Shower systematics in matching generators

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Experimentalist's perspective on

shower systematics in matching generators:

- argue why different approach is needed when using matched applications vs when using standalone generators (LO ME + PS, no matching) for shower systematics
- comment on scales choices, couplings, etc. between ME and PS
- comment on whether or not ISR and FSR systematics should be treated separately
- (not shower systematics but) comment on non-perturbative (colour reconnection and underlying event) systematics when using matching generators

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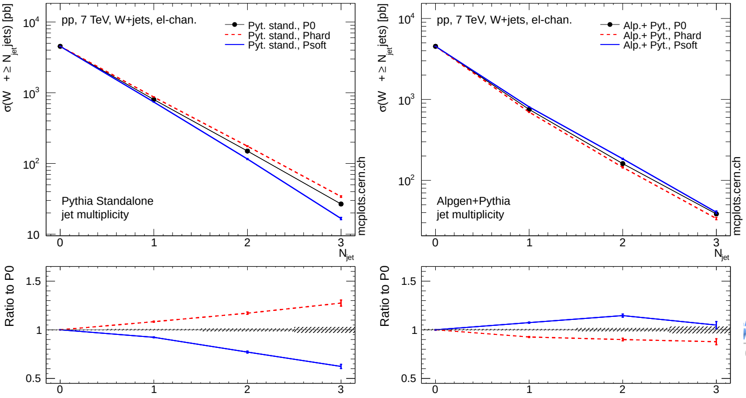
Disclaimers:

- As far as experimental efforts I am not aware of dedicated public tuning results of the matched generators from either of Tevatron or LHC collaborations. ⇒ I don't have ATLAS/experiment specific tuning results involving matching generators to show at this meeting.
- **lots of plots in the slides from:**
  B. Cooper, J. Katzy, M.L. Mangano, A. Messina, P. Skands, LM.:
  Importance of a consistent choice of alpha(s) in the matching of AlpGen and Pythia,
  Eur.Phys.J. C72 (2012) 2078 [1].
  lots of code used for plots: MCPLOTS project `http://mcplots.cern.ch/`
- most items discussed today are more relevant for matching applications (AlpGen, MadGraph) used with external parton shower code Pythia, Herwig, than they are for matching application that is developed with a dedicated parton shower (Sherpa).

Parton Shower Systematics : Standalone vs Matched

- Compare a central tune with its **soft** (less perturbative activity) and **hard** (more perturbative activity) variations developed for Pythia standalone
- for jet ($p_T > 20$ GeV and $|\eta| < 2.8$) multiplicity distribution in W+jets electron channel events in pp collisions at 7 TeV.
- samples generated with Pythia 6 standalone (left) , AlpGen + Pythia 6 (right).
- in matched case: **hard** tune is *softer* than the **soft** tune
  $\Rightarrow$ **shower syst. in the presence of matching cannot be done in the same way as for LO generator where no matching is used.** (Observation by A. Messina and B. Cooper)



What is happening here?

Please see [1] for theoretical discussion!

The observed is a symptom of a more general issue in ME-PS matched calculations for which:

- α_s definition (order, Λ_{QCD}) should be the same on both sides;
- in case this is not set internally by a generator, one should set Λ_{QCD} to the same values in ME and PS.
- This is not the case in the previous plots, and as a result the vetoing of the matching becomes too aggressive/passive under variation of Λ_{QCD} in the shower only.

Should Λ_{QCD} be varied in ISR and FSR separately?

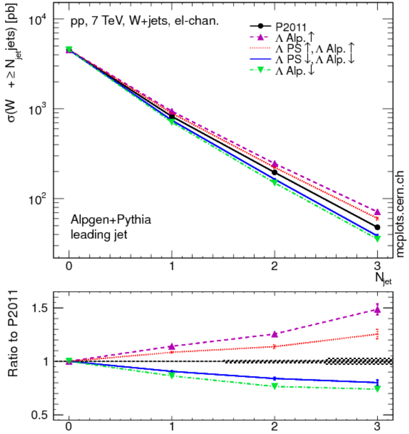
- **the considerations above introduce stronger motivation not to do so in the matching application case,**
- stronger = stronger than in the case of LO generator in the absence of matching.

