Status and Plans of the QCD (Jets & EW bosons) Group

Vieri Candelise

on behalf of the LHC Electroweak: Jets & EW Bosons Working Group

CERN, 18/12/2019

The “EWWG2”: Jets & EW bosons Group

Conveners Team

ATLAS: Eram Rizvi, Ben Nachman

CMS: Vieri Candelise, Hannes Jung

LHCb: Stephen Farry, Will Barter

Theory: Marek Schoenherr

QCD ~ Jets & EW bosons

Subgroups' twiki pages

- WG 1: Drell-Yan physics and EW precision measurements
- WG 2: Jets and EW bosons subgroup
- WG 3: EW multi-boson production

When we meet: Every 2nd Tuesday at 4pm on Vydio

Our Twiki page: https://twiki.cern.ch/twiki/bin/view/LHCPhysics/EWWG2

Our meeting page: https://indico.cern.ch/category/3290/

List of our ongoing activities

EWWG: Jet and EW bosons at work

- Collection of Rivet Routines for comparisons
- Benchmark comparison
- Recommendation for splitting of systematic sources due to JES uncertainties at 7 TeV: ATLAS PUB note 2014-020 CMS PAS note JME-14-003
- Recommendation for splitting of systematic sources due to JES uncertainties at 8 TeV: ATLAS PUB note 2015-049 CMS PAS note JME-15-001
- LHCJetSubstructureMeasurements

+ much more!

Main Ongoing Activities

- Benchmark Comparisons: historically the main task of the EW-VJ group, aiming for theory/data comparisons of selected processes (e.g. V+jets), observables and given predictions between ATLAS, CMS, LHCb at 7/8/13 TeV.
Collect and understand the mis-modellings and discrepancies observed.

- RIVET and HEP infos: well advanced topic where we aim to set a common strategy (format) about the storage and usage of uncertainty infos (correlations, tables…) across experiments.

- Jet Substructure: define common strategy on observables, ranges and binning definitions across experiment, collect and improve RIVET routines, measurements

RIVET Library

Crucial and Essential for our group is the collection of
RIVET routines to be used for comparisons

we have a “library” of RIVET routines for V+Jets -*like* measurements

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

we always encourage and advertise analyzers in our experiments meetings to update and send us their routines *(but this is often the bottleneck for us!)*

W/Z+jets

Rivet Routine	Process	Data Set	arXiv	Routine status
CMS_2015_I1310737	Z + jets	7TeV 2015	1408.3104	public
CMS_2014_I1303894	W + jets	7TeV 2014	1406.7533	public
CMS_2016_I1491953	W + jets	8TeV 2017	1610.04222	public
CMS_2017_I1610623	W + jets	13TeV 2017	1707.05979	public
CMS_xxxx_xxxxxxxx	Z + jets	13TeV 2018	1804.05252	in preparation
CMS_xxxx_xxxxxxxx	Z + jets	8TeV 2017	1611.03844	in preparation
ATLAS_2013_I1230812	Z + jets	7TeV 2011	1304.7098	public
ATLAS_2017_I1514251	Z + jets	13TeV 2015	1702.05725	public
ATLAS_2012_I1083318	W + jets	7TeV 2010	1201.1276	public
ATLAS_2014_I1319490	W + jets	7TeV 2011	1409.8639	public
ATLAS_xxxx_xxxxxxxxx	W(->ev) + jets	8TeV 2012	1711.03296	in preparation
LHCB_2014_I1262703	Z(->mumu)+jets	7 TeV 2011	1310.8197	public
LHCB_xxxx_xxxxxxxx	W/Z(->mu(mu))+jets	8 TeV 2012	1605.00951	in preparation

News from the Group

New proposals: PDFs benchmarking

(see dedicated talk later today!)

Bogdan Malaescu

Matthias Schott

- Evaluating the correlations between PDF sets for the first time
- LHC measurements correlated through PDFs
- Motivations: sin2 θW, mW , αS , data/theory comparisons

Proposed procedure

→ Proposal to evaluate correlations between PDF sets, originating from common experimental inputs, using coherently-generated pseudo-experiments

→ Use the xFitter framework to generate pseudo-experiments fluctuating the statistical and systematic experimental uncertainties, taking into account correlations, for an inclusive sample of data (covering all the data used for the various PDF fits)

→ For each generated pseudo-experiment, select the data points used by each PDF fitting group and re-do the corresponding fit

(Only the nominal fit has to be determined at this stage, not the eigenvectors)

(After validation and cross-checks – see next slides)

→ Use the ensemble of fitted pseudo-experiments to determine correlations between the uncertainties of various PDF sets

→ *For V+jets:* compare quantitatively theoretical predictions for various cross sections, using different PDFs

New Forum Topics: Jet Measurements in ALICE

Eliane Epple

James Mulligan

Inclusive jet reconstruction at 5.02TeV in pp and PbPb collisions with ALICE

Eliane Epple and James Mulligan

Los Alamos NATIONAL LABORATORY EST. 1943

Tue 5. Nov 2019

First ALICE talk in our LHCEW Jets & EW bosons working meeting!

- many interesting jets results from a different physics perspective in ALICE
- we are including ALICE in our LHCEW team
- in contact to engage two co-conveners

"Measurements of inclusive jet spectra in pp and central Pb–Pb collisions at psNN = 5.02 TeV"
based on arxiv.org/pdf/1909.09718.pdf

https://indico.cern.ch/event/860687/contributions/3624865/attachments/1939413/3215108/LHC-EW_WG.pdf

