Treatment of top-quark backgrounds in extreme phase spaces in ATLAS and CMS

Leonid Serkin

for the ATLAS and CMS Collaborations

INFN Gruppo Collegato di Udine and ICTP Trieste

18/09/2020

Motivation

- The top quark plays an important role in searches for physics beyond the SM, both as dominant background and as key signature for signal

- Main focus: **treatment of the top quark background** in BSM searches (high-pT and/or large multiplicity regimes)

  - cover new (mostly data-driven) techniques for ttbar estimation used in Exotics, SUSY, HDBS and B2G analyses

  - and when the top background is taken from MC: summary and discussion concerning the "top pT reweighting"

- Full list of results from BSM searches from both 

and 

Collaborations:

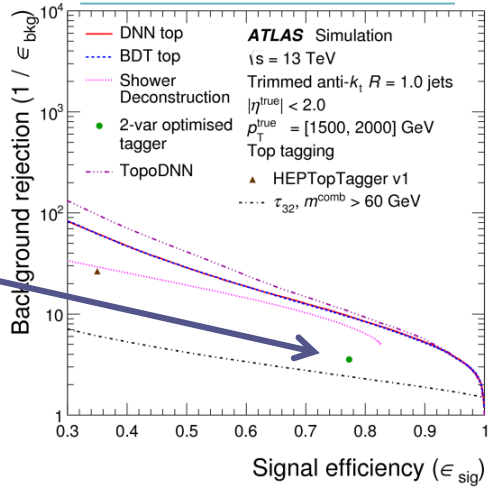
  - ATLAS: Exotics, SUSY, Higgs and Diboson searches
  - CMS: Exotica, SUSY, Beyond 2 Generations

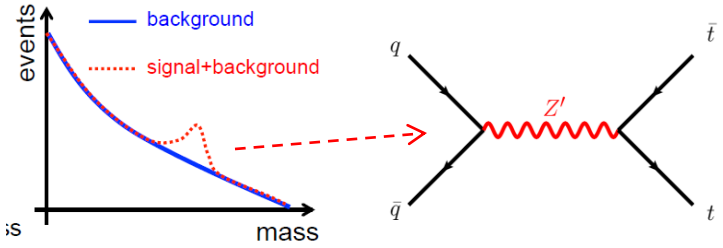
- Apologies if your preferred search is not included due to lack of time

Resonances decaying into 3rd generation quarks

- Search for ttbar resonances in fully hadronic states
  - First analysis in ATLAS using the new high level DNN top-tagger with several jet-moment observables related to substructure variables
  - Large improvement: 4 times better bkg rejection

ATLAS-JETM-2018-03



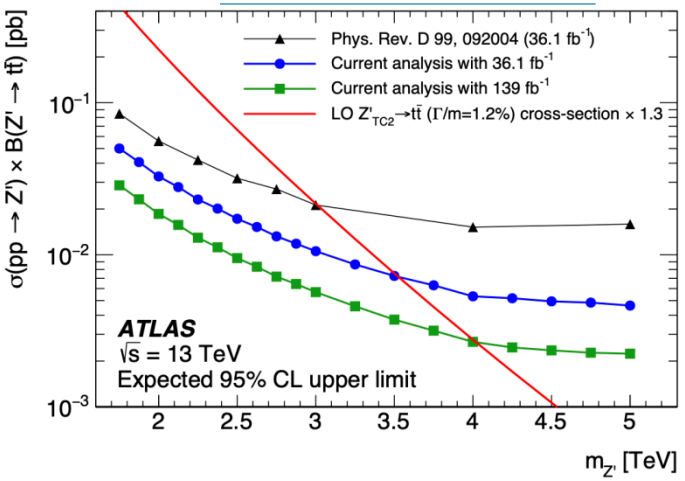


- Background spectrum **derived from data** by fitting a smoothly falling function to the m(tt) distributions

$$F(x) = p_0(1-x)^{p_1} x^{p_2+p_3\log(x)+p_4\log(x)^2}$$

  - functional form determined using combinations of data and simulated events
  - Wilk's test used to determine the optimal number of parameters to describe the function: most optimal with three shape parameters
  - spurius signal studies by performing S+B fits constructed under a background-only hypothesis

ATLAS-EXOT-2018-48

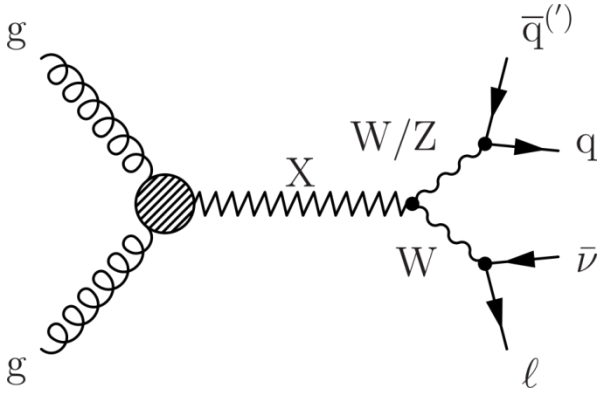


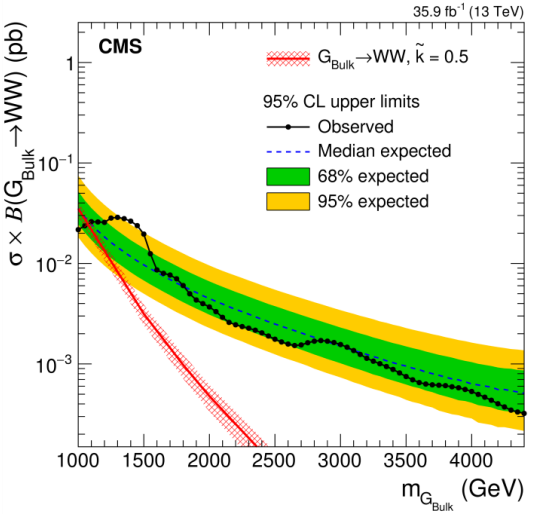
- 95 % C.L. exclusion of Z' with masses up to **3.9 TeV** (width = 1%)

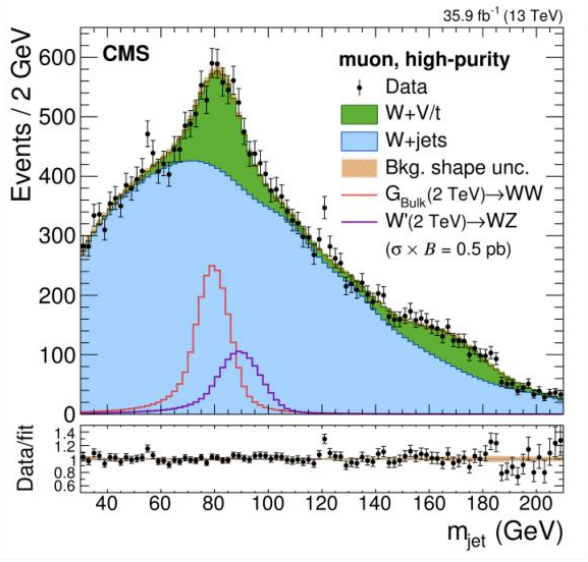
Heavy resonance decaying into vector bosons

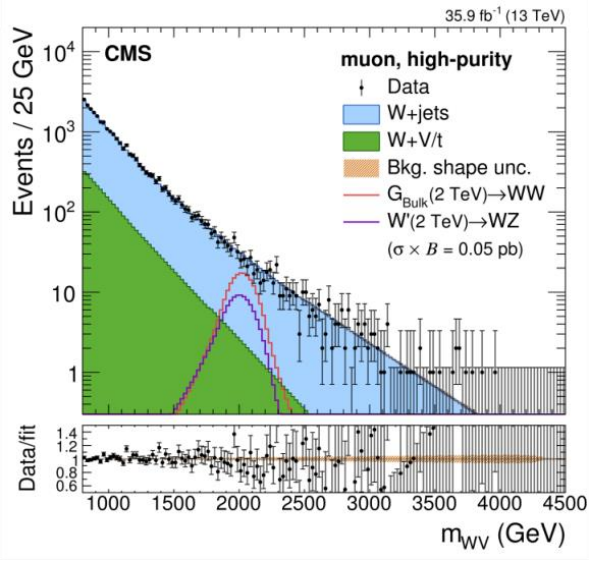
- Search for heavy resonance X decaying to a pair of vector bosons (WW or WZ) in the lepton plus merged jet final state
  - W → e (or μ) ν, while the other W,Z → qq' reconstructed as 1 large-R jet using jet substructure
- Novel 2D simultaneous maximum likelihood (m.l.) fit on m(WV) and m(V-jet): SM bkgs **estimated from data**
  - 2D conditional templates populated from simulation before detector simulation
  - scale and resolution model derived as function of gen. jet pT; templates populated as sums of 2D Gaussians – similar to kernel estimation

CMS-B2G-16-029







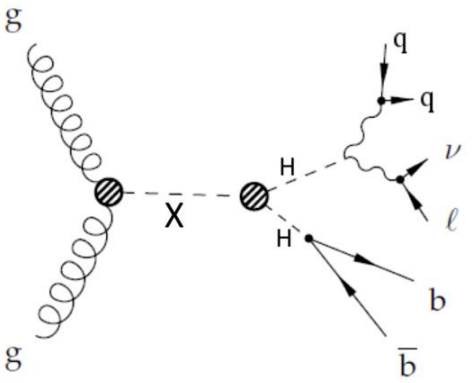


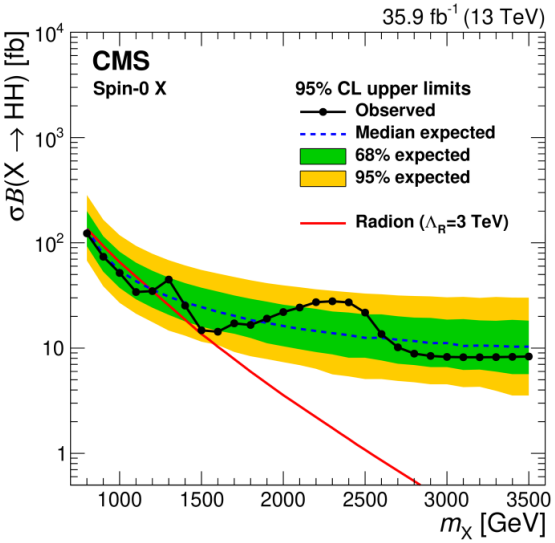
- W' HVT model B: excl. up to **3 TeV**
- Graviton (k=0.5) excl. up to **1 TeV**

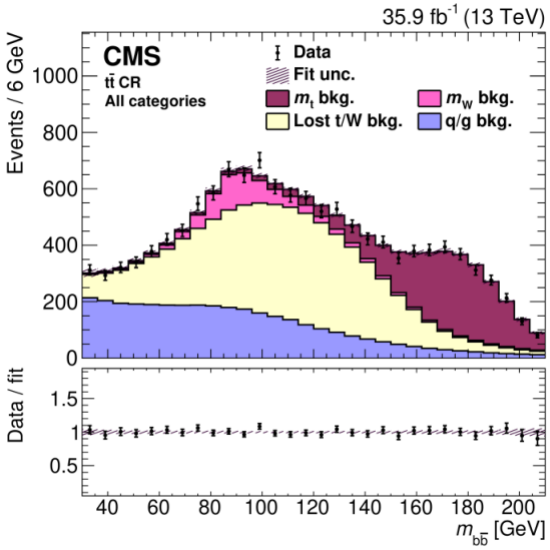
Resonance decaying to a pair of Higgs bosons

