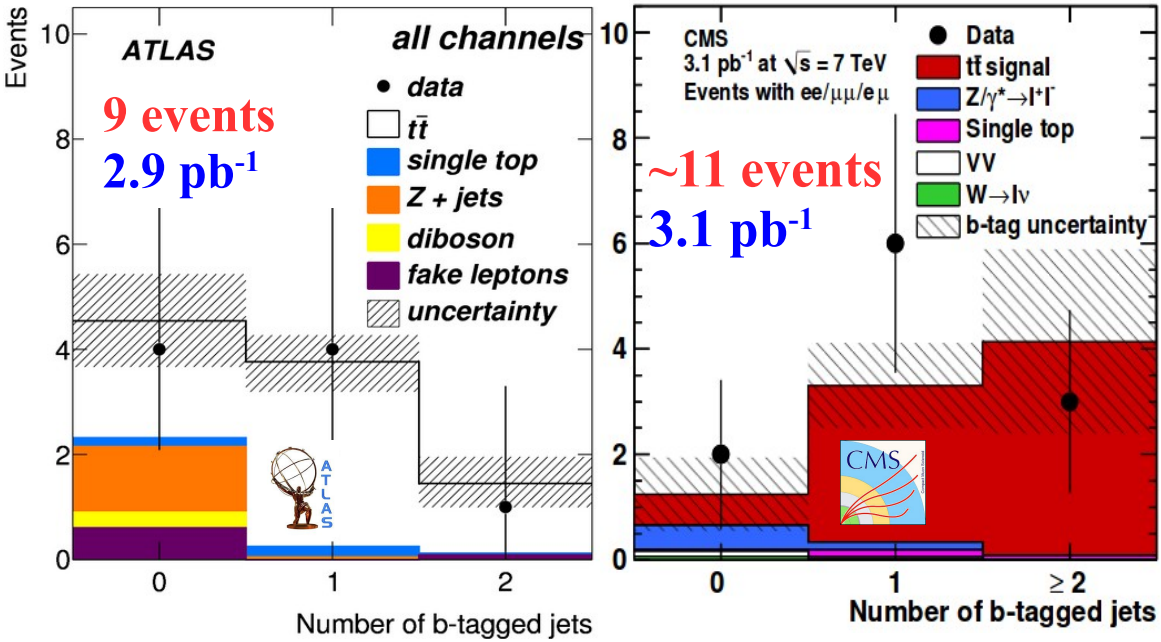
Dominant: pair production with strong interactions
Discovery with <20 events

Sub-dominant: single top production with EWK
Discovery with multivariate analysis

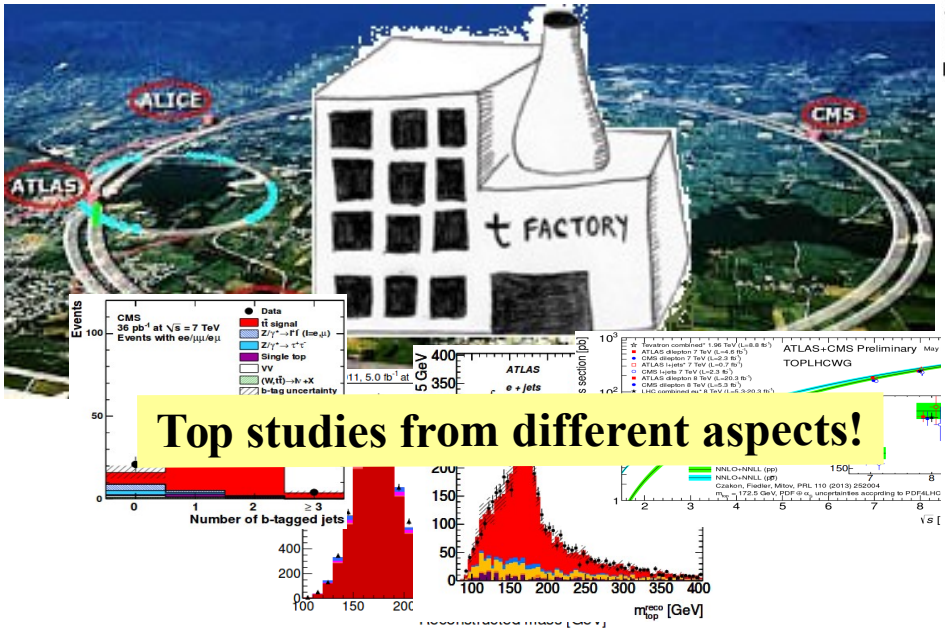
- A testing ground to validate SM or see hints for new physics
- Diversity of particles in final state → a commissioning tool for early data
- Large mass, short life time → bare quark properties
- Validate Monte-Carlo generators ...
- Background for searches …

The Top Quark *Factory*

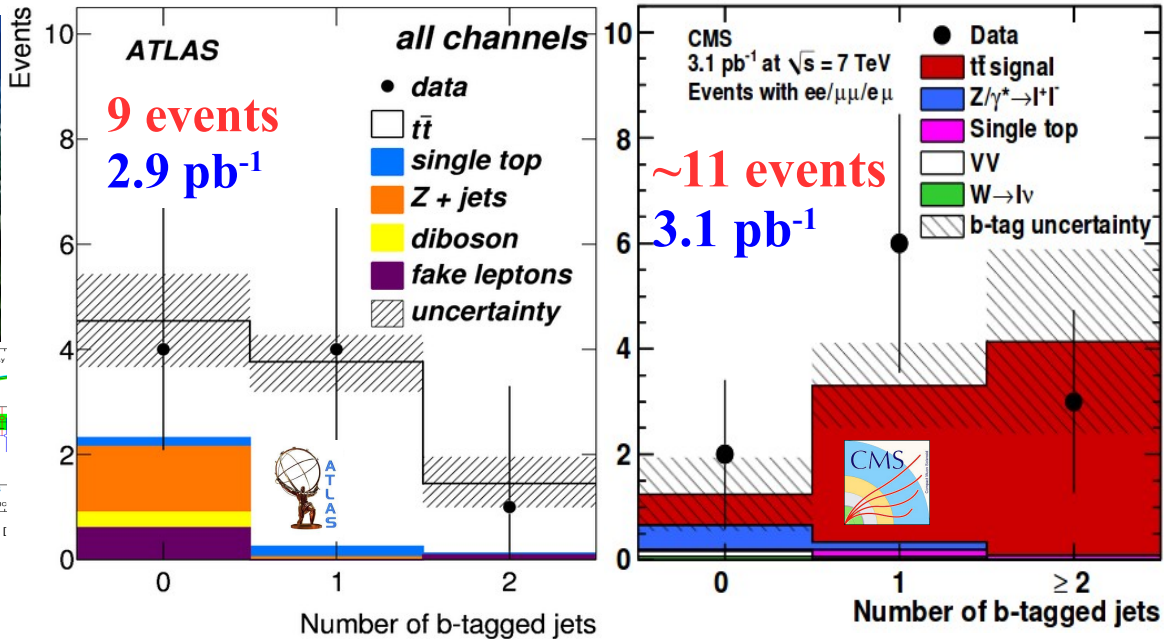
Rate ≥ 20 times larger than Tevatron

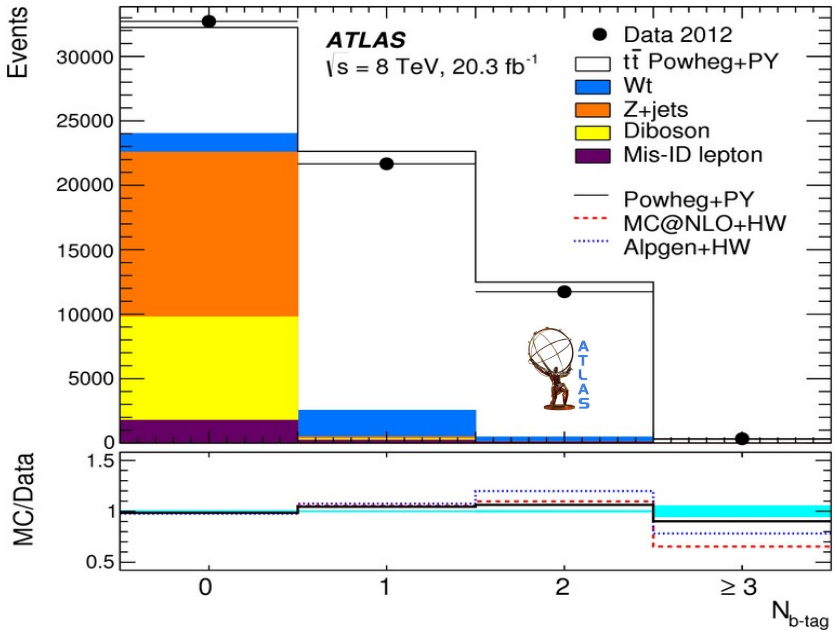


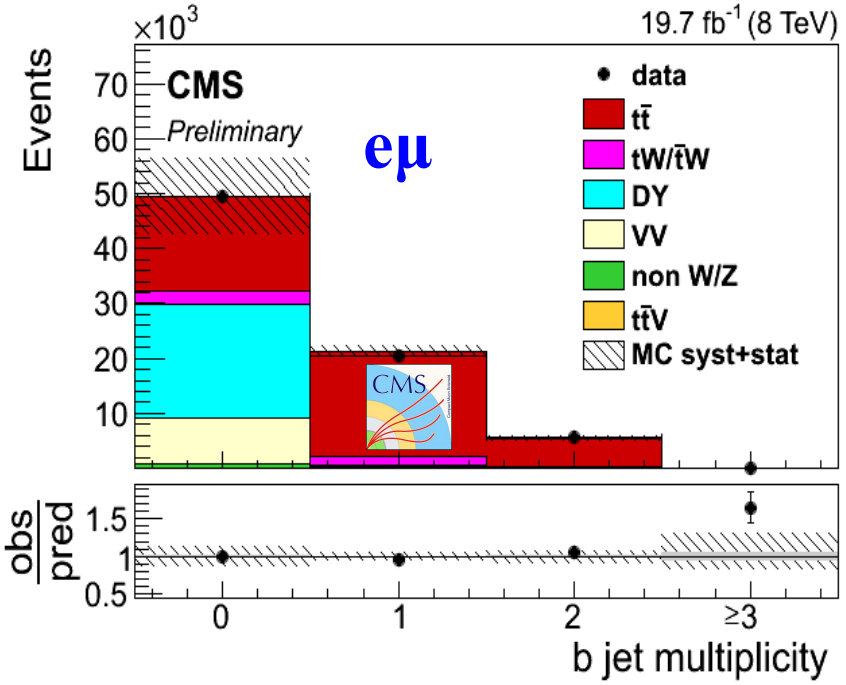
The Top Quark *Factory*



Top studies from different aspects!



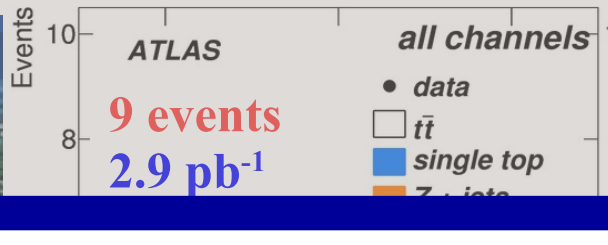


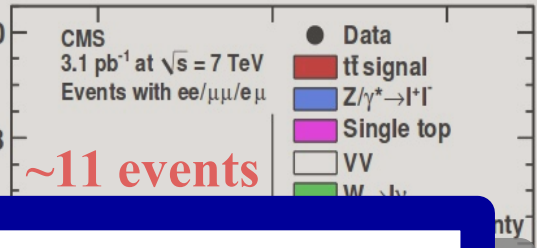


Larger statistics

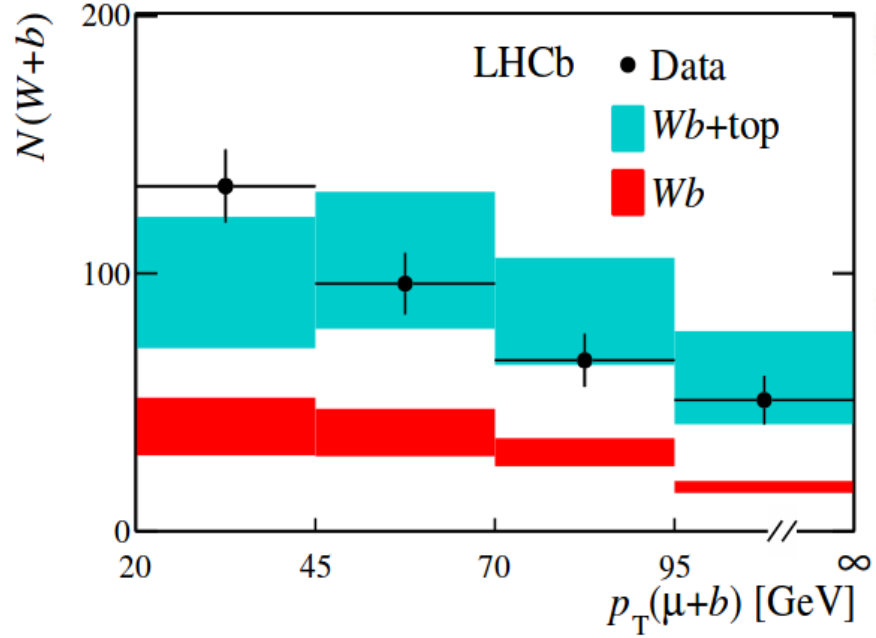
Limited by systematics

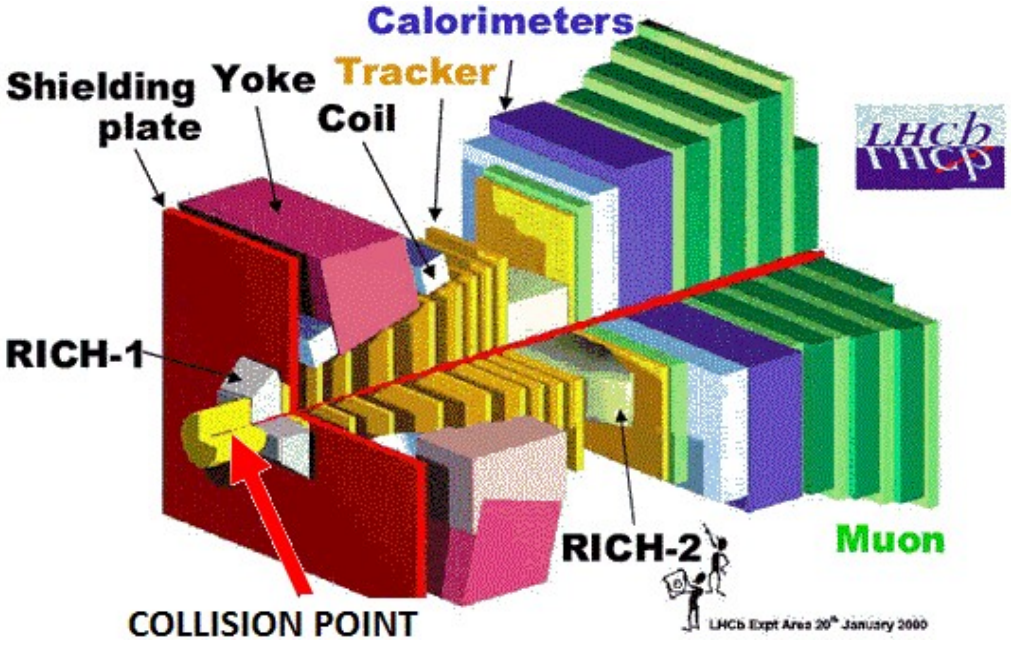
The Top Quark *Factory*



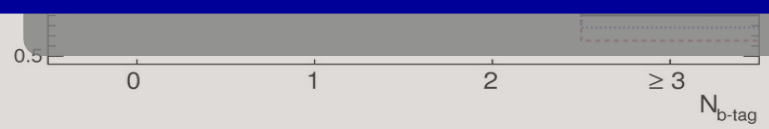


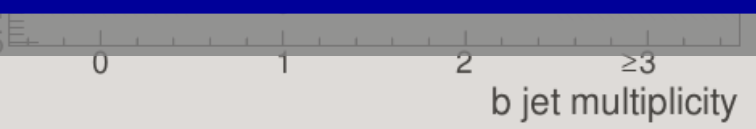
And the recent observation of the top quark in forward regions at LHCb



