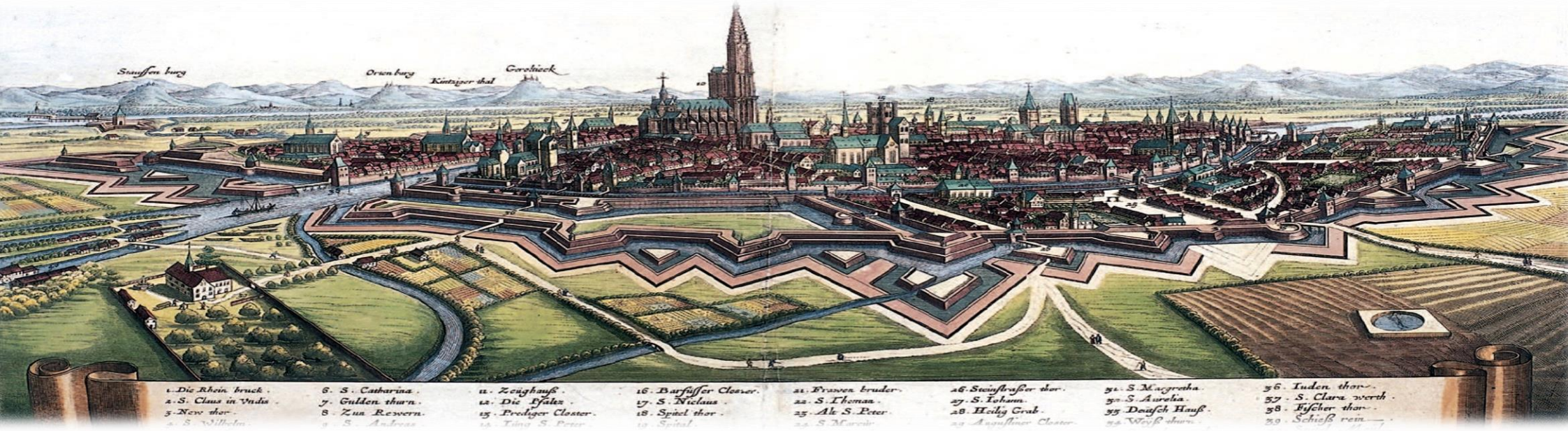
LHC *Top* Working Group report

Martijn Mulders (CERN)

3rd CMS Single Top Workshop, Strasbourg

June 2-3, 2016



LHC *Top* WG

Goal and structure:

- Combine measurements to obtain ultimate precision on top observables at the LHC
- Forum for discussions (ATLAS+CMS+LHCb+theory) on modeling, systematic effects and interpretation of LHC top physics measurements
- Two open meetings per year
- Regularly closed meetings
- Part of LPCC organization (LHC physics centre at CERN)

Results Obtained So far

In 5 years:

- 8 ATLAS-CMS TOP notes and 2 JetMET notes
- 1 World Average
- Agreements
- Summary Plots

+ NEW!

- Legacy(?) 8 TeV *Wt* combination

CMS-PAS-TOP-15-019
ATLAS-CONF-2016-023

Top WG documents

- Combination of ATLAS and CMS top-quark pair cross-section measurements using proton-proton collisions at √s = 7 TeV,
  ATLAS-CONF-2012-134
  CMS-PAS-TOP-12-003
- Combination of ATLAS and CMS results on the mass of the top quark using up to 4.9 fb−1 of data
  ATLAS-CONF-2012-095
  CMS-PAS-TOP-12-001
- Combination of the ATLAS and CMS measurements of the W-boson polarization in top-quark decays
  ATLAS-CONF-2013-033
  CMS-PAS-TOP-12-025
- Combination of ATLAS and CMS results on the mass of the top-quark using up to 4.9/fb of √s=7 TeV LHC data
  ATLAS-CONF-2013-102
  CMS PAS TOP-13-005
- Combination of single-top-quark cross section measurements in the t-channel at sqrt[s]=8 TeV with the ATLAS and CMS experiments
  ATLAS-CONF-2013-098
  CMS PAS TOP-12-002
- Combination of the charge asymmetry in t-tbar production at sqrt[s]=7 TeV with the ATLAS and CMS experiments
  ATLAS-CONF-2014-012
  CMS-PAS-TOP-14-006
- World average combination of the top quark mass, including results of the CDF and D0 experiments at the Tevatron, and of the ATLAS and CMS experiments
  http://arxiv.org/abs/arXiv:1403.4427
  ATLAS-CONF-2014-008; CDF-NOTE-11071; CMS-PAS-TOP-13-014; D0-NOTE-6416
- Combination of ATLAS and CMS top-quark cross-section measurements in the e-mu final states using proton-proton collisions at √s = 8 TeV
  ATLAS-CONF-2014-054
  CMS-PAS-TOP-14-016
- Combination of cross-section measurements for associated production of a single top-quark and a W boson at √=8 TeV with the ATLAS and CMS experiments
  ATLAS-CONF-2014-052
  CMS-PAS-TOP-14-009

https://lpcc.web.cern.ch/lpcc/index.php?page=top_wg

From Combinations to Publications

First round of combinations:

- Warning: most existing combinations outdated by now :-/
- But: allowed to discuss/compare beyond the strict collaboration rules
- differences in systematics treatment identified
- recommendations for systematics of future measurements

Towards *publication* of legacy Run-1 combinations:

- The ultimate experimental precision from the LHC Run-1
- Should not become obsolete any time soon..!
- Follow procedures, categorisations, initial agreements reached; some improvements compared to 1st round

Agreements / Recommendations

- Jet Energy Scale Uncertainties → splitting of JES components and correlations between ATLAS and CMS, see public notes
  - 7 TeV : ATLAS Pub 2014-020 // CMS JME-14-003
  - 8 TeV : ATLAS Pub 2015-049 // CMS JME-15-001

- B-tagging uncertainties → splitting of components and correlations
  - https://twiki.cern.ch/twiki/bin/view/LHCPhysics/BTaggingSystematics

- Particle-level objects and Pseudo-top-quark definitions
  - https://twiki.cern.ch/twiki/bin/view/LHCPhysics/ParticleLevelTopDefinitions

- Recommendations for Theory Modeling Uncertainties (to be updated)
  - https://twiki.cern.ch/twiki/bin/view/LHCPhysics/TheorySystematics

- Reference Cross-section predictions: agree on calculation, settings (top mass, alpha_s), uncertainties (scales, pdf)
  - NNLO+NNLL ttbar: https://twiki.cern.ch/twiki/bin/view/LHCPhysics/TtbarNNLO
  - NLO(+NNLL) single top: https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SingleTopRefXsec

Recent discussion: E_{beam} uncertainty

Relative uncertainty on LHC beam energy ~0.66%

- CERN-ATS-2013-040 : https://cds.cern.ch/record/1546734?ln=en
- Confirmation at 13 TeV requires special (short) p-Pb runs
- Goal for 'near future': provide official uncertainty at 0.1% level
  (J. Wenninger at https://indico.cern.ch/event/472719)

Effect on measured cross-sections

- Effect on analysis acceptance negligible (<< 0.1% for e-mu ttbar)
- Effect through background subtraction … probably negligible
- Variation of 'true' cross-section as function of $\sqrt{s}$ → can be sizable… estimated effect for ttbar (using theory prediction):

Process	7 TeV	8 TeV	13 TeV	typical precision
Top pair production	1.8%	1.7%	1.5%	3 - 4%
Single top t-channel		~1%		~9%

