24th LHC*top*WG Open Meeting

November 29 - December 1, 2023

Virtual Edition

Welcome to the second open session of 2023!

Introduction

Fabio Maltoni (Louvain/Bologna)
Wolfgang Wagner (Wuppertal)
Maria Aldaya (DESY)

LHC*top*WG and its mission

Forum for discussions between experiment and theory on combination and interpretation of top physics measurements at the LHC – since 2012

- Provide combinations of LHC top physics results
  - Reach highest precision and provide a unified experimental answer to the theory community
  - Compare results in a coherent way and understand possible differences

  ⇒ Requires detailed understanding of analysis methodologies, theoretical models used, categories of systematic uncertainties & correlations
- Provide recommendations and guidelines
  - Reference cross sections as common basis for measurements
  - Harmonize prescriptions to facilitate comparisons and combinations
- Provide summary plots of experimental results in comparison to theory predictions
- Ample discussion between experimental and theory communities
  - Open Meetings twice a year and on-demand seminars
  - Monthly closed meetings (conveners + contacts + invited experts on specific topics) to discuss experimental details

Documentation and coordinates

- Integrated in the LPCC structure at CERN: http://lpcc.web.cern.ch/lhc-working-groups
- Public twiki: https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCTopWG
- Public summary plots: https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCTopWGSummaryPlots
- Agendas: https://indico.cern.ch/categoryDisplay.py?categId=4463
- Main open mailing list: lhc-toplhcwg@cern.ch **Subscribe**

LHCtopWG contacts

- **Theory:** Fabio Maltoni
- **ATLAS:** Wolfgang Wagner
- **CMS:** Maria Aldaya
- **LHCb:** Katharina Mueller

Contacts for ongoing combinations / working groups:

- **Top mass:** Mark Owen (ATLAS), Martijn Mulders & Matteo Defranchis (CMS)
- **EFT:** Baptiste Ravina (ATLAS), Kirill Skovpen (CMS)
- **Common MC:** Michael Fenton, Dominic Hirschbühl, & Reinhard Schwienhorst (ATLAS), Giulia Negro, Markus Seidel, & Andris Potrebko (CMS)
- **$\Delta\varphi(ll)$ spin correlation:** Miriam Watson & James Howarth (ATLAS), Andy Jung, Giulia Negro & Afiq Anuar (CMS)
- **Harmonization of modelling uncertainties:** Andrea Knue & Dominic Hirschbühl (ATLAS), Efe Yazgan & Enrique Palencia (CMS)
- **Global EFT effort within the LHC EFT WG** (https://lpcc.web.cern.ch/lhc-eft-wg): Jacob Kempster (ATLAS), Robert Schoefbeck (CMS), Ken Mimasu (Theory)

Also contacts for dedicated topics as needed

(summary plots, theoretical calculations, JES, b-tagging, generators, etc)

Ongoing combinations and other efforts

- **Published** **"Run-1 Legacy"** tt inclusive cross section at 7 & 8 TeV + extraction top pole mass and α_s (Veronique Boisvert (ATLAS), Jan Kieseler (CMS)):
  JHEP 07 (2023) 213, arXiv:2205.13830 [hep-ex] New
- **"Run-1 legacy" top mass combination:** preliminary result released for **TOP2023,** New paper in final stages of review before submission – next slide

- Ongoing combinations under review within the collaborations:
  - **EFT combination at 13 TeV** – update today!
  - **Δφ(ll) spin correlation combination at 13 TeV**: finalizing writing the documentation

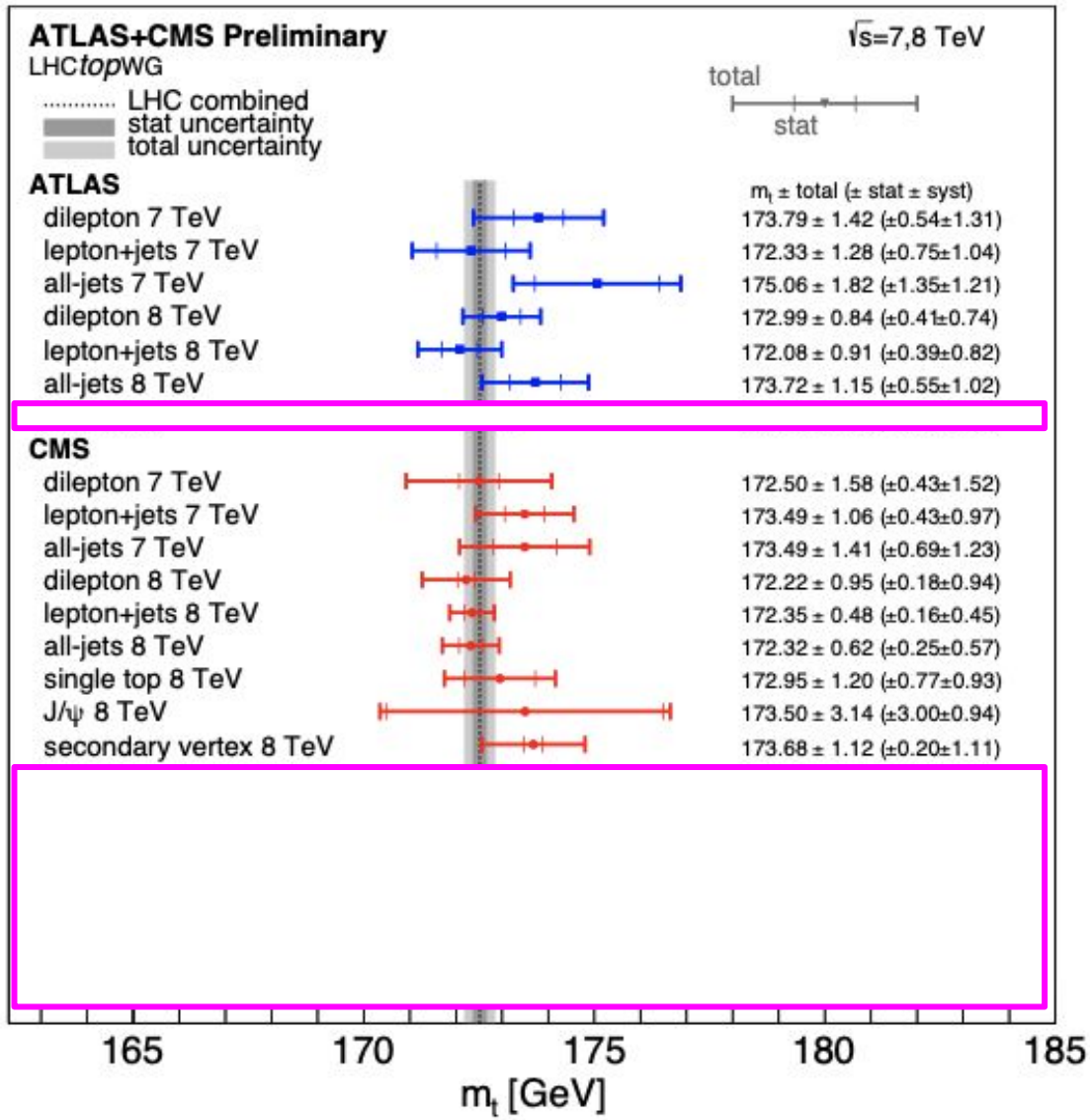
- Other efforts for upcoming Run-2 & Run-3 combinations and comparisons
  - **Common tt MC settings for ATLAS and CMS:** latest studies from June 2023 (CMS, ATLAS)
  - **Harmonization of systematic uncertainties**: started with ME and PS sources in tt
  - **Updating theory reference cross sections**: started with single top and tt, other processes soon to follow

