Meeting of the
LHC Electroweak Working Group

CERN, 13-14 December 2017

Contacts :

ATLAS : M. Boonekamp / U.Blumenschein
CMS : J. Bendavid, M. Velasco
LHCb : W. Barter, T. Shears
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LPCC : M.Mangano

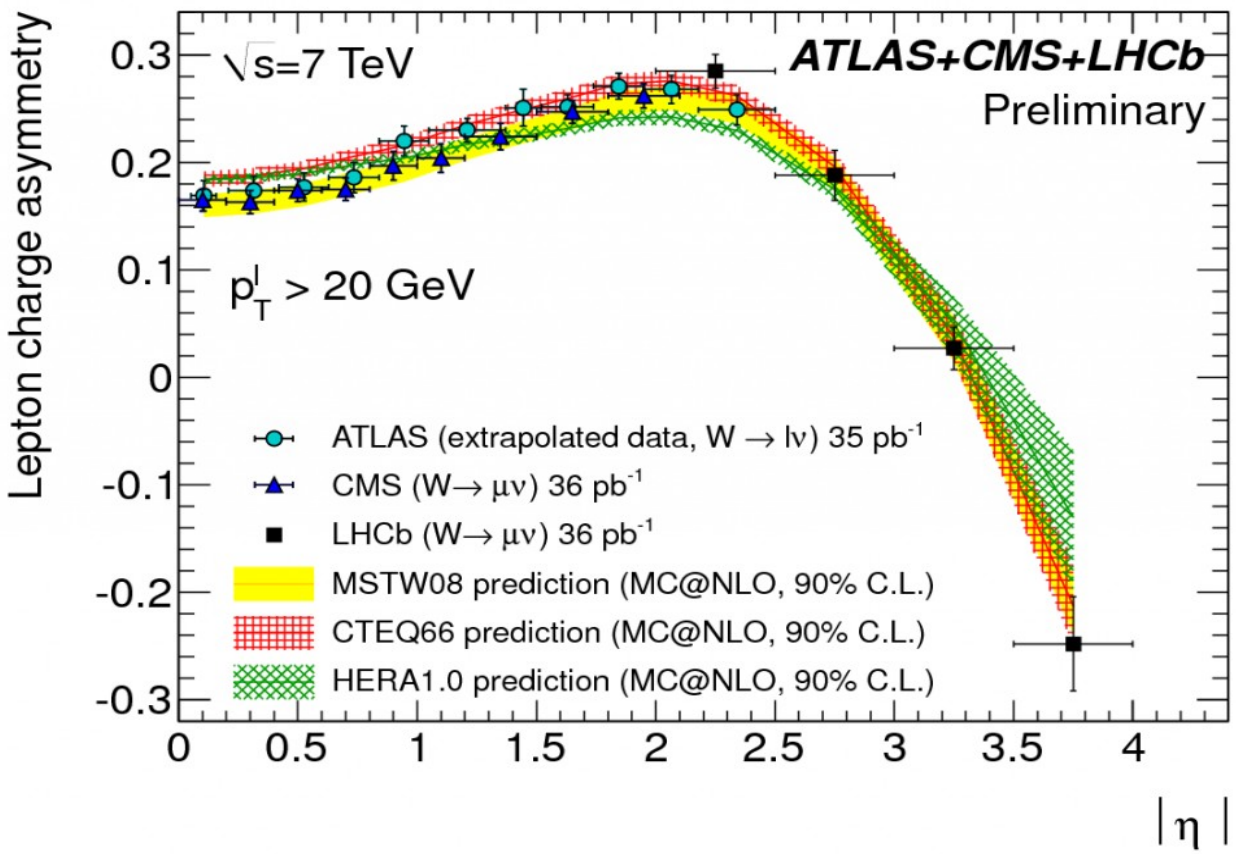
Indico : https://indico.cern.ch/category/3290/

Scope of this WG

- Support, compare and combine measurements probing the electroweak structure of the SM (fundamental electroweak parameters; tests of the gauge structure);
- Pursue theoretical developments in support of these measurements, and of their interpretation;
- compare and combine ancillary measurements performed in support of the EW precision measurements, and define how they constrain the theoretical uncertainties.
- Organize, compare and combine measurements of jet production; understand their implications on the strong interaction and PDFs.
- Final states:
  - Jet production (inclusive, and in association with vector boson)
  - Single vector boson production
  - Di-boson and multi-boson production

Past activity

- Measurements of W & Z production as tests of QCD
  - comparisons of experimental results; definition of theoretical predictions and uncertainties; combination of QCD and EW corrections



To be repeated with more data and many more final states...

Past activity

- W & Z production as tests of QCD
  - comparisons of experimental results; definition of theoretical predictions and uncertainties; combination of QCD and EW corrections

Precision Studies of Observables in $pp \to W \to l\nu_l$ and $pp \to \gamma, Z \to l^+l^-$ processes at the LHC

S. Alioli[a1], A.B. Arbuzov[a2,a3], D.Yu. Bardin[a2], L. Barzè[a4,a6], C. Bernaciak[a5], S.G. Bondarenko[a2,a3], C. Carloni Calame[a6], M. Chiesa[a6], S. Dittmaier[a7], G. Ferrera[a8], D. de Florian[a9,a10], M. Grazzini[a11], S. Höche[a12], A. Huss[a13], S. Jadach[a14], L.V. Kalinovskaya[a2], A. Karlberg[a15], F. Krauss[a16], Y. Li[a17], H. Martinez[a4,a6], G. Montagna[a4,a6], A. Mück[a18], P. Nason[a19], O. Nicrosini[a6], F. Petriello[a20,a21], F. Piccinini[a6], W. Płaczek[a22], S. Prestel[a12], E. Re[a23], A.A. Sapronov[a2], M. Schönherr[a11], C. Schwinn[a18], A. Vicini[a8], D. Wackeroth[a5,a24], Z. Was[a14], G. Zanderighi[a1,a15]

arXiv:1606.02330

  - Describes the state of the art in calculations of W and Z production.

    Benchmark results for total and fiducial cross sections.

    First step towards optimal tools combining all pieces, and required for high-precision measurements of electroweak processes and parameters

Past activity

- TH/EXP discussions in support of the measurement of m_W (and recently $\sin^2\theta_W$)
  - 1-2 meetings per year, accelerating
    - Florence, 2014 https://indico.cern.ch/event/340393/
    - CERN, 2015 https://indico.cern.ch/event/367442/
    - CERN, 2016 https://indico.cern.ch/event/533804/
    - Mainz, 2017 https://indico.cern.ch/event/595512/
    - CERN, 2017 https://indico.cern.ch/event/642499/
    - Orsay, 2017 https://indico.cern.ch/event/661916/
  - Generator developments; EW corrections; QCD predictions including p_T resummation..

