TOOLS AND MC (experimental)

V.Ciulli, Università and INFN Firenze

Les Houches Workshop Series
"Physics at TeV Colliders" 2017

Tools and MC

≡ Matrix Element + Parton Shower + Non Perturbative corrections

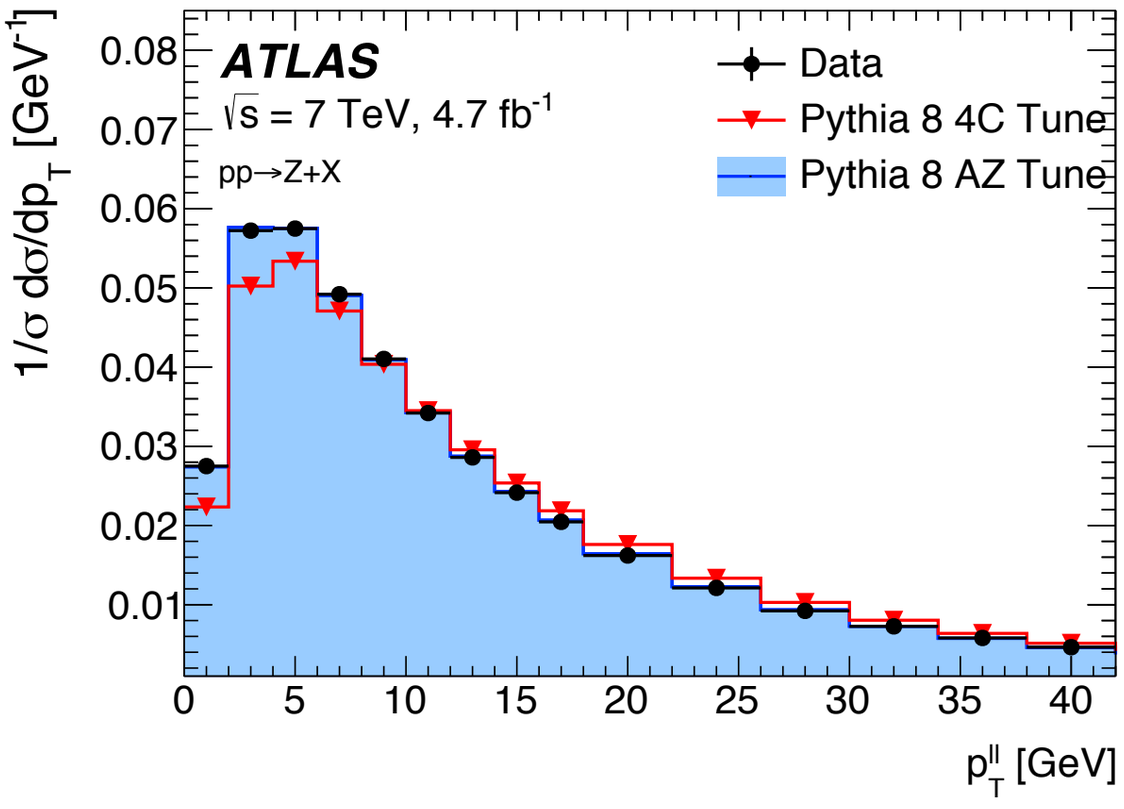
- Preliminary list of Topics
  - Uncertainties in HEP event generators
  - Applicability of matched/merged fixed-order+parton shower calculations
  - Treatment of charm/bottom quarks in parton showers, and in fixed order+parton shower calculations
  - Assessing higher-order parton shower effects
  - Addendums to common interfaces
- I will discuss some examples of problems/solutions in experimental analyses
- New topics, as usual, will be welcomed!

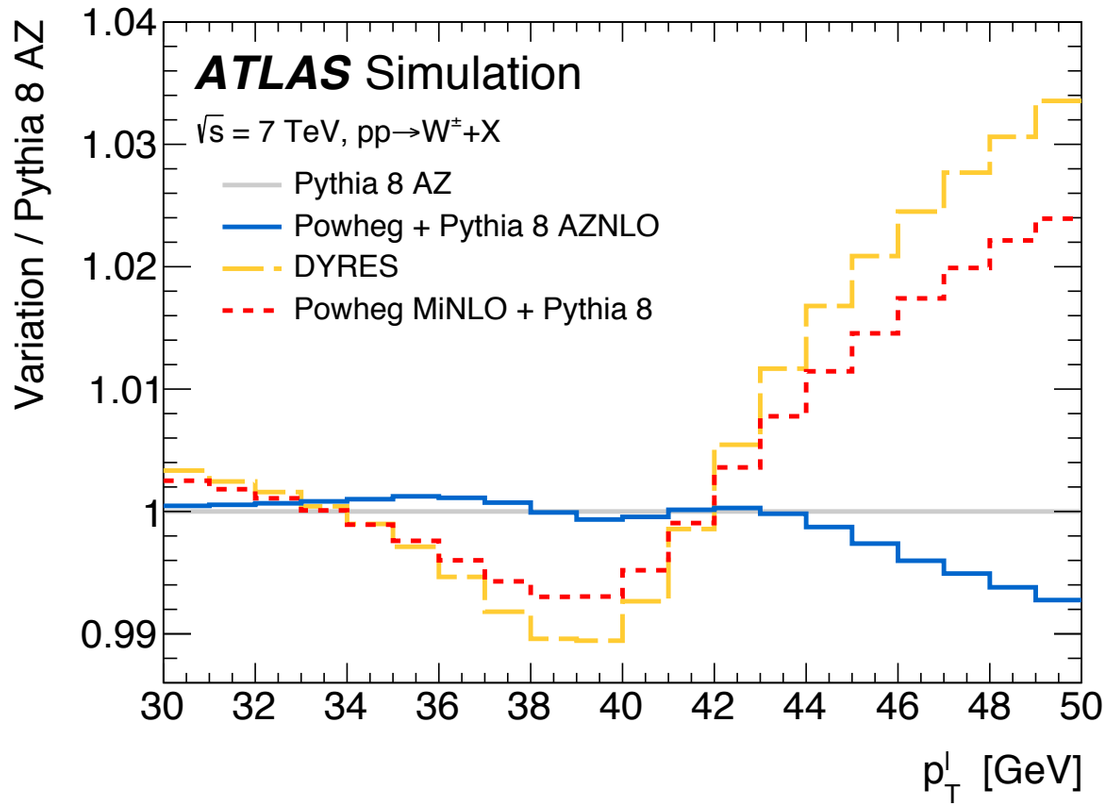
Uncertainties in HEP event generators

W mass measurement rely on exact description of boson pT:

- tension between NNLO+NNLL and the data for Z pT
- ATLAS developed a specific tuning of Pythia to describe Z pT

arXiv:1701.07240



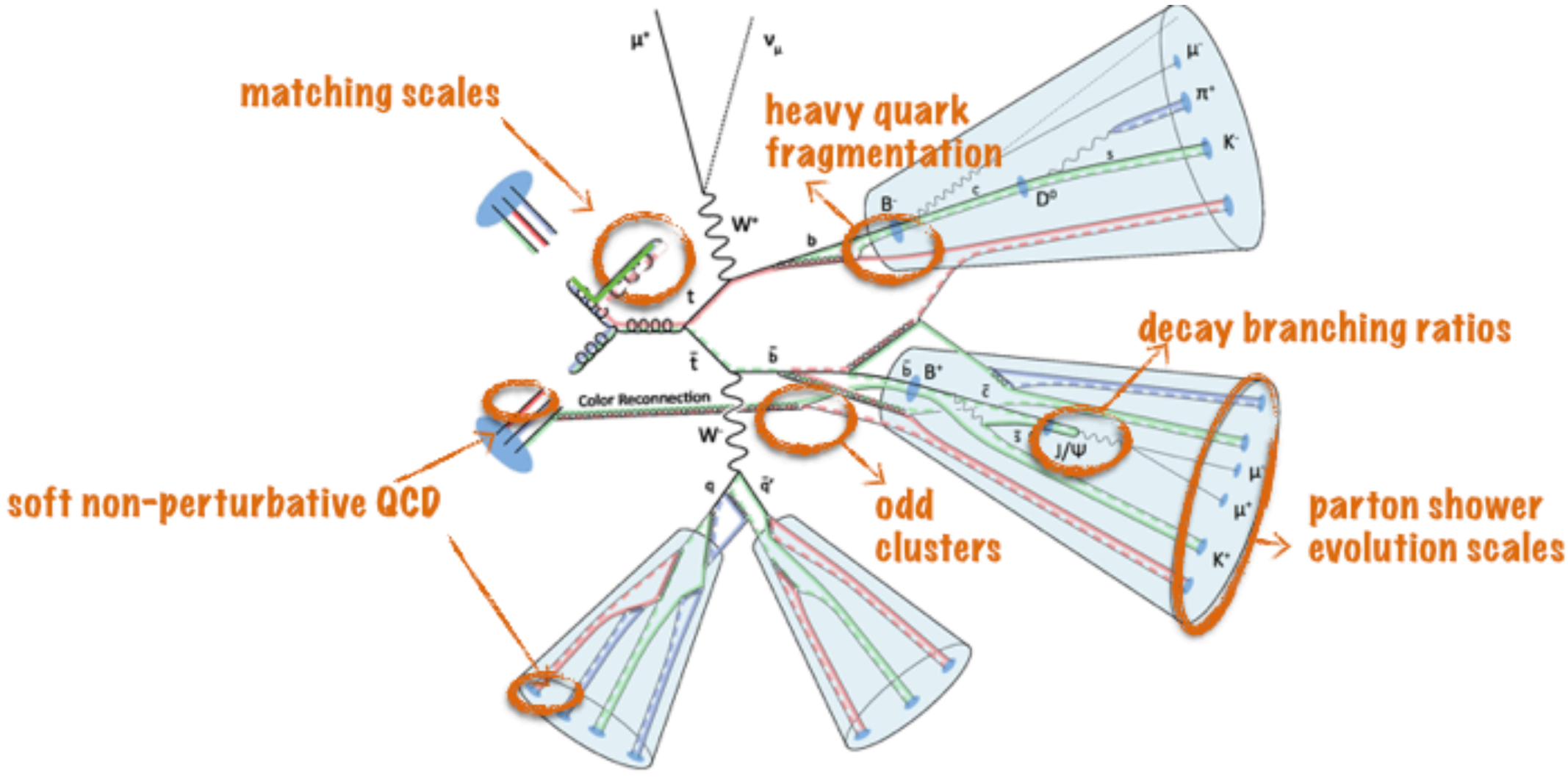


- can we extrapolate from Z to W assuming cancellations of theory uncertainties?
- why are NNLO+NNLL calculations worse than parton shower (+ ME corrections) when compared to data? is this due to a yet poorly understood treatment of heavy flavours?

