ATLAS and CMS perspectives on vector-boson (+ jets) physics

Mariarosaria D'Alfonso (MIT)

on behalf of ATLAS and CMS collaborations

Introduction

W/Z where discovered in the 80' *and we are still discussing how to improve our measurement*

Important test of:

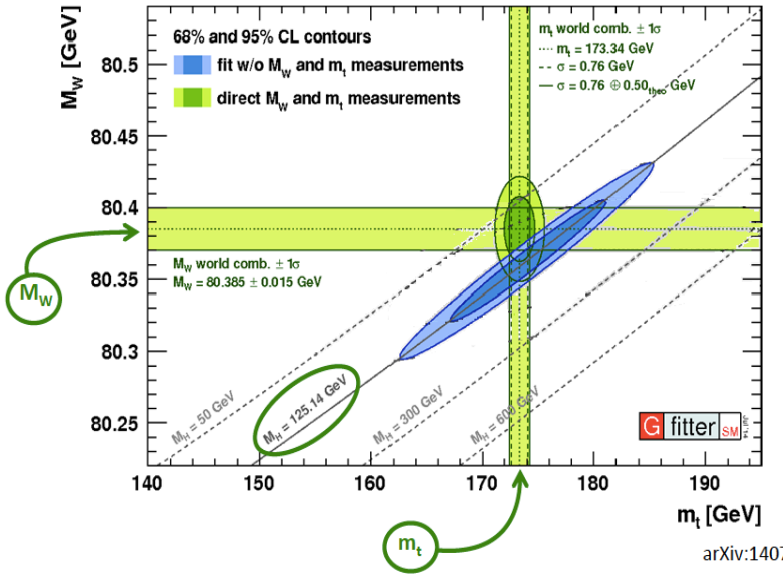
- perturbative QCD, pdf studies :

  good test bench for Higgs production studies

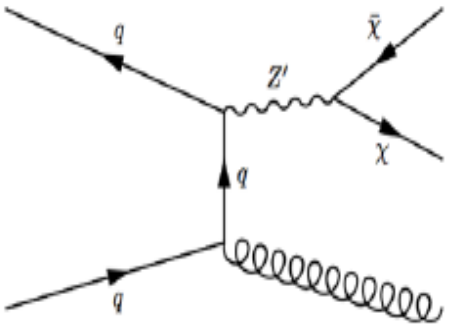
- EW lagrangian:

  Testing the consistency of the SM and probing beyond SM contributions

- irreducible backgrounds for Higgs /Top/ searches



arXiv:1407.3792



Experimental handles

Selection of W(e/μ+ν) or Z(ee/μμ) candidates:

- single lepton triggers used for online selection
- reconstruction of isolated charged leptons of pT > 20 or 25 GeV in detector acceptance

  Electron up to |η| = 2.4 CMS, |η| = 2.47 ATLAS

  Muon up to |η| = 2.4 CMS and ATLAS

In W analyses:

identify escaping neutrino reconstructing the hadronic recoil

Experimental uncertainties:

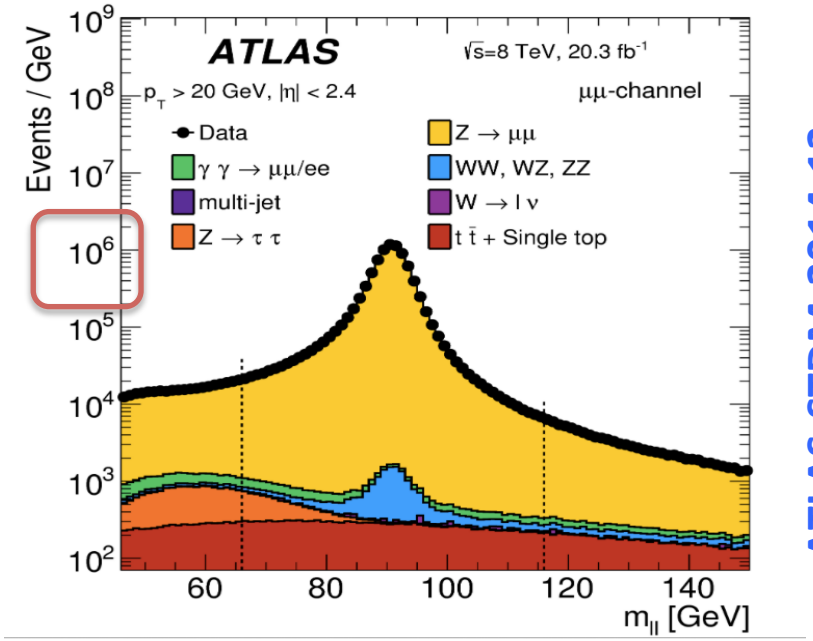
Luminosity ~2.5% , Lepton efficiencies 1-2 %, Recoil resolution O(10 GeV)

Experimental challenges ahead for the precision measurement:

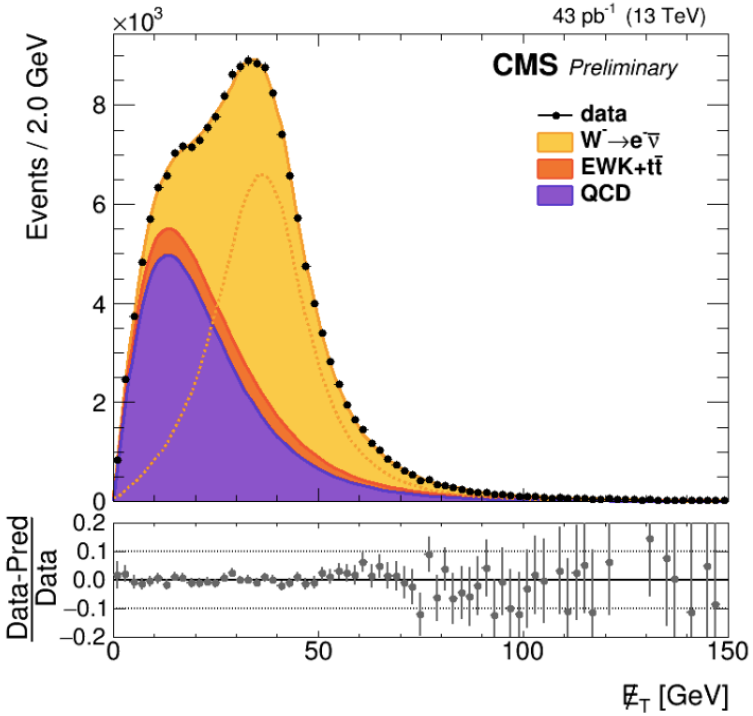
→ keep low triggers threshold

→ make even robust the PU mitigation

Experimental handles



ATLAS-STDM-2014-12



CMS-PAS-SMP-15-004

Large number of events allow to control systematics, monitor backgrounds, reduce backgrounds or systematics via tighter cuts, validate theoretical estimates and modeling …

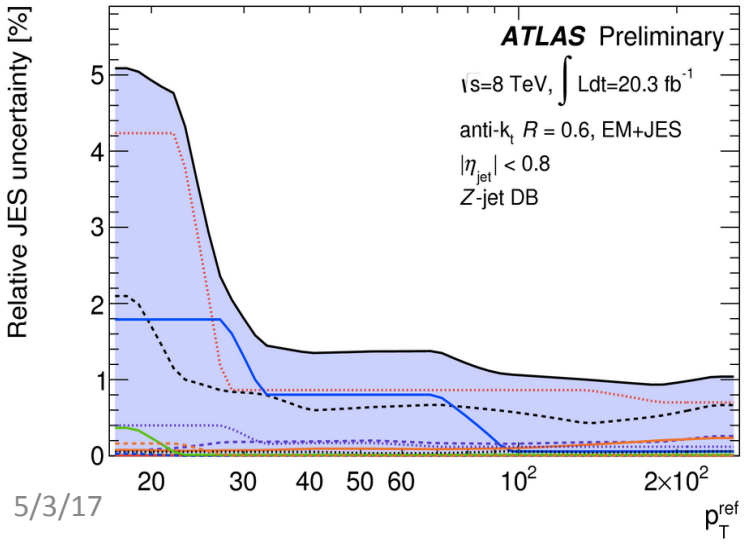
Experimental handles

Reconstruct and select jets:

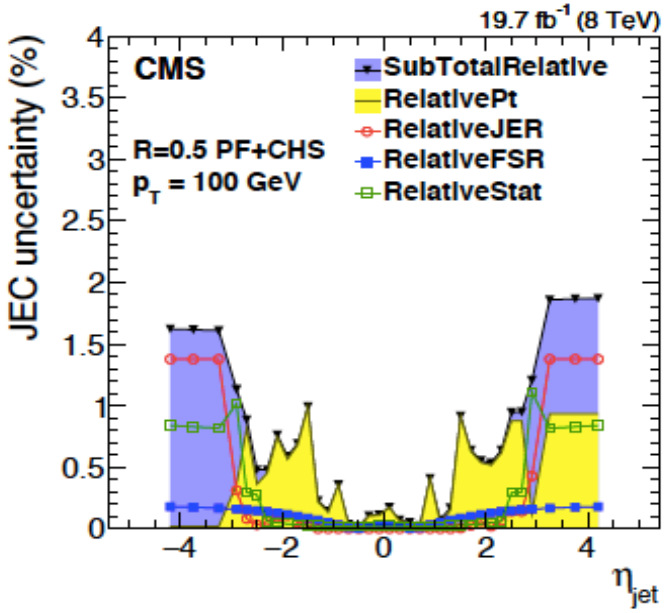
- Anti-kt ΔR = 0.4 CMS and ATLAS (=0.5 CMS Run I)
- Typical jet pT > 25 or 30 GeV
- Acceptance up to |y|<2.5 ATLAS, |η| = 2.4 CMS

Impact of JES uncertainties:

typically O(10%) when considering final state with >=3jets



ATLAS-CONF-2015-057

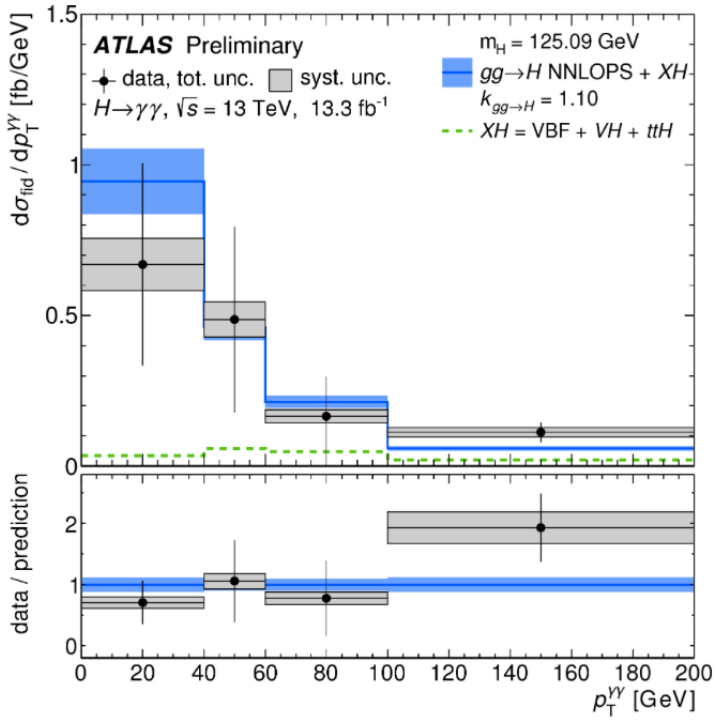


CMS-JME-13-004

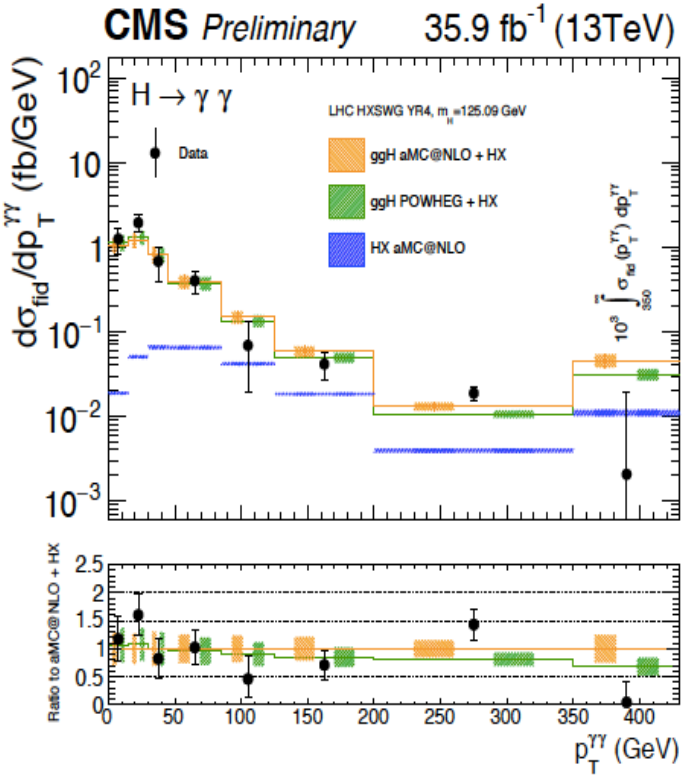
Main themes

Going differential !