Parton Shower Systematics : Matched tune variations

Doing it right (see Extra slides, Ref-s [1] and [2] for parameter variation details and data-MC):

- same distribution as before, generated with AlpGen + Pythia 6
- **blue** and **red** follow the prescription of the previous slide
- (**magenta** and **green** are variations in ME only)

yields expected results (hard tune is *harder* than the soft) .



Soft vs hard tune variations and MLM matching efficiencies

In more detail: the **soft** and **hard** tune are variations around Perugia0 (P0) tune named **Perugia Soft** and **Perugia Hard** of Ref. [2]. Perugia Hard and Perugia Soft differ in both perturbative and non-perturbative aspects.

Table below:

- impact of variations of the Pythia 6 tunes on the cross sections of AlpGen W+jets sub-samples with different matrix element parton multiplicities (NpX), and the total inclusive W cross section (after MLM matching).
- Gist: perturbative (ISR, IFSR) rather than non-perturbative (UE,CR) activity parameters are the ones that affect the MLM matching efficiencies.

tune	Np0	Np1	Np2	Np3	Np4+	total [pb]
Phard	7287 ± 3.9	728 ± 2.6	141 ± 1.3	27 ± 0.2	6.6 ± 0.2	8190 ± 8
P0	7556± 3.6	814 ± 2.7	166 ± 1.3	32 ± 0.3	7.8 ± 0.3	8576 ± 8
Psoft	7804 ± 3.4	944 ± 2.8	207 ± 1.5	42 ± 0.3	10.1± 0.3	9007 ± 8
P0 with Phard ISR	7207 ± 6.9	735 ± 2.6	143 ± 1.3	27 ± 0.2	6.9 ± 0.2	8119 ± 11
P0 with Psoft ISR	7831 ± 4.9	881 ± 2.7	186 ± 1.4	36 ± 0.3	8.8 ± 0.3	8943 ± 10
P0 with Phard FISR	7548 ± 6.0	814 ± 2.7	167 ± 1.3	32 ± 0.3	7.8 ± 0.3	8569 ± 10
P0 with Psoft FISR	7505 ± 6.1	878 ± 2.7	188 ± 1.4	37 ± 0.3	9.4 ± 0.3	8617 ± 10
P0 with Phard UE	7513 ± 6.1	826 ± 2.7	171 ± 1.4	33 ± 0.3	7.8 ± 0.3	8551 ± 10
P0 with Psoft UE	7576 ± 5.9	817± 2.7	166 ± 1.3	32 ± 0.3	8.1 ± 0.3	8599 ± 10
P0 with Phard CR	7561 ± 5.9	821 ± 2.7	167 ± 1.3	32 ± 0.3	8.1 ± 0.3	8589 ± 10
P0 with Psoft CR	7556 ± 5.9	815 ± 2.7	165 ± 1.3	32 ± 0.3	8.1 ± 0.3	8576 ± 10

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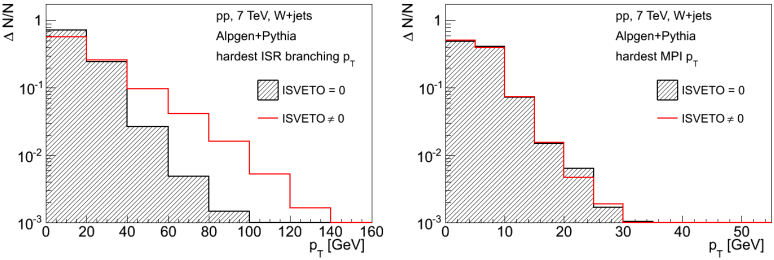
Non-perturbative systematics

- Distribution of the probabilities for the event acceptance (ISVETO=0) or rejection (ISVETO$\neq$0) during the MLM matching step, as a function of the largest p_T shower emission from the initial state radiation (left) and the largest p_T multiple proton-proton interaction in the event (right) in one of the NpX sub-samples.