very interesting discussion during the meeting

New Forum Topics: Jet Measurements in ALICE

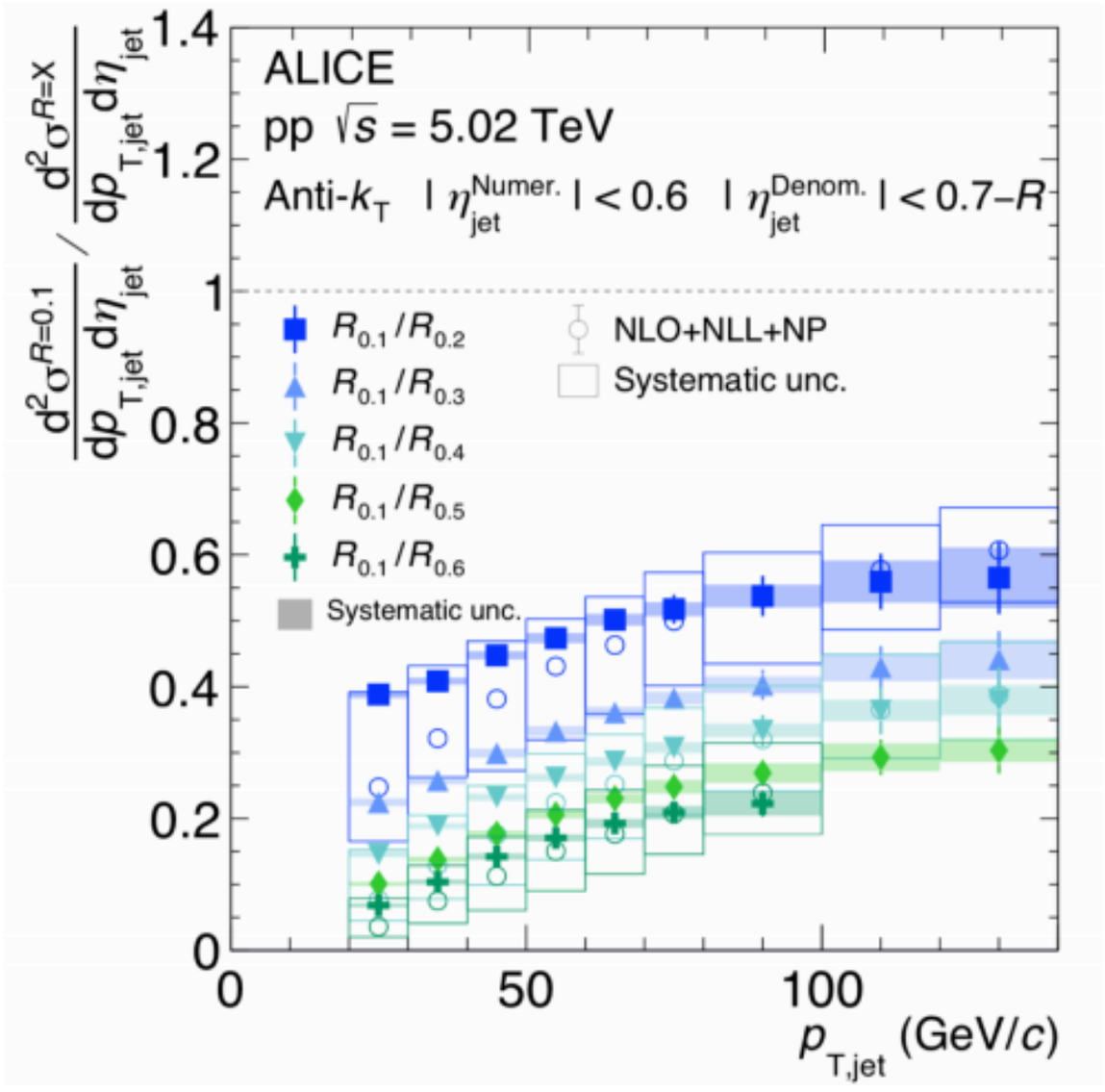
Eliane Epple

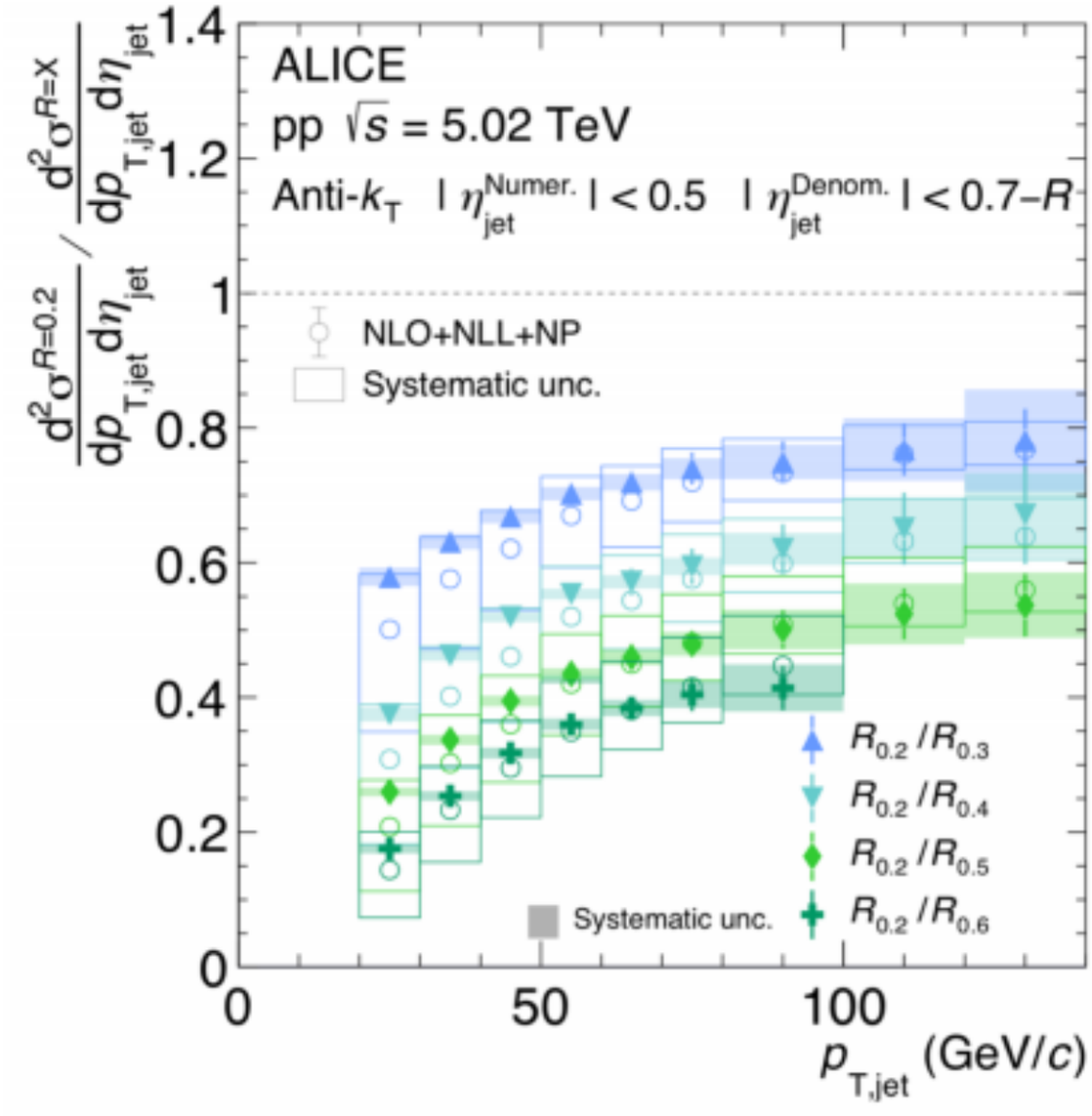
James Mulligan

Inclusive jet measurements in pp are a very useful probe for many purposes!

- At small radii they are useful to guide resummation techniques
- Measurements of different jet radii are important to disentangle non-perturbative effects (UE+Hadronization)
- At large radii they are useful to be part of common PDFs and α_s fits

some highlights on **pp**





New Forum Topics: Color Flow with Jet Pull

TO BE ADDED: waiting for the next Jets&EW bosons meeting

Status of Projects

Benchmark Comparisons

Purpose: collect RIVET routines of SM processes involving jets and W/Z bosons in the LHC experiments and perform data/MC comparisons at several √s. Understand the different definitions and descriptions of the physics and try to quantify the compatibility

Status: Available RIVET routines

V+Jets and V+ HF

- W+jets ATLAS, 7 TeV, 4.6 fb-1 Figures
- W+jets ATLAS ,7 TeV, 36 pb-1 Figures
- W+jets CMS, 7 TeV, 5 fb-1 Figures
- Z+ b jets ATLAS ,7 TeV, 4.6 fb-1 Figures
- Z+jets ATLAS ,7 TeV, 4.6 fb-1 Figures
- Z+jets CMS, 7 TeV, 4.9 fb-1 Figures
- Forward Z+jets, LCHb, 7 TeV Figures
- W+jets CMS, 8 TeV, 19.6 fb-1 Figures
- Z+b(b) CMS, 8 TeV, 19.8 fb-1 Figures
- Z+jets ATLAS ,13 TeV, 3.16 fb-1 Figures
- W+jets CMS ,13 TeV, 2.2 fb-1 Figures

LHCb

so far only Z+jets @ 7 TeV

Inclusive and dijets

- Inclusive jet, ATLAS, 7 TeV, 4.5 fb-1 Figures
- High-mass dijet cross section, ATLAS, 7 TeV, 4.5 fb-1 Figures
- Inclusive jet and dijet cross sections, ATLAS, 7 TeV, 36 pb-1 Figures
- Inclusive and dijet cross-sections of b-jets, ATLAS, 7 TeV, 34 pb-1 Figures
- Jet-pT and dijet mass, CMS, 7 TeV, 5 fb-1 Figures
- Inclusive b-jets, CMS, 7 TeV Figures
- Measurement of the inclusive jet cross-section, CMS, 7 TeV, 34 pb-1 Figures

What I would ask Santa

- manpower to work on BC!!