- Higgs or BSM signal significance optimized by categorizing events according to kinematic properties (e.g. jet bins, Higgs pt ...)
  - **Jet veto** for WW,tautau , **VBF** production



ATLAS-CONF-2016-067



CMS-PAS-HIG-17-015

Main themes

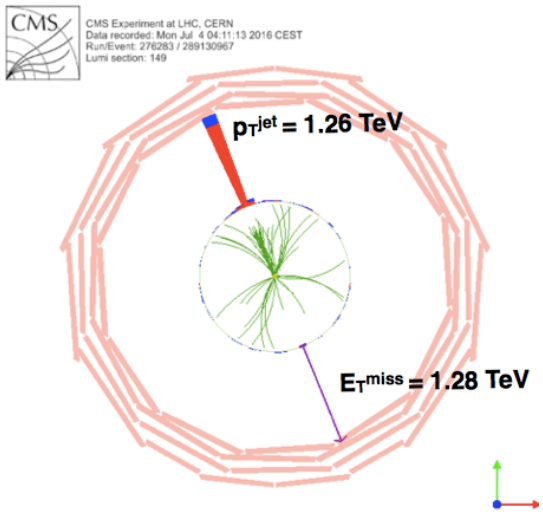
We're well past the "low hanging fuit" type of measurements

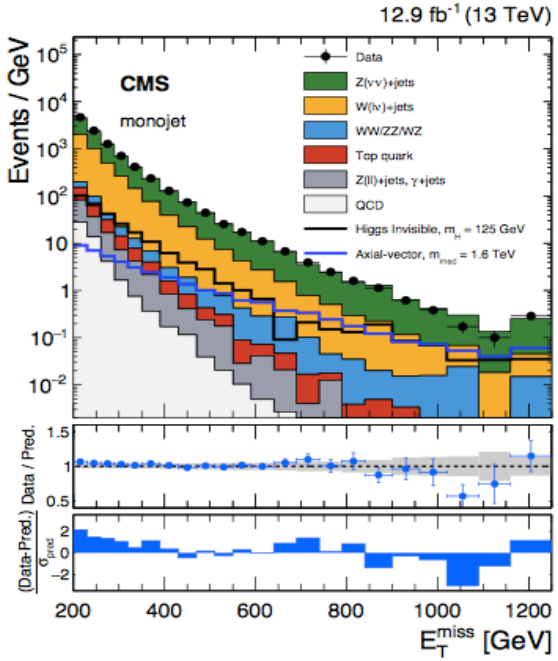
- measurements are systematics level dominated and we need to go beyond from the early type prescription

How much can the precision of SM predictions be improved ?

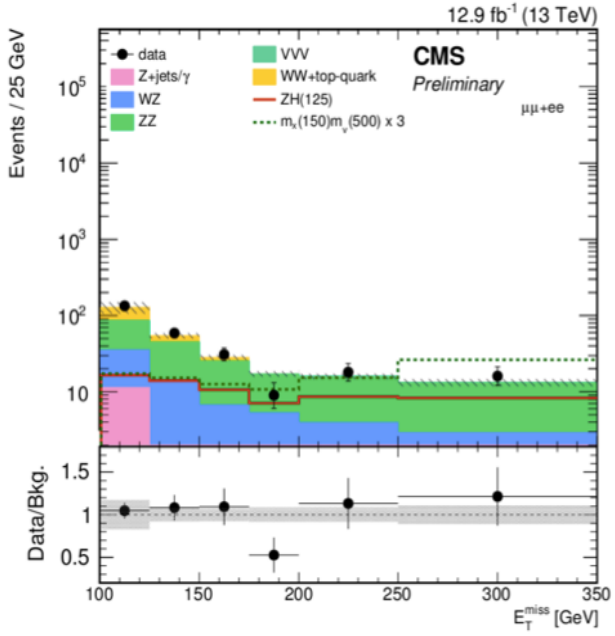
- Should be enough to be sensitive to small departures from SM behavior

CMS-EXO-16-037



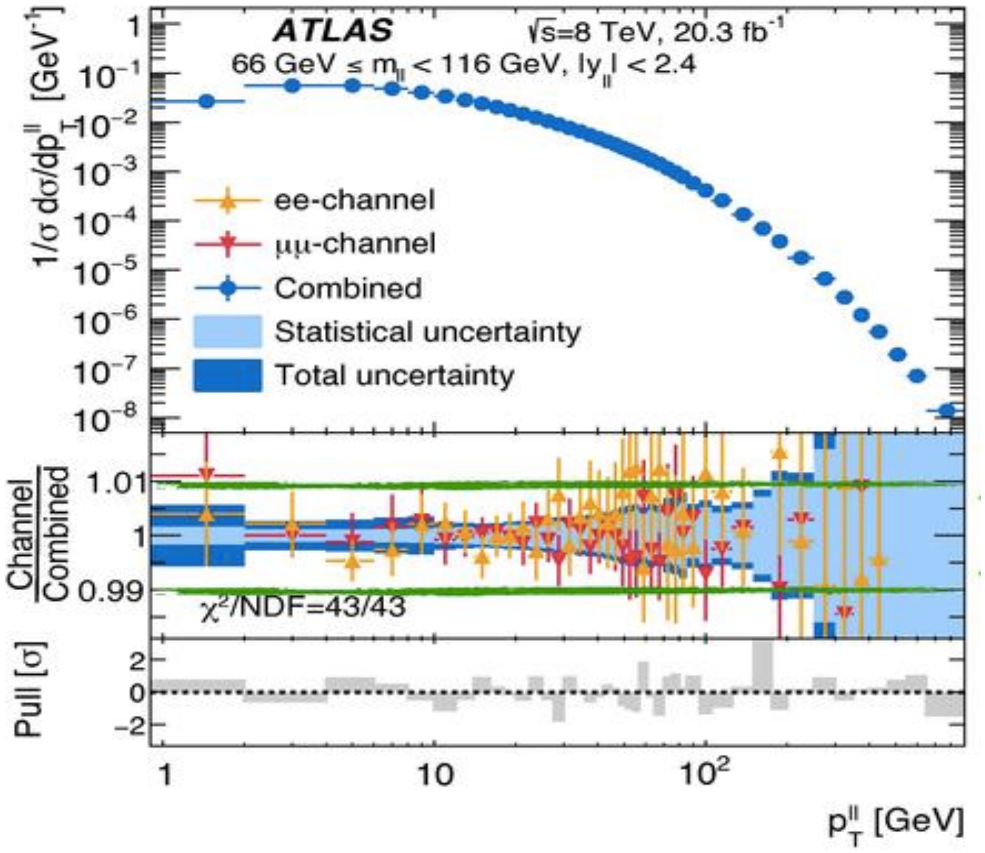


CMS-EXO-16-038



Z production

Eur. Phys. J. C 76 (2016) 291

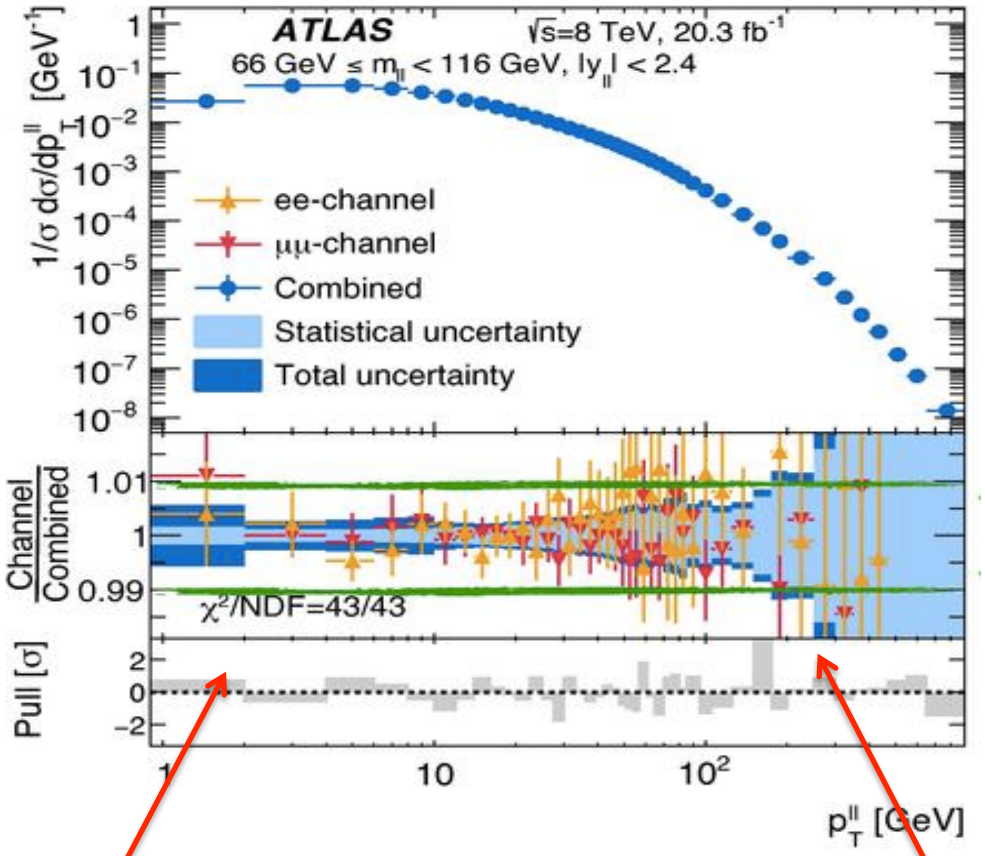


Normalised to Z fiducal σ

Esperimentally this is already at 1% for pt=1-200 GeV

Z production

Eur. Phys. J. C 76 (2016) 291



The entire Zpt spectrum cannot be described yet by the single MC calculation

Similar duality for the Higgs PT

ptV << MV:

