SUSY Stop Dilepton Preapproval Presentation January 21st, 2014

Brian Calvert (UMD)
on behalf of the Stop Dilepton analysis group

UNIVERSITY OF MARYLAND

CMS

Table of Contents

Last Slide Viewed

Introduction

Supersymmetry (SUSY) is a well-established theory for physics beyond the Standard Model (SM) that can address two of the current theoretical mysteries in the SM

– How can the Higgs mass be close to the electroweak scale without excessive fine-tuning? (Hierarchy problem)

– What is the underlying “particle” explanation, if any, for the dark matter signature observed by astrophysicists? (Dark matter problem)

One of the primary goals of the LHC when it turned on was the experimental confirmation of a light Higgs boson

Another, natural, goal of the LHC was to try and find the experimental signatures of non-SM physics, of which SUSY was perhaps the hallmark example.

Generic searches looking for the basic signatures of SUSY (high pT jets/leptons, lots of MET) have yielded null results thus far, however

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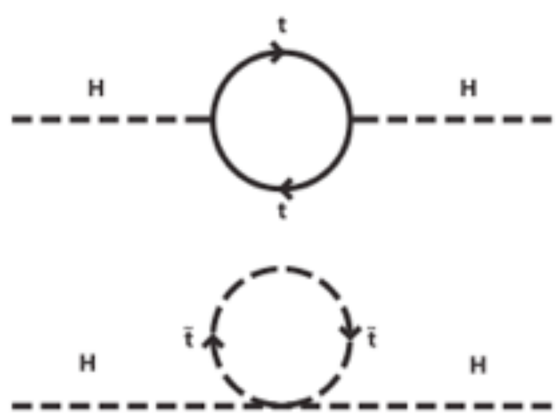

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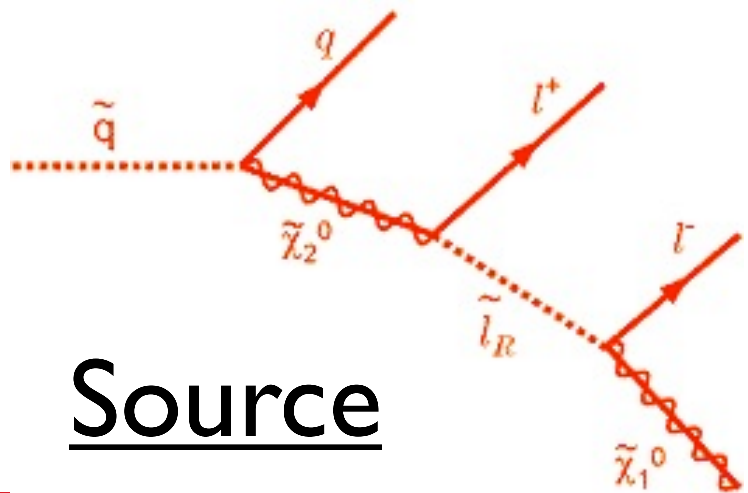
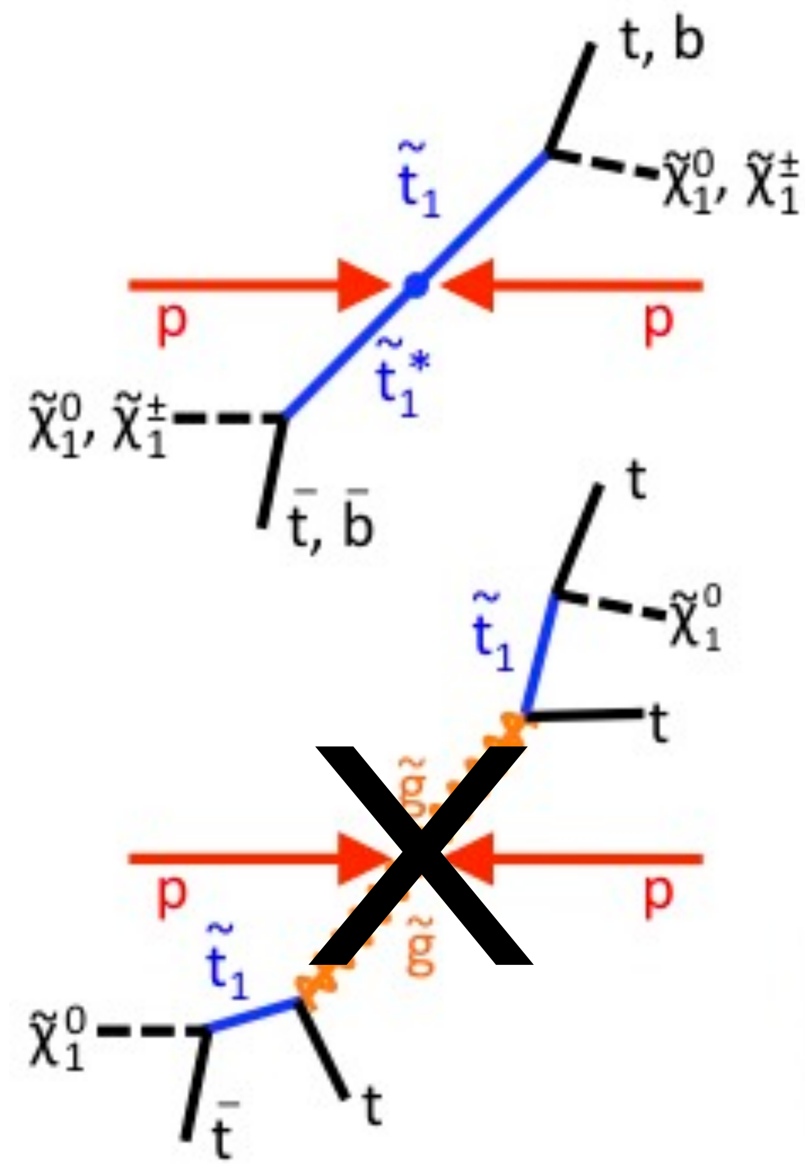


Introduction

- CMS and ATLAS's discovery of a Higgs boson at 125 GeV has further driven theoretical motivations for finding signatures of SUSY at the LHC
- Even with the current null results from generic SUSY searches, SUSY can still be natural if the superpartners for the Higgs, gluon, and third generation quarks have masses near the electroweak scale
- Searching for third generation superpartners can benefit from more specific analysis choices than just generic searches
- To that end, we have been developing an analysis to search for **direct** dileptonic pair production of Stops



Source

Introduction

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Even with the current null results from generic SUSY searches, SUSY can still be natural if the superpartners for the Higgs, gluon, and third generation quarks have masses near the electroweak scale

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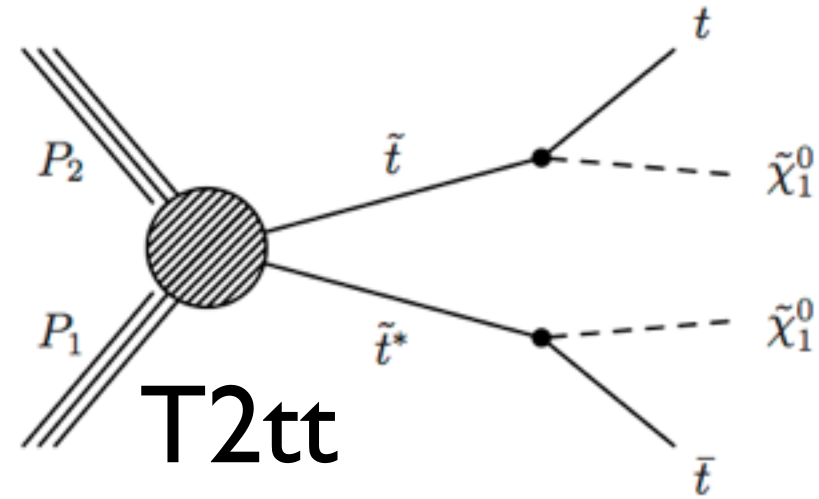
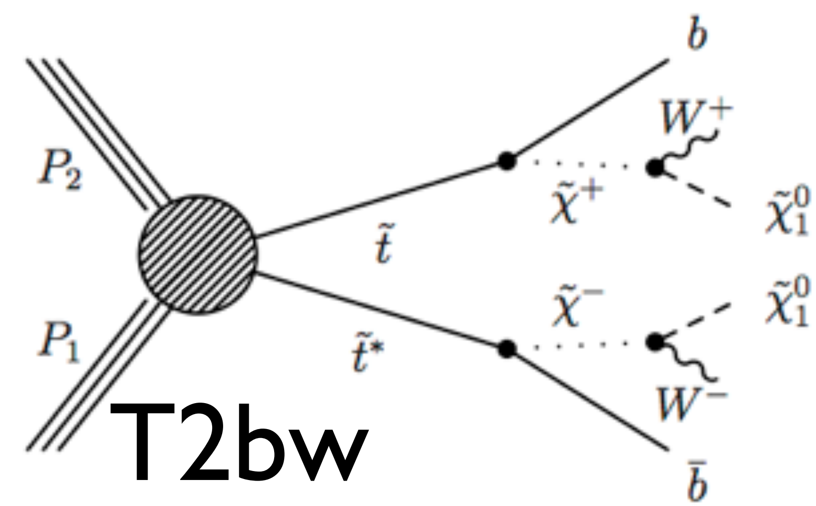
To that end, we have been developing an analysis to search for **direct** dileptonic pair production of Stops





Why dilepton?

The use of a dilepton final state means that for most SMSs considered, our maximal signal efficiency (relative to the total) is equal to the WW dilepton BR of 4%

Leptons, however, have strong reconstruction and trigger efficiency as well as energy resolution (relative to hadronic jets) in the CMS detector (so using dilepton events means we get these benefits[2])

Furthermore, the topology of the expected final state allows us to impose strong exclusion powers on a lot of SM backgrounds

For example, one nominal dileptonic final state for a prototypical SUSY model (actually the T2tt SMS) is the following,

$$pp \rightarrow \tilde{t} + \bar{\tilde{t}} + X \rightarrow \tilde{\chi}_0 t + \chi_0 \bar{t} + X \rightarrow \tilde{\chi}_0 b W^+ + \chi_0 \bar{b} W^- + X \rightarrow \tilde{\chi}_0 b \ell \bar{\nu}_\ell + \chi_0 \bar{b} \bar{\ell} \nu_\ell + X.$$

Why dilepton?

A very natural comparison is to SM ttbar production,

$$pp \rightarrow t + \bar{t} + X \rightarrow bW^{+} + \bar{b}W^{-} + X \rightarrow b\ell\bar{\nu}_{\ell} + \bar{b}\bar{\ell}\nu_{\ell} + X.$$

The major salient difference between SM ttbar and the expected SUSY signature is the presence of additional invisible particles.

While the overall amount of MET in the stop pair events may not be that different from SM ttbar (albeit a bit higher on average), the additional invisible particles affect the observed system kinematics of the events, in particular the relations/correlations between the visible particles and the composite MET of the event

Consequently, one can expect to see differences in the distributions of variables that account for these correlations

M_T

$$M_T = \sqrt{2E_\ell E_{\mathrm{T}}^{\mathrm{miss}}\left[1-\cos(\Delta\phi)\right]}$$

For some intra-experimental context, the single lepton stop search utilizes the transverse mass, M_T, as a key discriminating variable

For events where you have a single mother particle decaying invisibly, more specifically so that the **real** MET in the event stems from a single particle, M_T has a useful property in that its distribution has a kinematic edge at the mother particle mass.

For events where there are additional invisible particles providing real MET, or where nominally visible particles are not considered in the MET calculation (e.g. outside of detector acceptance) this kinematic edge does not exist.

For a dileptonic stop pair search, one can not utilize the standard version of M_T, as the sample of events nominally contain at least two invisible particles.

What we use, instead, is a generalized version of M_T, known as M_{T2}.

M_{T2}

$$M_T = \sqrt{2E_\ell E_\mathrm{T}^\mathrm{miss}\left[1 - \cos(\Delta\phi)\right]}$$

$$M_{T2}^2 = \min_{\mathbf{p}_{T1}^{miss}+\mathbf{p}_{T2}^{miss}=\mathbf{p}_T^{miss}}\left(\max\left[m_T^2(\mathbf{p}_T^{\ell 1},\mathbf{p}_{T1}^{miss}), m_T^2(\mathbf{p}_T^{\ell 2},\mathbf{p}_{T2}^{miss})\right]\right)$$

M_{T2} works to emulate the M_T variable for systems assuming that MET in the event stems from two invisible particles.

To calculate a given event's M_{T2} (i.e. to explain the formula above in words),

– Generate two hypothetical neutrinos that respect the constraint, $\mathbf{p_T}^{nu1} + \mathbf{p_T}^{nu2} = \mathbf{p_T}^{miss}$.

– For these two "neutrinos" find the maximum M_T from possible pairings of neutrinos with the two visible objects used (the formula above shows choosing to use leptons).

– Finally, explore the parameter space of hypothetical neutrinos, calculating the maximal M_T for each parameter space point, until you find the minimum of these "max M_T" values. This is the event's M_{T2}.

Some intuition about M_{T2}

M_{T2} depends strongly upon the geometric configuration of objects in the event (for example, the opening angle between the dilepton system and the MET vector shown here)

Through specific choices of visible particles used, M_{T2} can be made/constructed to respect kinematic edges at mother particle masses (similar to M_T in a single W event)

For example, for standard model dileptonic TTbar, or any other background where we have two W bosons providing not only the leptons, but also the only source of real MET (neutrinos), if you use the two leptons as the visible particles – denoted as M_{T2}(ll), you will find a kinematic edge in M_{T2}(ll) at the W mass (80 GeV).

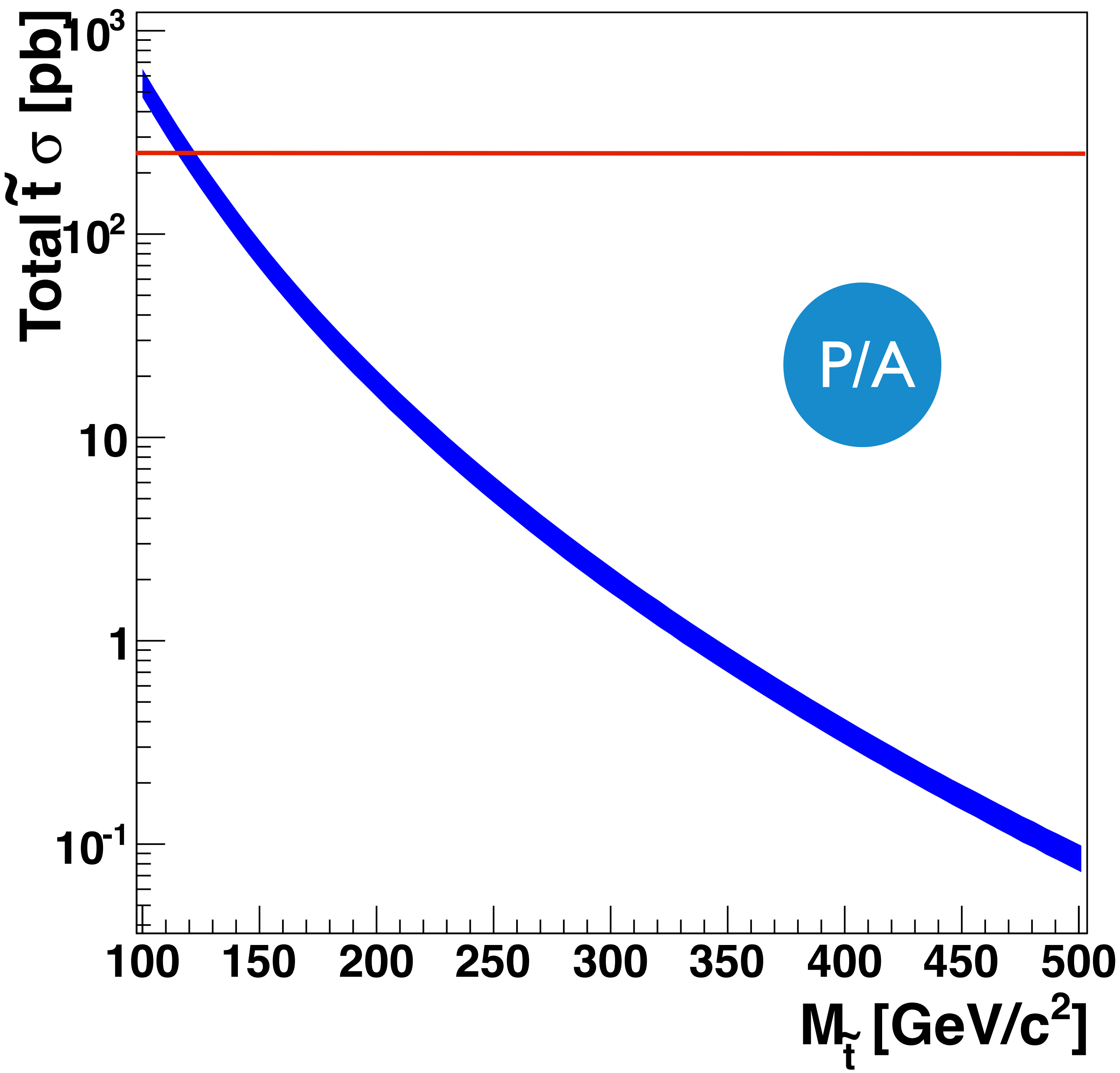
Just like M_T, events that deviate from the nominal topology, e.g. for M_{T2}(ll) if the hypothetical lepton-neutrino pairs do *not* come from W bosons (e.g. ZZ, DY +Jets) or if there is additional invisible particles beyond W boson neutrinos (i.e. the aforementioned SUSY signatures considered!) – will not respect this kinematic edge.

Some intuition about M_{T2}

As noted, the formula on slide 9 describes a minimization problem. In execution, what this means is that if there are configurations of the hypothetical neutrinos where the maximal M_T is 0, then the minimizer will find said configuration(s) and consequently return $M_{T2} = 0$ for the event.

An example of an event where this would occur is an event where two leptons are back-to-back in phi, with the MET vector pointing along one of the lepton directions (say, a Z boson decay at rest with minimal additional high p_T activity in the event). Any configuration of the "neutrinos" along the lepton-lepton line in phi will yield $M_T = 0$ and subsequently $M_{T2} = 0$.

Base expectation for Signal



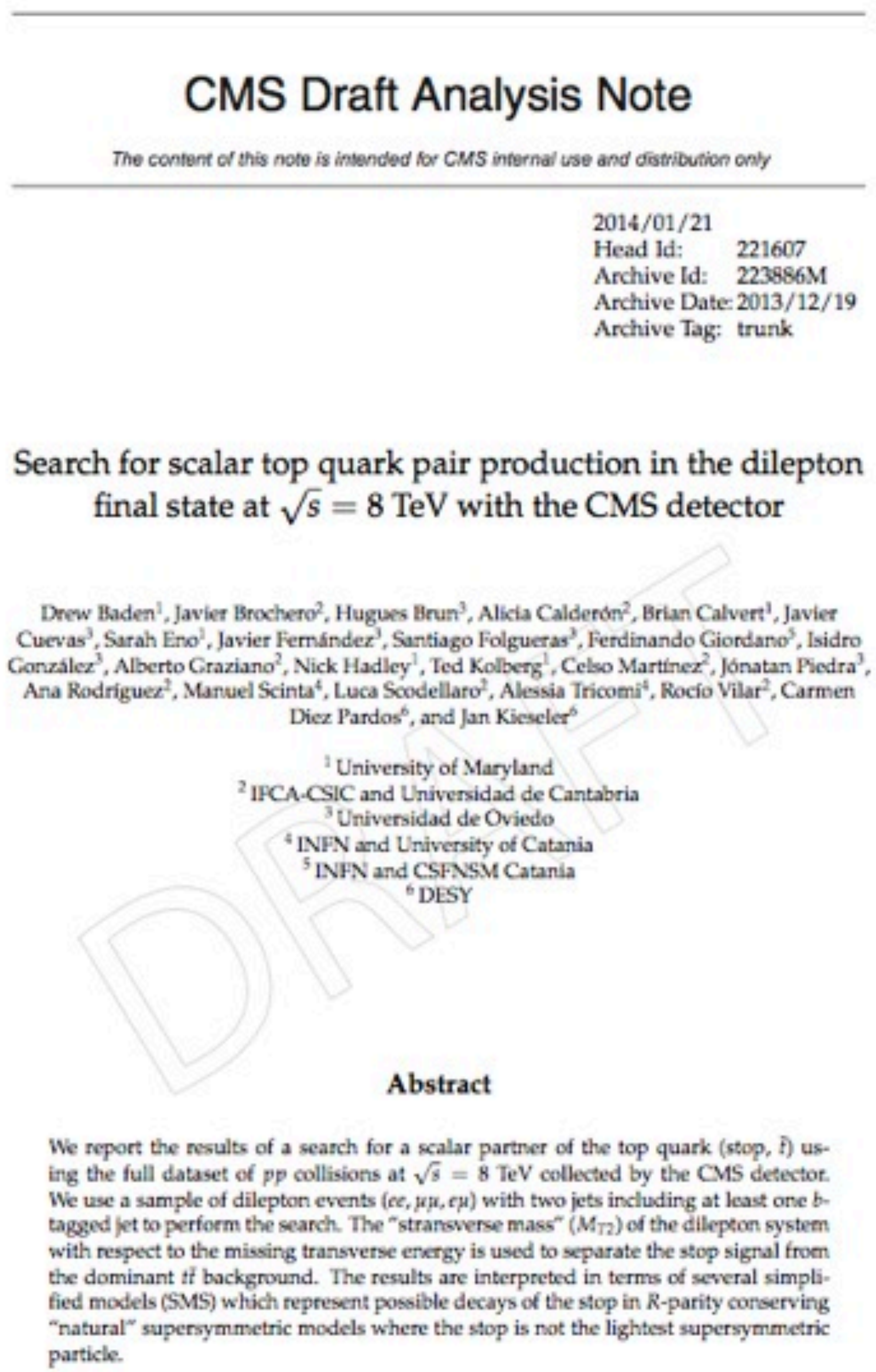
What is the baseline level of signal we expect?

The plot of the left is the production cross section for stop pairs at 8 TeV (line is nominal ttbar xsec of 245.8 pb) as calculated by LPCC xsec group

So, the initial expectation, with no cuts on discriminating variables is that our signal will be 1-3 orders of magnitude below a ttbar background, barring wildly different selection efficiencies

With no cuts on discriminating variables, a 2-sigma exclusion is obviously not doable, so the interesting thing to see is how well the nominal discriminating variable, M_{T2}(ll), can perform

Dilepton Analysis


CMS Draft Analysis Note

The content of this note is intended for CMS internal use and distribution only

2014/01/21
Head Id: 221607
Archive Id: 223886M
Archive Date: 2013/12/19
Archive Tag: trunk

Search for scalar top quark pair production in the dilepton final state at $\sqrt{s} = 8$ TeV with the CMS detector

Drew Baden[1], Javier Brochero[2], Hugues Brun[3], Alicia Calderón[2], Brian Calvert[1], Javier Cuevas[3], Sarah Eno[1], Javier Fernández[3], Santiago Folgueras[3], Ferdinando Giordano[5], Isidro González[3], Alberto Graziano[2], Nick Hadley[1], Ted Kolberg[1], Celso Martínez[2], Jónatan Piedra[3], Ana Rodríguez[2], Manuel Scinta[4], Luca Scodellaro[2], Alessia Tricomi[4], Rocío Vilar[2], Carmen Diez Pardos[6], and Jan Kieseler[6]

[1] University of Maryland
[2] IFCA-CSIC and Universidad de Cantabria
[3] Universidad de Oviedo
[4] INFN and University of Catania
[5] INFN and CSFNSM Catania
[6] DESY

Abstract

We report the results of a search for a scalar partner of the top quark (stop, $\tilde{t}$) using the full dataset of pp collisions at $\sqrt{s} = 8$ TeV collected by the CMS detector. We use a sample of dilepton events ($ee, \mu\mu, e\mu$) with two jets including at least one b-tagged jet to perform the search. The "stransverse mass" (M_{T2}) of the dilepton system with respect to the missing transverse energy is used to separate the stop signal from the dominant $t\bar{t}$ background. The results are interpreted in terms of several simplified models (SMS) which represent possible decays of the stop in R-parity conserving "natural" supersymmetric models where the stop is not the lightest supersymmetric particle.

To that end, we have prepared a analysis to look for signatures of the dileptonic decay of top super partners in the full 2012 8 TeV pp dataset

The supporting documentation, in the form of an AN and corresponding PAS, can respectively be found here and here.

Note about Plots

The following “stickers” will designate where the plot can be found

P/A	A	N
PAS and AN	Just AN	Not in AN or PAS (new plot)

Analysis Strategy

1a) Perform sequence of cuts to significantly reduce SM backgrounds

1b) Optimize object selection in the context of signal yield and define our signal region

–As part of 1b), we defined $M_{T2}(ll) > 80$ GeV as an initial data "blinding" region; we have since unblinded with the permission of the SUSY conveners

2) Utilize data-driven methods when possible to get a handle on remaining SM events in signal region

3) Perform studies (Data/MC comparisons as well as Gen-Level investigations) for the purpose of understanding the shape and modeling of our key variable, $M_{T2}(ll)$

Analysis Strategy

4) Account for systematics

5) Data/MC comparison checks in our signal region and some control regions

6) Optimize our cut point for $M_{T2}(ll)$ in the context of our expected limit

7) Execute the full chain with our cuts/selections from these studies and interpret the results

Prior Results/Studies

Two major status reports have been given

Pre-Unblinding

https://indico.cern.ch/getFile.py/access?contribId=3&resId=0&materialId=slides&confId=276285

Post-Unblinding

https://indico.cern.ch/getFile.py/access?contribId=0&resId=0&materialId=slides&confId=283932

In addition to these and other status reports we have done a number of specific studies into effects/behavior/issues. A list of these are contained in the backup

I will include key points and results from these studies, implemented with the current version of nTuples when needed (some of the aforementioned presentations were done with older versions of the nTuples)

Datasets/Triggers

Collision Datasets:

(**19.656** fb^{-1} processed using GT **FT_53_V21_AN3**):

/DoubleElectron/Run2012*-22Jan2013-v1/AOD

/MuEG/Run2012*-22Jan2013-v1/AOD

/DoubleMu/Run2012A-22Jan2013-v1/AOD

/DoubleMuParked/Run2012*-22Jan2013-v1/AOD

Datasets/Triggers

MC Samples processed (Global Tag **START53_V19PR**)

– Drell-Yan (both N_{Jets} inclusive and exclusive samples – Madgraph for both)

– TTbar (all channels): **Powheg**, MC@NLO, Madgraph

– DiEWK boson MC (Pythia)

– Single Top + W (Powheg)

– EWK boson + Gamma (Madgraph)

– W + Jets (Madgraph)

– “Rare” backgrounds: Higgs (125), TTbar + Vec boson, Triple Vec Boson (Powheg for Higgs, Madgraph for others)

Data and MC were both processed utilizing **CMSSW** version **5.3.9**

Datasets/Triggers

Channel	HLT path
ee	HLT_Ele17_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL_Ele8_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL*
$e\mu$	HLT_Mu17_Ele8_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL_v*
	HLT_Mu8_Ele17_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL_v*
$\mu\mu$	HLT_Mu17_(Tk)Mu8_v*

Table 3: HLT paths used to select events.

Triggers are applied to both Data and MC – with SFs used to correct for Data/MC trigger efficiency differences (see here)

Object/Event Selection

Cut	Value
Type	reco::Electron
p_T	> 20 GeV (leading)
p_T	> 10 GeV (lagging)
$\|\eta\|$	< 2.5
	veto EB/EE overlap region
conversion veto	applied
ID working point	VBTF WP80
relIso (ρ corrected)	< 0.15

Table 4: Electron object selection.

Cut	Value
algorithm	AK5PFchs
p_T	30 GeV
$\|\eta\|$	< 2.4
jet ID	loose PFJetID
b-tag	CSV medium

Table 6: Jet object selection

Cut	Value
Type	reco::Muon
ID	GlobalMuonPromptTight
p_T	> 20 GeV (leading)
p_T	> 10 GeV (lagging)
$\|\eta\|$	< 2.4
d_0	< 0.2 cm
d_z	< 0.5 cm
relIso($\delta(R) < 0.3$)	< 0.15

Table 5: Muon object selection.

Object	Selection
e, μ	At least two, oppositely charged
	Highest sum-p_T pair used
M_{ee} or $M_{\mu\mu}$	$M < 76 \cup M > 106$
E_T^{miss}	> 40 in $ee, \mu\mu$ channels
$M_{\ell\ell}$	> 20 GeV (all flavors)
N_{jets}	≥ 2
N_b	≥ 1

Table 7: Event selection

MET selection

Type 1 PF MET is used (w/ Type 0 and MET Phi asymmetry corrections)

The MET working group has a canonical list of filters to remove events where the MET is mis-reconstructed due to noise sources

For this analysis, we have applied the full suite of filters listed on this twiki (list in backup)

Background Estimation: DY

The combination of the *b*-jet cut along with same flavor Z-mass and MET cuts greatly reduces our expected DY background

We estimate the normalization of the remaining contribution using the $R_{out/in}$ method

The basic idea is the following

We assume that the DY MC models the shape of the dilepton invariant mass correctly

With this assumption we measure the ratio of events outside the Z mass window to those inside the Z mass window

$$R_{out/in} = \frac{N_{DYMC}^{out}}{N_{DYMC}^{in}}$$

We then count the number of events in data that pass our selection and fall inside the Z mass window, multiplying this number by $R_{out/in}$ gives us an estimate for the number of DY events in data that will pass our object selections and fall outside of the Z mass window (i.e. into our final selection)

Background Estimation: DY

To account for non-DY backgrounds contaminating this estimation, we subtract from our estimate the number of opposite flavor events we count in the Z mass window, scaled by a combinatorics factor as well as reconstruction scale factors

$$N_{out}^{l^+l^-,obs} = R_{out/in}^{l^+l^-}(N_{in}^{l^+l^-} - 0.5N_{in}^{e\mu}k_{ll})$$

where the reconstruction scale factors are defined as the following

$$k_{ee} = \sqrt{\frac{N_{in}^{e^+e^-}}{N_{in}^{\mu^+\mu^-}}} \quad k_{\mu\mu} = \sqrt{\frac{N_{in}^{\mu^+\mu^-}}{N_{in}^{e^+e^-}}}$$

This yields estimates for the same flavor channel; from these we can calculate Data/MC scale factors by directly comparing the estimated number of events

We then calculate an analogous scale factor for the opposite flavor channel as the geometric mean of the observed scale factors for the same flavor channels

Background Estimation: DY

	≥ 2 jets	≥ 2 jets + E_T^{miss}	≥ 2 jets + E_T^{miss} + b-tag
ee			
DY MC	14877.4 ± 53.0	2154.7 ± 18.0	236.13 ± 6.08
DY data-driven estimate	15613.0 ± 75.4	2626.2 ± 32.6	331.56 ± 14.54
$R_{out/in}$	0.1417 ± 0.0005	0.1644 ± 0.0015	0.1668 ± 0.0045
SF data/MC	1.0494 ± 0.0063	1.2188 ± 0.0183	1.4041 ± 0.0714
$\mu\mu$			
DY MC	27049.9 ± 73.6	4155.2 ± 25.2	415.00 ± 7.84
DY data-driven estimate	30217.7 ± 113.7	5361.6 ± 51.6	663.51 ± 22.68
$R_{out/in}$	0.1729 ± 0.0005	0.2144 ± 0.0014	0.2011 ± 0.0041
SF data/MC	1.1171 ± 0.0052	1.2904 ± 0.0147	1.5988 ± 0.0624
$e\mu$			
DY MC	2224.1 ± 16.5	2224.1 ± 16.5	208.65 ± 4.90
DY data-driven estimate	2408.0 ± 20.1	2408.0 ± 20.1	312.62 ± 12.42
SF data/MC	1.0827 ± 0.0041	1.0827 ± 0.0041	1.4983 ± 0.0480

Table 8: Data-driven Drell-Yan background estimation in the *ee* and $\mu\mu$ channels compared with simulation, for several steps of the analysis.

The Data/MC SF is the relevant parameter to extract from this table as it sets the normalization of our expected contribution from DY MC

We performed a cross-check on our estimate of the opposite flavor scale factor by performing a fit of the composite MC (broken down into DY and non-DY) to the invariant mass spectrum of opposite flavor events in data – c.f. backup)

Estimating Fake Lepton Bkgds

Semi-leptonic ttbar and leptonic W+Jet events can pass our tight dilepton selection if one of the jets gets mis-reco'ed as an isolated lepton. To guard against the possibility mis-modeling of this fake rate in the simulation we utilize a "tight-to-loose" method to estimate it in a data-driven fashion.

That is, we define a set of "tight" and "loose" ID/Iso cuts for leptons that subsequently are used to calculate fake and prompt ratios.

$$\text{Fake ratio}: \quad f(p_T,\eta) = \left.\frac{N^{\ell}_{tight}(p_T,\eta)}{N^{\ell}_{loose}(p_T,\eta)}\right|_{QCD-enriched\ \ region}$$

$$\text{Prompt ratio}: \quad p(p_T,\eta) = \left.\frac{N^{\ell}_{tight}(p_T,\eta)}{N^{\ell}_{loose}(p_T,\eta)}\right|_{DY-enriched\ \ region}$$

Estimating Fake Lepton Bkgds

Let $\varepsilon = \frac{f}{1-f}$ and $\eta = \frac{1-p}{p}$

$$\text{Pass}-\text{Pass}: \; w_{P_1P_2} = -\frac{\varepsilon_1\eta_1 + \varepsilon_2\eta_2 - \varepsilon_1\varepsilon_2\eta_1\eta_2}{(1-\varepsilon_1\eta_1)(1-\varepsilon_2\eta_2)} \tag{6}$$

$$\text{Fail}-\text{Fail}: \; w_{F_1F_2} = -\frac{\varepsilon_1\varepsilon_2}{(1-\varepsilon_1\eta_1)(1-\varepsilon_2\eta_2)} \tag{7}$$

$$\text{Pass}-\text{Fail}: \; w_{P_1F_2} = \frac{\varepsilon_2}{(1-\varepsilon_1\eta_1)(1-\varepsilon_2\eta_2)} \tag{8}$$

$$\text{Fail}-\text{Pass}: \; w_{P_2F_1} = \frac{\varepsilon_1}{(1-\varepsilon_1\eta_1)(1-\varepsilon_2\eta_2)} \tag{9}$$

To estimate our fake lepton yield, we apply our event selection in data, but only require the leptons to pass loose quality cuts

Then, for these events, we calculate the weights as per the formulas above, picking the formula based upon whether the considered lepton candidates pass or fail the tight selection

The total yield is then given by the sum of all event weights in each of the respective "pass/fail" final states.

Results: Fake Lepton Bkgds

Table 12: Measured electron and muon fake rates in bins of p_T and η of the fakeable object. Uncertainties are statistical only.

electron fake rate				
p_T (GeV)	$0 < \eta \leq 1.0$	$1.0 < \eta \leq 1.479$	$1.479 < \eta \leq 2.0$	$2.0 < \eta \leq 2.5$
$10 < p_T \leq 15$	0.51 ± 0.02	0.46 ± 0.03	0.46 ± 0.03	0.40 ± 0.03
$15 < p_T \leq 20$	0.36 ± 0.03	0.33 ± 0.04	0.34 ± 0.04	0.34 ± 0.04
$20 < p_T \leq 25$	0.36 ± 0.03	0.32 ± 0.03	0.32 ± 0.03	0.33 ± 0.03
$25 < p_T \leq 30$	0.38 ± 0.04	0.23 ± 0.04	0.29 ± 0.04	0.30 ± 0.03
$30 < p_T \leq 35$	0.28 ± 0.04	0.26 ± 0.06	0.23 ± 0.04	0.24 ± 0.05

muon fake rate				
p_T (GeV)	$0 < \eta \leq 1.0$	$1.0 < \eta \leq 1.479$	$1.479 < \eta \leq 2.0$	$2.0 < \eta \leq 2.4$
$10 < p_T \leq 15$	0.31 ± 0.03	0.32 ± 0.04	0.38 ± 0.05	0.44 ± 0.08
$15 < p_T \leq 20$	0.16 ± 0.03	0.17 ± 0.05	0.21 ± 0.06	0.19 ± 0.10
$20 < p_T \leq 25$	0.161 ± 0.016	0.17 ± 0.03	0.21 ± 0.03	0.30 ± 0.06
$25 < p_T \leq 30$	0.103 ± 0.019	0.24 ± 0.04	0.16 ± 0.04	0.38 ± 0.11
$30 < p_T \leq 35$	0.101 ± 0.024	0.10 ± 0.04	0.17 ± 0.05	0.15 ± 0.11

Results: Fake Lepton Bkgds

Table 10: Measured electron and muon prompt rates in bins of p_T and η of the fakeable object. Uncertainties are statistical only.

electron prompt rate		
p_T (GeV)	$0 < \eta \leq 1.4442$	$1.566 < \eta \leq 2.5$
$10 < p_T \leq 15$	0.833 ± 0.015	0.75 ± 0.02
$15 < p_T \leq 20$	0.872 ± 0.007	0.785 ± 0.013
$20 < p_T \leq 25$	0.902 ± 0.004	0.828 ± 0.008
$25 < p_T \leq 50$	0.9592 ± 0.0005	0.904 ± 0.001
$50 < p_T$	0.9783 ± 0.0010	0.942 ± 0.003

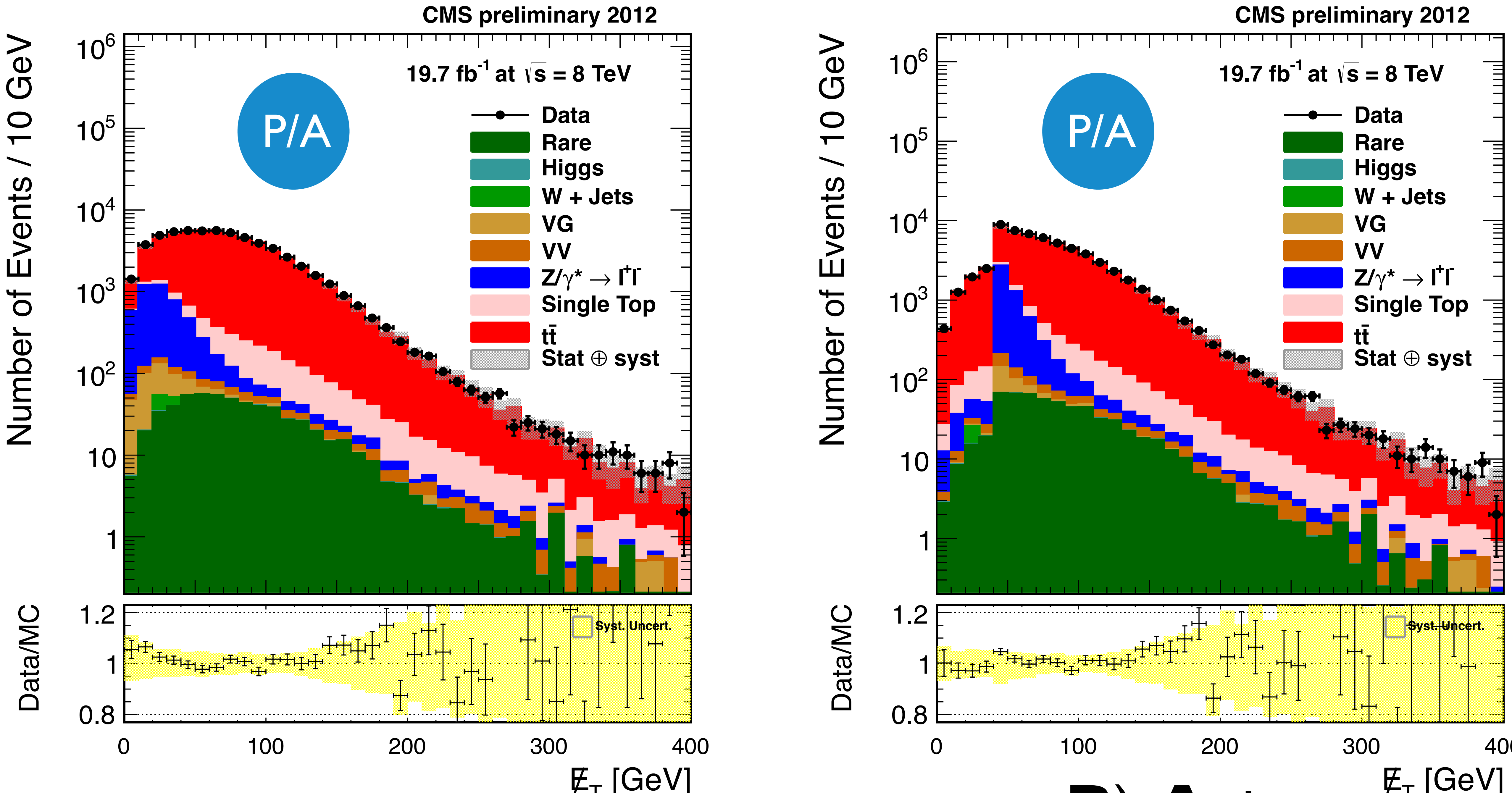
muon prompt rate		
p_T (GeV)	$0 < \eta \leq 1.479$	$1.479 < \eta \leq 2.4$
$10 < p_T \leq 15$	0.837 ± 0.009	0.844 ± 0.009
$15 < p_T \leq 20$	0.881 ± 0.005	0.895 ± 0.005
$20 < p_T \leq 25$	0.915 ± 0.003	0.935 ± 0.003
$25 < p_T \leq 50$	0.9754 ± 0.0003	0.9761 ± 0.0005
$50 < p_T$	0.9918 ± 0.0005	0.9921 ± 0.0008

Results: Fake Lepton Bkgds

after $N_{b-tags} \geq 1$				
channel	central value	stat.	syst.	stat. $\oplus$ syst.
$\mu\mu$	642	$\pm 18\%$	$\pm 4\%$	$\pm 18\%$
ee	97	$\pm 27\%$	$\pm 15\%$	$\pm 31\%$
$e\mu$	643	$\pm 28\%$	$\pm 6\%$	$\pm 29\%$
after $M_{T2}(\ell\ell) > 110$ GeV				
channel	central value	stat.	syst.	stat. $\oplus$ syst.
$\mu\mu$	1.09	$\pm 37\%$	$\pm 15\%$	$\pm 40\%$
ee	0.89	$\pm 24\%$	$\pm 18\%$	$\pm 30\%$
$e\mu$	0.91	$\pm 32\%$	$\pm 12\%$	$\pm 34\%$

Method to calculate statistical and systematic uncertainties on yields are described in <u>backup</u>

Effect of our selections



A) Jet Cuts + SF Z Veto

B) A + SF MET Cut (i.e. full selection)

MC Corrections: Lepton SFs

We apply two sets of scale factors to the MC in order to match observed efficiencies in data

Lepton Efficiency scale factors (Trigger and ID/Iso) are applied (see backup for more detail)

channel	ϵ_{data}	ϵ_{MC}	SF
ee	0.949 ± 0.003	0.879 ± 0.001	1.080 ± 0.011
$\mu\mu$	0.948 ± 0.001	0.966 ± 0.001	0.981 ± 0.010
$e\mu$	0.918 ± 0.002	0.911 ± 0.001	1.008 ± 0.010

SUSY Trigger Eff./SF

channel	ϵ_{data}	ϵ_{MC}	SF
ee	0.949 ± 0.003	0.938 ± 0.003	1.011 ± 0.011
$\mu\mu$	0.948 ± 0.001	0.969 ± 0.003	0.978 ± 0.010
$e\mu$	0.918 ± 0.002	0.941 ± 0.003	0.976 ± 0.011

TTBar Trigger Eff./SF

	Eff Data
Muon	0.9361 ± 0.0001
Electron	0.7871 ± 0.0002

Eff. FullSim	SF FullSim	Eff. FastSim	SF FastSim
0.9452 ± 0.0001	0.9904 ± 0.0002	0.9715 ± 0.0001	0.9636 ± 0.0002
0.8114 ± 0.0002	0.9701 ± 0.0002	0.8452 ± 0.0002	0.9312 ± 0.0002

Lepton ID/Iso Eff./SF

MC Corrections: Others

B-tagging scale factors are applied (see backup), with different ones for Signal (as it was produced in Fastsim)

N_{Vtx} distribution for MC is reweighted to match that of data, with different reweighting for Signal – again, produced in FastSim

The MET is smeared is utilizing template smearing functions (see backup for further discussion)

Simulation samples with gen-level ttbar pairs are given a reweighting based upon the gen-level top pTs

Signal simulation samples are given a "ISR correction" based upon the gen-level Stop system pT

Systematics Considered

We account for the following systematics:

1) Lepton Energy Scale (lepton POGs)

2) Jet Energy Scale (See backup)

3) Lepton Efficiency SF uncertainty (see backup)

4) Unclustered Energy Scale and Jet Smearing uncertainties (see here)

5) BTag SF uncertainty (see backup)

6) Generator-Level Top pT reweighting (see next slide)

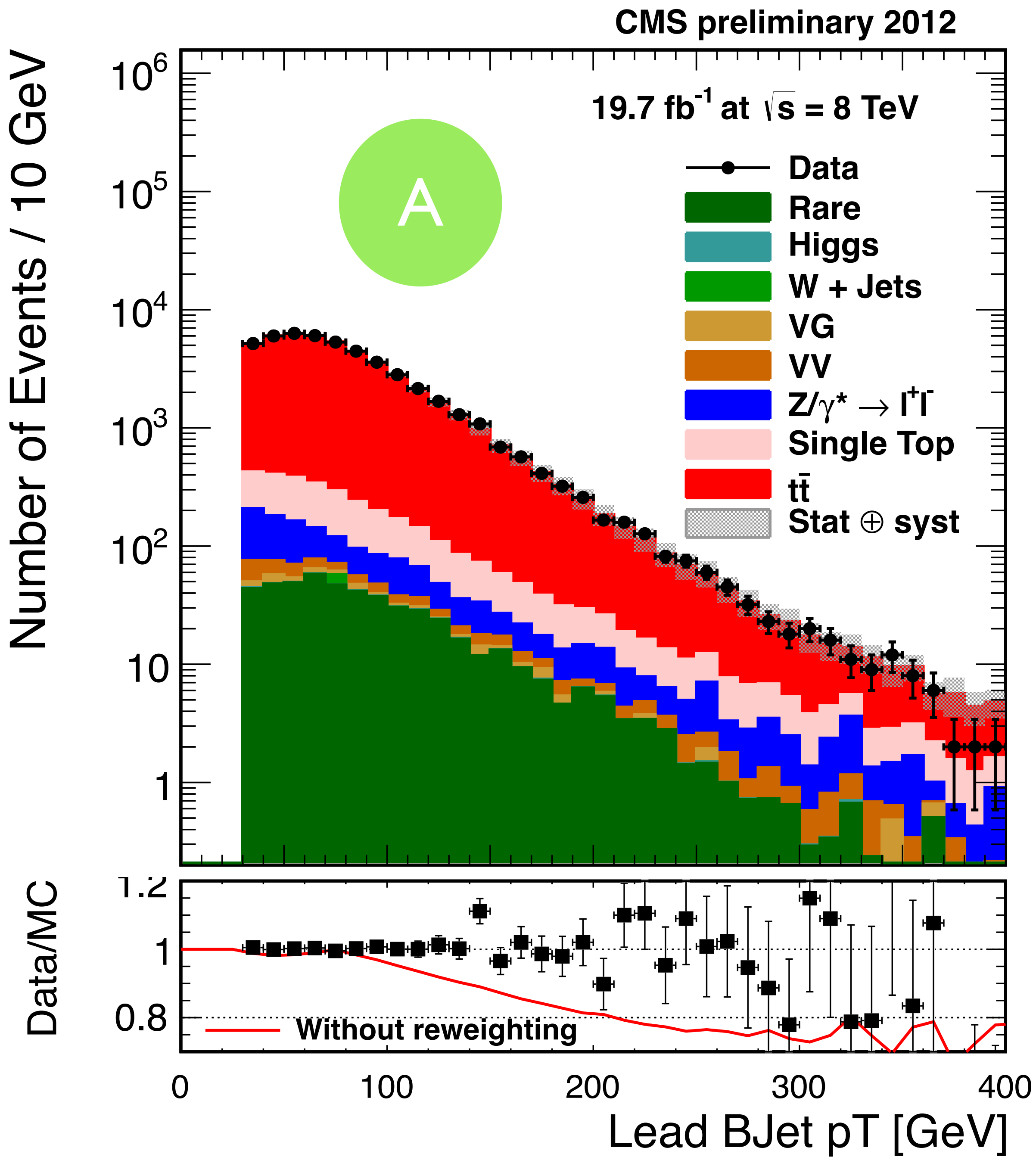
7) Theory Cross-section uncertainty on SMS mass points (Twiki)

8) "ISR correction" uncertainty (see this slide)

Systematics 7) and 8) are applied only on the signal samples. All other systematics, except for the gen-level top p_T reweighting are applied coherently across the board to the SM and Signal MC (gen-level top p_T applied only to ttbar)

The effects of systematics 1) - 6) can be seen here

Gen-level top p_T reweighting



Lead BJet p_T

Top PAG (spec. ttbar xsecs sub-group) found disagreements in data/MC modeling of ttbar p_T

https://indico.cern.ch/getFile.py/access?contribId=2&resId=0&materialId=slides&confId=252018

Twiki

Solution is to apply a reweighting to events utilizing generator level pT information

$w(pT) = \exp(0.156 - 0.00137 * p_T)$

For a given event we take the geometric mean of the calculated respective weights for the top and anti-top

Red bars in ratio plot on left shows nominal version of data/MC ratio (i.e. without reweighting)

Gen-level stop "ISR" reweighting

AN-2013-59 investigated mismodeling of the p_T spectrum of several common event topologies (Z+jets, ttbar, and WZ)

Twiki

The analysts found that the high p_T region is overestimated in simulation (see backup for an example)

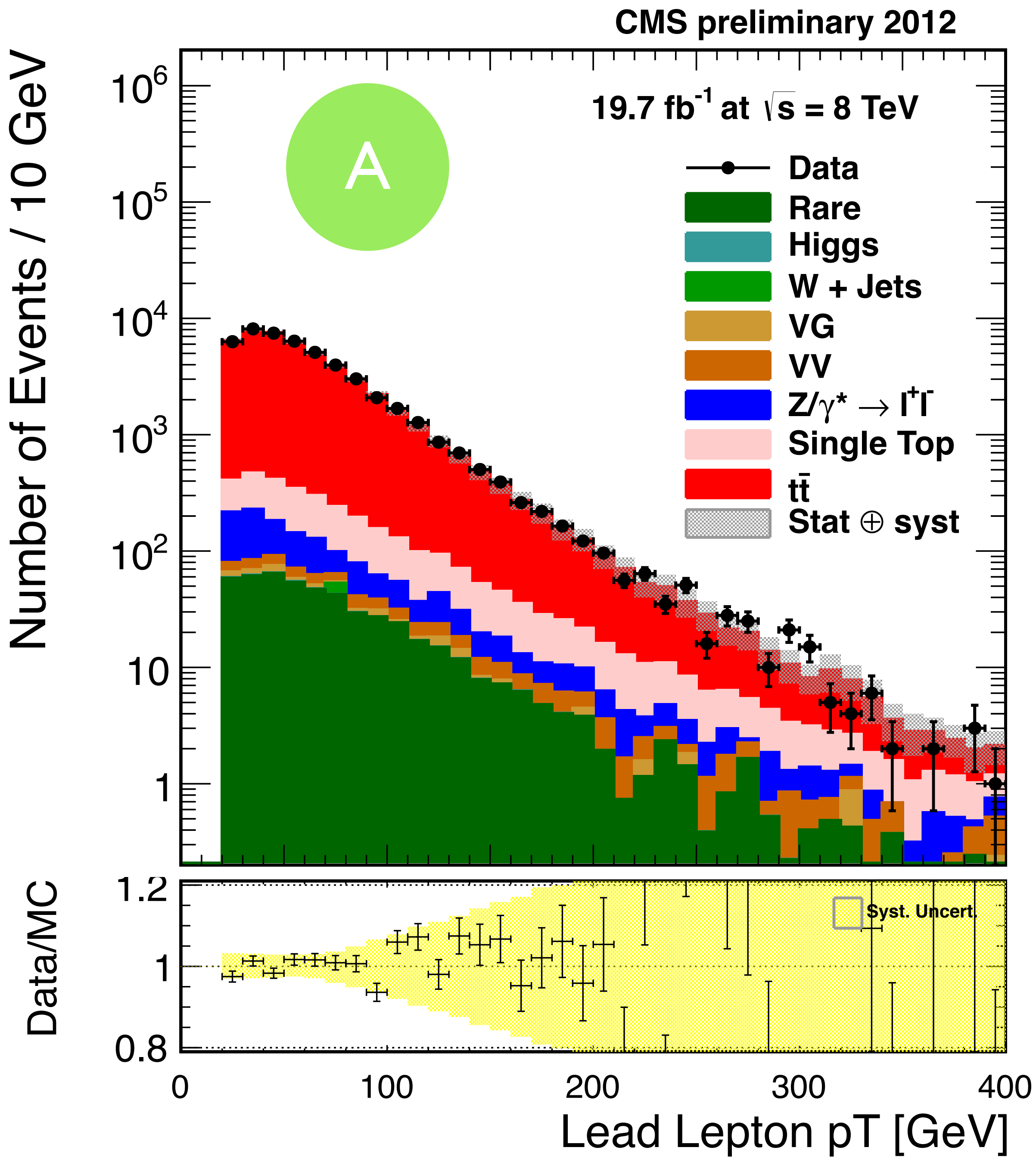
Solution is to apply a reweighting to events utilizing generator level system p_T information

So, for our signal samples, we apply this based on the gen-level Stop system p_T

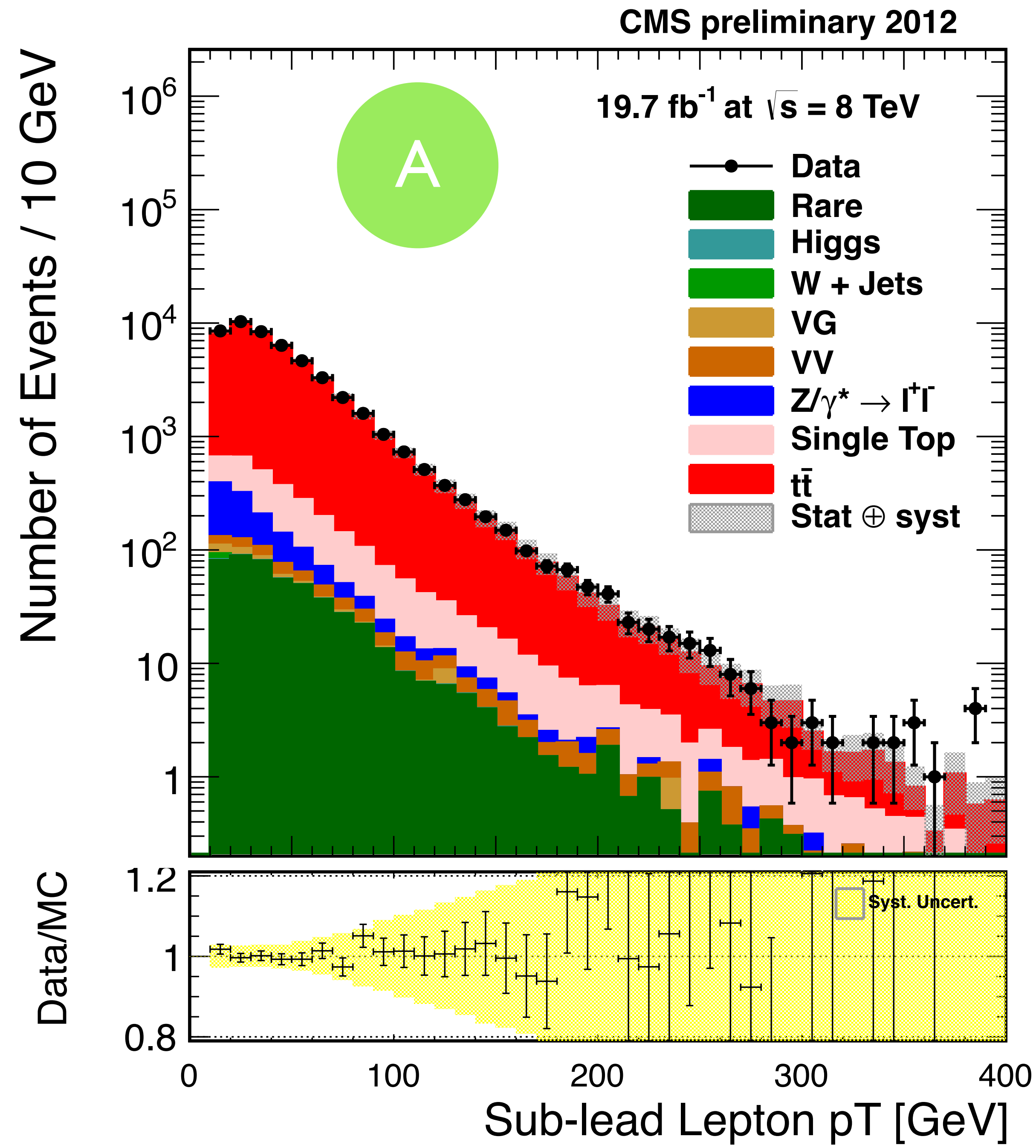
Table 3: Proposed central value and systematic weights from Z + jets.

p_T Bin [GeV]	Central Value Weight	Systematic Variation Weight
(0,120)	1.00	± 0.00
(120,150)	0.95	± 0.05
(150,250)	0.90	± 0.10
(250,∞)	0.80	± 0.20

Object Modeling (lepton p_T)

