CMS V+jets

Higgs+jets 2014
8-10 Dec 2014
IPPP, Durham (UK)

ETH zürich

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(on behalf of CMS collaboration)

Instead of an outline

- W+jets (7 TeV): http://arxiv.org/abs/1406.7533
  (accepted in PLB)
- Z+jets (7 TeV): http://arxiv.org/abs/1408.3104
  (submitted to PRD)
- Z+jets (8 TeV)
  - SMP-13-007: http://cds.cern.ch/record/1728322
  - SMP-14-009: http://cds.cern.ch/record/1728345
- R(Z+jets/γ+jets)
  - SMP-14-005: http://cds.cern.ch/record/1740969?ln=en

- All CMS V+jets results: link

Conventions during this talk

Two types of Data

- 7 TeV implies always 5 fb-1 pp collisions
- 8 TeV implies always 20 fb-1 pp collisions

Data shown here always corrected for detector efficiency & smearing; response matrix was obtained from LO+PS

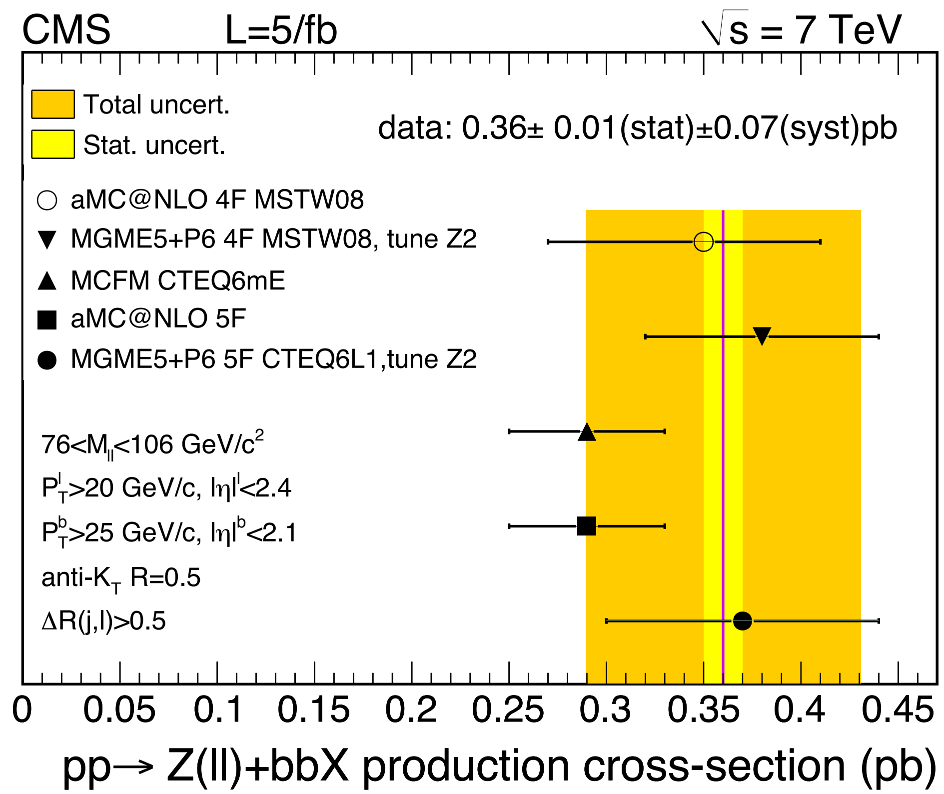
Three types of Theory (for the V+jets signal)

- **LO+PS:** always normalized to NNLO inclusive (FEWZ)
  - exception γ+jets analysis, where LO x-section was used
- **NLO:** always normalized to its native cross section
- **NLO+PS:** always normalized to its native cross section

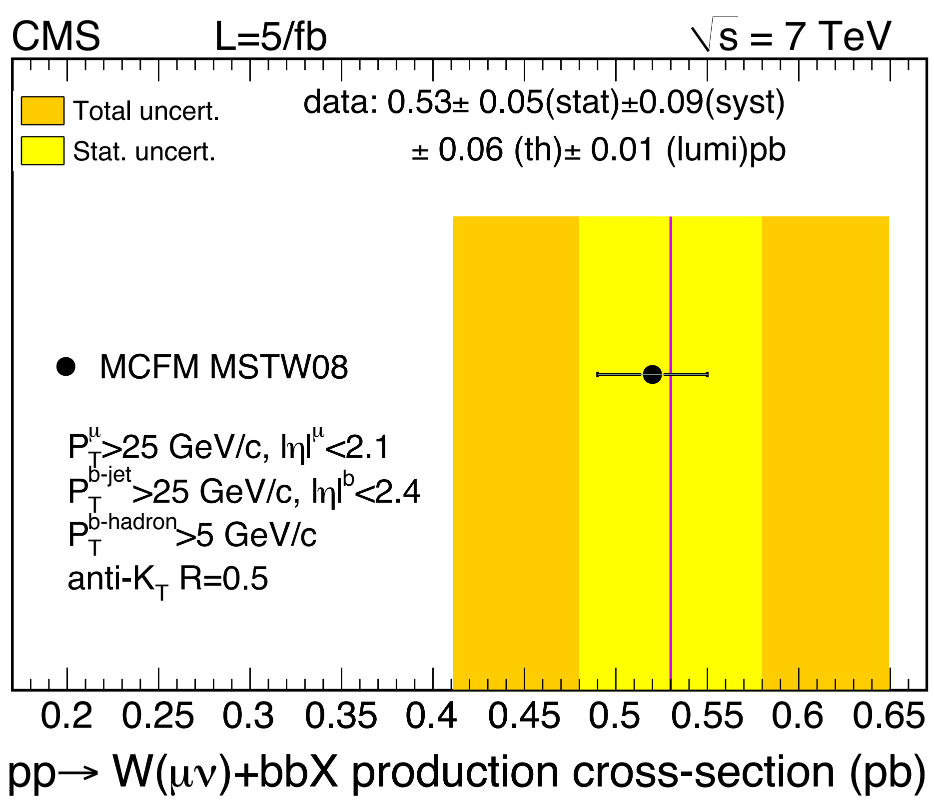
V+Heavy Flavor

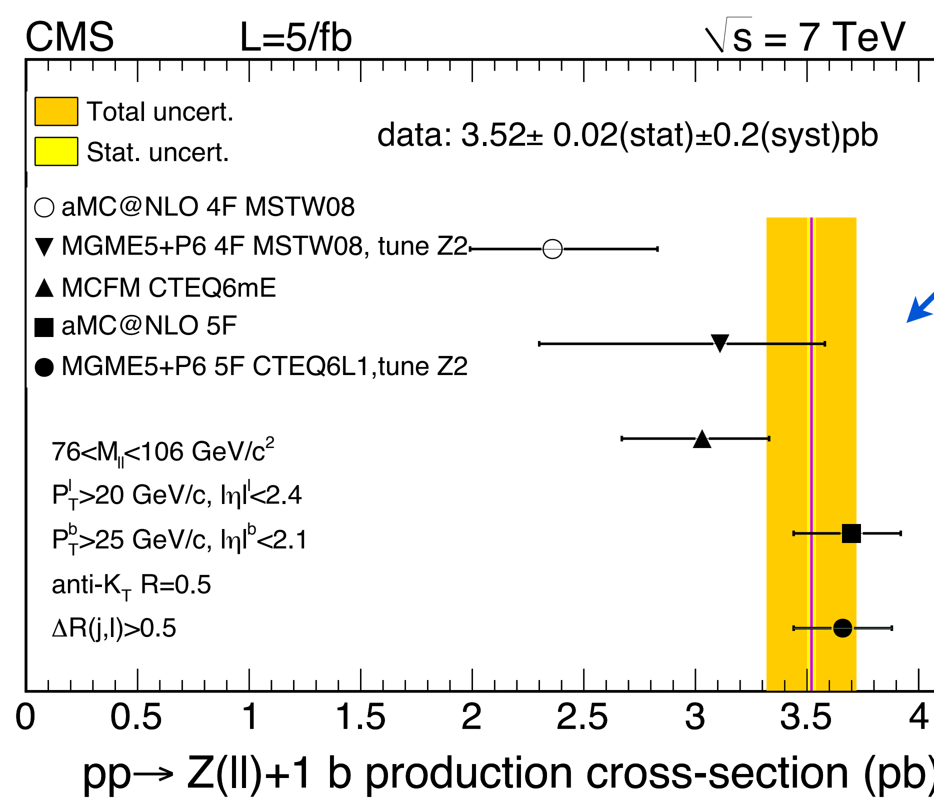
Will not cover it here, what we learn from those is:

- 4F vs 5F -- PDFs (to **b** or not to **b**)
- strange quark fraction
- collinear bbar
- aMC@NLO, MCFM, MG5+Pythia6



CMS-SMP-12-026
Phys. Lett. B 735 (2014) 204





CMS-SMP-13-004
JHEP 06 (2014) 120

	NLO ME	LO ME	PS	Channel	Data
BlackHat +Sherpa	≤ 4 jets	--	--	W+jets	7 TeV
Madgraph5	--	≤ 4 jets	Pythia6	W+jets	7 TeV
Sherpa1.4	--	≤ 4 jets	Sherpa	W+jets	7 TeV
Sherpa2β2 +BlackHat	≤ 1	≤ 4 jets	Sherpa	Z+jets	7 TeV
Madgraph5	--	≤ 4 jets	Pythia6	Z+jets	7 TeV
Powheg	1 jet	--	Pythia6	Z+jets	7 TeV
Sherpa2 +BlackHat	≤ 2 jets	≤ 4 jets	Sherpa	Z+jets	8 TeV
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Sherpa1.4	--	≤ 4 jets	Sherpa	Z+jets	8 TeV
Madgraph5	--	≤ 4 jets	Pythia6	γ+jets	8 TeV

will start with these

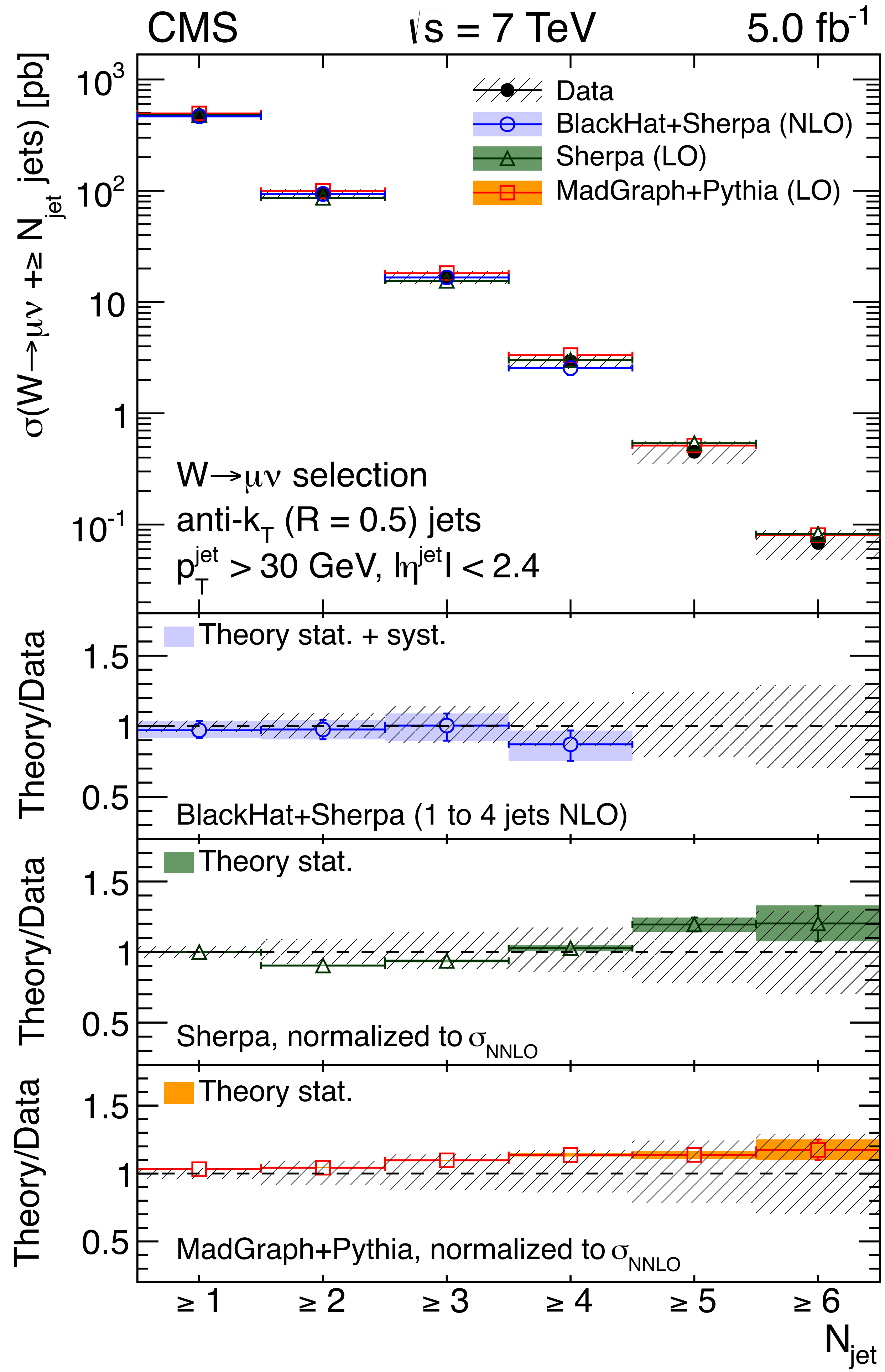
W+jets

Phase space

- muon p_T > 25 GeV, $|\eta|$ < 2.1
- jets: anti-k_T ΔR = 0.5
  - p_T > 30 GeV, $|\eta|$ < 2.4, $\Delta R(\text{jet},\mu)$ > 0.5

