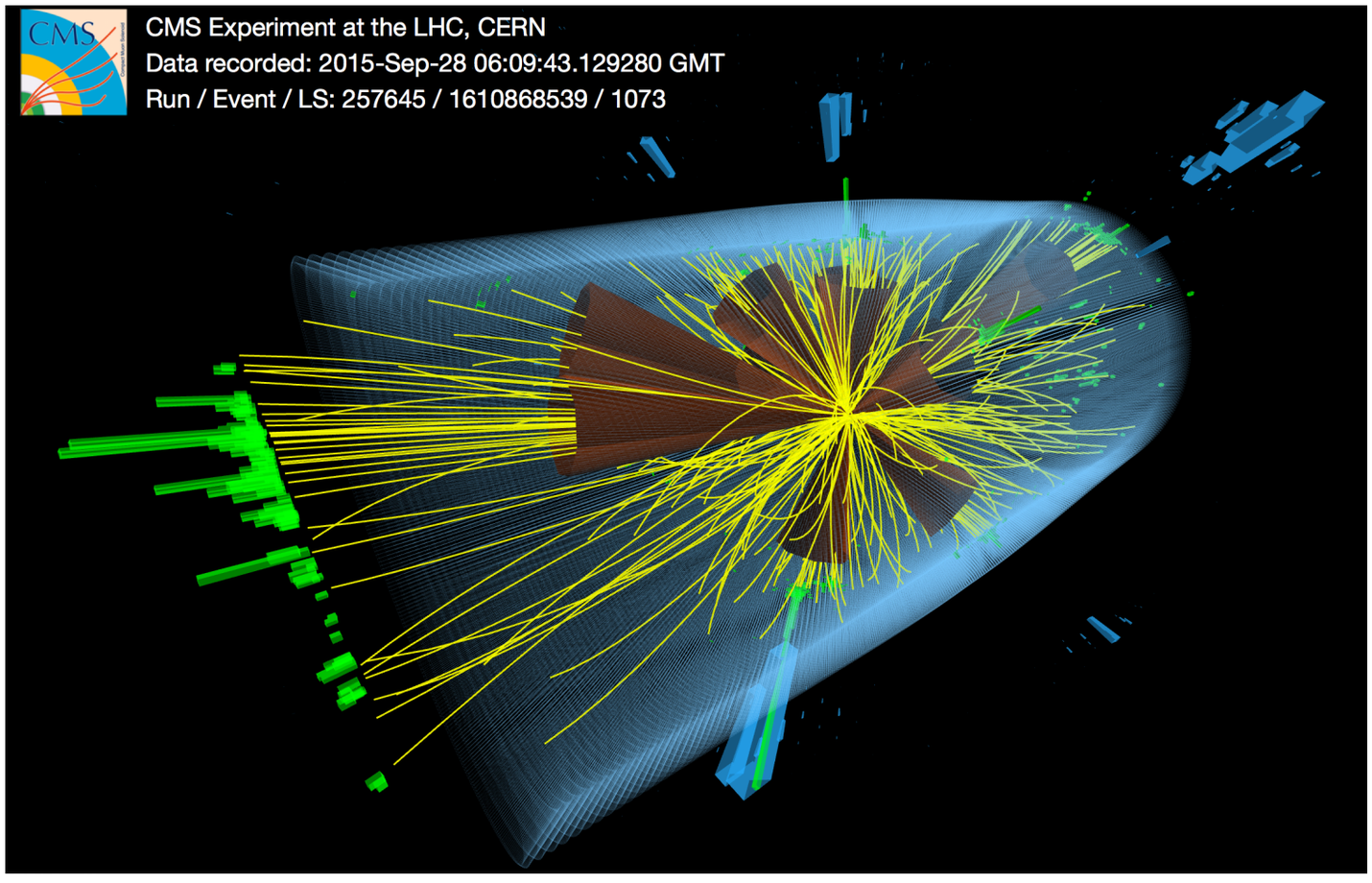
High Energy Jets (HEJ)



Jenni Smillie

with: Andersen, + Brooks, Cockburn, Maier, Medley

Introduction

- Previous picture = **12 jets** with p_T > **50 GeV** at CMS (13 TeV)

Many **Hard**

Introduction

- Previous picture = **12 jets** with p_T > **50 GeV** at CMS (13 TeV)

Many **Hard**

- Not just many jets, but also many scales: very difficult for theoretical descriptions.

- Phase space probed in Higgs boson analyses and searches for new physics put us right into the most difficult regions:

  Large rapidity separations or large invariant mass enhance (multi-)jet production (e.g. VBF)

  see ATLAS 1107.1641, D0 1302.6508, …

QCD at High Energy

- Extra power of α_s compensated by large phase space and large logarithms - **even more at 13 TeV, 100 TeV…**

- Already at the LHC, (n+1)-jet rates are not small compared to n-jet rates [0.2 rising to 0.3 after VBF cuts]

- Stability associated with NLO fails in difficult regions of phase space — demands a new approach

