Towards a ATLAS + CMS pole mass combination

Matteo Defranchis[1], Katerina Lipka[2], Marcel Vos[3], Andrej Saibel[3], Davide Mellini[3], Juan Fuster[3], **Sebastian Wuchterl**[1],

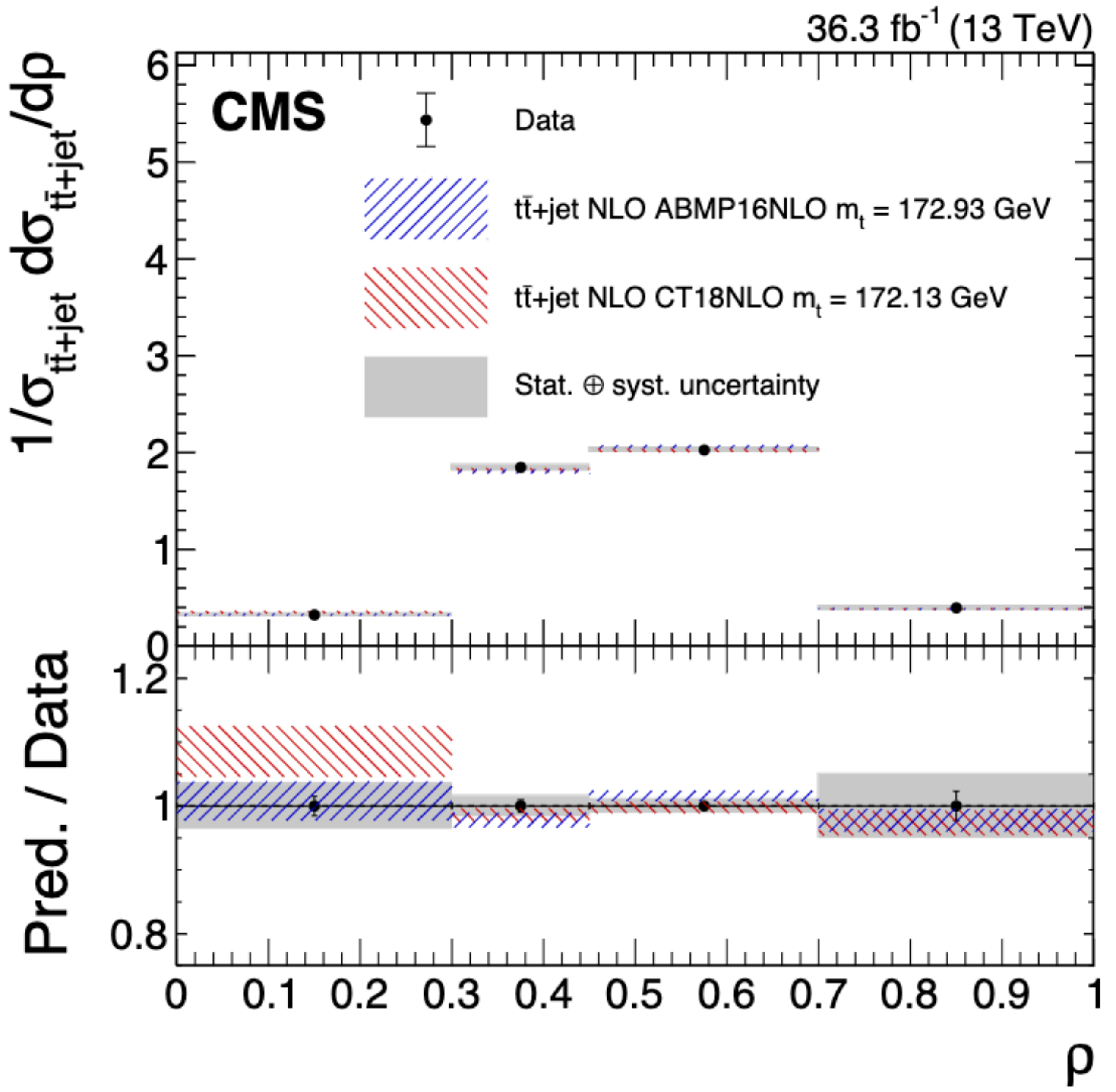
CERN[1], DESY[2], IFIC Valencia[3]

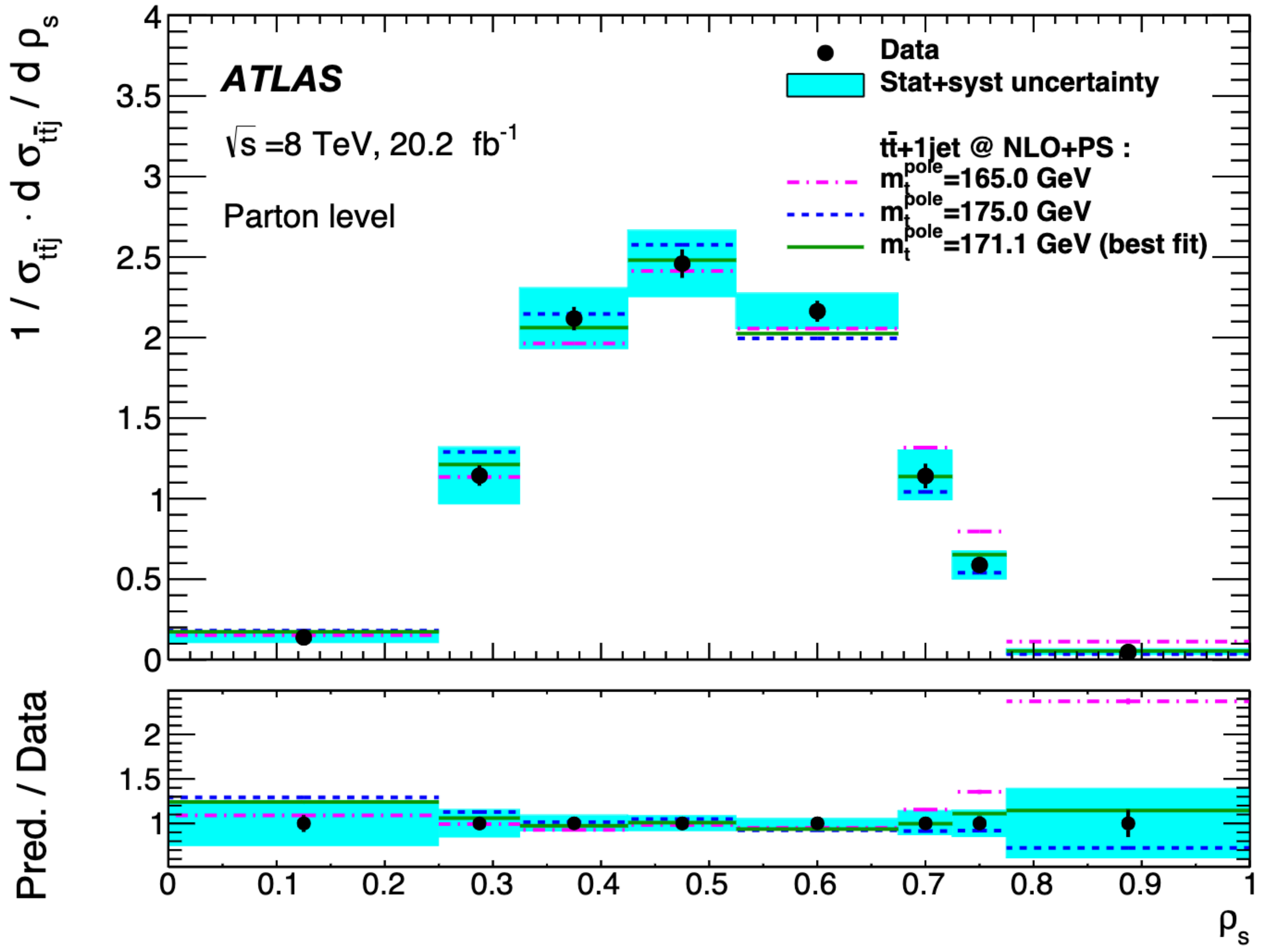
Theory-Experimental Top Quark Mass Workshop

30 January 2025

Introduction

- Based on discussion at several workshops:
  - Combination of ATLAS 8 TeV + CMS 13 TeV measurements
    - As exercise and a proof-of-principle study
  - Possible issues:
    - Different binning in ρ (4 vs. 8 bins)
    - Different CME (8 vs 13 TeV)
    - Different object definition (add. Jet p_T: 50 vs. 30 GeV)
    - Different theoretical prediction (fixed vs. dyn. scale)
    - Combination at mass level is unfeasible
  - Make a combined extraction using the same predictions for 8 and 13 TeV
    - Needs a combined cross section
    - But also allows for reinterpretations





Combining the differential cross section?

- Same problems here: binning, ρ definition, CME, …
- But, we can correlate the uncertainties and get two "combined" distributions
  - Means introducing 4+8 POIs in the combination
  - Needs ideally a full uncertainty breakdown

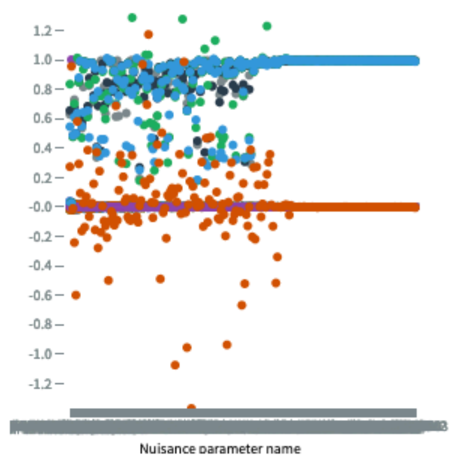
- CMS cross section based on likelihood unfolding:
  - Has nuisance parameters with correlations (constraints/pulls)
  - Provides the full covariance matrix, pulls, constraints, impacts, correlations, prefit and post fit on HEPData (<u>link</u>)

- ATLAS result based on bin-by-bin unfolding:
  - Auxiliary material only provides total normalised cov. matrix
  - No HEPData entry… (*Do we want to update this?*)

Showing 50 of 234 values — Show All 234 values

Nuisance parameter name	fit_obs_central	fit_obs_up	fit_obs_down	fit_exp_central	fit_exp_up	fit_exp_d
JESFlavorPureGluon	0.272689	0.545318	0.834019	0.0	0.654728	0.628291
rateTT0Jet	0.955	0.027	0.027	1.0	0.03	0.029
ELE_ID	-0.010569	0.486365	0.475508	0.0	0.484463	0.477583
PSSCALE_WEIGHT_4	-0.243075	0.611843	0.70161	0.0	0.674193	0.728531
MASS	-0.6	0.5	0.6	0.0	0.5	0.6
TOP_PT	0.580362	0.638779	1.012356	0.0	0.633722	0.994527
TRIG_EMU2016	0.292021	0.878101	0.84795	0.0	0.849682	0.852957
lumi2016	0.093503	0.991703	0.991818	0.0	0.991985	0.99199
JetPileupIDMistag	-0.16402	0.549315	0.469429	0.0	0.566893	0.534907
PSSCALE_WEIGHT_5	0.02686	0.641926	0.934649	0.0	0.600224	0.814537

Visualize



Sum errors ☑ Log Scale (Y) ☐

Deselect variables or hide different error bars by clicking on them.

