

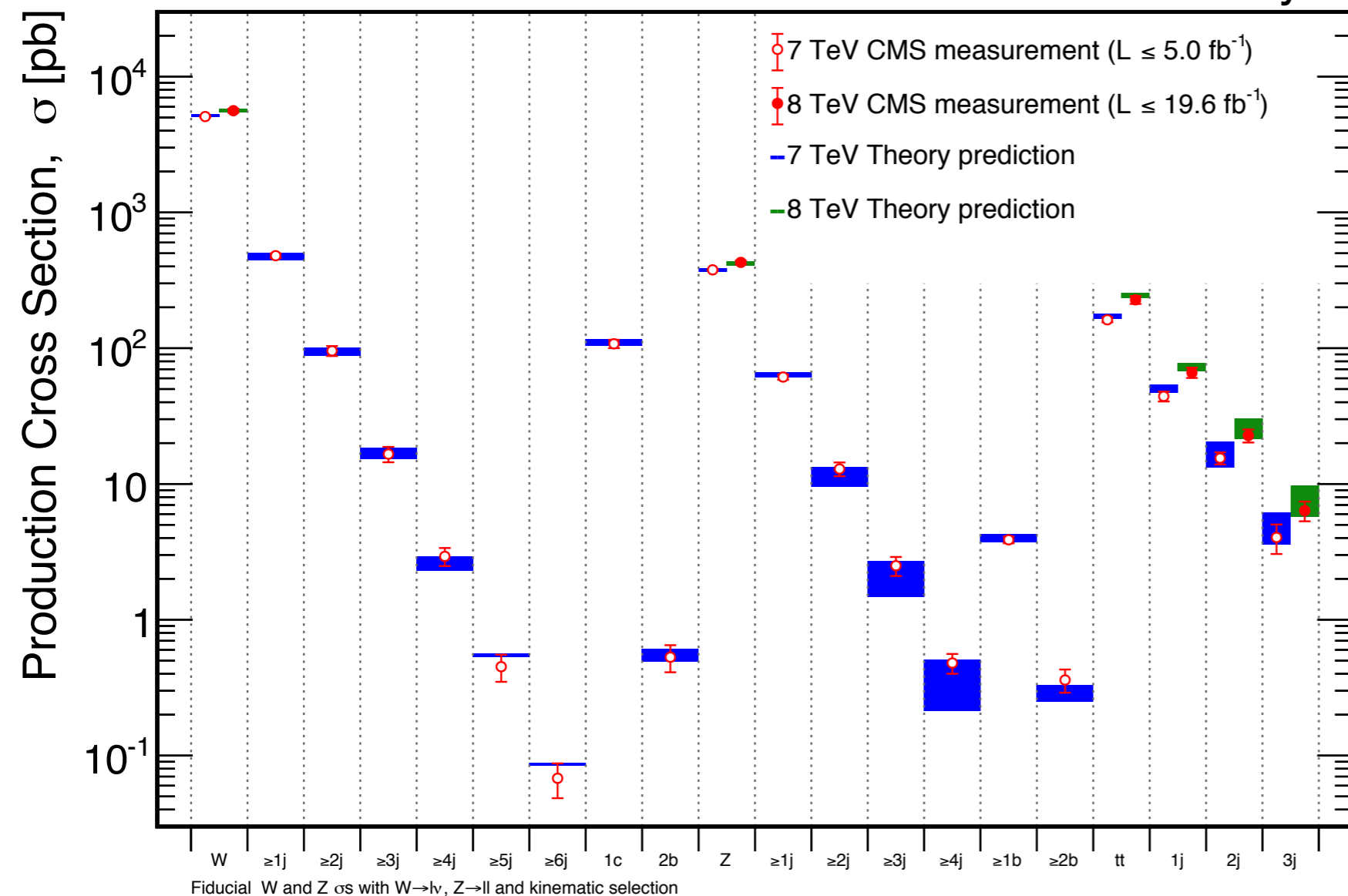
Vector boson production in association with jets and heavy flavor quarks at CMS

Marco Peruzzi (CERN)
on behalf of the CMS Collaboration

EPS-HEP 2015
Vienna, July 24th, 2015

CMS Preliminary

Mar 2014

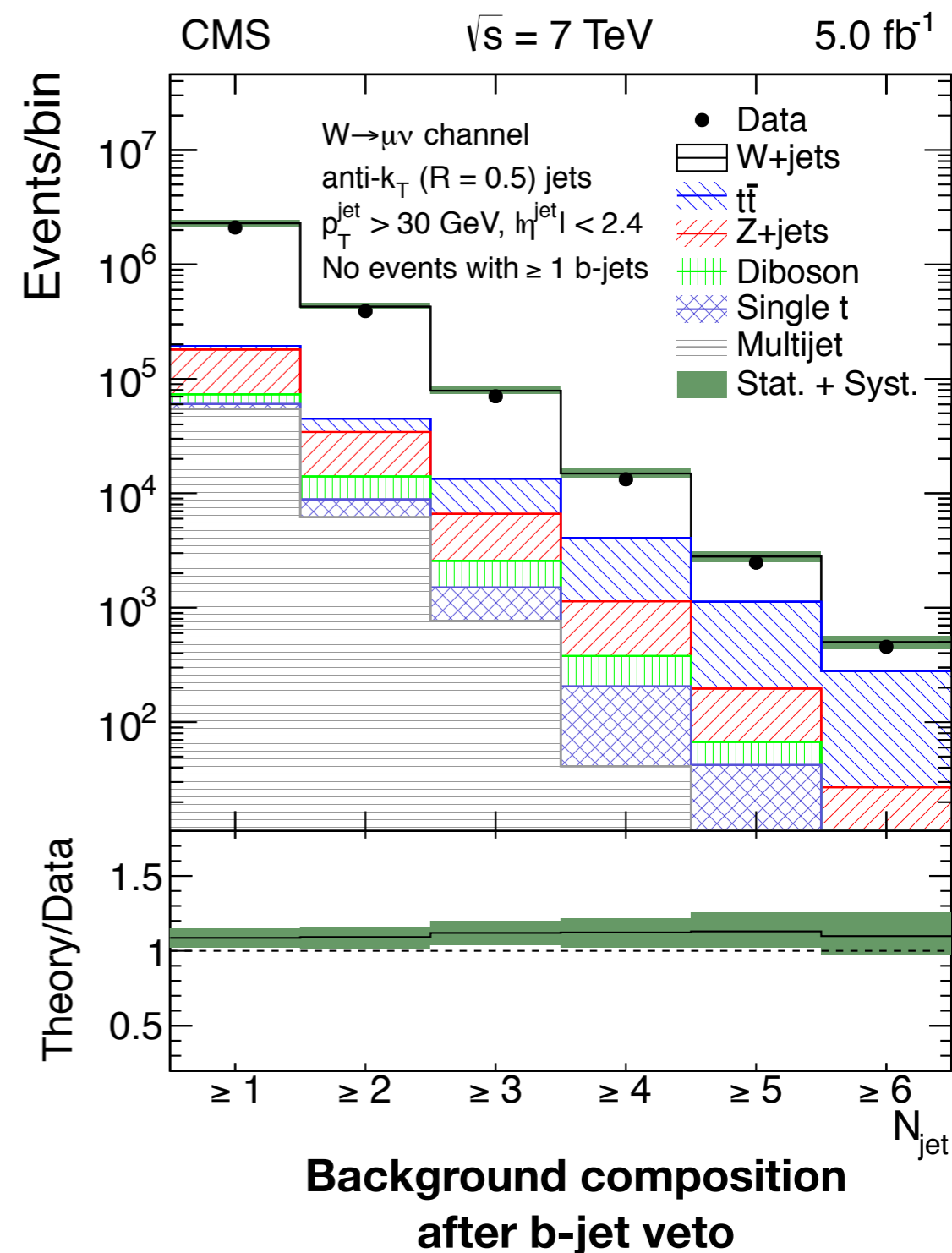
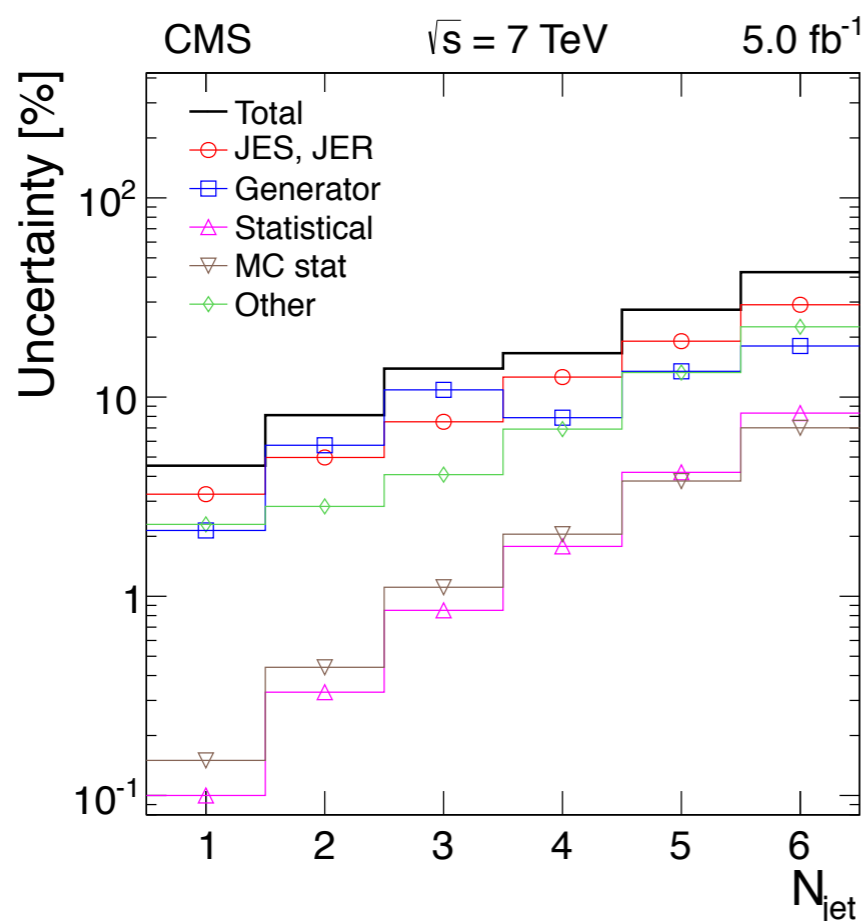


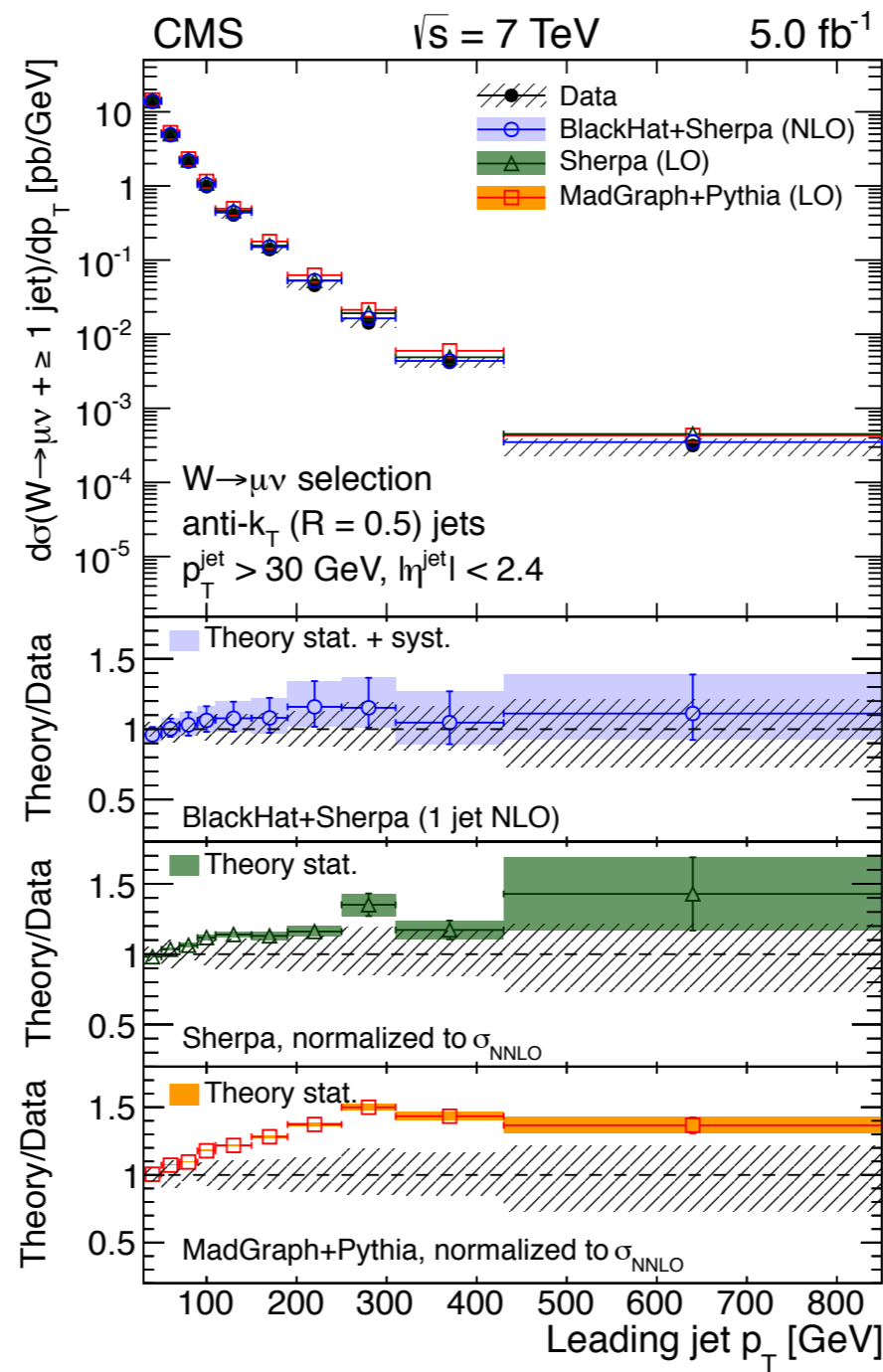
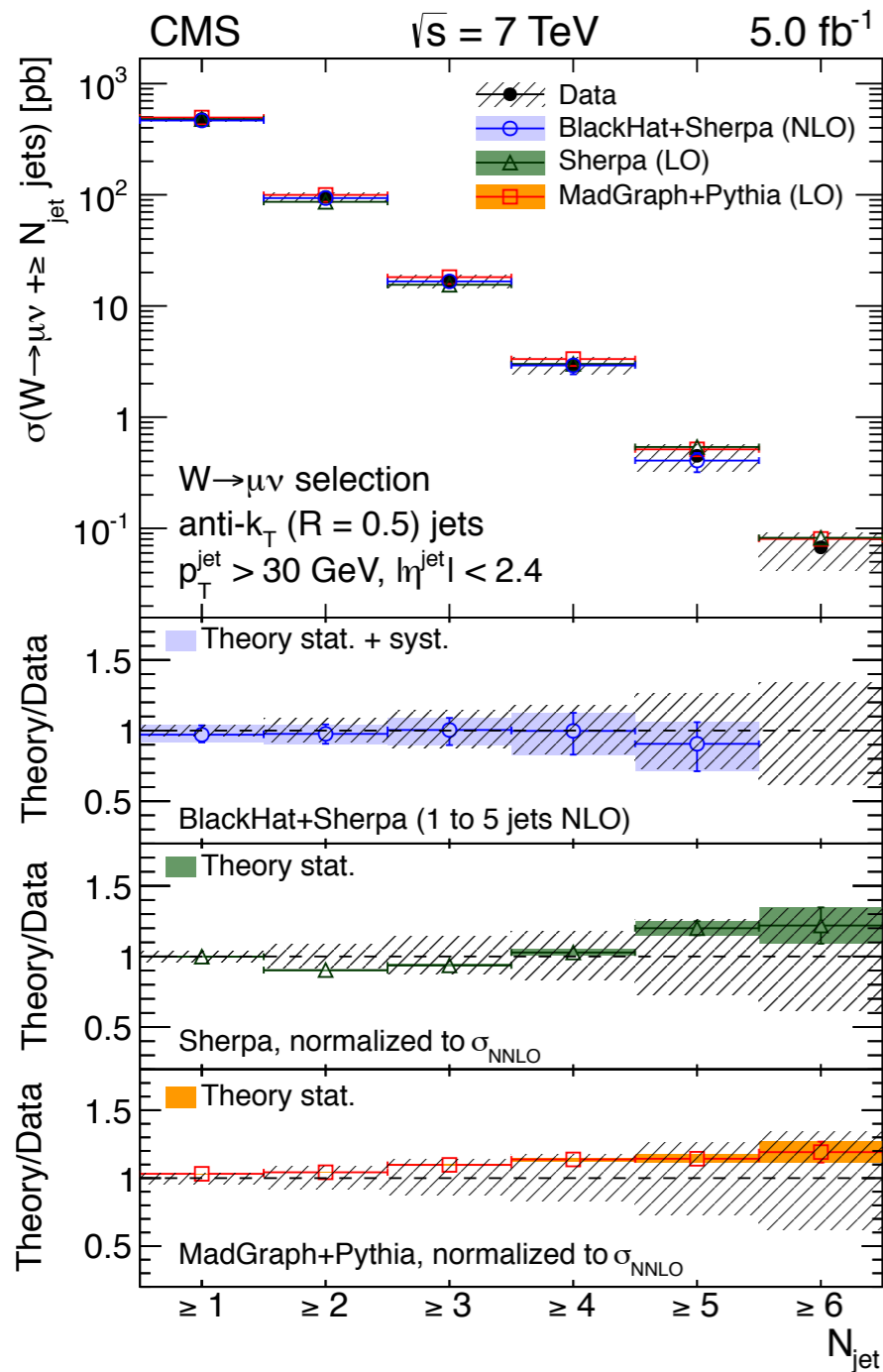
- ▶ Accurate modeling of V+jets production crucial for the CMS physics program
 - ◆ background to searches for BSM and Higgs analyses

- ▶ Sensitive to several aspects of QCD phenomenology
 - ◆ pQCD
 - ◆ PDFs and MC tunes

▶ Excellent overall agreement with SM theory over several orders of magnitude!