LHC Run-1 top quark mass combination

CMS-PAS-TOP-22-001, ATLAS-CONF-2023-066, CERN-LPCC-2023-02

Mark Owen (ATLAS); Steve Wimpenny †, Martijn Mulders & Matteo Defranchis (CMS)

- BLUE combination of 15 input top mass measurements from “top quark decays”
- from ATLAS and CMS
  - Profit from most precise results and those with different sensitivity to systematics
- Detailed mapping of systematic uncertainties (25 categories!) and assumed correlations
  - Both intra- and inter-experiment
- Extensive stability checks to test effect of correlation assumptions



LHC Run-1 top quark mass combination

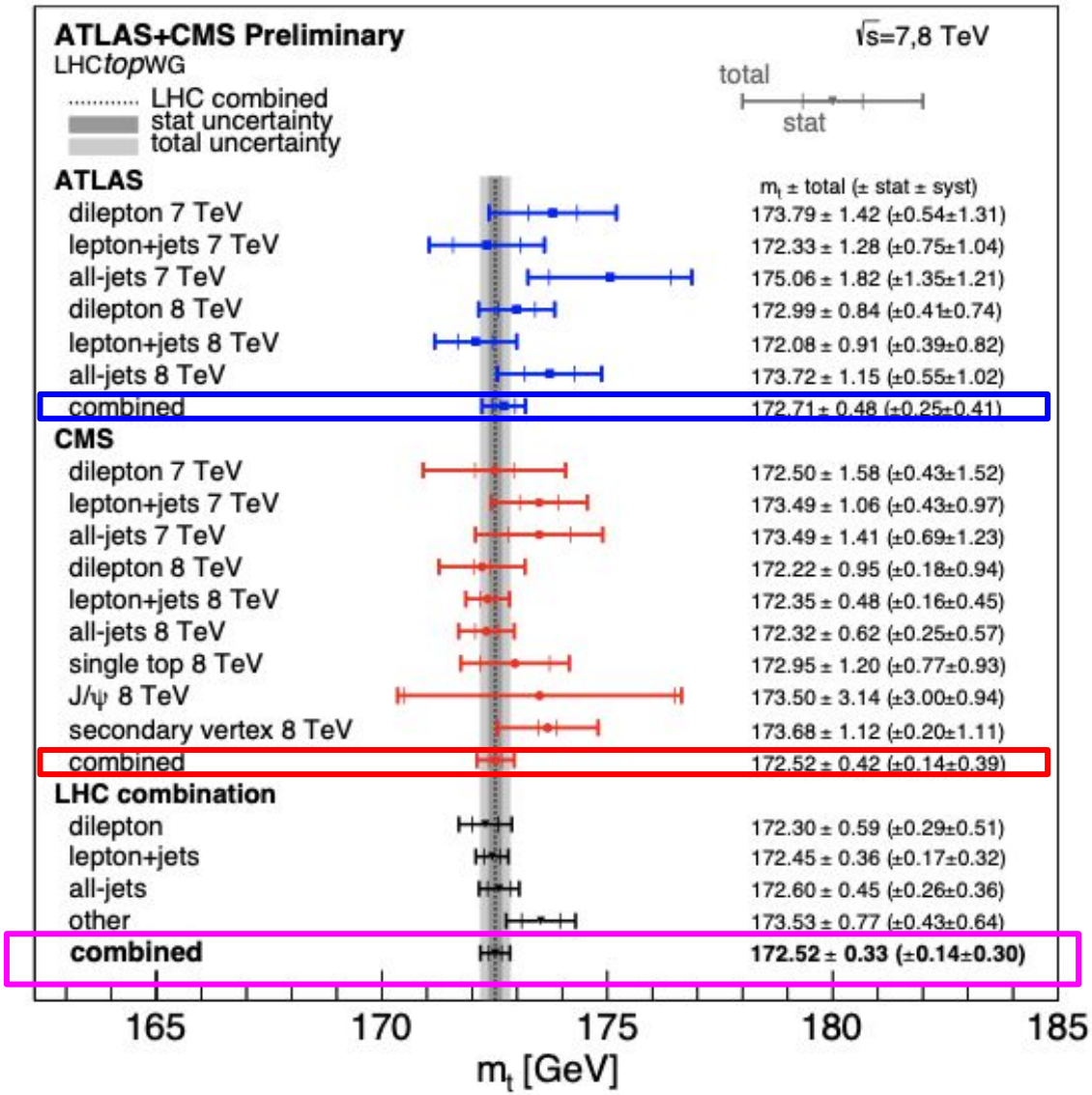
Mark Owen (ATLAS); Steve Wimpenny †,
Martijn Mulders & Matteo Defranchis (CMS)

CMS-PAS-TOP-22-001, ATLAS-CONF-2023-066, CERN-LPCC-2023-02

- Combination:

$$m_t = 172.52 \pm 0.14\,(\text{stat}) \pm 0.30\,(\text{syst})\ \text{GeV}$$

- Total uncertainty of 0.33 GeV
  - Most precise result to-date
- 30% improvement over most precise individual result
- Excellent compatibility among inputs
- Limited sensitivity to correlation assumptions
- Main systematics: JES, b-tagging, top modelling



