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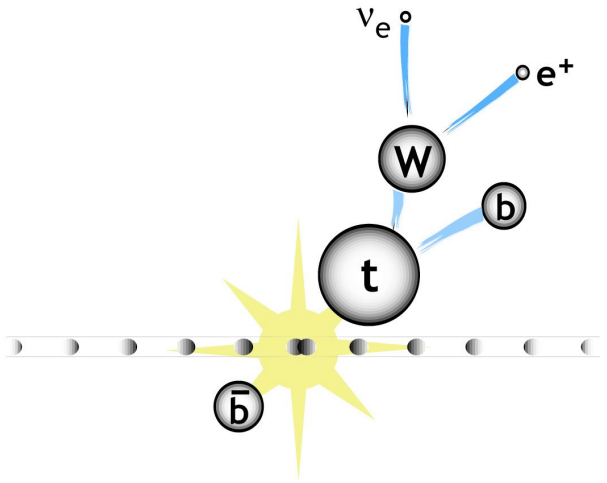
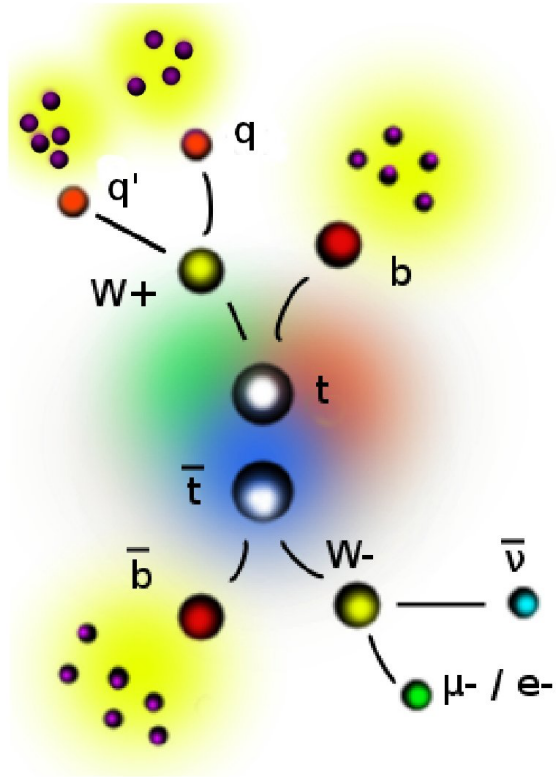
Highlights and stimulating results* at TOP2020

Wolfgang Wagner

Bergische Universität Wuppertal



ATLAS Weekly, September 22, 2020



* Disclaimer: (Necessarily) a subjective and incomplete selection.

Challenging the Standard Model with top quarks

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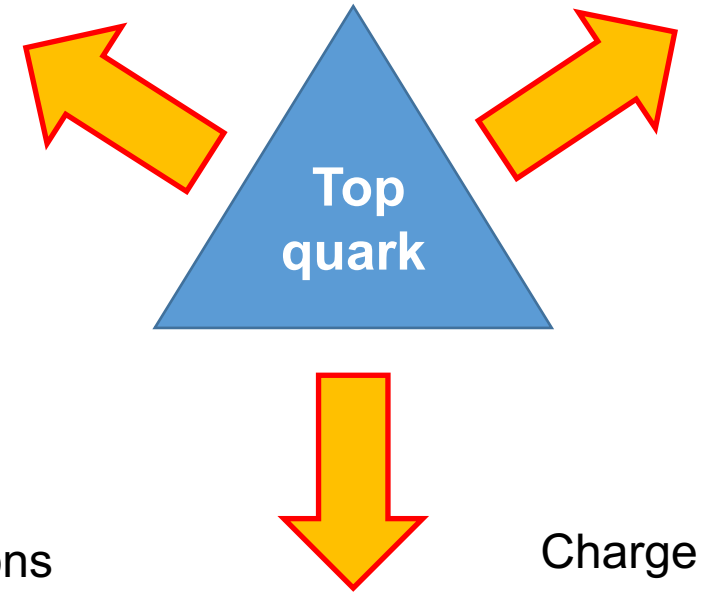
Physics of the top quark and with top quarks.



Leptoquarks

Supersymmetry

Vector-like quarks

Direct searches

Heavy Higgs bosons

Rare decays

CP violation

Indirect searches

Flavour-changing neutral currents

Lepton-flavour violation

Top-quark + X production

Spin correlations

Charge asymmetry

Precision measurements

Polarisation

Differential and total cross-sections

W helicity in top-quark decay

Top-quark mass

Top quarks as a tool

TOP2020 timetable

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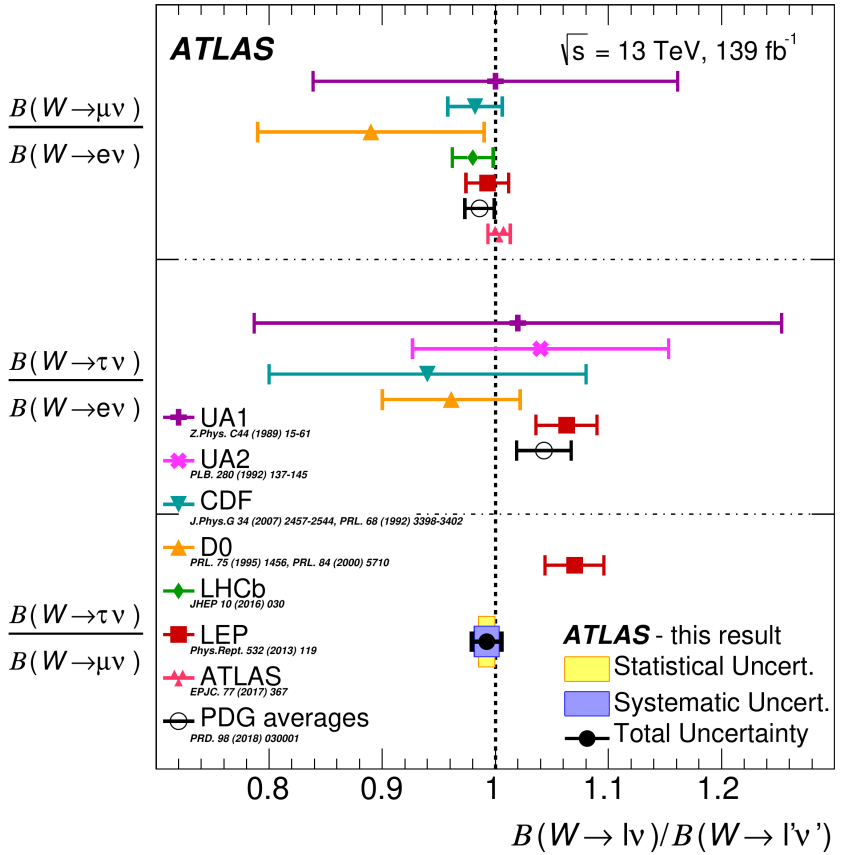
- Organised as an online conference.
- Agenda shortened, but all usual elements included.