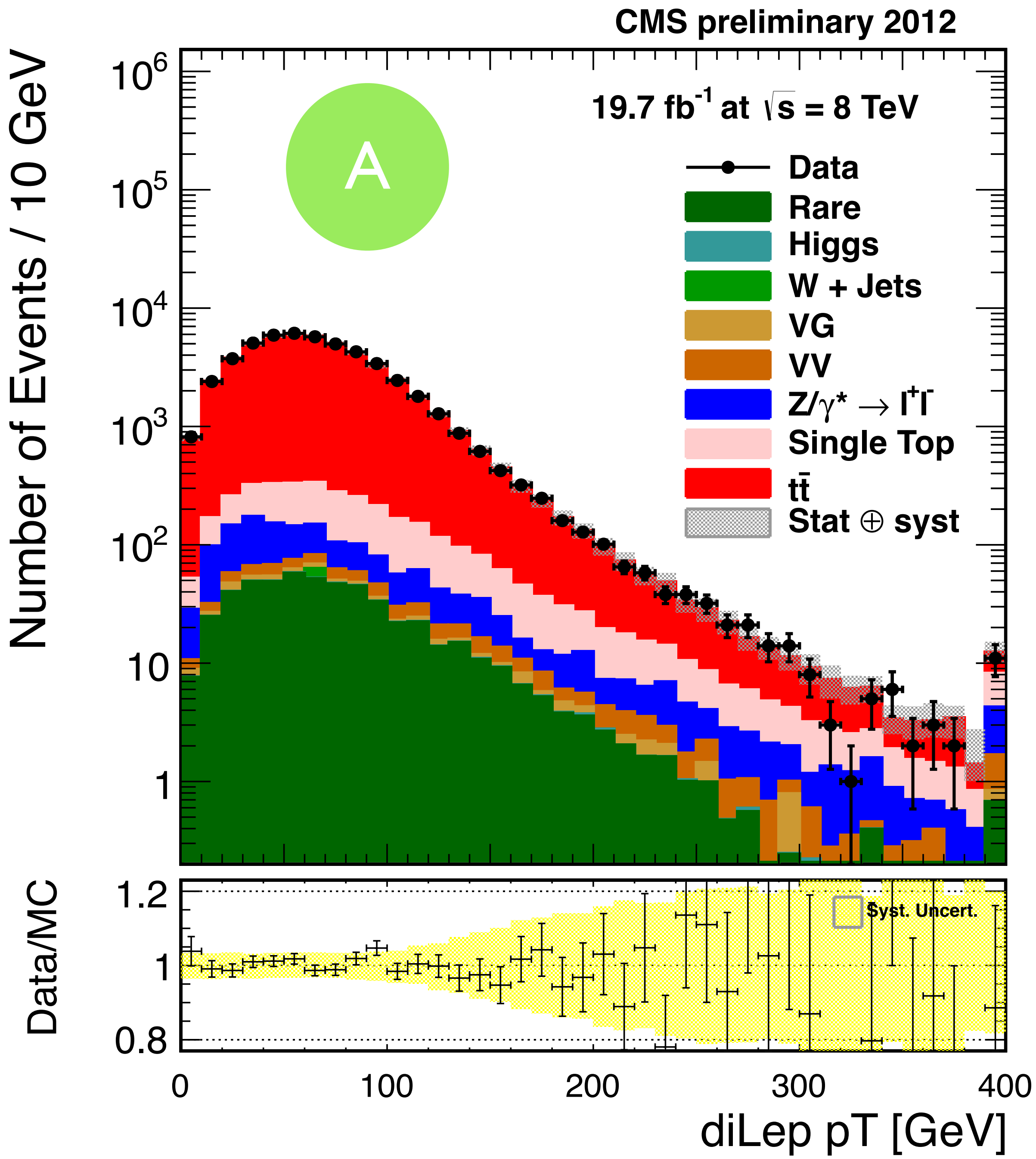


Lead Lepton p_T

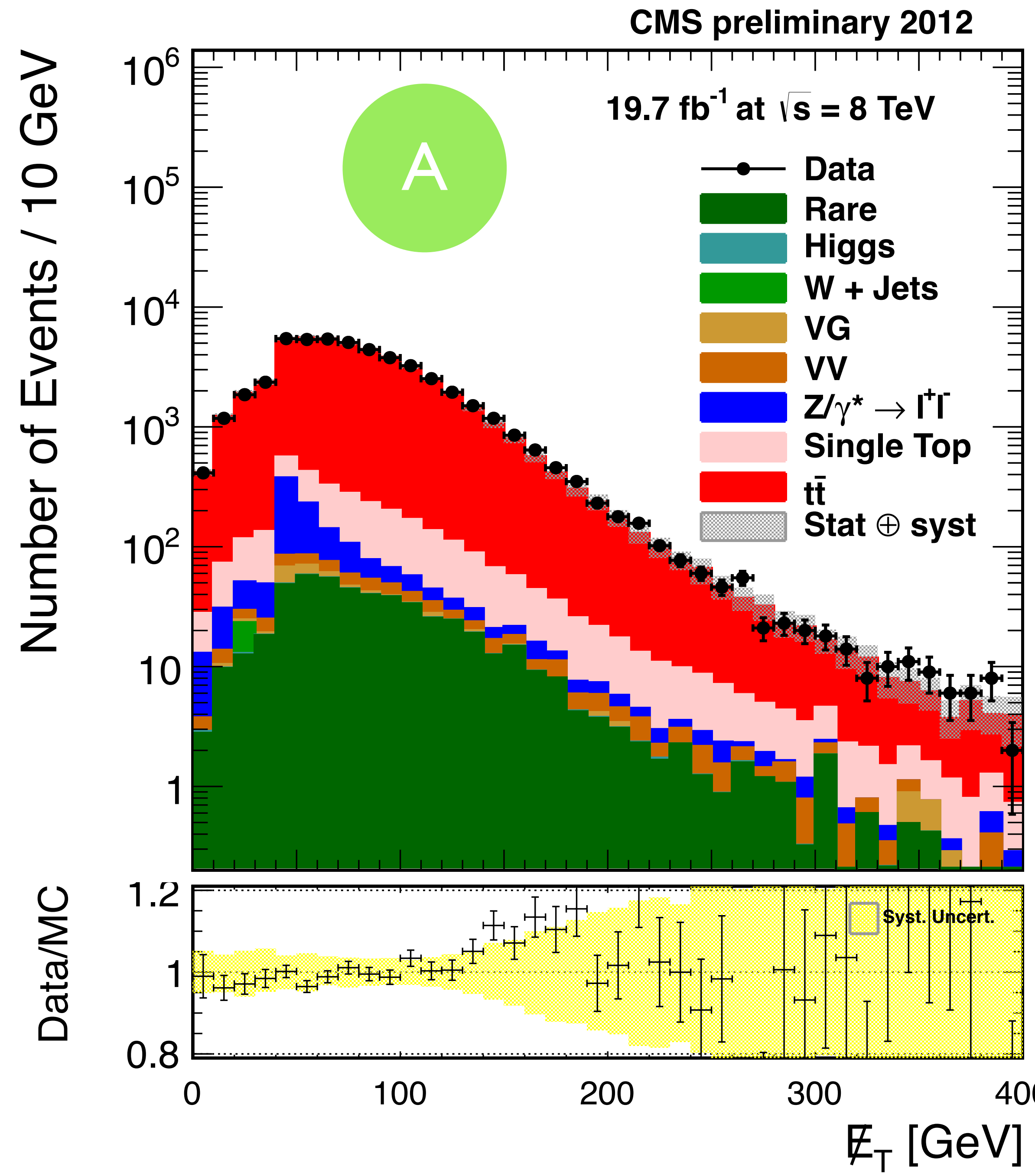


Sublead Lepton p_T

Object Modeling (MET)

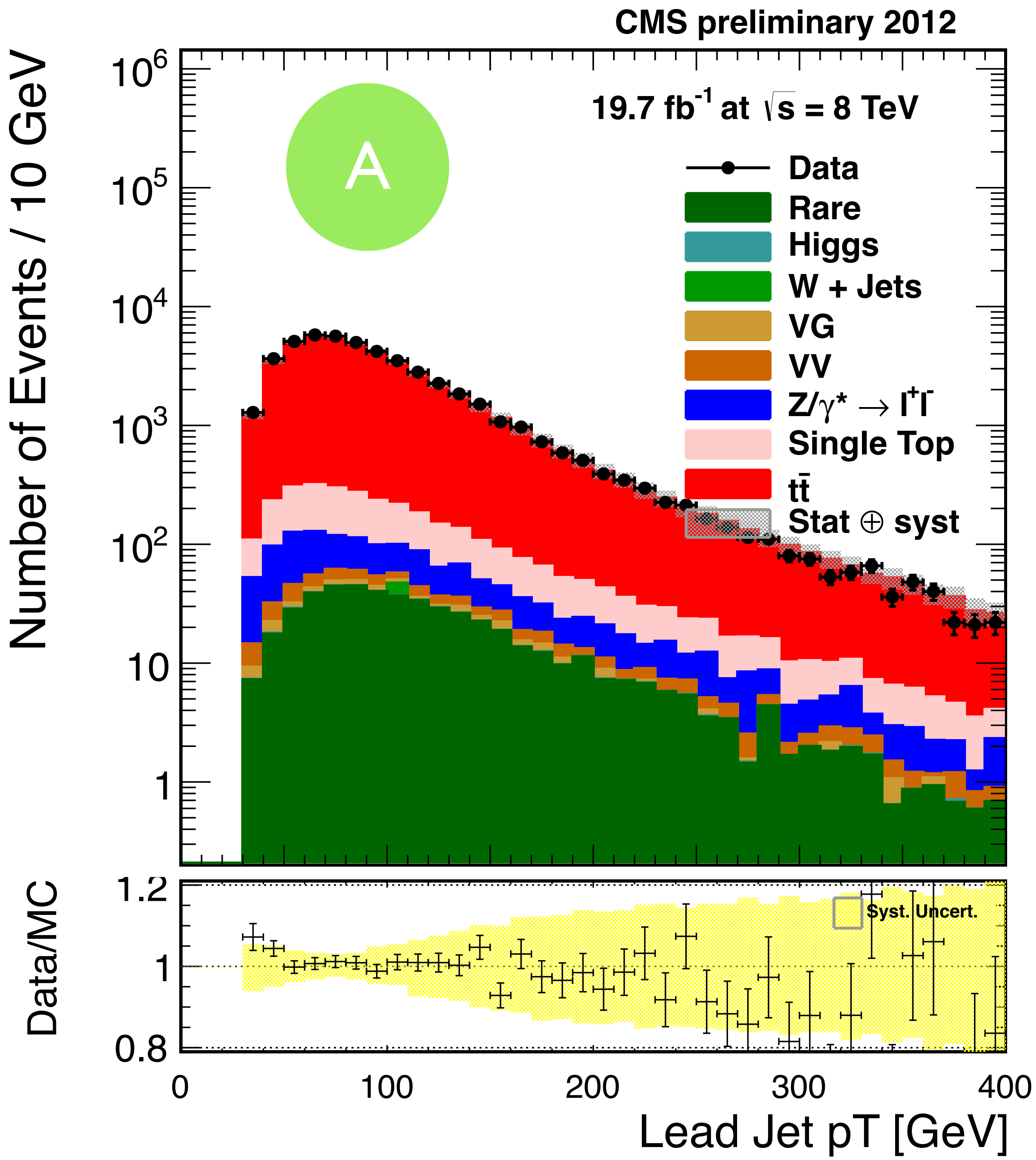


Dilepton pT

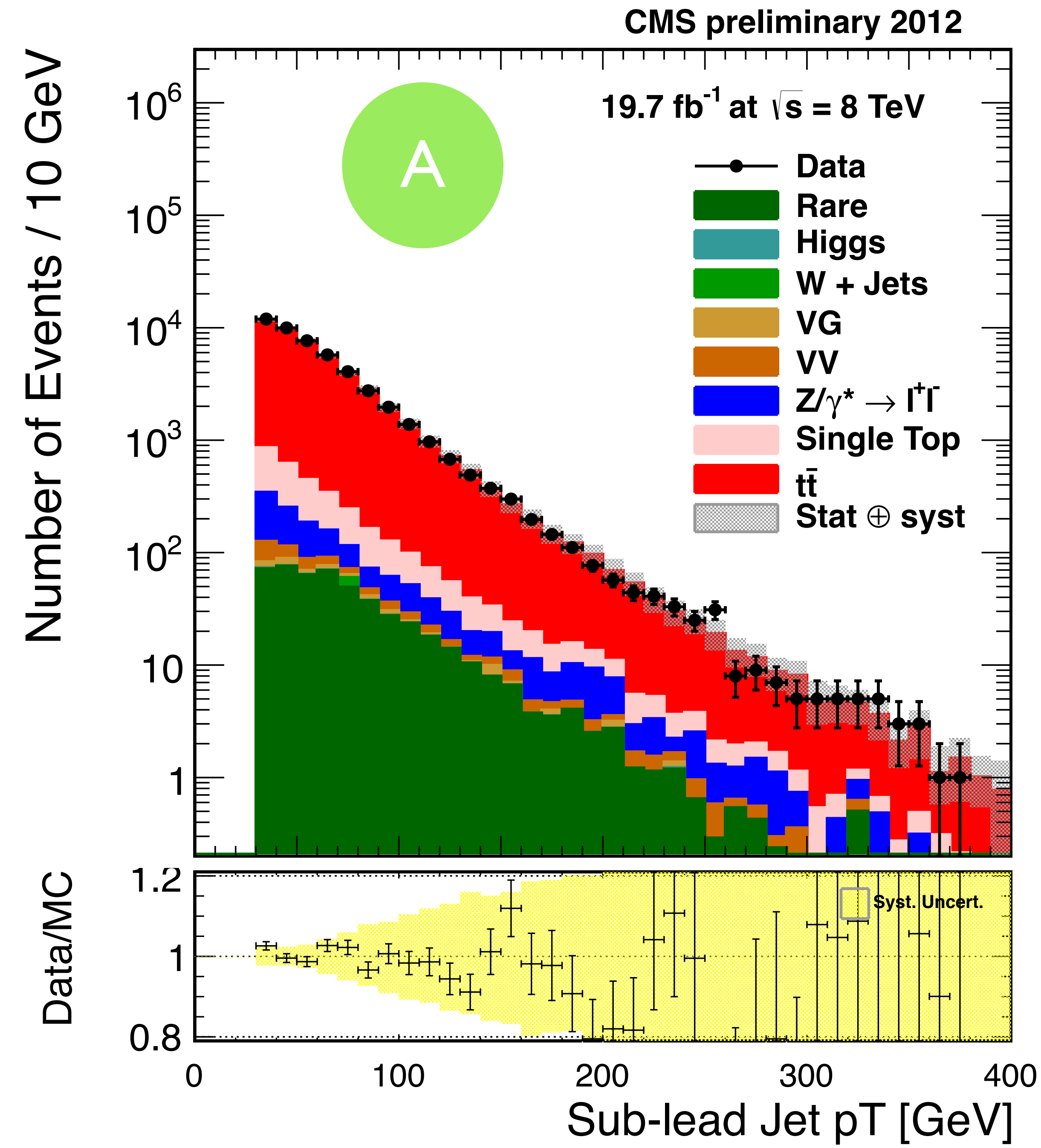


MET

Object Modeling (Jet p_T)

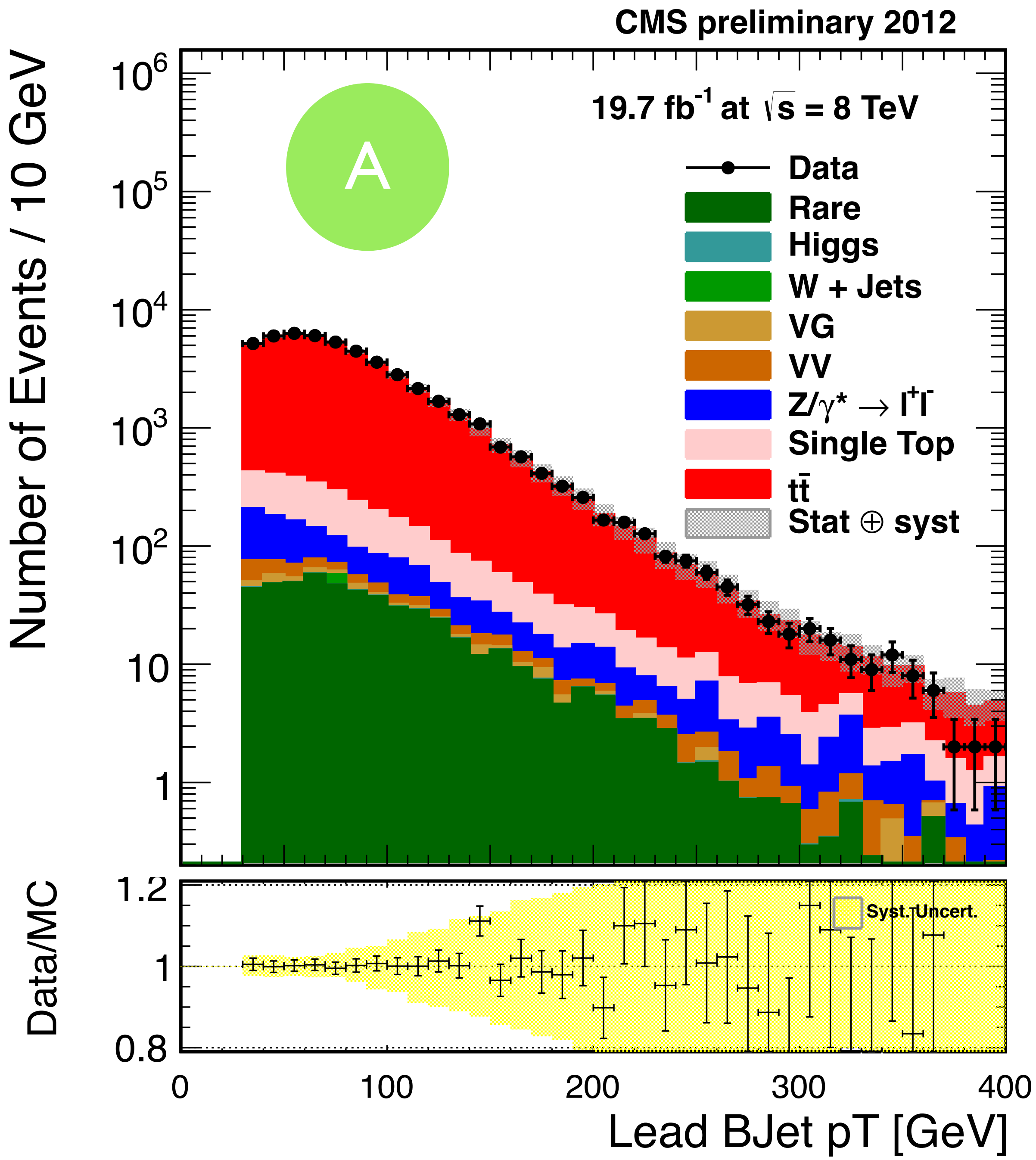


Lead Jet p_T

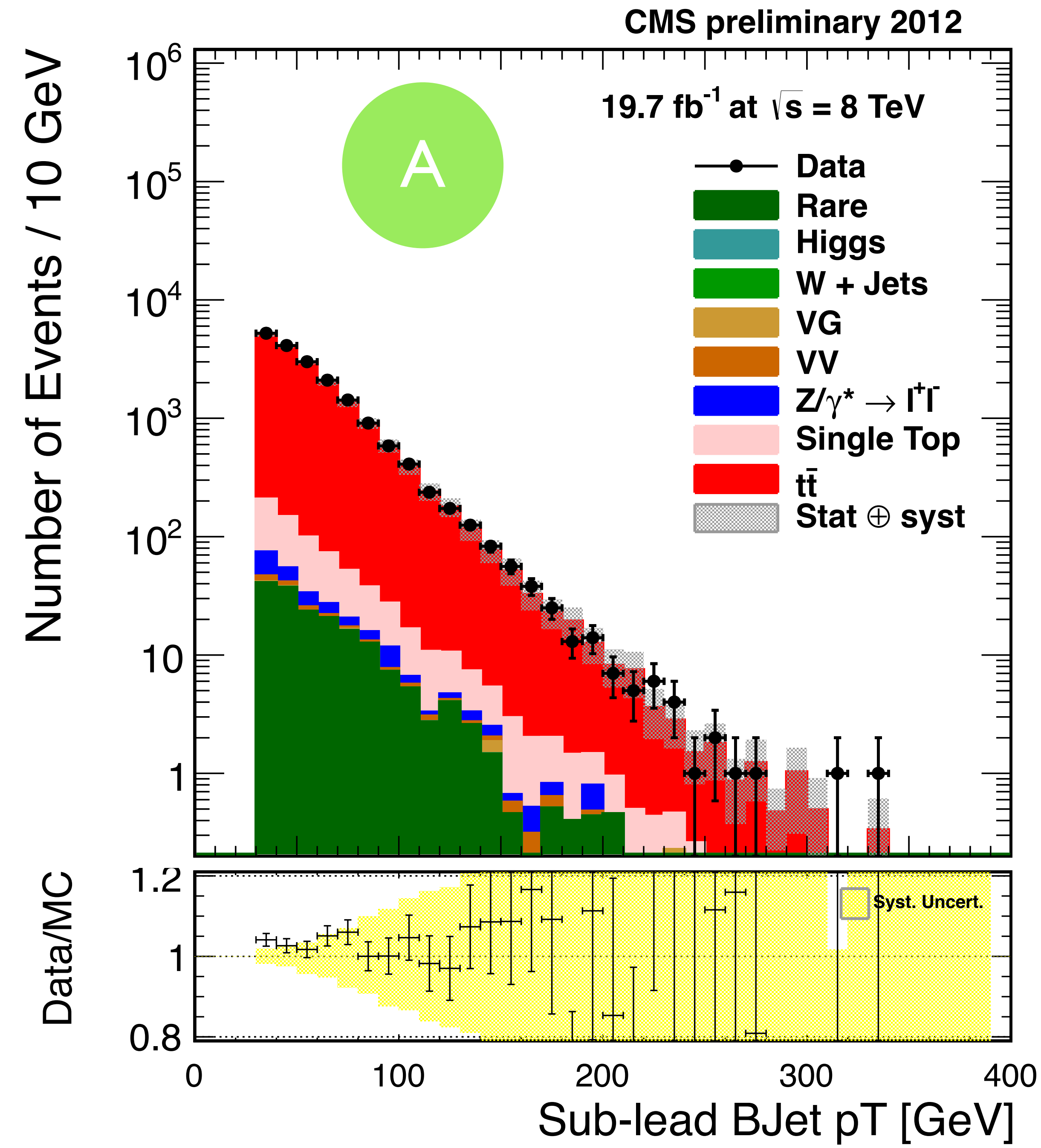


Sublead Jet p_T

Object Modeling (BJet p_T)

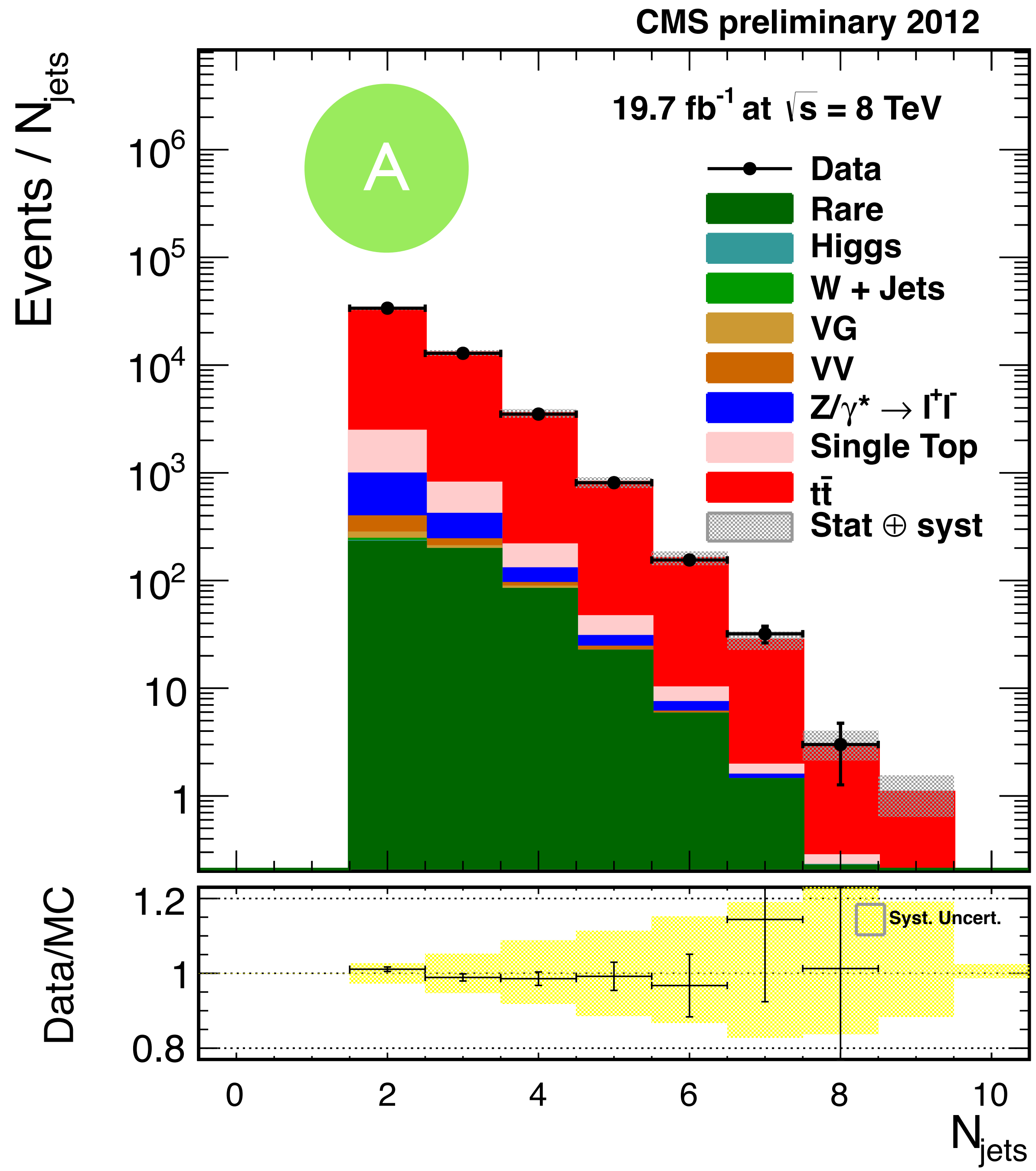


Lead B-Jet p_T

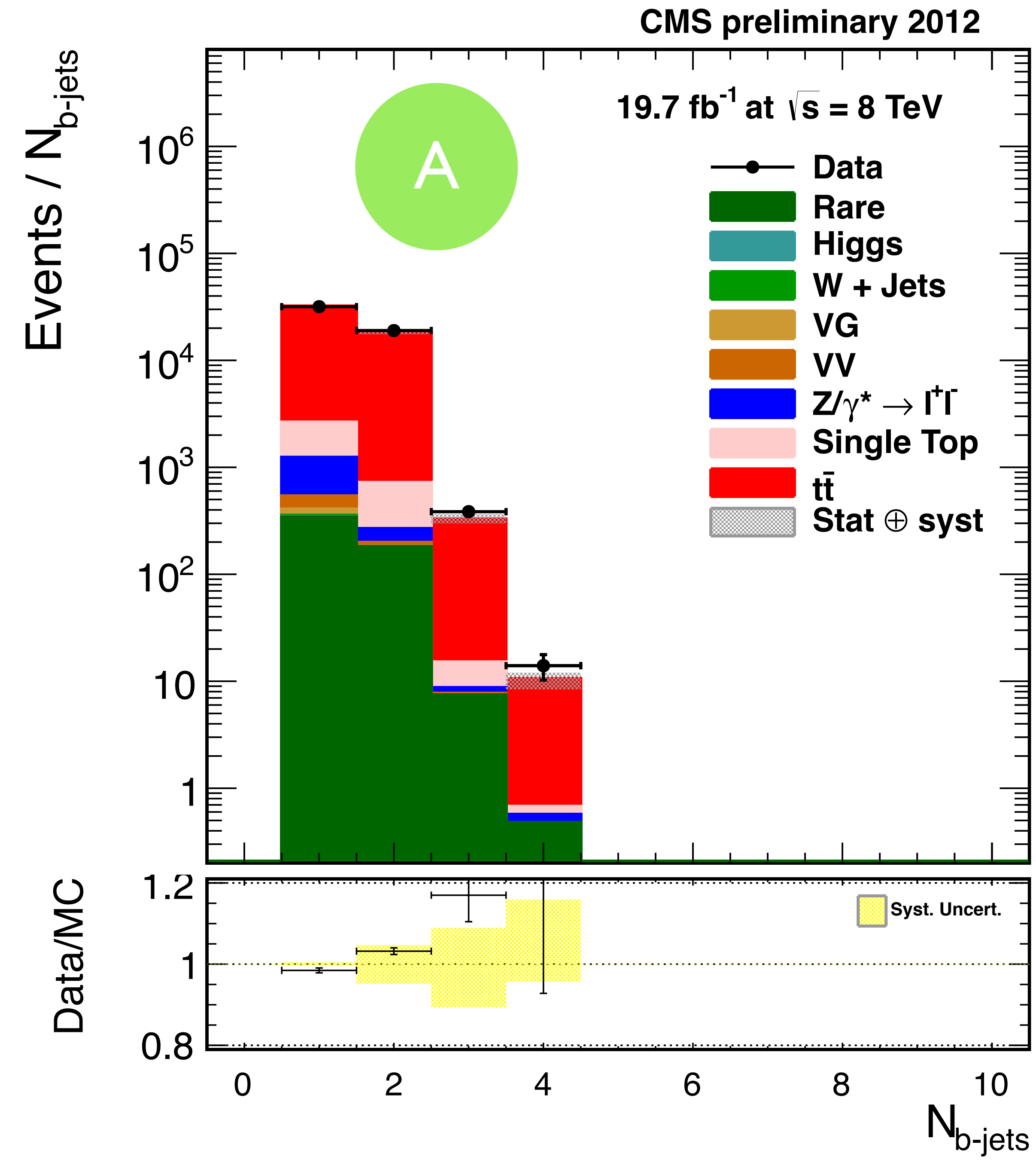


Sublead B-Jet p_T

Object Model (Jet Multiplicity)



N_{Jets} passing selection



$N_{BtagJets}$ passing selection

Data-Driven TTBar normalization

As have been previously mentioned (and has been made clear by plots), our largest background after all selections is by far SM TTbar

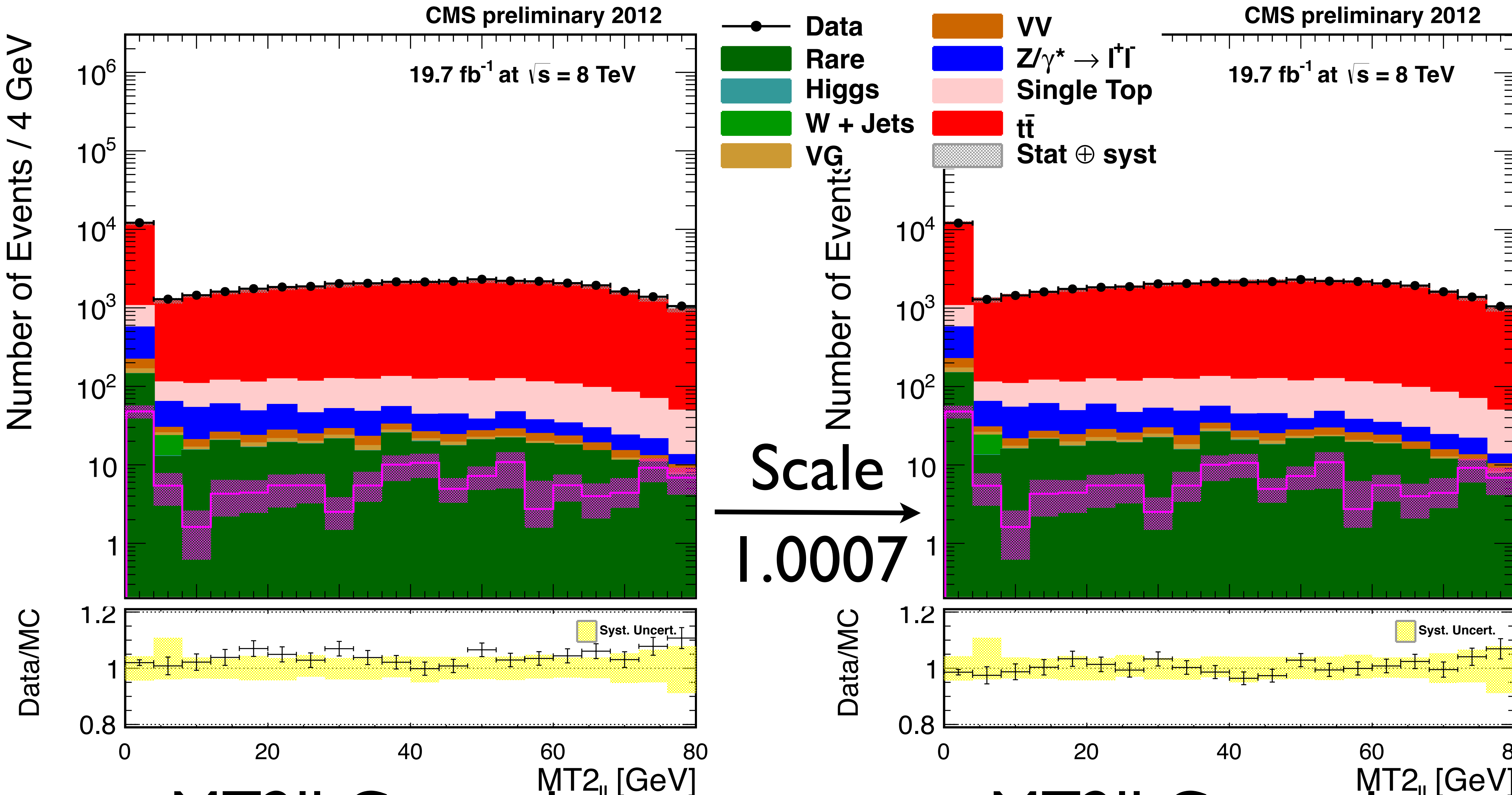
To account for the uncertainty of the SM TTbar production cross-section (and technically, also the BRs to relevant final states) we normalize the integral of our TTbar MC to match that of the data in the region $M_{T2}(ll) < 80$ GeV (after subtracting non-TTbar MC from data in that region)

When setting limits, we account for the signal contamination (using signal simulation) of this normalization in the control region for each point in SUSY mass parameter space we examine

Effect is vanishingly small except at low stop mass when the splitting between the stop and LSP is close to the top mass (can be as high as 10% there due to both shape and yield of the signal)

Calculated base scale factor => (Data - nonTTBar)/TTBar: **1.0007**

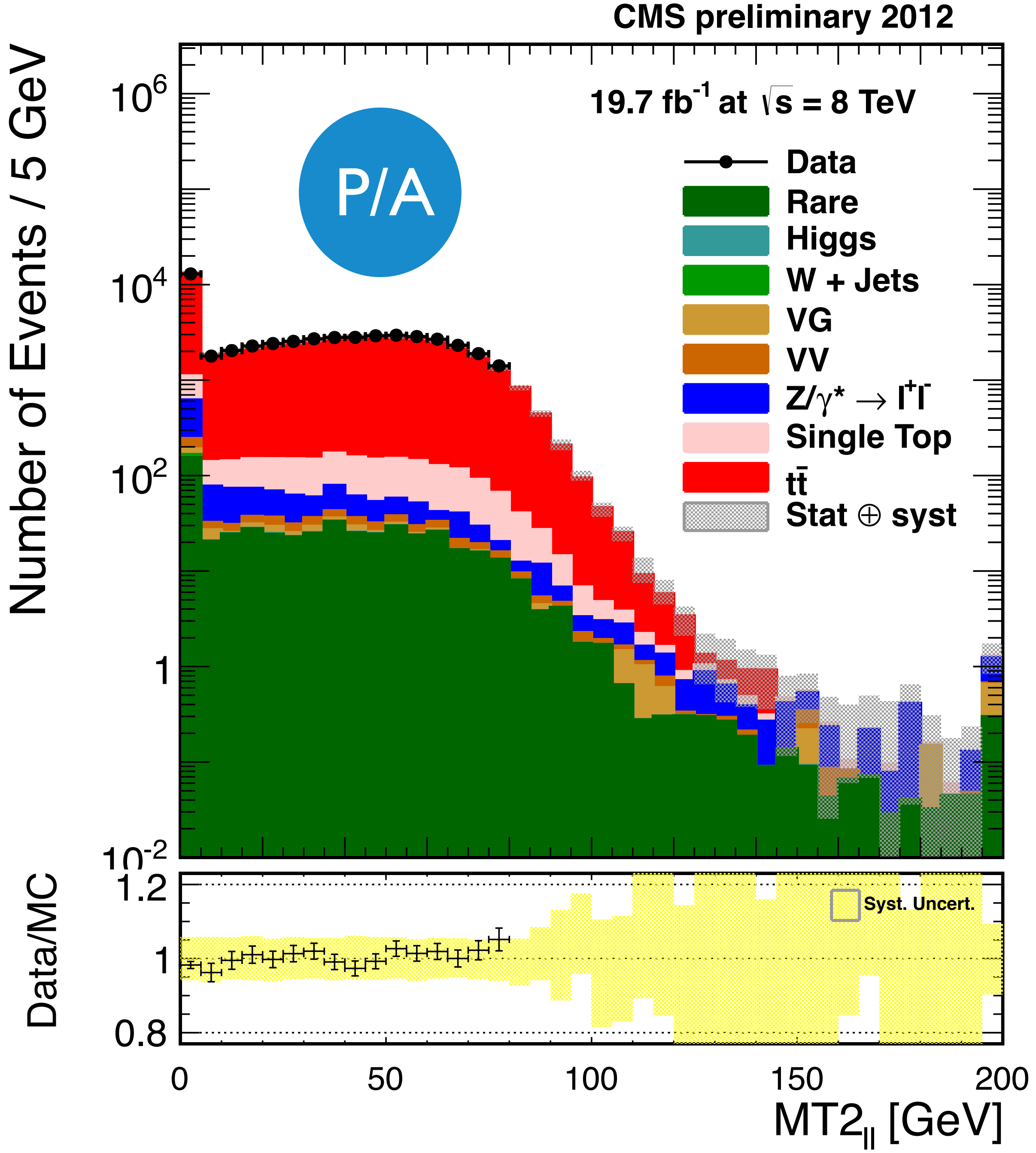
Data-Driven TTBar normalization



MT2ll Control region pre -TTbar RW

MT2ll Control region post -TTbar RW

Modeling of M_{T2}(ll)



All of the input objects for our analysis are well-modeled by the simulation

M_{T2}(ll), however, is a non-trivial variable.

The bulk of the distribution before the kinematic edge is well-modeled shape-wise, but the meat and potatoes of this analysis is in the region of the ttbar kinematic edge and beyond.

We thus spent a considerable amount of time investigating the nature of the shape of M_{T2}(ll) – both in the bulk control region as well as in the signal region – using a variety of techniques, including simulation (both full event simulation and "toy" models) and also statistically orthogonal selections

Modeling of M_{T2}(ll)

The three ingredients for M_{T2}(ll) are the the p_T vectors for the two selected leptons and the event MET.

Subsequently, the tail at high values of M_{T2}(ll) can stem from several sources

1) Resolution on the leptons' p_T vectors

2) Resolution on the MET p_T vector

2a) The gaussian MET resolution core stemming from the core of the hadronic resolution function

2b) Rare and/or extreme mismeasurements of objects that would populate the tail of the MET distribution

3) Backgrounds with tau leptons, as the leptonic decay of a tau provides not only a visible lepton that can pass our selection, but also an additional corresponding neutrino beyond those already present in the event

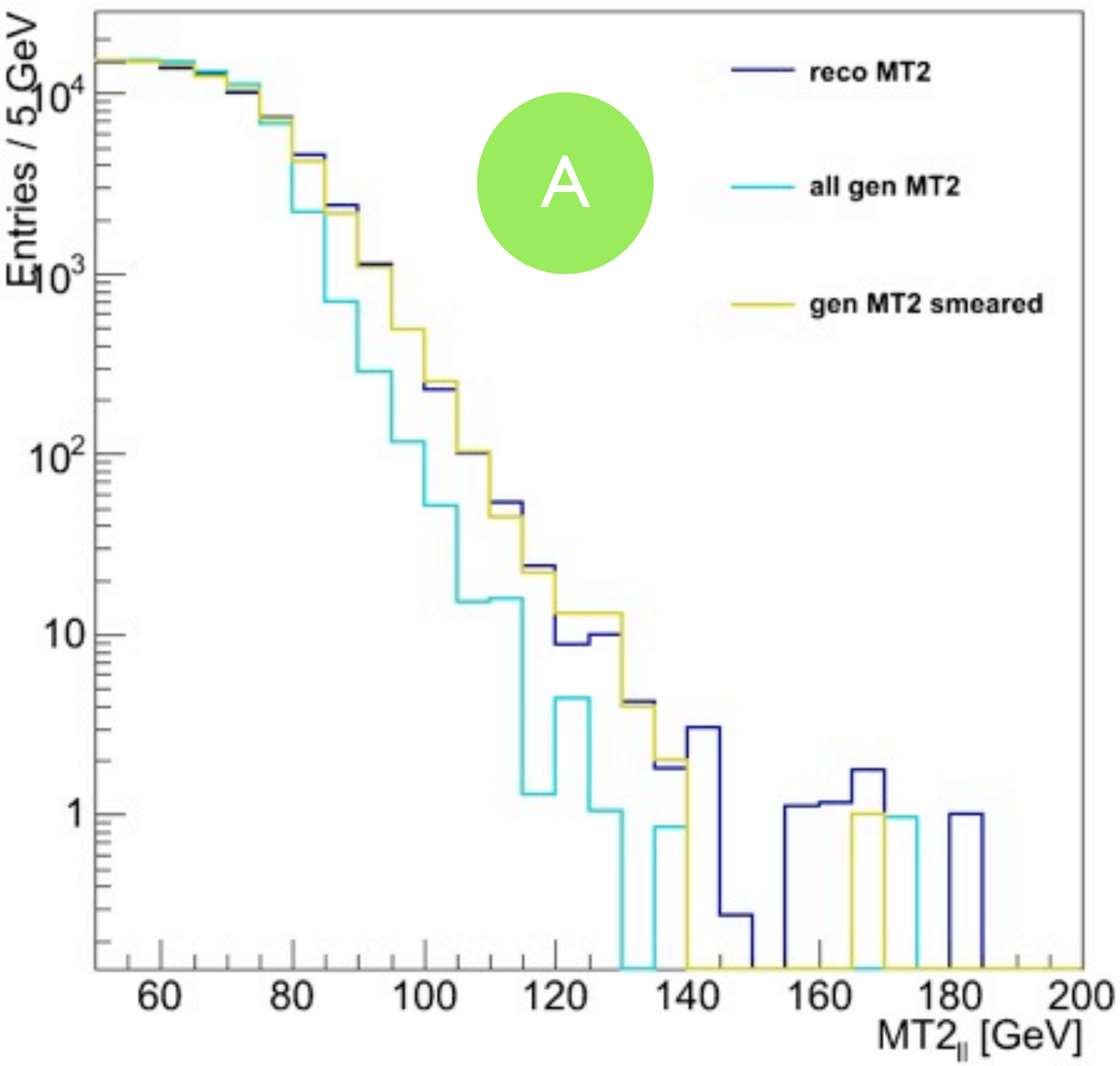
4) Intrinsic widths of produced particles (most notably the SM W bosons)

Of these, 1) is <u>irrelevant</u> (Leptons have O(10x) better resolution than hadrons at CMS)

Checks for 2a), 2b), 3), and 4) can be found, respectively

<u>here</u>, <u>here</u>, <u>here</u>, and <u>here</u>

M_{T2}(ll) and Gauss MET core



Looking at just ttbar simulation

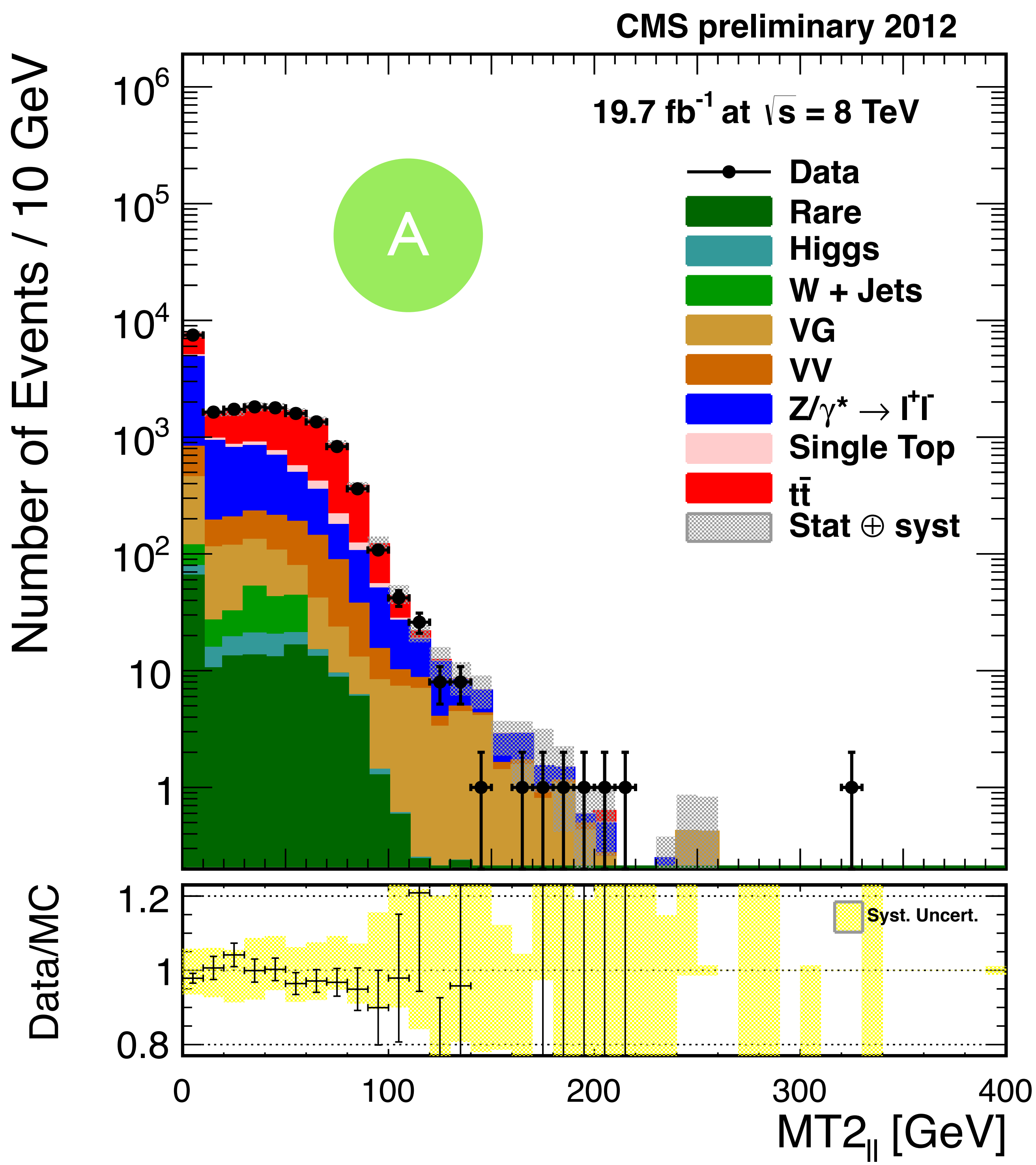
The full detector simulation M_{T2}(ll) is in blue: familiar falling edge shape as ttbar forms the bulk of this component in the composite distribution

M_{T2}(ll) constructed with generator level objects is in light blue: distribution is tighter, as one would expect

Gold M_{T2}(ll) was constructed with gen-level objects, except that the MET has had a gaussian smearing applied to its magnitude and direction. Distribution matches up very well with the reco-level M_{T2}(ll)

We interpret this to mean that the gaussian core of the MET resolution is the primary driving factor in the resolution of M_{T2}(ll)'s kinematic edge

MET Reco. Failure?



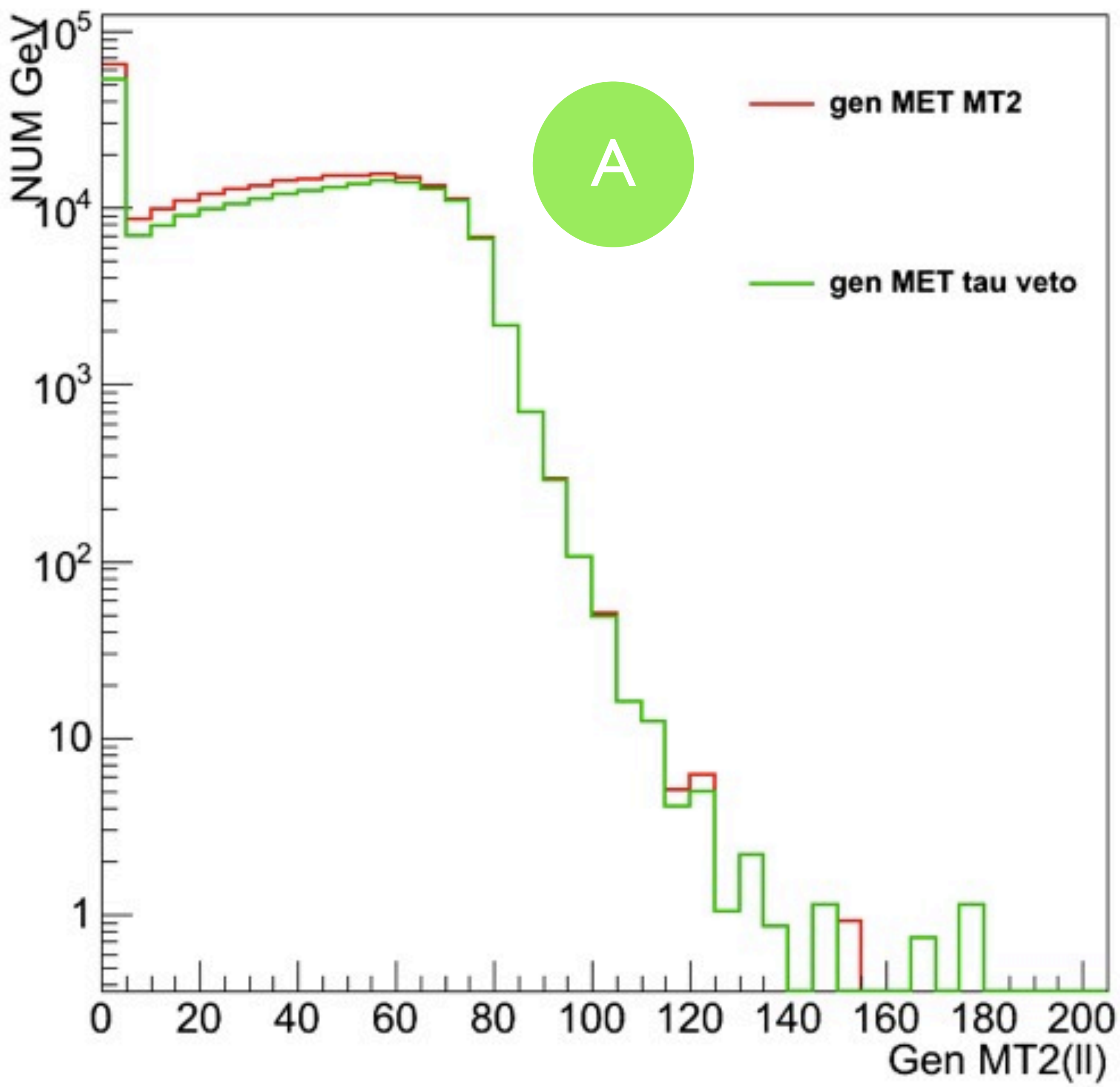
Plot on the left is M_{T2}(ll) with all selections applied except we reverse the *b*-jet requirement – i.e. # of *b*-jets = 0

Ignoring the bin in data that seems underpopulated (140-150 GeV) we see nothing that implies a gross discrepancy between MET reconstruction in data and the simulation (most notably, nothing in the far tail)

Aforementioned bin at 140 GeV could easily be just a statistical fluctuation (approx. 2 sigma as it is)

Event far in the tail in data appears to be either a standard Z + jets, or a ZZ event with one Z decaying invisibly (dilepton system mass is just outside our window cut and MET is back to back against dilepton system)

M_{T2}(ll) and Tau leptons



Looking at M_{T2}(ll) constructed with generator level object, so no detector resolution effects come into play

Veto on tau leptons at the generator level

No notable differences between the two M_{T2}(ll) spectra in our signal region – tau leptons do not cause a tail in M_{T2}(ll)

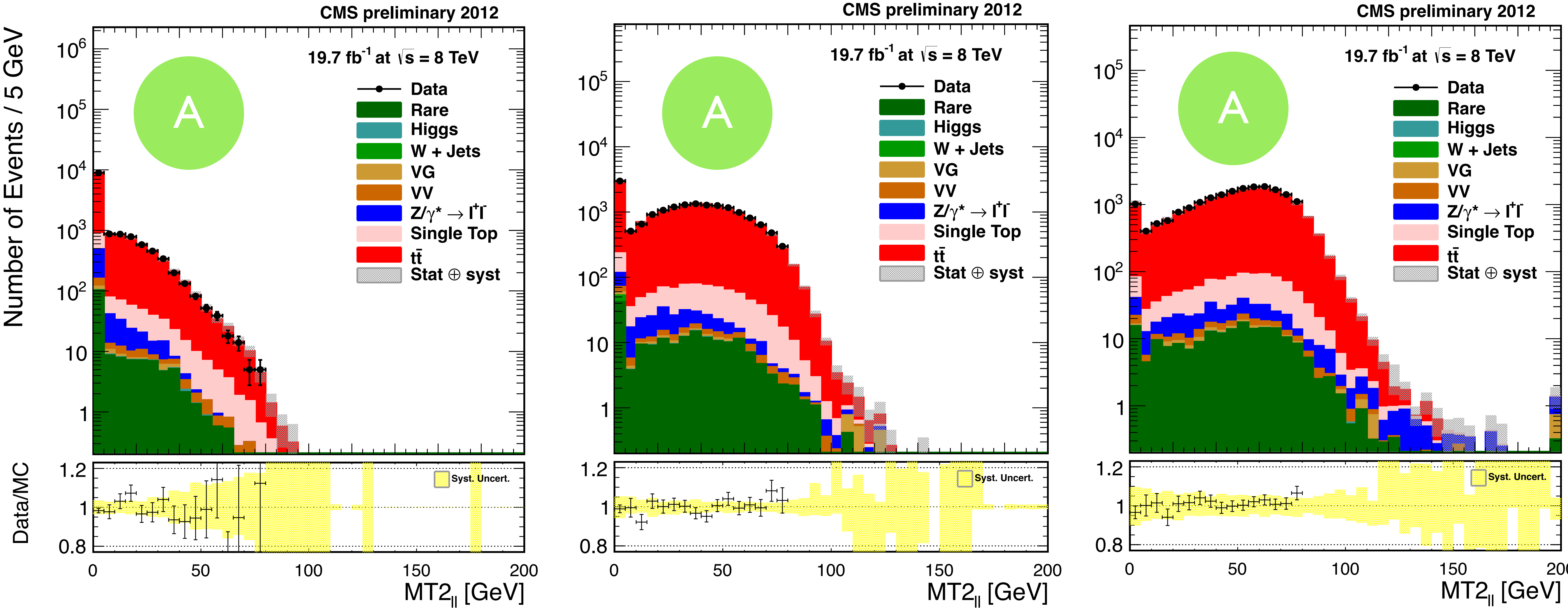
Modeling of M_{T2}(ll)

For smaller cut values of M_{T2}(ll) – 80 - 90 GeV, the modeling for the close end of the ttbar kinematic edge becomes the most relevant factor

In order to investigate the accuracy of the modeling of this shape, we looked at Data/MC comparisons with full selections applied in our control region (i.e. blinded to M_{T2}(ll) > 80 GeV)

Specifically, we considered three different classes of events, separated based upon the opening angle phi between the MET p_T vector and the p_T vector of the dilepton system. The expectation here is that high (low) values for this opening angle will correspond to high (low) values of M_{T2}(ll).

M_{T2}(ll) – diff. object geometry



DPhi is angular opening between $\mathbf{p_T}^{lep1}$ + $\mathbf{p_T}^{lep2}$ and $\mathbf{p_T}^{miss}$

DPhi < 1/3 Pi   1/3 Pi < DPhi < 2/3 Pi   DPhi > 2/3 Pi

Given strength of M_{T2}(ll) modeling in different angular regions, should *not* need additional "M_{T2}(ll) shape" systematic

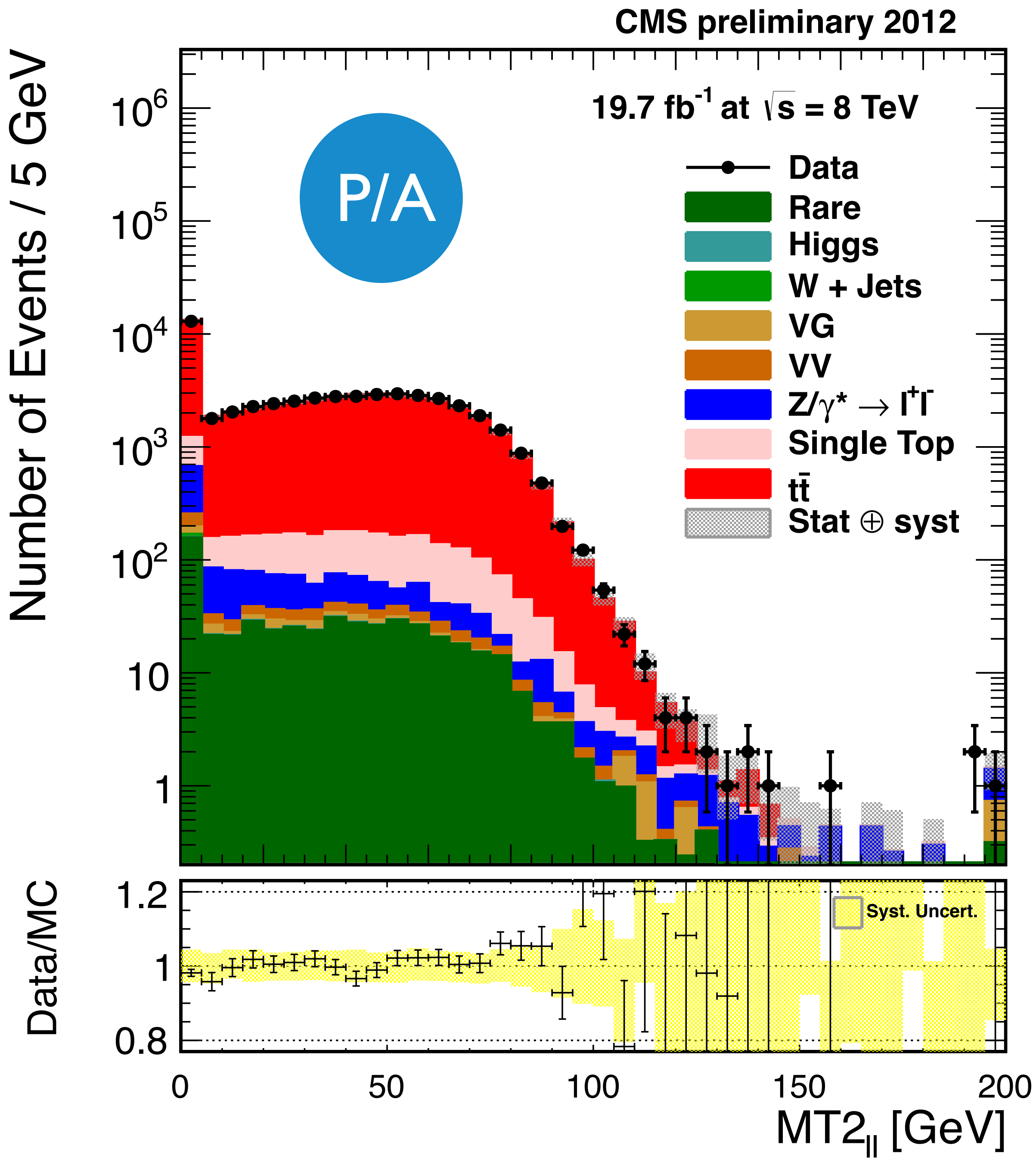
Modeling of M_{T2}(ll)

Thanks to the combination of the studies we performed, we believe we have a very robust understanding of not only the driving factors for the shape of the M_{T2}(ll) variable, but also the relative modeling quality of M_{T2}(ll) in the simulation **

With the permission of the SUSY conveners, we unblinded our signal region

** We are still performing some final additional tests/checks, for example, a check using a sewn-together combination of single W events in data and simulation to mimic a sample of WW events

M_{T2}(ll) after Full selection



The plot on the left shows the important groundwork come to fruition.

Looking at the region of the kinematic edge and beyond, we see Data/MC agreement within 1 sigma (stat + syst)

We investigated the three events a very high M_{T2}(ll) to make sure there weren't weird detector effects or reconstruction failures. See here

For some examples of this distribution with signal models overlaid, see here

Calculating Expected Limits

Due to our strong Data/MC agreement, we proceeded to set limits.

The first ingredient, of course, is the background prediction in the signal region.

M_{T2} value	Data	Expected bkg.	Stat. unc.	Sys. unc.	
80	1784	1702.4	17.2	+110.6	-113.1
90	426	414.0	8.2	+44.0	-38.8
100	106	101.5	3.9	+11.5	-12.7
110	30	28.2	2.0	+7.1	-2.4
120	14	12.9	1.2	+3.4	-1.4

Table 19: Data yields and background expectation for five different M_{T2} cut values.

Limit Setting (Bkgd. Est.)

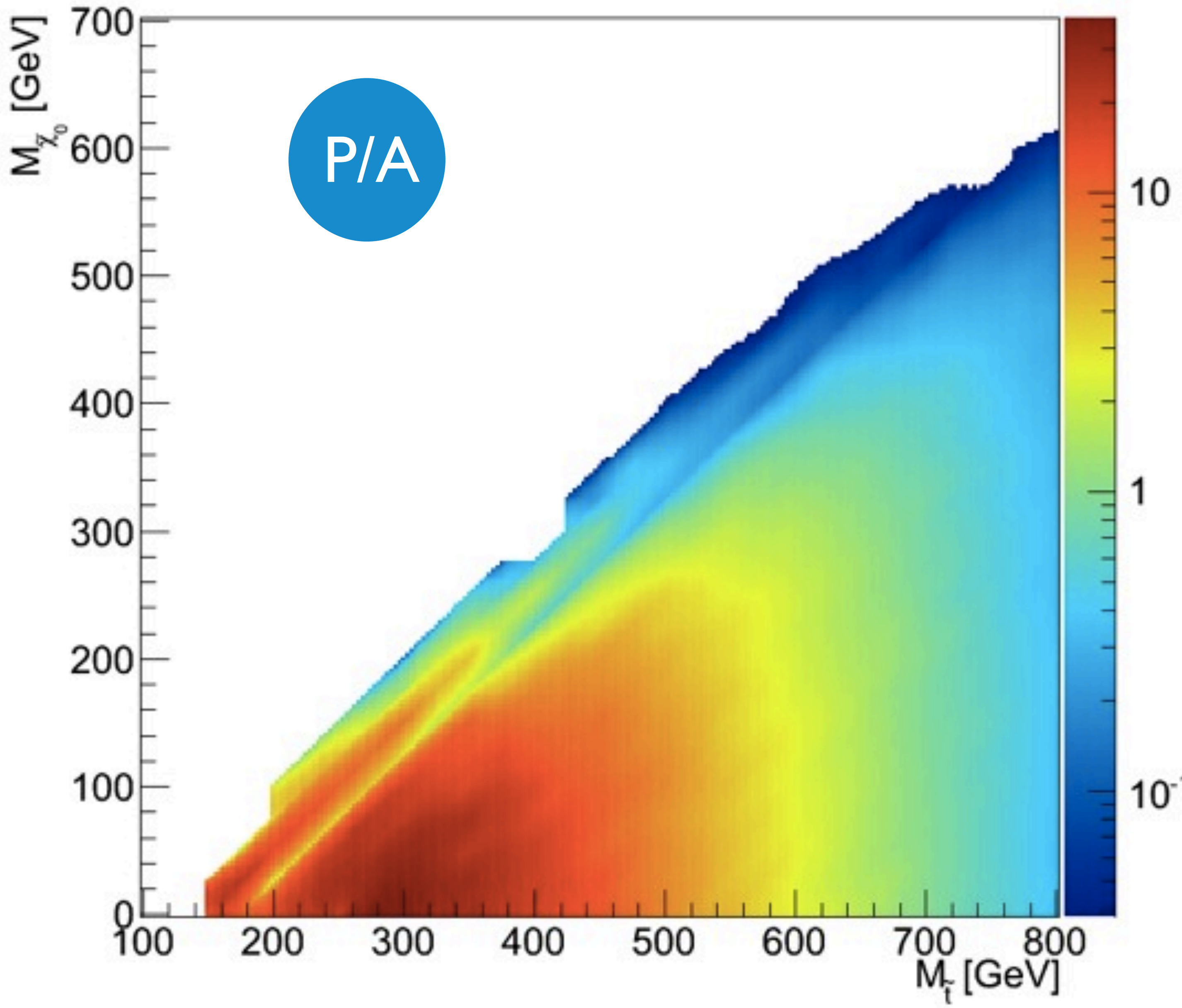
Bkg.	Events	Stat. unc.	Sys. unc.
$t\bar{t}$	15.2	1.6	+4.3 -1.5
DY + jet(s)	5.9	0.8	+2.9 -1.5
$V\gamma$	1.8	0.8	+3.2 -0.9
single t	2.0	0.1	+0.2 -0.2
VV	0.6	0.2	+0.2 -0.3
other (e.g. W, H)	2.7	0.2	+0.6 -0.5

Table 13: Background prediction in the signal region $M_{T2} > 110$ GeV with statistical (MC statistics) and systematic uncertainties.