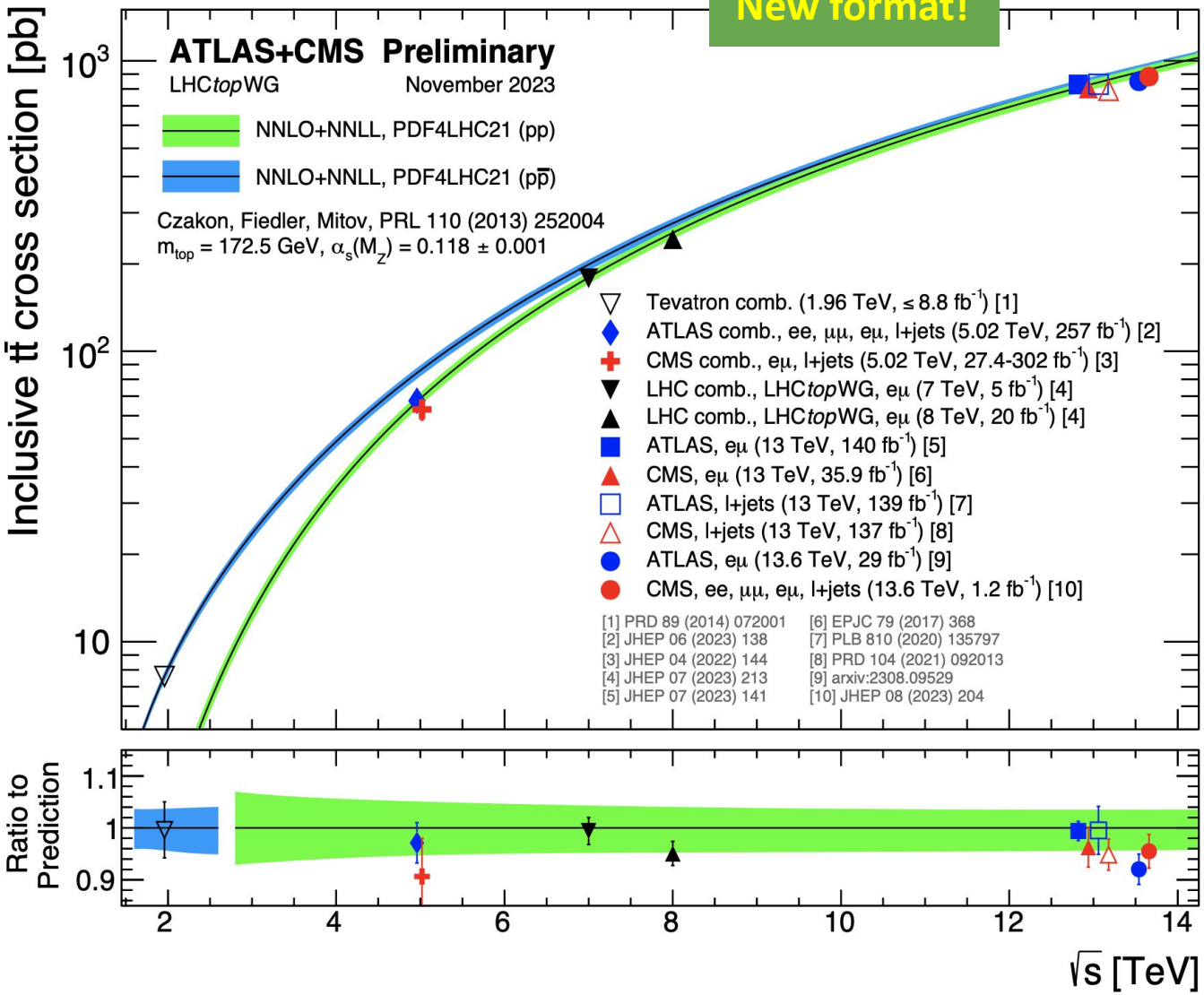
Summary plots

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCTopWGSummaryPlots (*)

Newly added/updated results & predictions since last Open Meeting and other updates – more than 30 plots, showcasing some examples only(**):

tt cross sections vs sqrt(s)

New format!