	Monday	Tuesday	Wednesday	Thursday	Friday
14:00 – 16:00	Keynote address Cross-sections	Modelling and MC generator setups $t\bar{t}+\gamma$ and $t\bar{t}+Z$	Poster session Joker talk Young Scientist Forum	Theory mini-workshop: Jets top physics	Joker talks Searches
Coffee break					
16:30 – 18:00	Differential cross-sections Parameter determination from cross-sections	$t\bar{t}+H$ $t\bar{t}+W$ $t\bar{t}+b\bar{b}$	$t\bar{t}$ at threshold b-fragmentation Anomalous couplings and FCNC	Asymmetries and lepton universality Effective field theory in top physics	Experimental and theory summaries

- Next edition (2021) hopefully in Durham.

Two true top highlights

Test of the universality of τ and μ lepton couplings in W-boson decays from $t\bar{t}$ events …



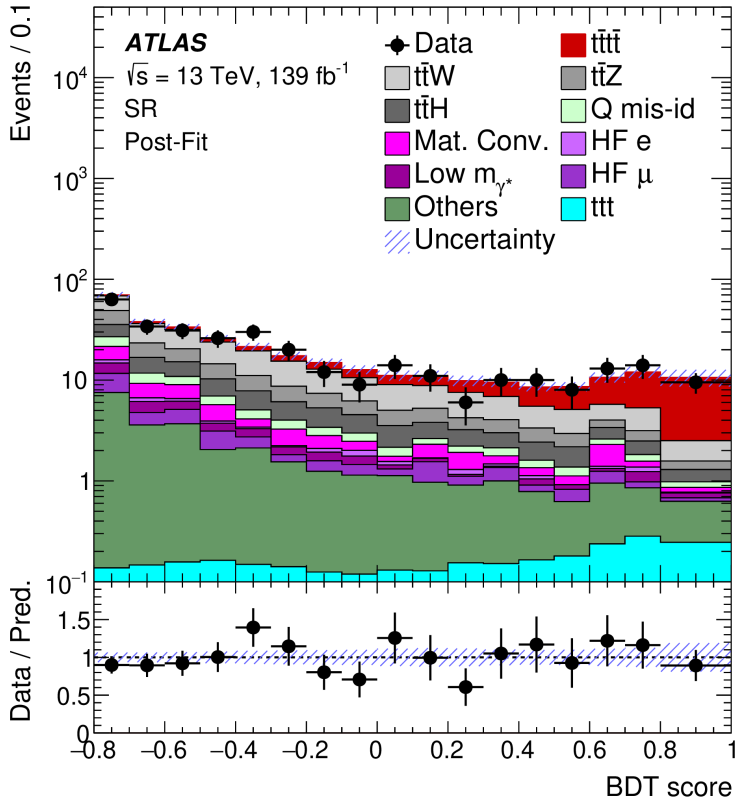
arXiv: 2007.14040

Submitted to Nature Physics

Close to resubmission, addressing requests by the journal referee

- Presented by Nello Bruscino in an ATLAS-only talk.
- Prime example for “top quarks as a tool” and ATLAS as a precision experiment.

Evidence for 4-top-quarks production

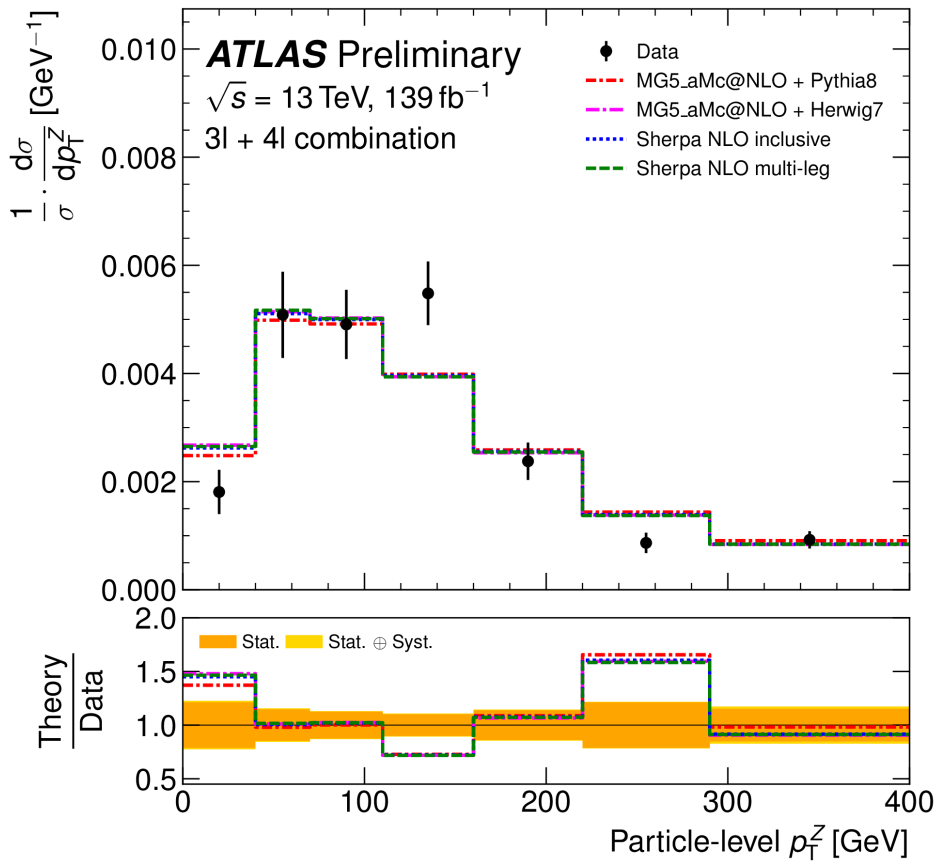


arXiv: 2007.14858

Ready for resubmission, addressing requests by the journal referee

- Presented by Erich Varnes as joker talk.
- Highlights the importance of the same-sign di-lepton and multi-lepton channels

Total and differential cross-sections of $t\bar{t} + Z$ production



- Presented by Rustem Ospanov.
- Worked out limitations of current analysis which had the focus on differential measurements:

Post-fit event yields in the combined 3l and 4l SR

	$t\bar{t}Z$	$t(\bar{t})X$	WZ	non-prompt	data	$\int \mathcal{L}$
CMS	455	105	54	33	660	77.5 fb^{-1}
ATLAS	518	114	46	37	732	139 fb^{-1}

- CMS: lower p_T thresholds and e/μ BDT $\rightarrow$ 20 to 30% higher acceptance

CMS BDT-based isolation working point

ATLAS muon isolation WPs

	$3 < p_T < 5$ GeV		$5 < p_T < 20$ GeV		$20 < p_T < 100$ GeV		$p_T > 100$ GeV	
Working point	ϵ_μ[%]	ϵ_{HF}[%]	ϵ_μ[%]	ϵ_{HF}[%]	ϵ_μ[%]	ϵ_{HF}[%]	ϵ_μ[%]	ϵ_{HF}[%]
Loose	63	14.3	86	7.2	97	6.1	99	12.7
Tight	53	11.9	70	4.2	89	1.0	98	1.6
PflowLoose	62	12.9	86	6.8	97	5.0	99	9.1
PflowTight	45	8.5	63	3.1	87	0.9	97	0.8
HighPtTrackOnly	92	35.9	92	17.2	92	4.5	92	0.6
TightTrackOnly	80	19.9	81	7.0	94	3.2	99	3.3
PLBDTLoose	81	17.4	83	5.1	93	1.3	98	1.7
PLBDTTight	57	9.6	69	2.7	87	0.5	98	1.7

