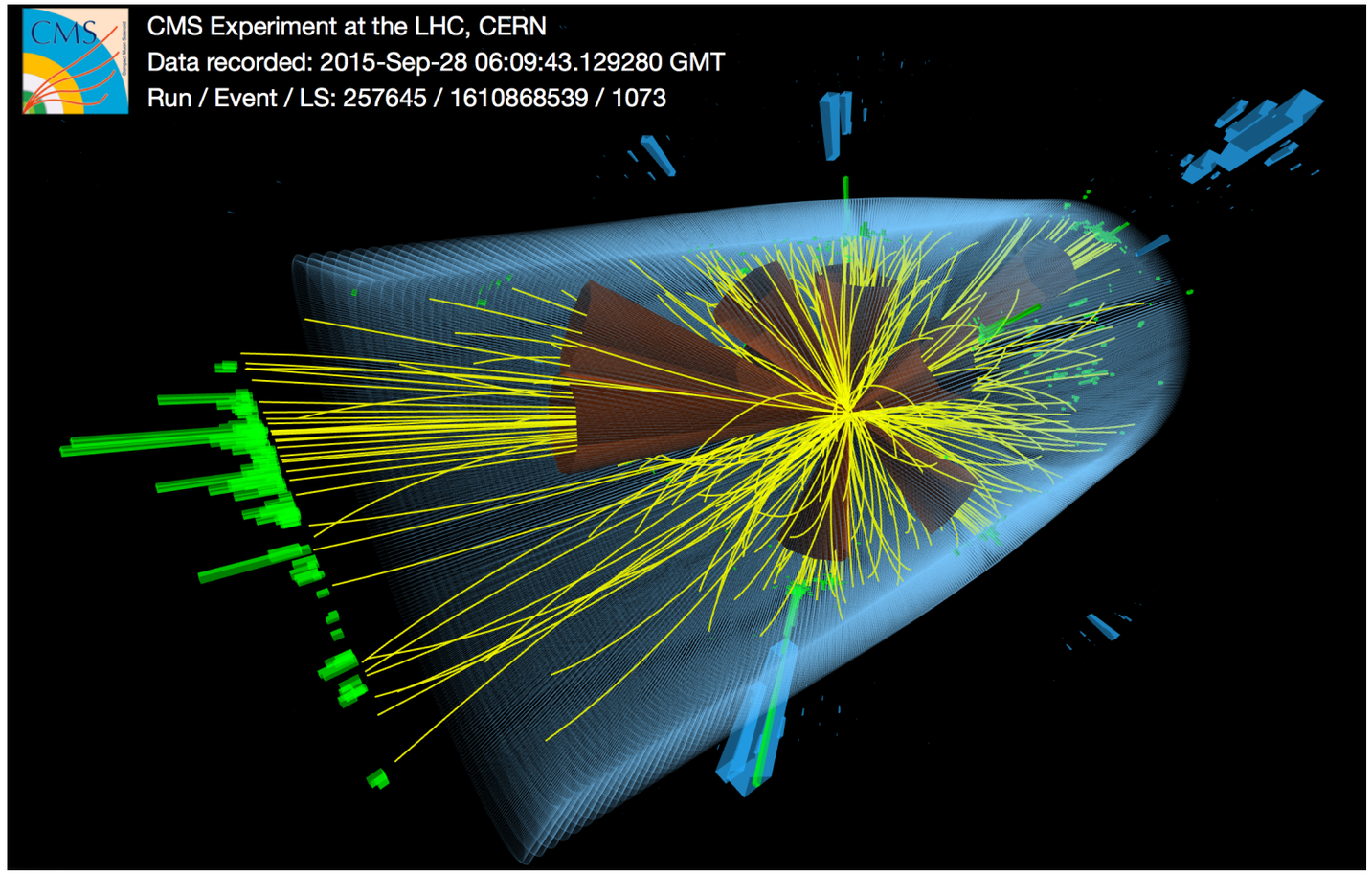
High Energy Jets at 100 TeV



Jenni Smillie

FCC Week, Rome 12 Apr 2016

Introduction

- First slide shows 12 jets with p_T > 50 GeV at CMS (13 TeV)
- There is a huge phase space for hard QCD emission already: will be impossible to ignore at 100 TeV!
- 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

QCD at High Energy

- 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]