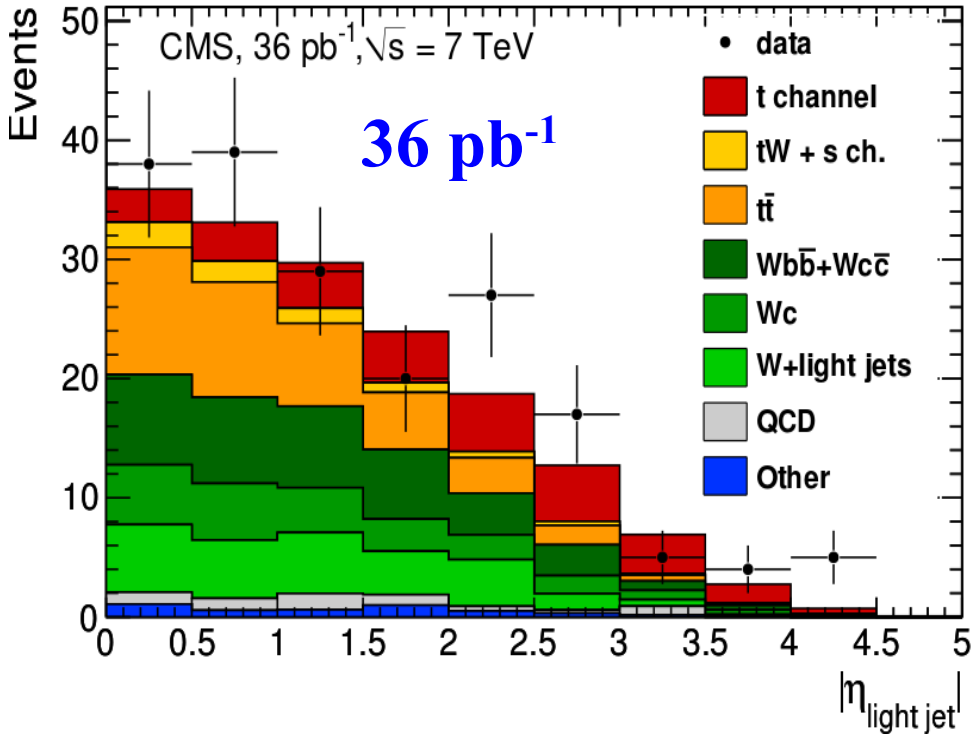


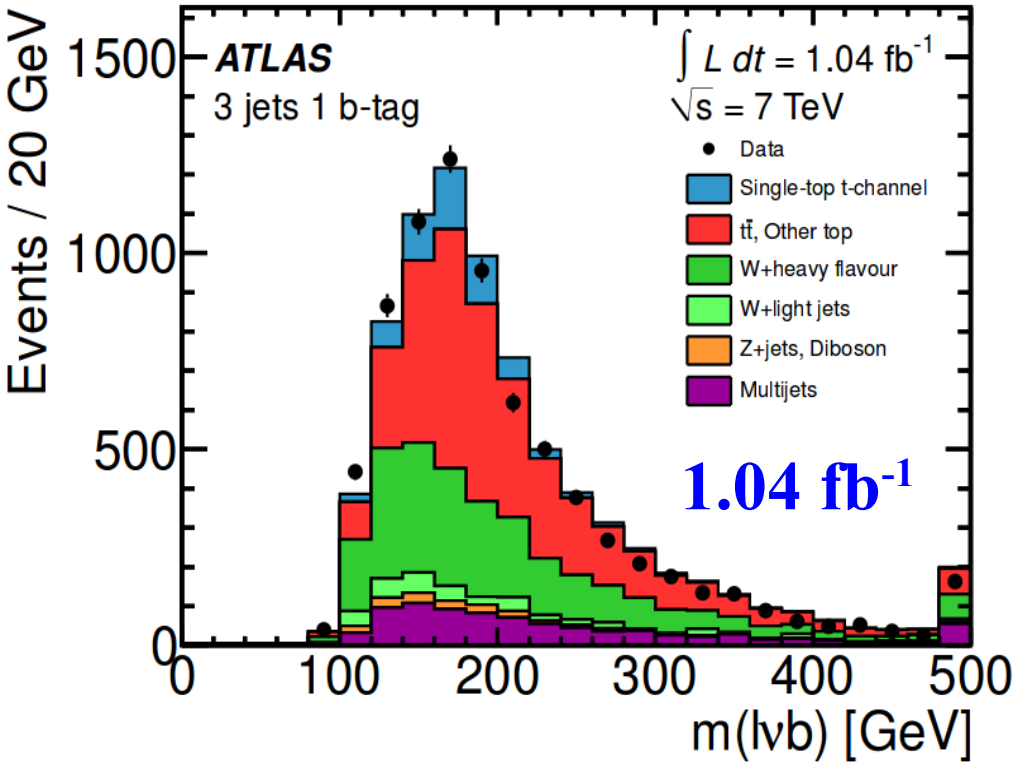
See the talk by Stephen Farry

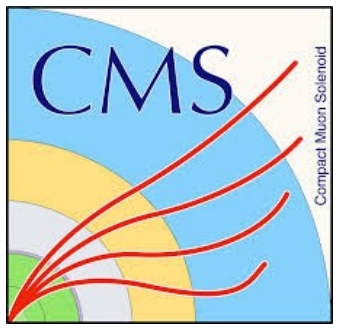




The *single*-Top Quark *Factory*



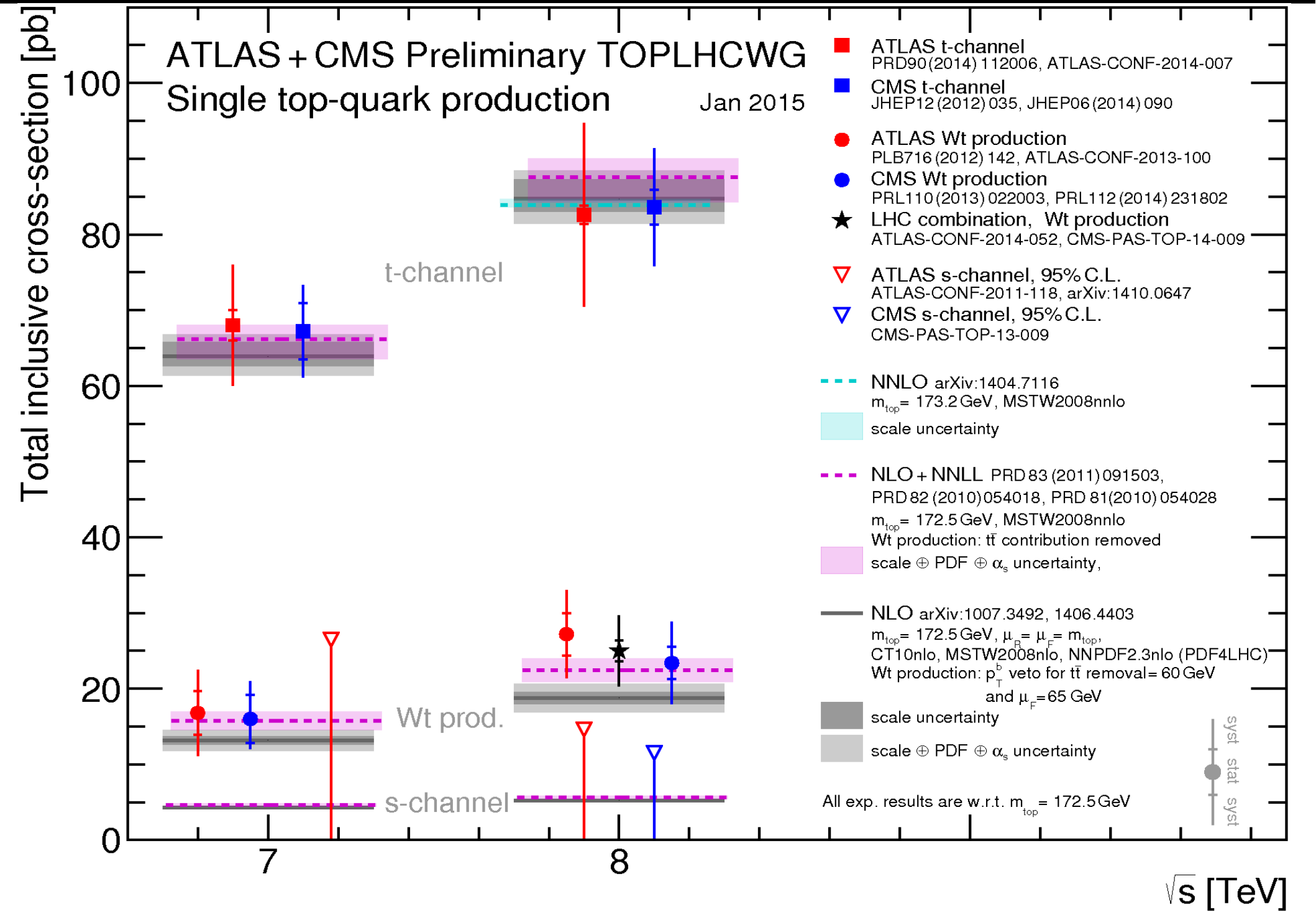


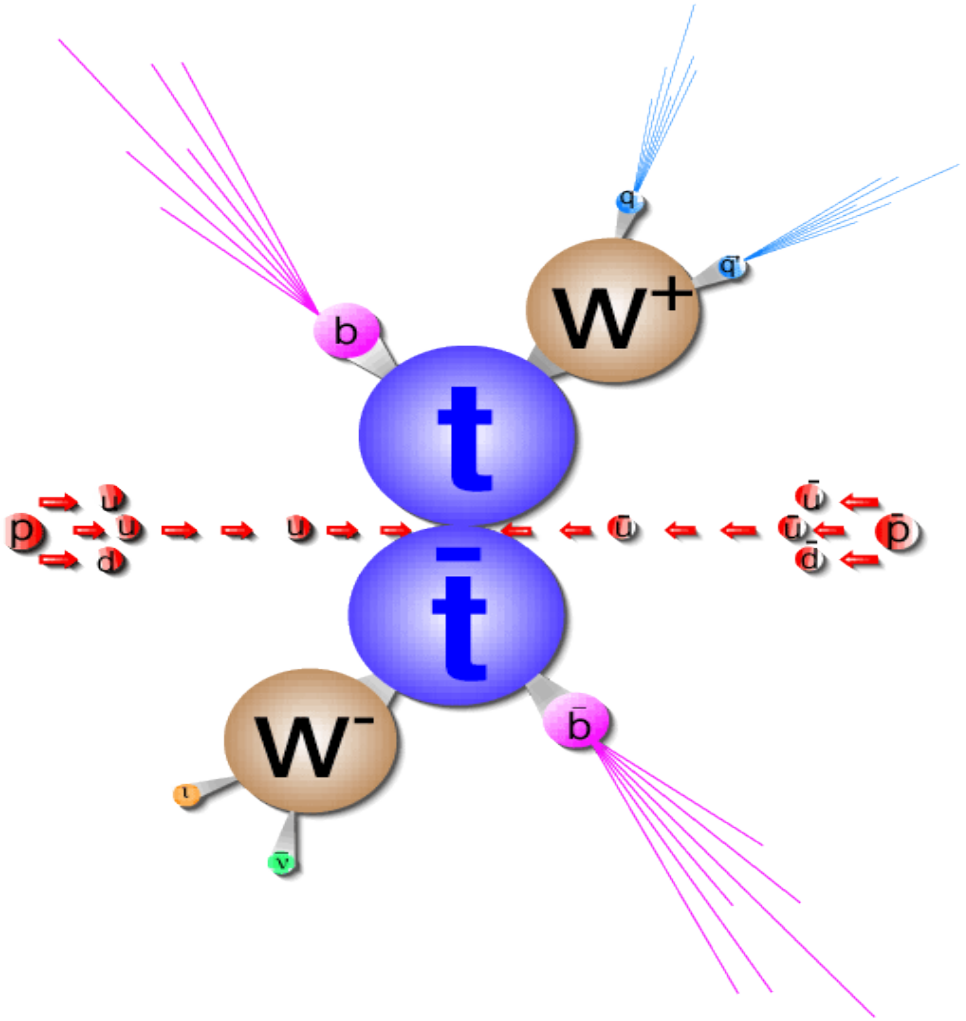


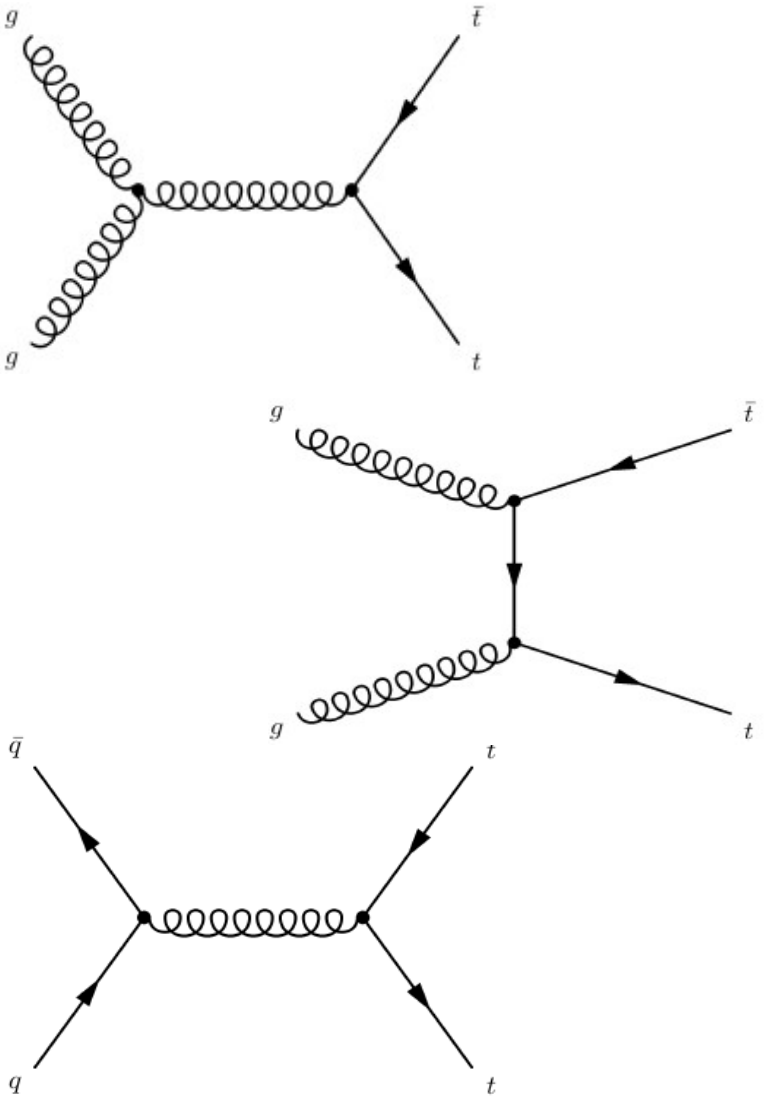
Single variable enough for measurement

Visible signal in top mass peak region

The *single*-Top Quark *Factory*



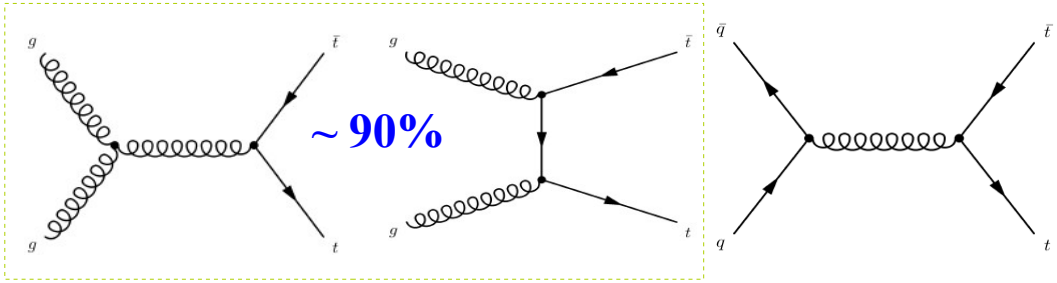




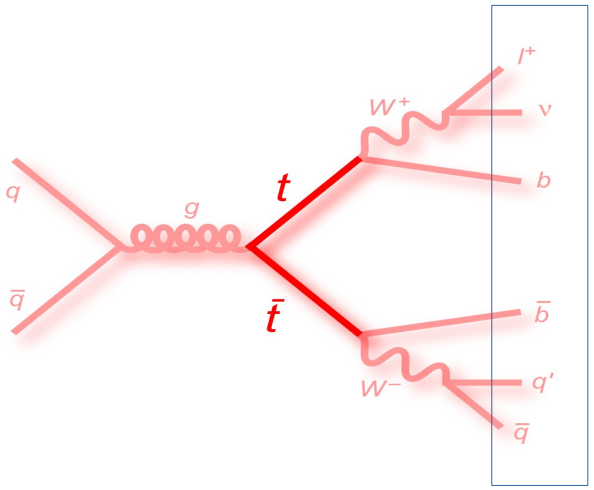
PAIR PRODUCTION

Top pair cross section and final states

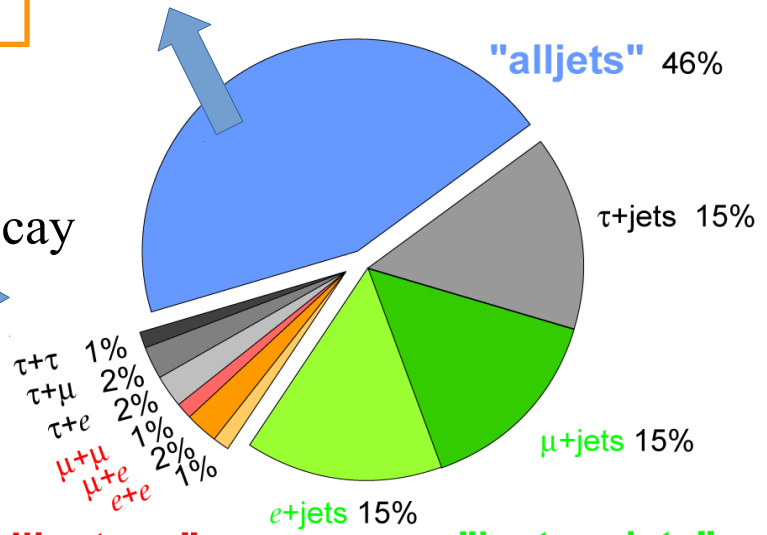
E_{COM}^{LHC}	σ_{tt} (m_t = 172.5 GeV)[1]
7 TeV	$177.31^{+10.1}_{-10.8}$
8 TeV	$252.89^{+13.3}_{-14.5}$
13 TeV	$831.76^{+40.2}_{-45.6}$



- high rate, large background
- Used with more data



Based on W decay



- Low rate but clean
- Early measurement

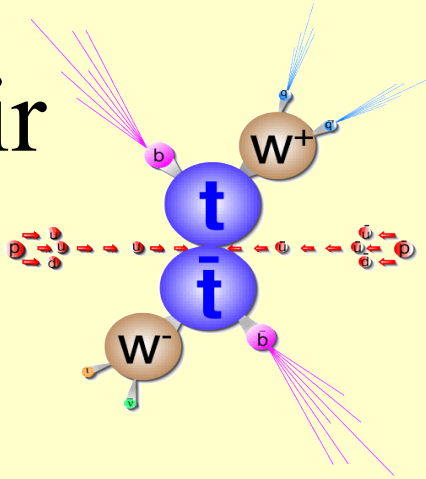
- Moderate rate, moderate background
- Early differential measurement

[1] https://twiki.cern.ch/twiki/bin/view/LHCPhysics/TtbarNNLO

Inclusive

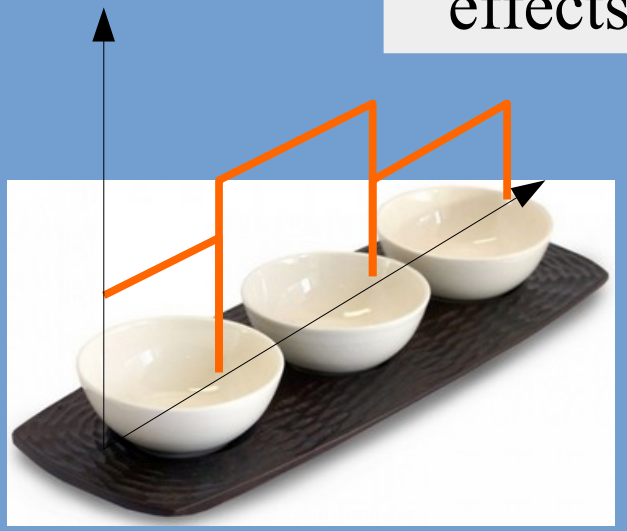
- Global picture
- Establish and validate the analysis strategy
- Sensitive to overall excess

Top pair cross section



Differential

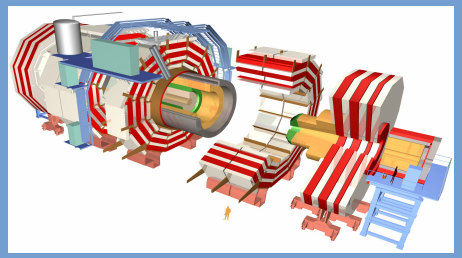
- Residual picture
- Detailed model validation
- Sensitive to residual BSM effects

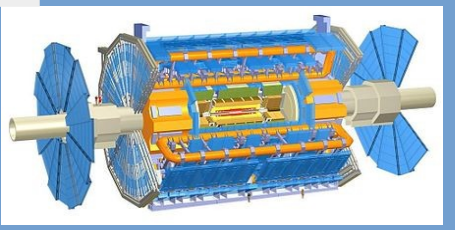


Fiducial

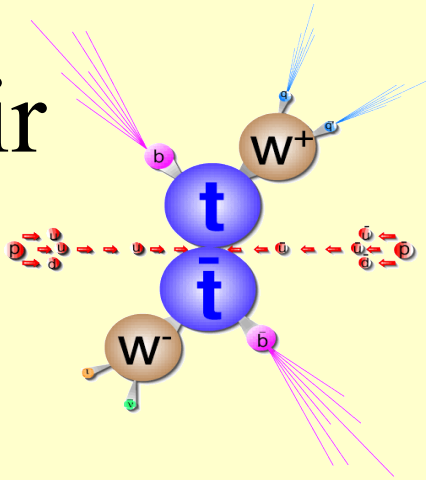
- Within the detector acceptance
- Algorithms similar to detector level
- Less dependence to extrapolation effects

Experiment





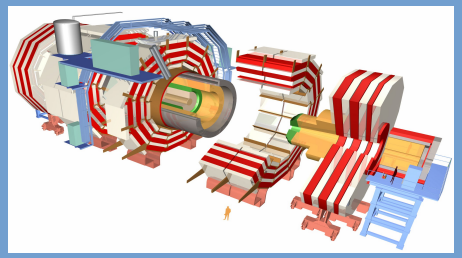
Top pair cross section

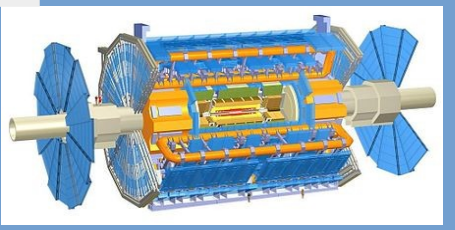


Fiducial

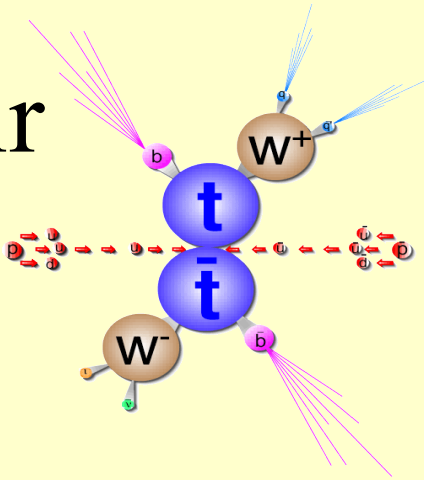
- Within the detector acceptance
- Algorithms similar to detector level
- Less dependence to extrapolation effects

Experiment

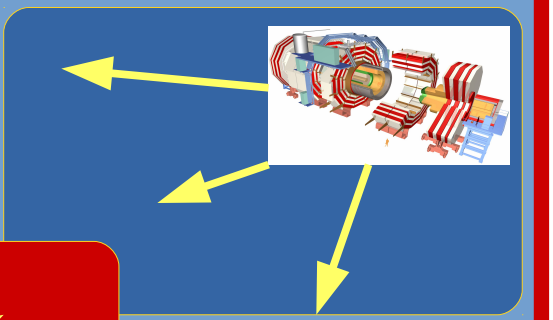


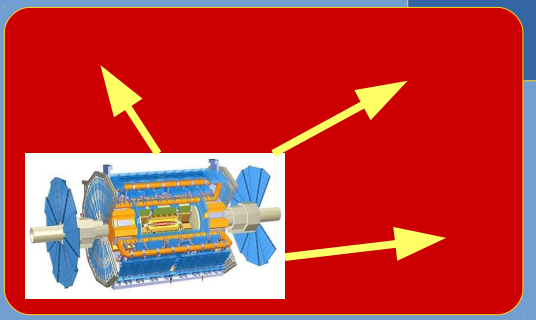


Top pair cross section



- Suitable to compare with recent QCD calculations

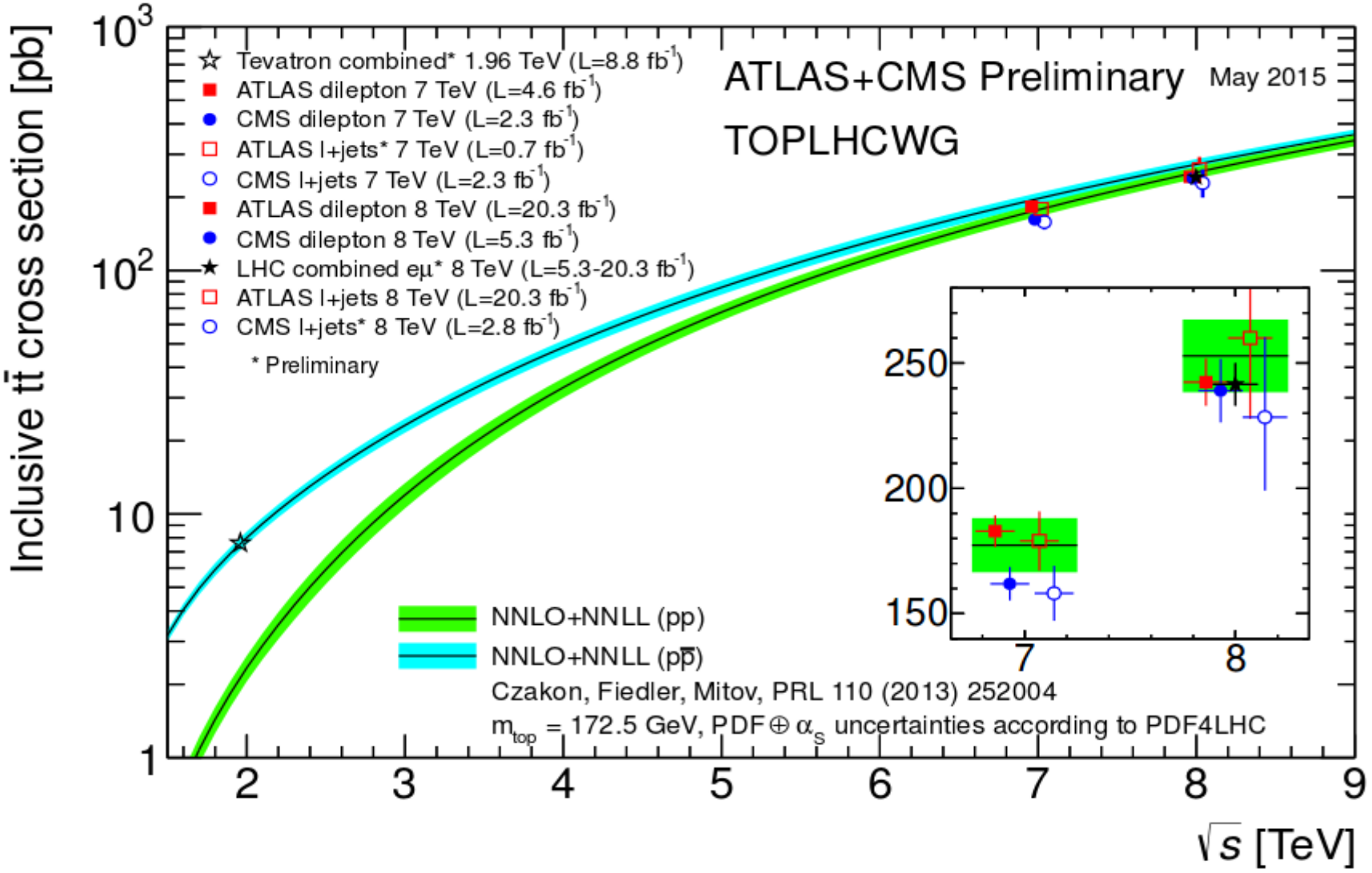




Full phase space

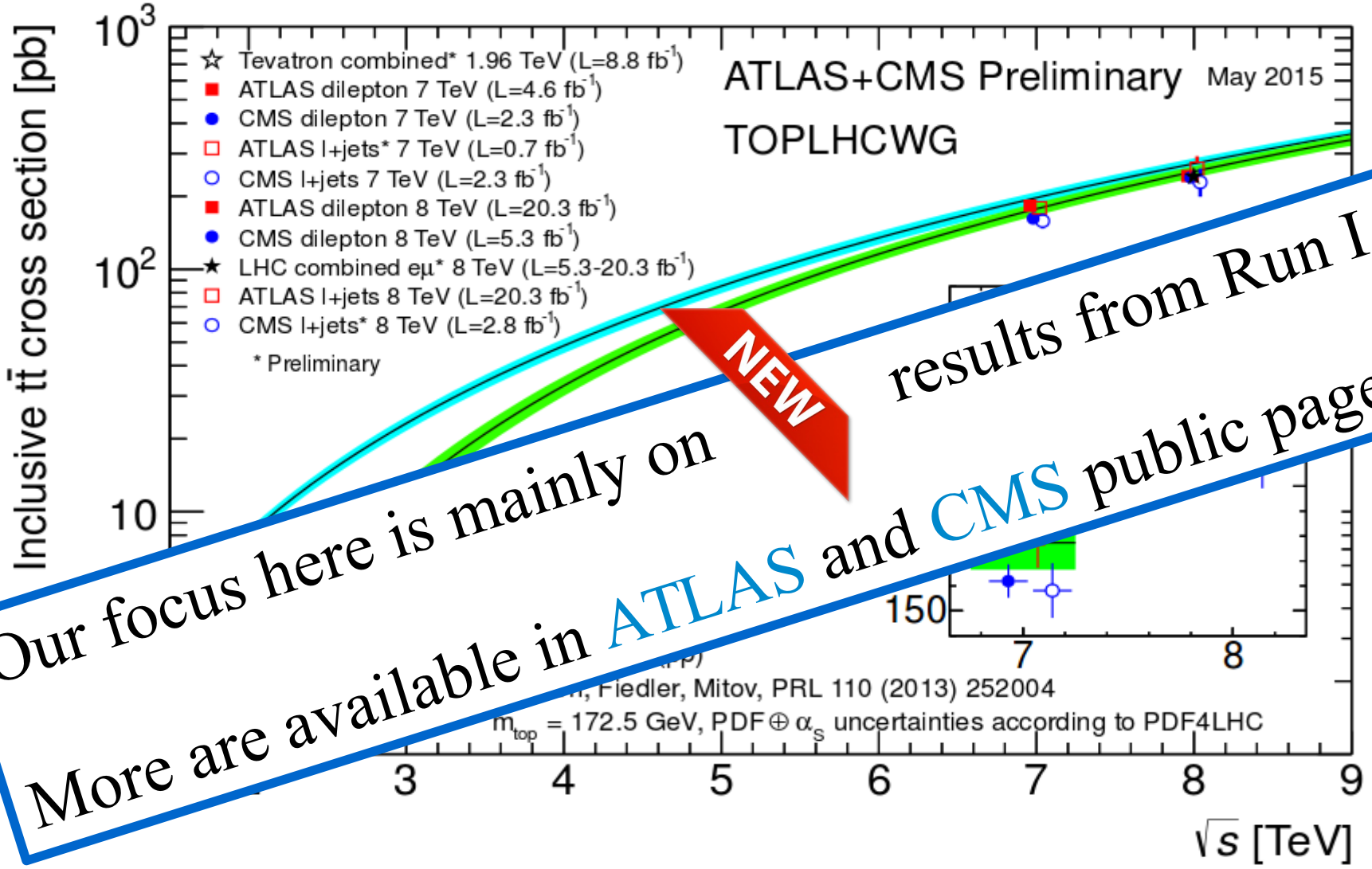
Theory

LHC RUN I



- Total recorded luminosity in Run I ~20 (8 TeV) + ~5 (7 TeV) fb^{-1}
- The run I data is still being exploited to achieve even better precision and to look into differential distributions and properties

LHC RUN I



Our focus here is mainly on results from Run I

More are available in ATLAS and CMS public pages

- Total recorded luminosity in Run I ~20 (8 TeV) + ~5 (7 TeV) fb^{-1}
- The run I data is still being exploited to achieve even better precision and to look into differential distributions and properties

INCLUSIVE

Top pair cross section ℓ+jets 8 TeV

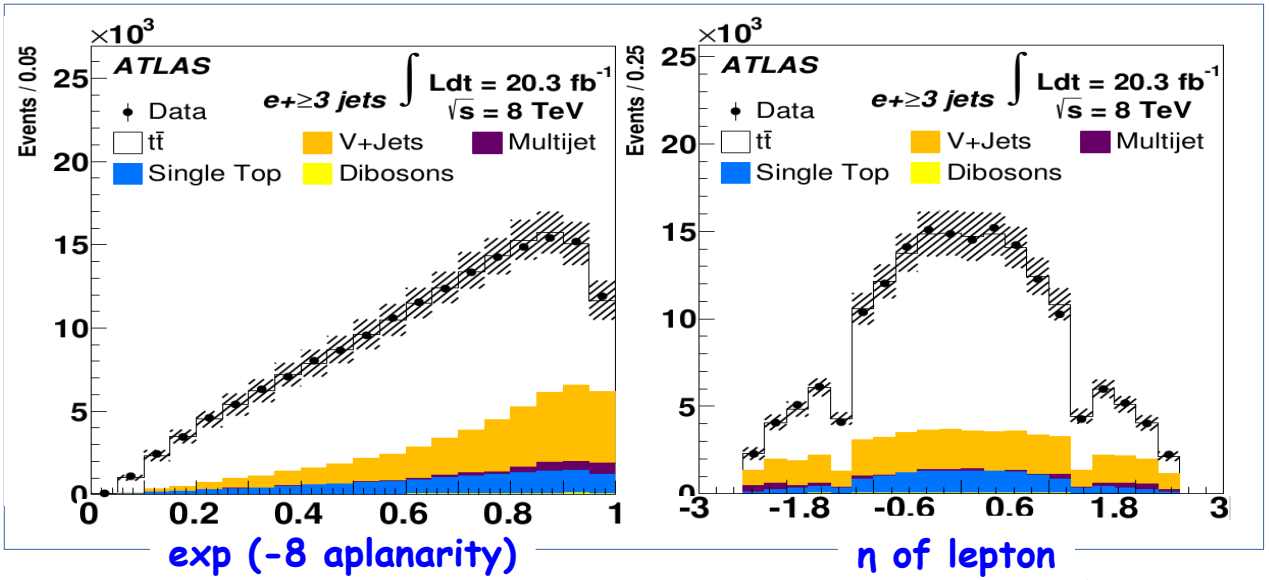
NEW

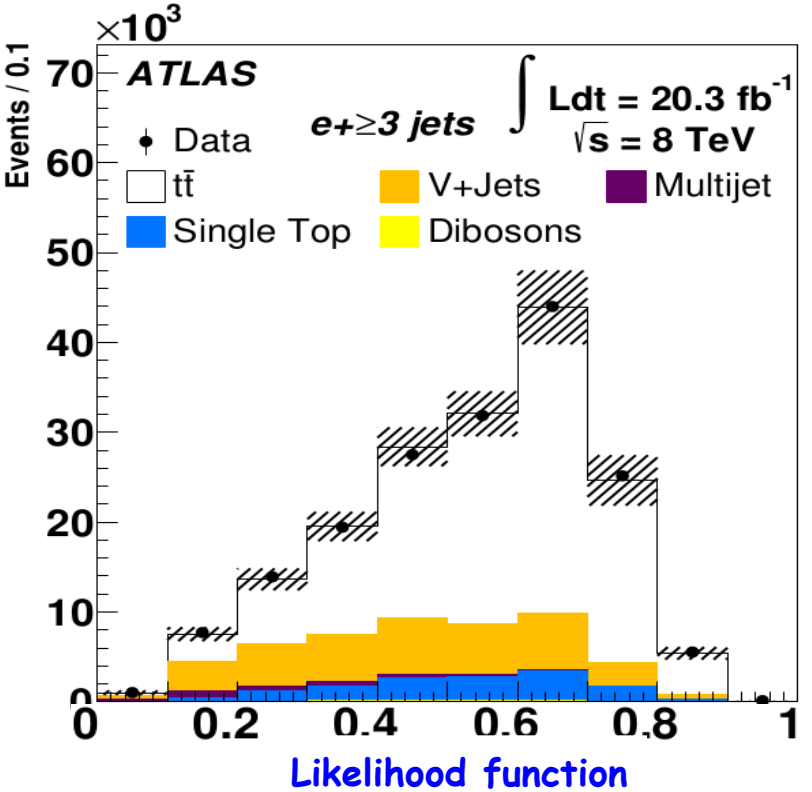
Selection:

- Exactly one muon or electron
- At least 3 jets
- At least 1 b-tagged

Signal extraction: A template fit to the likelihood model, constructed using the most discriminative variables

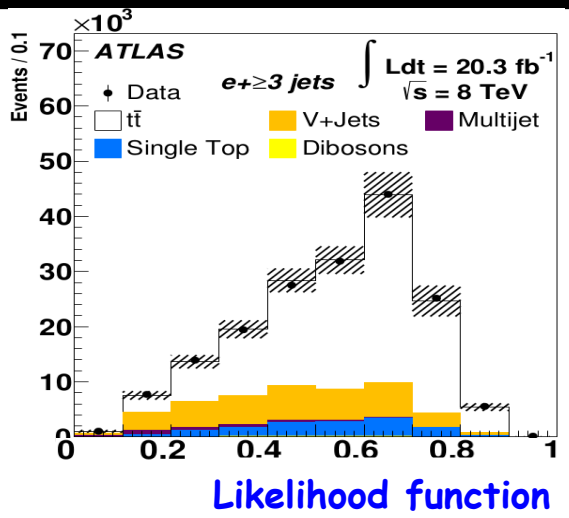
PRD91,112013(2015)





Top pair cross section ℓ+jets 8 TeV

NEW



Signal extraction: A template fit to the likelihood model, constructed using the most discriminative variables

PRD91,112013(2015)

$$\sigma_{t\bar{t}}^{lj} = 258 \pm 1\,(stat.)\,^{+22}_{-23}\,(syst.) \pm 8\,(lumi.) \pm 4\,(beam)\,pb$$

- Dominant systematics: PDF
- $\frac{\Delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}}}{\Delta m_t} = -1.1\%\,GeV^{-1}$

m_t = 172.5 GeV

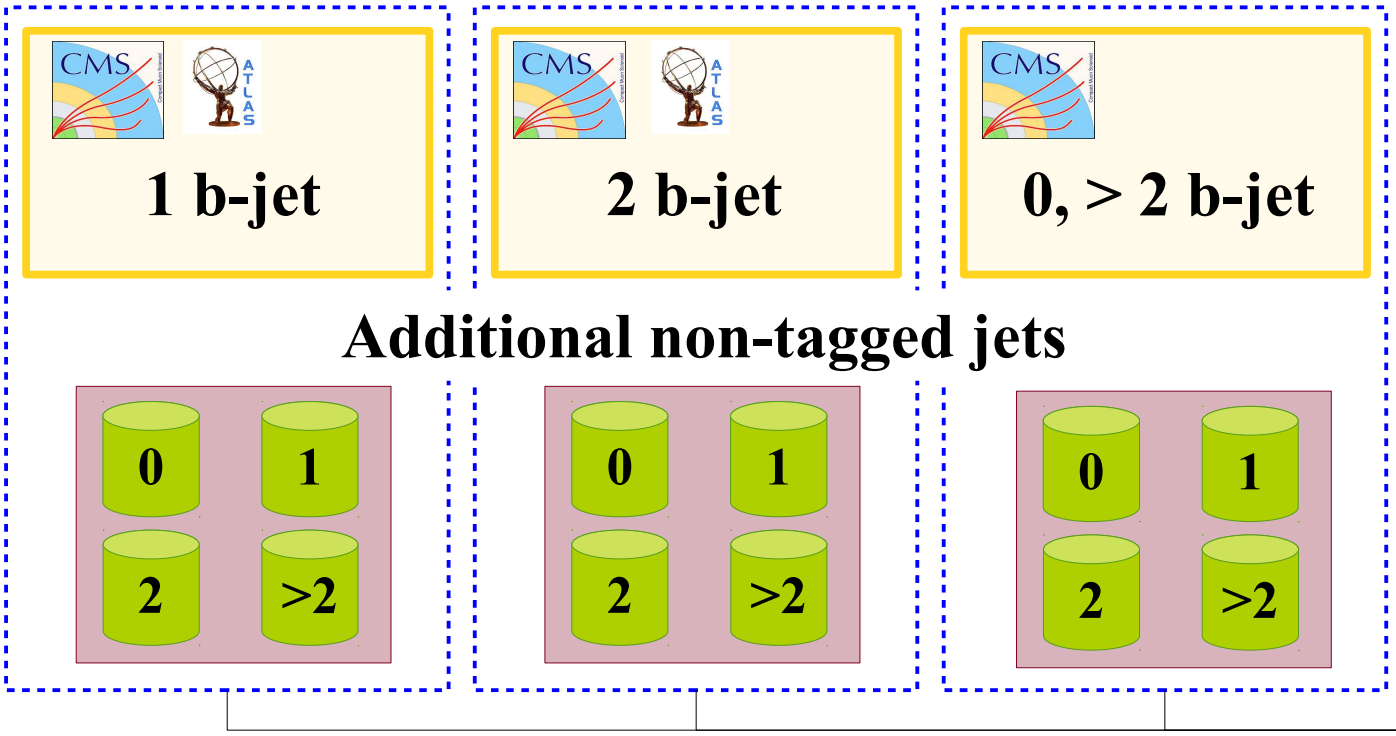
Fiducial: particle level reconstruction/selection close to detector level

$$\sigma_{t\bar{t}}^{lj} = 22.8 \pm 0.1\,(stat.)\,^{+1.9}_{-2.0}\,(syst.) \pm 0.7\,(lumi.) \pm 0.4\,(beam)\,pb$$