Event generator setups and modelling uncertainties

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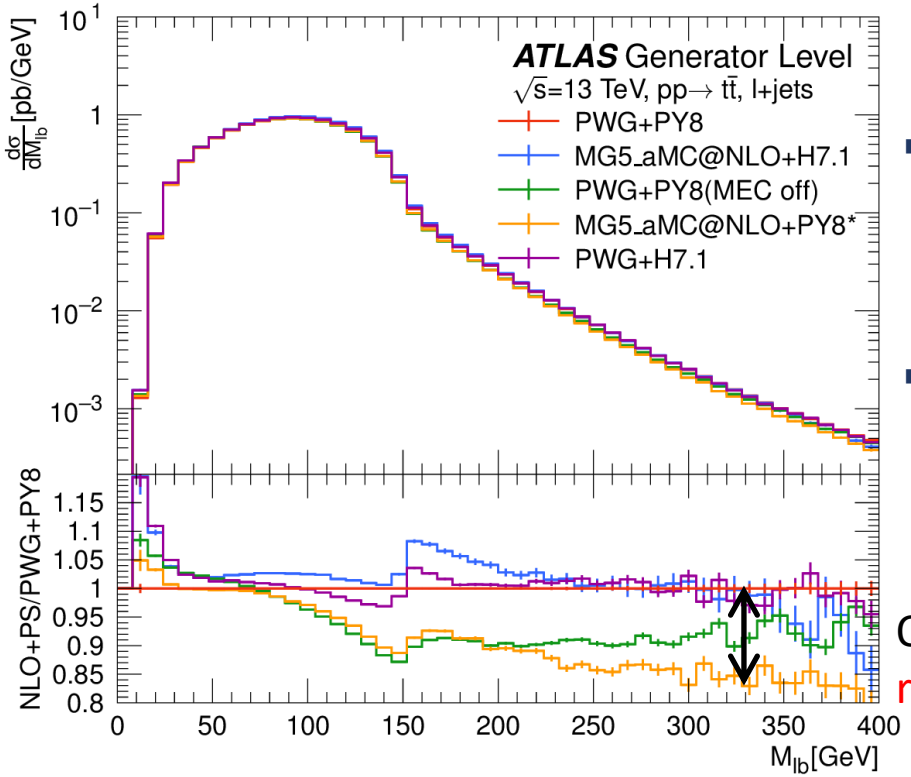
- Modelling of pp scattering process with Monte Carlo events is a limiting factor for a large number of measurements and searches in the top-quark sector.
- Work in two directions needed:
  - Improvement of generator setups
  - Adequate (= not conservative, but not too optimistic) assignment of modelling uncertainties
- ATLAS PMG group prepared two PUB notes for TOP2020.

- Study of top-quark pair modelling and uncertainties using ATLAS measurements at $\sqrt{s} = 13$ TeV, ATL-PHYS-PUB-2020-023.
- Presentation by Simone Amoroso.



- Example: MadGraph5_aMC@NLO versus Powheg comparison
- Original intention: Study algorithmic uncertainty in matching the NLO matrix element with the parton-shower program.
- Critical issue: Madgraph only works with Pythia if the matrix-element correction is turned off and global recoil is used for FSR emissions.

Original uncertainty estimate: red versus orange

Modelling of rare top-quark processes

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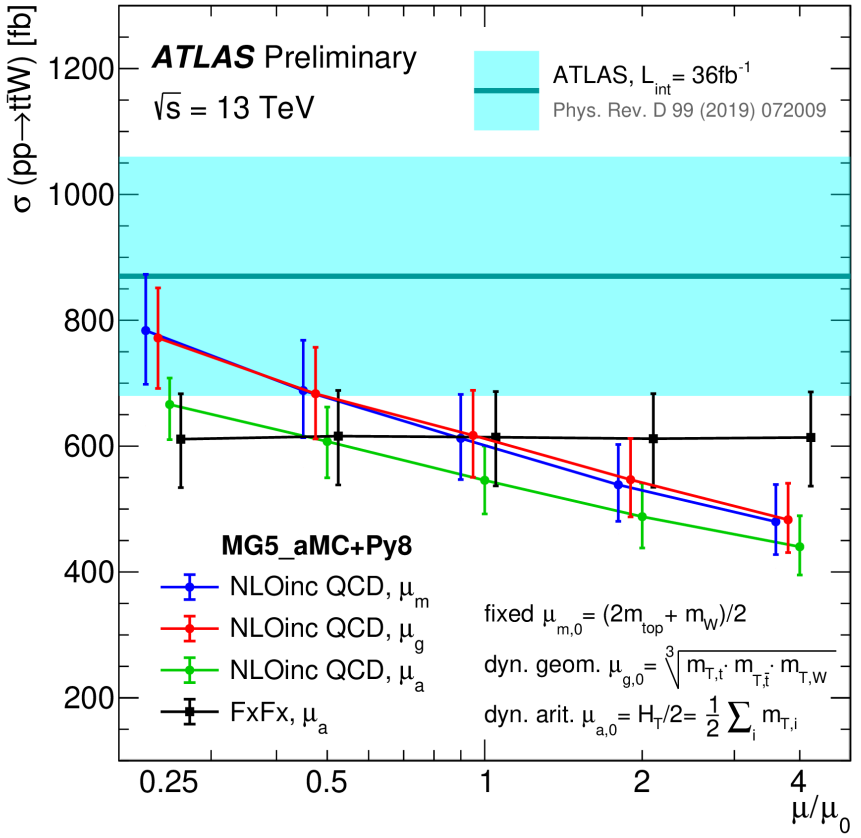
- Modelling of rare top-quark processes, ATL-PHYS-PUB-2020-024.
- Poster presented by Maria Moreno Llacer and Marcos Miralles Lopez on modelling of the $t\bar{t} + W$ process.
- Example:

Scale dependence of $\sigma(t\bar{t} + W)$

Disappears if MadGraph5_aMC@NLO is run with the FxFx option (NLO multileg merging)