Source	Uncertainty
ϵ(trigger)	1.2%
$\epsilon(\ell)$	1.8%
ℓ energy scale	1.7%
ϵ(b-tag)	5.0%
gen top p_{T}	0.5%
JES	13.5%
JER	9.3%
unclustered energy	7.3%
Total	19.1%

Table 15: Systematic uncertainties on the background yield in the signal region $M_{T2} > 110$ GeV by source. In cases where the error is asymmetric the larger of the two errors is displayed. The full asymmetric error is used in the limit calculation.

Optimizing the M_{T2}(ll) cut



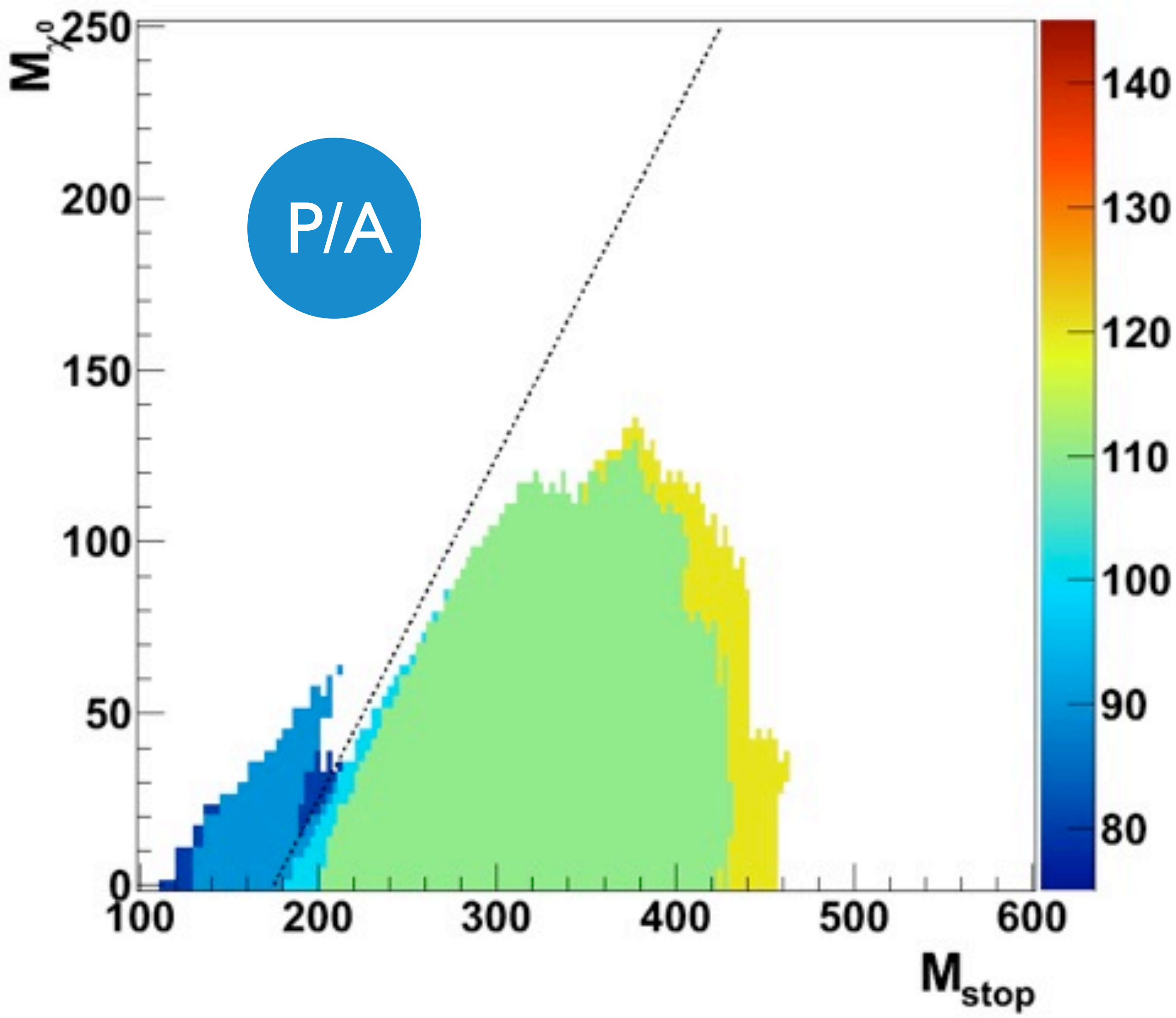
T2tt Central Value Signal Yield
M_{T2}(ll) > 110 GeV

The next ingredient is the expected signal yield in the signal region

As you can see from the left plot, the signal acceptance for a fixed M_{T2}(ll) cut depends upon the point in SUSY mass parameter space

Thus, for setting our expected and observed limits we performed an optimization of the M_{T2}(ll) cut used

Optimizing the M_{T2}(ll) cut



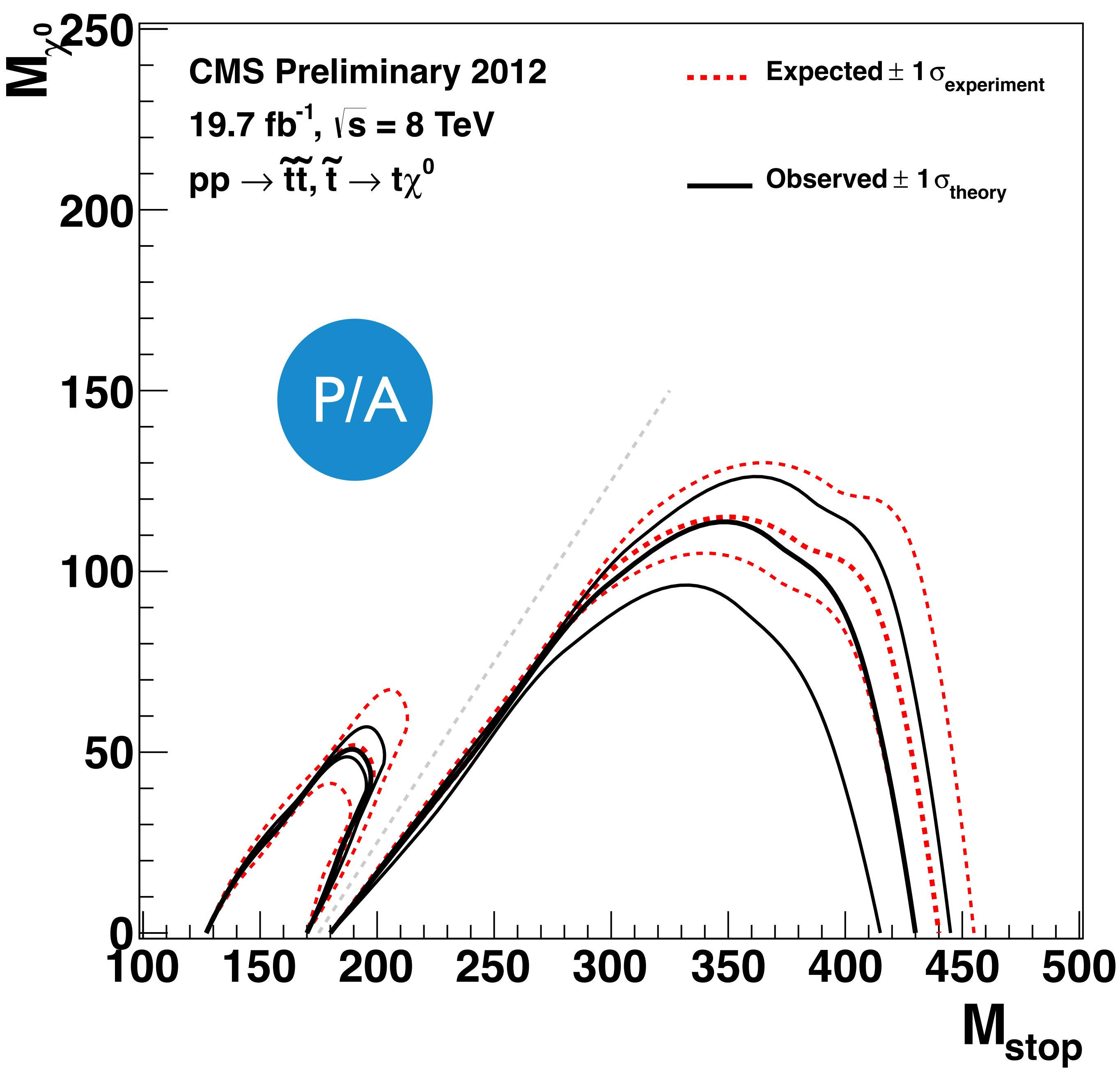
For each mass point, we iteratively (10 GeV steps) considered M_{T2}(ll) cuts between 80 and 140 GeV

For each cut for each mass point, we calculated the expected limit using the asymptotic CLs setting of the Higgs Limit tool

We determined the optimal M_{T2}(ll) cut as the cut that yielded the best expected limit on the signal strength

Optimal M_{T2}(ll) cut as determined by the expected limit

Calculating Expected Limits



Shown here are the expected 95% exclusion limits on mass points in the T2tt SMS signal samples utilizing these optimal M_{T2}(ll) cuts

We have some sensitivity in the region where the top is produced off-shell

Unfortunately, we don't seem to have 2-sigma sensitivity in the "diagonal" region, where the mass splitting between the stop and LSP is equal to the top mass

The strong Data/MC agreement gives us observed limits that are approximately equal to the expected limits

Note: these limits were calculated using the asymptotic CLs method (full frequentist limits are in production)

Conclusion

We have developed an analysis that utilizes dilepton events to search for signatures of the decay of a pair of scalar top superpartners

We utilized data-driven estimation methods to account for our expected contribution of Drell-Yan and Fake-lepton backgrounds and furthermore to normalize our expected contribution from SM ttbar production

We accounted for notable systematics and checked various aspects of our simulation modeling

– Basic object modeling, both multiplicity and kinematics, especially after applying our full suite of object/event selections was/is well understood

The modeling of our key discriminating variable, $M_{T2}(ll)$, was/is also well understood

Subsequently, we unblinded our signal region

Conclusion

We saw no major excess of data over the nominal expectation from simulation and thus proceeded to set limits

– For the SMS considered thus far, T2tt, we see that we have some exclusion power for low-value stop masses in the "off-shell top" region

– On the other side of the spectrum, we hit our upper bound on stop mass exclusion at approximately 425 GeV

There are a few minor checks/synchronizations to perform, but barring those, we feel ready to move to the next stage of the approval process

To-Do

Run T2bw SMS samples through the analysis chain – just need to run it through the $M_{T2}(ll)$ cut optimization and subsequently set limits

Run full frequentist limits on T2tt and T2bw

Perform some additional shape studies to quell any final concerns about our understanding of $M_{T2}(ll)$

BACKUP T.O.C.

Last Slide Viewed

Prior Results/Studies

Comparing Object Selections

–https://indico.cern.ch/getFile.py/access?contribId=0&resId=0&materialId=slides&confId=233686

M_{T2}(ll) tails in Z control region

–https://indico.cern.ch/getFile.py/access?contribId=5&resId=0&materialId=slides&confId=262922

–https://indico.cern.ch/getFile.py/access?contribId=4&sessionId=0&resId=0&materialId=slides&confId=264968

M_{T2}(ll) shape studies

https://indico.cern.ch/getFile.py/access?contribId=3&resId=0&materialId=slides&confId=264745

JER Smearing studies

– https://indico.cern.ch/getFile.py/access?contribId=5&sessionId=0&resId=0&materialId=slides&confId=281216

– https://indico.cern.ch/getFile.py/access?contribId=0&resId=0&materialId=slides&confId=282132

MC Datasets

Sample	Dataset path
Drell-Yan	DYJetsToLL_M-10To50filter_8TeV-madgraph DYJetsToLL_M-50_TuneZ2Star_8TeV-madgraph-tarball DY1JetsToLL_M-50_TuneZ2Star_8TeV-madgraph DY2JetsToLL_M-50_TuneZ2Star_8TeV-madgraph DY2JetsToLL_M-50_TuneZ2Star_8TeV-madgraph DY3JetsToLL_M-50_TuneZ2Star_8TeV-madgraph DY4JetsToLL_M-50_TuneZ2Star_8TeV-madgraph
$Z+\gamma$	ZGToLLG_8TeV-madgraph
$W+\gamma$	WGToLNuG_TuneZ2star_8TeV-madgraph-tauola
W	WJetsToLNu_TuneZ2Star_8TeV-madgraph-tarball
$t\bar{t}$	TT_CT10_TuneZ2star_8TeV-powheg-tauola TT_CT10_TuneZ2star_8TeV-powheg-tauola TTJets_MassiveBinDECAY_TuneZ2star_8TeV-madgraph-tauola TT_8TeV-mcatnlo TTJets_FullLeptMGDecays_8TeV-madgraph-tauola TTJets_FullLeptMGDecays_8TeV-madgraph TTJets_SemiLeptMGDecays_8TeV-madgraph TTJets_HadronicMGDecays_8TeV-madgraph
single t	T_t-channel_TuneZ2star_8TeV-powheg-tauola Tbar_t-channel_TuneZ2star_8TeV-powheg-tauola T_s-channel_TuneZ2star_8TeV-powheg-tauola Tbar_s-channel_TuneZ2star_8TeV-powheg-tauola
tW	TToDilepton_tW-channel-DR_8TeV-powheg-tauola TBarToDilepton_tW-channel-DR_8TeV-powheg-tauola
WW	WWJetsTo2L2Nu_TuneZ2star_8TeV-madgraph-tauola
WW (gluon fusion)	GluGluToWWTo4L_TuneZ2star_8TeV-gg2ww-pythia6
WW	WZ_TuneZ2star_8TeV_pythia6_tauola
ZZ	ZZ_TuneZ2star_8TeV_pythia6_tauola

MC Datasets

H_{125}	GluGluToHToWWTo2LAndTau2Nu_M-125_8TeV-powheg-pythia6 VBF_HToWWTo2LAndTau2Nu_M-125_8TeV-powheg-pythia6 GluGluToHToZZTo4L_M-125_8TeV-powheg-pythia6
"Rare"	WZ_TuneZ2star_8TeV_pythia6_tauola GluGluToHToWWTo2LAndTau2Nu_M-125_8TeV-powheg-pythia6 VBF_HToWWTo2LAndTau2Nu_M-125_8TeV-powheg-pythia6 GluGluToHToZZTo4L_M-125_8TeV-powheg-pythia6 WWGJets_8TeV-madgraph WZZNoGstarJets_8TeV-madgraph ZZZNoGstarJets_8TeV-madgraph WWZNoGstarJets_8TeV-madgraph WWWJets_8TeV-madgraph TTWJets_8TeV-madgraph TTZJets_8TeV-madgraph_v2 TTWWJets_8TeV-madgraph TTGJets_8TeV-madgraph
Signal SMS	SMS-T2tt_FineBin_Mstop-225to1200_mLSP-0to1000_8TeV-Pythia6Z SMS-T2tt_2J_mStop-500_mLSP-300_TuneZ2star_8TeV-madgraph-tauola SMS-T2tt_2J_mStop-750_mLSP-25_TuneZ2star_8TeV-madgraph-tauola SMS-T2tt_2J_mStop-600_mLSP-50_TuneZ2star_8TeV-madgraph-tauola SMS-T2tt_2J_mStop-400_mLSP-150_TuneZ2star_8TeV-madgraph-tauola SMS-T2tt_2J_mStop-250_mLSP-50_TuneZ2star_8TeV-madgraph-tauola SMS-T2tt_mStop-825to900_mLSP-1_and_mLSP-25to800_8TeV-Pythia6Zstar SMS-T2bw_2J_mStop-500to800_mLSP-0to700_x-025_TuneZ2star_8TeV-madgraph-tauola SMS-T2bw_2J_mStop-500to800_mLSP-0to700_x-050_TuneZ2star_8TeV-madgraph-tauola SMS-T2bw_2J_mStop-100to475_mLSP-0to375_x-050_TuneZ2star_8TeV-madgraph-tauola SMS-T2bw_2J_mStop-100to475_mLSP-0to375_x-075_TuneZ2star_8TeV-madgraph-tauola SMS-T2bw_2J_mStop-500to800_mLSP-0to700_x-075_TuneZ2star_8TeV-madgraph-tauola SMS-T2bw_2J_mStop-100to475_mLSP-0to375_x-025_TuneZ2star_8TeV-madgraph-tauola SMS-T2tt_2J_mStop-225to350_mLSP-25to250_LeptonFilter_TuneZ2star_8TeV-madgraph-tauola SMS-T2tt_2J_mStop-100to200_mLSP-1to100_LeptonFilter_TuneZ2star_8TeV-madgraph-tauola
QCD	QCD_Pt_20_30_EMEnriched_TuneZ2star_8TeV_pythia6 QCD_Pt_30_80_EMEnriched_TuneZ2star_8TeV_pythia6 QCD_Pt_80_170_EMEnriched_TuneZ2star_8TeV_pythia6 QCD_Pt_20_MuEnrichedPt_15_TuneZ2star_8TeV_pythia6 QCD_Pt_20_30_BCtoE_TuneZ2star_8TeV_pythia6 QCD_Pt_30_80_BCtoE_TuneZ2star_8TeV_pythia6 QCD_Pt_80_170_BCtoE_TuneZ2star_8TeV_pythia6

Further Specifics for Samples

Because it would be a bit difficult to list all salient technical details about the samples (both collision and simulation) processed, I ask you to please refer to the following database (stored on Google Docs)

Object/Event Selection

Our object selections are in sync with the RA4 single lepton analysis

We chose RA4 single lepton object selections after comparison (utilizing S/sqrt(B)) with the TTbar PAS-Top-12-007 object selections

Full set of slides here (key points/tables in backup):

https://indico.cern.ch/getFile.py/access?contribId=0&resId=0&materialId=slides&confId=233686

Object Selection Choices

Physics object definition - $t\bar{t}$ PAS-TOP-12-007

Muons (PF-POG loose)

- $p_T^\mu > 20$ GeV
- $|\eta| < 2.1$
- Global or Tracker Muon
- isolation: $\left(\frac{PF\ ISO^\mu}{p_T^\mu}\right)_{\Delta R=0.3}^{CHS+\Delta\beta\ corr} < 0.15$

Jets (AK5PFchs)

- $p_T > 30$ GeV
- $|\eta| < 2.5$
- $\Delta R(\text{jet, any selected } \ell) > 0.5$
- $N(\text{daughters}) > 1$

Electrons (PF)

- $p_T^e > 20$ GeV
- $|\eta| < 2.5$
- pass Conversion Veto
- IP cut: $|d0| < 0.04$ cm w.r.t. PV
- MVA ID > 0.5
- isolation: $\left(\frac{PF\ ISO^e}{p_T^e}\right)_{\Delta R=0.3}^{CHS+\rho\ corr} < 0.15$
- photon conversion rejection

MET and b-tagging

- MET PF Type I
- CSV with loose working point, Moriond recommendations

We compared our selection with that used for the TTBar PAS TOP-12-007

(shown above)

Object Selection Choices

Samples

- Signal:
  - /SMS-T2tt_FineBin_Mstop-225to1200_mLSP-0to1000_8TeV-Pythia6Z/Summer12-START52_V9_FSIM-v1/AODSIM
  - details here: → *DAS*, → *TWiki*
  - 50k events for each ($m_{\tilde{t}}$,$m_{\tilde{\chi}^0}$) point
  - 36 signal phase space points have been merged:
    - ⋆ $300 < m_{\tilde{t}} < 350\,\mathrm{GeV}$
    - ⋆ $200 < m_{\tilde{t}} - m_{\tilde{\chi}^0} < 250\,\mathrm{GeV}$ ($m_{\tilde{t}} - m_{\tilde{\chi}^0} > 180\,\mathrm{GeV}$ at GEN level)
  - cross sections are listed on *this TWiki*
- Backgrounds:
  - CMSSW_5_3_X
  - MadGraph $t\bar{t}$, w/o spin correlations (PowHEG is ready, though)
- Data:
  - dilepton trigger
  - dataset up to $\int \mathcal{L}\,\mathrm{d}t = 5311.0\,\mathrm{pb}^{-1}$ (Run2012 A+B)
  - CMSSW_5_3_X

Technical details of datasets for this comparison

Object Selection Choices

Results - Significance

after 1 b-tag	*stop*	$t\bar{t}$
$t\bar{t}_{dil}$	10050.3 ± 39.9	14077.5 ± 46.9
$Z + Jets$	444.4 ± 152.9	1284.4 ± 392.5
tW	438.3 ± 7.1	662.6 ± 8.6
VV	43.5 ± 0.7	154.8 ± 1.4
Non-W/Z leptons	96.8 ± 3.8	75.8 ± 4.3
Total bkg MC	11073.3 ± 158.2	16255.0 ± 395.4
Stop	69.9 ± 0.5	53.3 ± 0.4
$S/\sqrt{B}$	0.664 ± 0.007	0.418 ± 0.006

The stop selection seems to perform better in terms of $S/sqrtB$. The cuts turn out to suppress more background events than the $t\bar{t}$ selection does, while selecting more signal.

DY taken from data-driven estimation method

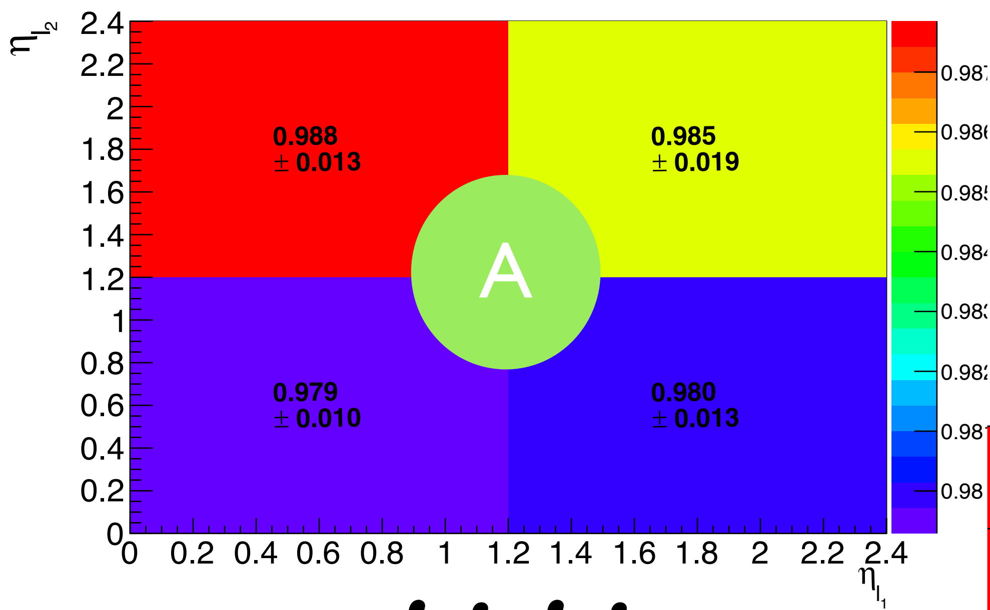
Sources for MC Scale Factors

Central Values for the Lepton Trigger Efficiency scale factors are calculated by investigating the correlation between dilepton and MET triggers – c.f. our AN, sec. 4.1

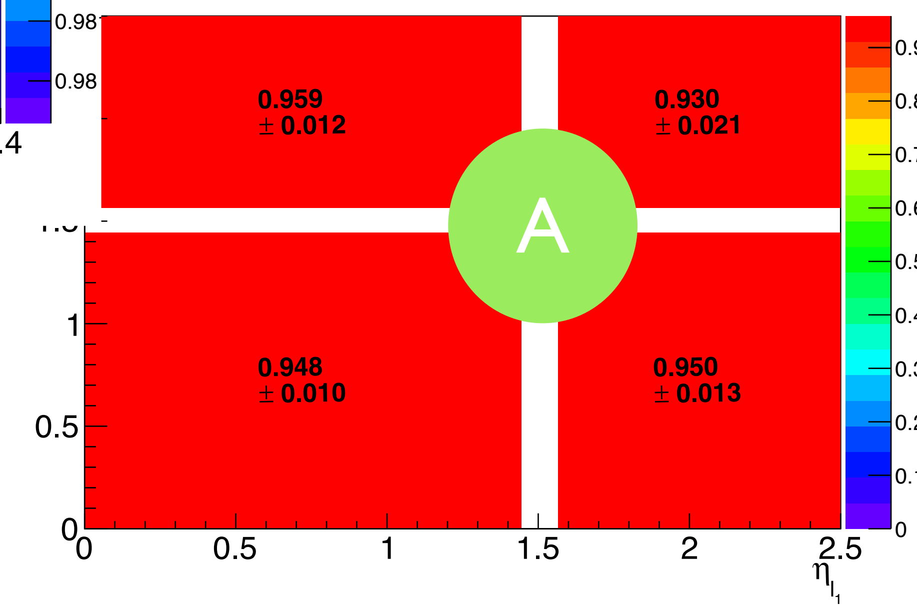
The ID and isolation efficiencies are calculated using a tag-and-probe method – c.f. our AN, sec. 4.2

B-tag SFs and associated uncertainties are taken from AN-12-470

Trigger Efficiency SF (FullSim)

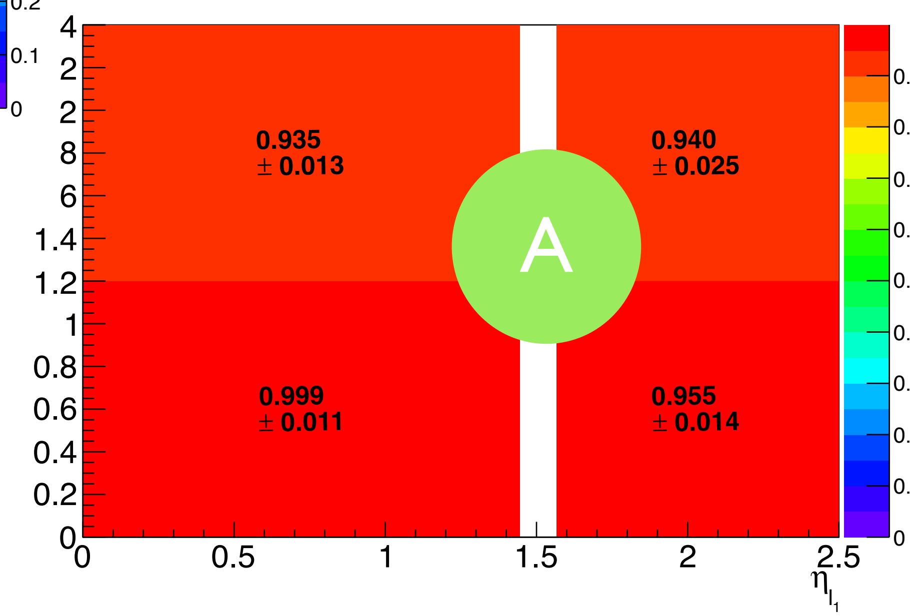


$\mu\mu$

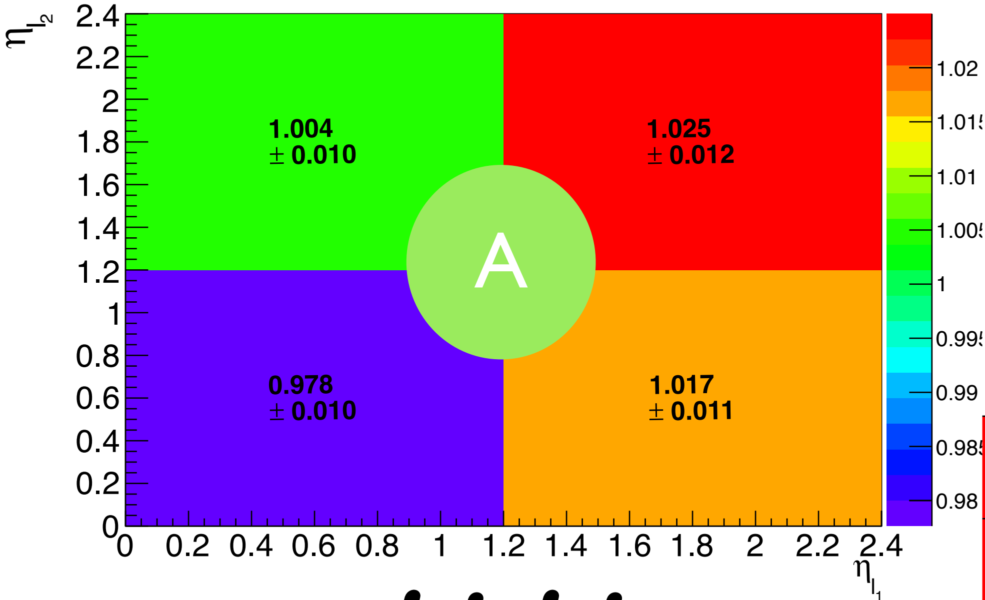


ee

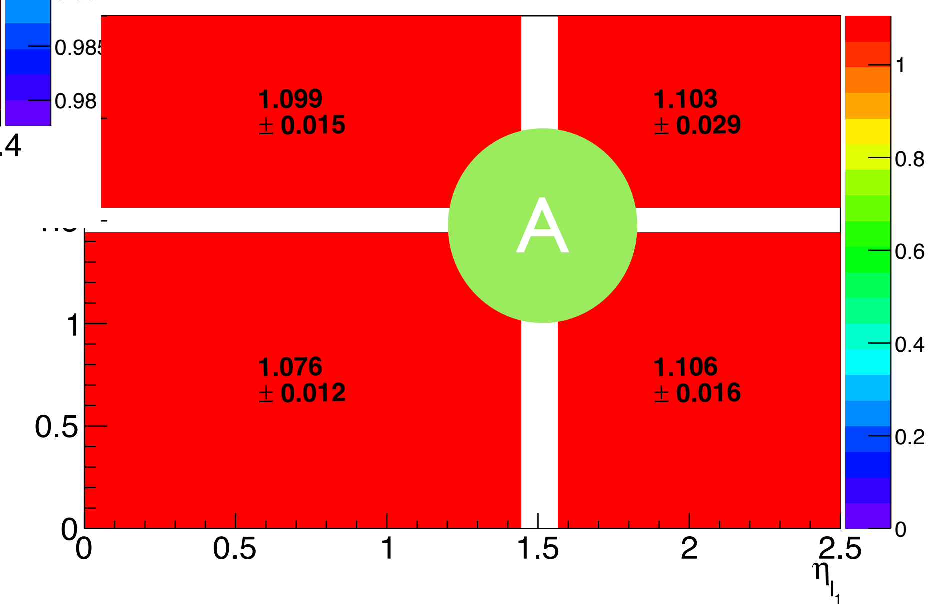
$e\mu$



Trigger Efficiency SF (FastSim)

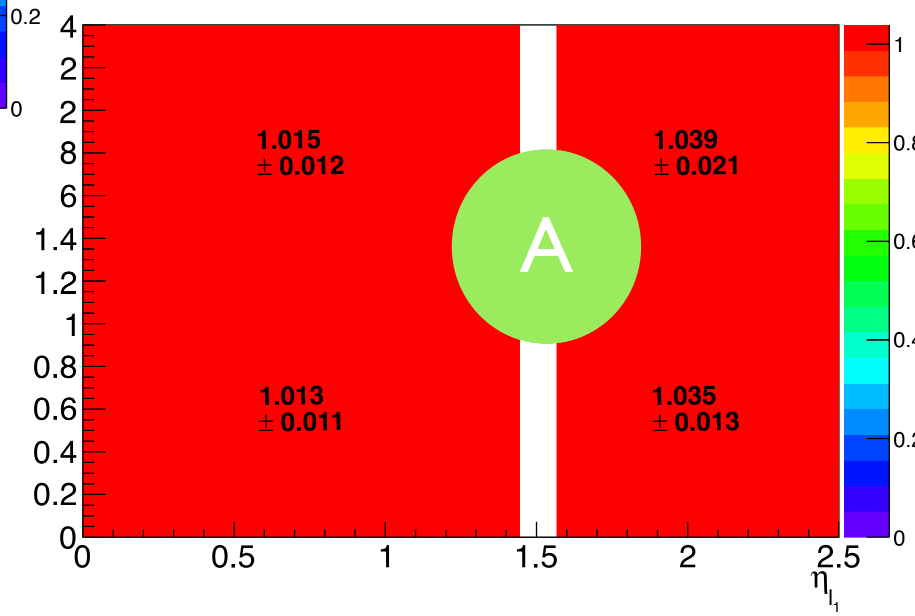


$\mu\mu$

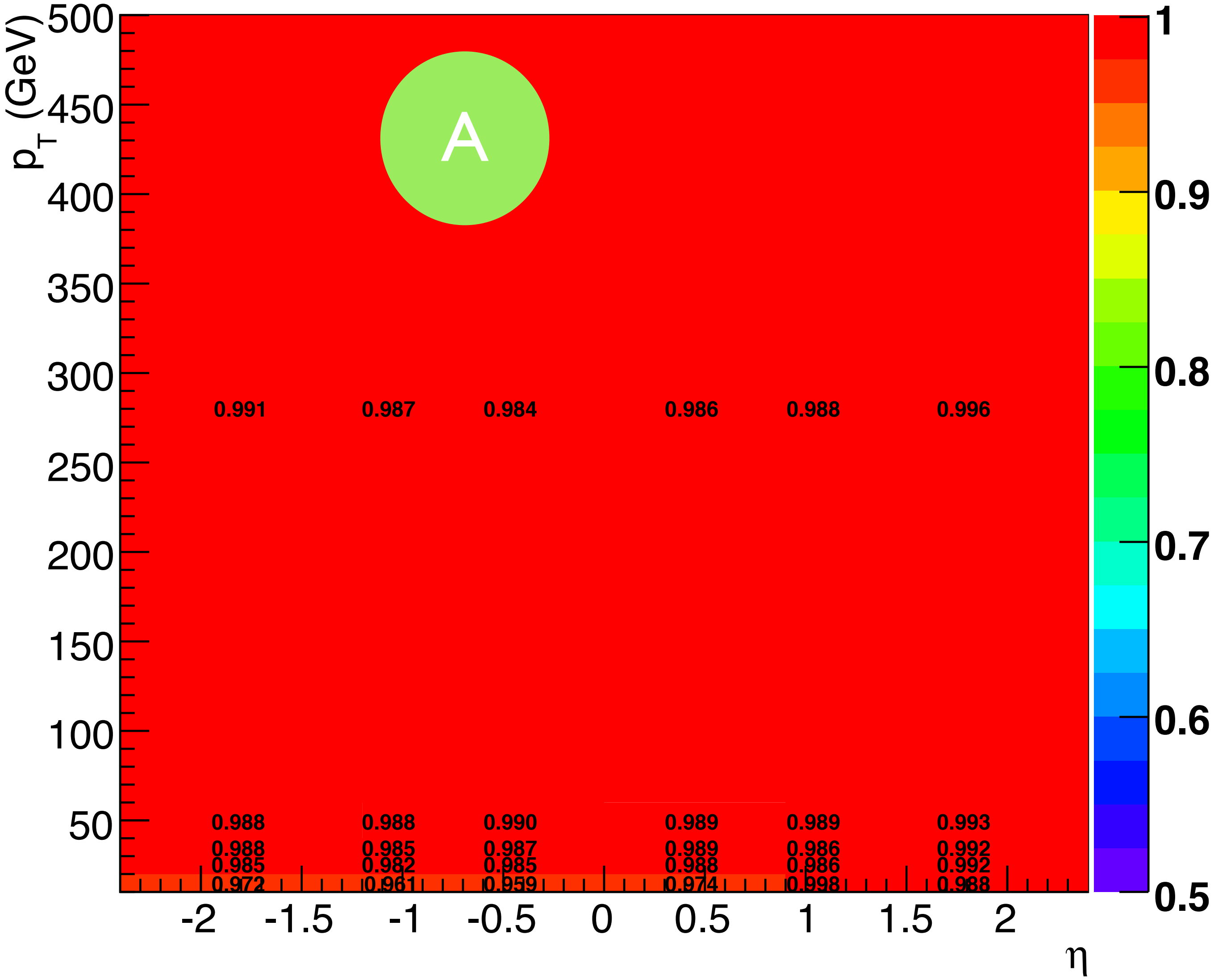


ee

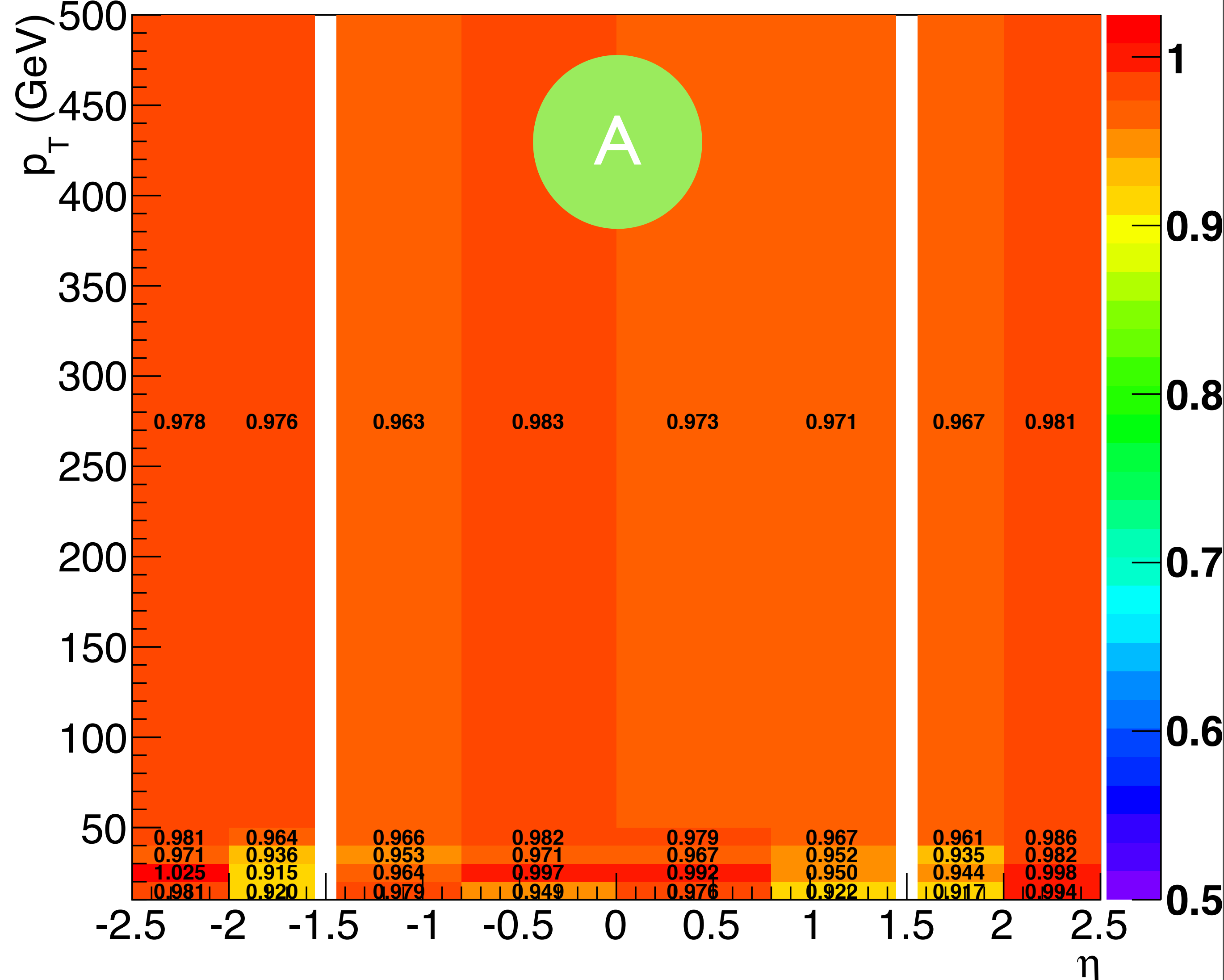
$e\mu$



Lepton ID/Iso Eff. SF (FullSim)

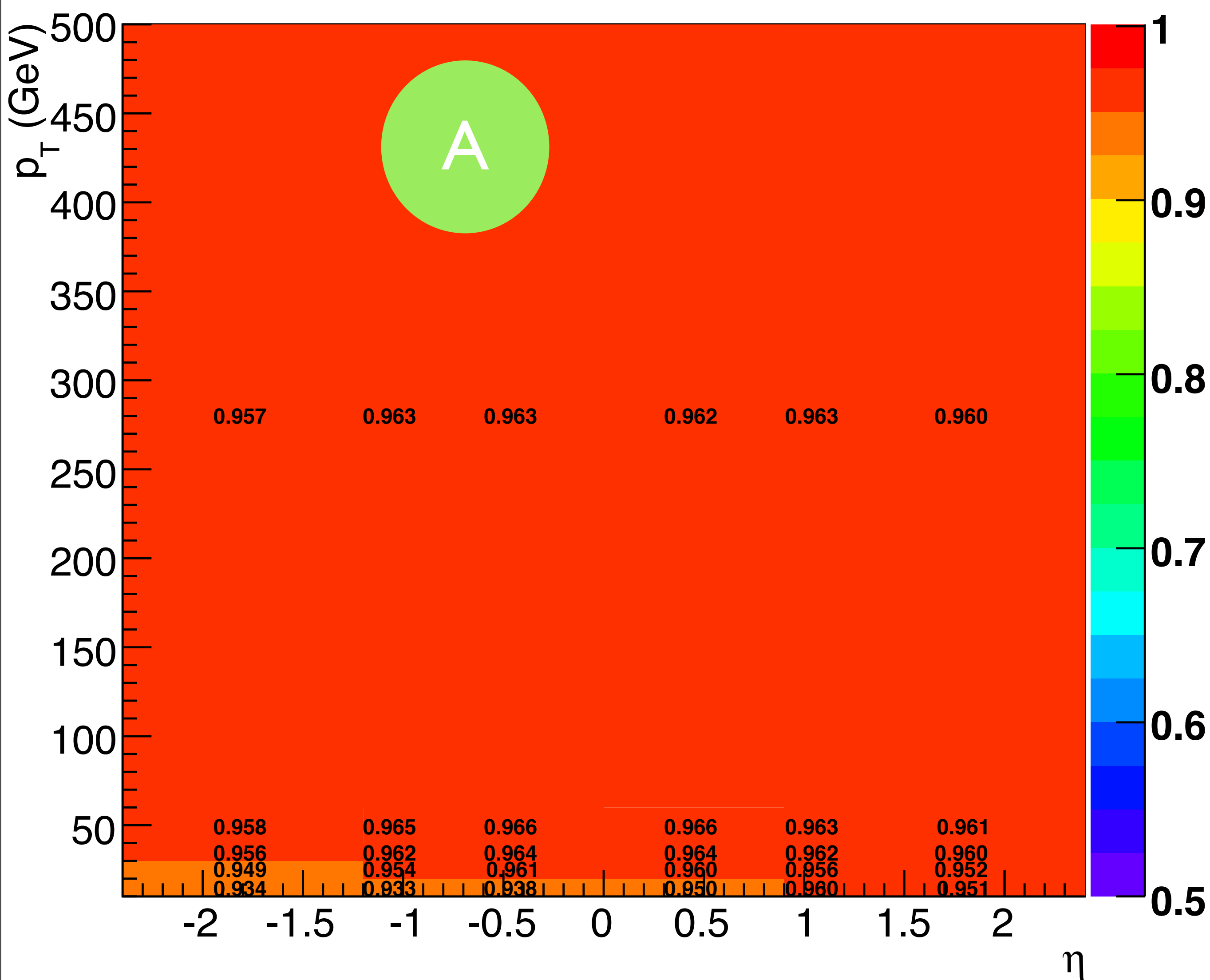


Muon SF (per Muon)

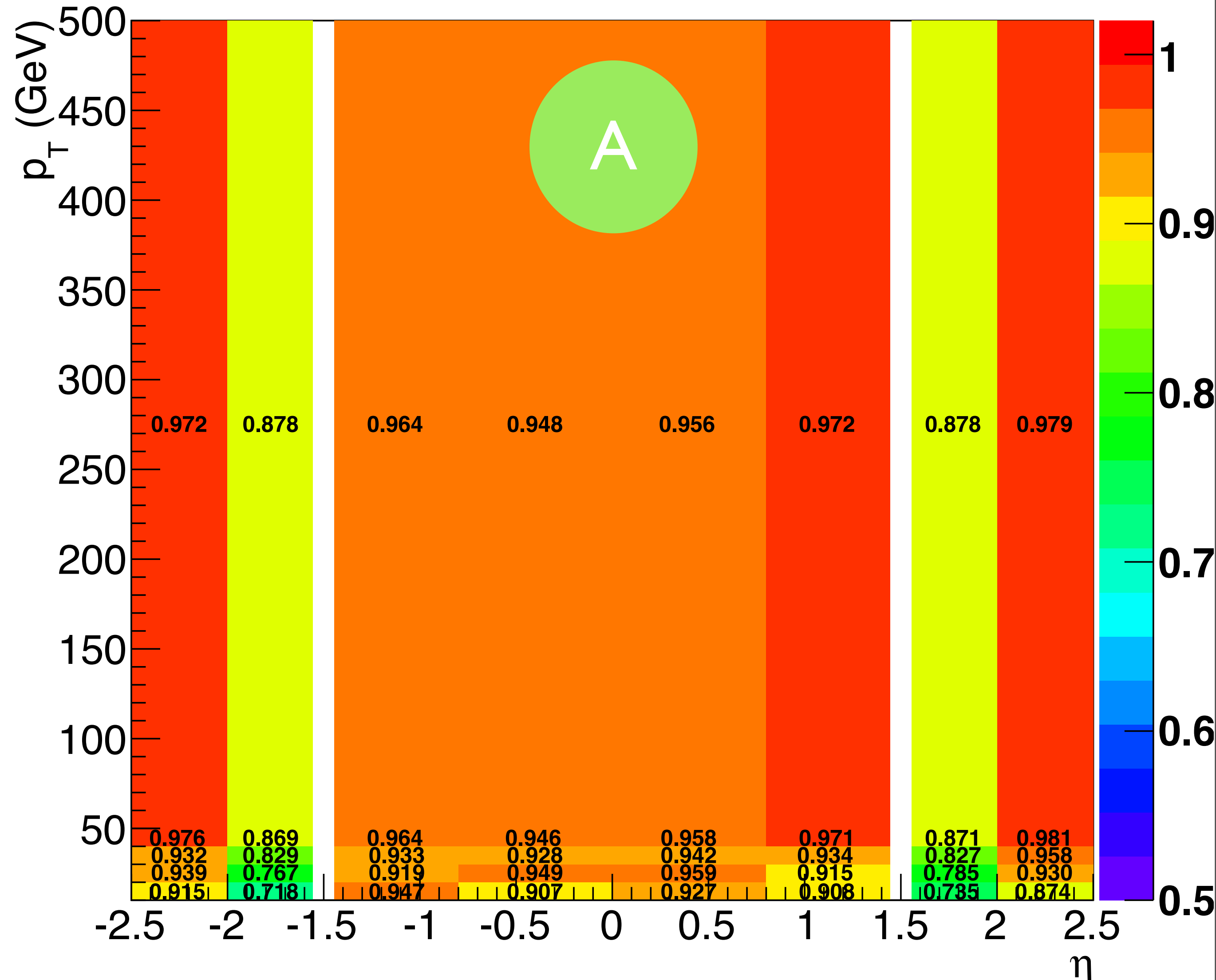


Electron SF (per Electron)

Lepton ID/Iso Eff. SF (FastSim)

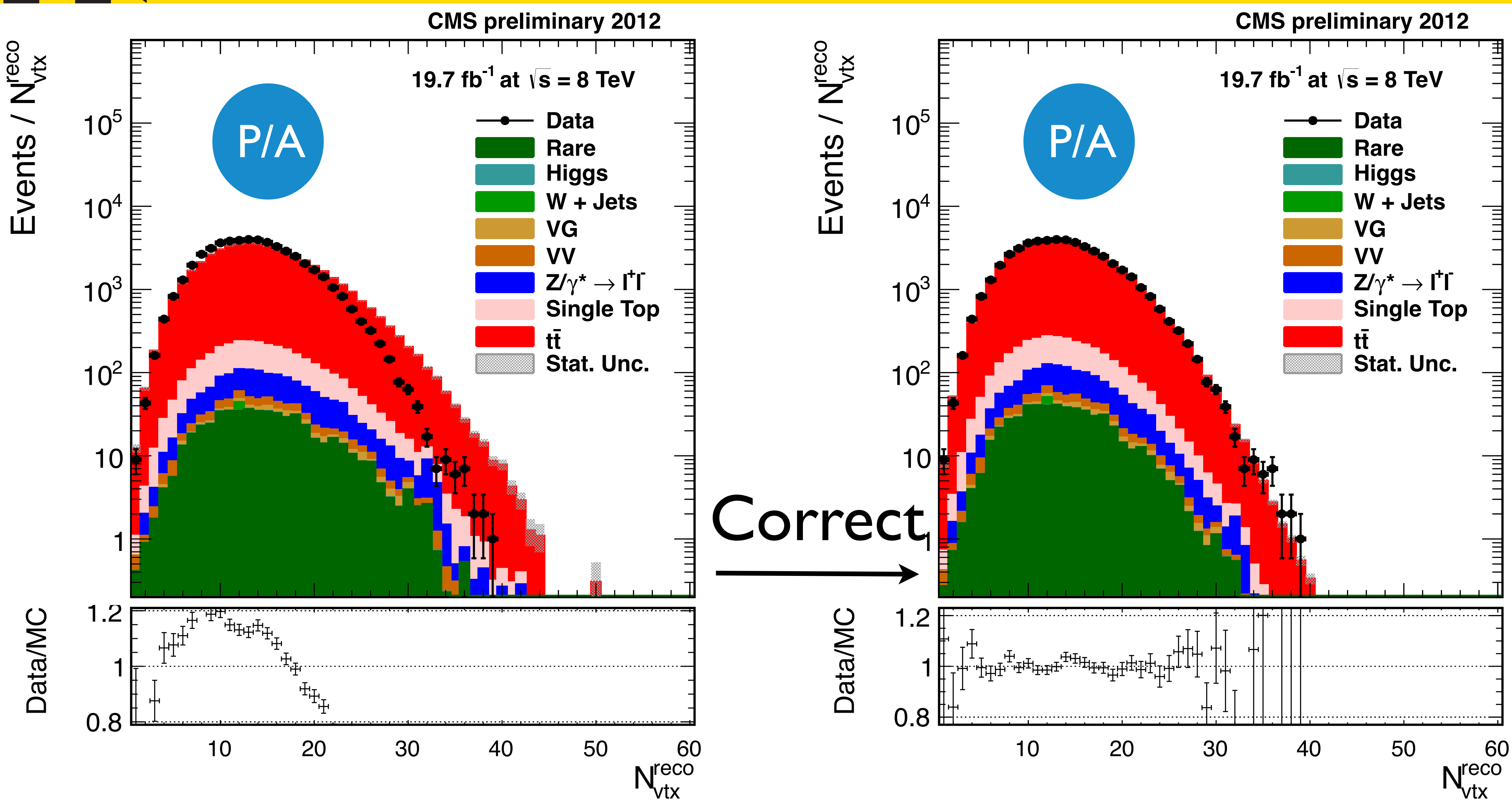


Muon SF (per Muon)



Electron SF (per Electron)

NVtx reweighting



The additional energy deposited in the detector from pileup events affects multiple aspects of this analysis so an accurate description is important

MET Filters Used

As noted before, for this analysis, we have applied the full suite of filters listed on this twiki,

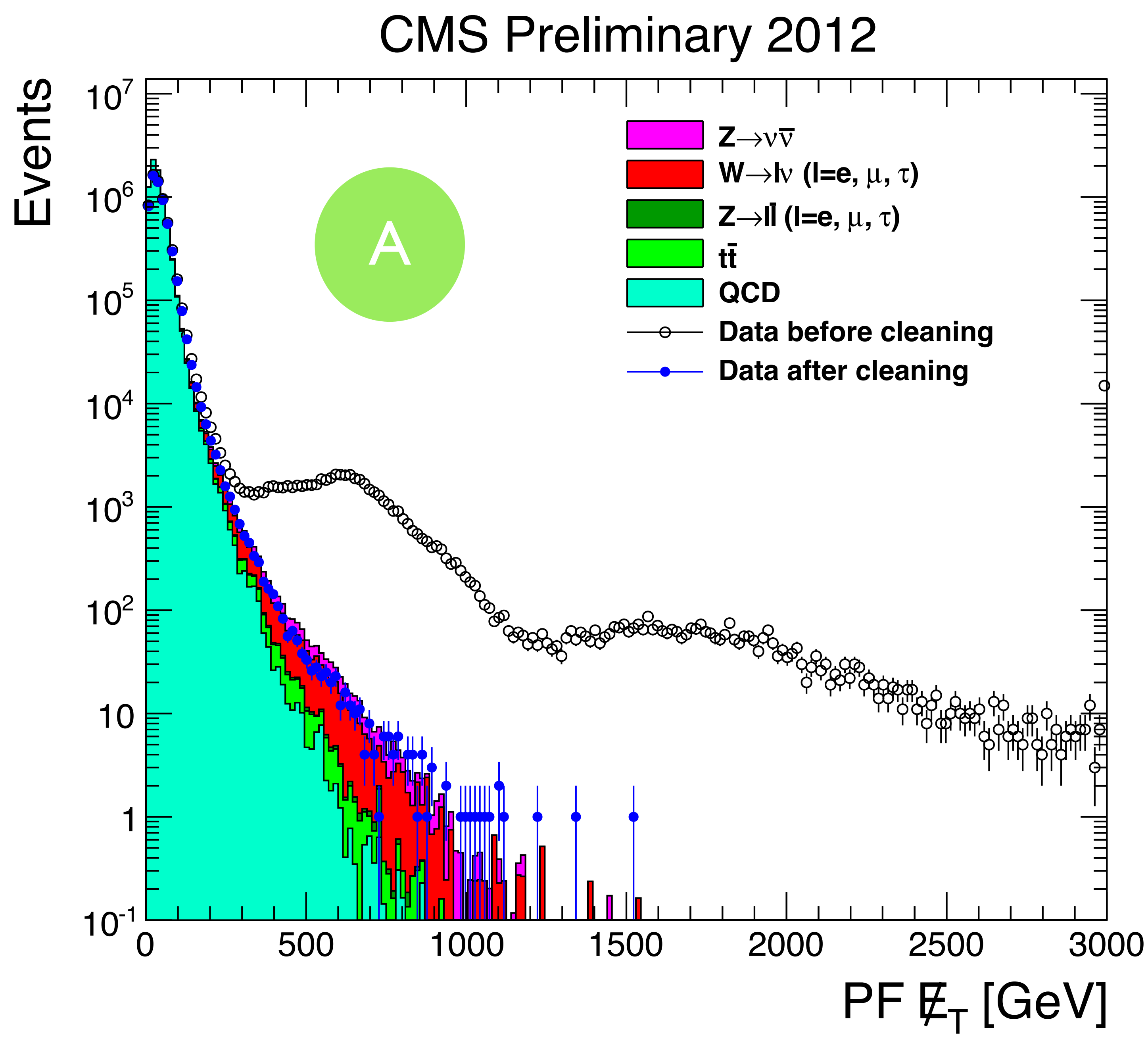
- CSC tight beam halo filter
- HBHE noise filter with isolated noise rejection
- HCAL laser filter
- ECAL dead cell trigger primitive filter
- Tracking failure filter
- Bad EE Supercrystal filter
- ECAL Laser correction filter
- Tracking POG filters

MET Filters Used

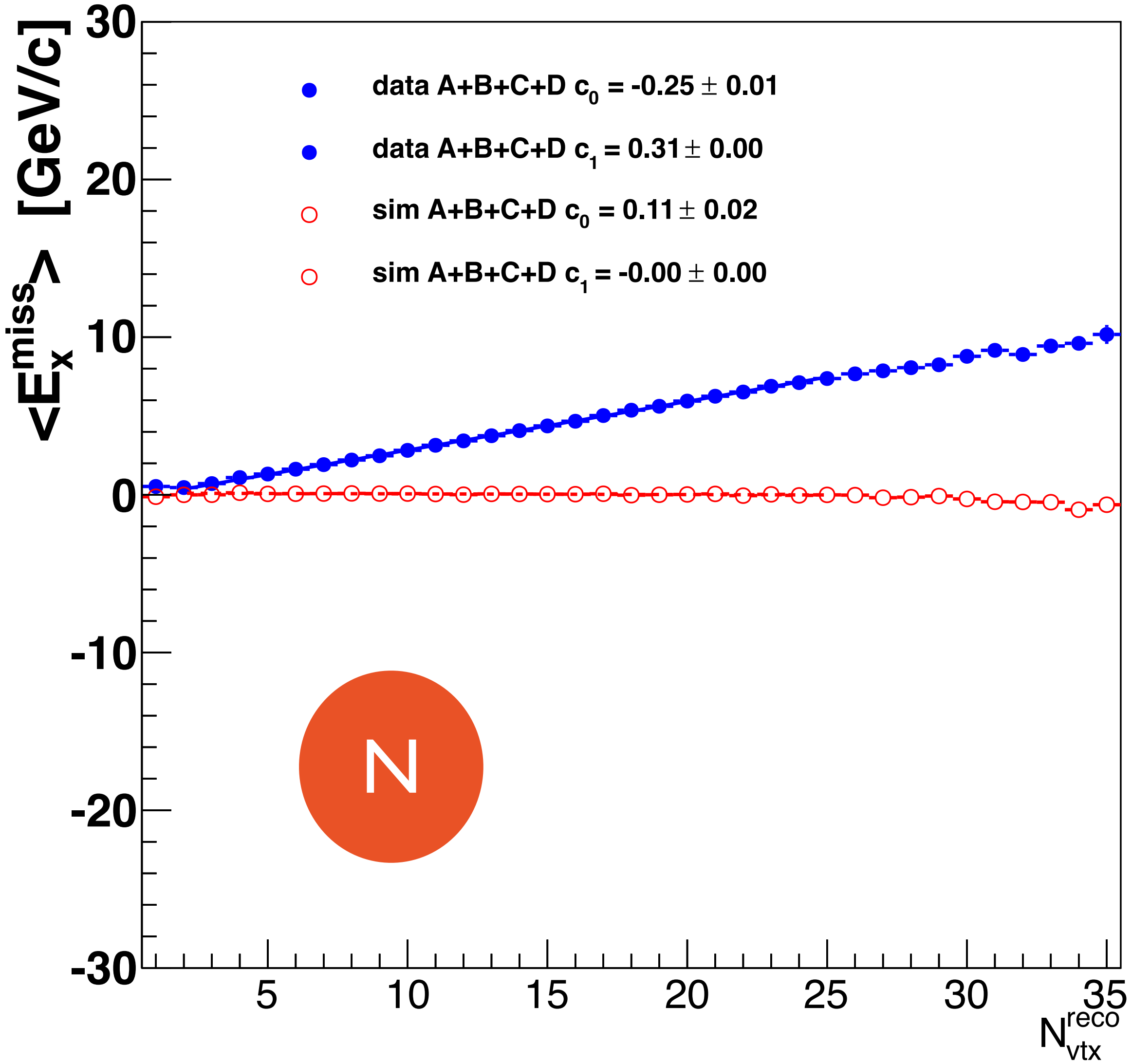
Shown on the right is the distribution of PF MET in dijet events, both with and without the standard MET filters applied