- ▶ $W \rightarrow \mu\nu + \text{at least 1 jet with } p_T > 30 \text{ GeV}$
- ▶ $M_T(\mu, \text{MET}) > 50 \text{ GeV}$
- ▶ Multi-jet background estimated from data reverting isolation cut
- ▶ Syst. uncertainties: JEC/JER, unfolding



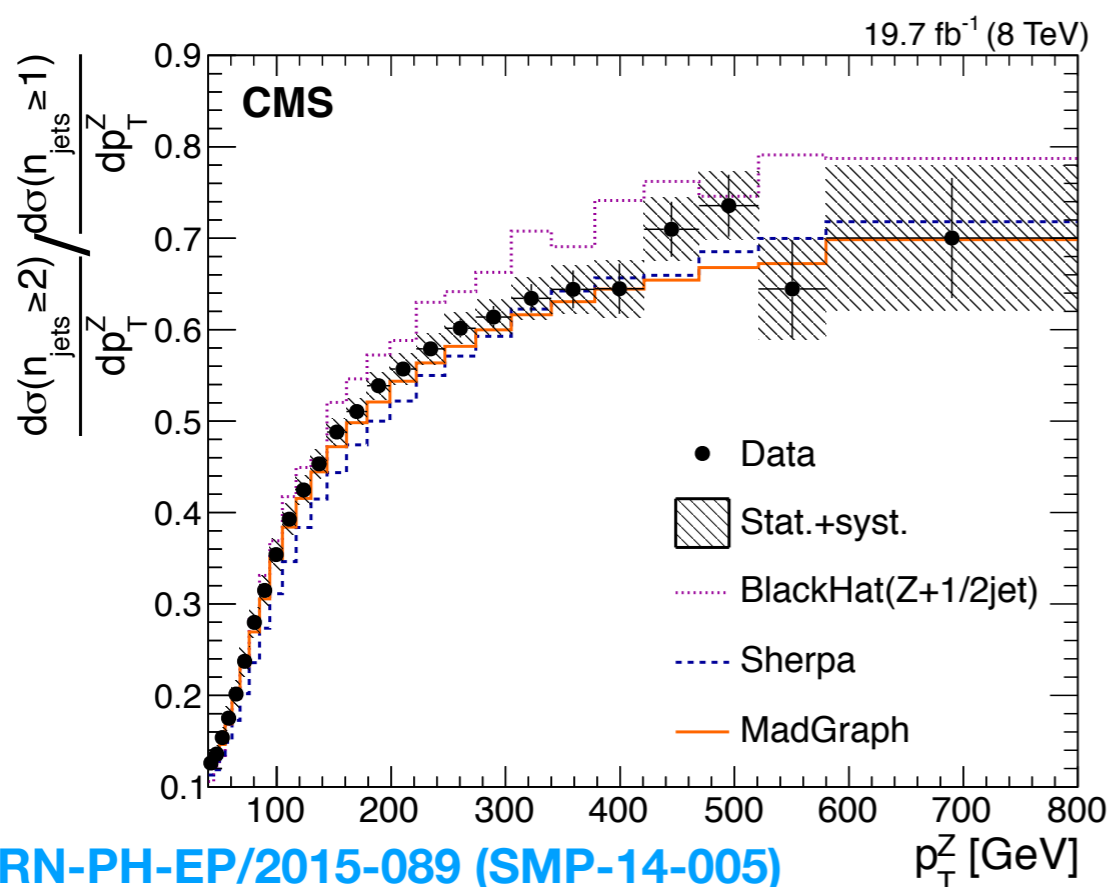


- ▶ Results unfolded to particle level
- ▶ Comparison with fixed-order NLO predictions and multi-leg generators
- ▶ Good agreement in jet multiplicity
- ▶ LO ME+PS generators overestimate the yield at high leading jet p_T

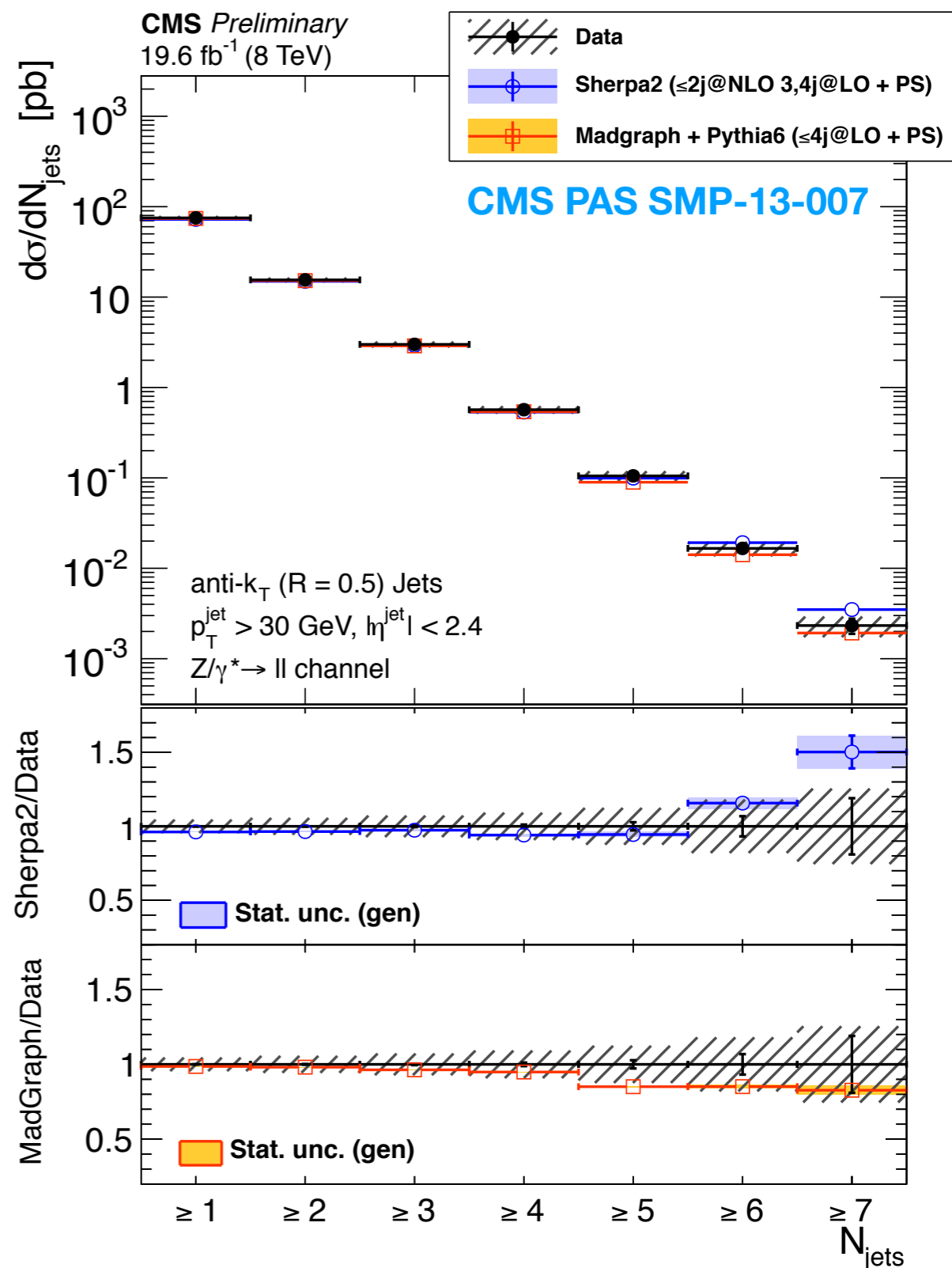
Differential Z + jets at 8 TeV

- ▶ $Z \rightarrow \mu\mu, ee$ + at least 1 jet, compared to:
 - ▶ Sherpa2: NLO ME (Z+0/1/2j) + LO ME ($\leq 4j$) + PS
 - ▶ Madgraph + Pythia ($\leq 4j$)
 - ▶ BlackHat + Sherpa

▶ **Good agreement in jet multiplicity**



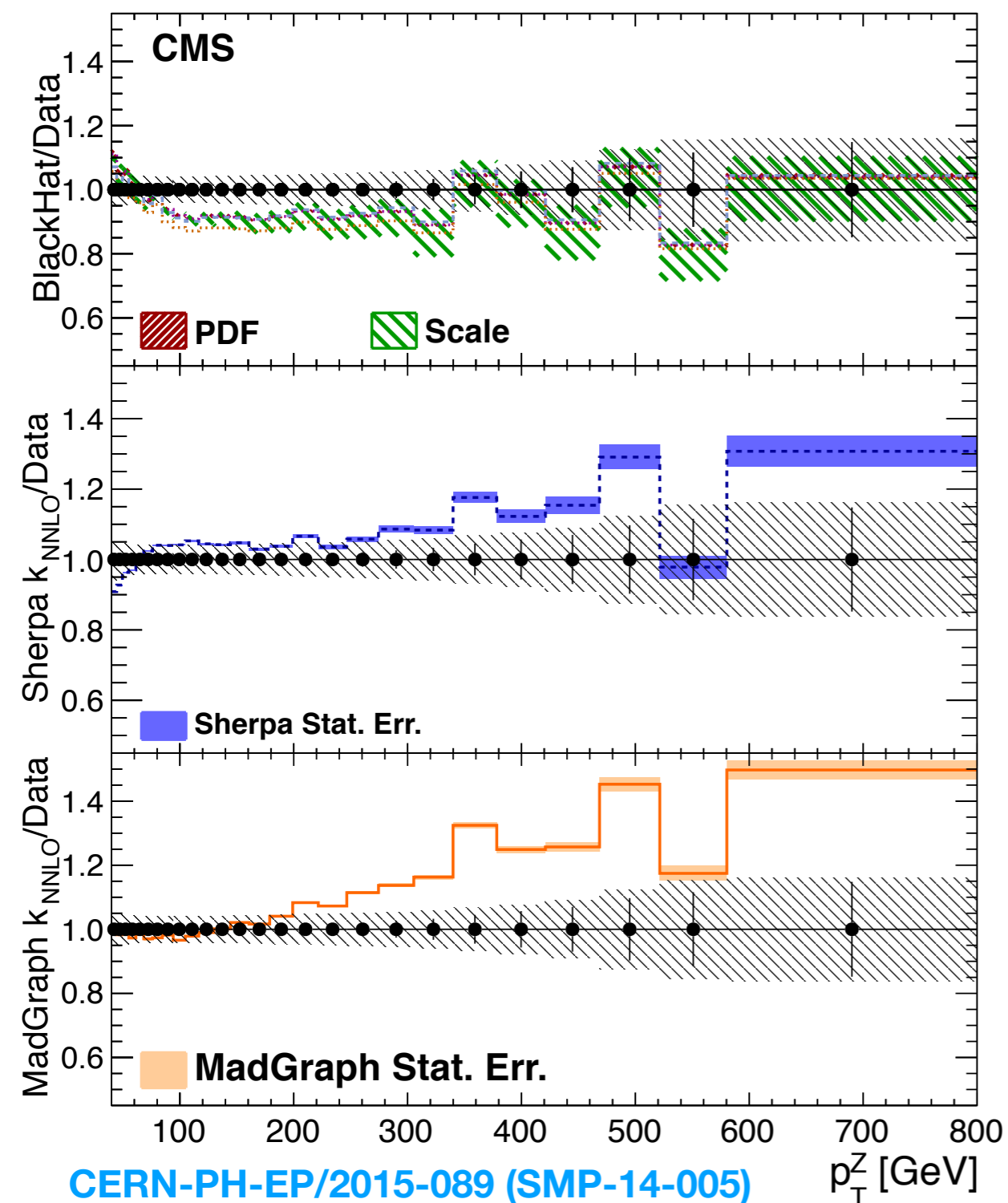
CERN-PH-EP/2015-089 (SMP-14-005)



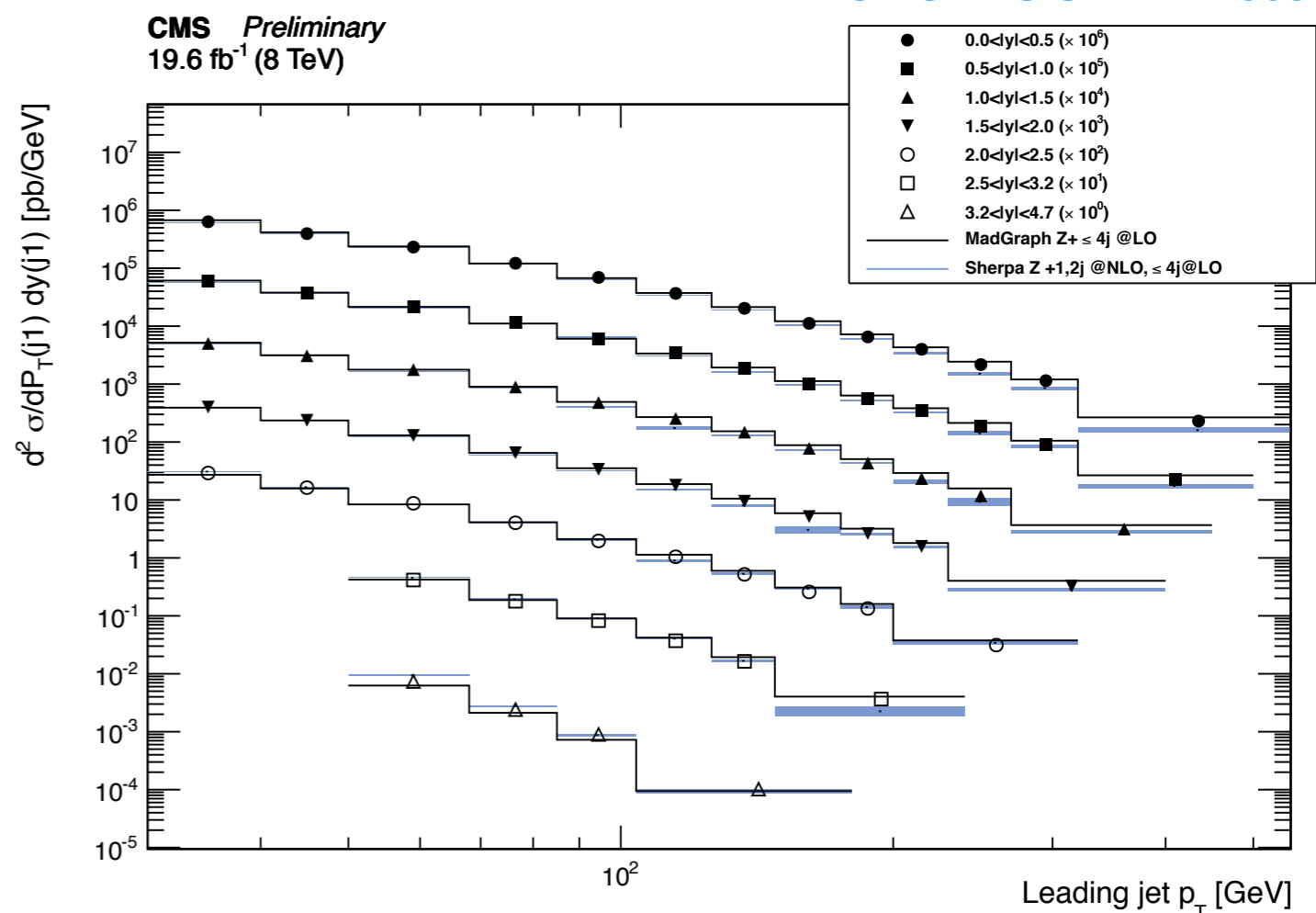
Differential Z + jets at 8 TeV

Differential cross section as a function of Z p_T
19.7 fb⁻¹ (8 TeV)

- ▶ Madgraph overestimates the cross section at high Z p_T
- ▶ BlackHat ratio to data is flatter
- ▶ Double differential measurements are also available:

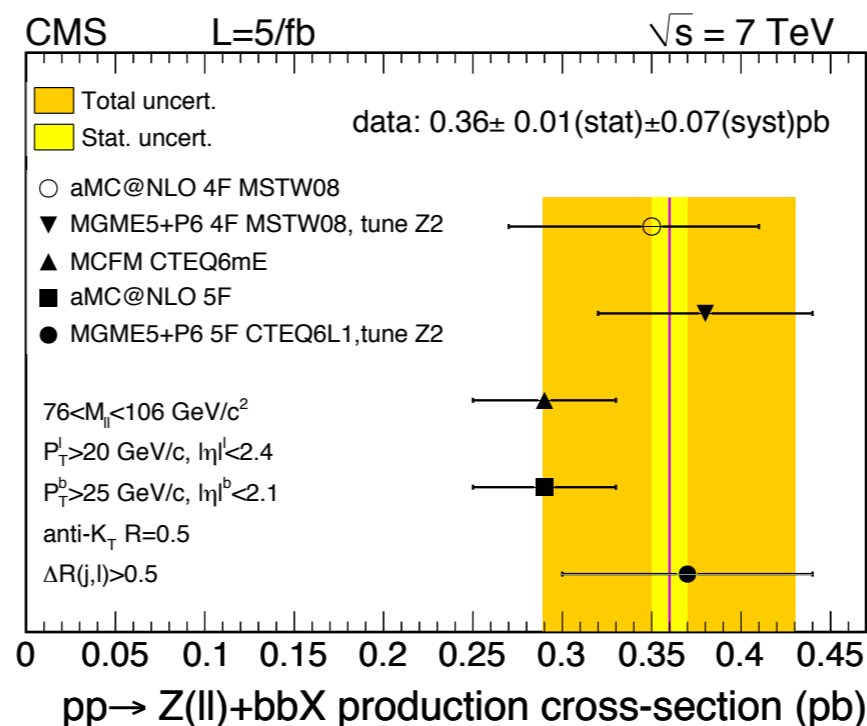
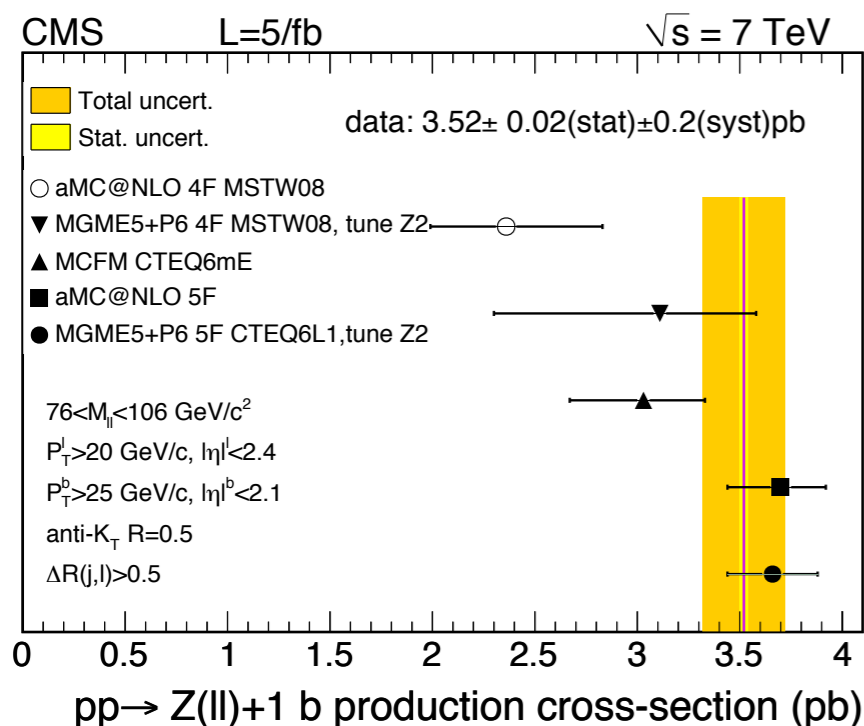


CMS PAS SMP-14-009

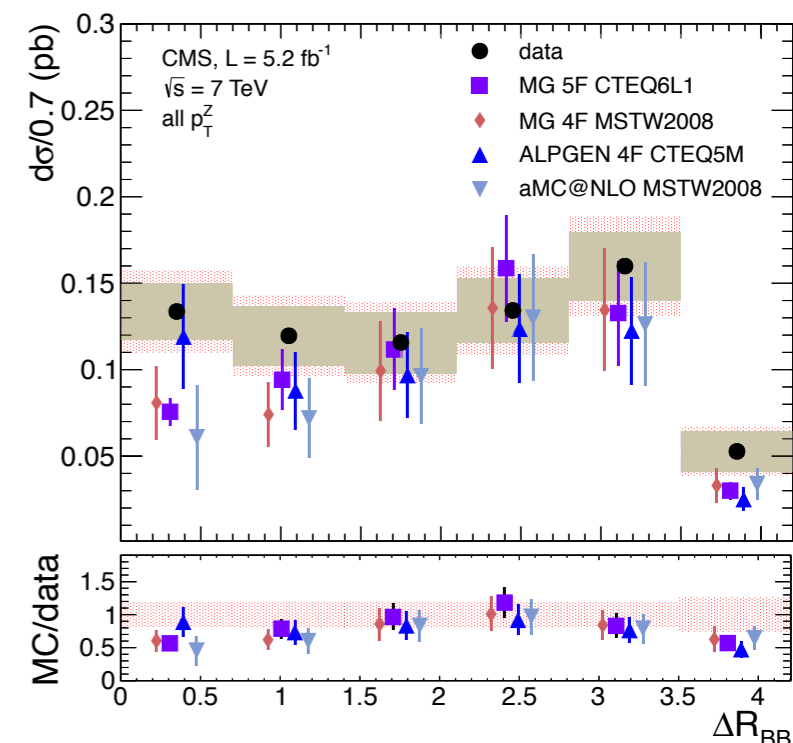


W, Z + heavy flavor

- **Z+b,bb: good agreement with NLO predictions, some discrepancy for nearby b-jets:**

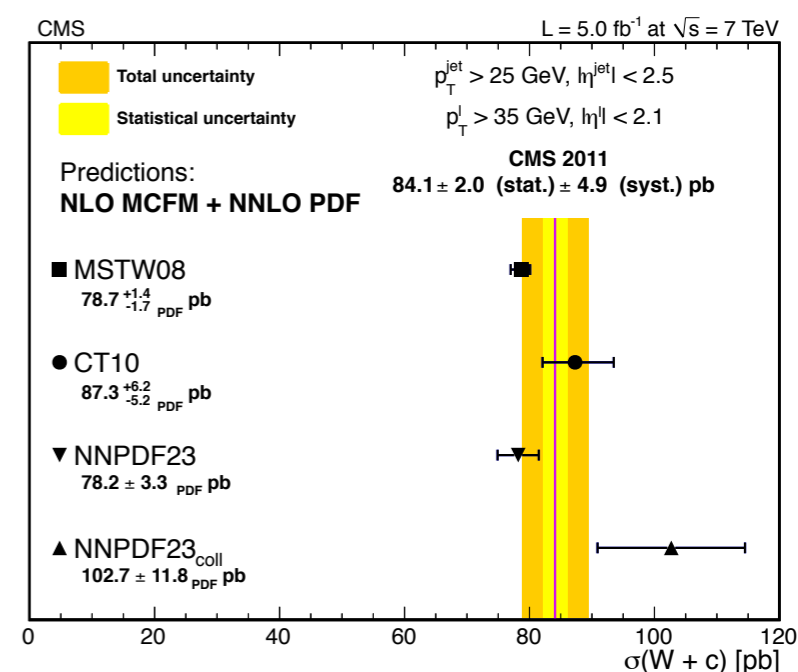
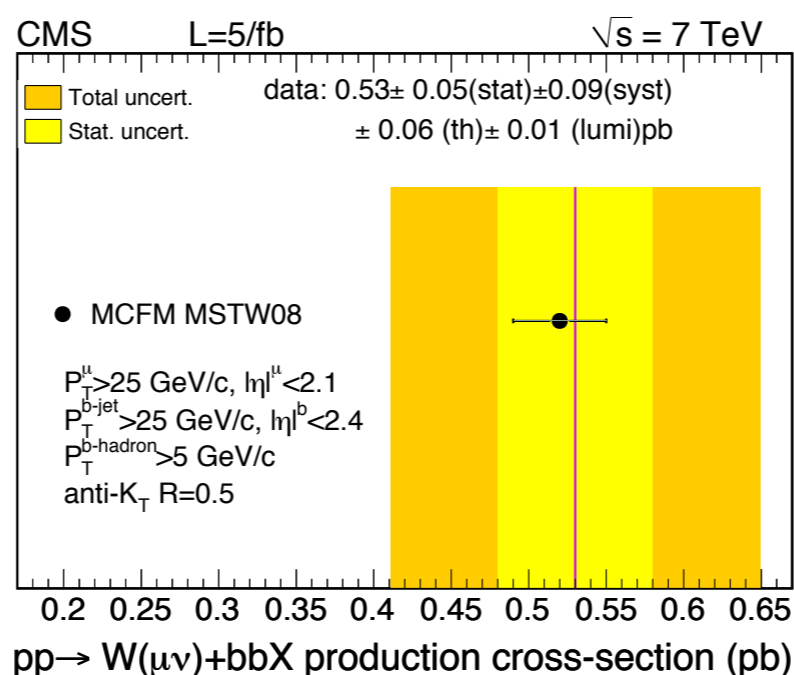


JHEP 12 (2013) 39, JHEP 06 (2014) 120



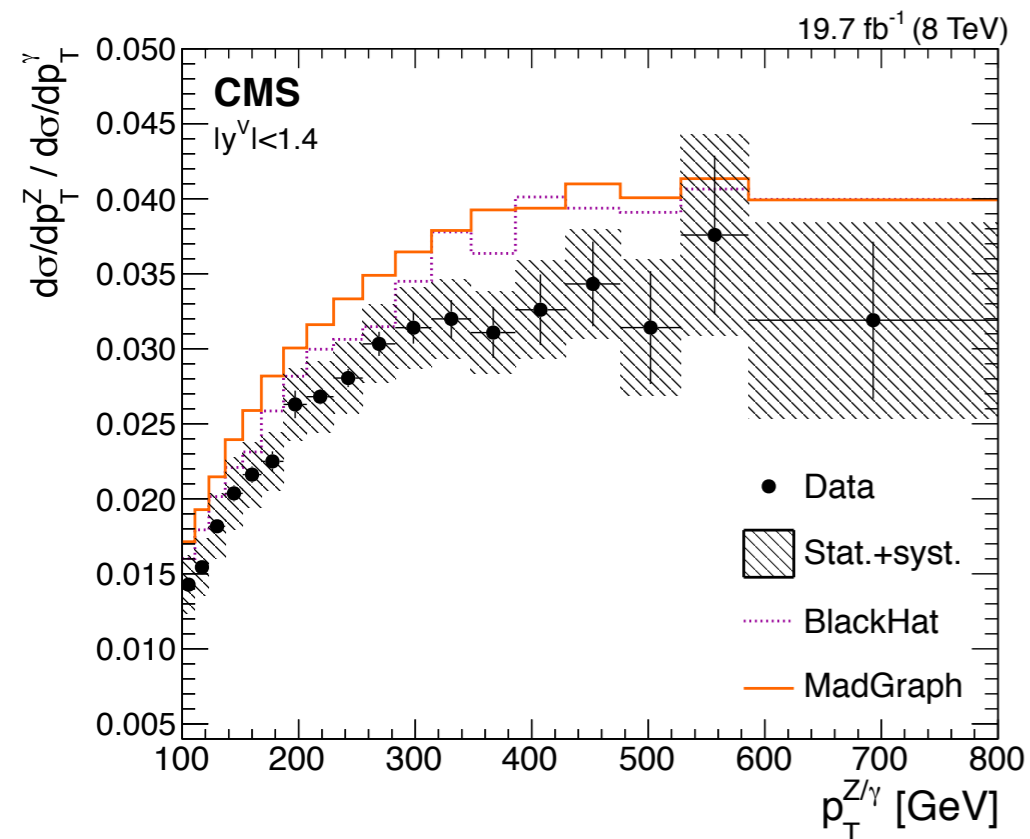
- Good agreement in **W+bb and W+charm:**

PLB 2014 06 041
 JHEP 02 (2014) 013



Differential Z/ γ ratio at 8 TeV

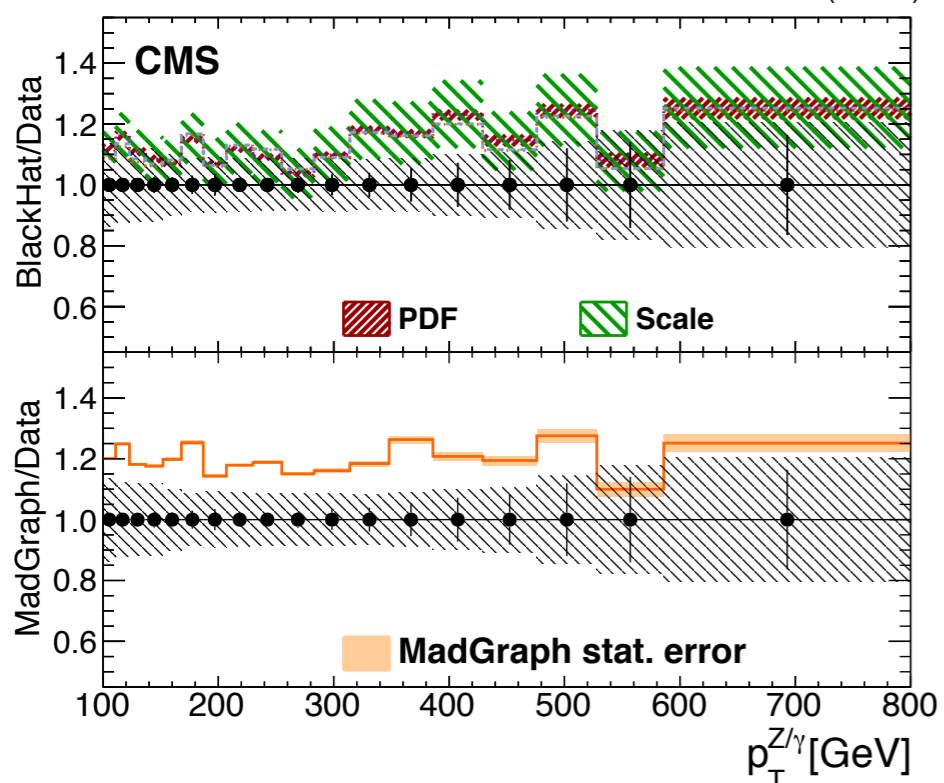
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- ▶ At high p_T , **Z/g cross section ratio** expected to **reach a plateau** at LO
- ▶ Important to model Z \rightarrow vv from data
- ▶ **Data/theory ratio is flat**
 - ◆ agreement at $\sim 20\%$ level
 - ◆ similar trend in all phase space regions

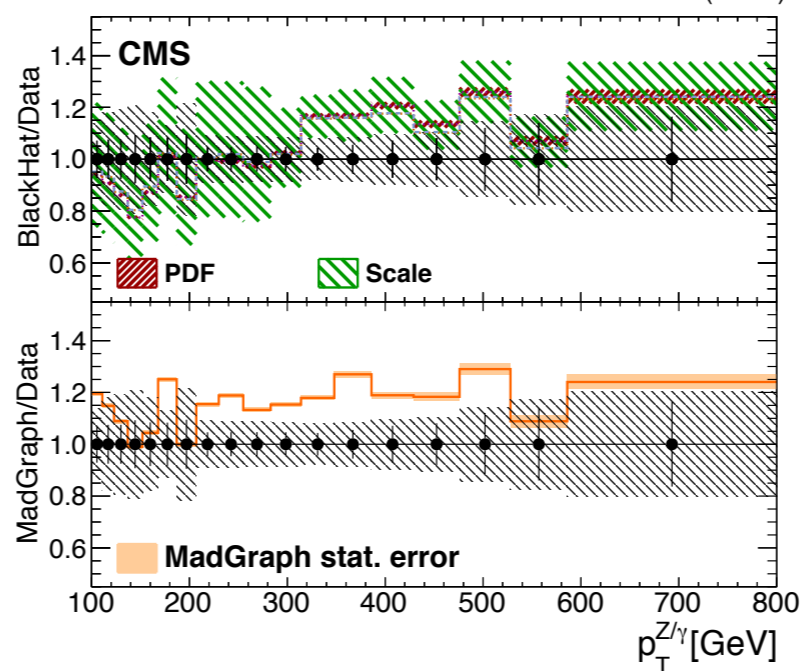
Inclusive phase space

19.7 fb⁻¹ (8 TeV)



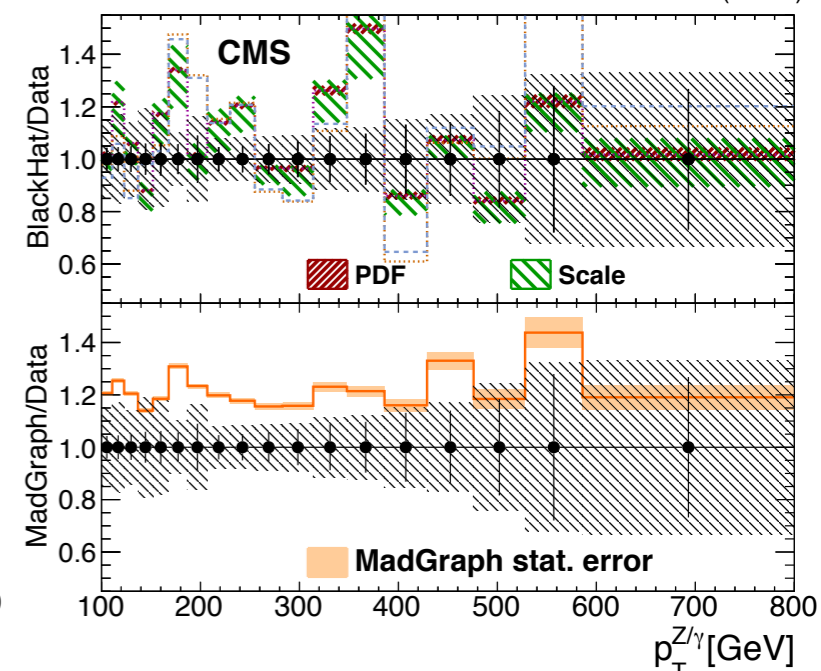
H_T > 300 GeV

19.7 fb⁻¹ (8 TeV)



