The High Energy Jets Framework

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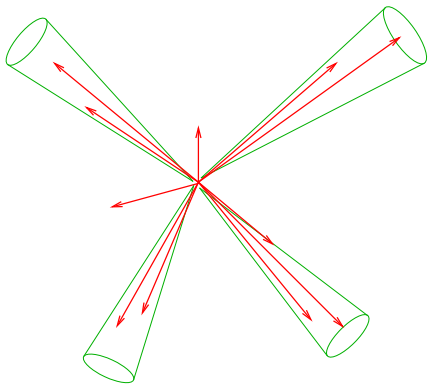

DIS Bonn 27 March, 2012

A New Framework for a New Era

High Energy Jets = flexible description of wide-angle QCD radiation

- Usual starting point = fixed-order calculation
- Standard to sum large effects from *small* s_{ij} between partons
  Parton showers describe soft and/or collinear well
- At LHC, effects from *large* s_{ij} are important
  These arise in wide-angle radiation (soft and hard)
  These are treated in High Energy Jets (HEJ)

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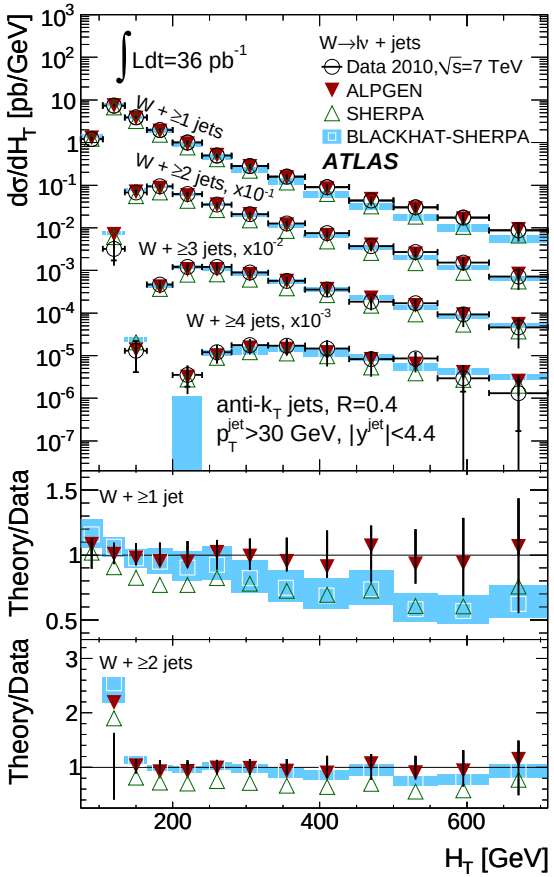
Additional tool for LHC, final aim = best bits of ALL

Why?

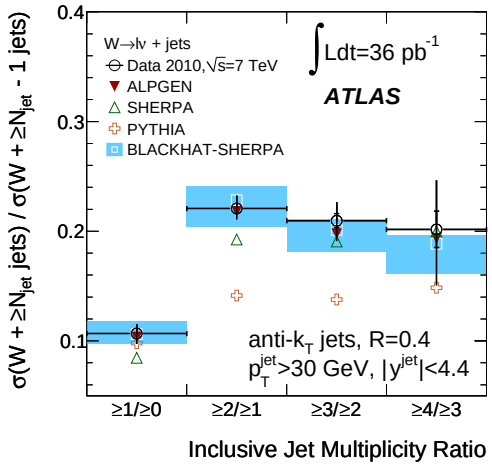
Higher energy at LHC $\Rightarrow$ increased impact of hard emissions



ATLAS W+jets, arXiv:1201.1276

High H_T: Inclusive 2j and 3j rate comparable to inclusive 1j

Relative cross sections also high:



Impact will be increased further at 8 TeV, then 14 TeV!!