Variables

fit_obs_central

fit_obs_up

fit_obs_down

fit_exp_central

ρ_s range	0.000 - 0.250	0.250 - 0.325	0.325 - 0.425	0.425 - 0.525	0.525 - 0.675	0.675 - 0.725	0.725 - 0.775	0.775 - 1.000
0.000 – 0.250	331.4	−187.6	95.9	30.8	−62.5	−3.7	−10.6	−5.4
0.250 – 0.325	−187.6	1278.6	−569.8	242.9	−66.9	−62.5	39.5	34.8
0.325 – 0.425	95.9	−569.8	2966.9	−1080.7	101.0	177.7	−3.4	−26.2
0.425 – 0.525	30.8	242.9	−1080.7	4737.8	−1082.2	−210.4	63.5	81.9
0.525 – 0.675	−62.5	−66.9	101.0	−1082.2	4286.1	−301.3	−248.7	−98.0
0.675 – 0.725	−3.7	−62.5	177.7	−210.4	−301.3	940.1	95.9	−75.8
0.725 – 0.775	−10.6	39.5	−3.4	63.5	−248.7	95.9	192.9	45.3
0.775 – 1.000	−5.4	34.8	−26.2	81.9	−98.0	−75.8	45.3	123.0

Combining the differential cross section?

- Davide provided the ATLAS 8 TeV results in original format (informally):
  - All uncertainties and their impact on the normalised cross section
  - Originally no information about the absolute one
  - ATLAS-internal procedure to smooth systematics and provide the full covariance matrix for the absolute cross section
  - → We can now combine the CMS +ATLAS absolute cross section directly!

- Andrej produced consistent 8 + 13 TeV predictions
  - PDF4LHC, NNPDF31, CT18, MHSTW, ABMP PDFs + uncertainties/mass variations

- We use Convino (Eur. Phys. J. C (2017) 77: 792)
  - Recovers the full likelihood
  - Can deal with externalised uncertainties (ATLAS) or nuisance parameters (CMS)

A method and tool for combining differential or inclusive measurements obtained with simultaneously constrained uncertainties

Jan Kieseler CERN, 1211 Geneva 23, jan.kieseler@cern.ch

August 2, 2018

Setting things up

- For CMS, straightforward:
  - Load HEPData entry
  - Read in all nuisances + POIs with their constraint & correlation
  - Read in externalised extrapolation uncertainties (for all modeling NPs)
  - Write in convino config file (232 nuisances)

```

[correlation matrix]

CMS_modelling_ttbar_bfrag (0.7250135)   1.0
CMS_modelling_ttbar_bfragPythiaDefault (1.024237)   -0.193875   1.0
CMS_modelling_ttbar_bfragPeterson (0.6336765)   -7.4e-05   0.000802   1.0
CMS_modelling_ttbar_bsemilep (0.9242395)   0.018051   0.024073   0.001167   1.0
CMS_eff_b_heavy_jes (0.850888)   0.09555   0.101324   -0.002341   0.021702   1.0
CMS_eff_b_light_corr (0.857371)   -0.101167   -0.111678   0.001681   0.027412   -0.107059   1.0
```

- We can validate the CMS only "combination":
  - Only write CMS inputs
  - Combine the single result, i.e., let Convino build the likelihood
  - Run a mass extraction on the "combined" result
  - <u>Spoiler</u>: Good closure, configuration works

NB: Only issue are the extrapolation uncertainties, as they are combined on HEPData (i.e. the total covariance). Breakdown and correlation found to have no impact.

Setting things up

- For ATLAS, it was a bit more complicated:
  - Information for all 8 bins
  - Stat. uncertainties in form of the correlation matrix
  - In total 122 syst. uncertainties
    - Added as external, non fitted uncertainties
  - Also here, “closure” on extracted mass

```
[correlation matrix]
    ATLAS_8TeV_2012_lj_abs_rho_0p0_0p25 (54.6146228278)  1.0
    ATLAS_8TeV_2012_lj_abs_rho_0p25_0p325 (98.2002194453)  -0.1698036622 1.0
    ATLAS_8TeV_2012_lj_abs_rho_0p325_0p425 (144.1914209146)  -0.0560923761 -0.185528228
    ATLAS_8TeV_2012_lj_abs_rho_0p425_0p525 (151.6300728552)  0.0229718393 -0.0371120669
    ATLAS_8TeV_2012_lj_abs_rho_0p525_0p675 (168.6938324232)  0.03382784 -0.0443593303 0.
    ATLAS_8TeV_2012_lj_abs_rho_0p675_0p725 (60.2973554966)  -0.1296522464 0.045880677 0.
    ATLAS_8TeV_2012_lj_abs_rho_0p725_0p775 (33.4017688451)  -0.0571443626 -0.0078879667
    ATLAS_8TeV_2012_lj_abs_rho_0p775_1p0 (22.2787133557)  0.0111945413 -0.0349918045 -0.
[end correlation matrix]
```

```
[not fitted]
    ATLAS_eff_b_heavy_0 ATLAS_eff_b_heavy_1 ATLAS_eff_b_heavy_2 ATLAS_eff_b_heavy_3 ATLAS
    ATLAS_8TeV_2012_lj_abs_rho_0p0_0p25 -0.016109284920532246 2.600361618571016б -2.73865
    ATLAS_8TeV_2012_lj_abs_rho_0p25_0p325 0.20841055028576214 4.50557983284921 -6.0609537
    ATLAS_8TeV_2012_lj_abs_rho_0p325_0p425 1.2580877407055555 10.95199272281495З -6.57984
    ATLAS_8TeV_2012_lj_abs_rho_0p425_0p525 0.7863068588861227 7.96858140267174 2.50986404
    ATLAS_8TeV_2012_lj_abs_rho_0p525_0p675 -1.705016744959332 -7.816737016732583 11.46784
    ATLAS_8TeV_2012_lj_abs_rho_0p675_0p725 -0.7140726053076729 -6.512604415453878 1.89883
    ATLAS_8TeV_2012_lj_abs_rho_0p725_0p775 -0.15101083222638084 -6.076797558343437 -0.142
    ATLAS_8TeV_2012_lj_abs_rho_0p775_1p0 0.34597284263398 -2.669706819940697 -0.808704722
[end not fitted]
```

Correlation assumptions: JES

- How do we decide on the correlations?
  - Work was ~already done: Run 1 direct top quark mass combination
  - → Fully applicable for JES and modeling
- Looking at TOPLHC NOTE: link

Description	Components, CMS	Components, ATLAS	Corr. range
1a. Statistical *in situ* terms	AbsoluteStat, SinglePionHCAL, RelativeStat[FSR][EC2][HF]	[11] **Z**-jet balance `stat./meth.` terms (p_T), [13] γ-jet balance `stat./meth.` terms (p_T), [10] multi-jet balance `stat./meth.` terms (p_T), η-intercalibration statistical term (p_T,η)	0%
1b. Detector *in situ* terms	AbsoluteScale, SinglePionECAL, RelativeJER[EC1][EC2][HF], RelativePt[BB][EC1][EC2][HF]	**Z**-jet balance `det.` term, γ-jet balance `det.` term, [2] correlated **Z**/γ-jet balance `det.` terms (p_T)	0%
2. Absolute balance modeling	AbsoluteMPFBias	[7] **Z**-jet balance `model` + `mixed` terms (p_T), [4] γ-jet balance `model` + `mixed` terms (p_T), [2] correlated **Z**/γ-jet balance terms (p_T), [5] multi-jet balance `model` + `mixed` terms (p_T)	0-50%
3. Relative balance modeling	RelativeFSR	η-intercalibration modeling (p_T,η)	50-100%
4. *g*-jet fragmentation	FlavorPureGluon	Flavor response (p_T,η)	100%
5. *b*-jet fragmentation	FlavorPureBottom	*b*-jet response (p_T)	50-100%
6. Other fragmentation types	FlavorPureQuark, FlavorPureCharm	Flavor composition (p_T,η)	0%
7. Pileup	PileupDataMC, PileupPt[Ref][BB][EC1][EC2][HF]	N_{PV} offset (p_T,η,N_{PV}), $\langle\mu\rangle$ offset (p_T,η,$\langle\mu\rangle$), p_T term (p_T,η,N_{PV},$\langle\mu\rangle$), ρ topology (p_T,η)	0%
8. High-p_T	Fragmentation	High-p_T (p_T)	0%
9. Single-experiment terms	TimeEta, TimePt	Fast simulation closure (p_T,η), punch-through (p_T,η,$N_{segments}$)	0%

Table 4: The range of correlation coefficients to be used for each individual ATLAS and CMS JES uncertainty source and component grouping when combining measurements between the experiments. The variables used to parametrize each ATLAS uncertainty component are listed in parentheses. If more than one ATLAS uncertainty component matches a given classification, the corresponding number is listed at the start in square brackets. The variable named $N_{segments}$ is the number of segments in the muon system behind the jet, as described in Ref. [10].

Implement it one to one:

```
# Obvious ones from the JES mapping
ATLAS_scale_b = (0.75)  CMS_scale_j_flavorBottom
ATLAS_scale_j_flavorresponse = (0.9)  CMS_scale_j_flavorGluon
ATLAS_scale_j_EtaIntercalibrationModel = (0.75)  CMS_scale_j_relativeFSR
CMS_scale_j_absoluteMPFBias = (0.25)  ATLAS_scale_j_Mix1
CMS_scale_j_absoluteMPFBias = (0.25)  ATLAS_scale_j_Mix2
CMS_scale_j_absoluteMPFBias = (0.25)  ATLAS_scale_j_Mix3
CMS_scale_j_absoluteMPFBias = (0.25)  ATLAS_scale_j_Mix4
CMS_scale_j_absoluteMPFBias = (0.25)  ATLAS_scale_j_Model1
CMS_scale_j_absoluteMPFBias = (0.25)  ATLAS_scale_j_Model2
CMS_scale_j_absoluteMPFBias = (0.25)  ATLAS_scale_j_Model3
CMS_scale_j_absoluteMPFBias = (0.25)  ATLAS_scale_j_Model4
```

Correlation assumptions: tt modeling

- Checking the analysis note of the Run 1 combination: link

- LHC Had: CMS b fragmentation and ATLAS Herwig vs Pythia

LHC HAD This term includes uncertainties associated with hadronisation. As discussed in Section 3, there are significant differences between ATLAS and CMS in the way the uncertainty is evaluated. The category is therefore treated as partially correlated (0.5).

- LHC Rad: ATLAS envelope of scales, hdamp, ISR/FSR
  CMS split of the same uncertainties

LHC RAD This term includes uncertainties in the amount of extra QCD radiation in $t\bar{t}$ events. As the nominal MC setups are different between ATLAS and CMS, the category is treated as partially correlated (0.5).

- Color reconnection and UE: ATLAS sum, CMS breakdown

Color reconnection and underlying event For both these categories, ATLAS and CMS rely on simulated event samples. The nominal tunes differ between the experiments and the variations, while similar as discussed in Section 3 are not identical, and hence these categories are assumed to be partially correlated between ATLAS and CMS.