≥ 3 jets

19.7 fb⁻¹ (8 TeV)





Differential $\gamma\gamma + \text{jets}$ at 7 TeV

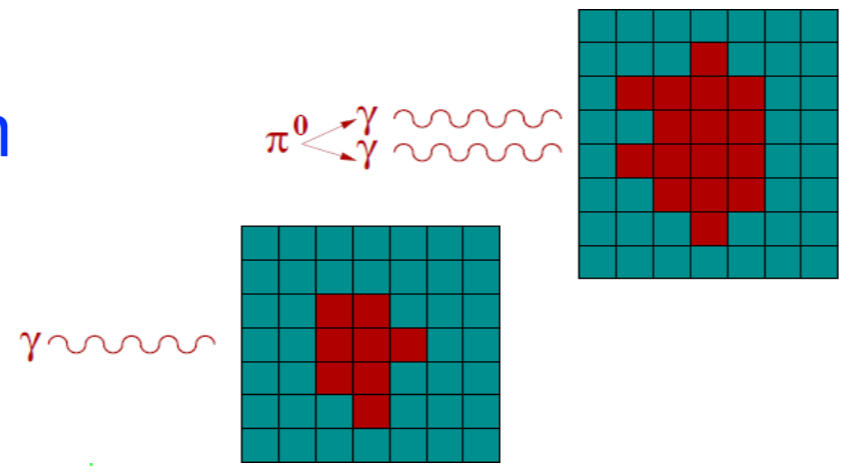
CMS PAS SMP-14-021



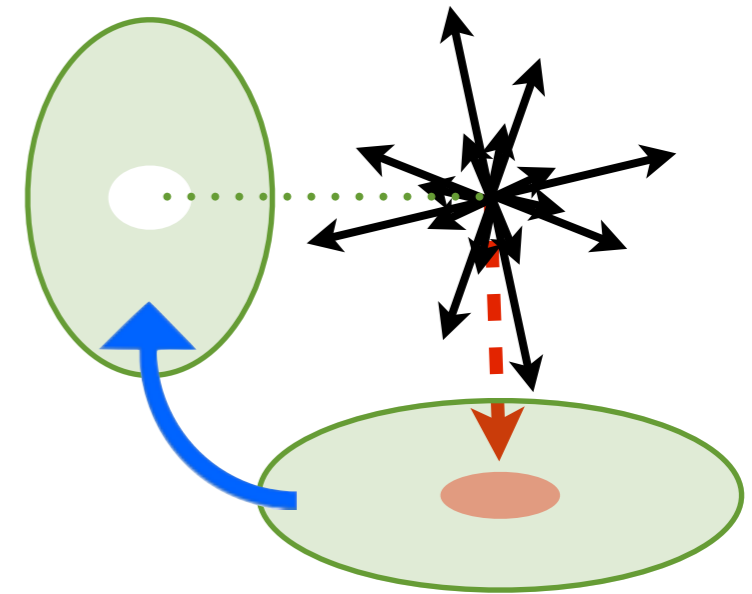
► First **differential $\gamma\gamma + \text{jets}$ measurement** at LHC

◆ photon $p_T > 40, 25$ GeV, jet $p_T > 25$ GeV

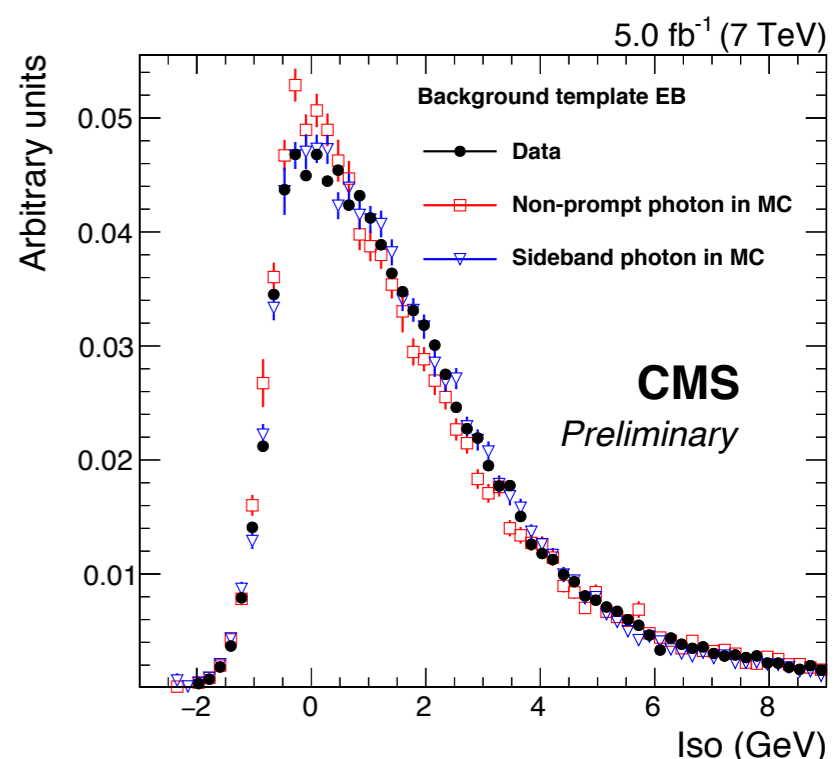
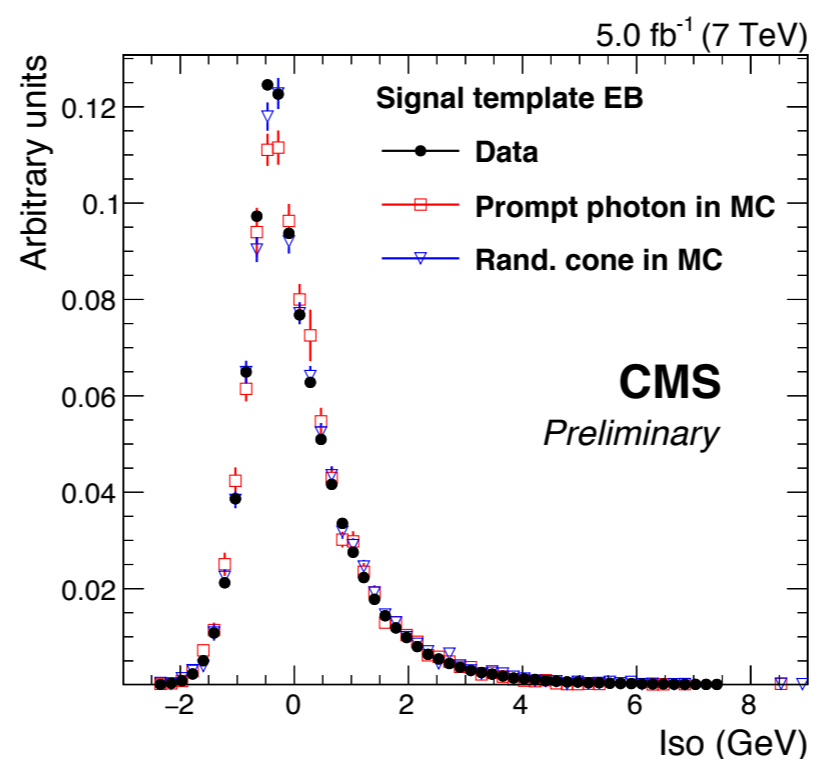
► Background from boosted neutral mesons in jets:



Random cone to predict isolation around prompt photons



► **Data-driven photon purity** from 2D template fit of particle-flow isolation

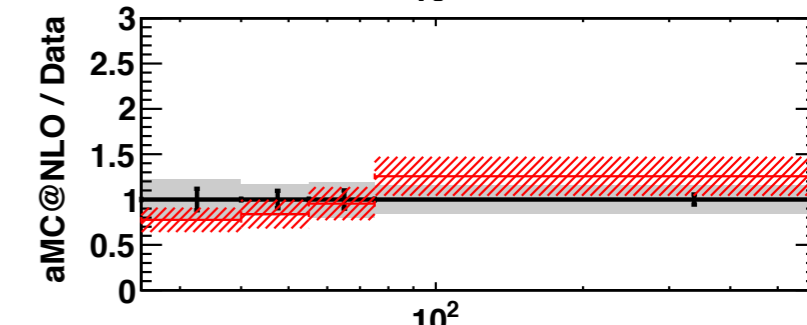
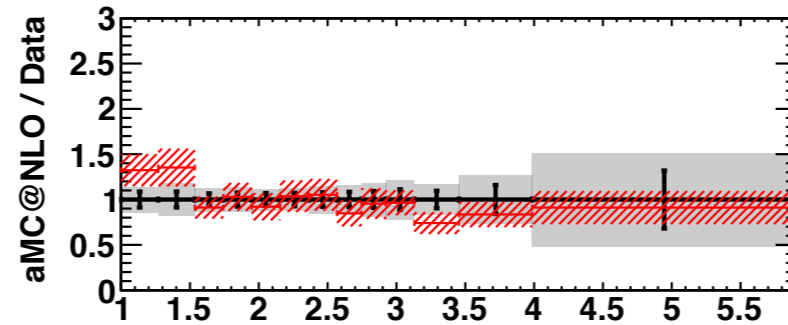
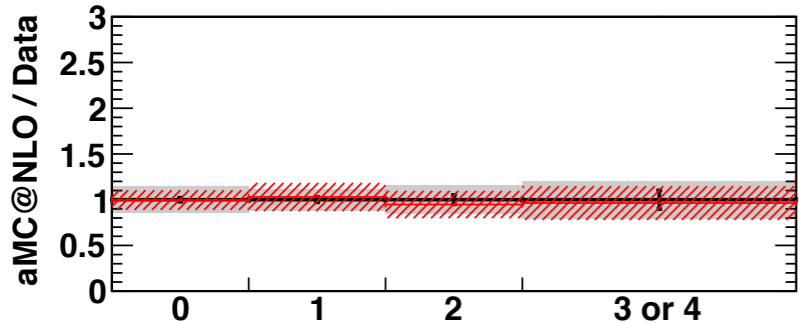
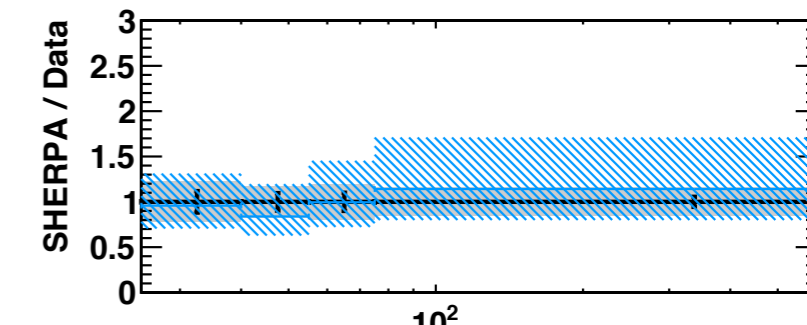
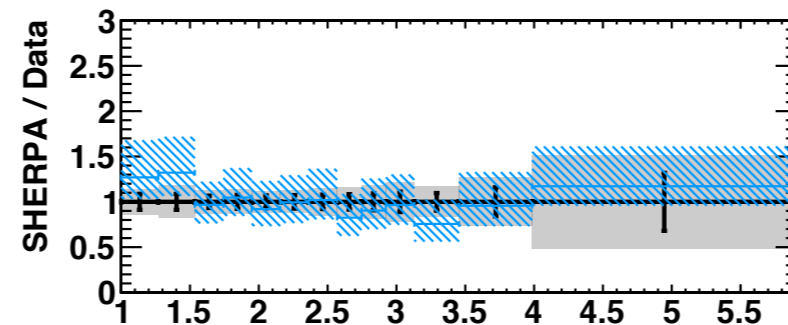
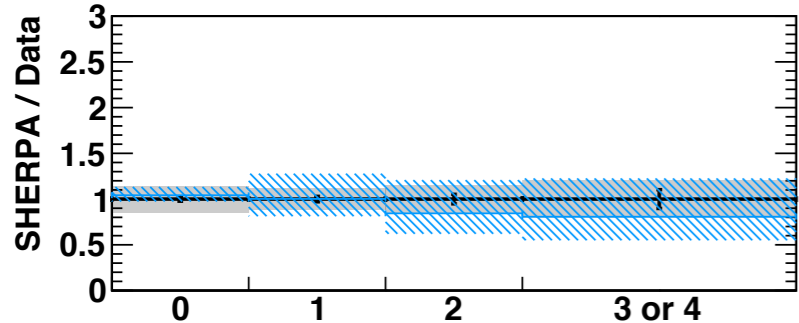
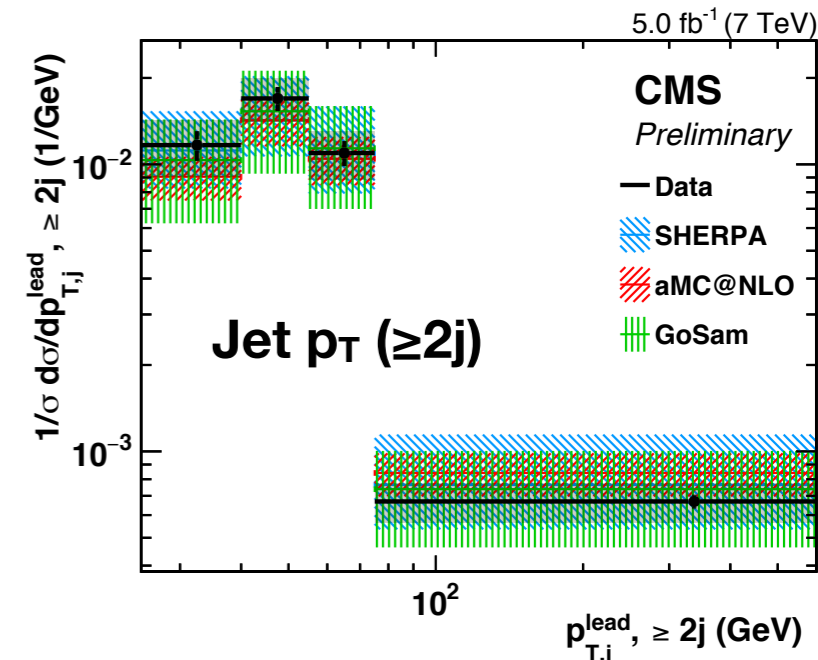
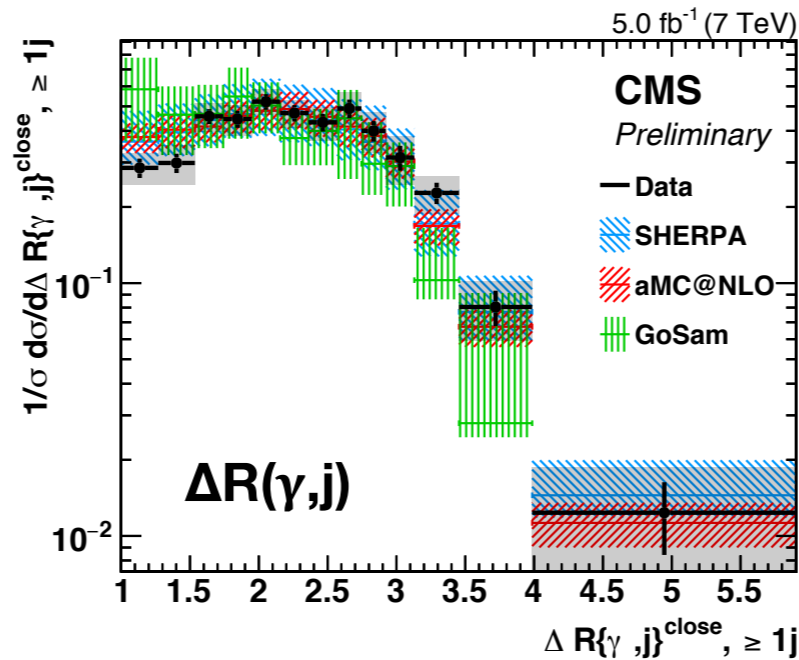
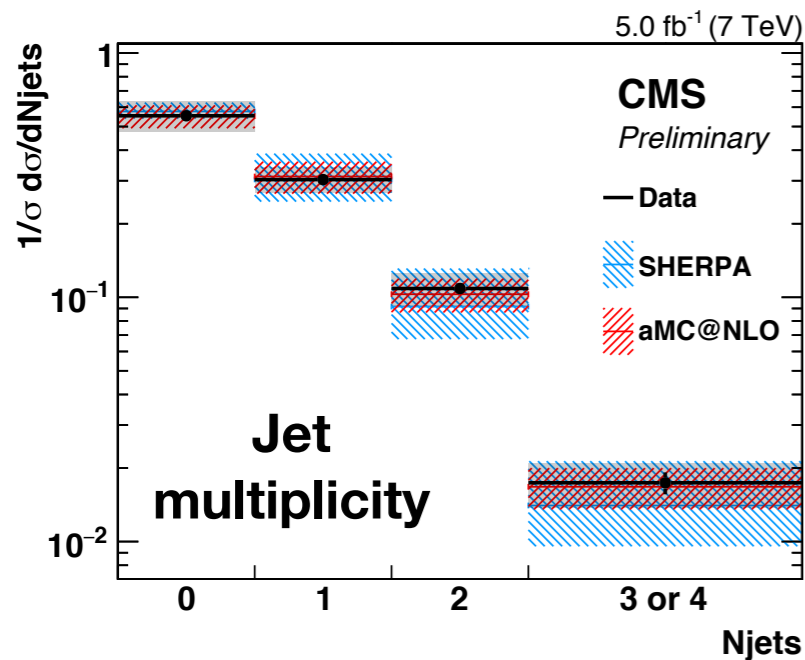