inclusive jet multiplicity spectrum has reasonable Data/Theory agreement

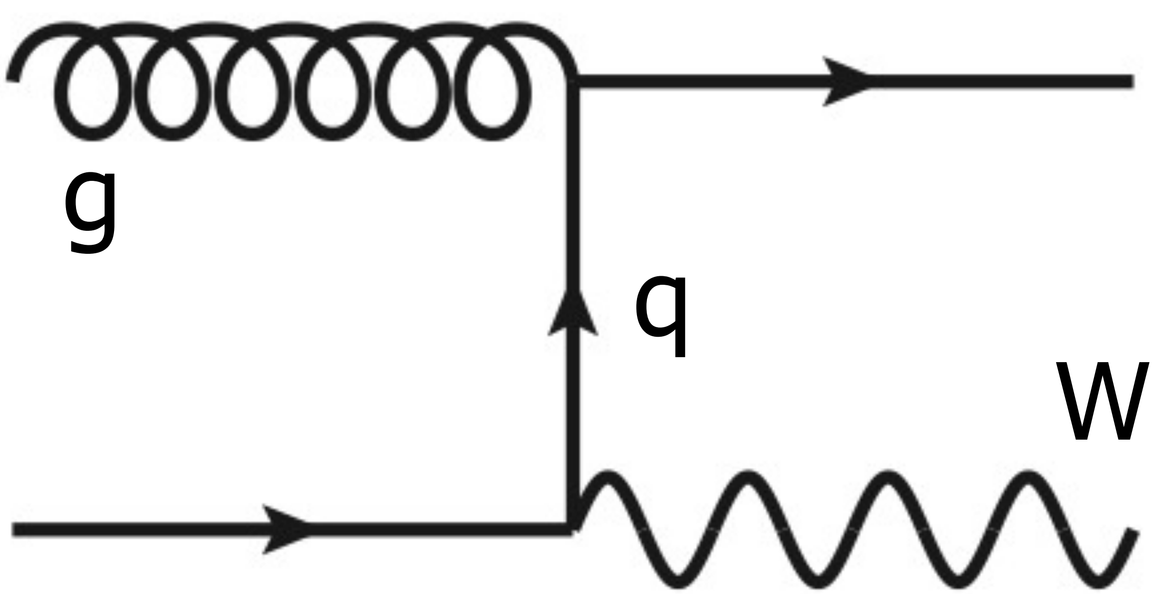
A 5th-jet Blackhat+Sherpa prediction will be added to the paper

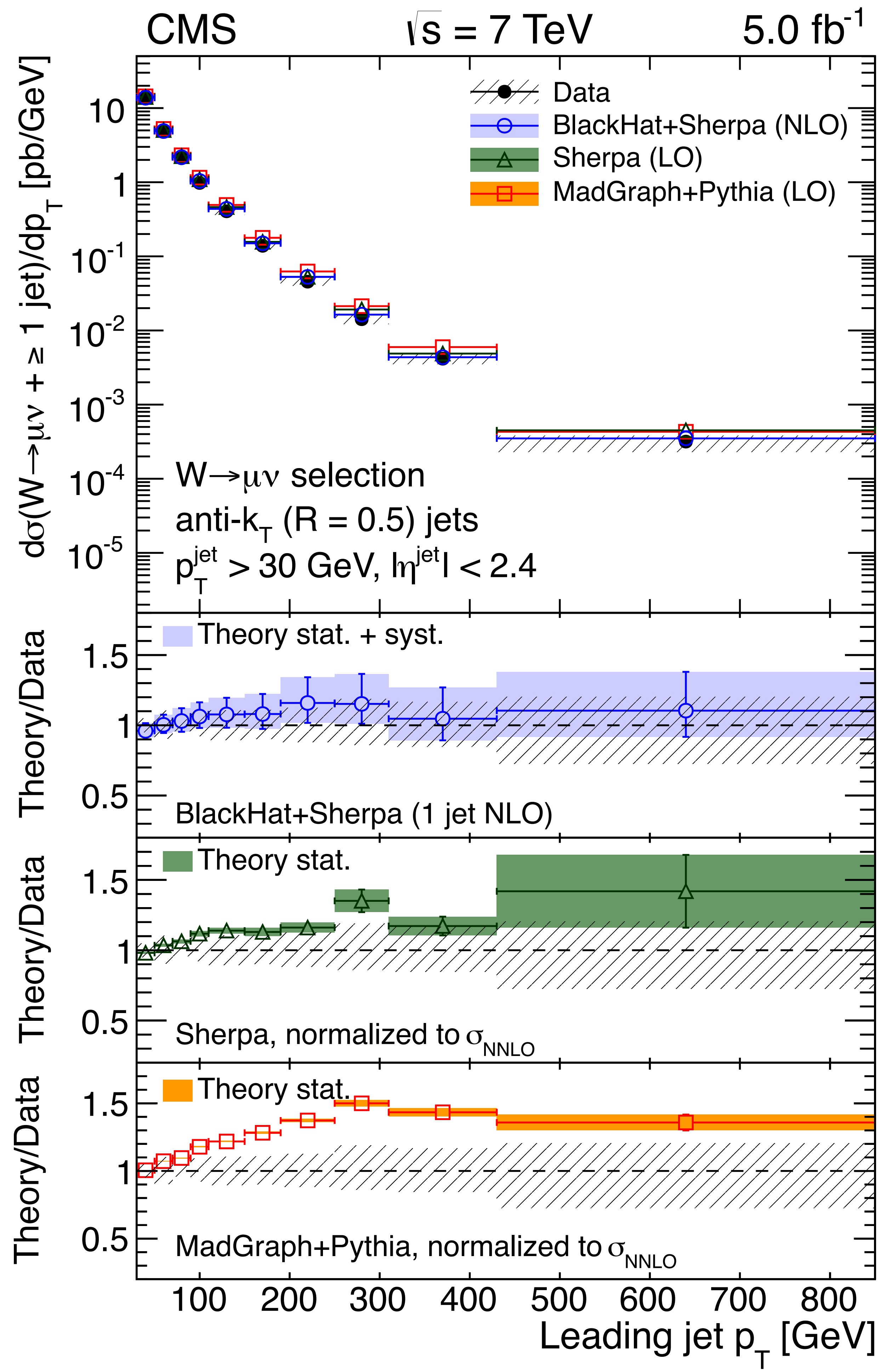


W+jets

Highly boosted W

- there are more predicted than observed
- LO+PS are accompanied with stat uncert., no theory systematic uncert., making the disagreement looking spectacular



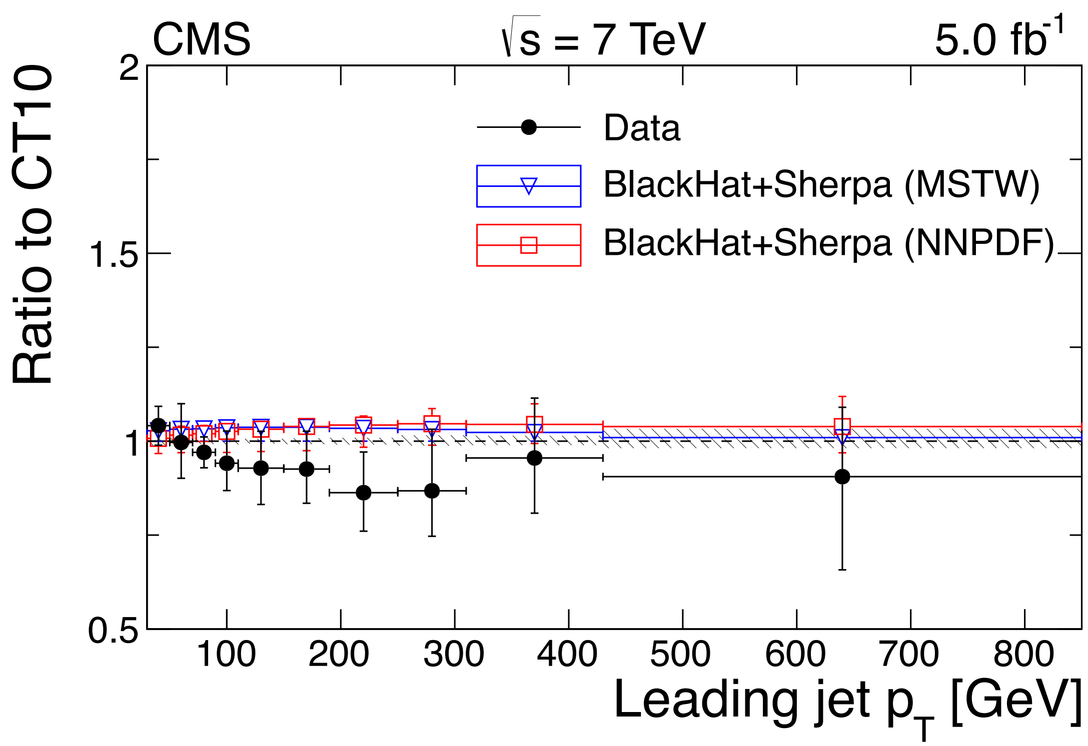


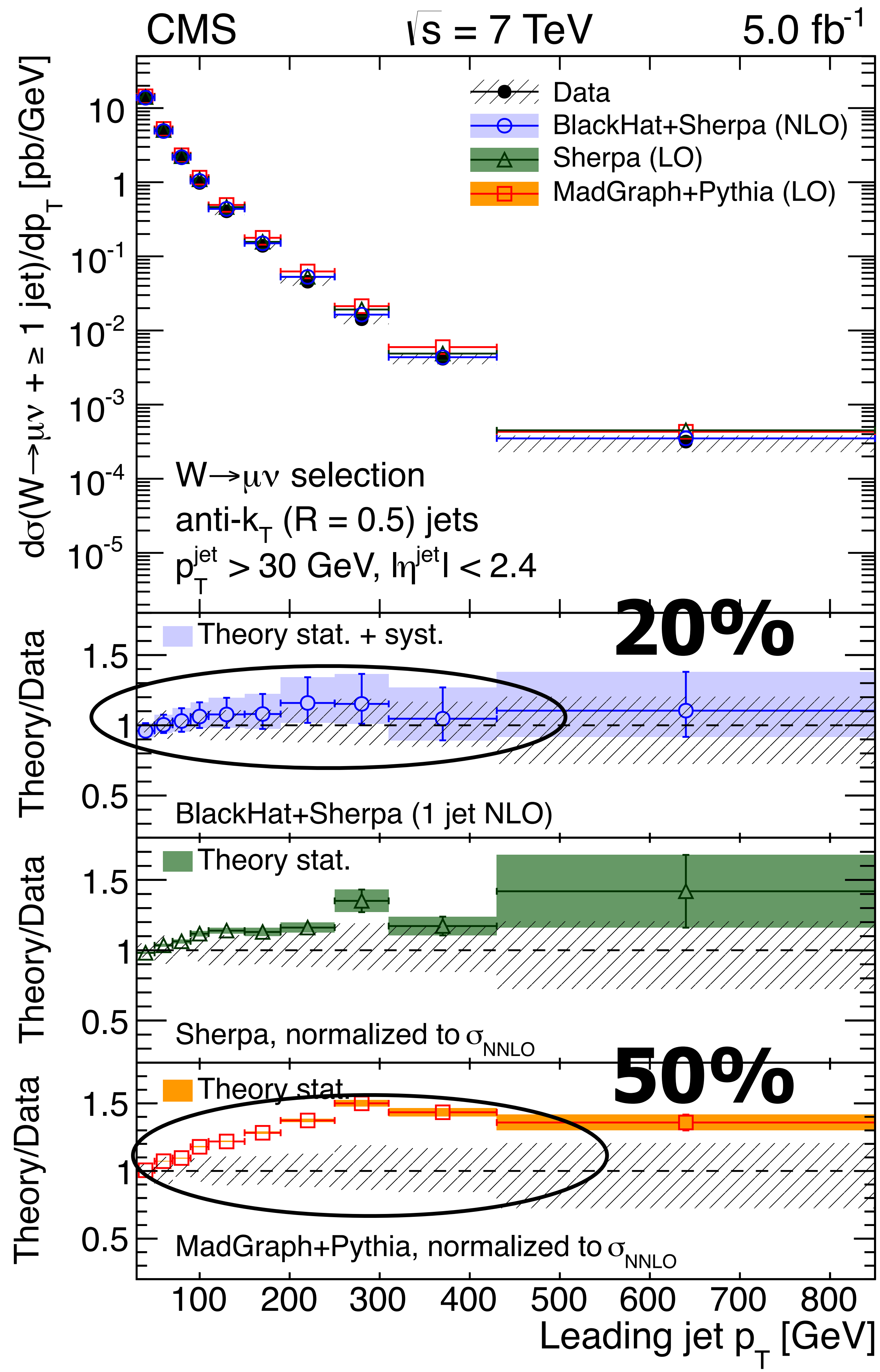
W+jets

Highly boosted W

- there are more predicted than observed
- same picture in Z+jets
- similar picture in γ+jets