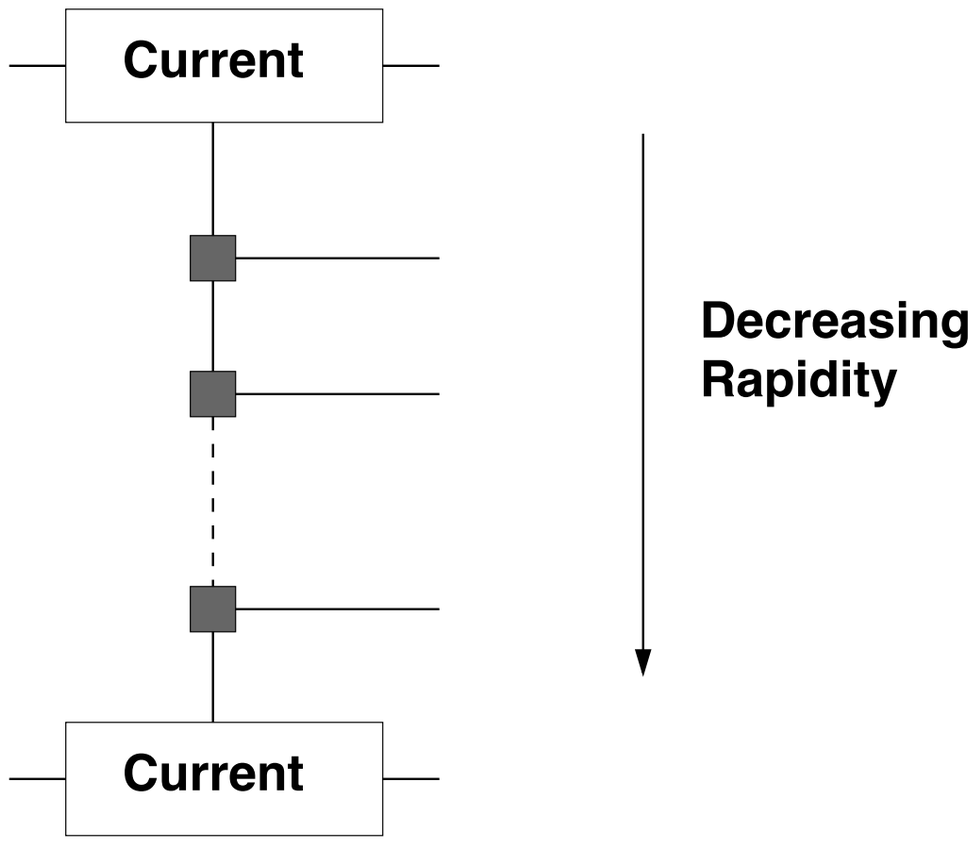
High Energy Jets (HEJ)

However, amplitudes themselves become simpler in the "high energy" limit

$\Delta y_{ij} \to \infty$, $|p_{Ti}|$ finite

Use this simpler structure to make an efficient event generator for arbitrary numbers of quarks/gluons.

Applies to loop diagrams too: gives leading log terms at all orders in α_s



Andersen & JMS arXiv:0908.2786, 0910.5113, 1101.5394, +Hapola 1201.6763, +Medley 1603.05460

HEJ Principles

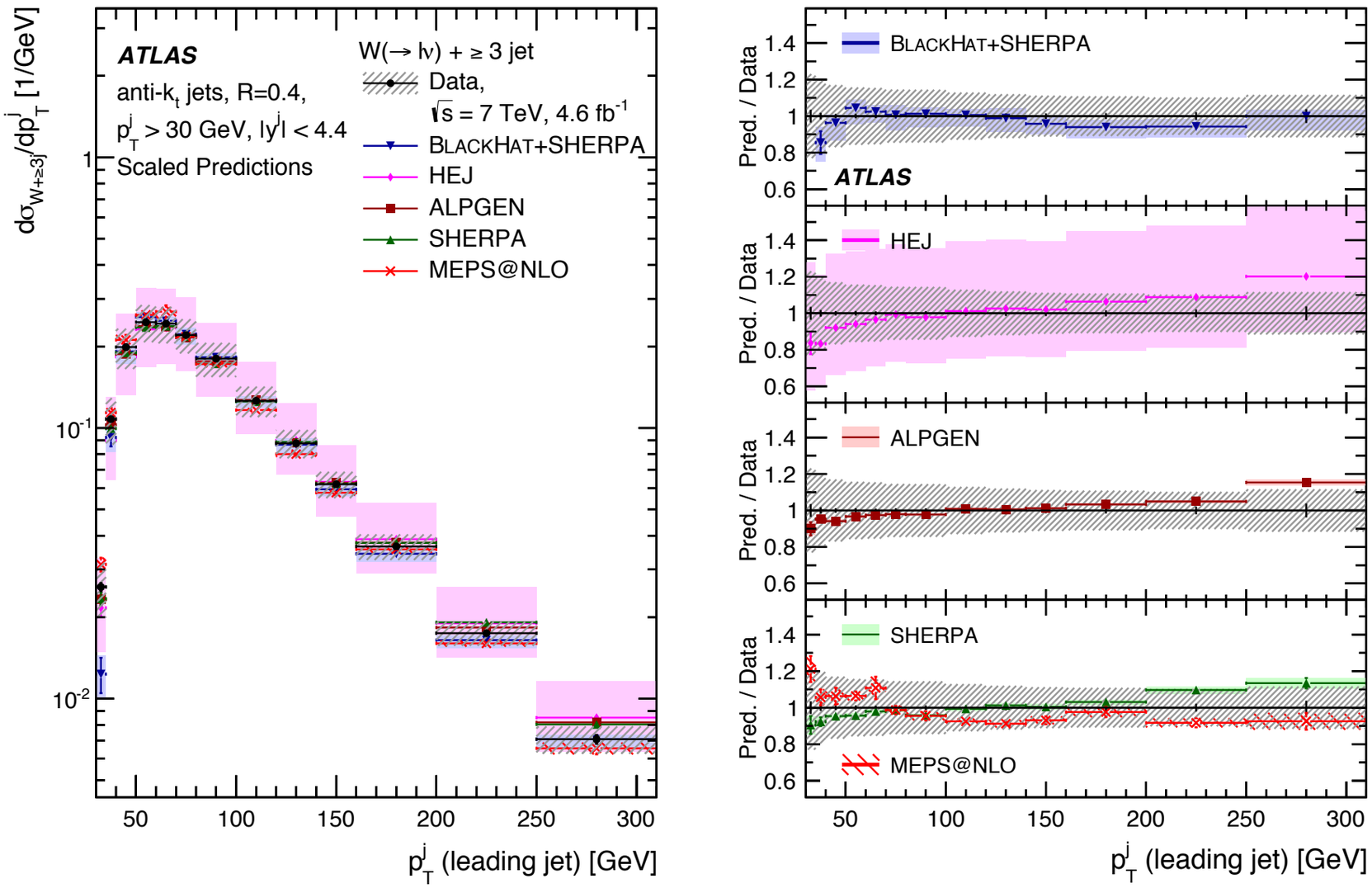
The HEJ description is:

- exact for simple processes (2 to 2 (+X))
- gauge invariant in all phase space
- sufficiently fast for numerical integration (up to 30 gluons)
- accurate to leading logarithm in s/t
- merged with LO samples for 2j, 3j and 4j