Uncertainties in HEP event generators

Simulation of ttbar events

- many ingredients



Uncertainties in HEP event generators

Simulation of ttbar events

- ATLAS prescription (LHC MC workshop)
  - Uses either two-point systematic comparison or parameter variations.

	RUN 1	RUN 2
Scale	Powheg μ_R, μ_F, hdamp variations	
Matrix Element	Powheg -vs- MC@NLO	Powheg -vs- MG5_aMC@NLO
Hadronisation	Herwig++ -vs- Pythia6	Herwig++(7) -vs- Pythia6(8)
Non-perturbative	Perugia Tunes	A14 Tunes
PDF	Envelope method	PDF4LHC eigenvectors
Other	Mass variations depending on analysis	

ATLAS-

Uncertainties in HEP event generators

Simulation of ttbar events

- CMS prescription (will be presented today in LHC TOP working group)

Parton shower uncertainties

Source	*handle*	*weights*	*variation*	*comment*
Shower scales	ISR scale (SpaceShower:renormMultFac)	N	1/2 - 2	see TOP-16-021
	FSR scale (TimeShower:renormMultFac)	N	1/2 - 2	can be $\sqrt{2}$ / $1/\sqrt{2}$ from LEP
Matching	hdamp	N	$h_{damp} = 1.581^{+0.658}_{-0.585} \times m_t$	see TOP-16-021
Soft QCD	underlying event (MultipartonInteractions:pT0Ref MultipartonInteractions:expPow ColourReconnection:range)	N	up/down	MPI and CR strength (doesn't affect resonance decays)
Odd clusters	colour reconnection (MPI-based + QCD-inspired + gluon move)	N	different simulations	affecting resonance decays -
Fragmentation	$x_b = p_T(B)/p_T(b\ jet)$	Y	Bowler-Lund param. unc. from	see TOP-16-022
Flavour response/ hadronization	Pythia vs Herwig	N	JES flavour group for light, g, c, b	
Decay tables	semi-leptonic BR	Y	vary by +0.77%/-0.45%	see PDG

Uncertainties in HEP event generators

Simulation of ttbar events

- common approach on scale uncertainty and hadronization
- differences between Pythia and Herwig PS not fully understood

Parton shower uncertainties

Source	*handle*	*weights*	*variation*	*comment*
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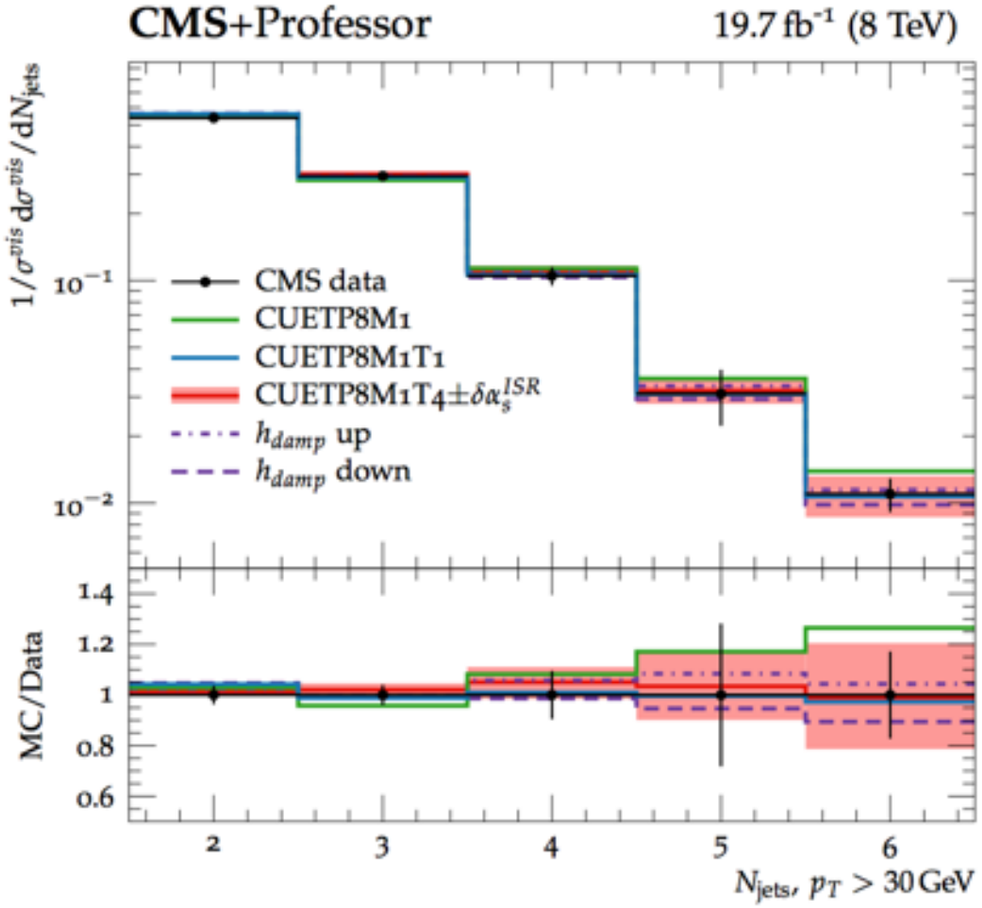
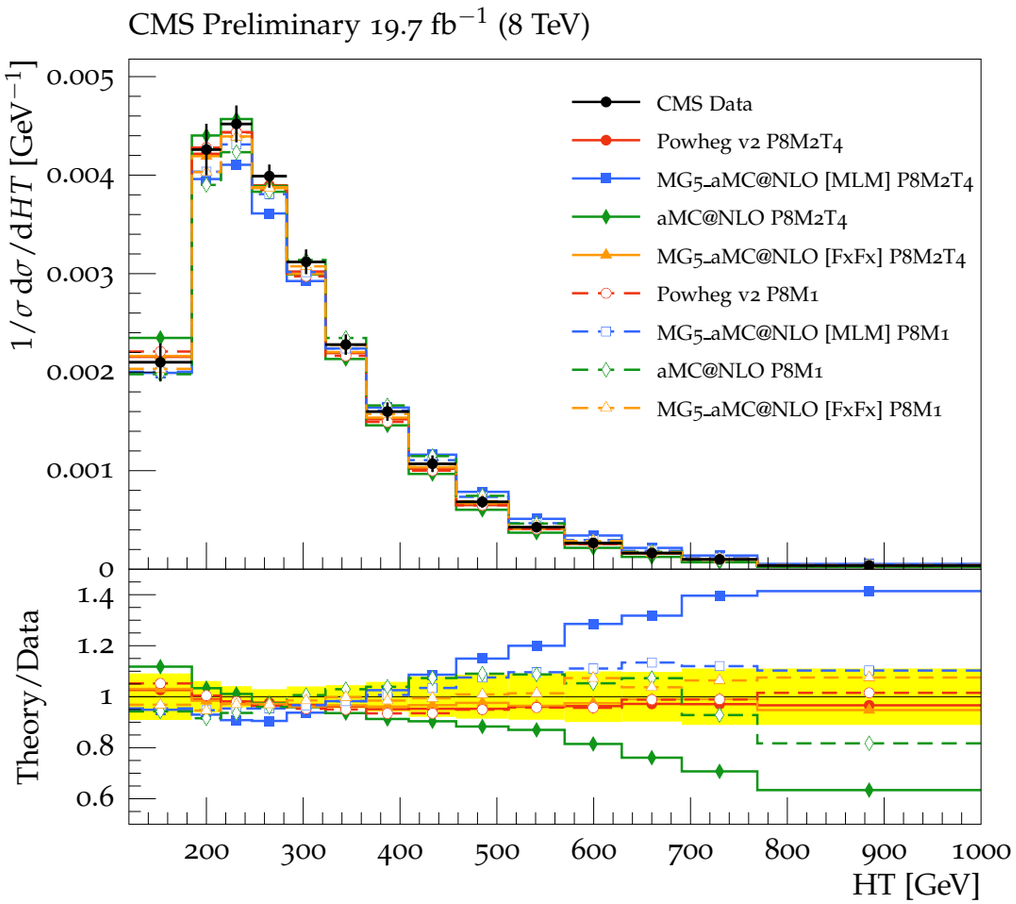
Uncertainties in HEP event generators