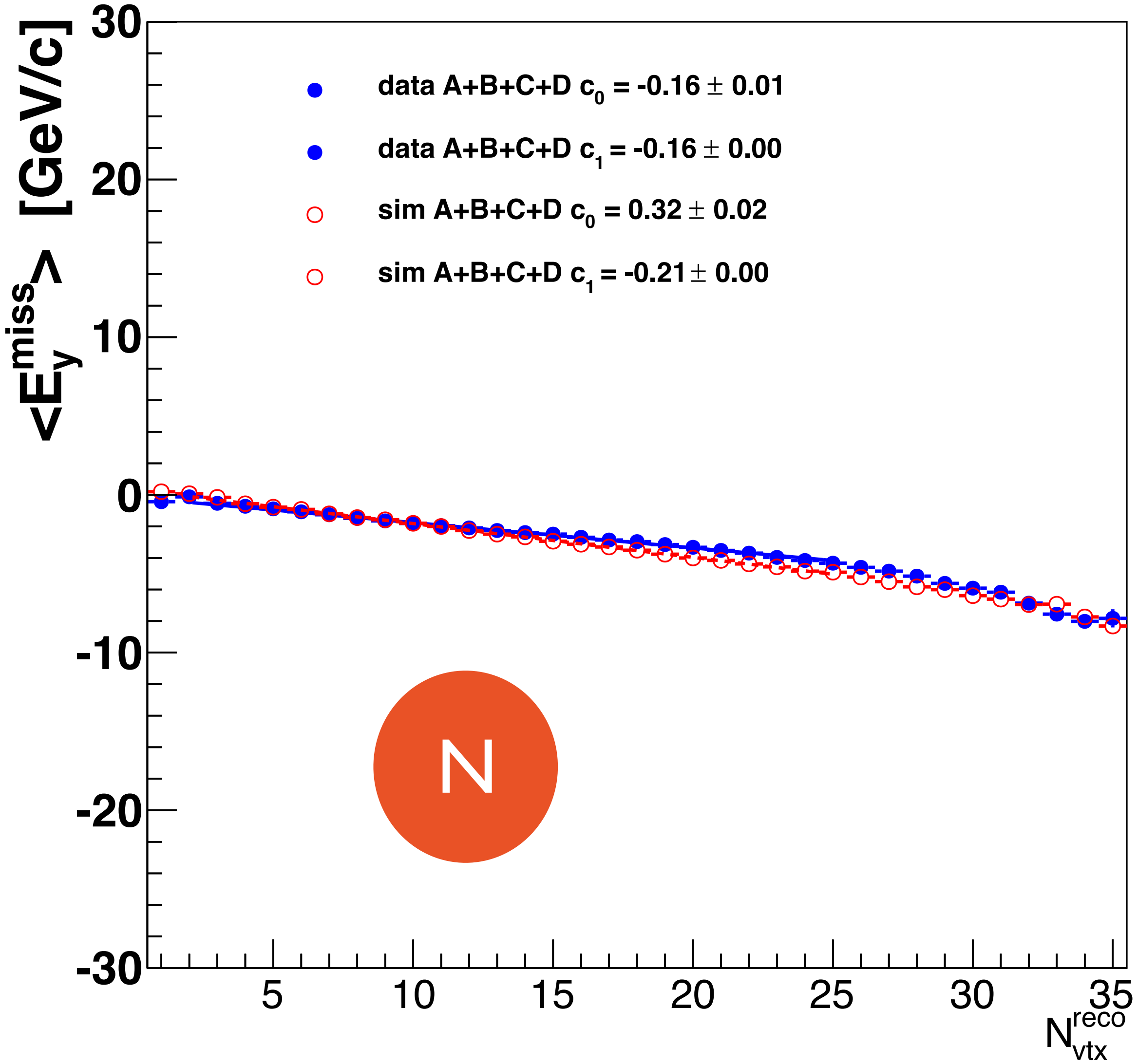
You can see the **strong** rejection power of anomolous MET events with the filters

– After application, Data and MC are in satisfactory agreement all the way out to high MET values



MET Phi corrections



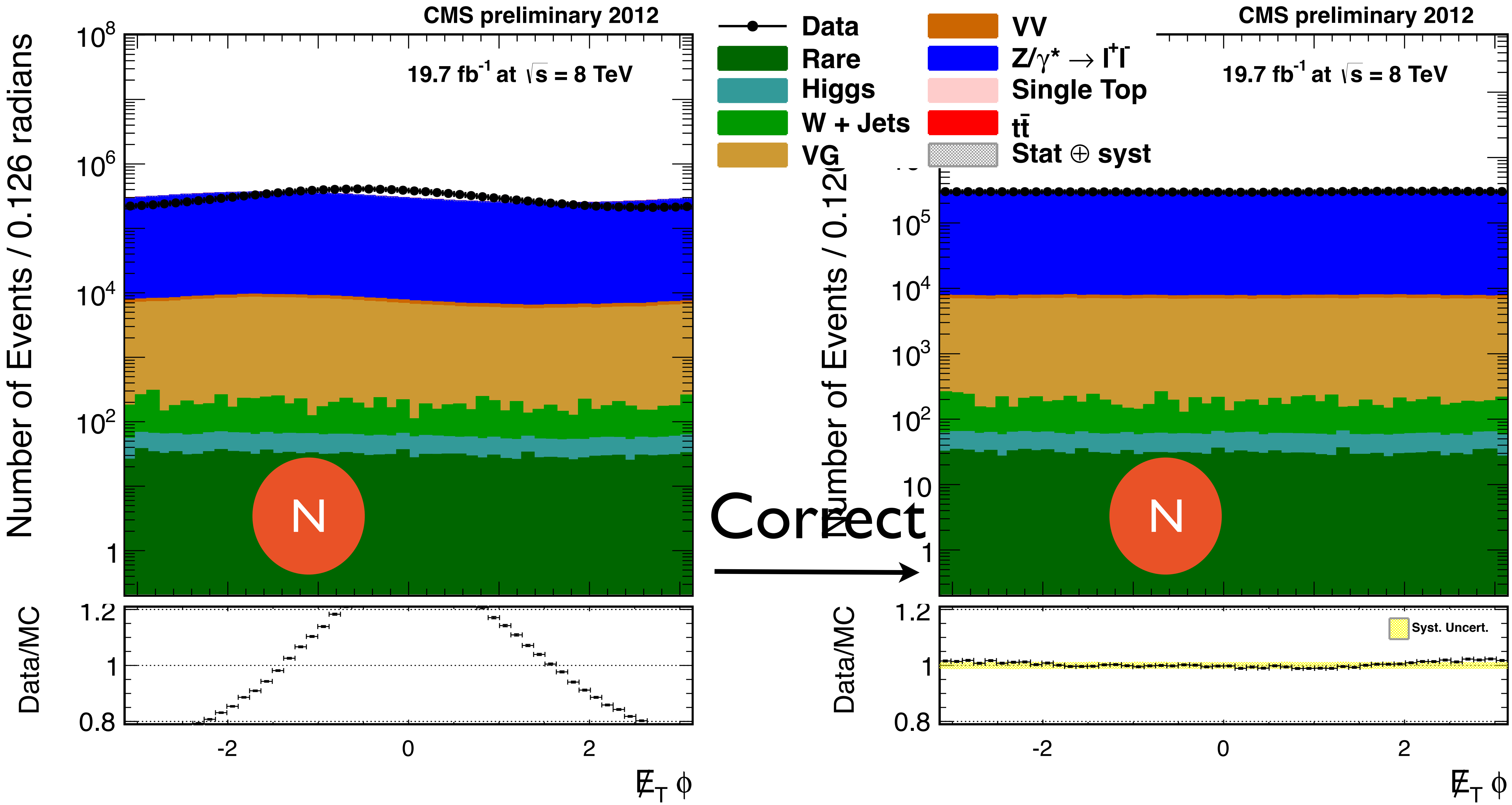


Fit <MET (*x*/*y*)> vs N_{Vtx} with a straight line

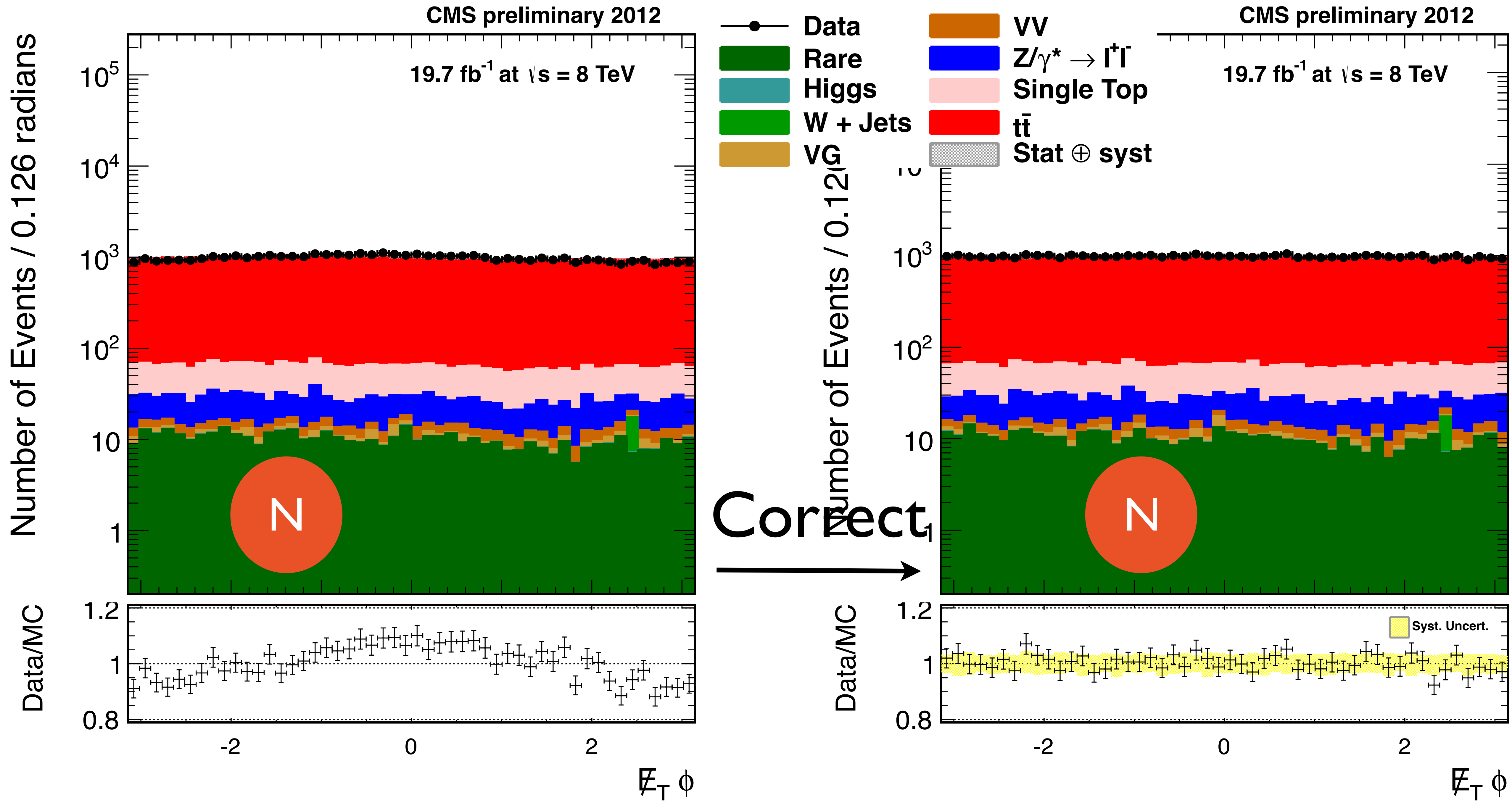
Correction is in the form of

Corr MET(*x*/*y*) = MET(*x*/*y*) - (c_0 + c_1 x N_{Vtx})

MET Phi corrections



MET Phi corrections



Minor bug with systematics not showing up on left plot

MET Smearing

Christian Veelken wrote a tool that smears out the jets in MC processing in the official JER prescription (I and other MET colleagues use this tool, for example, in the official MET WG performance studies)

Unfortunately, tool "has" to be implemented with full event information present (i.e. it utilizes the CMSSW data structures, albeit not in any complicated way)

Our nTuples weren't originally processed utilizing this tool – the updated nTuples have only recently become available – thus, we had to turn to other methods to account for this

– Attempts to rewrite tool by hand failed to achieve closure**

– Instead, I developed a separate but approximately equivalent "by-hand smearing" technique

**Ran into issues with calculating the intrinsic MC jet resolution

MET Smearing "by hand"

The "by hand" method utilizes NTuples that I and other members of the MET group generated for our MET performance studies

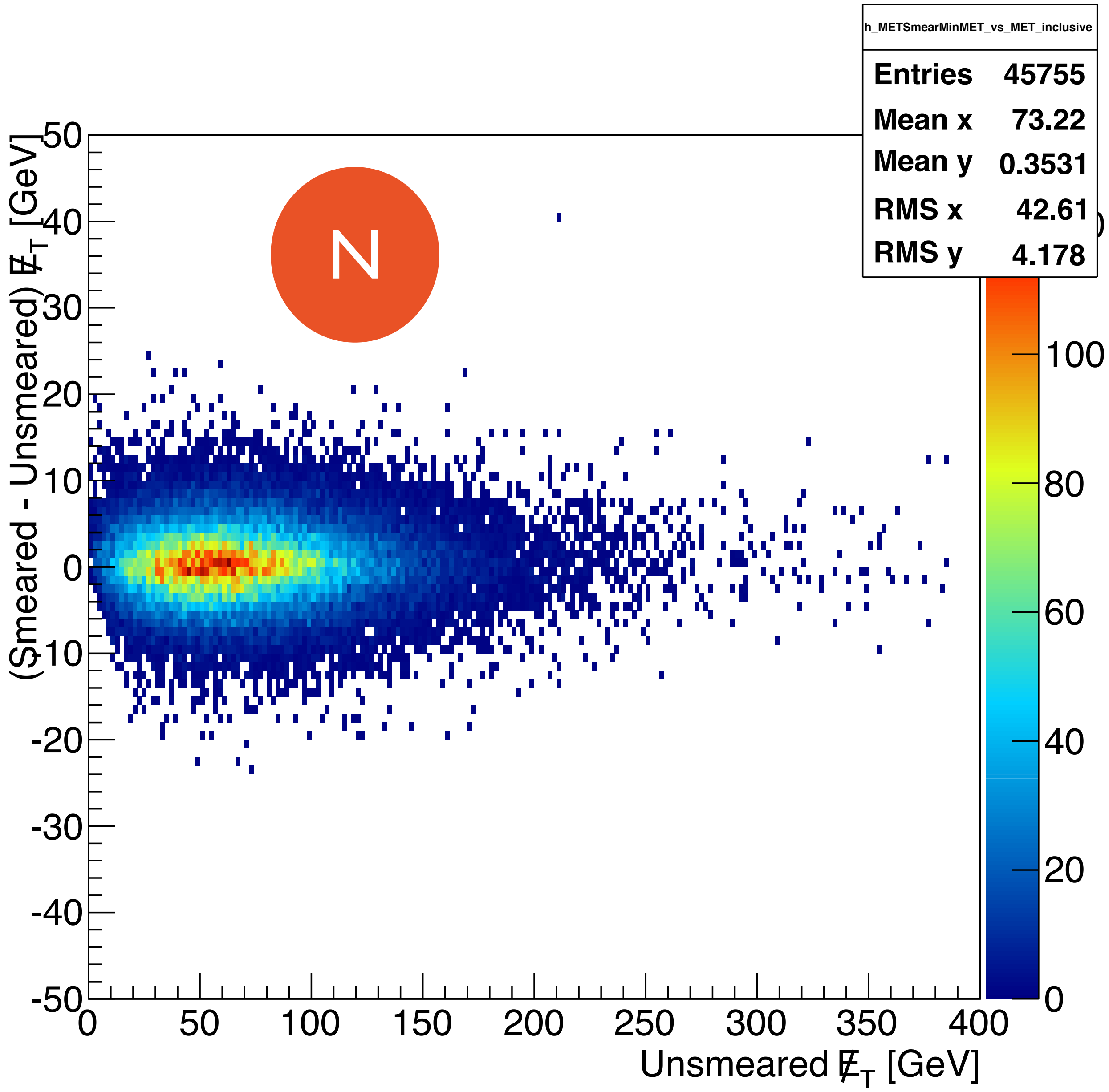
Said NTuples were made utilizing the official MET smearing prescription and contain information on the following (among other things):

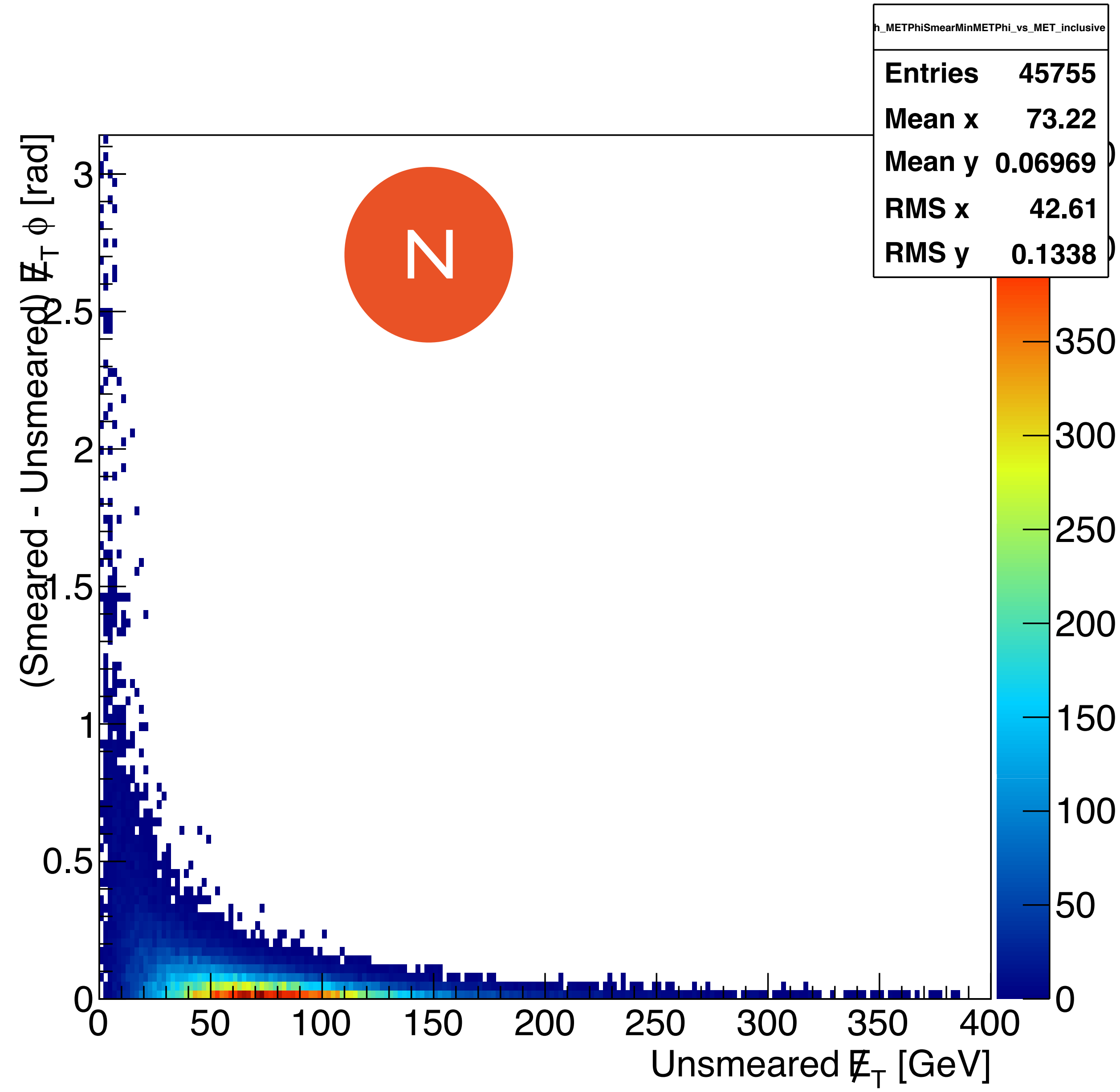
- (Smeared and Unsmeared) MET (individually p_T and Phi)
- Dilepton system (i.e. "Z" boson for DY events) pT

Using this information I generated 2D smearing templates based on the event-by-event difference between the smeared/unsmeared MET p_T/Phi versus the event's unsmeared MET

Because the effects of JER smearing on MET are topology dependent, I created separate versions of these template functions for different important topologies (ttbar, DY->ll, etc.)

2D Smearing Histograms

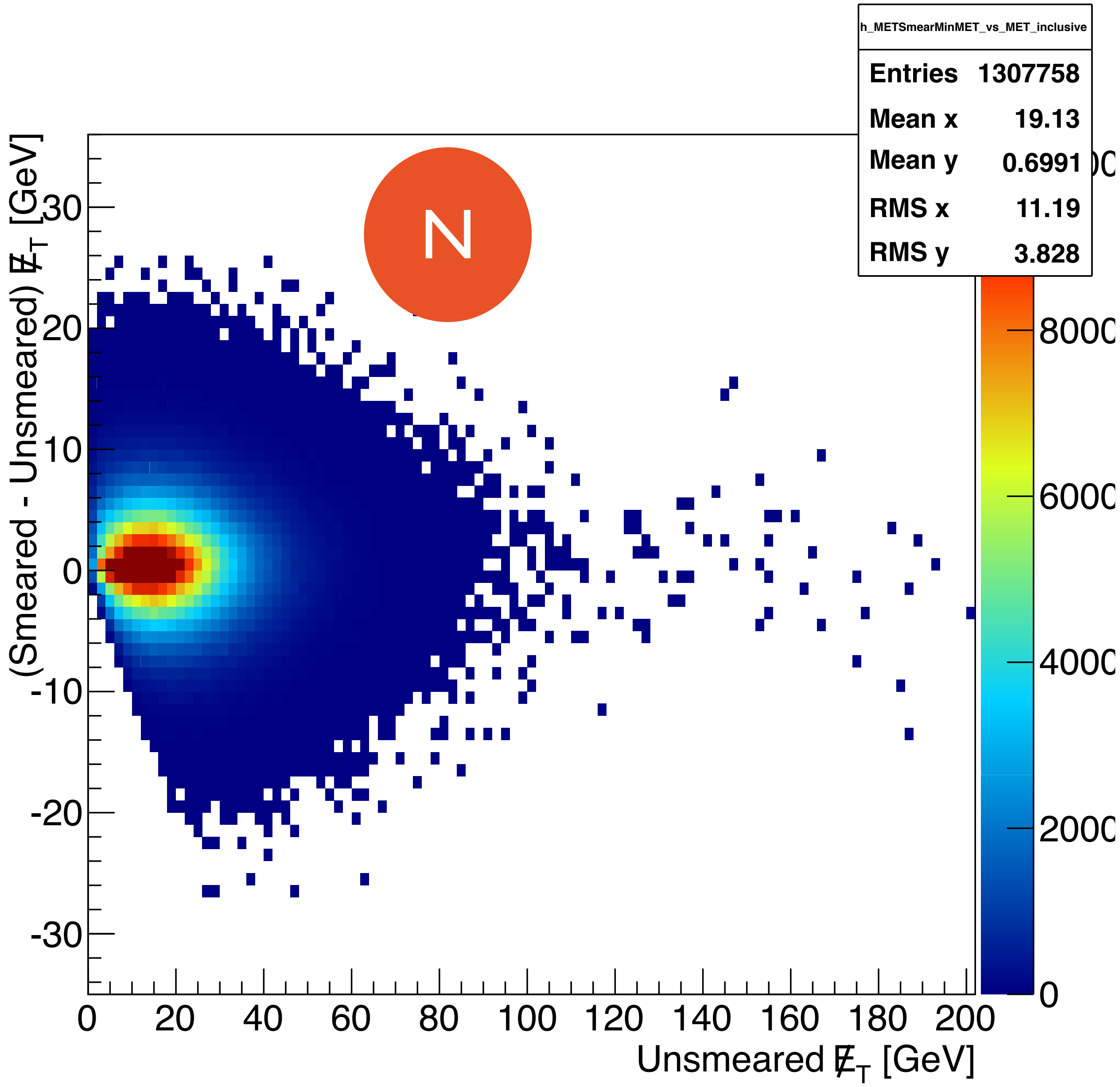


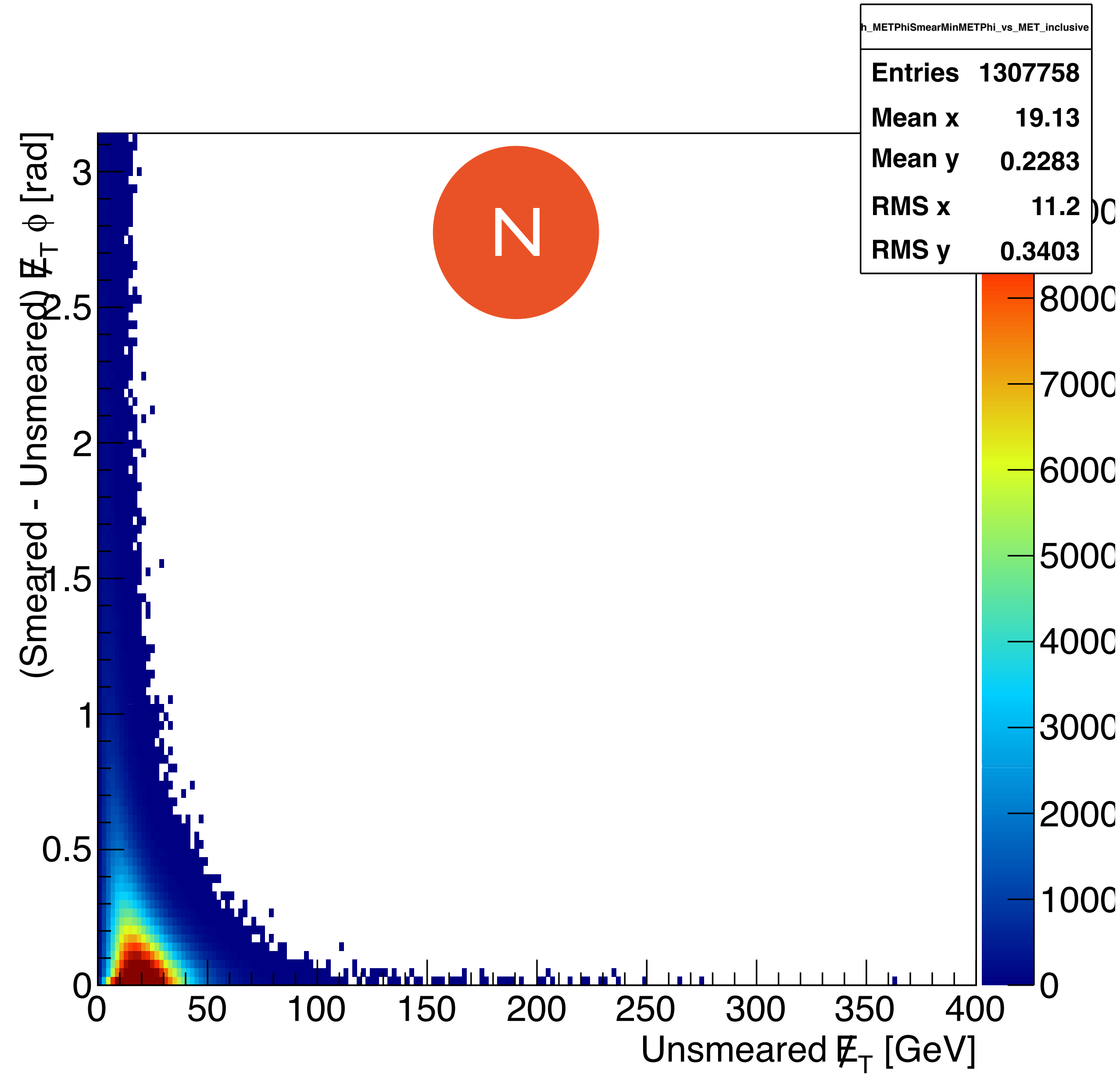


TTBar MET

TTBar MET Phi

2D Smearing Histograms



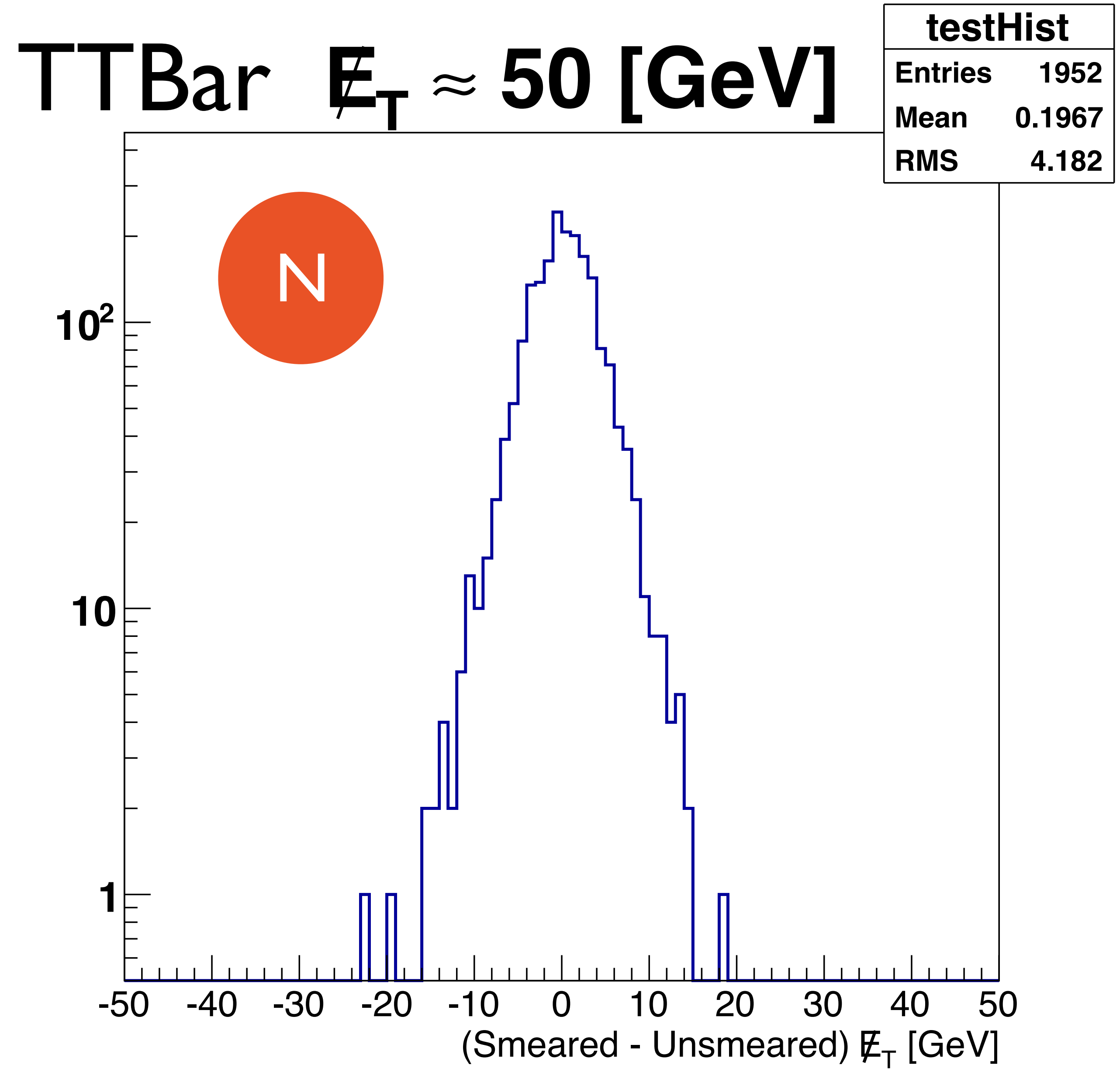


Gam + Jet (MadG) MET

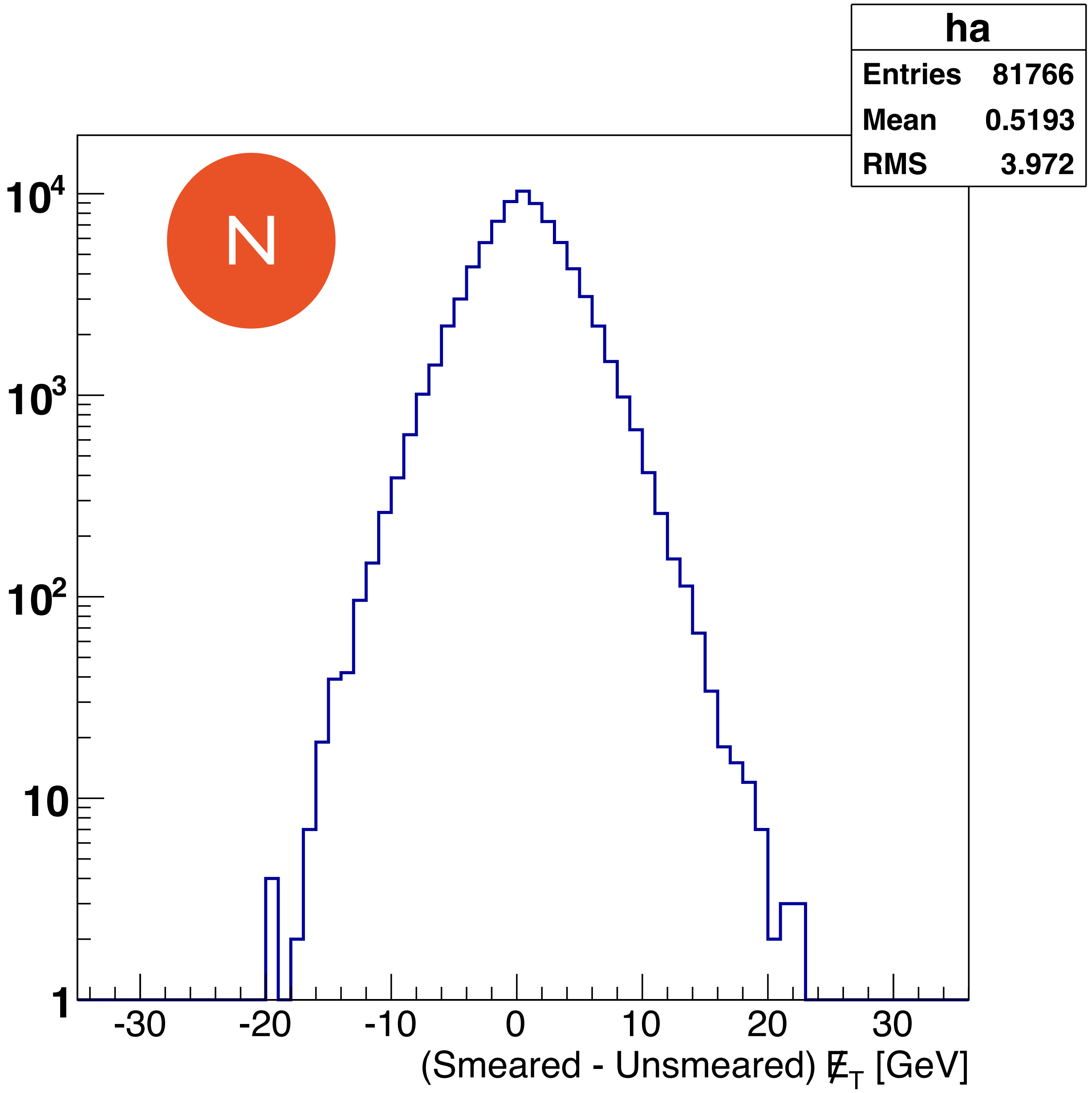
Gam + Jet (MadG) MET Phi

Smearing the MET

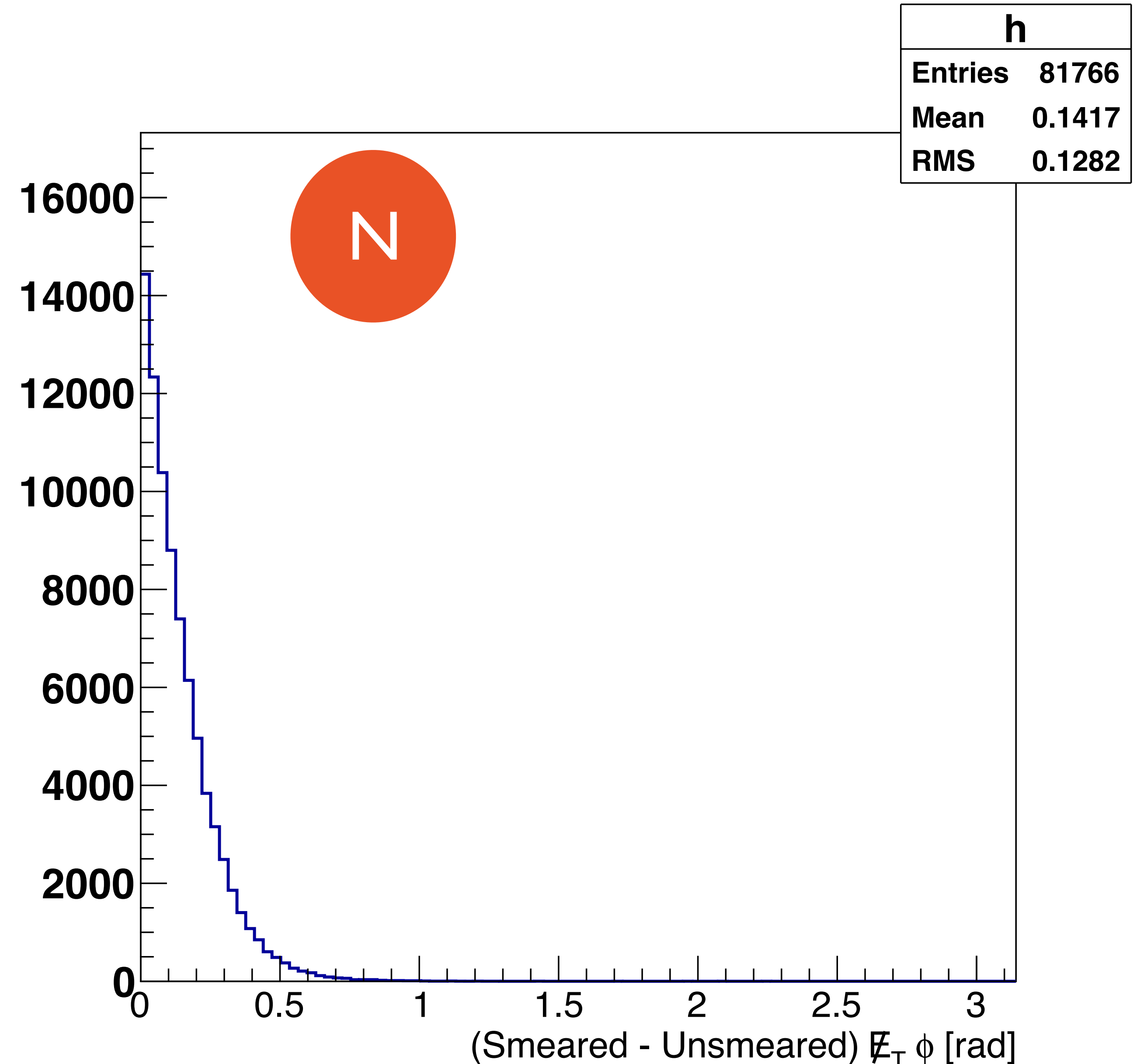
Utilize the "afore-shown" 2D histograms as a source of "Unsmeared" MET dependent smearing functions



1D Smearing Histograms



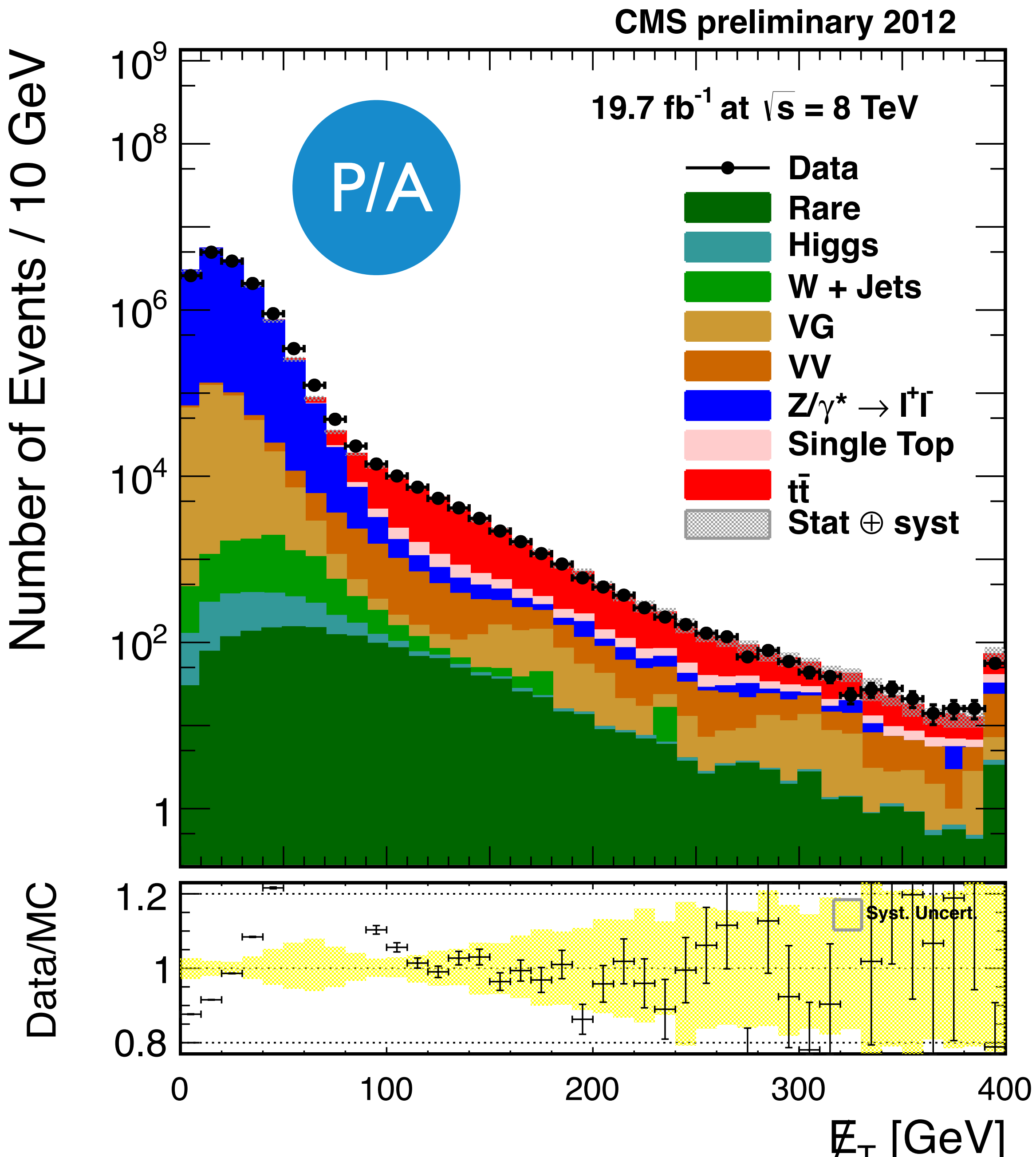
DY + Jet (MadG) MET (MET approx. 20 GeV)



DY + Jet (MadG) MET Phi (MET approx. 20 GeV)

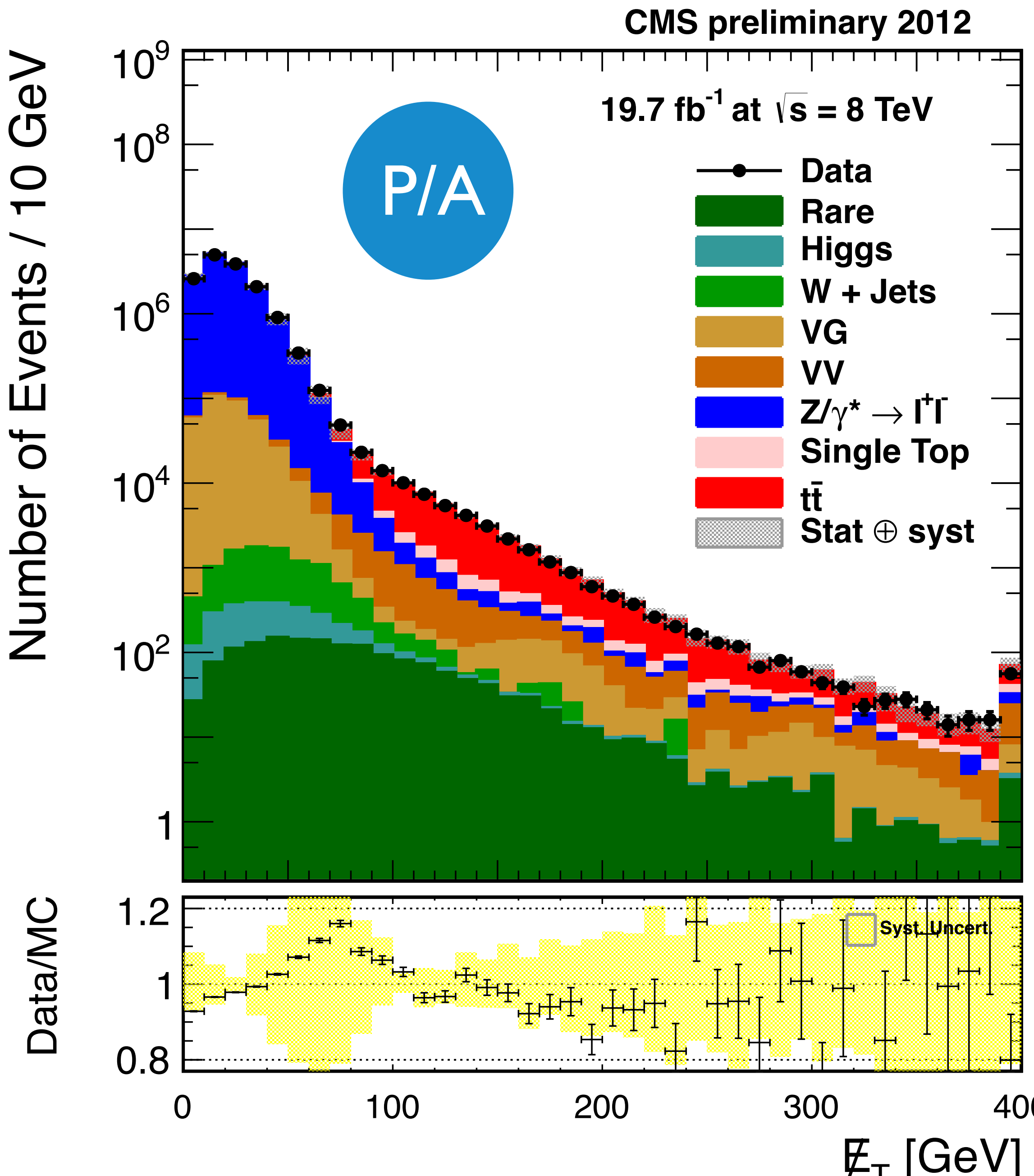
Wednesday, January 22, 14

MET Smearing results



Pre-Smearing

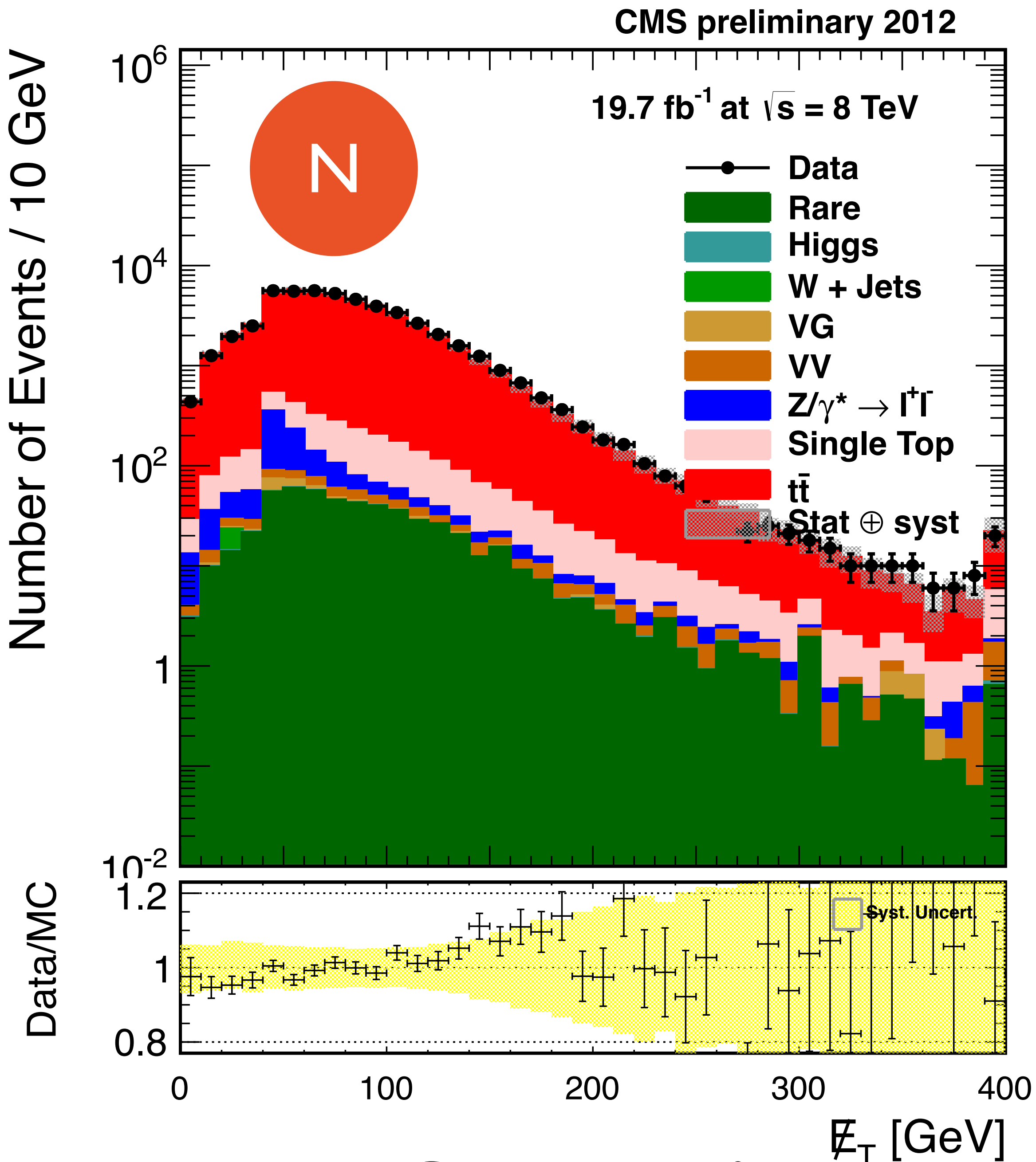
(just dilepton selection)



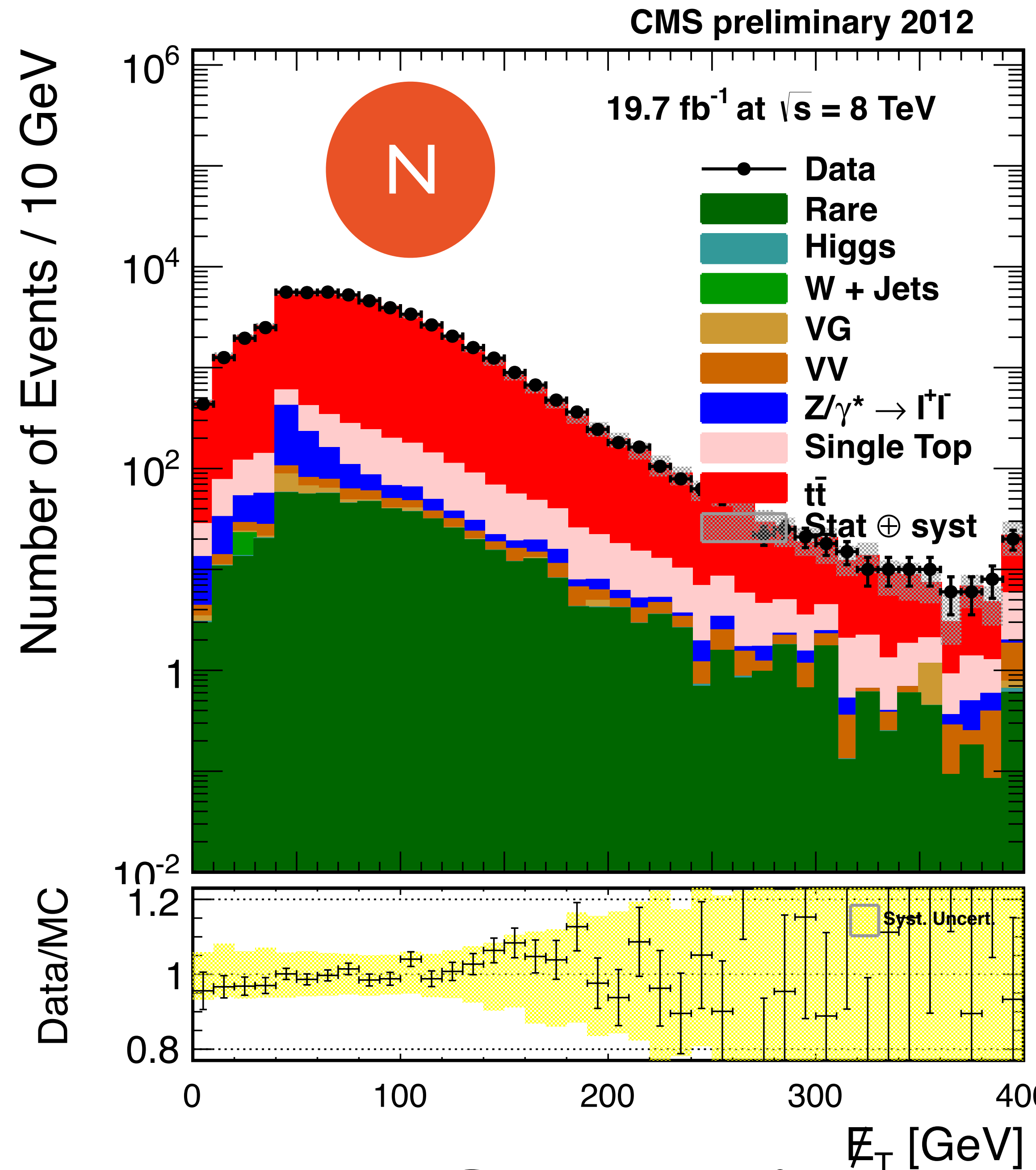
Post-Smearing

(just dilepton selection)

MET Smearing results

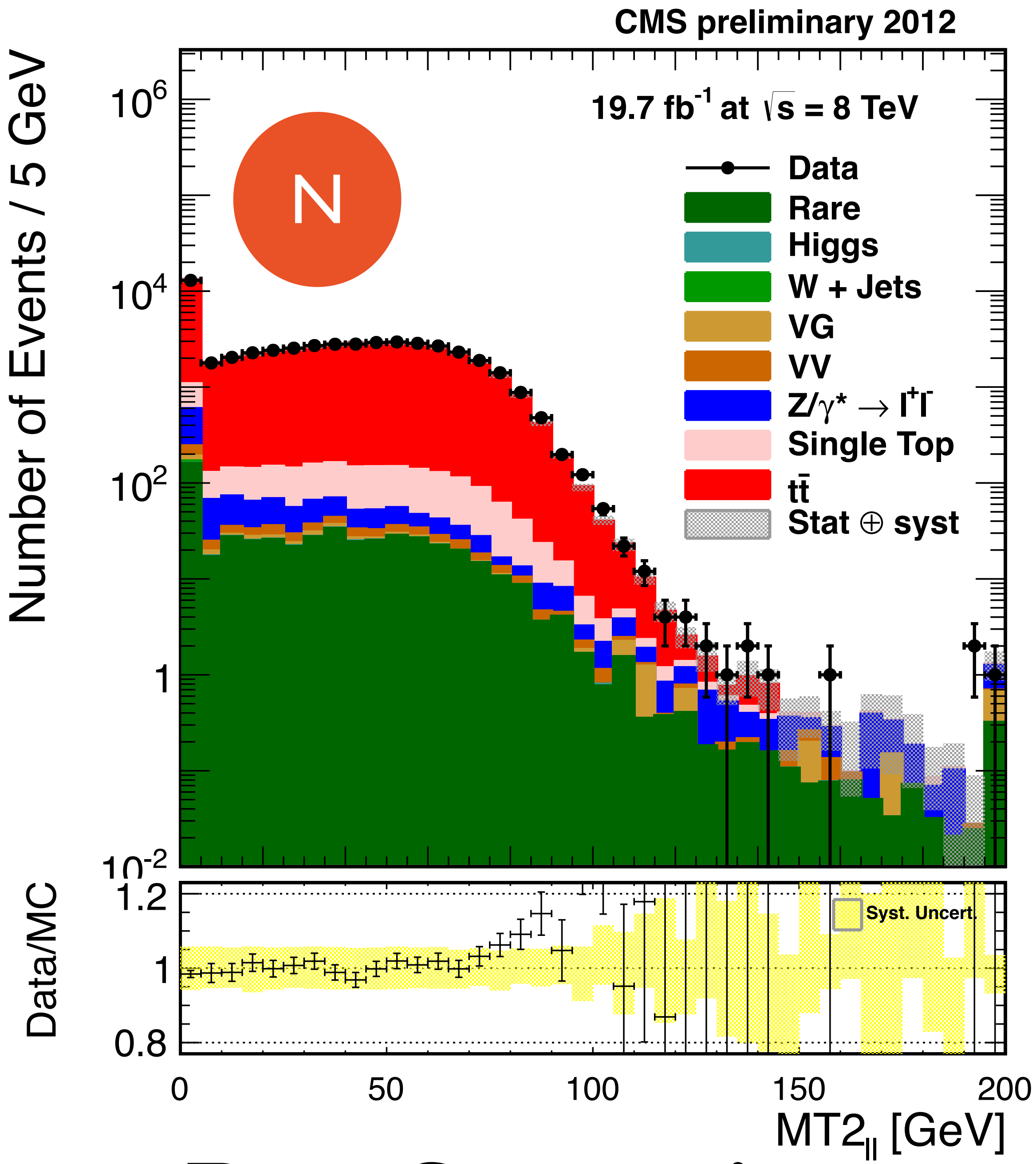


Pre-Smearing (Full selection)

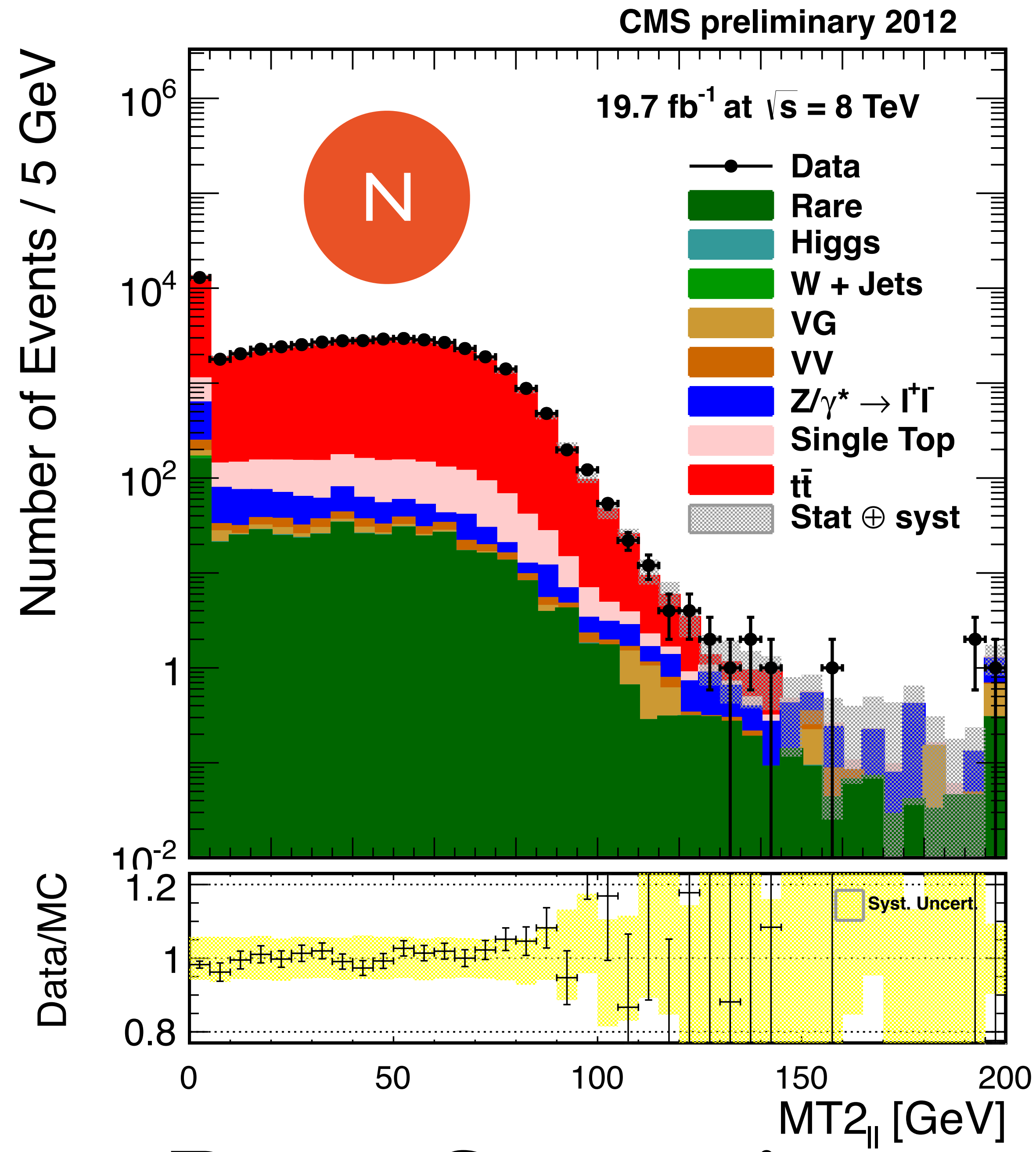


Post-Smearing (Full selection)

M_{T2}(ll) Smearing results



Pre-Smearing (Full selection)



Post-Smearing (Full selection)

Systematics of the smearing

Two of our systematics are currently handled utilizing these smearing template functions:

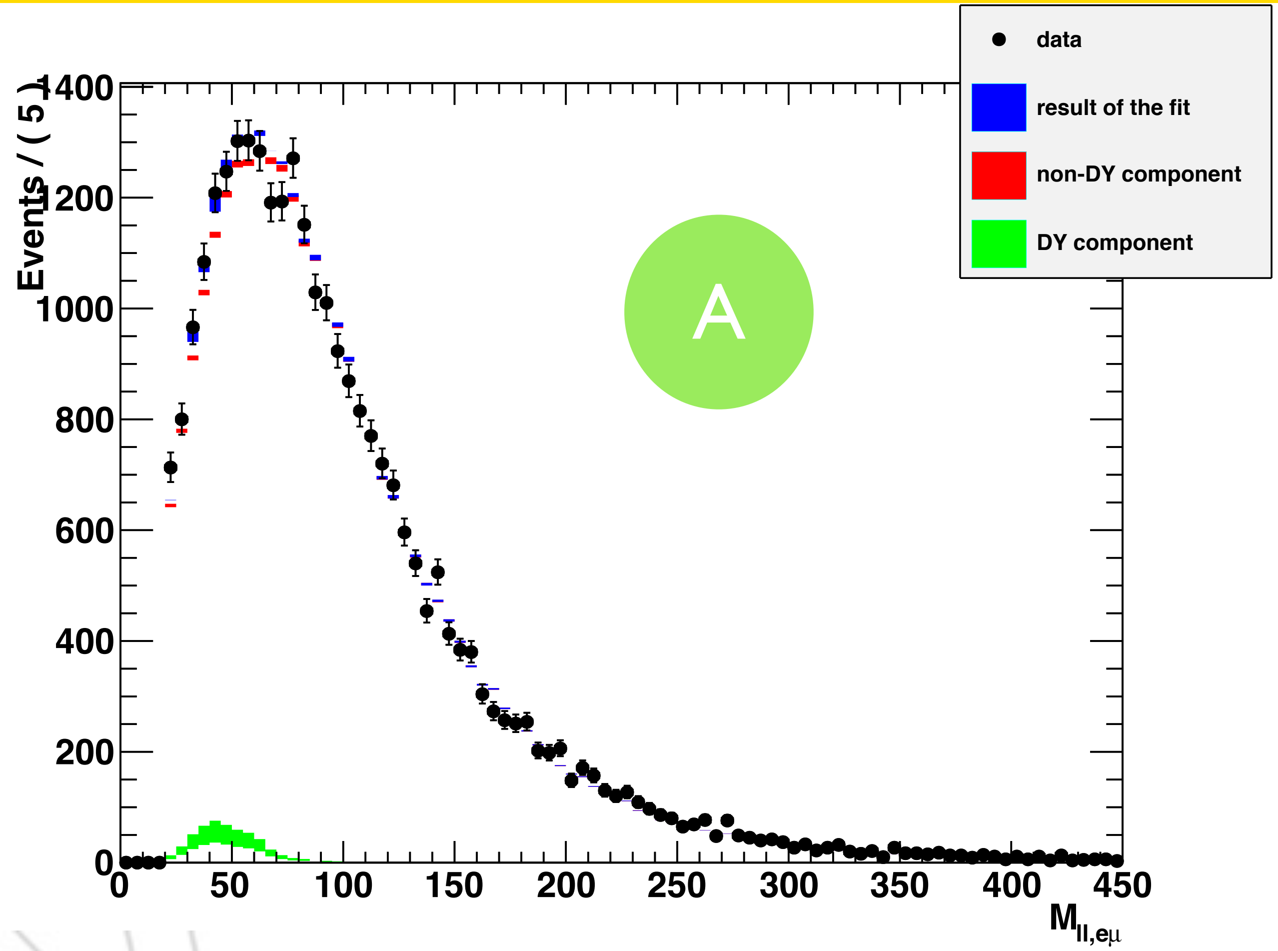
– Jet Energy Smear Factor systematic

– Unclustered Energy Scale systematic

That is, we have smearing template functions for the MET p_T and phi where the smearing took into account systematic shifts on the above mentioned variables

EMu DY estimation Fit

Estimate of EMu scale factor for full selection is statistically compatible with the estimate acquired through the listed method



	≥ 2 jets	≥ 2 jets + E_T^{miss}	≥ 2 jets + E_T^{miss} + b-tag
$e\mu$			
DY MC	2224.1 ± 16.5	2224.1 ± 16.5	208.65 ± 4.90
DY data-driven estimate	2317.9 ± 164.5	2317.9 ± 164.5	412.32 ± 137.01
SF data/MC	1.0422 ± 0.0746	1.0422 ± 0.0746	1.9761 ± 0.6584

Table 9: Data-driven Drell-Yan background estimation in the $e\mu$ channels compared with simulation, for several steps of the analysis.