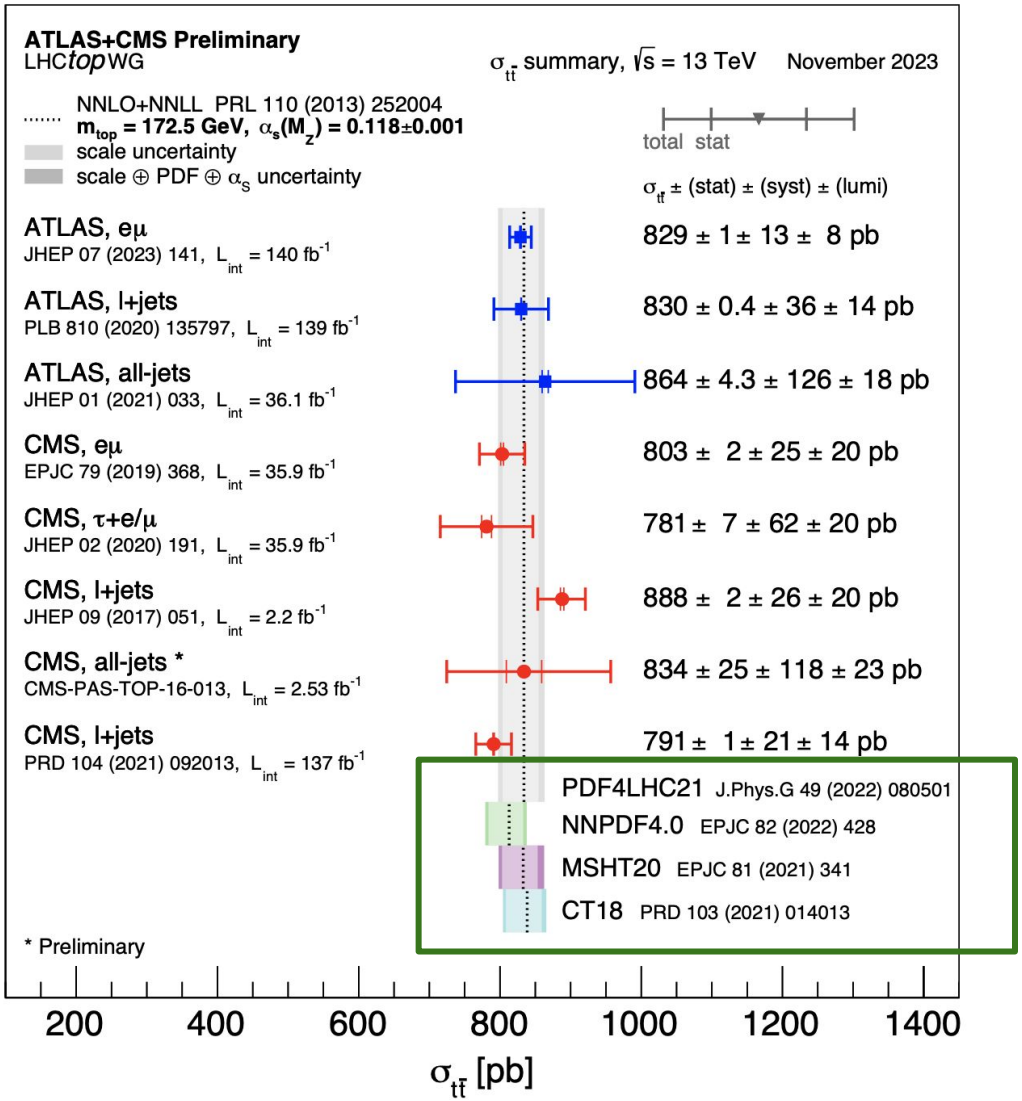


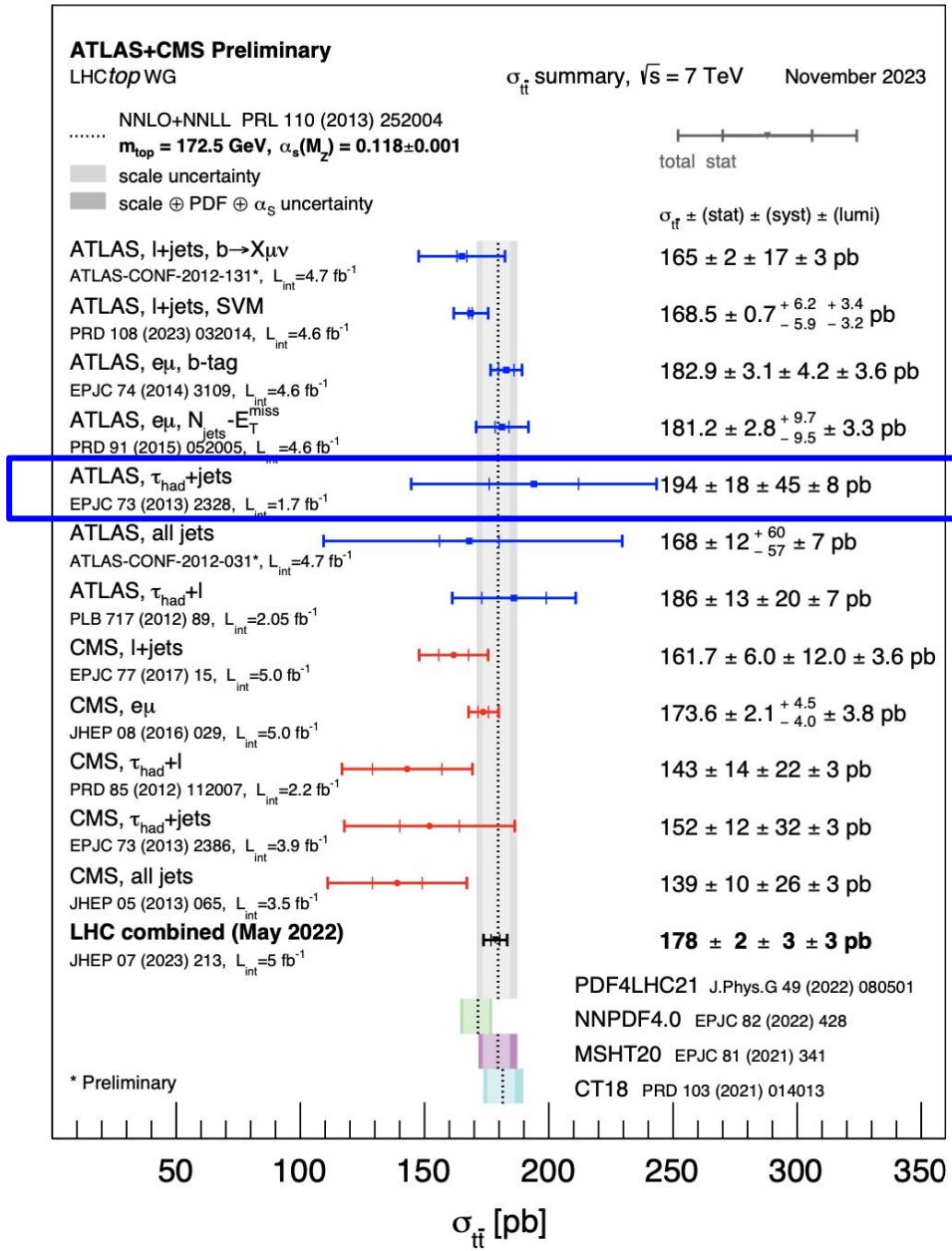
- Improved overall readability:
  - added ratio-to-predictions panel
  - removed inset for 13 and 13.6 TeV
- Added references for all results
- Updated PDF set for ppbar theory prediction

(*) All updated plots will be added to the twiki shortly

(**) FCNC plots in Daniel's talk today
Top EFT limit plots in Kirill's talk today

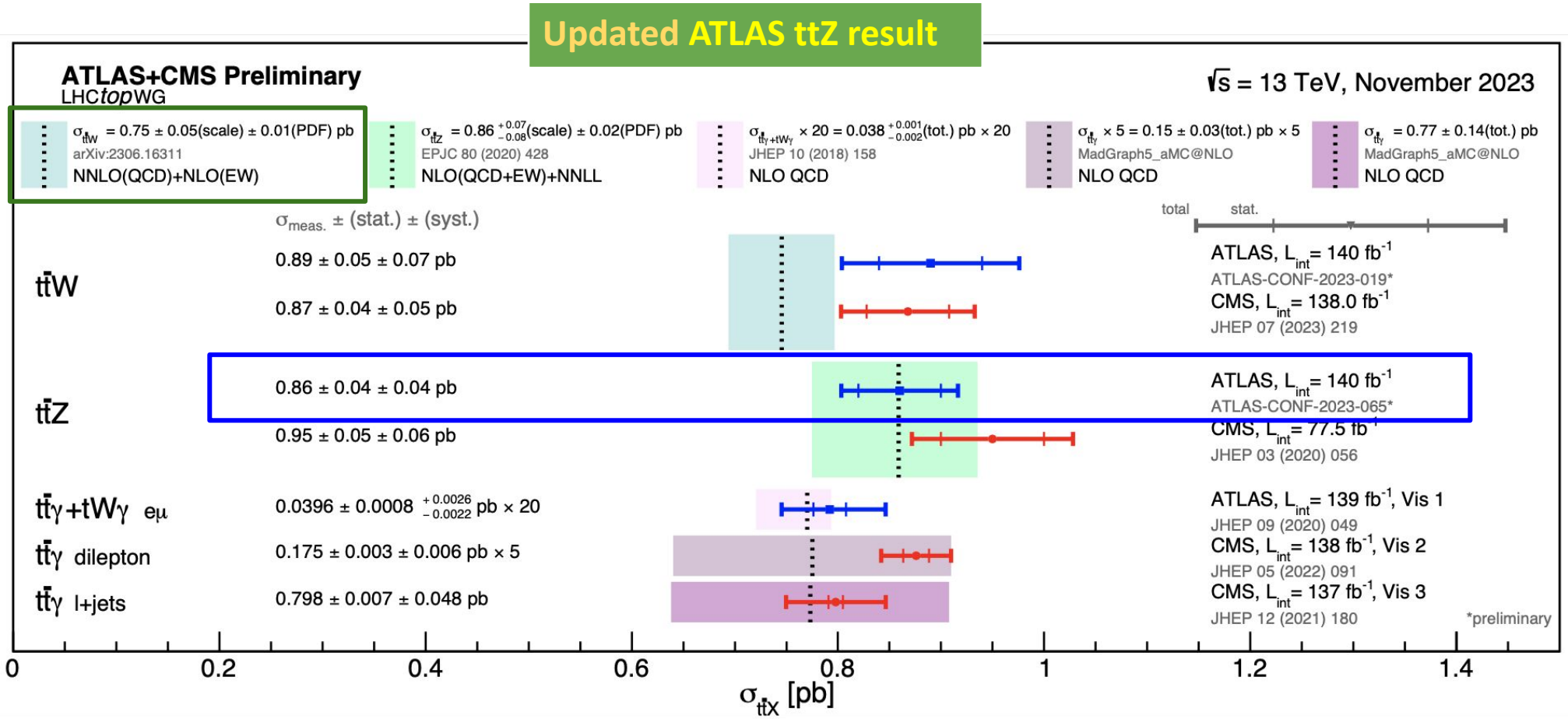
tt cross sections





- Added comparison to theory predictions using various recent PDF sets
- Updated references, sync'ed format for presenting results where possible
- Similar updates also for plots at 8 and 5.02 TeV