New E_{beam} proposal / agreement

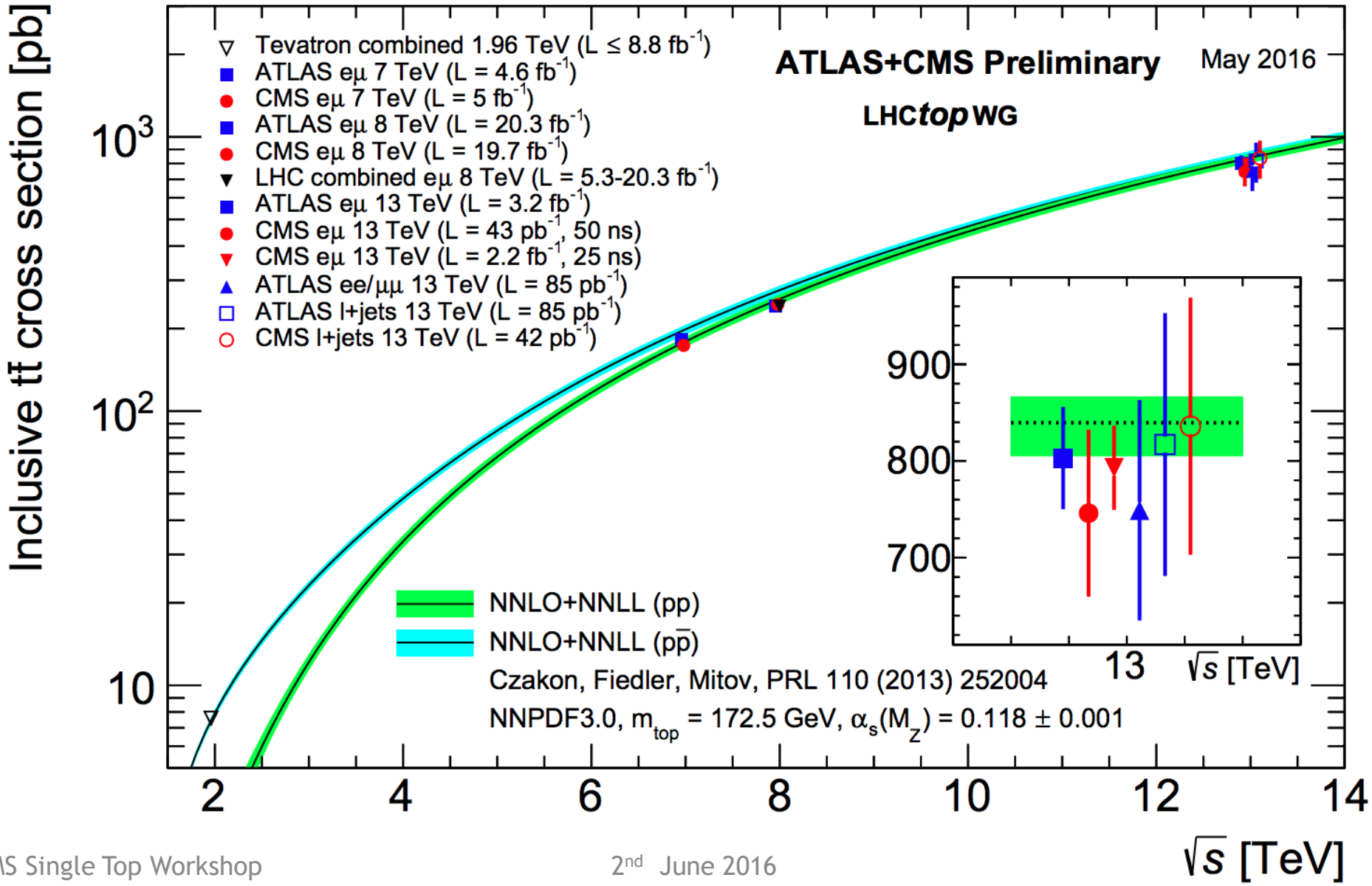
- **(Agreed)** For the measurement of an observable for which the theoretically predicted value depends on the LHC beam energy, **the size of the variation of the theory prediction** for this observable corresponding to the LHC beam energy uncertainty **should be mentioned** in the publication, if it matters

- **(Agreed) Inclusion** of this effect **as a systematic uncertainty**, quoted in the final measurement result, **is optional, unless** the result is an interpretation (eg extraction of Vtb or mt_pole), in which case the uncertainty must be included, if it matters

- **(Agreed)** For our summary plots we stay with the current previously agreed disclaimer, at least for now