Add. Info. Fake Lepton Est.

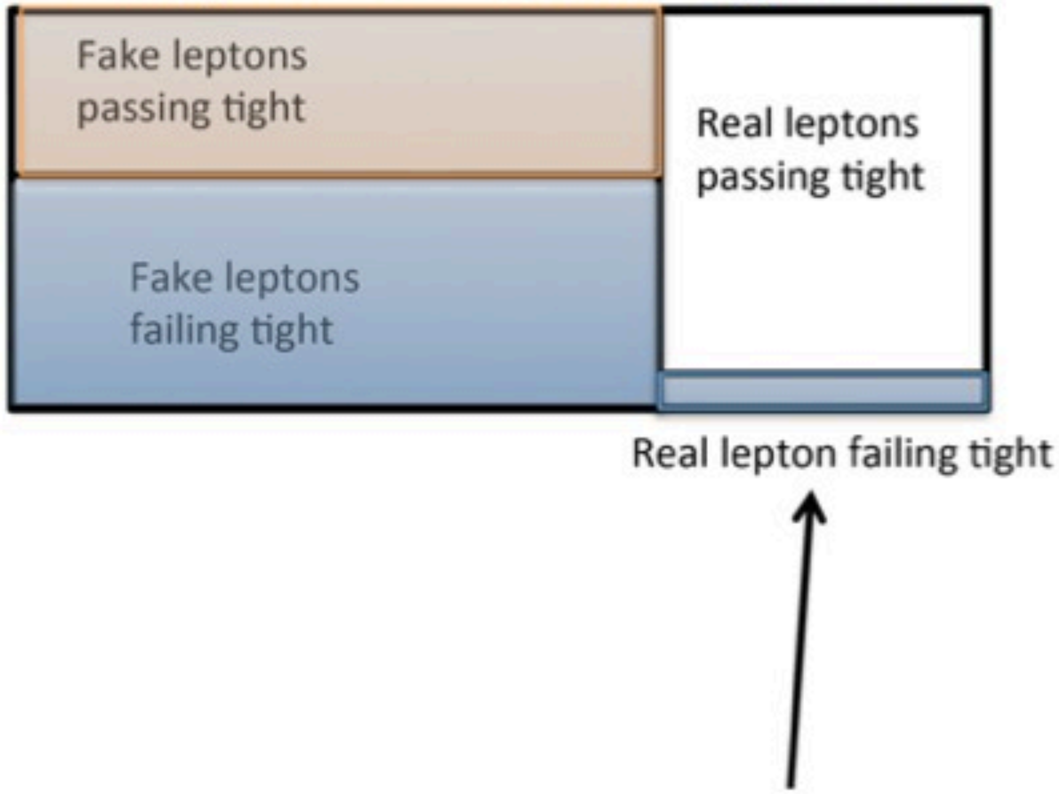
As noted in the main body of this talk, Alberto Graziano gave a detailed presentation to the SUSY fake-lepton group of the fake lepton estimation method we use in our analysis

The following slides are from that presentation and provide additional info not shown in the main body of this talk

Add. Info. Fake Lepton Est.

The extrapolation at a glance

Let's consider a simplified version of the method in which one lepton passes the tight cuts. The other lepton can be either real or fake, and it can pass or fail the tight cuts.



- pass-fail dilepton pairs are counted in data (blue area)
- the yield of events with fake leptons passing the tight cuts (red area) is given by

$$\sum \frac{f(p_T,\eta)}{1-f(p_T,\eta)}$$

The slight overestimate due to including also real leptons failing tight cuts is taken into account by a correction term depending on the prompt ratio.

Slides from Alberto Graziano

Add. Info. Fake Lepton Est.

Calibration sample for measuring the fake ratio

The fake ratio is measured from data in a calibration sample enriched with QCD di-jet events. Events with W and Z bosons are rejected by cutting on MET and $M_T(\ell, MET)$ and by applying a Z-veto.
Single lepton triggers are used.

Same-sign dileptons / ttW analysis

- $MET < 20$ GeV
- $M_T(\ell, MET) < 15\ (20)$ GeV for μ (e)
- exactly one loose lepton
- exactly one 'away jet' with $p_T > 65/40$ GeV and $\Delta\phi(\ell, j_{away}) > 2$

Dileptonic stop

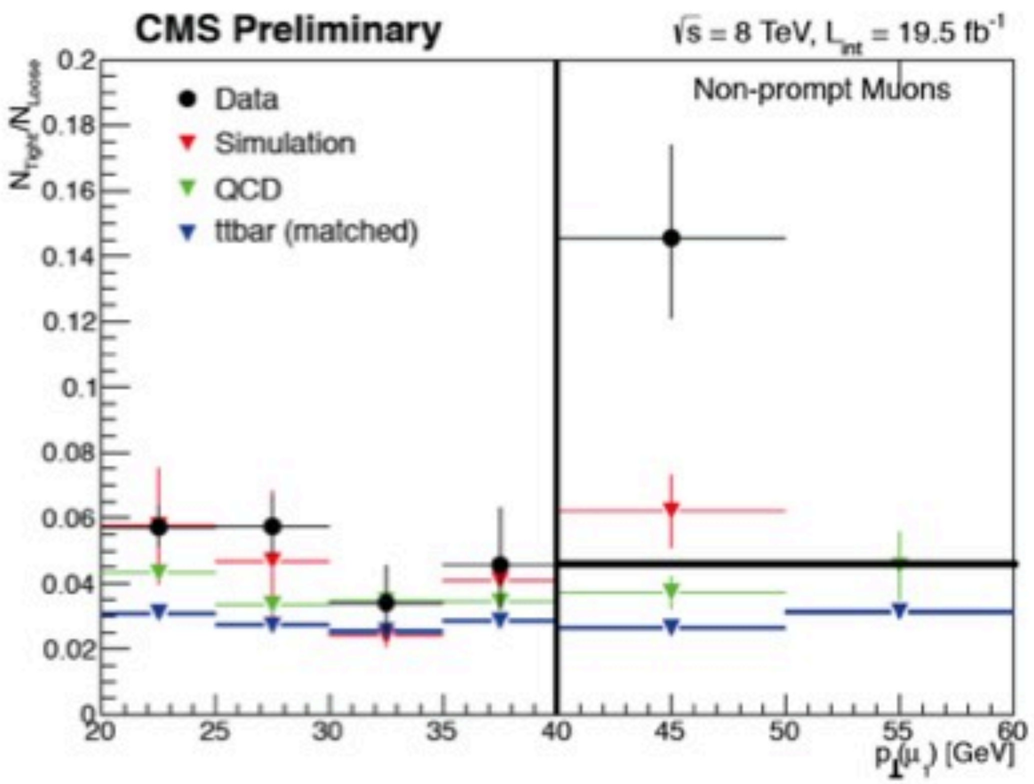
- $MET < 20$ GeV
- $M_T(\ell, MET) < 20$ GeV
- one jet with $\Delta R(\ell, j_{near}) < 0.3$
- one 'away jet' with $\Delta R(\ell, j_{away}) > 1$ and $p_T > 50\ (30)$ GeV for μ (e)
- if more than one lepton, $m_{\mu\mu} \notin (76, 106)$ GeV, $m_{ee} \notin (60, 120)$ GeV

Slides from Alberto Graziano

Add. Info. Fake Lepton Est.

$p_T^{flat}(\ell)$ for the fake ratio

In the absence of EWK subtractions, the fake ratio at high p_T^ℓ increases because of contaminations due to leptons originating from W and Z decays.



The fake ratio distribution is then assumed to be flat w.r.t. p_T^ℓ above a given threshold (30 GeV in the dileptonic stop analysis, 40 GeV in the same-sign dilepton one).
The f values in the uppermost (p_T, η) bins below this threshold are used also above it.

Slides from Alberto Graziano

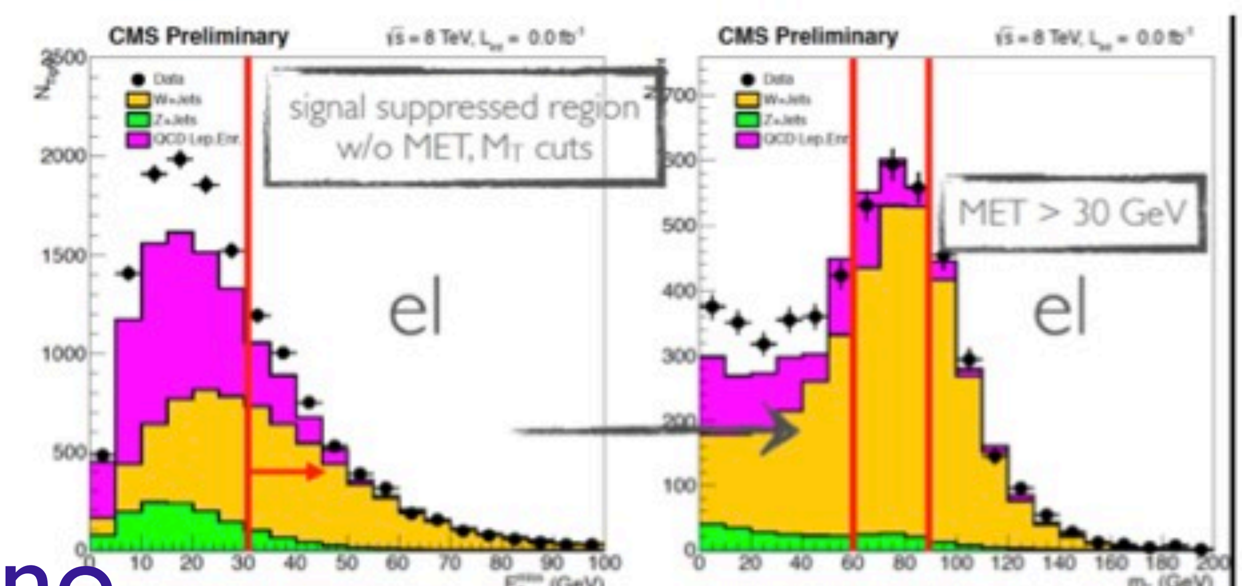
Add. Info. Fake Lepton Est.

EWK subtraction for the fake ratio

In the most recent version of the analyses, residual contaminations from W or Z boson decays are subtracted from the numerator and the denominator of the fake ratio:

$$f_{EWKcorr} = \frac{N_{tight}^{data} - N_{tight}^{W+jets} - N_{tight}^{Z+jets}}{N_{loose}^{data} - N_{loose}^{W+jets} - N_{loose}^{Z+jets}}$$

MC yields are normalised to the effective luminosity of the prescaled trigger paths. In the ttW analysis, they are also scaled by data/MC SF obtained after requiring $MET > 30$ GeV, $60 < M_T < 90$ GeV.



Slides from
Alberto Graziano

Add. Info. Fake Lepton Est.

Calibration sample for measuring the prompt ratio

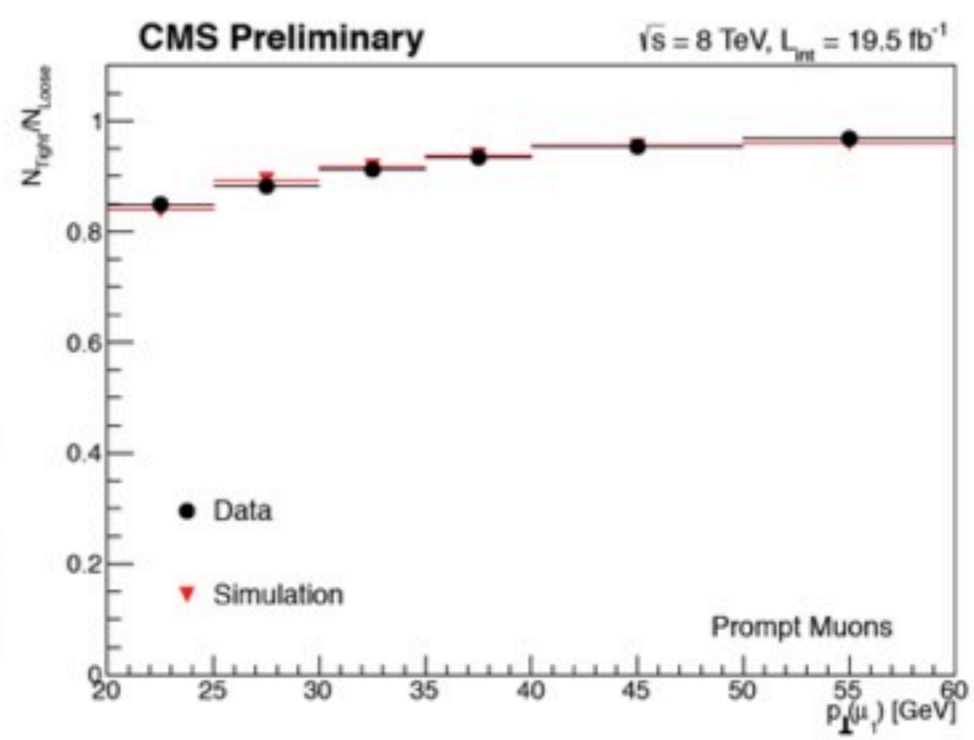
The prompt ratio is measured from a calibration sample enriched with $Z \to \ell\ell$ events. Like the fake ratio, it is binned in lepton p_T and η.

Same-sign dileptons

- two OS, SF leptons
- $|m_{\ell^+\ell^-} - m_Z| < 15$ GeV
- at least 2 jets
- $MET < 20$ GeV
- the softer of the two lepton is considered

Dileptonic stop

- two OS, SF leptons
- $|m_{\ell^+\ell^-} - m_Z| < 10$ GeV
- a standard tag-and-probe procedure is applied



Slides from Alberto Graziano

Add. Info. Fake Lepton Est.

Stat. and syst. uncertainties

- **stat.** $\rightarrow$ *from the statistical uncertainties on $f(p_T^\ell, \eta^\ell)$:*
  the value of f in each bin is varied up- and downwards by the stat. uncertainty on f and the largest difference w.r.t. the central value is taken as the statistical uncertainty.
- **syst.** $\rightarrow$ *from the away-jet p_T variation in the calibration sample:*
  the away-jet p_T threshold is moved up and down and the largest difference w.r.t. the central value is taken as the systematical uncertainty.

The total uncertainty is around 50% and it is dominated by the systematical one.

Slides from Alberto Graziano

Add. Info. Fake Lepton Est.

Closure test (dileptonic stop)

A closure test is performed on a same-sign loose-loose dilepton sample in data.

- assumption: the probability of a lepton being fake does not depend on its charge
- the method is run on a SS loose-loose dilepton sample and each event is assigned a weight
- the weighted SS distributions are compared with those extracted directly from SS tight-tight dilepton data, after the subtraction of MC events with prompt leptons (*i.e.* matched to GEN leptons from W decays)
- the two distributions are in good agreement

Slides from Alberto Graziano

Add. Info. Fake Lepton Est.

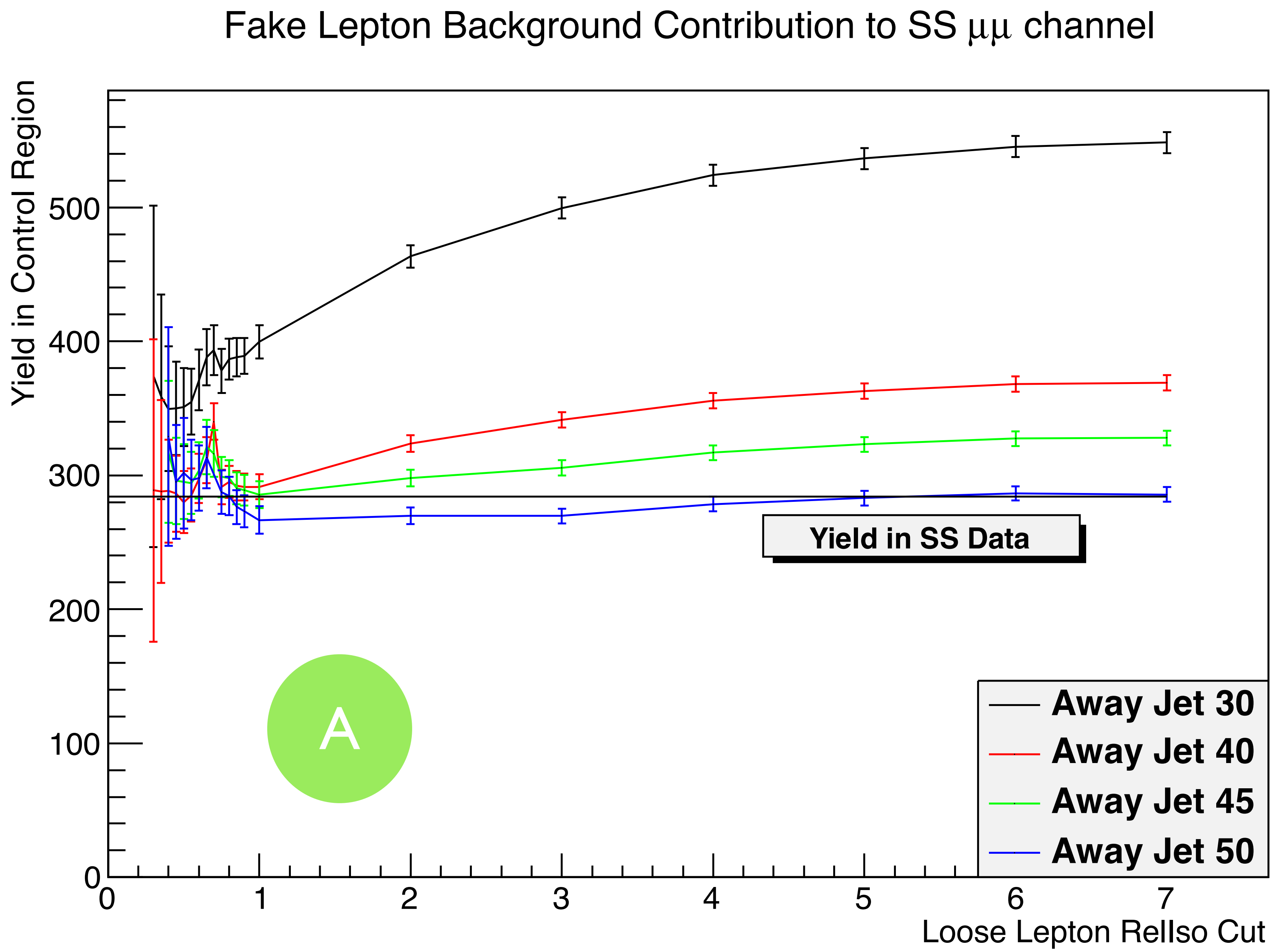
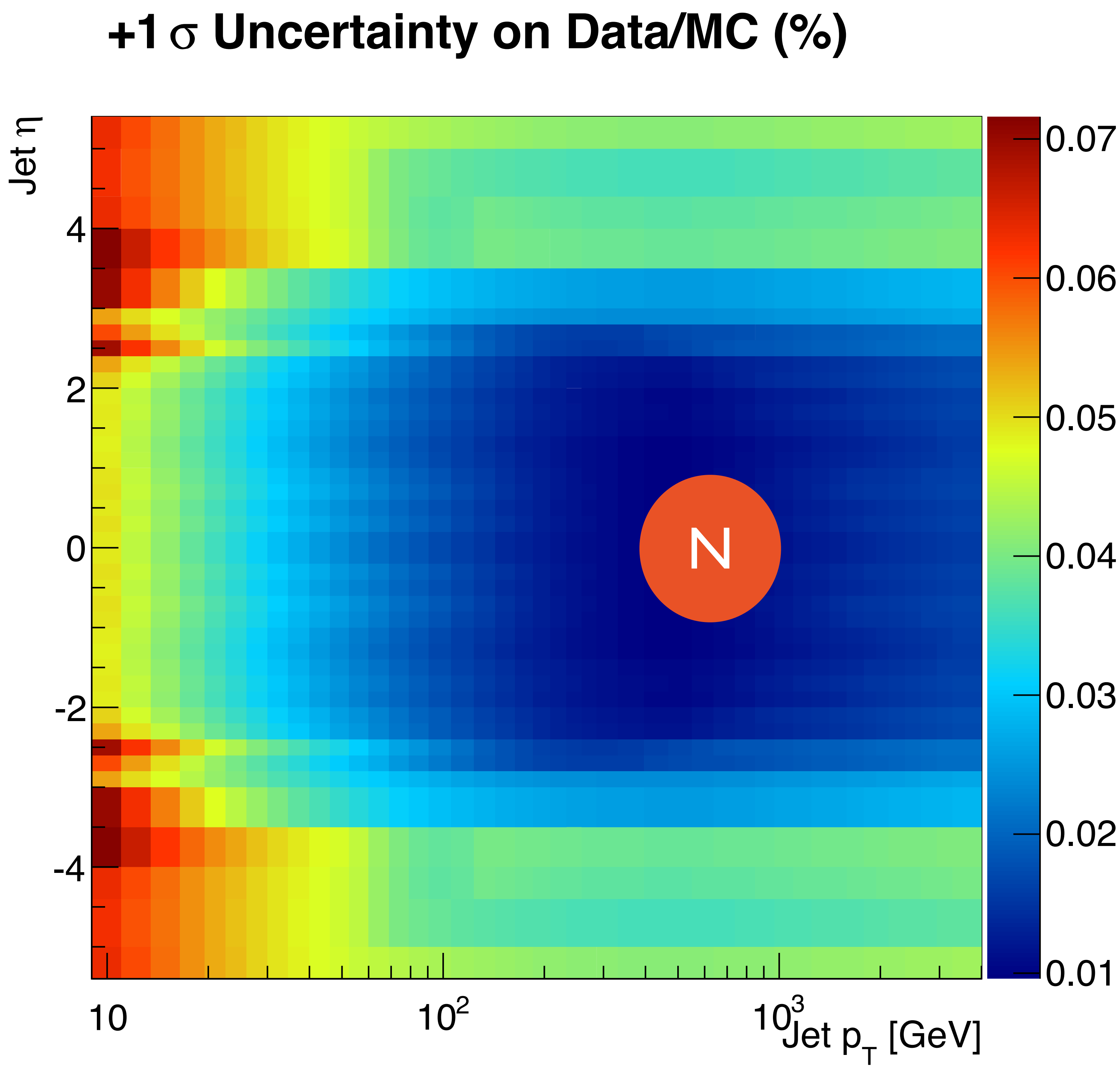


Figure 5: Comparison between lepton yields in the tight-tight same-sign dilepton region as a function of the corresponding threshold on the loose lepton relative isolation, for muons in the $\mu\mu$ channel. The colored lines refer to different jet p_T thresholds used to select events in the di-jet control sample. The black horizontal line refers to data minus backgrounds different from semileptonic or all-hadronic $t\bar{t}$ and W+jets, as obtained from a tight-tight same-sign dilepton sample enriched with W+jets events.

JES Uncertainty



Uncertainty is on the Type 1 Jet corrections Data/MC ratio

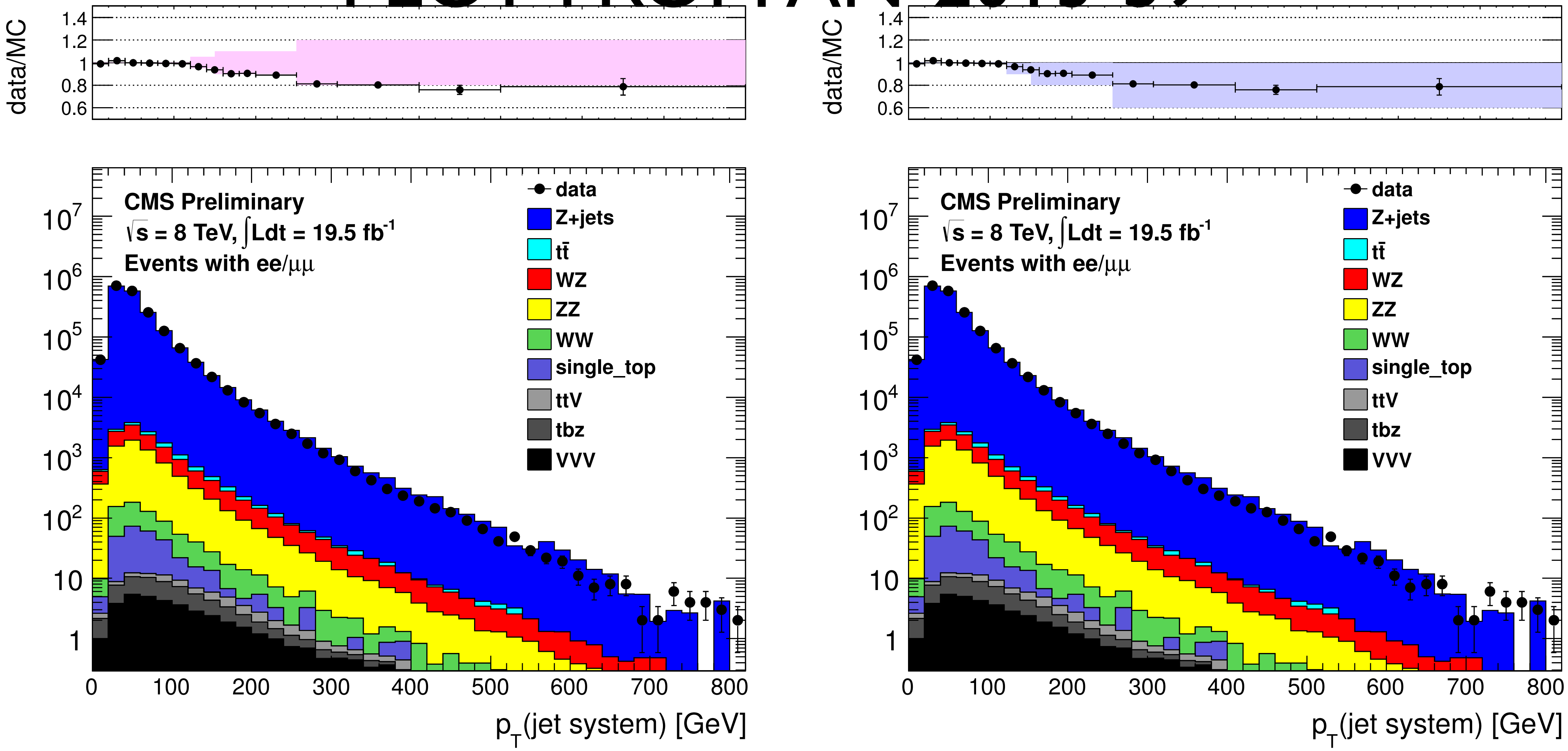
Apply on jet-by-jet basis to the jet 4-momenta

-1 sigma is exact same magnitude

Taken from official Summer 13 JetMET PF CHS Jet uncertainties

"ISR" Reweighting

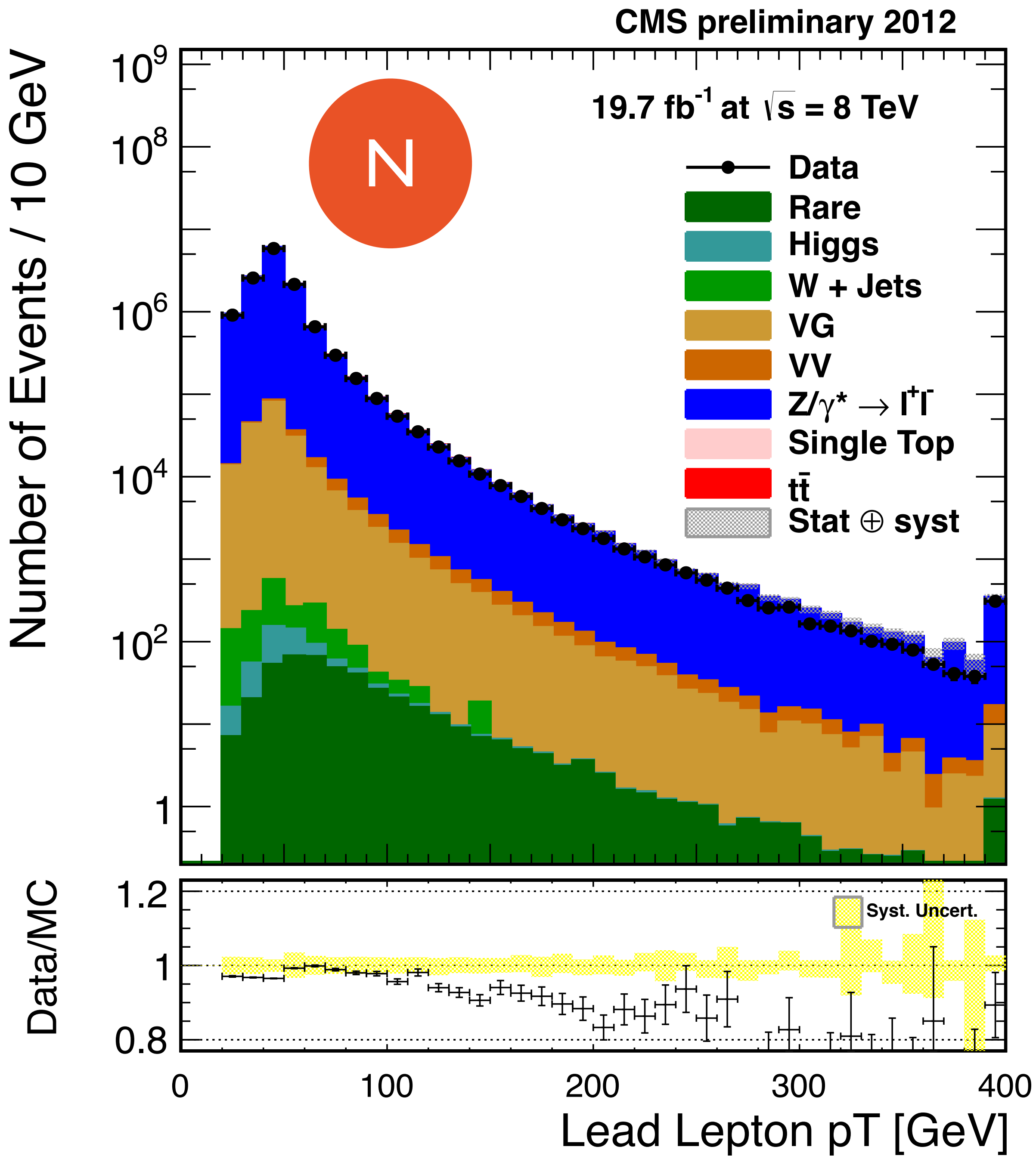
PLOT FROM AN-2013-59

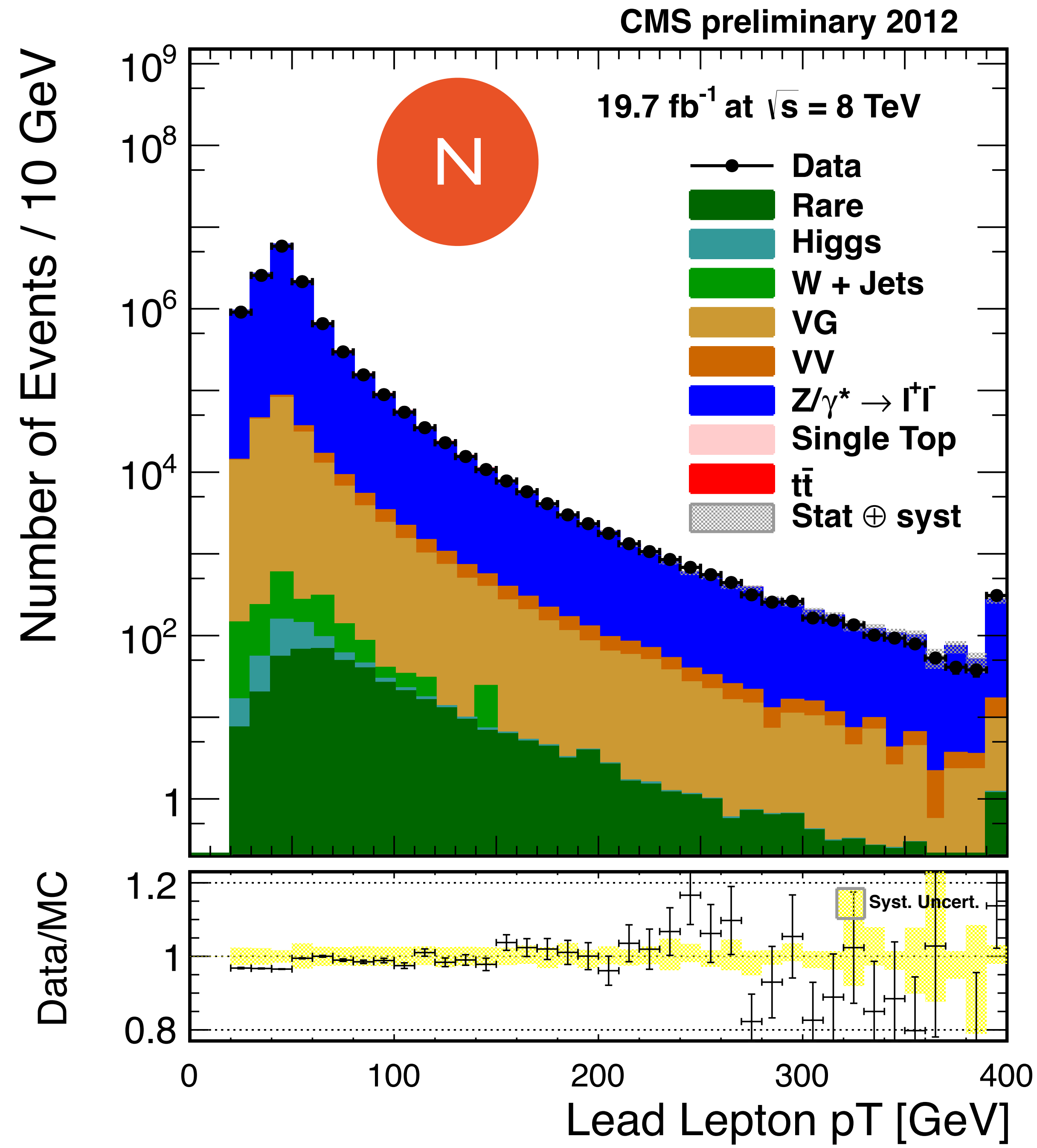


(a) Nominal central value (b) Reweighted central value

Figure 23: Comparison of data to MC prediction for jet recoil system p_T for Z+jets events. The ratio of data/MC is shown at the top of each figure. The light pink/blue bands show the proposed weight variation to assess systematic uncertainties. In Fig. (a), the central value is taken from the MC, while in Fig. (b), the central value in MC is corrected to data. The reweighting shown in (b) is proposed as the default procedure.