Implement it similarly:

```
# Other ones taken from the Run 1 mass combination
CMS_modelling_ttbar_bfrag = (0.50) ATLAS_modelling_ttbar_ShowerHadronization
CMS_modelling_ttbar_bfragPythiaDefault = (0.50) ATLAS_modelling_ttbar_ShowerHadronization
CMS_modelling_ttbar_bfragPeterson = (0.50) ATLAS_modelling_ttbar_ShowerHadronization
CMS_modelling_ttbar_erdOn = (0.50) ATLAS_modelling_ttbar_ColorReconnection
CMS_modelling_ttbar_tuneQCD  = (0.50) ATLAS_modelling_ttbar_ColorReconnection
CMS_modelling_ttbar_tuneGluon  = (0.50) ATLAS_modelling_ttbar_ColorReconnection
CMS_modelling_ttbar_hdamp = (0.50) ATLAS_modelling_ttbar_Radiation
CMS_modelling_ttbar_isr = (0.50) ATLAS_modelling_ttbar_Radiation
CMS_modelling_ttbar_fsr = (0.50) ATLAS_modelling_ttbar_Radiation
CMS_modelling_ttbar_tune = (0.50) ATLAS_modelling_ttbar_UnderlyingEvent
```

Correlation assumptions

- Numbers taken from final table
  - Correlation scans need to be done

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	—	—	—

Correlation assumptions

What matters?

ATLAS

Mass scheme	m_t^{pole} [GeV]	$m_t(m_t)$ [GeV]
Value	**171.1**	**162.9**
Statistical uncertainty	**0.4**	**0.5**
Simulation uncertainties		
Shower and hadronisation	0.4	0.3
Colour reconnection	0.4	0.4
Underlying event	0.3	0.2
Signal Monte Carlo generator	0.2	0.2
Proton PDF	0.2	0.2
Initial- and final-state radiation	0.2	0.2
Monte Carlo statistics	0.2	0.2
Background	<0.1	<0.1
Detector response uncertainties		
Jet energy scale (including *b*-jets)	0.4	0.4
Jet energy resolution	0.2	0.2
Missing transverse momentum	0.1	0.1
b-tagging efficiency and mistag	0.1	0.1
Jet reconstruction efficiency	<0.1	<0.1
Lepton	<0.1	<0.1
Method uncertainties		
Unfolding modelling	0.2	0.2
Fit parameterisation	0.2	0.2
Total experimental systematic	**0.9**	**1.0**
Scale variations	(+0.6, −0.2)	(+2.1, −1.2)
Theory PDF⊕α_s	0.2	0.4
Total theory uncertainty	**(+0.7, −0.3)**	**(+2.1, −1.2)**
Total uncertainty	**(+1.2, −1.1)**	**(+2.3, −1.6)**

CMS

Uncertainty Source	$\Delta\sigma^1_{t\bar{t}+jet}$ [%]	$\Delta\sigma^2_{t\bar{t}+jet}$ [%]	$\Delta\sigma^3_{t\bar{t}+jet}$ [%]	$\Delta\sigma^4_{t\bar{t}+jet}$ [%]
Experimental				
Muon identification	1.8	1.5	1.5	1.4
Muon energy scale and resolution	0.7	0.2	0.3	0.5
Electron identification	2.0	1.7	1.7	2.1
Electron energy scale and resolution	0.9	1.0	0.9	1.5
Jet energy scale	2.6	2.0	2.2	3.6
Jet energy resolution	0.6	0.5	0.5	0.4
Jet identification	1.1	0.8	0.8	1.3
p_T^{miss}	0.2	0.3	0.4	0.8
b jet identification	1.0	0.7	0.6	1.2
Trigger efficiency	1.8	1.2	1.1	1.8
Total	4.0	3.1	3.1	4.7
Background normalization				
$t\bar{t}$+0 jet	2.2	2.0	1.7	0.7
Z+jets	2.4	1.9	1.7	2.6
Single top quark	0.9	0.8	0.7	0.1
Total	3.1	2.5	2.4	2.7
Modeling				
Z+jets ME scale	0.7	0.4	0.2	0.3
Single top quark ME/FSR/ISR scales	1.2	0.6	0.4	0.1
$t\bar{t}$ PDF	0.1	0.1	0.1	0.6
$t\bar{t}$ ME scale	1.0	0.5	0.6	0.4
$t\bar{t}$ ISR scale	1.2	0.8	0.6	1.6
$t\bar{t}$ FSR scale	1.3	0.8	0.6	1.7
$t\bar{t}$ top quark p_T	2.0	1.3	0.1	1.2
b fragmentation	0.9	0.7	0.8	0.8
Color reconnection	0.5	0.6	0.2	0.7
$t\bar{t}$ matching scale	0.6	0.5	0.6	≤0.1
Underlying-event tune	0.2	0.5	0.2	0.5
Total	3.2	1.9	1.8	3.1
Integrated luminosity	1.2	1.4	1.3	1.2
m_t^{MC}	1.7	1.0	0.4	2.3
Finite size of simulated samples	2.0	1.4	1.3	2.2
Total systematic	5.0	3.4	3.2	5.6
Statistical	1.6	1.0	0.8	2.4
Total	5.2	3.6	3.3	6.1

Correlation assumptions

What matters?

- Numbers taken from final table
  - Correlation scans need to be done

- Our expectations are:
  - They shouldn't really matter, besides maybe
    - b-JES (also Run 1 combination)
    - tt0Jet normalization as it has a large impact for the CMS absolute measurement

Uncertainty Source	$\Delta\sigma^1_{t\bar{t}+jet}$ [%]	$\Delta\sigma^2_{t\bar{t}+jet}$ [%]	$\Delta\sigma^3_{t\bar{t}+jet}$ [%]	$\Delta\sigma^4_{t\bar{t}+jet}$ [%]
Experimental				
Muon identification	1.8	1.5	1.5	1.4
Muon energy scale and resolution	0.7	0.2	0.3	0.5
Electron identification	2.0	1.7	1.7	2.1
Electron energy scale and resolution	0.9	1.0	0.9	1.5
Jet energy scale	2.6	2.0	2.2	3.6
Jet energy resolution	0.6	0.5	0.5	0.4
Jet identification	1.1	0.8	0.8	1.3
p_T^{miss}	0.2	0.3	0.4	0.8
b jet identification	1.0	0.7	0.6	1.2
Trigger efficiency	1.8	1.2	1.1	1.8
Total	4.0	3.1	3.1	4.7
Background normalization				
$t\bar{t}$+0 jet	2.2	2.0	1.7	0.7
Z+jets	2.4	1.9	1.7	2.6
Single top quark	0.9	0.8	0.7	0.1
Total	3.1	2.5	2.4	2.7
Modeling				
Z+jets ME scale	0.7	0.4	0.2	0.3
Single top quark ME/FSR/ISR scales	1.2	0.6	0.4	0.1
$t\bar{t}$ PDF	0.1	0.1	0.1	0.6
$t\bar{t}$ ME scale	1.0	0.5	0.6	0.4
$t\bar{t}$ ISR scale	1.2	0.8	0.6	1.6
$t\bar{t}$ FSR scale	1.3	0.8	0.6	1.7
$t\bar{t}$ top quark p_T	2.0	1.3	0.1	1.2
b fragmentation	0.9	0.7	0.8	0.8
Color reconnection	0.5	0.6	0.2	0.7
$t\bar{t}$ matching scale	0.6	0.5	0.6	$\leq$0.1
Underlying-event tune	0.2	0.5	0.2	0.5
Total	3.2	1.9	1.8	3.1
Integrated luminosity	1.2	1.4	1.3	1.2
m_t^{MC}	1.7	1.0	0.4	2.3
Finite size of simulated samples	2.0	1.4	1.3	2.2
Total systematic	5.0	3.4	3.2	5.6
Statistical	1.6	1.0	0.8	2.4
Total	5.2	3.6	3.3	6.1

Looking at some impacts: no correlation setup

Little spoiler, but we look at the final numbers later

x-axis: relative impact in % (max. is 20%)

CMS uncertainties, grouped

ATLAS uncertainties, grouped

- As expected, no cross-impacts

Looking at some impacts: JES correlation setup

x-axis: relative impact in % (max. is 20%)

CMS uncertainties, grouped

ATLAS uncertainties, grouped

- JES and tt modeling impact the other measurement, although only JES correlated by hand

Looking at some impacts: JES+modeling correlation setup

x-axis: relative impact in % (max. is 20%)

CMS uncertainties, grouped

ATLAS uncertainties, grouped

- JES and tt modeling impact the other measurement, although only JES correlated by hand
- b jet efficiency and MC stat play a minor role, too

Looking at some impacts: JES+modeling+tt0jet correlation setup

CMS uncertainties, grouped

ATLAS uncertainties, grouped

- JES and tt modeling impact the other measurement, although only JES correlated by hand
- b jet efficiency and MC stat play a minor role, too
- Explicitly correlated tt0jet makes no difference, entered already before

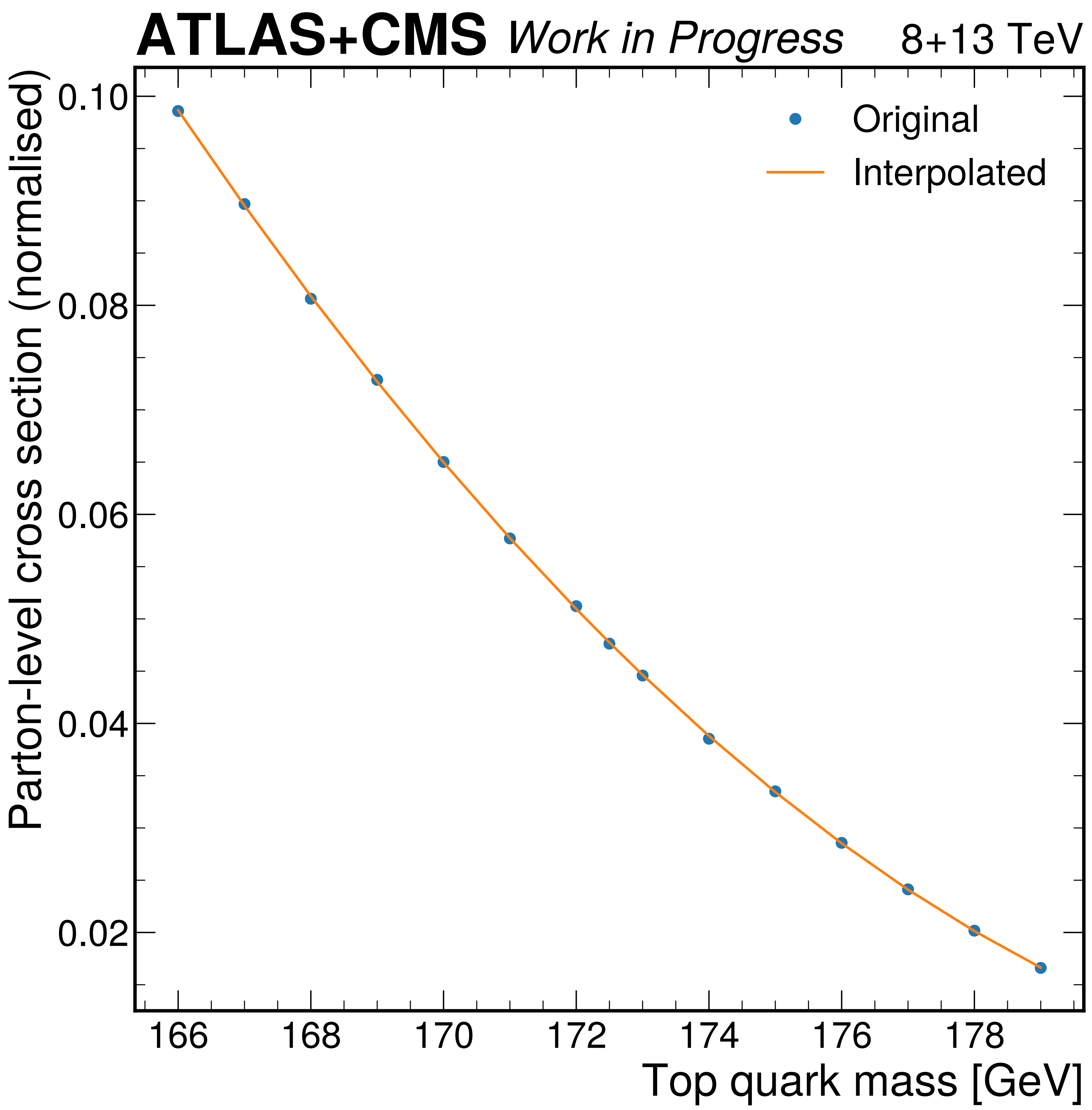
Technical implementation - fitting setup

Thanks mostly to Matteo!