Result: fully flexible (exclusive) MC event generator for
jets, W+dijets, H+dijets, Z+dijets
compatible with LHAPDF, Rivet, fastjet, …

http://cern.ch/hej

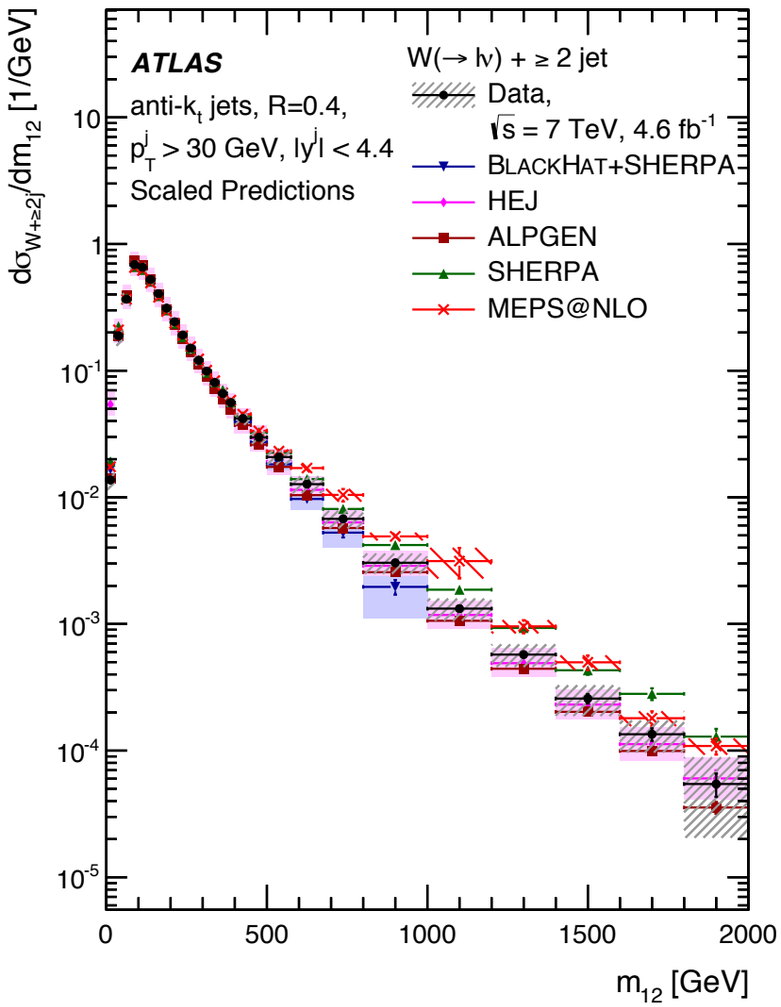
ATLAS W+Jets arXiv:1409.8639

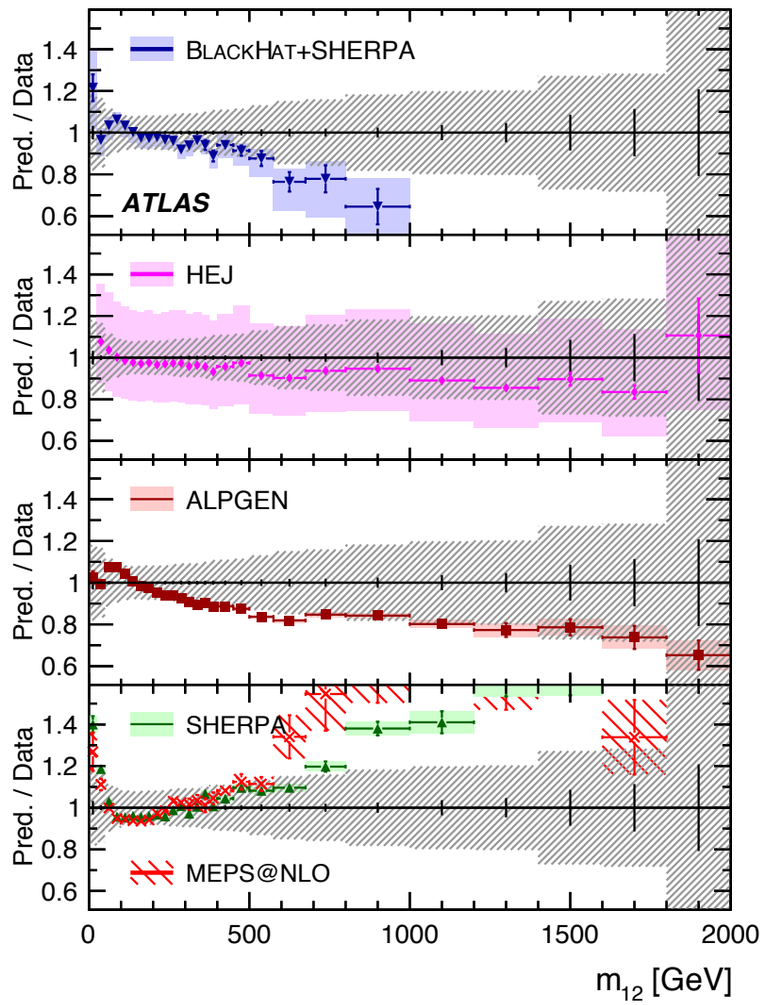


In this distribution (pT of the leading jet in inclusive 3j events), the theory predictions show similar levels of agreement. BlackHat+Sherpa is best.

Only top two have scale variations included. HEJ is basically LO scale var.

