



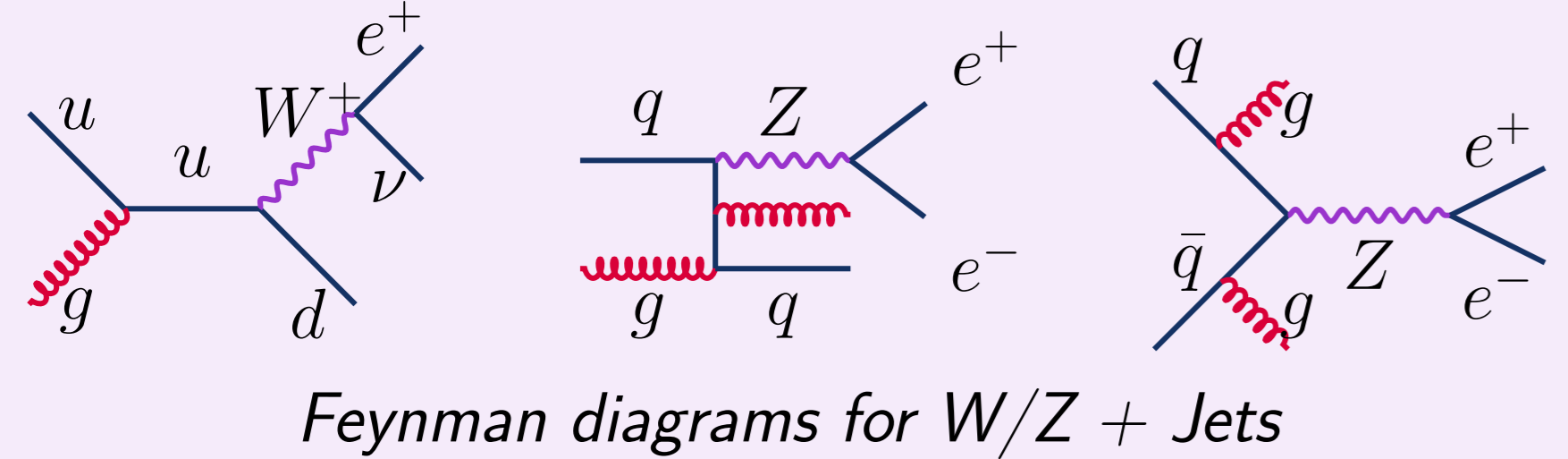
# Rates of Jets Produced in Association with W and Z Bosons in pp Collisions at $\sqrt{s} = 7$ TeV