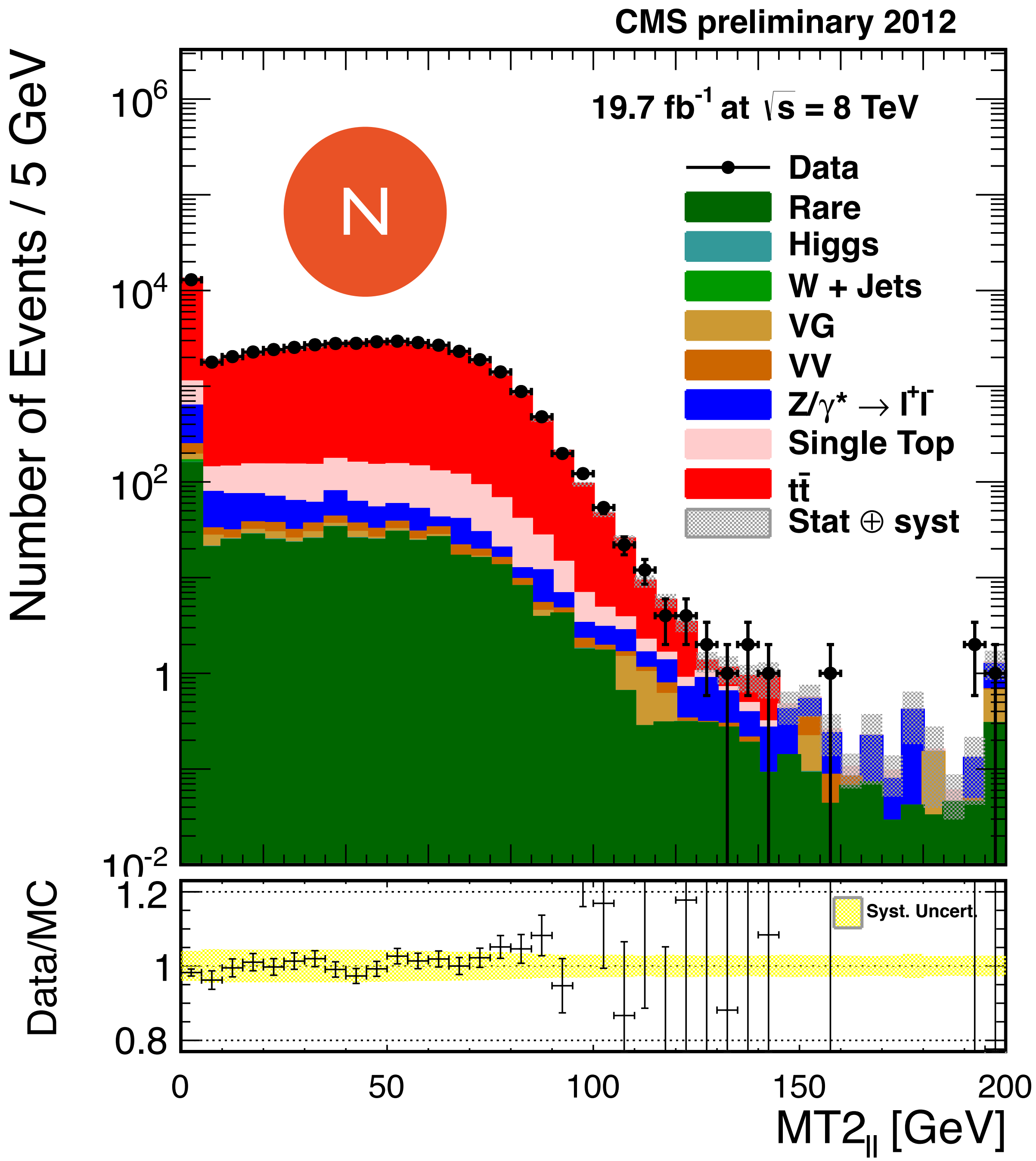
"ISR" correction on DiLeptons



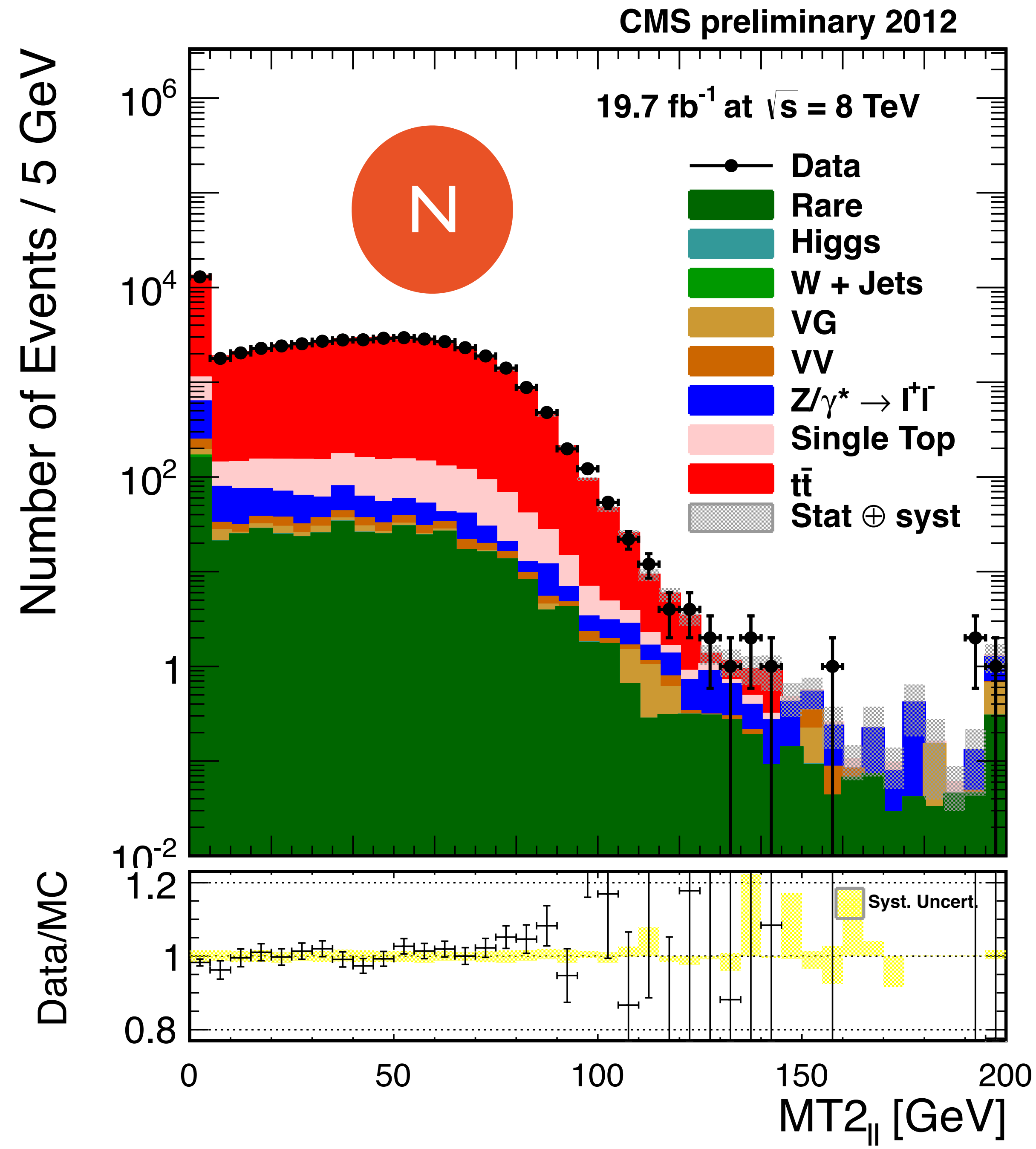


Basic dilepton selection in Z Mass region

Individual Systematics

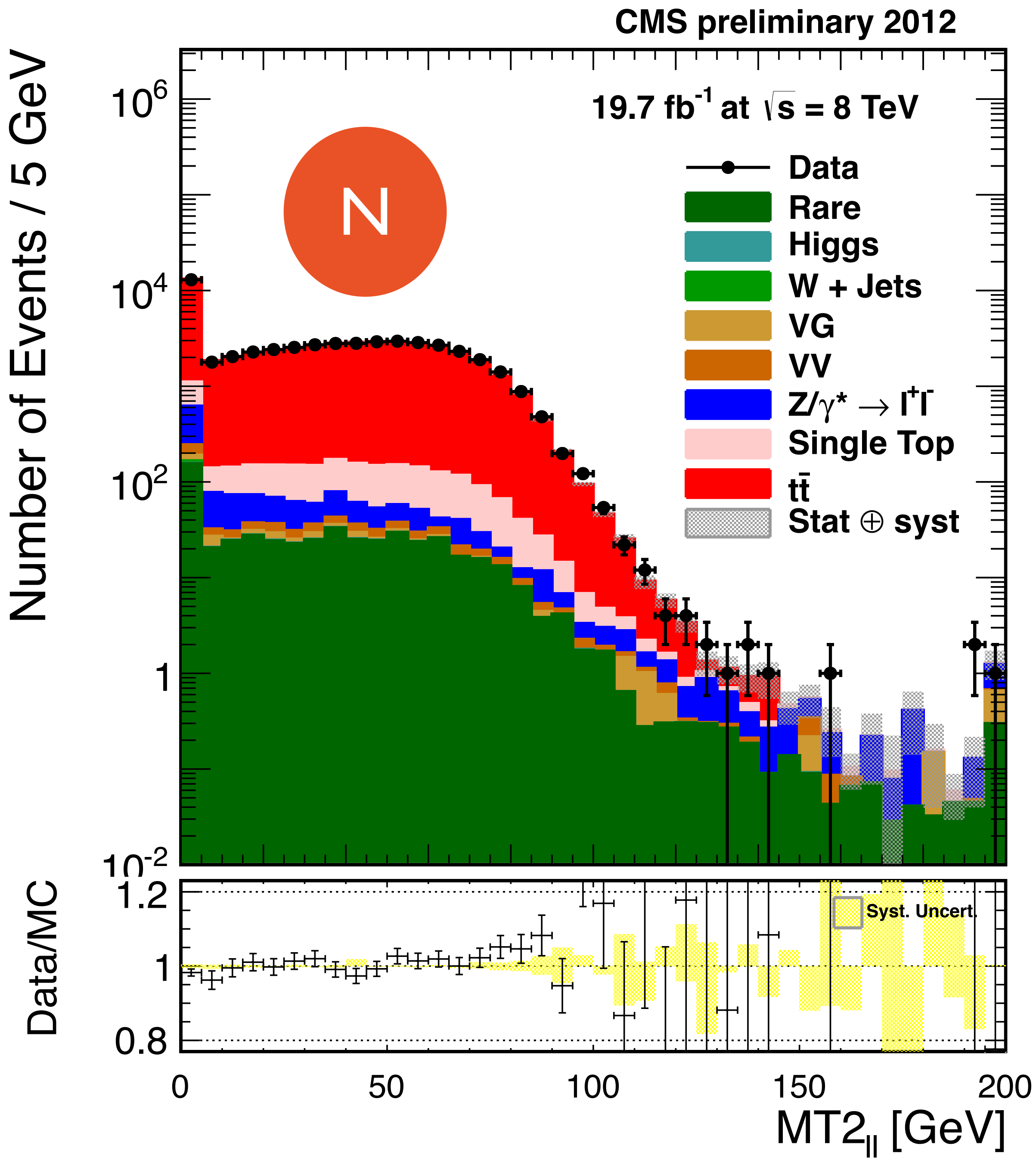


Lepton SF Systematic

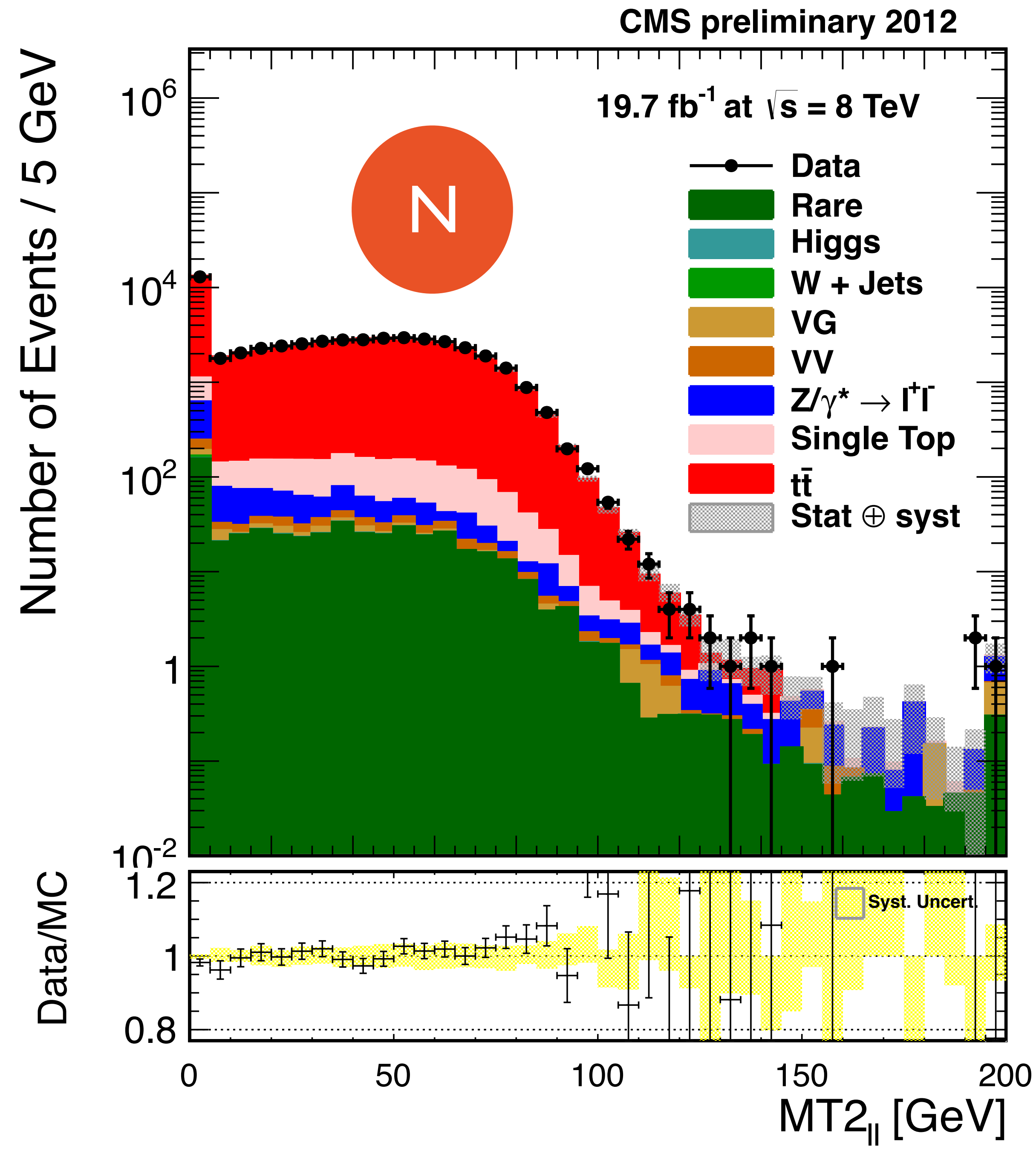


BTag SF Systematic

Individual Systematics

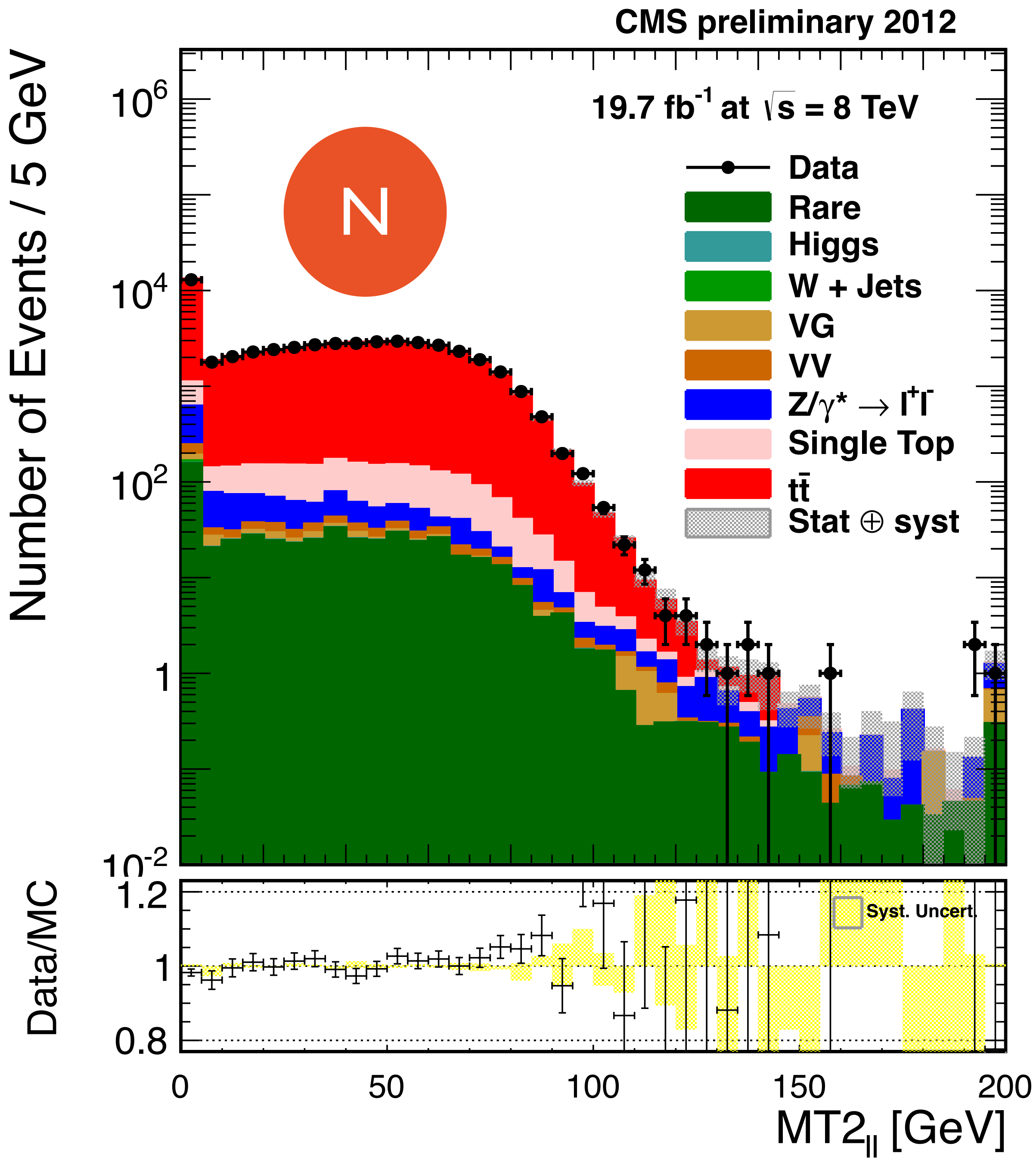


Lepton ES Systematic

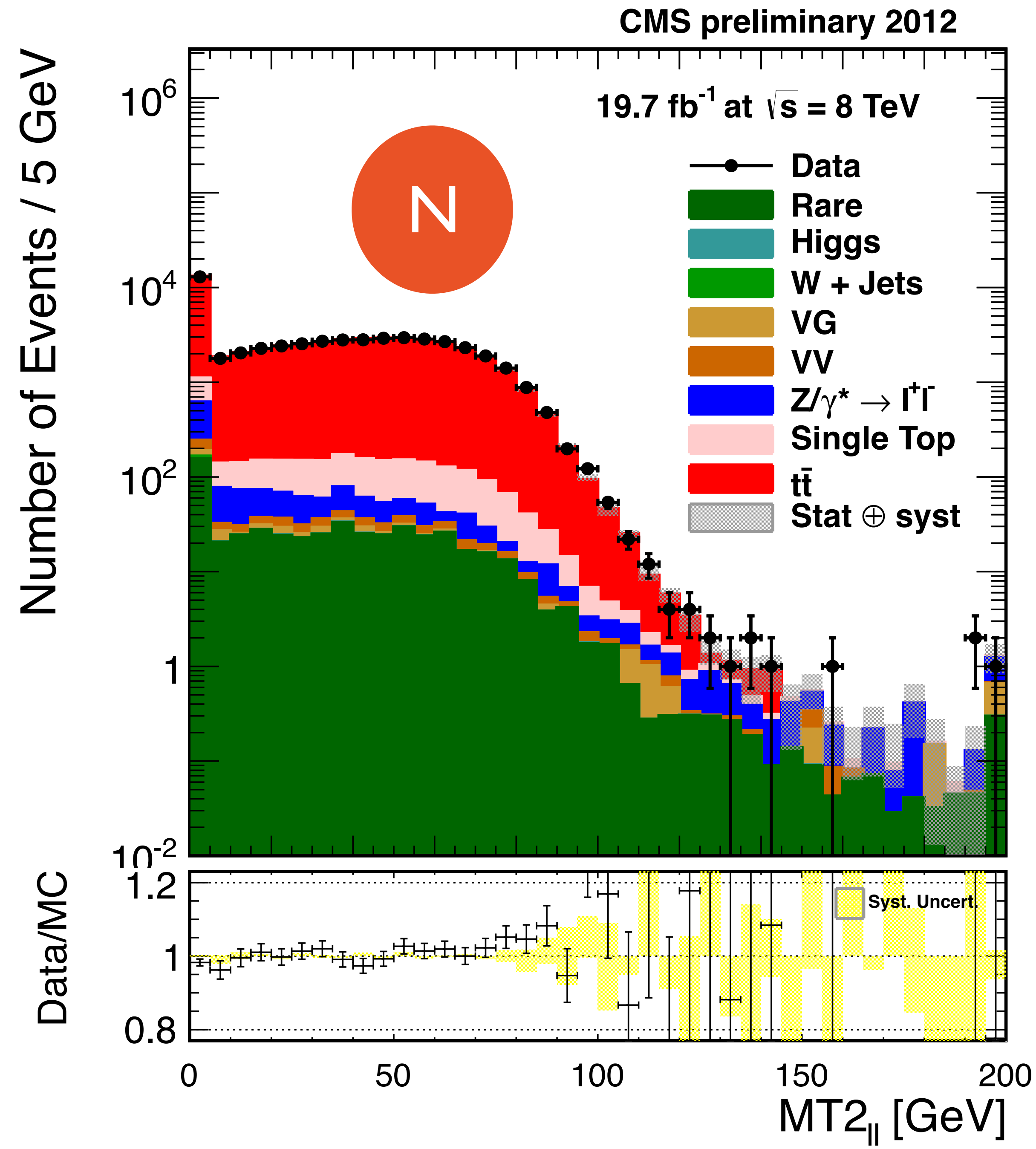


Jet ES Systematic

Individual Systematics

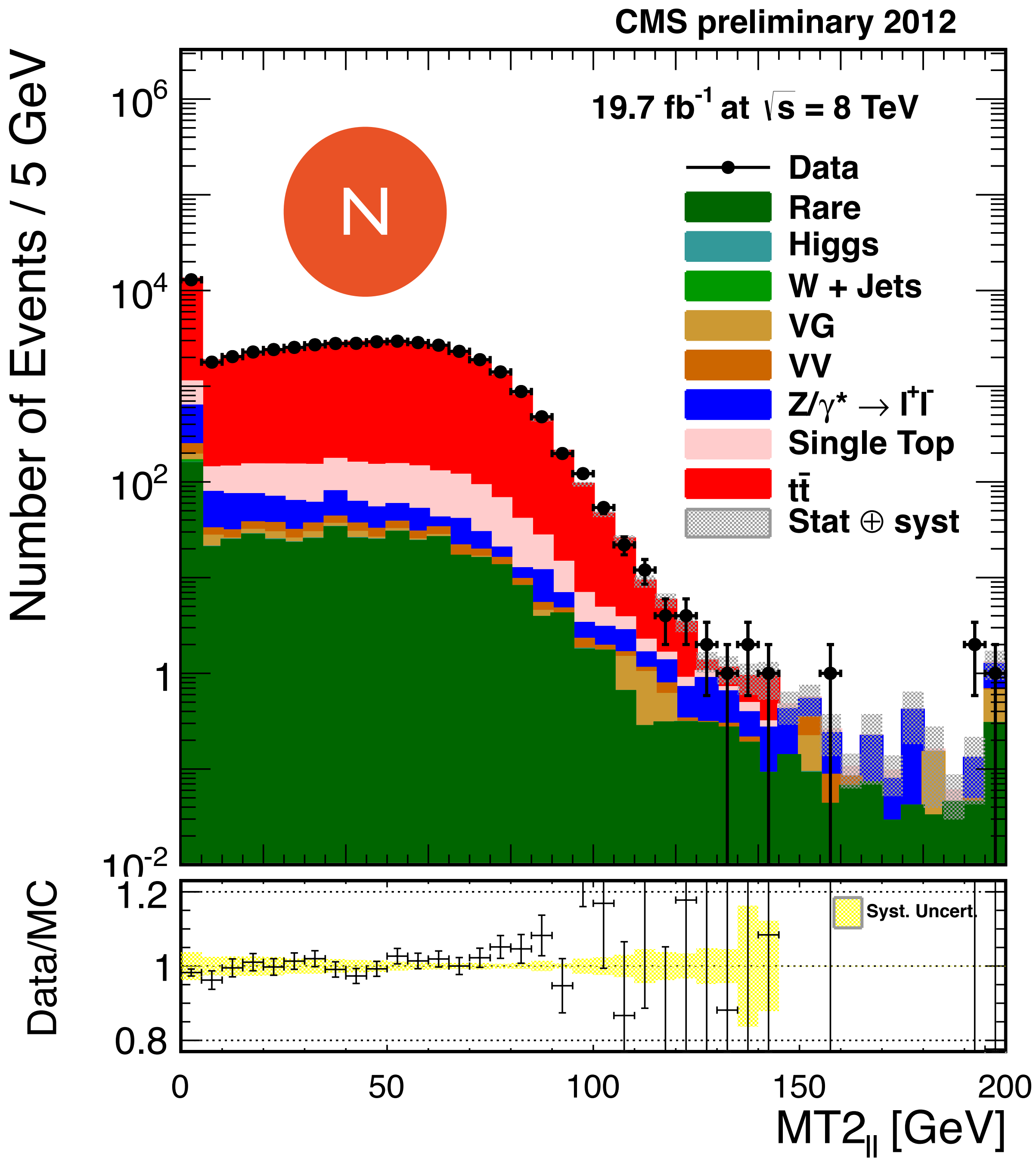


Unclust. En Systematic

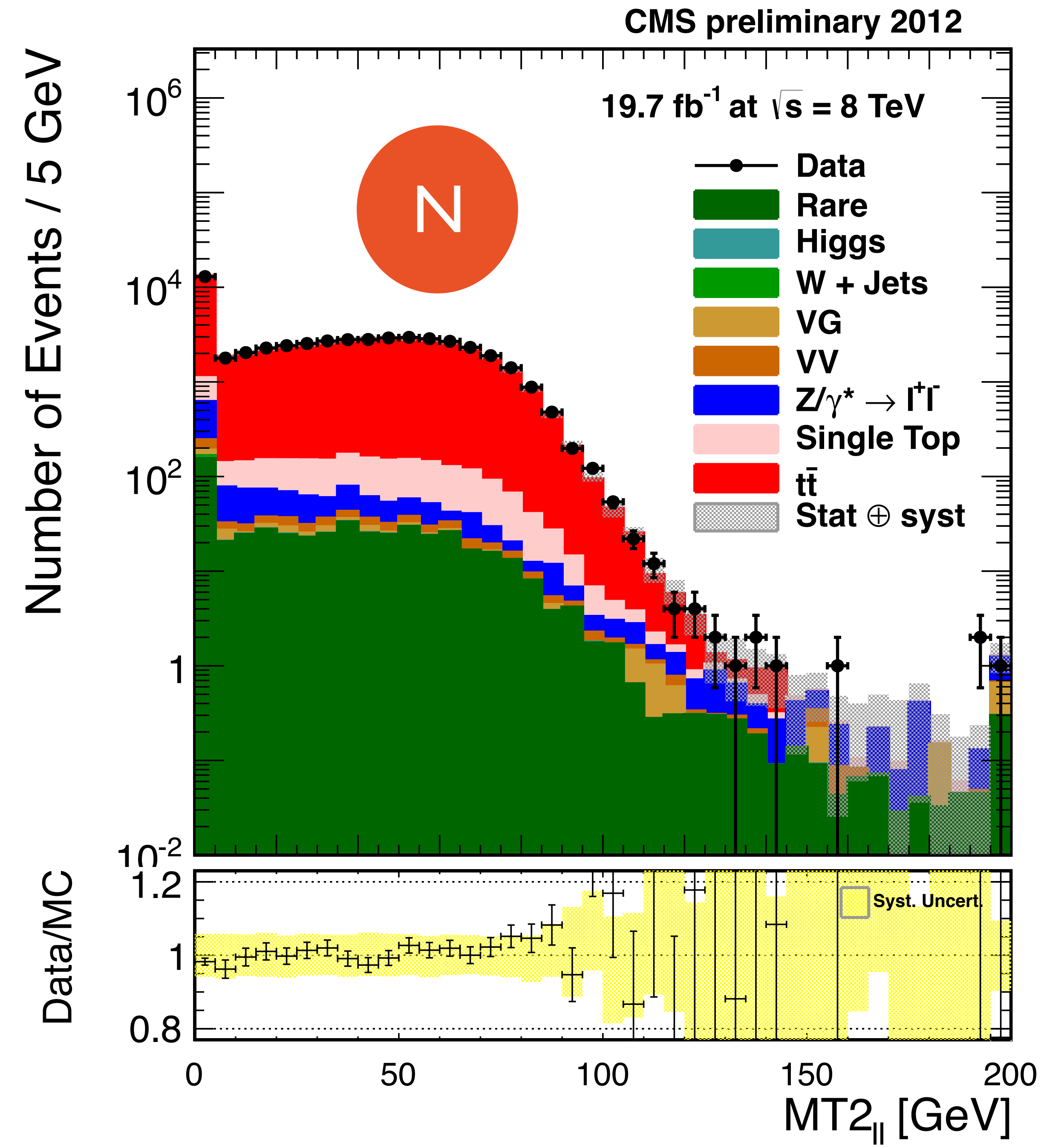


Jet Smear Systematic

Individual Systematics

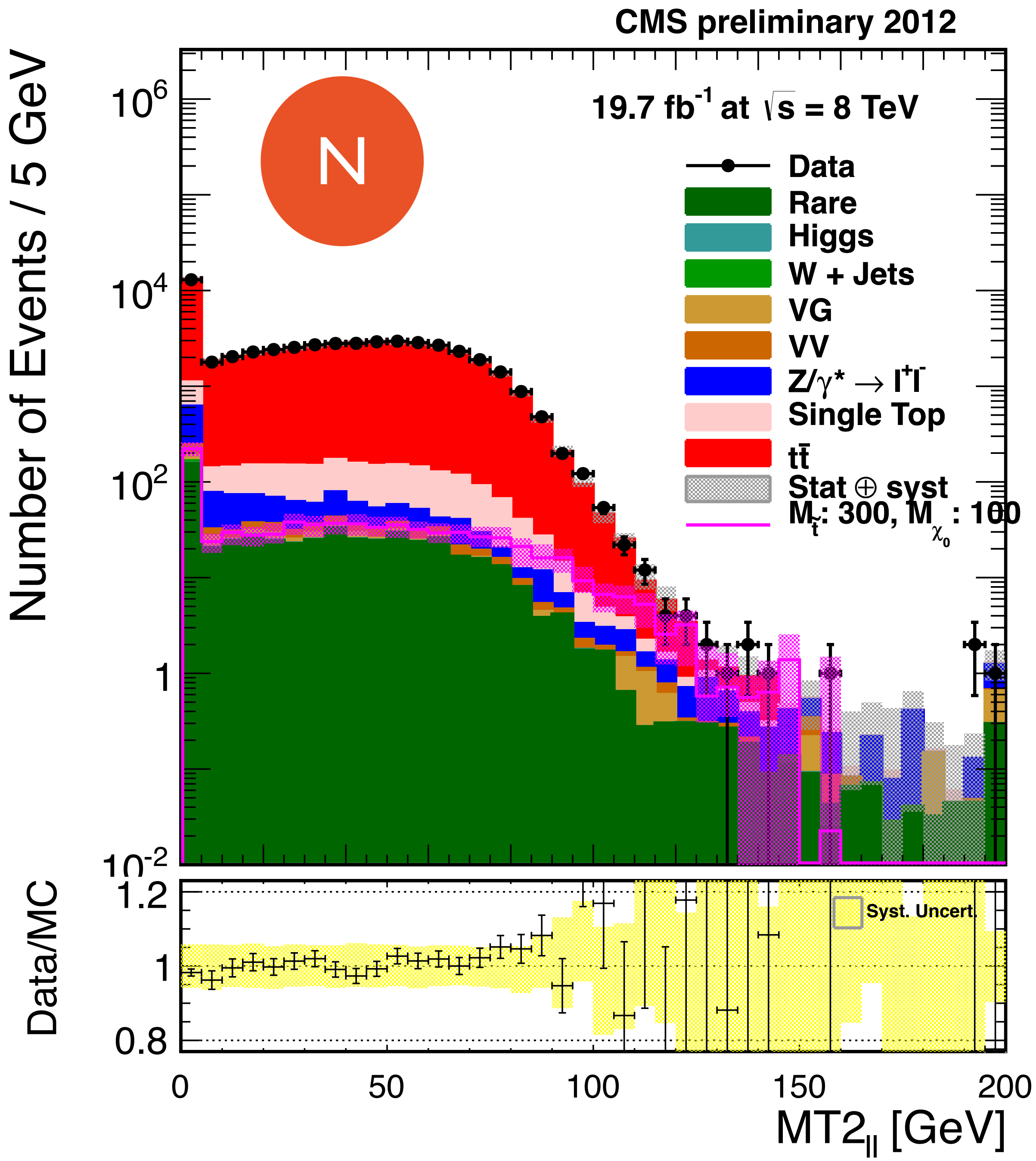


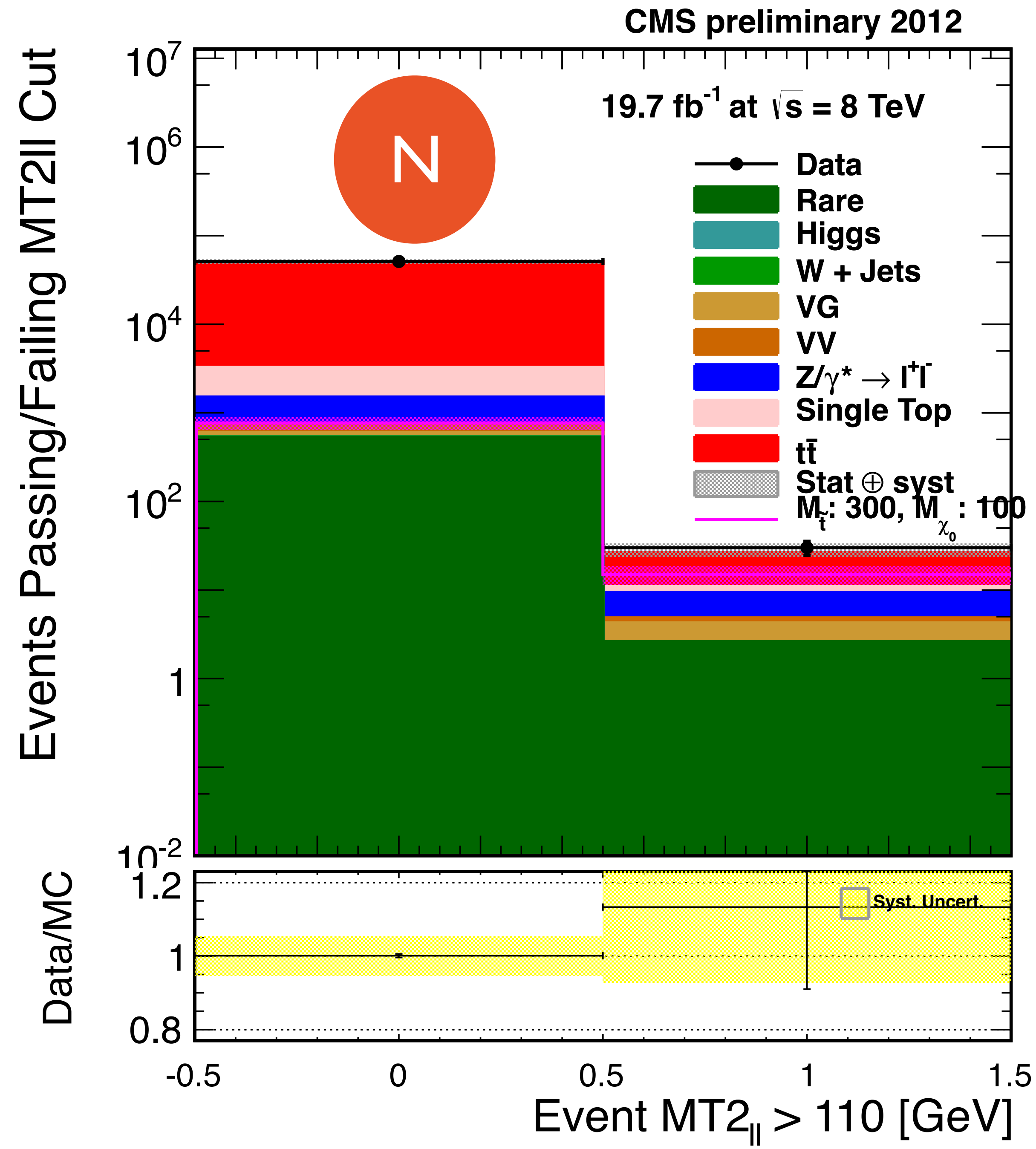
Gen Top RW Syst.



Full Systematics

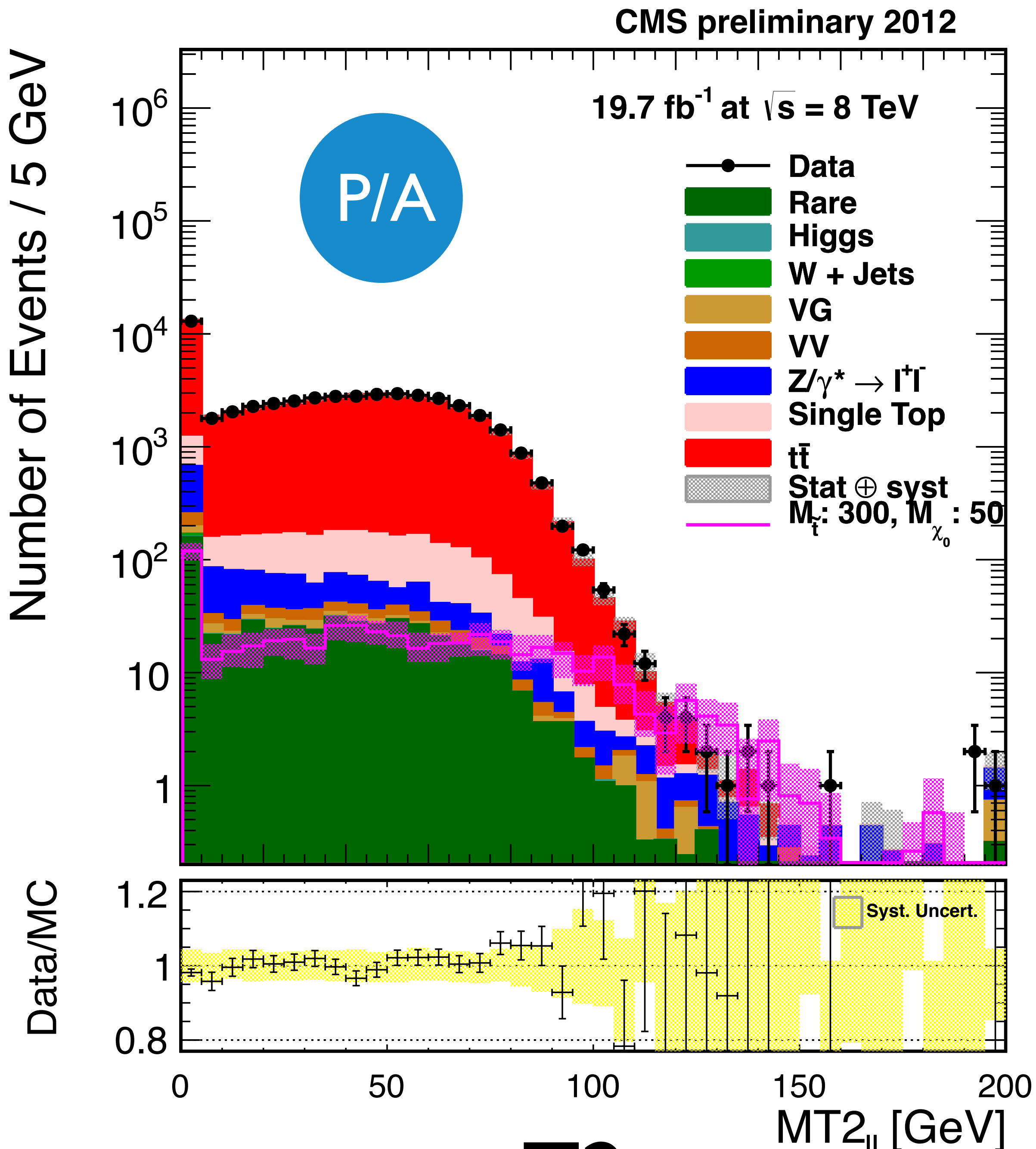
MT2(ll) after Full selection





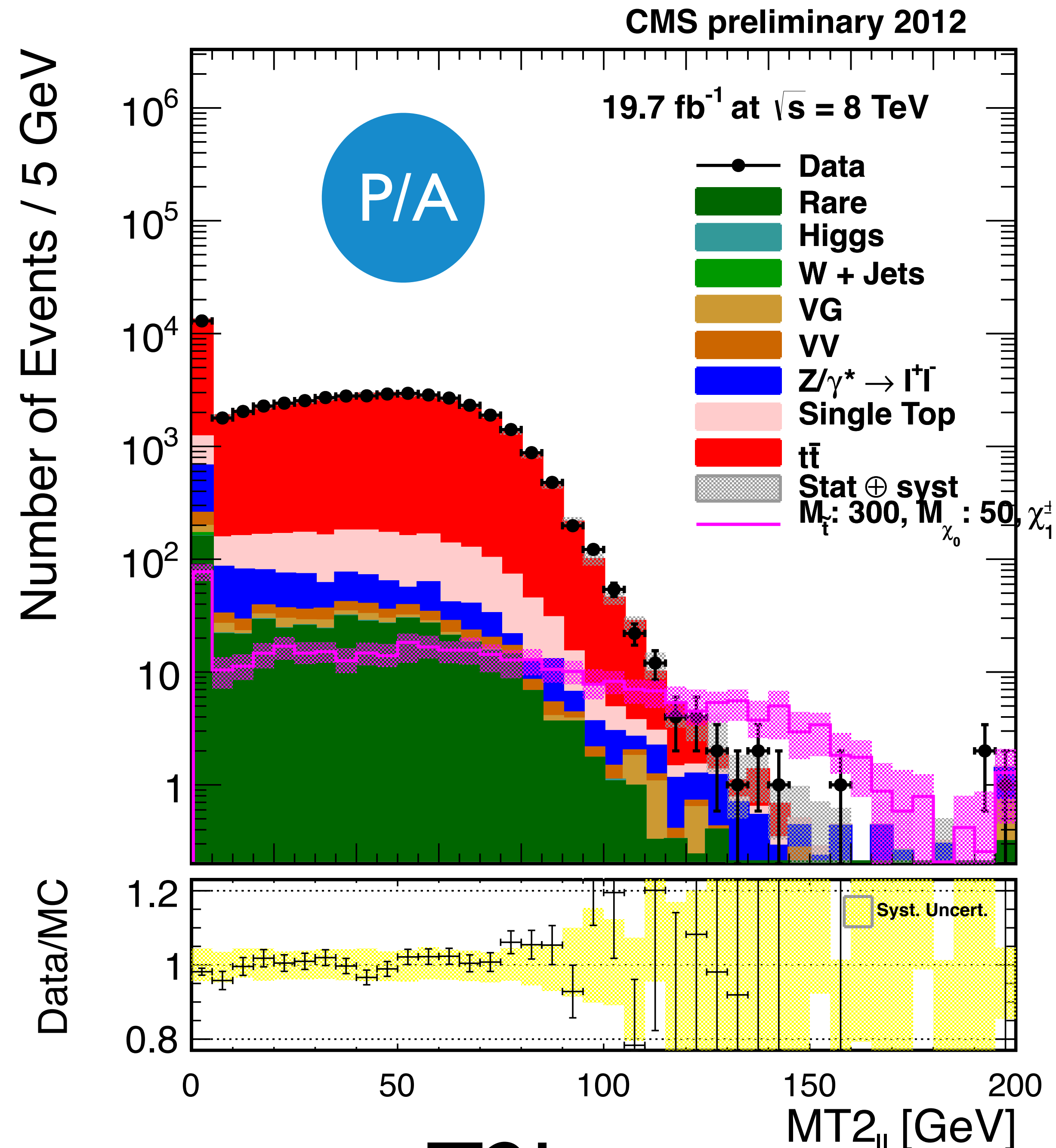
T2tt {Stop, Chi0} = {300, 100}

MT2(ll) after Full selection



T2tt

{300, 50}



T2bw

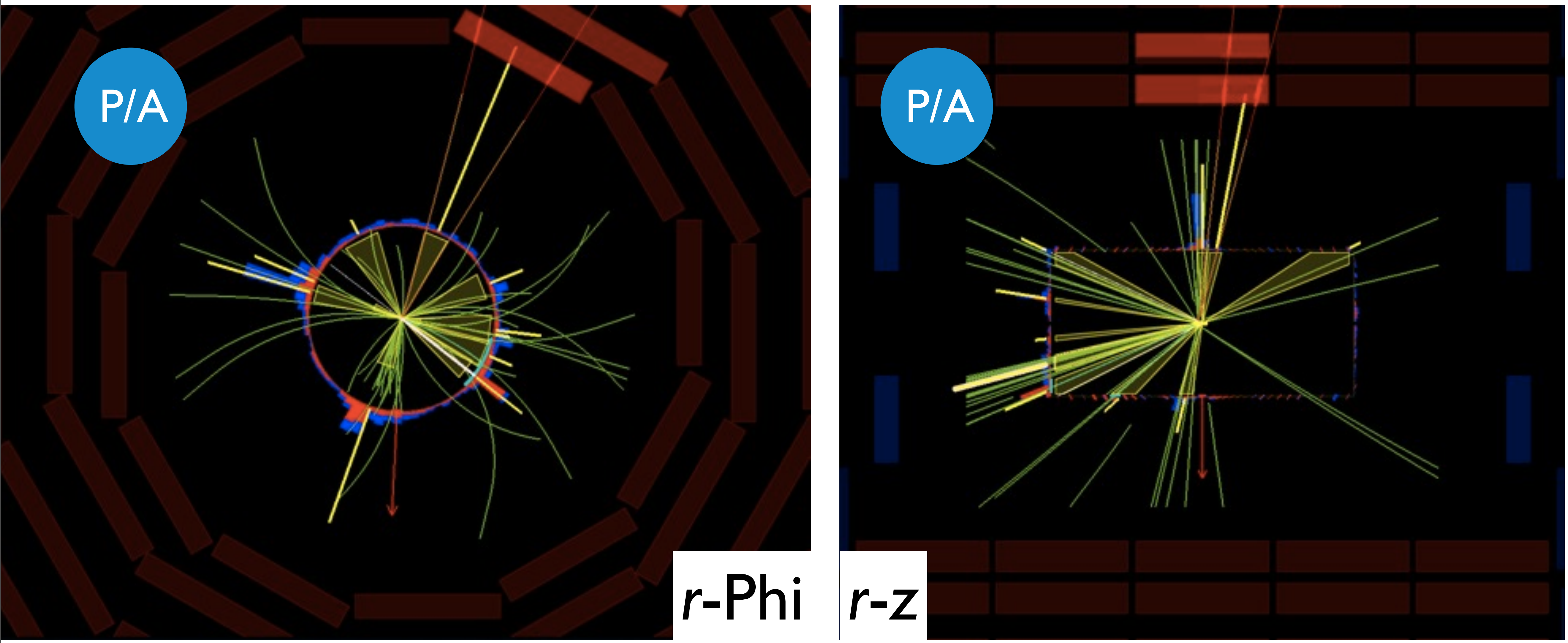
{300, 50} “x” = 0.75

High M_{T2}(ll) Events

Our unblinded M_{T2}(ll) distribution has three events at very high values (M_{T2}(ll) > 180 GeV)

In order to ensure that there wasn't some detector effect or reconstruction failure at play, we investigated these three events using the CMS Fireworks Event Display

MuMu 1: M_{T2}(ll) of 190 GeV



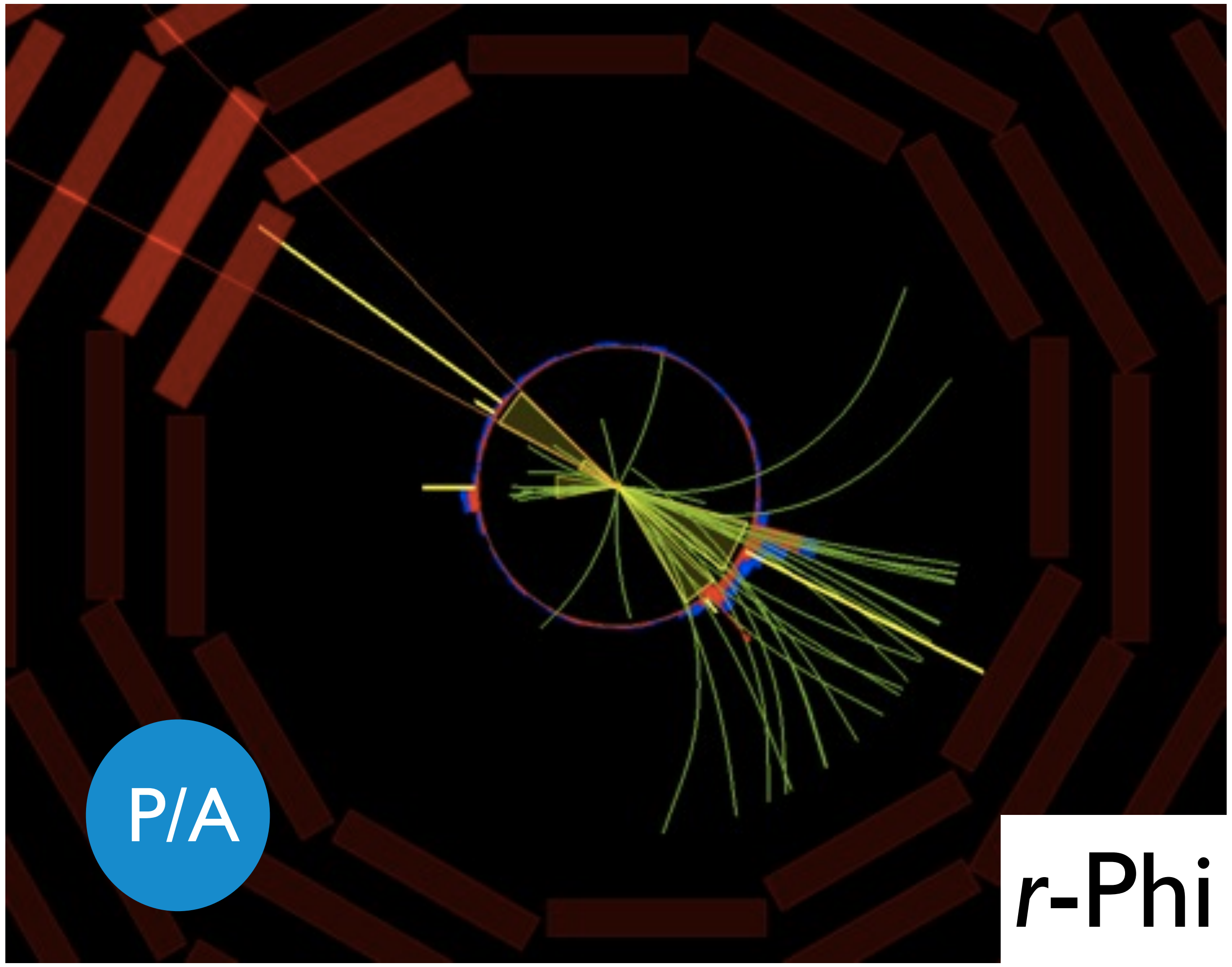
Dilepton Mass: 43 GeV

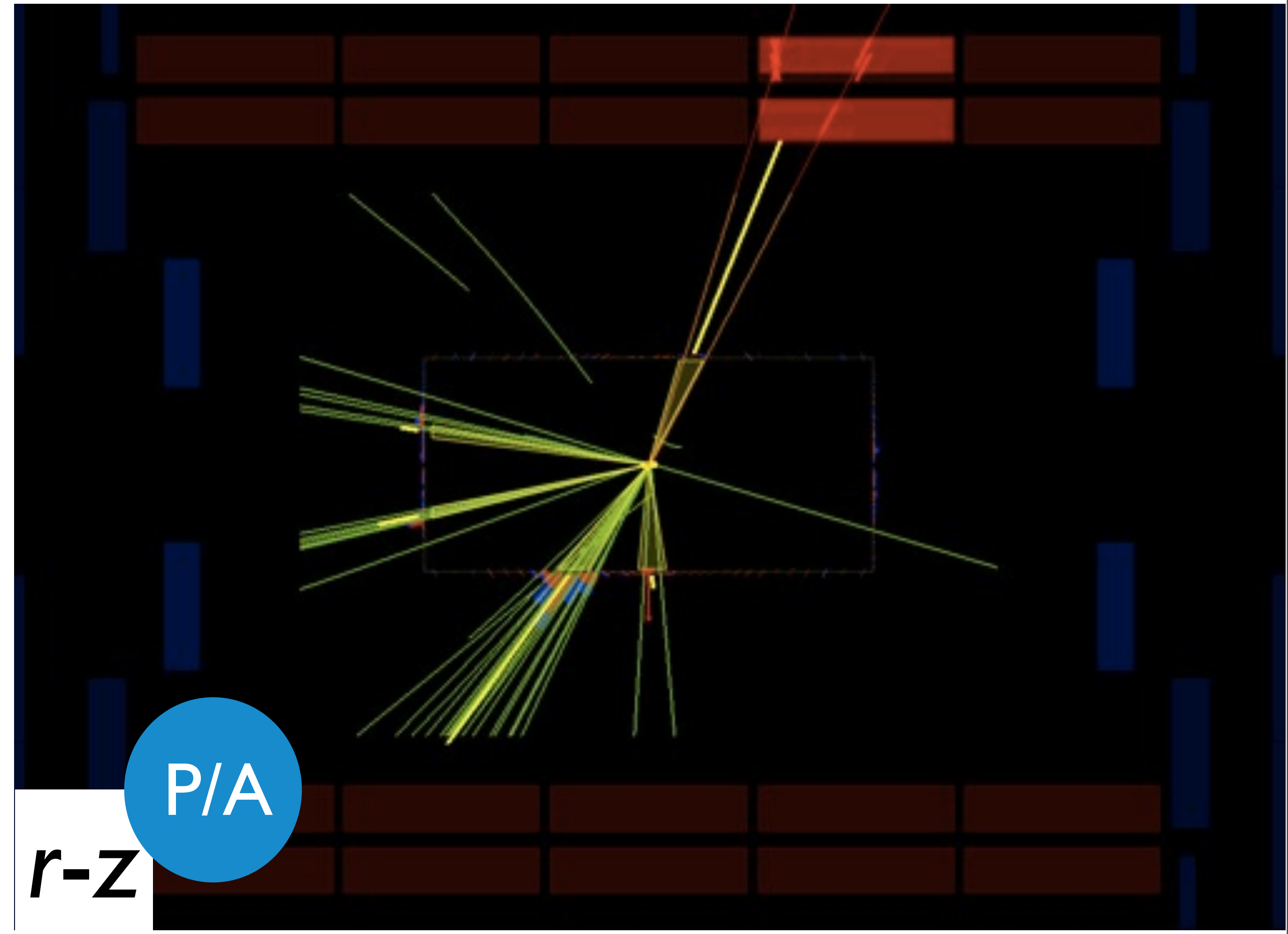
6 Jets with p_T > 50 GeV

MET: 140 GeV (points very close to 180 GeV jet)

DPhi(MuMu, MET) 2.7 radians

MuMu 2: M_{T2}(ll) of 190 GeV





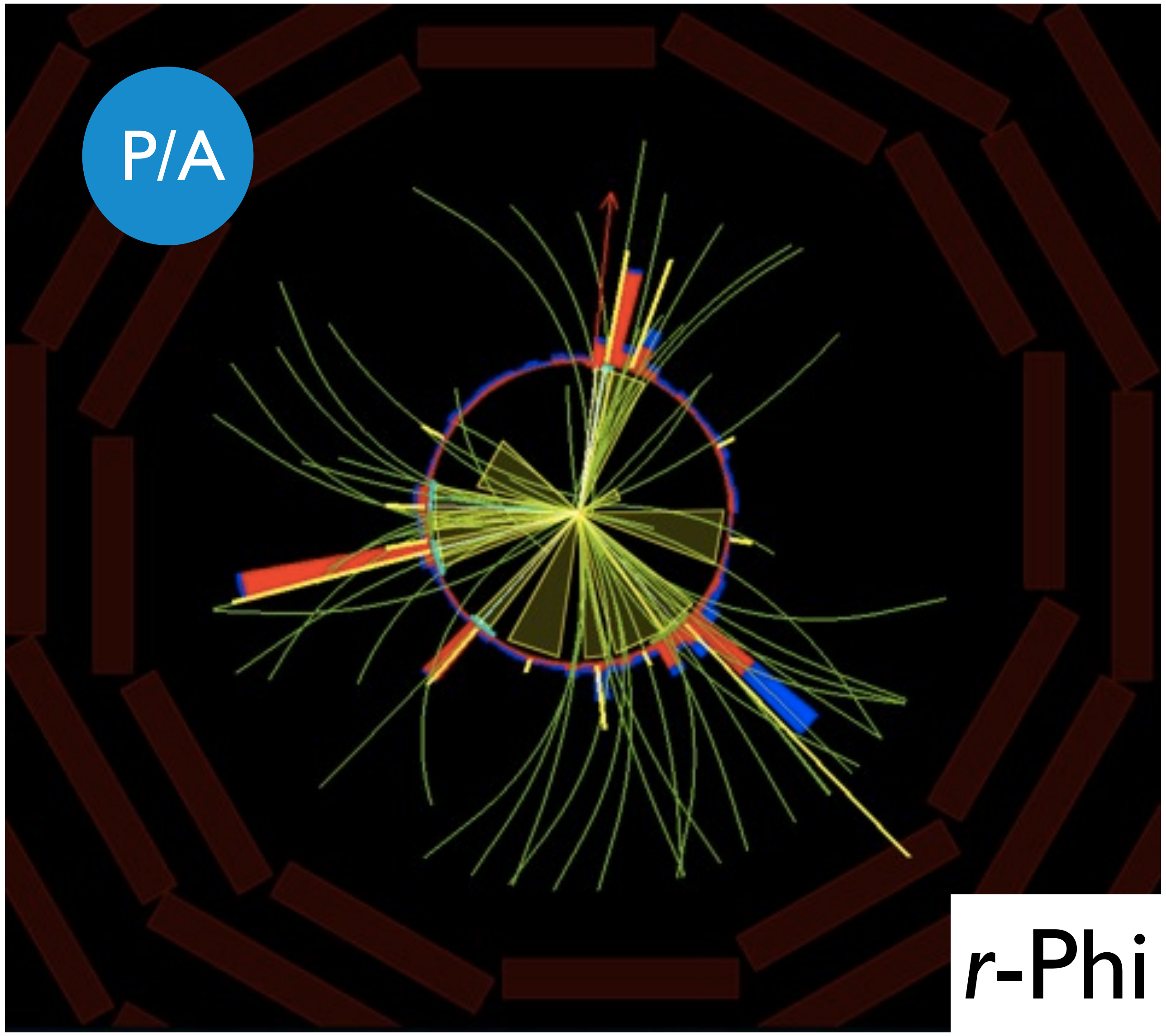
Dilepton Mass: 75 GeV

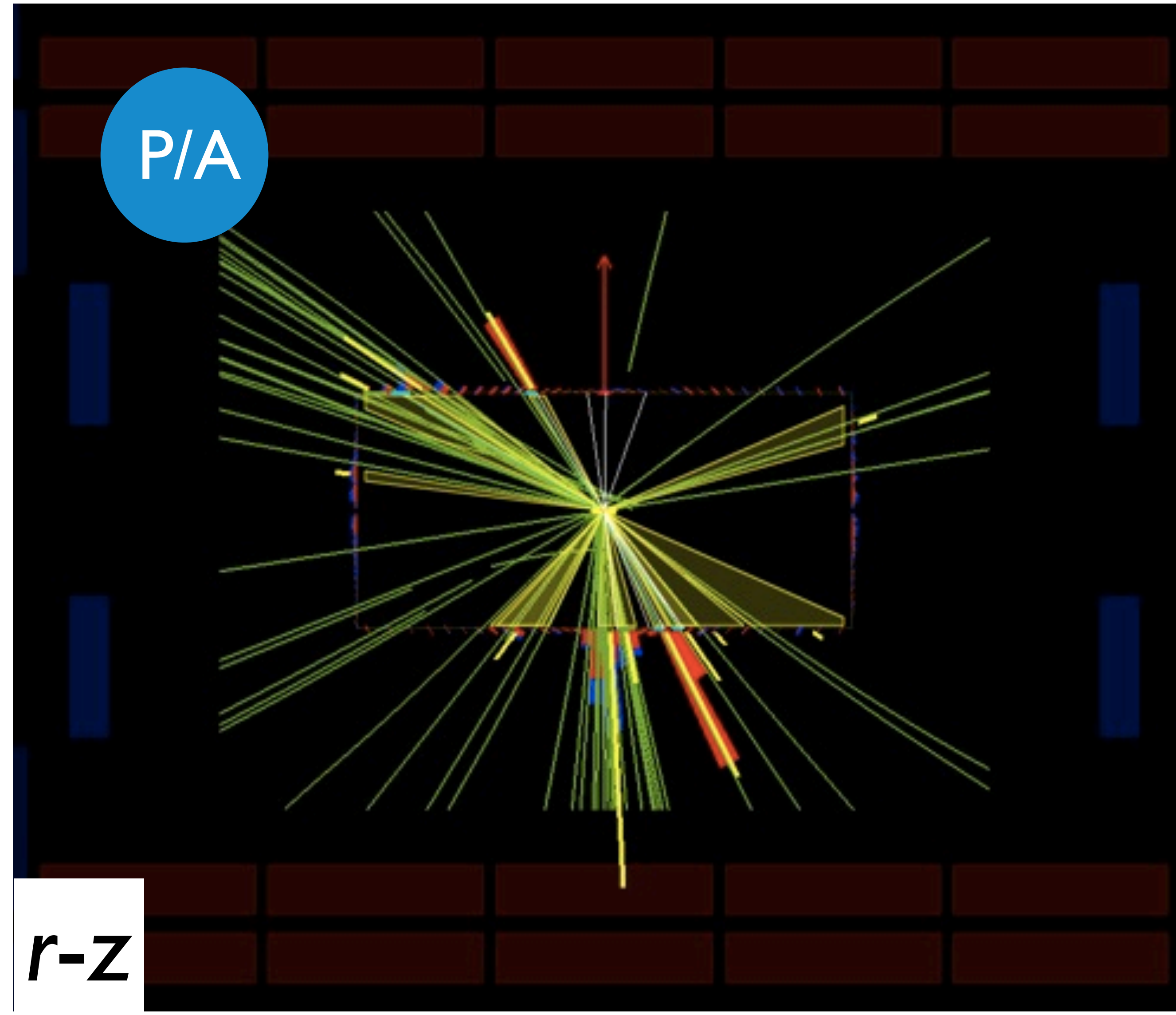
3 Jets with p_T > 50 GeV

MET: 100 GeV

DPhi(MuMu, MET) 2.9 radians

ElecElec 1: M_{T2}(ll) of 270 GeV





Dilepton Mass: 106.3 GeV

7 Jets with p_T > 50 GeV

MET: ??? GeV

DPhi(MuMu, MET) ??? radians

High M_{T2}(ll) Events

All three high M_{T2}(ll) events are same flavor, with large MET values that point close to high p_T jets

Two of the events have dilepton system masses extremely close to our ZMass cut window

NB that the simulation predicts that our far M_{T2}(ll) tail will be populated by same flavor Z + X events – this story is corroborated by all three of the observed events

Careful investigation of objects in the events didn't yield any irregularities

MT2(ll) and Intrinsic BW widths

Next few slides taken from a talk by Ted Kolberg:

First, a toy model

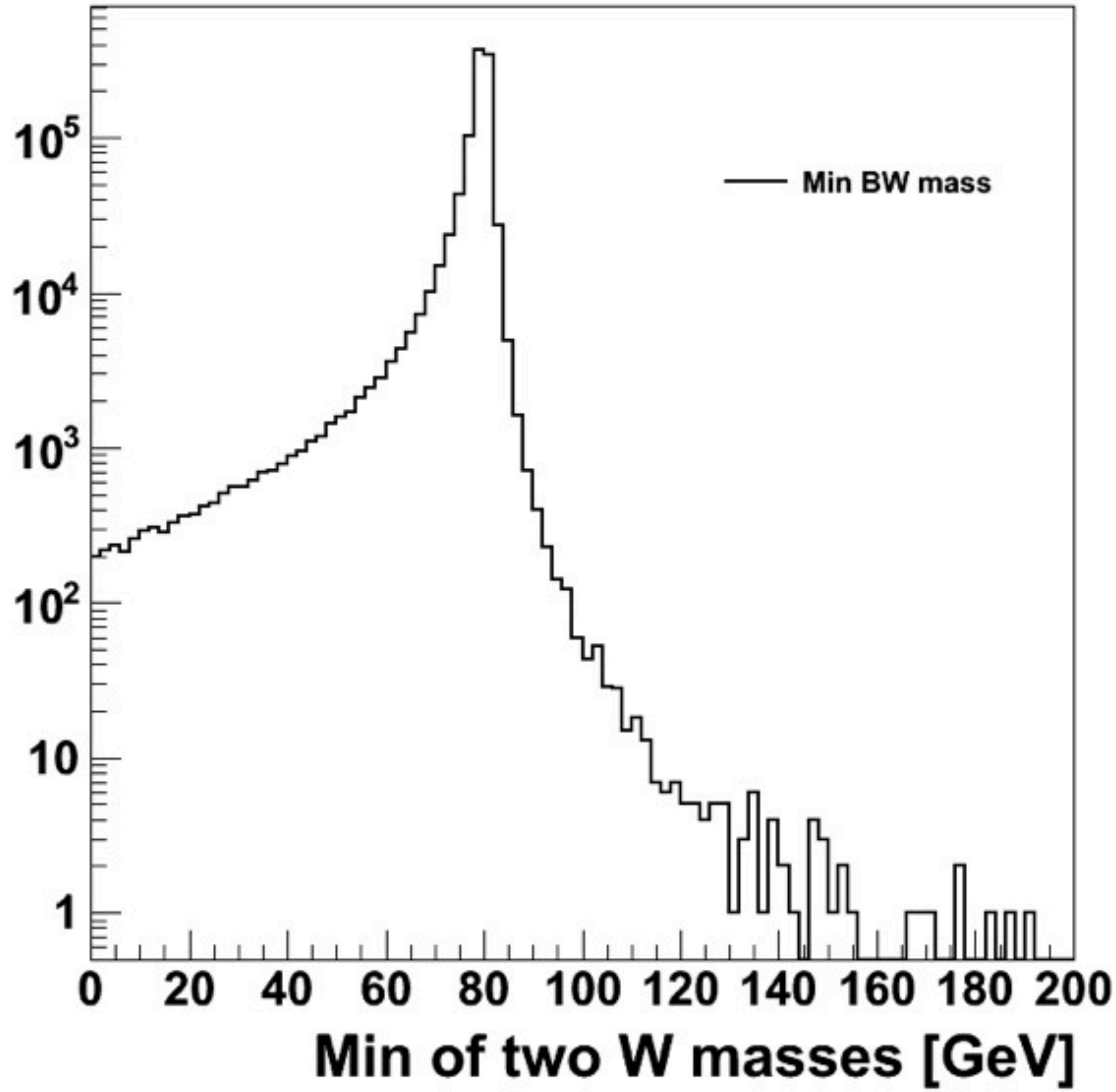
How sharp do we expect the MT2 shape to be, ignoring all detector effects?

The W width is not irrelevant. At > 2 GeV, we would not expect a sharp cutoff even with perfect event reconstruction.

Breit-Wigners only

To begin we simply generate two Ws and plot the minimum mass of the pair, in imitation of the minimization in the MT2 formula.

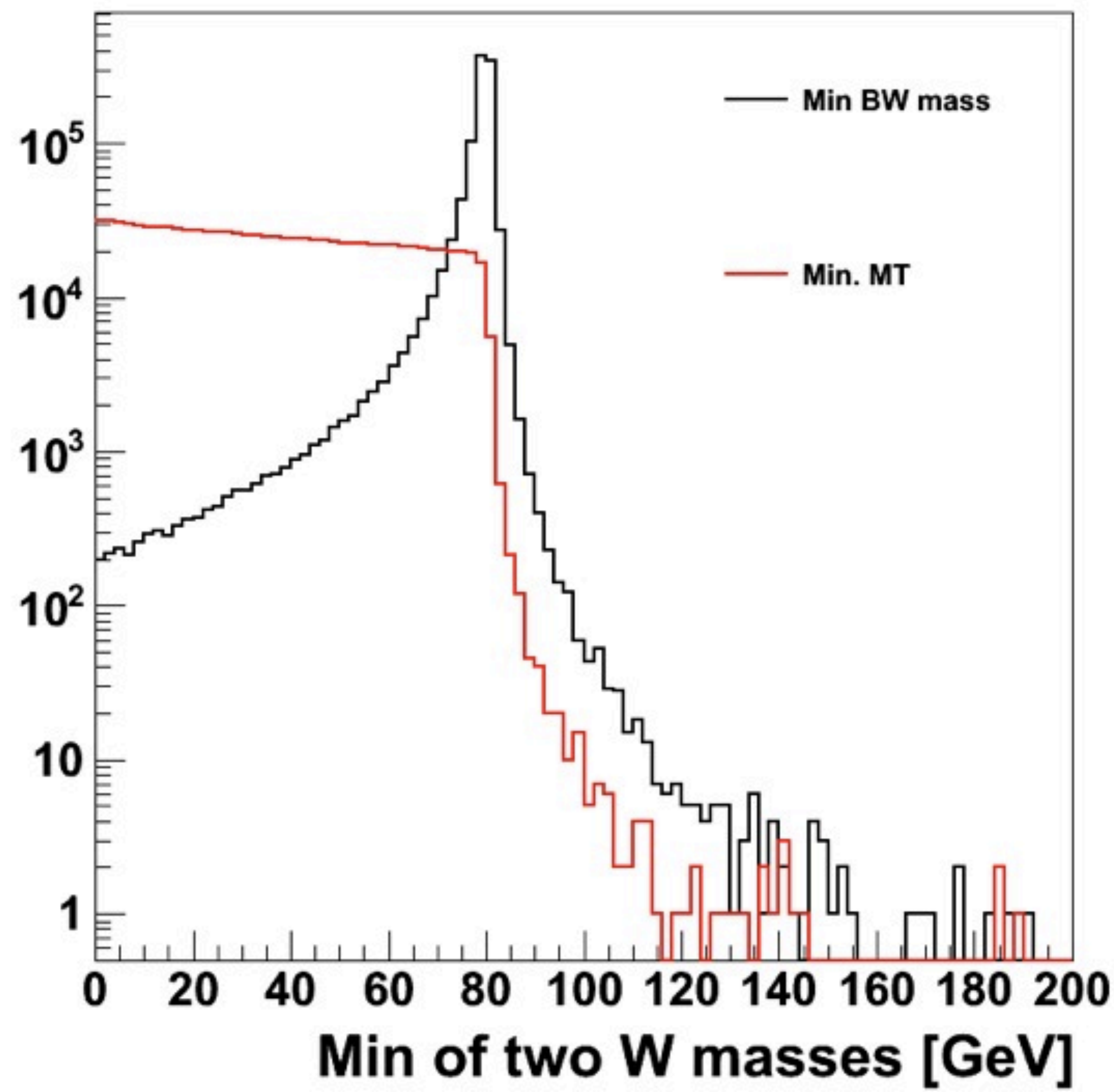
NB that even with perfect knowledge of the kinematics there is a significant tail to higher values due purely to the BW width!



Transverse mass

Next, look only at the transverse mass of the Ws (red). Again I plot the minimum of the pair.

Already the qualitative shape of the MT2 distribution starts to emerge. There are still a significant number of entries between 80 and 100, due entirely to the width of the W.

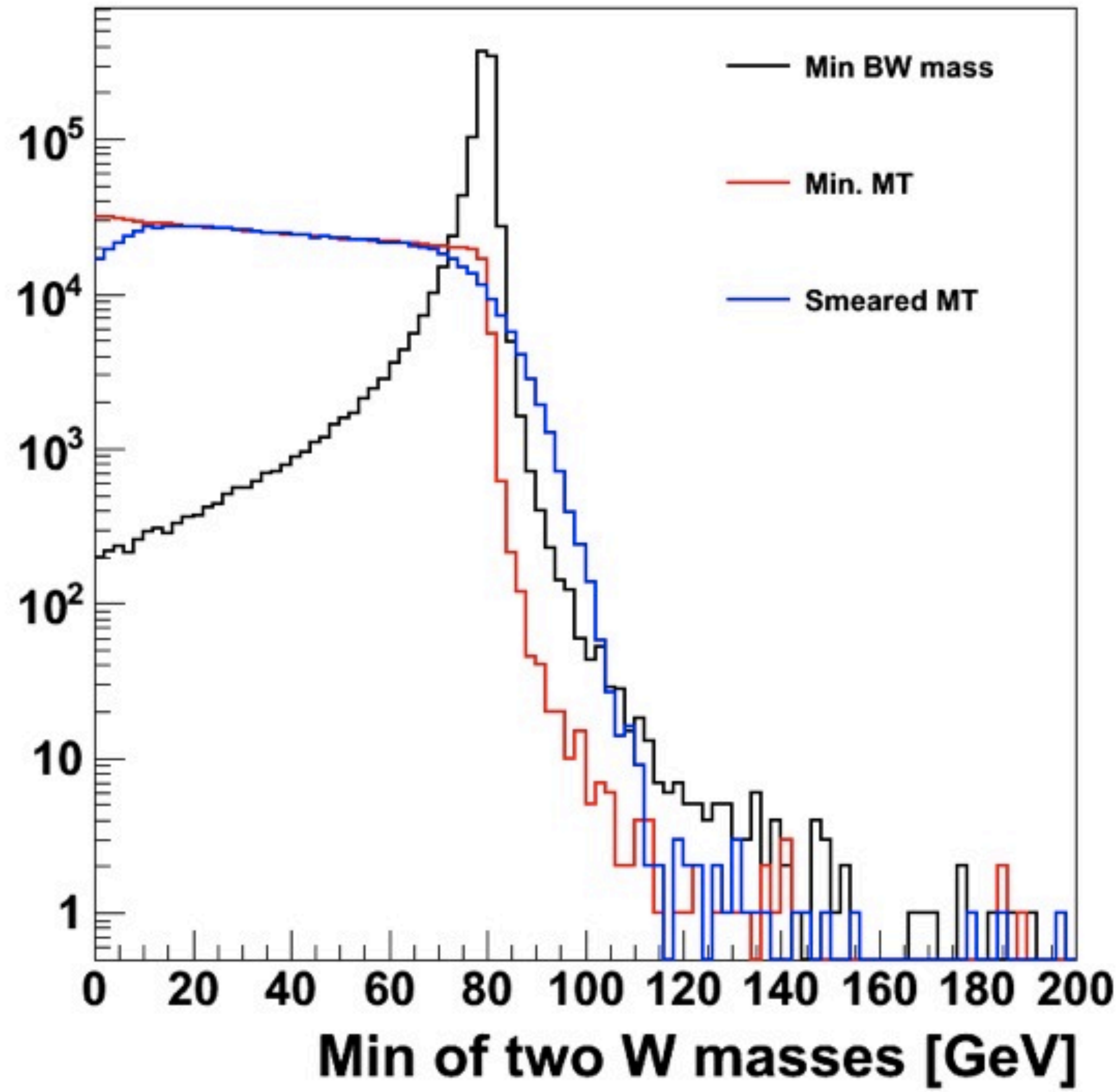


Smeared transverse mass

Next I smear the minimum MT plot by a resolution function (blue).

The MET resolution is about 18 GeV for events with the typical MET of a ttbar system. But, since the angle between MET and the leptons is basically random, we get an effective smearing of about 9 GeV.

The details of the shape are of course not exact, we have to account for the acceptance of our analysis cuts etc. But it suggest that the tails are not some mysterious manifestation of hard-to-model high MET events or something like that, but mostly the product of very simple physics properties of the system.



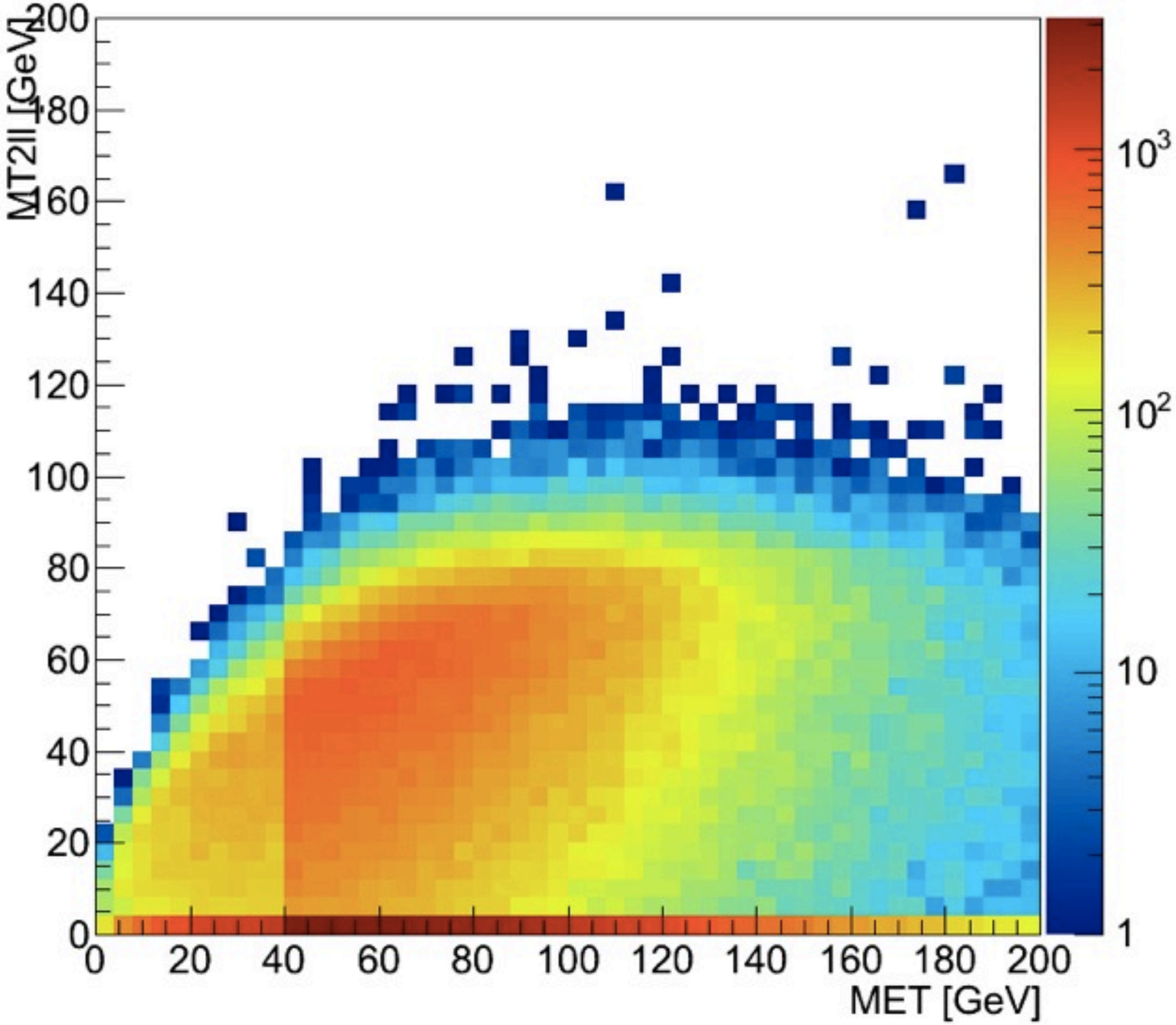
MET tails = MT2 tails?

We can further investigate if the MET tails are related to M_{T2} tails by looking at correlations between the two variables.

Our claim is that high values of M_{T2} (above M_W) are not very correlated with high values of MET. We can investigate this by looking at ttbar MC.