MLM matching veto probability is:

- LHS: larger for more ISR activity
- **RHS: independent of MPI activity**

The non-perturbative parameter variations/aspects do not impact the matching directly, which is an important distinction wrt. to I/FSR variations.

Best practice for shower systematics in matching generators

- Hopefully a brief example I presented conveys the point that a matched generator shower systematics should be done by simultaneous variations of parameters on the ME and PS side;
- a consistent choice of alpha(s) in the matching on each of the ME and PS generators matters and is not guaranteed by default when running e.g. MadGraph+Pythia, AlpGen +Herwig ...
- while it might be trivial, this observation has been duly ignored for much of the sample production by the experiments until recently

An imo reasonable approach to shower systematics in matching generators:

- start with a setup using a consistent alpha_s definition for both ME event generation and PS
- for systematics variations vary scales used in running alpha_s such that the consistent choice persist also for variation samples
- the above implies lambda_QCD in ISR and FSR we usually vary should be varied simultaneously

- Can we re-use ME 4-vectors for systematics:
  - for shower systematics: no
  - should be ok for NP systematics

Check with the data if such approach works.

References

1. B. Cooper et al., Importance of a consistent choice of alpha(s) in the matching of AlpGen and Pythia, Eur.Phys.J. C72 (2012) 2078 .
2. P. Z. Skands: Tuning Monte Carlo Generators, The Perugia Tunes, Phys. Rev. D82, 2010, arXiv:1005.3457 [hep-ph].
3. A. Buckley et al., Systematic event generator tuning for the LHC, Eur. Phys. J. C65, 2010, arXiv:0907.2973 [hep-ph].
4. CDF Collaboration, Measurement of the cross section for W-boson production in association with jets in ppbar collisions at s**(1/2) = 1.96-TeV, Phys. Rev. D77, 2008, arXiv:0711.4044 [hep-ex].
5. ATLAS Collaboration, Measurement of the production cross section for W-bosons in association with jets in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector, Phys.Lett.B, 2010, arXiv:1012.5382 [hep-ex].
6. ATLAS Collaboration, Study of Jet Shapes in Inclusive Jet Production in pp Collisions at sqrt(s) = 7 TeV using the ATLAS Detector, Phys. Lett. B698, 2011, arXiv:1101.0070 [hep-ex].

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Tune / parameters variation suggestion for AlpGen and Pythia 6

The parameters in the AlpGen and Pythia 6 codes that are important for ensuring the consistency of matching:

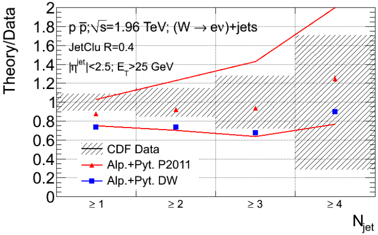
- Peter developed Perugia-2011 tunes (6.425) family that comply to the guidelines passed for consistent matching [2]; locks relevant Pythia parameters to the same values:
  - `PARP(61)` for Λ_{QCD} for ISR.
  - `PARJ(81)` for Λ_{QCD} for FSR inside resonance decays.
  - `PARP(72)` for Λ_{QCD} for FSR outside resonance decays (e.g., FSR off hard jets from the matrix element and/or from ISR).
  - ...
- Effective *value* for Λ_{QCD} set according to comprehensive Professor tunings [3] of the $p_\perp$-ordered shower in Pythia to event shapes and other LEP data:

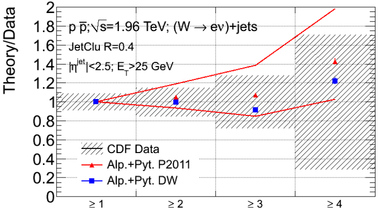
$$\Lambda_{\mathrm{QCD}}^{(5)} \sim 0.26$$

- Michelangelo introduced new Alpgen (v2.14) parameters (`ktfac` = 1.0) :
  - Λ_{QCD} (5-flavour): `xlclu` =0.26
  - Running order: `lpclu` = 1
- central suggestion for CTEQ5L, but similar CTEQ6L1 setup exists.