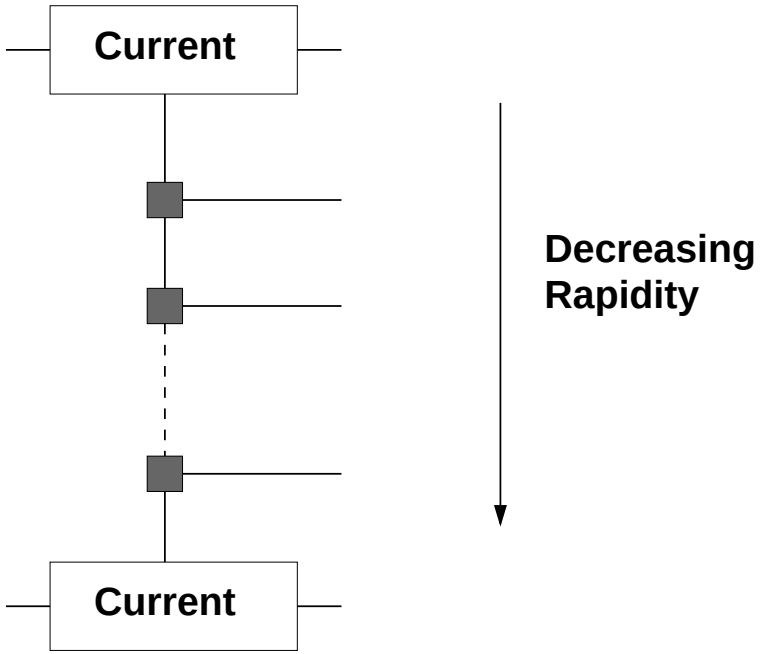
How?

Amplitudes factorise in the High Energy (HE) limit:

For all partons (i, j):

$$s_{ij} = (p_i + p_j)^2 \to \infty,$$
with $|p_\perp|$ fixed

In practice = well-separated partons



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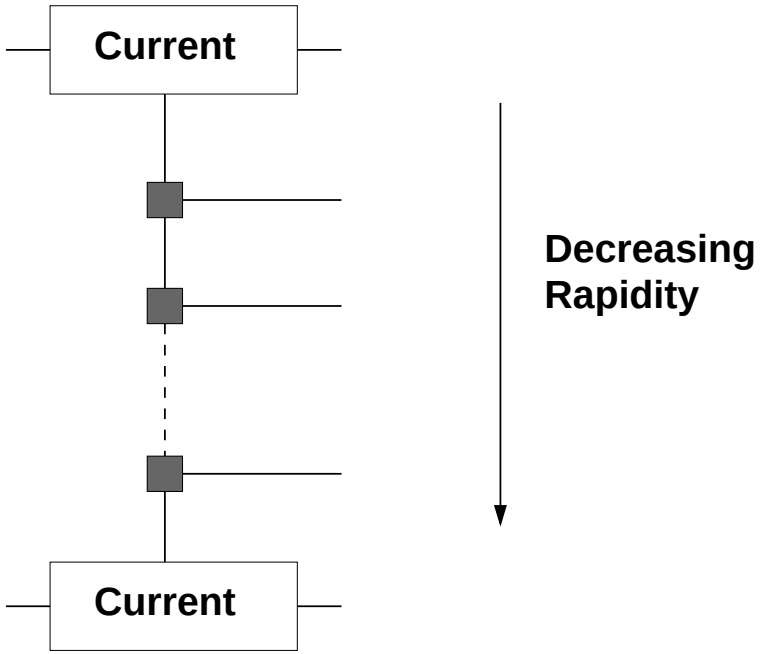
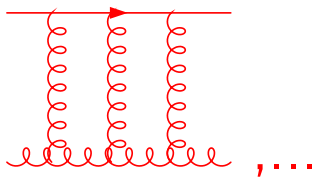


- Includes dominant pieces of *all* higher loops $\alpha_s^n \log^n\left(\frac{s_{ij}}{t}\right)$
- Scales simply with number of partons