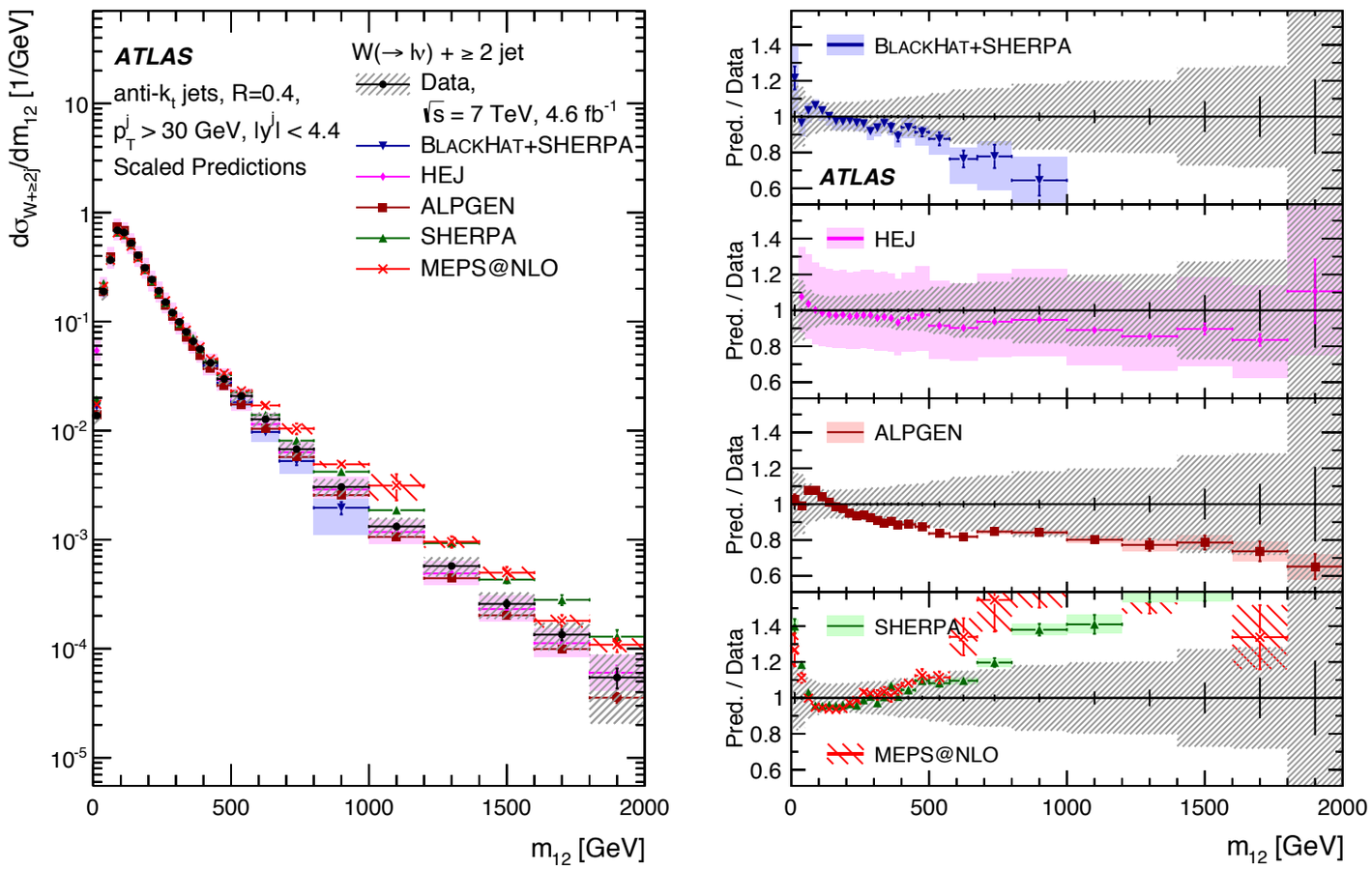
- Extra power of α_s compensated by large phase space and large logs: stability associated with NLO no longer there at 100 TeV.

- Demands a new approach: High Energy Jets (HEJ) is a flexible event generator which uniquely contains the dominant logarithms in the high energy limit at all orders

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

- These logs become large in regions of large invariant mass between jets (fixed pt) or large rapidity separations (e.g. > 3). **Exactly** regions studied for VBF analyses for example!