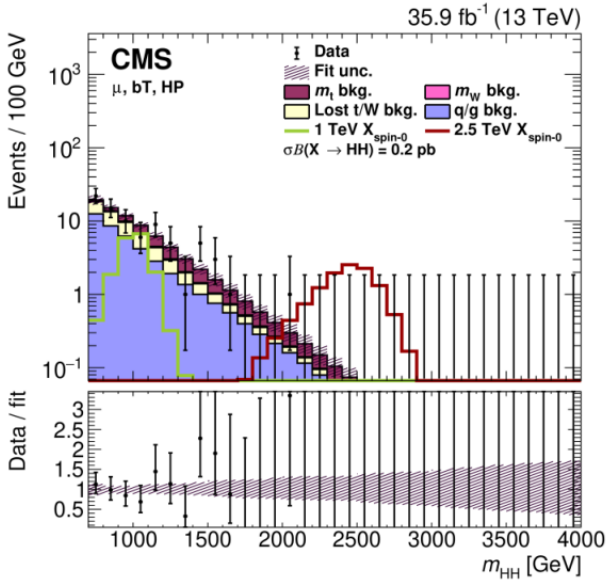
- Search for heavy resonance X decaying to a pair of Higgs bosons (HH → bb WW)
  - 1 lepton + MET + 1 large-R b-jet + 1 large-R jet
- Signal and SM bkg simultaneously estimated using **maximum likelihood fit to data** in the 12 event categories to 2D distributions of m(bb) and m(HH) mass plane
- All bgds defined in 4 generator level categories (number of gen. level quarks) with distinct m(bb) shapes
  - bkg. templates modeled as conditional probabilities of m(bb) as function of m(HH) using kernel estimation (KDE)

CMS-B2G-18-008







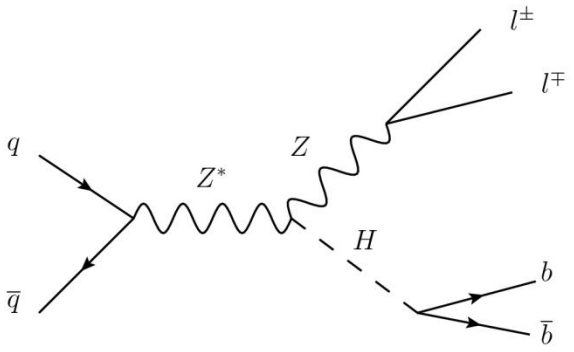


- obs. limit for spin-0 (8.3-123 fb) and spin-2 resonances (7.8-103 fb) for mass ranged of **3.5 - 0.8 TeV**

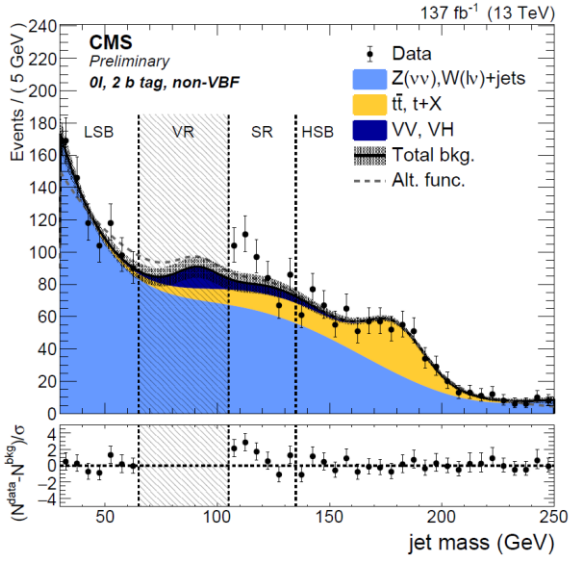
Resonance decaying to a Z and Higgs bosons

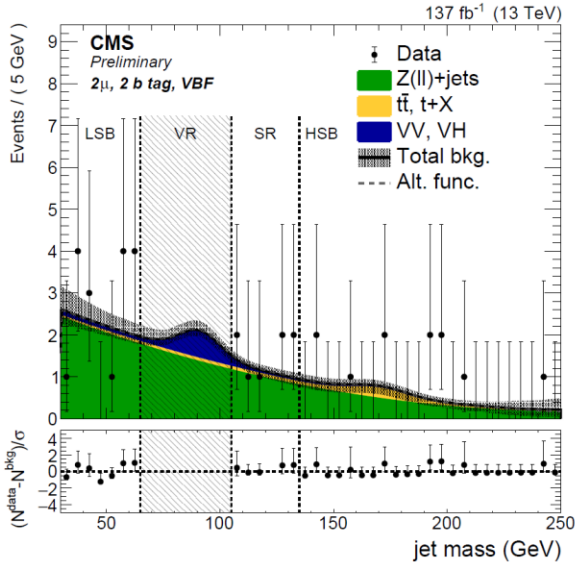
- Search for spin-1 resonance Z' decaying into a Z and H(125) bosons with Z → 2e,2μ,2ν and H → bb'

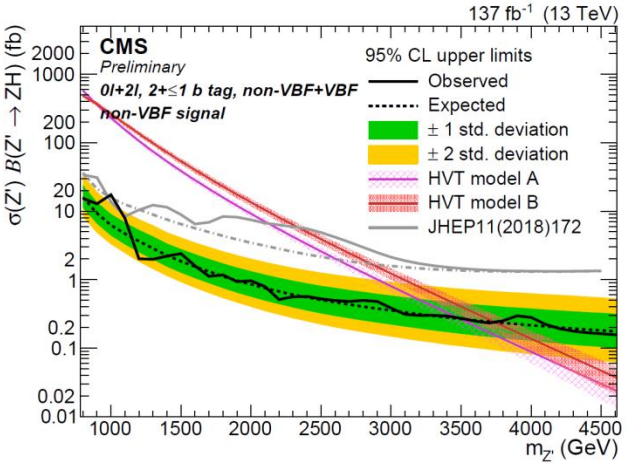
CMS-PAS-B2G-19-006



  - Higgs boson reconstructed as jet with substructure
  - 0 lepton (large MET) and 2 lepton channels, for the first time including VBF production (forward jets)
- m(Z') or mT(Z') distributions **estimated from data** in CRs from the sidebands (SB) of the Higgs candidate jet mass distribution
  - extrapolated to SRs through analytical functions derived from simulation
  - number of parameters for the fit to data is determined by a Fisher F-test







- Z' HVT model A (B): excl. up to **3.5 (3.7) TeV**

- Search for extremely rare 4 tops in 1L / 2OSL

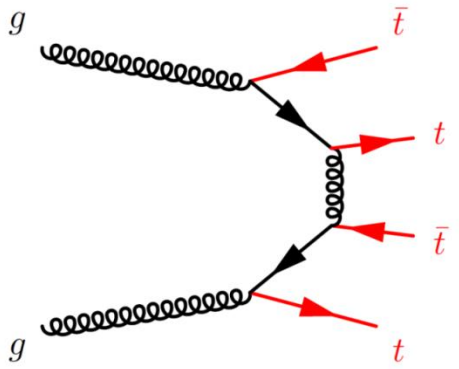
  - highest sensitivity categories in 1L (2OSL) requiere at least 10 (8) jets, 4 b-tagged jets and 2 (1) reclustered jets

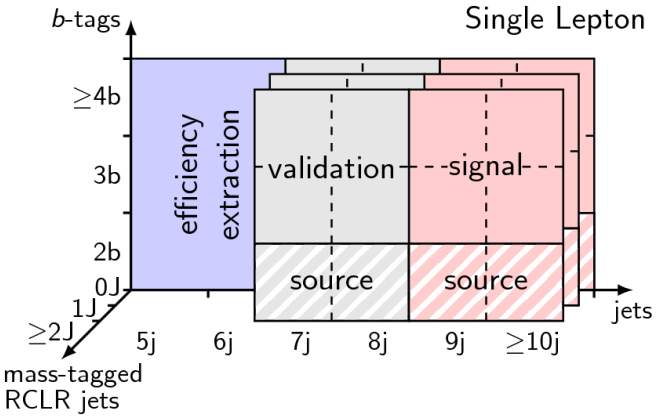
- **Data-driven** method to estimate tt+jets background

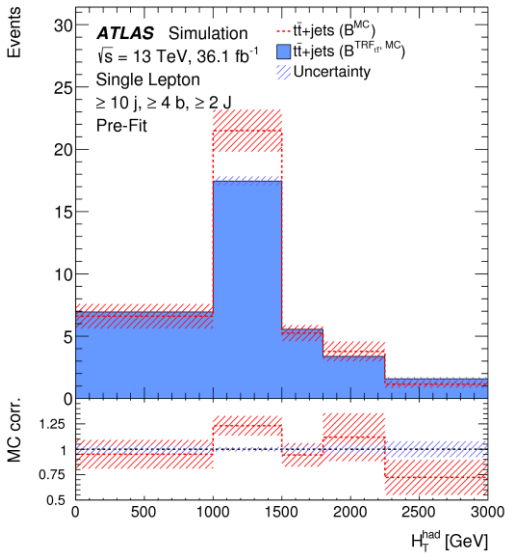
  - assume that the probability of b-tagging a jet in tt+jets event is essentially independent of the number of additional jets;

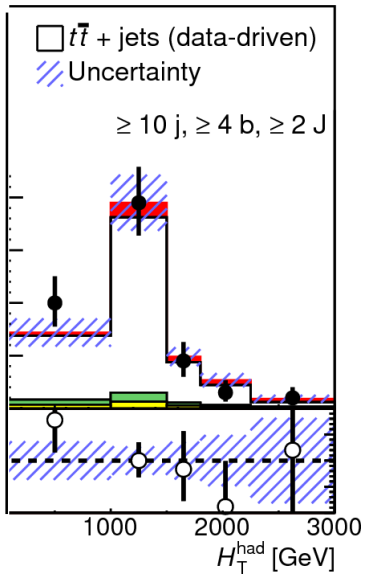
  - b-tagging efficiencies (ε_j) extracted as a function of jet p_T and the minΔR for the given jet wrt. to all other jets, multiplied by Nj

ATLAS-EXOT-2017-11









- Obs. (exp.) limits (95 % C.L.) of **5.1 (3.6)** x SM

- Limits on 4 tops via EFT

SUSY in 4 top + MET final states

- Search for SUSY in 1L and multiple jets

  - signal regions categories based on N-jets, N-bjets, MET and sum of masses of large-R jets (NJ)

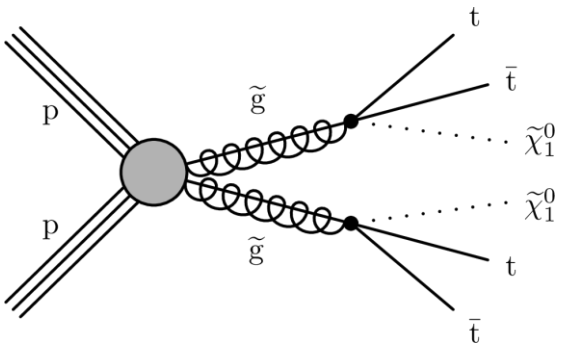
- Dominant ttbar bkg estimated with modified **ABCD** method in two uncorrelated planes of MJ and transverse mass mT

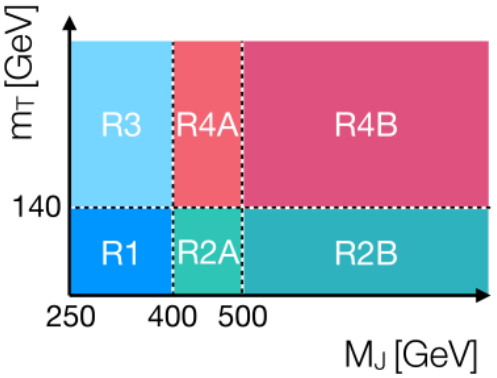
  - each event in low-mT data (R2A or R2B) is weighted with a *k factor*

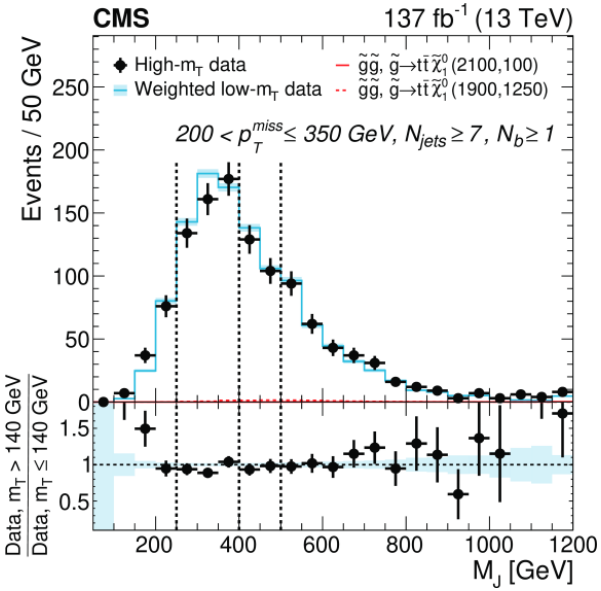
$$\kappa_A = \frac{N_{\mathrm{R4A}}^{\mathrm{MC,bkg}} / N_{\mathrm{R3}}^{\mathrm{MC,bkg}}}{N_{\mathrm{R2A}}^{\mathrm{MC,bkg}} / N_{\mathrm{R1}}^{\mathrm{MC,bkg}}},$$