Simulation of ttbar events

- CMS tunesPowheg+Pythia to fit jet multiplicity in ttbar events

CMS PAS TOP-16-021 $h_{\mathrm{damp}} = 1.581^{+0.658}_{-0.585} \times m_t$, $\alpha_s^{\mathrm{ISR}} = 0.1108^{+0.0145}_{-0.0142}$





- Higher values of h_{damp} and lower values of α_S preferred
- Similar results found by ATLAS
- New tune ok also for MG_aMC@NLO [FxFx], not for LO [MLM]

Uncertainties in HEP event generators

Simulation of ttbar events

- ATLAS compared MG_aMC@NLO and Sherpa to Powheg + Pythia and data

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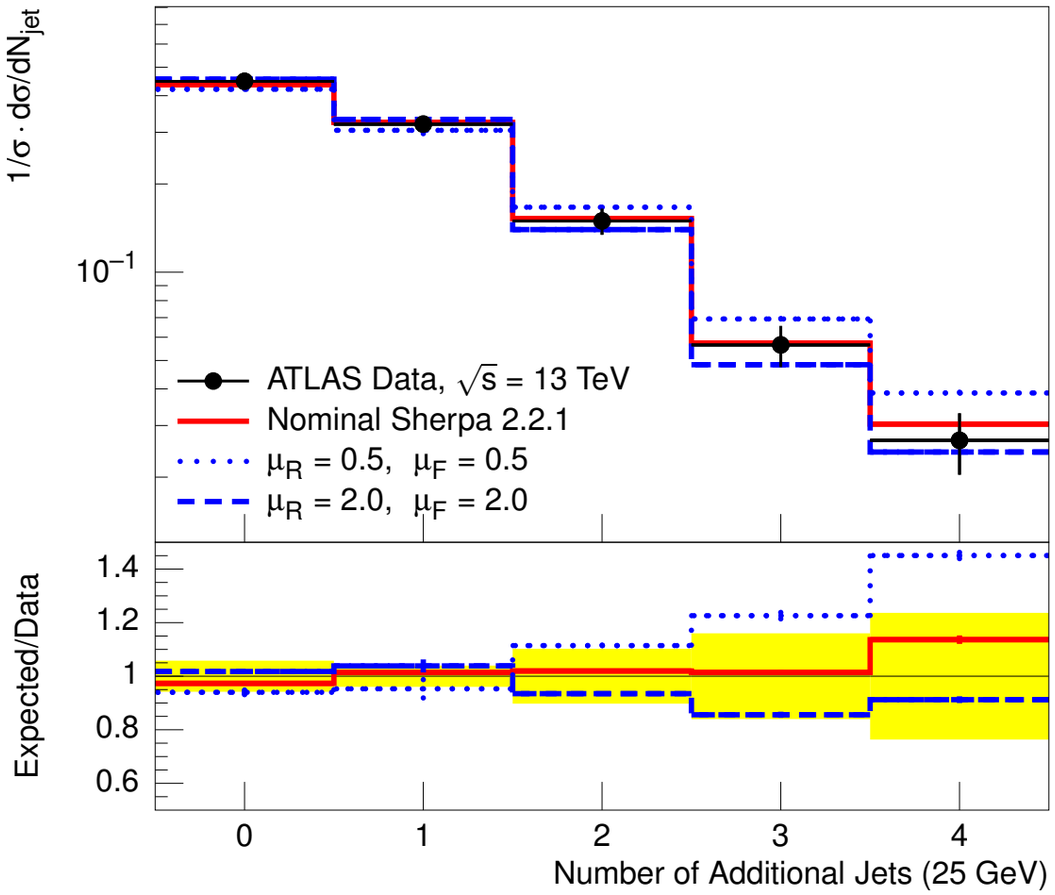
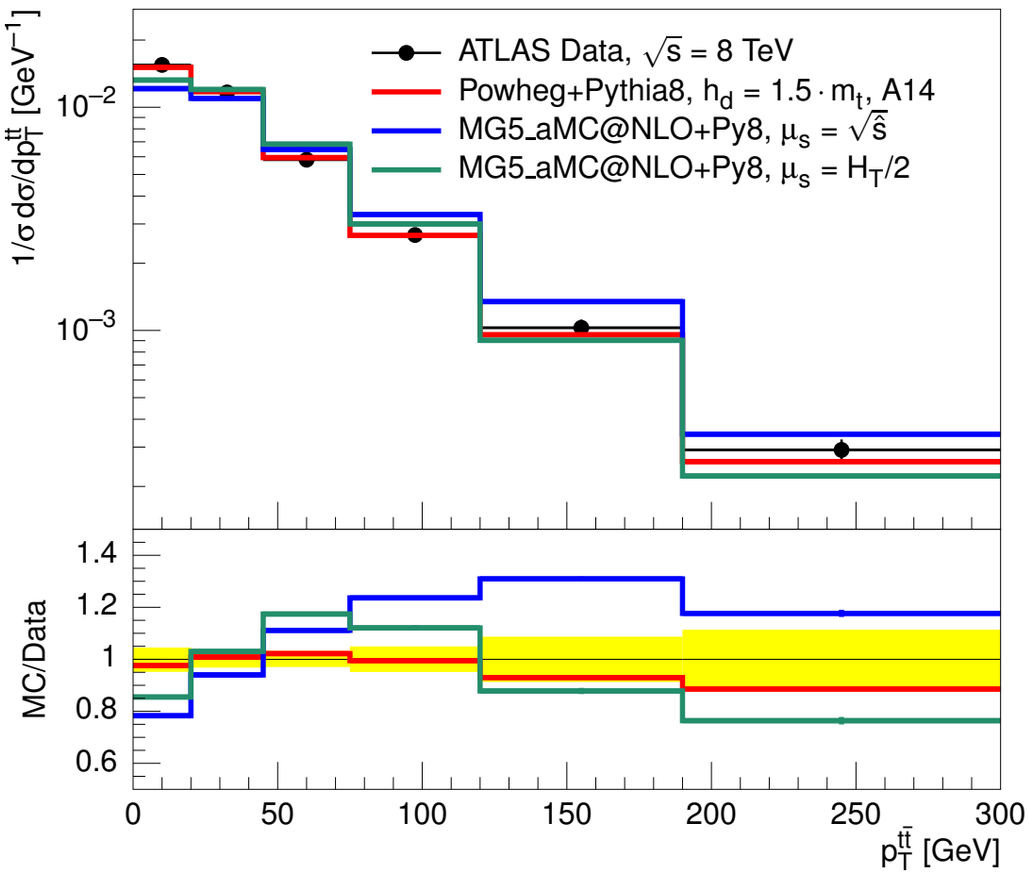
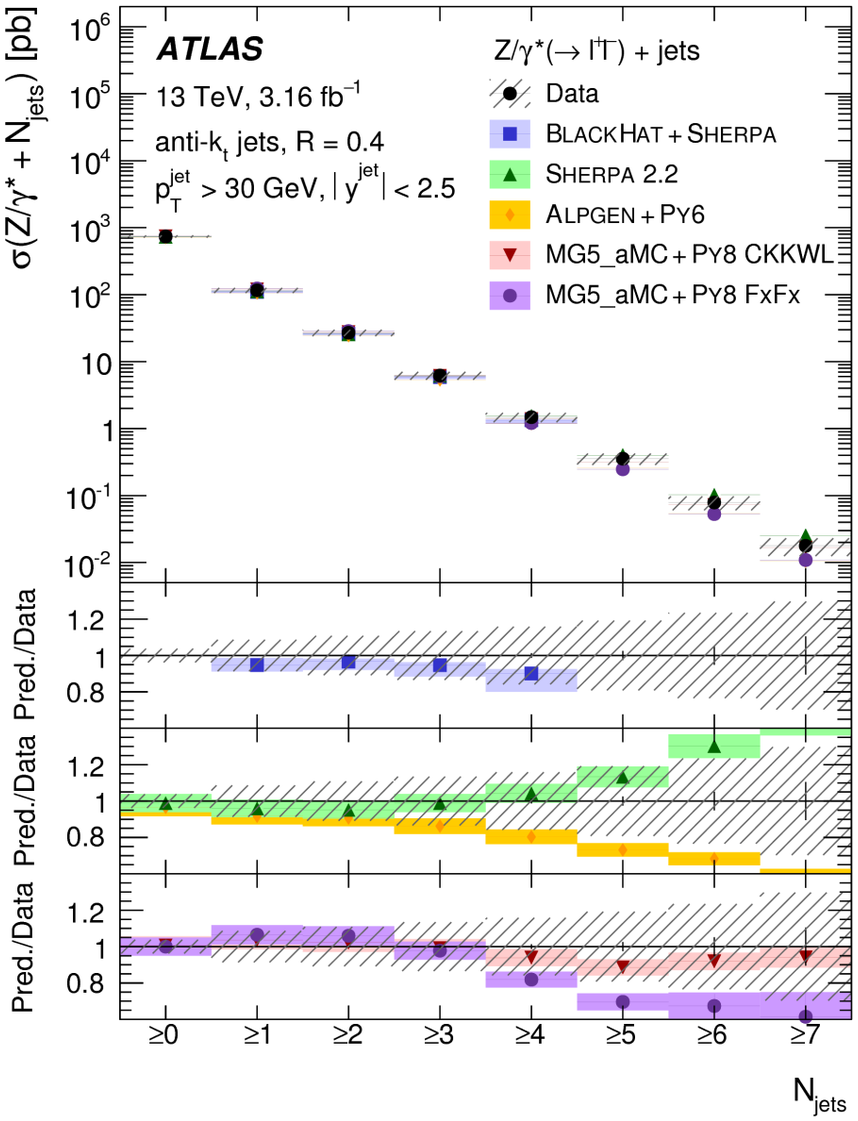