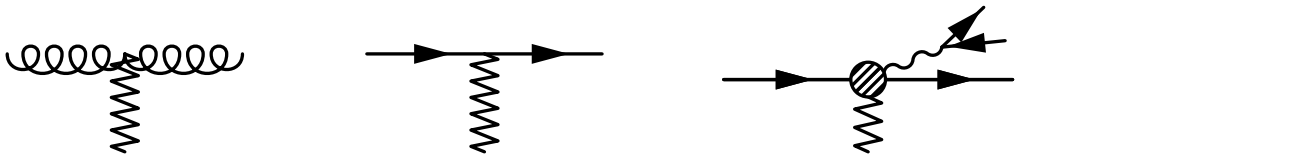


A HEJ Amplitude

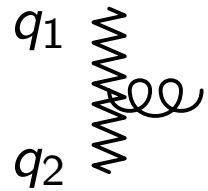
Andersen & JMS, arXiv:0908.2786, 0910.5113

Built from:

- Two currents $j^\mu = \bar{u}\gamma^\mu u$ (or generalisation for W/Z)



- Modified Lipatov vertex: $V^\rho(q_1, q_2)$



- Lipatov ansatz for virtual corrections:

$$= \frac{1}{t_i} \exp\left[\hat{\alpha}(q_i)(y_{i-1} - y_i)\right],\ \hat{\alpha} = -g_s^2 C_A \frac{\Gamma(1-\epsilon)}{(4\pi)^{2+\epsilon}} \frac{2}{\epsilon} \left(\frac{\mathbf{q}^2}{\mu^2}\right)^\epsilon$$

The HEJ Event Generator

Andersen & JMS, arXiv:1101.5394

Pieces implemented in public Monte Carlo Event Generator

Completely exclusive in final state momenta of partons

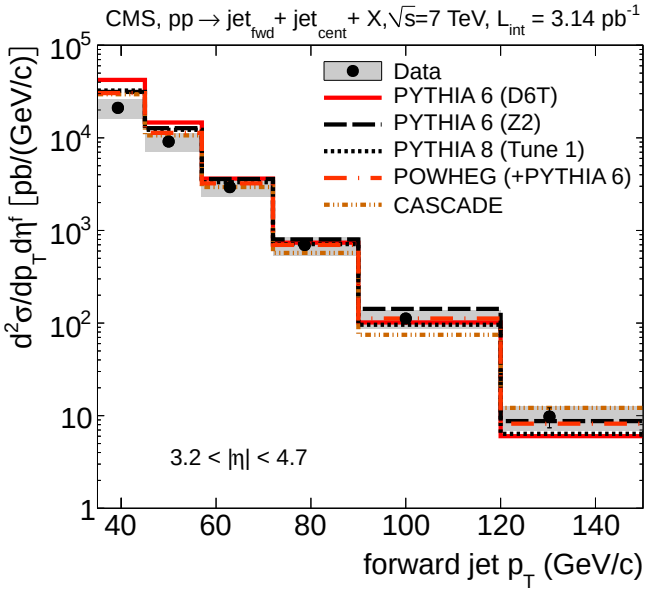
Flexible enough to merge with

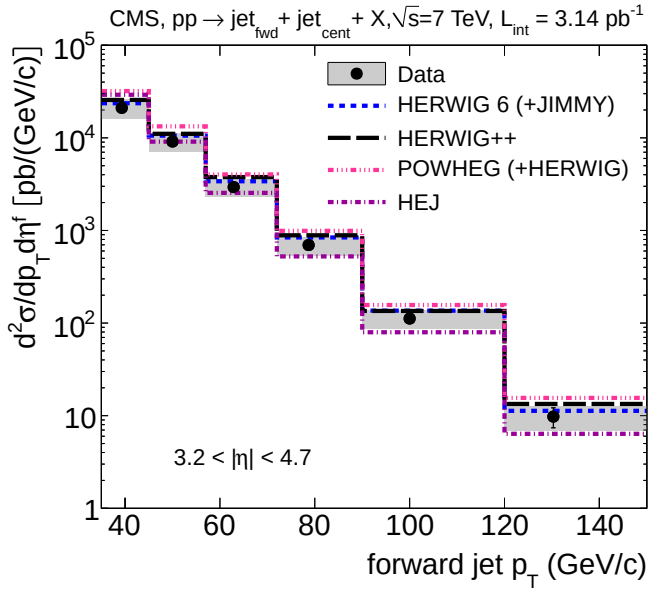
- LO matrix elements from MadGraph
- Parton shower (after careful treatment of overlap)
  - First implentation with Ariadne Andersen, Lönnblad, JMS, arXiv:1104.1316
  - Work in progress with authors of Sherpa, Pythia, Herwig++