- more (updated) RIVET routines!!

https://indico.cern.ch/event/868724/contributions/3662071/attachments/1955640/3248302/LHCEW_WG2_list_of_tasks.pdf

Benchmark Comparisons

Purpose: collect RIVET routines of SM processes involving jets and W/Z bosons in the LHC experiments and perform data/MC comparisons at several √s. Understand the different definitions and descriptions of the physics and try to quantify the compatibility

Status: Generators

	7 TeV	8 TeV	13 TeV
POWHEG+PYTHIA8			
dijet POWHEG	✓	✗	✗
$W + 2j$ POWHEG MiNLO	✓	✓	✓
$Z + 2j$ POWHEG MiNLO	✓	✓	✓
SHERPA			
dijet S-MC@NLO	✓	✗	✗
$W + 0, 1, 2j$@NLO $+ 3, 4, 5j$@LO	✗	✓	✓
$Z + 0, 1, 2j$@NLO $+ 3, 4j$@LO	✗	✗	✓
HERWIG7 +MADGRAPH +OPENLOOPS			
in the process of finalising the setups			

from Marek2018

we need more people on projects!

https://indico.cern.ch/event/868724/contributions/3662071/attachments/1955640/3248302/LHCEW_WG2_list_of_tasks.pdf

Benchmark Comparisons

Modelling and Theory Comparisons: Plans of the Projects

open projects

	POWHEG		MC@NLO		SHERPA	
DIJET	effect of MPI (MPI on/off) compare with different hdamp		DIJET	NLO comparisons, effect of MPI (MPI on/off) different merging scales	DIJET	NLO comparisons, effect of MPI (MPI on/off) different merging scales
TRIJET	comparisons with MiNLO, role of hdamp		2+3+4 Jets	NLO comparisons different merging scales	2+3+4 Jets	NLO comparisons different merging scales, PS on/off

V+Jets detailed NLO+PS studies with agreed PDF set (NNPDF31?) and Tune (CP5?)

1. Benchmark comparison

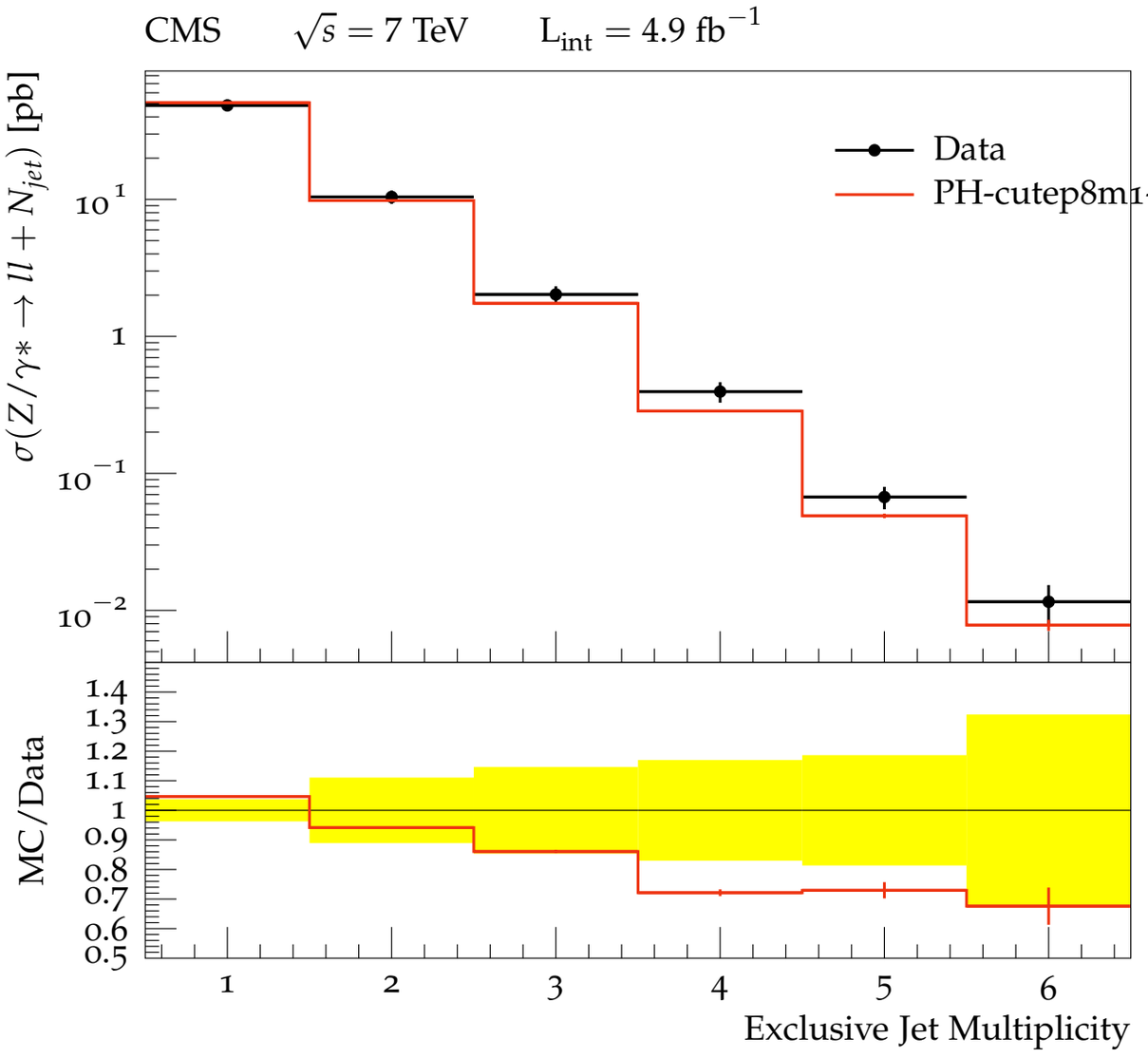
1. done for Powheg for V+jets for jets measurements for 7 TeV, 8 TeV and 13 TeV
2. done for Sherpa jets for 7 TeV
3. Herwig7 first results on Z+jets are done
4. Sherpa for 13 TeV Z+jets in the making