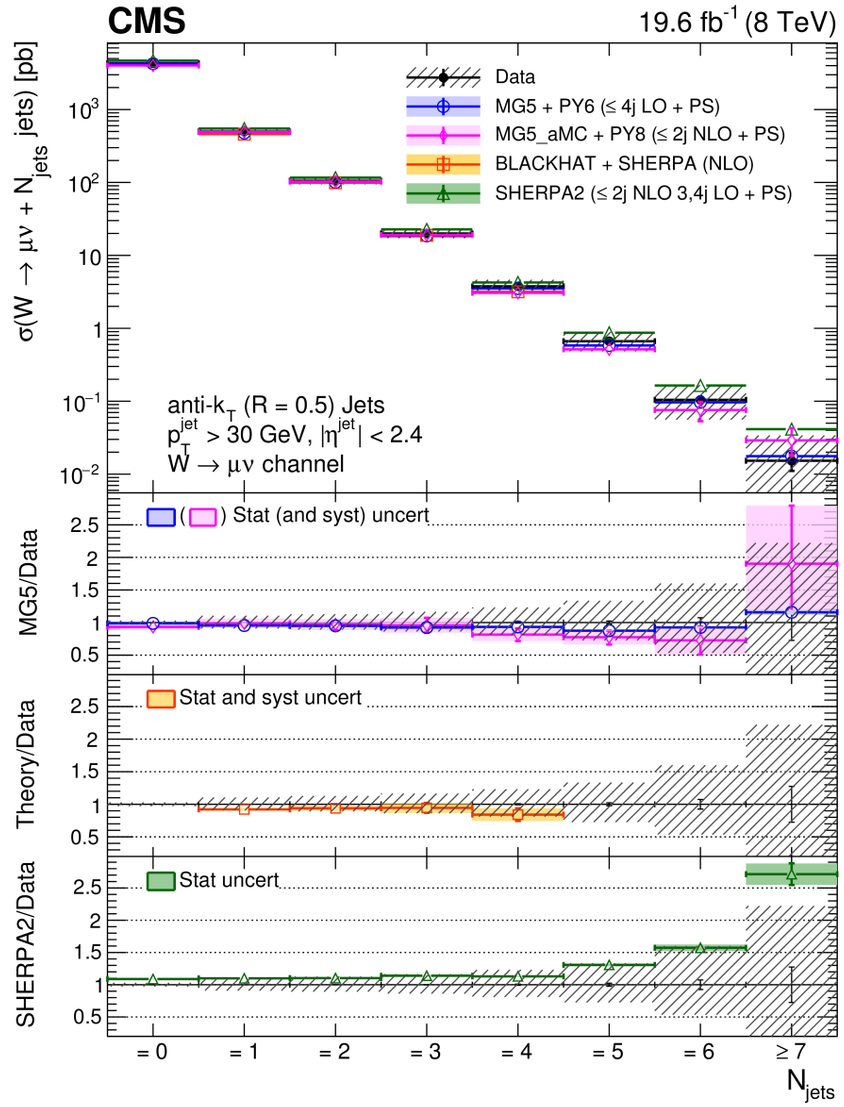


- Scale variations within measurement uncertainties for Sherpa and Powheg
- In MG_aMC@NLO shower starting scale varied but yet some disagreements with data observed

Uncertainties in HEP event generators

- in V+jets LO ME+PS good enough





Do we give up on tune and α_s universality?

- Are we tuning out discrepancies using data instead of understanding differences between PS, matching, etc ?
- How then should we assign systematics uncertainties?

Uncertainties in HEP event generators

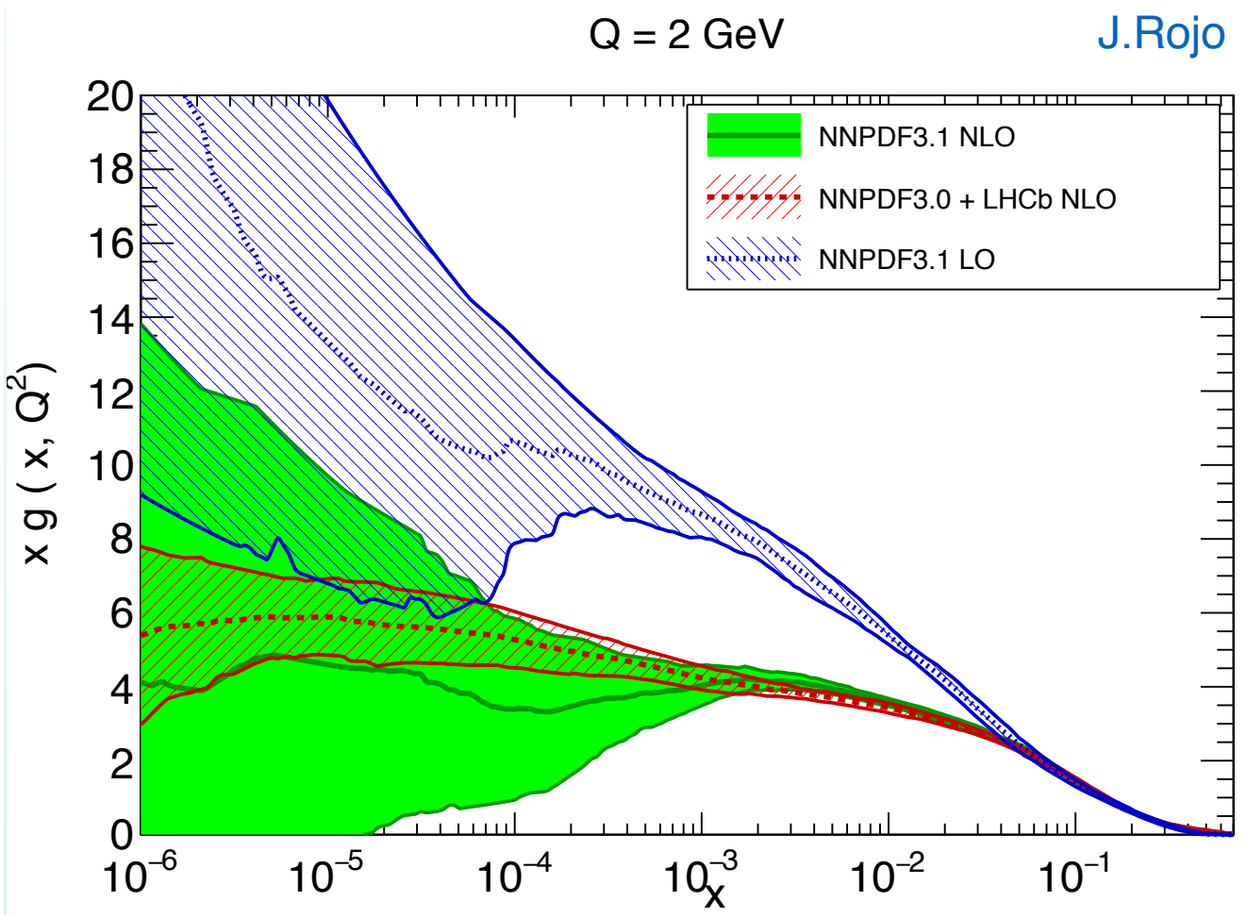
PDFs in MC generators

- which perturbative order for ME, ISR, UE and MPI?
- In the case of NLO/NNLO MC event generators, no question that NLO/NNLO PDFs must be used in the ME, but less obvious what is optimal for ISR/UE/MPI
- we need to consistently use the same PDF for ISR/UE/ MPI as the one used for the corresponding MC tune, to get soft QCD right
- different approaches:
  - CMS and ATLAS use LO PDFs for their tunes
  - Herwig7 has tunes based on NLO
  - Pythia8 uses LO
  - Sherpa uses NNLO
- at small-x gluon (especially relevant for MC tunes) large theoretical uncertainty
- but LO still preferred because positive-definite by definition

Uncertainties in HEP event generators

PDFs in MC generators

- ForcePositive option in LHAPDF6 now allows using NLO also in the PS
- switching to NLO PDFs would improve the stability of the tune when updating the PDFs



- by the way, subtraction terms in ME@NLO are not a problem when using LO PDFs?