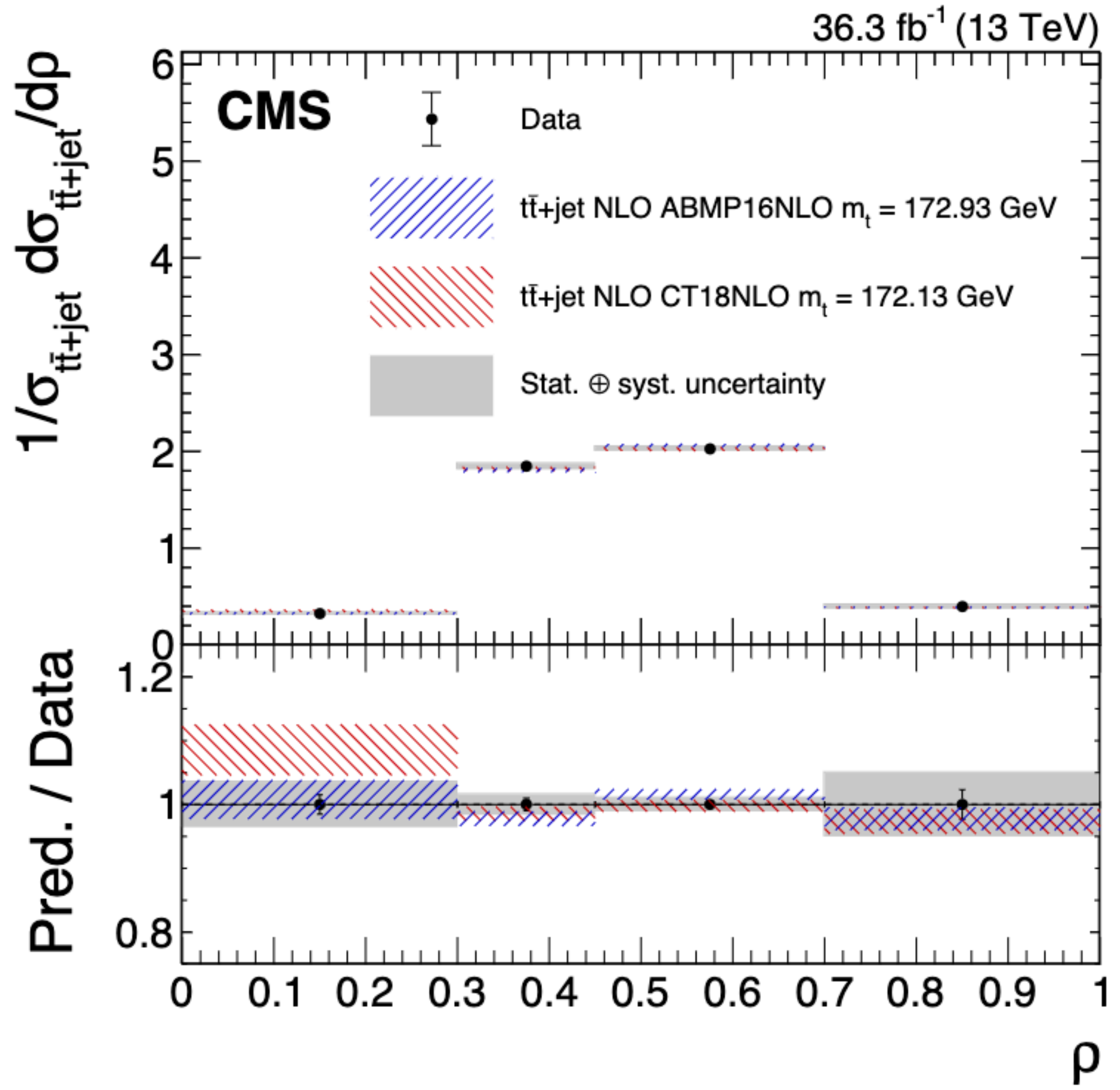
- Flexible setup in place: repository here
  - Fit "individual" measurements or combined 8+13 TeV cross sections
  - Consistent correlation of PDF uncertainties between centre-of-mass energies
  - Correlated/uncorrelated variation of ME scales
  - Freezing PDFs, different minimisers, …

- Using consistent NLO tt+j calculations (Thanks to Andrej!)
  - Powheg FO, alphaS = 0.118, scale = ET/2
  - Effectively smoothing theory prediction via polynomial interpolation of x-sec vs mass in each rho bin

- NB: For all results shown, I use the CT18NLO PDF set
- More to come soon (predictions for 8 TeV are running..)