Effect not related to PDFs

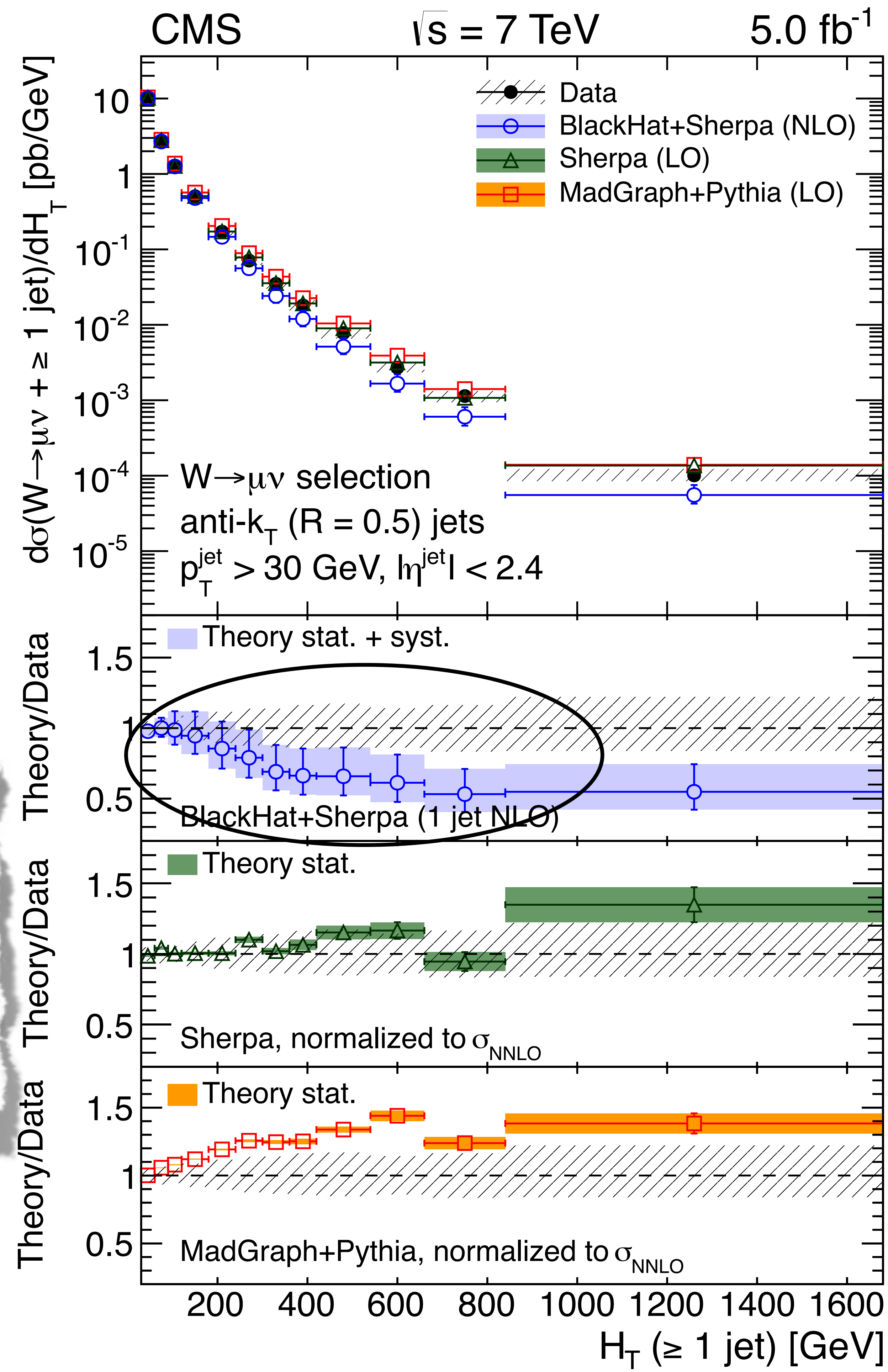




W+jets

H_T = scalar Σ p_T(jet)

- be aware: **H_T is a tricky observable**



NLO fixed order without PS can't model regions where the energy is distributed in many soft jets

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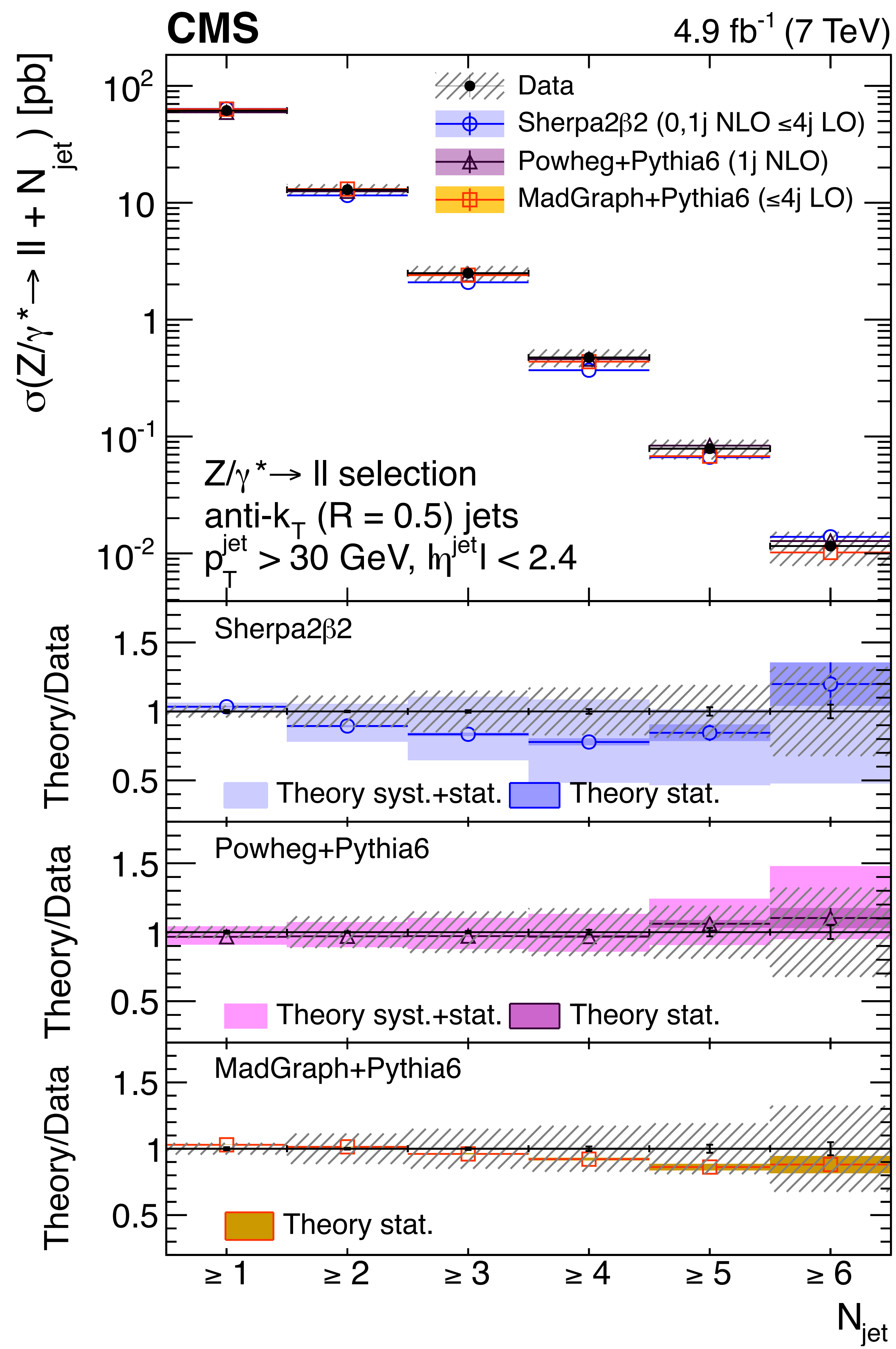
moving to Z+jets

Z+jets

Phase space

- lep p_T > 20 GeV, $|\eta|$ < 2.4
- 71 < Mll< 111 GeV
- jets: anti-k_T ΔR = 0.5
  - pT > 30 GeV, $|\eta|$ < 2.4, ΔR(jet,μ) > 0.5