Matched/merged fixed-order+parton shower

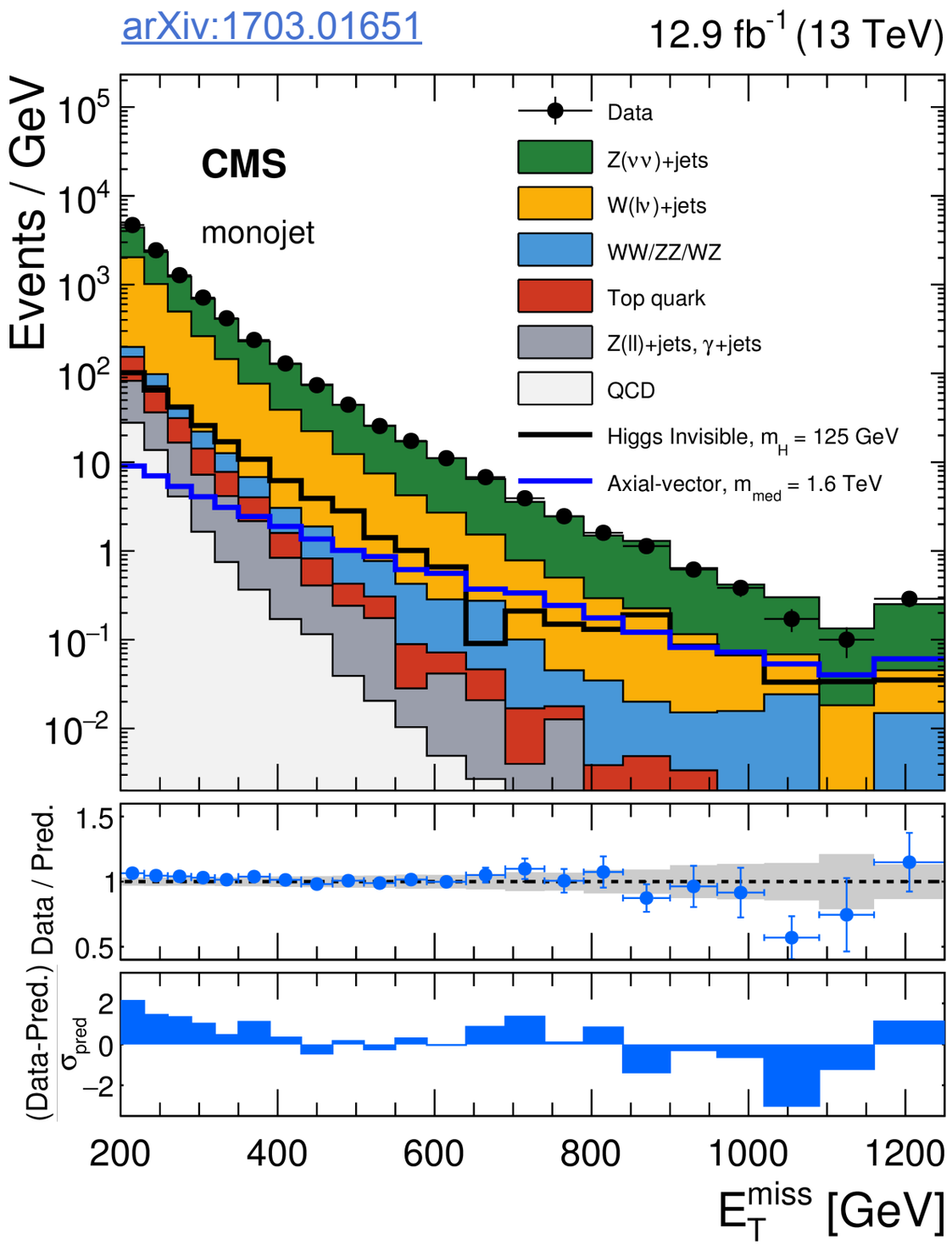
Uncertainty in Z+jets vs γ+jets and W+jets

- Very important to control Z $\longrightarrow \nu\nu$ background in V+jets dark matter searches
- NNLO QCD + nNLO EWK available
- uncertainty ~ few percent with MC reweighting ?

$$\frac{\mathrm{d}}{\mathrm{d}x}\frac{\mathrm{d}}{\mathrm{d}\vec{y}}\sigma^{(V)}(\vec{\varepsilon}_{\mathrm{MC}},\vec{\varepsilon}_{\mathrm{TH}}) =$$

$$= \frac{\mathrm{d}}{\mathrm{d}x}\frac{\mathrm{d}}{\mathrm{d}\vec{y}}\sigma^{(V)}_{\mathrm{MC}}(\vec{\varepsilon}_{\mathrm{MC}}) \left[\frac{\frac{\mathrm{d}}{\mathrm{d}x}\sigma^{(V)}_{\mathrm{TH}}(\vec{\varepsilon}_{\mathrm{TH}})}{\frac{\mathrm{d}}{\mathrm{d}x}\sigma^{(V)}_{\mathrm{MC}}(\vec{\varepsilon}_{\mathrm{MC}})}\right]$$

Any interesting studies to be done here in Les Houches?



Matched/merged fixed-order+parton shower

Uncertainty in Z+jets vs γ+jets and W+jets

J. M. Lindert et al. arXiv:1705.04664

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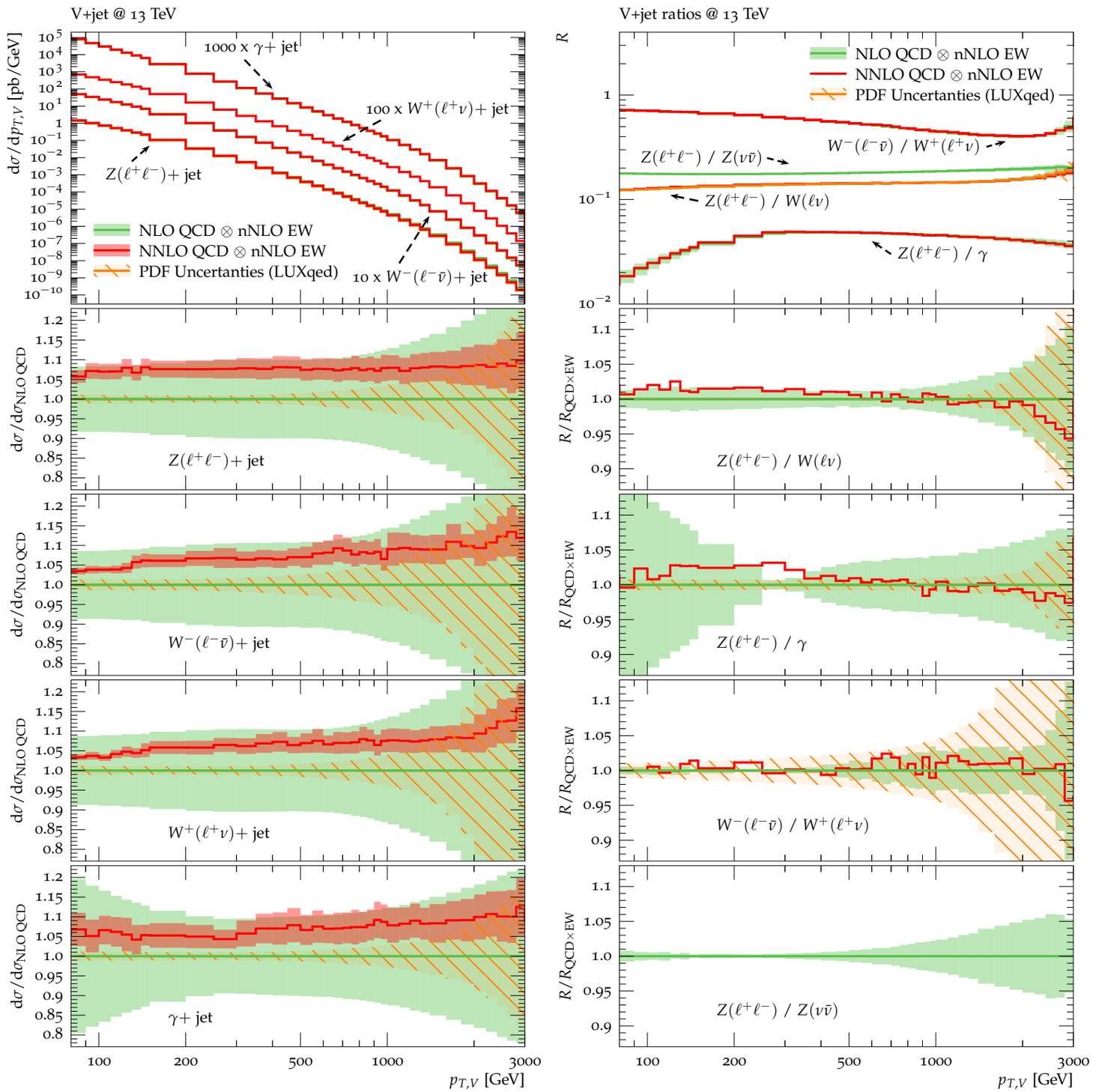


Matched/merged fixed-order+parton shower

Electroweak diboson production

- challenging process, very important for RunII
- available only at LO for most generators

ATL-PHYS-PUB-2017-005

		$VVjj$	VVj	VV
$VVjj = \ell^{\pm}\ell^{\mp}2\nu jj$	VBFNLO+PYTHIA8	LO	PS	PS
	MadGraph5_aMC@NLO+PYTHIA8	LO	PS	PS
$VVjj = \ell^{\pm}\ell^{\pm}2\nu jj$	Sherpa	LO	PS	PS
	PowhegBox+PYTHIA8	NLO	LO	PS
$VVjj = \ell\ell/\ell\nu/\nu\nu jj$	Sherpa	LO	PS	PS
	MadGraph5_aMC@NLO+PYTHIA8	LO	PS	PS
$Z\gamma jj = 2\ell\gamma jj$	Sherpa	LO	PS	PS
	VBFNLO+PYTHIA8	LO	PS	PS
	MadGraph5_aMC@NLO+PYTHIA8	LO	PS	PS