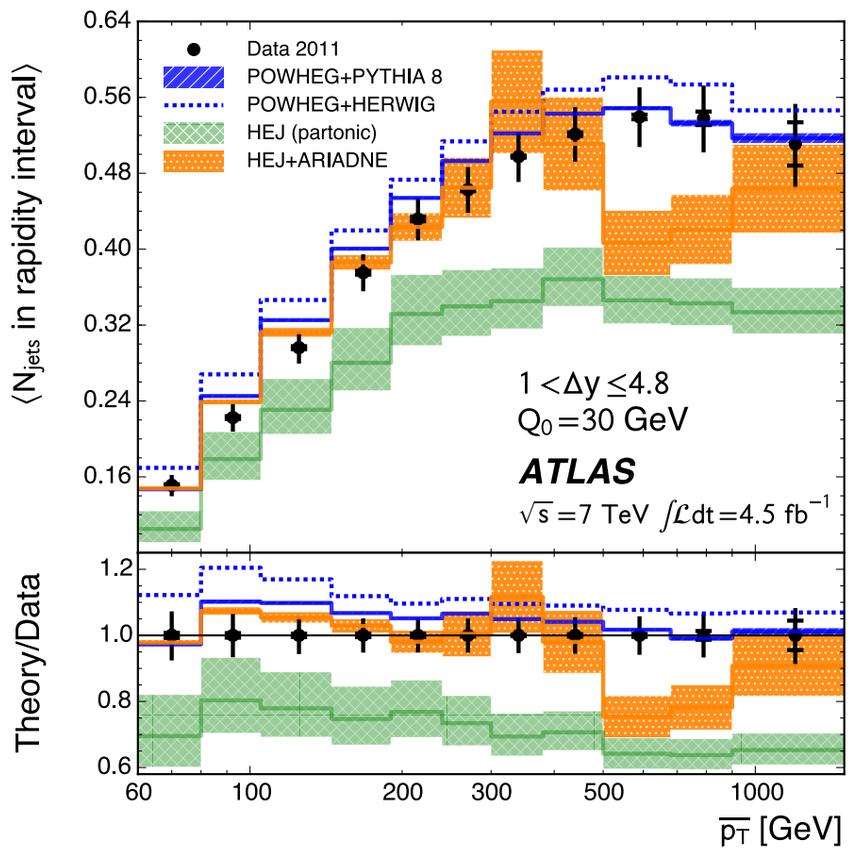
ATLAS W+Jets arXiv:1409.8639

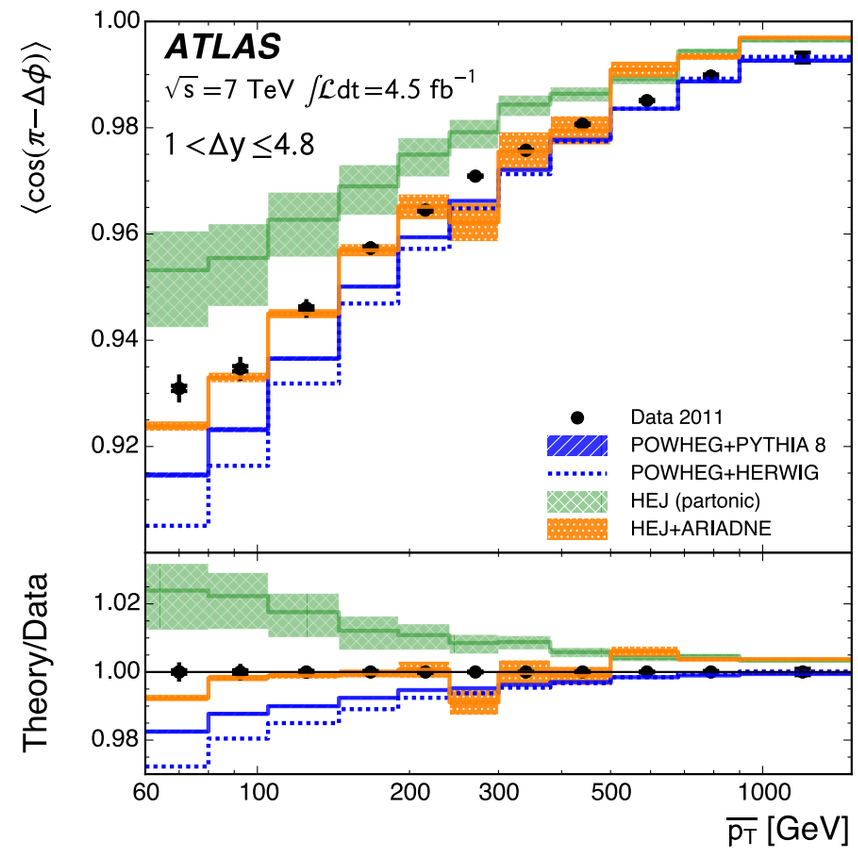


The logarithms uniquely described in the HEJ event generator become increasingly important as m_{12} increases. This is seen here where the HEJ prediction remains flat while others deviate.