Top pair cross section eμ "7+8" TeV

NEW LHCP 2015

- ***Multi-differential*** measurement in categories
- b-tag multiplicity used in signal extraction
- Additional non-tagged jets, p_T of softest jets:
  - Control extra radiations
- A simultaneous likelihood fit with systematics as nuisance parameters



TOP-13-004

The p_T of the softest additional non-tagged jet

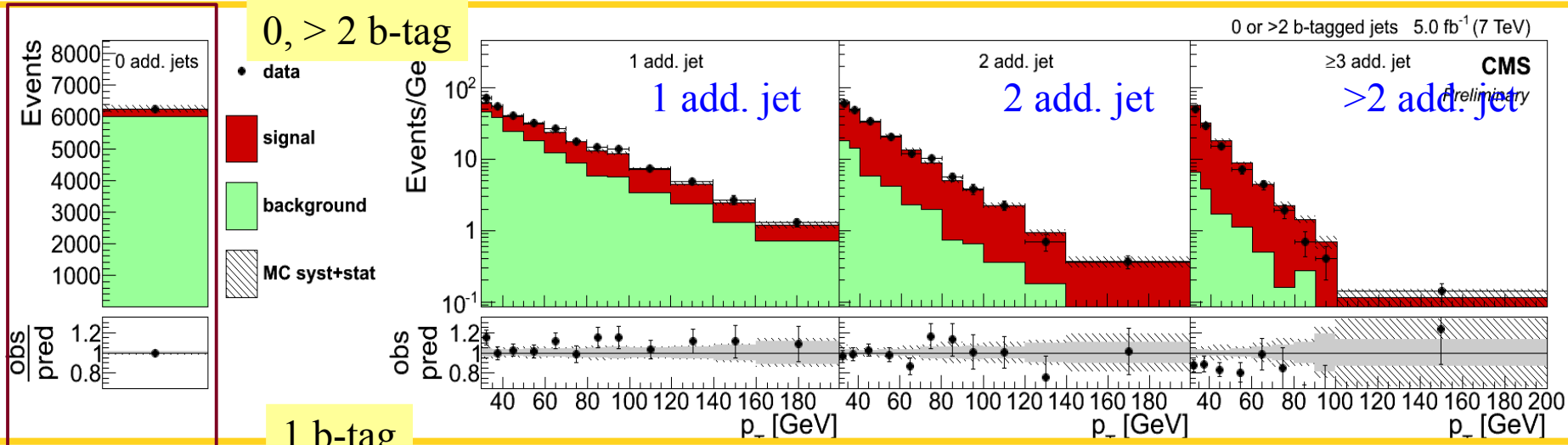
[1] ATLAS earlier measurement: Eur.Phys.J.C74(2014)3109

TOP-13-004

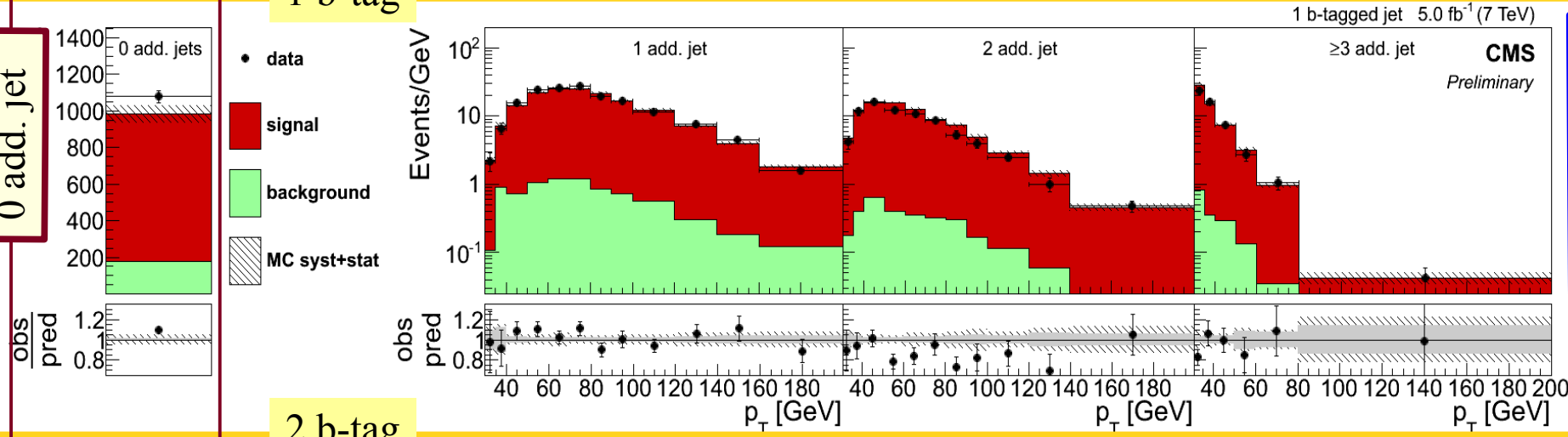
0 add. jet

Post-fit 7 TeV

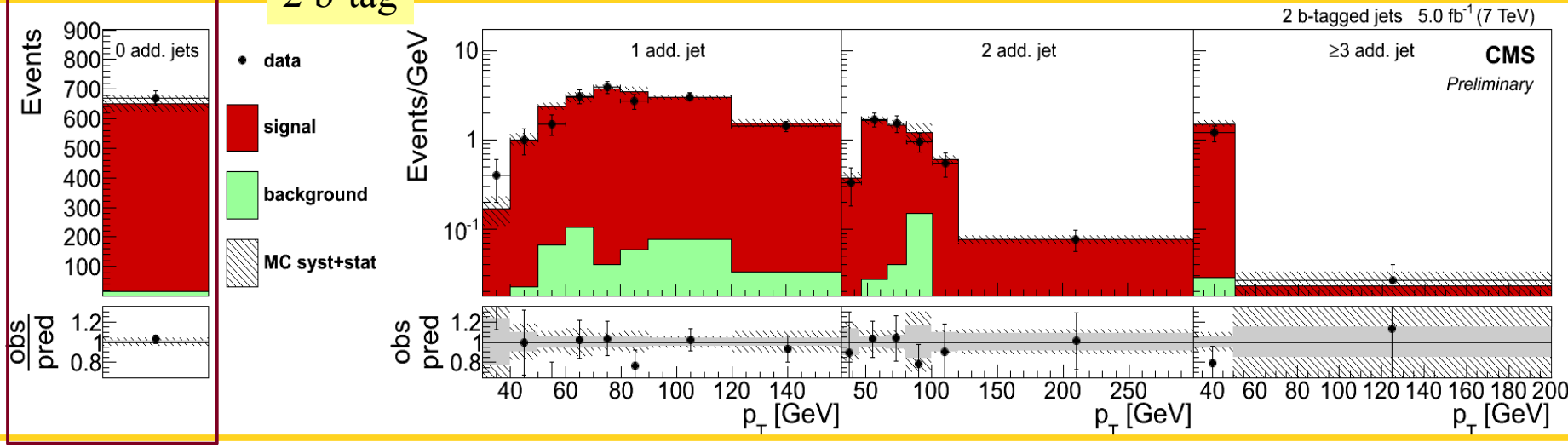
0, > 2 b-tag



1 b-tag

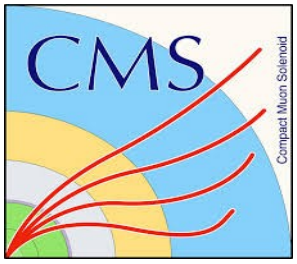


2 b-tag



Top pair cross section eμ "7+8" TeV

NEW



Fiducial

$$\sigma_{t\bar{t}}^{fid}(7\,TeV) = 3.05 \pm 0.04\,(stat.)\,{}^{+0.08}_{-0.07}\,(syst.) \pm 0.07\,(lumi.)\,pb$$

DY, Lepton

$$\sigma_{t\bar{t}}^{fid}(8\,TeV) = 4.24 \pm 0.02\,(stat.)\,{}^{+0.11}_{-0.10}\,(syst.) \pm 0.11\,(lumi.)\,pb$$

TOP-13-004

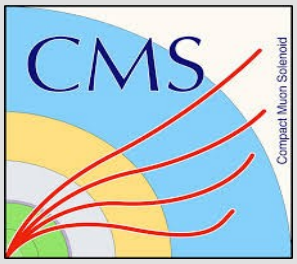
modeling

	7 TeV (pb)	8 TeV (pb)	$R_{t\bar{t}}$
Theory	(scale ± PDF+α_s)		1.43 ± 0.01
	$177.3\,{}^{+4.7}_{-6.0} \pm 7.1$	$252.9\,{}^{+6.7}_{-8.6} \pm 11.7$	
ATLAS [1]	182.9 ± 7.1	242.4 ± 10.3	1.33 ± 0.06
CMS	174.5 ± 6.2	245.6 ± 9.3	1.41 ± 0.06

[1] Eur.Phys.J. C74 (2014) 3109

Top pair cross section eμ "7+8" TeV

NEW



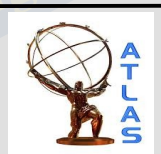
Fiducial

$$\sigma_{t\bar{t}}^{fid}(7\,TeV) = 3.05 \pm 0.04\,(stat.)\,{}^{+0.08}_{-0.07}\,(syst.) \pm 0.07\,(lumi.)\,pb$$

DY, Lepton

$$\sigma_{t\bar{t}}^{fid}(8\,TeV) = 4.24 \pm 0.02\,(stat.)\,{}^{+0.11}_{-0.10}\,(syst.) \pm 0.11\,(lumi.)\,pb$$

TOP-13-004

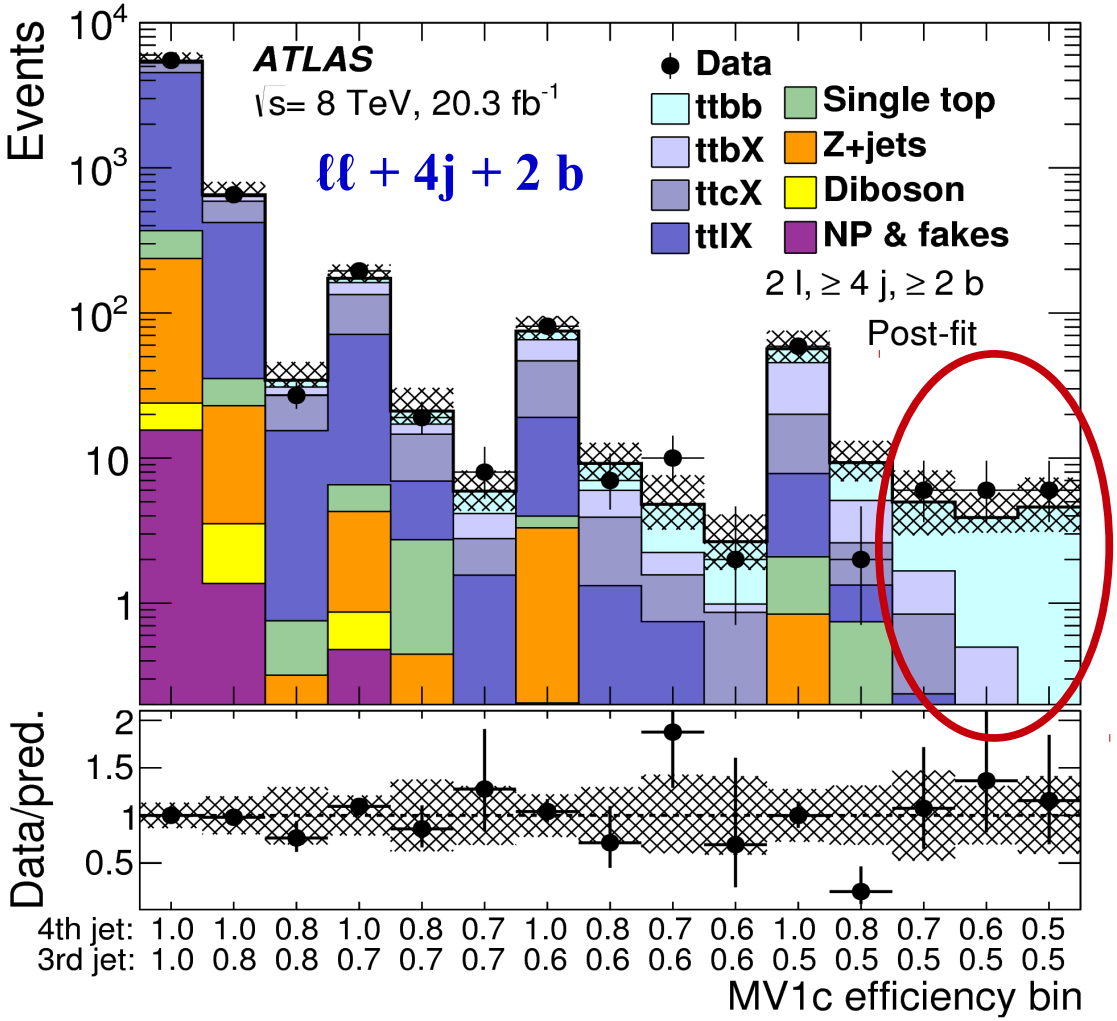
	7 TeV (pb)	8 TeV (pb)	$R_{t\bar{t}}$
Theory	(scale ± PDF+α_s)		
	$177.3\,{}^{+4.7}_{-6.0} \pm 7.1$	$252.9\,{}^{+6.7}_{-8.6} \pm 11.7$	1.43 ± 0.01
modeling  [1]	182 3.5% 1	242. 3.9% 3	1.33 ± 0.06
	174 3.5% 2	245 3.8% 3	1.41 ± 0.06

[1] Eur.Phys.J. C74 (2014) 3109

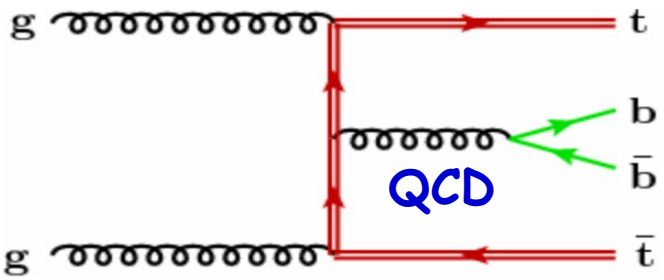
$t\bar{t}b(b)$ cross section 8 TeV

NEW LHCP 2015

arXiv:1508.06868



- Investigating NLO QCD
- Background to ttH, ttZ, …



- Based on the b-tag discriminator of the 3rd and 4th jets
- Ratio $\sigma_{ttbb}/\sigma_{ttjj}$ measured, too[1]

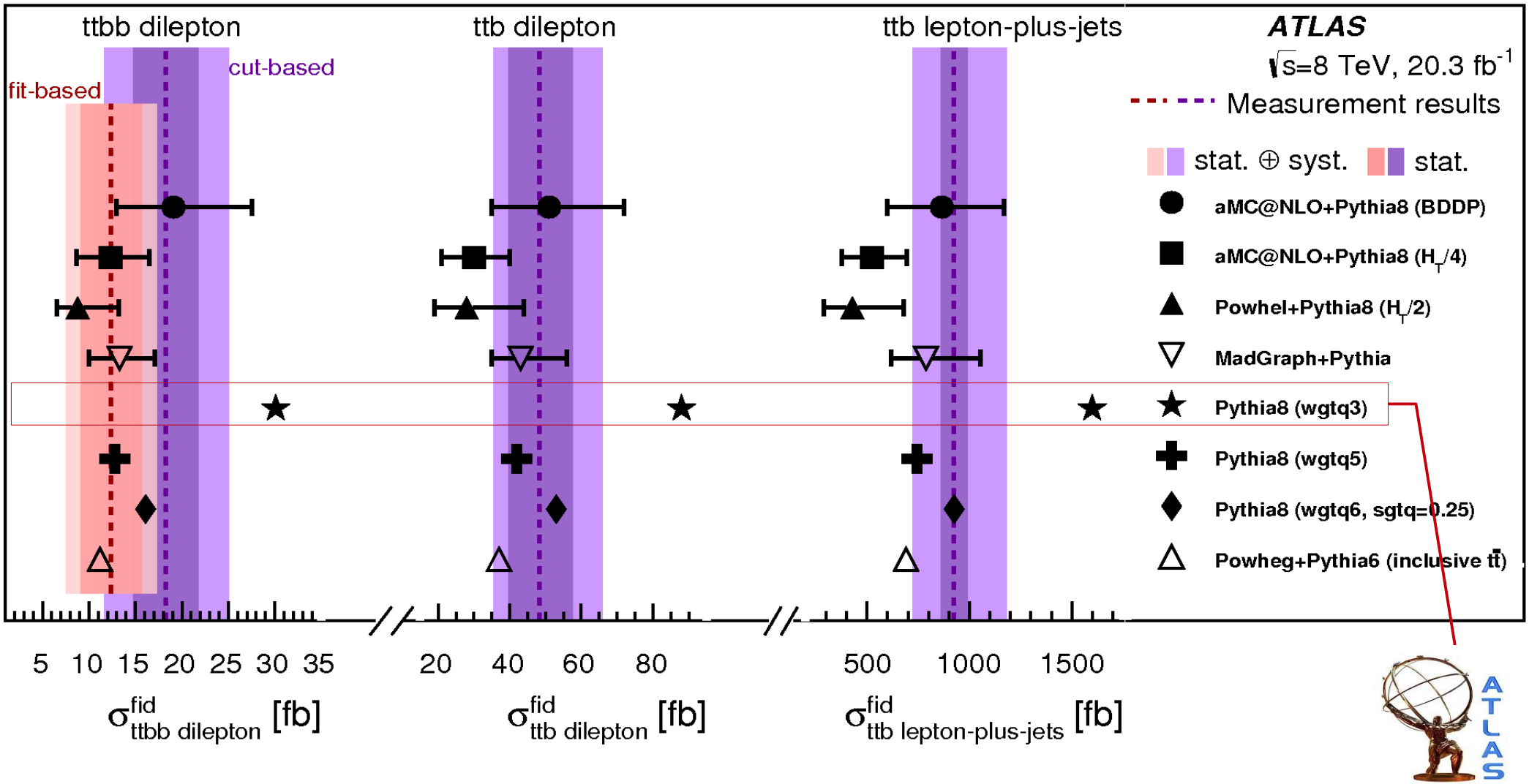
[1] CMS earlier measurement, 2ℓ: Phys. Lett.B746(2015)132, ℓ+jets: TOP-13-016

$t\bar{t}b(b)$ cross section 8 TeV

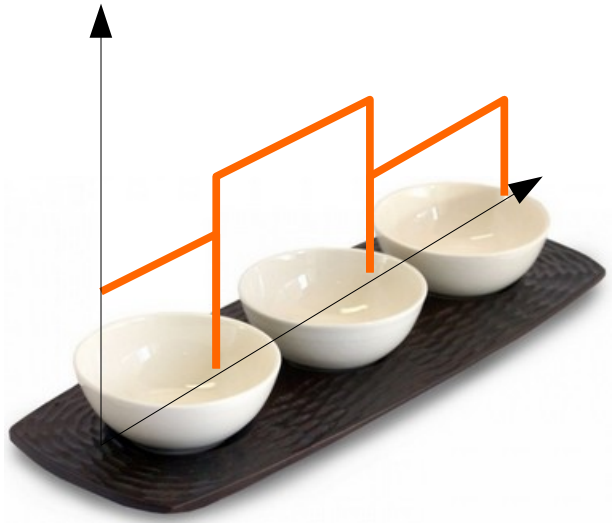
NEW

$\ell\ell + 4j + 2\,b$ $e\mu + 3\,b$ $\ell + 5j + 3\,b$

arXiv:1508.06868



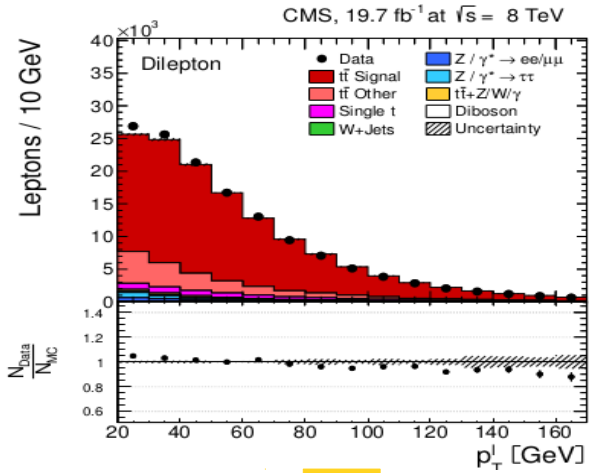
Parametrization maximizing $g \to b\bar{b}$ rate in Pythia8 disfavored



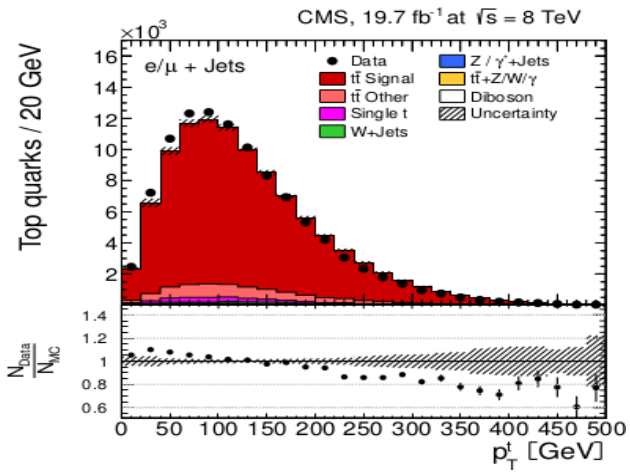
DIFFERENTIAL

Differential cross section

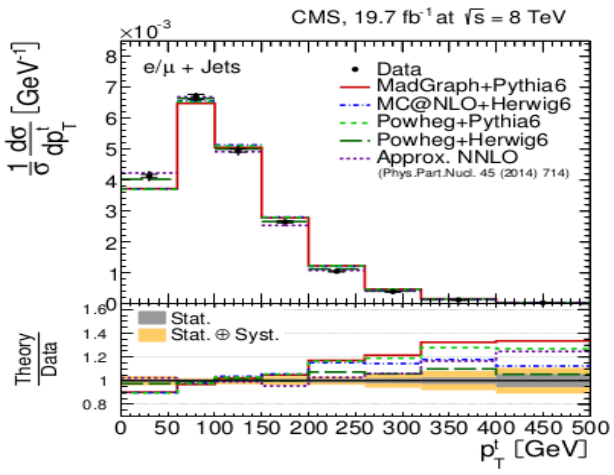
Object reconstruction



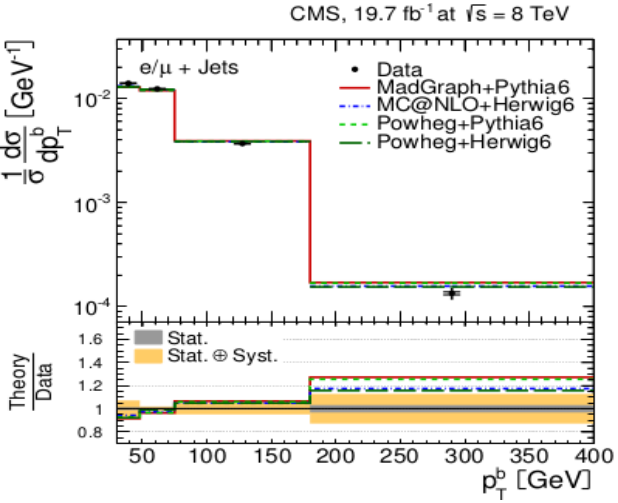
Top quark reconstruction



Compare to theory

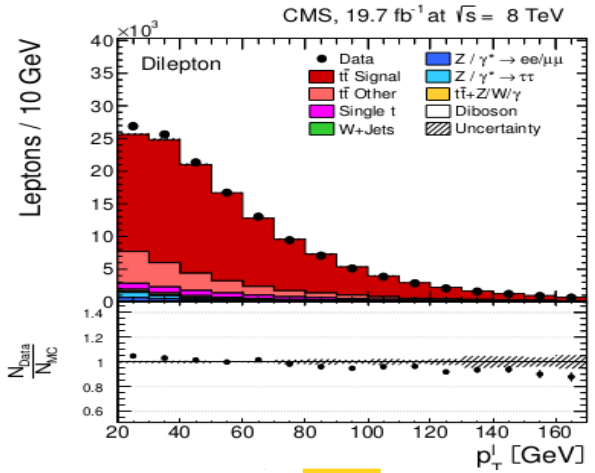


Compare to theory

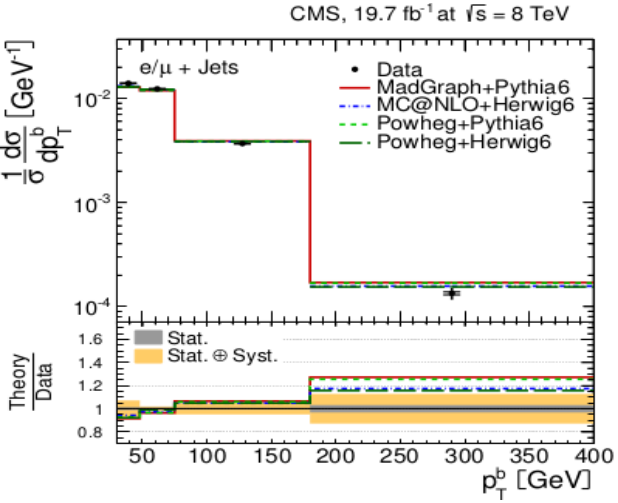


Differential cross section

Object reconstruction



Compare to theory



- Compare to ***particle level***

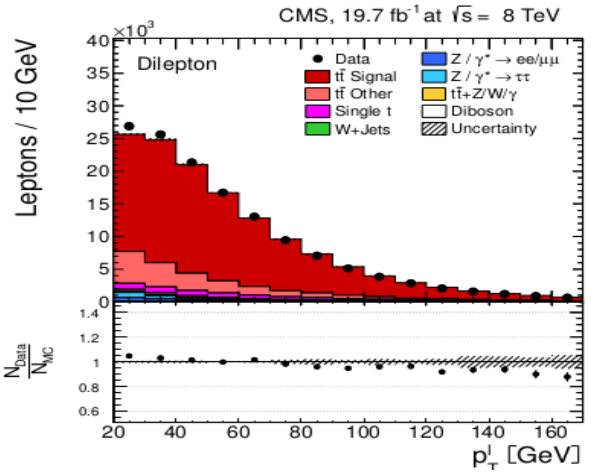
- *Reconstructed* such to resemble detector level objects
- *Selected* similarly to detector level objects

Stable particles after the full ME + PS

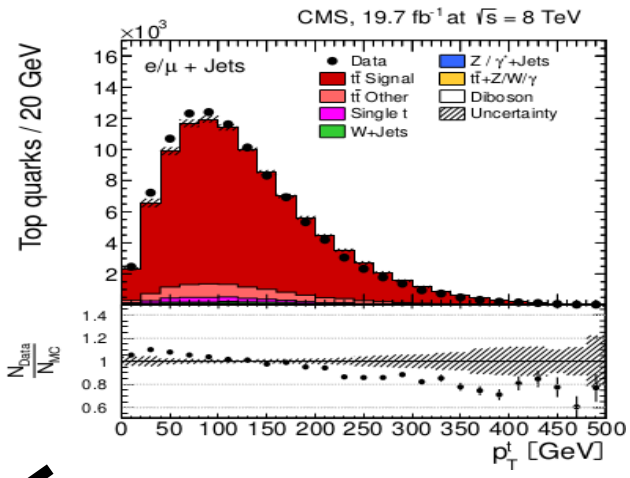
- *Example:*
- Jets are clustered from stable particles with the same jet algorithm as the detector level

Differential cross section

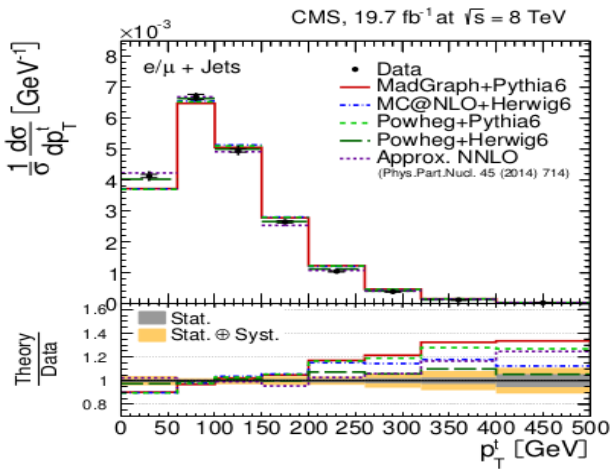
Object reconstruction



Top quark reconstruction



Compare to theory



- Reconstruction of the top quarks with kinematic constraints

- Compare to ***Parton level***

Top quark before decay, after QCD radiation

- Compare to ***Particle level***
- Similar reconstruction algorithm to detector level → ***pseudo-tops***