ATLAS W+Jets arXiv:1409.8639



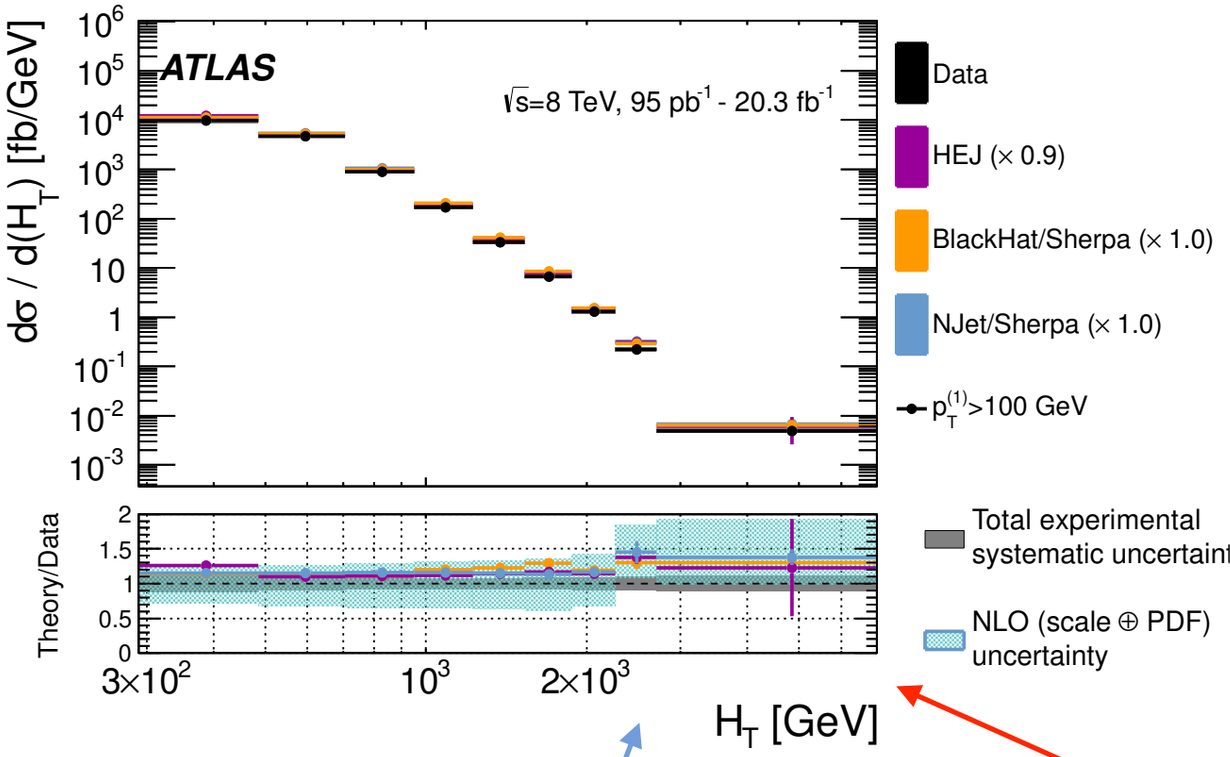


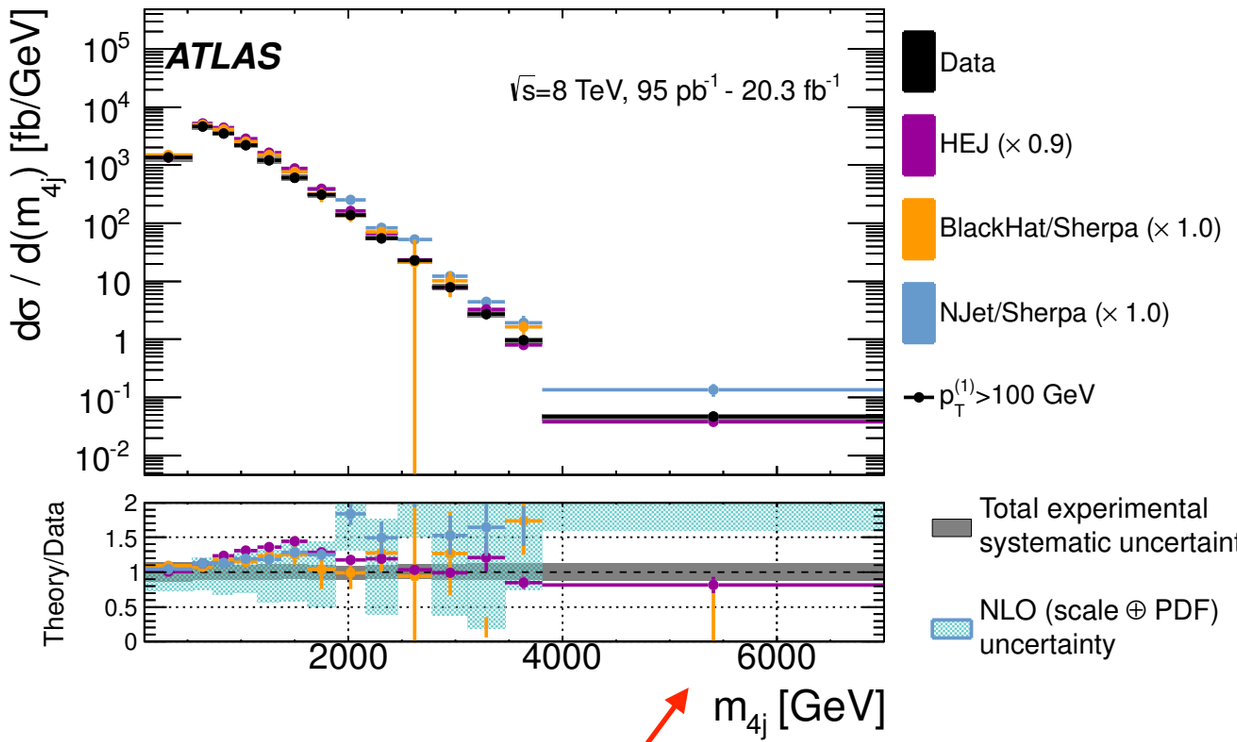
The logs uniquely described in HEJ become increasingly important as m_{12} increases. Seen here where the HEJ prediction remains flat while others deviate.

Some distributions show worse agreement with HEJ, but are improved by including sub-leading corrections (ongoing work).