Data comparisons: Tevatron W+jets

- The ratio of predicted theory and CDF measured data cross-sections for the production of a $W \to e\nu$ in association with at least $\mathrm{N_{jet}}$ jets [4].
- LHS: theory predictions not normalised to the data, RHS: theory predictions are normalised to the 1st data bin.
- jets : CDF JetClu alg., $R_{cone} = 0.4$, $p_T > 20$ GeV and $|\eta| < 2.5$.
- red lines: coherent rescaling of α_S with `ktfac` =0.5, 2 (has a little effect on the shapes of the differential cross-sections)





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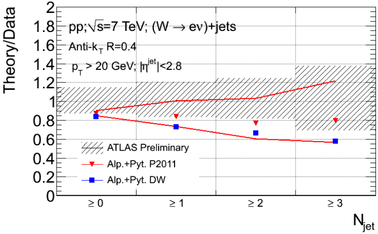
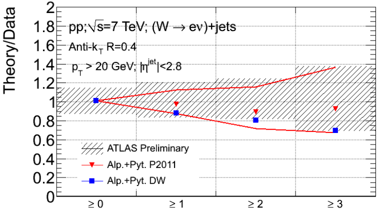
Data comparisons: LHC W+jets

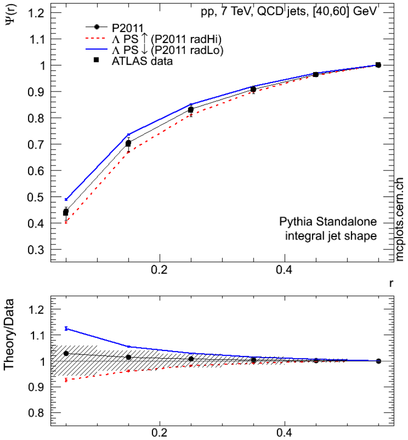
- ratio of predicted theory and ATLAS measured data cross-sections for the production of a $W \to e\nu$ in association with at least $\mathrm{N_{jet}}$ jets [5] (1.3 ipb!).
- LHS: theory predictions not normalised to the data, RHS: theory predictions are normalised to the 1st data bin.
- jets : anti-Kt alg., $R = 0.4$, $p_T > 20$ GeV and $|\eta| < 2.8$.
- red lines: coherent rescaling of α_S with `ktfac` =0.5, 2 (has a little effect on the shapes of the differential cross-sections)





Data comparisons: LHC QCD jet shapes 1

- integral jet shape distributions are compared to the ATLAS data [6] for the jets in the transverse momentum range of 40-60 GeV in the whole measured rapidity range ($|y| < 2.8$).
- Pythia 6 standalone (left) and AlpGen + Pythia 6 (right) with Perugia 2011,
- both provide reasonably good description of the jet shapes, but due to MLM matching the jets in the AlpGen + Pythia 6 case tend to be more narrow than in the Pythia 6 standalone case.



Data comparisons: LHC QCD jet shapes 2

- integral jet shape distributions are compared to the ATLAS data for the jets in the transverse momentum range of 260-310 GeV in the whole measured rapidity range ($|y| < 2.8$).
- Pythia 6 standalone (left) and AlpGen + Pythia 6 (right) with Perugia 2011,
- both provide reasonably good description of the jet shapes, but due to MLM matching the jets in the AlpGen + Pythia 6 case tend to be more narrow than in the Pythia 6 standalone case.