ttX

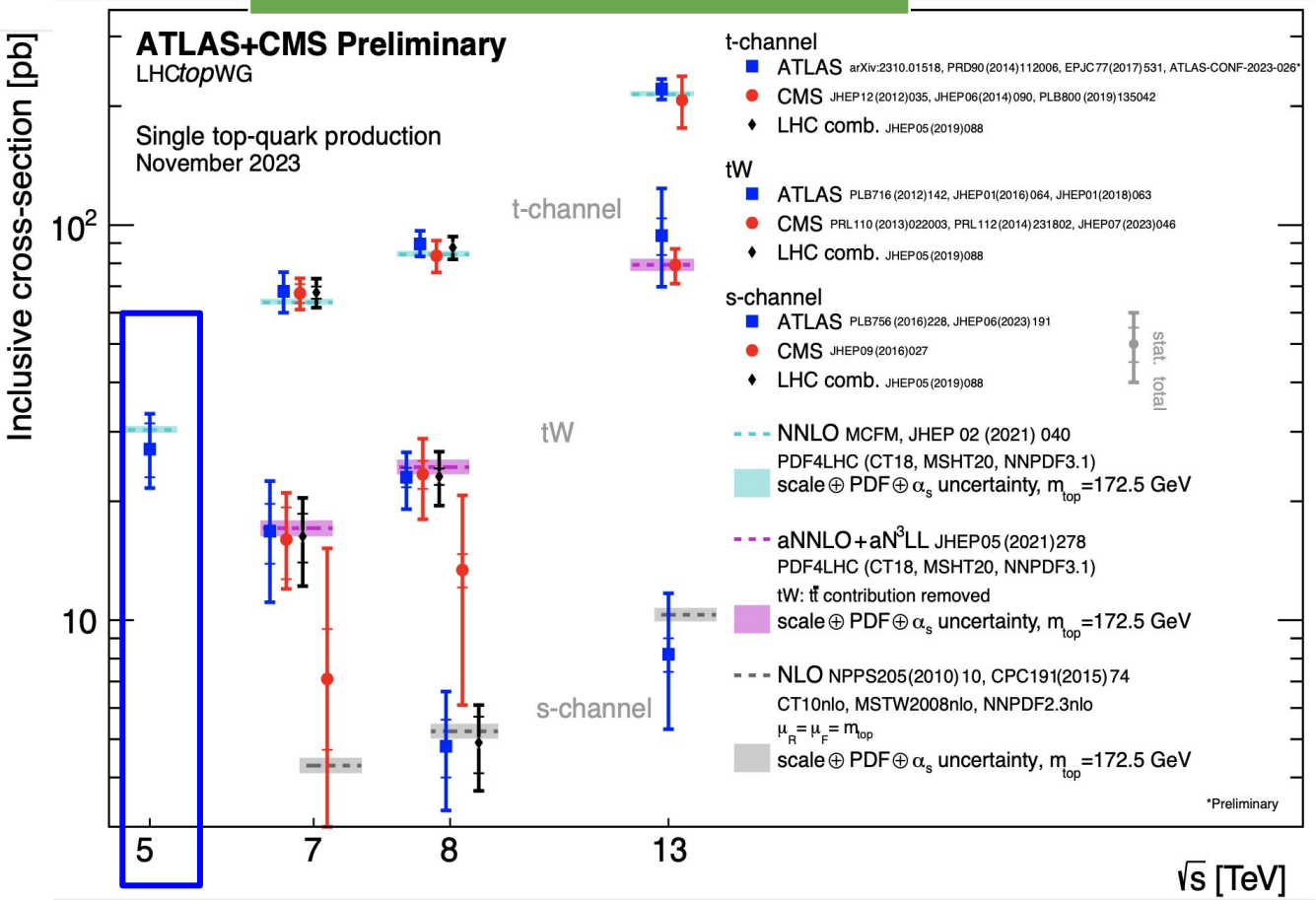


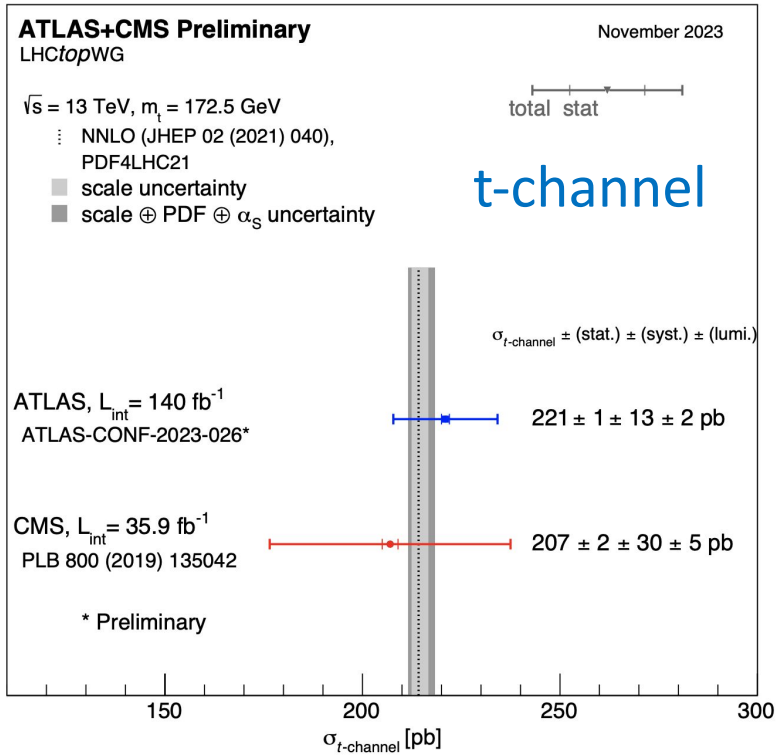
- Updated ttW theory prediction to the latest NNLO (QCD) + NLO (EW) from [arXiv:2306.16311 [hep-ph]]
- Updated references

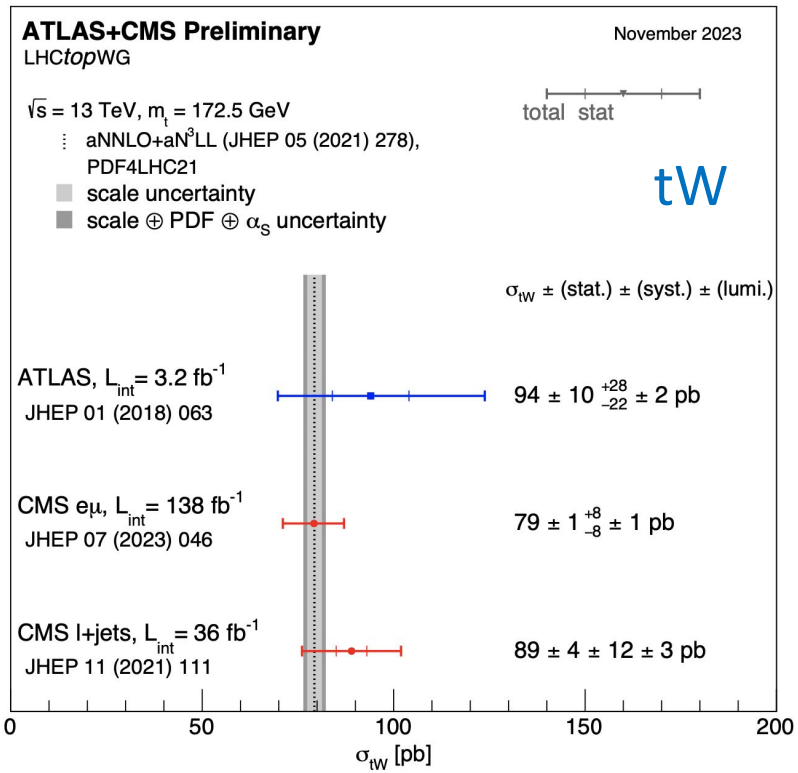
Single top production

All channels and sqrt(s)