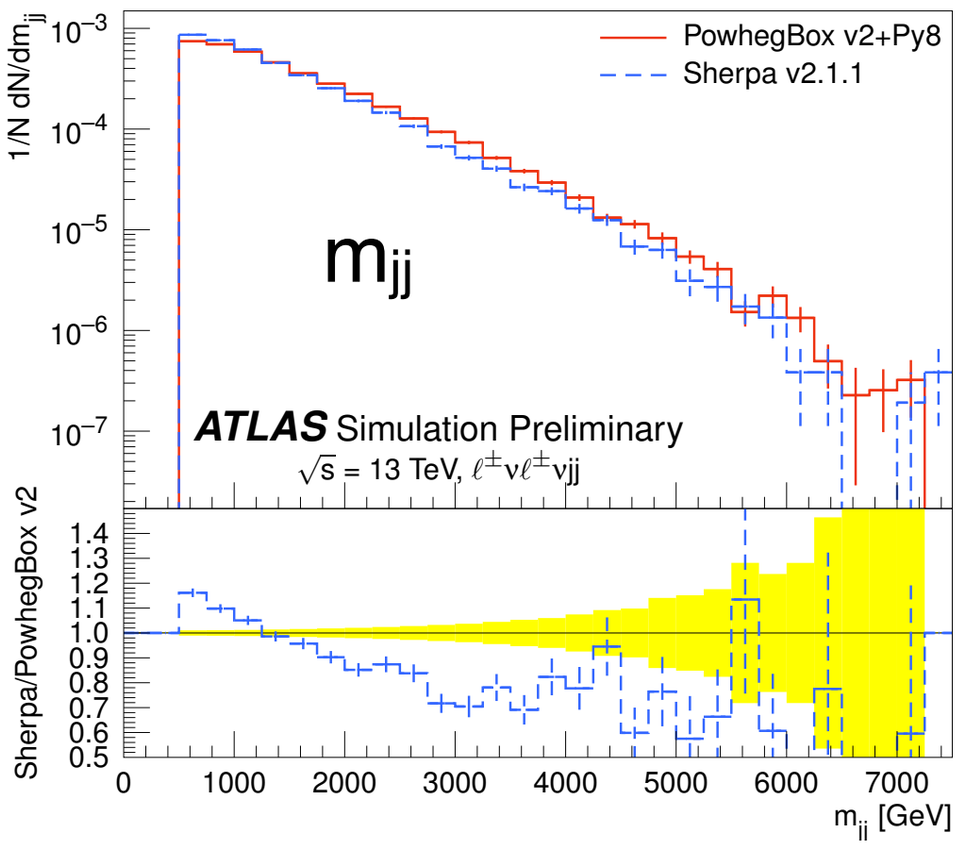
Matched/merged fixed-order+parton shower

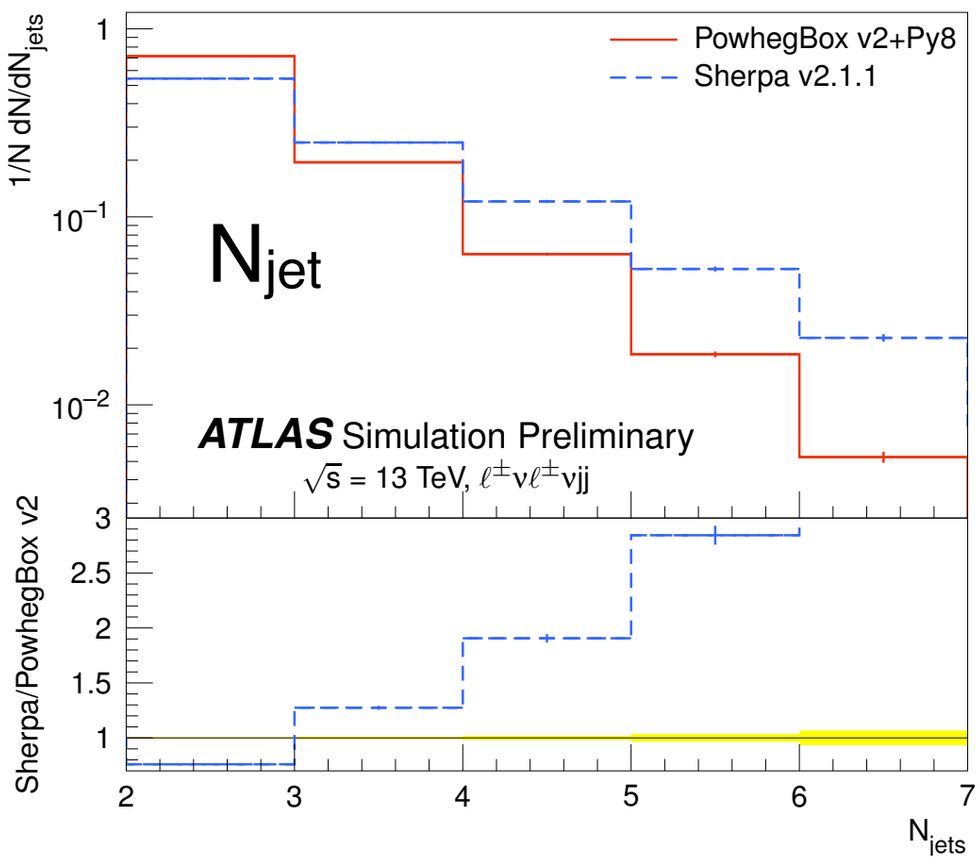
Electroweak diboson production

- large differences between LO and NLO for same sign lνlνjj
- but in Powheg number of intermediate bosons is restricted to two…

ATL-PHYS-PUB-2017-005

		$VV+2j$	$VV+3j$	$VV+\geq 4j$
$VVjj = \ell^{\pm}\ell^{\pm}2\nu jj$	Sherpa	LO	PS	PS
	PowhegBox+PYTHIA8	NLO	LO	PS