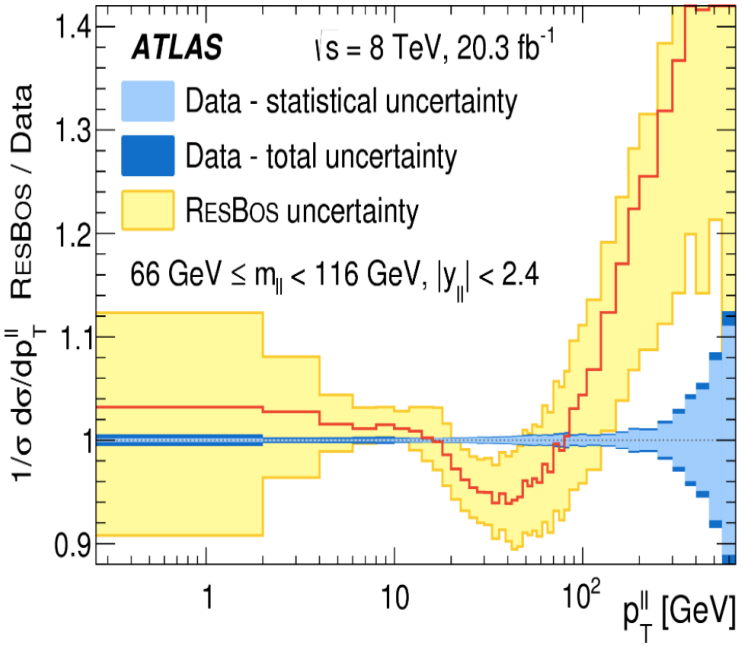
Soft gluon resummation
non perturbative effects

ptV ~ MV

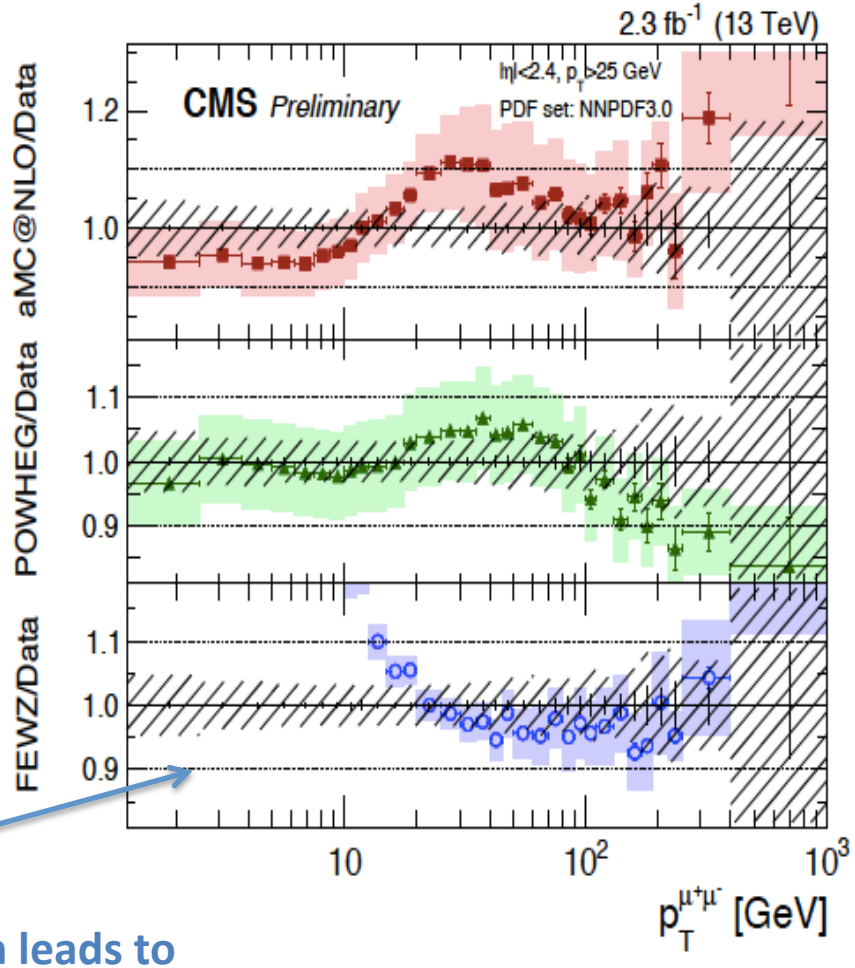
Fixed order perturbative QCD
Parton shower with the missing higher order QCD
EWK correction

Comparison with MC

Eur. Phys. J. C 76 (2016) 291



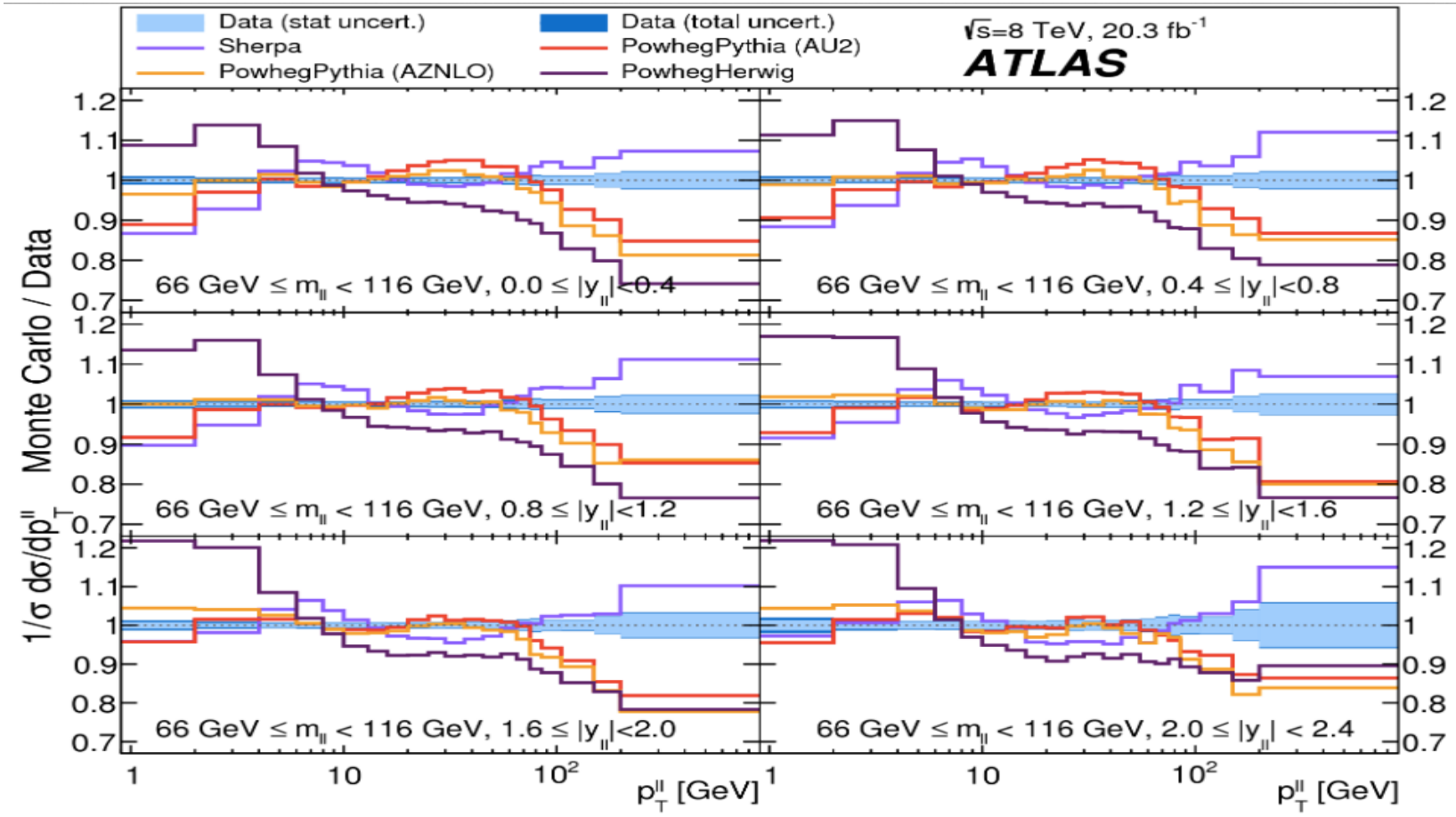
CMS-PAS-SMP-15-011



Absence of resummation in FEWZ calculation leads to expected deviations at low transverse momentum

Z production & parton shower

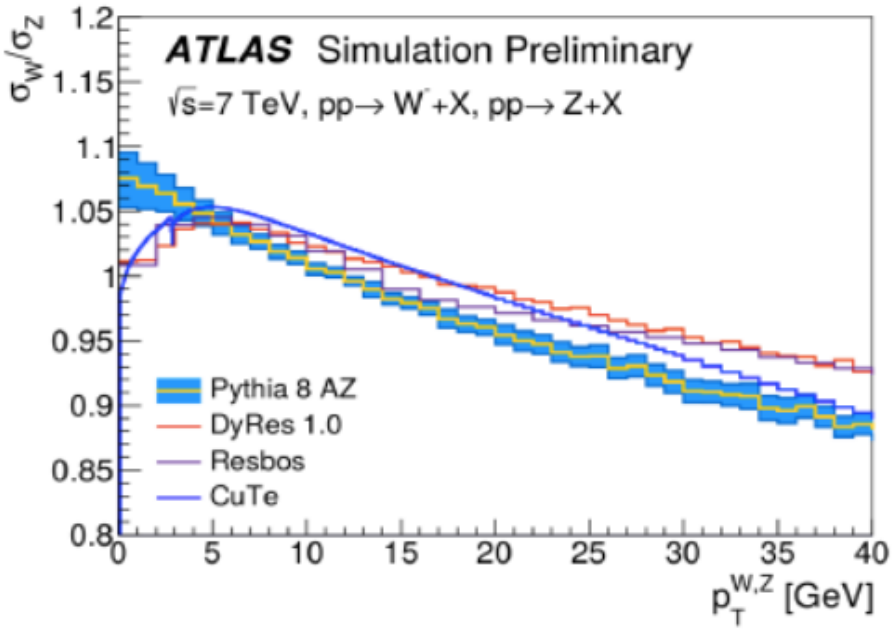
Eur. Phys. J. C 76 (2016) 291



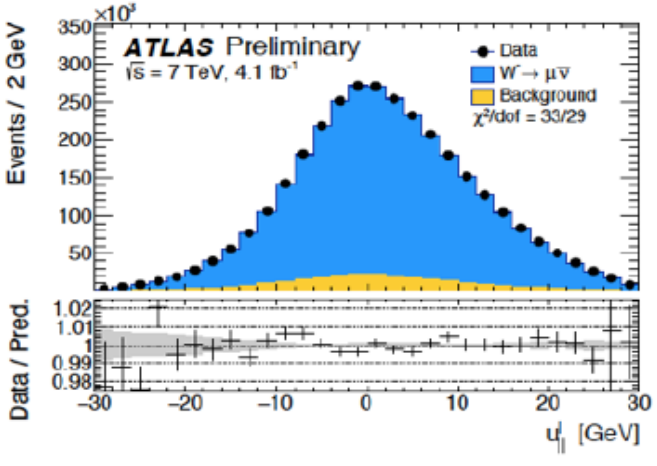
ATLAS tuned on Z @ 7TeV, give the best description at lowPT

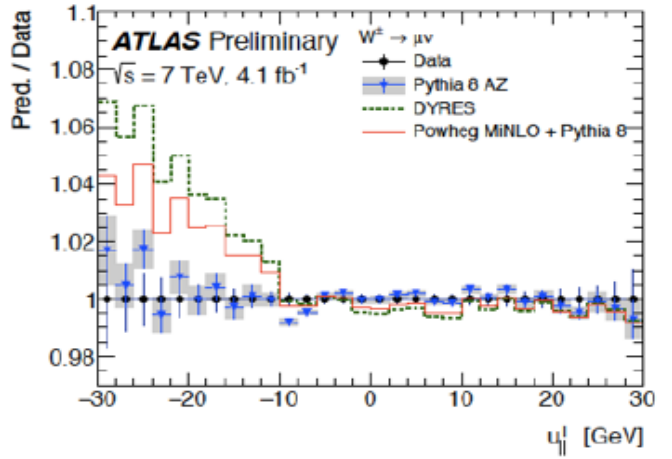
Low Z pt production (ptZ< MZ)

ATLAS-STDM-2014-18, submitted to EPJC



Resummation codes predict an harder pT W spectrum for a given measured pT Z spectrum