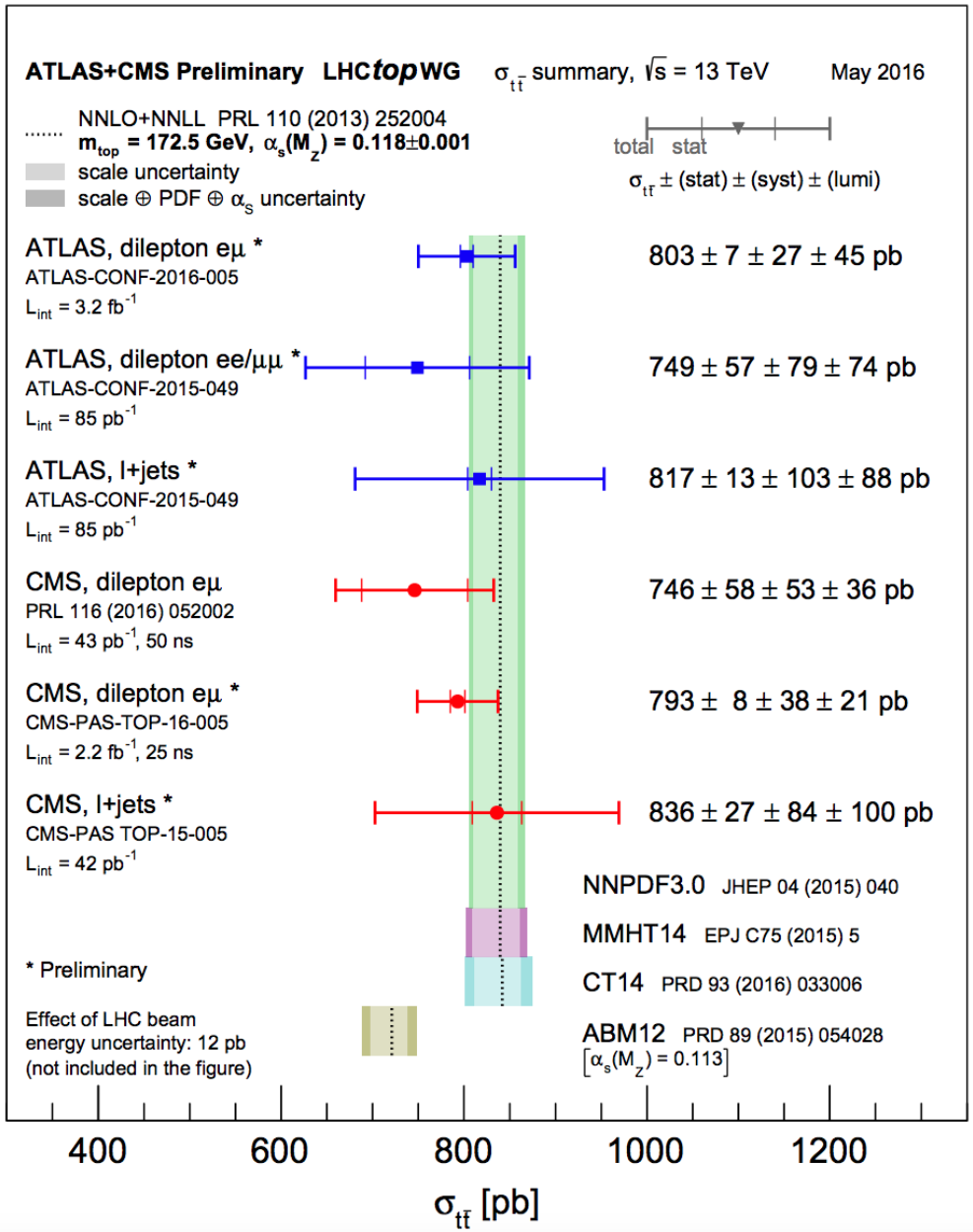
Summary Plots

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCTopWGSummaryPlots



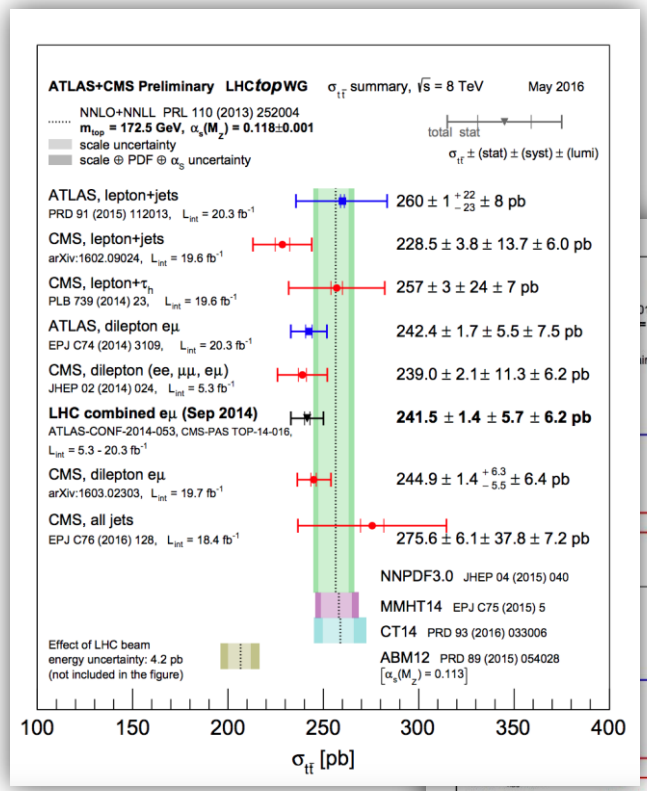
ttbar per energy:

13 TeV

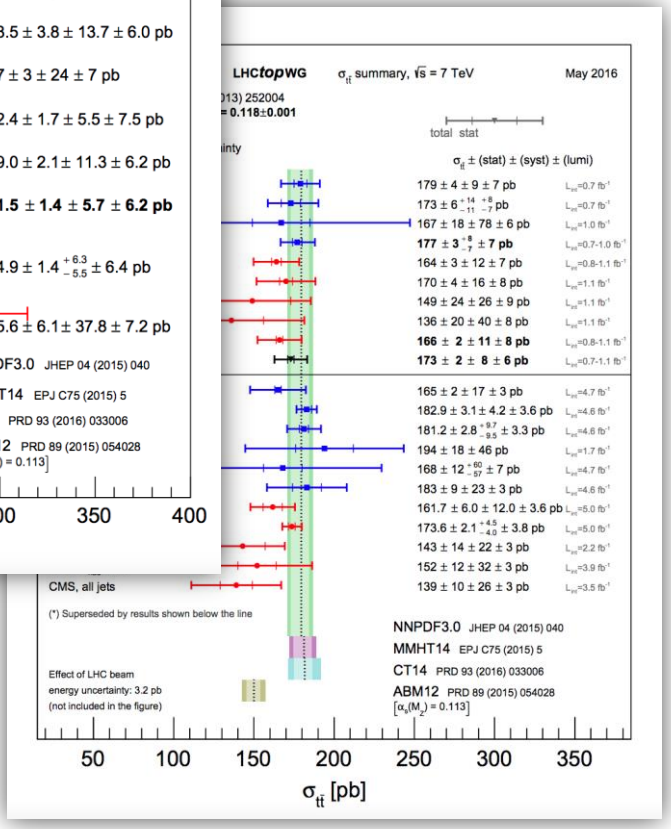


Note: new presentation of PDFs ; beam energy disclaimer as before

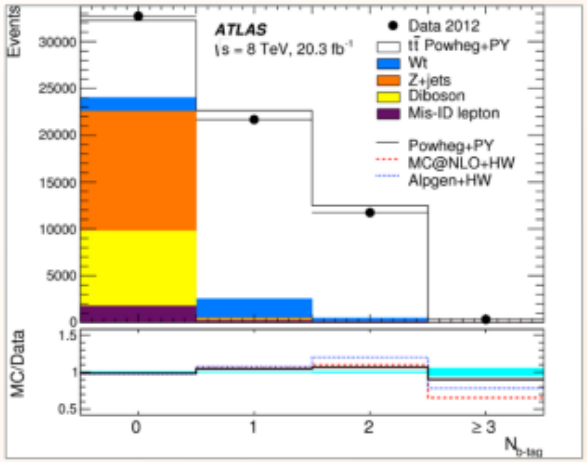
8 TeV

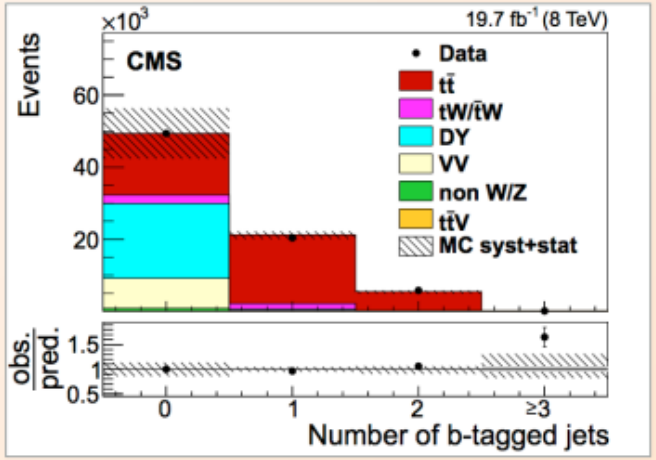


7 TeV



Prospects ttbar Combination





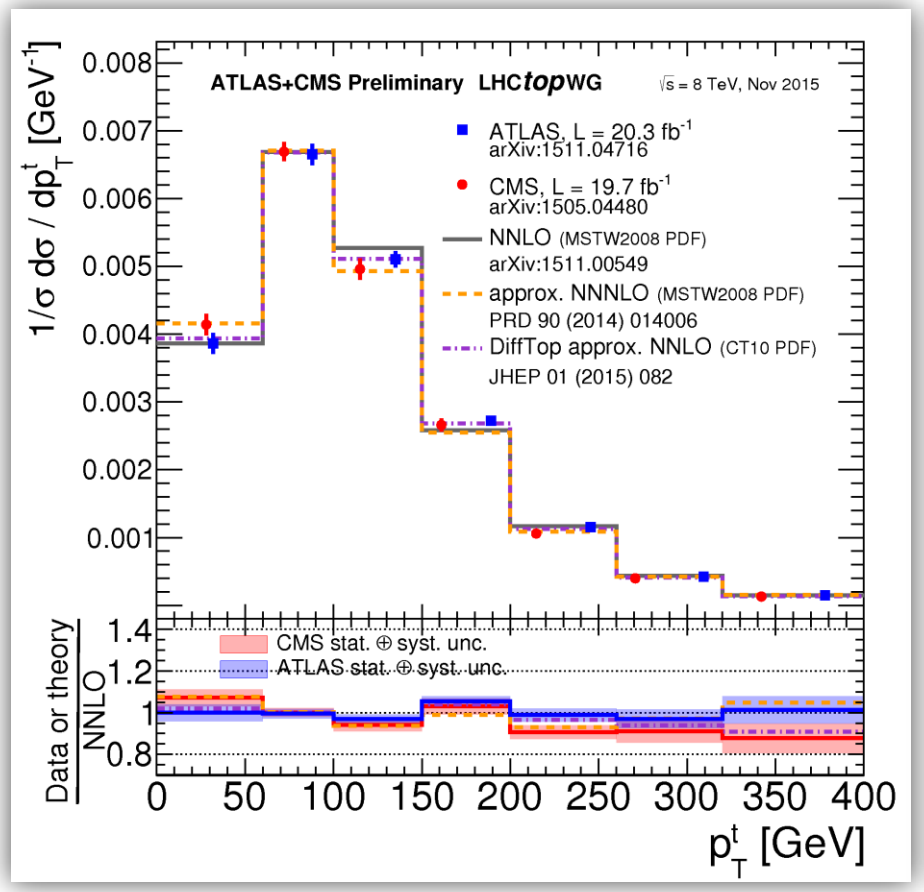
- **ATLAS**:
  - Luminosity
  - Statistics (7 TeV only)
  - Signal modelling
  - PDF
  - tW background