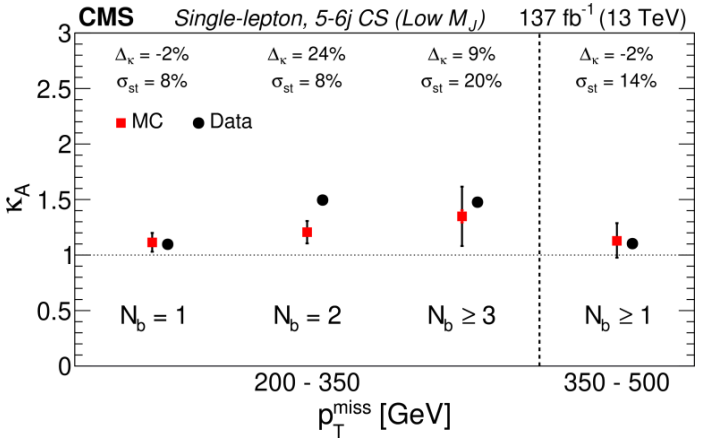
  - the total low-mT yield is normalized to the total high-mT yield in data

CMS-SUS-19-007







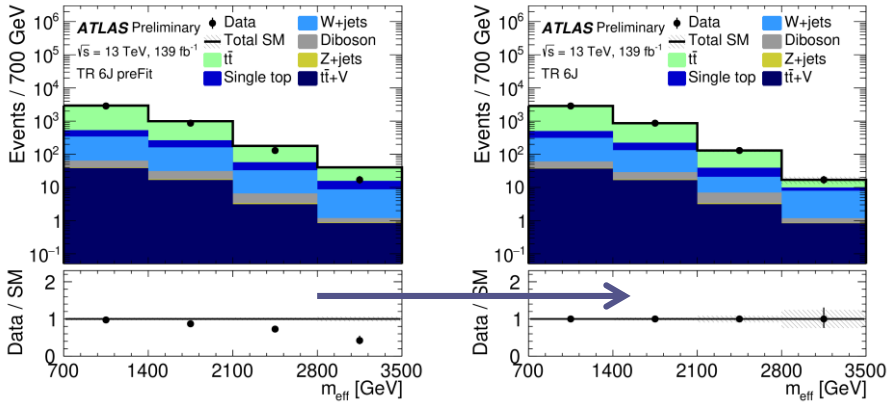


- excluded gluino masses up to **2150 GeV** for neutralino mass up to **700 GeV**

Trends from SUSY about top estimated from MC

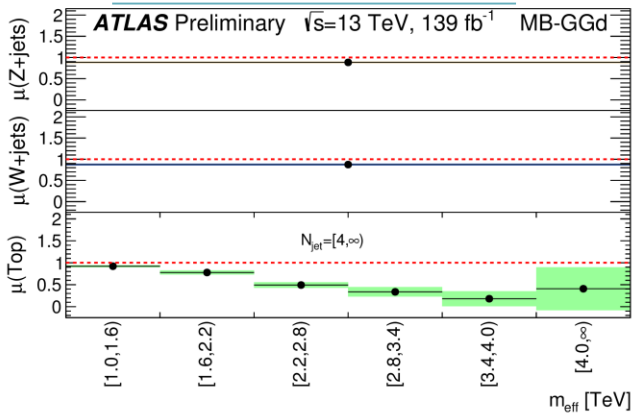
- mismodelling in M(eff): different top norm. parameters for each bin in the fit

ATLAS-CONF-2020-047



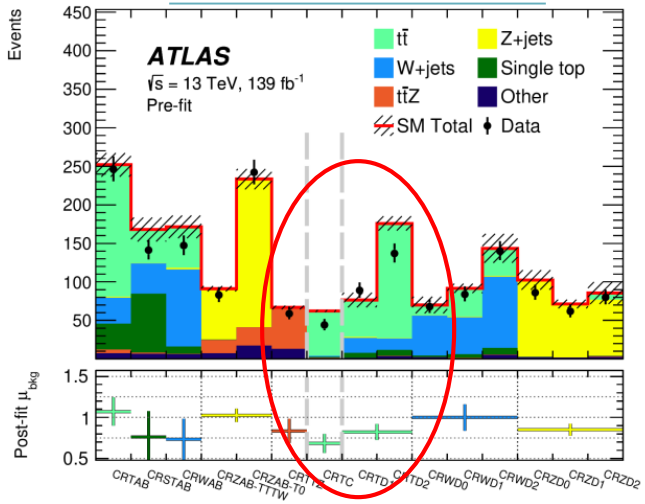
- fitted norm. factors away from 1: simulated top MC generally harder kinematics

ATLAS-CONF-2019-040



- Several SUSY scenarios searches use high-pT jets originating from ISR to improve sensitivity; norm. factors are <1 by 1-2 sigma: mismodelling in the ISR system in ttbar

ATLAS-SUSY-2018-12



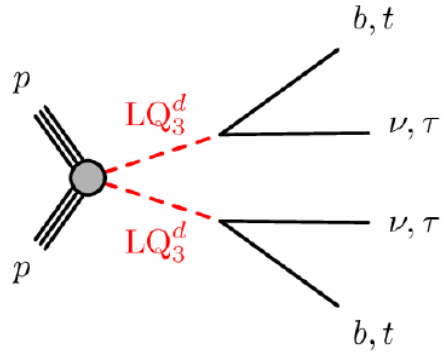
	tN_med	tN_high	tN_diag_low	tN_diag_high	bffN_btag	bffN_softb	DM
$t\bar{t}$ NF	$0.98^{+0.14}_{-0.12}$	0.90 ± 0.12	$0.88^{+0.13}_{-0.12}$	$0.73^{+0.14}_{-0.13}$	$0.80^{+0.09}_{-0.08}$	0.68 ± 0.10	$1.12^{+0.15}_{-0.13}$
$t\bar{t}V$ NF	$0.95^{+0.22}_{-0.20}$	0.92 ± 0.17	-	-	-	-	$1.18^{+0.20}_{-0.18}$
Single-top NF	$0.11^{+0.26}_{-0.11}$	$0.12^{+0.22}_{-0.12}$	-	-	-	-	-
W+jets NF	$0.96^{+0.25}_{-0.23}$	0.86 ± 0.17	-	-	0.83 ± 0.28	$1.04^{+0.22}_{-0.20}$	-

ATLAS-CONF-2020-003

Search for leptoquarks decaying into top and tau

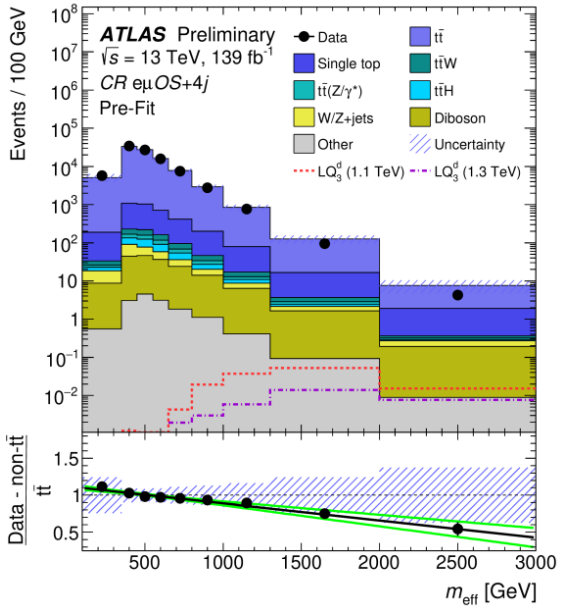
- Search for pair production of leptoquarks (LQ) decaying each in a top and tau-lepton

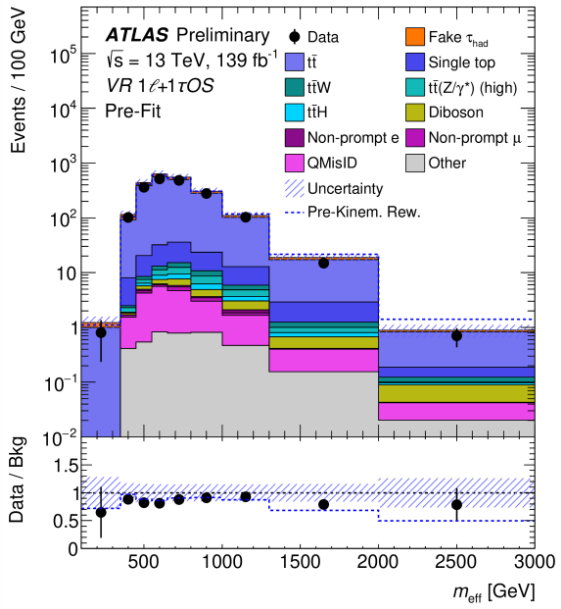
ATLAS-CONF-2020-029

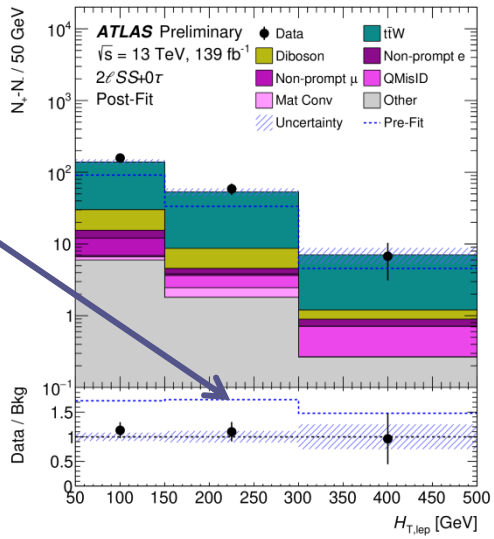


  - ≥1 e/μ + ≥1 τ(had) + ≥2 jets (1 b-jet)
  - Five final states, defined by the multiplicity and lepton flavour: 15 CRs, 6 VRs and 7 SRs

- **ttbar from MC**: kinematic reweighting as function of number of jets (nJ) and M(eff) derived in control region
  - correction factors (derived in OS eμ): ~0.4 for 3 TeV (nJ=4) difference in the slope derived in 1L1τ VR - systematic
  - ttW verified in 2LSS + 0τ : norm. factor *1.78 ±0.15*







- Excluded LQs decaying exclusively into tτ up to **1.43 TeV**

Common sentence in ATLAS and CMS when ttbar is from MC

and references therein, and Refs. [53–55]). The modeling of SM $t\bar{t}$ production in POWHEG is known to predict a harder p_T spectrum of the top quarks than observed in the data. An empirical reweighting for top quark pairs based on the p_T spectrum of generator-level top quarks is applied to obtain a better agreement with the measured differential $t\bar{t}$ cross section [56, 57].

terms, with Top++2.0 [33–39]. A correction depending on the top-quark p_T value is applied to account for shape effects due to NNLO QCD and NLO EW corrections according to Ref. [40]. The cross sections for

Differential measurements of $\sigma_{t\bar{t}}$ at $\sqrt{s} = 13\,\text{TeV}$ have demonstrated that the p_T distribution of the top quark is softer than predicted by the POWHEG simulation [67–69]. An additional uncertainty, referred to as "Top quark p_T", is estimated by reweighting the simulation. This

reweighting of the $t\bar{t}$ simulation has been applied to match the predictions to the data [42, 43]. The correction is applied as a function of the transverse momenta of the parton-level top quark and antiquark after initial- and final-state radiation. Specifically for this result, additional ded-

jets events, including those with no additional jets. In previous studies, better agreement between data and prediction was observed, particularly for the top quark p_T distribution, when comparing to NNLO calculations [77]. These small improvements to the modelling are incorporated by reweighting all $t\bar{t}$ samples to match their top quark p_T distribution to that predicted at NNLO accuracy in QCD [78, 79].

