Summary: Jets and EW bosons Working Group

Anastasia Grebenyuk on behalf of the Jets and EW bosons Working Group

14 December 2018

Structure of LHC Electroweak WG:

- ▶ WG1: DY physics and EW precision measurements
  - ▶ inclusive single boson production
  - ▶ from x-sections and constraints on QCD/PDFs to measurements of electroweak parameters
- ▶ WG2: Jets and EW bosons
  - ▶ Inclusive Jets and V+jets
  - ▶ Comparison of experimental results; correlation models;...
  - ▶ Comparison to theory; PDF interpretation
- ▶ WG3: EW multi-boson production
  - ▶ x-section measurements and comparison with theory
  - ▶ BSM interpretation aGC's, EFT, ...

Recent activity of WG2: Jets and EW bosons:

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/EWWG2
https://indico.cern.ch/category/3290/

Conveners:
ATLAS: Eram Rizvi, Heberth Torres
CMS: Hannes Jung, Anastasia Grebenyuk
LHCb: Stephen Farry, Will Barter
TH: Marek Schoenherr

- ▶ Benchmark comparison
  - ▶ Comparing ATLAS and CMS with the same theory prediction

- ▶ Common LHC tune for different NLO MC generators:
  - ▶ Provide a common benchmark tune for theory calculations

- ▶ HEPData, Rivet and correlated uncertainties:
  - ▶ Discussion on unified procedure for treating, storing and using correlated uncertainties

- ▶ First discussion on jet substructure

Benchmark comparison

Benchmark comparison

- Compare V+jets and dijets measurements between the experiments, either directly or via calculations to see if the experiments are consistent
- Do we have the same conclusion and findings in terms of model description in different experiments or not?
  - Would it be important to have common phase space?

Working plan:

- Define cross sections which should be described by all calculations
  - Inclusive jets and first jet p_T and y in V+jet events should be described with the same accuracy
    (multijets variables depend on how the additional jets are calculated: parton shower, ME, LO, NLO)

Recently we got common disk space: /eos/project/l/lhc-ewwg-eos/public/lhefiles

```
[jung@lxplus074 lhefiles]$ cd 13TeV/POWHEG/
drwxr-xr-x. 1 lhcweos def-cg 38G Dec  4 20:21 Dijet
drwxr-xr-x. 1 lhcweos def-cg 45G Dec  4 22:36 Z2jet-el
drwxr-xr-x. 1 lhcweos def-cg 45G Dec  6 06:31 Z2jet-mu
drwxr-xr-x. 1 lhcweos def-cg 45G Dec 10 08:05 W2jet-mu+
drwxr-xr-x. 1 lhcweos def-cg 45G Dec 10 08:05 W2jet-mu-
[jung@lxplus074 POWHEG]$ cd ../../8TeV/POWHEG/
drwxr-xr-x. 1 lhcweos def-cg 45G Dec  3 16:21 Z2jet-el
drwxr-xr-x. 1 lhcweos def-cg 45G Dec  3 21:58 Z2jet-mu
drwxr-xr-x. 1 lhcweos def-cg 44G Dec  3 23:34 W2jet-mu-
drwxr-xr-x. 1 lhcweos def-cg 45G Dec  4 05:49 W2jet-mu+
drwxr-xr-x. 1 lhcweos def-cg 19G Dec  4 06:25 Dijet
[jung@lxplus074 POWHEG]$ cd ../../7TeV/POWHEG/
drwxr-xr-x. 1 lhcweos def-cg 20G Dec  4 06:48 Dijet
drwxr-xr-x. 1 lhcweos def-cg 14G Dec  4 08:12 Z2jet-mu
drwxr-xr-x. 1 lhcweos def-cg 19G Dec  4 08:25 Z2jet-el
drwxr-xr-x. 1 lhcweos def-cg 38G Dec  4 09:32 W2jet-mu+
drwxr-xr-x. 1 lhcweos def-cg 25G Dec  4 19:32 W2jet-mu-
```