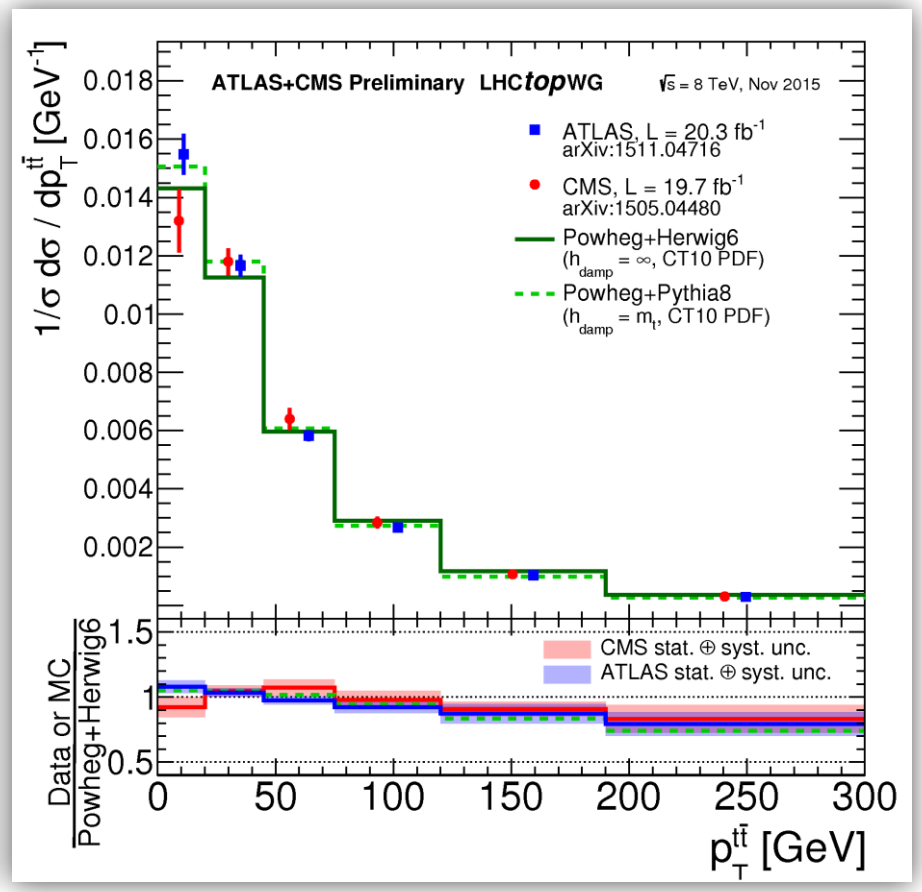
Uncorrelated
- Part of luminosity
- Statistics
- Lepton ID/isolation
- Trigger
- Jet resolution/ID

- **CMS**:
  - Luminosity
  - Lepton ID/Isolation
  - Z+jets background
  - Trigger
  - Statistics (7 TeV only)

- Combine precise ATLAS and CMS dilepton (e-μ) "legacy" measurements at 7 and 8 TeV and also extract top pole mass
- Expect significant gain in precision → Aim for publication

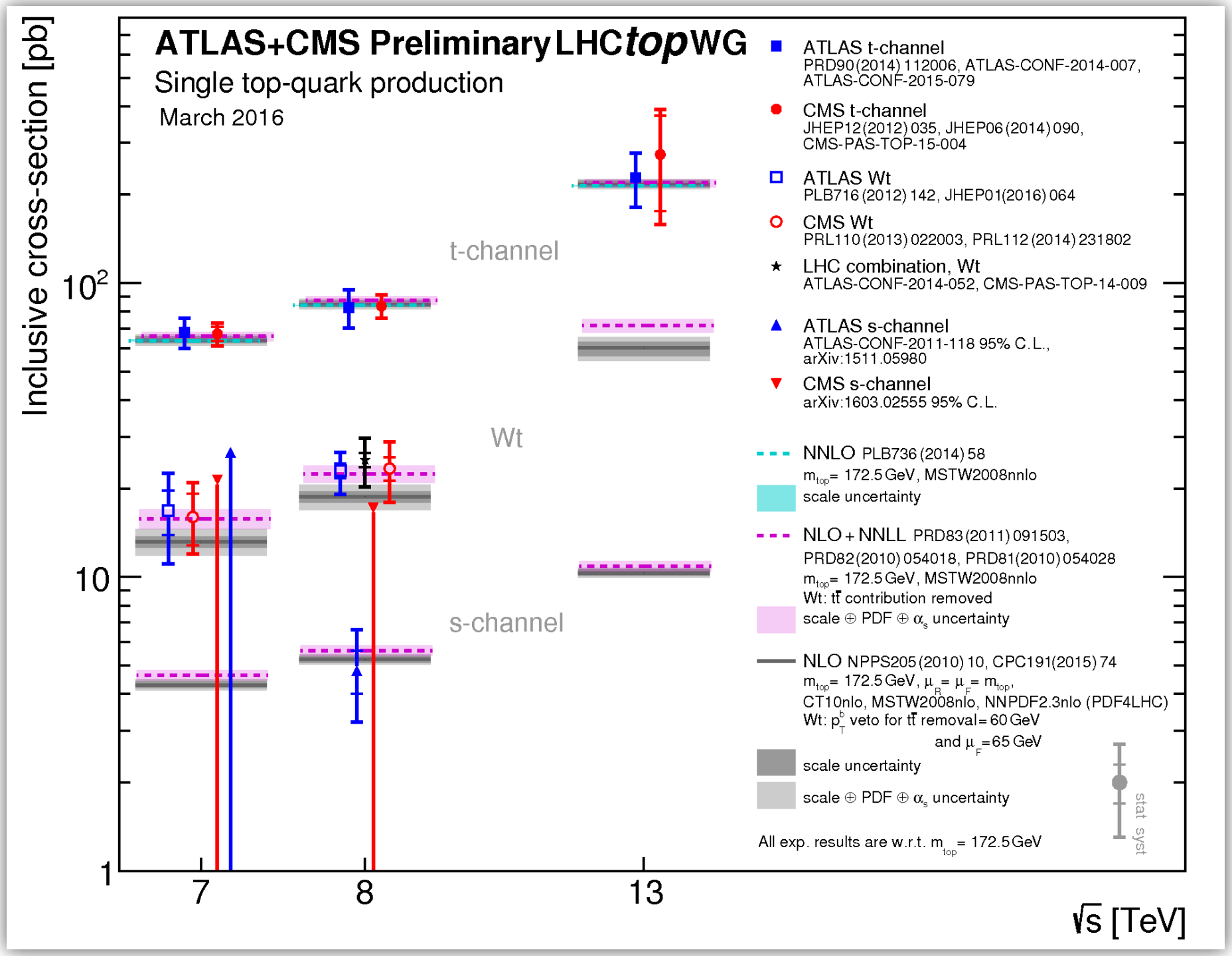
(differential) ttbar comparison plots:





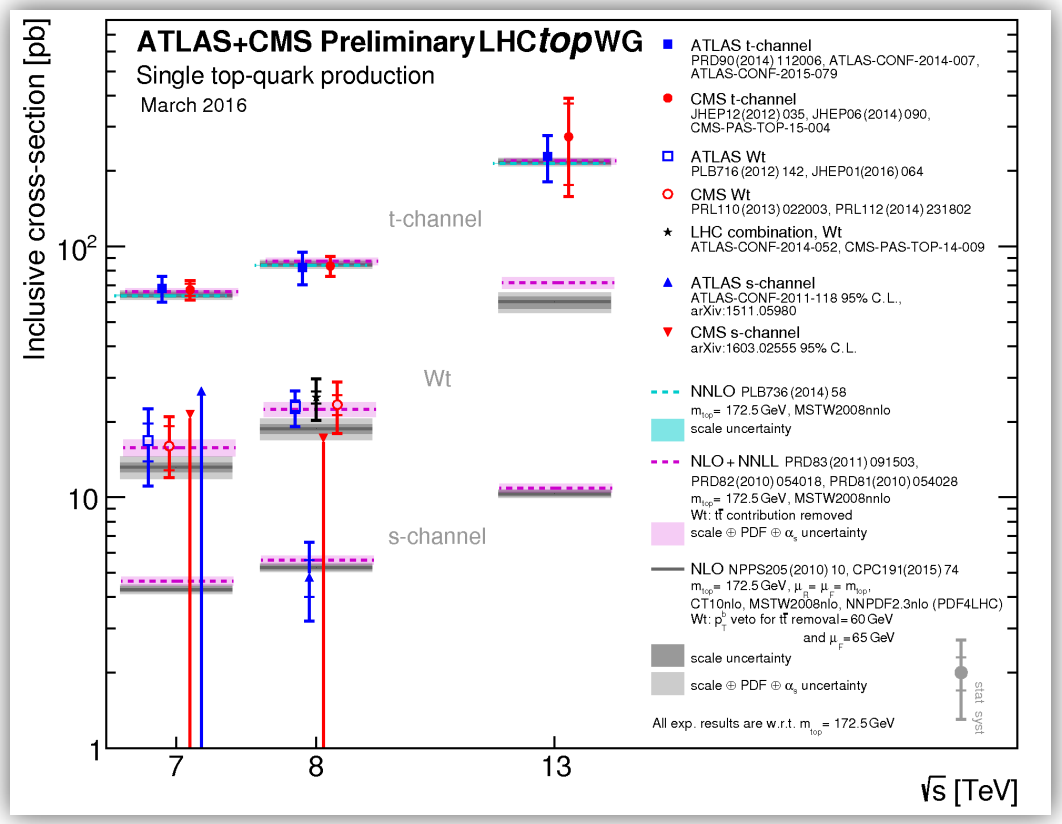
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCTopWGSummaryPlots

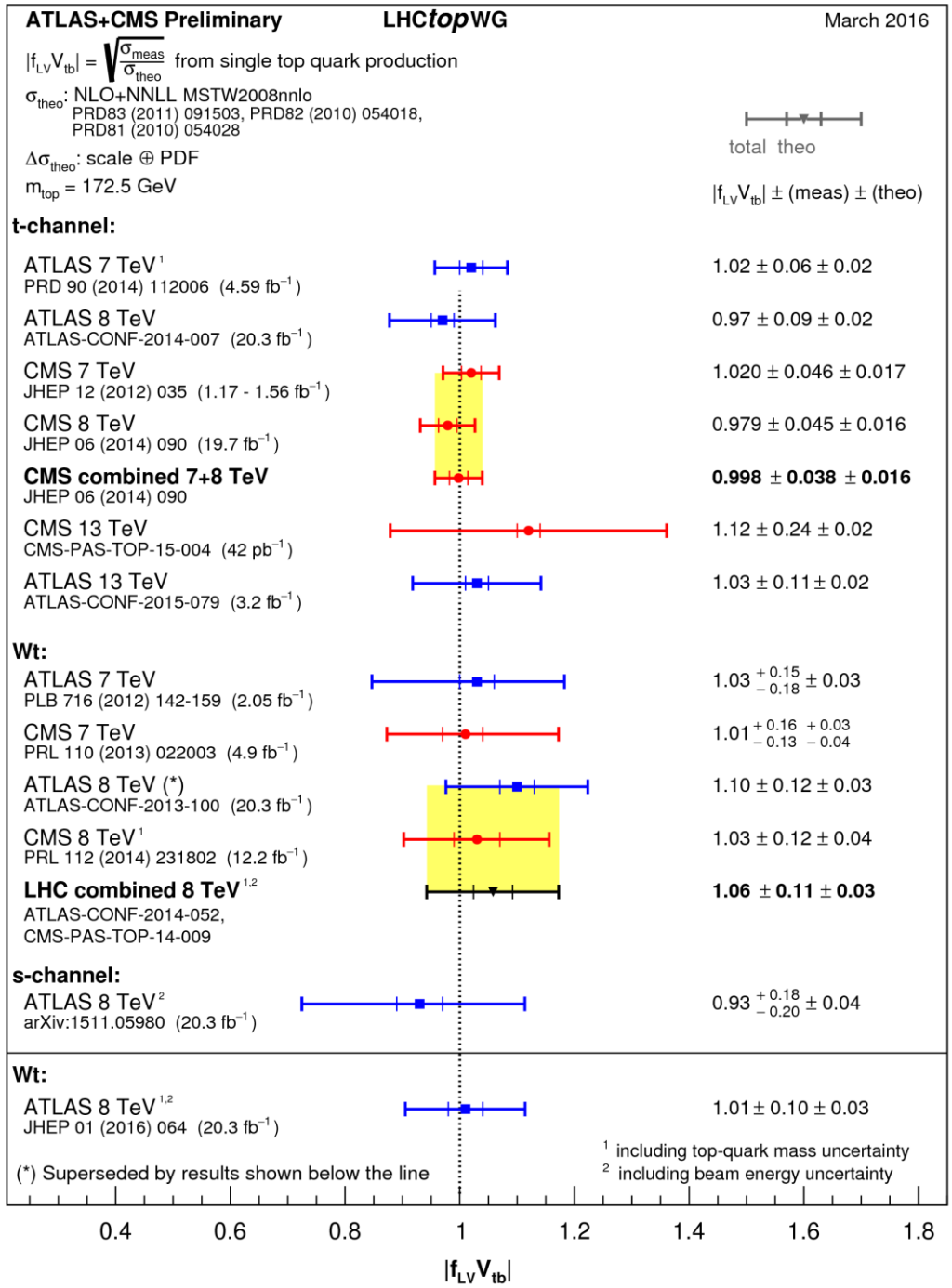
Single Top …


ATLAS+CMS Preliminary LHCtopWG
Single top-quark production
March 2016
Inclusive cross-section [pb]
t-channel
Wt
s-channel
10²
10
1
7
8
13
√s [TeV]
ATLAS t-channel
PRD90(2014) 112006, ATLAS-CONF-2014-007, ATLAS-CONF-2015-079
CMS t-channel
JHEP12(2012) 035, JHEP06(2014) 090, CMS-PAS-TOP-15-004
ATLAS Wt
PLB716(2012) 142, JHEP01(2016) 064
CMS Wt
PRL110(2013) 022003, PRL112(2014) 231802
LHC combination, Wt
ATLAS-CONF-2014-052, CMS-PAS-TOP-14-009
ATLAS s-channel
ATLAS-CONF-2011-118 95% C.L., arXiv:1511.05980
CMS s-channel
arXiv:1603.02555 95% C.L.
NNLO PLB736(2014) 58
m_top = 172.5 GeV, MSTW2008nnlo
scale uncertainty
NLO + NNLL PRD83(2011) 091503, PRD82(2010) 054018, PRD81(2010) 054028
m_top = 172.5 GeV, MSTW2008nnlo
Wt: tt̄ contribution removed
scale ⊕ PDF ⊕ α_s uncertainty
NLO NPPS205(2010) 10, CPC191(2015) 74
m_top = 172.5 GeV, μ_R = μ_F = m_top,
CT10nlo, MSTW2008nlo, NNPDF2.3nlo (PDF4LHC)
Wt: p_T^b veto for tt̄ removal = 60 GeV
and μ_F = 65 GeV
scale uncertainty
scale ⊕ PDF ⊕ α_s uncertainty
All exp. results are w.r.t. m_top = 172.5 GeV
stat
syst