Cross-check: CMS 13 TeV



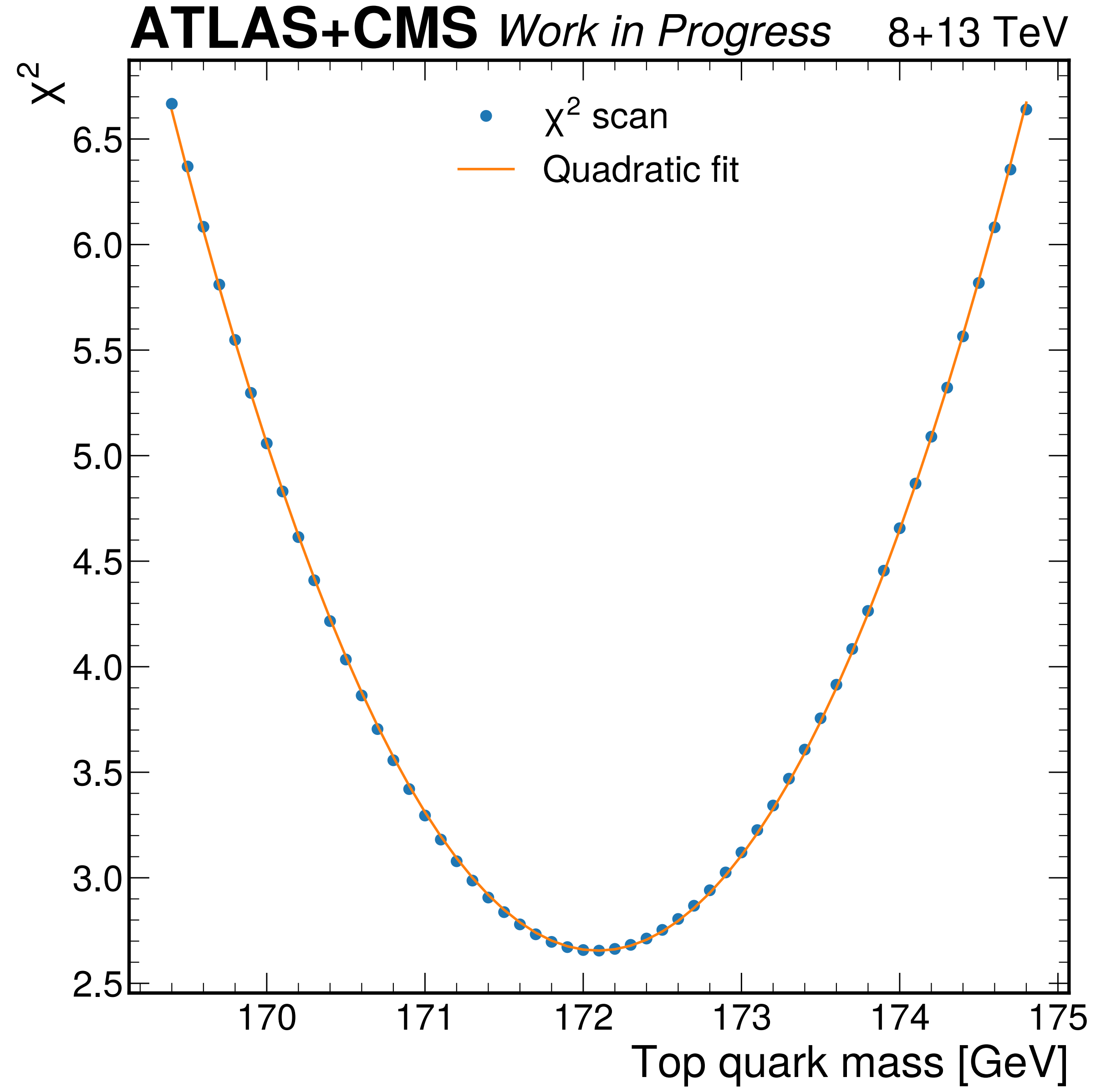
Published result

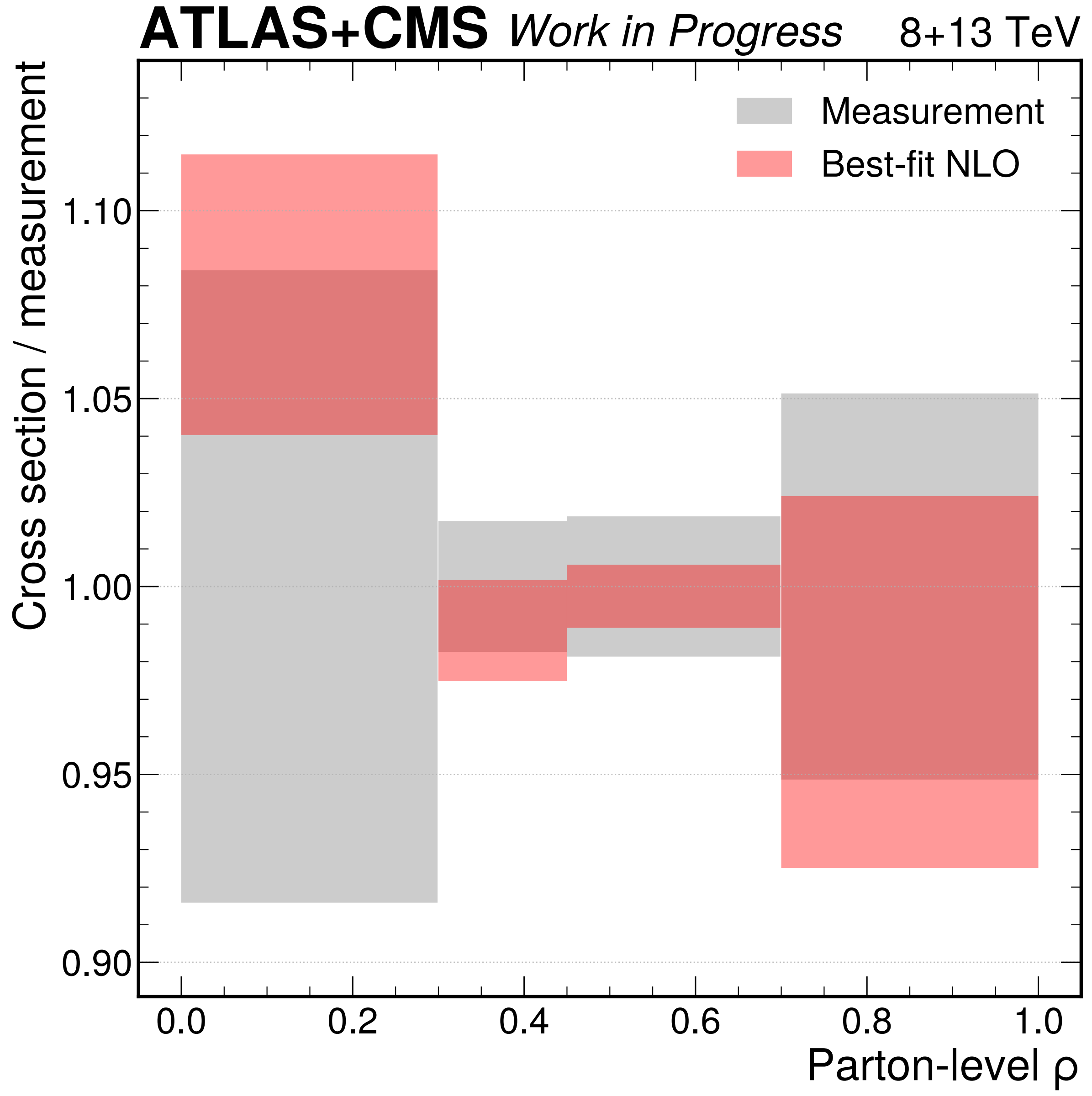
CT18 NLO (scale = HT/2)

$$m_t^{pole} = 172.13 \pm 1.34\,(\text{fit})\,^{+0.50}_{-0.40}\,(\text{scale})\,\text{GeV}$$

- Using the HEPData public info in the same setup as used for the combination
  - But, profiling the PDFs as in m_t running paper
  - **m_t = 172.08 ± 1.29 (exp) ± 0.41 (PDF) GeV**
  - Scale uncertainty = +0.32 -0.43 GeV
  - Good closure and consistent results (within 50 MeV!

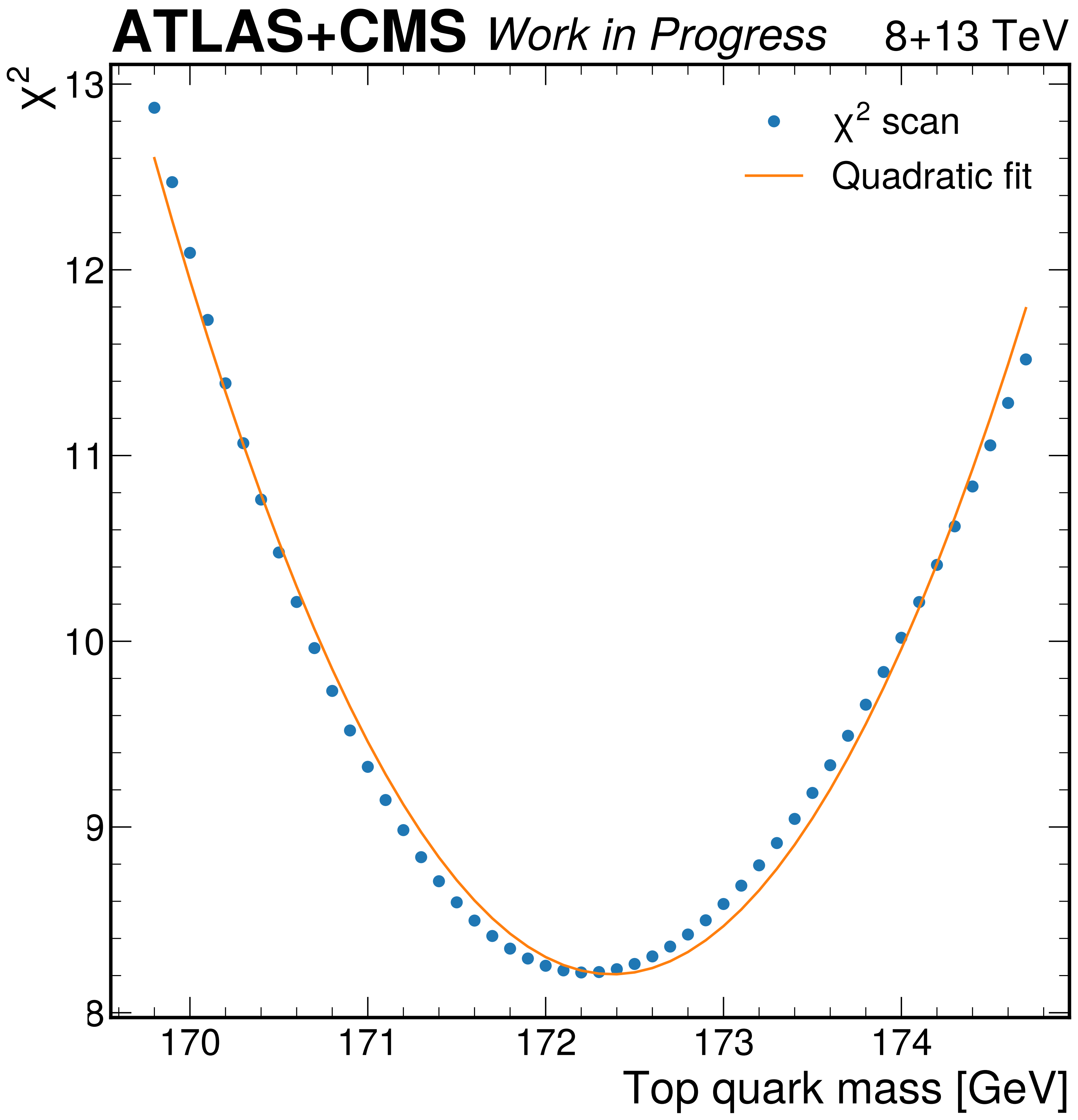
Theory band includes PDFs + m_t^{pole} post-fit uncertainty





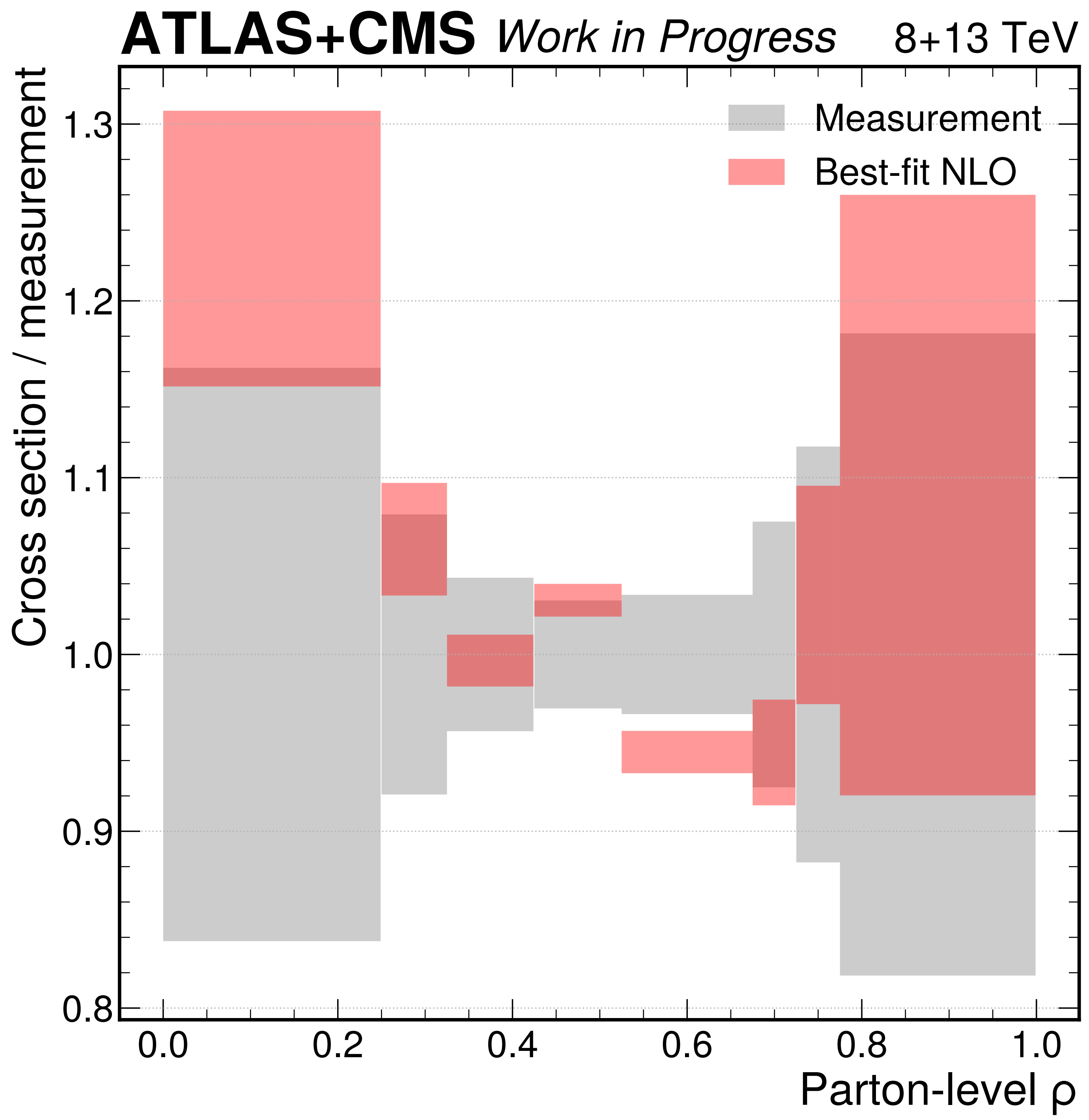
ATLAS reinterpretation

- Results not directly comparable:
  - Different theory prediction (dyn. scale)
  - Different fit setup (PDF and systematics in the chi2 fit)
  - **m_t = 172.23 ± 1.19 (exp) ± 0.27 (PDF) GeV**
  - Scale uncertainty = +0.11 -0.02 GeV