ATLAS 4-Jets arXiv:1509.07335

The first exp. analysis where HEJ predictions include subleading corrections





Large momentum usually difficult region for HEJ: good description now

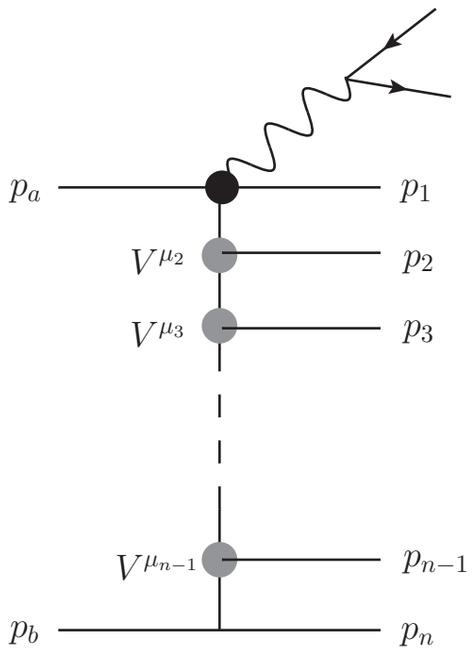
Very high energies measured (already at Run I)

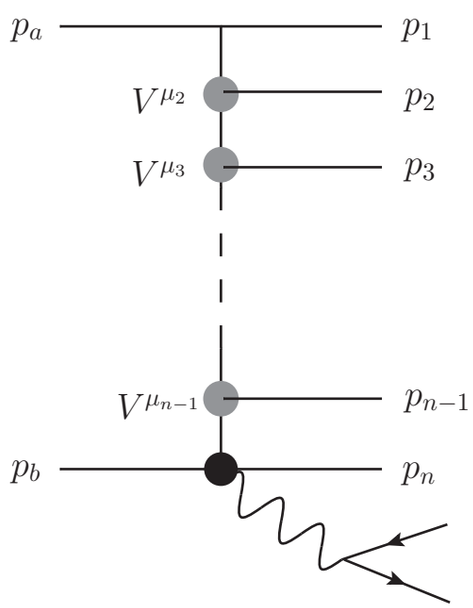
Z/γ^*+Jets

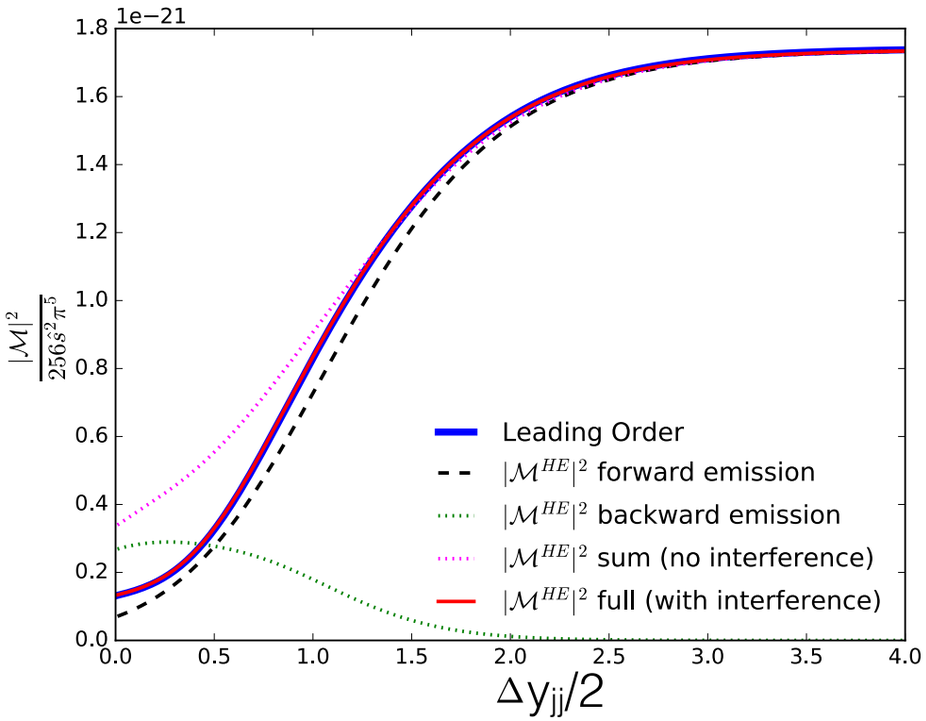
Interference effects from quark lines mean more complicated than W+Jets