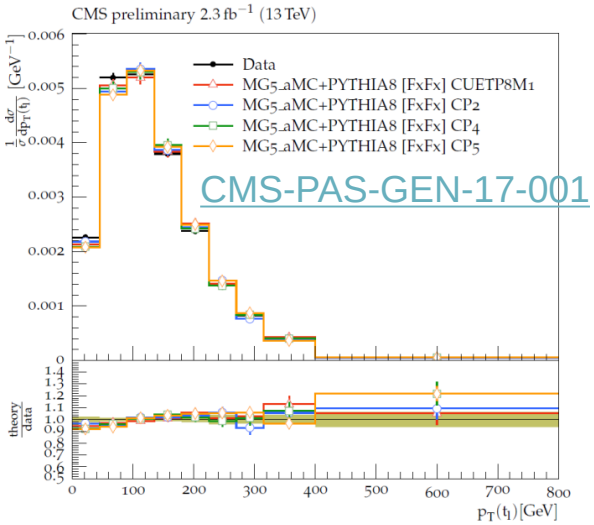
tively [22, 23]. In order to better describe the transverse momenta (p_T) distribution of the top quark in $t\bar{t}$ events, the top quark transverse momentum spectrum simulated with POWHEG is reweighted to match the differential top quark p_T distribution at NNLO QCD accuracy and including EW corrections calculated in Ref. [24]. The other SM background contributions from

The level of agreement between data and prediction for the lepton p_T and the leading jet p_T improves if the top-quark p_T distribution in the nominal $t\bar{t}$ simulation is corrected to match the top-quark p_T calculated at NNLO in QCD with NLO electroweak corrections [73]. In this analysis, the full difference between the

and many others. . .

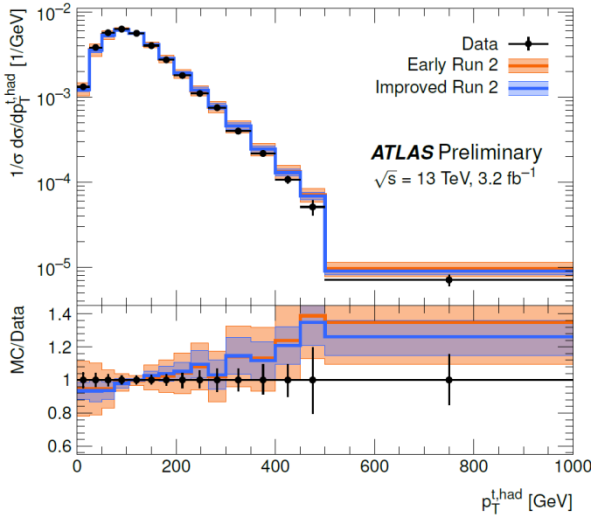
Top pT mismodelling: summary

- For full story of the top pT since 2013, see 'back in time' in the back-up
- As a summary:
  - general trend of the NLO predictions to overestimate the data at high pT(top)
  - same trends seen in resolved and boosted, consistent among experiments



CMS-PAS-GEN-17-001

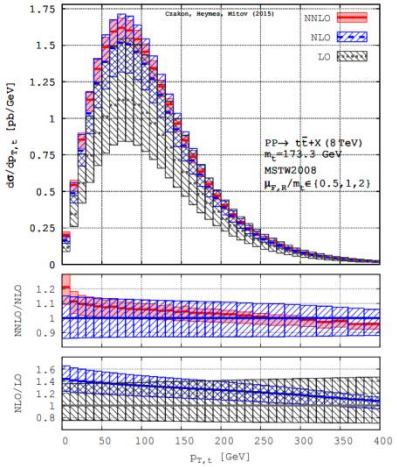
ATL-PHYS-PUB-2018-009

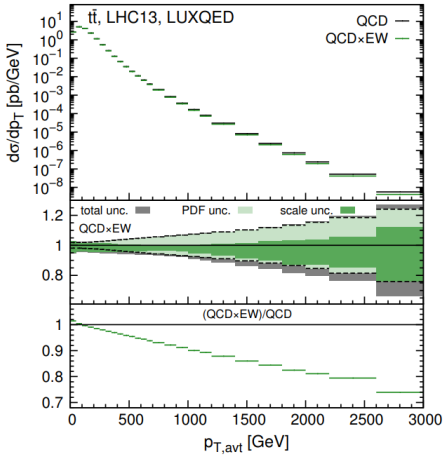


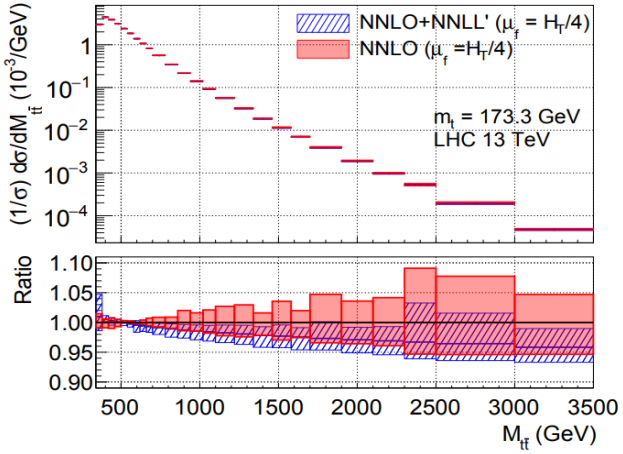
- Things to have in mind:
  - largely affect searches using simple variables such as HT or M(eff)
  - it's one of the main uncertainty if used in precise measurements
  - if reweighting is used: **case-by-case** assessment
  - previously shown data-driven methods are a potential way around it

Reweighting to fixed-order predictions

- Approaches taken up to now:
  - reweight parton-level kinematics (usually top and anti-top pT) to the best available fixed-order prediction







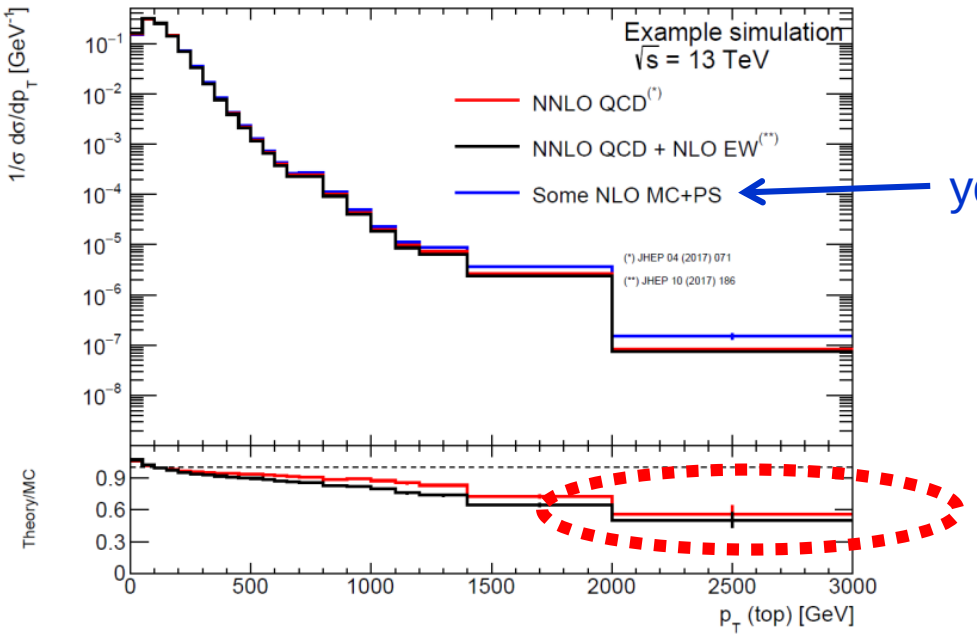
➢ In the last years, several high-order predictions available(*)

- M. Czakon et al., Phys. Rev. Lett. 116, 082003 (2016), NNLO QCD
- M. Czakon et al., JHEP 10 (2017) 186, NNLO QCD + NLO EW
- M. Czakon et al., JHEP 1805 (2018) 149, NNLO+NNLL' (boosted)
- C. Gütschow et al., Eur. Phys. J. C 78 (2018) 4, 317, MEPS@NLO QCD+EW
- M. Czakon et al., arXiv:1901.04442, NNLO+EW vs. MEPS@NLO
- S. Catani et al, JHEP 07 (2019) 100, NNLO, MATRIX
- M. Czakon et al., Chin. Phys. C 44 (2020) 8, 083104, NNLO+NNLL'
- N. Kidonakis, Phys. Rev. D 101, 074006 (2020), aN^{3}LO
- S. Catani et al, arXiv:2005.00557, NNLO in MS scheme

(*) this is a non-comprehensive list

Reweighting to fixed-order predictions

- Approaches taken up to now:
  - reweight parton-level kinematics (usually top and anti-top pT) to the best available fixed-order prediction
    - take the top pT distribution from you preferred calculation; extract from your MC sample (without selection) the (anti) top p_T histogram with the same binning (use “last top” in MC record, that is after radiation and before decay)
    - get the ratio between the two histograms, use this ratio to assign to each MC event a weight; in relevant cases, use this reweighted distribution as **nominal** (CMS) or as **systematic** (ATLAS) uncertainty

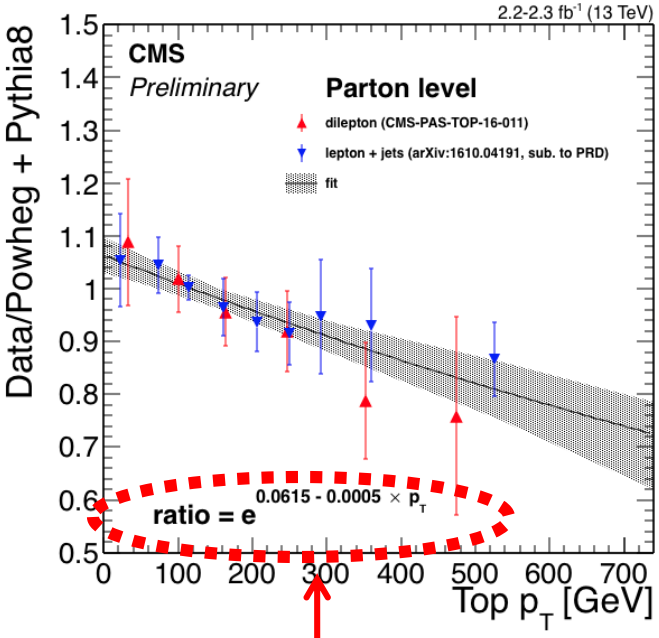


your preferred MC

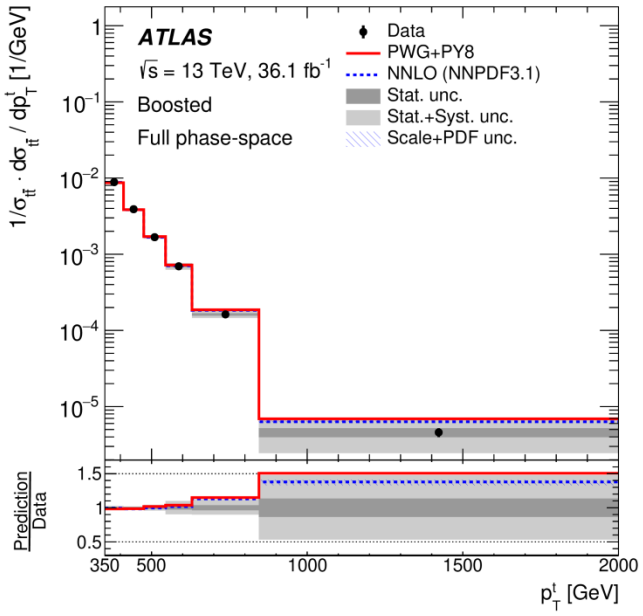
Reweighting to measured distributions

- Approaches taken up to now:
  - reweight parton-level kinematics to differential cross-section measurements
    - CMS often does not use the reweighted distributions as 'nominal' but rather takes the difference between reweighted and non-reweighted distributions as a syst. uncertainty. This is not recommended for searches in high pT due to the lack of statistics in deriving the weights in the tail