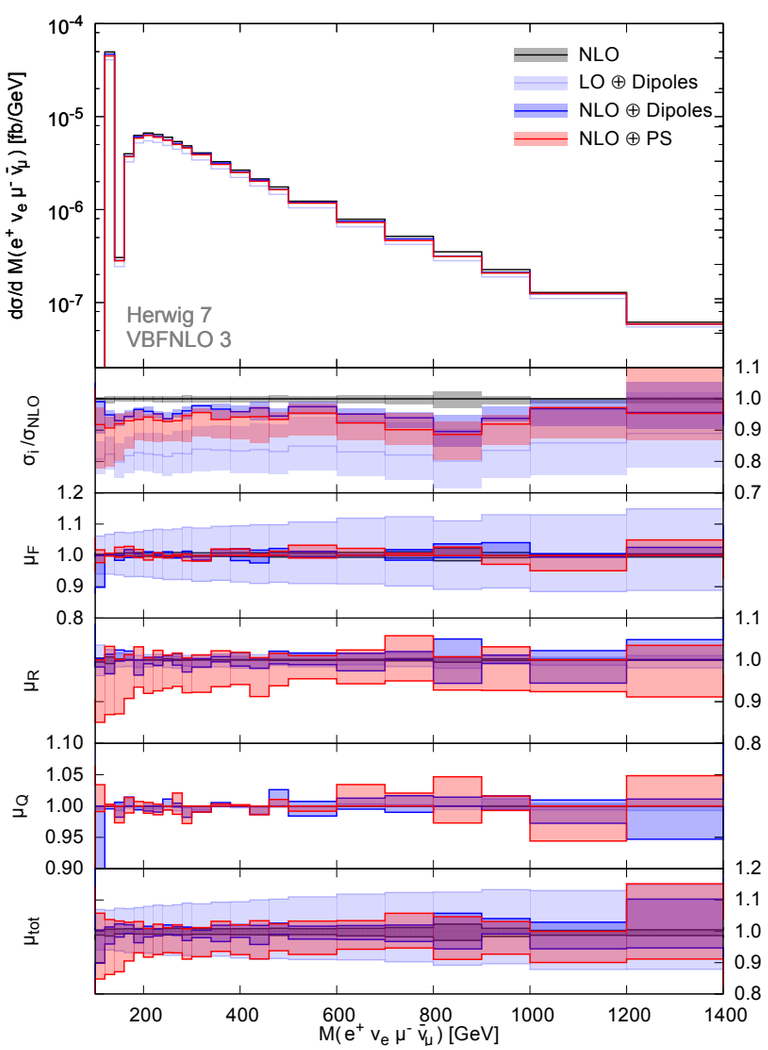


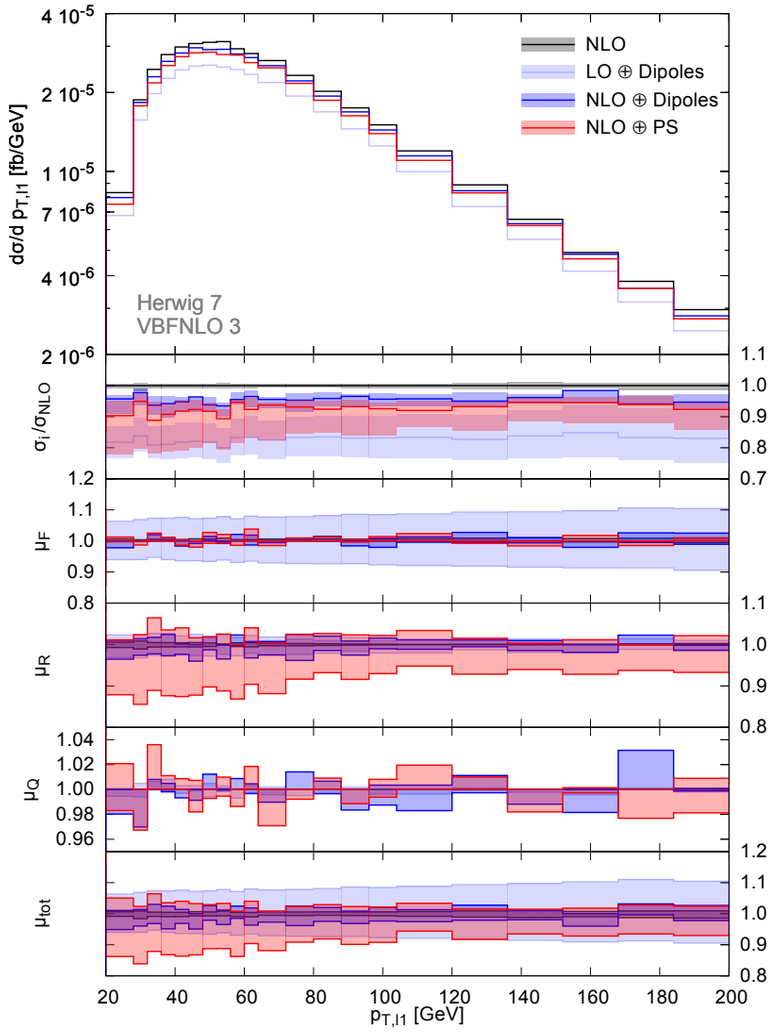
Matched/merged fixed-order+parton shower

Electroweak diboson production

- nice study of opposite sign eνμνjj using HERWIG7 + VBFNLO 3

M.Rauch, S. Plätzer, arXiv:1605.07851



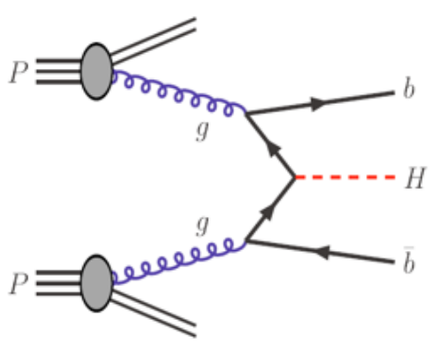


- No big effects in the shape here; only the cross-section change

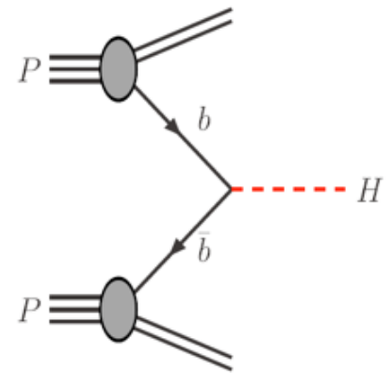
What can be said then about the uncertainty for LO predictions in VVjj?

Charm/Bottom quarks in parton showers

4- vs. 5-flavour matched ME/PS event simulation



NNLO correction in the 5FS



4F scheme

5F scheme

- “5F for rate/stability; 4F for kinematics” ⇒ norm vs. shape
- complicated by NLO and mass effects

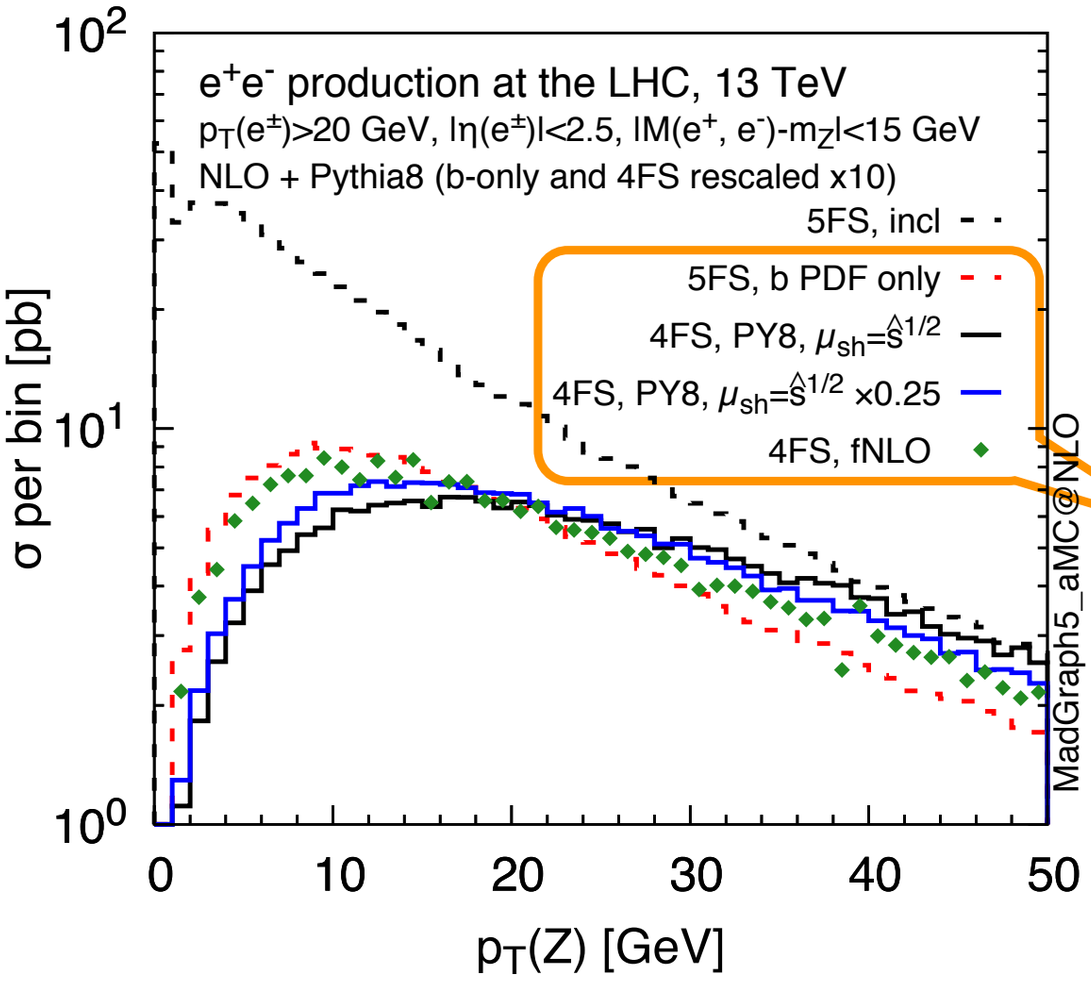
Combination of inclusive 5F with exclusive 4F scheme requires event vetoing to eliminate HF double-counting by parton shower emissions

Charm/Bottom quarks in parton showers

V+bb is still a very interesting subject

- key background for VH searches
- Z+bb important for W mass measurement

b-initiated contribution to Z pT in various approximations:



M. Zaro

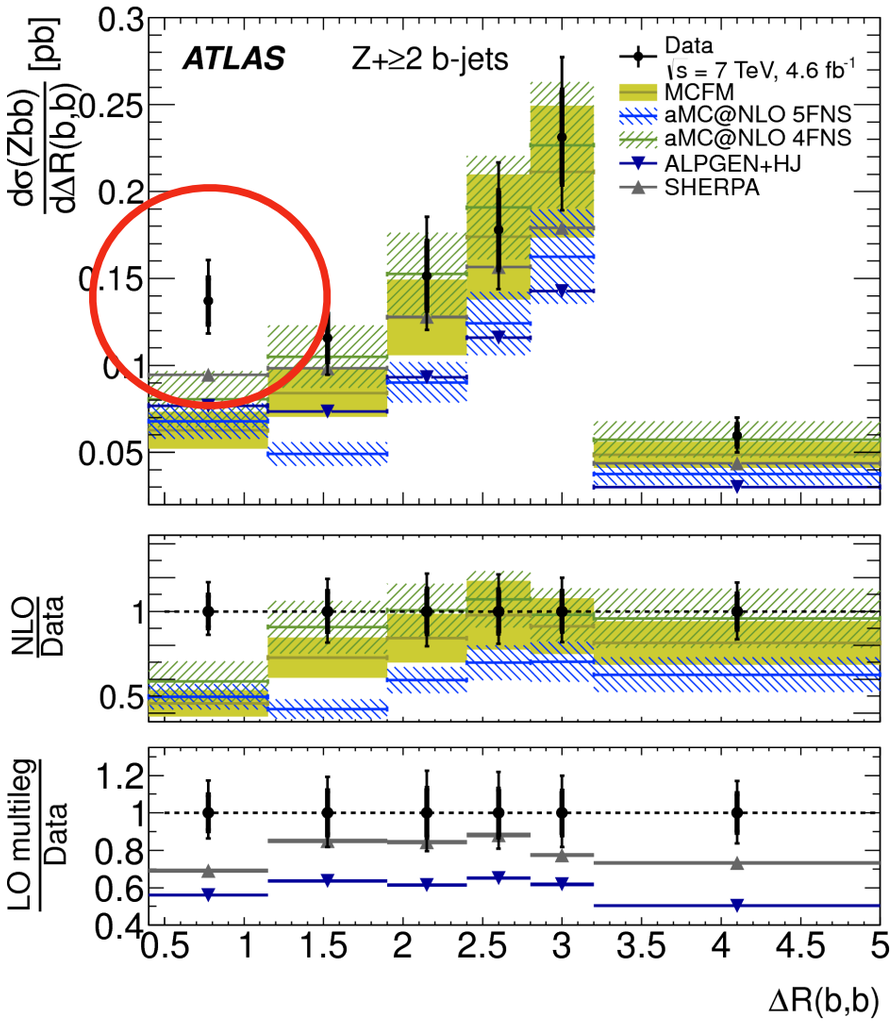
Flavour decomposition of the 5FS cross section