… and V_{tb}

Note: still to be added -- new CMS t-channel result at 13 TeV and Wt combination

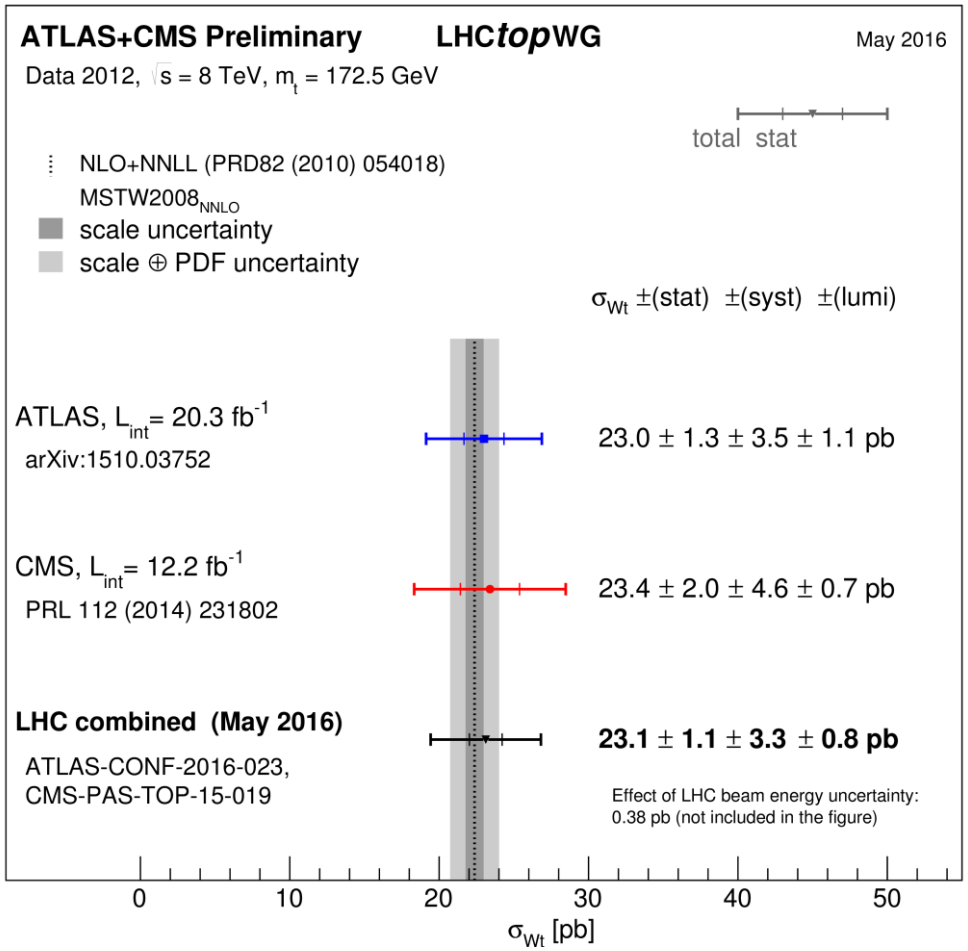




Single Top and V_{tb}

NEW: Wt combination @ 8 TeV

CMS-TOP-15-019 // ATLAS-CONF-2016-023



Plan for publication:

- Assume CMS 8 TeV Wt is final (?)
- Extract $|f_L V_{tb}|^2$ from *published* cross-sections in all 3 channels, at 7 and 8 (and maybe 13) TeV
- Assume Vtd and Vts are negligible in production and decay
- Assume SM-like kinematics
  - Coupling V-A structure
- No assumption on CKM unitarity
  - Sensitive to BSM effects
  - Top could mix eg with Top partners
- Discuss: update theory predictions?
  - Eg use NNLO in t-channel
  - Or consistently NLO everywhere?
- For future ideas, see Orso's talk: https://indico.cern.ch/event/403826

Other “Legacy” publications in pipeline

8 TeV ttV cross-sections and limits on anomalous couplings / EFT

- ATLAS and CMS ‘legacy’ 8 TeV results published
- Also include per-channel combinations
- No BLUE → likelihood-based combination (new for LHC*Top*WG!)

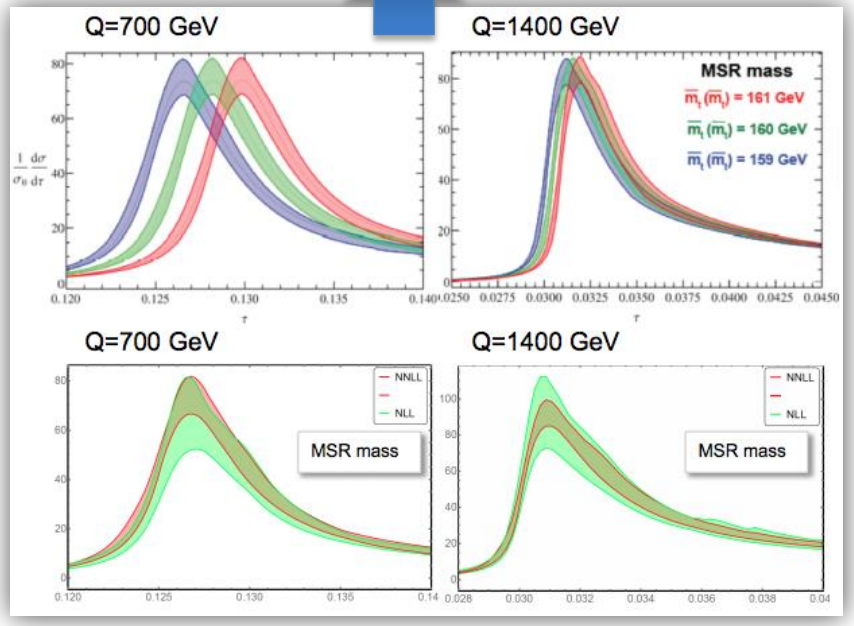
ttbar Charge Asymmetry at 8 TeV

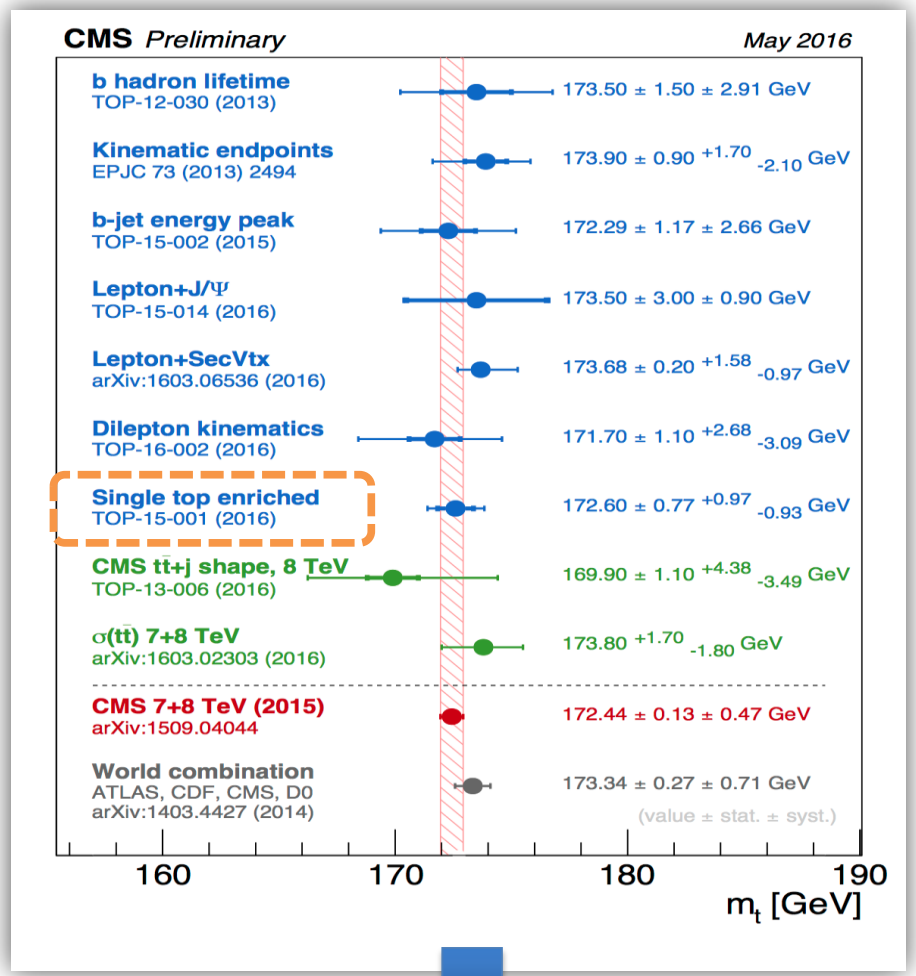
- ATLAS and CMS ‘legacy’ 8 TeV results published (l+jets)
- Aim for combination inclusive and differential (new!) results