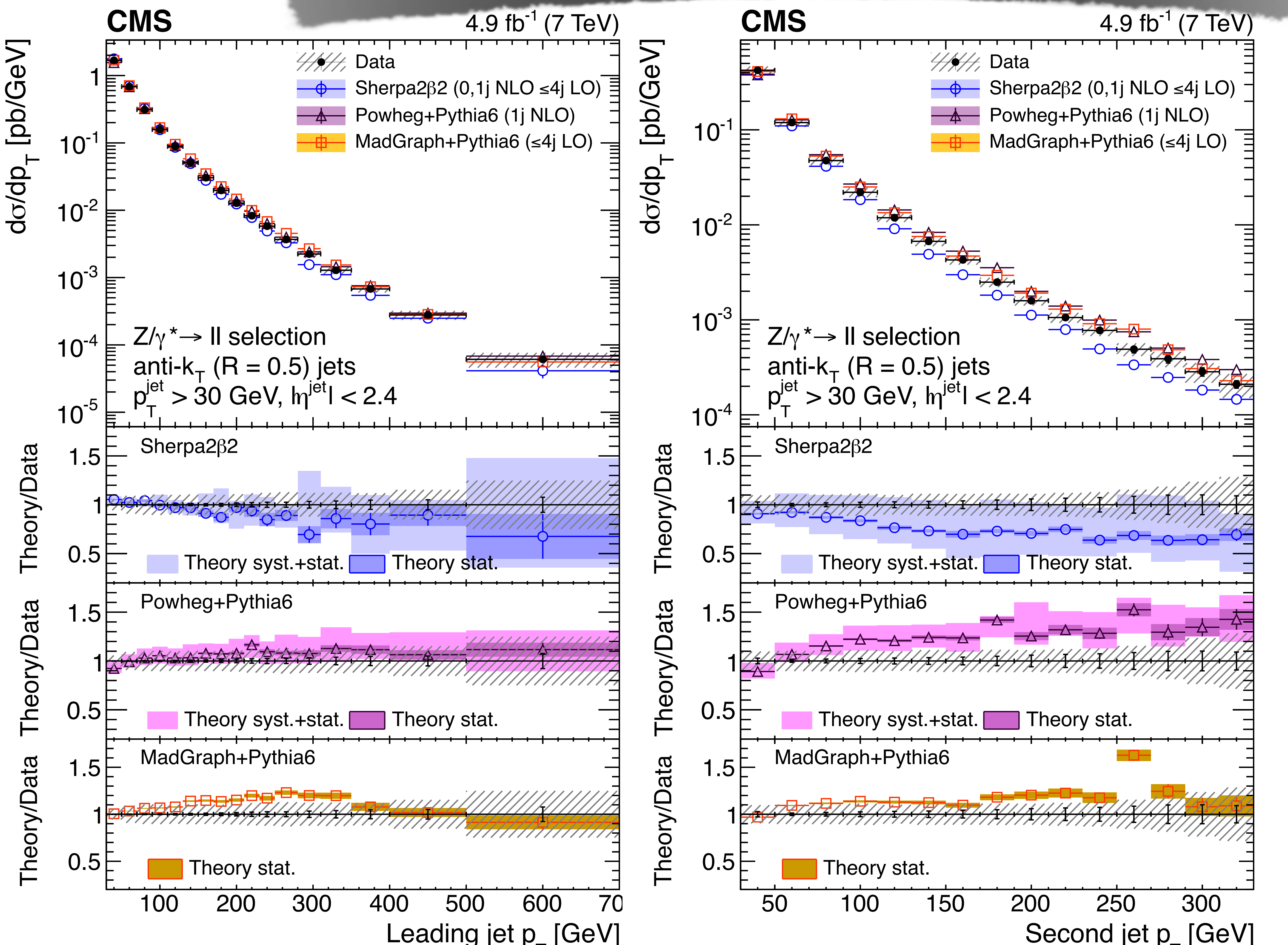
fairly good Theory/Data agreement



Z+jets

LO+PS overpredicts data, similarly to what was observed in W+jets

NLO+PS mixed picture



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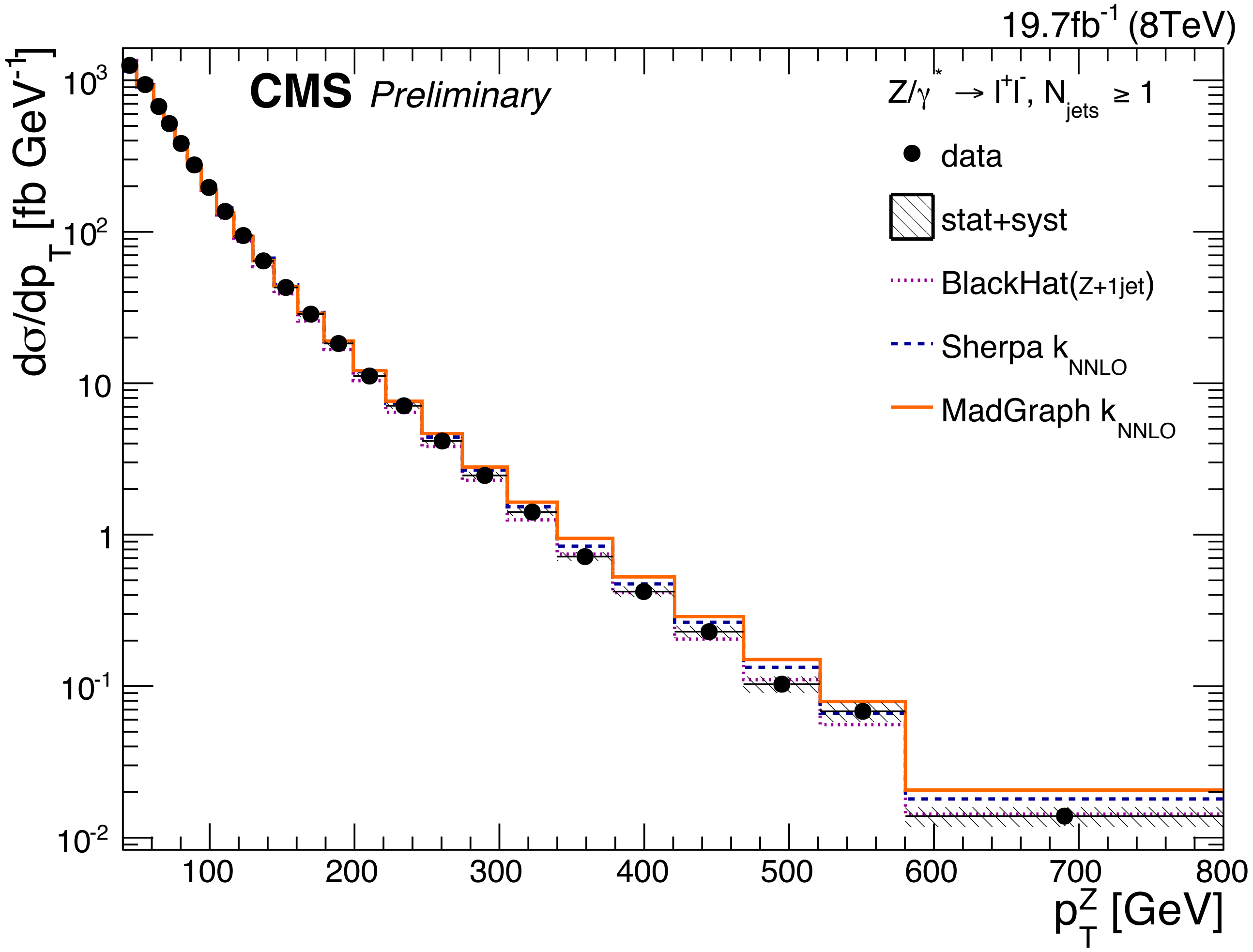
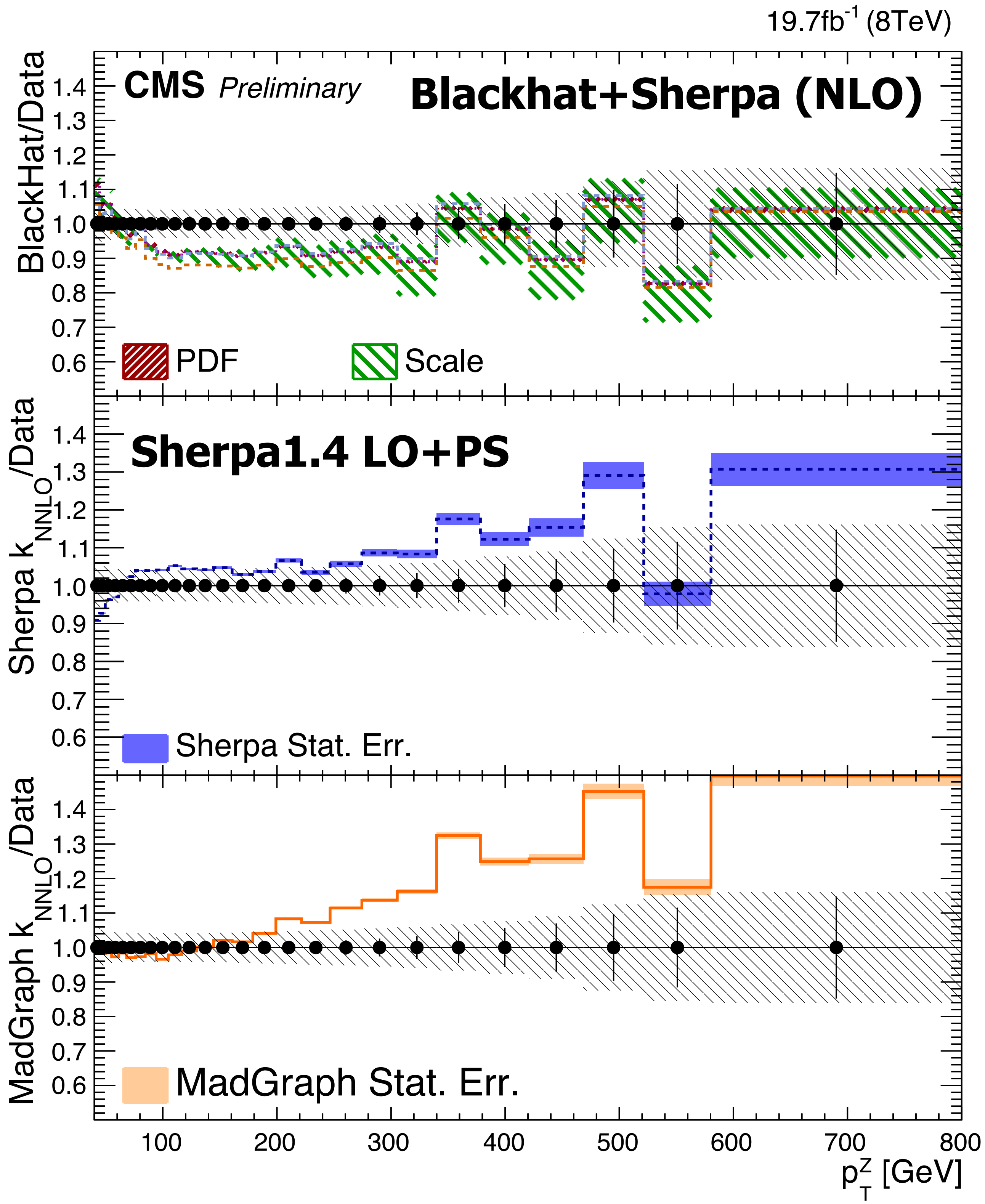
Z+jets / γ+jets

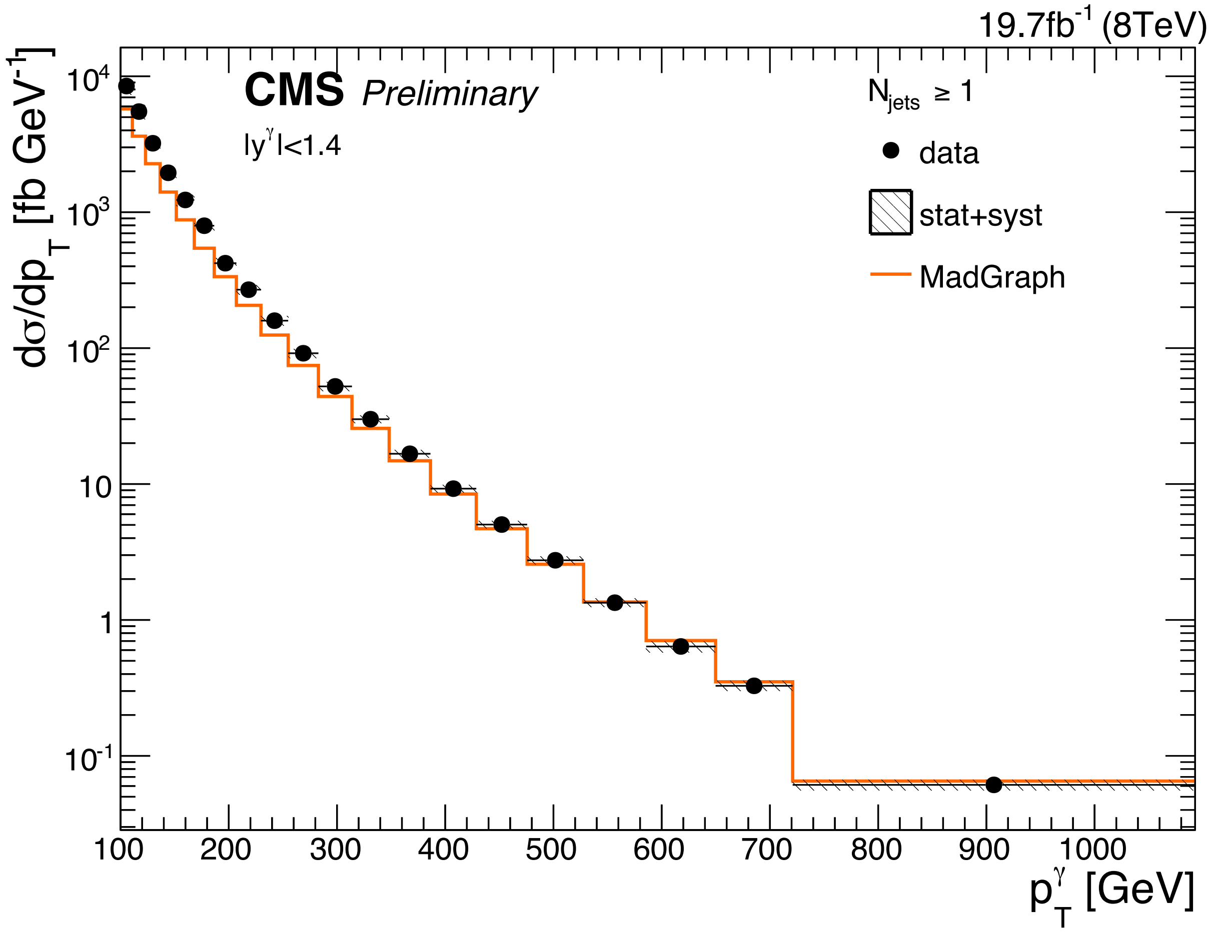
Z+jets (8 TeV)

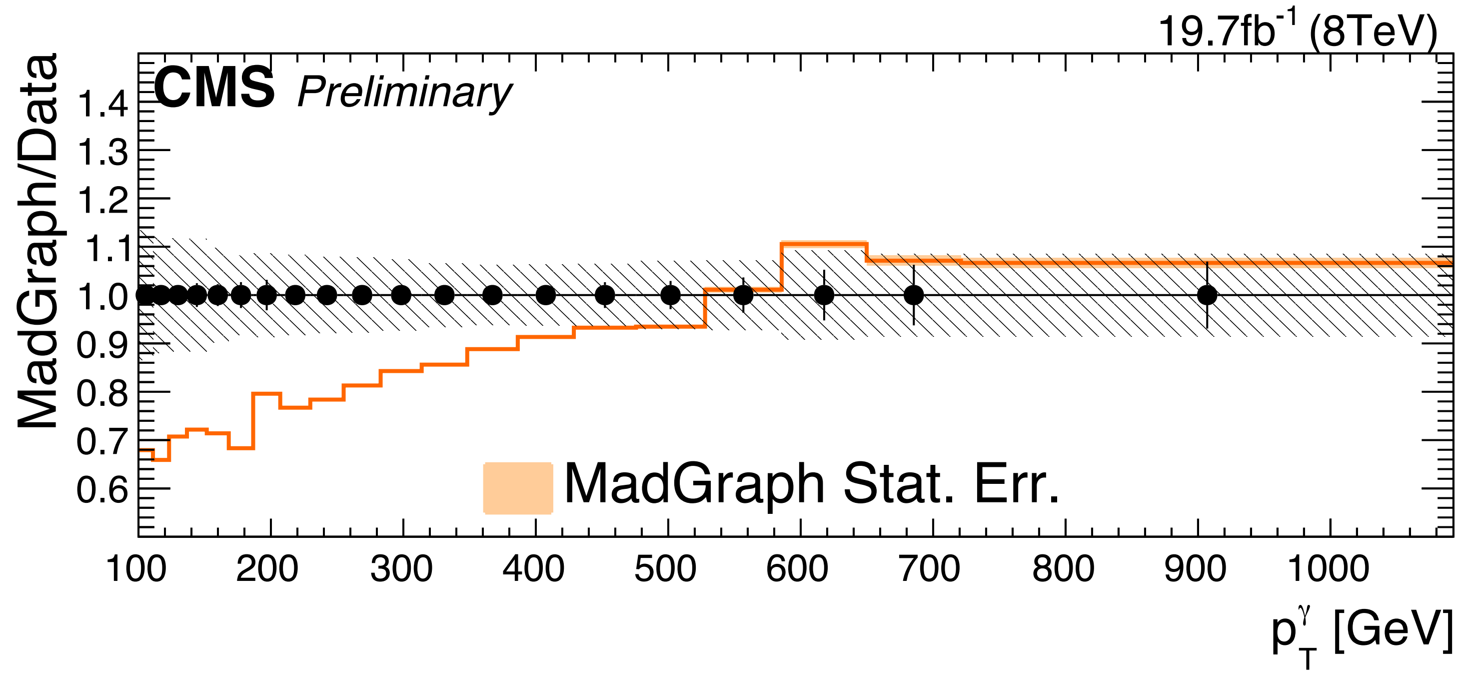




$p_T(Z)$ is a key observable that we don't get right with LO +PS -- think of $p_T(Z)$ as MET, when $Z \to \nu\nu$