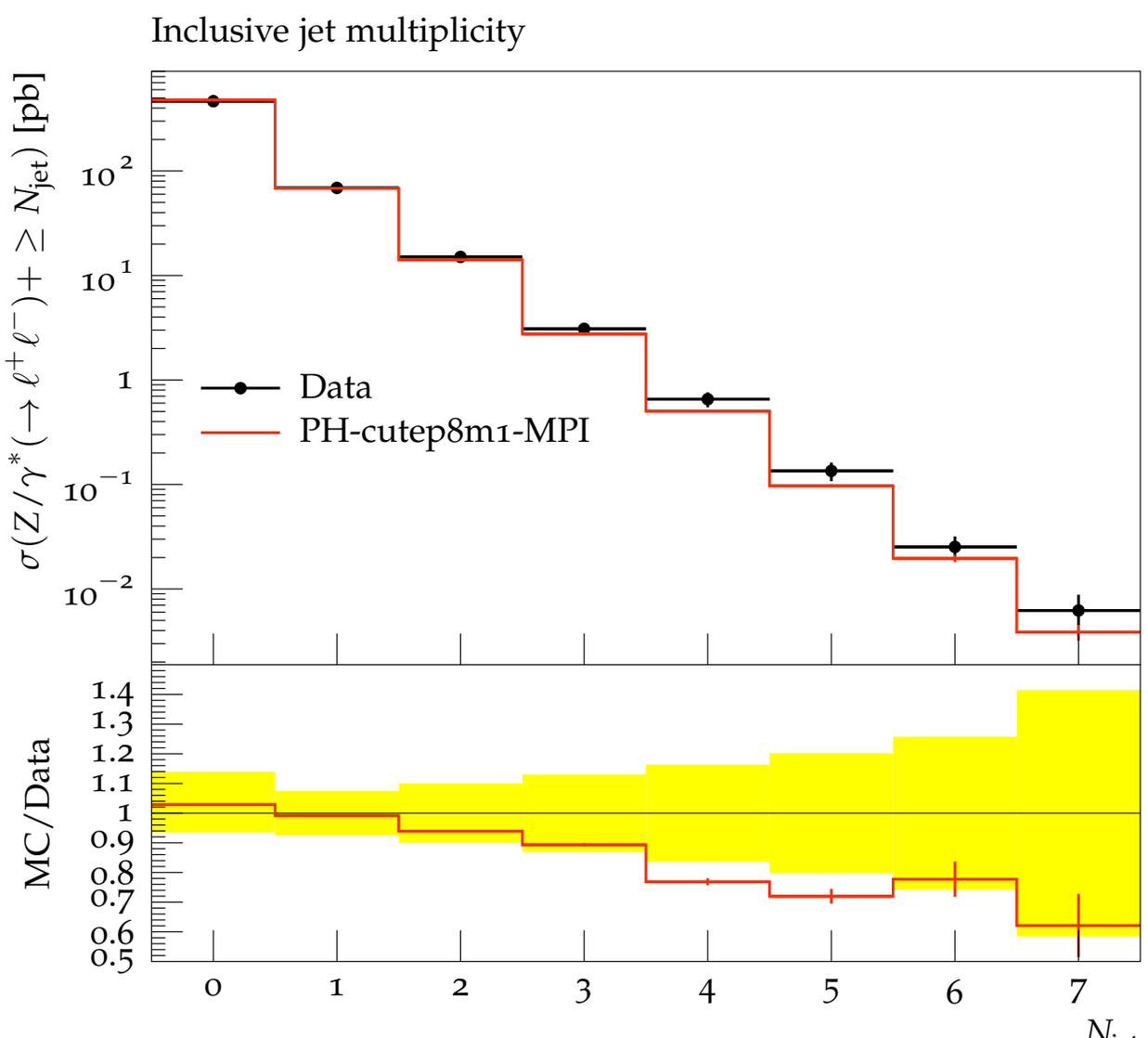
ongoing work

https://indico.cern.ch/event/868724/contributions/3662071/attachments/1955640/3248302/LHCEW_WG2_list_of_tasks.pdf

Benchmark Comparisons

Examples: Z+Jets @ 7 TeV





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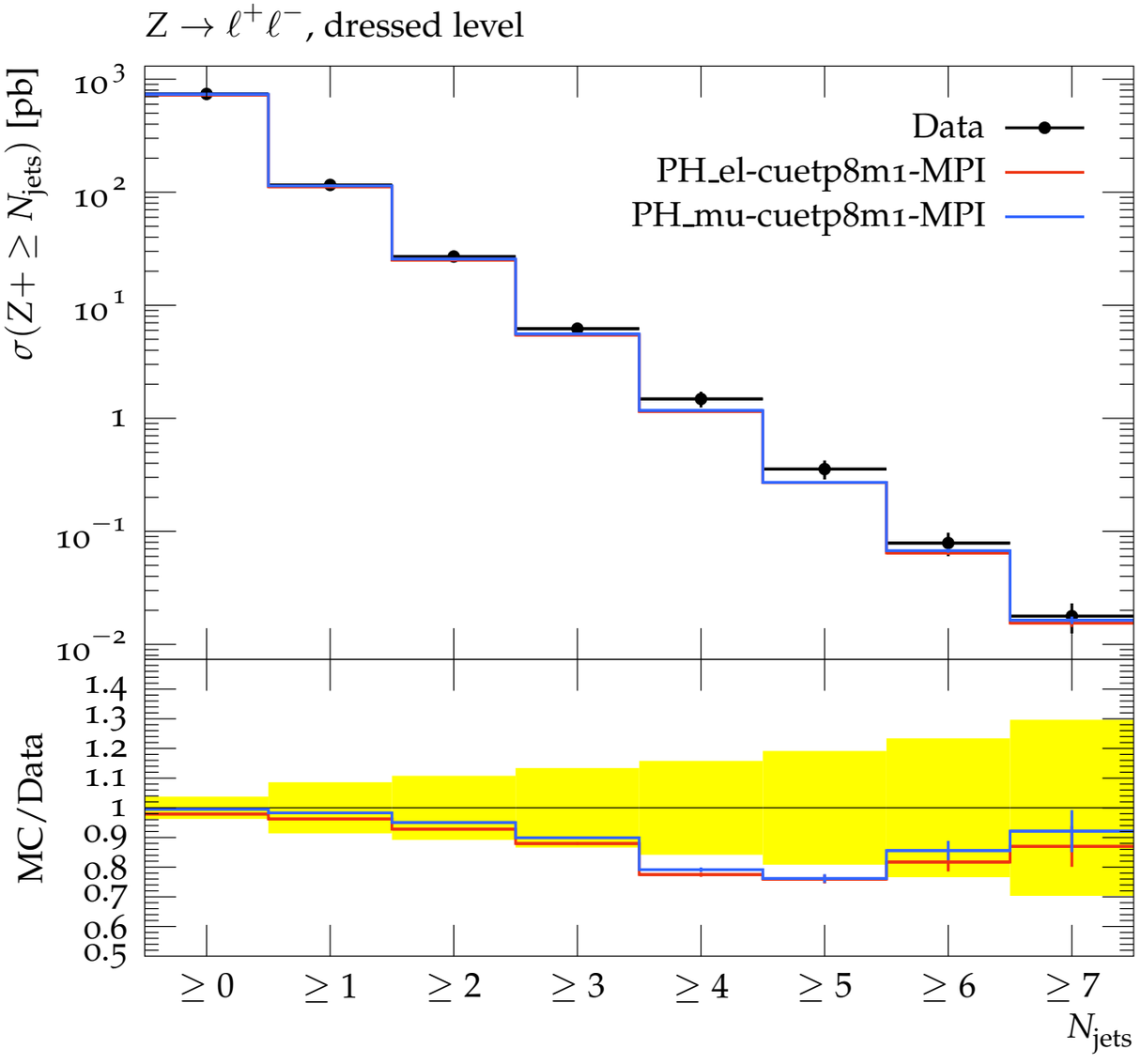
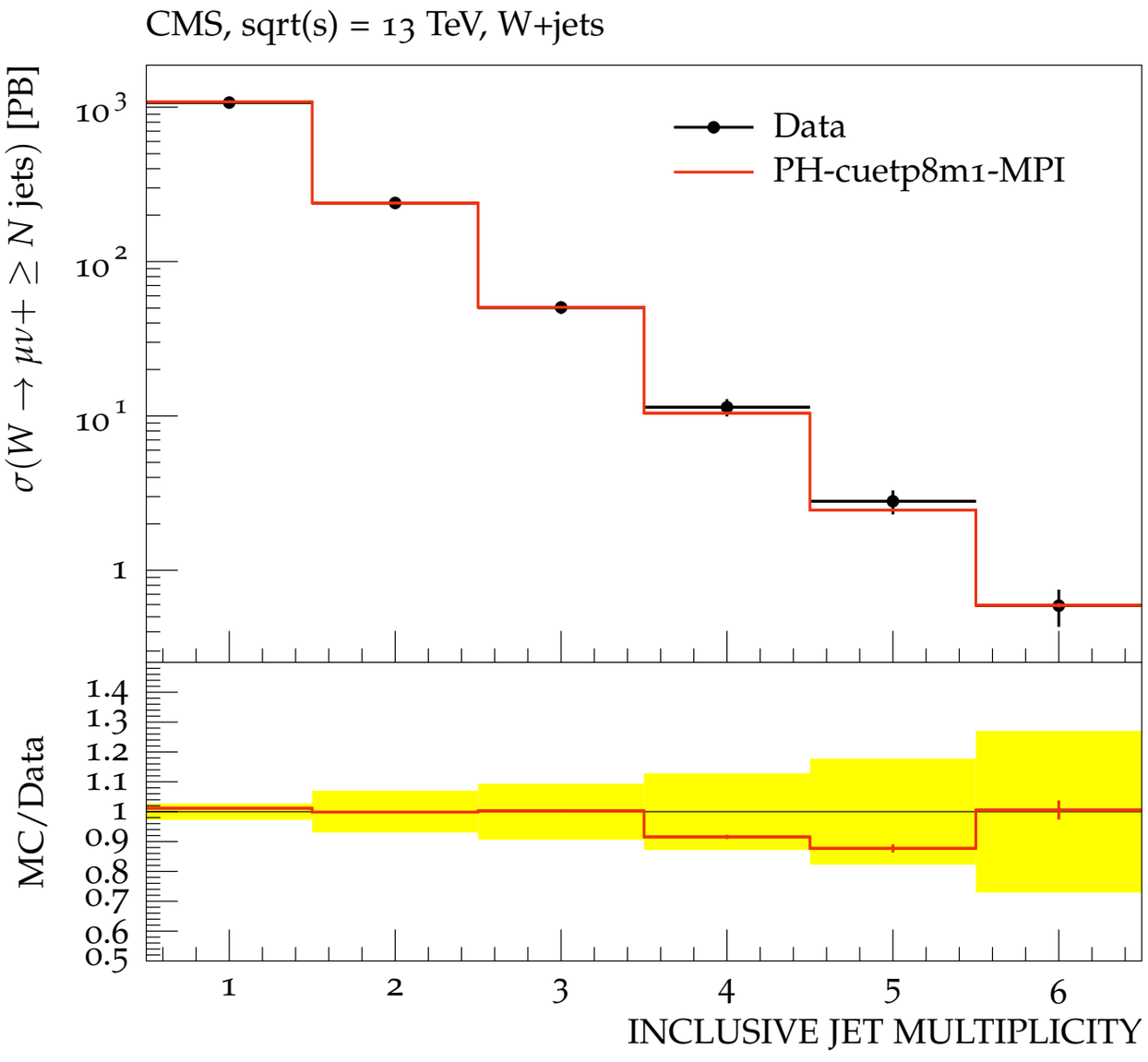
one of the few cases where we have same energy, observables and plot for at least 2 experiments!