Mass determination from differential cross-sections

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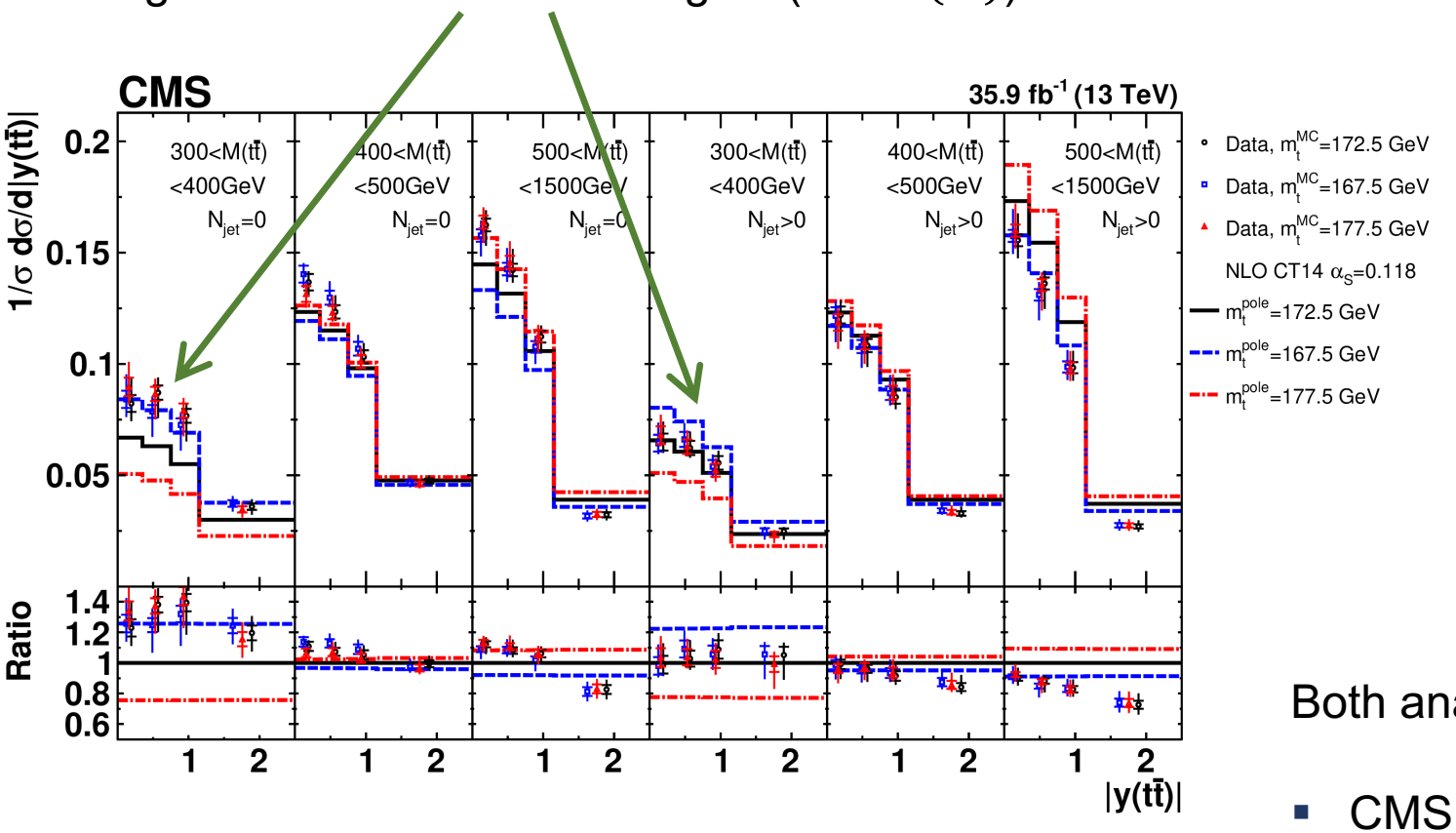
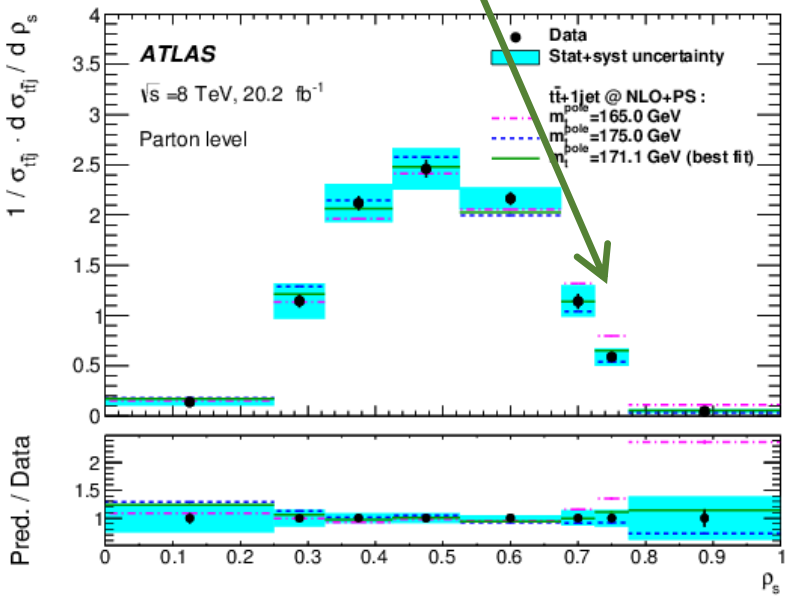
Measure top-quark pole mass from cross-section dependence.
Strong effect in the threshold region (low $m(t\bar{t})$)



- Not a new result: arXiv: 1904.05237 CMS-TOP-18-004 (10 April 2019)
- Measures also α_s and PDFs (3D diff. cross-section)
- Presentation by Matteo Defranchis at TOP2020

ATLAS measurement with $t\bar{t}$ + j events:
Sensitive to threshold region as well



Both analyses find relatively low values:

- CMS: $m_t = 170.5 \pm 0.8$ GeV/c^2
- ATLAS: $m_t = 171.1\ ^{+1.2}_{-1.1}$ GeV/c^2

compared to measurements from top-quark decay (resonance sensitive)