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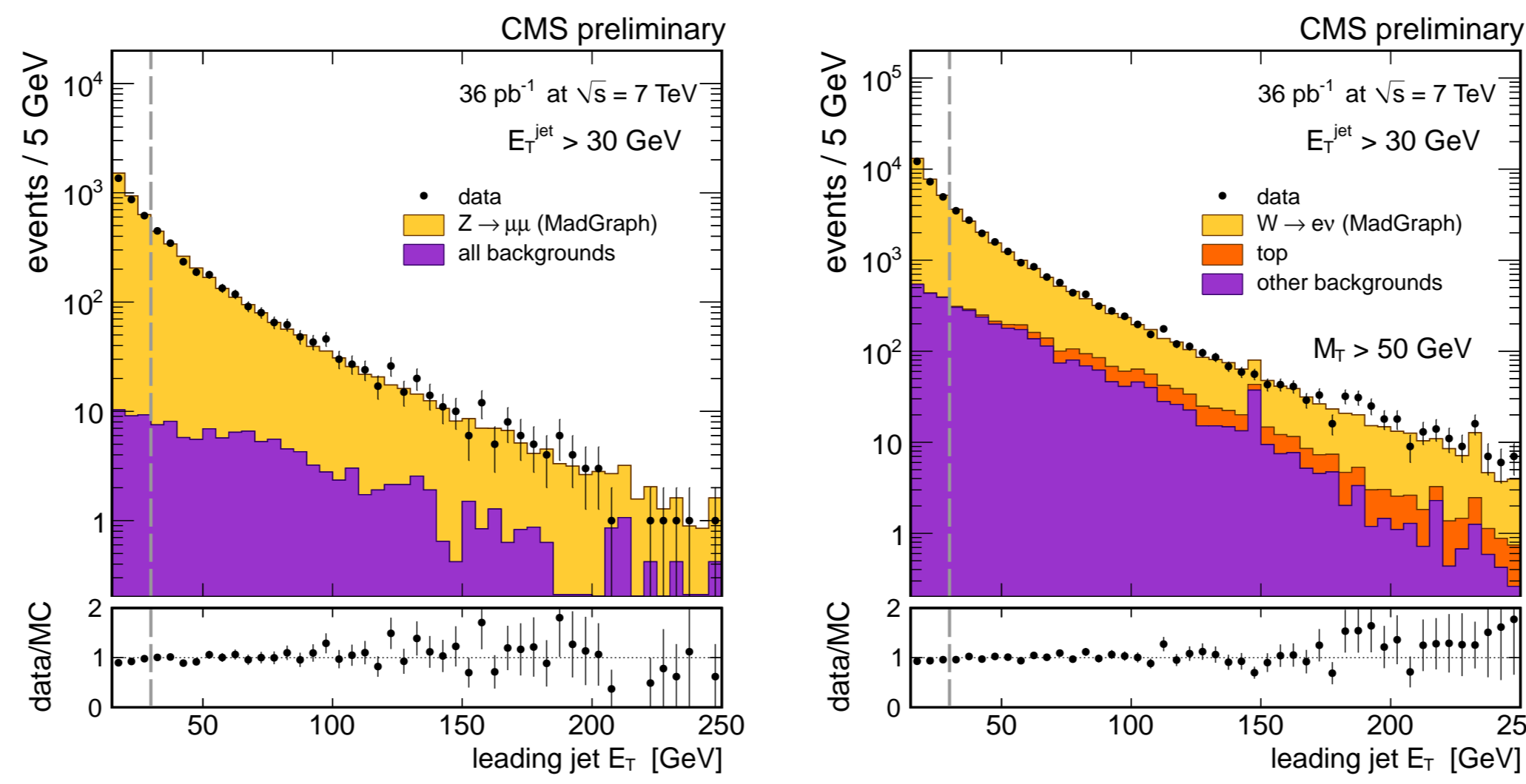


## Introduction

The results of jets produced in association with vector bosons are presented, using  $36 \text{ pb}^{-1}$  data collected by CMS during the 2010 run period at  $\sqrt{s} = 7$  TeV. The transverse energy distributions of the leading jets is measured and compared to theoretical expectations. The ratios of jet multiplicities,  $\sigma(V+n+1)/\sigma(V+n)$  and  $\sigma(V+n)/\sigma(V_{total})$  where n stands for number of jets, are also presented, corrected for efficiency and unfolded for detector effects. In addition, the first test of Berends-Giele scaling at the LHC is also shown.