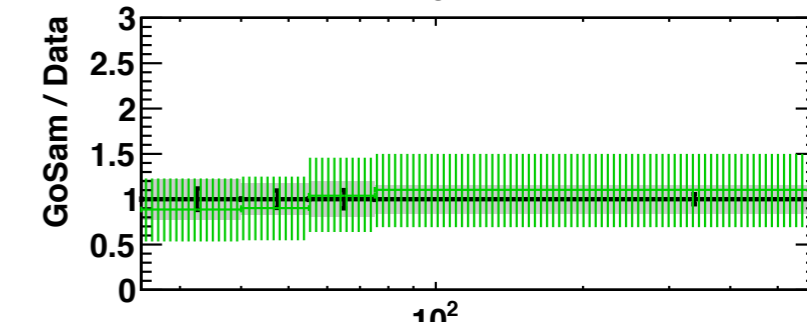
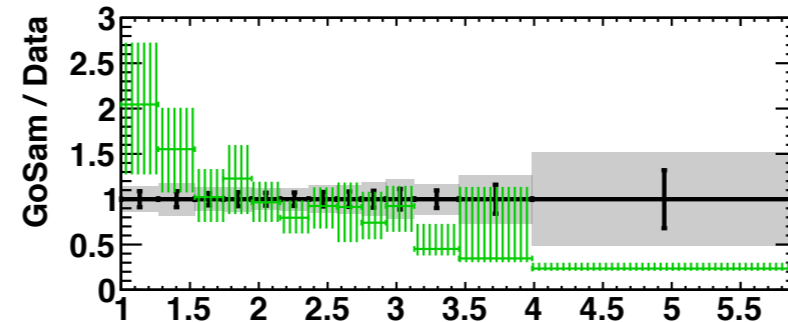
Differential $\gamma\gamma + \text{jets}$ at 7 TeV



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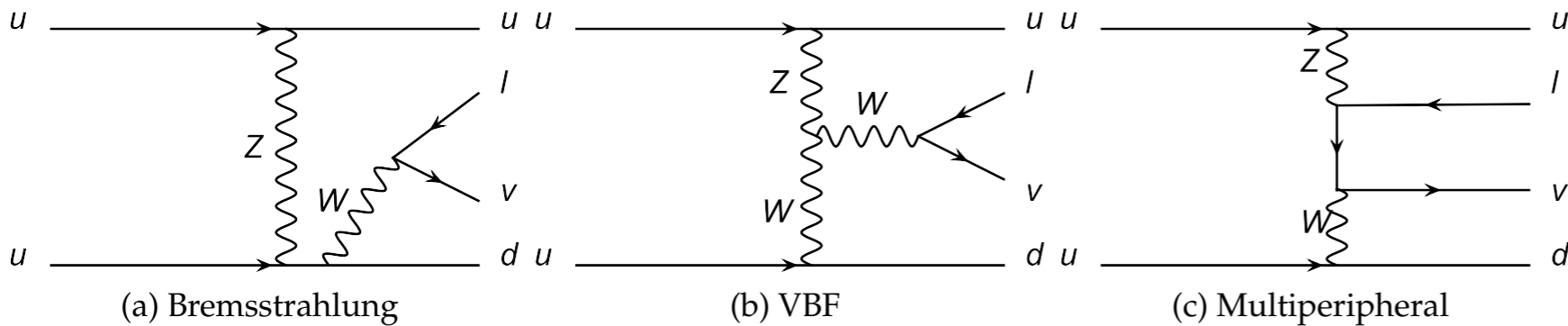
► Comparison with SHERPA, aMC@NLO and GoSam



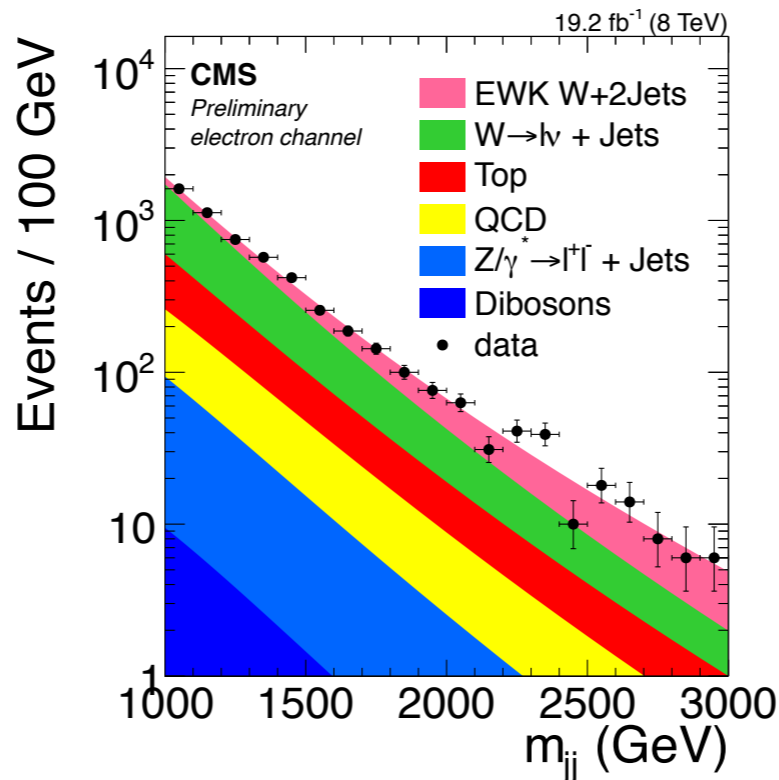
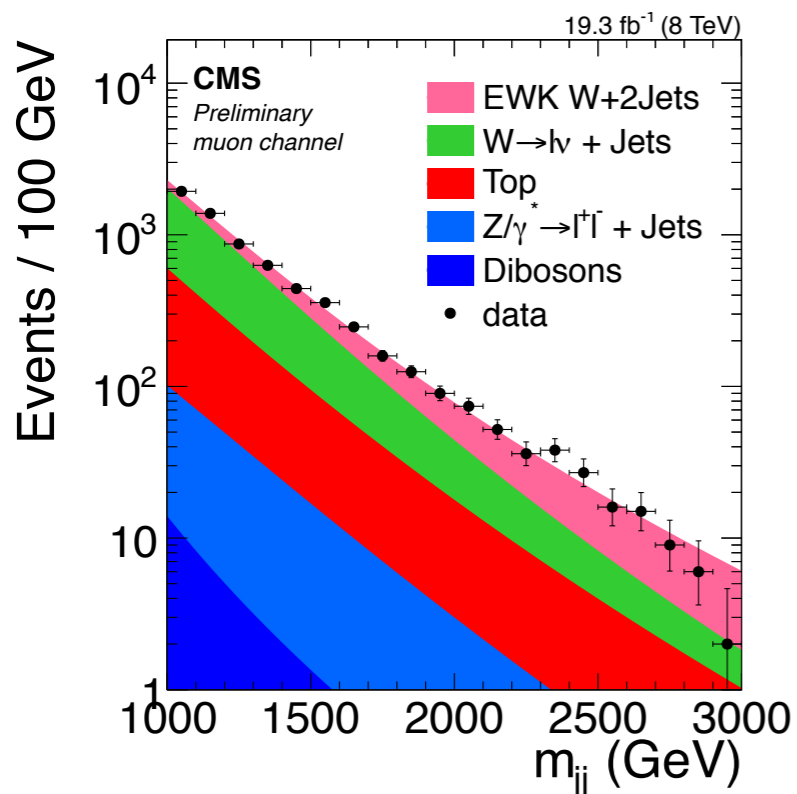
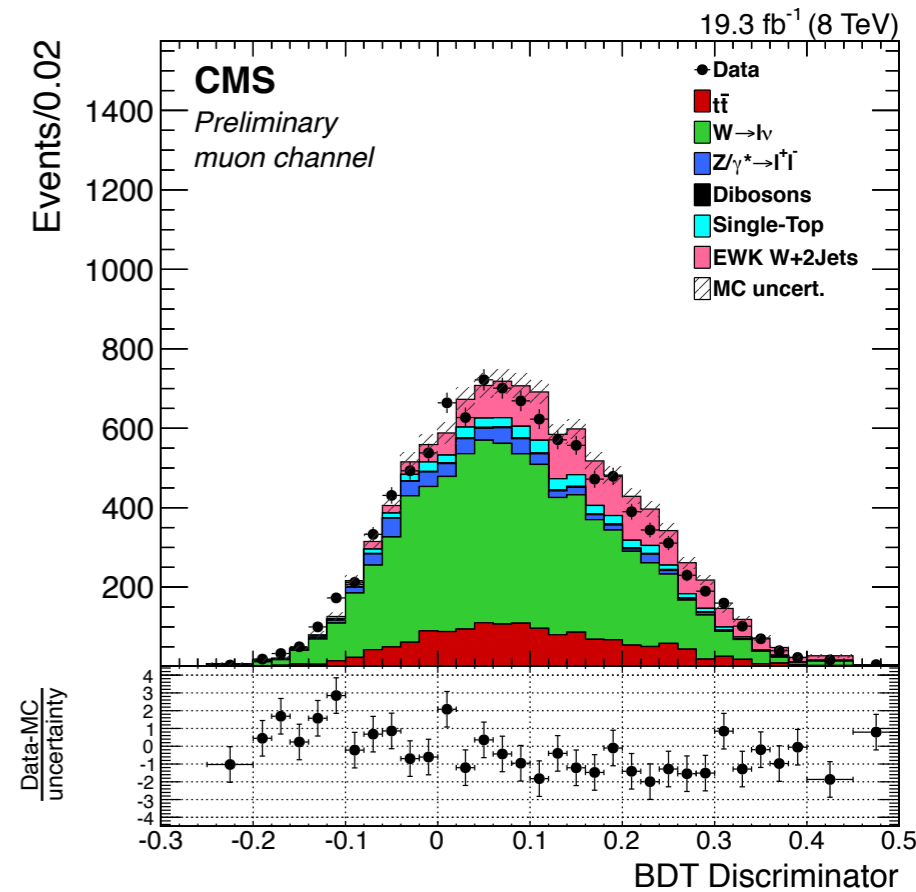


EWK W + 2 jets production

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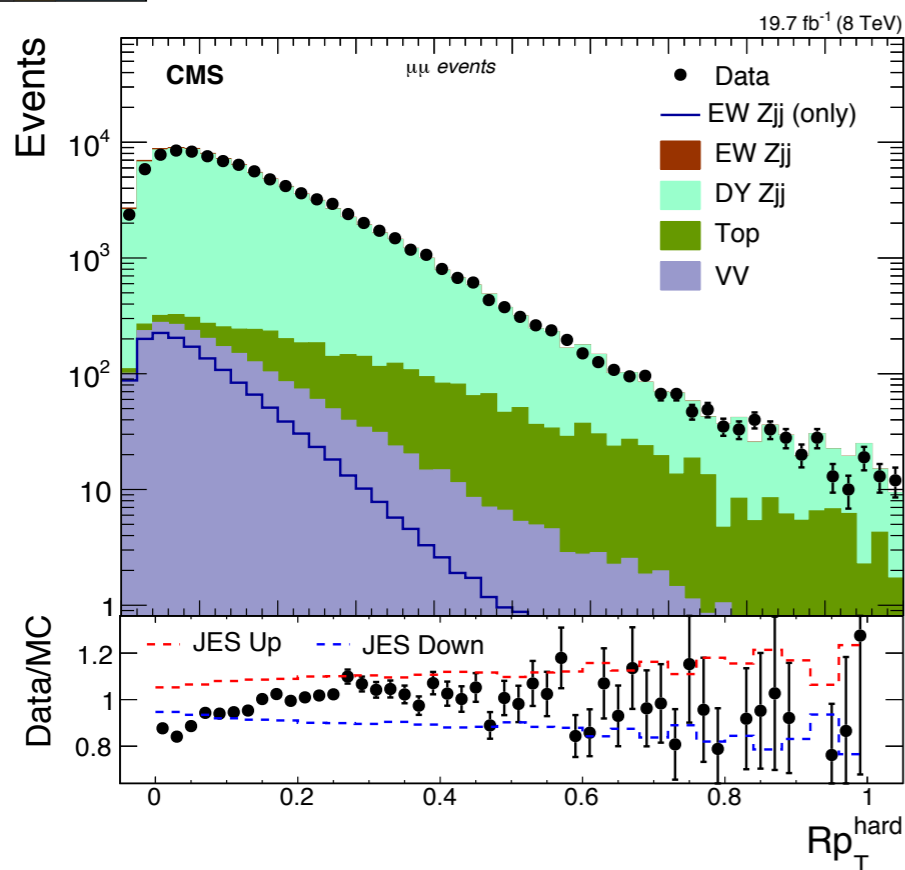


- ▶ Stringent test of SM (aTGC), background to VBF Higgs
- ▶ Different classes of interfering EWK diagrams
- ▶ **Two forward jets with large m_{jj} , discrimination against QCD W+jets from multivariate discriminant**

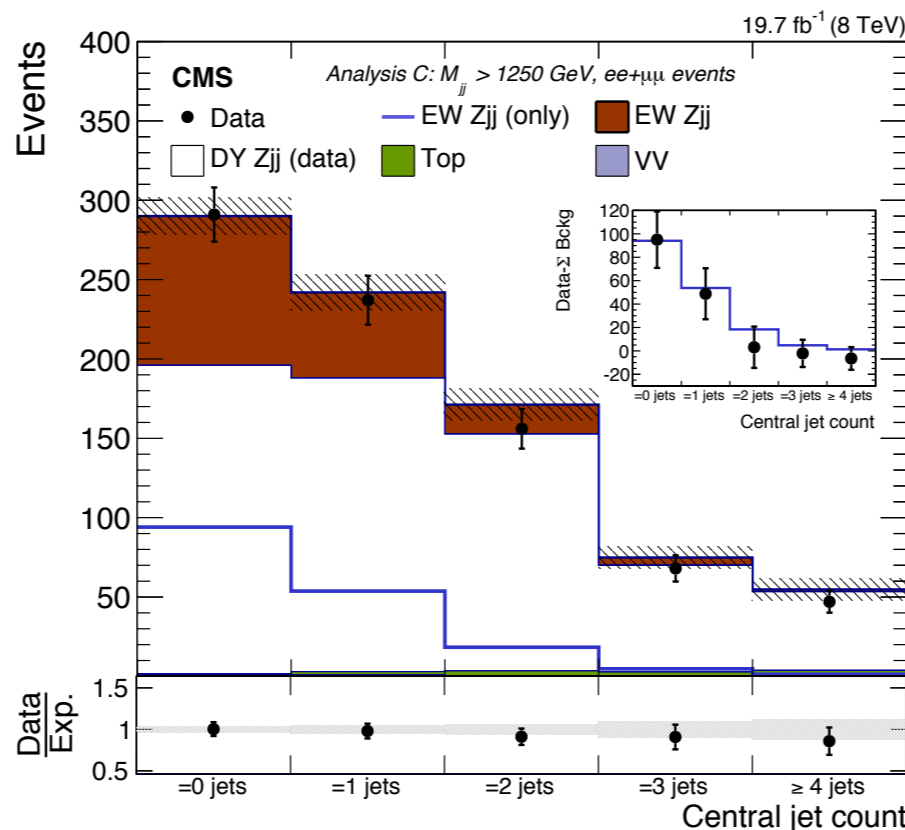
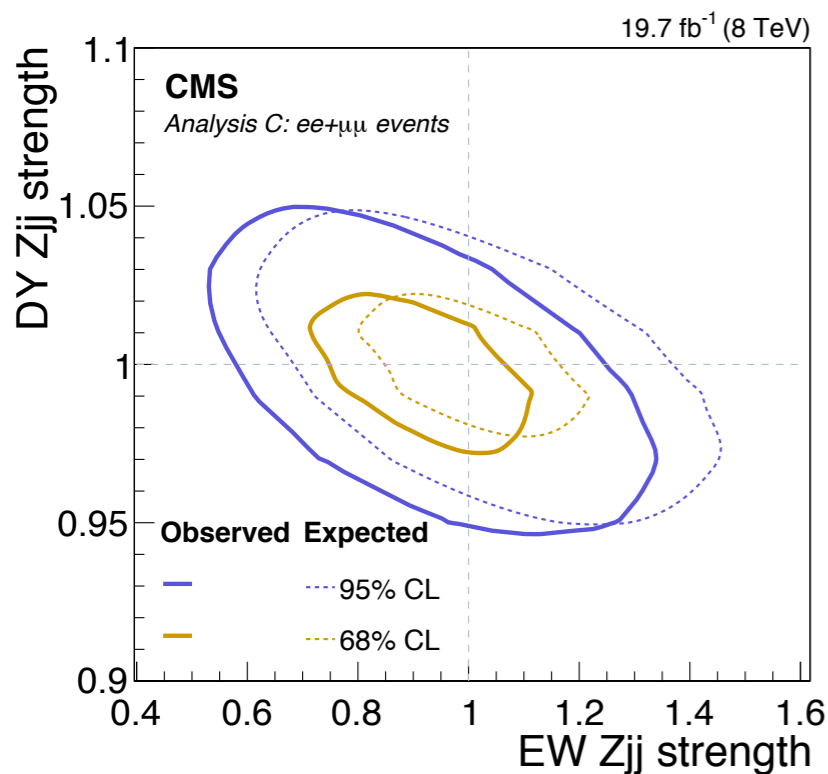