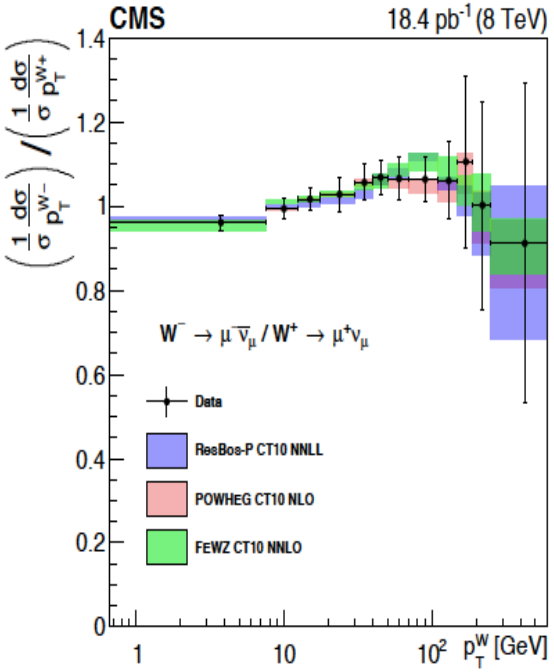


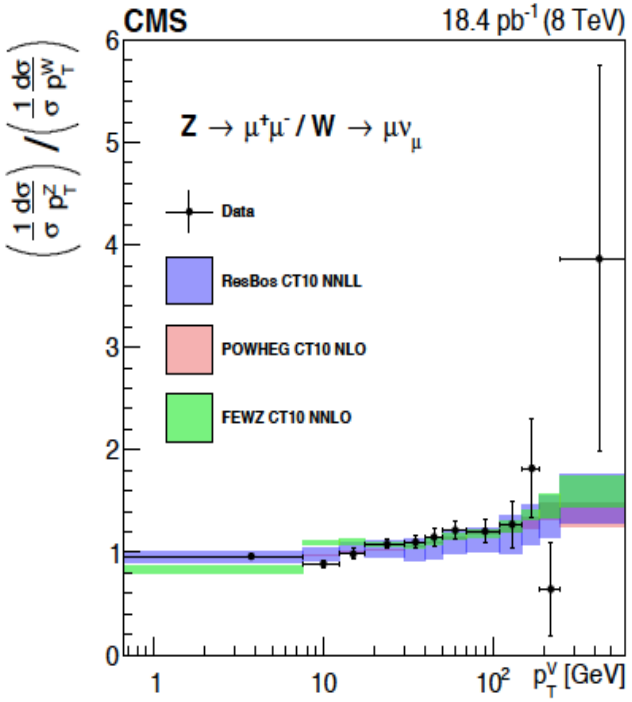
MINLO and NNLL resummed predictions as Resbos, Cute, and DyRes are strongly disfavoured by the u|| distribution in data

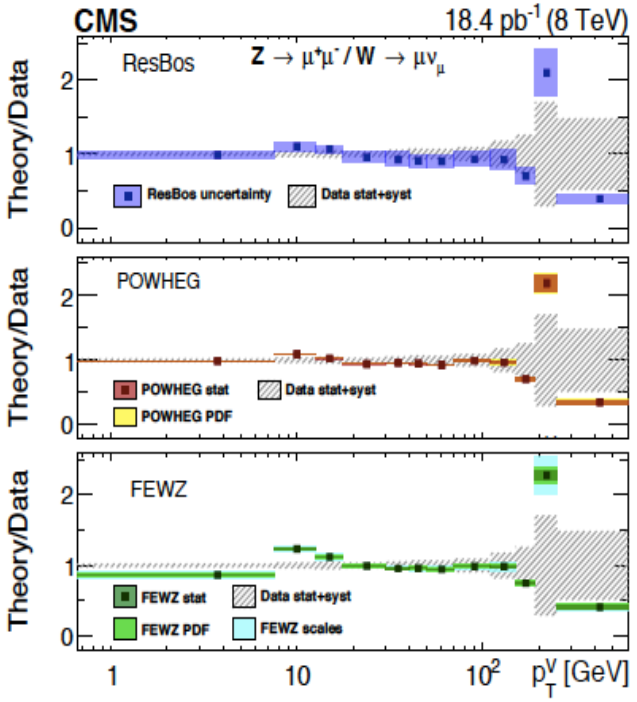
W/Z pt ratio

Special low pileup run at √s = 8 TeV

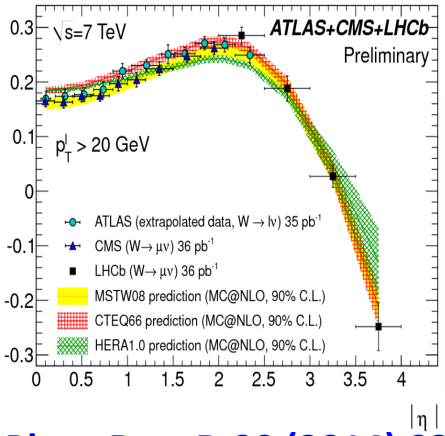
JHEP02(2017)096



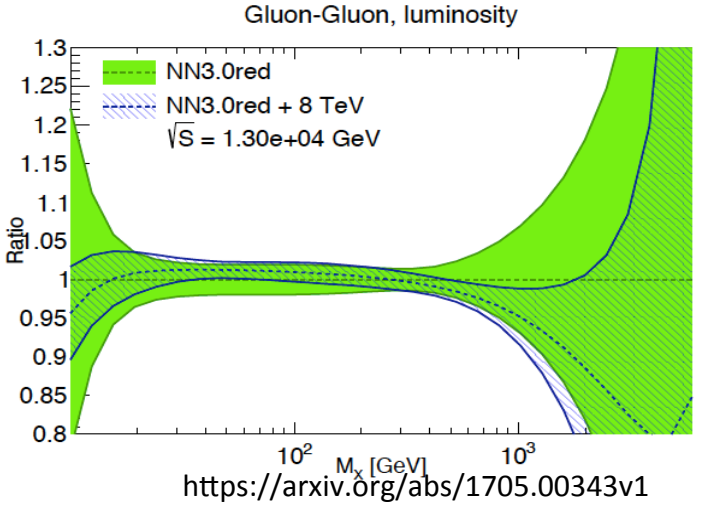




In general none of the prediction is able to describe the data completely.



W+/W-/Z & pdf

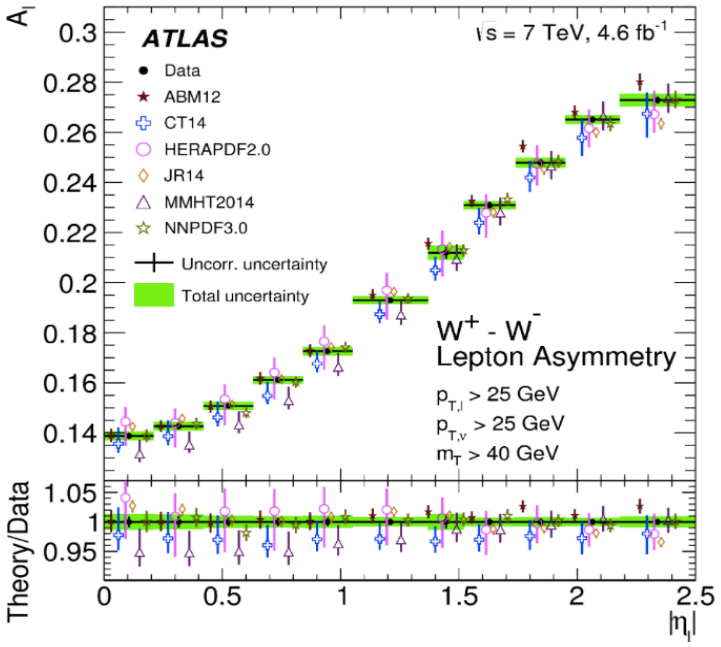


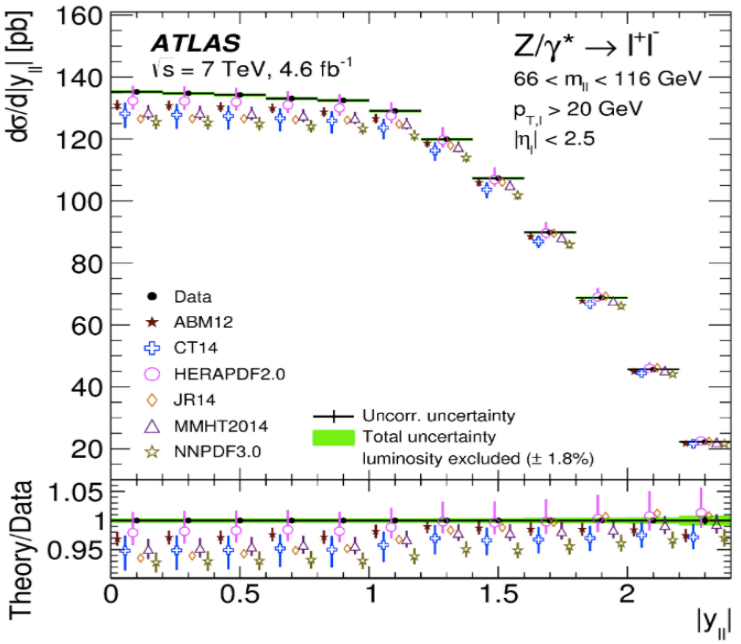
Phys. Rev. D 90 (2014) 032004

https://arxiv.org/abs/1705.00343v1

Early Charge Asymmetry measurement added into NNPDF3.0
Potential future impact of the Zpt into the NNPDF3.1
Experimental uncertainty (0.5 - 1%) is smaller than theoretical uncertainty

$$A(\eta) = \frac{d\sigma/d\eta(W^+ \to \ell^+\nu) - d\sigma/d\eta(W^- \to \ell^-\bar{\nu})}{d\sigma/d\eta(W^+ \to \ell^+\nu) + d\sigma/d\eta(W^- \to \ell^-\bar{\nu})}$$





ATLAS STDM-2012-20,submitted to EPJ

Angular coefficient

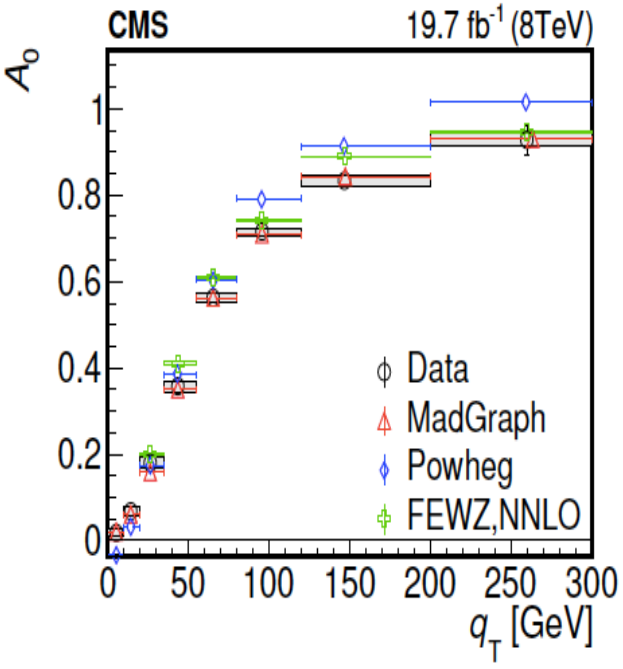
Angular coefficients not well reproduced by POWHEG, better agreement with aMC@NLO and NNLO fixed-order codes

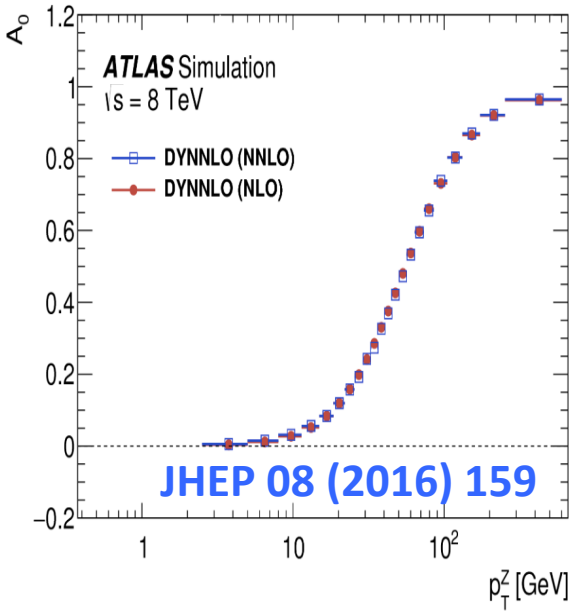
POWHEG+MinLO improves the agreement to the level of the NNLO fixed-order