Added ATLAS t-chan. at 5 TeV

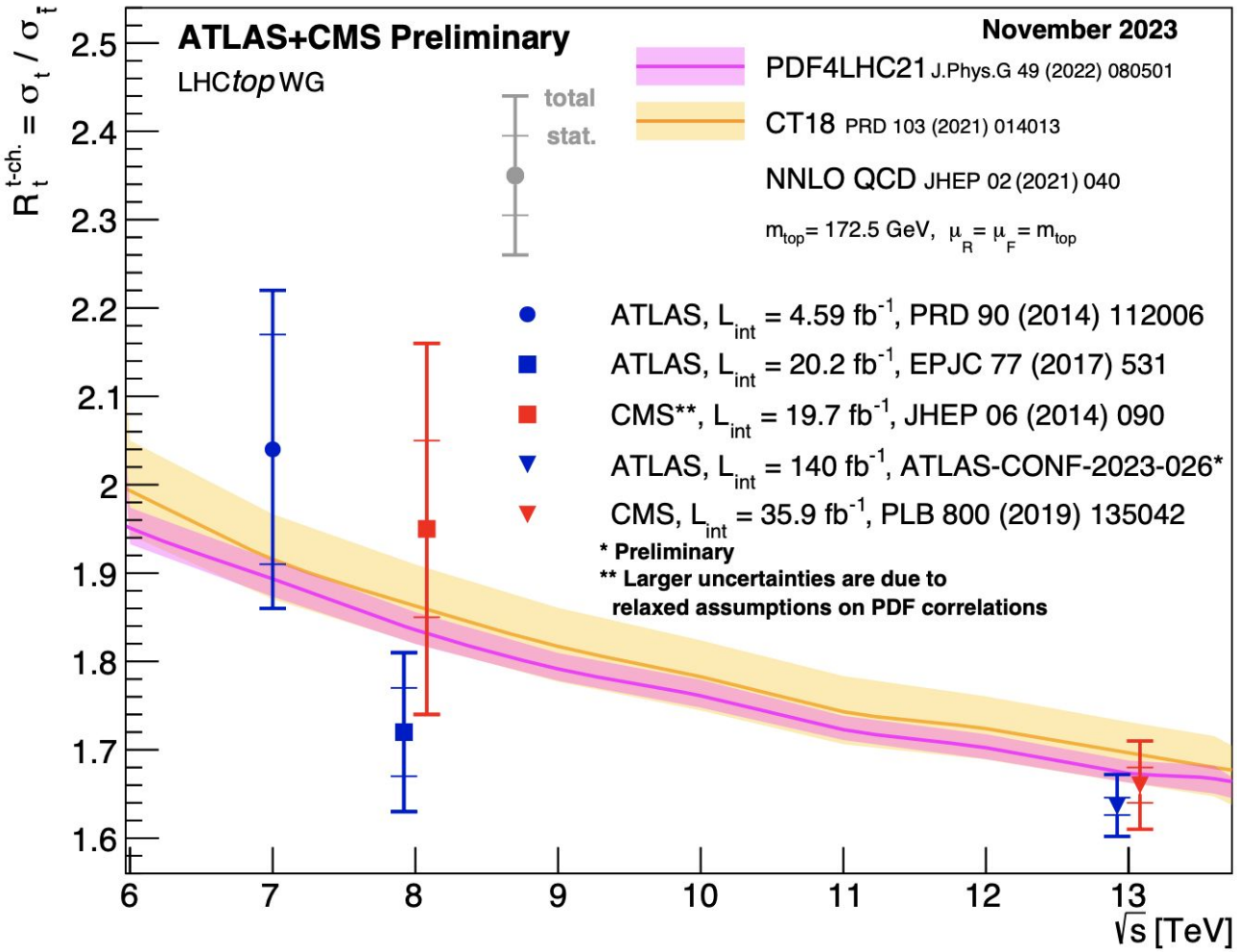


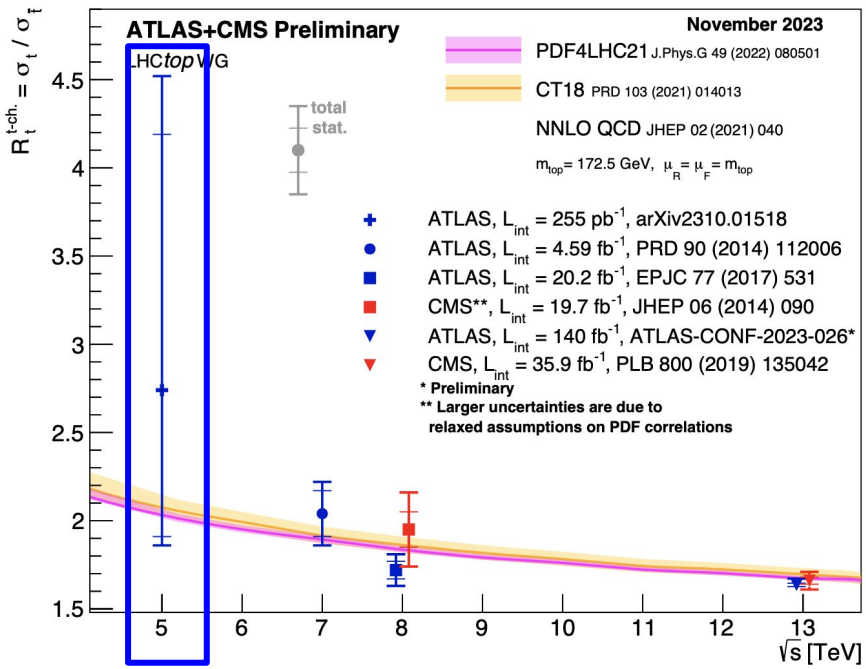




- Updated t-channel predictions using PDF4LHC21
- Updated references, sync'ed style across channels
- Similar updates for plots at all energies

Rt: ratio of σ(top) to σ(antitop)