And: top mass

Hot topic: *theory interpretation*

- MC mass vs Pole mass… is it “roughly the same thing” +- uncertainty (?)
- Ambiguity of pole mass vs other mass schemes only 200 – 70 MeV (?)
  (Beneke, Marquard, Nason, Steinhauser arXiv1605.03609)
- Calibrate theory vs MC mass (A. Hoang)





Alternative methods/ observables:

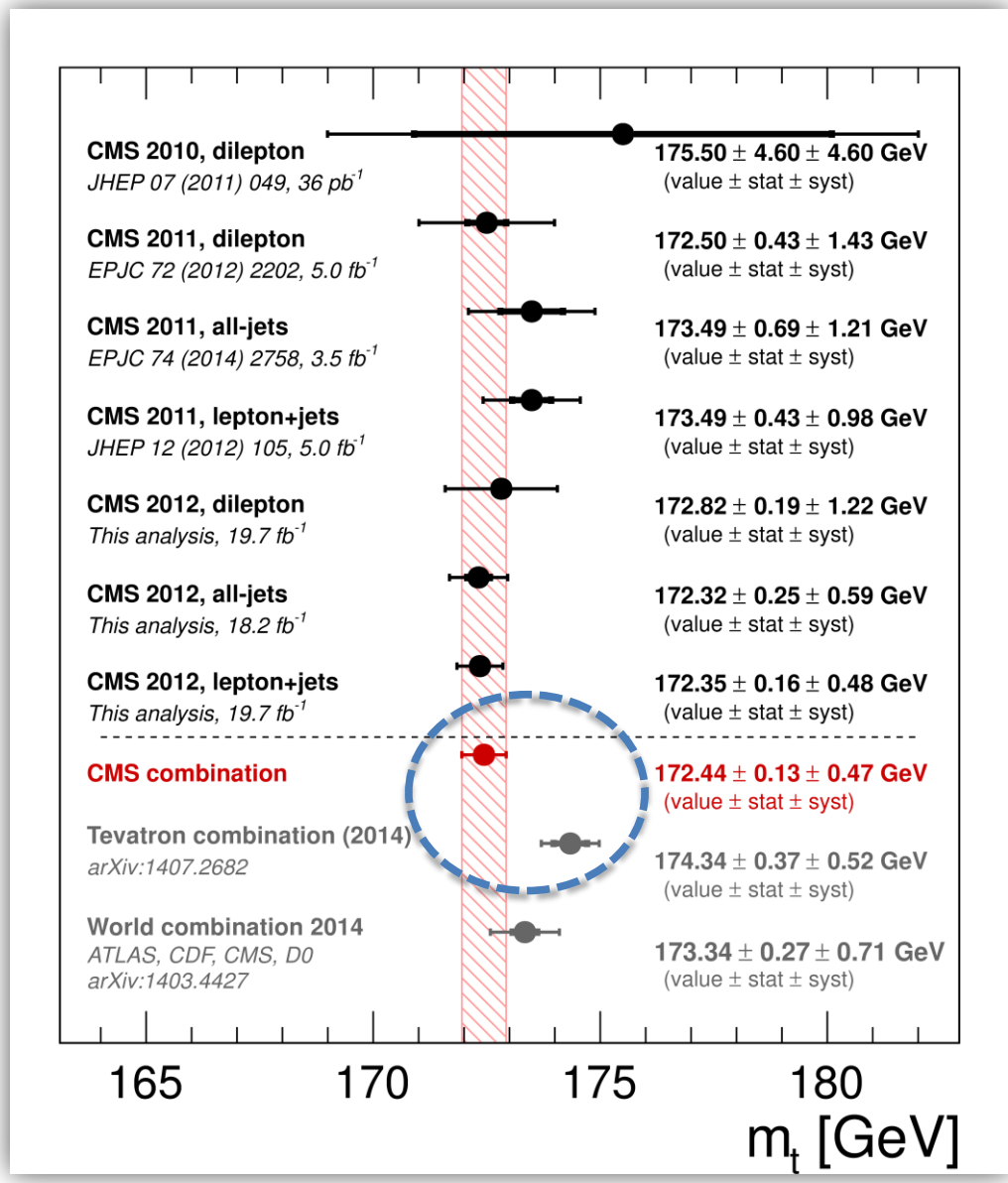
- Many new experimental results using different methods and observables
- Some observables can be calculated in QCD (without relying on MC)

Towards new top mass World Average

Still a number of steps:

- Finalize comparison D0 and CMS most precise results + provide public document
- Wait for final 8 TeV results (?)
- Decide which inputs to include besides “standard” results
- Agree on correlations & categorizations
- Perform combination (with BLUE) and write paper