CMS Top Summary



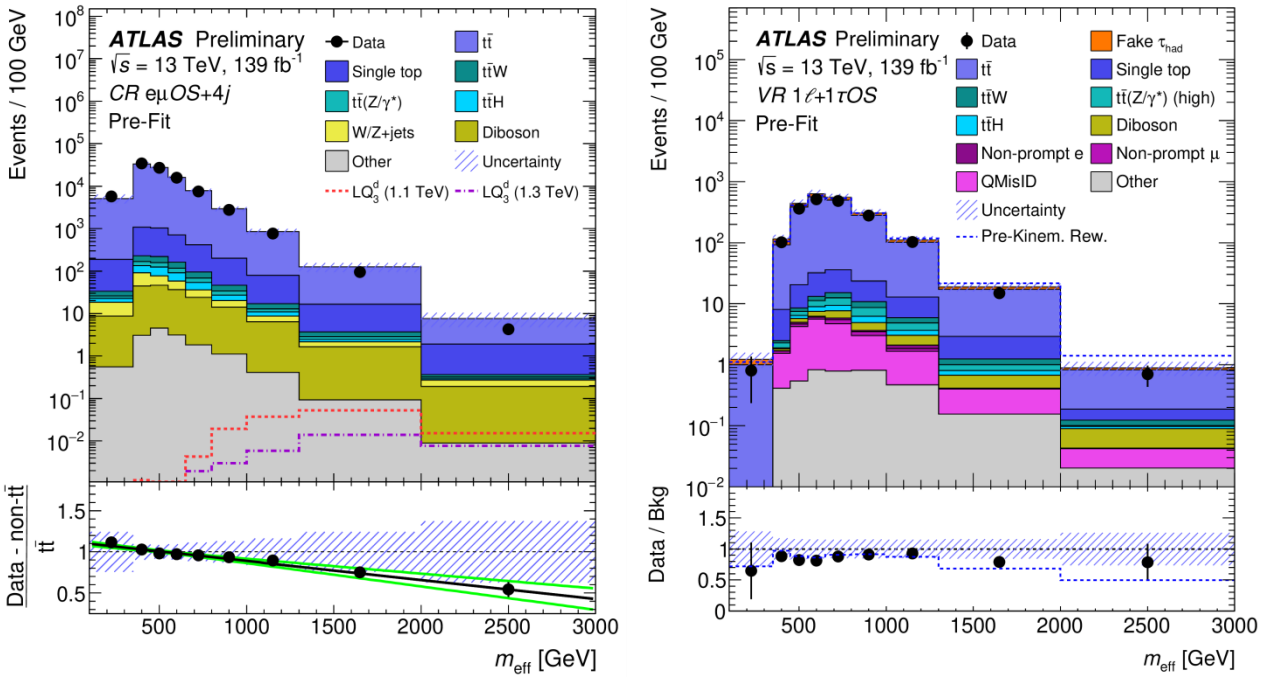
the reweighting function



Reweighting to distributions in control regions

- Approaches taken up to now:
  - derive ad-hoc reweightings to data in control regions using particular reconstructed distributions
    - ➢ often used in BSM searches, but what if we cannot define such a signal-free CR?

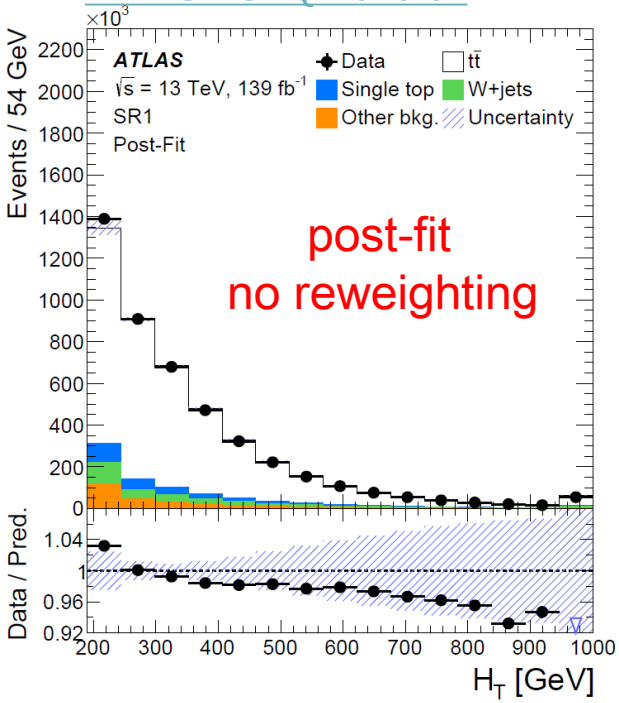
ATLAS-CONF-2020-029



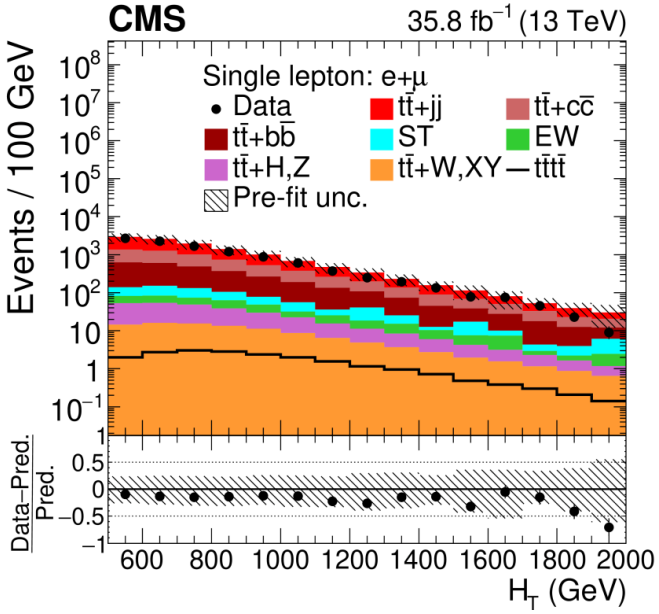
To reweight or not to reweight...

- Approaches taken up to now:
  - not to reweight (ATLAS), since the comparison of different MC predictions, when turned into systematic uncertainties, can (at least partially) cover the mismodelling
    - ➢ with the precision we have (from data) and we want (in precise measurements), we cannot anymore ignore this issue

ATLAS-TOPQ-2020-02



CMS-TOP-17-019



Here the nominal distribution is reweighted using information from the ttbar control region. A dedicated syst. uncert. is assigned. The CR happens to be the signal region of ttbar measurements.

Uncertainties derived by top pT reweighting

- In both ATLAS and CMS, the treatment changes **depending on the use case**, i.e. correcting effs. or acceptance in ttbar measurements, BSM searches, etc.
- If no control region in data is found for BSM searches, usually CMS corrects to the top pT to NNLO QCD + NLO EW correction by default, while ATLAS considers it as a systematic uncertainty

- Recent examples(*) of top pT reweightings and associated uncertainties:

Results	Reweighting to	Uncertainty (shape)
ttH ML (CMS-HIG-19-008)	NNLO QCD + NLO EW	Difference between weighted and un-weighted scenarios
tt cross-section (ATLAS-TOPQ-2020-02)	NNLO QCD + NLO EW	symmetrised full difference between on and off
Vector-like quarks (ATLAS-EXOT-2016-13)	NNLO QCD	full difference between applying and not applying
tt resonances (CMS-B2G-17-017)	function derived from data (p. 15)	symmetrised difference between on and off
SM 4 tops (CMS-TOP-17-019)	function derived from differential measurements	function variation within a ±1 sigma
Heavy H to ttbar (CMS-HIG-17-027)	function derived from differential measurements	varying the two parameters of the function

(*) this is a non-comprehensive list

Considerations on reweighting to fixed-order predictions

- Commonly raised points concerning the reweighting to fixed-order:
  - the latest NNLO calculations recommend different functional forms for the renormalisation and factorisation scales for different observables
  - PDFs, top mass, scale variations and scale choices not always easily available in theory predictions, nor match ATLAS/CMS settings

  - given that the baseline Powheg V2 ttbar MC in ATLAS and CMS uses the same fact. and ren. scales (sqrt[m^2+pT^2]), having calculations with the same scale for all variables would be helpful
  - having calculations with the same choices would help the Collaborations to apply the correction in a consistent way where needed (e.g. ATLAS/CMS uses top mass of 172.5 GeV in Powheg, while theory uses 173.3 GeV as input parameters for the calculation)

$$\mu = \frac{m_{T,t}}{2} \quad \text{for the } p_{T,t} \text{ distribution,} \tag{2.3}$$

$$\mu = \frac{m_{T,\bar{t}}}{2} \quad \text{for the } p_{T,\bar{t}} \text{ distribution,} \tag{2.4}$$

$$\mu = \frac{H_T}{4} = \frac{1}{4}\left(m_{T,t} + m_{T,\bar{t}}\right) \quad \text{for all other distributions,} \tag{2.5}$$

JHEP10(2017)186

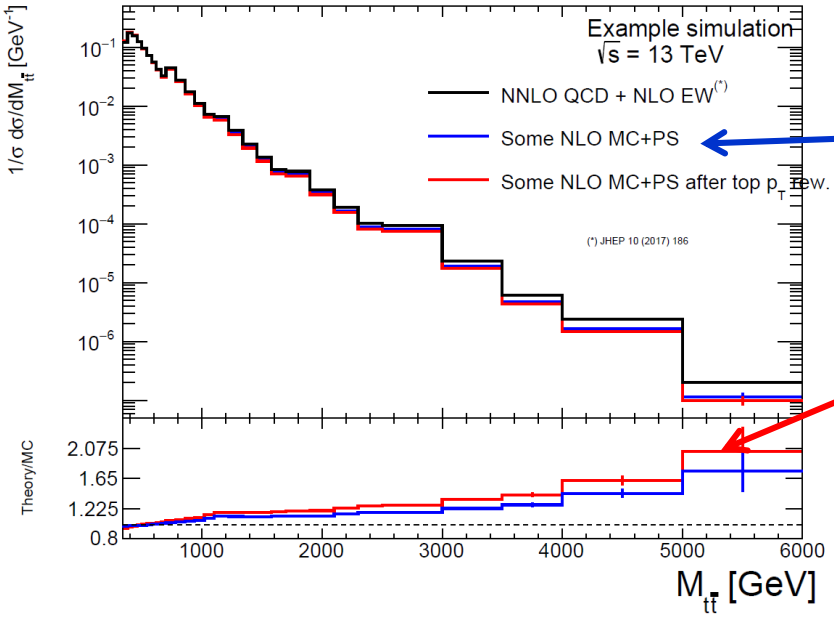
where $m_{T,t} \equiv \sqrt{m_t^2 + p_{T,t}^2}$ and $m_{T,\bar{t}} \equiv \sqrt{m_t^2 + p_{T,\bar{t}}^2}$ are the transverse masses of the top

Reweighting, but to which distribution?

- Commonly raised points concerning the reweighting to fixed-order:
  - top pT gets corrected, but what about other (partially correlated) variables, e.g. ttbar mass?

➢ usually analysers monitor the change in agreement between data and reweighted MC in other distributions (especially ttbar mass) and make sure that the reweighting does not spoil the agreement

➢ NNLO QCD and NLO EW predictions for top pT and ttbar-system mass are available



your preferred MC

after top pT rew. moves away from prediction

Options to explore: reweight to multiple distr. and recursive rew.

- Commonly raised points concerning the reweighting to fixed-order:
  - top pT gets corrected, but what about other (partially correlated) variables, e.g. ttbar mass?

➢ usually analysers monitor the change in agreement between data and reweighted MC in other distributions (especially ttbar mass) and make sure that the reweighting does not spoil the agreement

➢ NNLO QCD and NLO EW predictions for top pT and ttbar-system mass are available

➢ **2-D** reweighting (for example based on pT(top) and m(ttbar)) would account for correlations among variables from which the weights are derived

➢ Another option: the recursive approach. Reweight different distributions iteratively and repeat the procedure recursively (2 x 2) – giving a MC prediction which matches both top pT and ttbar mass NNLO predictions (can get further refined using other variables and become 3x3...)