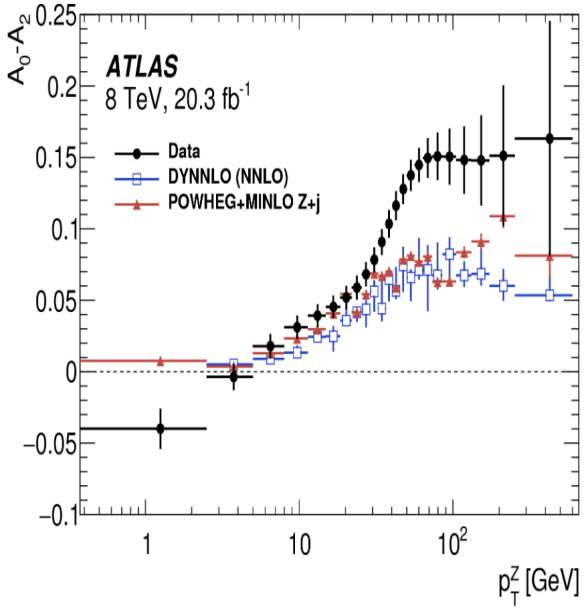
Observed the violation of the LamTung relation (A0 = A2)

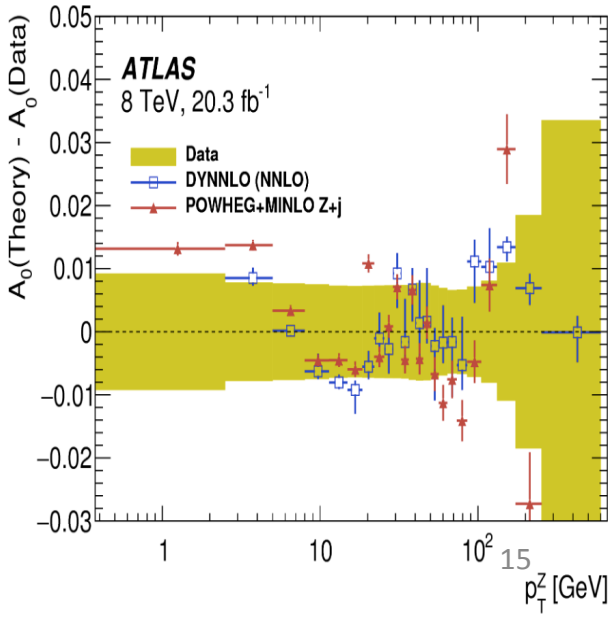
Much finer binning from ATLAS than in CMS

Phys.Lett.B750(2015)154

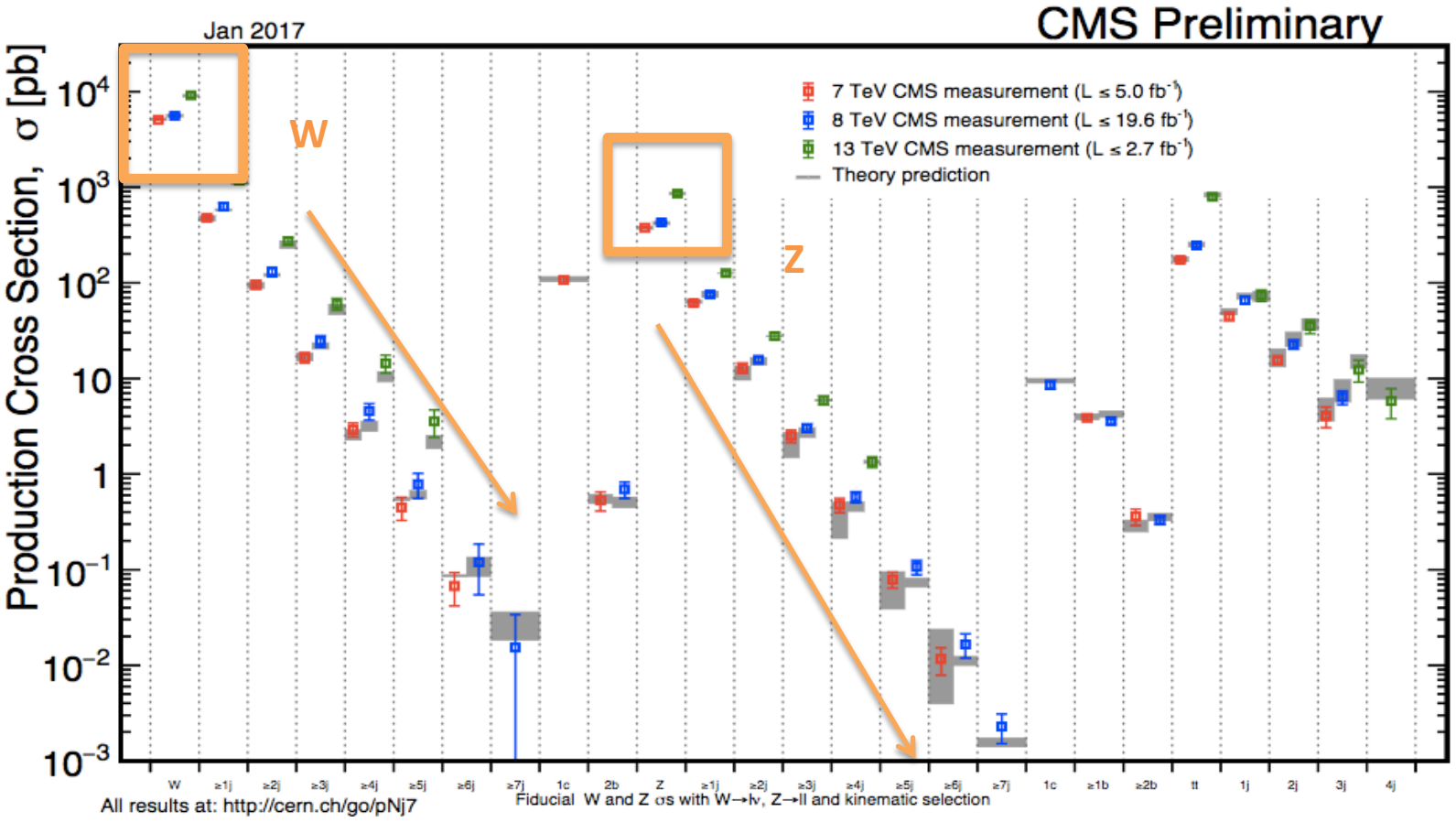






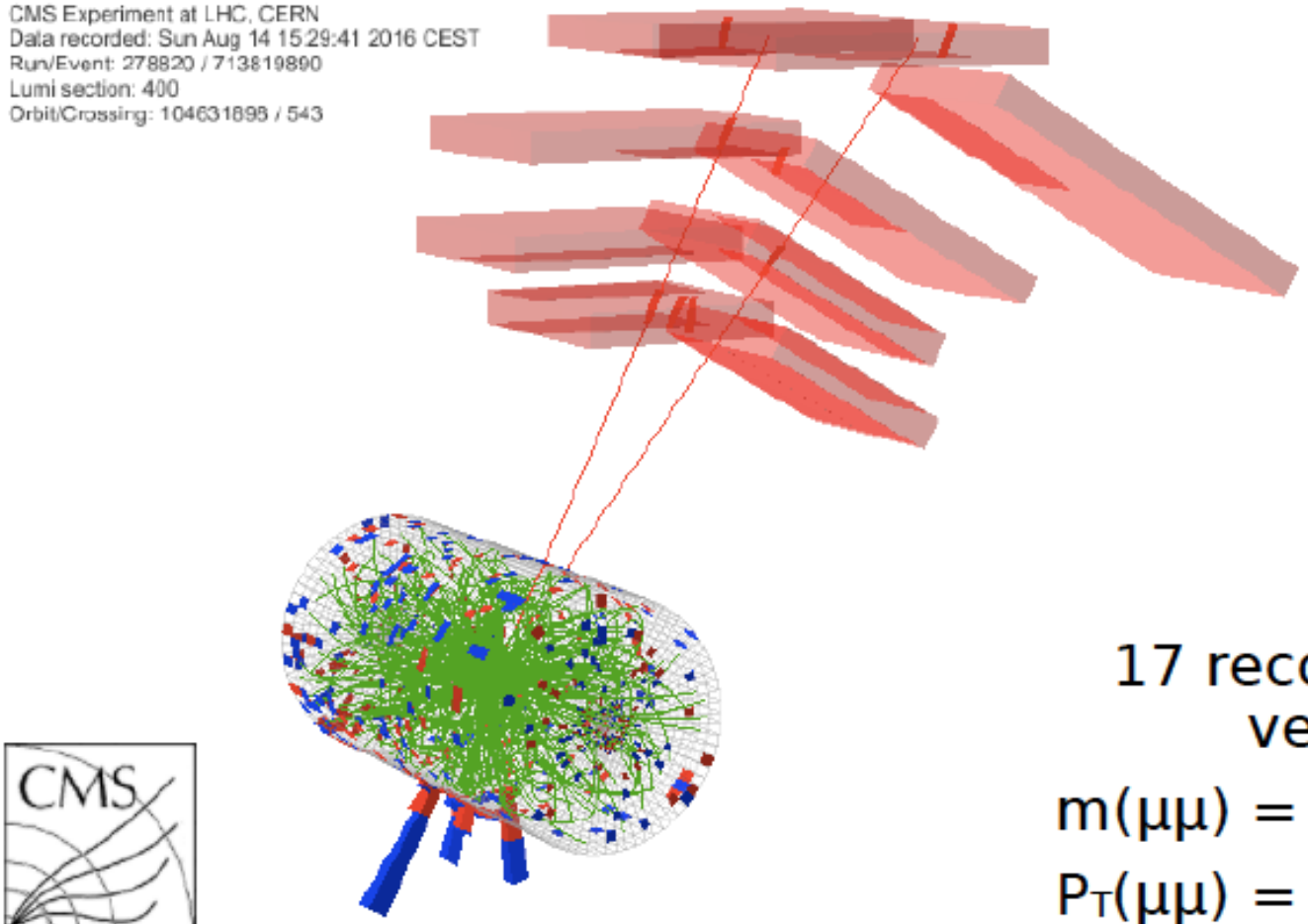


V to V+jets production



In order to have **p**T (V) != 0 the boson has to recoil against at least one parton.