Importance of Coulomb corrections near threshold

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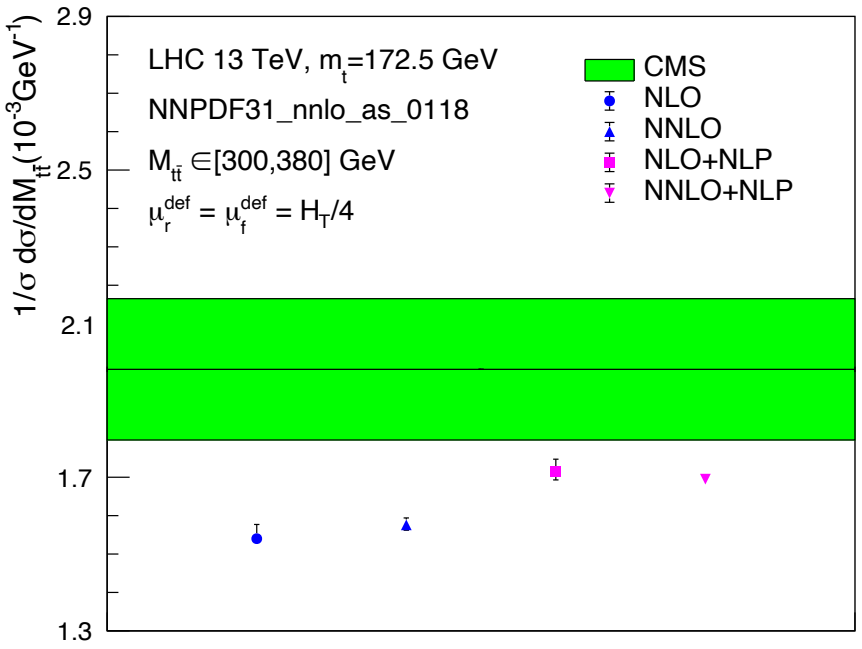
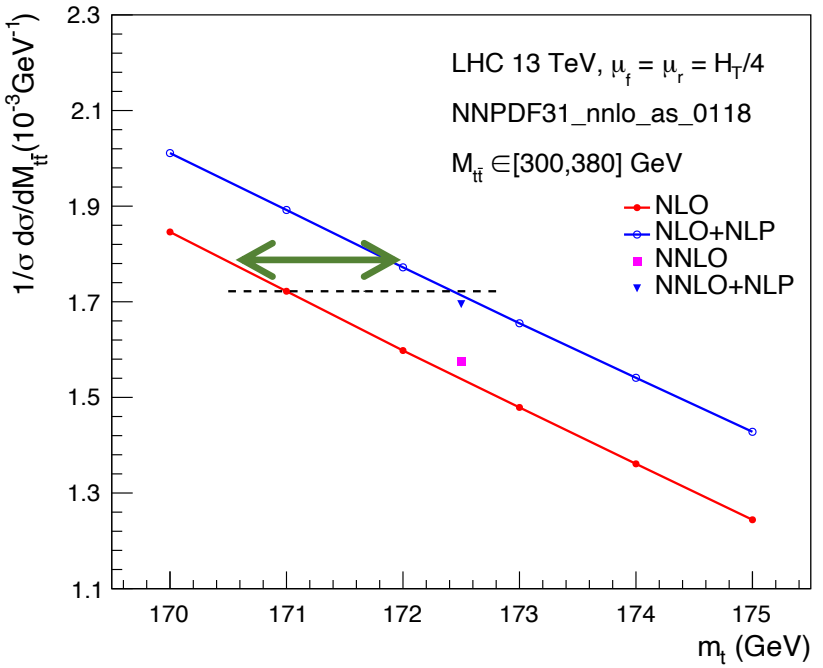
- Near the $t\bar{t}$ threshold ($m(t\bar{t}) \cong 350$ GeV$/c^2$) non-perturbative bound-state effects are relevant.
- Recent work by Li Lin Yang et al.: arXiv: 2004.03088, JHEP 06 (2020) 158. Presentation at TOP2020.
- Computed by resuming Coulomb corrections (NLP) to all orders in α_s in a basic EFT framework.
- Combined with NNLO fixed-order result.



The prediction for $m_t = 172.5$ GeV$/c^2$ moves towards the CMS measurements when including Coulomb corrections.



Including the Coulomb correction leads to a shift in m_t of about 1.4 GeV $/c^2$.
→ Better compatibility of mass measurements from production and decay

Determination of the top-quark Yukawa coupling Y_t

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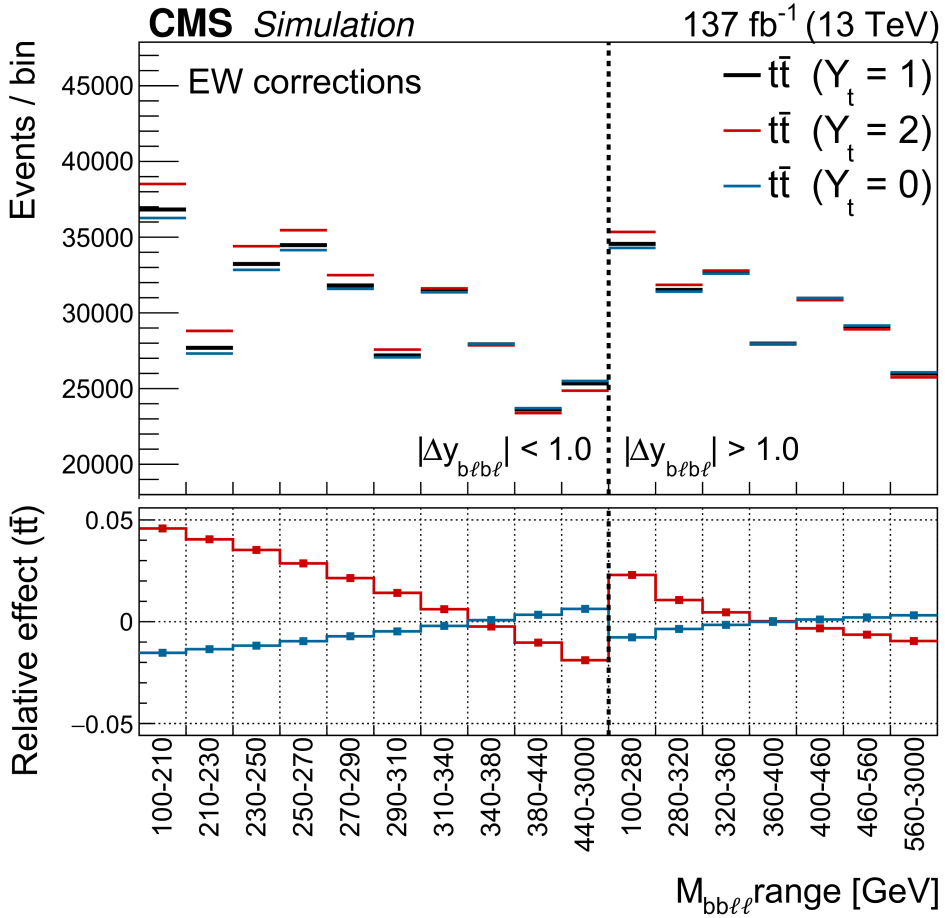
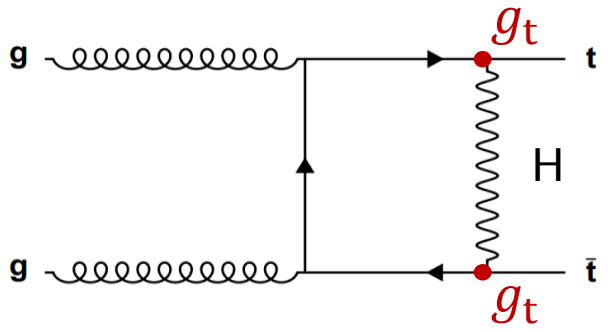
- Analyse same channel ($e\mu$ dilepton) and the variables: $m(t\bar{t}) \sim m(bb\ell\ell)$ and $\Delta y(t\bar{t}) = y(b\ell^+) - y(\bar{b}\ell^-)$.
- Use dependence of $\frac{d\sigma}{dm(bb\ell\ell)}$ and $\frac{d\sigma}{dy(bb\ell\ell)}$ on Y_t via a virtual Higgs exchange.
- arXiv: 2009.07123, CMS-TOP-19-008