- ▶ Signal extracted via parametric fit to m_{jj} distribution

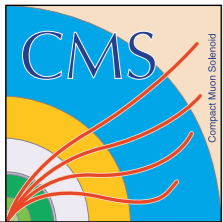
▶ **In agreement with SM**



- ▶ Experimentally challenging: low S/B
- ▶ Background reduced requiring balance between Z and jets + lepton and di-jet multivariate discriminants
- ▶ Data-based **DY Z+2j** prediction from photon control sample

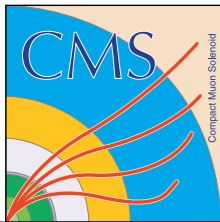


- ▶ **Signal strength in agreement with SM**
- ▶ **Observed suppression of central jet activity**

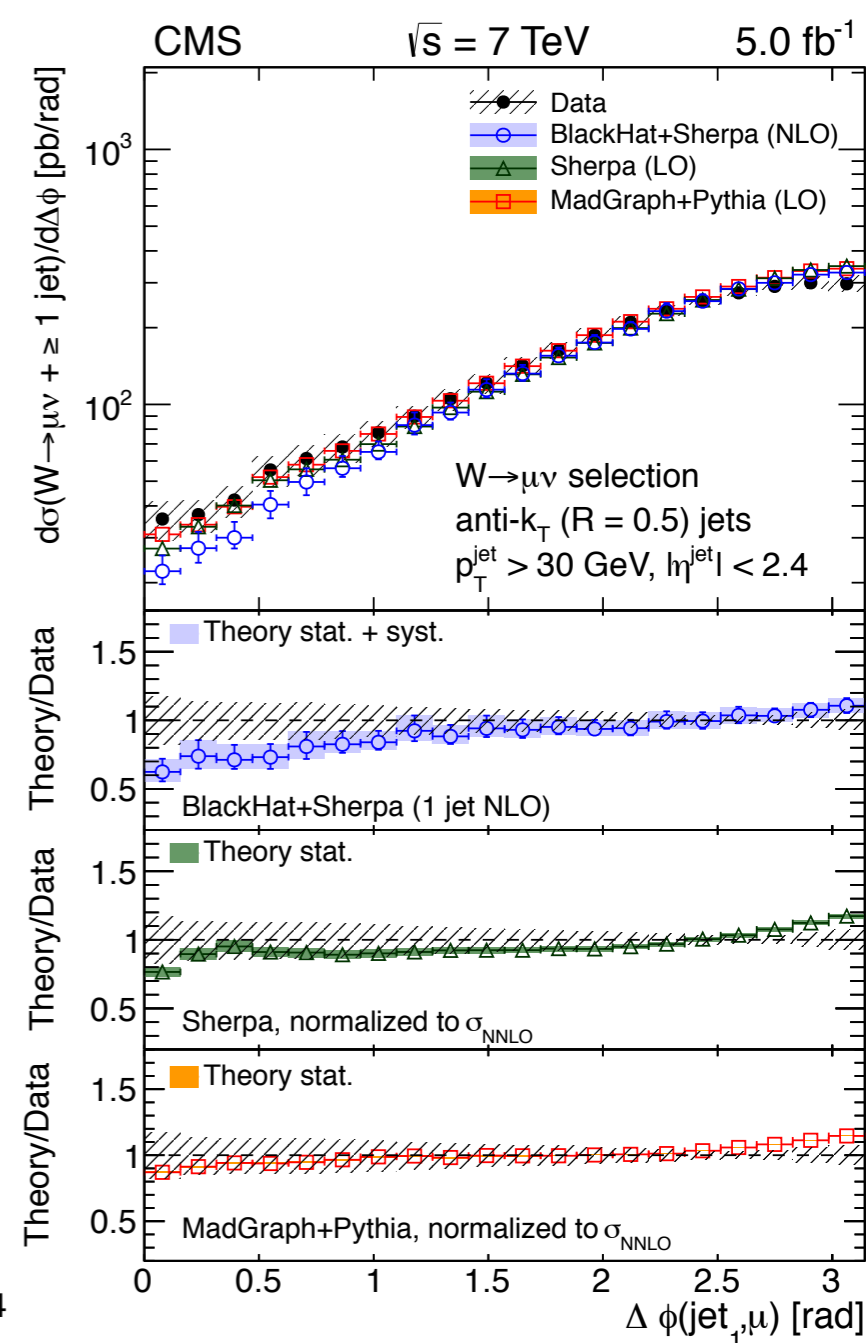
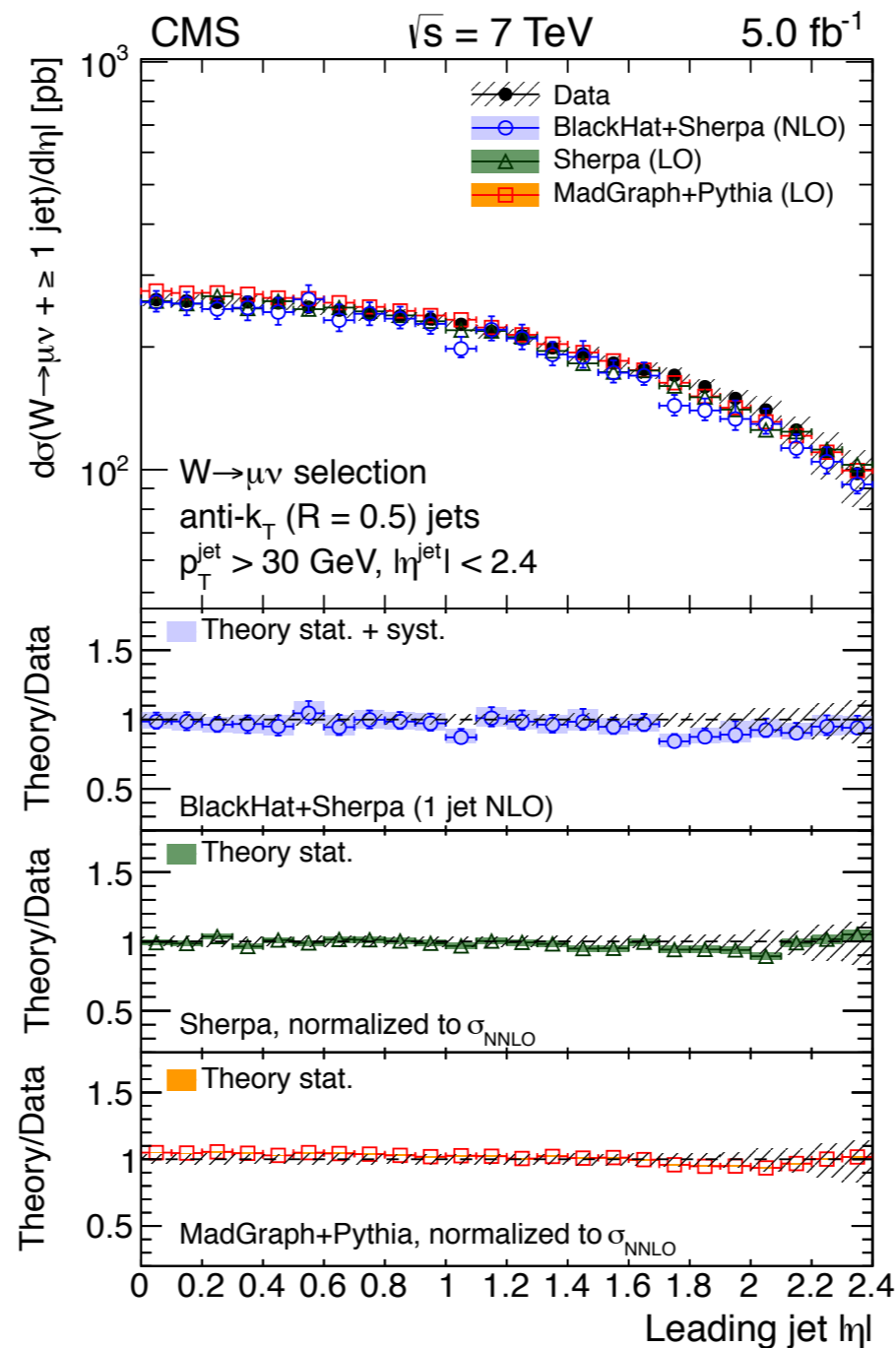
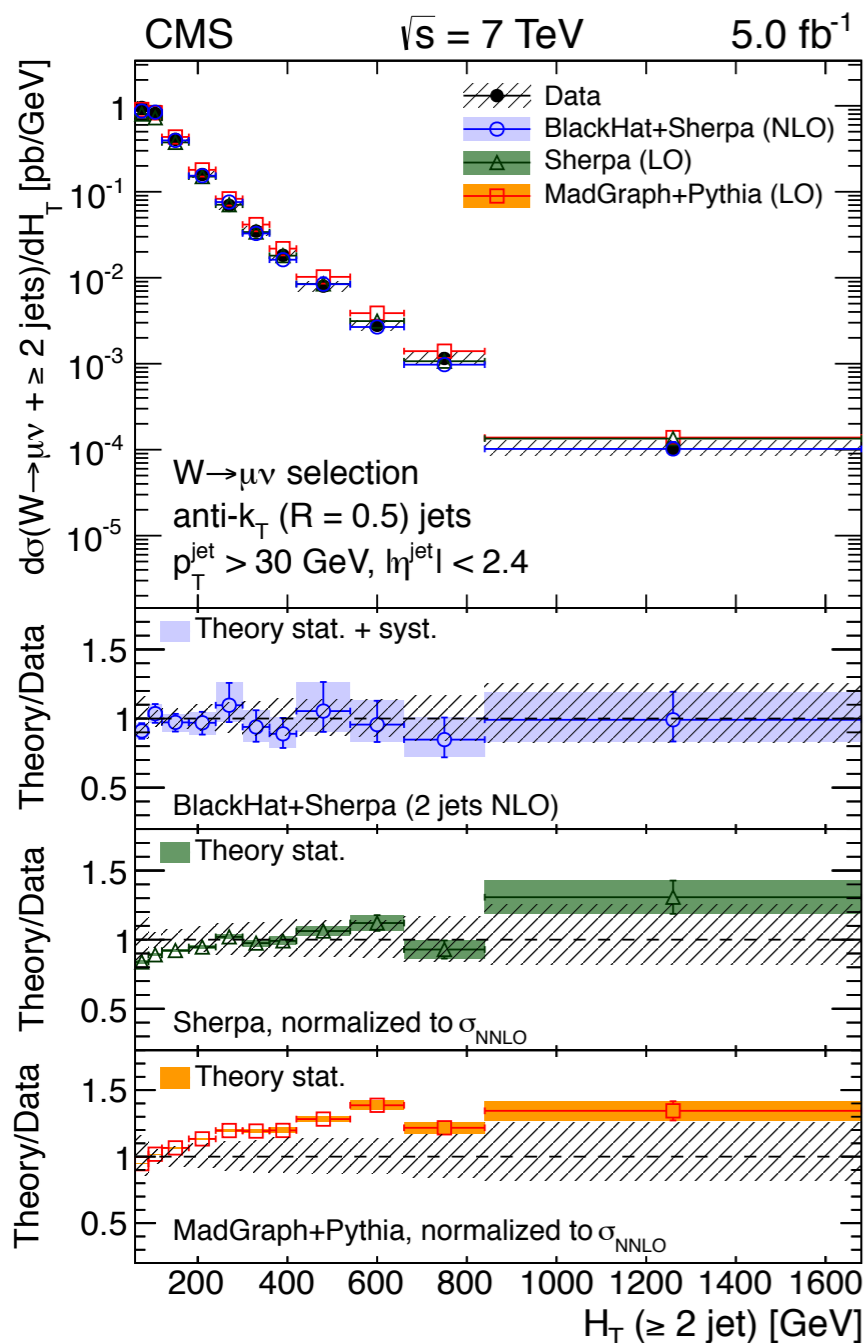


Conclusions

- ▶ Several measurement of $V + \text{jets}$ production at the LHC have been performed by CMS using the 2011 and 2012 datasets
- ▶ Deep understanding of these processes is a key ingredient for success in searches for new physics in Run 2
- ▶ Overall agreement between data and SM predictions is very good
 - ◆ Merged NLO calculations provide the most accurate description
- ▶ Looking forward to Run 2 data to extend the reach of the measurements to regions of the phase space not probed yet