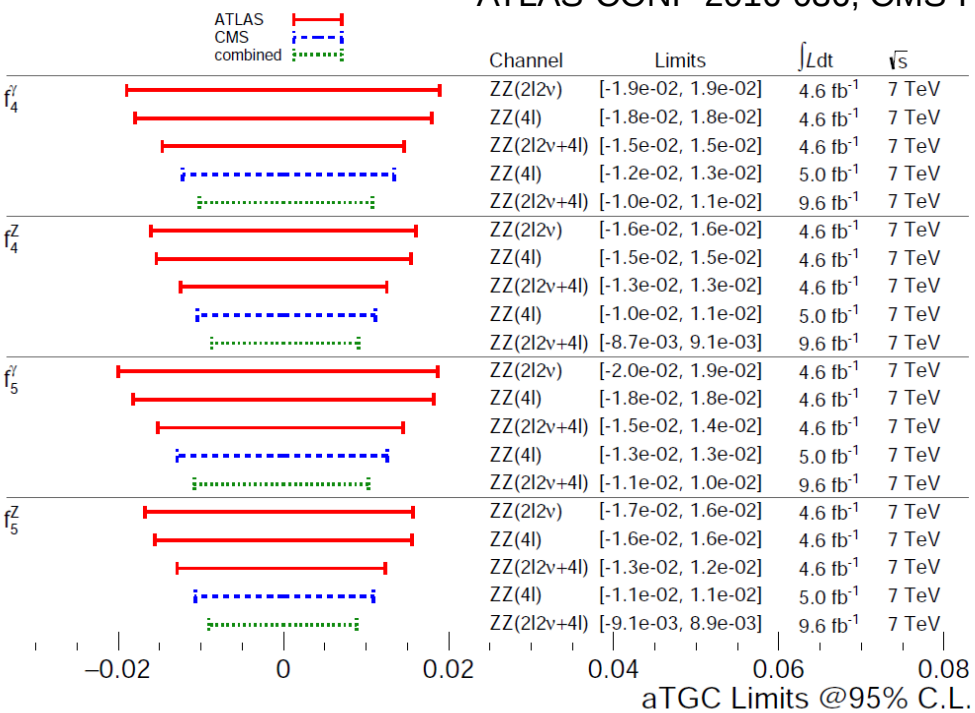
    Progress in identifying the relevant issues; need to start providing answers

- Jet production and V+jets : meetings in 2012 & 2013, not followed up

Past activity

- Di-boson and multi-boson production
  - Most active group in recent years
  - Common conventions on signal definitions, fiducial cuts for unfolded results, interpretation in terms of anomalous couplings

ATLAS-CONF-2016-036, CMS-PAS-SMP-15-001



To be extended with more data, final states; extend beyond traditional aTGC parameterisation

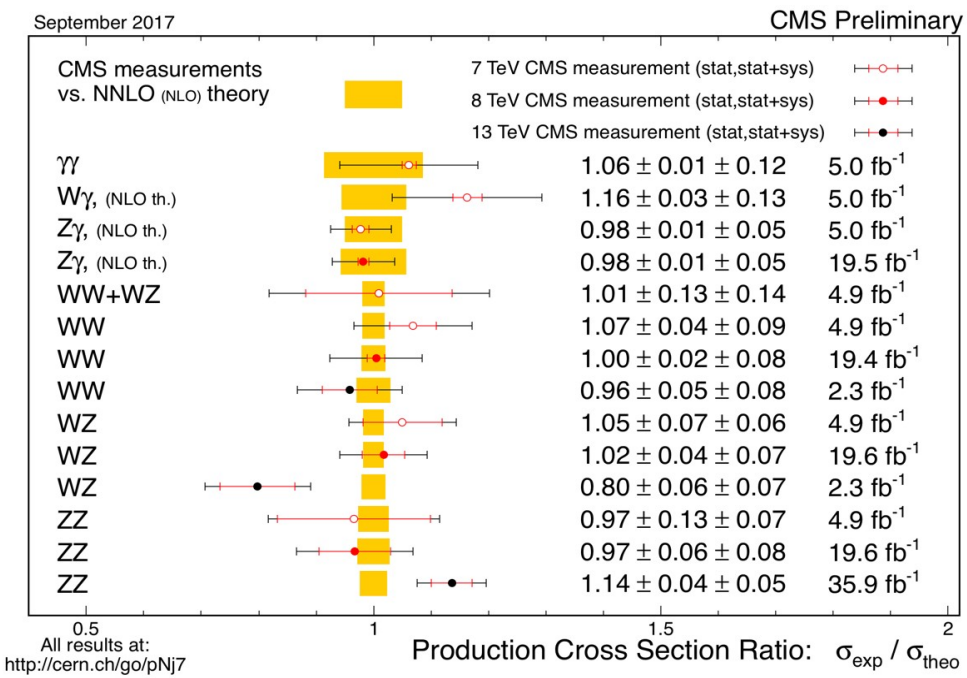
Most importantly : a proof of concept for future combinations