Other distributions (e.g. p_{T1}) show similar levels of agreement for all theory

ATLAS Jet Vetoes arXiv:1407.5756





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

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

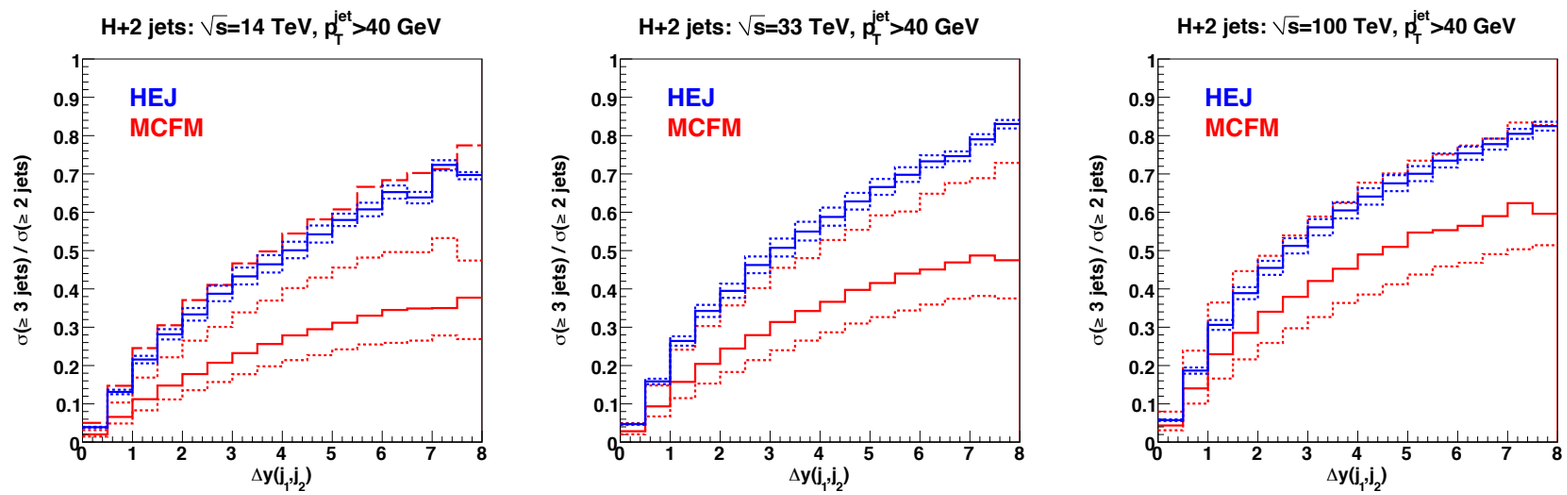
See also ATLAS 1509.07335, 1107.1641, CMS 1204.0696, D0 1302.6508