Very high pT Z+jets in CMS



DP2017_001

17 reconstructed vertices

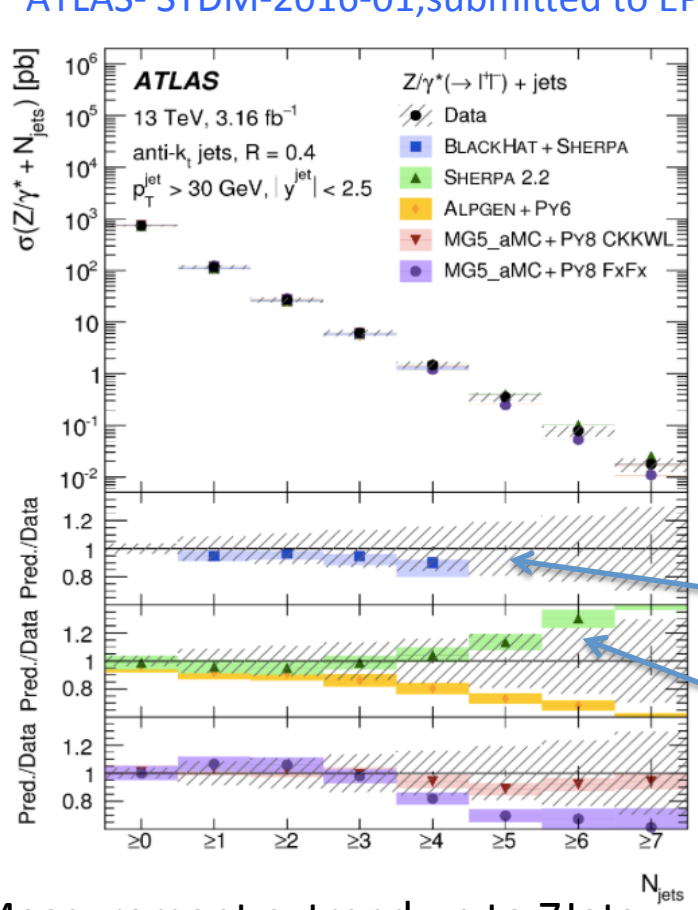
$m(\mu\mu) = 91$ GeV

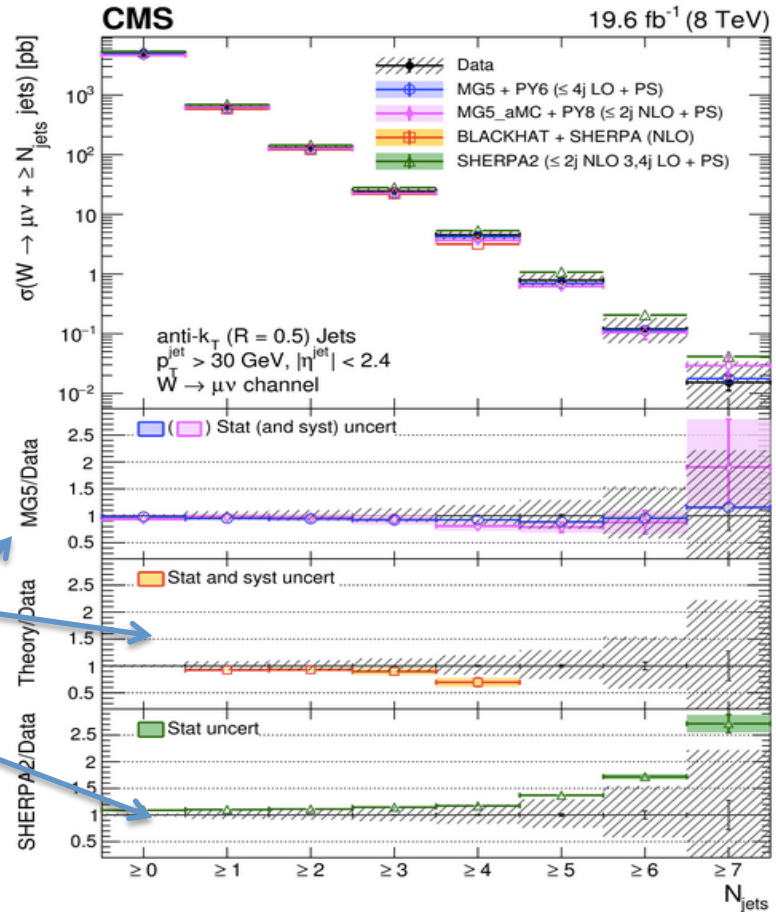
$P_T(\mu\mu) = 1260$ GeV

Z/W + Njets

ATLAS- STDM-2016-01,submitted to EPJ

Phys.RevD. 95.052002



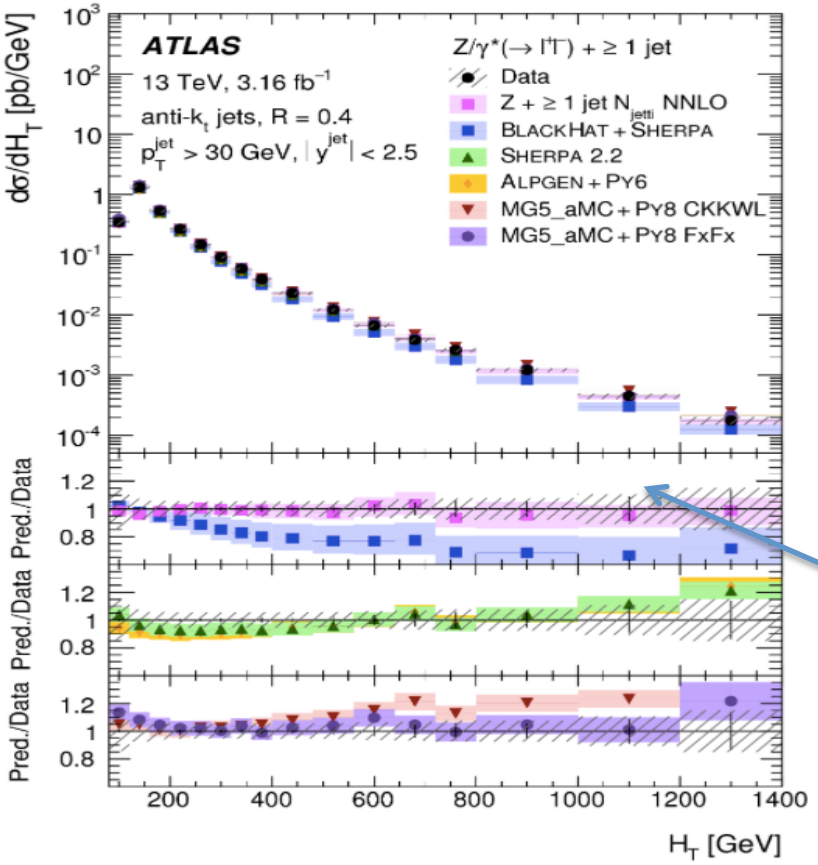


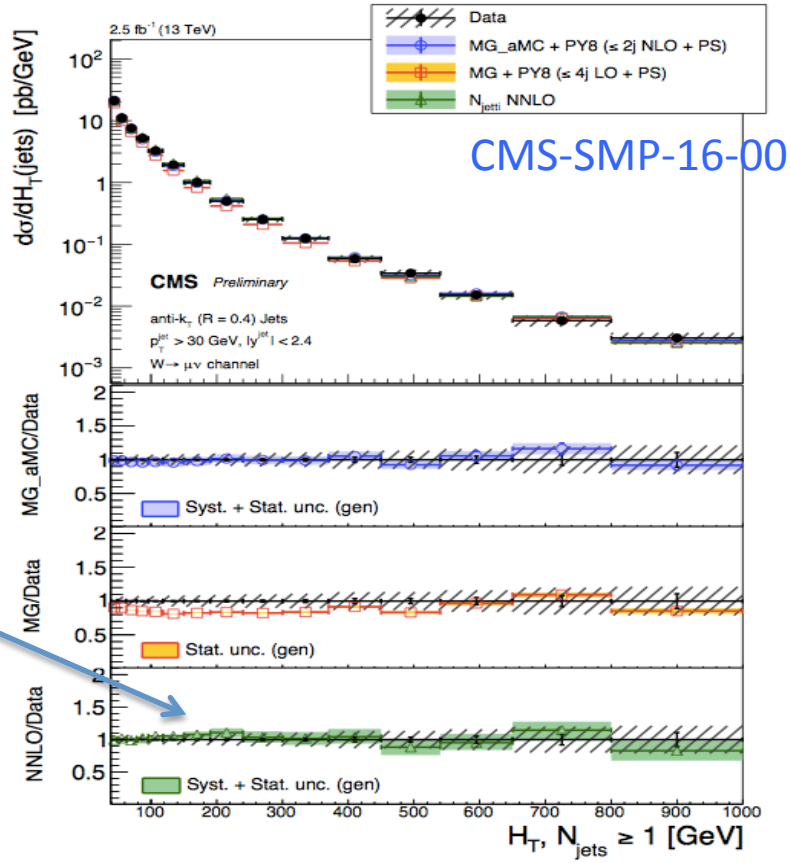
Measurement extrend up to 7Jets

Multiplicity up to 4 jets well reproduces, good data description from NLO + PS

Z/W + HT

ATLAS- STDM-2016-01,submitted to EPJ



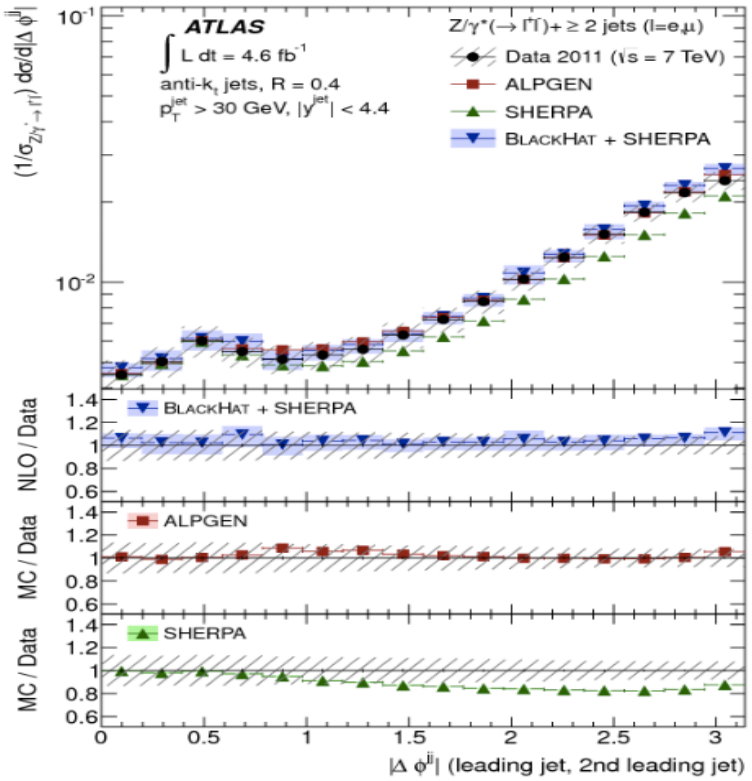


CMS-SMP-16-005

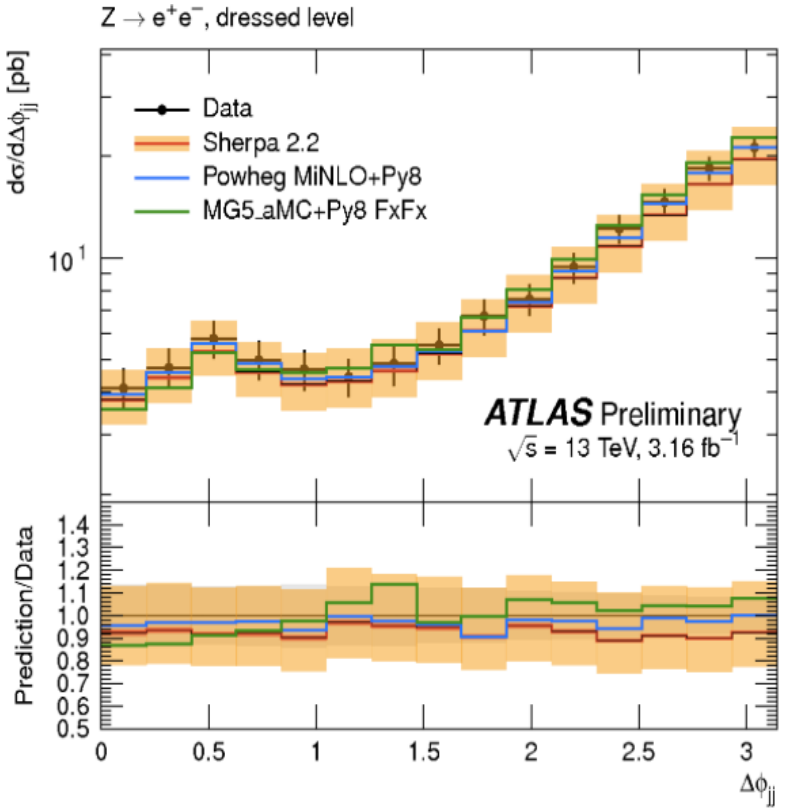
HT scale of the event is widely used in searches

- LO generators over-shooting at large HT → large scale uncertainty also expected
- Good data description from NLO (1,2 jets) + PS, may still have issues in events dominated by > 2 partons
- Very good agreement from NNLO predictions at all scales!