Granted, the simulation of MET tails due to detector effects is not perfect, but this should affect other backgrounds as well and can therefore be checked in data control regions.

MET vs MT2(ll)



Past M_W, higher values of MET are not really correlated with high values of M_{T2}. It could be true that there are classes of events, appearing only in data, where the two are related. But we have no indication of that from the Z control samples (see later in this talk).

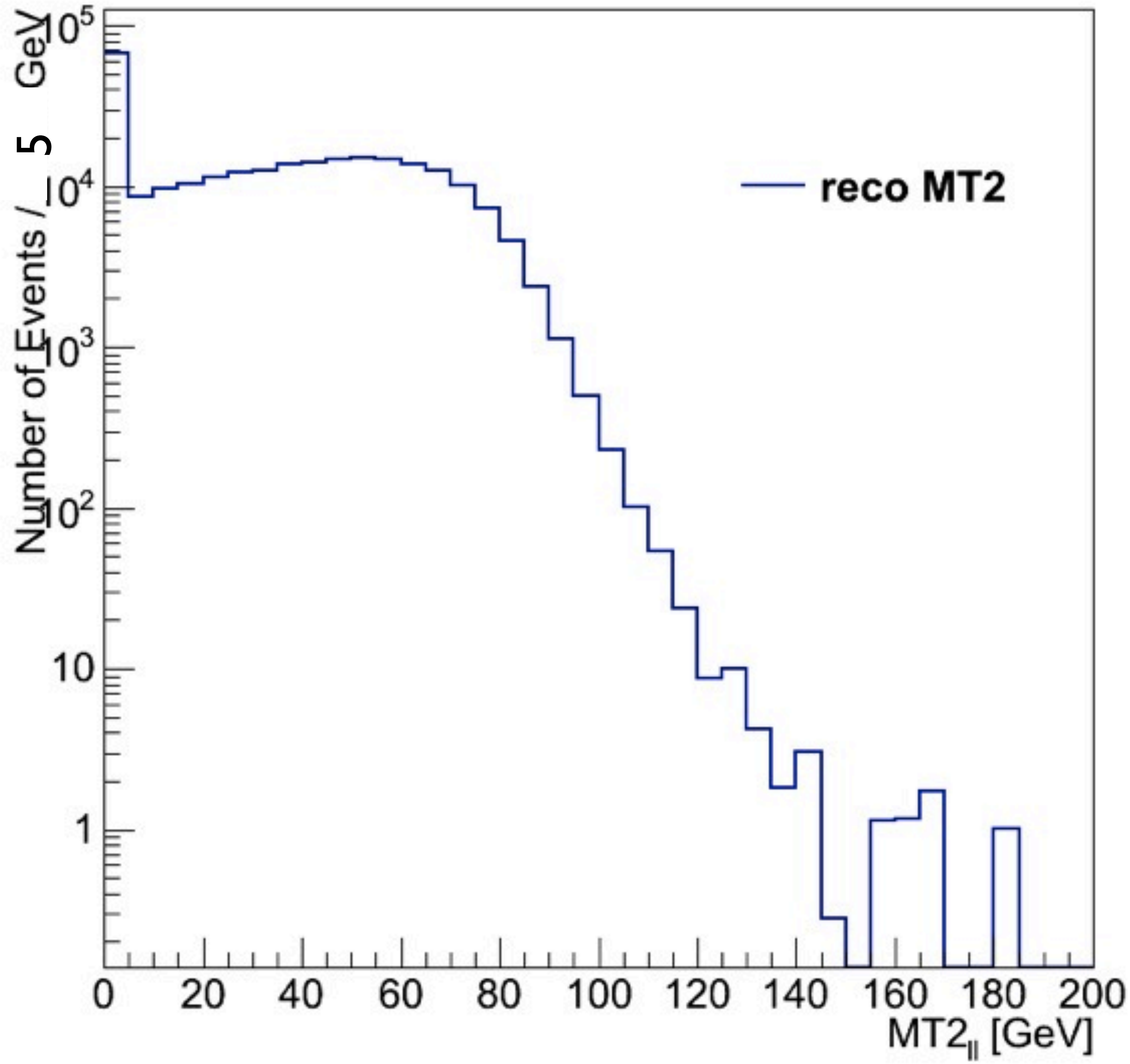
Understanding MT2 resolution

Still looking at the ttbar MC, we'll try to understand the following about the M_{T2} shape. What are the effects from...

- MET resolution, including acceptance issues (e.g. we miss a jet)?
- Taus, which mess up the lepton and MET measurements?
- Fake/mis-IDed leptons?

Reco MT2

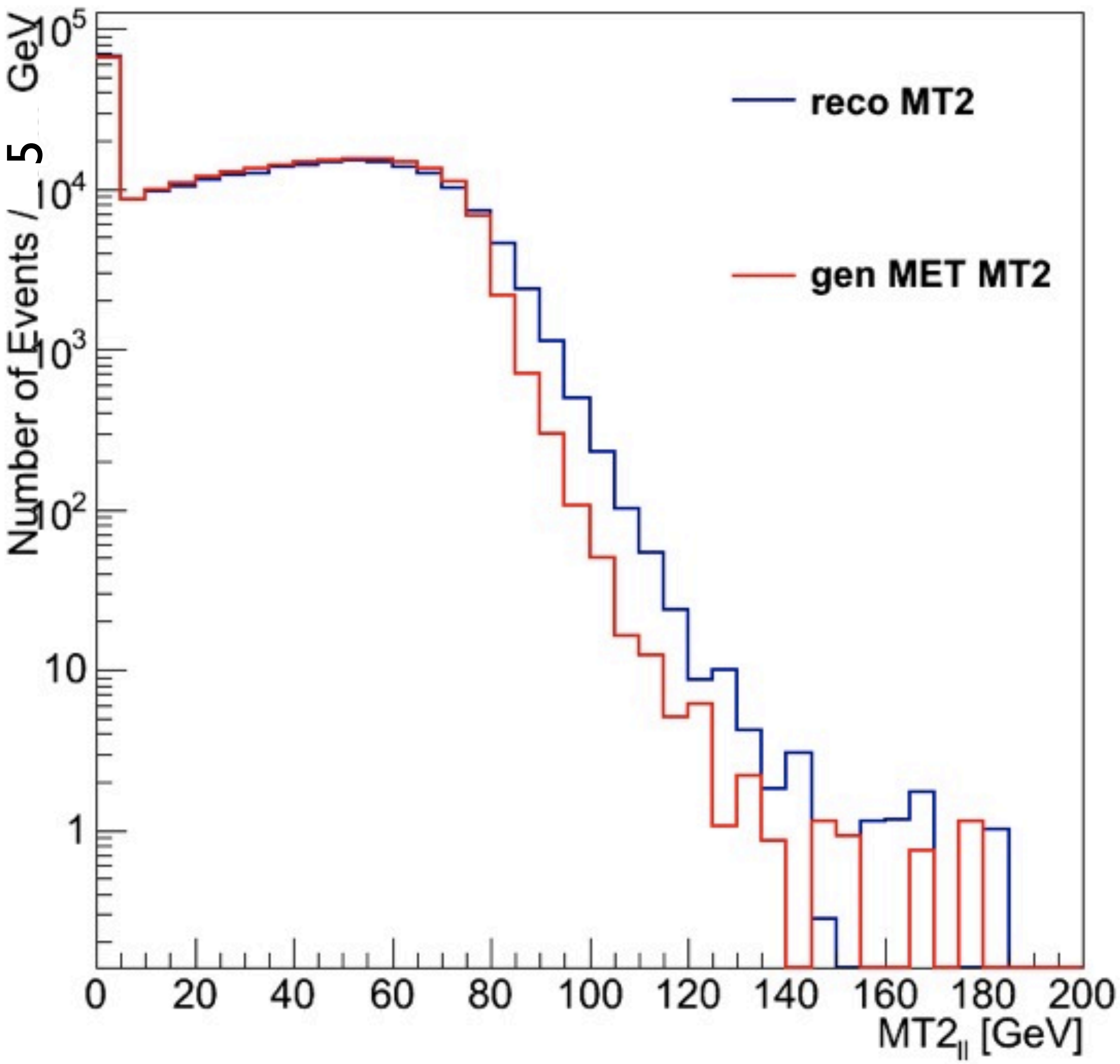
Start with raw M_{T2}, with its now familiar shape.



MT2 with GenMet

What happens if we replace reconstructed MET with GEN MET (perfect resolution/acceptance)?

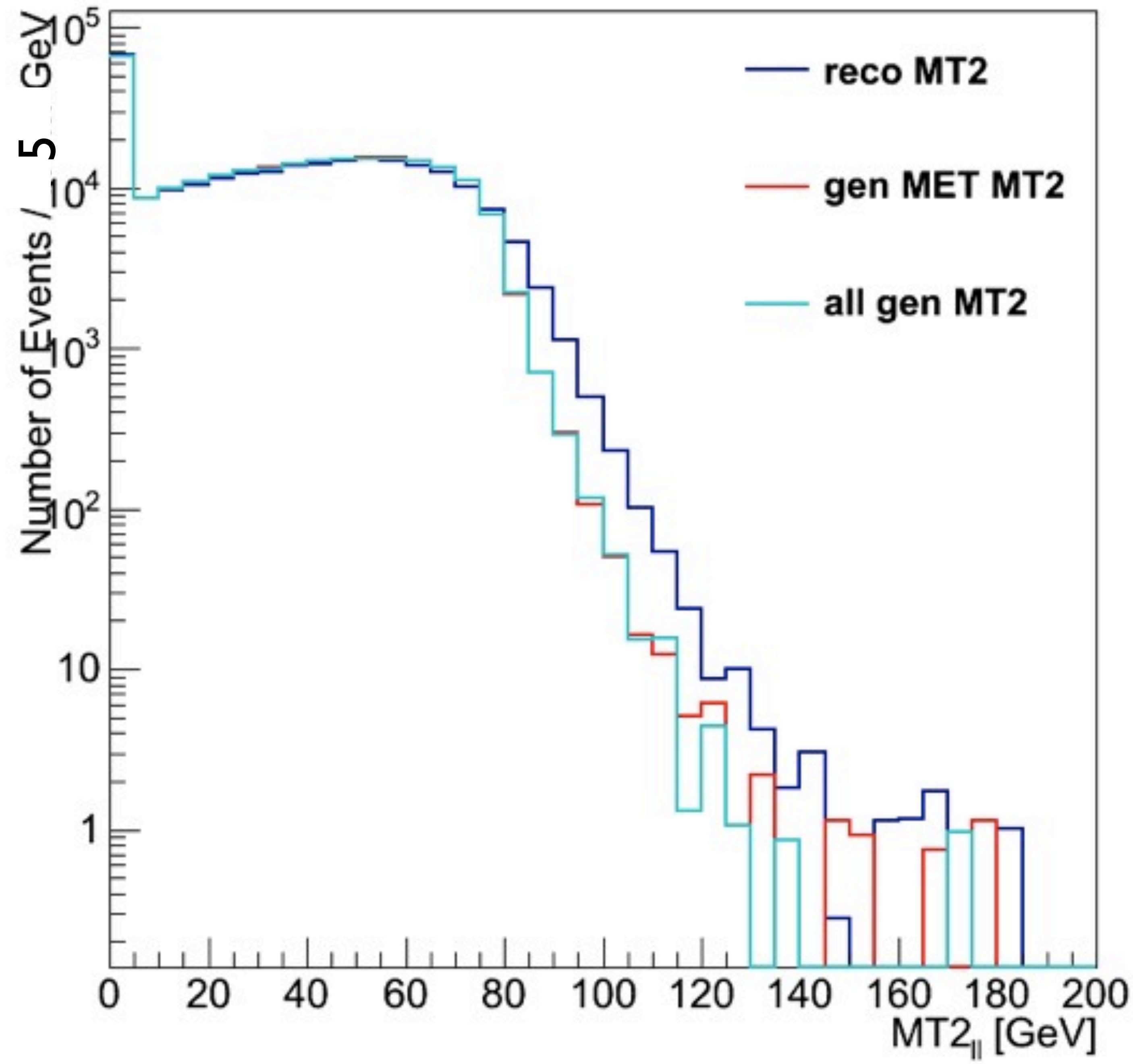
Basically, we have only the effect of the MET resolution smearing. Again, the tails are not because of badly measured MET values.



Wednesday, January 22, 14

GEN leptons + MET

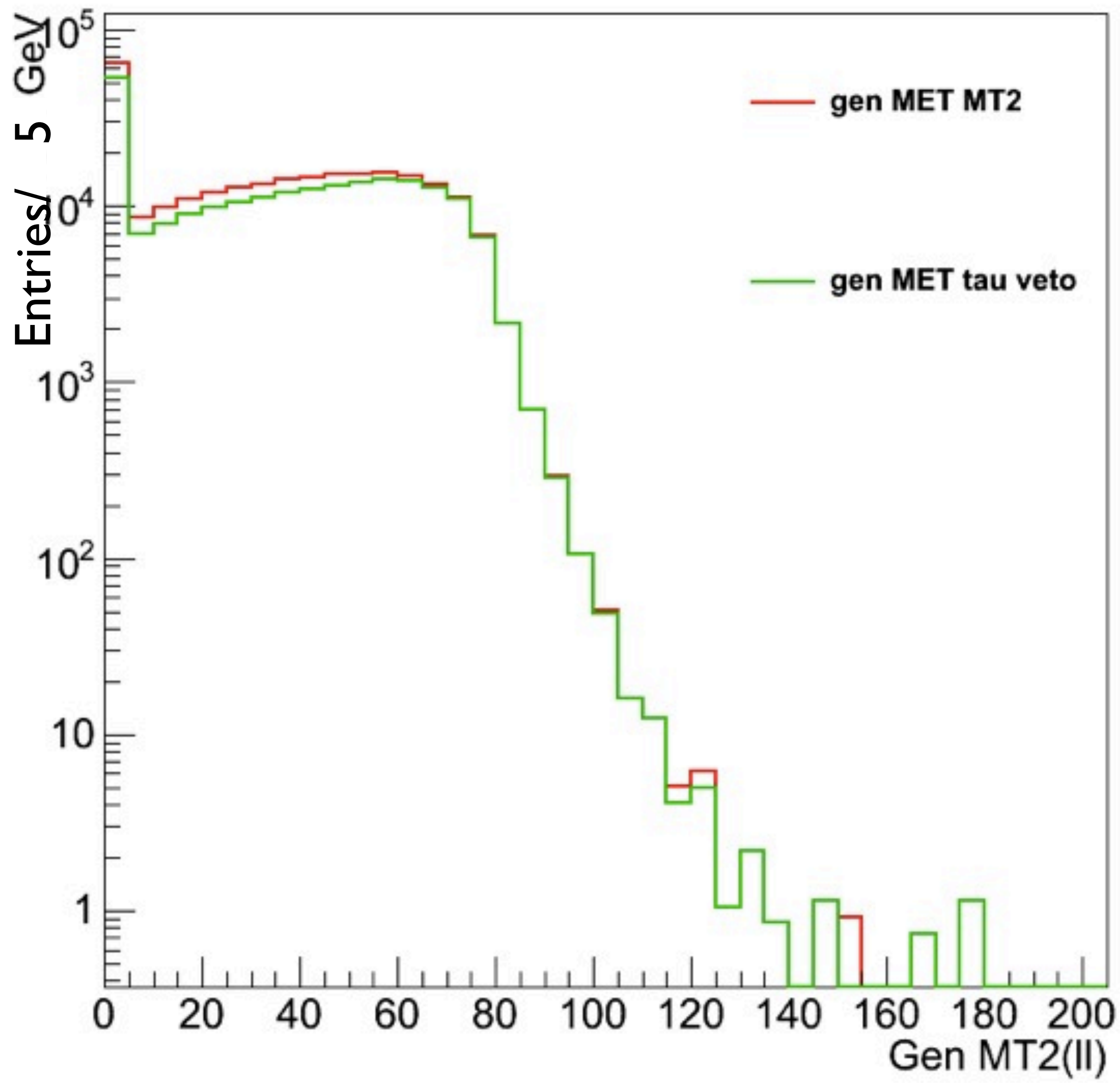
Using GEN leptons and GEN MET, we don't see a significant difference. (We already knew that the leptons were well measured relative to the MET.)



Excluding taus

What if we exclude taus at GEN level?

Taus are not in the tails.



The story so far

Before we look into the control regions in data, note that:

- Tails of $M_{T2}(ll)$ > MW are expected qualitatively even for a perfect detector.
- The tails are do not seem to be driven by MET mismeasurement, though the effect of finite resolution is apparent.
- The tails exist even for well measured and correctly IDed leptons (e.g. τ decays do not end up in the tails).

Now let's see what we can check using the data in control regions.

DeltaPhi(MET, Dileptons)

When a hypothetical neutrino is close [far] in a phi sense to a given lepton it's paired with, the 1-cos(phi) factor yields a small [large] MT2 value for that pairing

The effect this physics has on the MT2(ll) variable can be somewhat demonstrated by considering the opening angle between the MET vector and the four vector sum of the two leptons (i.e. the Z boson vector in DY events)

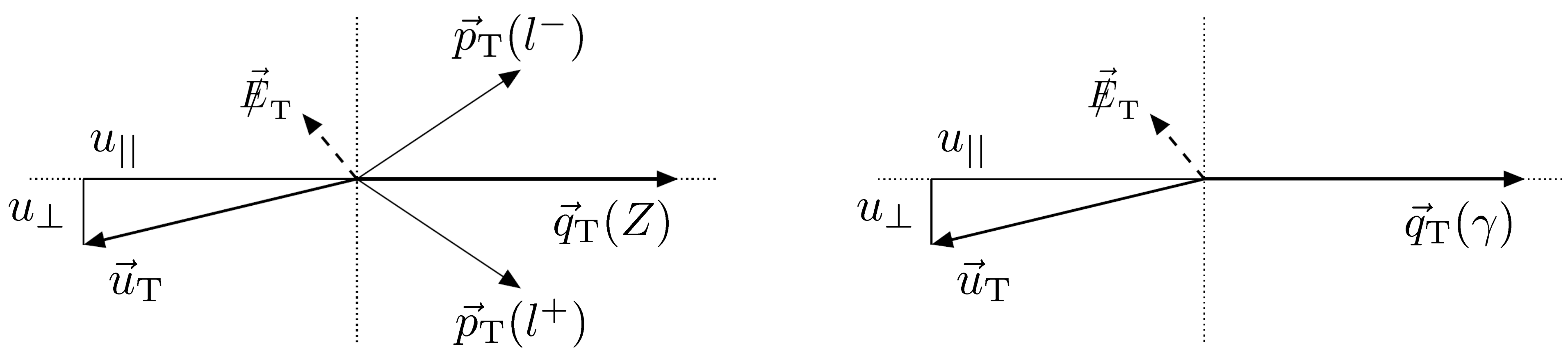


Figure 6: Illustration of $Z \to \ell^+\ell^-$ (left) and photon (right) event kinematics in the transverse plane. The $\vec{u}_T$ denotes the vectorial sum of all particles reconstructed in the event except for the two leptons from the Z decay (left) or the photon (right).

MET resolution in Z events

Excellent energy resolution on leptons means MET magnitude/direction are driven primarily by hadronic recoil energy resolution

Primary LO topology for Z + Jet events is single jet recoiling against the Z boson

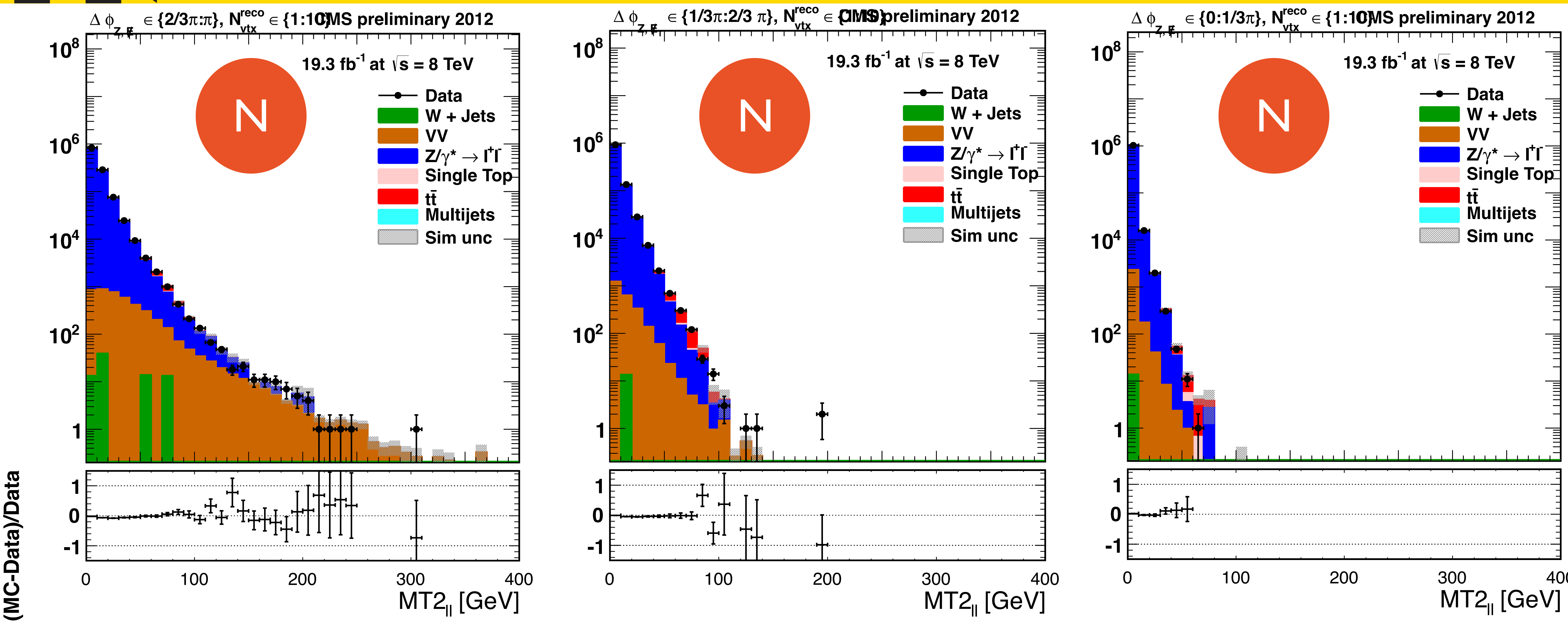
– MET will tend to be (anti-)parallel to the Z when the jet is over-measured (under-measured)

– leptons tend to be “loosely” parallel with Z direction

– higher Z pT leads to the two leptons having smaller intra-lepton opening angle

–> MET thus tends to be parallel or anti-parallel with the leptons, which when splitting the MET into hypothetical neutrinos has corresponding effects on MT2(ll)

MT2(ll) in ZMass, nVtx 1:10

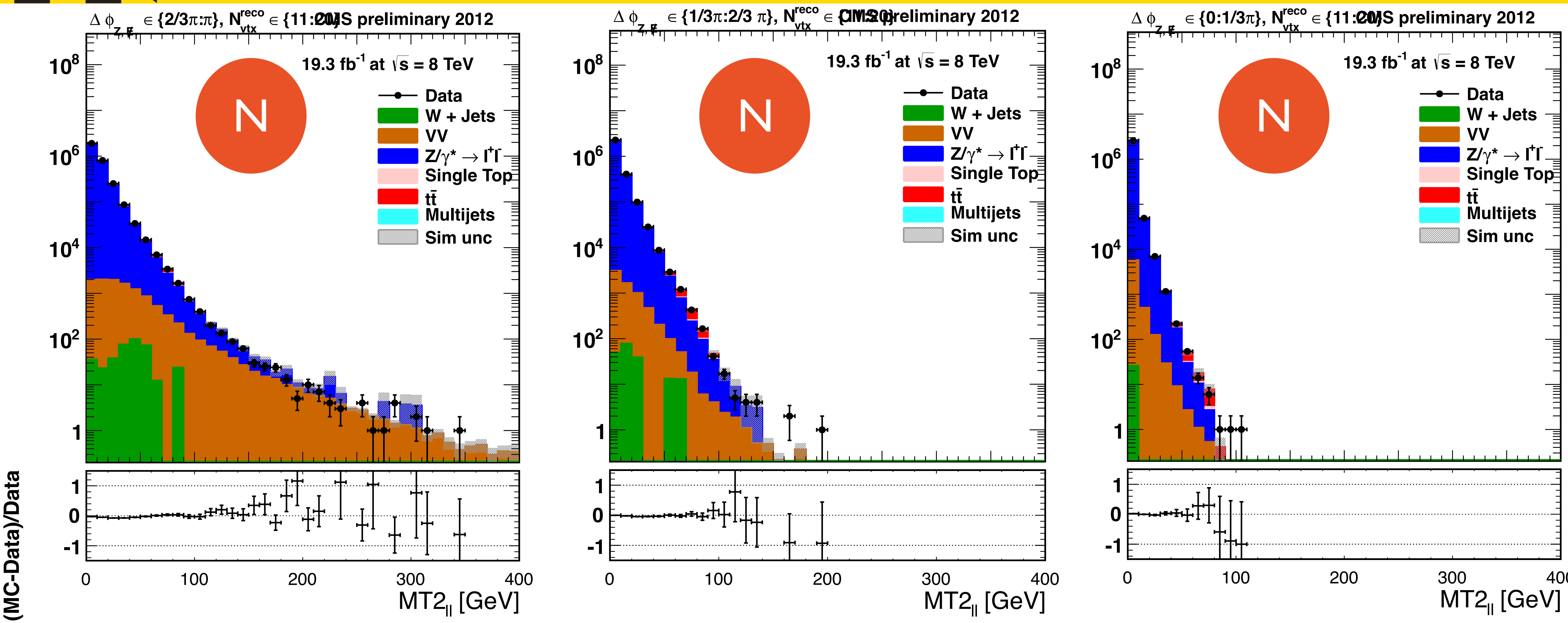


DPhi > 2/3 Pi   1/3 Pi < DPhi < 2/3 Pi   DPhi < 1/3 Pi

This + next 2 slides old version of nTuples

(see next slides for different nVtx conditions)

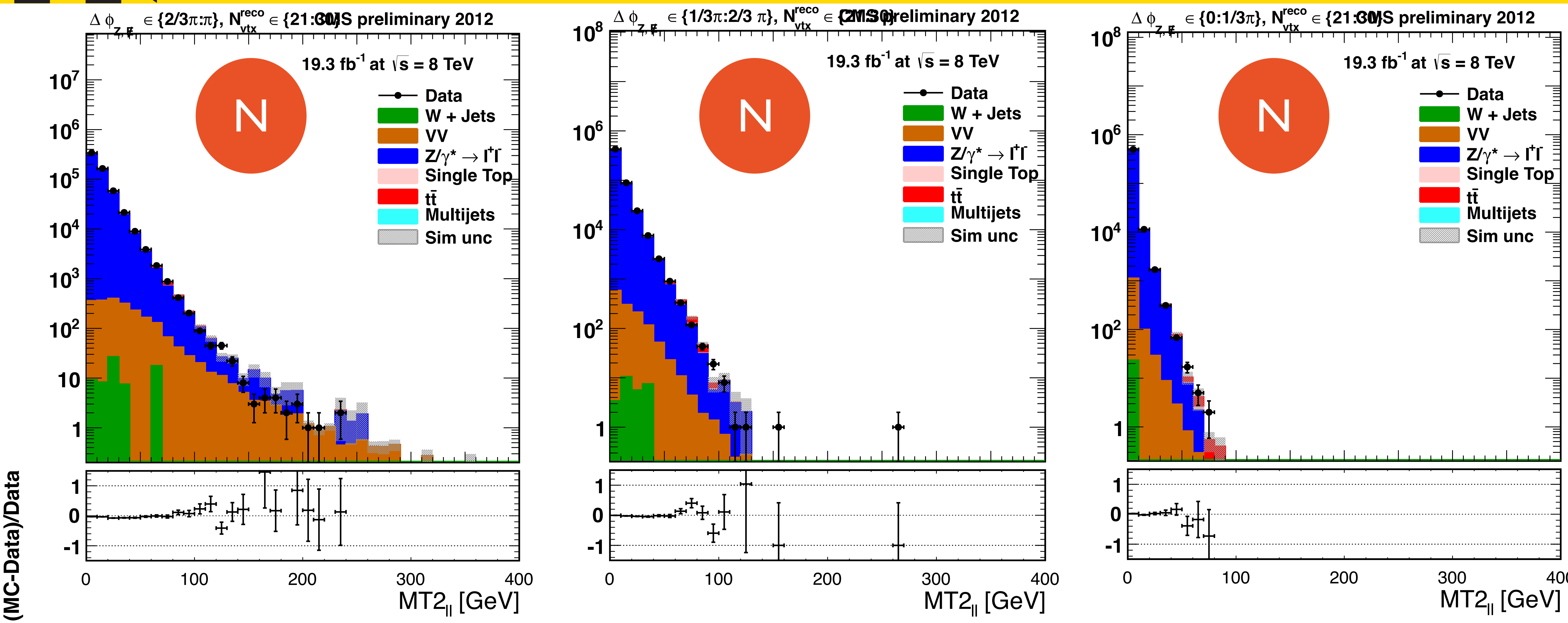
MT2(ll) in ZMass, nVtx 11:20



DPhi > 2/3 Pi   1/3 Pi < DPhi < 2/3 Pi   DPhi < 1/3 Pi

additional PU smears tail out a little, but opening angle for (MET, "Z") is *much* more important

MT2(ll) in ZMass, nVtx 21:30

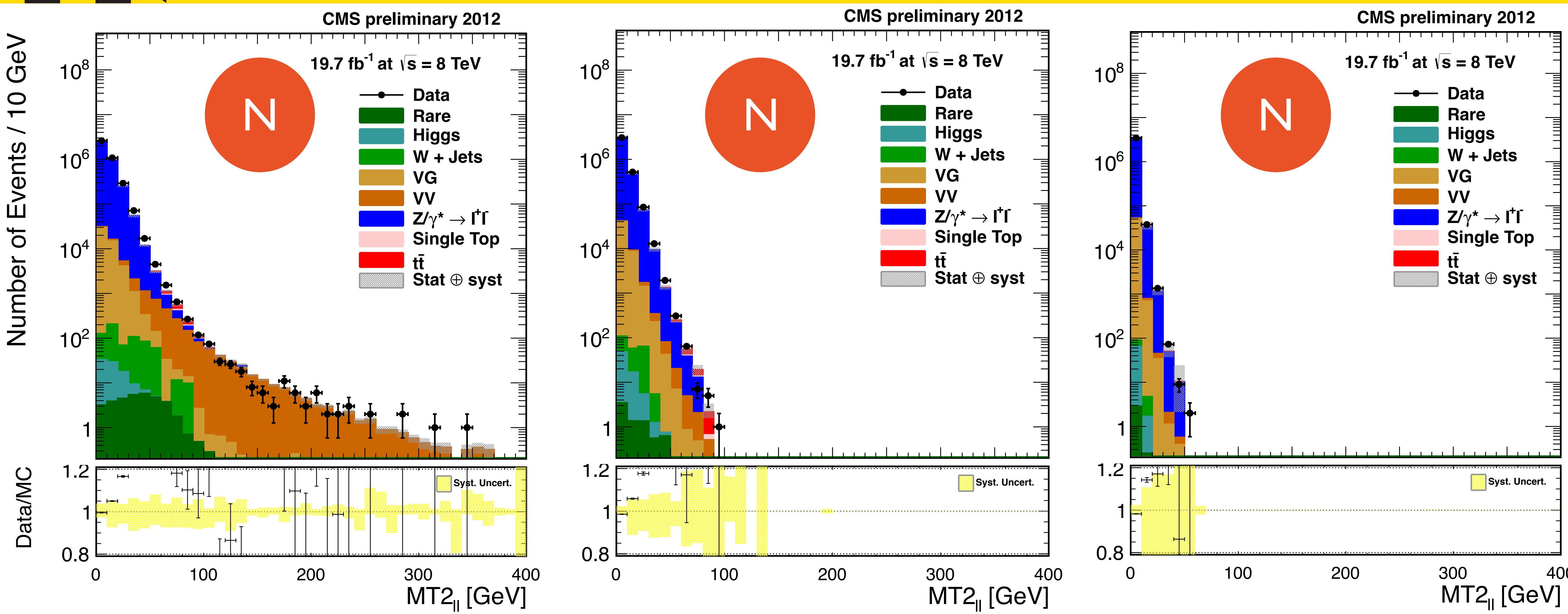


DPhi > 2/3 Pi 1/3 Pi < DPhi < 2/3 Pi DPhi < 1/3 Pi

I think stats run out slightly here

What about the effect of additional jets?

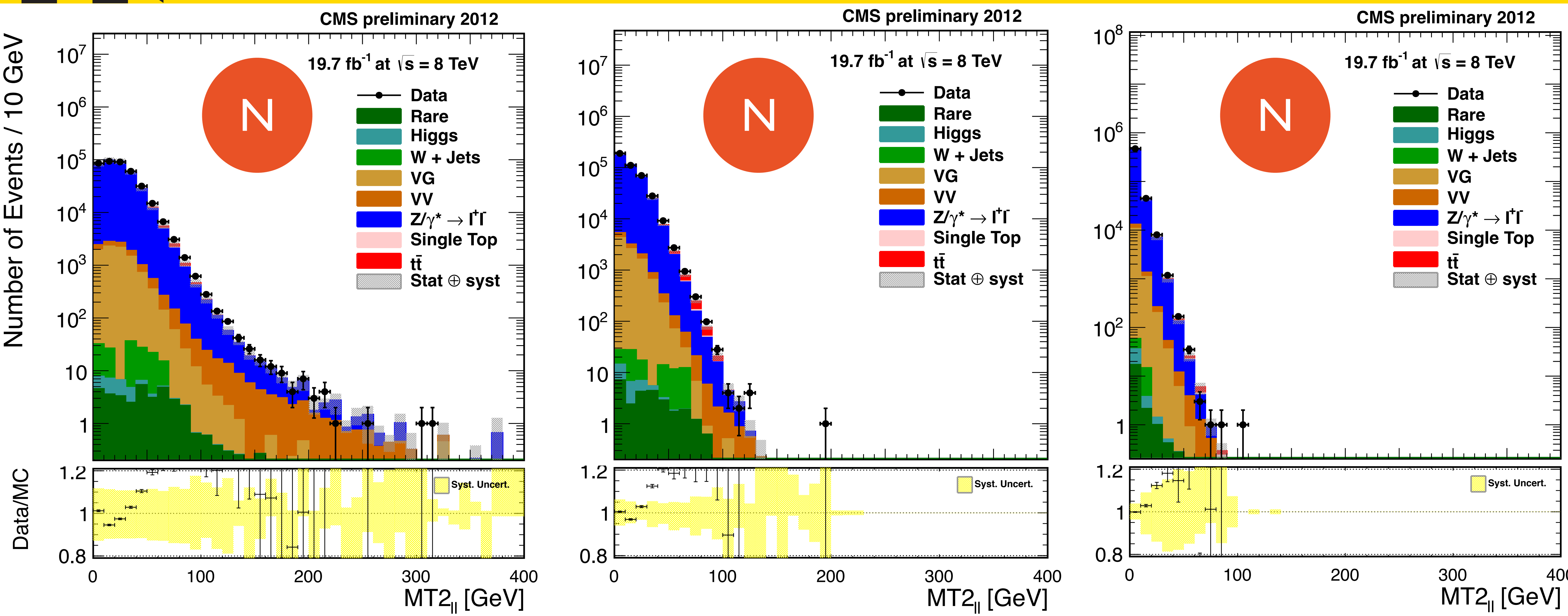
MT2(ll) in ZMass, nJets 0



DPhi > 2/3 Pi   1/3 Pi < DPhi < 2/3 Pi   DPhi < 1/3 Pi

If we end up using a 0 jets region as a control sample (we're not right now, nor for 1 jets) relative Data/MC agreement could prove an issue

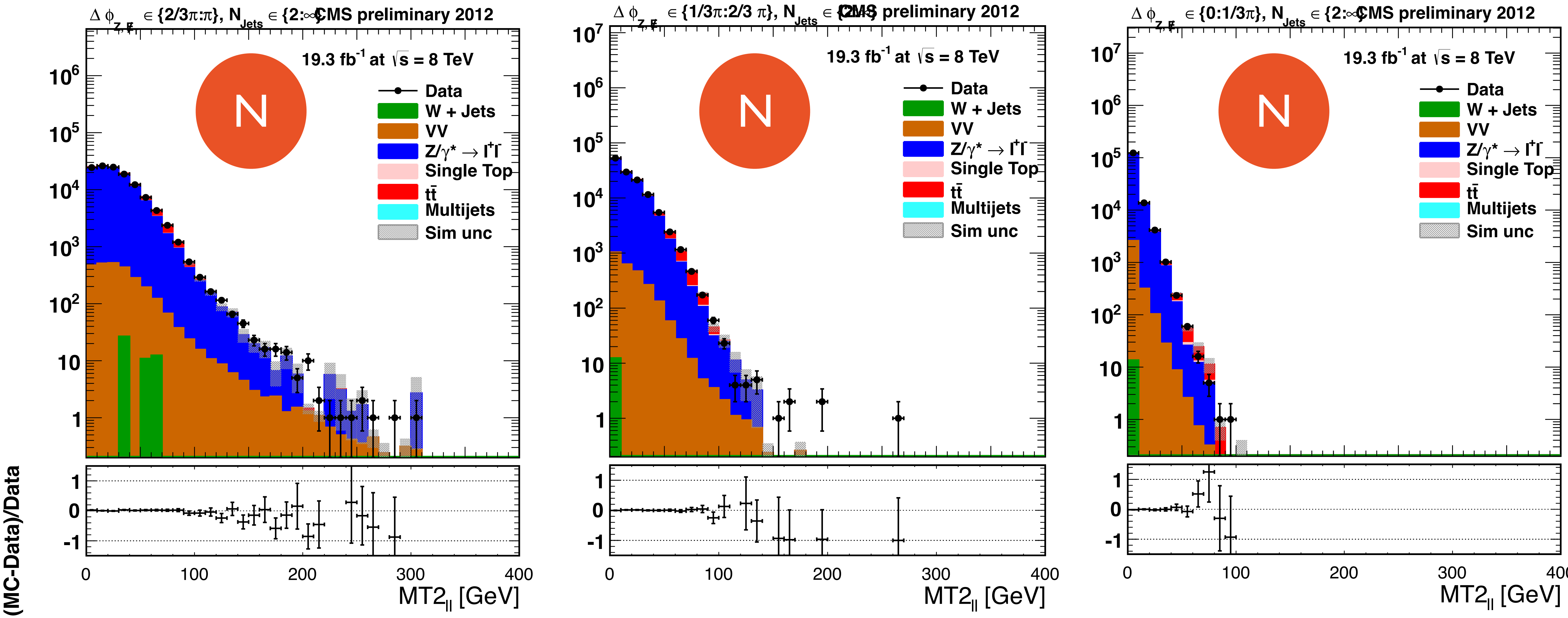
MT2(ll) in ZMass, nJets 1



DPhi > 2/3 Pi   1/3 Pi < DPhi < 2/3 Pi   DPhi < 1/3 Pi

Same story as N_{Vtx}, although the statistical composition of events is correlated with N_{Jets} (e.g. VV events)

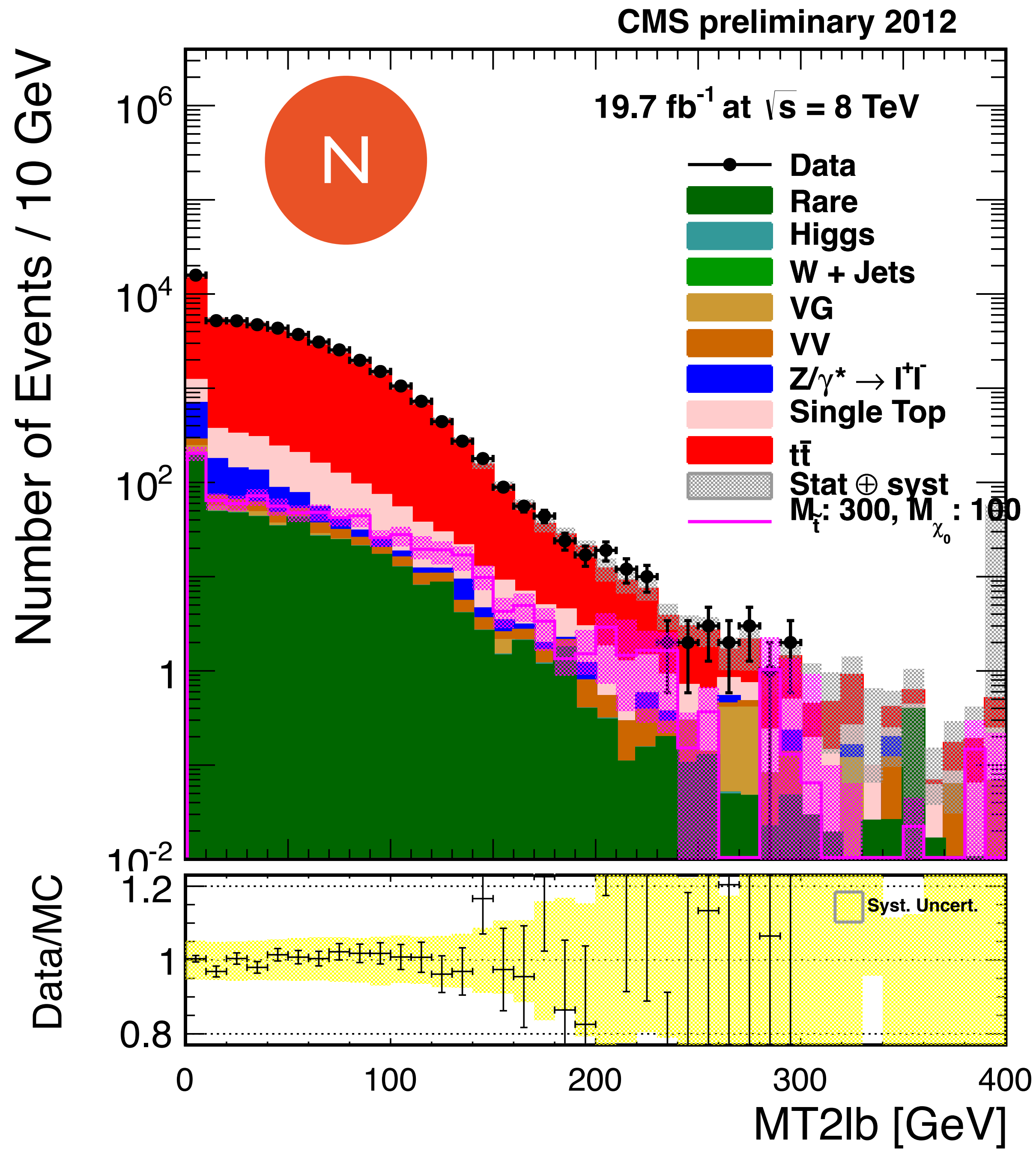
MT2(ll) in ZMass, nJets 2:Inf



DPhi > 2/3 Pi   1/3 Pi < DPhi < 2/3 Pi   DPhi < 1/3 Pi

Old version of nTuples!!

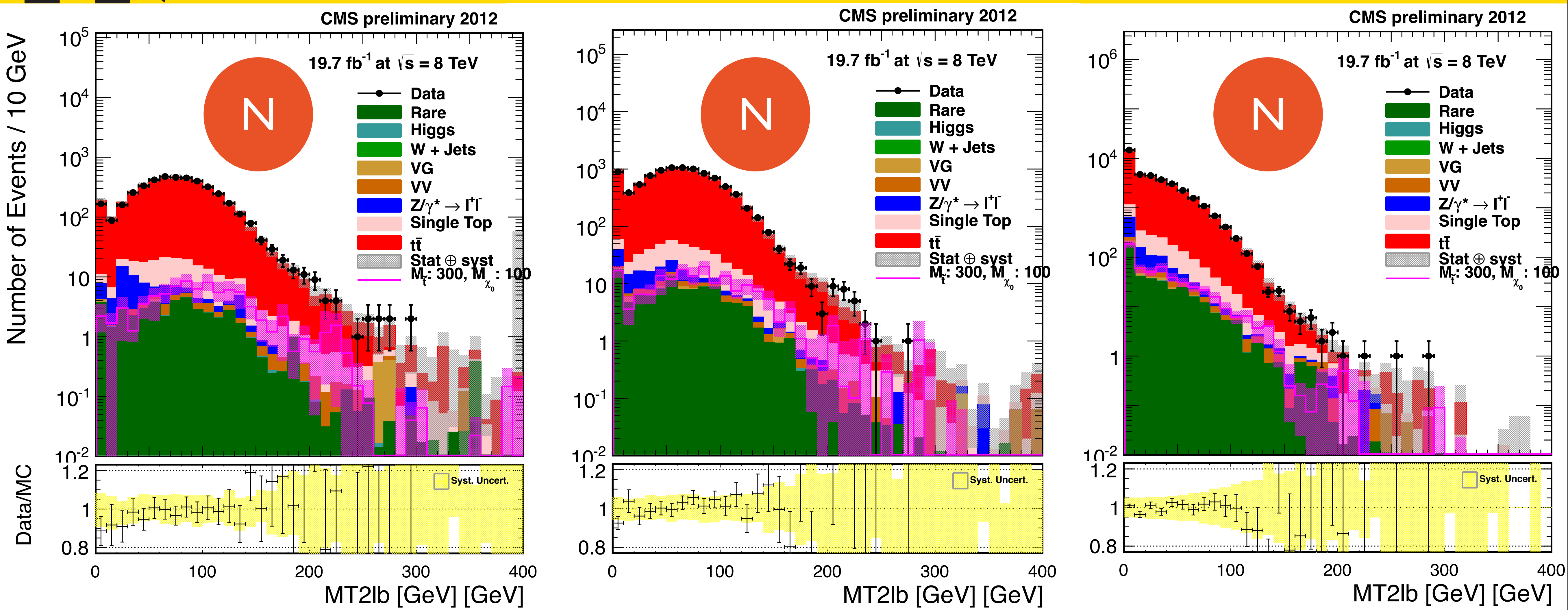
MT2(lb)(lb)



Addition of B-jets to the leptons should yield kinematic edge around the top quark mass (173 GeV)

(relatively) Poor resolution on B-jets significantly hurts this, however

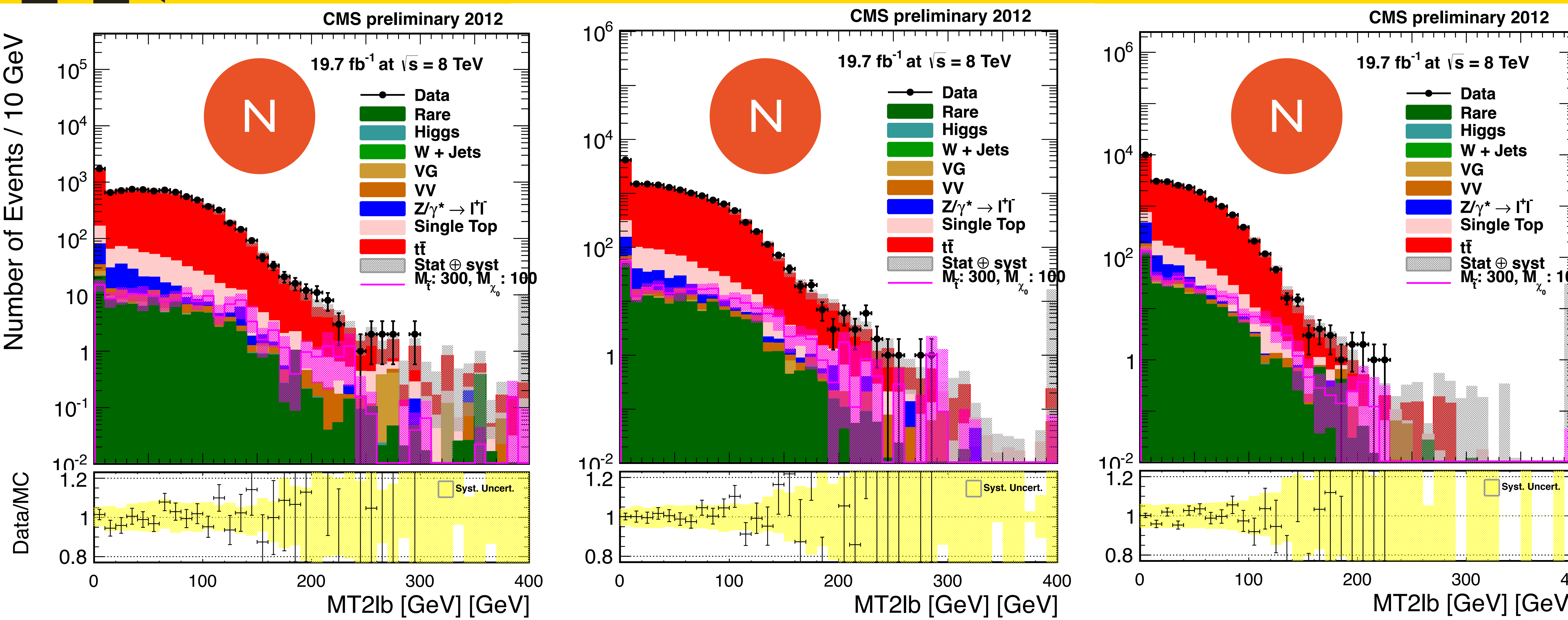
M_{T2}(lb)(lb) geom. dependence



DPhi < 1/3 Pi   1/3 Pi < DPhi < 2/3 Pi   DPhi > 2/3 Pi

M_{T2}(lb)(lb) still depends upon angular configuration of visible objects, however (DPhi between BLep objects)

M_{T2}(lb)(lb) geom. dependence



DPhi < 1/3 Pi   1/3 Pi < DPhi < 2/3 Pi   DPhi > 2/3 Pi

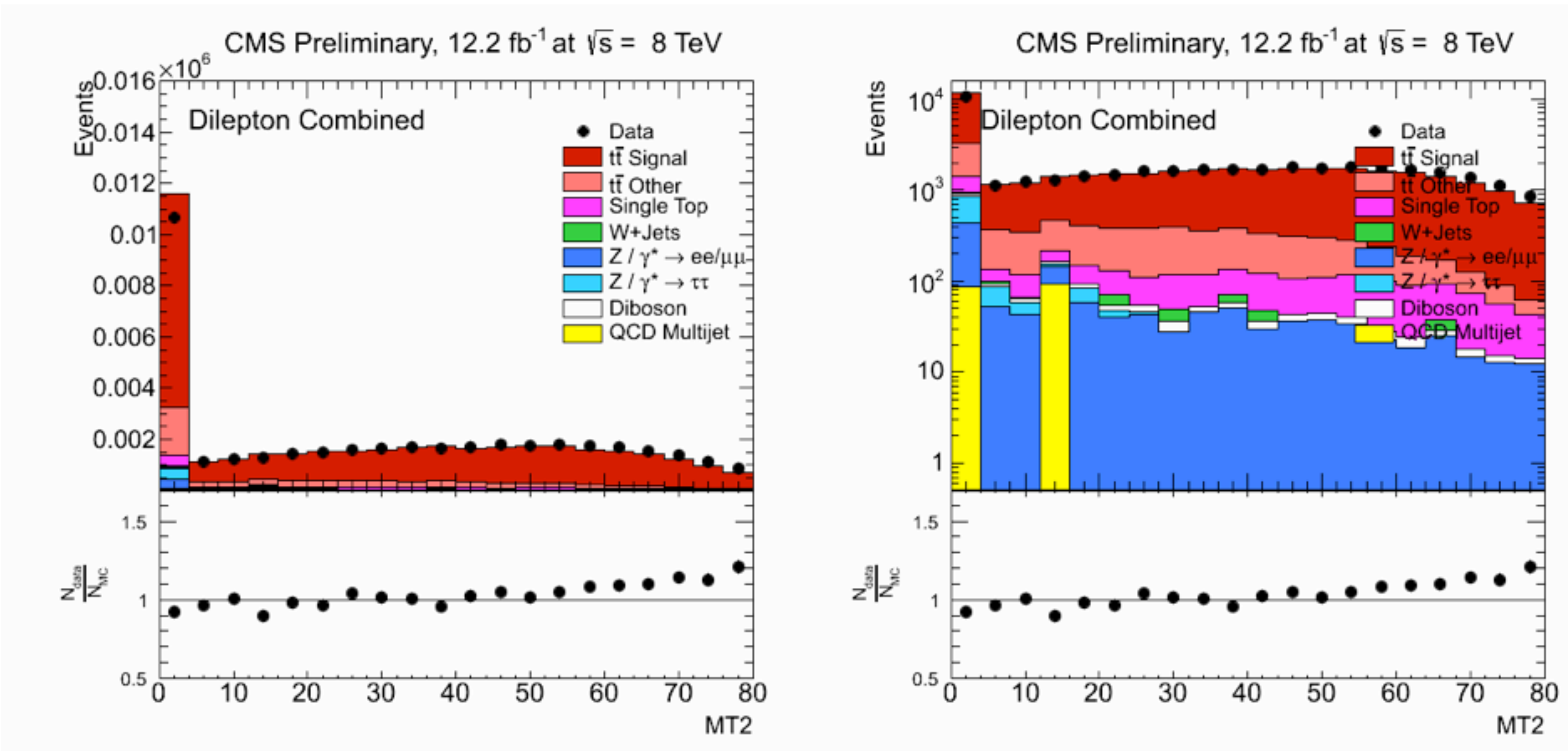
M_{T2}(lb)(lb) still depends upon angular configuration of visible objects, however (DPhi between selected jets)

TTBar Generator Motivation

Following slides are again, from a talk by Ted Kolberg

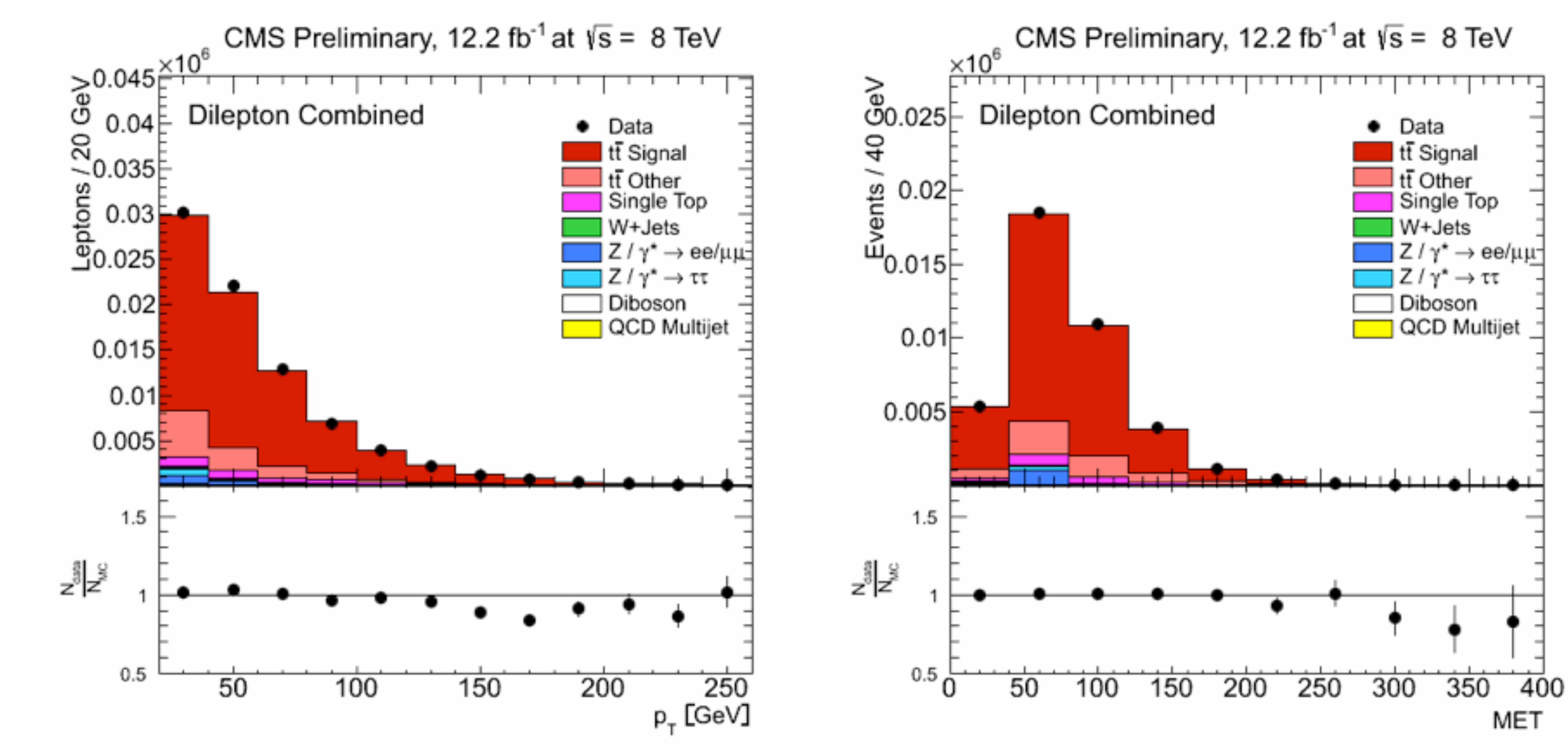
Investigation of issues with M_{T2}

In Madgraph top samples, there is a noticeable trend of increasing M_{T2} excess at high values in the M_{T2} control region (M_{T2} > 80 blinded in data). Causes a big systematic for the cut'n'count on M_{T2}:



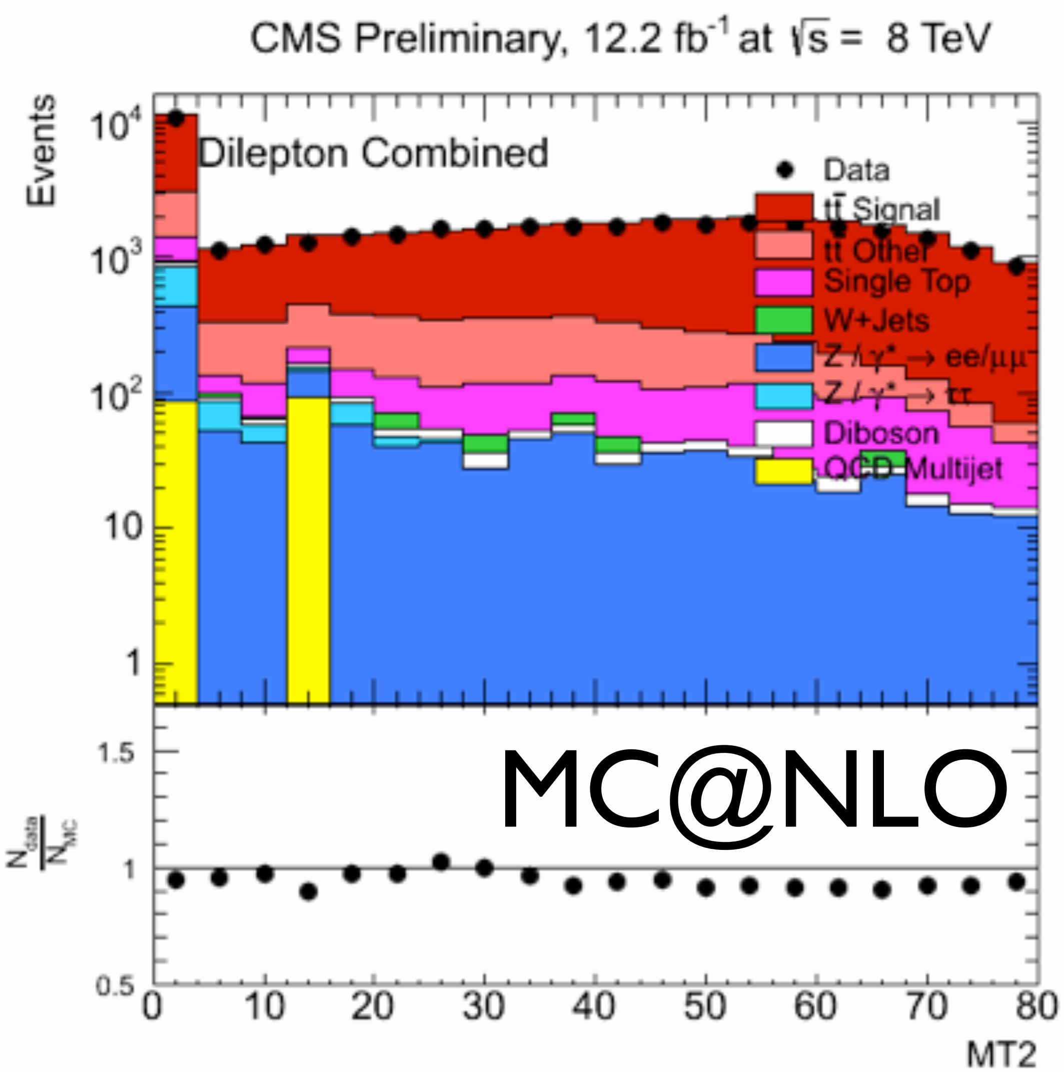
M_{T2} in Madgraph

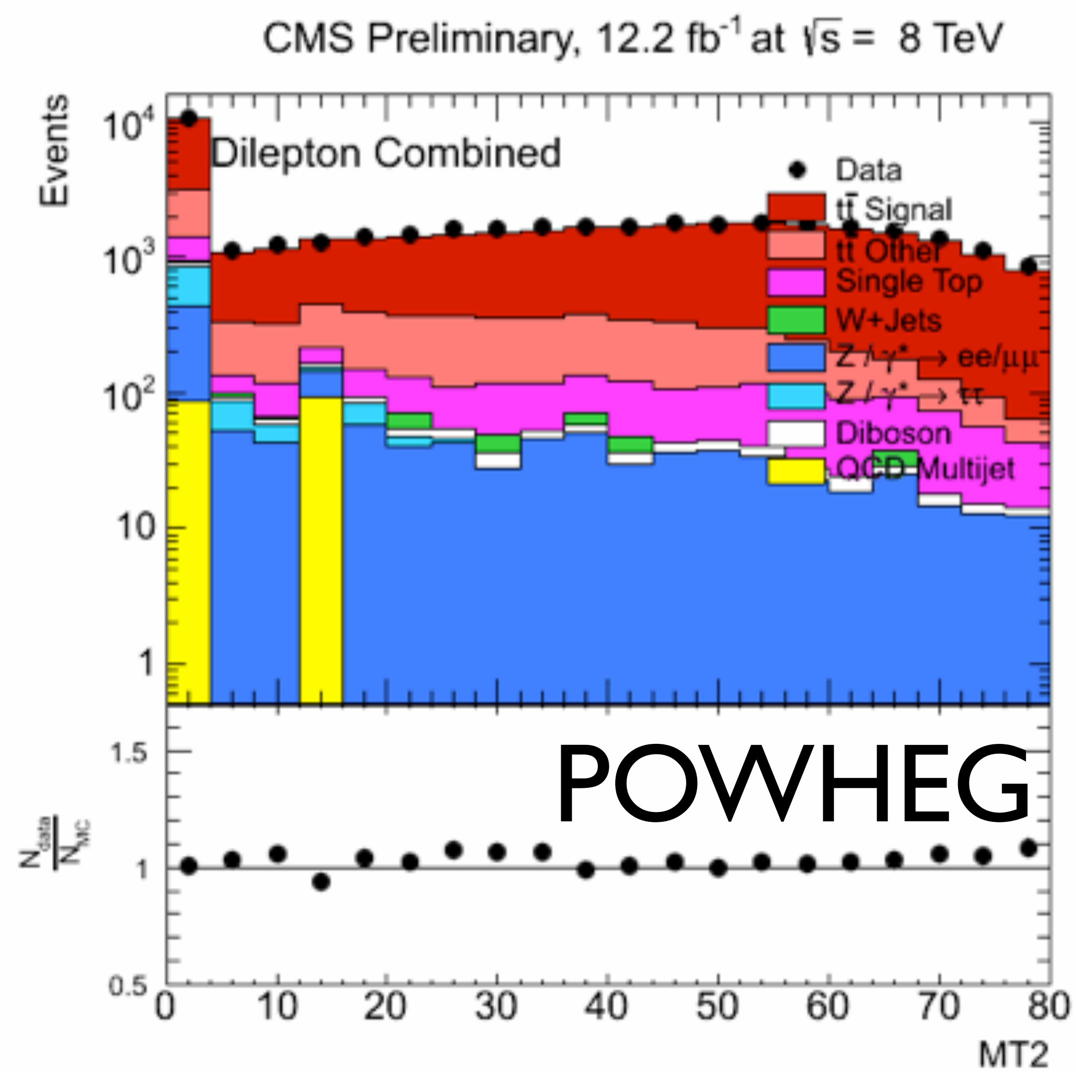
Inputs are lepton transverse momenta and MET. Agreement seems reasonable.