Benchmark Comparisons

Examples: Z+Jets & W+Jets @ 13 TeV





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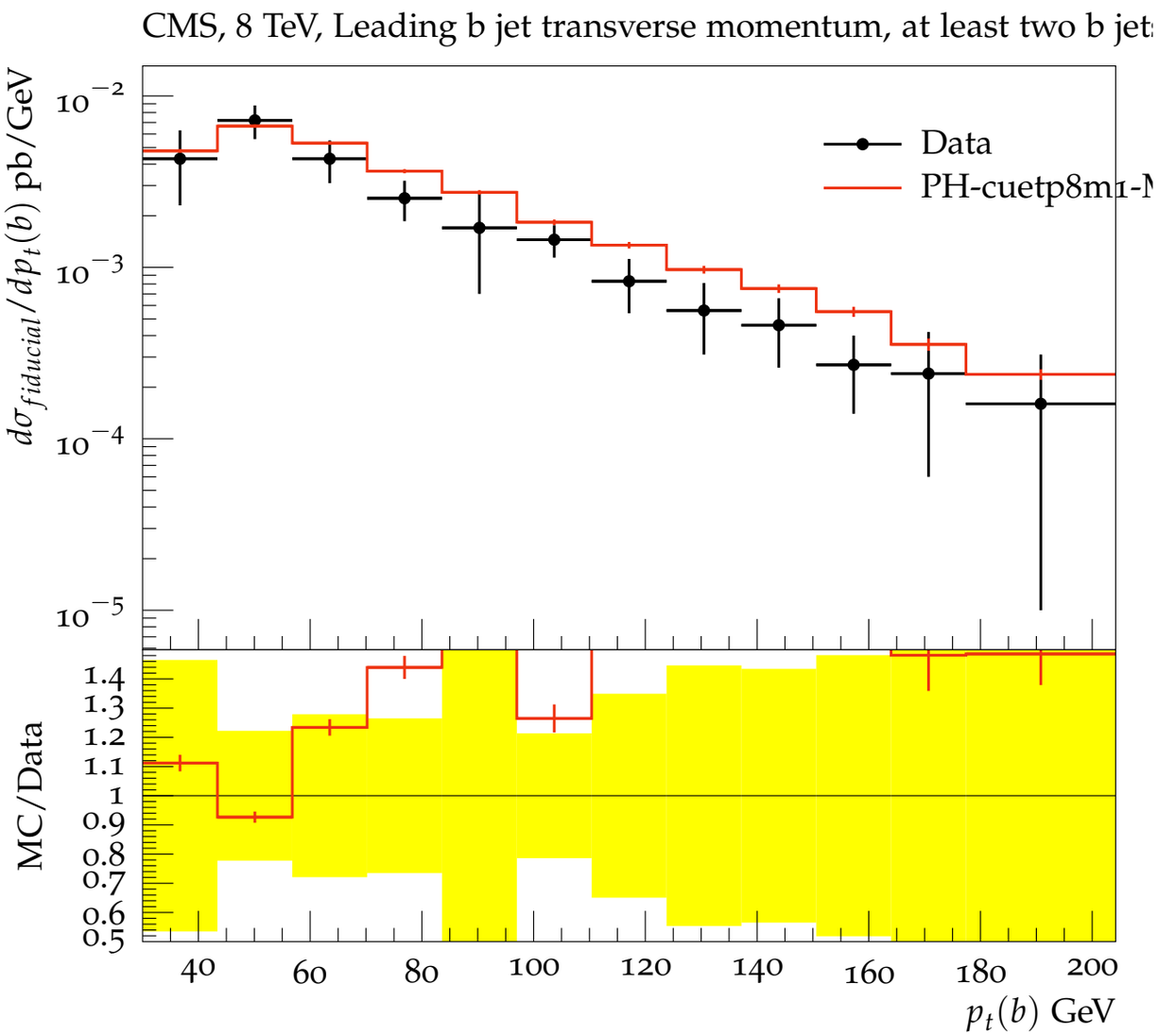
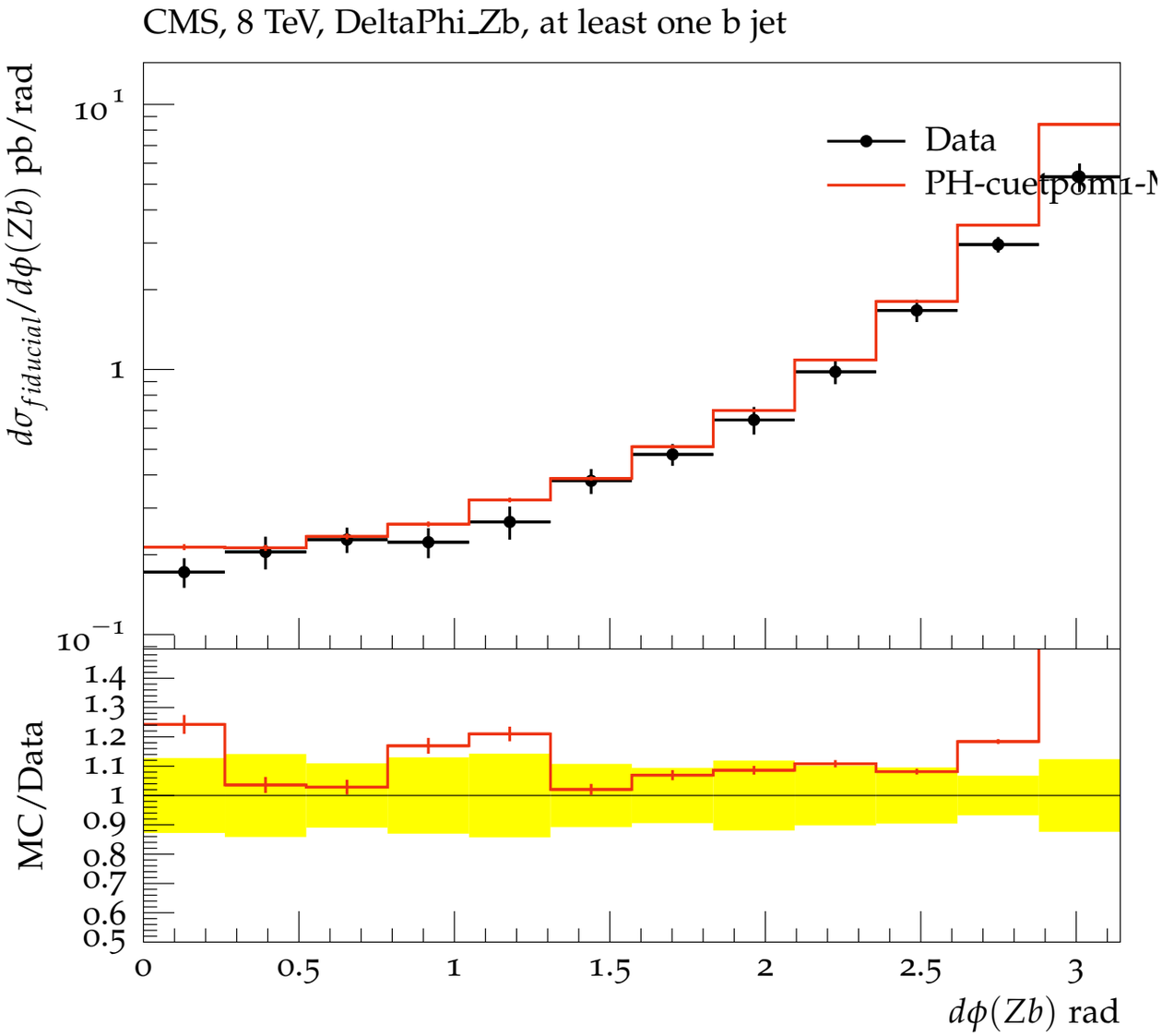
(missing RIVET routines!)