Jet differential measurement



ATLAS/STDM-2012-04



ATL- PHYS-PUB-2017-06

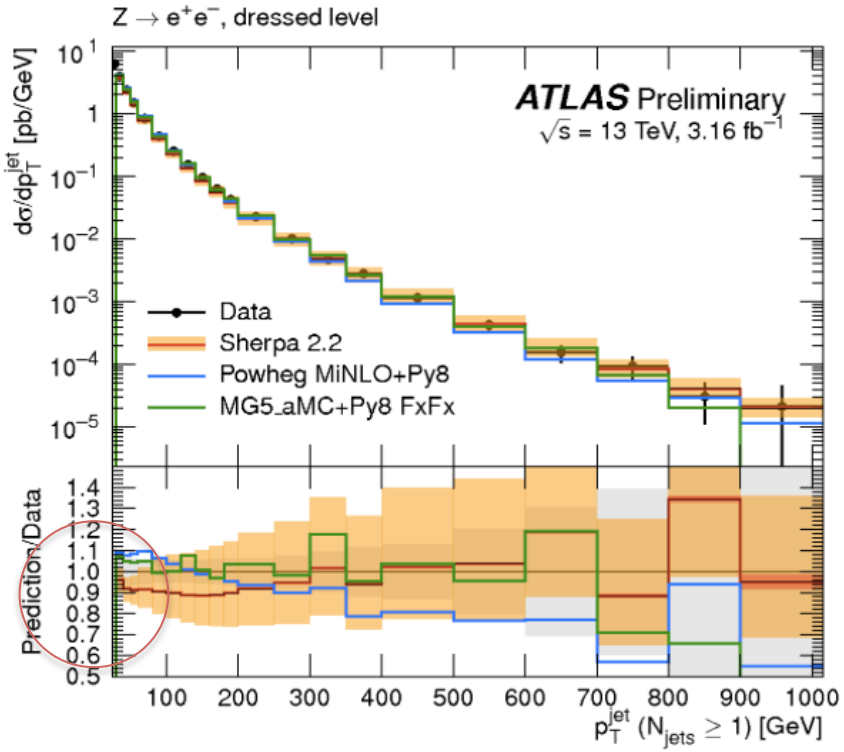
Hard radiation at large angles from matrix element

Soft collinear radiation from PS

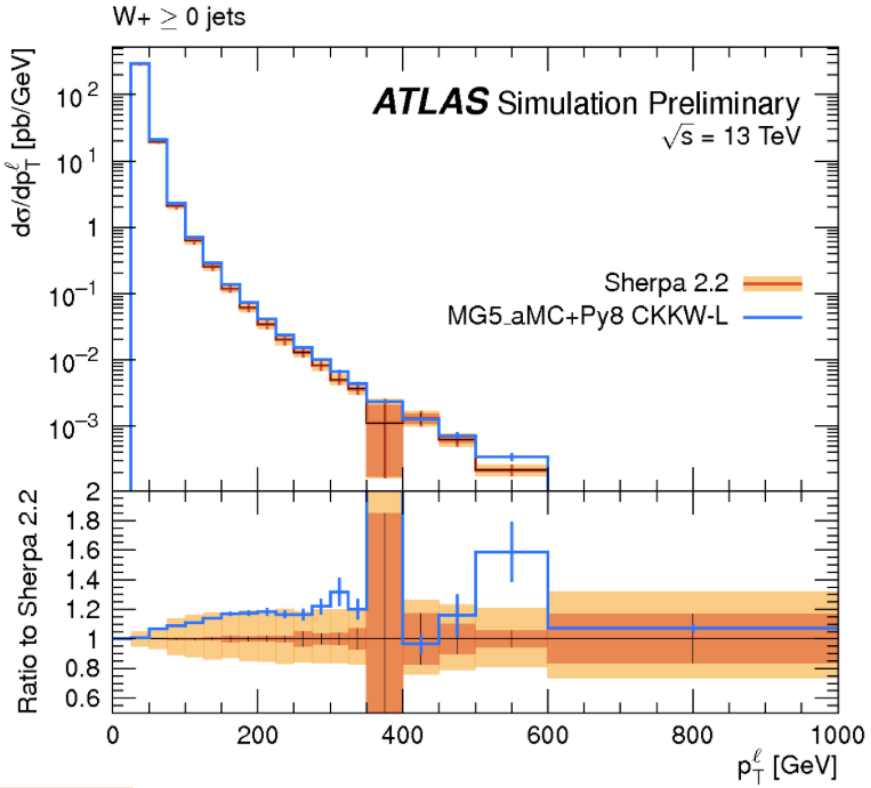
In general the modeling of many differential distribution much improved

More jet differential measurement

ATL- PHYS-PUB-2017-06



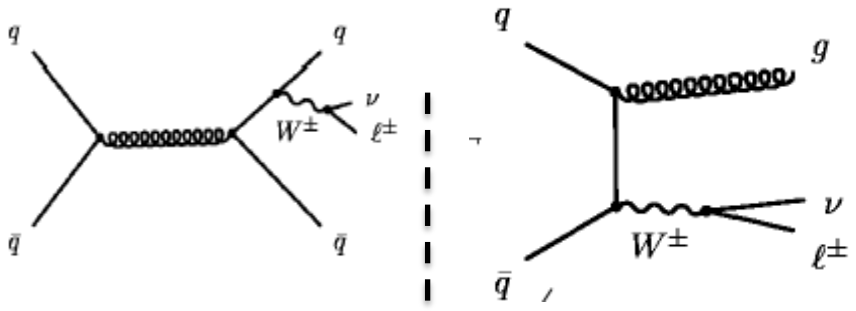
… still something to improve

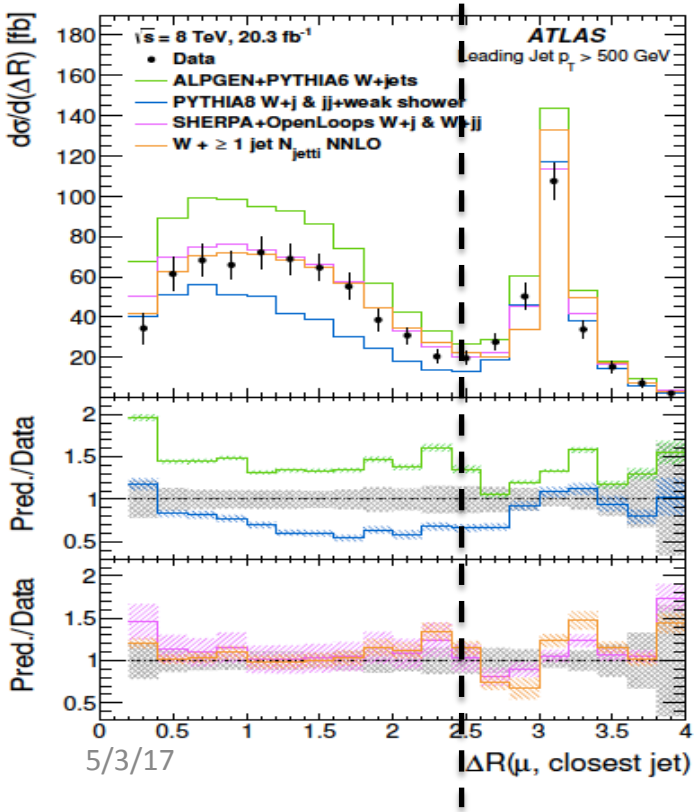


Early on observed pT balance between the Z and jet confirms that the jet energy scale section for Z+jet production
Now experimental uncertainties smaller of the ones assigned to the theory

Handling of weights give some unphysical events

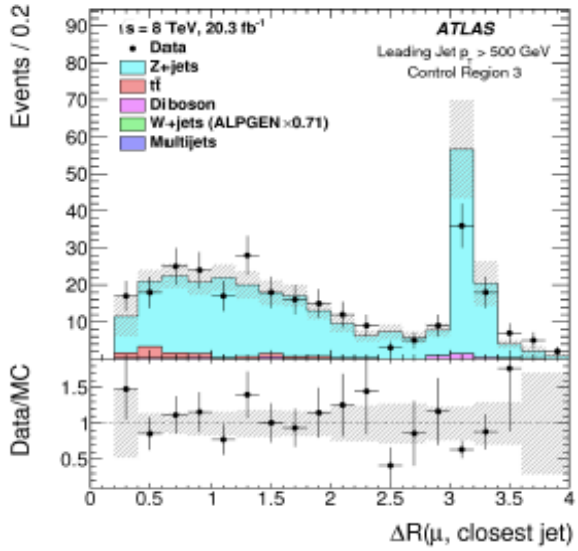
Collinear W/Z emission





Phys.Lett. B765 (2017) 132-153

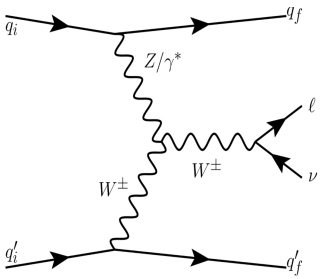
… also in Z+jets



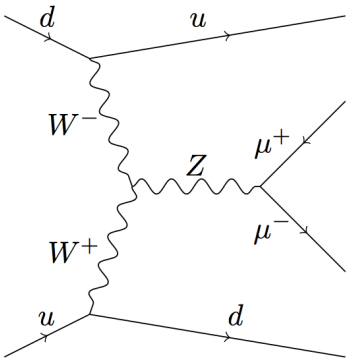
Increasing the pT of the leading jet (i.e. Ptj1>500GeV)

→ enrich events where a W is radiated from a quark leg in a dijet event

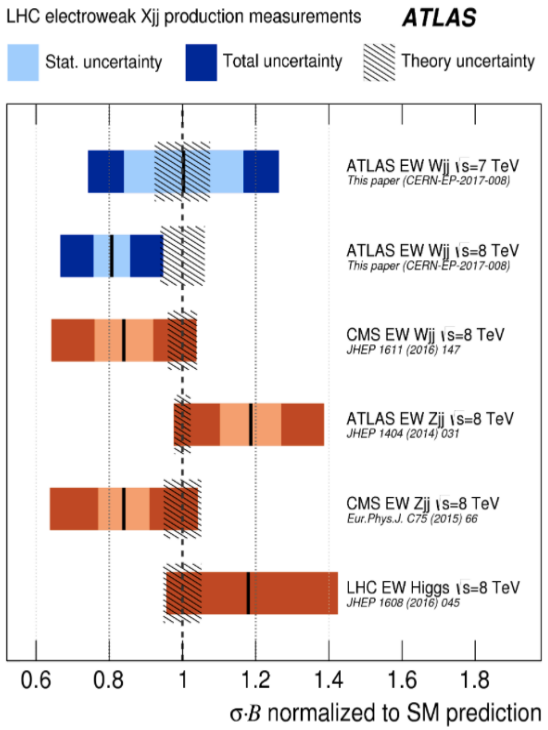
Sherpa and W+j (and jj) NNLO incorporating NLO QCD and EW corrections to both processes yield good description