Differential cross section ℓℓ, ℓ+jets 8 TeV

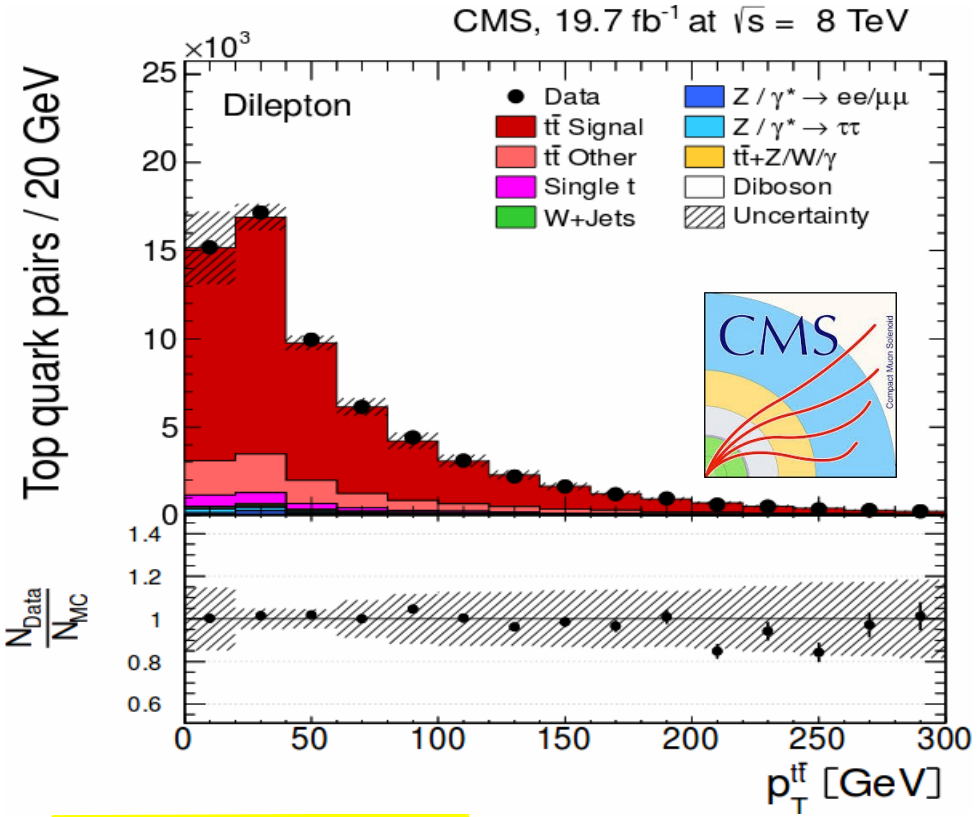
NEW

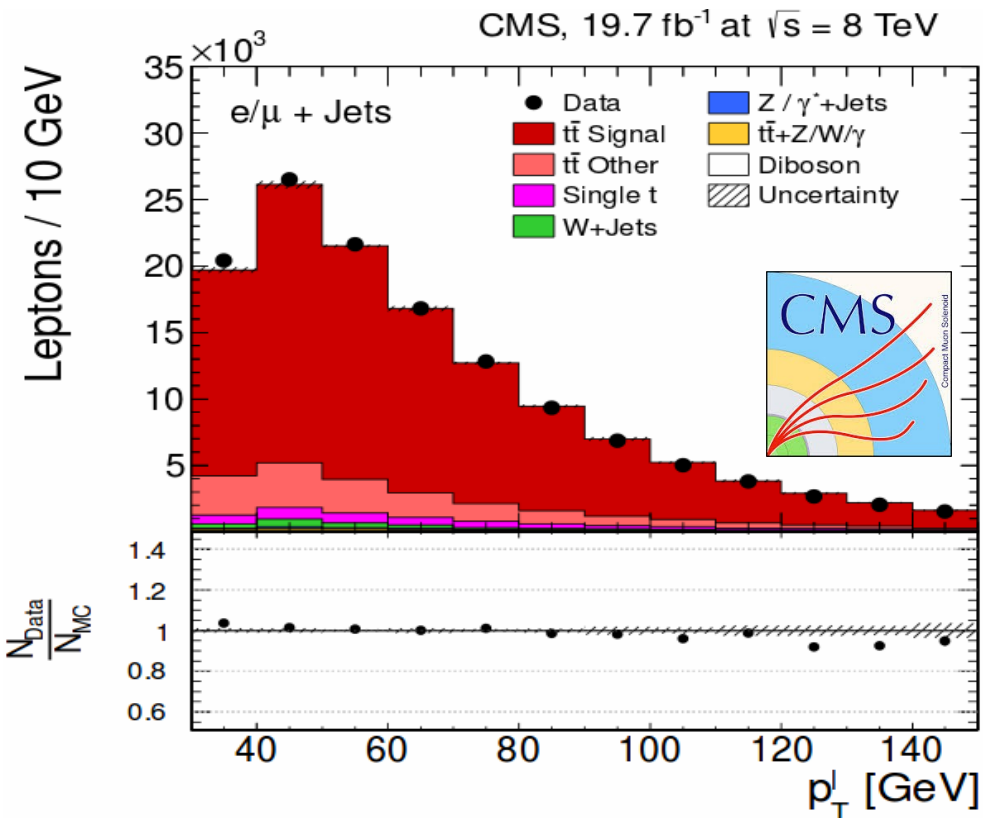
Di-lepton:

- Exactly two opposite sign leptons
- Not compatible with Z bososn
- At least 2 jets, at least 1 *b-tag*

Single lepton:

- Exactly one electron or muon
- At least 4 jets, at least *2 b-tag*, at least *2 non-tagged*

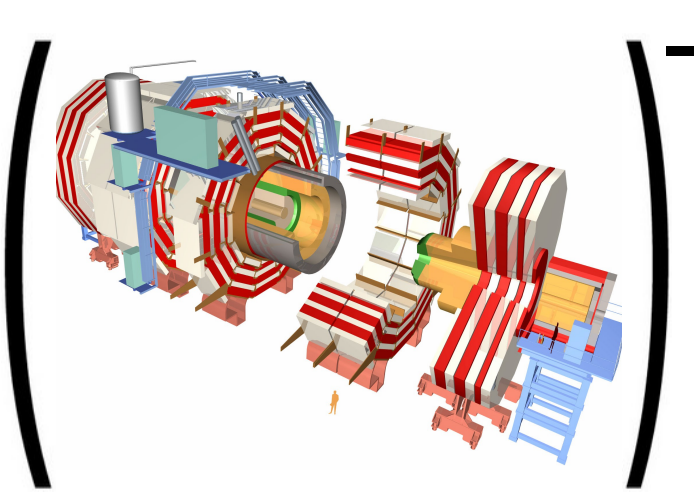




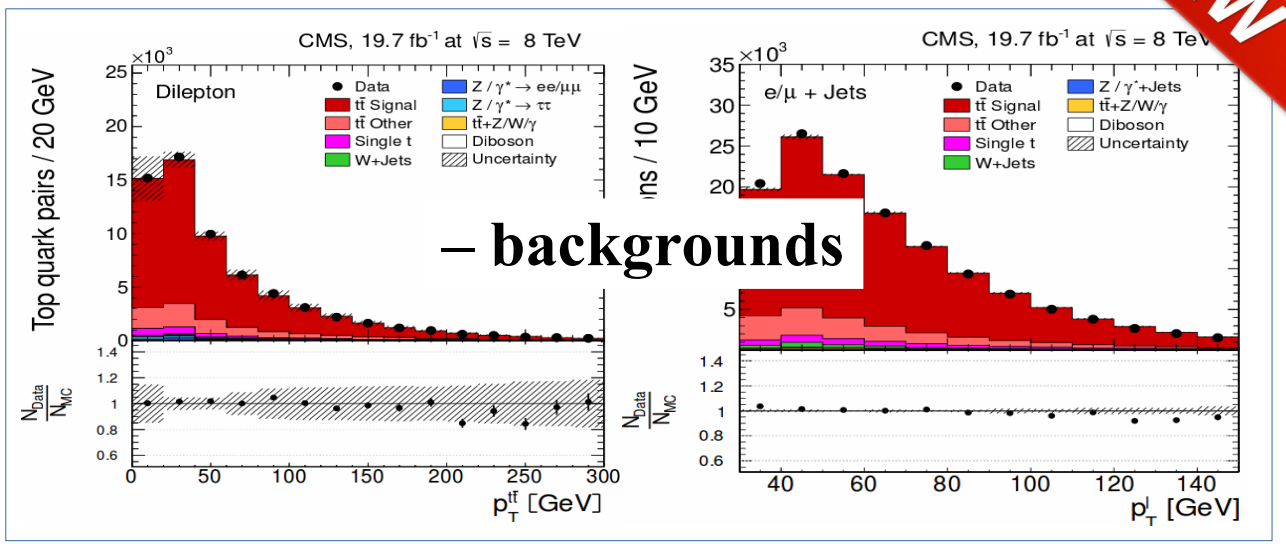
arXiv:1505.04480

Differential cross section ℓℓ, ℓ+jets 8 TeV

NEW



$\left(\frac{1}{\sigma}\frac{d\sigma}{dp_T^{t\bar{t}}}\right)^{-1}$ x

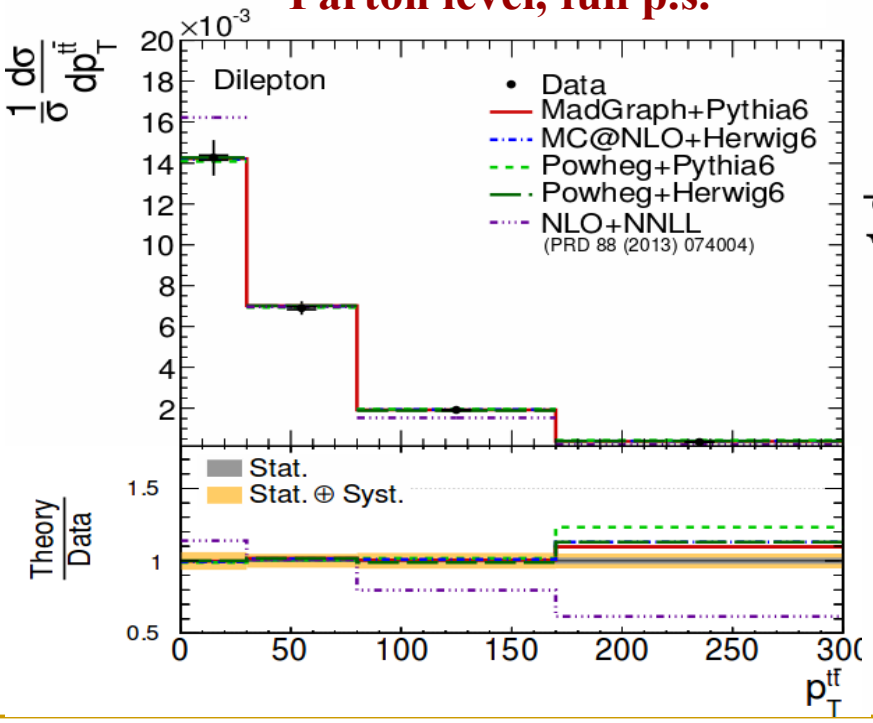


– backgrounds

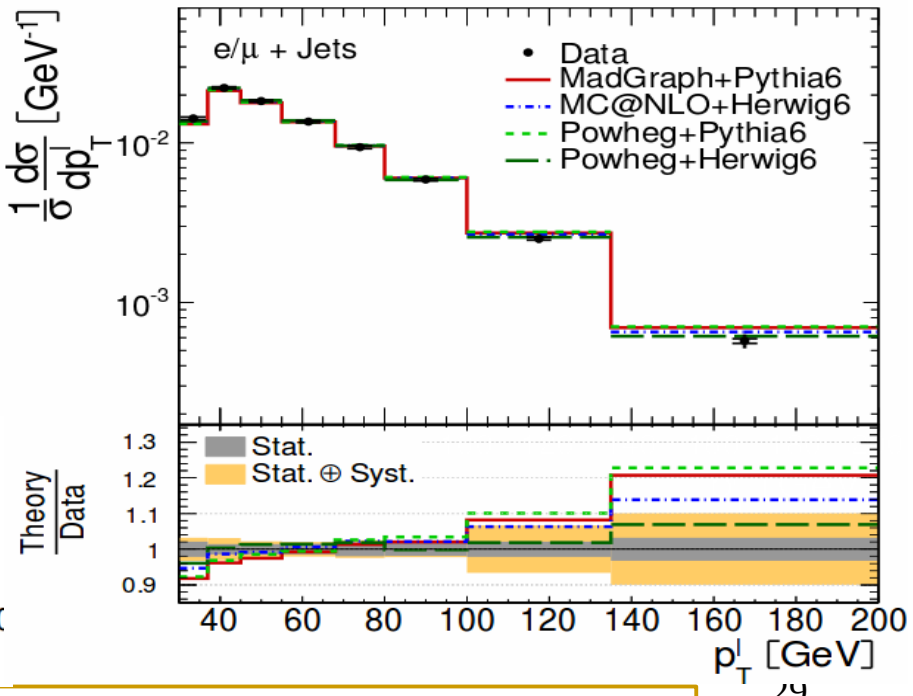
arXiv:1505.04480

Regularized unfolding

Parton level, full p.s.



Particle level, fiducial



Generally good agreement between data and simulation

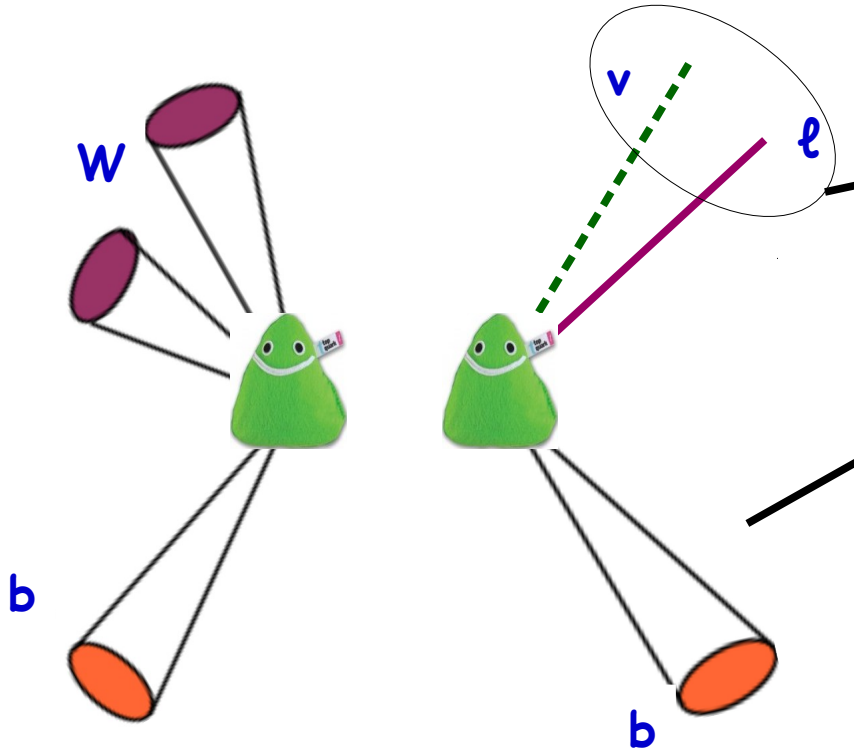
Differential cross section ℓ+jet 7 TeV

- Measurement at ***particle level*** in a ***fiducial*** region
- Only one electron or muon
- At least 2 jets, at least 2 b-tagged