Benchmark Comparisons

Examples: Z+bb @ 8 TeV





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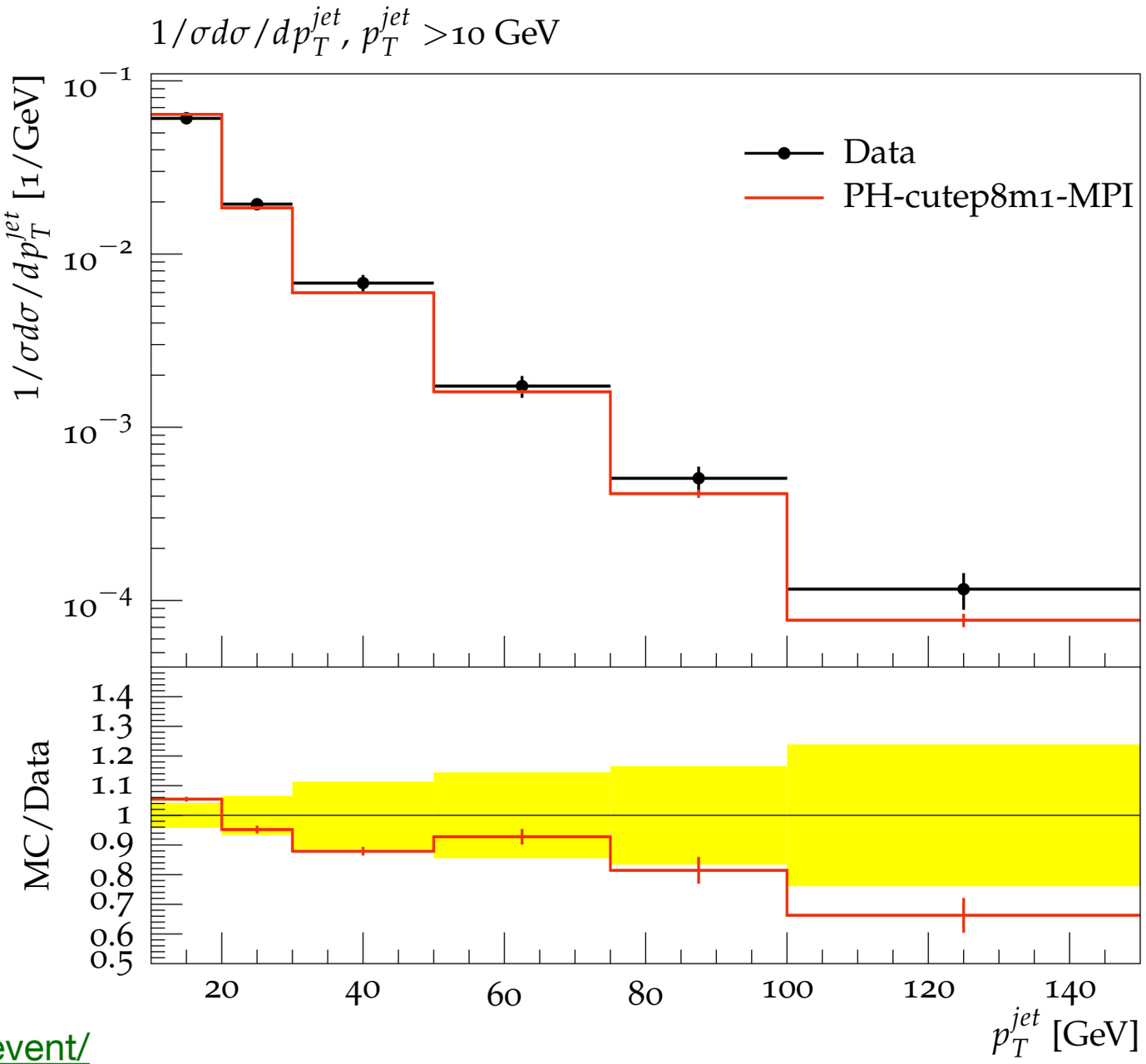
worst situation is with V+HF, missing RIVET at 7/8/13 TeV for many analyses

Benchmark Comparisons

Examples: Forward Z+jets (LHCb) @ 7 TeV



https://indico.cern.ch/event/868724/contributions/3662071/attachments/1955640/3248302/LHCEW_WG2_list_of_tasks.pdf

(need more RIVET routines from LHCb!)

HEPData Recommendations

- Are we routinely storing enough information on HEPData to efficiently re-use the measurements we make at the LHC?
  --> Not always! **small policy shifts can boost impact of analyses**

- Discussions over past year (see Dec 18, Feb 19, July 19) resulted in attempt to **formalise recommendations** and **document them in a note to be agreed between LHC experiments**
  - Give **recommendations on conventions to follow** depending on what level of re-interpretation is needed

- Recommendations discussed in dedicated presentations to experiments
  - ATLAS (SM, HDBS, PMG groups) Oct-Dec 2019
  - CMS (Generator Group) Late Oct 2019
  - LHCb (QEE Group) Nov 2019
  - ALICE : planned discussion in Jan 2019

Louie Corpe

HEPData Recommendations

- Identify different levels of recommendations, depending on the analysis type and how re-interpretable it needs to be:

Best case - aims to provide maximal information for reinterpretations. Should be gold standard for precision measurements

Scenario A - Maximum Re-interpretability

Scenario B - Approximate Re-interpretability

Scenario C - Minimum Requirements for Analysis Preservation

Bare minimum for a search to be re-interpretable

Closest to current situation. Plenty of information published. Not necessarily enough for strict combinations... but good enough for many analyses (especially searches)

- Details in Louie's dedicated talk on the subject.
- Headline changes:
  - Propose to always store breakdown of uncertainties on HEPData
  - Propose including SM Generator predictions as extra columns in tables
  - Encourage analysts to make Rivet routine at the same time as the paper

Louie Corpe

Precision Jet Substructure

Ben Nachman

Goal #1: maintain a database of measurements, encourage HepData+Rivet routines, and common observable definitions/binnings

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

References of recent measurements

- **ATLAS**
  - Lund jet plane @ 13 TeV (prelim.)
  - Mass in Z->(bb)+gamma @ 13 TeV
  - Fragmentation properties @ 13 TeV
  - JSS Observables in multijets & ttbar @ 13 TeV
  - g->bb @ 13 TeV
  - Jet pull @ 13 TeV
  - Jet mass @ 13 TeV
  - Fragmentation properties II @ 5.02 TeV
  - Fragmentation properties @ 5.02 TeV
  - Collinear W emission @ 8 TeV
  - Charged particles inside jets @ 8 TeV
  - Jet charge @ 8 TeV
  - Jet pull @ 8 TeV
  - Fragmentation properties @ 2.76 TeV
  - Jet shapes in ttbar events @ 7 TeV
  - Jet mass and other observables @ 7 TeV
  - Jet mass @ 7 TeV
  - Fragmentation properties @ 7 TeV
  - Fragmentation properties using track jets @ 7 TeV
  - Jet shapes @ 7 TeV
- **CMS**
  - Jet shapes in ttbar events @ 13 TeV

Work to do: ensure we have Rivet routines and HepData for our analyses. This is becoming more of a requirement in ATLAS and CMS, but is less so for LHCb and ALICE. We have recently added new routines from old(er) measurements to do MC comparisons with state-of-the-art PS MC setups.