- Detector-level profile-likelihood fit
- Result: $Y_t = 1.16^{+0.24}_{-0.35}$
- Improves on the result in the lepton+jets channel of last year ($Y_t = 1.07^{+0.34}_{-0.43}$)
- κ-framework: $Y_t = 0.98 \pm 0.14$
- YSF presentation by Evan Ranken.
- Interesting discussion: m_t uncertainty

Combined EFT fit in multi-lepton final states

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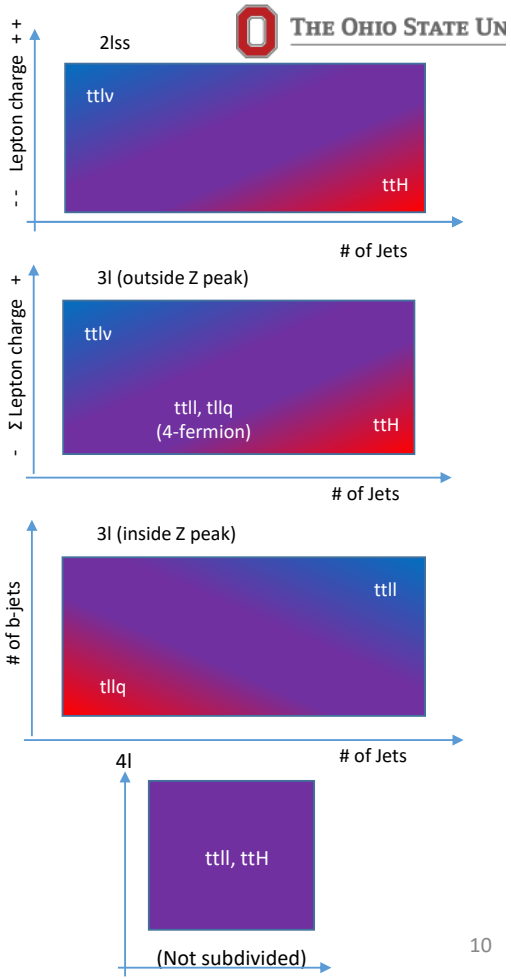
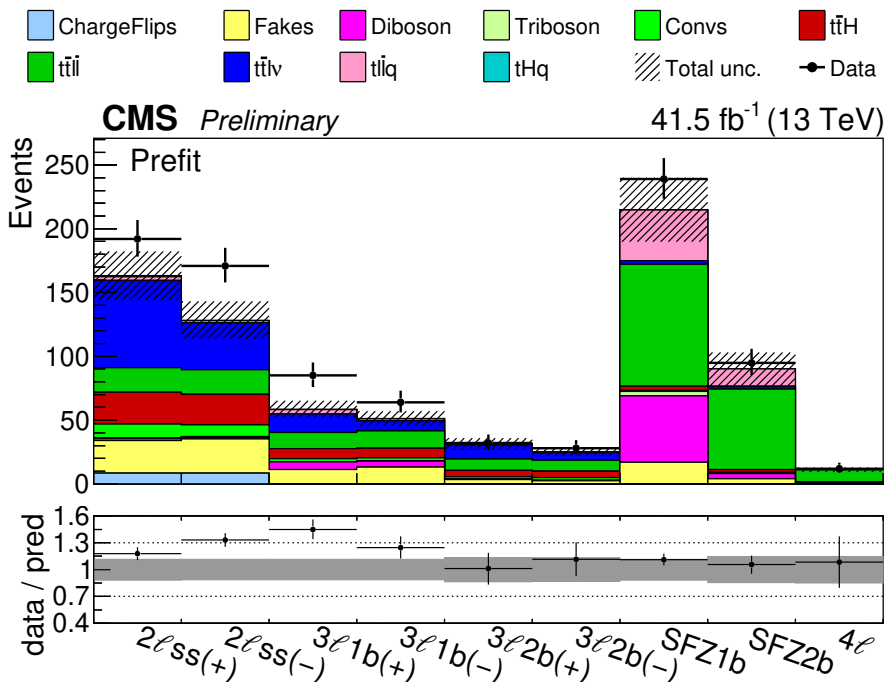
- Joker talk by Brent R. Yates.
- Analysis sensitive to $t\bar{t}+\ \ell\nu$, $t\bar{t}+H$, $t\bar{t}+\ \ell\ell$, $tq+\ell\ell$ final states.

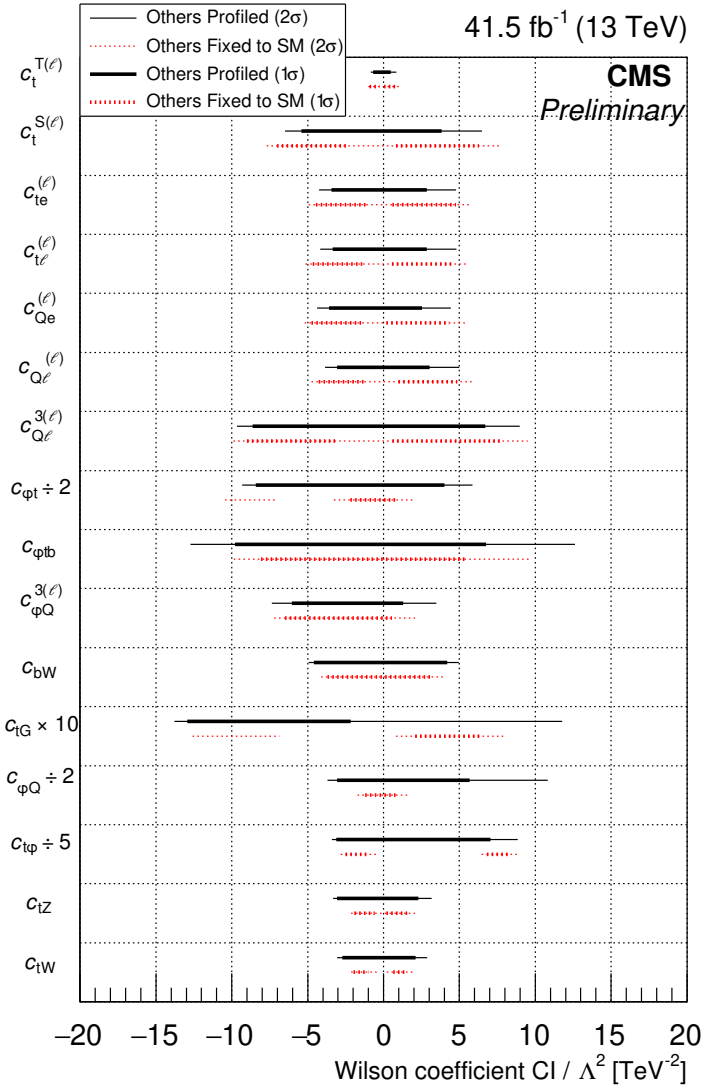




Aggregated view for display only. Fit is done in bins based on number of jets.

Discussion item: Can detector-level analyses be made accessible to others by publishing the likelihood?