JHEP 06(2015)100

Pseudo top

Top quark reconstruction at *particle* and *detector* level



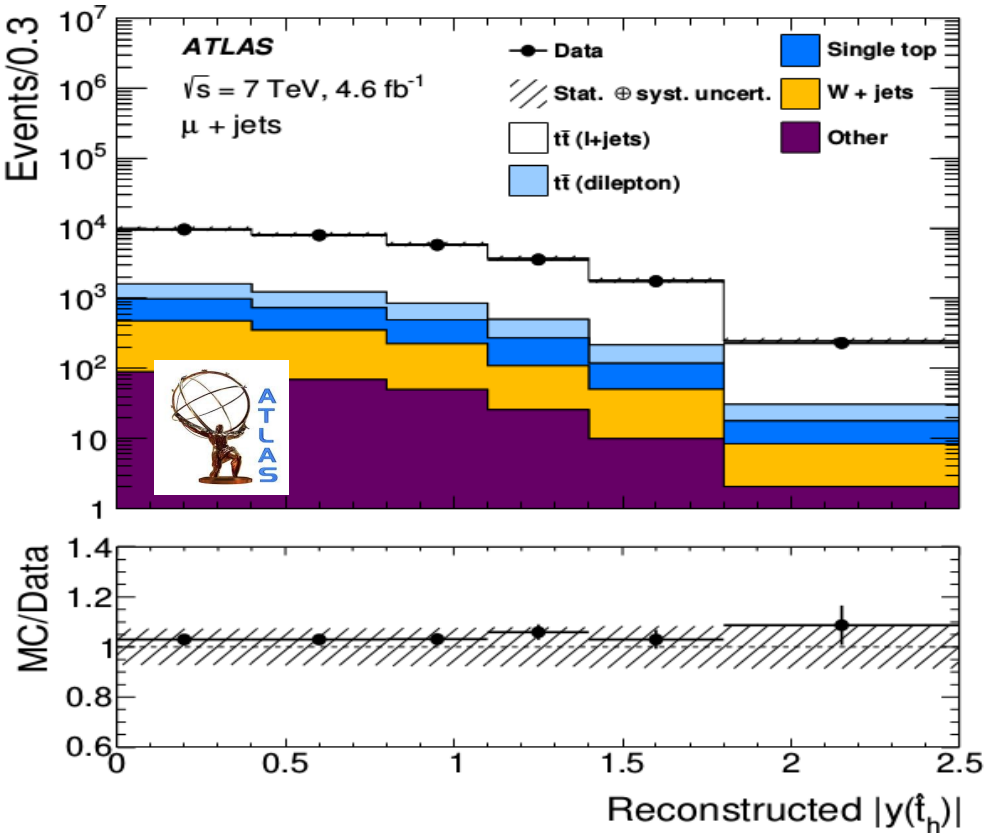
W boson with $m_W = 80.39$

Combined with closest b-jet

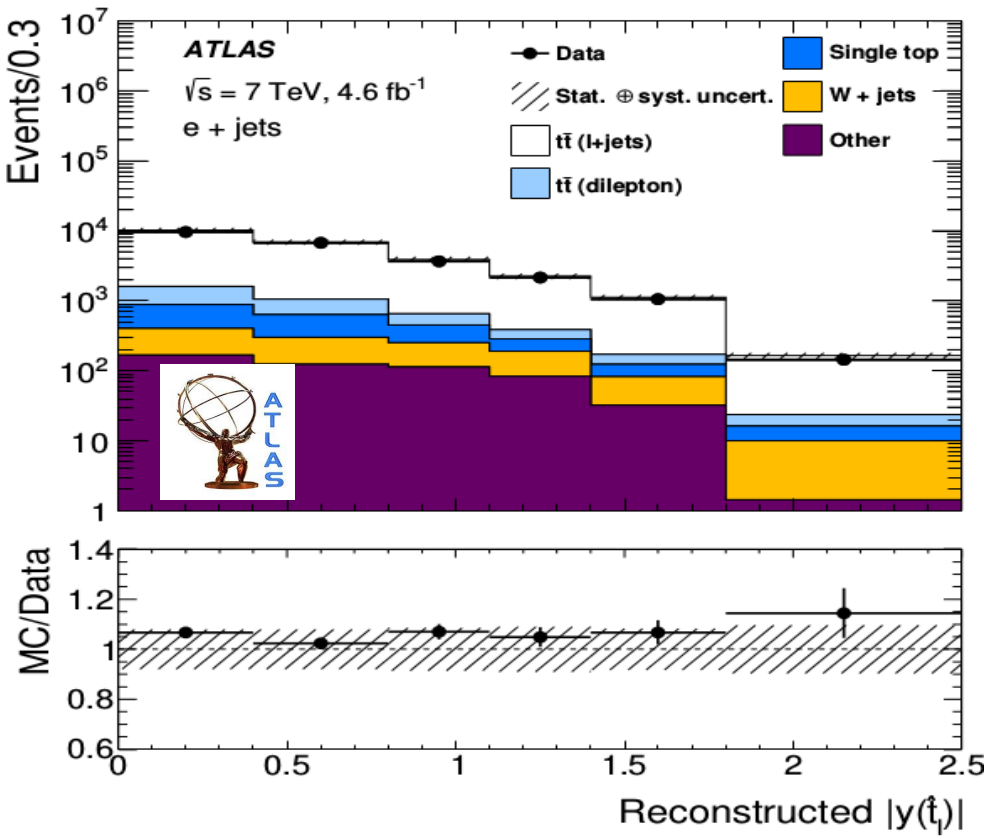
Other jets assigned to hadronic side

Differential cross section ℓ+jet 7 TeV

Rapidity of hadronic top

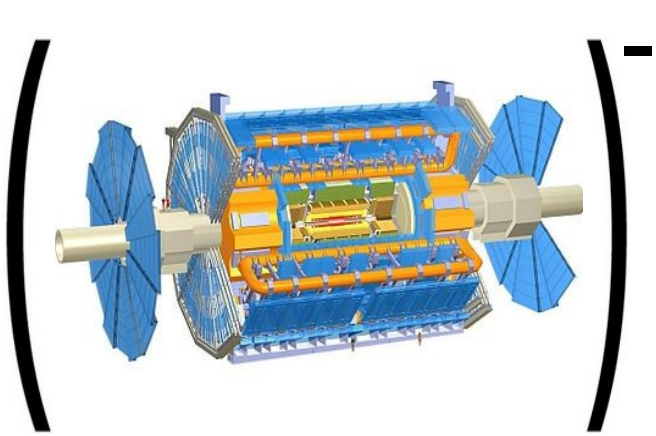


Rapidity of leptonic top



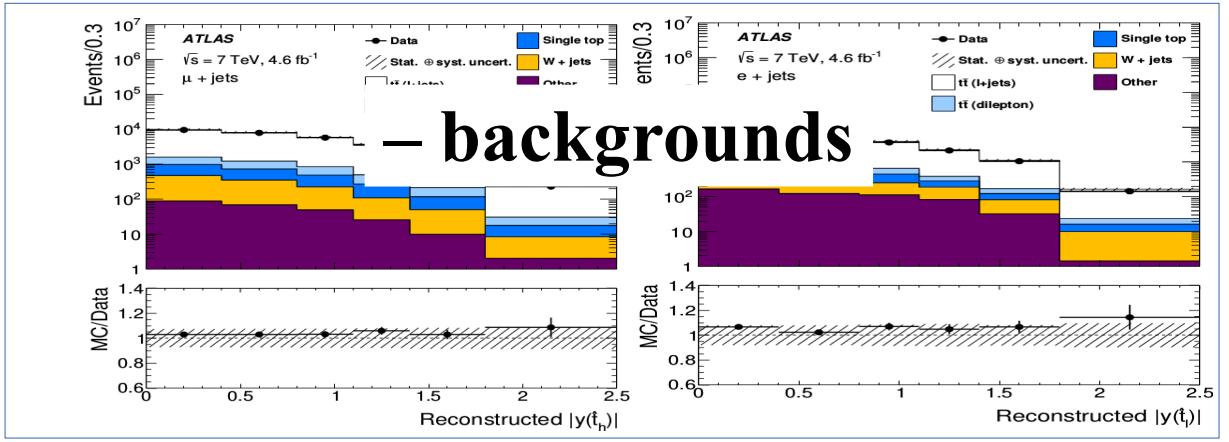
JHEP 06(2015)100

Differential cross section ℓ+jets 7 TeV

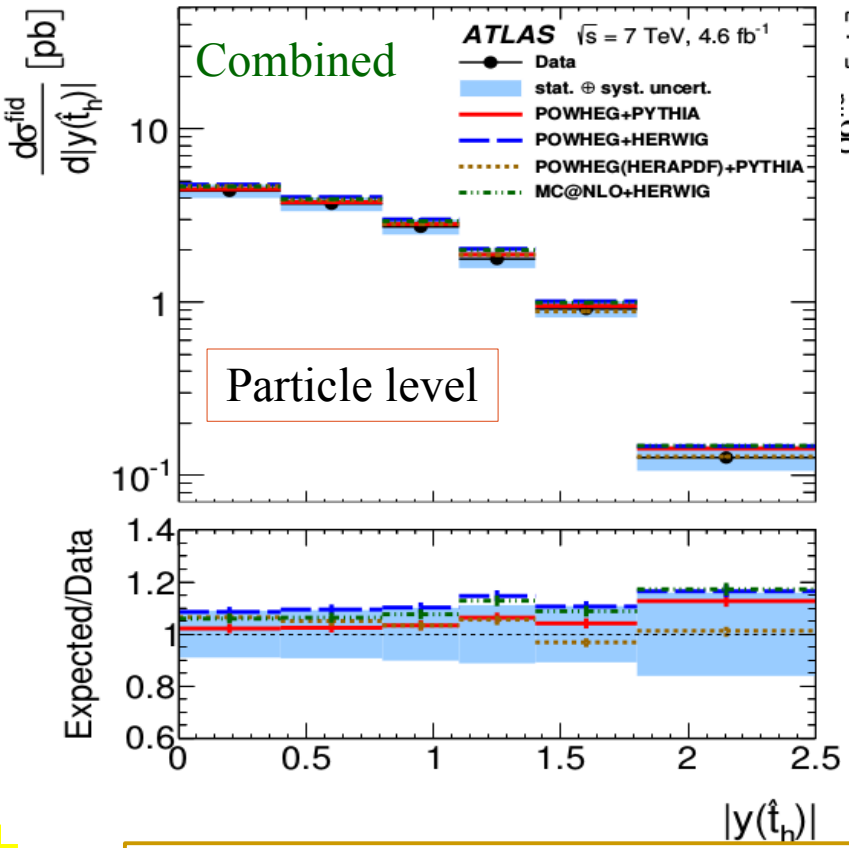


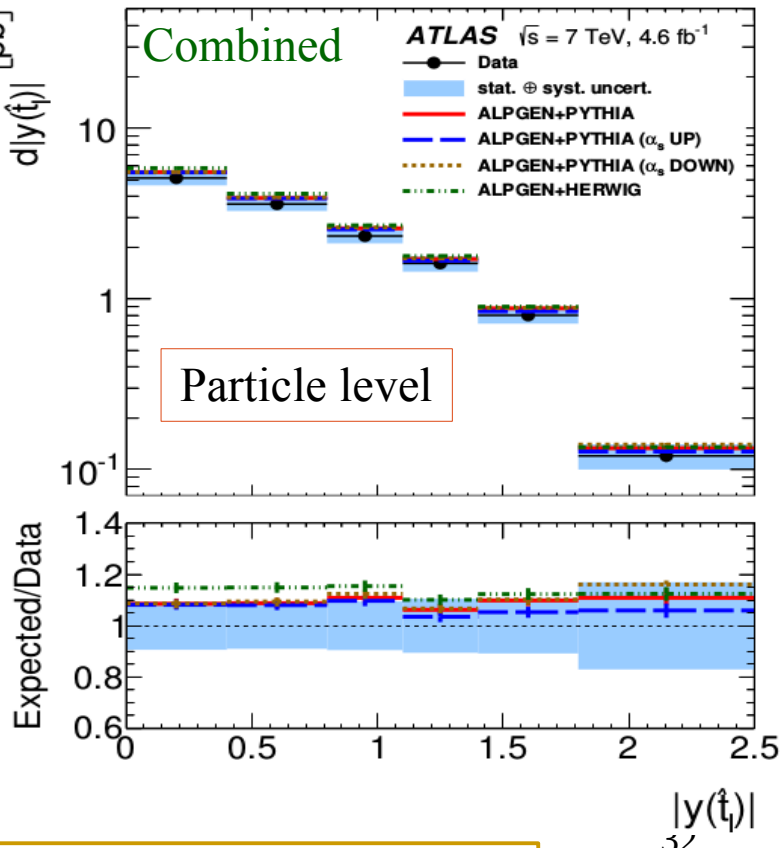
$^{-1}$

x



Regularized unfolding





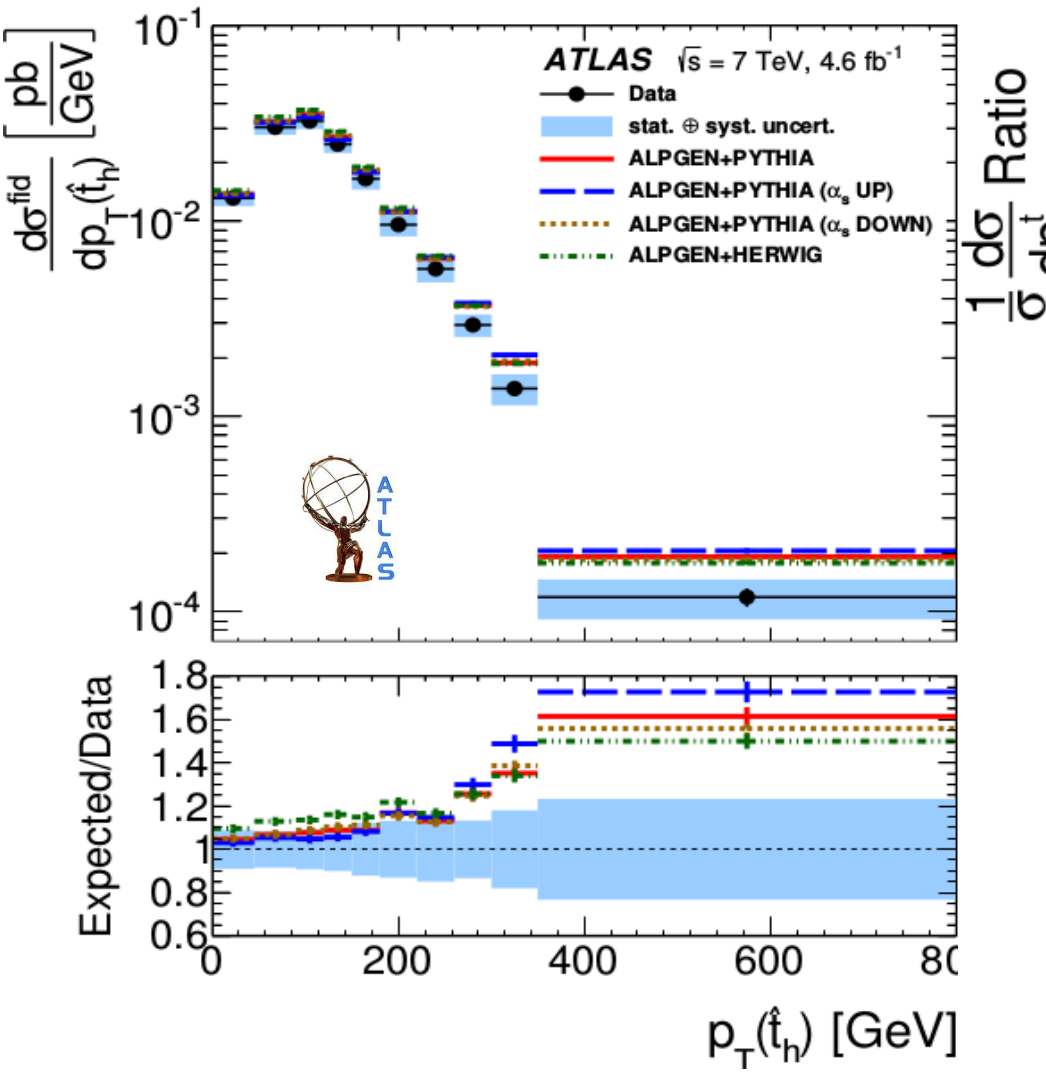
JHEP 06(2015)100

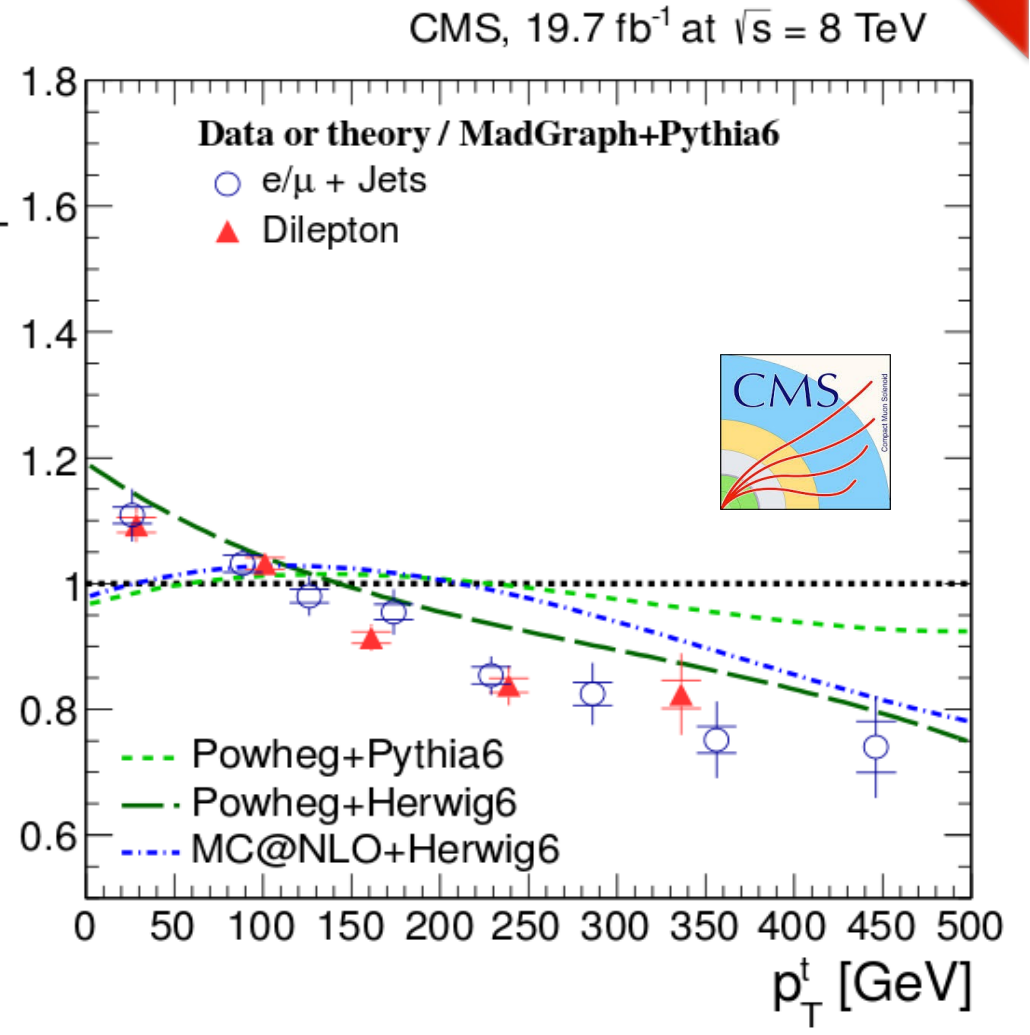
Larger event yield in simulation than in data

The p_T of the top quark

NEW

Softer spectrum in data than simulation



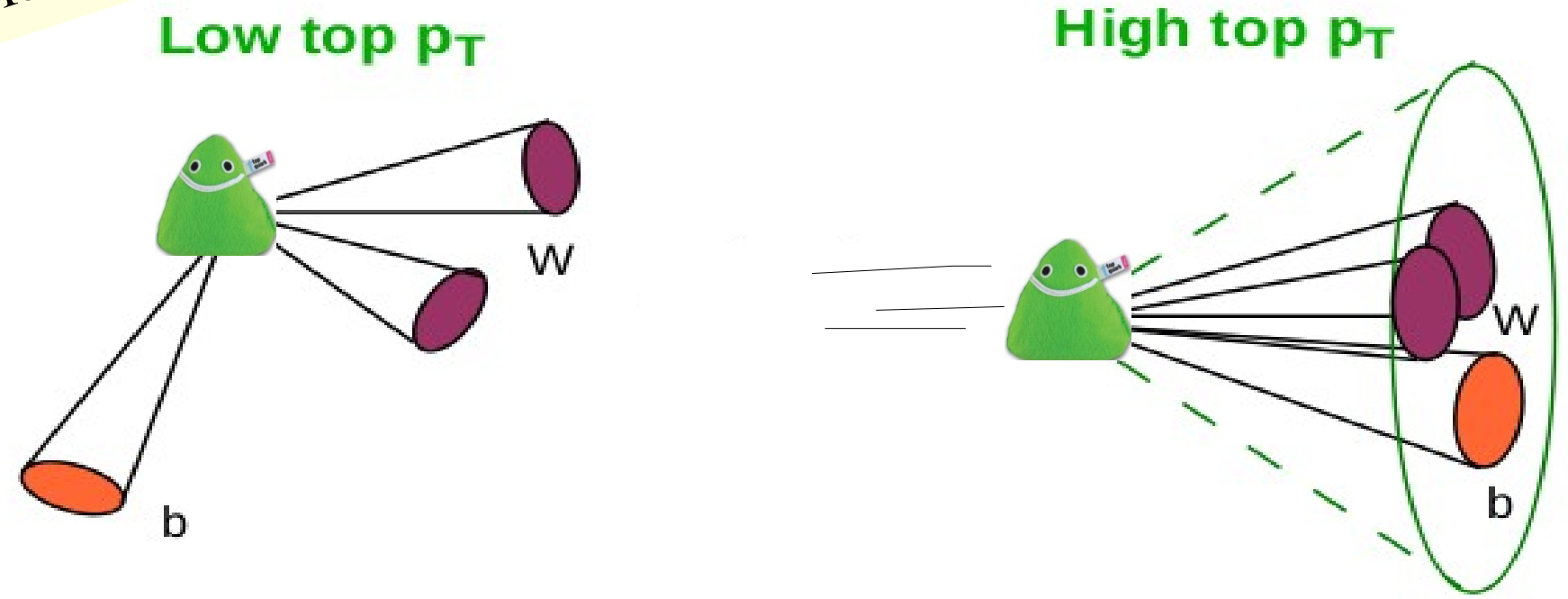


Fiducial, Particle level

Full phase space, Parton level

Modeling in high p_T

Sign of new physics?



Top quark is treated as a single jet!
Identified with jet substructure techniques …

BOOSTED REGIMES

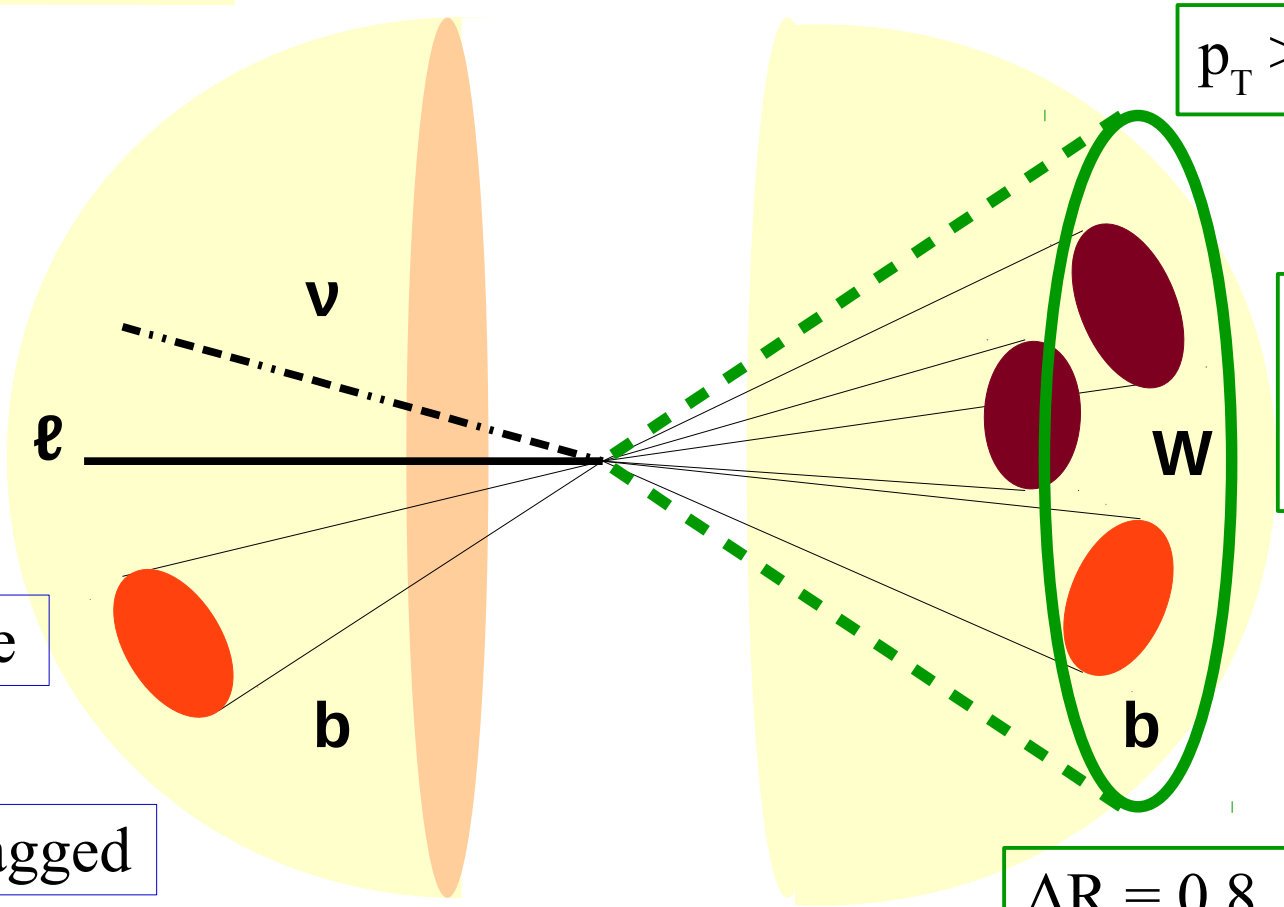
Differential σ_{tt} for high p_T tops at 8 TeV

NEW

TOP-14-012

$p_T > 400$ GeV

Non-isolated lepton



Different hemisphere than lepton

Same hemisphere

$\Delta R = 0.5$, b-tagged

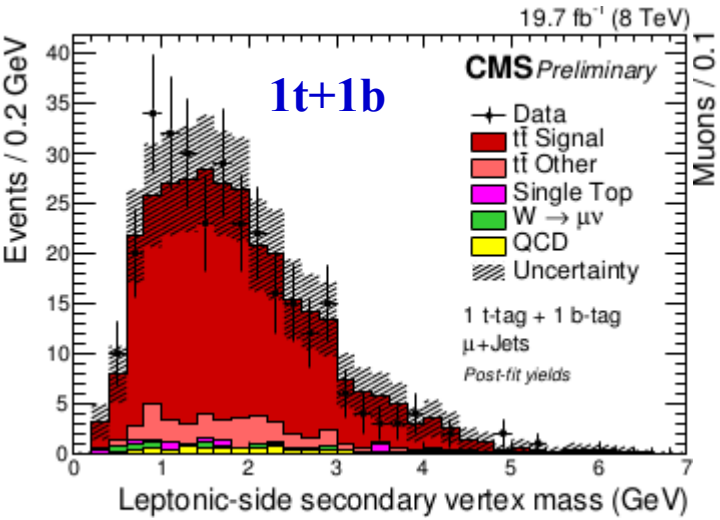
$\Delta R = 0.8$, top-tagged

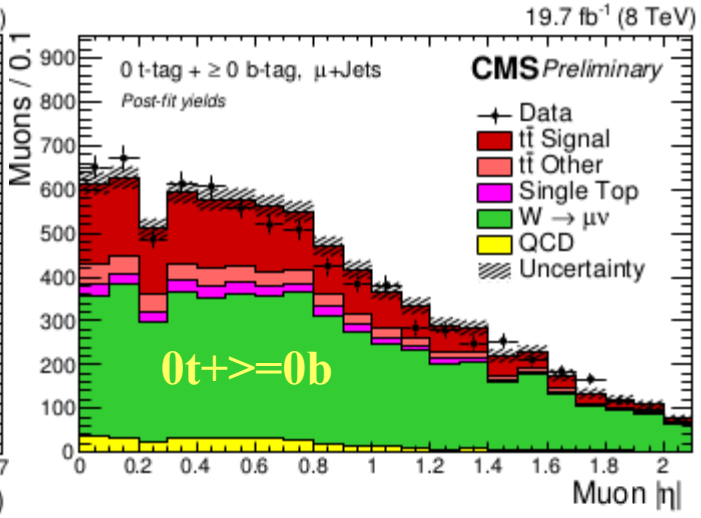
3 event categories: 0t, 1t+0b, 1t+1b

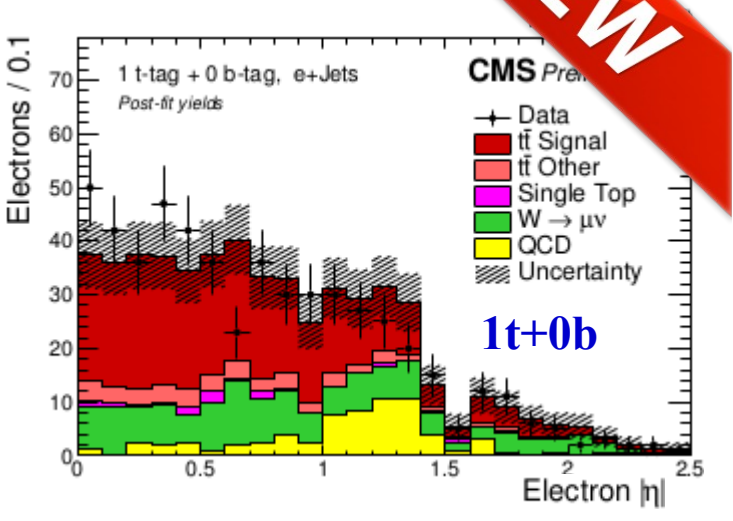
1 top-tag differential distributions

Differential σ_{tt} for high p_T tops at 8 TeV

NEW







Simultaneous MLL fit

TOP-14-012

Fiducial at particle level

$$\sigma_{t\bar{t}} = 1.28 \pm 0.09\,(stat.+syst.) \pm 0.1\,(PDF) \pm 0.09\,(Q^2) \pm 0.03\,(lumi.)\ pb$$

Fiducial at parton level (before decay after QCD radiations)

$$\sigma_{t\bar{t}} = 1.44 \pm 0.10\,(stat.+syst.) \pm 0.13\,(PDF) \pm 0.15\,(Q^2) \pm 0.04\,(lumi.)\ pb$$

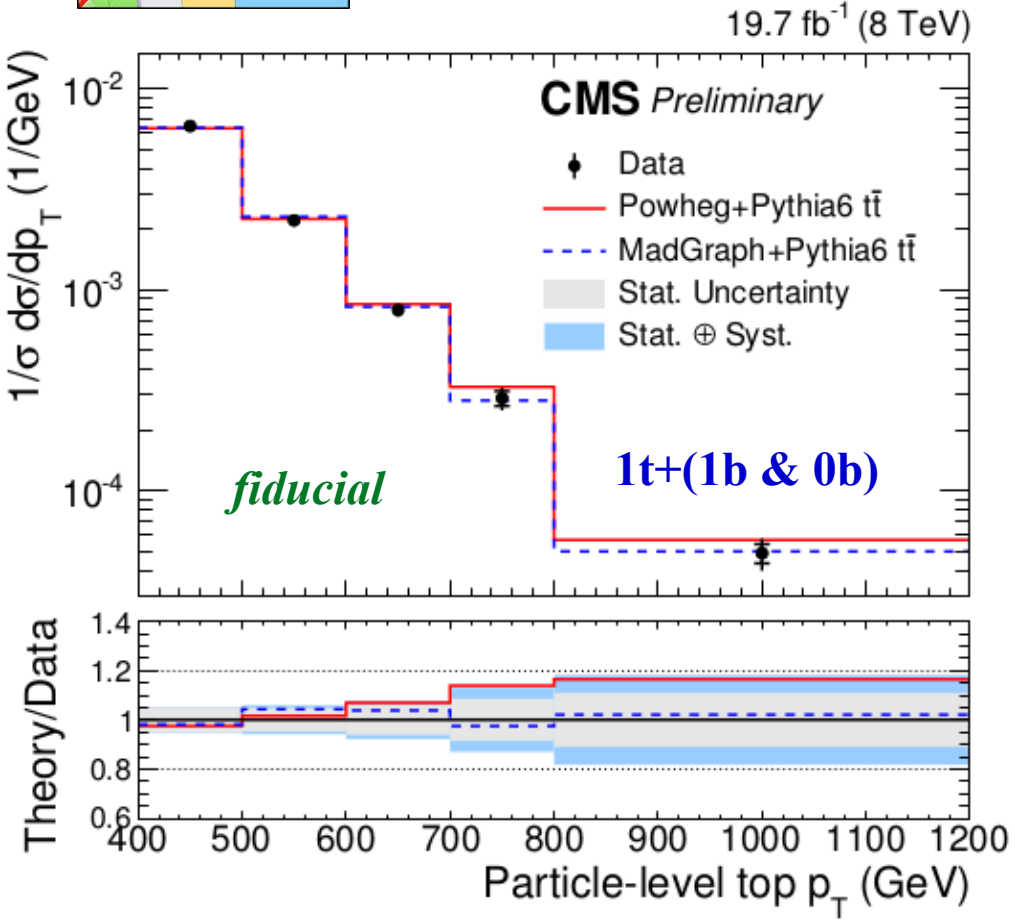
- PowHeg predicts 1.49 (1.67) pb at particle (parton) level
- About 14% higher, corresponding to 1.3σ (1.0σ)

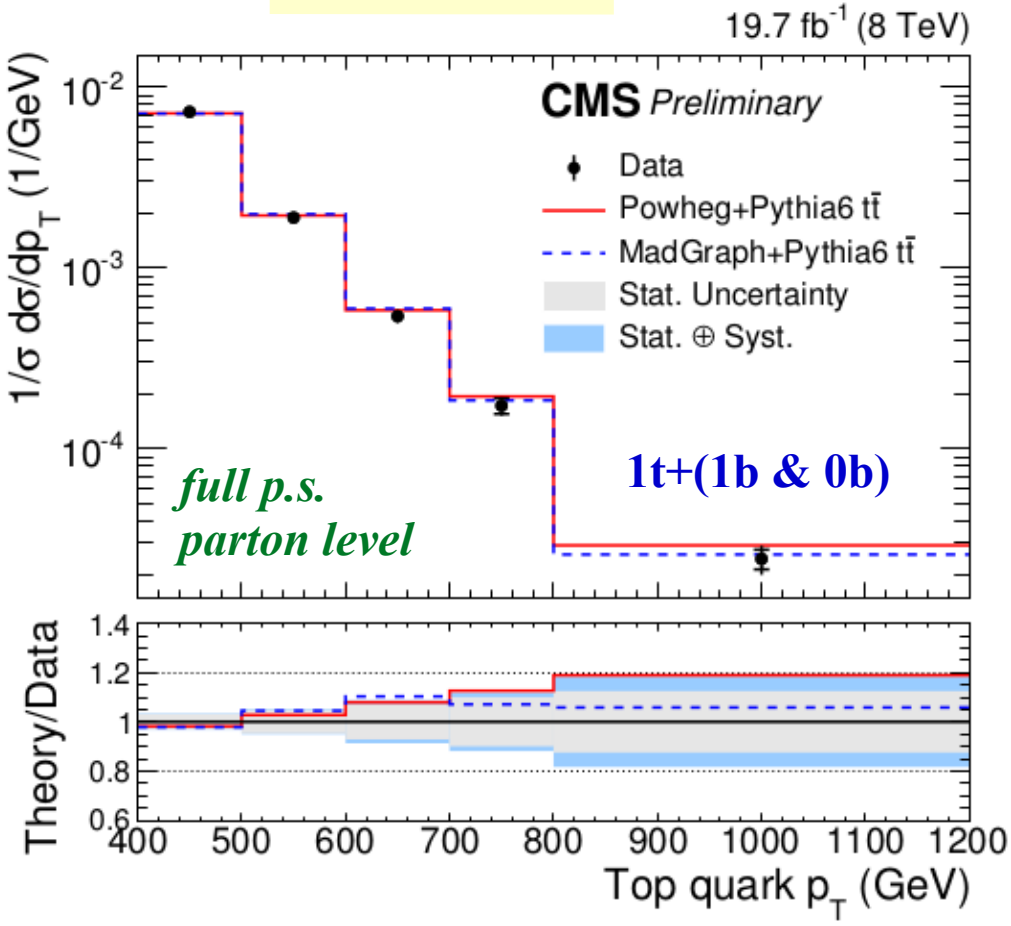
Differential σ_{tt} for high p_T tops at 8 TeV

NEW

After background subtraction and unfolding

TOP-14-012



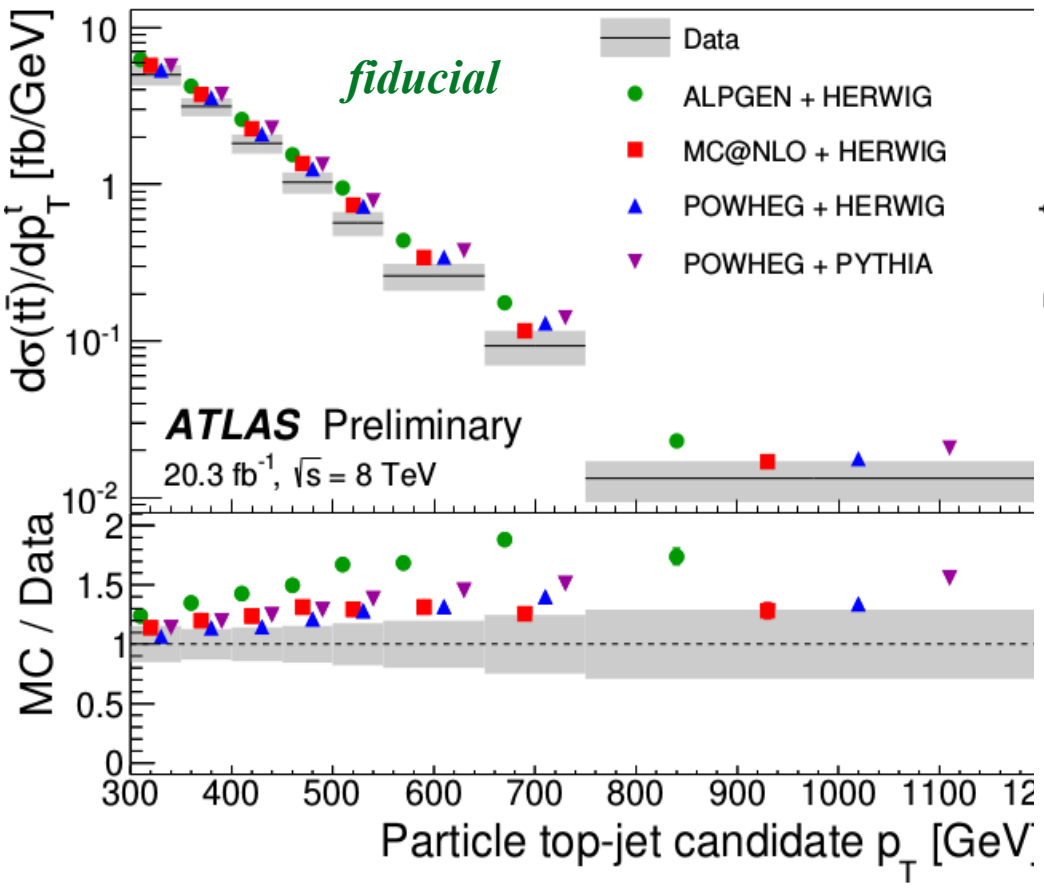


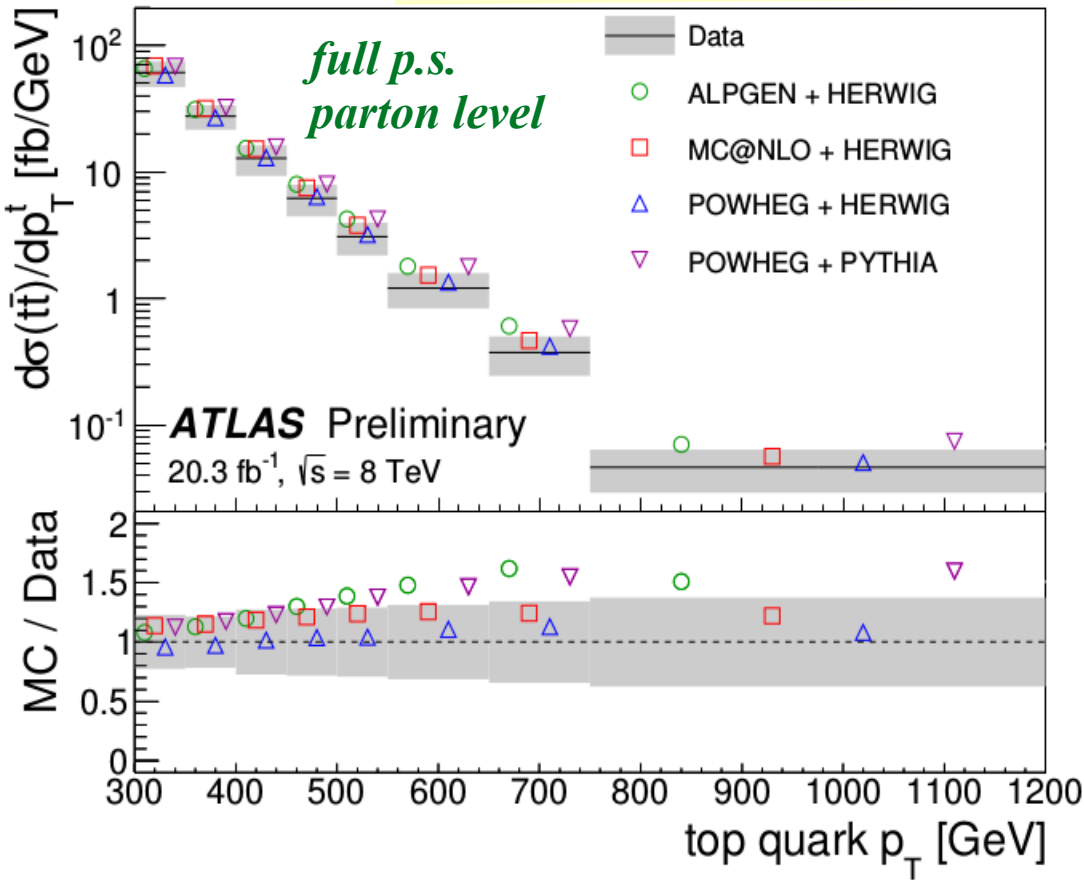
Still PowHeg shows trend to be harder than data (MadGraph ok)