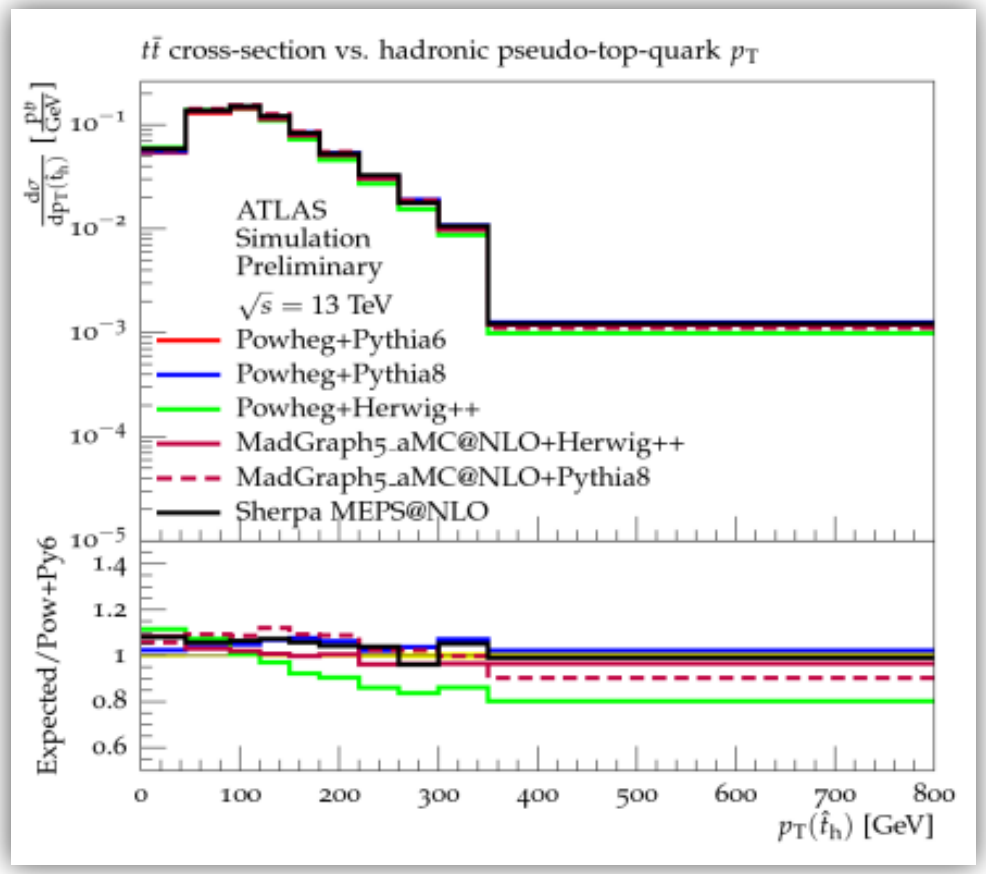
- *Review, Approve, Publish...!*

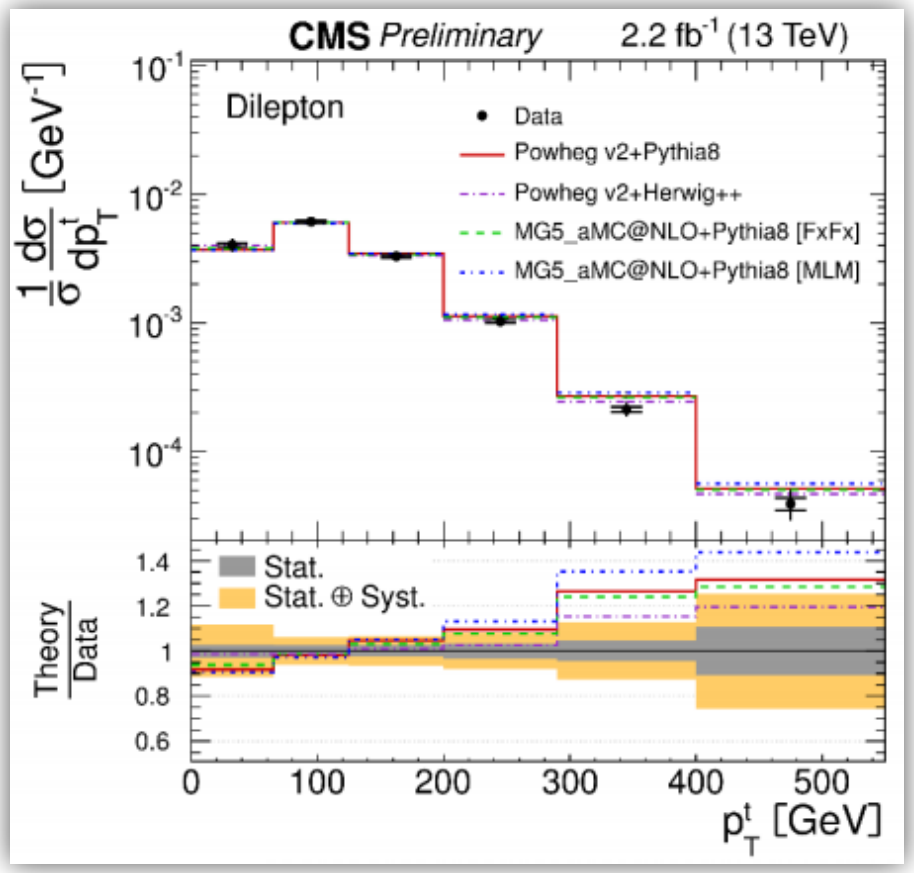


In parallel: preparing for Run2 Combinations…

Important ingredient: establish & compare baseline Run2 MC tools

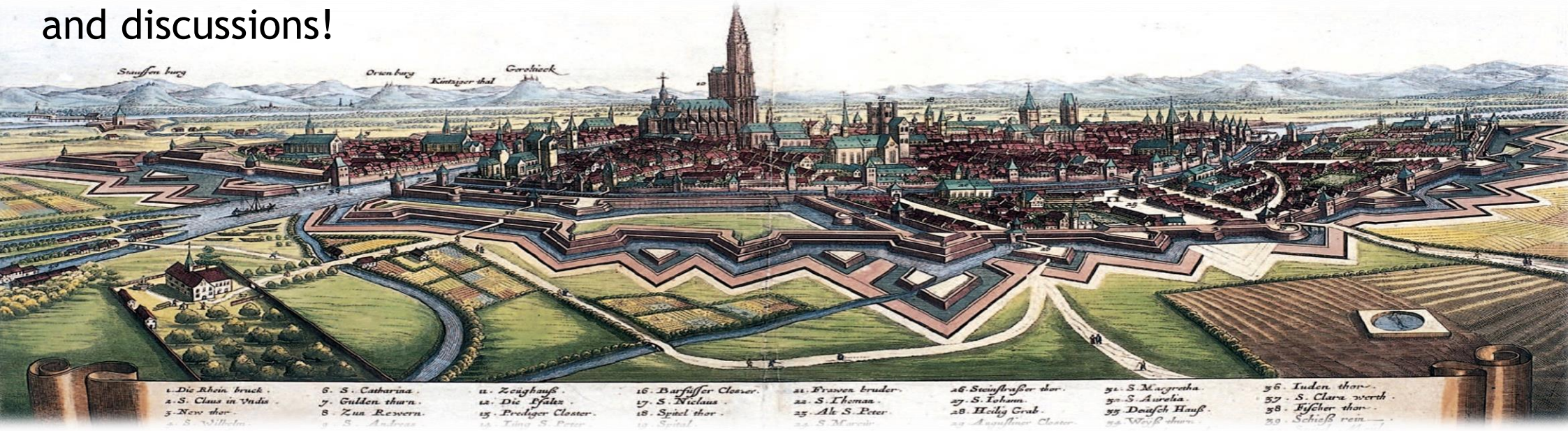
See talks by Ben Nachman at https://indico.cern.ch/event/403826/ and Javier Fernandez and John Keller at https://indico.cern.ch/event/472719/





Credits

Experiment+theory contacts: Victor Coco, Alison Lister, Michelangelo Mangano, MM + Combination contacts: Frederic Deliot, Thorsten Chwalek, Markus Cristinziani, Andrew Brinkerhoff, Elizaveta Shabalina, Jan Kieseler, Reinhard Schwienhorst, Nadjieh Jafari, Giorgio Cortiana, Steve Wimpenny, Francesco Spanò, Maria Aldaya + Topical Experts: Steven Schramm, Dimitris Varouchas, Mikko Voutilainen, Henning Kirschenmann, Kevin Finelli, Dominic Hirschbühl, Junghwan Goh, Orso Iorio, Mara Senghi, James Ferrando, Benedikt Maier, Markus Seidel, Martin zur Nedden, Liza Mijovic, Luca Scodellaro… AND ALL OF YOU who perform the measurements or calculations and/or join our meetings and discussions!



Conclusions

Exciting Times! Good collaboration & Lively discussions

- Working on first Run1 publications of combined results
  - ttbar
  - Single Top and Vtb !!
  - Charge Asymmetry
  - ttV
  - Top mass…
- Getting ready for Run2 combinations, with help of theory colleagues
- Possibly: workshop dedicated to Top couplings and EFTs this summer
- Next Open Meeting : Nov 21-22

More Info:

- LPCC Web Page https://lpcc.web.cern.ch/lpcc/index.php?page=top_wg
- LHCTopWG Twiki https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCTopWG
- Summary Plots https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCTopWGSummaryPlots
- Indico Category https://indico.cern.ch/category/4463/
- Join the public mailing list lhc-toplhcwg@cern.ch