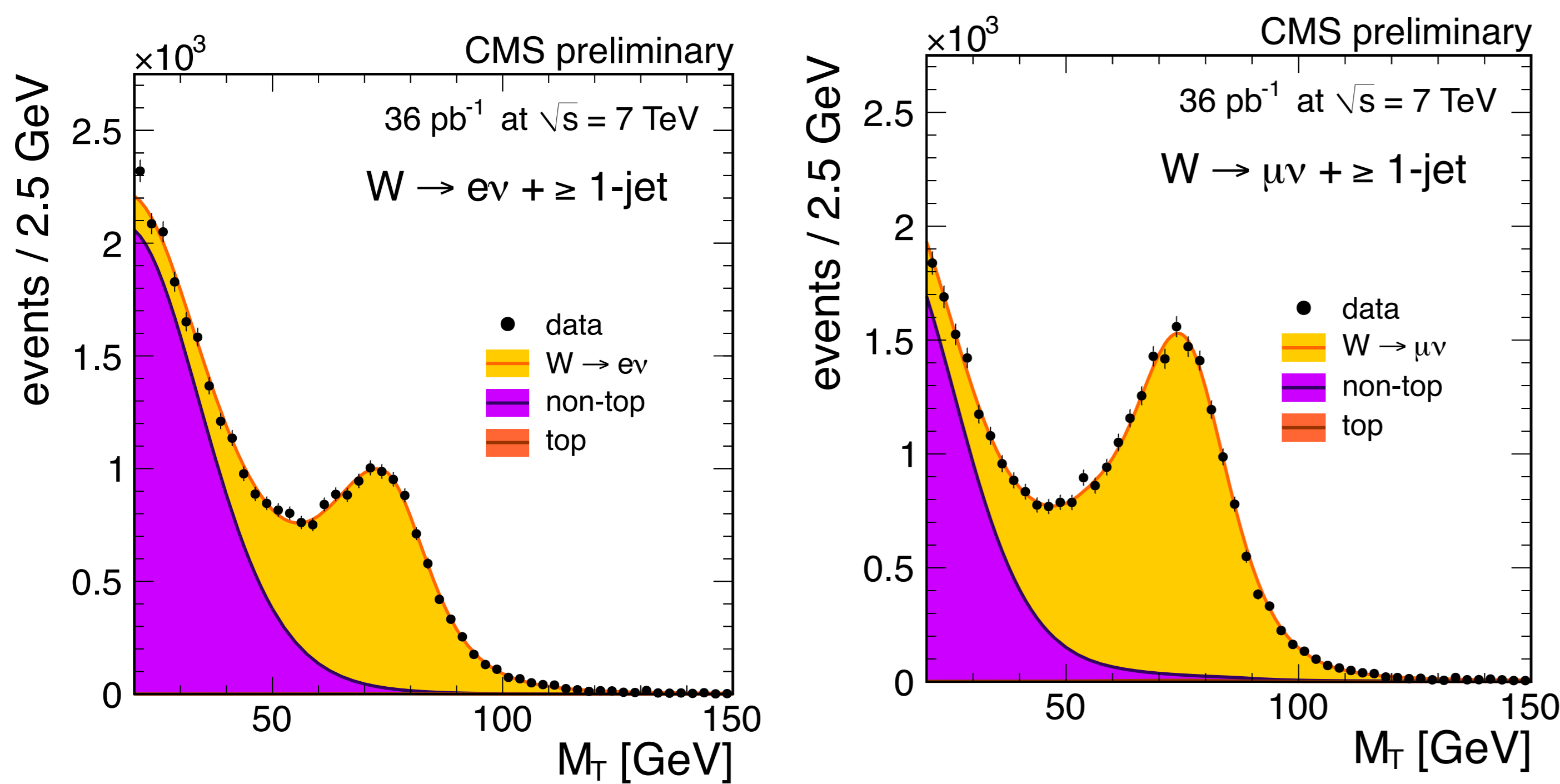
## Leading Jet Transverse Momentum



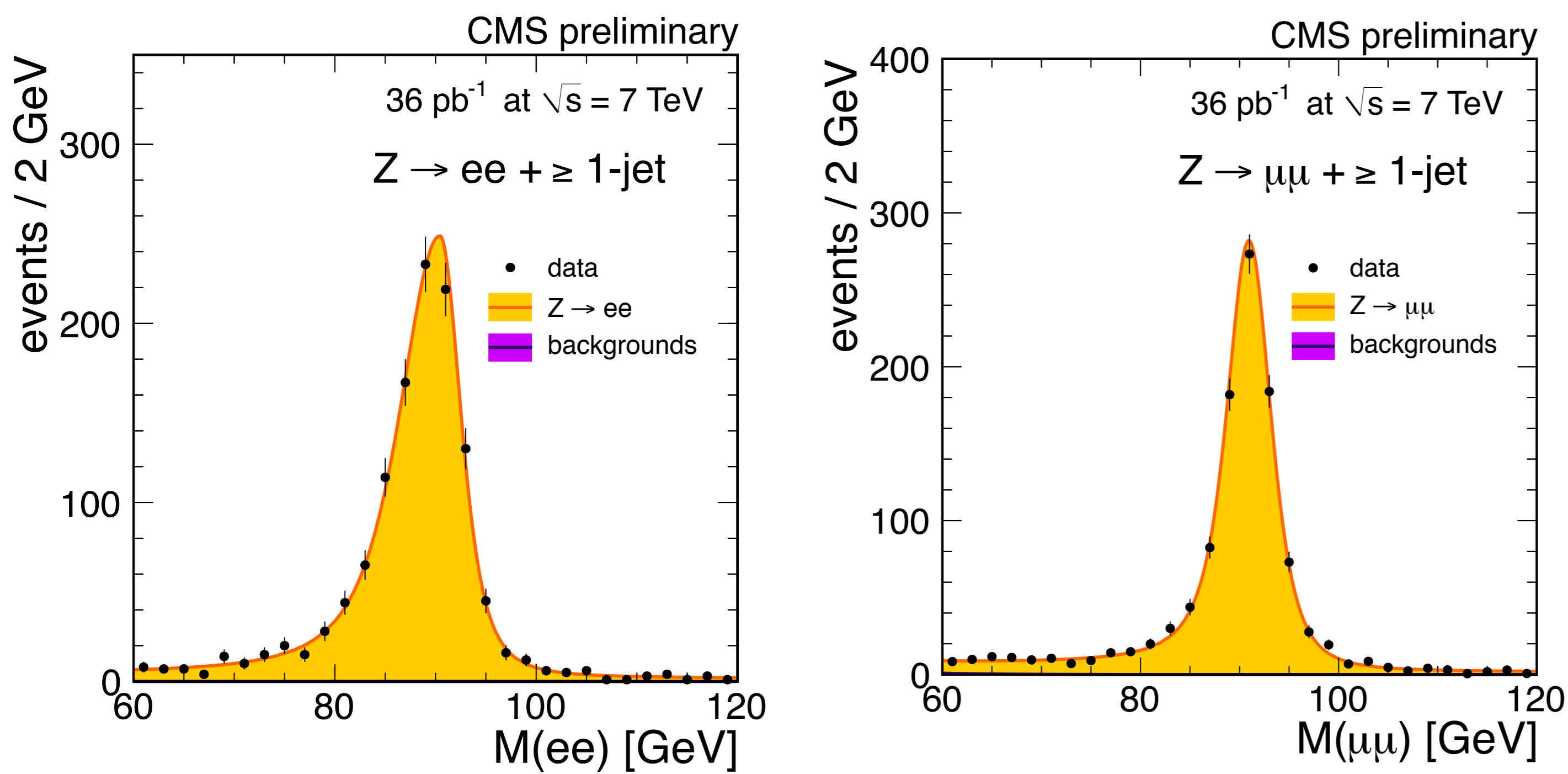
## Event Selection

Cut Variables	Electron (2 <sup>nd</sup> electron)	Muon (2 <sup>nd</sup> muon)
$p_T$	20 (10) GeV, expect energetic electron from boson	20 (10) GeV, expect energetic muon from boson
$ \eta $	2.5, tracker acceptance	2.1 (2.4), tracker and hlt acceptance
Identification	Distinguish from fake electrons	Distinguish fake muons, punch-through, noise
Conversion rejection	Discriminate against photons converting in the tracker	-----
Isolation	Eliminates electrons found in jets, $p_T$ dependent	Eliminates muons found in jets, $p_T$ dependent
Z selection	Two, one looser ID and Isolation $60 < m_Z < 120$ GeV	Two, one looser ID and Isolation $60 < m_Z < 120$ GeV
W selection	Exactly one, tight ID and Isolation, $m_T > 20$ GeV	Exactly one, tight ID and Isolation, $m_T > 20$ GeV