Several calculations are considered: Sherpa, Powheg **and** Herwig

- ▶ Sherpa MEPS@NLO: 0,1,2j@NLO and 3,4j@LO
  $\mu_{R/F} = \frac{1}{4}H_T$, $\mu_Q = \frac{1}{2}p_T^j$,
- ▶ Powheg: V+2 jets with MiNLO
  interfaced with Pythia8 with CUET8M1 tune and NNPDF2.3LO
- ▶ Herwig7.1.4: NLO matching with parton showers in the subtractive
 (MC@NLO-like) scheme
  Dipole shower tune

Calculations use the same $\alpha_s = 0.118$, **NNPDF 3.0 NNLO, but different tunes**

Generators	0j	1j	2j	3j	4j	>4j
Sherpa	NLO	NLO	NLO	LO	LO	PS
Powheg	NLO	NLO	NLO	LO	PS	PS
	(but not formally)	(but not formally)				
Herwig	NLO	NLO	LO	PS	PS	PS

$\rightarrow$ For V+1 jet all calculations are at NLO accuracy and should agree (within the uncertainty on parton shower)

- ▶ Benchmark comparison are shown in arXiv:1511.00847 where the authors
  compare V+jets from CMS and ATLAS with MADGRAPH5_aMC@NLO
  showered with Herwig++ and Pythia8
- ▶ We complement the studies by looking at different generators,
  center-of-mass energies, and LHCb measurements as well

W+jets at 7 TeV ATLAS, Data vs POWHEG with PS on and off:
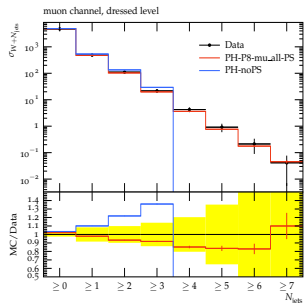
W+jets at 7 TeV ATLAS:
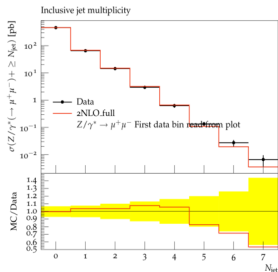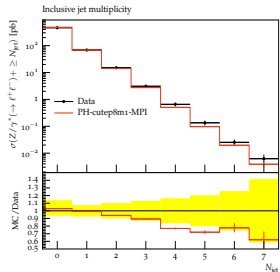ATLAS_2014_I1319490_MU; Eur.Phys.J.C(2015)75
Z+jets at 7 TeV ATLAS:
ATLAS_2013_I1230812_MU; JHEP07(2013)032

PS might affect V+1 jet cross section and need to be studied for different generators and PS models

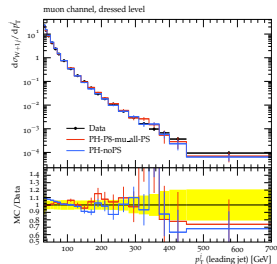**Z+jets 7 TeV, ATLAS DATA/POWHEG:**
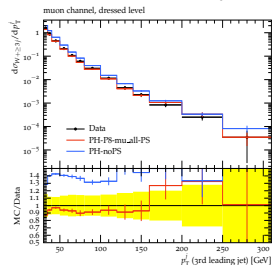

DATA/HERWIG: (thanks to Johannes Bellm)

W+jets at 7 TeV ATLAS

Leading jet p_T ($N_{jets} \geq 1$)

W+jets at 7 TeV CMS

Leading jet p_T ($N_{jets} \geq 1$)