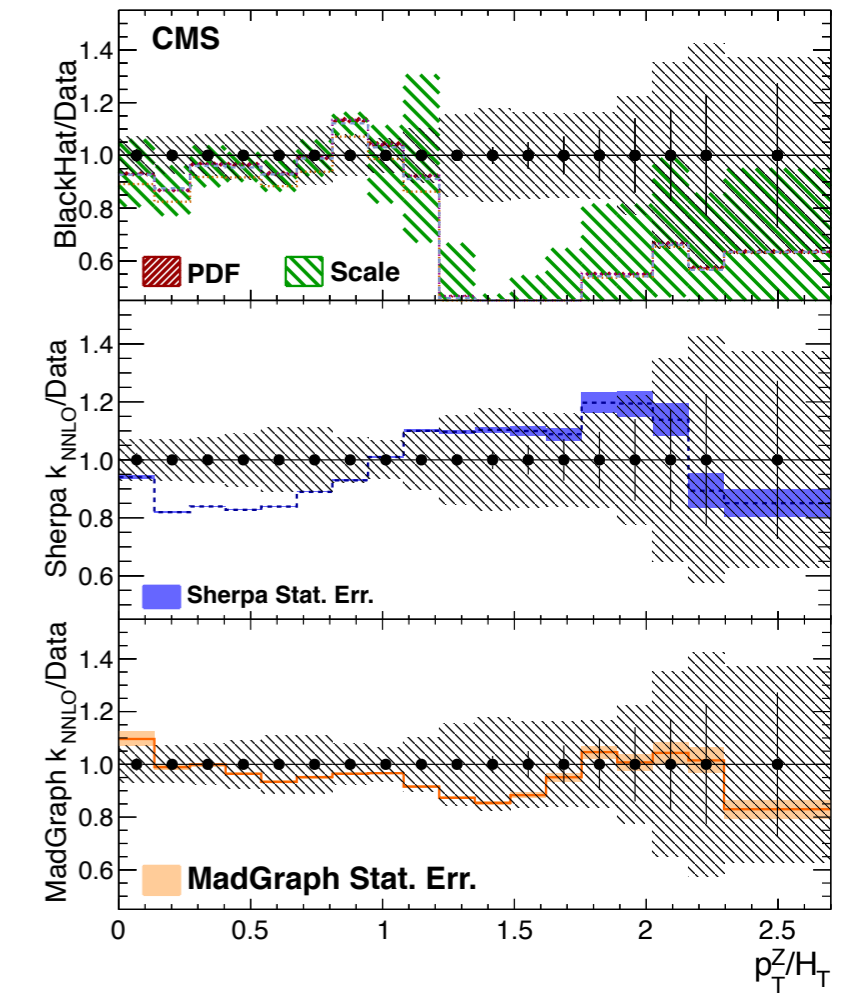
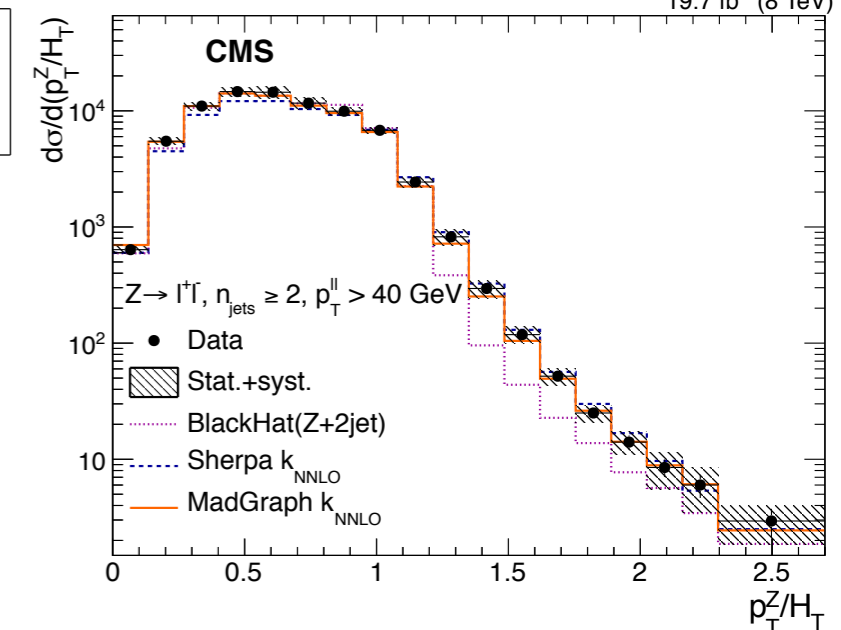
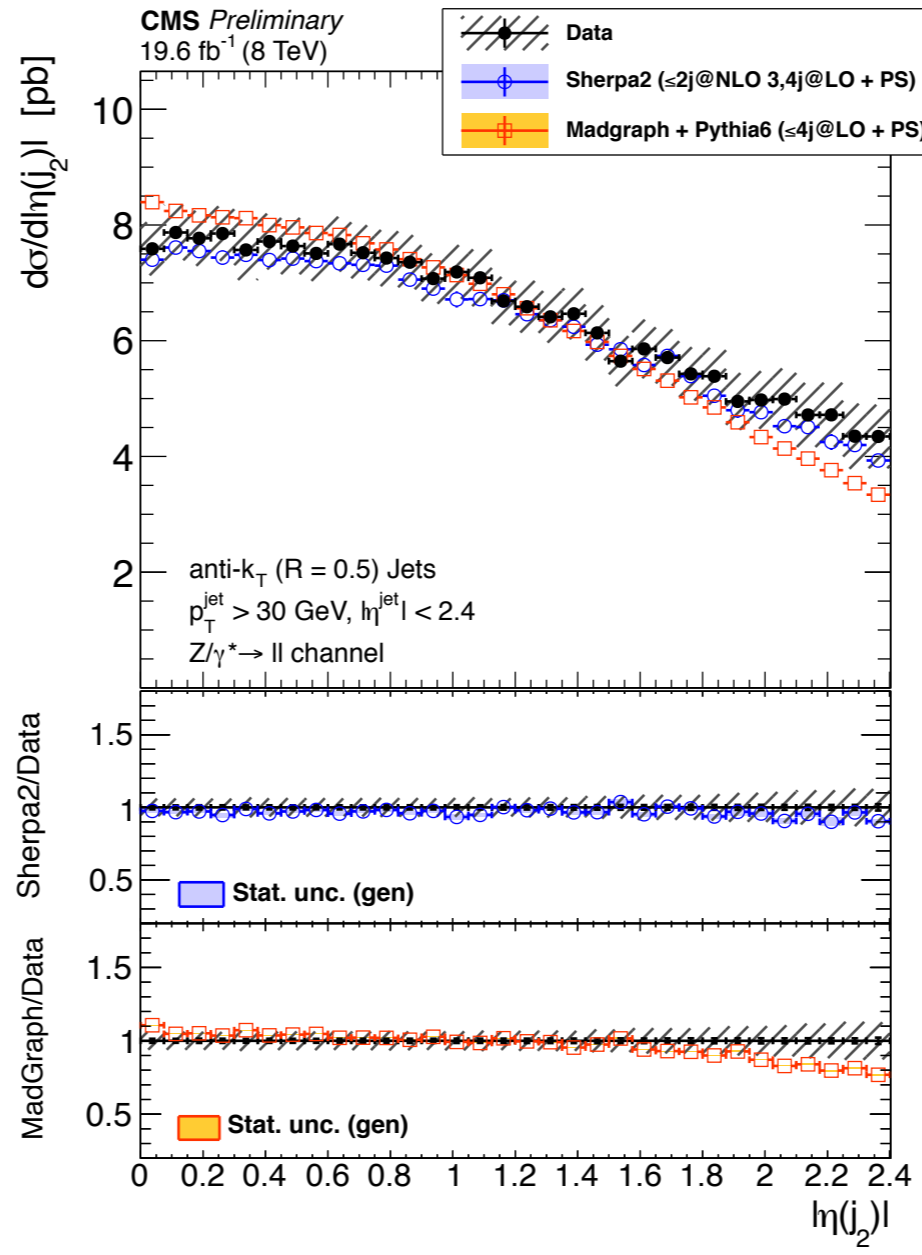
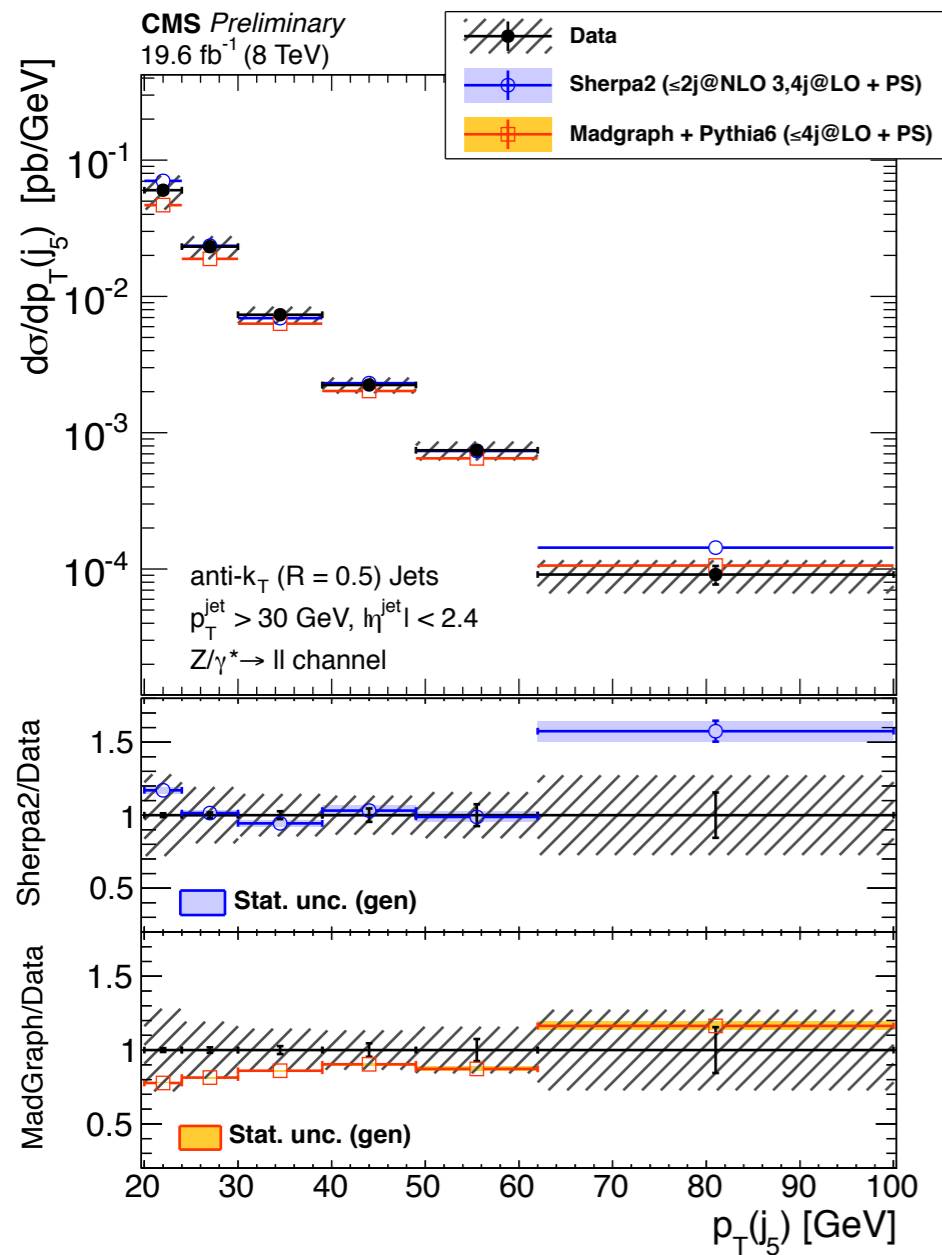


Backup slides



- ▶ H_T , jet η and angular correlation distributions are measured in several jet multiplicity bins

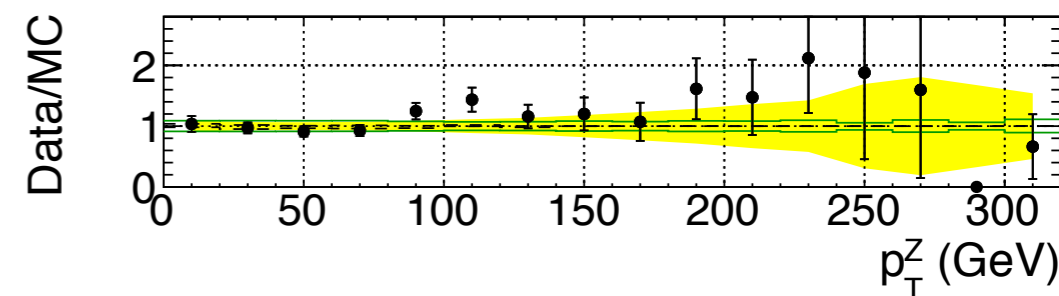
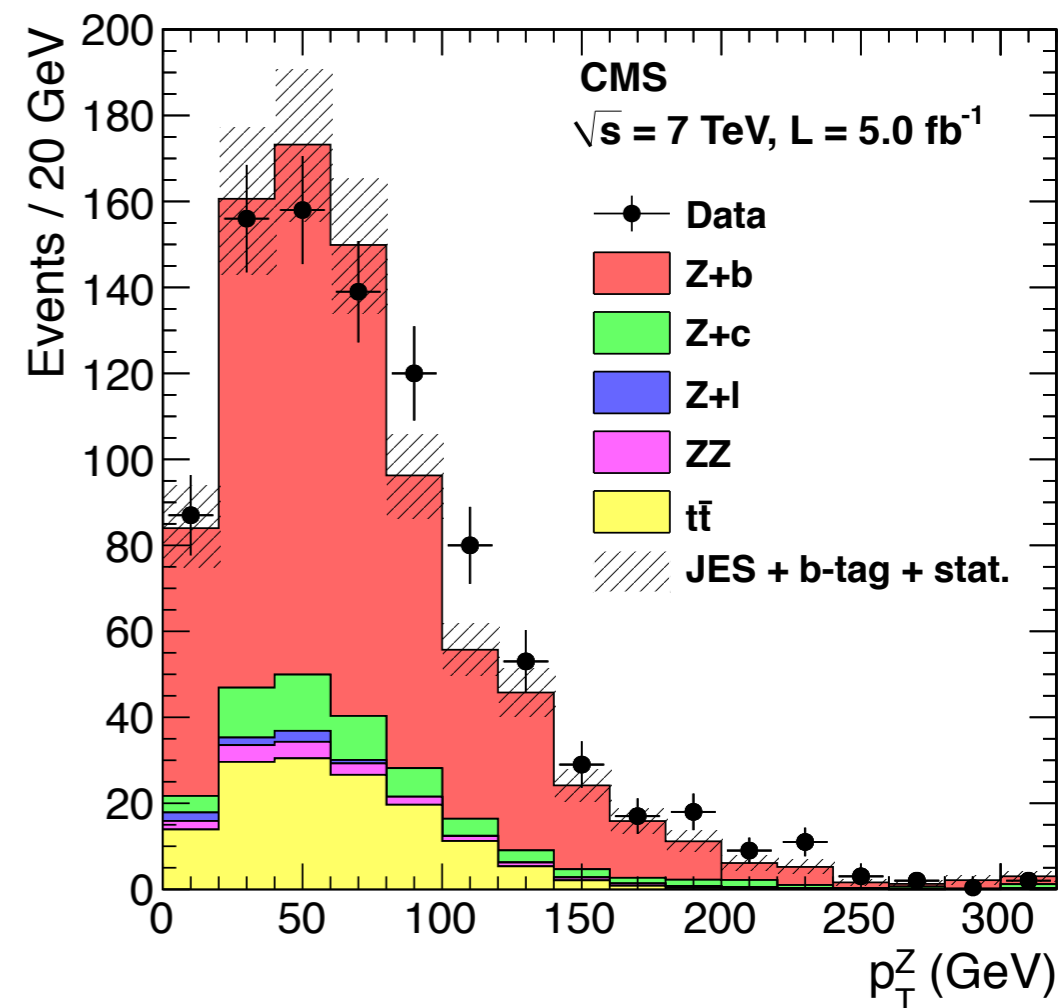
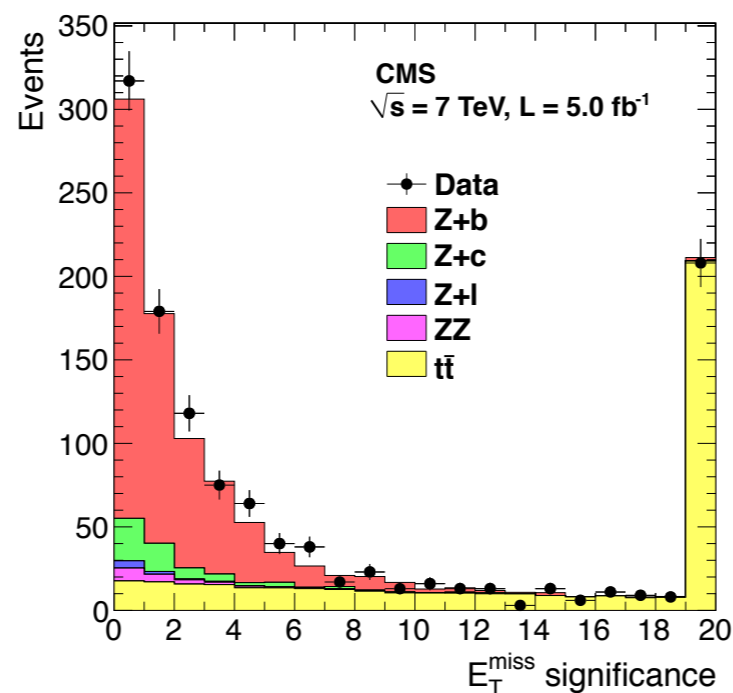
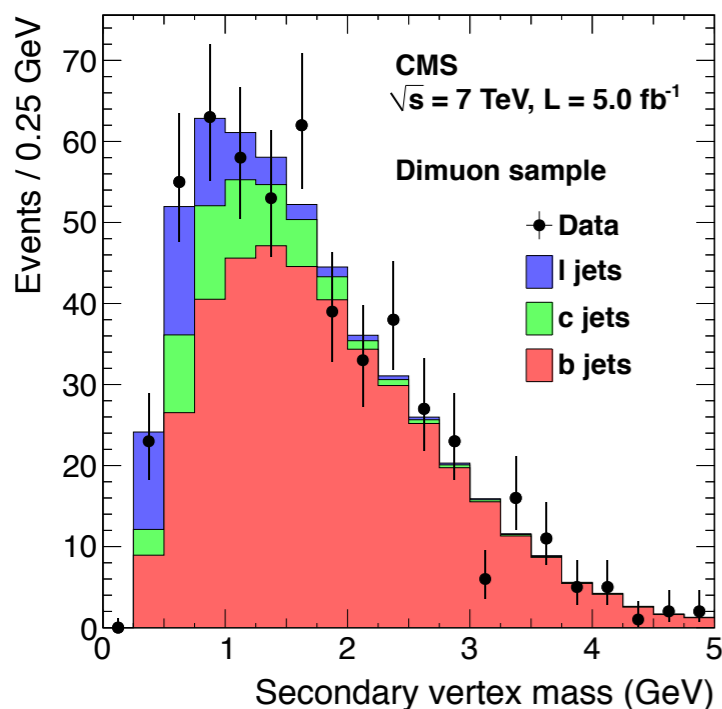
Differential Z+jets at 8 TeV



- Z+5j differential measurement, angular distributions, and Z+jets event observables