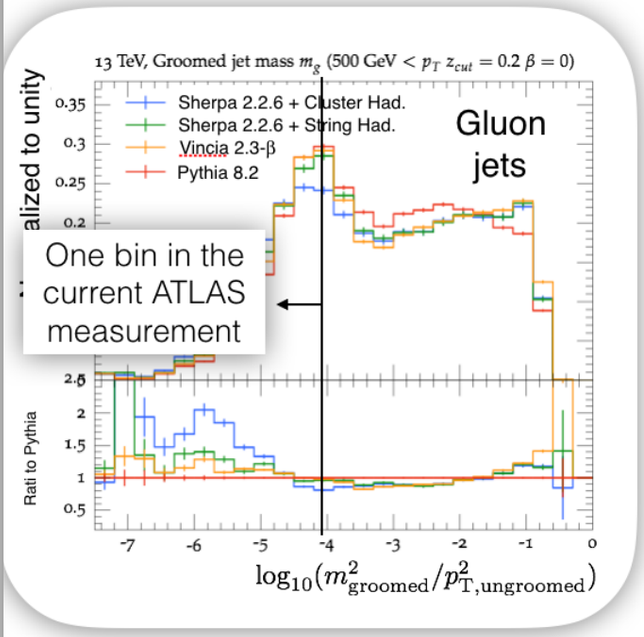
Precision Jet Substructure

Ben Nachman

Goal #2: study the impact of jet substructure measurements on FSR and NP PS MC tuning.

$O(\Lambda_{QCD})$: The low mass bump

9



For the **proceedings**: show NP parameter variations within a model & compare with analytic predictions.

Very sensitive to hadronization model.

string/cluster only change in the NP region (i.e. name make sense)

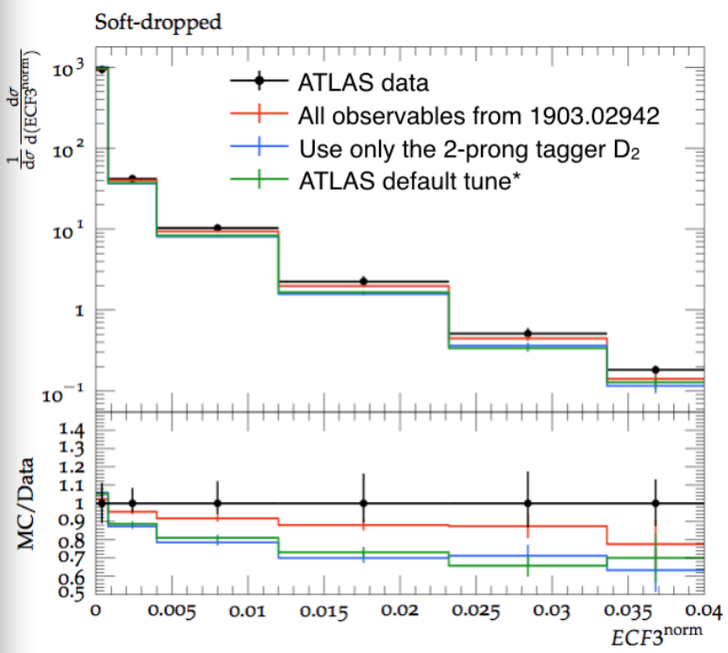
useful for tuning NP with LHC data?

Pythia is qualitatively different at high(er) masses even though it agrees ~well in the NP region.

to reiterate - seems the NP region is doing what it is supposed to!

O(10 GeV): Tuning with jet substructure

13



$$\text{ECF3}^{\text{norm}} = \frac{\sum p_{T,i} p_{T,j} p_{T,k} \Delta R_{ij} \Delta R_{ik} \Delta R_{jk}}{(\sum p_{T,i})^3}$$

*This is basically the JSS-sensitive parts of A14 and otherwise, Monash.

The work has just begun…

…but preliminary results indicate that multiple observables a can have a non-negligible impact on FSR parameters.

For the **proceedings**: complete a Les Houches jet substructure tune & determine sensitivity of individual measurements

see jet pull in the backup

This was started as part of the jet working group at Les Houches 2019.

Precision Jet Substructure

Ben Nachman

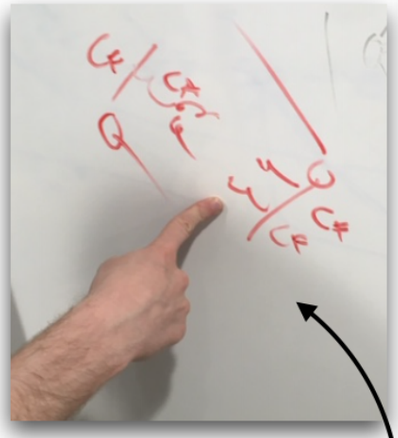
Goal #3: study the impact of jet substructure measurements on higher order effects in PS MCs.

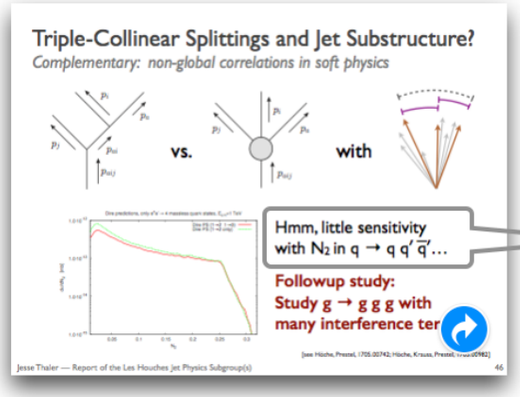
O(10+ GeV): Higher order showers

14

There is an impressive effort by the MC community to include higher-order effects in parton showers.

Key question: **what observables are sensitive to these innovations?**

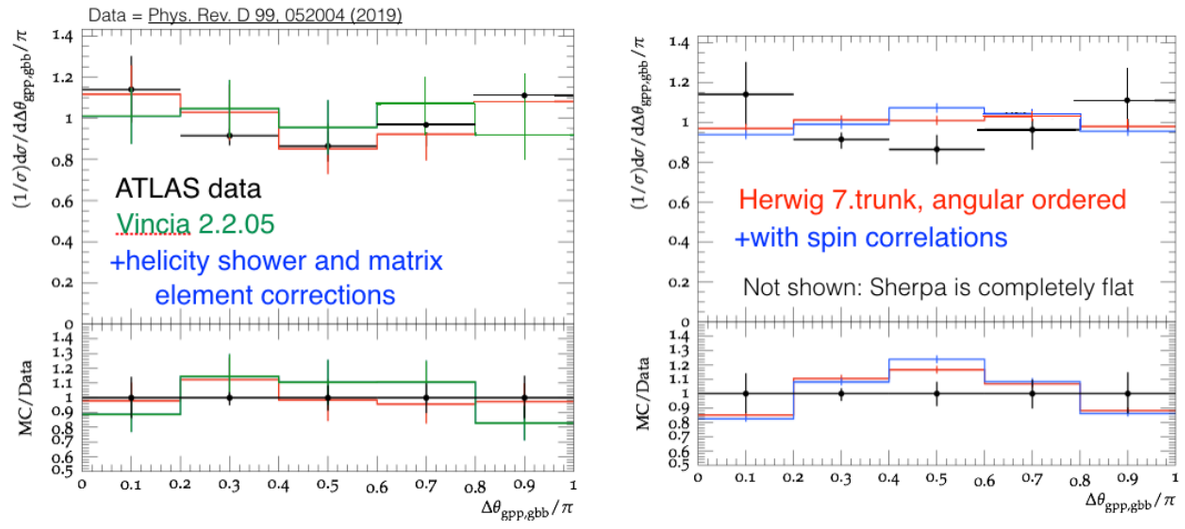




Attempt at LH17 to use jet substructure for probing the triple collinear splitting function … **without much luck**. What about the **double soft** splitting?