γ+jets (8 TeV)





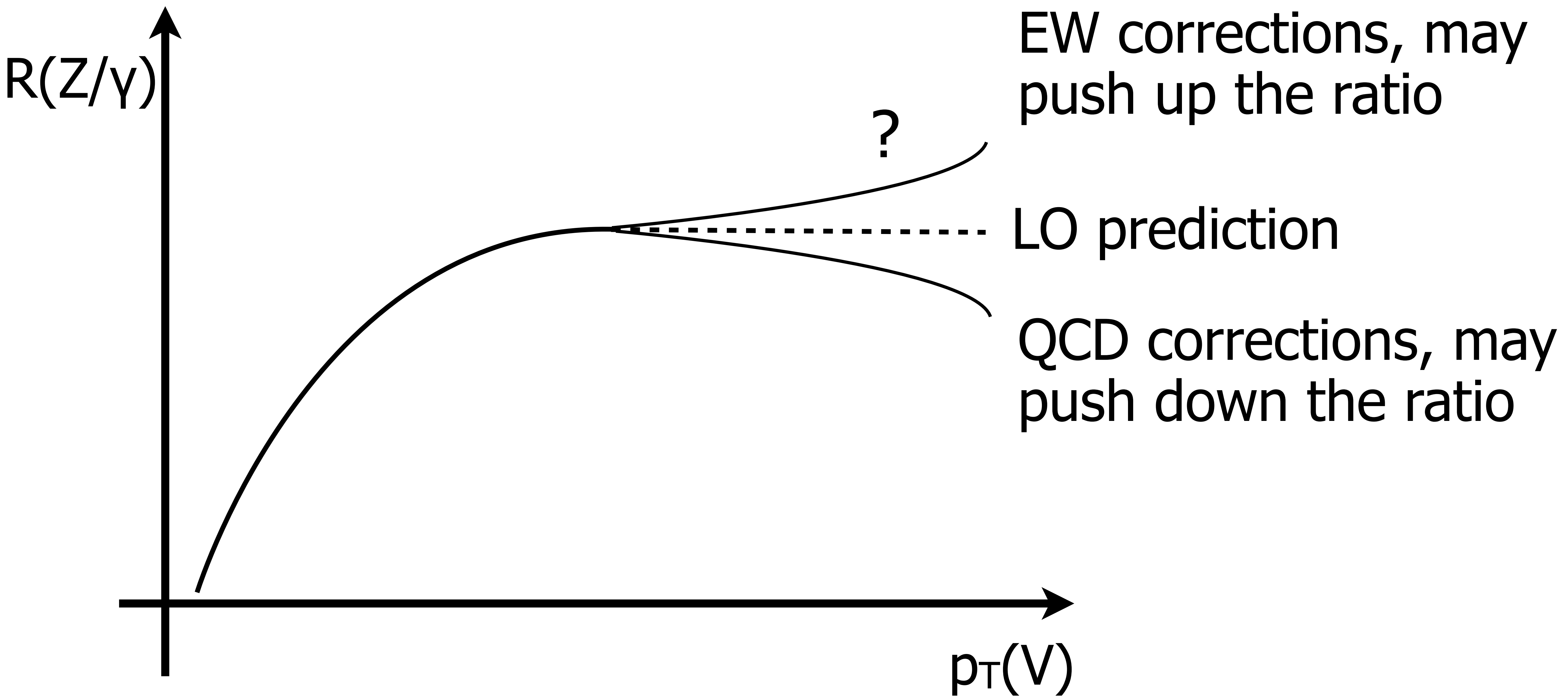
Preliminary results, only LO+PS comparison -- NLO will be put in place prior to the paper submission

- MC normalized to LO cross-section; not comparable to what was done for the Z+jets, which is LO+PS with NNLO norm
- however trend (slope) seems to be of similar strength

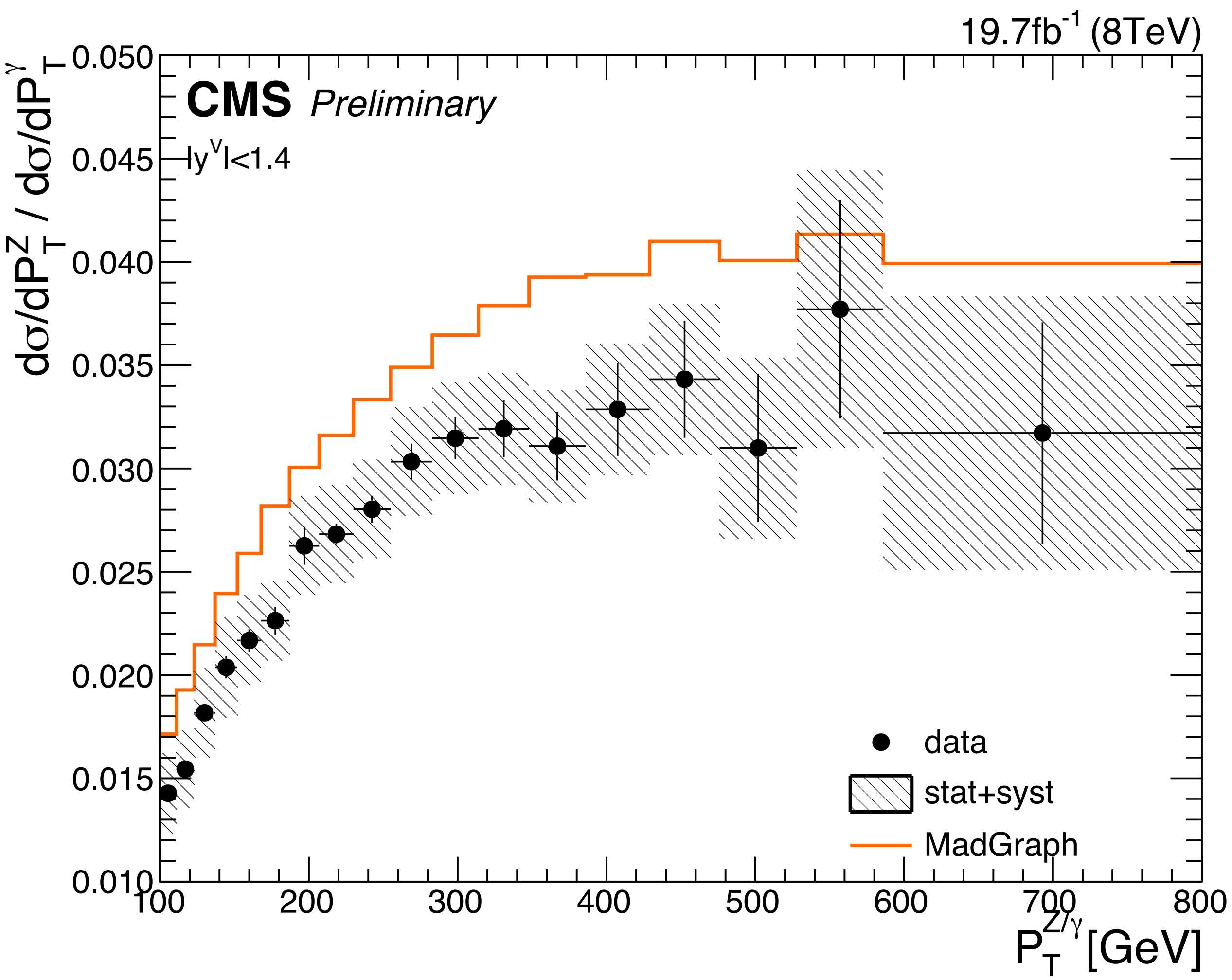
Ratio of σ(Z+jets)/σ(γ+jet)

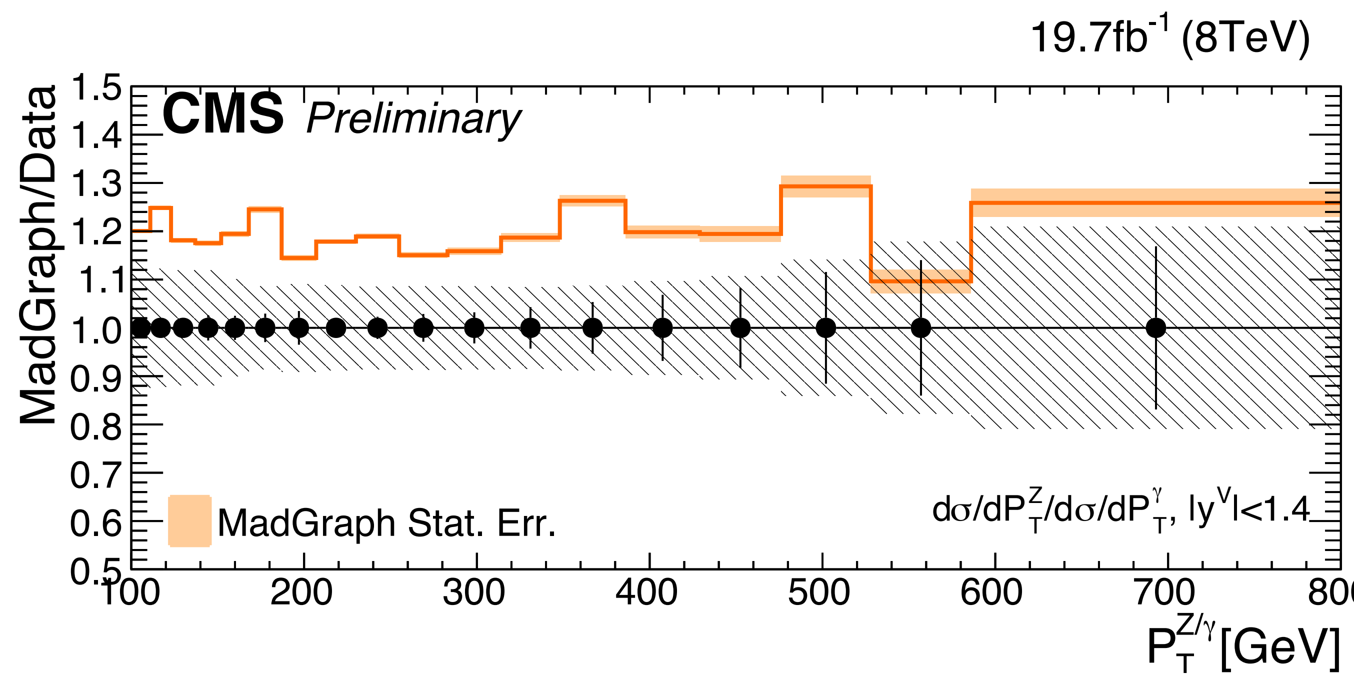
Important observable for new physics searches

- LO predicts a plateau at high $p_T(V)$
- The $p_T(\gamma)$ is used as proxy to estimate $p_T(Z \to \nu\nu)$ i.e. MET



R(Z+jets/γ+jets) (8 TeV)





R(Z+jets/γ+jets)**[data] /** R(Z+jets/γ+jets)**[MC]**

- double ratio ~1.2, is flat across all probed p_T [100,800] GeV
- observed bias as function of $p_T(V)$ seems to be universal across the different vector boson species
- no evidence for a deviation from flatness within uncertainties

Few words about LO+PS

They are still the main workhorses in LHC analyses

- **Searches for new phenomena use LO+PS:**
  - need detector level predictions -- i.e., particle level
  - need a fail-safe setup to perform closure tests of background estimation methods, e.g. we don't want "holes" in H_T or completely back-to-back events that fixed order may give to us
  - normalization ? either NLO, or NNLO or if needed data sidebands
- **Measurements (SM precision tests)**
  - background is subtracted from data using LO+PS predictions
  - unfolding of detector effects, response matrix is build from digitized full-sim, i.e. needs again particle level MC