## Fits to Z Mass and W Transverse Mass



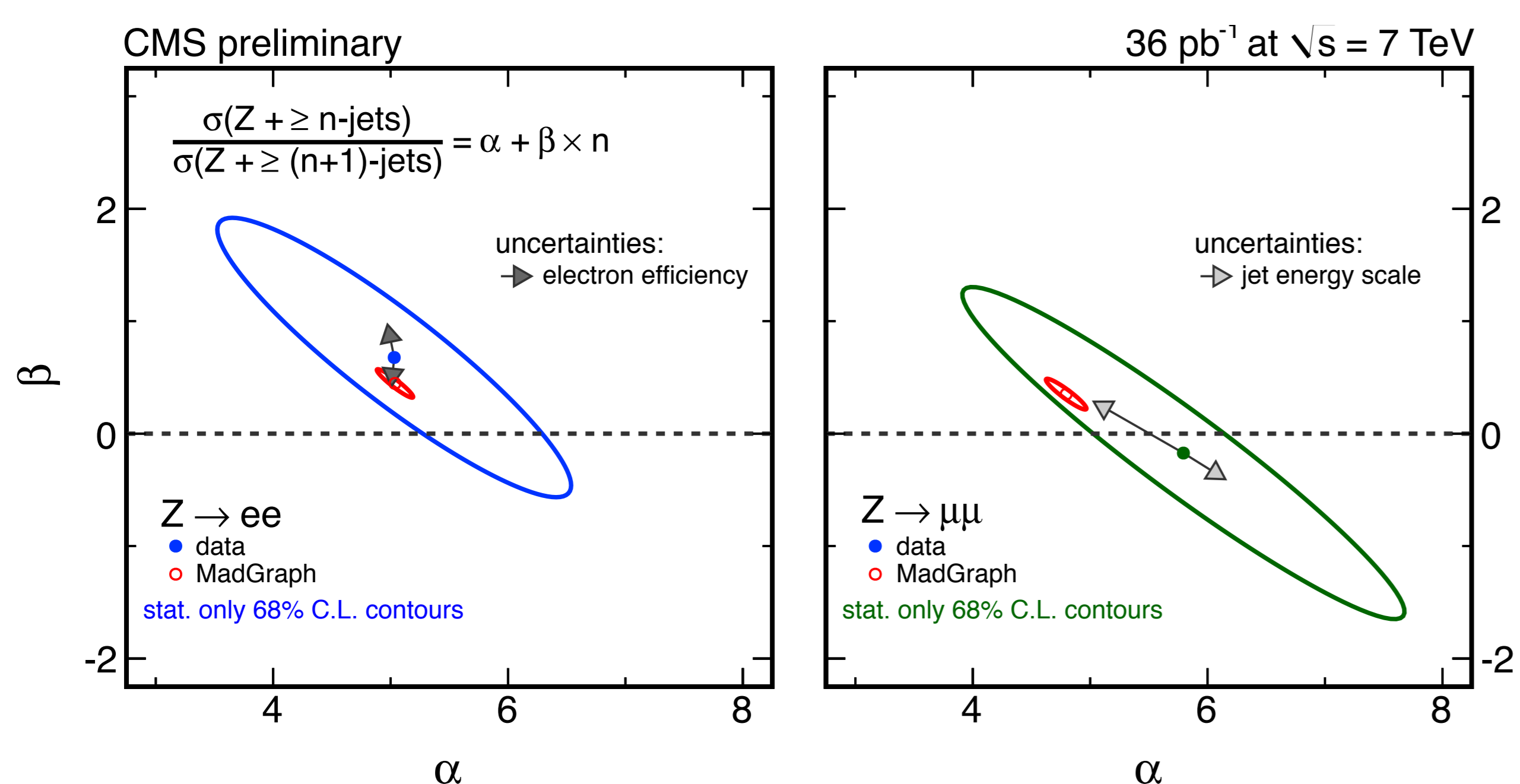
W transverse mass fit for electron channel (left) and muon channel (right), W+1 jet sample.