➢ yet, any reweighting is imperfect until the full kinematic dependence in the full phase space is known: NNLO MC + PS…

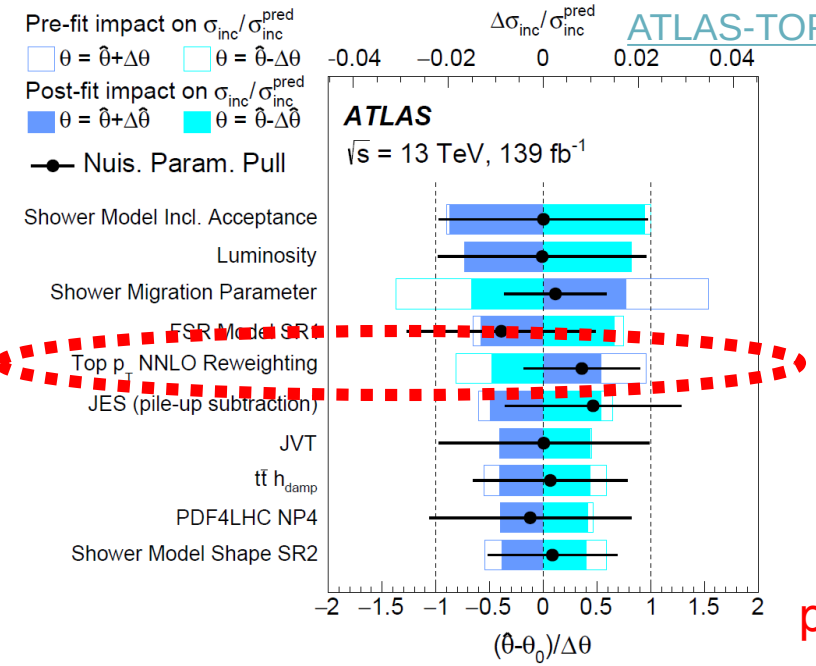
Top pT reweighting: systematic uncertainties

- Commonly raised points concerning the reweighting to fixed-order:
  - and finally, which uncertainty should be added?

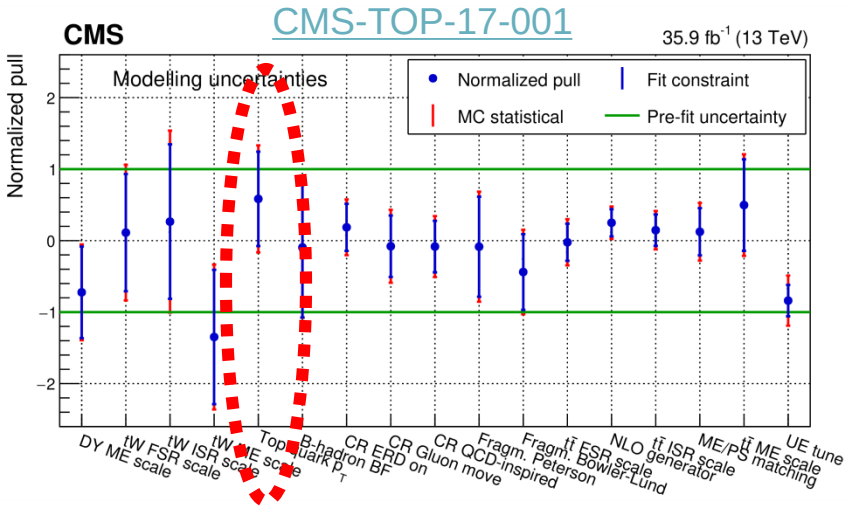
➢ ATLAS and CMS usually assign a systematic uncertainty derived from the difference between the applying and not the reweighing

➢ both searches and measurements profile this uncertainty; if the nuisance is pulled towards the NNLO prediction, this is expected

ATLAS-TOPQ-2020-02



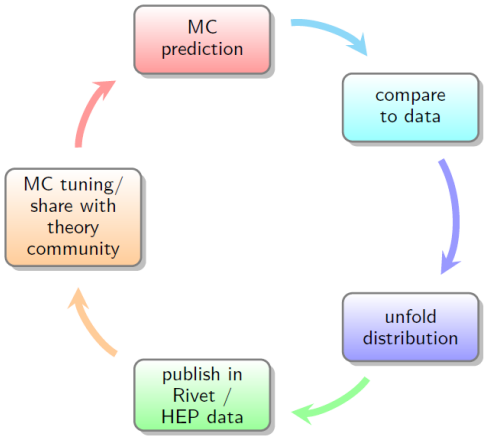
CMS-TOP-17-001



postfit pulls of this NP

Conclusions

- Many novel data-driven background (ttbar) estimation methods: really large amount of efforts by the Exotics, SUSY, B2G and Higgs communities
  - Allow to search for NP in extreme phase-spaces without dealing with top pT and other mismodellings (or lack of stats in the tails)
- Yet, top quark pT mismodelling is still one of the main issues with the current dataset
- Both ATLAS and CMS have a broad (multi-dimensional) differential measurements and MC tuning programs: the only way to solve this issue is to continue these efforts
  - MC tuning may improve the agreement, but if the discrepancy is really due to missing QCD and EW corrections, forcing the MC parameters to bring the top pT distribution in agreement with data is likely to break the agreement in other distributions



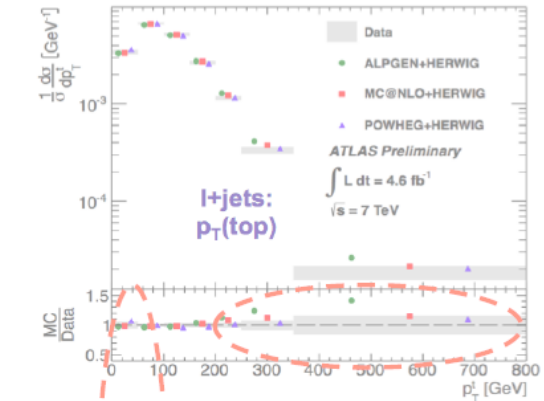
- Meanwhile, refined approaches to the “top pT reweighting” are possible
- Inputs from the theory community would be vital, as well as novel calculations and access to tools to perform NNLO computations
- Thanks to all my collegues from ATLAS and CMS who helped in preparing the talk, and you for the attention!

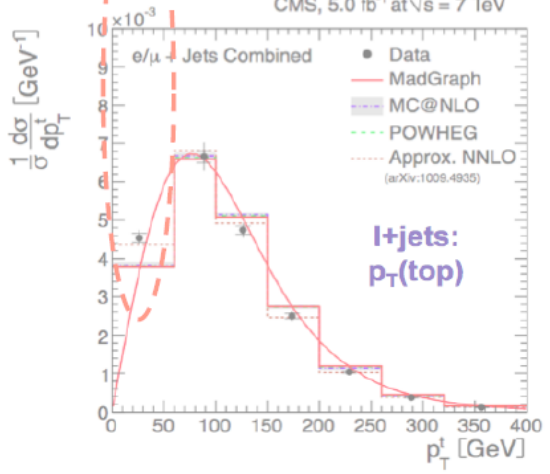
BACK-UP

TOP 2013: both ATLAS and CMS begin to see softer top pT in data

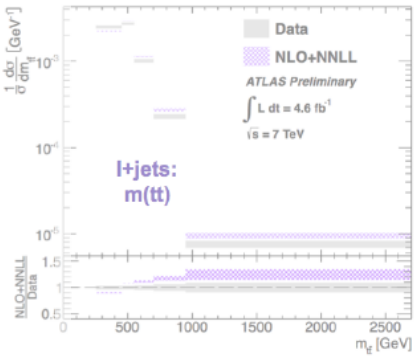
Differential Cross Sections: $p_{T,t}$, m_{tt}

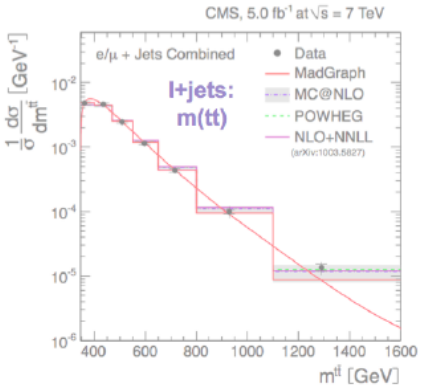
M. Aldaya





- Top p_T: in general softer spectrum in data than predicted by MCs.
- Some tension between ATLAS and CMS in the first bin affects conclusion on agreement with NLO+NNLL prediction.
- Partonic level defined in the same way?
  Non-perturbative corrections missing?





- m_{tt}: very sensitive to PDFs but also to NP. Beware of EW effects not accounted for!
- Somewhat contradictory conclusions by ATLAS and CMS regarding agreement with NLO+NNLL.

28

[slides at TOP 2013]

2013: CMS 'short-term solution': propose to use top pT reweighting

Measurement of the top quark mass using the B-hadron lifetime technique

CMS PAS TOP-12-030

The CMS Collaboration

an assumption on the mass hypothesis is made. The top p_T spectrum from simulation, assuming m_t=172.5 GeV, is compared to one observed in data [35–37]. The simulated top p_T spectrum is then re-weighted to the unfolded top p_T spectrum observed in data. The difference in $\widehat{L_{xy}}$ due to the re-weighting is interpreted as the uncertainty on m_t due to a potential mis-modeling of the top quark p_T distribution.

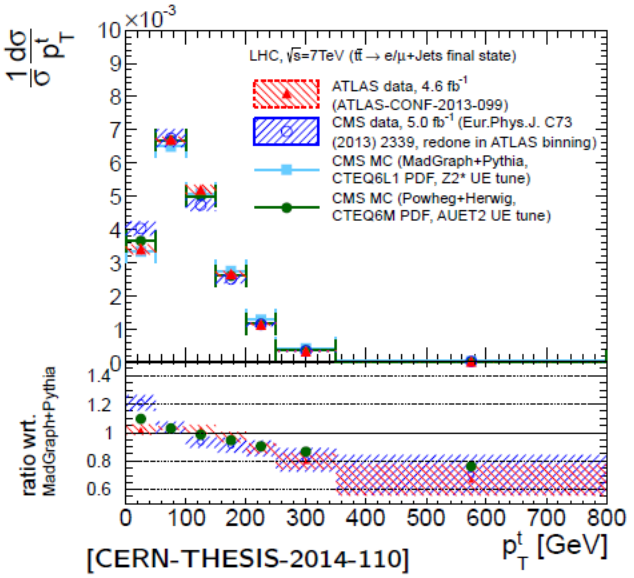
Source	Δm_t[GeV]		
	μ+jets	e+jets	$e\mu$
Top quark p_T modeling	3.27 ± 0.48	3.07 ± 0.45	2.36 ± 0.35

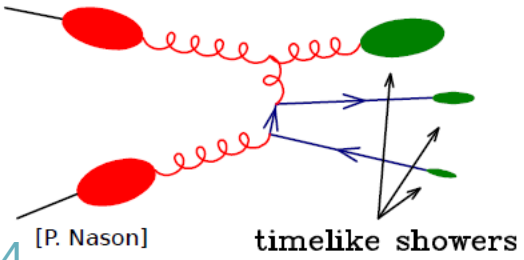
At present, this measurement of m_t is strongly limited by the systematic uncertainty on the top quark transverse momentum spectrum which makes further studies necessary. In general,

TOP 2014: further differential results about the top pT mismodelling appear

$t\bar{t}$ top-quark p_T (mis)modeling

- CMS sees softer top p_T in data, agreement with ATLAS at high p_T
- Powheg+Herwig6 seems to agree with data, rescaling of $t, \bar{t}, j$ momenta to give virtuality to extra jet
  [P. Nason, https://indico.cern.ch/event/301787]
- Different reshuffling schemes implemented in Herwig++ 2.7.1
- Pythia8: dipole-recoil vs. global recoil
- NNLO might be able to resolve
- CMS short-term solution: uncertainty from top p_T reweighting (similar approach at D0 for $t\bar{t}$ p_T)