NLO+PS is a promising replacement of LO+PS for Run2

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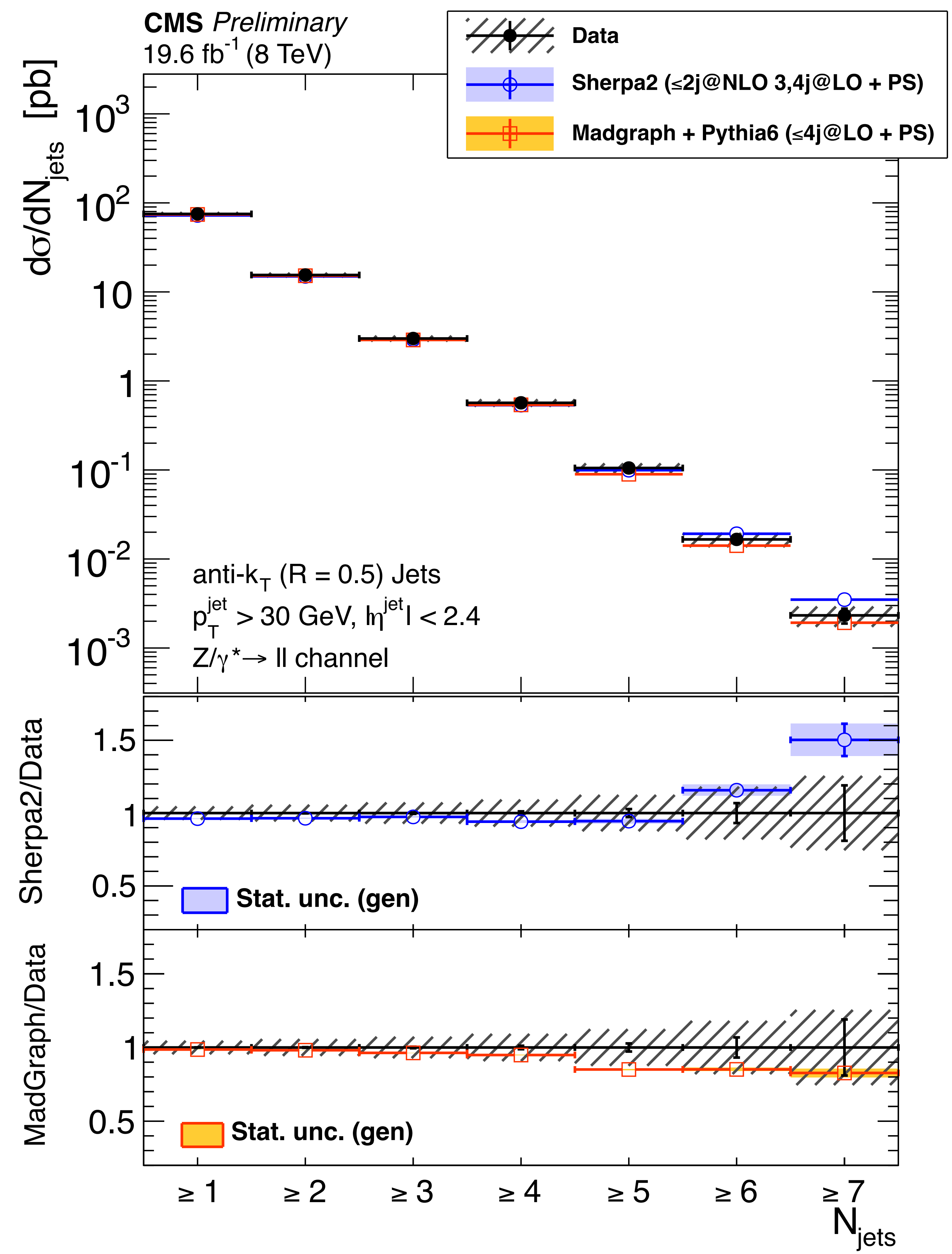
more Z+jets (8 TeV)

Z+jets (8 TeV)

Phase space

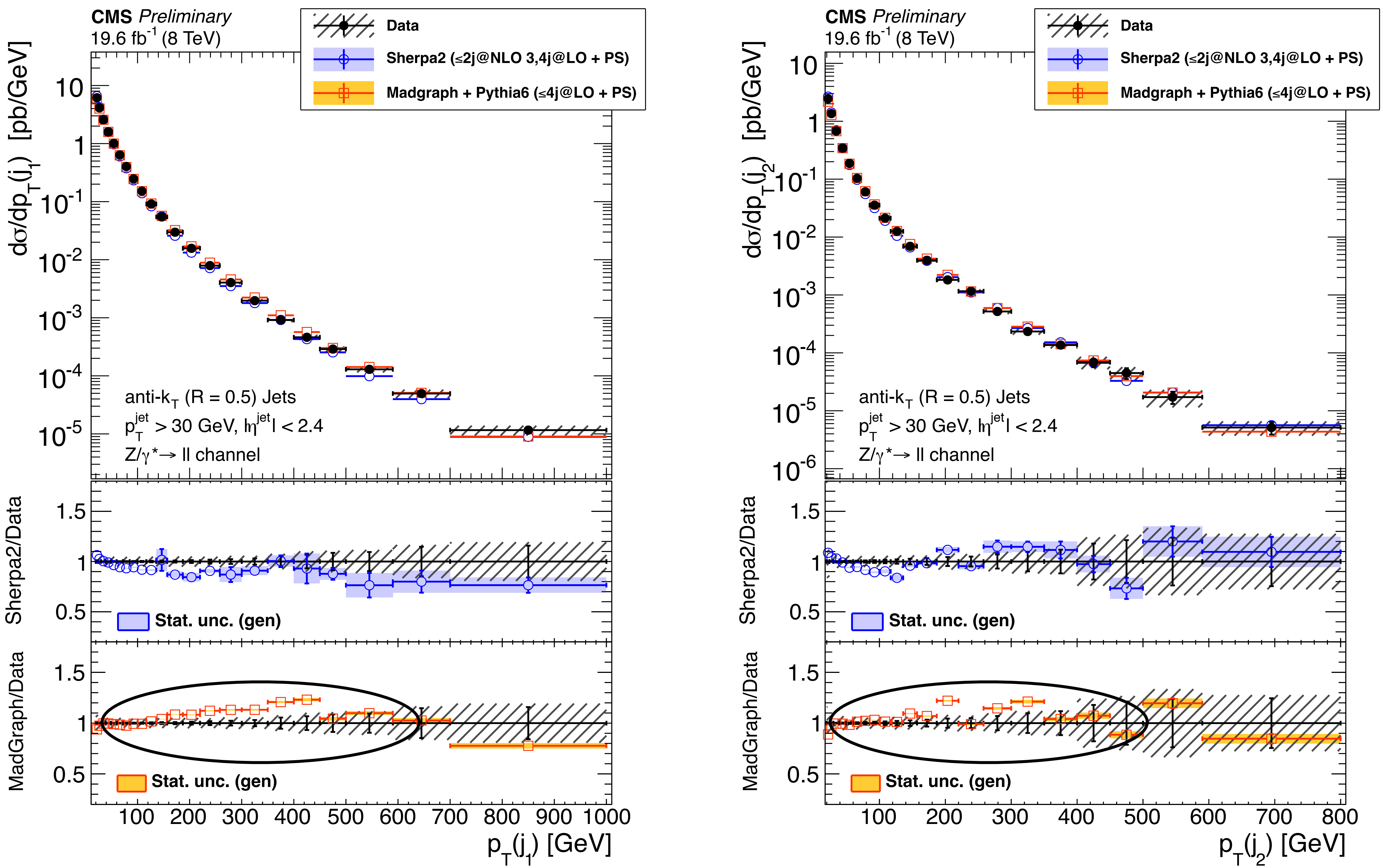
- lep p_T > 20 GeV, $|\eta|$ < 2.4
- 71 < Mll< 111 GeV
- jets: anti-k_T ΔR = 0.5
  - pT > 30 GeV, $|\eta|$ < 2.4, ΔR(jet,μ) > 0.5

Nice Theory/Data agreement



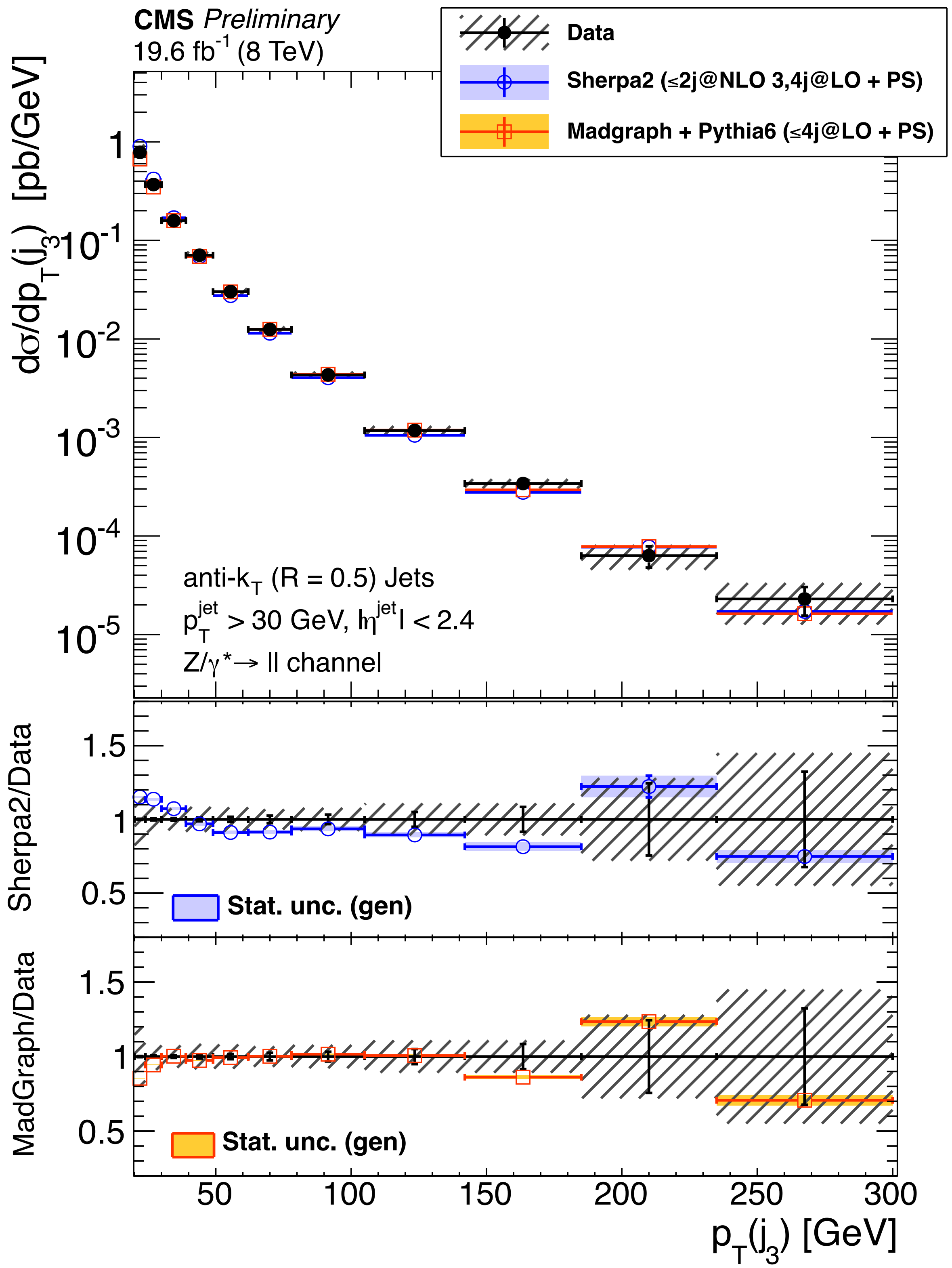
Z+jets (8 TeV)

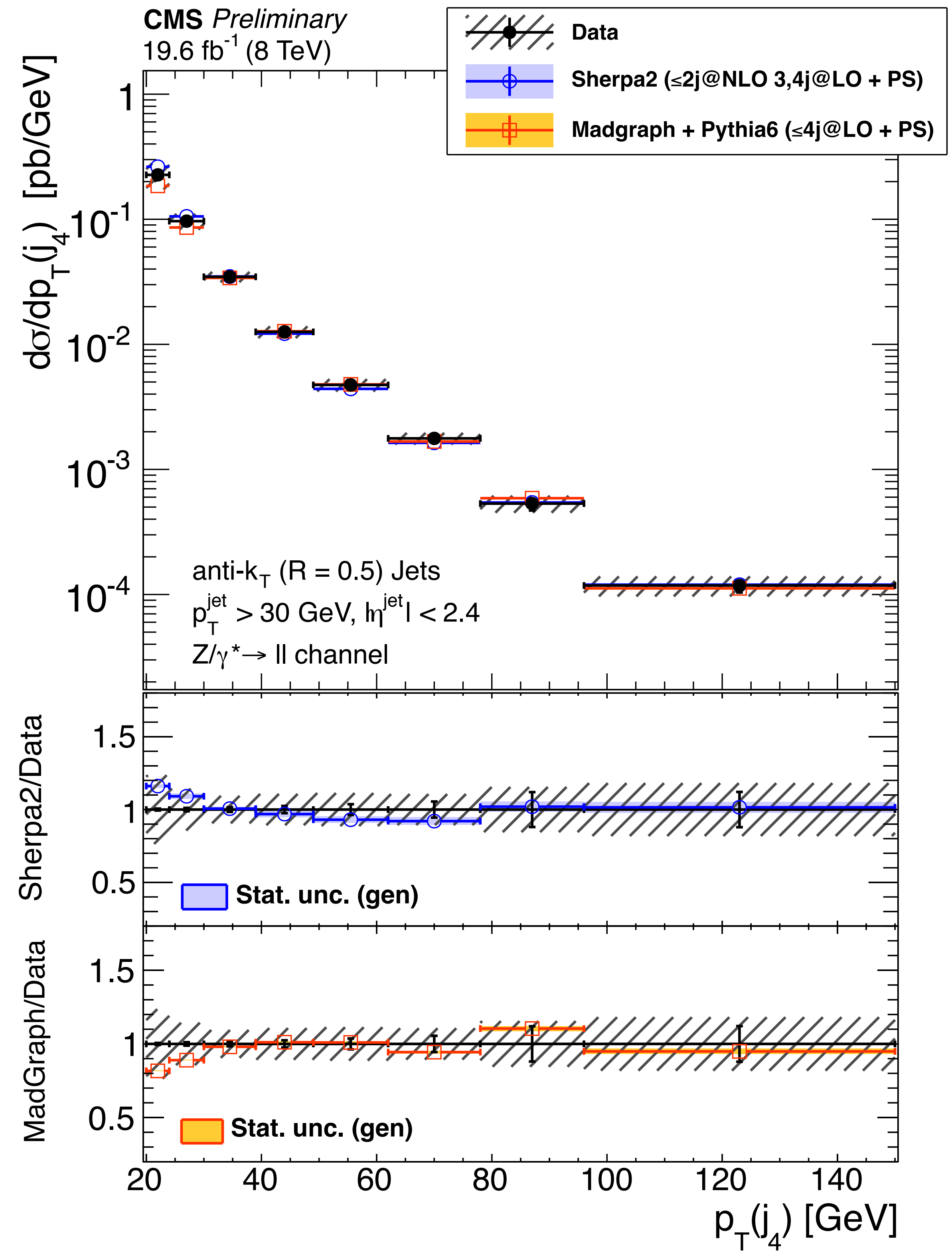
LO+PS glitches seen also at 7 TeV, effect is correlated with $p_T(Z)$