Differential σ_{tt} for high p_T tops at 8 TeV

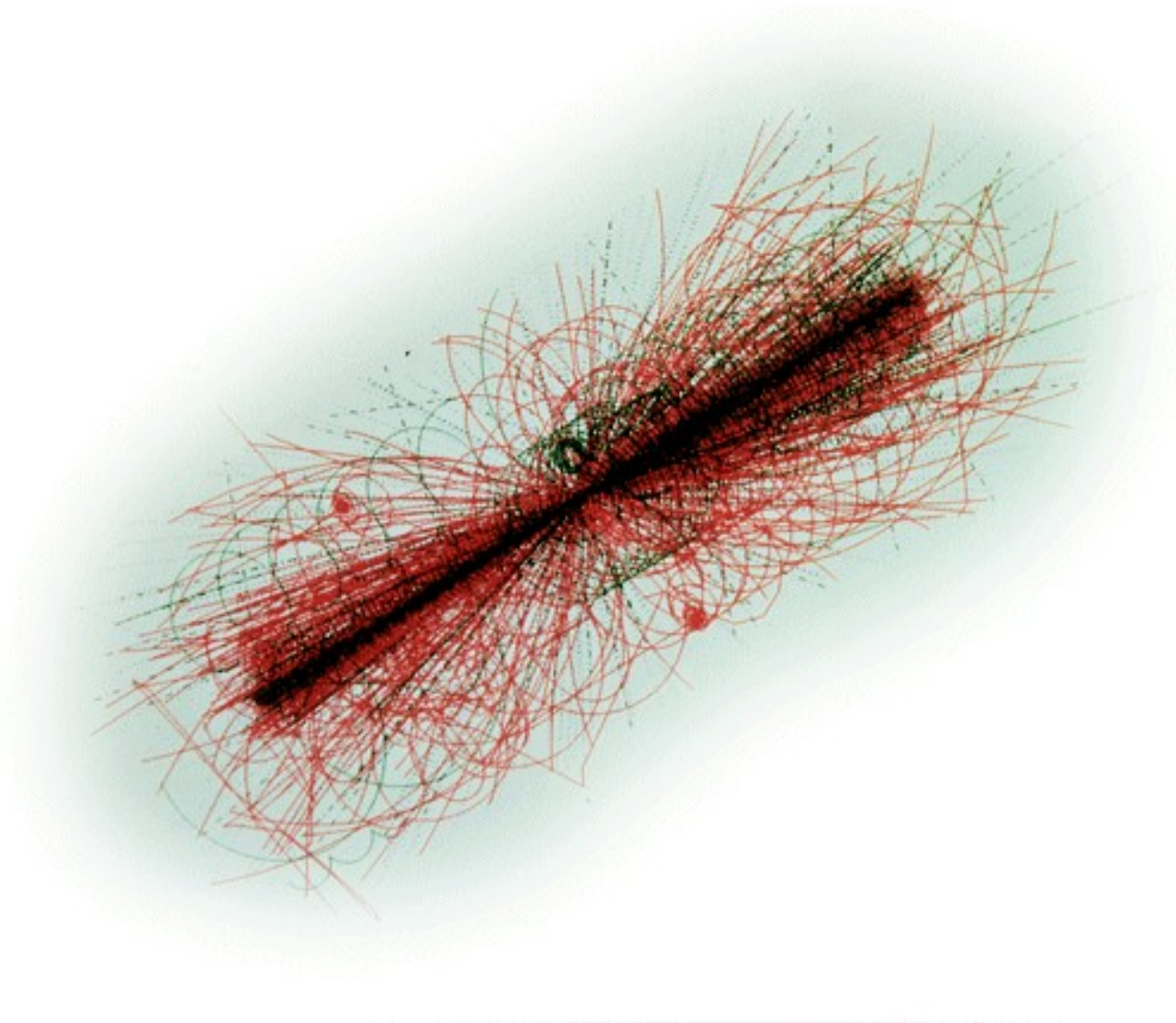
Similar observation in the *first* measurement by ATLAS

ATLAS-CONF-2014-057



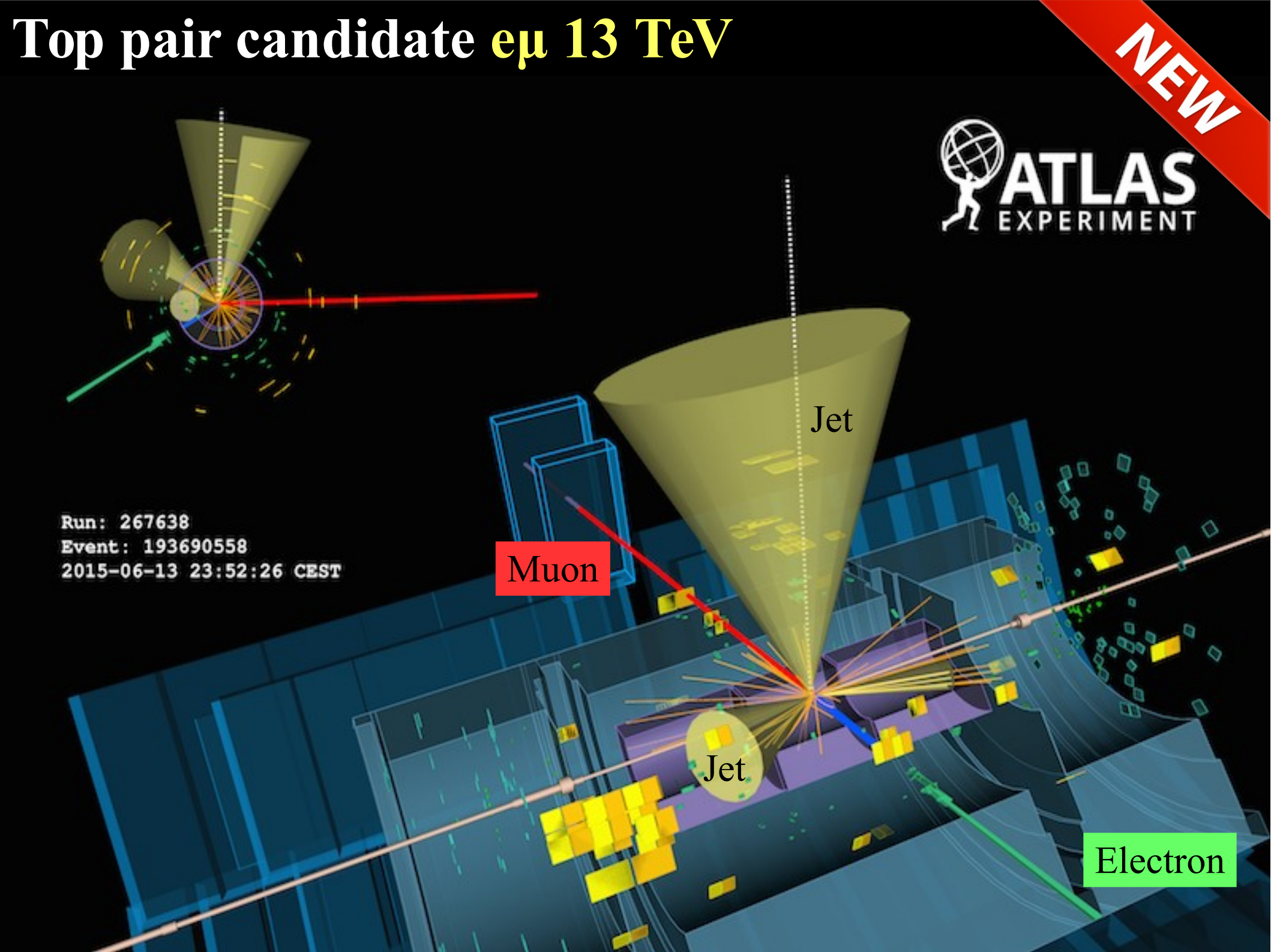


- The overestimation exists in almost all generators
- Increases with top p_T



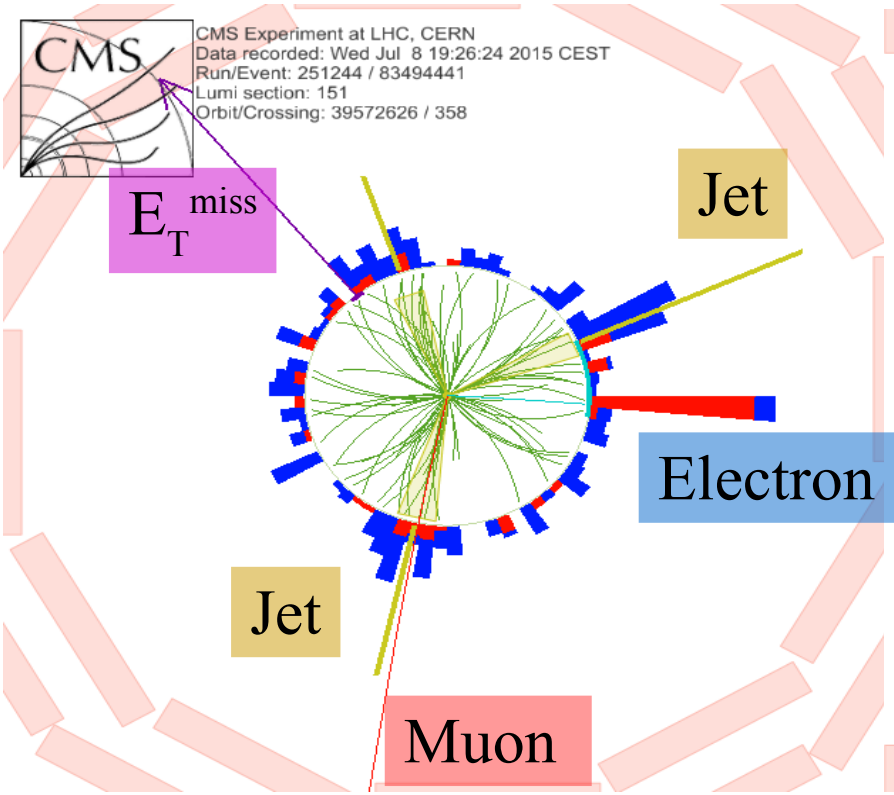
LHC RUN II

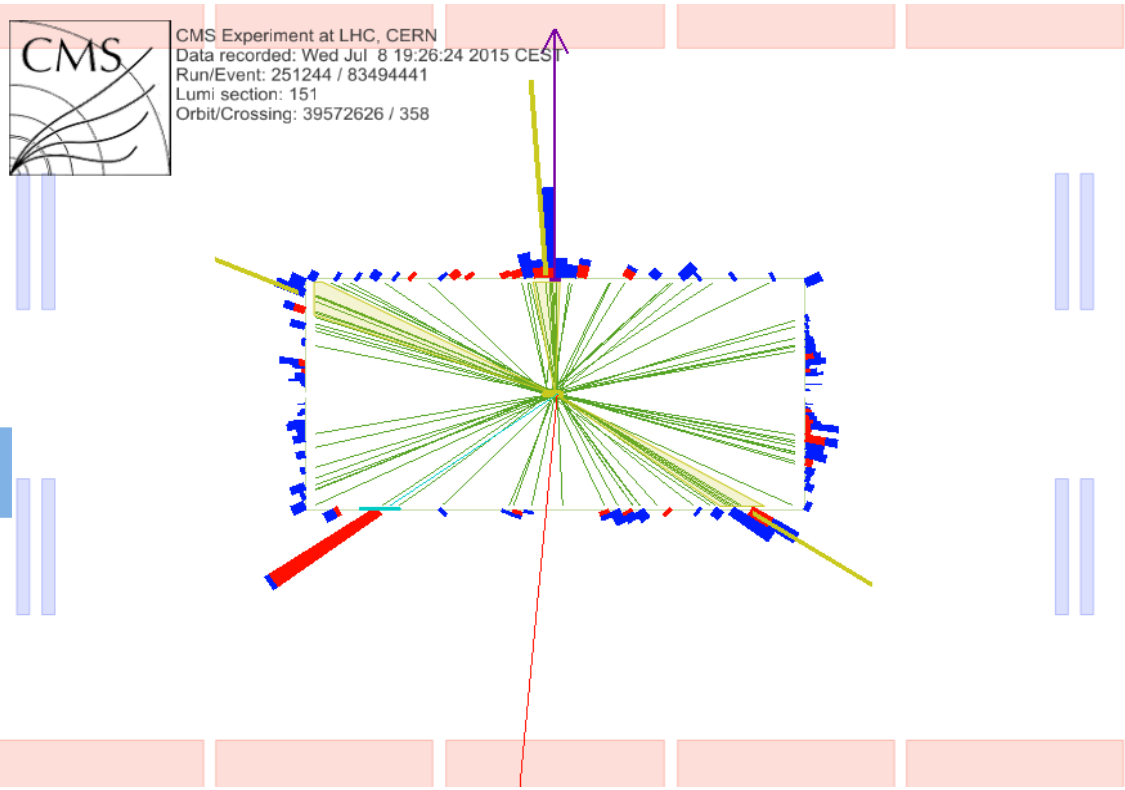
Top pair candidate eμ 13 TeV



Top pair candidate eμ 13 TeV

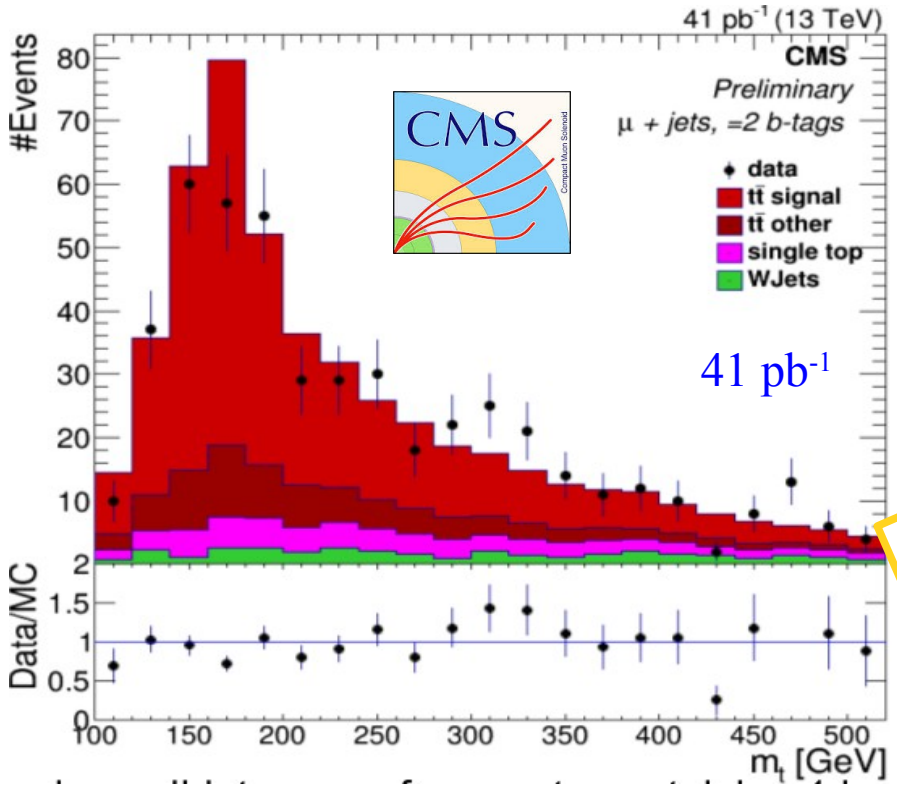
NEW



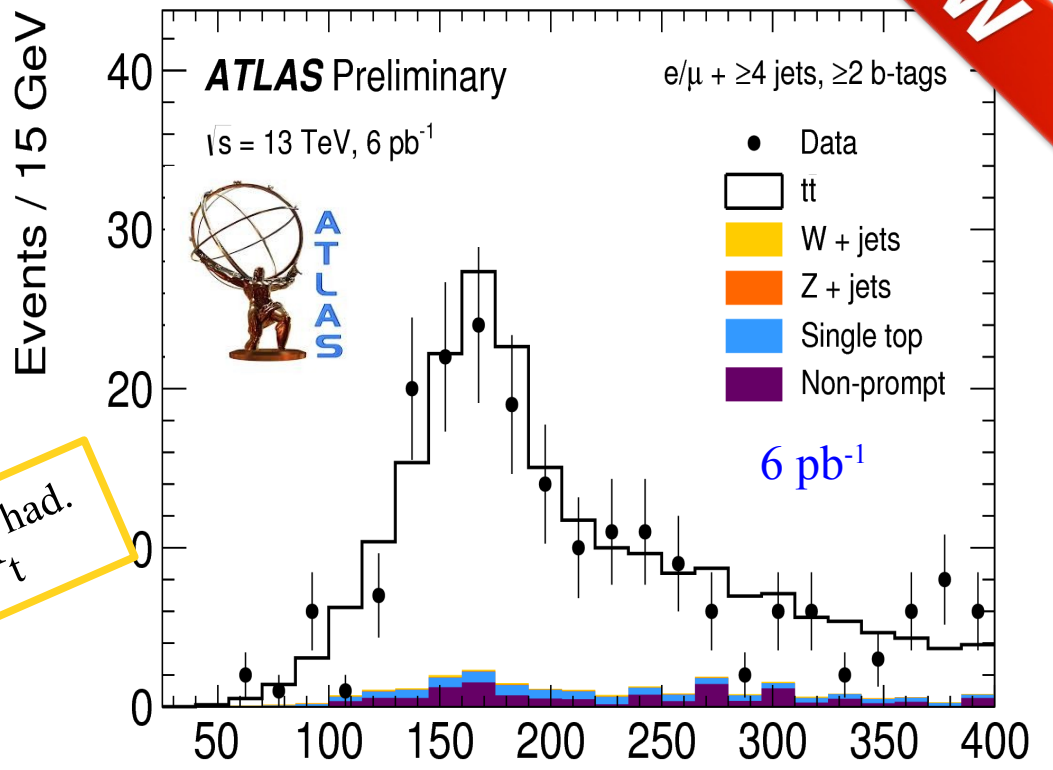


Top distributions with first 13 TeV collisions

NEW



$m_t^{had.}$



μ + at least 4 jets, 2 b-tagged (mva)

- $p_T^{\mu} > 30$ GeV, $|\eta| < 2.4$
- $p_T^{jet} > 30$ GeV, $|\eta| < 2.5$
- Leptonic W: m_W constraint on ℓ, υ
- Hadronic W: m_W constraint on two non-tagged jets
- b-jet and neutrino solution: best compatibility with m_{top}

CMS DP-2015/019

μ/e + at least 4 jets, at least 2 b-tag (mva)

- $P_t^{e/\mu} > 25$ GeV, $|\eta^{\mu}| < 2.5$, $|\eta^{e}| < 2.47$
- $p_T^{jet} > 25$ GeV, $|\eta| < 2.5$
- **e:** $m_T^W > 50$ GeV or $E_T^{miss} > 40$ GeV
- **μ:** $m_T^W + E_T^{miss} > 60$ GeV
- 2 b-jet with highest tag value
- Hadronic W: 2 other jets with highest p_T
- Hadronic top: b-jet with max. $\Delta R(j,\ell)$

ATL-PHYS-PUB-2015-017

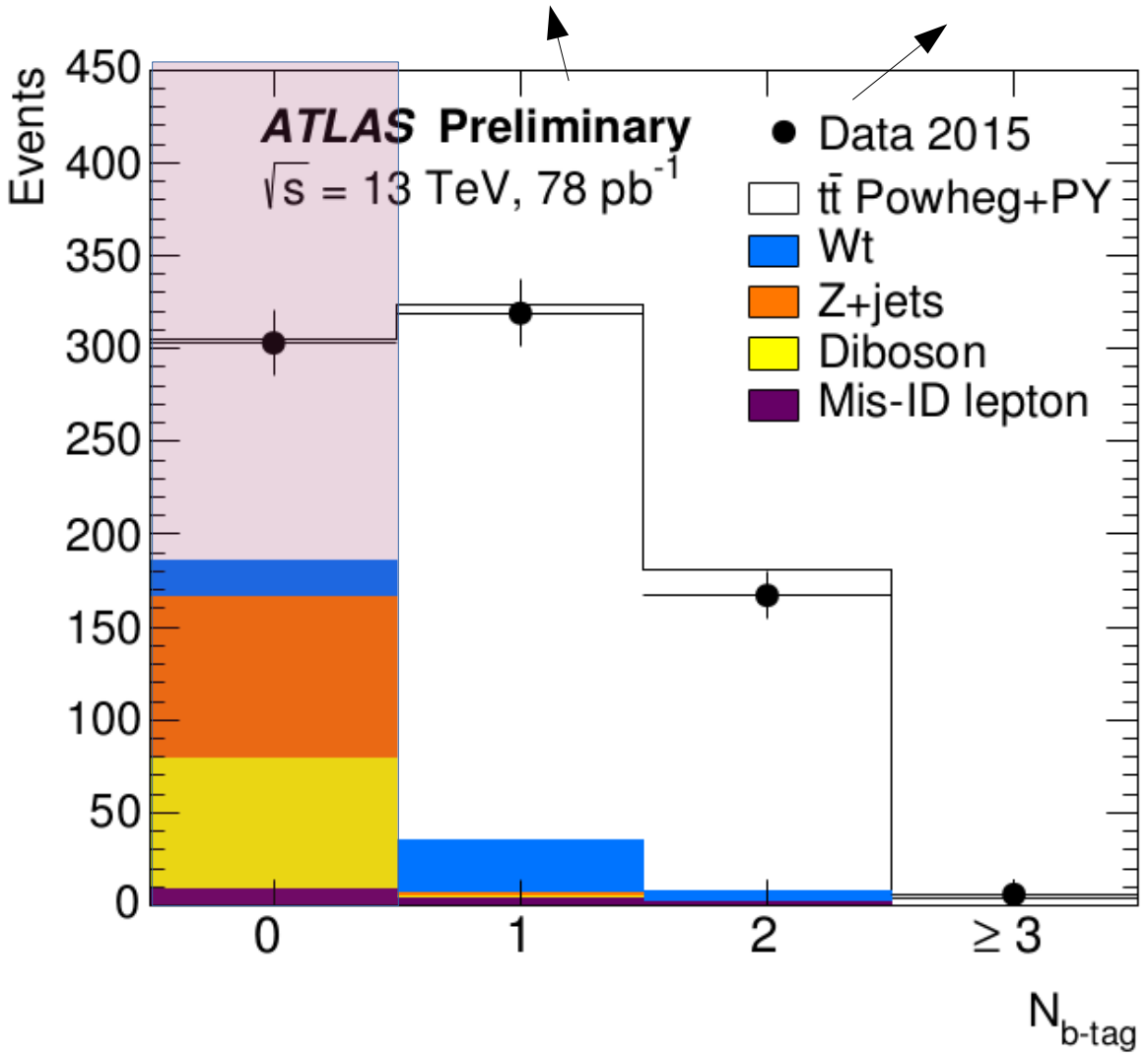
Top pair cross section eμ 78 pb^{-1} 13 TeV

NEW

In-situ measurement of σ_{tt} and b-jet finding efficiency, ε_b

$$N_{1b} = L\,\sigma_{tt}\,\epsilon_{e\mu}\,2\,\epsilon_b\left(1 - C_b\,\epsilon_b\right) + N_{1b}^{bkg}$$

$$N_{2b} = L\,\sigma_{tt}\,\epsilon_{e\mu}\,C_b\,\epsilon_b^2 + N_{2b}^{bkg}$$



Acceptance & b-tagging

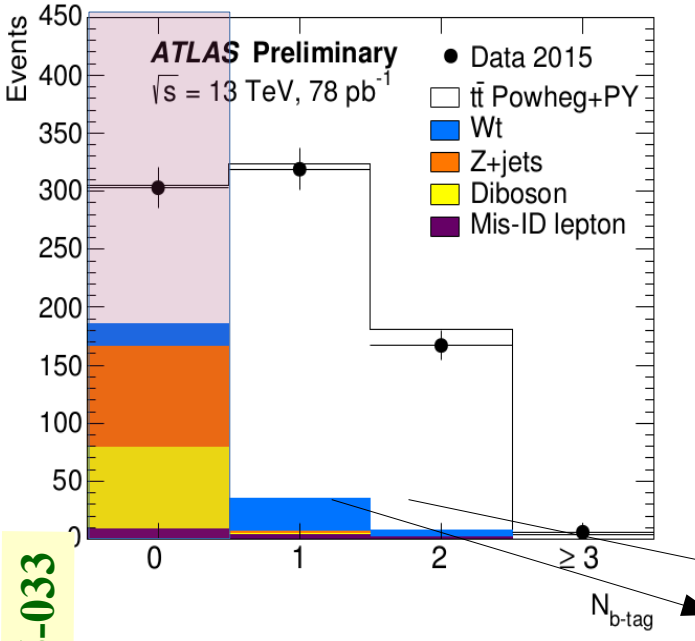
ATLAS-CONF-2015-033

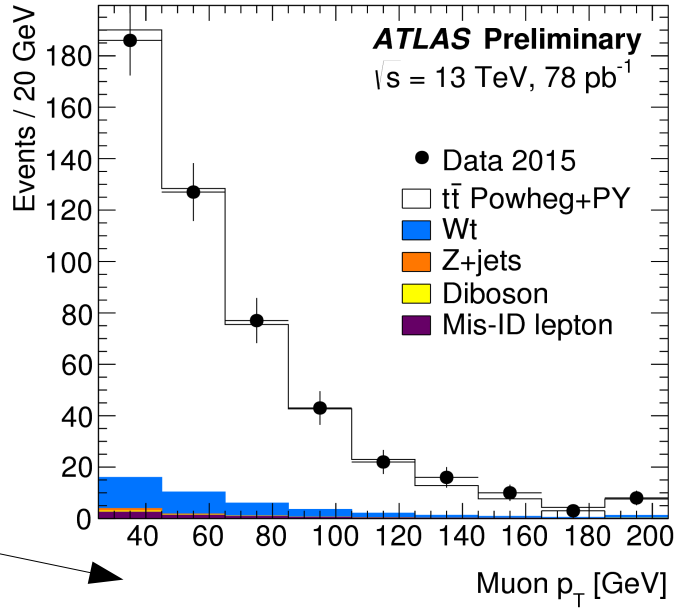
Top pair cross section eμ 78 pb^{-1} 13 TeV

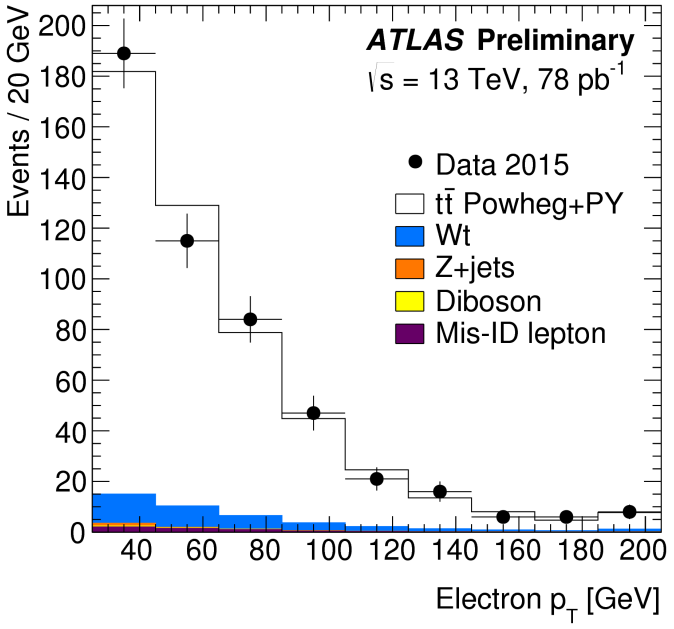
NEW

In-situ measurement of σ_{tt} and b-jet finding efficiency, ε_b

$$N_{1b} = L\,\sigma_{tt}\,\epsilon_{e\mu}\,2\,\epsilon_b\left(1 - C_b\,\epsilon_b\right) + N_{1b}^{bkg} \qquad N_{2b} = L\,\sigma_{tt}\,\epsilon_{e\mu}\,C_b\,\epsilon_b^2 + N_{2b}^{bkg}$$







Event counts	N_1	N_2
Data	319	167
Wt single top	29.0 ± 3.8	5.6 ± 2.0
Dibosons	1.1 ± 0.2	0.0 ± 0.0
$Z(\to \tau\tau \to e\mu)$+jets	1.3 ± 0.7	0.1 ± 0.1
Misidentified leptons	6.0 ± 3.9	2.8 ± 2.9
Total background	37.3 ± 5.5	8.5 ± 3.5

Small background in data

ATLAS-CONF-2015-033

Top pair cross section eμ 78 pb^{-1} 13 TeV

NEW

In-situ measurement of σ_{tt} and b-jet finding efficiency, ε_b

$$N_{1b} = L\,\sigma_{tt}\,\epsilon_{e\mu}\,2\,\epsilon_b\,(1 - C_b\,\epsilon_b) + N_{1b}^{bkg} \qquad N_{2b} = L\,\sigma_{tt}\,\epsilon_{e\mu}\,C_b\,\epsilon_b^2 + N_{2b}^{bkg}$$

From simulation

b-tagging correlation between top and anti-top and mis-tagged jets

- DY: taken from simulation, validated in data (lack of statistics)
- Non-prompts: from same-sign data, scaled by MC ratio of OS/SS

ATLAS-CONF-2015-033

Top pair cross section eμ 78 pb^{-1} 13 TeV

NEW

In-situ measurement of σ_{tt} and b-jet finding efficiency, ε_b

$$N_{1b} = L\,\sigma_{tt}\,\epsilon_{e\mu}\,2\,\epsilon_b\,(1 - C_b\,\epsilon_b) + N_{1b}^{bkg} \qquad N_{2b} = L\,\sigma_{tt}\,\epsilon_{e\mu}\,C_b\,\epsilon_b^2 + N_{2b}^{bkg}$$

From simulation

b-tagging correlation between top and anti-top and mis-tagged jets

- DY: taken from simulation, validated in data (lack of statistics)
- Non-prompts: from same-sign data, scaled by MC ratio of OS/SS

Expected ε_b=0.543

$$\epsilon_b = 0.527 \pm 0.026\,(stat.) \pm 0.006\,(syst.)$$

$$\sigma_{t\bar{t}} = 825 \pm 49\,(stat.) \pm 60\,(syst.) \pm 83\,(lumi.)\,pb$$

m_t = 172.5 GeV

Dominant systematics are
- Hadronization in signal: Herwig++ vs. Pythia6 (default)
- Electron identification