2nd leading jet p_T ($N_{jets} \geq 2$)
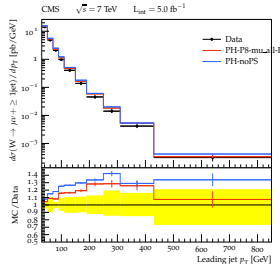
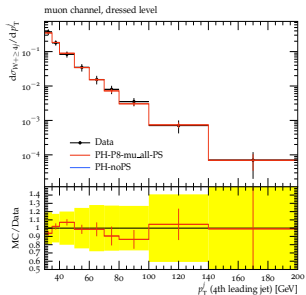**2nd leading jet p_T ($N_{jets} \geq 2$)**
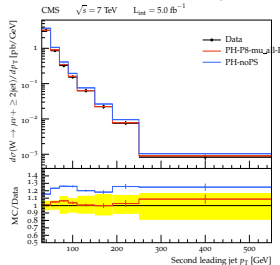
Different measurements use different fiducial phase space definitions, differences in description of CMS and ATLAS data may also stem from different levels of mismodeling in different phase space region
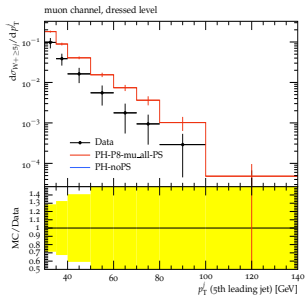
W+jets at 7 TeV ATLAS

4th leading jet p_T (N$_{jets}$ ≥ 4)

5th leading jet p_T (N$_{jets}$ ≥ 5)

W+jets at 7 TeV CMS

4th leading jet p_T (N$_{jets}$ ≥ 4)
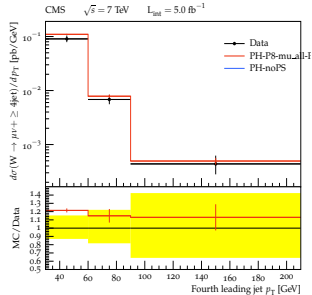
Jets are from parton shower

Large disagreemnts for 5th jet

Z+jets at 7 TeV ATLAS

ATLAS_2013_I1230812_MU; JHEP07(2013)032

Leading jet p_T (N$_{jets} \geq 1$)

4th leading jet p_T (N$_{jets} \geq 4$)

Z+jets at 7 TeV CMS

CMS_2015_I1310737, Phys.Rev.D91(2015)052008
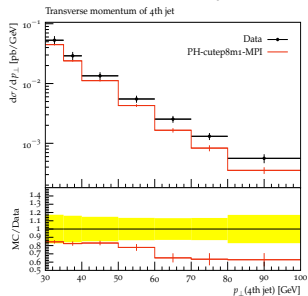
Leading jet p_T (N$_{jets} \geq 1$)

4th leading jet p_T (N$_{jets} \geq 4$)
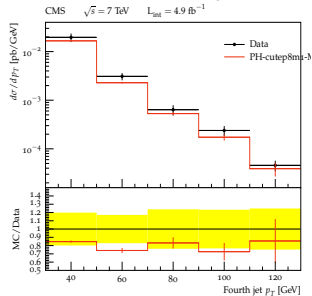
Leading jet p_T (N$_{jets} \geq 1$)
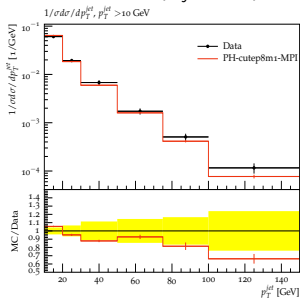
p_T(Z) (N$_{jets} \geq 1$)
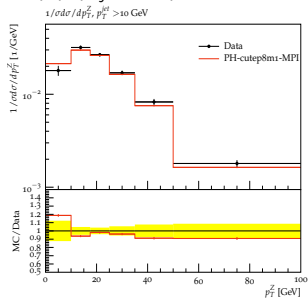
Leading jet η (N$_{jets} \geq 1$)
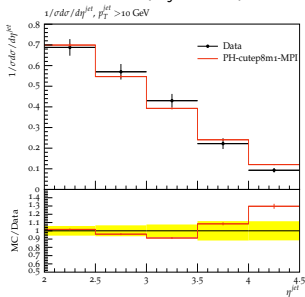
$\Delta\varphi$ between Z boson and leading jet

Exclusive N$_{jets}$

Leading jet p_T (N$_{jets} \geq 1$)
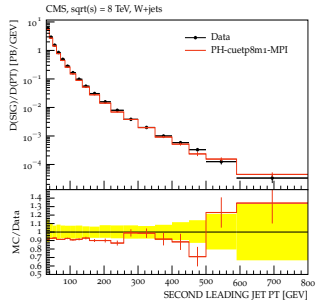
2nd leading jet p_T (N$_{jets} \geq 2$)