Di-lepton mass fit for electron channel (left) and muon channel (right), Z+1 jet sample.

## Berends-Giele Scaling

To leading order one expects  $\sigma(N_{jet}) = \exp(c\alpha_s N_{jet})$  for  $N_{jet} > 0$ . A second fit is performed on exclusive jet bins with the condition that they conform to the scaling function  $C_n = \frac{\sigma_n}{\sigma_{n+1}}$  where  $\sigma_n = \sigma(V+n \text{ jets})$ . To leading order  $C_n = \alpha$ , with  $\alpha$  proportional to the inverse of the strong coupling constant. To include Next-to-Leading-Order effects, we also use a parameter  $\beta$ :  $C_n = \alpha + \beta n$ . Because the  $n = 0$  sample has different production kinematics, i.e., no jets recoiling against the vector boson, the scaling is not expected to hold for  $n = 0$  and it is not included in the fit.



Fit results on the Berends-Giele scaling parameters  $\alpha$  and  $\beta$  for Z in muon and electron channels. Pile-up subtraction, efficiency corrections, and unfolding of detector effects have been applied. Data compared to MADGRAPH with PYTHIA Z2 tune.

## Signal Extraction

The signal yields are estimated using an extended likelihood fit to  $M_{l+l-}$  for the Z + jets sample and to  $M_T$  for the W + jets sample. For Z events, the fit uses two functions, one for signal and another for all backgrounds. For W events the backgrounds are separated into those that peak in  $M_T$ , dominated by  $t\bar{t}$ , and all others. The non-peaking backgrounds are distinguished in the fit to  $M_T$  while the top events are separated by using a fit to the distribution of the number of b-type jets. Fits are done for exclusive jet bins, for  $N \leq 3$  jets, and an inclusive  $\geq 4$  jet bin. The following function (Cruiff) is used for fitting to  $M_{l+l-}$  and  $M_T$ :