Now for 100 TeV

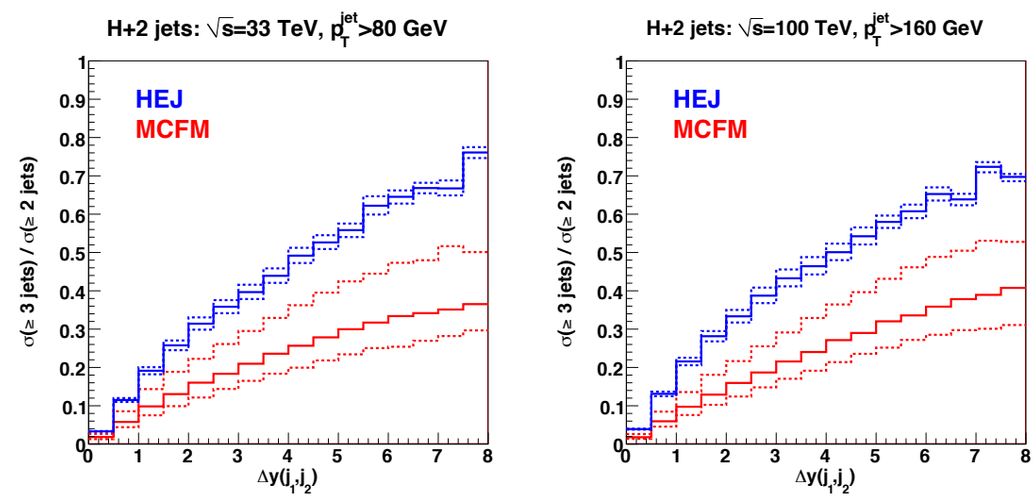
Example: Inclusive H + dijets

Campbell et al arXiv:1310.5189

p_{Tj} > 40 GeV



p_{Tj} > 80, 160 GeV

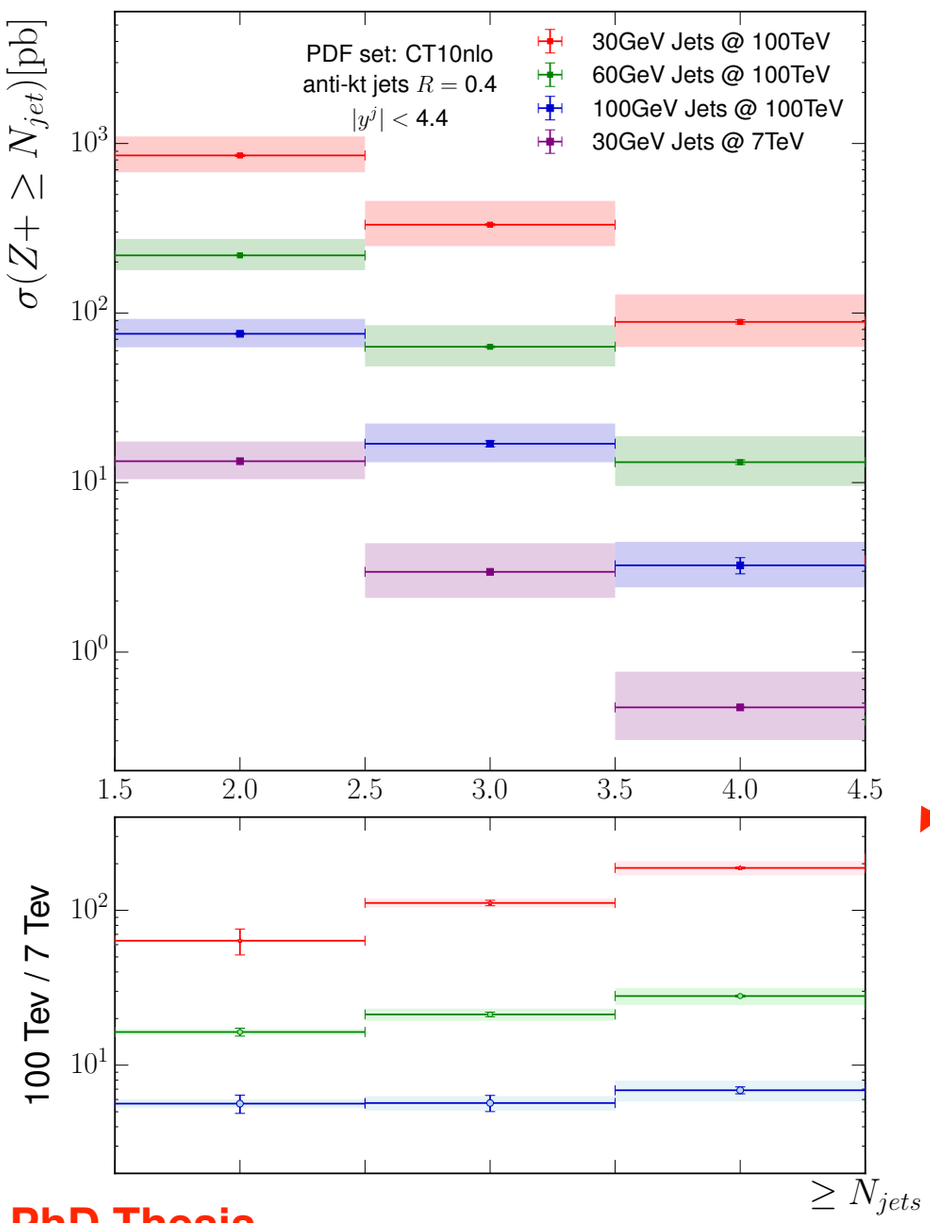


14 TeV 33 TeV 100 TeV

HEJ predicts clear enhancement relative to MCFM (pure NLO) **see Andersen et al arXiv: 1202.1475**