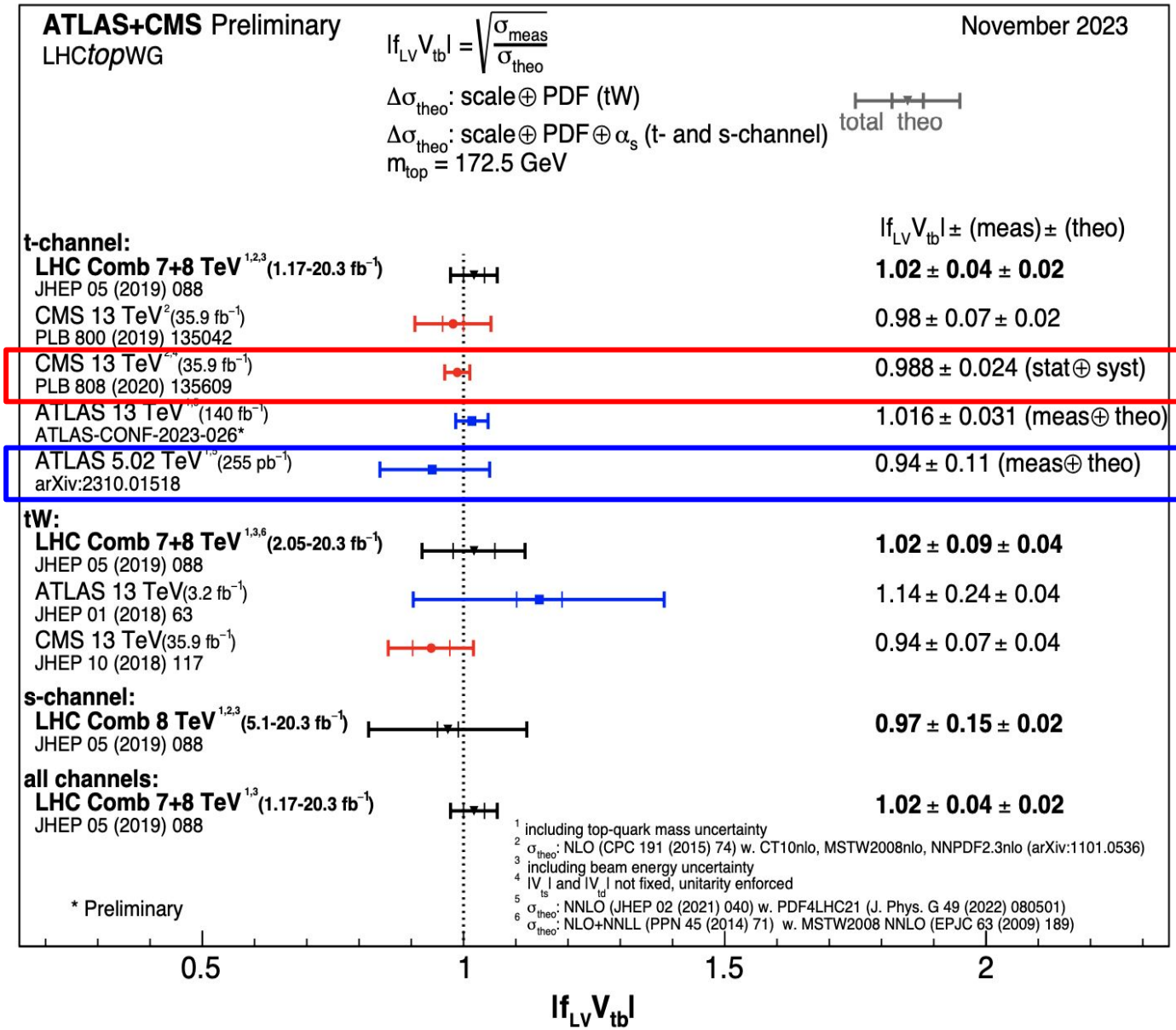


- Updated theory predictions from NLO to NNLO
- Used newer PDF sets in the predictions
- Updated references

- Same plot, including the latest ATLAS result at 5 TeV, also available

Vtb

Added CMS t-chan. at 13 TeV
Added ATLAS t-chan. at 5 TeV

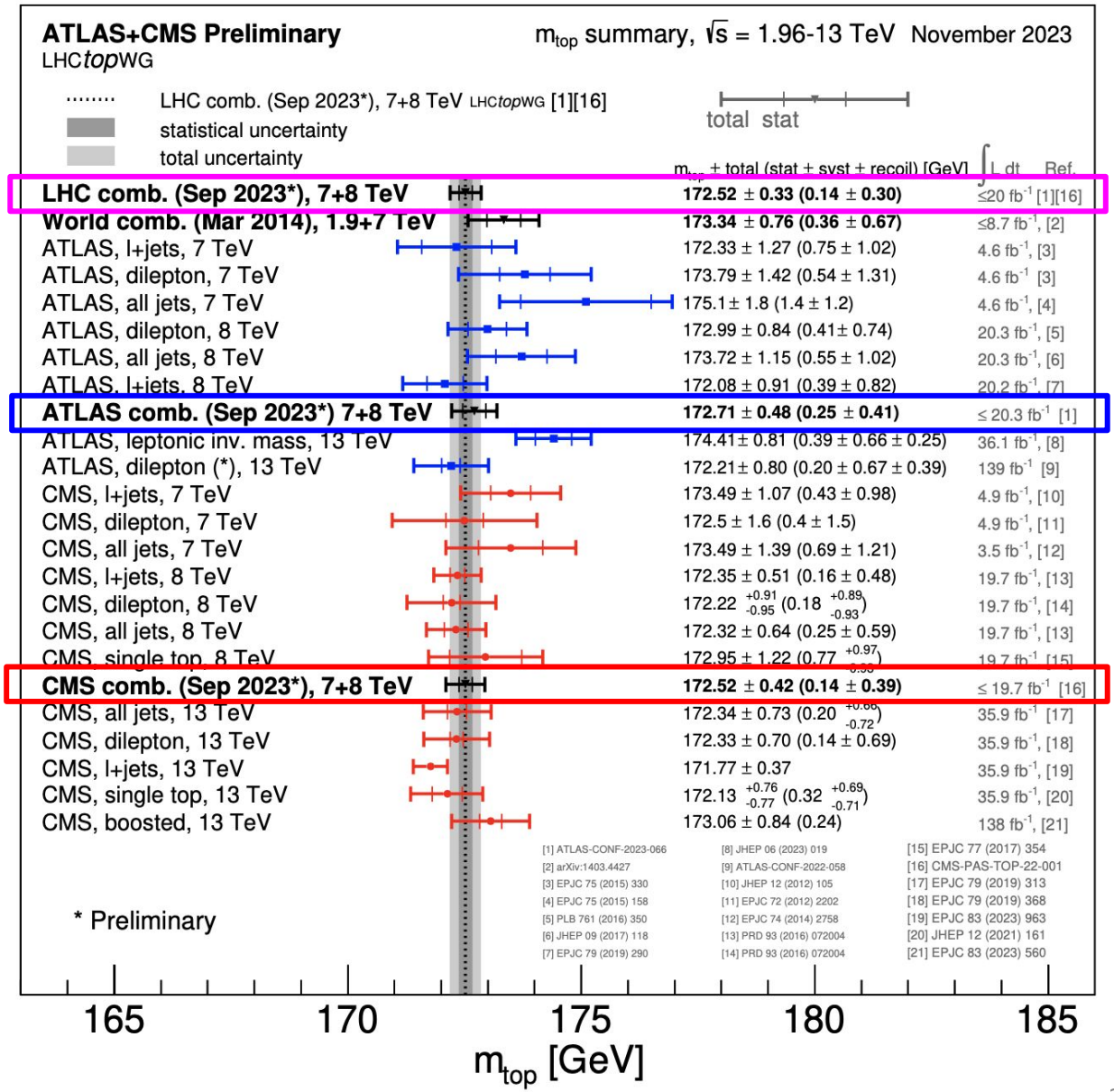


- Updated results as reported in the corresponding publications
- Updated references

Top mass

Top mass from decay

Added new CMS 7+8 TeV combination
Added new ATLAS 7+8 TeV combination
Added new LHC 7+8 TeV combination



- Removed all Run-1 results that did not enter the new LHC 7+8 TeV combination
- Added new LHC combination as reference (dotted line and grey bands)
- Updated results as reported in the corresponding publications
- Updated references