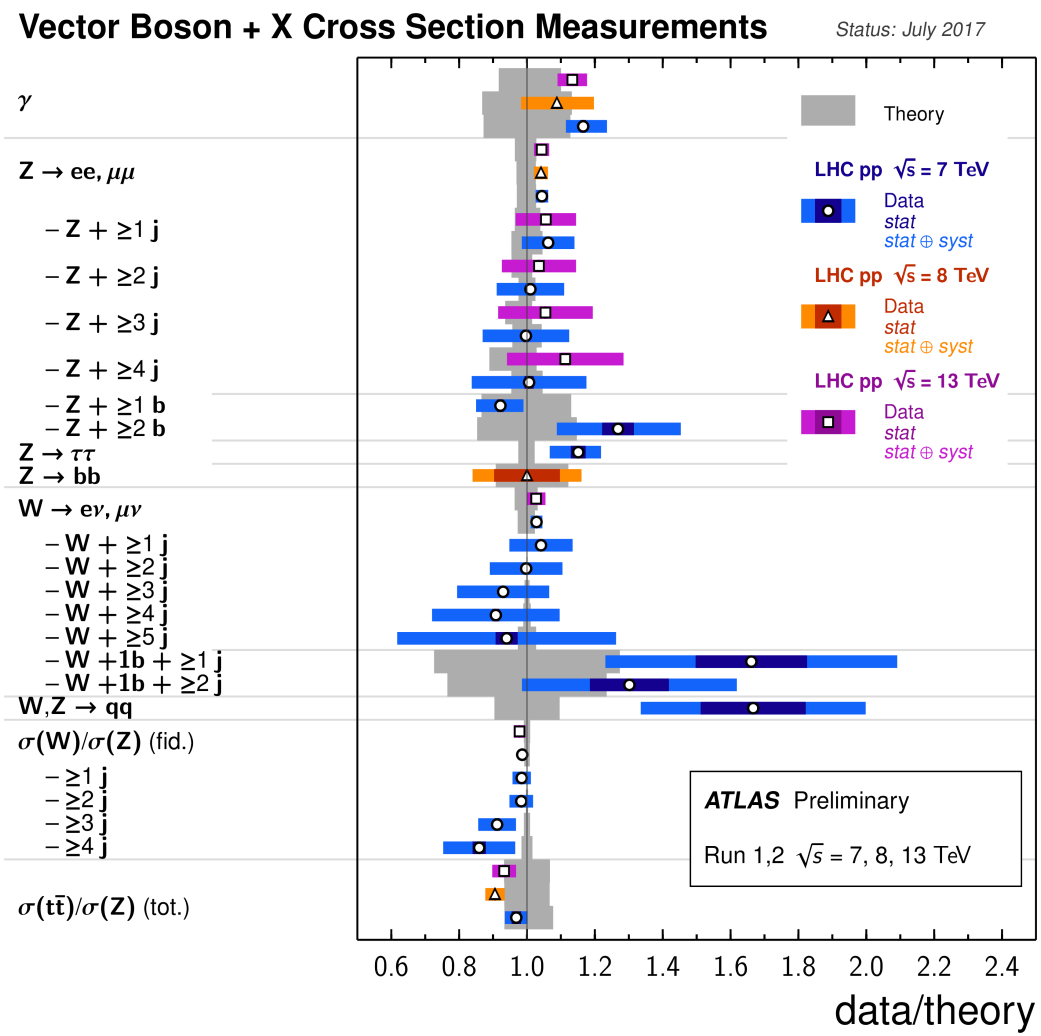
Emerging context

- A host of measurements now available,

  over the ~entire LHC energy domain

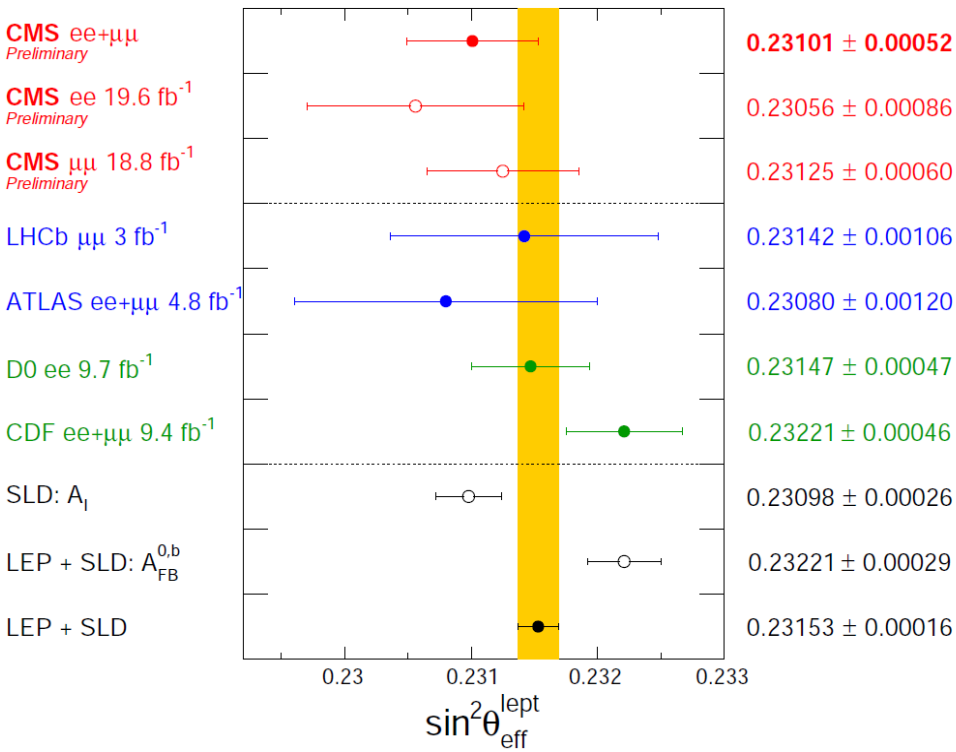
- Many measurements now reach the %-level (or below), testing the SM and imposing always stronger requirements on theoretical predictions

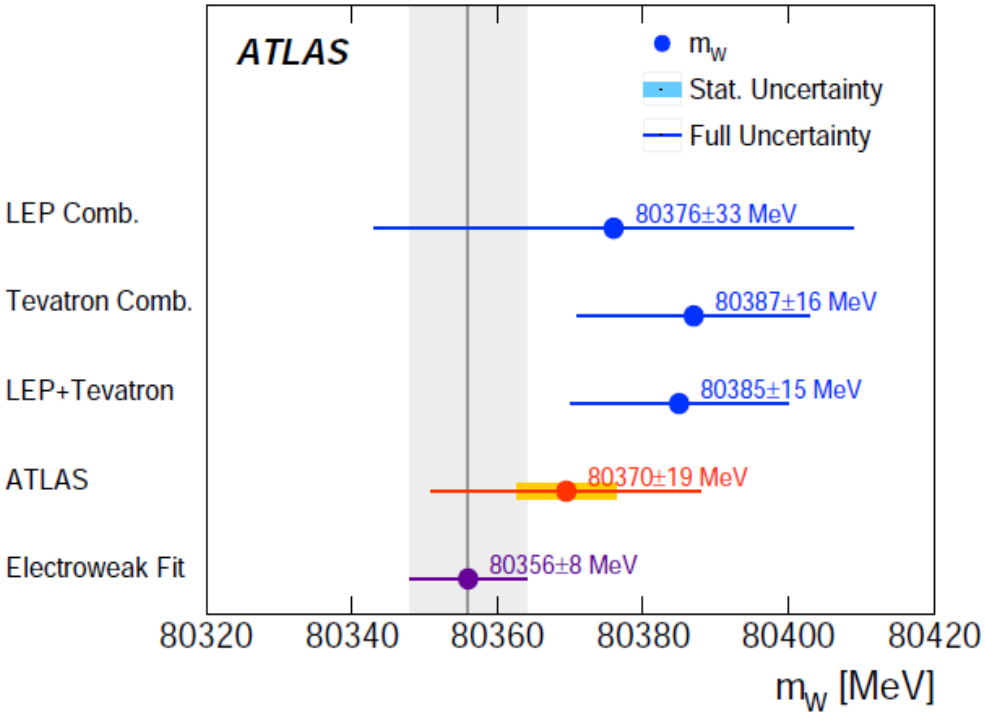




Emerging context

- The LHC experiments proved they will ultimately compete for the electroweak precision observables:

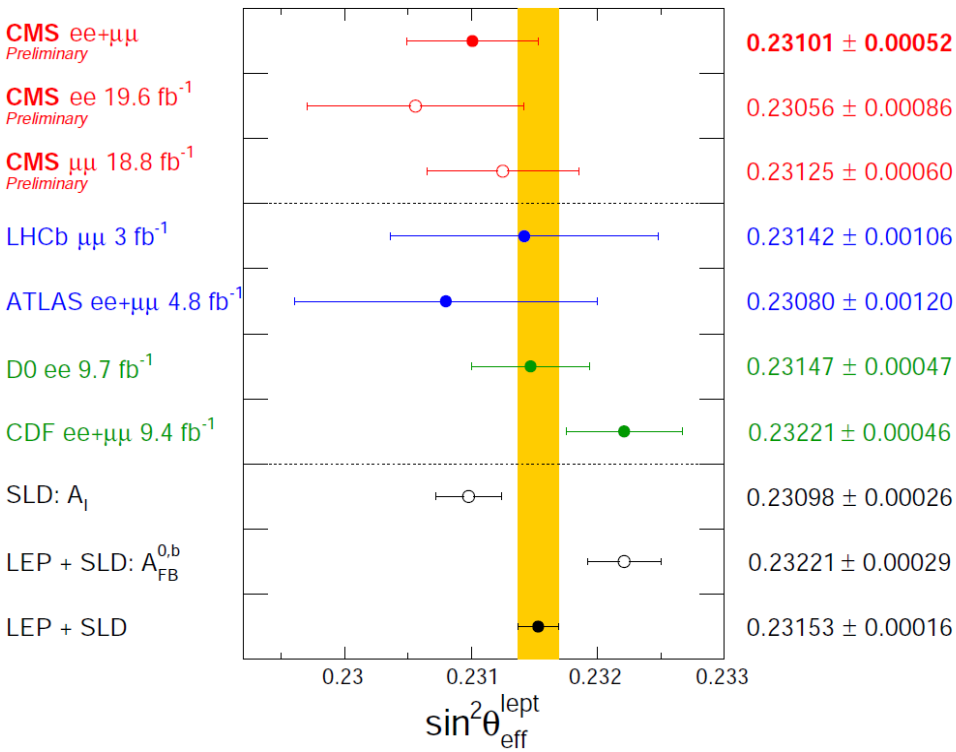


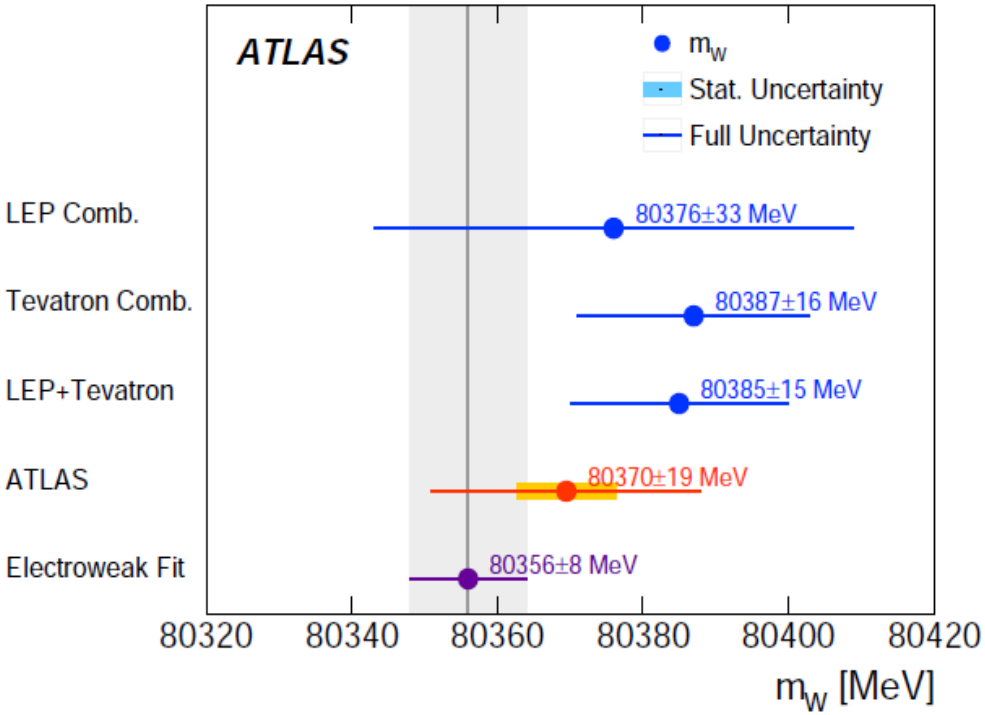


But this will not happen without **strong support from the theory community**, **precise measurements** to constrain the QCD d.o.f, and a **consistent interpretation** of the results in terms of PDFs, resummation and perturbative higher orders

Emerging context

- The LHC experiments proved they will ultimately compete for the electroweak precision observables:



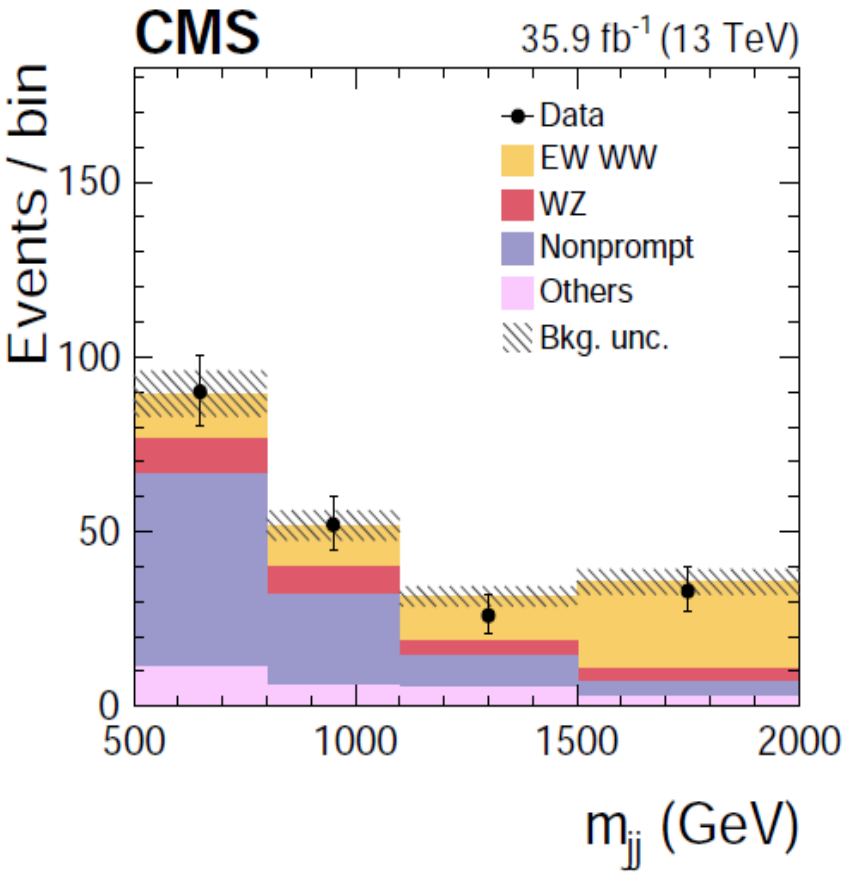


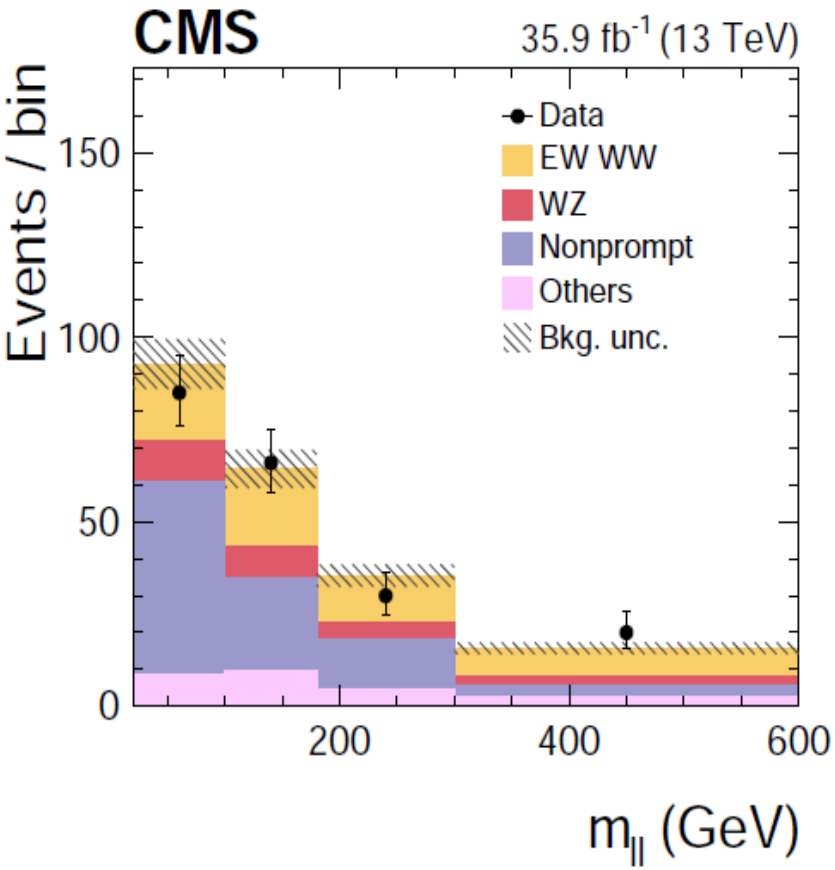
New challenges for the final interpretation of the results (EW fit, etc):

- Strongly correlated, theory-related systematic uncertainties
- Model dependence of the measurements?

Emerging context

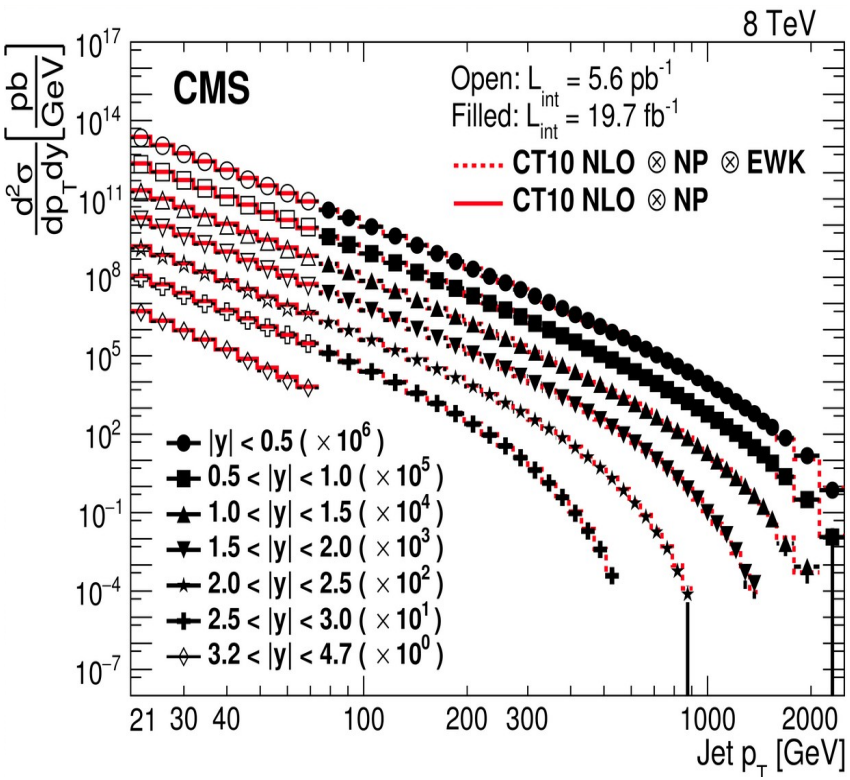
- The end of Run2 is near, and further probes of electroweak symmetry breaking enter the measurement phase:

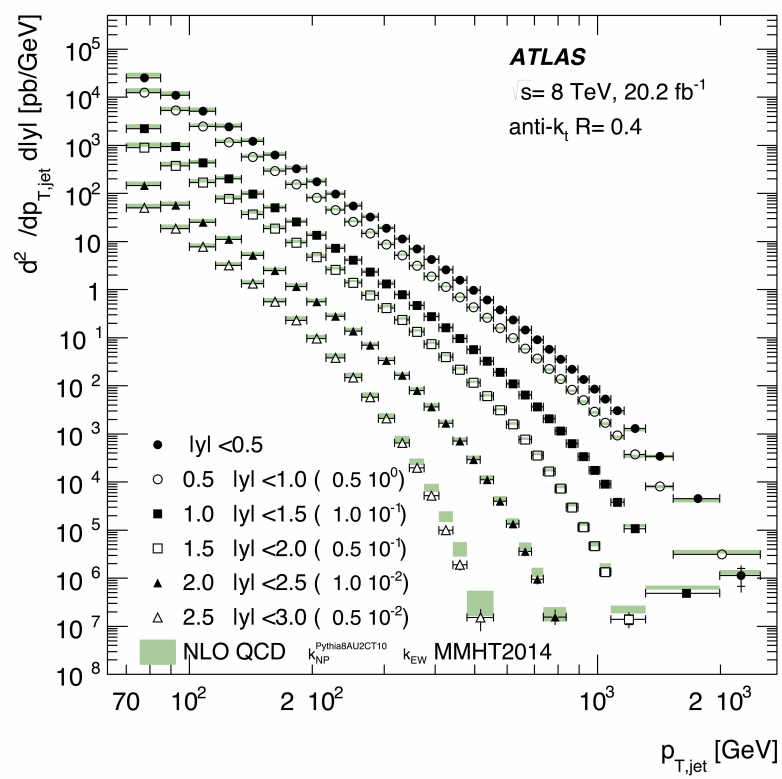




Open issues (examples)

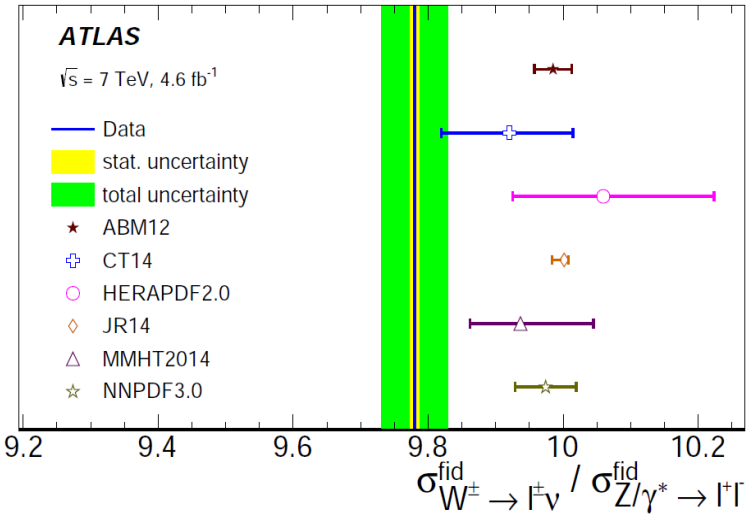
- Jet cross sections : comparisons at the experimental level; interpretation
  - Jet data notoriously difficult to interpret in the context of PDF fits. Jet scale correlations, …
  - Direct comparisons at the experimental level (with minimal theory input) are an important step in understanding the situation
  - need to agree on a common pT binning and JES correlation model