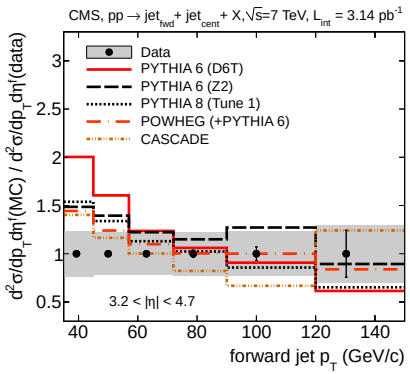
HEJ & HEJ+Ariadne available for jets: `www.cern.ch/hej`

CMS Analysis: One Central + One Forward Jet

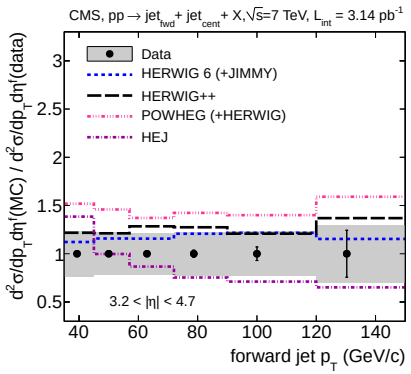
arXiv:1202.0704







Forward jet p_T



Described pretty well

CMS Analysis: One Central + One Forward Jet

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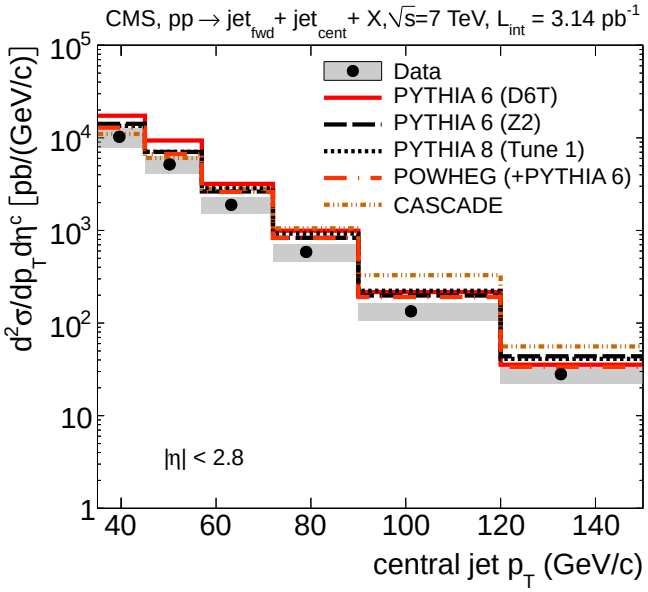
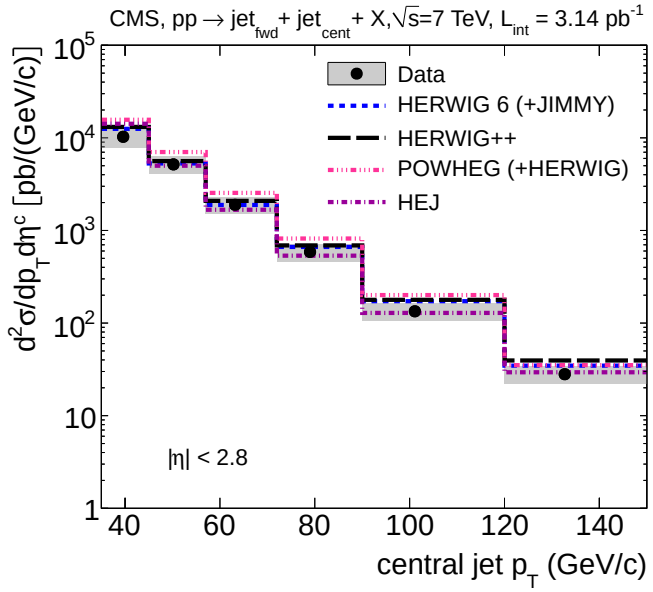
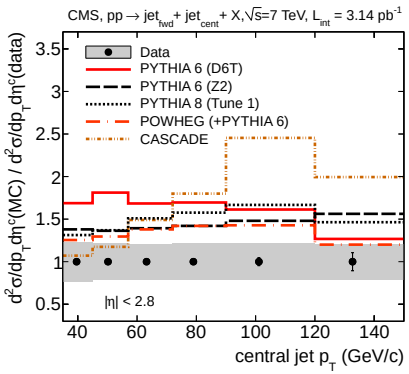
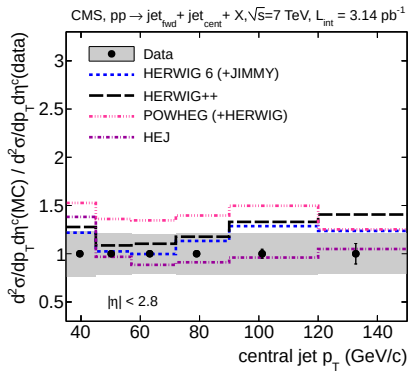