O(100 GeV): g → bb

19



Low-stats indication: Vincia + ME corrections w/ helicity shower show same trend as data - prediction confirmed!

This was started as part of the jet working group at Les Houches 2019.

Conclusions & Future Plans

- The group is very active on several fronts. Main projects (*benchmark comparisons*) are moving slow because of lack of manpower and RIVET routines: we need to find a way to attract people from our experiment subgroups to join us!

- We recently had ALICE joining us and we plan to have more reports in the nex future; two LHCEW-J&EWB conveners to be appointed

- New proposals and ideas: PDF studies, new comparisons, color flow measurements have been developed, news in the next meetings!

- Recommendations of HEP data storage of uncertainties is now a document discussed within experiments subgroup

- Jet substructure precision group is active and we will have new results in the f meetings of 2020

we nee to speed up activities, involve more people to have great results in 2020!

stay tuned (… and enjoy your holidays)!

backup

New Forum Topics: Jet Measurements in ALICE

some highlights on **PbPb**

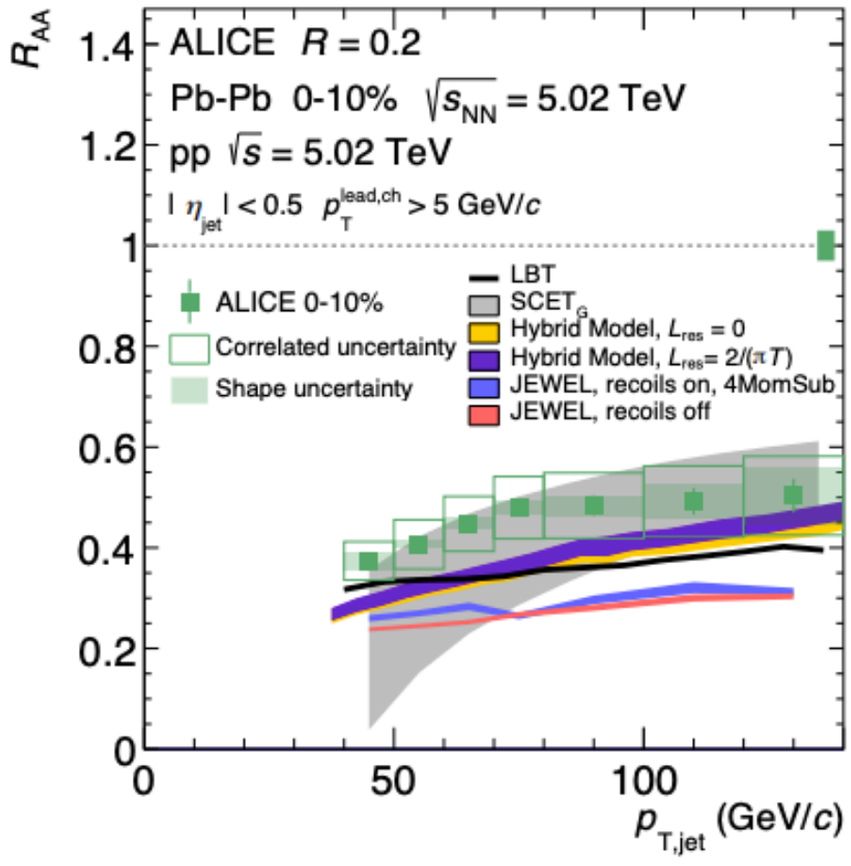
Eliane Epple

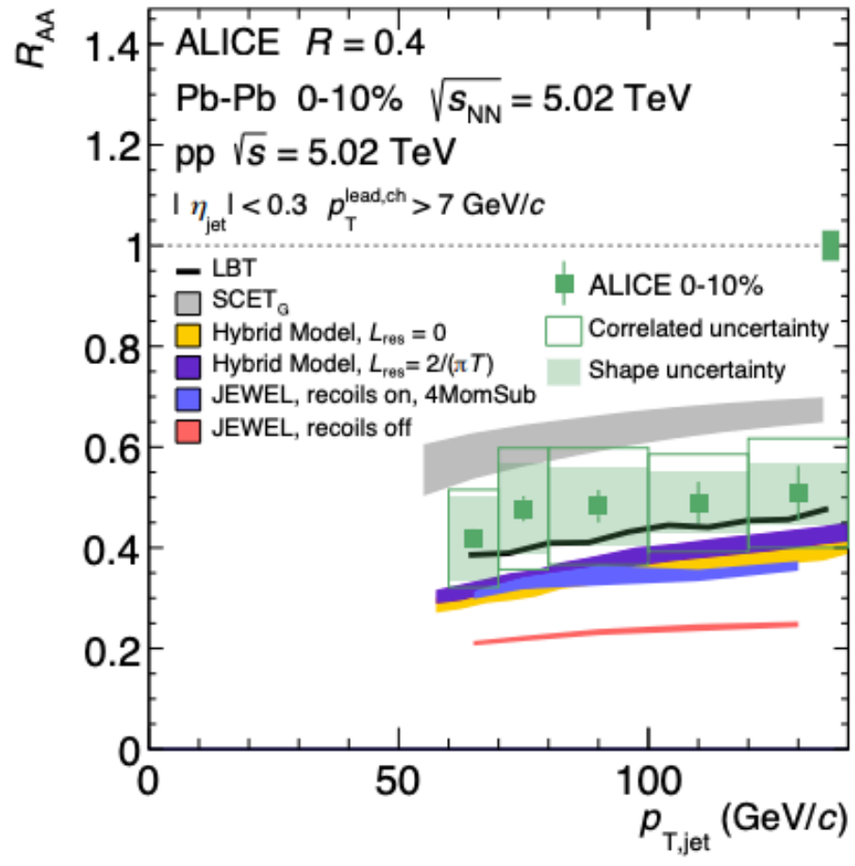
James Mulligan

- Medium influence on jets
- Direct comparison to models with different jet energy loss mechanisms
- Constrain global fits of jet energy loss models to extract medium properties (e.g. q-hat)

$$R_{AA} = \frac{\frac{1}{\langle T_{AA} \rangle} \frac{1}{N_{event}} \frac{d^2N}{dp_T d\eta}\Big|_{AA}}{\frac{d^2\sigma}{dp_T d\eta}\Big|_{pp}}$$

- Jet RAA shows strong suppression of jets in medium
- Visible pT dependence of this effect
- Models can describe the data qualitatively
- some slight discrepancies this needs a closer look from the theory side





LBT provided in arxiv:1809.02525
PRC 91 (0549098)

Hybrid model provided by Daniel Pablos
JHEP 10 (2014) 19 *JHEP 03 (2016) 53*
JHEP 03 (2017) 135 *JHEP 03 (2018) 10*

SCET$_G$ provided by Haitao Li
arxiv:1801.00008
PLB 769 (242)

JEWEL (generated internally)
JHEP 03 (2013) 80 *JHEP 07 (2017) 141*
EPJ C (2016) 76:695

New proposals: full Run II designing measurements

Idea presented last year at the LHCEW workshop
and discussed in Durham and at CERN

Bogdan Malaescu

Matthias Schott

- Defining V+Jets measurements with the Run II sample such that they are comparable between (ATLAS,CMS,LHC,ALICE) experiments

- Agreement on observables, binning, systematic uncertainties and the format (ongoing)

Systematics: establish plan for evaluating correlations across experiments
Combination: understand when it is useful to combine

Perform quantitative comparisons between measurements

Next steps: identify datasets and test on pseudoexperiments

timescale ~short term work leading to some document

New Forum Topics: Color Flow with Jet Pull

TO BE ADDED: waiting for the next Jets&EW bosons meeting

LHC Tune