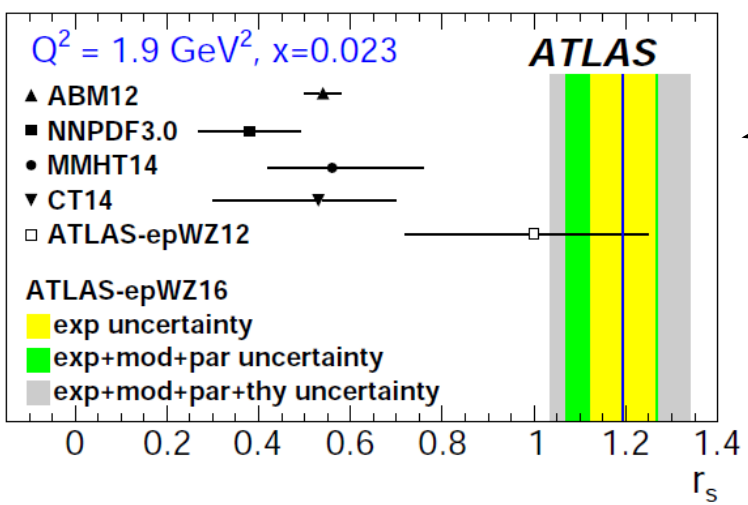


Open issues (examples)

- Precise W,Z cross sections : fixed-order predictions and PDF interpretation



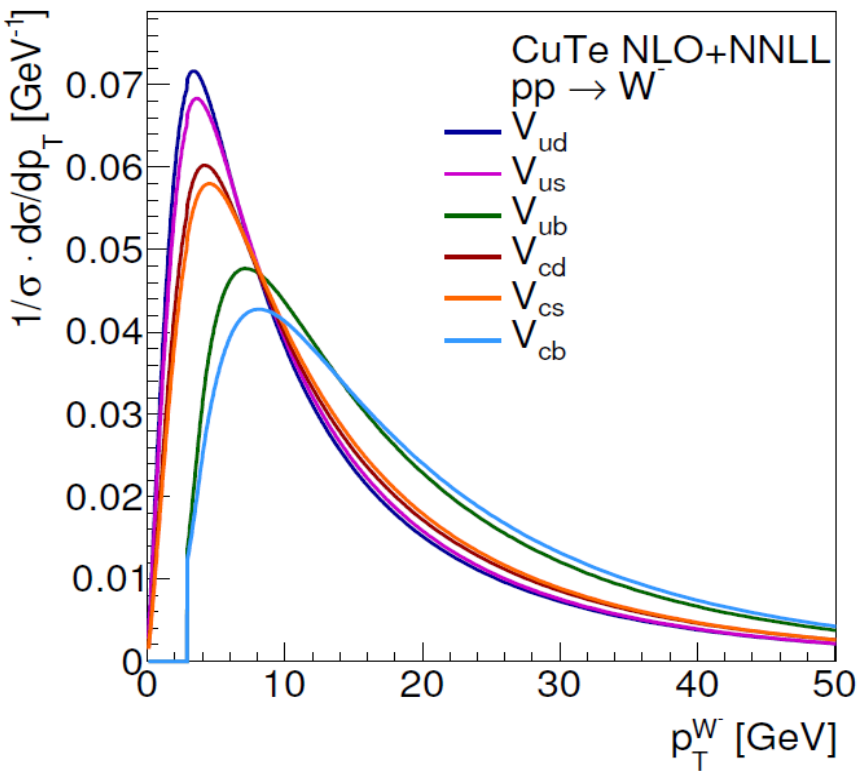
	$r_s = \frac{s+\bar{s}}{2\bar{d}}$	$R_s = \frac{s+\bar{s}}{\bar{u}+\bar{d}}$
Central value	1.19	1.13
Experimental data	±0.07	±0.05
Model (m_b, $Q^2_{\min}$, Q^2_0 & m_c)	±0.02	±0.02
Parameterization	$^{+0.02}_{-0.10}$	$^{+0.01}_{-0.06}$
α_S	$^{+0.00}_{-0.01}$	±0.01
EW corrections	±0.01	±0.00
QCD scales	$^{+0.08}_{-0.10}$	$^{+0.06}_{-0.07}$
FEWZ 3.1b2	+0.10	+0.08
Total uncertainty	$^{+0.15}_{-0.16}$	±0.11



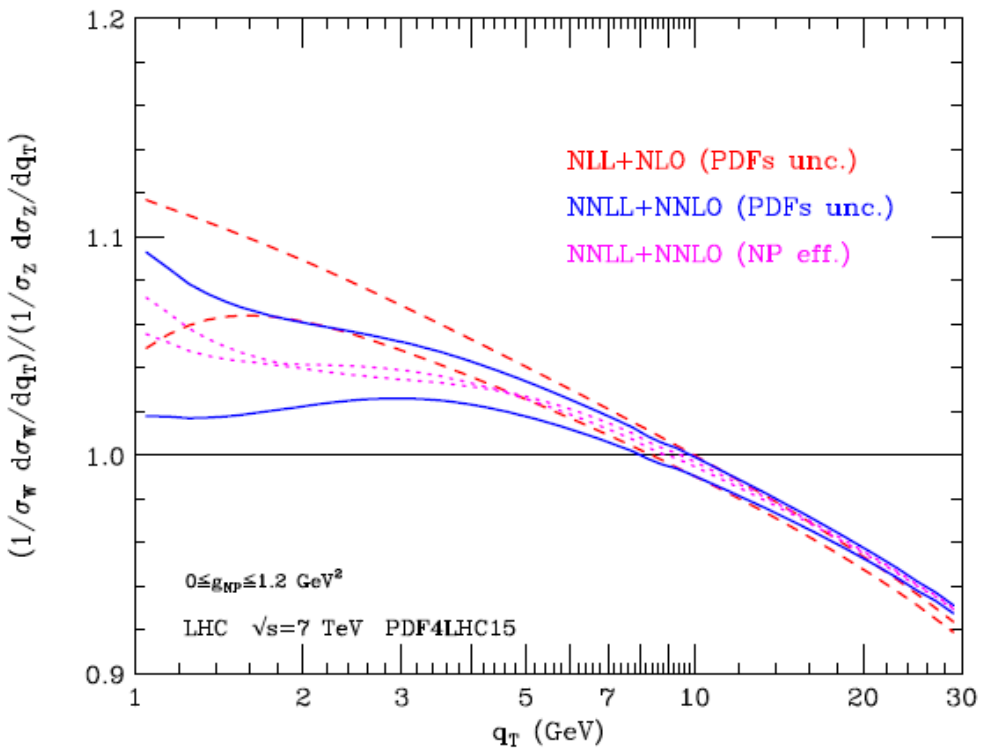
DYNNLO vs FEWZ dominates the uncertainty on the interpretation of the results.
Points to the influence of the assumed $p_T^{W,Z}$ distribution on fiducial cross sections.
→ effect on PDF determination?