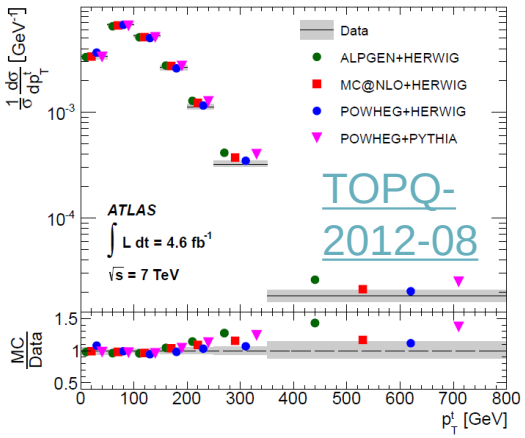


slides at Top 2014

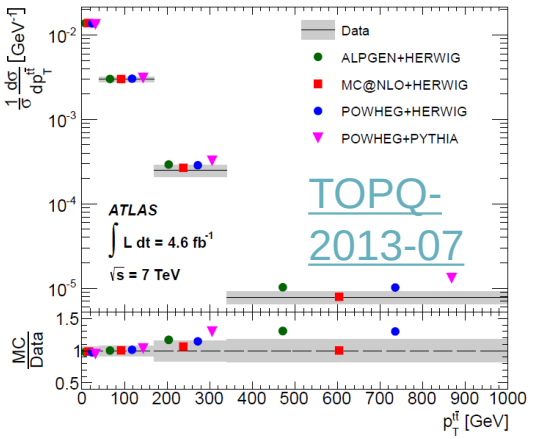
2014: ATLAS uses the top pT reweighting as well (+ ttbar pT reweighting)

Since the best possible modelling of the $t\bar{t}$+jets background is a key aspect of this analysis, a correction is applied to simulated $t\bar{t}$ events in POWHEG+PYTHIA based on the ratio of measured differential cross sections at $\sqrt{s} = 7$ TeV between data and the simulation as a function of top quark p_{T} and $t\bar{t}$ system p_{T} [54]. This significantly improves the agreement between simulation and data in the total number of jets (driven mostly by $t\bar{t}$ system p_{T} reweighting) and jet p_{T} (driven mostly by the top quark p_{T} reweighting). This reweighting is applied to all $t\bar{t}$+jets events, including the $t\bar{t}$+HF component. The

ATLAS-CONF-2014-011

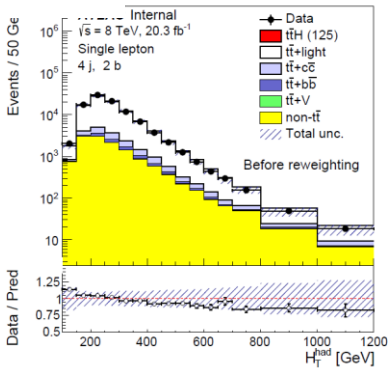


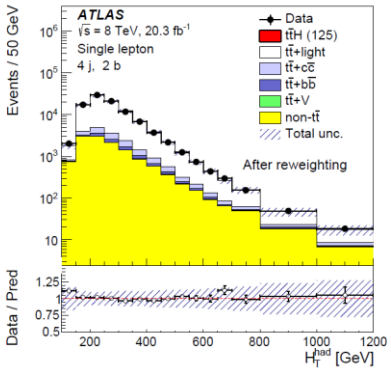
TOPQ-2012-08



TOPQ-2013-07

CERN-THESIS-2016-089



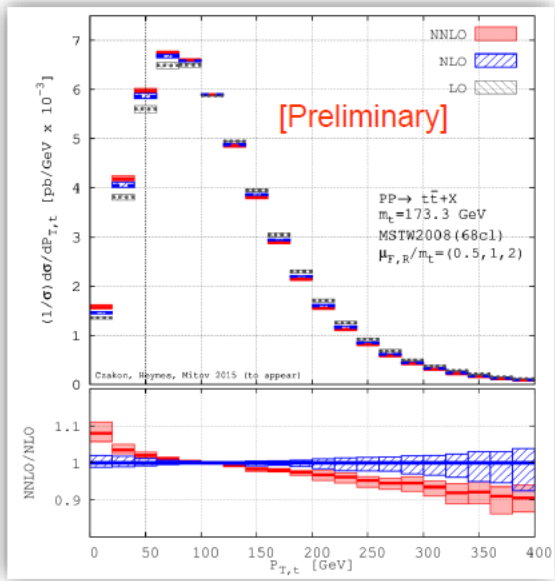


TOP 2015: both ATLAS and CMS see the slope in top pT

Top p_T modeling: the verdict

→ Heymes

Really NEW (yesterday!):



Full NNLO/NLO k-factor vs top pT : a slope!

- Full NNLO correction "confirms" observed slope, in direction closer to the data
- Use k-factors to reweight NLO+PS MCs ?
- Ultimately NNLO+PS would be great ☺

➔ Great to see this dialogue between LHC precision measurements and state-of-the art theory calculations

➔ Important step forward in our understanding of Top production !!

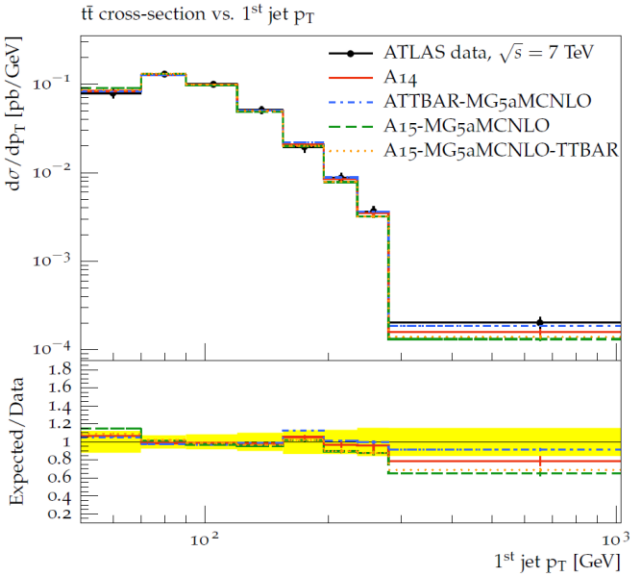
TOP 2015, Ischia Martijn Mulders (CERN) Experimental Summary

slides at TOP 2015

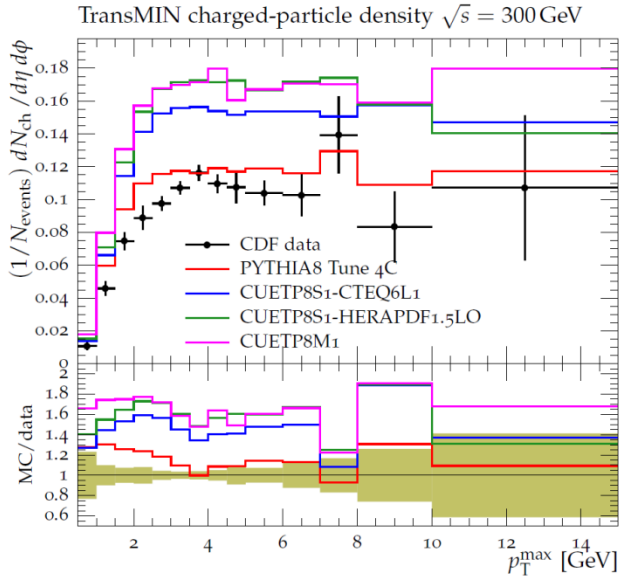
Back in time

2015: MC tuning efforts ramp up both in ATLAS and CMS

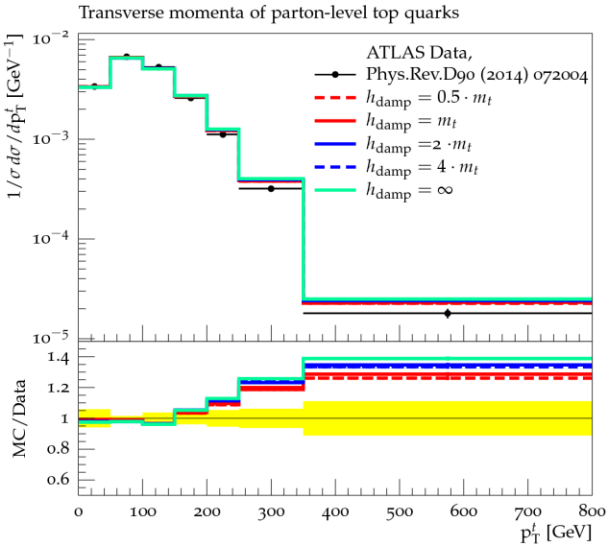
ATL-PHYS-PUB-2015-048



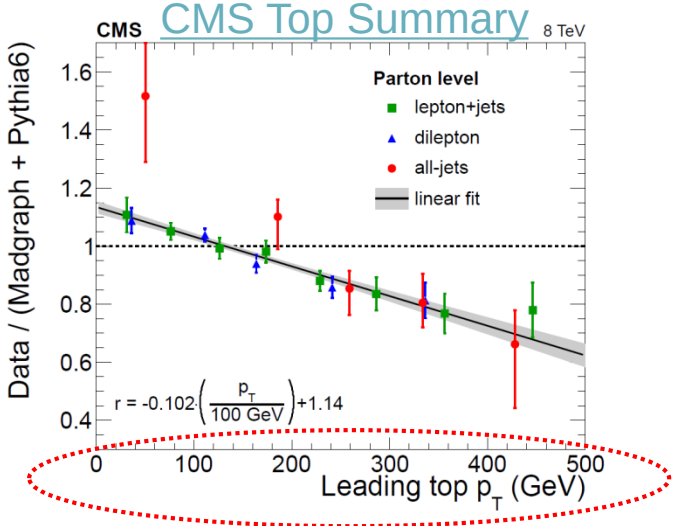
CMS-GEN-14-001



ATL-PHYS-PUB-2015-002



CMS Top Summary



slope seen in all decay channels

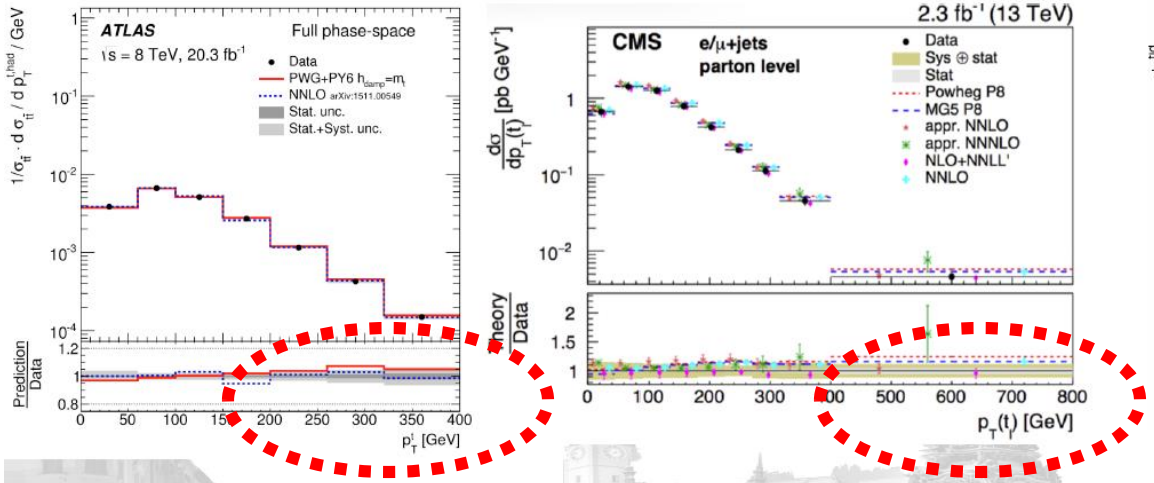
TOP 2016: many differential measurements confirm the findings