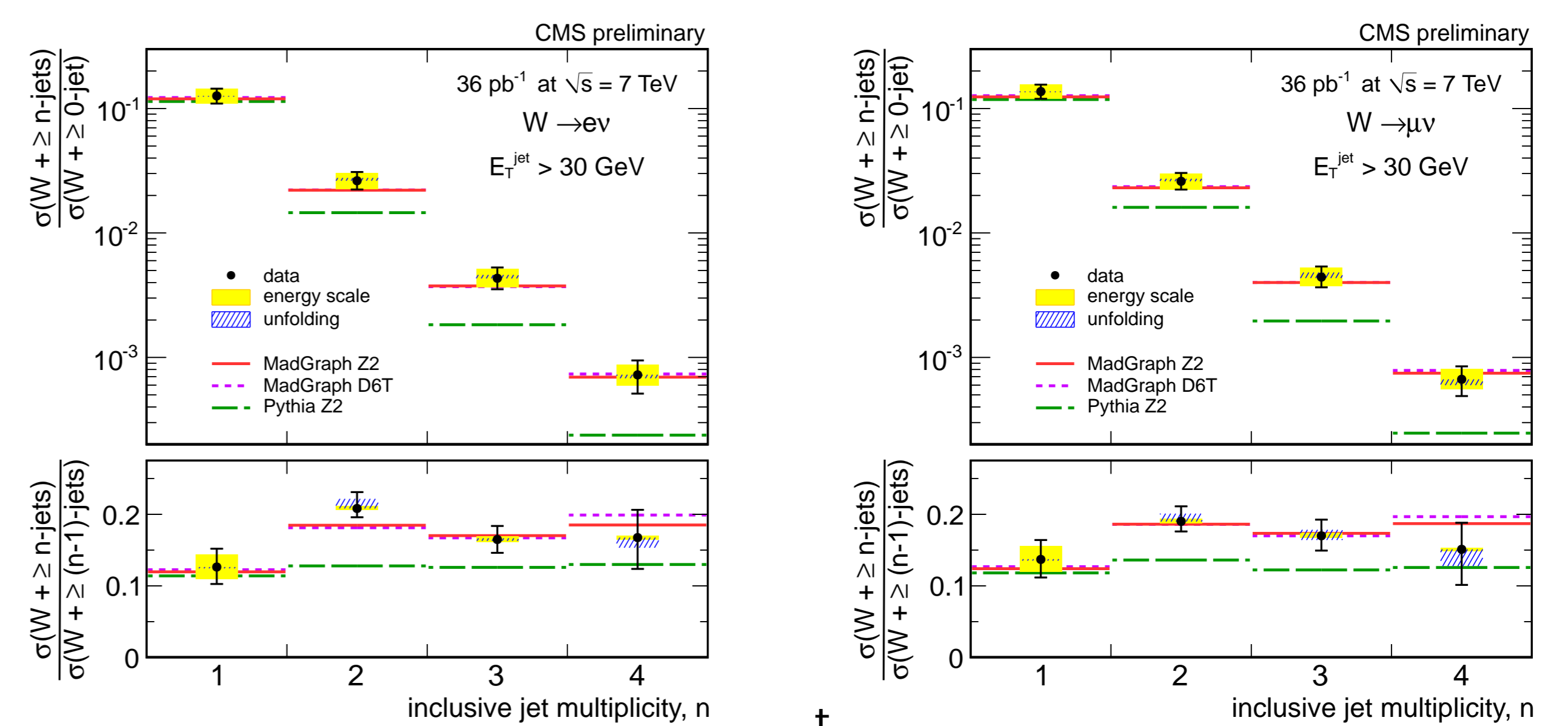
$$f(x; m, \sigma_L, \sigma_R, \alpha_L, \alpha_R) = N_s \cdot e^{-\frac{(x-m)^2}{2\sigma^2 + \alpha(x-m)^2}} \quad (1)$$

where  $\sigma = \sigma_L(\sigma_R)$  for  $x < m(x > m)$  and  $\alpha = \alpha_L(\alpha_R)$  for  $x < m(x > m)$ . Muon events are efficiency corrected by  $p_T$  and  $\eta$  before the fit, using the tag and probe method. For electrons the yields for each n-jet bin are adjusted for selection efficiency after fitting.