Central jet p_T

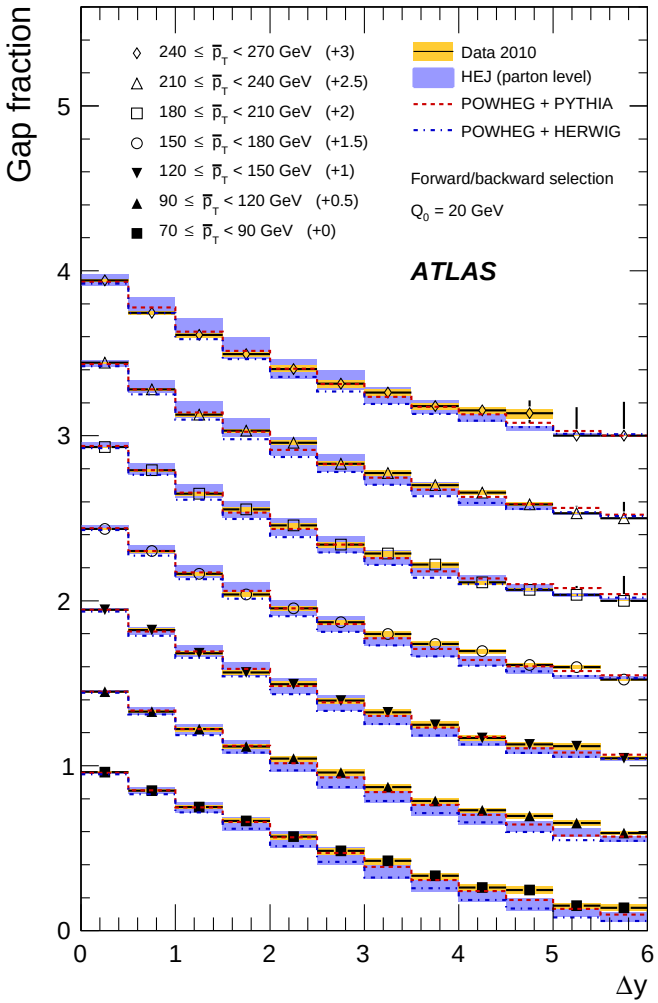


Small rapidity separation not described well

HEJ still good agreement

ATLAS Analysis: Gap Fraction/Jet Veto Analysis

arXiv:1107.1641



$$\text{Gap Fraction} = \frac{\text{no jets in gap}}{2j \text{ inclusive}}$$

$\overline{p}_T$ = average p_T of tagging jets

Here, tagging jets are most forward and most backward.