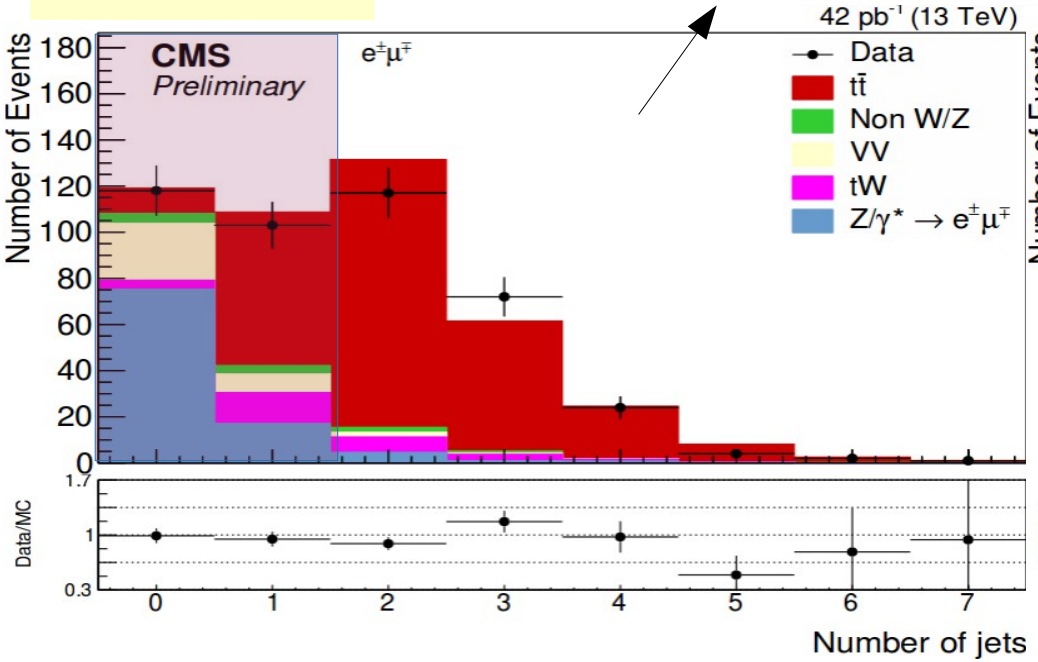
ATLAS-CONF-2015-033

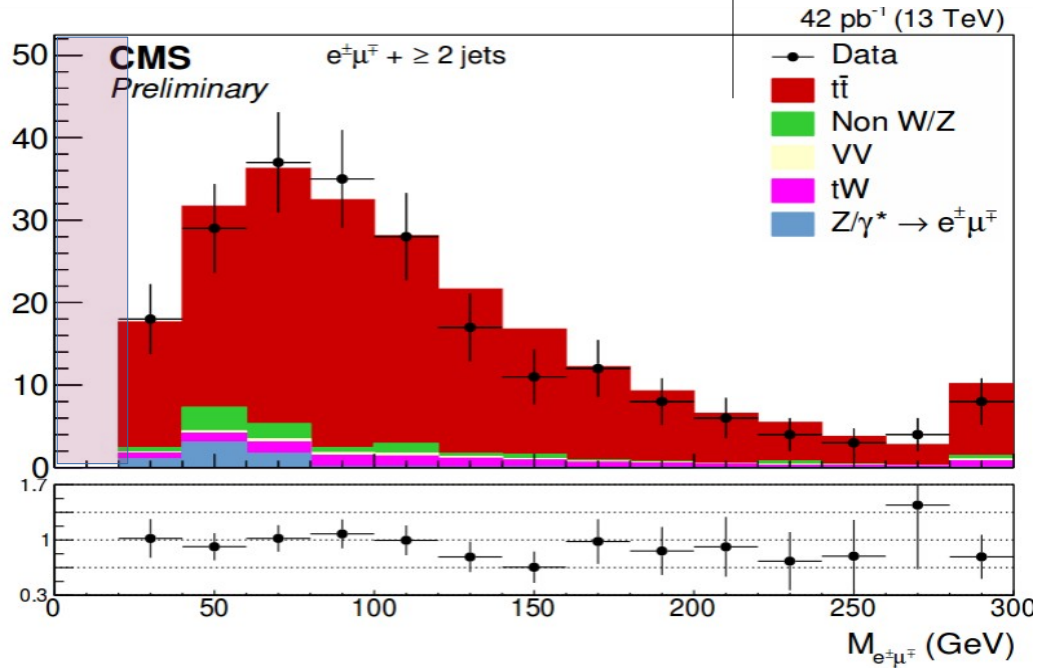
Top pair cross section eμ 42 pb^{-1} 13 TeV

NEW

- An electron-muon trigger for online selection
- Reject heavy flavor resonances with $m_{e\mu} < 20$ GeV
- At least two jets and no b-tagging requirement

TOP-15-003





Top pair cross section eμ 42 pb^{-1} 13 TeV

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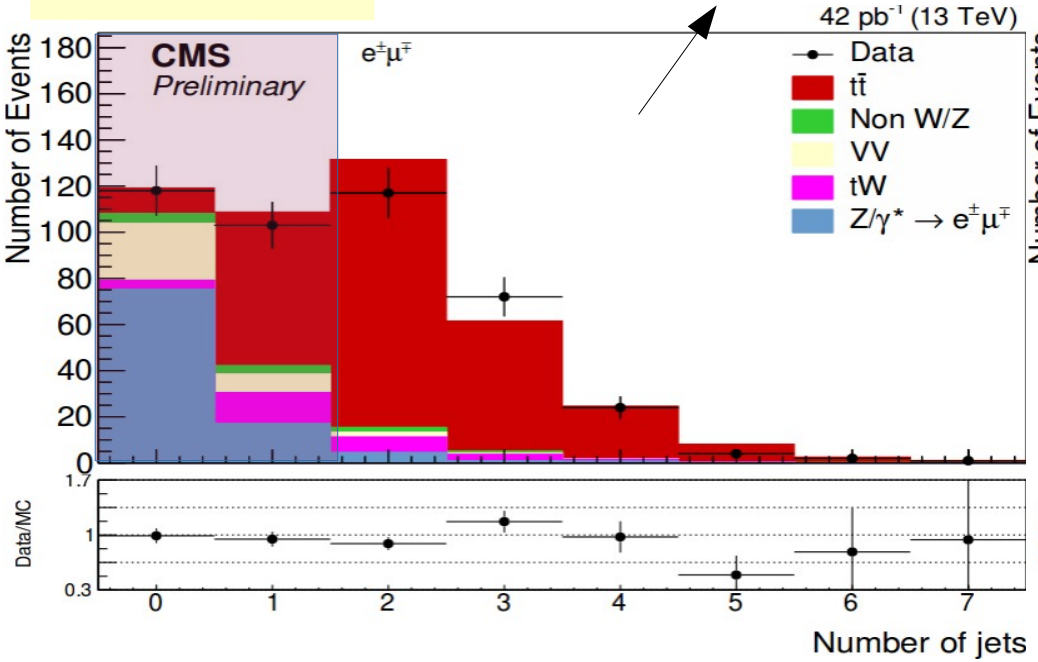
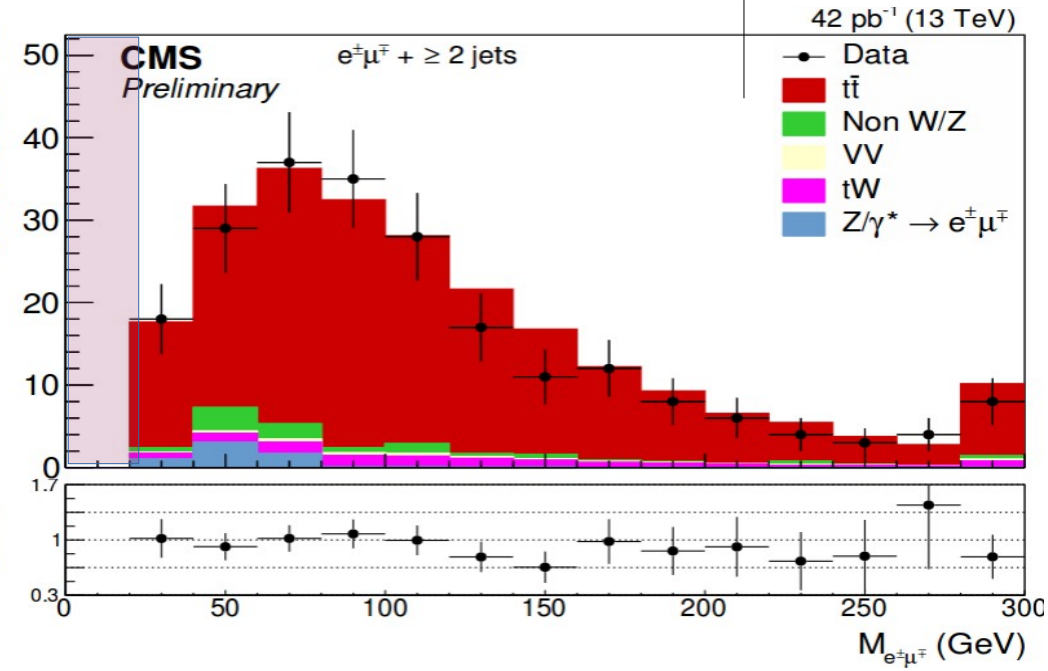
TOP-15-003

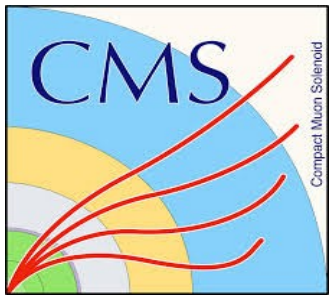




- **DY:** $R_{out/in}$ method in ee/μμ to correct the whole range using the Z-mass window. MC eμ is corrected with overall Data/MC SF of (1.06±0.17)
- **Non-prompt:** from same-sign data, scaled by MC scale of OS/SS

Top pair cross section eμ 42 pb^{-1} 13 TeV

NEW



TOP-15-003

- A counting experiment in the selected sample

Source	Number of events $e^{\pm}\mu^{\mp}$
Drell–Yan	6.4 ± 1.2
Non-W/Z leptons	8.5 ± 4.3
Single top quark	10.6 ± 3.4
VV (V = W or Z)	2.6 ± 0.9
Total background	28.1 ± 5.7
$t\bar{t}$ dilepton signal	206.7 ± 16.0
Data	220

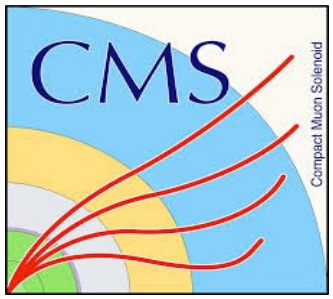
$m_t = 172.5$ GeV

$$A \times \epsilon_{sel.} \times Br(t \to e\mu) = (0.60 \pm 0.04)\%$$

$$\sigma_{t\bar{t}} = 772 \pm 60(stat.) \pm 62(syst.) \pm 93(lumi.)\, pb$$

Top pair cross section eμ 42 pb^{-1} 13 TeV

NEW



TOP-15-003

- A counting experiment in the selected sample

Source	Number of events $e^{\pm}\mu^{\mp}$
Drell–Yan	6.4 ± 1.2
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Single top quark	10.6 ± 3.4
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Data	220

$m_t = 172.5$ GeV

$$A \times \epsilon_{sel.} \times Br(t \to e\mu) = (0.60 \pm 0.04)\%$$

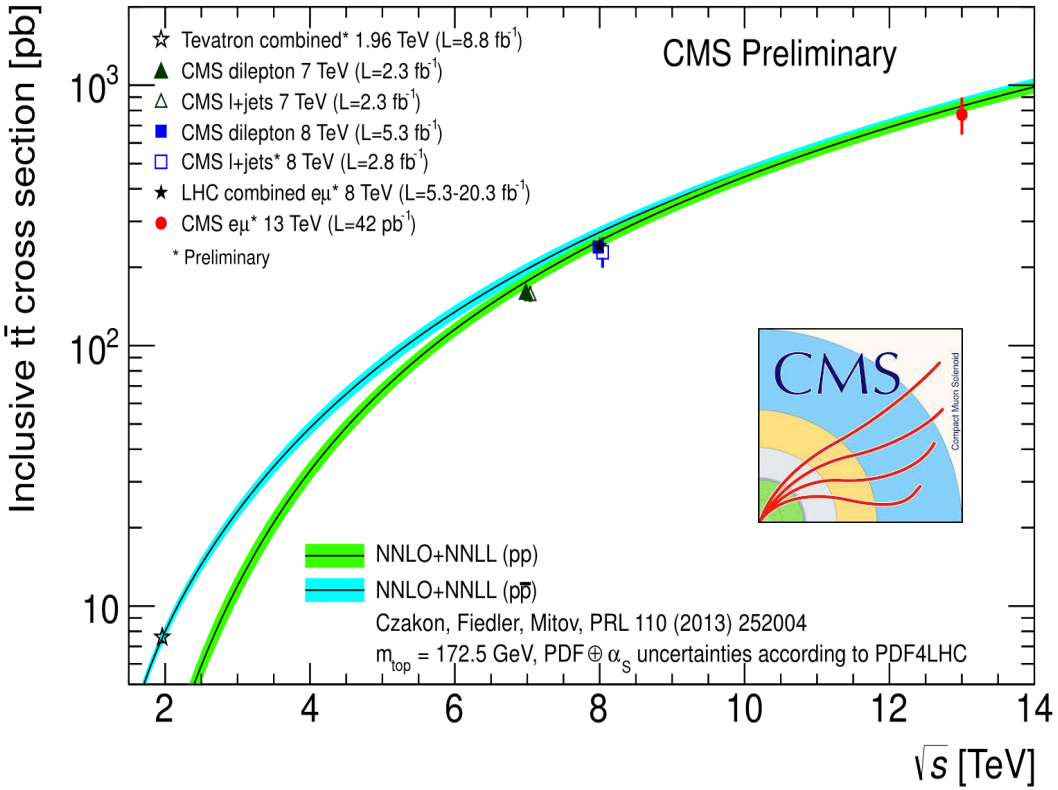
$$\sigma_{t\bar{t}} = 772 \pm 60(stat.) \pm 62(syst.) \pm 93(lumi.)\, pb$$

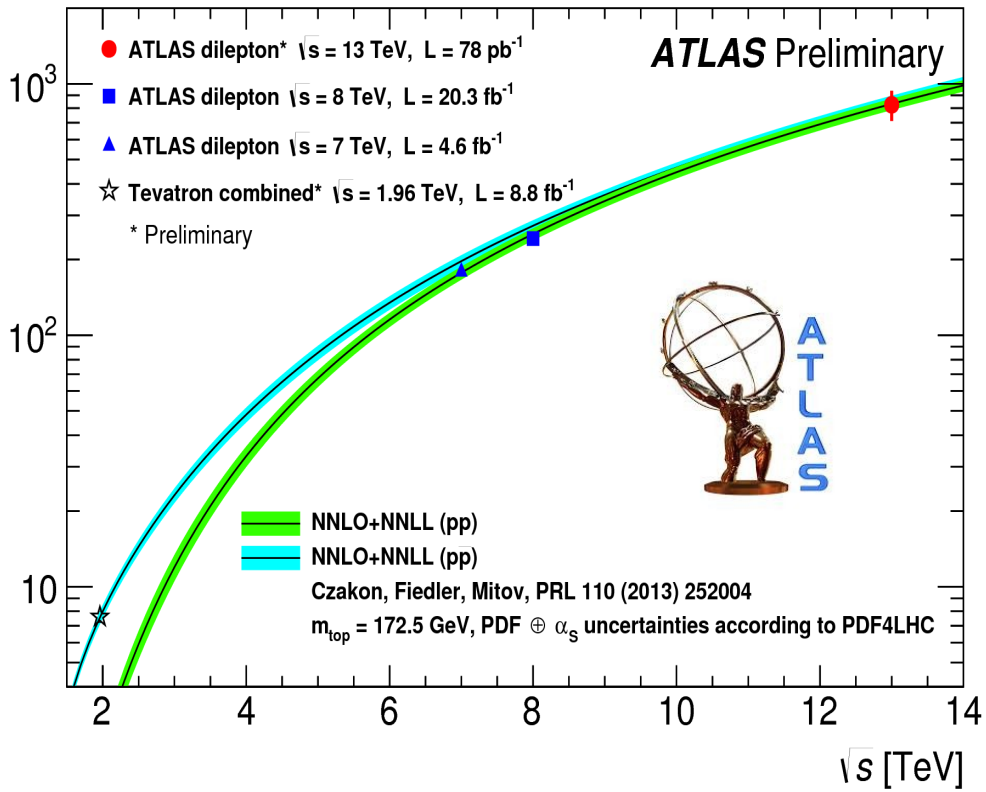
- **Dominant systematics** are lepton trigger and identification.
- Top mass dependence: small! 0.7% reduction on $m_t = 173.34$ GeV [1]
- Cross section in the **fiducial** volume:

$$\sigma_{t\bar{t}} = 12.9 \pm 1.0(stat.) \pm 1.1(syst.) \pm 1.5(lumi.)\, pb$$

[1] arXiv:1403.4427

Summary of eμ inclusive analyses at 13 TeV





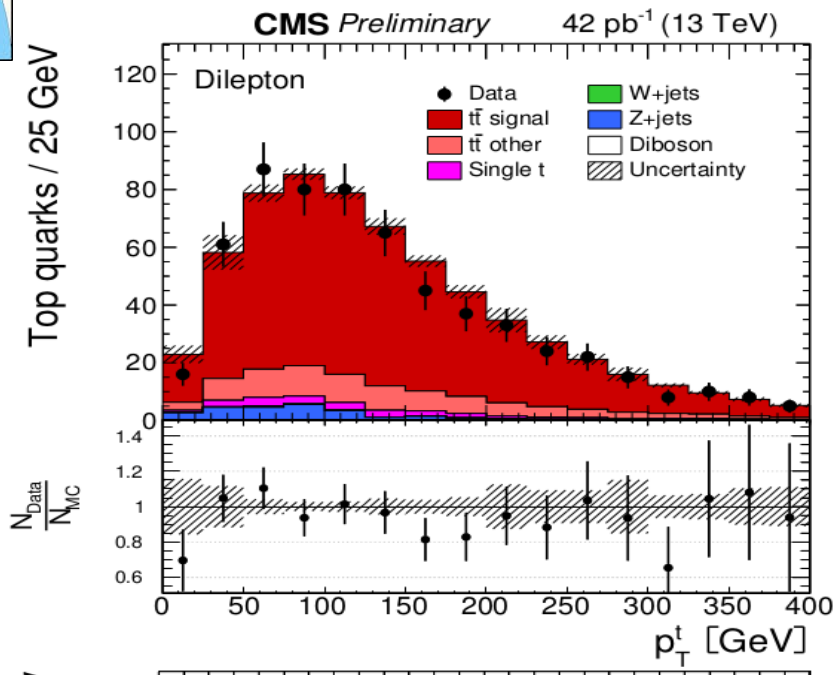
Uncertainties on the measurements are comparable with that of theory

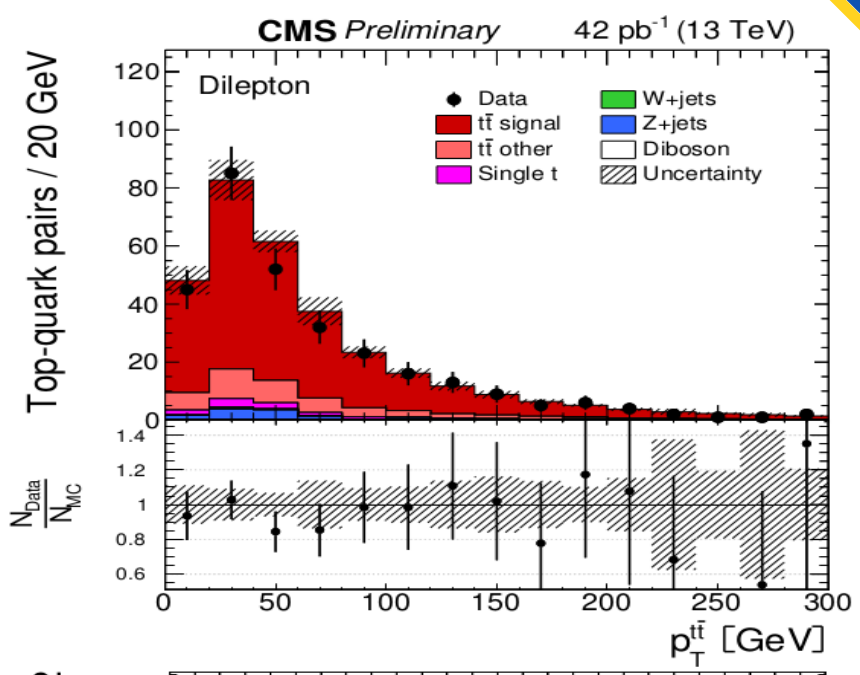
Differential cross section $\ell\ell$ 13 TeV

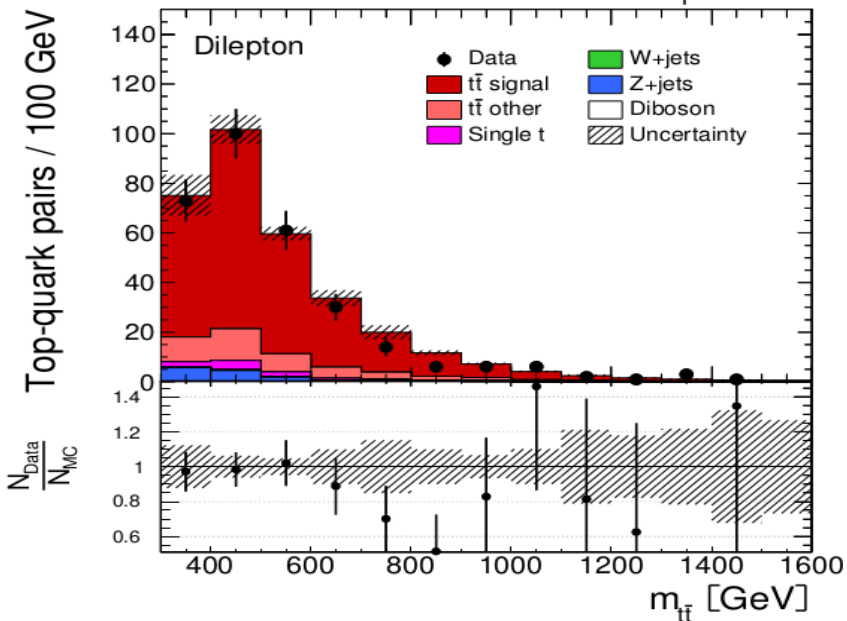
NEW LHCP 2015

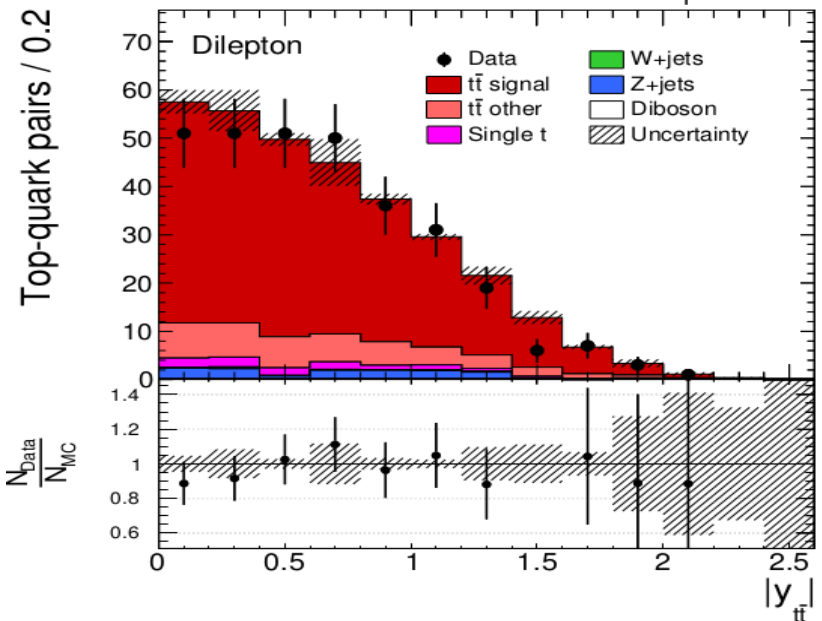
- Top quark properties and jet multiplicity
- All lepton flavors

TOP-15-010





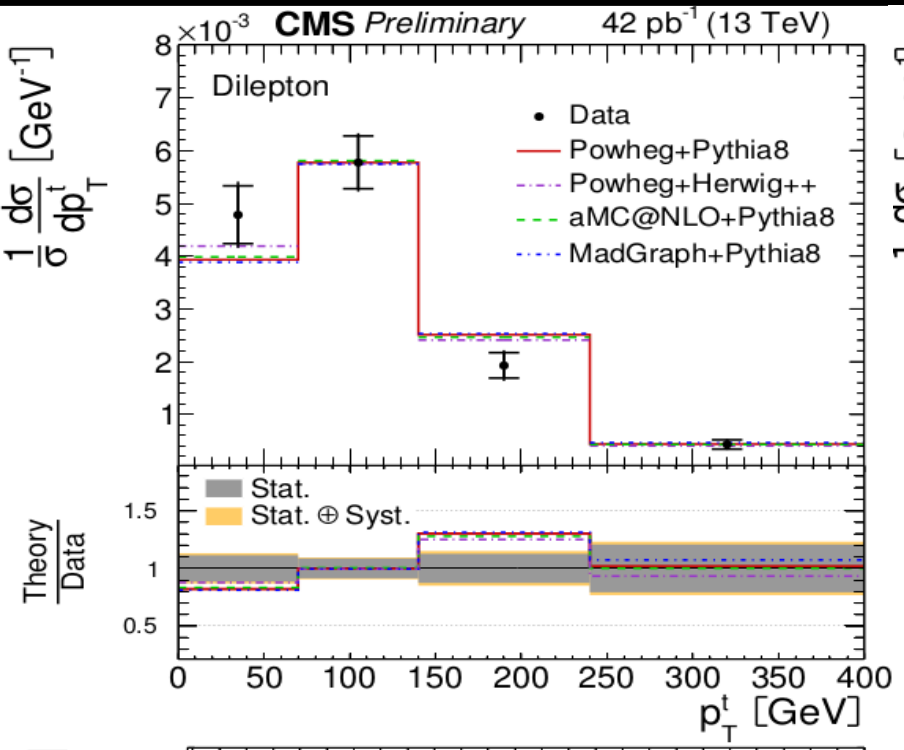


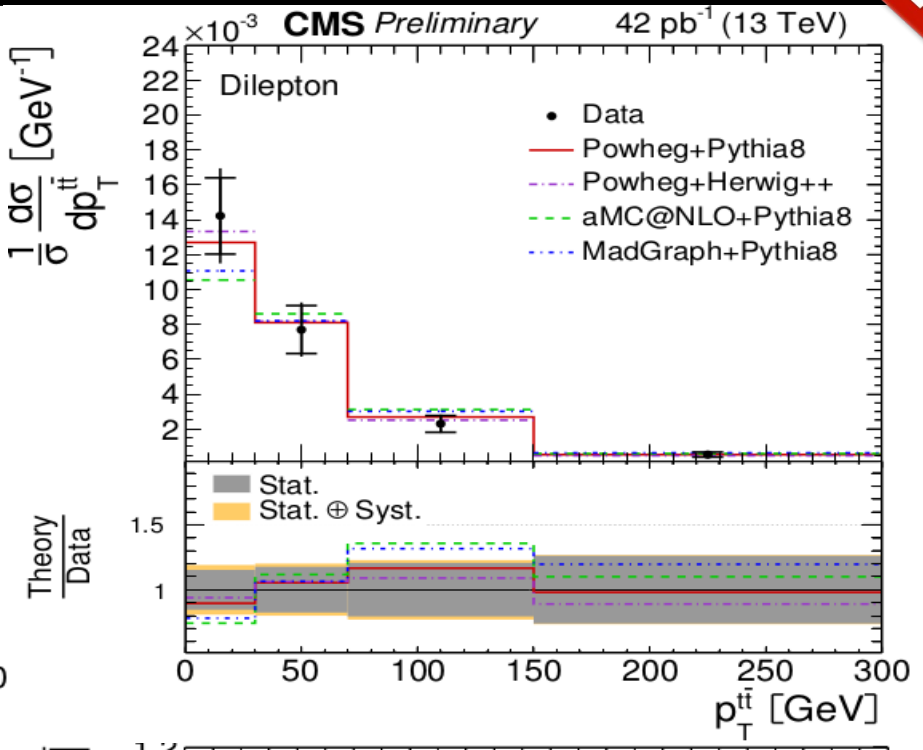


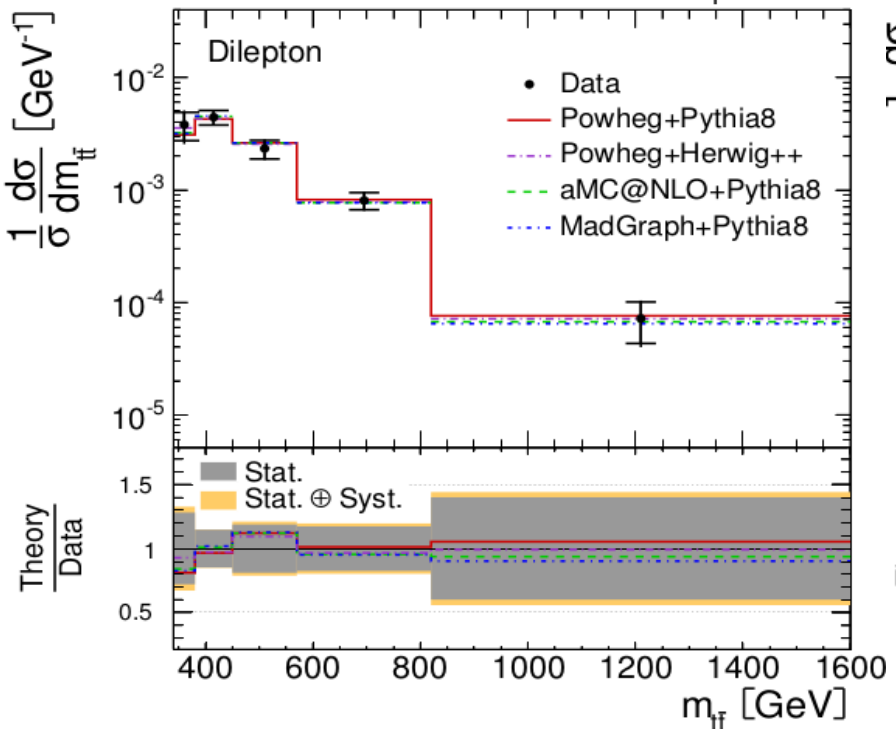
Differential cross section $\ell\ell$, 13 TeV