Published result

$$m_t^{\text{pole}} = 171.1 \pm 0.4\,(\text{stat}) \pm 0.9\,(\text{syst})\,^{+0.7}_{-0.3}\,(\text{theo})\ \text{GeV}.$$



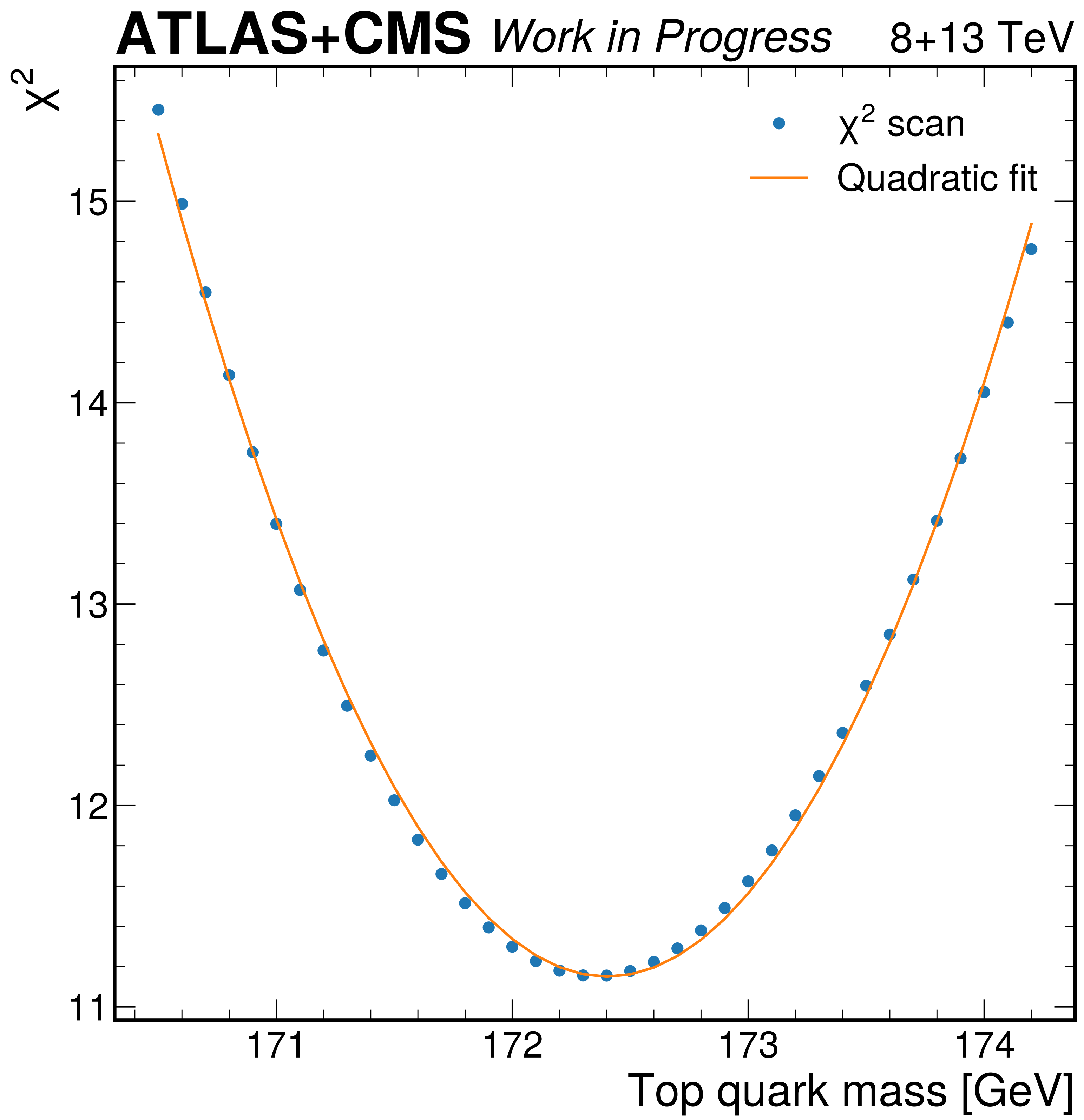
Combination results

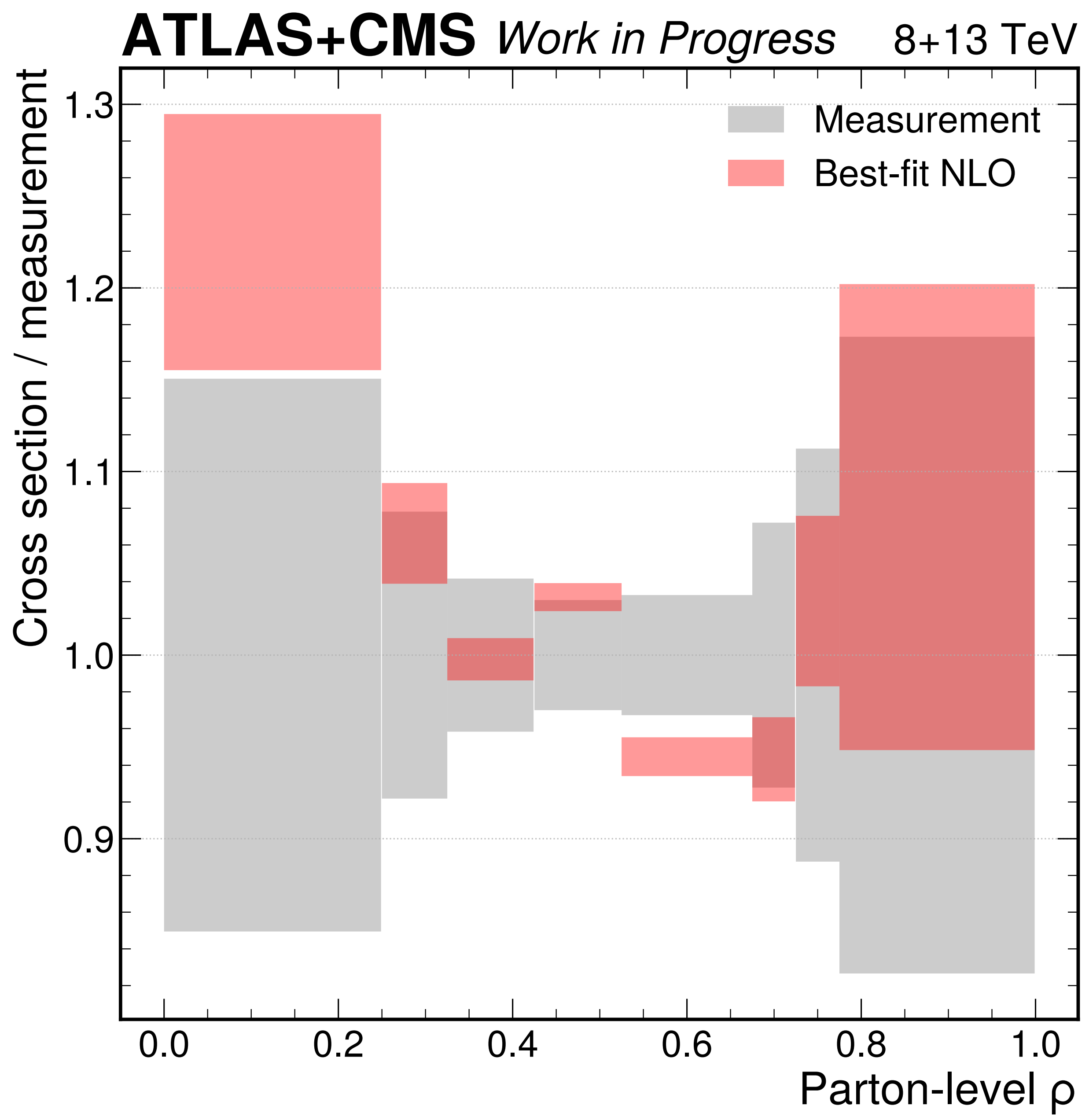
- mt = 172.25 ± 0.87 (exp) ± 0.28 (PDF) GeV
  - → 0.91 (exp+PDF) GeV

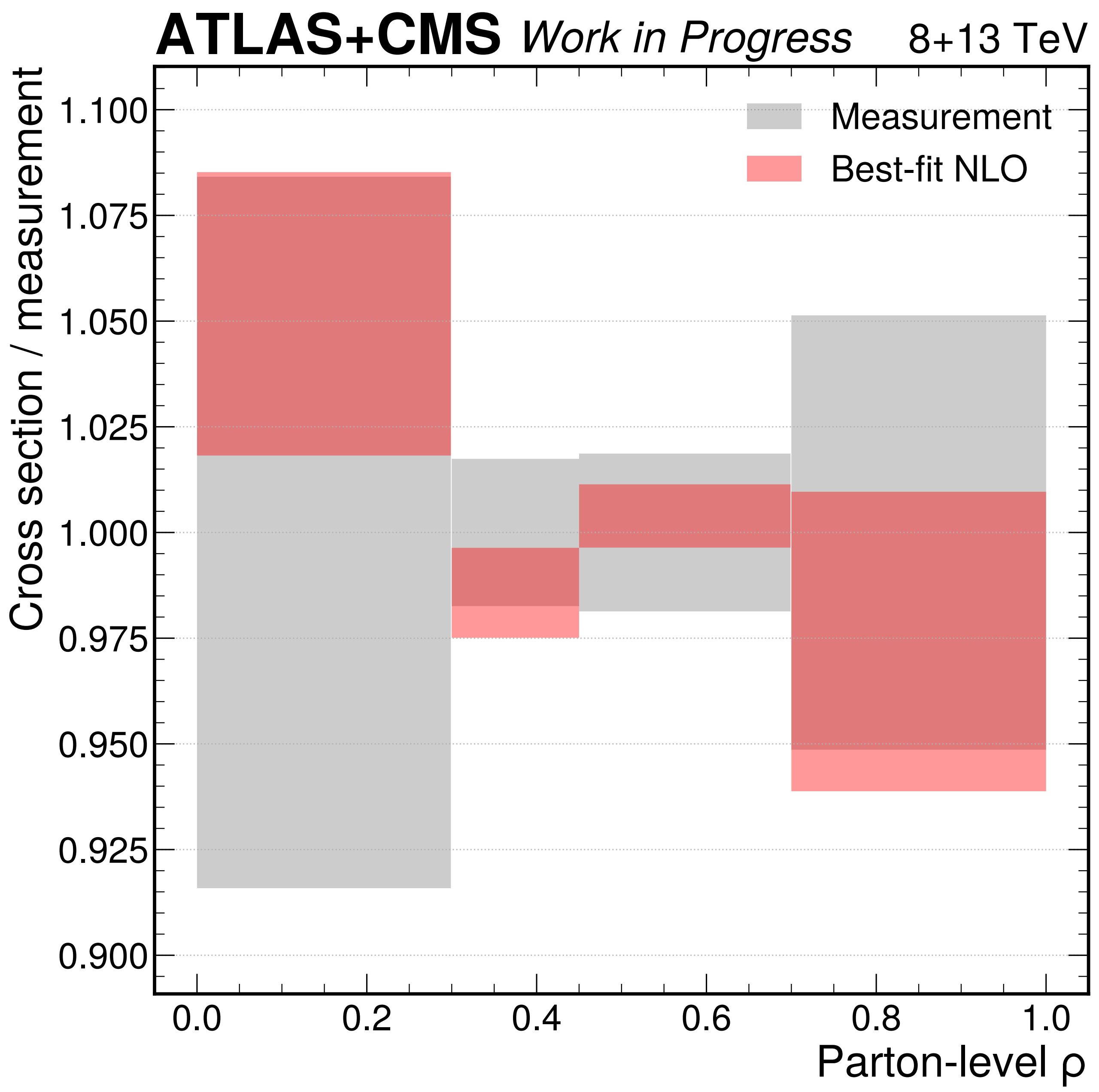
- Correlated scale uncertainty = +0.18 -0.19 GeV
- Uncorrelated scale uncertainty = +0.14 -0.18 GeV