Now for 100 TeV

Example: Inclusive Z/γ^* + dijets



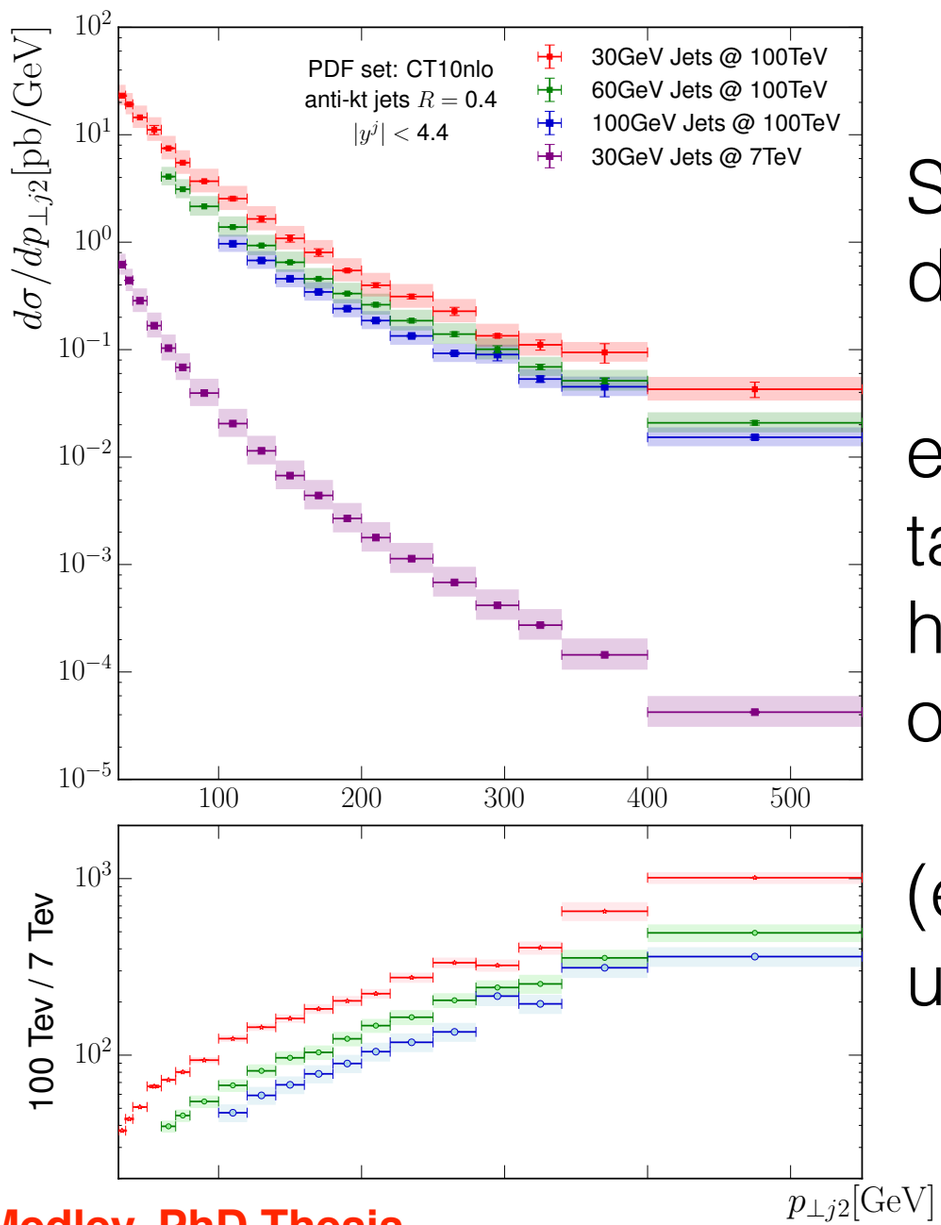
Identical jet cut at 100 Tev: see significant increase in relative importance of higher multiplicity terms

Increased jet cut (100 GeV) mediates this effect on total rates, but what about distributions?