Open issues (examples)

- Matters for m_W, as the strange density affects the p_T^W distribution (which affects p_T^l)
- Theory uncertainty on the ratio of the W and Z pT distributions (p_T^Z measured to ~0.5%)?



p_T^W per sub-process in CuTe



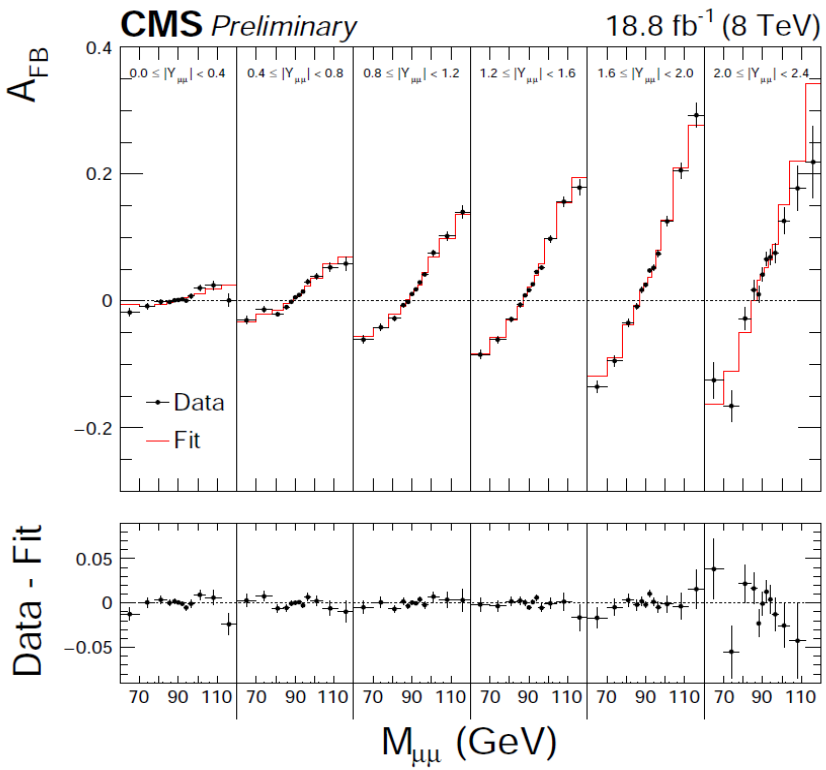
DYRES prediction for p_T^W/p_T^Z,
Assuming correlated QCD scale variations

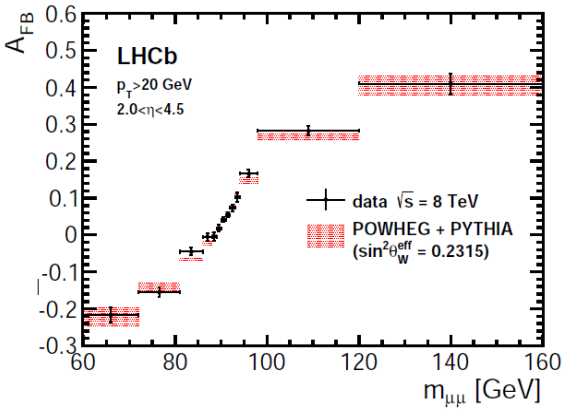
A study of the correlation of QCD uncertainties in W and Z production is crucial

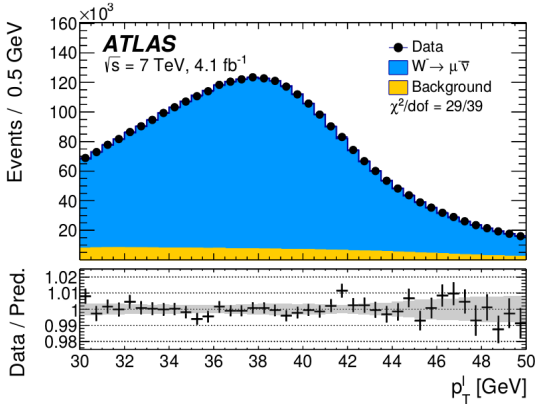
Open issues (examples)

- Model dependence of m_W and $\sin^2\theta_W$ measurements at hadron colliders?

  All measurements assume the SM to relate these parameters and the final state distributions used for their determination. Is there a fundamental limit to this approach?