0.92 GeV total

- → more than 20% improvement wrt. most precise input (ATLAS)





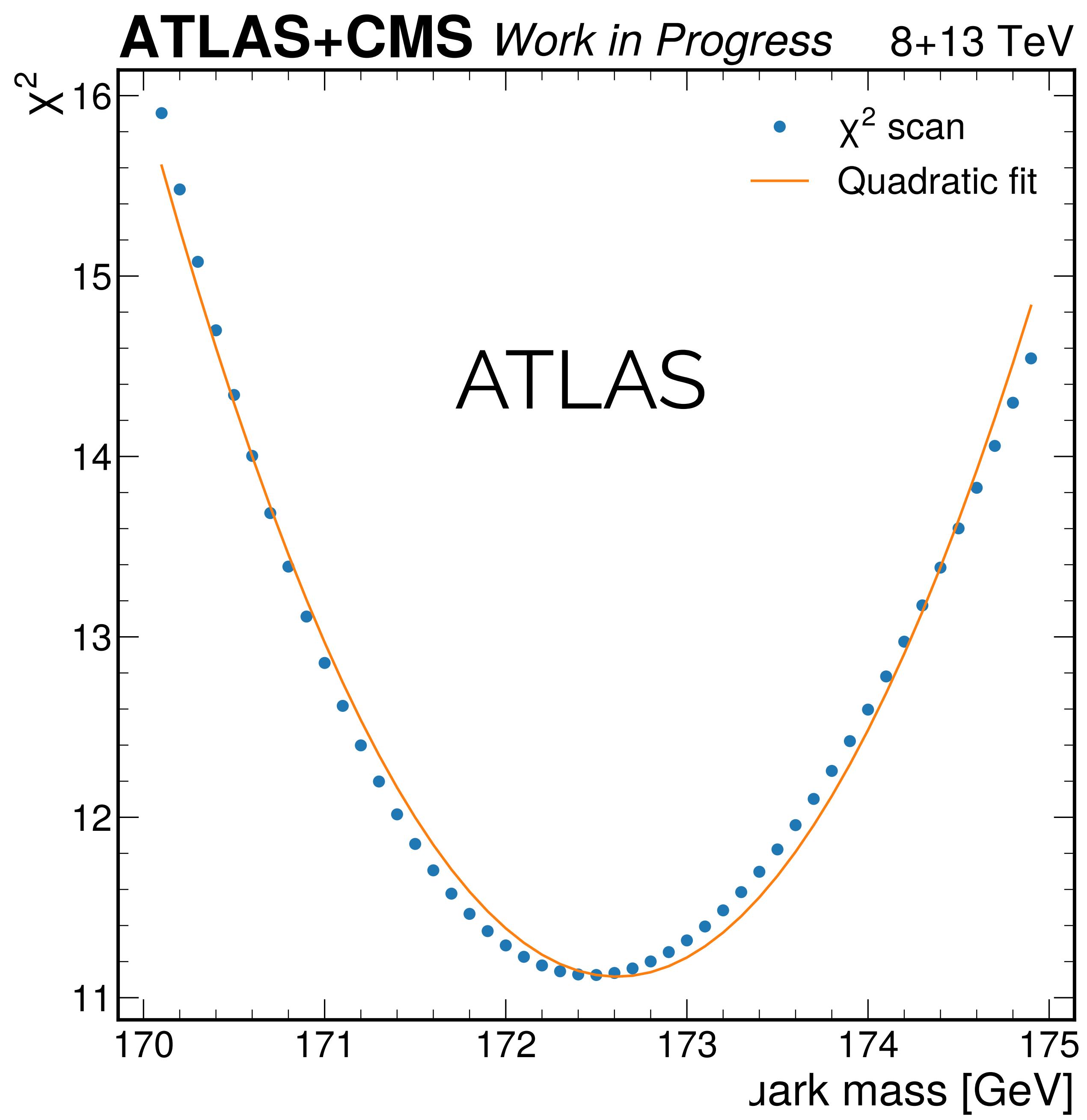


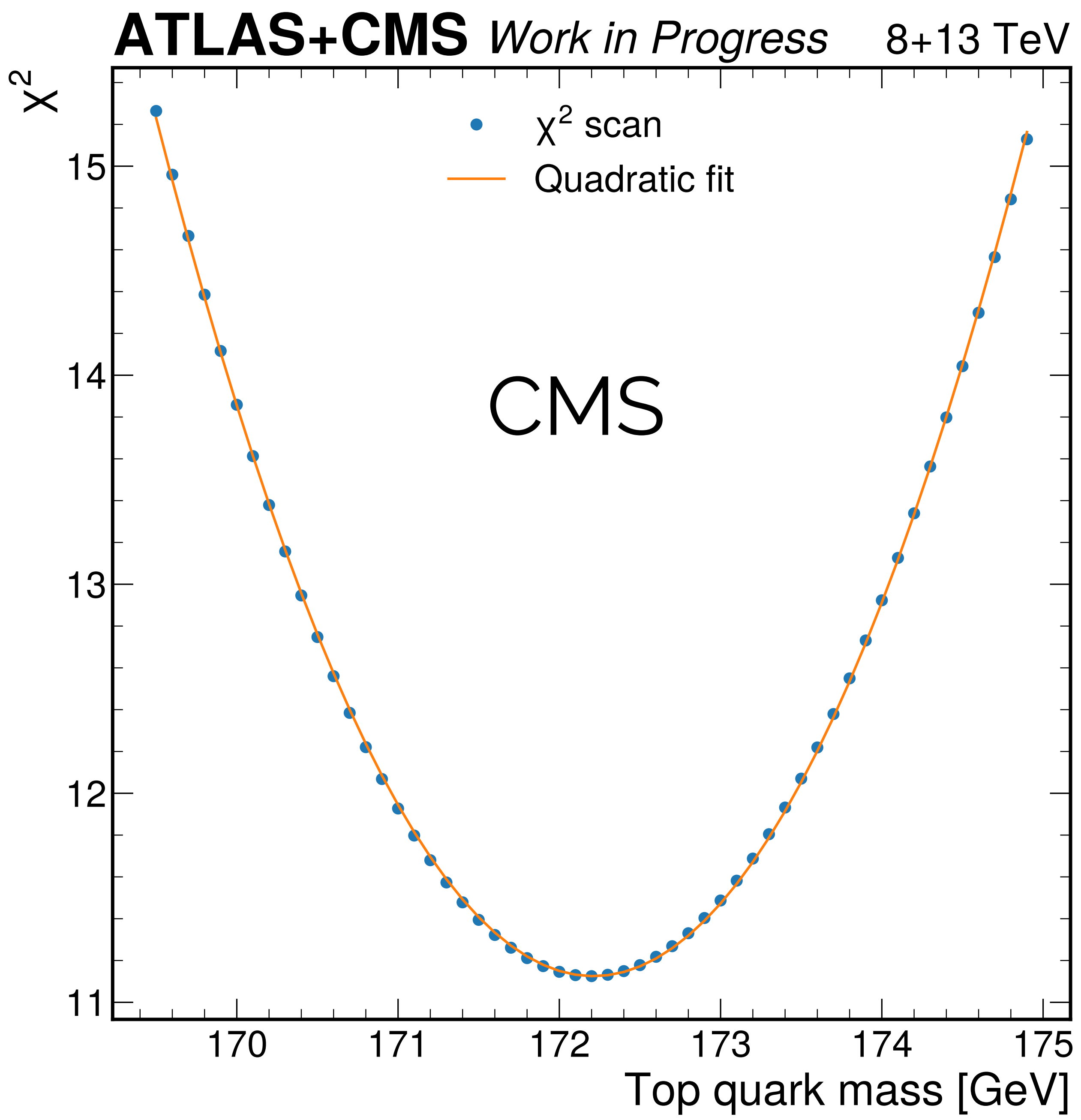
Consistency check: one parameter per experiment

- Two separate mass parameters fit *simultaneously* to ATLAS and CMS, taking correlations into account

- Correlation includes experimental (tt+0j, JES, modelling) and PDFs
- Mass values compatible within uncertainties

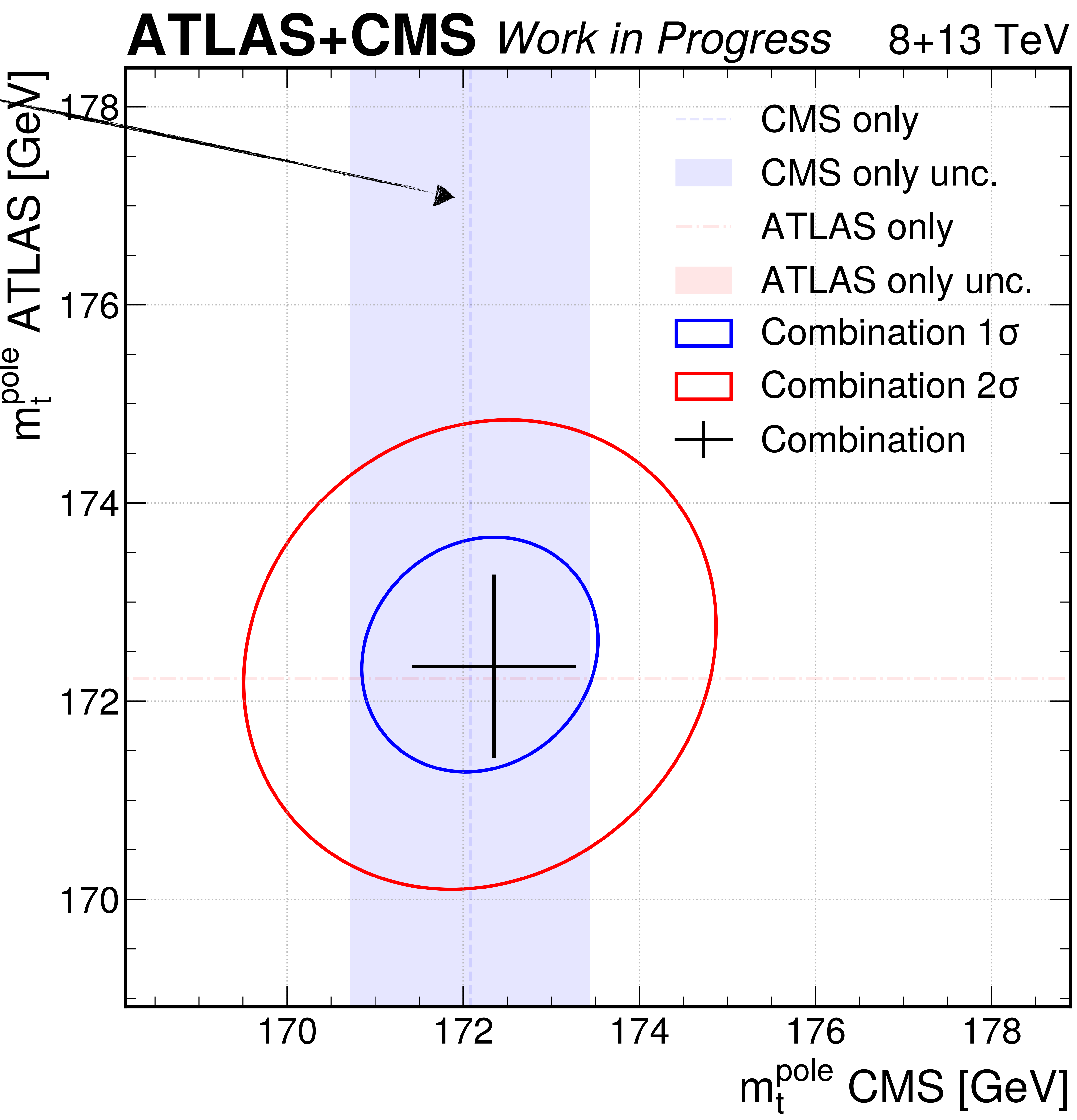
m_t CMS= 172.19 ± 1.28 (exp) ± 0.40 (PDF) GeV
m_t ATLAS = 172.47 ± 1.16 (exp) ± 0.24 (PDF) GeV
Correlation = 12.1 %
Difference = -0.3 ± 1.7 GeV
Ratio = 0.998 ± 0.010