CERN-PH-EP/2015-089 (SMP-14-005), CMS PAS SMP-13-007

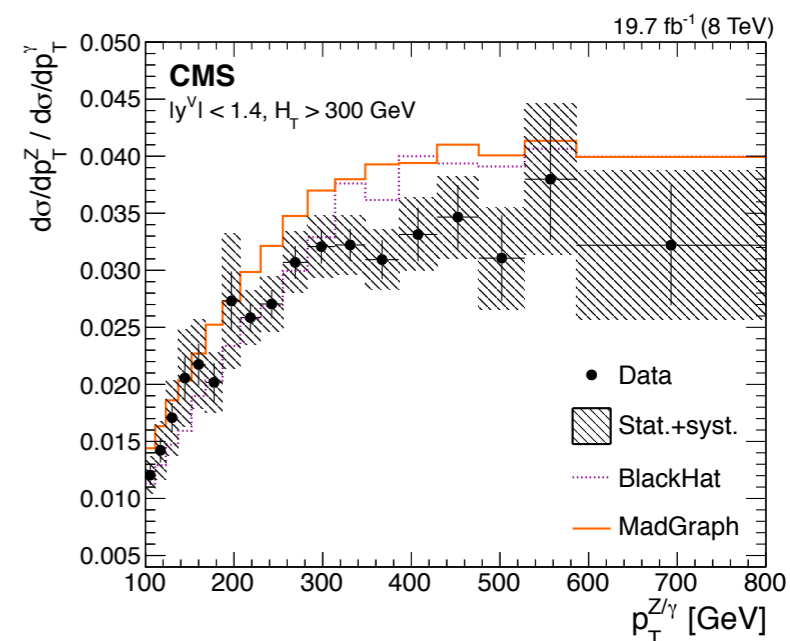
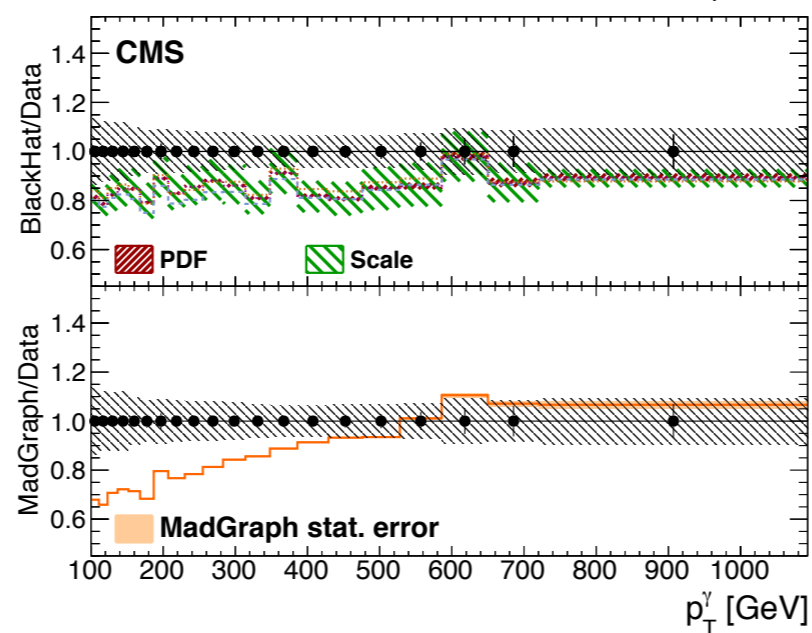
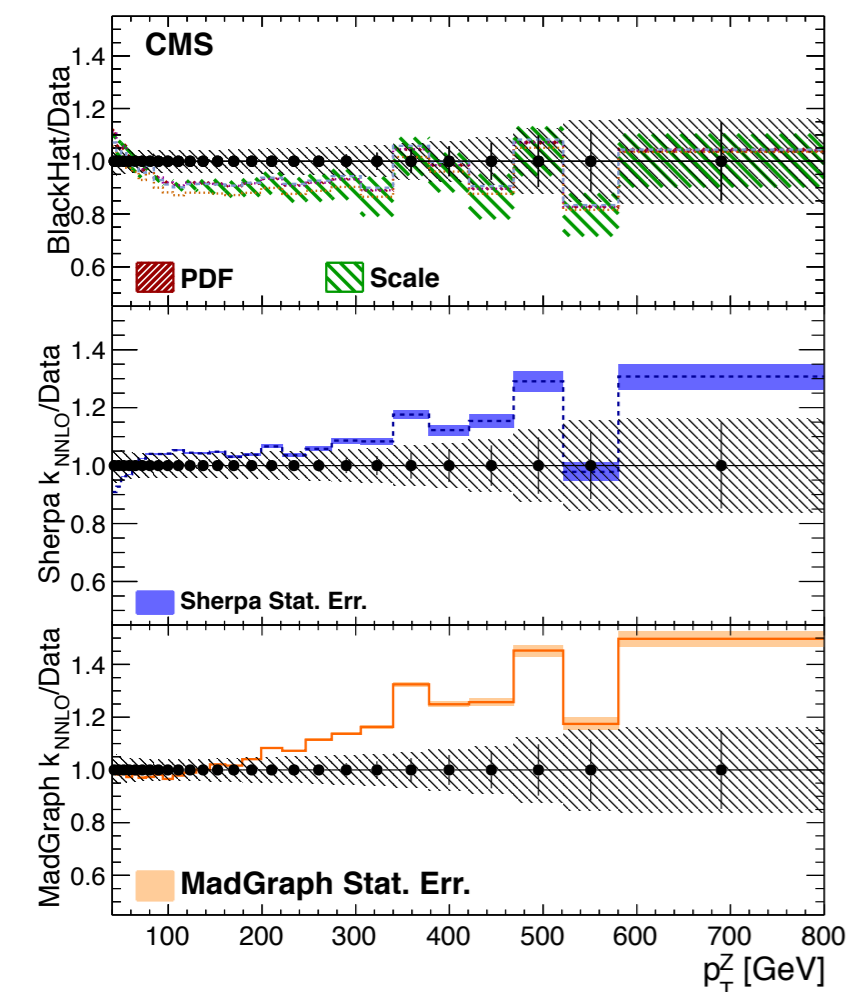
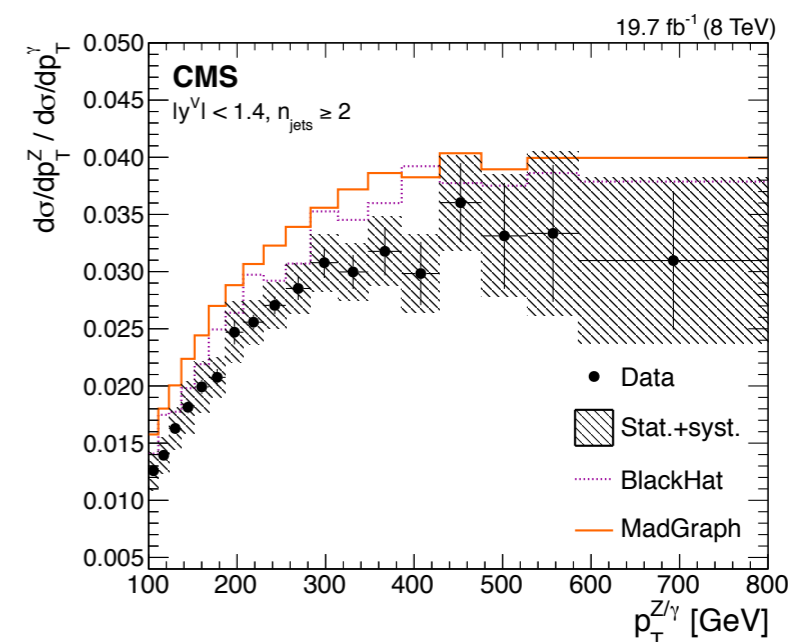
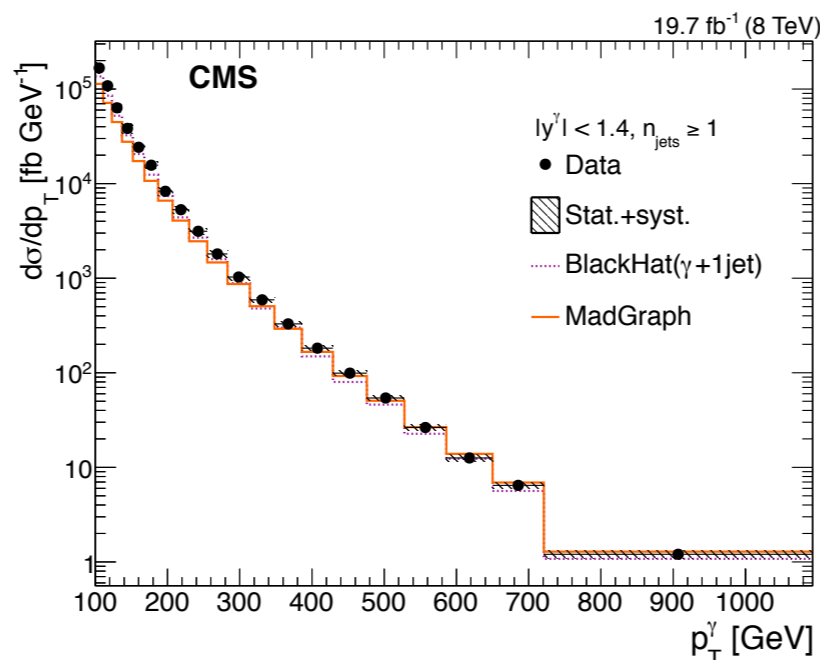
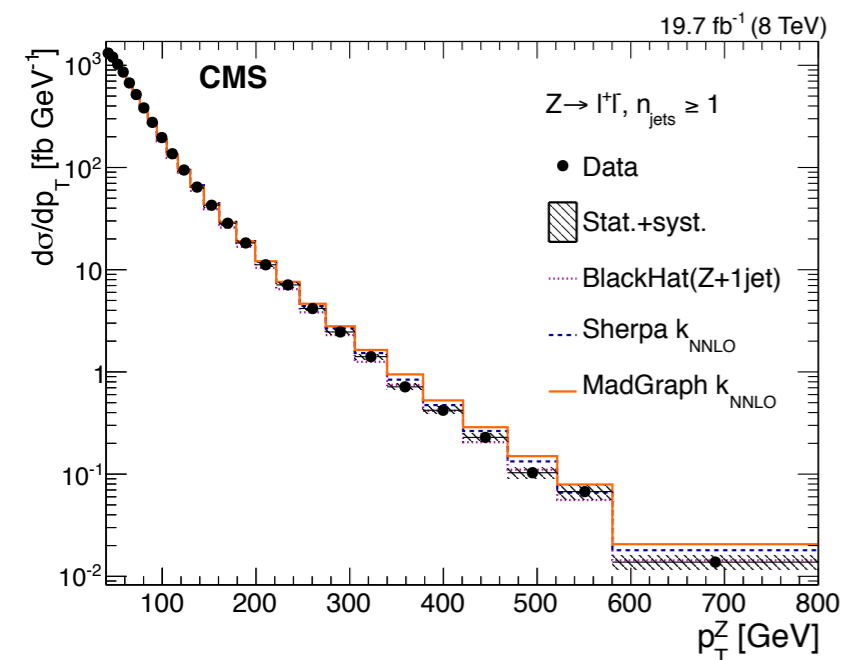
- ▶ Reject events with significant MET to reduce $t\bar{t}$ background
- ▶ b-jet mistag rate measured from template fit to secondary vertex mass
- ▶ Unfolding performed as a function of b-jet multiplicity



- ▶ Slightly harder $Z p_T$ spectrum w.r.t. Madgraph prediction

Differential Z/ γ ratio at 8 TeV

CERN-PH-EP/2015-089 (SMP-14-005)

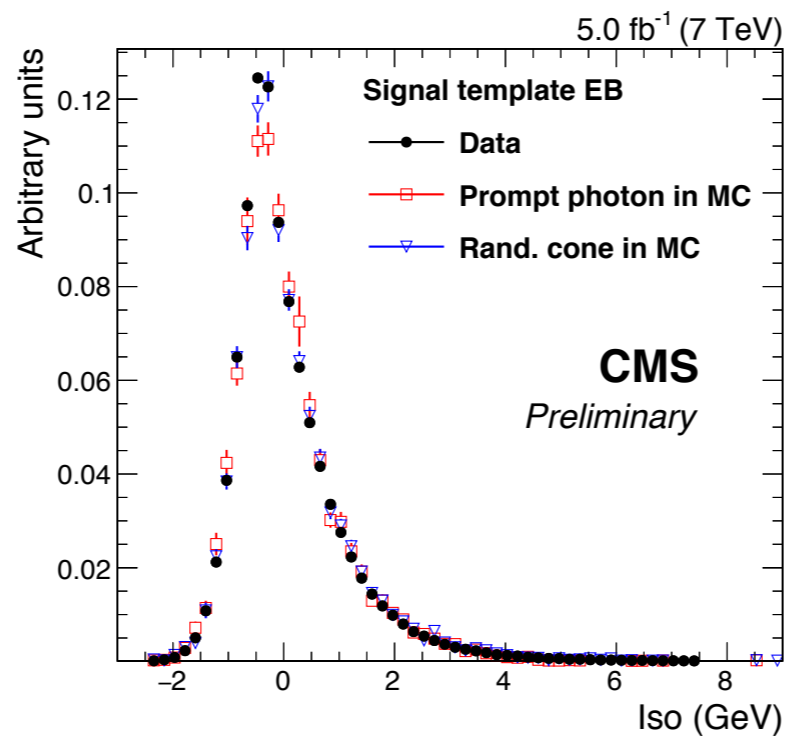
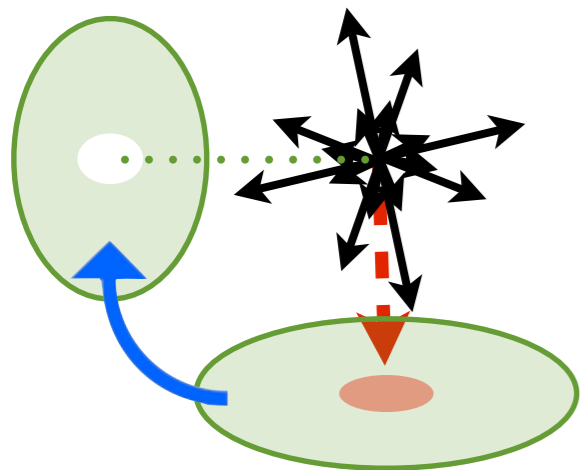


► Probing several regions of the phase space important for modeling Z → νν background

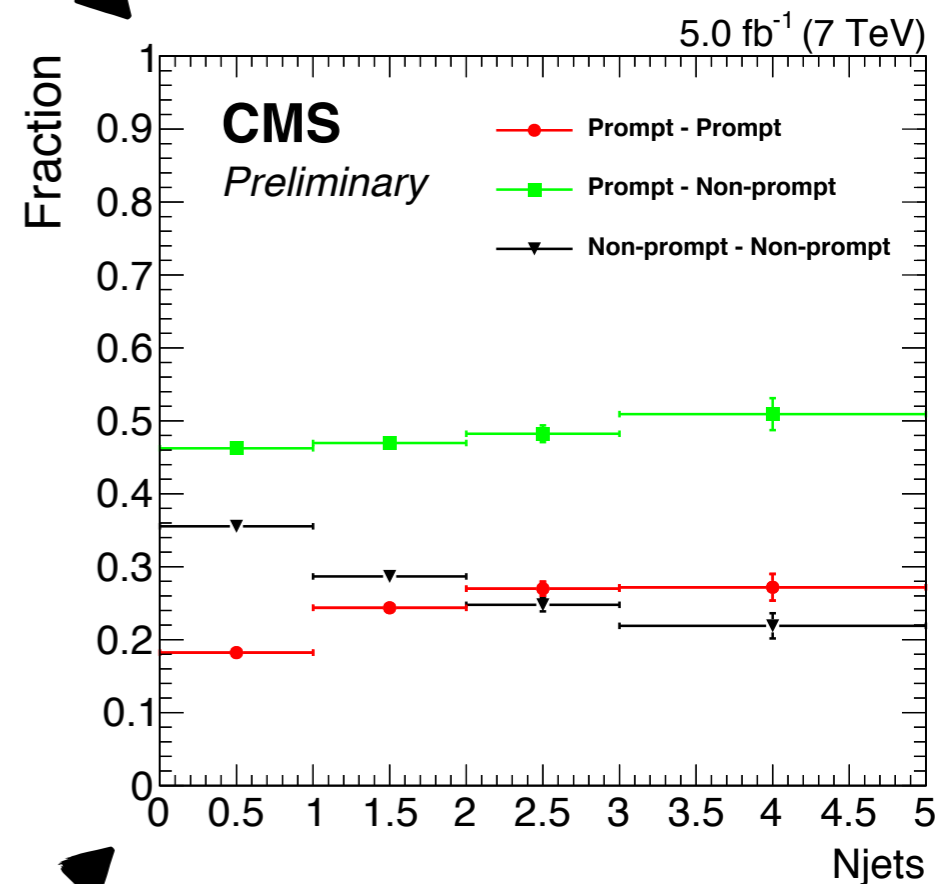
Differential $\gamma\gamma + \text{jets}$ at 7 TeV

CMS PAS SMP-14-021

Random cone to predict prompt photon isolation



► Diphoton purity fit based on isolation templates:

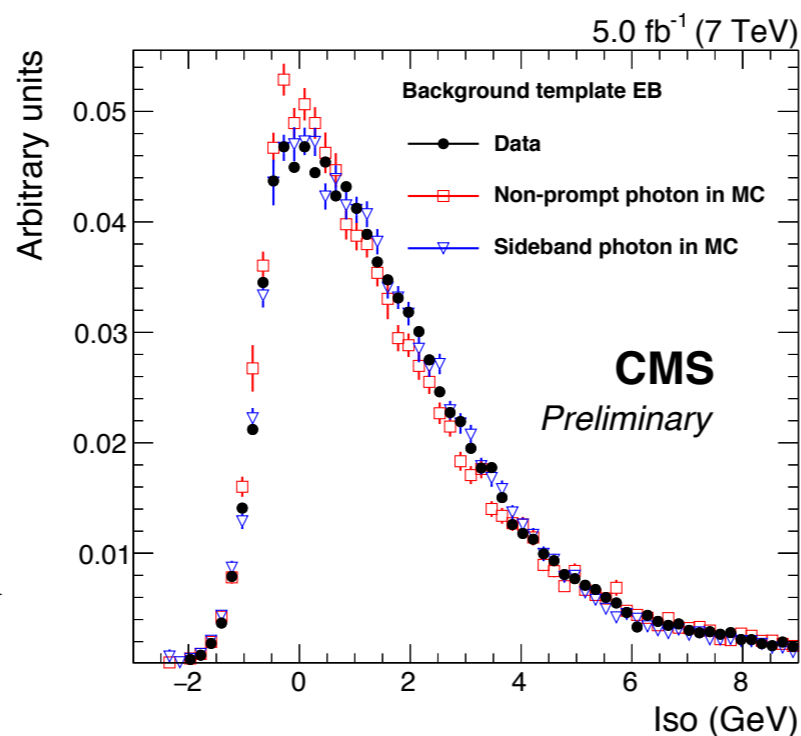


Selection region

γ

π^0

Shower width



Differential $\gamma\gamma + \text{jets}$ at 7 TeV

CMS PAS SMP-14-021