CMS-PAS-TOP-19-001



Tackling b-quark fragmentation at LHC

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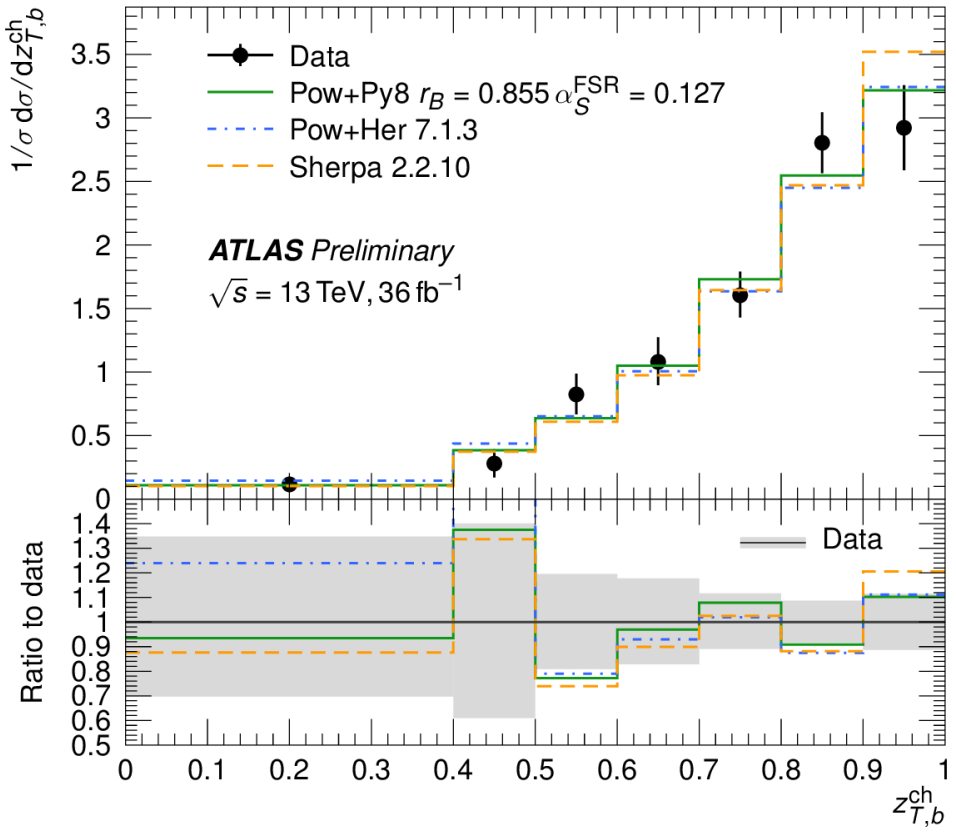
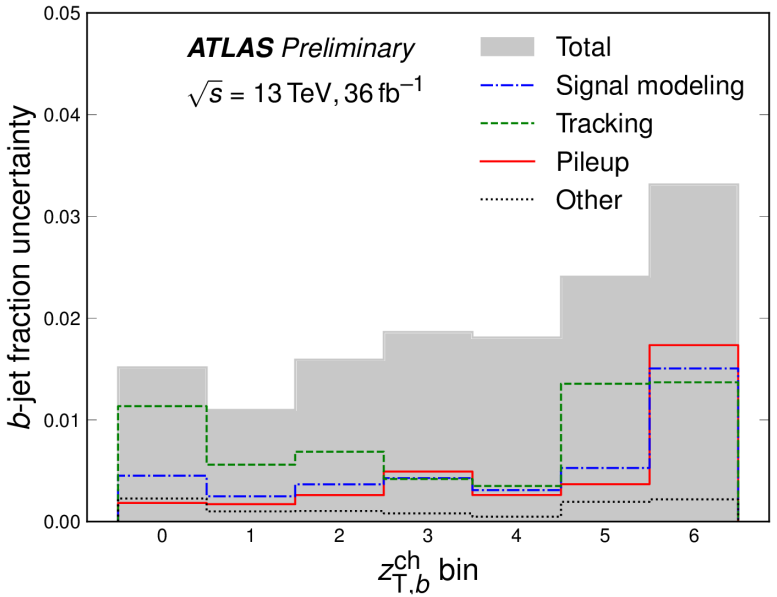
- New CONF-conversion for TOP2020: ATLAS-CONF-2020-050
  Measurements of b-jet moments sensitive to b-fragmentation in $t\bar{t}$ events at the LHC with the ATLAS detector
- Another example for “Top quarks as a tool”
- Understanding b-fragmentation is important to progress on top-quark mass measurements



Default generator setup Powheg+Pythia8 does well.



Presented at TOP2020 by Juan Gonzalez (CMS) in a dedicated talk.

Computing b-meson kinematic properties in $t\bar{t}$ production

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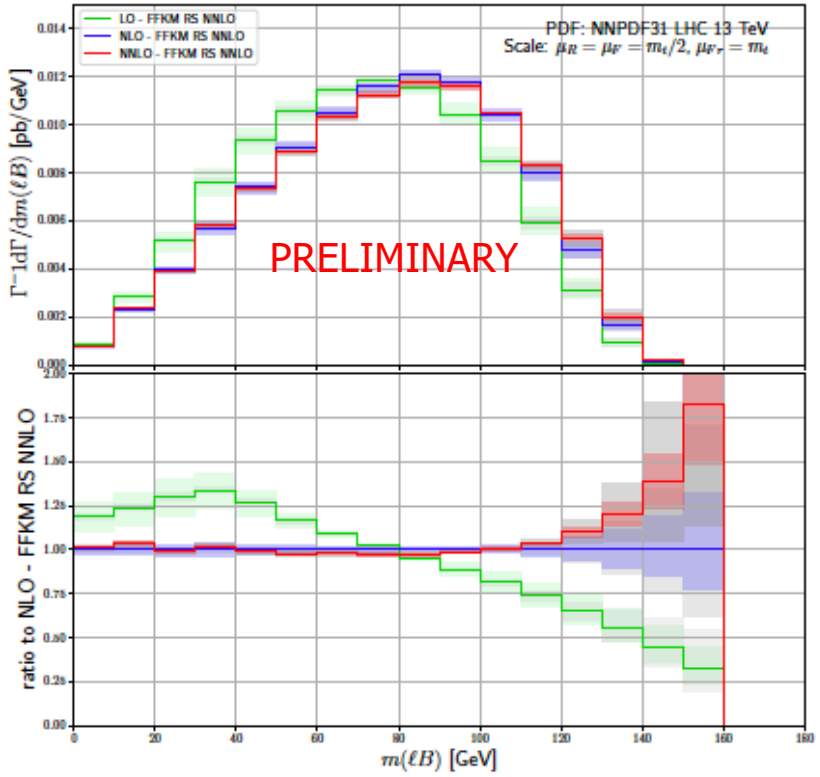
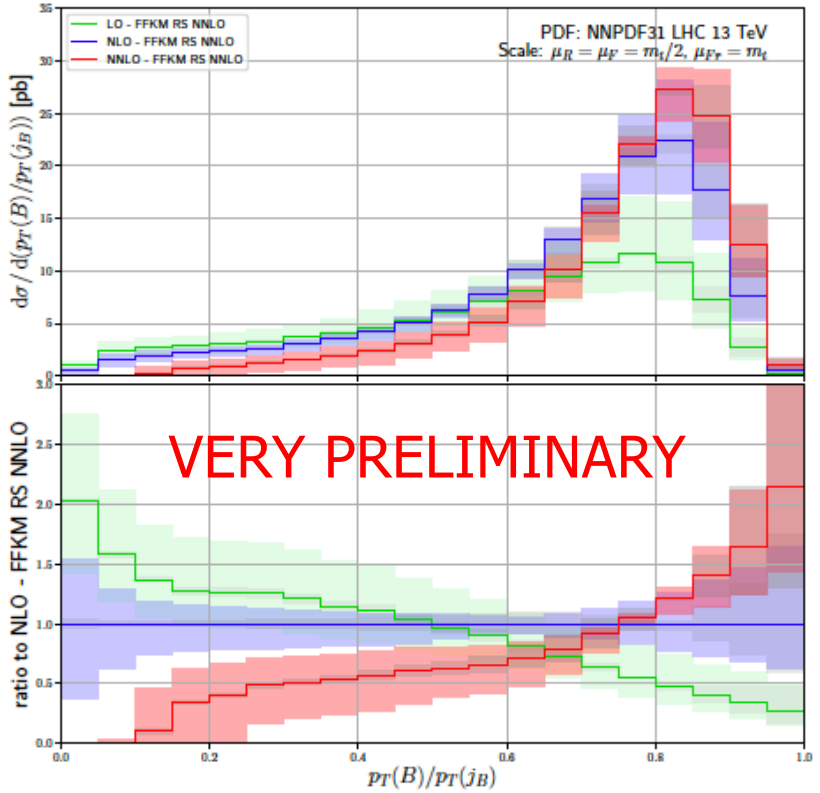
- Presentation by Alexander Mitov.
- Based on the Perturbative Fragmentation Function approach.
- Allows for predictions of interesting observables in top-quark physics:



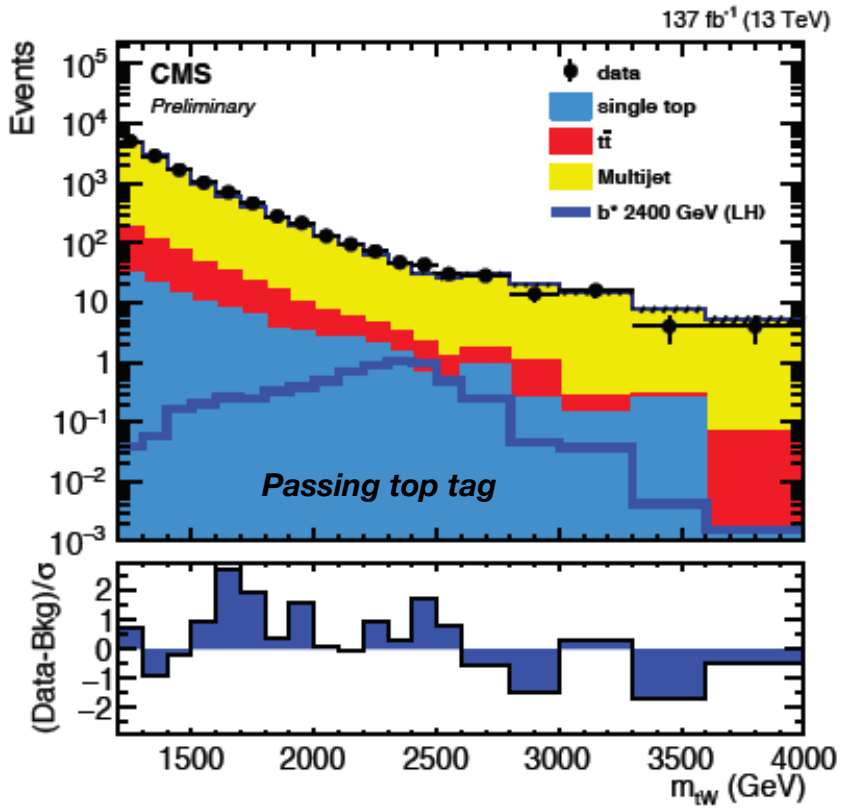
Relevant to determine the top-quark mass.

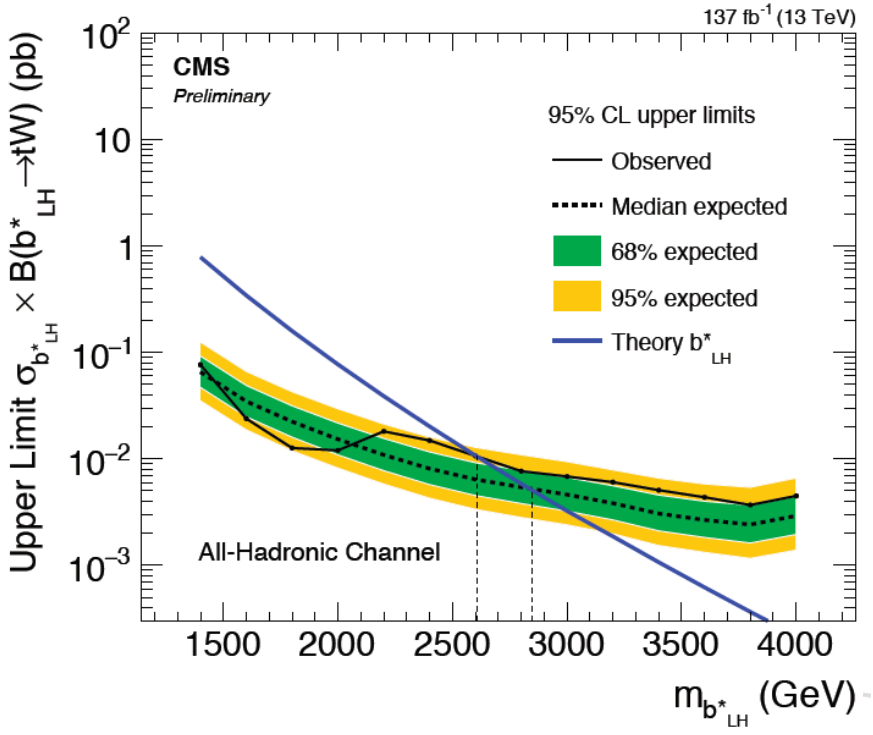


Potential to extract fragmentation function from ATLAS (CMS) data.

Search for $b^* \rightarrow tW$ production

- Require a boosted top-quark and a boosted W boson, both reconstructed as collimated jets (all-hadronic channel).





Mass limits:

2.6 TeV (left-handed b*)

2.8 TeV (right-handed b*)

3.0 TeV (vector-like chirality)

Summary

- TOP2020 was a successful online conference.
- Many interesting and useful discussions.
- Of course, not the same as an event where people are present in person.
- ATLAS showed
  - 5 new analyses with the full Run 2 data set published / submitted this year.
  - 2 new results based on a partial Run 2 data set (36 fb^{-1})
  - 2 new Run 1 results