New results extend HEJ method to Z plus jets

Andersen, Medley, JMS arXiv:1603.05460





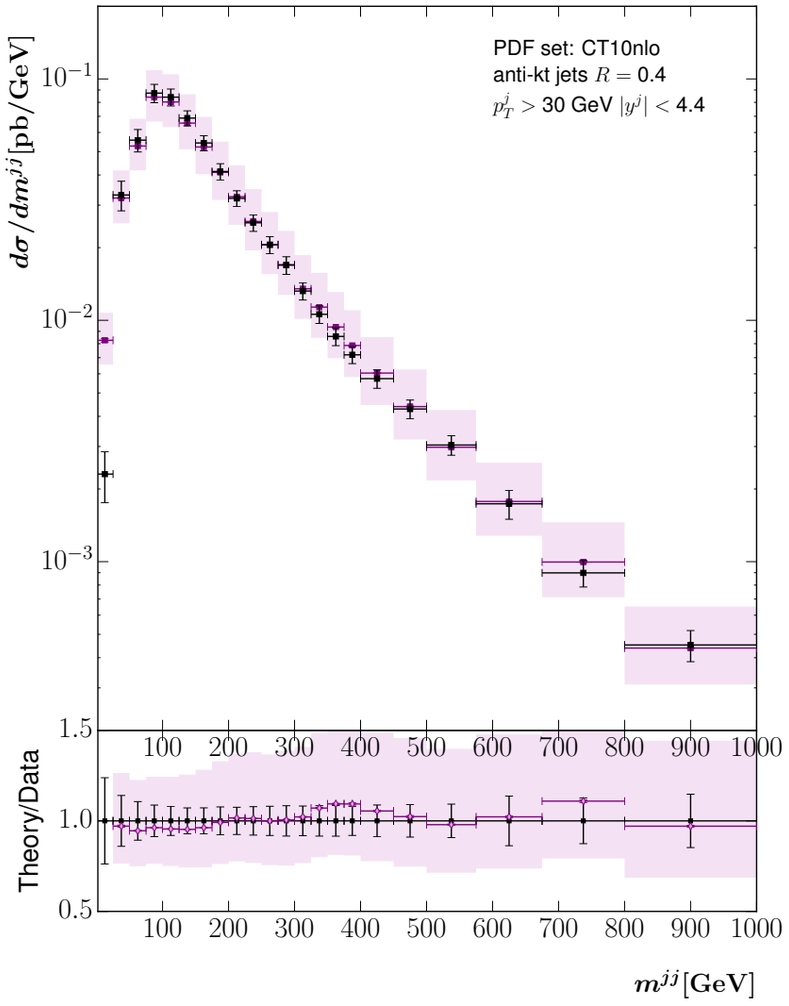


Only able to do this because we operate on the amplitudes and not amp-squared

Includes interference terms missing in e.g. electroweak shower