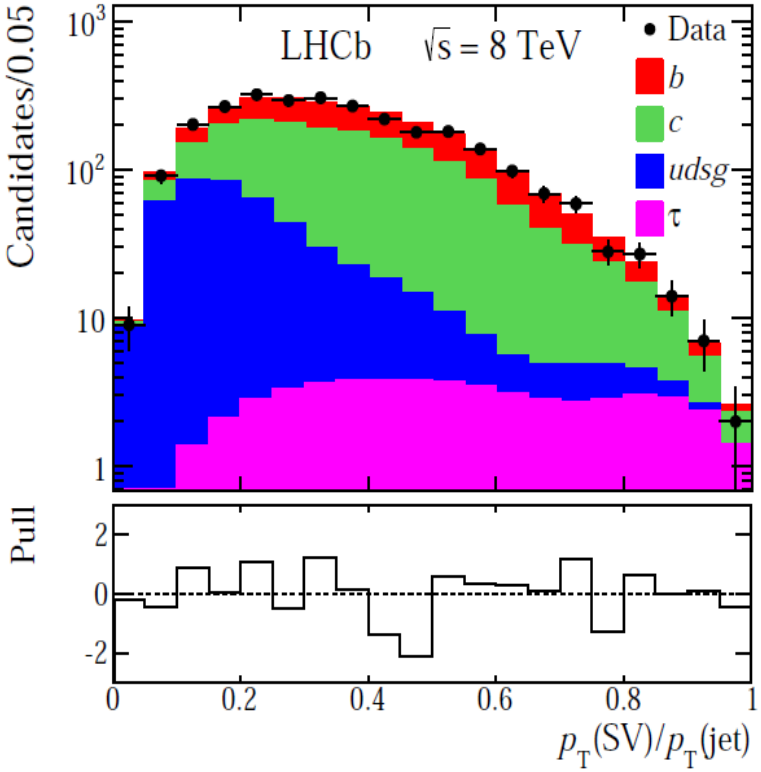


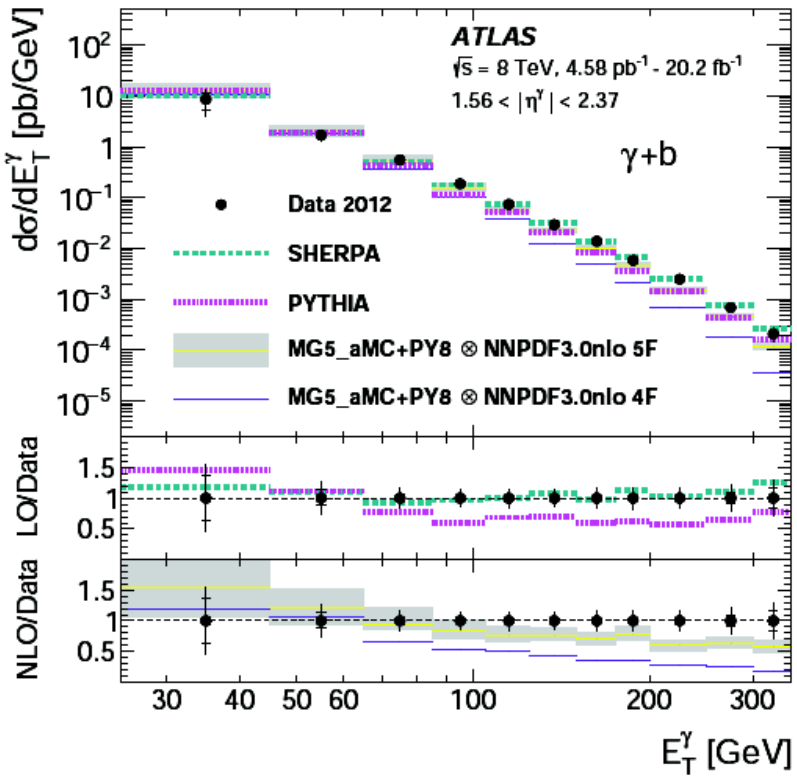


(do the kinematics depend on the details of the BSM contributions that affect $\sin^2\theta_W$ or m_W?)

Open issues (examples)

- Interpretation of V+HF production?
  - V+c/b (V=γ,W,Z) sensitive to the heavy flavour content of the proton
  - Interpretation needs proper definition of the signal, and accurate calculations for the hard process





Open issues (examples)

- Interpretation of diboson production : many discussions with theorists on EFTs
  - Relation between aTCGs and EFTs. Which models to choose? How to treat unitarity problems?
- Measurements with phase space restrictions
  - to deal with unitarity issues
  - to reduce numbers of SMEFT parameters
- Propagation to final analysis is somewhat slow....
  - now is the time that experiments start producing full Run-2 samples
  - Need pragmatic recipes
- Personpower currently focused on measurements. Interpretations, combinations to follow, but work should start (ZZ combination successful, but took > 1 year)

Structure of the EWWG

- Electroweak Precision Observables
  - Inclusive single-boson production,
  - from cross sections and constraints on QCD/PDFs to measurements of electroweak parameters

- Tests of QCD in jet and V+jet production
  - Inclusive jets and V+jets
  - Comparison of experimental results; correlations models; …
  - comparison to theory; PDF interpretation

- Multi-boson production
  - Cross section measurement and comparison with theory
  - BSM interpretation : aGC's, EFT, ...

Structure of the EWWG

- Electroweak Precision Observables
  - ATLAS : Maarten Boonekamp / Daniel Froidevaux
  - CMS : Michael Schmitt, Aram Apyan
  - LHCb : Olli Lupton, Tara Shears

- Tests of QCD in jet and V+jet production
  - ATLAS : Chiara de Benedetti
  - CMS : Hannes Jung, Emanuela Barberis
  - LHCb : Stephen Farry, Will Barter

- Multi-boson production:
  - ATLAS : Kristin Lohwasser
  - CMS : Senka Duric, Chia-Ming Kuo

- Overall coordination : see front page :)

2018 – and beyond

- Objectives to be defined (join the discussion Thursday afternoon!)
  - Scientific end-products on the experimental side
  - Theoretical work in support of the measurements and their interpretation
  - Documentation : theory summaries; experimental methods (combinations, fits, correlation models...)
- Timeline : ~LS2
- Meetings / workshops
  - Dedicated working meetings according to need, at the level of the sub-groups
  - Overall WG reunions : twice / year (?)
  - Cross-WG meetings? (common topics with Higgs and Top Wgs)
- Immediate issues to address:
  - Personpower! Achieving our objectives requires a significant amount of dedicated time from the experimental and theoretical communities
  - Strive to involve as much expertise as possible (our announcements do not reach all relevant people)

Agenda

WEDNESDAY, 13 DECEMBER

TH Conference room

09:15 → 09:45	**Welcome. Overview of the EWWG**	30m	4-3-006 - TH Conference Room
09:50 → 10:10	**Inclusive jet production (20' talk + 15' discussion)** **Speaker**: Klaus Rabbertz (KIT - Karlsruhe Institute of Technology (DE))	20m	4-3-006 - TH Conference Room
10:25 → 10:45	**Vector boson production with jets (20' talk + 15' discussion)** **Speaker**: Arantxa Ruiz Martinez (Carleton University (CA))	20m	4-3-006 - TH Conference Room
11:00 → 11:20	**Coffee**	20m	4-3-006 - TH Conference Room
11:20 → 11:40	**Vector boson production with heavy flavours (20' talk + 15' discussion)** **Speaker**: Philip Ilten (University of Birmingham (GB))	20m	4-3-006 - TH Conference Room
11:55 → 12:25	**Jet & V+jet production : theory overview (30' talk + 30' discussion)** **Speaker**: Marek Schoenherr (University of Durham)	30m	4-3-006 - TH Conference Room
13:00 → 15:15	**Lunch**	2h 15m	4-3-006 - TH Conference Room
15:15 → 15:45	**Multi-boson production : theory overview (30' talk + 30' discussion)** **Speaker**: Dr. Stefan Kallweit (University of Mainz)	30m	4-3-006 - TH Conference Room
16:15 → 16:45	**Experimental overview (30' talk + 15' discussion)** **Speaker**: Joshua Milo Kunkle (University of Maryland (US))	30m	4-3-006 - TH Conference Room
17:00 → 17:20	**Past LHC EW Multiboson Discussions and Perspectives for the Future (20' talk + discussion)** **Speaker**: Kristin Lohwasser (University of Sheffield (GB))	20m	4-3-006 - TH Conference R...

Agenda

THURSDAY, 14 DECEMBER

09:00	→ 09:20	**PDFs for electroweak precision (20' talk + 20' discussion)** **Speaker**: Robert Samuel Thorne (University College London (UK))	20m	40-S2-B01 - Salle Bohr
09:40	→ 10:00	**Electroweak precision measurements: ATLAS perspective (20' talk + 15' discussion)** **Speaker**: Aaron James Armbruster (CERN)	20m	40-S2-B01 - Salle Bohr
10:15	→ 10:35	**Electroweak precision measurements: CMS perspective (20' talk + 15' discussion)** **Speaker**: Michael Schmitt (Northwestern University (US))	20m	40-S2-B01 - Salle Bohr
10:50	→ 11:10	**Electroweak precision measurements: LHCb perspective (20' talk + 15' discussion)** **Speaker**: Olli Lupton (CERN)	20m	40-S2-B01 - Salle Bohr
11:25	→ 11:55	**Electroweak precision measurements : theory overview (30' talk + 30' discussion)** **Speaker**: Fulvio Piccinini	30m	40-S2-B01 - Salle Bohr
12:15	→ 14:00	**Lunch**	1h 45m	4-3-006 - TH Conference Room
15:15	→ 16:30	**Discussion : planning and objectives**	1h 15m	4-3-006 - TH Conference Room

Salle Bohr (B.40)

TH Conference room