Good agreement with POWHEG+PYTHIA and HEJ

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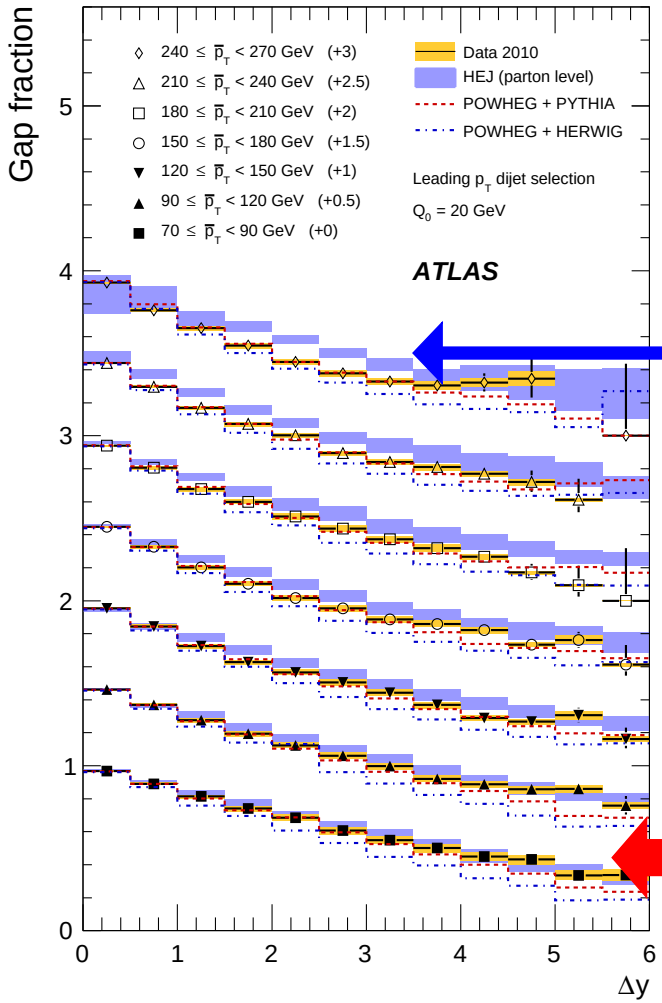


Here tagging jets are leading p_T

Two visible drivers of radiation:

1. Hierarchy in p_T (up to factor 10!)

systematic p_T evolution not included (yet!) in HEJ: description poor, but understood

2. Evolution in rapidity

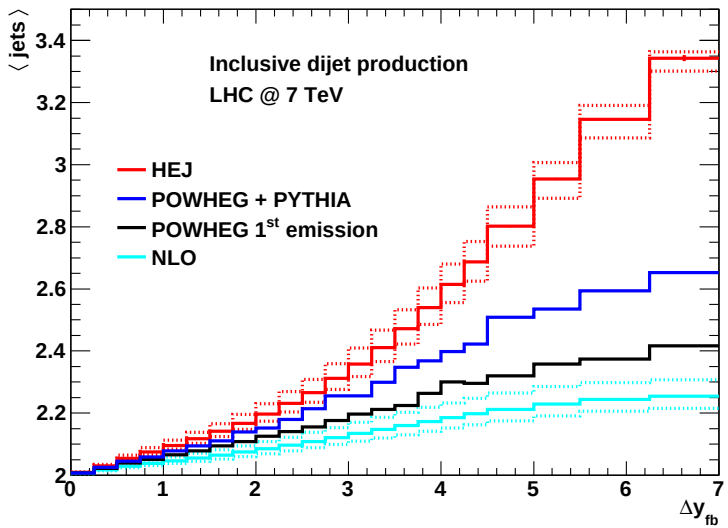
HEJ description good, POWHEG undershoots