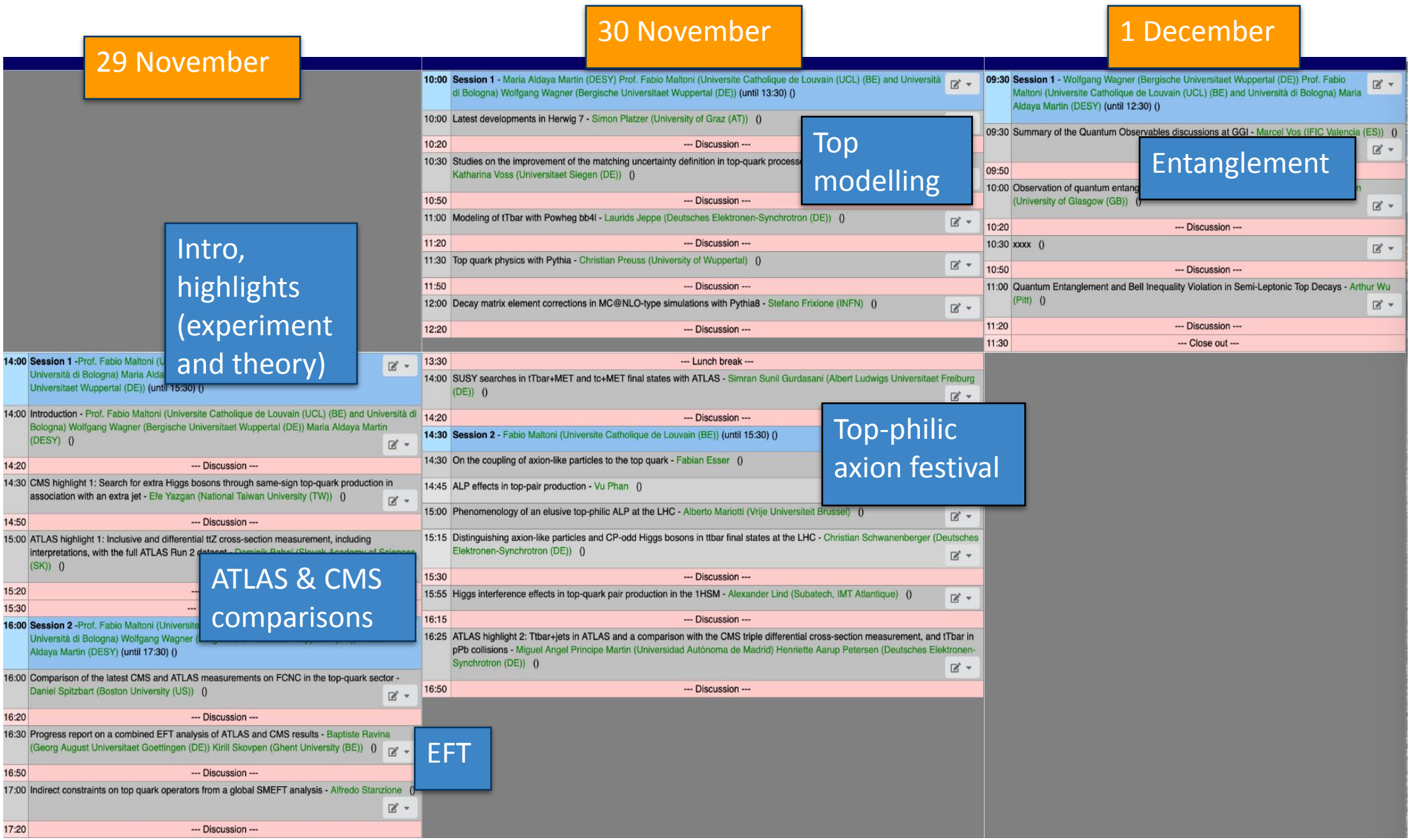
Next Open Meeting

- Planned for May/June 2024
  - In-person, with the usual zoom connection
  - Sessions will be recorded and uploaded on the agenda after the meeting

- Current scheme: one in-person and one virtual Open Meeting per year
  - Please let us know if you prefer both in-person

- Your feedback is important –let us know if you have suggestions for improving the meetings!

This week's agenda



Additional information

LHC Run-1 top quark mass combination

LHC top WG

[CMS-PAS-TOP-22-001](), [ATLAS-CONF-2023-066](), CERN-LPCC-2023-02

Mark Owen (ATLAS); Steve Wimpenny †, Martijn Mulders & Matteo Defranchis (CMS)

Systematic correlations

Statistical and other uncorrelated components of JES

Light flavour uncertainties approach different for ATLAS and CMS

Correlation from reliance on MC for flavour composition in the tt calibration samples

Uncertainty category	ρ	Scan range	$\Delta m_t/2$ [MeV]	$\Delta\sigma_{m_t}/2$ [MeV]
LHC JES 1	0	—	—	—
LHC JES 2	0	[−0.25, +0.25]	8	7
LHC JES 3	0.5	[+0.25, +0.75]	1	<1
LHC b-JES	0.85	[+0.5, +1]	26	5
LHC g-JES	0.85	[+0.5, +1]	2	<1
LHC l-JES	0	[−0.25, +0.25]	1	<1
CMS JES 1	—	—	—	—
JER	0	[−0.25, +0.25]	5	1
Leptons	0	[−0.25, +0.25]	2	2
b tagging	0.5	[+0.25, +0.75]	1	1
p_T^{miss}	0	[−0.25, +0.25]	<1	<1
Pileup	0.85	[+0.5, +1]	2	<1
Trigger	0	[−0.25, +0.25]	<1	<1
ME generator	0.5	[+0.25, +0.75]	<1	4
LHC radiation	0.5	[+0.25, +0.75]	7	1
LHC hadronization	0.5	[+0.25, +0.75]	1	<1
CMS B hadron BR	—	—	—	—
Color reconnection	0.5	[+0.25, +0.75]	3	1
Underlying event	0.5	[+0.25, +0.75]	1	<1
PDF	0.85	[+0.5, +1]	1	<1
Top quark p_T	—	—	—	—
Background (data)	0	[−0.25, +0.25]	8	2
Background (MC)	0.85	[+0.5, +1]	2	<1
Method	0	—	—	—
Other	0	—	—	—

ATLAS EXPERIMENT

CMS

Different JES calibrations, but sensitive to same MC modelling of radiation

similar MC comparisons (Pythia v Herwig)

No large changes in central value.

C. Nellist | Top Mass Combination | TOP2023 | 26/09/2023

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Slide from C. Nellist at [TOP2023]()

LHC Run-1 top quark mass combination

[CMS-PAS-TOP-22-001](), [ATLAS-CONF-2023-066](), CERN-LPCC-2023-02

Mark Owen (ATLAS); Steve Wimpenny †,
Martijn Mulders & Matteo Defranchis (CMS)

Uncertainty category	Uncertainty impact [GeV] LHC	ATLAS	CMS
LHC b-JES	0.18	0.17	0.25
b tagging	0.09	0.16	0.03
ME generator	0.08	0.13	0.14
LHC JES 1	0.08	0.18	0.06
LHC JES 2	0.08	0.11	0.10
Method	0.07	0.06	0.09
CMS B hadron BR	0.07	—	0.12
LHC radiation	0.06	0.07	0.10
Leptons	0.05	0.08	0.07
JER	0.05	0.09	0.02
Top quark p_T	0.05	—	0.07
Background (data)	0.05	0.04	0.06
Color reconnection	0.04	0.08	0.03
Underlying event	0.04	0.03	0.05
LHC g-JES	0.03	0.02	0.04
Background (MC)	0.03	0.07	0.01
Other	0.03	0.06	0.01
LHC l-JES	0.03	0.01	0.05
CMS JES 1	0.03	—	0.04
Pileup	0.03	0.07	0.03
LHC JES 3	0.02	0.07	0.01
LHC hadronization	0.02	0.01	0.01
p_T^{miss}	0.02	0.04	0.01
PDF	0.02	0.06	<0.01
Trigger	0.01	0.01	0.01
Total systematics	0.30	0.41	0.39
Statistical	0.14	0.25	0.14
Total	0.33	0.48	0.42