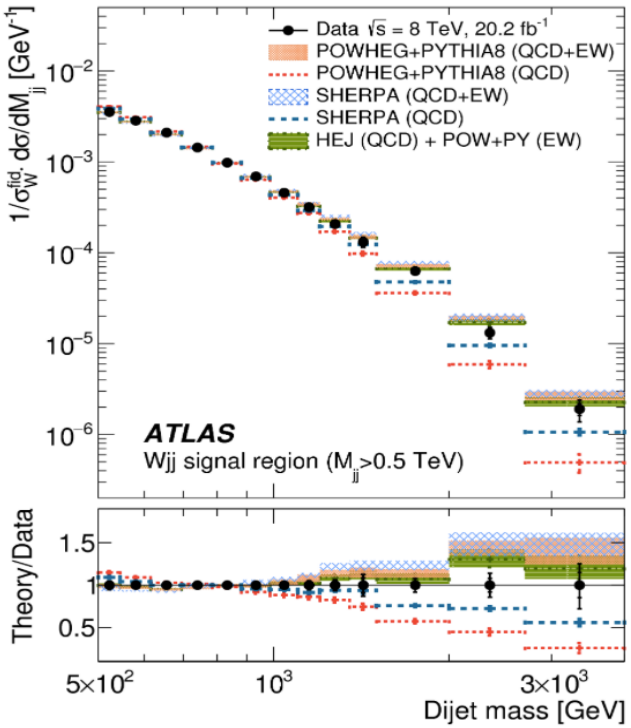
EWK Z/W+jj production



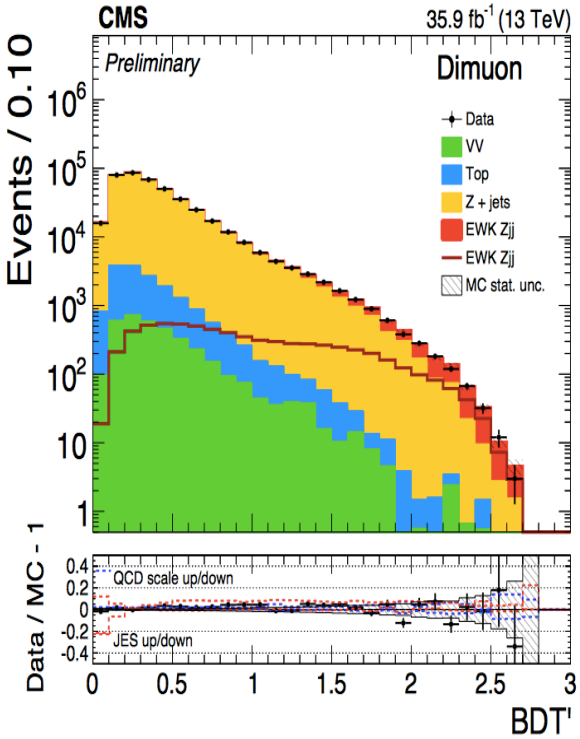
Roughly ten times lower cross sections than QCD Production
Important for VBF production studies of Higgs boson
Exp Key : Exploit rapidity gap structure of events in order to enhance signal, constrain modeling from data



EWK Wjj ATLAS-STDM-2014-11

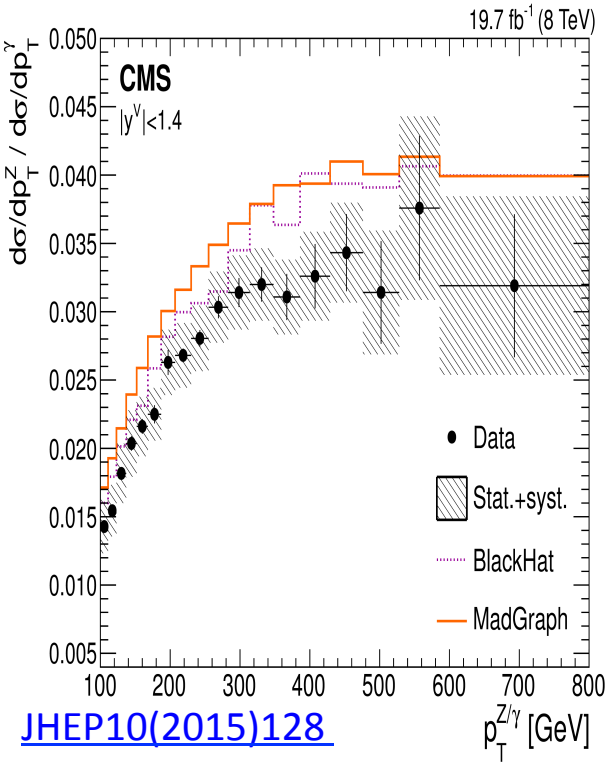


EWK Zjj CMS-SMP-16-018

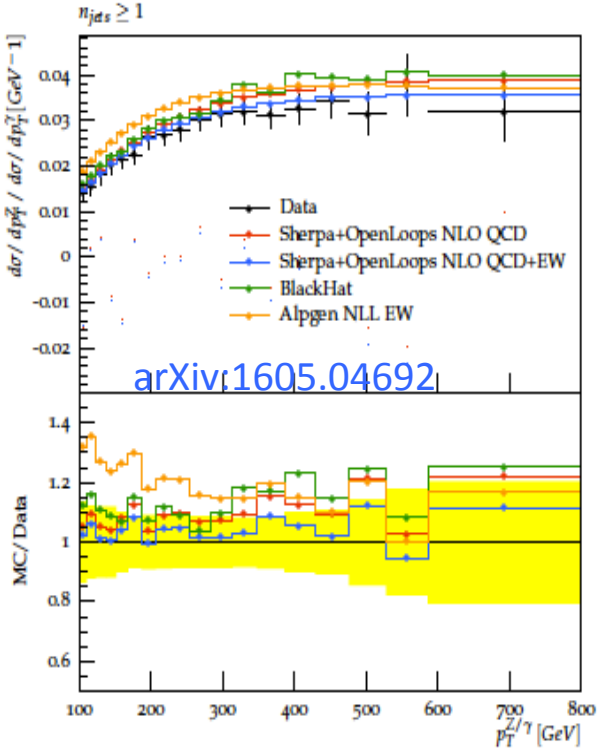


Z/γ*+jet and γ+jet ratio

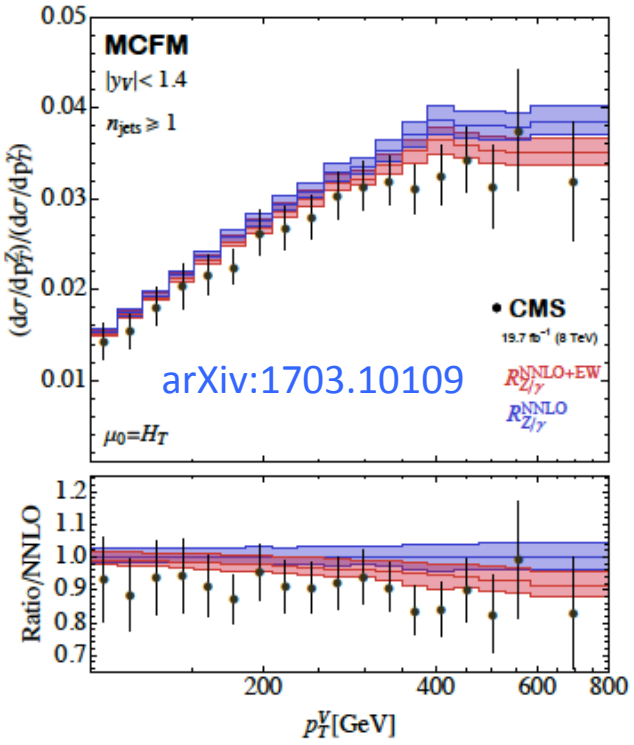
Differential cross section ratio as a function of boson p_T
Compared to Madgraph and BLACKHAT (QCD-NLO) calculation
Inclusion of EW corrections results in better agreement



JHEP10(2015)128



arXiv:1605.04692

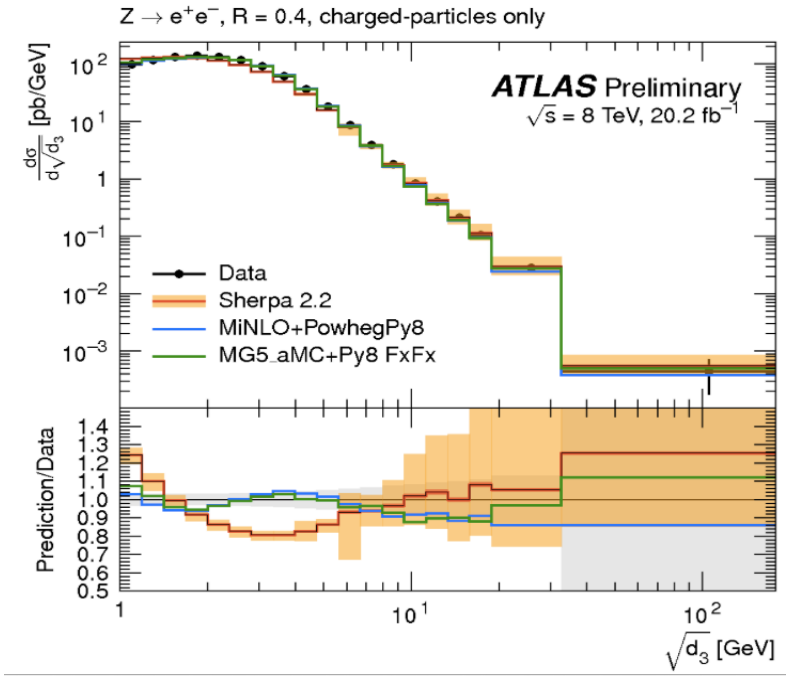


arXiv:1703.10109

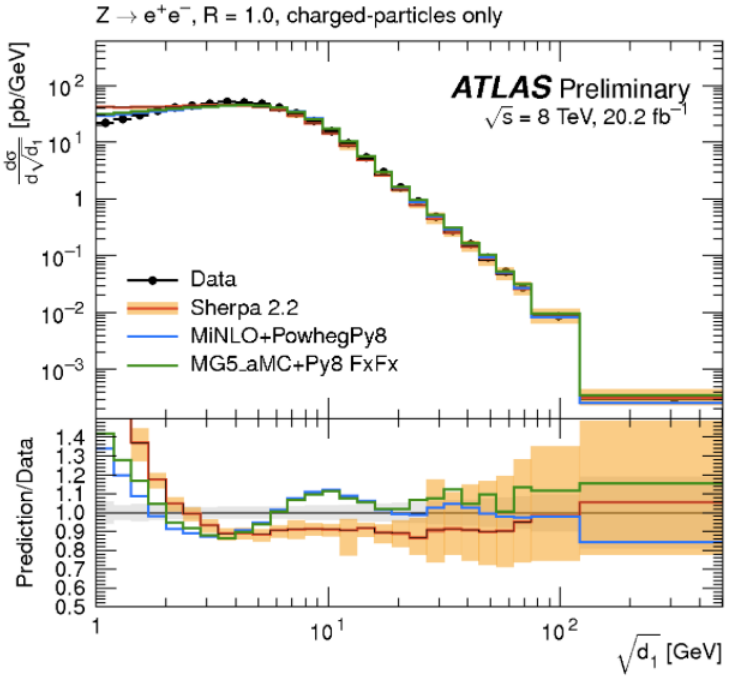
Splitting Scales in Z events

Measure production cross-section as a function of kt algorithm step for R =0.4 and R = 1.0

$$d_{ij} = \min\left(p_{\mathrm{T},i}^2, p_{\mathrm{T},j}^2\right) \times \frac{\Delta R_{ij}^2}{R^2},$$
$$d_{ib} = p_{\mathrm{T},i}^2,$$
$$d_k = \min_{i,j}(d_{ij}, d_{ib}).$$



STDM-2015-14, ATL- PHYS-PUB-2017-06



observe similar behavior in the description:
general underestimate of the bulk, and overestimate of the low region and tail

Summary

Large database of information extracted from LHC Run I and II data for further improvement of MC predictions

More on V+heavy flavor and multijet in other talks in this workshop

Discussed in this talk

Zpt,phi*

- ATLAS-STDM-2014-12 (8TeV) Eur. Phys. J. C 76 (2016) 291
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- ATLAS- STDM-2016-01 (Z) 13TeV 2015, submitted to EPJ
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- CMS-PAS-SMP-14-005 JHEP10(2015)128
- ATLAS-PAPERS/STDM-2015-16 (W/ZhighPT ewk) 8TeV Phys.Lett. B765 (2017) 132-153
- EWK Wjj ATLAS-STDM-2014-11,
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