4th leading jet p_T (N$_{jets} \geq 4$)

Leading b jet p_T ($N_{bjets} \geq 1$)

$p_T(Z)$ ($N_{bjets} \geq 1$)

H_T ($N_{bjets} \geq 1$)
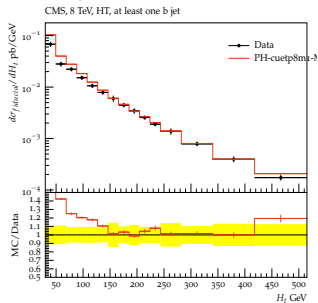
Subleading b jet p_T ($N_{bjets} \geq 2$)
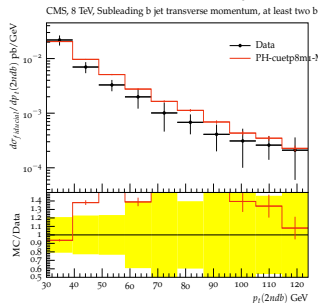
Exclusive jet multiplicity
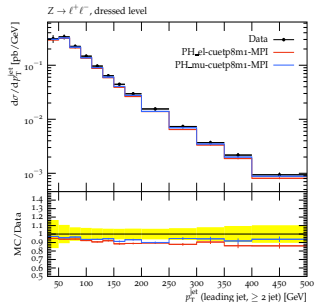
Leading jet p_T ($N_{jets} \geq 1$)

Leading jet p_T ($N_{jets} \geq 2$)
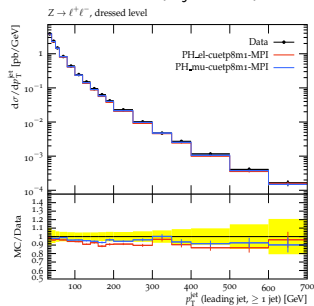
Leading jet p_T ($N_{jets} \geq 4$)
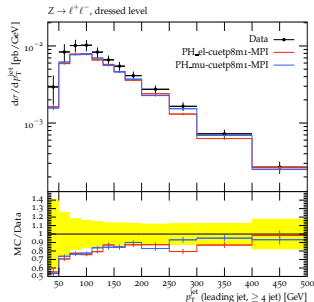
Outlook

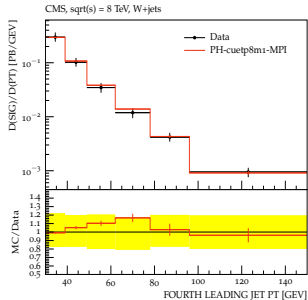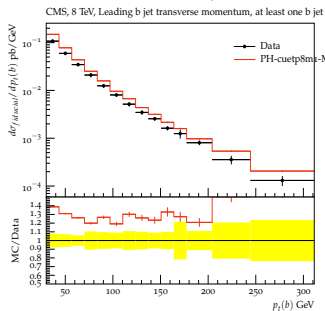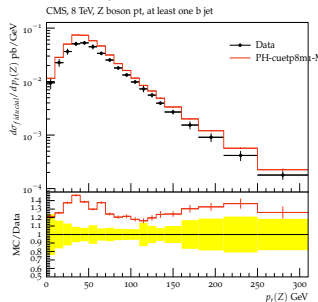- We have a first complete set of comparisons with POWHEG using all available Rivet plugins for 7,8 and 13 TeV for V+jet and dijets
  - 7 TeV: V+$\leq$ 4 jets are reasonable described by POWHEG; 5th jet shows differences
  - 8 TeV: Z+b jets measurements show disagreement with POWHEG
- First results from HERWIG
- Comparison between experiments is done for 7 TeV (Rivet routines are missing)
  - different level of Data/MC agreement between CMS and ATLAS is seen for the 1st leading jet p_T