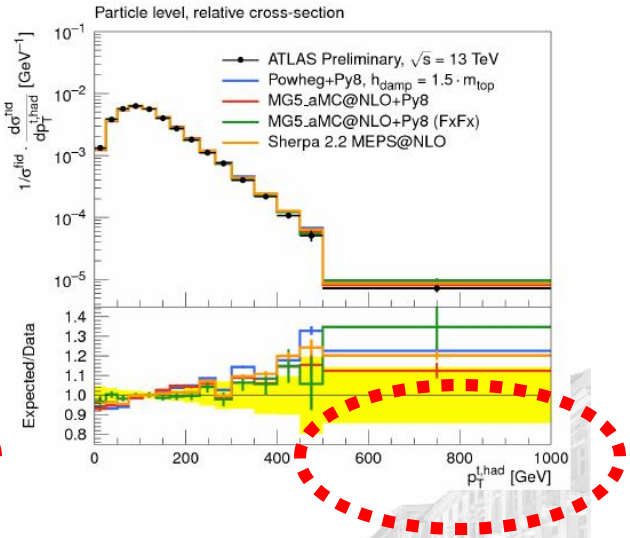
The top Pt modeling story

S. Henkelmann

- slope in the top pt distribution: data softer than MC predictions
  - largely improved by NNLO computations
  - modern NLO+PS MC can also cope for part of the discrepancy

parton level

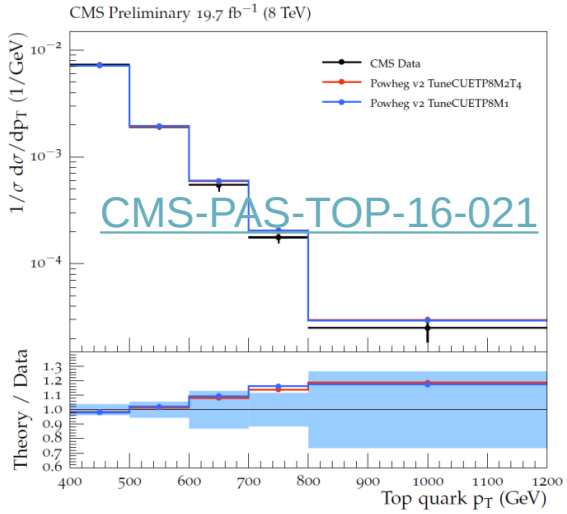




slides as TOP 2016

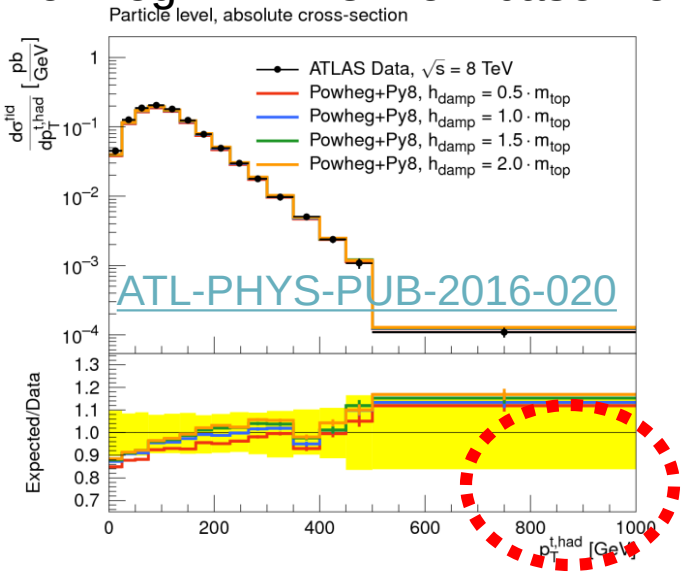
TOP 2017: top quark modelling and tuning from ATLAS and CMS

Powheg V2 as baseline, new CMS tune



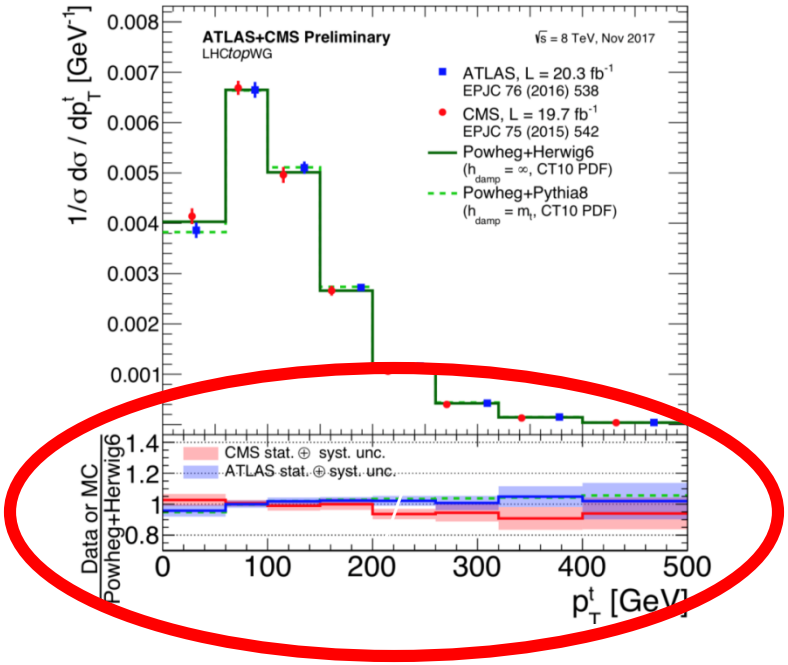
CMS-PAS-TOP-16-021

Powheg V2 + P8: new baseline in ATLAS



ATL-PHYS-PUB-2016-020

LHCTopWGSummaryPlots

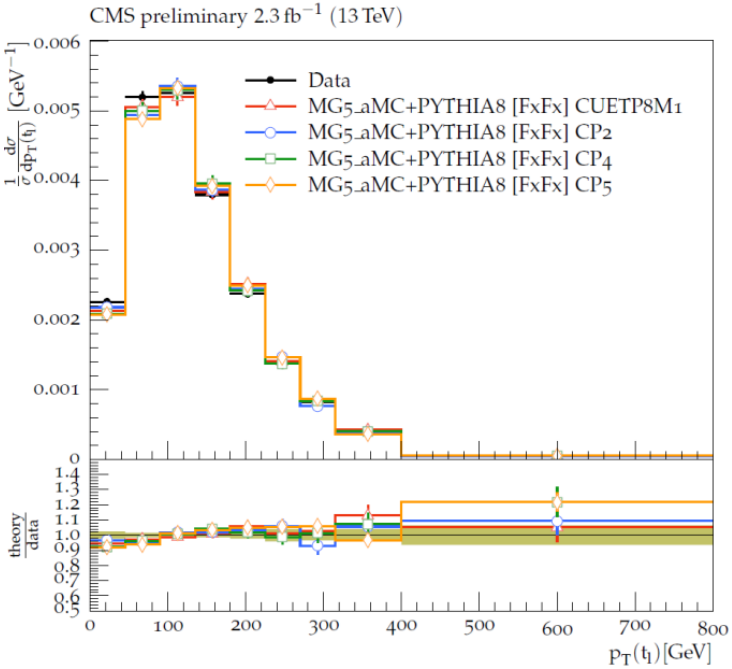


comparisons between ATLAS and CMS

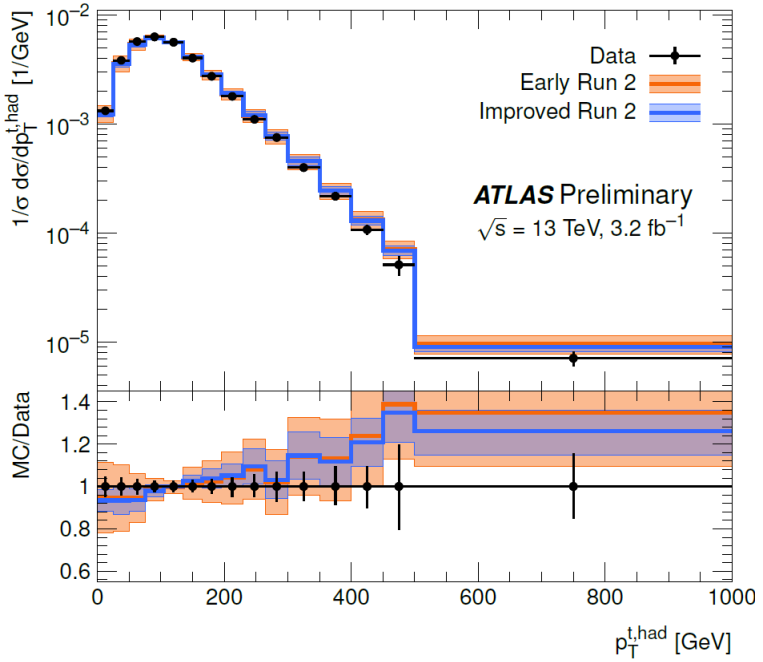
Back in time

TOP 2018: improvements in modelling ongoing, still not perfect

CMS-PAS-GEN-17-001



ATL-PHYS-PUB-2018-009

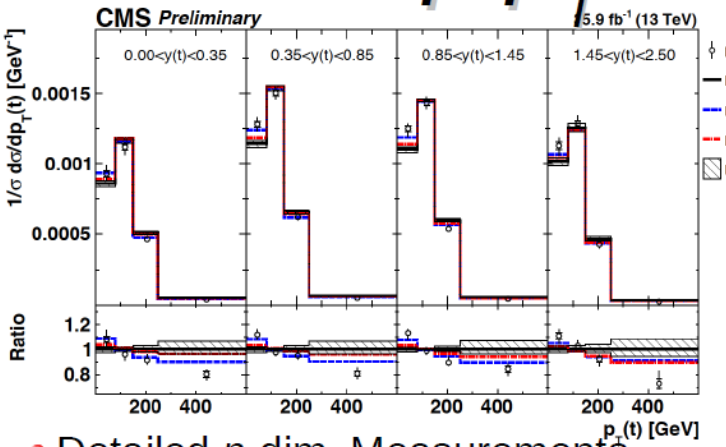


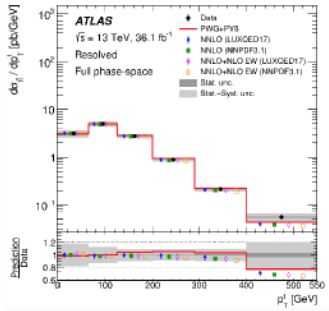
Precise predictions in top-quark physics must take into account both QCD and EW effects in order to correctly identify possible BSM effects.

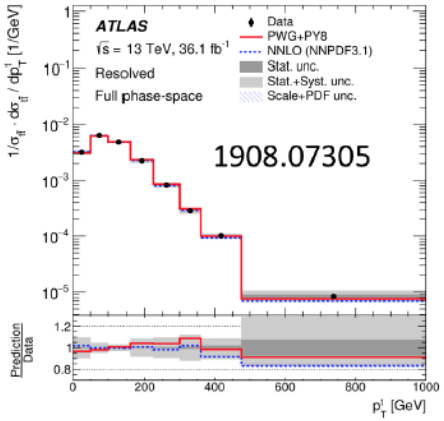
D. Pagani

TOP 2019: more and more precise differential measurements

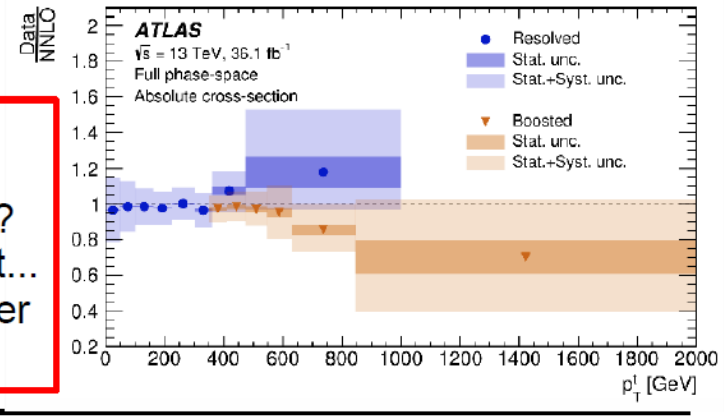
The top p_T saga...continued Boisvert







- Detailed *n*-dim. Measurements
- Common binning – study EW corrs.



- Slopes in 13 TeV ATLAS & CMS data
- Large systematic uncertainty – further understanding, common procedure ?
- To be continued in LHCtopWG context...
- Theory can help: experiments are eager to use an "NNLO MC"

slides at TOP 2019