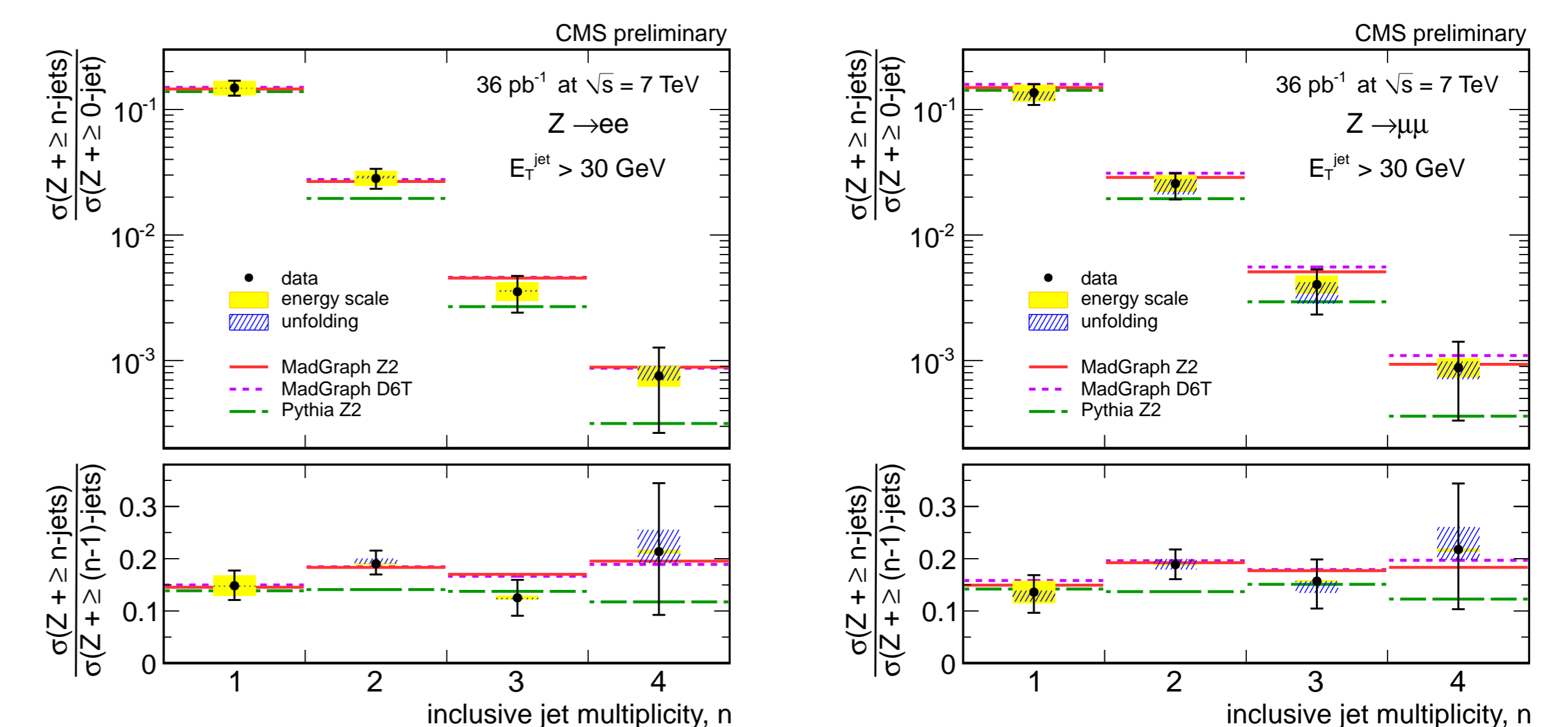
The exclusive cross sections, within the acceptance, are then unfolded using the SVD unfolding algorithm. The unfolding procedure removes the effects of imperfect jet energy resolution and reconstruction efficiency, and yields a result closer to the true, particle level, distribution of jets.

## Cross section by Jet Multiplicity

The  $V+\geq N$ -jet cross-section results are given relative to the inclusive cross section (upper of the two joined plots), and relative to  $\sigma(\geq N-1)$ -jet (lower of the joined plots), to reduce systematic effects. Luminosity uncertainty cancels, JES uncertainty is reduced, and efficiency correction uncertainties are reduced since they are applied bin-by-bin. All results shown have pile-up effects subtracted, been corrected for efficiency, and are unfolded for detector effects.



The ratios  $\sigma(W + N \text{ jets})/\sigma(W)$  and  $\sigma(W + N \text{ jets})/\sigma(W + N - 1 \text{ jets})$  in the electron channel (left) and muon channel (right) compared to expectations from MADGRAPH and PYTHIA.



The ratios  $\sigma(Z + N \text{ jets})/\sigma(Z)$  and  $\sigma(Z + N \text{ jets})/\sigma(Z + N - 1 \text{ jets})$  in the electron channel (left) and muon channel (right) compared to expectations from MADGRAPH and PYTHIA.

## References

[1] CMS Collaboration, "Measurements of Inclusive W and Z Cross Sections in pp Collisions at  $\sqrt{s} = 7$  TeV", CMS PAS EWK-2010-002 (2010)