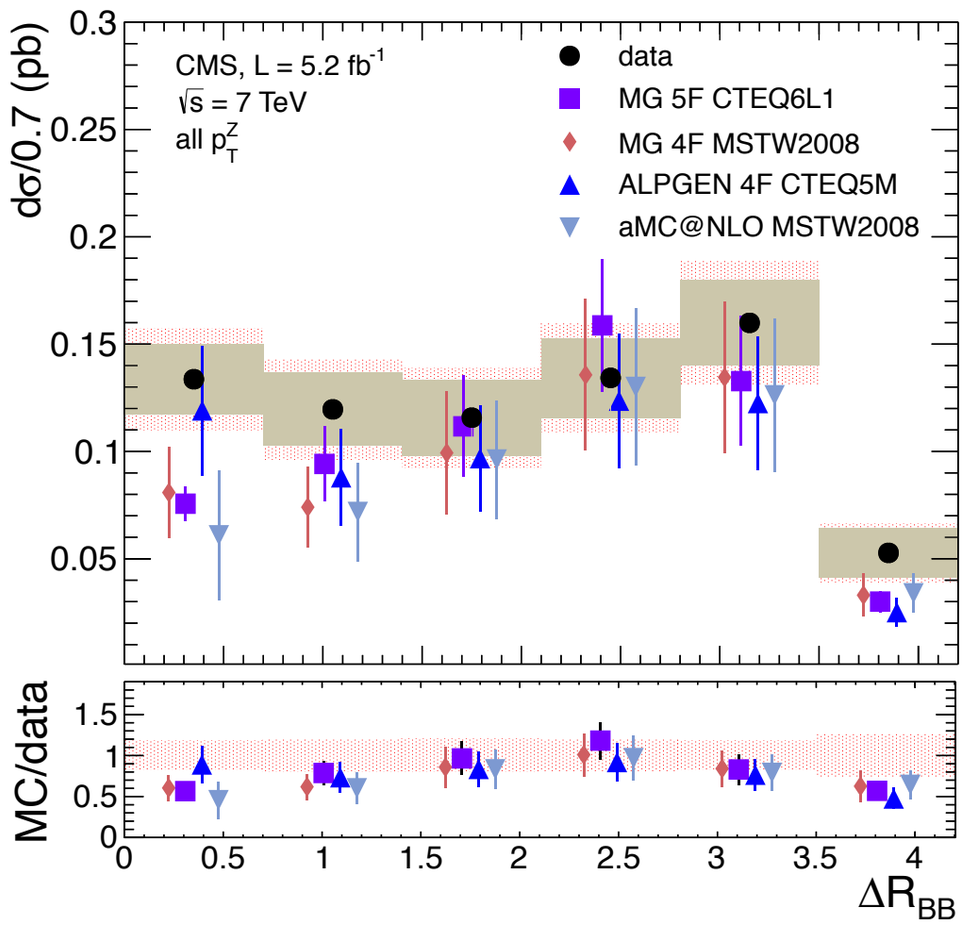
initial state quark	cross section (pb)	%
u	374.44 ± 0.62	35.0
d	391.15 ± 0.63	36.5
c	91.44 ± 0.34	8.6
s	170.43 ± 0.45	15.9
b	43.13 ± 0.26	4.0
total	1070.58 ± 0.86	100.0

Charm/Bottom quarks in parton showers

g →bb in Z+bb ?

Discrepancies observed for low ΔR(b,b)





We did a study of V+bb at Les Houches 2015: anything else?

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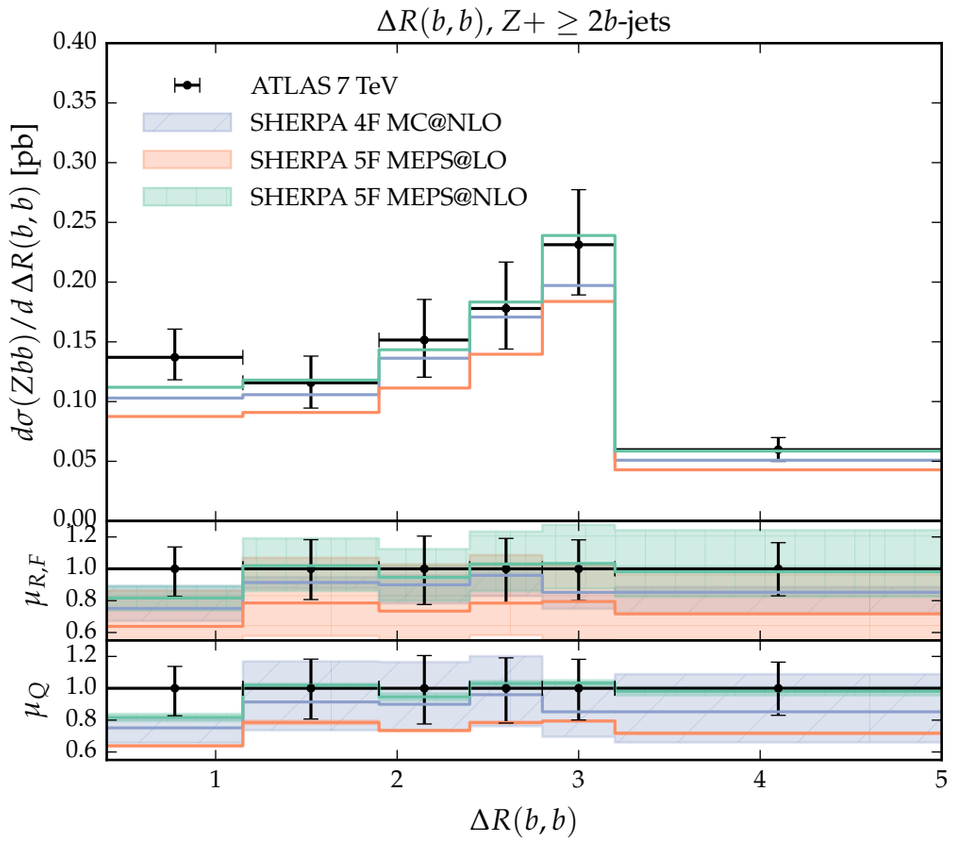
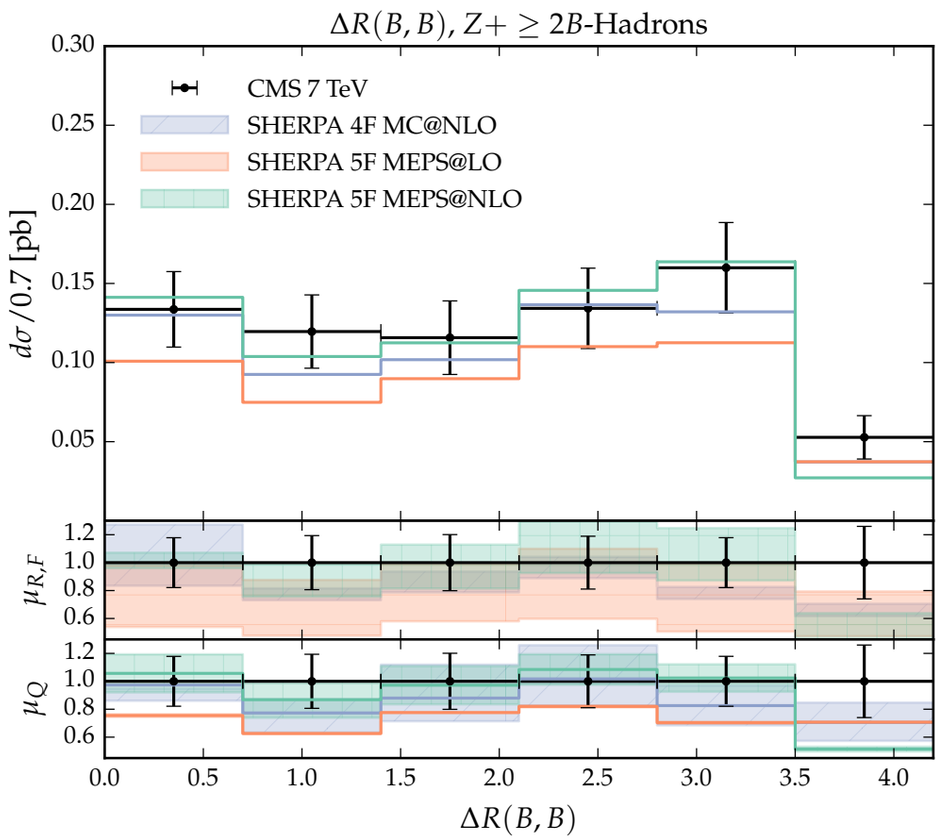
F.Krauss et al. Phys. Rev. D 95, 036012 (2017)





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Summary

Several “hot” topics mentioned:

- tuning of Z pT for W mass
- ttbar simulation: uncertainties in PS and scales
- order of PDFs in MCs
- EWK corrections to V+jets at high pT
- reliability of LO VVjj predictions
- g $\longrightarrow$bb

For sure something missing, but probably already too many for one Les Houches session…

Let’s see who is interested and don’t forget that more ideas are welcome…