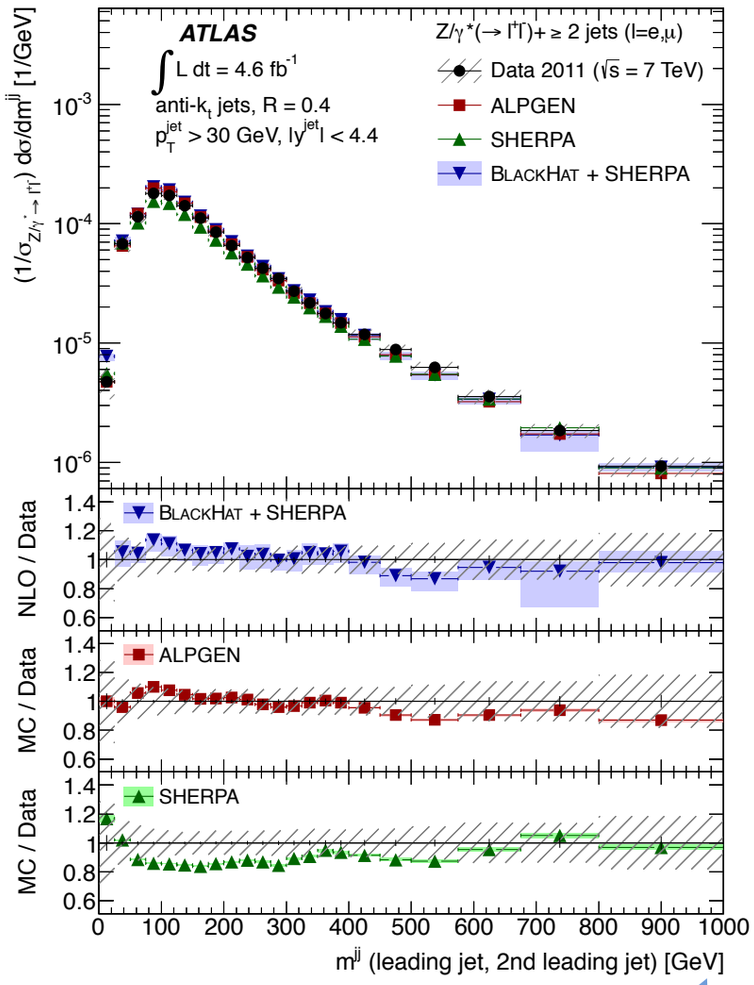
Z+Jets vs Data

Andersen, Medley, JMS arXiv:1603.05460



HEJ gives good description in this process too

ATLAS arXiv:1304.7098

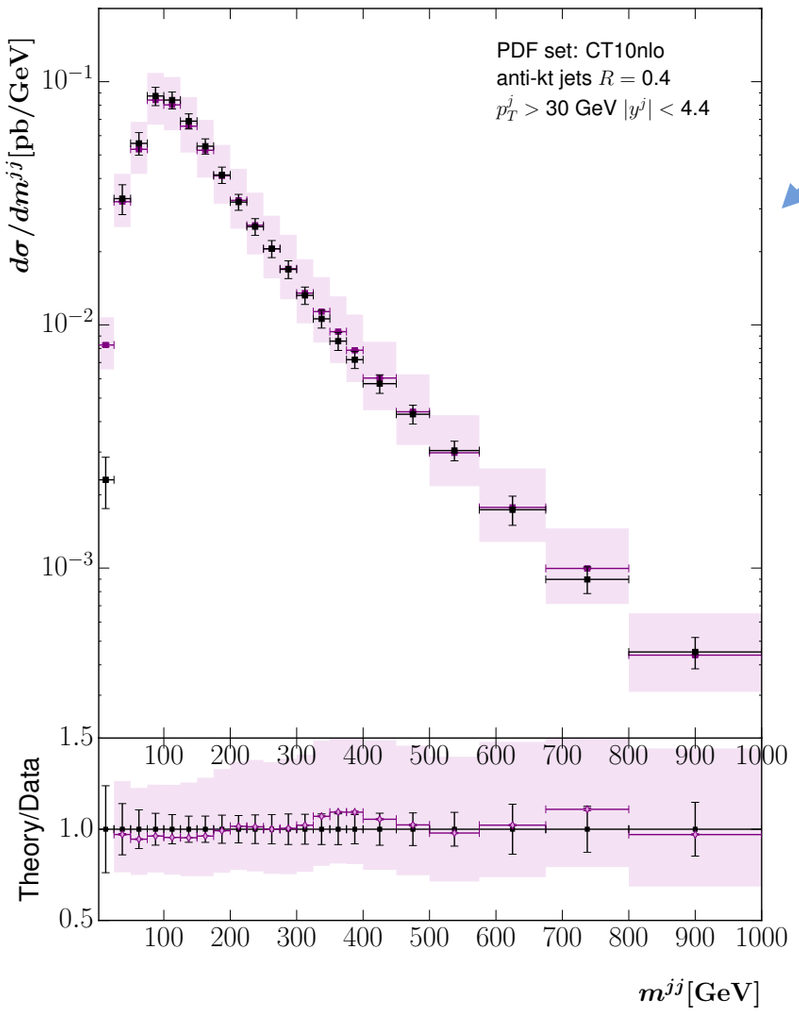


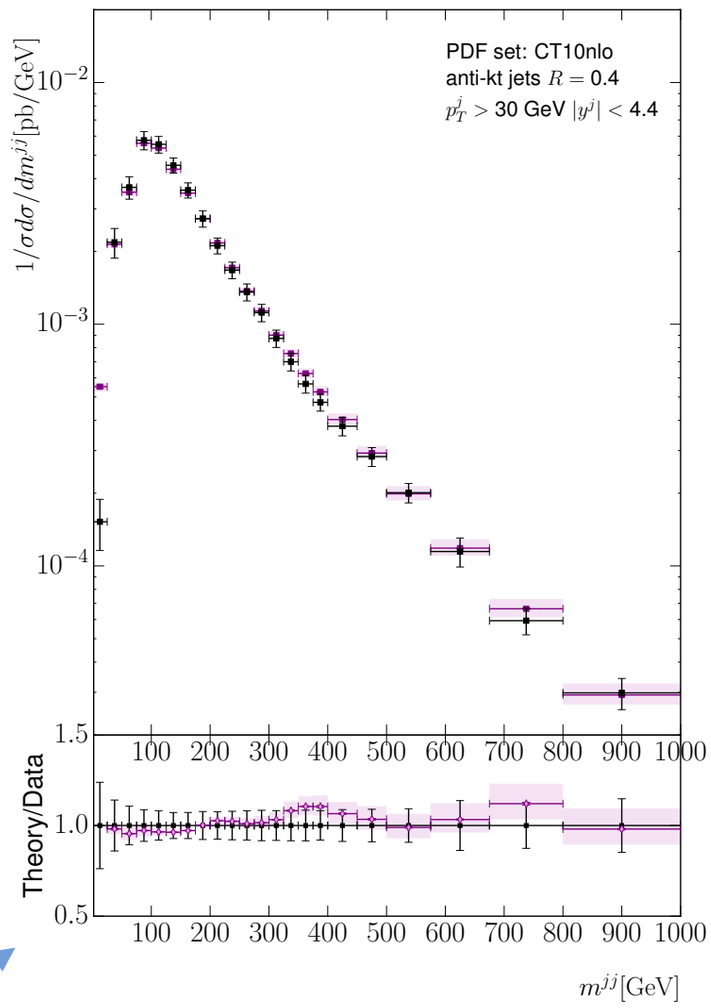
Note range is only half of earlier W + dijets