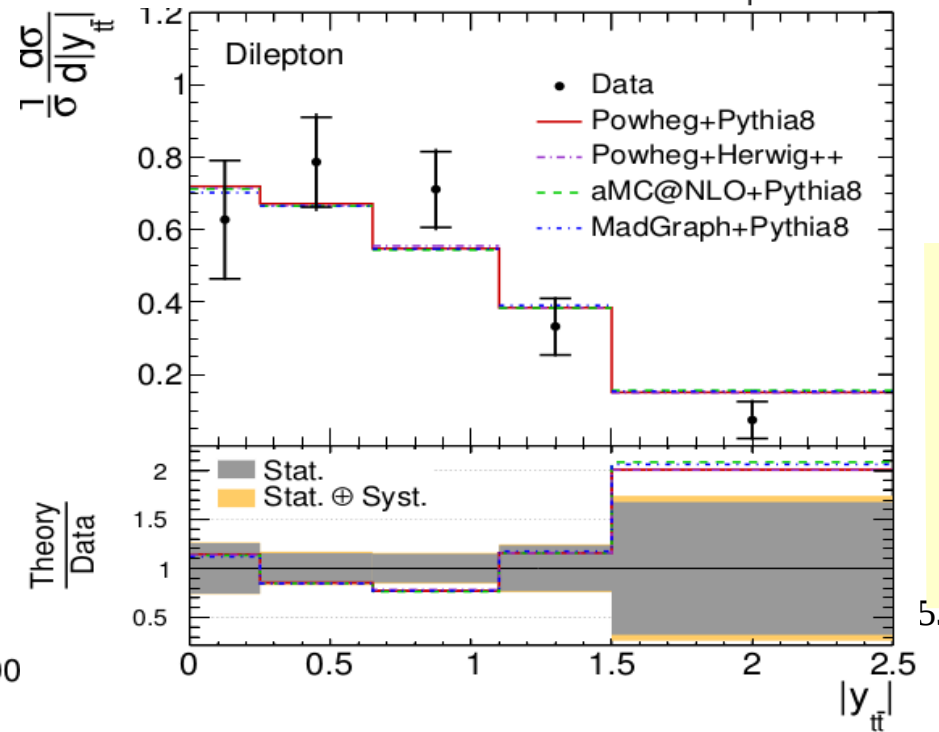
NEW

Generally good agreement between data and simulation









Parton level, full phase space

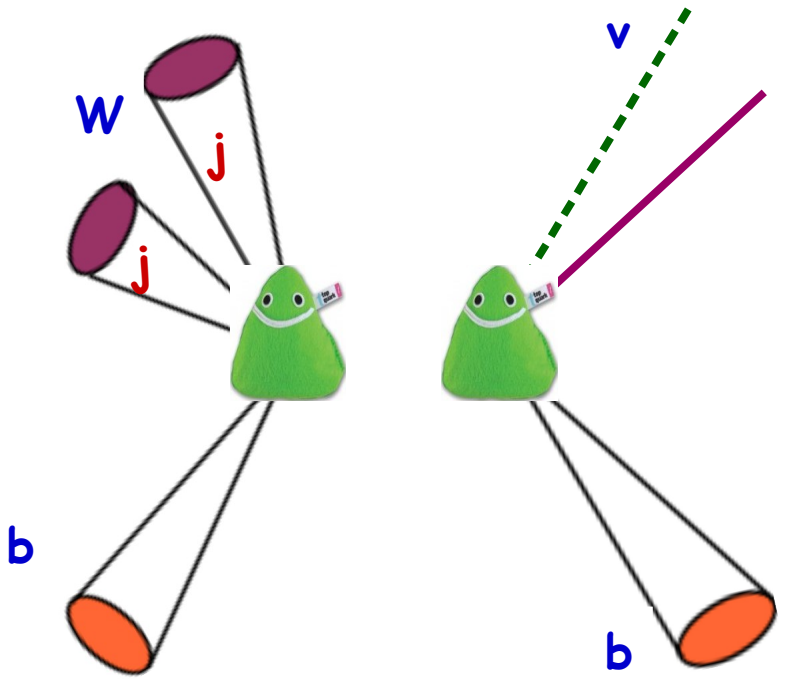
TOP-15-010

Differential cross section ℓ+jets 13 TeV

NEW LHCP 2015

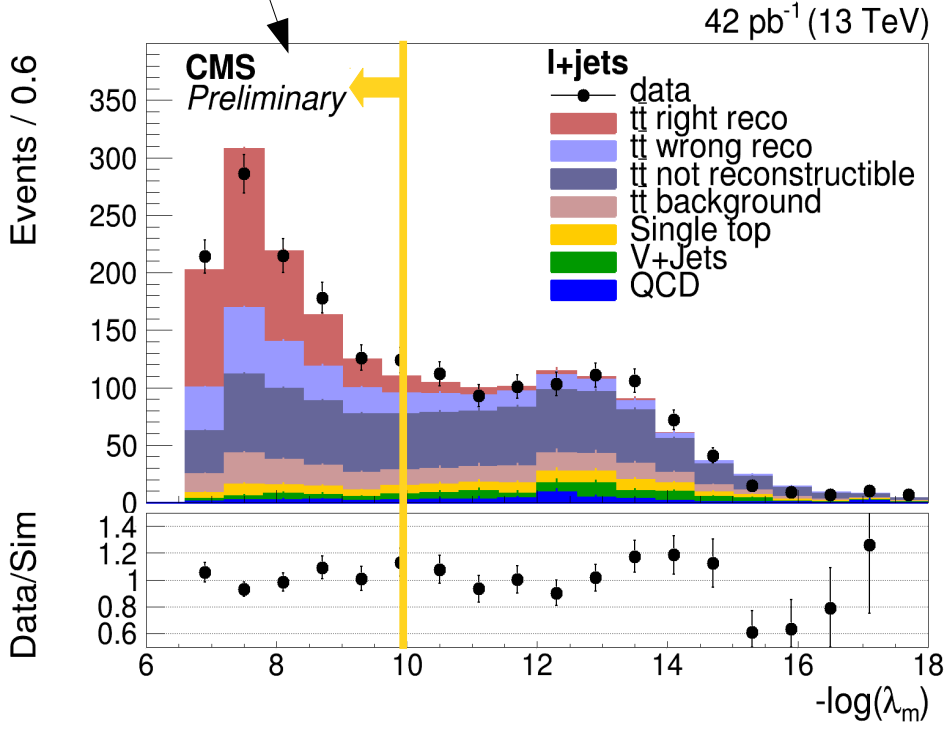
TOP-15-005

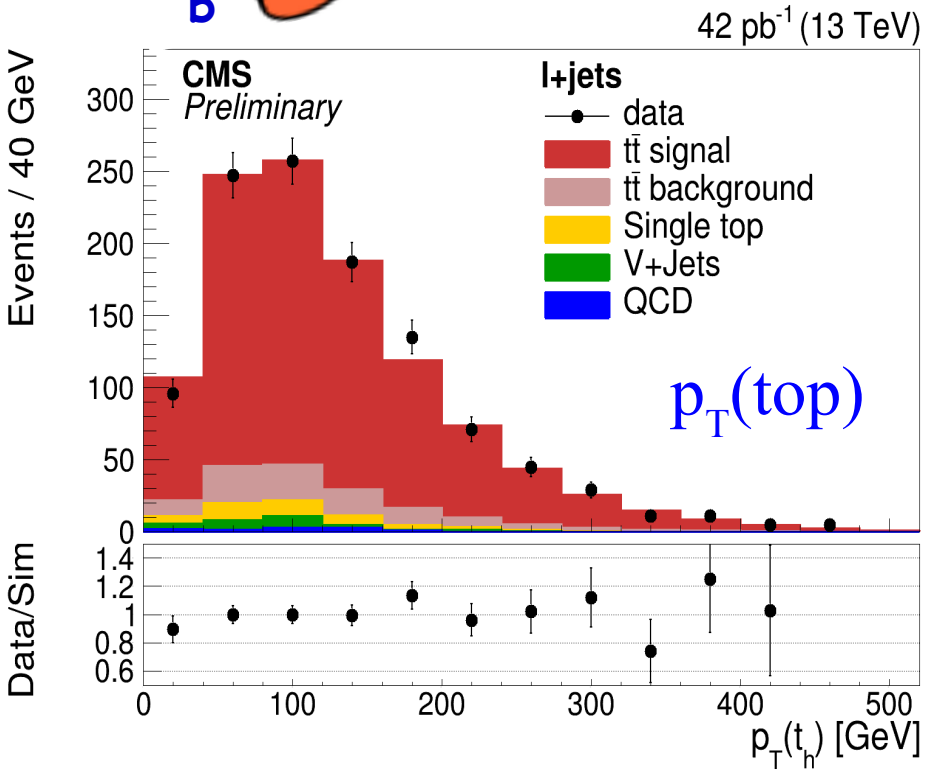
2D probability of mjj vs. mjjb



$$(p_\ell + p_\nu)^2 = m_W^2$$
$$(p_\ell + p_\nu + p_b)^2 = m_t^2$$

Select events with high probability





Differential cross section ℓ+jets 13 TeV

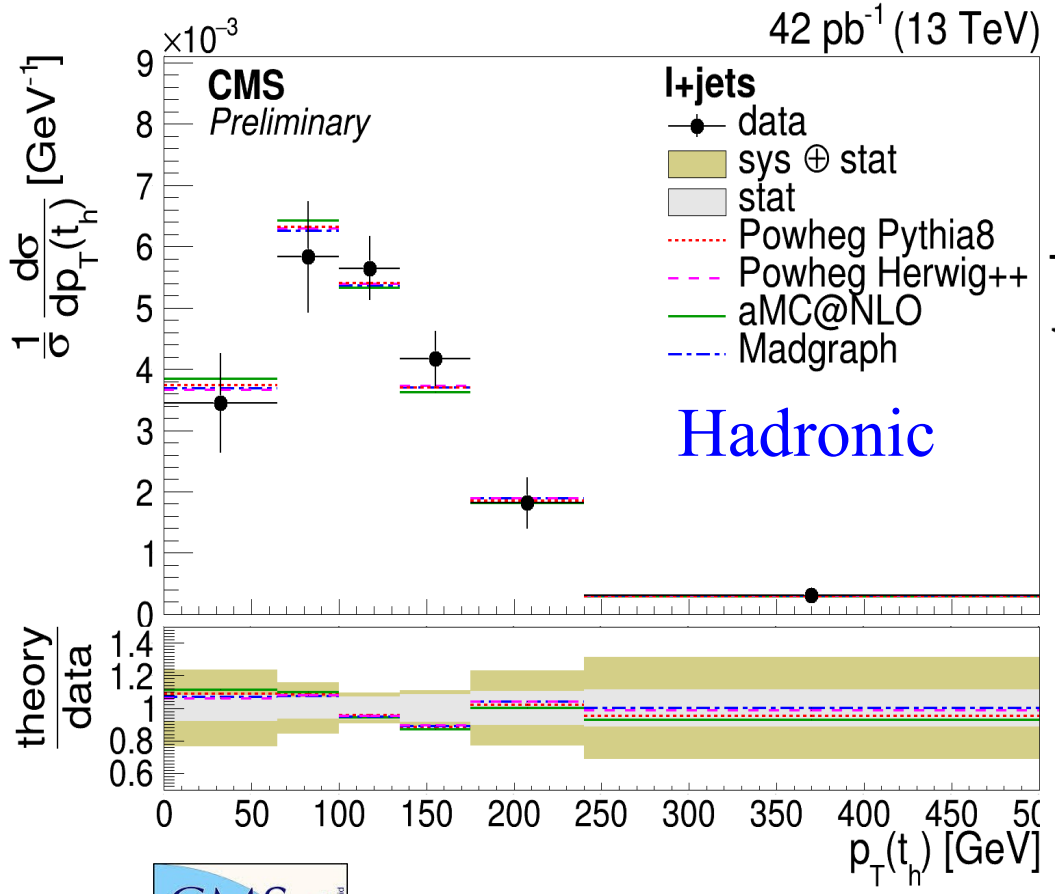
NEW

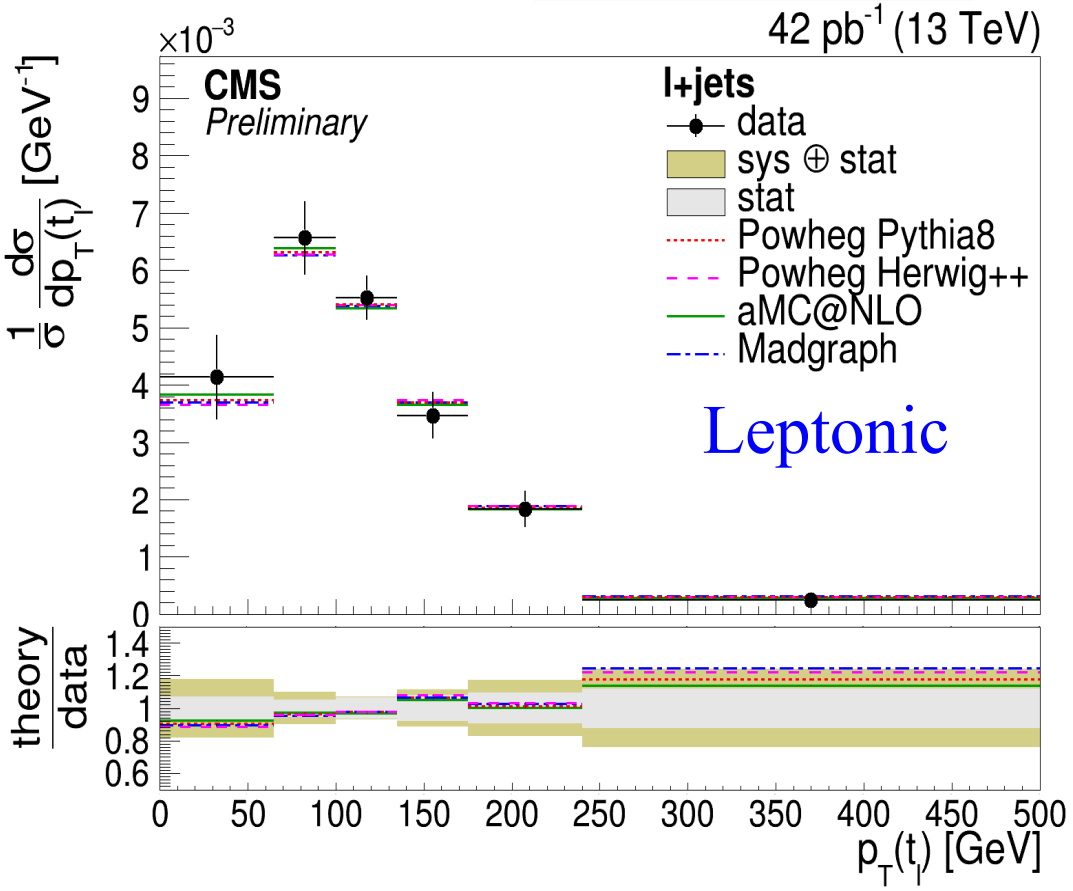
Backgrounds from simulation

$$\sigma_{t\bar{t}} = 836 \pm 27(stat.) \pm 84(syst.) \pm 100(lumi.)\, pb$$

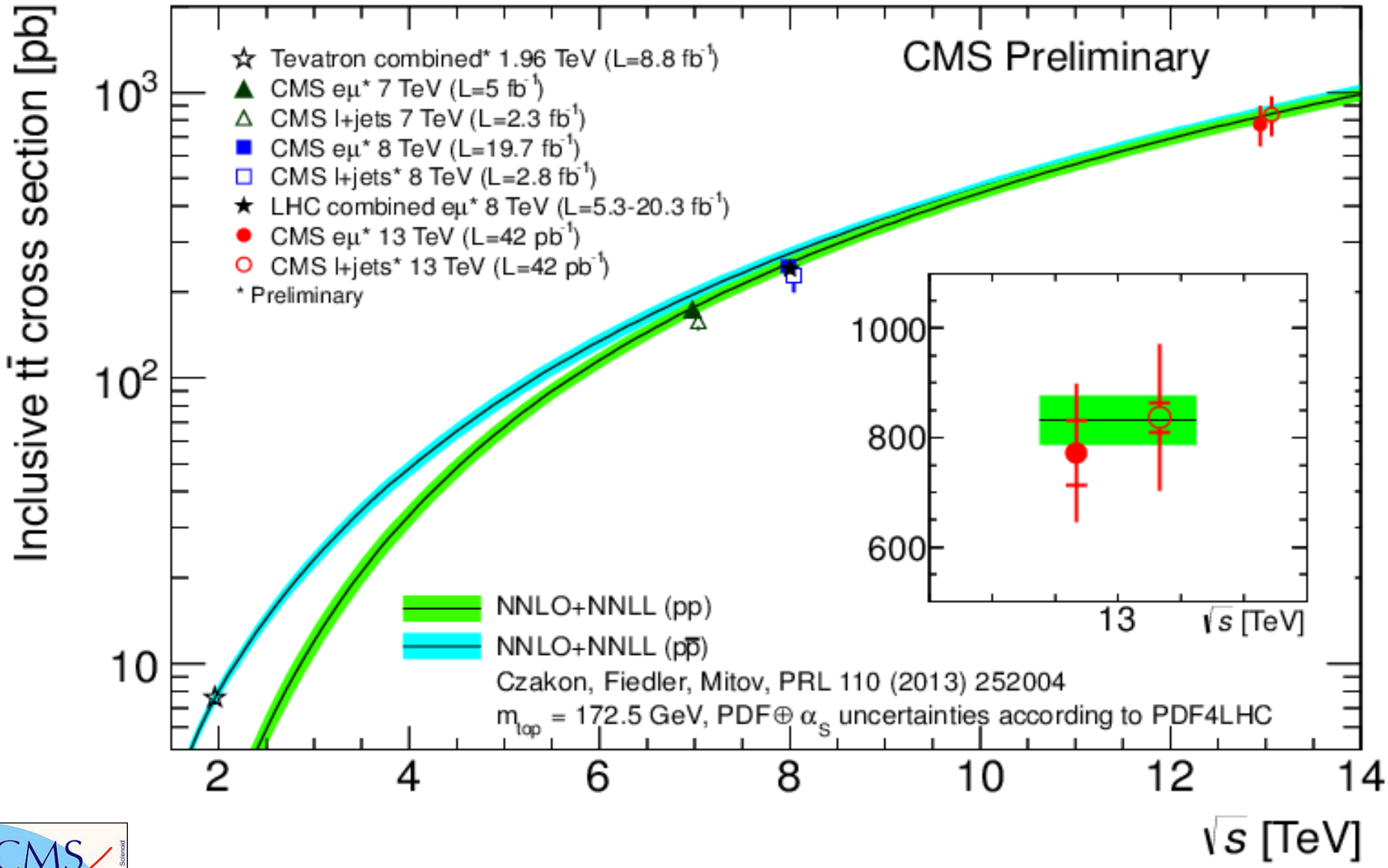
TOP-15-005

b-tagging ~ 5%

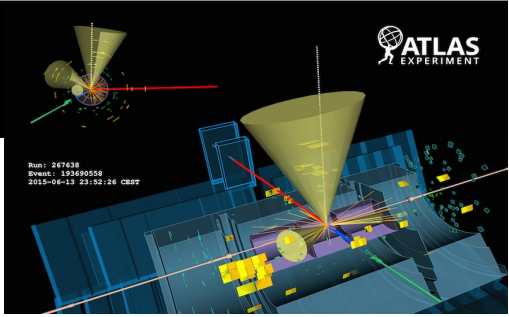




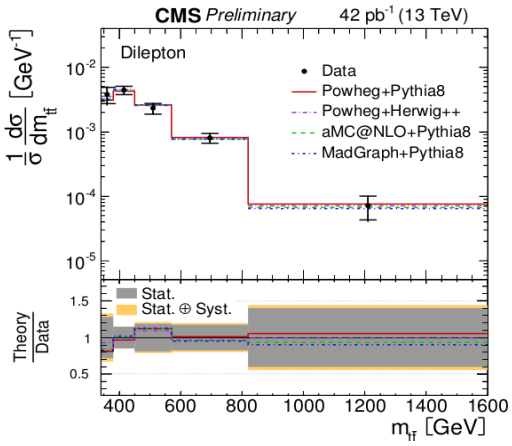
Generally good agreement between data and simulation


CMS Preliminary
Tevatron combined* 1.96 TeV (L=8.8 fb-1)
CMS eμ* 7 TeV (L=5 fb-1)
CMS l+jets 7 TeV (L=2.3 fb-1)
CMS eμ* 8 TeV (L=19.7 fb-1)
CMS l+jets* 8 TeV (L=2.8 fb-1)
LHC combined eμ* 8 TeV (L=5.3-20.3 fb-1)
CMS eμ* 13 TeV (L=42 pb-1)
CMS l+jets* 13 TeV (L=42 pb-1)
* Preliminary
NNLO+NNLL (pp)
NNLO+NNLL (pp̄)
Czakon, Fiedler, Mitov, PRL 110 (2013) 252004
m_top = 172.5 GeV, PDF⊕α_S uncertainties according to PDF4LHC
Inclusive tt̄ cross section [pb]
√s [TeV]
1000
800
600
13
√s [TeV]

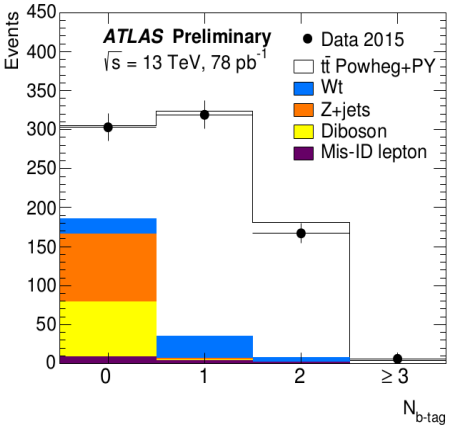
Summary



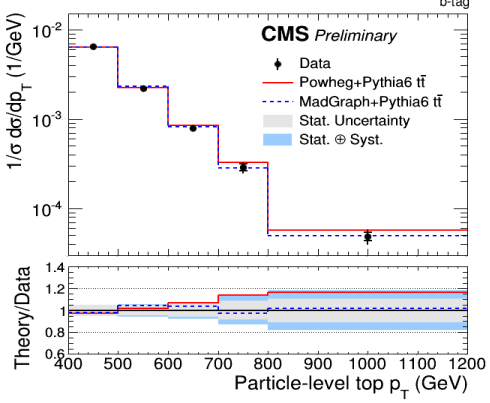
- The LHC experiments studied the very first top quarks from pp collisions at 13 TeV
- The production rate of $t\bar{t}$ is measured inclusively and in bins of top quark properties together with lepton and jets



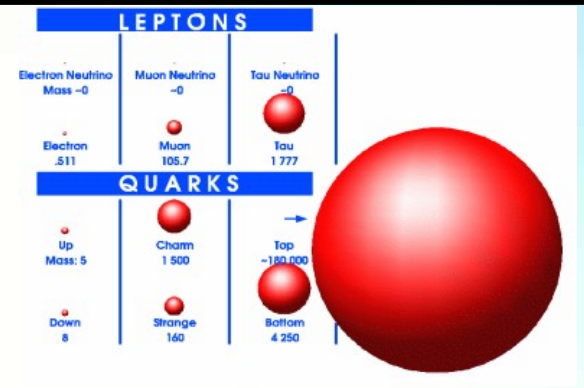
- More precise results are obtained using the full LHC data set in Run I
  - Boosted regimes are explored thanks to the large statistics



- It's only the beginning with the 13 TeV data
  - More fun and excitement are underway
  - Stay tuned ...



St Petersburg artists inspired by top quark!



THANK YOU!

BACKUP

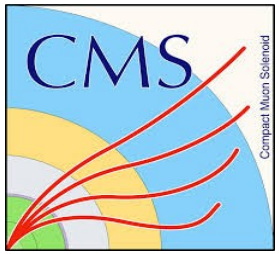
Top pair cross section ℓ+jets 8 TeV

Background:

- QCD: matrix method
- Rest from simulation
- Systematics from pseudo experiments

PRD91,112013(2015)

Top pair cross section eμ "7+8" TeV



Background:

- Shape from MC
- Normalization in the fit

TOP-13-004

Differential cross section ℓℓ, 13 TeV

The total systematic uncertainty on the normalized differential cross sections is typically around 8.5%. This value is calculated as the median of the distribution of the total systematic uncertainties over all bins of all measured observables. Typical values for the dominant contributions to the systematic uncertainty for rapidity observables (all other observables) are: generator, with 3.4% (1.6%); hadronization and parton showering, with 2.3% (2.9%); PDF, with 1.5% (0.5%); JES, with 1.2% (1.2%); JER, with 0.7% (0.8%); b-tagging, with 0.6% (0.9%).

The total uncertainty on the measurement is typically 19.2%, dominated by the statistical uncertainty.

$t\bar{t}b(b)$ cross section 8 TeV

ATLAS-CONF-2015-247

Source	$\sigma^{\text{fid}}_{t\bar{t}b}$ Lepton-plus-jets uncertainty (%)	$\sigma^{\text{fid}}_{t\bar{t}b}$ $t\bar{t}b$ $e\mu$ uncertainty (%)	$\sigma^{\text{fid}}_{t\bar{t}bb}$ Cut-based uncertainty (%)	$\sigma^{\text{fid}}_{t\bar{t}bb}$ Fit-based uncertainty (%)	$R_{t\bar{t}bb}$ Fit-based uncertainty (%)
Total detector	+17.5 −14.4	+11.6 −8.0	±14.5	+11.9 −13.1	+10.9 −12.5
Jet (combined)	+3.9 −2.7	+10.1 −6.1	±5.5	+6.0 −8.5	+8.7 −10.7
Lepton	±0.7	+1.0 −0.5	±2.0	+2.4 −2.7	+0.8 −1.6
b−tagging effect on b−jets	+4.4 −4.0	+3.6 −3.1	±12.9	+9.4 −9.0	+6.0 −5.8
b−tagging effect on c−jets	+16.2 −13.4	+4.0 −3.6	±1.7	± 1.4	+1.2 −1.3
b−tagging effect on light jets	+3.1 −2.0	+1.9 −2.0	±4.3	+3.3 −2.9	+2.2 −1.9
Total $t\bar{t}$ modelling	+13.1 −13.7	+23.8 −16.1	±23.8	±21.7	±16.1
Generator	+1.1 −1.4	+23.3 −15.1	±16.9	±17.4	±12.4
Scale choice	±4.3	+1.1 −2.7	±14.2	±9.5	±6.0
Shower/hadronisation	+11.4 −12.1	+3.0 −3.4	±8.2	±8.7	±7.1
PDF	+4.7 −4.5	±3.3	±3.3	±0.8	±4.1
Removing/doubling $t\bar{t}V$ and $t\bar{t}H$	±0.4	+1.1 −0.9	±1.5	+3.1 −2.7	+3.0 − 2.6
Other backgrounds	±0.8	+0.9 −0.8	±1.6	+3.5 −3.3	±2.5
MC sample size	< 1	< 1	±9.6	±7.4	±7.4
Luminosity	±2.8	±2.8	±3.2	±2.9	±0.1
Total systematic uncertainty	+25.5 −19.2	+30.5 −19.9	±29.5	+26.4 −26.9	+21.1 −21.9
Statistical uncertainty	±7.1	+19.2 −17.9	±18.4	±24.6	±25.2
Total uncertainty	+26.5 −20.5	+36.0 −26.8	±35.2	+36.1 −36.4	+32.9 −33.4

Changing templates and redo the fit

Differential cross section ℓℓ, ℓ+jets 8 TeV

Background

- DY in ℓℓ from data

Systematics

arXiv:1505.04480

Relative systematic uncertainty (%)				
Source	Lepton and b jet observables		Top quark and $t\bar{t}$ observables	
	ℓ+jets	dileptons	ℓ+jets	dileptons
Trigger eff. & lepton selec.	0.1	0.1	0.1	0.1
Jet energy scale	2.3	0.4	1.6	0.8
Jet energy resolution	0.4	0.2	0.5	0.3
Background (Z+jets)	—	0.2	—	0.1
Background (all other)	0.9	0.4	0.7	0.4
b tagging	0.7	0.1	0.6	0.2
Kinematic reconstruction	—	<0.1	—	<0.1
Pileup	0.2	0.1	0.3	0.1
Fact./renorm. scale	1.1	0.7	1.8	1.2
ME-PS threshold	0.8	0.5	1.3	0.8
Hadronization	2.7	1.4	1.9	1.1
Top quark mass	1.5	0.6	1.0	0.7
PDF choice	0.1	0.2	0.1	0.5

Changing source and redo the calculation

Differential cross section ℓ+jet 7 TeV

JHEP 06(2015)100

Selection

- 1 lepton + >= 4jets + >= 2b

Background

- Dilepton tt: simulation, corrected for acceptance, etc.
- W+jets
  - normalization from charge asymmetry,
  - HF from MC

Systematics

- Measurements are currently limited by the systematic uncertainty
- The main components
  - b-tagging uncertainty,
  - Jet energy measurement
  - Modelling uncertainty of the initial and final state parton showers