Z+jets (8 TeV)

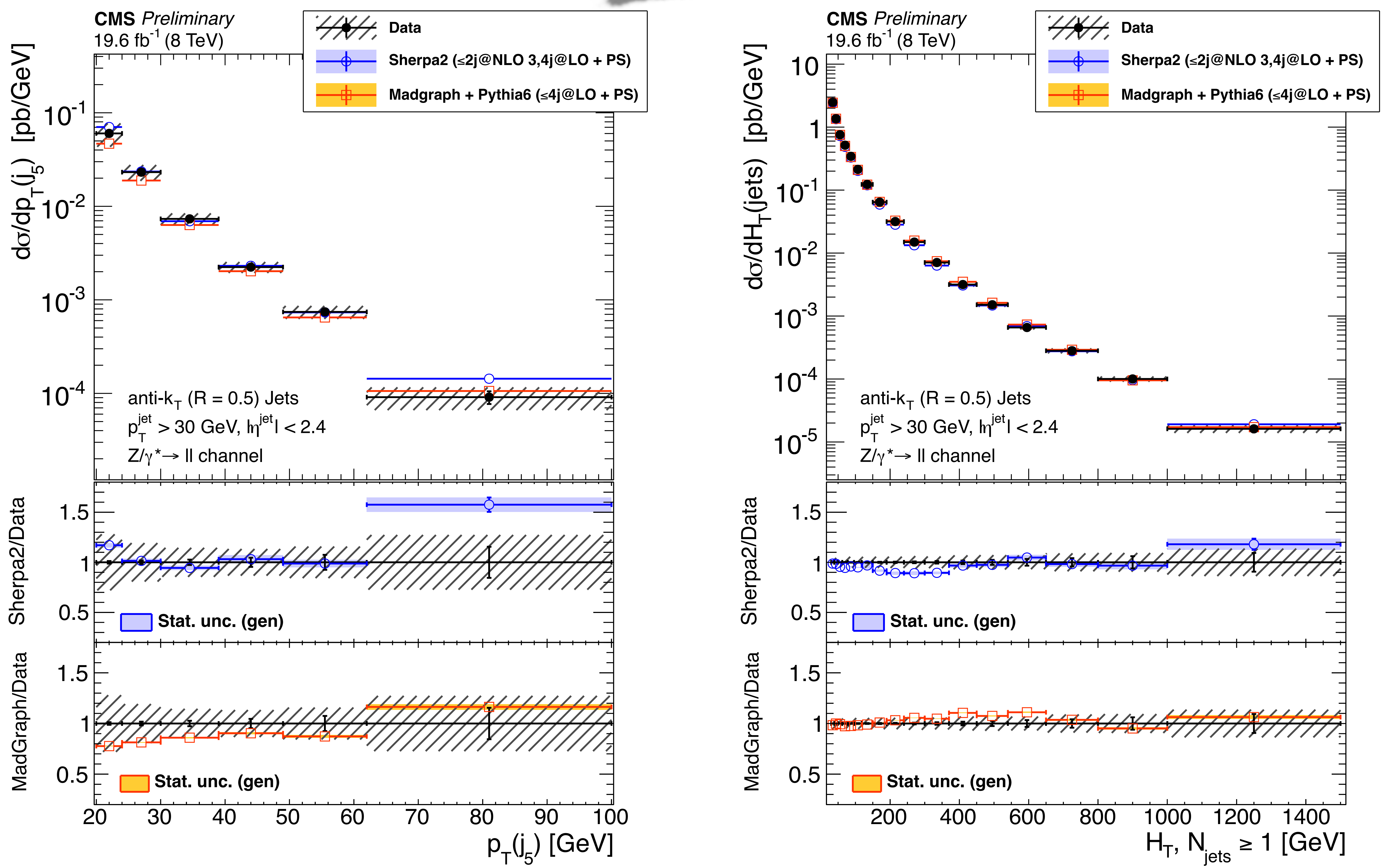
higher jet multiplicities in LO+PS suffer less, cancellation of competing effects ?



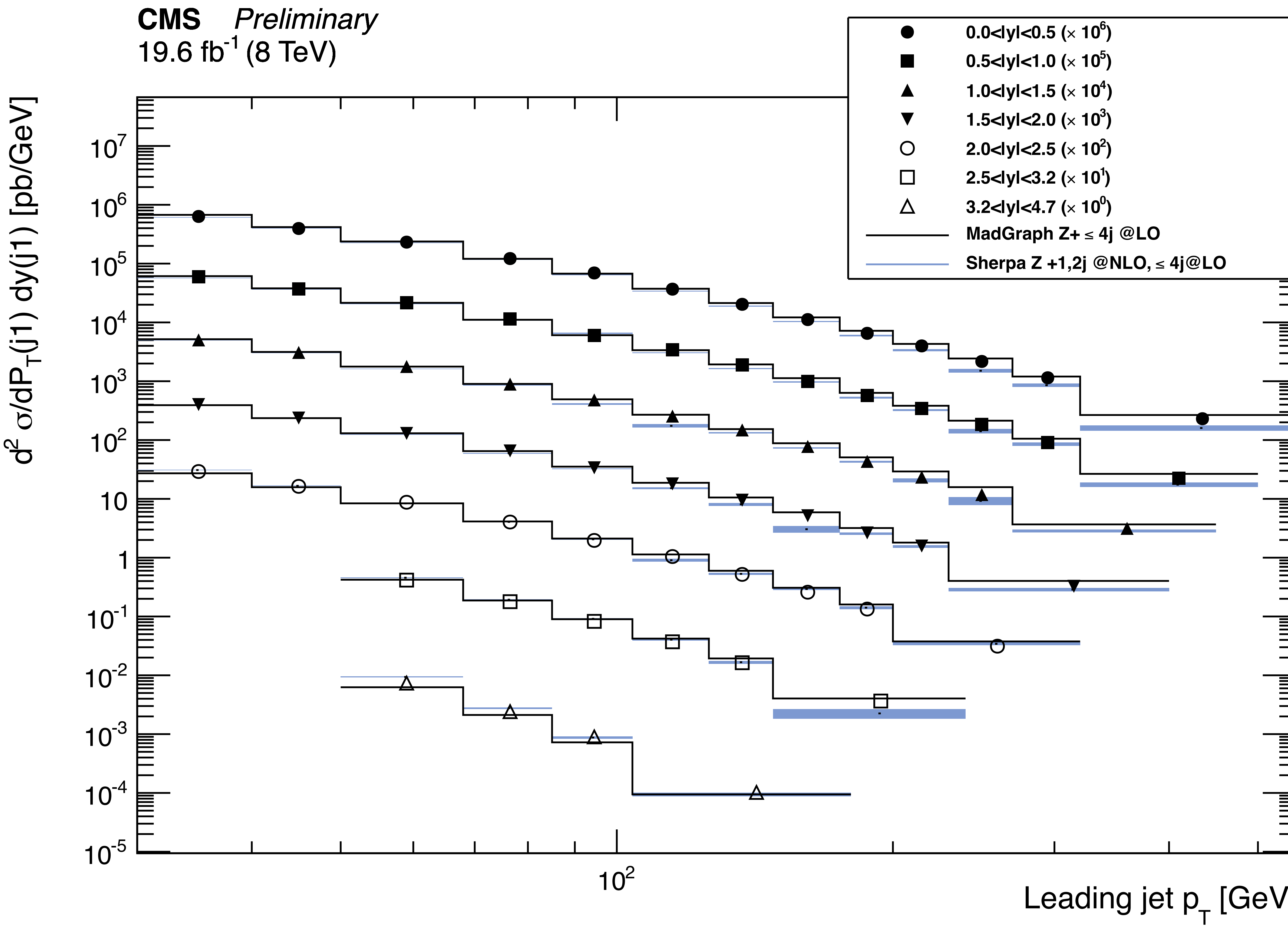


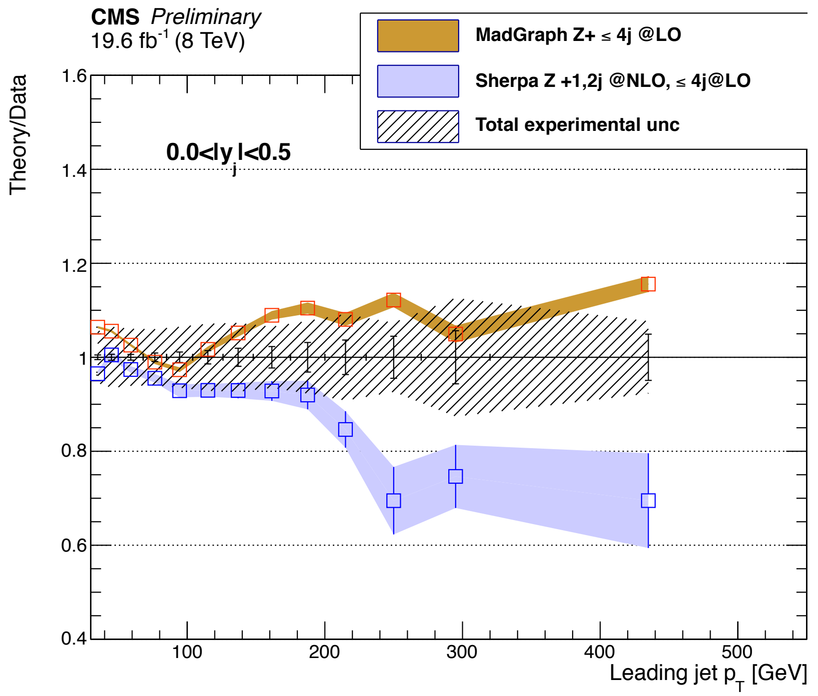
Z+jets (8 TeV)

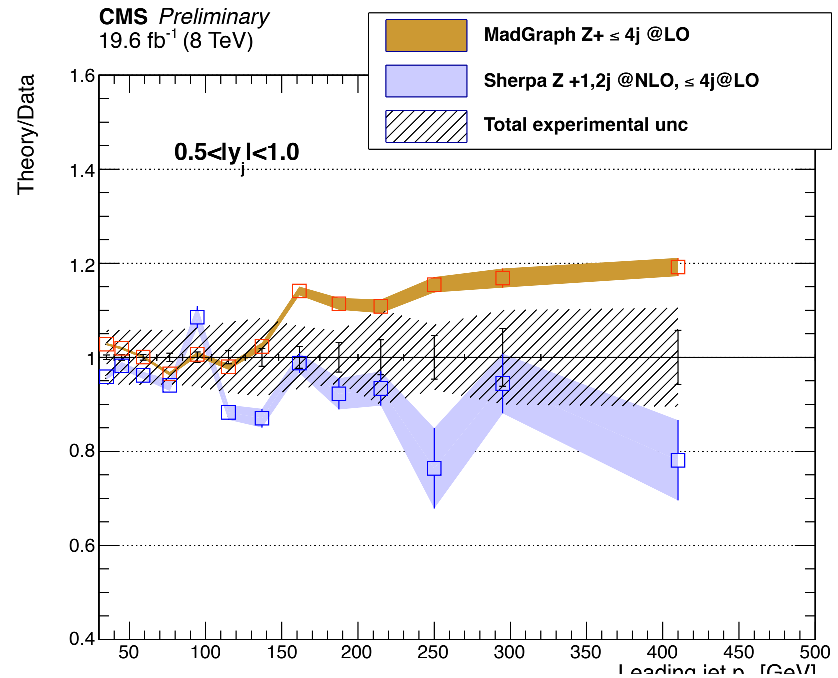
Sherpa2 describes all jet related observables, even the H_T; notice that 8 TeV has NLO up to 2 jets while 7 TeV was limited to 0,1 NLO