Z+Jets

We don't need to normalise to give good agreement

Andersen, Medley, JMS arXiv:1603.05460



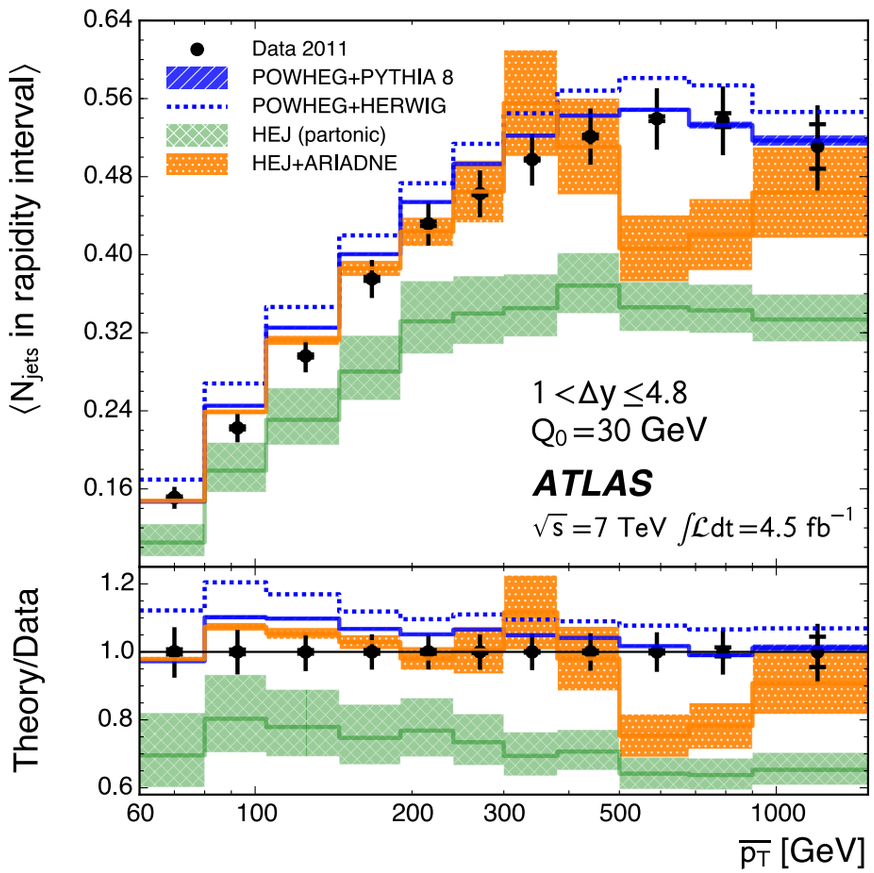


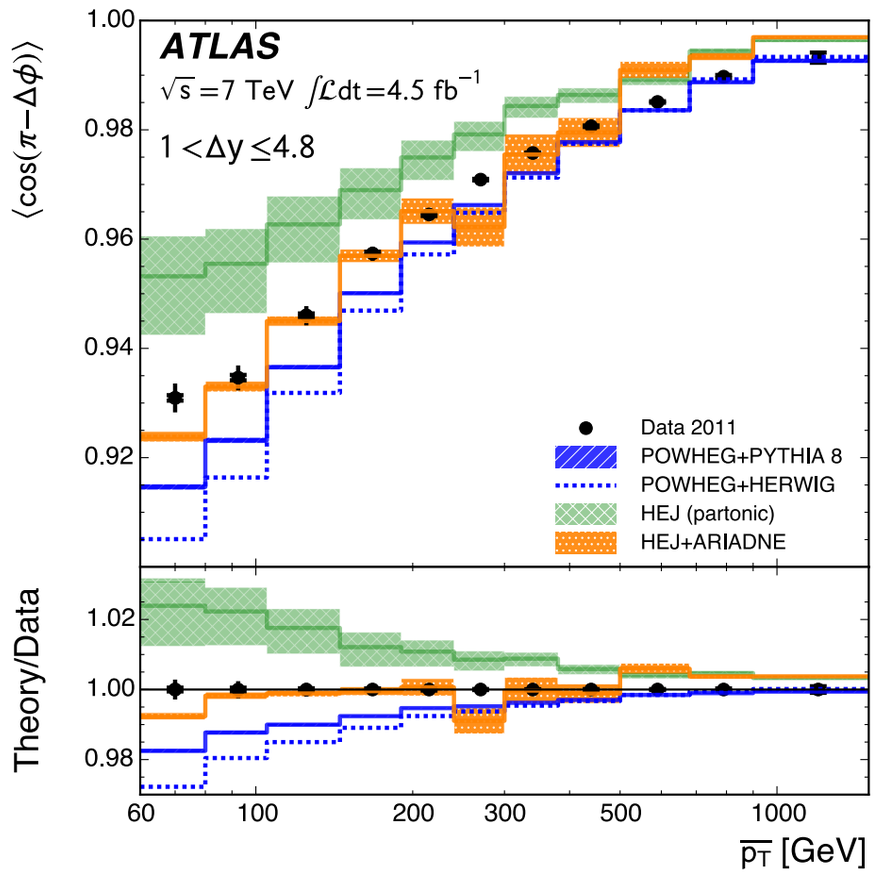
If normalise, theory uncertainty massively reduced; agreement still as good.
Shows agreement of central line is significant despite large band

Combining with Parton Shower

Green = "pure" HEJ, orange = HEJ + Ariadne (parton shower), blue = POWHEG

ATLAS arXiv:1405.5756

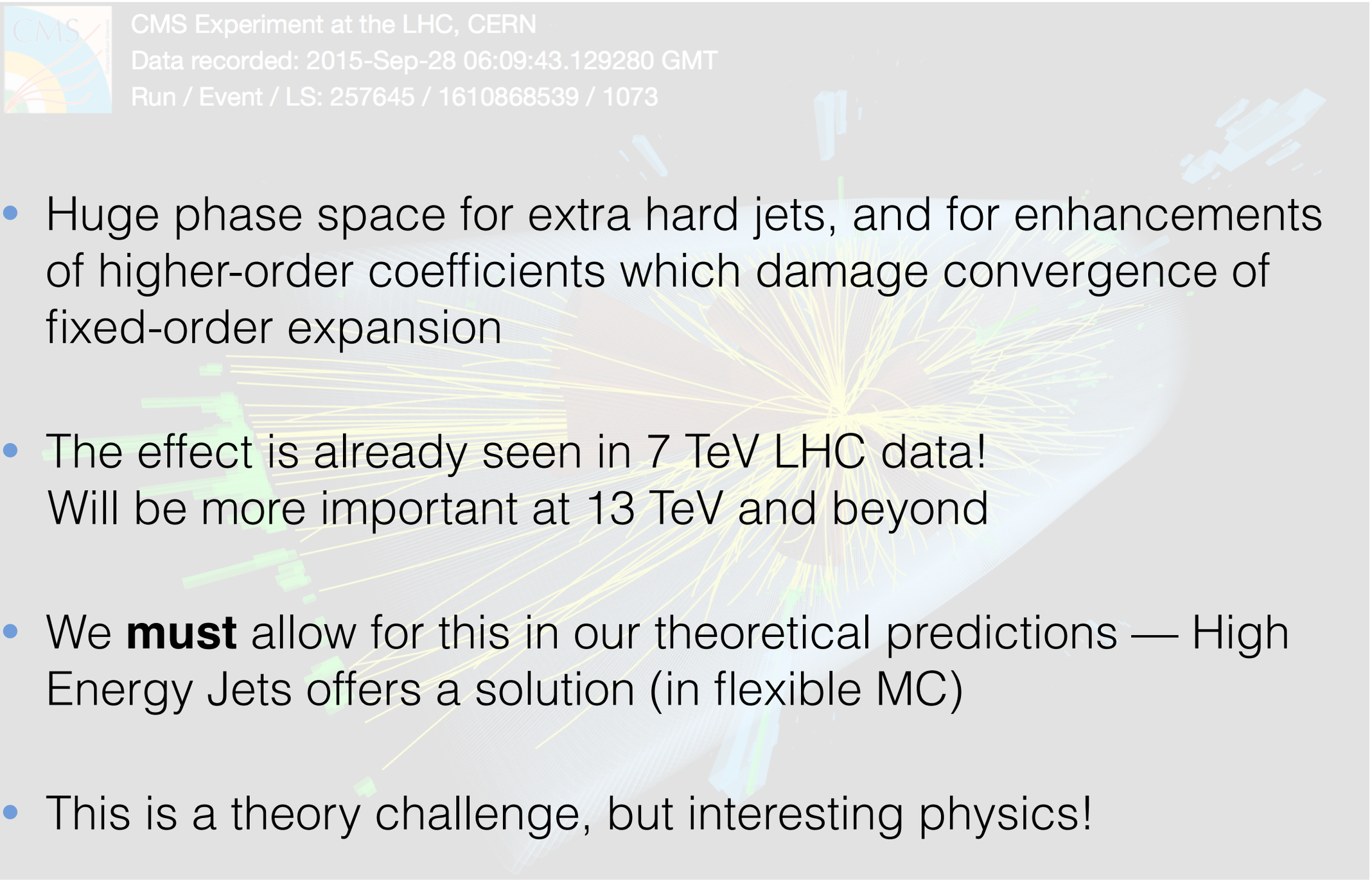




Analysis clearly testing shower effects as effects are large.
But **also** clear still need HEJ corrections to describe some distributions.

See also ATLAS 1107.1641, CMS 1202.0704, 1204.0696, 1601.06713, D0 1302.6508

Conclusions



- Huge phase space for extra hard jets, and for enhancements of higher-order coefficients which damage convergence of fixed-order expansion

- The effect is already seen in 7 TeV LHC data!
  Will be more important at 13 TeV and beyond

- We **must** allow for this in our theoretical predictions — High Energy Jets offers a solution (in flexible MC)

- This is a theory challenge, but interesting physics!