- Next steps
  - Work is going on to get SHERPA and HERWIG predictions
  - Waiting for more plugins complete the comparison for 8 and 13 TeV

  Full set of benchmark comparison is:
  `https://twiki.cern.ch/twiki/bin/view/LHCPhysics/BenchmarkComparison`

Common LHC tune

(Credits to Paolo Gunnellini who presented the idea of common LHC tune at MPI@LHC last week)

In addition to the single hard interaction with large p_T:

Parton Shower
(initial and final
state radiation)

Hadronisation
modelling

Beam remnants,
primordial k_T

Multiple parton
interactions
(Underlying Event)
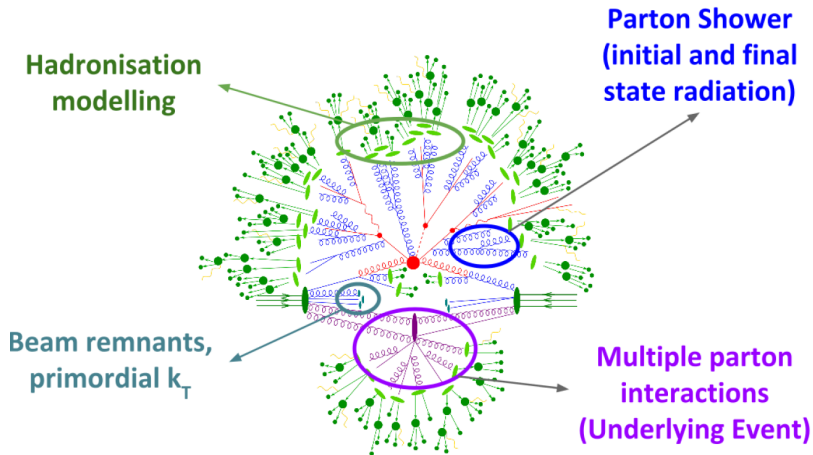
From Frank Siegert

Standard MC (PYTHIA, HERWIG, SHERPA) have adjustable parameters to control the behavior of their event modeling which are tuned:

- ▶ Primordial k_T: width of the Gaussian used for modeling the parton primordial k_T inside the proton
- ▶ Parton shower: strong coupling value, regularization cut-off, upper scale
  - ▶ shall we tune the parameters or should they come from the PDF?
- ▶ MPI: proton matter distribution profile, colour reconnection
- ▶ Hadronisation: length of fragmentation strings, strange baryon suppression

We tune to achieve:
- ▶ Good physics predictions (correct evaluation of physics effects)
- ▶ Correct description of the data (pile-up simulation, evaluation of detector effects and unfolding, estimation of background, etc.)

Common LHC tune:

- ▶ Last LHC tune, Monash tune, was performed in 2013 (Eur.Phys.J. C74 (2014) no.8, 3024). It used data from LEP and SLD to constrain hadronisation parameters; and SPS, Tevatron and LHC data to constrain PS parameters, MPI and energy scaling
- ▶ Based on that tune LHC collaborations developed their own tunes based on their own data

Our goal: Common LHC tune for different NLO MC generators

Working plan:

- ▶ Have the same ME for PYTHIA, HERWIG, SHERPA: set LO ME ($2\rightarrow2$) settings
- ▶ Reference PDF for the calculations
- ▶ Define common data set for the calculations (nowadays different generators uses different data sets as input)
  - ▶ Measurement sensitive to higher order should not be used for tuning
  - ▶ Define measurement sensitive to UE and hadronisation and perform the tuning
- ▶ Validate the tune for the matched/merged calculations

Sensitivity to higher order

Difference in terms of performance for a LO (PYTHIA8) or a multileg (MADGRAPH) ME, when comparing predictions to LEP observables, e.g. event shapes:

PYTHIA standalone
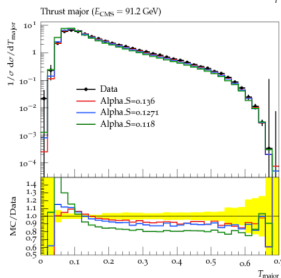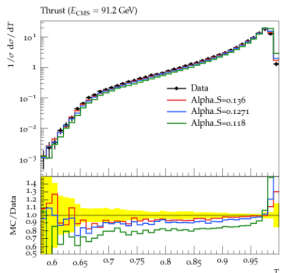
MADGRAPH LO (2→2,3,4 partons)
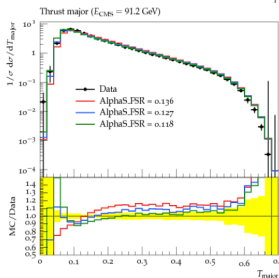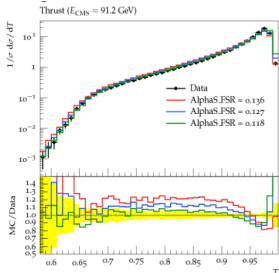
Eur.Phys.J.C35:457-486,2004

PYTHIA8 predictions prefer a high value of α_s^{FSR}, while multileg matrix elements prefer a lower value of α_s^{FSR}.

Different values of α_s^{FSR} have consequences on LHC comparisons

Sensitivity to higher order

Among different higher-order matrix elements as well, one can observe difference:

CMS-PAS-GEN-17-001;
Phys.Rev. D 95 (2017) 092001 ($t\bar{t}$); Eur. Phys. J. C 78 (2018) 965 (Z+jets)

POWHEG: NLO $t\bar{t}$ ME
$N_{jets} \geq 2$ produced by PS   MG5_aMC: NLO Z+2 parton ME
$N_{jets} \geq 4$ produced by PS
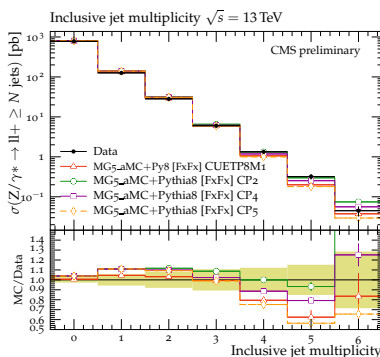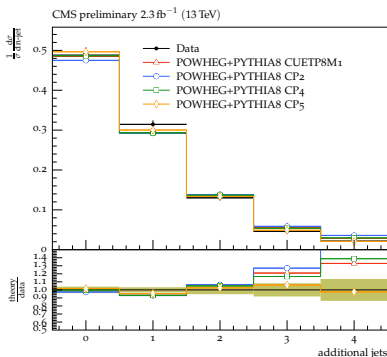
CP2:
α_s^{ISR}=0.136
CP4:
α_s^{ISR}=0.118
(Rap.Ord.=off)
CP5:
α_s^{ISR}=0.118
(Rap.Ord.=on)

▶ No strong tune sensitivity for MG5_aMC+PYTHIA 8 for this observable
▶ Larger tune sensitivity for POWHEG+PYTHIA 8

Outlook

- Goals of an LHC tune are various:
    - independently of experiments, it can produce a benchmark set of comparisons
    - it aims for a full retune of the underlying-event components
    - particular attention is given to matched/merged configurations for various hard processes
    - it aims to show when tune is independent of the hard process/configuration and when not
- Feedback is very welcome
- We need person-power to achieve this and there the experiments must contribute
    - We need service points for this work to get people

HEPData, Rivet and correlated uncertainties

(summary of Louie Corpe presentation from yesterday)

- Data/MC comparison in presence of correlated systematic uncertainties is an increasingly important topic in HEP $\rightarrow$ need access to systematic covariance matrix from measurements

  - Where should covariance information be accessible from?
  - How should we communicate covariance information?
  - What technical developments are needed?
  - How can we use the covariance information?
  - Where do we go from here?