M_{T2} POWHEG/MC@NLO

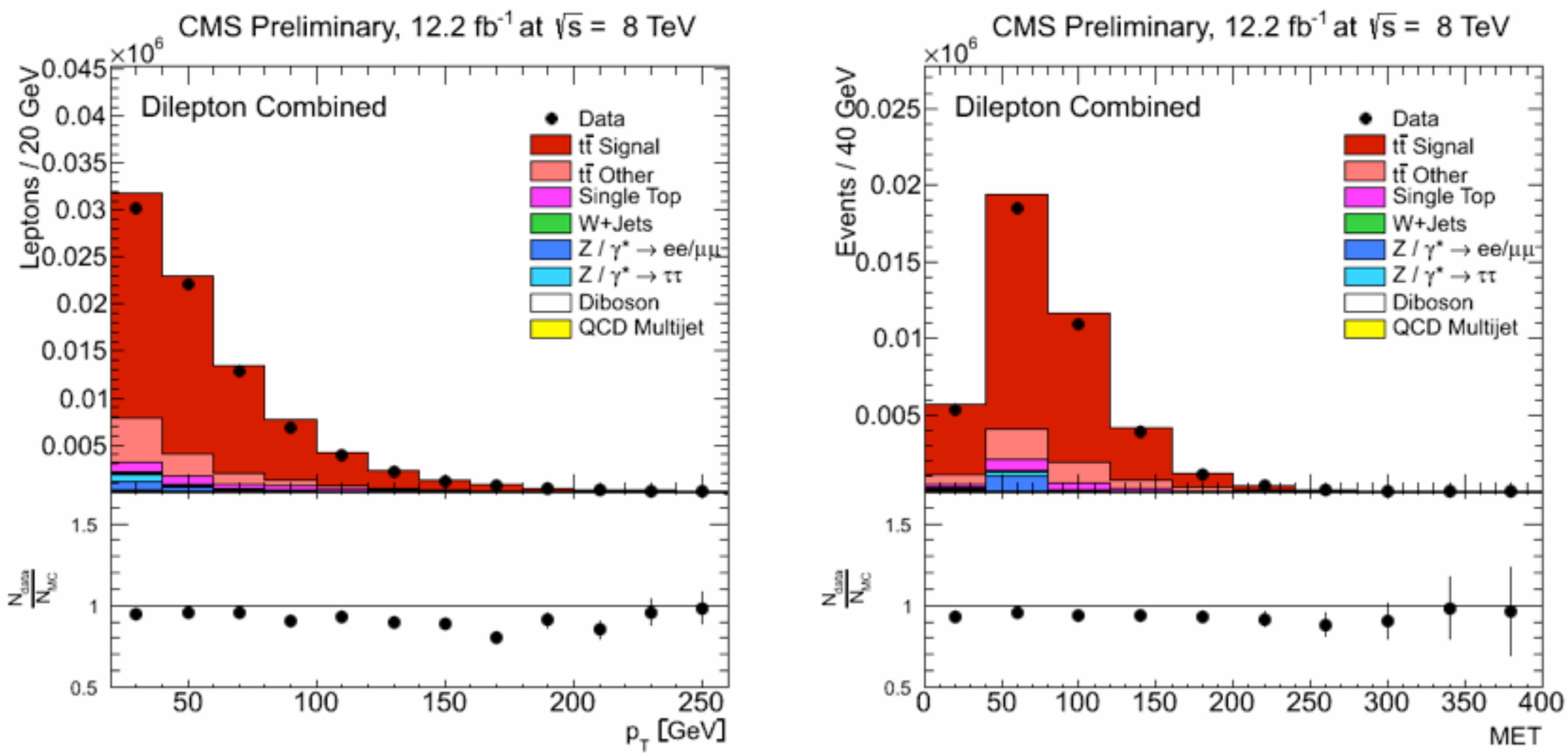
We observe much better (flat ratio data/MC) agreement in M_{T2} shape in control region using MC@NLO / POWHEG:





Inputs (MC@NLO)

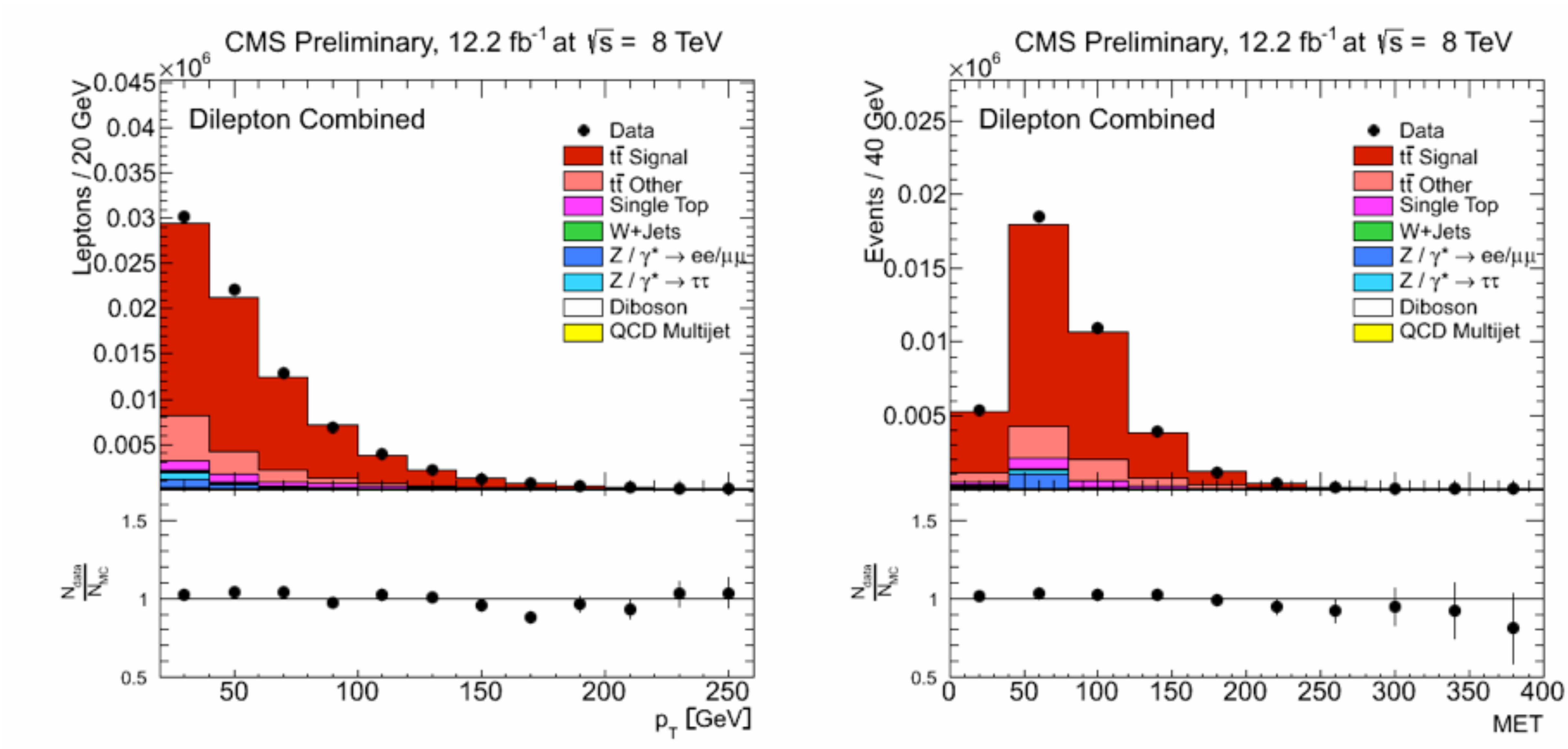
Lepton pT / MET in MC@NLO. Level of agreement similar to MadGraph.



Inputs (POWHEG)

Lepton pT / MET in POWHEG. Level of agreement is similar to MadGraph.

I conclude that modeling of the lepton pT and MET distributions is not responsible for systematic difference in M_{T2}.



Generator differences

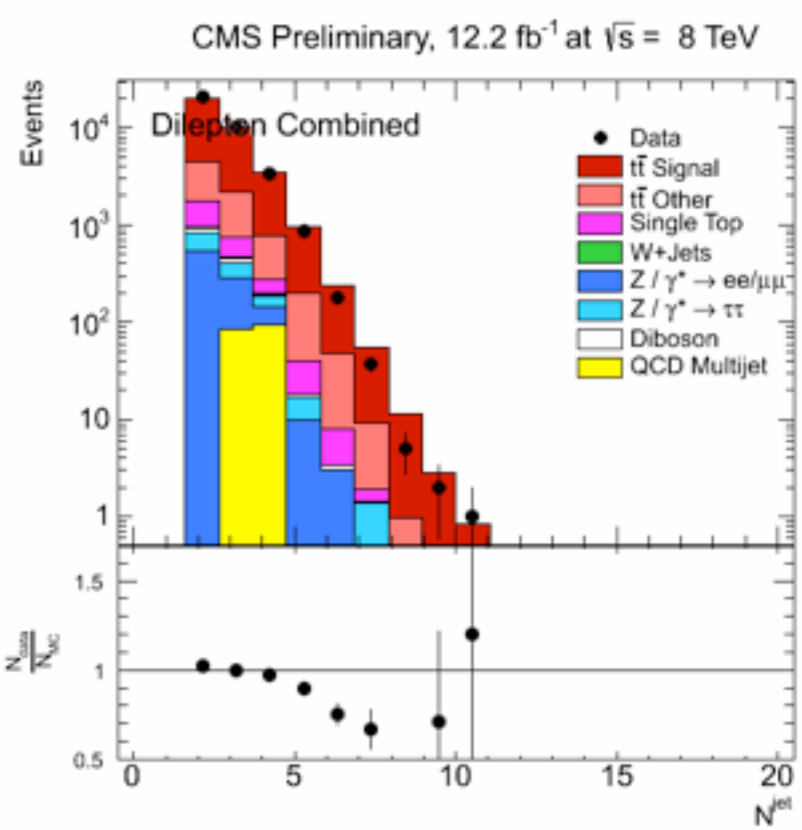
MadGraph does LO (+ showering).

MC@NLO/POWHEG do NLO.

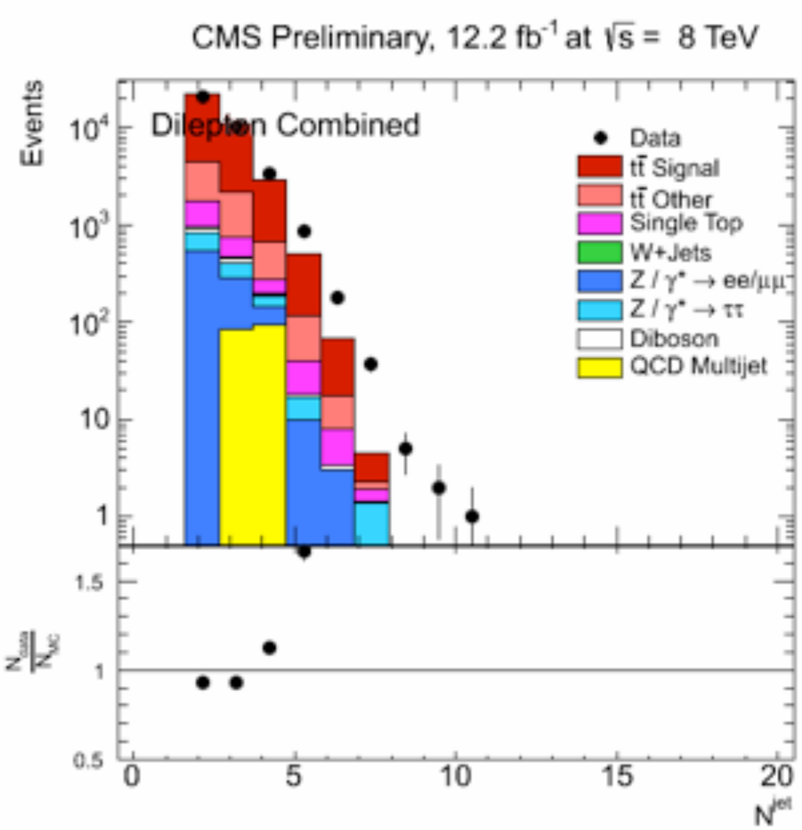
Since additional jets can affect kinematics of the events, we could see differences in additional jet modeling as responsible for the difference.

In fact MadGraph and POWHEG do about equally well on this and MC@NLO messes it up completely. So the difference in MT2 modeling is not likely due to this effect.

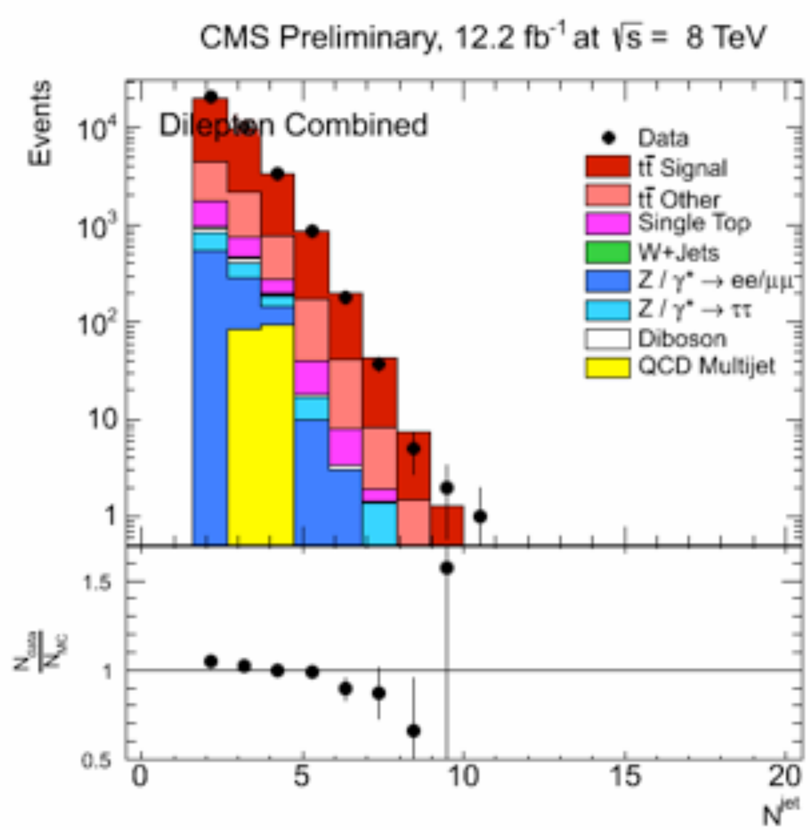
MadGraph



MC@NLO



POWHEG



Generator differences (cont.)

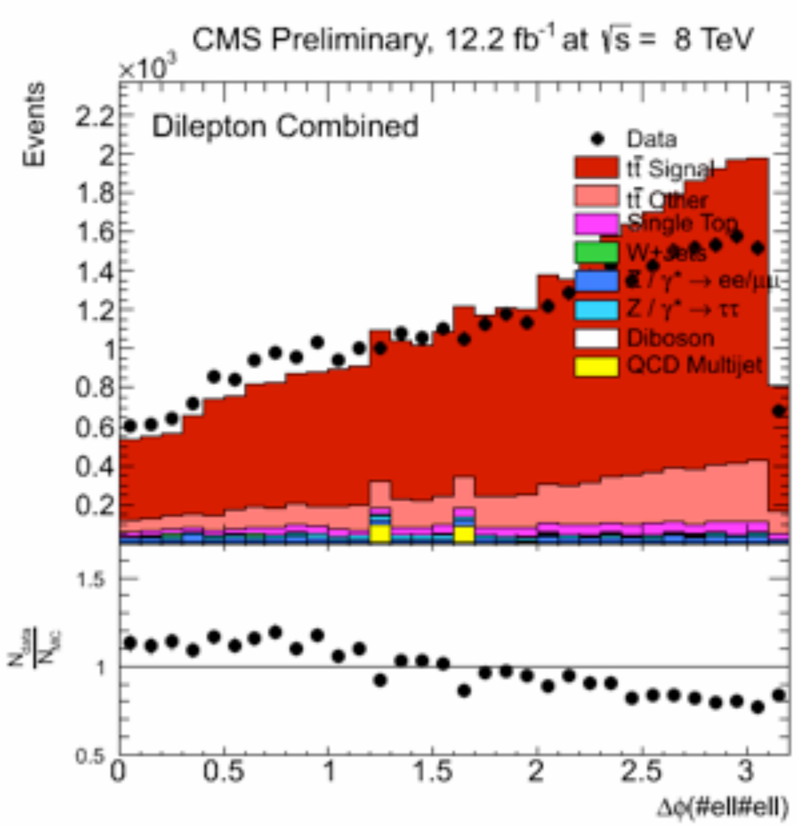
MadGraph does not account for spin correlations in the top pair decay by default.

MC@NLO/POWHEG do account for spin correlations.

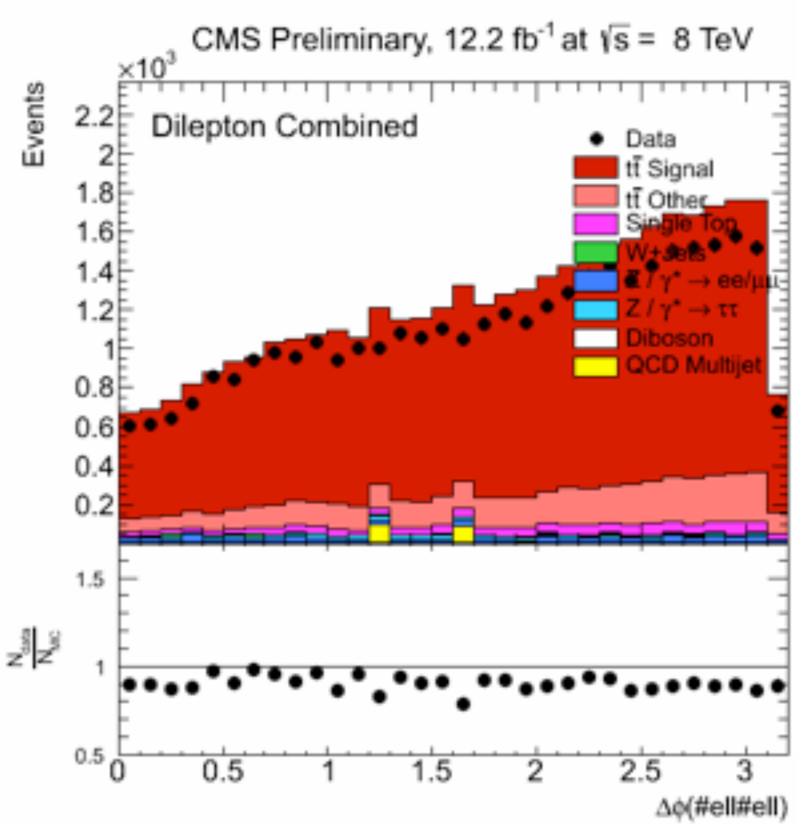
Since MET is partitioned between the two lepton systems in M_{T2} calculation, arrangement of leptons in the rΦ plane due to spin correlations can be responsible for differences in the quality of the modeling.

Here is the culprit. MadGraph systematically underestimates the number of back-to-back leptons in favor of small angle configurations. MC@NLO and POWHEG have flat data/MC ratios. The small angle case is associated with large M_{T2} values.

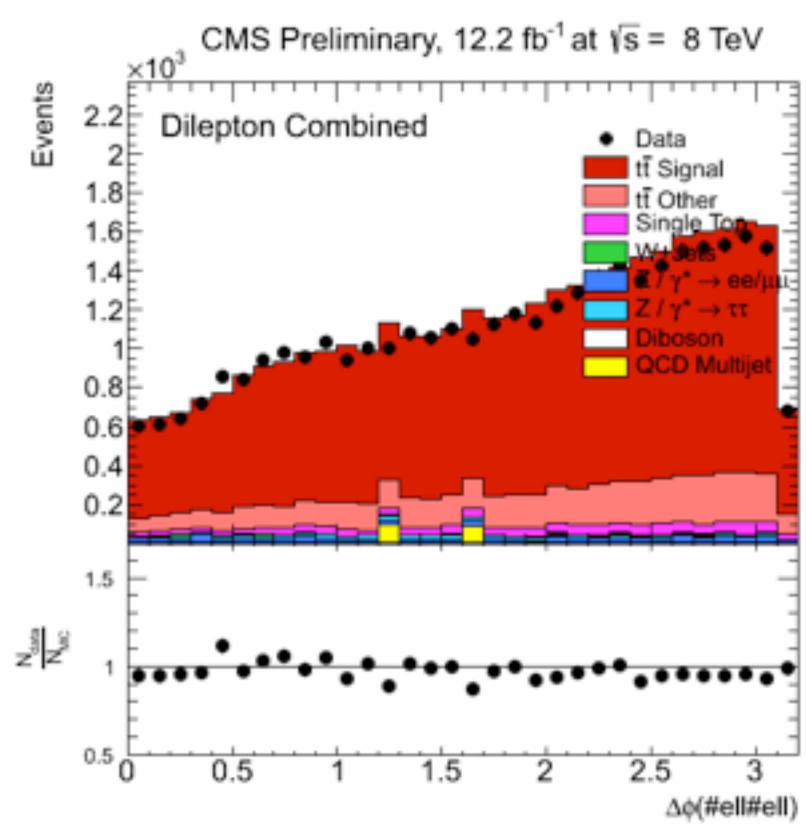
MadGraph



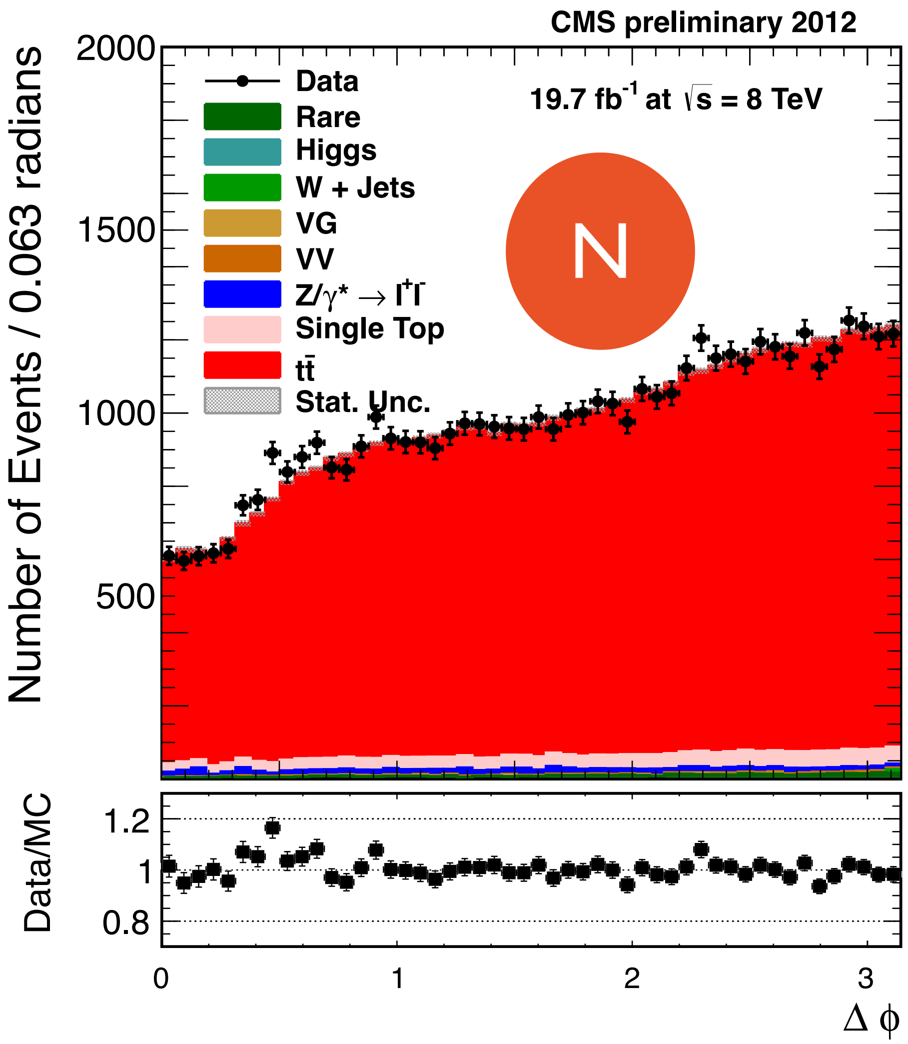
MC@NLO

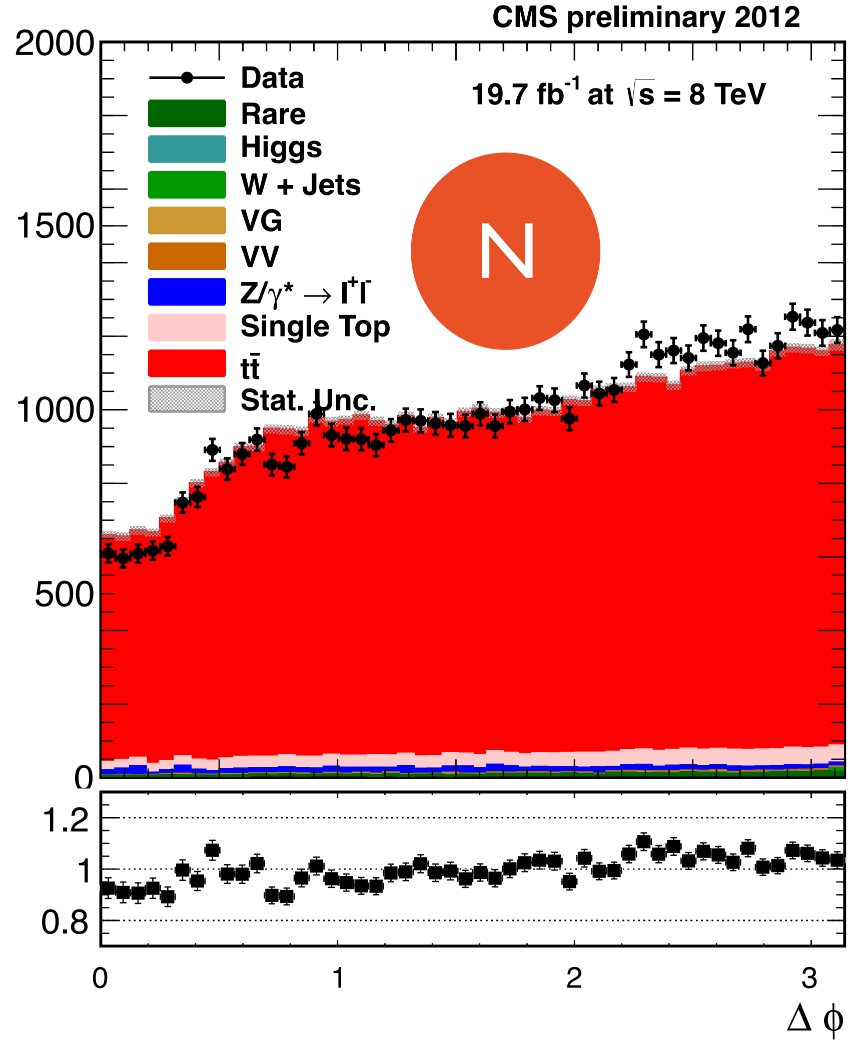


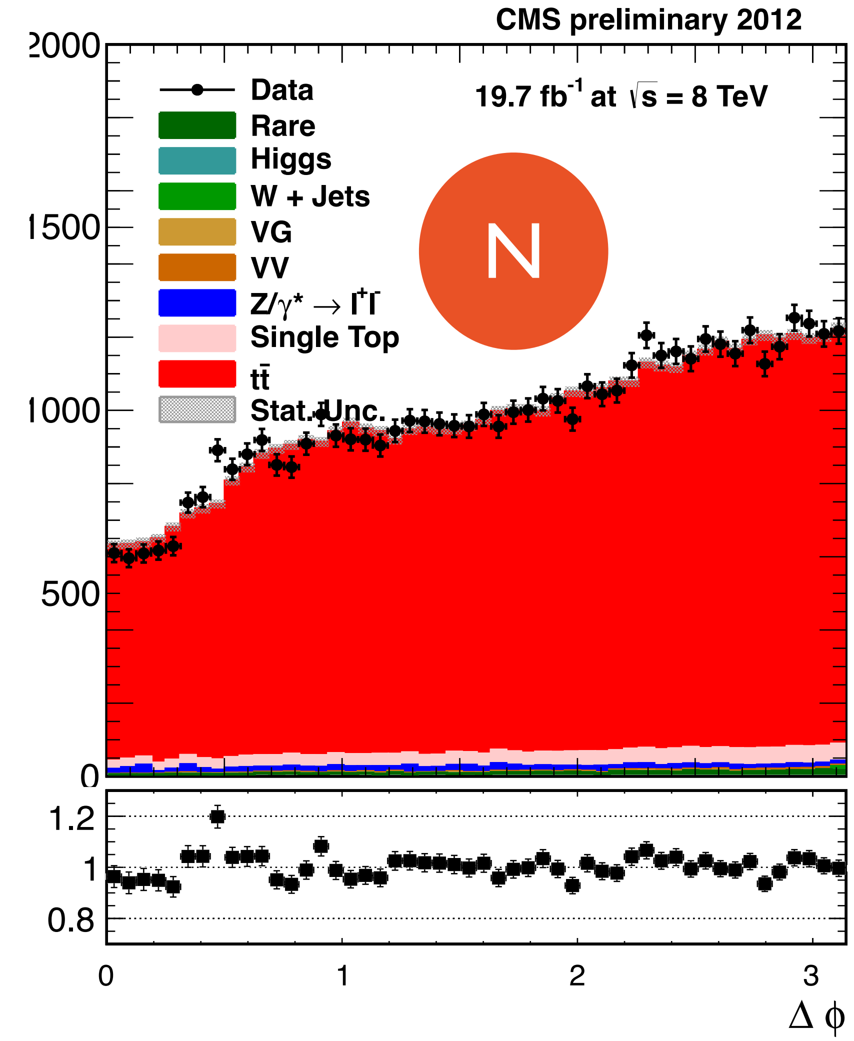
POWHEG



Motivating Choice of Powheg



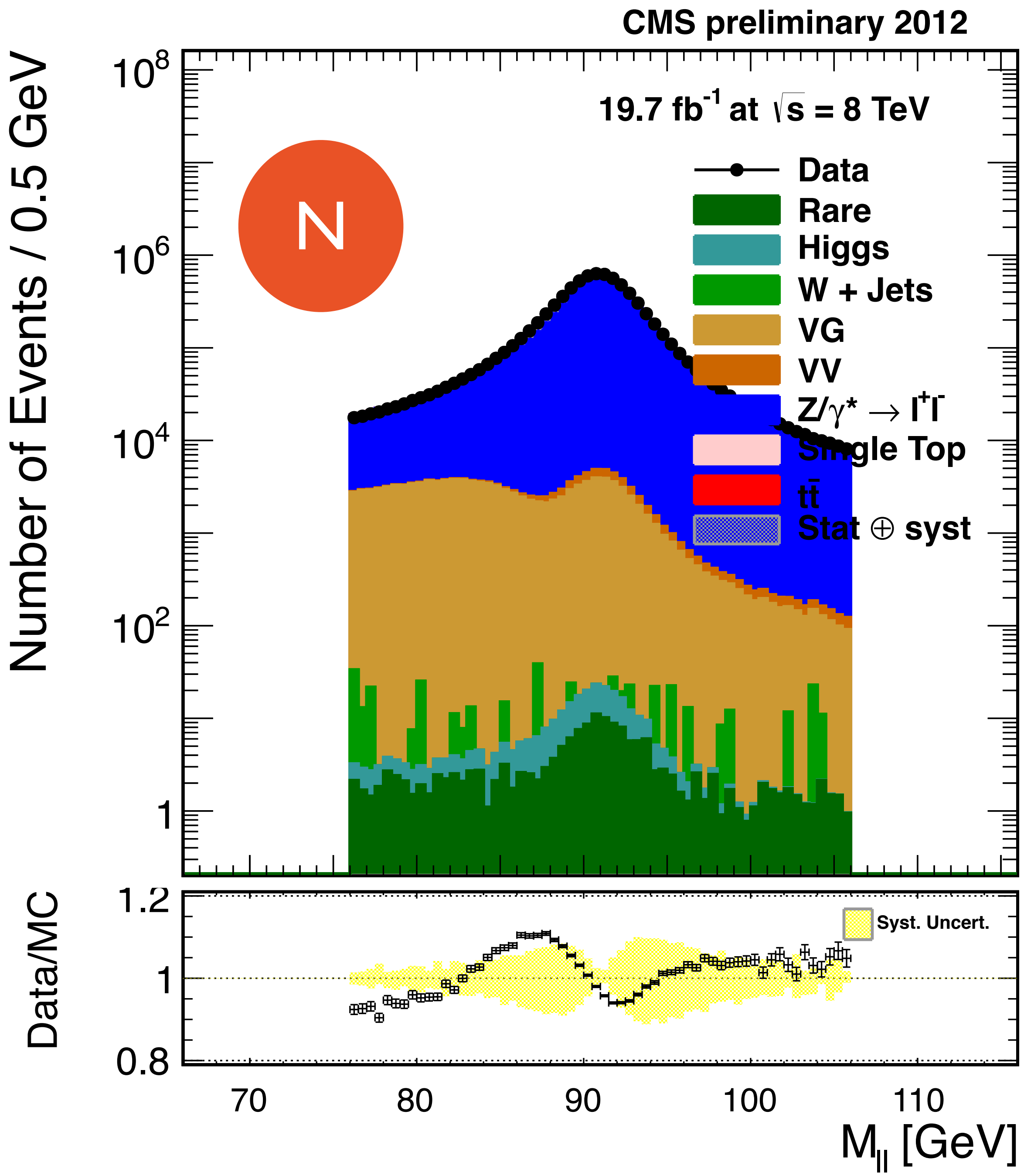




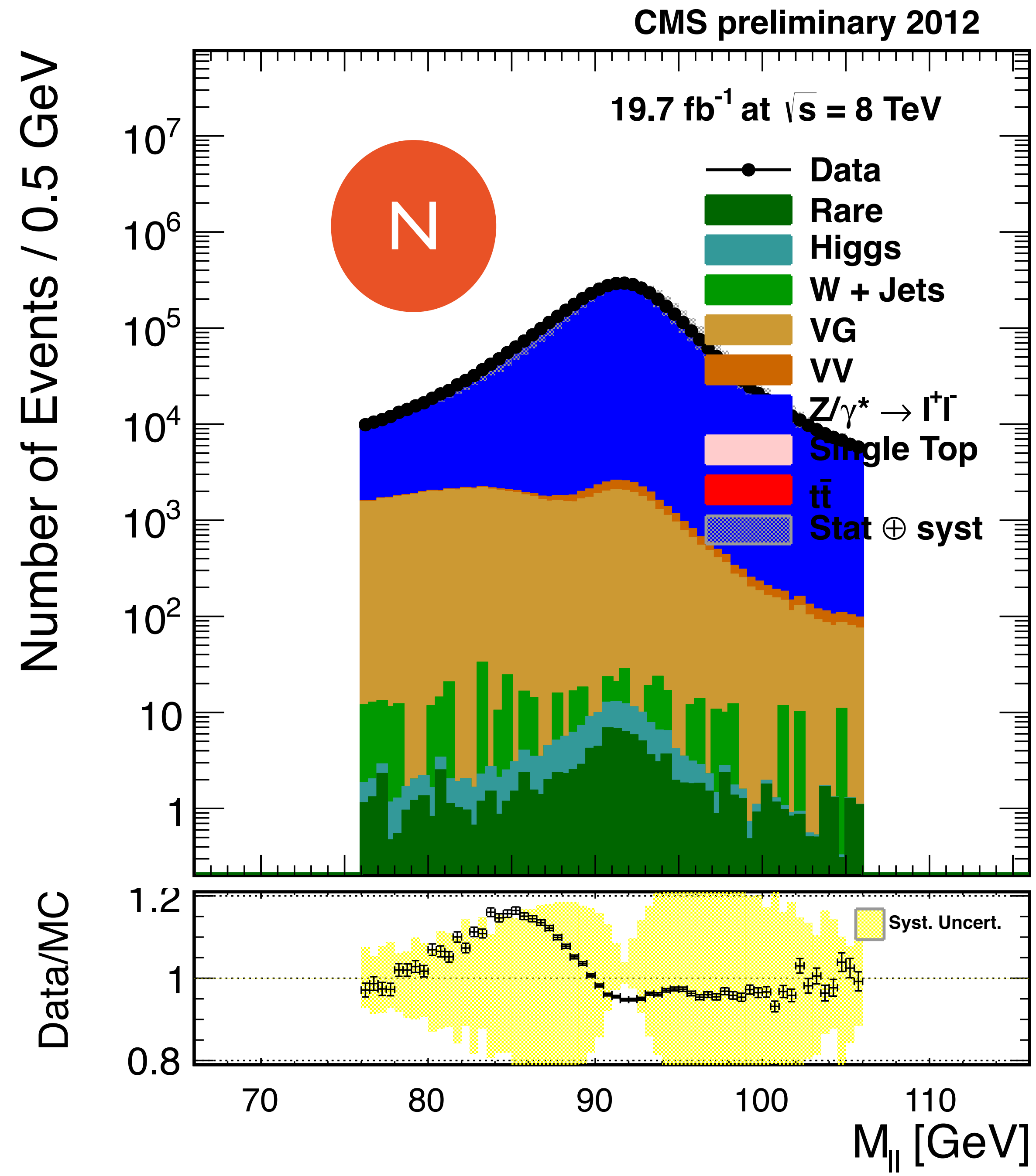
Madgraph MC@NLO Powheg

MC@NLO seems off now -- I think Madgraph is ok because we upgraded to version w/ proper spin correlations but need to confirm this; regardless Powheg is still fine

ZMass peak (inclusive)

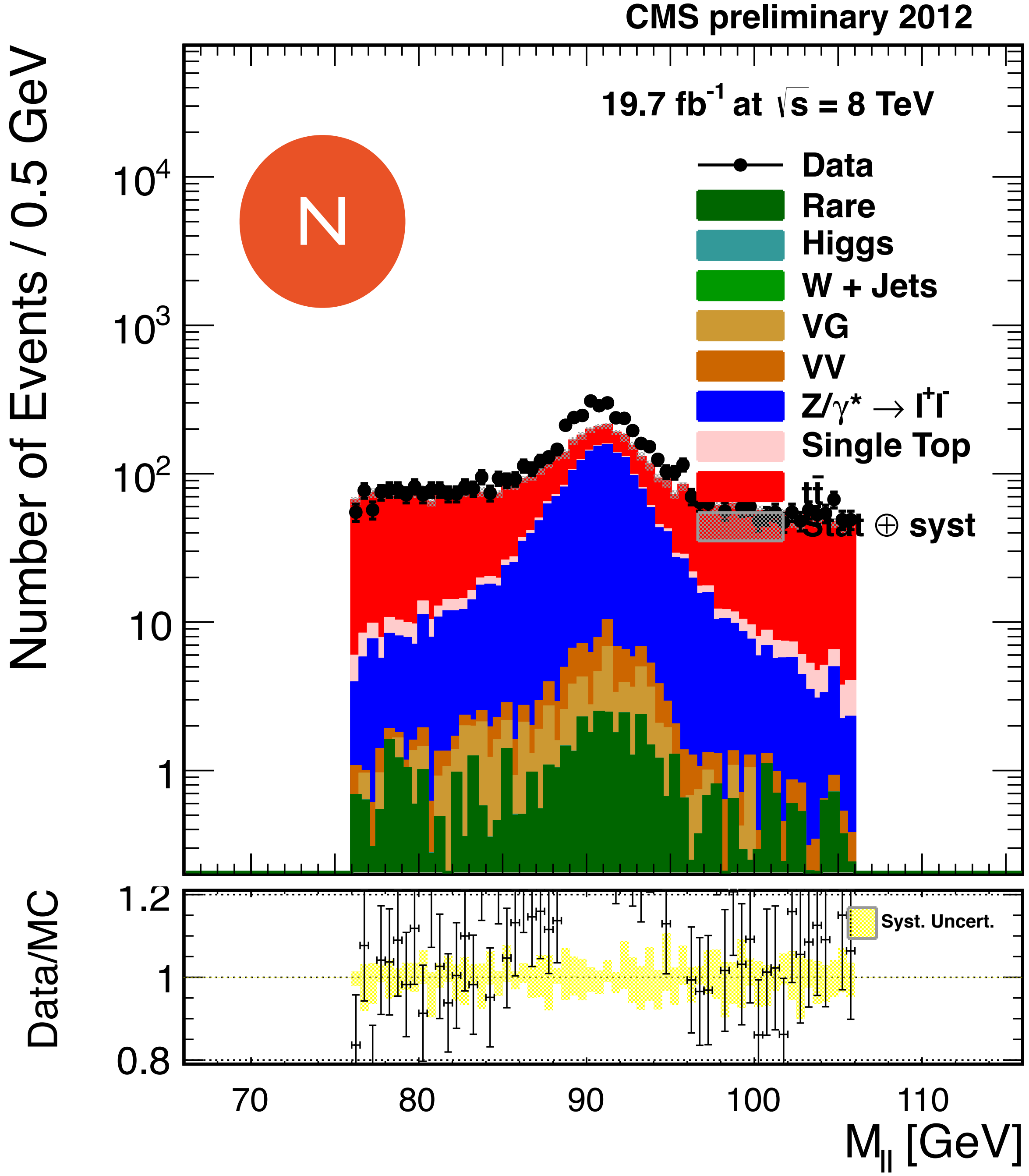


$$Z \to \mu\mu$$

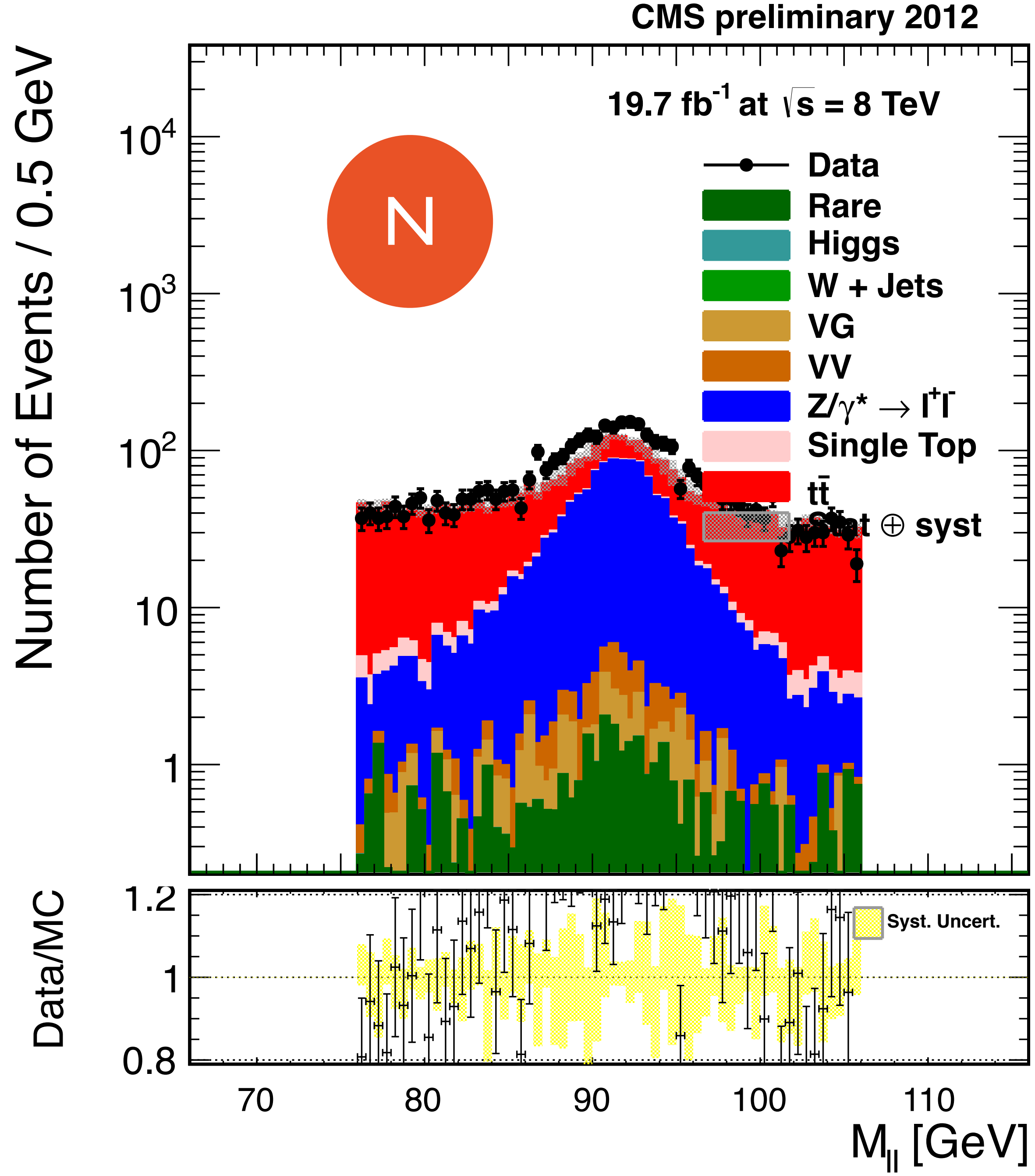


$$Z \to ee$$

ZMass peak (Full Selection)

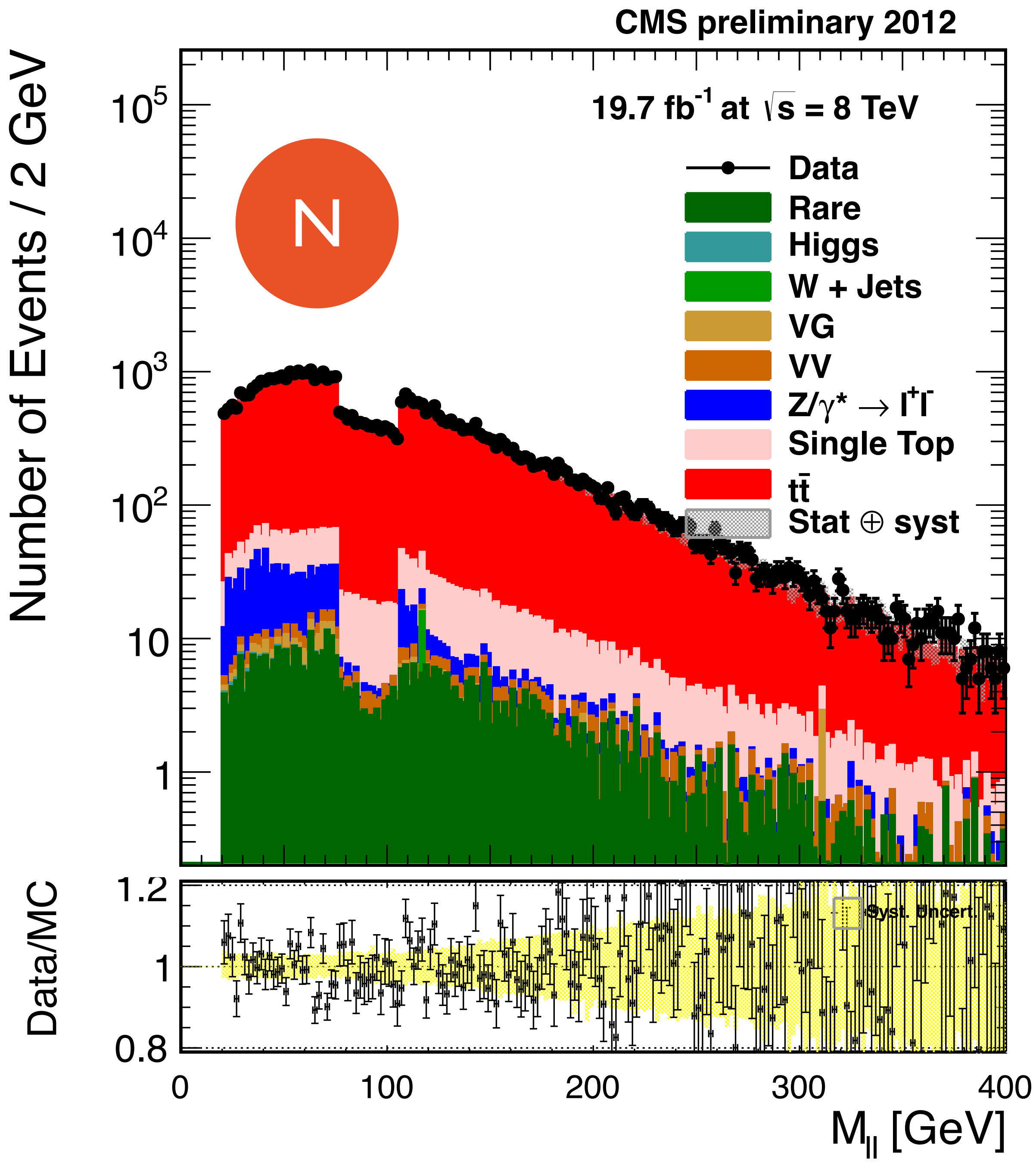


$$Z \rightarrow \mu\mu$$



$$Z \rightarrow ee$$

Dilepton Mass (full selection)



This is the dilepton invariant mass for events we utilize – i.e. after the full selection with veto on the ZMass in same flavor states

ZMass peak

Z Mass peaks in the *only* dilepton selection plots display a clear energy scale offset for the leptons

However, the existing lepton energy scale systematic almost entirely covers the di-muon channel (and handles the di-electron channel)

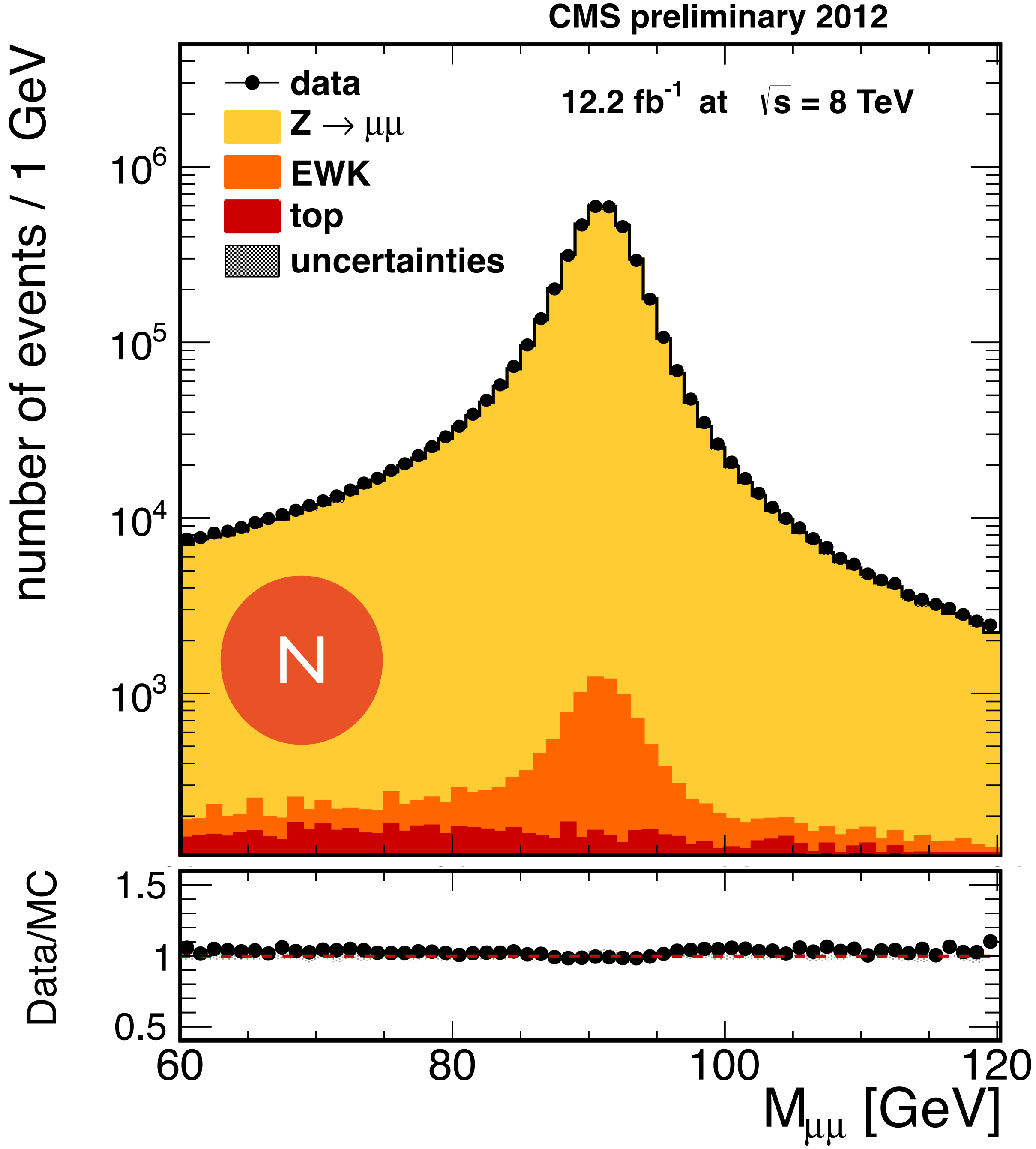
Furthermore, implementing the full selection greatly reduces this effect, but introduces another effect which looks like an O(20%) offset in DY xsec

Of course, we have a data-driven estimation method in place for handling the Drell-Yan anyway, so this overall normalization effect is *not* an issue

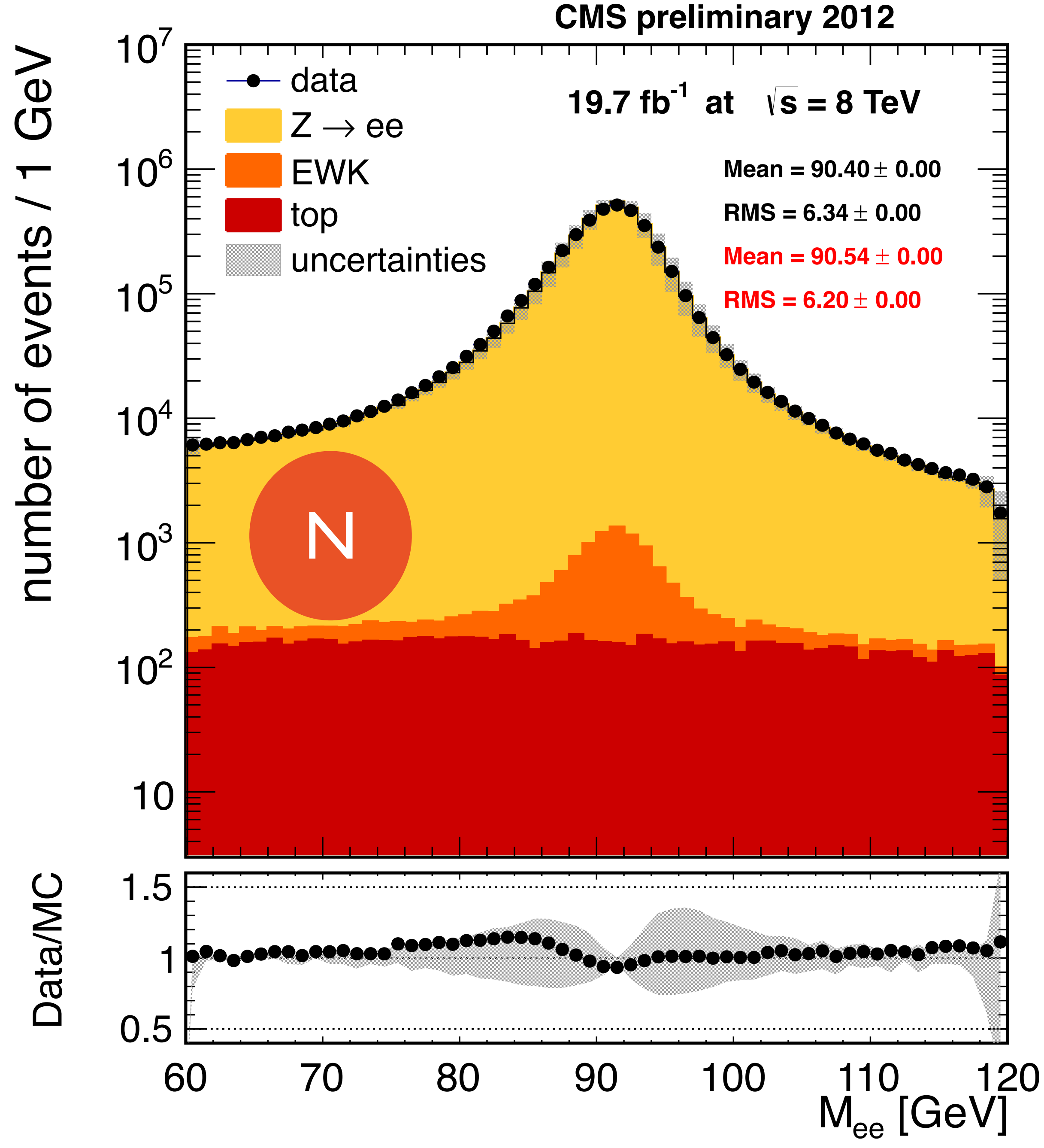
If absolutely need be, can apply energy scale corrections to the leptons (similar thing done for the MET PAS – see next slide)

As of 1/22/13, Old Discussion

ZMass peak



$$Z \rightarrow \mu\mu$$



$$Z \rightarrow ee$$