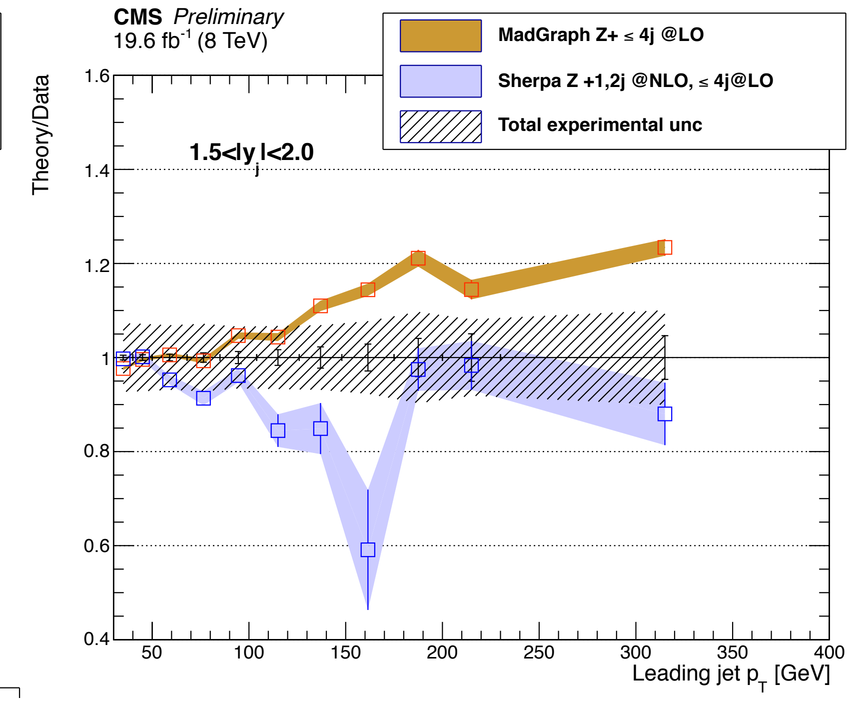


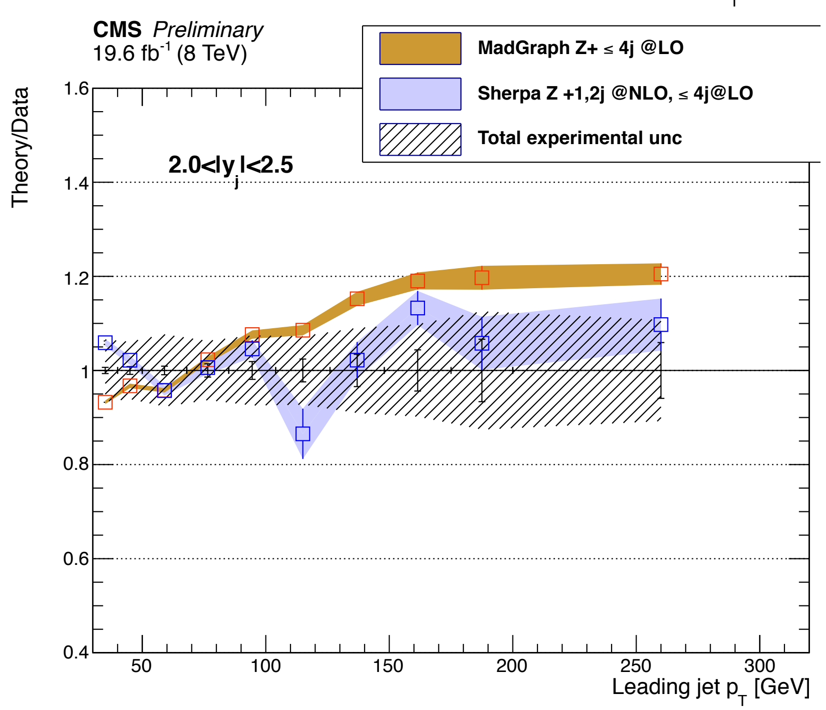
Z+jets (8 TeV) -- 2D

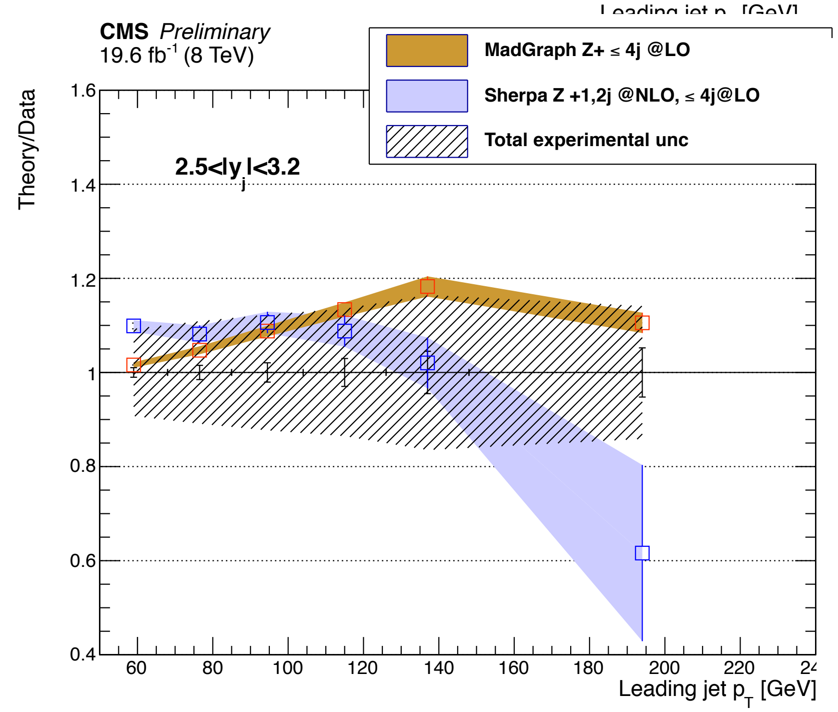


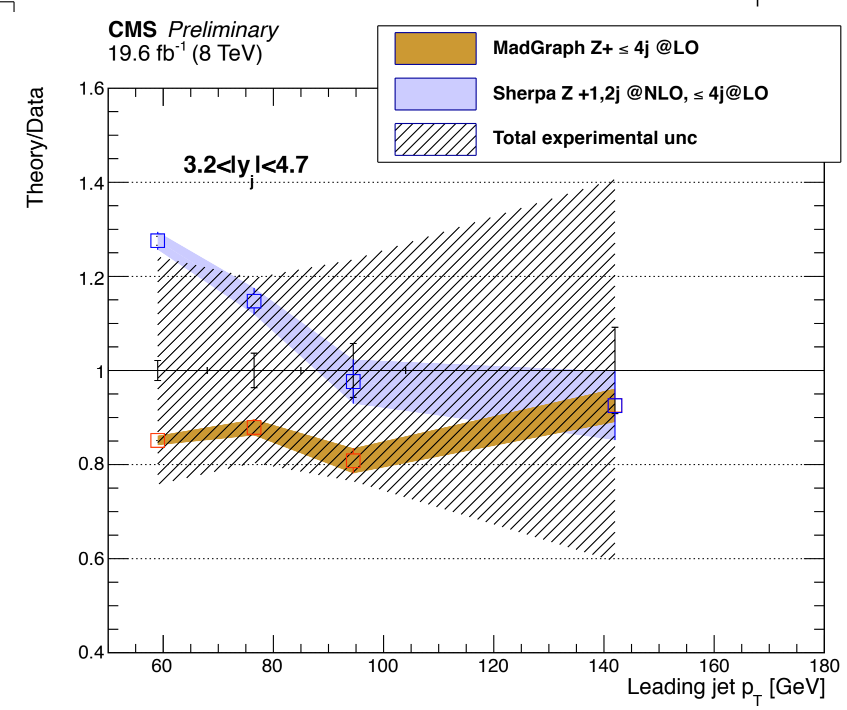


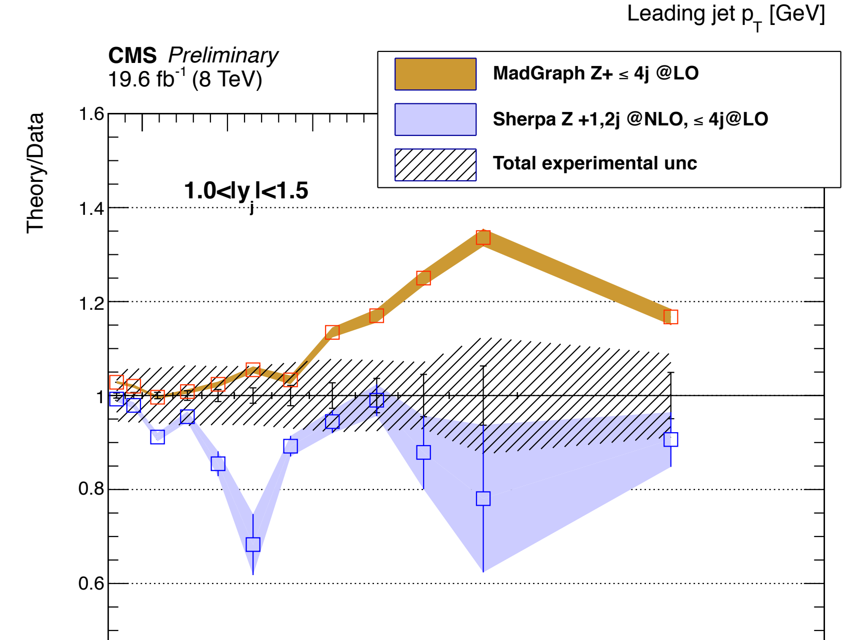












results are **preliminary**, currently producing more Sherpa to decrease stat. uncert.; negative weights in Sherpa make a non-trivial the computational task

Summary

LO+PS

- Inclusively jet multiplicity in V+jets comes out nice
- Nice picture ameliorates, when focusing in highly boosted topologies; effect seems to be universal for V=W, Z or γ
- LO+PS if of fundamental importance for searches and precision SM measurements

NLO

- Leading edge calculations, performs better, as expected, but with known limitations due to the lack of PS

NLO+PS

- NLO ≤2 jets merged with LO 3,4 jets and PS satisfactory describe most V+jets observables studied at 8 TeV

Having ≥2 independent (N)LO+PS MC generators is important

References

- All CMS V+jets results: link
- W+jets (7 TeV): http://arxiv.org/abs/1406.7533
  (accepted in PLB)
- Z+jets (7 TeV): http://arxiv.org/abs/1408.3104
  (submitted to PRD)
- Z+jets (8 TeV)
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- R(Z+jets/γ+jets)
  - SMP-14-005: http://cds.cern.ch/record/1740969?ln=en

Backup Slides

Few words on detector unfolding

It's an ill-posed problem

- Minimizes theory dependency e.g., on the generated p_T
- But detector response depends on how collimated and busy are the events, some model dependency on σ_{MC} is inevitable
- We need a minimum of 2 independent ME+PS generators to feel comfortable and assess systematic uncertainties
- Never attempted so far to get response matrix from NLO+PS

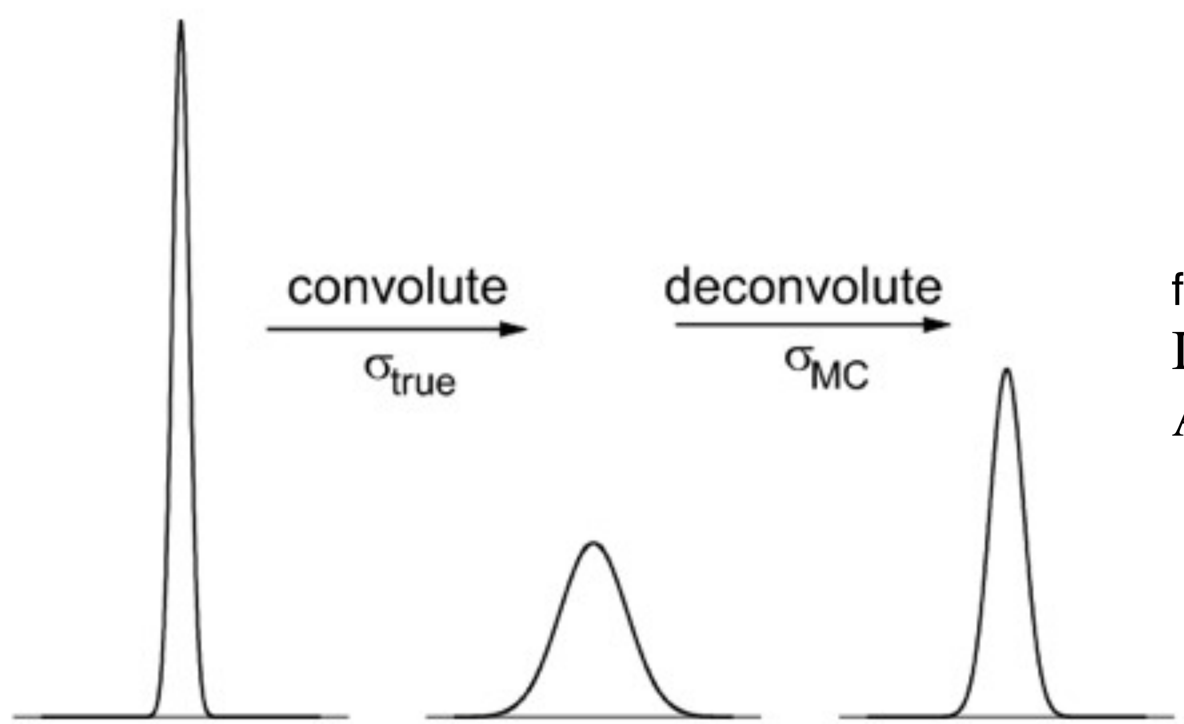

Fig. 9.2. Effect of deconvolution with a resolution wrong by 10%.

from: Gerhard Bohm, Günter Zech
Introduction to Statistics and Data Analysis for Physicists