- **Where should covariance information be accessible from?**
  - HEPData.net is obvious choice: Supports N-dimensional histograms and internal converter from YAML to ROOT, YODA and CSV
- **How should we communicate covariance information?**

Error breakdown

Each point on HEPData has error breakdown split by individual systematic contribution. Cov matrix can be reconstructed and correlated with other measurements

To produce covariance matrix
↓

Direct propagation of errors
Fast, easy to implement, but cannot handle asymm errors

Pseudo-experiments (toys)
Slow, depends on Ntoys but can handle asymmetric errors

YAML <u>Converter</u>* YODA*

***- need to be modified to allow error breakdown for each point**

Explicit covariance matrix

Explicit covariance matrix provided directly. Not always possible to correlate with other measurements...

↓

YAML format can store 2D histograms covariance matrix

Need: a way to link a particular bin in a distribution to a row in the cov matrix (both for YAML format and for YODA)

Technical developments for covariance info (for Error breakdown)

YAML $\underrightarrow{\text{Converter}^*}$ YODA*

- ▶ Louie and Andy Buckley (Rivet dev) implemented technical solution to store uncertainty breakdown of a YODA object as an annotation

- ▶ Louie and Graeme Watt (HEPData dev) implemented changes to HEPData which takes the additional labels from a HEPData entry and converts them to the Annotation format in YODA. This functionality was deployed on HEPData.net!
  - ▶ Previous HEPData entries where a breakdown was provided (even if just stat, sys, lumi) will be able to be downloaded as YODA with annotations...
  - ▶ ...but HEPData entries which used different conventions (e.g. uploaded error breakdowns as additional tables) need to be tweaked to be used in this way

Example of a full work-flow is in the Louie's slides.

Tools are available on gitlab: https://gitlab.cern.ch/lhcewkwg/lhcewkwg-vjets

Outlook and plans

- ▶ We need to start using covariance information for Data/MC comparison
  - ▶ Also benchmark comparison would need full treatment of the correlated uncertainties
- ▶ Ideally, access detailed breakdown of errors and/or exact covariance matrices

  - ▶ Full work-flow have been developed and tested in case of breakdown of errors
- ▶ We propose to change to the new format and we ask for the experiments to support this
- ▶ We need help to convert older HEPData entries to the newer one

Jet substructure

What we would like to address:

- Can one compare jet substructure measurements between the experiments, either directly or via calculations to see if the experiments are consistent?
  - Is there an issue that ATLAS and CMS are doing things differently?
- Do we have the same conclusion and findings in CMS and ATLAS or are there different conclusions?
  - Would it be important to have common phase space, similar models to compare?
- Agreement of a benchmark calculation with which one should compare?
- Theory

We had a kick-off meeting this Tuesday between ATLAS, CMS, LHCb and theorists

- CMS-ATLAS comparison is difficult: different data, binning, uncertainty
- Work is going on to complete Rivet routines for the studies
- Use jet substructure to investigate p_T or angular ordering?
- Investigation of gluon splitting (for example to $c\bar{c}$ and $b\bar{b}$ in boosted jets)
- Define clear regions, where PS can be tested against analytical resummation and where hadronisation plays a role
- Plan is to organise a technical meeting in January

Timescale, further idea

Future ideas and plans of the group

- ▶ Use of multi-jet+ merged/matched PS predictions as compared to fixed-order times NP

- ▶ Theory uncertainties: scale choice for inclusive jets, V+jets

- ▶ Factorisation of EWK correction

- ▶ New approaches: TMDs for hard processes

- ▶ Role of vector-bosons in PDFs at the TeV scale

- ▶ V-boson in pA and AA

Perspective for the Yellow report

Realistic to have something substantial for spring or summer 2019 (definitely for winter)

We would like to do not hurry and provide more studies from completed Run2:

- ▶ Complete set of benchmark comparison with the new LHC tunes and including the correlated uncertainties
  - ▶ based on this studies we could suggest (or not) the common phase space for the measurements for Run3
- ▶ Check the alternative approaches (TMD)

Now due to the long shutdown it is perfect time to prepare for the precise measurements of Run3 and the document can be a perfect place to collect together all findings with legacy Run2 comparison and provide recommendations for the new data coming period

Summary

- The group has several outgoing activities and many good ideas for the future

- Person-power is strongly needed. We should make possible that people from experiments get service points for work on the LHC tune and converting the older HEPData format to the newer one

Thank you!