Everything in one plot

Standalone CMS

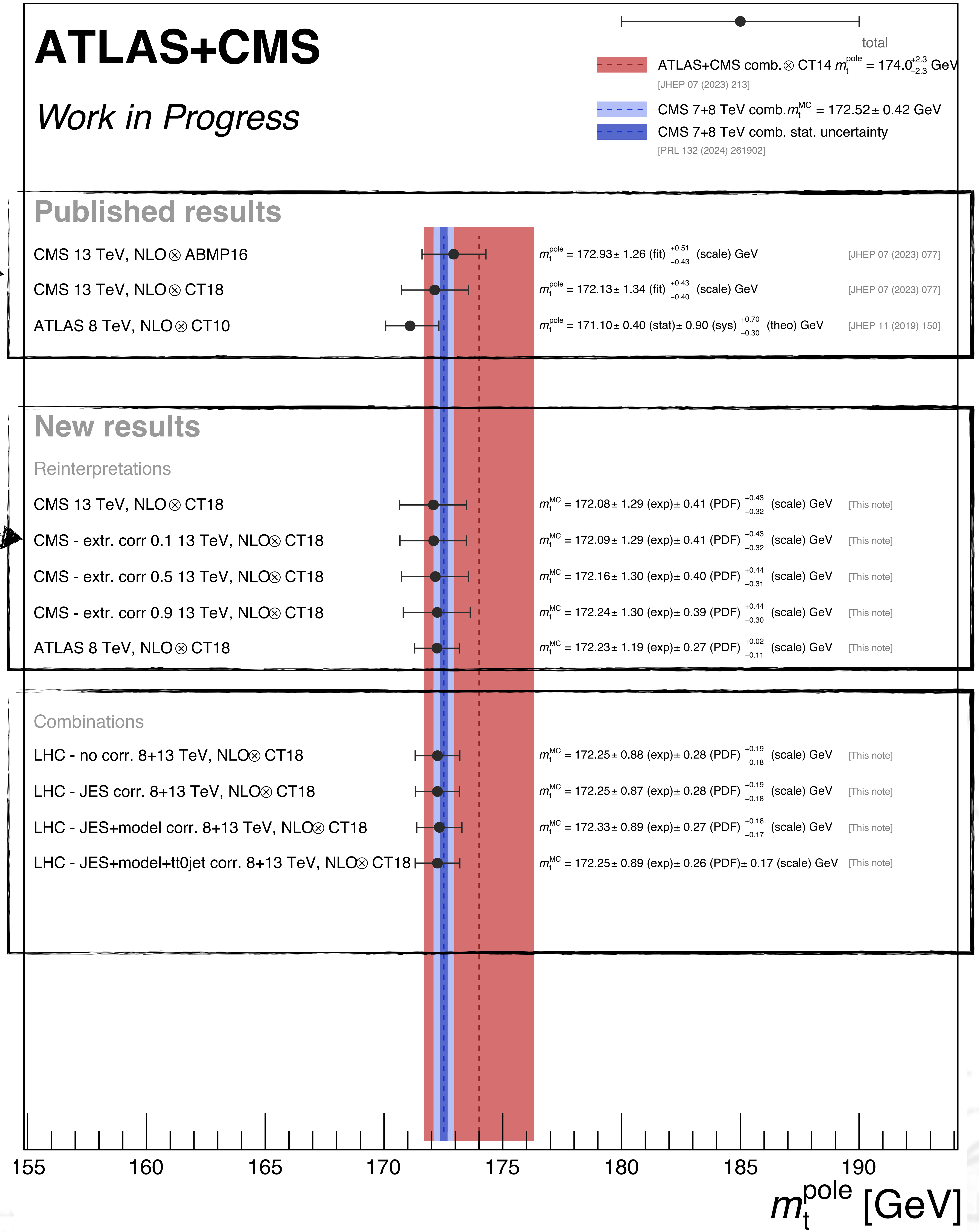


Standalone ATLAS

Contour from the 2D fit

Let's put it in comparison

- Input measurements as published
- Reinterpretation standalone
  - CMS results closes within 50 MeV
    - New chi2 fit method, PDF as nuisance
  - Testing extrapolation unc. assumptions
- ATLAS result moves by 1.1 GeV towards CMS result
  - ~10% more precise
- Combination:
  - Testing different correlation assumptions
    - No correlation: 172.25 +/- 0.92 (total) GeV
    - JES only: 172.25 +/- 0.91 (total) GeV
    - JES+modeling: 172.33 +/- 0.93 (total) GeV
    - JES+modeling+tt0jet: 172.35 +/- 0.93 (total) GeV

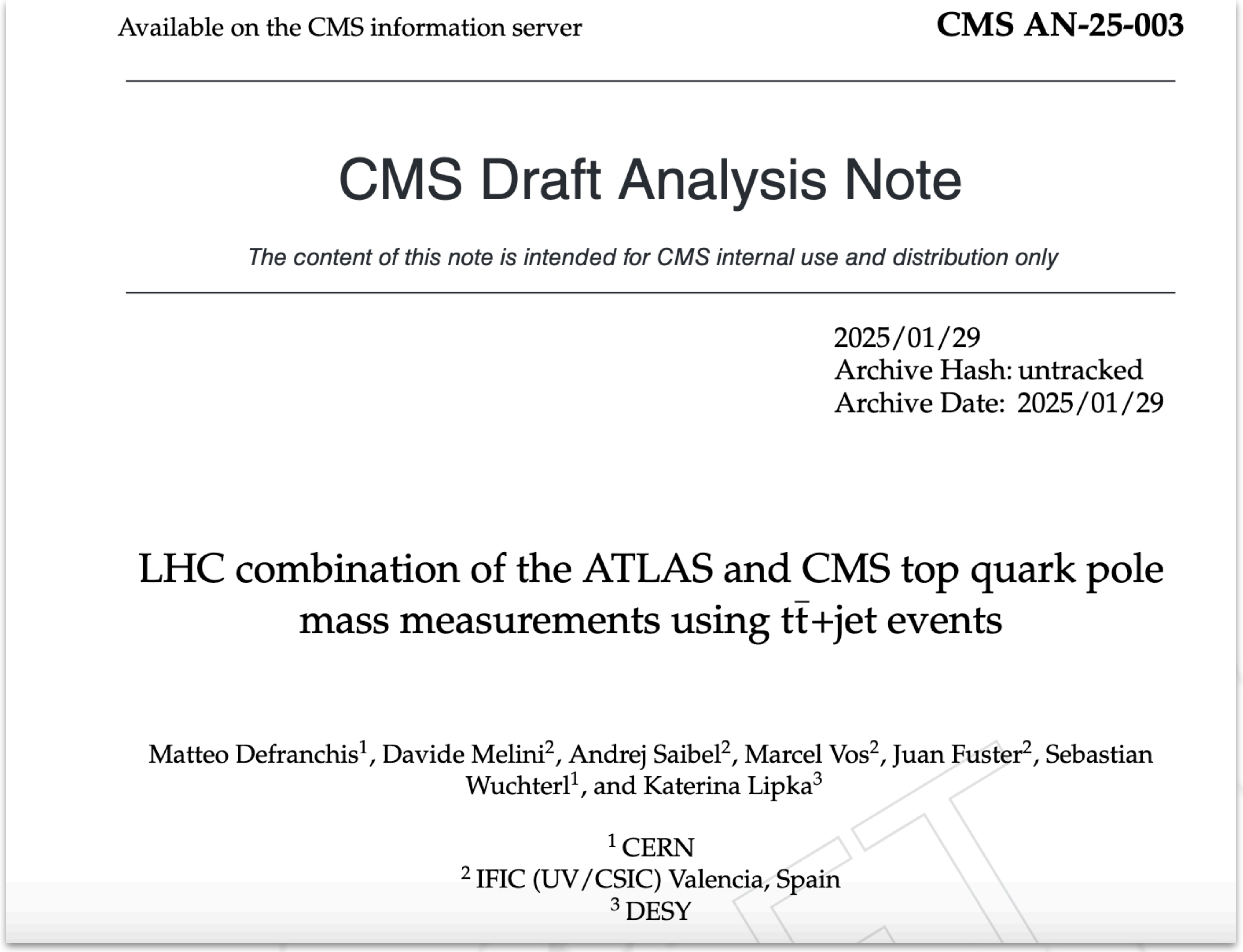


Conclusions and outlook

- We have a closed LHC top WG meeting 14th February
- We have started writing a note
  - Want to finalise most of it by the meeting

- Additional correlation scans to be done
- Inclusion of different PDF sets

- Can only improve with published new 13 TeV results!



Available on the CMS information server **CMS AN-25-003**

CMS Draft Analysis Note

The content of this note is intended for CMS internal use and distribution only

2025/01/29
Archive Hash: untracked
Archive Date: 2025/01/29

LHC combination of the ATLAS and CMS top quark pole mass measurements using $t\bar{t}$+jet events

Matteo Defranchis[1], Davide Melini[2], Andrej Saibel[2], Marcel Vos[2], Juan Fuster[2], Sebastian Wuchterl[1], and Katerina Lipka[3]

[1] CERN
[2] IFIC (UV/CSIC) Valencia, Spain
[3] DESY