Medley, PhD Thesis

Now for 100 TeV

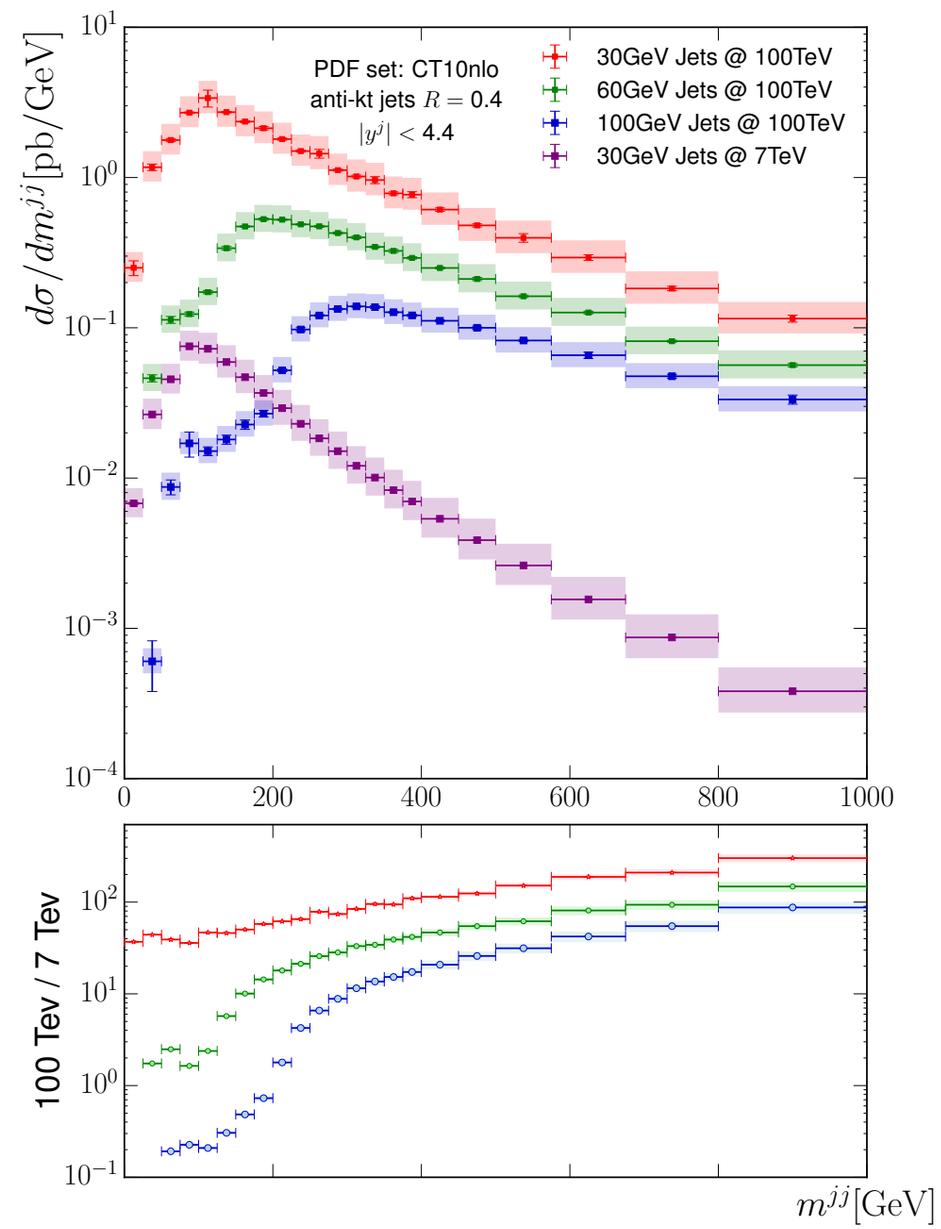
Example: Inclusive Z/γ^* + dijets



Significant shape differences remain:

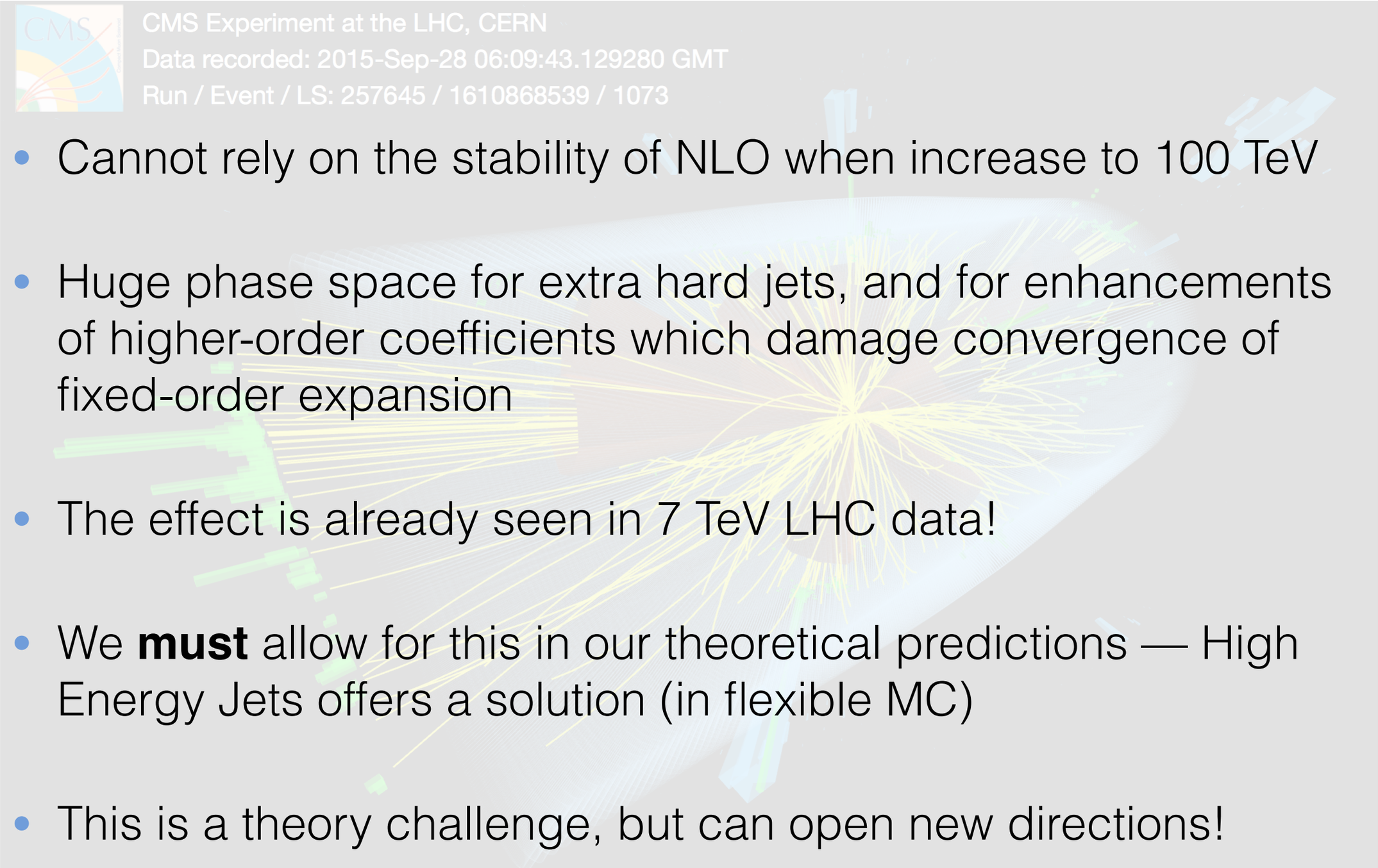
e.g. broadening of tails at high pT and high mjj, and here only up to 1 TeV

(earlier LHC results up to 2 TeV)



Medley, PhD Thesis

Conclusions



- Cannot rely on the stability of NLO when increase to 100 TeV
- 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!
- We **must** allow for this in our theoretical predictions — High Energy Jets offers a solution (in flexible MC)
- This is a theory challenge, but can open new directions!