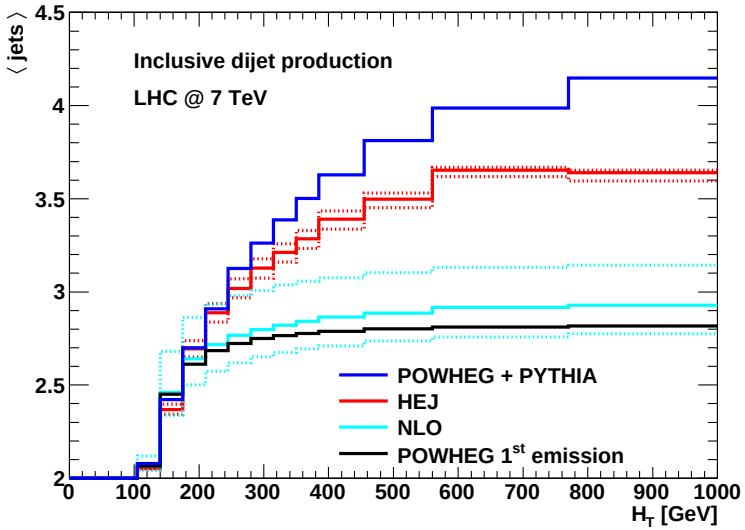
Dijet Comparison of HEJ and POWHEG

Alioli, Andersen, Oleari, Re, JMS, arXiv:1202.1475

Have seen POWHEG and HEJ can give similar predictions.

Can the descriptions be distinguished?





$p_{T,j} > 35$ GeV, $p_{T,j1} > 45$ GeV, $|y_j| < 4.7$

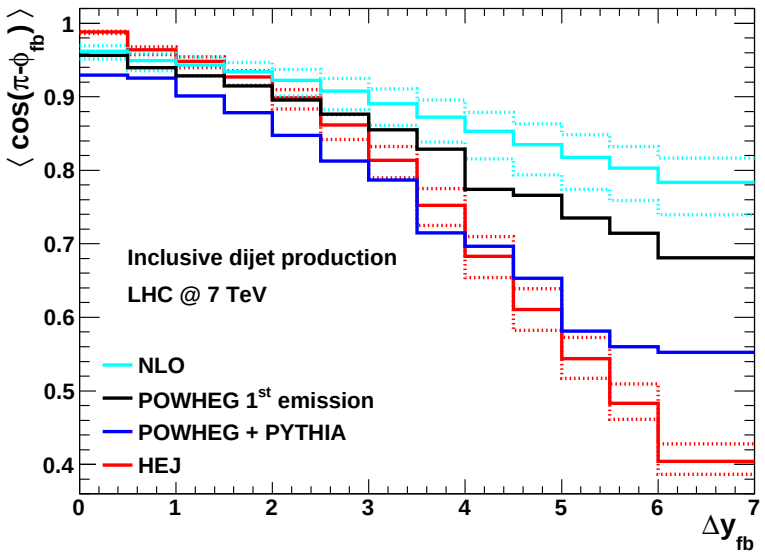
- Cuts here do not induce p_T hierarchy
- Average number of jets more sensitive to 4j, 5j,...

Dijet Comparison of HEJ and POWHEG

Alioli, Andersen, Oleari, Re, JMS, arXiv:1202.1475

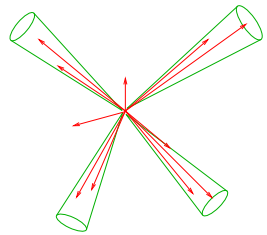
Other variables show little difference, e.g. $\cos\phi_{fb}$,

ϕ_{fb} = azimuthal angle between most forward and most backward jet



Azimuthal decorrelation gives measure of additional radiation (deviation from back-to-back)

Summary



- Jets important across LHC physics programme
  Are our theoretical descriptions adequate at LHC?
- High Energy Jets resums contributions from wide-angle radiation, publicly available as fully-flexible Monte Carlo
- These contributions have *already* been seen in early data!
- New parton shower releases coming soon!
- Also relevant for W, Z, H+jets and beyond. See
  - Les Houches proceedings
  - Work in progress with Andersen, Maître, Winter